2. SUMMARY OF RENDEZVOUS OPERATIONS

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Introduction

One of the major objectives of the Gemini Program was to develop and to demonstrate techniques for the rendezvous and docking of space vehicles. This objective is of vital importance since rendezvous and docking is mandatory for success in many future manned space-flight programs. For example, lunar orbital rendezvous has been selected as the primary mode for the Apollo lunar-landing mission which requires one rendezvous and two dockings. Other programs requiring rendezvous are planetary missions, manned space stations, and unmanned satellite inspection and repair missions.

During the Gemini Program, the following types of rendezvous techniques were evaluated: fourth orbit ($M=4$), third orbit ($M=3$), first orbit ($M=1$), optical rendezvous, rendezvous from above, stable orbit rendezvous, and optical dual rendezvous. These techniques were used successfully in the completion of 10 rendezvous operations (table 2–I). A major factor in achieving success during these operations can be attributed to the implementation of an extensive analysis, simulation, and training program leading first to the Gemini VI–A rendezvous mission, and subsequently to more complex missions. During the Gemini III mission, the spacecraft propulsion system and the guidance and control system were evaluated. On the Gemini IV mission, a plan was developed and an attempt was made to station keep and rendezvous with the spent second stage of the launch vehicle. During Gemini V, a phantom rendezvous and a spacecraft radar-to-ground transponder tracking test were performed. The phantom rendezvous involved a series of maneuvers based upon ground tracking and computations, and precisely duplicated the maneuver sequence and procedures planned for the midcourse phase of the Gemini VI–A mission.

TABLE 2–I.—*Mission Summary*

Gemini mission	Type of rendezvous
VI–A	Fourth orbit ($M=4$)
VIII	Fourth orbit ($M=4$)
IX–A	Third orbit ($M=3$)
	Optical re-rendezvous
	Re-rendezvous from above
X	Fourth orbit ($M=4$)
	Optical dual
XI	First orbit ($M=1$)
	Stable orbit
XII	Third orbit ($M=3$)

Sufficient data were obtained from the spacecraft radar tracking test during the Gemini V mission to adequately flight-qualify the radar for the Gemini VI–A flight. Even though the rendezvous operations planned for the first three manned Gemini flights were not all successful, they were extremely valuable to the program since they provided flight experience and indicated areas requiring further analysis, simulation, and training.

On December 15, 1965, the Gemini VI–A crew, using the Gemini VII spacecraft as the target vehicle, completed the first space rendezvous operation. Although this mission did not include a docking, it was successful and after lift-off proceeded almost precisely as planned. On the following mission, the Gemini VIII crew successfully performed the first rendezvous and docking with a Gemini Agena Target Vehicle. Subsequent, more complex,

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rendezvous operations were successfully performed during the Gemini IX–A, X, XI, and XII missions. These successes have provided confidence in the ability to accomplish such operations. However, rendezvous must still be recognized as a highly precise operation that is rather unforgiving of errors which occur during the final approach, details of which will be discussed in this paper.

Review of Rendezvous Operations Development

An explanation of rendezvous can be greatly simplified by a description of the relative-motion concept. Figure 2–1 shows a coordinate system centered on the target vehicle in a circular orbit with the X– and Y–axes in the target orbital plane. The Y–axis rotates with the target vehicle and is positive radially upward; the X–axis is curvilinear and positive opposite the direction of motion. The out-of-plane parameter is the Z–axis, which completes the right-hand coordinate system. The motion of the spacecraft with respect to this reference is illustrated in figure 2–2.

Figure 2–2(*a*) shows the spacecraft in a lower circular orbit. It should be noted that

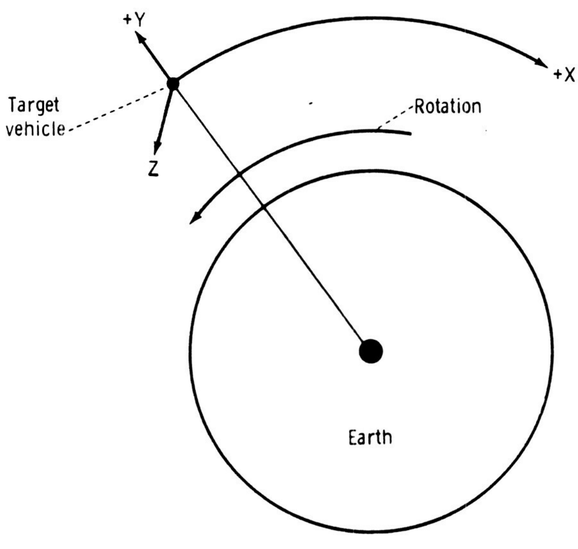

FIGURE 2–1.—Target-centered coordinate system.

