Thermal and Mechanical Stability of the WF/PC 11 Optical Alignment

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The Wide. Field/Planetary Camera (WF/PC), developed by the Jet Propulsion Laboratory (JPL) under contract to the National Aeronautics and Space Administration (NASA), is the principal science instrument on the Hubble Space Telescope (HST). The HST, shown in Figure 1, was launched on April 24, 1990. Shortly thereafter, it became. evident that spherical aberration of the primary mirror limited the performance of the HST science instruments. As the HST was designed for on-orbit servicing, to repair and refurbish the observatory and to upgrade its capabilities, a mission was planned to re.place **the misting** WF/PC 1 with a modified version of its spare instrument, designated WF/PC II (Figure 2). The WF/PC II would be equipped with a prescription to its optical train, Figure 3, to correct for the spherical aberrat ion of the HST primary mirror.

The optical fix requires the virtual image of the. aberrated HST primary mirror to be reimaged on inversely aberrated secondary mirrors of the WF/PC 11 relay optics. An order of magnitude increase in the accuracy of the alignment of the two aberrated pupils is necessary in order for the prescription to be effective. This task is complicated by the WF/PC II design which contains four optical channels, each channel requiring, the precise alignment. Three factors that could cause misalignment of the optical train following insertion of the instrument into the HST: 1) Mechanical tolerances in the instrument to telescope interface; 2) tilt and decenter of the telescope. secondary mirror; and 3) changes in the environment from alignment on earth to operation in space, especially in temperatures and thermal gradients. To assure the required alignment can be achieved and maintained on orbit, mechanisms have been added to control tip and tilt of four elements of the WF/PC II optical train. The purpose of this paper is to present the detailed thermal and mechanical analyses used to determine the effects of environmental changes on the WF/PC 11 optical alignment. The analysis results are used to determine. the performance. specifications for the mechanisms used to align the WF/PC 11.

All of the optics are mounted to a kinematically supported optical bench shown in Figure 4. The optical bench consists primarily of four graphite/epoxy panels enclosing four bulkheads. Three of the bulkheads are constructed from high purity Invar and support the fold mirrors, pyramid mirror, and relay optics. The pickoff mirror is cantilevered from the optical bench on a graphite/epox y arm. All optical elements arc mounted to the optical bench through a set of flexures. The flexures provide a stiff support system but allow radial motion of the optics relative to the bench.

Both thermal deformation and gravity release. affect the. alignment of the optical train. Thermal deformation results from two different environmental effects. First, the uniform change in temperature from alignment on earth (20°C) to operation in space (10°C) due to the different CTE's of the materials used on the optical bench. Thermal distortion analysis was performed using the optical bench finite element model shown in Figure 5, A uniform temperature change. was placed on the mode]. The difference between the coefficient of thermal expansion of the Invar bulkheads to the graphite/epoxy panels resulted in the bending of the optical bench as diagrammed in Figure 6. The resulting displacements and tip/tilts of the optical elements were used to perform ray trace analysis to determine the change in optical alignment caused by the 10°C change in temperature.

Second, temperature gradients across the optical bench resulted from thcllS'1'satellite. moving in and out of the earth's shadow within each orbit. The finite element model was used to determine the motion and tilt of the optical elements due to the temperature gradient. Again, ray tracing, was employed to determine its effect on the optical alignment.

Finite element models were also constructed of each of the individual optical element assemblies. The finite element model of the relay optics is shown in Figure 7. Sine vibration testing was performed on the optical elements to tune the properties of the model to match the test natural frequencies. These subassembly finite clement models were used with the optical bench finite element model to determine the total effect of gravity release cm optical alignment.

