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31 OCTOBER 1962

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DIRECT FLIGHT APOLLO STUDY

ERRATA SHEET

Page 1-15	2nd line from bottom, "VHF transmitter/" should be "UHF transmitter/"
Page 1-16	4th line, "VHF-DSIF" should be "UHF-DSIF"
Page 2-2	Figure 2-1, replace with new figure transmitted herein
Page 2-5	Figure 2-4, lower right hand corner of page, "52-79702 - Battery (3 req'd.)" should be "52-79702-5 Battery (3 req'd.)"
Page 2-7	Figure 2-5, "MAIN" and "SQUIB" battery callouts should be the same as Page 2-8, Figure 2-6
Page 2-15	Section 2.1.4, delete item C.
Page 3-33	Figure 3-26, lower right hand sketch, ".84 min." should be ".80 min."

~~CONFIDENTIAL~~

DIRECT FLIGHT APOLLO STUDY

LUNAR GEMINI I & II
GENERAL ARRANGEMENT

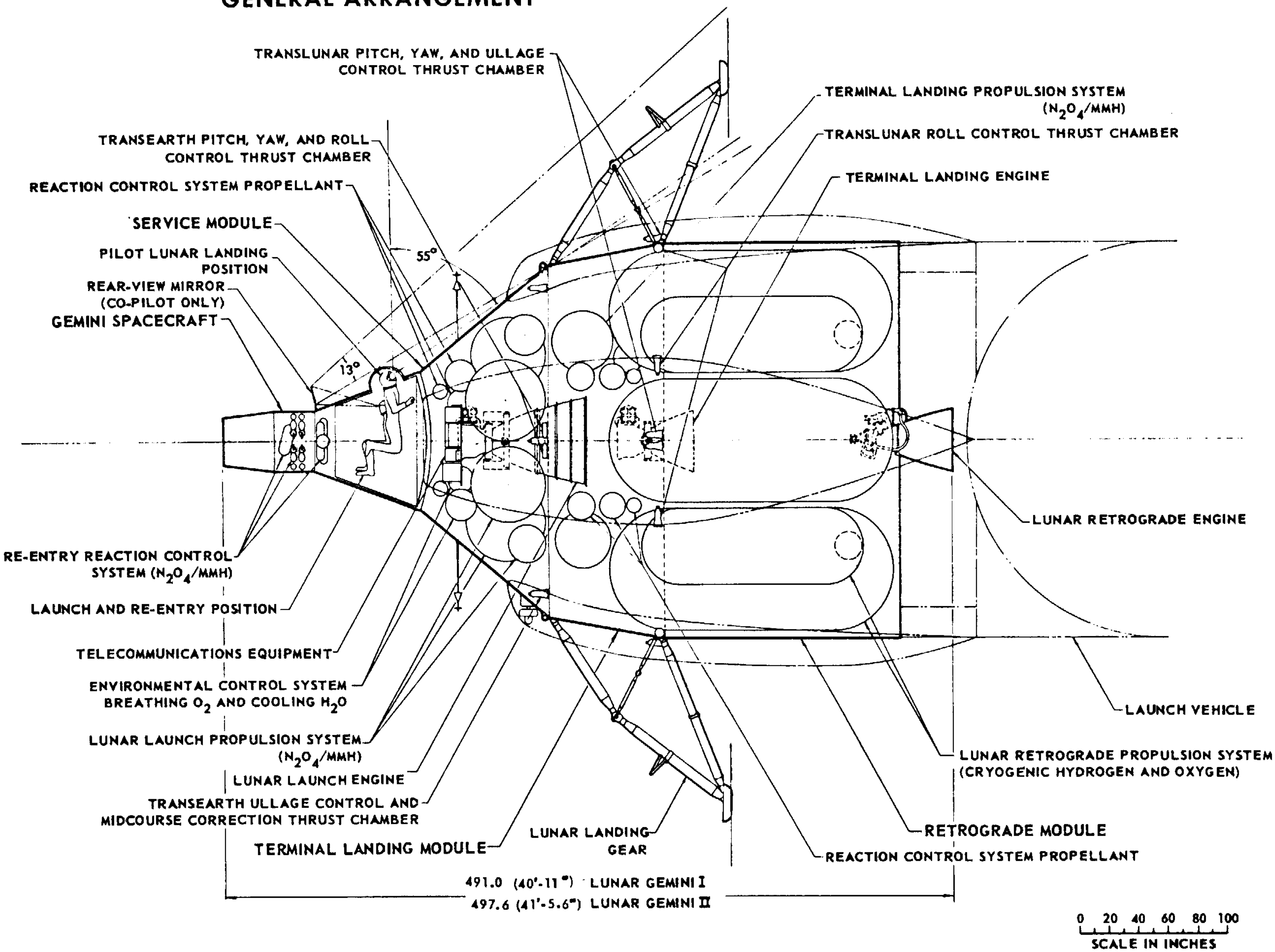

FIGURE 2–1

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REPORT NO. 9182
31 OCTOBER 1962

DIRECT FLIGHT APOLLO STUDY

Volume II:

Gemini Spacecraft Applications

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TABLE OF CONTENTS

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This report consists of the following pages:

INTRODUCTION

This report presents the results of a study conducted by McDonnell Aircraft Corporation of the feasibility of performing the manned lunar landing mission by the direct flight mode employing two-man spacecraft. The study was conducted under NASA Contract NASw-522. Corresponding to the three parts of the statement of work, Reference (1-1), the report is divided into three volumes.

Volume I - TWO-MAN APOLLO SPACECRAFT - Presents the results of a design study of a lunar landing spacecraft incorporating a two-man command module similar in external shape to the present three-man Apollo command module.

Volume II - GEMINI SPACECRAFT APPLICATION - Presents the results of a study of the modifications required to the Gemini spacecraft to provide it with the capability of performing the lunar landing mission.

Volume III - RESCUE VERSIONS - Presents the results of a study of the modifications required to provide the spacecraft of Volumes I and II with the capability for use in rescue operations.

This volume (II) is in response to the Part II guidelines of Reference (1) which designated the McDonnell Aircraft Corporation (M.A.C.) to perform a conceptual design study to "evaluate the capability of the presently conceived Gemini Spacecraft to perform the two-man lunar landing mission and to determine the modifications and their weight, which may be needed to provide this capability if it does not presently exist".

1. SUMMARY

Results of studies performed during Part II indicate that Gemini can, with modest revisions, be made compatible with the lunar landing mission when used in conjunction with the Saturn C-5 launch vehicle and the spacecraft propulsion stages defined in the Part I study (Volume I of this report). It is further shown that utilization of a conventional parachute system in lieu of the paraglider earth-landing system results in an improved equipment capability while realizing increased weight growth margin.

1.1 Study Ground Rules - The basic ground rules for the Part II study were established by Reference (1-1). Detailed ground rules were supplied in References (1-3), (1-4), and (1-5) and verbally by the Office of Systems, Office of Manned Space Flight. Major ground rules established for the Part II study are listed below.

A. Launch vehicle is the Saturn C-5, injecting 90,000 pounds to a lunar transfer orbit.

B. Flight profile and velocity increments are as given in Reference (1-3).

C. Spacecraft main propulsion systems and staging arrangement is same as selected during the Part I study.

D. Mission duration is eight days (two and one-half days flight time to moon, one day on lunar surface plus one day contingency, two and one-half days return time plus one day contingency) plus seven days post landing (one day habitable environment plus six days survivable environment).

E. No weight to be added for radiation or micrometeoroid protection but attention to be given to design details to provide maximum inherent protection.

1.1 (Continued)

F. Lunar surface characteristics are as given in Reference (1-6).

G. L/D in re-entry configuration to be minimum of 0.25.

H. Earth landings may normally be made in water.

I. First operational flight during the first half of calendar year 1967 shall be assumed.

The detail design criteria established by the contractor for use in the study are given in Section 2.6.

1.2 Configuration Selection - In assessing the feasibility of using the Gemini spacecraft for performing the two-man lunar landing mission, the propulsion characteristics selected for the Two-Man Apollo configuration during the Part I study (Volume I) are applied without change. The retrograde module and terminal landing modules defined in the Part I study are compatible, as configured, with the requirements for Lunar Gemini. The service module is revised only to that extent required to effect the transition between the terminal landing module and the Gemini command module and to incorporate internal changes necessitated by differences in equipment characteristics. Therefore, the primary concern in the Part II study is the application of the Gemini command module and the associated Gemini subsystems to the lunar landing mission.

Three versions of the Gemini spacecraft, representing variations in extent of modification and capability, have been studied. Each of the versions offers discrete advantages as described below.

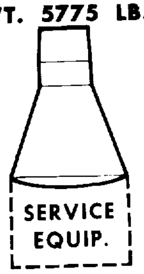
Lunar Gemini I uses the presently configured, 14 day, earth orbital Gemini command module and service equipment with only those changes considered necessary to effect compatibility with the direct flight lunar landing mission. The changes and associated weights are shown in Figure 1-1.

A number of methods for providing the crew with a field of view of the lunar surface during the landing maneuver appear feasible and attractive from the standpoint of minimizing changes to the basic Gemini configuration. The most promising of these are: 1) use of the existing Gemini window with an erectable external mirror to provide a downward field of view with the crewman lying in the normal position and 2) use of an auxiliary transparent canopy (or use of the Gemini hatch in open position with cabin depressurized). In the latter method, the crewman is in a rotated (semi-prone) position and views the lunar surface directly. A combination of (1) and (2) are selected for Lunar Gemini I

DIRECT FLIGHT APOLLO STUDY

CHANGES FROM BASIC GEMINI

14 DAY
EARTH ORBITAL GEMINI
WT. 5775 LB.



LUNAR GEMINI I
WT. 6802 LB.

14 Day Earth Orbital Gemini	Changes	Lunar Gemini I
STRUCTURE & HEAT PROTECTION 1600 LB.	THICKEN ABLATIVE MATERIAL ON HEATSHIELD, CONVERT TO ABLATION COOLED AFTERBODY; ADD VIEWING DOME TO HATCH	1913 LB.
EARTH LANDING SYSTEM 794 LB.		794 LB.
ENVIRONMENTAL CONTROL SYSTEM 710 LB.	INCREASE SECONDARY O_2; DECREASE LiOH & PRIMARY O_2 DECREASE H_2O IN SERVICE MODULE	684 LB.
ELECTRICAL POWER SYSTEM 824 LB.	INCREASE SEQUENTIAL PROVISIONS DECREASE FUEL CELL REACTANTS	764 LB.
GUIDANCE & NAVIGATION SYSTEM 207 LB.	ADD AUTOSEXTANT, TRACKING RADAR, LANDING RADAR, SUN SENSOR	250 LB.
STABILIZATION & CONTROL SYSTEM 242 LB.	ADD IMU STRAPDOWN & SUN-CANOPUS SENSORS INCREASE RCS FUEL, INCREASE CONTROL ELECTRONICS	413 LB.
TELECOMMUNICATIONS SYSTEM 295 LB.	ADD DSIF SYSTEM REMOVE S-BAND BEACON & DIGITAL COMMAND	494 LB.
CREW SYSTEMS 929 LB.	INCREASE DRINKING WATER; REDUCE FOOD SUPPLY ADD PORTABLE ECS BACKPACKS & RECHARGE PROVISIONS ADD EXTRAVEHICULAR CLOTHING & INFLIGHT REPAIR TOOLS	1049 LB.
CONTROLS & DISPLAYS 174 LB.	REMOVE NON-APPLICABLE CONTROLS & DISPLAYS INCREASE PROPULSION & RCS CONTROLS & DISPLAYS ADD LUNAR LANDING CONTROLS & DISPLAYS	281 LB.
SCIENTIFIC EQUIPMENT 0 LB.	ADD PROVISIONS FOR 85 LB. IN COMMAND MODULE	85 LB.
ECCENTRICITY BALLAST 0 LB.	ADD BALLAST TO OBTAIN .25 L/D	75 LB.

FIGURE 1-1

1.2 (Continued)

with the R.H. crewman provided a mirror and the L.H. crewman provided a transparent canopy through which he may observe the lunar surface while rotated in the present Gemini seat. In conjunction with this position, instruments necessary for control of the lunar landing are provided in an extendable panel located in the service module within the crewman's field of view. Necessary controls are provided adjacent to the seat sides.

Lunar Gemini II utilizes the alternate Gemini 84 foot diameter single parachute recovery system in lieu of the paraglider system and associated landing gear. The weight and space savings thus effected permit the installation of improved navigation and telecommunications capability while increasing the margin for potential weight growth. Earth landings are effected in water and, in the event of emergency recovery over land, the crew utilizes the ejection seats to separate from the capsule and terminate the descent with personal parachutes. Crew lunar landing vision provisions are the same as described for Lunar Gemini I. The subsystem changes from the basic 14 day earth orbital Gemini and their associated weights are shown in Figure 1-2.

Lunar Gemini III is modified to accept a tower-mounted rocket launch escape system in lieu of ejection seats, thus providing an improved launch abort capability. The paraglider and landing gear are replaced by three 71 foot diameter parachutes with normal earth recovery being effected over water. Means are provided for emergency earth recovery over land either through bail-out capability with personal parachutes or, by the use of shock attenuating couches to make land impacts in the command module tolerable. The use of positionable shock attenuated couches in lieu of ejection seats permits the incorporation of a crew "sit-up" lunar landing capability facilitated by a direct view through a

[redacted]

CHANGES FROM BASIC GEMINI

14 DAY EARTH ORBITAL GEMINI

5775 LB.

LUNAR GEMINI II

6376 LB.

14 Day Earth Orbital Gemini	Changes	Lunar Gemini II
STRUCTURE & HEAT PROTECTION 1600 LB.	THICKEN ABLATIVE MATERIAL ON HEAT SHIELD· CONVERT TO ABLATION COOLED AFTERBODY; ADD VIEWING DOME TO HATCH	1883 LB.
EARTH LANDING SYSTEM 794 LB.	REMOVE PARAGLIDER & LANDING GEAR ADD 84' DIA. PARACHUTE SYSTEM	149 LB.
ENVIRONMENTAL CONTROL SYSTEM 710 LB.	INCREASE SECONDARY O_2 DECREASE LiOH & PRIMARY O_2 DECREASE H_2O IN SERVICE MODULE	681 LB.
ELECTRICAL POWER SYSTEM 824 LB.	INCREASE SEQUENTIAL PROVISIONS DECREASE FUEL CELL REACTANTS	803 LB.
GUIDANCE & NAVIGATION SYSTEM 207 LB.	ADD MANUAL SEXTANT/TELESCOPE ; TRACKING RADAR; LANDING RADAR; NAVIGATION BASE; SUN SENSOR ROLL MOMENTUM WHEEL	276 LB.
STABILIZATION & CONTROL SYSTEM 242 LB.	ADD IMU STRAPDOWN, & SUN-CANOPUS SENSORS INCREASE R.C.S. FUEL, INCREASE CONTROL ELECTRONICS	406 LB.
TELECOMMUNICATIONS SYSTEM 295 LB.	ADD DSIF SYSTEM ; USE APOLLO TYPE NEAR EARTH SYSTEM ADD APOLLO TYPE DATA PROCESSING & INSTRUMENTATION SYST. REMOVE S-BAND BEACON & DIGITAL COMMAND	673 LB.
CREW SYSTEMS 929 LB.	INCREASE DRINKING WATER ; REDUCE FOOD SUPPLY ADD PORTABLE ECS BACKPACKS & RECHARGE PROVISIONS ADD EXTRAVEHICULAR CLOTHING & INFLIGHT REPAIR PROV.	1049 LB.
CONTROLS & DISPLAYS 174 LB.	REMOVE NON-APPLICABLE CONTROLS & DISPLAYS INCREASE PROPULSION & RCS CONTROLS & DISPLAYS ADD LUNAR LANDING CONTROLS & DISPLAYS	296 LB.
SCIENTIFIC EQUIPMENT 0 LB.	ADD PROVISIONS FOR 85# IN COMMAND MODULE	85 LB.
ECCENTRICITY BALLAST 0 LB.	ADD BALLAST TO OBTAIN .25 L/D	75 LB.

FIGURE 1-2

[redacted]

1.2 (Continued)

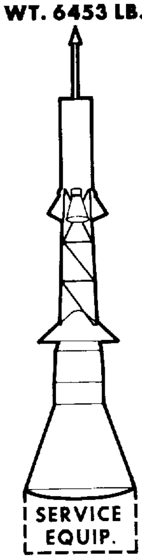
large window in the left-hand hatch. The subsystem changes between the basic 14 day earth orbital Gemini and Lunar Gemini III are shown, along with their corresponding weights in Figure 1-3.

CHANGES FROM BASIC GEMINI

14 DAY EARTH ORBITAL GEMINI

WT. 5775 LB.

LUNAR GEMINI III
WT. 6453 LB.*



14 Day Earth Orbital Gemini	Changes	Lunar Gemini III
STRUCTURE & HEAT PROTECTION 1600 LB.	REINFORCE STRUCTURE FOR LAUNCH TOWER & LAND IMPACT THICKEN ABLATIVE MATERIAL ON HEATSHIELD CONVERT TO ABLATION COOLED AFTERBODY	1984 LB.
EARTH LANDING SYSTEM 794 LB.	REMOVE PARAGLIDER & LANDING GEAR ADD THREE 71' DIA. PARACHUTE SYSTEM	273 LB.
ENVIRONMENTAL CONTROL SYSTEM 710 LB.	INCREASE SECONDARY O_2; DECREASE LiOH & PRIMARY O_2 DECREASE H_2O IN SERVICE MODULE	681 LB.
ELECTRICAL POWER SYSTEM 824 LB.	INCREASE SEQUENTIAL PROVISIONS DECREASE FUEL CELL REACTANTS	803 LB.
GUIDANCE & NAVIGATION SYSTEM 207 LB.	ADD MANUAL SEXTANT / TELESCOPE, TRACKING RADAR, LANDING RADAR, NAVIGATION BASE, SUN SENSOR, & ROLL MOMENTUM WHEEL	276 LB.
STABILIZATION & CONTROL SYSTEM 242 LB.	ADD IMU STRAPDOWN, & SUN-CANOPUS SENSORS, INCREASE R.C.S. FUEL, INCREASE CONTROL ELECTRONICS	406 LB.
TELECOMMUNICATIONS SYSTEM 295 LB.	ADD D.S.I.F. SYSTEM; USE APOLLO TYPE NEAR EARTH SYSTEM ADD APOLLO TYPE DATA PROCESSING & INSTRUMENTATION SYST. REMOVE S-BAND BEACON & DIGITAL COMMAND	673 LB.
CREW SYSTEMS 929 LB.	INCREASE DRINKING WATER; REDUCE FOOD SUPPLY ADD PORTABLE ECS BACKPACKS & RECHARGE PROVISIONS ADD EXTRAVEHICULAR CLOTHING & INFLIGHT REPAIR PROV. REPLACE EJECTION SEATS WITH ATTENUATED COUCHES.	911 LB.
CONTROLS & DISPLAYS 174 LB.	INCREASE PROPULSION & RCS CONTROLS & DISPLAYS ADD LUNAR LANDING CONTROLS & DISPLAYS REMOVE NON-APPLICABLE CONTROLS & DISPLAYS	271 LB.
SCIENTIFIC EQUIPMENT	ADD PROVISIONS FOR 85# IN COMMAND MODULE	85 LB.
ECCENTRICITY BALLAST	ADD BALLAST TO OBTAIN .25 L/D	90 LB.

*LAUNCH ESCAPE TOWER WEIGHT IS NOT INCLUDED

FIGURE 1-3

1.3 Weight Margins - Since the propulsion stages defined in Volume I are sized to the full capability of the specified launch vehicle, the Lunar Gemini command module and service equipment weights may be compared directly with this payload capability after adjusting for a slight difference in service module structure. The resulting payload capability, after making this adjustment, is 7743 pounds (compared to 7655 pounds for the Two-Man Apollo configuration). The weight growth margin may then be expressed as a percentage when the Lunar Gemini command module and service equipment weights are compared with the allowable payload weight as follows:

$$\%\ \text{Margin} = \left[\frac{\text{Allowable payload weight}}{\text{Command module weight + service equipment weight}} - 1\right] \times 100$$

For the three Lunar Gemini versions the margins based on the above are:

Lunar Gemini I (weight margin = 1026 lbs.)

$$\%\ \text{Margin} = \left[\frac{7743}{5540 + 1177} - 1\right] \times 100 = 15.2\%$$

Lunar Gemini II (weight margin = 1452 lbs.)

$$\%\ \text{Margin} = \left[\frac{7743}{5072 + 1219} - 1\right] \times 100 = 23.0\%$$

Lunar Gemini III (weight margin = 1375 lbs.)

$$\%\ \text{Margin} = \left[\frac{7743}{5178 + 1190} - 1\right] \times 100 = 21.6\%$$

1.4 Summary Statements - Summaries of the major sections of the remainder of the report (section numbers indicated in parentheses) follow. Where sections are essentially the same as in Volume I, thus not repeated in this volume, a summary of the contents of that section in Volume I is included and, where applicable, exceptions noted.

Spacecraft Configuration (2.) - Three modified Gemini lunar landing spacecraft are presented. These spacecraft differ primarily in the configuration and capabilities of the command module. Only slight modifications to the service module and no change to the terminal landing and retrograde modules presented in Volume I are required.

Command Module (2.1) - Lunar Gemini I is identical in external appearance to the present Gemini except for the lunar landing canopy. Detail changes to Gemini include:

A. Increased heat shield thickness and addition of ablative afterbody panels.

B. Re-entry attitude control propellant is increased.

C. Oxygen and cooling water is increased.

D. Additional navigation and guidance read-outs and displays are included. (Autosextant added to service module).

E. Additional communication provisions are included.

F. Additional propulsion controls are provided.

G. Slight modification of the crew hatches for lunar egress and ingress.

H. Lunar landing visibility canopy is incorporated in the pilot hatch.

I. External mirror for copilot lunar landing visibility is added.

Lunar Gemini II differs from Lunar Gemini I only in the following:

A. Replace paraglider and landing gear system with single parachute.

B. Service module autosextant is replaced by the Apollo sextant/telescope unit.

1.4 (Continued)

C. Gemini communication equipment is replaced by Apollo equipment.

Lunar Gemini III has the same general external appearance of the orbital Gemini differing only in the forward cylindrical section and the crew hatch. Changes from the Lunar Gemini II configuration include:

A. A tower mounted escape system is added.

B. A three parachute system replaces the single parachute system.

C. Ejection seats are replaced with impact attenuating couches.

D. Direct horizontal and downward vision is provided for lunar landing. (Canopy is replaced by flat windows.)

<u>Service Module (2.2)</u> - This module is a truncated cone with a $39\text{-}1/2°$ half angle located between the command and terminal landing modules. It contains the lunar launch and transearth storable hypergolic propulsion system, electrical power, portions of the environmental control, communication and navigation systems, and a reaction control system.

<u>Terminal Landing Module (2.3)</u> - The terminal landing module with the integral lunar landing gear, is designed to provide a low landing silhouette. The module contains the storable hypergolic propulsion system for hover, translation and lunar landing, and a reaction control system for translunar ullage control and spacecraft attitude stabilization and control.

<u>Lunar Landing Configuration (2.4)</u> - The three modules described in the preceding paragraphs form the lunar landing spacecraft. Lunar Gemini I and II use a visibility canopy to provide the pilot direct vision of the lunar horizon and landing site. Lunar Gemini III provides a pilot's hatch with flat windows and the pilot is positioned to allow direct horizontal and downward vision. All versions provide a mirror system for the co-pilot.

Retrograde Module (2.5) - The cylindrical retrograde module houses the cryogenic propulsion system used for translunar midcourse connections, injection into lunar orbit, rejection from lunar orbit, and final retrograde to approximately 6000 feet above the lunar surface. At this altitude, the module is jettisoned and final descent accomplished with the lunar landing spacecraft.

Weight Summary (2.6) - The weights of the Lunar Gemini I, II and III spacecraft are:

	Lunar Gemini		
	I	II	III
Command Module	* 5625	* 5157	* 5263
Service Module Equipment	1177	1219	1190
Spacecraft Weight Margin	1026	1452	1375
Service Module	22192	22192	22192
Terminal Landing Module	6030	6030	6030
Retrograde Module	53787	53787	53787
Launch Escape System	-	-	2600
Landing Gear Fairing	1400	1400	1400
Gross Weight at Launch	91237	91237	93837
Less (1-% effective) Jettisonable Items	-1359	-1359	-3837
Effective Launch Weight	89,878	89878	90000

*Includes 85 pounds of scientific payload transferred to the command module prior to lunar launch.

Design Criteria (2.7) - The Lunar Gemini spacecraft designs are in accordance with the criteria presented in Section 2.7, Volume I, where practicable.

Guidance and Navigation (3.1) - Each of the guidance and navigation systems for Lunar Gemini I, II, and III consists of the basic system for the Gemini plus optical and radar sensors for the lunar mission. The major Gemini components utilized are the inertial system and computer. Additions for Lunar Gemini I include an autosextant and the Apollo tracking and landing radars (total system weight - 341 pounds). Additions for Lunar Gemini II and III include the Apollo

[redacted]

1.4 (Continued)

sextant/telescope, the Apollo tracking and landing radars, and a roll momentum wheel for use during manual navigation (total system weight - 366 pounds).

Stabilization and Control (3.2) - The stabilization and control system translates commands from the pilot or the navigation and guidance system into signals to the reaction control system (RCS) and the main engine gimbal and throttle actuators. Modes ranging from fully manual to fully automatic, depending on crew desires, are provided for both attitude and thrust control with redundancy in equipment, signal path, and torque application. Roll control is provided by the fixed thrust RCS thrust chambers at all times. Pitch and yaw control is obtained by main engine gimbaling during thrusting periods and by the RCS at all other times.

Long-term attitude reference signals are provided by redundant optical sensors (Sun-Horizon-Canopus). Short-term attitude memory is derived from a strapdown inertial unit. Rate gyros provide signals for tight-loop rate stabilization and rate command follow-up. Derived rate stabilization is used to achieve low fuel-consumption attitude hold during long low-disturbance coast phases without requiring direct sensing of the very low rates.

Manual attitude control is accomplished in a rate command mode by proportional hand controller displacements or in a high-reliability backup mode providing direct command control of the RCS solenoids, gimbal servos, and throttle actuators. A single-pulse direct mode is provided for fine manual rate control. SCS weight is 89 pounds heavier than the Gemini SCS due to increased electronics (60 pounds), additional strapdown IMU (17 pounds) and additional sun and Canopus sensors (12 pounds).

Environmental Control (3.3) - The environmental control system is identical to the equipment in the Gemini spacecraft with the exception of some small

[redacted]

1.4 (Continued)

differences in expendables.

Hydrogen and oxygen is stored in the super-critical state for the fuel cells and the ECS in the service module. The tanks are protected by the super insulation to eliminate boiloff during all phases of the mission. The hydrogen tanks for the lunar retrograde stage are insulated solely to prevent liquefaction of air during the pre-launch and launch phase while the oxygen tanks require no insulation. Low emissivity coatings are provided on outer surfaces of tanks and inner walls of the module to prevent boiloff during the launch and translunar phases.

Electronic equipment is mounted on cold plates with temperatures being maintained at required levels by a coolant fluid that circulates through the cold plates and the space radiator.

Electrical Power (3.4) - The power system provided is essentially the same as that used in the 14-day Gemini with some off-loading of fuel cell reactants and the addition of increased sequential control provisions. A detailed electrical load analysis indicates that the mission requirements are 660 watts average for Gemini I and 880 watts average for Lunar Gemini II and III. Sufficient fuel has been provided for the full 8 day mission, two days of which are contingency.

Telecommunications (3.5) - The telecommunication system operates with existing ground stations to provide a virtually continuous, two-way voice link between the spacecraft crew and the mission control center. In addition, television and spacecraft data may be transmitted to the earth.

For near-earth operations, primary voice communication is between a VHF/AM transceiver, using an omnidirectional antenna, and the Mercury/Gemini ground network. Data transmission is provided by a VHF/FM transmitter. Primary communication during the transit and lunar phases is by a 1 or 20 watt VHF transmitter/receiver system, with 4 foot diameter parabolic antennas, which operates in

1.4 (Continued)

conjunction with the DSIF on earth. This system provides for both voice and data transmission.

Ground tracking of the spacecraft is aided by a C-Band transponder located in the command module. The VHF-DSIF transmitter and receiver operate as a phase coherent transponder to allow two-way doppler and "turn-around" range tracking by the DSIF network.

Full crew intercommunication is included and a relay transceiver provides crew communication during extravehicular operation. Recovery aids include both HF and VHF beacons and transceivers.

Lunar Gemini I retains the Gemini VHF voice transceiver, telemetry transmitter, C-Band transponder and PCM data system and adds DSIF provisions. Some loss in capability is realized near-earth compared to Lunar Gemini II and III.

Lunar Gemini II and III use the same systems as Two-Man Apollo.

Structure (3.6) - Conventional spacecraft structures are employed in all modules, following the proven materials and concepts demonstrated in the Mercury and Gemini designs. Primary structure of each module consists of a semimonocoque shell with reinforcements around cut-outs and fittings to distribute localized loads. Titanium is used as the basic shell material in all modules except the service module where beryllium sheet is used for the structural radiator shell. The Lunar Gemini command modules are modifications of the Gemini spacecraft.

Heat Protection (3.7) - Re-entry heat protection is conservatively designed for a shallow long range re-entry or a 20 g structural limit re-entry, whichever results in the greater protection requirements. The ablative material is MAC Thermorad Shield S-3 elastomeric composite. Nominal thermophysical properties are used in the calculations and a 1.15 factor is applied to predicted heating rates. The total ablative material design weight is 511 pounds for Lunar

1.4 (Continued)

Gemini I and II, and 488 pounds for Lunar Gemini III.

Beryllium is used for the external structure of the service module for application as a radiator and to withstand aerodynamic heating during launch. The launch escape system tower legs of Lunar Gemini III are covered with an ablative material in critical areas. Fiberglass landing gear fairings protect the lunar landing gear during launch.

<u>Mechanical Systems (3.8)</u> - Crew escape provisions in Lunar Gemini I and II are identical to those designed for Gemini. Lunar Gemini III incorporates a tower escape system similar to Project Mercury and provides bail-out parachutes for the crew.

Crew hatches are similar to the current Gemini design in Lunar Gemini I and II except for the addition of a canopy in the left-hand hatch and the addition of crew ingress provisions for use on the lunar surface. The left-hand hatch of Lunar Gemini III includes two flat windows for downward vision during lunar landing.

The Lunar Gemini I earth landing system is identical to that designed for Project Gemini. Lunar Gemini II uses a single parachute system and Lunar Gemini III three parachutes. Lunar Gemini II and III are designed for landing normally on water with alternate methods of emergency crew recovery over land.

Command-to-service module structural and services disconnects are similar to those designed for Project Gemini.

The lunar landing gear stows against the lunar retrograde structure and is protected during launch by fairings. Erection is accomplished by simple dual torsion springs.

<u>Propulsion (3.9)</u> - The characteristics of the propulsion systems for the service, terminal landing and retrograde modules are the same as Two-Man Apollo (Volume I).

1.4 (Continued)

Reaction Control (3.10) - The characteristics of the reaction control systems for the service, terminal landing and retrograde modules are the same as the Two-Man Apollo (Volume I).

Command Module (3.10.1) - The Lunar Gemini command module reaction control systems are identical to the Project Gemini spacecraft except that the propellant is increased from 74 pounds to 131 pounds and the pressurization gas is changed from nitrogen to helium. The system total impulse is 39,300 pound-seconds and the system weight is 274 pounds.

Launch Escape Propulsion (3.11) - The present Gemini ejection seats are used to provide crew escape on Lunar Gemini I and II. The launch escape propulsion system of the Gemini III configuration consists of a tower mounted, solid propellant, stepped thrust rocket motor together with a tower jettison rocket for separating from the command module after escape rocket burnout. Lateral separation is obtained through thrust alignment to a predetermined eccentricity.

Lunar Touchdown (3.12) - The lunar landing gear consists of four legs each having three telescoping members. Impact energy is dissipated by crushing aluminum honeycomb cartridges within each telescoping leg. Dynamic stability during landing is achieved by selection of the relative crushing strength of the honeycomb in each strut element.

Earth Landing (3.13) - Lunar Gemini I uses a paraglider-landing gear system identical to the current Gemini spacecraft. Lunar Gemini II and III are normally designed for parachute landings on water. When land impact is unavoidable, ejection seats are used for crew escape in Lunar Gemini II. In Lunar Gemini III, the crew has the option of using personnel parachutes or landing in the spacecraft with impact accelerations held within emergency allowables by the load attenuating couches.

1.4 (Continued)

Command Module Size and Arrangement (4.1) - The command module size is the same as the Gemini re-entry spacecraft. A spectrum of interior arrangements is possible within this constraint. These versions are primarily functions of four systems or features, i.e., earth launch escape system, earth landing and impact system, crew arrangement, and navigation system. Three versions, representing incremental degrees of modification, are presented for fulfilling the lunar mission.

Spacecraft Staging (4.2) - Results are presented in Volume I of trade-off studies involving number of stages, propellant combinations, and stage-apportioned incremental velocities. The spacecraft selected is based on a compromise between a number of factors. The more important of these are:

A. A minimum number of stages is desirable from a mechanization standpoint.

B. It is not desirable to land and launch with the same module because of possible stage damage during the landing operation.

C. While cryogenics are favored for the large translunar ΔV's, they are considered less desirable than earth storables for the final landing phase because of the ignition system requirement.

Trajectory Analysis (4.3) - Effect of the reduced L/D of the Lunar Gemini command module is offset by controlling the skip during earth re-entry as a means of achieving range control. The use of ejection seats in the Lunar Gemini I and II precludes immediate crew separation from a malfunctioning launch vehicle during a portion of earth launch.

Aerodynamics (4.4) - Current Gemini aerodynamic coefficients are presented and estimates are made of the abort configuration characteristics for Lunar Gemini III with LEPS.

Propellant Margin (4.5) - Incremental velocity margins were assigned for each major contingency and apportioned to the various stages and phases of the

1.4 (Continued)

mission. The results indicate that the ten percent margin specified in Reference 1-3 is realistic, but that individual module margins should range from 8.5% to 18%.

Radiation (4.6) - The minimum inherent shielding provided is equivalent to 1.4 grams per square centimeter of aluminum. The shielding in the Lunar Gemini is about the same as that for the Two-Man Apollo.

For a first approximation in computing dosage, the shielding for the Two-Man Apollo can be used for the Lunar Gemini. Shielding values for the eyes in Lunar Gemini for the entire mission will be similar to that shown for the eye in the navigation position of Two-Man Apollo.

Meteoroid Protection (4.7) - In the command module, multiple walls, separated by low density insulation, provide inherent meteoroid protection for the pressurized volume and the crew. In the lower modules, various degrees of protection are provided by the multiple-wall effect of tankage and structural shells. However, the open ends of the propulsion modules expose the propellant tanks to direct meteoroid impact. It is shown that the weight associated with increasing meteoroid protection is well within the contingencies which are included in the tankage weights to assure a high degree of confidence in the stage performance analysis.

Weight Derivation (4.8) - The weights of the Lunar Gemini spacecraft are derived where possible by evaluation of specific design changes to current Gemini data. Detail calculations based on design layouts, strength analyzed structure and system schematics are utilized where extreme extrapolation of Gemini and/or Mercury data must be made or the data is not applicable. Whenever detail calculations are utilized, non-optimum factors based on airplane and missile experience are included.

2. SPACECRAFT CONFIGURATIONS

Three spacecraft general arrangements are shown in Figures 2-1 and 2-2. They are geometrically similar to the configuration shown in Volume I, Section 2, with modified Gemini command modules replacing the 33 degree conical command module of Volume I. Stage sequencing, velocity increment requirements, and major operational procedures of these spacecraft are the same as those presented in Volume I. These configurations do, however, utilize different versions of modified Gemini command modules.

2.1 Command Module - Conceptual design studies to evaluate the ability of a modified Gemini spacecraft to perform the two-man lunar landing mission show that a number of alternative arrangements provide the required capability. Three of these are selected as representative of trade-offs which may be made in terms of extent of modification and capability. They are identified as Lunar Gemini I and II, corresponding to Figure 2-1, and Lunar Gemini III, corresponding to Figure 2-2.

Lunar Gemini I involves the minimum modification to the present Gemini spacecraft of the three versions selected. These modifications are:

A. Heat shield thickness increased, afterbody shingles replaced with single face corrugated panels covered with ablative material, and panel insulation density increased. See Figures 2-3 and 3-27.

B. Earth entry attitude control fuel and tankage increased without change to basic system.

C. Additional tankage for oxygen, cooling water, and additional radiator area added in service module without changing basic system.

D. Auto-sextant and other navigation and guidance components added to service module with displays added in service module and command module.

LUNAR GEMINI I, & II
GENERAL ARRANGEMENT

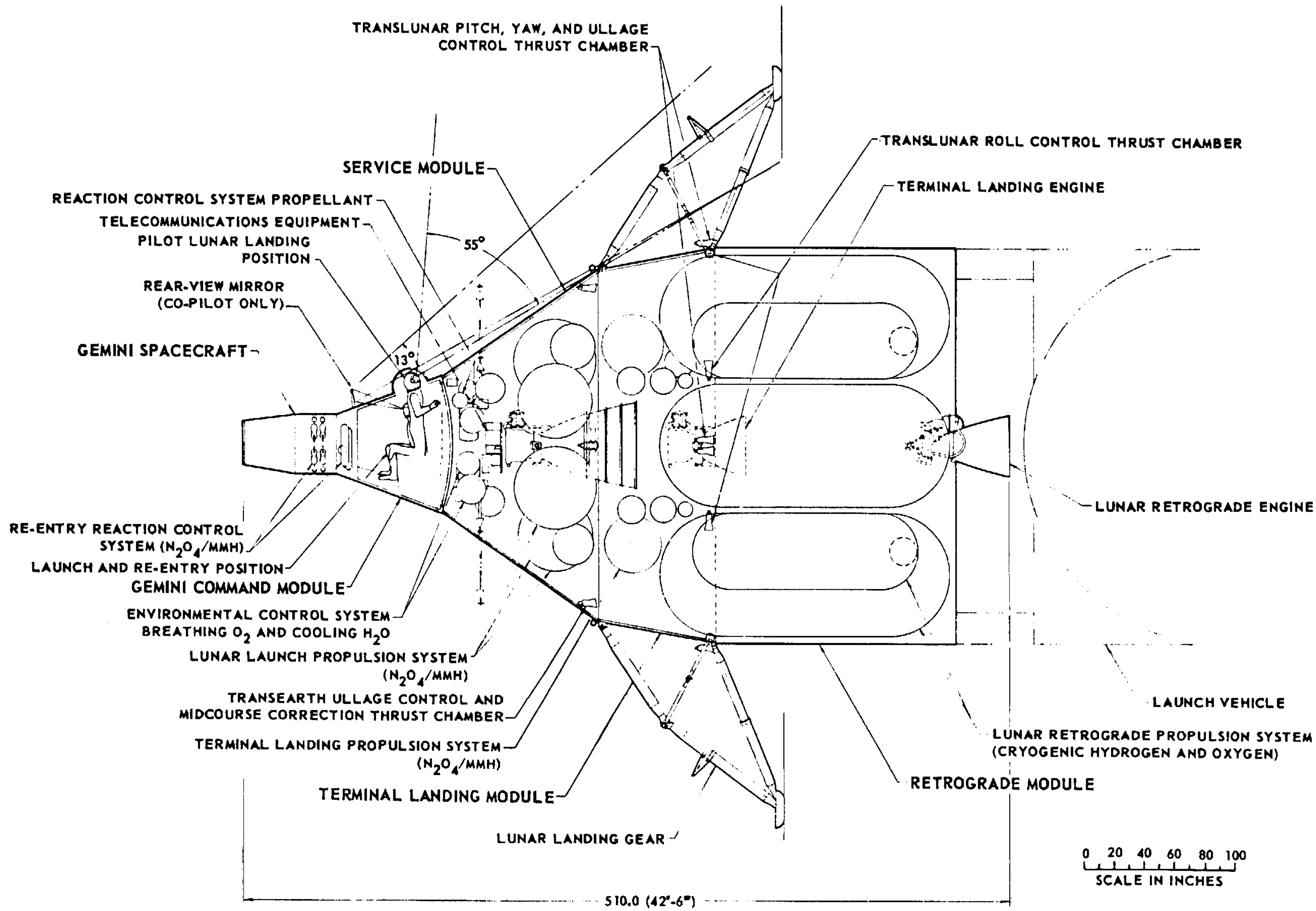


FIGURE 2-1

LUNAR GEMINI III
GENERAL ARRANGEMENT

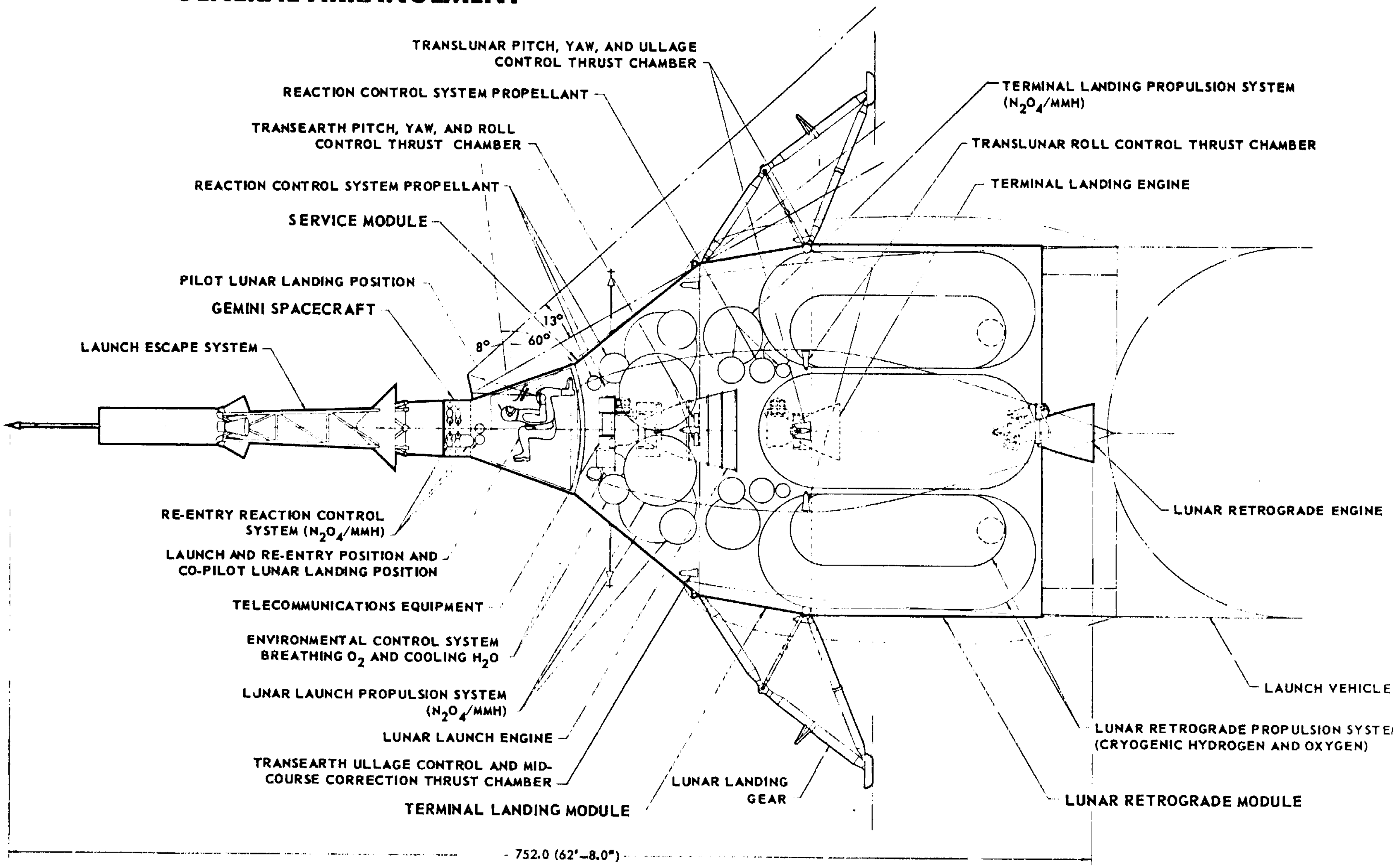


FIGURE 2–2

2.1 (Continued)

LUNAR GEMINI I AND II

TYPICAL AFTERBODY HEAT PROTECTION

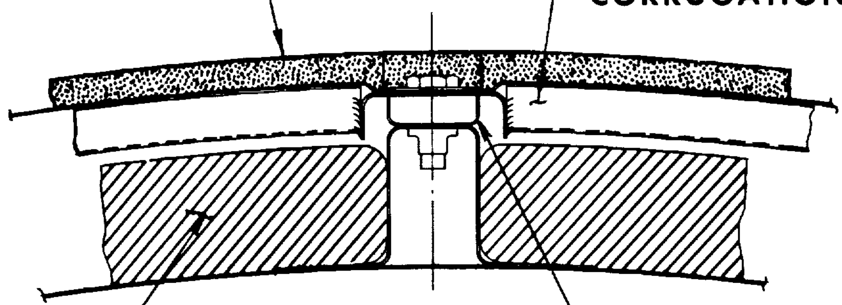


FIGURE 2-3

E. DSIF communication provisions added to service module with associated displays and controls added to command module.

F. Off load expendable supplies for shorter mission duration.

G. Add portable ECS, insulation garments and radiation detectors.

H. Add bubble canopy on left hand side and mirror system on right hand side to provide crew visual reference during lunar landing.

