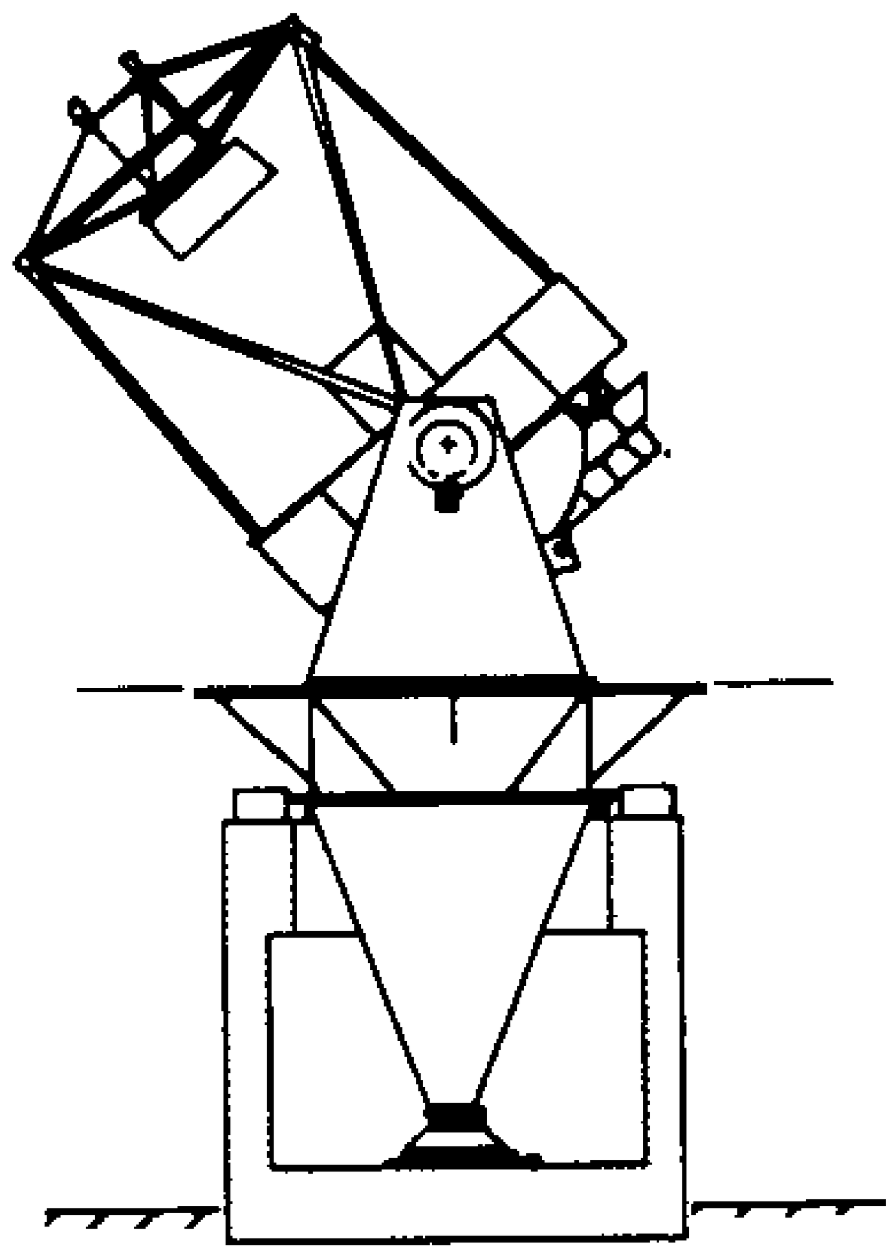
Wisconsin
Indiana
Yale
NOAO



3.5 Meter Telescope

Scientific & Technical Requirements for the WIYN 3.5 Meter Telescope

WODC 00-01-04

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Title: Scientific and Technical Requirements for the WIYN 3.5 Meter Telescope

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Reviewed and approved:

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Project Manager Date

/Gus Oemler
Scientific & Advisory Committee Date

/Blair Savage
WIYN Board Date

REVISION LIST

Revision 4: Date: 5/12/91

.1 Section 1. Purpose of project, paragraph 1, is changed to state that first light is planned for 1994.

.2 Section 6.3: Faint limit for the image analyzer is $m_V = 9$.

