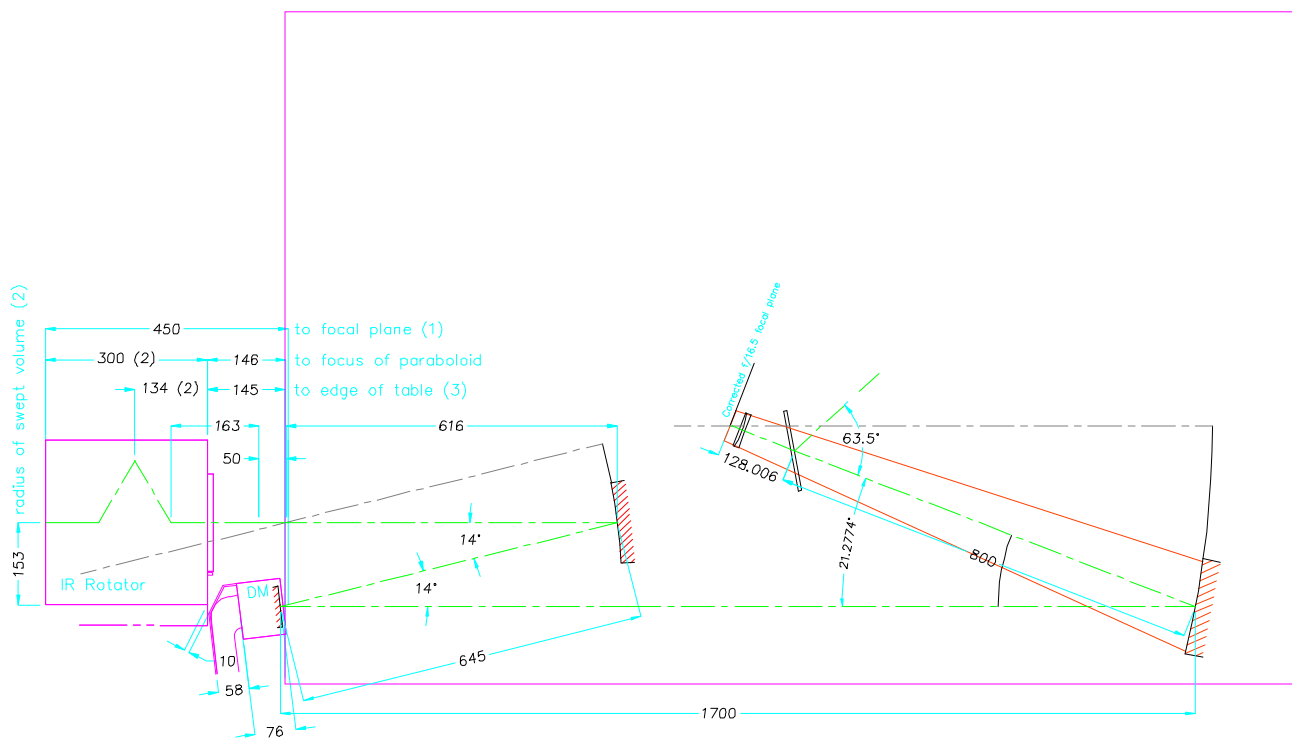


Document Number N/EA/OPTIC3/DOC

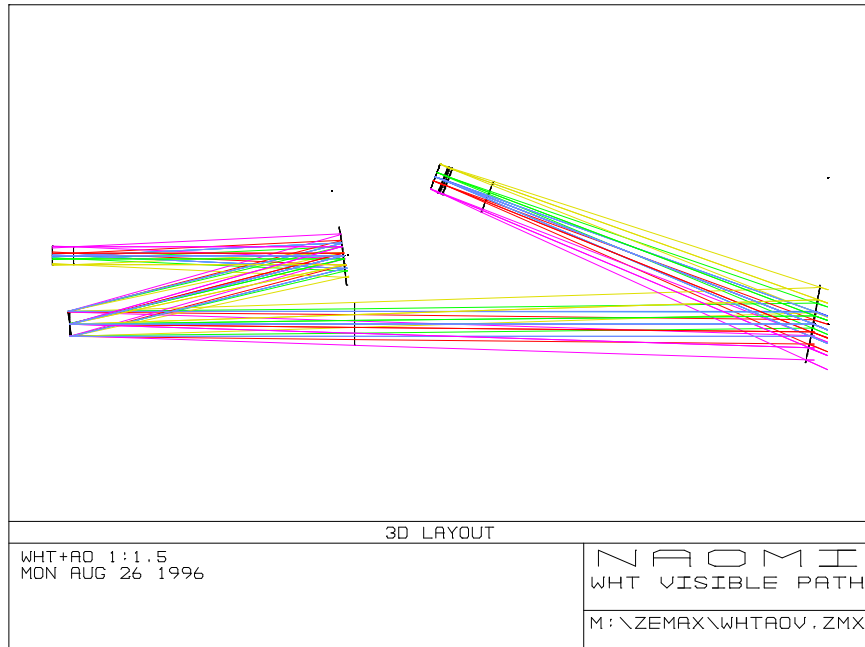
Version date 6/9/96

1. DESCRIPTION

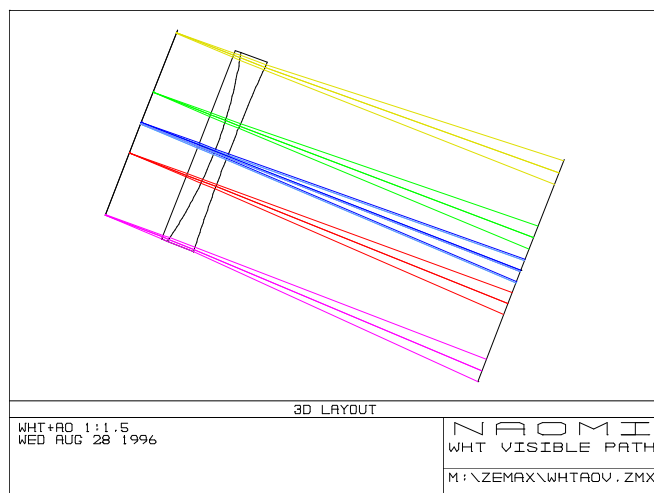
The f/10.94 beam and +/- 1.5 arcmin FOV from the WHT (plate scale=4.51"/mm or 222 μm/arcsec) are collimated by an off-axis paraboloid P1 (Rc= 1213.702 ; clear aperture=110mm;off-axis angle of 14 degrees; off-axis distance 149.024),mounted in a fast-steering platform . The 56 mm collimated beam is then reflected by a deformable mirror positioned at the pupil image of the primary mirror