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The first of three solicited letters to users of Ritchey-Chretien telescopes looking to get the most from their instruments.

Although it is widely appreciated among astronomers both amateur and professional that the Ritchey-Chretien improves on the Cassegrain optical design by correcting for off-axis coma, it is perhaps less widely known that the off-axis performance of the Ritchey-Chretien is itself limited by residual field curvature and astigmatism. The diffraction-limited field of view in Ritchey-Chretien systems can, however, be greatly extended by the addition of a simple zero-power field corrector near the focal plane. The corrector accomplishes this feat by balancing the astigmatism and field curvature residuals present in the R-C design against small amounts of overcorrecting field curvature and astigmatism introduced by the corrector. Furthermore, the corrector can be designed to provide a back focal length adequate for coupling most popular cameras (both film & CCD based), and/or the introduction of filters into the optical path

This letter is written to communicate the results of a design study showing the improvements that can be realized to several commercially available R-C telescopes via the addition of a two element, zero power field corrector.

To provide a meaningful basis for comparison of the investigated designs, four general constraints were imposed:

1. The net optical power in the corrector is always zero. This means that addition of the corrector does not change the telescope focal length or F/#.

2. The image format is always a 40 mm diameter circle on a flat focal surface. Note that this field is large enough to cover all of the CCD formats currently offered by Apogee Instruments without vignetting, with the 4096 x 4096 pixel AP16E excepted.

3. The airspace between the last corrector lens vertex and the focal plane is fixed at four inches, to allow adequate clearance for installation of filters and/or camera mechanics

4. The spectral bandwidth was fixed at 350 – 1000 nm, with a spectral weighting function chosen to mimic the response of a typical SITE back-side illuminated CCD detector (see table 1 below for spectral weighting function used). No attempt was made to adjust the spectral weights for variations introduced by the finite bandwidth of the optical coatings, since the design of these coatings is yet TBD.

For each design investigated, three figures of merit are reported; the polychromatic Strehl ratio across the field, the Polychromatic MTF out to a spatial frequency of 55 LP/mm, (this is the Nyquist frequency for a 9 micron pixel detector), and geometric spot diagrams for several points in the field of view. The Strehl ratio and MTF analyses account for the effects of diffraction at the aperture and the central obstruction on the final image. In the spot diagram plots, the circles represent the diameter of the Airy disc (first minimum). The investigated designs were:

1. A 12.5 inch aperture, F/9 Ritchey Chretien having a back focal length of approximately 11.5 inches.
2. A 14.5 inch aperture, F/7.9 Ritchey Chretien having a back focal length of approximately 12.2 inches.
3. A 16 inch aperture, F/8.4 Ritchey Chretien having a back focal length of approximately 13.8 inches.
4. A 20 inch aperture, F/8.1 Ritchey Chretien having a back focal length of approximately 14.0 inches.

The above designs were first analyzed over a 40 mm image format without any corrector optics present, and then a two element corrector lens was added and optimized across all four designs, keeping the effective focal length and image format unchanged. As a final exercise, figures of merit were also calculated for the equivalent Cassegrain design (i.e. parabolic primary, hyperbolic secondary chosen to correct only spherical aberration). The data are presented graphically first, with captions identifying the design to which the data refer. A brief conclusion summarizes the data in tabular form.

Table 1: spectral weighting function used to evaluate telescope + corrector.

350 nm	400 nm	450 nm	500 nm	600 nm	700 nm	800 nm	900 nm	1000 nm
0.35	0.63	0.70	0.75	0.83	0.86	0.78	0.53	0.20