I. Add strap-down gyros for IMU backup and sun and star trackers.

The interior arrangement of Lunar Gemini I is shown in Figure 2-4.

Lunar Gemini II has improved navigation and communications systems and a lighter earth landing system than Lunar Gemini I. The additional modifications are:

A. Replace paraglider and landing gear earth landing system with single, 84 foot diameter parachute developed for Gemini. This change restricts normal landing to water sites.

LUNAR GEMINI I
INTERIOR ARRANGEMENT

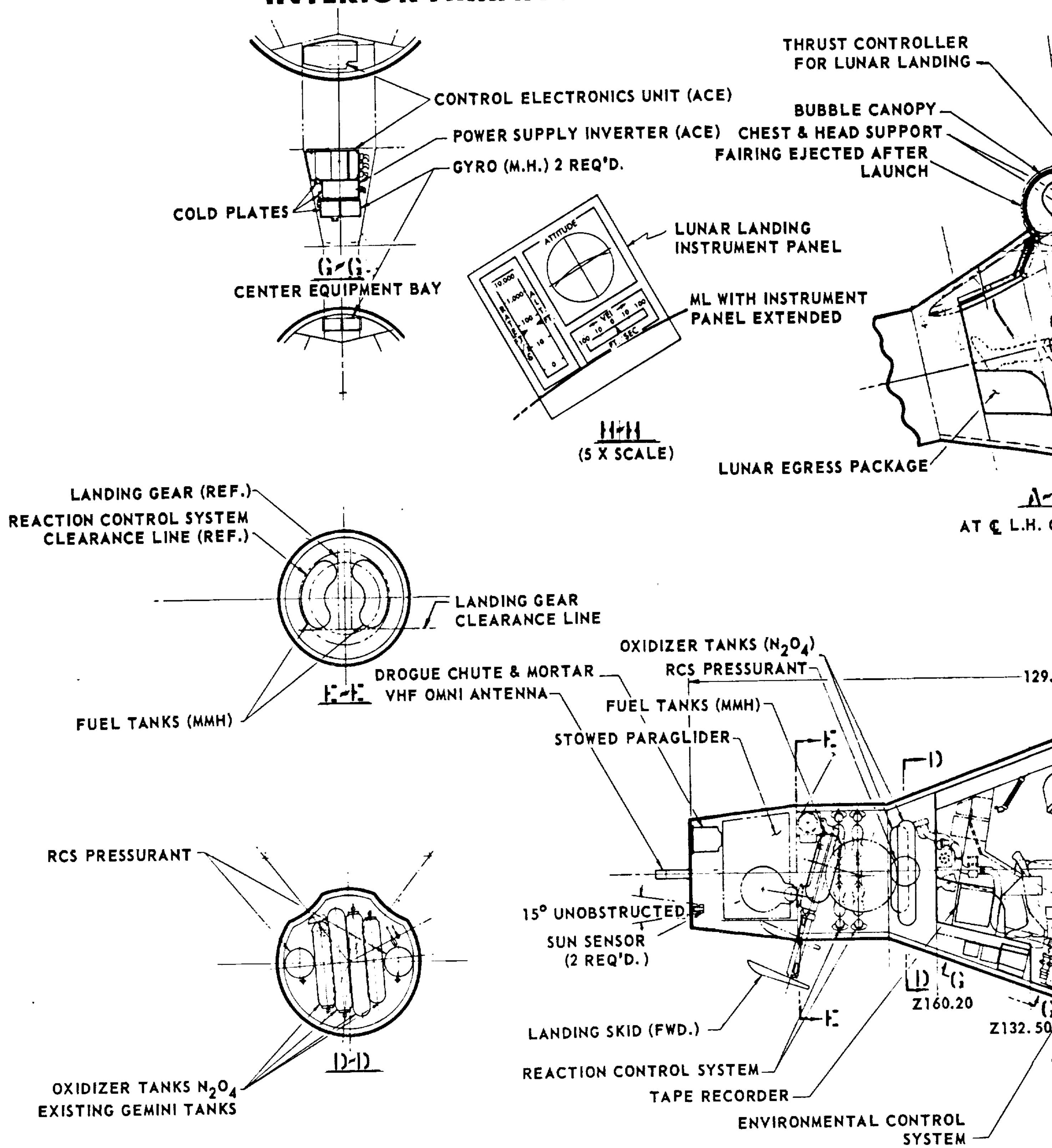


FIGURE 2-4

EMINI I
RANGEMENT

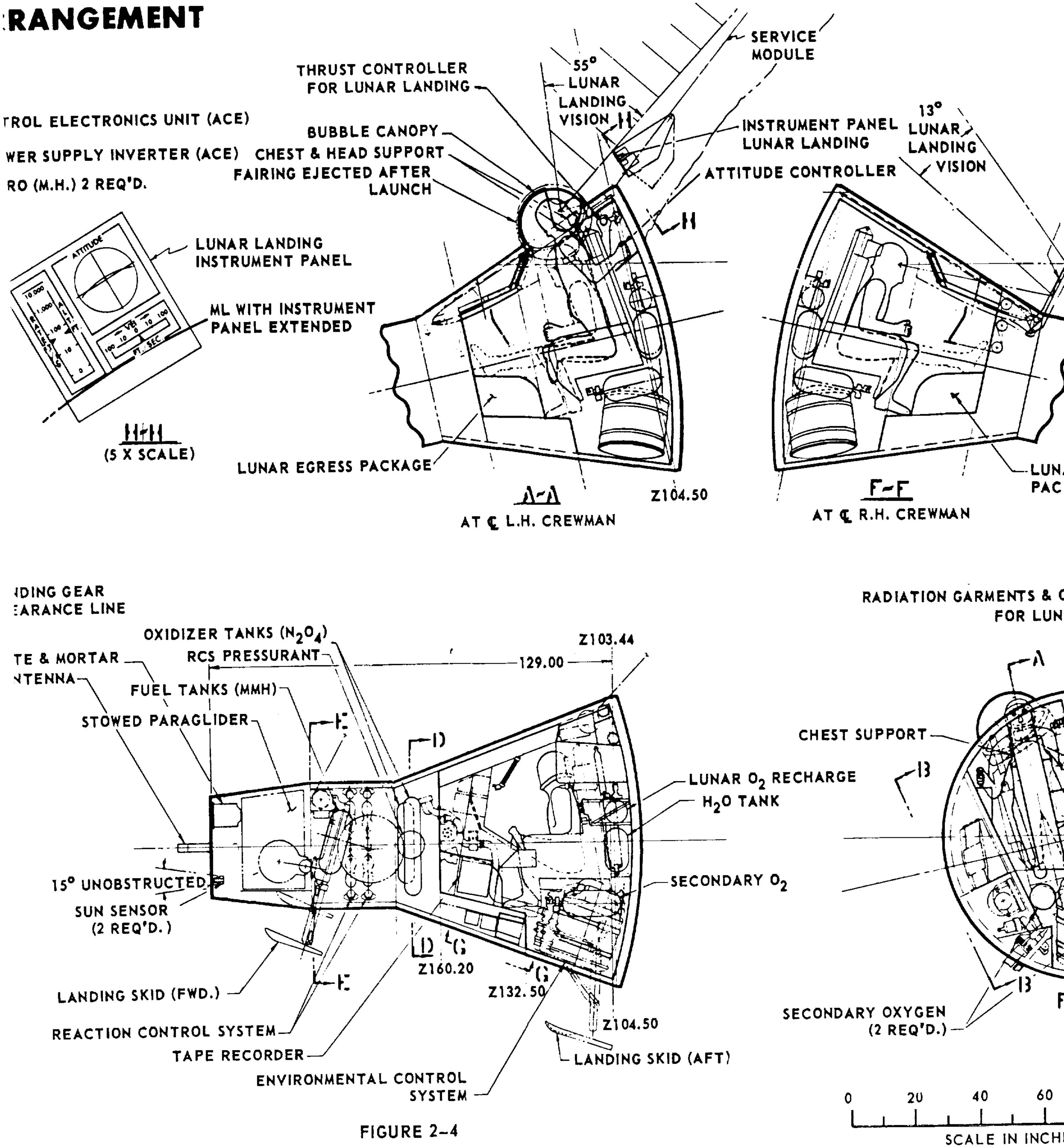
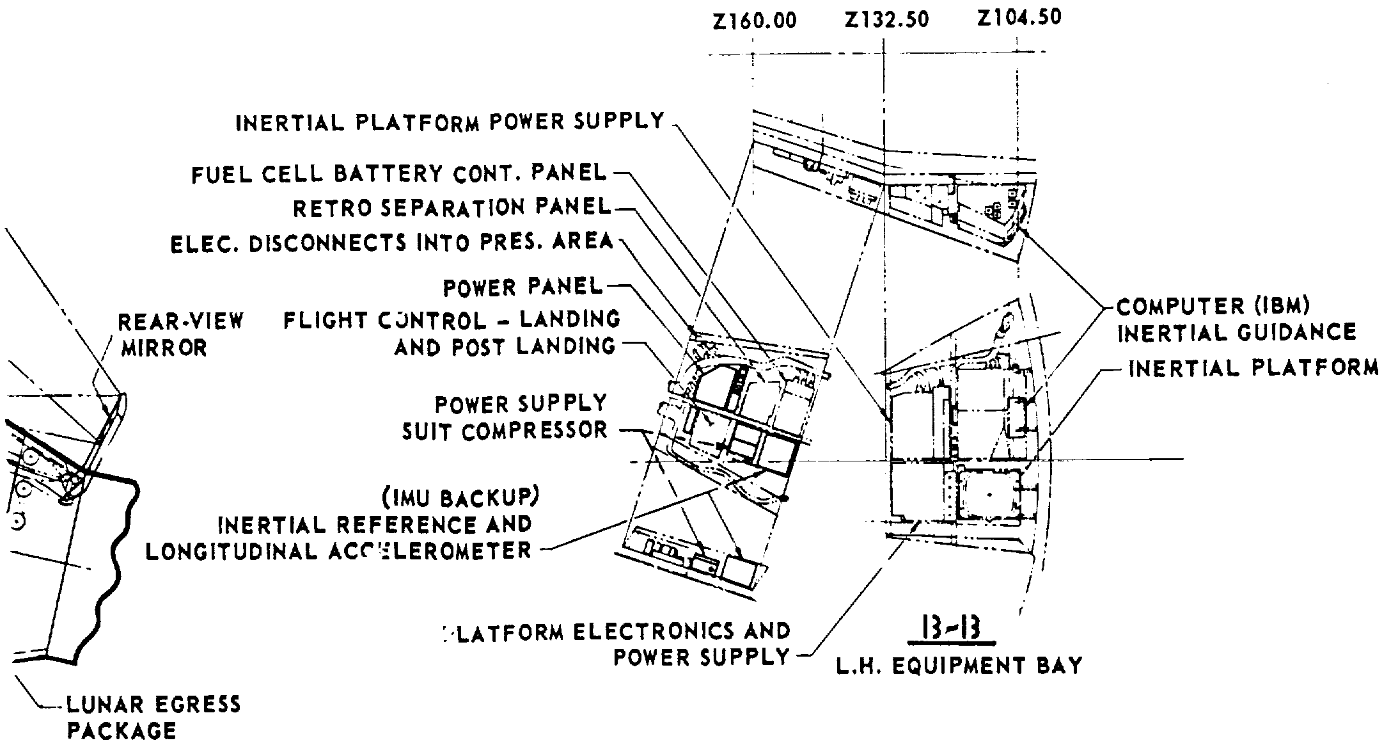
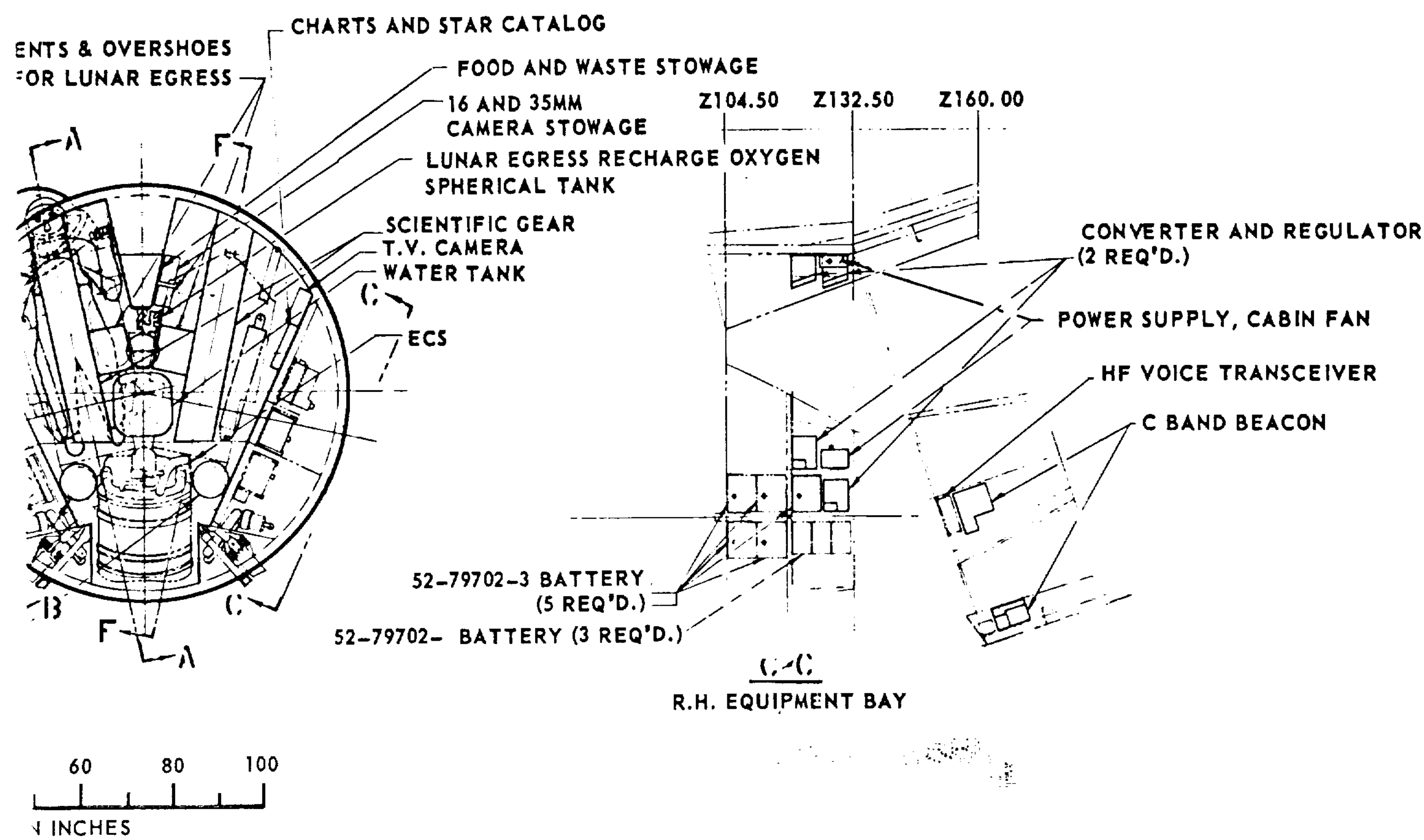


FIGURE 2-4



B-B
L.H. EQUIPMENT BAY



C-C
R.H. EQUIPMENT BAY

FOLDOUT FRAME 3

2.1 (Continued)

B. Replace auto sextant in service module with manual sextant in command module.

C. Replace Gemini data processing and near-earth communication systems with Apollo systems.

The interior arrangement of Lunar Gemini II is shown in Figure 2-5.

Lunar Gemini III, when compared to Lunar Gemini II, has an alternate earth landing system, lunar landing crew arrangement, and earth launch escape system. These further changes are:

A. Replace crew ejection seat escape system with tower-mounted launch escape rocket. Retain personal parachutes.

B. Replace single parachute landing system with three simultaneously deployed parachutes. Add impact attenuation system to crew seats. Normal landing at water site. Emergency landing at ground site.

C. Add windows, controls and displays for left-hand crewman to sit up and have direct vision during lunar landing.

The interior arrangement of Lunar Gemini III is shown in Figure 2-6.

Specific details of necessary changes and additions to the basic Gemini and their corresponding weights, power requirements, volumes and operation may be found under the appropriate sections in this report; however, a description of the resulting systems is presented in the following paragraphs.

2.1.1 General Configuration

A. Modified ballistic, 20 degree, circular cone with 90 inch diameter heat shield and 38 inch diameter cylindrical section at the apex. Pressurized volume, 100 cubic feet.

LUNAR GEMINI II
INTERIOR ARRANGEMENT

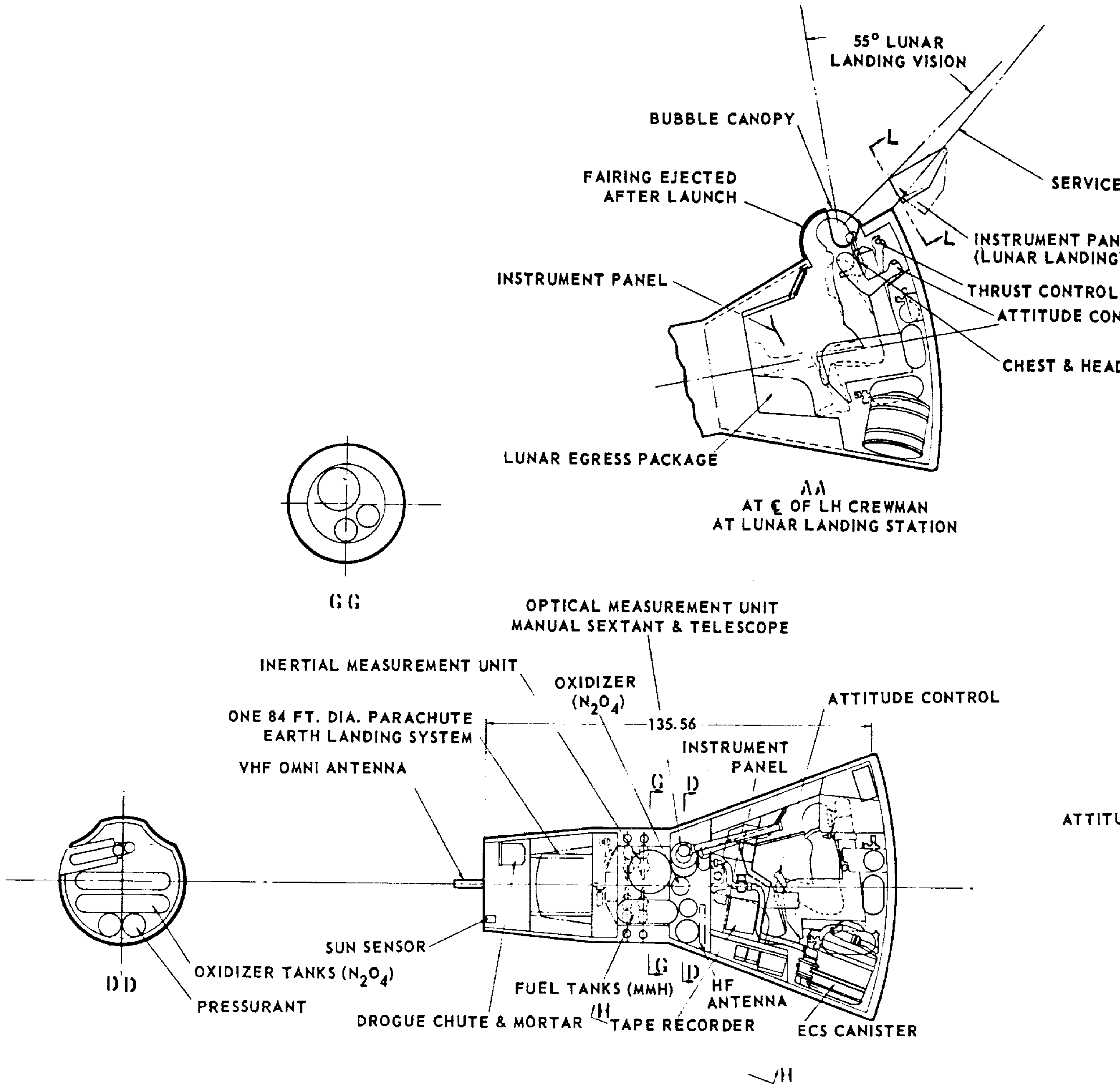


FIGURE 2-5

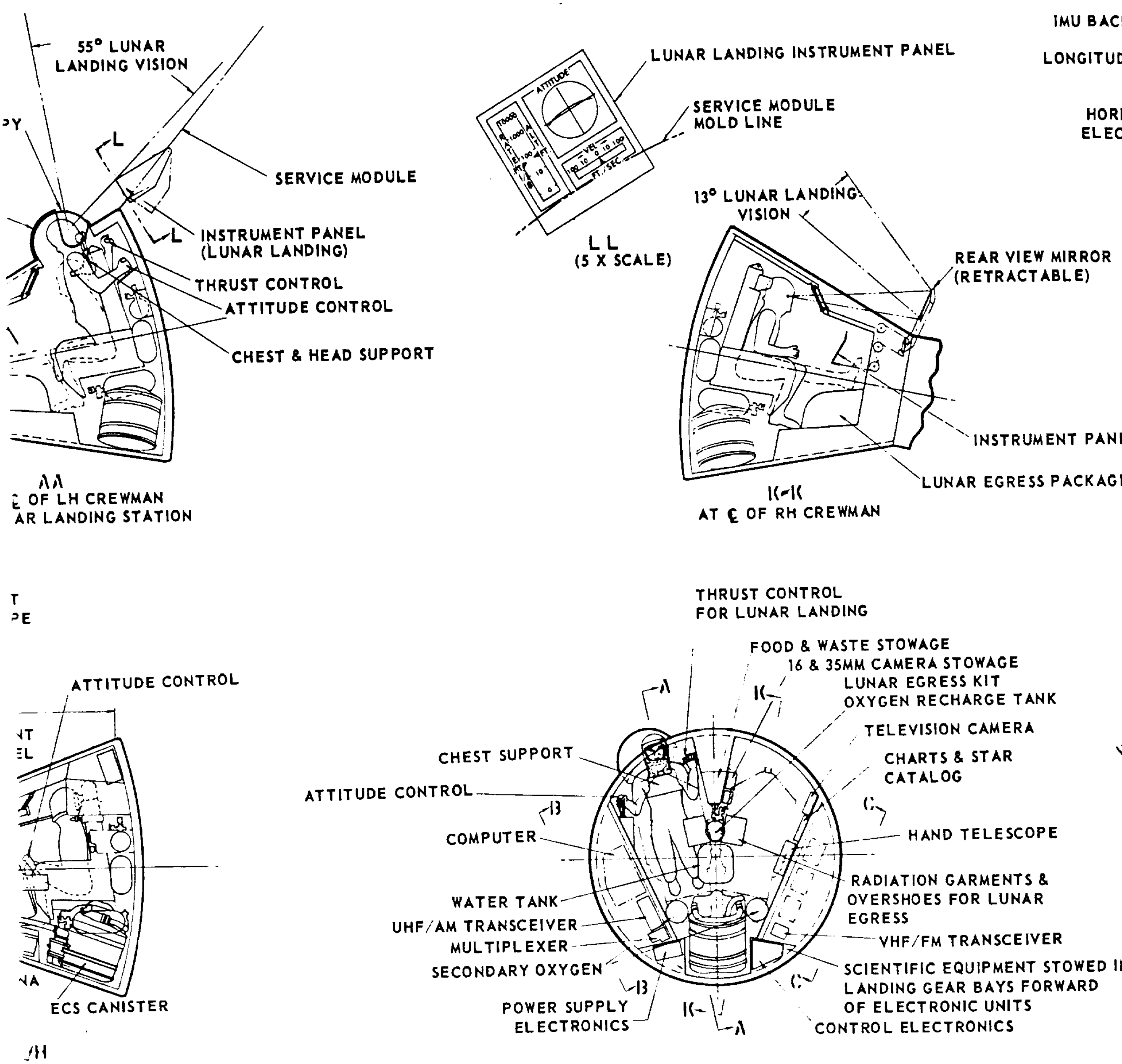
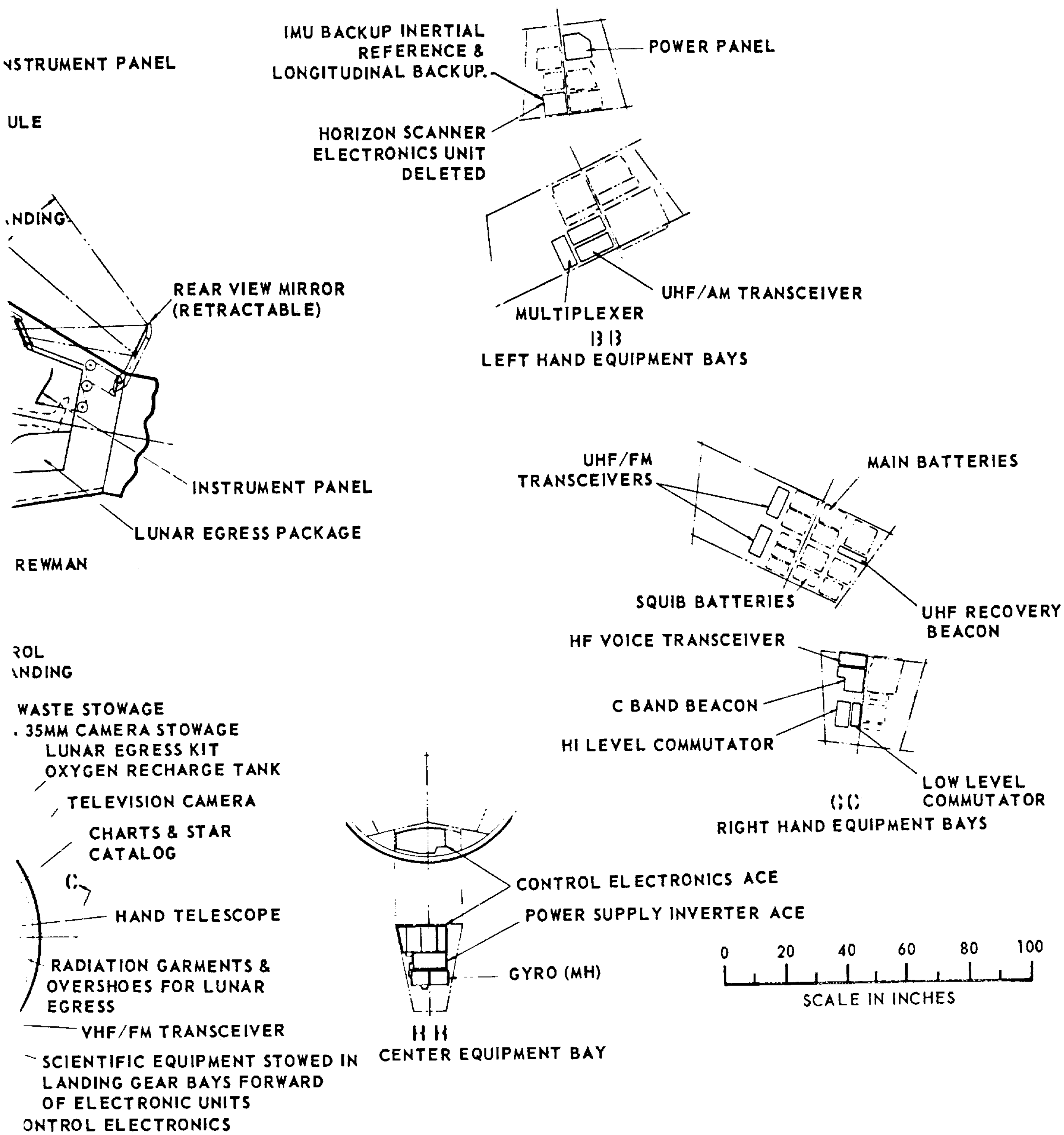

IMU BAC
LONGITUD
HORI
ELEC
55° LUNAR LANDING VISION
L
SERVICE MODULE
INSTRUMENT PANEL (LUNAR LANDING)
THRUST CONTROL
ATTITUDE CONTROL
CHEST & HEAD SUPPORT
A A
OF LH CREWMAN
AR LANDING STATION
LUNAR LANDING INSTRUMENT PANEL
SERVICE MODULE MOLD LINE
ATTITUDE
VEL
FT./SEC.
L L
(5 X SCALE)
13° LUNAR LANDING VISION
REAR VIEW MIRROR (RETRACTABLE)
INSTRUMENT PAN
LUNAR EGRESS PACKAG
K-K
AT ℄ OF RH CREWMAN
T
PE
ATTITUDE CONTROL
NT
EL
NA
ECS CANISTER
THRUST CONTROL FOR LUNAR LANDING
FOOD & WASTE STOWAGE
16 & 35MM CAMERA STOWAGE
LUNAR EGRESS KIT
OXYGEN RECHARGE TANK
TELEVISION CAMERA
CHARTS & STAR CATALOG
HAND TELESCOPE
RADIATION GARMENTS & OVERSHOES FOR LUNAR EGRESS
VHF/FM TRANSCEIVER
SCIENTIFIC EQUIPMENT STOWED I
LANDING GEAR BAYS FORWARD OF ELECTRONIC UNITS
CONTROL ELECTRONICS
CHEST SUPPORT
ATTITUDE CONTROL
COMPUTER
WATER TANK
UHF/AM TRANSCEIVER
MULTIPLEXER
SECONDARY OXYGEN
POWER SUPPLY ELECTRONICS
A
B
C
K

FIGURE 2-5



FOLDOUT FRAME 3

LUNAR GEMINI III
INTERIOR ARRANGEMENT

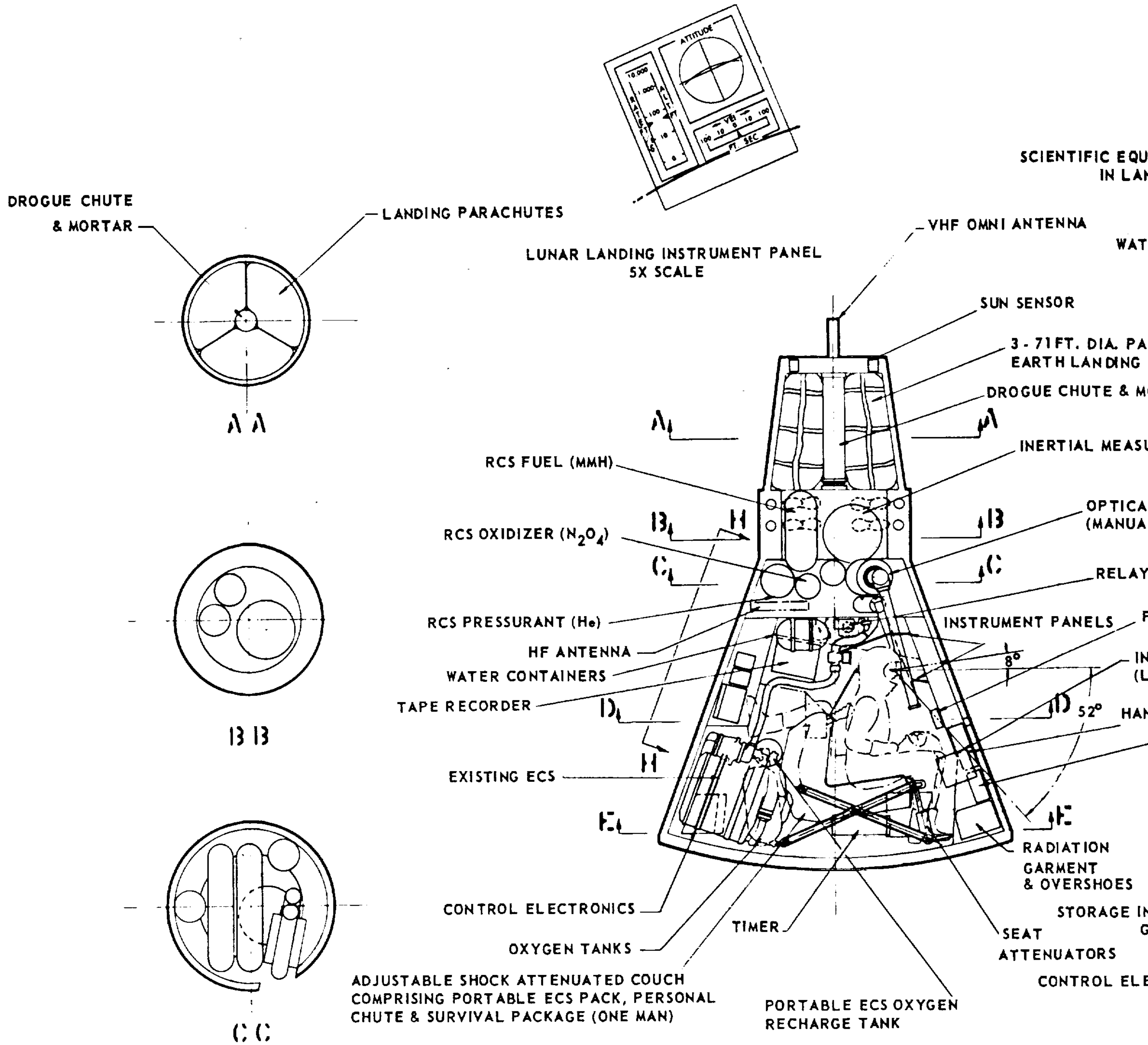


FIGURE 2-6

INI III
RANGEMENT

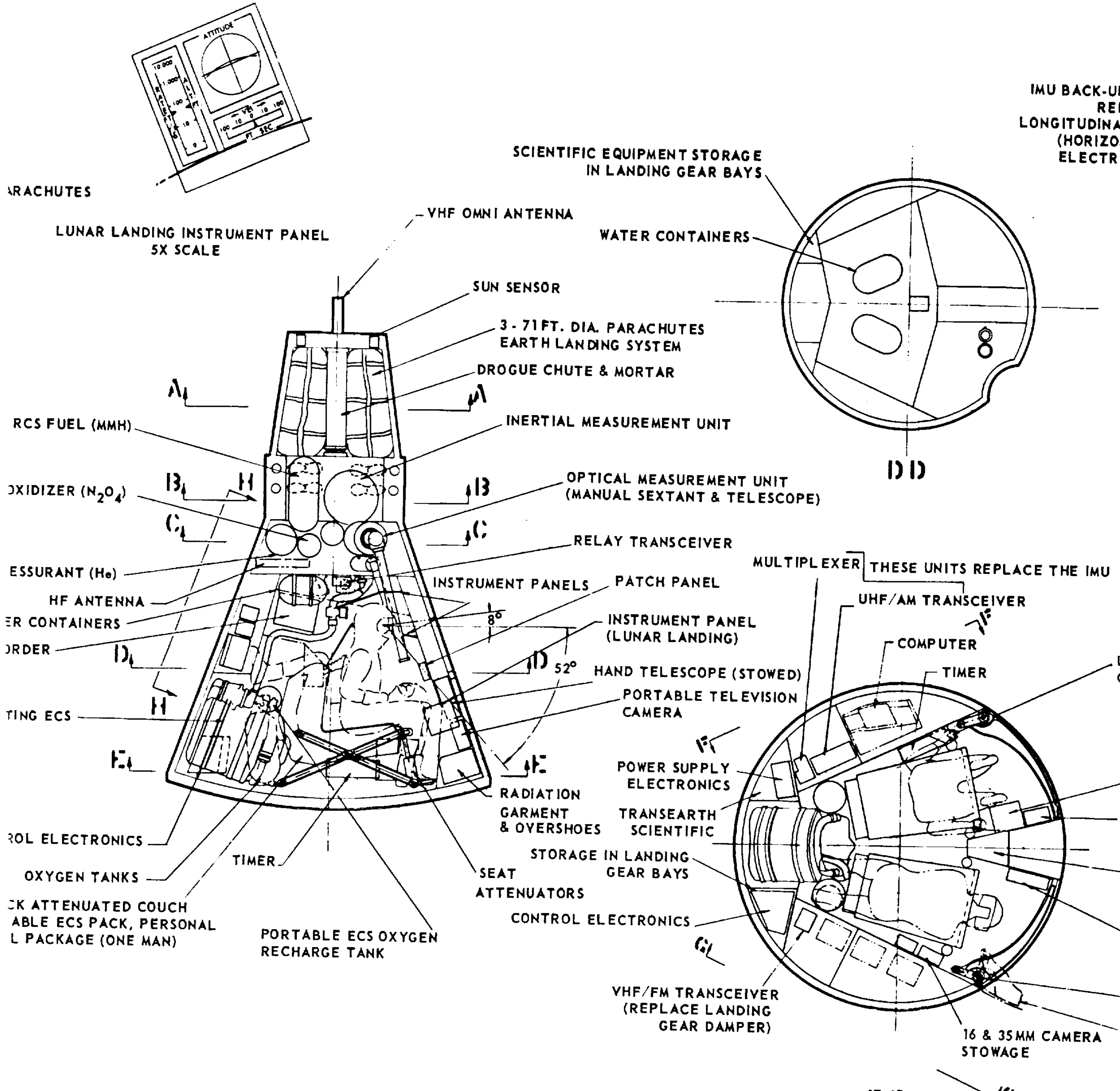
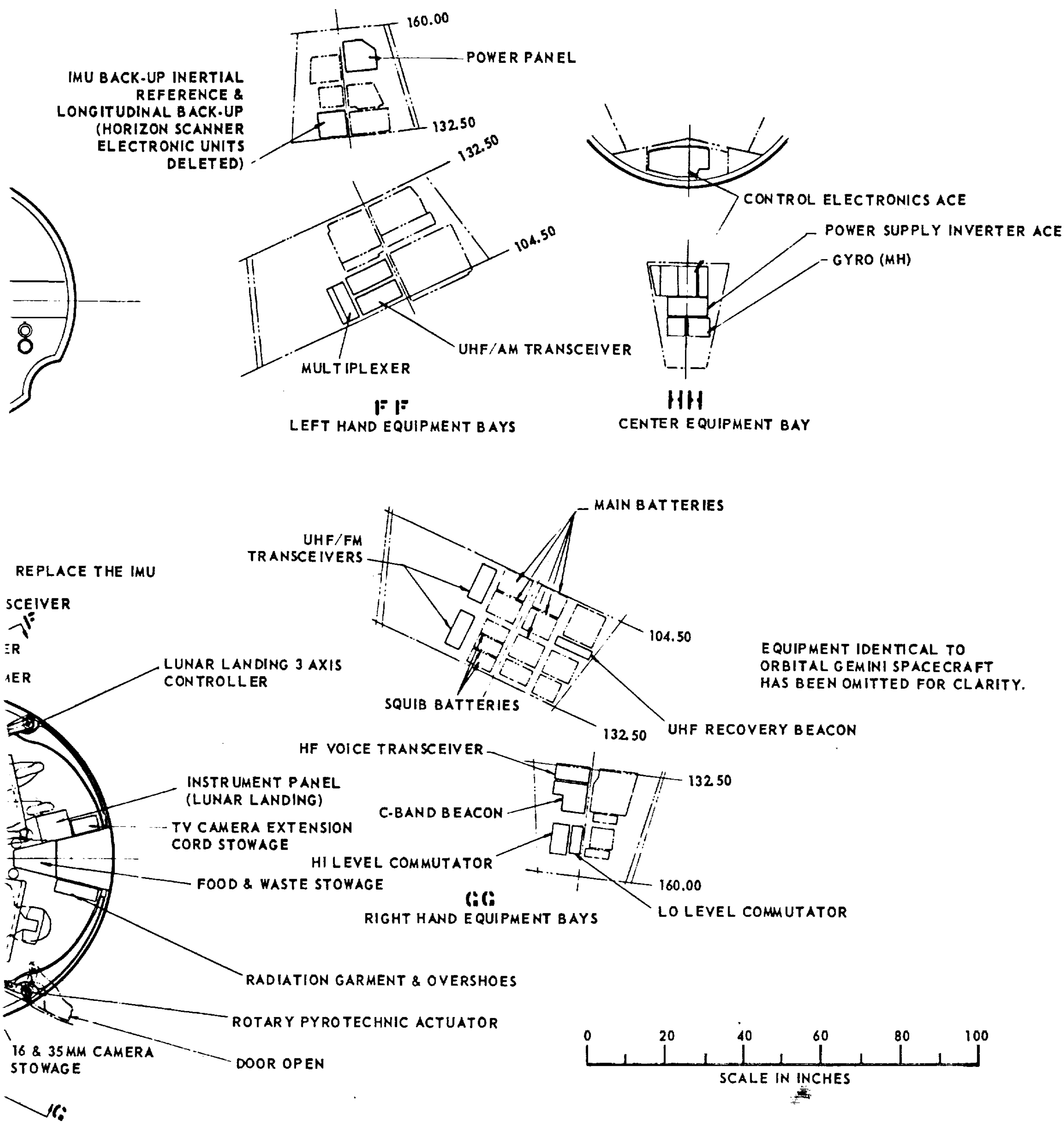


FIGURE 2-6


160.00
POWER PANEL
IMU BACK-UP INERTIAL REFERENCE & LONGITUDINAL BACK-UP (HORIZON SCANNER ELECTRONIC UNITS DELETED)
132.50
132.50
104.50
UHF/AM TRANSCEIVER
MULTIPLEXER
FF
LEFT HAND EQUIPMENT BAYS
CONTROL ELECTRONICS ACE
POWER SUPPLY INVERTER ACE
GYRO (MH)
HH
CENTER EQUIPMENT BAY
MAIN BATTERIES
UHF/FM TRANSCEIVERS
REPLACE THE IMU
SCEIVER
LUNAR LANDING 3 AXIS CONTROLLER
104.50
EQUIPMENT IDENTICAL TO ORBITAL GEMINI SPACECRAFT HAS BEEN OMITTED FOR CLARITY.
SQUIB BATTERIES
132.50
UHF RECOVERY BEACON
HF VOICE TRANSCEIVER
132.50
INSTRUMENT PANEL (LUNAR LANDING)
C-BAND BEACON
TV CAMERA EXTENSION CORD STOWAGE
HI LEVEL COMMUTATOR
FOOD & WASTE STOWAGE
160.00
GG
RIGHT HAND EQUIPMENT BAYS
LO LEVEL COMMUTATOR
RADIATION GARMENT & OVERSHOES
ROTARY PYROTECHNIC ACTUATOR
0 20 40 60 80 100
SCALE IN INCHES
16 & 35MM CAMERA STOWAGE
DOOR OPEN

2.1.1 (Continued)

B. Earth launch escape systems:

1. Lunar Gemini I and II - crew ejection seats and personal parachutes.

2. Lunar Gemini III - command module with abort tower and clustered parachute landing system.

C. Lunar landing crew stations:

1. Lunar Gemini I and II - crew side-by-side with left-hand crewman prone on seat with head in bubble canopy, right-hand crewman supine with mirror view of landing area.

