

Stray Light Analysis of the Apache Point 3.5-m Telescope

**Prepared for
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Final Report

16 July 2001

1.0 Introduction

The University of Washington has developed the Apache Point Observatory 3.5 meter telescope system and desires a stray light analysis of the system to understand the performance in a future wide-field imaging mode. This system consists of a telescope, field flattener lens system, and a future CCD wide-field camera operating at visible wavelengths.

The purpose of this study is to assess the stray light performance of this system, identify where modification(s) would improve the off-axis rejection characteristics, and assess the effectiveness of those modifications.

2.0 Computer Model

2.1 System Geometry

The ASAP model of the Apache Point observatory was constructed from a series of 2D DXF files furnished by Dr. Jeff Morgan/University of Washington. We used RhinoCad to view and extract dimensions from these files. Since all of this work was accomplished “by hand” without the use of automatic translation software, there may be some slight discrepancies between the ASAP model and the DXF data. However, given the excellent agreement between the measured data and the computer-generated pinhole images, we believe these differences to be small.

With a model of this complexity, it is difficult to highlight and show all of the structures. Figures 1 through 9 attempt to show the telescope system from several viewpoints.

Appendix A contains a listing of the ASAP model of the telescope.

2.2 Surface Treatments and BRDF Models

Table 1 lists the various surfaces used in the observatory. The surfaces were compared to a database of surface properties and to published papers on surface measurements to arrive at an accepted optical scatter model of each surface.

2.2.1 White Paint Scatter Model

Most white paints exhibit fairly Lambertian scatter characteristics. Lacking specific measured BRDF data on this paint, we therefore simulated the white paint with a Lambertian scatter model with 80% diffuse reflectivity.

2.2.2 Aeroglaze Z306 Scatter Model

Figure 10 shows the BRDF model of Aeroglaze Z306 that is based upon actual measurements. (The axis labeling is a bit confusing in this plot. On the x-axis we plot $\log_{10} |\beta - \beta_0|$, where β and β_0 are the sines of the scatter and specular angles measured from the surface normal. On the y-axis we plot the \log_{10} BRDF.)

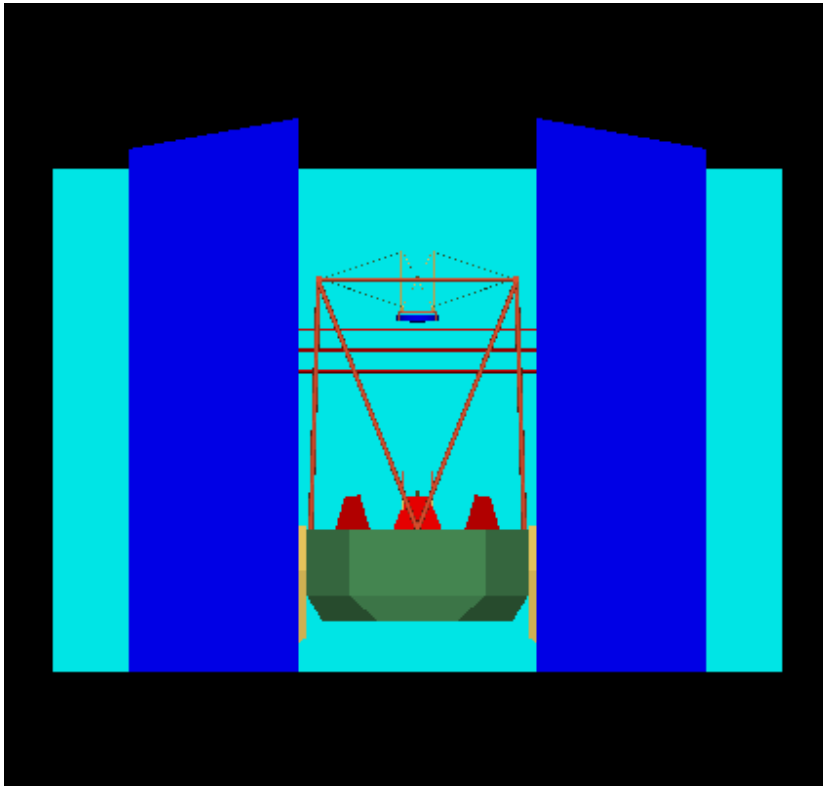


Figure 1 Telescope System Looking North

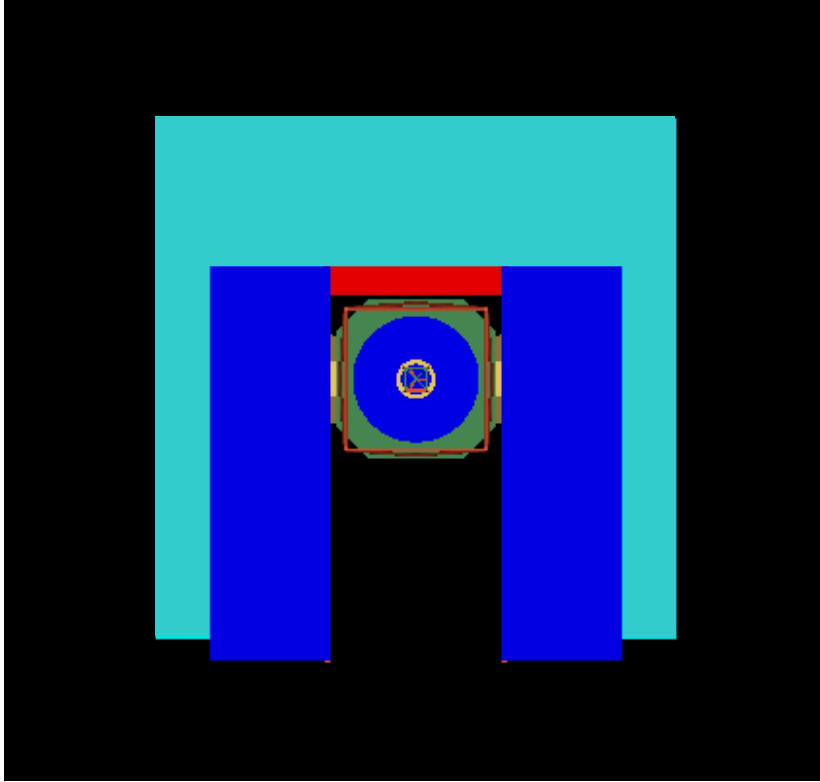


Figure 2 Telescope System Looking Down

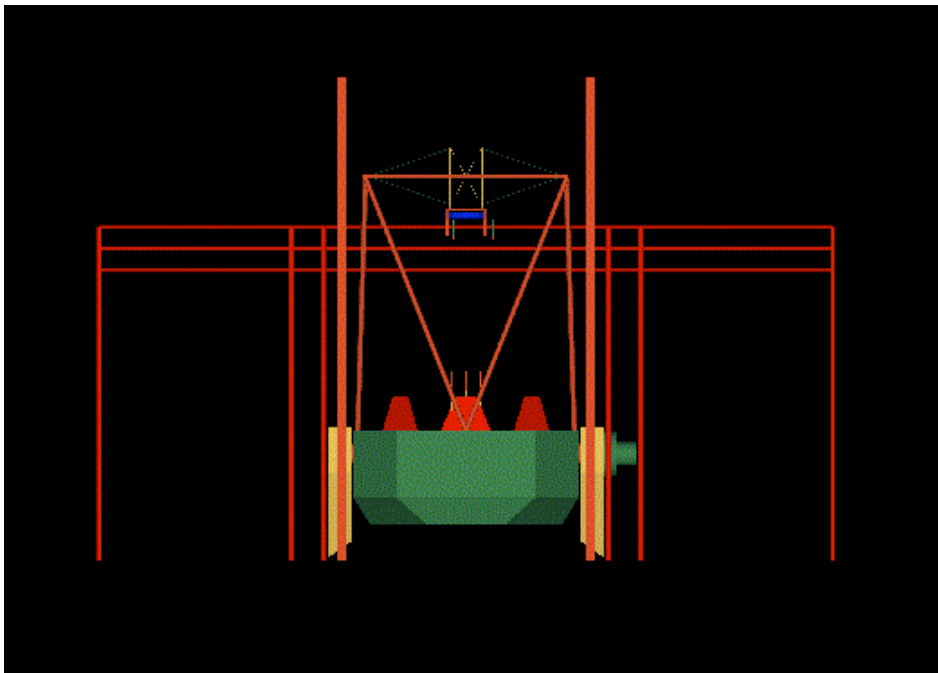


Figure 3 Telescope System Looking North w/Roof Removed (Note camera on east fork)

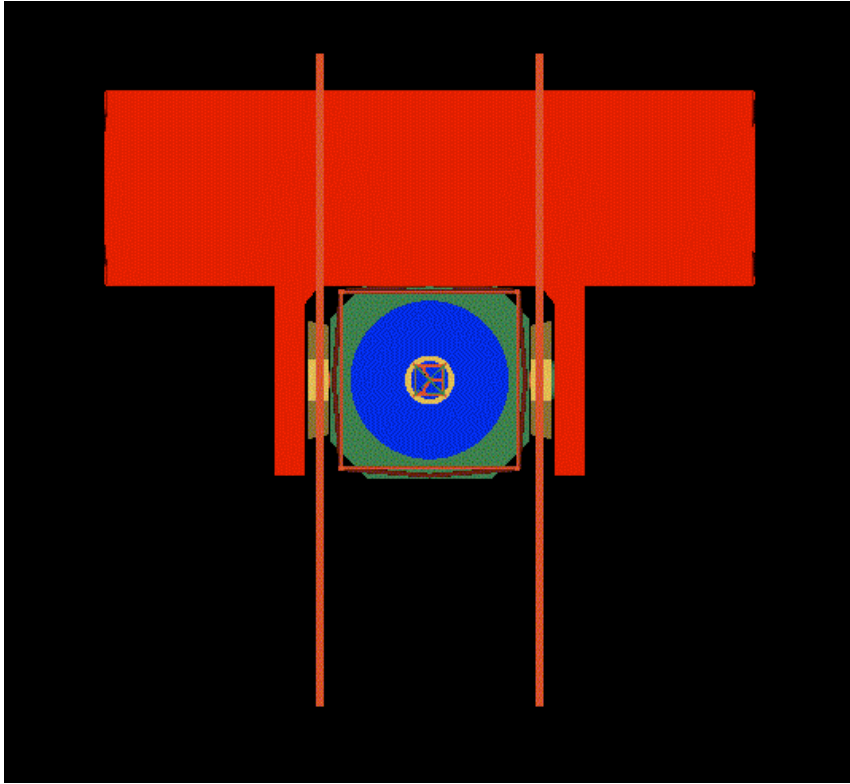


Figure 4 Telescope System Looking Down w/Roof Removed

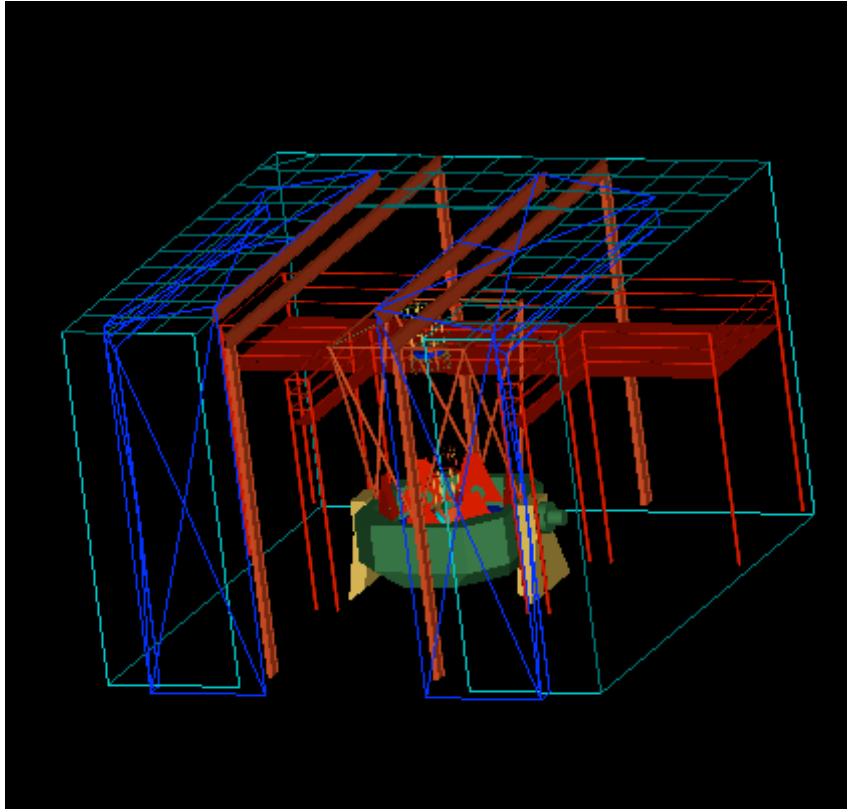


Figure 5 Telescope System Looking Northwest (Telescope housing and slit are shown as a wireframe.)

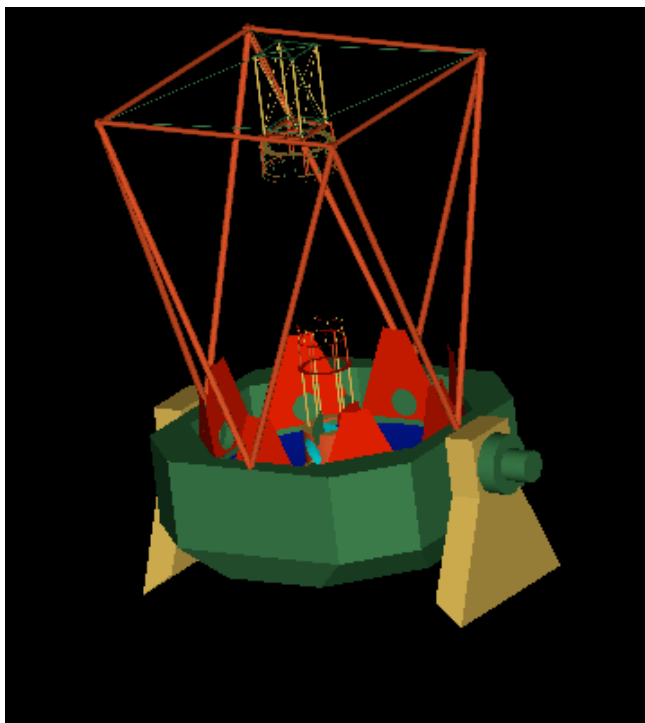


Figure 6 Telescope

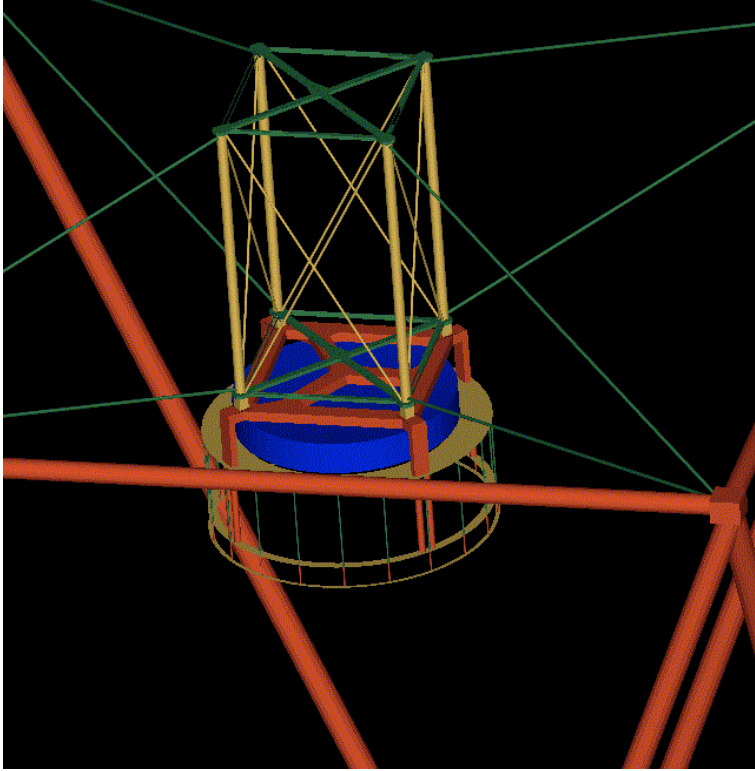


Figure 7 View of Secondary Mirror Support (The secondary mirror is the blue cylindrical object in this rendering.)

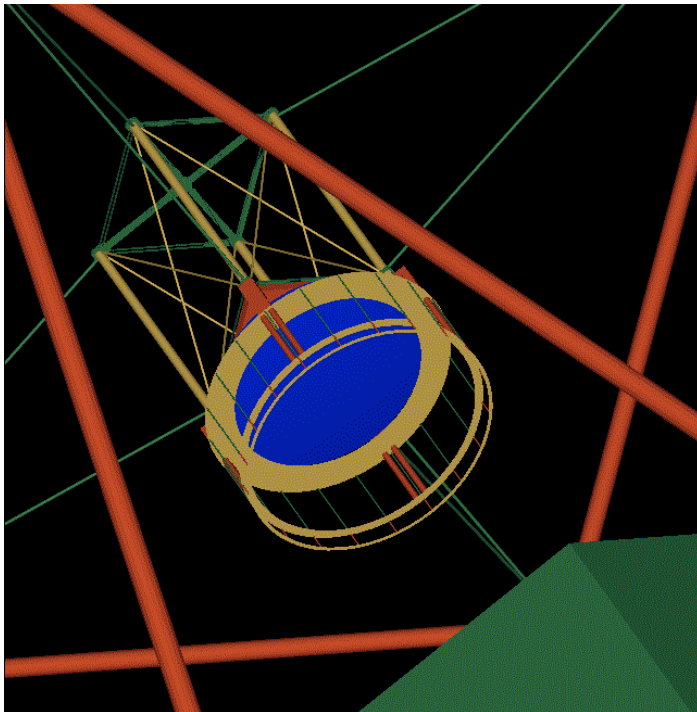


Figure 8 View of Secondary Mirror and Support (The secondary mirror is the blue disk in this rendering.)

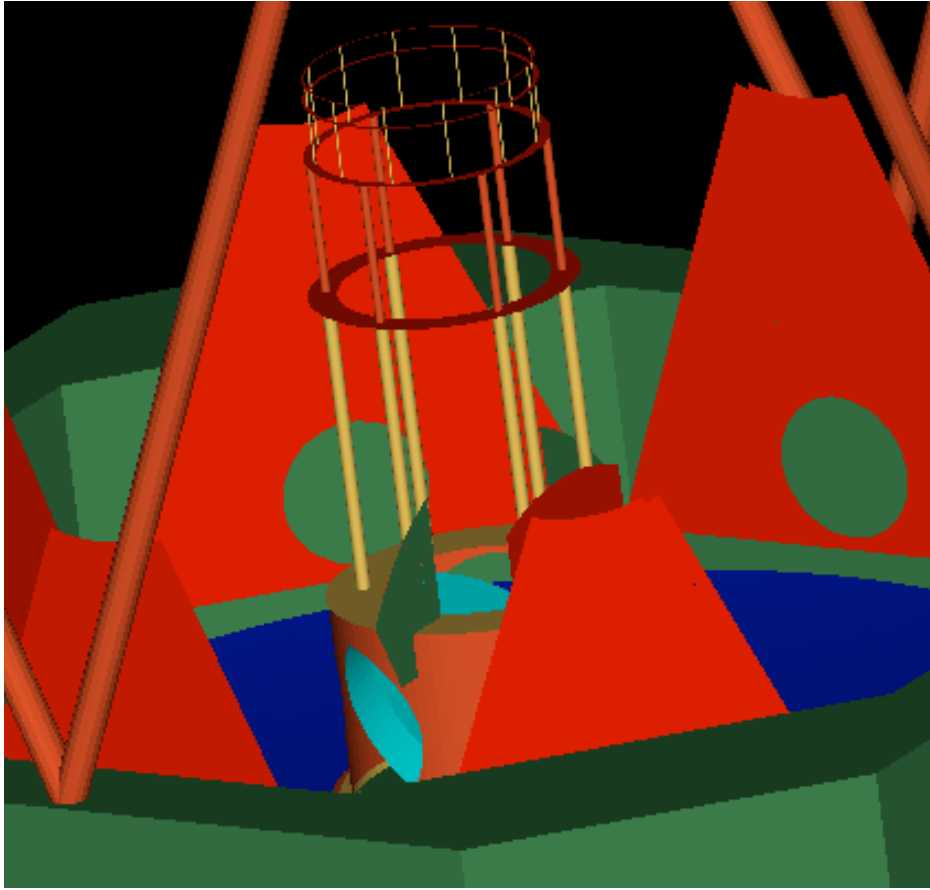


Figure 9 View of Nasmyth Fold Mirror and Baffles (The fold mirror is light blue in the rendering; the primary mirror is dark blue.)