.3 Section 6.6: Two banks of flat field lamps will be provided: a high intensity set for quick exposures and a continuum set with color balance filters.

.4 Section 7: The following specifications for the wide-field Nasmyth (MOS Port) are changed:

Back focus distance from S:	533.4 $\pm$ 0.6 mm nominal.
Imbalance about axis:	150 N-m max.

.5 Section 7: Added specifications for the folded cassegrain instrument mount.

.6 Section 7: Added specifications for the modified cassegrain instrument mount.

General Scientific & Technical Requirements

1. Purpose of project

New capabilities in astronomical instruments in combination with more sophisticated theories are leading to rapid advances in our understanding of the universe. As a result, the demand for large telescope time far exceeds the time available on existing instruments. NOAO is joining with the University of Wisconsin, Indiana University, and Yale University to build a 3.5-meter telescope on Kitt Peak to improve the facilities and to expand capabilities available to the U.S. astronomical community and give the three universities assured access to a large telescope . First light is planned for 1994.

The consortium has identified optical spectroscopy as the area in which the WIYN telescope can have the greatest impact. The development of fiber optics enabling simultaneous observations of a large number of objects has greatly improved the efficiency of spectroscopy. For a number of years NOAO has employed fibers to pipe light to instruments off the telescope.[1] About half of the WIYN telescope time will be devoted to multi-fiber spectroscopy. An automated fiber positioner with a capability of 100 blue-optimized and 100 red-optimized fibers is currently under construction at NOAO and is described by Barden and Rudeen.[2] A bench mounted, fiber-fed Multi-Object Spectrograph (MOS) capable of taking 100 spectra simultaneously is also being constructed[3]. These instruments will initially be used on the Kitt Peak 4-m telescope and eventually they will become part of WIYN.

The telescope will also be used for a variety of instruments developed by the universities and NOAO. A large format CCD imager is the first of such instruments and others are planned. Excellent imaging performance is an important goal for the telescope.

While the main purpose of the WIYN project is to provide a state of the art facility for astronomical research, the telescope will serve as a test bed for new technology being developed as part of NOAO's 8-m Telescopes Project. The WIYN primary mirror supports and ventilation system are prototypes for the larger telescopes, and WIYN's experience with active optics and distributed control systems will also be applicable to the 8-m effort.

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[1] S. C. Barden, "Fiber Optics at Kitt Peak National Observatory", *Instrumentation for Ground-Based Optical Astronomy"*, ed. L. B. Robinson, 1988.

[2] S. C. Barden and A. Rudeen, "The Kitt Peak National Observatory Fiber Actuator Device", *Instrumentation in Astronomy VII*, ed. D. L. Crawford, vol. 1235, SPIE, 1990.

[3] D. Vaughnn, BAAS **22**, p. 887, 1990.

2. General Considerations

The scientific and technical requirements in this document represent engineering tasks of varying difficulty. These requirements, separated into two categories, are classified as specifications or goals according to the following definitions:

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

A goal is a performance capability that has been recommended by the SAC but which requires 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 will design to the goals and report to the SAC when changes are advisable. Proposed modifications will include an assessment of the technical impact and budgetary and schedule implications. Modifications to goals will be approved by the SAC. Goals will be converted to specifications by the SAC as development allows. Goals which 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 are 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 are goals. Requirements without a G-label are specifications.

2.1 Basic design

The telescope will benefit from experience gained from the Astronomical Research Corporation 3.5-m telescope, having a compact altitude-azimuth design with rolling element bearings and friction drives. For simplicity, cost and operational ease, it will have a single secondary and all instruments will share a common back-focus. The two Nasmyth foci will be the principal instrument positions. The telescope will have a wide field of view to take advantage of recent advances in fiber fed instrumentation and will be designed to take advantage of excellent imaging expected at the site.

[G]

Two additional foci are being planned for future expansion: a folded-cassegrain port on the top side of the optical support structure (OSS) and a modified-cassegrain focus immediately below the primary mirror. The beam will be directed to the folded-cassegrain focus by rotating the tertiary 90° about the primary optical axis from the Nasmyth positions. The tertiary will fold out of the way to allow the beam to reach the modified cassegrain focus. The initial design of the telescope will not include instrument rotators for these foci or the tertiary folding mechanism.

