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Report No. A320 • 13 November 1963

**SUMMARY REPORT**

# GEMINI SPACECRAFT STUDY
## FOR
# MORL FERRY MISSIONS (U)

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# GEMINI SPACECRAFT STUDY

*SUMMARY REPORT*

REPORT A320 ~ 13 NOVEMBER 1963

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This report consists of the following pages:

1. Introduction - A summary of the results of a Gemini Spacecraft Study for MORL Missions are presented in this report. These results are reported in detail in Reference 1. This study which was conducted under NASA Contract NAS1-3121 has shown the Gemini Spacecraft to be readily adaptable for MORL ferry and ferry supply missions. The systems and technology developed for Gemini are also directly applicable to the design of unmanned supply spacecraft logistics support of the MORL.

2. MORL Mission - The laboratory mission described in Reference 2 provided the basis for this study. Features of the mission of interest for Gemini applications are shown in Figure 2-1.

**MORL MISSION**

- 4-6 MAN SPACE STATION
- PERIODIC CREW ROTATION AND/OR SUPPLY BY
  - FERRY SPACECRAFT
  - UNMANNED SUPPLY SPACECRAFT
  - COMBINATION FERRY/SUPPLY SPACECRAFT
- ONE-YEAR STATION DURATION
  - 6-8 MONTH FERRY STANDBY
- ORBIT
  - ALTITUDE: 160-250 NA.MI.
  - INCLINATION: 28.5°
- ZERO g OR ARTIFICIAL GRAVITY OPERATION

FIGURE 2-1

3. Gemini Applications - Various methods of utilizing Gemini in support of the MORL, as shown in Figure 3-1, involve a Ferry Spacecraft, a Ferry/Supply Spacecraft, and Unmanned Supply Spacecraft.

The Ferry Spacecraft is essentially an existing Gemini spacecraft with modifications necessary to accomplish the MORL mission. It is used to transport crewmen to and from the laboratory, and is launched by the Gemini Launch Vehicle (GLV), a modified Titan II.

## GEMINI APPLICATIONS TO MORL MISSION

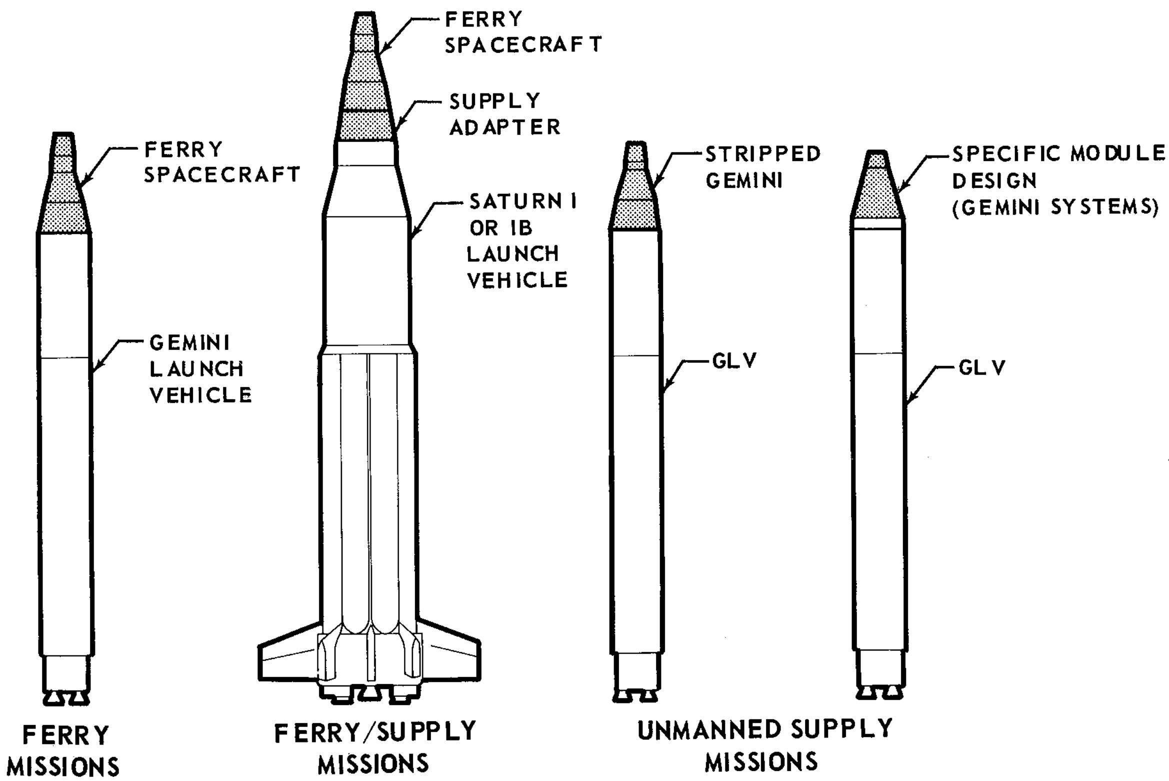


FIGURE 3–1

The Ferry/Supply Spacecraft consists of the Ferry Spacecraft described with a cargo adapter added to the aft end. This spacecraft serves as both a crew and supply transport.

There are two versions of Unmanned Supply Spacecraft launched by GLV. One is a Gemini Spacecraft, stripped of all equipment and structure unnecessary for a supply mission. Available space is loaded with supplies for the MORL. The other is a new spacecraft, designed specifically for a supply mission, but utilizing Gemini systems and technology wherever possible. Neither of these spacecraft is recoverable.

Primary effort was directed toward detail definition of modifications to the present NASA Gemini necessary for the ferry mission. This data was used in investigations of Ferry/Supply and Unmanned Supply Spacecraft. The specific features of

3. (Continued)

these spacecraft were examined to a lesser degree of detail than the Ferry Spacecraft.

4. Design Parameters - Design studies of Ferry Spacecraft are based on defining changes to the two-day rendezvous mission version of the present Gemini, as configured on August 31, 1963. Specific features of the MORL system concept which most affect the design are discussed in the following sections.

4.1 Mission Profile - The nominal profile for the ferry mission (including Ferry/Supply) is shown in Figure 4.1-1. The portion of the mission between launch and mooring is also applicable to the Unmanned Supply Spacecraft. This mission is similar to the existing Gemini, with the following exceptions.

A. Orbit Altitude - Initial optimization studies of MORL operational altitudes have indicated that altitudes as high as 250 na. mi. may be desirable, compared to the 161 na. mi. operational altitude of the present Gemini. The higher altitude reduces the weight-in-orbit capability of the launch vehicle and leads to changes in the spacecraft retrograde and heat protection systems. Configurations shown in this report are for an operational altitude of 250 na. mi. which is the most severe case from a weight standpoint.

B. Catch-up Time - The maximum time (19.9 hours) required for the Ferry or Supply Spacecraft to catch up with the station after orbit injection is approximately one day less than that in the present Gemini rendezvous. This is considered reasonable, since it is assumed that launch control techniques will be developed to permit more accurate timing of launches in the MORL time period. The reduced catch-up time permits reduction in quantities of expendables for the electric power and environmental control systems.

C. Stand-by - Based on MORL scheduling, some of the Ferry Spacecraft remain moored to the station in a deactivated condition for periods of 6 to 8 months.

## MISSION PROFILE

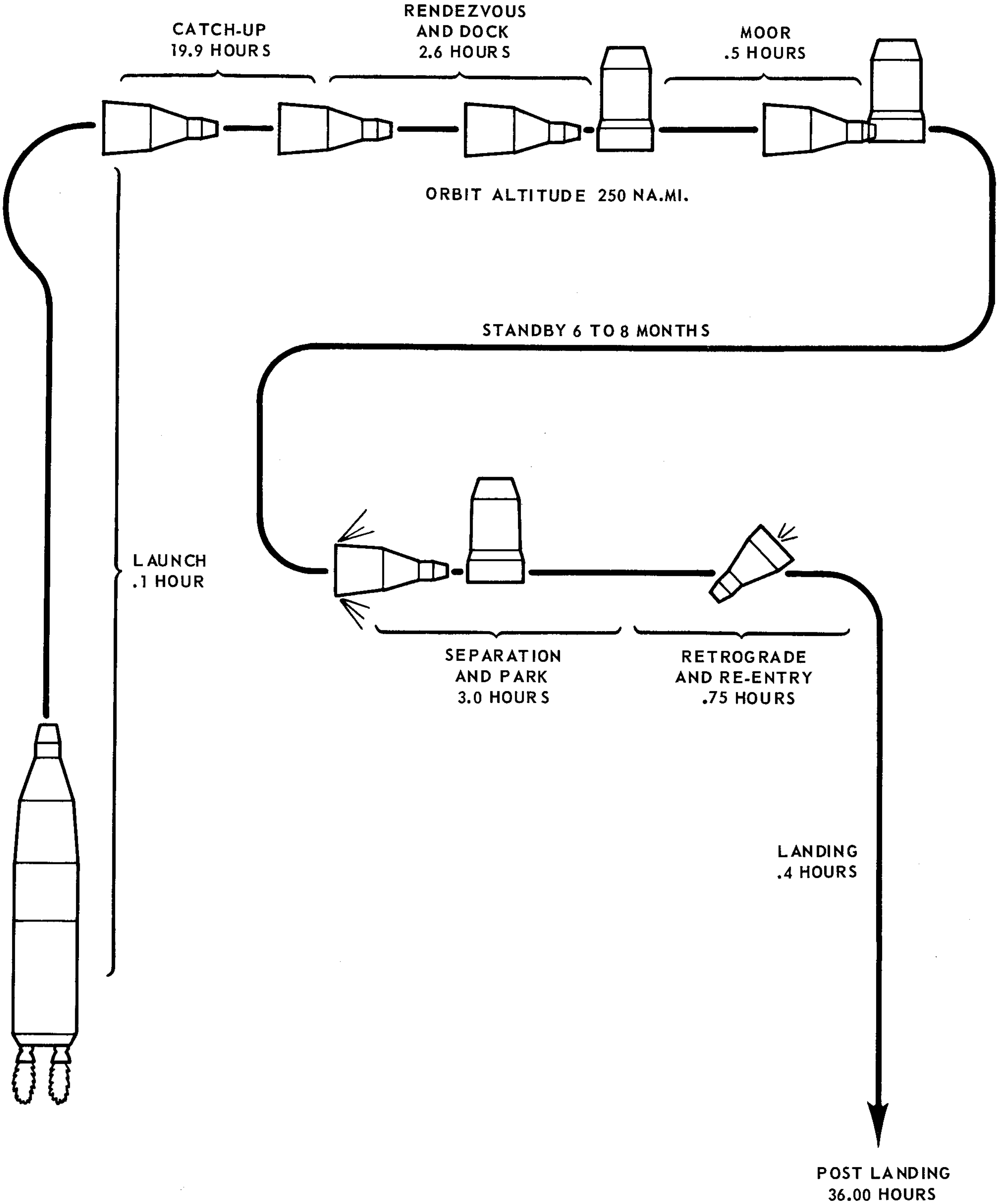


FIGURE 4.1-1

4.1 (Continued)

Since the present Gemini is designed for 14 days in orbit, several modifications are necessary to provide reasonable assurance of proper operation of the Ferry for safe return to earth after this long period of exposure to the space environment. The stand-by requirement also results in the addition of provisions for environmental protection of some systems or elimination or replacement of systems which cannot be practically protected.

D. Post Separation Park and Increased Re-entry Times - The three-hour maximum parking orbit after separation from the station is an emergency consideration based on the time required to reach a land landing site. NASA has provided data indicating that the maximum wait time from any point in orbit to land at one of 472 world-wide paraglider landing sites is 2 hrs-10 min. and at one of 341 parasail landing sites is 2 hr.-28 min. Normally, the spacecraft separation from the station would be timed for a landing at a pre-selected site with only a short time in orbit.