**Table 1
Surface Treatments**

Item Name	Surface Description
2 nd Backup Frame	White Paint:
2 nd Baffle Posts	Aeroglaze Z306
2 nd Baffle Spacers #1	Aeroglaze Z306
2 nd Baffle Spacer #2	Aeroglaze Z306
2 nd Bottom Baffle	Aeroglaze Z306
2 nd Frame	Aluminum Tape
2 nd Frame Turnbuckle Clamp	
2 nd Middle Baffle	Aeroglaze Z306
2 nd Spider Rods	Aeroglaze Z306
2 nd Top Baffle	Aeroglaze Z306
2 nd Truss Bottom	White Paint:
2 nd Truss Clevis	White Paint:
2 nd Truss Ends	White Paint:
2 nd Truss Spreader Rods	White Paint:

2 nd Truss Top	White Paint:
2 nd Xlink Blocks	White Paint:
2 nd Xlink Center	White Paint:
2 nd Xlink Rods	White Paint:
3 ^{ry} Baffle Base	Aeroglaze Z306
3 ^{ry} Baffle Large Posts	Aeroglaze Z306
3 ^{ry} Baffle Small Posts	Aeroglaze Z306
3 ^{ry} Baffle Top Plate 1	Aeroglaze Z306
3 ^{ry} Baffle Top Plate 2	Aeroglaze Z306
3 ^{ry} Baffle Top Plate 3	Aeroglaze Z306
3 ^{ry} Baffle Top Plate 4	Aeroglaze Z306
3 ^{ry} Baffle Top Spacers 1	Aeroglaze Z306
3 ^{ry} Baffle Top Spacers 2	Aeroglaze Z306
3 ^{ry} Base	
3 ^{ry} Bearing	
3 ^{ry} Bearing Housing	
3 ^{ry} Bearing Housing Clamp	Black Paint:
3 ^{ry} Bearing Shaft	
3 ^{ry} Bearing Shaft Clamp	
3 ^{ry} Cap	Aeroglaze Z306
3 ^{ry} NA Baffle Plate 1	Aeroglaze Z306
3 ^{ry} NA Baffle Plate 2	Aeroglaze Z306
3 ^{ry} NA Baffle Plates 3	Aeroglaze Z306
3 ^{ry} NA Baffle Spacers	Aeroglaze Z306
Fork Tines	Blue Paint: Dupont Centari Semi-Gloss Grabber Blue
M1	Bare Aluminum Coating
M2	Bare Aluminum Coating
M3	Bare Aluminum Coating
Main Truss	Aluminum Tape
Mirror Covers (closed)	White Paint:
Mirror Covers (open)	Aeroglaze Z306
NA axle	
NA-2 Baffle Plates	Aeroglaze Z306
Primary Mirror Cell	White Paint: Dupont Centari Acrylic Enamel 817A
Observing Floor-NA hatches	Brushed Aluminum
Observing Floor (other than NA hatches)	Grey Linoleum
Enclosure walls (including slit)	White Paint:

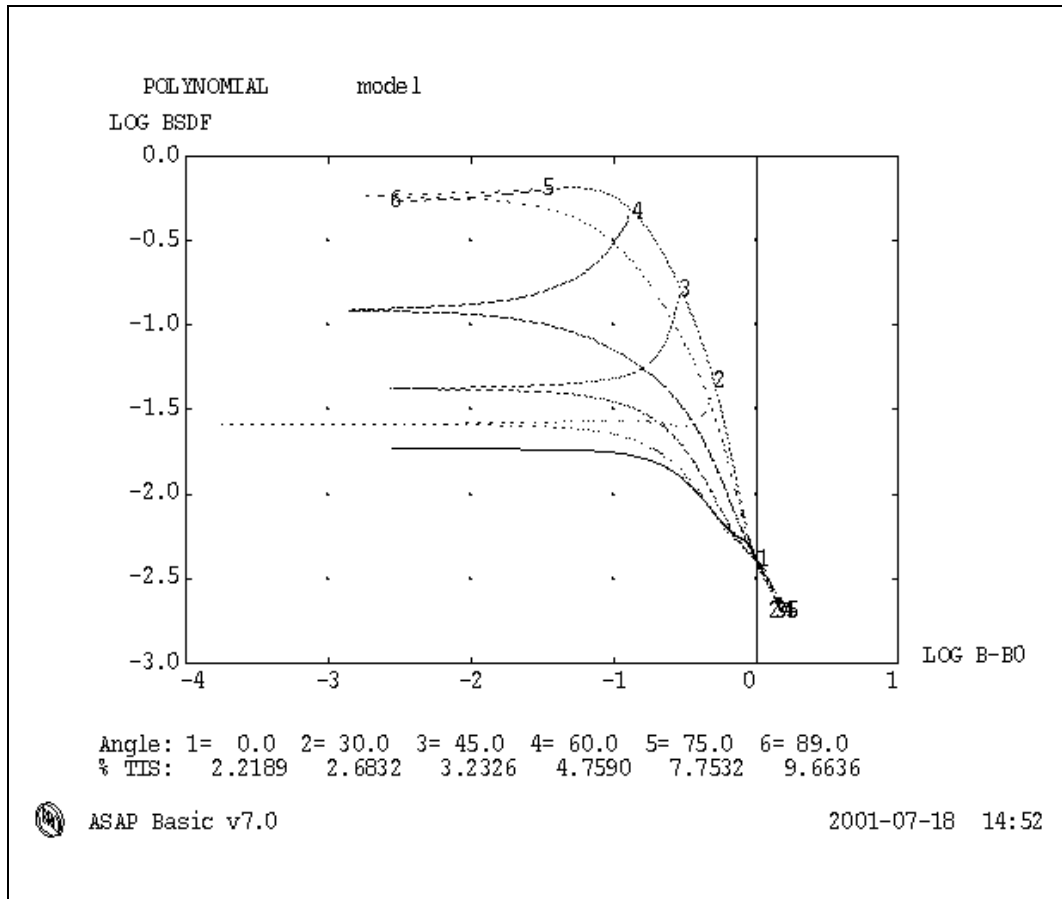


Figure 10 BRDF Model of Aeroglaze Z306

Since the BRDF of an ideal Lambertian scatterer is a constant for all angles, this data indicates that the scatter from Aeroglaze is not Lambertian. Instead it shows an increasing forward-scatter component that means that significant amounts of power will be scattered at larger angles of incidence.

2.2.3 Mirror Surface Models

The mirror surfaces were assigned composite models to represent both specular and scatter characteristics.

2.2.3.1 Bare Aluminum Mirror Coating

We assumed an 89% specular reflectivity on the primary, secondary, and Nasmyth fold mirrors. This is consistent with the reflectivity of an overcoated aluminum coating in the visible.

2.2.3.2 Level 500 Particulate Scatter Model

Since the particulate deposition rates in observatories are not well-studied, ideally we would have preferred to have the mirror surfaces examined and particulate counts made in order to properly model the scatter properties of the contaminated surfaces.

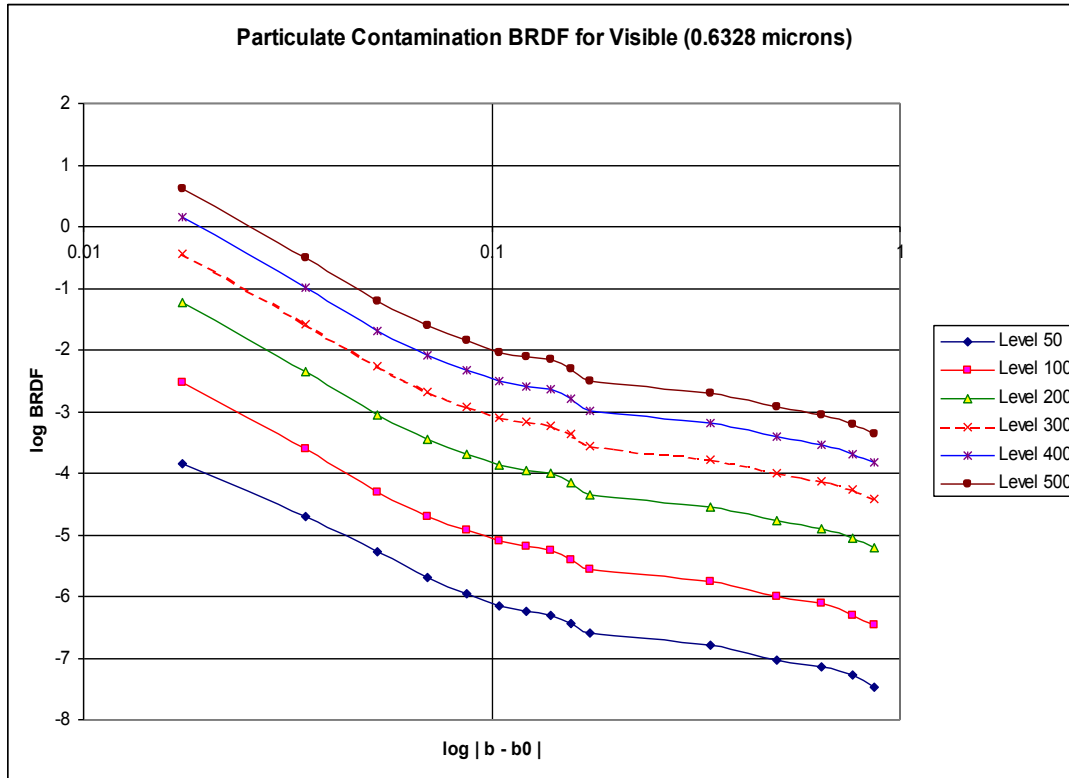


Figure 11 BRDF Models for Particulate Contamination

Lacking specific information, we decided to use the MIL-1246B particulate model commonly used in industry. (See Figure 11, Ref. 1) It is traceable and well-known. Its major drawbacks are (1) it tends to overestimate the number of particles (at least relative to cleanroom measurements) and is therefore conservative and (2) as with any generic model, it may not represent our specific case.

The cleanliness level is determined by exposure; the longer the surface is exposed to the environment, the “dirtier” it becomes. Since the telescope mirrors are cleaned on a regular basis, we expect significant variation in particulate count over time. (However it is important to note that not all particles can be cleaned from a surface. Small particles are held onto the surface by Van de Waals forces and cannot be removed by mechanical means.) Taking (another) conservative approach we assumed level 500 particulates; a surface contaminated at this level is visibly “dirty” (i.e., the observer can see particles on the surface) but only 0.3% of the surface is actually obscured with particles.

2.2.4 Aluminum Tape

We modeled the aluminum tape that covers the main truss and the secondary frame as having an 85% specular reflectivity.

2.2.5 Blue Paint

According to Dr. Morgan's notes, the telescope fork tines are painted with Dupont Centari Semi-Gloss Grabber Blue paint. Since the fork tines are not involved in any first-level scatter path, we did not include a blue paint scatter model.

2.3 Telescope Orientation

For a correct understanding of the telescope pointing, in order to compare to telescope data, we have to establish how the computer stray light model is oriented and how it moves. Figure 12 shows the orientation of the telescope when it is pointed at 0 degrees azimuth and 0 degrees elevation (i.e., due south).

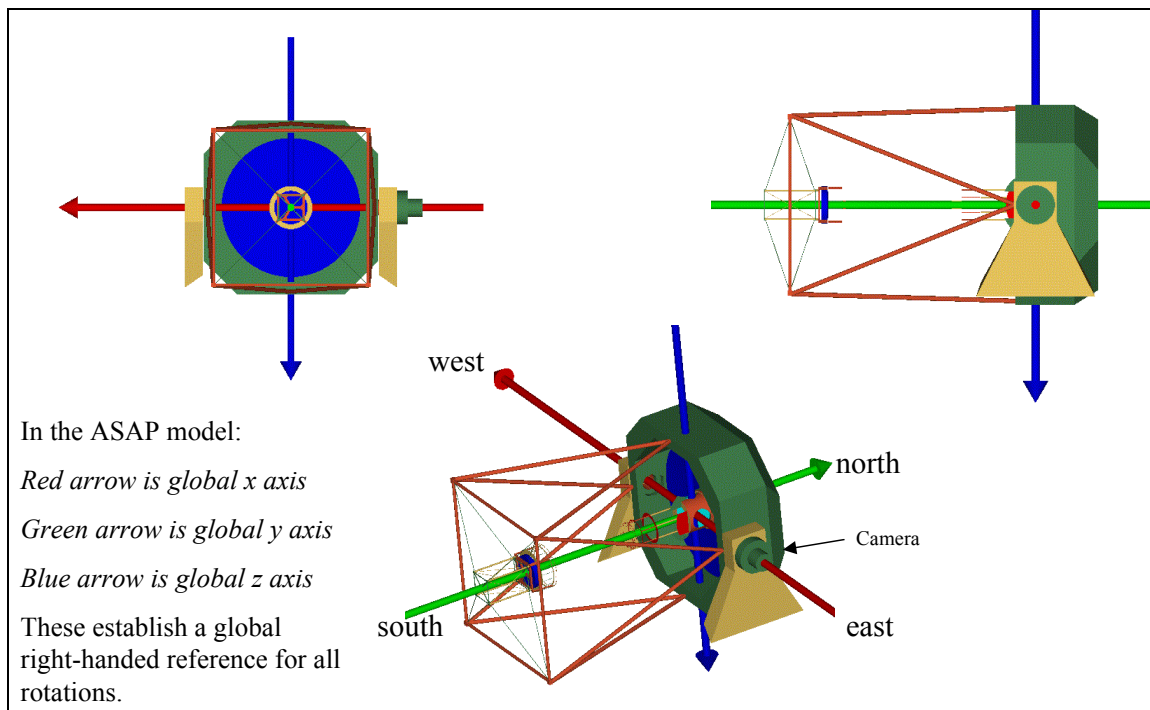


Figure 12 Telescope Orientation When Pointed 0 Degrees Azimuth, 0 Degrees Elevation (Telescope Points Due South.)

Figure 13 shows the orientation of the telescope when rotated to -90 degrees azimuth. In this case the telescope points west. A +90 degrees azimuth rotation would point the telescope east.

Figure 14 shows the orientation of the telescope when rotated to +90 degrees elevation. In this case the telescope points at zenith.

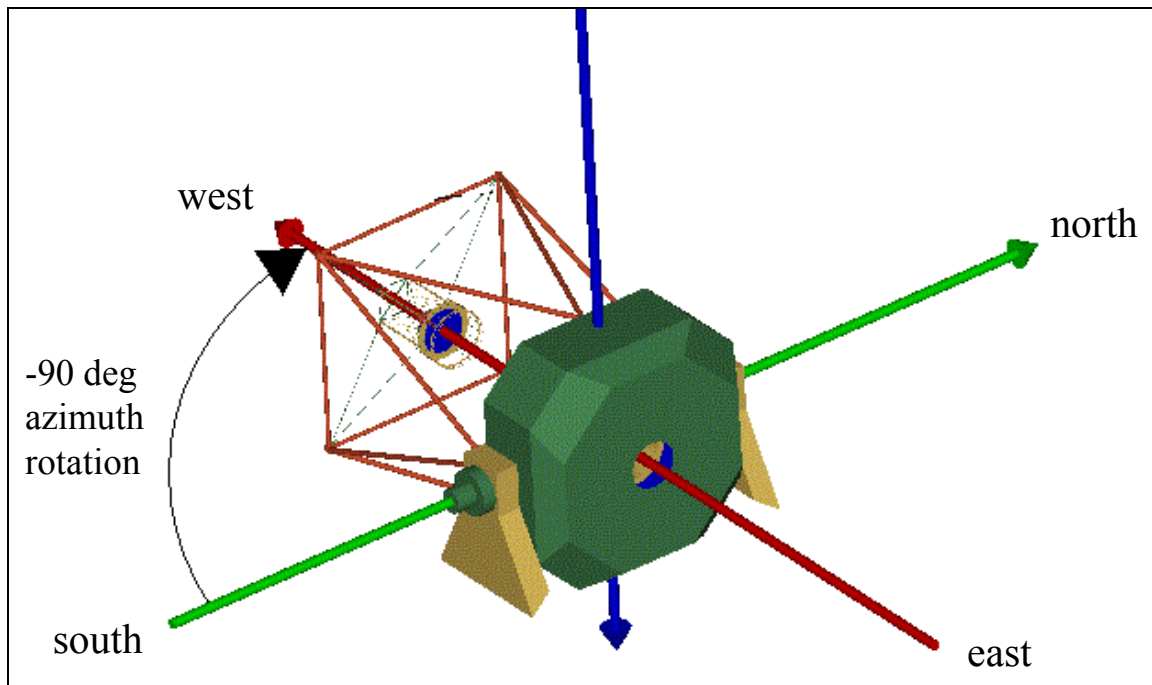


Figure 13 Telescope Pointing -90 Degrees Azimuth, 0 Degrees Elevation

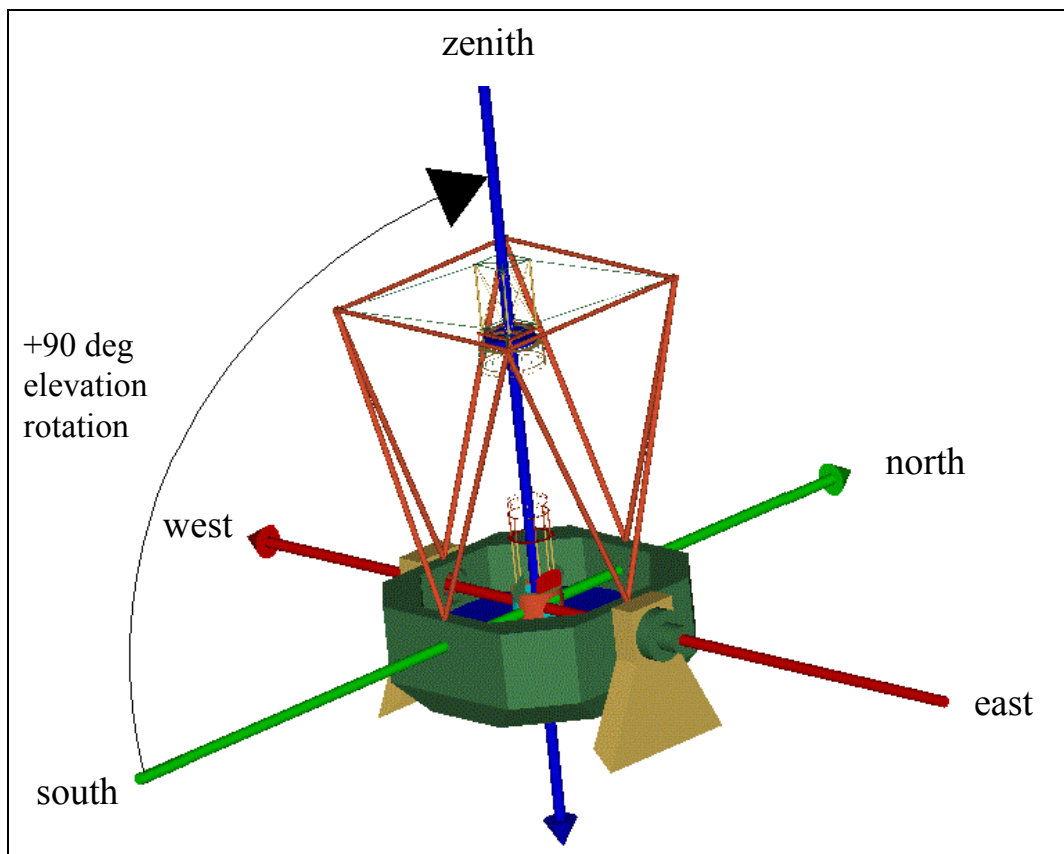


Figure 14 Telescope Pointing $+90$ Degrees Elevation, 0 Degrees Azimuth

3.0 Model Verification Using Pinhole Images

Dr. Morgan furnished a series of pinhole images taken with the Apache Point telescope on 7 January 2001 for verification of and comparison with the computer model.

The images were taken at the telescope focal plane. At a distance of 118.0 inches from the axis of the Nasmyth fold mirror (3.05 inches from the focal plane), a pinhole aperture was placed in the optical path. The specific diameter of the aperture was not specified, and so we used a 400 micron diameter aperture in the model.

The optical path consisted of the primary, secondary, and Nasmyth fold mirrors; no other camera lenses were placed in the optical path for these photographs.

The moon and Jupiter, shining at magnitudes -12.94 and -2.7 , respectively, were visible during this observing session and were considered the most significant out-of-field light sources.

Dr. Morgan provided tables of right ascension and declination coordinates of the moon and Jupiter during the observing session, as well as elevation and azimuth angles describing the pointing of the telescope. We converted the lunar and Jovian coordinates into altitude and zenith distance angles and then converted these data into a format convention understood by ASAP.

Table 2 shows a comparison of the telescope pointing, the location of Jupiter, and the observing notes for 5 selected pinhole images. In all cases except the first, the model and the observation notes agree to within 0.1 degree. The pointing for the en01.007 image appeared to be “off” by a greater than expected amount and so we asked Dr. Morgan to verify the pointing of the telescope. In a fax dated 23 May 2001, he reported that a review of the telescope log indicated that the telescope was pointed 0.5 degrees from Jupiter. We were not able to reconcile the difference, but there is a more detailed discussion below of the that comparison shown in Figure 15.

In all other cases the computer model shows excellent agreement with the actual pinhole images. A comparison of the pinhole images with the computer images shows a remarkable consistency. Figures 18, 19, 20, and 21 show the actual and simulated en01.009, en01.011, en01.013, and en01.017 images.

Figure 15 shows a comparison of the actual and simulated (modeled) en01.007 images. It is immediately obvious that, in addition to the expected image of the primary mirror, there is an additional scatter “ghost” image. Looking back at the ASAP output, we discovered that this ghost image was largely the result of scatter from the Nasmyth fold mirror.

Since we were already suspicious of the en01.007 pointing, we conducted some experiments with the computer model. Our first experiment was to determine which areas of the optical elements could be illuminated by a source 0.4 degrees off-axis. (We used 0.4 degrees rather than 0.5 degrees for the calculations for consistency with our own model. The results and conclusions are the same.) Figure 16 shows a comparison between the axial raytrace and a raytrace for a point source 0.4 degrees off-axis. In both cases the primary and secondary mirrors are more or

less illuminated over the same area. (This explains why the computer model does not show a third “ghost” from the secondary mirror – the scatter from the primary and secondary mirrors overlaps.) However the illuminated area on the Nasmyth fold mirror moves away from the axis.

