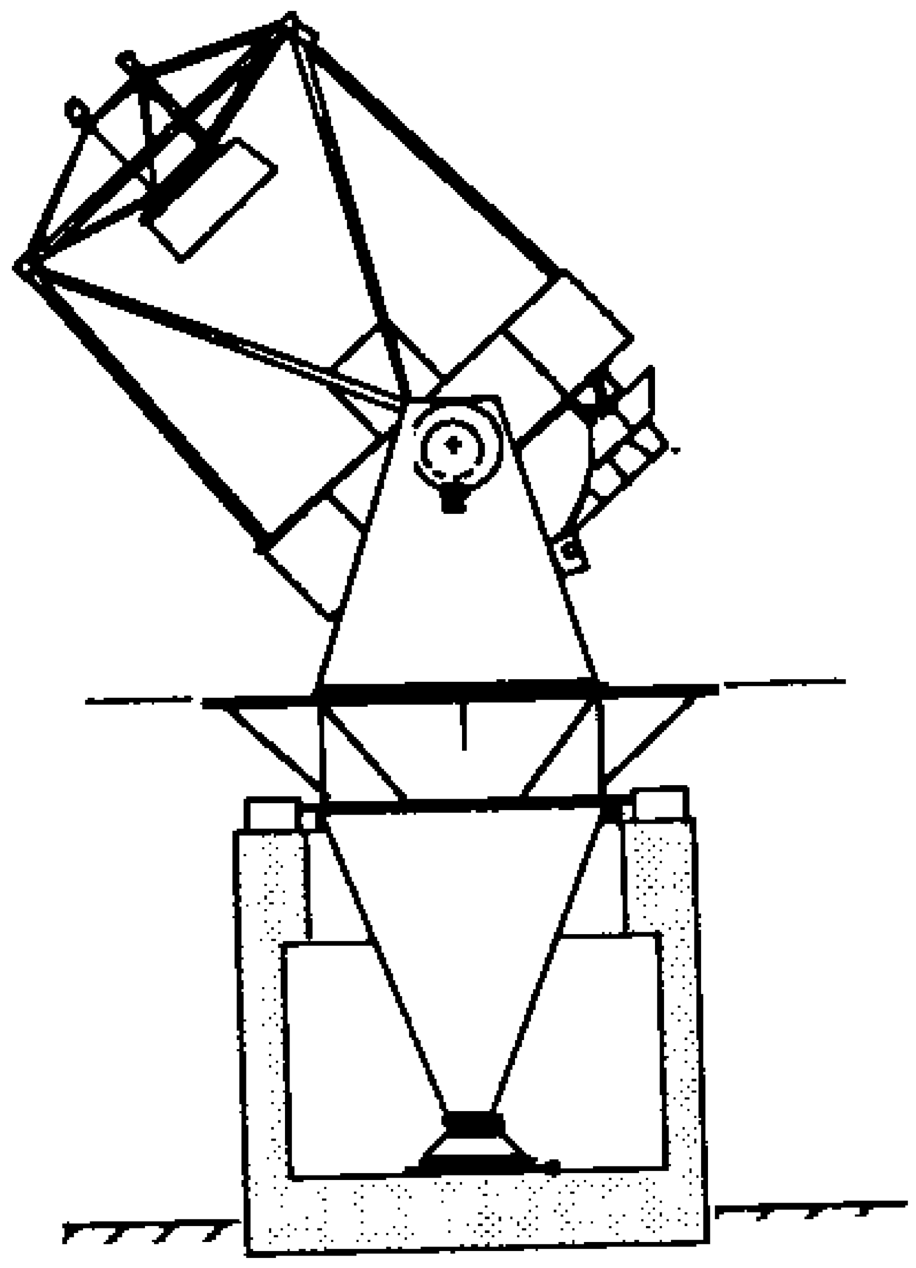
WISCONSIN
INDIANA
YALE
NOAO



3.5 METER TELESCOPE

The WIYN 3.5 Meter Telescope Project

WODC 02-25-01

Presented at *Advanced Technology Optical Telescopes*, SPIE vol. 2199-01, Kona 1994.

2/26/94

The WIYN 3.5 Meter Telescope Project

Matt Johns & Daniel R. Blanco

National Optical Astronomy Observatories*
P. O. Box 26732, Tucson AZ 85726

ABSTRACT

The WIYN Observatory is a joint project of the University of Wisconsin, Indiana University, Yale University and the National Optical Astronomy Observatories to build a 3.5 meter ground-based telescope on Kitt Peak, Arizona. The observatory is currently under construction and nearing completion. This paper presents the current status of the project.

1. INTRODUCTION

The University of Wisconsin, Indiana University, Yale University and the National Optical Astronomy Observatories (NOAO) have joined to build and operate a 3.5-meter telescope on Kitt Peak, Arizona. Observing time will be shared by the partners with NOAO's time being available to the general astronomical community.

Plans for the WIN Telescope were described by Johns and Pilachowski (1990). Yale University has since joined the project and the name was changed to WIYN. A corporation, WIYN Incorporated, was created to oversee the construction and operation of the observatory. Directors for the corporation come from the four institutions. Technical direction for the project is provided by the WIYN Science Advisory Committee. NOAO will operate the observatory with a site manager appointed by the WIYN Board.

Programs in optical spectroscopy and CCD imaging guided the design of WIYN. At the time the observatory was conceived NOAO was actively engaged in building multi-object spectrographs that used optical fibers to bring light from the telescope to a stationary spectrograph located in a nearby temperature controlled room. The WIYN telescope's relatively fast f/6.3 focal ratio and 1° field were selected to efficiently couple to the fibers and provide an adequate field of view for the MOS spectrograph and HYDRA fiber positioner then under development at the KPNO 4 meter telescope.

