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DESIGN AND PERFORMANCE OF THE TELESCOPE AND DETECTOR COVERS ON THE EXTREME ULTRAVIOLET EXPLORER SATELLITE

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ABSTRACT

Two cover mechanisms were designed and developed for the Extreme Ultraviolet Explorer (EUVE) science payload to keep the EUVE telescope mirrors and detectors sealed from the atmospheric environment until the spacecraft was placed into orbit. There were four telescope front covers and seven motorized detector covers on the EUVE science payload. The EUVE satellite was launched into orbit in June 1992 and all the covers operated successfully after launch. This success can be attributed to high design margins and extensive testing at each level of assembly. This paper describes the design of the telescope front covers and the motorized detector covers. This paper also discusses some of the many design considerations and modifications made as performance and reliability problems became apparent from each phase of testing.

INTRODUCTION

The EUVE science payload consists of three scanning telescopes and a deep survey spectrometer (DS/S) telescope. Figure 1 is an artist's sketch of the EUVE science payload shown with the telescope front covers in the open position. Within each telescope are microchannel plate imaging detectors each housed in a vacuum chamber. There is a detector in each scanning telescope and four detectors in the DS/S telescope. Each telescope contains Wolter-Schwarzchild type grazing incident mirrors which focus onto the microchannel plate detectors. The mirror and optical elements in each telescope are extremely sensitive to particulate and molecular contamination which would degrade the optical transmissivity. The microchannel plate detectors contain various types of filters for imaging at various wavelengths and in addition to being sensitive to contamination, are also sensitive to degradation by atmospheric oxygen. Figure 2 is a cross-sectional view of the scanning telescope and Figure 3 is a cross-sectional view of the DS/S telescope. To prevent contamination of the optics, the telescopes were designed to be contained within a sealed cylindrical housing, as shown in Figures 2 and 3, where the optics cavity was maintained at a positive pressure with high purity dry nitrogen until deployed into orbit. The detectors were designed to be contained within a vacuum chamber that is continuously maintained at a vacuum below 10^{-5} torr. Each detector vacuum chamber contains a motorized cover, as shown in Figures 2 and 3, which provides a vacuum seal around the opening to the detector imaging area. While on the ground, the optical cavity of each telescope was periodically repressurized through a valve on each of the front covers. Each front cover also contains a breather assembly to allow the pressure within the telescope to vent during launch or be backfilled with atmospheric air should the spacecraft be retrieved from space to Earth.

THE TELESCOPE FRONT COVERS

Each of the three scanning telescopes and the DS/S telescope were designed with identical front cover plates where one front cover design could be used to seal the 41-cm-diameter opening on each telescope. Figure 4 shows the configuration of the front cover assembly. The basic design concept for the front covers was based on using stored energy of springs to power the cover into the open position. Such a mechanical energy system was considered simpler and more reliable than an electrically-powered motor-driven system, especially where there were no requirements to operate the cover after being opened in orbit. The front cover is pivoted about two support arms and contains a captive o-ring seal around the perimeter of the cover. Two types of springs were used to open the cover. One was a pair of compression springs with a high spring constant (580 $^{kg}/_{cm}$ each) and with a linear travel of 2.5 cm. The second type was a pair of torsion springs each with a torsional spring constant of 98 $^{kg \cdot cm}/_{radian}$ and with an angular travel of 180 degrees. Figure 5 shows the front cover in various positions from the fully closed position. The high force compression spring was designed to ensure the unsealing of the o-ring sealed cover, especially should the seal force become large, as a result of stiction from the o-ring being in a sealed condition for a long (2 year) period of time. The torsion springs were designed to swing the cover into the fully open position. To prevent the cover from stopping with a large impact force at the end of travel, a honeycomb crush pad was designed to absorb the residual energy in the spring-driven system. The development of the telescope front covers entailed refinements and changes made to meet several requirements of the front cover. Some of these requirements were to achieve a reliable long-term front cover seal, to have a reliable mechanism to release the sealed front cover, and to have a positive means to retain the cover in the fully open position. The force to operate this mechanism was designed with a margin of 5. This margin was intended to provide adequate force in the event of potential inadvertent obstructions from spacecraft wiring or thermal blanketing. The following paragraphs describe and discuss some areas of development and testing to verify and qualify the front cover design for flight.

The Front Cover Seal

The front cover seal was designed with the capability of maintaining a positive gauge pressure over 14 kPa within the optics cavity of the telescopes without the need for frequent repressurization. There were a total of 16 o-ring seals in the optics cavity of the scanning telescope including seals around the focal plane plate, detector chamber, motorized cover, structural interfaces, electrical feedthrus, and a number of devices on the front cover. An initial source of leakage found in the front cover o-ring seal was attributed to deflection in the cover resulting from the large single point bolting force required for an 18% o-ring compression. The amount of deflection of the cover was reduced by increasing the depth of the o-ring groove to lower the o-ring compression force without losing o-ring contact for a pressure-tight seal.