2. Lunar Gemini III - left-hand crewman sits on back of launch couch with direct vision of landing area and right-hand crewman supine with mirror view of landing area.

D. Controls and displays:

1. Launch, re-entry and flight controls and displays for all Lunar Gemini versions are shown in Figure 2-7.

2. Lunar landing displays for Lunar Gemini I and II are mounted on the service module and retracted during launch. These are shown in Figure 2-4 and 2-5 respectively.

3. Landing displays for Lunar Gemini III are mounted within the pressurized cabin and are shown in Figure 2-6.

E. Separation from the service module accomplished with dual shaped charge cutting action at three positions around the interface.

F. Hypersonic $L/D_{max} = 0.25$.

G. Earth landing system:

1. Lunar Gemini I - Gemini paraglider and landing gear system with ejection seat and personnel parachutes for back-up.

CONTROL DISPLAY ARRANGEMENT

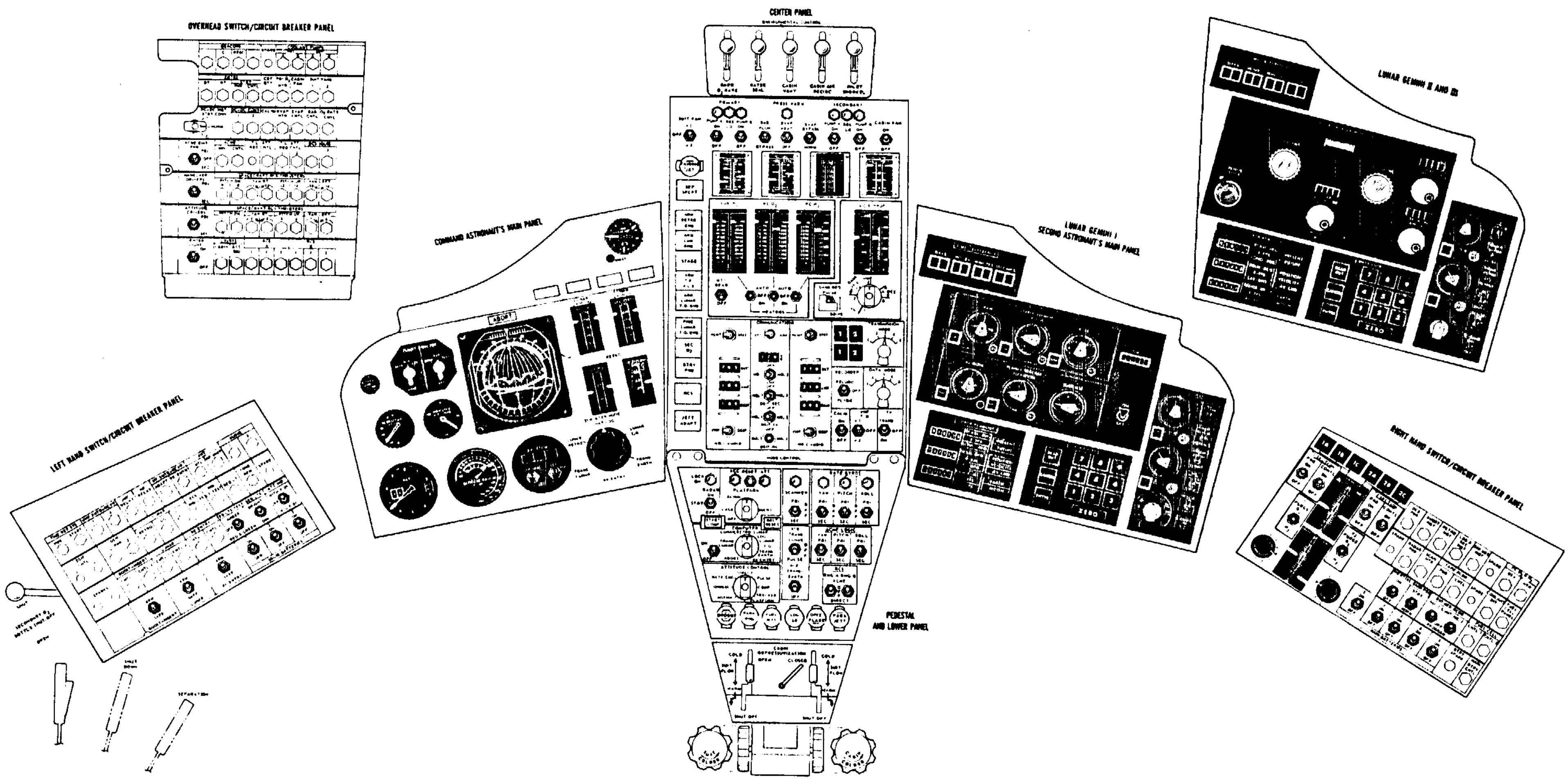


FIGURE 2–7

2.1.1 (Continued)

2. Lunar Gemini II - single 84 foot diameter Gemini parachute. System is restricted to water impacts with ejection seat and personnel parachutes for use under eminent ground impact conditions.

3. Lunar Gemini III - three simultaneously deployed 71 foot diameter parachutes. Normal landings are in water with crew bail-out under eminent ground impact conditions. Hydraulic snubbing of crew couches permits alternate emergency land landing as shown in Figure 2-8.

Section 3.13 contains a detailed description of these systems. Figures 2-9 and 2-10 show weight and volume comparisons.

2.1.2 <u>Structure</u>

A. Pressure walls - single-faced titanium corrugation; .010 skin and .010 corrugation.

B. Titanium sheet metal stringers .020 and .025 thick on Gemini I and II; .032 and .040 thick on Gemini III.

C. Pressure bulkheads - single-faced titanium corrugations, .010 skin and .010 corrugation.

D. Outer shingles - M.A.C. Thermorad S-3 elastomeric composite, .20 to .31 inches thick on single-faced titanium corrugations; .008 skin and .008 corrugation.

E. Heat shield - M.A.C. Thermorad S-3 elastomeric composite, 1.10 to 1.81 inches thick on fiberglass honeycomb support.

2.1.3 <u>Environmental Control</u>

A. Atmosphere

1. Pressure - 5 psi normal, 3 1/2 psi emergency.

2. Temperature - $70^\circ\ ^{+20^\circ}_{-10^\circ}$ F

LUNAR GEMINI III

COUCH ATTENUATION

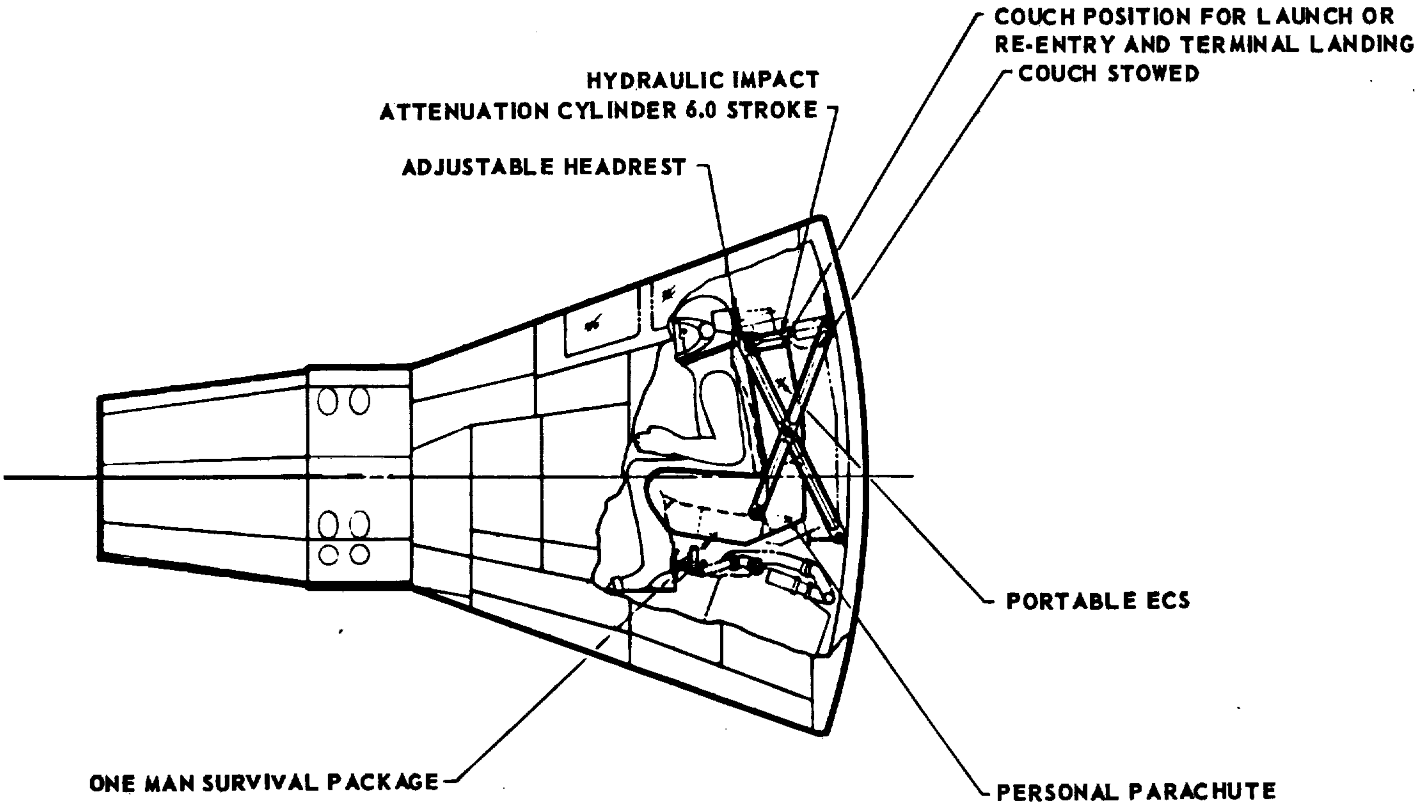


FIGURE 2-8

EARTH LANDING AND RECOVERY SYSTEMS COMPARISON

EARTH ORBITAL GEMINI VS. LUNAR GEMINI II

2 MAN 14 DAY EARTH ORBITAL GEMINI		WT LB	LUNAR GEMINI II
WEIGHT ⚠1 ⚠2 771.81 LB.	• REMOVE MAIN & NOSE LANDING GEAR SYSTEM	−230.9	WEIGHT ⚠1 137.60 LB.
	• REMOVE PARAGLIDER SYSTEM & DROGUE	−534.3	
	• ADD 84.2 FT DIA SINGLE PARACHUTE SYSTEM	+105.9	
VOLUME ⚠2 16.62 FT^3	• ADD 18.4 FT DIA DROGUE PARACHUTE	+15.1	VOLUME 5.58 FT^3
	• ADD PARACHUTE & DROGUE SYSTEM MISC COMPONENTS	+7.6	
	• INCREASE RECOVERY AIDS	+2.4	
	TOTAL	-634.2 LB.	

⚠1 WEIGHT DOES NOT INCLUDE CIRCUITRY, STRUCTURE OR MOUNTING PROVISIONS
⚠2 SYSTEM, VOLUME AND WEIGHT SAME FOR LUNAR GEMINI I

FIGURE 2-9

EARTH LANDING AND RECOVERY SYSTEMS COMPARISON

EARTH ORBITAL GEMINI VS. LUNAR GEMINI III

2 MAN 14 DAY EARTH ORBITAL GEMINI		WT. LB.	LUNAR GEMINI III
	• REMOVE MAIN AND NOSE LANDING GEAR SYSTEM	-230.9	
	• REMOVE PARAGLIDER SYSTEM	-534.3	
⚠1 WEIGHT ⚠2 771.81 LB.	• ADD PARACHUTE SYSTEM (3 MAIN)	+222.0	WEIGHT ⚠1 262.01 LB.
	• ADD DROGUE AND BACK-UP SYSTEM	+25.0	
	• ADD PARACHUTE & DROGUE SYSTEM MISC. COMPONENTS	+6.0	
VOLUME ⚠2 16.62 $FT.^3$	• ADD TOWER ABORT SYSTEM (6% OF LANDING WT.)	3060 (REF. ONLY)	VOLUME 10.50 $FT.^3$
	• INCREASE RECOVERY AIDS	+2.4	
	TOTAL	-509.8 LB.	

⚠1 WEIGHT DOES NOT INCLUDE CIRCUITRY, STRUCTURE OR MOUNTING PROVISIONS.
⚠2 SYSTEM VOLUME & WEIGHT SAME FOR LUNAR GEMINI I

FIGURE 2-10

2.1.3 (Continued)

3. Relative humidity - 55 ± 20%

4. Composition - O_2

5. Crew O_2 consumption rate - 1.8 lb/man day

6. Cabin leakage rate - nominal 0.15 lb/hr

7. Normal O_2 supply - stored in service module

8. Emergency and re-entry O_2 supply - 20 lbs. gaseous in two containers

9. CO_2 partial pressure - 7.6 mm Hg maximum

10. CO_2 production rate - 2.3 lb/man day

11. CO_2 removal - lithium hydroxide

12. Odor removal - activated charcoal

13. Humidity control - condensation and wick-type water separation

B. Temperature Control

1. Heat provided by electrical equipment, metabolic and solar heat

2. Metabolic heat - 11,300 btu/man/day

3. Crew cooled by ventilation and evaporation

4. Atmosphere cooled by OS-139 heat exchanger

5. Equipment cooled by OS-139 cold plates

6. Equipment isolated from inhabited volume

7. OS-139 cooling by service module system

8. Re-entry cooling - crew by secondary O_2, equipment utilizes thermal capacity

9. Stringers insulated by 0.35 MIN-K-501 strips

10. Pressure compartment insulated by 1.0 RF-700 on side walls, .38 RF-300 on bulkhead, and 1.0 RF-1000 top and bottom

2.1.4 Electrical Power

A. Five primary batteries and three separate batteries for pyrotechnic firing located in command module.

B. Fuel cells with cryogenically stored reactants located in service module.

C. Inverters for A.C. power requirements located in command module.

2.1.5 Communications

A. DSIF receivers and transmitters.

B. Near-earth VHF/AM trans./rec. and FM transmitter.

C. HF voice and recovery beacon.

D. C-band beacon.

E. VHF recovery.

F. Intercom relay transceiver.

Section 3.5 contains detailed descriptions of these systems.

2.1.6 Navigation

A. Attitude reference - Sun-Canopus system using sun and star sensors and inertial platform memory.

B. Transit guidance:

1. Lunar Gemini I - Autosextant (in service module) and digital computer
2. Lunar Gemini II and III - manual sextant (in command module) and digital computer

2.1.7 Attitude Control

A. Spacecraft transit orientation - roll axis on sun line with command module toward sun. Yaw axis in the sun-Canopus-spacecraft plane.

B. Attitude orientation held to $\pm$ 5 degrees.

C. Re-entry reaction controls identical to Gemini.

2.1.8 Crew Support - These items are essentially the same as those mentioned in Volume I, Section 2.1, except that Lunar Gemini I and II include a bail-out kit that is not included in Lunar Gemini III or Two-Man Apollo. Weight and volume comparisons for these items are shown in Figure 2-11 and 2-12.

CREW SYSTEMS COMPARISON

EARTH ORBITAL GEMINI VS. LUNAR GEMINI I & II

2 MAN 14 DAY EARTH ORBITAL GEMINI

WEIGHT
⚠ 929.09 LB.

VOLUME
33.75 FT.^{3}

	WT. LB.
● INCREASE PRESSURE SUITS	+1.4
● ADD PORTABLE E.C.S. BACKPACKS & RECHARGE PROVISIONS	+79.8
● ADD SOLAR RADIATION GARMENTS & OVERSHOES	+8.0
● ADD INFLIGHT REPAIR KIT	+12.0
● ADD PRIVACY CURTAIN	+1.0
● INCREASE DRINKING WATER & CONTAINER	+29.0
● INCREASE PERSONNEL COMMUNICATIONS UNITS	+4.3
● REDUCE FOOD & CONTAINER	-12.0
● REDUCE PERSONAL PARACHUTES	-6.0
TOTAL	- 117.5 LB.

LUNAR GEMINI I AND II

WEIGHT
⚠ 1046.60 LB.

VOLUME
38.00 FT.^{3}

⚠ WEIGHT DOES NOT INCLUDE CIRCUITRY, STRUCTURE OR MOUNTING PROVISIONS

FIGURE 2-11

CREW SYSTEMS COMPARISON

EARTH ORBITAL GEMINI VS. LUNAR GEMINI III

2 MAN 14 DAY EARTH ORBITAL GEMINI

WEIGHT
⚠ 929.09 LB.

VOLUME
33.75 FT.^{3}

	WT. LB.
● ADD SHOCK ATTENUATED SEATS (2 REQ.)	+158.4
● INCREASE PRESSURE SUITS	+ 1.4
● ADD PORTABLE E.C.S. BACKPACKS & RECHARGE PROVISIONS	+79.8
● ADD SOLAR RADIATION GARMENTS & OVERSHOES	+8.0
● ADD INFLIGHT REPAIR KIT	+12.0
● ADD PRIVACY CURTAIN	+1.0
● INCREASE DRINKING WATER & CONTAINER	+29.0
● INCREASE PERSONNEL COMMUNICATIONS UNITS	+4.3
● REMOVE EJECTION SEATS	-270.1
● REDUCE FOOD AND CONTAINER	-12.0
● REDUCE PERSONAL PARACHUTES	-6.0
● REMOVE EGRESS KITS	-26.4
TOTAL	- 20.6 LB.

LUNAR GEMINI III

WEIGHT
⚠ 908.49 LB.

VOLUME
36.01 FT.^{3}

⚠ WEIGHT DOES NOT INCLUDE CIRCUITRY, STRUCTURE OR MOUNTING PROVISIONS.

FIGURE 2-12

2.2 Service Module - Figure 2-13 shows the general arrangement of the service modules for Lunar Gemini I, II and III. This module is a truncated cone of 39 1/2 degrees half-angle. It is the same length and includes the same basic features as the service module shown for the Two-Man Apollo (Volume I, Section 2.2). The command-to-service-module interface diameter is smaller to accommodate the smaller Gemini configuration. Separation from the command module is by dual, shaped-charge cutting action at three tension strap tie positions about the interface. The umbilicals are integral with the tension straps and the shaped charges are interconnected by continuous cord fusing, ignited simultaneously at the three separation points.

Other than slightly different equipment arrangement, the addition of an auto-sectant in Lunar Gemini I, and the addition of extendable lunar landing instruments in Lunar Gemini I and II, the service modules are identical for all versions.

Except for the items noted above and minor structural changes due to weight and equipment differences, the operational and structural features of the service module are the same as those presented in Volume I, Section 2.2.

LUNAR GEMINI
SERVICE MODULE

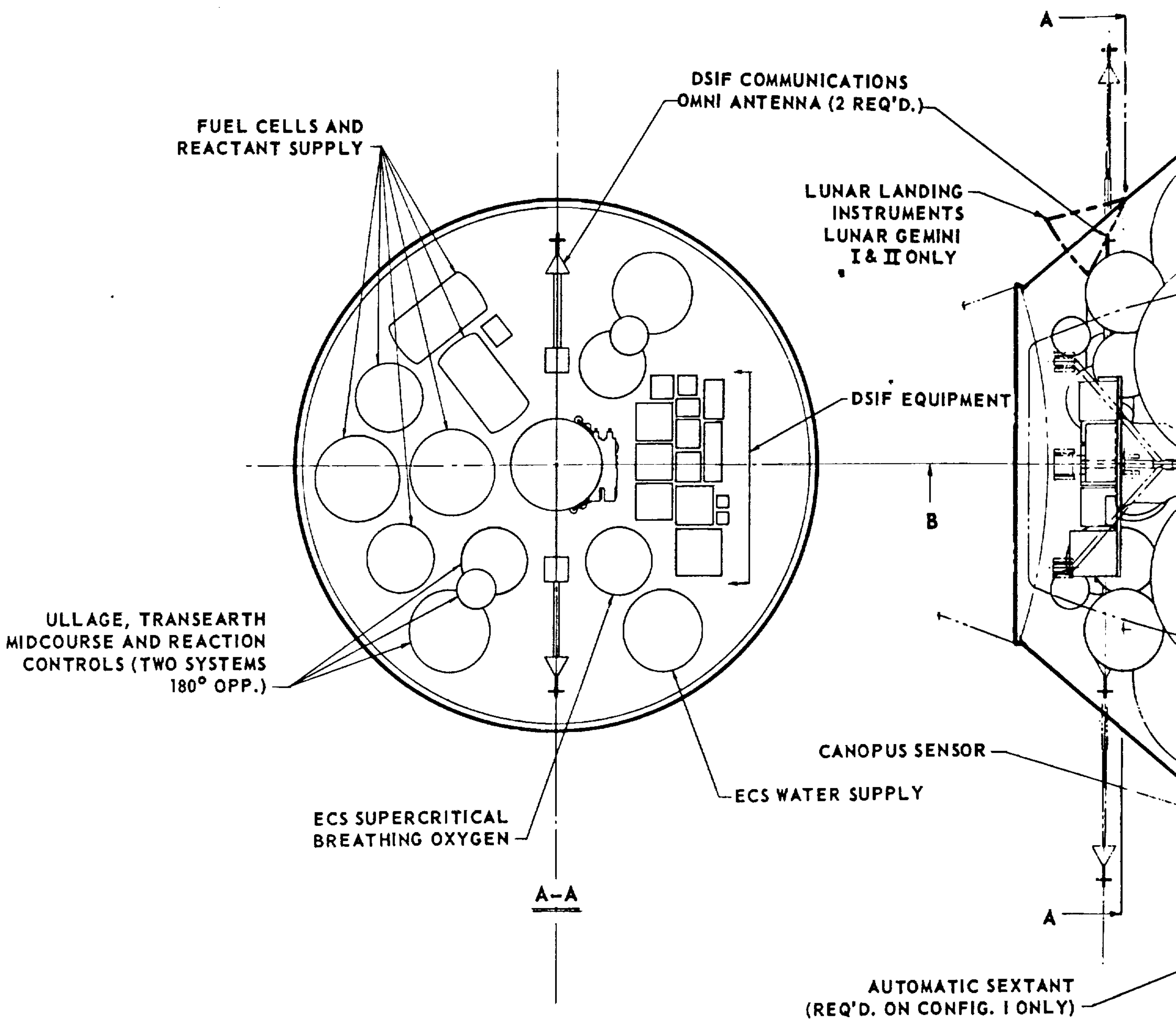


FIGURE 2-13

AR GEMINI
CE MODULE

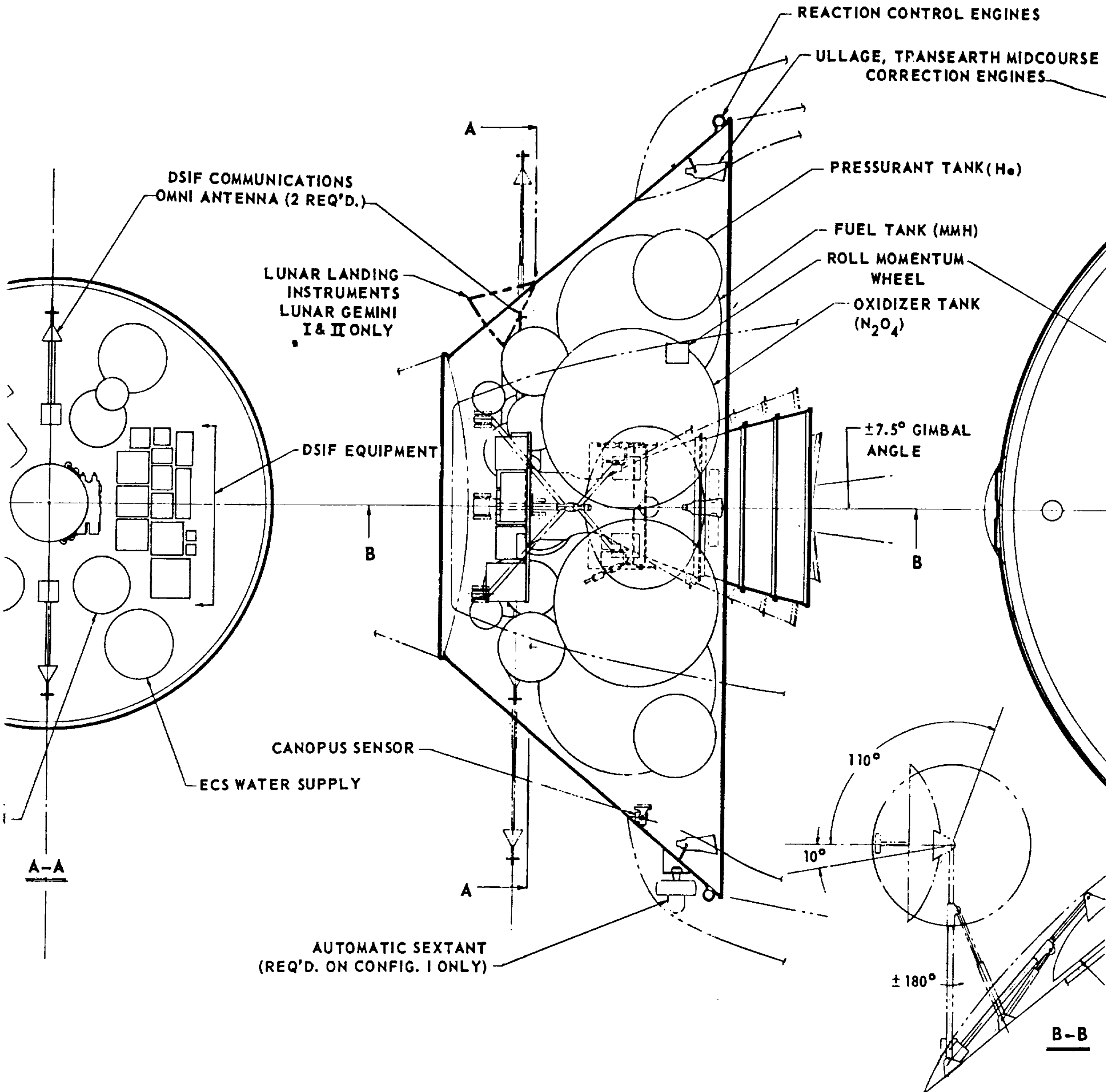
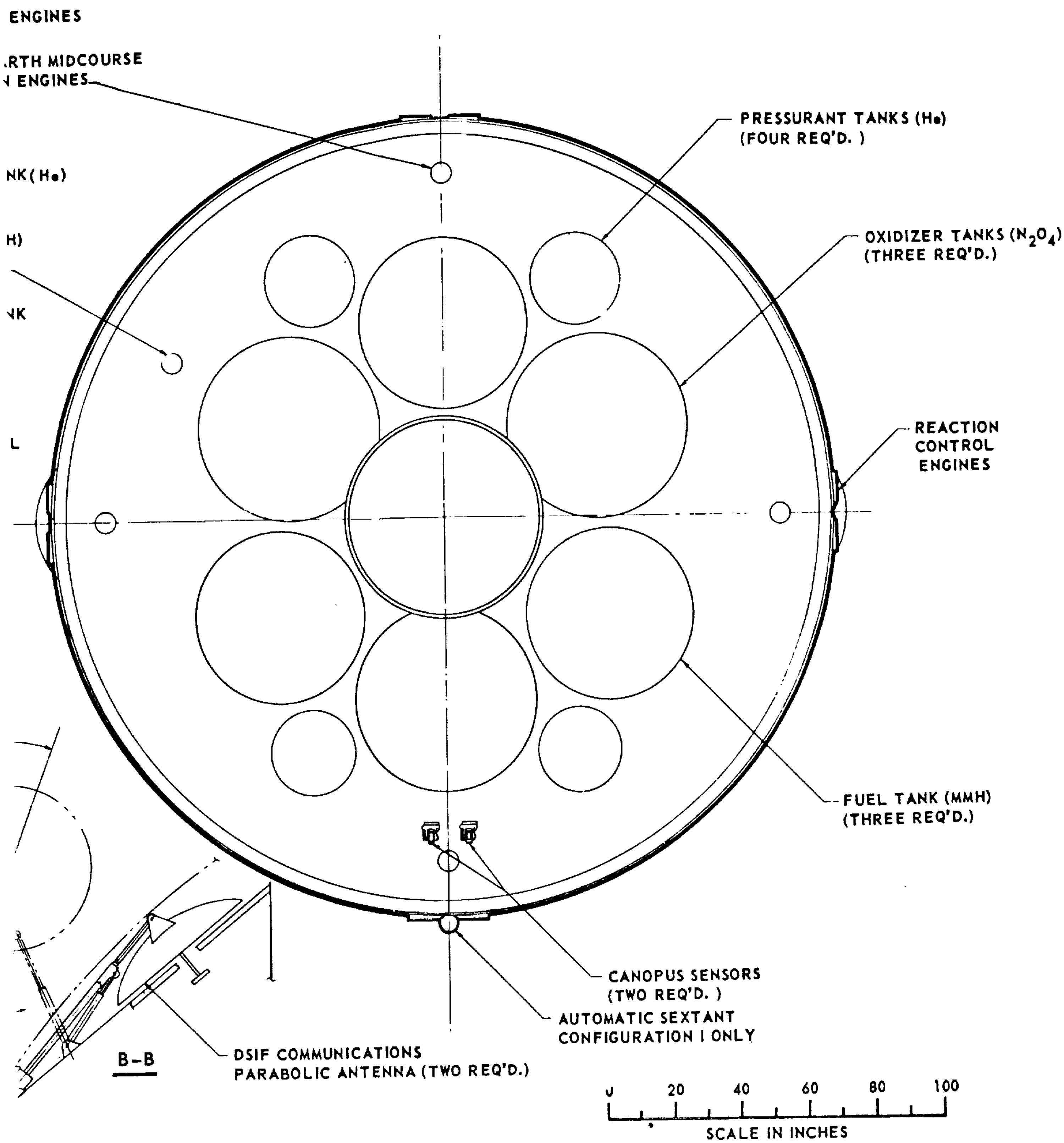


FIGURE 2–13


ENGINES
.RTH MIDCOURSE
N ENGINES
NK(He)
H)
NK
L
PRESSURANT TANKS (He)
(FOUR REQ'D.)
OXIDIZER TANKS (N_2O_4)
(THREE REQ'D.)
REACTION
CONTROL
ENGINES
FUEL TANK (MMH)
(THREE REQ'D.)
CANOPUS SENSORS
(TWO REQ'D.)
AUTOMATIC SEXTANT
CONFIGURATION I ONLY
DSIF COMMUNICATIONS
PARABOLIC ANTENNA (TWO REQ'D.)
B-B
0
20
40
60
80
100
SCALE IN INCHES

2.3 Terminal Landing Module - This module is identical to that shown and described in Volume I, Section 2.3.

2.4 Lunar Landing Configuration - The lunar landing configuration consists of command module, service module and terminal landing module with extended landing gear. The propulsion located in the terminal landing module is used for final maneuver before touchdown on the lunar surface. This operation, gear geometry, clearances, and landing procedures are the same as those shown and described in Volume I, Section 2.4.

Lunar Landing crew visibility for Lunar Gemini I, II and III and crew stations during landing are shown in Figure 2-14. Lunar Gemini I and II retain the right-hand crewman in the normal seated position and provide lunar surface visibility with a mirror system located just outside the hatch window. The left-hand crewman is provided with a bubble canopy which permits a direct view of the lunar surface with the crewman rotated into a prone position. Lunar Gemini III provides a redesigned hatch with windows allowing direct vision of the lunar surface and horizon with the left-hand crewman positioned in an upright seated position. The right-hand crewman is provided a mirror view of the lunar surface as described for Lunar Gemini I and II.

The terminal landing module with the integral landing gear is detached from the service module and serves as the launch platform for lunar launch of the trans-earth configuration.

2.5 Retrograde Module - This module is identical to that shown and described in Volume I, Section 2.5.

LUNAR LANDING CONFIGURATIONS

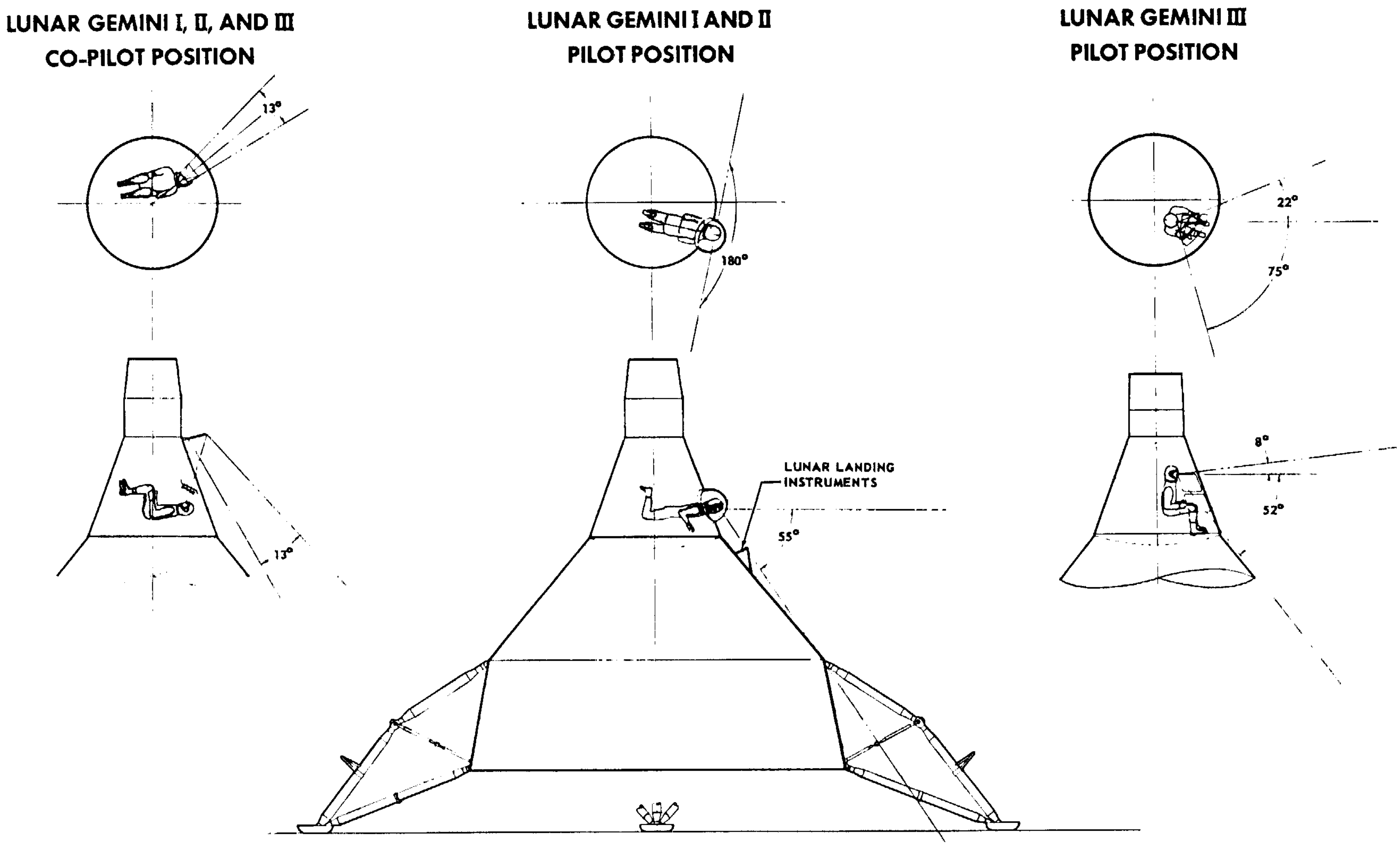


FIGURE 2-14

2.6 Weight Summary - Weight summaries of Lunar Gemini I, II, and III, are presented in Table 2-1. The service module, terminal landing module and retrograde are the same as presented in Volume I, Section 4.8, for the Two-Man Apollo spacecraft except that service module sidewalls are revised to accommodate the different command modules.

