JSC-07954

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 17 MISSION

ANOMALY REPORT NO. 2

MAPPING CAMERA EXTENSION MECHANISM OPERATED ERRATICALLY

LYNDON B. JOHNSON SPACE CENTER

HOUSTON, TEXAS

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PREFACE

This anomaly report fulfills the requirements of Anomaly Report No. 3 for the Apollo 15 Mission Report and Anomaly Report No. 7 for the Apollo 16 Mission Report.

MAPPING CAMERA EXTENSION MECHANISM OPERATED ERRATICALLY

STATEMENT

The mapping camera extension mechanism operated erratically during all missions on which it was flown.

SYSTEM DESCRIPTION

The mapping camera assembly was located in the upper portion of the scientific instrument module bay of the service module (fig. 1). The assembly consisted of a metric camera for photographing the lunar surface and a stellar camera for photographing star fields to provide attitude references when reducing the metric camera film data. The angle between the deployment axis of the stellar camera and the metric camera was 96 degrees (fig. 2). A laser altimeter, mounted directly on the mapping camera assembly, provided precise time-correlated altitude information that was used in conjunction with the metric camera photography. The camera assembly was mounted on a deployment mechanism (fig. 3) that moved the assembly approximately 18 inches outward from the stowed position in the service module so that the spacecraft would not appear in the stellar-camera field of view.

Contamination covers (fig. 4) protected the camera and laser altimeter optics from the effects of waste water dumps, fuel cell purges, and reaction control system engine firings. The mapping camera/laser altimeter cover was controlled by a cabin switch. The stellar camera lens was protected by a spring-loaded plume shield. Camera motion during deployment opened the plume shield and held the shield open until the camera assembly was retracted.

The camera was deployed by a drive screw turning within a drive nut that was bolted to the camera assembly (fig. 5). A dry-powder film lubricant of molybdenum disulphide and sodium silicate was used on the drive screw. This lubricant was chosen specifically for its low outgassing quality in the space environment to preclude contamination of the optical surfaces. Friction at the drive nut/screw interface was minimized by the use of recirculating streams of ball bearings (fig. 6). Two deployment rails attached to the bottom of the camera also passed through bushings containing recirculating ball bearings (figs. 3 and 5). The bushings were lubricated with versilube, a mixture of silicone oil and lithium soap thickener. This lubricant was also used in the motor clutches and on the ball bearings in the drive assembly.

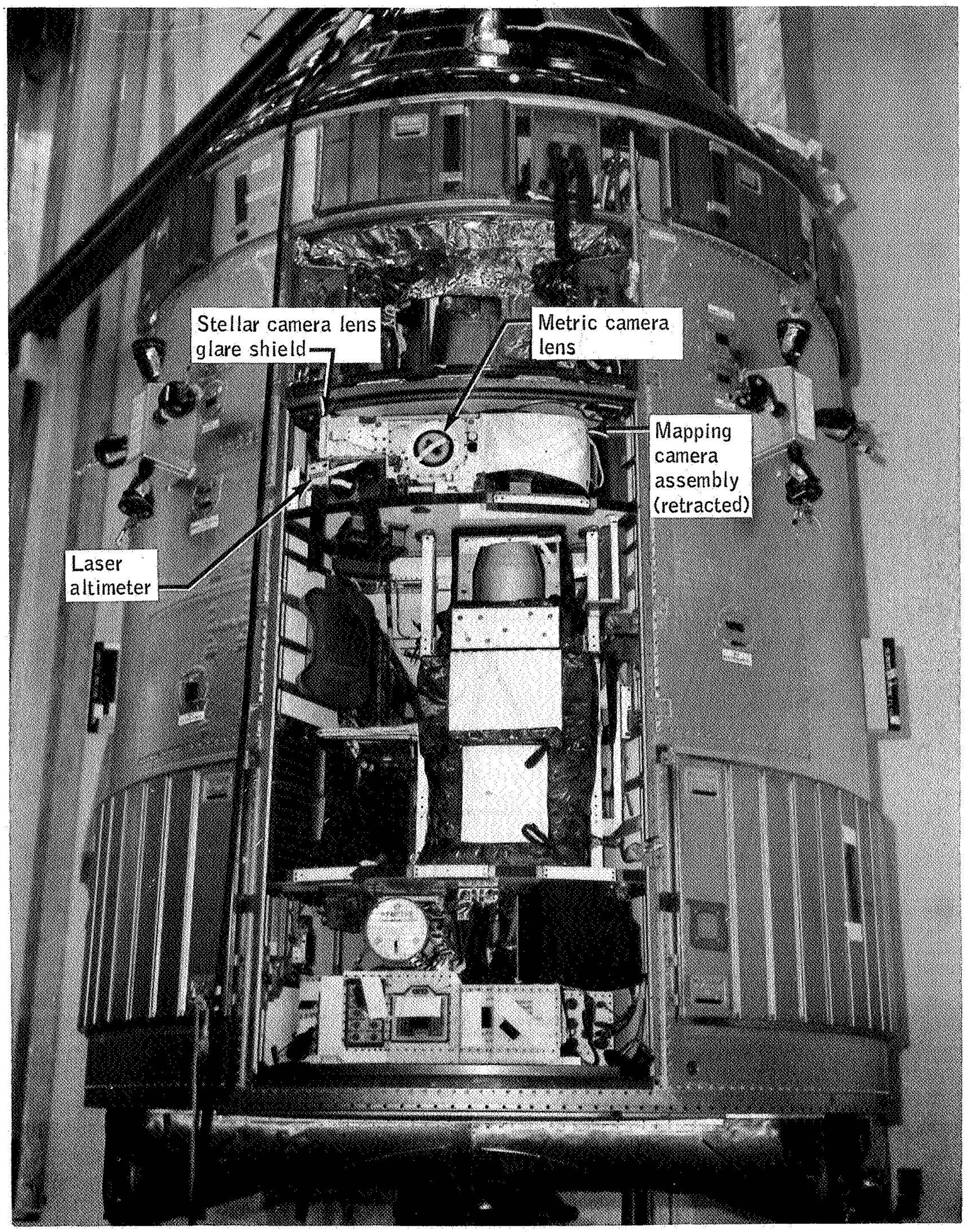

Figure 1.- Apollo 15 scientific instrument module.