Additional distortion of the front cover was caused by the excessive clamping force of the single retention bolt acting on the cantilevered tongue of the cover. To reduce this distortion, a procedure was implemented to prevent over-tightening of the clamping bolt once the front cover o-ring and springs were fully compressed.

Pyro-actuated Release of the Front Cover

The front cover was held in the closed position by a single 0.8-cm-diameter bolt that passes through the opening of two pyro actuated bolt cutters as shown in Figure 4. The bolt cutter farthest from the front cover was the prime cutter, and the bolt cutter closer to the front cover was the back-up cutter. From extreme temperature testing, the pyros were found to leak small amounts of explosive (gun) powder at low (-50° C) temperatures. This was a concern for contamination of the telescope mirrors. As a result, an enclosure was designed around the pyro bolt cutters to contain possible particulates from the cutters. In addition, the thickness of a captive plate for the severed bolt and nut was increased to prevent the plate from being bent by the high velocity impact of the severed parts.

Positive Front Cover Latching Mechanism

The front cover opens in about 0.3 second and stops against a honeycomb crush pad. As the cover engages the crush pad, ratchets on each side of the cantilevered tongue of the cover engage pawls to provide positive retention of the front cover in the fully open position. Although the residual torsion spring force was adequate to keep the front cover in the fully open position against the crush pad, a two fault tolerate mechanism to retain the front cover was a shuttle safety requirement. During vibration testing, the adequacy of the two latching mechanisms was verified. It was found that the vibration of the front cover mass between the latch and honeycomb crush pad resulted in repetitive impact on the crush pad to eventually crush the residual amount of honeycomb. However, it was found that with the latching mechanism disabled during vibration testing, the front cover was able to gradually swing against the torsion spring force and return against the crush pad without large impact forces. The latch retention mechanism was retained in the flight design to comply with the two-fault tolerant requirements. Figure 6 is a photo of the front cover assembly on the DS/S with the honeycomb crush pad and latching pawls installed.

THE MOTORIZED DETECTOR COVERS

Each of the seven detectors on the science payload was enclosed within a vacuum chamber. Figure 7 shows the configuration of the motorized door assembly which was designed as a self-contained modular unit. The motorized door assembly fits onto the focal plane adjacent to the detector vacuum chamber and seals the 8.6-cm-diameter opening of the vacuum chamber as shown on the telescope cross-sectional views in Figures 2 and 3. The motorized door assembly uses a four-bar linkage with an over-center position to provide positive locking of the cover in the sealed position. Each motorized door assembly has a pyro-actuated opening mechanism that would be used in the event of a failure in the mechanical, electrical, or command/control system. The pyro-actuated mechanism severs a bolt to allow compressed bevel springs to disengage miter gears to the drive motor and also moves the detector cover to the fully open position. The following paragraphs will discuss the design changes implemented after a number of vibration and thermal cycle tests. Changes were made in the detector cover adjustment mechanism, bearings, and brushes on the DC motors, and refinements were made to the support housing to alleviate failure from fatigue stresses.

Detector Cover Adjustment Provision

The detector cover was initially designed with a compression spring between the cover and actuating arm to achieve a more constant sealing force from variations in the travel of the actuating arm as shown in Figure 8, which is an assembly drawing of the motorized door. This spring loading turned out to be undesirable because the fundamental frequency of the spring was very close to the resonant frequency of the focal plane plate on which the detector mounts. Attempts were made to shift the frequency with a vibration damper but a tuned damper was sensitive to mounting accuracy and it was difficult to achieve repeatable results. Testing showed that without a spring interconnection, the detector cover o-ring sealed satisfactorily under random vibration loads. The compression spring was replaced by a threaded attachment to the actuating arm where each cover was individually adjusted for the proper O-ring seal compression and a locking screw was used to prevent movement from the adjusted position.

Because of contamination concerns, the use of lubricants for a good vacuum seal was limited to a few possibilities. Braycote 601 was an acceptable lubricant for use in preventing stiction but was not a good vacuum seal grease between the viton o-ring and the stainless steel flange. Repeated testing revealed that a good vacuum seal between a viton o-ring and stainless steel could be achieved without the use of any lubricants.

The housing for the motorized door was of a cylindrical shape with a cutout for the actuating mechanisms as shown in Figure 9. This cutout finally resulted in a fatigue failure from repeated vibration testing. Although the design loads were not extremely high, the failure was analyzed as fatigue and stress concentration caused by the small radii of the cutouts. This was modified by a using a thicker cylinder wall and enlarging the radii around the cutout in the cylinder. There were no failures after the modification.