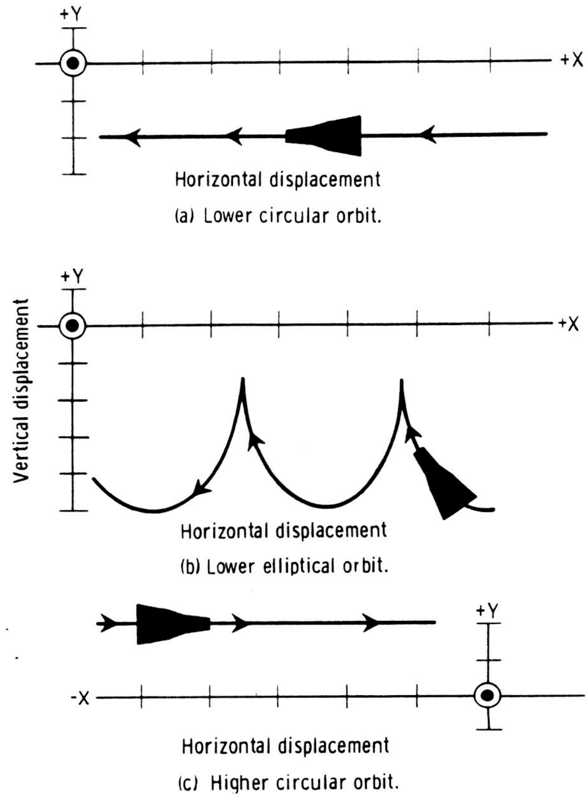

FIGURE 2–2.—Motion relative to a target-centered coordinate system.

the radial displacement Y is constant while the trailing displacement X decreases with time, since the spacecraft in the lower orbit has a higher angular rate. Figure 2–2(*b*) shows a lower elliptical orbit. As can be expected, this orbit has a catchup rate; however, the radial displacement also changes, with the low points representing perigees, and the high points, apogees. Figure 2–2(*c*) illustrates a spacecraft in a circular orbit higher than the target orbit. The radial distance is constant, as in the case of the lower circular orbit; however, in this case the trailing displacement changes since the target now has the higher angular rate. The following paragraphs use this coordinate system in describing the Gemini rendezvous operations.

The development of the operational rendezvous missions required extensive analyses as previously described in reference 1. For

Gemini VI, many concepts were evaluated and three were selected as candidates for the Gemini VI mission. The first was the tangential concept which included the tangential approach of the spacecraft to the target vehicle following four orbits of ground-controlled midcourse maneuvers. The second concept had a similar catchup sequence, except that the final midcourse maneuver established a coelliptical approach trajectory, and the spacecraft closed-loop guidance system was then used to establish a collision course. A third concept featured rendezvous at first spacecraft apogee. Following a tangential approach of the spacecraft to the target, the spacecraft would be inserted on a collision course with the target, and the spacecraft closed-loop system would be used to correct insertion dispersions.

After the three concepts had been selected, analyses were performed to determine the concept best suited for the Gemini VI mission. In June 1964, prior to the flight of Gemini II, the coelliptical rendezvous concept was selected for the Gemini VI mission.

Description of Initial Rendezvous Operations

Gemini VI–A, VIII, and X

Figures 2–3 and 2–4 present typical relative trajectory plots of the fourth-orbit rendezvous conducted on Gemini VI–A, VIII, and X. On each mission, the spacecraft was inserted into an orbit essentially coplanar with the target vehicle. The first orbit was left free of rendezvous maneuvers to allow the crew sufficient time to verify satisfactory spacecraft operation. A number of midcourse corrections were performed before completing the rendezvous during the fourth spacecraft orbit near the end of the fourth darkness period. At the first spacecraft perigee, an apogee height-adjust maneuver N_H was performed to correct for in-plane insertion dispersions. At the second apogee, a phase-adjust maneuver N_{C1} was performed to raise the perigee, thus providing the catchup rate required for proper phasing of the terminal-phase initiation near the fourth darkness entry. An out-of-plane correction