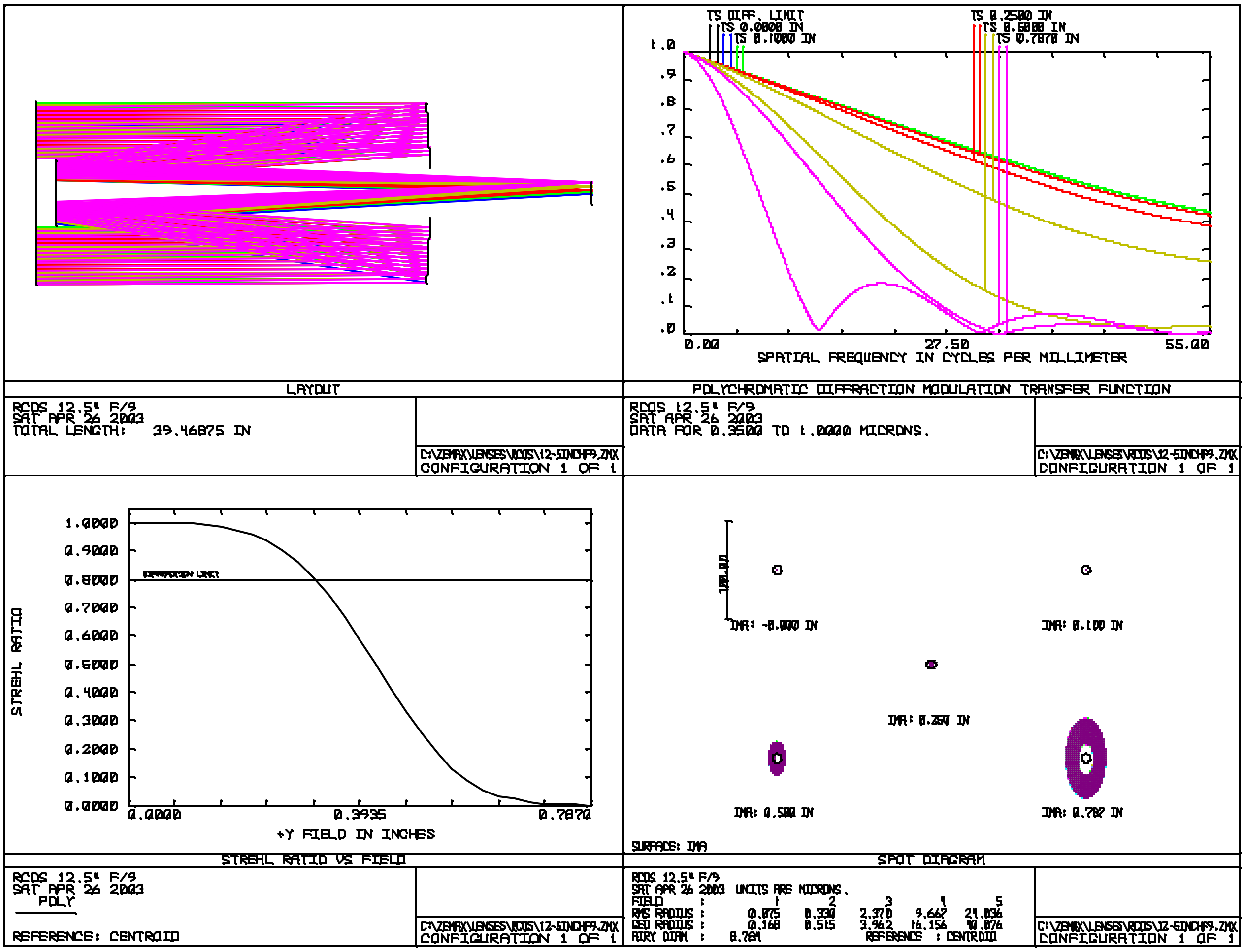

Figure 1 Figures of merit for a 12.5” F/9 aperture R-C telescope without field flattener

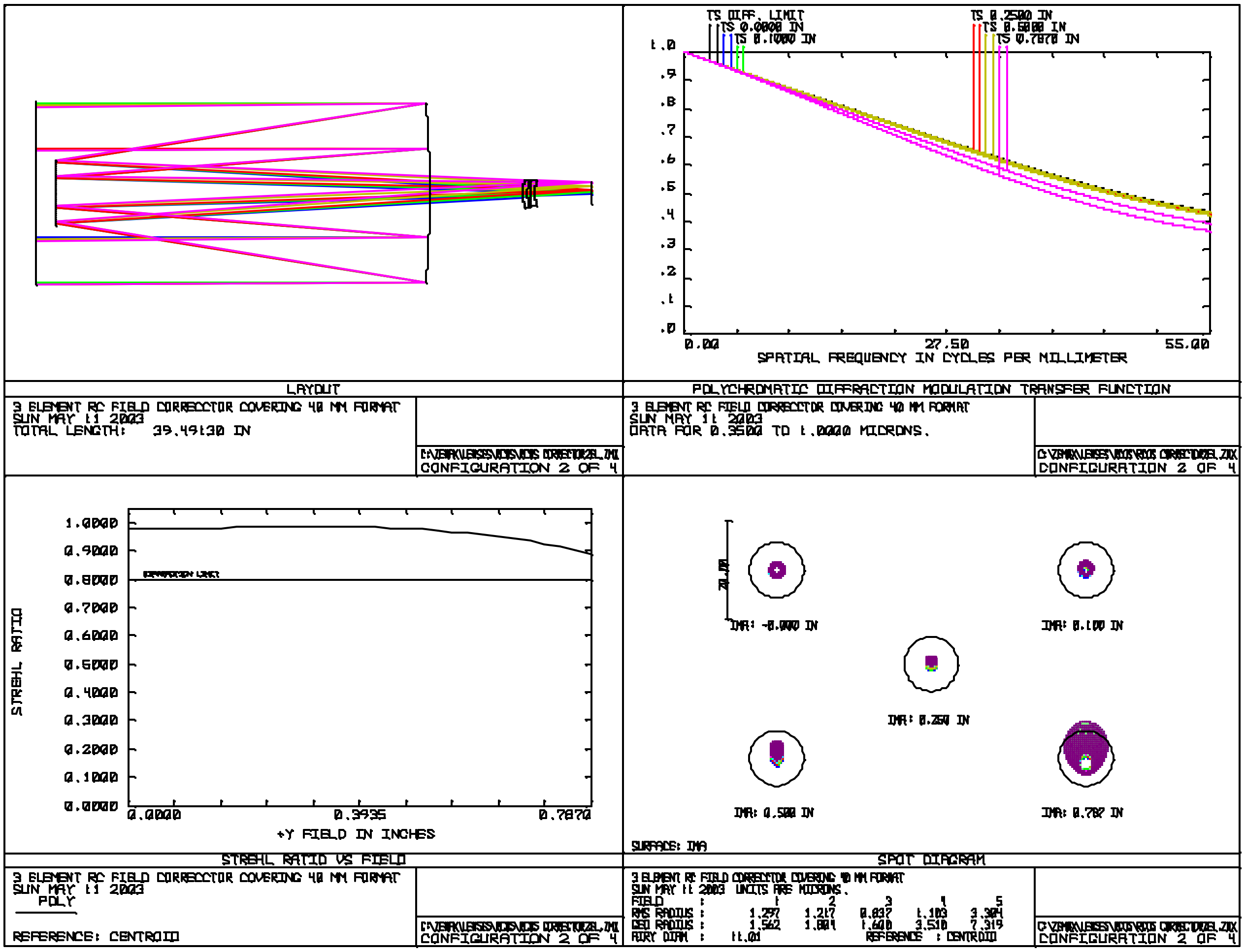

Figure 2 Figures of merit for a 12.5” aperture F/9 R-C telescope with 2 element field flattener