The site of KPNO's #1-36 inch telescope was site selected for the WIYN Observatory. The 36-inch telescope and enclosure were removed and the ground leveled to make way for WIYN. The observatory is located on the edge of a sharp drop-off with an unobstructed exposure to the prevailing south-west winds and promises some of the best seeing on the mountain. The image error budget for the telescope and dome were chosen such that the estimated median seeing of 0.7 arcsecond FWHM are not degraded by more than 10%.

Construction of the observatory is nearing completion and the telescope is expected to go into operation in 1995. The anticipated cost including instruments is $13.8M US.

2. TELESCOPE STRUCTURE

The preliminary design for the telescope was reported by Johns and Pilachowski (1990). The major change to the 1990 design has been the addition of a mechanism to allow the tertiary mirror to fold out of the beam and provide an additional focus behind the primary mirror. Auxiliary optics are required to bring the focus to a usable position behind the primary mirror cell. Removing the tertiary mirror from the optical path eliminates polarization of the beam caused by the 90 reflection and allows WIYN to be used for polarimetry.

The WIYN telescope is based on the Astronomical Research Corporation (ARC) 3.5-meter alt-azimuth design. The design

*Operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.

was modified to accommodate WIYN's faster focal ratio and larger field of view. In addition, WIYN's removable primary mirror cell required various changes to the structure. Other improvements were made to optimize the stiffness and tracking performance of the mount and including new drives and encoder mounts.

The alt-az configuration provides a stiff yet lightweight structure that responds rapidly to temperature changes and resists wind shake in the wide-open WIYN dome. The lowest calculated vibration modes are above 8 Hz. The rotating weight of the telescope is 36,000 kg of which approximately 50% is above the floor level. Typical plate thicknesses for the exposed structure are 10-20 mm. A ventilation system, separate from the enclosure and primary mirror ventilation systems, draws air through the telescope to reduce its thermal time constant and scavenge warm air from the drives, on-board control electronics and instruments.

Rolling element bearings are used on both the altitude and azimuth axes. They have the advantage of low cost, negligible power dissipation and ease of maintenance. The friction of the bearings is greater than for hydrostatic bearings but manageably small for a lightweight 3.5-meter class telescope.

The main axes are driven by a frameless torque motors mounted on shafts with 4" diameter steel drive rollers ("capstans") that are preloaded against the steel drive disks. Each axis has two drives. No gearing other than that provided by the ratio of the capstan to disk diameter is involved. The capstans have a relief cut in the center of their drive surface that leaves a clear central track for the friction coupled encoders. The azimuth drive disk is a circular disk 140" in diameter. The upper azimuth axis is held in place by the drive capstans and idlers bearing against the drive disk. This sets the precision requirements for the drive surface which was ground to 230 microinches peak-to-valley. The elevation axis has two 60" radius drive sectors: one mounted on each side of the telescope tube. The outside diameter of the elevation disks were ground in place.

Heidenhain ROD800 incremental encoders are coupled to the main axes with crowned steel rollers that are preloaded against the surface of the drive disks. A flexure mount was designed that incorporates steering and preload adjustments with a load cell to measure side loads that result from steering misalignments. The preload force is 5-10 pounds. Two encoders are used for azimuth and one for altitude.

The rotators for the Nasmyth instrument ports are built into the azimuth fork structure. The circular instrument mounting plates are driven with a servo gearmotor and drive roller preloaded against edge of the plate. A friction coupled incremental encoder measures the rotator angle.

The telescope design was a joint effort involving the WIYN staff, Steve Gunnels of Paragon Engineering, Tehachapi CA, and L&F Industries, Huntington Park CA. L&F fabricated the mount and it was installed in the spring, 1993. Figure 1 shows the telescope in the dome prior to the installation of the cells and optics.

