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SECTION 2

SUBSECTION 2.13

DOCKING AND TRANSFER

2.13.1 INTRODUCTION.

This section contains the information identifying the physical characteristics of the docking system and the operations associated with docking and separation.

2.13.1.1 Docking Operational Sequence.

The following sequence of docking illustrations and text describes in general the functions that are performed during docking. These activities will vary with the different docking modes.

After the spacecraft and third stage have orbited the earth, possibly up to three revolutions, the third stage is reignited (figure 2.13-1) to place the spacecraft on a translunar flight.

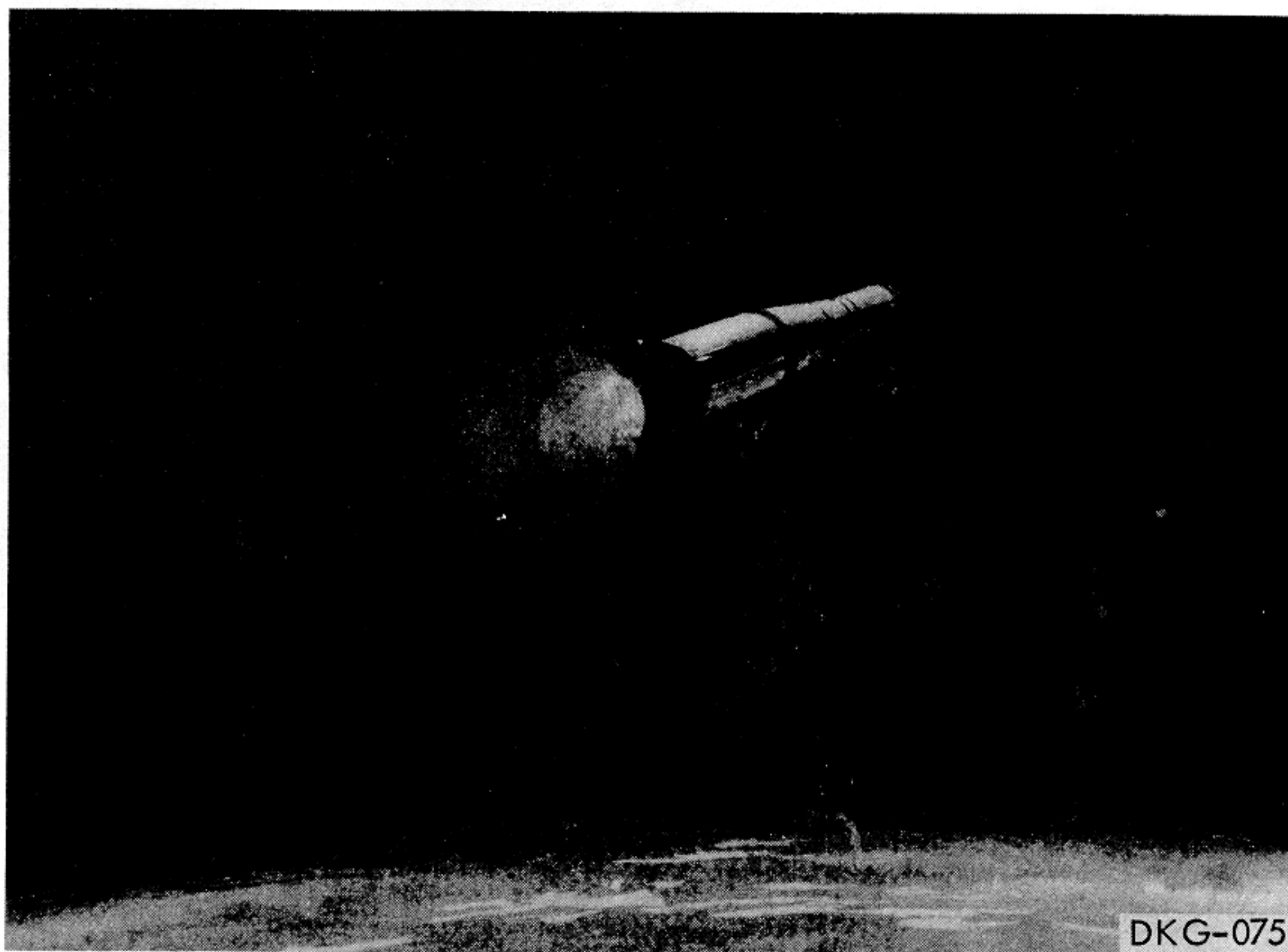


Figure 2.13-1. SIVB Ignition

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Shortly after translunar injection, the spacecraft transposition and docking phase takes place (figure 2.13-2). When the CSM is separated from the third stage, docking is achieved by maneuvering the CSM close enough so that the extended probe (accomplished during earth orbit) engages with the drogue in the LM. When the probe engages the drogue with the use of the capture latches, the probe retract system is activated to pull the LM and CSM together.

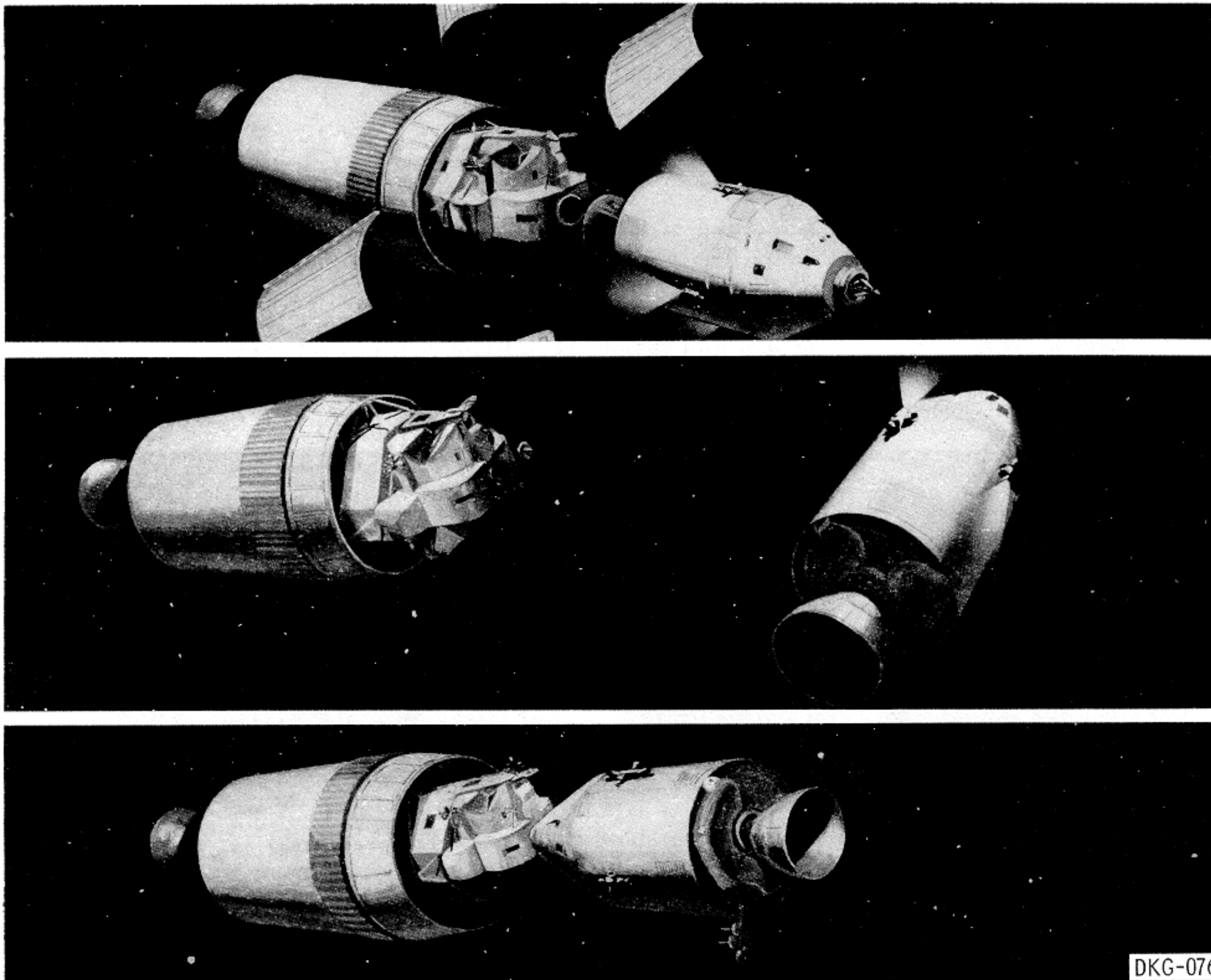


Figure 2.13-2. Transposition and Docking

Upon retraction, the LM tunnel ring will activate the 12 automatic docking ring latches on the CM and effect a pressure seal between the modules through the two seals in the CM docking ring face. After the two vehicles are docked, the pressure in the tunnel is equalized from the CM through a pressure equalization valve. The CM forward hatch is removed

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and the actuation of all 12 latches is verified. Any latches not automatically actuated will be cocked and latched manually by the crewman. The LM to CM electrical umbilicals are retrieved from their stowage position in the LM tunnel and connected to their respective connectors in the CM docking ring.

The vehicle umbilicals supply the power to release the LM from the SLA. Once the hold-down straps are severed, four large springs located at each attachment point push the two vehicles apart (figure 2.13-3) and the combined CSM/LM continues towards the moon.

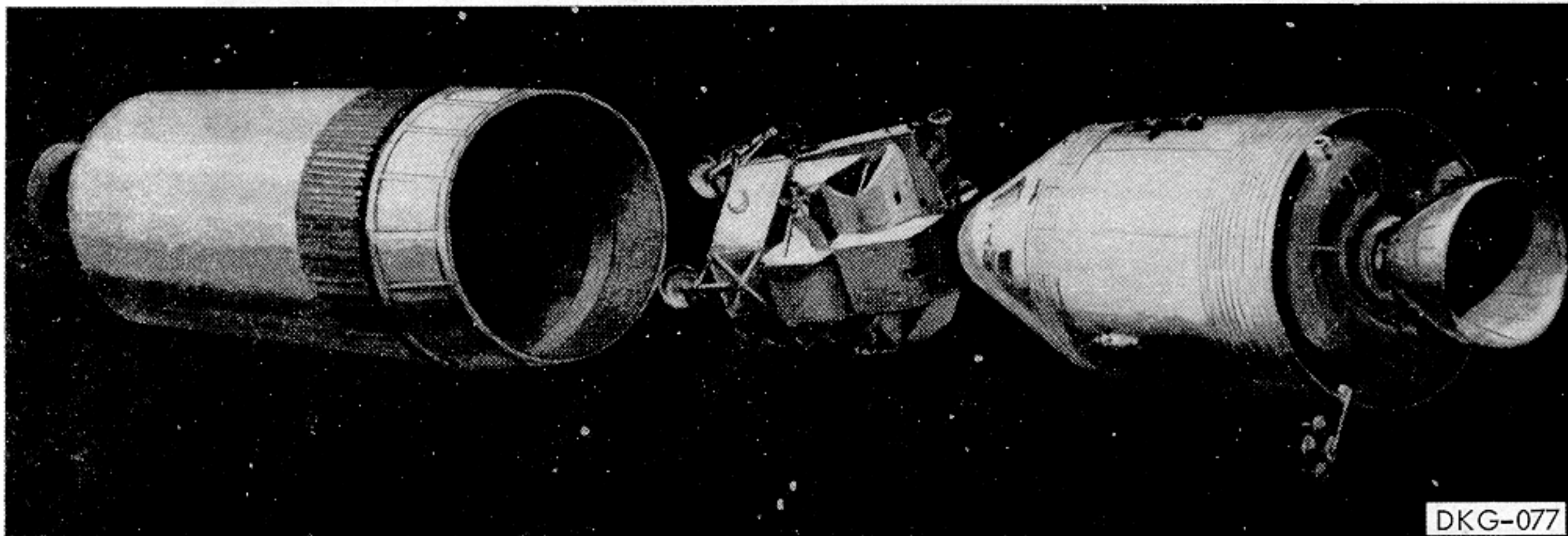


Figure 2.13-3. LM Removal

Once in lunar orbit, the tunnel is repressurized. The probe assembly and drogue assembly are removed from the tunnel and stowed in the CM. The pressure in the LM is equalized through the LM hatch valve. With the pressure equalized, the LM hatch is opened and locked in the open position to provide a passageway between the two modules. (See figure 2.13-4.)

After two crewmen transfer to the LM, the CM crewman retrieves the drogue from its stowage location in the CM, passes it through the tunnel, and helps to install and lock it in the tunnel. The drogue may be installed and locked by the LM crewmen, if they choose. The probe assembly is then retrieved from its stowage location in the CM and installed and preloaded to take all the load between the modules. This accomplished, the LM hatch is closed by the LM crewmen. The 12 docking latches are released and cocked by the crewman in the CM so that the latches are ready for the next docking operation. The CM forward hatch is reinstalled and checked to assure a tight seal. The modules are now prepared for separation.

