(NASA-TM-84099) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX C SECTION 1 (NASA) 440 p

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REPORT OF APOLLO 204 REVIEW BOARD

TO

THE ADMINISTRATOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NAS-TM-X-70156) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX C, SECTION 1 (NASA) 440 p

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APPENDIX C

SECTION 1

(NASA-TM-X-70156) REPORT OF APOLLO 204 REVIEW BOARD, APPENDIX C, SECTION 1 (NASA) 440 p LIMITED ACCESS

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LIST OF EFFECTIVE PAGES

NOTE: The portion of the text affected by the current changes is indicated by a vertical line in the outer margins of the page.

TOTAL NUMBER OF PAGES IN THIS PUBLICATION IS 816, CONSISTING OF THE FOLLOWING:

CHANGE INFORMATION

This handbook is subject to continuous change or revision, on a priority basis, to reflect current engineering or mission changes, or to improve content or arrangement. The content and the changes are accounted for by the above List of Effective Pages, and by the following means:

Record of Publication: The publication date of each basic issue and each change issue is listed on page B as a record of all editions.

Page Change Date: Each page in this handbook has space for entering a change date. The latest publication date will be entered in this space each time a page is changed from the basic issue.

*The asterisk indicates pages changed, added, or deleted by the current change.

Manuals will be distributed as directed by the NASA Apollo Program Office. All requests for manuals should be directed to the NASA Apollo Spacecraft Program Office at Houston, Texas.

RECORD OF PUBLICATION

This issue of the Apollo Operations Handbook, Spacecraft 012, dated 12 November 1966, constitutes a revision of the handbook, dated 16 September 1966. Subsequent changes may be issued to maintain information current with spacecraft configuration through completion of the mission. This record will reflect the publication date of any released changes.

LATE TECHNICAL CHANGES

The items listed below represent technical changes which have been approved too late for inclusion in the 12 November 1966 printing of the Apollo Operations Handbook.

Source	Description of Change	Section Affected
MCR A1735	Change S/M RCS fuel from blended hydrazine mixture to monomethylhydrazine	2.5
MCR 1591 REV 3.	Addition of inverter synchronizer power panel which provides circuit breakers for the control of power to the phase synchronizer unit.	2, 3
FEO M-53025 (10-13-66)	This is a nomenclature correction for the S-Band switch on the MDC panels No. 13, 23 and 26. This change is required due to wiring changes. The S-Band switch was marked "PTT", "OFF" and "VOX". The switch is now marked "OFF", "OFF" and "T/R".	2.8 and 3
MCR A1733 (10-11-66)	Modification of Crew Couch Lockouts. This MCR removes the lockout solenoid actuator and wire harness from the X-X axis strut lockout mechanism. Add an adapter to the lockout mechanism assembly to fix in the locked position. The switch on panel No. 9 and the wire harness assembly on the struts will be removed.	1, 2, 3

SYNOPSIS OF SIGNIFICANT CHANGES

This tabulation does not list all changes, additions, and/or deletions in the handbook. Its purpose is to assist the reader in determining the significant technical changes in each system.

PART I. TECHNICAL CHANGES

Handbook Section(s) Affected	Description	Handbook System(s) Affected
1	Updated lockout mechanisms on shock struts.	GEN
1	Updated forward hatch cover.	GEN
2	Revised RCSC circuit diagram to include entry battery backup power to pyro bus.	SEQ
2	H_2 purge line heater	EPS
2	Fuel cell H_2 and O_2 reactant shutoff valves holding voltage control	EPS
2	Cryogenic system response and operation	EPS
2	Revised, updated, and assembled end-to-end circuit and system diagrams. Added electrical power distribution diagrams and power requirements. Added operating ranges and panel references to measurement lists.	PROP
4	Added tabular data for color markings contained on indicator displays and updated art.	SPS, EPS and ECS
4	Added typical charts from MMDB to determine S/C consumable data.	RCS, SPS and EPS
4	Added data on S/C attitude controls.	RCS
4	Updated SPS Delta V and Engine Gimbal Angle charts.	SPS

FOREWORD

This handbook and its contents are restricted to the requirements for Spacecraft 012. It presents, in one document, descriptions of the spacecraft systems and equipment, and listings of the flight crew operational procedures necessary for the safe and efficient function of the spacecraft throughout its planned mission. This handbook is designed primarily for use by the flight crew, and secondarily for use by the mission flight controllers, flight planners, and trainer operators.

NASA comments or suggested changes to this handbook should be addressed to the Flight Planning Section, FCSD, MSC, Office Code CF 32, Telephone HU3-4271.

TABLE OF CONTENTS

SECTION 1

GENERAL INFORMATION

INTRODUCTION.

This section contains information relating to the Apollo spacecraft 012 configuration, and a description of the launch vehicle and booster used for the mission.

1.1 SPACECRAFT 012 CONFIGURATION.

Spacecraft 012 (figure 1-1) conforms to a Block I CSM configuration consisting of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft lunar excursion module adapter (SLA). This spacecraft, designed for an earth orbital mission, does not contain a lunar module (LM) within its adapter. (For a description of the launch vehicle used with spacecraft 012, refer to paragraph 1.2)

NOTE The Block I configuration missions for the Apollo program provide the following:

- Command module and service module development for earth orbital missions
- Demonstration of systems operational capabilities including all types of aborts, land and water recovery, Saturn IB and Saturn V operation and capability, and systems operation during earth orbit
- Development of qualified teams for checkout, launch, manned space flight network (MSFN), recovery, and flight analysis.

1.1.1 LES ASSEMBLY.

The LES assembly (figure 1-1) provides the means for separating the C/M from the launch vehicle during pad or suborbital aborts. This assembly consists of a Q-ball instrumentation assembly (nose cone), ballast compartment, canard surfaces, pitch control motor, tower jettison motor, launch escape motor, a structural skirt, an open-frame tower, and a boost protective cover (BPC). The structural skirt at the base of the housing, which encloses the rocket motors, is secured to the upper portion of the tower.

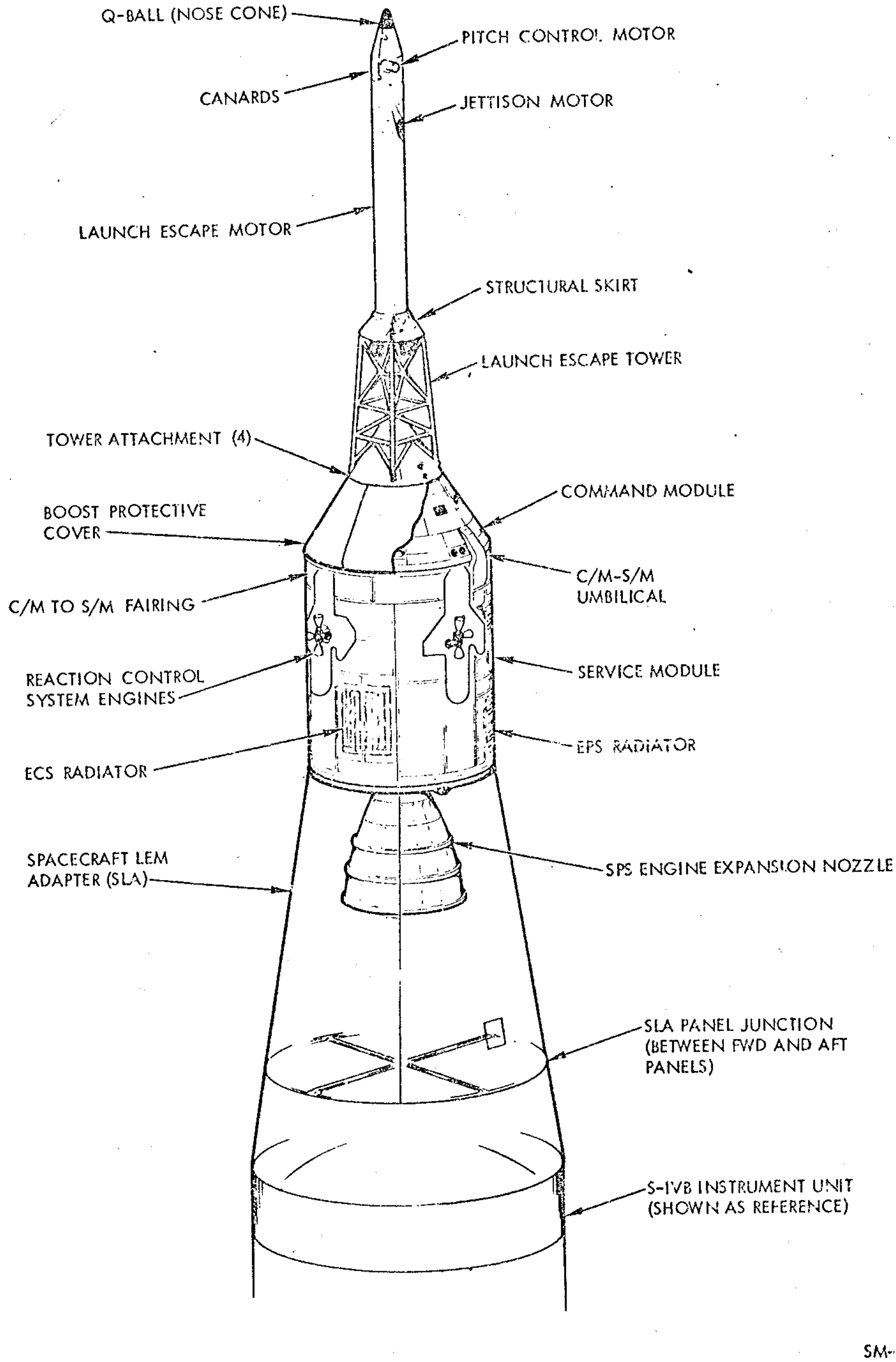


Figure 1-1. Spacecraft 012 Configuration (Sheet 1 of 2)

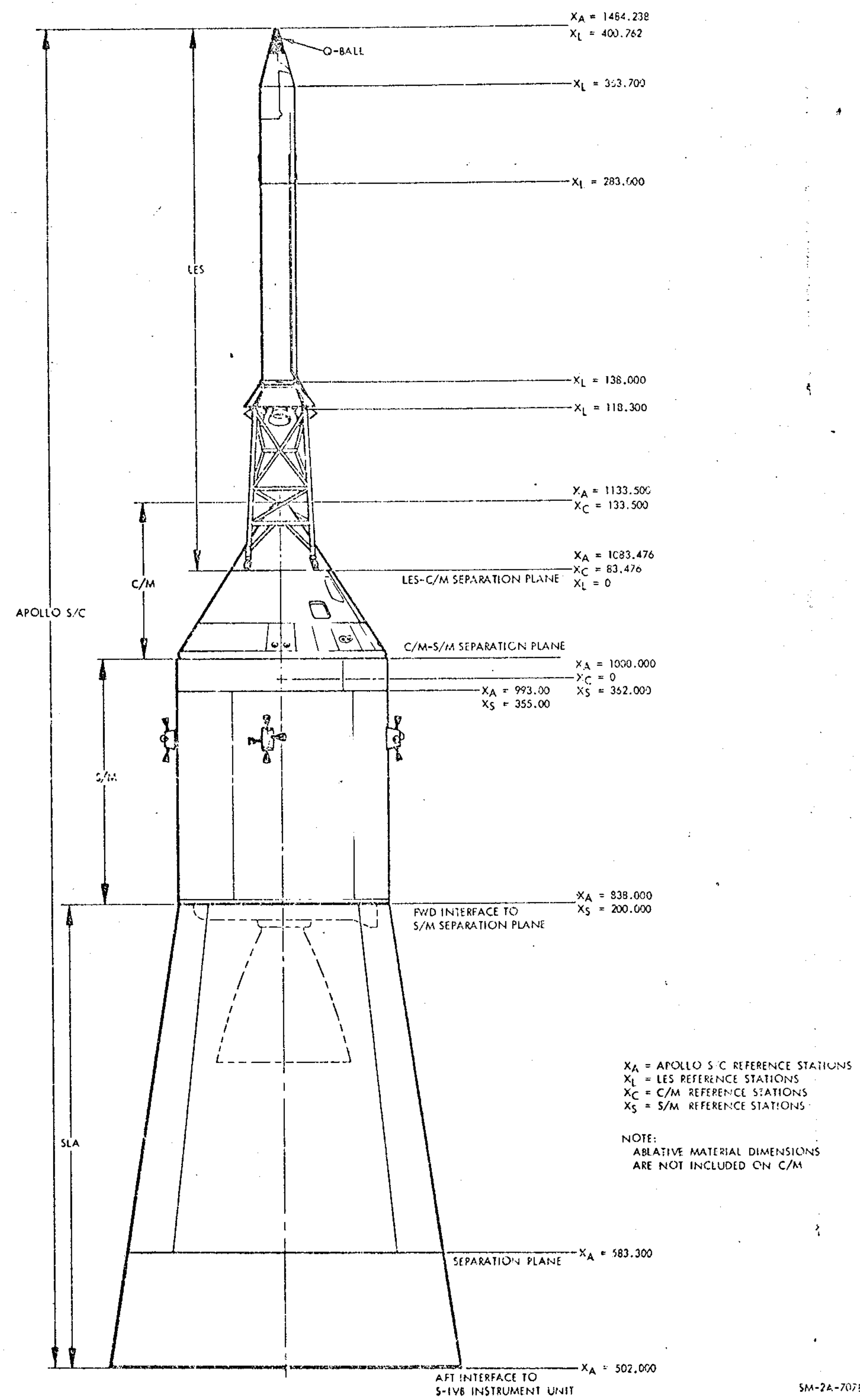


Figure 1-1. Spacecraft 012 Configuration (Sheet 2 of 2)

The BPC (figure 1-2) is attached to the lower end of the tower to protect the C/M from thermal heat during boost and from exhaust damage by the launch escape and tower jettison motors. Explosive nuts, one in each tower well leg, secure the tower to the C/M structure. (For additional information, refer to the sequential systems in section 2.)

1.1.2 COMMAND MODULE.

The C/M (figure 1-3) forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and conform of the crew. The module is an irregular-shaped, primary structure encompassed by three heat shields (coated with ablative material and joined or fastened to the primary structure) forming a conical-exterior shape. The C/M consists of a forward compartment, a crew compartment, and an aft compartment.