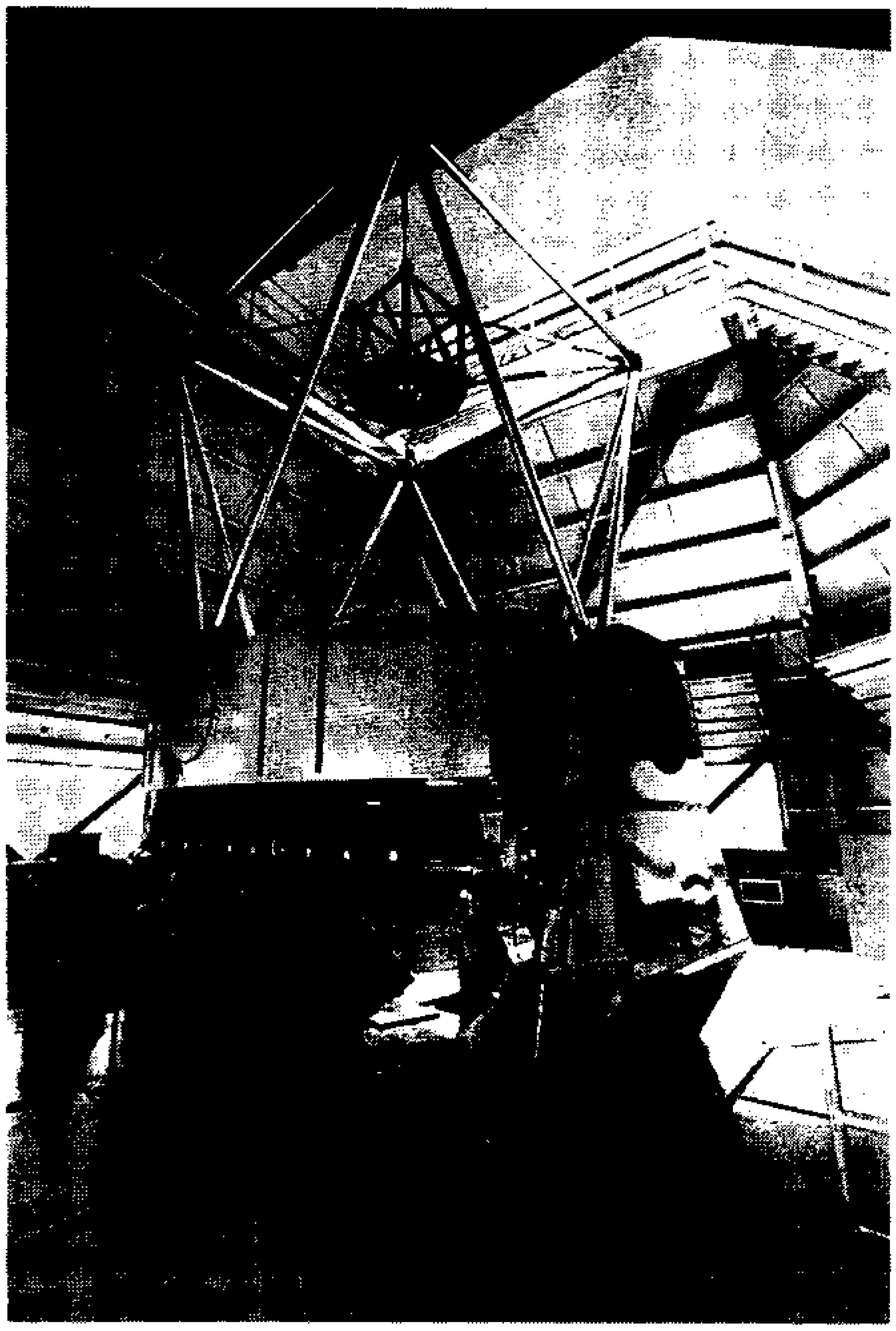


Figure 1. WIYN Telescope prior to installation of mirror cells and optics.

3. OPTICS

3.1 Optical Design

The Ritchey-Chretien design uses a single, non-interchangeable, secondary mirror. The principal instrument ports are the two Nasmyth positions. A two-element corrector on the "MOS" port provides a 1° field-of-view for the MOS spectrograph. The "WIYN" port on the opposite side has a 12 arcminute FOV than can be extended to 0.5° with a field corrrector and atmospheric dispersion compensator (ADC). The tertiary mirror rotates to direct the beam to one side or the other.

