

## FLIGHT SUPPORT SYSTEM MECHANISMS

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### SUMMARY

The Flight Support System (FSS) contains twelve mechanisms (six different types) which are used for retention and positioning of a Multimission Modular Spacecraft (MMS) within the Space Shuttle's cargo bay during launch, retrieval, and servicing missions. Retention latches were designed to provide the capability for structural support of the MMS during launch and retrieval, and during servicing operations the mechanisms on the Positioning Platform provide the capability for positioning the MMS in virtually any orientation necessary for the work to be performed. In addition, there are mechanisms for mating and demating umbilical connectors and a mechanism for locking the Positioning Platform during maneuvers. Each mechanism is driven by a Common Drive Unit. Manual overrides have been provided for those mechanisms that would present a safety hazard for the crew, if they should fail.

### INTRODUCTION

The Flight Support System (FSS) is a reuseable piece of equipment which provides the mechanical, thermal, and electrical interfaces between the Multimission Modular Spacecraft (MMS) and the Space Shuttle for launch, retrieval, and on-orbit servicing missions.

The MMS is a reuseable platform which provides a user with systems for attitude control, power, commands and data handling. It was designed to be compatible with both the Delta launch vehicle and the Space Shuttle. The interface with the Space Shuttle is through the FSS.

The first user of the MMS was the Solar Maximum Mission (SMM), which was launched into earth orbit by a Delta 3910 in the first quarter of 1980. The SMM was originally scheduled for retrieval in 1985, but malfunctions which developed in the Attitude Control Subsystem caused it to become a candidate for a servicing mission now planned in 1983.

Figure 1 shows the SMM spacecraft affixed to the baseline FSS in a typical position within the Shuttle cargo bay. The FSS baseline configuration (see Figure 2) consists of three structural cradles, avionics, and twelve mechanisms for spacecraft retention and positioning. The twelve mechanisms are shown in Figure 3, and include three retention latches for supporting the spacecraft during launch or landing, three berthing latches which hold the spacecraft to the Positioning Platform during orbital operations, one mechanism each for pivoting, rotating, and translating the Positioning Platform, two mechanisms for mating and demating the spacecraft umbilical connectors,

and a mechanism (identical to the retention latches) which locks the Positioning Platform to the cradles during launch or landing.

#### COMMON DRIVE UNIT

Each of the twelve FSS mechanisms is driven by a Common Drive Unit (CDU), of which there are two types: high speed and low speed. Both have the same mounting and output shaft interfaces and both provide the same amount of stall torque, 31 Nm (275 in. lb.).

Each CDU (see Figure 4) consists of two (three-phase, 115-V, 400-Hz) motors, gearing, an automatic electromagnetic brake and an automatic overload switch. Full redundancy is provided up to the output shaft. The high-speed unit uses the larger motor to provide a no-load output speed of 90 rpm. The low-speed unit has an additional gear reduction and gives a no-load output speed of 9 rpm. If both motors of a CDU are powered simultaneously, the speed would be twice these values, and the stall torque would be the same.

The electromagnetic brake locks the motor shaft when power is removed, and thereby prevents the motor from being backdriven in either direction. The overload switch prevents damage to the motor during stall conditions.

#### SWITCHES

End-of-travel limit switches have been included in the design of each mechanism. These switches are used for automatic cutoff of the CDU's and provide status data to the crew. In the event of failure of a switch, the mechanism is driven to a hard stop. All mechanisms were designed to withstand this condition.

#### RETENTION LATCHES

Three retention latches are attached to Cradle A. They are used to support the MMS during Shuttle launch and return. Each mechanism was designed to a limit load of 127,000 Newtons (28,500 lb.), using a factor of safety of 2 based on yield. (Design yield load 254,000 N.)

As shown in Figures 5 and 6, the latch operates as follows: a high-speed CDU drives an Acme screw which causes a linear motion of the barrel. A segmented collet closes around the MMS trunnion pin as the barrel moves forward. At the end of travel, the collet very nearly fills the volume between the barrel and the pin. A gap of about 0.025 mm (0.001 in.) is left. This gap enables the latch to restrain the pin radially while allowing it to move freely in the axial direction. By using three latches on Cradle A (as shown in Figure 3), an MMS is self-aligned during Shuttle maneuvers.

In order to meet the requirement that the latch be capable of withstanding being driven against a hard stop, a torque-limiting clutch had to be incorporated between the CDU and the gears (to protect the gears). The torque limiter operates at about 1600 Nm (180 in. lb.).

Design of the retention latch includes a means for an astronaut to manually drive it in the event of a failure in the CDU or in the driver electronics. As shown in Figure 7, the astronaut inserts a standard-size socket tool into a fitting on the side of the cradle. He engages a clutch by depressing the shaft until it locks (by means of the ball detents). The output of the clutch drives the Acme screw of the latch through a gear box at the rear of the mechanism.

#### PLATFORM LOCK

The mechanism which is used to lock the Positioning Platform to the cradles during launch or landing is identical to the three retention latches just described. Its location is shown in Figure 3.

#### BERTHING LATCH

Three berthing latches are used to hold the MMS to the Positioning Platform. Each latch consists of a pair of jaws which close around a berthing pin attached to the lower MMS structure. The jaws were designed to capture a pin if it is within  $\pm 5$  cm (2 in.) of the desired final position. They were designed for an impact load of 6,450 N (1,450 lb.) when open, and for a limit load of 40,000 N (9,000 lb.) when closed. Both design loads assume a factor of safety of 2 based on yield.

As shown in Figure 8, the berthing latch operates by means of an Acme screw which actuates a linkage for each jaw. The screw is driven by a high-speed CDU through a gear train. As with the retention latches, a small gap exists between the fully closed jaws and the berthing pin so that only radial loads are reacted. By using three latches, as on the FSS, the MMS is automatically aligned.

The design includes means whereby an astronaut can manually open the jaws in the event a failure occurs while an MMS is secured. As shown in Figure 9, an astronaut can use a standard-sized tool to unscrew the jaw pivot pins. Note that this method only allows for release of a spacecraft. No means is provided for berthing one under failure conditions, because this situation does not present a safety hazard for the crew or the orbiter.

#### UMBILICAL CONNECTOR ACTUATOR

Two umbilical connector actuators are mounted to the Positioning Platform as shown in Figure 3. Each one provides a remotely controlled means for mating and demating a spacecraft umbilical connector. Each has a stroke of 10 cm (4 in.) and can press the connectors together or pull them apart with a force of 1,800 N (400 lb.).

The mechanism, shown in Figure 10, consists of a connector holder which rides on two parallel rails driven by a low-speed CDU through a bellcrank. The connector is mounted to the holder on a spring-loaded frame, which takes up misalignment up to 0.3 cm (1/8 in.).

In the event of a failure while the connectors are mated, an astronaut can demate them manually as shown in Figure 11. The entire mechanism is mounted to a moveable frame. Using a standard-size tool, an astronaut turns the override screw and the mechanism is pulled away from the spacecraft, demating the connectors. This override is a one-way device in that it can only be used for demating. Failure to mate is not considered a safety hazard.

#### ROTATOR

The rotator is a mechanism which is used to rotate the Positioning Platform ring about its centerline through  $\pm 175$  degrees. It can be operated for any pivot position, thus providing considerable flexibility for servicing operations.

As shown in Figure 12, it drives a large ring gear mounted to the moveable platform. It simply consists of a low-speed CDU and a gear box and can supply a torque of 210 Nm (24,000 in. lb.). If a failure occurs, it can be overridden manually by an astronaut using a standard-size tool. He must loosen two drive unit bolts, slide a spacer under one of them and retighten the bolts. This frees the ring gear from the CDU and permits it to be driven manually through an idler. It can be driven in either direction.

#### PIVOTER

The pivoter is a mechanism which moves the Positioning Platform from the horizontal position to the vertical position, or to any desired position in between. The horizontal position is used for launch, landing and orbital maneuvers, the vertical position is used for deploy-retrieve requirements, and other positions are used during servicing operations.

The pivoter is shown in Figure 13. It consists of a compound planetary gear assembly driven by a low-speed CDU. It drives the Positioning Platform through a splined output shaft, and is capable of supplying an output torque of 800,000 Nm (90,000 in. lb.).

If a failure occurs which prevents pivoter operation, it can be driven manually (see Figure 14). With a standard-size tool an astronaut can remove the bolts which fasten the two turnbuckles on the pivoter housing to the stationary part of the Positioning Platform. Using the same tool, he can then turn the idler which operates the pivoter. The pivoter can be moved manually in either direction.

