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FOCUS DRIVE MECHANISM
for the
IUE SCIENTIFIC INSTRUMENT

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ABSTRACT

A compact, lightweight mechanism was developed for in-orbit adjustment of the position of the secondary mirror (focusing) of the International Ultraviolet Explorer (IUE) telescope. This device is a linear drive with small (.0004") and highly repeatable step increments. Extremely close tolerances are also held in tilt and decentering. The unique mechanization is described with attention to the design details that contribute to positional accuracy. Lubrication, materials, thermal considerations, sealing, detenting against launch loads, and other features peculiar to flight hardware are discussed. The methods employed for mounting the low expansion quartz mirror with minimum distortion are also given. The paper concludes with the results of qualification and acceptance testing.

INTRODUCTION

The International Ultraviolet Explorer (Figure 1) is a stellar astronomical observatory which will be positioned over the Atlantic Ocean at synchronous altitude. The satellite will provide uninterrupted coverage of over 85% of the sky for ground observing facilities in the United States and Europe.

The scientific instrument is a Richey Chretien telescope (Figure 2) coupled with a dual spectrograph. The telescope assembly is a 45 cm diameter f/15 cassegrain design consisting of a beryllium concave hyperbolic primary mirror and a convex hyperbolic fused silica secondary mirror nine centimeters in diameter mounted on a focus drive mechanism. The function of the focus drive mechanism is to provide for precise axial positioning of the secondary mirror to optimize image size in orbit. The application also requires close control of tilt and decentering over the full range of axial adjustment.

FOCUS DRIVE MECHANISM

The focus drive mechanism is shown in Figures 3 and 4. The secondary mirror is mounted on a beryllium platen (described in detail later) which is attached at three points to the ends of ball screw. These three points define the mirror support plane which must be translated with a minimum of tilt and decentering errors. This is achieved by driving integral 64 tooth gears on the three ball screw nuts synchronously thru a common 94 tooth center gear. The center gear is driven by a size 11, 45° step, permanent magnet stepper motor through a 13 tooth pinion and 300 tooth reduction gear. The ball screw lead is .04 inches resulting in a linear motion of .0004 inches per step.

Each screw assembly has 2 individual ball nuts which are precisely shined to a light preload to remove all axial play. Each ball nut assembly is rigidly supported by a duplex pair of preloaded bearings at one end, and a single spring preloaded bearing at the other end. This arrangement removes all sources of tilt error except for lead inaccuracy in the ball screws (less than 200 μ in) and the backlash of the center gear mesh reflected to the output (less than 10 μ in). The mechanism drives smoothly and at low torque (less than 2 in oz at the center shaft) despite the rigid constraint on undesired axial and decentering motions. The specifications for the ball screws and support bearing are given in Tables 1 and 2.

The gears and ball screws are lubricated with a light coat of low vapor pressure Krytox grease. The bearing retainers are vacuum impregnated with Krytox 143 AB oil with an additional 1.5 mg of free oil added to the raceways. The entire mechanism is sealed by "O" rings and flexible metal bellows on each ball screw as an added precaution against loss of lubricant.

MIRROR SUPPORT

Considerable attention was given to the secondary mirror mount to achieve stress free support over a wide temperature range. The mirror (the back of which is ground flat) is supported on three pads on a beryllium platen which is lapped flat to better than 50 μ in. The mirror is clamped by three elastomer (solithane 113) pads on the front of the mirror symmetrically located with respect to the platen support areas to avoid bending stresses in the mirror. The elastomer pads are bonded to "C" shaped clamps which are adjusted to give a compressive force of 20 lb at each support which assures that the mirror does not lift off during launch shock and vibration. The clamps also center the mirror and are shined to provide .001 inch of clearance at the edge of the mirror to accommodate the differential expansion of the fused silica mirror and beryllium structure over the design temperature range.

There are six heaters mounted in series and parallel on the back of the mirror to maintain the temp of the mirror at 0°C during flight.

