OPTICAL SYSTEMS FOR THE 'LARGE IMAGING TELESCOPE' (LITE)

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1. Task and Attempt at a Solution

With the first demands to the LITE-project being available in summer 1992, it was obvious that the known systems such as Slevogt, Schmidt or Ritchey-Chrétien-Cassegrain did not offer an attempt at a solution.

A telescope with a 2 to 2.5m Schmidt correction plate was far out of any implementation possibility (costs). The technological efforts for a large Schmidt system are considerable, and thus the Tautenburg telescope has not remained the largest of its kind by chance. Apart from the immense overall length, the curved focal plane (to be compensated by a flattening lens), also the chromatic aberration of the Schmidt correction plate and of the flattening lens are favourable for such a solution to the LITE-project. A system with refracting elements close to the entrance pupil is unrealistic for these dimensions not only for reasons of costs.

The RCC with field correction system seemed to be a possible system in the beginning. This field corrector (Gascoigne-Schmidt plate and flattening lens) represents a very good solution for a 1:8 telescope but it is not appropriate for an aperture ratio of 1:4 and a high demand in image quality.

A further system is the 3-mirror-RC (the Gascoigne-Schmidt plate works as reflector). The aperture ratio of 1:4 already demands a high-grade deformation of the secondary mirror and the Gascoigne plate. Thus, the optical effect of the Gascoigne plate (as mirror) is no longer sufficient.

2. Principal Solution

The 3-Mirror Systems seemed to be the alternative. Paul Baker's and Dietrich Korsch's (1972) attempts at solution — known from the literature — are not appropriate due to their unfavourable mirror position (very large vignette) and an insufficient aperture ratio (max. up to 1:6).

The developed optical versions of 3-mirror systems permit aperture ratios up to 1:2.5 and image fields up to 3.5° approximately. Two of these versions are specifically appropriate for the LITE-project.

