SECTION 2

SUBSECTION 2.9

SEQUENTIAL SYSTEMS

2.9.1 INTRODUCTION.

Sequential systems include certain detection and control subsystems of the launch vehicle (LV) and the Apollo spacecraft (SC). They are utilized during launch preparations, ascent, and entry portions of a mission, preorbital aborts, early mission terminations, docking maneuvers, and SC separation sequences. Requirements of the sequential systems are achieved by integrating several subsystems. Figure 2.9-1 illustrates the sequential events control subsystem (SECS) which is the nucleus of sequential systems and its interface with the following subsystems and structures:

- Displays and controls
- Emergency detection (EDS)
- Electrical power (EPS)
- Stabilization and control (SCS)
- Reaction control (RCS)
- Docking (DS)
- Telecommunications (T/C)
- Earth landing (ELS)
- Launch escape (LES)
- Structural

2.9.1.1 Sequential Events Control Subsystem.

The SECS is an integrated subsystem consisting of twelve controllers which may be categorized in seven classifications listed as follows:

- Two master events sequence controllers (MESC)
- Two service module jettison controllers (SMJC)
- One reaction control system controller (RCSC)
- Two lunar module (LM) separation sequence controllers (LSSC)
- Two lunar docking events controllers (LDEC)
- Two earth landing sequence controllers (ELSC)
- One pyro continuity verification box (PCVB)

The relationship of these controllers and their sources of electrical power are illustrated in figure 2.9-2. Five batteries and three fuel cells are the source of electrical power. The SMJC is powered by fuel cells; however, battery power is used for the start signal. The RCSC is powered by the fuel cells and batteries. The remaining controllers of the SECS are powered by batteries exclusively.

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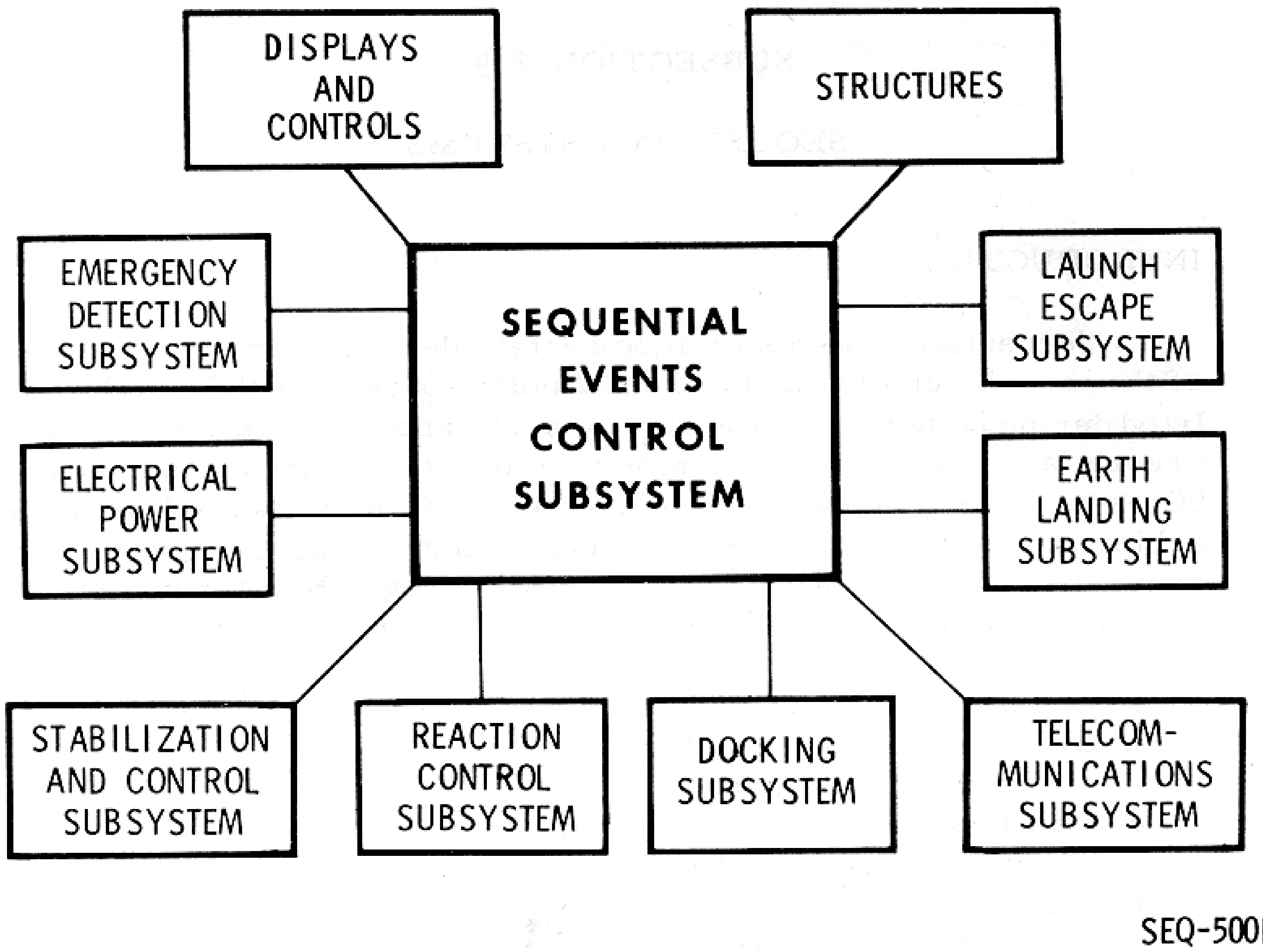

Figure 2.9-1. SECS Interface

2.9.1.2 MESC, ELSC, LDEC, and PCVB Locations.

Four controllers of the SECS are located in the right-hand equipment bay (RHEB) of the CM. (See figure 2.9-3.)

2.9.1.3 SMJC Location.

Installation of the redundant controllers on the forward bulkhead of the SM in sector 2 is illustrated in figure 2.9-4. The fuel cells, which supply power for the SMJC, are also located in the SM.

2.9.1.4 RCSC Location.

The location of the RCSC in the aft equipment bay of the CM is illustrated in figure 2.9-5.

2.9.1.5 LSSC Location.

Redundant controllers are located in the spacecraft LM adapter (SLA) just forward of the LV instrumentation unit (IU); this location is

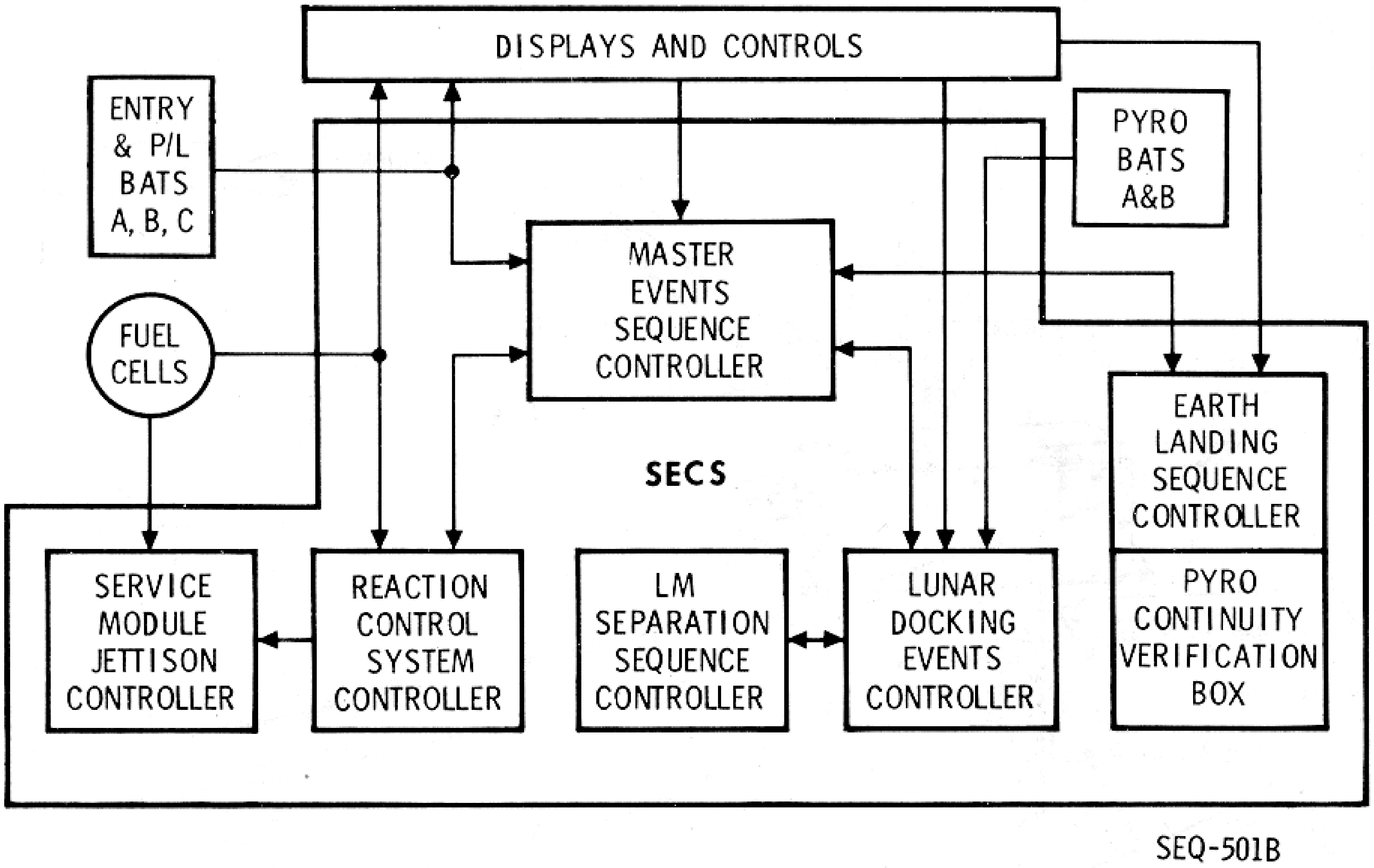

Figure 2.9-2. SECS Controllers

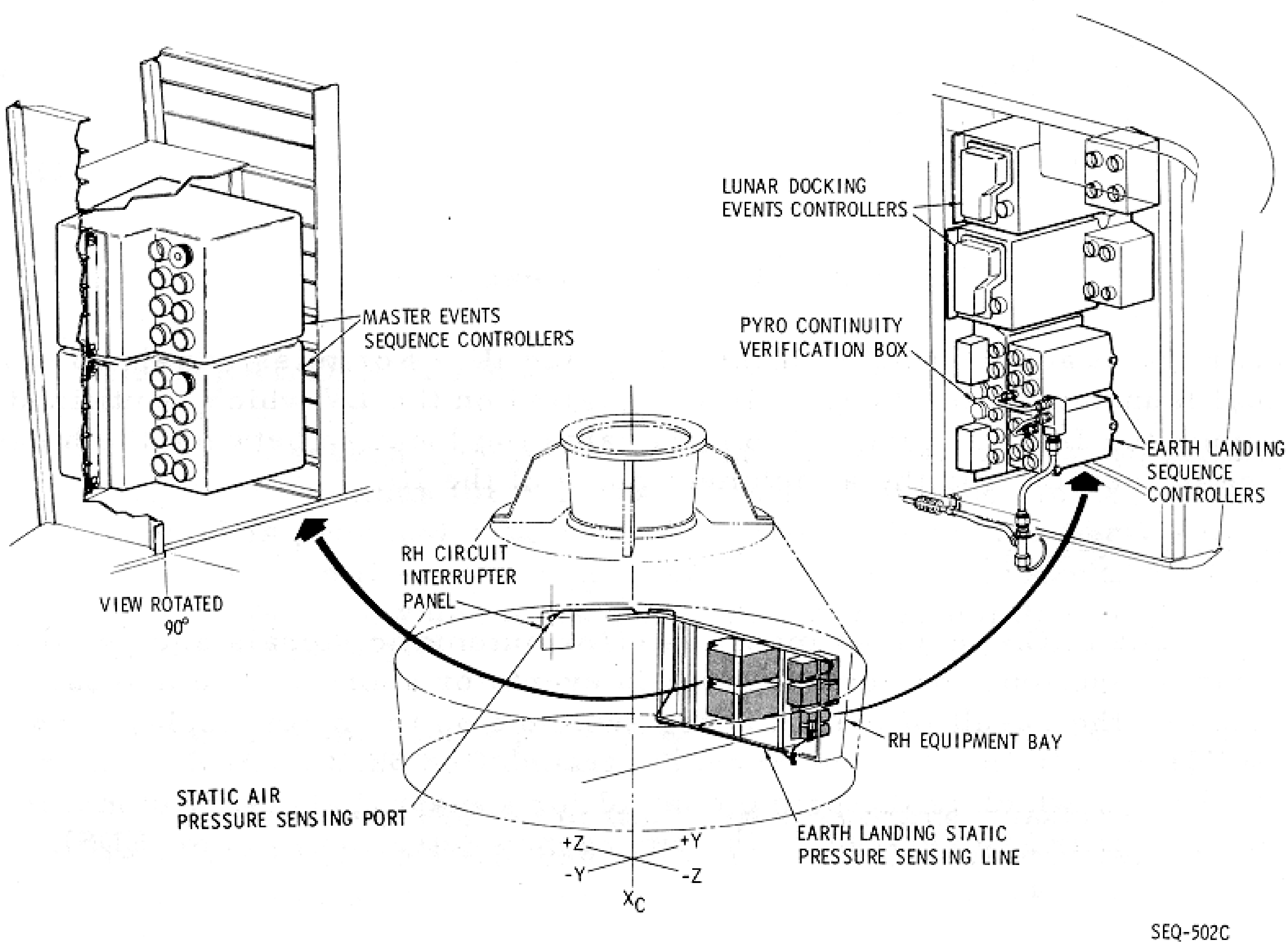

Figure 2.9-3. MESC, ELSC, LDEC, and PCVB Locations

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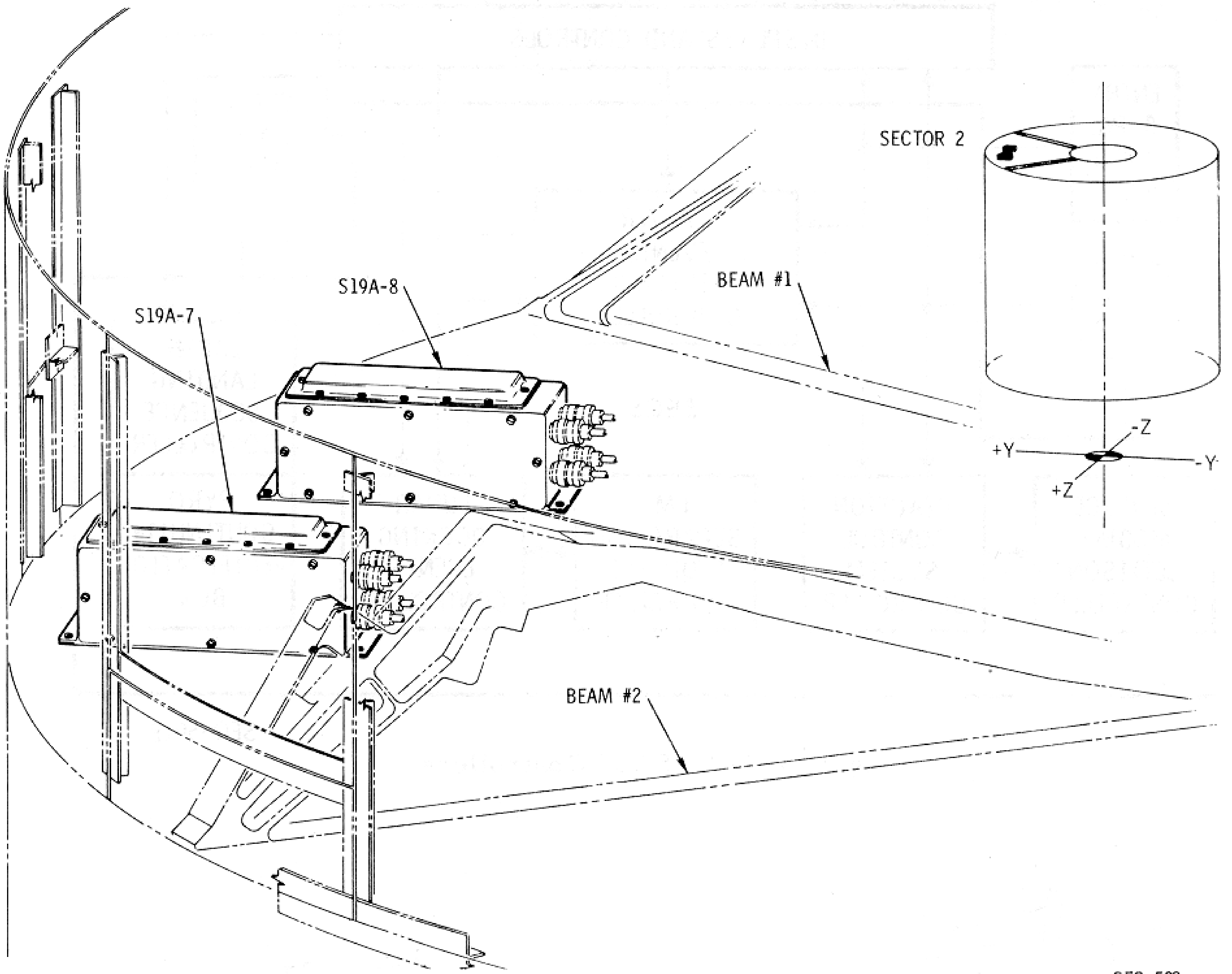

Figure 2.9-4. SMJC Location

near the attachment point of the LM to the IU. For missions that require dual launchings, the LSSC will be installed on the LV which is utilized to launch the LM. Figure 2.9-6 illustrates the location between the hinge line of the SLA and the attachment plane of the IU.

2.9.1.6 Origin of Signals.

The SECS receives manual and/or automatic signals and performs control functions for normal mission events or aborts. The manual signals are the result of manipulating switches on the main display console (MDC) or rotating the Commander's translation hand control counterclockwise, which is the prime control for a manual abort. Automatic abort signals are relayed by the emergency detection system (EDS).

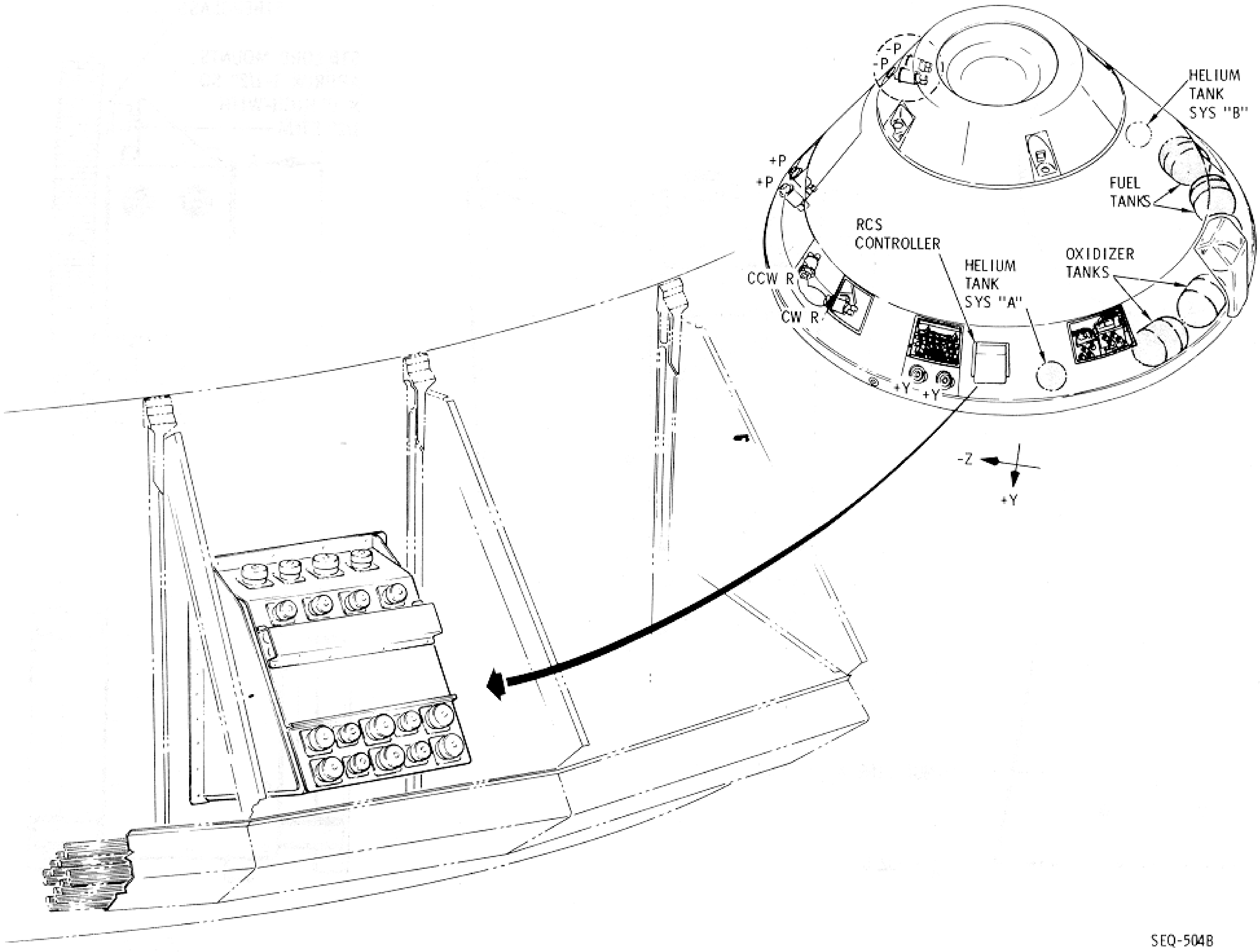

Figure 2.9-5. RCSC Location

2.9.2 GENERAL DESCRIPTION.

In several instances, normal mission events are initiated manually with no provisions for automatic control. In other instances, automatic control is provided with manual control included for backup or override. In addition to the control functions, the sequential systems incorporate visual displays which allow the flight crew to monitor parameters associated with the LV.

2.9.2.1 Launch Escape Tower Assembly.

The apex section of the boost protective cover (BPC) (figure 2.9-7) is attached to the LET legs and also to another section of the BPC which is described in Section 1, Spacecraft. The LET is fabricated from welded

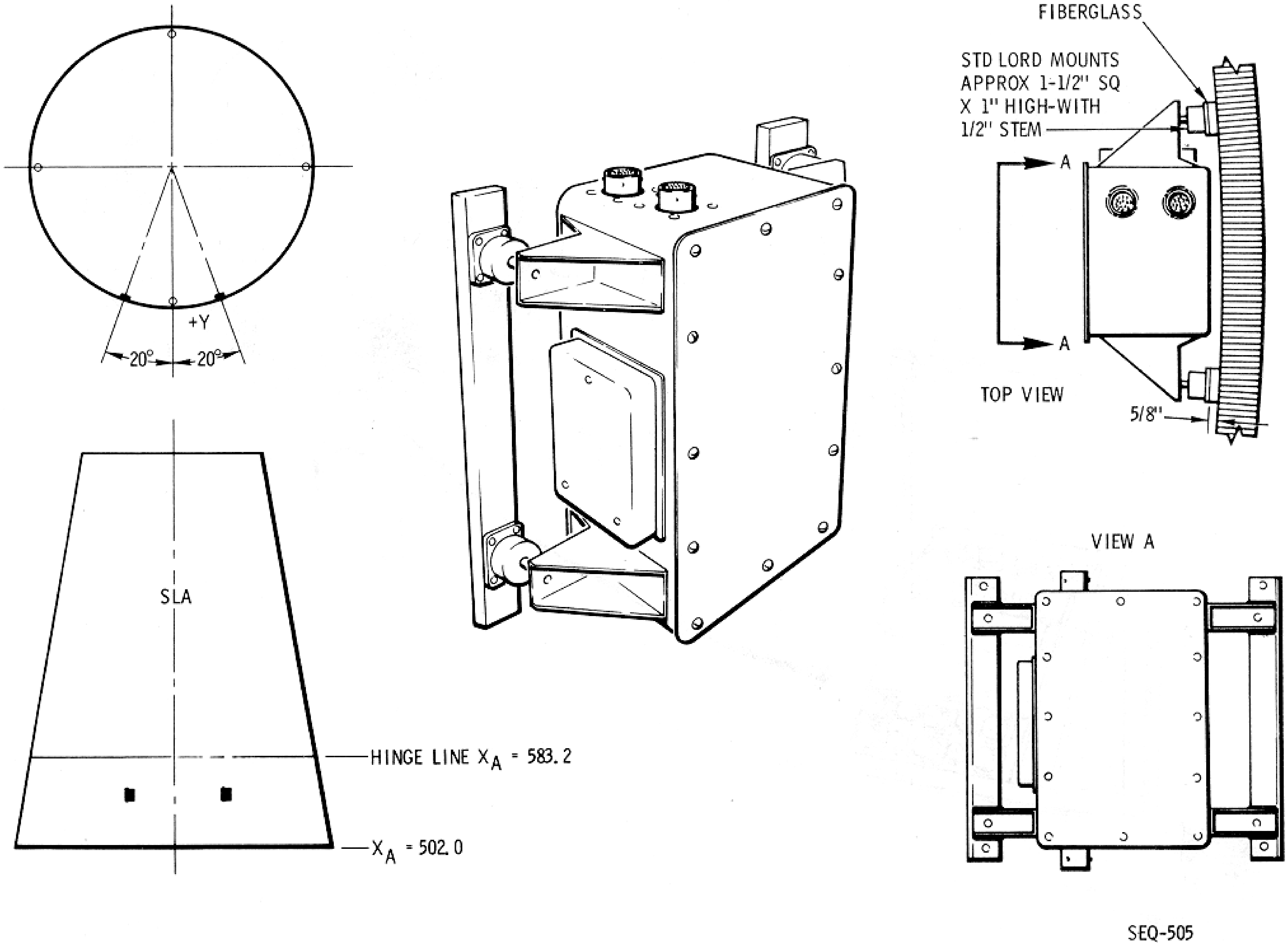

Figure 2.9-6. LSSC Location

titanium tubing which is insulated against heat of rocket motor plumes. Two Saturn V dampers, one of which cannot be illustrated in this perspective, interface with a tower arm of the mobile launcher. Switches in the tower arm are tripped by the dampers, and clamps are mechanized to secure the LET legs to prevent sway caused by wind loads.

Circuits of the SECS integrate the MESC, ELSC, and LDEC providing manual and/or automated controls for initiating ordnance devices which are utilized in the following:

a. Breaking frangible nuts which retain the LET legs to the CM structure.

b. Igniting the launch escape motor (LEM), tower jettison motor (TJM), and pitch control motor (PCM) as required for nominal mission or abort maneuvers.

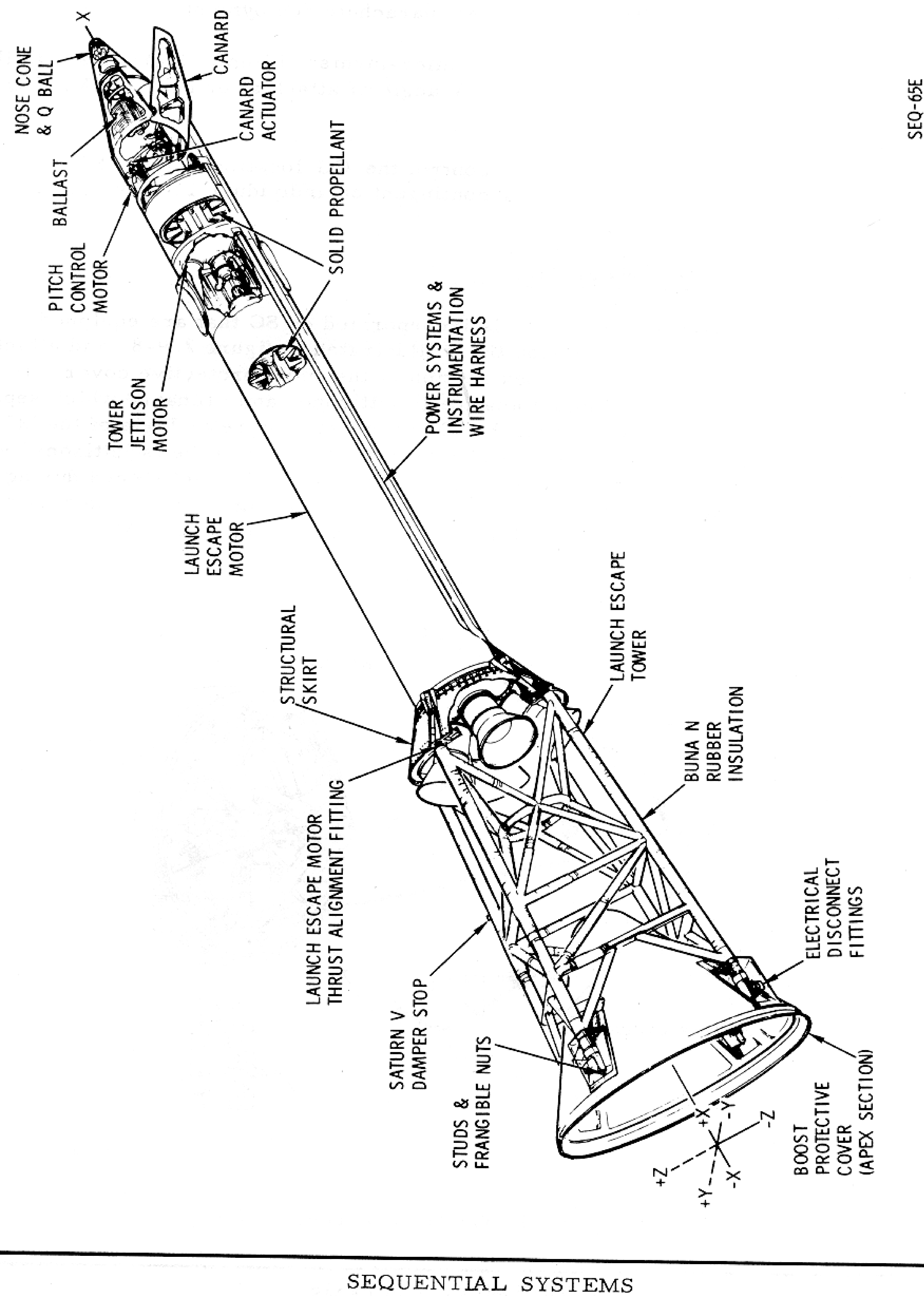

Figure 2.9-7. Launch Escape Tower Assembly

c. Deployment of the canards as required to orient the launch escape vehicle (LEV) with the aft heat shield forward during LES aborts. This orientation contributes to efficient parachute deployment.

A Q-ball, which is a customer-furnished item, interfaces with the sequential systems to monitor LV angle of attack at or near the MAX Q region during ascent.

Ballast is installed to control the CG location of the LEV. The amount of ballast required is contingent on individual LEV weight and balance data.

2.9.2.2 Probe Passive Tension Tie.

A passive tension tie is incorporated on SC that are equipped with a docking probe. The tension tie is illustrated in figure 2.9-8, and attaches the docking probe to the apex section of the boost protective cover. During LES aborts the LET is automatically jettisoned and ordnance which separates the docking ring from the CM is initiated by relay logic of the MESC and LDEC; therefore, in this sequence the docking probe is jettisoned with the LET because of the tension tie. When the LET is jettisoned during a nominal ascent the docking ring ordnance is not initiated and the tension tie is snapped from the docking probe by thrust from the TJM.