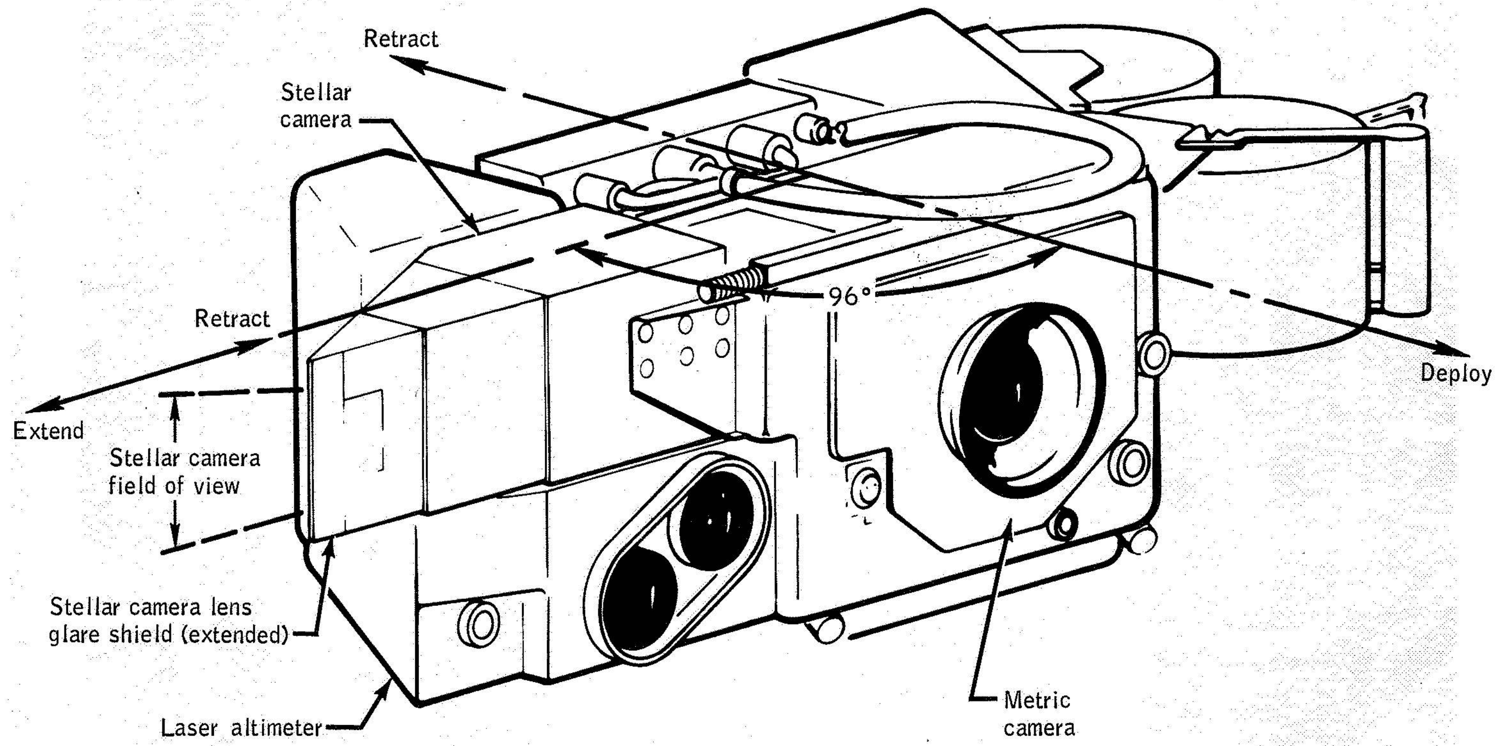

Figure 2.- Mapping camera assembly.