Analysis results of the WF/PC I instrument were compared to on-orbit observances to verify the analytical models. The expected changes in the optical alignment of the WF/PC II instrument were then determined following the same procedures. The analysis results show that the primary effect of the environmental changes is a rigid body motion of the optical bench relative to the HST optical axis. The rigid body motion is both a one time effect due primarily to gravity release and a reoccurring effect due to the changing thermal gradients within an orbit. A secondary effect of the environmental changes is bending of the optical bench due both to gravity release and thermal distortion caused by the uniform change in temperature. The secondary effect of optical bench.bending is a significant concern as it effects the alignment of each optical channel in different ways.

Although rigid body motion of the. optical bench may not be determined from the on-orbit images, cm-orbit data may be used to determine the secondary effect of optical bench binding. The predicted WF/PC I motion compares well with on-orbit data, with excellent agreement with the. gravity release. predictions. 'l-he analytical predicted motion of the. WF/PC 11 optical elements showed that the. four mechanisms added to the WF/PC II optical train will be able to maintain instrument alignment through the entire range of environmental changes from alignment cm earth to operation in space..

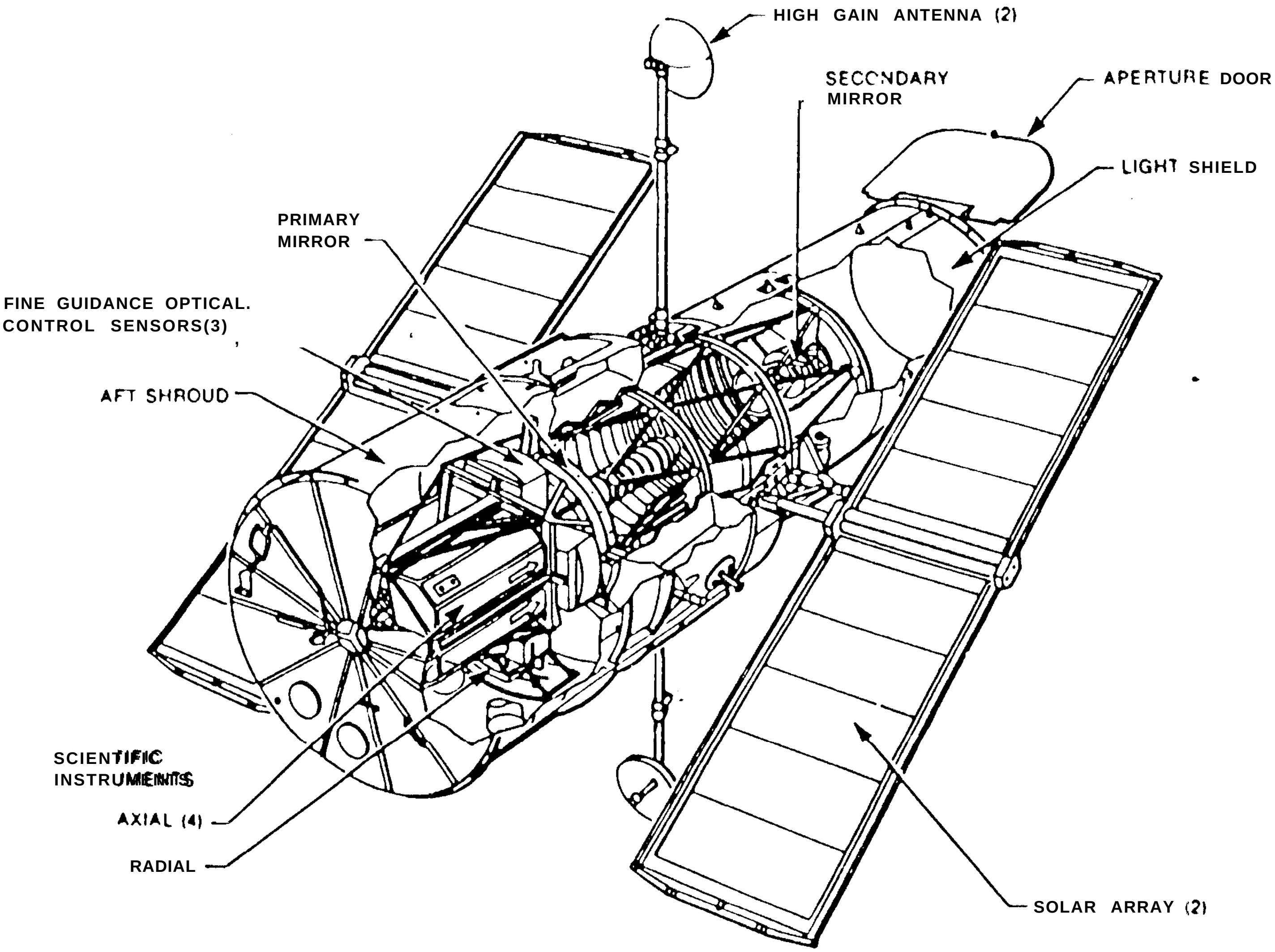

Figure 1: The Hubble Space Telescope

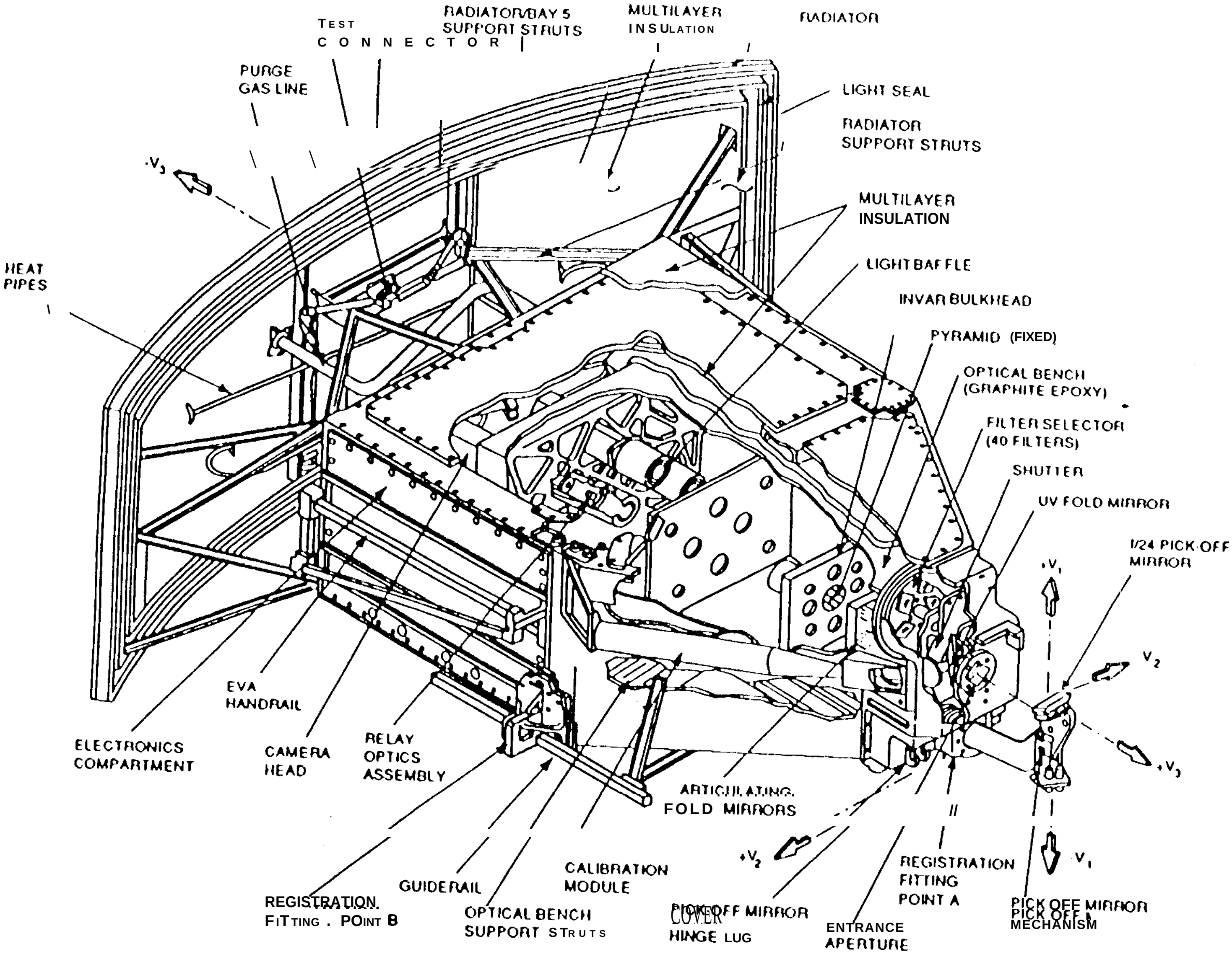

Figure 2: The Wide Field/Planetary Camera 11

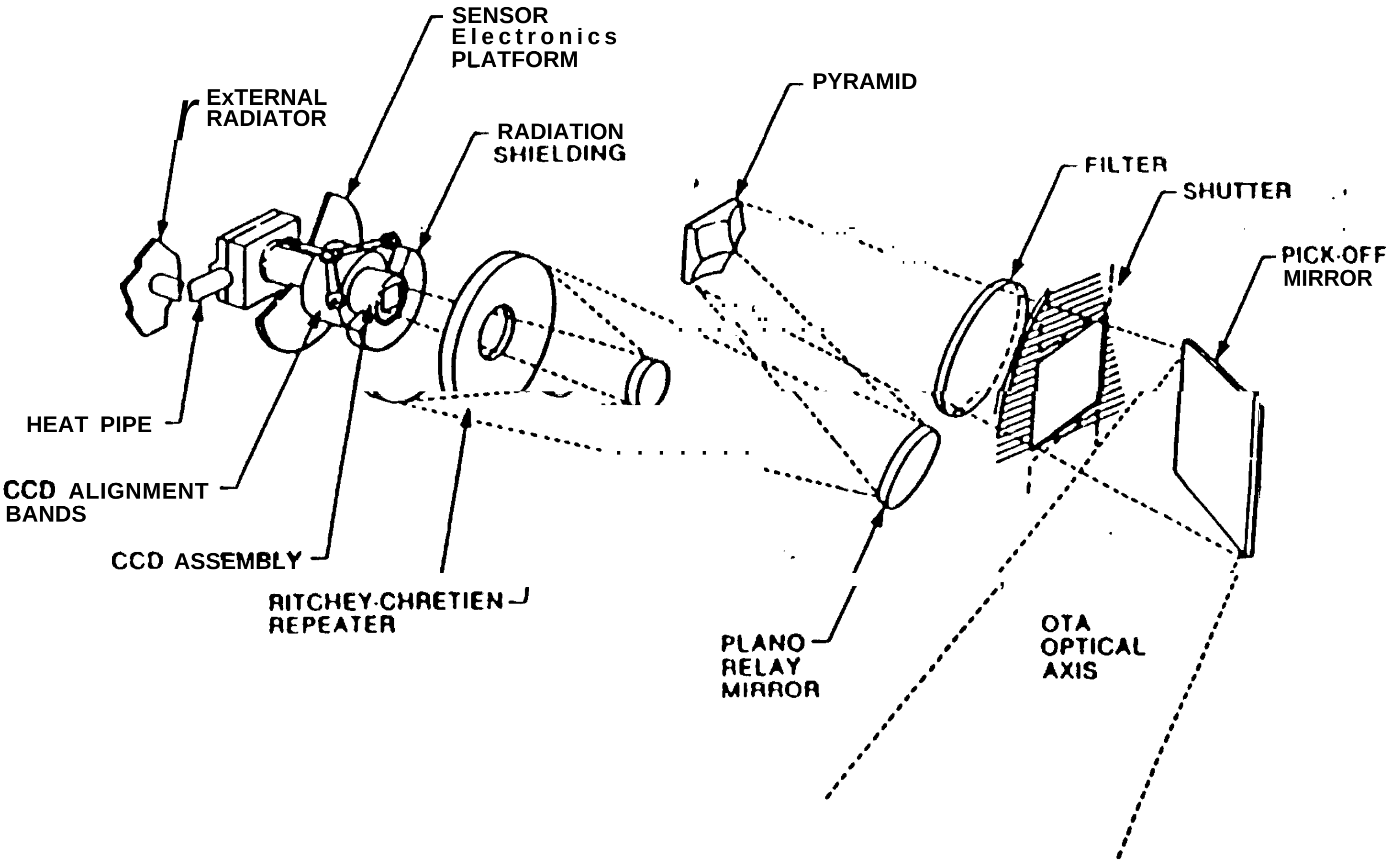

Figure 3: The Wide Field/Planetary Camera Optical Train

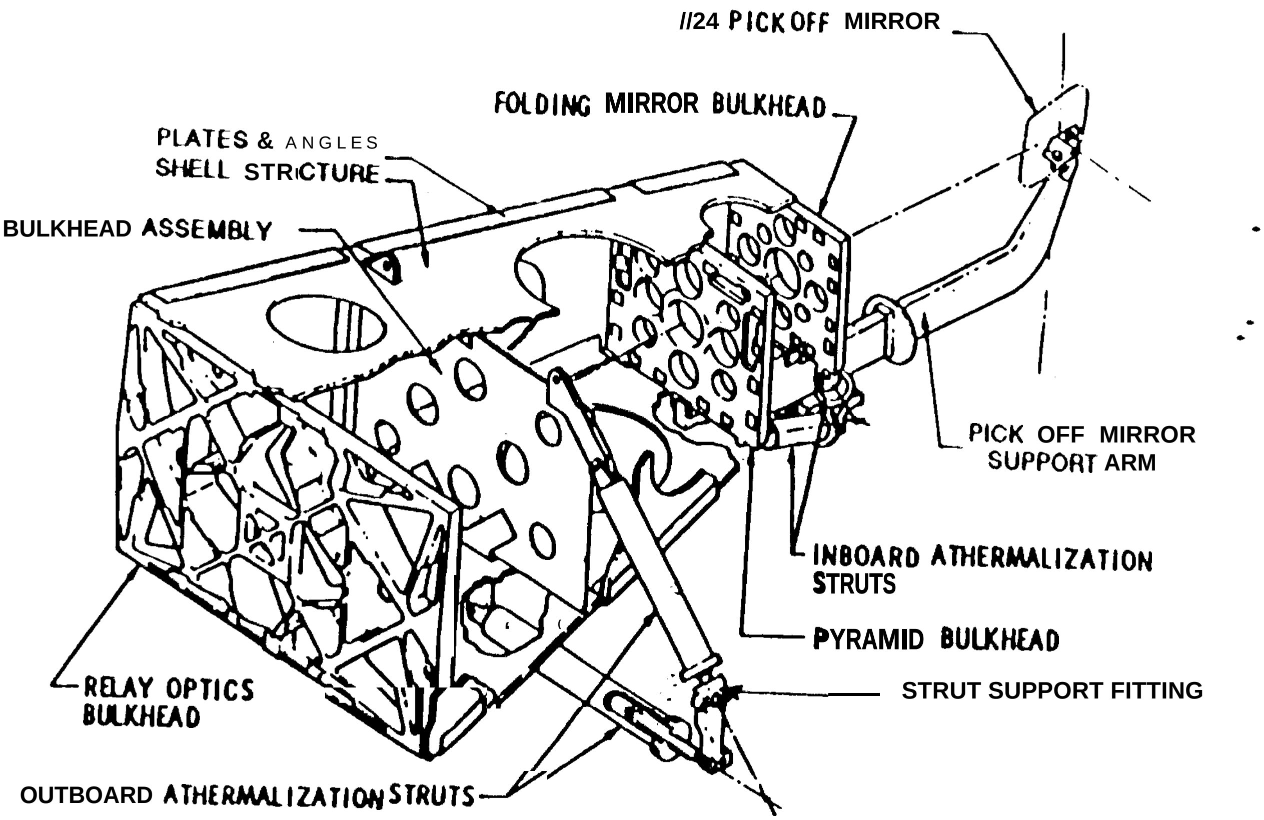

