18. MISSION PLANNING

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Summary

Project Mercury was a focal point for the development of the types of mission-planning techniques that are being used in the Gemini Program. The philosophies, mission-design requirements, and constraints used for Gemini follow, in many cases, the pattern established in the Mercury Program. This effort, in turn, will contribute directly to the Apollo and future space programs. The inclusion of the orbital attitude and maneuver system, the inertial guidance system, and the fuel-cell power system in the Gemini spacecraft provides a tremendous amount of flexibility in the types of missions that can be designed. This flexibility has required the development of a mission-planning effort which exceeds that required for Mercury missions by several orders of magnitude.

Introduction

The mission-planning activities for the Gemini Program can be categorized into four basic phases. First, the mission-design requirements were developed. These requirements influenced the systems configuration of the Gemini spacecraft and the modifications required for the target and launch vehicles. Second, design reference missions were established, which permitted the development of hardware specifications. Third, operational mission plans were developed for each flight, along with the formulation of mission logic in the ground control complex. This permits the fourth phase, real-time mission planning, to be used as circumstances require during a specific flight.

Mission-Planning Phases

Development of Mission-Design Objectives

In Gemini as in other space programs, launch vehicle performance has had a major influence on the design of the spacecraft and the development of mission plans. For example, early analyses showed that, due to spacecraft weight limitations, a source of electrical power lighter in weight than silver-zinc batteries was necessary for the long-duration missions. These analyses established the requirement for the development of a fuel-cell power system and influenced an early decision to plan the rendezvous missions for 2-day durations so they could be accomplished using battery power, should problems occur in fuel-cell development.

To satisfy the rendezvous objective, analyses established the requirement for the development of several new systems, including the radar, the digital command system, the inertial guidance system, and the orbital attitude and maneuver system.

The rendezvous objective required extensive analyses to establish the spacecraft maneuvering requirements and to optimize the launch window, orbit inclination, and target orbit altitude. In these analyses, the control of the out-of-plane displacement was a prime consideration.

Selecting a target orbit inclination that is slightly above the latitude of the launch site makes the out-of-plane displacement reasonably small for a relatively long period of time (fig. 18–1). By varying the launch azimuth so that the spacecraft is inserted parallel to the target-vehicle orbit plane, the out-of-plane displacement of the launch site at the time of launch becomes the maximum out-of-plane displacement between the two orbit planes. This variable launch-azimuth technique may also be used with guidance in yaw during second-stage powered flight to minimize the out-of-plane displacement. This is accomplished by biasing the launch azimuth of the spacecraft so that the launch azimuth is an optimum angle directed

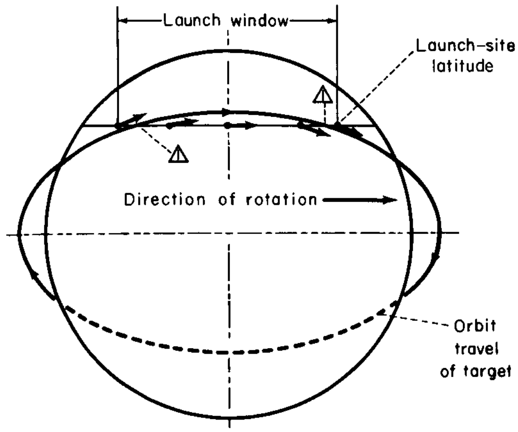


FIGURE 18-1.—Variable-azimuth launch technique.

toward the target-vehicle orbit plane. As a result, the out-of-plane distance is reduced prior to the initiation of closed-loop guidance during second-stage flight. The use of this technique is an effective way of using the launch-vehicle performance capability to control an out-of-plane displacement. However, since this technique requires additional launch-vehicle performance, a decision was made to also allocate spacecraft propellant for the correction of an out-of-plane displacement.

Analysis of launch vehicle insertion dispersions, ground tracking dispersions, and spacecraft inertial guidance dispersions established the spacecraft orbital-attitude-and-maneuver-system propellant-tankage requirement for rendezvous at 700 pounds, of which 225 pounds was allocated for an out-of-plane displacement correction. This amount of propellant would allow the spacecraft to correct an out-of-plane displacement of up to approximately 0.53°.