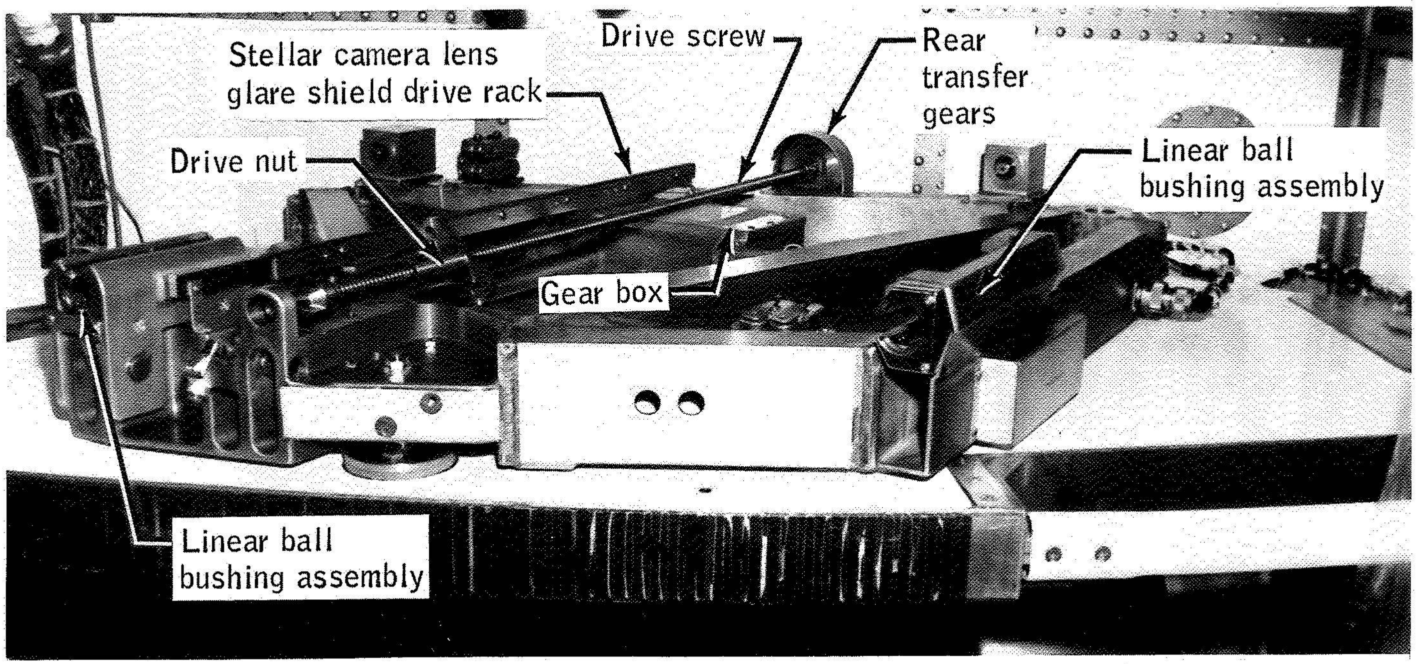

Figure 3.- Mapping camera deployment mechanism (camera removed).

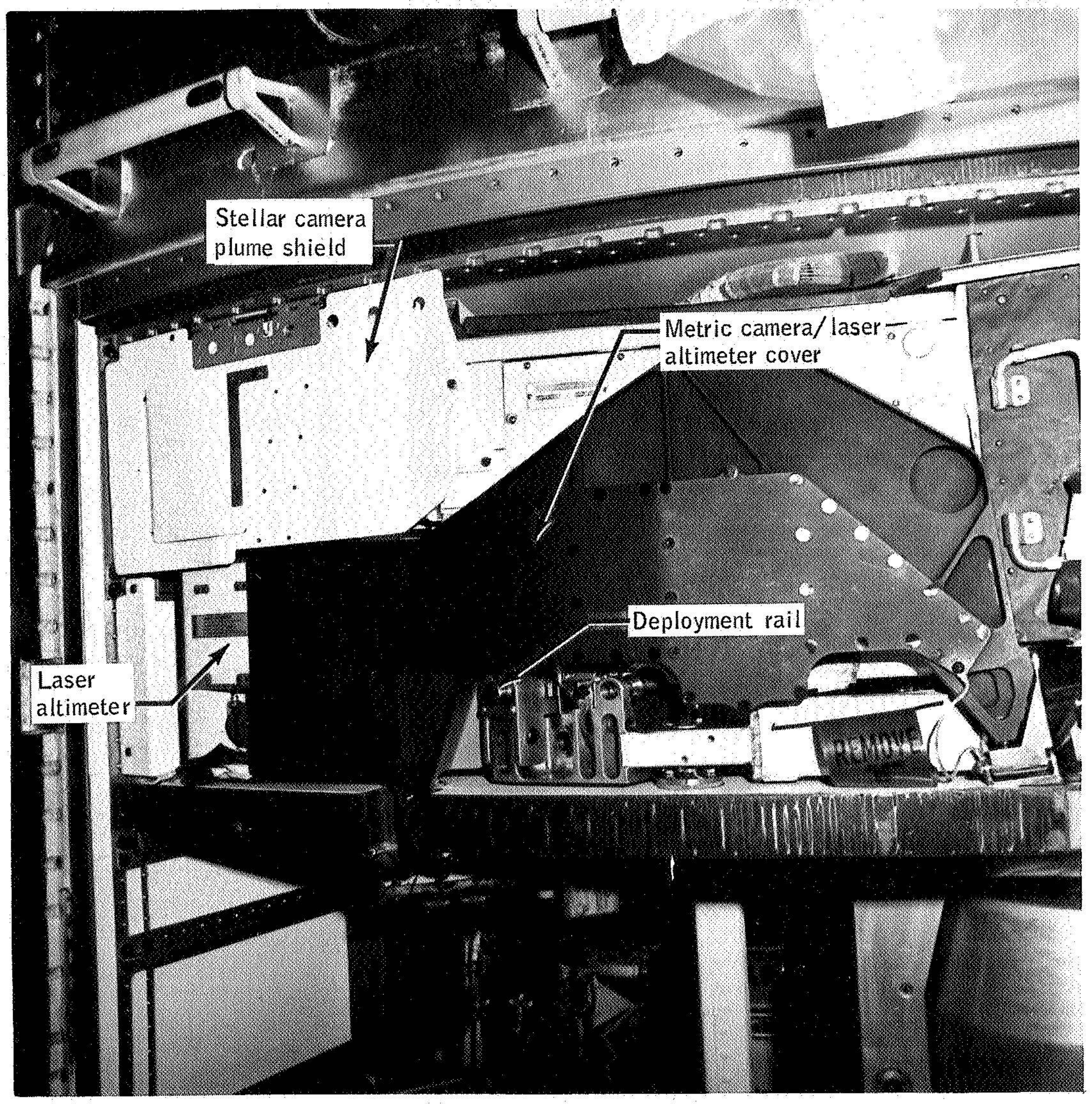

Figure 4.- Contamination covers.