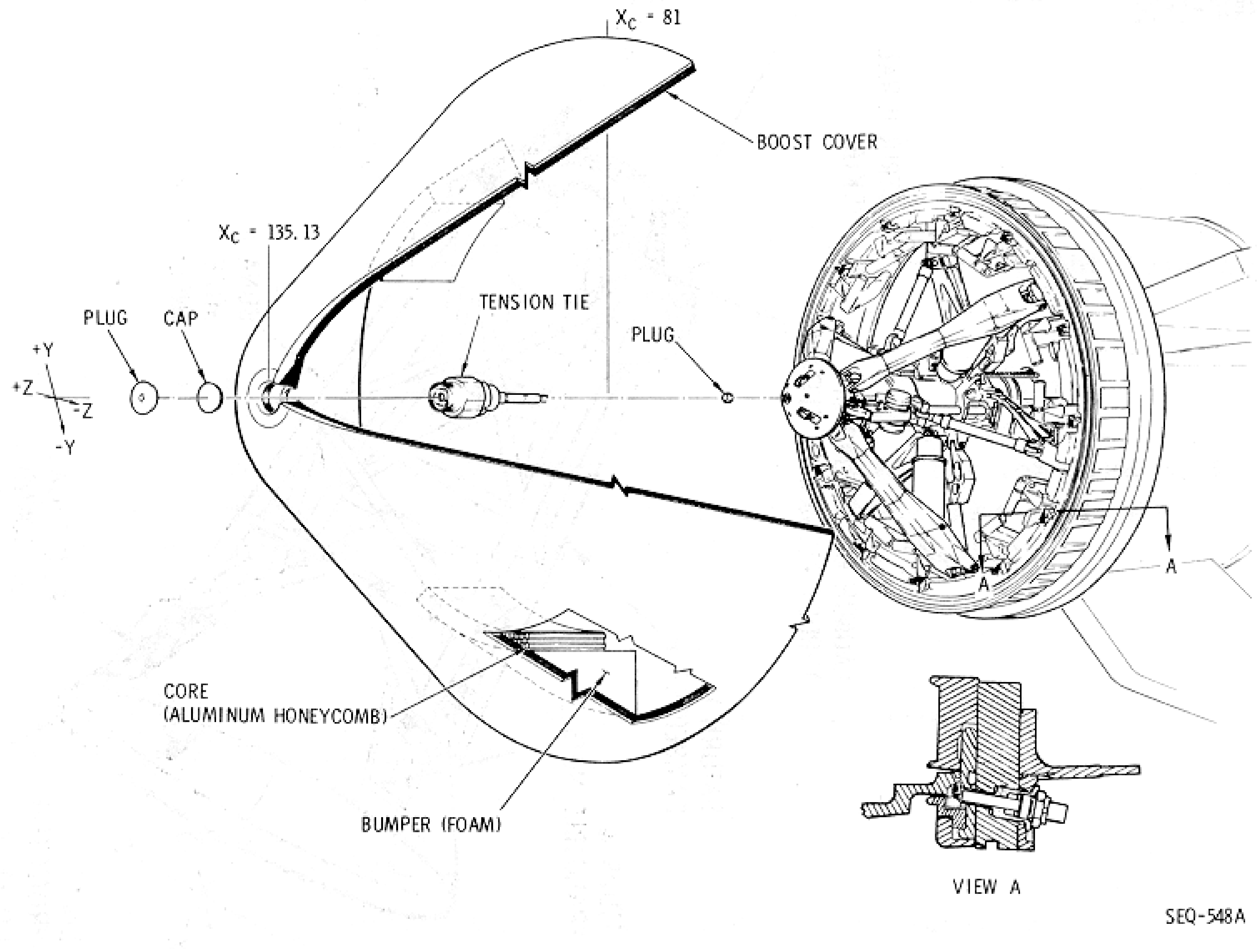

Figure 2.9-8. Probe Passive Tension Tie

2.9.2.3 Docking Probe Retraction.

On SC so equipped, docking probe retraction requires pyro power from the SECS. Burst diaphragms are used to contain nitrogen in four high-pressure cylinders which are included within the docking probe. The nitrogen is used to retract the probe, and the diaphragms are ruptured by plungers which are activated by ordnance devices. Mechanization and control of the docking probe is included in Section 2.13, Docking and Crew Transfer.

2.9.2.4 S-IVB/LM Separation.

After transposition and docking, the crew will connect the umbilicals which will mate the CM and the LM electrical circuits, section 2.13. This electrical interface will enable the utilization of the integrated LDEC and LSSC for S-IVB/LM separation. The LM legs are secured to the SLA by clamps which are unlatched by ordnance devices.

2.9.2.5 Separation of the CSM From the LV.

When the command service module (CSM) is to be separated from the LV either for nominal mission or abort requirements, the MESC and LDEC are utilized (figure 2.9-9). Manual controlled or automated circuits,

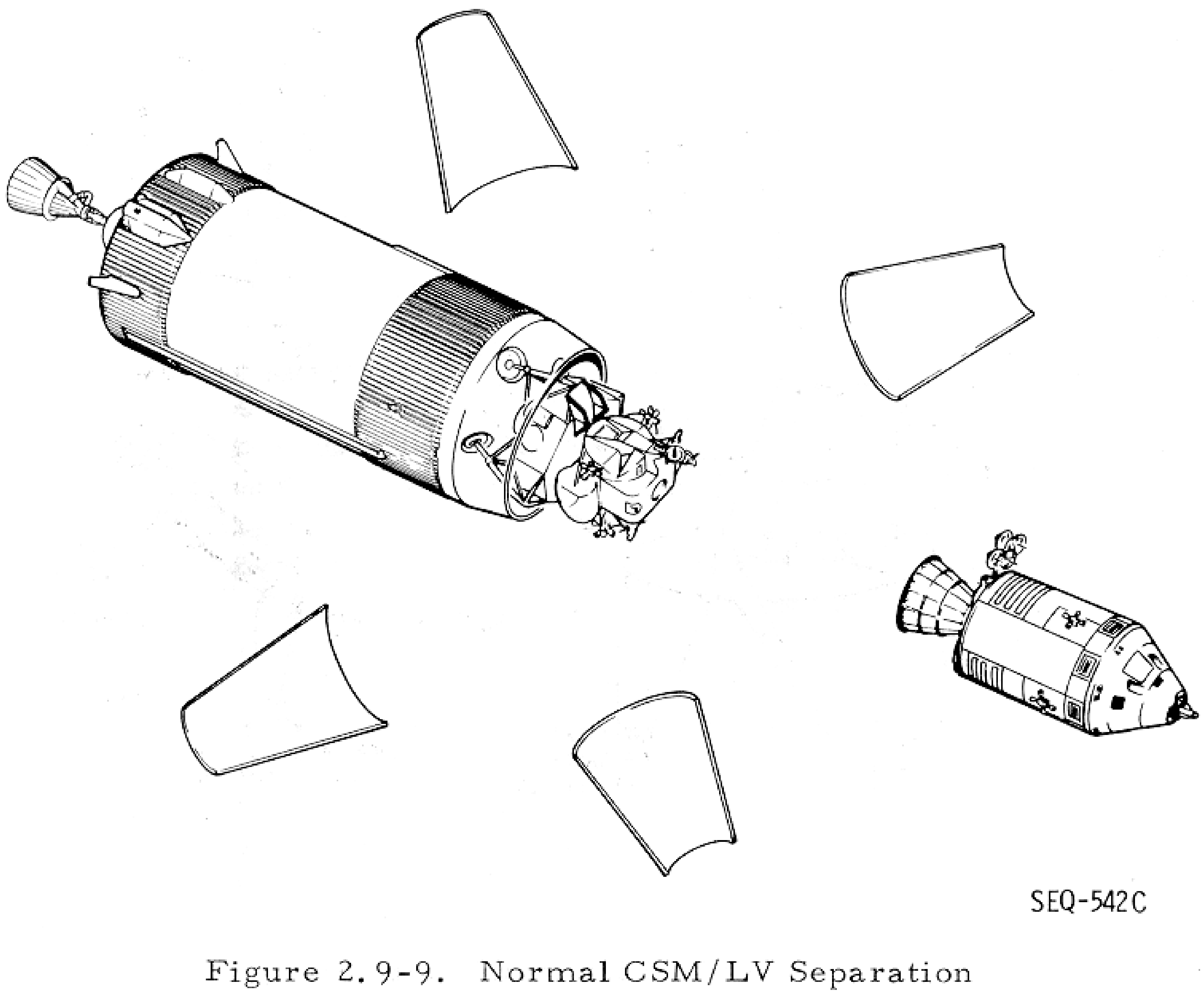

Figure 2.9-9. Normal CSM/LV Separation

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whichever are utilized, will initiate explosive trains that will sever and jettison the SLA panels (figure 2.9-10).

2.9.2.6 CM-SM Separation and SM Jettison.

Prior to the entry phase of a nominal mission, the MESC and LDEC will be utilized to separate the CM from the SM and the SMJC will automate jettisoning the SM (figure 2.9-11).

2.9.2.7 Forward Heat Shield (Apex Cover).

Section 1 includes a description of the forward heat shield structure; automated and manual controlled circuits for jettisoning this heat shield are included in the integrated MESC, ELSC, and LDEC. Mechanization of apex cover jettison is accomplished by the use of thrusters and a drag parachute. Figure 2.9-12 illustrates pressure cartridges installed in a breech. When gas pressure is generated by the pressure cartridges, two pistons will be forced apart and a tension tie will be broken. The lower piston will be forced against a stop and the upper piston will be forced out of its cylinder. The piston rod ends are fastened to forward heat shield fittings and the apex cover is forced away from the CM. Only

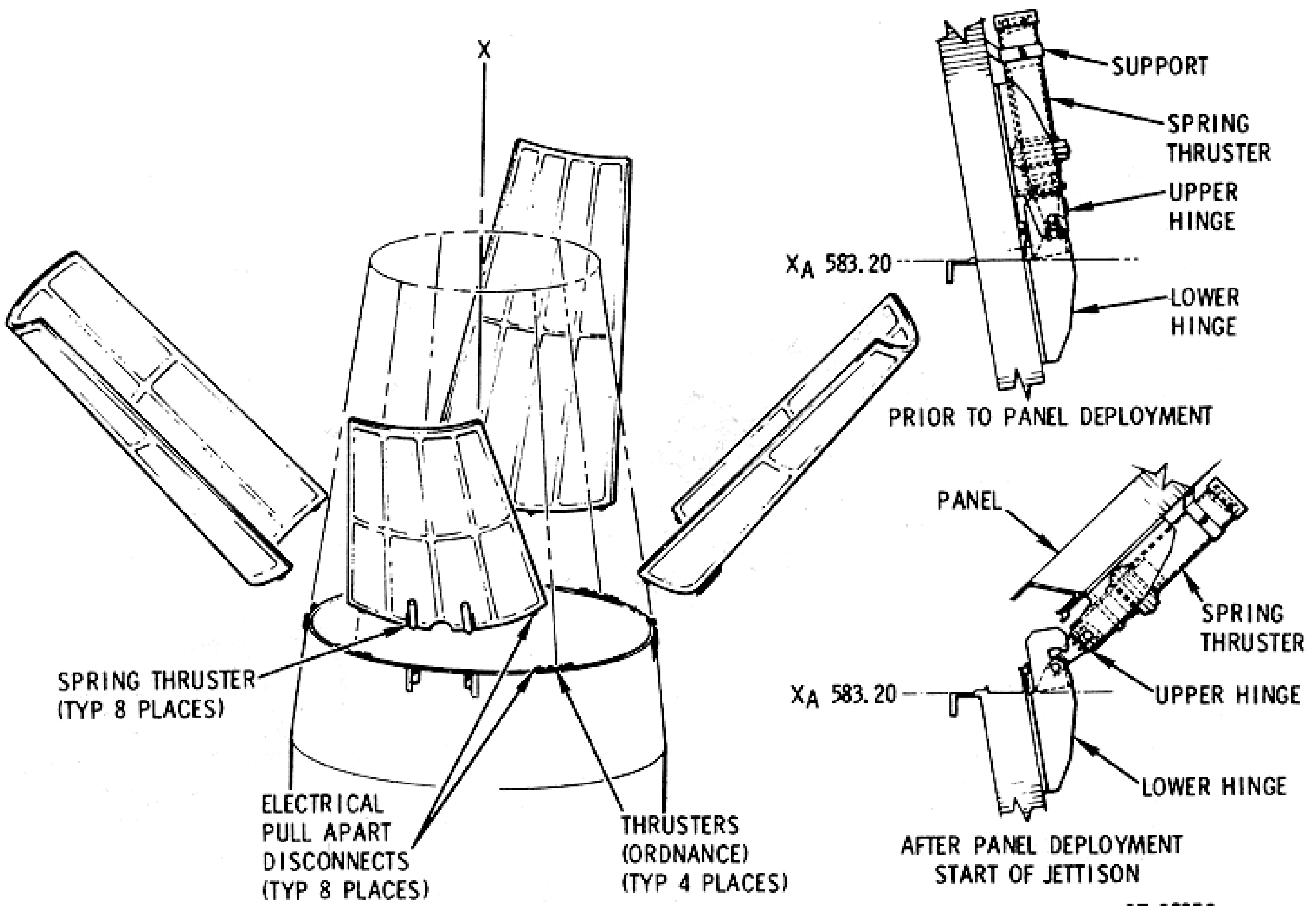

Figure 2.9-10. SLA Panel Jettison

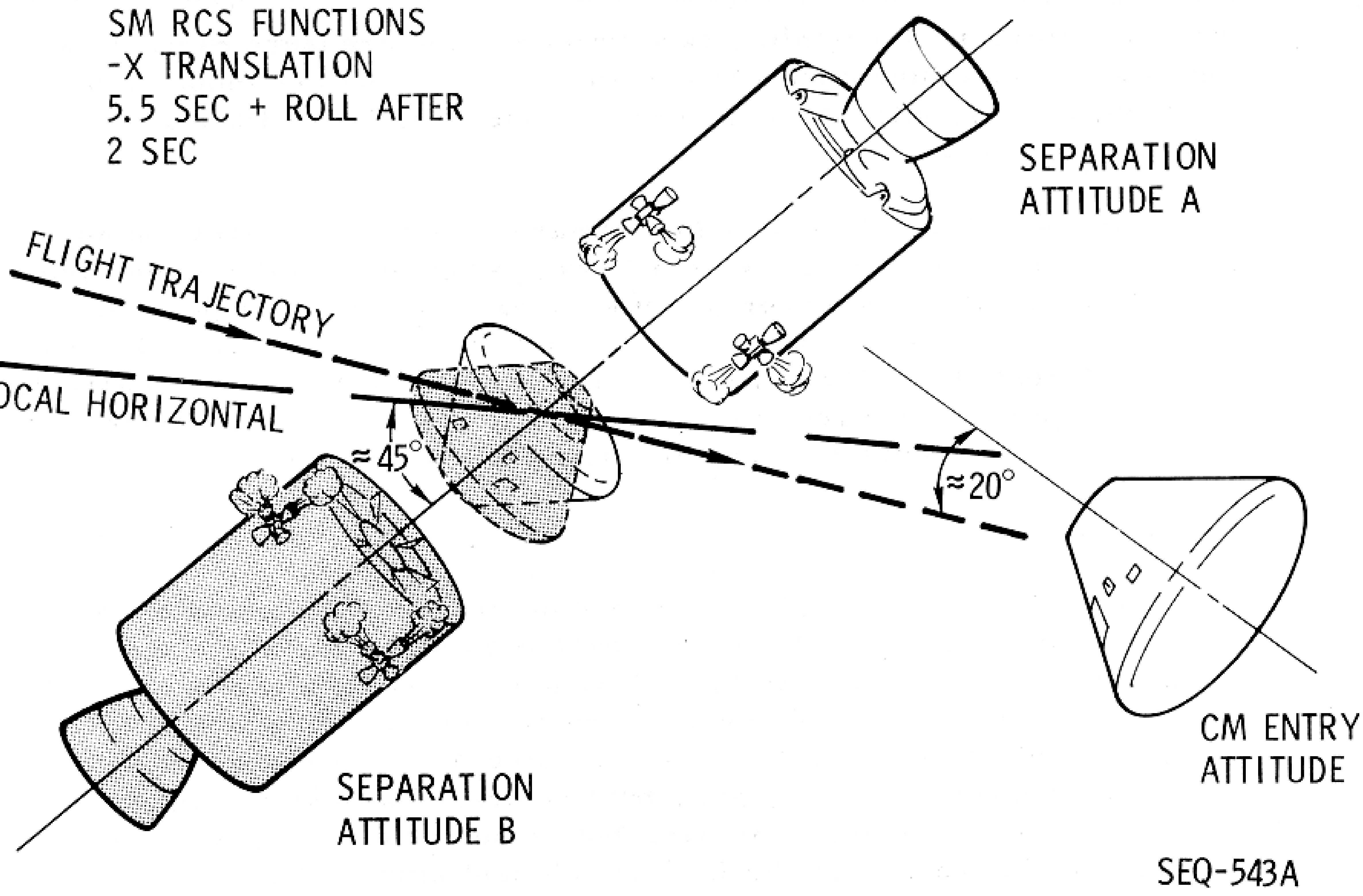

Figure 2.9-11. Normal CM-SM Separation and SM Jettison

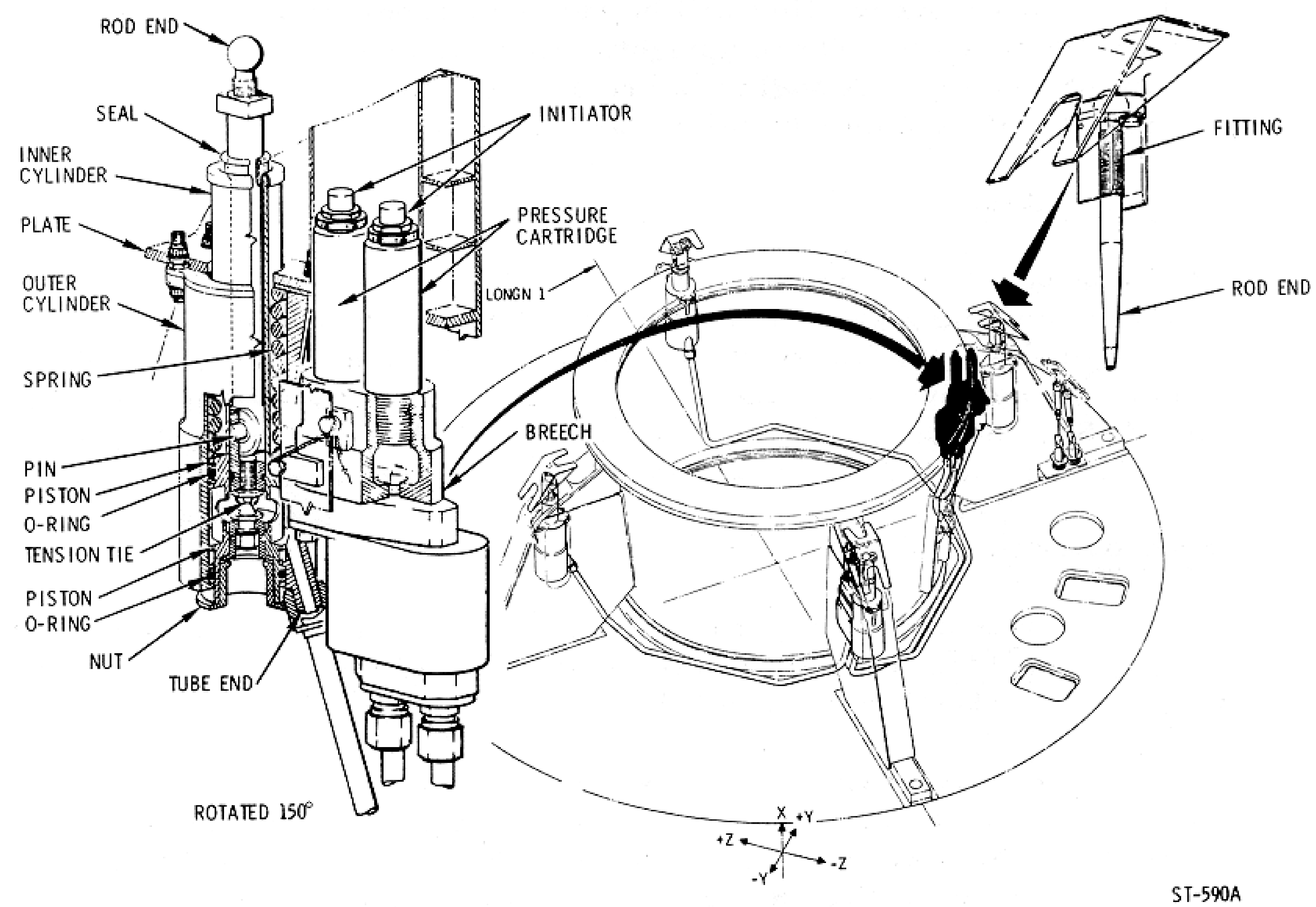

Figure 2.9-12. Forward Heat Shield Attachment and Thruster Assembly

two of the thruster assemblies have breeches and pressure cartridges installed and plumbing connects the breeches to thrusters mounted on diametrically opposite CM structural members; this constitutes redundancy.

Figure 2.9-13 illustrates the forward heat shield separation augmentation system. The mortar deployed drag parachute, as the name implies, is used to drag the apex cover out of an area of negative air pressure following the CM and will prevent recontact of the apex cover with the CM. Lanyard-actuated switches are used to initiate mortar pressure cartridges. A lanyard-actuated electrical disconnect will deadface the electrical circuitry involved after the drag parachute has been deployed.

2.9.2.8 ELS Equipment.

The apex cover must be jettisoned before the ELS equipment may be utilized. Figure 2.9-14 illustrates how the ELS equipment is installed beneath the forward heat shield. All parachutes are mortar-deployed to insure that they are ejected beyond boundary layers and turbulent air around and following the CM. An RCS engine protector prevents damage to CM RCS rocket engines by parachute risers. Parachute risers are also protected from damage by parachute riser protectors, which are spring-loaded covers over the LET attachment studs. The LES tower electrical receptacles are used to connect LET interface wiring, and the mating parts of the receptacles are pulled apart when the LET is jettisoned. A sea recovery sling will be removed from stowage by members of the recovery team. Three uprighting flotation bags are installed under the main parachutes. A switch is provided for the crew to deploy the sea dye marker and swimmer umbilical any time after landing.

2.9.2.9 ELS Parachutes.

Eight parachutes are used in the ELS parachute system (figure 2.9-15). The drogue and main parachutes are deployed in a reefed condition to prevent damage from transient loads during inflation. The ELSC will automate the deployment of these parachutes when activated by relay logic in the MESC. Switches are provided for the flight crew to disable the automation and deploy the parachutes by direct manual control.

2.9.2.10 Reefing System.

The drogue and main parachutes are reefed with lines rove through reefing rings, which are sewn to the inside of the parachute skirts and reefing line cutters (figure 2.9-16).

When the suspension lines stretch, a lanyard will pull the sear release from the reefing line cutter, and burning of a time-delay compound will be started (figure 2.9-17). When the compound has burned, a propellant will be ignited and a cutter will be driven through the reefing line.

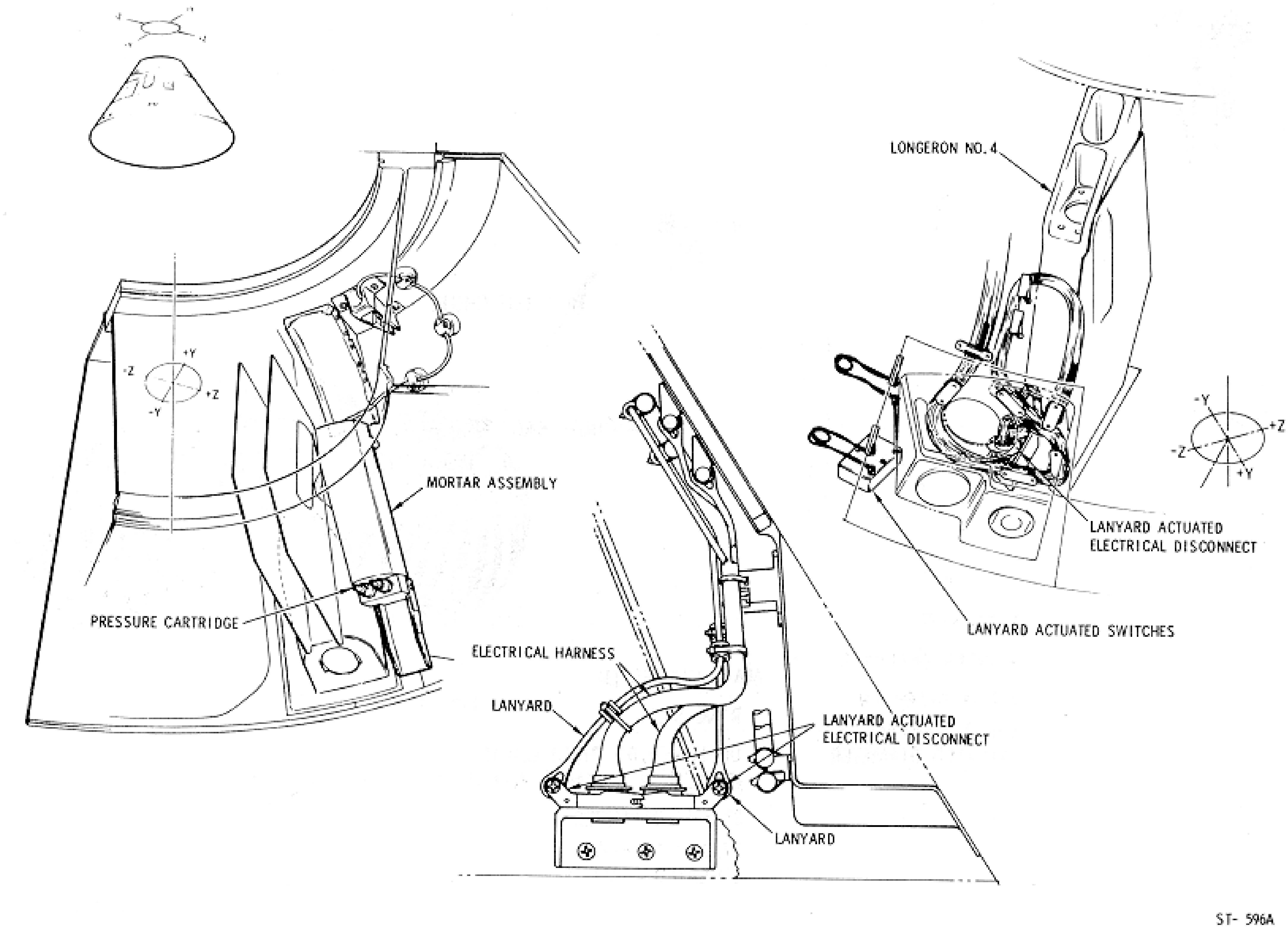

Figure 2.9-13. Forward Heat Shield Separation Augmentation System

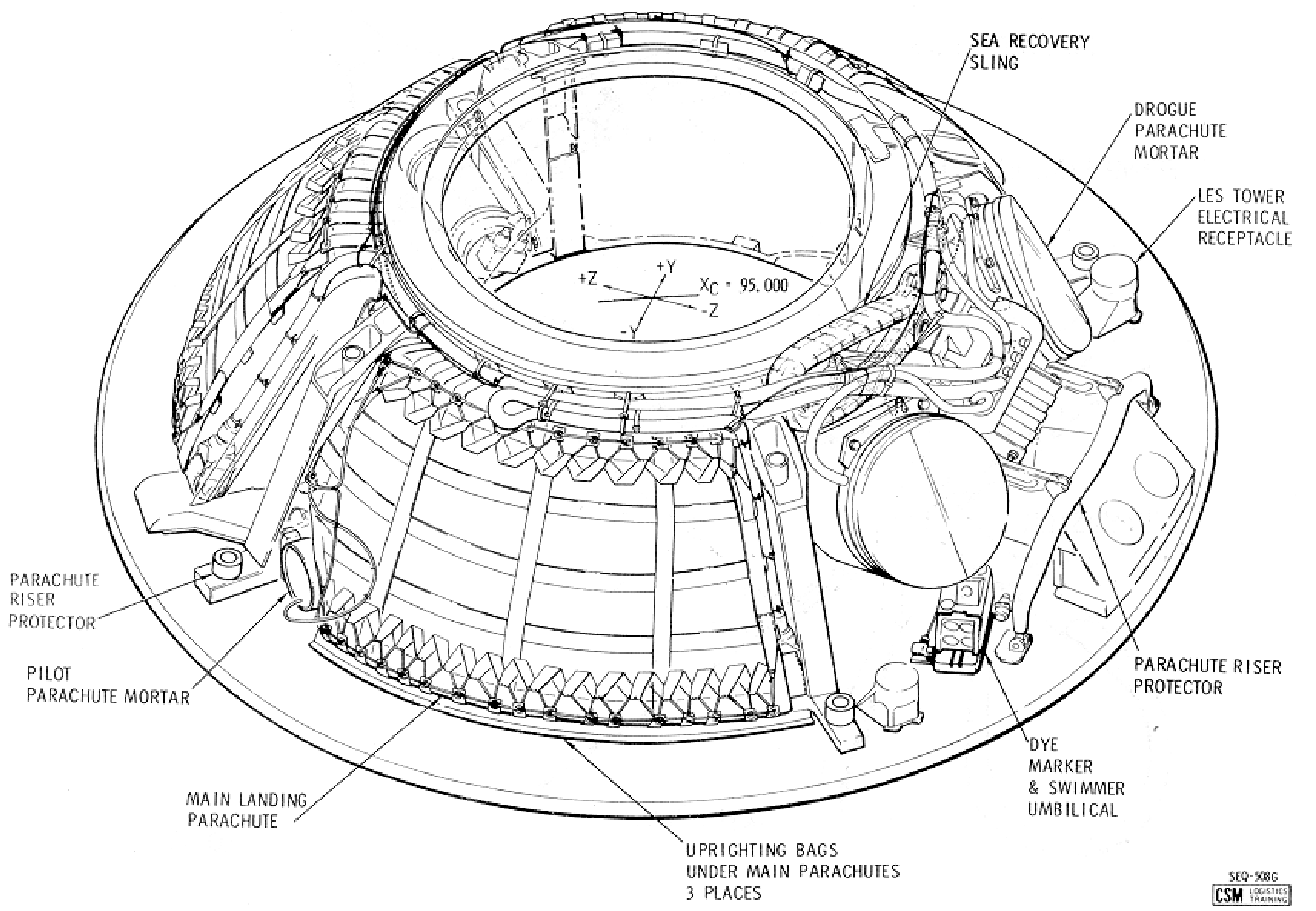

Figure 2.9-14. ELS Equipment

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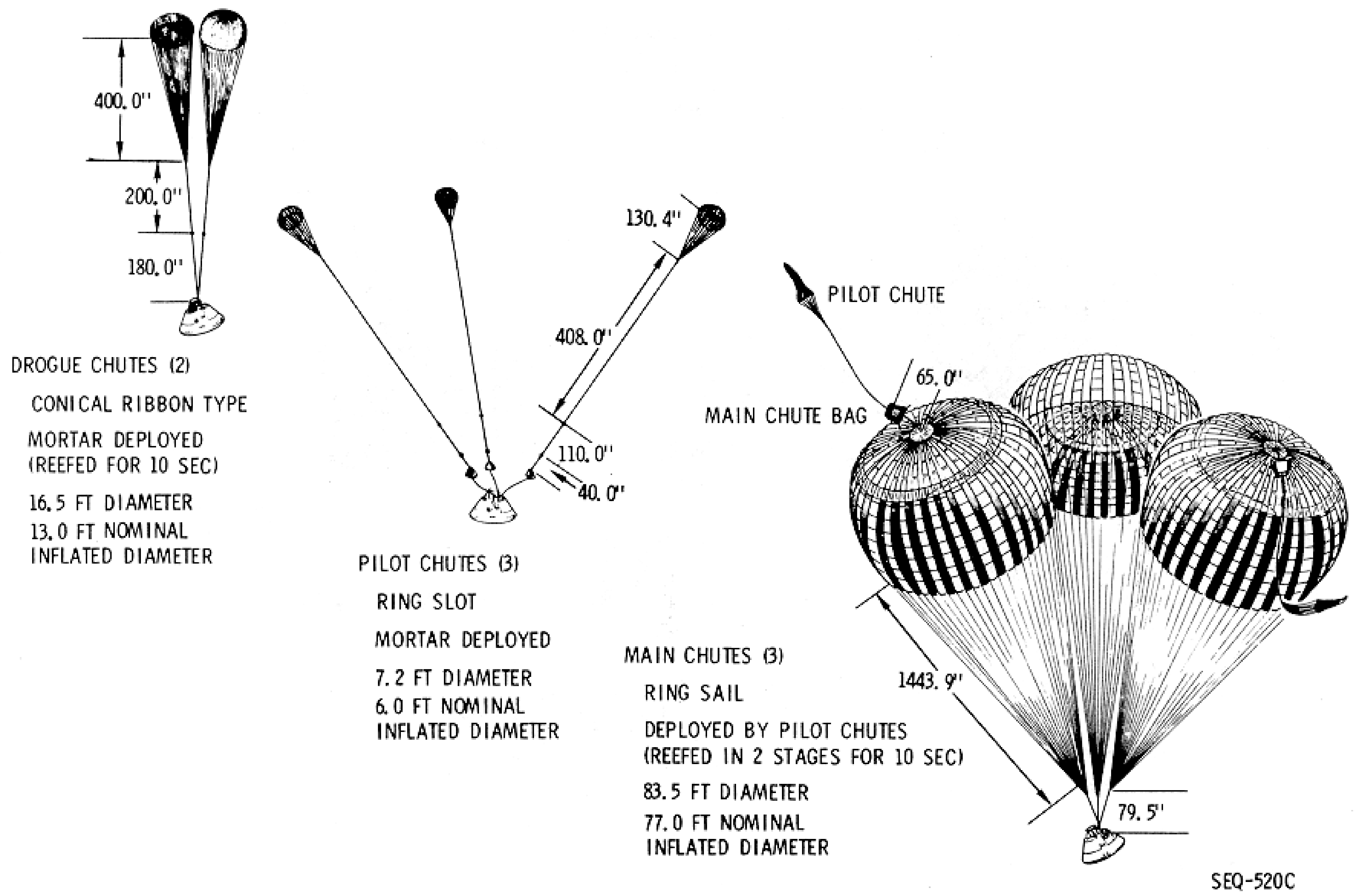

