WISCONSIN
INDIANA
YALE
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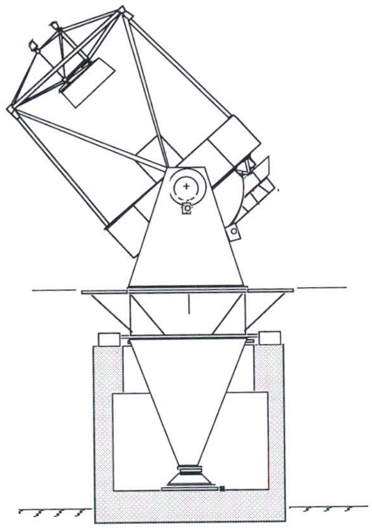

3.5 METER TELESCOPE

WIYN Operations Readiness Review: Review of Control System Design Requirements

WODC 02-39-01

Title: Operations Readiness Review (ORR) of Control System Design Requirements for the WIYN 3.5 Meter Telescope

Document number: WODC TBD

Reviewed and approved:

/David Silva

Project Manager Date

/Jeff Lewis

NOAO MPG Representative Date

/Jeff Percival

UW Controls Group Representative Date

Glossary

ADC	Atmospheric Dispersion Corrector
CLI	Command Line Interpreter
CS	Control Subsystem
GUI	Graphical User Interface
IAS	Instrument Adapter Subsystem
LAN	Local Area Network
KPNO	Kitt Peak National Observatory
OSS	Optical Support Structure
NIR	Nasmyth Instrument Rotator
NOAO	National Optical Astronomy Observatories
PFI	Program File Interface
PMS	Primary Mirror Subsystem
SI	Science Instrument
TBD	To be determined.
TBR	To be resolved.
TMR	Tertiary Mirror Rotator
UPS	Uninterruptible Power Supply

1. Purpose & Scope

This document reviews the requirements of the Control Subsystem (CS) as specified in the document "Control System Design Requirements for the WIYN 3.5m Telescope (WODC 01-20-11, dated 5/6/92).

The CS controls and monitors: the telescope mount, secondary and tertiary mirrors, instrument rotators, dome rotation, mirror covers and other auxiliary equipment associated with the operation of the telescope. It provides appropriate User/Operator interfaces for commanding the telescope and displaying status and diagnostics including daily start-up of the observatory, normal and emergency shutdown of the observatory, and the monitoring and display of environmental data and time. The CS supplies electrical power and data interface cabling between hardware located in the control and computer rooms and mounted on the telescope and in locations around the dome.

The requirements specified in WODC 01-20-11 represented engineering tasks of varying difficulty. These requirements, separated into two categories, were classified as specifications or goals according to the following definitions:

Specifications described the design or performance capabilities of the observatory that had been approved by the board to meet the science goals of the project. These specifications were reviewed by the project staff for technical difficulty and judged to be achievable with the approved budget and schedule. Changes to specifications required a review by the Scientific Advisory Committee (SAC) and approval by the board.

A goal was a performance capability that had been recommended by the SAC but which required further study and development due to an uncertainty in its technical feasibility or the project's ability to achieve it with the allocated resources. The project staff designed to the goals and reported to the SAC when changes are advisable. Proposed modifications included an assessment of the technical impact and budgetary and schedule implications. Modifications to goals were approved by the SAC. Goals were converted to specifications by the SAC as development allowed. Goals that cannot be achieved within the approved budget and schedule and which, in the judgment of the SAC, significantly affect the capabilities of the observatory will be referred to the board with the SAC's recommendation.

Requirements that were goals are labeled with a [G]. A [G] at the head of a subsection or category indicates that all requirements included in the subsection or category were goals. Requirements without a G-label were specifications.

This document follows the structure of WODC 01-20-11. In areas where specifications were met or completed, that achievement is simply noted. In areas where specifications required verification, were not met, or were not tested, the relevant descriptions from WODC 01-20-11 are given (in *italics*) followed by commentary.

2. Telescope mount

Completed as specified in WODC 01-20-11.

2.1 Azimuth/Elevation Axis Control

Completed as specified in WODC 01-20-11 except as follows:

Additional terms will be added to correct the following predictable sources of error:

- *Pointing errors due to active mirror adjustment.*

This functionality has not been implemented in its final form. Currently, secondary auto-collimation corrections are being accounted for in the telescope pointing model as generic pointing errors as a function of elevation. In the near future, these corrections will be compensated for by changing the telescope software boresight in equal and opposite amount whenever the secondary is tip/tilted, thus removing these secondary adjustments as a pointing "feature" requiring compensation in the pointing model.