and then converted to a f/16.83 beam by a second off-axis paraboloid P2 (Rc= 1785.015; clear aperture 170mm; off-axis angle of 21.2774,off-axis distance 335.304). The plate scale at the f/16.83 is 2.93"/mm or 341 μm/arcsec).A dichroic (6mm thick and tilted by 31.75 deg.), reflecting the IR and transmitting the Visible is inserted at 800 mm from P2. In the visible path a field lens (doublet) and a set of pick-off mirrors feed the tracking sensor,the wavefront sensors and the acquisition camera.



2. OPTICAL LAYOUT

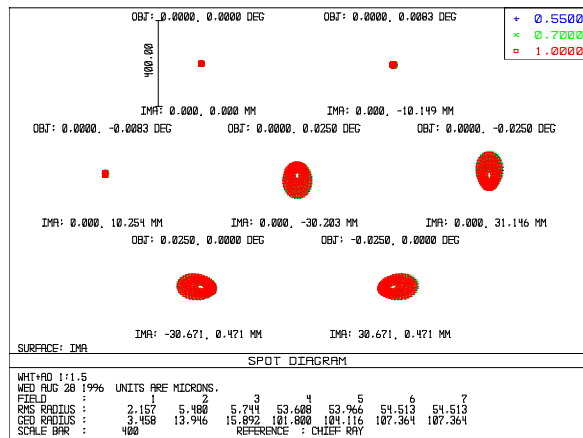


FIELD LENS :