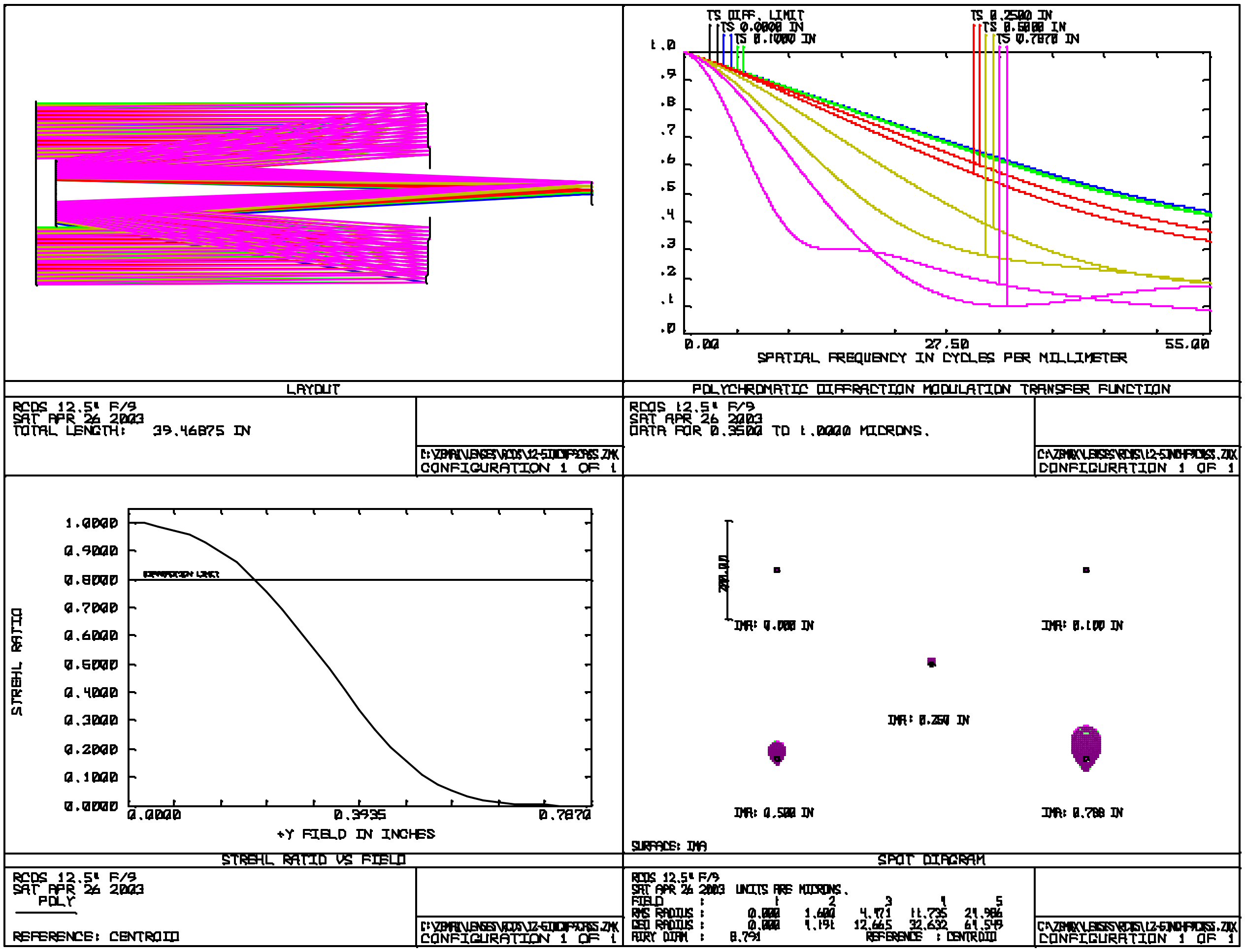

Figure 3 Figures of merit for a 12.5" aperture F/9 Cassegrain telescope without field flattener