3. Optical Design

The parent design of the telescope optics is Ritchey-Chrétien. The principal foci will be at the two Nasmyth locations. A third, folded Cassegrain, focus will be accessible for future use. Nominally all three foci will be parfocal. A fourth focus located in the center hole of the mirror cell will be used for polarimetry. Auxiliary optics will shorten the back focal distance for that focus.

3.1 Principal optics

Primary Mirror:	
Shape:	Concave hyperboloid
Diameter	3.5 meter
Focal ratio:	f/1.75
Central hole diameter:	0.96 meter
Radius of curvature:	12.250 meter
Conic constant:	-1.070833
Secondary Mirror:	
Shape:	Convex hyperboloid
Diameter:	1.2 meter
Radius of curvature:	5.332 meters
Conic constant:	-3.731667
Tertiary Mirror:	
Shape:	Plano, quasi-elliptical.
Major diameter:	1.10 meter
Minor diameter:	0.77 meter

3.2 Specification of foci

All foci except modified Cassegrain:		
Focal ratio:	f/6.3	
Plate scale:	9.36 arcsec./mm	
Bare R-C without corrector:		
Nominal field of view:	15 arcminutes.	
Linear field:	96 mm.	
Field radius of curvature:	2.11 meter.	
Distance to exit pupil:	8.5 meter from focal surface.	
Wide-field Nasmyth (MOS Port):		
Corrector:	Doublet, all spherical surfaces, AR coat.	[G]
Corrected field of view:	1°	
Linear field:	385 mm.	
Wavelength range[1]:	3300 A - 1.5 μm.	[G]
Field radius of curvature:	5.51 meter.	[G]
Broadband focus tolerance:	$\delta\lambda/\lambda$ = 0.5 for 0.1 arcsec. enlargement	

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[1] Wavelength range over which images will meet the error budget. The range is set by the corrector design. The corrector will transmit down to the atmospheric cut-off with the image quality unspecified outside of the nominal range. [G]

The wide-field use of the telescope will be primarily for multi-object spectroscopy (MOS). MOS uses 200- and 300-micron optical fibers corresponding to 2 and 3 arcseconds on the sky respectively and doesn't require the sub-arcsecond images of the narrow field applications. The wide-field image budget is made larger to simplify the control requirements at the wide-field port. Should a requirement arise for improved wide-field imaging, guide/focus sensors and a wavefront analyzer could be provided at that port to achieve 0.38 arcsecond telescope performance.

The image budget applies to zenith distances up to 60°. The telescope will operate at lower elevations as specified in a section 5. The contribution to image size from seeing grows as $(\cos z)^{-3/5}$ where z is the zenith distance. The image budgets for the telescope and enclosure are allowed to increase according to the same law thus keeping the relative contributions the same.

The environmental conditions under which the image budget applies are: nighttime observing, wind speeds up to 10 m/sec. and outside air temperature gradients less than 0.5°C/hour. (10 m/sec. is approximately the 90 percentile wind speed on Kitt Peak).

The error budget for alignment includes the effects of despacing of the optical elements (focus) and collimation. The collimation term will be mostly effected by decentration and tilt of the secondary mirror with respect to the optical axis of the primary and, to a lesser extent, by decentration and tilt of the correctors.

The tracking error budget includes the effects of the telescope mechanical motions ("drives"), wind shake, and guide errors ("control system") including errors in matching field rotation.

The budgets for thermal degradation include the effects of thermal distortion of the optics and mirror seeing.

5. Telescope

[G]

Axis motion:	
Azimuth:	+/- 270°
Zenith angle, observing:	0.4° < z < 75°
Zenith angle, hard stops:	-2° and 90°
Zenith blind spot:	0.8° diameter max.
Slewing:	
Maximum slew rate:	5°/sec.
Slew ramp:	$1°/sec^2$
Settling time:	10 sec. max.
Time for track to track:	100 sec. max., < 360° azimuth rotation. 20 sec. max, < 10° offset & < 10° azimuth.