POSITION READOUT

The position of the platen supporting the secondary mirror is monitored by a Linear Voltage Differential Transformer (LVDT). The housing of the LVDT is attached to the body of the mechanism while the position slug is attached to the platen, then any movement of the platen is indicated by a voltage change in the LVDT. The focus drive is aligned for flight such that the LVDT reads zero voltage in orbit focus position. Therefore steps in either the plus or minus direction indicate shortening or lengthening the intervertex distance of the telescope. One step of the focus drive give a 40 millivolts change in the readout of the LVDT.

PERFORMANCE

The performance specifications are given in the following table

FOCUS DRIVE MECHANISM PERFORMANCE SPECIFICATIONS

Size	4 inches diameter x 4 inches max length
Weight	2.5 lbs maximum excluding secondary mirror
Focus Increment	.00042 inches
No. of Focus Steps	180
Focus Range	.0756 inches
Tilt Angle Tolerance	20 arc-seconds maximum
Centering Tolerance	.001 inches maximum
Torque Margin	5 to 1
Detent Capability	150 lbs. minimum
Step Repeatability	Better than + 0.1 step
Operational Temp. Range	-20°C + 50°C
Leak Rate	less than 1×10^{-6} cc helium/sec.

ENVIRONMENTAL TEST

The focus drive was subjected to the following environmental tests:

1. Sinusoidal Vibration 20 g's 0 to peak maximum (thrust axis)
2. Random Vibration .05g²/Hz max
3. Shock 300 g's maximum at 1500-4000 Hz
4. Thermal-Vacuum
 Heat Soak +50°C 1 x 10⁻⁵ torr vacuum for 24 hrs.
 Cold Soak -30°C 1 x 10⁻⁵ torr vacuum for 24 hrs.

The mechanism was required to demonstrate cold start capability at least 3 times during the 24 hour cold exposure. Due to the increased viscosity of the lubricant at cold temperature, the mechanism required a 5 minute warm up period at -30°C before stepping. At -20°C the mechanism stepped without a warm up period.

TABLE 1

BALL BEARING SCREW AND NUT
ASSEMBLY SPECIFICATIONS

Type	Beaver Precision Products No. B-15468 Duplex Preload Ball Nuts
Material	440C Stainless Steel
Lead Accuracy	.0005 inches/ft. for .05 inches
Preload	Zero backlash to one oz.-inch max. drag torque
Gear	to be intergral part of duplex nut housing
Gear Diametral Pitch	72
No. of Teeth	61
Pitch Diameter	0.8472 - .0010
Outside Diameter	0.8750 - .002

TABLE 2

BALL SCREW SUPPORT BEARINGS
SPECIFICATION

Manufacture	Split Ball Bearing Co.
Type (Duplex) (Single)	3 TAWR 12-19-63 3 TKRSS 21-28-136
Outside Diameter	1.1875 inches
Inside Diameter	0.7500 inches
No. of Balls	18
Ball Diameter	0.125 inches
Radial Play	0.0009-.0013 inches
Contact Angle	25°
Precision	ABEC-7
Duplex Preload	15 lbs.
Mean Hertz Stress @ 500 g's load (350,000 psi allowable)	177,000 psi
Retainer Material	Phenolic
Ball & Race Material	400C
Lubricant	Krytox 143AB
Shield	Double
Capacity	
Dynamic Radial	690 lbs
Static Radial	432 lbs
Static Thrust	880 lbs
Weight (each)	0.037 lbs.