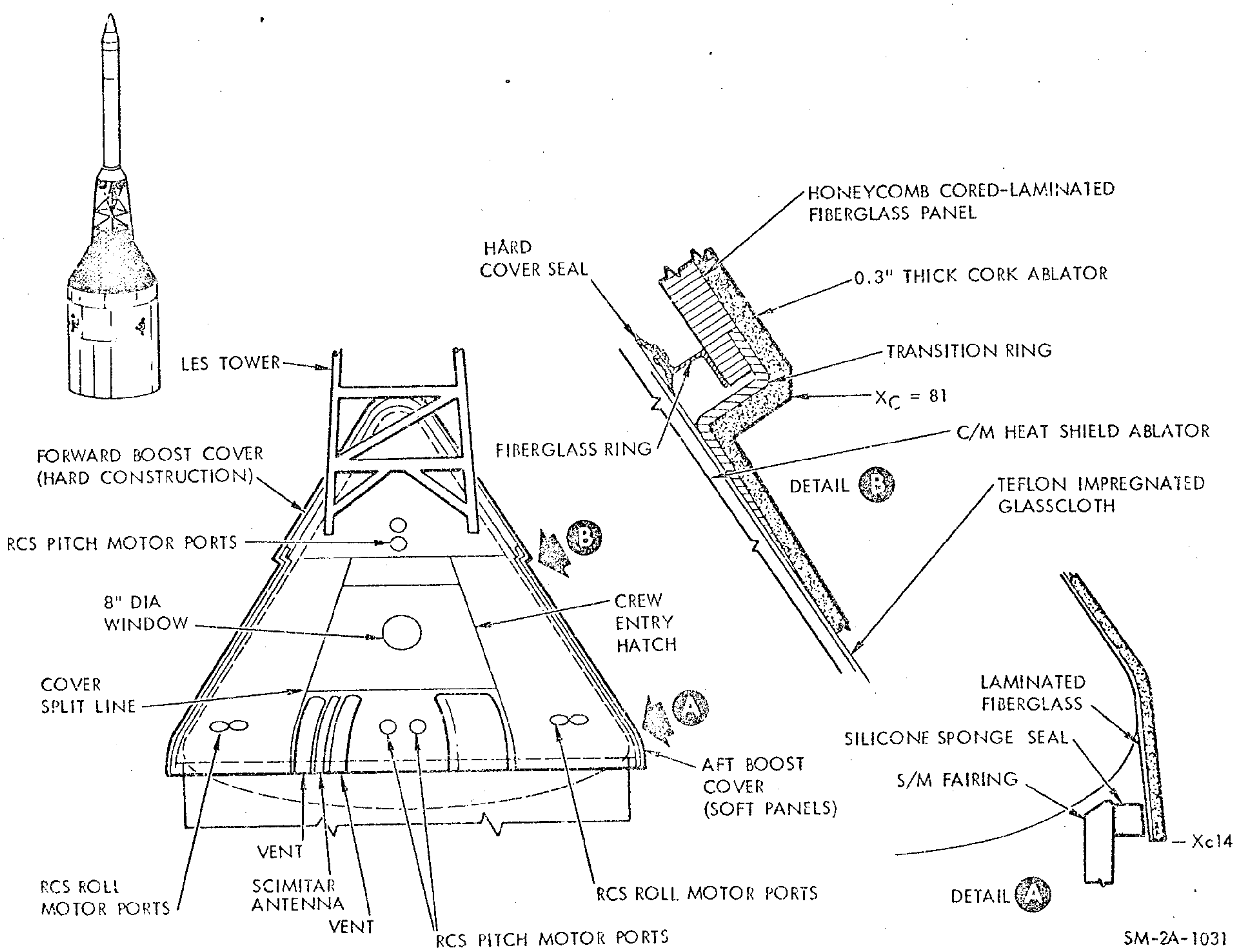
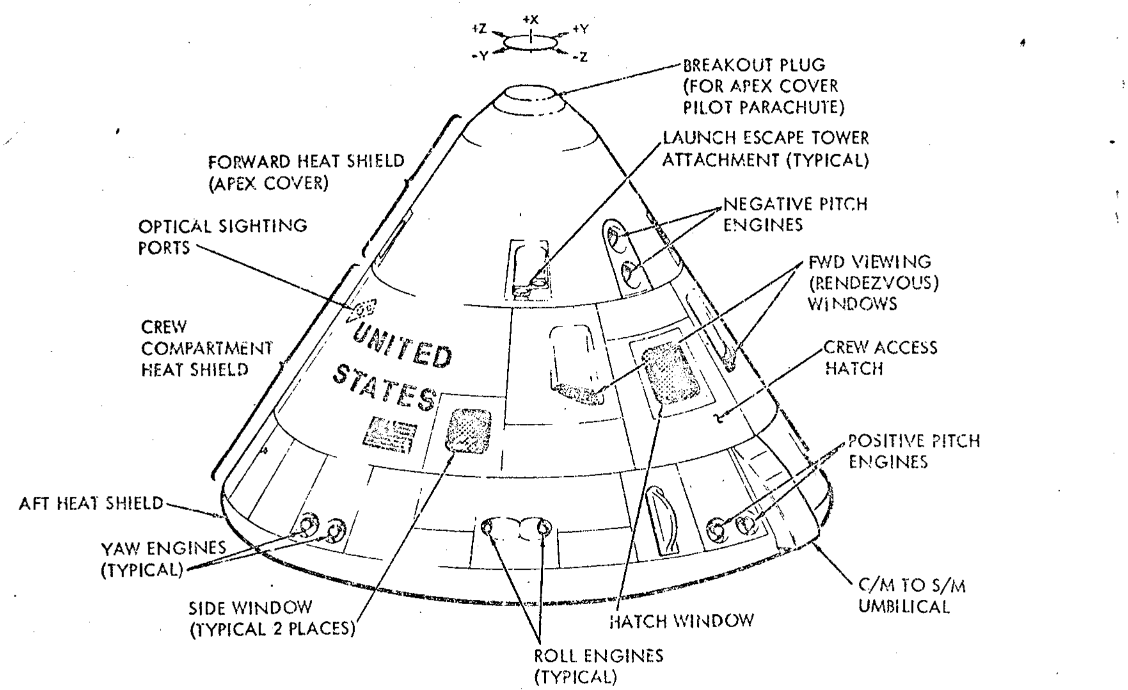


Figure 1-2. Boost Protective Cover



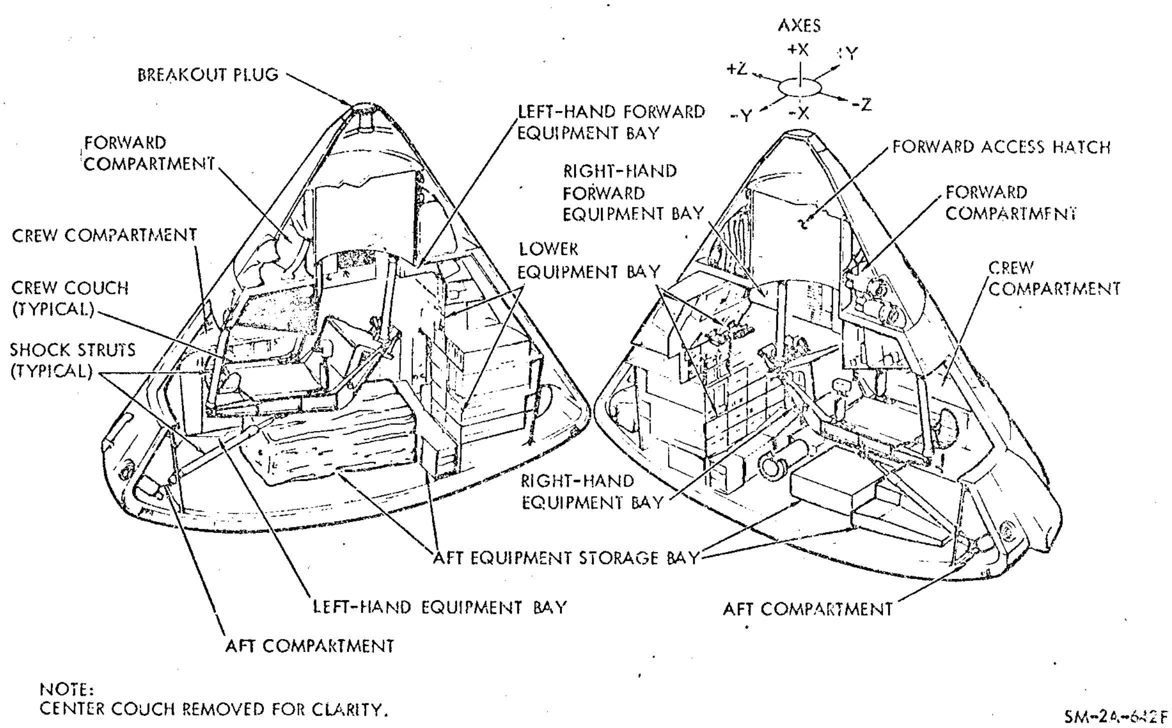


Figure 1-3. Spacecraft 012 Command Module

1.1.2.1 Forward Compartment.

The forward compartment (figure 1-3) is the area outside the forward access tunnel, forward of the crew compartment forward bulkhead and is covered by the forward heat shield. Four 90-degree segments around the perimeter of the tunnel contain the recovery equipment, two negative-pitch reaction control system engines, and the forward heat shield release mechanism. Most of the equipment in the forward compartment consists of earth landing (recovery) system components.

The forward heat shield, or apex cover, is made of brazed stainless-steel honeycomb and covered with ablative material. It contains four recessed fittings which permit the launch escape tower to be attached to the C/M inner structure. Jettison thrusters separate the apex cover from the C/M after entry or after the launch escape assembly is separated during an abort. (For additional information, refer to the sequential systems in section 2.)

1.1.2.2 Crew Compartment.

The crew compartment or inner structure (figure 1-3) is a sealed cabin with pressurization maintained by the environmental control system (ECS). The compartment, protected by a heat shield, contains controls and displays for operation of the spacecraft and spacecraft systems; contains mechanical adjustments for the crew couches, restraint harness assemblies, hatch covers, window shades, etc.; and is provided with crew equipment, food and water, waste management provisions, survival equipment, and scientific experiments equipment. Access hatches, observation windows, and equipment bays are attached as part of the compartment structure.

The crew compartment heat shield, like the apex cover, is made of brazed stainless-steel honeycomb and covered with ablative material. This heat shield, or outer structure, contains the S/C umbilical connector outlet, ablative plugs, and a copper heat sink for the optical sighting ports in the lower equipment bay, two side observation windows, two forward viewing windows, and the outer cover for the side access hatch which also contains an observation window.

1.1.2.3 S/C Controls and Displays.

Information relating to controls and displays for operation of the spacecraft and its systems is provided in section 3.

1.1.2.4 C/M Mechanical Controls.

Mechanical controls (figure 1-4) are provided in the crew compartment for manual operation of the crew couch assembly, side access hatch covers, forward access hatch cover, and manual override levers for the

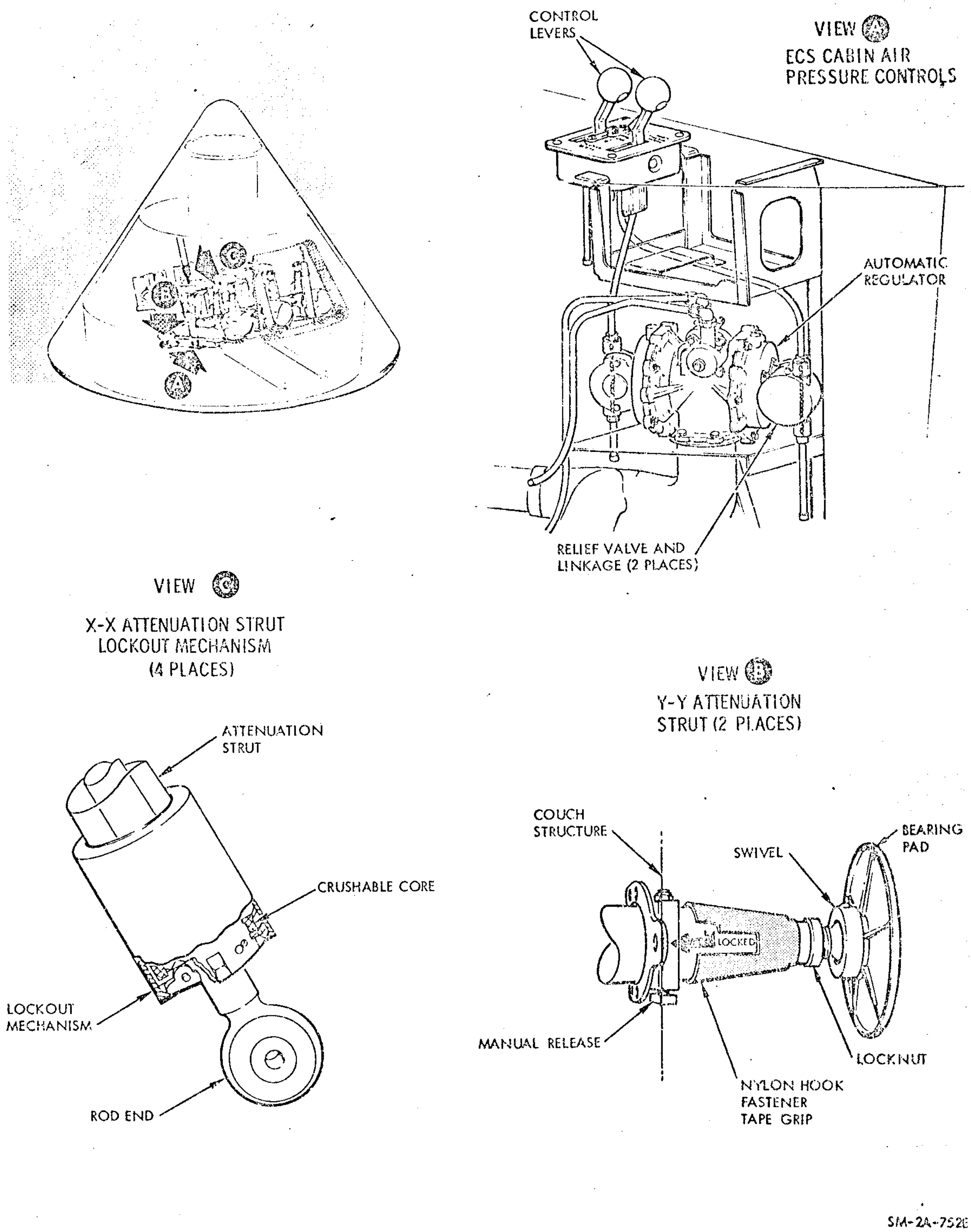


Figure 1-4. C/M Mechanical Controls (Sheet 1 of 3)

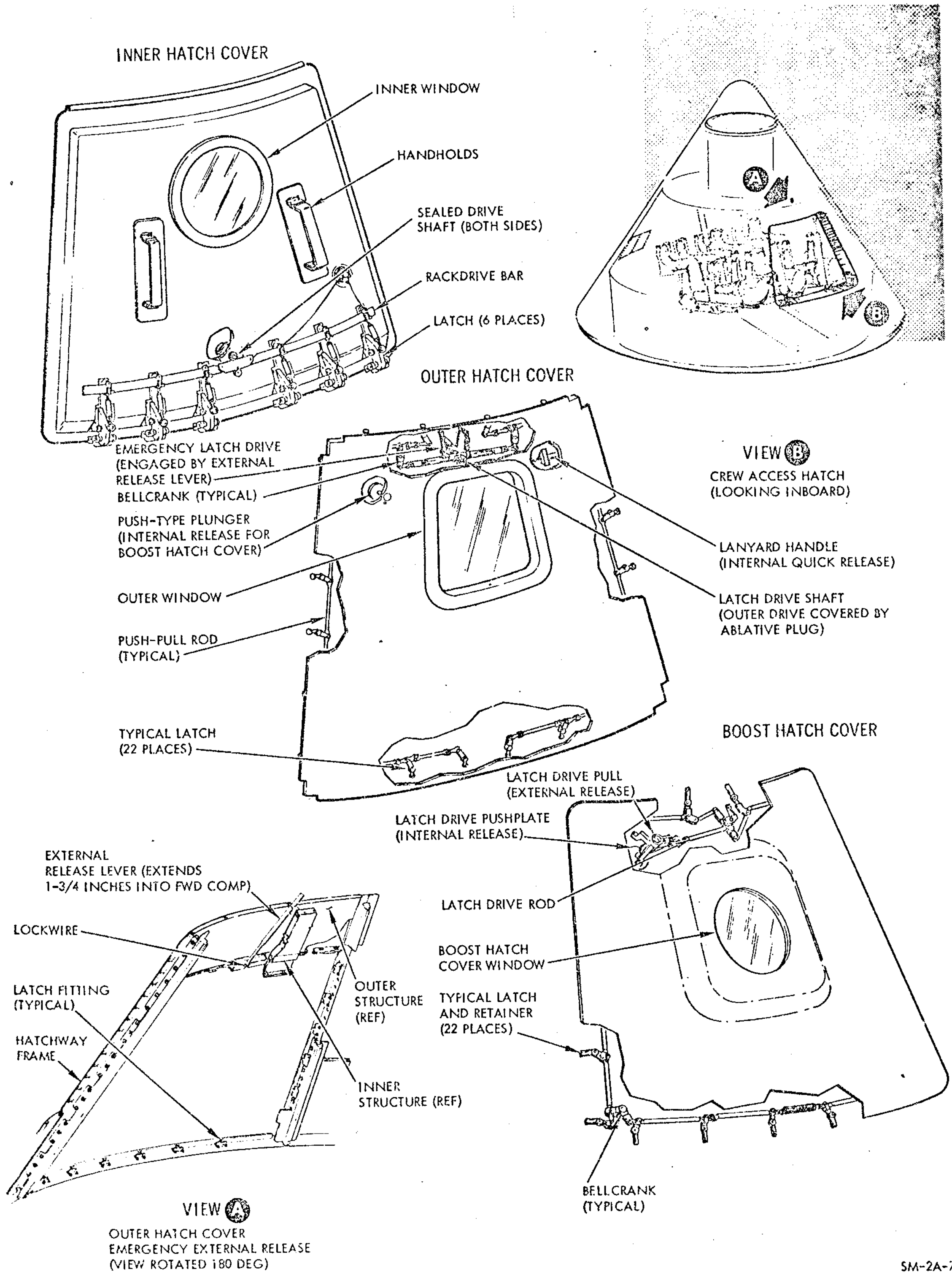


Figure 1-4. C/M Mechanical Controls (Sheet 2 of 3)

