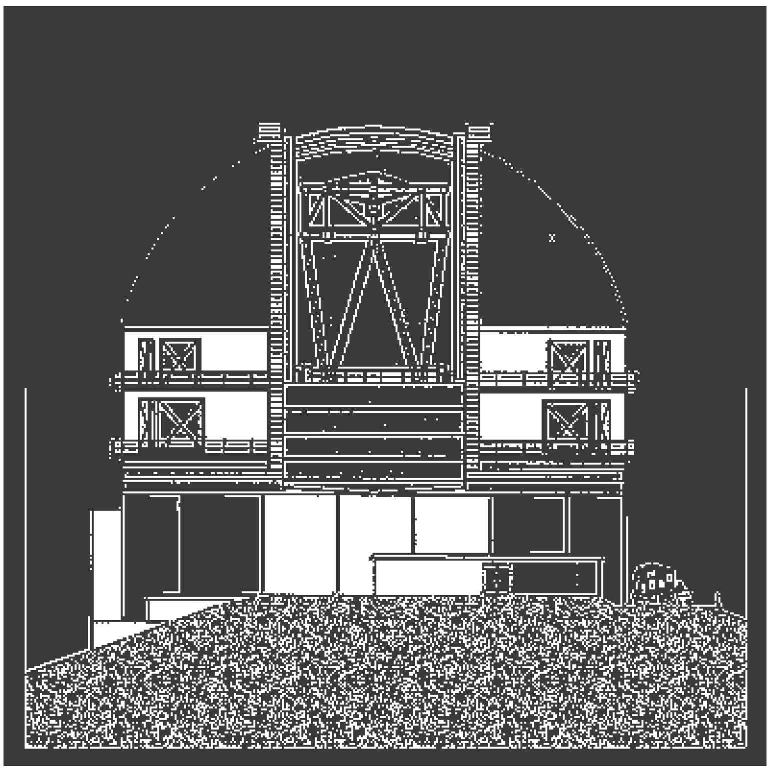
GEMINI
8-M Telescopes
Project

TN-S-G0010

Primary Mirror F/# Trades
Technical Assessments



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Introduction

Various technical assessments are summarized within this technical note which have been made regarding trades in primary mirror F-number considered in the past. The scientific considerations have been discussed in a write-up "Imaging Performance Tradeoff with Primary F/#" by F. Gillett, 22 March 1993. To summarize this briefly, the scientific assessment favored about an F/1.8 primary for 10 micron imaging with chopping and slightly favored an f/# around f/1.5 - f/1.8 for 2.2 micron imaging (though not a strong effect). A copy of this is attached for reference in Appendix B.

In the write-up mentioned above, most of the technical considerations are mentioned. The purpose of this document is to provide further explanation and summary of these technical assessments and trades. These trades/assessments were done in most cases comparing various effects at f/#'s between f/1.2 and f/1.8 since most options considered at one time or another were in this range.

Relative difficulty is assessed regarding the following areas:

- Alignment sensitivities
- Manufacture of the primary mirror
- Manufacture of the secondary mirror
- Other effects

In each area, some quantitative indication of the magnitude of the technical trades are given, but only qualitative assessment of degree of difficulty and cost are suggested. Detailed assessment of difficulty and costs are only possible through complete design and costing of options considered. Since the science requirements stated use of an f/1.8 primary and the imaging performance trades done by F. Gillett suggest this was a good choice, only these few cases on technical concerns were assessed to ensure we were not asking for something more difficult at f/1.8 than faster f ratios.

Summary

In most cases, the faster f/1.2 - f/16 system is judged to be more difficult to manufacture and align than a slower f/1.8 - f/16 system. For each area, a brief summary is given:

Alignment sensitivities: Tighter requirements at faster f numbers

Manufacture of the Primary: Further departure from sphere, but not a major effect since faster mirrors at reasonable sizes have been demonstrated

Manufacture of Secondary: 20% smaller size, but further departure (more than twice) from sphere which does make elimination of high frequency zones much more difficult

Other: Radius of curvature of focal plane twice as small (1 meter instead of 2)

This would impose further difficulties on instrument re-imaging

Alignment Sensitivity

Table 1, below, gives tolerance sensitivities for various alignment errors for an f/1.8 primary and f/1.2 primary system (both had final f/#'s of f/16). The average tolerance is 2.5 times easier for the f/1.8 configuration as compared to the f/1.2. The focus movement of the secondary for the f/1.2 case is especially tight at 1.5 microns. Also, the tolerances on the conic constants for the primary and secondary are very tight. The tolerances are based upon Code V calculations producing an enlargement of 0.01 arcseconds in the 50% encircled energy.