Modifications to the DC Motors

The detector doors were operated by DC motors retrofitted with Bartemp bearings; Braycote 601 lubricant was applied with a hypodermic needle directly onto the ball bearings to minimize potential contamination; conventional motor brushes were replaced with silver impregnated brushes; and stiffer brush springs were used for more reliable contact pressure. These modifications were made to prevent stalling of the motor and erratic (arcing) motor currents at low temperatures. Figure 10 is a photo of the motorized cover assembly during testing.

SUMMARY

The EUVE science payload contained eleven mechanical devices (four telescope covers and seven detector covers). A failure in any one of them would have resulted in the functional loss of an instrument. Repetitive functional and environmental testing at the component level helped to provide early identification of problems in design, manufacturing, materials, and assembly. However, the possibility of a malfunction or failure of the mechanisms after a long dormant state was difficult to assess as there were no trivial tests for time degradation in lubrication effectiveness, stiction in o-ring seals, and potential increases in static friction from handling and shipping loads. Assembly of all the telescopes was completed in January 1990 at which point the mechanisms on the telescopes were last operated in a vacuum during calibration. After launch of the EUVE satellite in June 1992, all four telescope front covers opened successfully with the prime pyro actuating system. Additionally the motorized covers continue to operate successfully to date after 19 months in orbit. The successful operation of all the mechanisms on the EUVE payload can finally be attributed to adequate testing and design margins.

ACKNOWLEDGMENTS

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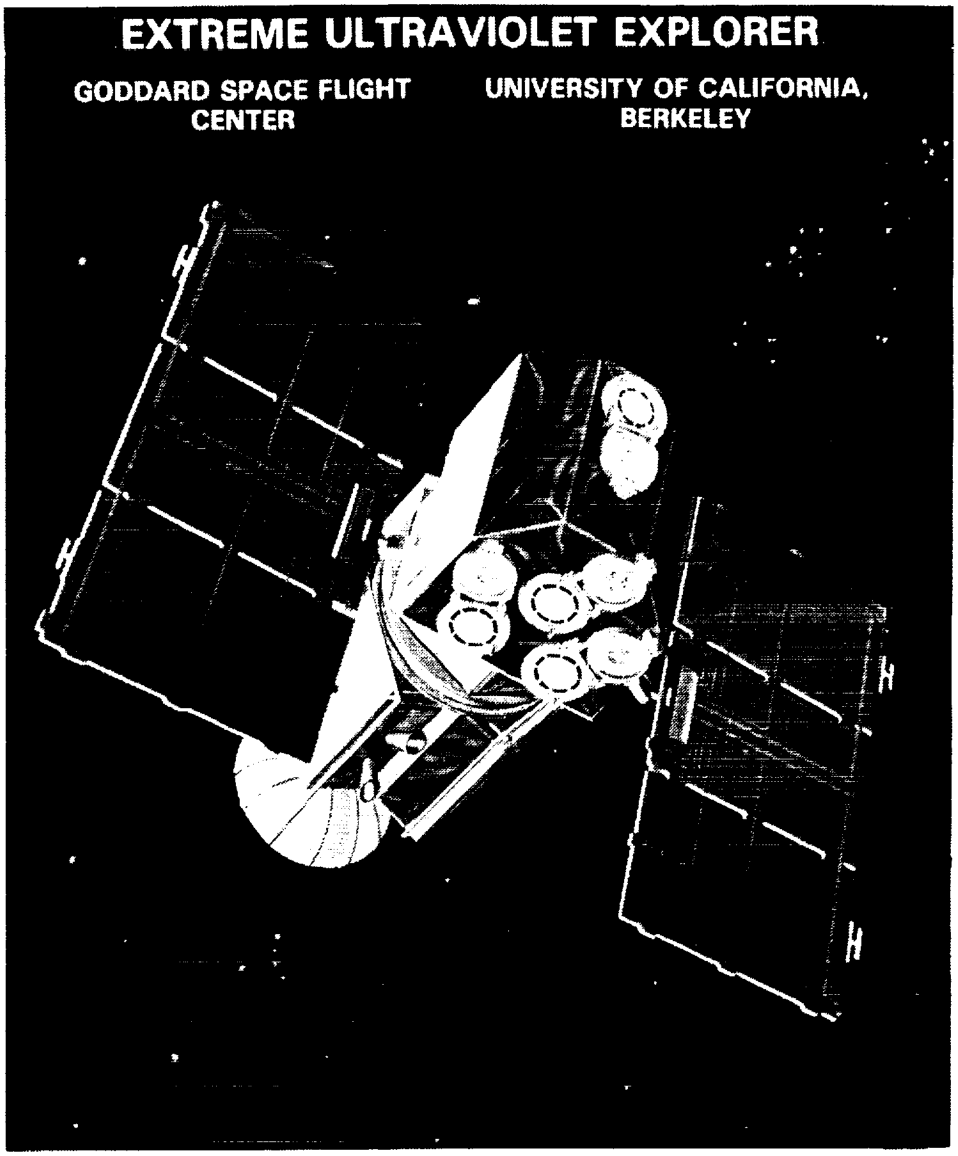