Field acquisition:	
Sensor type:	TBD.
Field of view:	1.5 arcminute
Limiting magnitude:	$m_V = 21$ in 10 seconds with a dark sky.
Set-up time:	5 seconds.
Guider:	
Number:	Two probes.
Sensor type:	TBD.
Field of view:	1.5 arcminute.
Sensitivity:	Centroid to 10% of seeing disk at $m_V = 16$ & 1 Hz.
Update rate:	0.1 Hz. to 1 Hz.
Set-up time:	10 seconds.
Autofocus:	
Sensitivity:	5% degradation of delivered image at $m_V = 16$ averaged over 30 seconds.
Update rate:	30 seconds.
Set-up time:	10 seconds.
Program interruption:	None allowed.
Image analyzer:	
Faint limit:	$m_V = 9$.
Integration time:	30 seconds.
Set-up time:	15 seconds.
Program interruption:	≤ 2 minutes including active collimation.
Update requirement:	≥ 30 minutes.
Internal Calibration sources:	
Beam shape:	TBD.
Wavelength calibration:	TBD.
Continuum source:	TBD.
Atmospheric dispersion compensator (ADC):	
Type:	4-element, 2 rotating groups, AR coatings.
Optical design:	Coma correction over 30 arcminute field. Parfocal with R-C focus.
Design wavelengths:	3500A - 1.1 micron.
Estimated throughput:	
3341A:	49%
3500A:	73%
4000A:	89%
1.1 micron:	89%
Set-up time:	10 seconds.
Time to insert:	1 minute, manual operation.

Usable with field acquisition, guiders, autofocus, image analyzer, and calibration sources.

Folded Cassegrain:

Mounting surface (S):	Flange on center section of OSS.
Back focus distance from S:	977.9 $\pm$ 0.6 mm nominal.
Instrument weight:	400 kg max.
Cantilever moment from S:	2000 N-m max.

Modified Cassegrain:

Mounting surface (S):	Flange on bottom of mirror cell assembly.
Back focus distance from S:	1941.8 $\pm$ 0.6 mm nominal.
Distance of S to elevation axis:	1233.17 mm
Instrument weight:	175 kg max.
Cantilever moment from S:	400 N-m max.

8. Instrument support

Requirements for power, gasses, vacuum, waste heat extraction and cabling at the various scientific instrument locations.

8.1 Nasmyth instruments

[G]

Services provided for instrument support at each Nasmyth focus. Unless noted, termination will be on a panel fixed to the fork tine.

Power:

Uninterruptible clean power:	120 VAC, 15 amp.
Dirty power:	120 VAC, 15 amp.

Signal lines (from computer room):

Control:	Serial TBD, three cables.
Data:	Optical fiber, number TBD.
	Coaxial cable, number TBD.
Video acq./guide/wavefront:	Serial TBD, four cables.
Camera gain:	Four twisted pairs.

Fiberoptic feed to spectrograph room:
Cableway for four 100 optical fiber cables in four 2" diameter armored flex-conduits. Fibers will be terminated on the instrument.

Gasses & coolant:

Dry filtered N_2:	10 cfh at 5 psi.
Coolant (piping only):	2 lines, 0.38" ID terminate in mech. rm.

Waste heat scavenge:
Connection to mount exhaust plenum through fitting on tine.

9.1 HYDRA

[G]

Description:

Robot for positioning fiber optics in the focal plane of the MOS port. See Appendix A[1]. HYDRA will mount directly to the instrument rotator and place its focal plane at the appropriate position as specified in section 7. The fibers will pipe light to a spectrograph off the telescope. Means will be provided for acquiring the field and for sensing guide errors, field rotation and focus errors. An alignment camera with the ability to simultaneously view the superimposed images of the fiber and program object will provide a check of fiber positioning.

Positioner:

Usable field diameter:	385 mm.
Field curvature compensation:	TBD.
Area lost to steps:	$\leq$TBD.
Mechanical positioning accuracy:	$\leq 20\,\mu m$.
Min. fiber-fiber spacing:	3.5 mm.
Mean setup time per fiber:	≤ 9 sec.
Max. number of fibers:	200.
Min. number of science fibers:	180.
Size:	1.5 m x 1.5 m x 0.9 m D.
Weight:	227 kg.
Power:	TBD.
Temperature range:	TBD.
Humidity:	TBD.

Fiber placement camera:

Type:	Intensified CCD (Amperex 1610).
Input photocathode:	S25 with extended blue response.
Brightness operating range:	m_V = 8-21.
Active imaging diameter:	18 mm.
Controls:	Power & gain.
Output:	RS170 standard video format.