#### TRANSLATOR

The translator is a device designed to prevent impact between a stowed MMS and the Positioning Platform during dynamic loading conditions. It is capable of moving the platform to a position 9 cm (3.5 in.) away from a stowed MMS.

Figure 14 shows the overall configuration of the translator. A low-speed CDU located at the top center of the ring drives two shafts extending on either side. As shown in Figure 15, each shaft drives a large Acme screw through a set of helical gears. Since translator failure is not considered a safety hazard, no means for manual operation was provided.

#### CONCLUSION

A summary of data for all twelve mechanisms is listed in Table 1. Operating times shown are for single motor operation. For dual motor operation, times are one-half of those given. Structurally, the design of each mechanism incorporates a limit-to-yield safety factor of 2.0.

All mechanisms have been fabricated and assembled, and are presently undergoing testing.

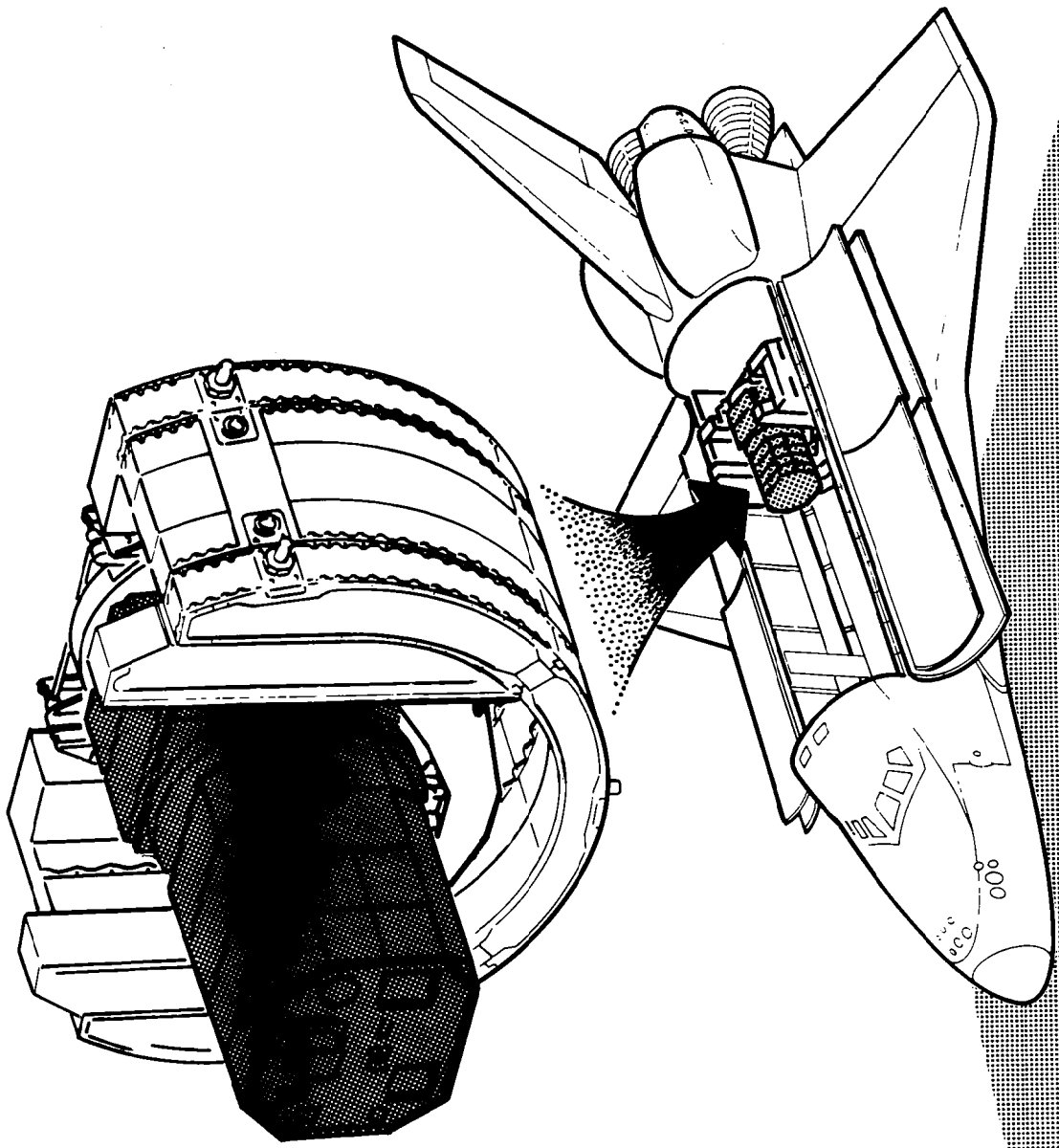
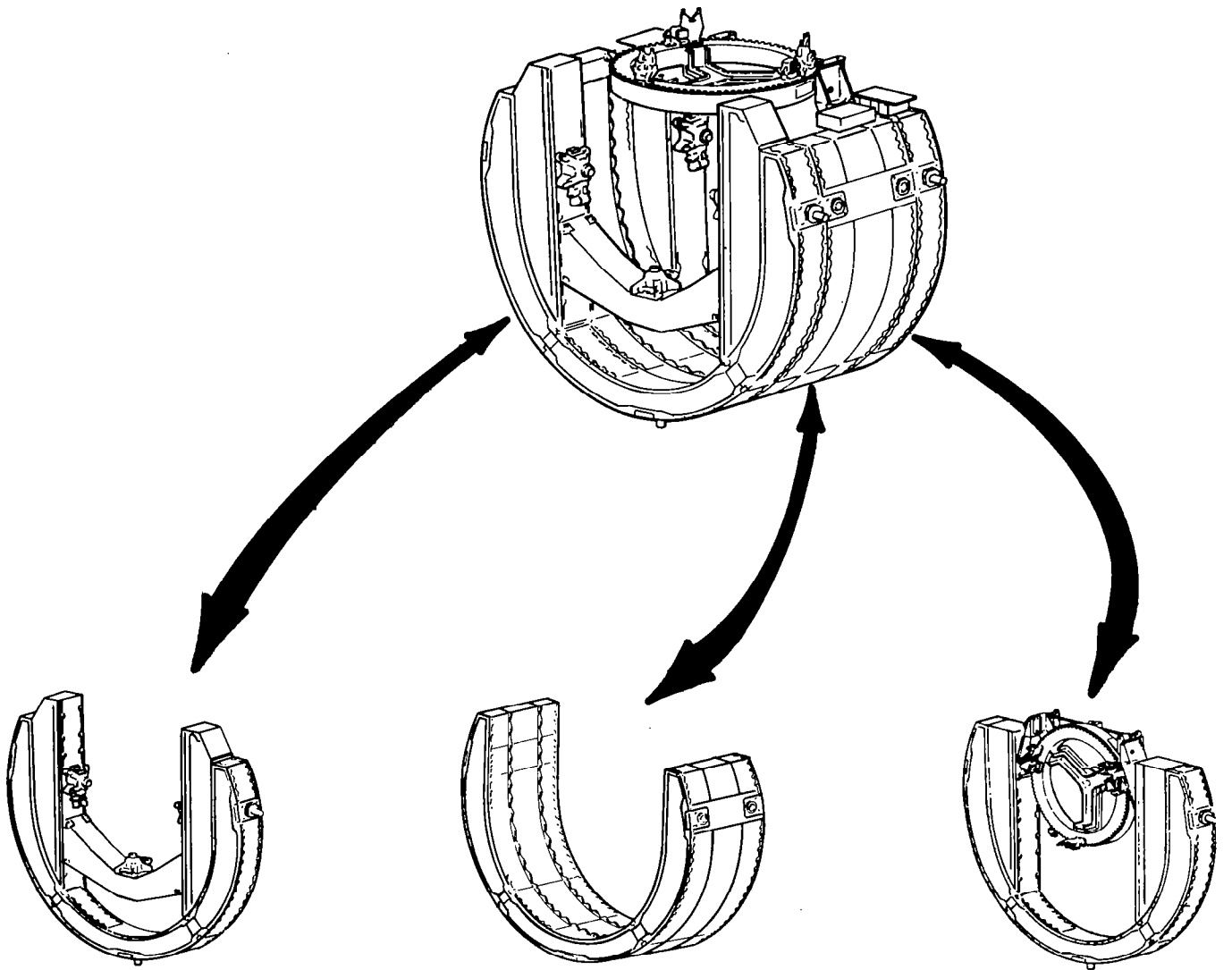