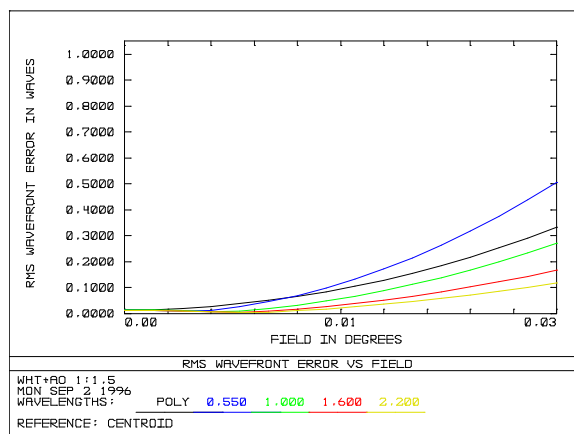


3. IMAGE QUALITY

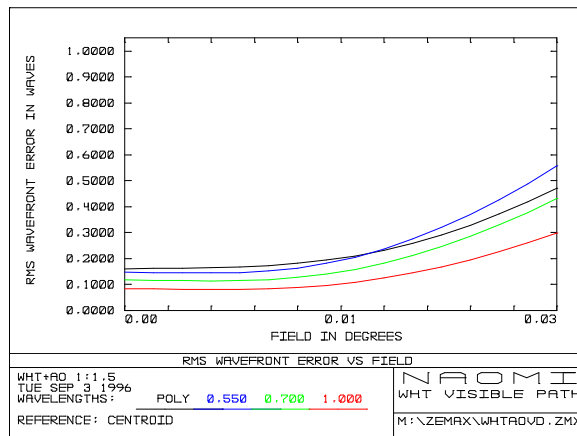
SPOT DIAGRAM : AO+FIELD LENS



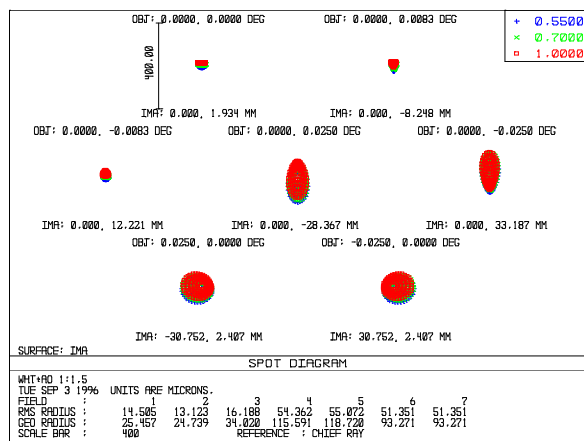
RMS WAVEFRONT ERROR VS FIELD (AO+FIELD LENS)



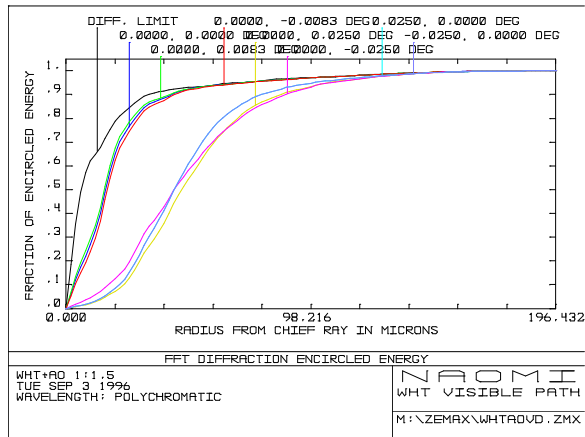
RMS WAVEFRONT ERROR VS FIELD (AO+DICHROIC+FIELD LENS)



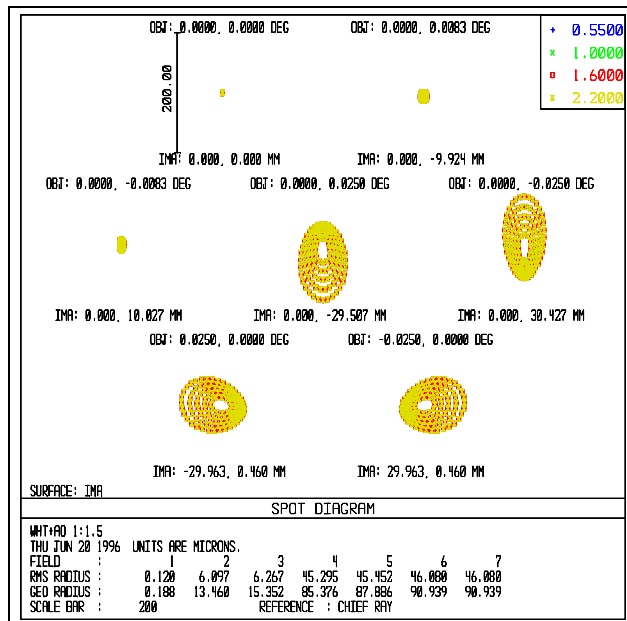
SPOT DIAGRAM (AO+DICHROIC+FIELD LENS)



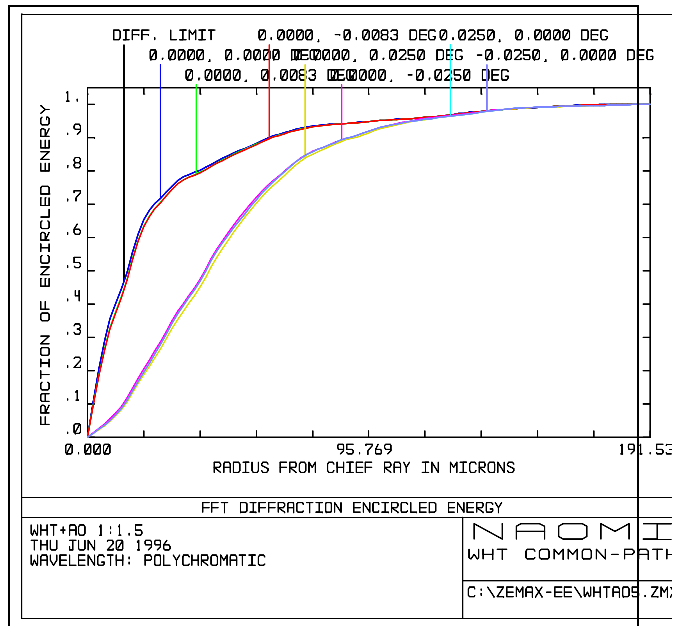
ENCIRCLED ENERGY (AO+DICHROIC +FIELD LENS)