The mission history summary of Lunar Gemini I is presented in Table 2-2 for the abort condition of a touch and go lunar landing which, as in the case of Two-Man Apollo, is the design mission. The abort mission is similar to the normal mission except that expendables normally left on the lunar surface are carried during the return phase while scientific payload normally transferred to the command module while on the lunar surface is omitted.

Table 2-3 reflects the Lunar Gemini I mission history for a normal mission.

TABLE 2-3

LUNAR GEMINI

MISSION HISTORY

NORMAL MISSION

NORMAL MISSION	COMMAND MODULE	SERVICE MODULE EQUIPMENT	SERVICE MODULE	TERMINAL LANDING MODULE	RETRO MODULE	LES & FAIRING	TOTAL
ON PAD LAUNCH	6566	1177	22192	6115	53787	1400	91237
TOTAL EXPENDED ITEMS FOR FIRST PORTION OF MISSION (SAME AS ABORT)		-41		-3380	-53787	-1400	-58608
LUNAR TOUCH DOWN							32629
LESS: INERT				-2650			-2650
ECS EXPENDABLES		-147					-147
SCIENTIFIC EQUIPMENT TRANSFER	+85			-85			-
LUNAR LAUNCH							29832
LESS: LAUNCH PROPELLANT			-18957				-18957
RCS AND ULLAGE			-16				-16
BEGIN TRANSEARTH							10859
LESS: MIDCOURSE CORRECTION			-376				-376
RCS			-103				-103
WEIGHT AT STAGING							10380
LESS: INERT		-972	-2740				-3712
ECS EXPENDABLES		-17					-17
WEIGHT AT EARTH RE-ENTRY - PROPULSION CAPABILITY	6651						6651
LESS: SPACECRAFT WEIGHT MARGIN	-1026						-1026
EARTH RE-ENTRY WEIGHT (DERIVED)	5625						5625

[redacted]

TABLE 2-1

LUNAR GEMINI I, II, & III
SPACECRAFT WEIGHT SUMMARY

GROUP	WEIGHT - POUNDS		
	LUNAR GEMINI		
	I	II	III
COMMAND MODULE	(5625)	(5157)	(5263)
STRUCTURE	1187	1157	1264
HEAT SHIELD	672	672	666
CREW SYSTEMS	1049	1049	911
DISPLAYS	252	267	271
TELECOMMUNICATIONS	282	428	428
GUIDANCE AND NAVIGATION	207	260	260
STABILIZATION AND CONTROL	97	97	97
REACTION CONTROL	274	267	267
ELECTRICAL POWER	321	321	321
ENVIRONMENTAL CONTROL	330	330	330
EARTH LANDING	794	149	273
SCIENTIFIC EQUIPMENT *	85	85	85
ECCENTRICITY BALLAST	75	75	90
SERVICE MODULE EQUIPMENT	(1177)	(1219)	(1190)
STRUCTURAL SUPPORTS	54	54	54
DISPLAYS	29	29	
TELECOMMUNICATIONS	212	245	245
GUIDANCE AND NAVIGATION – STABILIZATION AND CONTROL	85	58	58
ELECTRICAL POWER	443	482	482
ENVIRONMENTAL CONTROL	354	351	351
SPACECRAFT WEIGHT MARGIN	1026	1452	1375
SERVICE MODULE	(22192)	(22192)	(22192)
STRUCTURE	991	991	991
PROPULSION SYSTEM	1294	1294	1294
PROPELLANT (INCL. TRAPPED)	19188	19188	19188
EQUIPMENT	80	80	80
REACTION CONTROL SYSTEM	639	639	639
TERMINAL LANDING MODULE	(6030)	(6030)	(6030)
STRUCTURE	724	724	724
PROPULSION SYSTEM	456	456	456
PROPELLANT (INCL. TRAPPED)	2668	2668	2668
REACTION CONTROL AND ULLAGE SYSTEM	1005	1005	1005
EQUIPMENT (INCL. 165 LB. SCIENTIFIC EQUIPMENT)	437	437	437
LANDING GEAR (INCLUDING CARRY-THROUGH)	740	740	740
RETROGRADE MODULE	(53787)	(53787)	(53787)
STRUCTURE	2364	2364	2364
PROPULSION SYSTEM	3289	3289	3289
PROPELLANT (INCL. TRAPPED)	48020	48020	48020
EQUIPMENT	114	114	114
LAUNCH ESCAPE SYSTEM (L.E.S.)			2600
LANDING GEAR AND RADIATOR FAIRING	1400	1400	1400
GROSS WEIGHT AT LAUNCH	91237	91237	93837

* THE 85 LB. SCIENTIFIC EQUIPMENT IS TRANSFERRED TO COMMAND MODULE WHILE ON LUNAR SURFACE

TABLE 2-2

LUNAR GEMINI
MISSION HISTORY
TOUCH AND GO LUNAR LANDING

CONFIGURATION	COMMAND MODULE (1)	SERVICE MODULE EQUIP.	SERVICE MODULE	TERMINAL LANDING MODULE (1)	RETRO MODULE	LES & FAIRING	TOTAL
ON PAD LAUNCH	6566	1177	22,192	6115	53,787	1400	91,237
LESS: FAIRING (1 – % EFF.)						-1335	-1335
ECS EXPENDABLES		-24					-24
EFFECTIVE LAUNCH WEIGHT							89,878
LESS: FAIRING (% EFF.)						-65	-65
ECS EXPENDABLES		-1					-1
RCS FLUIDS				-53			-53
SEPARATION DEVICE					-82		-82
BEGIN TRANSLUNAR							89,677
LESS: ULLAGE AND MIDCOURSE CORRECTION				-178	-1992		-2170
BEGIN RETROGRADE MANEUVER							87,507
LESS: ULLAGE AND RCS PROPELLANT				-358			-358
RETROGRADE PROPELLANT					-19,772		-19,772
LUNAR ORBIT WEIGHT							67,377
LESS: ULLAGE AND RCS PROPELLANT				-80			-80
TRANSFER AND RETRO PROPELLANT					-25,776		-25,776
WEIGHT AT STAGING							41,521
LESS: TRAPPED PROPELLANT					-480		-480
PRESSURE GASES					-172		-172
ECS EXPENDABLES		-16					-16
INERT					-5513		-5513
BEGIN TERMINAL PHASE							35,340
LESS: PROPELLANT				-2642			-2642
RCS				-69			-69
LUNAR TOUCHDOWN							32,629
LESS: INERT				-2650			-2650
ECS EXPENDABLES							—
TRANSFER SCIENTIFIC EQUIPMENT				-85			-85
LUNAR LAUNCH							29,894
LESS: LAUNCH PROPELLANT			-18,996				-18,996
RCS AND ULLAGE			-16				-16
BEGIN TRANSEARTH							10,882
LESS: MIDCOURSE CORRECTION			-376				-376
RCS			-103				-103
WEIGHT AT STAGING							10,403
LESS: INERT		-1119	-2701				-3820
ECS EXPENDABLES		-17					-17
WEIGHT AT EARTH RE-ENTRY – PROPULSION CAPABILITY	6,566						6566
LESS: SPACECRAFT WEIGHT MARGIN	-1026						-1026
EARTH RE-ENTRY WEIGHT (DERIVED)							5,540

(1) ON THE ABORT MISSION OF TOUCH AND GO LUNAR LANDING 85 POUNDS OF SCIENTIFIC GEAR IS NOT TRANSFERRED TO THE COMMAND MODULE.

2.6 (Continued)

These mission histories are typical for Lunar Gemini II and III except for differences in derived service module equipment and command module weight which affect only the spacecraft weight margin. A comparison of derived command module weights, propulsion system command module capability, and weight margin for the three Lunar Gemini configurations is:

Lunar Gemini	Command Module (Derived)*	Command Module (Capability)*	Weight Margin
I	5625	6651	1026
II	5157	6609	1452
III	5263	6638	1375

*Weights based on normal mission re-entry and includes 85 pounds of scientific payload transferred to the command module prior to lunar launch.

2.7 Design Criteria - The Lunar Gemini spacecraft are designed in accordance with the criteria of Volume I wherever possible. The exceptions and additions are as noted in the following paragraphs.

2.7.1 Mission Criteria - The incremental velocity requirements and the mission time apportionments are as used in Volume I.

2.7.2 Structural Design Criteria -

A. Design factors for loads and heat effects - These are the same as used in Volume I except that an ultimate factor of 1.36 shall apply to limit loads on the command module in all versions and the launch escape system in Lunar Gemini III.

B. Boost Phase - Conditions are the same as Volume I except that Lunar Gemini I and II are not designed for a tumbling abort.

C. Lunar Landing - The structural design criteria for lunar landing are the same as employed in Volume I.

D. Re-entry - The structural design criteria for re-entry are the same as employed in Volume I.

E. Earth Landing -

1. Lunar Gemini I

   a. Use Gemini paraglider and landing gear system for land or water landings.

2. Lunar Gemini II

   a. Load from single main parachute.

   b. Sink speed of 30 feet per second at sea level.

   c. Landing on water with spacecraft canted 55 degrees from vertical to reduce impact loads. Wind velocity up to 51 feet per second.

   d. No provision for land landing impact attenuation. Crew must eject and use personal parachutes.

2.7.2 (Continued)

3. <u>Lunar Gemini III</u>

a. Loads from main parachutes as determined by optimum reefing with any rational order of deployment.

b. Sink speed of 30 feet per second at 5000 feet altitude with two of three main parachutes.

c. Primary method of landing is on water with the spacecraft canted 55 degrees to reduce impact loads. Wind velocity up to 51 feet per second.

d. In emergency land landings the spacecraft attitude is changed to upright. Wind velocity up to 30 feet per second. Hydraulic seat attenuation system to keep crew within emergency load factor limits.

2.7.3 <u>Guidance and Navigation System Design Criteria</u> - The criteria used in the guidance and navigation system design are the same as outlined in Volume I.

2.7.4 <u>Stabilization and Control System Design Criteria</u> - The criteria used in the stabilization and control system design are the same as outlined in Volume I.

2.7.5 <u>Environmental Control System Design Criteria</u> - The criteria used in the environmental control system design are the same as outlined in Volume I.

2.7.6 <u>Electrical Power System Design Criteria</u> - The criteria used in the electrical power system design is the same as outlined in Volume I except for the following.

A. <u>Lunar Gemini I</u> -

1. Provisions for 660 watt average load for 8 day mission.

2. Nominal loads: 620 watt average, 1460 watts peak.

3. Emergency loads: 1020 watts peak.

2.7.6 (Continued)

B. Lunar Gemini II and III

1. Provisions for 880 watt average load for 8 day mission.
2. Nominal loads: 835 watt average, 1650 watts peak.
3. Emergency loads: 1160 watts peak.

2.7.7 Telecommunications System Design Criteria - The criteria used in the telecommunication system design are the same as outlined in Volume I.

2.7.8 Heat Protection System Design Criteria - The criteria used in the heat protection system design are as outlined in Volume I with the following exceptions:

A. Re-entry Heating

1. 1959 ARDC atmosphere
2. Design re-entry envelope
   a. initial flight path angles (@400,000 ft) = -6.7° to -9.15°
   b. angle of attack = -20°
   c. lift-drag ratio = 0.3
   d. range traveled during re-entry, approximately 4000 nautical miles.

2.7.9 Service Module Propulsion Design Criteria - The criteria used in the service module propulsion design are the same as outlined in Volume I.

2.7.10 Terminal Landing Module Propulsion Design Criteria - The criteria used in the terminal landing module propulsion design are the same as outlined in Volume I.

2.7.11 Retrograde Module Propulsion Design Criteria - The criteria used in the retrograde module propulsion design are the same as outlined in Volume I.

2.7.12 Command Module Reaction Control System Design Criteria - The criteria used in the command module reaction control system design are the same as outlined in Volume I.

2.7.13 <u>Service Module Reaction Control System Design Criteria</u> - The criteria used in the service module reaction control system design are the same as outlined in Volume I.

2.7.14 <u>Terminal Landing Module Reaction Control System Design Criteria</u> - The criteria used in the terminal landing module reaction control system design are the same as outlined in Volume I.

2.7.15 <u>Launch Escape System Design Criteria</u> - The criteria used in the design of the launch escape system for Lunar Gemini III are the same as outlined in Volume I. Lunar Gemini I and II retain the ejection seats used in the present Gemini spacecraft.

2.7.16 <u>Human Factors Criteria</u> - The human factors criteria utilized for the Lunar Gemini study are as outlined in Volume I. Crew accommodations shall be sized for the 15th through the 75th percentile man size as defined in WADC TR 52-321 "Anthrometry of Flying Personnel, 1950" dated September, 1954.

[redacted]

3. SPACECRAFT SYSTEMS

3.1 Guidance and Navigation

3.1.1 Summary - The Gemini guidance and navigation system, with the addition of optical and radar sensors, is compatible with the requirements for the lunar mission and compares favorably with the corresponding Apollo system described in Volume I. In addition, the Gemini components are designed to provide high reliability without requiring in-flight maintenance. Therefore, Lunar Gemini I, II and III utilize the Gemini guidance and navigation system as described below.

Lunar Gemini I guidance and navigation equipment, shown in Figure 3-1, represents a minimum change. This is accomplished by the addition of an autosextant, located in the service module, for navigation during midcourse and lunar orbit, and Apollo type tracking and landing radars, located in the terminal landing module, for navigation during lunar approach and landing. A sun sensor is located in the service module to assist in acquiring the sun for vehicle orientation during midcourse.

GUIDANCE AND NAVIGATION SYSTEM COMPARISON

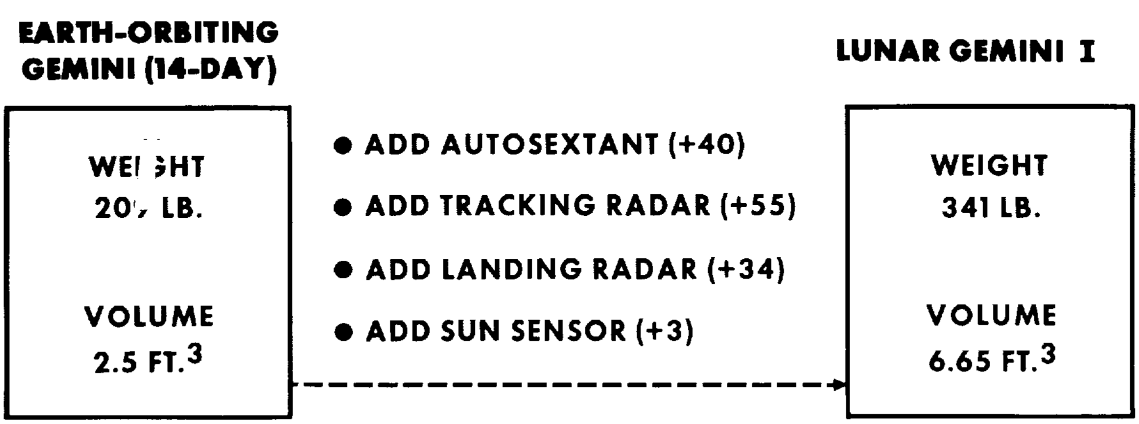


FIGURE 3-1

[redacted]

3.1.1 (Continued)

Lunar Gemini II and III guidance and navigation equipment, shown in Figure 3-2 is the same as that provided for Lunar Gemini I except that a manual sextant is installed in the command module in lieu of the autosextant installed in the service module. This change requires the addition of a navigation base, joining the sextant and inertial platform, and a roll momentum wheel for rate control during sightings.

GUIDANCE AND NAVIGATION SYSTEM COMPARISON

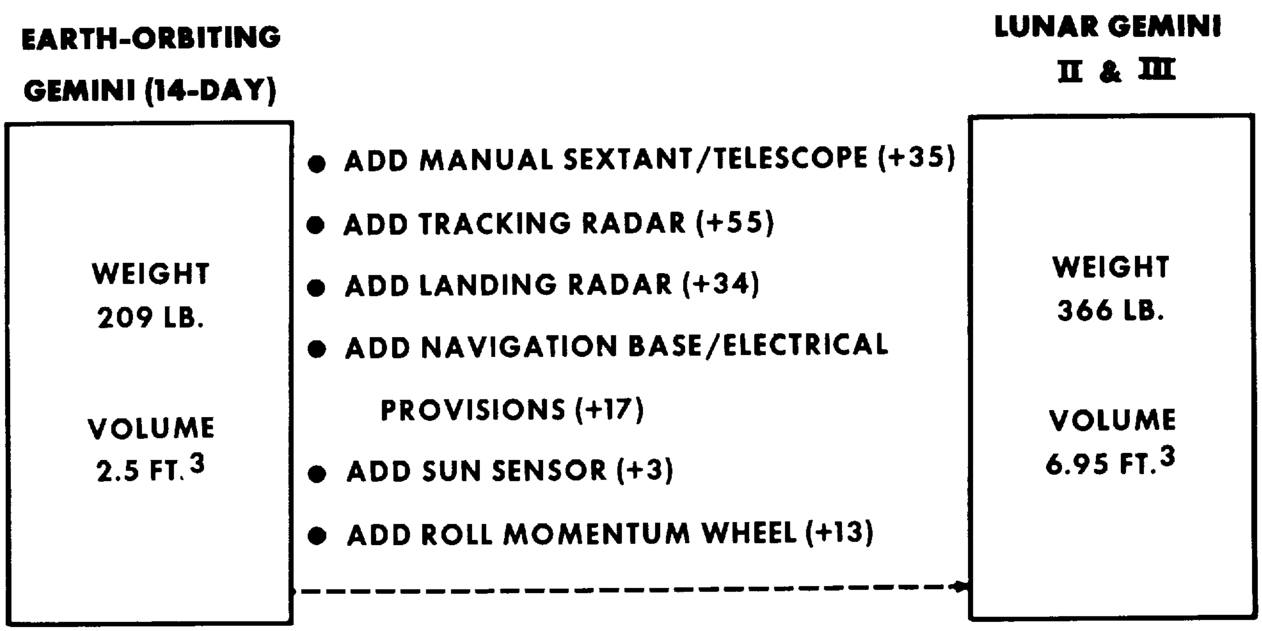


FIGURE 3-2

3.1.2 Functions - Each of the guidance and navigation systems for Lunar Gemini I, II, and III performs the same functions as the systems for the Two-Man Apollo, described in Section 3.1.2 of Volume I.

3.1.3 Description - System for Lunar Gemini I - The guidance and navigation equipment consists of an inertial system for attitude memory and acceleration measurements, navigation sensors (optical, radar, and DSIF), and a computer for computation of guidance and display signals for normal and abort trajectories. Weights for major components are presented in Figure 3-3. Weights are compared with the 14-day Gemini (Reference 3-1) in Figure 3-4. Power requirements are presented in Figure 3-5.

Inertial System - The inertial system monitors launch vehicle operation and measures accelerations and provides attitude reference during the lunar landing, lunar launch, and earth re-entry. It is normally off during translunar and transearth flight to conserve life and power. The system consists of the Gemini inertial measurement unit (IMU), with characteristics presented in Figure 3-6, and the associated electronics. A detailed comparison of IMU characteristics with those for the Apollo IMU (Figure 3-5, Volume I) reveals that the two equipments have essentially equal performance if the accuracy of the gimbal pickoffs in the Gemini IMU is improved. Since the Gemini IMU incorporates four platform gimbals (as compared with three gimbals in the Apollo IMU), it offers the advantage of complete angular maneuvering freedom of the spacecraft.

In the event of a failure, a strapdown IMU (included as part of the stabilization and control system) is used. The strapdown IMU operation is discussed in Section 3.1.4, Volume I.

[redacted]

GUIDANCE AND NAVIGATION SYSTEM WEIGHTS

SUBSYSTEM	WEIGHT - LB.	
	LUNAR GEMINI I	LUNAR GEMINI II & III
INERTIAL SYSTEM	119	119
OPTICAL MEASUREMENT UNIT	40	35
COMPUTER	62	62
RADARS	89	89
CHARTS AND STAR CATALOG	2	2
MISCELLANEOUS	29	59
TOTAL WEIGHTS	341	366

FIGURE 3–3

GUIDANCE AND NAVIGATION DETAIL WEIGHT SUMMARY

COMPONENT	EARTH-ORBITING GEMINI (14-DAY)			LUNAR GEMINI I			LUNAR GEMINI II & III		
	LOCATION	WT.-LB.	VOL.-FT.^{3}	LOCATION	WT.-LB.	VOL.-FT.^{3}	LOCATION	WT.-LB.	VOL.-FT.^{3}
INERTIAL SYSTEM									
IMU	CM	32	0.5	CM	32	0.50	CM	32	0.50
IMU ELECTRONICS	CM	87	1.5	CM	87	1.50	CM	87	1.50
OPTICAL MEASUREMENT UNIT									
AUTOSEXTANT	—	—	—	SM	40	1.10	—	—	—
MANUAL SEXTANT	—	—	—	—	—	—	CM	27	0.60
TELESCOPE	—	—	—	—	—	—	CM	8	0.20
COMPUTER SYSTEM									
COMPUTER	CM	62	1.0	CM	62	1.00	CM	62	1.00
COMPUTER SPARES	—	—	—	—	—	—	—	—	—
RADARS									
RENDEZVOUS RADAR AND ANTENNA	—	—	—	—	—	—	—	—	—
TRACKING RADAR	—	—	—	TLM	55	1.00	TLM	55	1.00
ANTENNA - TRACKING RADAR	—	—	—	TLM	—	18" DIA.	TLM	—	18" DIA.
LANDING RADAR	—	—	—	TLM	17	1.00	TLM	17	1.00
ANTENNA - LANDING RADAR	—	—	—	TLM	17	14" DIA.	TLM	17	14" DIA.
DISPLAYS AND CONTROLS									
CHARTS AND STAR CATALOG	CM	2	0.1	CM	2	0.10	CM	2	0.10
MAP AND VISUAL DISPLAY	—	—	—	—	—	—	—	—	—
MISCELLANEOUS									
NAVIGATION BASE	—	—	—	—	—	—	CM	10	0.10
STRUCTURAL SUPPORTS	CM	9	0.1	CM	9	0.10	CM	9	0.10
ELECTRICAL PROVISIONS	CM	11	0.2	CM	11	0.20	CM	18	0.60
ENVIRONMENTAL CONTROL	CM	6	0.1	CM	6	0.10	CM	6	0.10
SUN SENSOR	—	—	—	SM	3	0.05	SM	3	0.05
ROLL MOMENTUM WHEEL	—	—	—	—	—	—	SM	13	0.10
TOTALS		209	2.5		341	6.65		366	6.95

FIGURE 3–4

[redacted]

WATT HOUR REQUIREMENTS - GUIDANCE AND NAVIGATION

LUNAR GEMINI I

EQUIPMENT	UNIT WATTS	LAUNCH (0.2)	INJECT (2)	TRANSLUNAR (56)	MIDCOURSE CORRECTION (4)	LUNAR ORBIT (2)	LUNAR LAND (1.3)	LUNAR REST (48)	LUNAR LAUNCH (4)	TRANSEARTH (80)	MIDCOURSE CORRECTION (4)	RE-ENTRY (0.5)	POST LAND (24)
INERTIAL MEASUREMENT UNIT	370	74 (0.2)	740 (2)	–	–	740 (2)	481 (1.3)	–	1480 (4)	–	–	185 (0.5)	–
IMU ELECTRONICS	100	20 (0.2)	200 (2)	–	400 (4)	200 (2)	130 (1.3)	–	400 (4)	–	1480 (4)	50 (0.5)	–
OPTICAL MEASUREMENT UNIT	50	–	100 (2)	550 (11)	200 (4)	100 (2)	65 (1.3)	–	100 (2)	550 (11)	1480 (4)	–	–
COMPUTER	90	18 (0.2)	180 (2)	–	360 (4)	180 (2)	117 (1.3)	–	360 (4)	–	1480 (4)	45 (0.5)	–
TRACKING RADAR	60	–	–	–	–	120 (2)	78 (1.3)	–	–	–	–	–	–
LANDING RADAR	100	–	–	–	–	–	130 (1.3)	–	–	–	–	–	–

LUNAR GEMINI II & III

EQUIPMENT	UNIT WATTS	LAUNCH (0.2)	INJECT (2)	TRANSLUNAR (56)	MIDCOURSE CORRECTION (4)	LUNAR ORBIT (2)	LUNAR LAND (1.3)	LUNAR REST (48)	LUNAR LAUNCH (4)	TRANSEARTH (80)	MIDCOURSE CORRECTION (4)	RE-ENTRY (0.5)	POST LAND (24)
INERTIAL MEASUREMENT UNIT	370	74 (0.2)	740 (2)	–	–	740 (2)	481 (1.3)	–	1480 (4)	–	–	1.85 (0.5)	–
IMU ELECTRONICS	100	20 (0.2)	200 (2)	–	400 (4)	200 (2)	130 (1.3)	–	400 (4)	–	1480 (4)	50 (0.5)	–
OPTICAL MEASUREMENT UNIT	150	–	300 (2)	1650 (11)	600 (4)	300 (2)	–	–	300 (2)	1650 (11)	600 (4)	–	–
COMPUTER	90	18 (0.2)	180 (2)	–	360 (4)	180 (2)	117 (1.3)	–	360 (4)	–	1480 (4)	45	–
TRACKING RADAR	60	–	–	–	–	120 (2)	78 (1.3)	–	–	–	–	–	–
LANDING RADAR	100	–	–	–	–	–	130 (1.3)	–	–	–	–	–	–
ROLL MOMENTUM WHEEL	64	–	–	–	–	–	–	–	–	192 (3)	–	–	–

NOTE: FIGURES IN PARENTHESES ARE HOURS, EITHER FOR PHASE OR FOR OPERATION OF EQUIPMENT

FIGURE 3-5

GEMINI INERTIAL MEASUREMENT UNIT (HONEYWELL)

FOUR GIMBALS:
1) OUTER GIMBAL – ROLL: 360°
2) SECOND GIMBAL – YAW: 360°
3) THIRD GIMBAL – INNER ROLL: ± 20°
4) INNER GIMBAL – PITCH: 360°

PICKOFFS:
1) TYPE: PRECISION RESOLVER AND SYNCHRO ANALOG PICKOFF
2) ACCURACY: 4 ARC MINUTES MINUTES R.M.S.

INITIAL ALIGNMENT ACCURACY:
1) OVER-ALL USING AUTOSEXTANT: 10 ARC MINUTES
2) OVER-ALL USING MANUAL SEXTANT: 5 ARC MINUTES

THREE GYROS:
1) TYPE: DGG 8001 B–17, MINIATURE INTEGRATING GYRO (MIG)
2) BIAS DRIFT (COMPENSATED): 0.1 DEG./HOUR
3) MASS UNBALANCE (COMPENSATED): 0.3 DEG./HOUR/G
4) ANISOELASTICITY: 0.02 DEG./HOUR/G^2

THREE ACCELEROMETERS:
1) TYPE: DGG 116A–9, PULSE REBALANCE
2) SCALE FACTOR ERROR STABILITY: 200 PPM
3) REBALANCE ACCURACY: 250 PPM

TEMPERATURE CONTROL:
1) OPERATING: 70° F. TO 88° F.

FIGURE 3–6

Optical Measurement Unit (OMU) - The autosextant measures the direction of the earth and moon relative to stars, measures the subtended angle of the diameters of the earth and moon, and determines the attitude of the spacecraft relative to the stars. The autosextant is a gimbal-mounted platform stabilized by two fixed star trackers (a third spare star tracker is also provided) and has the characteristics shown in Figure 3-7. The planet tracker on the star-stabilized platform utilizes an epicyclic scan to determine planet center and diameter when the planet is partially illuminated.

The development of a portable space sextant (not presently available) as a supplement or alternative to the autosextant may become attractive as studies of midcourse navigational techniques progress. Funded studies of this type are presently being conducted by Kollsman Instrument Company (Reference 3-2).

LUNAR GEMINI I
AUTOSEXTANT (NORTRONICS)

THREE GIMBALS SUPPORT PLATFORM:
1) OUTER – YAW: 360°
2) MIDDLE – PITCH: ± 45°
3) INNER – ROLL: ± 45°

SUPPORT GIMBAL PICKOFFS:
1) ACCURACY: 1 ARC MINUTE

PLANET TRACKER:
1) ACCURACY OF PLANET DIRECTION: 8 ARC SECONDS SMOOTHED
2) ACCURACY OF PLANET SUBTENSE ANGLE: 6.5 ARC SECONDS SMOOTHED
3) MAXIMUM SUBTENSE ANGLE: 160°

FIGURE 3–7

Kollsman has completed six months of a nine month study, most of which has been devoted to a literature search. The studies have included manual techniques to determine orbital parameters, and manual measurements and computing schemes applicable to midcourse navigation. The results from these studies are summarized in Figure 3-8.

<u>Computer</u> - The computer is provided to monitor boost-orbit-injection trajectories, to determine trajectory corrections, and to determine abort trajectories. Inputs to the computer are from accelerometers, platform and sextant angle transducers, the radars, and the crew, via the manual keyboard. Outputs from the computer are displayed to the crew for trajectory and attitude control with outputs also fed to the telemetry system. Characteristics of the Gemini computer are summarized in Figure 3-9. Comparison of these characteristics with those for the Apollo computer (Figure 3-7, Volume I) reveals that the two equipments have essentially equal capability.

[redacted]

SUMMARY OF KOLLSMAN STUDIES

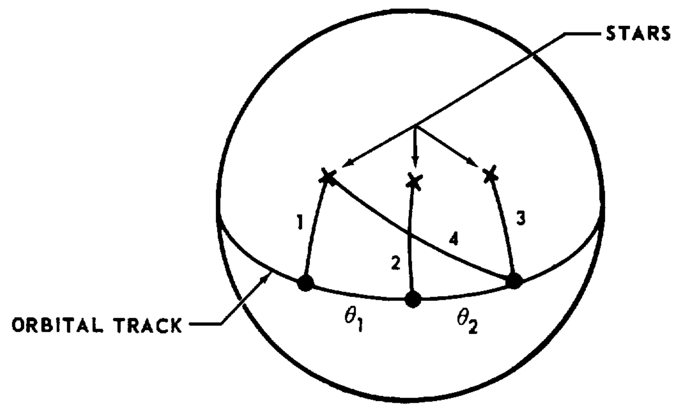
1. SAFETY OF ORBIT

TIME: IMMEDIATELY AFTER INJECTION
MEASUREMENTS (3): STADIAMETRIC RANGE WITH HAND HELD DEVICE
HORIZON REFERENCE: 5577° A AIRGLOW LINE
OUTPUTS:

QUANTITY	ACCURACY
ORBIT ECCENTRICITY	$\sigma_{\epsilon} = 0.001$
DISTANCE OF CLOSEST APPROACH	$\sigma_{d_c} = 2 - 3$ MI.
SEMI-MAJOR AXIS	
ORBITAL PERIOD	

2. ORBITAL PARAMETERS

GEOMETRY:



MEASUREMENTS (4): STAR–LOCAL VERTICAL
CALCULATIONS (2): θ_1 AND θ_2 BASED ON SAFETY OF ORBIT MEASUREMENTS AND TIME
COMPUTATIONS: USE ABOVE 4 MEASUREMENTS AND 2 CALCULATIONS TO ADJUST ARMILLARY SPHERE
OUTPUT: POSITION WITHIN 30 N.M.

3. MIDCOURSE (STADIAMETRIC)

MEASUREMENTS (6 OR MORE): STADIAMETRIC RANGE WITH HAND HELD DEVICE WITH ROTATING ELEMENTS FOR USE ON CRESCENTS
COMPUTATIONS: LANNING–BATTIN USING ANALOG COMPUTER
MEASUREMENT ACCURACY: $1\sigma = 20$ ARC SECONDS
OUTPUT: TRAJECTORY PARAMETERS

4. MIDCOURSE (TRIANGULATION)

MEASUREMENTS: STAR ELEVATION ANGLES USING SEXTANT
COMPUTATIONS: HUGHES MANUAL DIGITAL COMPUTER

5. MIDCOURSE (PHOTOGRAPHIC)

SAME AS ABOVE

FIGURE 3–8

GEMINI COMPUTER (IBM)

TYPE:
1) ORGANIZATION: GENERAL PURPOSE, BINARY, SERIAL, FIXED-POINT ARITHMETIC.
2) CONSTRUCTION: FIELD REPLACEABLE ENCAPSULATED MODULES.

MEMORY:
1) TYPE: RANDOM ACCESS, NON-DESTRUCTIVE READ-OUT
2) CAPACITY: 4096–39 BIT WORDS. DIVISION BETWEEN INSTRUCTION AND DATA STORAGE IS FLEXIBLE.

WORD MAKEUP (39 BITS):
1) DATA: 25 BITS AND SIGN/WORD.
2) INSTRUCTION: 13 BITS/INSTRUCTION.

ARITHMETIC TIMES:
1) ADD, SUBTRACT, TRANSFER – 140 MICROSECONDS.
2) MULTIPLICATION (FULL PRECISION) – 420 MICROSECONDS.
3) DIVISION (FULL PRECISION) – 840 MICROSECONDS
4) MULTIPLY OR DIVIDE MAY BE PROGRAMMED CONCURRENTLY WITH ADD, SUBTRACT, OR TRANSFER OPERATIONS.

CLOCK RATES:
1) 500 KC ARITHMETIC BIT RATE, 250 KC MEMORY CYCLE RATES.

INPUTS:
1) DISCRETES: 40
2) COUNTERS: 4
3) GIMBAL ANGLE CHANNELS: 3
4) DATA CHANNELS: 3

OUTPUTS:
1) DISCRETES: 20
2) COUNTERS: 3
3) DIGITAL ANALOG: 3
4) DATA CHANNELS: 2

FIGURE 3–9

Both computers can accommodate approximately 12,000 instructions. The Gemini computer is about four times faster and has the additional capability of simultaneously performing addition (or subtraction) and multiplication (or division). The Apollo computer uses less power but must operate for a longer time than the Gemini computer to solve the same problem. Thus from a computational viewpoint either computer is suited to a lunar mission. Since the Gemini computer interfaces are designed to match the rest of the Gemini guidance and navigation system, it is preferred over the Apollo computer.

<u>Radars</u> - A tracking radar and doppler radar are provided to make navigational measurements prior to and during lunar landing. The tracking radar measures altitude relative to the lunar surface during lunar orbit, and measures range and attitude relative to a transponder during lunar descent. The doppler radar measures altitude and three components of velocity during lunar landing. Characteristics of the Apollo radars are presented in Section 3.1.3, Volume I.

3.1.3 (Continued)

Charts and Star Catalog - A book of navigational charts, computer cross-check data, abort data, and a star catalog is provided for the astronauts.

3.1.4 Description - System for Lunar Gemini II and III - The equipment is the same as that for Lunar Gemini I (described in previous paragraphs) except that the Apollo-type sextant/telescope unit described in Section 3.1.3, Volume I performs the optical measurement functions.

3.1.5 System Operation - Operation of each of the three Lunar Gemini configurations is the same as described in Section 3.1.4, Volume I.

3.2 Stabilization and Control

3.2.1 Summary - The stabilization and control systems (SCS) for Lunar Gemini I, II, and III are identical. They are similar to the system used in Project Gemini (14-day) with provisions added for thrust vector control. The system weight is increased 89 pounds. As indicated in Figure 3-10, this weight increase is due to; (a), the addition of a strapdown IMU (17 lbs.), (b), an increase in control electronics capacity and the addition of a spare unit (60 lbs.), and (c), the addition of sun and Canopus sensors (12 lbs.). In addition, the horizon sensors are replaced by units more suitable for a lunar mission.

STABILIZATION AND CONTROL SYSTEM COMPARISON

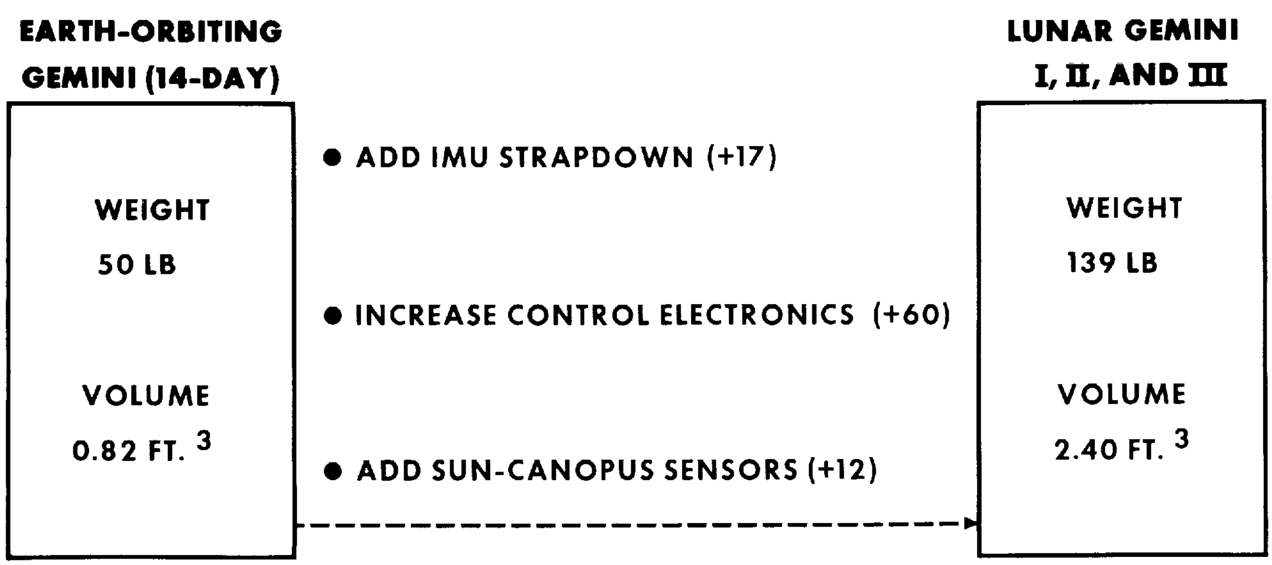


FIGURE 3-10

3.2.2 Operational Functions - The operational functions of the SCS are described in Section 3.2.2, Volume I.

3.2.3 System Description - The SCS consists of an IMU strapdown unit for short term attitude memory and longitudinal acceleration measurement, rate sensors, a control electronics unit for mechanization of control logic, and nongyroscopic

3.2.3 (Continued)

attitude sensors (sun-horizon-Canopus) for long-term attitude reference. Switches on the control panel provide selection of control modes. Weights for each of these subsystems are listed in Figure 3-11 and compared with weights for the 14-day Gemini (Reference 3-1) in Figure 3-12. Power requirements are listed in Figure 3-13.

LUNAR GEMINI I, II, AND III

STABILIZATION AND CONTROL SYSTEM WEIGHTS

SUBSYSTEM	WEIGHT - LB.
IMU STRAPDOWN	17
RATE SENSORS	9
CONTROL ELECTRONICS	90
SUN-HORIZON-CANOPUS SENSORS	12
DISPLAYS AND CONTROLS	—
MISCELLANEOUS	11
TOTAL VOLUME = 2.4 FT^3	TOTAL WEIGHT = 139 LB.