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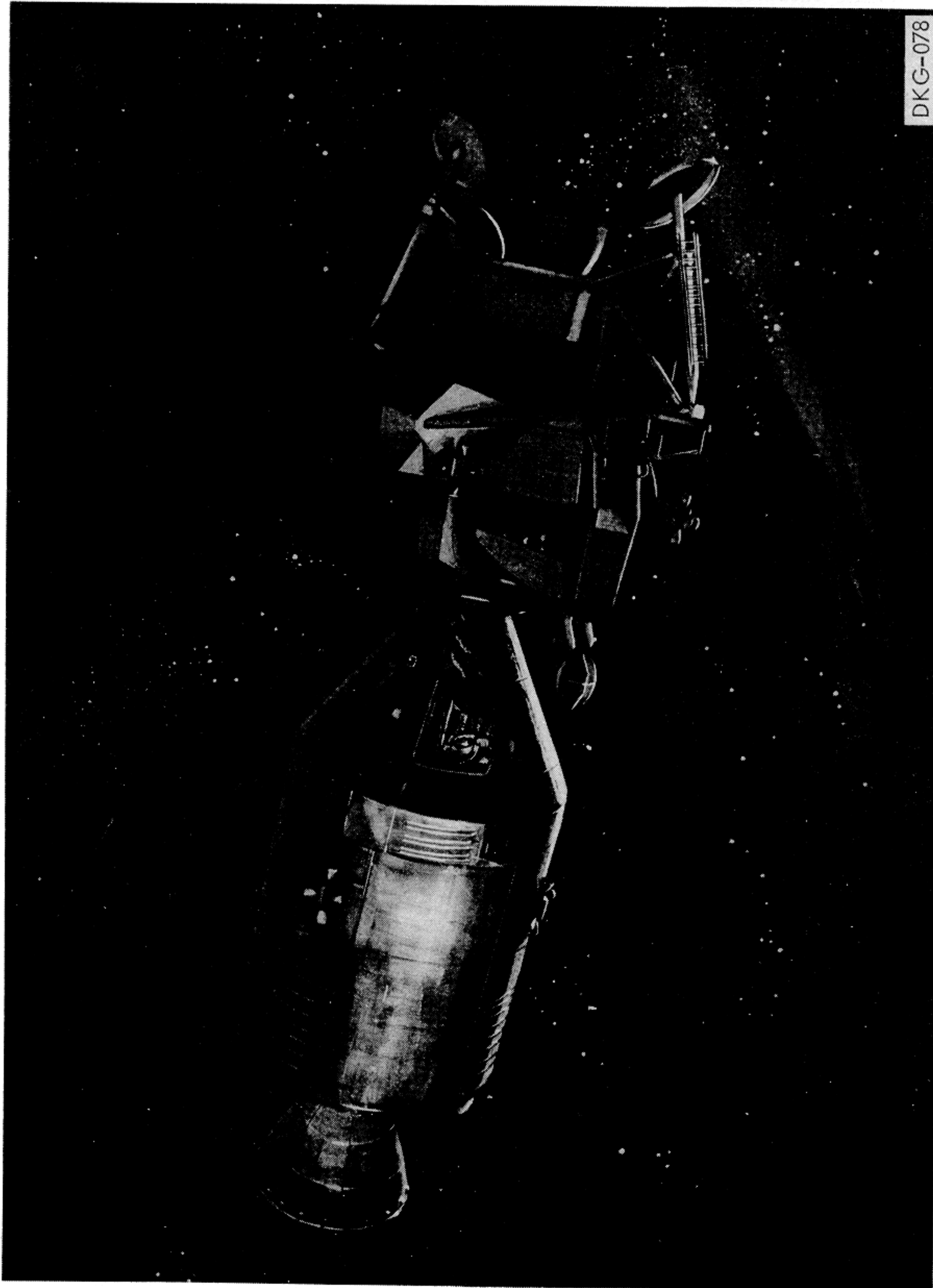


Figure 2.13-4. CSM-LM Docked Crew Activities

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The probe EXTEND RELEASE/RETRACT switch in the CM (MDC-2) is placed in the EXTEND position, energizing the probe extend latch. The probe extends and during extension will activate a switch energizing an internal electric motor to unlock the capture latches. After the probe extends, the LM pulls away from the CM (figure 2.13-5) and descends to the lunar surface.

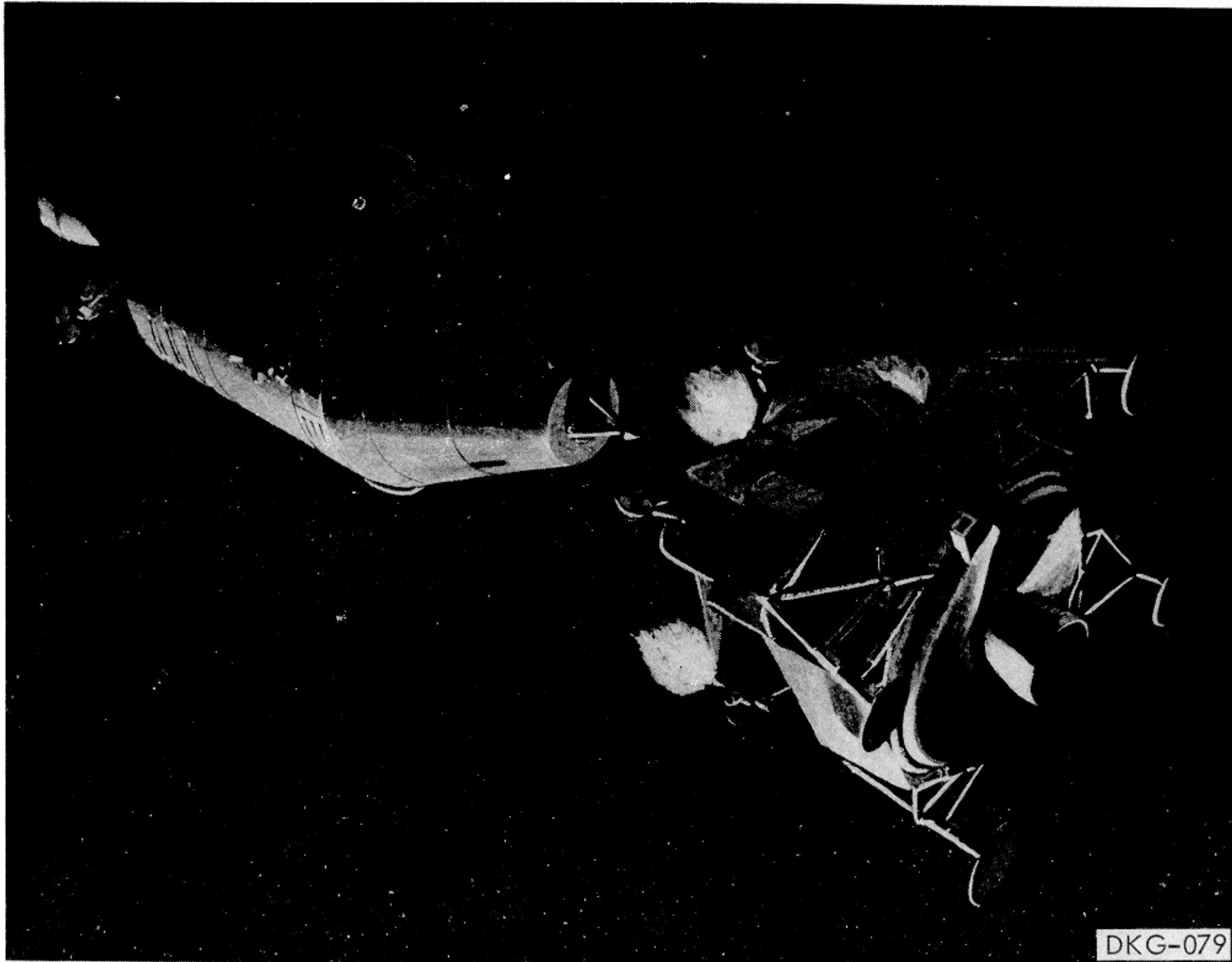


Figure 2.13-5. LM Separation From CSM

After landing, it will be several hours before the first man steps foot on the moon. They spend the first couple of hours checking the LM ascent stage. This completed, the cabin is depressurized and one of the crewmen descends to the lunar surface and walks on the moon. Following a period of crew transfer, the second crewman descends to the surface. They have many tasks to perform, including sample collections, photography, exploration of the lunar surface up to about 1/4 mile from the LM, and erection of a station that will continue to send scientific data to earth after they leave.

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Following completion of the lunar surface exploration the ascent engine is fired using the depleted descent stage as a launch platform (figure 2.13-6).



Figure 2.13-6. LM Ascent Stage Lunar Launch

After rendezvous and docking in lunar orbit, the LM crewmen transfer back to the CM (figure 2.13-7). After the CSM and LM pressures have equalized the LM crew opens the LM hatch while the CM pilot removes the tunnel hatch. The drogue and probe are removed and stowed in the LM. Lunar samples, film and equipment to be returned to earth are transferred from the LM to the CM; equipment in the CM that is no longer needed is put into the LM, and the LM hatch is closed, the CM hatch is replaced, and the seal checked.

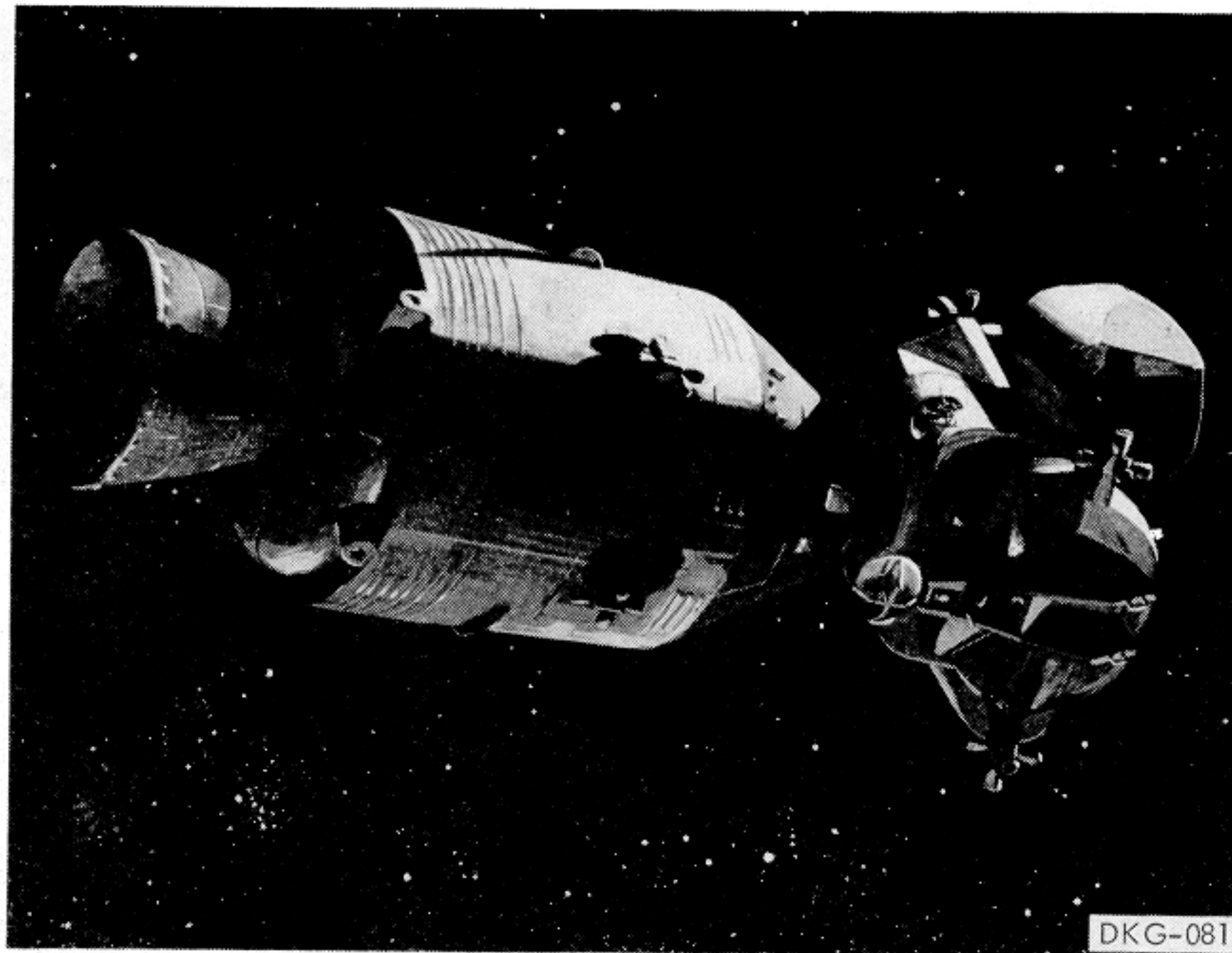


Figure 2.13-7. Post Lunar Docking Crew Transfer

The LM is then released by firing the separation system (detonating cord) located around the circumference of the docking ring, thus severing the ring and separating the LM (figure 2.13-8). This completed, the CM SPS engine is fired placing the spacecraft in a return trajectory toward the earth (figure 2.13-9).