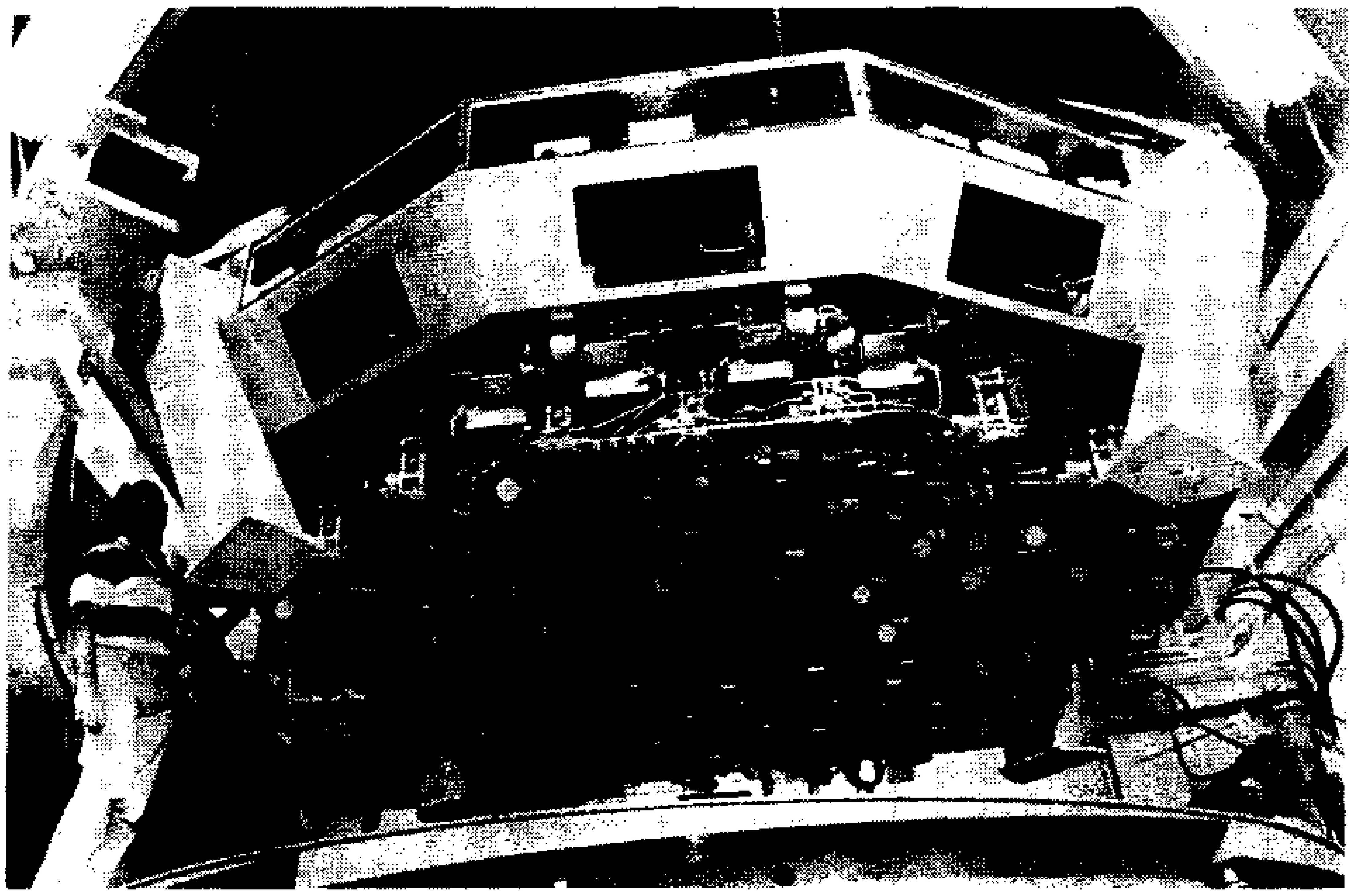


Figure 2. Primary mirror cell with temporary legs attached.

3.2 Primary Mirror

The 3.5 meter structured borosilicate primary mirror blank was cast at the Steward Observatory Mirror Lab (SOML) in 1988. The mirror was generated and polished to a sphere at NOAO and used for mirror support and thermal control tests as part of NOAO's technology development program for large telescopes.

Following the conclusion of the tests the mirror returned to SOML where it was ground and polished by a team of SOML and NOAO opticians using a stressed lap. The final surface figure of 21 nm RMS was achieved in March 1993. The mirror was shipped to Kitt Peak in February 1994 and is currently waiting aluminization and installation in the telescope.

NOAO is providing the primary mirror cell, supports and thermal controls (Figure 2). The mirror is supported from the back by 66 actuators that carry the axial load and a separate 24 actuators that carry the lateral load. The axial actuators are grouped in three zones of 22 units that define the piston/tip/tilt of the mirror. Actuators within a group are hydraulically interconnected for load sharing. The overturning moment that develops at off-zenith elevation angles as a result of supporting the mirror entirely from the back is reacted by cross coupling the lateral and axial supports using a second set of hydraulic cylinders in the axial supports supplied by the fluid in the lateral system.

Force actuators and load-cell read-out in the axial supports provide active mirror figure control. The support is described in detail by Stepp, et. al. (1991).

Due to its relatively high CTE, thermal gradients in the glass will warp the mirror. Temperature uniformity must remain within +/- 0.2° C to preserve the mirror figure. In addition the temperature of the mirror top surface must be kept within approximately 0.5° C of a degree of the ambient air temperature to eliminate mirror seeing. The thermal control system designed to address these effects uses 12 blowers mounted around the perimeter of the primary mirror cell circulate conditioned air through the internal mirror cells forcing rapid thermalization (Goble, 1991). Heat exchangers in the loop condition the air and remove excess heat. An off-telescope chiller supplies coolant to the heat exchangers. The measured thermal time constant of the system is around 60 minutes.

The polished primary mirror was installed in its cell under the NOAO test tower for full-up tests. After adjusting the active supports a surface figure of 24 nm RMS was achieved. Figure 3 is the calculated point spread function assuming perfect optics for the rest of the telescope.

The primary mirror cell has been mounted on the telescope and preparations are underway for installation of the mirror.