Figure 1. SIM Stowed in Cargo Bay



**ADLE A WITH LATCH BEAM**

**CRADLE B**

**CRADLE A' WITH POSITIONING SYSTEM**

Figure 2. Flight Support System

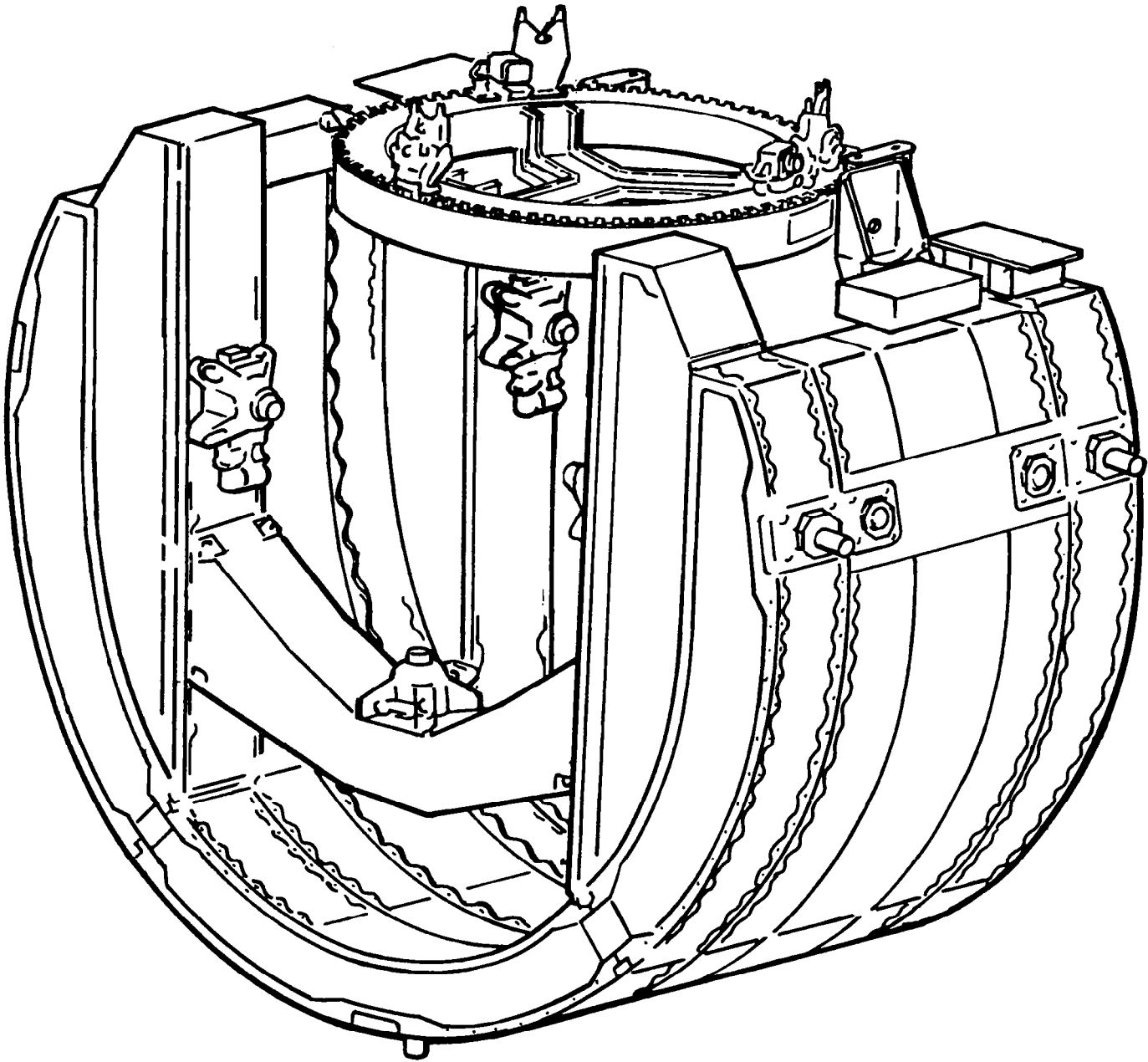


Figure 3. Flight Support System



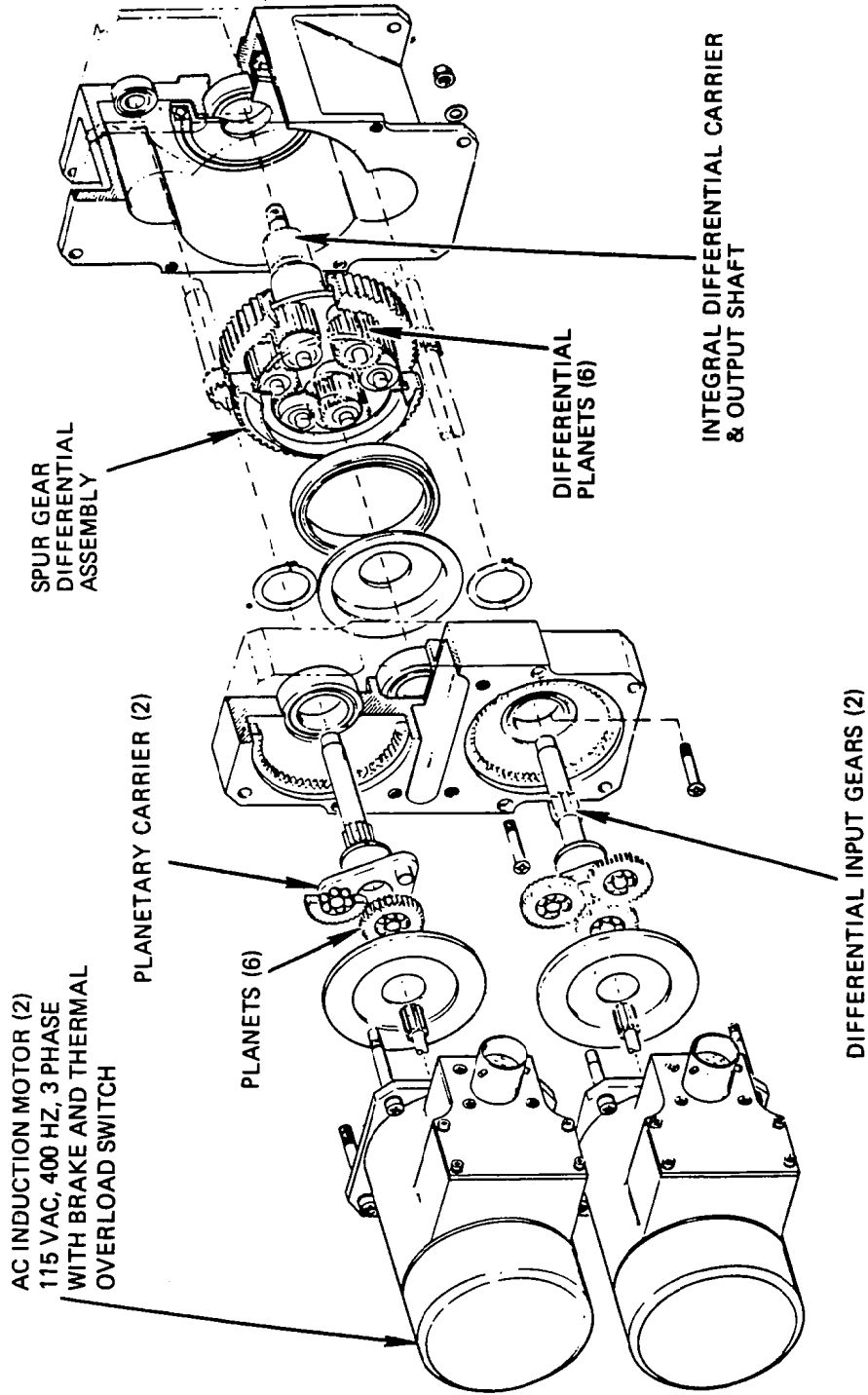


Figure 4. Common Drive Unit (Large Motor Size)