Table 2
Telescope Pointing, Jupiter Position, and Observation Notes

Image		Direction Cosines			Dot Product (deg.)	Observation Notes
		A	B	C		
en01.007	JUPITER	-7.32E-02	0.224215	0.971784		
	TEL.	-7.28E-02	0.230525	0.970338		
	Product	5.33E-03	5.17E-02	9.43E-01	0.375950	0.5 degrees N of Jupiter
en01.009	JUPITER	-0.19947	0.214188	0.956209		
	TEL.	-0.19827	0.229613	0.952874		
	Product	3.95E-02	4.92E-02	9.11E-01	0.905340	1 degree N of Jupiter
en01.011	JUPITER	-0.27518	0.203499	0.93961		
	TEL.	-0.2768	0.235738	0.931564		
	Product	7.62E-02	4.80E-02	8.75E-01	1.906173	2 degrees N of Jupiter
en01.013	JUPITER	-0.34898	0.189443	0.917782		
	TEL.	-0.3663	0.643501	0.672108		
	Product	1.28E-01	1.22E-01	6.17E-01	29.935489	30 degrees N of Jupiter
en01.017	JUPITER	-0.48999	0.149747	0.858768		
	TEL.	-0.50114	0.215514	0.8381		
	Product	2.46E-01	3.23E-02	7.20E-01	4.001586	4 degrees N of Jupiter
en01.024	JUPITER	-0.94093	-0.27014	0.204147		
	TEL.	-0.90022	-0.35116	0.25747		
	Product	8.47E-01	9.49E-02	5.26E-02	6.030128	6 degrees N of Jupiter

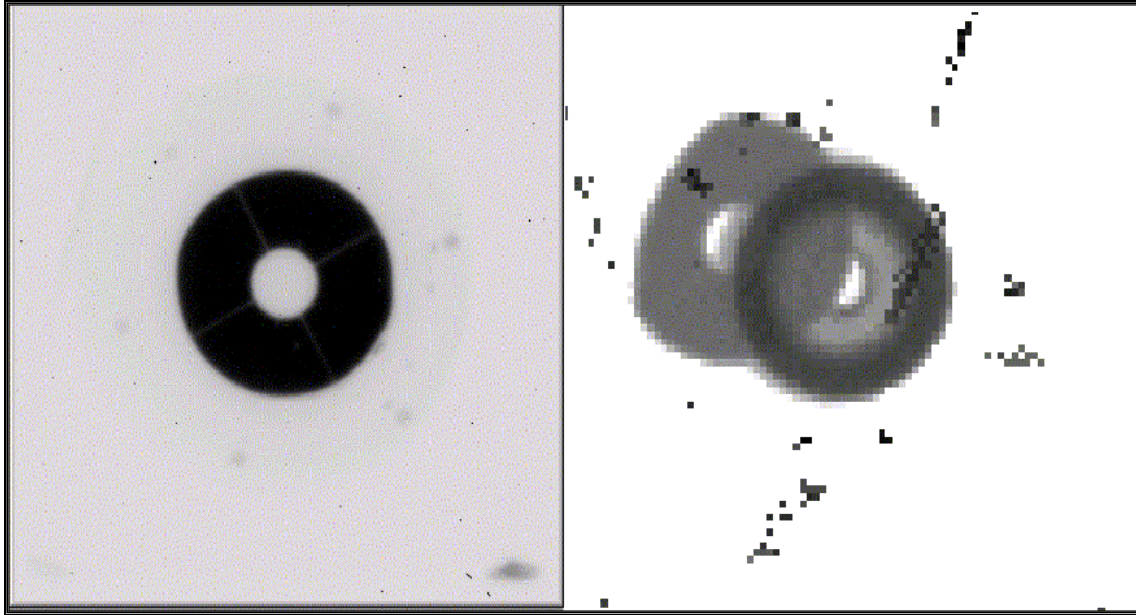


Figure 15 Actual (left) and Simulated (right) EN01.007 Images

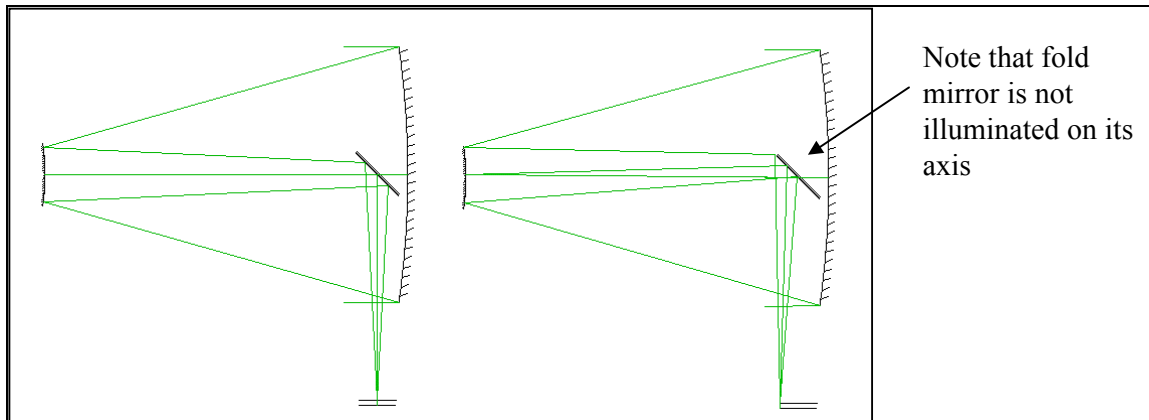


Figure 16 Axial and 0.4 degree Off-Axis Illumination of the Telescope Optical System

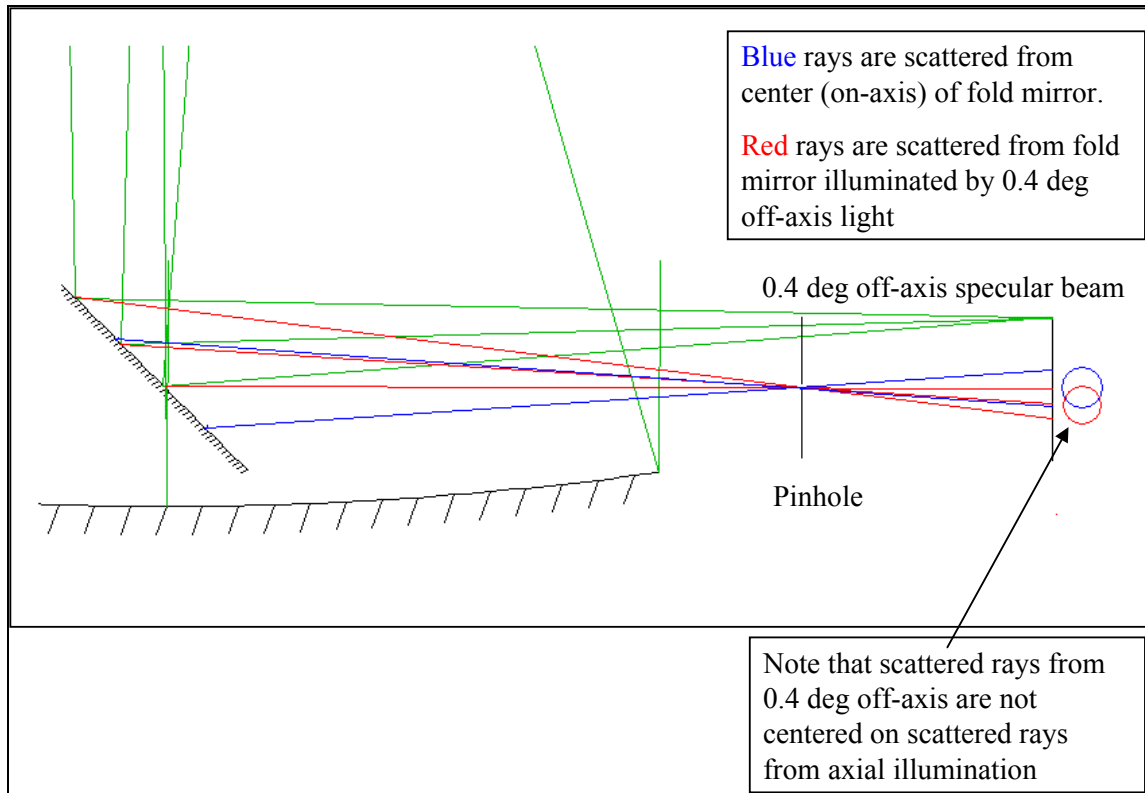


Figure 17 Propagation of Scattered Light from Off-Axis Area on Nasmyth Fold Mirror

Figure 17 shows the propagation of scattered light from the Nasmyth fold mirror in the two cases. When the axial portion of the fold mirror is illuminated, it scatters light along the axis and merges with the scatter from the primary and secondary mirrors. However when the off-axis section of the mirror is illuminated, the scattered light enters the pinhole at an angle and produces an off-centered ghost. *This is what the computer model predicts.*

All things considered, we believe that the discrepancy between the computer model and the pinhole image is due to one of the following factors:

1. Some structure (telescope slit?) very close to the telescope axis obscures the light from Jupiter
2. The Nasmyth fold mirror is *much* cleaner (=fewer particulates) than we have assumed. (In the computer model, we assumed that the surfaces of all three mirrors were equally contaminated.)
3. There yet remains a pointing error in the computer model. This is not likely because of the excellent agreement with the other pinhole images. Furthermore the ghost image can be explained by a point source 0.5 degrees off-axis.

For the other comparisons, we were very pleased with our modeling techniques and the veracity of the computed images.

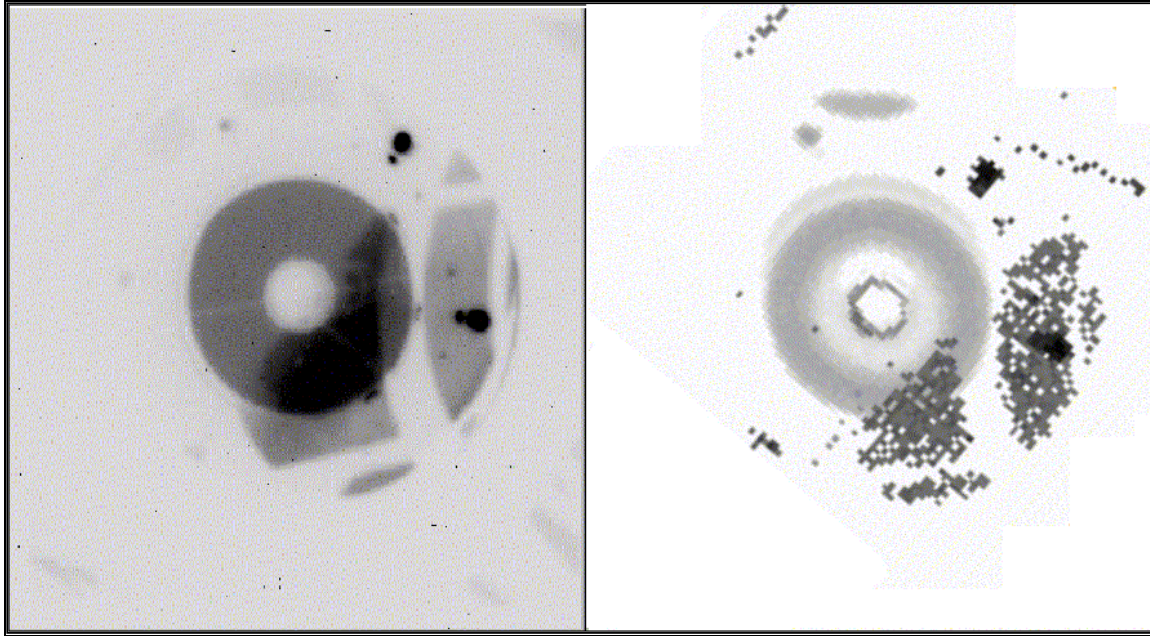


Figure 18 Actual (left) and Simulated (right) EN01.009 Images

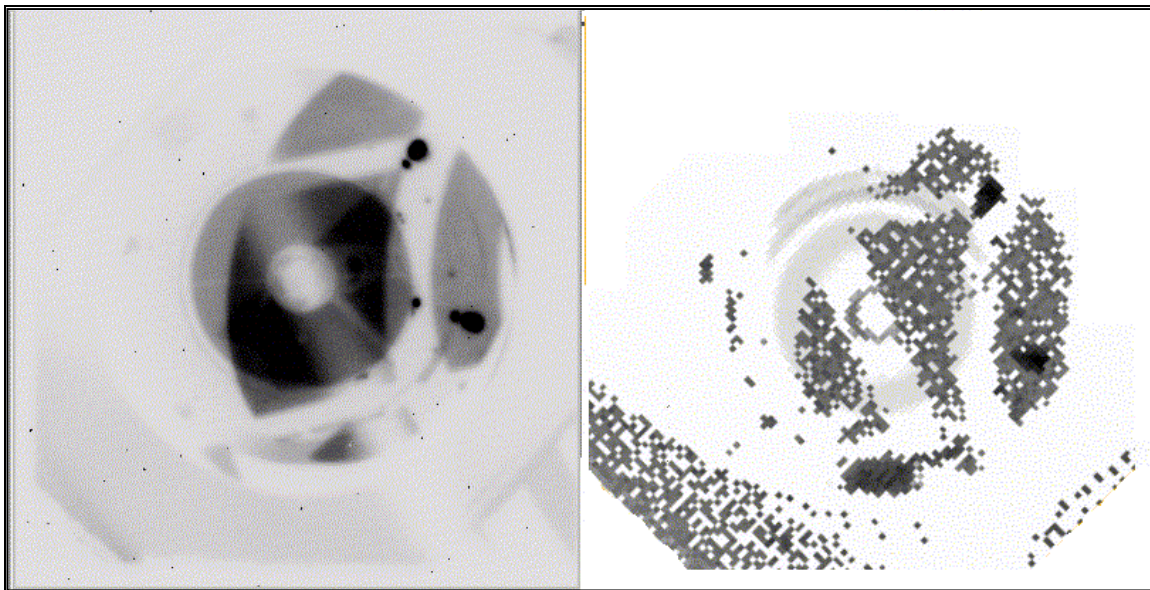


Figure 19 Actual (left) and Simulated (right) EN01.011 Images

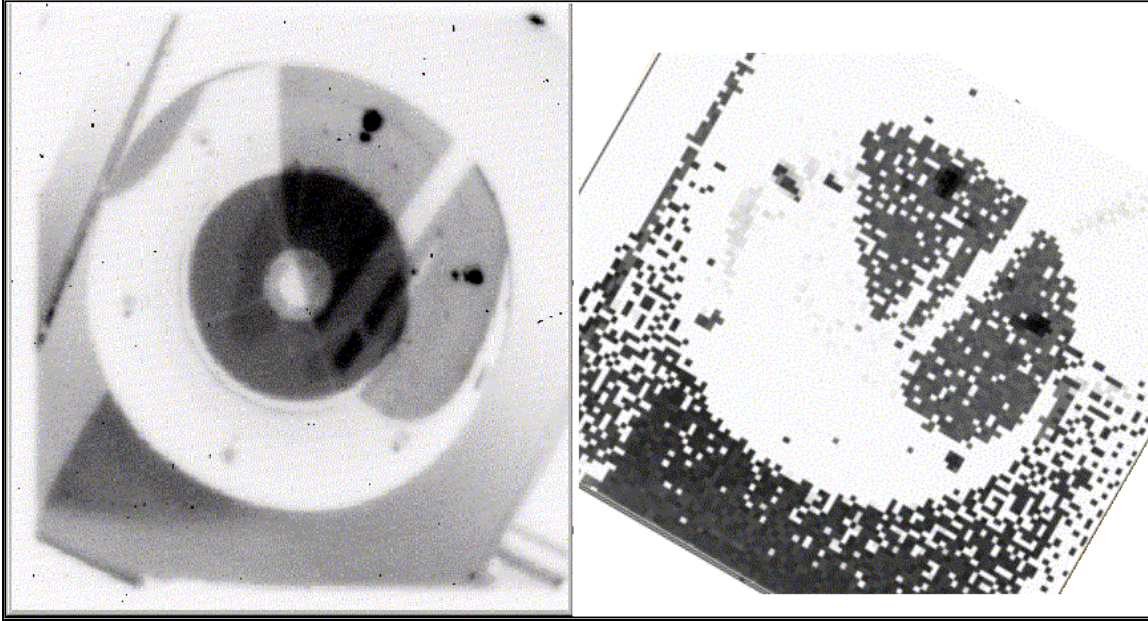


Figure 20 Actual (left) and Simulated (right) EN01.013 Images (A power threshold setting used in the computer analysis was responsible for the missing image of the primary mirror in the simulated image.)

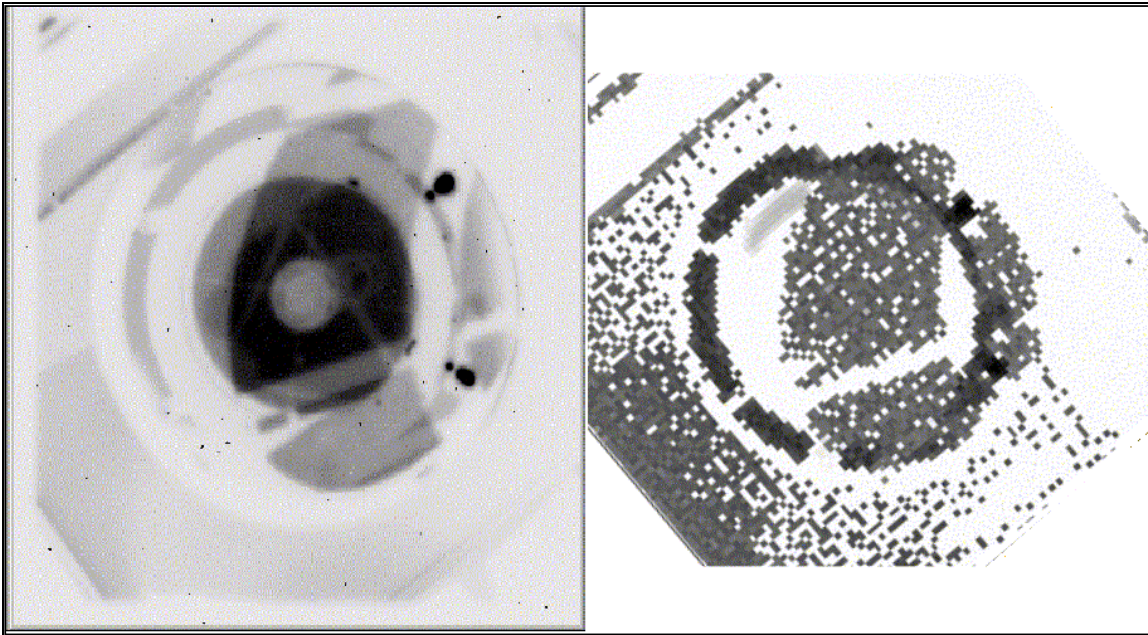


Figure 21 Actual (left) and Simulated (right) EN01.017 Images (A power threshold settings was responsible for the missing image of the primary mirror in the simulated image.)

4.0 PST Analyses of Existing Observatory Configuration

4.1 PST Definition

The Point Source Transmittance (PST) is a commonly used metric for assessing the stray light characteristics of an opto-mechanical system. The PST does not attempt to identify source(s) of stray light but instead combines all stray light mechanisms into a single number that is convenient for comparing systems, enhancements, etc.

More specifically the PST is a transfer function relating the irradiance at the focal plane due to stray light mechanisms to the irradiance at the entrance aperture of the telescope produced by a distance point source, viz.

$$PST(\theta) = \frac{\text{focal plane irradiance}}{\text{entrance aperture irradiance}(\theta)} \quad (1)$$

This definition is particularly applicable to systems with obscured or varying apertures. (There are other PST definitions based upon power ratios, but they are much less appropriate for obscured systems.)

4.2 Assumptions

For our PST calculations of the existing observatory configuration, we made the following assumptions:

1. The entrance aperture irradiance is unity. Since this appears in the denominator of the PST equation, it is a convenient normalization.
2. The focal plane is 4 inches in diameter. This is a smaller focal plane than was used for the pinhole image calculations. (For the sake of these calculations, it is not important if the focal plane is an array or continuous surface.)
3. The “NA 2 Baffle Rot” baffle with an aperture 3.08 inches in diameter was removed from model. According to Dr. Morgan, this baffle is only used for pinhole calculations.
4. The telescope is rotated to 0 deg azimuth (telescope pointing south), 60 deg elevation position (See Figure 22)
5. Relative to the nominal telescope pointing, the PST is calculated over the range from –60 degrees to +60 degrees in the “elevation” direction. This is referred to as the “elevation PST scan”. (See Figure 23)
6. Relative to the nominal telescope pointing, the PST is calculated over the range from –70 degrees to +70 degrees in the “side-to-side” direction. (See Figure 24). The “side-to-side” direction is perpendicular to the elevation direction and passes through the nominal telescope pointing (60 degree elevation).
7. PST calculations are performed with slit and telescope housing in place so obscurations are properly accounted for

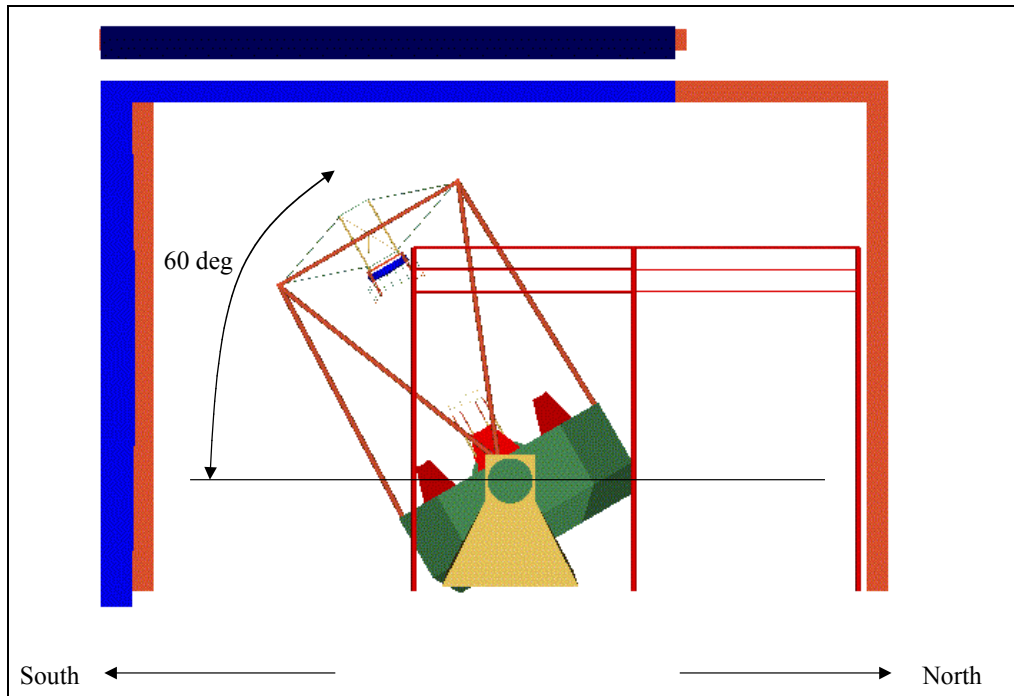


Figure 22 Orientation of Telescope for PST Calculations (Looking West)

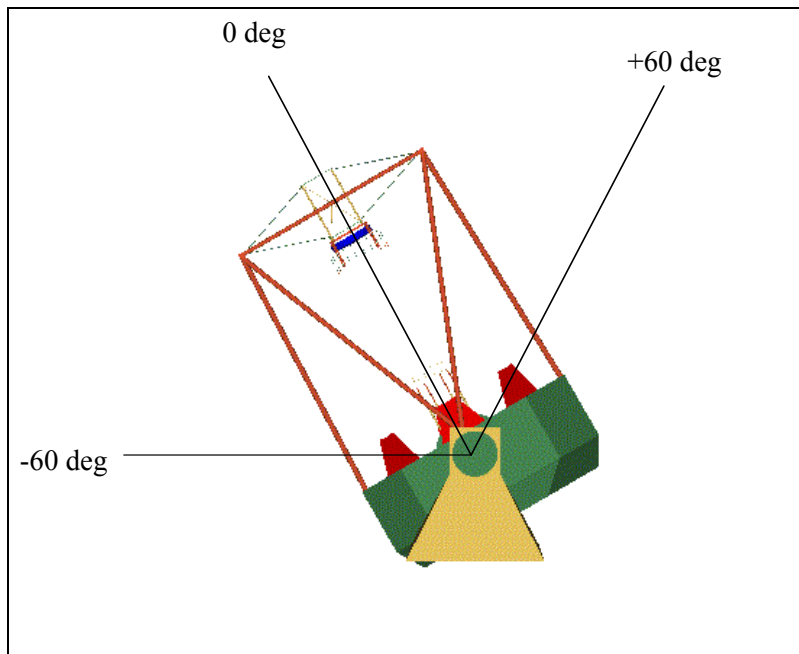


Figure 23 Convention for Elevation PST Scan (Remember telescope and observatory are fixed during these calculations; the only thing that changes is the incoming direction of the rays.)