Field alignment/guide camera:

Type:	Intensified Lens coupled CCD.
Designation:	NOAO type ILS.
Input photocathode:	S25.
Brightness operating range:	m_V = 11-17.
Active imaging diameter:	16 mm.
Controls:	Power & gain.
Output:	RS170 standard video format.

[1] S. C. Barden and A. Rudeen, "The Kitt Peak National Observatory fiber actuator device", *SPIE 1236*, 1990.

Collimator:

Focal length:	1020 mm.
Aperture:	240 mm.

MOS Glass Filters	
F1:	RG-610
F2:	RG-695
F3:	GG-375
F4:	GG-420
F5:	GG-495
F6:	BG-38
F7:	BG-39

MOS Interference Filters			
		λc	$\delta\lambda$
IF1:	Mg I	5174A	17A
IF2:	Li I	6712A	28A
IF3:	H-alpha	6562A	28A

WIYN/MOS Low Dispersion Gratings

				Red Camera			Blue	
Camera	Grating	Ruling	θ_B	Order	λ_c	$\delta\lambda/\delta x$	λ_c	$\delta\lambda/\delta x$
		lines/mm	degrees		A	A/mm	A	A/mm
G1: TBD.								

θ_B : Blaze angle; λ_c: Wavelength; $\delta\lambda/\delta x$: Dispersion.

Low resolution gratings:

Type:	Plane reflection.
Size:	204 mm x 254 mm nominal.
Selection:	See table above.

Echelle:

Type:	Plane reflection.
Size:	203 mm x 381 mm.
Ruling:	316 l/mm.
Blaze:	63.5°.

Cross dispersion:

Type:	TBD.
Ruling:	TBD.
Order separation (echelle):	TBD.

Camera 1 ("Red"):

Type:	Refractive.
Focal length:	267 mm.
Aperture:	210 mm.
Central obscuration:	None.
Wavelength range:	3800A - 1.5 micron.
Usable field:	60 mm nominal.

9.3 CCD Imager

[G]

Description:

Wide-field CCD imager for use on the WIYN Port. The imager will mount on the Instrument Adapter with its focal plane appropriately spaced as specified in Section 7. The probes in the Instrument Adapter will be used for field acquisition and guiding. A shutter, automated filter wheel and a selection of broadband filters will be provided with the instrument.

Detector:	
Type:	Thinned, backside illuminated CCD.
CCD format:	≥ 2048 x 2048 pixels, mosaic or single CCD.
Pixel size:	15-22 μm.
Noise:	≤ 8e rms.
CTE:	≥ 0.99999
Efficiency:	
350-500 nm:	> 0.30
500-850 nm:	> 0.50
850-950 nm:	> 0.20
Dark current:	TBD.
Filter Carousel:	
Configuration:	Automated turret with manually changeable carousels.
Carousel capacity:	8 filters each.
Filter size:	4-inch diameter.
Filter slide:	
Configuration:	In-line with carousel, manual change.
Capacity:	1.
Filter size:	4-inch diameter.
Filter selection:	Harris UBVRI, H-alpha (20Å), ...

Controller:

Same as for MOS.

10. Enclosure

Description:

See Appendix TBD.

Dome rotation:		
Azimuth range:	Unlimited.	
Slew rate:	-4°/sec. to +4°/sec.	[G]
Track rate:	-0.5°/sec. to +0.5°/sec.	[G]
Slew Ramp:	0.75°/sec^2	[G]
Tracking accuracy:	0.5°	[G]

12.2 Survival requirements

Earthquake: UBC Zone 2

Worst case weather conditions at the site at which time the dome will be parked with the shutters and windows closed:

Peak wind speed: 150 mph

Snow load: 24 inches

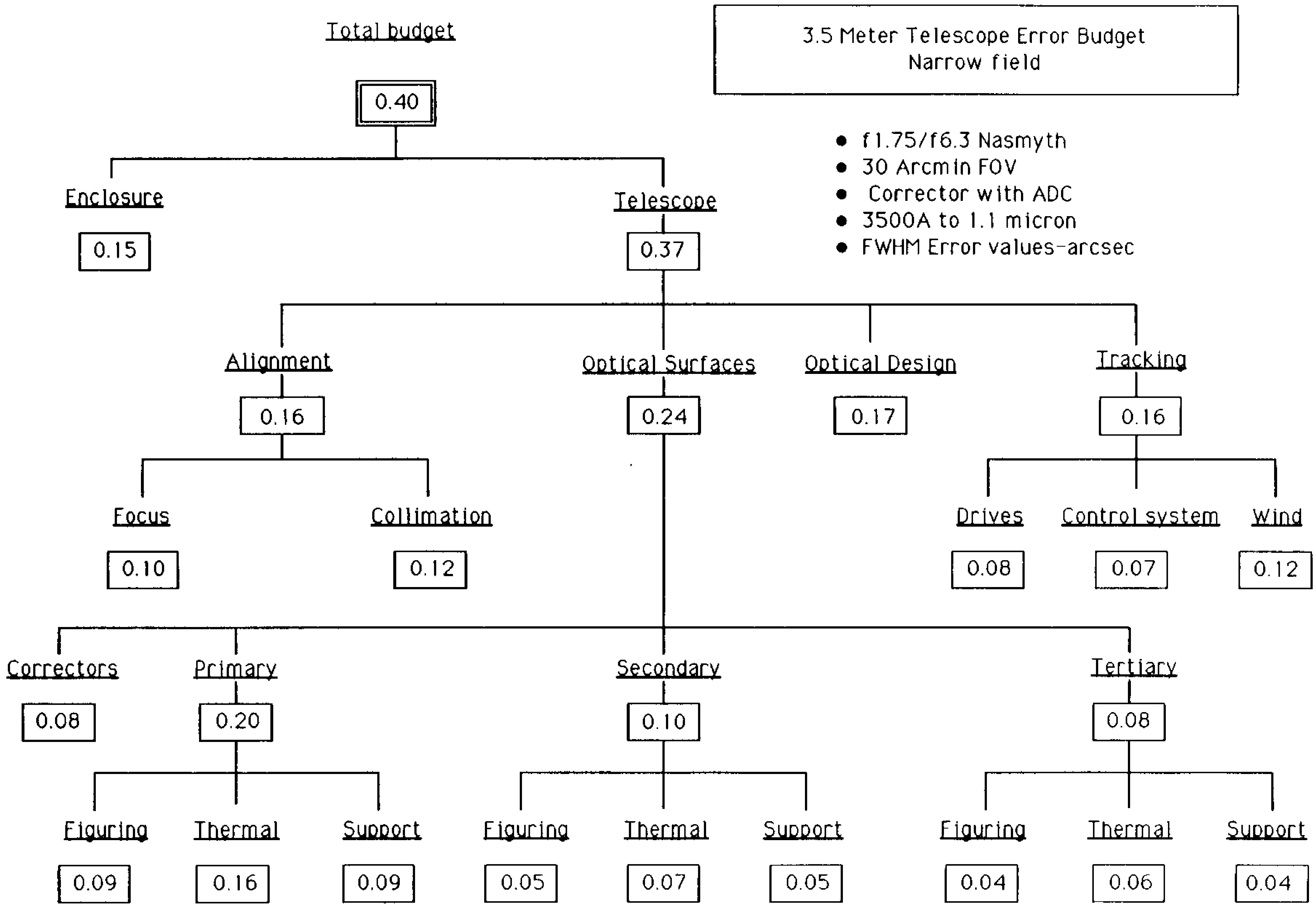
3.5 Meter Telescope Error Budget
Narrow field
f1.75/f6.3 Nasmyth
30 Arcmin FOV
Corrector with ADC
3500A to 1.1 micron
FWHM Error values-arcsec
Total budget
0.40
Enclosure
0.15
Telescope
0.37
Alignment
0.16
Optical Surfaces
0.24
Optical Design
0.17
Tracking
0.16
Focus
0.10
Collimation
0.12
Drives
0.08
Control system
0.07
Wind
0.12
Correctors
0.08
Primary
0.20
Secondary
0.10
Tertiary
0.08
Figuring
0.09
Thermal
0.16
Support
0.09
Figuring
0.05
Thermal
0.07
Support
0.05
Figuring
0.04
Thermal
0.06
Support
0.04