Apple Computer

Press Release

May 17, 1996

Apple Announces Developer Release of MkLinux, Linux for Power Macintosh

Leading User-Supported Version of UNIX to be Available to Power Macintosh Users

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WWDC, SAN JOSE. California--May 17, 1996--Apple Computer, Inc. announced today that it is making available the Developer Release 1 CD of MkLinux. Linux is a freely distributable version of UNIX. Apple, in conjunction with the Open Software Foundation (OSF), has ported Linux to support a variety of Power Macintosh products. MkLinux (Microkernel Linux) operates on the OSF Mach Microkernel which will be running natively on the PowerPC microprocessor.

The Developer Release 1 CD is being distributed free to attendees at the Linux session at Apple's World Wide Developer's Conference, being held in San Jose this week. The Developer's Release 1 available this week will allow software developers to use a pre-release version of the product, and provide feedback to Apple for the final version.

In addition, Apple has authorized Prime Time Freeware (http://www.ptf.com) to publish Apple's reference release of MkLinux for the Power Macintosh. Prime Time Freeware, a publisher of freely redistributable software for technical and professional markets, has scheduled the release of "MkLinux: Mach/Linux for the Power Macintosh" for September 1996. The product, retailing for U.S. $50, will contain an installable version of MkLinux, source code, and extensive documentation on Linux, Mach, MkLinux, and the Power Macintosh.

"Apple is supporting Linux as part of an overall effort to embrace more open industry standards, particularly those popular in the Internet community," said Ike Nassi, vice president of Apple system software technologies. "This software will be particularly popular with Mac users in higher education and the scientific research communities."

Specification: The CS will provide the capability for tracking both axes at sidereal and non-sidereal rates up to the maximum track rates specified. Non-sidereal rates will be specified as constant velocities in RA and Dec. Tracking uses the same motors and encoders as positioning.

Non-sidereal tracking was implemented as described but has not been adequately tested yet.

2.2 Mount specifications

These numbers should be verified by Project Engineer (Blanco).

2.2.1 Mechanical Properties

[G]

Weight of the OSS Assembly:	*32,660 lb.*
Rotating weight of the Telescope Assembly:	*80,000 lb.*
OSS Moment of Inertia about Elevation axis:	*5.5e5 lb.-sec^2-in.*
Telescope Moment of Inertia about the Azimuth Axis:	*1.1e6 lb.-sec^2-in.*
Azimuth Total Bearing and Drive Friction:	*3640 in-lb.*
Elevation Total Bearing and Drive Friction:	*1550 in-lb.*
Azimuth utility drape torque:	*TBD.*
Elevation utility drape torque:	*TBD.*
Elevation Imbalance torque:	*TBD.*
Maximum wind load:	
Azimuth:	*4500 lb-in.*
Elevation:	*4170 lb-in.*
Structural modes and frequencies:	
Fore-aft Translation:	*7.3 Hz.*
Lateral Translation:	*7.6 Hz.*
Locked Rotor Azimuth Axis:	*8.8 Hz.*
Locked Rotor Elevation Axis:	*10.6 Hz.*

These numbers should be compared to as-built numbers by Project (Blanco/Silva).

2.2.2 Azimuth and Elevation Ranges

Complete as specified in WODC 01-20-11.

2.2.3 Accelerations and Rates

The control system will limit accelerations and rates to the following ranges:

[G]

Azimuth Accelerations:		*-1°/sec^2 to +1°/sec^2.*
Azimuth Rates:		
	Elevation >30°:	*-5°/sec to +5°/sec.*
	20° < Elevation <30°:	*-2°/sec to +2°/sec.*
	Elevation <20°:	*-1°/sec to +1°/sec.*
Elevation Accelerations:		*-1°/sec^2 to +1°/sec^2.*

Elevation Rates:

	Elevation > 85°	*-5°/sec to +1°/sec.*
	30° < Elevation < 85°:	*-5°/sec to +5°/sec.*
	20° < Elevation < 30°:	*-2°/sec to +5°/sec.*
	Elevation < 20°:	*-1°/sec to +5°/sec.*

The telescope shall meet the tracking specifications of sections 2.3.3 and 2.3.4 for the following range of track rates and accelerations:

Track rates, both axes: *-0.5°/sec to +0.5°/sec.*
Track Accelerations, both axes: *-0.1°/sec^2 to +0.1°/sec^2.*

Rates outside the following ranges will be detected as an error condition and cause power to be removed from the drives and the axis brakes applied as described in section 14 (Interlocks):

Azimuth safe rates:

	Elevation >20°:	*-7.5°/sec to +7.5°/sec.*
	Elevation <20°:	*-2°/sec to +2°/sec.*

Elevation safe rates:

	Elevation > 85°	*-7.5°/sec to +2°/sec.*
	20° < Elevation < 85°:	*-7.5°/sec to +7.5°/sec.*
	Elevation < 20°:	*-2°/sec to +7.5°/sec.*

Verification of these specifications is reported in the ORR of the Science & Technical Requirements document (Blanco & Sawyer, WODC TBD).