Launch times must be chosen so that the magnitude of the out-of-plane displacement does not exceed the spacecraft or launch-vehicle performance capabilities. By selecting an inclination of 28.87°, which is 0.53° above the launch-site latitude, and by using a variable-azimuth launch technique, the out-of-plane displacement can be controlled to within 0.53° for 135 minutes (fig. 18-2). With a maximum acceptable displacement of 0.53°, increasing the inclination to 30° reduces the plane window from one 135-minute window to two 33-minute windows (fig. 18-3). From these two curves it can be seen

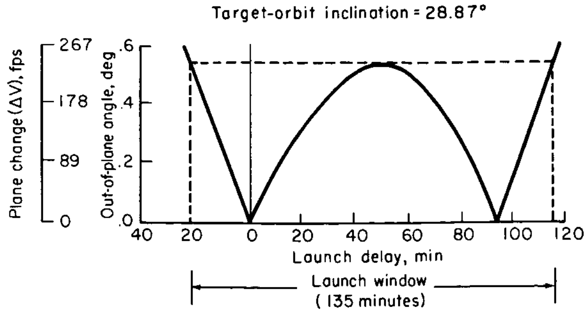


FIGURE 18-2.—Variable-azimuth launch window for target orbit inclination of 28.87°.

that the quantity of propellant required to provide a launch window of a given duration is very sensitive to target orbit inclination. With a maximum acceptable out-of-plane displacement of 0.53°, a target inclination of 28.87°, and a fixed-azimuth launch, the plane window is reduced to 17 minutes (fig. 18-4). The results of these analyses established the requirement to implement a variable launch azimuth guidance capability in both the spacecraft and launch vehicle and to establish the target orbit inclination at 28.87°.

The next parameter to be considered in this phase of mission planning was the desired orbit altitude for the rendezvous target vehicle. A near-optimum altitude would provide a zero phasing error simultaneously with the zero out-of-plane displacement near the beginning of the launch window on a once-per-day basis. This near-optimum condition for a target inclination of 28.87° occurs on a once-per-day basis at 99, 260, and 442 nautical miles. Because of launch-vehicle performance, the 260- and 442-nautical-

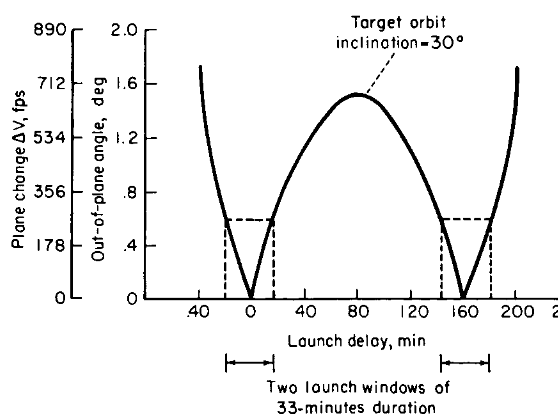


FIGURE 18-3.—Variable-azimuth launch windows for target orbit inclination of 30°.

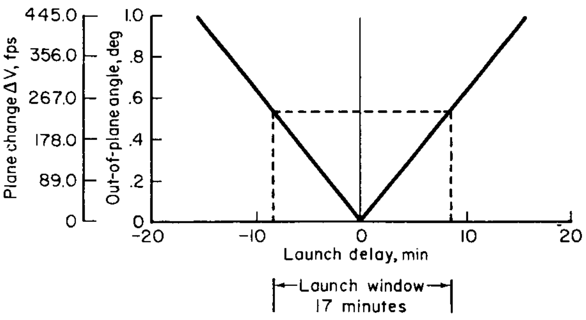


FIGURE 18–4.—Fixed-azimuth launch window for target orbit inclination of 28.87°.

mile orbits were not considered. The 99-nautical-mile orbit was not considered because of the relatively short lifetime of this orbit. Other altitudes—125, 150, 160, and 175 nautical miles—were evaluated. A rendezvous target orbit altitude of 161 nautical miles was selected. This altitude provided launch opportunities with zero phasing errors within the 135-minute launch window on a once-per-day basis, and provided near-optimum phasing conditions for the second day (fig. 18–5). The decision to select this altitude had an influence on the retrorocket systems design and on the thermodynamic design of the spacecraft, the target vehicle, and the target docking adapter.