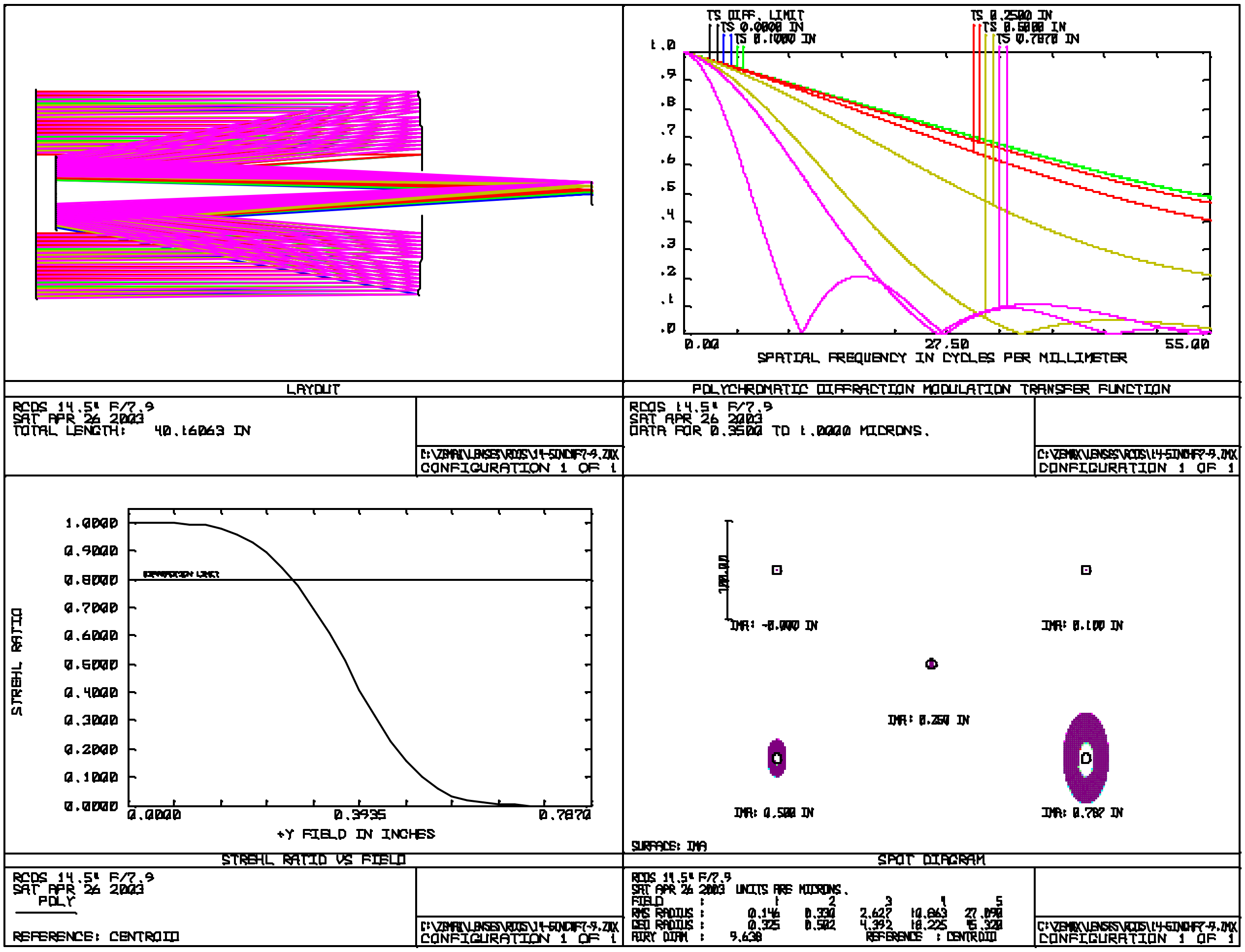

Figure 4 Figures of merit for a 14.5" aperture F/7.9 R-C telescope without field flattener

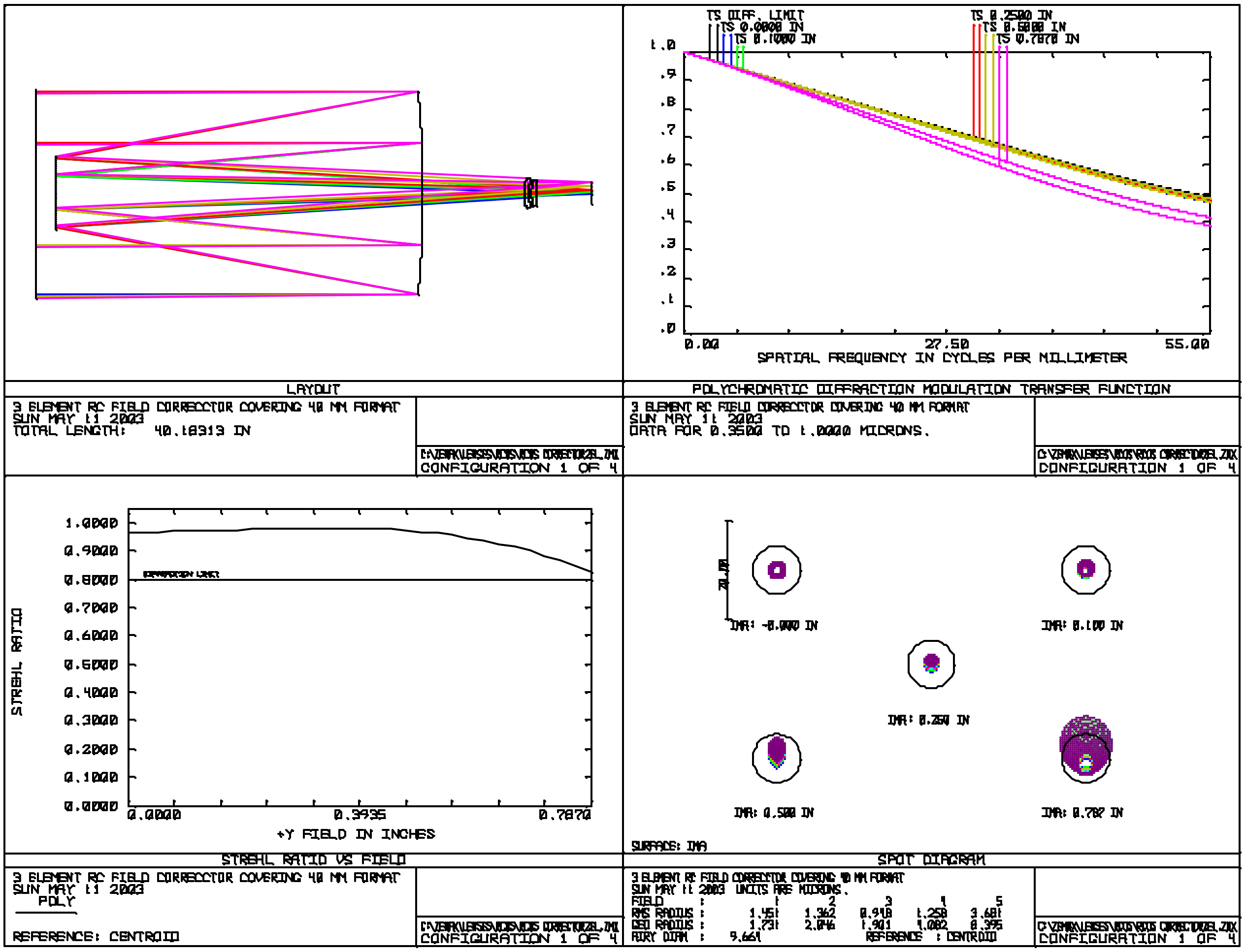

Figure 5 Figures of merit for a 14.5" aperture F/7.9 R-C telescope with 2 element field flattener