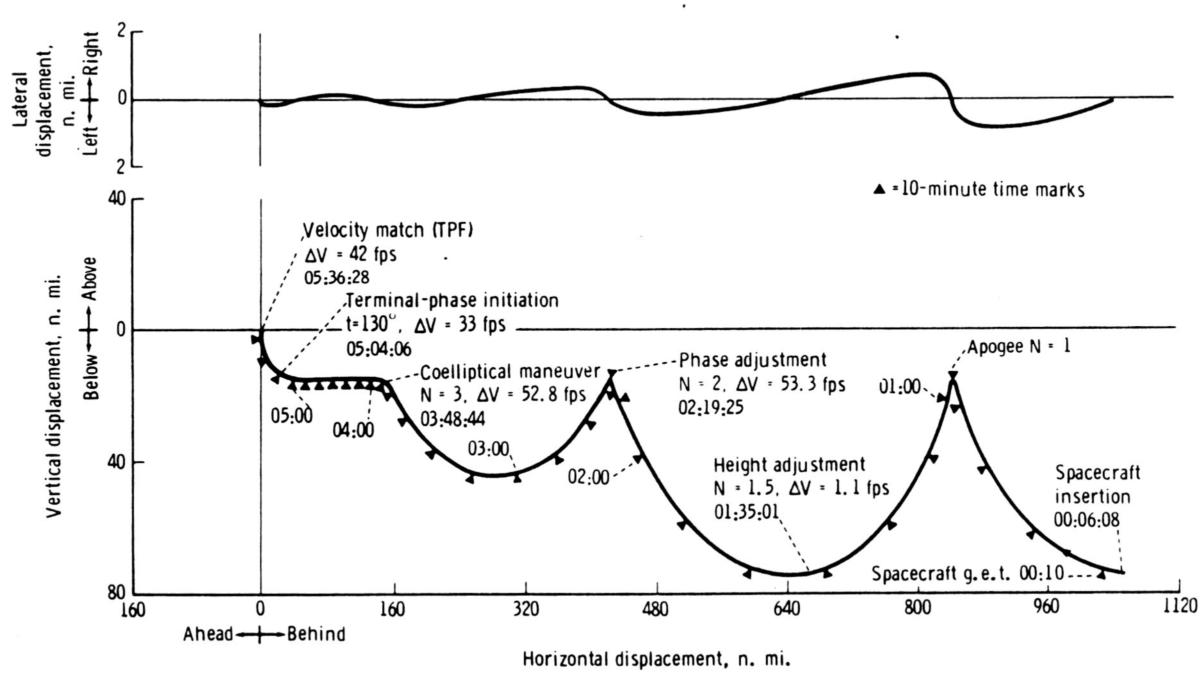

FIGURE 2–3.—Typical relative trajectory of spacecraft from insertion to rendezvous in target-vehicle curvilinear coordinate system. Gemini VI–A, VIII, and X missions.

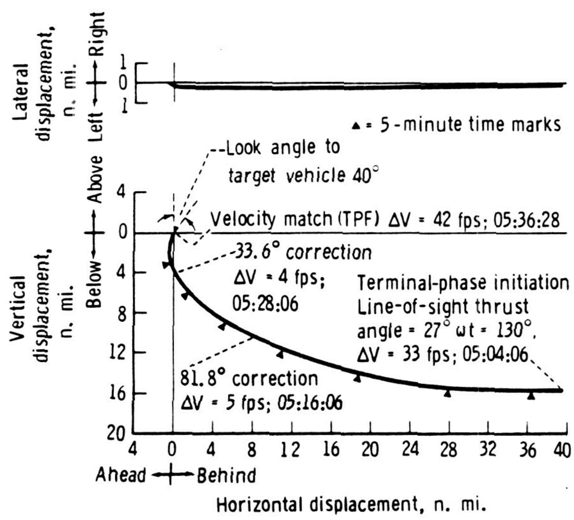

FIGURE 2-4.—Typical relative trajectory of spacecraft from terminal-phase initiation to rendezvous in target-vehicle curvilinear coordinate system. Gemini VI–A, VIII, and X missions.

P_C was applied at the nodal crossing after the second apogee to correct out-of-plane insertion dispersions. At the third spacecraft apogee, a coelliptical maneuver N_{SR} was performed to produce a constant altitude differential of 15 nautical miles. The onboard system then provided solutions for the terminal-phase-initiation (TPI) maneuver, which would occur when the line-of-sight elevation angle reached the nominal value of 27°. Two vernier corrections followed at 12-minute intervals. Finally, braking (terminal-phase finalization (TPF)) and line-of-sight rate control were effected by a manual operation based upon radar and visual data.