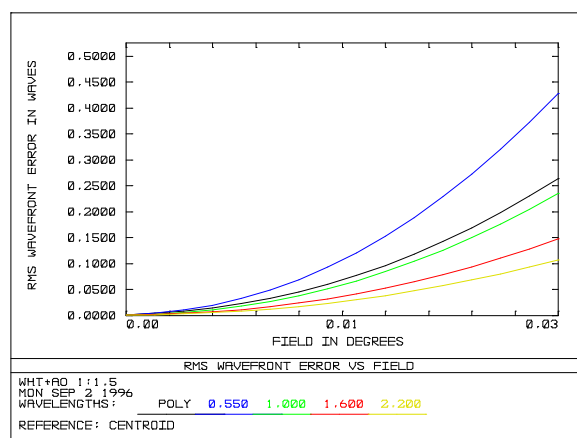
SPOT DIAGRAM : AO (NO FIELD LENS; COMMON PATH).



ENCIRCLED ENERGY : AO (NO FIELD LENS;COMMON PATH)



RMS WAVEFRONT ERROR VS FIELD (COMMON-PATH)



3. GENERAL LENS DATA

Surfaces : 43
Stop : 5
System Aperture : Entrance Pupil Diameter
Ray aiming : Off
Apodization : Uniform, factor = 0.000000
Eff. Focal Len. : -65850.4 (in air)
Eff. Focal Len. : -65850.4 (in image space)
Total Track : 10519.1
Image Space F/# : 15.7537
Para. Wrkng F/# : 15.759
Working F/# : 16.7863
Obj. Space N.A. : 2.09e-007
Stop Radius : 2090
Parax. Ima. Hgt.: 28.7327
Parax. Mag. : 0
Entr. Pup. Dia. : 4180
Entr. Pup. Pos. : 8394.4
Exit Pupil Dia. : 254.176
Exit Pupil Pos. : 3904.25
Field Type : Angle in degrees
Maximum Field : 0.025
Primary Wave : 0.550000
Lens Units : Millimetres
Angular Mag. : 16.4453

Fields : 7

Field Type: Angle in degrees

#	X-Value	Y-Value	Weight
1	0.000000	0.000000	1.000000
2	0.000000	0.008330	1.000000
3	0.000000	-0.008330	1.000000
4	0.000000	0.025000	1.000000
5	0.000000	-0.025000	1.000000
6	0.025000	0.000000	1.000000
7	-0.025000	0.000000	1.000000

Wavelengths : 3

Units: Microns

#	Value	Weight
1	0.550000	1.000000
2	0.700000	1.000000
3	1.000000	1.000000

SURFACE DATA SUMMARY (WHT+IMAGE ROTATOR+AO+FIELD LENS)

Surf	Type	Comment	Radius	Thickness	Glass	Diameter	Conic
OBJ	STANDARD		Infinity	Infinity			
1	STANDARD		Infinity	400		4187.325	
2	STANDARD		Infinity	0		4186.976	
3	STANDARD		Infinity	0		4186.976	
4	STANDARD		Infinity	7994.4		4186.976	
STO	STANDARD		Infinity	105.9		4180	
6	STANDARD		-20879	-8034.961	MIRROR	4180.001	-1
7	STANDARD		-6231.38	9969.75	MIRROR	972.0992	-2.53287
8	STANDARD		Infinity	84			
9	COORDBRK		-----	0		-----	
10	STANDARD		Infinity	0	MIRROR	178.5608	
11	COORDBRK		-----	-134		-----	
12	COORDBRK		-----	0		-----	
13	STANDARD		Infinity	0	MIRROR	83.67378	
14	COORDBRK		-----	134		-----	
15	COORDBRK		-----	0		-----	
16	STANDARD		Infinity	0	MIRROR	127.2986	
17	COORDBRK		-----	-163		-----	
18	STANDARD		Infinity	-50		44.38411	
19	STANDARD		Infinity	-616		39.98415	
20	COORDBRK		-----	0		-----	
21	STANDARD		Infinity	-9.1489			
22	COORDBRK		-----	0		-----	
23	STANDARD		1213.702	0	MIRROR	110.0	-1
24	COORDBRK		-----	9.1489		-----	
25	STANDARD		Infinity	645			
26	COORDBRK		-----	0		-----	
27	STANDARD		Infinity	0	MIRROR	57.51365	
28	COORDBRK		-----	0		-----	
29	STANDARD		Infinity	-650		57.30973	
30	STANDARD		Infinity	-1050		98.52954	
31	STANDARD		Infinity	-31.4924			
32	COORDBRK		-----	0		-----	
33	STANDARD		1785.015	0	MIRROR	170.0	-1
34	COORDBRK		-----	0		-----	
35	STANDARD		Infinity	31.4924			
36	COORDBRK		-----	0		-----	
37	STANDARD		Infinity	800			
38	STANDARD		Infinity	99		74.98465	
39	STANDARD		-531.1744	4.256	BK7	63.95176	
40	STANDARD		143.2352	5.5	LLF6	63.66394	
41	STANDARD		Infinity	19.25		63.59303	
42	STANDARD		Infinity	0		62.50112	
IMA	STANDARD		Infinity	0		62.50112	