Figure 1

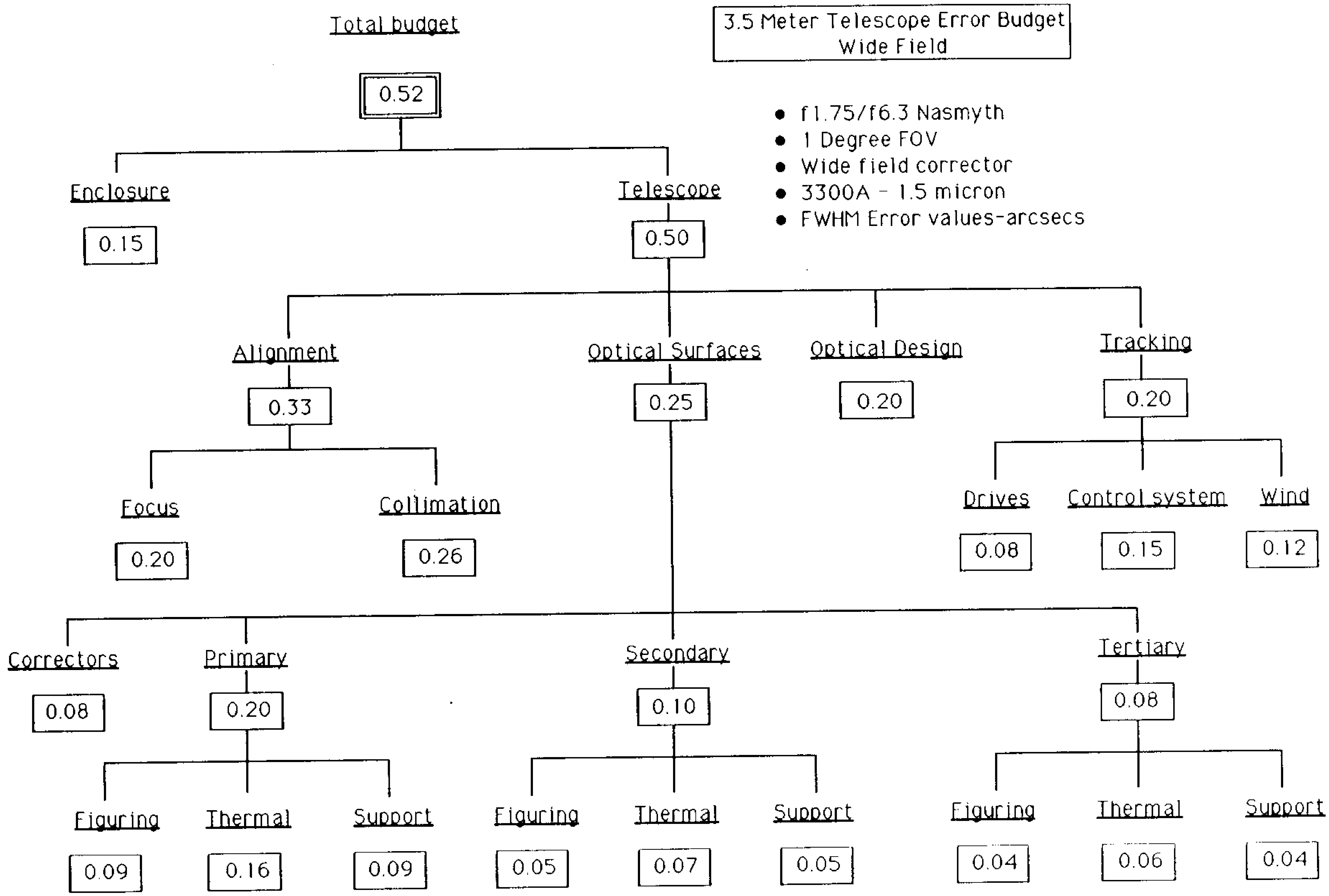
3.5 Meter Telescope Error Budget
Wide Field
f1.75/f6.3 Nasmyth
1 Degree FOV
Wide field corrector
3300A - 1.5 micron
FWHM Error values-arcsecs
Total budget
0.52
Enclosure
0.15
Telescope
0.50
Alignment
0.33
Focus
0.20
Collimation
0.26
Optical Surfaces
0.25
Optical Design
0.20
Tracking
0.20
Drives
0.08
Control system
0.15
Wind
0.12
Correctors
0.08
Primary
0.20
Figuring
0.09
Thermal
0.16
Support
0.09
Secondary
0.10
Figuring
0.05
Thermal
0.07
Support
0.05
Tertiary
0.08
Figuring
0.04
Thermal
0.06
Support
0.04

Figure 2

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