The 45-minute re-entry time is 8.3 minutes longer than for Gemini due to the higher orbital altitude.

These times affect the amount of onboard expendables necessary after separation.

4.2 Docking, Mooring and Crew Transfer - Capability for docking and mooring at the station, and for remaining moored under zero or artificial gravity operation, is required. In addition, provisions for crew transfer between the Ferry Spacecraft and MORL and for crew access to, and transfer of, cargo in the Supply Spacecraft is necessary. Variations in the design of Ferry and Supply Spacecraft occur as a result of the method of docking, mooring and crew and cargo transfer.

5. Ferry Spacecraft - Three types of Ferry spacecraft were investigated, involving different methods of docking and mooring to the MORL. These three

5. (Continued)

(Figure 5-1) are (1) the nose dock-nose moor Ferry, (2) the nose dock-side moor Ferry, and (3) the aft dock-aft moor Ferry.

FERRY VARIATIONS

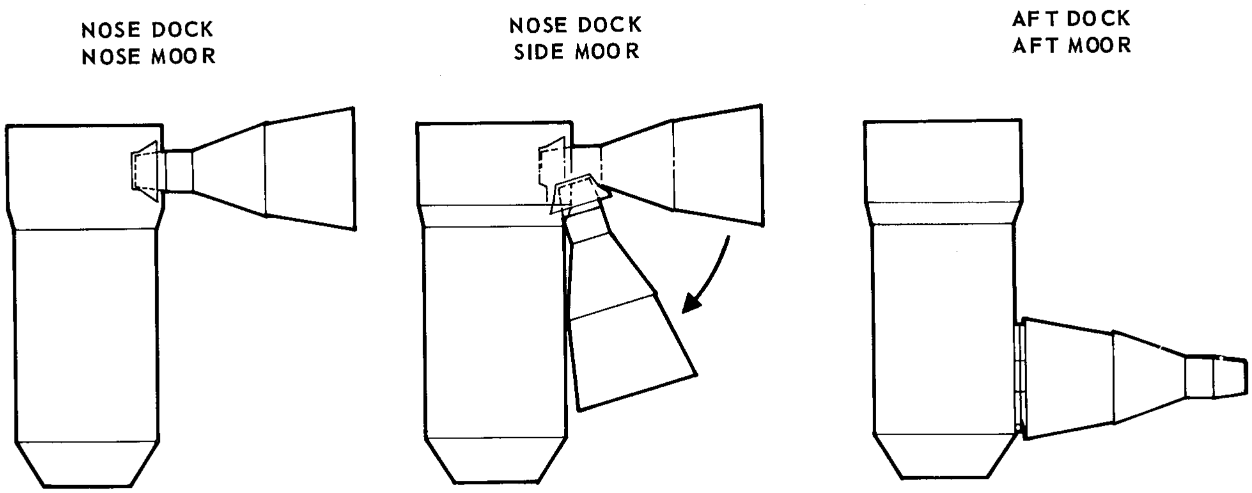


FIGURE 5-1

Designs are presented for Ferry Spacecraft with parachute landing systems. However, weights information is also presented for spacecraft with paragliders and parasails.

5.1 General Arrangement

Nose Dock-Nose Moor Ferry - This spacecraft docks nose first to the Laboratory and is moored in this position in the same manner as the present Gemini is docked and moored to the Agena. Crew transfer is accomplished through space via the existing Gemini hatch, in pressurized pressure suits. The general arrangement of this spacecraft is shown in Figure 5.1-1 with differences from Gemini called out. This version represents the minimum change to Gemini to accomplish the MORL ferry mission, but extravehicular crew transfer, during which there is no back up for the pressure suit, is involved. The various major changes, together with weights, are summarized in Figure 5.1-2.

Nose Dock-Side Moor Ferry - This spacecraft is similar to the nose dock-nose

## FERRY SPACECRAFT
## NOSE DOCK – NOSE MOOR

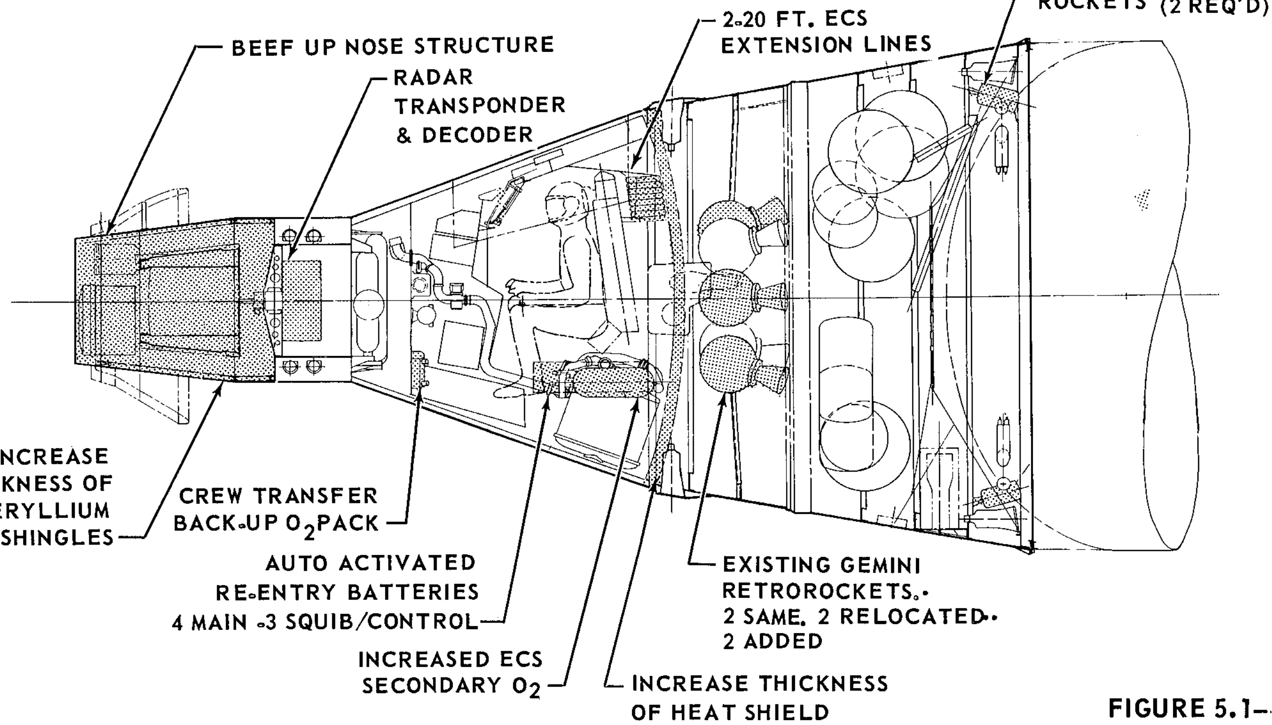


FIGURE 5.1–1

## WEIGHT SUMMARY
## NOSE DOCK – NOSE MOOR
### FERRY SPACECRAFT

| ● CHANGE | WEIGHT INCREMENT (LB.) |
|---|---|
| ● NOSE STRUCTURE BEEF-UP | 15.0 |
| ● PROVISIONS FOR EXTERNAL CREW TRANSFER | 43.0 |
| ● TWO ADDITIONAL RETRO ROCKETS | 165.0 |
| ● INCREASED HEAT SHIELD THICKNESS | 18.0 |
| ● INCREASED BERYLLIUM SHINGLES THICKNESS | 13.0 |
| ● OXYGEN FOR POST SEPARATION | 40.0 |
| ● BATTERIES FOR POST SEPARATION | 151.0 |
| ● TWO SOLID SEPARATION ROCKETS | 25.0 |
| ● DATA LINK FOR RENDEZVOUS BACK-UP | 40.0 |
| ● STANDBY TEMPERATURE CONTROL EQUIPMENT | 44.0 |
| ● REDUCED CATCH-UP TIME | –46.0 |
| ● DELETED R & D INSTRUMENTATION | –67.0 |
| ● C.G. ECCENTRICITY BALLAST | –36.0 |
| TOTAL INCREASE OVER GEMINI | 405.0 |

| | PARACHUTE | PARASAIL | PARAGLIDER |
|---|---|---|---|
| ● GROSS WEIGHT – NOSE DOCK – NOSE MOOR FERRY | 7367 | 7865 | 8098 |

FIGURE 5.1–2

5.1 (Continued)

moor version, except that after docking the Ferry is swung to the side of the MORL, bringing the hatch in contact with a tunnel to the airlock in MORL to permit enclosed crew transfer. An auxiliary hatch is added within the Gemini hatch to provide a practical seal between the Ferry and the MORL, to maintain the structural integrity of the pressurized Ferry and to allow space for crew transfer as shown in Figure 5.1-3. Although involving more change than the nose dock-nose moor Ferry, this version represents a minimum change to provide inherent enclosed crew transfer with pressure suit back-up. The differences between nose dock-side moor and nose dock-nose moor Ferry Spacecraft are indicated in Figure 5.1-4.

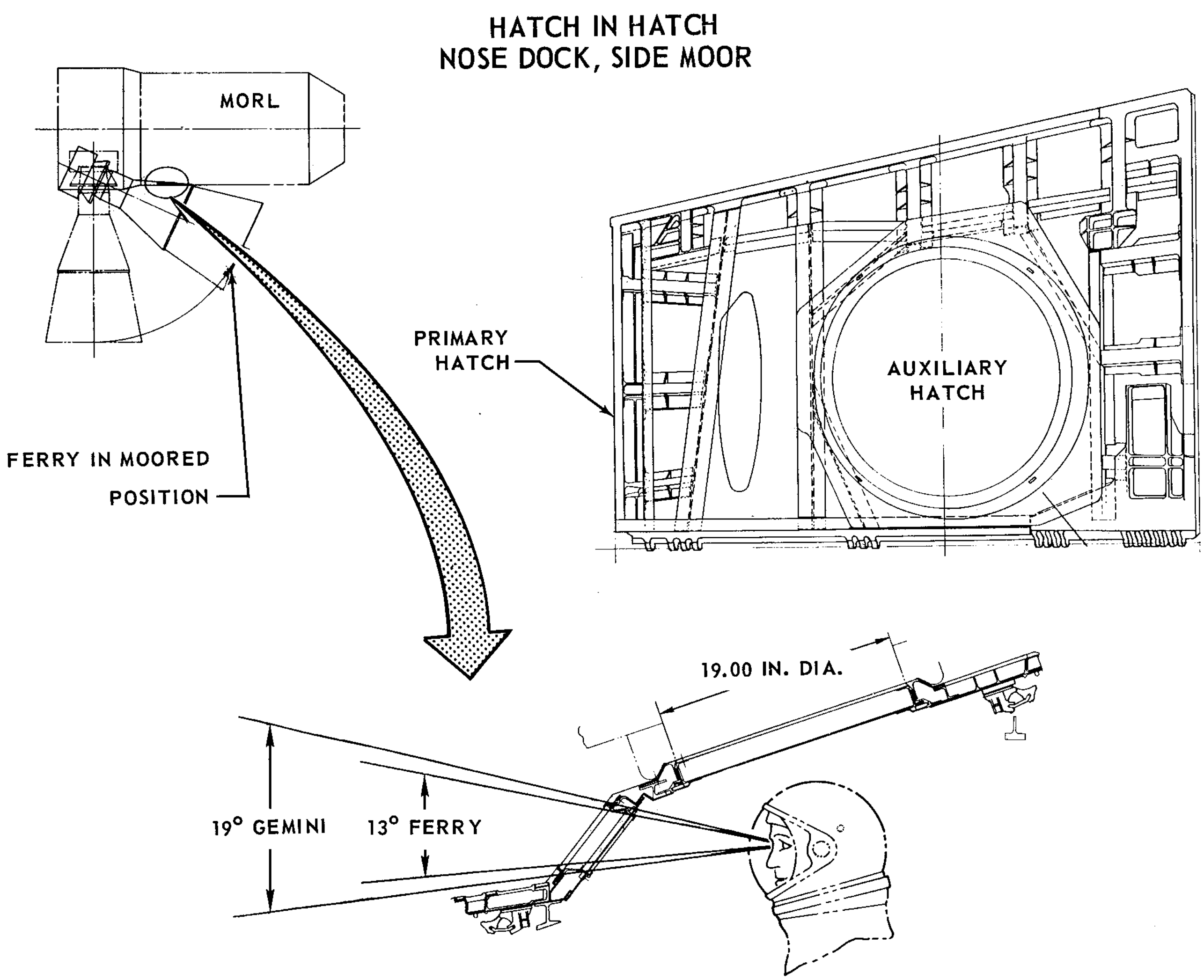


FIGURE 5.1-3

5.1 (Continued)