Table 1
Alignment / Tolerance Sensitivities for F/1.8 versus F/1.2 Systems

Description of Error	F/1.8 - F/16	F/1.2 - F/16
Decentration, primary to secondary (microns)	33	17
Tilt, secondary about its CG (microradians)	18	13
Focus movement of secondary (microns)	2.4	1.5
De-space, primary to secondary (microns)[1]	84	19
Change of back focal distance (millimeters)	6.7	3.4
Conic constant of primary (parts per million)[1]	55	16
Conic constant of secondary (parts per million)[1]	600	200

[1]Error limited by spherical aberration, after re-focusing

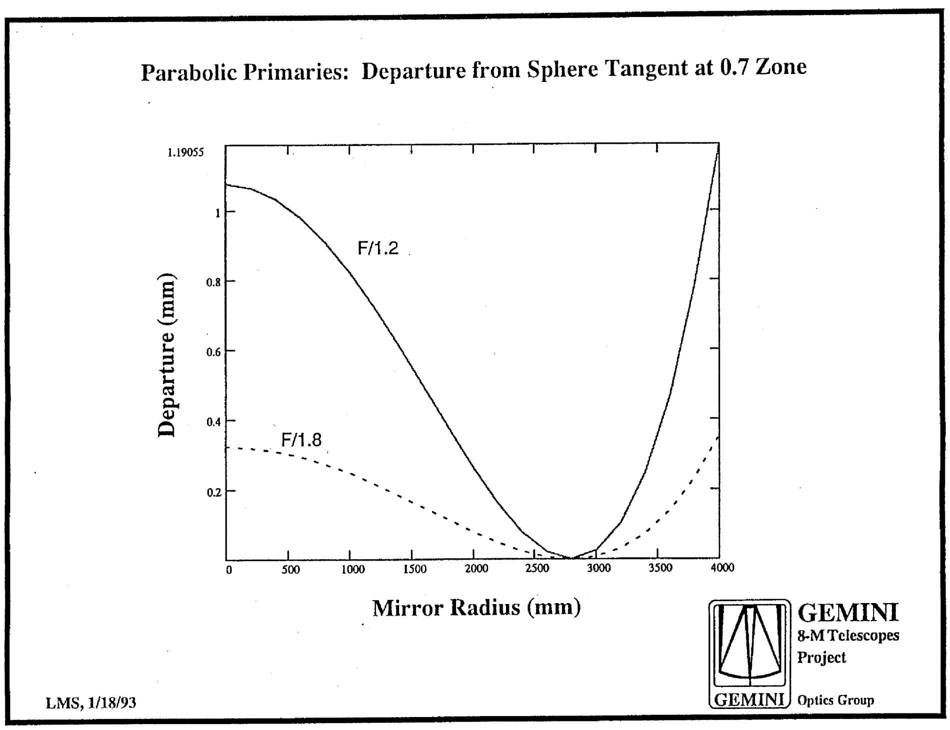
None of these tolerances are believed to be impossible to reach, but the difficulty is always increased somewhat with tighter tolerances (and hence the cost). Another way to look at it would be that for a given resolution for control of alignment and/or a given amount of mechanical misalignment, the system with the f/1.2 primary would produce more error in the wavefront than a system with an f/1.8 primary.

For wind induced misalignments, as shown in the referenced scientific write-up, the structure for the telescope for the f/1.2 -f/16 system will be more stiff against most types of wind shake. When coupled with the optical alignment sensitivities discussed here, the net effect on image quality was small in comparison between the two f ratios.

Manufacturability of Primary

Primary mirrors of considerable size have been made at various f/#'s from about f/1 to greater than f/1.8. Depending on the method used, the faster aspheric mirrors are generally considered more difficult to make due to a larger departure from a sphere (and larger slopes involved. Some methods of producing these concave aspheres have reduced the relative difficulty to a small difference. The graph following shows the departure from a sphere for the two cases studied, an f/1.2 -f/16 system and an f/1.8 - f/16 system. Note that the total departure from a sphere is about three times greater for the f/1.2 primary. Any increase in difficulty is offset by slightly added difficulty in testing the f/1.8 mirror. This requires the interferometer to be further from the mirror surface (larger test tower and longer path length).

One way to minimize risk in manufacture is to minimize the differences from mirrors being made prior to the Gemini primary mirrors. On the eight meter scale, there are several meniscus mirrors currently in production for the ESO VLT program and the Subaru program. All are being made at f ratios of about f/1.8 and all are meniscus type mirrors of similar thickness. Gemini will benefit significantly from these efforts (using similar mirror types and f ratios).



Manufacturability of Secondary

The secondary has two major areas to consider: the size of the blank and the surface. The baseline design calls for manufacture from light-weighted silicon carbide as the substrate.