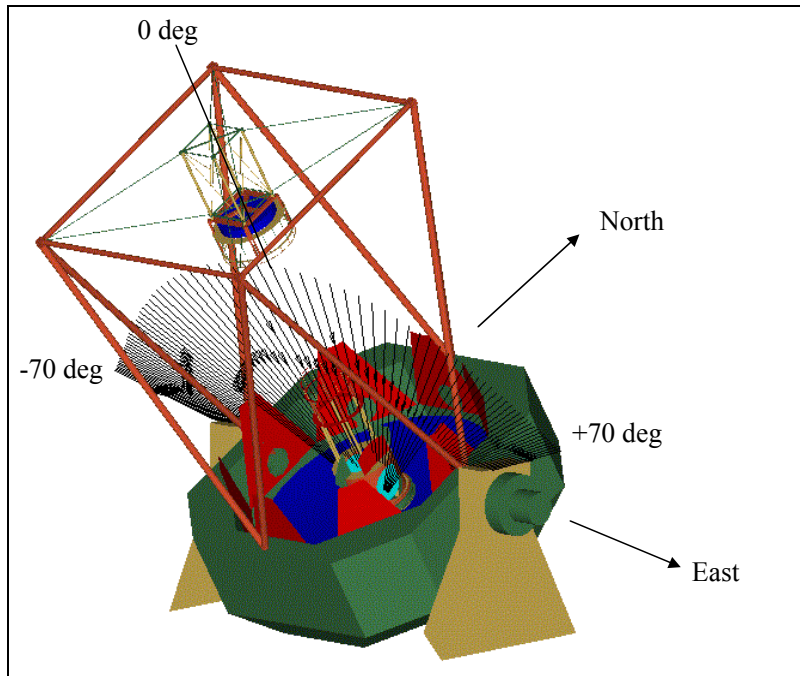


Figure 24 Convention for Side-To-Side PST Scan

4.3 PST Calculations

As shown in Figure 25, the nominal PST in the elevation direction is relatively flat as a function of angle. The only prominent “feature” is the on-axis peak due to near-specular Lorentzian scatter from the mirror surfaces. At high elevation angles we observe some roll off from transmission through catwalk.

In the “side-to-side” scan (Figure 26), the PST drops off with negative angle (i.e., the point source is moving west, away from the Nasmyth fold mirror) because of the shadowing of the telescope slit. In the positive angle direction (i.e., the point source is moving east), the Nasmyth fold mirror and associated structures are illuminated and can scatter directly into the focal plane. Consequently the PST stays high until the telescope slit cuts off the illumination.

To diagnose the cause of these relatively constant PST values, we need to consider how stray light propagates through the system. Workers in the stray light analysis field typically consider two classes of structures: “illuminated” objects and “critical” objects. “Illuminated” objects are those objects directly or indirectly (i.e., by reflection) illuminated by the point source. “Critical” objects are those objects that can be seen either directly or indirectly (i.e., by reflection) by the focal plane. If a structure is simultaneously illuminated by the point source and can be seen by the focal plane, then we have a potentially significant stray light path. (We call this a “potential” stray light path because the structure in question must have a scatter function that radiates energy into the direction of the focal plane in order to transfer energy.)

The structures of the telescope are largely exposed to the point source over the entire elevation PST scan and so virtually every objects can be considered an “illuminated” object.

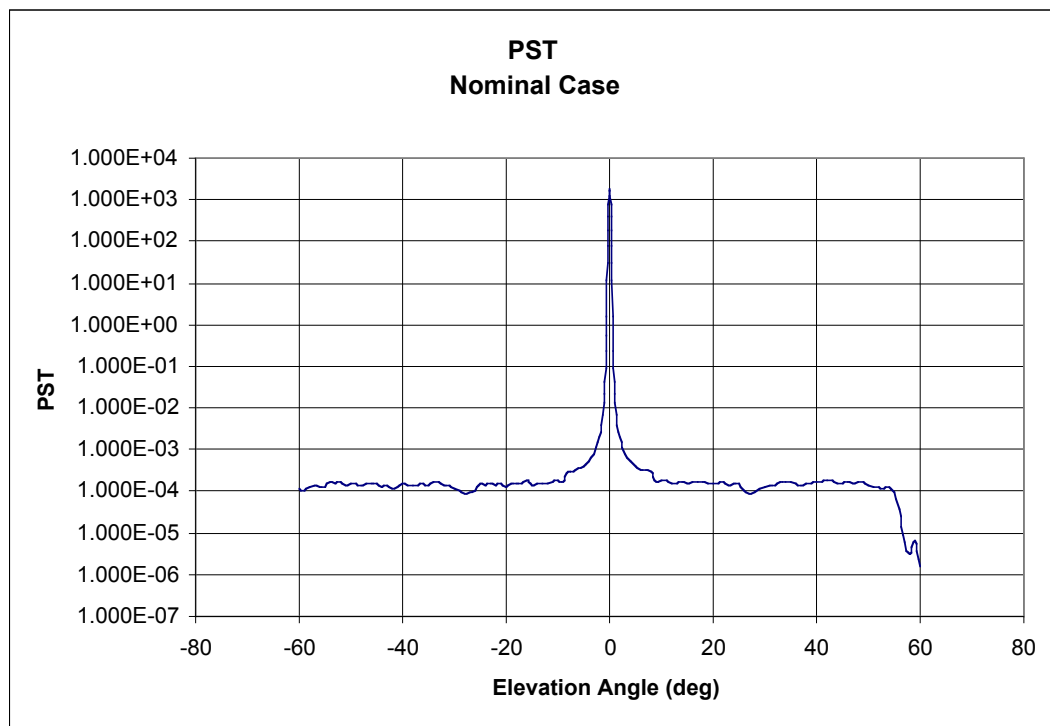


Figure 25 Elevation PST for Existing Observatory Configuration

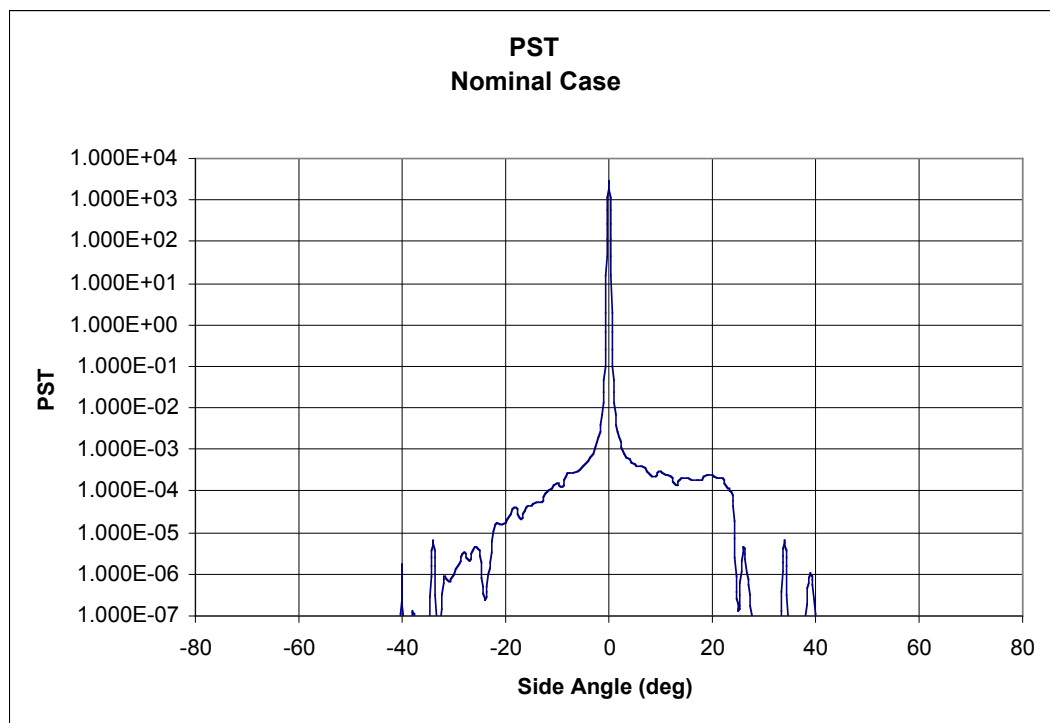


Figure 26 Side PST for Existing Observatory Configuration

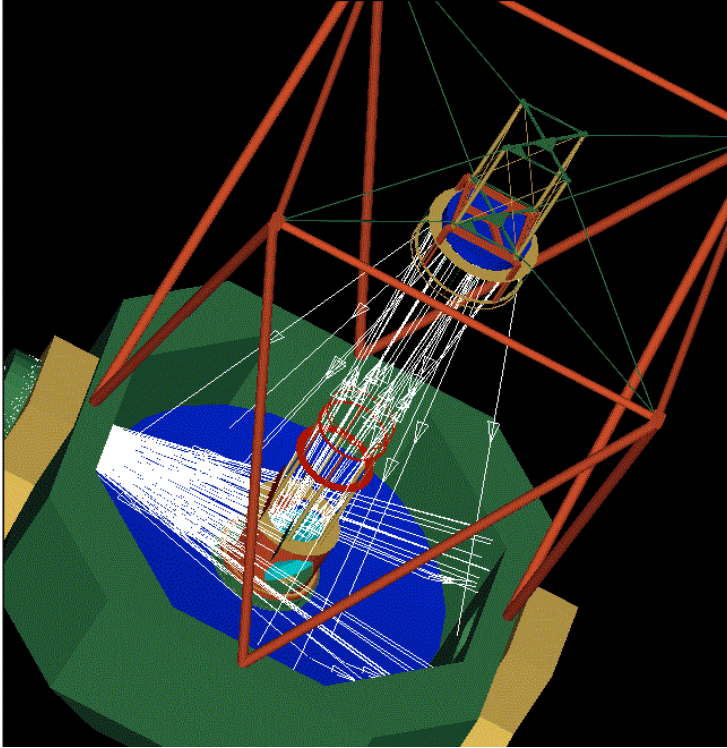


Figure 27 Tracing Rays Backwards from the Focal Plane to Identify “Critical” Objects that can be seen from the focal plane

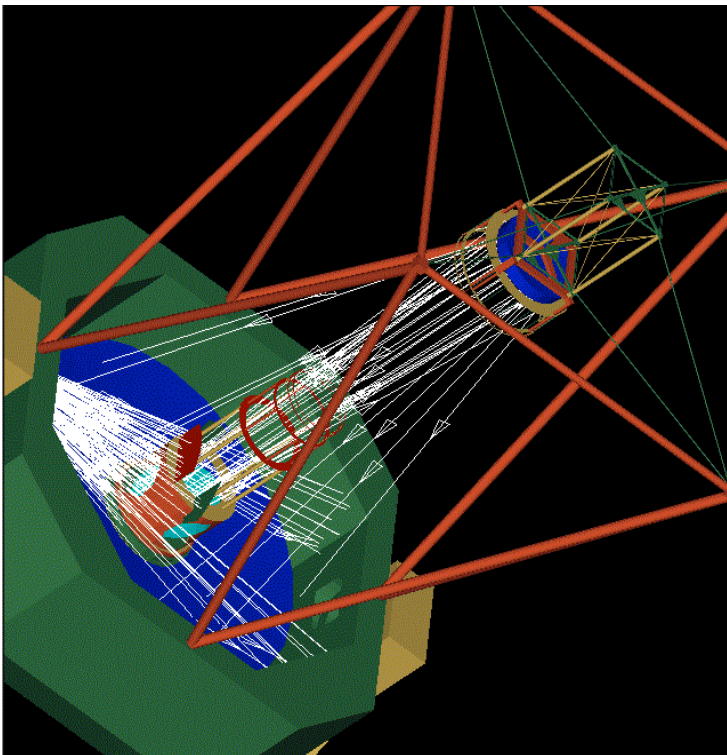


Figure 28 Tracing Rays Backwards from the Focal Plane to Identify “Critical” Objects

In order to determine what the focal plane can see, we can trace rays backward through the system and note which structures are intersected. Ideally the focal plane would only see the surfaces of the Nasmyth fold mirror, secondary and primary mirrors. However as shown in Figures 27 and 28, the focal plane can see the Nasmyth mirror and cell, portions of the primary mirror cell, planar baffles mounted on top of the Nasmyth mirror cell (3RY NA Baffles), and the last annulus of the primary mirror baffle. (These figures were generated prior to adding the primary mirror petal covers to the model, which is why they are missing. The focal plane can certainly see several of the petals as well.) Since these structures are always seen by the focal plane, and they are almost always illuminated by the point source, the system has a first-level scatter path that does not drop off with angle and therefore the elevation PST stays relatively constant with off-axis angle.

For comparison, we isolated the scatter contributions from the three mirrors and plotted their PST with the complete system PST. These are shown in Figures 29 and 30. Our goal was to assess the relative magnitude of the stray light relative to the ubiquitous mirror scatter. (Within the field-of-view, mirror scatter is always important. Outside the field-of-view, the Lorentzian scatter function drops with angle until the optics are shadowed and no longer directly illuminated by the point source. In this case however the optics are illuminated over a broad range of elevation angles and so we observe only the Lorentzian falloff.)

In the absence of a main telescope baffle (“telescope tube”), these PST calculations indicate the minimum amount of stray light that can be achieved.

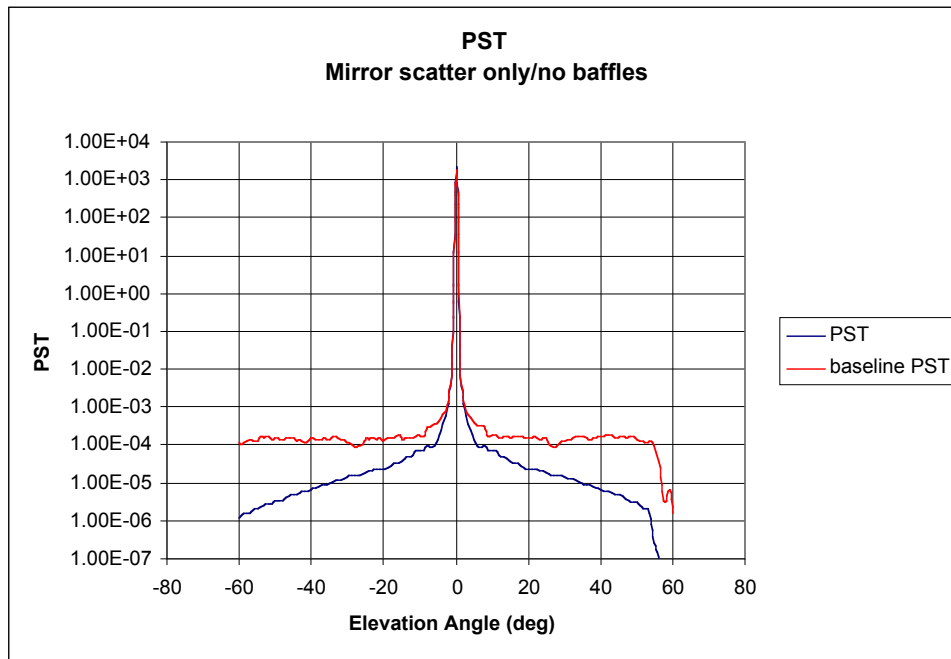


Figure 29 Elevation PST for Existing Observatory Configuration with Mirror Scatter Isolated and Shown for Comparison

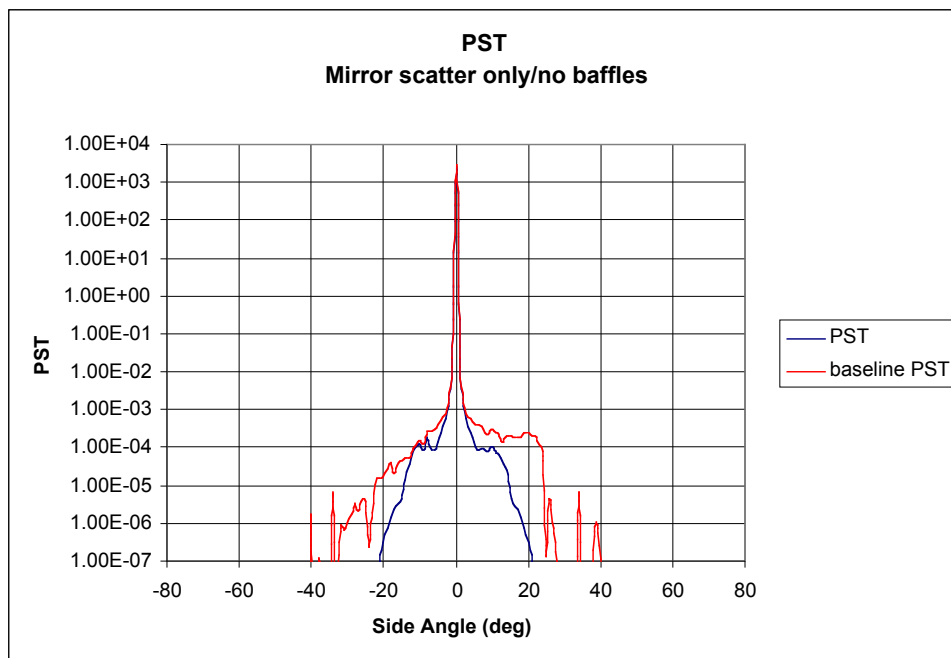


Figure 30 Side PST for Existing Observatory Configuration with Mirror Scatter Isolated and Shown for Comparison

5.0 PST Analyses of Improved System

5.1 Annular Baffle

Upon examination of the baseline PST, it is clear that limiting the field-of-view of the focal plane could reduce the stray light levels. Ideally the focal plane should only see the optical surfaces, but this is not practical in most systems, particularly those without a relay between first focus and the final image. Consequently the best one can do is to insert some new limiting aperture between the focal plane and the Nasmyth fold mirror.

Ray tracing the FOV corresponding to the 4-inch diameter focal plane we decided to employ a 7.6-inch inner diameter baffle at the primary mirror cell. (See Figure 31) This is the smallest aperture that could be used without vignetting the FOV.

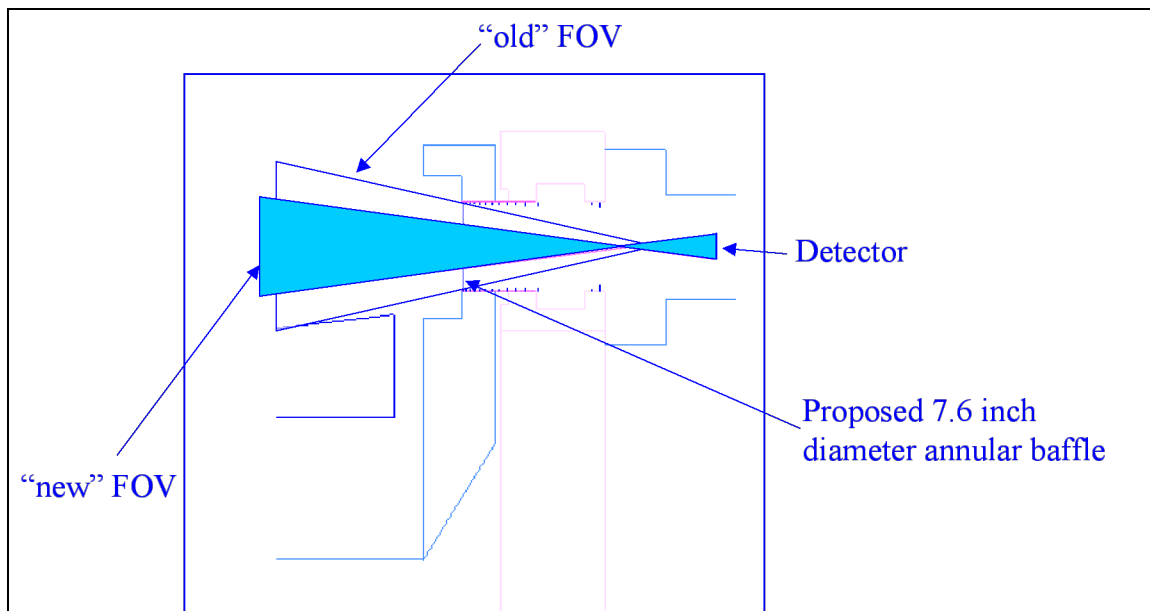


Figure 31 Limiting the FOV of the Focal Plane (Detector) with a New Annular Baffle

Figures 32 and 33 show the PST scans with the annular baffle. (For comparison we plotted the baseline and “mirrors only” PST scans as well.) It is immediately obvious that adding the baffle has the effect of reducing the elevation PST, dropping it an order of magnitude at ± 60 degrees off-axis.

The annular baffle also eliminates the asymmetry in the side PST scan by blocking a scatter path from the Nasmyth mirror mount. (See Figure 33)

Since the proposed annular baffle appears straightforward to implement (and represents a simple and effective “fix”), we added it to the model for all subsequent calculations.

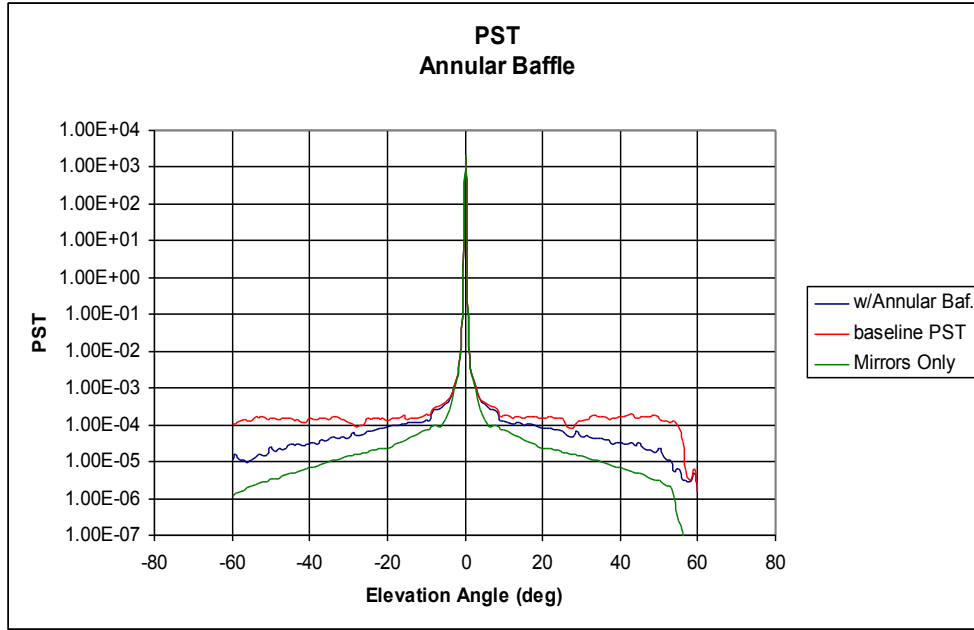


Figure 32 Elevation PST w/Annular Baffle (Mirror scatter and baseline shown for comparison.)