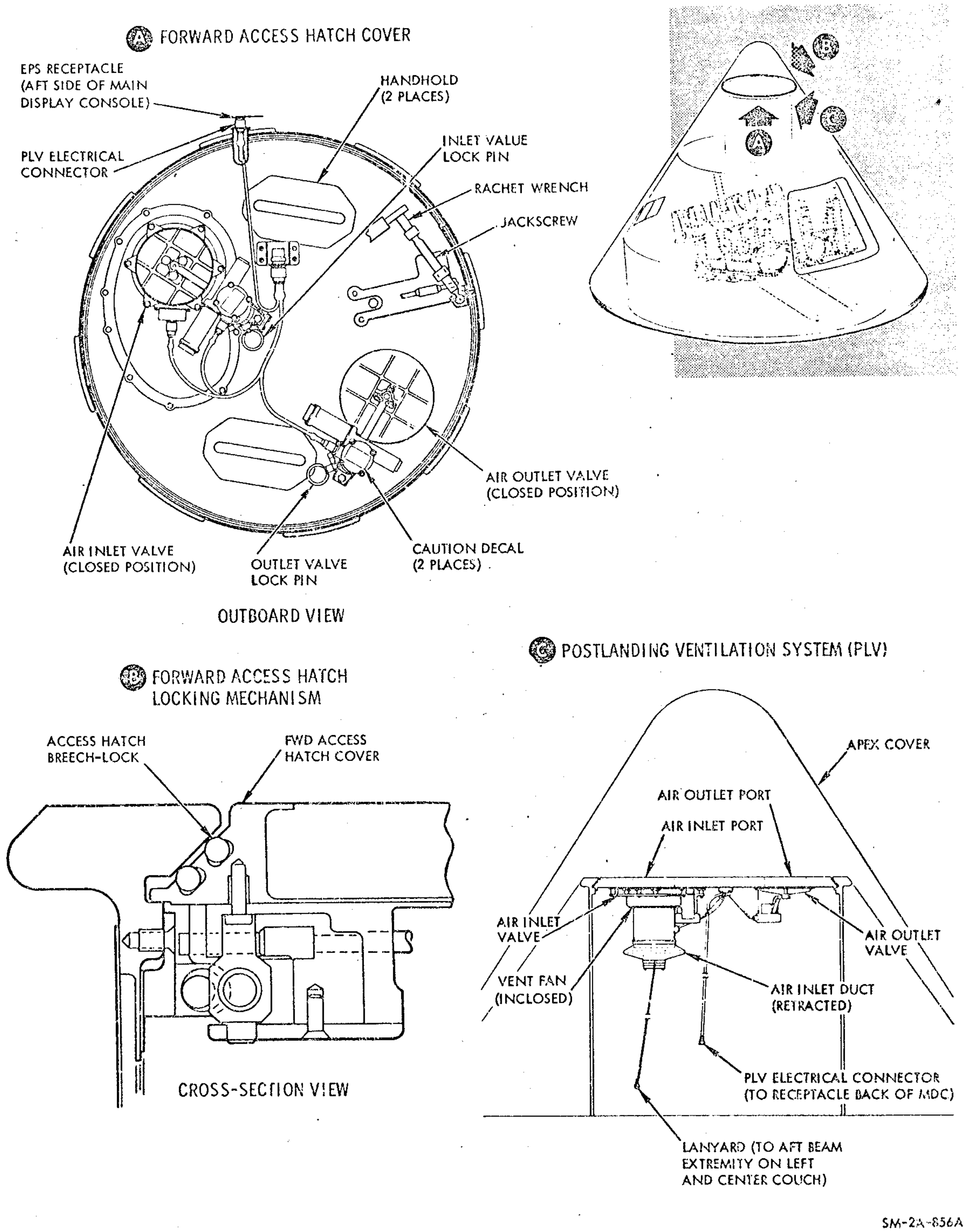


Figure 1-4. C/M Mechanical Controls (Sheet 3 of 3)

ECS cabin pressure regulator. Tools for opening or securing the hatch covers are in the stowage area under the work table in the lower equipment bay; the tools are components of the in-flight tool kit.

1.1.2.4.1 Crew Couch Controls.

Crew couch manual controls for each headrest, armrest, and seat pan assembly are provided for individual crew comfort. The crew couch assembly can also be manually adjusted for crew positioning during simulated docking maneuvers, crew convenience in getting in and out of the couches, and crew access to all equipment bays in the C/M. (For additional information, refer to crew couch assembly in section 6.)

1.1.2.4.2 Couch Attenuation Struts.

Eight attenuation struts are provided for connecting the crew couches to the C/M inner structure. (See figure 1-5.) Each strut is capable of absorbing energy at a predetermined rate through crushable aluminum

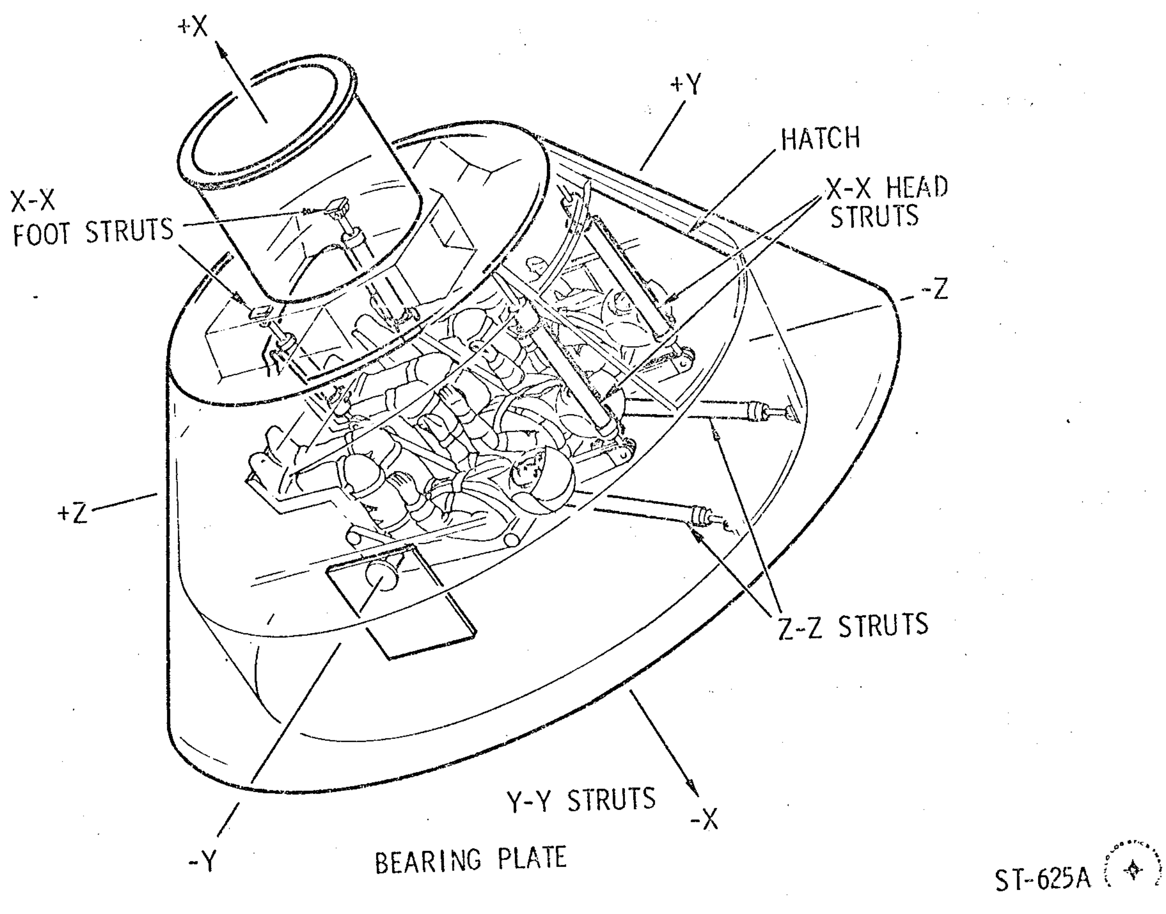


Figure 1-5. Internal Attenuation System

honeycomb cores contained within the strut cylinders. In effect, the strut piston action during C/M impact absorbs energy that the crew is not capable of absorbing.

Two Y-Y axis struts are located at the outer extremities of the couch assembly at the hip beam. The cylinder end of each strut is firmly attached to the unitized couch while the piston end, containing a flat circular foot, reacts against a flat bearing plate (attenuation panel) attached to the structure.

Two Z-Z axis struts are attached to the main couch beams under the unitized backrest and the aft bulkhead of the structure, just below the side access hatch. In addition to the crushable cores within the struts, friction brake snubbers are provided on the end of the pistons for additional breaking action. During a compression stroke or initial tension load, these friction brakes act in conjunction with the inner pistons which simultaneously crush the cylinder inner cores. Additional tension loads are absorbed by a combination of the outer and inner friction mechanisms which continue the crushing action of the cylinder cores.

Four X-X axis struts are attached to the forward C/M structure and the beam extremities of the couch. These struts, except for the addition of lockout mechanisms, are basically the same as the Z-Z axis struts. A lockout mechanism, is provided on each strut to prevent any strut attenuation prior to impact (during normal mission flight loads). Upon impact the honeycomb core will be crushed, allowing the piston rod to stroke.

1.1.2.4.3 Crew Access Hatch Covers.

The C/M crew access hatch is provided with three covers (inner, outer, and boost) and the necessary latching mechanisms for securing the covers to the C/M. (See figure 1-4.) Latches for these covers can be manually operated from either side of the hatch by a removable handcrank or torque wrench with a 7/16-inch drive. The inner cover is equipped with a sealed drive, a rack-drive bar, and six latches which engage fittings on the C/M inner structure (to preload the hatch for sealing). The outer cover is equipped with bellcranks, rollers, and push-pull rods, an overcenter lock, and 22 latches which engage fittings on the C/M outer structure. An ablative screw-in plug is used to protect the outer driver shaft in the outer hatch cover. This plug must be removed before a handcrank can be inserted into the drive shaft from outside the C/M. An emergency latch release is also provided for the outer hatch cover, but can only be operated by personnel outside the C/M during recovery procedures. The boost hatch cover is also equipped with mechanical components (including 22 latches) for installing it flush with the boost protective cover. This hatch cover makes it possible for the crew to get in and out of the S/C during prelaunch operations. A ground support tool (G15-824105 handle) is used to remove (pull) the boost cover from the outside the C/M. A plunger on the inside of the outer hatch engages a latch drive push-plate to release the boost hatch cover from inside the C/M.

1.1.2.4.4 Forward Access Hatch Cover

The C/M forward access hatch is provided with a cover that can be operated from either the inside or outside the crew compartment. (Outside operation is possible only after the launch escape system, boost protective cover, and forward heat shield have been jettisoned. (See figure 1-4.) A breech-lock method is used to engage and rotate the cover in the forward end of the tunnel ring. The internal pressure of the C/M will assist to seal the hatch cover by forcing it against its seat. A jackscrew (with a hex socket at one end) is mounted on the cover and will bear against a bracket on the tunnel wall. When turned by a handcrank or torque wrench with a 5/32-inch drive, the jackscrew will intend and allow the cover to be rotated and removed. The cover is rotated by use of the inside handholds or the outside by an item of GSE and can only be retrieved from within the crew compartment end of the tunnel.

1.1.2.4.5 Windows and Shades.

Five windows are provided through the inner structure and heat shield of the C/M: two forward viewing, two side observation, and the crew access hatch windows. (See figure 1-3.) During orbital flight, photographs of external objects will be taken through the viewing and observation windows. The inner windows (including the circular inner hatch window) are made of tempered silica glass with 0.25-inch-thick double panes, separated by 0.1 inch of space, and have a softening temperature point of 2000°F. The outer windows (including the square outer hatch window) are made of amorphous fused silicon with a single 0.7-inch-thick pane. Each pane contains an antireflecting coating on the external surface, and has blue-red reflective coating on the inner surface for filtering out most infrared and all ultraviolet rays, a softening temperature point of 2800°F, and a melting point of 3110°F.

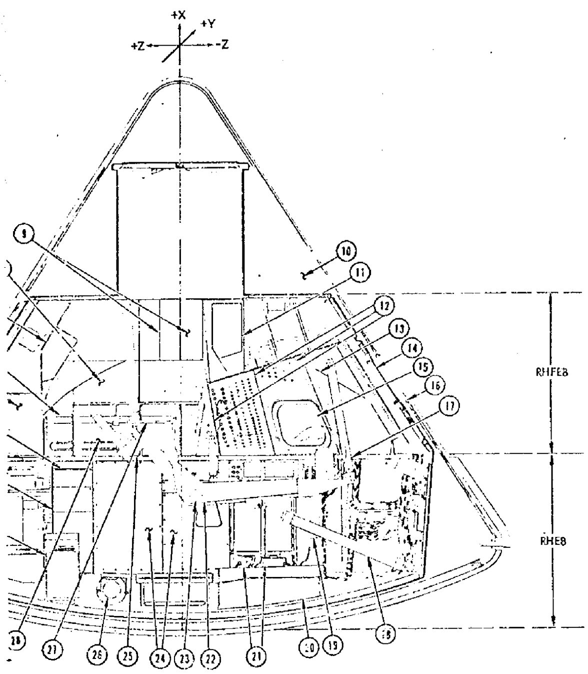
Shades are provided for controlling external light entering the C/M through the triangular forward viewing windows, the square side observation windows, and the circular inner hatch window. These shades, individually designed for each window configuration, are made of mylar film which has been heat-treated to roll up when not held flat. The shades are opaque for zero light transmittal, have a nonreflective inner aluminized surface, two snap fasteners and fabric handles for attaching or removing from a particular window, and a 3/4-inch strip of Velcro hook material around the outer surface for holding the shade against the Velcro pile around the perimeter of the window. If desired, a shade can be peeled back from the Velcro pile material and stowed in place on one side of the window.

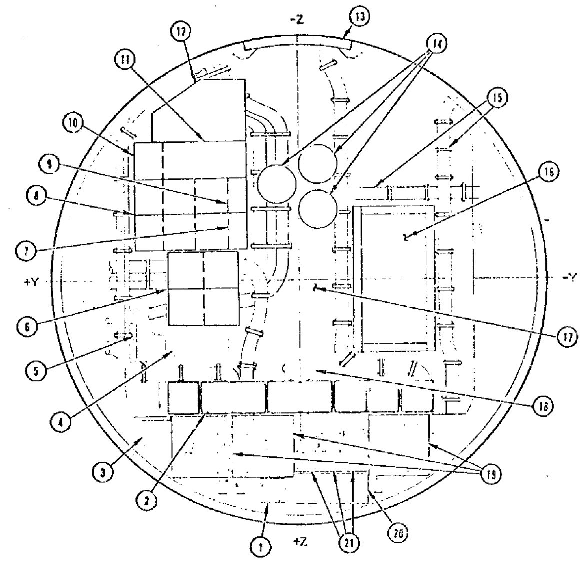
1.1.2.4.6 Cabin Pressure Controls.

Two control levers for manually operating the ECS cabin pressure relief valves are located near the C/M left couch and left side window. (See figure 1-4.) These levers are provided as a mechanical override for opening and closing the redundant sides of the automatic cabin pressure regulator. (For additional information, refer to the environmental control system in section 2.)

1.1.2.5 Crew Equipment and Equipment Bays.

Each crewmember has personal and accessory equipment provided for his use in the crew compartment. Major items of personal equipment consist of a pressure garment assembly (PGA) with attaching hose and umbilical, a communications assembly, a constant-wear garment, biomedical sensors, and radiation dosimeters. Major items of accessory equipment shared by the crew consist of an in-flight tool set and a medical kit. (For a detailed list of crew equipment, refer to section 6.) (Specific items contained in the C/M equipment and storage bays are listed in figure 1-6.)