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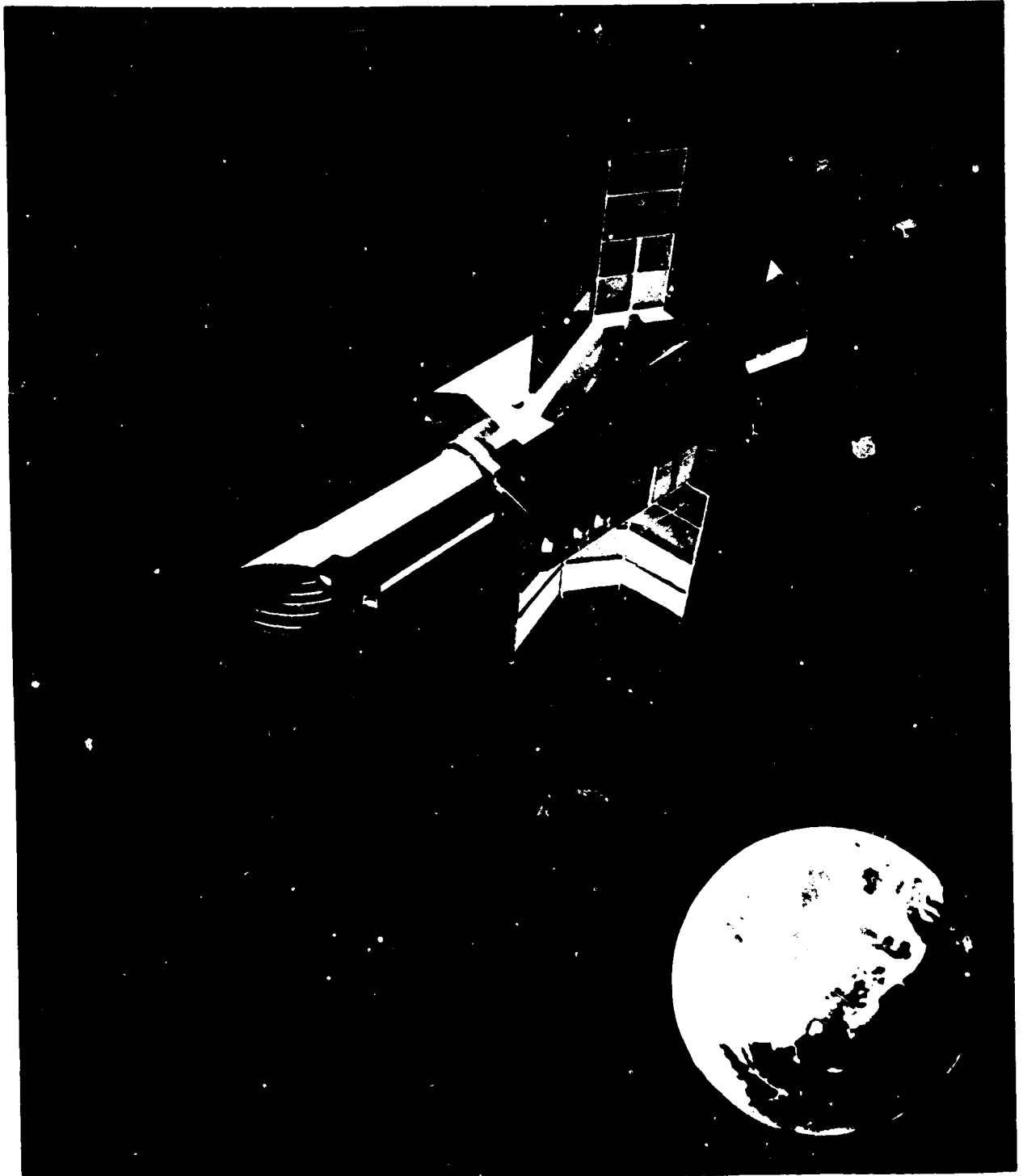