FIGURE 3-11

STABILIZATION AND CONTROL DETAIL WEIGHT SUMMARY

COMPONENT	EARTH-ORBITING GEMINI (14-DAY)			LUNAR GEMINI I			LUNAR GEMINI II & III		
	LOCATION	WT.-LBS.	VOL.-FT.^{3}	LOCATION	WT.-LBS.	VOL.-FT.^{3}	LOCATION	WT.-LBS.	VOL.-FT.^{3}
IMU STRAPDOWN									
INERTIAL REFERENCE	—	—	—	CM	12	0.30	CM	12	0.30
LONGITUDINAL ACCELEROMETER	—	—	—	CM	5	0.03	CM	5	0.03
RATE SENSORS									
RATE GYRO PACKAGE (2)	CM	9	0.10	CM	9	0.10	CM	9	0.10
RATE GYRO SPARE	—	—	—	—	—	—	—	—	—
CONTROL ELECTRONICS									
ATTITUDE CONTROL ELECTRONICS	CM	16	0.40	CM(2)	30	0.60	CM(2)	30	0.60
MANEUVER ELECTRONICS	SM	7	0.10	SM(2)	30	0.60	SM (2)	30	0.60
POWER SUPPLY	CM	7	0.10	CM(2)	30	0.40	CM(2)	30	0.40
SUN - HORIZON - CANOPUS SENSORS									
SUN SENSOR (2)	—	—	—	CM	2	0.05	CM	2	0.05
HORIZON SENSOR (2)	(REF. UNDER DISPLAYS)			(REF. UNDER DISPLAYS)			(REF. UNDER DISPLAYS)		
CANOPUS SENSOR (2)	—	—	—	SM	10	0.20	SM	10	0.20
DISPLAYS AND CONTROLS	—	—	—	—	—	—	—	—	—
MISCELLANEOUS									
STRUCTURE	—	—	—	—	—	—	—	—	—
ELECTRICAL PROVISIONS	CM	9	0.10	CM	9	0.10	CM	9	0.10
ELECTRICAL PROVISIONS	SM	2	0.02	SM	2	0.02	SM	2	0.02
ENVIRONMENTAL CONTROL	—	—	—	—	—	—	—	—	—
TOTALS		50	0.82		139	2.40		139	2.40

FIGURE 3–12

LUNAR GEMINI I, II, & III
WATT HOUR REQUIREMENTS - STABILIZATION AND CONTROL

EQUIPMENT	UNIT WATTS	LAUNCH (0.2)	INJECT (2)	TRANSLUNAR (56)	MIDCOURSE CORRECTION (4)	LUNAR ORBIT (2)	LUNAR LAND (1.3)	LUNAR REST (48)	LUNAR LAUNCH (4)	TRANSEARTH (80)	MIDCOURSE CORRECTION (4)	RE-ENTRY (0.5)	POST LAND (24)
IMU STRAPDOWN	9	—	—	—	36 (9)	—	—	—	—	—	36 (9)	—	—
RATE SENSORS	15	3 (0.2)	30 (2)	825 (56)	60 (4)	30 (2)	19.5 (1.3)	—	60 (4)	1200 (80)	60 (4)	7.5 (0.5)	—
CONTROL ELEC	3	0.6 (0.2)	6 (2)	168 (56)	12 (4)	6 (2)	3.9 (1.3)	—	12 (4)	240 (80)	12 (4)	1.5 (0.5)	—
MANUAL CONT	6	1.2 (0.2)	12 (2)	336 (56)	24 (4)	12 (2)	7.8 (1.3)	—	24 (4)	480 (80)	24 (4)	3 (0.5)	—
DISPLAYS	30	6 (0.2)	60 (2)	330 (11)	120 (4)	60 (2)	39 (1.3)	—	120 (4)	330 (11)	120 (4)	15 (0.5)	—
POWER SUPPLIES	24	4.8 (0.2)	48 (2)	1340 (56)	96 (4)	48 (2)	31.2 (1.3)	—	96 (4)	1920 (80)	96 (4)	12 (0.5)	—
OPTICAL SENSORS	5	1 (0.2)	10 (2)	280 (56)	20 (4)	10 (2)	6.5 (1.3)	—	20 (4)	400 (80)	20 (4)	2.5 0.5	—

NOTE: FIGURES IN PARENTHESES ARE HOURS, EITHER FOR PHASE OR FOR OPERATION OF EQUIPMENT

FIGURE 3–13

3.2.3.1 IMU Strapdown - The IMU strapdown unit is identical to that described in Section 3.2.3, paragraph A of Volume I.

3.2.3.2 Rate Sensors - Two sets of three rate gyros are provided. One set is operated continuously to allow use of the manual rate command mode or automatic sensed rate modes without delay for rate gyro warm-up.

3.2.3.3 Control Electronics - This unit provides the same capability as the unit described in Section 3.2.3, paragraph C of Volume I, but consists of two sets of attitude control and maneuver electronics (ACME), used in Project Gemini Reference (3-3) with the following changes and additions:

A. Add wiring to allow use of the automatic sensed rate control mode which is available, but not used, in the Gemini computer and ACME.

B. Modify input mixing circuits and derived rate circuits to provide for control of the spacecraft as configuration varies with mission phase.

C. Add provisions for (a), derived rate control of yaw from the sun sensor, (b), derived rate control of pitch from either the horizon scanner or sun sensor, and (c), derived rate control of roll from the horizon scanner, canopus sensor, or DSIF antennas.

D. Remove the thrust chamber selection unit from ACME and provide thrust chamber selection for both ACME and direct control in a manually operated switching matrix.

E. Add provisions to allow simultaneous pitch, yaw, and forward acceleration control with the same set of longitudinal firing thrust chambers. This is necessary to retain attitude control when using the RCS for ullage and midcourse corrections.

3.2.3.3 (Continued)

F. Add electronics to provide manual rate command signals and automatic sensed rate control signals to the propulsion engine(s) gimbal servos for thrust vector control.

G. Add electronics to allow automatic linear acceleration control.

3.2.3.4 Non-Gyroscopic Attitude Sensors - The non-gyroscopic attitude sensors are identical to those described in Section 3.2.3, paragraph D of Volume I.

3.2.4 Control Modes - The control modes are the same as in Section 3.2.4 of Volume I.

3.2.5 Control Torque Devices - The criteria for selecting RCS thrust chamber sizes are the same as in Section 3.2.5 of Volume I. The estimated control accelerations are the same as those presented in Section 3.2.5, Volume I, except for the re-entry vehicle. The RCS in the re-entry module provides a $9.3^\circ/\text{sec.}^2$ roll acceleration and $12.7^\circ/\text{sec.}^2$ pitch and yaw accelerations. The roll acceleration may be doubled by using all the jets that can produce rolling moments instead of only half as is done in the earth-orbiting Gemini.

3.3 Environmental Control

3.3.1 Crew and Equipment - The environment for the equipment and crew in the Lunar Gemini I, II and III Spacecraft is controlled in the same manner as described in Volume I of this report for the Two-Man Apollo.

The crewmen are paralleled in a closed loop suit ventilating circuit having manually selectable ventilation rate and inlet temperature. The environmental control system (ECS) hardware is identical to that used in Project Gemini, except that different quantities of O_2, LiOH and H_2O are provided for the 8-day lunar mission. Figures 3-14 and 3-15 indicate the magnitude of the volume and weight changes for Lunar Gemini I, II and III. The same type pressure suits are utilized as intended for Project Gemini, thus requiring the torso of each crewman to be continuously ventilated. The cold plates provided for cooling the electronic equipment are mounted on the exterior surfaces of the cabin pressurized walls, permitting temperature control of the cabin walls to the average value of the coolant fluid flowing through the cold plates. This nominal wall temperature supplements the ECS cabin heat exchanger in maintaining acceptable cabin gas temperatures.

ENVIRONMENTAL CONTROL SYSTEMS COMPARISON

14 DAY EARTH ORBITAL GEMINI		LUNAR GEMINI I
*WEIGHT 659.4 LB. VOLUME 13.41 FT.^{3}	● INCREASE SECONDARY OXYGEN SYSTEM +28.2 ● REDUCE PRIMARY OXYGEN SYSTEM −15.9 ● REDUCE LITHIUM HYDROXIDE SYSTEM −37.6 TOTAL −25.3	*WEIGHT 634.1 LB. VOLUME 12.86 FT.^{3}

*WEIGHT DOES NOT INCLUDE CIRCUITRY, STRUCTURE AND MOUNTING PROVISIONS

FIGURE 3-14

ENVIRONMENTAL CONTROL SYSTEMS COMPARISON

14 DAY EARTH ORBITAL GEMINI		LUNAR GEMINI II & III
*WEIGHT 659.4 LB. VOLUME 13.41 FT.^{3}	● INCREASE SECONDARY OXYGEN SYSTEM +28.2 ● REDUCE PRIMARY OXYGEN SYSTEM −15.9 ● REDUCE LITHIUM HYDROXIDE SYSTEM −37.6 ● REDUCE COOLING WATER −3.0 TOTAL −28.3	*WEIGHT 631.1 LB. VOLUME 12.92 FT.^{3}

* WEIGHT DOES NOT INCLUDE CIRCUITRY, STRUCTURE AND MOUNTING PROVISIONS

FIGURE 3-15

3.3.2 <u>ECS Description</u> - The environmental control system is identical to that described in Section 3.3.2, Volume I, with the exception of water tank capacity.

3.3.3 <u>Operation</u> - The operational techniques required for the Lunar Gemini I, II and III Spacecraft are identical to those described in Sections 3.3.3, 3.3.4, 3.3.5, and 3.3.6, Volume I.

3.3.4 <u>Water Management</u> - The fuel cell water production (which varies with electrical load) and the effectiveness of the service module mounted radiator at the 39.5° angle selected, result in the water inventories shown in Figures 3-16 and 3-17. The water storage tankage in the service module is sized for 22 pounds of water in Lunar Gemini I and 26 pounds in Lunary Gemini II and III. The water quantities are based on the requirement for a two day stay at a lunar site that imposes the most severe usage of water.

LUNAR GEMINI I

WATER INVENTORY

- LUNAR LANDING AT SITE REQUIRING MAXIMUM H_2O USAGE
- TWO DAY LUNAR STAY
- 39½ DEG. CONICAL HALF ANGLE ON RADIATORS

MISSION PHASE *	COMMAND MODULE WATER TANK (LB.)	SERVICE MODULE WATER TANK (LB.)
EARTH LAUNCH	40	3
TRANS LUNAR	23	0
LUNAR REST	40	22
LUNAR LAUNCH	0	0
TRANSEARTH	1	0
POST LANDING	31**	0

*QUANTITIES SHOWN ARE AT START OF EACH INDICATED MISSION PHASE.

** 11 ADDITIONAL POUNDS OF WATER ARE IN THE SURVIVAL KIT.

FIGURE 3-16

LUNAR GEMINI II & III
WATER INVENTORY

- LUNAR LANDING AT SITE REQUIRING MAXIMUM H_2O USAGE
- TWO DAY LUNAR STAY
- 39½ DEG. CONICAL HALF ANGLE ON RADIATORS

MISSION PHASE*	COMMAND MODULE WATER TANK (LB.)	SERVICE MODULE WATER TANK (LB.)
EARTH LAUNCH	40	0
TRANSLUNAR	18	0
LUNAR REST	40	26
LUNAR LAUNCH	4	0
TRANSEARTH	6	0
POST LANDING	40**	0

*QUANTITIES SHOWN ARE AT START OF EACH INDICATED MISSION PHASE.
** 11 ADDITIONAL POUNDS OF WATER ARE IN THE SURVIVAL KIT.

FIGURE 3-17

3.3.5 Lunar Landing Site Effects - Lunar landing sites on the lighted side of the moon, at sites between +53° and -27° from the subsolar point, require supplementing the radiator cooling capacity by water evaporation. The effect of lunar landing site on initial (earth launch) water is shown in Figure 3-18. Landings on the dark side of the moon will require covering 125 square feet of the radiator to prevent freezing of the OS 139 coolant. Alternate techniques such as by-passing portions of the radiator may also be feasible.

EFFECT OF SELECTION OF LUNAR LANDING SITE ON INITIAL WATER REQUIREMENT

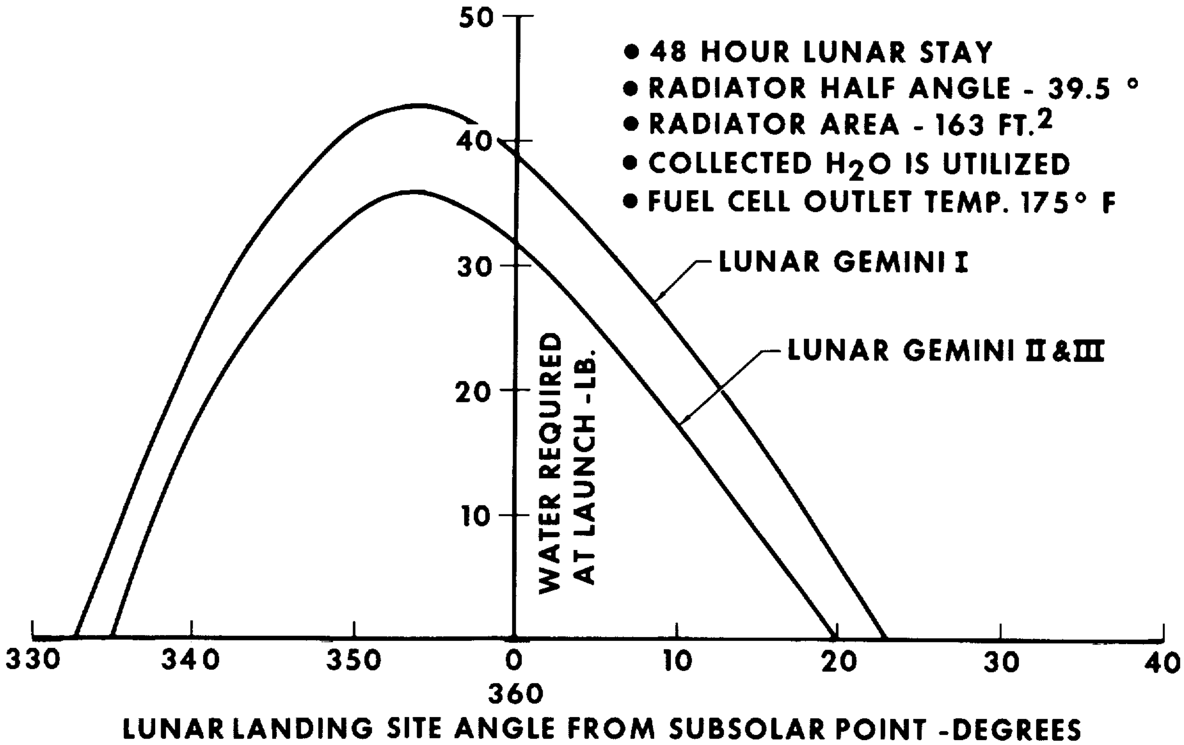


FIGURE 3-18

3.4 <u>Electrical Power</u> - The design objectives of the electrical power system for Lunar Gemini, are the same as presented in Section 3.4, Volume I. The system is similar to that used in Gemini (14-day) except for additional sequential controls and a reduction in fuel cell reactant weight. The total weight of the electrical power supply is 763 lbs for Lunar Gemini I and 802 lbs for Lunar Gemini II and III, distributed as shown in Section 4.8. Modifications accounting for the weight differences between the Lunar Gemini spacecraft and the 14-day Gemini are presented in Figures 3-19 and 3-20. The power supply schematic is identical to Figure 3-17, Volume I.

ELECTRICAL POWER SYSTEM COMPARISON

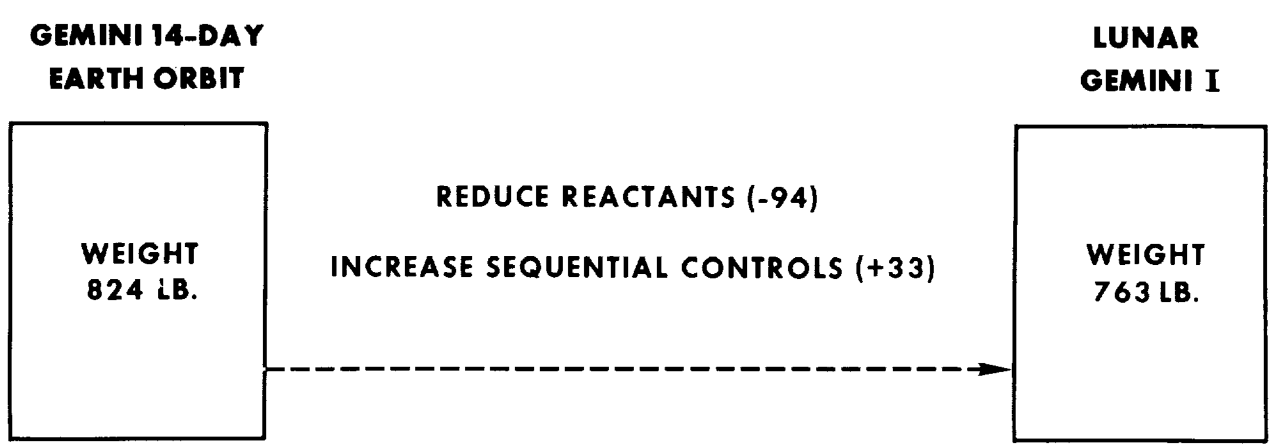


FIGURE 3-19

3.4 (Continued)

ELECTRICAL POWER SYSTEM COMPARISON

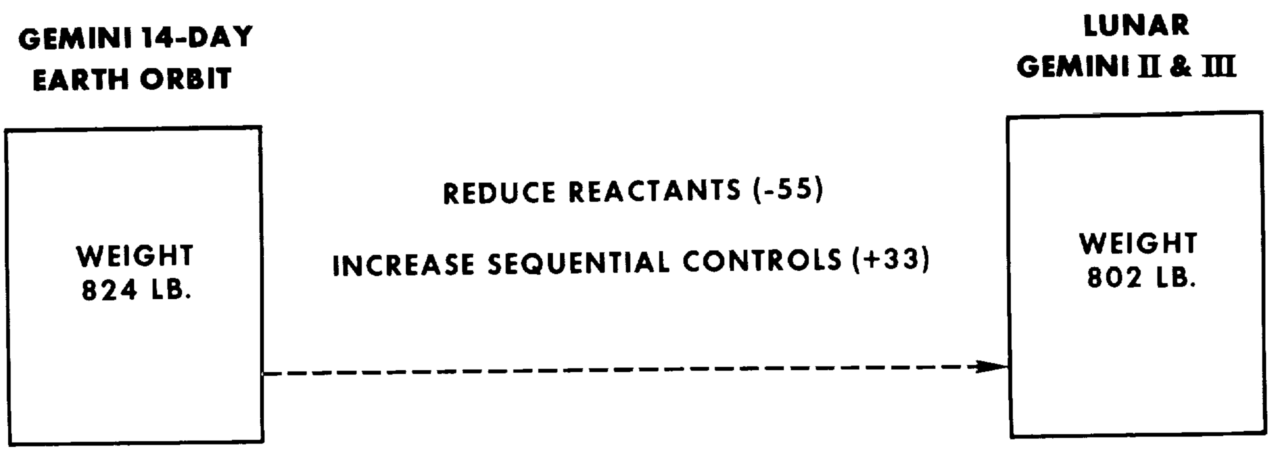


FIGURE 3-20

3.4.1 Power System Comparison - The power system comparison, contained in Section 3.4.1 of Volume I is applicable to Lunar Gemini.

3.4.2 Normal and Emergency Power Spectra - The general discussion in Section 3.4.2 of Volume I is applicable except that the total average electrical load during each mission phase is shown in Figure 3-21 and 3-22 for Lunar Gemini I and Lunar Gemini II and III, respectively. Tables 3-1 and 3-2 summarize individual system load requirements for Lunar Gemini I and Lunar Gemini II and III, respectively.

[redacted]

LUNAR GEMINI I
ELECTRICAL LOAD PROFILE
1.45 KW PEAK, 127 KW-HR AT 660 WATT AVERAGE

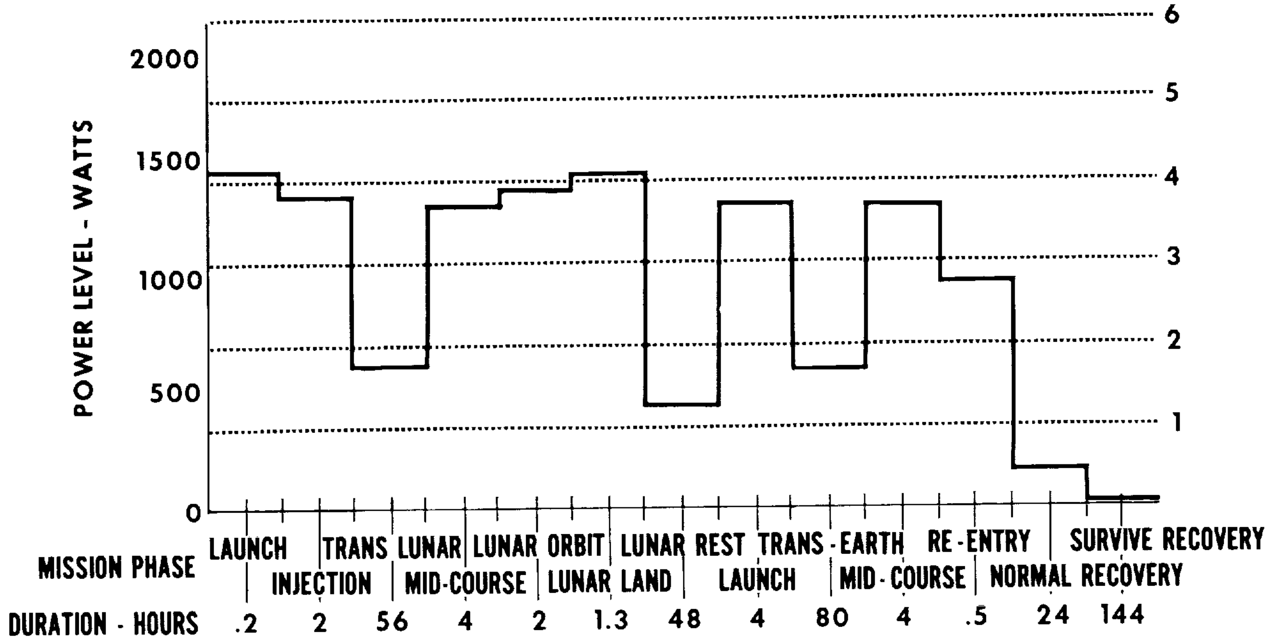


FIGURE 3-21

LUNAR GEMINI II & III
ELECTRICAL LOAD PROFILE
1.65 KW PEAK, 169 KW-HR AT 880 WATT AVERAGE

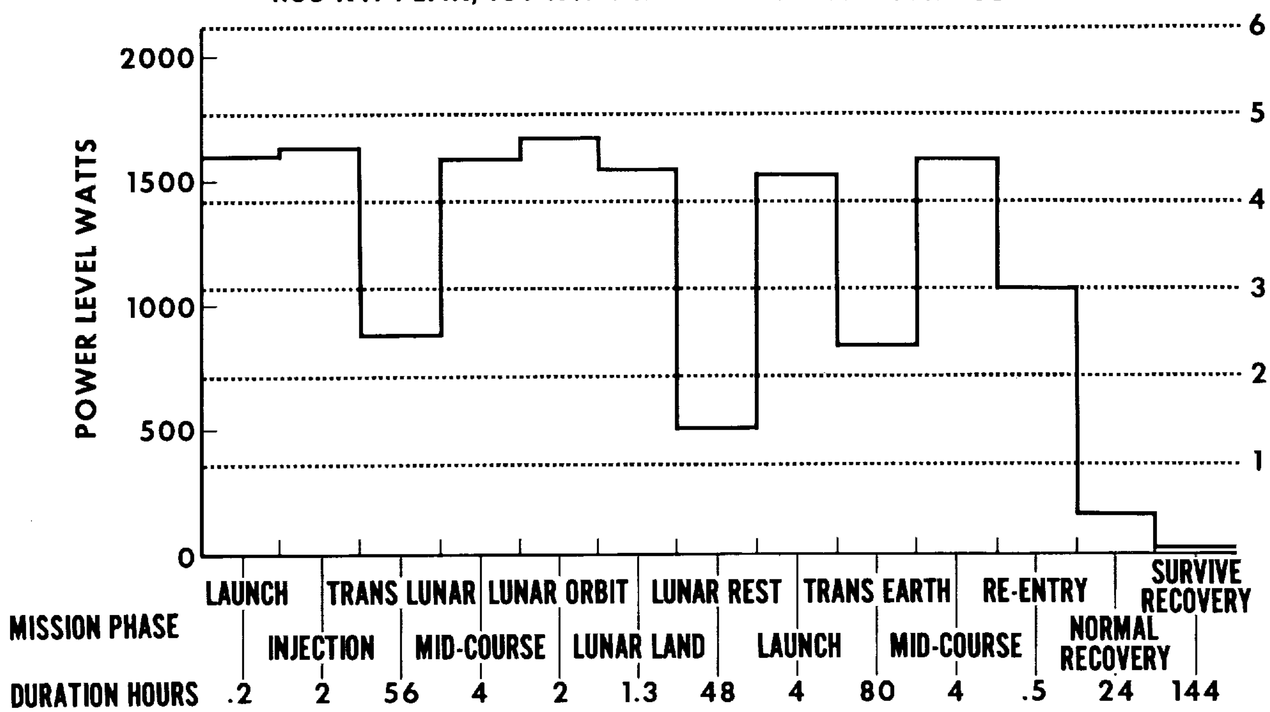


FIGURE 3-22

[redacted]

TABLE 3-1
LUNAR GEMINI I
ELECTRICAL LOAD SUMMARY - WATTS (AVERAGE)

EQUIPMENT	LAUNCH	INJECTION	TRANS LUNAR	MID COURSE	LUNAR ORBIT	LUNAR LAND	LUNAR REST	LAUNCH	TRANS EARTH	MID COURSE	RE-ENTRY	RECOVERY NORMAL	RECOVERY SURVIVE
COMMUNICATIONS	200	206	111	181	182	173	81	181	111	181	174	54	19
LIGHTING	33	33	33	33	33	33	33	33	33	33	33	33	—
ENVIRONMENTAL CONTROL	290	279	283	279	280	279	289	279	283	279	—	100	—
NAVIGATION & GUIDANCE	595	628	29	630	690	740	—	635	26	630	580	—	—
STABILIZATION & CONTROL	80	83	59	83	83	84	—	83	57	83	84	—	—
MISCELLANEOUS	260	117	100	112	120	120	59	110	74	112	88	19	—

TABLE 3-2
LUNAR GEMINI II AND III
ELECTRICAL LOAD SUMMARY - WATTS (AVERAGE)

EQUIPMENT	LAUNCH	INJECTION	TRANS LUNAR	MID COURSE	LUNAR ORBIT	LUNAR LAND	LUNAR REST	LAUNCH	TRANS EARTH	MID COURSE	RE - ENTRY	RECOVERY NORMAL	RECOVERY SURVIVE
COMMUNICATIONS	340	340	196	297	307	266	132	298	196	297	300	49	14
LIGHTING	33	33	33	33	33	33	33	33	33	33	33	33	—
ENVIRONMENTAL CONTROL	290	279	283	279	280	279	289	279	283	279	—	100	—
NAVIGATION & GUIDANCE	440	627	125	532	687	590	—	557	113	532	428	—	—
STABILIZATION & CONTROL	225	225	143	223	223	223	—	223	137	223	224	—	—
MISCELLANEOUS	260	117	100	112	120	119	59	110	74	112	88	19	—

[redacted]

3.4.3 Basic Generating Principle and Operating Modes - The discussion in Section 3.4.3 of Volume I is applicable except that reactants are provided for 660 watts and 880 watts, for Lunar Gemini I and Lunar Gemini II and III, respectively, for the 8 day duration.

3.4.4 Distribution and Regulation - The discussion in Section 3.4.4 of Volume I is applicable to Lunar Gemini.

3.4.5 Control Modes - The discussion in Section 3.4.5 of Volume I is applicable to Lunar Gemini.

3.4.6 Maintenance and Serviceability - The discussion in Section 3.4.6 of Volume I is applicable to Lunar Gemini.

3.4.7 Deviation from Apollo Statement of Work - The deviations discussed in Section 3.4.7 of Volume I are applicable to Lunar Gemini.

3.5 Telecommunications System

3.5.1 Summary - The telecommunication equipment for the Lunar Gemini spacecraft provides the same primary functions as in the Two-Man Apollo (Volume I). The system for Lunar Gemini I represents a minimum modification to the present Gemini. The equipment for Lunar Gemini II and III are essentially identical to that defined for the Two-Man Apollo and described in Section 3.5, Volume I. A summary weight comparison of these systems to those of Project Gemini is presented in Table 3-3.

TABLE 3-3

TELECOMMUNICATION SYSTEM WEIGHT COMPARISON

SUBSYSTEM	EARTH-ORBITING GEMINI (14-DAY MISSION)	LUNAR GEMINI I	LUNAR GEMINI II & III
DSIF SUBSYSTEM		39LB.	39 LB.
NEAR-EARTH SYSTEMS	54.54 LB.	18.1	53
INTERCOM	1.69	4.4	4.4
RECOVERY	9.8	6.3	6.8
DATA PROCESSING	31	31	60
SPARES	—	—	20
INSTRUMENTATION	41.43	88.1	116
ANTENNAS	24.29	104.6	105.9
WIRING, ENVIRONMENTAL & STRUCTURAL PROVISIONS	134.53	203	218
TOTAL WEIGHT	**287.29 LB**	**494.5 LB**	**673.1 LB**
TOTAL VOLUME	**5.488 FT^3**	**7.999 FT^3**	**10.237 FT^3**

3.5.2 Lunar Gemini I - The telecommunications system for Lunar Gemini I is functionally the same as described in Section 3.5, Volume I, however, primary consideration is given to maximum utilization of applicable components of the present Gemini. A detailed list of components is presented in Table 3-4. An electrical load analysis is contained in Table 3-5.

DIRECT FLIGHT APOLLO STUDY

TABLE 3-4
TELECOMMUNICATION DETAIL WEIGHT SUMMARY

SPACECRAFT / SUBSYSTEM	EARTH - ORBIT GEMINI 14 DAY			LUNAR GEMINI I			LUNAR GEMINI II & III		
	LOCATION	WT - LB	VOL - FT^3	LOCATION	WT - LB	VOL - FT^3	LOCATION	WT - LB	VOL - FT^3
DSIF SUBSYSTEM									
DSIF RECEIVER TRANSMITTER	—	—	—	SM (2)	9	.210	SM (2)	9	.210
DSIF POWER AMPLIFIER	—	—	—	SM (2)	30	.550	SM (2)	30	.550
NEAR EARTH SYSTEMS									
VHF/AM TRANSCEIVER	CM (2)	6.0	.076	CM (2)	6.0	.076	CM (2)	20	.350
VHF/FM TRANSMITTER	CM (2)	4.62	.052	CM (2)	4.62	.034	CM (2)	20	.210
C-BAND TRANSPONDER	CM (1)	7.49	.072	CM (1)	7.49	.072	CM (1)	13	.186
S-BAND TRANSPONDER	SM (1)	8.34	.072	—	—	—	—	—	—
ACQ. AID BEACON	SM (1)	1.13	.012	—	—	—	—	—	—
DIGITAL COMMAND	SM (1)	24.65	.470	—	—	—	—	—	—
VHF/FM TRANSMITTER	SM (1)	2.31	.026	—	—	—	—	—	—
INTERCOM									
RELAY TRANSCEIVER	—	—	—	CM (1)	3.0	.031	CM (1)	3.0	.031
CABIN SPEAKER	CM (1)	1.0	.004	CM (1)	1.0	.004	CM (1)	1.0	.004
HAND MIKE	CM (1)	0.69	—	CM (1)	0.4	—	CM (1)	0.4	—
RECOVERY									
HF VOICE/BEACON	CM (1)	3.5	.042	CM (1)	3.5	.042	CM (1)	4.0	.076
VHF RECOVERY	CM (1)	2.8	.024	CM (1)	2.8	.024	CM (1)	2.8	.024
HF VOICE T/R	SM (1)	3.5	.042	—	—	—	—	—	—
DATA PROCESSING									
LL COMMUTATOR	CM (1)	1.6	.035	CM (1)	1.6	.035	CM (2)	3.2	.070
LL COMMUTATOR	SM (1)	1.6	.035	SM (1)	1.6	.035	SM (2)	3.4	.070
HL COMMUTATOR	CM (1)	2.4	.035	CM (1)	2.4	.035	CM (4)	9.6	.140
HL COMMUTATOR	SM (1)	2.4	.035	SM (1)	2.4	.035	SM (2)	4.8	.070
PROGRAMMER	CM (1)	11.0	.203	CM (1)	11	.203	CM (1)	11.0	.203
RECORDER	CM (1)	12	.425	CM (1)	12	.425	CM (2)	28	.463
SPARES	—	—	—	—	—	—	CM	20	.400
INSTRUMENTATION									
SENSORS	CM	4.05	.081	CM	10	.200	CM	18	.500
SENSORS	SM	0.6	.001	SM	15	.300	SM	25	.500
SIGNAL CONDITIONING	CM	11.75	.328	CM	18.18	.328	CM	21	.328
SIGNAL CONDITIONING	SM	4.03	.250	SM	5.45	.250	SM	7.5	.250
16MM CAMERAS	—	—	—	—	—	—	CM (2)	20	.148
35MM CAMERA	—	—	—	CM (1)	5	.111	CM (1)	5	.111
TELESCOPE	—	—	—	CM (1)	5	.028	CM (1)	5	.028
TV CAMERA	—	—	—	—	—	—	CM (1)	12	.145
TV CAMERA	—	—	—	—	—	—	SM (1)	12	.145
TIMING	—	—	—	CM (1)	7.5	.194	CM	7.5	.194
PATCH PANELS	—	—	—	—	—	—	CM	12	.055
POWER SUPPLY	CM (1)	14	.028	CM (1)	14	.028	CM (1)	14	.028
POWER SUPPLY	SM (1)	7	.014	SM (1)	7	.014	SM (1)	7	.014
ANTENNAS									
DSIF ANT. & DRIVE	—	—	—	SM (2)	50	—	SM (2)	50	—
EARTH TRACKER	—	—	—	SM (2)	6	.042	SM (2)	6	.042
DSIF OMNI ANT.	—	—	—	SM (2)	0.5	.029	SM (2)	0.5	.029
C-BAND ANTENNA	CM (3)	1.7	.004	CM (3)	1.7	.004	CM (3)	3.0	.003
C-BAND ANTENNA	SM (1)	0.16	.002	—	—	—	—	—	—
PHASE MODULATOR	CM (1)	1.7	.026	CM (1)	1.7	.026	CM (1)	1.7	.026
VHF OMNI ANTENNA	CM (1)	0.2	.004	CM (1)	4	.007	CM (1)	4	.007
VHF OMNI ANTENNA	SM (1)	1.0	.020	—	—	—	—	—	—
MULTIPLEXER	CM (1)	3.5	.058	CM (1)	9	.151	CM (1)	9	.151
MULTIPLEXER	SM (1)	1.7	.058	—	—	—	—	—	—
S-BAND ANTENNA	SM (1)	0.69	.014	—	—	—	—	—	—
VHF RECOVERY ANT.	CM (1)	0.2	.004	CM (1)	1.25	.041	CM (1)	1.25	.041
HF RECOVERY ANT.	CM (1)	7.13	.144	CM (1)	4	.010	CM (1)	4.0	.010
ASSOC. COMPONENTS	CM	2.7	.054	CM	16.5	.320	CM	16.5	.32
ASSOC. COMPONENTS	SM	0.61	.013	SM	10.0	.200	SM	10.0	.20
VHF STUB ANTENNA	CM (1)	2.0	.040	—	—	—	—	—	—
VHF EXTENDABLE ANT.	SM (1)	1.0	.020	—	—	—	—	—	—
MISCELLANEOUS									
STRUCTURAL SUPPORTS	CM	15.73	.320	CM	20	.239	CM	20	.239
STRUCTURAL SUPPORTS	SM	21.70	.425	SM	40	.818	SM	40	.818
ENVIRONMENTAL CONTROL	—	—	—	CM	20	.407	CM	20	.407
ELECTRONIC INTERFACE	—	—	—	CM	8	.151	CM	8	.151
ELECTRICAL PROVISION	CM	72.10	1.420	CM	80	1.590	CM	90	1.590
ELECTRICAL PROVISION	SM	25.00	.500	SM	35	.700	SM	40	.700
TOTALS		287.28	5.488		494.59	7.999		673.15	10.237

[redacted]

3.5.2 (Continued)

TABLE 3-5

LUNAR GEMINI I

TELECOMMUNICATION ELECTRICAL LOAD - WATT HOURS

MISSION PHASE / SUBSYSTEM	SYSTEM LOAD WATTS	LAUNCH (0.2)*	INJECTION (2)	TRANSLUNAR (56)	MIDCOURSE CORRECTION (4)	LUNAR ORBIT (2)	LUNAR LANDING (1.3)	LUNAR REST (48)	LUNAR LAUNCH (4)	TRANSEARTH (80)	MIDCOURSE CORRECTION (4)	RE-ENTRY (0.5)	POST LANDING NORMAL (24)	POST LANDING SURVIVAL (144)
DSIF SUBSYSTEM	69.5	3.9	39	1372	278	139	90	1023	278	1960	278	—	—	—
NEAR-EARTH SYSTEMS	100	20	200	—	—	—	—	—	—	—	—	50	84	—
INTERCOM	9	1.2	12	336	24	12	7.8	360	24	480	24	3	144	—
RECOVERY	44.5	—	—	—	—	—	—	—	—	—	—	—	1068	2778
DATA PROCESSING	25	7	70	1455	140	55	46	1080	140	2080	140	12.5	—	—
INSTRUMENTATION	51	8	85	2500	250	125	80	1375	250	3560	250	21	—	—
ANTENNA SYSTEMS	12	—	6	560	40	40	—	46	40	800	40	—	—	—
PHASE TOTALS		40	412	6223	732	368	224	3884	732	8880	732	86.5	1286	2778
MISSION TOTAL	26,377.5 WATT-HOURS													

NOTE: FIGURES IN PARANTHESES DENOTE PHASE TIME IN HOURS

DSIF System - To enable the Gemini spacecraft to communicate at lunar distances, communication equipment compatible with the DSIF network is added. The DSIF equipment and associated antennas considered for this application are the same as those described in Section 3.5, Volume I.

Near Earth Systems - The VHF/AM voice transceivers and VHF/FM data transmitters of the Gemini are retained. Both provide an RF power output of 3 watts as compared to 20 watts for the comparable equipment of the Two-Man Apollo. As a result, communications during the transition from near-earth to DSIF operation may be interrupted on some missions. The C-Band transponder from Gemini is retained providing a peak power output of 1000 watts as compared to 2500 watts in the Two-Man Apollo.

Data Processing - The PCM data processing of the Gemini spacecraft is retained in this application. The equipment is capable of commutating and

3.5.2 (Continued)

encoding 300 channels of data at a composite rate of 50,000 bits per second. The tape recorder from Gemini is retained to provide temporary storage of data during periods when communication with earth is interrupted.

<u>Instrumentation</u> - The instrumentation for Lunar Gemini I is similar to that of the 14-day Gemini with the addition of photographic equipment and additional sensors. Television capability is not included.

<u>Other Systems</u> - The HF and VHF recovery systems from the Gemini spacecraft are retained. A relay transceiver is added to accomodate extravehicular communication.

3.5.3 <u>Lunar Gemini II and III</u> - Telecommunication for Lunar Gemini II and III is essentially the same as that described in Section 3.5, Volume I with the exception of minor variations resulting from the different command module configuration. A detail weight summary is contained in Table 3-4. The electric loads are considered to be the same as that shown in Table 3-9, Volume I.

3.6 Structure - Structural design is based on the criteria of Section 2.7. The command module factor of safety is 1.36, consistent with the present Gemini structural design philosophy. Command module primary structure is designed to withstand loads from launch abort, paraglider or parachute, pressurization and earth landing conditions. Primary structure below the command module is essentially the same as described in Section 3.6, Volume I.

Structural design launch loads for Lunar Gemini I and II command modules are the same as Gemini design loads and are shown in Figure 3-23. Lunar Gemini III command module launch and abort loads are shown in Figures 3-24 and 3-25.

3.6.1 Structural Description - Conventional spacecraft structures are employed in the Lunar Gemini spacecraft as described for the Two-Man Apollo spacecraft in Paragraph 3.6.1, Volume I.

3.6.2 Command Module - Lunar Gemini I and II command modules are structurally identical to the Gemini spacecraft except for certain equipment mounting details. The primary structure is mainly, AMS 4901 titanium and the basic shell is 0.010 titanium with longitudinal 0.020 - 0.025 titanium stiffeners. The crew compartment pressurized wall is located within the outer conical shell, and most of the equipment is located between this pressure wall and the outer shell. The equipment is accessible through removable structural panels in the structural shell. Two structural hatches are designed with adequate strength to permit rapid opening in sequence with the ejection seats during aborts at maximum dynamic pressure.

Ablation panels similar to those described in Paragraph 3.6.2, Volume I, provide afterbody thermal protection. The front face heat shield backup structure is a fiberglass honeycomb sandwich, similar to that used on Gemini, and is strengthened for the increased weight, and abort re-entry load factor. For this construction, the bond line temperature is limited to 500°F.