RD EQUIPMENT BAY (RHFEB) AND RIGHT-HAND EQUIPMENT BAY (RHEB)

ment (ref)

(ref)

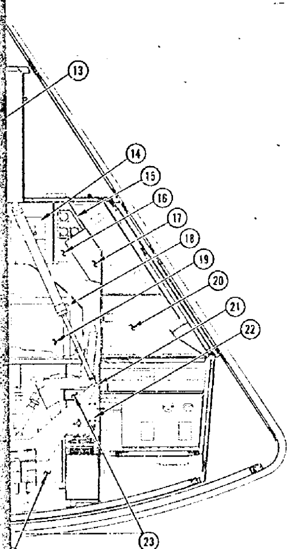
17 Crew attenuation strut (X-X axis)
18 Crew attenuation strut (Z-Z axis)
19 Phase correcting capacitor fuse box
20 Compartments T, S and Z (ref)
21 Circuit interrupter
22 Right crew couch
23 Crew attenuation strut (Y-Y axis)
24 Side shock attenuation panels
25 Waste storage inlet (on bulkhead)
26 Stowed fecal canister (ref)
27 Sanitation supply stowage
28 Scientific equipment compartment E
29 Battery charger (ref)

AFT EQUIPMENT STOWAGE BAY (AESB)

1 Battery charger
2 CO_2 absorber containers
3 Pyro batteries and circuit breaker panel
4 Fecal canister (stowed)
5 TV lens storage
6 CO_2 absorber containers (4)
7 Pen lights compartment Z
8 CO_2 absorber containers (6)
9 Compartment Y
10 Compartment T
11 Compartment S
12 PGA and sleep restraint stowage bag
13 Crew access hatch (ref)
14 PGA helmet, comm soft hat, light wt headset stowage
15 Bulkhead wireways (typical)
16 Spacesuit (2), life vest (3), sleeping restraint (1) stowage bag
17 Aisleway (under center couch)
18 Fecal canister (usage position)
19 Electrical inverters
20 AC power box
21 Spacecraft storage batteries

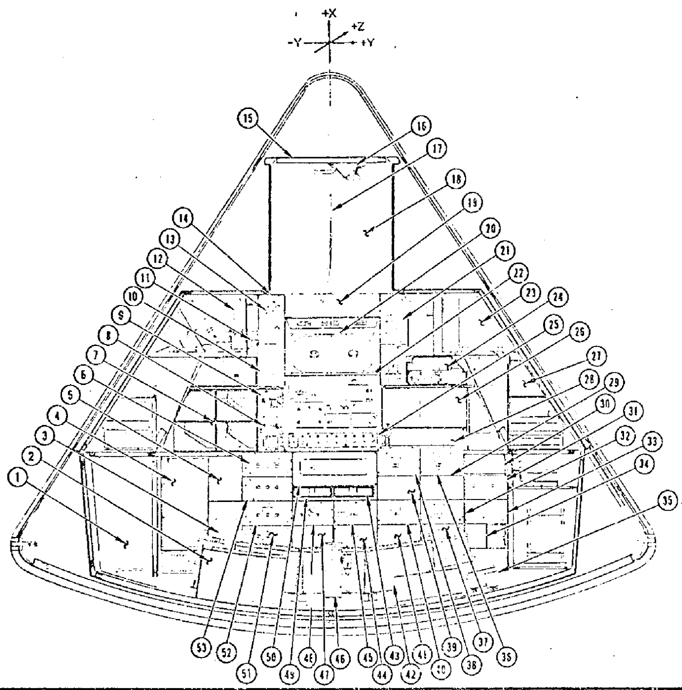
SM-2A-817E

Figure 1-6. C/M Equipment and Stowage Bays



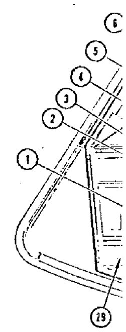
LEFT-HAND EQUIPMENT BAY (LHEB)

- ock and event timer panel
- ;N loose parts storage
- xtant and telescope compartment (ref)
- ew attenuation strut (X-X axis)
- othing storage compartment
- rtial measurement unit (ref)
- t crew couch (attenuated)
- ygen control panel
- dical kit (left couch)
- e shock attenuation panels (removable)
- cesuit stowage bag and scientific equipment stowage (ref)
- S valves
- S oxygen, water, and glycol equipment



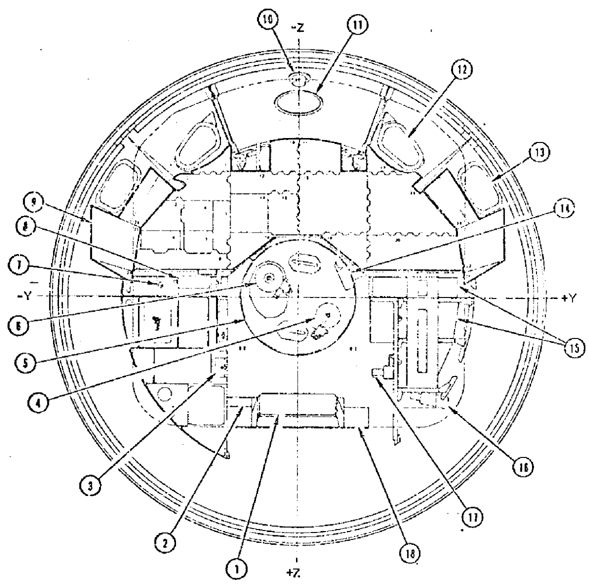
LOWER EQUIPMENT BAY (LEB)

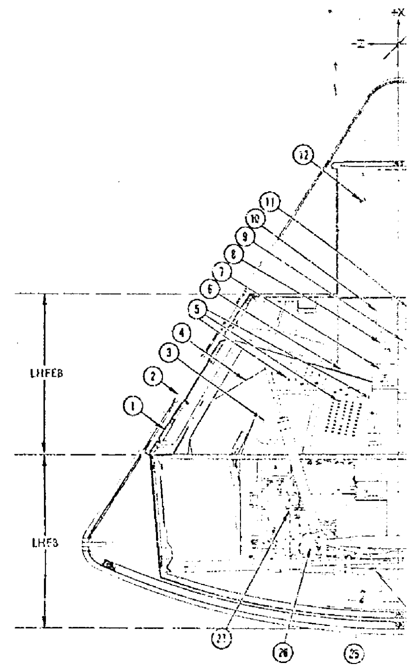
1. ECS components (ref)
2. Spacesuit stowage bag and scientific equipment stowage (ref)
3. Gas chromatograph
4. Flight qualification tape recorder
5. Scientific equipment compartment A
6. Display/attitude gyro-accelerometer (ECA)
7. Food storage (5 containers)
8. Attitude gyro and accelerometer
9. Rate gyro
10. Coupling and display panel
11. Sr pilot suit connector panel and electrical connector (ref)
12. Cabin air recirculation fan (ref)
13. IMU control panel
14. Lighting control
15. Forward access hatch cover (ref)
16. Postlanding ECS air outlet duct
17. Postlanding ECS power cable
18. Forward access hatch (ref)
19. Sextant telescope eyepiece stowage
20. Sextant and telescope panel
21. Computer display and control panel
22. G&N control panel IMU
23. Survival provisions (ref)
24. Clinical monitoring instrument set compartment
25. Power servo assembly (PSA)
26. Data storage equipment
27. Towel storage
28. Signal conditioning equipment
29. VHF multiplexer
30. Data wiring
31. Premodulation processor
32. VHF recovery beacon and VHF-AM transmitter-receiver
33. Audio center
34. Central timing
35. TV optics storage (ref)
36. Pulse-code modulation (PCM) unit 2 telemetry equipment
37. VHF-FM transmitter and HF transceiver
38. Pulse-code modulation (PCM) unit 1 telemetry equipment
39. Scientific equipment compartment C
40. S-band power amplifier
41. C-band transponder
42. CO_2 absorber container (ref)
43. Food and work table (in-flight tool set)
44. Digital up-data link
45. Unified S-band equipment
46. Fecal canister (positioned)
47. Scientific equipment compartment B
48. Roll channel ECA
49. Data package container (also on outboard couch beams)
50. G&N computer
51. Pitch channel ECA
52. Auxiliary ECA
53. Yaw channel ECA



RIGHT-HAND E

1. CO_2 absorber contain
2. Waste management sys
3. Computer
4. Vacuum cleaner comp
5. IMU compartment (ref)
6. Medical accessories ki
7. Sextant and telescope
8. Food stowage
9. Survival provisions
10. RCS pitch control engi
11. TV camera mount
12. Side console panels (ri
13. Rendezvous window ho
14. Inner hatch cover
15. Side window
16. Outer hatch cover





FORWARD REFERENCE VIEW

1 Optics shroud
2 LEB lighting control panel
3 Food reconstitution device
4 Postlanding ECS air outlet duct
5 Forward access hatch cover
6 Postlanding ECS air inlet duct
7 Water delivery valve
8 Water delivery unit
9 Main display console (MDC panels 1 through 26)
10 Crew access hatch actuator (inner cover)
11 Crew access hatch inner window
12 Forward viewing or rendezvous window (2 places)
13 Side window (2 places)
14 TV camera (launch and entry)
15 Survival provisions
16 TV camera mount (optional)
17 Measurement system instrumentation
18 Apollo guidance computer navigational display keyboard

LEFT-HAND FORWARD EQUIPMENT BAY (LHFE[illegible]

1 Inner hatch cover
2 Outer hatch cover
3 Side window
4 Rendezvous window housing
5 Side console panels (left)
6 Main display console (ref)
7 Comdr suit connector panel and electrical connector
8 Sr pilot suit connector panel and electrical connector
9 Pilot suit connector panel electrical connector
10 Scientific equipment compartment D
11 Cabin air recirculation fan
12 Forward access hatch or egress tunnel (ref)
13 Postlanding ECS air inlet duct (extended)

1.1.2.6 Food and Water.

Food and water provisions, including water delivery and food preparation equipment, are available in the crew compartment LHEB and LEB, (figure 1-6) for the length of the mission. Food may be prepared by adding water to plastic bags containing the dehydrated food and kneading the mixture. Prepared food can be squeezed directly into the mouth of an astronaut. Hot or cold water is available at the potable water supply panel for food reconstitution. Chilled drinking water is supplied to the crew through a flexible hose from the water delivery unit. The potable water is a by-product of the EPS fuel cells.

1.1.2.7 Waste Management.

Waste management provisions in the crew compartment RHFEB and AESB (figure 1-6) consist of equipment for collecting, sterilizing, and storing human fecal matter and personal hygiene wastes (such as used cleansing pads, towels, etc.). Fecal matter and personal hygiene wastes are collected in polyethylene bags, disinfected, and stored in a vented area. Urine is expelled overboard into space.

1.1.2.8 Survival Equipment.

The survival kits stowed in the crew compartment RHFEB (figure 1-6) are available for the postlanding phase of the mission (land or water). The major items contained in each kit include 6 pounds of water, a desalter kit, a one-man life raft, radio transceiver, portable light, sunglasses, and a machete. Life vests worn by the crew during lift-off and entry are stowed in the space suit stowage bag during the orbit phase of the mission. (See figure 1-6.)

1.1.2.9 Aft Compartment.

The aft compartment (figure 1-3) is the area encompassed by the aft portion of the crew compartment heat shield, aft heat shield, and aft portion of the primary structure. This compartment contains 10 reaction control engines, an impact attenuation structure, instrumentation, and storage tanks for water, fuel, oxidizer, and gaseous helium. (Four crushable ribs, along the S/C +Z axis, are provided as part of the impact attenuation structure to absorb energy during a land impact.)

The aft heat shield, which encloses the large end of the C/M, is a shallow spherically contoured assembly. It is made of the same type of materials as other C/M heat shields. However, the ablative material on this heat shield has a greater thickness for the dissipation of heat during entry. External provisions are made on this heat shield for connecting the C/M to the S/M.

1.1.3 SERVICE MODULE.

The S/M is a cylindrical structure formed by 1-inch-thick aluminum honeycomb panels. Radial beams, from milled aluminum alloy plates, separate the structure interior into six unequal sectors around a circular center section. (See figure 1-7.) Equipment contained within the service module is accessible through maintenance doors located strategically around the exterior surface of the module. Specific items, such as flight control system (SPS and RCS) and most of the S/C on-board consumables (and storage tanks) contained in the S/M compartments, are listed in figure 1-7.

Radial beam trusses on the forward portion of the S/M structure (figure 1-7) provide a means for securing the C/M to the S/M. Alternate beams, one, three, and five, have compression pads for supporting the C/M. Beams two, four, and six, have shear-compression pads, and tension ties. A flat center section in each tension tie incorporates redundant explosive charges for S/M-C/M separation. These beams and separation devices are enclosed within a fairing (26 inches high and 13 feet in diameter) between the C/M and S/M.

1.1.4 SPACECRAFT LEM ADAPTER.

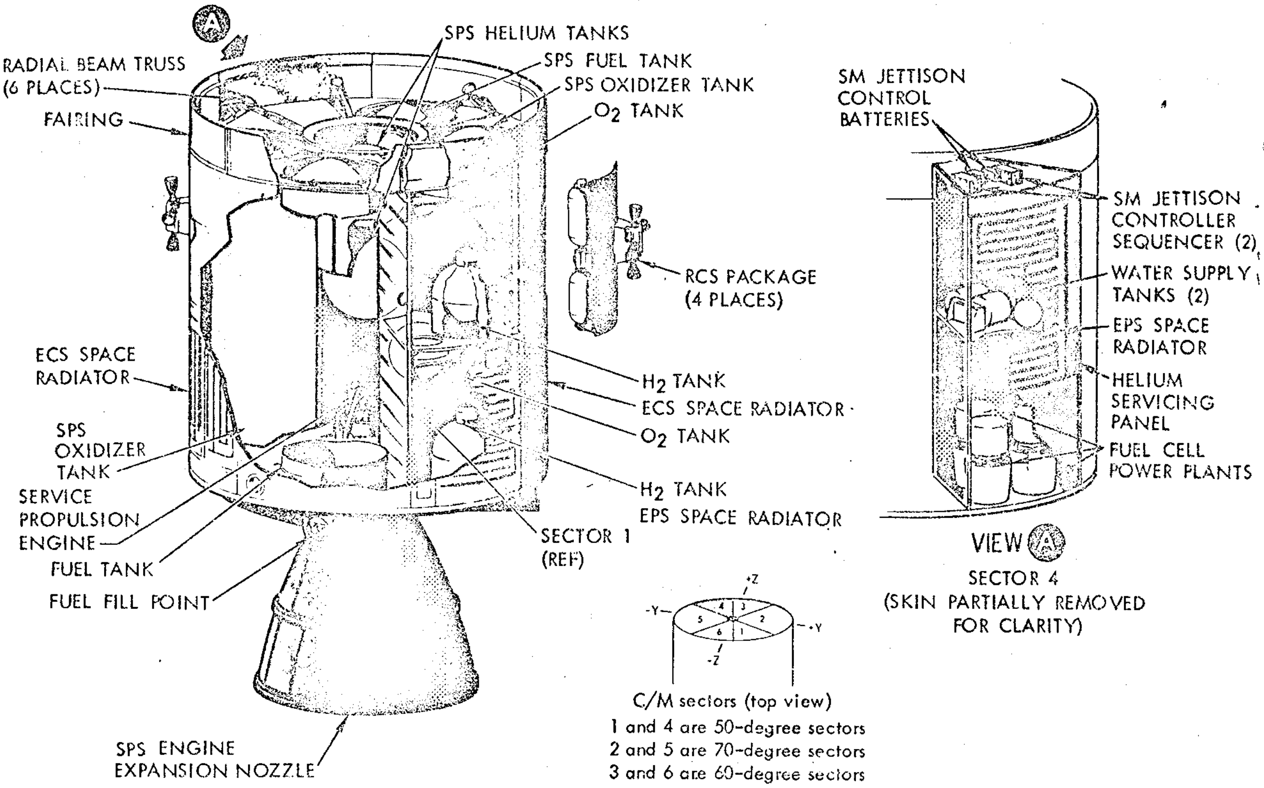
The spacecraft LEM adapter (SLA) is a truncated cone which connects the CSM to the S-IVB instrument unit on the launch vehicle. (See figure 1-1.) This adapter, constructed of eight 2-inch-thick aluminum panels, is 154 inches in diameter at the forward end (C/M interface) and 260 inches at the aft end. Separation of the spacecraft from the SLA is accomplished by means of explosive charges which permit the four SLA forward panels (above station 583.3) to disengage from the CSM and rotate outward 45 degrees from vertical. The four aft panels remain attached to the S-IVB instrument unit. For mission 204A, a cross-shaped stiffener is installed within the SLA in place of a LEM. The S/M SPS nozzle extends into the SLA which also houses an umbilical cable for connecting circuits between the launch vehicle and the spacecraft.