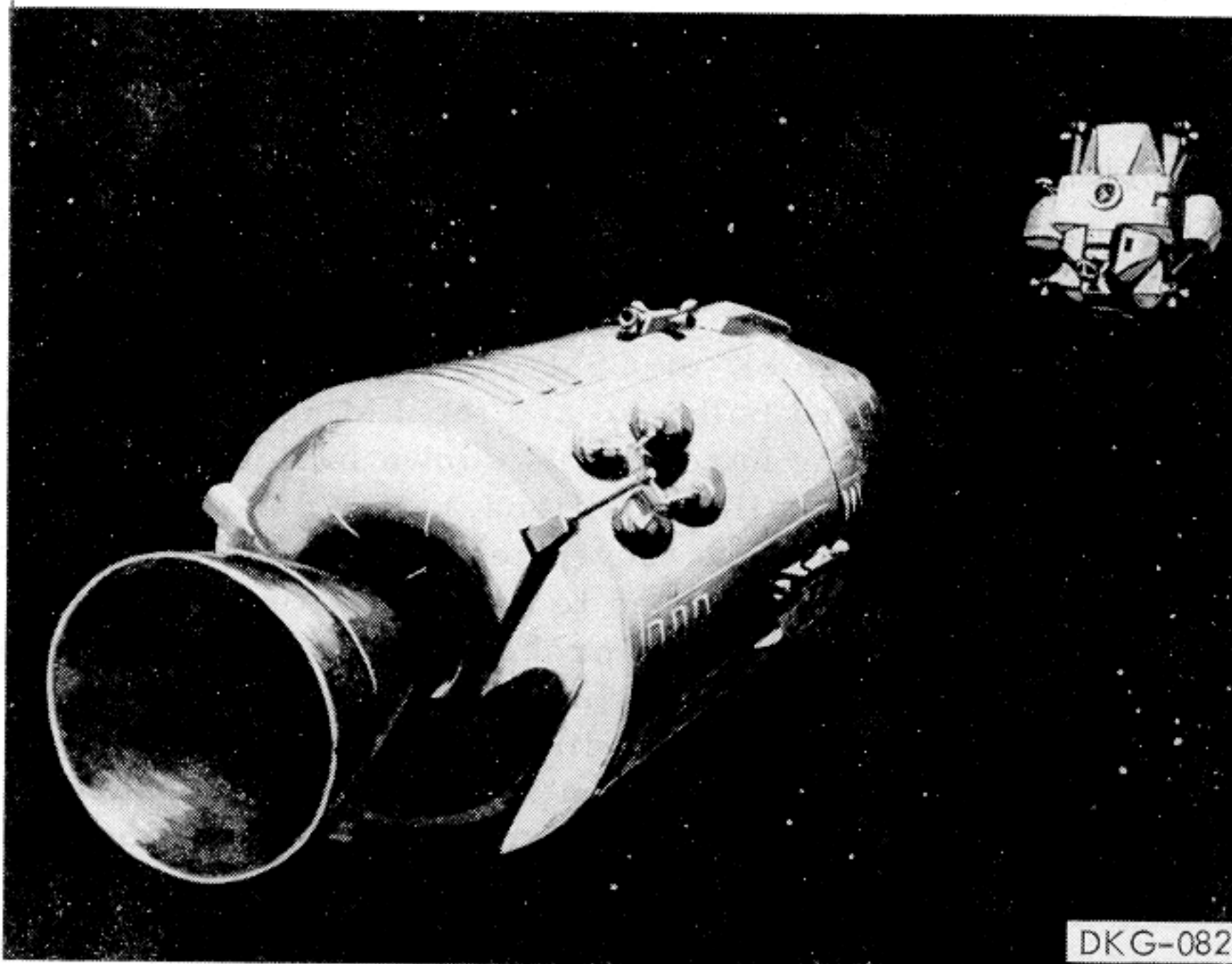


Figure 2.13-8. LM Ascent Phase Separation From CSM

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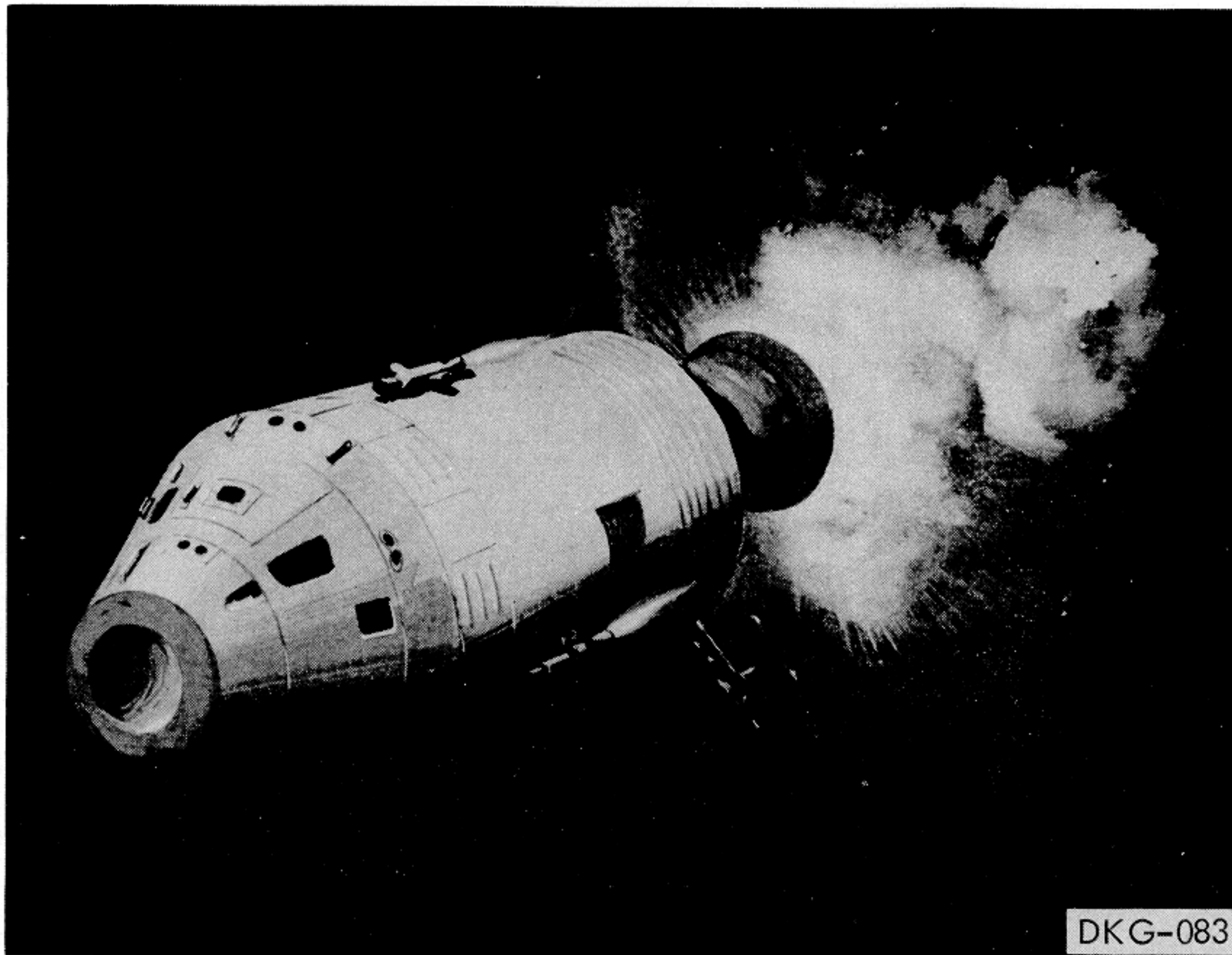


Figure 2.13-9. CSM Transearth Injection

2.13.2 FUNCTIONAL DESCRIPTION.

The docking system is a means of connecting and disconnecting the LM/CSM during a mission and of providing for intravehicular transfer between the CSM and LM of the flight crew and transferable equipment.

The crew transfer tunnel, or CSM/LM interlock area, is a passageway between the CM forward bulkhead and the LM upper hatch. The hatch relationship with the docking hardware is shown in figure 2.13-10. (The figure does not show the installed positions.) For descriptive purposes that portion of the interlock area above the CM forward bulkhead to the docking interface surface is referred to as the CM tunnel. The CM tunnel incorporates the CM forward hatch, probe assembly, docking ring and seals, and the docking automatic latches. That portion of the interlock outboard of the LM upper hatch extending to the docking interface surface is referred to as the LM tunnel and contains a hinged pressure hatch, drogue support fittings, drogue assembly, drogue locking mechanism, and LM/CM electrical umbilicals.

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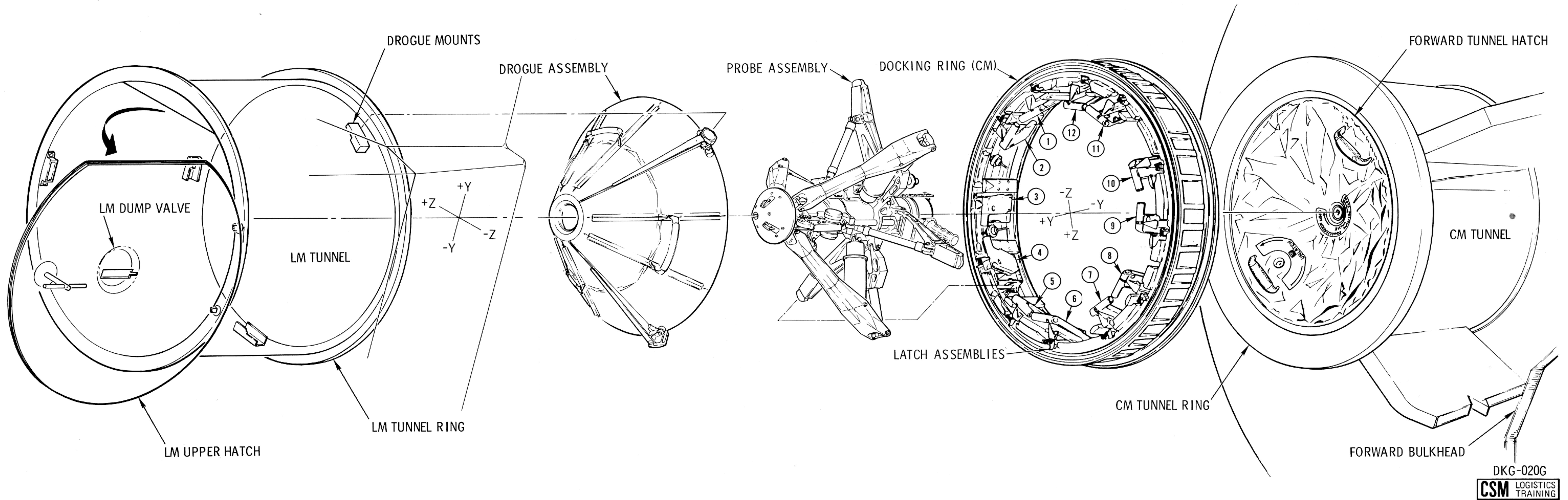


Figure 2.13-10. Docking System - Major Assemblies

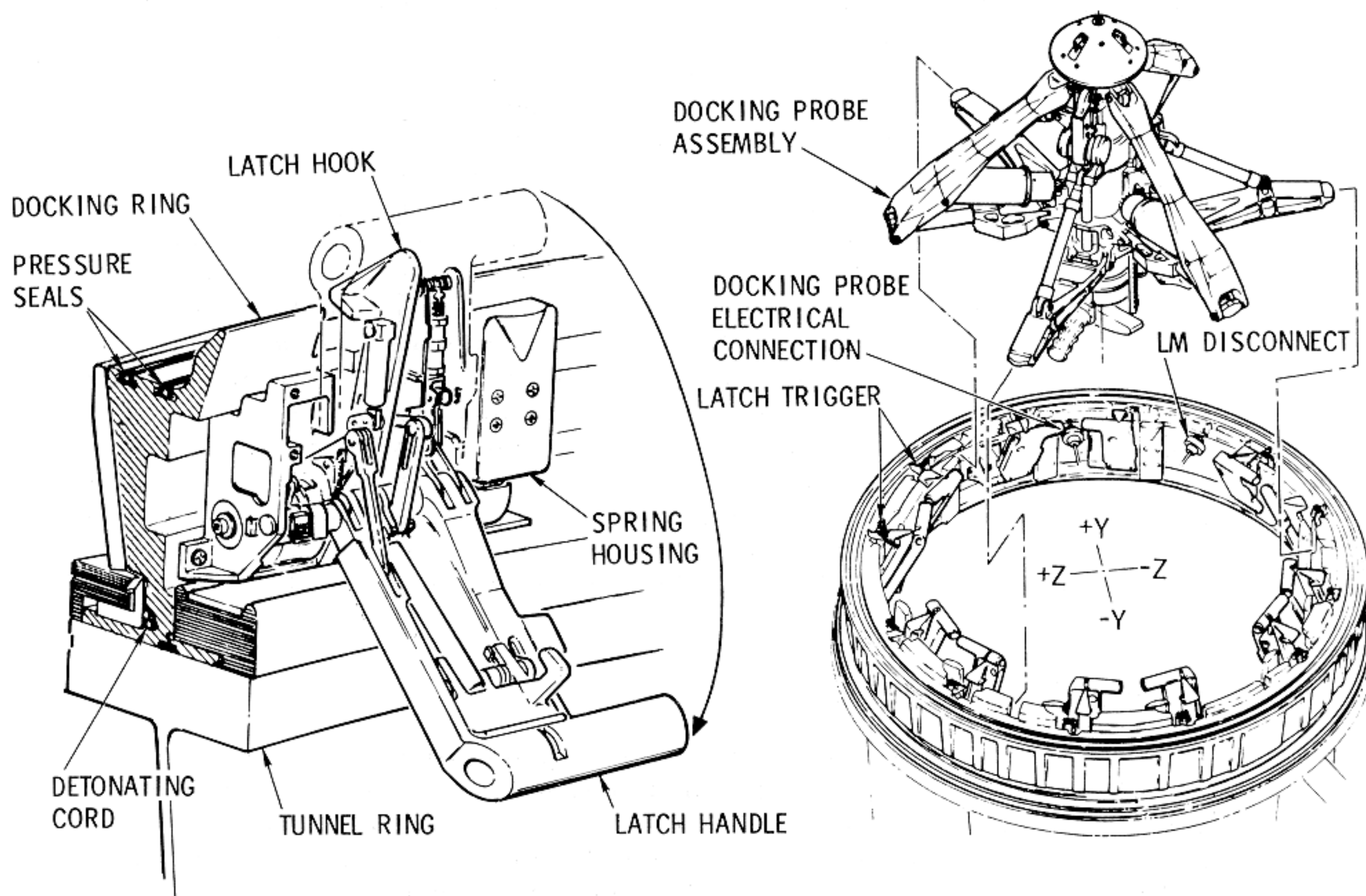
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2.13.3 COMPONENT DESCRIPTION.