The selection of the Gemini insertion altitude was influenced by the launch-vehicle radio-guidance-system accuracies which are a function of the elevation angle at sustainer engine cutoff, of the spacecraft and the launch-vehicle second-stage exit-heating requirements, and of the launch vehicle performance capability. Based on an evaluation of these factors, an altitude of 87 nautical miles was established for the design requirement.

Establishment of Design Reference Missions

After the mission-design requirements were developed for the spacecraft, for the target vehicle, and for the launch vehicles, three basic types of design-reference missions were specified so that hardware development plans could be established for the airborne and ground systems. These types of mission were (1) unmanned ballistic for systems and heat protection qualification, (2) manned orbital 14-day with closed-loop guidance reentry, and (3) manned orbital rendezvous and docking with closed-loop guidance reentry. It is important to note that within

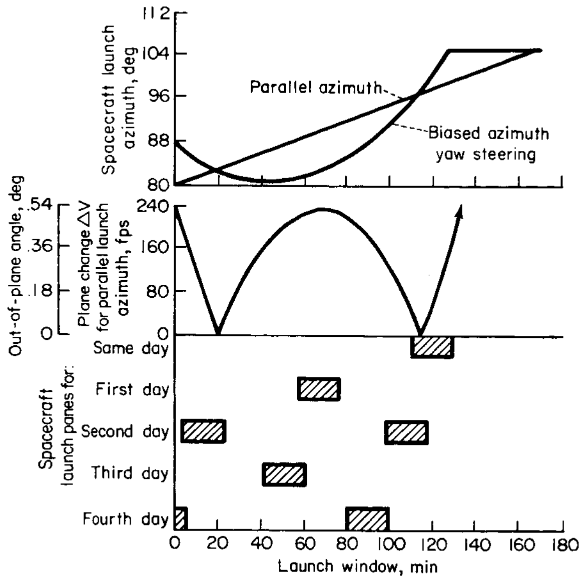


FIGURE 18–5.—Space-vehicle launch windows for rendezvous target orbit altitude of 161 nautical miles.

the framework of the long-duration and rendezvous missions, many other objectives can be accomplished, such as extravehicular activity and experiments.

Development of Operational Mission Plans

In the development of the detailed operational mission plans to satisfy the program objectives, the requirement has been to insure the highest probability of success by minimizing, within the limits of practicality, any degradation of the mission objectives resulting from systems failures or operational limitations. To accomplish this requirement, operational mission plans were developed which provided a logical buildup in the program objective accomplishment. The operational mission plans which were developed to accomplish this buildup are shown in table 18–I.

Qualification of the launch-vehicle and spacecraft systems was the primary objective of Gemini I and II. The objectives of Gemini III, the first manned flight, included the evaluation of spacecraft maneuvering in space, a requirement for the rendezvous missions; the qualification of the spacecraft systems to the level of confidence necessary for committing the spacecraft and crew to long-duration flight; the development of procedures necessary to conduct long-duration, rendezvous, and a closed-loop re-

TABLE 18–I.—*Operational Mission Objectives*

Objective / Mission	G–I	G–II	G–III	G–IV	G–V	G–VI	G–VII
Closed-loop reentry guidance:							
System qualification		●					
Procedure development			●				
Demonstration				○	○	○	○
EVA				●			
Long duration:							
System qualification	●	●	●		○		
Procedure development			○				
4 day				●			
8 day					●		
14 day							●
Rendezvous:							
System qualification	●	●	●	○	○		
Procedure development			○	○	○		
Rendezvous evaluation					○		
Rendezvous						●	
Experiments	0	0	3	13	17	3	20

● Primary objective.
○ Secondary objective.

entry; and the execution of three inflight experiments. The plans for Gemini IV included the first long-duration objective (4 days), extravehicular activity, further development of the rendezvous procedures, a demonstration of a closed-loop reentry, and the execution of 13 inflight experiments.

Gemini V, an 8-day flight, was the second step in the development of the long-duration capability. Other objectives planned for this flight were the final qualification of the rendezvous systems and procedures necessary for the Gemini VI mission, evaluation of the fuel-cell power system required for long-duration flights, the demonstration of the capabilities of the closed-loop reentry guidance, and the execution of 17 inflight experiments. Designating the primary objectives of the first five flights as nonrendezvous permitted the development of efficient checkout and launch procedures, a requirement for on-time launch. Early development of these procedures was mandatory to satisfy the rendezvous objective of the Gemini VI mission. The primary objective of Gemini VII, of course, was long duration (14 days). Three experiments were planned for Gemini VI and 20 experiments for Gemini VII. Plans for both of these flights included a demonstration of closed-loop reentry guidance.