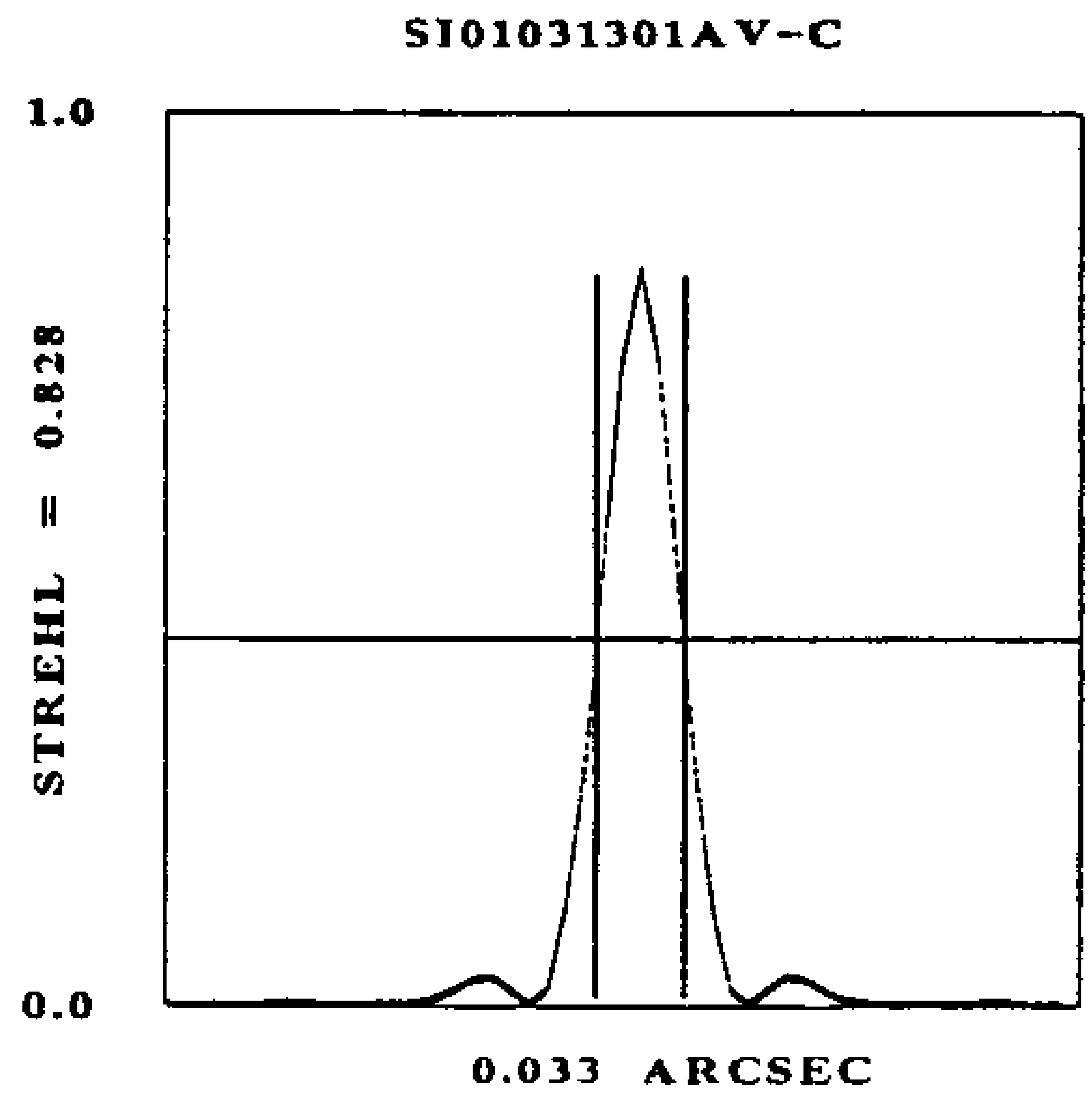


Figure 3. PSF for the primary mirror on its supports.

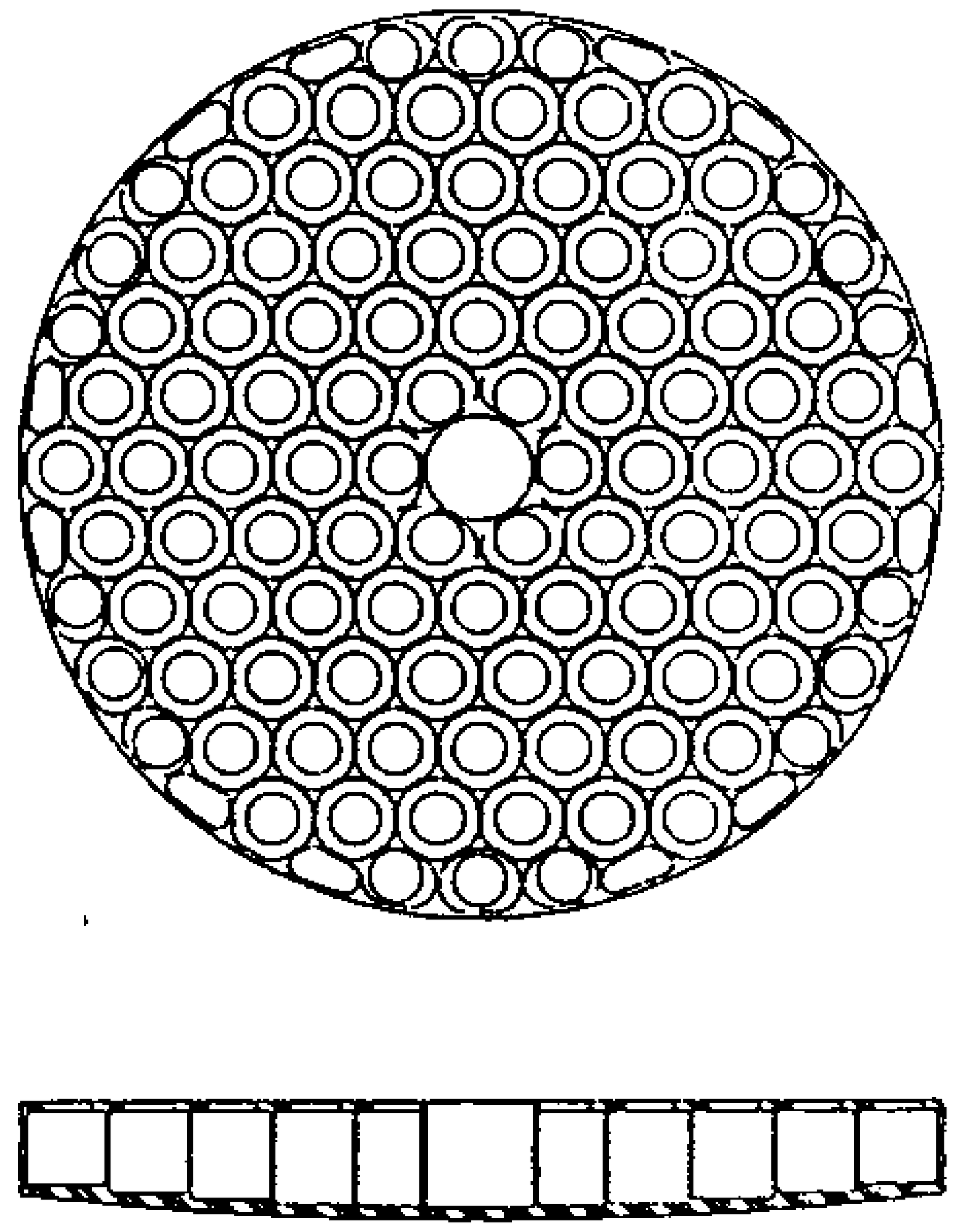


Figure 4. WIYN 1.2 meter secondary mirror.