Figure 2.9-15. ELS Parachutes

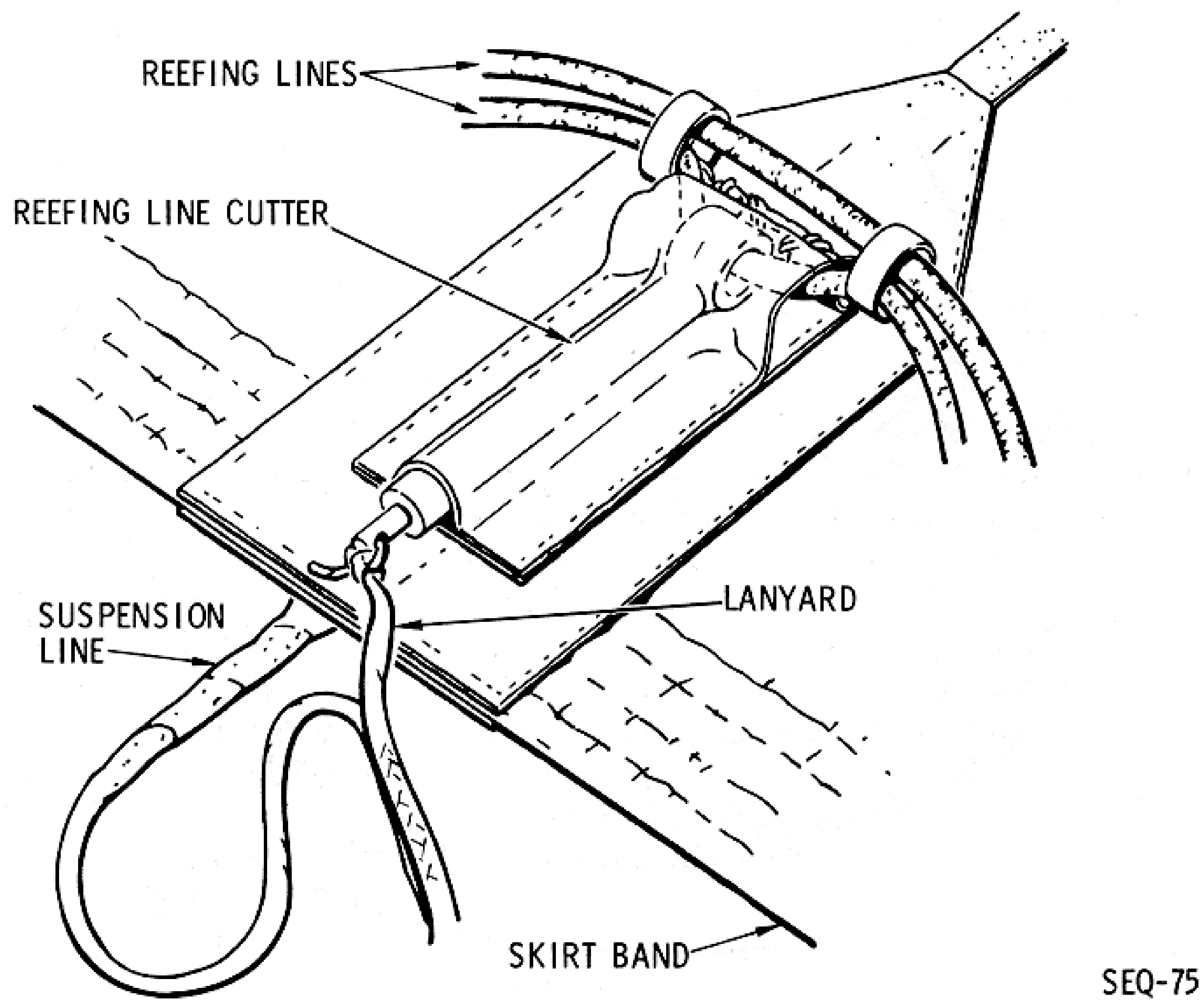

Figure 2.9-16. Reefing Line Cutter Installation

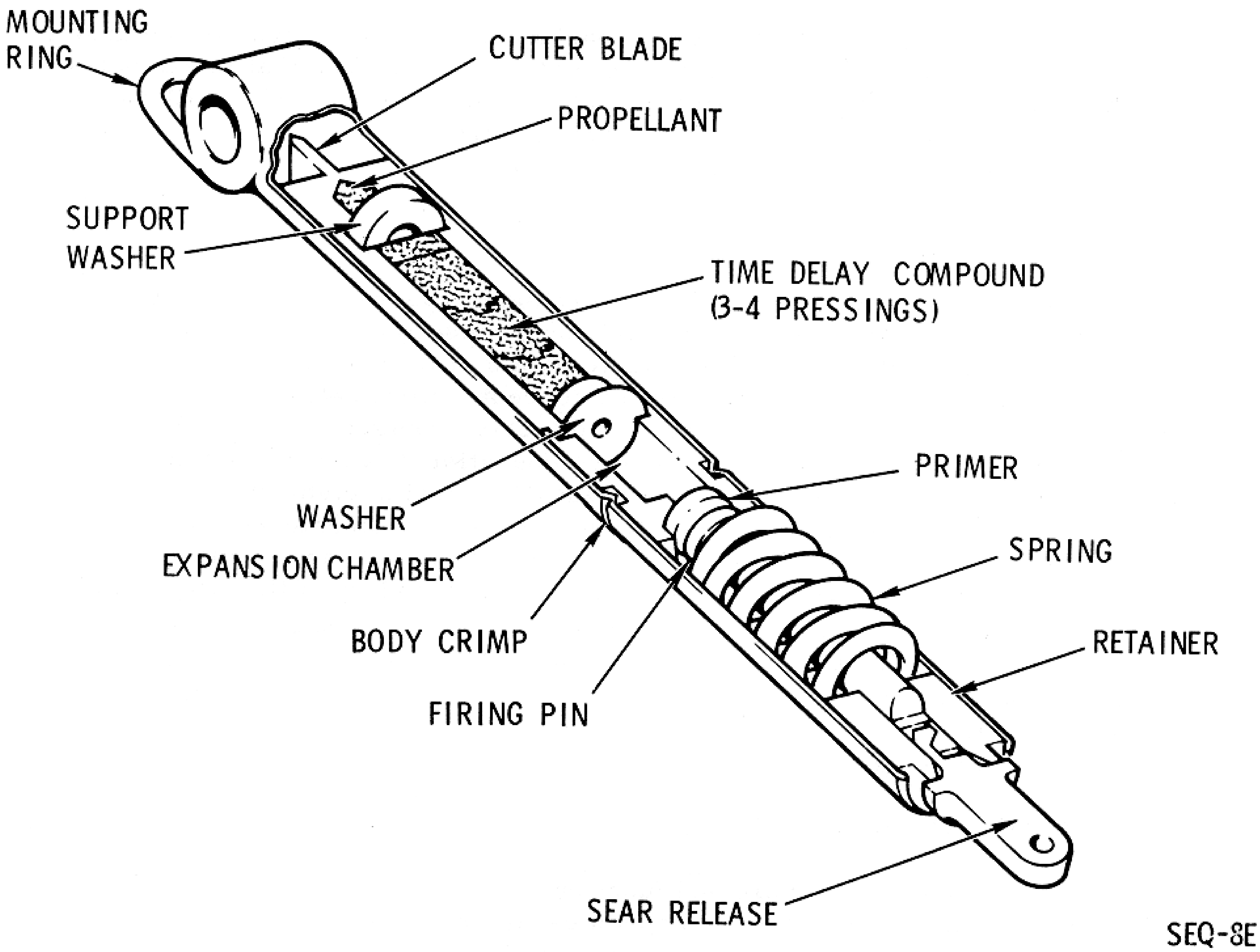

Figure 2.9-17. Reefing Line Cutter

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Each of the drogue parachutes has two reefing lines with two cutters per line to prevent disreefing in case any one reefing line cutter should fail prematurely because a single reefing line cut in one place will disreef a parachute. Each of the three main parachutes has three reefing lines with two cutters per line. The time delay of four of the cutters on each main parachute (two lines) is 6 seconds. At this time the main parachutes will be allowed to open slightly wider than when deployed. The time delay of the remaining two cutters on each main parachute is 10 seconds. At this time the parachutes will be allowed to inflate fully.

Reefing line cutters are also utilized in the deployment of two very high frequency (VHF) antennas and one flashing beacon light during descent. These recovery devices are retained by spring-loaded devices which are secured with parachute rigging cord. The cord is rove through reefing line cutters and the sear releases are pulled by lanyards secured to the main parachute risers.

2.9.2.11 Design Criteria.

Dual redundancy with manual backup has been employed in the design of the sequential system critical circuits. This ensures that in all cases the effects of a component failure, in the prime failure mode, will not:

a. Prevent system operation when required
b. Cause inadvertent system operation.

2.9.2.12 Circuit Concept.

In most Apollo applications, premature operation of an ordnance system is hazardous to the crew and could cause loss of mission objectives. Identification and correction of single points of failure, therefore, are prime objectives in the SECS circuit concept. Elimination of single failures is accomplished by the addition of series contacts (dual) in each firing circuit. The probability of premature operation of an ordnance device has been greatly reduced by the utilization of series elements. On the other hand, the reliability of the firing network to operate has been reduced. The overall firing circuit reliability is enhanced by the use of redundant firing circuits. Each circuit is independent of the other with each output controlling its own ordnance component. Each of these redundant circuits is contained in independent systems which are designated systems A and B. Figure 2.9-18 illustrates one of the redundant systems of a typical firing network. This illustration also shows that some control circuits for sequential events utilize the same circuit concept.

2.9.3 FUNCTIONAL DESCRIPTION.

The origin of signals and functions of the sequential systems are illustrated in figure 2.9-19. Launch escape system (LES) aborts may be executed from the launch pad, or during ascent, until launch escape tower (LET) jettison. Prior to lift-off, LES abort signals are initiated by manual control only because the automatic abort circuits of the EDS are activated at lift-off. Thereafter LES aborts may be initiated by manual control or by automatic control during the period that the EDS automatic abort circuits are active. LES aborts are categorized as modes 1A, 1B, and 1C aborts. Service propulsion system (SPS) aborts are categorized as modes 2, 3, and 4 aborts and may be initiated after the LET has been jettisoned. No provisions are made to initiate SPS aborts automatically.

2.9.3.1 Normal Mission Functions.

In addition to control for aborts, the sequential systems provide for the monitoring of vital LV parameters and control for other essential mission functions as follows:

a. Sensing and displaying LV status:
   1. Thrust OK lights for all booster engines

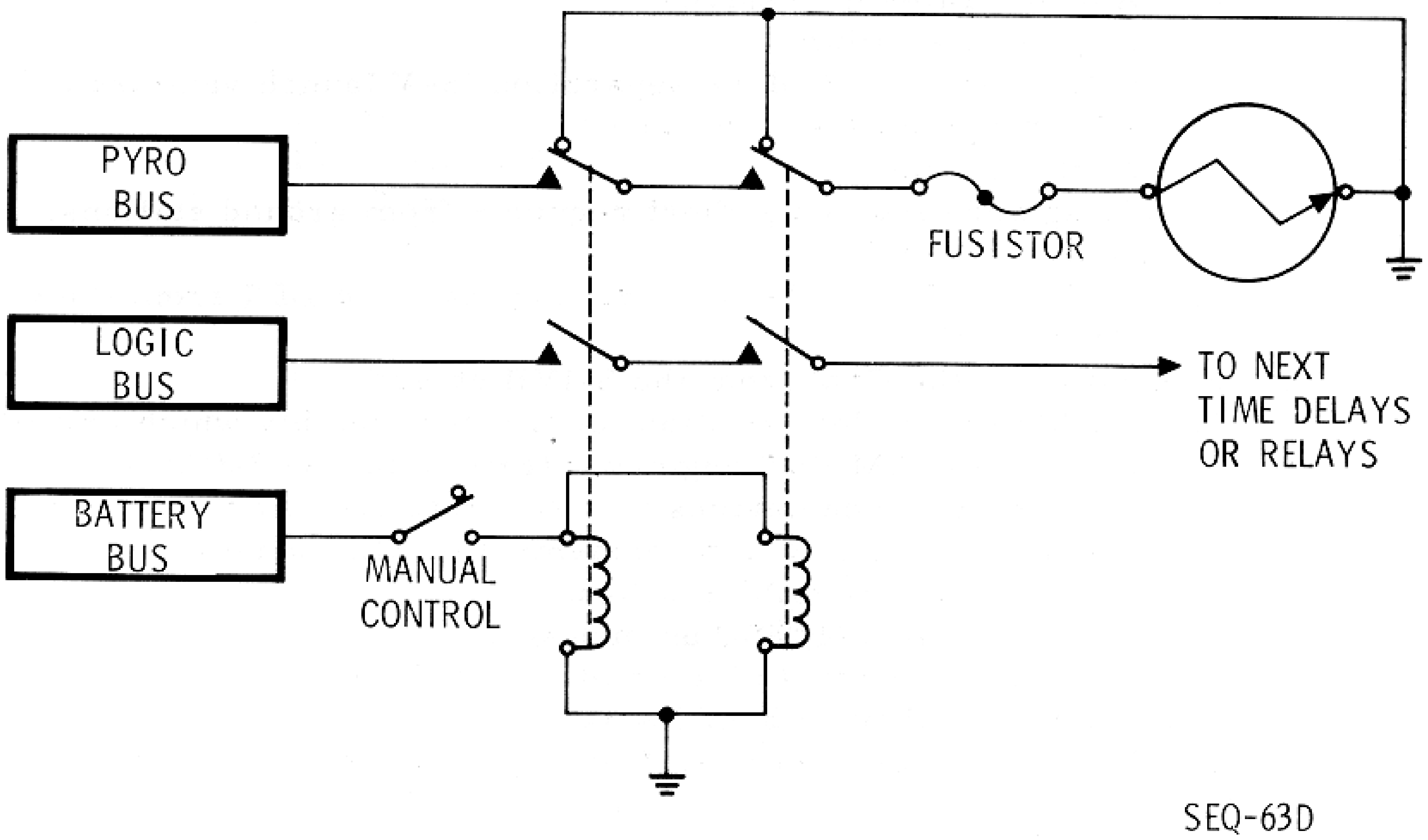

Figure 2.9-18. Circuit Concept

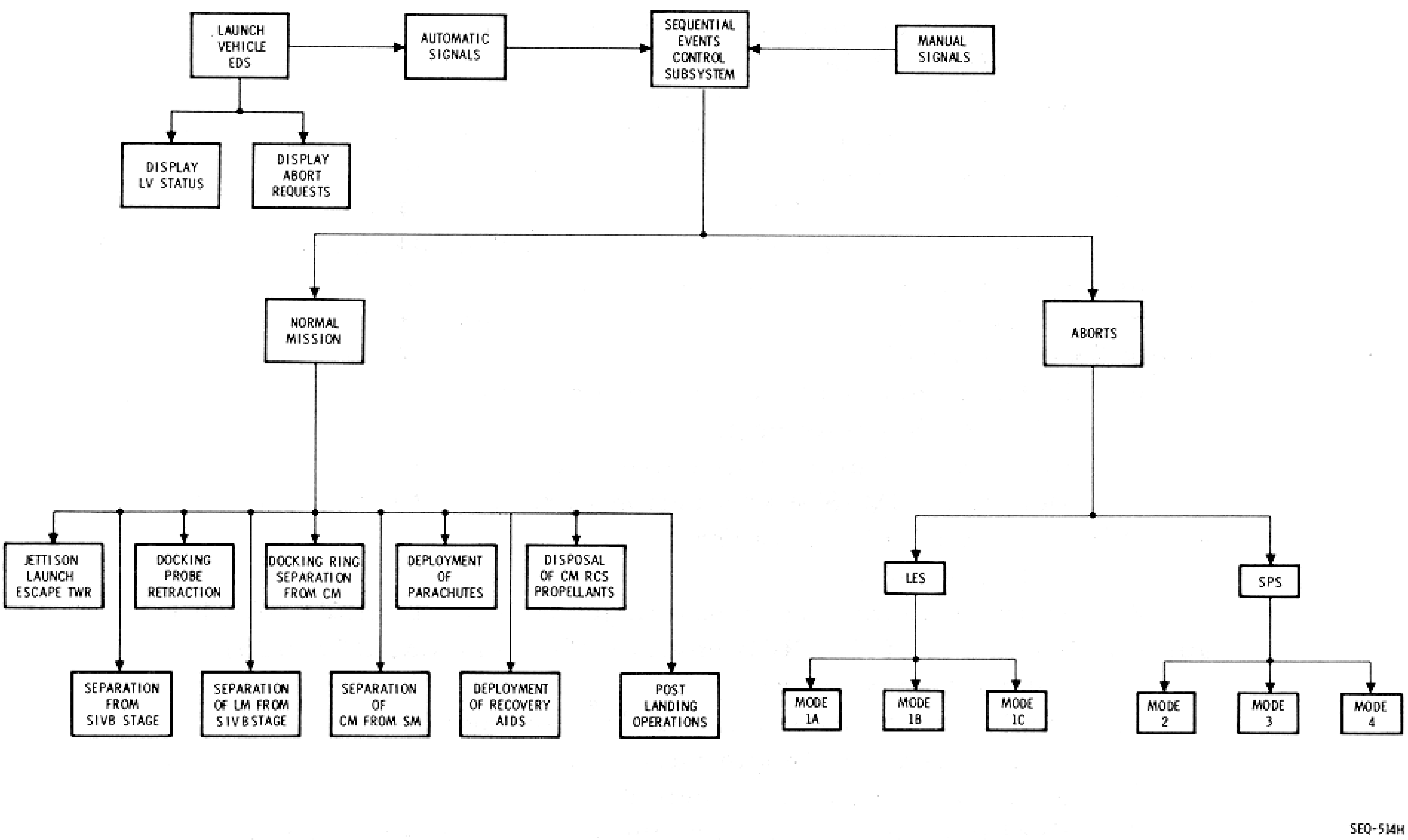

Figure 2.9-19. Sequential Systems Functional Block Diagram

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2. Angular rates excessive
3. IU guidance failure
4. S-II stage second plane separation (S-V launch vehicles only)
5. LV propellant tank pressures
6. Angle of attack.

b. Receiving and displaying abort requests from ground stations.

c. Jettisoning of the LET:
1. Initiate ordnance devices that separate the LET from the CM
2. Ignite TJM.

d. Separation of the CSM from the S-IVB stage:
1. Enable controller reaction jet on/off assembly which provides automatic control of SM RCS engines. (Enable SM RCS/SCS.)
2. Initiate ordnance devices that separate the SLA:
(a) Initiate cutting and deployment of SLA panels
(b) Separate SC/LV umbilical
(c) Separate LM/GSE umbilical.

e. LM docking probe retraction on SC so equipped.

f. Separation of LM from S-IVB stage:
1. Initiate ordnance devices that separate the LM legs from the SLA
2. Deadface LM pyro separation power
3. Initiate SLA/LM umbilical guillotine.

g. Separation of the LM docking ring on SC so equipped.

h. Separation of the CM from the SM.
1. Start SMJC:
(a) Lock up fuel cell power to SMJC
(b) Start -X jets of SM RCS
(c) Start +roll jets of SM RCS
(d) Stop +roll jets of SM RCS.
2. Deadface CM-SM umbilical power.
3. Pressurize CM RCS
4. Transfer electrical power from SM RCS engines to CM RCS engines and deadface SMJC start signal
5. Transfer entry and postlanding battery power to main d-c buses (main bus tie)
6. Initiate separation ordnance devices:
(a) CM-SM tension ties
(b) CM-SM umbilical guillotine
7. Deadface CM-SM separation pyro power (pyro cutout).

i. Deployment of ELS parachutes:
1. Activate ELSC
2. Disable controller reaction jet on/off assembly which inhibits automatic control of CM RCS engines (Disable CM RCS/SCS)
3. Jettison apex cover
4. Deployment of apex cover drag parachute
5. Deployment of drogue parachutes
6. Release of drogue parachutes
7. Deployment of pilot parachutes of the main parachutes.

j. Deployment of recovery devices:
   1. Two VHF antennas
   2. One flashing beacon light.
k. Burning of CM RCS propellants and pressurant.
l. Postlanding functions:
   1. Release of main parachutes.

2.9.3.2 Mode 1A Abort.

The functions of a mode 1A abort are:

a. Relay booster engine cutoff (BECO) signal to the IU
b. Reset and start the commander's event timer
c. Separation of the CM from the SM.
   1. Deadface CM-SM umbilical power
   2. Pressurize CM RCS
   3. Transfer electrical control from SM RCS engines to CM RCS engines
   4. Transfer entry and postlanding battery power to main d-c buses (main bus tie)
   5. Initiate separation ordnance devices:
      (a) CM-SM tension ties
      (b) CM-SM umbilical guillotine.
   6. Fire LEM and PCM
   7. Start automated rapid propellant dump (CM RCS propellant and pressurant jettison):
      (a) Initiate oxidizer dump
      (b) Initiate interconnect of A and B fluid systems
      (c) Close propellant shutoff valves
      (d) Initiate fuel dump
      (e) Initiate helium dump (purge).
d. Deploy canards
e. Deployment of ELS parachutes:
   1. Activate ELSC
   2. Disable controller reaction jet on/off assembly which inhibits automatic control of CM RCS engines (Disable CM RCS/SCS)
   3. Jettison LET
   4. Separate LM docking ring on spacecraft so equipped
   5. Jettison apex cover
   6. Deployment of apex cover drag parachute
   7. Deployment of drogue parachutes
   8. Release of drogue parachutes
   9. Deployment of pilot parachutes of the main parachutes.
f. Deployment of recovery devices:
   1. Two VHF antennas
   2. One flashing beacon light.
g. Postlanding functions:
   1. Release of main parachutes.

2.9.3.3 Modes 1B and 1C Aborts.

The functions of the modes 1B and 1C aborts are the same as those for a mode 1A abort with the following exceptions:

a. Firing of the PCM is inhibited

b. Automated rapid propellant jettisoning is inhibited. Propellants and pressurant of the CM RCS are disposed of as in a nominal entry and landing procedure.

c. Enable controller reaction jet on/off assembly which provides automatic control of CM RCS engines (Enable CM RCS/SCS).

2.9.3.4 Modes 2, 3, and 4 Aborts.

The functions of the sequential systems portion of an SPS abort are:

a. Relay BECO signal to the IU

b. Reset and start commander's event timer

c. Initiate CSM direct ullage (+X translation)

d. Relay signal to SCS to inhibit pitch and yaw rate stabilization

e. Separate CSM from the LV:

   1. Initiate ordnance devices that separate SLA:

      (a) Initiate severance and deployment of SLA panels

      (b) Separate SC/LV umbilical

      (c) Separate LM/GSE umbilical.

f. Enable controller reaction jet on/off assembly which provides automatic control of SM RCS engines (Enable SM RCS/SCS).

2.9.4 OPERATIONAL DESCRIPTION.

Figure 2.9-20 illustrates the operation and functions of the integrated sequential systems and zone references to this illustration are used in subsequent paragraphs. This is an operational/functional diagram and should not be misconstrued as an electrical schematic since many details of the electrical system are not included, i.e., ground returns are not shown except for the clarification of unique circuits. Also, initiator firing circuits are not complete in the operational/functional diagram. Figure 2.9-18 illustrates that normally closed contacts of firing relays are utilized to short the initiator to ground and that all initiator firing circuits are protected with fusistors. All initiators are grounded by relay logic and fusistors are incorporated even though the operational/functional diagram does not illustrate this feature. Generally, only one of the redundant systems is illustrated, which in this instance is system A; however, the redundant system is included when the two are not identical. Numerous crossover networks are illustrated where vital functions are concerned; in these instances, systems A or B components will activate and/or initiate the discrete requirements. Interface with other systems is limited to the effect the interfacing system has on sequential systems.

Figure 2.9-20. Sequential Systems Operational/Functional Diagram (Sheet 1 of 3)

Figure 2.9-20. Sequential Systems Operational/Functional Diagram (Sheet 2 of 3)

Figure 2.9-20. Sequential Systems Operational/Functional Diagram (Sheet 3 of 3)

2.9.4.1 Logic Power. (Zones 43-A and -B)

The source of logic power for the sequential systems is entry and postlanding batteries A, B and C which are described in Section 2.6, Electrical Power. Utilization of the circuit breakers in these power circuits is also described in the electrical power section.

2.9.4.1.1 Arming Sequential Systems Logic Circuits. (Zones 38 and 39-C and D)

Three circuit breakers are utilized in the system A sequential systems logic arming circuits, and their counterparts (not illustrated) are utilized in the system B circuits. The system A circuit breakers are ELS BAT A (CB 45), SEQ EVENTS CONT SYS LOGIC A BAT A (CB 3), and SEQ EVENTS CONT SYS ARM A BAT A (CB 1). The SEQ EVENTS CONT SYSTEM LOGIC switches 1 and 2 (S11 and S15) are two pole lever-lock switches and their function is SECS logic arming. When either of these switches is closed, the MESC LOGIC ARM relays will be energized in systems A and B and the MESC logic buses of both systems will be armed if the breakers of systems A and B have been closed.

2.9.4.2 Pyro Power. (Zones 38 through 43-E and -F)

Normally the source of pyro power is pyro batteries A and B; however, entry and postlanding batteries may be used as backup sources of pyro power. Closure of SEQ A or B circuit breakers (CB 16 or 17), zone 41-E, will complete battery power circuits to pyro system A or B. The condition of the pyro batteries may be determined by the use of a d-c voltmeter (M10) and selector switch (S27), zones 40, 41-E, and -F. If the voltage of either of the pyro batteries should be too low for crew safety, entry battery power may be utilized. Opening the appropriate PYRO/SEQ circuit breaker and closing the appropriate BAT BUS TO PYRO TIE circuit breaker (CB 18 or 19), zones 41-D and -E, will execute the selection of backup power.

SEQ

2.9.4.2.1 Arming Pyro Buses. (Zones 38 and 39-E and -F)

The system A SECS pyro buses are armed with a motor switch in the LDEC primarily for power conservation. When the motor is driven to either position, power is not required to hold the switch contacts in the selected position. The PYRO ARM switch (S10), zone 38-C, is used to control the LDEC motor switch (K1), zones 39, 40-E, and -F. Contacts of the motor switch control power to the LDEC, RCSC, and MESC pyro buses. Pyro power for the ELSC is derived from the MESC pyro bus.

2.9.4.2.2 SIVB/LM Separation (Zone 39-F)

Two circuit breakers are incorporated in the pyro power systems that are required to separate the LM from the SIVB stage. When mission requirements include this function, it will be necessary to close the SIVB/LM SEP, PYRO A, and/or PYRO B circuit breakers (CB 3 or CB 4).

2.9.4.2.3 Main Parachute Release (Zone 37-E)

Two circuit breakers are incorporated in the pyro power systems that are required to release the main parachutes from the CM. This is a design change to eliminate the hazard of main parachute release during descent. Closure of MAIN RELEASE, PYRO A and/or PYRO B circuit breakers (CB 48 or CB 49), should be accomplished as a post-landing operation only.

2.9.4.3 EDS Bus Changeover. (Zones 36, 37-A, and -B)

Battery C provides an alternate power source for the automatic initiation of an abort in the EDS and LET separation functions. These circuits are normally powered by batteries A and B. This is accomplished by the EDS bus changeover circuits in each MESC. Closure of the EDS POWER switch (S1), zones 37-A and -B, energizes EDS CHANGEOVER relays. When these relays are energized, battery A is coupled to system A and battery B is coupled to system B. In the event of a power failure in either system A or B, the relay logic will remove the existing battery and couple battery C to the system which had a power failure.

2.9.4.4 Lift-Off.

The lift-off originated in the IU, zones 34-A and -C, is the result of two L/V events:

a. Thrust commit activates lift-off enable circuitry when the first stage LV engines are producing the required level of thrust.

b. Disconnection of the IU umbilical will drop out lift-off holding circuits, which, in turn will switch the lift-off signal power to the CSM. The umbilical will be disconnected at the instant of actual lift-off.

If the appropriate circuit breakers and switches are in the configuration intended for a nominal launch the lift-off signal will initiate five events, zones 29 through 32-C and -D:

a. Reset and start event and mission timers (two each).

b. Start the automatic PROPELLANT DUMP AND PURGE DISABLE timer

c. Illuminate the white LIFT OFF light

d. Provide power to illuminate the red NO AUTO ABORT light in the event the MESC automatic abort circuits are not enabled

e. Enable the MESC automatic abort circuits by energizing the AUTO ABORT ENABLE relays.

2.9.4.5 Emergency Detection System.

The LV EDS monitors critical parameters associated with LV powered flight. Emergency conditions associated with these parameters are displayed to the crew on the MDC to indicate necessity for abort action. An additional provision of this system is the initiation of an automatic abort in the event of certain extreme time critical conditions, listed as follows:

a. Loss of thrust on two or more engines on the first stage of the LV.

b. Excessive vehicle angular rates in any of the pitch, yaw, or roll planes.

Concurrent with abort initiation (either manual or automatic), the system provides BECO action except for the first 30 seconds of flight in the case of a S-V LV. Range safety requirements impose the time restrictions.

2.9.4.5.1 EDS Automatic Abort Activation and Deactivation. (Zones 35 and 36-C through -E)

The EDS automatic abort circuits in the CSM are activated automatically at lift-off and deactivated automatically at LET jettison. Switches are provided on the MDC to deactivate the entire automatic abort capability or the TWO ENGINES OUT and EXCESSIVE RATES portions of the system independently. Deactivation of the two automatic abort parameters are also accomplished automatically in the IU just prior to inboard engine cutoff (IECO) as a backup to the manual deactivation by the flight crew.

2.9.4.5.2 Launch Vehicle Status.

The electrical circuits that provide illumination power and control the LV status lights are in the IU. The LV RATE light, zones 24 and 25, will illuminate when LV roll, pitch, or yaw rates are in excess of predetermined limits. To indicate loss of attitude reference in the IU guidance unit, the red LV GUID and the LV RATE lights illuminate during first stage boost, then only LV GUID will illuminate. The yellow LV ENGINES lights illuminate when a respective LV operating engine is developing less than the required thrust output. The engine lights provide four cues: (1) ignition, (2) cutoff, (3) engine below thrust, and (4) physical stage separation. A red SII SEP light will illuminate at SII first-plane separation and is extinguished at second-place separation on vehicles launched with an S-V booster. Each of these status lights has an A and B redundant circuit operation with separate lamps in each circuit.

2.9.4.5.3 Abort Request Light. (Zone 31-E)

The ABORT light, is a red lamp assembly containing four bulbs that provide high-intensity illumination. Two bulbs are in system A, and two are in system B. The ABORT light is illuminated if an abort is requested by launch control center for a pad abort or an abort during lift-off via up-data link (UDL). The ABORT light can be illuminated after lift-off by the range safety officer transmitting a DESTRUCT ARM COMMAND, zone 33-E. An abort may also be requested via UDL from the manned space flight network (MSFN). The ABORT lamps, systems A and/or B may be extinguished by UDL reset commands; however, the flight crew can extinguish the lamps in system B only with the UP TELEMETRY COMMAND switch (S39), zones 27 through 30-E and -F.

2.9.4.5.4 Launch Vehicle Tank Pressure Monitor.

A time-shared display is used to indicate LV propellant tank pressures and SPS gimbal position, zones 30 and 31-E and -F. The LV/SPS IND selector switch (S53), zone 32-F, is used to select the parameters to be displayed. Meter movement selector switches and operational power circuits are included in section 2.3.

2.9.4.6 LV Auto Abort Logic.

The EDS will automatically initiate an abort signal when two or more first stage engines are out, zone 34-D, or when LV excessive rates are sensed by gyros in the IU, zones 34-C and -D. These abort signals will energize an ABORT BUS which will energize AUTO ABORT INITIATE relays, zones 33-C and -D. When the AUTO ABORT INITIATE relays in the IU are energized, the auto abort voting relays in the MESC are deenergized, paragraph 2.9.4.7. Three matrices of relay contacts, each of which constitutes 2 of 3 voting logic, are in the abort signals to the ABORT BUS and the functions of these relays are automatic abort deactivate, paragraph 2.9.4.5.1, zones 34-C and -D. The source of power to energize the AUTO ABORT DEACTIVATE relays is in the IU, zones 36-C, -D and -E, and may be controlled by switches in the CM. If the 2 ENG OUT switch (S64), zone 36-E, is placed in the OFF position, the 2 ENG OUT AUTO ABORT DEACTIVATE relays will be energized and the 2 engines out signal from the first stage will be inhibited from initiating an automatic abort. If the LV RATES switch (S65), zone 36-D, is placed in the OFF position, the EXCESSIVE RATES AUTO ABORT DEACTIVATE relays will be energized and the abort signals from the IU gyros will be inhibited from initiating an automatic abort.

2.9.4.7 MESC Auto Abort Voting Logic.

When the EDS bus changeover circuits are energized (paragraph 2.9.4.3), three hot wire loops are established between the CM and LV. Power from the EDS buses 1, 2, and 3 energize the EDS ABORT relays 1, 2, and 3 in the MESC, zones 31 and 32-A and -B. The three legs of EDS bus power are through three matrices of relay contacts of the AUTO ABORT INITIATE relays (paragraph 2.9.4.6), zones 33-A through -D. When an automatic abort is initiated in the IU the EDS ABORT relays in the MESC are de-energized, this constitutes three abort votes in the MESC. The MESC A 2 of 3 voting logic is illustrated with matrices of EDS ABORT relay contacts, zones 30 and 31-A. The automatic abort signal through this voting logic is described in paragraph 2.9.4.14.