2.3 Performance goals

2.3.1 Telescope Pointing and Tracking Accuracy

[G]

The CS will control telescope pointing. Pointing accuracy will be measured at the instrument aperture and include all auxiliary optics contributions.

2.3.2 Absolute Pointing and Offsetting

The CS will have absolute telescope pointing accurate to within 2 arcseconds RMS for nighttime observing measured over the full azimuth and elevation observing range of the telescope. The pointing specification will apply when the active optics of the primary and secondary mirror subsystems are operating and after pointing corrections have been applied.

Absolute pointing will be measured and calibrated by performing a mapping of stars distributed over the observing range and the pointing error will be the RMS of the residual pointing errors. Nightly recalibration using a small number of stars will be permitted to meet the pointing specification. Nightly recalibration should take no longer than 10 minutes.

Current absolute telescope pointing accuracy does not meet the required specified accuracy. Typical delivered all-sky pointing accuracy is 10 - 15 arcseconds RMS, although 5 - 10 arcseconds RMS accuracy is sometimes achieved. The exact causes for this level of pointing inaccuracy are currently unknown but suspected to be a combination of encoder performance deficiencies and improper compensation and/or modeling of active optics updates.

The procedure for "cold-start" recalibration of the incremental encoders involves slewing the telescope in elevation until the upper soft limit is reached. Next the azimuth is slewed until the azimuth mid-range switch changes state. Both axes are then backed off until an index mark is reached. The encoders are set at these calibrated positions. Repeatability of the index positions will be <5 arcseconds [G]. Final calibration of the incremental encoders will be done with observations of position standard stars.

Operates as specified.

An offset is a relative move in azimuth and elevation from a known position. Blind offsets rely on the mechanical repeatability of the telescope and encoders and the pointing accuracy of the control system. Offset accuracy is specified for elevations below 85° and is a function of the angular distance moved.

Offsetting accuracy,	*offset < 1°:*	*0.2 arcsecond RMS.*
	1° ≤ offset < 10°:	*1.0 arcsecond RMS.*

The offset pointing error will be measured by selecting 24 pairs of objects uniformly distributed across the sky. Pair separations will be approximately 1° and 10° for the respective specifications. The telescope will be aligned on the first object of a pair and commanded to offset to the second object. The offset pointing error will be the RMS value of the measurements.

The “short distance” offsetting accuracy specification has been achieved. However, the described test requires pairs of stars with absolute astrometry RMS errors smaller than the specification located randomly over the sky. While generating such a list is technically possible, operationally it becomes very time consuming. Therefore, the following test was substituted:

At 24 positions uniformly distributed across the sky within the operating range of the telescope, a baseline star from the HST Guide Star Catalog (GSC) was selected and at least five (5) additional HST Guide Stars less than 1 deg away (radially) from the baseline stars. All stars in a given set were selected from the same Schmidt survey plate as catalogued in the GSC. For stars selected from the same plate, the GSC has a mean astrometric accuracy of approximately 0.2 arcsecond RMS. The telescope was then commanded to offset between the baseline star and each of the auxiliary stars. Offsetting accuracy was monitored using a video signal and a centroiding algorithm accurate to 0.05 arcseconds. Offsetting errors for each individual offset was defined to be the difference between the video position of the baseline star before offsetting and the position of the auxiliary star after offsetting. For each of the 24 positions, a mean offsetting error was computed. The global all-sky offsetting RMS was computed from that mean.

The “long distance” offsetting accuracy specification has not been as thoroughly tested but preliminary results suggest that the telescope meets that specification as well. Nevertheless, this requires further verification.

Offsetting accuracy testing is more thoroughly described in “WIYN Telescope Offsetting Accuracy Testing” by Silva & Lewis (WODC TBD).

2.3.3 Open Loop Tracking

[G]

The telescope will open loop track to 0.1 arcsecond RMS or better for periods of time up to 2 minutes and 0.5 arcsecond RMS or better for periods of time up to 15 minutes. Maximum excursions shall not exceed 0.5 and 1.0 arcseconds respectively.

The tracking error will be determined by pointing the telescope at a reference star, tracking open loop for 15 minutes and measuring the pointing error after 2 and 15 minutes. This process will be repeated 24 times on objects distributed over the observing range of the telescope and the maximum and RMS values of the 2 minute and 15 minute trials will be calculated. These goals have not been achieved. They were tested by placing a star in the center of a video centroiding box and then measuring its centroid for the specified period. At no position on the sky were the goals achieved. Drift rates of 0.1 arcsec/min to 0.5 arcsec/min were measured. Note that these drifts were “smooth” and the scatter about the drift trend was typically 0.2 arcsec RMS or less. This is not unexpected given the current all-sky absolute pointing accuracy. In fact, the sky positions with the worst open-loop tracking performance appear to be correlated with sky positions with worst pointing residuals. In our opinion, it will not be possible to approach this goal until the all-sky pointing accuracy is significantly improved.