### WEIGHT SUMMARY
### NOSE DOCK – SIDE MOOR FERRY

**NOSE DOCK NOSE MOOR FERRY**

| ● WEIGHT (LB.) | |
|---|---|
| PARACHUTE | 7367 |
| PARASAIL | 7865 |
| PARAGLIDER | 8098 |

| | WEIGHT (LB.) |
|---|---|
| **● REMOVE** | |
| ● NOSE BEEF-UP | –15.0 |
| ● EXTERNAL CREW TRANSFER EQUIPMENT | –43.0 |
| **● ADD** | |
| ● AUXILIARY HATCH | 30.0 |
| ● SIDE MOOR FITTINGS | 14.0 |
| ● ECCENTRICITY BALLAST | 23.0 |
| **● WEIGHT INCREASE** | 9.0 |

**NOSE DOCK SIDE MOOR FERRY**

| ● WEIGHT (LB.) | |
|---|---|
| PARACHUTE | 7376 |
| PARASAIL | 7874 |
| PARAGLIDER | 8107 |

FIGURE 5.1-4

Aft Dock-Aft Moor Ferry - The spacecraft is docked and moored at the aft end. Enclosed crew transfer is accomplished through hatches in the heat shield and large pressure bulkhead and a tunnel in the adapter which mates to the MORL airlock. A crew station is provided at the aft end of the tunnel for docking control. The general arrangement of this spacecraft is shown in Figure 5.1-5. More change to Gemini is involved than for either of the nose dock versions. The approach is attractive when used in conjunction with some type of pressurized compartment attached to the aft end to which in-space access is desired. The major differences between aft dock-aft moor and nose dock-nose moor Ferry Spacecraft are shown in Figure 5.1-6.

5.2 Standby Analysis - The effects of the space environment which may represent a hazard to Ferry Spacecraft equipment during the six-month standby period are summarized in Table 5.2-1.

## FERRY SPACECRAFT
## AFT DOCK – AFT MOOR

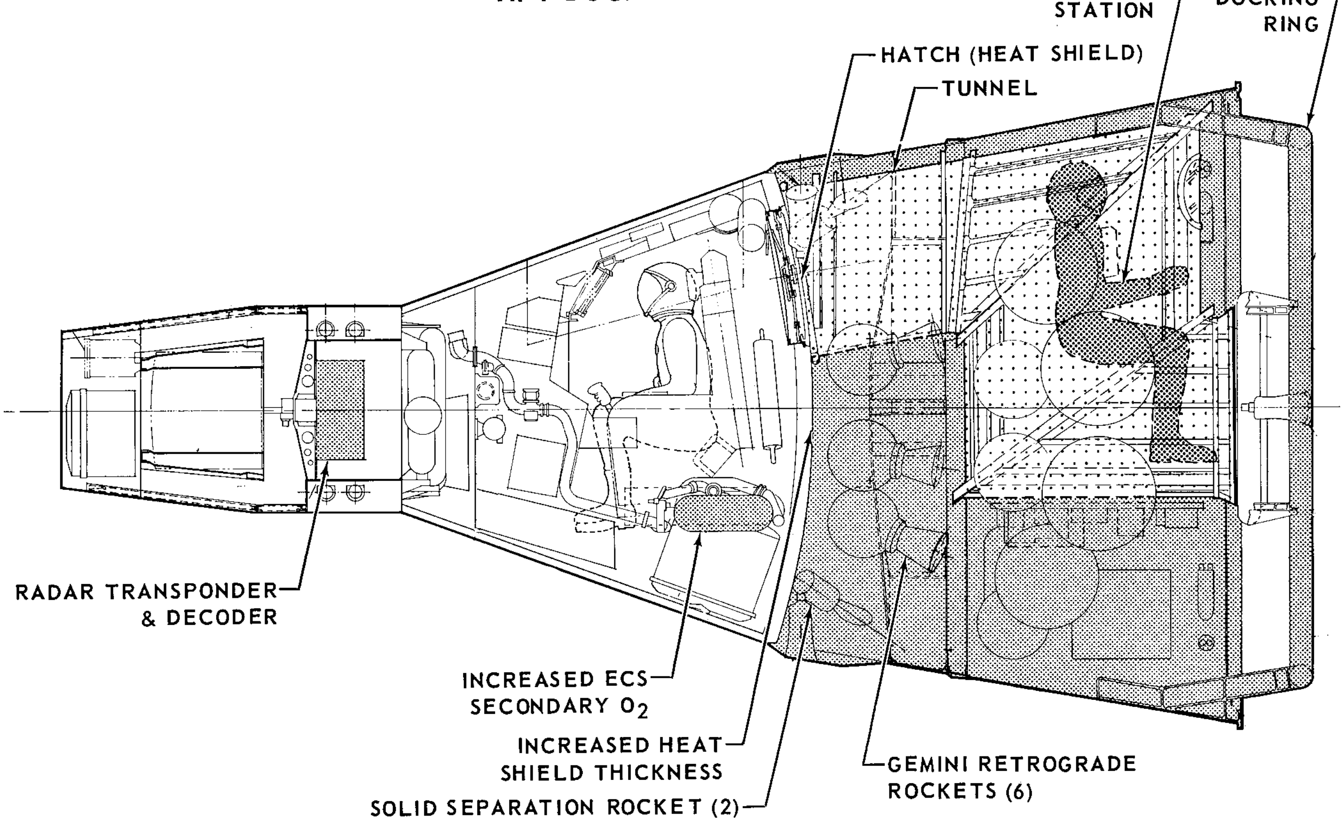


FIGURE 5.1–5

## WEIGHT SUMMARY
## AFT DOCK – AFT MOOR FERRY

**NOSE DOCK NOSE MOOR FERRY**

| WEIGHT (LB.) | |
|---|---|
| PARACHUTE | 7367 |
| PARASAIL | 7865 |
| PARAGLIDER | 8098 |

⇨

| ● REMOVE | WEIGHT (LB.) |
|---|---|
| ● NOSE BEEF-UP | –15.0 |
| ● CREW TRANSFER EQUIPMENT | –28.0 |
| ● NOSE DOCK PROVISIONS | –24.0 |
| **● ADD** | |
| ● HATCH IN HEAT SHIELD & BULKHEAD | 42.0 |
| ● ADAPTER TUNNEL | 210.0 |
| ● AFT DOCKING CONTROLS | 23.0 |
| ● DOCKING RING | 40.0 |
| ● 100 LB. THRUST ENGINE | 10.0 |
| ● ECCENTRICITY BALLAST | 22.0 |
| **● WEIGHT INCREASE** | **280.0** |

⇨

**AFT DOCK AFT MOOR FERRY**

| WEIGHT (LB.) | |
|---|---|
| PARACHUTE | 7647 |
| PARASAIL | 8145 |
| PARAGLIDER | 8378 |

FIGURE 5.1–6

5.2 (Continued)

as to the exact capability of the Ferry Spacecraft to withstand the environment. A standby test program to substantiate estimates and analyses, was derived. In some cases, protective measures are needed to maintain equipment within specified environmental limits, as summarized in Table 5.2-2.

TABLE 5.2-2
STANDBY PROTECTION

| POSSIBLE PROTECTIVE TECHNIQUE | HAZARDS PROTECTED AGAINST | | | | | |
|---|---|---|---|---|---|---|
| | COLD WELDS | VACUUM OUTGASSING | FREEZING | LEAKAGE | RADIATION DAMAGE | METEOROID PUNCTURE |
| • PRESSURIZE CABIN TO .10 PSI | X | X | | | | |
| • COAT ADAPTER TO CONTROL TEMPERATURE | | | X | | | |
| • ADD HEATERS | | | X | | | |
| • ENCAPSULATE SPACECRAFT | X | X | X | | X | X |
| • SELECTIVE MANUFACTURING PROCESSES | X | X | | | | |
| • INCREASE QUANTITY OF FLUIDS AND GASES | | | | X | | |
| • ELIMINATE NEED FOR SYSTEM AFTER STANDBY | X | X | X | X | X | X |

Equipment will be tested under simulated space conditions to verify its capability. Estimated program costs include a substantial amount of this type of testing.

By extrapolation of existing data, and use of engineering judgement it is concluded that most equipment has inherent capability of operating satisfactorily after exposure to the space environment for long periods.

Equipment which is unusually difficult to protect is not used after standby, and alternate systems are employed, as shown in Table 5.2-3.

TABLE 5.2-3

ALTERNATE SYSTEMS FOR POST STANDBY OPERATION

| FUNCTION | SYSTEM THAT WOULD NORMALLY BE USED BUT ELIMINATED DUE TO STANDBY PROBLEMS | ALTERNATE USED IN LIEU OF ELIMINATED SYSTEM |
|---|---|---|
| STATION SEPARATION | ORBIT ATTITUDE AND MANEUVER SYSTEM (OAMS) | TWO SOLID ROCKETS |
| ATTITUDE CONTROL & RETRO POSITIONING | OAMS | RE-ENTRY CONTROL SYSTEM |
| ELECTRIC POWER | FUEL CELLS | AUTO-ACTIVATED BATTERIES |
| SPACECRAFT COOLING | SPACE RADIATOR | WATER EVAPORATOR |
| BREATHING OXYGEN SUPPLY | SUPERCRITICAL OXYGEN STORAGE SYSTEM | ORBIT OXYGEN ADDED TO GASEOUS SECONDARY OXYGEN SUPPLY |

Minimum Systems Required for Safe Return to Earth - Although the primary consideration in providing standby protection is to permit normal operation of the Ferry Spacecraft after standby, exceptional attention should be given to those operations and systems which are essential to insure safe re-entry and landing. Safe return is dependent primarily on the availability of electric power and breathing oxygen and on the operation of several pyrotechnic devices and the Re-entry Control System. The necessary operations and the associated required systems, along with the amount of back-up, are shown in Table 5.2-4.

6. Ferry/Supply Spacecraft - Several spacecraft were configured which combine the crew and supply transport functions. These configurations provide logistics support to MORL with astronaut control onboard the spacecraft.

The Ferry/Supply Spacecraft are outgrowths of the three Ferry Spacecraft and consist of a Ferry and a cargo adapter which is sized for the capability of the Saturn IB launch vehicle, and which can be off-loaded for launch by the Saturn I. Variations in docking and mooring modes are indicated in Figure 6-1.