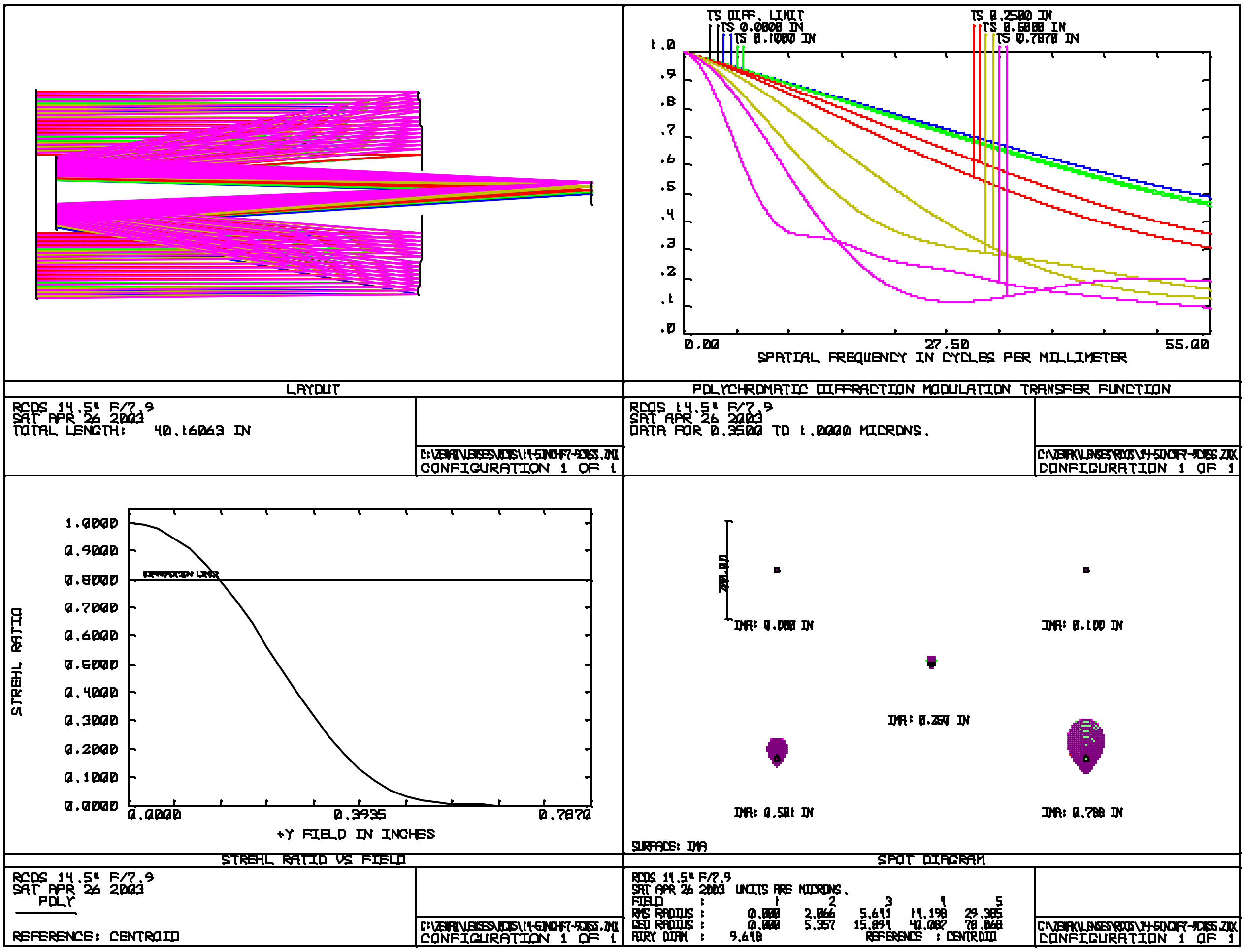

Figure 6 Figures of merit for a 14.5" aperture F/7.9 Cassegrain telescope without field flattener

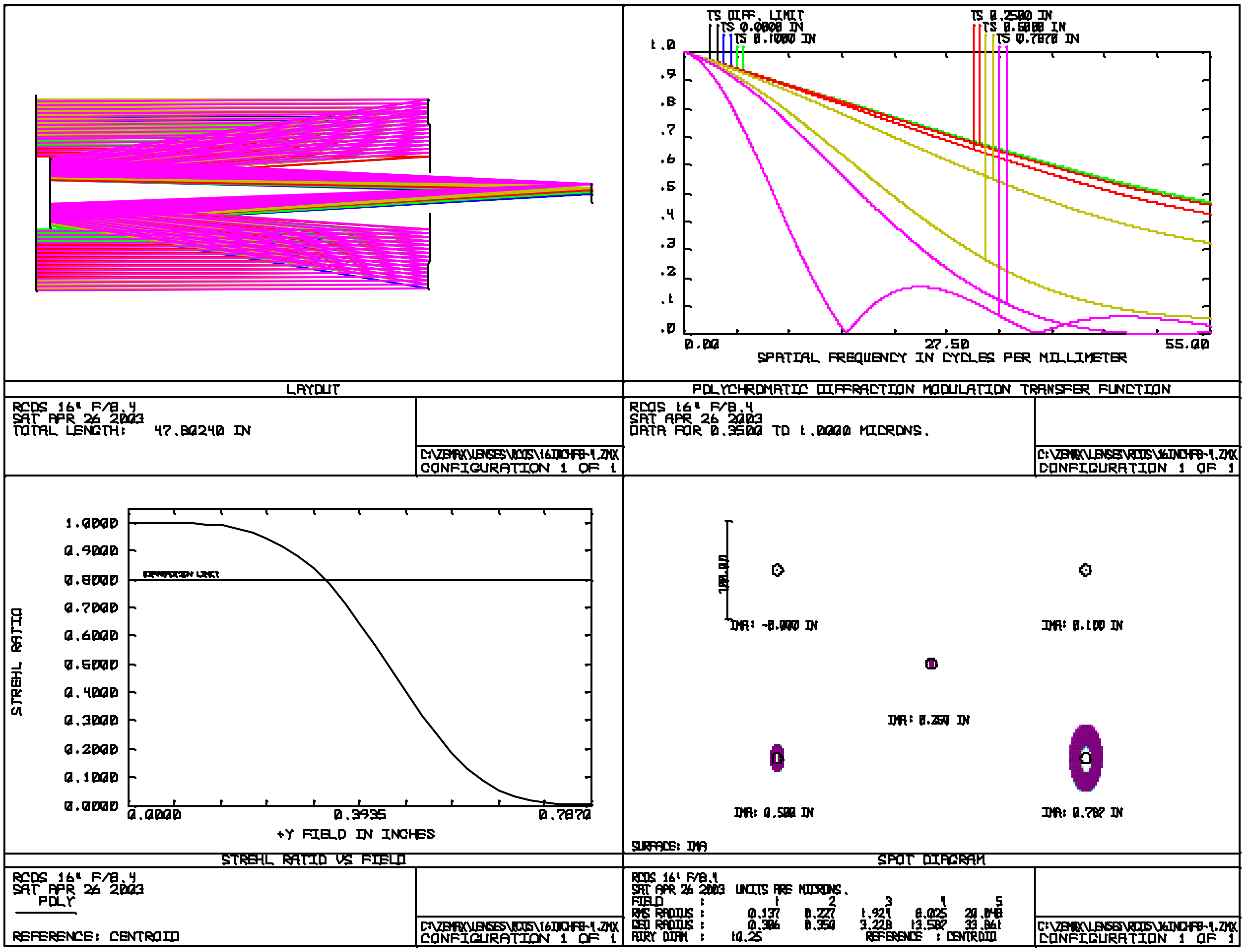

Figure 7 Figures of merit for a 16” aperture F/8.4 R-C telescope without field flattener