Figure 4: WF/PC Optical Bench

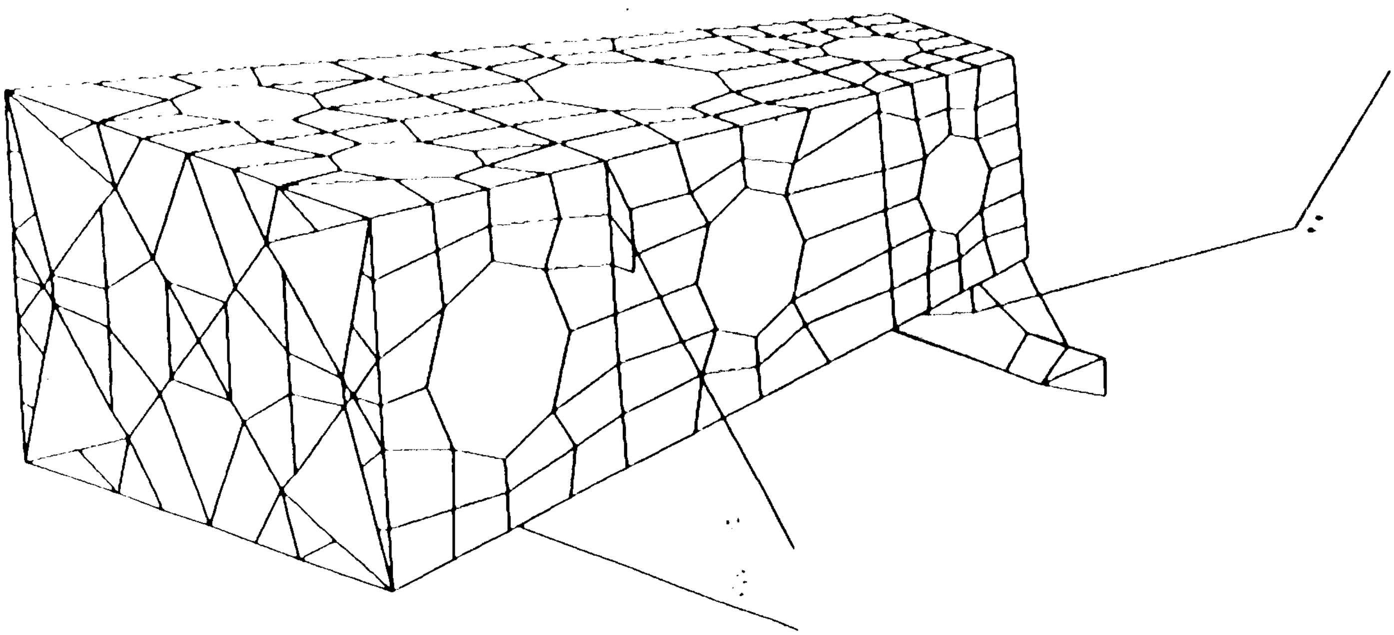

Figure 5: optical Bench Finite Element Model

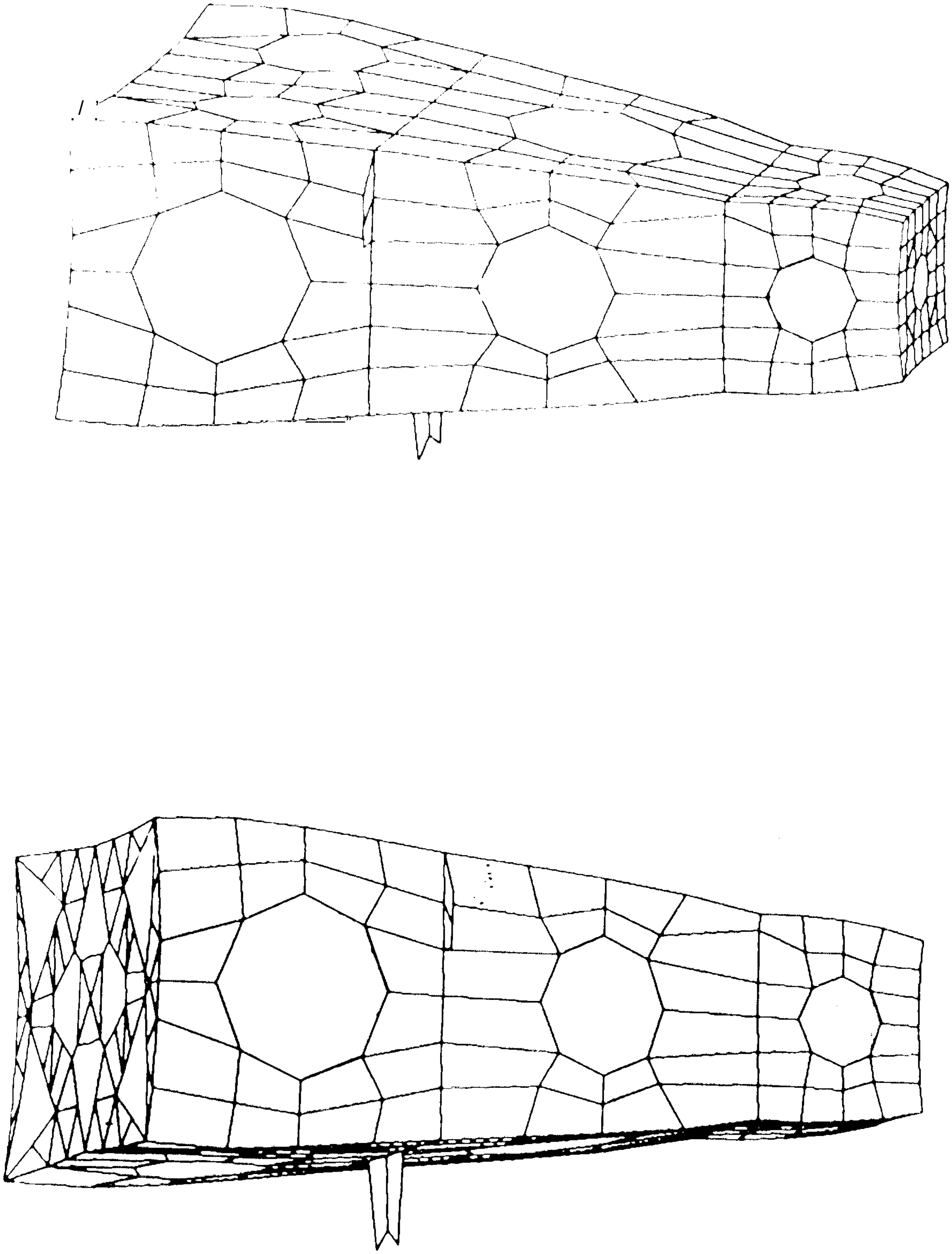

Figure 6: Thermal Distortion of the Optical Bench

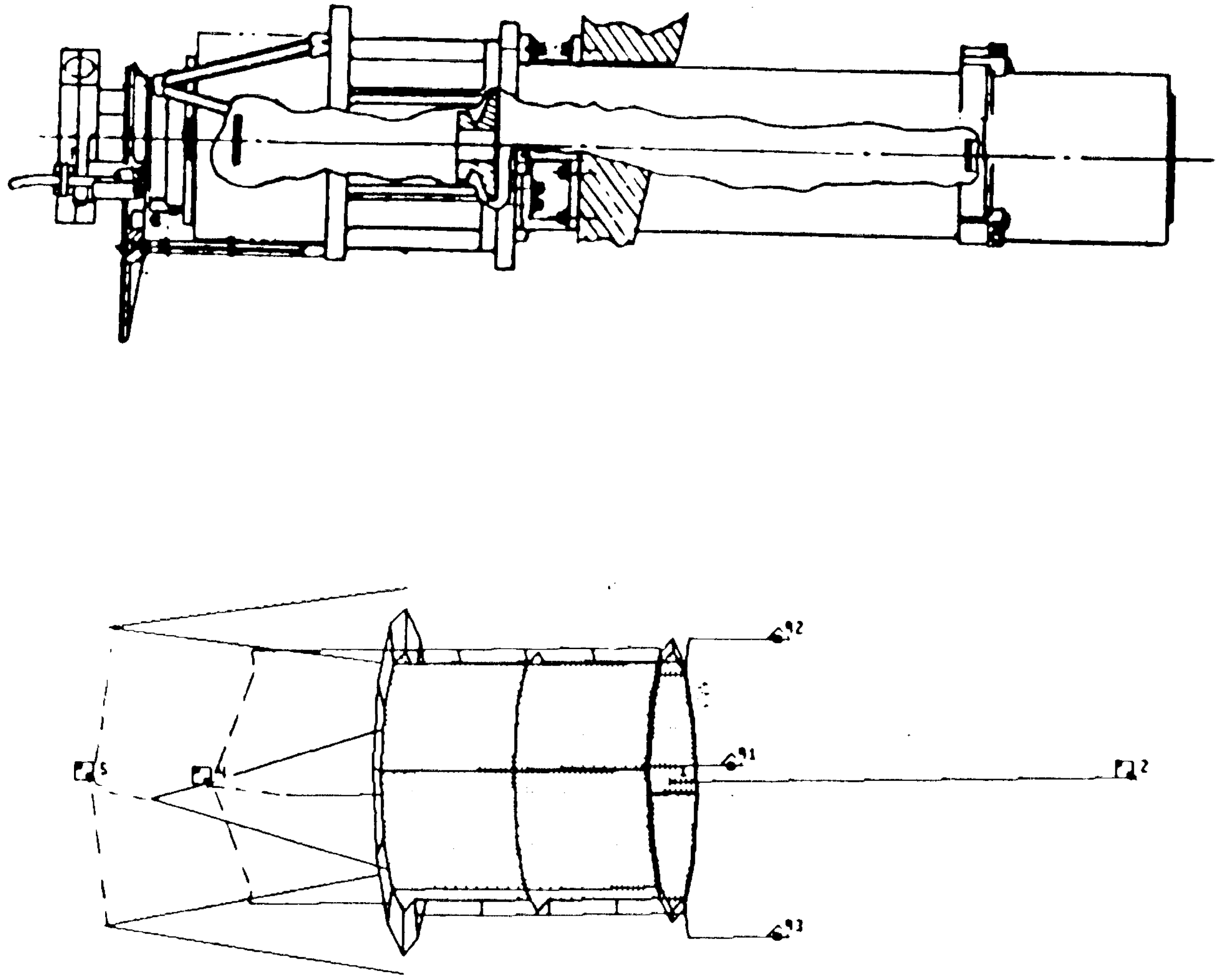

Figure 7: Relay Optics Finite Element Model