TABLE 5.2-4
MINIMUM SYSTEMS FOR SAFE RETURN TO EARTH

| REQUIREMENT | PRIMARY SYSTEM | BACKUP CAPABILITY |
|---|---|---|
| ELECTRIC POWER | AUTO-ACTIVATED BATTERIES 7 ON MAIN BUS 3 ON SQUIB/CONTROL BUS | FOR MINIMUM SYSTEM OPERATION: ONLY 2 SQUIB/CONTROL BATTERIES REQUIRED |
| ASTRONAUT BREATHING AND SUIT PRESSURIZATION | TWO OXYGEN BOTTLES | ONE OXYGEN BOTTLE SUFFICIENT FOR BOTH ASTRONAUTS |
| RELEASE MOORING LATCHES | MECHANICAL RELEASE ON MORL | PYROTECHNIC RELEASE ON GEMINI |
| SEPARATE FROM STATION | TWO SOLID ROCKETS | ONE ROCKET PROVIDES SUFFICIENT SEPARATION IMPULSE |
| ATTITUDE INDICATION | INERTIAL REFERENCE SYSTEM | VISUAL REFERENCE THROUGH WINDOW |
| POSITION TO RETRO ATTITUDE AND HOLD | RE-ENTRY CONTROL SYSTEM | TWO COMPLETELY SEPARATE SYSTEMS INSTALLED – ONE REQUIRED |
| JETTISON EQUIPMENT SECTION | PYROTECHNIC SHAPED CHARGE, WIRE BUNDLE GUILLOTINES, AND TUBE CUTTERS | ALL DEVICES INSTALLED IN PAIRS FOR 100% REDUNDANCY |
| RETROGRADE | 5 SOLID ROCKETS | 6 ROCKETS INSTALLED TO PROVIDE 1 BACKUP |
| JETTISON RETROGRADE SECTION | PYROTECHNIC SHAPED CHARGE | DUAL INSTALLATION FOR 100% REDUNDANCY |
| RE-ENTRY CONTROL | RE-ENTRY CONTROL SYSTEM | TWO COMPLETELY SEPARATE SYSTEMS INSTALLED – ONE REQUIRED |
| RECOVERY AND LANDING | PARACHUTE, PARASAIL OR PARAGLIDER | EJECTION SEAT SYSTEM |

## 6.1 General Arrangement

Nose Dock-Nose Moor Ferry/Supply Spacecraft - The spacecraft consists of a nose dock-nose moor Ferry Spacecraft and a cargo adapter, as shown in Figure 6.1-1. Docking and mooring of this spacecraft is accomplished in two steps, as illustrated in Figure 6-1. The spacecraft is positioned near the MORL by the astronauts, with the aft end facing the MORL. At this point, an astronaut onboard the laboratory takes over and aft docks the spacecraft by means of a remote control link. The Ferry Spacecraft is separated from the cargo section and docked by the ferry crewmen in a manner identical to that used for the nose dock-nose moor Ferry Spacecraft.

## FERRY/SUPPLY VARIATIONS

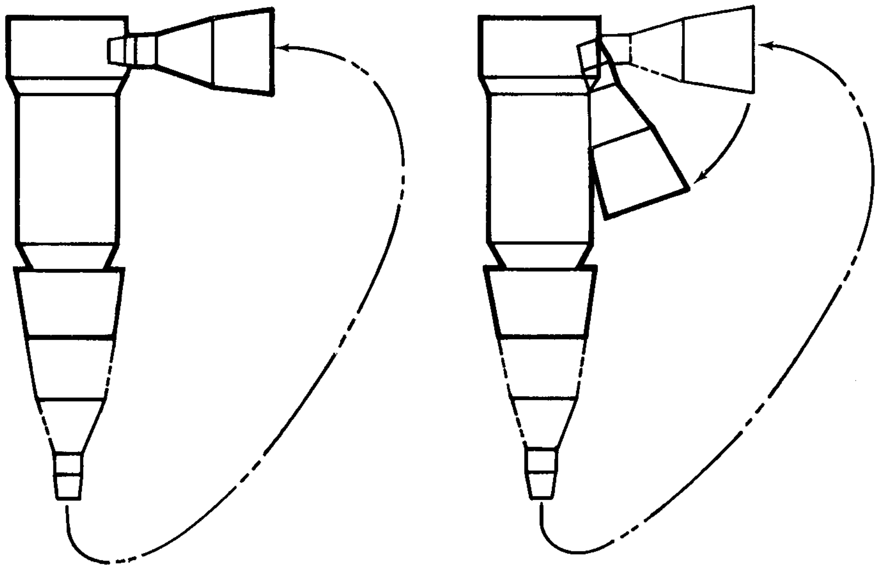


FIGURE 6-1

## FERRY/SUPPLY SPACECRAFT
## NOSE DOCK-NOSE MOOR FERRY

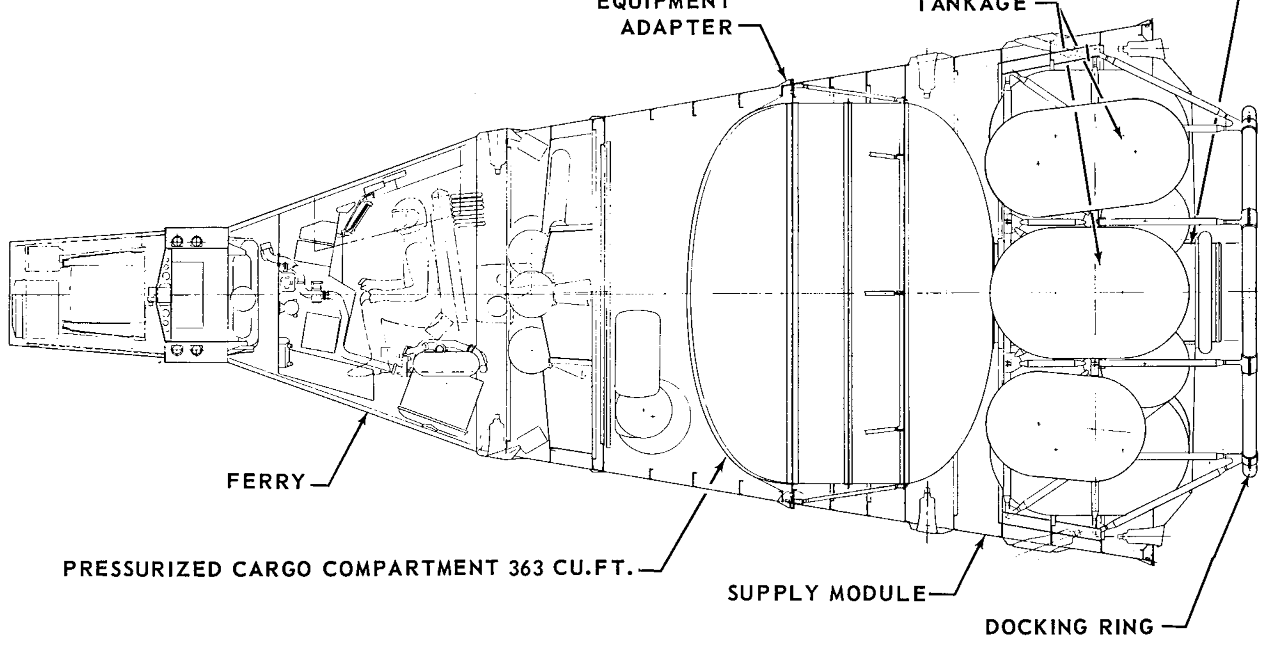


FIGURE 6.1-1

6.1 (Continued)

<u>Nose Dock-Side Moor Ferry/Supply Spacecraft</u> - These spacecraft differ from the nose moor Ferry/Supply Spacecraft only in the use of a side moor Ferry. Docking is again accomplished in a two-step manner.

<u>Aft Dock-Aft Moor Ferry/Supply Spacecraft</u> - The aft docking version is shown in Figure 6.1-2. It consists of a modified aft dock-aft moor Ferry Spacecraft with a cargo adapter. The remote crew station and docking ring are located to the aft end of the cargo adapter. Docking is a one-step operation controlled by the astronauts in the Ferry/Supply Spacecraft. Transfer to the MORL is through the tunnel which extends through the supply adapter. The Ferry remains attached to the supply module until it is utilized for a return flight.

FERRY/SUPPLY SPACECRAFT
AFT DOCK-AFT MOOR

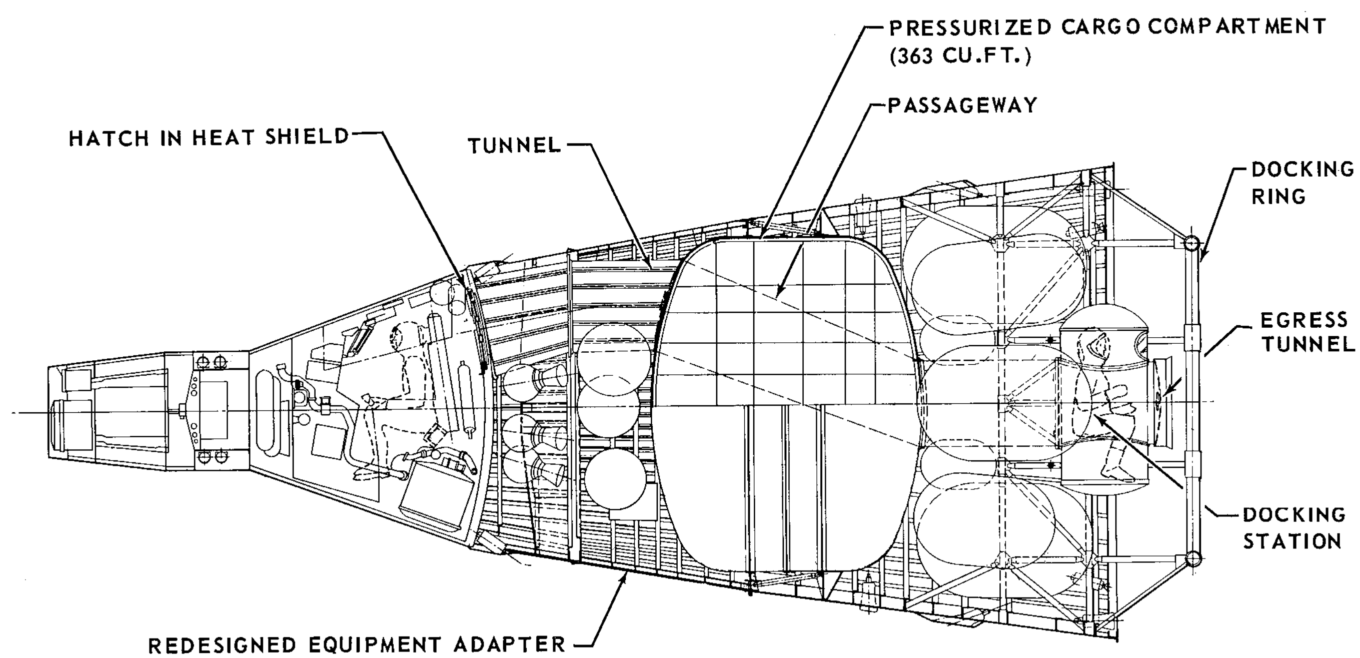


FIGURE 6.1-2

6.2 <u>Escape Systems</u> - Analysis conducted of Saturn fireball heating envelopes indicate that the ejection seats are possibly inadequate for escape. Escape system capability qualitatively similar to that for Mercury appears necessary. One means of providing such capability, shown in Figure 6.2-1, consists of the addition of a Mercury-type escape tower which propels the ferry portion of the spacecraft away from the explosion heating zone. The Ferry is separated from the adapter in the usual manner.