A more complete report of these test will be presented in "Testing WIYN Telescope Open-Loop Tracking Performance" by Silva & Lewis (WODC TBD).

2.3.4 Closed Loop Tracking

Closed loop tracking (autoguiding) is defined as tracking a celestial object using an external error signal such as provided by the Instrument Adapter Subsystem or by a Science Instrument. The CS will provide a means for guiding the telescope from these signals.

The error signals will be updated at a maximum rate of 10 Hz and will be supplied to the control system in the natural coordinate system of the guider ("guider coordinates"). The "gain" and "bandwidth" of the correction feedback loop will be adjustable in software through the user interface. The telescope shall track the error signal to 90% or 0.05 arcseconds, whichever is greater, within 1 second for an error signal of less than 2 arcseconds [G]. The guide specifications when guide errors exceed 2 arcseconds are the same as for offsetting. Completed as specified except as follows:

- The current maximum update rate of the Imager guider is 2 Hz. Planned Imager guider modifications will increase this to the specified 10 Hz. The Hydra/FOPS guider can issue updates at 10 Hz.
- Inspection of servo error data recorded at 200 Hz suggests that the "restoration" goal has been met but more vigorous analysis of the data is required to confirm this conclusion.

2.3.5 Maximum Times to Reposition Telescope

[G]

The time to reposition the telescope is defined as the time to move between two positions within the azimuth and elevation observing range ending up with the telescope pointing and open loop tracking within specifications. The time to reposition shall not exceed the following:

Offsets up to 0.5° and ΔAz < 1°:	*3 seconds.*
Traverse angle <10° and ΔAz < 10°:	*20 seconds.*
Between any two allowed positions:	*100 seconds worst case.*

Worst case includes the situation where the azimuth is required to rotate more than 360° to avoid cable wrap-up.

The "short" and "intermediate" repositioning time specifications have been met. The "maximum" repositioning specification is *ab initio* unachievable given the speeds and accelerations specified in WODC 01-20-11. In testing, the delivered "maximum" repositioning time was measured to be roughly 150 secs.

2.3.6 Unbalanced torques

Completed as specified in WODC 01-20-11.

2.4 Limit switches and Azimuth Midrange Switch

Completed as specified in WODC 01-20-11.

2.5 Velocity Limit Switches

The velocities of the elevation and azimuth axes will be limited to the "safe" values specified in section 2.2.3. In normal operation, the maximum rates permitted under software control are less than the "safe" rates and no error condition exists. Velocity transducers on the axes and associated logic will detect a runaway condition and *bring the telescope to a stop by shutting off the servo power and applying the brakes. Tilt sensitive switches on the OSS will be used to select the appropriate trip velocities as specified in 2.2.3. These are in addition to the limit switches described in section 2.4. The control system will detect when an over-velocity condition occurs and signal the operator.*

The operation of the "safe" velocity limits shall not depend on the axis control hardware and software in such a way that a single point failure of the system could cause an uncontrollable runaway condition of either axis.

The control system will provide inputs, power, cabling and interlocks for implementing the velocity limit switches. The switches and transducers will be supplied with the telescope. The selection of transducers and switches will be coordinated with the telescope mount task.

NEED TO REVIEW WITH BLANCO/SAWYER.

2.6 Brakes

Completed as specified in WODC 01-20-11.

2.7 Telescope Balance Sense

The required accuracy for sensing the current is 100 ma with a goal of 1% at constant track rate.

NEED TO REVIEW WITH BLANCO/SAWYER

3. Secondary Mirror

Completed as specified in WODC 01-20-11 except as follows:

Default settings will be used from the previous night and current structure temperature for the initial set-up.

The previous night settings are not used automatically as this is not sensible given the active nature of secondary positioning during the night.

Pointing accuracies due to motion of the secondary are included in and will be consistent with the previously defined telescope pointing and tracking requirements.

As described in Section 2.1, this is currently not handled correctly but will be soon.

3.1 Secondary Mirror Position Specifications

Completed as specified in WODC 01-20-11.

3.2 Autofocus & Autocollimation

Completed as specified in WODC 01-20-11 except as follows:

Focus and collimation errors will be corrected by piston and tilt motions of the secondary mirror. Two modes of autofocus and autocollimation will be provided. In the open-loop mode, focus and tilt corrections will be calculated from the elevation angle and OSS structure temperature. These will be used to derive corrective motions of the position actuators. The temperature sensors, read electronics, and control software are all part of the CS task.

Open-loop temperature based focus compensation has not been completed at this time but is currently undergoing testing and should be completed by 1 March 1996. There are no immediate plans in implement open-loop temperature based tilt corrections.

A closed-loop autofocus capability will also be provided to take external focus information from the Instrument Adapter Subsystem or directly from the Science Instrument and produce the appropriate focus motions of the actuators. This capability will override open loop operation when enabled. The minimum update period is 30 seconds.