H. T. MacGillivray et al. (eds.), Astronomy from Wide-Field Imaging, 93–99.

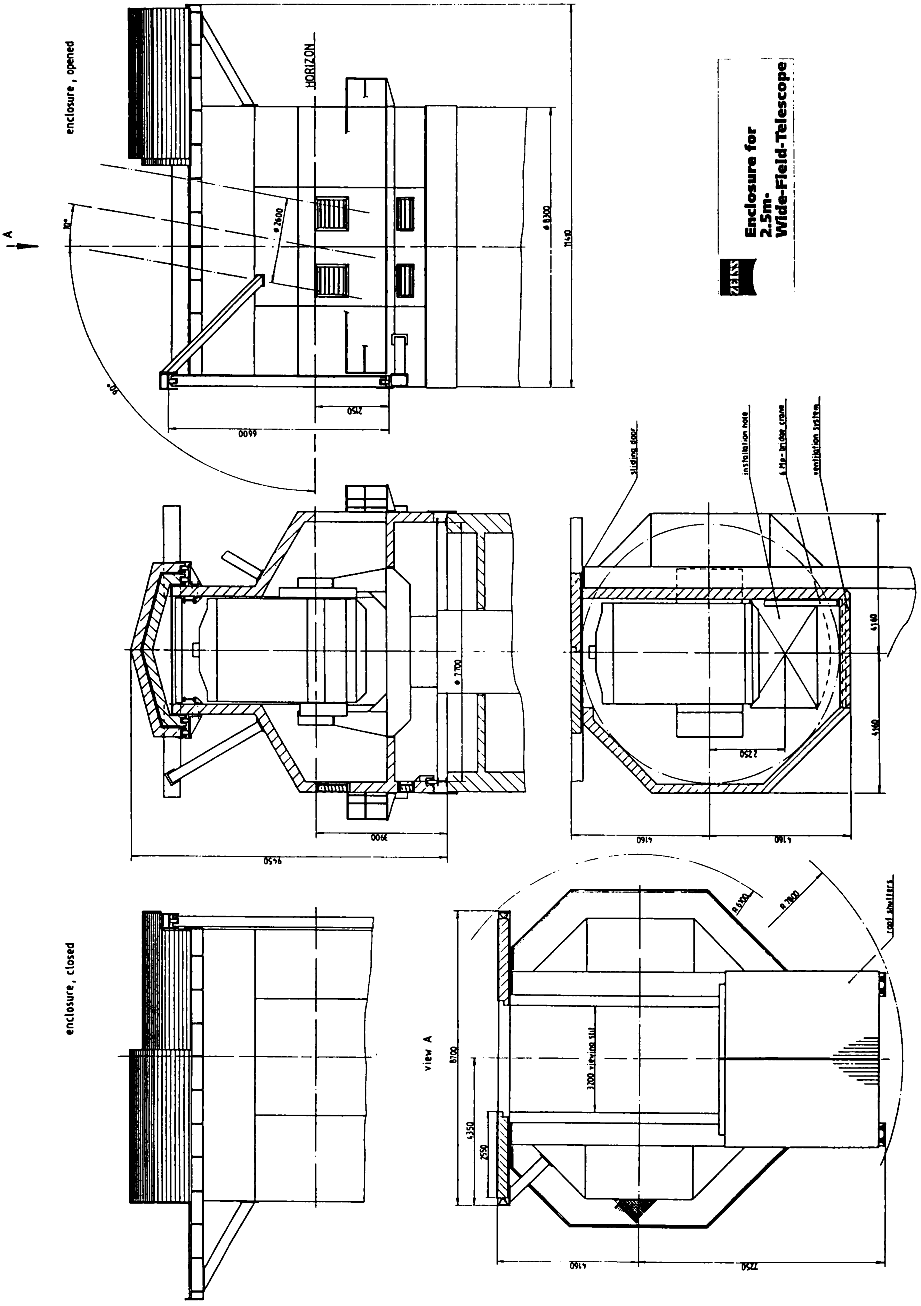

Figure 1.

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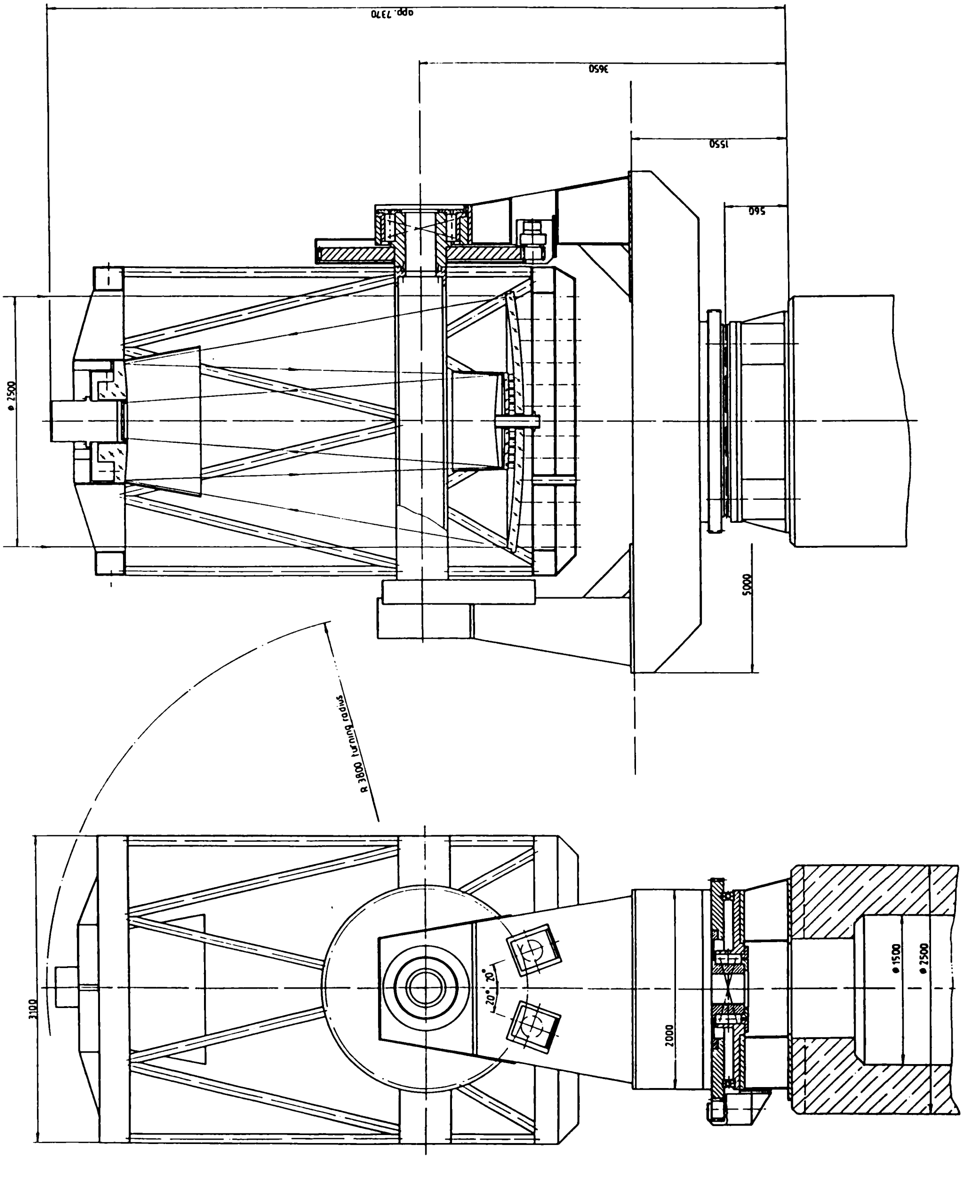