Figure 1. Artist rendition of the Extreme Ultraviolet Explorer with the front covers on the 3 Scanning Telescopes and the Deep Survey Spectrometer shown in the **OPEN** position

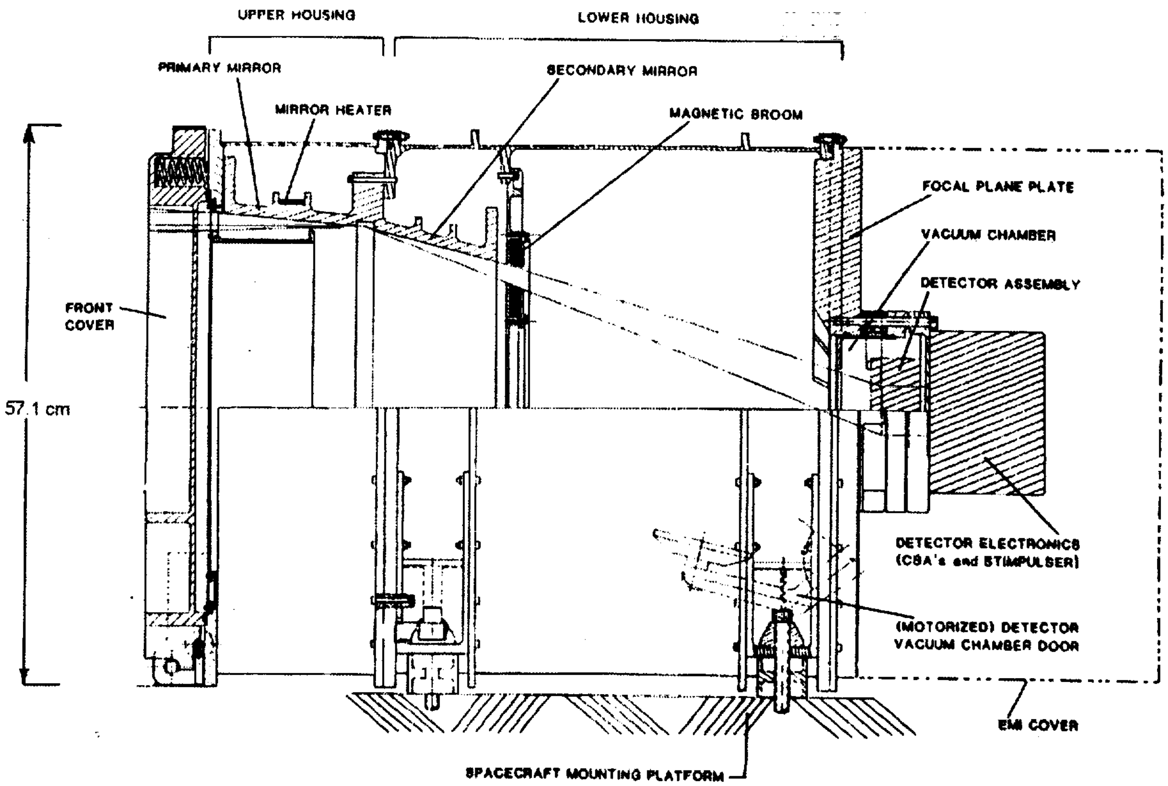