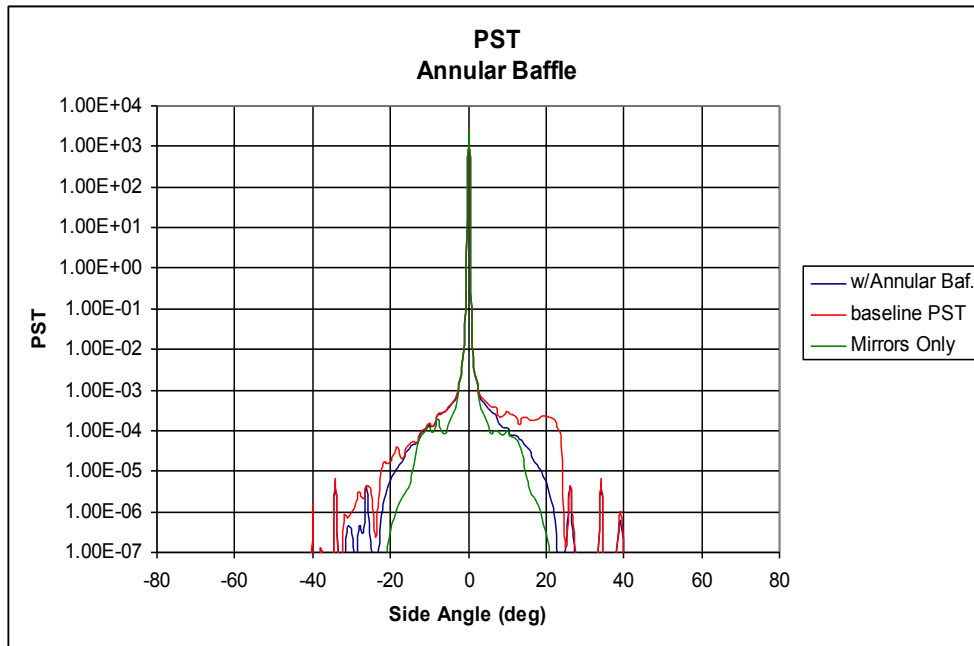


Figure 33 Side PST w/Annular Baffle (Mirror scatter and baseline shown for comparison.)

5.2 Slit Windscreen

We have seen in the previous PST calculations that the observatory slit is an effective stray light baffle in the side-to-side direction because it shadows the telescope. In the elevation direction however the telescope can be illuminated over a large range of angles. This suggests that an

effective baffle strategy would be to close off the slit except where it needs to be open for the telescope FOV.

Figure 34 shows the addition of an adjustable slit windscreen-type structure above and below the telescope's FOV.

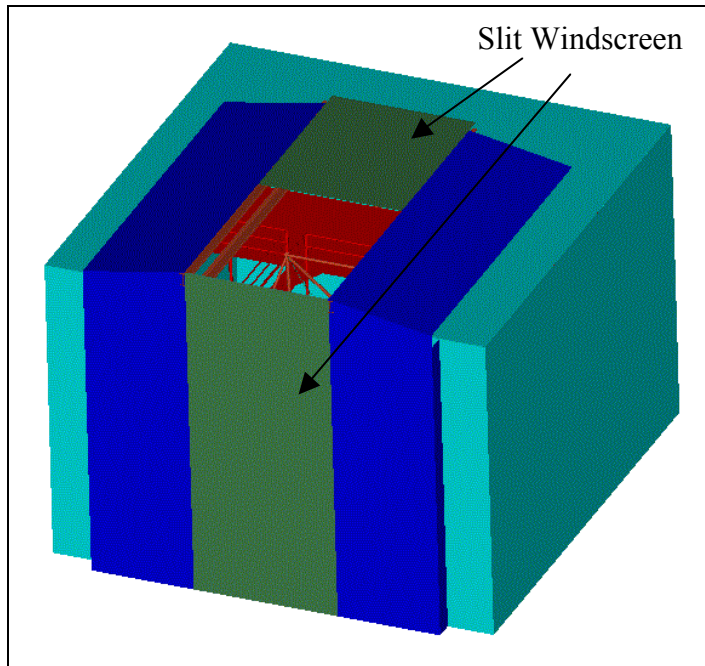


Figure 34 Observatory w/Slit Windscreen

Figures 35 and 36 show the PST scans with the slit windscreen in place. (Recall that the previously discussed annular baffle is also included in the model.) Compared to the baseline (existing) observatory configuration, these two modifications significantly reduce the elevation PST.

The asymmetry in the elevation PST is due to the placement of the slit windscreens.

Since the slit windscreen has no effect on the side PST scan, Figure 36 and Figure 33 are identical.

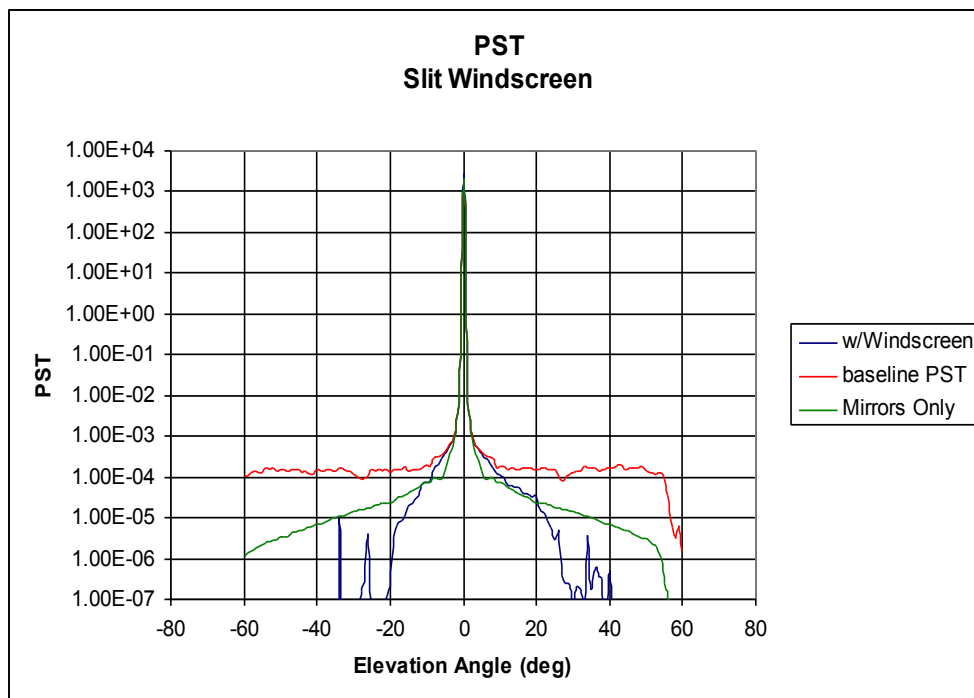


Figure 35 Elevation PST w/Slit Windscreen (Mirror scatter and baseline shown for comparison.)

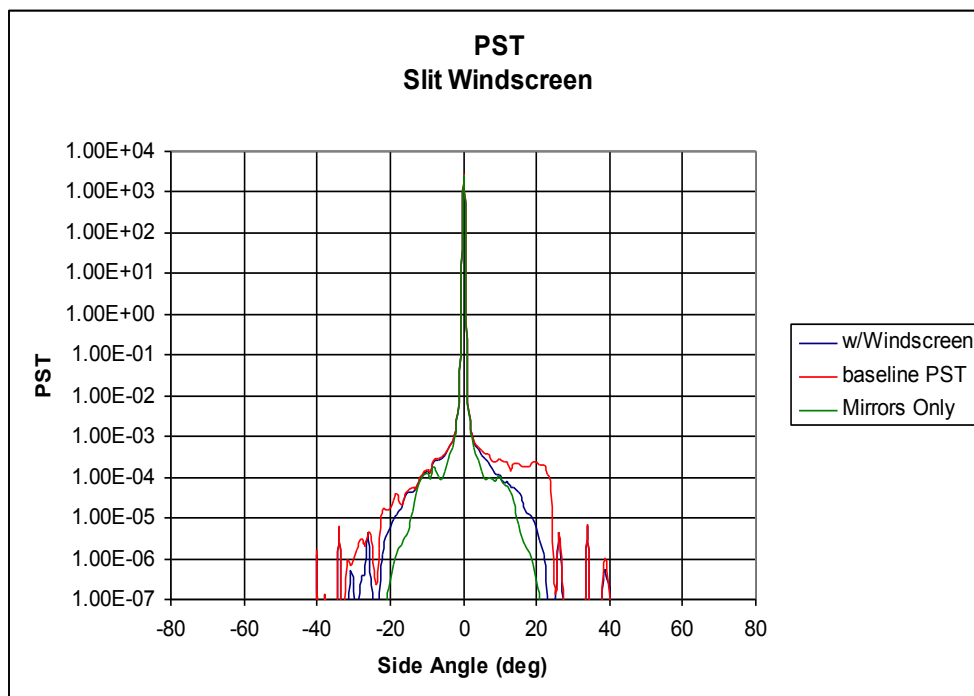


Figure 36 Side PST w/Slit Windscreen (Mirror scatter and baseline shown for comparison.)

5.3 North and South Shrouds

With the goal of shadowing the primary mirror and the Nasmyth fold mirror mounting, another alternative is to surround the main truss with some opaque material that can act as a telescope “tube”.

Enclosing the main truss would upset the airflow in the telescope system, to name one disadvantage, so we looked at the effect of covering only the north and south sides of the main truss with an opaque structure. (See Figure 37) In our model we assumed that this opaque structure was black on both sides with a BRDF similar to that of Aeroglaze Z306.

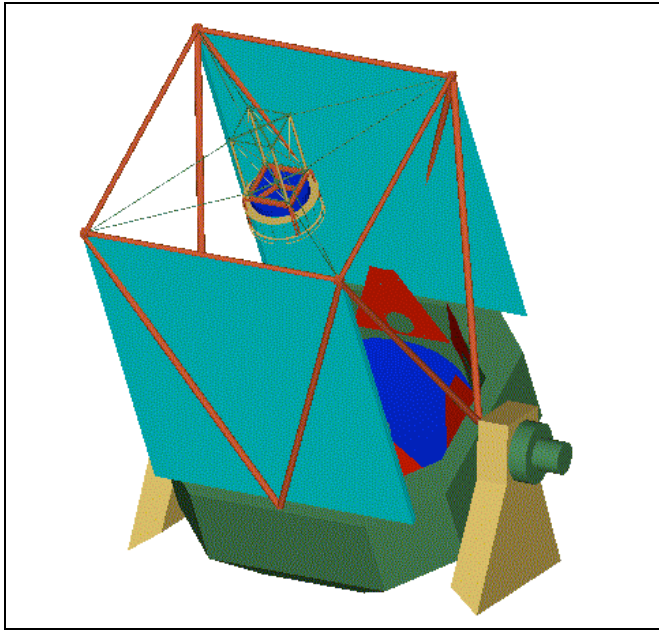


Figure 37 Telescope w/North and South Shrouds (Baffles)

Figures 38 and 39 show the PST scans with the north and south shrouds in place. (Recall that the previously discussed annular baffle is also included in the model.) It is interesting to note that, while the north and south shrouds reduce the PST relative to the baseline (existing) configuration, they do not do as well as the slit windscreen (Figure 35). The reasons for this are twofold: (1) the slit windscreen is physically farther from the telescope and so it casts a shadow at a smaller off-axis angle (effectively shadowing the telescope at approximately ± 20 -25 degrees off-axis) and (2) the black shroud can itself scatter light.

Since the shroud is not present in the side-to-side direction, it is not surprising that it has no effect on the PST in that direction. Hence Figures 39, 36, and 33 are identical.

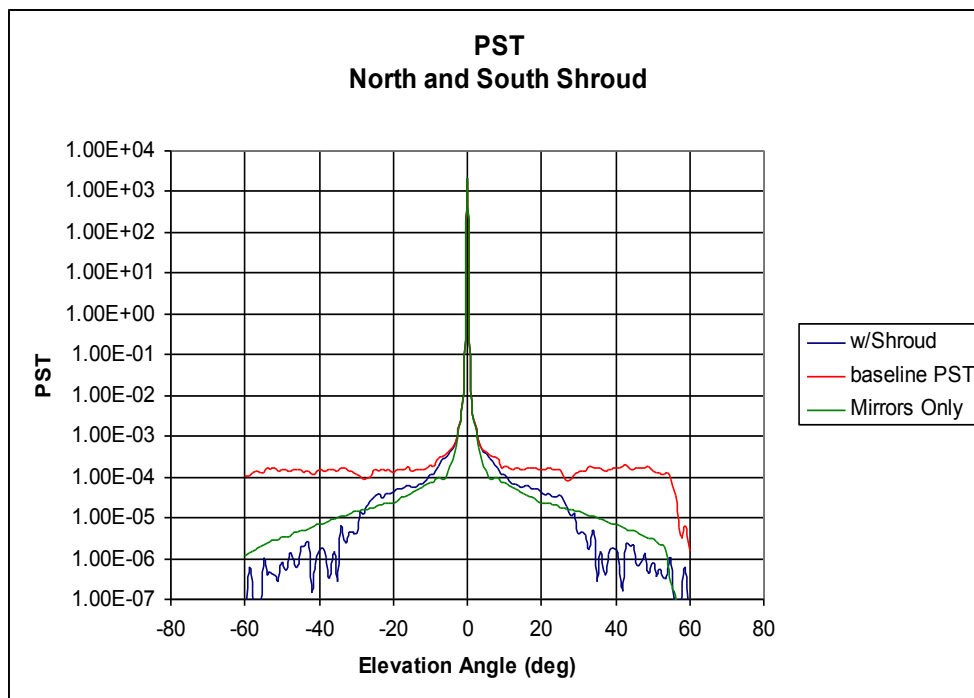


Figure 38 Elevation PST w/North and South Shroud (Mirror scatter and baseline shown for comparison.)

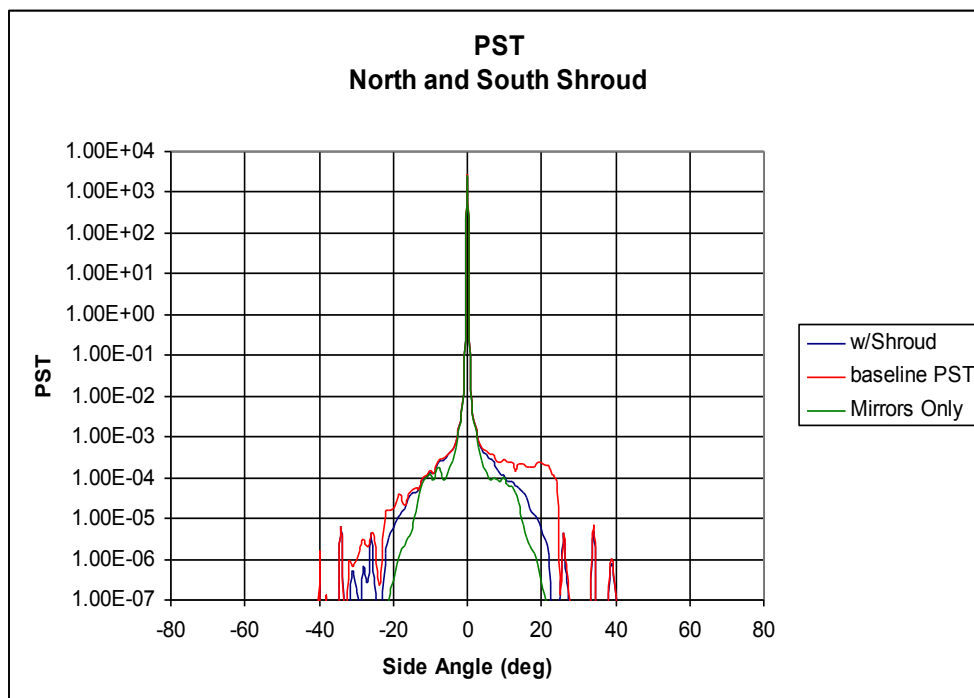


Figure 39 Side PST w/North and South Shroud (Mirror scatter and baseline shown for comparison.)

5.4 Modified Secondary and Nasmyth Baffles

In its unbaffled form, the image plane in a Cassegrain telescope is flooded with out-of-field stray light that bypasses the secondary mirror and enters the central hole in the primary mirror. The common solution to this problem has been to implement a conical baffle around the secondary mirror and a second conical baffle extending from the primary mirror.

In the design of these baffles, the usual strategy is to adjust the dimensions and locations of the baffles to block the “limiting ray”, that is, the ray that intersects the edge of the secondary mirror baffle, the open aperture of the primary conical baffle, and the edge of the image plane itself. (See Figure 40) (Actually most baffle designers select a point somewhat away from the edge of the image plane to allow for tolerances.)

It turns out that there are an infinite number of solutions for the dimensions and locations of the two conical baffles that block the limiting ray. However we generally want are the most effective baffles that also present the least amount of obscuration to the incoming light.

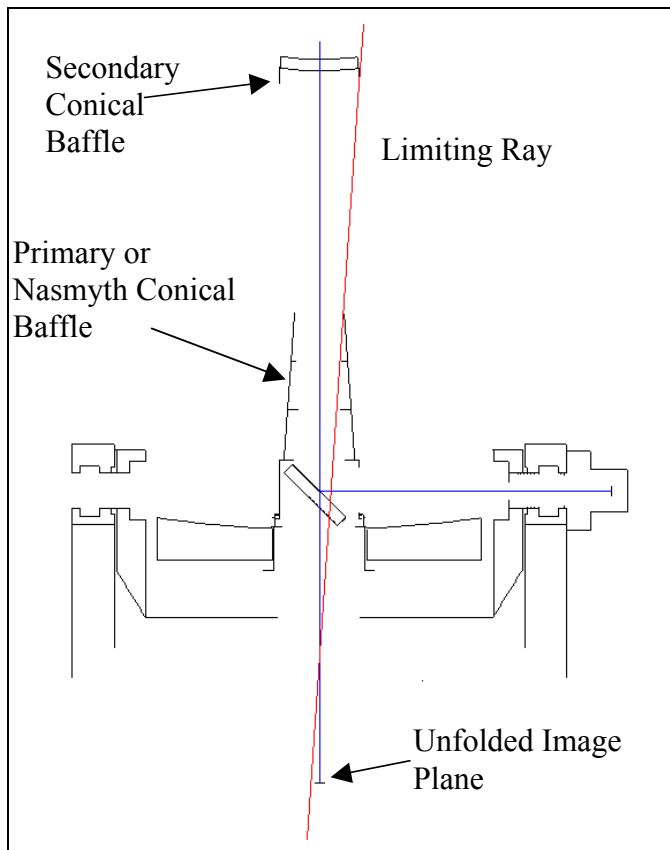


Figure 40 Limiting Ray in the Apache Point Telescope

We have software tools that determine these optimum baffle dimensions and locations. Table 3 gives the parameters of the baffles for a “protected” image plane diameter of 4.2 inches.

Table 3
Optimum Baffle Parameters**

Baffle	Z Location (inches)	Semi diameter (inches)
Primary or Nasmyth	89.800	10.263
Secondary	184.971	16.311

** Z locations are relative to the vertex of the primary mirror.

To block grazing incidence reflections from the sidewall of the primary baffle, it is generally necessary to add vanes along the length. After deciding that two vanes could be reasonably effective, we computed vane inner diameters that don't vignette the imaging rays from the edge of the 4-inch diameter field. Table 4 gives the vane parameters.

Table 4
Primary or Nasmyth Vane Parameters**

Vane	Z Location (inches)	Aperture Semi-diameter (inches)
1	69.800	9.427
2	49.800	8.576

** Z locations are relative to the vertex of the primary mirror.

The use of a black-flocked surface usually provides a more surface for such baffles, as these surfaces have lower reflection and scatter than smooth painted surfaces at almost all angles of incidence. According to our database on such surfaces, a typical quality flocked-type surface would have a measured total hemispherical reflectivity of approximately 1.2% in the visible. (To put this into perspective, Martin Black, a black surface treatment for aluminum used on many space telescopes, has a total hemispherical reflectivity several times higher.) Furthermore black flock surfaces have a significantly lower BRDF at larger angles than a glossy paint such as Aeroglaze Z302 or diffuse Aeroglaze paints.

After reviewing the black-flocked surface BRDF data, we decided to represent the surface as a Lambertian scatterer with a total hemispherical reflectivity of 1.5%.

Figures 41 and 42 show the PST scans with the secondary and Nasmyth baffles in place. (Recall that the previously discussed annular baffle is also included in the model.) In the elevation scan, the optimized baffles appear to reduce the PST by over an order of magnitude; however by comparing Figure 32 with Figure 41, we note that half of the improvement is due to annular baffle. (Therefore relative to the existing annular rings and support tubes, these enclosing baffles are about a factor of 3x better.) In the side PST scan, there is a more subtle improvement. (Compare Figures 42 and 39.)

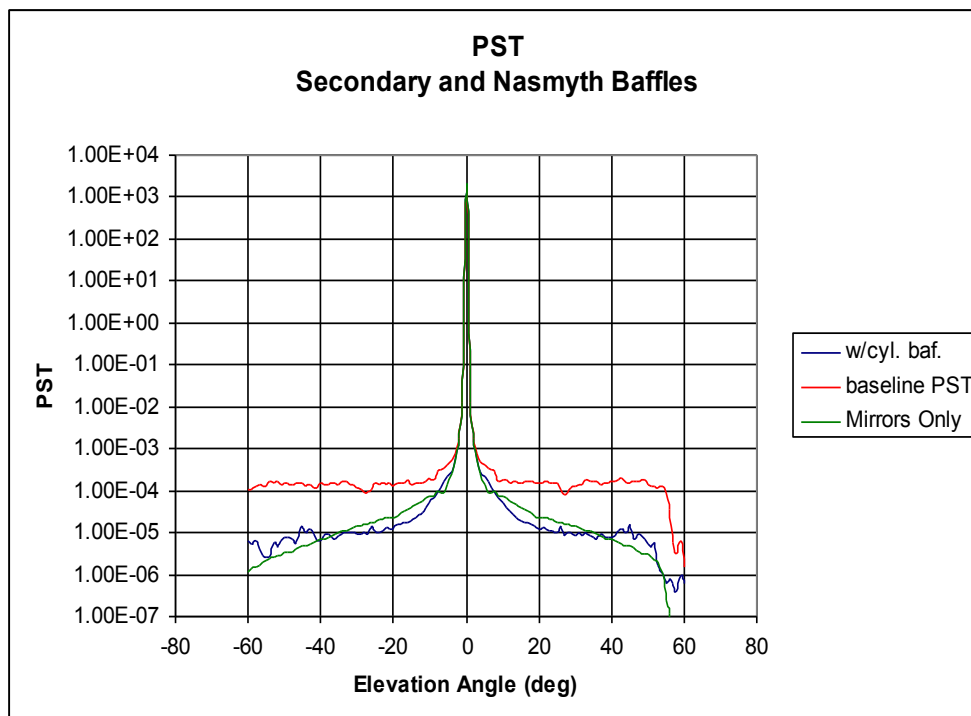


Figure 41 Elevation PST w/Secondary and Nasmyth Baffles (Mirror scatter and baseline shown for comparison.)