2.9.4.7.1 Launch Escape Tower Physically Attached.

One of the requirements for the automatic abort circuits to be enabled is to have the LET physically attached to the CM (figure 2.9-7). Another requirement is logic power to the circuits associated with tower attachment. The power may be from the EDS bus changeover circuits (paragraph 2.9.4.3) or from the MESC LOGIC bus (paragraph 2.9.4.1.1). The LET PHYSICAL SEPARATION MONITOR relays, zone 25-F, have ground wires routed through the tower legs. One pair of contacts of these relays is in the holding circuit to the AUTO ABORT ENABLE relays (paragraph 2.9.4.7.2), zone 31-D. An automatic abort is impossible after the tower has been jettisoned because the AUTO ABORT ENABLE relays will have been de-energized.

2.9.4.7.2 Auto Abort Enable.

The last requirement for an abort initiate signal to be automated is to have the MESC automatic abort circuits enabled. If the EDS switch (S67), zone 29-D, is in the AUTO position, a lift-off signal (paragraph 2.9.4.4) from the IU will enable these circuits. Relay logic in the automatic abort enable circuits are designed to establish holding circuits on battery bus power. These holding circuits are required to maintain the automatic abort circuits in an enabled state since the lift-off signals are discontinued from the IU at IECO. For the holding circuits to be established, power must be made available from the SECS LOGIC CB3 (paragraph 2.9.4.1.1), and the LET must be physically attached and electrically mated (paragraph 2.9.4.7.1). Normally closed contacts of the system B AUTO ABORT ENABLE relays are installed in the negative return of the red NO AUTO ABORT light. Therefore, when the automatic abort circuits are enabled, the red NO AUTO ABORT light will not be illuminated. The LIFT OFF and NO AUTO ABORT lights are combined in an illuminated pushbutton (IPB) which is the only illuminated switch in this group. Illumination of the red light would be the indication that complete enabling of both systems had not been established. If the white LIFT OFF light should not illuminate at lift-off, the most probable cause would be a failure of both lift-off signals in the IU. In this event, the IPB should be depressed momentarily to allow the automatic abort circuits to be enabled from the alternate battery bus power source; neither of the lights would be illuminated in this instance.

2.9.4.8 Normal Ascent.

Figure 2.9-21 illustrates the normal ascent for S-V launch vehicles.

A T + 42 seconds, the ABORT SYSTEM PRPLNT switch (S63), zone 20-B, will be changed from the DUMP AUTO position to the RCS CMD position. The DUMP AUTO contacts of the switch are in series with contacts of the PROPELLANT DUMP AND PURGE DISABLE timer which was started at lift-off (paragraph 2.9.4.4). Additional information relative to this time delay and procedural switching is included in section 2.5, RCS and paragraph 2.9.4.14.5.

2.9.4.8.1 Angle of Attack Monitor. (Zones 35 through 37-E and -F)

A Q-ball (figure 2.9-22) mounted above the LES motors, provides an electrical signal input to the LV AOA/SPS P_c indicator and an electrical signal input to ground control via telemetry. The Q-ball has eight static ports for measuring ΔP which is a function of angle of attack. The pitch and yaw ΔP signals are electronically vector-summed in the Q-ball and displayed on the indicator. The indicator is monitored for the LV AOA

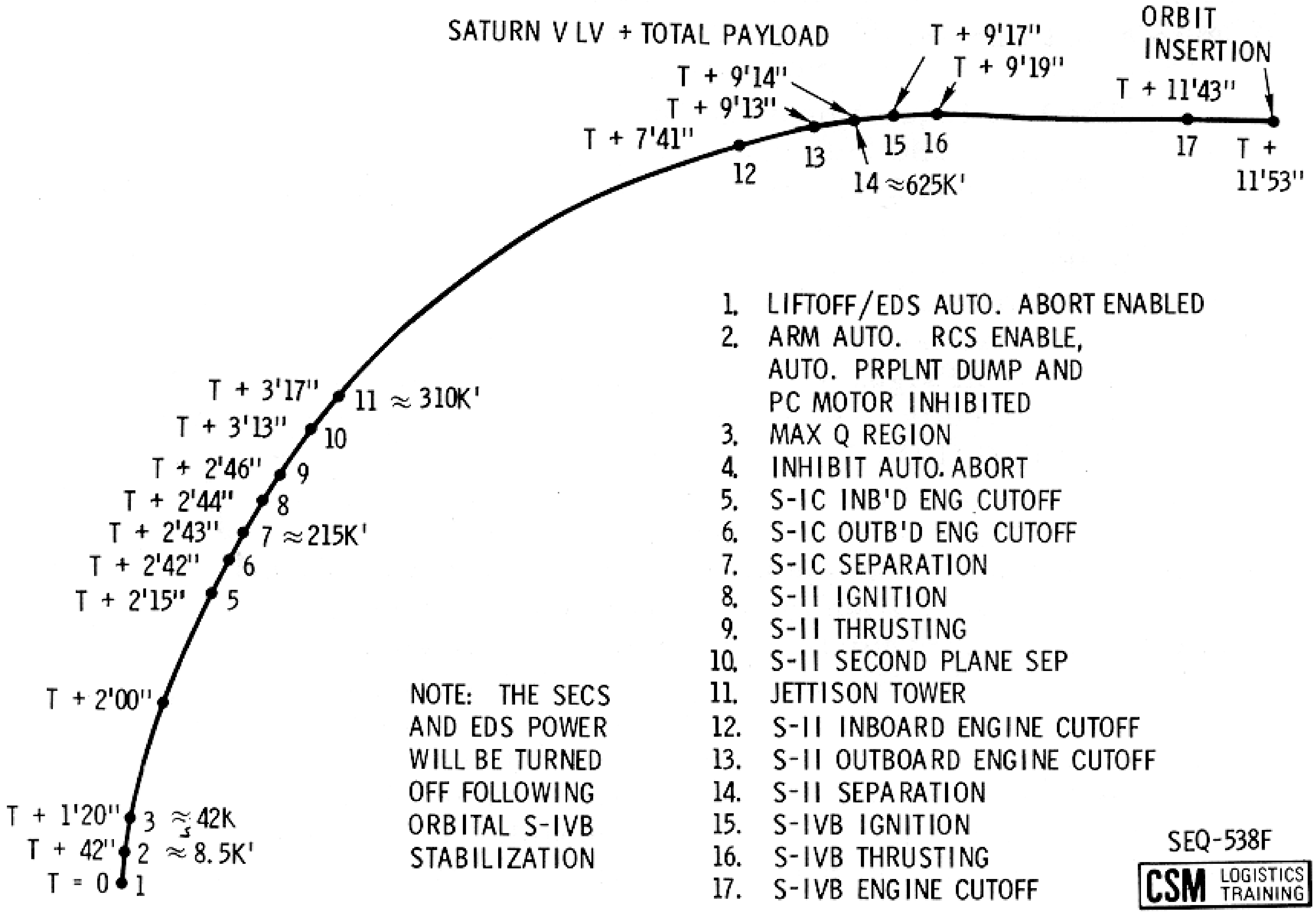

Figure 2.9-21. Event Profile, Normal Ascent S-V LV

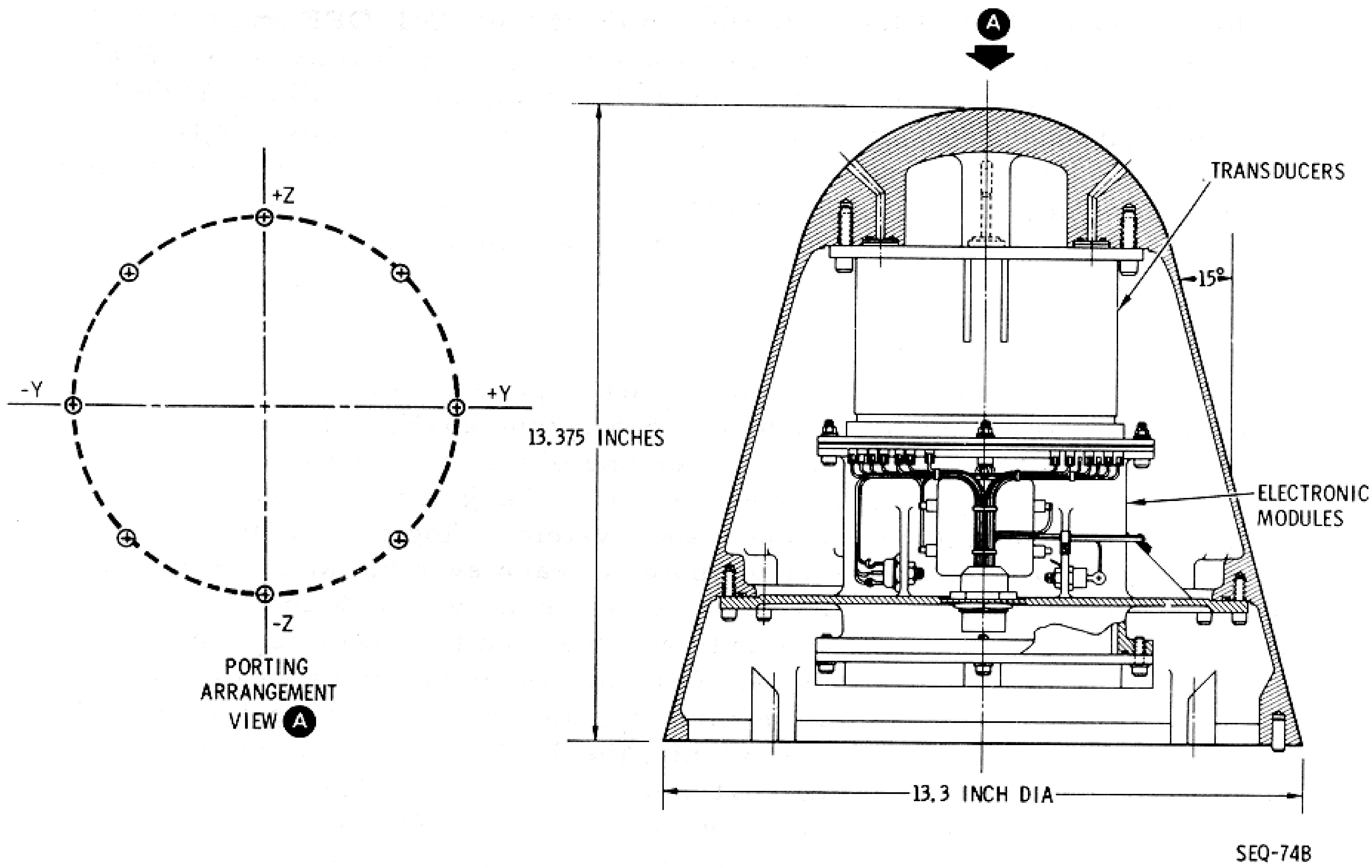

Figure 2.9-22. EDS Q Ball

function during ascent when the LV is at or near the max Q region. This is a time-shared instrument with the service propulsion system (SPS), and the 150-percent graduation is because of SPS start transients. Use of the scale during the LV AOA period will be as a trend indicator only with abort limits established in mission rules.

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2.9.4.8.2 EDS Automatic Abort Deactivate.

The entire automatic abort capability or a portion of the circuits may be deactivated by the flight crew prior to staging (paragraph 2.9.4.5.1). If the EDS switch (S67), zone 29-D, is switched to the OFF position, the entire EDS automatic abort capability will be deactivated (paragraph 2.9.4.7.2). If the 2 ENG OUT switch (S64) and/or LV RATES switch (S65) are switched to the OFF position, the appropriate automatic abort parameter will be deactivated (paragraph 2.9.4.6). Automated switching in the IU SWITCH SELECTOR, zone 35-E, will also deactivate the two automatic parameters as a part of the staging sequence.

2.9.4.8.3 Extinguish LIFT OFF and NO AUTO ABORT Lights.

Just before IECO, the LIFT OFF ENABLE INHIBIT relay contacts in the IU are opened, zones 34-A and -C. This interrupts EDS bus power which is required to illuminate the lamps of the LIFT OFF and NO AUTO ABORT displays. If the EDS switch (S67) is used to deactivate the EDS automatic abort circuits (paragraph 2.9.4.8.2), the NO AUTO ABORT lamps will have been illuminated and will be extinguished at this time. When the EDS bus power is interrupted by this IU relay logic, the mission and event timers, which were started at lift-off, will continue to operate because of internal holding circuits in these units.

2.9.4.8.4 Launch Escape Tower Jettison

After staging, the LET is jettisoned (figure 2.9-23). Normally, both of the TWR JETT switches (S66 and S96), zone 26-F, will be used to initiate this function; however, either one of the switches will initiate systems A and B tower jettison circuits. Each of these switches, No. 1 and 2, are double pole switches and system A logic or EDS change-over power will enable one of the poles of each switch. Moreover, one pole of each switch will activate the circuits of system A and the other pole system B. The frangible nuts which attach the tower legs to the CM are illustrated in figure 2.9-24. Each nut assembly includes two detonators, one initiated by system A circuits, and the other by system B. The tower jettison circuits will also ignite the TJM. The cue which the flight crew will use when initiating LET jettison is the S-II SEP light. Utilization of the event timer in conjunction with the visual light cue will enable the crew to jettison the LET at the correct time. If the TJM should fail to

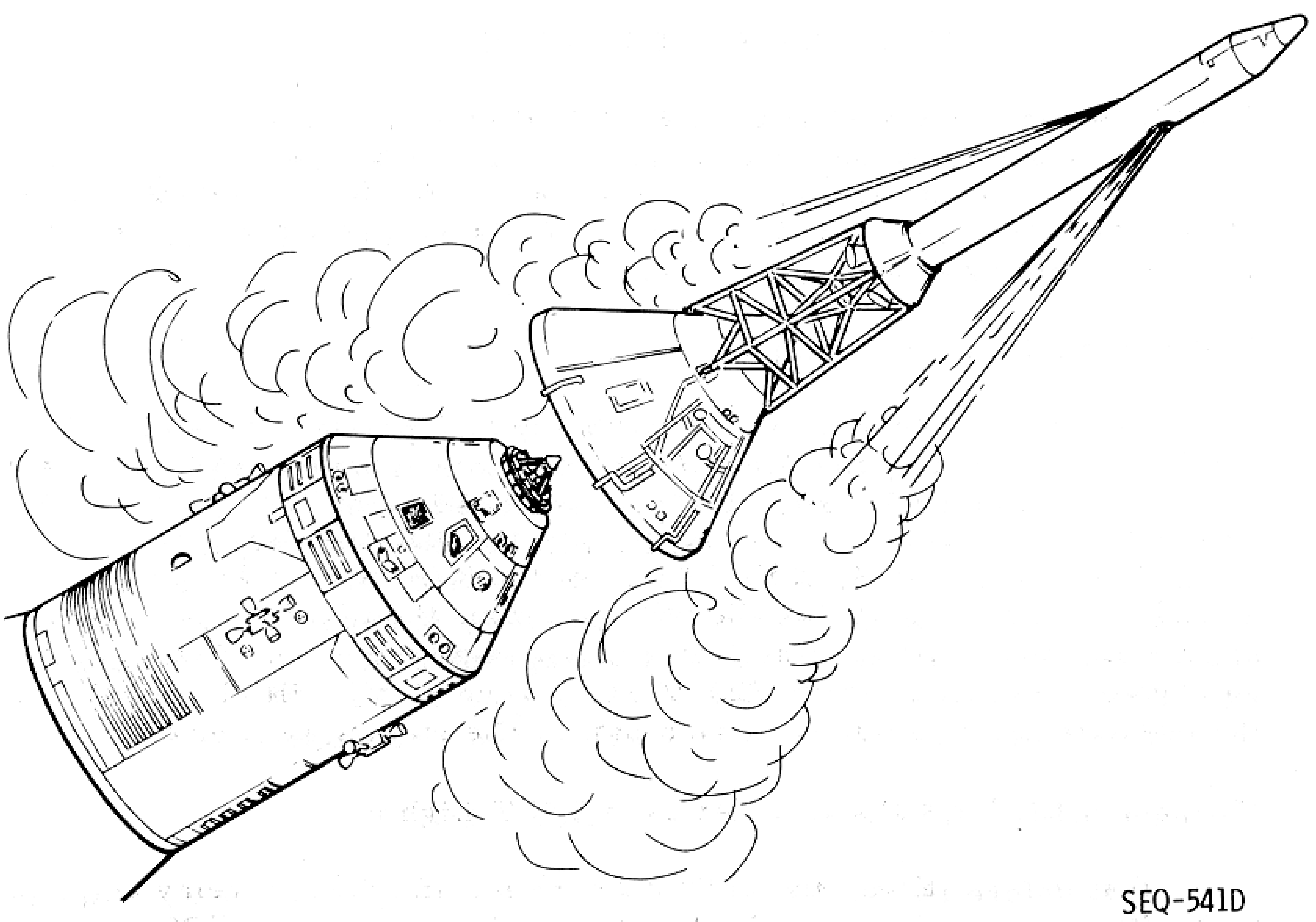

Figure 2.9-23. Normal Tower Jettison

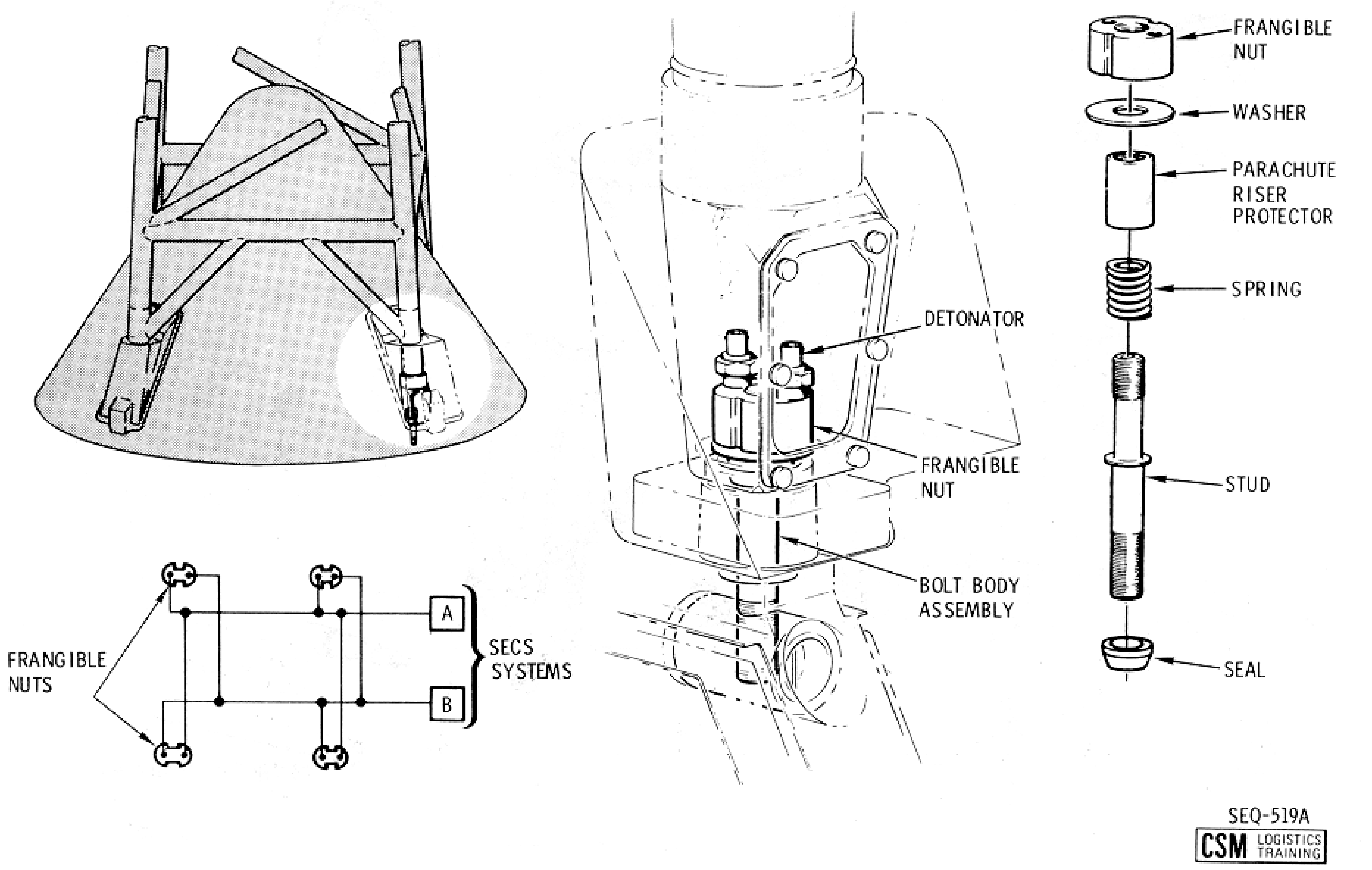

Figure 2.9-24. Tower Separation System

ignite, an alternate method may be used to jettison the LET. The LES MOTOR FIRE switch (S31), zone 19-C, will ignite the LEM which is flight-qualified to jettison the LET. If this alternative should be necessary, it is vital that the detonators of the frangible nuts shall have been initiated before the LES MOTOR FIRE switch is depressed. The TWR JETT switches are the only controls that will initiate the detonators of the frangible nuts.

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2.9.4.9 Separation of the Spacecraft From the Launch Vehicle.

The next maneuver that the sequential systems will be utilized to perform is CSM/LV separation (figure 2.9-25). Closing the CSM/LV SEP switch (S35), zone 10-B, will energize the CSM/LV SEPARATE relays, which will fire initiators of the explosive trains that sever and jettison the SLA panels. The same explosive train will separate the CSM/LV and LM/GSE umbilicals.

2.9.4.9.1 Enable Automated Control of the SM RCS.

The CSM-LV SEPARATE relay will, in addition to initiating the explosive train, energize the RCS ENABLE ARM relays, zone 8-A,

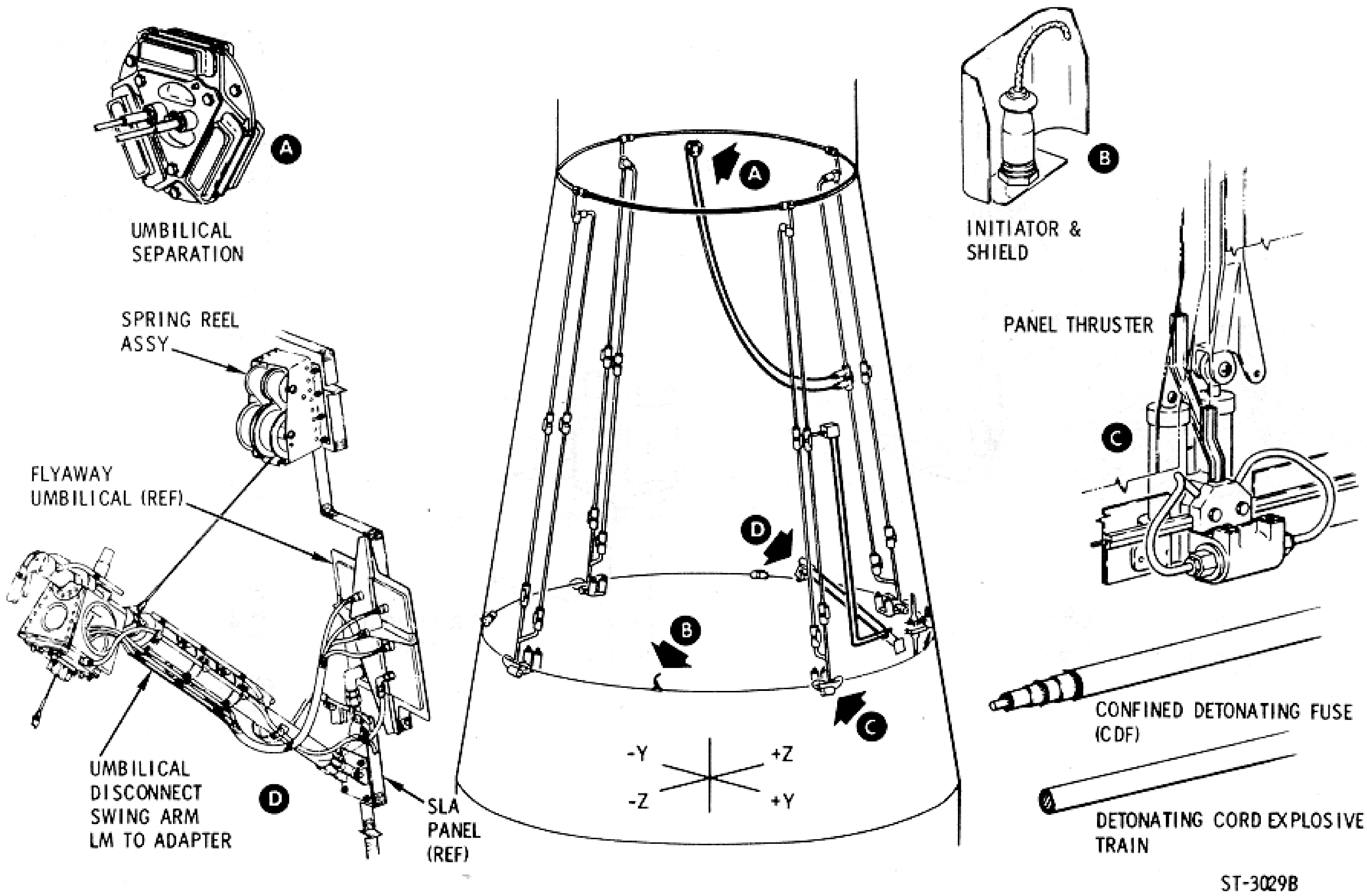

Figure 2.9-25. Adapter Separation System

which, in turn, will energize the latching coils of the RCS ENABLE relays, zone 7-A. This relay logic will enable the controller reaction jet on/off assembly which couples the SCS jet selection logic and SM RCS, section 2.5, RCS.

2.9.4.10 Docking Probe Retraction.

This system is designed for two retractions with backup for each. Since there are four retraction cylinders, however, four retractions are possible under ideal circumstances.

The DOCK PROBE RETRACT PRIM and/or SEC switches (S2 and S3), zones 13-E and -F, are armed when four conditions are satisfied. These are:

a. The appropriate buses are energized and the appropriate circuit breakers are closed, zones 15-E and -F.

b. The EXTEND/REL switch (S1), zones 14-E and -F, is in the RETRACT position.

c. The latch indicating switches in the docking ring latches are closed (system A and/or B as required).

d. The capture latches sensing switches are closed (probe head latched in LM drogue).

When these conditions are satisfied, the DOCK PROBE RETRACT switches may be utilized to energize the LM DOCKING PROBE RETRACT No. 1 and 2 relays as required. Contacts of these relays will fire the initiators and retraction will be executed.

2.9.4.11 Separation of LM From S-IVB.

Pyro power circuits to the LSSC include a circuit breaker which is described in paragraph 2.9.4.2.2. The S-IVB/LM SEP PYRO A circuit breaker (CB3), zone 39-F, must be closed to complete the system A LSSC pyro circuit. The LDEC is also required in this automation.

Closing the S-IVB/LM SEP switch (S108), zone 18-E, will start the following sequence:

a. The LM/SLA SEP (LM LEGS) relays of the LSSC, will be energized and their contacts will fire the initiators of the frangible links which retain the LM legs.

b. The nonlatching relay and the latching coils of the latching relay of the LM/SLA SEP INITIATE relays in the LSSC will be energized after a time delay of 30 milliseconds.

c. The LM/SLA SEP (GUILLOTINE) relays of the LSSC, will be energized after a time delay of 30 milliseconds.

Contacts of the LM/SLA SEP INITIATE relays will deadface LSSC pyro power which was utilized to fire the frangible links of the LM legs. Contacts of the system B LM/SLA SEP INITIATE relays are in the system A deadfacing circuits for series/parallel redundancy; system A contacts are utilized in system B (not illustrated) for the same reason.

LDEC pyro power fires the umbilical guillotine through contacts of the LM/SLA SEP INITIATE relays in the LDEC and the LM/SLA SEP (GUILLOTINE) relays in the LSSC. Deadfacing of LDEC pyro power is accomplished when the switch is allowed to return to its maintain position and the relay coils are de-energized. The contacts of the nonlatching relays will return to their initial state but the contacts of the latching relay will not revert to their initial positions.

2.9.4.12 LM Docking Ring Separation.

Logic power through the momentary contacts of either of the CSM/LM FINAL SEP switches (S109 or S112), zone 26-D, will energize the LM DOCKING RING FINAL SEPARATION relays in the LDEC. These are the firing relays for the ordnance which severs the docking ring from the CM tunnel.

2.9.4.13 Nominal Pre-entry and Descent.

Arming the SECS is the first requirement of the sequential systems preparatory to a nominal entry and descent (paragraphs 2.9.4.1 and 2.9.4.2). If mission rules require a checkout of the CM RCS prior to CM/SM separation, it is vital that electrical control of the RCS be placed in the SM RCS configuration prior to initiating the separation (paragraph 2.9.4.13.2). Figure 2.9-26 illustrates a nominal pre-entry and descent profile.

2.9.4.13.1 CM/SM Separation Control.

When either of the CM/SM SEP switches (S110 or S111), zones 24-C and -D are closed, logic power will start the automated sequence of CM/SM separation. Each of these switches, No. 1 and 2, is a double-pole switch with one pole controlling system A components and the other pole controlling system B components. When either or both of these

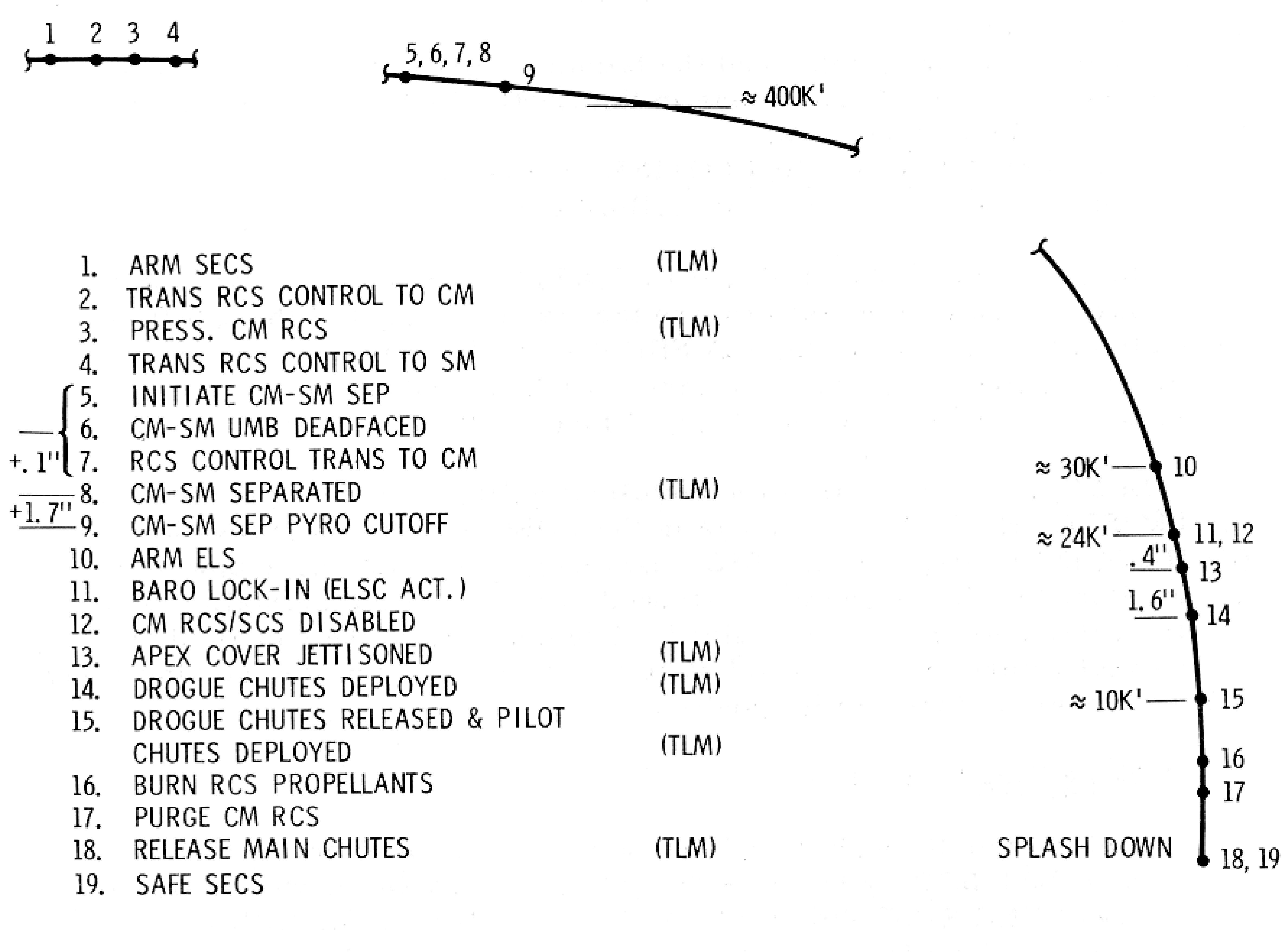

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Figure 2.9-26. Event Profile, Nominal Pre-Entry and Descent switches are utilized for CM/SM separation, they should be held closed for approximately 0.1 of a second to allow the time-delay relay logic to function properly (paragraph 2.9.4.13.5).