**ESCAPE TOWER**
**FERRY/SUPPLY SPACECRAFT**

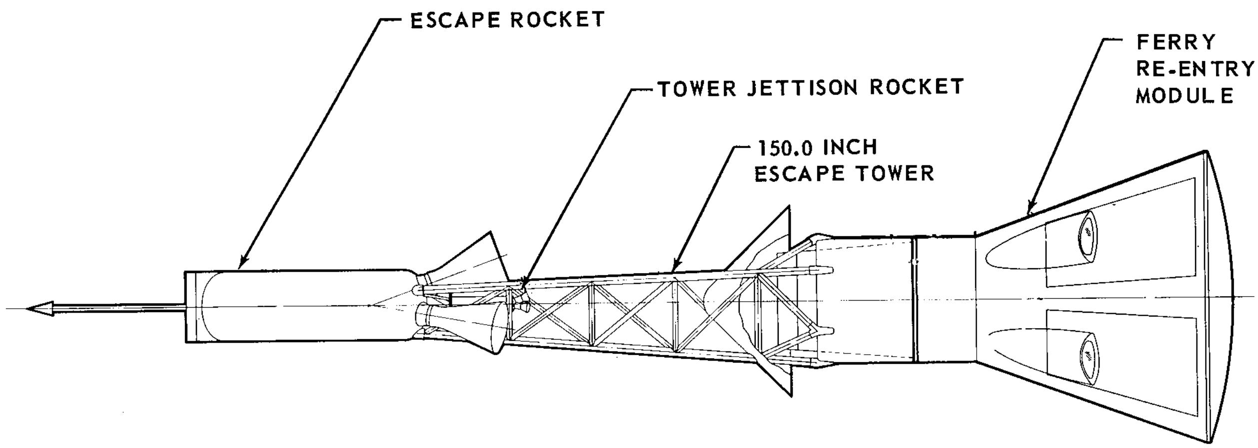


**FIGURE 6.2-1**

6.3 <u>Weight Summary</u> - Ferry/Supply Spacecraft weights and cargo plus growth offset capabilities are shown in Table 6.3-1. Cargo plus growth offset capabilities of about 10,000 pounds for Saturn I launches, and about 19,000 pounds for Saturn IB launches, exist for all versions.

TABLE 6.3-1

FERRY/SUPPLY WEIGHTS – 250 NA.MI. ORBIT
(SATURN I CAPABILITY – 21,650 LB.)

| | PARACHUTE | | PARASAIL | | PARAGLIDER | |
|---|---|---|---|---|---|---|
| | GROSS WEIGHT | MARGIN* | GROSS WEIGHT | MARGIN* | GROSS WEIGHT | MARGIN* |
| | LB. | LB. | LB. | LB. | LB. | LB. |
| NOSE DOCK NOSE MOOR | 11,355 | 10,295 | 11,853 | 9,797 | 12,086 | 9,564 |
| NOSE DOCK SIDE MOOR | 11,364 | 10,286 | 11,862 | 9,788 | 12,095 | 9,555 |
| AFT DOCK AFT MOOR | 11,414 | 10,236 | 11,912 | 9,738 | 12,145 | 9,505 |

*CARGO PLUS GROWTH OFFSET CAPABILITY
PAYLOAD INCREASE WITH SATURN IB LAUNCH –– 8500 LB.

7. Unmanned Supply Spacecraft - The Unmanned Supply Spacecraft, launched by GLV, supply MORL with supplies at three to four month intervals.

Two configurations analyzed are a modified Gemini re-entry module and adapter and a specifically designed spacecraft. Both configurations include a self-inject (onboard) propulsion system to increase payload capabilities, and utilize Gemini systems and components to decrease cost and development time. Both are nose docked and moored. Solid cargo is manually transferred through the pressurized nose section. Fluid cargo is transferred through umbilical connections directly to MORL.

7.1 General Arrangement

Stripped Gemini - Gemini structure and systems, as applicable, are utilized. The configuration is illustrated in Figure 7.1-1. Items deleted from Gemini include those for crew provisions, retrograde and re-entry. Items added (aside from cargo and supplies) include electronics for remote rendezvous and docking, rockets to provide separation and subsequent orbit decay into a burn trajectory and the propulsion system for MORL orbit maintenance. Existing Gemini tankage is utilized for

7.1 (Continued)

stowage of propellant. The spacecraft is capable of supplying MORL solid and fluid cargo requirements for about 83 days.

UNMANNED SUPPLY SPACECRAFT – STRIPPED GEMINI

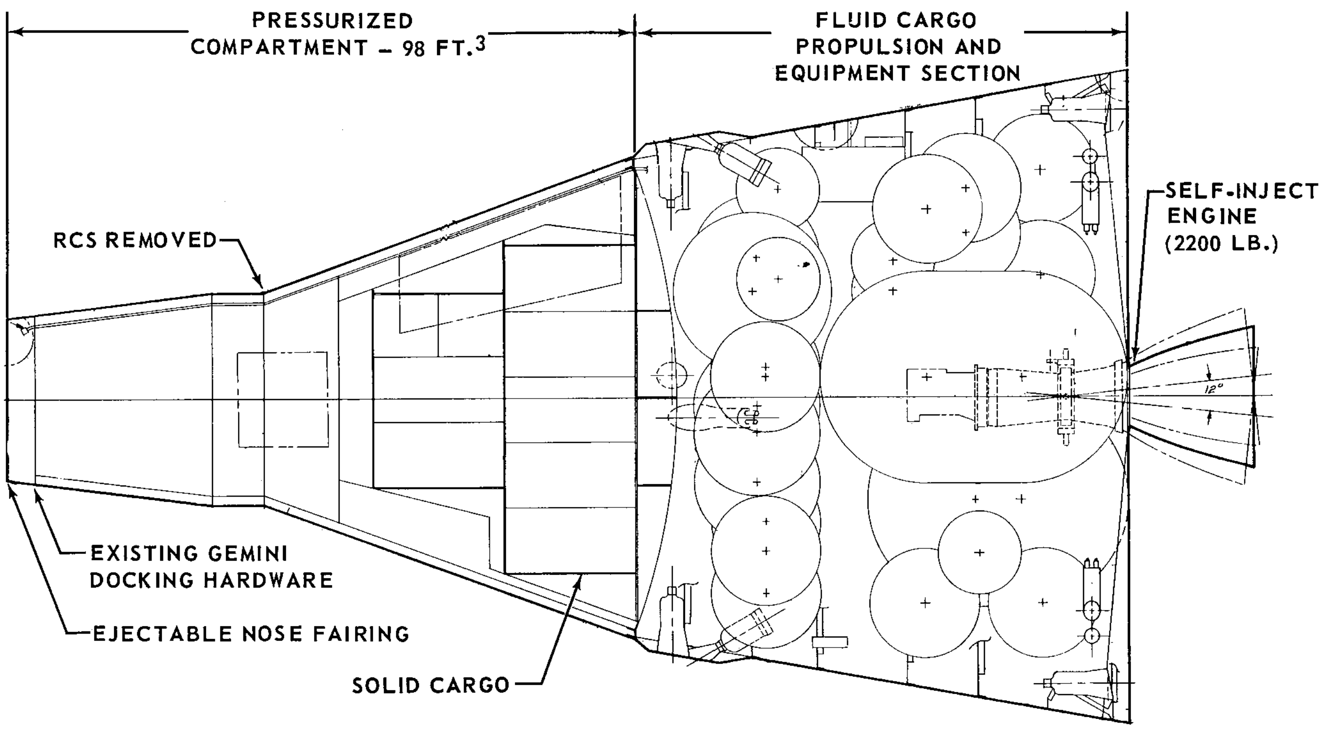


FIGURE 7.1-1

Specific Design - Structure, cargo compartment and cargo tankage are designed specifically for supply missions while utilizing existing Gemini subsystem hardware and gross aerodynamic characteristics. The configuration is shown in Figure 7.1-2. A higher payload capability, than Stripped Gemini, is thus achieved with relatively low subsystem development, and hardware costs. The spacecraft is capable of supplying MORL requirements for 110 days.

7.2 Weight Summary - Weight and cargo plus growth offset capabilities are shown in Table 7.2-1. Cargo plus growth offset capabilities of about 4700 pounds for Stripped Gemini, and about 5200 pounds for the specific design, are indicated.

## UNMANNED SUPPLY SPACECRAFT - SPECIFIC DESIGN

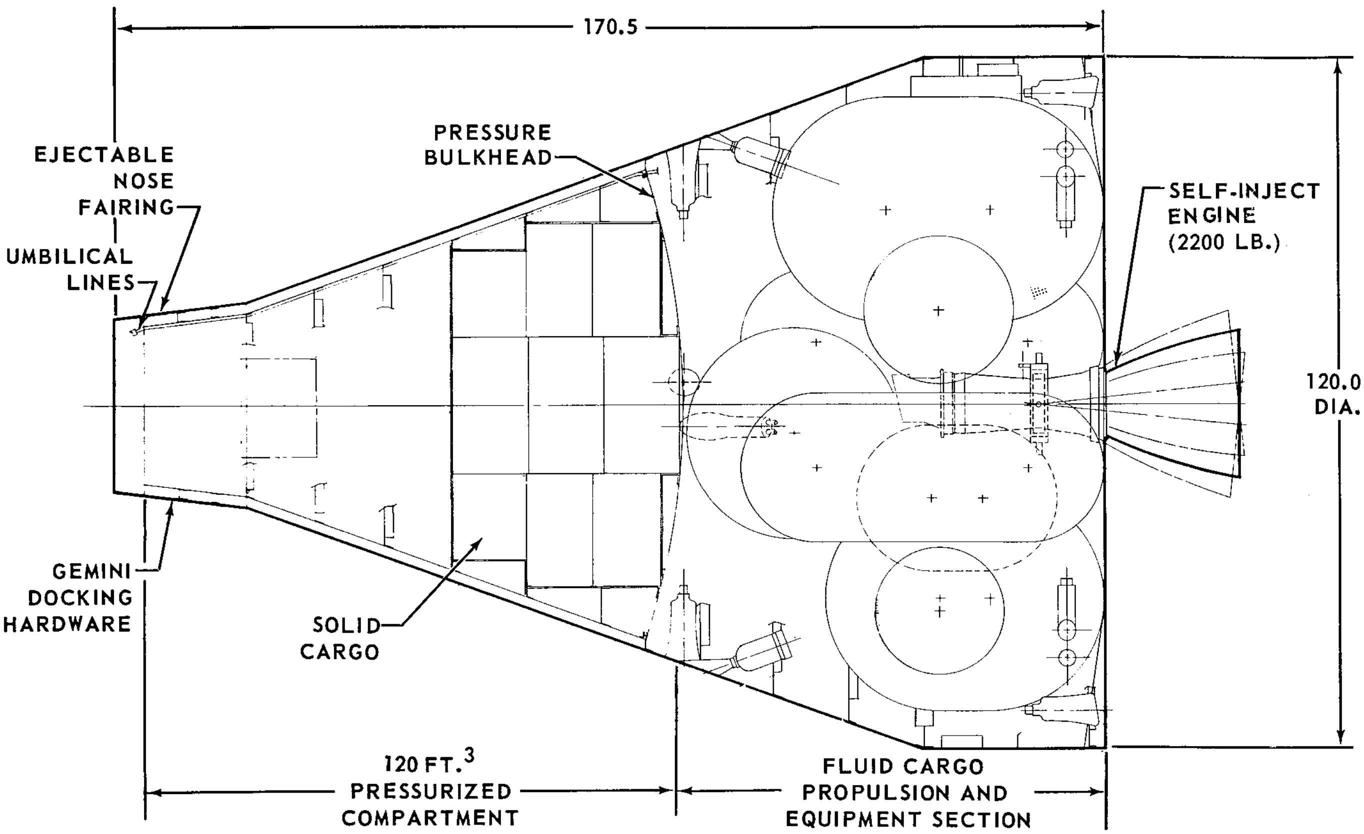


FIGURE 7.1-2

### TABLE 7.2-1
### UNMANNED SUPPLY WEIGHTS
### 250 NA.MI. ORBIT

| SPACECRAFT | GROSS LAUNCH WEIGHT - LB. | INJECTED WEIGHT - LB. (87-250 NA.MI.) | INJECTED SPACECRAFT SYSTEM WEIGHT - LB. | MARGIN LB.** |
|---|---|---|---|---|
| BASIC GEMINI (REFERENCE) | 6962 | | | |
| STRIPPED GEMINI | 12918 | 9245 | 4606 | 4639 |
| SPECIFIC DESIGN | 12918 | 9245 | 3990 | 5255 |

*2200 LB. THRUST GIMBALLED ENGINE
**CARGO PLUS GROWTH OFFSET CAPABILITY

8. Weight Margins - The difference between the estimated weight of the various spacecraft and the launch vehicle capability provides a margin for growth as the design approaches the hardware stage.