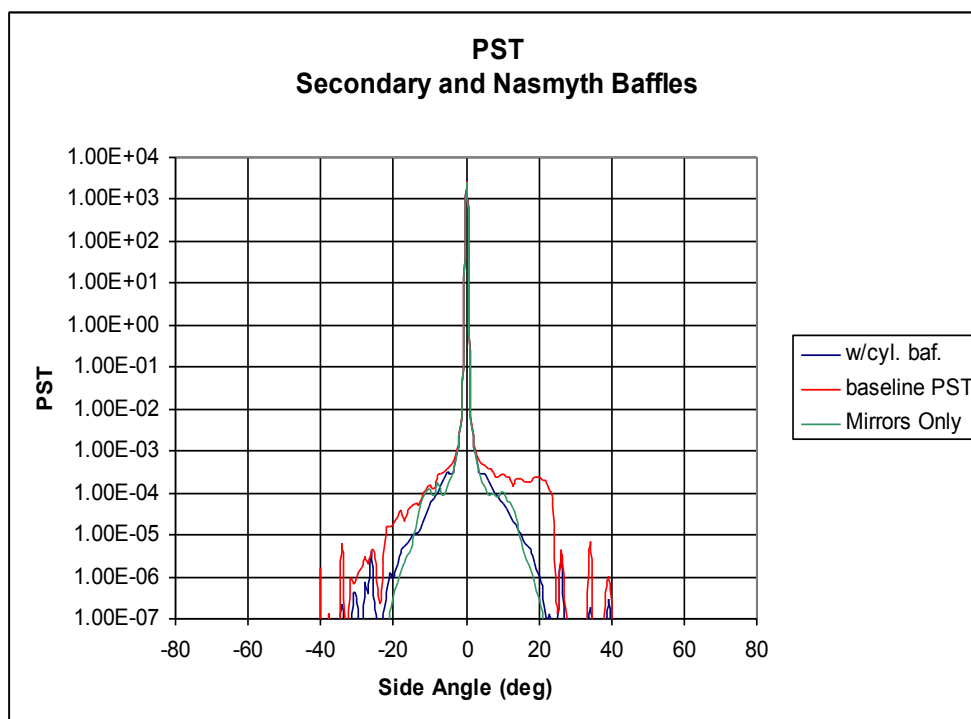


Figure 42 Side PST w/ Secondary and Nasmyth Baffles (Mirror scatter and baseline shown for comparison.)

7.0 Recommendations and Conclusions

A detailed computer model of the Apache Point observatory has been developed from CAD drawings. After assigning scatter models to the various components, we duplicated pinhole images taken with the telescope with the computer model, thereby verifying the model.

The baseline PST of the existing system shows virtually no falloff with off-axis angle in the plane of the observatory slit. This is the result of (1) the focal plane having a large, unobstructed view of the Nasmyth mirror and cell, primary mirror cell, and baffles mounted on the Nasmyth cell, (2) relatively unobstructed illumination of telescope over a large range of angles in the plane of the slit, and (3) secondary and Nasmyth baffles that are not enclosed. These attributes create a series of first-level scatter paths that directly illuminate the focal plane.

Our approach to stray light reduction was to address the light paths revealed by the various PST calculations. Our calculations have shown that the most dramatic gains can be realized from the two items described below:

1. To reduce the FOV of the focal plane, a simple annular baffle at the primary mirror cell can be used. A relay optic would probably be more effective, but is much more complex to implement.
2. To reduce the illumination of the telescope, the installation of a slit windscreen would be effective. Such a screen caused a dramatic drop in the PST. Shrouds on the north and south sides of the main truss are an optically less effective alternative because the black surfaces can scatter.

A factor of 3 improvement in the PST can also be realized by replacing the annular rings and support tubes with enclosing secondary and Nasmyth baffles designed for the specific FOV. The use of high performance coatings with these vaned baffles is necessary to achieve these gains.

8.0 References

1. Spyak, P., Wolfe, W., "Scatter from particulate-contaminated mirrors. Part 4: properties of scatter from dust for visible to far-infrared wavelengths", *Optical Engineering*, Vol. 31, No. 8, August 1992, pp.1775-1784.

ASAP is a proprietary product of Breault Research Organization, Inc., Tucson, AZ.
RhinoCad is a proprietary product of Robert McNeel & Associates, Seattle, WA.

Appendix A ASAP Model Listing

```
!!
!!ZEMAX to ASAP translator  (Vers 1.0)
!!Thu Feb 15 22:26:03 2001
!!Translated from ZEMAX file 'E:\projects\Apache Point\APO35mnew.ZMX'
!!
!!REVISION HISTORY
!! 15 FEB 2001      TRANSLATED ZEMAX FILE INTO ASAP FORMAT
!!                  CONVERTED EVERYTHING TO INCHES FOR CONSISTENCY WITH
!!                  DXF FILE
!! 16 FEB 2001      ADDED MORE STRUCTURE
!! 17 FEB 2001      ADDED MORE STRUCTURE
!! 1 MAR 2001        FURTHER WORK ON TERTIARY BAFFLE
!! 4 MAR 2001        FURTHER WORK ON TERTIARY BAFFLE;
!!                  CORRECTED SOME ERRORS
!! 9 MAR 2001        ADDED 3RY BAFFLES
!! 12 MAR 2001       CORRECTED 2ND FRAME AND ADDED POSTS
!! 27 MAR 2001       ADDED 3RY-NA BAFFLES
!! 1 APR 2001        ADDED FORK TIMES, PASSTHROUGH TUBE
!! 6 MAY 2001        ADDED OBSERVATORY DOME/SLIT (SCOTT ELLIS)
!!                  MODIFIED FOR BATCH RUNS
!! 21 MAY 2001       ADDED NA 2 BAFFLE ROT PER CONVERSATION W/JEFF MORGAN
!! 30 MAY 2001       SETUP FOR PST CALCULATIONS; REMOVED NA2 BAFFLE ROT
!!                  PER CONVERSATION W/JEFF
!! 8 JUN 2001        ADDED NEW BAFFLES ON NASMYTH MOUNT
!! 13 JUN 2001       CHANGED IMAGE PLANE TO 4 INCHES SQUARE; ADDED PRIMARY MIRROR
!!                  COVERS
!! 14 JUN 2001       SCOTT ADDED ROOF, CATWALK, ETC
!! 27 JUN 2001       ADDED HOLES IN PRIMARY MIRROR PETALS; CORRECTED ROOF LAYOUT
!!                  PER CONVERSATION W/JEFF
!! 6 JUL 2001        ADDED TRANSMISSION FUNCTION FOR CATWALK PER JEFF MORGAN
!!
!!=====
!!===== FINAL PRODUCTION VERSION =====
!!=====

!!COLORS
RED=2
ORANGE=4
YELLOW=5
STRAW=18
GREEN=13
DKGREEN=17
MDBLUE=3
BLUE=11
LTBLUE=9
VIOLET=12
UMBER=24

!!----- SETUP VARIABLES -----
DOLENSES=0
DOPIN=0
DO3RY=1
DOVANES=0
OPEN=1

!!----- MODEL STARTS HERE -----
SYSTEM NEW
RESET
RAYS 0

UNIT INCHES !! TO AGREE WITH CAD DRAWING

WAVELENGTH 0.55 MICRONS

COATING PROPERTIES
0.0 1.0 'TRANSMIT'
0.89 0.0 'REFLECT'
0.85 0.0 'ALTAPE'
```

```

!!----- PRIMARY MIRROR -----
SURFACE
  TUBE Z 0 2@19.529 15 2@19.529
  OPTICAL Z 0 -483.452756 -1.01927 ELLI 67.02
  OBJECT 'PRIMARY.MIRROR'
  INTERFACE COATING "REFLECT"
  BOUNDS .2

SURFACE
  PLANE Z 12.653 ELLI 67.02
  OBJECT 'PRIMARY.BACK'
  BOUNDS .3

  OBJECT; .3 'PRIMARY.HOLE'
  BOUNDS -.1 .2

SURFACE
  TUBE Z -5 2@67.02 15 2@67.02
  OBJECT 'PRIMARY.EDGE'
  BOUNDS -.2 .3

$DO 1 4
  OBJ .?; REDEFINE COLOR BLUE.

!!----- SECONDARY MIRROR -----
!!ORIGINAL SEMIDIAMETER WAS 15.159449
SURFACE
  OPTICAL Z 0 -124.527559 -2.1831 ELLI 16.10
  OBJECT 'SECONDARY.MIRROR'
  INTERFACE COATING "REFLECT"

SURFACE
  OPTICAL Z -4.766 -124.527559 -2.1831 ELLI 16.10
  OBJECT 'SECONDARY.BACK'

SURFACE
  TUBE Z 0 2@16.10 -8 2@16.10
  OBJECT 'SECONDARY.EDGE'
  BOUNDS .2 -.3

GROUP -3
  SHIFT Z 6.538547-196.850394

$DO 1 3
  OBJ .?; REDEFINE COLOR BLUE.

!!----- NASMYTH FOLD MIRROR (TERTIARY) -----
TERTRAD=31.2/2

SURFACE
  PLANE Z 0 ELLI TERTRAD.
  OBJECT 'TERTIARY.MIRROR'
  INTERFACE COATING "REFLECT"

SURFACE
  PLANE Z 5 ELLI TERTRAD.
  OBJECT 'TERTIARY.BACK'

SURFACE
  TUBE Z 0 2@TERTRAD. 5 2@TERTRAD.
  OBJECT 'TERTIARY.EDGE'

GROUP -3
  ROTATE X 45
  SHIFT Z 180.850394-196.850394

$DO 1 3
  OBJ .?; REDEFINE COLOR LTBLUE.

$IF DOLENSES. EQ 0

```

```

$GO nolenses
!!----- COMM FFE 1 -----
SURF
  OPTICAL Y 0 26.842875 0 ELLI 8.228
  OBJECT 'COMM.FFE1.SURF1'
  INTERFACE COATING "TRANSMIT" "AIR" "UNUSUAL_FUSILIC"

SURF
  OPTICAL Y 0.9332 106.6013 0 ELLI 8.228
  OBJECT 'COMM.FFE1.SURF2'
  INTERFACE COATING "TRANSMIT" "UNUSUAL_FUSILIC" "AIR"

SURFACE
  TUBE -Y 0 2@8.228 2 2@8.228
  LOCAL -4@8.2323 -2 2 Z .998
  OBJECT 'COMM.FFE1.EDGE'

  OBJ .1; BOUNDS .3 -.2

GROUP -3
  SHIFT Y 111.95118
  SHIFT Z 180.850394-196.850394

$DO 1 3
  OBJ .?; REDEFINE COLOR BLUE.

!!----- COMM FILTER -----
SURF
  PLANE Y 0 ELLI 8.228
  OBJECT 'COMM.FILTER.SURF1'
  INTERFACE COATING "TRANSMIT" "AIR" "SCHOTT_BK7"

SURF
  PLANE Y 0.314961 ELLI 8.228
  OBJECT 'COMM.FILTER.SURF2'
  INTERFACE COATING "TRANSMIT" "SCHOTT_BK7" "AIR"

SURFACE
  TUBE -Y 0 2@8.228 1 2@8.228
  OBJECT 'COMM.FILTER.EDGE'
  BOUNDS -.2

GROUP -3
  SHIFT Y 113.474932
  SHIFT Z 180.850394-196.850394
RET

$DO 1 3
  OBJ .?; REDEFINE COLOR RED.

!!----- LENS MOUNT -----
!! THIS IS OBVIOUSLY JUST TO SEAL THE VOLUME
SURFACE
  PLANE Y 0 ELLI 2@(17.5/2) 8.228/(17.5/2)
  OBJECT 'LENS.MOUNT'
  REDEFINE COLOR DKGREEN.
  SHIFT Y 113.474932
  SHIFT Z 180.850394-196.850394

!!----- COMM FFE 2 -----
SURF
  OPTICAL Y 0 -47.4446 0 ELLI 8.228
  OBJECT 'COMM.FFE2.SURF1'
  INTERFACE COATING "TRANSMIT" "AIR" "UNUSUAL_FUSILIC"

SURF
  OPTICAL Y 1.5748 23.431891 0 ELLI 8.228
  OBJECT 'COMM.FFE2.SURF2'
  INTERFACE COATING "TRANSMIT" "UNUSUAL_FUSILIC" "AIR"

SURFACE

```

```

TUBE -Y -2 2@8.228 4 2@8.228
OBJECT 'COMM.FFE2.EDGE'
BOUNDS .3 -.2

GROUP -3
SHIFT Y 115.9874
SHIFT Z 180.850394-196.850394
RET

$DO 1 3
OBJ .?; REDEFINE COLOR UMBER.

nolenses

!!----- 2ND FRAME -----
MK2NDFRAME { 1
SURFACE
TUBE X -74.5-1.5 2@1.5 74.5+1.5 2@1.5
OBJECT '2ND.FRAME.#1'
SHIFT Y 74.5
ROTATE Z #1*90 0 0
}
Enter side number >

$DO 1 4
MK2NDFRAME ?

GROUP -4
SHIFT Z -221.326-1.5

$DO 1 4
OBJ .?; REDEFINE COLOR UMBER.

MK2NDFRAMEPOST { 1
EDGES
RECT Z 0 2@(4.5/2)
RECT Z -3.5 2@(4.5/2)
OBJECT; .1 '2ND.FRAME.POST.TOP.#1'
OBJECT; .2 '2ND.FRAME.POST.BOT.#1'
OBJECT; .1 .2 '2ND.FRAME.POST.SIDE.#1'
GROUP -3
SHIFT 74.5 74.5 -221.326+0.25
ROTATE Z #1*90 0 0
RET
}
Enter post number>

$DO 1 4
MK2NDFRAMEPOST ?

$DO 1 12
OBJ .?; REDEFINE COLOR UMBER.

!!----- 2ND SPIDER RODS -----
MK2SPDR { 2
SURFACE
TUBE +Y ZL. 2@.25 146.3/2 2@0.25
OBJECT '2ND.SPIDER.#1.#2'
ROTATE X SANG. 146.3/2 0
ROTATE Z -45 0 146.3/2
SHIFT Z -222.826
SHIFT X 146.3/2
ROTATE Z #3 0 0
}
Enter label (A, B, C, D)>
Enter rotation angle (deg)>

SANG=13.5
ZL=-16
MK2SPDR A TOP 0
MK2SPDR B TOP 90

```



```

MK2SPDR C TOP 180
MK2SPDR D TOP 270

SANG=-13.5
ZL=-16
MK2SPDR A BOTTOM 0
MK2SPDR B BOTTOM 90
MK2SPDR C BOTTOM 180
MK2SPDR D BOTTOM 270

$DO 1 8
  OBJ .?; REDEFINE COLOR DKGREEN.

!!----- 2ND BACKUP FRAME -----
EDGES
  POINTS Z 0,
    -13.35 15.05 1,
    -11.60 13.35 1,
    11.60 13.35 1,
    13.35 15.05 1,

    15.05 13.35 1,
    13.35 11.60 1,
    13.35 -11.60 1,
    15.05 -13.35 1,

    13.35 -15.05 1,
    11.60 -13.35 1,
    -11.60 -13.35 1,
    -13.35 -15.05 1,

    -15.05 -13.35 1,
    -13.35 -11.60 1,
    -13.35 11.60 1,
    -15.05 13.35 1

EDGES
  POINTS Z 0,
    -10.8 10.8 1,
    -1.3 10.8 1,
    -1.3 0.7 1,
    -10.8 -4.9 1

EDGES
  REPEAT .1
    ROTATE Y 180 0 0

EDGES
  POINTS Z 0,
    0 -1.5 1,
    10.8 -7.7 1,
    10.8 -10.8 1,
    -10.8 -10.8 1,
    -10.8 -7.7 1

  OBJECT; .4 '2ND.BACKUP.FRAME.TOP'
  BOUNDS .1 .2 .3

EDGES
  REPEAT .4
    SHIFT Z -1.5

  OBJECT; .1 '2ND.BACKUP.FRAME.BOTTOM'
  BOUNDS .2 .3 .4

  OBJECT; .1 .5 '2ND.BACKUP.FRAME.OUTER.EDGE'

EDGES
  REPEAT .4
    SHIFT Z -1.5
  REPEAT .4

```

```

    SHIFT Z -1.5
  REPEAT .4
    SHIFT Z -1.5

  OBJECT; .3 .7 '2ND.BACKUP.FRAME.INNER.EDGE.A'

  OBJECT; .2 .6 '2ND.BACKUP.FRAME.INNER.EDGE.B'

  OBJECT; .1 .5 '2ND.BACKUP.FRAME.INNER.EDGE.C'

GROUP -6
  SHIFT Z -197.676
RET

$DO 1 6
  OBJ .?; REDEFINE COLOR UMBER.

MKFRMBLCKS { 1
  EDGES
    RECT Z 0 2.5/2 1/2
    RECT Z -8.0373 2.5/2 1/2
    OBJECT; .1 .2 '2ND.BKUP.FRAME.BLOCK.#1'
      REDEFINE COLOR UMBER.
      SHIFT Y 19.638
      SHIFT Z -190.86
      ROTATE Z (#1-1)*90+45 0 0
  }
Enter block number>

$DO 1 4
  MKFRMBLCKS ?

!!----- 2ND TRUSS ENDS -----
EDGES
  POINTS Z 0,
    -12.45 13.33 1,
    -11.70 13.33 1,
    -10.70 12.33 1,
    10.70 12.33 1,
    11.70 13.33 1,
    12.45 13.33 1,
    13.33 12.45 1,
    13.33 11.70 1,
    12.33 10.70 1,
    12.33 -10.70 1,
    13.33 -11.70 1,
    13.33 -12.45 1,
    12.45 -13.33 1,
    11.70 -13.33 1,
    10.70 -12.33 1,
    -10.70 -12.33 1,
    -11.70 -13.33 1,
    -12.45 -13.33 1,
    -13.33 -12.45 1,
    -13.33 -11.70 1,
    -12.33 -10.70 1,
    -12.33 10.70 1,
    -13.33 11.70 1,
    -13.33 12.45 1,
    -12.45 13.33 0,

    0 .7 1,
    10.9 11.7 1,
    -10.9 11.7 1,
    0 .7 0,

    .7 0 1,
    11.7 10.9 1,
    11.7 -10.9 1,
    .7 0 0,

```

```

    0 -.7 1,
    10.9 -11.7 1,
    -10.9 -11.7 1,
    0 -.7 0,

    -.7 0 1,
    -11.7 10.9 1,
    -11.7 -10.9 1,
    -.7 0 0

EDGES
  REPEAT .1
    SHIFT Z -.5

  OBJECT; .2 '2ND.TRUSS.END.A.TOP'
  OBJECT; .1 '2ND.TRUSS.END.A.BOTTOM'
  OBJECT; .1 .2 '2ND.TRUSS.END.A.SIDES'

EDGES
  REPEAT .2
  REPEAT .2

  OBJECT; .2 '2ND.TRUSS.END.B.TOP'
  OBJECT; .1 '2ND.TRUSS.END.B.BOTTOM'
  OBJECT; .1 .2 '2ND.TRUSS.END.B.SIDES'

GROUP .4 .5 .6
  SHIFT Z -201.072

GROUP .1 .2 .3
  SHIFT Z -244.077

$DO 1 6
  OBJ .?; REDEFINE COLOR DKGREEN.

!!----- 2ND BOTTOM BAFFLE -----
SURFACE
  PLANE Z 0 ELLI 2@(41.55/2) 31.5/41.55
  OBJECT '2ND.BOTTOM.BAFFLE'
  REDEFINE COLOR STRAW.
  SHIFT Z -190.85

!!----- 2ND MIDDLE BAFFLE -----
SURFACE
  PLANE Z 0 ELLI 2@(41.29/2) 38.54/41.29
  OBJECT '2ND.MIDDLE.BAFFLE'
  REDEFINE COLOR STRAW.
  SHIFT Z -178.44

!!----- 2ND TOP BAFFLE -----
SURFACE
  PLANE Z 0 ELLI 2@(41.61/2) 40.40/41.61
  OBJECT '2ND.TOP.BAFFLE'
  REDEFINE COLOR STRAW.
  SHIFT Z -175.223

!!----- 2ND XLINK RODS -----
MKXLINK { 1
SURFACE
  TUBE Z -48.2/2 2@(.375/2) 48.2/2 2@(.375/2)
  OBJECT '2ND.XLINK.ROD.A.#1'
  REDEFINE COLOR STRAW.
  ROTATE X 57/2 0 0

SURFACE
  TUBE Z -48.2/2 2@(.375/2) 48.2/2 2@(.375/2)
  OBJECT '2ND.XLINK.ROD.B.#1'
  REDEFINE COLOR STRAW.
  ROTATE X -57/2 0 0

GROUP -2

```

```

SHIFT X 12.1
SHIFT Z -223.189+.5
ROTATE Z #1*90 0 0
RET
}
Enter xlink number>

$DO 1 4
MKXLINK ?

!!----- 2ND BAF SPACER 1 -----
MKSPCR1 { 1
SURFACE
TUBE -Z 0 2@.125 -12.163 2@.125
OBJECT '2ND.BAF.SPACER.1.#1'
REDEFINE COLOR DKGREEN.
SHIFT Y 41.1/2
SHIFT Z -178.587
ROTATE Z #1*18+9 0 0
}
Enter spacer number>

$DO 1 20
MKSPCR1 ?

!!----- 2ND BAF SPACER 2 -----
MKSPCR2 { 2
SURFACE
TUBE -Z 0 2@.125 -3.126 2@.125
OBJECT '2ND.BAF.SPACER.2.#1'
REDEFINE COLOR UMBER.
SHIFT Y 41.1/2
SHIFT Z -175.399
ROTATE Z #1*18+9 0 0
}
Enter spacer number>

$DO 1 20
MKSPCR2 ?

!!----- 2ND BAF POSTS -----
MK2NDBAFPOSTS { 1
SURFACE
TUBE -Z 0 2@.5 -12.163 2@.5
OBJECT '2ND.BAF.POSTS.A.#1'
REDEFINE COLOR UMBER.
SHIFT Y 19.865
ROTATE Z 4.8/2 0 0
SHIFT Z -178.587

SURFACE
TUBE -Z 0 2@.5 -12.163 2@.5
OBJECT '2ND.BAF.POSTS.B.#1'
REDEFINE COLOR UMBER.
SHIFT Y 19.875
ROTATE Z -4.8/2 0 0
SHIFT Z -178.587

GROUP -2
ROTATE Z #1*90+45 0 0
}
Enter post number>

$DO 1 4
MK2NDBAFPOSTS ?

!!----- 2ND TRUSS SPREADER RODS -----
MKSPDRODS { 1
SURFACE
TUBE -Z 0 2@(1.5/2) -42.2 2@(1.5/2)
OBJECT '2ND.TRUSS.SPREADER.ROD.#1'

```

```

        REDEFINE COLOR STRAW.
        SHIFT Y 17.1119
        SHIFT Z -201.734
        ROTATE Z (#1-1)*90+45 0 0
    }
Enter spreader number>

$DO 1 4
    MKSPDRODS ?

!!----- 2ND TRUSS BOTTOMS -----
MKTRUSSBOTTOM { 1
    EDGES
    RECT Z 0 2@0.75
    RECT Z -2 2@.75
    OBJECT; .1 .2 '2ND.TRUSS.BOTTOM.#1'
    REDEFINE COLOR STRAW.
    SHIFT Z -199.172
    SHIFT Y 17.1119
    ROTATE Z (#1-1)*90+45 0 0
}
Enter truss bottom number>

$DO 1 4
    MKTRUSSBOTTOM ?

!!----- 3RY BAFFLE LARGE POSTS -----
MKBAFLARGEPOSTS { 1
    SURFACE
    TUBE -Z 0 2@(1.5/2) -33.35 2@(1.5/2)
    OBJECT '3RY.BAFFLE.LARGE.POSTS.#1'
    REDEFINE COLOR STRAW.
    SHIFT X 25.2/2
    SHIFT Z -28.943
    ROTATE Z (#1-1)*60 0 0
}
Enter post number>

$IF DO3RY. EQ 1 2
    $DO 1 6
        MKBAFLARGEPOSTS ?

!!----- 3RY BASE -----
!! THIS STRUCTURE IS UNDERNEATH THE PRIMARY MIRROR AND SO
!! EXTREME ACCURACY IS NOT REQUIRED
SURFACE
    PLANE Z 0 ELLI 2@(46.5/2) 37.5/46.5
    OBJECT '3RY.BASE.DISK'

SURFACE
    TUBE -Z 0 2@(37.5/2) -18 2@(37.5/2)
    OBJECT '3RY.BASE.CYLINDER'

GROUP -2
    SHIFT Z 17
RET

$DO 1 2
    OBJ .?; REDEFINE COLOR STRAW.

!!----- 3RY BEARING HOUSING -----
SURFACE
    PLANE Z 0 ELLI 2@(39.86/2) 30/39.86
    OBJECT '3RY.BEARING.HOUSING.BOTTOM'

SURFACE
    TUBE Z 0 2@(36.5/2) -4.1 2@(36.5/2)
    OBJECT '3RY.BEARING.HOUSING.CYLINDER'

SURFACE
    PLANE Z -4.1 ELLI 2@(39/2) 36.6/39