Figure 2.

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3. Tolerances and Adjustments

Very important features of the 3-mirror systems are tolerances and sensitivity of adjustment: four optically effective components have to be considered (3 mirrors and the focal plane). But with regard to tolerances, a difference has to be made between 3-mirror systems of long design and compact systems. In contrast to the usual systems of long design, only 2 units have to be considered in the compact systems. The first unit comprises the primary mirror and the third secondary mirror. Referred to the entire length of the telescope the mirror distance (on the optical axis) is not significant, even a common (active) mounting could be possible. The second group comprises the 2nd secondary mirror and the focal plane (CCD-camera system). This is as well a compact mechanic-optical unit. Thus, specifically the effective surface tilt effects caused by the tube deflection are limited to these groups. Compared to conventional RCC-systems, the tolerances and sensitivity of adjustment are mainly characterized by the large aperture ratio of 1:4.

A complete mechanic-optical simulation of the telescope can be the basis for a possible compensation by the active mirror bearing. These models are simplified by the azimuthal mounting. An active adjustment control is a prerequisite for long-time stability over several hours. Carl Zeiss Jena has gained valuable practical experience in this field due to the participation in the HEXAPOD-telescope project.

4. The Optical Solutions in Detail

For a 1:4 system, the vignetting conditions permit image fields of approximately 350 mm (2°). The actual CCD-receiver system of LITE uses only an image field of 280 mm (1.55°). Thus, the optics offer the option for a larger, more effective CCD-receiver.

The two versions are available as 2500/10000 (1:4) 3-mirror system with an image field of 2°. The focus is located 300 mm in front of the vertex of the 2nd secondary mirror. Both systems are presented in a design with sectional drawing, transverse aberration and spot diagrams. The constructional length has been measured from the main mirror vertex to the focal plane.

Version 1 is a 3-mirror system with over-deformed faces, divergent from the conic section. The constructional length is 2952 mm.

Version 2 is a 3-mirror system with pure hyperbolic faces. The constructional length is 3641 mm.

Both versions achieve nearly the same good image quality, the spot concentration is clearly below 20 µm. The image quality varies only slightly over the image field, also vignetting is mainly constant.

At first sight, the shorter compact system 1 (factor 0.81*) offers an advantage (tube length and smaller enclosure). But the fabrication of this system is more demanding (more tightened and over-deformed mirror shapes). There might also occur difficulties in compensating the weight around the declination (elevation) axis. The primary mirror cell shall face only a low tube weight.

The final selection of the system is mainly determined by the mechanical conditions and the tolerance fields. Both systems can be practically realized by means of modern fabrication and test technologies.

The quartz end window arranged in the dewar chromatically affects the high image quality of the 1:4-3-mirror system. This is mainly caused by the longitudinal chromatic aberration which cannot be compensated and which is already disturbing at the required window and filter thicknesses. Important features are the spectral range and the required resolution.