The development of operational mission plans for implementing the mission objectives requires that extensive analyses be performed in the trajectory and flight-planning areas. In Gemini, detailed trajectory and flight planning has been found to be essential for mission success and must be done in such a way as to afford mission flexibility.

Trajectory Planning

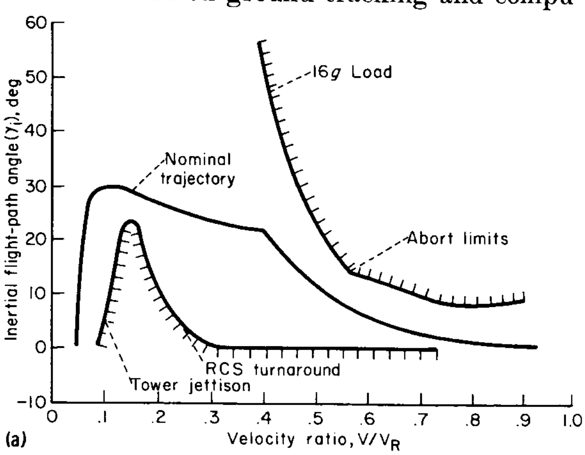
During Project Mercury, a major part of the trajectory-planning effort was spent in the development of the philosophy and techniques for monitoring the powered-flight trajectory, for determining when launch abort action was necessary, and for establishing go—no-go criteria for the acceptability of the orbit after the completion of launch-vehicle thrusting. These Mercury analyses were directly applicable to the Gemini Program. Generally, it was merely necessary to identify the most limiting trajectory criteria—that is, the trajectory conditions beyond which abort action is not safe due to such factors as exceeding spacecraft reentry heating, or aerodynamic load-design limits that were applicable to the Gemini spacecraft. The character of the resulting abort-limit lines used on the flight controller plotboards is very similar to that designed for Project Mercury (figs. 18–6(a) and 18–6(b)).

If a Mercury spacecraft failed to achieve orbit, only two possible courses of action were available: fire the retrorockets for an immediate abort, or do nothing. The maneuvering capability of the Gemini spacecraft provides a third, more desirable choice, which is using the orbital attitude and maneuver system as a third-stage propulsion system to achieve orbit (figs. 18–7(a) and 18–7(b)).

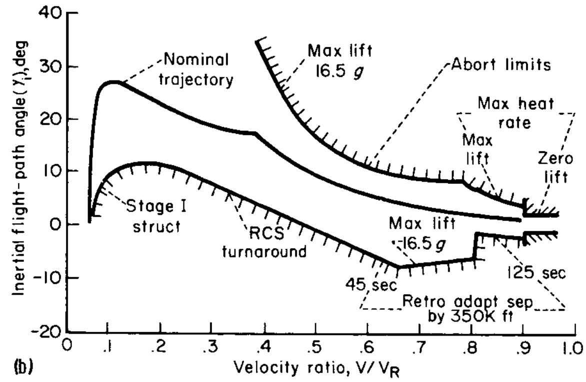
Abort actions or the use of orbital attitude and maneuver system into orbit has never been necessary; however, all possible contingency situations must have been analyzed, and corrective procedures developed.

The capabilities of the Gemini spacecraft provide a tremendous amount of flexibility in the types of missions which can be designed. This flexibility has allowed modification of mission plans both before and during an actual flight. For example, during the Gemini V mission, problems with the spacecraft electrical power system made it necessary to abandon the rendezvous evaluation pod test. The objectives of the test were accomplished, however. This was possible because mission-planning personnel conceived, planned, and set up the so-called phantom rendezvous and a spacecraft radar-to-ground transponder tracking test within a 1-day period during the 8-day flight. The phantom rendezvous, which involved a series of maneuvers based on ground tracking and computations, almost precisely duplicated the maneuvers planned for the midcourse phase of the Gemini VI flight. This series of maneuvers executed by the Gemini V flight crew were a milestone—the first in-orbit maneuvers carried out with the precision necessary for performing a space rendezvous. The near-perfect performance of the Gemini V spacecraft, flight crew, and the ground personnel verified the accuracy which could be expected during the rendezvous missions. Sufficient data were obtained from the spacecraft radar tracking test, and from the rendezvous evaluation pod test prior to its termination, to adequately flight-quality the spacecraft radar system for the Gemini VI mission.