2.13.3.1 CM Docking Ring.

The docking ring is mounted and bolted to the forward ring of the CM tunnel. The docking ring is capable of withstanding all interface loads and maintains the docked alignment of the modules.

The docking ring also serves as a support for the probe, the 12 automatic docking latches (figure 2.13-11), a pyrotechnic charge, passageway for the electrical harness, and the two interface seals. A continuous wire passageway and attachment covers are provided in the docking ring. The passageway is covered by a protective cover with an opening to allow the individual harnesses to enter or exit the passageway. The two concentric



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Figure 2.13-11. Automatic Docking Latches

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interface seals will enable pressurization of the crew tunnel and vented spacesuit operation within the tunnel. The docking seals are round and hollow; the inner seal is vented to the crew compartment pressure, and the outer seal is vented to ambient pressure. The seals are of sufficient size to allow for maximum warpage/waviness gap between the flanges. To remove the docking ring and attached hardware during CSM/LM final separation, or should an abort be initiated, a detonating fuse (MDF) is fired to sever the docking ring. During an abort, the severed ring and attached parts will be pulled away from the CM by the launch escape system (LES). The charge is initiated by a switch on the main display console (MDC) within the CM.

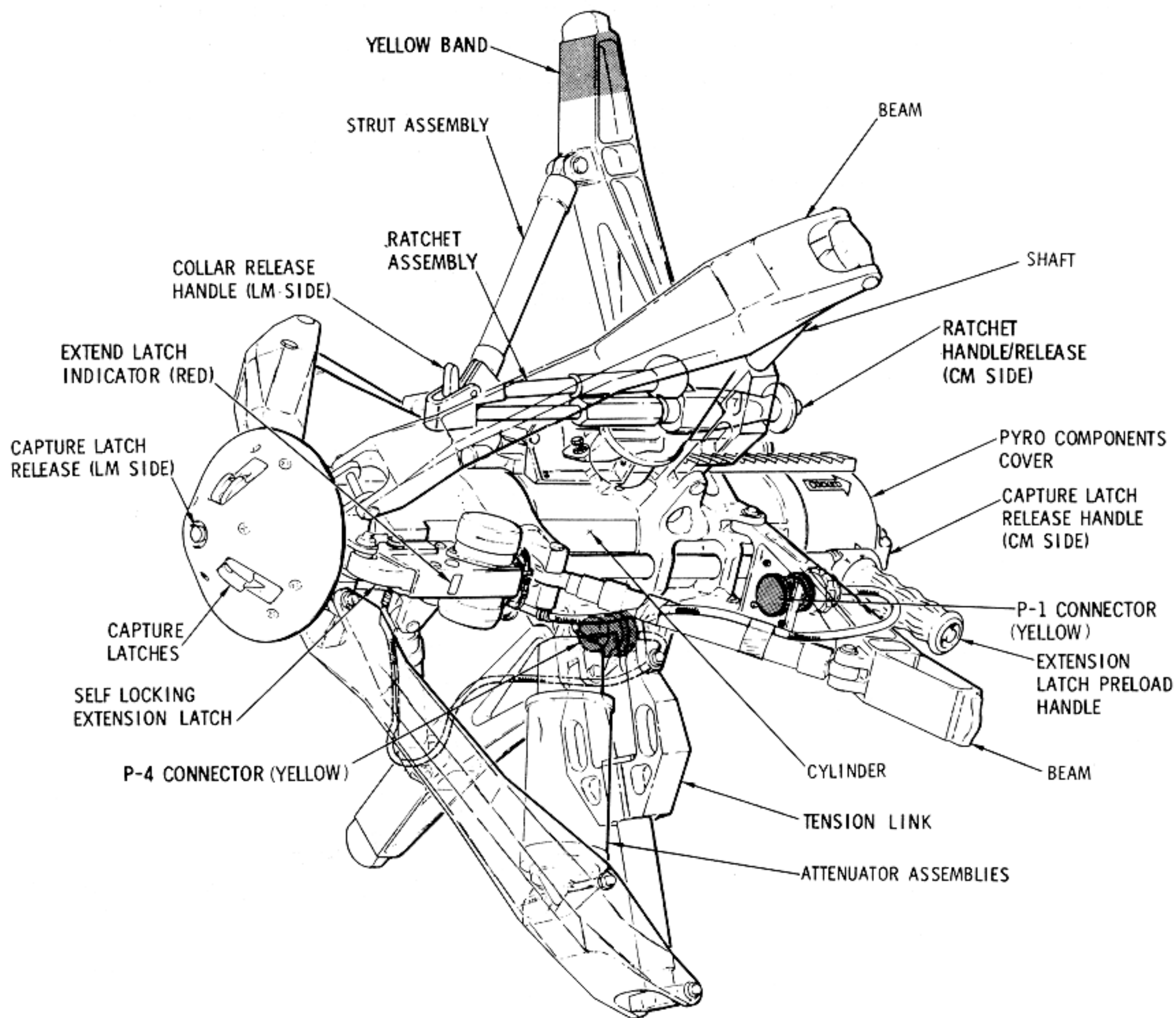
2.13.3.2 Docking Latches.

Twelve automatic locking latches are equally spaced about the inner periphery of the docking ring. When latched, they provide a means of effecting structural continuity and pressurization capability between the CSM and LM in the docked configuration. The docking latches will automatically self-seek and engage the LM docking flange back surface upon activation of the latch trigger mechanism when making contact with the LM docking flange. Should a latch be inadvertently triggered, the latch components will not prevent a successful LM and CM docking and sealing operations. A red button will protrude out of the handle indicating an unlocked condition. Any three latches located approximately 120° apart engaged and latched will hold the CSM and LM together with the tunnel pressurized. The individually triggered latch may later be rearmed and released manually by the crewman for CM to LM engagement. The latch mechanism will exert a preload or hook pulling force of 2700 pounds minimum. This preload force will retract the hook, seat the hook on the back of the LM docking flange, accommodate for flange warpage/waviness, and compress the docking seals. Release of the latch will be accomplished by the crewman pulling the individual latch handle for a double throw. The release of the latch will also cock the latch for the next docking engagement. Fairings are installed in the area between the latches providing a smooth inner mold line.

2.13.3.3 Docking Probe Assembly.

The primary function of the docking probe assembly is to provide initial vehicle CSM/LM coupling and attenuate impact energy imposed by vehicle contact. The docking probe assembly (figure 2.13-12) consists of a central body, probe head and capture latches, pitch arms and tension linkages, shock attenuators, ratchet assembly, support structure, extension latch and preload torque shaft, probe retraction system, probe electrical umbilicals, and the electrical circuitry necessary to accomplish the functions described herein. The docking probe may be folded for removal and stowage and is capable of being removed from either end of the crew transfer tunnel.

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Figure 2.13-12. Probe Assembly Docking System

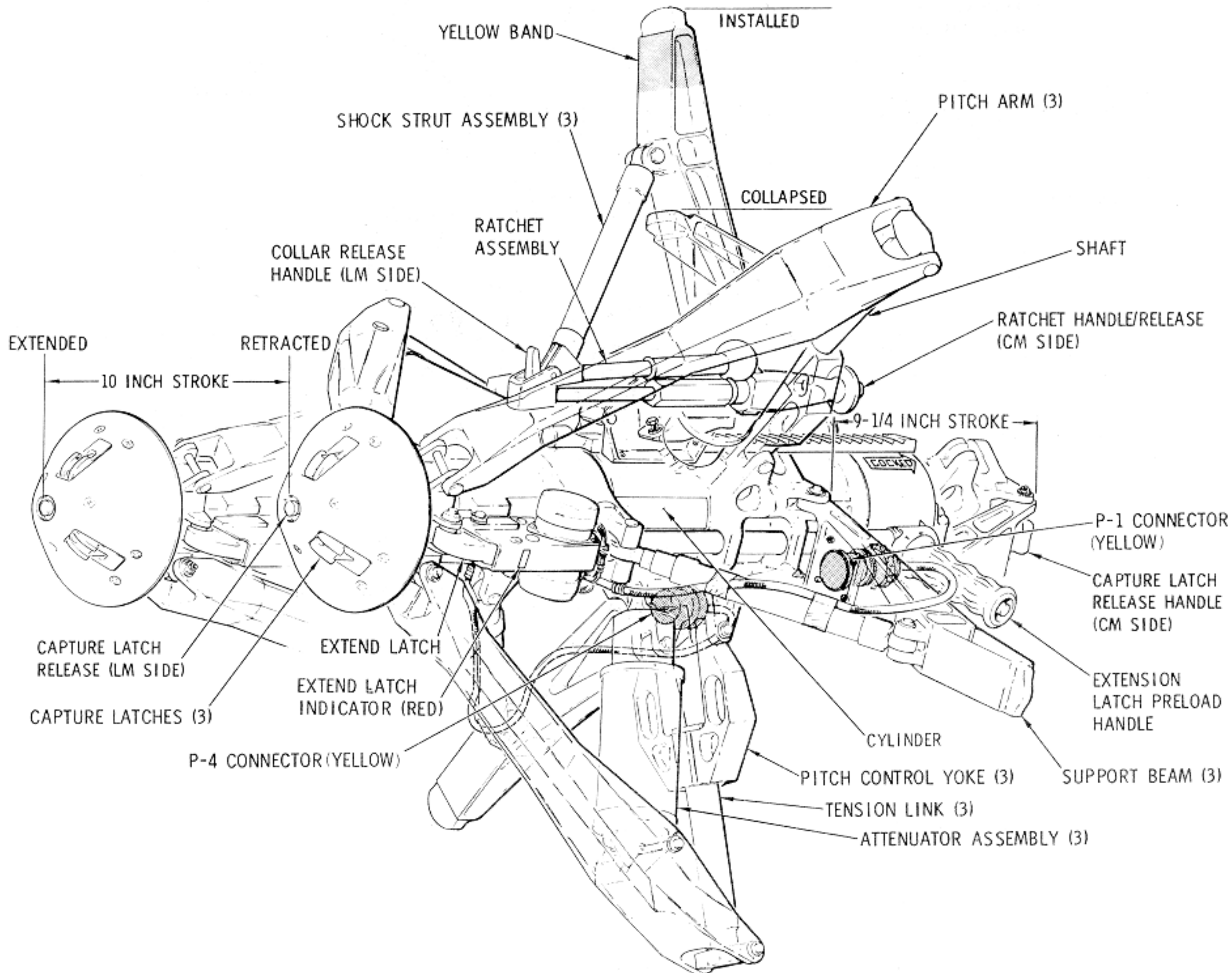
2.13.3.3.1 Support Structure.

The probe is tripod-mounted to the docking ring by a support structure attached to the outer collar of the probe. The supports are designed to collapse (fold) to allow removal of the probe from either module. (See figure 2.13-13.) Collapse of the probe consists of reducing the diameter of the three mount legs to approximately 24-3/4 inches in diameter making the probe small enough for passage. This is accomplished by unlatching the collar with the ratchet handle and allowing the collar to slide aft approximately 9-1/4 inches on the probe cylinder. Connected between each support leg and the probe cylinder is a semi-rigid shock strut assembly (see figure 2.13-13). The strut assemblies contain Bellville washers which help in attenuating the high lateral loads. The washers are

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concave in shape and are arranged to provide a rigid strut in tension and a high rate of spring action in compression. One of the support legs is marked yellow to correspond with a matching color on the docking ring socket fairing. The probe installation support strut is stowed on the yellow support beam, whereas the other two support legs contain stowage receptacles for the probe umbilicals.



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Figure 2.13-13. Probe Operational Positions

2.13.3.3.2 Pitch Arms and Tension Linkages.

The pitch arms will make contact with the drogue surface during the probe retraction cycle if the CM and LM tend to jackknife. The tension links transmit the pitch arm loads and torque loads to the probe outer

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cylinder during an axial displacement. Together the pitch arms and tension linkage induce the required kinematics causing compression of the shock attenuators, attenuating the loads necessary to meet the docking requirements (figure 2.13-14).