This functionality has not been implemented yet but is an approved software improvement project.

Adjustment errors from the focus probe will be stored and become the default values on startup.

These errors are not stored as the current focus adjustment system is differential, not absolute.

A closed-loop autocollimation capability will be provided to take collimation information from the Primary Mirror Subsystem (PMS) and produce the appropriate tilt motions of the actuators. This capability will override the open-loop operation when enabled. Minimum update period is 30 seconds.

While the PMS does issue collimation updates to the secondary and these updates are applied, this operation is open-loop, not closed-loop, in the sense that these updates are generated from as a function of telescope elevation from a previously determined lookup table. There is no provision for measuring collimation in real-time and updating the secondary tilt in a true closed-loop manner.

Motors shall be turned off when not operating to minimize heat dissipation at the top of the telescope. The mechanical design will ensure that the secondary position does not creep with motor power off.

The motors are currently always left on because secondary position commands are issued asynchronously creating the possibility that one positioning command could turn off the motors before a simultaneous positioning command was completed. The new secondary control interface which is nearing final release acts as a buffer for all secondary commands, essentially queuing them up and executing them in a known and controlled sequence. This will ultimately allow these motors to be turned off every time the positioning command queue has been completed.

4. Tertiary Mirror

Completed as specified in WODC 01-20-11 except as follows:

The status of the operation and the tertiary position will be made available to the operator on the System Status Display.

This information is not currently displayed on the SSDs but is readily available elsewhere. It could be easily added to the SSD at a later date if deemed desirable.

4.1 Tertiary Rotation Specifications

4.2 Tertiary Folding Mechanism Specifications

Verification of the specifications listed in Sections 4.1 and 4.2 of WODC 01-20-11 are discussed in the ORR of the top-level Science & Technical Requirements document (Blanco and Sawyer, WODC TBD).

5. Instrument Rotators

Completed as specified in WODC 01-20-11 except as follows:

The NIR will operate in either manual or automatic mode as selected by the operator. In automatic mode, the instrument rotation will be transparent to the user after initialization. At any time the operator may reinitialize the rotator angle, command the rotator to move to a specified angle or command the rotator to rotate by a fixed incremental angle. When rotating by a fixed increment, the amount of track rotation lost during the move is added to the final position.

The authors of this document do not completely understand the intend of the last sentence of the above paragraph. Nevertheless, the NIR tracking as implemented does not lose rotational position during a telescope move, although the telescope move can be completed before the NIR reaches the correct position.

The rotator position relative to the reference mark will be monitored and shown on the System Status Display. Recalibration of the rotation angle zero point by the operator from observations of star pairs will be permitted.

The described recalibration is not forbidden but there is no implemented functionality for this operation.

The accuracy of the position angle control will be measured by selecting pairs of stars on opposite sides of the field and measuring the relative rotation of the two images with guide probes (a) after a repositioning of the rotator and (b) while tracking the telescope. Development of a procedure and software for measuring rotator accuracy is included in the CS rotator task.

The described procedure and software has not been implemented and there are no current plans for its implementation.

5.1 Instrument Rotator Mechanical Specifications

Completed as specified in WODC 01-20-11 except as follows:

[G]

Accuracy: *5 arcseconds.*

This has not been verified at this time.

6. Mirror Covers

Completed as specified in WODC 01-20-11.

7. Flat-field Lamps

Completed as specified in WODC 01-20-11.

8. OSS Counterbalance

Completed as specified in WODC 01-20-11 except as follows:

Limit switches will be provided at the ends of travel of the weights. Absolute encoders will measure their positions. The CS will provide a lookup table for various telescope/instrument configurations that may need automatic movement of the counterweights to compensate for balance changes during, for example, tertiary fold-up or mirror cover operation.

Open-loop counterweight adjustments has not been implemented but is in the current software improvement projects queue at a low priority.

9. Dome

Completed as specified in WODC 01-20-11.

9.1 Dome Mechanical

9.1.1 Dome Positioning

The CS will provide the capability to automatically synchronize the dome to the telescope position and maintain a clear field-of-view during telescope tracking and guiding. The dome position error when synchronized will be controlled by the software with the finest level of control approximately ± 3 cm RMS when measured from the center of the dome opening to the telescope optical axis.

The CS will also provide the capability of positioning the dome to a commanded position independent of the telescope position with an accuracy of ± 5 cm. measured at the dome encoder.

On-site testing demonstrates that the dome repositions to $\pm$ 1 “tooth” which is within both specifications described above.

9.1.2 Brakes and Clamp Mechanisms

9.1.3 Mechanical Properties

9.1.4 Dome Motions

Sections 9.1.2, 9.1.3, and 9.1.4 completed as specified in WODC 01-20-11 except as follows:.