1.1.5 SPACECRAFT SYSTEMS.

Data relating to the operational spacecraft systems and interface information are presented in section 2 of this handbook.

1.2 LAUNCH VEHICLE CONFIGURATION.

A two-stage Saturn IB launch vehicle, consisting of an S-IB booster and an S-IVB second stage, is scheduled to provide the required thrust for inserting S/C 012 into orbit (figure 1-8.) An instrumentation unit, located between the S-IVB and the SLA, controls each of the two boost stages during flight. The total length of the Saturn IB launch vehicle, including the spacecraft, is approximately 224 feet. An emergency detection system sequencer display panel, in the C/M, enables the crew to monitor launch vehicle engine performance during lift-off. (Refer to the sequential systems in section 2.)



SERVICE MODULE ITEMS

Sector 1
- Electrical power system space radiator
- Super-critical oxygen tank (two)
- Super-critical hydrogen tank (two)

Sector 2
- Environmental control system space radiator
- Service propulsion system oxidizer tank
- Reaction control system package (+Y-axis)
- Space radiator isolation valve (two)

Sector 3
- Service propulsion system fuel tank
- Reaction control system package (+Z-axis)
- Service propulsion system helium tanks (two)

Sector 4
- Electrical power system space radiator
- Fuel cell power plant (three)
- Helium servicing panel
- Reaction control system control unit
- Electrical power system power control relay box
- Service module jettison control battery (two)
- Service module jettison controller sequencer (two)
- Water supply tank (two)

Sector 5
- Environmental control system space radiator
- Service propulsion system oxidizer tank
- Reaction control system package (-Y axis)

Sector 6
- Space radiator selection valve, (two)
- Glycol shutoff valves (two)
- Reaction control system package (-Z axis)
- Service propulsion system fuel tank

Center section
- Service propulsion system helium tank (two)
- Service propulsion system engine

SM-2A-643 E

Figure 1-7. Spacecraft 012 Service Module

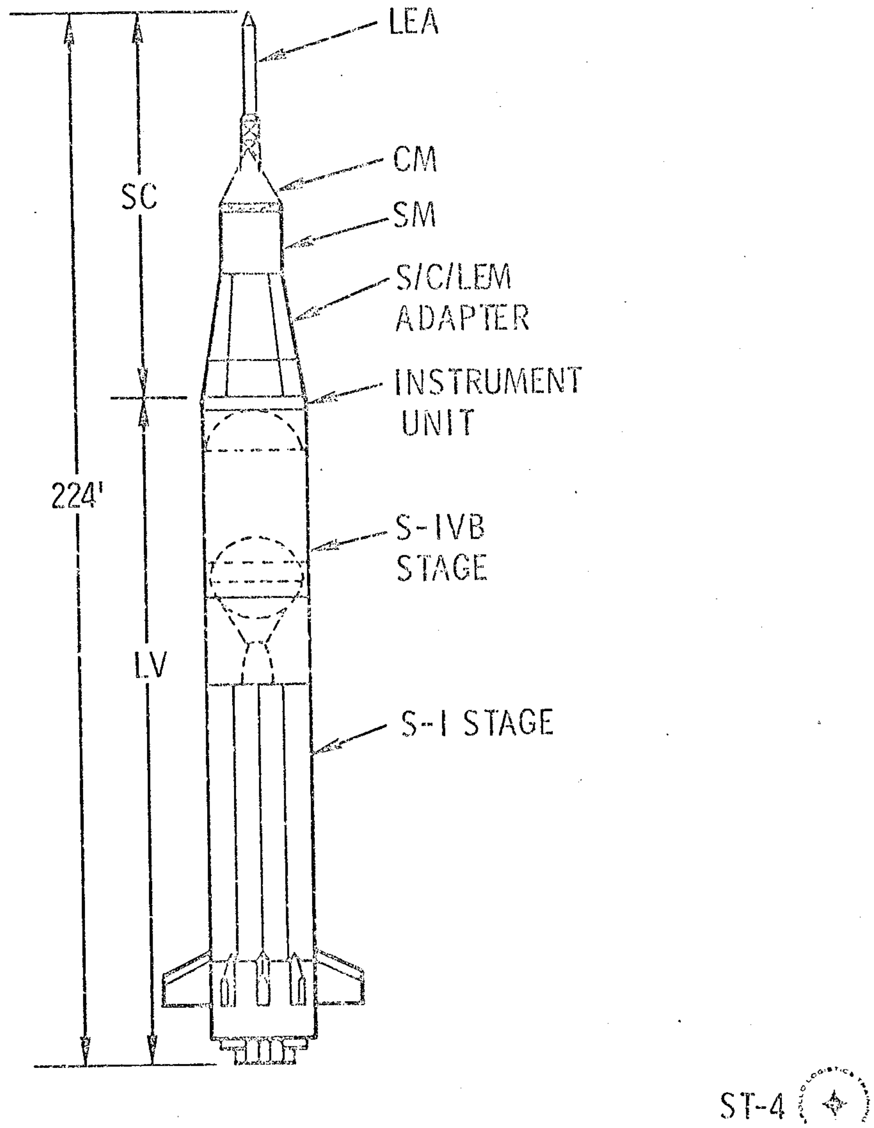


Figure 1-8. Apollo Launch Vehicle (Saturn IB)

1.2.1 S-IB BOOSTER.

The S-IB booster (first stage) for Saturn IB is manufactured by the Chrysler Corporation. This booster is 257 inches in diamater, 82 feet in length, and is powered by eight Rocketdyne H-1 engines. Each engine, burning RP-1 and liquid oxygen, produces 200,000 pounds of thrust for a total stage thrust over 1,600,000 pounds.

1.2.2 S-IVB SECOND STAGE.

The S-IVB second stage for Saturn IB is manufactured by the Douglas Aircraft Company. This stage is 260 inches in diameter, 58 feet in length, and is powered by a single Rocketdyne J-2 engine. The engine, burning liquid hydrogen and oxygen, produces a stage thrust of approximately 200,000 pounds. During flight, the J-2 engine uses three different mixture ratios, resulting in values of thrust ranging from 190,000 to 230,000 pounds.

1.3 MISSION 204A WEIGHT STATUS.

NOTE The NASA-MSC is responsible for providing a detailed weight status for Apollo mission 204A as available in the MSC Reference Trajectory Document.

1.4 POSTLANDING AND RECOVERY.

Information relating to postlanding recovery aids is provided under sequential systems in section 2. Postlanding ventilation for the crew is supplied through two vent valves in the forward access hatch cover. (See figure 1-4.) A handpump and flexible hose, stored under the right crew couch (figure 1-6), is used to obtain water from the sea for conversion to potable water. (Refer to crew equipment in section 6.) An Apollo Recovery Operations Handbook will provide a detailed description of recovery equipment and rescue procedures.

SECTION 2

SYSTEMS DATA

INTRODUCTION.

Systems data include description of operations, component description and design data, operational limitations and restrictions, and telemetry measurements. Subsection 2.1 describes the overall spacecraft navigation, guidance, and control requirements and the resultant systems interface. Subsections 2.2 through 2.10 present data grouped by spacecraft systems, arranged in the following order: guidance and navigation, stabilization and control, service propulsion, reaction control, electrical power, environmental control, telecommunications, sequential, and cautions and warnings. Subsection 2.11 deals with miscellaneous systems data.

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CA[illegible] AND [illegible]

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SECTION 2

SUBSECTION 2.1

GUIDANCE AND CONTROL

2.1.1 SYSTEMS INTERFACE, GUIDANCE AND CONTROL.

Apollo CSM atmospheric and space flight is achieved by application of controlled translation forces and rotational force moments. Guidance and control initiates and terminates the thrust and rotational forces and force moments as a function of the magnitude of the change required. Guidance and control provides the following basic functions:

- Attitude Control
- Guidance
- Navigation

Attitude control is a function associated with spacecraft orientation with respect to an inertial reference or a known coordinate system. Guidance is a function requiring a combination of attitude control with rate stabilization and steering commands for the purpose of modifying spacecraft trajectory via major velocity changes. Navigation determines spacecraft position and velocity, and predicts future position.

To accomplish mission requirements, the guidance and navigation, stabilization and control, service propulsion, and reaction control systems, plus the astronauts, are integrated into an automatic/manual closed loop control system.

Guidance and control activity is grouped into three profiles of flight: coasting, powered, and atmospheric. The primary control loops involved are illustrated in figures 2.1-1 through 2.1-4. Figure 2.1-1 is an abbreviated integration of all major equipments necessary to accomplish the activities in all three flight profiles. Figures 2.1-2 through 2.1-4 divide the equipment into the proper perspective for each profile.

It must be noted that in figure 2.1-1, the loops are closed that represent coasting flight (CF) functions. For powered flight (PF) or atmospheric flight (AF), open the coasting flight loops and close contacts representing the desired loops.

2.1.2 COASTING FLIGHT

The guidance and control activities involved in coasting flight are accomplished through the basic functional loops shown in figure 2.1-2.

These loops provide attitude reference, attitude control, attitude hold, and automatic and manual maneuver capabilities necessary to accomplish the several tasks involved during coasting flight. They are also the central reference and control loops required for all phases of flight.

A reference attitude frame is established by the G&N inertial measurement unit (IMU), and/or by the SCS body-mounted attitude gyros (BMAGs), and attitude gyro coupling unit (AGCU). Inertial sensors sense S/C motion contrary to the reference frame. The sensed attitude errors and rates are conditioned through servo electronics and logic to initiate countermotions via the reaction jet control (RCS) which nullifies the original motion. The AGC inserts automatic control and maneuver commands into the loop. The rotation, translation, and attitude impulse controls insert manual commands into the loop. The flight director attitude indicator (FDAI) is the S/C attitude visual display.

2.1.3 POWERED FLIGHT.

Powered flight is considered that which will use the S/M service propulsion system (SPS) engine to initiate a major velocity change. Figure 2.1-3 illustrates those basic loops necessary for the tasks involved. As shown, the loops are an extension of those required for coasting flight. Added, are the (SPS) engine on-off thrust logic and the SPS gimbal control loops. In coasting flight, all attitude control is through the RCS. Powered flight, by the SPS engine, requires roll control through the RCS, and pitch and yaw control by gimbaling the SPS engine nozzle. Primary control of thrusting is by the AGC. However, figure 2.1-3 shows how various manual controls can be used instead of or to backup automatic functions.

2.1.4 ATMOSPHERIC FLIGHT

Atmospheric flight is encountered during the entry phase of the mission at which time the S/C experiences aerodynamic forces. Figure 2.1-4 illustrates the basic loops required for control of the S/C during this phase. The central loop is identical to that in figure 2.1-2. The main difference is that service module/command module (S/M-C/M) separation has taken place, and the command module RCS system is used. Another difference is that the aerodynamic forces will stabilize the C/M in pitch and yaw, and the entry g-level (lift vector control) will increase or decrease through roll control. Primary control is automatic, with manual rotation control available, in event of automatic control malfunctions.

For detailed operation of the several loops involved in guidance and control, refer to the descriptions of the guidance and navigation system, subsection 2.2, and the stabilization and control system, subsection 2.3.

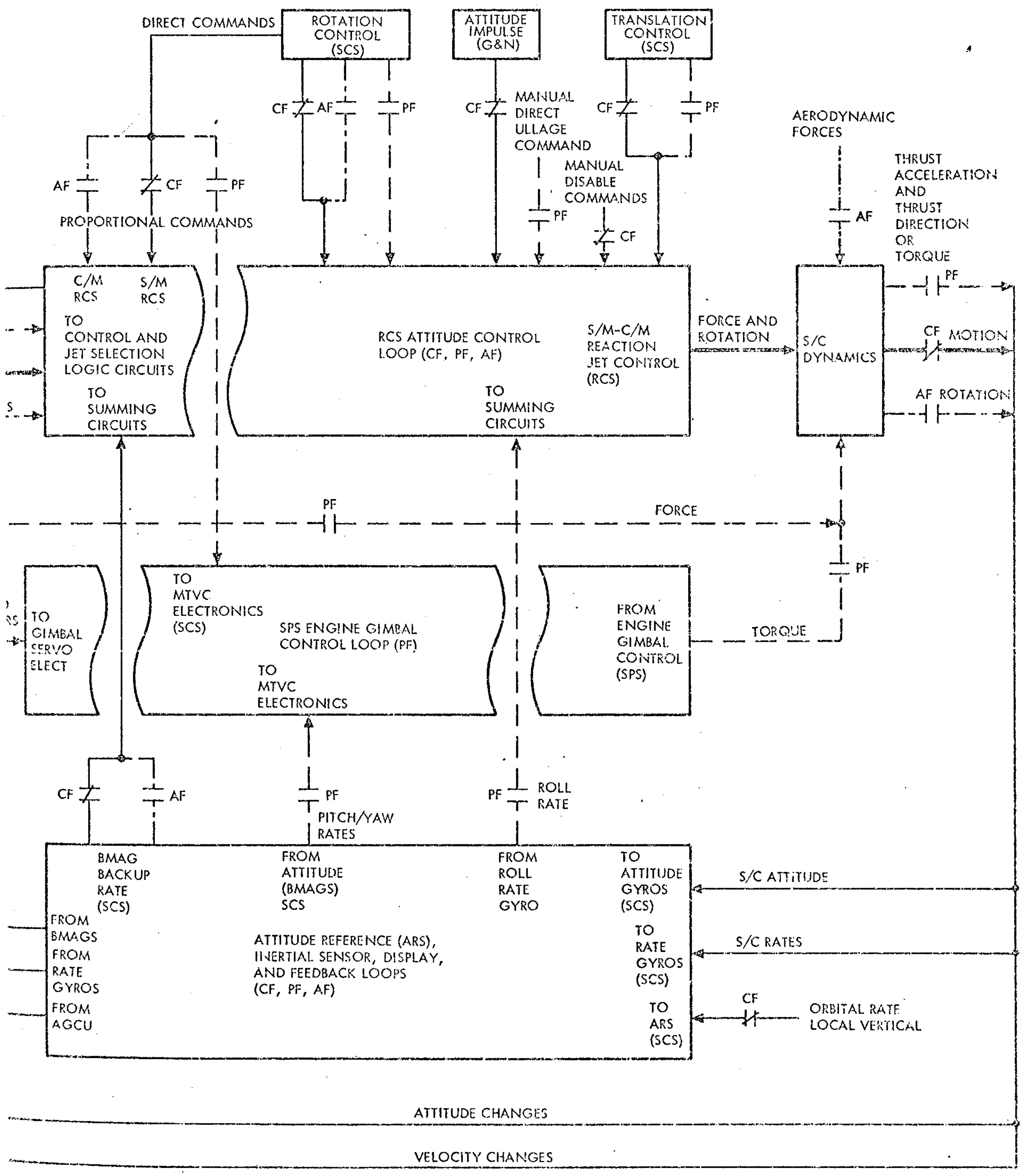
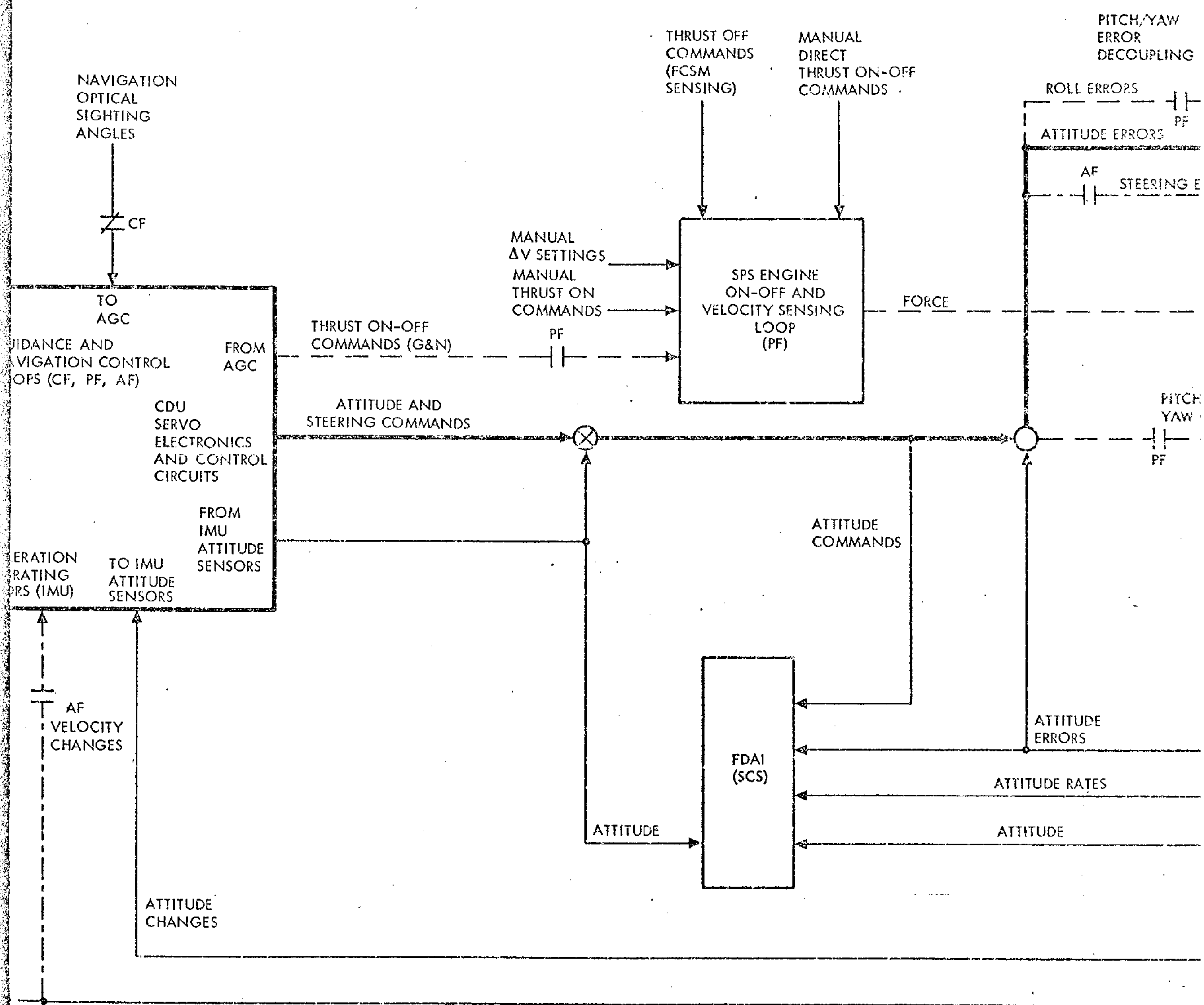
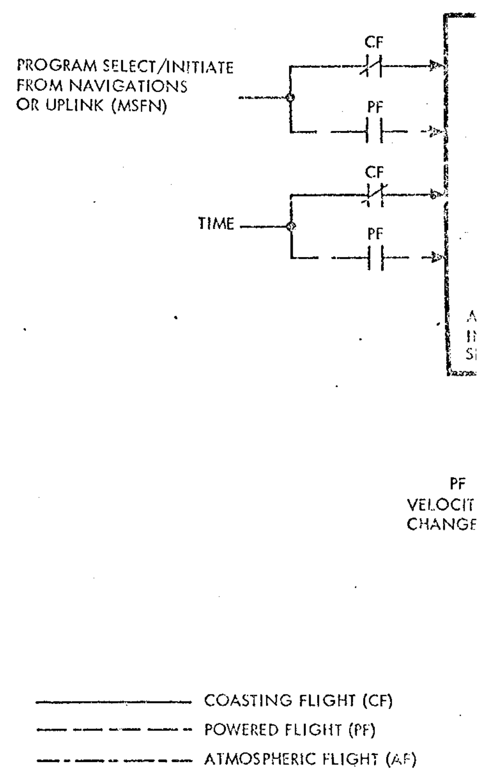