SURFACE DATA DETAIL:

Surface OBJ : STANDARD
Surface 1 : STANDARD
Surface 2 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 609
Maximum Radius : 2200
Surface 3 : STANDARD
Surface 4 : STANDARD
Surface STO : STANDARD
Surface 6 : STANDARD
Surface 7 : STANDARD
Surface 8 : STANDARD
Surface 9 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 60
Tilt About Y : 0
Tilt About Z : 0
Surface 10 : STANDARD
Surface 11 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 60
Tilt About Y : 0
Tilt About Z : 0
Surface 12 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : -30
Tilt About Y : 0
Tilt About Z : 0
Surface 13 : STANDARD
Surface 14 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : -30
Tilt About Y : 0
Tilt About Z : 0
Surface 15 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 60
Tilt About Y : 0
Tilt About Z : 0
Surface 16 : STANDARD

Surface 17 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 60
Tilt About Y : 0
Tilt About Z : 0
Surface 18 : STANDARD
Surface 19 : STANDARD
Surface 20 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : -14
Tilt About Y : 0
Tilt About Z : 0
Surface 21 : STANDARD
Surface 22 : COORDBRK
Decenter X : 0
Decenter Y : -149.024
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Surface 23 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 66.5
Y- Decenter : 149.024
Surface 24 : COORDBRK
Decenter X : 0
Decenter Y : 149.024
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Surface 25 : STANDARD
Surface 26 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 7
Tilt About Y : 0
Tilt About Z : 0
Surface 27 : STANDARD
Surface 28 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 7
Tilt About Y : 0
Tilt About Z : 0
Surface 29 : STANDARD
Surface 30 : STANDARD
Surface 31 : STANDARD

Surface 32 : COORDBRK
Decenter X : 0
Decenter Y : -335.304
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Surface 33 : STANDARD
Aperture : Circular Aperture
Minimum Radius : 0
Maximum Radius : 88.5
Y- Decenter : 335.304
Surface 34 : COORDBRK
Decenter X : 0
Decenter Y : 335.304
Tilt About X : 0
Tilt About Y : 0
Tilt About Z : 0
Surface 35 : STANDARD
Surface 36 : COORDBRK
Decenter X : 0
Decenter Y : 0
Tilt About X : 21.2774
Tilt About Y : 0
Tilt About Z : 0
Surface 37 : STANDARD
Surface 38 : STANDARD
Surface 39 : STANDARD
Surface 40 : STANDARD
Surface 41 : STANDARD
Surface 42 : STANDARD
Surface IMA : STANDARD

SOLVE AND VARIABLE DATA:

Semi Diam 8 : Fixed
Semi Diam 21 : Fixed
Semi Diam 23 : Fixed
Thickness of 24 : Solve, pick up value from 21, scaled by -1.00000
Parameter 2 Surf 24: Pickup from 22 times -1.000000
Semi Diam 25 : Fixed
Semi Diam 31 : Fixed
Semi Diam 33 : Fixed
Parameter 2 Surf 34: Pickup from 32 times -1.000000
Thickness of 35 : Solve, pick up value from 31, scaled by -1.00000
Semi Diam 35 : Fixed
Semi Diam 37 : Fixed

INDEX OF REFRACTION DATA:

Surf	Glass	0.550000	0.700000	1.000000
39	BK7	1.51852239	1.51306400	1.50750220
40	LLF6	1.53404072	1.52682584	1.52013994

F/# DATA:

F/# calculations consider vignetting factors and ignore surface apertures.