To minimize power dissipation while tracking, the dome will move in discrete steps and the power will be turned off while stopped.

Has not been verified at this time.

9.2 Maintenance Hand paddle

A portable hand paddle that bypasses the control system will be provided for rotating the dome. It will provide the following functions:

- *Rotate CW.*
- *Rotate CCW.*
- *Rate control.*
- *Clamp control.*

The hand paddle will plug into permanently mounted connectors located (a) near the drive controllers, (b) outside on the maintenance platform, and (c) in two locations on the observing floor near the drive motors. A fifty foot cable will be provided with the controller.

A keyed, three-position, panel mounted switch near the drive controllers will select between service and computer controlled modes (AUTO or OPERATOR). Three positions will be provided: "AUTO", "LOCKED" and "MAINTENANCE". In the "LOCKED" position both hand paddle and computer generated commands are inhibited and the rotation clamps are set. In the "MAINTENANCE" position, hand paddle functions are enabled and computer generated moves are inhibited. In "AUTO" position, both AUTO and OPERATOR modes are available as enabled by the selected software mode and maintenance hand paddle commands are inhibited.

The control system will sense the state of the switch and signal an error condition if the operator attempts to move the dome with the control system while the switch is in the LOCKED or MAINTENANCE position.

The CS task will provide the hand paddle, cabling, and mode control switch.

Functionality has not been verified at this time.

10. Time Standards

Completed as specified in WODC 01-20-11.

11. Environmental Data

Completed as specified in WODC 01-20-11 except as follows:

The CS will monitor temperatures on the telescope structure. Sensors will be placed in 16 places about the telescope and have an accuracy of 0.3°C over the operating temperature range of the telescope.

The temperature sensors are current out-of-spec but hardware has recently arrived which should allow them to be brought into spec by 1 March 1996.

Survival conditions:

Temperature:	*-20°C to 50°C*
Wind speed:	*150 mph.*
Humidity:	*100% rain, ice, snow.*
Altitude:	*6838'.*

Weather station sensors will be mounted on an existing tower approximately 100' from the control building.

The authors note that survival from lightening strike is not specified as a survival condition although that is the most likely failure mode of this system given its location.

12. Operator Controls

Completed as specified in WODC 01-20-11.

12.1 Control Panel Functions

Completed as specified in WODC 01-20-11.

12.2 Console

Completed as specified in WODC 01-20-11.

12.3 System Status Display

Completed as specified in WODC 01-20-11.

12.4 Telescope Manual controllers

Completed as specified in WODC 01-20-11.

12.4.1 Functional Requirements

Completed as specified in WODC 01-20-11 except as follows:.

Mount motion commands will be interpreted according to a software settable mode as (1) equatorial, (2) alt-az, or (3) guider coordinates. On system initialization, the default mode will be equatorial coordinates.

Handpaddle controlled mount motion in guider coordinates currently not implemented. On system initialization, the default mode is alt-az, not equatorial coordinates as specified.

12.4.2 Locations.

Completed as specified in WODC 01-20-11.

12.5 Graphical User Interface

The specifications in Sections 12.5 and 12.5.1 to 12.5.9 of WODC 01-20-11 were superseded by the document "Design Requirements for the Graphical User Interface (GUI) for the WIYN 3.5M Telescope" (WODC 01-22-2). That document is reviewed in TBD.

12.6 Command Line Interface

Completed as specified in WODC 01-20-11 except as follows:

A Command Line Interface (CLI) will provide access to the complete set of telescope functions and diagnostics. It will include, in addition to the commands provided with the GUI, commands for:

- *Reading positions, limit switches and status information.*
- *Reading motor current in the mount drives.*

The CLI was designed and implemented to issue commands only. The specified telemetry features are provided by the Engineering Data System as sketched out in section 15.3.

12.7 Program File Interface

The Program File Interface (PFI) will be implemented in a second development phase of the control system. The PFI will use the syntax of the CLI but will include additional control structures to allow unattended ("programmed") operation of the telescope. PFI commands would normally be entered into a file that would be executed by the telescope and science instrumentation at the appropriate times.

The following capabilities are required:

- *Execute CLI commands.*
- *Forward Science Instrument commands to the Science Instrument.*
- *Forward Instrument Adapter commands to the Instrument Adapter Subsystem.*
- *Check the status return for all commands.*
- *Branching.*

- *Loops.*
- *Pause/signal for operator intervention/input.*
- *Maintain observing log.*

Development of the PFI will be undertaken after completion of the other CS tasks. The implementation of the CLI should provide the appropriate hooks and handshake signals for this expansion.

This functionality is available but not as described as the CS evolved differently than envisioned here.

12.8 Access Permission

The control system shall provide a mechanism for controlling access to specific commands. Permissions shall be granted by network node for each command.

The master WIYN router can only block commands from specific IP addresses, it cannot block specific commands. The mpgrouter has increased functionality in this area and eventually the two routers should be merged.