2.9.4.13.2 Jettisoning the SM. (Zones 19 through 22-E and -F)

A manually initiated CM/SM separation signal will start the SMJC with logic battery power through contacts of the RCSC motor switch (S1), zone 23-E. The motor switch must be in the SM control position for the start signal to activate the SMJC (paragraph 2.9.4.13). Latching relays are utilized to couple fuel cell electrical power to the SMJC and to energize the manual coils of the SM RCS -X engines. Fuel cell power to the SMJC is through contacts of motor switches, zones 23-E and -F, which are described in Section 2.6, Electrical Power. The control circuits in the SMJC constitute a crossover network; either system A or B will energize the manual coils of both of the SM RCS redundant engine systems. The +roll engines will be started 2.0 seconds after the SMJC is started and will operate for 5.5 seconds. The -X translation engines will continue to burn until the propellants are depleted or the fuel cells are expended, whichever occurs first.

2.9.4.13.3 Deadfacing the CM-SM Umbilical.

Closure of either of the CM/SM SEP switches will energize the CM/SM DEADFACE relays to the MESC, zone 23-C. These relays are utilized to initiate the ordnance devices of the CM-SM electrical circuit interrupter (figure 2.9-27) and the SM circuit interrupter (figure 2.9-28). These relays may be considered as pilot relays to the automation of other CM-SM separation functions which includes interface with the CM-RCS.

2.9.4.13.4 Separation of the CM From the SM.

When the CM-SM SEPARATE relays in the MESC are energized after a time delay of 0.1 second, ordnance devices required for CM-SM separation are initiated. These are the guillotine blades of the CM-SM umbilical assembly (figure 2.9-29) and three tension ties between the CM and SM structures (figure 2.9-30). The time delay is required in this circuit so that the guillotine blades will cut wires which were deadfaced (paragraph 2.9.4.13.3).

2.9.4.13.5 Pyro Cutout.

The pyro cutout circuits are incorporated to eliminate the possibility of draining pyro power through wiring which may have one or two strands shorted by umbilical blades, or any other high resistance short. Fusistors afford protection against "dead shorts" (figure 2.9-18 and paragraph 2.9.4). The PYRO CUTOUT relays, zone 20-B, are energized 1.7 seconds after the CM-SM SEPARATE relays. Contacts

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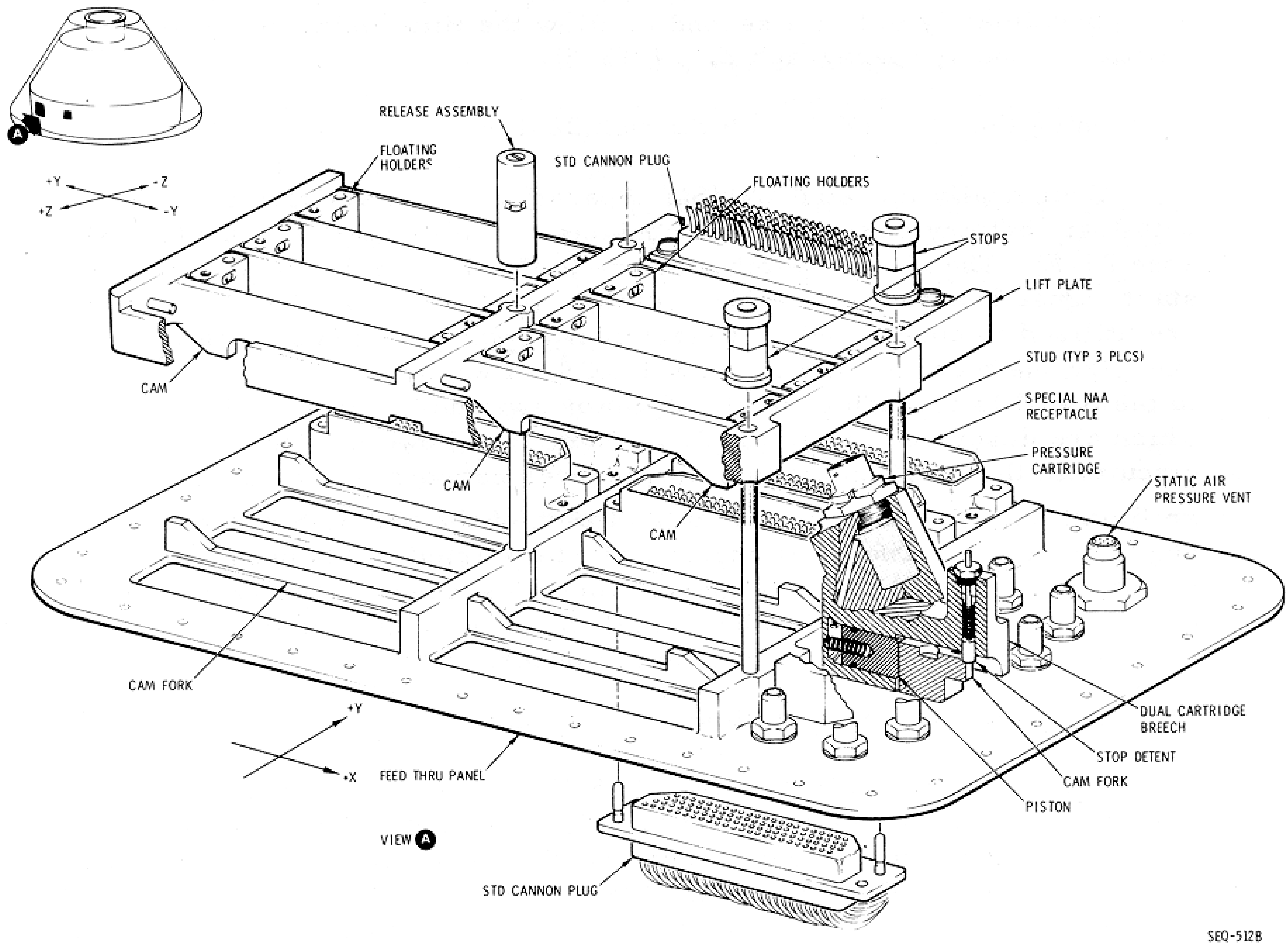

Figure 2.9-27. CM-SM Electrical Circuit Interrupter

of the PYRO CUTOUT relays are in the logic circuits to the CM-SM DEADFACE relays, zone 23-D. Contacts of the PYRO CUTOUT relays are also in the pyro circuits to the initiators that are expended in the separation sequence, zones 20 through 23-C and -D. This relay logic is an arc suppression system since electrical energy is removed from initiator firing relay contacts at the time they return to their normal state. When the CM/SM SEP switch is released it will return to its normally open state and all relays in this logic, including the PYRO CUTOUT relays, will be de-energized.

2.9.4.13.6 CM RCS Interface.

Any time a CM-SM separation signal is initiated in the MESC, a signal is automated for the initiation of two CM RCS functions. These are:

a. Fluid systems pressurization, zones 21 through 23-A and -B. The system 1 CM-RCS PRESS relay logic provides firing circuits to

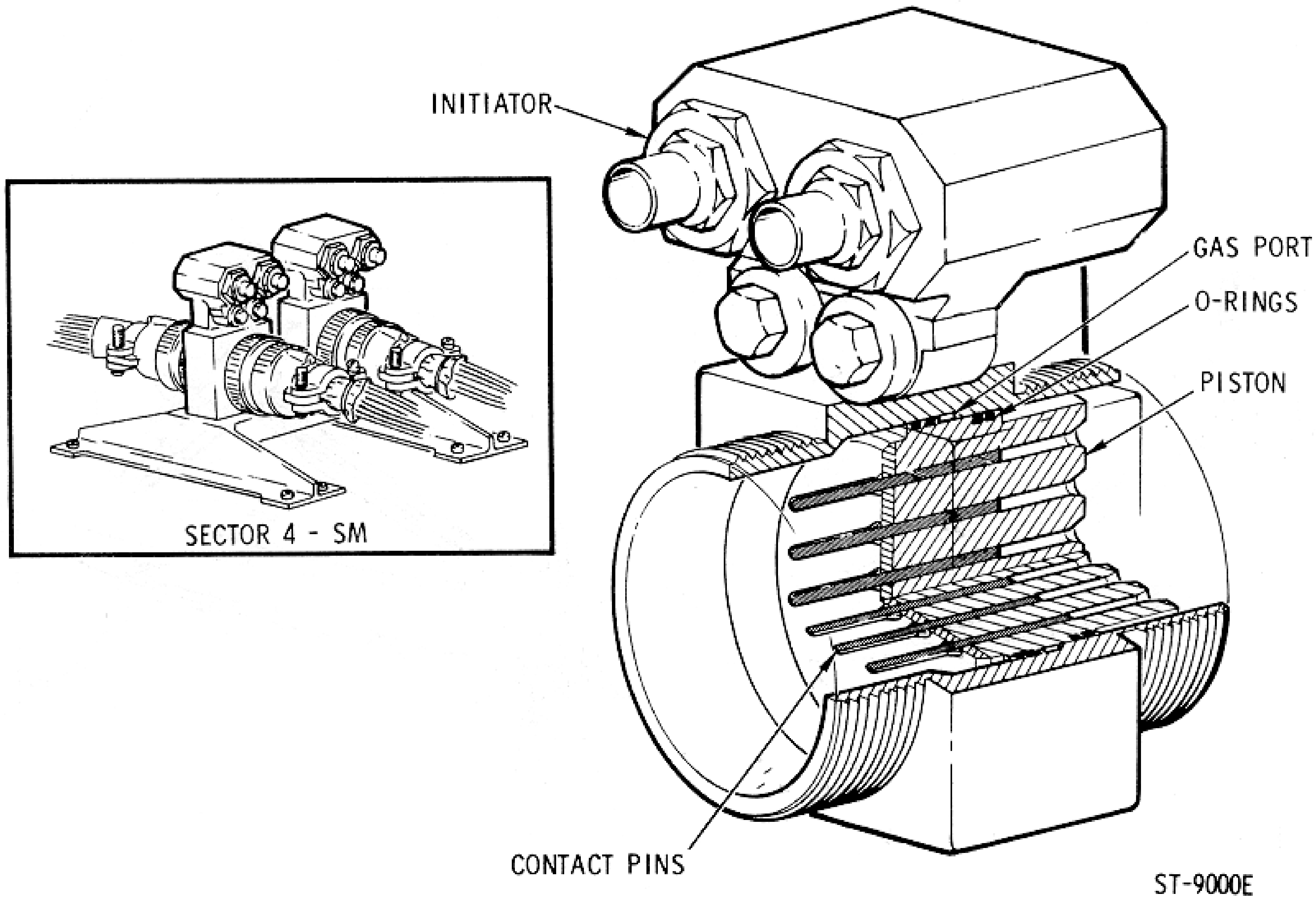

Figure 2.9-28. SM Circuit Interrupter

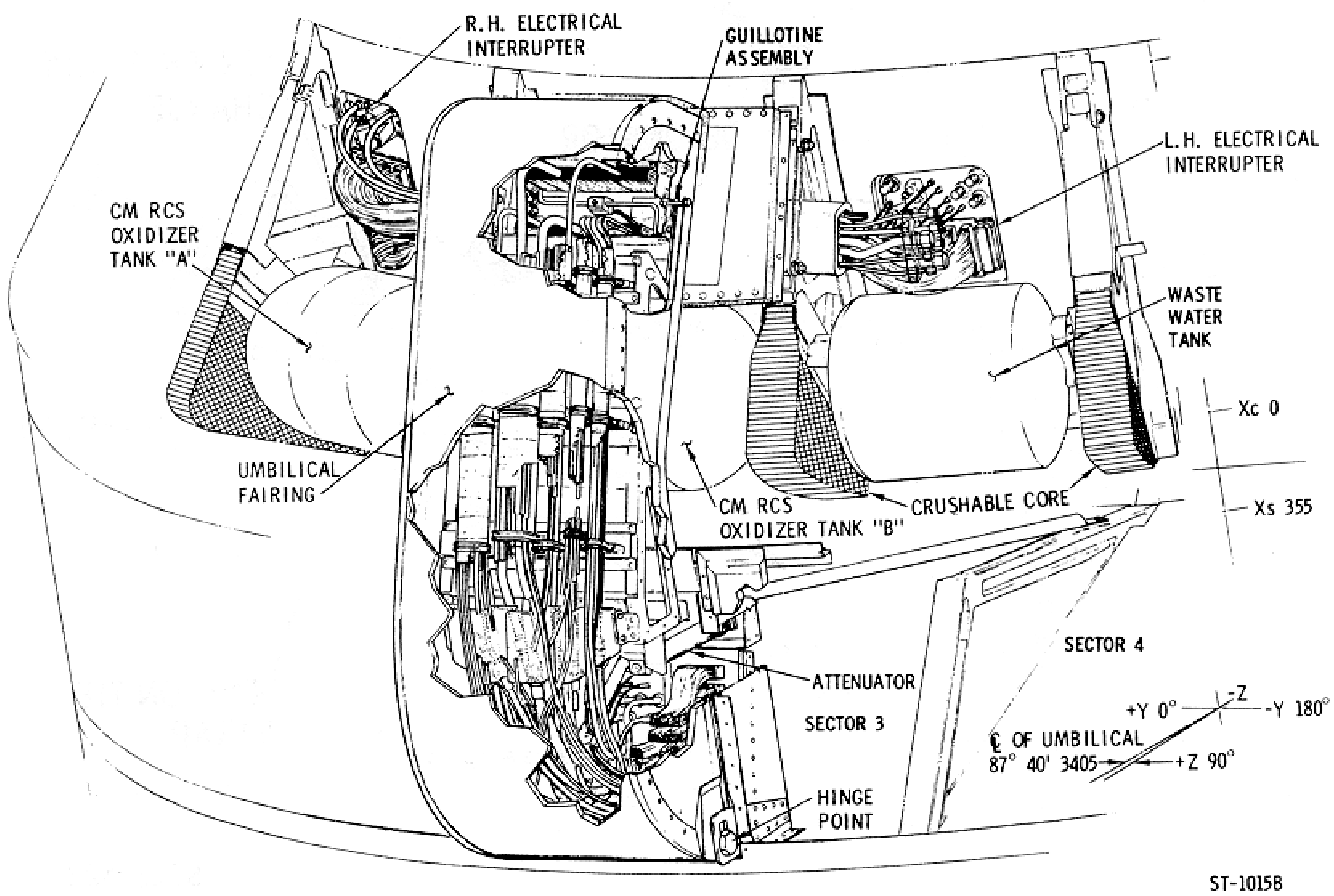

Figure 2.9-29. CM-SM Umbilical Assembly

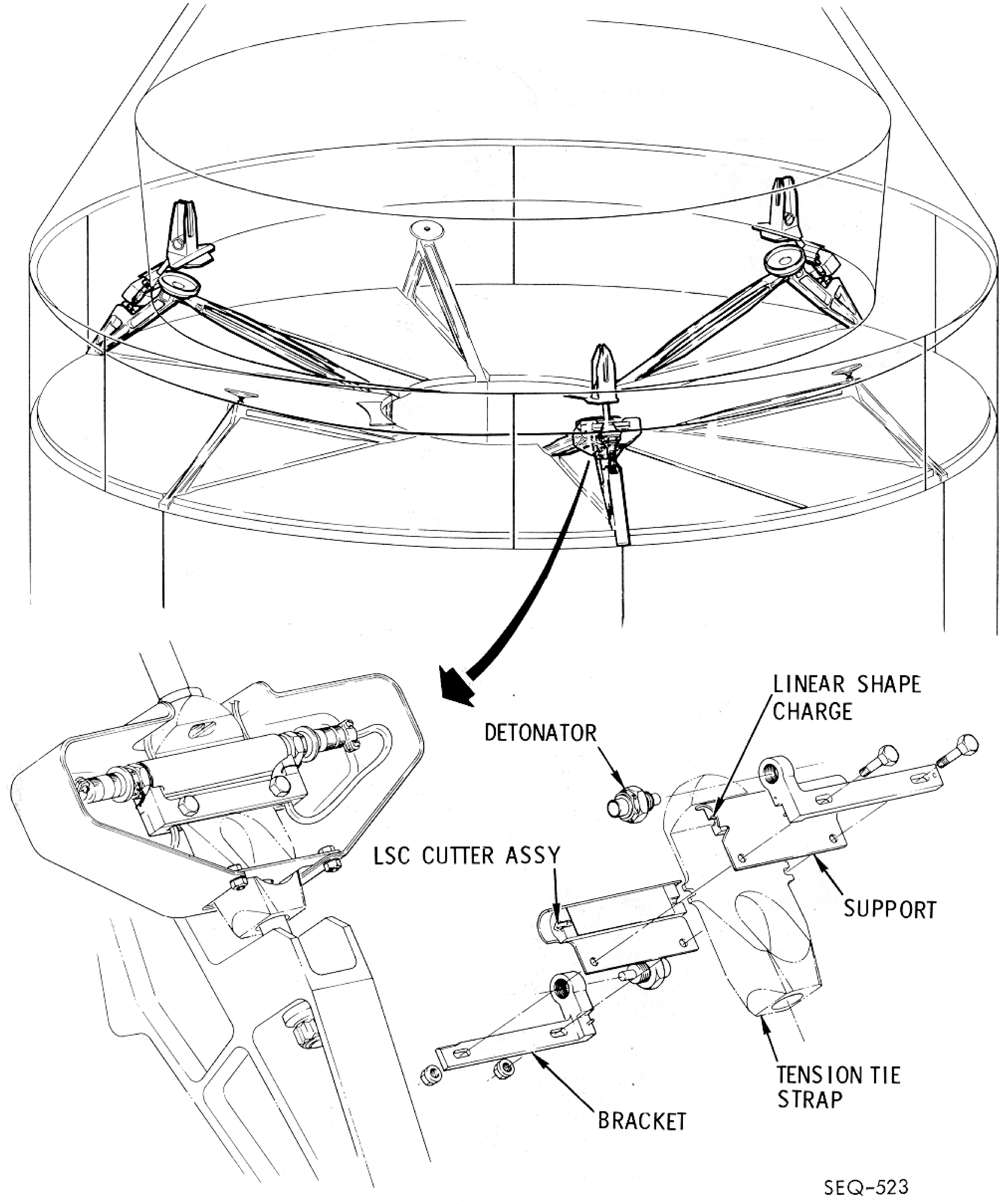

Figure 2.9-30. CM-SM Separation System

one of the HELIUM SQUIB ISOLATION valves in each of the redundant fluid systems of the CM RCS (Section 2.5, RCS).

b. Transfer electrical control from the SM RCS to the CM RCS, zones 18 through 20-A and -B. RCS CM-SM TRANSFER relay logic in the RCSC will drive the transfer motor switch to the SM position. Moreover, contacts of the motor switch are utilized to deadface the SMJC start signal, zone 23-E. There is a time delay of approximately 50 milliseconds in this deadfacing function which is explained as the time it takes the motor switch contacts to change state.

2.9.4.13.7 Main Bus Tie.

Relay logic of the RCSC, zones 11 through 13-C and -D, will couple ENTRY AND POSTLANDING batteries A, B and C to the main buses providing certain circuit breakers and switches of the electrical power system (Section 2.6) are in the correct position for this automation.

2.9.4.13.8 Arm ELSC.

Closure of the ELS LOGIC switch (S44), zone 10-D, will complete logic power circuits to redundant transistorized switches in the MESC. These solid state switches function as a pair of AND gates, each of which requires two inputs to emit. One of the inputs is satisfied when the logic power circuits are completed.

2.9.4.13.9 Activate ELSC.

Logic power circuits to the ELSC, including ground returns for the components in this controller, are not completed until the ELSC ACTIVATE relays in the MESC are energized, zone 8-C. The solid state switches (paragraph 2.9.4.13.8) control the logic power required to energize these relays. Assuming that the ELS switch (S63), zone 8-E, is in the AUTO position, closure of the 24,000 FT BARO SWITCHES will satisfy the second input to the solid state switches. Logic power in this instance is derived from a point between the ELS LOGIC switch and the solid state switches. It is wired, through a resistor, to a point between the redundant baro switches. Both baro switches will be closed at the same time, and the reduced logic power, because of the resistor, will be sufficient to trigger the solid state switches; however, the reduced logic power is not sufficient to energize relay coils of the ELSC. When the ELSC ACTIVATE relays are energized, another crossover network is established; system B relay logic will establish holding circuits to the system A relays; moreover, system B relay logic can energize system A relays.

2.9.4.13.10 24,000 ft Baro Switch Lock Up.

In addition to activating the ELSC (paragraph 2.9.4.13.9), closure of the 24,000 FT BARO SWITCHES will energize the 24,000 FT LOCK

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UP relay in the ELSC, zone 7-D. This relay logic, together with the system B counterpart, will establish logic power holding circuits which bypass the 24,000 FT BARO SWITCHES.

2.9.4.13.11 Disable CM RCS/SCS.

A signal is relayed to the unlatching (disable) coils of the RCS/SCS ENABLE relay, zone 7-A, when the ELSC is activated (paragraph 2.9.4.13.9). This relay logic disables the controller reaction jet on/off assembly (Section 2.5, RCS).

2.9.4.13.12 Apex Cover Jettison.

When the ELSC has been activated (paragraph 2.9.4.13.9), the first function that will be automated is apex cover jettison (figure 2.9-31).

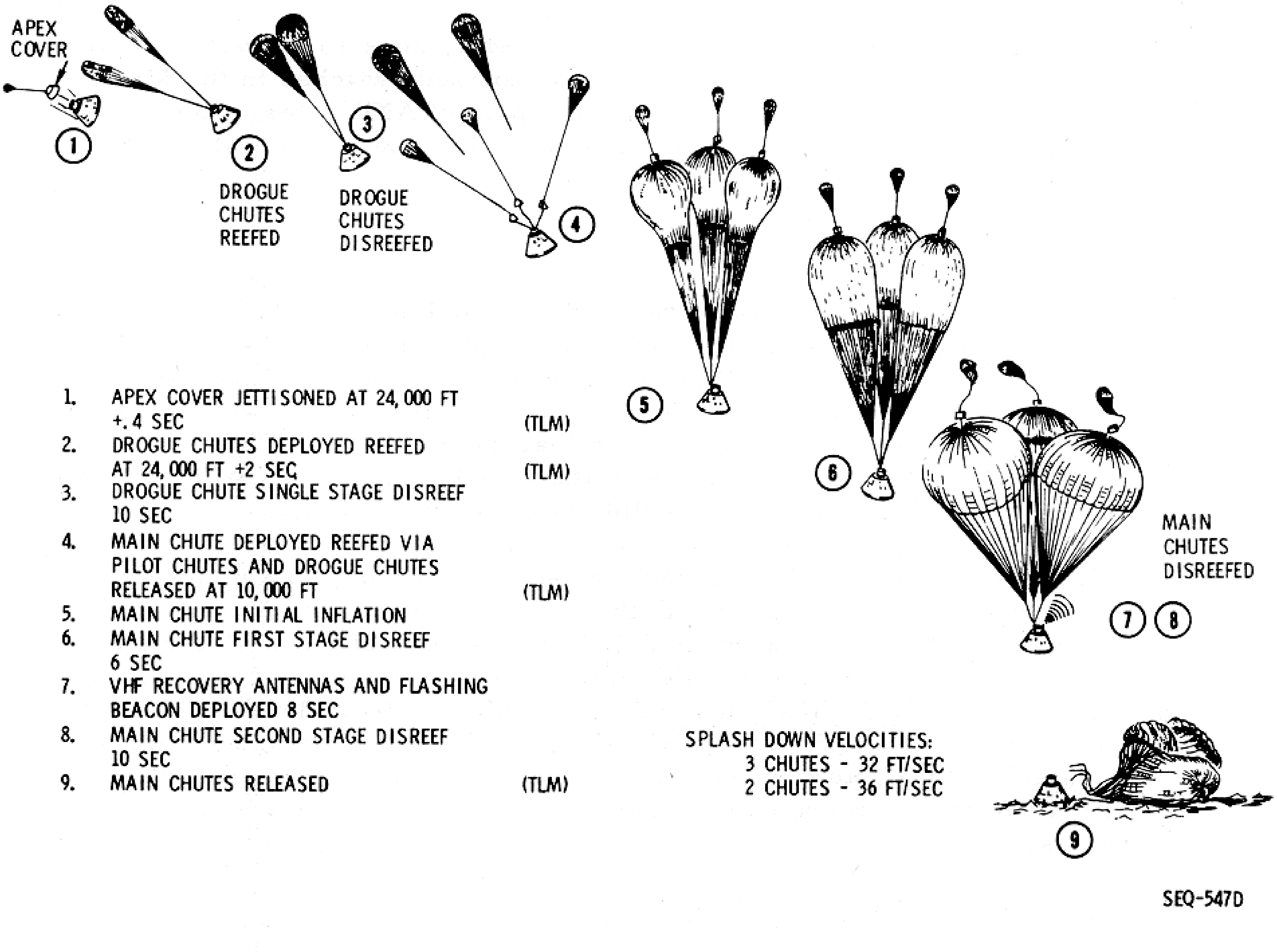

Figure 2.9-31. Earth Landing System, Normal Sequence

The APEX COVER JETTISON relays in the MESC are energized after a time delay of 0.4 second, zones 5 and 6-E. The holding circuits of these firing relays are one of the numerous crossover networks described in paragraph 2.9.4. The ordnance devices which are initiated in this function are described in paragraph 2.9.2.7. In addition to initiating the ordnance devices, this relay logic will also arm lanyard-actuated switches, zone 5-F, which are used to deploy the apex cover drag parachute. The lanyard pulls holding pins from the switches which, because of spring loading, will close circuits. Closure of these switches will energize the DRAG PARACHUTE DEPLOY relays in the MESC which initiate the drag parachute mortar.

2.9.4.13.13 Deployment of Drogue Parachutes.

The DROGUE IGNITER relays in the ELSC and PCVB, zones 4 and 5-D, are energized by ELSC ACTIVATE relay logic (paragraph 2.9.4.13.9) after a time delay of 2 seconds. Another crossover is established in this relay logic wherein the systems A and B PCVB relays cross-couple each other with holding circuits. Moreover, each system initiates ordnance devices of both systems.

2.9.4.13.14 Deployment of Main Parachutes and Release of Drogues.

Closure of the 10,000 FT BARO SWITCHES, zone 6-C, will energize the PILOT CHUTES AND DROGUE RELEASE relays in the ELSC and the PCVB. The PCVB relays in this logic are again cross-coupled, systems A and B, into crossover holding circuits. The ordnance initiator circuits are also arranged into a crossover network.

2.9.4.13.15 Burning of the CM RCS Propellants.

Switches in the CM RCS, zones 40-C and -D, are used to energize the direct coils of ten CM RCS jets, zones 15 and 16-A. The correct utilization of these switches is described in Section 2.5, RCS.

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2.9.4.13.16 Release of Main Parachutes.

Closure of the MAIN RELEASE switch (S71), zones 4 and 5-C, will energize the MAIN CHUTE RELEASE relays in the PCVB. These relays are used to initiate ordnance which will drive cutter chisels through the main parachute risers (figure 2.9-32).

2.9.4.14 Aborts.

Abort signals may be initiated manually by rotating the commander's translation hand control counterclockwise into a detent. Two cam-operated micro switches, zone 31-B, are included in the control. Batt. power through these switches will energize the BOOSTER CUTOFF AND LES OR SPS ABORT START RELAYS in the MESC, zone 29-A.

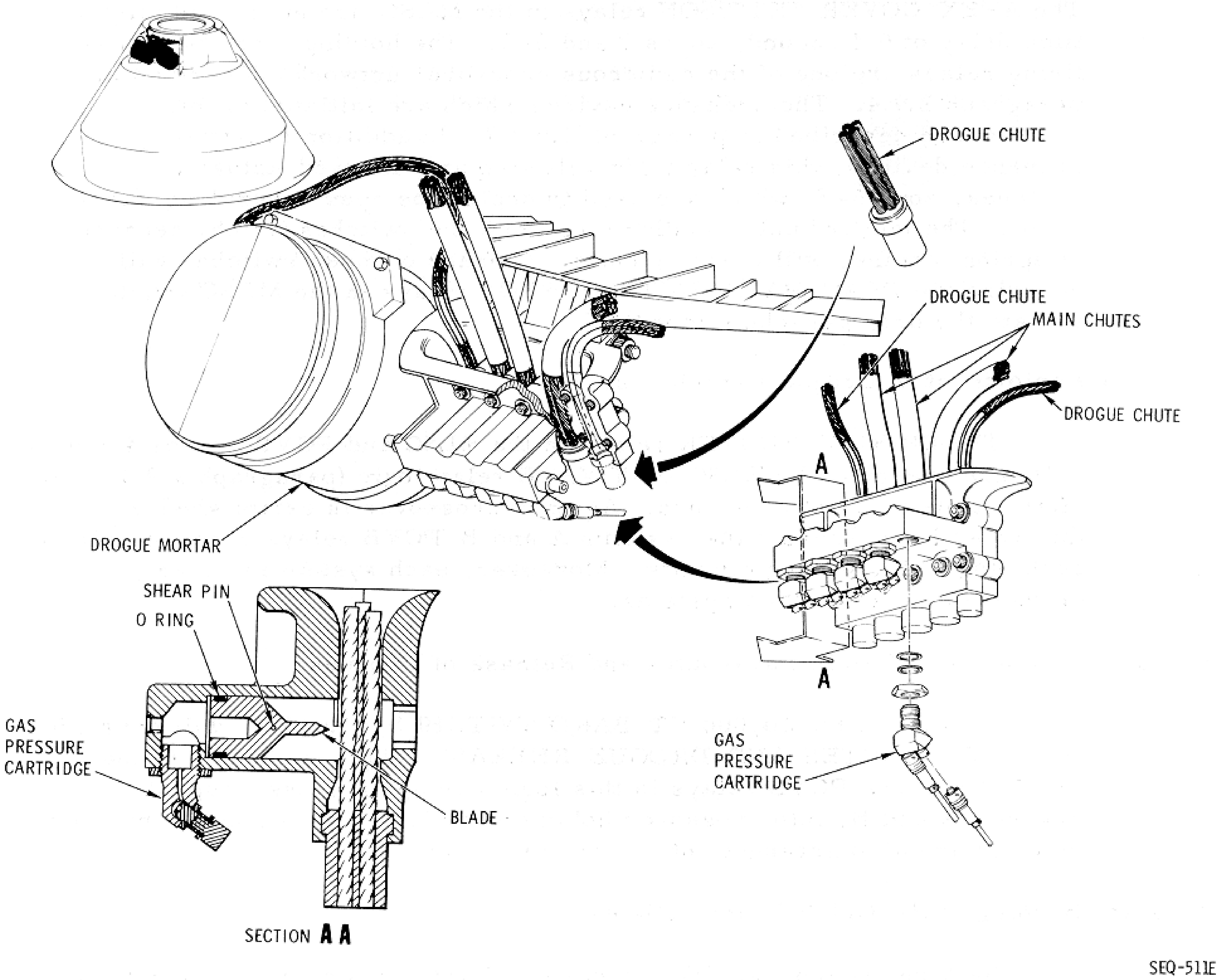


Figure 2.9-32. Parachute Disconnect (Flower Pot)

These relays may also be energized by an EDS automatic abort signal (paragraph 2.9.4.7) through 30-millisecond time delays. The reason for the time delays is to insure against spurious signals initiating an abort. EDS bus changeover power (paragraph 2.9.4.3) is utilized to energize the BOOSTER CUTOFF AND LES OR SPS ABORT START relays in the event of an EDS automatic abort. Any abort signal will automate two functions which are common to all abort sequences. These are:

a. BECO, zones 27 and 28-A and -B, is inhibited by IU relay logic until T + 30 seconds in the S-V LV configuration because of range safety requirements.

b. Reset and start the commander's event timer, zone 27-D. It is necessary for the EVENT TIMER START switch (S56), zone 32-C, to be in the CENTER ON position for this function to be automated.

2.9.4.14.1 Abort Start. (Zones 27 and 28-C and -D)

Two pairs of LET PHYSICAL SEPARATION MONITOR relay contacts (paragraph 2.9.4.7.1) are in the abort start relay logic. One pair is normally closed and the other is normally open. The state of these contacts at the time an abort is initiated will determine whether an LES or SPS abort is automated in the sequential systems. When the BOOSTER CUTOFF AND LES OR SPS ABORT START relays are energized (paragraph 2.9.4.14), the LES ABORT relays may or may not be energized; if they are energized, an LES abort will be started if not, an SPS abort will be started.

2.9.4.14.2 LES Abort Start.

Initially the sequential events of all LES aborts are identical. In addition to the functions that are common to all aborts (paragraph 2.9.4.14), separation of the CM from the SM is automated. The automated CM/SM separation sequence is the same as the manually initiated separation sequence described under nominal pre-entry, entry, and descent (paragraphs 2.9.4.13 through 2.9.4.13.7) with two exceptions which are:

a. The SMJC is not started when the separation sequence is started by a LES abort signal, zone 24-D.

b. In an LES ABORT the CM/SM separation sequence includes the firing of the LEM, zones 14 through 21-C.

2.9.4.14.3 Mode 1A Abort.

A mode 1A abort (figure 2.9-33) is initiated prior to the expiration of the PROPELLANT DUMP AND PURGE DISABLE TIMER (TD1) in the RCSC, zone 18-B. This time-delay relay logic is started at lift-off (paragraph 2.9.4.4) providing two conditions are satisfied. These are:

a. The RCSC motor switch (S1), zone 19-A, must be in the SM RCS control position (as illustrated).

b. The CM RCS LOGIC switch (S46), zone 40-D, must be in the CM RCS LOGIC position.