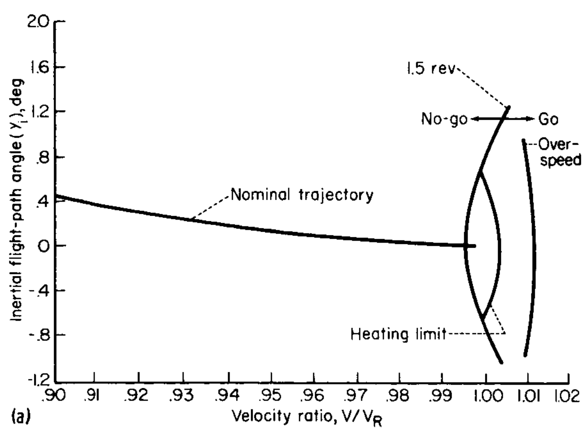
The changes made before the Gemini VII flight are well known. In order to utilize the Gemini VII spacecraft as a target for the Gemini VI-A mission, it was necessary to change the Gemini VII launch-azimuth and orbital-



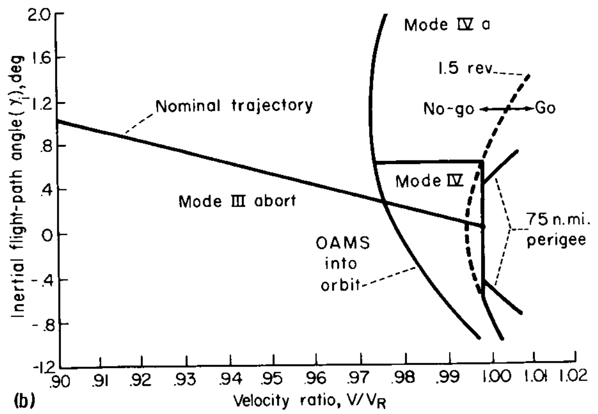
(*a*) Project Mercury.
FIGURE 18–6.—Abort limit lines launch trajectory monitoring.



(*b*) Gemini Program.
FIGURE 18–6.—Concluded.



(*a*) Project Mercury.
FIGURE 18–7.—Go—no-go criteria for acceptability of orbit after completion of thrust by launch vehicle.



(b) Gemini Program.
FIGURE 18-7.—Concluded.

insertion requirements. In addition, a radar transponder and acquisition lights were installed on spacecraft 7, and logic and computer programs were developed for selecting the Gemini VII in-orbit maneuvers required to arrive at the optimum conditions for rendezvous with a minimum expenditure of fuel. This was all accomplished within a 6-week period after the first Gemini VI launch attempt. It is interesting that, except for the development of a quick turnaround capability, the plan for Gemini VI–A was relatively unchanged. In fact, since the Gemini VII spacecraft was maneuvered precisely to the planned orbital inclination of 28.87° and altitude of 161 nautical miles, the Gemini VI–A mission was accomplished almost exactly as planned.

The point to be made here is that, to get the most out of each Gemini flight, the capability must exist to allow rapid response to changes in mission requirements. To provide this capability, a staff of experienced personnel must have carried out a wide variety of analyses and studies upon which they can quickly draw, both before and during the actual mission.

Flight planning.—The term "flight planning," as used in manned space flight, is the development of a schedule of inflight crew activities. Such a plan is required to insure that the most effective use is made of flight time. Detailed flight planning starts after mission objectives have been clearly defined and the trajectory profile has been established. The first task is to determine the exact operational procedures that are necessary to accomplish each of the mission activities. Operational procedures are developed by careful analyses and simulations. These analyses and simulations also establish the time, propellant, and electrical power that are required to accomplish each task. With these results, flight planning personnel can then establish the total quantity of consumables—propellant, electrical power, oxygen, food, and water—that will be necessary for a specific mission.