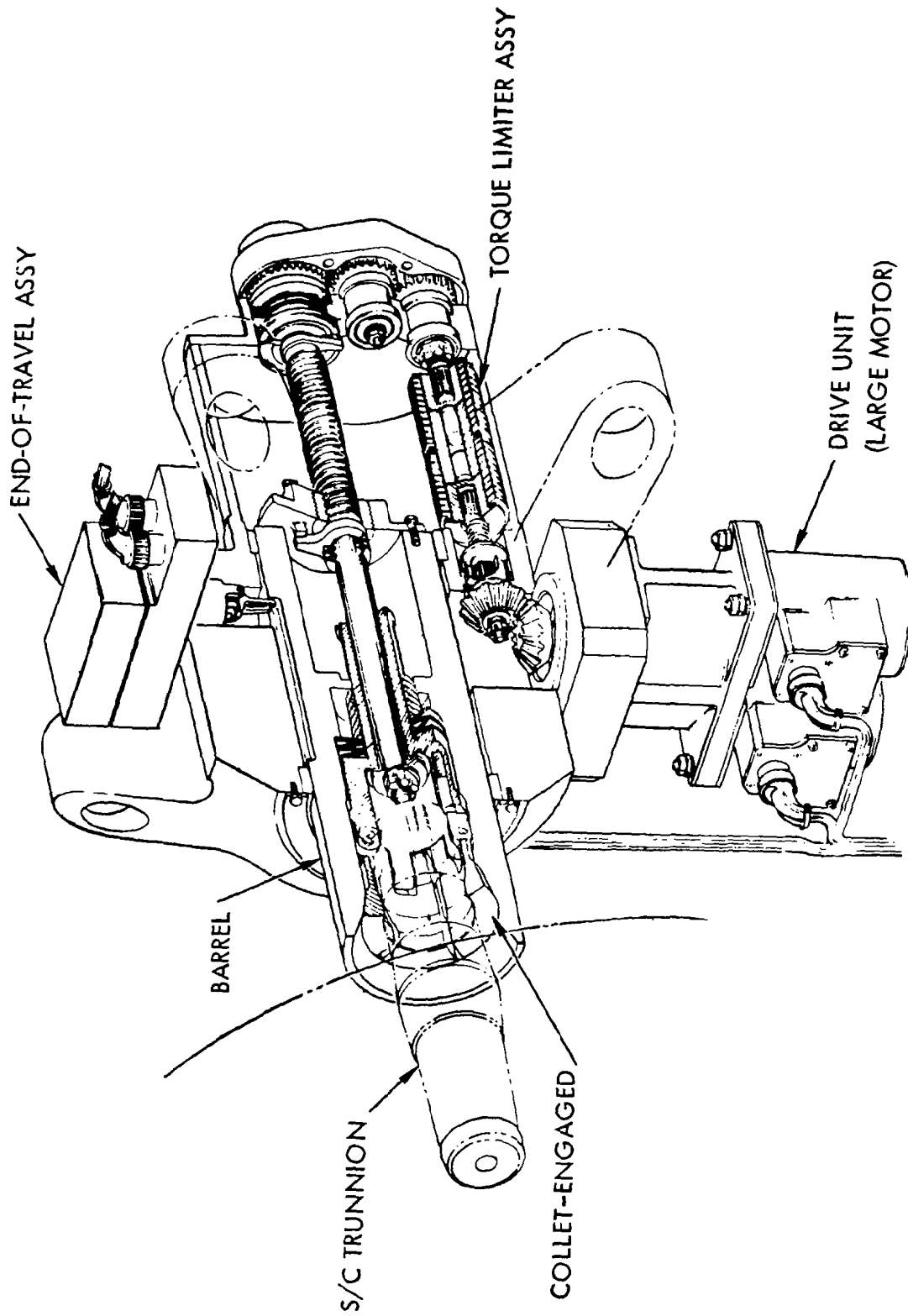


Figure 5. Spacecraft Retention Latch-Engaged

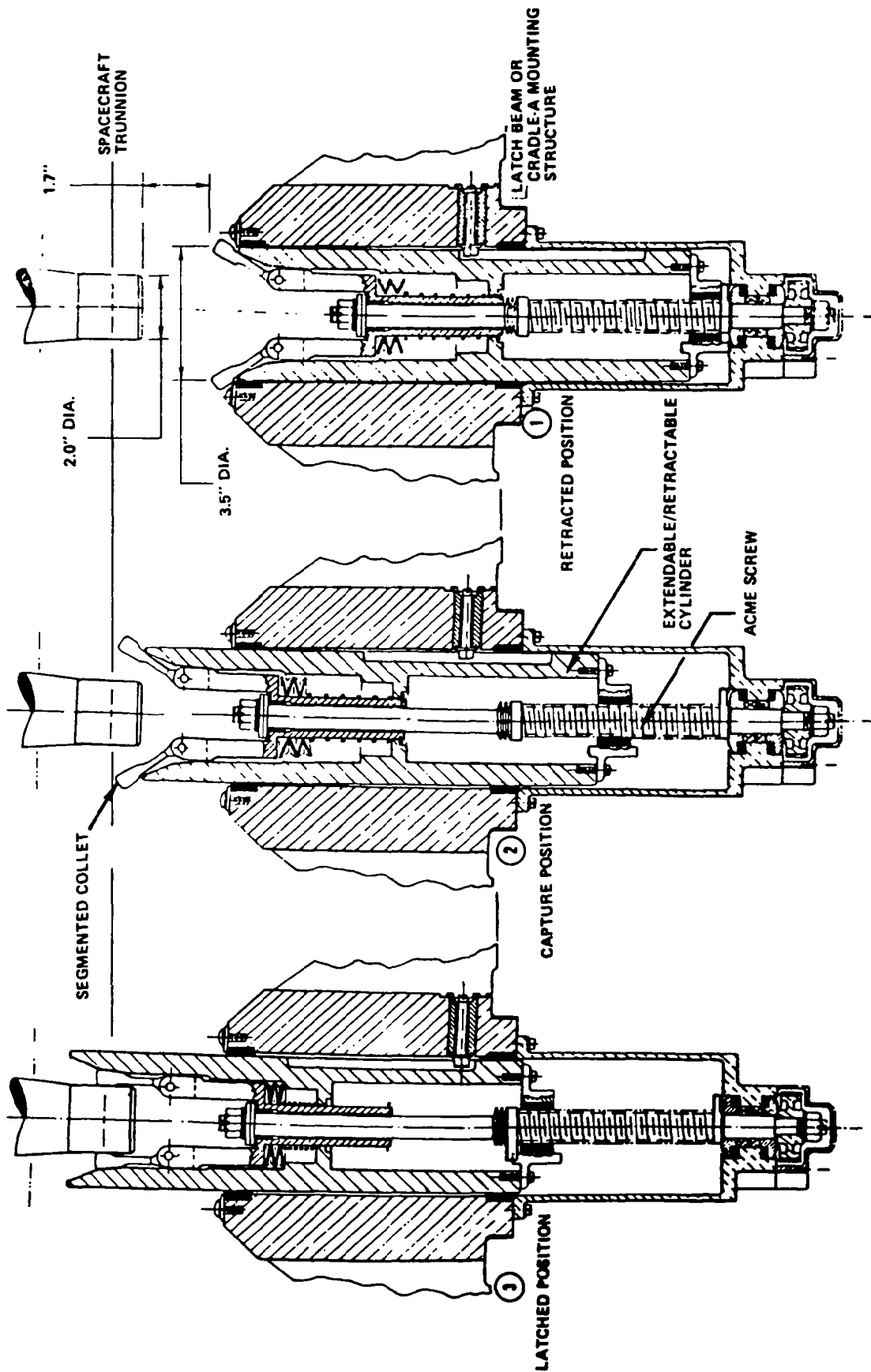


Figure 6. Retention Latch Operational Sequence