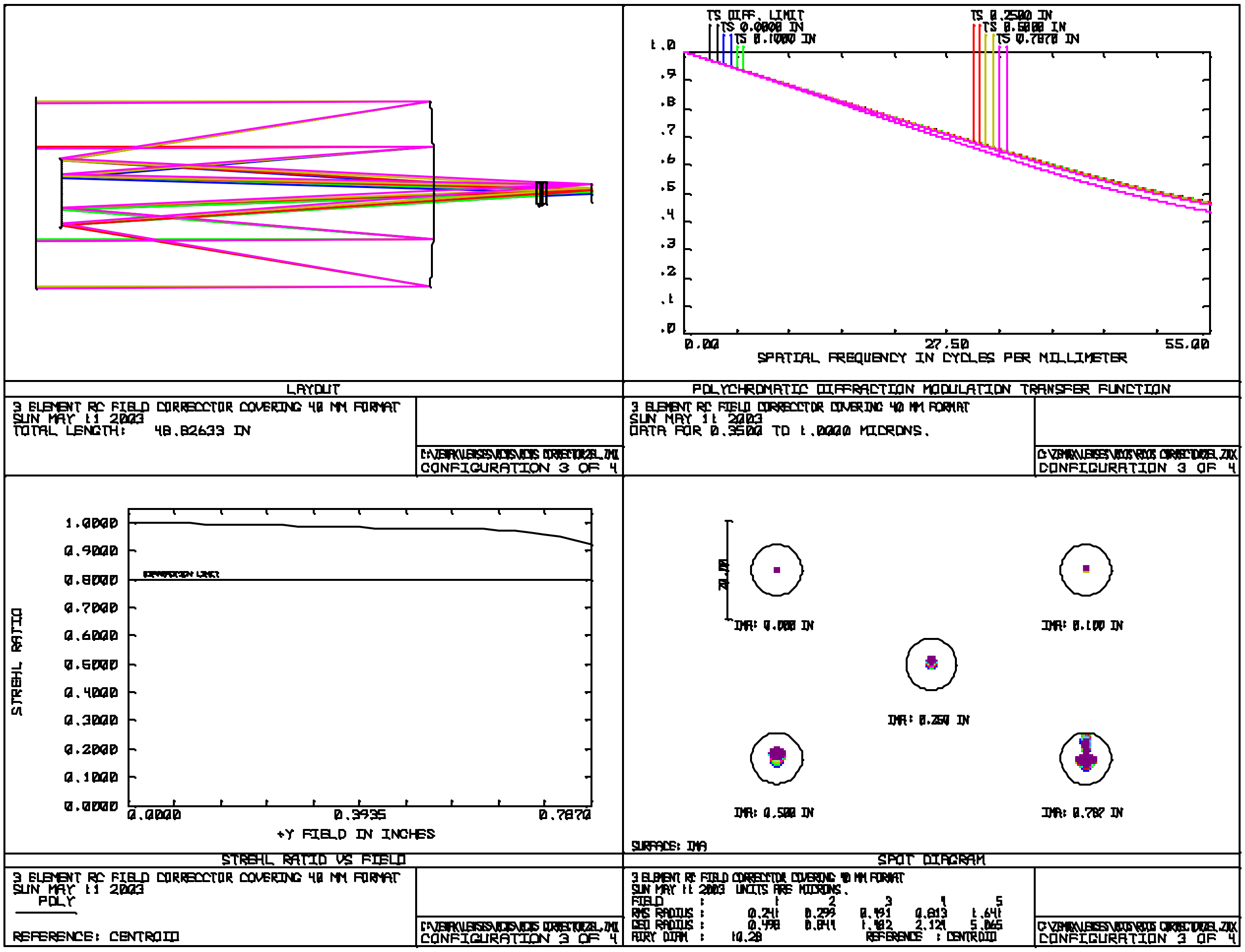

Figure 8 Figures of merit for a 16” aperture F/8.4 R-C telescope with 2 element field flattener