```

```

OBJECT '3RY.BEARING.HOUSING.TOP'

GROUP -3
  SHIFT Z -.91

$DO 1 3
  OBJ .?; REDEFINE COLOR DKGREEN.

!!----- 3RY BEARING HOUSING CLAMP -----
SURFACE
  TUBE Z 0 2@(37/2) -1.43 2@(37/2)
  OBJECT '3RY.BEARING.HOUSING.CLAMP.CYLINDER'

SURFACE
  PLANE Z -1.43 ELLI 2@(37/2) 35.6/37
  OBJECT '3RY.BEARING.HOUSING.CLAMP.TOP'

GROUP -2
  SHIFT Z -5.025

$DO 1 2
  OBJ .?; REDEFINE COLOR UMBER.

!!----- 3RY BEARING SHAFT CLAMP -----
SURFACE
  TUBE Z 0 2@(33/2) -1.1 2@(33/2)
  OBJECT '3RY.BEARING.SHAFT.CLAMP.CYLINDER'

SURFACE
  PLANE Z -1.1 ELLI 2@(36.4/2) 33/36.4
  OBJECT '3RY.BEARING.SHAFT.CLAMP.TOP'

GROUP -2
  SHIFT Z -5.037

$DO 1 2
  OBJ .?; REDEFINE COLOR STRAW.

!!----- 3RY BEARING SHAFT -----
EDGES
  POINTS Z 0,
    1.536 13.317 2,
    27.679 0 COS[64],
    1.536 -13.317 1

SURFACE
  TUBE Z 0 2@(3.5/2) 1 2@(3.5/2)
  SHIFT -13.669 -5.702 0

SURFACE
  PLANE Z 0 ELLI 35.5/2
  OBJECT '3RY.BEARING.SHAFT'
  BOUNDS .2 .3
  SHIFT Z -4.46
  REDEFINE COLOR DKGREEN.

!!----- MAIN TRUSS -----
MKTRUSS { 1
  EDGES
    OVAL Z -33 2@2
    SHIFT Y -80.925
    OVAL Z -221.326 2@2
    SHIFT -75 -75 0
    OBJECT; .1 .2 'MAIN.TRUSS.SIDE#1.A'

  EDGES
    OVAL Z -33 2@2
    SHIFT Y -80.925
    OVAL Z -221.326 2@2
    SHIFT 75 -75 0
    OBJECT; .1 .2 'MAIN.TRUSS.SIDE#1.B'

```

```

GROUP -2
  ROTATE Z #1*90 0 0

$DO 1 2
  OBJ .?; REDEFINE COLOR UMBER.
}
Enter truss side>

$DO 1 4
  MKTRUSS ?

!!----- PRIMARY MIRROR CELL -----
SURFACE
  TUBE Z 0 2@(34/2) 1 2@(34/2)
  PLANE Y -72
  PLANE Y 72
  TUBE Y -72-6.363 2@12 72+6.363 2@12
  SHIFT Z 17.07

EDGES
  POINTS Z 0,
    -51.75 84 1,
    51.75 84 1,
    84 51.75 1,
    84 -51.75 1,
    51.75 -84 1,
    -51.75 -84 1,
    -84 -51.75 1,
    -84 51.75 1

  POINTS Z 0,
    -29.809 72 1,
    29.809 72 1,
    72 29.809 1,
    72 -29.809 1,
    29.809 -72 1,
    -29.809 -72 1,
    -72 -29.809 1,
    -72 29.809 1

OBJECT; .1 .2 'PRIMARY.MIRROR.CELL.TOP'

EDGES
  REPEAT .1
    SHIFT Z 50.063+19.575

OBJECT; .1 .2 'PRIMARY.MIRROR.CELL.INNER'
  BOUNDS .4

EDGES
  REPEAT .3
    SHIFT Z 50.063

OBJECT; .1 .4 'PRIMARY.MIRROR.CELL.OUTER'
  BOUNDS .5

OBJECT; .5 'PRIMARY.MIRROR.CELL.PASSTHRU.A'
  BOUNDS .6

OBJECT; .5 'PRIMARY.MIRROR.CELL.PASSTHRU.B'
  BOUNDS -.7

OBJECT; .1 .2 'PRIMARY.MIRROR.CELL.BOTTOM.SIDES'

OBJECT; .2 'PRIMARY.MIRROR.CELL.BOTTOM'
  BOUNDS .8

SURFACE
  PLANE Y 72+6.363 ELLI 2@(24/2) 15/24
  OBJECT 'PRIMARY.MIRROR.CELL.PLATE.A'

```

```

SHIFT Z 17.07

SURFACE
TUBE Y 72+6.363 2@(15/2) 84 2@(15/2)
OBJECT 'PRIMARY.MIRROR.CELL.TUBE.A'
SHIFT Z 17.07

SURFACE
PLANE Y 84 ELLI 2@(24/2) 15/24
OBJECT 'PRIMARY.MIRROR.CELL.OUTER.PLATE.A'
SHIFT Z 17.07

SURFACE
PLANE Y -72-6.363 ELLI 2@(24/2) 15/24
OBJECT 'PRIMARY.MIRROR.CELL.PLATE.B'
SHIFT Z 17.07

SURFACE
TUBE Y -72-6.363 2@(15/2) -84 2@(15/2)
OBJECT 'PRIMARY.MIRROR.CELL.TUBE.B'
SHIFT Z 17.07

SURFACE
PLANE Y -84 ELLI 2@(24/2) 15/24
OBJECT 'PRIMARY.MIRROR.CELL.OUTER.PLATE.B'
SHIFT Z 17.07

GROUP -13
SHIFT Z -33.1

$DO 1 13
OBJ .?; REDEFINE COLOR DKGREEN.

!!----- PRIMARY MIRROR COVER -----
MKCOVER { 1
  THIS=#1
SURFACE
  TUBE X 0 2@8 1 2@8
  SHIFT Y 9.44
EDGES
POINTS X 0,
  0.0      0.0  1,
  0.0      27.856 1,
  52.492   6.113 2,
  50.319   0.0   COS[19.57],
  52.492  -6.113 1,
  51.799  -6.4   1,
  52.411  -7.878 1,
  0.0     -29.588 1
OBJECT; .1 'PRIMARY.MIRROR.COVER.#1'
  REDEFINE COLOR RED.
$IF THIS. NE 5
  BOUNDS .2
  ROTATE X -90 0 0
$IF OPEN. EQ 0
  ROTATE Y 90 0 0
  SHIFT X (144/2)-2.5
  SHIFT Z -6.675
  ROTATE Z (#1-1)*45
}
Enter cover petal number>

$DO 1 8
MKCOVER ?

!!----- FORK TINES -----
MKTINE { 1
EDGES
RECT Y 84.95 33.5/2 36/2 16
RECT Y 84.95+17.5 33.5/2 36/2 16
OBJECT; .1 .2 'FORK.TINE.#1.TOP'

```



```

SHIFT Z 16.75-19.3871

EDGES
ELLI Y 84.95 2@(19.521/2)
ELLI Y 84.95+17.5 2@(15/2)

OBJECT; .2 .4 'FORK.TINE.#1.ENT'
OBJECT; .1 .3 'FORK.TINE.#1.EXIT'

SURFACE
TUBE Y 84.95 2@(19.521/2) 84.95+1.25 2@(19.521/2)
OBJECT 'FORK.TINE.#1.INNER.TUBE.1'

SURFACE
PLANE Y 84.95+1.25 ELLI 2@(19.521/2) 15/19.521
OBJECT 'FORK.TINE.#1.INNER.PLATE.1'

SURFACE
TUBE Y 84.95+1.25 2@(15/2) 84.95+1.25+4.75 2@(15/2)
OBJECT 'FORK.TINE.#1.INNER.TUBE.2'

SURFACE
PLANE Y 84.95+1.25+4.75 ELLI 2@(21/2) 15/21
OBJECT 'FORK.TINE.#1.INNER.PLATE.2'

SURFACE
TUBE Y 84.95+1.25+4.75 2@(21/2) 84.95+1.25+4.75+8 2@(21/2)
OBJECT 'FORK.TINE.#1.INNER.TUBE.3'

SURFACE
PLANE Y 84.95+1.25+4.75+8 ELLI 2@(21/2) 15/21
OBJECT 'FORK.TINE.#1.INNER.PLATE.3'

SURFACE
TUBE Y 84.95+1.25+4.75+8 2@(15/2) 84.95+1.25+4.75+8+3.5 2@(15/2)
OBJECT 'FORK.TINE.#1.INNER.TUBE.4'

EDGES
RECT Z 33.5/2+16.75-19.3871 36/2 17.5/2 4
SHIFT Y 84.95+17.5/2
POINTS,
92.094/2 84.95 33.5/2+16.75-19.3871+51 1,
100/2 84.95+17.5 33.5/2+16.75-19.3871+63 1,
-100/2 84.95+17.5 33.5/2+16.75-19.3871+63 1,
-92.094/2 84.95 33.5/2+16.75-19.3871+51 1
OBJECT; .1 .2 'FORK.TINE.#1.SIDE.A'

GROUP -11
SHIFT Z -16
ROTATE Z (#1-1)*180 0 0
RET

$DO 1 11
OBJ .?; REDEFINE COLOR STRAW.
}
Enter tine number>

$DO 1 2
MKTINE ?

!!----- OBSERVATORY DOME/SLIT -----
!! SOME CORRECTIONS MADE TO MAKE THE GEOMETRY WORK
!! SPOKE TO JEFF MORGAN 28 JUNE 2001 FOR COMMENTS

PRI .1
$GRAB 'OBJECT' START

MKSLIT { 1
SIDE=#1 SIGN=-2*SIDE+3 !!FLIP SIGN

EDGES

```

```

POINTS,
SIGN*90.0      420.0      0.0 1,
SIGN*90.0      420.0     -209.4 1,
SIGN*218.4     396.6     -209.4 1,
SIGN*218.4     396.6      209.4 1,
SIGN*90.0      420.0      209.4 1
OBJECT; .1 'SLIT.TOP.#1'

EDGES
POINTS,
SIGN*90.0      420.0      209.4 1,
SIGN*218.4     396.6      209.4 1,
SIGN*218.4      0.0      209.4 1,
SIGN*90.0      0.0      209.4 1
OBJECT; .1 'SLIT.FRONT.#1'

EDGES
POINTS X SIGN*218.4,
381.0 -209.4 1,
365.4 -209.4 1,
365.4 186.6 1,
381.0 209.4 1
POINTS X SIGN*218.4,
373 0 1,
373 0 1,
373 0 1,
373 0 1
OBJECT; .1 .2 'SLIT.SIDE.A.#1'

EDGES
POINTS X SIGN*218.4,
0.0 186.6 1,
0.0 209.4 1,
381.0 209.4 1,
365.4 186.6 1
POINTS X SIGN*218.4,
190 184 1,
190 184 1,
190 184 1,
190 184 1
OBJECT; .1 .2 'SLIT.SIDE.B.#1'

GROUP -4
ROTATE X -90 0 0
ROTATE Z 90 0 0
SHIFT Z 91
SHIFT X -120+28+3

$DO 1 4
  OBJ .?; REDEFINE COLOR BLUE.
}
Enter slit number >

$DO 1 2
  MKSLIT ?

EDGES
POINTS Z 0,
129 -276 1,
276 -276 1,
276 276 1,
-276 276 1,
-276 -276 1,
-129 -276 0
REPEAT .1
  SHIFT Z -381
OBJECT; .1 .2 'TELESCOPE.ENCLOSURE'

EDGES
POINTS Z 0,
0 276 1,

```

```

    276    276 1,
    276   -276 1,
    129   -276 1,
    129    120 1,
   -129    120 1,
   -129   -276 1,
   -276   -276 1,
   -276    276 1
SURFACE
  PLANE Z -381 RECT 276 276
  OBJECT 'TELESCOPE.ENCLOSURE.ROOF'
  BOUNDS -.2

GROUP -2
  ROTATE Z -90 0 0
  SHIFT Z 91
RET

$DO 1 2
  OBJ .?; REDEFINE COLOR LTBLUE.

GROUP -10
  ROTATE Z 180 0 0
  SHIFT Z -16
RET

!!----- HORIZONTAL I-BEAMS -----

MKHIBEAM { 1
  EDGES
    POINTS -276 0 0 REL,
      0 0 6 1,
      0 -1 6 1,
      0 -1 4 1,
      0 -14.6 4 1,
      0 -14.6 6 1,
      0 -15.6 6 1,
      0 -15.6 0 1,
      0 -14.6 0 1,
      0 -14.6 2 1,
      0 -1 2 1,
      0 -1 0 1,
      0 0 0 1
    POINTS 276 0 0 REL,
      0 0 6 1,
      0 -1 6 1,
      0 -1 4 1,
      0 -14.6 4 1,
      0 -14.6 6 1,
      0 -15.6 6 1,
      0 -15.6 0 1,
      0 -14.6 0 1,
      0 -14.6 2 1,
      0 -1 2 1,
      0 -1 0 1,
      0 0 0 1
    OBJECT; .1 .2 'HIBEAM.#1'
    REDEFINE COLOR UMBER.
  }
Enter horizontal I-beam number>

$DO 1 4
  MKHIBEAM ?

OBJECT HIBEAM.1
  SHIFT 0 -90 -290.4
  ROTATE X 90 -90 -290.4

OBJECT HBEAM.2
  SHIFT 0 96 -290.4
  ROTATE X 90 96 -290.4

```

```

OBJECT HBEAM.3
  SHIFT 0 -90 -327.5
  ROTATE X 90 -90 -327.5

OBJECT HBEAM.4
  SHIFT 0 96 -327.5
  ROTATE X 90 96 -327.5

GROUP -2
  SHIFT X 24
RET

SURFACE
  PLANE X -129 0 0

OBJECT HBEAM.3;BOUNDS .1
OBJECT HBEAM.4;BOUNDS .1

!!----- VERTICAL I-BEAMS -----
MKVIBeam { 1
  EDGES
    POINTS 0 0 64 REL,
            6 0 0 1,
            6 1 0 1,
            4 1 0 1,
            4 14.6 0 1,
            6 14.6 0 1,
            6 15.6 0 1,
            0 15.6 0 1,
            0 14.6 0 1,
            2 14.6 0 1,
            2 1 0 1,
            0 1 0 1,
            0 0 0 1
    POINTS 0 0 -290.4 REL,
            6 0 0 1,
            6 1 0 1,
            4 1 0 1,
            4 14.6 0 1,
            6 14.6 0 1,
            6 15.6 0 1,
            0 15.6 0 1,
            0 14.6 0 1,
            2 14.6 0 1,
            2 1 0 1,
            0 1 0 1,
            0 0 0 1
    OBJECT; .1 .2 'VIBeam.#1'
    REDEFINE COLOR UMBER.
  }
Enter vertical I-beam number>

$DO 1 4
  MKVIBeam ?

OBJECT VIBeam.1
!!  SHIFT -276 90 0
    SHIFT -276 96 0
    ROTATE Z -90 -276 96 0

OBJECT VIBeam.2
!!  SHIFT -276 -105.6 0
    SHIFT -276 -90 0
    ROTATE Z -90 -276 -90 0

OBJECT VIBeam.3
!!  SHIFT 270 90 0
    SHIFT 260.4 96 0
    ROTATE Z -90 260.4 96 0

```

```

OBJECT VIBEAM.4
!!  SHIFT 270 -105.6
    SHIFT 260.4 -90 0
    ROTATE Z -90 260.4 -90 0

!!----- SECONDARY SERVICING PLATFORM -----
ZPLATFORM=-137

EDGES
POINTS -244 -276  ZPLATFORM. 1,
        -80  -276  ZPLATFORM. 1,
        -80  -130.5 ZPLATFORM. 1,
        80   -130.5 ZPLATFORM. 1,
        80   -106.5 ZPLATFORM. 1,
        -80  -106.5 ZPLATFORM. 1,
        -80   106.5 ZPLATFORM. 1,
        80   106.5 ZPLATFORM. 1,
        80   130.5 ZPLATFORM. 1,
        -80   130.5 ZPLATFORM. 1,
        -80   276   ZPLATFORM. 1,
        -244  276   ZPLATFORM. 1
OBJECT 'SECONDARY.SERVICE.PLATFORM'
REDEFINE COLOR RED.

!!----- CORNER POSTS FOR PLATFORM -----

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT -244 -274 0
OBJECT 'PLATFORM.POST.1'

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT -80 -274 0
OBJECT 'PLATFORM.POST.2'

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT -80 -130.5 0
OBJECT 'PLATFORM.POST.3'

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT 80 -130.5 0
OBJECT 'PLATFORM.POST.4'

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT 80 -106.5 0
OBJECT 'PLATFORM.POST.5'

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT -80 -106.5 0
OBJECT 'PLATFORM.POST.6'

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT -80 106.5 0
OBJECT 'PLATFORM.POST.7'

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT 80 106.5 0
OBJECT 'PLATFORM.POST.8'

SURFACE
TUBE Z 64 2@2 -185 2@2
SHIFT 80 130.5 0

```

```

OBJECT 'PLATFORM.POST.9'

SURFACE
  TUBE Z 64 2@2 -185 2@2
  SHIFT -80 130.5 0
  OBJECT 'PLATFORM.POST.10'

SURFACE
  TUBE Z 64 2@2 -185 2@2
  SHIFT -80 274 0
  OBJECT 'PLATFORM.POST.11'

SURFACE
  TUBE Z 64 2@2 -185 2@2
  SHIFT -244 274 0
  OBJECT 'PLATFORM.POST.12'

$DO 1 12
  OBJ .?; REDEFINE COLOR RED.

!!----- PLATFORM RAILINGS -----

MKRAILING { 1
EDGES
  ELLIPSE Y 0 1 1/COS[45]
  SHIFT -244 274 0
  ROTATE Z -45 -244 274 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT -244 -274 0
  ROTATE Z 45 -244 -274 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT -80 -274 0
  ROTATE Z -45 -80 -274 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT -80 -130.5 0
  ROTATE Z -45 -80 -130.5 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT 80 -130.5 0
  ROTATE Z -45 80 -130.5 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT 80 -106.5 0
  ROTATE Z 45 80 -106.5 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT -80 -106.5 0
  ROTATE Z 45 -80 -106.5 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT -80 106.5 0
  ROTATE Z -45 -80 106.5 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT 80 106.5 0
  ROTATE Z -45 80 106.5 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT 80 130.5 0
  ROTATE Z 45 80 130.5 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT -80 130.5 0
  ROTATE Z 45 -80 130.5 0

  ELLIPSE Y 0 1 1/COS[45]
  SHIFT -80 274 0

```

```

ROTATE Z 45 -80 274 0

OBJECT; .1 1 .2 1 .3 1 .4 1 .5 1 .6 1 .7 1 .8 1 .9 1 .10 1 .11 1 .12 1 'RAILING.#1'
REDEFINE COLOR RED.
SHIFT Z ZPLATFORM.-16*#1
}
Enter number railings>

$DO 1 3
MKRAILING ?

GROUP -16
SHIFT X -10
RET

PRI .1
$GRAB 'OBJECT' END

!!----- CORRECT ORIENTATION BY PLACING CAMERA EAST
GROUP -(END-START)
ROTATE Z 180 0 0
RET

!!----- INNER TINE TUBE -----
SURFACE
TUBE Y 72+6.363 2@(15/2-.01) 90.95 2@(15/2-.01)
OBJECT 'FORK.TINE.1.INNER.TUBE'

SURFACE
TUBE Y -72-6.363 2@(15/2-.01) -90.95 2@(15/2-.01)
OBJECT 'FORK.TINE.2.INNER.TUBE'

GROUP -2
SHIFT Z -16

$DO 1 2
OBJ .?; REDEFINE COLOR UMBER.

!!----- 3RY CAP -----
!! NOTE -> CUTOUTS MAY BE ELLIPTICAL NOT CIRCULAR
!! BEST ESTIMATE IS 19.05 INCHES HIGH X 14 INCHES WIDE
SURFACE
ELLIPSOID 19.05/2 19 19.05/2
SHIFT Y 33/2
SHIFT Z -10.184
ELLIPSOID 19.05/2 19 19.05/2
SHIFT Y 33/2
SHIFT Z -10.184
ROTATE Z 120 0 0
ELLIPSOID 19.05/2 19 19.05/2
SHIFT Y 33/2
SHIFT Z -10.184
ROTATE Z -120 0 0

SURFACE
PLANE Z 0 ELLI 2@(35.5/2) 33/35.5
OBJECT '3RY.CAP.BOTTOM'

SURFACE
TUBE Z 0 2@(33/2) -22.62 2@(33/2)
OBJECT '3RY.CAP.CYLINDER'
BOUNDS .3 .4 .5

SURFACE
PLANE Z -22.62 ELLI 2@(33/2) 27.5/33
OBJECT '3RY.CAP.TOP'

GROUP -3
SHIFT Z -5.95

$DO 1 3