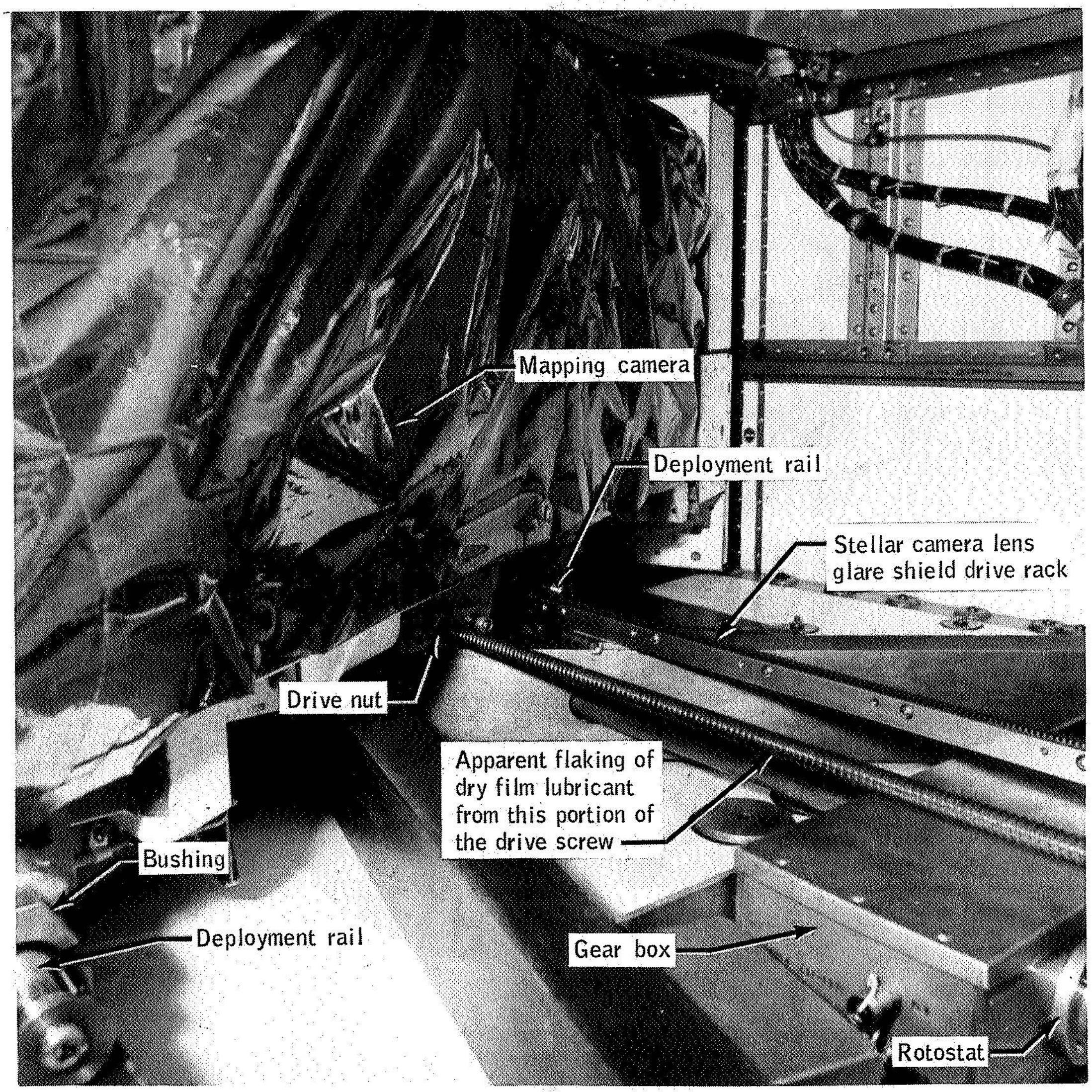

Figure 5.- Apollo 15 camera deployed during preflight checks (as seen from inside service module).