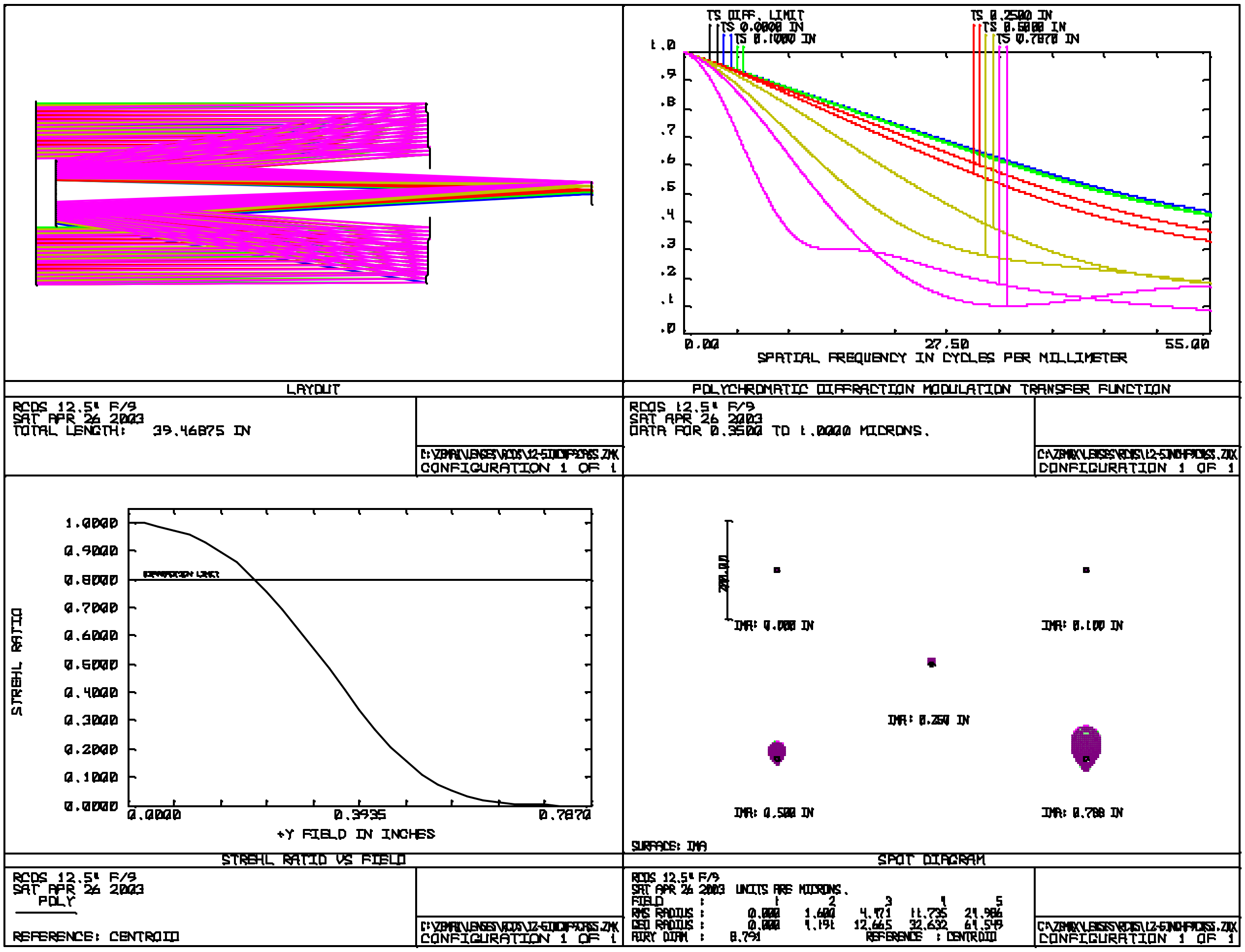

Figure 9 Figures of merit for a 16" aperture F/8.4 Cassegrain telescope without field flattener

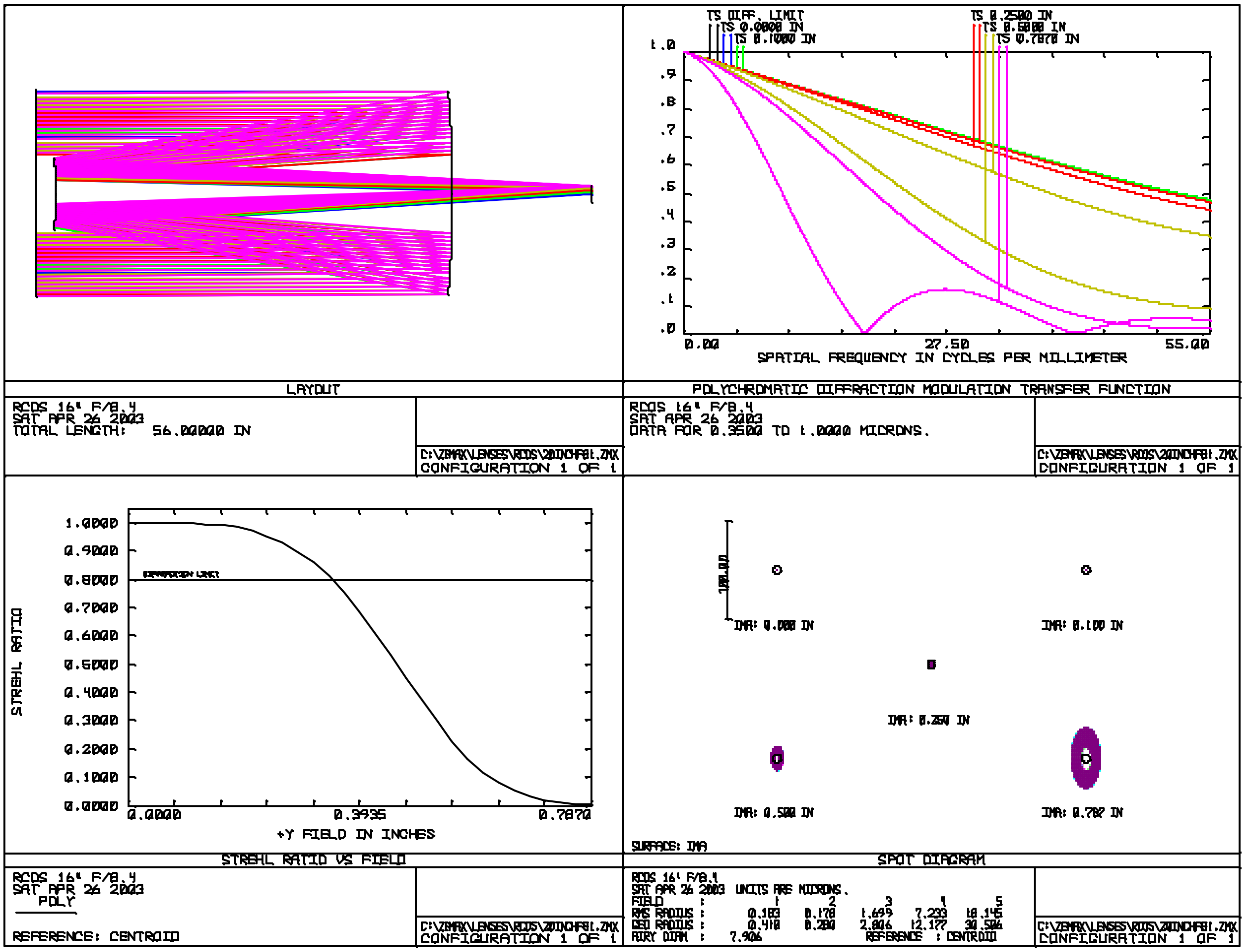

Figure 10 Figures of merit for a 20" aperture F/8.1 R-C telescope without field flattener

