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A TELESCOPE SUITABLE FOR ROCKET BORNE INSTRUMENTATION

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INTRODUCTION:

Recent experiments to photograph the sun in the near ultra-violet (Mg II, λ2802.7Å)[1] included a telescope as part of the instrumentation package. Rather than undertake the optical and mechanical design of a telescope, a suitable commercially available unit was sought.

The telescope chosen was a Questar - (Questar Corporation, New Hope, Pennsylvania). The Maksutov-Cassegrain type telescope was chosen because it combines a very compact, closed construction with high resolution, a long effective focal length and excellent imaging qualities.

OPTICAL SYSTEM:

The primary and secondary mirrors are both spherical mirrors with a focal length of approximately 192 mm and 50 mm respectively. The secondary mirror is integral with the corrector plate, mounted in the front end of the tube. All optics were made of fused silica, with mirror surfaces of evaporated aluminum without a protective overcoating. The f/19 system has an aperture of 8.9 cm with an effective focal length of 169 cm. Figure 1 shows the light path through the optical system and Figure 2, the mechanical configuration.

(1) Fredga, K. (1966) Rocket Spectroheliograph for the Mg II line at 2802.7Å Goddard Space Flight Center Note X-614-66-213

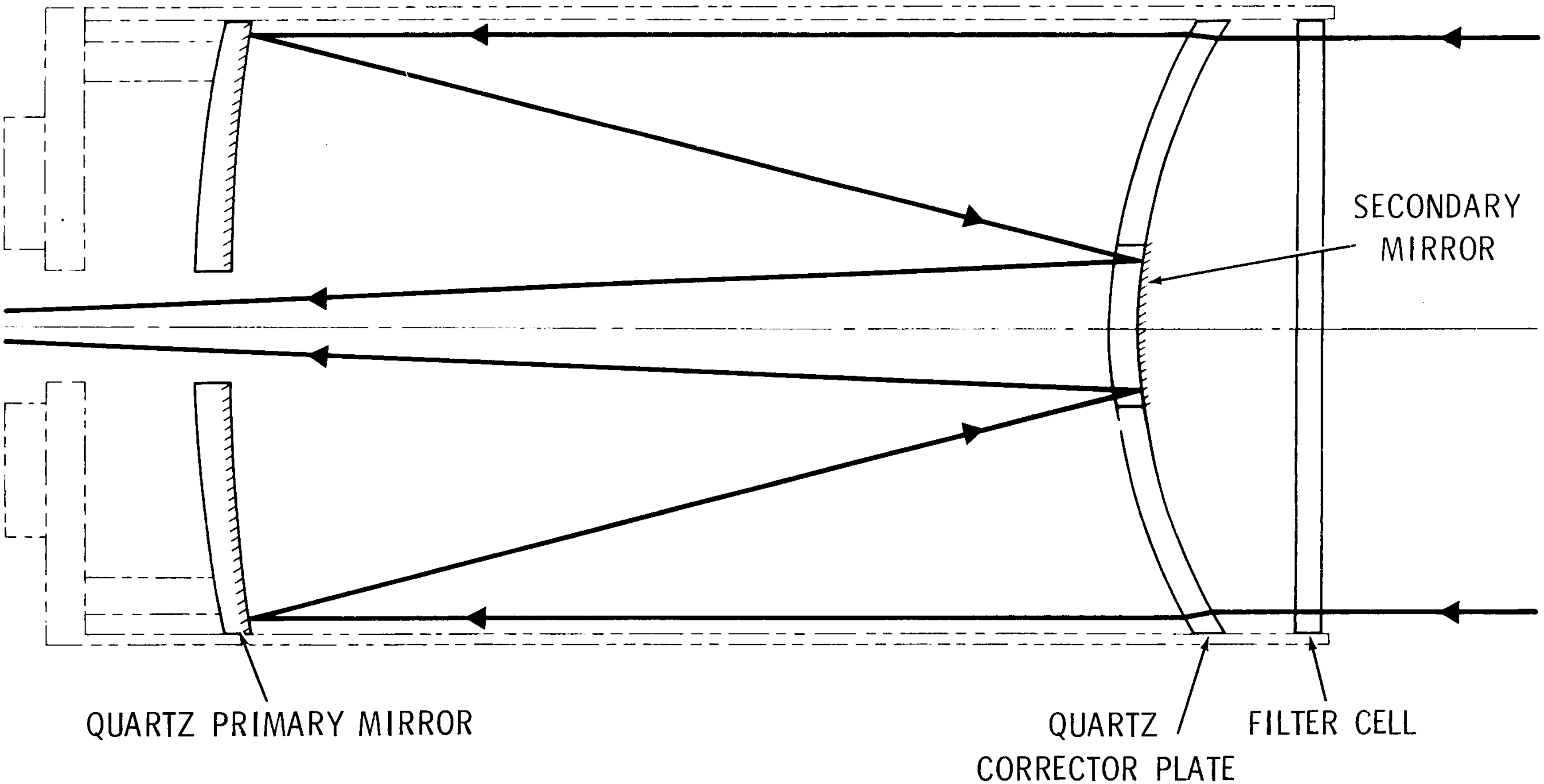

Figure 1. - Optical System Light Path.