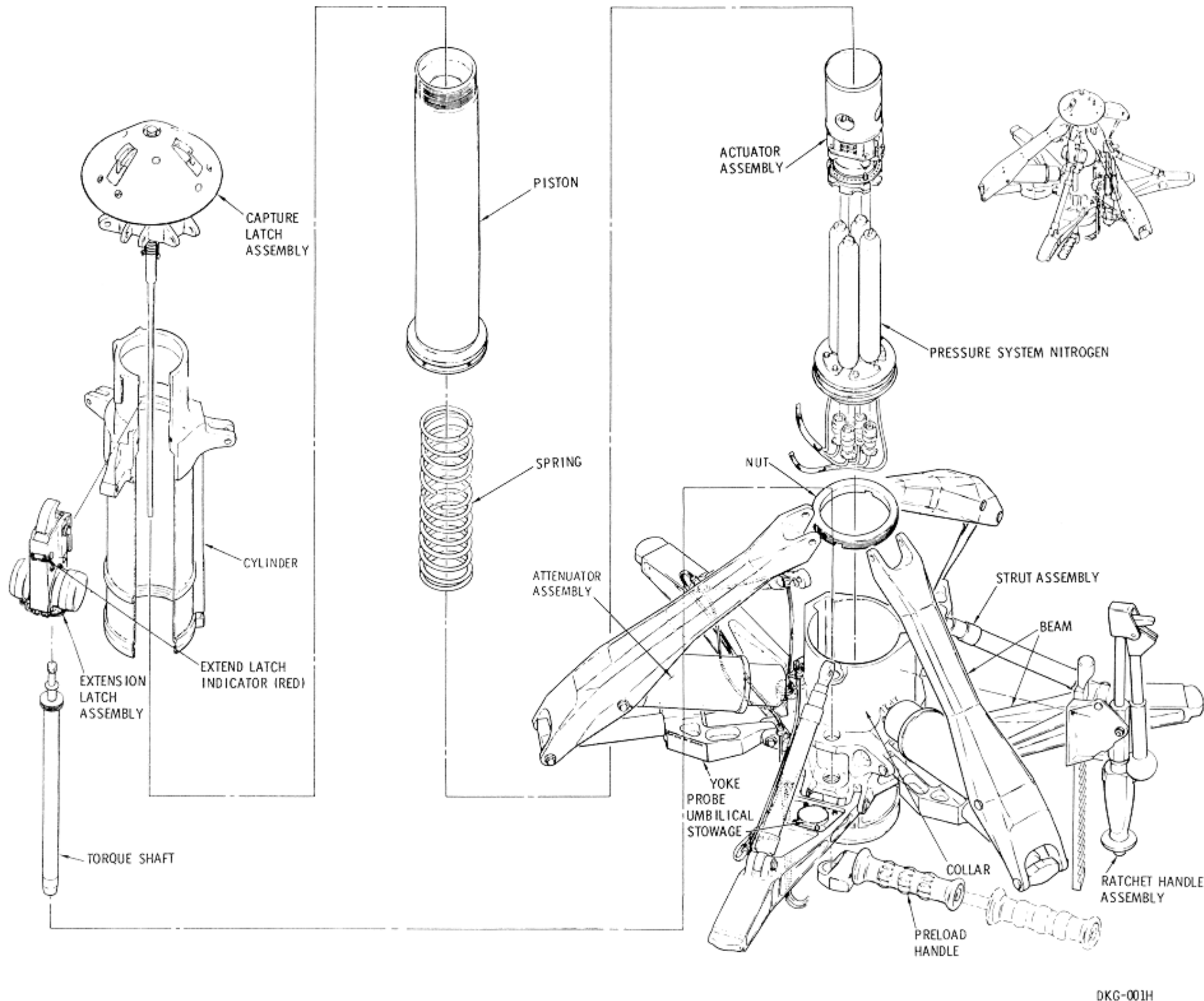


Figure 2.13-14. Exploded View - Probe Assembly

2.13.3.3.3 Shock Attenuators.

The shock attenuators are piston, variable-orifice, fluid-displacement type units (figure 2.13-15). The attenuators are attached to the probe assembly so that all axial loads or side loads will be attenuated to or below the required level for the docking mechanism. The attenuator cylinders are filled with a Orinite 70 fluid at a temperature of  $70 \pm 3^\circ\text{F}$ .

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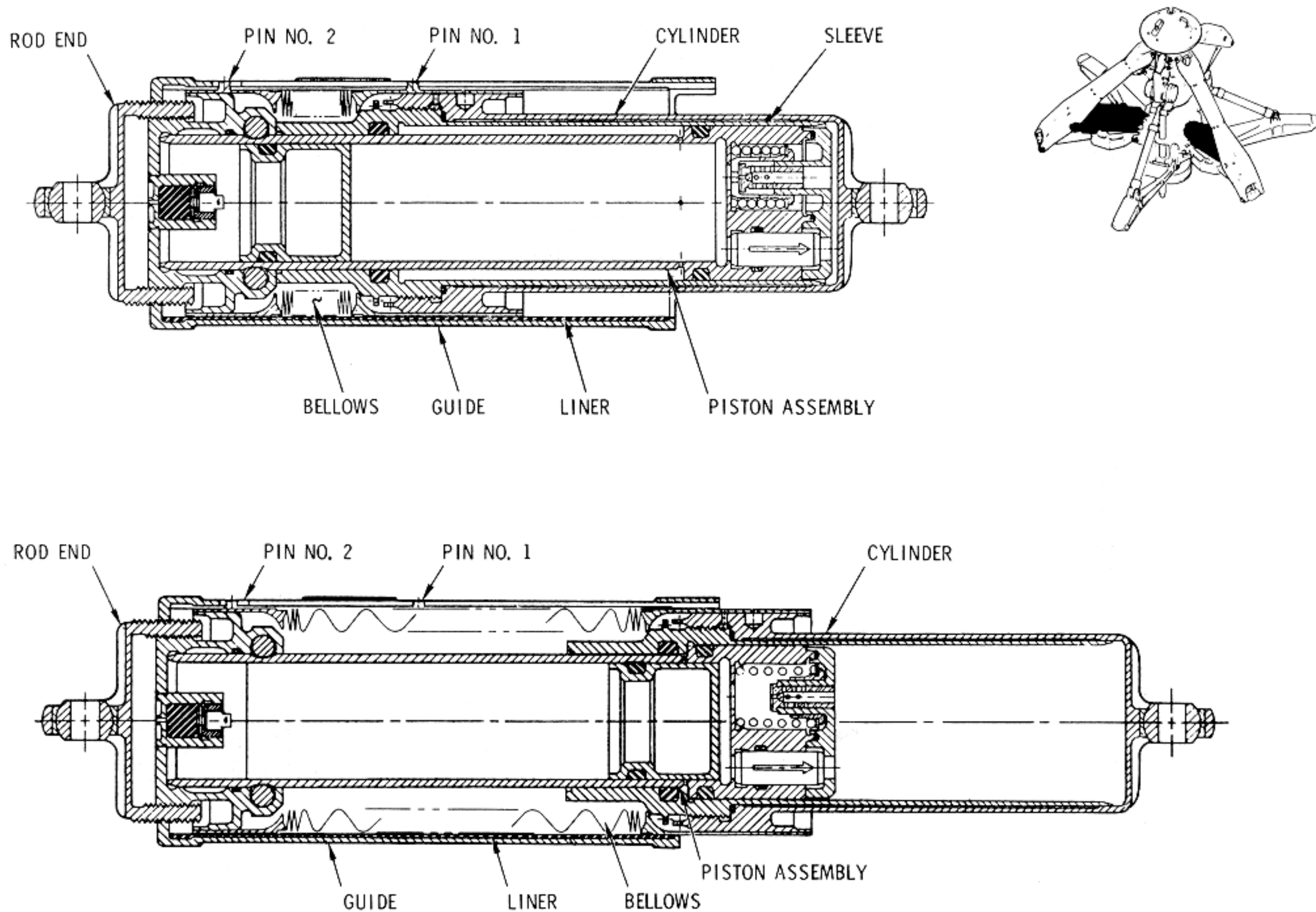
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Figure 2.13-15. Docking Probe Attenuator Assembly

With the piston assembly extended a mixture of argon and helium gas is inserted through a plug located under the rod end. The gas is injected with the aid of a hyperdermic needle to a pressure of  $30 \pm 3$  psig at  $70 \pm 5^\circ\text{F}$ . The purpose for pressurizing with gas is to provide an air spring and pressure for attenuator extension. This stored energy within the attenuators will cause the collar assembly to move aft when released, pulling the support structure from its mount.

2.13.3.3.4 Probe Body—Extension Latch Assembly.

The probe body consists of an inner and outer cylinder, sized to allow a 10-inch maximum travel of the inner cylinder (figure 2.13-12). Attached to the probe body is an extension latch which will engage and

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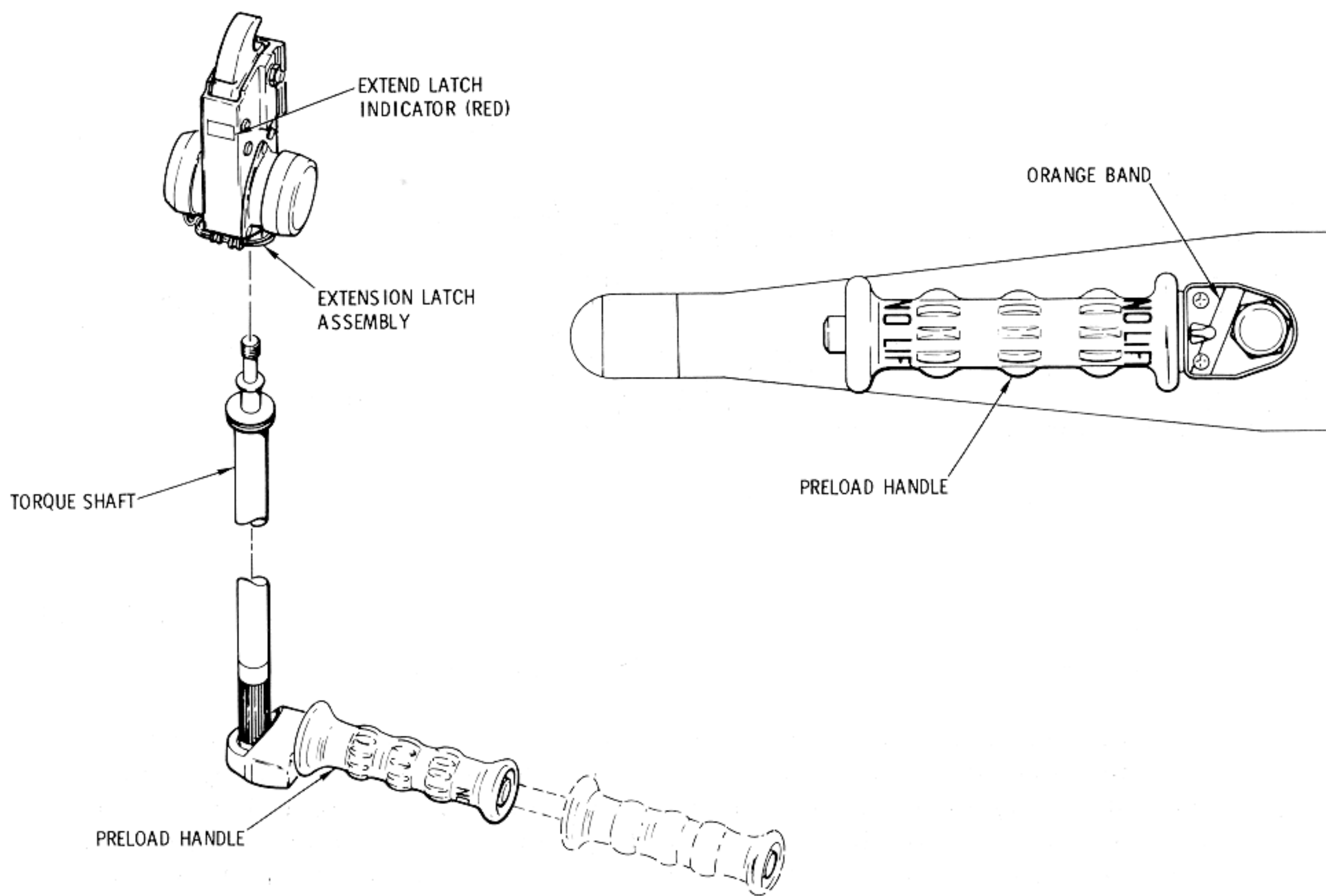
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retain the probe in the fully retracted position (figure 2.13-16). The large coil spring located within the inner cylinder will extend the probe upon release of the extension latch.

Located within the preload torque shaft is a spring allowing the extend latch to be free-floating and self-locking. This assures automatic capture of the probe piston by the extension latch when the probe retracts. An indicator is provided to indicate a fully engaged latch. The indicator (red) protruding above the housing shows that the hook has not fully engaged the roller on the probe piston. If this situation exists, the extend latch assembly can be altered by applying a CCW ratchet torque extending the latch assembly until the indicating pin retracts.



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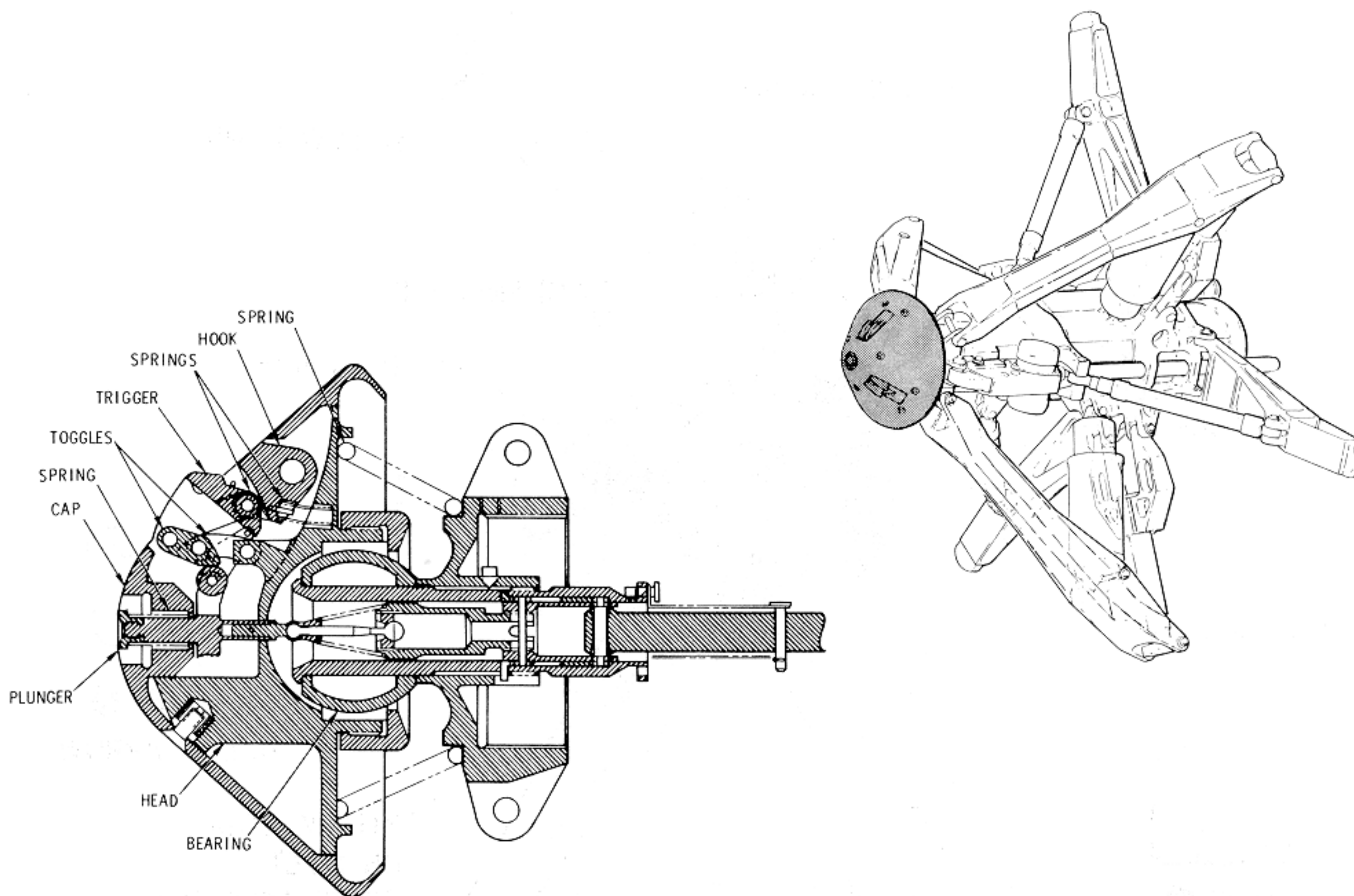
Figure 2.13-16. Extension Latch Assembly

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Prior to separation in lunar orbit the probe is pre-loaded with the extend latch assembly to maintain tunnel pressurization while the 12 docking latches are released and cocked. To preload the probe the ratchet selector is positioned on the preload handle so that the ratchet will rotate clockwise. The handle is ratcheted until the load limiter releases.