Figure 2. Cross-sectional View of Scanning Telescope

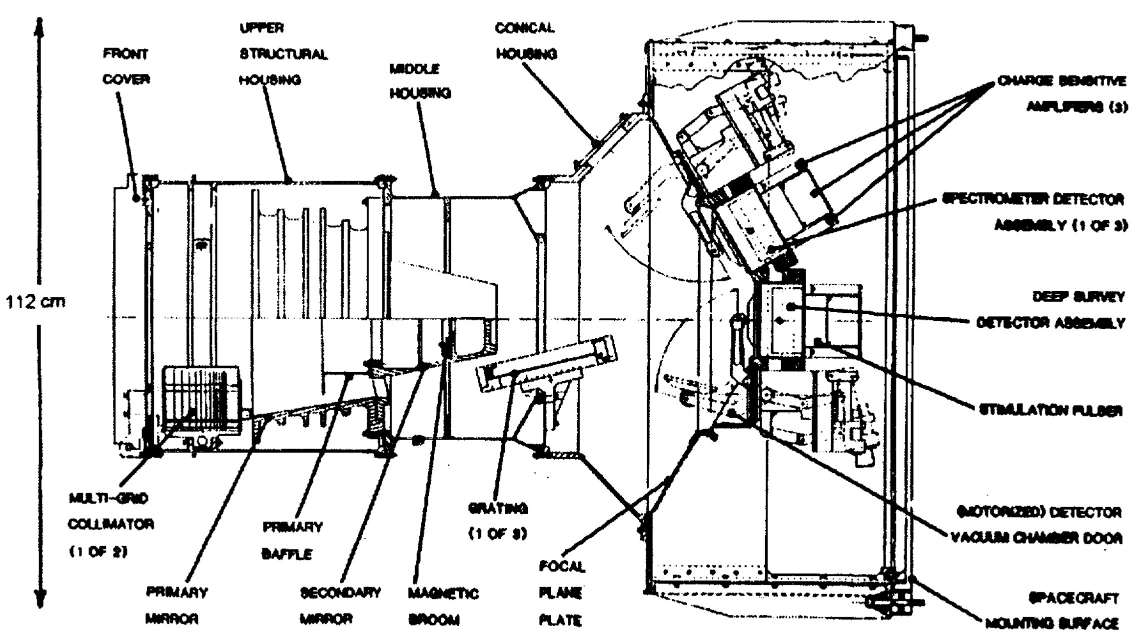


Figure 3. Cross-sectional View of Deep Survey/Spectrometer Telescope

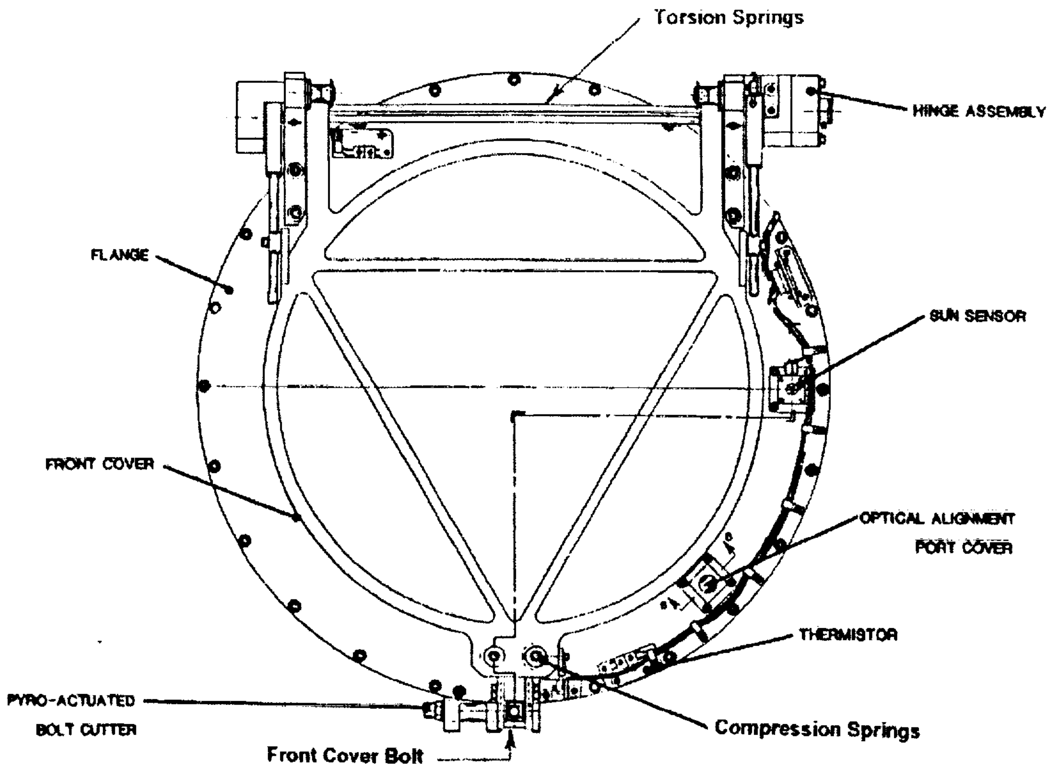
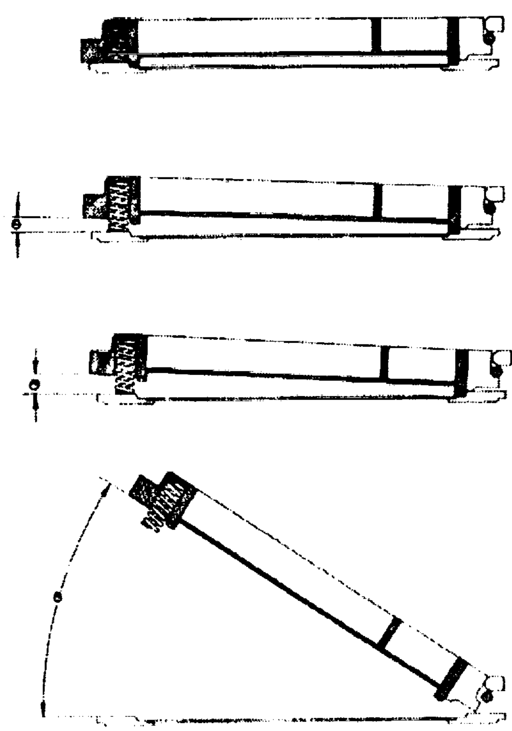