Figure 2.1-1. Integrated Flight Profile Functional Flow Diagram



NAVIGATION OPTICAL SIGHTING ANGLES
CF
TO AGC
UIDANCE AND AVIGATION CONTROL OPS (CF, PF, AF)
FROM AGC
CDU SERVO ELECTRONICS AND CONTROL CIRCUITS
FROM IMU ATTITUDE SENSORS
ERATION RATING RS (IMU)
TO IMU ATTITUDE SENSORS
AF
VELOCITY CHANGES
ATTITUDE CHANGES
THRUST ON-OFF COMMANDS (G&N)
PF
ATTITUDE AND STEERING COMMANDS
THRUST OFF COMMANDS (FCSM SENSING)
MANUAL DIRECT THRUST ON-OFF COMMANDS
MANUAL ΔV SETTINGS
MANUAL THRUST ON COMMANDS
SPS ENGINE ON-OFF AND VELOCITY SENSING LOOP (PF)
FORCE
ATTITUDE COMMANDS
FDAI (SCS)
ATTITUDE
PITCH/YAW ERROR DECOUPLING
ROLL ERRORS
PF
ATTITUDE ERRORS
AF
STEERING E
PITCH YAW
PF
ATTITUDE ERRORS
ATTITUDE RATES
ATTITUDE


PROGRAM SELECT/INITIATE
FROM NAVIGATIONS
OR UPLINK (MSFN)
CF
PF
TIME
CF
PF
PF
VELOCIT
CHANGE
COASTING FLIGHT (CF)
POWERED FLIGHT (PF)
ATMOSPHERIC FLIGHT (AF)

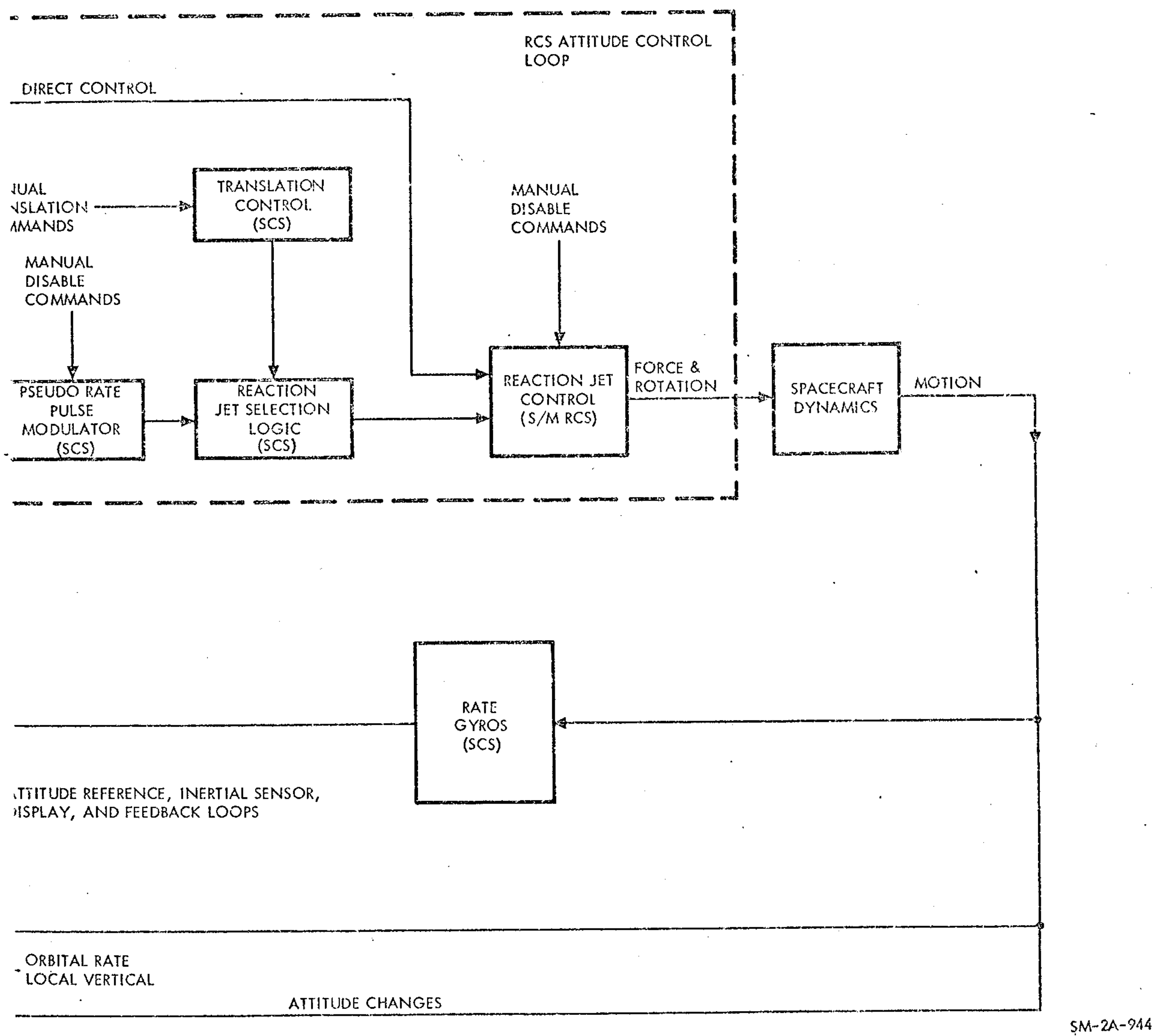
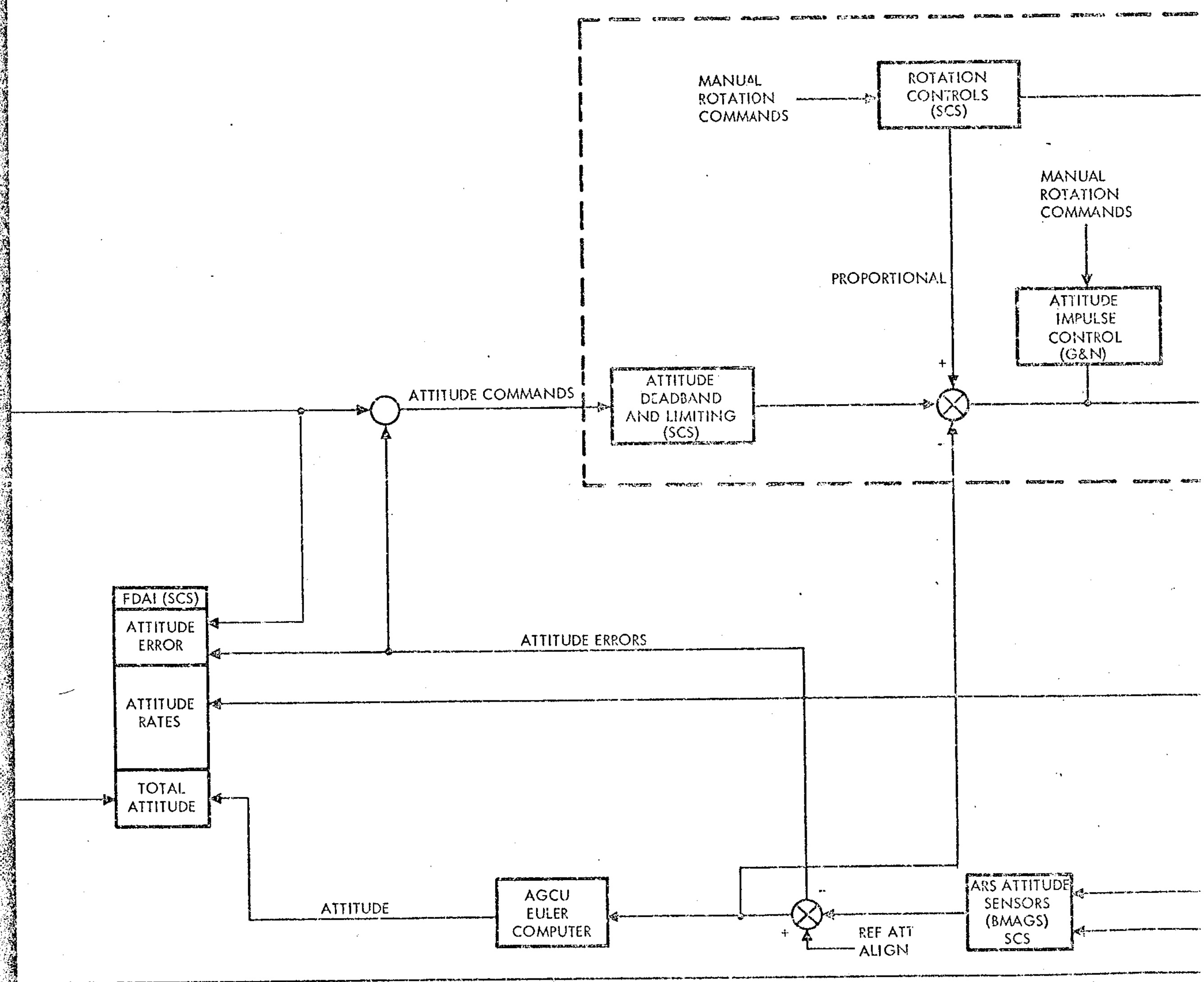
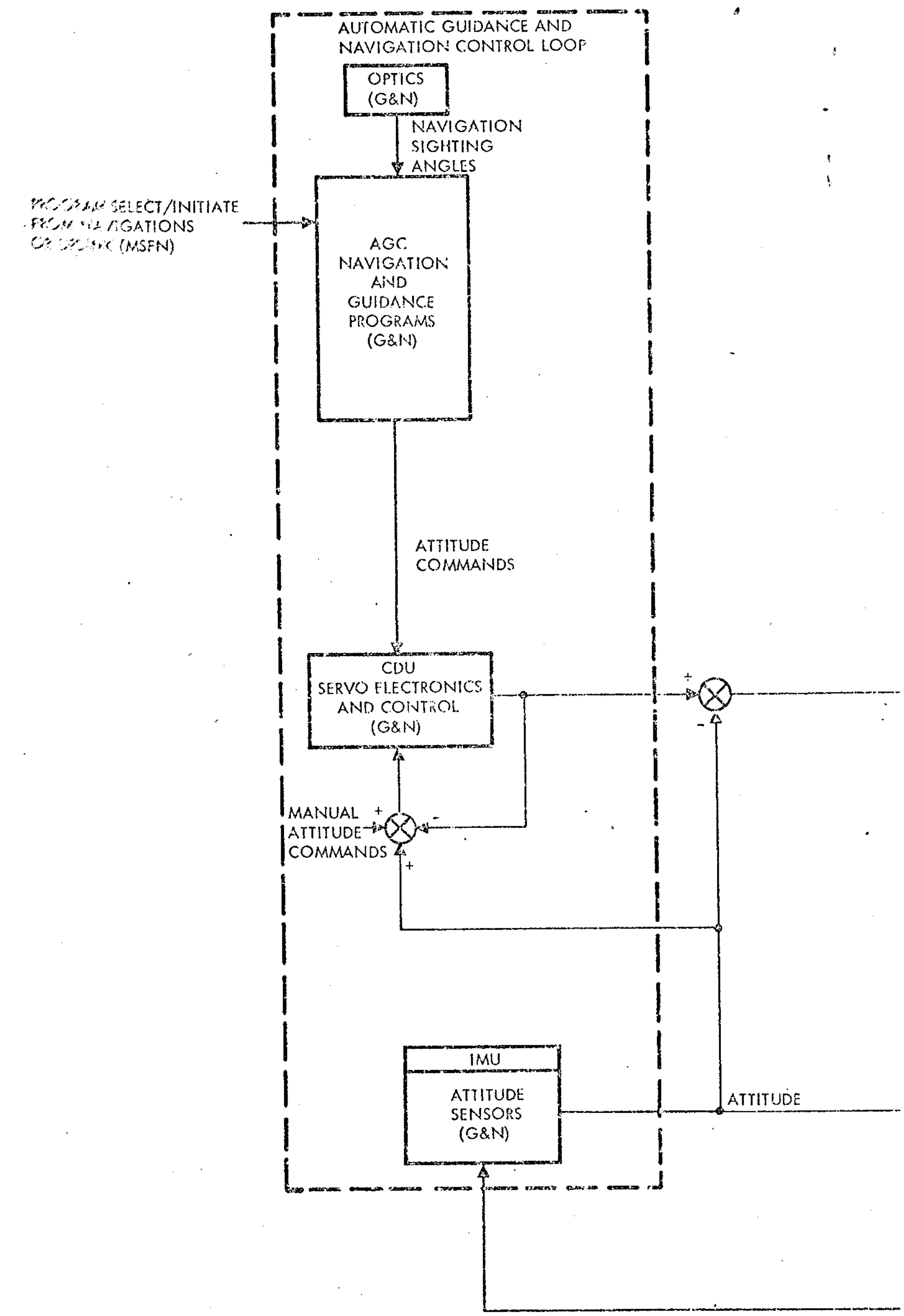