#	Field	Wavelength: 0.550000		0.700000		1.000000	
		Tan	Sag	Tan	Sag	Tan	Sag
1	0.0000, 0.0000 deg:	16.7863	16.7863	16.7865	16.7865	16.7851	16.7851
2	0.0000, 0.0083 deg:	16.6264	16.7899	16.6266	16.7902	16.6250	16.7887
3	0.0000, -0.0083 deg:	16.9702	16.7900	16.9703	16.7903	16.9687	16.7888
4	0.0000, 0.0250 deg:	16.3765	16.8193	16.3756	16.8193	16.3732	16.8174
5	0.0000, -0.0250 deg:	17.4158	16.8209	17.4149	16.8208	17.4122	16.8189
6	0.0250, 0.0000 deg:	16.8145	16.8894	16.8144	16.8884	16.8125	16.8859
7	-0.0250, 0.0000 deg:	16.8145	16.8894	16.8144	16.8884	16.8125	16.8859

GLOBAL VERTEX COORDINATES AND DIRECTIONS:

Surf	X coord	Y coord	Z coord	X direc	Y direc	Z direc
1	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000
2	0.000000	0.000000	400.000000	0.000000	0.000000	1.000000
3	0.000000	0.000000	400.000000	0.000000	0.000000	1.000000
4	0.000000	0.000000	400.000000	0.000000	0.000000	1.000000
5	0.000000	0.000000	8394.400000	0.000000	0.000000	1.000000
6	0.000000	0.000000	8500.300000	0.000000	0.000000	1.000000
7	0.000000	0.000000	465.339000	0.000000	0.000000	1.000000
8	0.000000	0.000000	10435.089000	0.000000	0.000000	1.000000
9	0.000000	0.000000	10519.089000	0.000000	-0.866025	0.500000
10	0.000000	0.000000	10519.089000	0.000000	-0.866025	0.500000
11	0.000000	0.000000	10519.089000	0.000000	-0.866025	-0.500000
12	0.000000	116.047404	10586.089000	0.000000	-1.000000	-0.000000
13	0.000000	116.047404	10586.089000	0.000000	-1.000000	-0.000000
14	0.000000	116.047404	10586.089000	0.000000	-0.866025	0.500000
15	0.000000	-0.000000	10653.089000	0.000000	-0.866025	-0.500000
16	0.000000	-0.000000	10653.089000	0.000000	-0.866025	-0.500000
17	0.000000	-0.000000	10653.089000	0.000000	0.000000	-1.000000
18	0.000000	-0.000000	10816.089000	0.000000	0.000000	-1.000000
19	0.000000	-0.000000	10866.089000	0.000000	0.000000	-1.000000
20	0.000000	-0.000000	11482.089000	0.000000	-0.241922	-0.970296
21	0.000000	-0.000000	11482.089000	0.000000	-0.241922	-0.970296
22	0.000000	146.810670	11454.913970	0.000000	-0.241922	-0.970296
23	0.000000	146.810670	11454.913970	0.000000	-0.241922	-0.970296

24	0.000000	2.213319	11490.966139	0.000000	-0.241922	-0.970296
25	0.000000	-0.000000	11482.089000	0.000000	-0.241922	-0.970296
26	0.000000	-156.039623	10856.248257	0.000000	-0.121869	-0.992546
27	0.000000	-156.039623	10856.248257	0.000000	-0.121869	-0.992546
28	0.000000	-156.039623	10856.248257	0.000000	0.000000	-1.000000
29	0.000000	-156.039623	10856.248257	0.000000	0.000000	-1.000000
30	0.000000	-156.039623	11506.248257	0.000000	0.000000	-1.000000
31	0.000000	-156.039623	12556.248257	0.000000	0.000000	-1.000000
32	0.000000	179.264377	12587.740657	0.000000	0.000000	-1.000000
33	0.000000	179.264377	12587.740657	0.000000	0.000000	-1.000000
34	0.000000	-156.039623	12587.740657	0.000000	0.000000	-1.000000
35	0.000000	-156.039623	12587.740657	0.000000	0.000000	-1.000000
36	0.000000	-156.039623	12556.248257	0.000000	0.362884	-0.931834
37	0.000000	-156.039623	12556.248257	0.000000	0.362884	-0.931834
38	0.000000	134.267339	11810.780707	0.000000	0.362884	-0.931834
39	0.000000	170.192825	11718.529097	0.000000	0.362884	-0.931834
40	0.000000	171.737258	11714.563210	0.000000	0.362884	-0.931834
41	0.000000	173.733119	11709.438120	0.000000	0.362884	-0.931834
42	0.000000	180.718630	11691.500308	0.000000	0.362884	-0.931834
43	0.000000	180.718630	11691.500308	0.000000	0.362884	-0.931834