Figure 4. Telescope Front Cover Assembly



Front Cover Positions	Angle of Cover, θ (Degrees)	Stored Energy (kg-cm) Coil + Torsion	
CLOSED & SEALED	0	330 + 2200	Difference in Energy to Unseal O-ring
O-RING FULLY UNSEATED	1.8	45 + 2100	
COIL SPRINGS FULLY EXTENDED	2.9	0 + 2055	difference in Energy to Pivot Cover
COVER PIVOTS 177° TO CRUSH PAD	180	0 + 190	

Figure 5. Front Cover Positions and Stored Energy of Springs

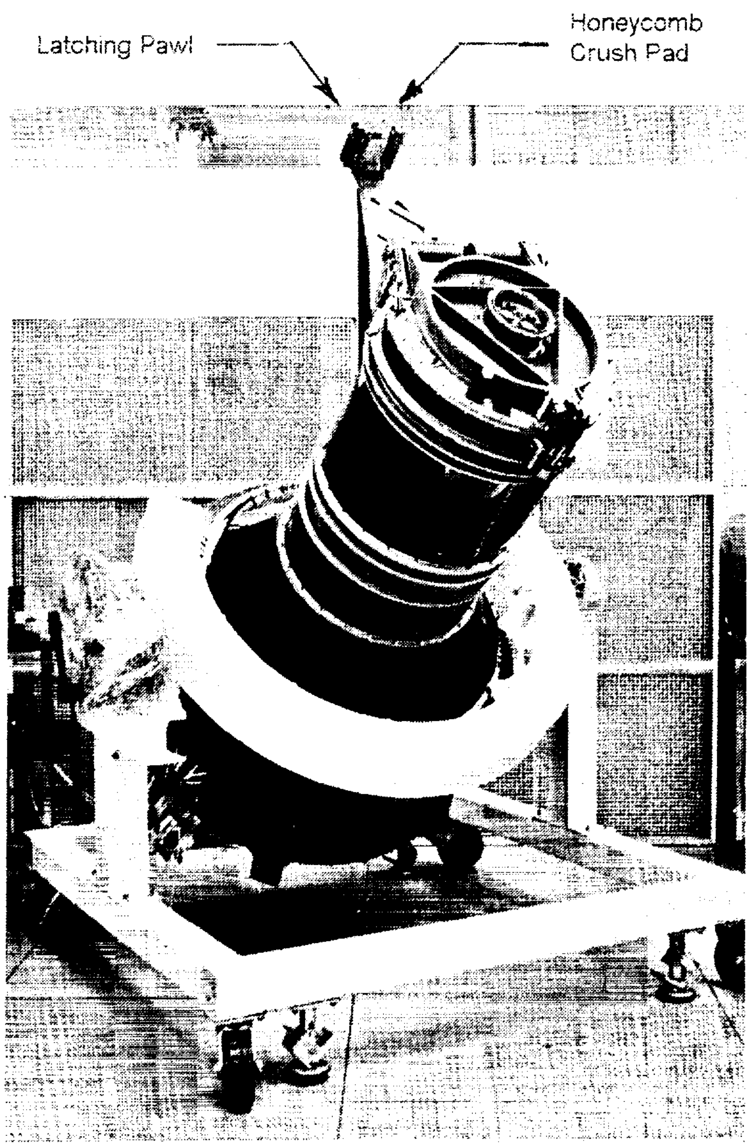


Figure 6.
Front Cover Assembly on the
Deep Survey Spectrometer

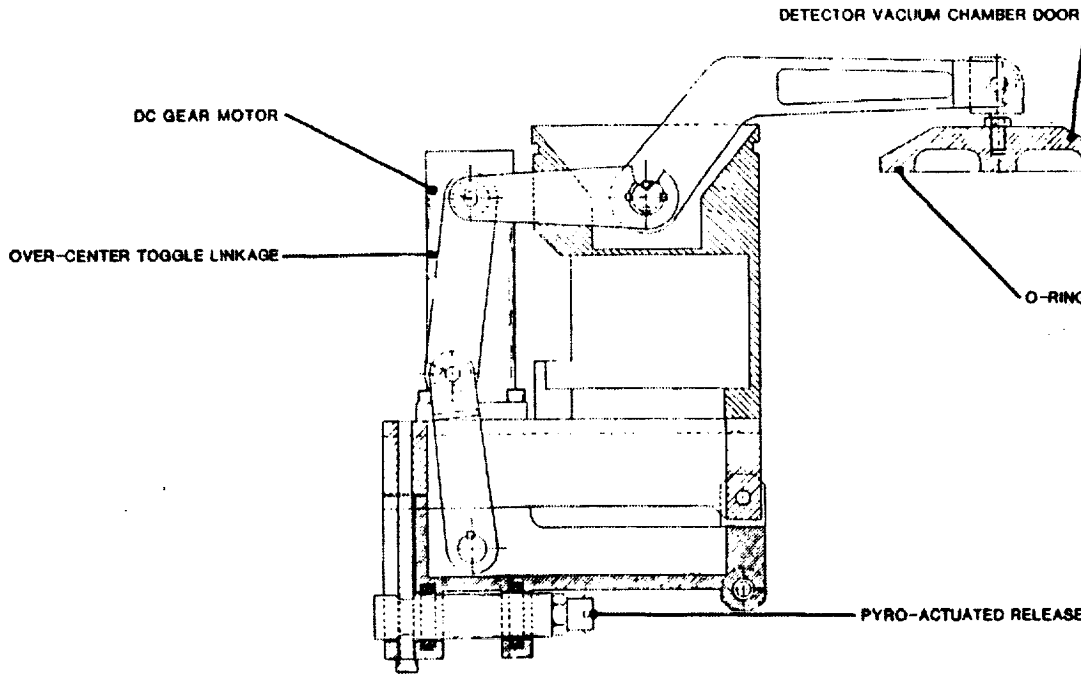


Figure 7. Motorized Detector Door Assembly