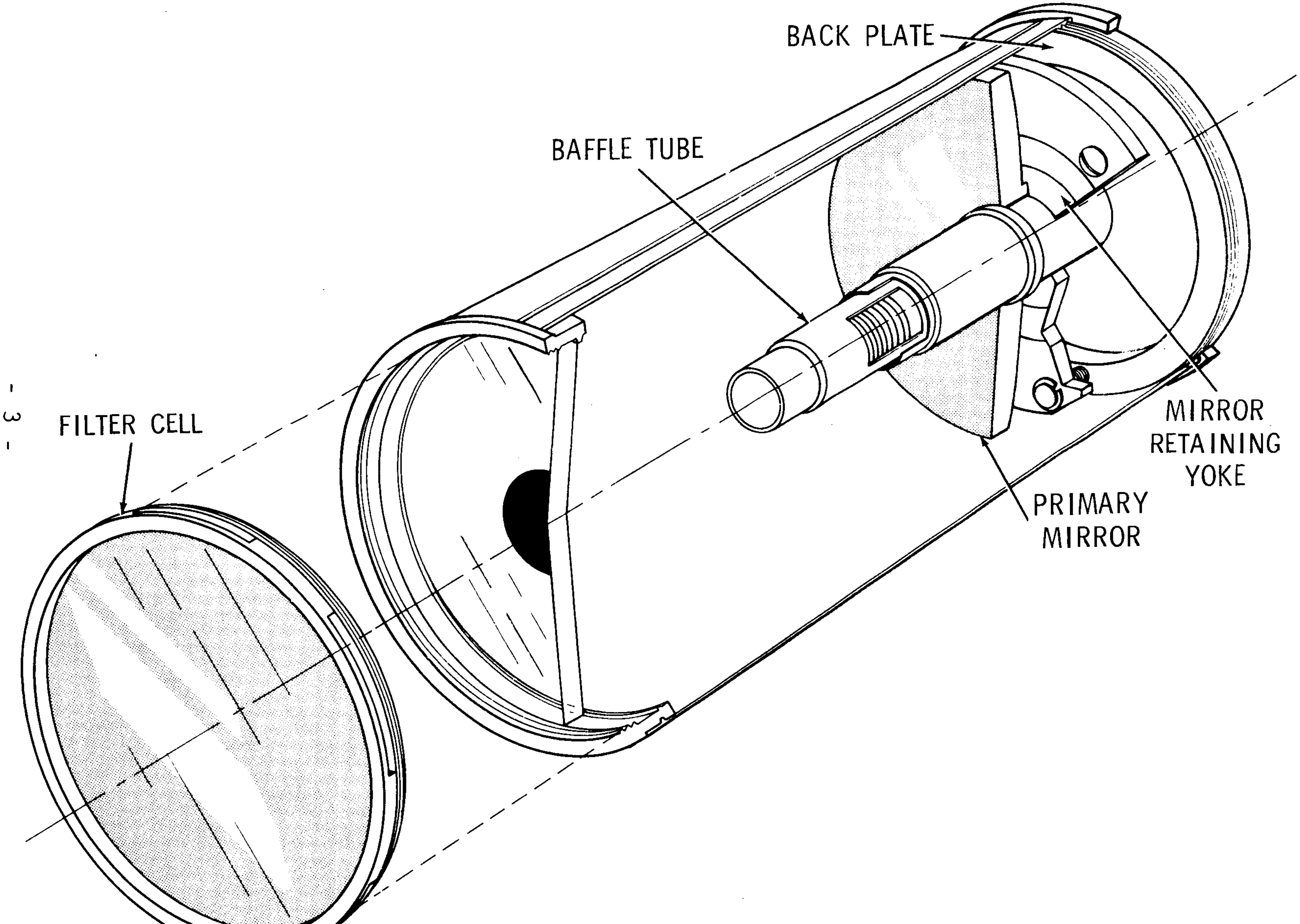

Figure 2. - Mechanical Configuration

MECHANICAL CONSIDERATIONS:

Initially, a standard field-model Questar was hard mounted (Ref. Figure 3) and subjected to the qualification vibrational levels suggested for Aerobee 150 payloads. These specifications were as follows:

lateral "X" and "Y" axes - 10 G Rms, 20-2000 cps random for 2 minutes (constant acceleration with varying displacement)

longitudinal "Z" axis - 15 G Rms, 20-2000 cps random for 2 minutes (constant acceleration with varying displacement)

After vibration, there was no visible damage and the focus knob which had been locked prior to the test, remained locked. The focus was then checked and was found to have changed. Dissassembly of the instrument and inspection of each component revealed a deformation of approximately .015" to the mirror retaining yoke supporting the primary mirror. This failure is understandable since the yoke was supported at only one point by attachment to the focusing rod.

Some mechanical modifications of the commercially available model were obviously necessary to adapt the telescope for rocket use. The thickness of the yoke was increased from 1/16" aluminum to 5/32" stainless and the baffle tube was attached by being pressed and turned rather than being a press fit only. In addition to the stainless steel focusing rod, two more rods were attached to the yoke spaced by 120 degrees. These rods

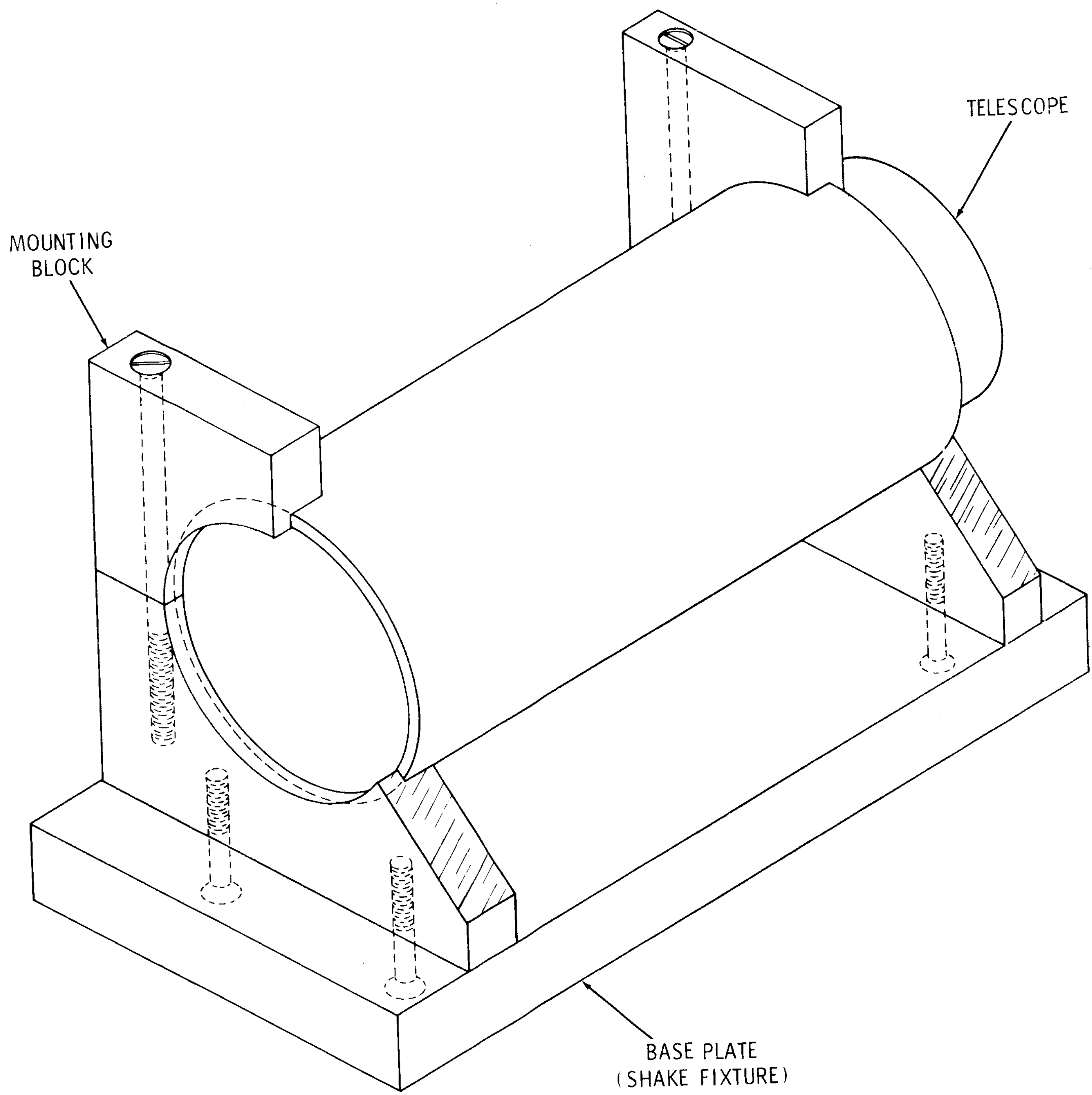

Figure 3. - Vibration Test Mount

provided adequate additional support for the primary mirror and were locked by means of a nylon set screw as was the focus rod. The back plate was changed from aluminum to stainless and was "beefed up" to provide more bearing surface for the support and guide rods.

THERMAL CONSIDERATIONS:

The telescope is extremely sensitive to changes in the distance separating the two mirrors. At the focal length used, the focal plane will change as much as 70 times the change that may take place in the separation of the mirrors. Using the original 20 cm aluminum telescope barrel, a 10°C change in temperature causes a 3.5 mm shift in the position of the focal plane. This would usually not cause a problem on the ground where the focus can be readjusted until the telescope has adopted the ambient temperature, but for a rocket flight the focus must remain fixed over a wide temperature range. To overcome this problem, the barrel was made of a 20 cm Invar tube, the thermal expansion of which was compensated by the three 2 cm stainless steel rods supporting the primary mirror. The resulting thermal expansion for the mounting system very closely balances the thermal expansion for the quartz optics, giving a satisfactorily small change in the focal plane position of less than 0.002 mm per degree C.

An additional thermal consideration includes surrounding the barrel with a tight fitting shield consisting of a white epoxy coating on aluminum, a layer of synthane, an inner aluminum tube and a paper layer next to the telescope barrel. This shield would only be necessary where the barrel is exposed to direct solar radiation.

VACUUM CONSIDERATIONS:

A ventilated filter cell which screws into the front of the telescope barrel required some modification. The ventilating slots were enlarged to permit equalization of pressure within the telescope to the pressure outside throughout the flight. The manufacturer uses tape at several points around the corrector plate to provide a firm mounting yet allow for expansion and contraction without distorting the corrector. Outgassing tests were performed on this tape (3M, Scotch Brand, #681-PHC-13LF1A5) by placing the tape in close proximity to a quartz slide and pulling a vacuum of 10^{-6} mm Hg for several hours. Measuring the transmission of the quartz plate before and after the vacuum test revealed no difference in the transmission at 2800 Angstroms. Outgassing of the tape, if any, would not affect the optics in the wavelength of interest.

FINAL MECHANICAL PERFORMANCE:

The final telescope was mounted on a baseplate to be flown on an Aerobee 150 Solar Pointed experiment and again subjected to vibration. The suggested vibrational levels for flight testing of the entire experimental package were as follows:

lateral "X" and "Y" axes - 6.6 G Rms, 20-2000 cps random for one minute (constant acceleration with varying displacement) longitudinal "Z" axes - 10 G Rms, 20-2000 cps random for one minute (constant acceleration with varying displacement)

For this particular experiment a sine sweep was performed at a level not greater than 0.5 G Rms to determine amplification and resonance. It was found that around 1100 cps there was an amplification of approximately six times (6X) in the baseplate area where the telescope was mounted. This does not imply that conditions-"G" loading, frequency and amplification ever combined simultaneously to produce 35-60 G's at the telescope. Higher "G" forces than those applied during environmental testing were reached, however, as explained in the following section.

FLIGHT PERFORMANCE:

After being flown and recovered the experiment package was checked for focus and alignment of the telescope, neither of which had changed. It is of interest to note that instantaneous "G" loading on the payload at the time of main parachute deployment is in excess of 15 G, (between 15 G and 30 G). This payload was flown a second time with the telescope performing equally as well as the first time.

A modified field model Questar has been flown and used successfully in the Gemini cockpit. The modifications necessary for Gemini were not the same as those performed for the Aerobee

150 flights. Although this writer is not familiar with these particular changes, the vendor has a record of such alterations.

SUMMARY:

The same modified Questar telescope has performed exceptionally well for two Aerobee 150 flights and was recovered in a condition acceptable for immediate re-use.

All design modifications were the result of a joint effort between the technical personnel at Goddard Space Flight Center and Questar Corporation with the vendor performing all the work except for the rough machining of the special barrel.