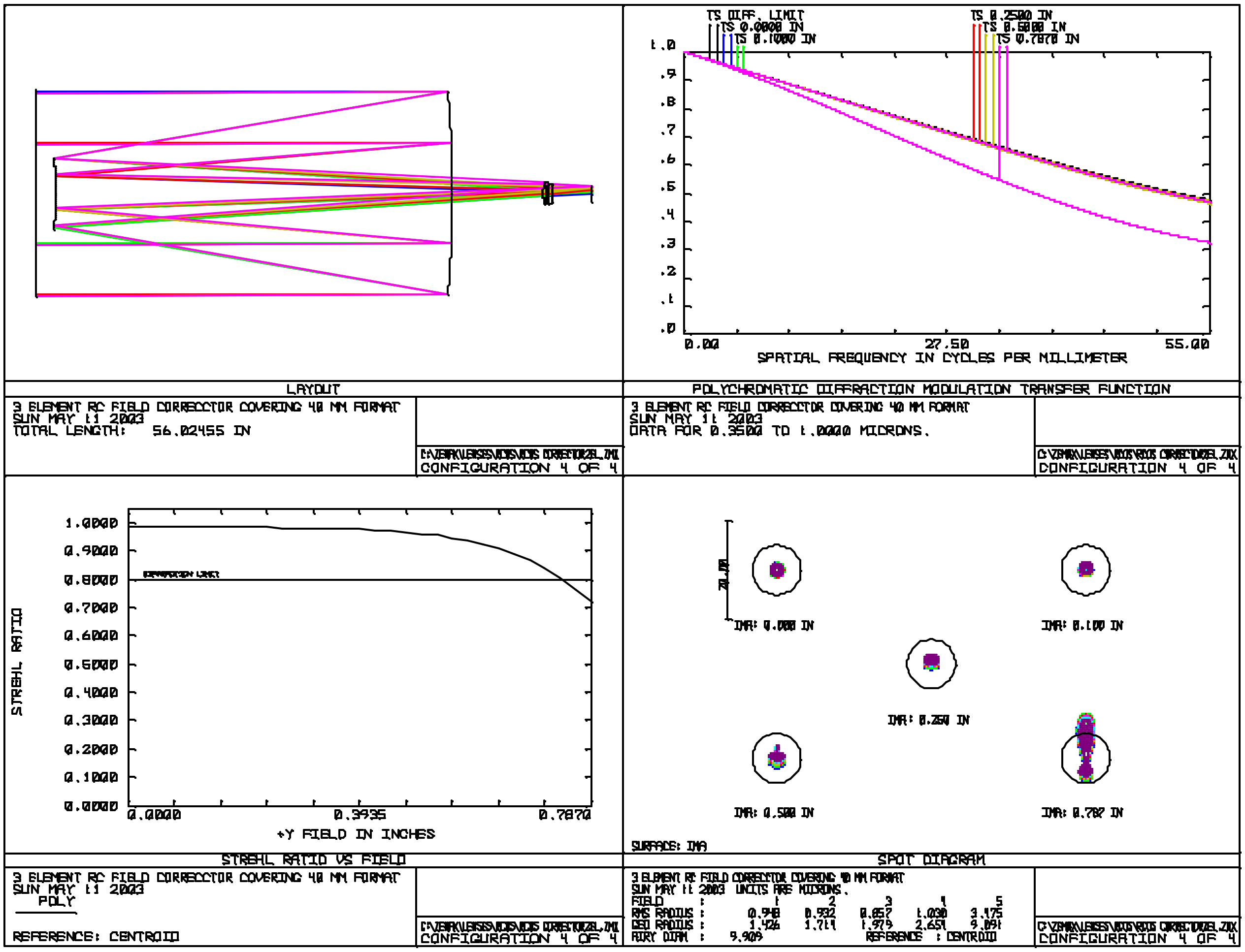

Figure 11 Figures of merit for a 20” aperture F/8.1 R-C telescope with 2 element field flattener

Discussion:

Examination of figures 1-9 supports the following observations:

1. Without field correction optics, the three investigated R-C designs all create an area of diffraction limited imagery (as determined by the polychromatic Strehl ratio having a value > 0.80) that is approximately 14-18 mm in diameter.

2. The equivalent Cassegrain systems exhibit diffraction limited image circles of between 8 and 9 mm diameter.

3. The difference between the Cassegrain and Ritchey-Chretien systems is explained by the presence of Seidel coma in the off-axis image formed by the Cassegrain design, and the absence of coma in the Ritchey-Chretien. That the difference is not primarily due to the small difference in astigmatism between the two designs can be inferred by observing that the largest circle of excellent imagery occurs in the R-C design having the largest focal length (and hence the smallest angular field of view), whereas the largest excellent image circle for the Cassegrain designs occurs for the system with the smallest numeric aperture (i.e. largest F-number). We may therefore conclude that the off-axis performance of the R-C design is limited by an aberration with a strong dependence on the field coordinate (i.e. astigmatism), whereas the Cassegrain off-axis image is more strongly limited by an aberration with a strong dependence on the pupil coordinate (i.e. coma).

4. **Addition of a simple 2 element field corrector to the R-C designs enlarges the area of diffraction limited imagery by a factor of at least 4-7 X when compared against the same design without field correction optics.**

Table 2 Summary of investigated designs

Design	Diffraction limited image circle diameter without corrector (mm)	Diffraction limited image circle diameter with corrector (mm)
12.5” F/9 Ritchey-Chretien	16.6	>40.0
12.5” F/9 Cassegrain	10.7	Not investigated
14.5” F/7.9 Ritchey-Chretien	14.7	>40.0
14.5” F/7.9 Cassegrain	7.9	Not investigated
16” F/8.4 Ritchey-Chretien	17.3	>40.0
16” F/8.4 Cassegrain	9.3	Not investigated
20” F/8.1 Ritchey-Chretien	18.0	37.0
20” F/8.1 Cassegrain	7.9	Not investigated