```

```

OBJ .?; REDEFINE COLOR UMBER.

!!-- AXIAL VANES --
$IF DOVANES. EQ 0
  $GO novanes

SURFACE
  ELLIPSOID 19.05/2 19 19.05/2
    SHIFT Y 33/2
    SHIFT Z -10.184
  ELLIPSOID 19.05/2 19 19.05/2
    SHIFT Y 33/2
    SHIFT Z -10.184
    ROTATE Z 120 0 0
  ELLIPSOID 19.05/2 19 19.05/2
    SHIFT Y 33/2
    SHIFT Z -10.184
    ROTATE Z -120 0 0

SURFACE
  PLANE Z -22.62 ELLI 2@(40/2) 33/40
  OBJECT '3RY.VANE.1'
  BOUNDS .2 .3 .4

SURFACE
  PLANE Z -18.62 ELLI 2@(40/2) 33/40
  OBJECT '3RY.VANE.2'
  BOUNDS .3 .4 .5

SURFACE
  PLANE Z -14.62 ELLI 2@(40/2) 33/40
  OBJECT '3RY.VANE.3'
  BOUNDS .4 .5 .6

SURFACE
  PLANE Z -10.62 ELLI 2@(40/2) 33/40
  OBJECT '3RY.VANE.4'
  BOUNDS .5 .6 .7

SURFACE
  PLANE Z -6.62 ELLI 2@(40/2) 33/40
  OBJECT '3RY.VANE.5'
  BOUNDS .6 .7 .8

SURFACE
  PLANE Z -2.62 ELLI 2@(40/2) 33/40
  OBJECT '3RY.VANE.6'
  BOUNDS .7 .8 .9

GROUP -6
  SHIFT Z -5.95

$DO 1 6
  OBJ .?; REDEFINE COLOR DKGREEN.
novanes

RET

!!----- 3RY BAFFLE BASE -----
SURFACE
  PLANE Z -28.6 ELLI 2@(33.5/2) 21/33.5
  OBJECT '3RY.BAFFLE.BASE'
  REDEFINE COLOR STRAW.

!!----- 3RY BAF SMALL POSTS -----
MKSMALLPOSTS3 { 1
  SURFACE
    TUBE -Z 0 2@(1.0/2) -15.386 2@(1.0/2)
    OBJECT '3RY.BAF.SMALL.POSTS.#1'
    REDEFINE COLOR UMBER.
    SHIFT Y 12.6837

```



```

        SHIFT Z -62.543
        ROTATE Z (#1-1)*60+30 0 0
    }
Enter spacer number>

$IF DO3RY. EQ 1 2
    $DO 1 6
        MKSMALLPOSTS3 ?

!!----- 3RY BAF TOP SPCR1 -----
MK3RYTOPSPCR1 { 1
    SURFACE
        TUBE -Z 0 2@(0.25/2) -6.225 2@(0.25/2)
        OBJECT '3RY.BAF.TOP.SPCR1.#1'
        REDEFINE COLOR STRAW.
        SHIFT Y 12.319
        SHIFT Z -78.179
        ROTATE Z #1*30+15 0 0
    }
Enter spacer number>

$IF DO3RY. EQ 1 2
    $DO 1 12
        MK3RYTOPSPCR1 ?

!!----- 3RY BAF TOP SPCR2 -----
MK3RYTOPSPCR2 { 1
    SURFACE
        TUBE -Z 0 2@(0.25/2) -2.2701 2@(0.25/2)
        OBJECT '3RY.BAF.TOP.SPCR2.#1'
        REDEFINE COLOR STRAW.
        SHIFT Y 12.319
        SHIFT Z -84.529
        ROTATE Z #1*30+15 0 0
    }
Enter spacer number>

$IF DO3RY. EQ 1 2
    $DO 1 12
        MK3RYTOPSPCR2 ?

!!----- 3RY BAFFLE TOP PLT 1 -----
$IF DO3RY. EQ 0
    $GO nobaftop
    SURFACE
        PLANE Z -62.418 ELLI 2@(29.31/2) 22.96/29.31
        OBJECT '3RY.BAFFLE.TOP.PLT.1'
        REDEFINE COLOR RED.

!!----- 3RY BAFFLE TOP PLT 2 -----
SURFACE
    PLANE Z -78.054 ELLI 2@(26.57/2) 23.96/26.57
    OBJECT '3RY.BAFFLE.TOP.PLT.2'
    REDEFINE COLOR RED.

!!----- 3RY BAFFLE TOP PLT 3 -----
SURFACE
    PLANE Z -84.4665 ELLI 2@(25.44/2) 24.30/25.44
    OBJECT '3RY.BAFFLE.TOP.PLT.3'
    REDEFINE COLOR RED.

!!----- 3RY BAFFLE TOP PLT 4 -----
SURFACE
    PLANE Z -86.799 ELLI 2@(25.02/2) 24.39/25.02
    OBJECT '3RY.BAFFLE.TOP.PLT.4'
    REDEFINE COLOR RED.
nobaftop

!!----- 3RY NA BAFFLE 3 -----
$IF DO3RY. EQ 0
    $GO nonabaf

```

```

EDGES
  POINTS Y 0,
    0      0      1,
    -13.454 0      1,
    -13.454 -5.7   1,
    -18.2803 -5.7   1,
    -18.2803 -8.8942 1,
    -10.433 -12.406 2,
    -3.364  -7.776  COS[16.7411]
    SHIFT X -22.4658/2
  OBJECT; .1 '3RY.NA.BAFFLE.3A'
  REDEFINE COLOR DKGREEN.

EDGES
  POINTS Y 0,
    0      0      1,
    -13.454 0      1,
    -13.454 -5.7   1,
    -18.2803 -5.7   1,
    -18.2803 -8.8942 1,
    -10.433 -12.406 2,
    -3.364  -7.776  COS[16.7411]
    ROTATE Z 180 0 0
    SHIFT X 22.4658/2
  OBJECT; .1 '3RY.NA.BAFFLE.3B'
  REDEFINE COLOR DKGREEN.

GROUP -2
  ROTATE X 180 0 0
  SHIFT Z -42.1
  SHIFT Y 2.1
RET
nonabaf

!!----- 3RY NA BAFFLE 1 -----
$IF DO3RY. EQ 0
  $GO nonabaf
  EDGES
    POINTS Y 0,
      0      11.1  1,
      -9.9816 11.1  1,
      -9.9816 -11.1 1,
      0      -11.1 2,
      5.292   0    COS[25.4269]
      SHIFT Y -11.73
      ROTATE X 180 0 0
      SHIFT Z -38.59
    OBJECT; .1 '3RY.NA.BAFFLE.2'
    REDEFINE COLOR RED.
  nonabaf

!!----- NA2 BAFFLE PLATES -----
WID1=.186   DZ1=0
WID2=.205   DZ2=.59
WID3=.227   DZ3=.67
WID4=.251   DZ4=.75
WID5=.278   DZ5=.85
WID6=.309   DZ6=.96
WID7=.343   DZ7=1.08
WID8=.382   DZ8=1.21
WID9=.425   DZ9=1.35
WID10=.474  DZ10=1.5
WID11=.528  DZ11=1.7
WID12=.589  DZ12=1.89
WID13=.300  DZ13=9.033
WID14=.923  DZ14=1.381

YS=78.452

MKNA2BAFFPLATES { 1
  SURFACE

```

```

    PLANE Y YS+DZ#1. ELLI 2@7.5 (7.5-WID#1.)/7.5
    OBJECT 'NA2.BAFF.PLATE.#1'
    REDEFINE COLOR BLUE.
    SHIFT Z -16

    YS=YS+DZ#1.
}
Enter baffle number>

$DO 1 14
    MKNA2BAFFPLATES ?

!!----- NA BAF ROT -----
$GO nobaff
EDGE
    RECT Y 105.014 2@(3.08/2)
SURFACE
    PLANE Y 105.014 ELLI 15.3/2
    OBJECT 'NA.BAF.ROT'
    BOUNDS .2
    REDEFINE COLOR BLUE.
    SHIFT Z -16
nobaff

!!----- CAMERA BOX 1 -----
SURFACE
    TUBE Y 0 2@(32.8/2) 10 2@(32.8/2)
    OBJECT 'CAMERA.BOX'

SURFACE
    PLANE Y 10 ELLI 2@(32.8/2) 17.5/32.8
    OBJECT 'CAMERA.BOX.PLATE1'

SURFACE
    TUBE Y 10 2@(17.5/2) 25 2@(17.5/2)
    OBJECT 'CAMERA.BOX.EXTENSION'

SURFACE
    PLANE Y 25 ELLI 17.5/2
    OBJECT 'CAMERA.BOX.BACK'

GROUP -4
    SHIFT Y 102.5
    SHIFT Z 180.850394-196.850394
RET

$DO 1 4
    OBJ .?; REDEFINE COLOR DKGREEN.

!!----- PINHOLE -----
RADPIN=(.4/2)/25.4    !!400 MICRONS DIAMETER
$IF DOPIN. EQ 0
    $GO nopin
SURFACE
    PLANE Y 0 ELLI 2@(17.5/2) (RADPIN.*2)/17.5
    OBJECT 'PINHOLE'
    REDEFINE COLOR DKGREEN.
    SHIFT Y 118.0
    SHIFT Z 180.850394-196.850394
nopin

!!----- IMAGE -----
!!IMAGE DIMENSIONS MEASURED FROM DXF FILE
!! IMAGE PLANE DIMENSIONS CHANGED PER JEFF MORGAN 12 JUNE 2001
!! PREVIOUS DIMENSIONS ARE FOR WIDE ANGLE CAMERA
SURFACE
!! PLANE Z 0 RECT 4.85/2 12.3/2
    PLANE Z 0 ELLI 2 2
    OBJECT 'IMAGE'
    REDEFINE COLOR BLUE.
    ROTATE X 90

```

```

$IF DOLENSES. EQ 0
  SHIFT Y 120.7558      !!NOMINAL IMAGE LOCATION
$IF DOLENSES. EQ 1
  SHIFT Y 121.1334      !!IMAGE LOCATION W/LENSES
  SHIFT Z 180.850394-196.850394
RETURN

!!----- NEW STRAY LIGHT BAFFLES -----

SURFACE
  PLANE Y 78.55 ELLI 2@7.5 3.8/7.5
  SHIFT Z -16
  OBJECT 'STRAY.LIGHT.BAFFLE'
  REDEFINE COLOR BLUE.
RET

$GO nobaff
SURFACE
  TUBE Z -89.8 2@10.263 -22.62 2@(29.31/2)
  OBJECT '3RY.TEST.BAFFLE'
  REDEFINE COLOR BLUE.

SURFACE
  TUBE Z -190.85 2@16.3109 -184.9711 2@16.3109
  OBJECT '2NDY.TEST.BAFFLE'
  REDEFINE COLOR BLUE.

!!-- SEALING OFF SLIT
EDGES
  POINTS Z 209.4,
    90 420 1,
   -90 420 1,
   -90  0 1,
    90  0 1
  OBJECT; .1 'SLIT.BOTTOM.COVER'
  REDEFINE COLOR DKGREEN.
  ROTATE X -90 0 0
  ROTATE Z 90 0 0
  SHIFT Z 91
  SHIFT X -120+28+3
  SHIFT Z -16
RET

SURFACE
  PLANE Z -345 RECT 110 90
  SHIFT X 30
  OBJECT 'SLIT.TOP.COVER'
  REDEFINE COLOR DKGREEN.

RET

SURFACE
  PLANE Y -75.9
  PLANE Y 75.9
  TUBE Z -221.326-1.5 2@76 -33 2@76, 1 1
  OBJECT 'MAIN.BAFFLE.SHROUD'
  BOUNDS -.2 .3
  REDEFINE COLOR LTBLUE.
RET

nobaff

!!----- MODEL ENDS HERE -----

BEAMS INCOHERENT GEOMETRIC

NSCAT=10
PANGLE=RADPIN/1387

!!----- SPYAK DATA AT 632.8 NM -----
!!Level 100      0-10 deg      0.00966158      -2.9412

```

```

!!              10-90 deg          0.000117615      -1.2449

!!Level 200      0-10 deg          0.192637898      -3.0035
!!              10-90 deg          0.001548245      -1.1844

!!Level 300      0-10 deg          1.158331682      -3.0035
!!              10-90 deg          0.009309596      -1.1844

!!Level 400      0-10 deg          4.482105978      -3.0035
!!              10-90 deg          0.036023011      -1.1844

!!Level 500      0-10 deg          13.4              -3.0035
!!              10-90 deg          0.139             -1.1844

MKCHEM306                !!(1)  CHEMGLAZE Z306 BLACK PAINT

MODELS
  LAMBERTIAN 0.8          !!(2)  SIMPLE WHITE PAINT MODEL
  HARVEY 1.158 -3.0035    !!(3)  SPYAK LEVEL 300 0-10 DEG
  HARVEY 0.0093 -1.1844  !!(4)  SPYAK LEVEL 300 10-90 DEG
  SUM 3 4                !!(5)  SPYAK LEVEL 300
  HARVEY 13.4 -3.0035    !!(6)  SPYAK LEVEL 500 0-10 DEG
  HARVEY 0.139 -1.1844  !!(7)  SPYAK LEVEL 500 10-90 DEG
  SUM 6 7                !!(8)  SPYAK LEVEL 500

EDGE 501                !!IMPORTANCE EDGE FROM PRIMARY
!! RECT Z -241.7559      .5 1.1
  ELLI Z -241.7559      0.35 0.35

EDGE 502                !!IMPORTANCE EDGE FROM SECONDARY
!! RECT Z 104.7379 4.85/2 12.3/2
  ELLI Z 104.7379 2 2

EDGE 503                !!IMPORTANCE EDGE FROM TERTIARY
!! RECT Z 0 4.85/2 12.3/2
  ELLI Z 0 2 2
  ROTATE X 90
  SHIFT Y 120.7558
  SHIFT Z -16

EDGE 504                !!IMPORTANCE EDGE FROM TOP OF TELESCOPE
  POINTS Z -33.1,
    -29.809 72 1,
    29.809 72 1,
    72 29.809 1,
    72 -29.809 1,
    29.809 -72 1,
    -29.809 -72 1,
    -72 -29.809 1,
    -72 29.809 1
RET

OBJECT PRIMARY.MIRROR; SCATTER MODEL 8; TOWARDS EDGE 501 NSCAT.

OBJECT SECONDARY.MIRROR; SCATTER MODEL 5; TOWARDS EDGE 502 NSCAT.

OBJECT TERTIARY.MIRROR; SCATTER MODEL 8; TOWARDS EDGE 503 NSCAT.

$DO 1 4
  OBJ 2ND.FRAME.?.; INTERFACE COATING ALTAPE

OBJ 2ND.BACKUP.FRAME.TOP; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BACKUP.FRAME.BOTTOM; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BACKUP.FRAME.OUTER.EDGE; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BACKUP.FRAME.INNER.EDGE.A; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BACKUP.FRAME.INNER.EDGE.B; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BACKUP.FRAME.INNER.EDGE.C; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BKUP.FRAME.BLOCK.1; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BKUP.FRAME.BLOCK.2; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BKUP.FRAME.BLOCK.3; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.
OBJ 2ND.BKUP.FRAME.BLOCK.4; SCATTER MODEL 2; TOWARDS EDGE 502 NSCAT.

```

```

$DO 1 4
{ OBJ 2ND.BAF.POSTS.A.?. SCATTER MODEL 1; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 501 NSCAT.
  OBJ 2ND.BAF.POSTS.B.?. SCATTER MODEL 1; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 501 NSCAT.
}

$DO 1 20
{ OBJ 2ND.BAF.SPACER.1.?. SCATTER MODEL 1; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 501 NSCAT.
  OBJ 2ND.BAF.SPACER.2.?. SCATTER MODEL 1; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 501 NSCAT.
}

OBJECT 2ND.BOTTOM.BAFFLE; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.;
TOWARDS Z NSCAT. PANGLE. 0

OBJECT 2ND.MIDDLE.BAFFLE; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.;
TOWARDS Z NSCAT. PANGLE. 0

OBJECT 2ND.TOP.BAFFLE; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.
TOWARDS Z NSCAT. PANGLE. 0

OBJ 3RY.CAP.BOTTOM; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.CAP.CYLINDER; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.CAP.TOP; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.
TOWARDS EDGE 503 NSCAT.

$IF DO3RY. EQ 1 18
$DO 1 4
  OBJ 3RY.BAF.TOP.PLT.?. SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.

$DO 1 6
  OBJ 3RY.BAF.SMALL.POSTS.?. SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.

$DO 1 6
  OBJ 3RY.BAFFLE.LARGE.POSTS.?. SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502
NSCAT.

$DO 1 12
  OBJ 3RY.BAF.TOP.SPCR1.?. SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.

$DO 1 12
  OBJ 3RY.BAF.TOP.SPCR2.?. SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.

  OBJ 3RY.NA.BAFFLE.2; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.;
TOWARDS EDGE 503 NSCAT.
  OBJ 3RY.NA.BAFFLE.3A; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.;
TOWARDS EDGE 503 NSCAT.
  OBJ 3RY.NA.BAFFLE.3B; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.;
TOWARDS EDGE 503 NSCAT.

OBJ 3RY.BEARING.HOUSING.BOTTOM
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.BEARING.HOUSING.CYLINDER
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.BEARING.HOUSING.TOP
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.BEARING.HOUSING.CLAMP.CYLINDER
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.BEARING.HOUSING.CLAMP.TOP
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.BEARING.SHAFT.CLAMP.CYLINDER
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.BEARING.SHAFT.CLAMP.TOP
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ 3RY.BEARING.SHAFT
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.

OBJ PRIMARY.MIRROR.CELL.PASSTHRU.A; SCATTER MODEL 1; TOWARDS EDGE 503 NSCAT.

OBJ PRIMARY.MIRROR.CELL.TOP; SCATTER MODEL 2; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 503 NSCAT.
OBJ PRIMARY.MIRROR.CELL.INNER; SCATTER MODEL 2; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 503 NSCAT.

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```

!!INSIDE OF COVERS IS CHEMGLAZE; OUTSIDE OF COVERS IS WHITE PAINT
$DO 1 8
{ OBJ PRIMARY.MIRROR.COVER.?
  SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.
}

$DO 1 4
{ OBJ MAIN.TRUSS.SIDE?.A; INTERFACE COATING ALTAPE
  OBJ MAIN.TRUSS.SIDE?.B; INTERFACE COATING ALTAPE
}

$DO 1 4
{ OBJ HIBEAM.?; SCATTER MODEL 2; TOWARDS EDGE 504 NSCAT.
  OBJ VIBEAM.?; SCATTER MODEL 2; TOWARDS EDGE 504 NSCAT.
}

$DO 1 12
  OBJ PLATFORM.POST.?; SCATTER MODEL 2; TOWARDS EDGE 504 NSCAT.

!!OBJECT MAIN.BAFFLE.SHROUD
!! SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.; TOWARDS EDGE 503 NSCAT.

$IF DOVANES. EQ 1 2
$DO 1 6
  OBJ 3RY.VANE.?; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.

$IF DO3RY. EQ 0 3
OBJECT 3RY.TEST.BAFFLE; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.

OBJECT 2NDY.TEST.BAFFLE; SCATTER MODEL 1; TOWARDS EDGE 501 NSCAT.; TOWARDS EDGE 502 NSCAT.

RET

!!----- CALCULATION SETUP -----
BEAMS INCOHERENT GEOMETRIC
WAVELENGTH 0.55

RADGRID=200
NGRID=201

$GO nostars
!! AZ ANGLES FOR ALL OBJECTS ASSUME +Y IS DUE NORTH
!! COORD REF FOR MOON AND JUPITER AZ INPUTS (E OF N):
!!      0 DEG = DUE NORTH, +90 DEG = DUE EAST
!!      --> SUBTRACT AZ FROM 270
!! COORD REF FOR TELESCOPE AZ:
!!      0 DEG = DUE SOUTH, +90 DEG = DUE EAST
!!      --> ADD AZ TO 90

MKELANG { 3
  XDEG=#1 XMIN=#2 XSEC=#3 ELANG=XDEG+XMIN/60+XSEC/3600
}
Enter elevation deg>
Enter elevation min>
Enter elevation sec>

MKAZANG { 3
  XDEG=#1 XMIN=#2 XSEC=#3 AZANG=270-(XDEG+XMIN/60+XSEC/3600)
}
Enter azimuth deg>
Enter azimuth min>
Enter azimuth sec>

!!-- MOON --
MKELANG 21 16 54.6
MOON_ELANG=ELANG.

MKAZANG 117 57 35.3
MOON_AZANG=AZANG.

MOON_MAG=-12.94

```

```

GRID ELLIP Z 0 -4@RADGRID. 2@NGRID.
SOURCE DIRECTION Z MOON_ELANG. MOON_AZANG.

!!-- JUPITER --
MKELANG 13 38 34.7
JUP_ELANG=ELANG.

MKAZANG 198 5 14
JUP_AZANG=AZANG.

JUP_MAG=-2.7
GRID ELLIP Z 0 -4@RADGRID. 2@NGRID.
SOURCE DIRECTION Z JUP_ELANG. JUP_AZANG.
FLUX 0 2.512^(MOON_MAG-JUP_MAG) SOU .1

MOVE TO Z -1000
nostars

$IO

!!-- TELESCOPE --
!! POINT TELESCOPE PER JEFF'S INSTRUCTIONS
TEL_ELANG=60
TEL_AZANG=90+(0)
GROUP 1:162 219:281
!!GROUP 1:156 213:241 !!FOR DO3RY=0
    ROTATE Y 90-TEL_ELANG. -16 0
RET
$DO 501 504
    EDGE ?; MATRIX PREVIOUS
RET
GROUP
    ROTATE Z TEL_AZANG. 0 0
RET
$DO 501 504
    EDGE ?; MATRIX PREVIOUS
RET

!!-- SET EFFECTIVE TRANSMISSION OF SECONDARY SERVICE PLATFORM (CATWALK)
OBJ SECONDARY.SERVICE.PLATFORM; INTERFACE 0 -.969*COS[TEL_ELANG]+.72 AIR AIR
RET

!!-- CONTINUE WITH CALCULATIONS
RAYS 0
CON ALL

EVANGLE=-59
SDANGLE=0

$GO notest
GRID ELL Z 0 -4@RADGRID. 2@NGRID.
SOU DIR 0 0 1
    SHIFT 0 8 -2.14359
    ROTATE Y SDANGLE. -2.14359 0
    ROTATE X -30 8 -2.14359
    ROTATE X EVANGLE. 8 -2.14359
RET

MOVE BY -200
WIN -Z Y; PIXEL 362; PRO OVER; SPOTS P
notest

!!$GO nopst
PSTCALC {
    $SCR 1
    >>>NOW DOING ELEVATION ANGLE \EVANGLE.\ AND SIDE-SIDE ANGLE \SDANGLE.\
    RAYS 0
    CON ALL
    GRID ELL Z 0 -4@RADGRID. 2@NGRID.
    SOU DIR 0 0 1
    SHIFT 0 8 -2.14359

```



```

    ROTATE Y SDANGLE. -2.14359 0
    ROTATE X -30 8 -2.14359
    ROTATE X EVANGLE. 8 -2.14359

MOVE BY -1000

LEVEL 1
SPLIT OFF

TRACE

CON ONLY IMAGE
PATHS .001 TOT

STATS
POWER=0.0
$GRAB 'TOTAL' 0 2 POWER

$ECHO NONE
$IO OUTPUT DUMP6.OUT +13
$SCR 1
\EVANGLE.\ \SDANGLE.\ \POWER. \
$IO OUTPUT CLOSE
}

$ECHO NONE
$IO OUTPUT DUMP6.OUT 13
$SCR 1
    PST CALC W/NORTH AND SOUTH MAIN BAFFLE
$IO OUTPUT CLOSE

SDANGLE=0
$ITER EVANGLE -60 60 -121, POWER
    PSTCALC

EVANGLE=0
$ITER SDANGLE -70 70 -141, POWER
    PSTCALC

END

!!--- CRITICAL OBJECTS ----
nopst

$ECHO ALL

NRAYS=20000
ANGLE=90
EMITTING DISK X -120.75 2@2 NRAYS. ANGLE.
    SHIFT Z -16
RET

LEVEL OFF
SPLIT OFF

```