A pair of latching contacts, which are closed when the timer is reset by GSE, are in series with the PRPLNT DUMP AUTO contacts of the ABORT SYSTEM PRPLNT switch (S63), zone 20-B. When this switch is in the PRPLNT DUMP AUTO position, and before the timer contacts are opened, the requirements peculiar to a mode 1A abort may be automated. These are:

a. The PCM is fired by the same relay logic that ignites the LEM, zone 19-D. Logic power for energizing the PCM firing relays is derived through the closed contacts of the PROPELLANT DUMP AND PURGE DISABLE timer, zone 19-B.

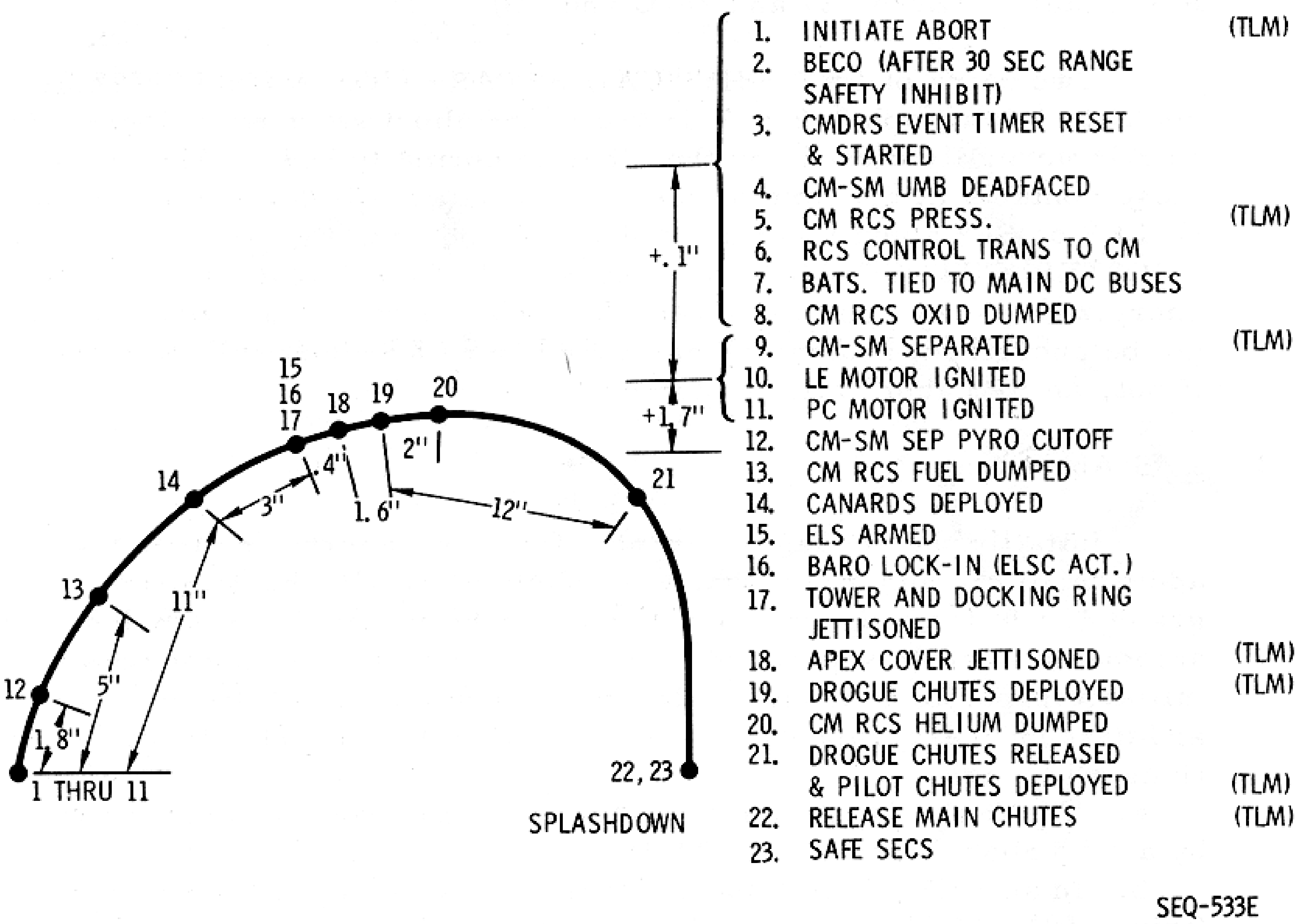


Figure 2.9-33. Event Profile, Mode 1A Abort

b. The OXIDIZER DUMP RELAYS, zone 17-B, are energized immediately with an abort initiate signal resulting in four CM RCS functions: (1) closure of the PROPELLANT SHUTOFF valves, zone 14-A; (2) energization of the INTERCONNECT AND PROPELLANT BURN relays, zones 16 and 17-A; (3) initiation of the OXID PUMP squib valves, zone 13-B; (4) initiation of the HELIUM and OXID INTERCONNECT squib valves, zones 13 and 14-A. The FUEL INTERCONNECT squib valve is initiated by the B system relay logic of the SECS.

c. Five seconds after the abort initiate signal, the FUEL DUMP squib valve, zone 14-B, is initiated by time-delay relay logic in the RCSC, zone 16-B.

d. Thirteen seconds later, or 18 seconds after the abort initiate signal, the FUEL AND OXID BYPASS RELAYS are energized, zone 15-B. This time-delay relay initiates the squib valves which will purge the CM RCS fluid systems in addition to depleting the pressurant, zone 13-A.

2.9.4.14.4 Canard Deploy and ELSC Arm.

Eleven seconds after the initiation of any LES ABORT, canard deployment is automated, zones 25 and 26-C and -D. This relay logic will also arm the ELSC, zone 10-D. Contacts of the CANARD DEPLOY relay are incorporated parallel to the ELS LOGIC switch (S44) which must be in the OFF position during the launch and ascent phases of a mission. When arming of the ELSC is automated, through 3.0-second time delays, the same functions which are described in paragraph 2.9.4.13.8 will result.

2.9.4.14.5 ELSC Operation.

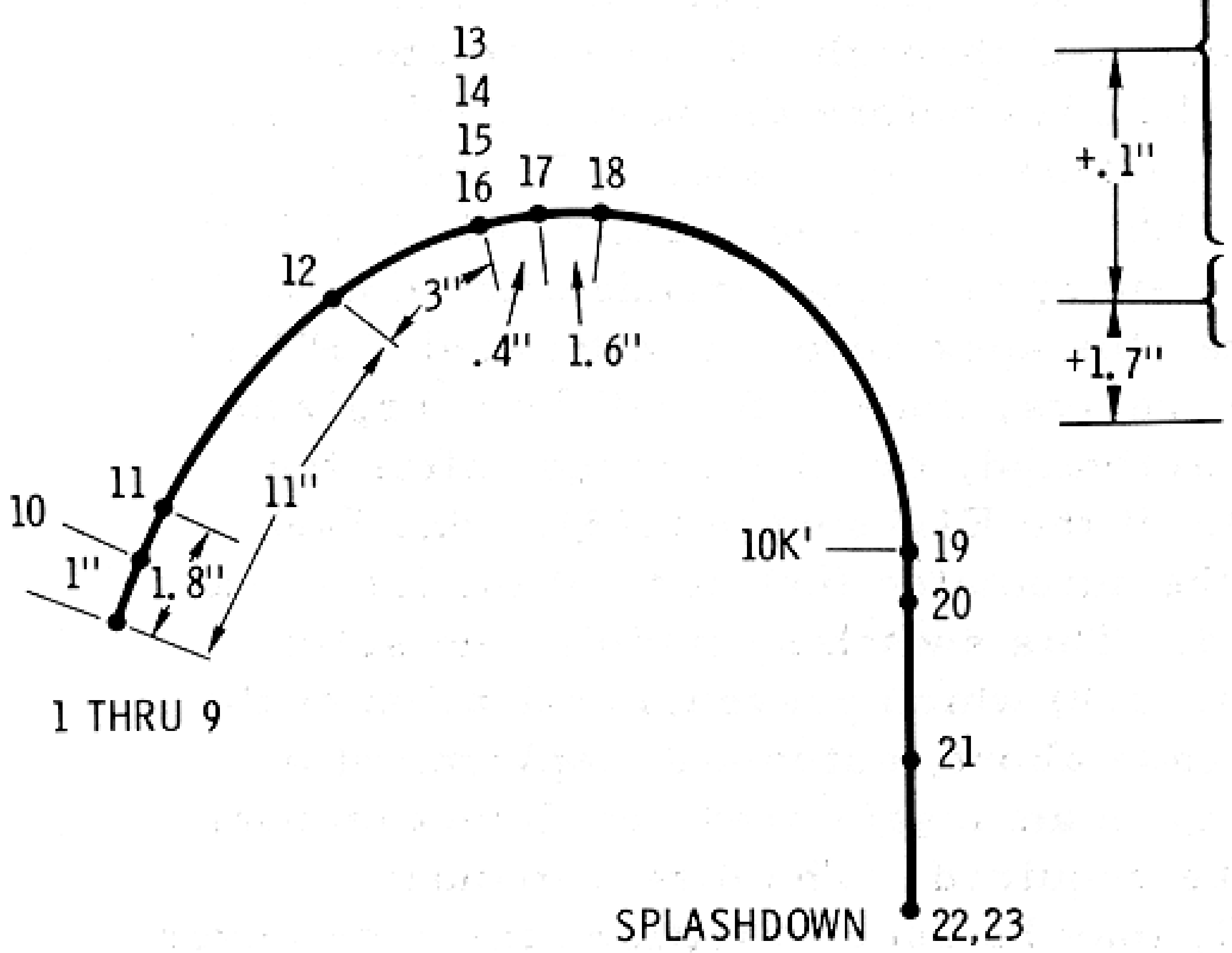
Functions of the ELSC may be initiated by baro switches time-delay relay logic or direct manual control. Baro switches are opened and closed by aneroid cells and are calibrated to close at approximately 24,000 and 10,000 feet during a nominal entry. During a nominal launch and ascent the 10,000-foot baro switches will open at approximately 18,000 feet and the 24,000-foot baro switches will open at approximately 40,000 feet. This is the result of several variables which include spacecraft velocity, attitude, and atmospheric conditions. During a mode 1A abort, for example, closure of CANARD DEPLOY relay contacts, zone 10-D, will not only arm the ELSC but will also activate it because the 24,000-foot baro switches will be closed in this instance. When the ELS ACTIVATE relays, zone 8-C, are energized, a signal will be relayed from a point starting at zone 7-D to the LET JETTISON AND FRANGIBLE NUTS relays, zone 26-F. This results in automatic LET jettison and, if the spacecraft is equipped with a docking probe, LM docking ring separation, zones 24 through 26-D and - E. Also, when the ELS ACTIVATE relays are energized, a signal will be relayed from a point starting at zone 7-E to the unlatching coils of the RCS ENABLE-DISABLE RELAYS, zone 7-A. This disables automatic control of the CM RCS. Time-delay relay logic is incorporated in the integrated MESC and ELSC, zones 6-C through -E, to automate the required functions at the lower altitudes before the baro switches are opened. The APEX COVER JETTISON relays, zone 5-E, will be energized 0.4 second after the ELSC is activated. DROGUE IGNITER relays, zones 4 and 5-D, will be energized 2.0 seconds after the ELSC is activated, or 1.6 seconds after the apex cover is jettisoned. PILOT CHUTES & DROGUE RELEASE relays, zone 5-B, will be energized 14.0 seconds after the ELSC is activated, or 12.0 seconds after the drogue parachutes are deployed. If the ELS switch (S63), zone 8-E, is placed in the MAN position, the automated functions of the integrated MESC and ELSC will be disabled. This switching inhibits the solid state switches (paragraph 2.9.4.13.8) which prevents activation of the ELSC. In the event of a worse case abort, automatic deployment of parachutes could result in landing in an unsafe area and direct manual control of ELS functions would be required. The direct manual switches, zones 6-B through -E, may be used to jettison the apex cover, deploy drogue parachutes, release drogue parachutes, and deploy the pilot parachutes of the main parachutes.

2.9.4.14.6 LES Abort Mode Switchover.

A configuration change is made in a portion of the SECS when the ABORT SYSTEM PRPLNT switch (S63), zone 20-B, is placed in the RCS CMD position. Normally this switching is concurrent with the expiration of the PROPELLANT DUMP AND PURGE DISABLE timer (paragraph 2.9.4.8). Requirements peculiar to a mode 1A abort (paragraph 2.9.4.14.3) are inhibited at this time and the requirements of any other mode abort, or a nominal mission, will be automated as a part of the CM/SM separation sequence. When the latching coils of the RCS ENABLE-DISABLE relays are energized, zone 7-A, the controller jet on/off assembly is enabled. This makes automatic control of the CM RCS possible (section 2.5, RCS).

2.9.4.14.7 Mode 1B Aborts.

Mode 1B aborts may be categorized according to the altitude at which the abort is initiated. Figure 2.9-34 illustrates the profile of an abort initiated after abort mode switchover (paragraph 2.9.4.14.5) and before reaching an altitude of approximately 30,000 feet. Figure 2.9-35 illustrates the profile of an abort initiated between the approximate altitudes of 30,000 and 100,000 feet. Part of the ELSC functions (items 12 through 17, figure 2.9-34) are automated by time-delay relay logic (paragraph 2.9.4.14.5) during mode 1B aborts initiated at the lower altitudes.



1. INITIATE ABORT (TLM)
2. BECO
3. CMDRS EVENT TIMER RESET & STARTED
4. CM-SM UMB DEADFACED
5. CM RCS PRESS. (TLM)
6. RCS CONTROL TRANS TO CM
7. BATS. TIED TO MAIN DC BUSES
8. CM-SM SEPARATED (TLM)
9. LE MOTOR IGNITED
10. CM RCS/SCS ENABLED (TLM)
11. CM-SM SEP PYRO CUTOFF
12. CANARDS DEPLOYED
13. ELS ARMED
14. BARO LOCK-IN (ELSC ACT.)
15. CM RCS/SCS DISABLED
16. TOWER AND DOCKING RING JETTISONED
17. APEX COVER JETTISONED (TLM)
18. DROGUE CHUTES DEPLOYED (TLM)
19. DROGUE CHUTES RELEASED & PILOT CHUTES DEPLOYED (TLM)
20. BURN RCS PROPELLANTS
21. PURGE CM RCS
22. RELEASE MAIN CHUTES (TLM)
23. SAFE SECS

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Figure 2.9-34. Event Profile, Mode 1B Abort
T + 42 Sec to ≈ 30,000 Feet

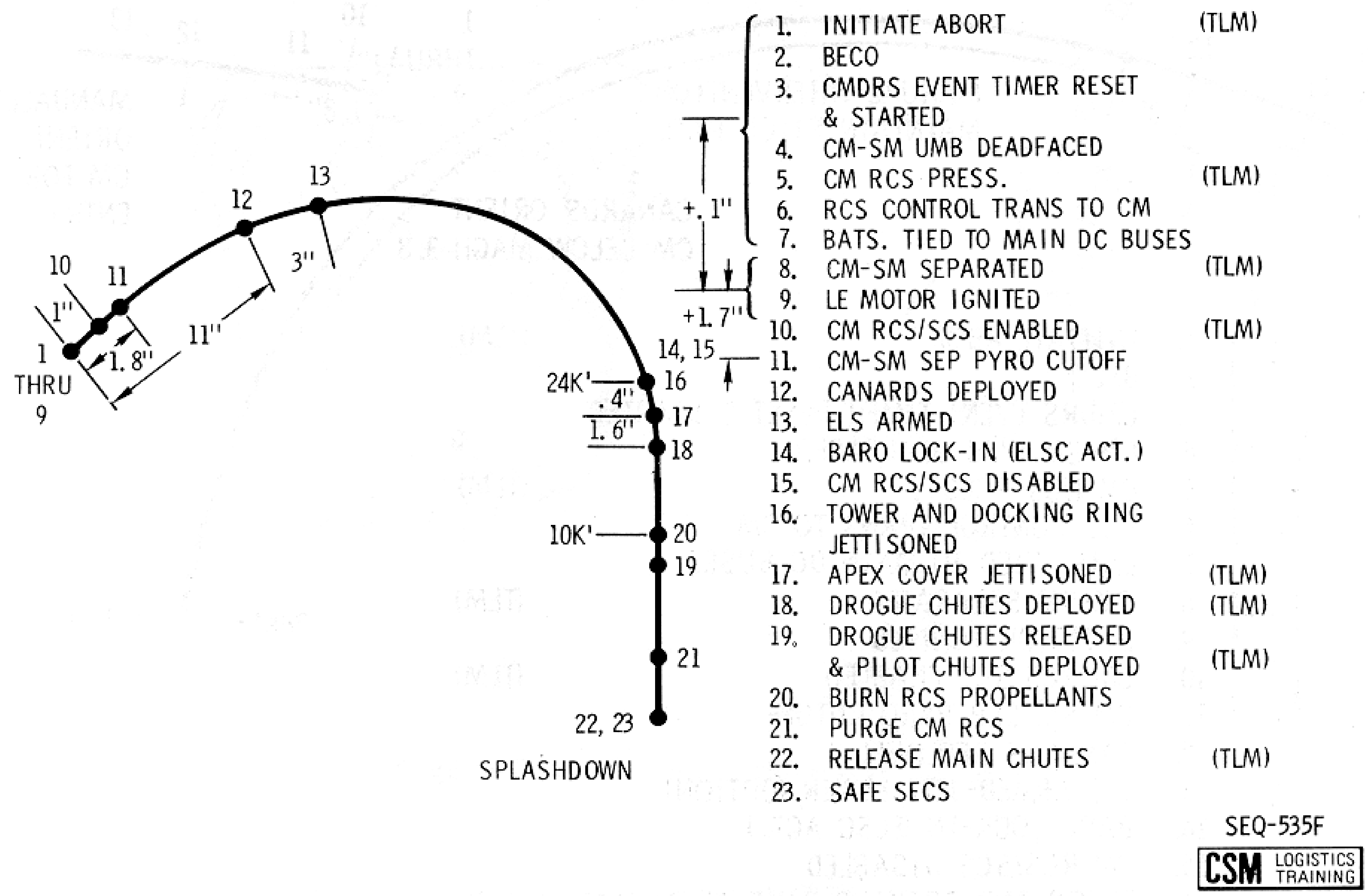

Figure 2.9-35. Event Profile, Mode 1B Abort
≈ 30,000 Feet to 100,000 Feet

All of the ELSC functions are automated by normal baro switch operation (items 13 through 18, figure 2.9-35) during mode 1B aborts initiated at the higher altitudes. Manually initiated requirements during descent and postlanding functions of mode 1B aborts are the same as during a nominal descent (paragraphs 2.9.4.13.15 and 2.9.4.13.16).

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2.9.4.14.8 Mode 1C Abort.

Mode 1C aborts (figure 2.9-36) are initiated at a time when the velocity of the LV is higher than the trim point of the canards. This is between an approximate altitude of 100,000 feet and normal LET jettison. The crew has the prerogative of jettisoning the LET shortly after the abort is initiated and utilizing the CM RCS for orientation similar to nominal entry maneuvers; or allowing the canards to orient the LEV when the free fall velocity is reduced to the trim point. If the latter option is elected there is a slight probability of an apex forward capture and violent rotational rates when the canards become effective aerodynamically. This slight probability can be avoided by imparting energy to the falling LEV. The CM RCS may be utilized to maintain a +pitch rate and this should be in excess of 5°/sec. There is no upper limit

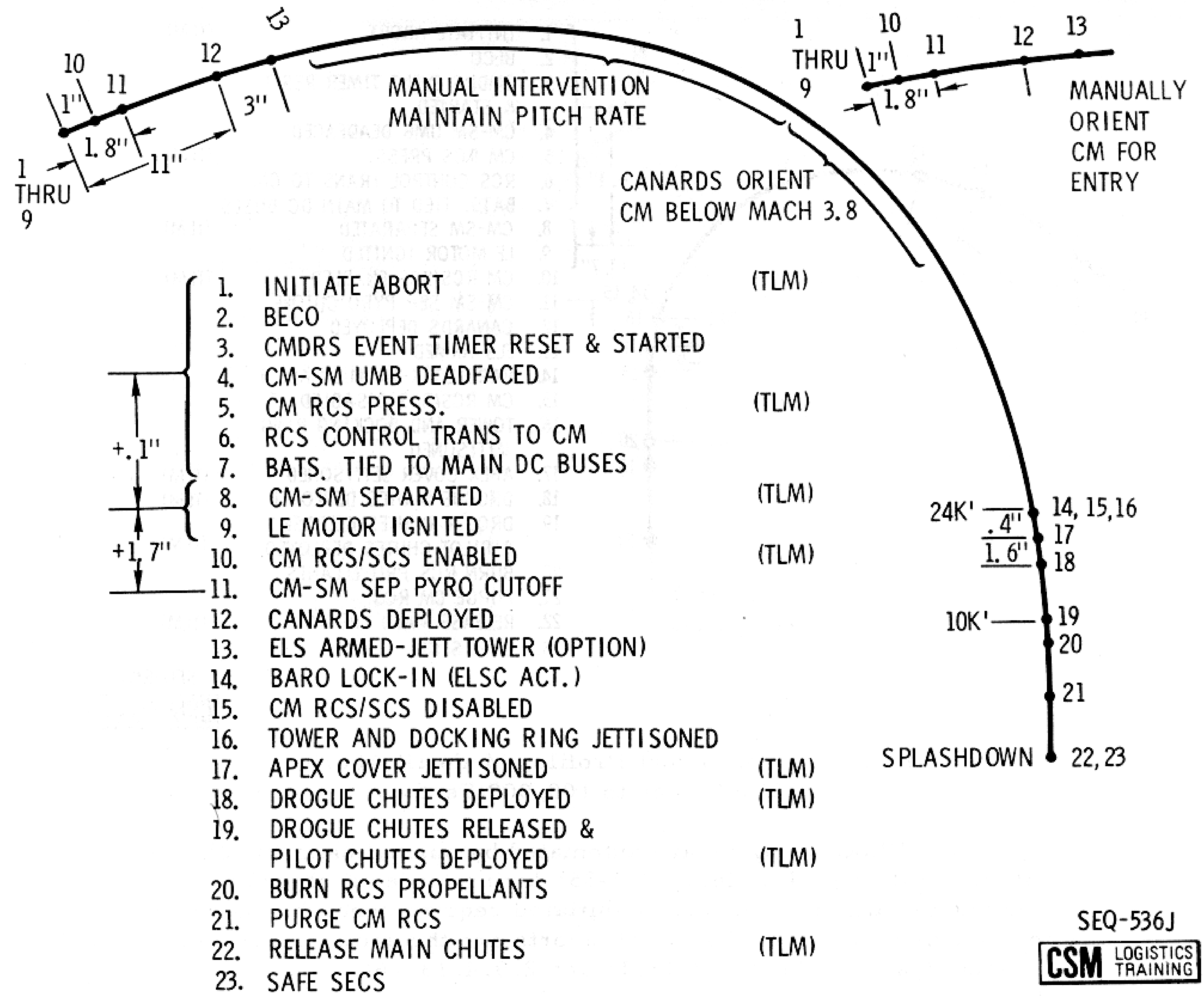

Figure 2.9-36. Event Profile, Mode 1C Abort

of rates since the CM RCS is limited under these flight conditions. Automation of ELSC functions during parachute descent and postlanding functions are the same as a nominal descent.

2.9.4.14.9 SPS Abort.

Sequential systems functions during an SPS abort are designed to separate the CSM from the LV with automation conducive to utilization of the SPS as required. Firing the SPS is not a function of the sequential systems. The way this propulsion system is utilized, or if it is utilized, is contingent on time into the mission, and maneuvering requirements for a safe recovery. Sequential systems automation is the same in all SPS aborts, figure 2.9-37. This type abort may be initiated any time after the LET is jettisoned until the CSM is separated from the LV. All

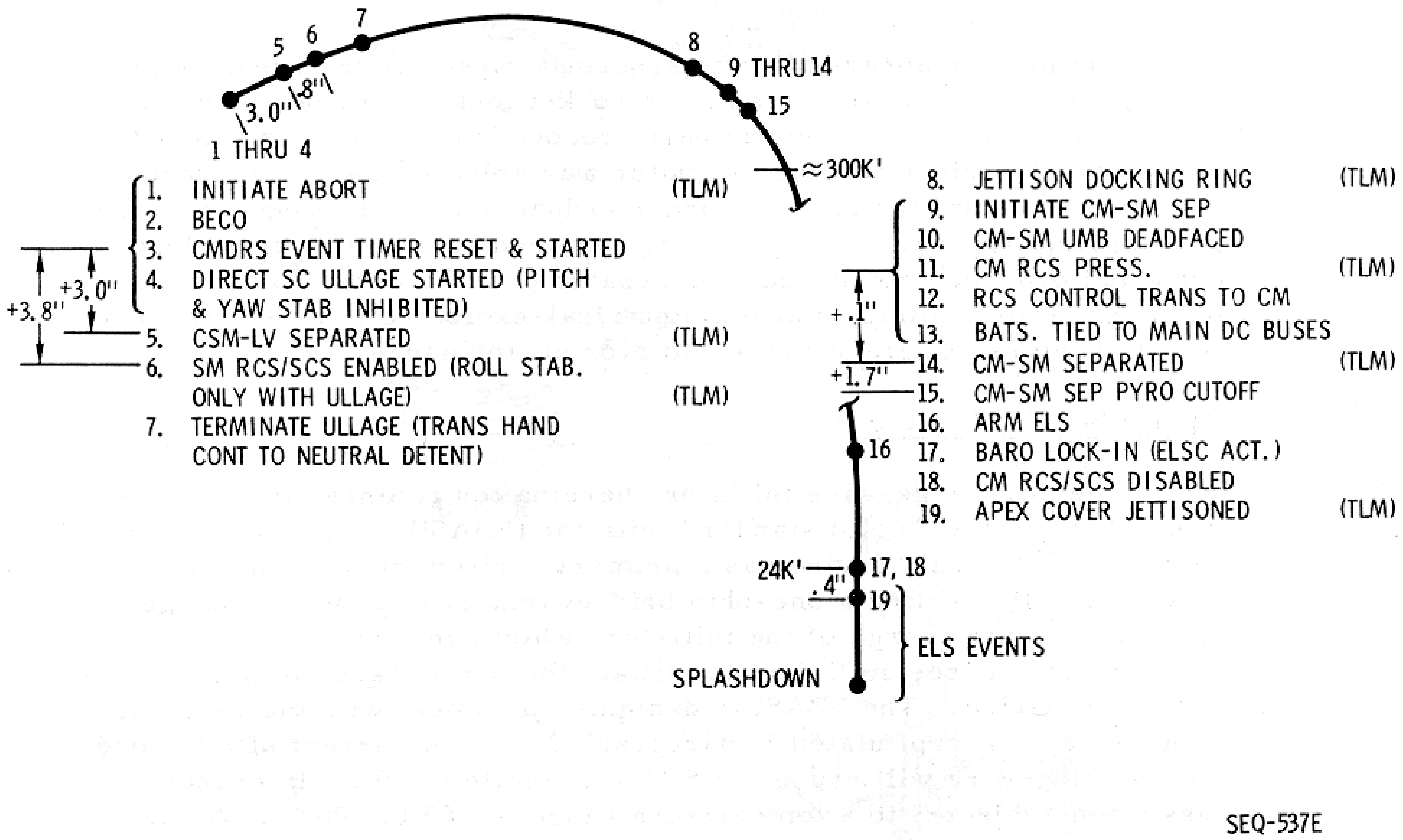

Figure 2.9-37. Event Profile, SPS Abort

SPS aborts must be initiated manually because the EDS automatic abort capability is lost when the LET is jettisoned (paragraph 2.9.4.8.4). Moreover, jettisoning of the LET results in configuration change in the abort start circuits (paragraph 2.9.4.14.1). ULLAGE relays in the MESC, zone 11-B, are energized when the abort is initiated and the +X translation engines of the SM RCS are fired. The same signal that fires the engines also inhibits pitch and yaw rate stabilization in the SCS. CSM-LV SEPARATE relays, zone 9-B, are energized after a time delay of 3.0 seconds and the SC will be separated from the LV (paragraph 2.9.4.9). RCS ENABLE ARM relays, zone 8-A, are energized after a time delay of 0.8 second and automated control of the SM RCS will be enabled (paragraph 2.9.4.9.1). If the SC is equipped with a docking probe it will be necessary to separate the LM docking ring (paragraph 2.9.4.12) at some time conducive to the situation. CM/SM separation and descent operations are the same as during a nominal entry (paragraphs 2.9.4.13.1 through 2.9.4.13.16).

2.9.5 PERFORMANCE AND DESIGN DATA.

The need is apparent in the sequential systems for one-shot, high-energy, quick-response systems for rocket motor ignition, physical separations, and deployment of earth recovery devices. To support these needs, an electrical hot-wire initiator was selected as the standard activation medium for the high-order ordnance systems required to satisfy vehicle requirements. Range safety requirements dictate that electrically activated ordnance components be capable of withstanding one watt and one ampere for 5 minutes at the electrical-explosive interface without firing or without degradation of initiator performance.

2.9.5.1 Apollo Standard Initiator.

The hot bridge-wire initiator, hereinafter referred to as the single bridgewire Apollo standard initiator (SBASI), is illustrated in figure 2.9-38. This device has a primary ignition charge that is ignited by electrically heating a one-ohm bridgewire. The primary charge ignites the main charge of the initiator, which, in turn, generates high-temperature gasses sufficient to initiate the main charge of specialized explosive device. The SBASI is designed to comply with the range safety requirements recapitulated in paragraph 2.9.5. A current of 3.5 amperes on the bridgewire will cause the SBASI to ignite in 10 milliseconds or less when subjected to a temperature range of -65 to 300°F. A current of 5.0 amperes on the bridgewire will cause the SBASI to ignite in 15 milliseconds or less from -260 to -65°F.

2.9.5.2 Compliance With Design Requirements.

The basic electrical design criteria for initiators are rigidly specified in the Air Force Eastern Test Range Manual, Range Safety Manual, AFE TRM127-1 (1 November 1966). In addition to the design criteria specified in this manual, the following Apollo requirements have been satisfied:

a. The electroexplosive devices are electrically shorted until they are fired to prevent inadvertent ignition (figure 2.9-18, paragraph 2.9.4).

b. At least two individually operated switching circuits are incorporated between the initiators and their pyrotechnic battery terminals. These are "arming" switches and "firing" switches which are illustrated in figure 2.9-20.

c. Logic control circuits of ordnance firing circuits receive operating power from a source other than pyrotechnic batteries.

d. All logic and pyrotechnic firing circuits are at least dual redundant.

e. All logic timing circuits will fail in the $T = \infty$ mode.

2.9.5.3 Component Selection and Installation.

A portion of the high reliability achievement of the sequential systems is because basic rules in component design, assembly and testing

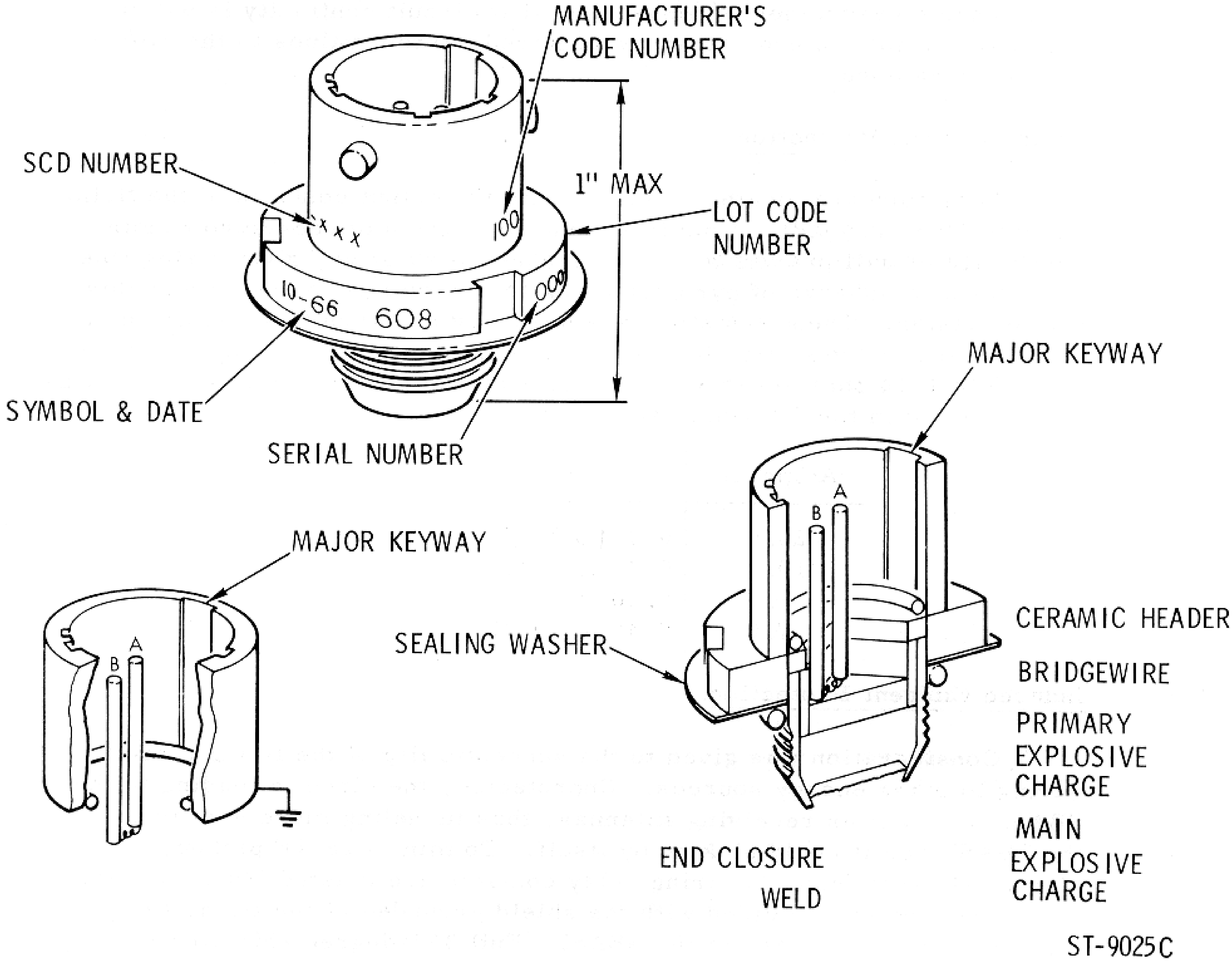

Figure 2.9-38. Single Bridgewire Apollo Standard Initiator

are closely followed. Carefully prepared specifications for components include the expected maxima of shock, vibration, acceleration, temperatures, margins, etc., not only at the time and interval of use, but throughout the whole flight. Relay contact environment has been controlled by hermetically sealed cases and potting. Components are screened 100 percent; that is, each relay is individually tested through repeated cycling prior to acceptance. In the implementation of the series contact circuits, the physical relays are mounted orthogonal to each other to ensure the abnormal vibration or acceleration forces, which may be of sufficient magnitude to prematurely close a given set of contacts, will not be reflected into the same actuation plane of the other relay of the same firing circuit. Verification of circuit integrity is important to ensure that all circuit elements have been properly assembled and installed.