5. Coarse Specification

5.1 2.5 m WIDE FIELD TELESCOPE

Optics

3-mirror system M1, M2, M3 with SQ1-window, to be actively adjustable:
1) primary mirror M1, diameter 2500 mm clear, thickness approx. 88 mm, D/h ■ 30, meniscus-shaped, born on structure via piezo actuators, active change;
2) secondary mirror M2, diameter 1180 mm clear, thickness 300 mm, D/h ■ 4, passive;
3) secondary mirror M3, diameter 940 mm, thickness approx. 25 mm, D/h ■ 30, meniscus-shaped, linked with M1 via special bedding, passive;
4) SQ1-window, diameter 370 mm clear, alternative thicknesses: 20 mm and 30 mm;
5) focal length of system: 10,000 mm
6) field radius: approx. 1°.

Mechanics

Lattice tube in altazimuthal mounting:
1) lattice tube comprising the structure with M1/M3 including the sky baffle, the central body and the spider with focussing for M2 including sky baffle, the SQ1-window as well as the focal instrumentation, lattice construction, welded, formed by means of FEM;
2) easy-to-change dewar, focussing distance and velocity to be defined;
3) central body flanged with elevation axis;
4) structure for M1/M3 with piezo actuators, to be mounted from the rear;
5) fork is a welded construction of high stiffness;
6) bearing for elevation axis consisting of two preloaded bearing units free of backlash;
7) bearing for azimuth axis consisting of a combination of axial ball bearing and a preloaded diagonal bearing unit;
8) drive modules (motor, tacho, encoder) gripped by spur wheels run the two main axes of the telescope;
9) position measurement is via strip encoders or specifically linked incremental encoders.

Control

1) the two telescope axes (elevation, azimuth) and the focussing are controlled, a special interface is defined for the active optics;
2) the motion of the enclosure will be integrated into the telescope control;
3) use of a computer (basis 80486) with databus and modular standard interface cards;
4) use of a PC with completely integrated control and an external electronics box for the drive power components.

Enclosure

1) octagonal building, fully mobile in azimuth — synchronous with the telescope motion

(attached rotation);
2) axial moving gear, radial support, lift-off safety device;
3) opening: two roof slides, travelling into each other, two laterally movale gate slides;
4) 6 Mp bridge crane;
5) temperature behaviour: high insulating values of the entire building, possibility of fast air exchange by ventilation ducts and ventilators.

Technical Parameters

Telescope

	Elevation		Azimuth
Weight	≤ 1.5x104 kg		≤ 3.5x104 kg
Inertia	≤ 7x105 Nm^2		≤ 1.5x106 Nm^2
Rotation range	0° to 100°		± 200°
Max. velocity		2°s-1	
Max. tracking speed		1°s-1	
Max. acceleration		0.3s-2	
Max. tracking acceleration		0.025°s-2	
Stiffness of drives		≥ 3 x 108 Nm rad-1	
Transmission of the spur gears	i=10		i=11
Max. moment by wind		≤ 700 Nm	
Max. moment by balance error		≤200 Nm	
Friction of bearing system	≤ 500 Nm		≤ 100 Nm
Lowest natural frequency		≥ 10s-1	
Resolution of encoders:			
absolute:		≤ 0.5 arcseconds	
incremental:		≤ 0.1 arcsecond	
Range of operating temperature		-20° to +40°	

Enclosure

Weight	approx. 2.5 x 104 kg
Diameter of supporting rail	7700 mm
Motion range of rotation	± 200°
Max. velocity	2°s-1
Max. tracking speed	1°s-1
Max. acceleration	0.3°s-2
Max. tracking acceleration	0.025°s-2
Max. velocity — roof slide	approx. 2.5 m min-1
Max. velocity — gate slide	approx. 2.5 m min-1
Clear width for telescope tilt, elevation	3200 mm
6Mp bridge crane	
travelling speed	0 to 2.5 m min-1
lifting/lowering	0 to 2.5 m min-1
K-value of the insulation	≤ 0.3W m-2K-1
Temperature range	-30° to +60°C
Wind resistance for	

observations	up to 20 ms-1
closed	up to 70 ms-1
Structural stability in case of earthquakes	value VII, Richter scale
Ice and snow load	to be specified, depending on the site
Ventilation and cooling system for maintaining the temperature in the enclosure	outside temperature tA ± 0.1°C
range of operating temperature	-20° to +40°C

The ventilators shall be variably controllable (connected with a thermometer) to be able to generate air stream velocities corresponding to the wind velocities.

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