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LIMIT DESIGN LOADS
GEMINI RE-ENTRY MODULE
BOOST PHASE LOADS

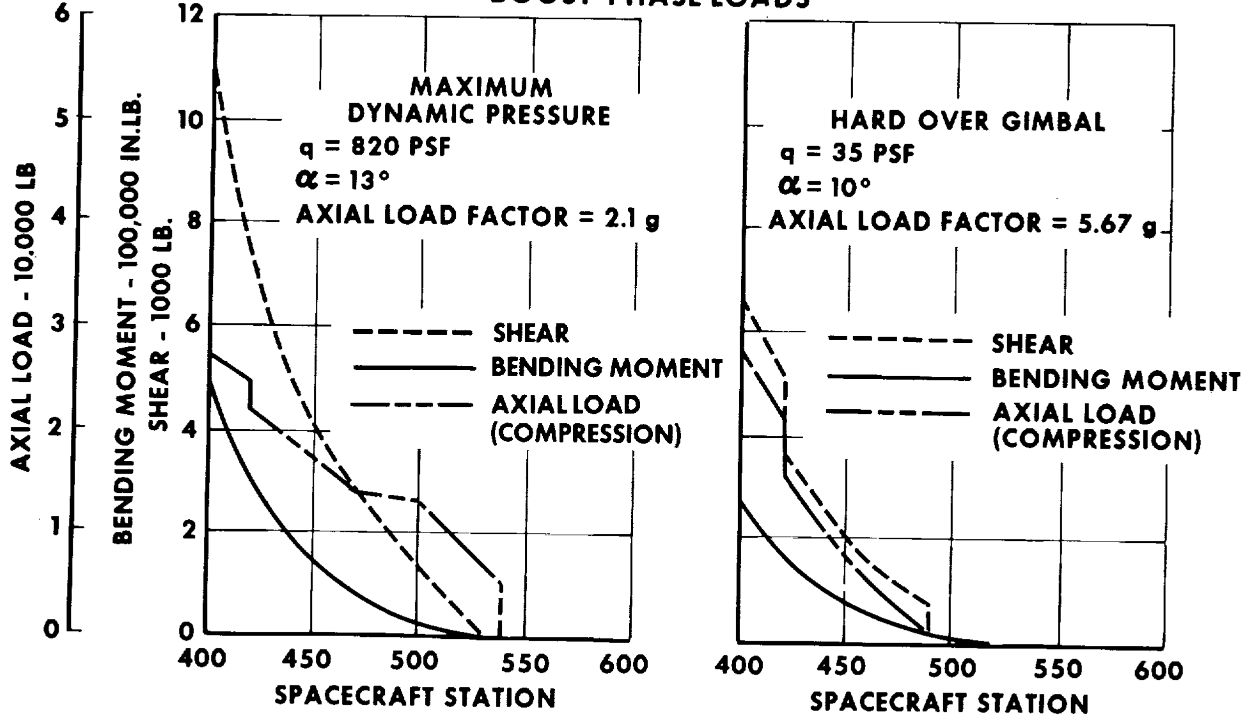


FIGURE 3-23

LUNAR GEMINI III
LIMIT DESIGN LOADS
BOOST PHASE

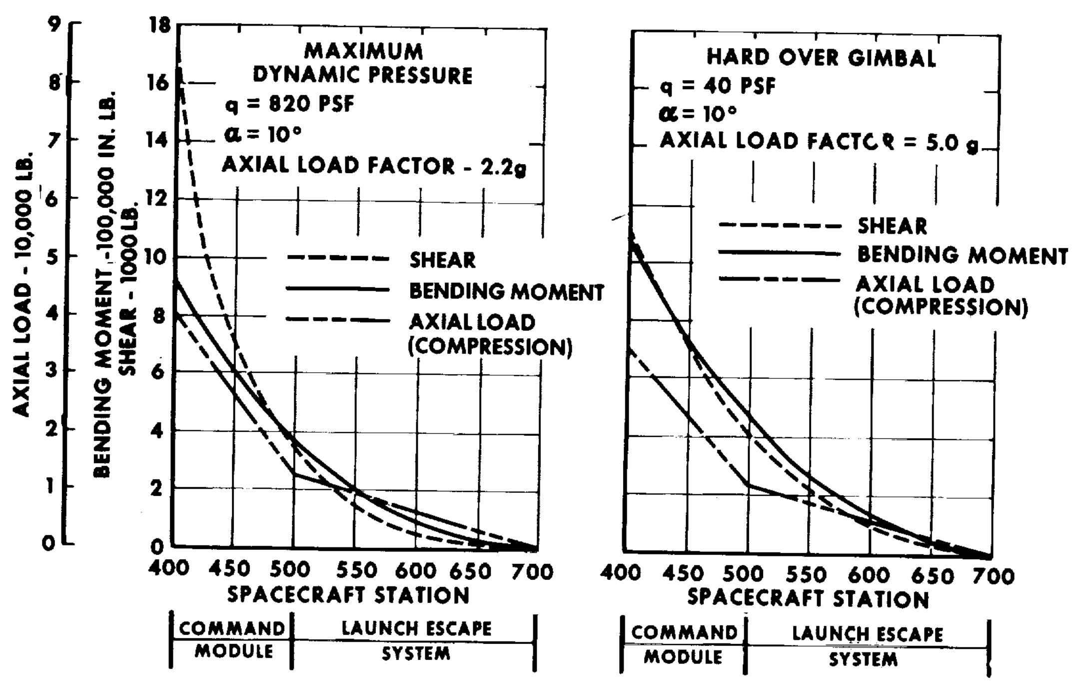


FIGURE 3-24

LUNAR GEMINI III

LIMIT DESIGN LOADS

TUMBLING ABORT

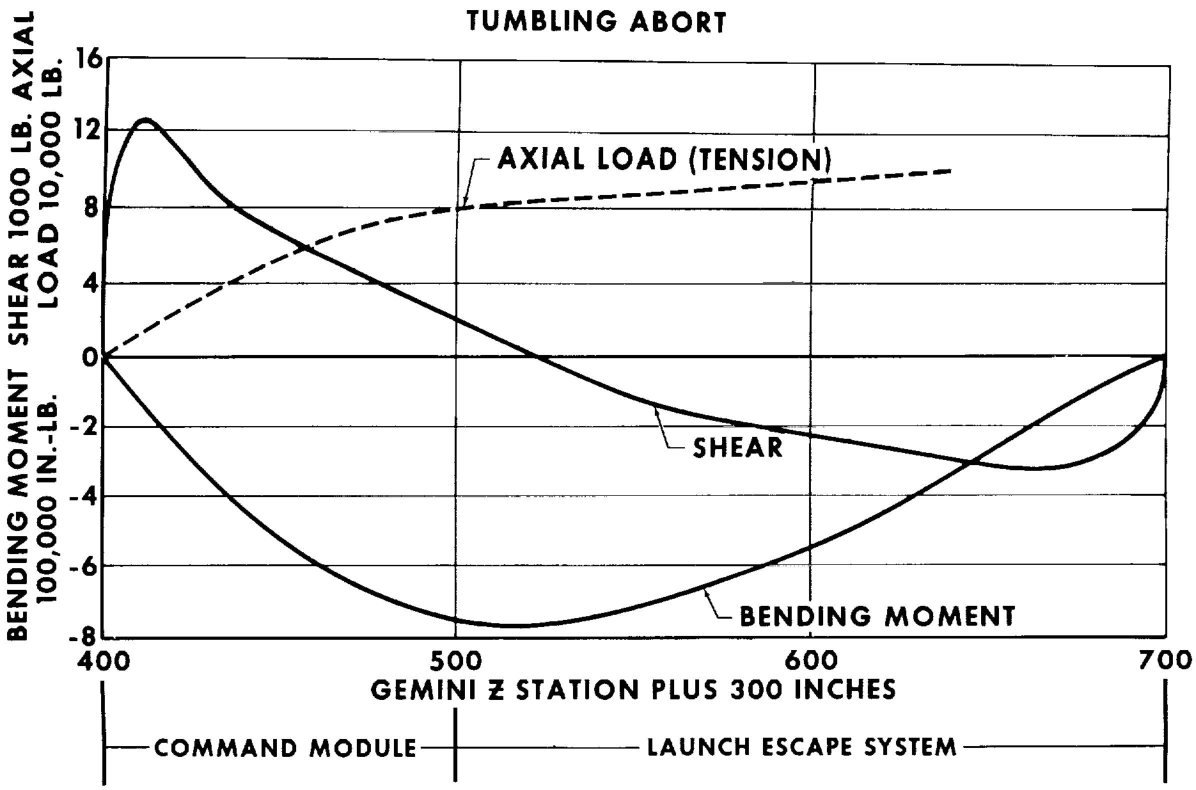


FIGURE 3-25

A

3.6.2 (Continued)

With some improvement in the state-of-the-art of beryllium fabrication, a heat shield structure of beryllium faced stainless steel honeycomb sandwich will allow a weight saving of 70 pounds for Lunar Gemini I or II and 50 pounds for Lunar Gemini III by permitting higher bond line temperatures thus substantially reducing the thickness of ablative material. The heat shield structures are illustrated in Figure 3-26.

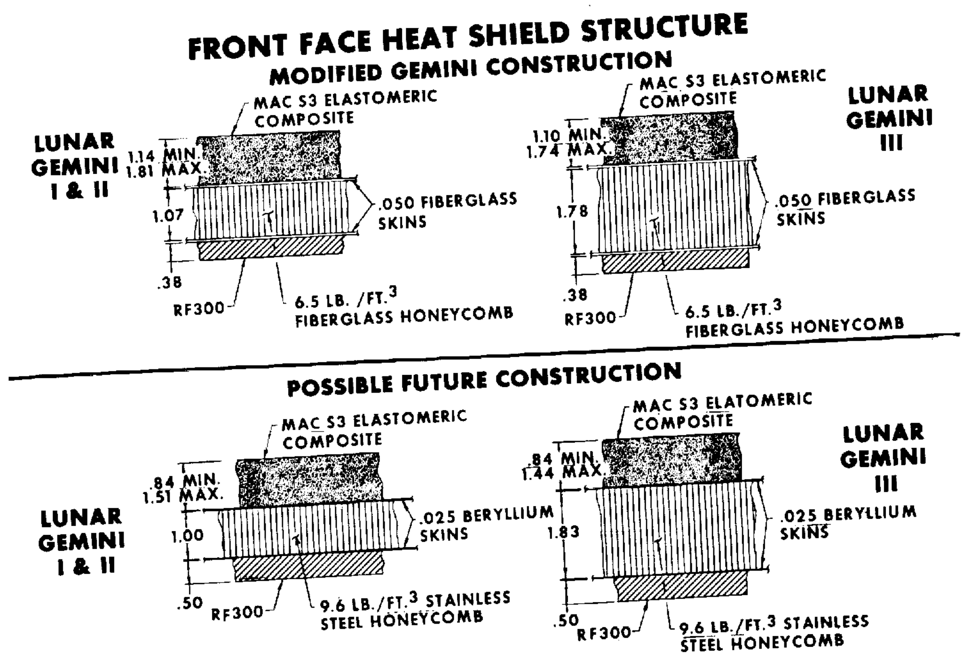


FIGURE 3–26

The Lunar Gemini III command module is basically the same as Lunar Gemini I except for structural reinforcements associated with the higher launch and abort loads due to the escape tower.

Structural modifications consist of increasing skin gages and stringer sizes in both the cylindrical and conical shell. Although basically the same as for Lunar Gemini I and II, the recovery compartment is completely redesigned to accommodate the escape tower and parachute.

3.6.2 (Continued)

Elimination of ejection seats on Lunar Gemini III permits a reduction in the weight of the escape hatch actuating system and associated structure since rapid opening of the hatches at the high dynamic pressures associated with launch escape is not required.

Lunar Gemini III command module structural modifications are shown in Figure 3-27.

Ultimate load factors on the order of 100 g's are anticipated on the Lunar Gemini III command module structure during land impact requiring structural changes for crew protection. Structural changes consist of adding a beam between the two crewmen, on the spacecraft centerline, and adding a beam below the crewmen between the two flat pressure walls. The cabin pressure walls are strengthened in the vicinity of the pressure bulkhead, and where attachment is made to the added beams in order to distribute the earth impact forces to the structural shell.

3.6.3 <u>Service Module</u> - The service module is similar to that described in Paragraph 3.6.1, Volume I, with longitudinal stiffeners increased one gage in thickness and radiator coolant tubes changed to beryllium to withstand the higher launch temperatures, as discussed in Paragraph 3.7.1.

3.6.4 <u>Terminal Landing Module</u> - The terminal landing module is the same as described in Paragraph 3.6.4, Volume I.

3.6.5 <u>Retrograde Module</u> - The retrograde module is the same as described in Paragraph 3.6.5, Volume I.

3.6.6 <u>Separation Joints</u> - Lunar Gemini separation joints are the same as described in Paragraph 3.6.6, Volume I, except for the command module to service module interface. These modules are structurally connected by three tension straps, cut at separation by dual flexible linear shaped charges (FLSC), which

LUNAR GEMINI II
STRUCTURAL MODIFICATIONS

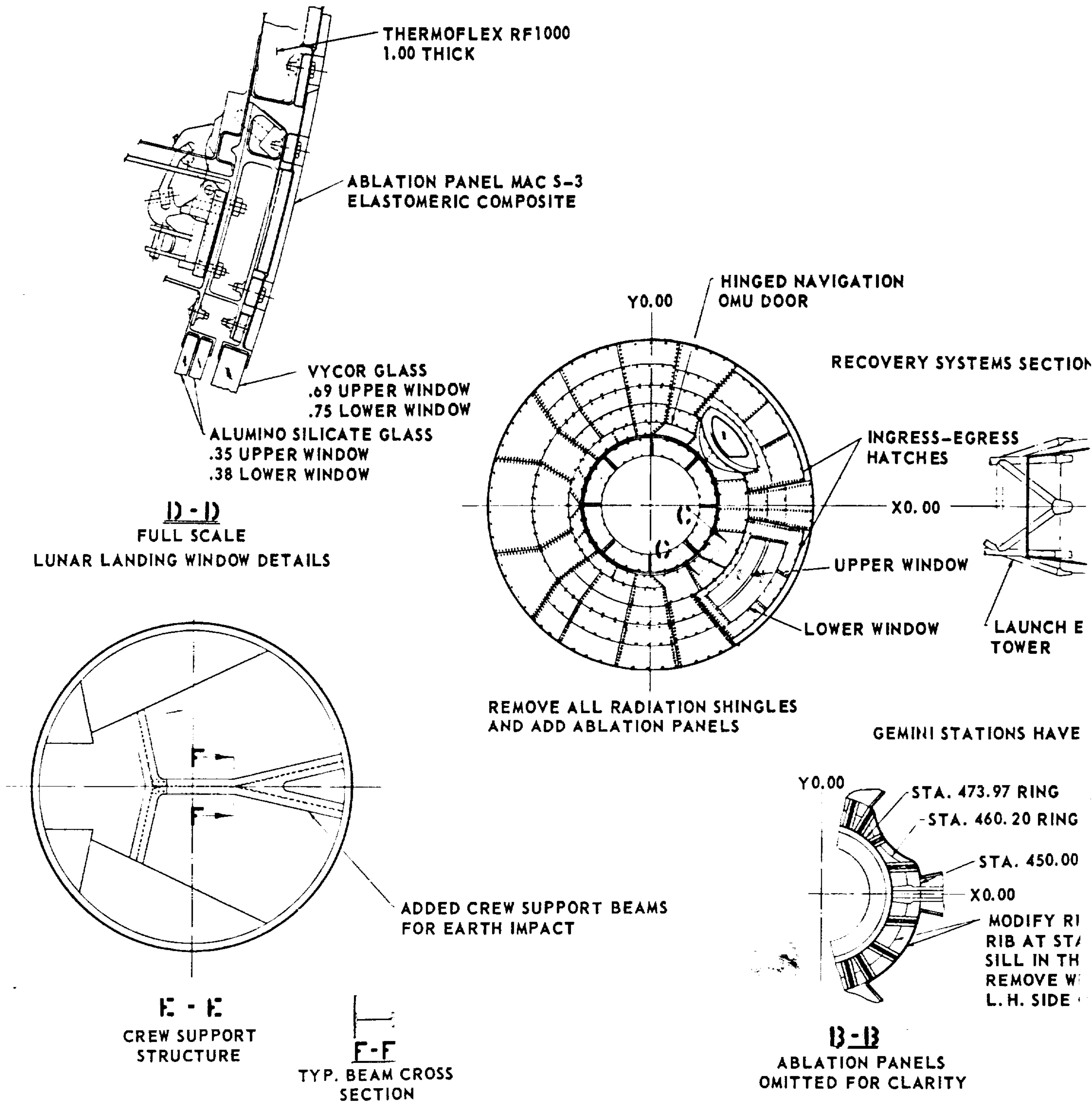


FIGURE 3-27

LUNAR GEMINI II
CTURAL MODIFICATIONS

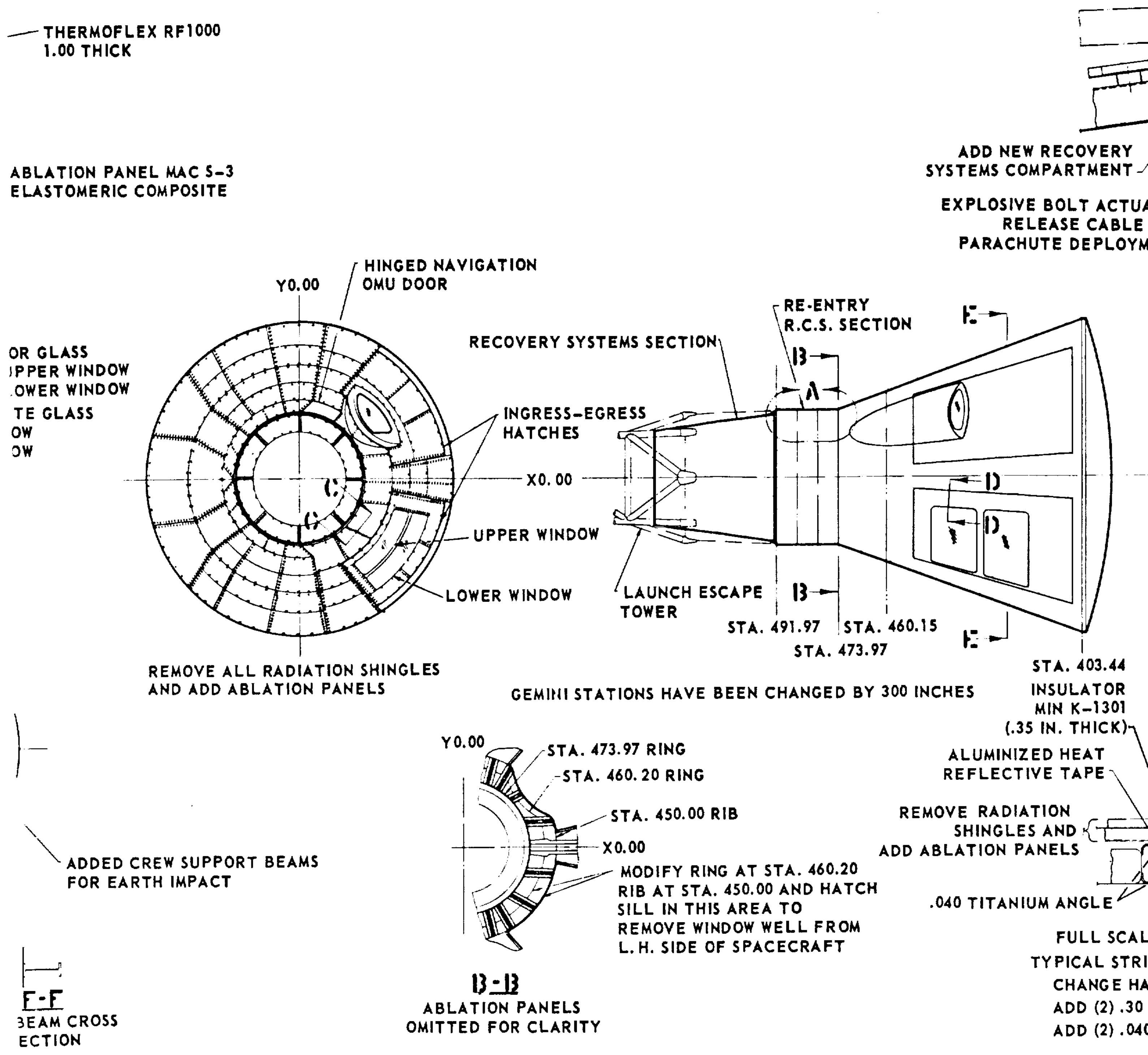
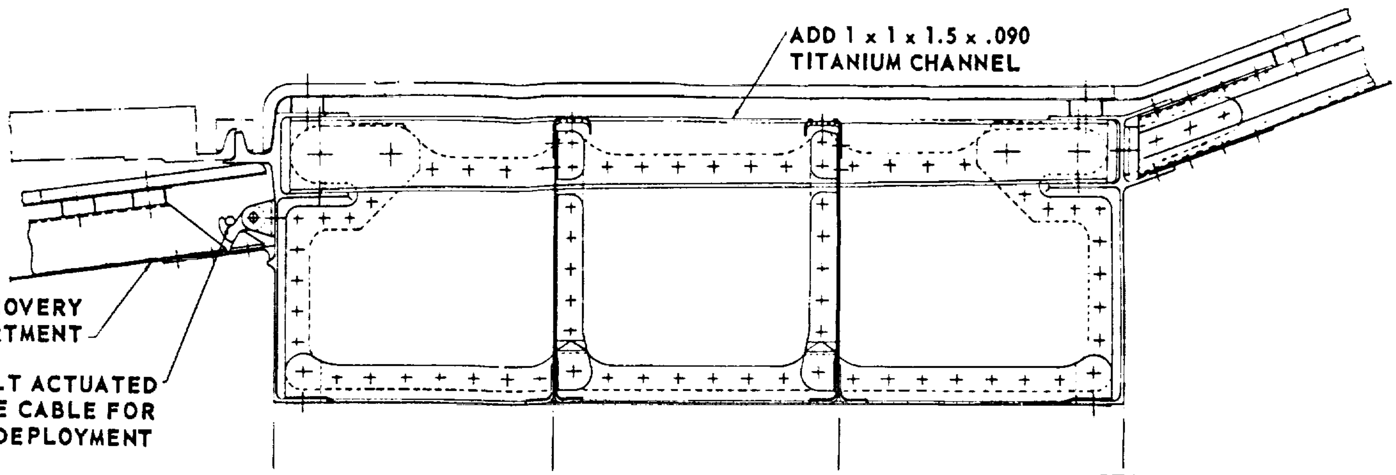
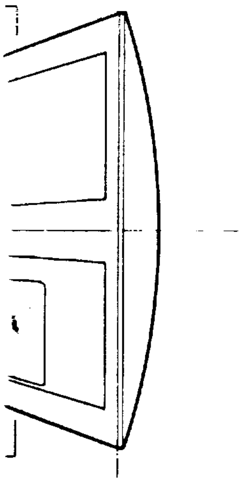


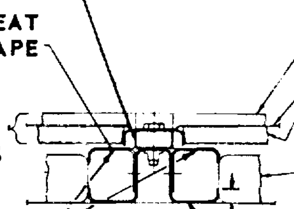
FIGURE 3-27



SECTION A
10 X SCALE

BASIC CHANGES FOR THE SECTION ARE:
1. REDESIGN RING AT STA. 491.97
2. REDESIGN RING AT STA. 473.97
3. ADD CHANNEL NEAR OUTER ML (8 PLACES).
4. REMOVE BERYLLIUM SHINGLES AND ADD MAC S-3
ELASTOMERIC COMPOSITE ABLATION PANELS





C - C
FULL SCALE ROTATED (130°)
TYPICAL STRINGER REDESIGN
CHANGE HAT GAGE FROM .032 TO .040
ADD (2) .30 FLANGES TO BASIC HAT
ADD (2) .040 TITANIUM ANGLES TO TOP OF HAT

SCALE IN INCHES

FOLDOUT FRAME 3

3.6.6 (Continued)

also sever wire bundles and fluid and oxygen lines. The FLSC's are pyrotechnically interconnected by mild detonating fuses (MDF) for positive all-fire assurance.

3.6.7 Tankage - The Lunar Gemini spacecraft utilize the same tankage as described in Paragraph 3.6.7, Volume I.

3.7 Heat Protection

3.7.1 Launch - Structural temperatures are determined using the Eckert reference temperature method, assuming a local transition Reynolds number of 100,000. Escape tower legs for Lunar Gemini III are covered with an ablative material as required, based on Project Mercury experience.

The selected design of a 39-1/2 degree half-cone angle on the service module and the 20° half-cone angle of the command module results in high local heating areas of the service module, caused by oblique shock wave impingement. In order to obtain high service module radiator efficiencies during space flight, and withstand the high aerodynamic heating during launch, beryllium is chosen for the external structure of the service module. With an external coating, which provides an emissivity of 0.8, the beryllium skins are expected to reach a peak temperature of 1225°F during launch.

3.7.2 Space Flight - External heat loads and passive environmental control of equipment discussed in Section 3.3, Volume I, are applicable to the Lunar Gemini spacecraft.

3.7.3 Re-entry - Re-entry heat loads are influenced by the amount of longitudinal range desired and the initial re-entry angle. Convective heating increases with increasing range, and gaseous radiative heating increases as the initial re-entry angle becomes steeper. The heat protection system is designed for re-entry within the heating limits of a shallow long range re-entry and by a 20 g structural limit steep re-entry. Re-entry heat loads following an abort do not exceed these design conditions.

A. Re-entry Heat Loads - Re-entry heat loads and heating distributions are determined by the methods discussed in Section 3.7.3, Volume I. The Project Mercury and preliminary Project Gemini wind tunnel test results are directly applicable to the convective heating distributions

3.7.3 (Continued)

on Lunar Gemini. The heating distributions for the front face and afterbody are as shown in Figures 3-27a and 3-27b.

FRONT FACE HEATING DISTRIBUTION

q''_{REF} BASED ON STAGNATION POINT OF HEMISPHERE (RADIUS = R_N)

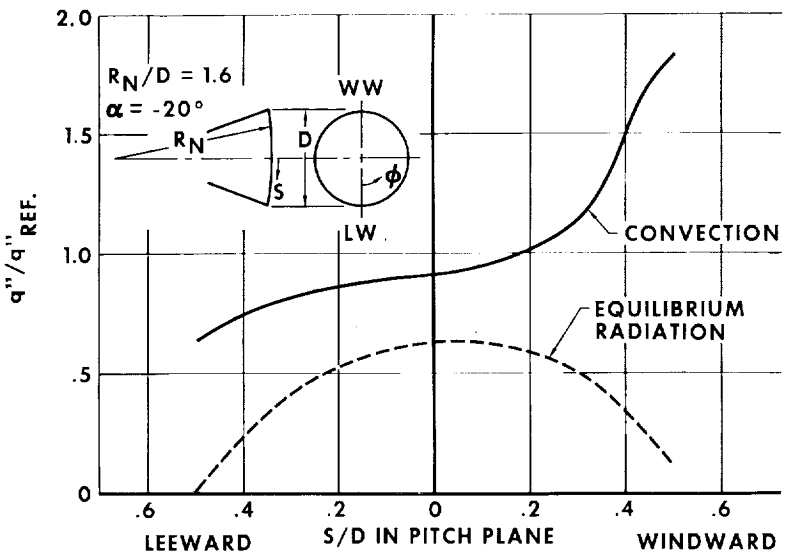


FIGURE 3-27a

ESTIMATED AFTERBODY CONVECTION DISTRIBUTION

q''_{REF} BASED ON STAGNATION POINT OF HEMISPHERE (RADIUS = R_N)

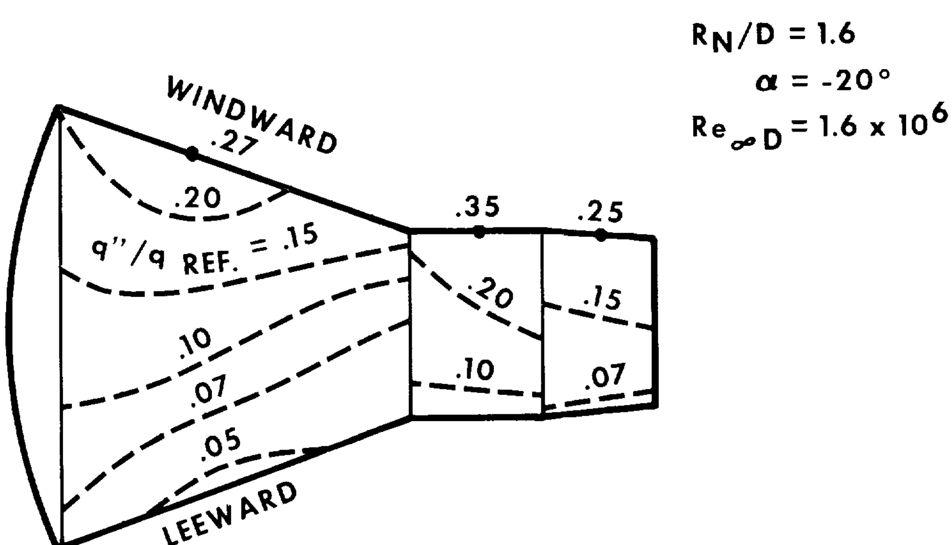


FIGURE 3-27b

3.7.3 (Continued)

B. Re-entry Heat Protection - The ablative material on the command module is M.A.C. Thermorad Shield S-3 elastomeric composite. (See Figures 2-3 and 3-26.) The selection of this material is discussed in Section 3.7.3, Volume I.

Command module ablative material distribution is determined with the following considerations:

1. A 1.15 factor applied to predicted heating rates.
2. Nominal thermophysical properties based on available test results.
3. Material behavior in the combined convection and gaseous radiation environment based on NASA-Ames investigations.

The front face ablative material distribution is shown in Figure 3-27c for Lunar Gemini I for a long range re-entry and a 20 g re-entry. The front face ablative heat shield is designed with linear thickness variations between several points which provides adequate ablative material for either re-entry condition. The resulting design thickness at several points on the front face and afterbody is shown in Figure 3-28. The ablative material thickness requirement is the same for Lunar Gemini I and II, and is slightly less for Lunar Gemini III. The resulting weights are shown in Figure 3-28.

The requirements for the insulation design are similar to the discussion in Section 3.7.3, Volume I. Insulation weights are summarized in Figure 3-28.

REQUIRED FRONT FACE ABLATIVE MATERIAL

MAC THERMORAD SHIELD S-3 ELASTOMERIC COMPOSITE
500°F MAXIMUM BOND TEMPERATURE

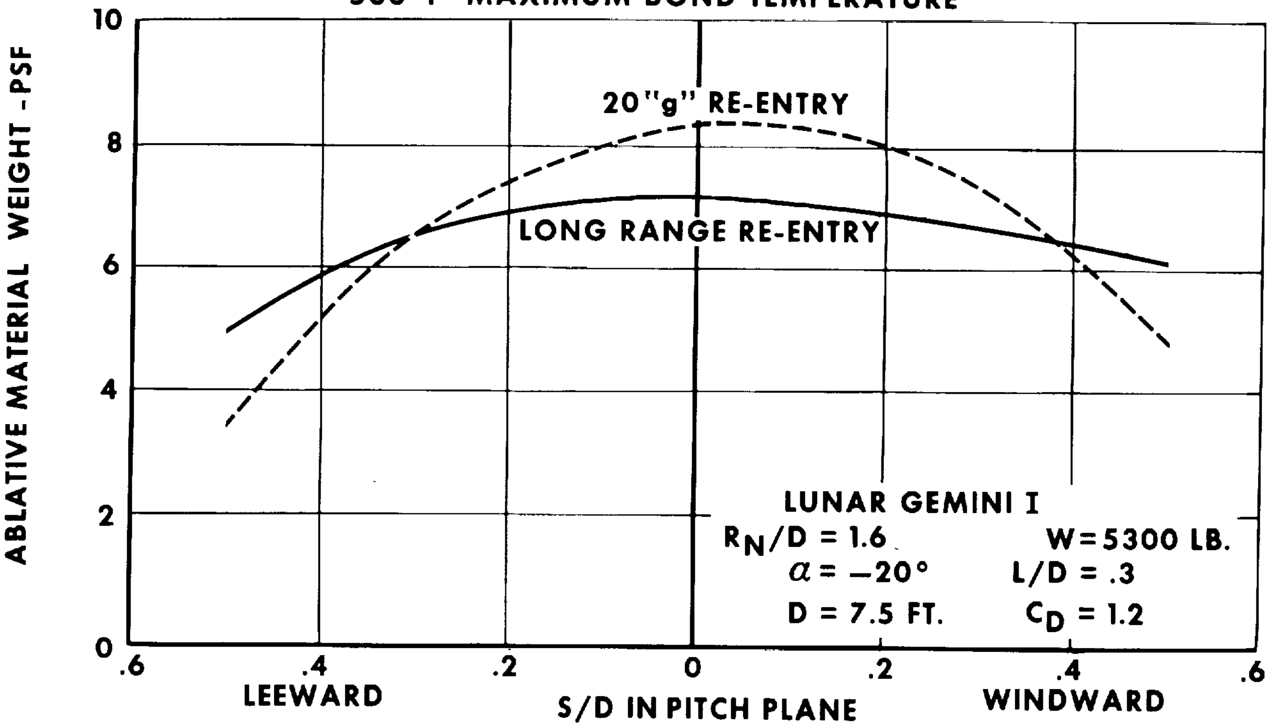
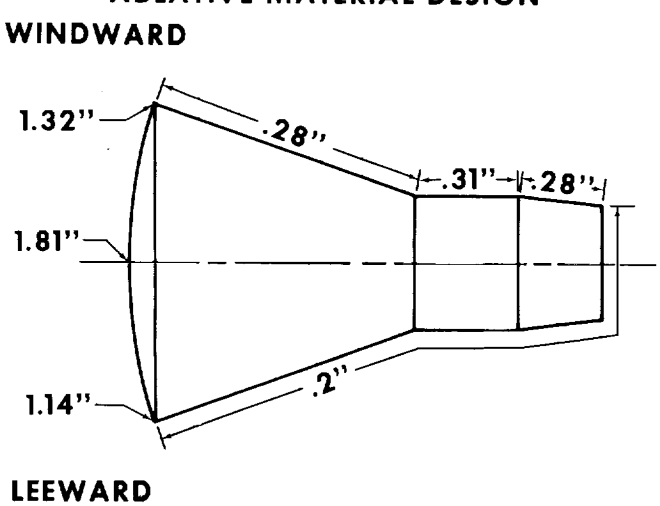


FIGURE 3–27c

LUNAR GEMINI I & II*

HEAT PROTECTION WEIGHT SUMMARY

ABLATIVE MATERIAL DESIGN



*LUNAR GEMINI III TOTAL IS 589 LB.

WEIGHT SUMMARY

FRONT FACE	
ABLATIVE MATERIAL (MAC THERMORAD SHIELD S-3, 55 PCF)	342 LB.
INSULATION (.375" RF 300, 3 PCF)	4 LB.
AFTERBODY	
ABLATIVE MATERIAL (MAC THERMORAD SHIELD S-3, 55 PCF)	169 LB.
INSULATION (1" RF 1000, 10 PCF & 1" RF 700, 7 PCF)	101 LB.
TOTAL	616 LB.*

FIGURE 3–28

[redacted]

BUBBLE CANOPY DETAIL

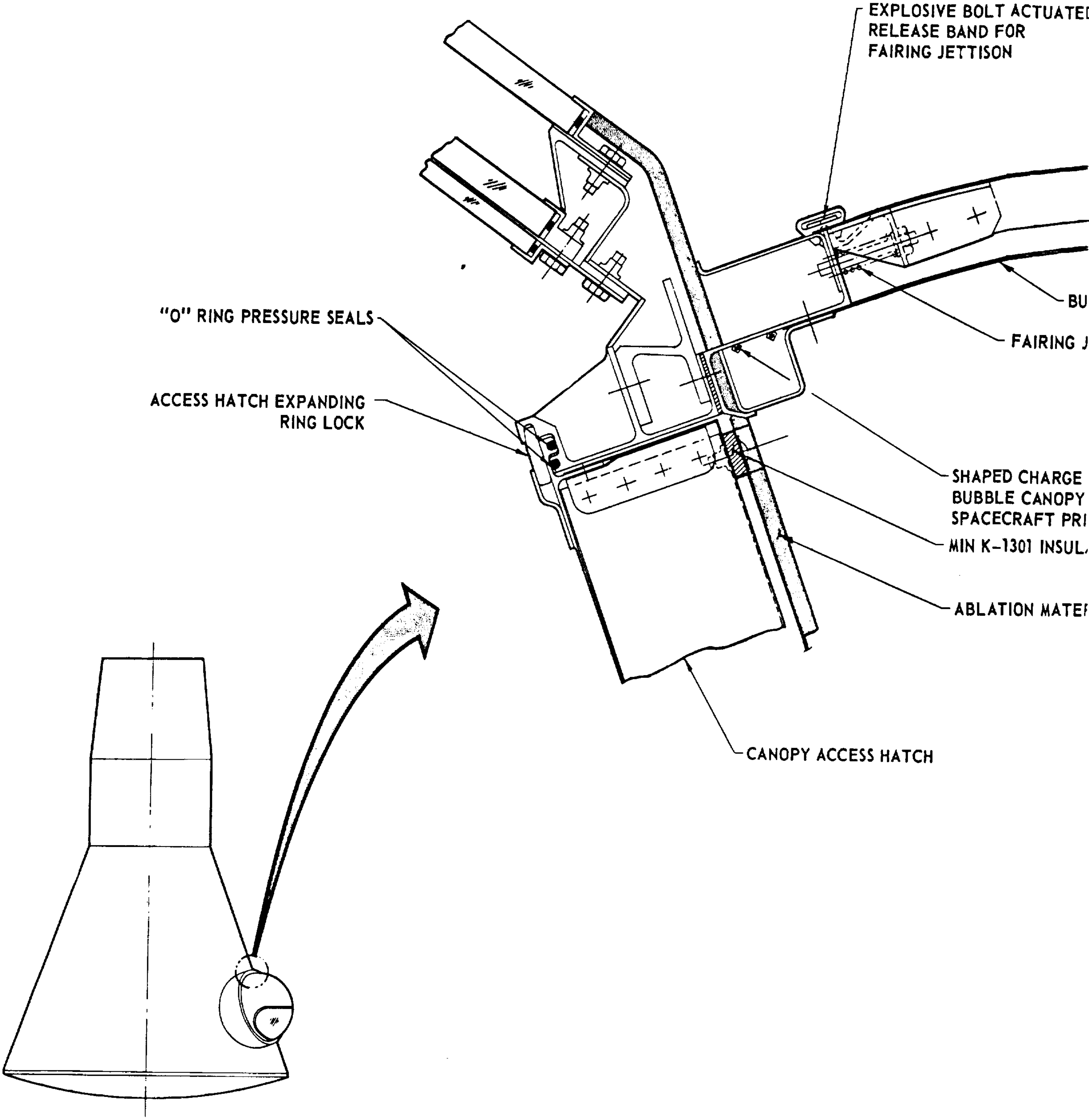
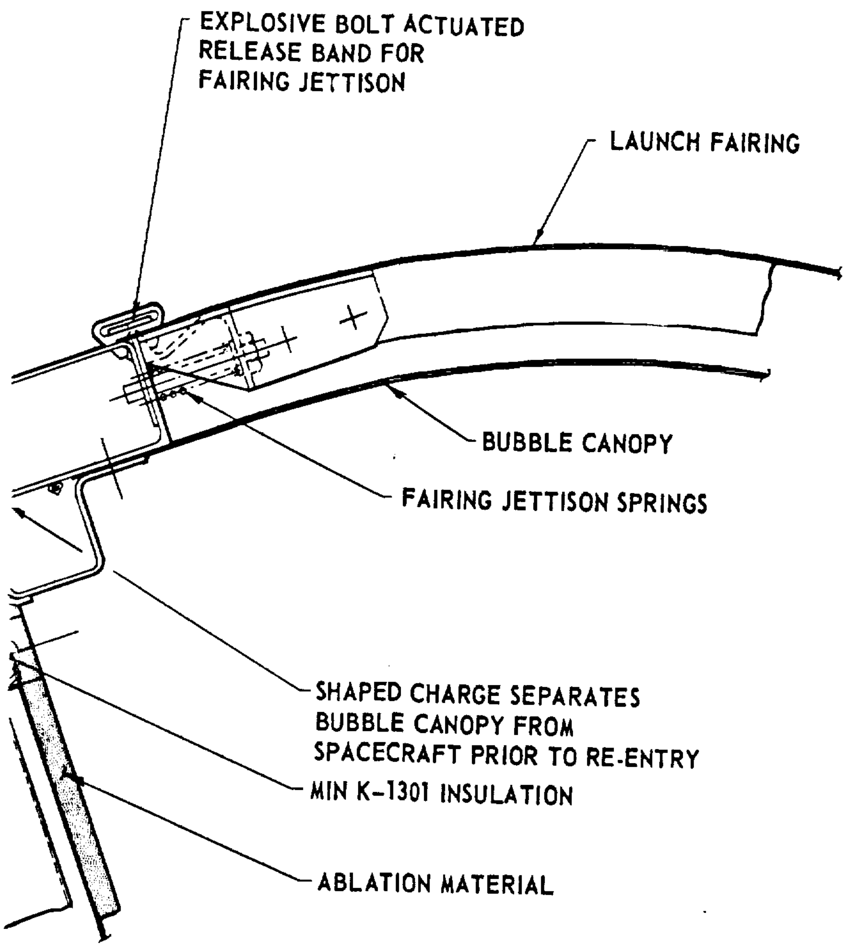
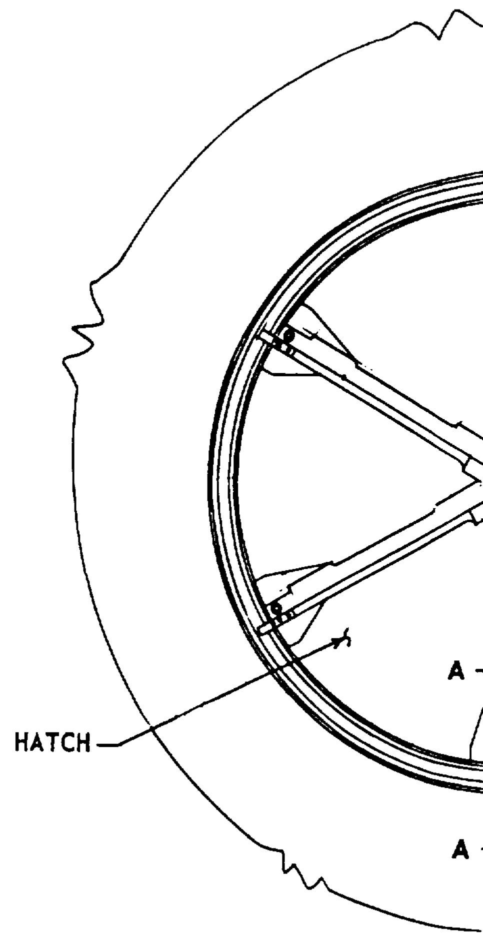


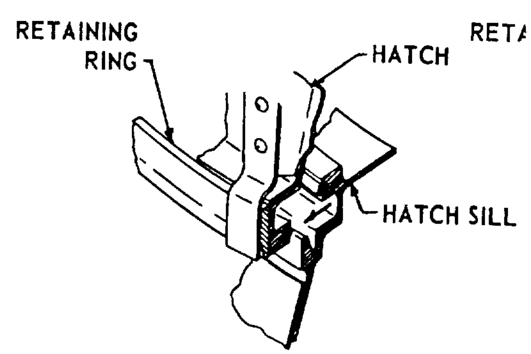
FIGURE 3-29





CANOPY ACCESS HATCH

CANOPY

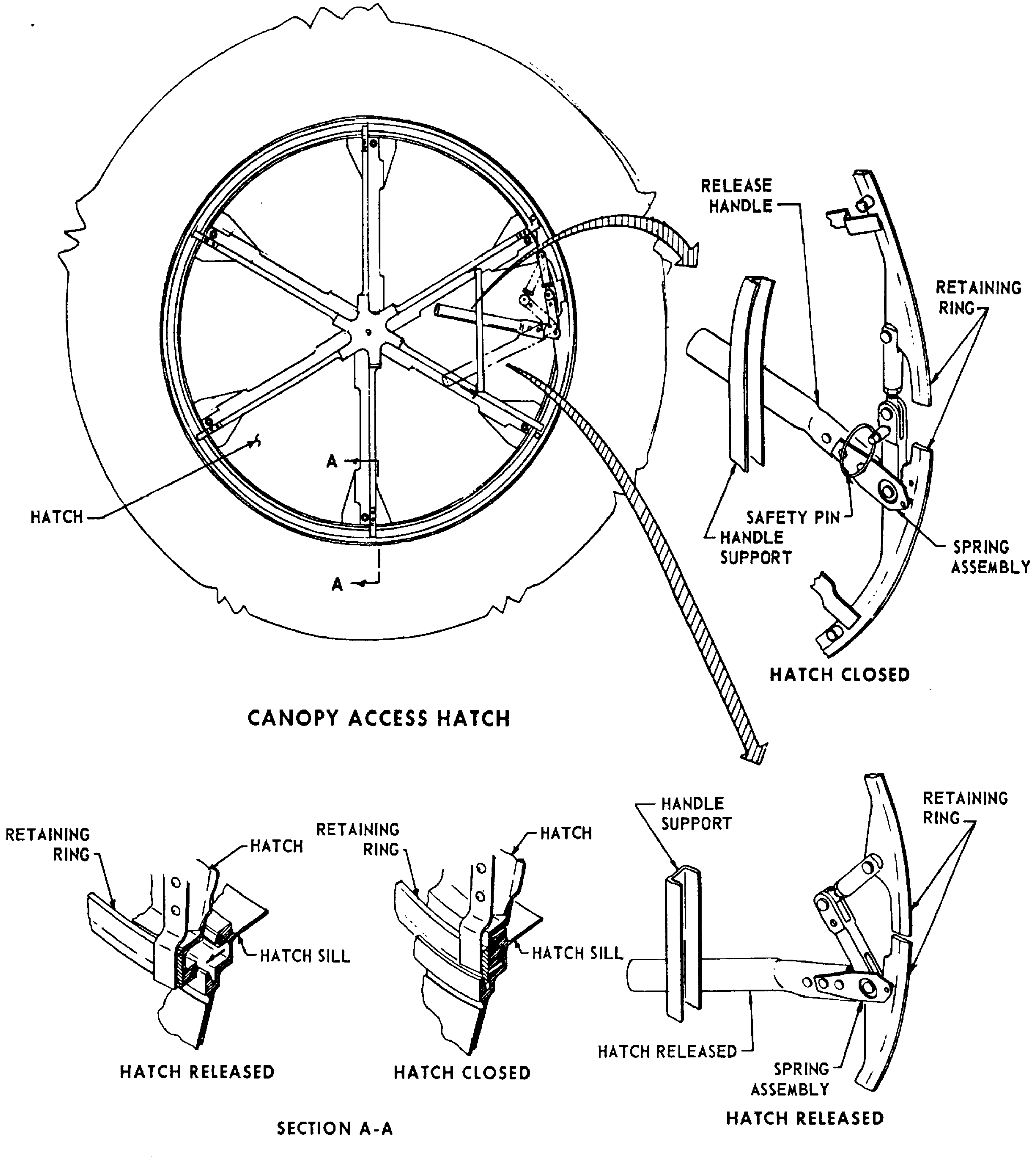


HATCH RELEASED

SECTION

FIGURE 3-29

FOLDOUT FRAME 2


RELEASE HANDLE
RETAINING RING
SAFETY PIN
HANDLE SUPPORT
SPRING ASSEMBLY
HATCH CLOSED
HATCH
A
A
CANOPY ACCESS HATCH
RETAINING RING
HATCH
HATCH SILL
HATCH RELEASED
RETAINING RING
HATCH
HATCH SILL
HATCH CLOSED
SECTION A-A
HANDLE SUPPORT
RETAINING RING
HATCH RELEASED
SPRING ASSEMBLY
HATCH RELEASED

3.8.4 (Continued)

points. This system is illustrated in Figure 3-30. Other umbilicals are identical with those described in Section 3.8.3, Volume I.