McDonnell experience has shown that the weight increase between proposal and hardware stage, independent of capability increases, is approximately eight percent.

Due to the near hardware status of Gemini, the variations considered do not require "proposal stage" weight margins.

Adequate margins based on the status of the over-all spacecraft design are compared to available margins for a 250 na. mi. orbit in Table 8-1.

Margins for the Ferry/Supply and Supply Spacecraft are large due to the fact that the minimum number of launches needed have a greater cargo capability than that required for one year of MORL operation.

The effect of orbit altitude on weight margin for various Ferry Spacecraft with parachute recovery systems is shown in Figure 8-1.

9. Development Schedule - The Ferry and Supply Spacecraft development schedule is presented in Table 9-1. The schedule is divided into two parts: Preliminary Design (Phase II), and Development and Delivery (Phase III). Under the Development Delivery phase, schedules of three different groups of hardware are shown. Group A represents the minimum change items, Group B the moderate change items, and Group C the maximum change items. These groups are typified, respectively, by the nose dock - nose moor Ferry, the nose dock - nose moor Ferry with supply adapter, and the aft dock - aft moor Ferry.

Timing of all programs is based on a Phase II go-ahead in January 1964.

In the manufacturing phase, equal amounts of time are shown for each group. For example, eight months are required for fabrication regardless of which group (A, B, or C) is selected. This time represents the minimum time that the particular operation would require for the minimum change group. For any other group more

## TABLE 8-1

## MARGIN COMPARISON – POUNDS
### FERRY SPACECRAFT

| SPACECRAFT | REQUIRED MARGIN (FOR NORMAL GROWTH) | MARGIN AVAILABLE | AVAILABLE / REQUIRED (PERCENT) |
|---|---|---|---|
| GLV–LAUNCHED | | | |
| F–1 | 145 | 133 | 92 |
| F–2 | 144 | 124 | 86 |
| F–3 | 165 | –147 | – |
| SATURN I LAUNCHED | | | |
| FS–1 | 413 | 3417 | 830 |
| FS–2 | 414 | 3408 | 825 |
| FS–3 | 438 | 3358 | 765 |
| SATURN 1B LAUNCHED | | | |
| FS–1 | 446 | 4889 | 1090 |
| FS–2 | 447 | 4880 | 1090 |
| FS–3 | 472 | 4830 | 1020 |
| GLV LAUNCHED UNMANNED SUPPLY WITH SELF-INJECT | | | |
| US–1 | 290 | 1187 | 410 |
| US–2 | 292 | 656 | 225 |

F–1 = FERRY SPACECRAFT NOSE DOCK – NOSE MOOR
F–2 = FERRY SPACECRAFT NOSE DOCK – SIDE MOOR
F–3 = FERRY SPACECRAFT AFT DOCK – AFT MOOR
FS–1 = FERRY SUPPLY SPACECRAFT NOSE DOCK – NOSE MOOR
FS–2 = FERRY SUPPLY SPACECRAFT NOSE DOCK – SIDE MOOR
FS–3 = FERRY SUPPLY SPACECRAFT AFT DOCK – AFT MOOR
US–1 = UNMANNED SUPPLY SPACECRAFT – STRIPPED GEMINI
US–2 = UNMANNED SUPPLY SPACECRAFT – SPECIFIC DESIGN

## MARGIN vs ORBIT ALTITUDE

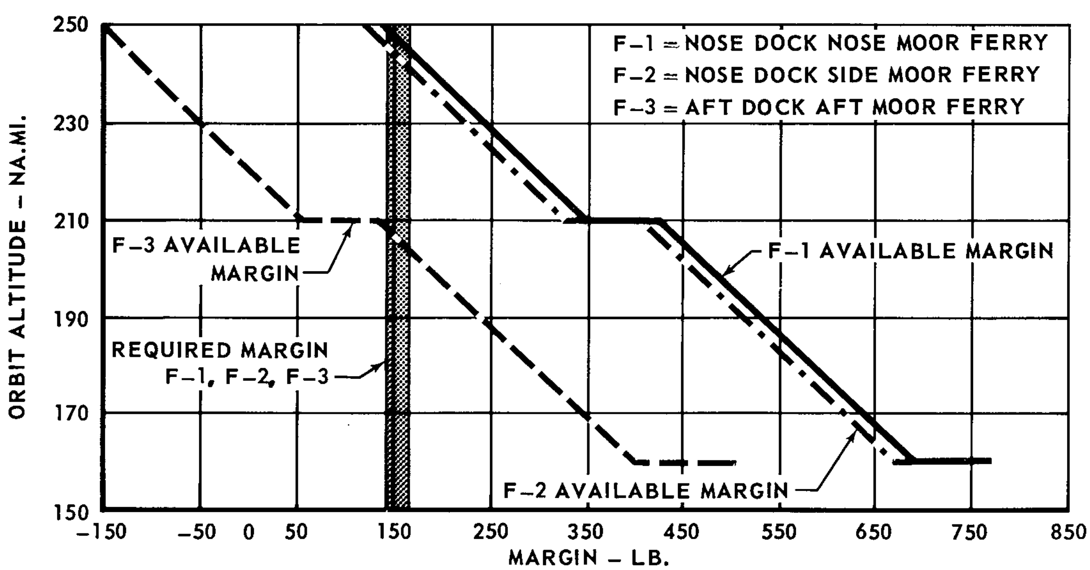


FIGURE 8–1

[redacted]

# GEMINI SPACECRAFT STUDY

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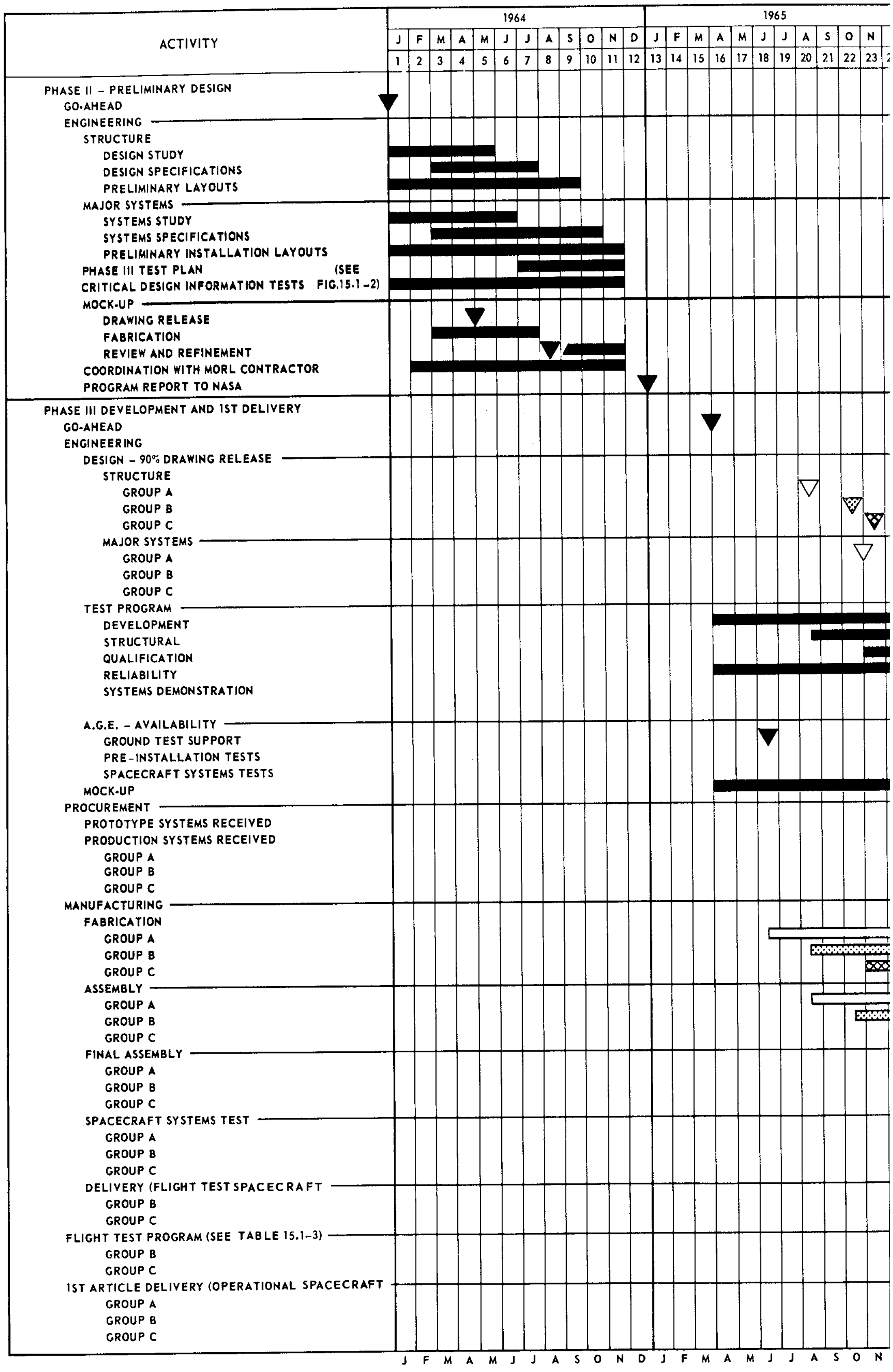
## TABLE 9-1
## DEVELOPMENT SCHEDULE-FERRY AND SUPPLY SPACECRAFT




NOTE: F-1 = FERRY (NOSE DOCK - NOSE MOOR), F-2 = FERRY (NOSE DOCK - SIDE MOOR), F-3 = FERRY (AFT DOCK - AFT MOOR), US-1 = UNMANNED SUPPLY (STRIPPED GEMINI), US-2 = UNMANNED SUPPLY (SPECIFIC DESIGN).

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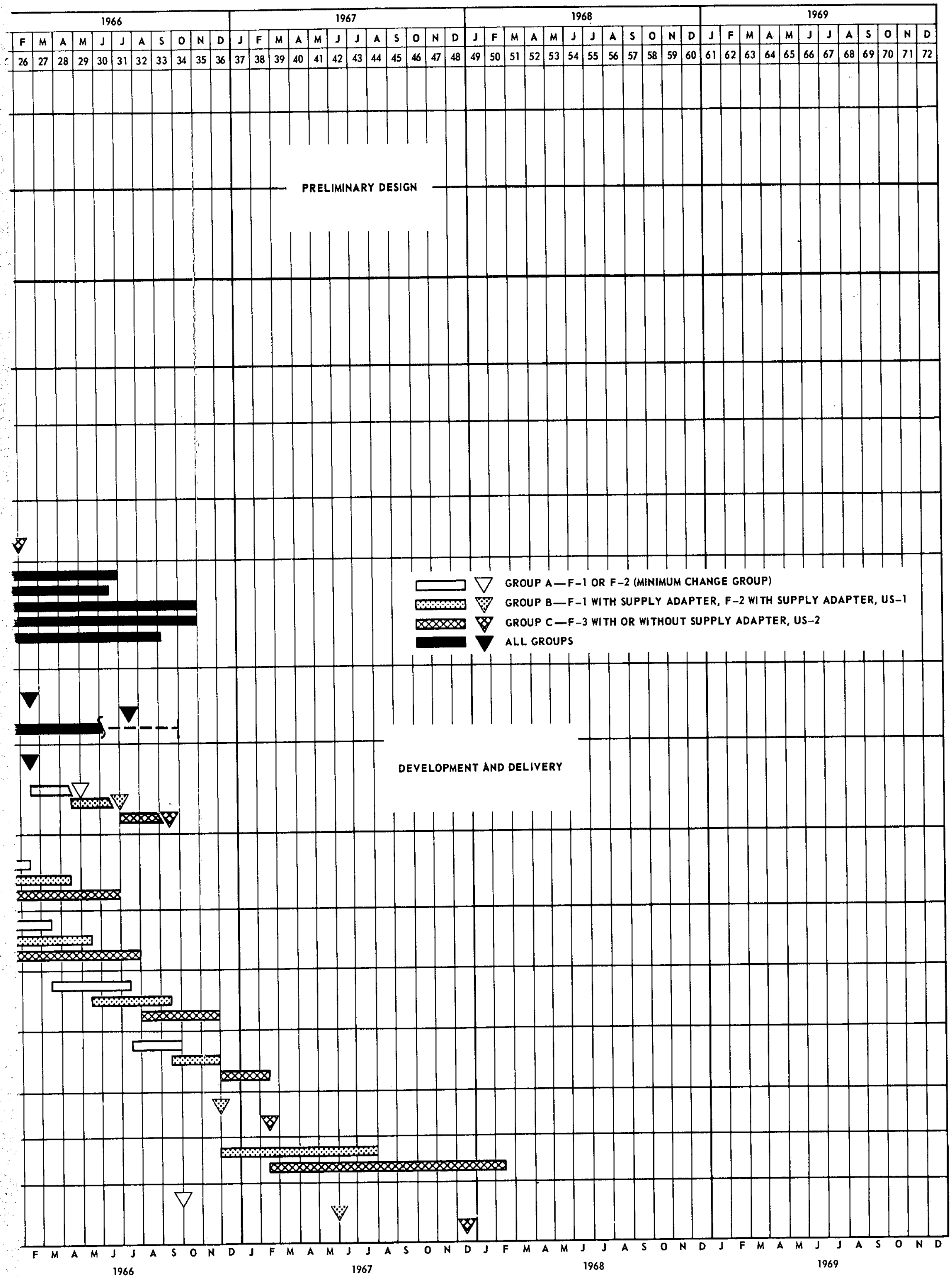
1966
1967
1968
1969
F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72
PRELIMINARY DESIGN
GROUP A—F-1 OR F-2 (MINIMUM CHANGE GROUP)
GROUP B—F-1 WITH SUPPLY ADAPTER, F-2 WITH SUPPLY ADAPTER, US-1
GROUP C—F-3 WITH OR WITHOUT SUPPLY ADAPTER, US-2
ALL GROUPS
DEVELOPMENT AND DELIVERY