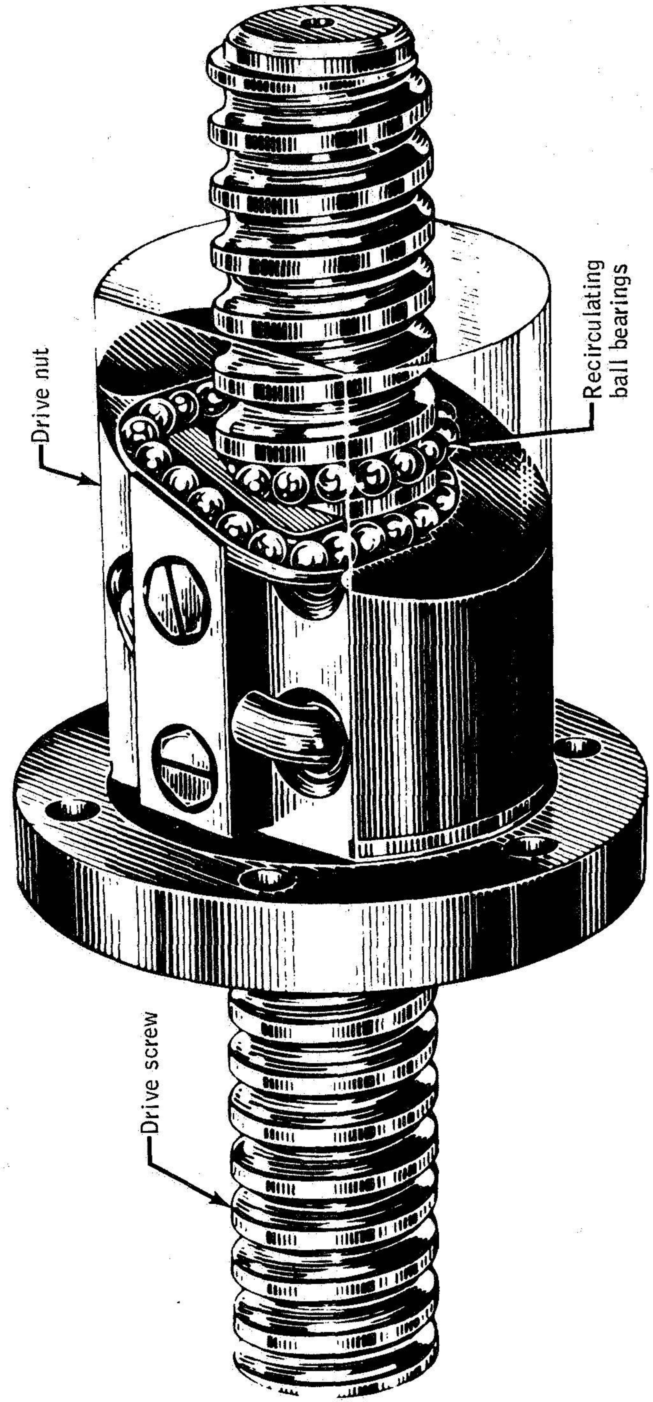

Figure 6.- Drive nut assembly.

Two 28-volt-dc motors, each capable of deploying or retracting the camera should the other fail, powered the drive screw through a drive train consisting of clutches, gearing, bearings, front and rear thrust bearings on the drive screw, and a non-reversing device (rotostat) that locked the deployment mechanism when power was removed from the motors. The motors, clutches, and most of the gearing were contained within a gear box (fig. 5). Each motor had a separate clutch so that if either motor seized, the clutch would decouple that motor from the drive train.

The stellar camera lens glare shield was extended and retracted as the mapping camera assembly was deployed and retracted (fig. 7). As the camera assembly was deployed outside the service module mold line, camera assembly motion caused a camera-mounted pinion gear to mesh with a stationary drive rack on the deployment frame (fig. 5). The pinion gear drove a gear train in the camera assembly that, in turn, extended the stellar camera lens glare shield approximately perpendicular to the deployment motion of the camera assembly. As the camera assembly was retracted, the pinion gear moved back along the drive rack, the gear train was driven in the opposite direction and the stellar camera lens glare shield was retracted. The glare-shield drive train contained a slip clutch to prevent the main assembly drive mechanism from jamming, should the glare-shield drive train jam. The stationary drive rack was installed in fittings on the deployment frame to permit alignment and gear engagement adjustments during camera assembly installation.

DISCUSSION

Apollo 15

The first deployment/retraction cycle of the camera assembly during the Apollo 15 mission was normal (the normal time for a deployment of retraction was about 1 minute and 20 seconds), but the time required for all subsequent deployments and retractions was two to three times longer than normal. On the last scheduled cycle (fifteenth) the camera assembly would not retract.

Slow deployment/retraction times were duplicated in ground tests by applying a low voltage (12 volts) to the motors; however, the voltages were normal during the mission. Also, deployment/retraction times during ground tests were normal with one drive motor failed.

Thermal/vacuum tests with the complete deployment mechanism under simulated zero-g conditions showed normal deployment and retraction times. Other tests indicated that the drive screw rear thrust bearing could be damaged by stalling the drive mechanism. A damaged drive screw rear thrust bearing could cause slow deployment and retraction.