3.8.5 <u>Control Linkages</u> - Control linkages are similar to those designed for the orbital Gemini.

3.8.6 <u>Erectable Mirrors</u> - These features are identical to those of Section 3.8.6, Volume I.

3.8.7 <u>Lunar Landing Mechanism</u> - The lunar landing mechanism is identical with that shown in Figure 3-45, Volume I.

3.8.8 <u>Earth Landing Systems</u>

A. Lunar Gemini I design is identical to the present Gemini design and includes lock-out of main gear extension for water landings. Gear oil-strut shock absorbers are sealed from the effects of space environments and all bearing surfaces are moly-disulfide coated. No unusual or complex motions are necessary for gear extension.

B. Lunar Gemini II design incorporates a parachute system identical to that developed for the present Gemini. Ejection and bail-out provisions are also identical with those of the present Gemini.

C. Lunar Gemini III landing is accomplished with a three parachute system as described in Section 3.13.1, Volume I, and also includes a spacecraft parachute inversion system to allow for capsule corner entry in water landings. An operational discussion of the above system is presented in Section 3.13.

3.8.9 <u>Pyrotechnic Systems</u> - Pyrotechnic systems are identical with those described in Section 3.8.9 of Volume I.

COMMAND-SERVICE MODULE STRUCTURE AND UMBILICALS

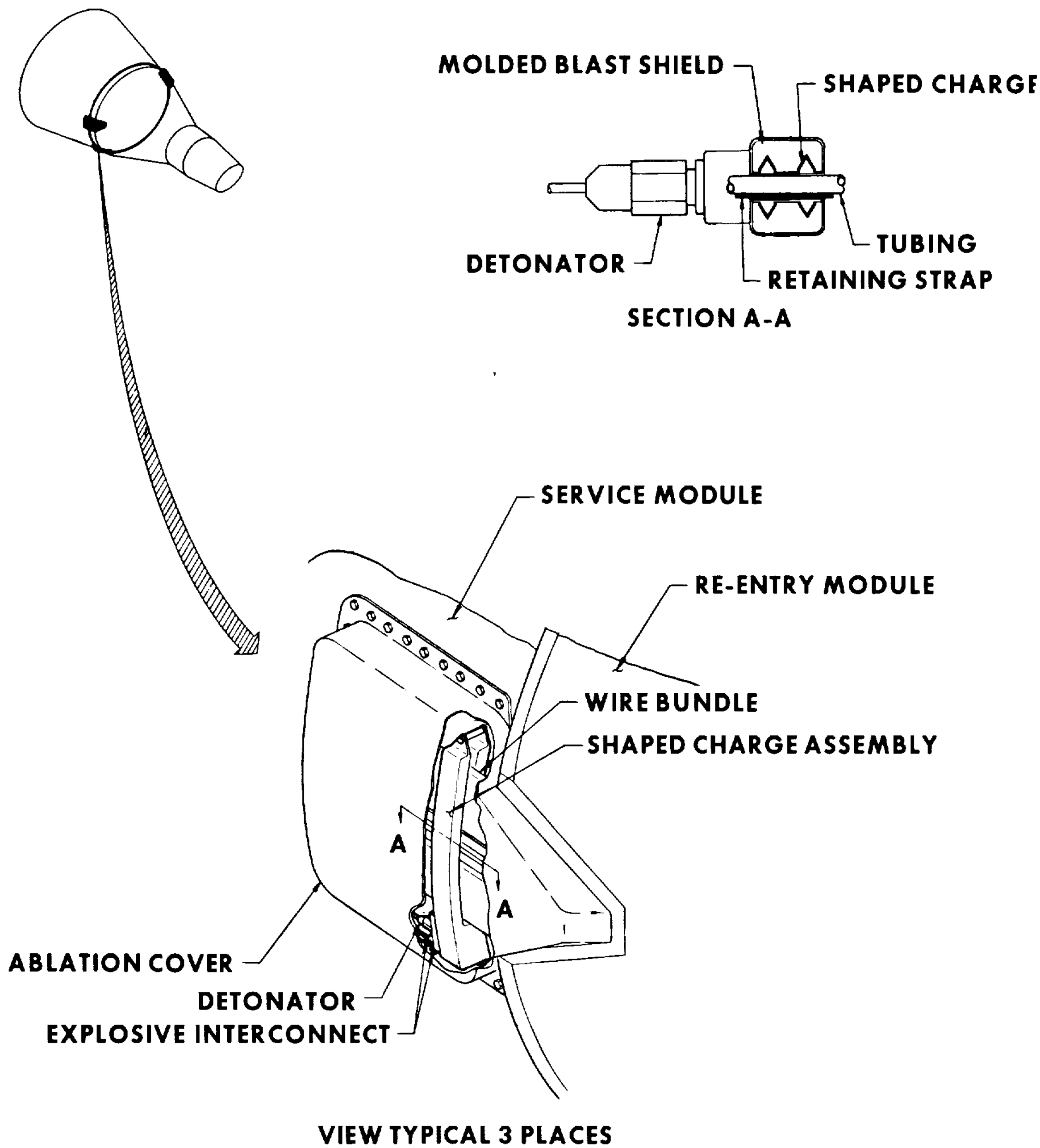


FIGURE 3-30

3.9 <u>Propulsion</u> - The propulsion systems utilized in the Lunar Gemini spacecraft are identical to those in the Two-Man Apollo spacecraft, discussed in Section 3.9, Volume I.

3.10 <u>Reaction Control</u> - The reaction control systems (RCS) in the Lunar Gemini spacecraft are basically the same as those in the Two-Man Apollo spacecraft discussed in Section 3.10, Volume I, with the exception of the systems located in the command module.

3.10.1 <u>Command Module</u> - The command module reaction control system is the same as the 14-day Gemini RCS except for modification of the propellant tanks to accommodate the increased propellant loading (from 74 pounds to 131 pounds). The Gemini RCS is described in detail in Reference 3-4 and the system specifications are covered in Reference 3-5.

3.11 Launch Escape - The launch escape system for Lunar Gemini I and II is the system presently designed for Gemini. Rocket propelled seats are used for ejection and separation from the spacecraft. Automatic man-seat separation and parachute deployment is provided.

Lunar Gemini III utilizes a tower-mounted launch escape propulsion system designed to the criteria presented in Section 3.11, Volume I.

3.11.1 System Performance - The envelope of off-the-pad ejection for the Gemini seat from the Saturn C-5 launch vehicle is shown in Figure 3-31. Parachute deployment time is 4.5 seconds and a two-second dispersion in parachute opening time is shown for each performance boundary. Also shown are several values of shock wave overpressure based on an equivalent weight of TNT equal to 10% of first stage propellants. Figure 3-32 presents the variation of blast wave overpressure experienced by the crew as a function of warning time. Also indicated are the estimated lethal and lung damage overpressure thresholds. This figure indicates that a minimum of two seconds warning of an impending explosion is required to satisfy crew safety in the event of minimum ejection seat performance.

A time history of fireball geometry compared to ejection seat displacement is shown in Figure 3-33 for zero seconds warning time. The two-second warning time dictated by Figure 3-32 yields a minimum distance between the fireball extremity and seat of approximately 425 feet.

The Lunar Gemini III LEPS performance is essentially as presented for the Two-Man Apollo spacecraft in Section 3.11, Volume I.

3.11.2 Rocket Motor Characteristics - The LEPS rocket motor characteristics for Lunar Gemini III are the same as presented in Section 3.11.2, Volume I.

3.12 Lunar Touchdown - The lunar landing gear is the same as discussed in Section 3.12, Volume I.

[redacted]

GEMINI EJECTION SEAT OFF-THE-PAD TRAJECTORY

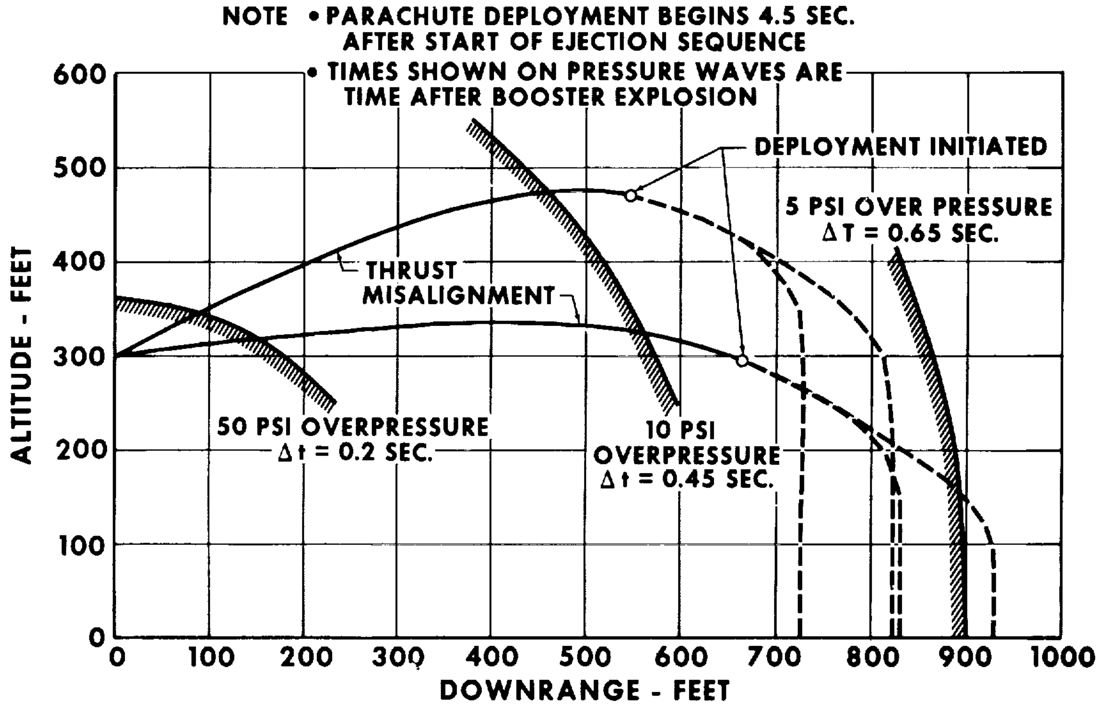


FIGURE 3-31

BLAST WAVE OVERPRESSURE VS. WARNING TIME FOR EJECTION SEAT OPERATION

WARNING TIME IS TIME OF EJECTION SEQUENCE INITIATION PRIOR TO EXPLOSION

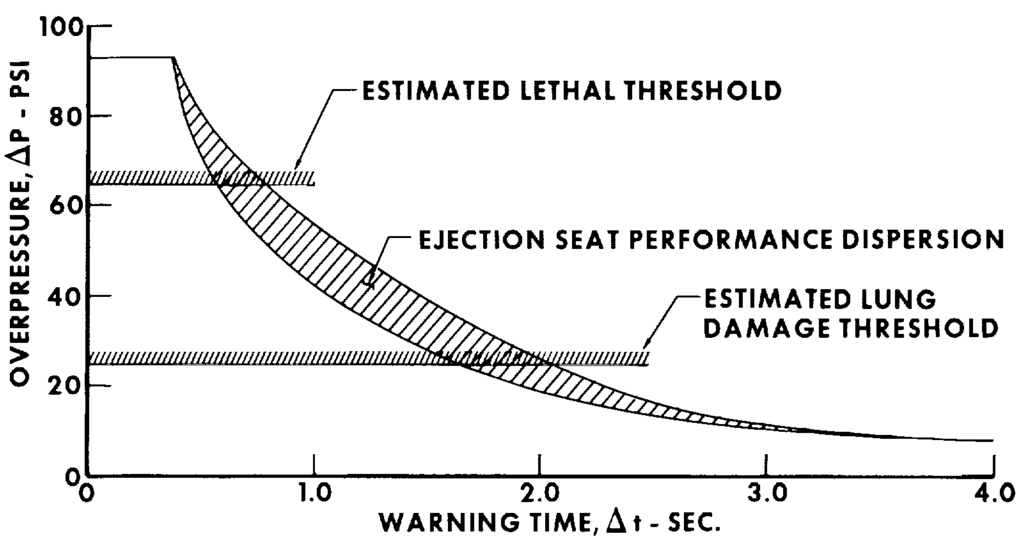


FIGURE 3-32

[redacted]

GEMINI EJECTION SEAT OFF-THE-PAD TRAJECTORY

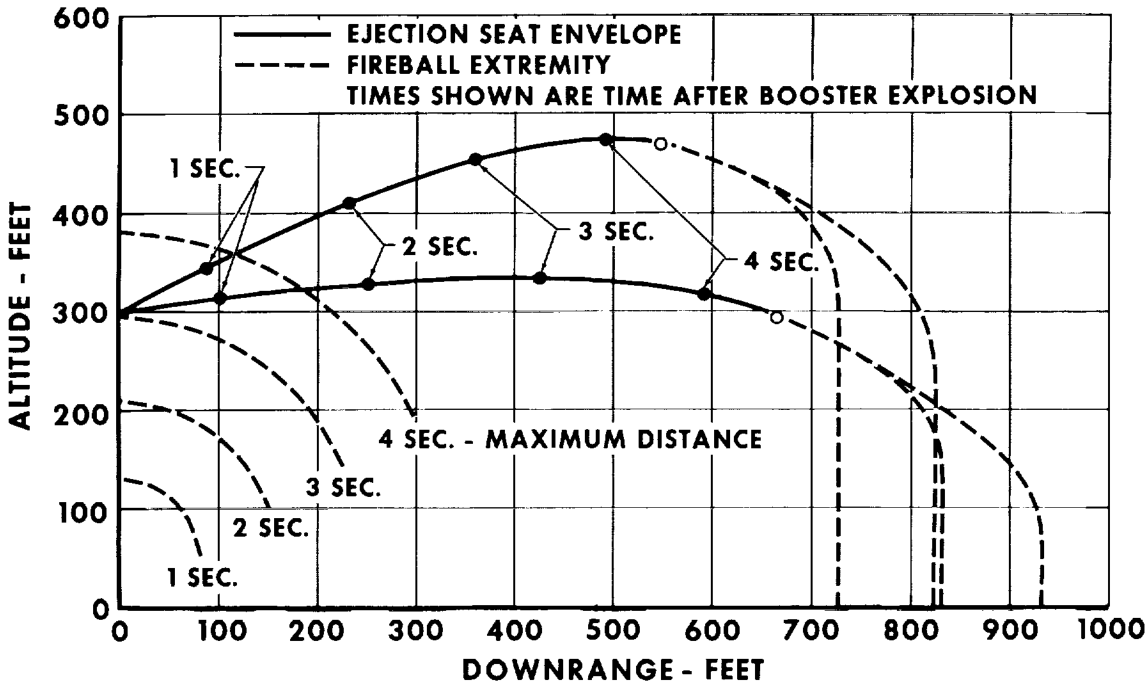


FIGURE 3-33

3.13 Earth Landing - The earth landing systems for Lunar Gemini are described in the following paragraphs.

3.13.1 Vertical Descent Control

A. Lunar Gemini I - This system consists of a drogue parachute and inflatable paraglider system identical to that presently being designed for Gemini. The drogue parachute is deployed at approximately 80,000 feet to stabilize the re-entry spacecraft and to separate the recovery section cover from the command module, exposing the paraglider. After deployment and inflation of the paraglider, the spacecraft is maneuvered by manipulation of shroud cables to an altitude of 125 feet, where a touchdown flare maneuver is performed by unreeling a fixed length of additional nose cable. After landing, pyrotechnic cable cutters are fired, releasing the paraglider suspension cables from the spacecraft.

B. Lunar Gemini II - The alternate 84-foot diameter parachute Gemini landing system is used which suspends the spacecraft at an angle to achieve corner-first penetration of the spacecraft during water landings. A reefed drogue parachute (18.4 feet diameter) is mortar deployed at approximately 10,600 feet. At approximately 10,000 feet, the drogue separates the recovery compartment cover and the main parachute deployment bag from the spacecraft and deploys the main parachute. After main parachute deployment, pyrotechnic disconnects release bridle cables which suspend the spacecraft at a 55^{o} angle from the vertical. Upon impact, the bridles are pyrotechnically released separating the parachute from the spacecraft.

C. Lunar Gemini III - This system is identical to that described in Paragraph 3.13.1, Volume I, except for the addition of a bridle system to suspend the spacecraft at 55^{o} from the vertical for corner penetration

3.13.1 (Continued)

in water landings. In event of impending land landing, one of the bridle elements is pyrotechnically released to reorient the spacecraft to a vertical suspension. This system consists of three parachutes simultaneously deployed by a drogue or a reserve pilot parachute. Opening of two of the three main parachutes is sufficient to limit vertical velocity to 30 feet per second at 5000 feet altitude.

3.13.2 Impact Attenuation

A. Lunar Gemini I - Lunar Gemini I command module utilizes the three skid Gemini landing gear for land landings. For water landings, the main (aft) skids are not extended.

B. Lunar Gemini II - Lunar Gemini II command module is designed to normally land on water. The module is suspended beneath the parachute at an angle of 55 degrees from the vertical to take advantage of corner penetration to reduce the landing load factor. If it is apparent that impact will be on land, the crew will leave the spacecraft and descend by personnel parachutes.

C. Lunar Gemini III - Lunar Gemini III command module is designed to normally land on water. The module is suspended beneath the parachute at an angle of 55 degrees from the vertical to take advantage of corner penetration to reduce the landing load factor. If it is apparent that the landing will be on land, the crew normally leave the spacecraft and descend by personnel parachutes. In the event the crew elect to stay with the spacecraft, one supporting bridle is cut, permitting the spacecraft to descent in a vertical attitude and impact energy is absorbed by crushing spacecraft structure and by viscous dampers supporting the couches. The stroke of the dampers is sufficient to limit the crew load factors to emergency limits.

4. SUPPORTING STUDIES AND INFORMATION

4.1 Command Module Size and Arrangement - The size and external configuration of the command module is basically that of the Gemini re-entry spacecraft. Design studies within this constraint demonstrate that the features and systems which most effect interior arrangement are; a) the earth launch escape system, b) navigation system, c) crew arrangement during lunar landing and d) the earth landing and impact system. Additionally, a constraint in equipment location is imposed by the design goal of obtaining a c.g. position compatible with a hypersonic L/D maximum of 0.25. Of these four, the achievement of a satisfactory crew arrangement during lunar landing is the most formidable task from a design standpoint. Several lunar landing crew arrangements studied are shown in Figure 4-1. From these the bubble canopy is selected as the most desirable pilot arrangement for Lunar Gemini I and II, and the side window as the pilot arrangement for Lunar Gemini III. Further, the mirror arrangement is selected for the copilot in all versions.

Numerous command module configurations, utilizing various combinations of the four features and systems above, are possible. To reduce the study to manageable proportions, three configurations, representing incremental progression in module modification, are selected. These are the Lunar Gemini I, II and III described in Section 2.1. A spectrum of intermediate versions may be obtained by substitution of features among the configurations.

4.2 Spacecraft Staging - Section 4.2 of Volume I presents a study of various staging arrangements and the effect of different propellant combinations. Since the propulsion characteristics for the Two-Man Apollo and all Lunar Gemini spacecraft are identical, the study in Volume I is applicable.

4.3 Trajectory Analysis - The trajectory analysis presentation of Section 4.3, Volume I, is essentially applicable to the direct lunar landing mission utilizing the Gemini spacecraft as a command module. Areas of exception are re-entry control and abort capability during earth launch.

CREW ARRANGEMENTS FOR LUNAR LANDING

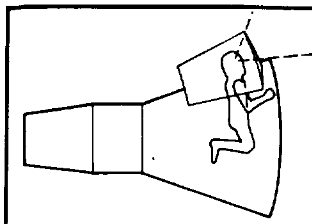
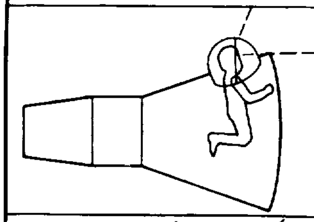
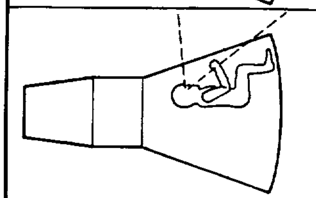
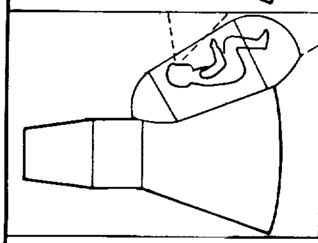
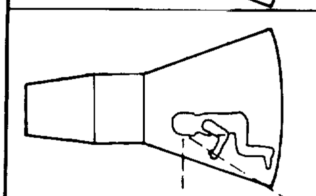
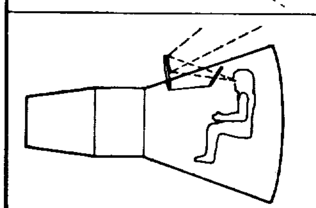
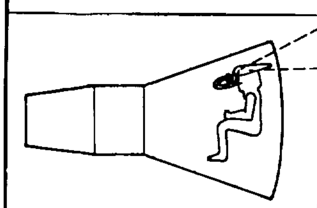
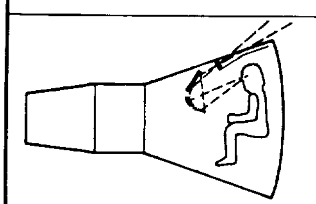
	**OPEN HATCH - OPTIONAL ZIPPED IN PRESSURE SEAL** MINIMUM WEIGHT MINIMUM STRUCTURAL REVISION REQUIRES CABIN DEPRESSURIZATION
	**BUBBLE CANOPY** REQUIRES REVISED DOOR STRUCTURE LAUNCH HEATING AND BUFFET PROBLEMS LUNAR GEMINI I AND II SELECTED PILOT ARRANGEMENT
	**WINDOW - LEEWARD SIDE** REQUIRES STRUCTURAL REVISION REQUIRES ARTICULATED INSTRUMENT PANEL LUNAR GEMINI III SELECTED PILOT ARRANGEMENT
	**GONDOLA** MAXIMUM WEIGHT LAUNCH HEATING, BUFFET AND ABORT PROBLEMS
	**WINDOW - WINDWARD SIDE** REQUIRES STRUCTURAL REVISION REQUIRES ECS RELOCATION REQUIRES WINDOW COVERS FOR RE-ENTRY
	**MIRROR OPTICS** LOW WEIGHT AND STRUCTURAL REVISION REVERSED IMAGE SELECTED CO-PILOT ARRANGEMENT
	**FIBER OPTICS** POOR RESOLUTION REVERSED IMAGE
	**LENS - MIRROR OPTICS** STRUCTURAL REVISION REVERSED IMAGE

FIGURE 4-1

4.3.1 Lunar Retrograde to Terminal Staging Altitude - The discussion in Section 4.3.1, Volume I, is directly applicable to the Lunar Gemini spacecraft.

4.3.2 Trajectory Control During Main Descent - The trajectory control considerations for the Lunar Gemini spacecraft are identical to Section 4.3.2 of Volume I.

4.3.3 Staging Altitude to Lunar Surface - The terminal descent phase for the Lunar Gemini spacecraft is identical to Section 4.2.6 of Volume I.

4.3.4 Launch from Lunar Surface - The study of launch from the moon in Section 4.3.4, Volume I, is directly applicable.

4.3.5 Abort - Lunar Gemini I and II utilize ejection seats as presently configured for Gemini as a means of providing crew separation from a malfunctioning launch vehicle. Section 3.11.1 presents the seat performance envelopes for an off-the-pad abort compared with overpressure and fireball calculations based on Saturn C-5. After lift-off, the ejection seats are used until the launch vehicle environment exceeds the limits of the seat-man combination. This limit occurs approximately 100 seconds after lift-off and is indicated on the launch profile of Figure 4-2. Subsequent to this time, no immediate separation capability exists until the drag decreases to the approximate magnitude of the service module thrust. This void in separation capability is also indicated on Figure 4-2. During this period, delay of separation until the coasting launch vehicle reaches a low drag environment is the apparent recourse. Lunar Gemini III utilizes a launch escape propulsion system which is capable of immediate separation as discussed in Section 3.11.1, Volume I.

Figure 4-3 presents the 10 g and 20 g recovery ceilings for Lunar Gemini I, II and III superimposed on the abort apogee conditions for Lunar Gemini III. Abort apogees for Lunar Gemini I and II will be less than or equal to those for Lunar Gemini III. This figure indicates that re-entry load factors following an abort will be less than the 20 g emergency limit.

LAUNCH ESCAPE LIMITS

SATURN C5 LAUNCH TO PARKING ORBIT

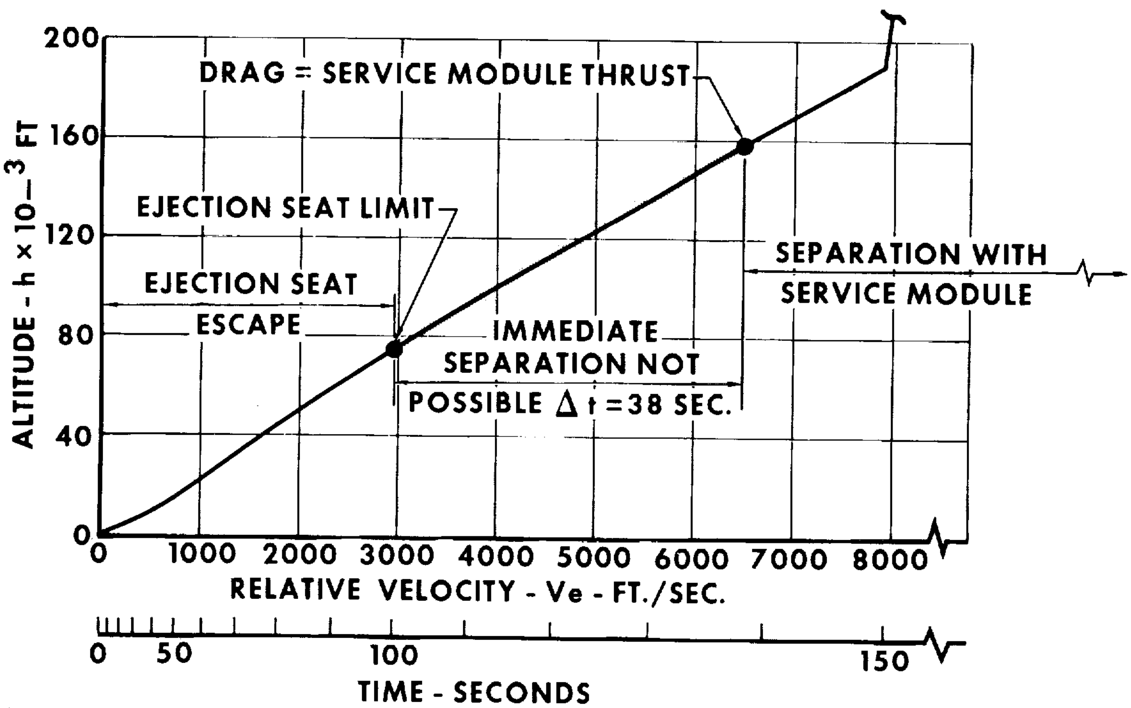


FIGURE 4–2

ABORT RECOVERY CEILINGS

SATURN C5 LAUNCH TO PARKING ORBIT

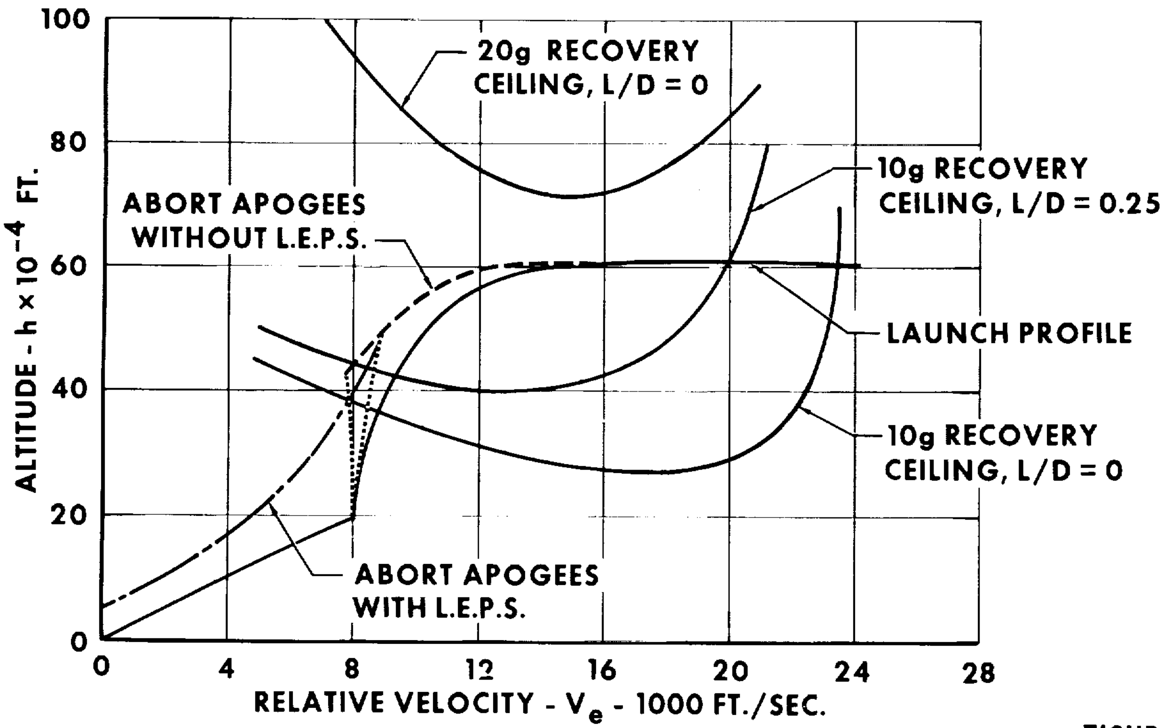


FIGURE 4–3

4.3.5 (Continued)

All aborts subsequent to earth-orbit injection are identical to those discussed in Section 4.3.5, Volume I.

4.3.6 Re-entry Flight Path Control - An essential consequence of using Gemini as the command module for the direct flight Apollo mission is that the aerodynamic lift-to-drag ratio available for flight path control during re-entry will be considerably less than the 0.5 specified in Reference 4-1. The Gemini L/D is about 0.25, and it is probably impractical to effect any significant increase. This does not necessarily mean a corresponding reduction in range capability because flight path control at supercircular speed can produce intentional skip to achieve the desired range. Hence there is no clearly defined "footprint" range limit; control accuracy is what determines the practicable range. Figure 4-4 shows the effect of L/D on the allowable velocity component errors at initiation of typical skips having apogee altitudes under 400 nautical miles yet range sufficient for maximum lunar-declination return trajectories at inclinations compatible with Mercury tracking facilities. It is assumed that ground-based tracking or on-board orbit determination can establish the actual trajectory during the skip. Therefore, the allowable skip initiation errors are limited only by the amount of range adjustment possible during the subcircular speed re-entry after the skip. In calculating the allowable errors shown in Figure 4-4 it was assumed that both velocity components are in error the same amount and in the direction to make the effects add. The results of this study show that the particular skip conditions do not greatly affect the allowable initiation errors, although at L/D values typical of Gemini it is slightly better to control to a shallow flight path angle at exit. For L/D = 0.25 the velocity errors would have to be less than 16 fps even in the more favorable case shown. Practical problems involved in achieving this precision in the supercircular control phase have not been analyzed in detail. If it is not feasible to obtain the control

4.3.6 (Continued)

ALLOWABLE VELOCITY COMPONENT ERRORS AT INITIATION OF SKIP

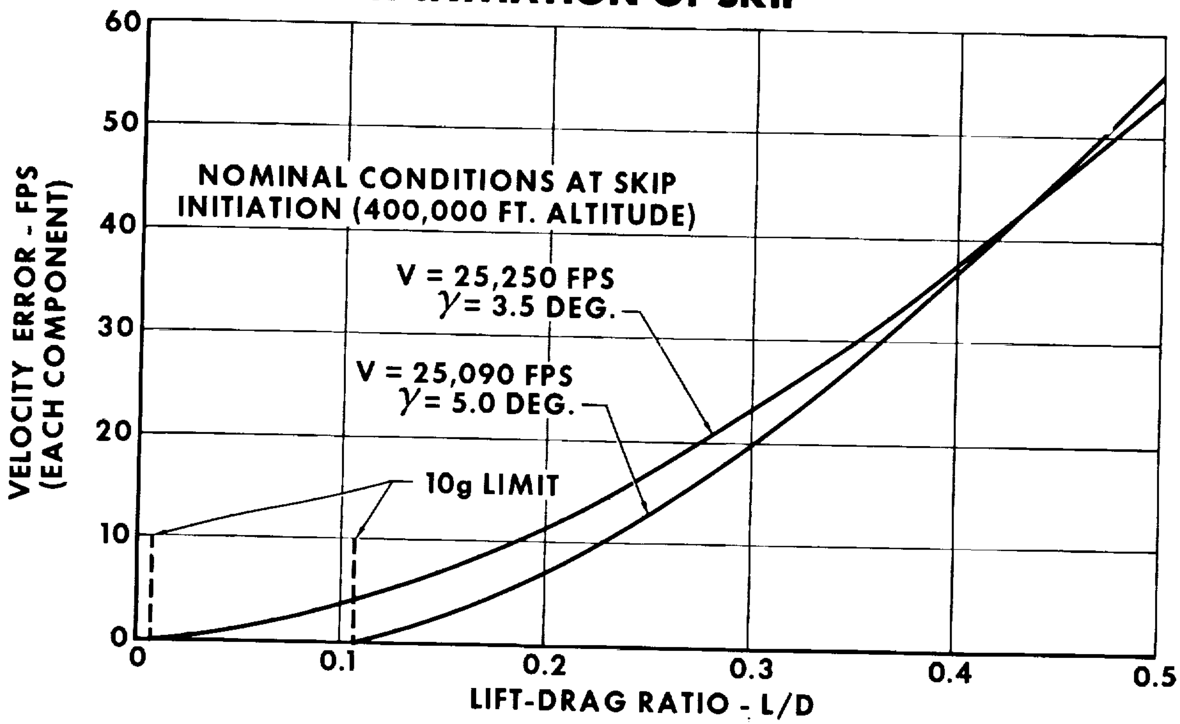


FIGURE 4-4

accuracy required for the long range skip, it will be necessary to decrease the required re-entry range by either increasing the inclination of the return orbit trajectory when the moon is at northern declinations, restricting the mission to the southern declination portion of the month, or choosing a landing site outside continental U.S., e.g. a water landing in the Pacific Ocean.

4.4 Aerodynamics - The three Lunar Gemini command modules of this study have the same re-entry configuration, but Lunar Gemini III has a launch escape propulsion system for aborts within the atmosphere. The Lunar Gemini III abort configuration is very similar to the Project Mercury spacecraft. Aerodynamic coefficients for the re-entry and Lunar Gemini III abort configurations are shown in Figure 4-5, 4-6 and 4-7.

Trimmed lift-to-drag ratio as a function of c.g. offset for three longitudinal c.g. positions is shown in Figure 4-8. Design points for the three study spacecraft are plotted on the figure.