When all of the details of each mission have been worked out, plans for accomplishing the mission are documented in a flight plan. The flight plan provides a detailed schedule of the flight-crew and ground-station activities, checklists for normal and emergency procedures, a detailed procedure for conducting each planned activity, consumables allocations and nominal-usage charts, and an abbreviated schedule showing major events to be conducted throughout the flight. Figures 18-8(a) and 18-8(b) are samples of the detailed flight plan for the Gemini VII mission during the period from the lift-off through launch vehicle staging. Figure 18-9 is a sample of the abbreviated flight plan during the period from lift-off through the first 4 hours of flight, and figures 18-10(a) and 18-10(b) are examples of the procedures section showing the propellant usage summary and an operational test description.

The contents of the flight plan vary according to the mission. For example, for the Gemini VII flight, the detailed plan was written only through the launch vehicle station-keeping period because the remainder of the 14-day flight was preplanned to be conducted in real time. This approach was unique since, on previous missions, the complete flight plan was developed prior to launch, and real-time planning was adopted only when inflight anomalies occurred. On the Gemini VII mission, premission planning was oriented toward a general sequencing of the tests and experiments required in the flight in order to establish the required timelines. Detailed procedures for each crew activity were established for crew training; therefore, a majority of the real-time effort consisted of scheduling each activity. On Gemini VII this procedure proved to be quite satisfactory, and all objectives were accomplished except where equipment failure or the weather precluded completion of some activities.

Real-Time Mission Planning

Development of the mission design requirements, the operational mission plans, and documentation as previously mentioned is only part of the overall mission planning task. The next step is to make the plan work. This depends to a great extent on whether the launch vehicle and spacecraft perform as predicted. When an abnormal situation does arise, as during Gemini V, the planned activities must be rescheduled and, in some cases, compromised to make maximum use of the systems performance as it exists.

The necessity of being prepared to handle whatever contingency develops as the mission progresses has led to the development of a highly sophisticated and complex real-time flight-control computer program.

(a)

TIME HR:MIN:SEC	COMP	PLAT	CNTL MODE	ACTION	
				COMMAND PILOT	PILOT
0:00:00	ASC	FREE		CNV-REPORT LIFT-OFF A-REPORT CLOCK START (EVENT TIMER)	
0:00:19	ASC	FREE		A-REPORT ROLL PROGRAM INITIATED	
0:00:20	ASC	FREE		A-REPORT ROLL PROGRAM COMPLETE	
0:00:23	ASC	FREE		A-REPORT PITCH PROGRAM INITIATED	
0:00:50	ASC	FREE		CNV-GIVE 50 SEC TIME-HACK FOR CHANGE TO DELAYED-LAUNCH MODE II	
				A-CONFIRM REPORTED CHANGE TO DELAYED-LAUNCH MODE II RELEASE 'D'-RING	A-RELEASE 'D' RING. UNCLIP KEYING SWITCH
				NOTE 'D'-RING STOWED AFTER INSERTION. CMD PILOT WILL USE THE KEYING SWITCH ON THE HAND CONTROLER	