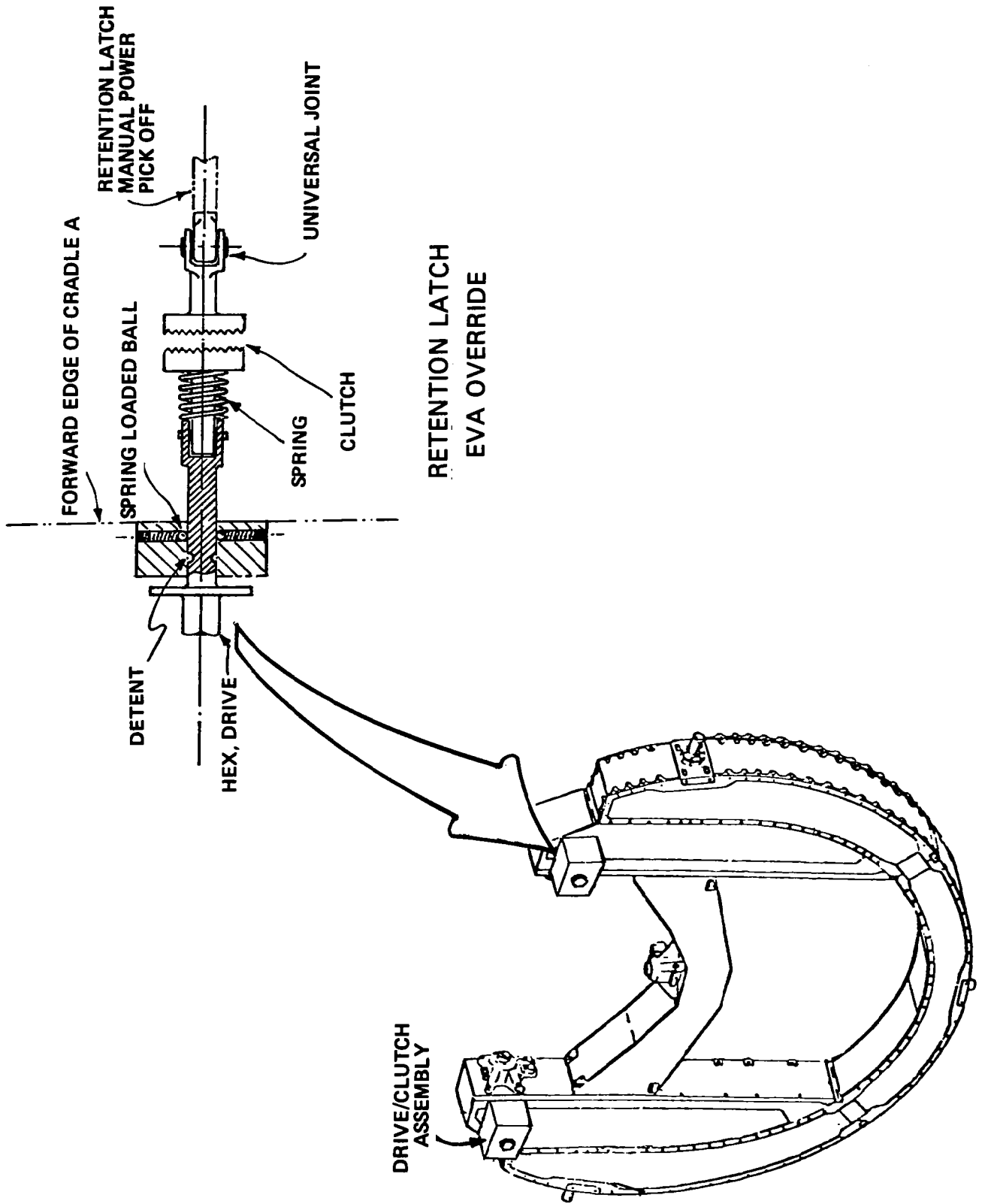


Figure 7. Override Drive Concept Retention Latches

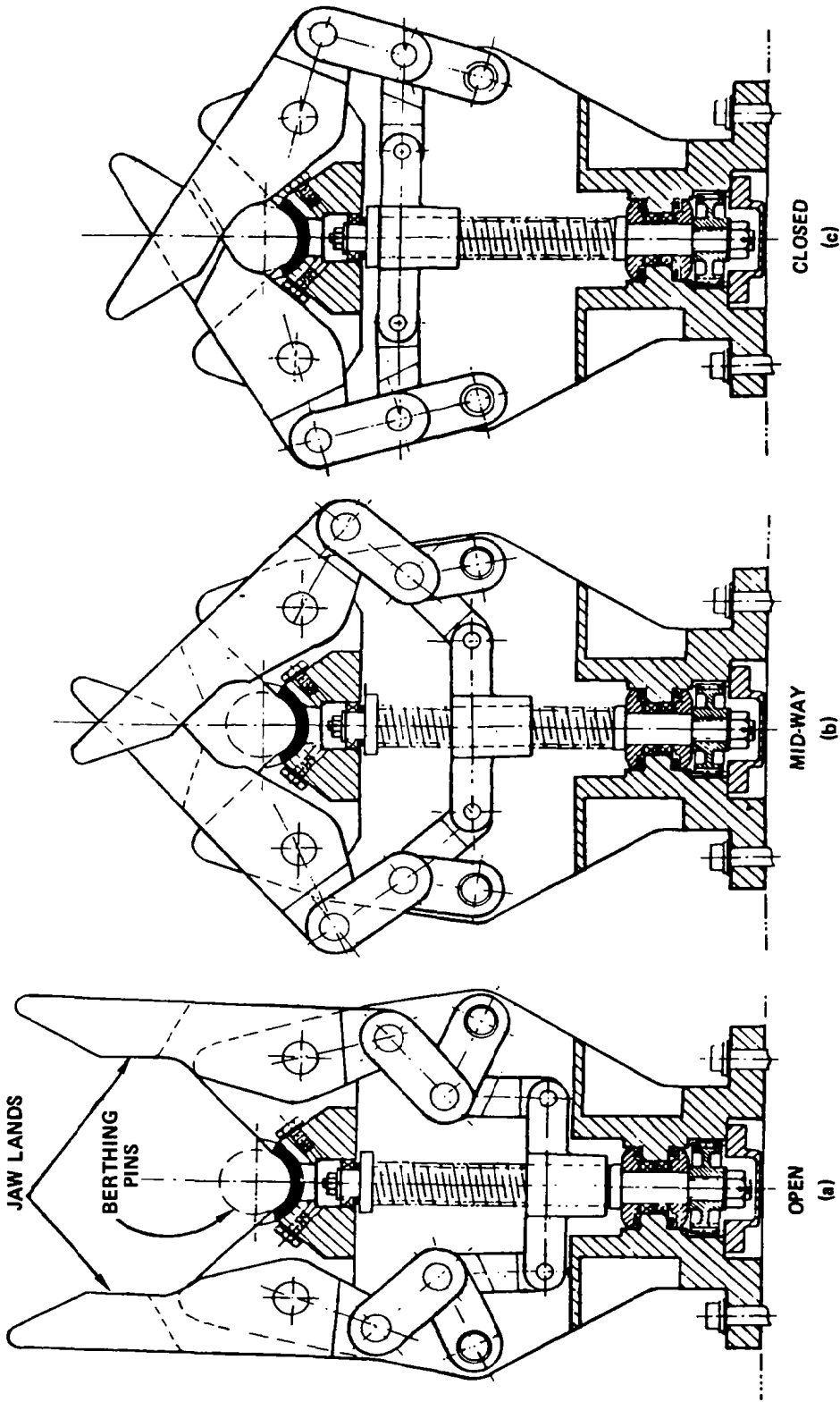


Figure 8. Berthing Latch Mechanism Operating Sequence