GEMINI RE-ENTRY CONFIGURATION AERODYNAMIC CHARACTERISTICS VS ANGLE OF ATTACK

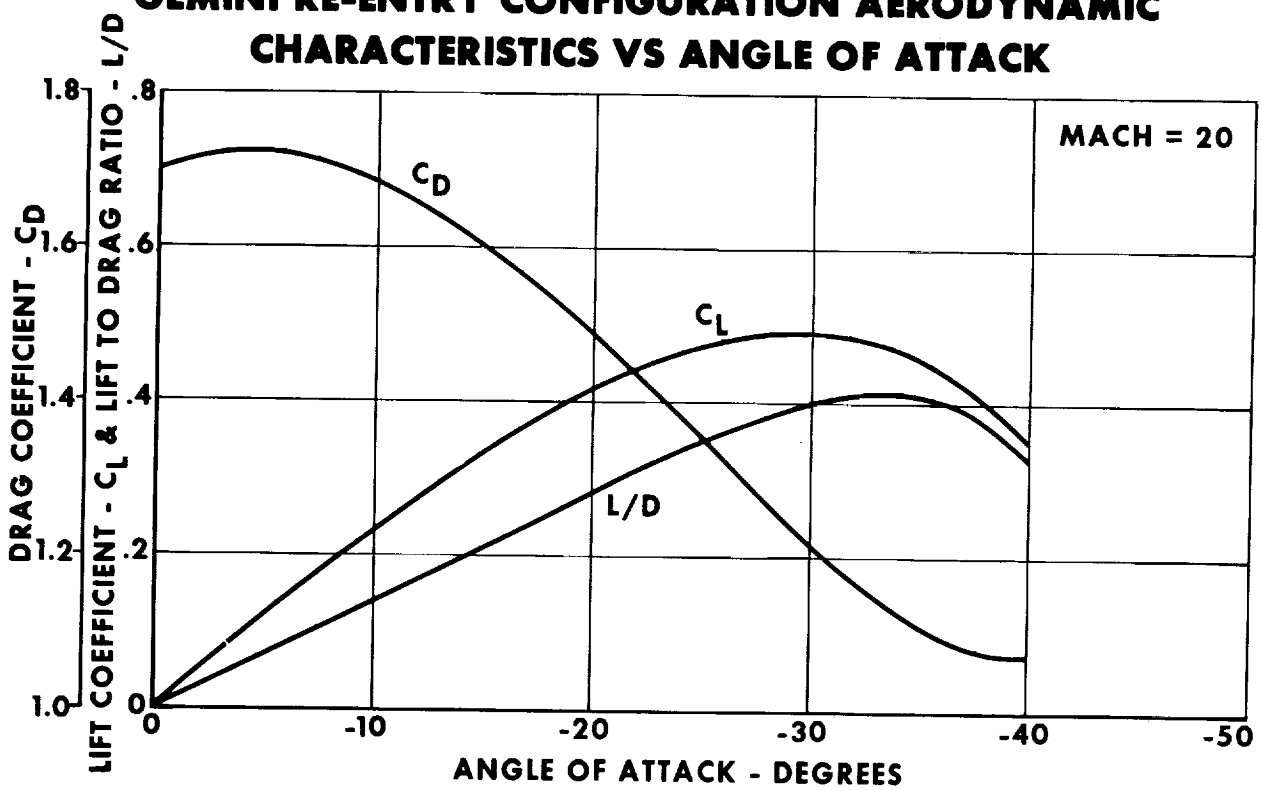


FIGURE 4-5

STATIC STABILITY IN ABORT CONFIGURATION AFTER ROCKET BURNOUT

CG @ Z = 1.01D, Y = .016D

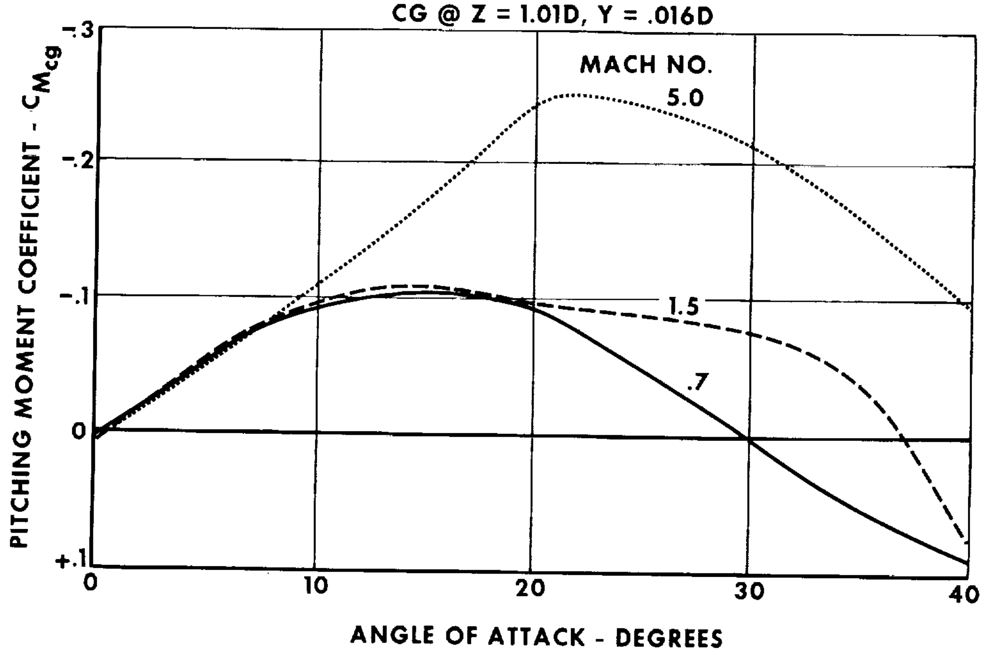


FIGURE 4-6

DRAG COEFFICIENT VS. ANGLE OF ATTACK FOR ABORT CONFIGURATION

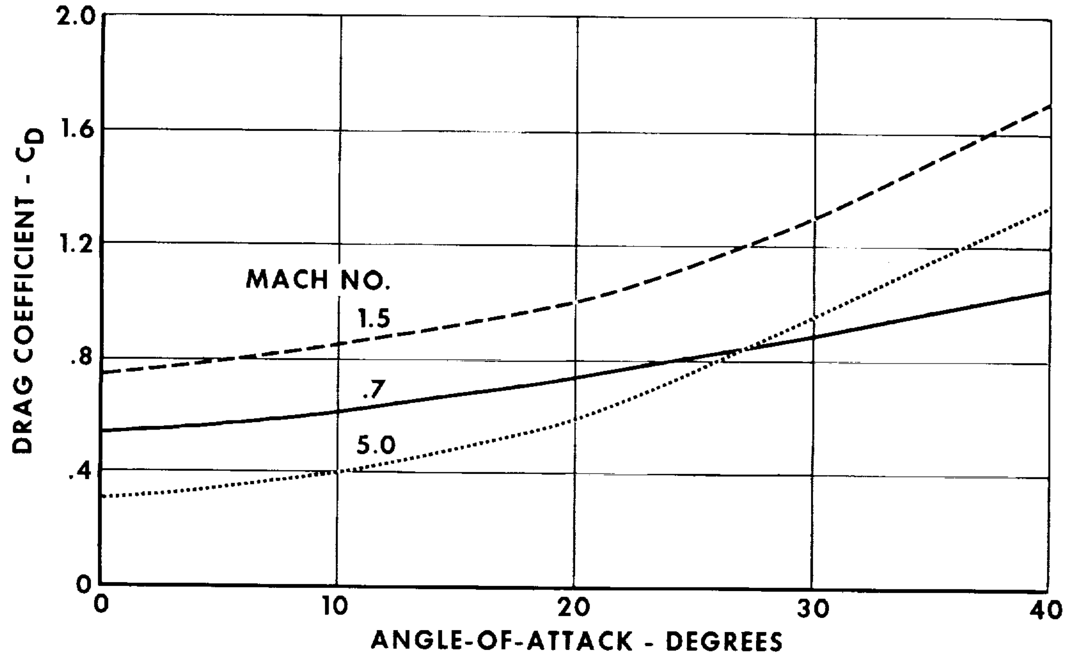


FIGURE 4-7

EFFECT OF LONGITUDINAL C.G. (Z/D)AND C.G. OFFSET (Y/D) ON LIFT TO DRAG RATIO (L/D)

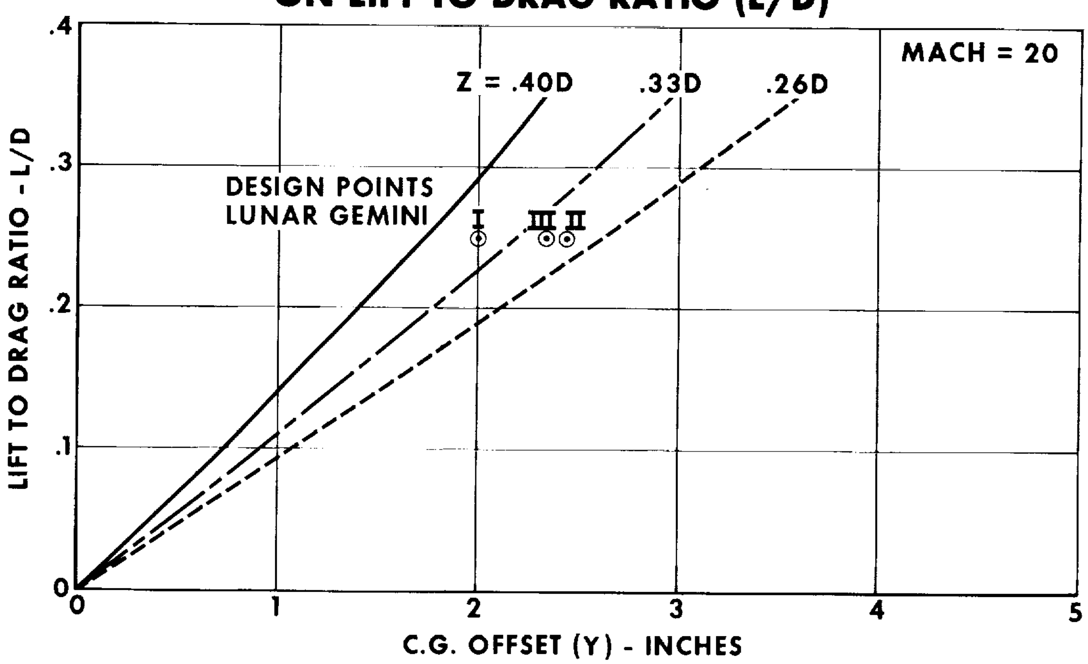


FIGURE 4-8

4.5 Propellant Margins - The discussion in Section 4.5 of Volume I is directly applicable to the Lunar Gemini spacecraft.

4.6 Radiation - The inherent shielding provided by the structure and equipment of the Lunar Gemini spacecraft is summarized below for a point on the astronaut's abdominal skin.

TABLE 4-1

Inherent Shielding

Fraction Solid Angle	Shielding g/cm^2 Aluminum
.215	1.4
.110	6.9
.150	13.9
.065	26.5
.460	41.6

As a first approximation, the shielding for the eyes in the Lunar Gemini is assumed to be the same as that shown for the navigation position for Two-Man Apollo in Section 4.6, Volume I.

4.7 Meteoroid Protection - The Lunar Gemini command module provides a high degree of inherent meteoroid protection as does the Two-Man Apollo command module described in Section 4.7, Volume I. Meteoroid protection for the Lunar Gemini spacecraft is summarized in Figure 4-9 along with weight penalties associated with increased protection.

METEOROID PROTECTION

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PENETRATION EQUATION

$$\frac{P}{d} = \gamma \left(\frac{\rho_p}{\rho_t}\right)^{1/3} \left(\frac{V_p}{C_t}\right)^{1/3}$$

WHERE

P = DEPTH OF PENETRATION
d = PROJECTILE DIAMETER
γ = A CONSTANT = 4
ρ_p = PROJECTILE DENSITY
ρ_t = TARGET DENSITY
V_p = PROJECTILE VELOCITY
C_t = SPEED OF SOUND IN TARGET MATERIAL

PROTECTION

ITEM	PROBABILITY OF NO PENETRATION (p)	ADDED WEIGHT FOR p = .990	ADDED WEIGHT FOR p = .999
COMMAND MODULE - CREW	.99917	—	—
PRESSURE WALL	.99902	—	—
SERVICE MODULE TANKAGE	.7320	13.5 LB.	128 LB.
TERMINAL LANDING MODULE TANKAGE	.99979	—	—
RETROGRADE MODULE TANKAGE	.0590	254 LB.	2950 LB.
(REDUCTION IN ALLOWABLE COMMAND MODULE WEIGHT)		(60 LB.)	(668 LB.)

FIGURE 4-9

4.8 Weight Derivation - Weight estimates are based primarily on modifications to the current Gemini weights. The summary of the command module and service module equipment weights for Lunar Gemini I, II, III and the current earth orbital Gemini, 14-day mission, are presented in Table 4-2.

TABLE 4-2

COMMAND AND SERVICE MODULE EQUIPMENT WEIGHT SUMMARY

GROUP	EARTH ORBITAL GEMINI	LUNAR GEMINI		
		I	II	III
COMMAND MODULE	4711	5625	5157	5263
STRUCTURAL SYSTEM	(1546)	(1859)	(1829)	(1930)
BASIC STRUCTURE	1319	1187	1157	1264
HEAT SHIELD	227	672	672	666
CREW SYSTEM	929	1049	1049	911
COMMUNICATIONS AND INSTRUMENTATION	(362)	(534)	(695)	(699)
DISPLAYS	174	252	267	271
TELECOMMUNICATIONS	188	282	428	428
GUIDANCE AND NAVIGATION	207	207	260	260
STABILIZATION AND CONTROL	40	97	97	97
REACTION CONTROL	193	274	267	267
ELECTRICAL POWER	300	321	321	321
ENVIRONMENTAL CONTROL	340	330	330	330
EARTH LANDING	794	794	149	273
SCIENTIFIC EQUIPMENT		85	85	85
ECCENTRICITY BALLAST		75	75	90
SERVICE MODULE EQUIPMENT	1064	1177	1219	1190
STRUCTURAL SUPPORTS	54	54	54	54
TELECOMMUNICATIONS	107	212	245	245
GUIDANCE AND NAVIGATION		43	16	16
STABILIZATION AND CONTROL	9	42	42	42
ELECTRICAL POWER	524	443	482	482
ENVIRONMENTAL CONTROL	370	354	351	351
DISPLAYS		29	29	

4.8.1 Command Module and Service Module Equipment - The detail comparison of the earth orbital Gemini with Lunar Gemini I, II, and III follows:

4.8.1.1 Structural System - Table 4-3 presents the weight breakdown of the structural system. The major weight differences between the earth orbital Gemini and Lunar Gemini I, II and III are:

[redacted]

TABLE 4-3

STRUCTURAL SYSTEM WEIGHT COMPARISON

STRUCTURE BASIC	GEMINI EARTH ORBITAL		LUNAR GEMINI					
			I		II		III	
	C.M. 1319.44	S.M. 53.6	C.M. 1187.4	S.M. 54.0	C.M. 1157.0	S.M. 54.0	C.M. 1264.4	S.M. 54.0
SIDEWALLS	(252.80)		(243.2)		(243.2)		(301.6)	
SKIN AND STIFFENERS	39.64		39.6		39.6		38.2	
STRINGERS	79.52		79.6		79.6		119.5	
RINGS	78.54		68.9		68.9		88.8	
EQUIPMENT ACCESS DOORS	55.10		55.1		55.1		55.1	
AFT BULKHEAD	61.35		61.4		61.4		103.4	
FORWARD BULKHEAD	15.42		15.4		15.4		15.4	
TOWER/PARAGLIDER ATTACH.	5.73		5.7		5.7		5.5	
FOREBODY ATTACH.	10.50		10.5		10.5		10.5	
HATCHES AND WINDOWS	(352.10)		(382.1)		(382.1)		(401.5)	
HATCH – EJECTION	297.45		297.4		297.4			
UMBILICAL	10.00		10.0		10.0		10.0	
LANDING GEAR	10.00		10.0		10.0		10.0	
ECS BAY	33.45		33.5		33.5		33.5	
MISC.	1.20		1.2		1.2		1.2	
BUBBLE WINDOW			30.0		30.0			
HATCH – LATCHED							133.7	
HATCH AND OBSERVATION WINDOW							213.1	
SHINGLES/ABLATION BACK-UP	216.39		89.5		89.5		86.9	
INSULATION	174.62		170.8		170.8		165.8	
HOISTING	7.70		7.7		7.7		7.7	
CLAMP RING ATTACH.	20.00		20.0		20.0		20.0	
CHUTE PROVISIONS					21.0		15.0	
EQUIPMENT MOUNTING	(55.80)		(55.8)		(55.8)		(55.8)	
CABIN WALL	47.80		47.8		47.8		47.8	
EQUIPMENT BAY	8.00		8.0		8.0		8.0	
PARAGLIDER AND GEAR BACKUP	47.53		47.5					
PAINT AND SEALANT	11.70		11.7		11.7		11.7	
NOSE ANTENNA AND JETTISONED	35.26		13.6		13.6		15.0	
MISCELLANEOUS STRUCTURE	(52.54)		(52.5)		(48.6)		(48.6)	
INTERNAL STRUCTURE	29.33		29.3		29.3		29.3	
BALLAST MOUNTING	1.00		1.0		1.0		1.0	
SNORKEL INLET	3.60		3.6		3.6		3.6	
MISCELLANEOUS	17.19		17.2		13.3		13.3	
FIXED ANTENNA	1.42		1.4		1.4		1.4	
HEAT SHIELD	227.00		672.0		672.0		665.6	
FOREBODY	(210.43)		(480.5)		(480.5)		(484.8)	
FOREBODY ABLATION MATERIAL	96.25		342.0		342.0		329.0	
ABLATION RING	33.98		46.0		46.0		46.0	
MOUNTING PROVISIONS	4.08		4.1		4.1		4.1	
FOREBODY BACK-UP	76.12		88.4		88.4		105.7	
AFTERBODY			(191.5)		(191.5)		(180.8)	
AFTERBODY ABLATION MATERIAL			169.1		169.1		159.1	
AFTERBODY MOUNTING			22.4		22.4		21.7	
GROWTH ALLOWANCE	16.57							

4.8.1.1 (Continued)

	Lunar Gemini		
	I	II	III
Remove Docking and Rendezvous Provisions	-44	-44	-44
Revise Heat Protection	(323)	(323)	(315)
Remove Shingles	-216	-216	-216
Add Afterbody Ablation Backup	89	89	87
Add Afterbody Ablation Material	192	192	181
Increase Forebody Ablation Material	246	246	233
Increase Forebody Backup Structure	12	12	30
Shorten Paraglider Housing			-16
Beef-up Structure for Tower Loads			75
Remove Paraglider-Gear Beef-up		-51	-51
Add Bubble Viewport	30	30	
Revise Hatch-window System			49
Add Parachute Provisions		21	15
Revise Aft Bhd. for Impact Loads			42

4.8.1.2 Guidance and Navigation System - Table 4-4 presents the weight breakdown of the navigation and guidance system. The major weight differences between the earth orbital Gemini and Lunar Gemini I, II and III are:

	Lunar Gemini		
	I	II	III
Add Autosextant	40		
Add Manual Sextant, Telescope and Base		45	45
Add Roll Momentum Wheel		13	13

4.8.1.3 Stabilization and Control System - Table 4-5 presents the weight breakdown of the stabilization and control system. The major weight differences between the earth orbital Gemini and Lunar Gemini I, II and III are:

	Lunar Gemini		
	I	II	III
Add IMU Strapdown System	17	17	17
Increase Control Electronics Capability and Redundancy	60	60	60
Add Sun and Canopus Sensors	12	12	12

TABLE 4-4

NAVIGATION AND GUIDANCE SYSTEM WEIGHT COMPARISON

NAVIGATION AND GUIDANCE	GEMINI EARTH ORBITAL		LUNAR GEMINI					
			I		II		III	
	C.M. 206.63	S.M.	C.M. 206.6	S.M. 43.0	C.M. 259.6	S.M. 16.0	C.M. 259.6	S.M. 16.0
INERTIAL SYSTEM								
PLATFORM	31.77		31.8		31.8		31.8	
PLATFORM POWER SUPPLY	42.63		42.6		42.6		42.6	
PLATFORM ELECTRONICS	44.21		44.2		44.2		44.2	
COMPUTER SYSTEMS								
COMPUTER	61.51		61.5		61.5		61.5	
OPTICAL MEASUREMENT SYSTEM								
AUTOSEXTANT				40.0				
MANUAL SEXTANT					27.0		27.0	
TELESCOPE					8.0		8.0	
DISPLAYS AND CONTROLS	1.80		1.8		1.8		1.8	
MISCELLANEOUS								
NAVIGATION BASE					10.0		10.0	
STRUCTURAL SUPPORTS	9.14		9.1		9.1		9.1	
CIRCUITRY	10.01		10.0		18.0		18.0	
E.C.S. PROVISIONS	5.56		5.6		5.6		5.6	
SUN SENSOR				3.0		3.0		3.0
ROLL MOMENTUM WHEEL						13.0		13.0

TABLE 4-5

STABILIZATION AND CONTROL SYSTEM WEIGHT COMPARISON

STABILIZATION AND CONTROL	GEMINI EARTH ORBITAL		LUNAR GEMINI					
			I		II		III	
	C.M. 40.40	S.M. 9.24	C.M. 97.5	S.M. 42.0	C.M. 97.5	S.M. 42.0	C.M. 97.5	S.M. 42.0
IMU STRAPDOWN								
INERTIAL REFERENCE			12.0		12.0		12.0	
ACCELEROMETER			5.0		5.0		5.0	
RATE SENSORS								
RATE GYROS	8.50		8.5		8.5		8.5	
CONTROL ELECTRONICS								
CONTROL-ELECTRONICS	15.90	7.24	30.0	30.0	30.0	30.0	30.0	30.0
INVERTER	7.00		30.0		30.0		30.0	
SUN SENSOR			2.0		2.0		2.0	
CANOPUS SENSOR				10.0		10.0		10.0
CIRCUITRY	9.00	2.00	10.0	2.0	10.0	2.0	10.0	2.0

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4.8.1.4 Reaction Control System - Table 4-6 presents the weight breakdown of the reaction control system. The major weight change occurs with the increase in propellant from 74 to 131 pounds.

TABLE 4-6

REACTION CONTROL SYSTEM WEIGHT COMPARISON

REACTION CONTROL SYSTEM	GEMINI EARTH ORBITAL C.M.	LUNAR GEMINI I C.M.	LUNAR GEMINI II C.M.	LUNAR GEMINI III C.M.
	192.70	273.6	266.7	266.7
PRESSURIZATION SYSTEM	(29.26)	(28.4)	(28.4)	(28.4)
GAS	2.80	.7	.7	.7
TANK	4.40	6.0	6.0	6.0
VALVING, REGULATOR ASSEMBLY	20.26	20.5	20.5	20.5
INSTALLATION	1.80	1.2	1.2	1.2
PROPELLANT SYSTEM	(90.88)	(158.9)	(152.4)	(152.4)
PROPELLANT – USABLE	70.00	126.0	126.0	126.0
PROPELLANT – TRAPPED	4.00	5.0	5.0	5.0
PROPELLANT TANKAGE	16.88	27.9	21.4	21.4
THRUST CHAMBERS	36.80	48.0	48.0	48.0
INSTALLATION, VALVING, CIRCUITRY	35.76	38.3	37.9	37.9

4.8.1.5 Earth Landing System - Table 4-7 presents the weight breakdown of the earth landing system. The major weight differences between the earth orbital Gemini and Lunar Gemini I, II and III are:

	Lunar Gemini I	Lunar Gemini II	Lunar Gemini III
Remove Paraglider System		-519	-519
Remove Skid Gear System		-253	-253
Add Single 84 Foot Diameter Parachute System		113	
Add Three 71 Foot Diameter Parachute System			222

4.8.1.6 Electrical System - Table 4-8 presents the weight breakdown of the electrical system. The major weight differences between the earth orbital Gemini and Lunar Gemini I, II, III are:

TABLE 4-7

EARTH LANDING SYSTEM WEIGHT COMPARISON

LANDING SYSTEM	EARTH ORBITAL GEMINI C.M. 793.81	LUNAR GEMINI I C.M. 793.8	LUNAR GEMINI II C.M. 149.0	LUNAR GEMINI III C.M. 273.4
MAIN CHUTE/CHUTE CLUSTER			(112.6)	(222.0)
CANOPY AND RISERS			100.0	207.0
BAG AND INSTALLATION			12.6	15.0
DROGUE CHUTE & MORTAR			13.6	19.0
PILOT CHUTE	15.13	15.1		6.0
CONTROLS/BAROSTATS			2.4	6.0
PARAGLIDER SYSTEM	519.22	519.2		
CIRCUITRY – CHUTE SYSTEM			10.0	10.0
RECOVERY SYSTEM	(6.55)	(6.6)	(10.4)	(10.4)
RECOVERY LIGHT	3.75	3.8	3.8	3.8
DYE MARKER	2.80	2.8	2.8	2.8
CHAFF/SHARK REPELLANT			2.4	2.4
MOUNTING AND CIRCUITRY			1.4	1.4
SKID GEAR ASSEMBLY	252.91	252.9		

TABLE 4-8

ELECTRICAL SYSTEM WEIGHT COMPARISON

ELECTRICAL SYSTEM	GEMINI EARTH ORBITAL C.M. 300.14	GEMINI EARTH ORBITAL S.M. 523.69	LUNAR GEMINI I C.M. 320.5	LUNAR GEMINI I S.M. 442.5	LUNAR GEMINI II C.M. 320.5	LUNAR GEMINI II S.M. 481.5	LUNAR GEMINI III C.M. 320.5	LUNAR GEMINI III S.M. 481.5
BATTERIES	(138.50)		(138.5)		(138.5)		(138.5)	
MAIN	110.00		110.0		110.0		110.0	
SQUIB	28.50		28.5		28.5		28.5	
FUEL CELL SYSTEM	(8.98)	(445.06)	(9.0)	(351.1)	(9.0)	(390.1)	(9.0)	(390.1)
FUEL CELLS		119.20		119.2		119.2		119.2
FUEL CELL REACTANTS		202.25		108.3		147.3		147.3
REACTANT CONTAINERS		114.61		114.6		114.6		114.6
PLUMBING		9.00		9.0		9.0		9.0
CONTROLS	8.98		9.0		9.0		9.0	
CIRCUITRY – POWER	(33.63)	(27.72)	(33.6)	(27.7)	(33.6)	(27.7)	(33.6)	(27.7)
POWER RELAYS, FUSES, ETC.	29.73		29.7		29.7		29.7	
DIODE PANEL	3.90		3.9		3.9		3.9	
CIRCUITRY–DC POWER		27.72		27.7		27.7		27.7
UMBILICAL	3.00	2.00	3.0	2.0	3.0	2.0	3.0	2.0
DISCONNECTS	8.00	2.40	8.0	7.2	8.0	7.2	8.0	7.2
CIRCUITRY–UTILITY	78.77	7.38	93.8	7.4	93.8	7.4	93.8	7.4
CIRCUITRY–RETROGRADE	20.62							
CIRCUITRY–PROPULSION			26.0	8.0	26.0	8.0	26.0	8.0
INSTALLATION PARTS	8.64	39.13	8.6	39.1	8.6	39.1	8.6	39.1

4.8.1.6 (Continued)

	Lunar Gemini I	Lunar Gemini II	Lunar Gemini III
Reduce Fuel Cell Reactants	-94	-55	-55
Increased circuitry from Propulsion stages	18	18	18
Increased Internal Circuitry	15	15	15

4.8.1.7 Display System - Table 4-9 presents the weight breakdown of the display system. The major weight differences between the earth orbital Gemini and Lunar Gemini I, II and III are:

	Lunar Gemini I	Lunar Gemini II	Lunar Gemini III
Add Additional Communications Display	8	8	10
Increase Platform and Sextant Display			14
Increased Sequence Panels and Overrides	8	8	8
Add Thrust Control Flight Indicators	12	12	12
Increased Propulsion Displays	8	8	8
Add Lunar Landing Mirror System	20	20	20
Increased Circuitry Allowance	23	23	23

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TABLE 4–9

DISPLAY SYSTEM WEIGHT COMPARISON

DISPLAY SYSTEM	EARTH ORBITAL GEMINI C.M. 173.91	LUNAR GEMINI I C.M. 251.5	LUNAR GEMINI I S.M. 29.0	LUNAR GEMINI II C.M. 266.5	LUNAR GEMINI II S.M. 29.0	LUNAR GEMINI III C.M. 270.5
COMMUNICATIONS AND INSTRUMENTATION	(6.30)	(14.3)		(16.3)		(16.3)
VOICE CONTROL	6.30	6.3		6.3		6.3
COMMUNICATIONS CONTROL		8.0		8.0		8.0
TV MONITOR				2.0		2.0
GUIDANCE AND NAVIGATION	(21.94)	(20.5)		(35.0)		(39.0)
PLATFORM GROUP	1.49	1.5		6.0		6.0
SXT AND SCT				10.0		10.0
COMPUTER GROUP	4.88	4.9		4.9		4.9
CLOCK	4.07	4.1		4.1		4.1
TIMER	7.50	(SEE TELECOMMUNICATION)				
RADAR INCREMENT VELOCITY	4.00		4.0		4.0	4.0
ANGLE GROUP		4.0		4.0		4.0
POWER CONTROLS – SENSOR ORIENT		6.0		6.0		6.0
STABILIZATION AND CONTROL	(45.90)	(52.5)		(52.5)		(52.5)
CONTROLLER 3 AXIS	4.50	4.5		4.5		4.5
MANUAL THRUST CONTROL – LUNAR LANDING		3.0		3.0		3.0
MODE SELECTOR LUNAR LANDING		2.0		2.0		2.0
FLIGHT DIRECTOR CENTER	5.60	2.0		2.0		2.0
FLIGHT DIRECTOR INDICATOR	16.80	10.0	10.0	10.0	10.0	10.0
FLIGHT INDICATORS (THRUST CONTROL)						
TRANSLATIONAL VELOCITY		6.0		6.0		6.0
ENGINE GIMBAL ANGLE		6.0		6.0		6.0
HORIZON SCANNERS	19.00	19.0		19.0		19.0
LAUNCH – RE-ENTRY – ABORT	(12.77)	(26.5)		(25.0)		(25.0)
PARAGLIDER PRESSURE INDICATOR	.50	.5				
AIRSPEED	1.00	1.0				
BOOSTER MONITOR	4.00	4.0		4.0		4.0
ACCELEROMETER	.85	2.0		2.0		2.0
ALTIMETER	2.00	4.0		4.0		4.0
ABORT CONTROL		4.0		4.0		4.0
RATE OF DESCENT	1.00					
SEQUENCE PANELS AND OVERRIDES	3.42	11.0		11.0		11.0
ALTITUDE/RATE INDICATOR			3.0		3.0	
UTILITY CONTROLS AND DISPLAYS	(23.52)	(31.4)		(31.4)		(31.4)
ENVIRONMENTAL CONTROL SYSTEM						
CABIN PRESSURE	1.00	1.0		1.0		1.0
OXYGEN INDICATOR	2.75	2.8		2.8		2.8
SUIT TEMPERATURE AND PRESSURE	2.00	2.0		2.0		2.0
CONTROLS	7.87	7.9		7.9		7.9
POWER DISTRIBUTION	7.60	7.7		7.7		7.7
PROPULSION	2.30	10.0		10.0		10.0
LUNAR LANDING MIRROR SYSTEM		20.0		20.0		20.0
ELECTRICAL PROVISIONS	37.18	60.0	4.0	60.0	4.0	60.0
STRUCTURE – PANEL AND CONSOLES	26.30	26.3	8.0	26.3	8.0	26.3

4.8.1.8 Telecommunications System - Table 4-10 presents the weight breakdown of the telecommunications System. The major weight differences between the earth orbital and Lunar Gemini I, II and III are:

	Lunar Gemini		
	I	II	III
Add DSIF Equipment	95	95	95
Increase VHF AM and VHF FM Power		29	29
Increase Recorder & Data Processing		29	29
Add Spares		20	20
Increased Sensors and Signal Conditioning	29	52	52
Add Cameras, telescopes and TV Systems	10	54	54
Add Environmental Control	20	20	20
Add Electronic Interface	8	8	8
Increase Circuitry Allowance	19	34	34
Increase Antennas & Assoc. Components	19	20	20
Add Patch Panels		12	12

4.8.1.9 Environmental Control - Table 4-11 presents the weight breakdown of the environmental control system. The major weight differences between the earth orbital Gemini and Lunar Gemini I, II and III are:

	Lunar Gemini		
	I	II	III
Increase Emergency O_2 System	28	28	28
Reduce CO_2 Absorber Capacity	-37	-37	-37
Reduce O_2 Required	-13	-13	-13

4.8.1.10 Crew Systems - Table 4-12 presents the weight breakdown of the crew system. The major weight differences between the earth orbital Gemini and Lunar Gemini I, II and III are:

	Lunar Gemini		
	I	II	III
Add Back Pack and Recharge	82	82	82
Remove Egress Kit			-26
Remove Seat Catapult			-109
Reduce Food Requirements	-12	-12	-12
Increase Water System	29	29	29
Add Miscellaneous Furnishings	27	27	27

TABLE 4-10

TELECOMMUNICATIONS SYSTEMS WEIGHT COMPARISON

TELECOMMUNICATIONS	GEMINI EARTH ORBITAL		LUNAR GEMINI I		LUNAR GEMINI II		LUNAR GEMINI III	
	C.M. 188.23	S.M. 106.88	C.M. 281.7	S.M. 212.0	C.M. 428.0	S.M. 245.2	C.M. 428.0	S.M. 245.2
DSIF SUBSYSTEM								
RECEIVER/TRANSMITTER				9.0		9.0		9.0
POWER AMPLIFIER				30·0		30.0		30.0
NEAR EARTH SYSTEMS								
VHF/AM TRANS./RCVR.	6.00		6.0		20.0		20.0	
VHF/FM TRANS.	4.62	2·31	4.6		20.0		20.0	
C-BAND BEACON	7.49		7.5		13.0		13.0	
S-BAND BEACON		8.34						
ACQ. AID BEACON		1.13						
DIGITAL COMMAND		24.65						
RECOVERY								
HF VOICE	3.50	3.50	3.5		4.0		4.0	
VHF RECOVERY	2.80		2.8		2.8		2.8	
INTERCOMMUNICATIONS								
MIKE & SPEAKER	1.69		1.4		1.4		1.4	
RELAY TRANSCEIVER			3.0		3.0		3.0	
DATA PROCESSING								
LL COMMUTATOR	1.60	1.60	1.6	1.6	3.2	3.4	3.2	3.4
HL COMMUTATOR	2.40	2.40	2.4	2.4	9.6	4.8	9.6	4.8
PROGRAMMER	11.00		11.0		11.0		11.0	
RECORDER	12.00		12.0		28.0		28.0	
SPARES					20.0		20.0	
INSTRUMENTATION								
SENSORS	4.05	.06	10.0	15.0	18.0	25.0	18.0	25.0
SIGNAL CONDITIONING	11.75	4.03	18.2	5.5	21.0	7.5	21.0	7.5
16MM CAMERA					20.0		20.0	
35MM CAMERA			5.0		5.0		5.0	
TELESCOPE			5.0		5.0		5.0	
TV CAMERA					12.0	12.0	12.0	12.0
TIMING			7.5		7.5		7.5	
PATCH PANELS					12.0		12.0	
POWER SUPPLY	14.00	7.00	14.0	7.0	14.0	7.0	14.0	7.0
ANTENNA SYSTEMS								
DSIF ANTENNA AND DRIVE				50.0		50.0		50.0
EARTH TRACKER				6.0		6.0		6.0
ASSOCIATED COMPONENTS				5.0		5.0		5.0
DSIF OMNI				.5		.5		.5
ASSOCIATED COMPONENTS				5.0		5.0		5.0
C-BAND ANTENNA	1.70	.16	1.7		3.0		3.0	
PHASE MODULATOR	1.70		1.7		1.7		1.7	
VHF OMNI	.20	1.00	4.0		4.0		4.0	
MULTIPLEXER	3.50	1.70	9.0		9.0		9.0	
S-BAND		.69						
VHF RECOVERY	.20		1.3		1.3		1.3	
HF RECOVERY	7.13		4.0		4.0		4.0	
VHF STUB	2.00							
VHF EXTENDED		1.00						
ASSOCIATED COMPONENTS	2.70	.61	16.5		16.5		16.5	
MISCELLANEOUS								
STRUCTURAL SUPPORTS	15.70	21.70	20.0	40.0	20.0	40.0	20.0	40.0
ENVIRONMENTAL CONTROL			20.0		20.0		20.0	
ELECTRONIC INTERFACE			8.0		8.0		8.0	
CIRCUITRY	70.50	25.00	80.0	35.0	90.0	40.0	90.0	40.0

TABLE 4-11

ENVIRONMENTAL CONTROL SYSTEM

ENVIRONMENTAL CONTROL SYSTEM	GEMINI EARTH ORBITAL		LUNAR GEMINI					
			I		II		III	
	C.M.	S.M.	C.M.	S.M.	C.M.	S.M.	C.M.	S.M.
	339.56	369.51	330.1	353.6	330.1	350.6	330.1	350.6
SUIT PRESSURE AND BREATHING	(158.32)	(153.79)	(120.7)	(137.9)	(120.7)	(137.9)	(120.7)	(137.9)
O_2		106.00		92.8		92.8		92.8
O_2 BOTTLE		38.92		36.2		36.2		36.2
O_2 VALVING		8.87		8.9		8.9		8.9
COMPRESSORS	9.40		9.4		9.4		9.4	
CO_2 ABSORBERS	108.60		71.0		71.0		71.0	
VALVING & DUCTING	40.32		40.3		40.3		40.3	
EMERGENCY O_2	(61.08)		(89.3)		(89.3)		(89.3)	
O_2	14.00		20.0		20.0		20.0	
O_2 BOTTLE	42.68		64.0		64.0		64.0	
VALVING INSTALLATION	4.40		5.3		5.3		5.3	
EQUIPMENT COOLING	(92.81)	(180.87)	(92.8)	(180.8)	(92.8)	(180.8)	(92.8)	(180.8)
COMPRESSOR	14.50	61.64	14.5	61.6	14.5	61.6	14.5	61.6
HEAT EXCHANGER	14.10	23.60	14.1	23.6	14.1	23.6	14.1	23.6
VALVES, DUCTING, MISC.		18.12		18.1		18.1		18.1
COOLING FLUID	15.76	38.31	15.8	38.3	15.8	38.3	15.8	38.3
COLD PLATES/PROV.	32.45	9.20	32.4	9.2	32.4	9.2	32.4	9.2
COOLING LINES	16.00	30.00	16.0	30.0	16.0	30.0	16.0	30.0
WATER SYSTEM		7.00		7.0		4.0		4.0
POST LANDING VENT	3.17		3.2		3.2		3.2	
CABIN PRESSURE RELIEF	3.34		3.3		3.3		3.3	
MOUNTING	10.84	23.85	10.8	23.9	10.8	23.9	10.8	23.9
CIRCUITRY	10.00	4.00	10.0	4.0	10.0	4.0	10.0	4.0

TABLE 4-12

CREW SYSTEM WEIGHT COMPARISON

CREW SYSTEM	EARTH ORBITAL GEMINI	LUNAR GEMINI		
		I	II	III
	C.M.	C.M.	C.M.	C.M.
	929.09	1048.8	1048.8	910.7
ASTRONAUT	360.00	360.0	360.0	360.0
BALLAST PROVISIONS	3.00	3.0	3.0	
PRESSURE SUIT	58.60	60.0	60.0	60.0
SURVIVAL KIT	53.00	53.0	53.0	53.0
BACK PACKS		60.0	60.0	60.0
BACK PACK RECHARGE		22.0	22.0	22.0
PERSONAL CHUTES	46.00	40.0	40.0	40.0
EGRESS KIT	26.40	26.4	26.4	
SEAT INCL. RESTRAINT AND PADS	158.40	158.4	158.4	158.4
SEAT CATAPULT	108.66	108.7	108.7	
FIRST AID PACK	10.00	10.0	10.0	10.0
FOOD DRY	39.50	27.5	27.5	27.5
WATER SYSTEM	20.44	(49.4)	(49.4)	(49.4)
WATER		40.0	40.0	40.0
CONTAINER		9.4	9.4	9.4
RELIEF PROVISIONS	8.00	8.0	8.0	8.0
PERSONAL HYGIENE	18.60	18.6	18.6	18.6
NUCLEAR INDICATOR	7.00	7.0	7.0	7.0
BIOMEDICAL INSTRUMENTATION	6.00	6.0	6.0	6.0
PERSONAL COMMUNICATIONS		6.0	6.0	6.0
LIGHTING	3.80	3.8	3.8	3.8
OVERSHOES		1.0	1.0	1.0
SOLAR RADIATION GARMENT		7.0	7.0	7.0
SLEEPING AND PRIVACY		1.0	1.0	1.0
EXTRA VEHICULAR ACCESSORIES		12.0	12.0	12.0
CIRCUITRY	1.69			

4.8.2 <u>Propulsion Module</u> - The lunar Gemini I, II and III propulsion modules are the same as Two-Man Apollo, Volume I, with the exception of service module structure.

The following is the comparison of Lunar Gemini and Two-Man Apollo service module structure:

	Two-Man Apollo	Lunar Gemini I, II, III
Structure	(1079)	(991)
Sidewalls	389	389
Higher Sidewall Temperature		57
Support Structure	489	489
Fairing/Separation Devices	201	
Tension Ties (Similar to Orbital Gemini)		56