Figure 2.1-2. Coasting Flight Profile Functional Flow Diagram



MANUAL ROTATION COMMANDS
ROTATION CONTROLS (SCS)
MANUAL ROTATION COMMANDS
PROPORTIONAL
ATTITUDE IMPULSE CONTROL (G&N)
ATTITUDE COMMANDS
ATTITUDE DEADBAND AND LIMITING (SCS)
FDAI (SCS)
ATTITUDE ERROR
ATTITUDE ERRORS
ATTITUDE RATES
TOTAL ATTITUDE
ATTITUDE
AGCU EULER COMPUTER
REF ATT ALIGN
ARS ATTITUDE SENSORS (BMAGS) SCS



AUTOMATIC GUIDANCE AND NAVIGATION CONTROL LOOP
OPTICS (G&N)
NAVIGATION SIGHTING ANGLES
SELECT/INITIATE
(MSFN)
AGC NAVIGATION AND GUIDANCE PROGRAMS (G&N)
ATTITUDE COMMANDS
CDU SERVO ELECTRONICS AND CONTROL (G&N)
MANUAL ATTITUDE COMMANDS
IMU
ATTITUDE SENSORS (G&N)
ATTITUDE

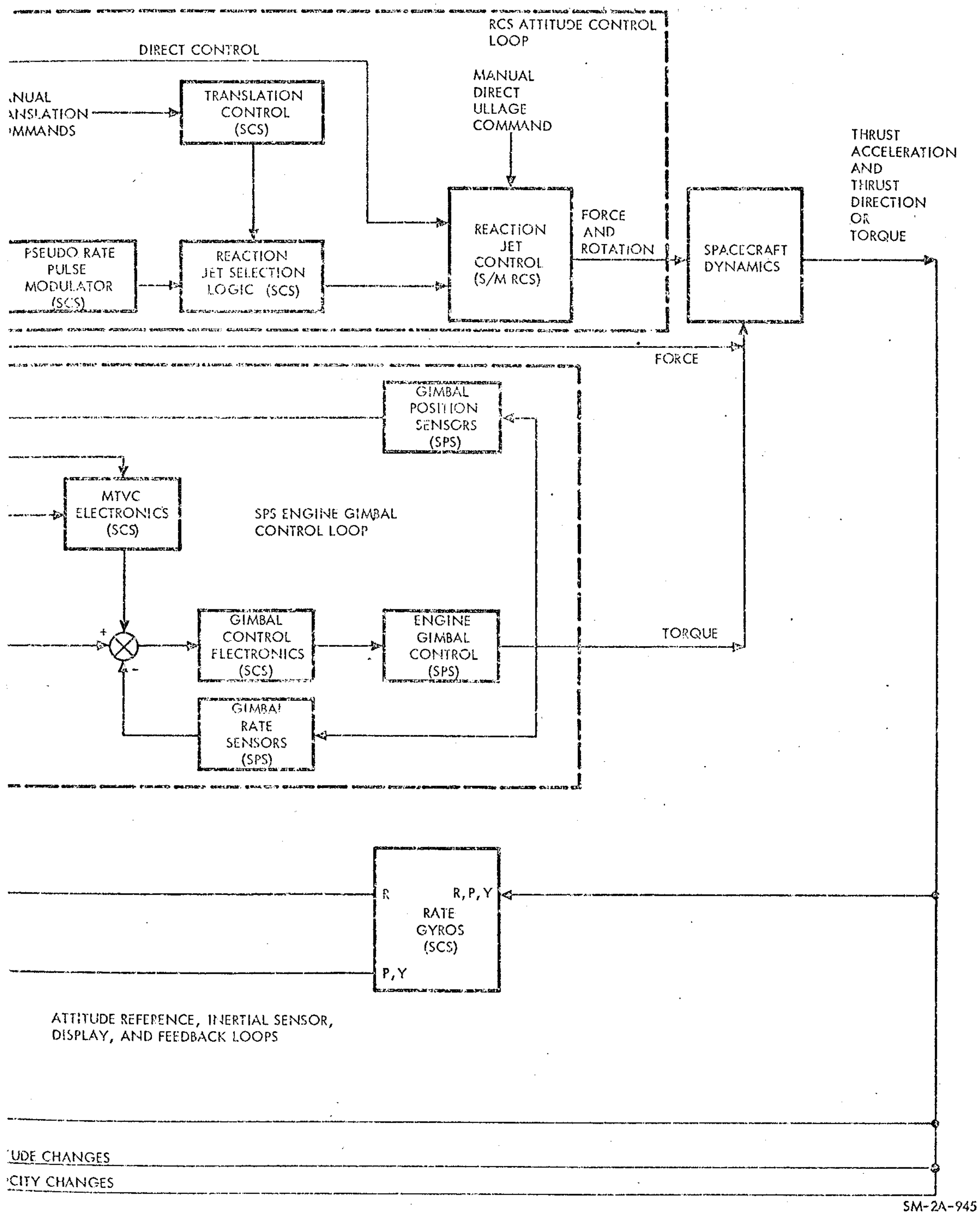
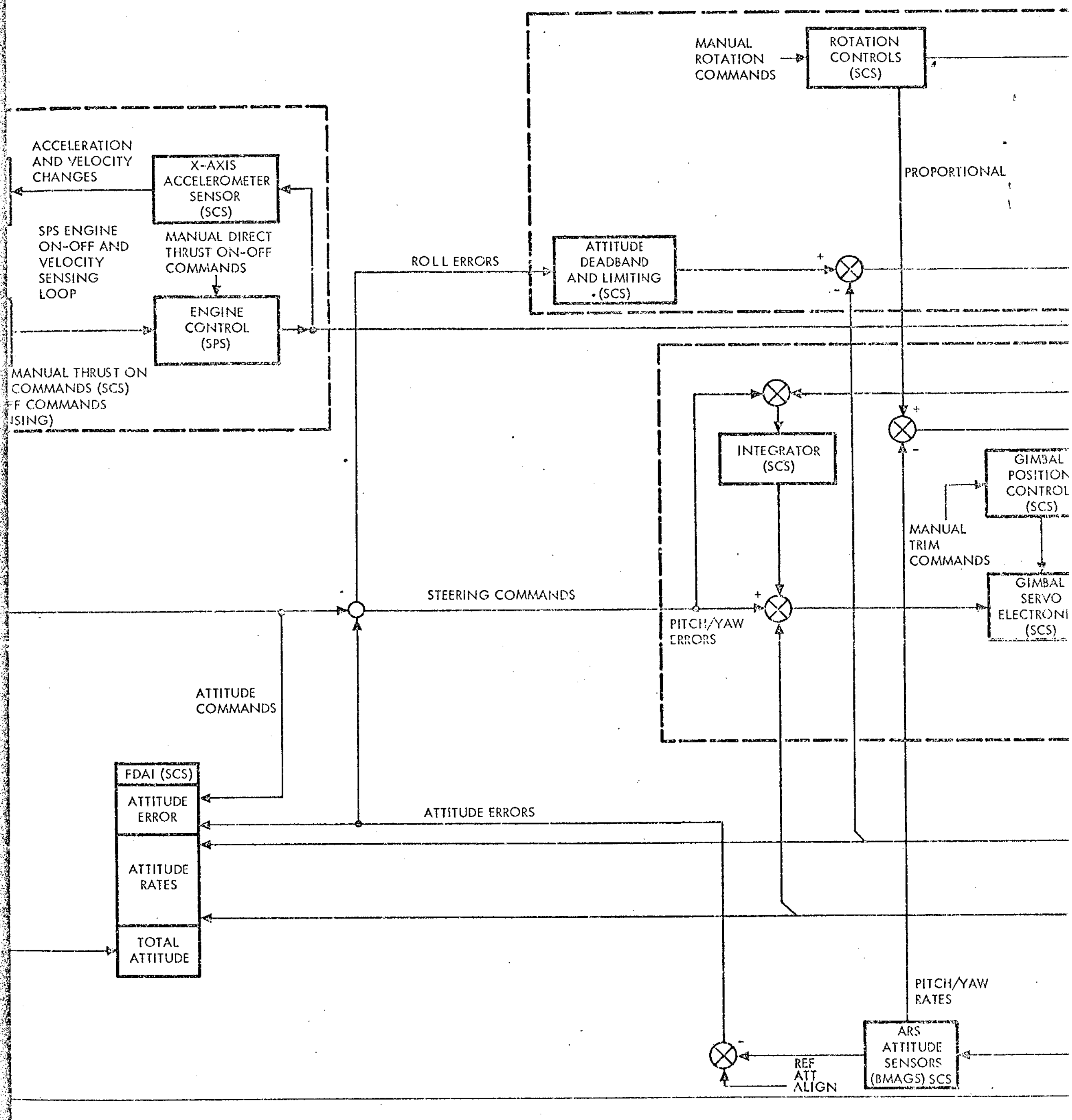
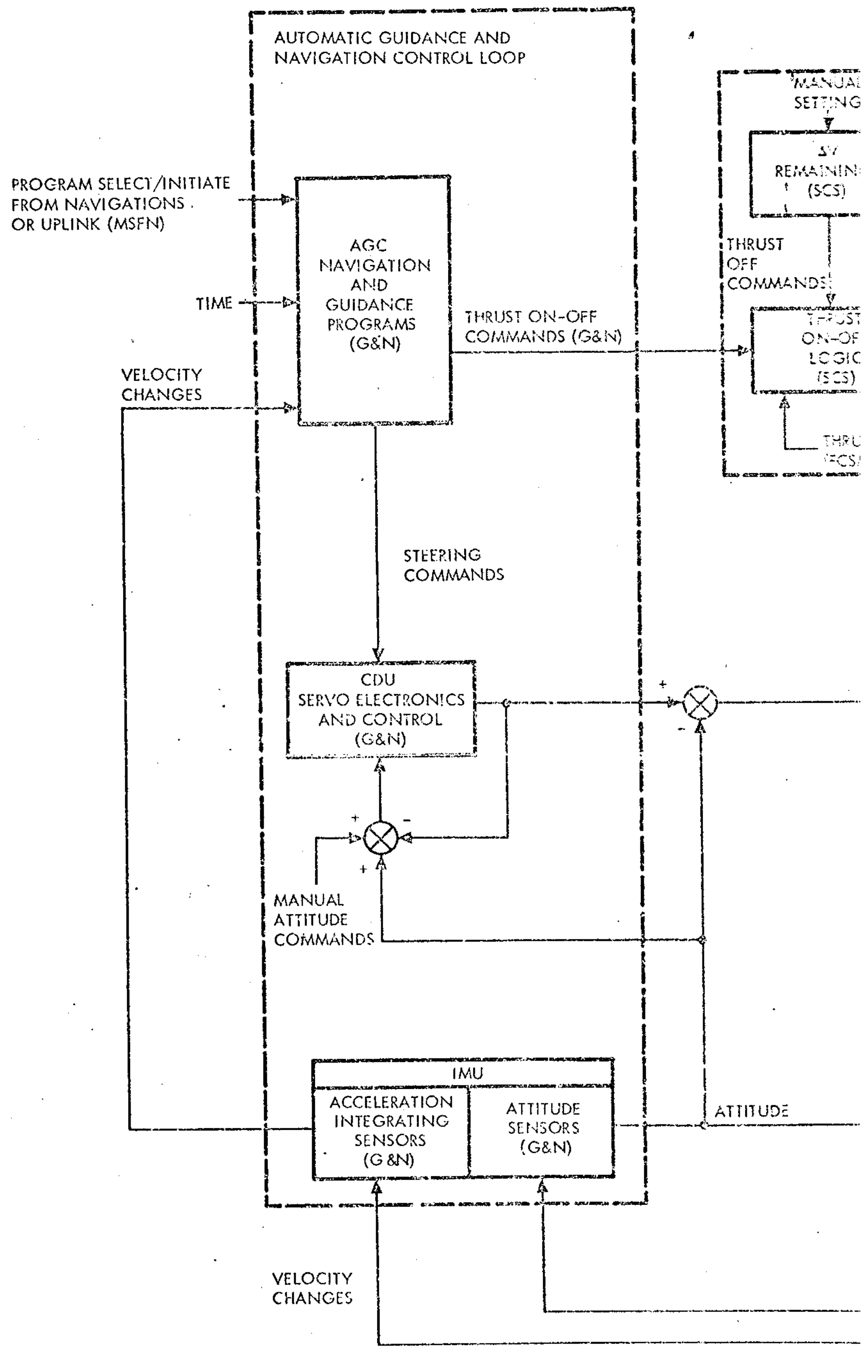


Figure 2.1-3. Powered Flight Profile Functional Flow Diagram


MANUAL ROTATION COMMANDS
ROTATION CONTROLS (SCS)
PROPORTIONAL
ACCELERATION AND VELOCITY CHANGES
X-AXIS ACCELEROMETER SENSOR (SCS)
SPS ENGINE ON-OFF AND VELOCITY SENSING LOOP
MANUAL DIRECT THRUST ON-OFF COMMANDS
ENGINE CONTROL (SPS)
MANUAL THRUST ON COMMANDS (SCS)
F COMMANDS
ISING)
ROLL ERRORS
ATTITUDE DEADBAND AND LIMITING (SCS)
INTEGRATOR (SCS)
GIMBAL POSITION CONTROL (SCS)
MANUAL TRIM COMMANDS
STEERING COMMANDS
PITCH/YAW ERRORS
GIMBAL SERVO ELECTRONI (SCS)
ATTITUDE COMMANDS
FDAI (SCS)
ATTITUDE ERROR
ATTITUDE RATES
TOTAL ATTITUDE
ATTITUDE ERRORS
PITCH/YAW RATES
REF ATT ALIGN
ARS ATTITUDE SENSORS (BMAGS) SCS


AUTOMATIC GUIDANCE AND NAVIGATION CONTROL LOOP
PROGRAM SELECT/INITIATE FROM NAVIGATIONS OR UPLINK (MSFN)
TIME
VELOCITY CHANGES
AGC NAVIGATION AND GUIDANCE PROGRAMS (G&N)
THRUST ON-OFF COMMANDS (G&N)
THRUST OFF COMMANDS
(SCS)
STEERING COMMANDS
CDU SERVO ELECTRONICS AND CONTROL (G&N)
MANUAL ATTITUDE COMMANDS
IMU
ACCELERATION INTEGRATING SENSORS (G&N)
ATTITUDE SENSORS (G&N)
ATTITUDE
VELOCITY CHANGES