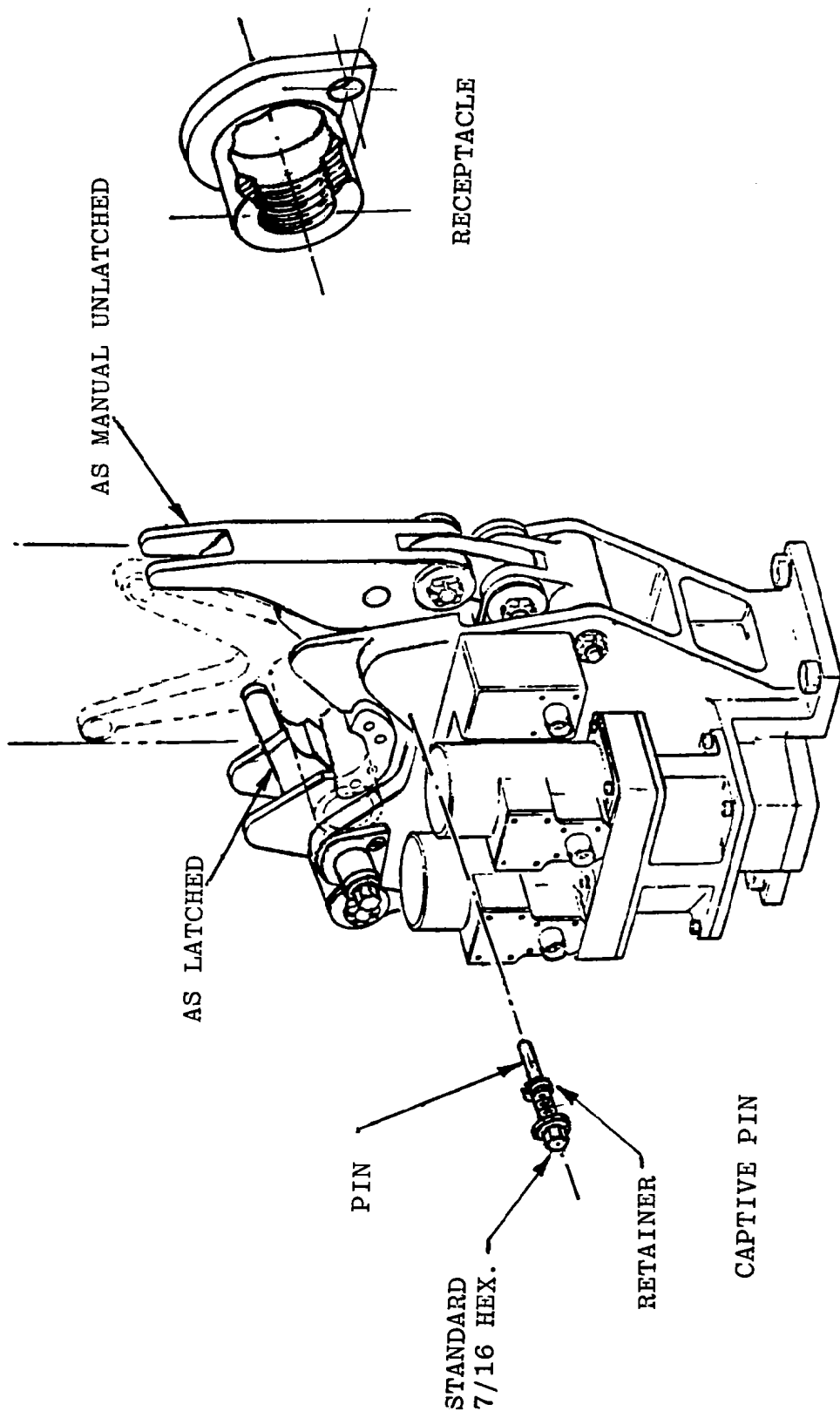


Figure 9. Berthing Latch Manual Unlatch

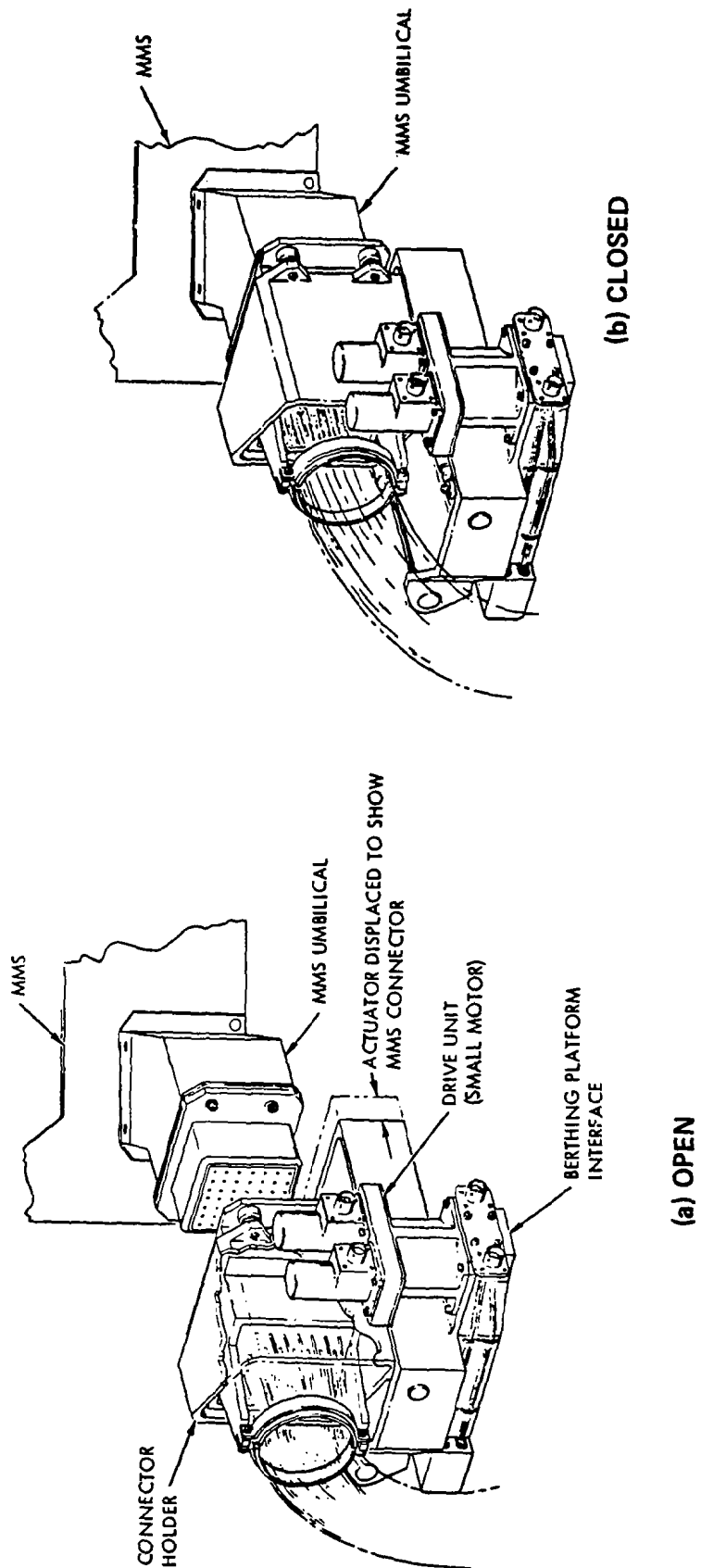
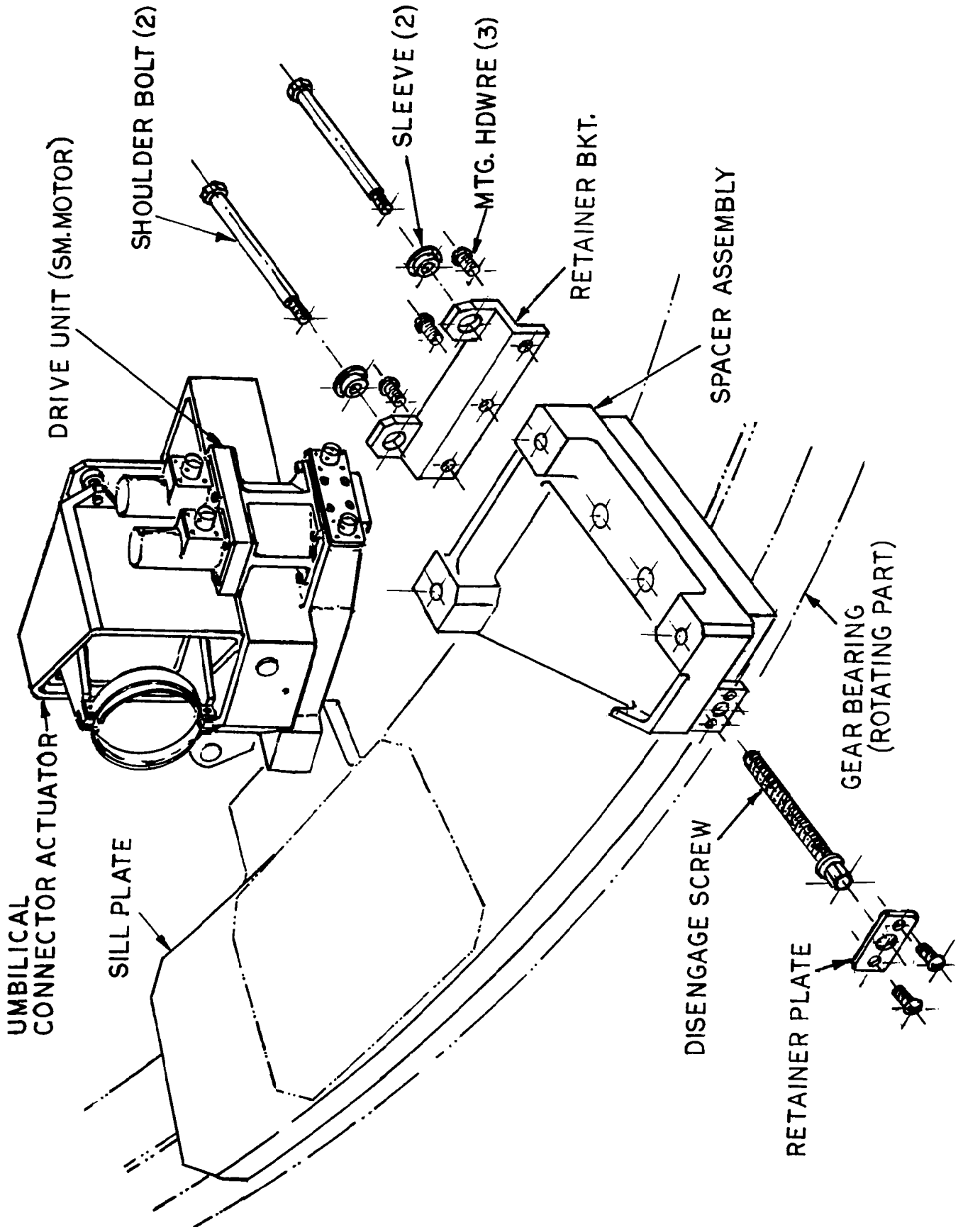