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Resistance measurements can validate that circuit continuity is within acceptable limits in order that the required current values to the SBASI can be guaranteed.

2.9.5.4 Firing Circuit Protection.

Fusistors are located in series with the output contacts of the firing relays (figure 2.9-18). Thus individual protection of each pyrotechnic firing circuit will prevent a current leakage path on any given firing line. A continual discharge of pyrotechnic battery power is impossible in this circuit design. These fusistors are specially designed to withstand high acceleration and vibration levels. The resistance value of these devices is 0.95 to 1.10 ohms at 25°C. The time-current operating characteristics are reflected in the following tabulation:

Amperes	Seconds
20.0	0.03 to 0.17
10.0	0.20 to 1.20
8.0	0.30 to 8.00
7.0	0.40 to 20.00

2.9.5.5 Induced Current Protection.

Consideration was given to the susceptibility of the firing circuit wiring to other energy sources. Unprotected, the circuits leading to the SBASI could act as receiving antennas, thus funneling more energy to the SBASI than it could pick up by itself. To minimize RF pickup, the electrical leads from the firing relay contacts are twisted (20 twists per 12 inches) and are shielded with the shield grounded at the firing relay interface and at the case of the SBASI. Full 360-degree shielding is provided between the shield and the SBASI case.

2.9.5.6 Pyro Arm Switch Lock.

The Range Safety Manual requires that a positive mechanical lock be used in the ARM/SAFE actuation device to prevent movement from the safe to the armed position. A device developed for this purpose is illustrated in figure 2.9-39. Removal of the lock is accomplished by the insertion of a key that is provided to the astronaut during the final pre-launch preparations.

2.9.5.7 Tower Jettison Motor.

The TJM (figure 2.9-40) is intended to provide thrust capability, under normal mission operation, to effect adequate separation of the LES from the CM, while the latter is undergoing acceleration by the second stage booster; and, under abort conditions, to achieve adequate

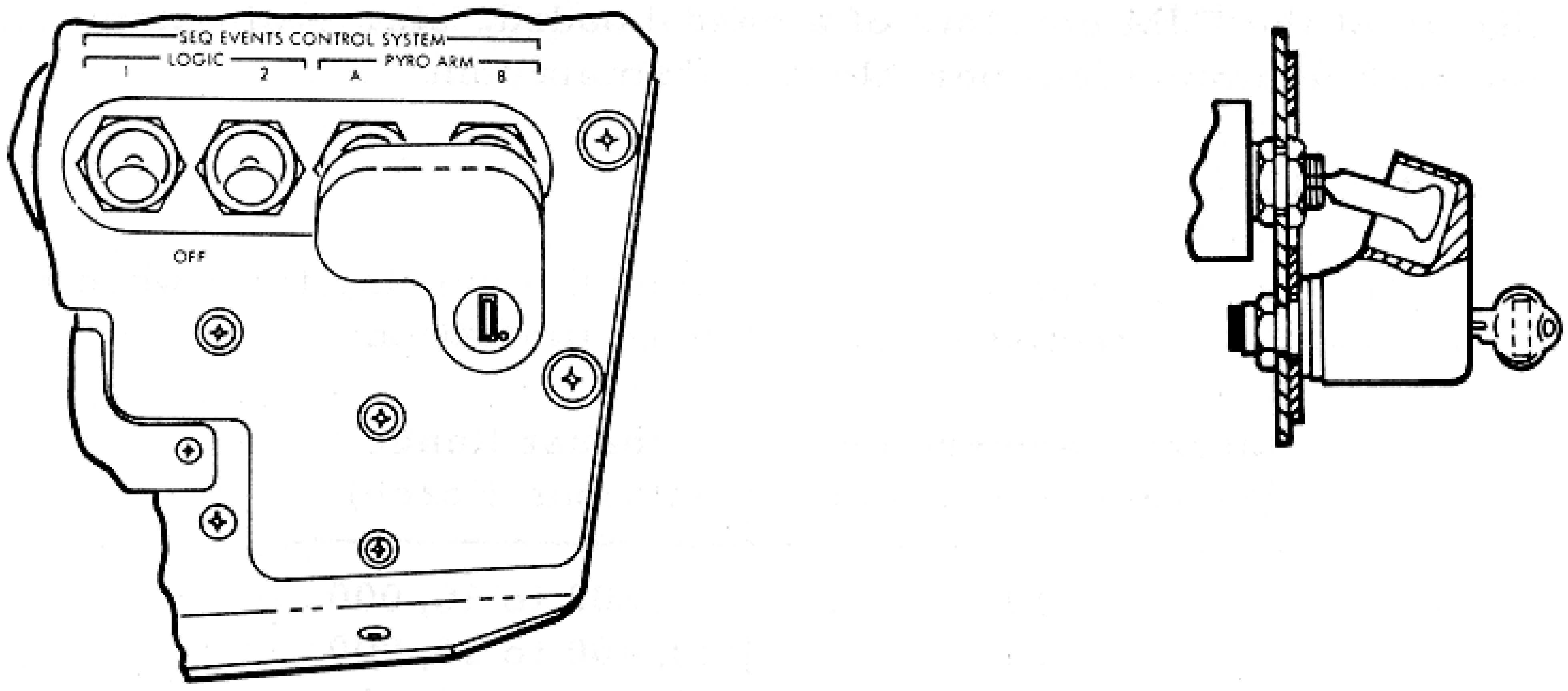

Figure 2.9-39. Pyro Arm Switch Guard

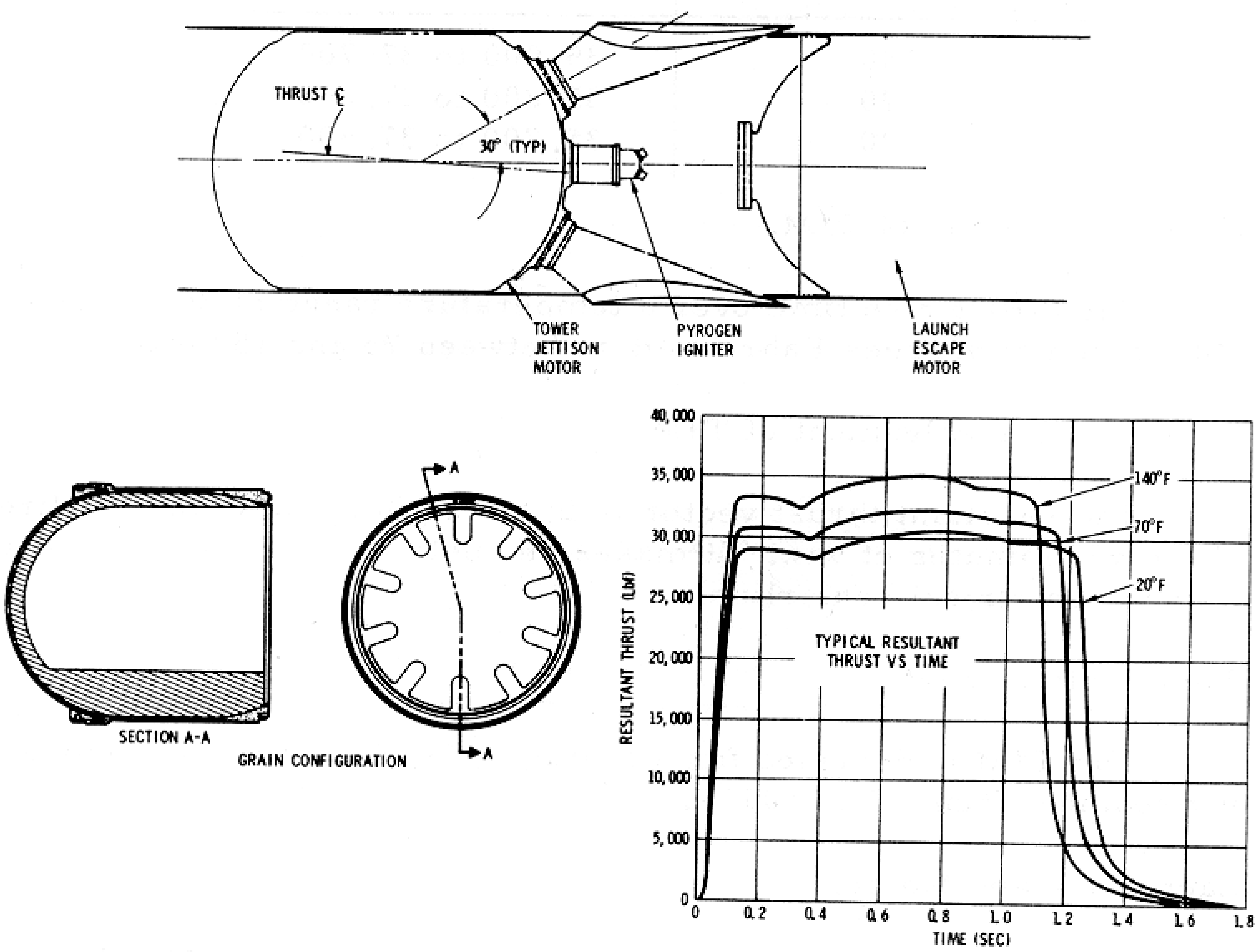

Figure 2.9-40. Tower Jettison Motor

separation of the LES from the CM after LEM burn out. The propellant charge of the TJM consists of a case-bonded, star grain employing a polysulfide ammonium perchlorate formulation.

2.9.5.7.1 Thrust of TJM.

The average resultant thrust over the burning time when measured at sea level is reflected in the following tabulation:

Motor Temperature (Degrees Fahrenheit)	Thrust Range (Pounds Force)
140	31,200 to 36,000
70	29,400 to 33,900
20	28,000 to 32,400

2.9.5.7.2 Total Impulse of TJM.

The resultant impulse at sea level (calculated) over the action time is reflected in the following tabulation:

Motor Temperature (Degrees Fahrenheit)	Total Impulse Range (Pounds-Seconds)
140	35,900 to 37,700
70	35,800 to 37,600
20	35,700 to 37,500

2.9.5.7.3 Thrust Rise Time of TJM.

The thrust rise time over a temperature range of 20 minimum to 140 maximum degrees Fahrenheit is between 75 and 150 milliseconds.

2.9.5.7.4 Thrust Vector Alignment of TJM.

The resultant thrust vector is in the pitch plane in the +Z direction within ±30 minutes of yaw. It makes an angle of 3 to 4.5 degrees to the motor geometrical centerline.

2.9.5.7.5 Useful Life of TJM.

The TJM is designed for a storage life of 5 years in a temperature environment from 25 to 105°F.

2.9.5.8 Launch Escape Motor.

The LEM (figure 2.9-41) in conjunction with the PCM, is intended to provide capability for the safe removal of the crew, inside the CM, from a malfunctioning LV at any time from access arm retraction until

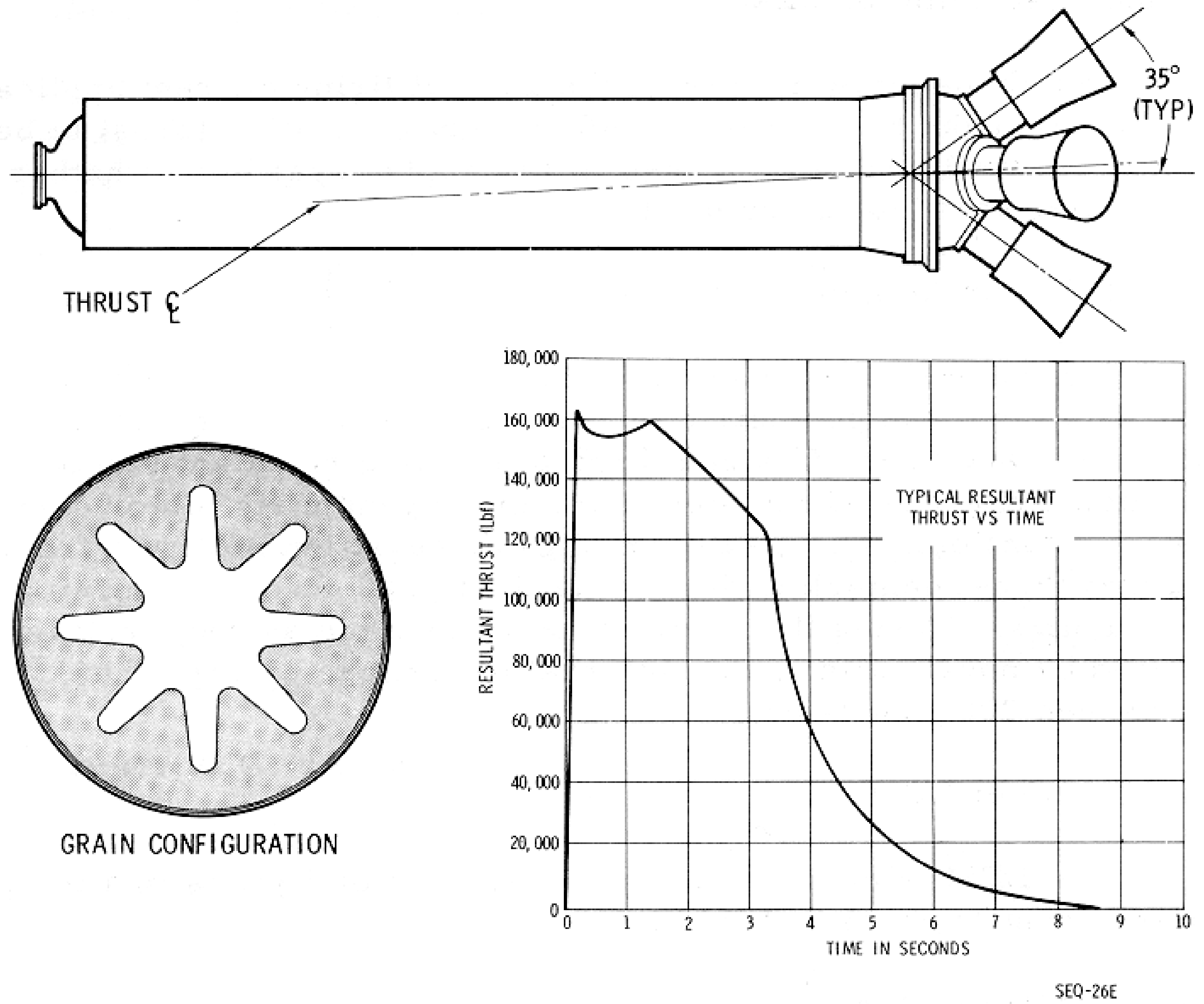

Figure 2.9-41. Launch Escape Motor

successful completion of second-stage ignition. The propellant of the LEM consists of a case-bonded, eight-point star grain employing a polysulfide ammonium perchlorate formulation.

2.9.5.8.1 Thrust of LEM.

Resultant thrust of the LEM will fall within the following limits when corrected to a temperature of 70°F and sea-level barometric pressure:

a. Thrust will not be greater than 177,000 pounds force (lbf). (This is equal to 200,000 lbf at 120°F in a vacuum.)

b. Thrust between 0.2 and 2.0 seconds after firing, current application will not be less than 135,000 lbf. (This is equivalent to 121,000 lbf at 20°F and sea-level barometric pressure.)

2.9.5.8.2 Total Impulse of LEM.

The minimum delivered total impulse of the LEM is 515,000 pound-seconds. The minimum delivered total impulse between 0.12 and 2.00 seconds is 233,064 pound-seconds.

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2.9.5.8.3 Thrust Rise Time of LEM.

The thrust rise time from the time of firing current application to the time that the thrust reaches 90 percent of ignition thrust is between 50 and 120 milliseconds. These limits apply regardless whether one or two igniter cartridges are used.

2.9.5.8.4 Thrust Vector Alignment of LEM.

The centerline of each nozzle forms an angle of 35 degrees ±15 minutes with the mean geometric motor centerline. The nozzles located in the pitch plane have off-sized throats to give a resultant thrust vector oriented 2 degrees 45 minutes to the mean geometric motor centerline in the -Z direction. The maximum angular deviation of thrust from the nominal thrust centerline during the first 0.20 second of burning is ±15 minutes. During this same time period, the average roll moment induced by nozzle alignment, internal ballistics, or any other cause will not exceed 200 pound-feet.

2.9.5.8.5 Useful Life of LEM.

The LEM is designed for a storage life of 5 years in a temperature environment from 25 to 105°F.

2.9.5.9 Pitch Control Motor.

The PCM (figure 2.9-42) in conjunction with the LEM, is employed to place the LEV in the correct flight attitude for a successful escape during mode 1A aborts. The propellant of the PCM consists of a case-bonded, 14-point star grain employing a polysulfide ammonium perchlorate formulation.

2.9.5.9.1 Thrust of PCM.

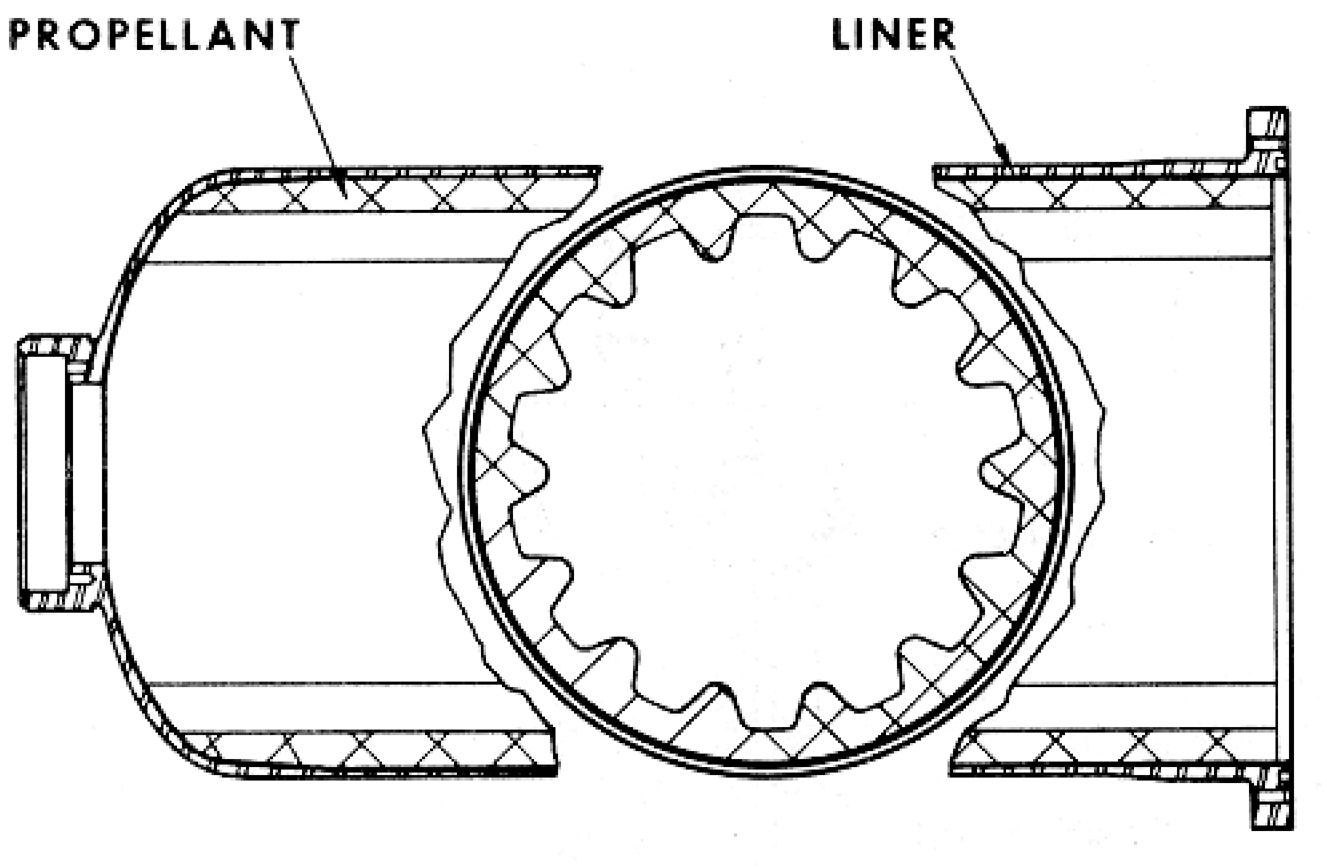
Resultant thrust of the PCM will not exceed 3550 lbf at 70°F and sea-level barometric pressure. This is equivalent to 4000 lbf at 140°F in a vacuum.

2.9.5.9.2 Total Impulse of PCM.

The total delivered impulse of the PCM will be 1750 pound-seconds ±3 percent at 70°F and sea-level barometric pressure.

2.9.5.9.3 Thrust Rise Time of PCM.

The thrust rise time from time of firing current application to the time at which the thrust reaches 80 percent of maximum will be between 60 and 120 milliseconds at 70°F.



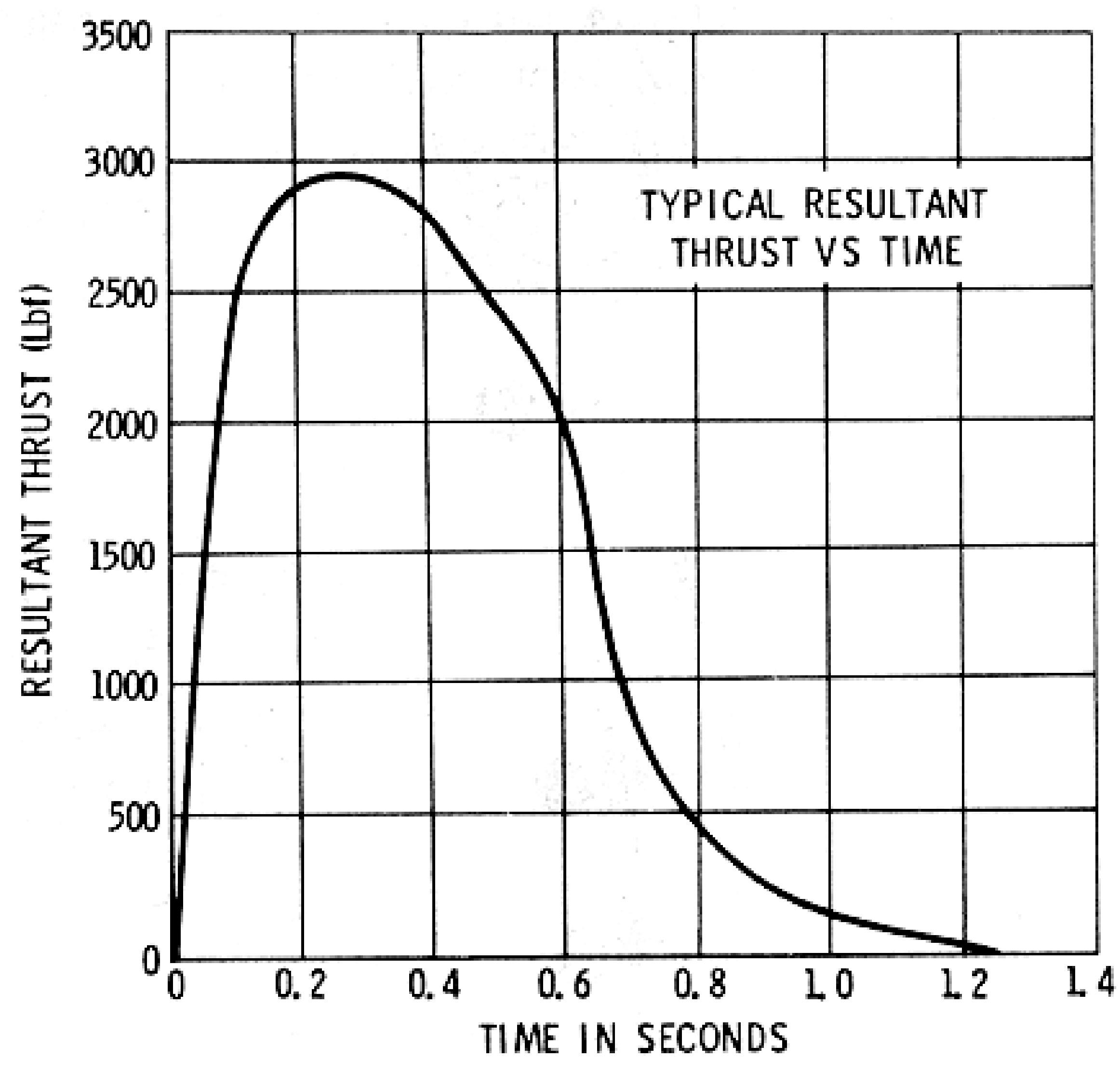


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Figure 2.9-42. Pitch Control Motor

2.9.5.9.4 Thrust Vector Alignment of PCM.

The PCM is designed so that the resultant thrust vector coincides with the centerline of the motor chamber mounting surfaces within ±30 minutes.

2.9.5.9.5 Useful Life of PCM.

The PCM is designed for a storage life of 5 years in a temperature environment from 25 to 105°F.

2.9.5.10 LES Igniter.

Two initiators are installed in each LES igniter (figure 2.9-43). Boron pellets are ignited and they in turn ignite the main charge of Pyrogen which spews flame into the grain of the rocket motor.

2.9.5.11 Squib Valves

Hot gas pressure generated by the SBASI actuates the squib valve (figure 2.9-44). The spool shears the ends of inlet and outlet plumbing which is sealed initially. Sixteen valves of this configuration are incorporated in the fluid systems of the CM RCS (section 2.5, RCS).

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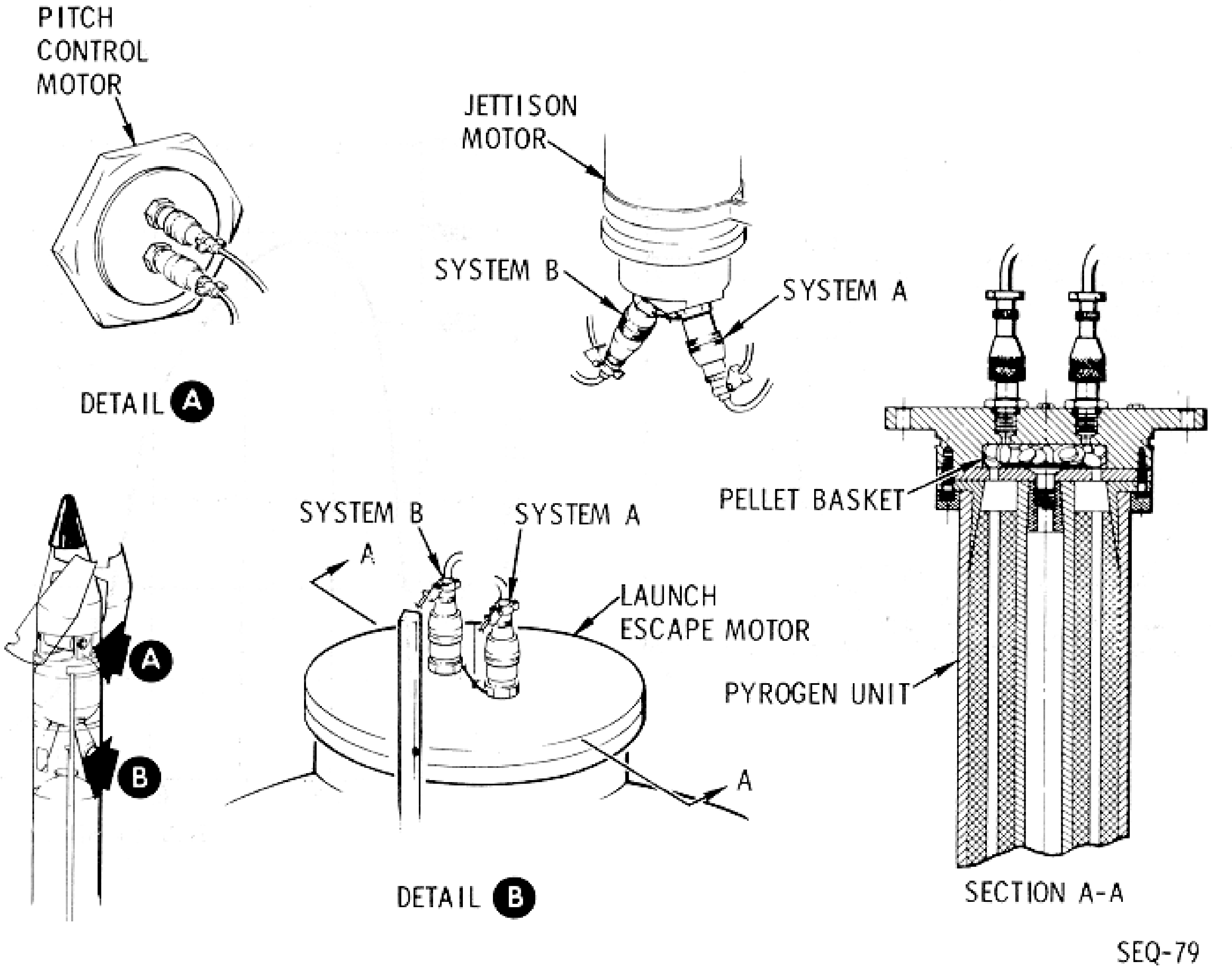

Figure 2.9-43. LES Igniters

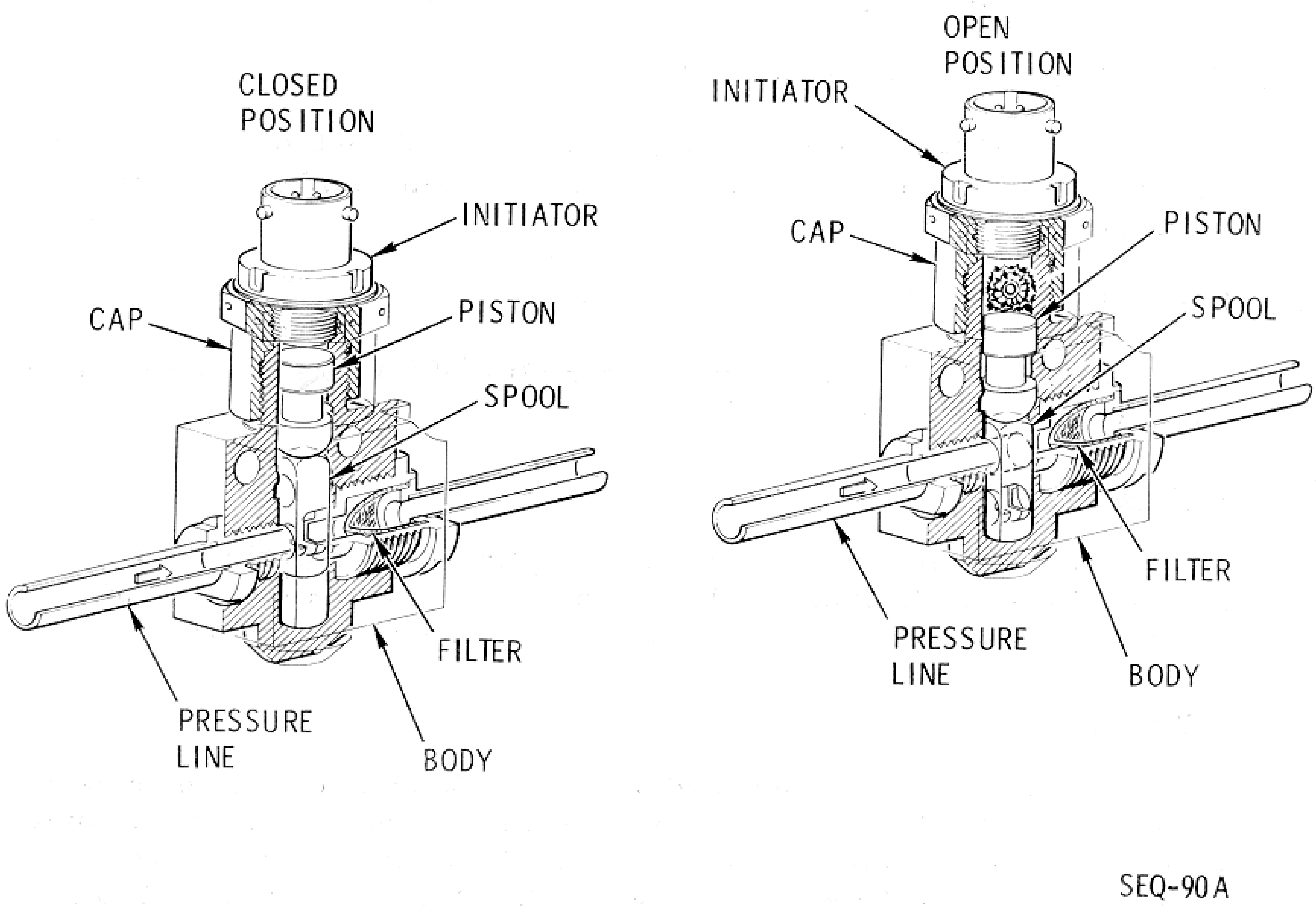

Figure 2.9-44. Squib Valve

2.9.5.12 Detonators.

One of the specialized explosive devices used in some of the Apollo ordnance systems is the detonator cartridge (figure 2.9-45). The SBASI is used in this application to ignite additional explosive charges which are usually composed of lead azide and RDX.