3.3 Secondary Mirror

Schott Glaswerke in Mainz generated the 1.2 meter diameter Zerodur™ secondary mirror (Figure 4). The mirror was lightweighted to approximately 28% of its solid blank weight by machining and acid etched at NOAO to relieve microfractures from the generation process.

Contraves USA in Pittsburgh polished the secondary mirror using NOAO's 100" reflective sphere and a null lens for testing. A final surface figure of 15 nm RMS was achieved.

The secondary mirror will be supported axially by a partial vacuum applied behind the mirror in the space between the mirror back and cell. Three flexures at approximately the 0.7 radius define its axial position. Lateral support is provided by a central flexure in the CG plane. The linear actuators that attach the cell to the telescope provide tip, tilt, and piston (focus) control.

Fabrication of the secondary mirror cell is near completion and the mirror is ready to be installed in the cell.

3.4 Tertiary Mirror

Schott also generated and lightweighted the 1.1 meter by 0.75 meter elliptical Zerodur™ tertiary mirror. The mirror was polished by Eastman Kodak in Rochester using a combination of planetary polisher and ion figuring to a 17 nm RMS surface figure.

The tertiary mirror will be supported on an airbag with flexures reaching up through the holes in the back plate of the mirror to define the axial and lateral position. No active control is provided for the tertiary mirror aside from the rotation and fold-up mechanisms used to re-direct the telescope beam to different ports.

Fabrication of the tertiary mirror cell is near completion and the mirror is ready to be installed in the cell.

3.5 Wide-field Corrector

The two 500 mm diameter fused silica corrector lenses have been generated and are being polished. Completion is expected in May 1994.

3.6 Active Control

A wavefront sensor will be provided in the focal plane to close the loop on the active optics. The wavefront curvature method using in- and out-of-focus images has been selected to measure aberrations and derive corrections to the support forces and mirror positions. The method is already in use at NOAO for diagnostic programs (Roddier, 1991) and software is under development for a system integrated with the telescope controls. The active optics will be used to recalibrate the support forces and mirror alignment typically on 30 minute intervals. In between updates the forces and alignment will be maintained open-loop with look-up tables.

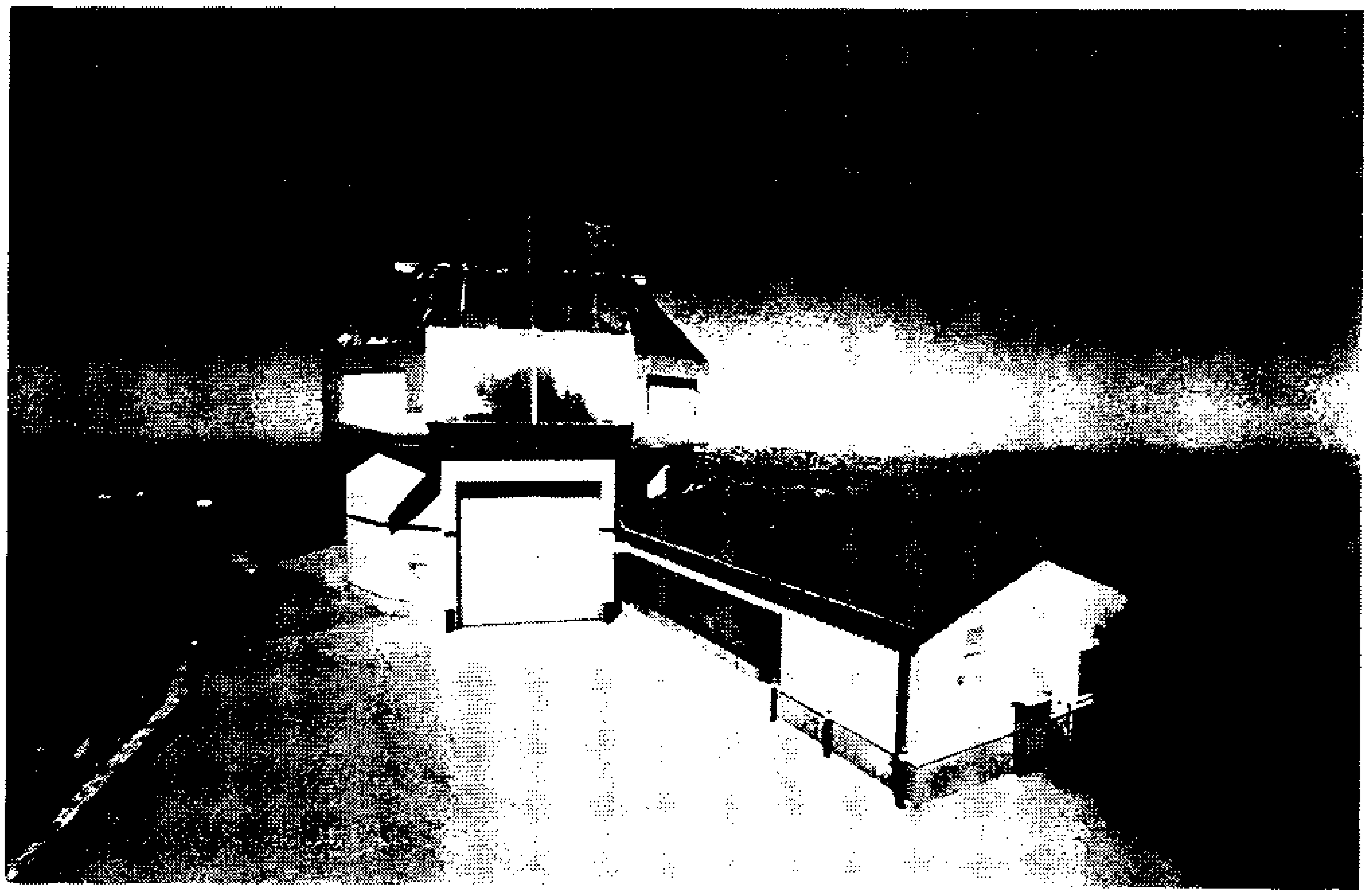


Figure 5. WIYN 3.5 meter telescope enclosure.