Figure 1. IUE Scientific Instrument

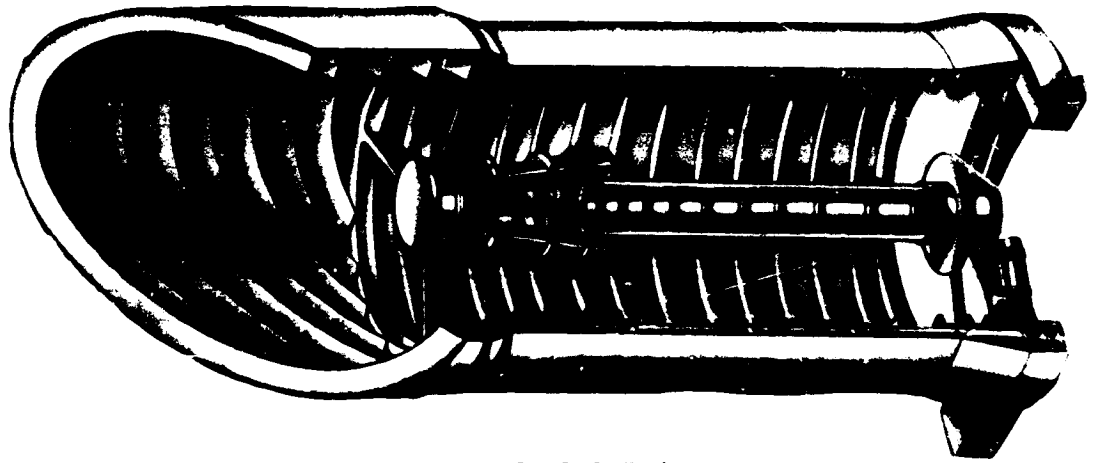


Figure 2. IUE Telescope



Figure 3. Focus Drive Mechanism

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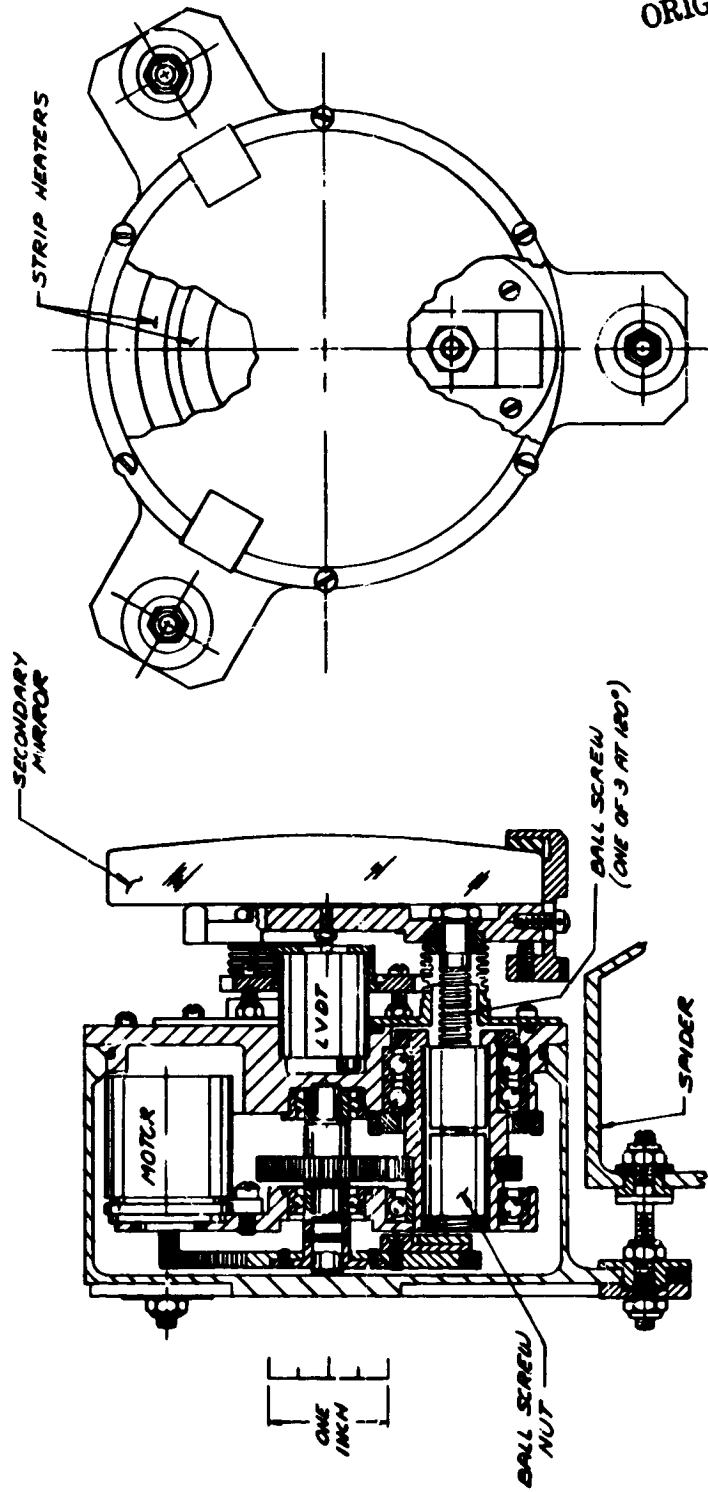


Figure 4. IUE Focus Drive Assembly

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