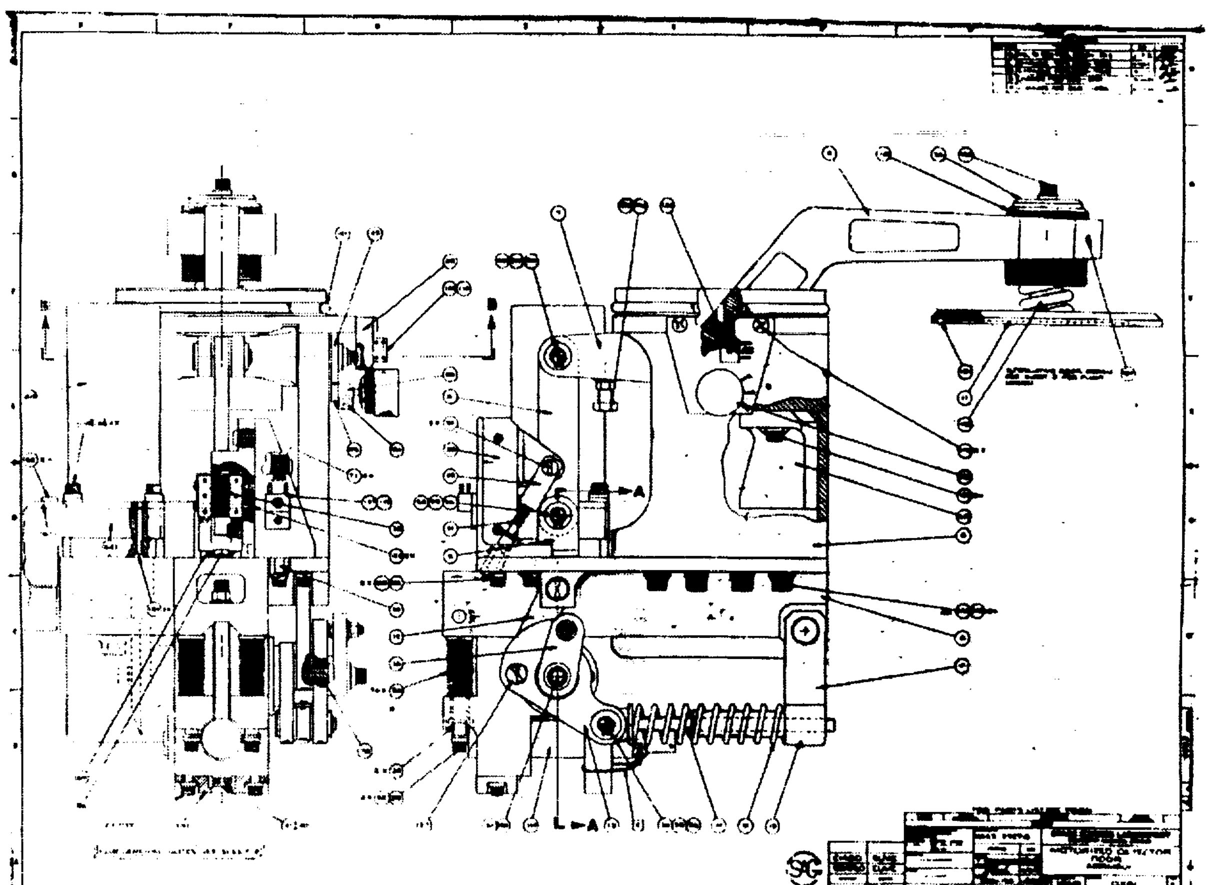


Figure 8. Drawing of the Motorized Detector Door Assembly

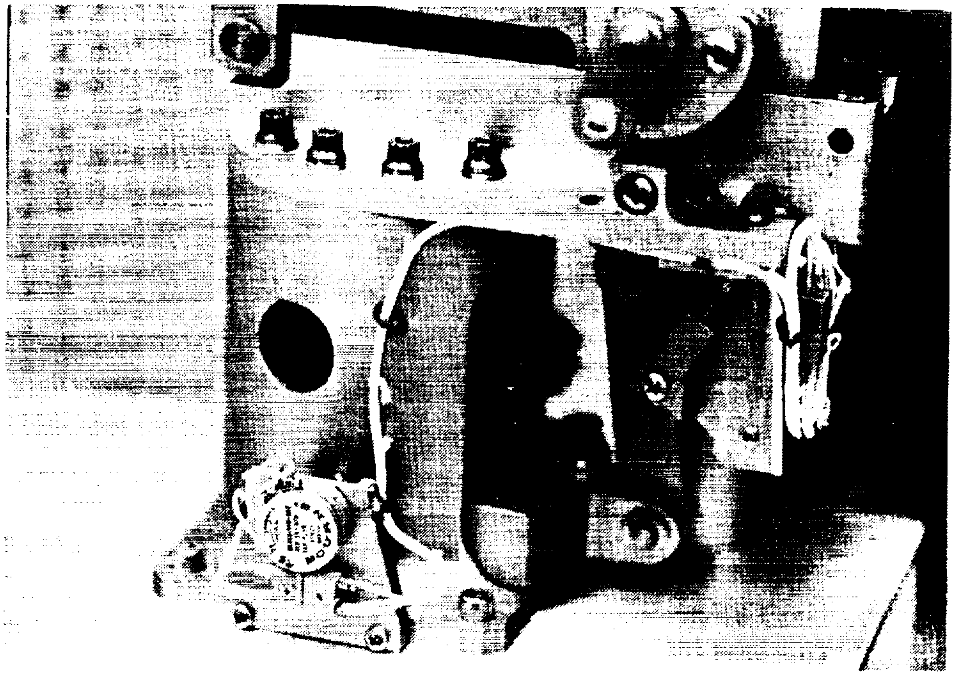


Figure 9. Cylindrical Housing of the Motorized Cover Assembly

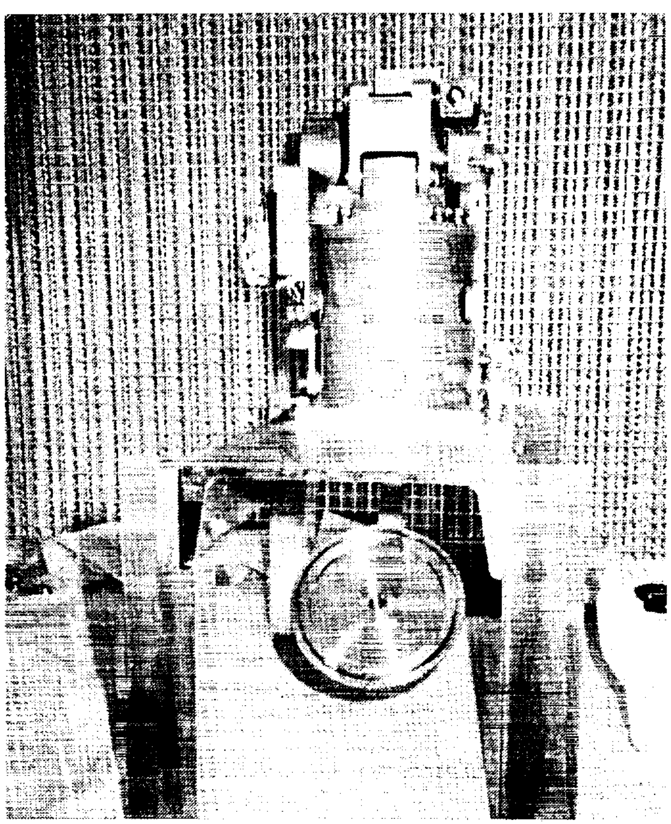


Figure 10. Testing of the Motorized Cover Assembly on a Clean Bench