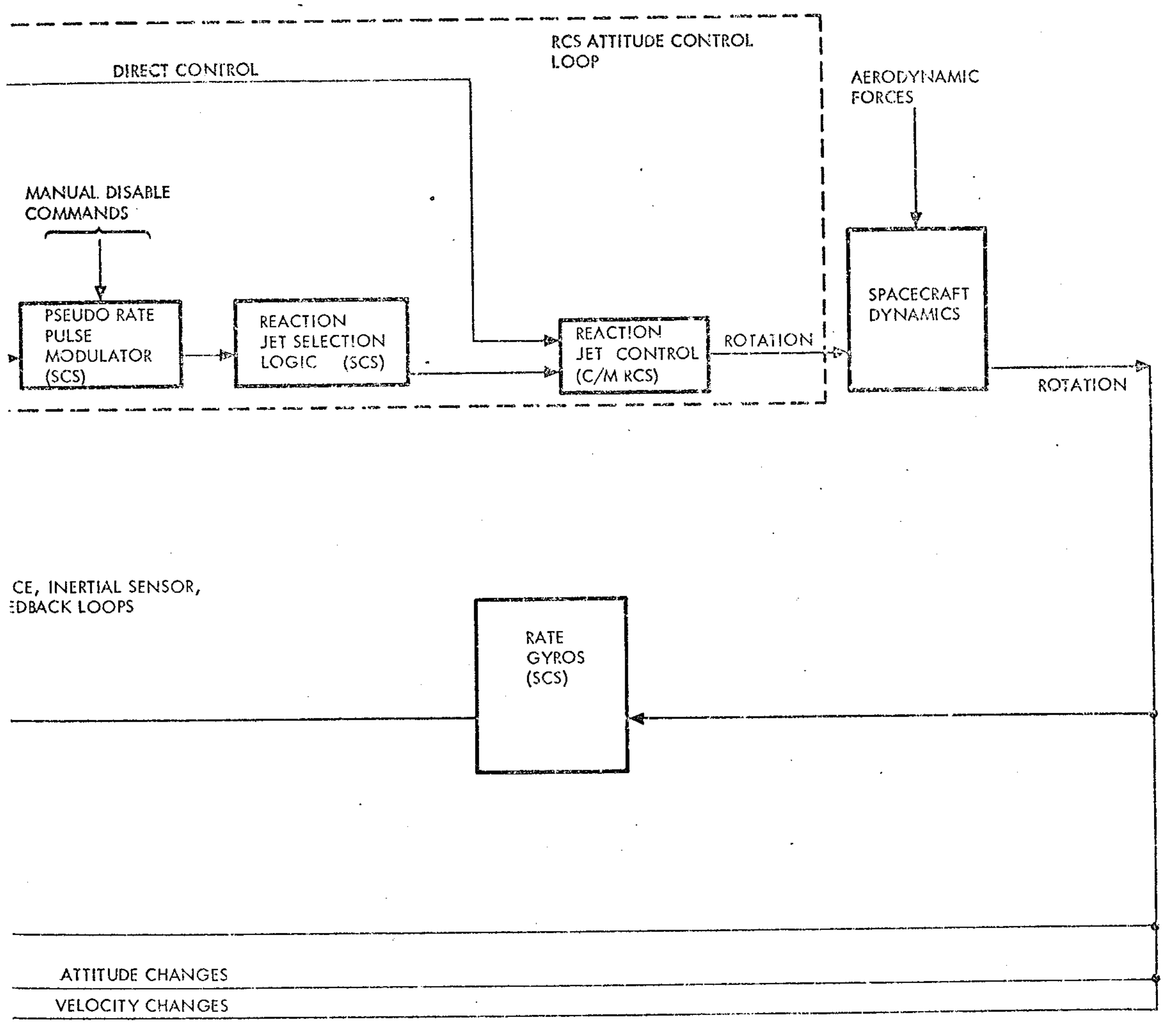
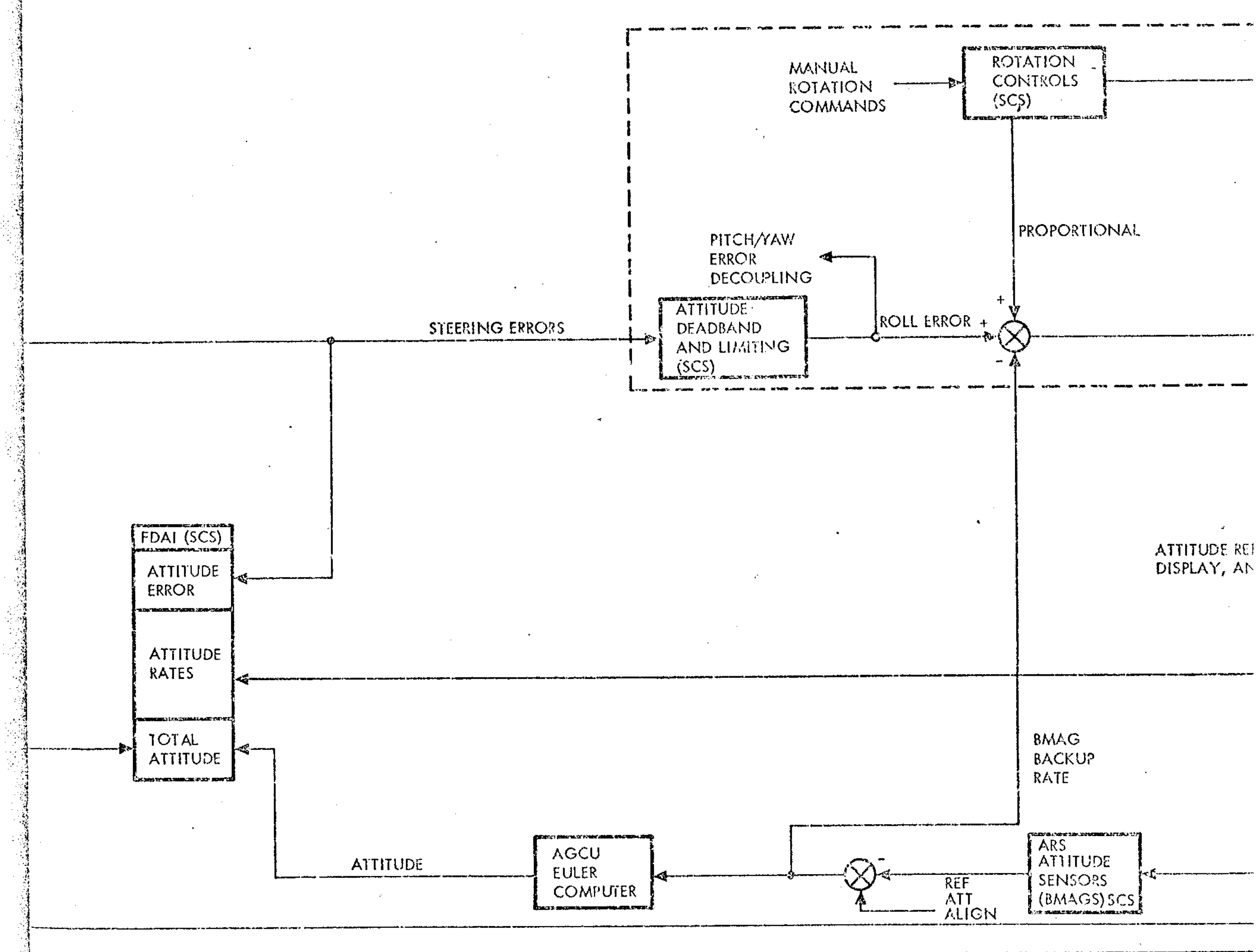
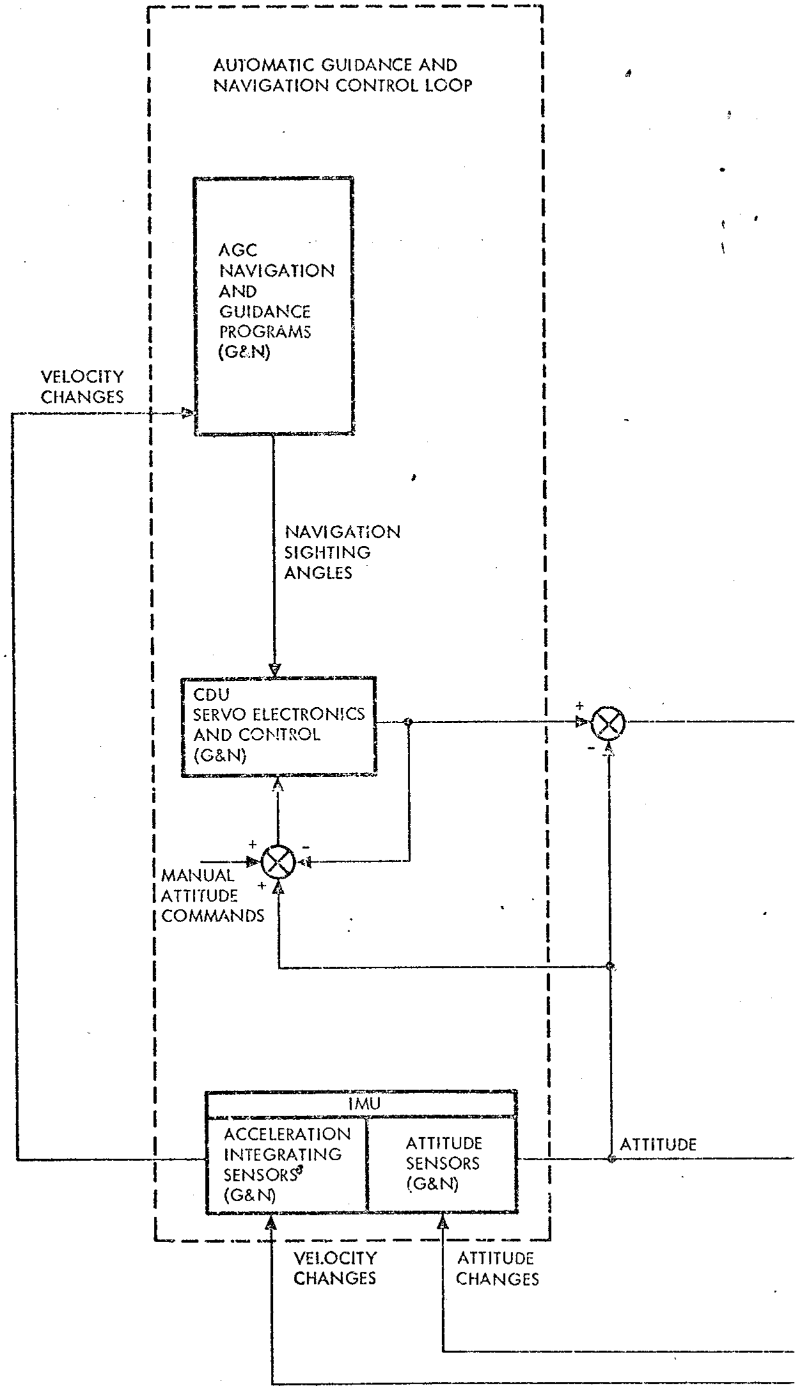


Figure 2.1-4. Atmospheric Flight Profile Functional Flow Diagram



MANUAL ROTATION COMMANDS
ROTATION CONTROLS (SCS)
PROPORTIONAL
PITCH/YAW ERROR DECOUPLING
STEERING ERRORS
ATTITUDE DEADBAND AND LIMITING (SCS)
ROLL ERROR
FDAI (SCS)
ATTITUDE ERROR
ATTITUDE RATES
TOTAL ATTITUDE
BMAG BACKUP RATE
ATTITUDE
AGCU EULER COMPUTER
REF ATT ALIGN
ARS ATTITUDE SENSORS (BMAGS) SCS



AUTOMATIC GUIDANCE AND NAVIGATION CONTROL LOOP
AGC NAVIGATION AND GUIDANCE PROGRAMS (G&N)
VELOCITY CHANGES
NAVIGATION SIGHTING ANGLES
CDU SERVO ELECTRONICS AND CONTROL (G&N)
MANUAL ATTITUDE COMMANDS
IMU
ACCELERATION INTEGRATING SENSORS (G&N)
ATTITUDE SENSORS (G&N)
ATTITUDE
VELOCITY CHANGES
ATTITUDE CHANGES

SECTION 2

SUBSECTION 2.2

GUIDANCE AND NAVIGATION SYSTEM (G&N)

2.2.1 INTRODUCTION.

The guidance and navigation (G&N) system measures spacecraft attitude and velocity, determines trajectory, controls spacecraft attitude, controls the thrust vector of the service propulsion engine, and provides abort information and display data. Primary determination of the spacecraft velocity and position, and computation of the trajectory parameters is accomplished by the manned space flight network (MSFN).

The G&N system consists of three subsystems as follows:

- Inertial subsystem (ISS)
- Computer subsystem (CSS)
- Optics subsystem (OSS)

The inertial subsystem is composed of an inertial measurement unit (IMU), part of the power and servo assembly (PSA), part of the controls and displays, and three inertial coupling display units (CDUs). The IMU provides an inertial reference with a gimbaled, three-degree-of-freedom, gyro stabilized stable platform.

The computer subsystem is composed of an Apollo guidance computer (AGC), and two display and keyboard panels (DSKYs), which are part of the controls and displays. The AGC is a digital computer which processes and controls information to and from the IMU and optics, and stores programs and reference data.

The optics subsystem is composed of a scanning telescope (SCT), a sextant (SXT), drive motors for positioning the SCT and SXT, parts of the PSA, part of the controls and displays, and two optics CDUs. The SCT and SXT are used to determine the spacecraft position and attitude with relation to stars and/or landmarks.

The three G&N subsystems are configured such that the CSS and OSS may be operated independently. This allows continued use of the CSS and/or OSS in the event of a malfunction in one of these subsystems or the ISS. System power requirements and reference signals are provided by the power and servo assembly (PSA). Major components of the system are located in the command module lower equipment bay (figure 2.2-1). System circuit breakers, caution and warning indicators, and one of the DSKYs are located on the main display console.

2.2.2 FUNCTIONAL DESCRIPTION.

The guidance and navigation system provides capabilities for the following:

- Inertial velocity and position (state vector) computation
- Optical and inertial navigation measurements

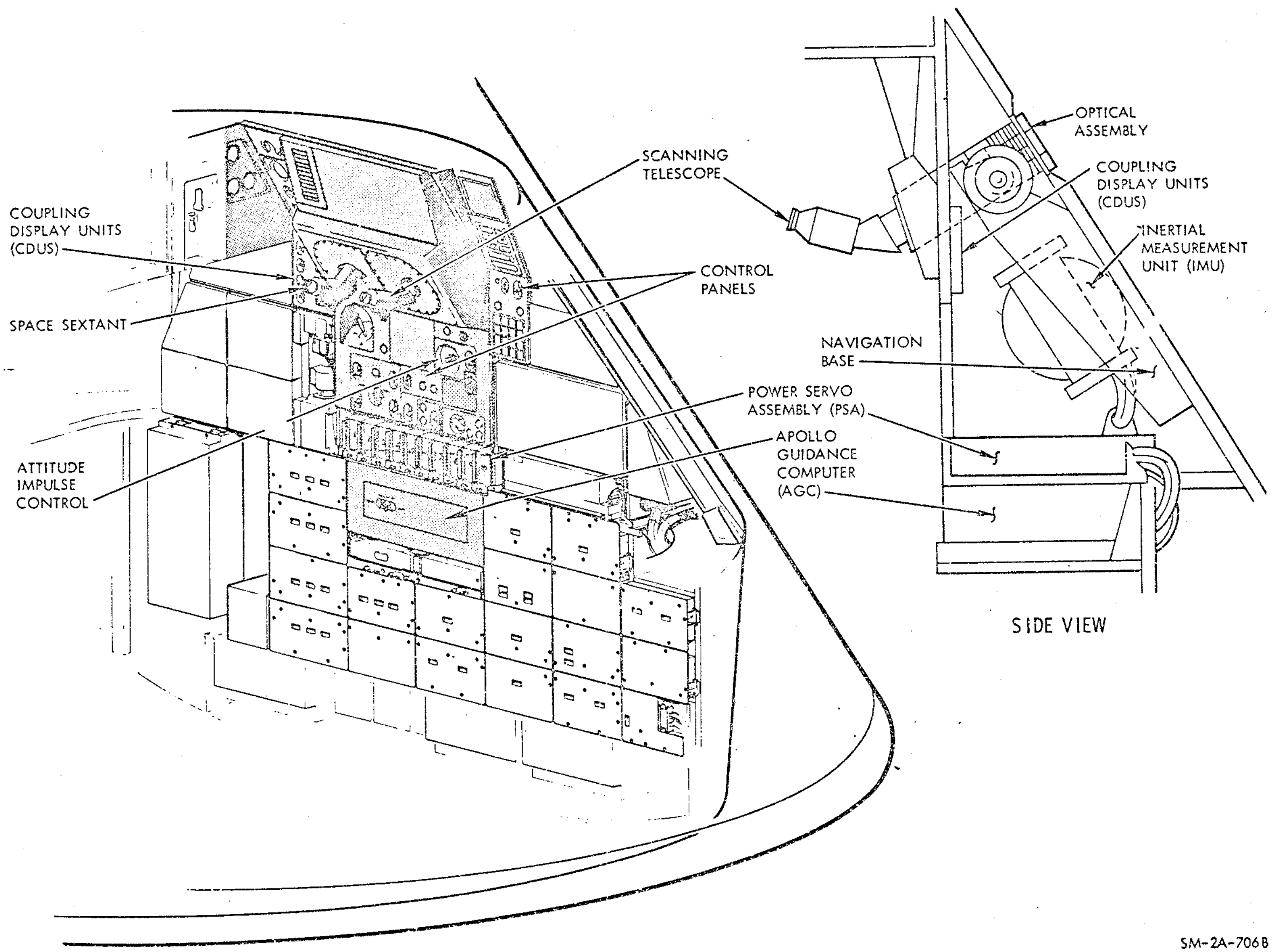


Figure 2.2-1. G&N Equipment Location