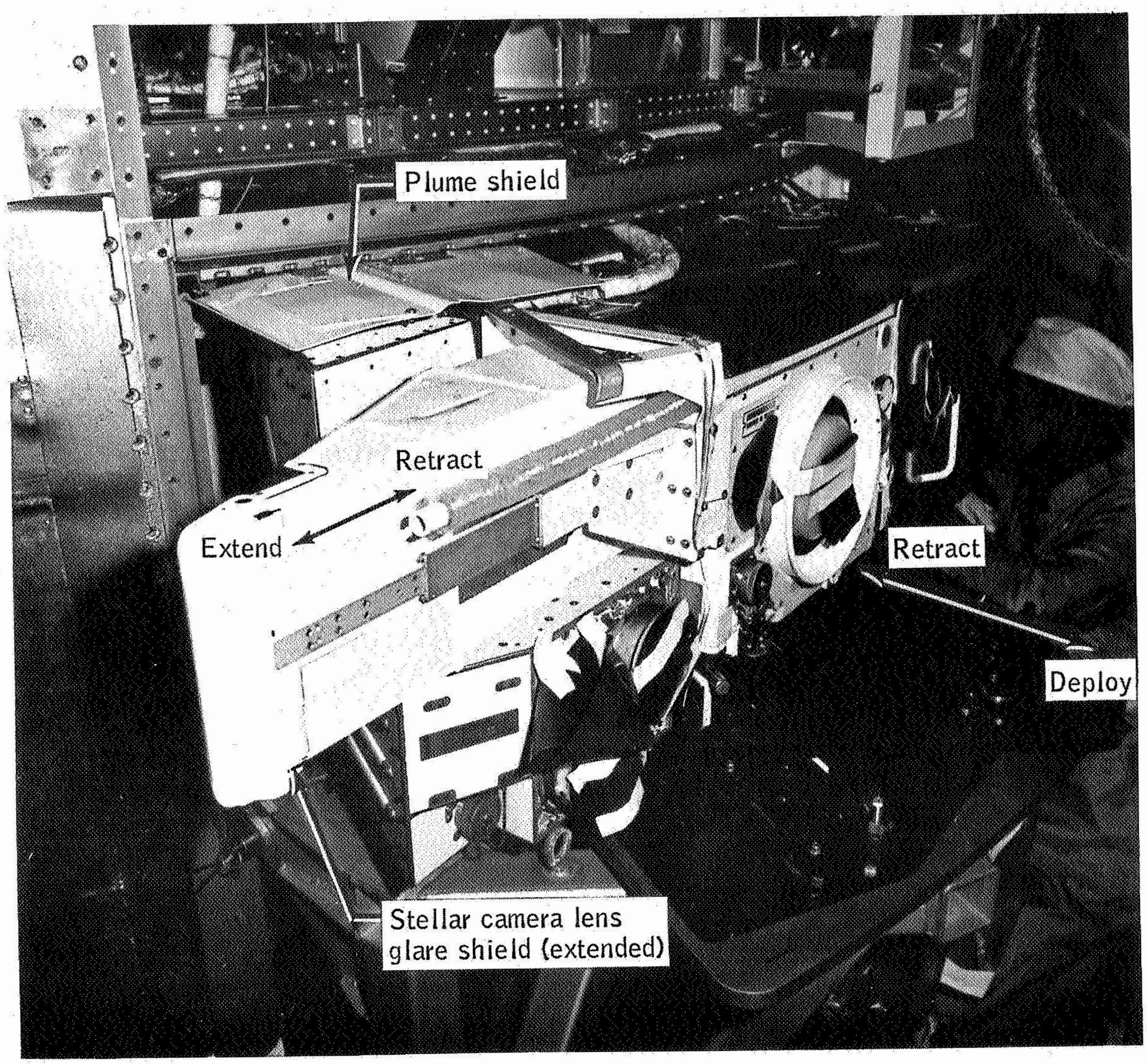

Figure 7.- Apollo 16 mapping camera during installation checks.

Testing also showed that the dry-film lubricant used on the Apollo 15 camera assembly drive screw flaked (fig. 5). As a result, the lubricant was changed to a wet film of versilube on the Apollo 16 assembly.

Apollo 16

The first deployment of the camera assembly on Apollo 16 mission was normal, but the retraction required 2 minutes and 54 seconds. The second and third retractions required about 3 minutes; whereas, the fourth retraction and fifth deployment were normal (1 minute and 18 seconds). The time required for the fifth and final retraction was 1 minute and 34 seconds.

Inflight photographs of a deployment/retraction cycle showed that the deployment rate was slow, but uniform. Also, the retraction rate was normal until the camera had retracted about half-way, when the retraction rate slowed to approximately the deployment rate for that cycle. This speed change may have been due to the tension in the power and signal cable which terminated at the top of the camera assembly. As the camera retracted, the cable tension was gradually relieved until it no longer aided the reverse drive, thus the camera retracted slower for the remainder of the cycle. However, the failure mode that caused the drive train torque to be reduced to the point where cable tension could appreciably affect the retraction speed of the system is unexplained.

Tests showed that power and signal cable tension could drive the rotostat output shaft faster than the input shaft during retraction. Under these conditions, the rotostat would periodically lock up, and release as the input shaft caught up, causing drive train chatter. Since the results of the chattering in zero-g conditions are unknown, the locking rollers (fig. 8) were removed from the rotostats on the remaining flight deployment mechanism. The chatter was eliminated, but the locking feature of the rotostat was also disabled. Tests conducted on the Apollo 17 camera assembly and two other units with the rotostat disabled indicated that sufficient friction was present in the drive train to preclude camera assembly movement after power was removed from the motors.

During the Apollo 16 extravehicular activity for film retrieval, the stellar camera lens glare shield was found in the extended position and jammed against the service module mold line and handrail. The jammed glare shield could have resulted from a loss of gear engagement between the drive rack and pinion gear when the camera assembly was fully deployed in zero gravity. This condition could occur if the camera assembly became misaligned when fully extended. The drive rack position was adjustable and the rack could have been slightly misaligned. During retraction, the rack and pinion re-engagement could then occur at a point where the glare shield would not have been sufficiently retracted to clear the vehicle