4. TOLERANCE ANALYSIS (CODEV)

DEFINITION OF PARAMETER TYPES

BRL	Rotation (in radians) of the group of surfaces about the Z-axis
BTX	Tilt in X (in radians) of the group of surfaces about the pole of the first surface
BTY	Tilt in Y (in radians) of the group of surfaces about the pole of the first surface
CYD	Cylinder (at 45 degrees) irregularity in fringes at 546.1 nm. over the clear aperture
CYN	Cylinder (at 0 degrees) irregularity in fringes at 546.1 nm. over the clear aperture
DLA	Tilt (in radians) of the surface in the Y-Z plane about its pole
DLB	Tilt (in radians) of the surface in the X-Z plane about its pole
DLF	Test plate fit (power) in fringes at 546.1 nm. over the clear aperture
DLG	Rotation (in radians) of the surface about the Z-axis
DLR	Change of radius in mm.
DLT	Change of thickness in mm.
DLX	Lateral displacement of the surface in the X-direction in mm.
DLY	Lateral displacement of the surface in the Y-direction in mm.
DSX	Lateral displacement of the group of surfaces in the X-direction in mm.
DSY	Lateral displacement of the group of surfaces in the Y-direction in mm.
TRX	Total indicator runout in X (resulting in a surface tilt) at the clear aperture in mm.
TRY	Total indicator runout in Y (resulting in a surface tilt) at the clear aperture in mm.
DSZ	Axial displacement of the group of surfaces in mm.
DAK	Conic constant

DEFINITION OF SURFACE NUMBERS:

Number	Component
19	WHT f/11 focal plane
23	off-axis paraboloid P1
27	Deformable Mirror DM
33	off-axis paraboloid P2
38	f/16.8 focal plane

20-Jun-96

CODE V

POSITION 1

SENSITIVITY ANALYSIS
RMS WAVEFRONT ABERRATION

WHT +IMROT + AO(1.5)

NOMINAL RMS = 0.036

Manufacturing errors		changes in rms for + and - manufacturing errors		rms change wavefront	DLT S19	DLT S38
type	change					
DLR S23	1.0000000v	0.000	0.000	0.000	-0.500000	-0.04
DAK S23	0.0010000v	0.000	0.000	0.001	-0.055840	-0.15
DAK S33	0.0010000v	0.000	0.000	0.002	0.115487	0.22
DLR S33	2.0000000v	0.000	0.000	0.000	-0.194743	0.50
CYD S23	0.2500000v	0.000	0.000	0.000	0.001749	0.00
CYN S23	0.2500000v	0.000	0.000	0.000	0.002296	0.002
CYD S33	0.2500000v	0.000	0.000	0.000	-0.000021	0.00
CYN S33	0.2500000v	0.000	0.000	0.000	-0.000356	0.00
DLA S23	0.0003000v	0.002	0.000	0.007	0.184111	0.50
DLB S23	0.0003000v	0.001	0.001	0.006	0.000000	0.0
DLA S33	0.0001000v	0.000	0.000	0.002	0.057375	0.16
DLB S33	0.0001000v	0.000	0.000	0.002	0.000000	0.00
DLG S23	0.0010000v	0.000	0.000	0.000	0.000000	0.00
DLG S33	0.0010000v	0.000	0.000	0.000	0.000000	0.00
DLX S23	0.1000000v	0.000	0.000	0.000	0.000000	0.00
DLY S23	0.1000000v	0.000	0.000	0.000	0.114754	0.31

DLX S33	0.1000000v	0.000	0.000	0.000	0.000000	0.00
DLY S33	0.1000000v	0.000	0.000	0.000	0.000441	0.00
DLF S27	1.0000000v	0.000	0.000	0.001	-0.391182	0.25
CYD S27	0.2500000v	0.004	0.004	0.016	-0.048898	0.03
CYN S27	0.2500000v	0.002	0.007	0.019	-0.038269	0.09
DLA S27	0.0001000v	0.000	0.001	0.005	-0.095364	-0.21
DLB S27	0.0001000v	0.000	0.000	0.004	0.000000	0.00
DLG S27	0.0010000v	0.000	0.000	0.000	0.000000	0.00
DLX S27	0.1000000v	0.000	0.000	0.000	0.000000	0.00
DLY S27	0.1000000v	0.000	0.000	0.000	0.000000	0.00
DSX S20..37	0.1000000v	0.000	0.000	0.000	0.000000	0.00
DSY S20..37	0.1000000v	0.000	0.000	0.000	0.115196	0.37
DSZ S20..37	0.1000000v	0.000	0.000	0.000	-0.131783	0.00
BTX S20..37	0.0010000v	0.000	0.000	0.001	0.000000	0.00
BTY S20..37	0.0010000v	0.000	0.000	0.001	0.329162	0.50
BRL S20..37	0.0010000v	0.000	0.000	0.000	0.000000	0.00