13. Subsystem Interfaces

13.1 Electrical Supplies

Completed as specified in WODC 01-20-11.

13.2 Observatory LAN

Completed as specified in WODC 01-20-11.

13.3 Primary Mirror Subsystem

Completed as specified in WODC 01-20-11.

13.4 KPNO WWV Time Distribution Network

Completed as specified in WODC 01-20-11.

13.5 Instrument Adapter Subsystem

Completed as specified in WODC 01-20-11 except as follows:.

The probes will be able to track independently of the telescope tracking to allow guiding on objects at non-sidereal rates. Non-sidereal track rates will be specified as constant velocities in RA and Dec.

This functionality has not been implemented and there are no plans to implement it at this time. However, there is nothing hindering future implementation if that is deemed desirable.

The raw image frames will be available over the observatory LAN.

This specification is ambiguous. The observatory Ethernet LAN is not designed to transmit raw video signals as output by the guide and focus probes. It might be possible to digitize individual frames or a sequence of frames and transmit that over the Observatory LAN but that functionality is not currently implemented. The guide and focus probe video signals are distributed throughout the Observatory using the video distribution system, which is some sense a different kind of LAN.

The output of the wavefront sensor will go directly to Primary Mirror Subsystem over a bus TBD and will be reduced by the PMS.

Not currently implemented but part on an active improvement project.

13.6 Mountain Ethernet LAN

Functionality implemented as specified in WODC 01-20-11.

13.7 Science Instrument & Data Reduction Computers

Completed as specified in WODC 01-20-11 except as follows:

The control system will accept status from the SI. Status information will include such items as:

- *Instrument ID.*
- *Instrument configuration.*
- *Observation in progress.*
- *Otherwise busy.*
- *Duration of current activity.*
- *Observation done.*
- *Ready.*
- *Error.*

The CS architecture evolved differently than envisioned in WODC 01-20-11. The as-implemented CS does accept not this information nor do the SI broadcast all the information specified.

The control system will maintain a configuration file for each instrument with such information as:

- *Instrument ID.*
- *Focus offsets for various filters and instrument configurations.*
- *Coordinates of focal surface center relative to the instrument mount.*
- *Orientation and scale for guide probes.*
- *Counterweight position.*
- *Instrument rotator software limits.*

Provisions for this functionality have been implemented in the higher level Graphical User Interface.

13.8 Remote Stations

The CS will interface to remote stations over the mountain LAN and possibly by dedicated leased lines. The CS will make the following available to the remote stations:

- *Telescope and dome control as specified in section 12.*
- *Position display and status information included in the System Status Display.*
- *Access to SIs and the IAS.*

Access to commands will be controlled by as specified in section 12.8.

All functionality implemented except access to the SIs. Making the SIs more remote access "friendly" is part of an on-going remote observing initiative.

13.9 Uninterruptible Power Supplies

Completed as specified in WODC 01-20-11.

14. Interlocks

Completed as specified in WODC 01-20-11 except as follows:.

† *Emergency Stop: Hardwired control removes power from the telescope and dome drives and sets brakes in response to activation of an "Emergency Stop" button or shutdown of the system key lock. "Emergency Stop" pushbuttons will be provided in the control room, on the observing floor, on the second level and inside the pier. Pushbuttons will remain activated until manually reset. An emergency stop will be detected by the control system and cause a software reset of the drive controls for the telescope and dome. System restore requires activation of the key lock on the console.*

Additional E-stops were installed on the telescope itself near each of the NIRs, the pinch points near the elevation axis, and near the mirror cover pinch point.

† *Elevation runaway: Removes power from the telescope drives and sets the brakes in response to a runaway condition of the OSS as described in section 2.5. Maximum velocities are specified in section 2.2.3, Accelerations and Rates.*

† *Azimuth runaway: Removes power from the telescope drives and sets the brakes in response to a runaway condition of the OSS as described in section 2.5. Maximum velocities are specified in section 2.2.3, Accelerations and Rates.*

Reviewed in the ORR of the top-level Science & Technical Requirements document (Blanco and Sawyer, WODC TBD).

15. Utility Software

15.1 Coordinate transformations

The control system task will include all necessary software for transforming coordinate systems from equatorial and galactic coordinates to mount and focal plane coordinates. Time and epoch conversion and reduction of celestial coordinates for precession, aberration, nutation, refraction and proper motion will be provided. Reduction to focal plane coordinate will correct for optical distortion of the field. The user will input catalogue positions to the CS and the CS will use these routines in pointing the telescope.

The specified optical distortion correction has not been implemented and it is not clear that this is necessary or desirable.

15.2 Generating pointing maps

Completed as specified in WODC 01-20-11.