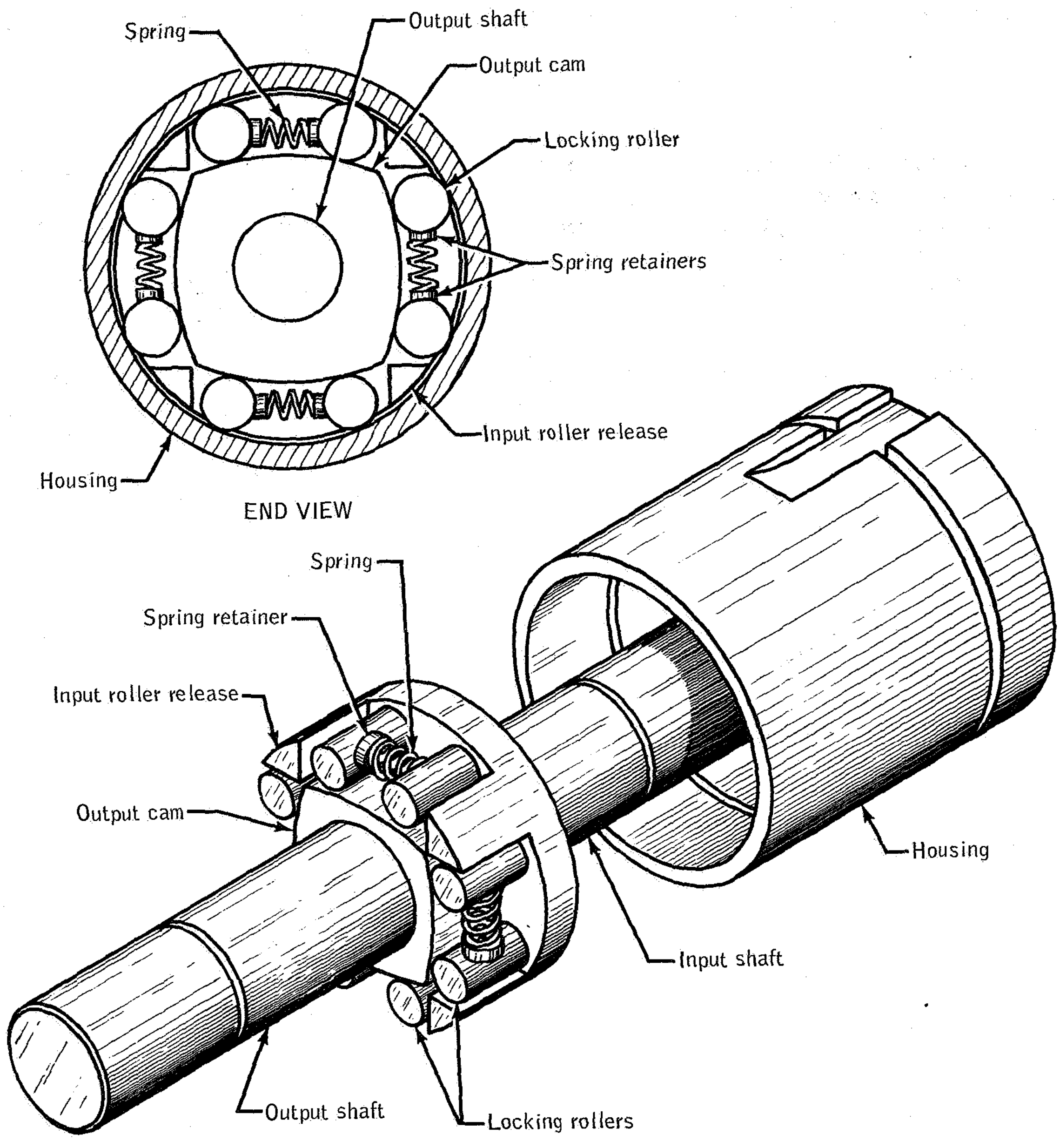

Figure 8.- Exposed view of rotostat.

mold line. As a result of this problem on Apollo 16, the Apollo 17 drive rack was aligned for proper pinion gear engagement when the camera assembly was fully deployed. Zero-g conditions were approximated by supporting the camera assembly to remove the assembly weight from the rail/bushing interface.

Additional analyses after the Apollo 16 mission showed that debris resulting from jettisoning the scientific instrument module bay door could enter various openings in the deployment mechanism. As a result, openings in the gear box were sealed with pressure-sensitive tape for the Apollo 17 flight unit. In addition, excess lubricant was removed from the drive screw to preclude adhesion of debris, and the cover over the two rear transfer gears was redesigned to better enclose the gears.

Apollo 17

Deployment and retraction cycling was minimized during the Apollo 17 mission because of the problems experienced with the mapping camera assembly on the two previous missions. After a normal first deployment, the retraction time was a few seconds longer than normal. The second deployment and retraction time was 3 minutes and 20 seconds, and about 4 minutes, respectively. The third deployment time was normal. The final retraction again required a greater length of time than normal. In addition, photography of the service module taken during rendezvous operations (after the second deployment, but before the second retraction) showed that the stellar camera plume shield was either jammed or stuck open, even though the camera assembly was fully retracted (fig. 9). However, during the transearth extravehicular activity, the stellar camera plume shield was closed and all other visible equipment in and around the camera assembly appeared normal. The failure mode that caused the shield to remain open on the previous deployment cycle was apparently overcome during the final deployment cycle.

GENERAL

Because of the similarity of symptoms in the deployment/retraction times on the Apollo 15, 16, and 17 mission; the crushing of the stellar camera lens glare shield on Apollo 16 mission, and the unretracted plume shield on the Apollo 17 mission; a common cause is most likely. However, analyses and ground tests have failed to identify the exact cause of the problem.