9. (Continued)

personnel would be used to accomplish the increased work within the specified time.

The earliest first article delivery date of any group is October 1966 (Group A). This delivery would support a MORL launch in January 1967. For the maximum change spacecraft (Group C) the first article delivery date is December 1967, which would support a MORL launch in March 1968.

10. Costs - The Estimated Costs of the changes to Gemini for the Ferry Mission are shown in Table 10-1.

The total program costs for one year support of the MORL for various modes of supply are shown in Table 10-2. The costs are based on a four man station with five crew rotation launches plus necessary supply launches.

The various schedules and space vehicle combinations result from the variety of spacecraft and launch vehicles considered, and from the variation in the quantity of supplies that can be launched on board the MORL depending upon the launch vehicle and the mode of launch.

Costs for back-up space vehicles to achieve an over-all mission reliability of 0.90 are included in the total costs.

## TABLE 10-1

## SPACECRAFT UNIT COST
### (MILLIONS OF DOLLARS)

| | F-1 OR F-2 | | F-3 | | FERRY /SUPPLY MODULE | | US-1 | | US-2 | | REFURBISHED US-1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NR | R | NR | R | NR | R | NR | R | NR | R | NR | R |
| COST OF BASIC PROJECTED GEMINI RE-ENTRY MODULE | | 6.61 | | 6.61 | | — | | 6.61 | | 6.61 | | 4.15 |
| COST OF BASIC PROJECTED GEMINI ADAPTER | | 1.58 | | 1.58 | | 1.58 | | 1.58 | | 1.58 | | 1.58 |
| TOTAL GEMINI | | 8.19 | | 8.19 | | 1.58 | | 8.19 | | 8.19 | | 5.73 |
| CHANGES: | | | | | | | | | | | | |
| GENERAL STRUCTURE | | | | | 9.1 | +1.20 | 2.9 | -.10 | 8.3 | -.80 | 2.9 | -.10 |
| NOSE BEEF-UP | 1.2 | +.03 | | | | | | | | | | |
| RETROGRADE SYSTEM | .6 | +.02 | .6 | +.02 | .6 | +.02 | .9 | -.07 | .9 | -.07 | .9 | -.07 |
| HEAT SHIELD THICKNESS INCREASE | 1.2 | +.03 | 1.2 | +.03 | | | | | | | | |
| DELETE HEAT SHIELD | | | | | | | | -.11 | | -.11 | | -.11 |
| ENVIRONMENTAL CONTROL SYSTEM | 12.2 | +.18 | 6.3 | +.03 | .4 | +.03 | 2.9 | -.21 | 2.9 | -.21 | 2.9 | -.21 |
| ELECTRICAL SYSTEM | 2.8 | -.03 | 2.8 | -.03 | 1.9 | -.02 | 1.4 | -.19 | 1.4 | -.19 | 1.4 | -.19 |
| ADDITION OF SEPARATION ROCKETS | 1.0 | +.03 | 1.0 | +.03 | 1.0 | +.03 | | | | | | |
| DATA LINK FOR RENDEZVOUS BACK-UP | 2.5 | +.10 | 2.5 | +.10 | | | | | | | | |
| STANDBY TEMPERATURE CONTROL EQUIPMENT | .3 | +.03 | .3 | +.03 | | | | | | | | |
| DELETION OF R & D INSTRUMENTATION | .1 | -.14 | .1 | -.14 | .1 | -.07 | .2 | -.46 | .2 | -.46 | .2 | -.46 |
| HATCH IN HEAT SHIELD | | | 4.5 | +.24 | | | | | | | | |
| HATCH IN PRESSURE BULKHEAD | | | 1.9 | +.32 | | | | | | | | |
| DELETE NOSE DOCKING PROVISIONS | | | .1 | -.09 | | | | | | | | |
| ADAPTER TUNNEL | | | 11.3 | +.35 | | | | | | | | |
| AFT DOCKING CONTROLS | | | 2.0 | +.12 | | | | | | | | |
| AFT DOCKING RING | | | .3 | +.03 | | | | | | | | |
| DOCKING COMMAND RECEIVER | | | | | .3 | +.03 | | | | | | |
| ORBIT AND MANEUVERING SYSTEM | | | | | 19.1 | +.51 | | | | | | |
| SELF INJECTION SYSTEM | | | | | | | 27.4 | +.79 | 27.4 | +.79 | 27.4 | +.79 |
| GUIDANCE, CONTROL, & R.C.S. | | | | | | | 2.3 | -.57 | 2.3 | -.57 | 2.3 | -.57 |
| COMMUNICATIONS | | | | | | | .6 | -.18 | .6 | -.18 | .6 | -.18 |
| C.G. BALLAST REMOVAL | | | | | | | | -.02 | | -.02 | | -.02 |
| DELETE LANDING SYSTEM | | | | | | | | -.13 | | -.13 | | -.13 |
| DELETE RECOVERY SYSTEM | | | | | | | | -.04 | | -.04 | | -.04 |
| DELETE BIO-MED SYSTEM | | | | | | | | -.09 | | -.09 | | -.09 |
| DELETE RADAR, ADD TRANSPONDER | | | | | | | .6 | -.12 | .6 | -.12 | .6 | -.12 |
| DELETE CREW AND SURVIVAL EQUIPMENT | | | | | | | | -.35 | | -.35 | | -.35 |
| PROVISION FOR INTERACTION ON OTHER SYSTEMS, INCREASED ENVIRONMENTAL PROBLEMS, ETC. | 12.2 | +.10 | 12.2 | +.10 | | | 4.2 | +.01 | 4.2 | +.01 | 4.2 | +.01 |
| TOTAL UNIT COST | 34.1 | 8.54 | 47.1 | 9.33 | 32.5 | 3.31 | 43.4 | 6.35 | 48.8 | 5.65 | 43.4 | 3.89 |

NR = NONRECURRING
R = RECURRING

F-1 = FERRY SPACECRAFT NOSE DOCK – NOSE MOOR
F-2 = FERRY SPACECRAFT NOSE DOCK – SIDE MOOR
F-3 = FERRY SPACECRAFT AFT DOCK – AFT MOOR
FS-1 = FERRY SUPPLY SPACECRAFT NOSE DOCK – NOSE MOOR
FS-2 = FERRY SUPPLY SPACECRAFT NOSE DOCK – SIDE MOOR
FS-3 = FERRY SUPPLY SPACECRAFT AFT DOCK – AFT MOOR
US-1 = UNMANNED SUPPLY SPACECRAFT – STRIPPED GEMINI
US-2 = UNMANNED SUPPLY SPACECRAFT – SPECIFIC DESIGN

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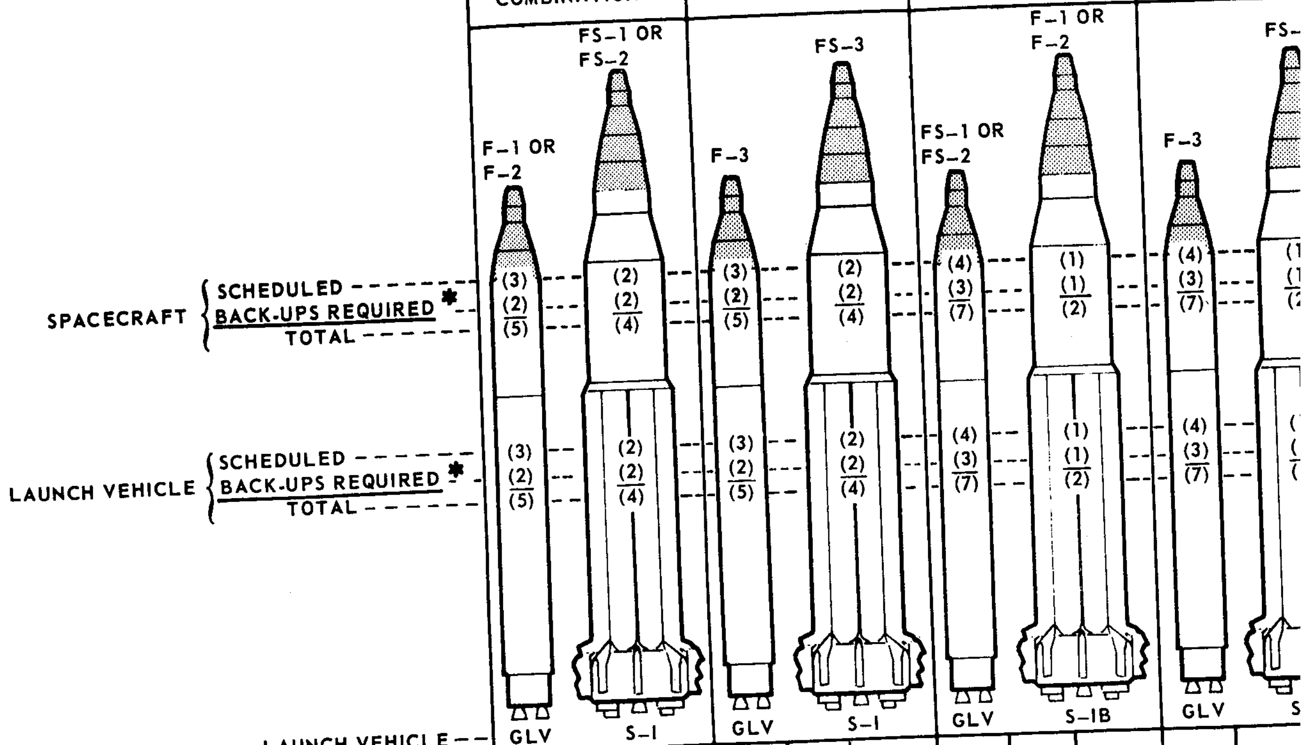
## TABLE 10-2
## FERRY PROGRAM COST
## (MILLIONS OF DOLLARS)