Figure 10. Umbilical Actuator Positions





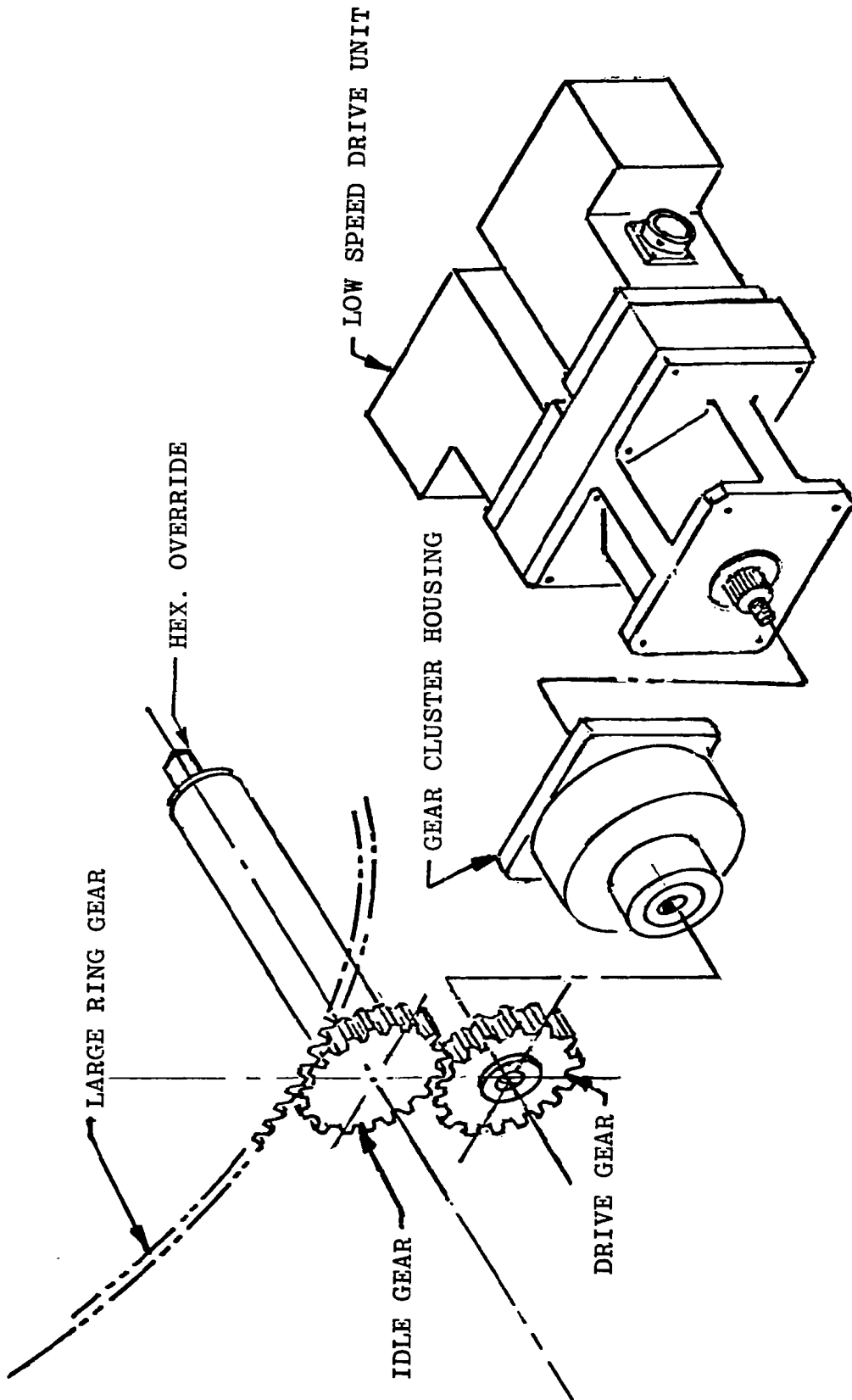


Figure 12. Rotator

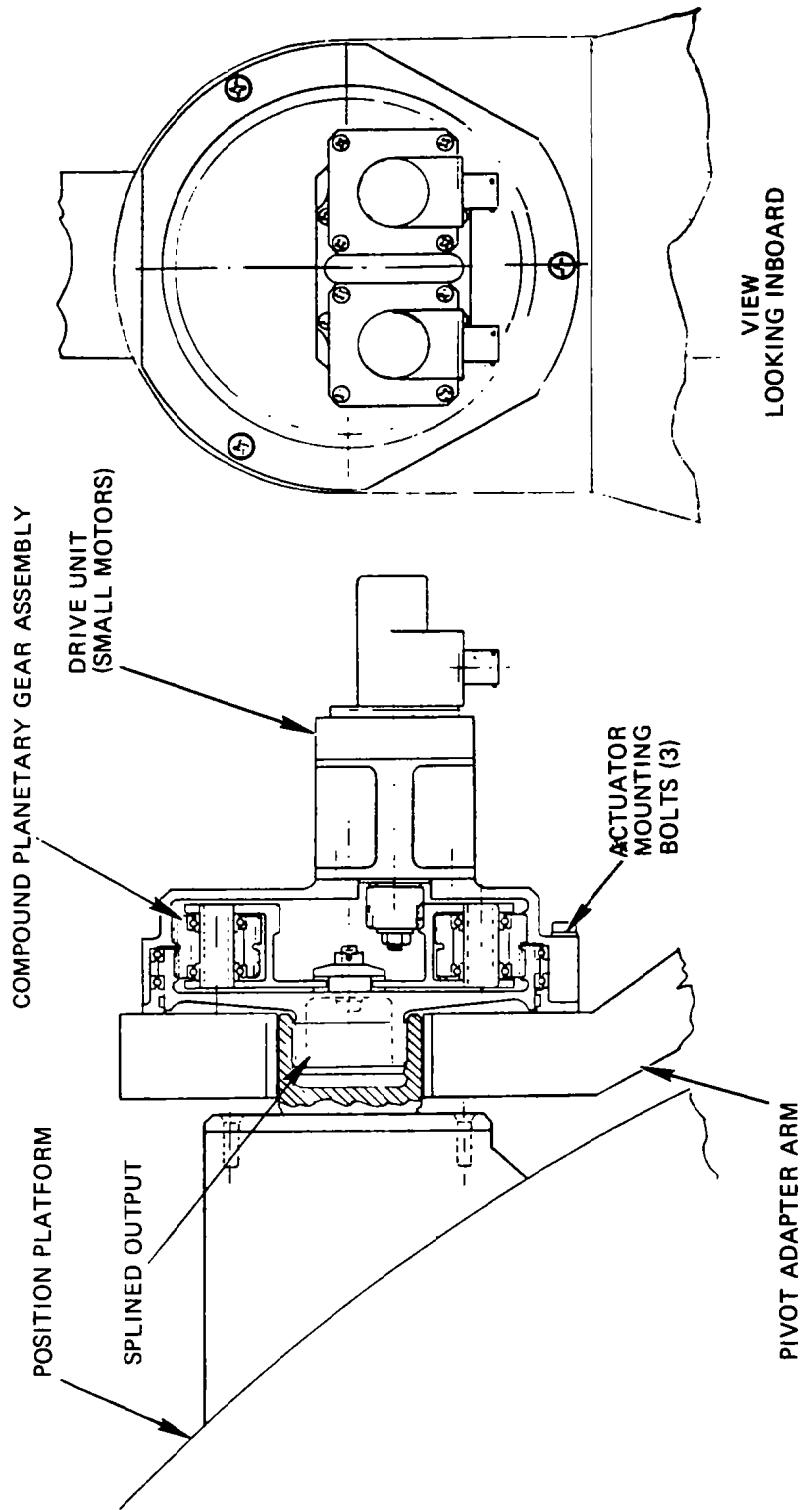


Figure 13. Platform Pivot Actuator Detail

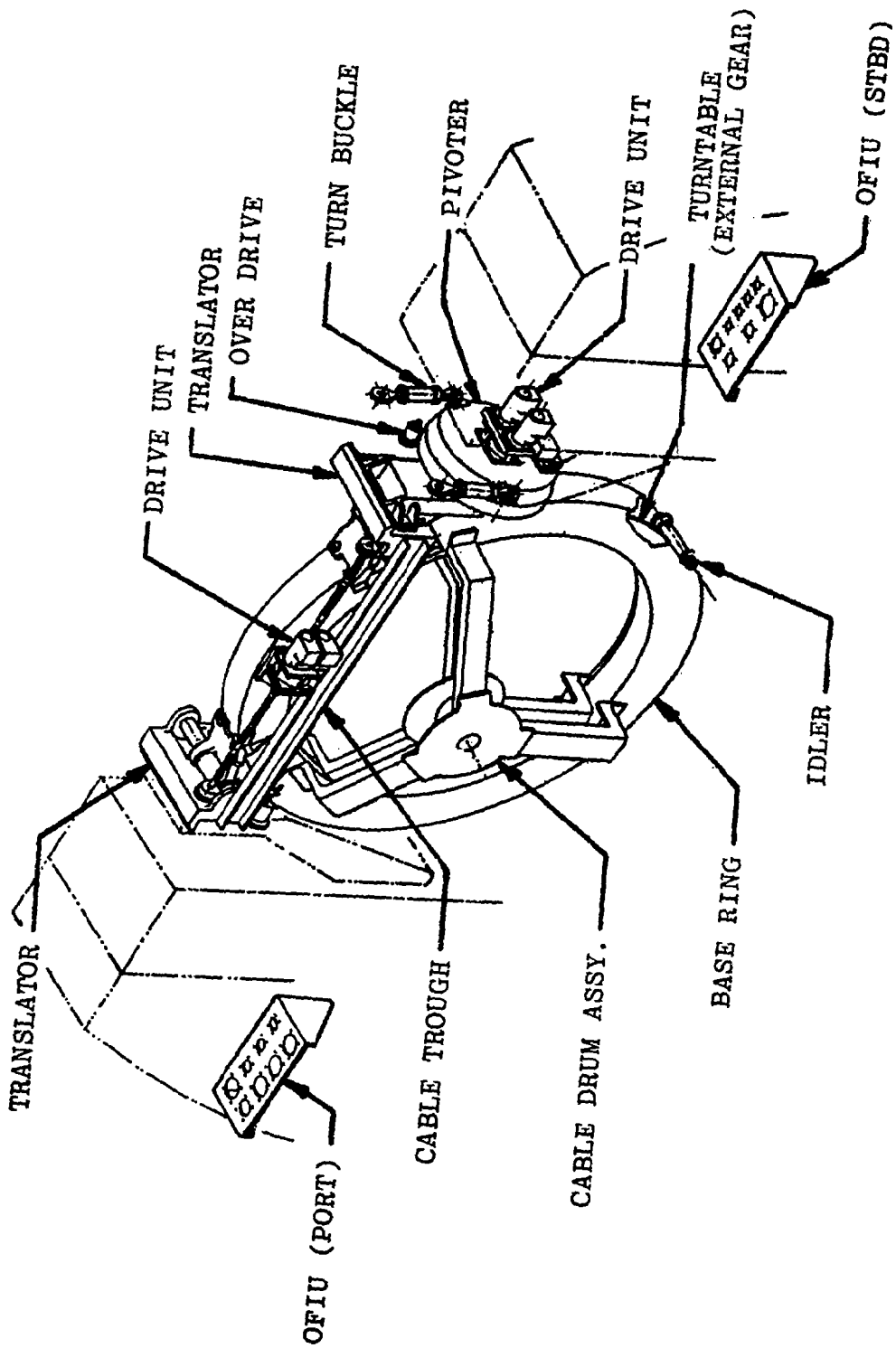


Figure 14. Manual Pivoter Operation

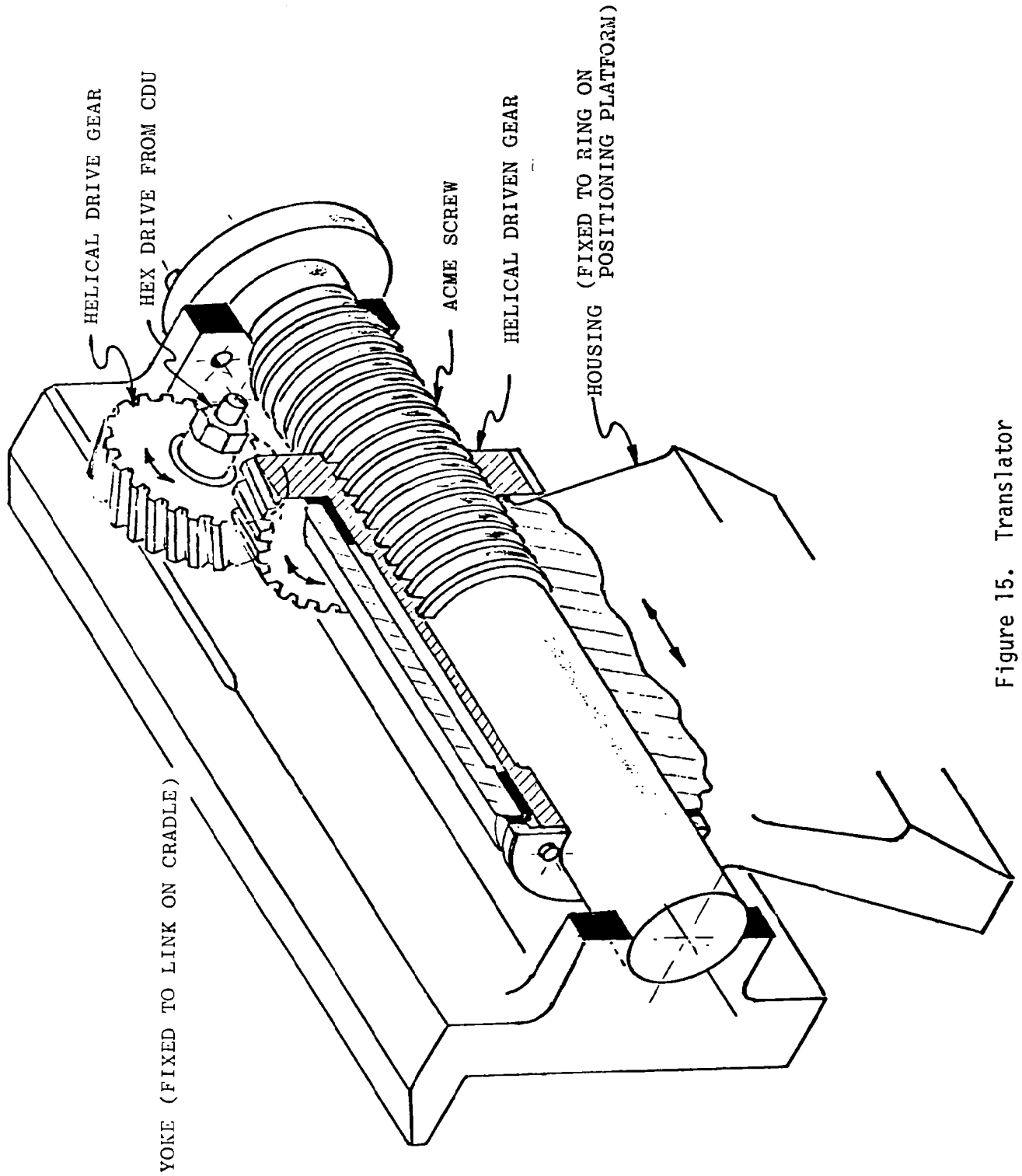


Figure 15. Translator

Table 1. FSS Mechanisms

Mechanism	Number	Operating Time, Sec	Drive Unit		Weight Newtons (lbs.)
			High Speed	Low Speed	
<u>Positioning System</u>					
o Pivot	(1)	600 (90°)		X	406 (91.2)
o Rotator	(1)	100 (180°)		X	130 (30)
o Translator	(1)	320		X	210 (47.2)
o Lock	(1)	24	X		486 (109.2)
<u>Berthing Platform</u>					
o Berthing Latches	(3)	18	X		268 (60.2)
o Umbilical Drive	(2)	10		X	102 (22.9)
<u>Retention System</u>					
o Spacecraft Retention Latch	(3)	24	X		486 (109.2)

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Mr. Leavy has been employed as an aerospace engineer for NASA-Goddard Space Flight Center since 1959. He holds two patents for mechanisms used on spacecraft. Mr Leavy received his B.S. degree in Aeronautical Engineering from Polytechnic Institute of Brooklyn in 1958 and an M.S. degree in Aerospace Engineering from Catholic University in 1965.