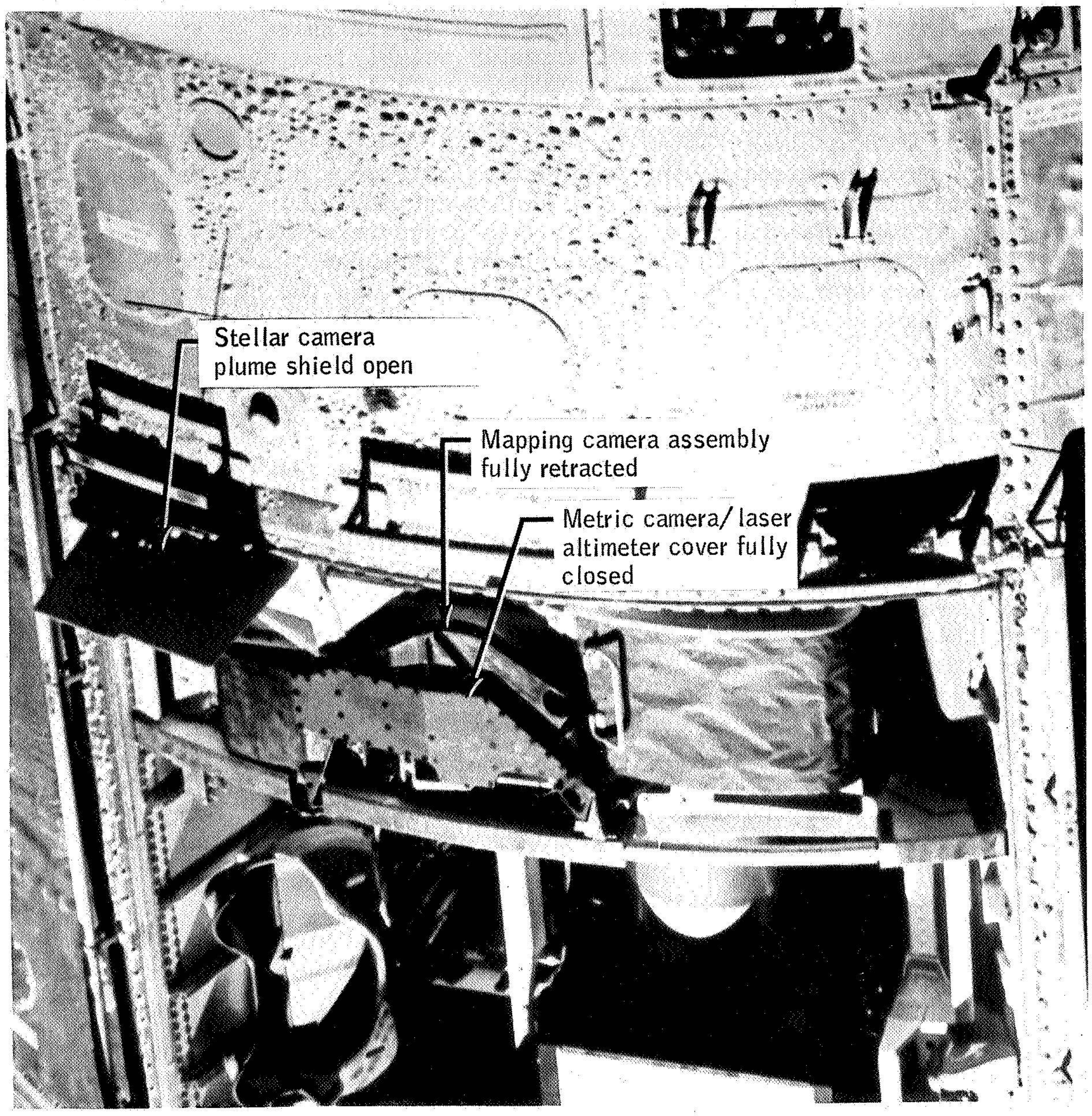

Figure 9.- Plume shield open during rendezvous on the Apollo 17 mission.

All of the Apollo orbital experiments that used deployment/retraction mechanisms experienced sluggish operation and/or a considerable increase in travel time from stop to stop. These included the gamma ray spectrometer, mass spectrometer, lunar sounder, and mapping camera. On the Apollo 15 mission, the mapping camera deployment/retraction mechanism failed completely. The Apollo 16 mass spectrometer drive mechanism also failed completely and was jettisoned.

In all cases, some degree of sliding between metal surfaces was required and this suggests a possible common factor. Friction between the metal surfaces may have been significantly increased by the hard vacuum affects which are unobtainable in large ground test chambers.

The coefficient of friction between two metallic surfaces that rub, slide, or roll against one another is determined by the properties of their respective surface oxides, and the surface adhesion layers of oxygen and water vapor, as well as the lubricant used. On ferrous materials in a vacuum of 10^{-6} torr (the level to which the hardware was tested), the adhesion layer will outgas for a period of time and the coefficient of friction will rise slightly. When the vacuum reaches 10^{-9} torr (as can be obtained in cislunar space), the ferrous metal oxides become chemically unstable, and with the addition of the heat of friction, decomposition into metal and oxygen begins. The coefficient of friction rises by a factor of four to ten. Ferrous alloys usually have a much lower shear strength than their oxides, thus causing an increase in adhesion of material from surface to surface. This increase in friction and the adhesion continues until welding occurs. Of course, the process is subject to the effects of other factors such as loads; lubricant coefficient of friction and evaporation rate; method of load application; impurities in the metal surfaces; time exposed to hard vacuum; and surface sliding velocity.

CONCLUSIONS

The exact causes of the problems with the scientific equipment module deployment mechanisms have not been identified. However, the possibility of increased friction in hard vacuum is implied.

Since hard vacuum conditions are not attainable in large chambers, realistically loaded components could be tested in small chambers that are capable of vacuums down to 10^{-14} torr.

CORRECTIVE ACTION

The Apollo 17 mission was the last for the mapping camera deployment mechanism consequently, no corrective action is required. However, materials, lubricants, and their methods of application are being reviewed for Skylab experiments which are exposed to the hard vacuum environment.