2.13.3.3.5 Probe Head - Capture Latches.

The probe head is self-centering and is gimbal-mounted to the piston of the probe assembly (figure 2.13-17). It houses the capture latches and is designed so that the probe head will deflect toward the drogue socket through all contact attitudes within the design parameters. The capture latches will automatically engage the drogue socket when the probe head centers and bottoms in the drogue. The capture latches are capable of



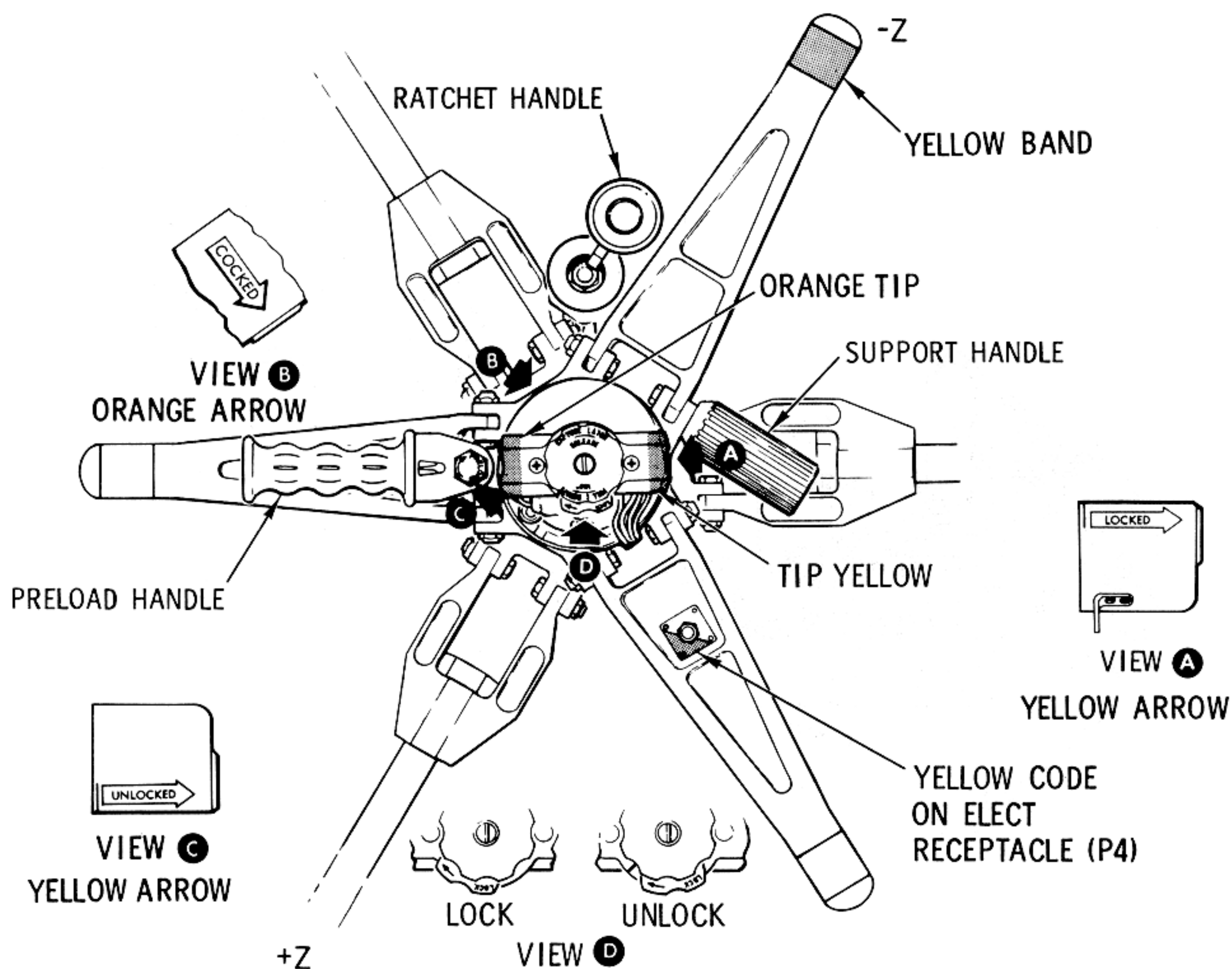
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Figure 2.13-17. Probe Capture Latch Assembly

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remote and manual release from the CM side, and manual release from the LM side. Release of the capture latches will permit withdrawal or insertion of the probe head assembly. Electrical release is accomplished by switching power through probe umbilicals to motors within the probe body (figure 2.13-14) causing the torque shaft to rotate and allow release of the latches. Manual release of the capture latches from the CM side is accomplished by a built-in release knob and handle on the CM side of the probe. (See figure 2.13-18.) In unlocking the capture latches, the capture latch release knob and handle is pulled aft 1/2 inch and rotated 180 degrees CW. This can be accomplished only with the probe piston in the retract position. When the probe is being collapsed, the probe collar contacts the release handle, which in turn will telescope and remain operable with the probe installed or folded. (See figure 2.13-19.) The capture latch release handle must be rotated fully CCW to an indicating arrow to make the capture



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Figure 2.13-18. Aft View Docking Probe

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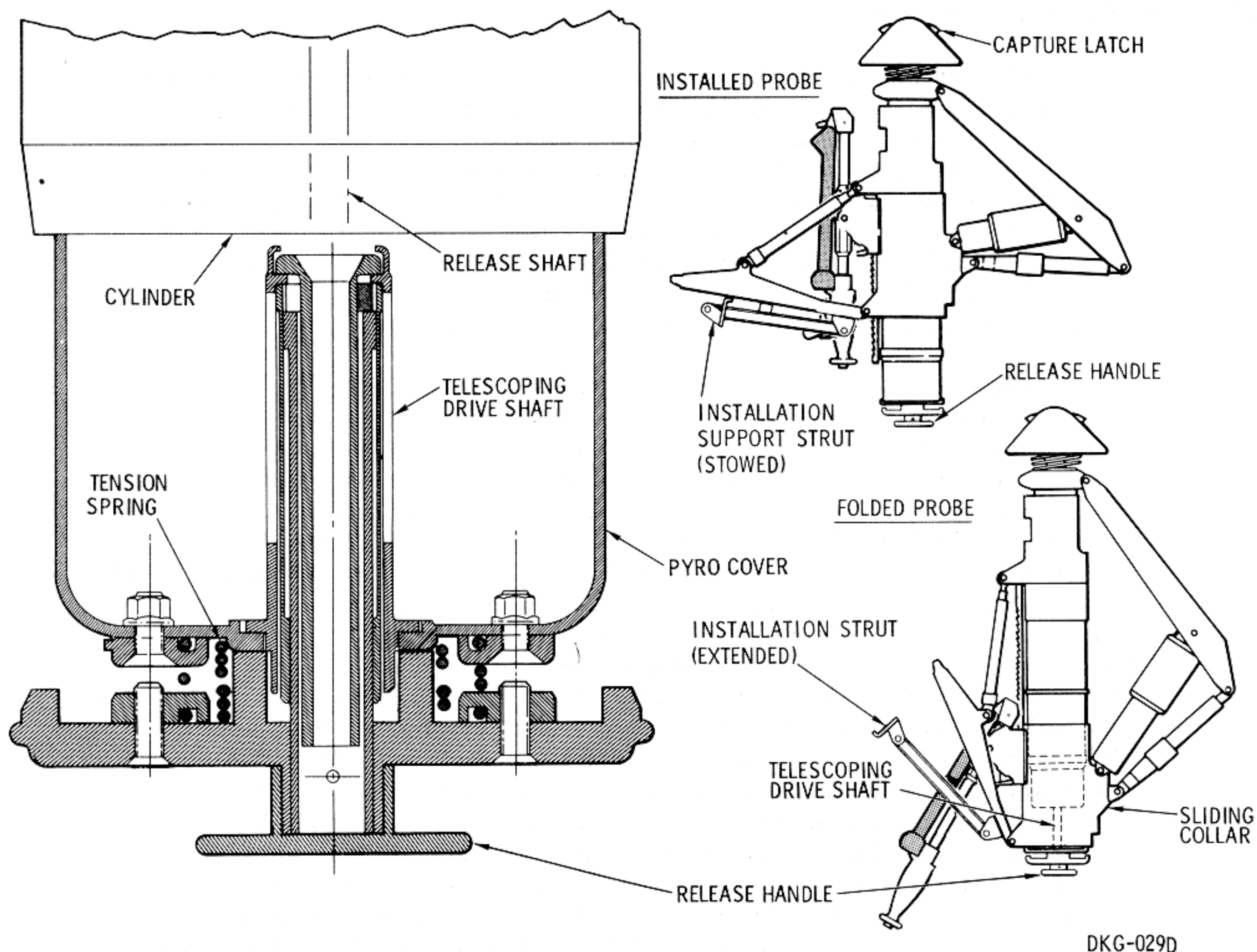


Figure 2.13-19. Capture Latch Release

latches "cocked." This means the capture latches will capture when all three latches have penetrated the drogue ring simultaneously. Release of the capture latches from the CM side is accomplished by depressing the capture latch release plunger approximately 5/16-inch below, flush with the probe head by using tool B of the CM-LM tool set.

If the retracted position is selected on the RETRACT EXTD/REL switch located on MDC-2, capture latch engagement will close a switch within the probe, initiating operations of the retraction mechanism.

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2.13.3.3.6 Ratchet Assembly.

The integrated ratchet assembly provides a handhold for handling the probe, assists in installing and removing the probe assembly, and performs the ratcheting operation that slides the collar forward or aft, extending or collapsing the probe pitch and support arms (figure 2.13-20). The ratchet assembly will lock/unlock the sliding collar by pivoting the handle away from the probe centerline either from the CM or LM side. The jack handle is stowed and locked by a lug which engages the handle on the CM side. A release button is provided on the CM handle and a trigger release on the LM handle to unlock the ratchet assembly.

Figure 2.13-21 shows the various ratchet handle positions for probe removal and installation. View A shows the jack handle and ratchet assembly in the locked and stowed position. View B shows the 30-degree stroke required to unlock the sliding collar from the CM side. To unlock the sliding collar from the CM side, grasp the jack handle at the CM end, depress the slide release button, and pull the handle all the way aft. Secondly, push the handle forward to the first detent and swing the handle out 30 degrees from the probe centerline. In the last 5 degrees of pivoting, the pawls are lifted from the rack, the collar will slide aft, and the probe will collapse because of the spring and attenuators stored energy. View C shows the unlocking operation from the LM side. First, depress the release button on the LM side of the jack handle and push aft to the first detent. Second, unstow the foldable lever by pulling on the handle knob and rotate the lever upward against the stop. Third, rotate the handle assembly inboard until the collar is released. Again hold the knob until the probe folds. View D shows the 25-degree stroke used when installing the probe. After the probe is locked in the drogue, unstow the support strut located on the support beam, and position against the ledge on the tunnel hatch seal ring. Pull the jack handle to its extreme aft position. Grasp the support handle with the left hand and with the right hand jack the probe collar forward extending the support legs into the three support sockets in the CM docking ring. While pumping the handle, maintain a thrust load on the tunnel ring through the support strut. The maximum push force on the handle should not exceed 60 pounds for the working stroke of 25 degrees. Installation is complete when the collar uncovers a cross-hatched area on the probe conduit. To ensure the operator that the pawls are seated in the rack, a pawl indicator is located on the ratchet mechanism. (See figure 2.13-20.) Operation is complete when the indicating button is flush with the housing. With the probe installed, stow the handle by holding it parallel with the centerline of the probe and by depressing the button release while thrusting the handle toward the probe head. The socket of the handle will lock on a lug and prevent further handle movement.