15.3 System diagnostics

System diagnostic software necessary for verifying system performance as specified herein is included in the CS task. It will include:

- *Focus stability.*
- *Dome pointing and tracking.*

Additional software will be provided at the subsystem level for checking the operation of motors, encoders, sensors, switches, etc. These diagnostics will be available at the system level through the user interface and at the subsystem level through a terminal connected at that level or by other means.

The Observatory is somewhat deficient in this area. Although there are routines which do some of the envisioned system diagnostic tasks (e.g. TPOINT), the Observatory would clear benefit from an organized improvement project to design and implement a more comprehensive suite of diagnostic tools.

15.4 Engineering data logs

The CS will create a process for time tagging and logging engineering data from the Control System, Primary Mirror Subsystem, Instrument Adapter Subsystem and any other connected subsystem that sends to the logger. The CS task will define a standard format for the data and a masking mechanism for letting the operator select what data is recorded.

Engineering data that will be generated within the CS include:

- *Configuration changes.*
- *Telescope moves.*
- *Dome moves.*
- *Track corrections.*
- *Focus corrections.*
- *Environmental data.*
- *Error conditions.*

The baseline system only masks this information at the Engineering Data Record level. An EDR contains a complete system telemetry set. EDRs are issued at 1 Hz. The mpgrouter can filter information at the individual parameter level.

16. General Design Requirements

16.1 Environments

Completed as specified in WODC 01-20-11.

16.2 Design Guidelines

The authors stipulate that all engineers and programs involved in CS implementation tried to adhere to these guidelines.

16.3 Hardware Standards

- *Commercially produced circuit boards will be favored over custom designed boards.*
- *Cabling is an initial expense and maintenance problem that should be minimized. Serial, party-line, communication between subsystems should be used wherever possible.*
- *High reliability connectors will be used and cables will be strain relieved.*
- *Mechanical design will be ruggedized to industrial standards.*

- *Spares will be provided to allow repair of equipment by board replacement. Board repair will be accomplished off-line.*
- *Computers will provide a port for maintenance terminal support including a user interface for performing maintenance and diagnostic functions.*
- *Equipment will be energy efficient. Waste heat production will be minimized in the dome.*

In general, these guidelines were followed satisfactorily. Nevertheless, we recommend that the Site Manager reviewed the delivered hardware to assure adequate spares and to develop repair and maintenance procedures.

16.4 Chassis and panels

Completed as specified in WODC 01-20-11 except as follows:

- *Equipment installed in the telescope enclosure will be mounted in standard 19" EIA instrument racks or wall mounted panels with power strips and a duct for connecting to the ventilation system. Cable routing is TBD.*

The equipment racks installed at Location B do not connect to the enclosure ventilation system and currently deposit their waste heat directly into the telescope enclosure. A long planned but lower priority improvement project to connect these racks to the enclosure ventilation system has not been completed.

16.5 Electrical power

Completed as specified in WODC 01-20-11.

16.6 Thermal Requirements

Maintaining a "clean" thermal environment around the telescope is of prime importance. Equipment that releases waste heat into the telescope beam will be limited to 10 Watts average, 25 Watts maximum. Waste heat in excess of this will have to be trapped and exhausted away from the telescope. Total released waste heat in the telescope chamber during observing due to the control system excluding motors is 100 Watts average, 200 Watts maximum.

Equipment on the telescope may be connected to ventilation ducts in the telescope mount for extracting waste heat.

The Optical Support Structure Control System chassis mounted on the OSS remains a thermal problem during the day when its power supplies are on but the telescope ventilation system is off. This results in differential heading of the OSS, which may be causing some of the comatic aberration often seen at the beginning of the night. The Site Manager intends to install a fan to exhaust the heat from the chassis into the dome during the day which should greatly mitigate this problem.

17. Documentation

A complete set of documentation will be provided with the control system. This will include:

Design Documents:

- *System requirements.*
- *System specification.*
- *Interface Control.*

- *Schematic drawings and wiring diagrams.*
- *Parts lists.*
- *Operator and maintenance manuals.*

Software:

- *Block diagrams.*
- *Software listings.*
- *Descriptions of subroutines & algorithms.*
- *Operator's manuals.*

CS documentation is currently under review. A list of missing documentation which is also desired will be generated. The Site Manager will then work with the appropriate groups to acquire and/or complete the CS documentation.

18. Maintenance & Upgrades

A detailed plan for maintaining and periodically upgrading the Control Subsystem over its lifetime will be part of the CS task. The plan will consider:

- *Maintenance requirements including an estimate of required resources.*

- *The method of upgrading the system to add capabilities and performance. Areas where upgrades are anticipated should be identified with an estimate of the required effort and resources.*

These issues will be addressed in the context of the mountain environment where the system will be operating. The plan will be delivered with the control system.

Such a detailed plan does not exist at this time. We recommend that the WIYN Site Manager consider convening a working group to develop and implement such a plan at their earliest convenience.