4. ENCLOSURE

The enclosure is a three story structure that places the elevation axis of the telescope 9.1 m above ground level (Figure 5). The octagon-style dome rotates independently of the telescope mount. A control building attached to the side of the enclosure contains the only heated spaces in the observatory. The design and engineering were done by M3 Engineering, Tucson Az.

A primary consideration in the enclosure design was reducing the effects of dome seeing. The overall strategy adopted to deal with this problem was to provide a well ventilated and low thermal mass structure and eliminate sources of heat in the telescope chamber. Some of the measures employed to implement this strategy are:

- The structure of the dome is made primarily of thin cross-section steel covered with light weight insulated panels.
- An insulated wood floor is used on the observing level.
- Large vent openings are provided in the walls of the dome. With the shutters and vents open about 25% of the dome surface area is open.
- Fans draw air through the telescope and enclosure during observing to prevent warm air from rising into the telescope chamber. The air is released 36 meters from the telescope down wind in the prevailing wind direction.
- Major heat sources in the enclosure have been eliminated or are actively ventilated. There are no heated rooms in the main enclosure.
- Reflective tape has been used on the dome exterior and upper end of the telescope to reduce heating due to daytime insolation and to reduce radiation to the night sky.

The thermal design and preliminary measurements are discussed by Blanco and Johns (1994).

Construction of the observatory started in the spring of 1992 and was completed early in 1993.

5. CONTROL SYSTEM

The basic control system for the observatory is being provided by the University of Wisconsin. The observatory staff will develop extensions including a graphical user interface and active optics software. Figure 6 shows the system configuration.

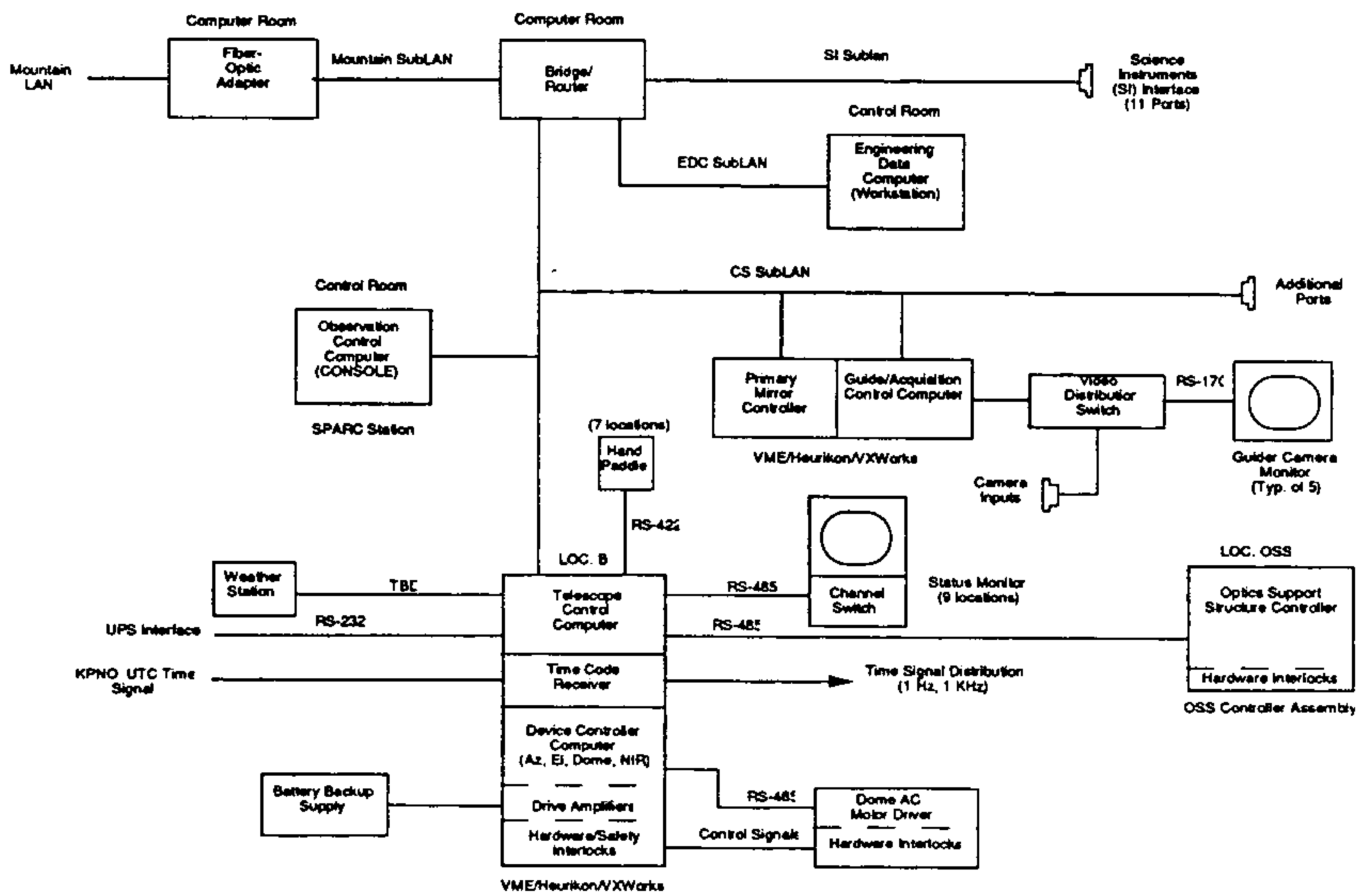


Figure 6. Control system block diagram.