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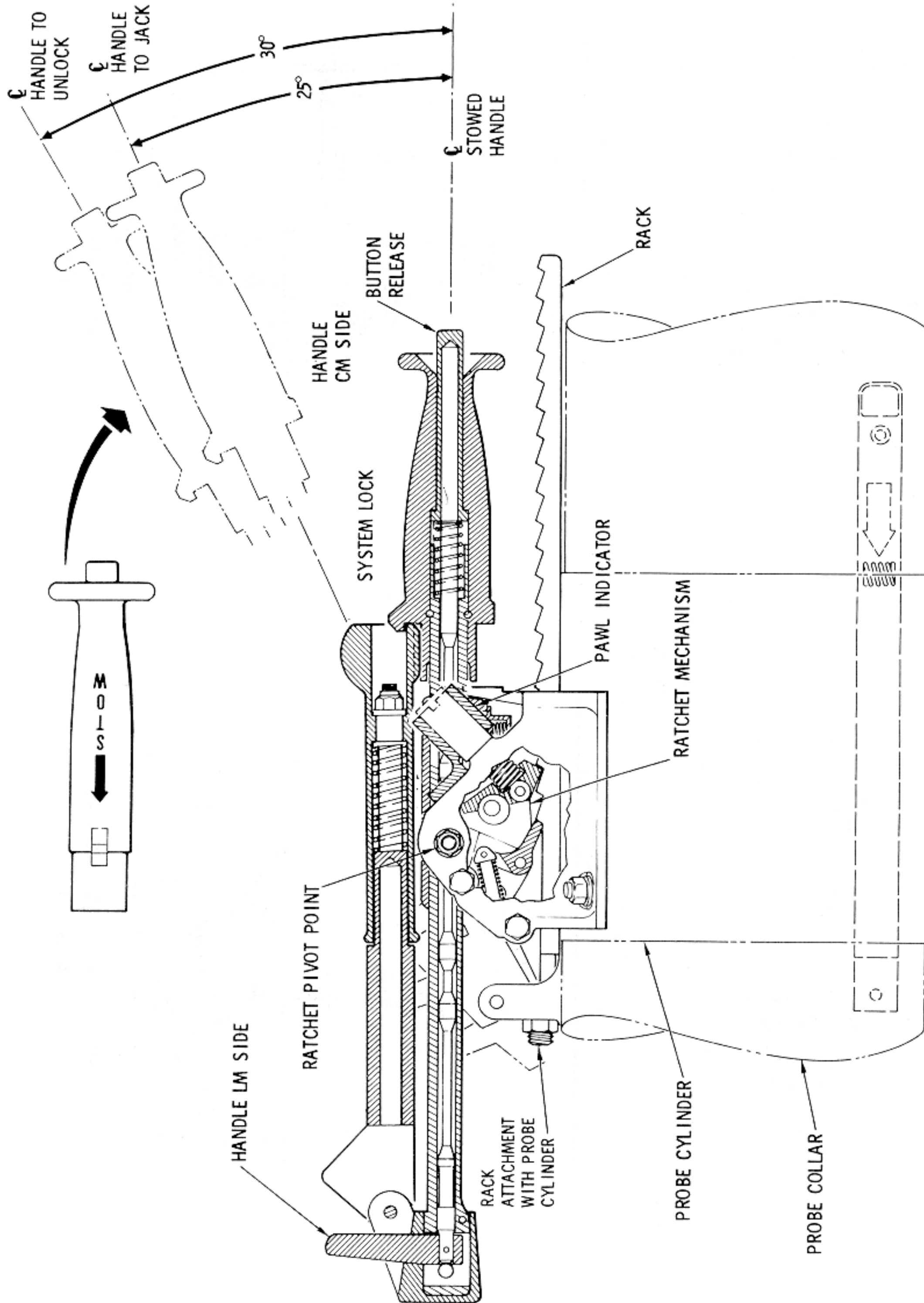
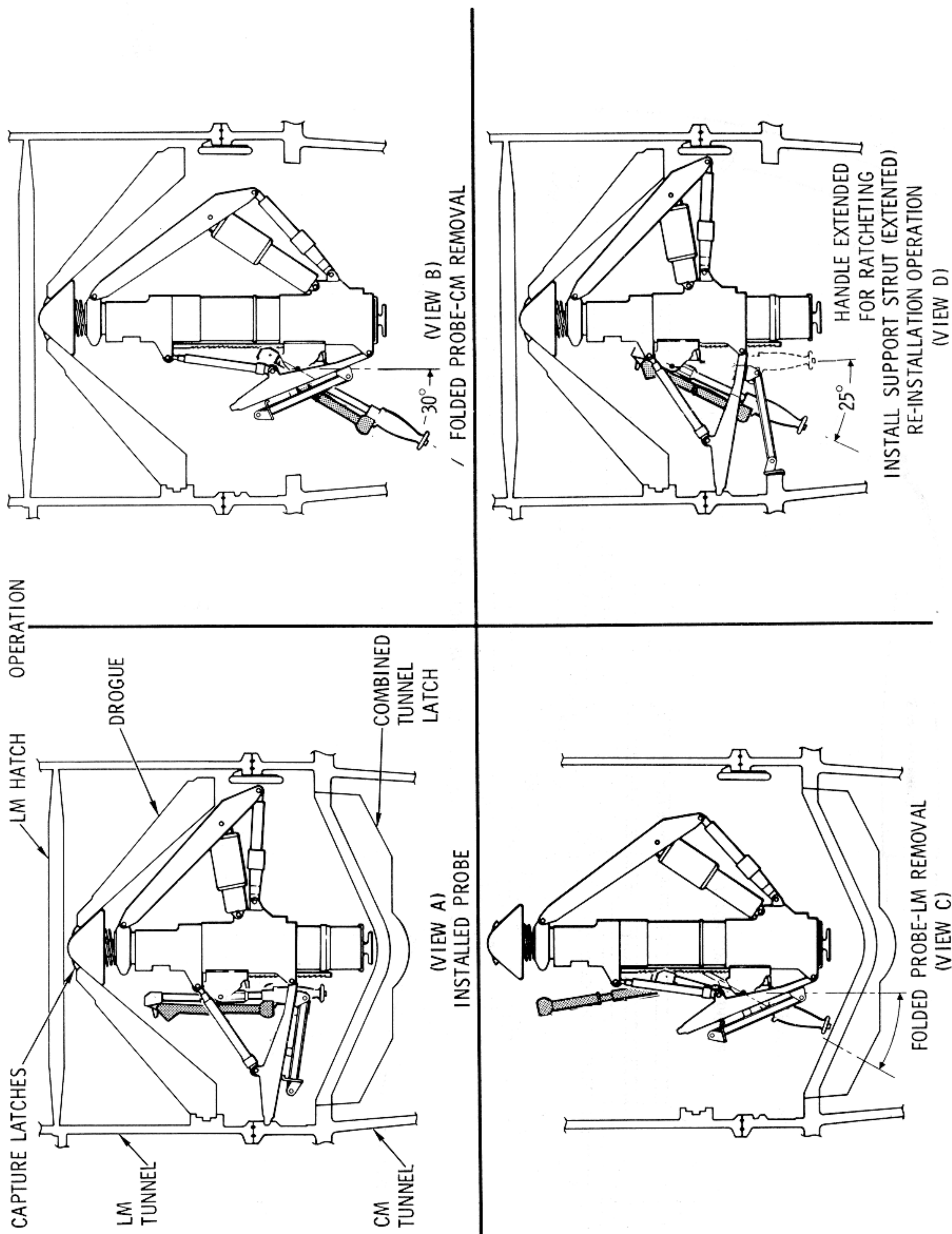


Figure 2.13-20. Integrated Ratchet Assembly

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Figure 2.13-21. Integrated Ratchet Assembly Operation

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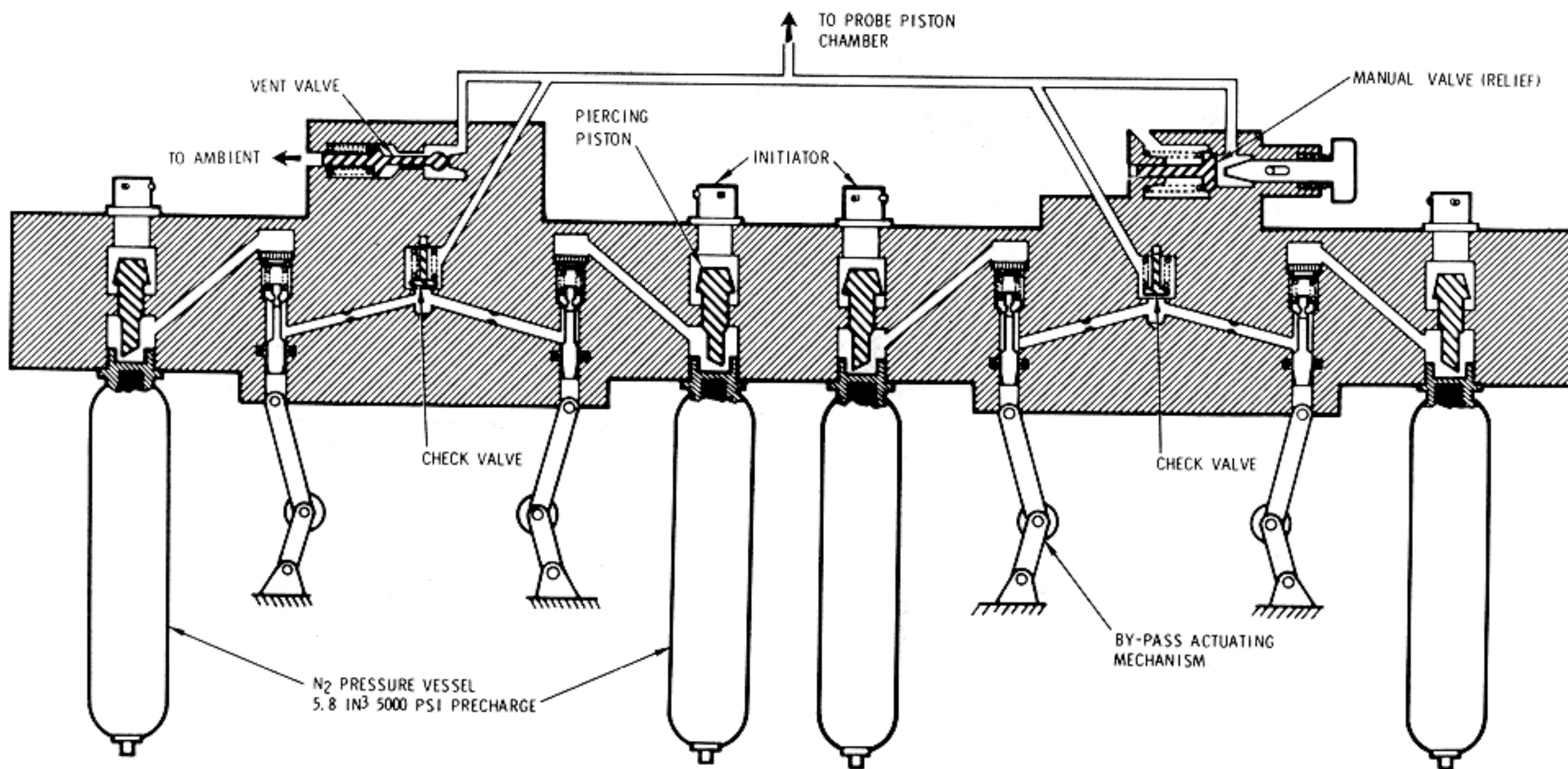
2.13.3.3.7 Retraction System.

The retraction system consists of a cold gas system pressurized from four hermetically sealed nitrogen bottles located inside the probe body (figure 2.13-22). Gas pressure is released when pyrotechnic ignition is initiated manually by a crewman within the CM or automatically by capture latch action. Releasing the nitrogen gas causes the inner piston to retract. The retraction force is sufficient to draw the modules together, compress the interface seals, and allow engagement of the automatic locking latches.

The residual gas will be bled off by the astronaut allowing the probe to extend when the extend-latch is energized. Pressure release is accomplished by a manual relief valve located as part of the gas manifold. This valve is opened by depressing a red thumb button on the aft end of the probe. The button and pyro components are protected from handling damage by a protective cover.