2.9.5.12.1 LET Frangible Nuts.

In one application, the high-energy concussion of detonators is used to break frangible nuts (figure 2.9-24). Two detonators are installed in each nut and connected to firing circuits A and B. Normally both detonators of each nut will fire and the nut will be broken into two parts; however, if one detonator should fail, the nut will be spread enough for thread clearance.

2.9.5.12.2 SLA Separation Ordnance System.

Confined detonating fuse is used to transmit detonation from detonators to detonating cord which is installed along cutting planes of the SLA (figure 2.9-25). Two detonators are utilized in this explosive train for redundancy. One detonator is initiated by system A firing circuits and the other by system B. Either of the detonators will activate the entire ordnance system. Umbilical separation disconnect plug assemblies are blown

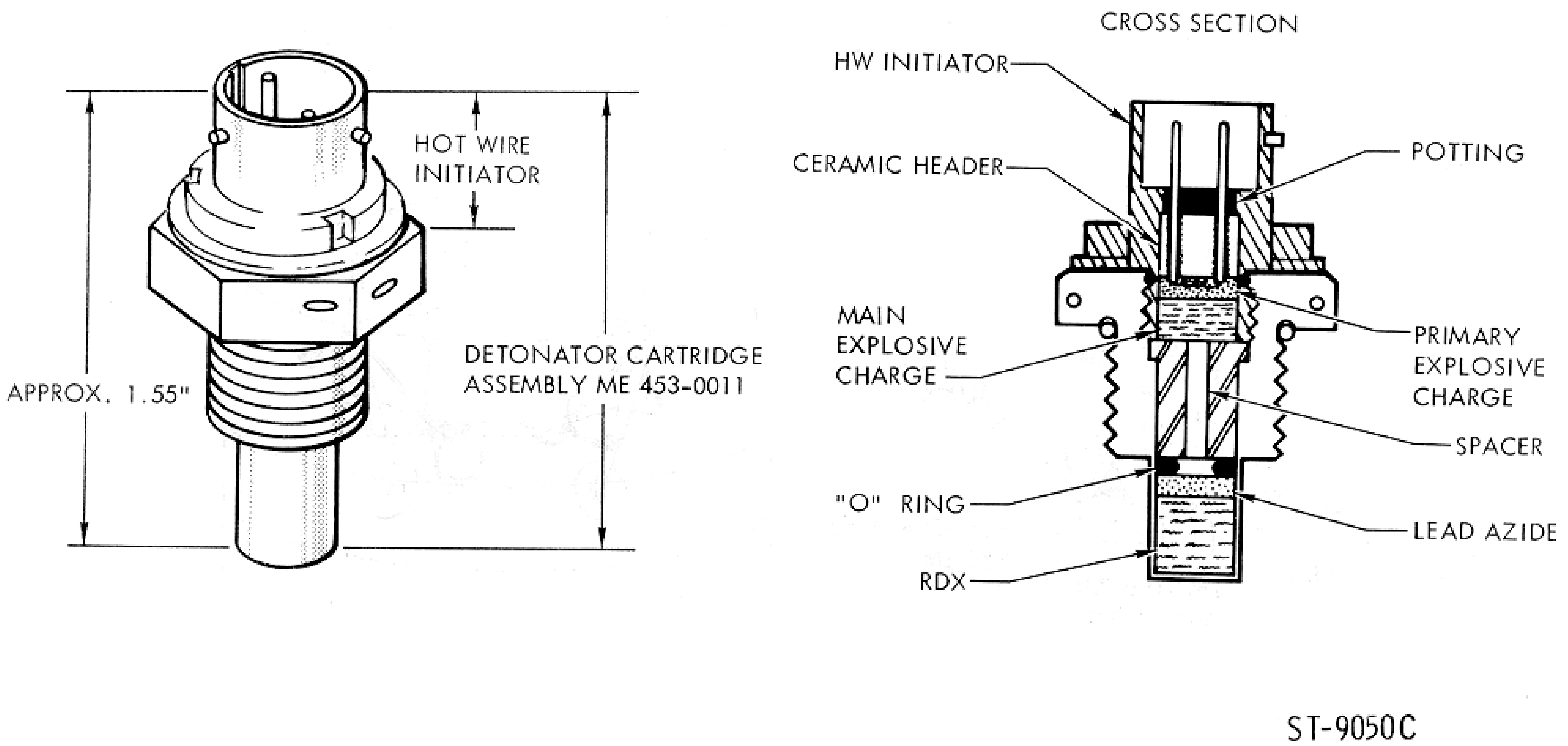

Figure 2.9-45. Detonator Cartridge Assembly

apart disconnecting the electrical wiring between the LV and CSM. An umbilical disconnect swing arm is activated, which is the interface between the LM and the GSE flyaway umbilical on one of the SLA panels. Eight panel thrusters are also activated to start deployment of the SLA panels.

2.9.5.12.3 LM Separation System.

Frangible links retain the clamps which are used to secure the LM legs to the SLA. Detonators are used to break the links and spring-loading opens the clamps (figure 2.9-46). Either of the detonators will break the frangible link. A pair of detonators is also utilized to activate guillotine blades of the lower umbilical; these detonators are not sympathetic and either guillotine blade will cut the wire bundle. Deadfacing in this instance is accomplished by relay logic (paragraph 2.9.4.11).

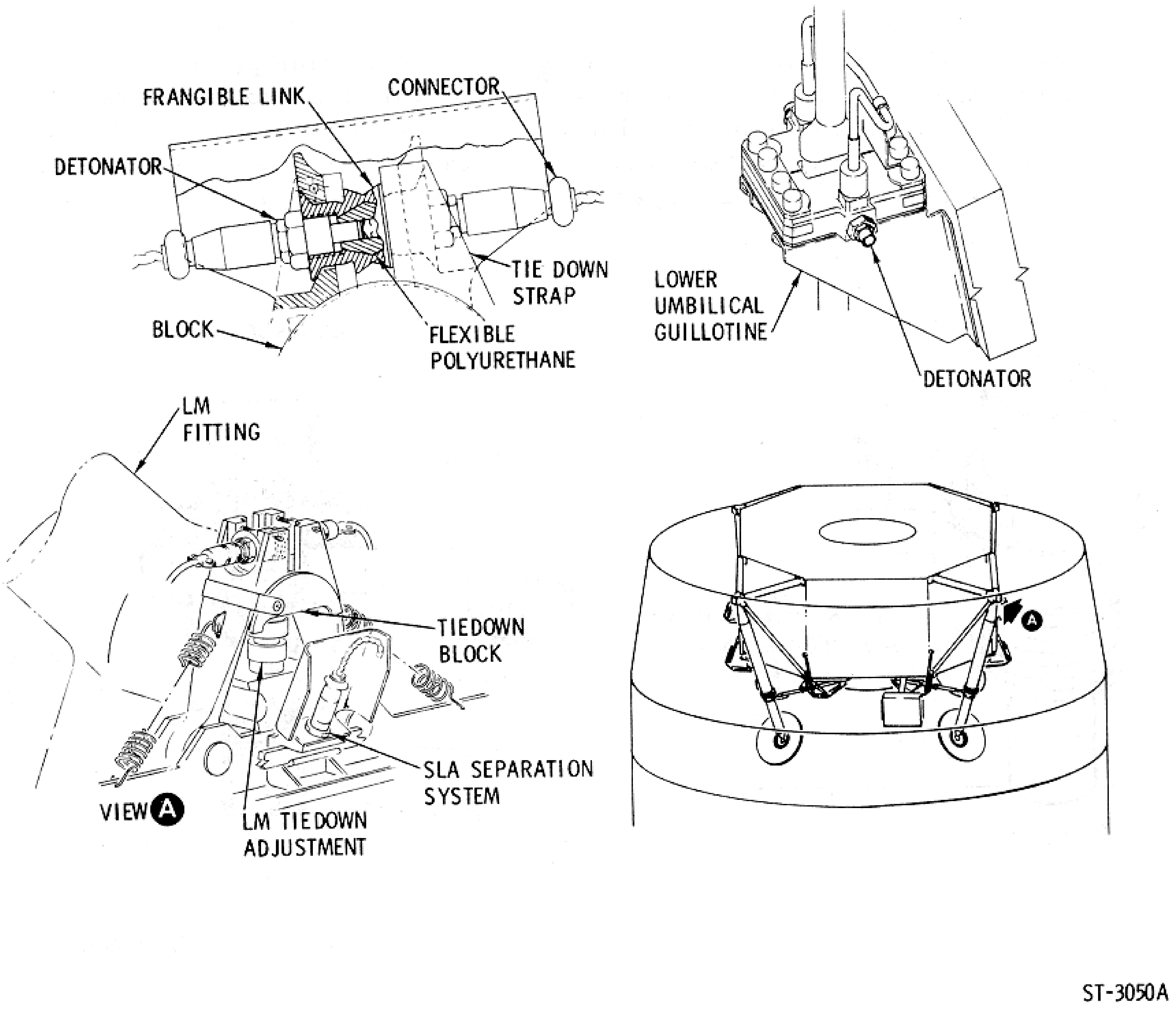

Figure 2.9-46. LM Separation System

2.9.5.12.4 CM-SM Separation System.

Redundant linear-shaped charges are used to cut three tension tie straps which constitute the physical bond of the CM and SM (figure 2.9-30). A detonator is used to explode each linear-shaped charge which is sympathetic to the other. Either of the linear-shaped charges will cut the tension tie strap it is mounted on; therefore, the sympathetic nature is not required to meet minimum reliability requirements. The electrical-explosive interface wiring to each detonator is also cut by the linear-shaped charges.

2.9.5.13 Pressure Cartridge Assemblies.

Solid propellant pressure cartridges (figure 2.9-47) have several applications in Apollo ordnance systems. The SBASI is used to initiate a propellant charge. The size of the main charge required is contingent on pressure requirements.

2.9.5.13.1 Electrical Circuit Interrupters.

Two types of circuit interrupters are actuated when the CM and SM are deadfaced during the separation sequence. Two CM-SM circuit interrupters (figure 2.9-27) are mechanized by cams. Gas pressure forces a piston to move into a locked position and the piston is connected to cam forks. Inclined planes on the cam forks forces lift plates up which separate the mating parts of electrical receptacles. Two SM circuit interrupters will deadface battery power, together with ground returns, to the SM main buses (figure 2.9-28). Gas pressure forces pistons against stops and the pins of the electrical receptacles are pulled from the mating part. The piston assemblies include the contact pins.

2.9.5.13.2 Canard Actuators.

Two gas pressure cartridges are used to actuate canard deployment (figure 2.9-48). Hot gas on one side of a piston will cause the actuator shaft to retract. A closed hydraulic system on the opposite side of the piston dampens transient loads, and check valves in the fluid systems will maintain the piston in its actuated position. The actuator shaft also incorporates a mechanical lock in the actuated position.

2.9.5.13.3 Parachute Mortars.

Two drogue parachutes, three pilot parachutes of the main parachutes, and one drag parachute of the apex cover augmentation system are deployed by mortar assemblies (figure 2.9-49). Two sympathetically initiated pressure cartridges are mounted on the breech assembly of each mortar. A sabot, which is effectively a fiberglass piston, is incorporated to protect the parachute fabric from hot gas. The covers of the mortars

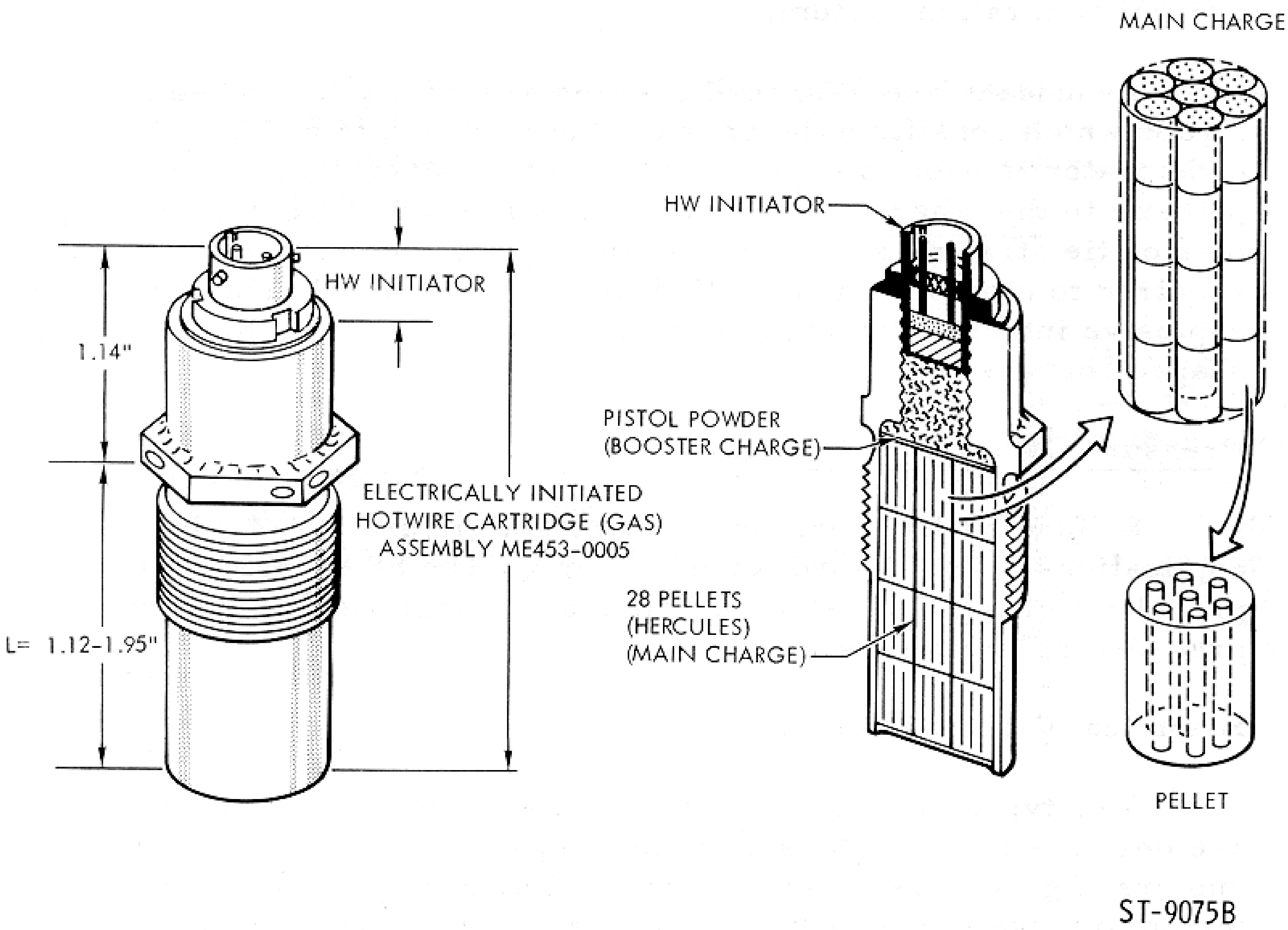

Figure 2.9-47. Pressure Cartridge Assembly

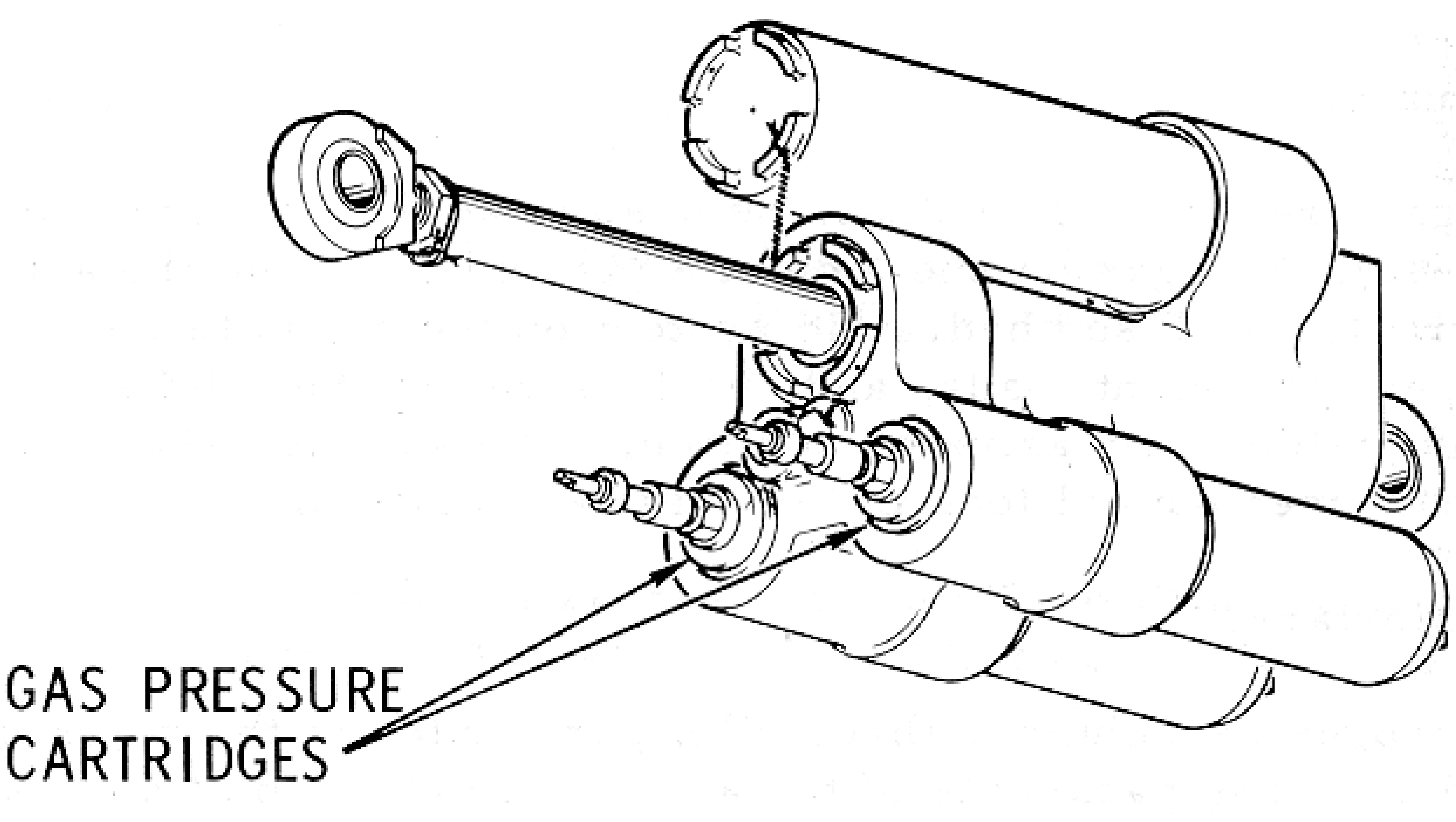

Figure 2.9-48. Canard Actuator

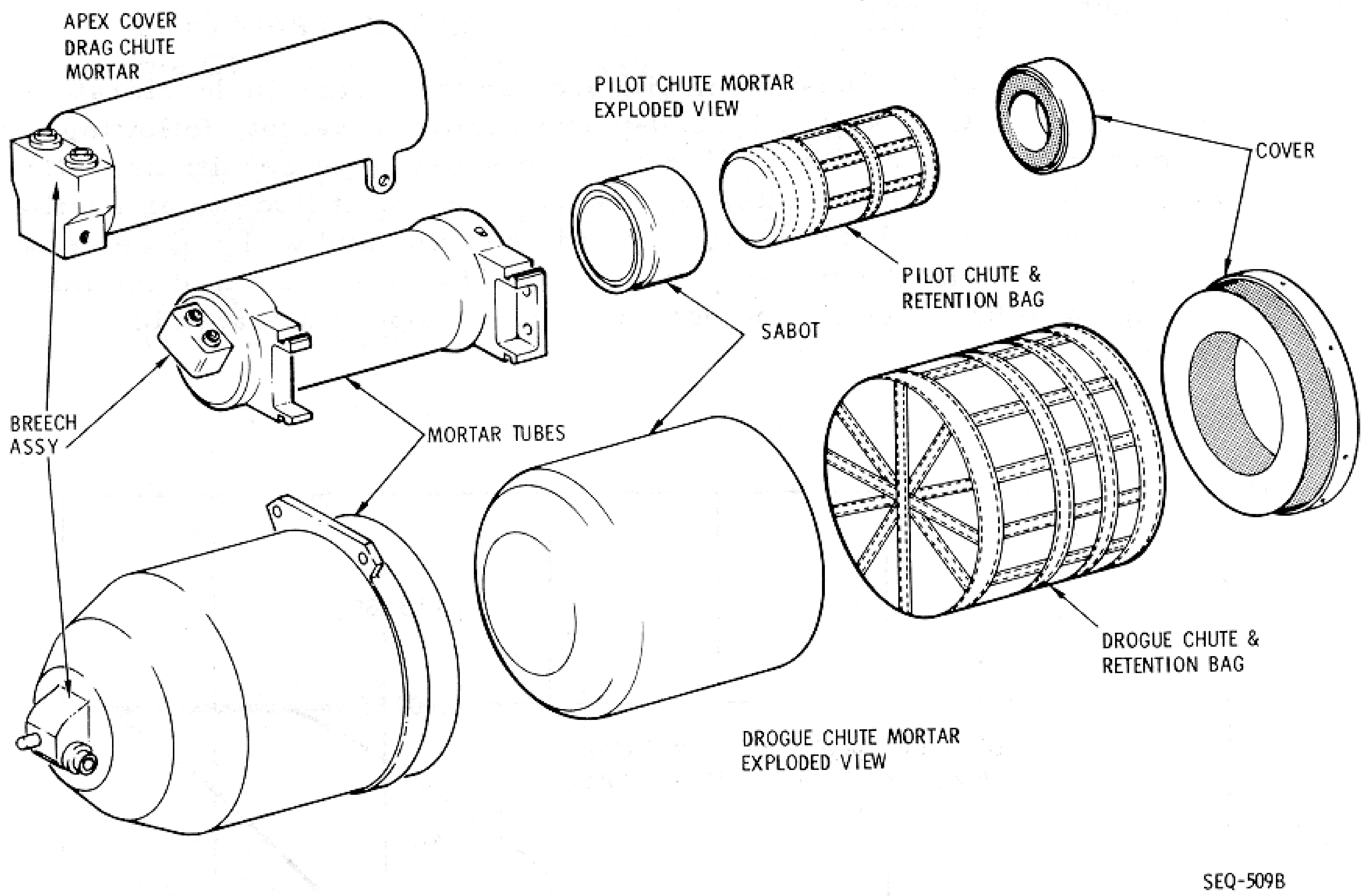

Figure 2.9-49. Parachute Mortar Assemblies

are riveted and, when the gas pressure causes the rivets to shear, the parachutes are ejected with considerable force.

2.9.5.13.4 Parachute Disconnect.

Five chisels are used to cut the risers of the drogue and main parachutes (figure 2.9-32). Gas-pressure cartridges are used to drive the chisels through the risers immediately above the point where they are swaged. Two initiators are used on each gas pressure cartridge.

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2.9.5.14 Reefing Line Cutters.

Reefing line cutters (figure 2.9-17) are designed to sever any coreless nylon cord with a breaking strength of 2000 pounds or less. The unit is mechanically initiated and provides a time elapse between initiation and the severing of the cord. The primer, time-delay train, and output charge are hermetically sealed. A storage life of 3 years in a temperature environment from 20° to 140°F is designed into the cutter. These cutters will not ignite or fire when subjected to a temperature of 275°F for one hour; however, a cutter is not required to perform after having been exposed to this temperature.

2.9.5.15 Parachute Subsystem.

The parachute subsystem will provide the means to decelerate and safely land the CM, with a 13,000-pound recovery weight, following entry from terrestrial orbit, lunar flight, or mission abort conditions. Deployment of the drogue parachutes will reduce the CM attitude to an oscillatory, or stable, aft heat shield forward condition and will reduce velocity to a point that will assure proper deployment and operation of the main landing parachutes within the operational envelope illustrated in figure 2.9-50.

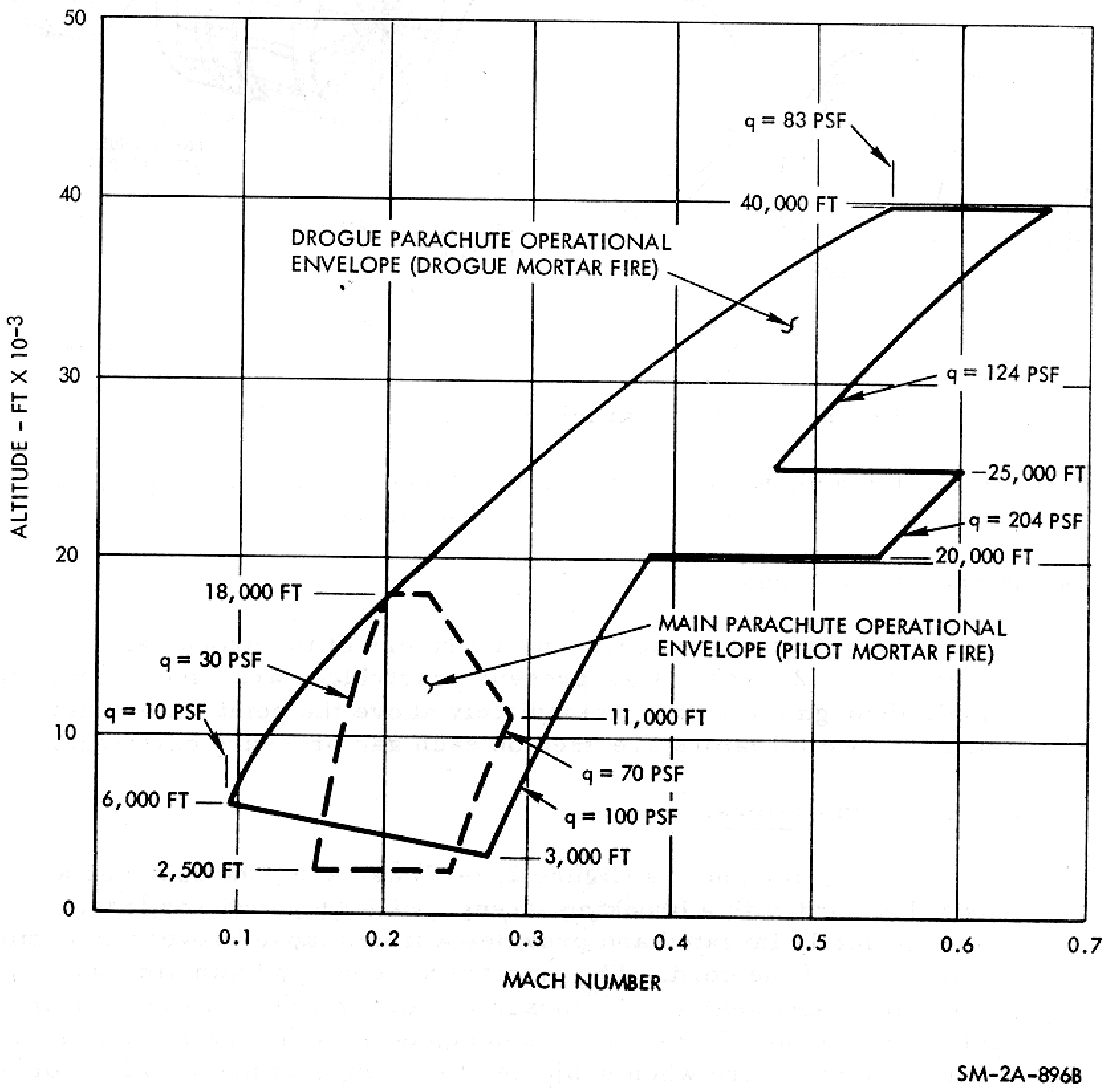

Figure 2.9-50. Parachute Design Envelope

2.9.6 OPERATIONAL LIMITATIONS AND RESTRICTIONS.

Since the sequential systems include numerous controls for manual backup and/or intervention of automated functions, and since several of the functions are time-critical, certain precautions should be observed. Moreover, considerable versatility has been designed into the systems, such as alternate electrical power selection. Serious damage could result if correct procedures are not followed.

2.9.6.1 Alternate Selection of Logic Power.

It would be possible to couple a defective battery to a good one, and serious damage to the electrical power supply could result if the circuit breakers, described in paragraph 2.9.4.1, are not utilized properly. The BAT C TO BAT BUS A and B circuit breakers (CB15 and CB24), zone 42-B, are included in the system to enable the utilization of ENTRY AND POST LANDING BATTERY C in the event of a power failure in either of the ENTRY AND POST LANDING BATTERIES A or B. If the contigency of alternate power utilization should occur, the defective battery should be isolated before the appropriate BAT C TO BAT BUS A or B circuit breaker is closed. Additional information on this subject is included in section 2.6, Electrical Power.

2.9.6.2 Alternate Selection of Pyro Power.

If the circuit breakers described in paragraph 2.9.4.2 are not utilized properly, serious damage to the electrical supply could result. The potential hazard is the same as described in paragraph 2.9.6.1 except in this instance the electrical power of the PYRO Systems, zones 41 through 43-D and -E, is concerned. The BAT BUS A and B TO PYRO BUS TIE circuit breakers (CB18 and CB19) are included in the system to be used in the event of a failure of PYRO BATTERY A or B. If such a power failure should occur, the appropriate SEQ A or B circuit breaker (CB16 or CB17) should be opened before coupling the appropriate ENTRY AND POST LANDING battery to the PYRO power system.

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2.9.6.3 Control for Arming Pyro Systems.

Battery power is required to arm or safe PYRO buses (paragraph 2.9.4.3). It is therefore necessary to close the SECS ARM BAT A circuit breakers (CB1), and/or its counterpart in system B, zone 39-C, before the motor switch (K1) in the LDEC, zones 39 and 40-E and -F, can be operated to energize or de-energize the PYRO buses. This feature is designed into the system for power conservation during a mission when the docking probe is being used. The procedures for the utilization of battery power for control of PYRO power will consequently differ somewhat during the various phases of a mission.

2.9.6.4 Status of Logic and Pyro Buses.

It will be necessary for the flight crew to verify the status of LOGIC and PYRO buses, i.e., armed or safe, through the MSFN. Displays for this status are not included in the CM.

2.9.6.5 Utilization of Controls for CSM/LV Separation.

When the CSM/LV SEP switch is used (paragraph 2.9.4.9), it should be held closed for approximately one second (0.8 second minimum) for the time-delay-relay logic to perform as it was designed.

2.9.6.6 Utilization of Controls for CM/SM Separation.

When the CM/SM SEP switches are used, they must be held closed for 0.1 of a second for the time-delay-relay logic to perform as it was designed (paragraph 2.9.4.13.1).

2.9.6.7 Manual Control of ELSC Functions.

Under certain entry conditions, erratic aerodynamic damping coefficients, wind gusts, and shears, the CM may become unstable. If this should occur, the apex cover and drogue parachutes may be manually deployed early. This will stabilize and keep the CM in the proper descending attitude. See figure 2.9-50 for the drogue deployment design envelope. The following precautions should be observed:

a. Manual initiation of drogue parachute deployment should never be accomplished above 40,000 feet during entry.

b. The CM RCS must be turned off prior to apex cover jettison.

c. Manual initiation of apex cover jettison must not be executed with the LET attached.

d. Manual initiation of drogue parachute deployment must not be executed with the apex cover on the vehicle.

e. Manual initiation of main parachute deployment must not be executed prior to drogue deployment.

f. Manual initiation of main parachute deployment must be accomplished above 2500 feet.

g. Two circuit breakers are incorporated in MESC PRYO circuits to the main parachute release ordnance devices. These circuit breakers should not be closed until after the CM has landed (paragraph 2.9.3.4.2.3).

h. It is impossible to release the main parachutes with the ELS switch in the MAN position. This switch must be in the AUTO position and the 14-second time delays in the ELSC (TD 3 and TD 4), zone 6-C, expired before the MAIN RELEASE switch is armed.