The system is highly networked with subLANs for telescope control and science instrumentation. The software is being developed to accommodate remote observing and much of the installation and testing is currently being done from Wisconsin over the Internet.

The real-time control of the telescope uses Heurikon™ single board computers programmed in C running under VXWORKS. The high level control uses SUN Microsystems computers that communicate with the low-level controls over ethernet. The System Status Displays have their own RS485 bus and a separate broad band video bus is provided for the display of guider images.

6. INSTRUMENTATION

Two facility instruments are initially planned for the WIYN Observatory: a MultiObject Spectrograph (MOS) and a CCD imager. Facility instruments will be available to all users. In addition, the university partners in WIYN are building instruments for their private use.

The MOS has been developed by NOAO and is currently in use on the Kitt Peak National Observatory 4 meter telescope. It is being modified to work at WIYN. The stationary MOS spectrograph sits in a temperature controlled room and light is brought to it by optical fibers. Up to 100 fibers will be active at a time. The fibers are held in position the telescope focal plane with magnetic buttons on a steel plate. The buttons are set in place by the "HYDRA" robotic x-y-z positioner. The instrument is described by Barden, et. al. (1994).

A general instrument adapter is being developed by the WIYN staff. This will provide guide cameras, wavefront sensor, ADC control, and calibration lamps.

A filter wheel and shutter assembly are currently being fabricated for the CCD imager. CCD types are being evaluated and a final selection is expected in the near future. The imager will use the NOAO CCD controller hardware and be compatible the other imagers on Kitt Peak.

7. STATUS

Optics are currently being installed in the telescope. Commissioning activities will start in May 1994 following final integration of the control system. Commissioning of the telescope and science instruments is expected to continue through the end of 1994.

8. ACKNOWLEDGMENTS

The WIYN Project is the result of the efforts of many people. Direction and oversight has been provided by the WIYN Science Advisory Committee including, at various times, Gus Oemler (Yale), Art Code (U. Wisconsin), Kent Honeycutt (Indiana U.), Caty Pilachowski (NOAO), Dave DeYoung (NOAO) and the President of WIYN, Blair Savage.

C. Harmer was responsible for optical design of the telescope and wide-field corrector. Liang Ming designed the 0.5° FOV corrector/ADC.

The primary mirror team included L. Stepp, R. Wolff, L. Goble, N. Roddier, J. Richardson and G. Poczulp. B. Martin and D. Anderson led the polishing effort at SOML.

The controls group at Wisconsin includes E. Richards, J. Sitzman, J. Percival, S. Ellington, and M. Warner. Principal investigator for the effort is A. Code. J. Little coordinates the controls effort for WIYN.

The site supervisor during observatory construction was J. Scott. D. Sawyer is the current site manager. J. Duffek is the lead mechanical designer.

Development of the MOS/HYDRA spectrograph is directed by S. Barden (NOAO) and T. Armandroff (NOAO). K. Honeycutt (Indiana U.) is responsible for the CCD imager.

9. REFERENCES

1. S. C. Barden, T. Armandroff, G. Muller, A. C. Rudeen, J. Lewis, L. Groves, "Modifying Hydra for the WIYN telescope- an optimum telescope, fiber MOS combination", *Instrumentation in Astronomy VIII.*, vol. 2198, SPIE, Kona, 1994

2. D. Blanco and M. Johns, "Thermal Design of the WIYN 3.5 Meter Telescope Enclosure", *Advanced Technology Optical Telescopes V*, vol. 2199, SPIE, Kona, 1994

3. L. Goble, "Temperature Control of the 3.5-Meter WIYN Telescope Primary Mirror", *Analysis of Optical Structures*, vol. 1532, SPIE, San Diego, 1991

4. L. Goble, G. Poczulp, N. Roddier, L. Stepp, "Results of Testing the 3.5m WIYN Telescope Primary Mirror and its Support, Thermal Control, and Active Optics Systems", *Proceedings of the ESO Workshop on Progress in Telescope and Instrumentation Technologies*, Garching, 1992

5. M. Johns and C. Pilachowski, "The WIN 3.5 Meter Telescope Project", *Advanced Technology Optical Telescopes IV*, vol. 1236, SPIE, Tucson, 1990

6. N. Roddier, "Algorithms for wavefront reconstruction out of curvature sensing data", *Active and Adaptive Optical Systems*, vol. 1542, SPIE, San Diego, 1991

7. L. Stepp, "3.5m Mirror Project at NOAO", *Advanced Technology Optical Telescopes IV*,, ed. L. Barr, vol. 1236, SPIE, Tucson, 1990

8. L. Stepp, N. Roddier, D. Dryden, and M. Cho, "Active Optics System for a 3.5-meter structured Mirror", "*Active and Adaptive Optical Systems*", SPIE Vol. 1542, San Diego, 1991