2.13.3.3.8 Probe Umbilicals.

Two microdot connectors and harness assemblies are provided for probe instrumentation and probe logic power. The connectors are installed normal to the docking ring so they are visible and can be demated and mated from either the CM side or the LM side of the combined vehicles (figure 2.13-23). The connectors utilize a notched



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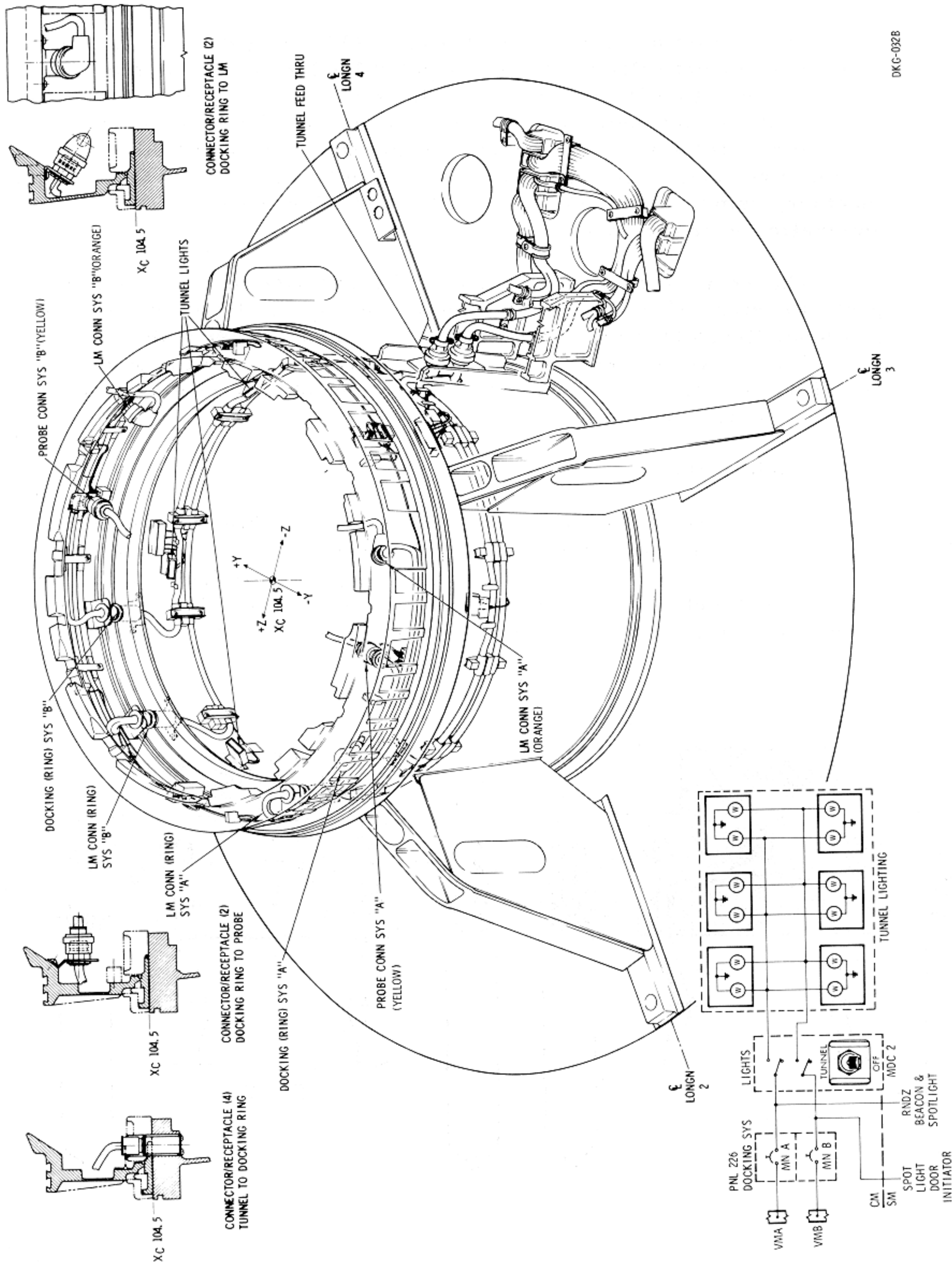
Figure 2.13-22. Probe Retraction System

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Figure 2.13-23. Tunnel Lighting and Electrical System

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handle that will provide a positive grip for twist and pull action. Part of the connector and the probe harness may protrude into the tunnel when the probe is installed, but when the probe is removed the fixed portion of the connector will be covered by a hinged protective cover. This provides a smooth surface for crewman passage through the tunnel. When disconnecting or reconnecting the probe electrical connectors from the CM side, the EXT/REL-OFF-RETRACT switch should be in the OFF position, and CB2 on panel 276 open, to assure that no instrumentation power exists.

2.13.3.4 Drogue Assembly.

The drogue assembly consists of an internal conical surface facing the CM, a support structure and mounting provisions that interface with three mounts in the LM tunnel. One of the tunnel mounts contains a locking mechanism to secure the drogue and prevent it from turning during the docking maneuvers. Unlocking and removing the drogue may be accomplished from either end of the crew transfer tunnel. To aid in the removal and installation, three handles are provided on the LM side (figure 2.13-24).

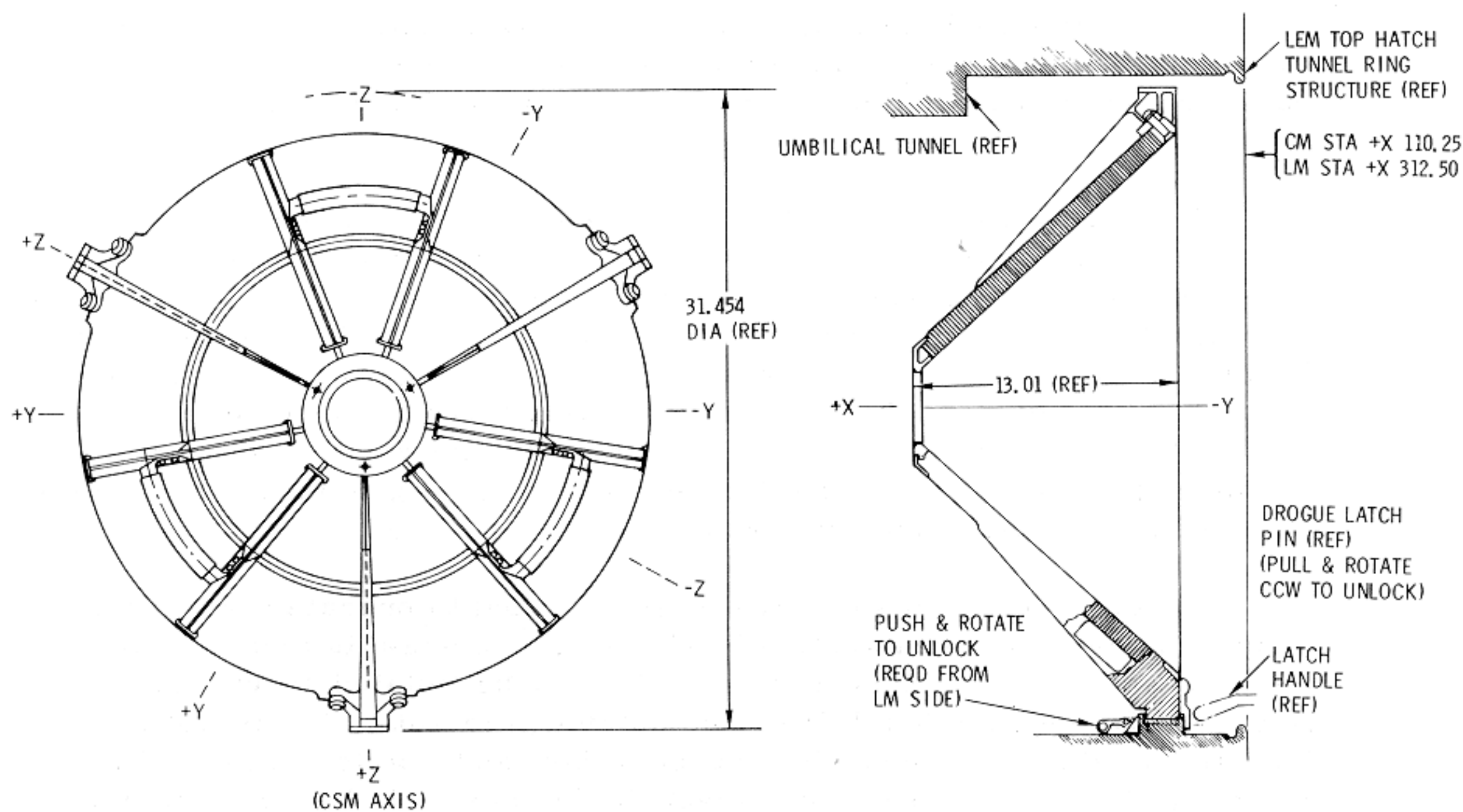


Figure 2.13-24. Drogue Assembly

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2.13.3.5 Vehicle Umbilicals.

Two electrical umbilicals are installed in the LM tunnel at launch. One end is attached to the LM connectors, the other end routed and attached to stowage connectors on the LM tunnel wall. These stowage connectors are physically clear of the drogue supports and probe supports and pitch arms. The connectors are accessible from the CM tunnel between the drogue periphery and the LM tunnel wall. In this manner CM connections can be accomplished after transposition and docking, without requiring probe or drogue removal. (See figure 2.13-23.)

2.13.3.6 Forward Tunnel Hatch.

The forward hatch in the CM tunnel enables crew access to the LM-CM interface and may be used for emergency egress after postlanding. (See figure 2.13-25.) The hatch is removable only into the crew compartment. The reinforced flange on the forward tunnel ring for the pressure seal and latch engagement prevents an outward removal. The hatch is retained at the forward end of the CM tunnel by six separate jointed latches whose linkage is driven by an actuating handle from within the crew compartment. A drive is provided on the LM side (outside) opposite the actuating handle drive, permitting hatch removal by using the B tool of the in-flight tool-set. A pressure equalization valve, which can be opened or closed from either side, is provided on the hatch. This valve is used to equalize pressure in the tunnel and LM prior to hatch removal.

A single activating handle is provided to open or close the hatch. This actuating handle is an integral part of the gear box and requires only one hand for operation. Manipulating the actuating handle will extend or retract the six latches (figure 2.13-26). The operating distance of the handle is approximately 80 degrees. The working stroke to operate the latches is only 60 degrees. The handle has a three-position selector L-N-U (Latch-Neutral-Unlatch). A sturdy aluminum cover supporting the insulation and covering the latches is provided to minimize the possibility of condensation and ice formation.

An auxiliary means of latching is provided to operate the latches should the gear box or actuating handle fail. To use this means of latching, the gear box is disconnected and the ring rotated to engage the latches. To open the hatch from the outside (LM side), the B tool is inserted in the drive opposite the gear box and rotated CCW. Total rotational travel necessary to retract the latches is 167 degrees with the first 30 degrees disconnecting the gear box. Two hand holds for handling are attached to the ablator on the outside.

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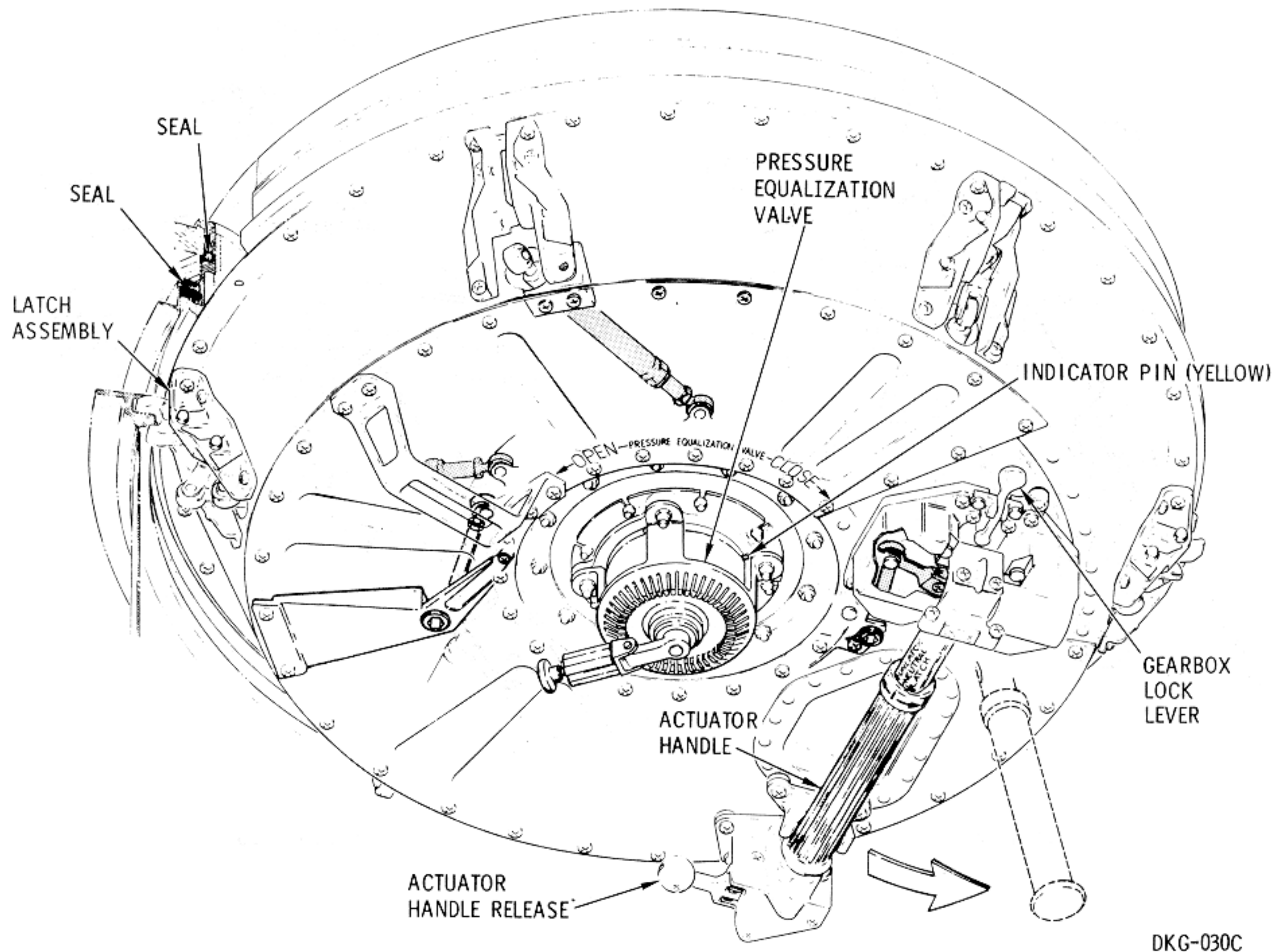


Figure 2.13-25. Forward Pressure Hatch

2.13.3.7 LM Tunnel Hatch.

The LM hatch is not removable but is hinged to open 75 degrees into the LM crew compartment. (See figure 2.13-10.) A hatch operating handle is provided on each side of the hatch on a common shaft. The LM upper hatch is opened by rotating the handle approximately 90 degrees clockwise from the CM side, counterclockwise from the LM side. Handle rotation in the opposite direction is required to re-engage the latching mechanism. A pressure dump (equalization) valve, manually operable from either side, is provided in the LM upper hatch. This valve is basically required for pressure dump capability from the LM cabin.

DCT