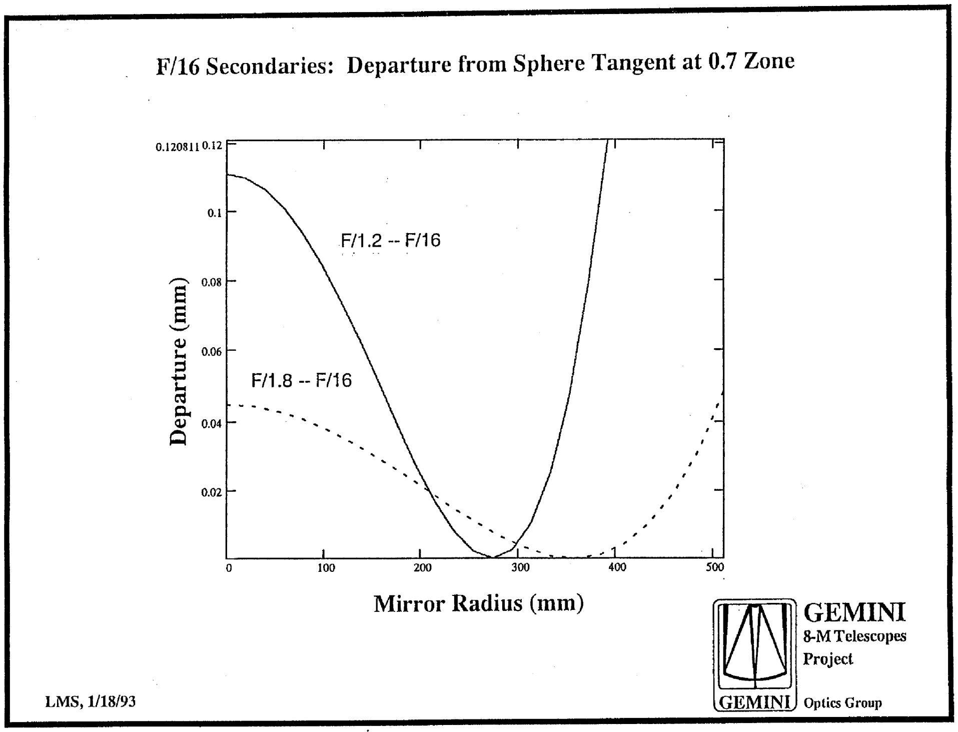
Size:
The size of the secondary versus f number is as follows:

- f/1.8 - f/16 1.02 meters
- f/1.5 - f/16 0.90 meters
- f/1.2 - f 16 0.78 meters

All of the cases shown represent secondaries of substantial size. The difficulty in manufacturing a blank of the sizes needed is roughly the same for the cases shown above (according to several manufactures of silicon carbide mirrors). Several manufactures of silicon carbide currently have the facilities or need minor upgrades to existing facilities to handle a 1-meter blank. Some are already engaged in producing blanks on the order of the size required by Gemini. There seemed to be little difference in difficulty for the range of sizes discussed here (0.8 to 1 meter). Further details on manufacturing capabilities of various manufactures is available in a trip report on silicon carbide manufacturers dated 3/11/93-3/19/93. This report is not included here since it is procurement sensitive.

Surface:

As the primary f number becomes smaller, the secondary becomes smaller in size, but the departure from a sphere becomes greater. This is illustrated in the graph following of departure from a sphere for an f/1.2 and f/1.8 system. Note the drastic increase in slope for the faster f ratio over the f/1.8 system. As shown in the graph, the total departure from a sphere is about 2.5 times greater for the f/1.2 system. The slope increase is even more dramatic since this larger departure from a sphere occurs over a smaller diameter. On convex secondaries, this typically leads to much greater difficulties in obtaining a smooth surface on the mirror. High frequency zonal errors are extremely common on convex aspheric secondary mirrors. Though we have an active primary which will help correct for some general shape errors, the high frequency zone type surface errors may not be corrected in this manner. Since the major concern on the secondary is these zones, reasonable subaperture testing may be applied to any mirror in this size range to measure these effects. Another way to look at these zonal errors is that for a given technique and level of effort (cost), the steeper asphere associated with the f/1.2 - f/16 system would produce more degradation in image quality (especially at visible wavelengths).



Again, this is not to say that an adequate secondary mirror can not be manufactured for the faster f ratios system, but it will involve much more effort to obtain a given surface quality for the faster system as compared to the slower f/1.8 system. This may likely lead to a higher cost (even though a smaller blank is used) for the f/1.2 -f/16 secondary mirror as compared to the f/1.8 - f/16 secondary. Though complete estimates have not been prepared for these two cases, the attached fax (see Appendix A) from one potential supplier expresses the same opinion.

Other Considerations

One other consideration mentioned in the imaging performance assessment is the effect of the curved image plane produced by the telescope. For example, an f/1.8 - f/16 system will have radius of curvature of the image field of about 2 meters. This is shortened to about 1 meter for the f/1.2 - f/16 system. This is a tighter input condition for any wide field correctors/field flattening optics to be used. It is not of as much importance for narrow field considerations. Again, detailed assessment of this may not be done without going into fairly detailed design of these corrector optics.

APPENDIX A:

Hughes Danbury Communications

APPENDIX B:

Imaging Performance -
Tradeoff with Primary F/#

F. Gillett
22 March 1993