MISSION	EDITION	DATE	STATION	AOS	LOS	TOTAL	REV	PAGE
GEMINI VII	FINAL	11/15/65	CNV	0:00:00	0:06:57	6:57	LAUNCH	1

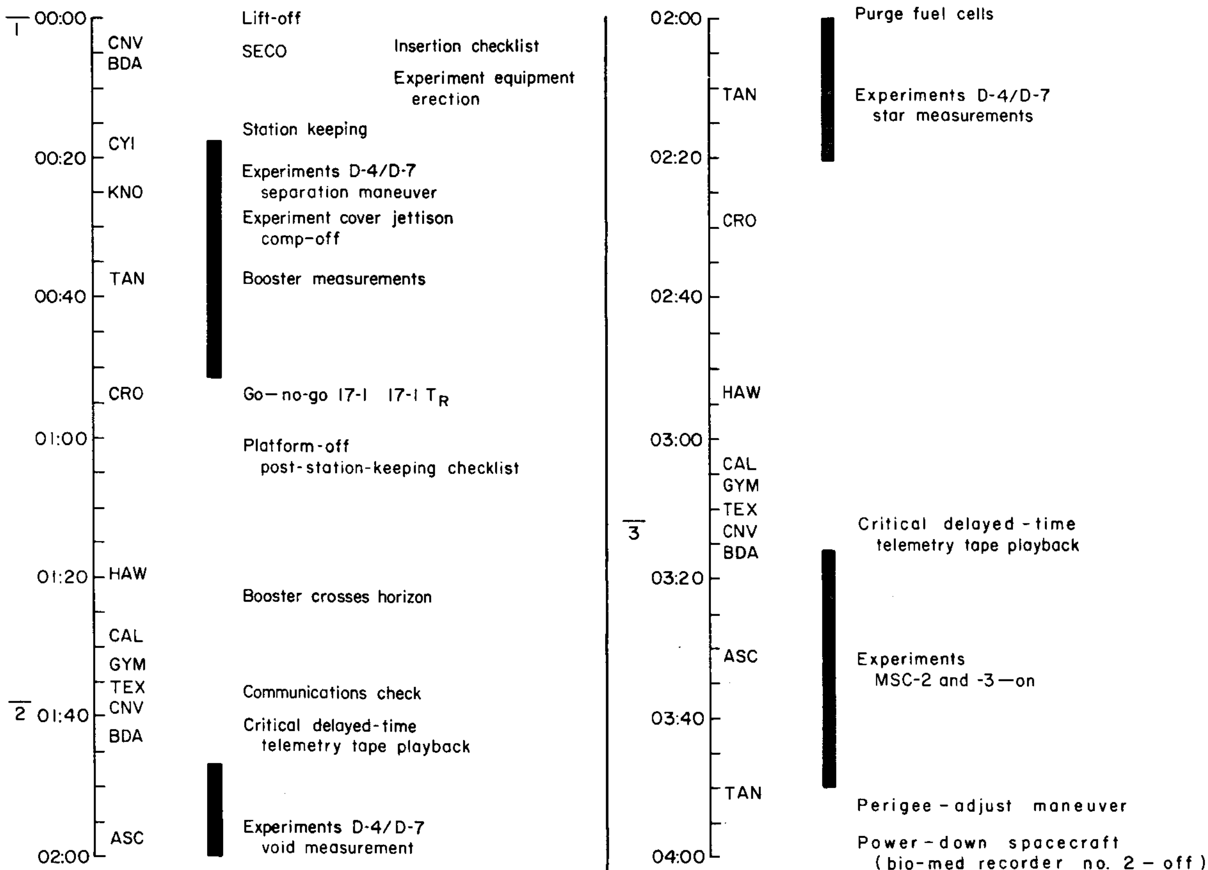
(*a*) Lift-off through first 50 seconds.
FIGURE 18-8.—Example of detailed flight plan.

(b)

TIME HR:MIN:SEC	COMP	PLAT	CNTL MODE	ACTION: COMMAND PILOT	ACTION: PILOT
0:01:00	ASC	FREE			A-REPORT CABIN PRESSURE HOLDING AT___PSID
0:01:40	ASC	FREE		CNV-REPORT CHANGE TO LAUNCH MODE II (70K FT) A-CONFIRM REPORTED CHANGE TO LAUNCH MODE II	
0:01:45	ASC	FREE			A-RESET DCS LIGHT. REPORT DCS UPDATE RECEIVED
0:02:15	ASC	FREE		A-REPORT STAGE II GO	
0:02:25	ASC	FREE			A-RESET DCS LIGHT. REPORT DCS UPDATE RECEIVED
0:02:35	ASC	FREE		STAGING NOTE ENGINE I LIGHTS-FLICKER ENGINE II LIGHT-OUT A-REPORT STAGING STATUS CHECK 'G'-LEVEL FDI SCALE RANGE-HI	