RSS 0.028

PROBABLE CHANGE IN RMS 0.006

PROBABLE CHANGE OF COMPENSATORS (+/-)	dlt s19	0.87
	dlt s38	1.04

Units - linear dimensions in mm. angles in radians,
fringes in wavelengths at 546.1 nm.
RMS is in wavelengths (averaged over spectral region)

The probable change in RMS assumes a uniform distribution of manufacturing errors over the range for all parameters except tilt and decenter which have a truncated Gaussian distribution in X and Y

CUMULATIVE PROBABILITY	CHANGE IN RMS	
50.0 PCT.	0.002	* If it is assumed that the errors can
84.1 PCT.	0.004	only take on the extreme values
97.7 PCT.	0.006 *	of the tolerances, the 97.7 percent
99.9 PCT.	0.008	probable change in RMS is 0.009

LATERAL IMAGE SHIFT (mm)

MANUFACTURING ERROR TYPE	CHANGE	SHIFT
DLR S23	1.000000	0.000000
DAK S23	0.001000	0.000000
DAK S33	0.001000	0.000000
DLR S33	2.000000	0.000000
CYD S23	0.250000	0.000471
CYN S23	0.250000	0.000000
CYD S33	0.250000	0.000234
CYN S33	0.250000	0.000000
DLA S23	0.000300	0.000000
DLB S23	0.000300	-0.549838
DLA S33	0.000100	0.000000
DLB S33	0.000100	-0.181758
DLG S23	0.001000	0.000000

DLG S33	0.001000	0.000000
DLX S23	0.100000	0.149853
DLY S23	0.100000	0.000000
DLX S33	0.100000	0.100051
DLY S33	0.100000	0.000000
DLF S27	1.000000	0.000000
CYD S27	0.250000	0.000001
CYN S27	0.250000	0.000000
DLA S27	0.000100	0.000000
DLB S27	0.000100	0.183372
DLG S27	0.001000	0.000000
DLX S27	0.100000	0.000000
DLY S27	0.100000	0.000000
DSX S20..37	0.100000	0.249904
DSY S20..37	0.100000	0.000000
DSZ S20..37	0.100000	0.000000
BTX S20..37	0.001000	-0.645878
BTY S20..37	0.001000	0.000000
BRL S20..37	0.001000	-0.345966
RSS		1.000376

PERFORMANCE SUMMARY:

WAVELENGTH
1600.0 NM

RELATIVE FIELD	DESIGN	DESIGN + TOL *	COMPENSATOR RANGE (+/-) *	
			DLT S19	DLT S38
0.00, 0.00	0.036	0.042	0.872514	1.037480
0.00,-1.00	0.174	0.180	0.872514	1.037480
0.00, 1.00	0.186	0.191	0.872514	1.037480

* The change in RMS is a mean plus 2 Sigma value (97.7 percent) and assumes a uniform distribution of manufacturing errors over the range for all tolerances except decentration errors which have a truncated Gaussian distribution in X and Y

The compensator range is a mean plus 2 Sigma value.
Linear compensators are in units of millimeters.

5. TECHNICAL SPECIFICATION AND ADJUSTMENTS REQUIRED FOR THE OFF-AXIS PARABOLOIDS:

These are related to the precision achieved in the manufacturing of the off-axis paraboloids and the image quality required at the f/16.8 focus. I assumed that the rms wavefront error shall be <150 nm over the central 1 arcmin field and <300nm at the edge of the field. Practically the deformable mirror should be able to correct for imperfect optics as well as telescope aberrations and atmospheric wavefront errors.

The 2 off-axis mirrors will be manufactured with a surface accuracy of 125 nm P-V or 25 nm RMS over the clear aperture. The off-axis distance of P1 will be 149.0±0.5 mm and P2 335.3±0.5mm. Their respective focal lengths (measured along optical axis from vertex to focus position) are 606.85±3.0 mm and 892.51±4.0 mm.

The adjustments on the tilt of the OAP that are required for alignment and testing: 2 axis tilts covering a 6 deg angular range with a 0.3 arcsec angular resolution and 3 linear motions (x,y,z) covering ±10 mm travel range and a linear resolution <2?m.

6. TOLERANCE REQUIREMENT ON FLEXURE, THERMAL, VIBRATION...FOR THE OPTICS:

An rms of 0.006 arcsec for jitter on the optical bench means that the image should not shift by more than 2 μ m rms at the f/16.8 focal plane. The first paraboloid P1 should not tilt by more than 0.22 arcsec and decenter by more than 1.3 μ m ; the second one P2 should not tilt by more than 0.23 arcsec and decenter by more than 2 μ m. The whole optical chassis should not tilt by more than 0.6 arcsec .