| | SCHEDULE A | | | | | | SCHEDULE B | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | COMBINATION 1 | | | COMBINATION 2 | | | COMBINATION 1 | | | COMBINATION | |
| LAUNCH VEHICLE | GLV | S-I | | GLV | S-I | | GLV | S-IB | | GLV | S |
| | R | NR | TOTAL | R | NR | TOTAL | R | NR | TOTAL | R | NR |
| FERRY RE-ENTRY MODULES | (9)62.0 | 25.4 | 87.4 | (9)65.2 | 30.0 | 95.2 | (9)62.0 | 25.4 | 87.4 | (9)65.2 | 30.0 |
| FERRY ADAPTERS | (9)14.9 | 8.7 | 23.6 | (9)18.8 | 17.1 | 35.9 | (9)14.9 | 8.7 | 23.6 | (9)18.8 | 17.1 |
| SUPPLY MODULES | (4)13.2 | 32.5 | 45.7 | (4)13.2 | 32.5 | 45.7 | (2) 6.6 | 32.5 | 39.1 | (2) 6.6 | 32.5 |
| UNMANNED SUPPLY SPACECRAFT | | | | | | | | | | | |
| FERRY/SUPPLY LAUNCH ESCAPE SYSTEM | (4) 2.8 | 6.9 | 9.7 | (4) 2.8 | 6.9 | 9.7 | (2) 1.4 | 6.9 | 8.3 | (2) 1.4 | 6.9 |
| SPACECRAFT SPARES | 18.6 | | 18.6 | 20.0 | | 20.0 | 17.0 | | 17.0 | 18.4 | |
| SPACECRAFT LAUNCH SERVICE | 21.8 | | 21.8 | 22.7 | | 22.7 | 20.8 | | 20.8 | 21.7 | |
| SPACECRAFT PROPELLANT & TRANSPORTATION | 1.8 | | 1.8 | 1.9 | | 1.9 | 1.7 | | 1.7 | 1.8 | |
| GEMINI LAUNCH VEHICLES | (5) 55.0 | | 55.0 | (5) 55.0 | | 55.0 | (7)77.0 | | 77.0 | (7)77.0 | |
| SATURN LAUNCH VEHICLES | (4)100.0 | | 100.0 | (4)100.0 | | 100.0 | (2)60.0 | | 60.0 | (2)60.0 | |
| A.G.E. (FERRY & SUPPLY) | | 54.6 | 54.6 | | 56.7 | 56.7 | | 50.7 | 50.7 | | 52.8 |
| LAUNCH PAD CONVERSION | | 0.8 | 0.8 | | 0.8 | 0.8 | | 0.8 | 0.8 | | 0.8 |
| TRAINERS & SUPPORT | | 0.8 | 0.8 | | 1.1 | 1.1 | | 0.8 | 0.8 | | 1.1 |
| DEVELOPMENT FLIGHT TEST | | 89.0 | 89.0 | | 133.4 | 133.4 | | 94.0 | 94.0 | | 143. |
| TOTAL PROGRAM COST → | | | 508.8 | | | 578.1 | | | 481.2 | | |

NOTES:
1. R = RECURRING COSTS, NR = NONRECURRING COSTS, GLV = GEMINI LAUNCH VEHICLE, S-1 = SATURN 1 LAUNCH VEHICLE S-IB = SATURN IB LAUNCH VEHICLE, F-1 – FERRY (NOSE DOCK – NOSE MOOR), F-2 = FERRY (NOSE DOCK – SIDE MOOR). FS-1 FERRY SUPPLY (NOSE DOCK – NOSE MOOR), FS-2 = FERRY/SUPPLY (NOSE DOCK-SIDE MOOR), FS-3 = FERRY/SUPPL
US-1 = UNMANNED SUPPLY (STRIPPED GEMINI),
US-2 = UNMANNED SUPPLY (SPECIFIC DESIGN).
2. QUANTITY OF ARTICLES SHOWN IN ( ).

* BACK-UP VEHICLES SHOWN ARE QUANTITIES REQUIRED TO OBTAIN OVER-ALL MISSION RELIABILITY OF .90.



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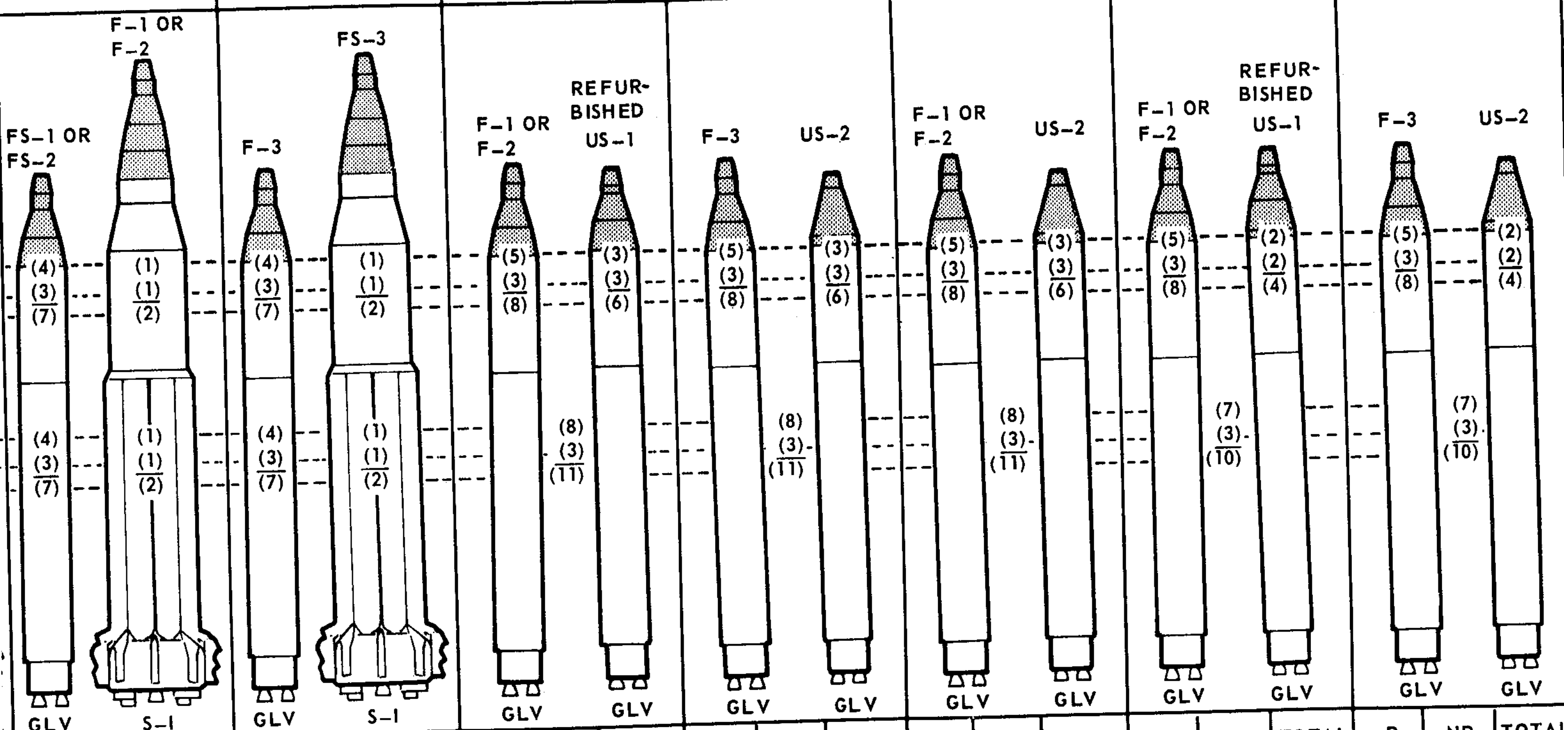
| SCHEDULE C | | | | | | SCHEDULE D | | | | | | | | | SCHEDULE E & F | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COMBINATION 1 | | | COMBINATION 2 | | | COMBINATION 1 | | | COMBINATION 2 | | | COMBINATION 3 | | | COMBINATION 1 | | | COMBINATION 2 | | |




| R | NR | TOTAL | R | NR | TOTAL | R | NR | TOTAL | R | NR | TOTAL | R | NR | TOTAL | R | NR | TOTAL | R | NR | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (9)62.0 | 25.4 | 87.4 | (9)65.2 | 30.0 | 95.2 | (8)55.1 | 25.4 | 80.5 | (8)57.9 | 30.0 | 87.9 | (8)55.1 | 25.4 | 80.5 | (8)55.1 | 25.4 | 80.5 | (8)57.9 | 30.0 | 87.9 |
| (9)14.9 | 8.7 | 23.6 | (9)18.8 | 17.1 | 35.9 | (8)13.2 | 8.7 | 21.9 | (8)16.7 | 17.1 | 33.8 | (8)13.2 | 8.7 | 21.9 | (8)13.2 | 8.7 | 21.9 | (8)16.7 | 17.1 | 33.8 |
| (2) 6.6 | 32.5 | 39.1 | (2) 6.6 | 32.5 | 39.1 | (6)23.3 | 43.4 | 66.7 | (6)33.9 | 48.8 | 82.7 | (6)33.9 | 48.8 | 82.7 | (4)15.6 | 43.4 | 59.0 | (4)22.6 | 48.8 | 71.4 |
| (2) 1.4 | 6.9 | 8.3 | (2) 1.4 | 6.9 | 8.3 | 18.6 | | 18.6 | 22.0 | | 22.0 | 20.7 | | 20.7 | 16.9 | | 16.9 | 19.6 | | 19.6 |
| 17.0 | | 17.0 | 18.4 | | 18.4 | 27.2 | | 27.2 | 28.0 | | 28.0 | 27.2 | | 27.2 | 24.0 | | 24.0 | 24.8 | | 24.8 |
| 20.8 | | 20.8 | 21.7 | | 21.7 | 1.9 | | 1.9 | 2.2 | | 2.2 | 2.1 | | 2.1 | 1.7 | | 1.7 | 2.0 | | 2.0 |
| 1.7 | | 1.7 | 1.8 | | 1.8 | | | | | | | | | | | | | | | |
| (7)77.0 | | 77.0 | (7)77.0 | | 77.0 | | | | | | | | | | | | | | | |
| (2)50.0 | | 50.0 | (2)50.0 | | 50.0 | (11) 121.0 | | 121.0 | (11) 121.0 | | 121.0 | (11) 121.0 | | 121.0 | (10) 110.0 | | 110.0 | (10) 110.0 | | 110.0 |
| | 50.7 | 50.7 | | 52.8 | 52.8 | | 62.0 | 62.0 | | 64.6 | 64.6 | | 62.5 | 62.5 | | 47.1 | 47.1 | | 49.7 | 49.7 |
| | 0.8 | 0.8 | | 0.8 | 0.8 | | 1.9 | 1.9 | | 1.9 | 1.9 | | 1.9 | 1.9 | | 1.3 | 1.3 | | 1.3 | 1.3 |
| | 0.8 | 0.8 | | 1.1 | 1.1 | | 2.3 | 2.3 | | 2.4 | 2.4 | | 2.3 | 2.3 | | 2.3 | 2.3 | | 2.4 | 2.4 |
| | 89.0 | 89.0 | | 133.4 | 133.4 | | 20.9 | 20.9 | | 68.3 | 68.3 | | 20.2 | 20.2 | | 20.9 | 20.9 | | 68.3 | 68.3 |
| | | 466.2 | | | 535.5 | | | 424.9 | | | 514.8 | | | 443.0 | | | 385.6 | | | 471.2 |

RRY (AFT DOCK – AFT MOOR),
CK – AFT MOOR),

## 11. References

1. McDonnell Report No. A172, "Gemini Spacecraft Study for MORL Ferry Missions, Final Report," dated 13 November 1963.

2. NASA Request for Proposal L-3408, "Gemini Spacecraft Study for Manned Orbiting Research Laboratory Ferry Missions," dated 18 April 1963.