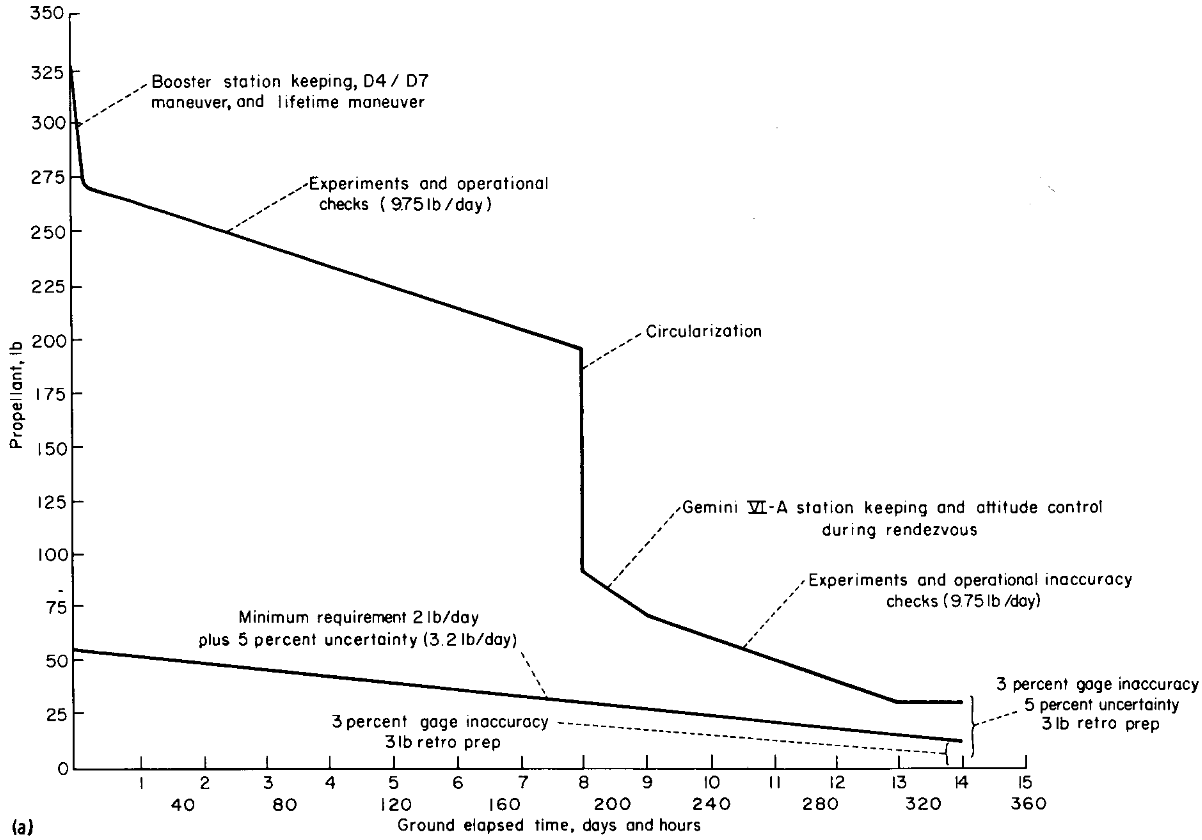
MISSION	EDITION	DATE	STATION	AOS	LOS	TOTAL	REV	PAGE
GEMINI VII	FINAL	11/15/65	CNV	0:00:00	0:06:57	6:57	LAUNCH	2

(*b*) One minute through 2 minutes 35 seconds after lift-off.
FIGURE 18–8.—Concluded.



Mission	Edition	Date	Time	Revolution	Page
Gemini VII	Final	November 15, 1965	00:00 to 04:00	1-3	1

FIGURE 18–9.—Example of abbreviated flight plan.



(*a*) **Estimated propellant usage for Gemini VII mission.**
FIGURE 18-10.—Example of procedures section of the flight plan.

(b)

RADAR TRANSPONDER TEST

Purpose

To verify calculated warm-up and cool-down curves for the transponder and as an operational check.

Spacecraft Systems Configuration

1. Reticle installed (for operational check)

2. AC POWER - ACME

3. ATTITUDE CONTROL - PULSE

Procedure

1. Temperature Check
   TRANSPONDER - ON AT AOS
   TRANSPONDER - OFF AT LOS

   Note: 1. Check temperature every 12 hrs until temperature stabilizes, then every 24 hours.
   2. Ground will monitor and plot the temperature trend.

2. Operational Check
   TRANSPONDER - ON
   Align spacecraft on radar located at Cape Kennedy.
   TRANSPONDER - OFF after LOS.

   Note: The operation check will be conducted on passes which occur at approximately VII lift-off plus 48 hours and VI-A lift-off minus 72 hours (total of 2 runs required).

Propellant Required

2 runs x 1 lb run = 2 lb

(*b*) Radar transponder test.
FIGURE 18-10.—Concluded.

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