The transfer trajectory was selected to satisfy several of the mission requirements in the area of onboard procedures. First, in order to provide a backup reference direction for the terminal-phase-initiation maneuver in case of a guidance-system failure, the maneuver had to be performed along the line of sight to the target. The second requirement was a low terminal line-of-sight angular rate and a low closing rate. Finally, the terminal-phase-initiation point had to be below and behind the target vehicle; and the final approach, from below and ahead of the target vehicle, in order to optimize the lighting. These factors were evaluated, and a 130° transfer was selected.

The selection of the nominal coelliptical differential altitude of 15 nautical miles was based upon a tradeoff between two considerations. First, the range to the target at the terminal-phase-initiation point had to be small enough to assure visual acquisition. Second, a large differential altitude was required to minimize the effect of insertion dispersions and catchup maneuver errors on the location of the terminal-phase-initiation point. For example, a differential altitude of 15 nautical miles resulted in a 3-sigma dispersion of ±8 minutes in the timing of the terminal-phase-initiation maneuver. Early error analysis indicated a ±15-minute variation in terminal-phase-initiation timing for a differential altitude of 7 nautical miles. Flight experience demonstrated that the launch vehicle and spacecraft guidance systems accuracies, crew procedures, and ground-tracking accuracy were better than had been expected; as a result, the altitude differential was reduced to 5 and 7 nautical miles in the later rendezvous operations.

Gemini IX–A and XII

A second primary rendezvous technique was utilized on Gemini IX–A and XII (figs. 2–5 and 2–6). This technique resulted in rendezvous in the third spacecraft orbit near the end of the third spacecraft darkness period. A phase-adjust maneuver N_{C1} was performed at first spacecraft apogee to provide the correct phasing at the second apogee. Approximately three-fourths of an orbit later, the first of a set of two maneuvers was performed: a combination phasing, height-adjust, and out-of-plane correction. The first maneuver N_{CC}, combined with the following coelliptical maneuver, provided a fixed rendezvous time with minimum propellant usage. The out-of-plane portion of the first maneuver established a node at the following coelliptical maneuver point. The coelliptical maneuver N_{SR} eliminated the out-of-plane

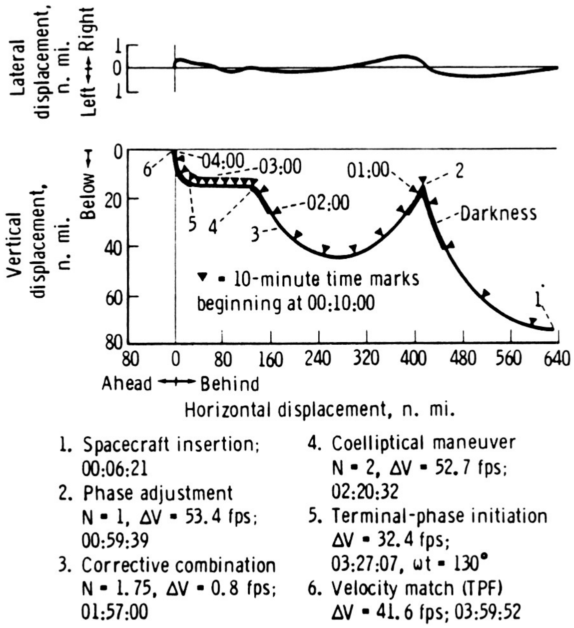

FIGURE 2-5.—Typical relative trajectory. Gemini IX-A and XII missions.

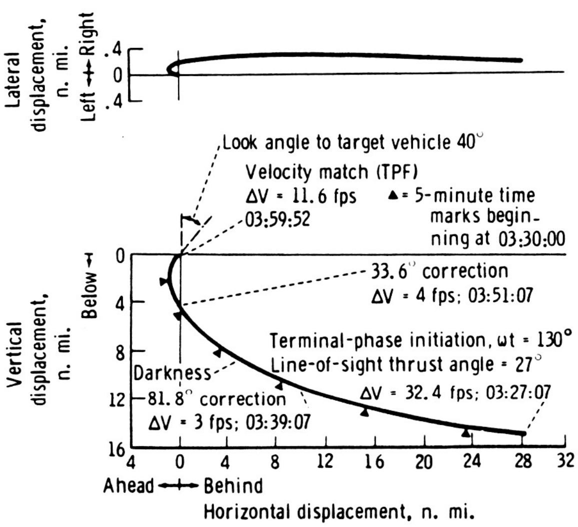

FIGURE 2-6.—Typical relative trajectory, terminal phase. Gemini IX-A and XII missions.

motion and established coelliptical orbits with an altitude differential that varied within certain limits. The terminal phase of this technique was the same as the fourth-orbit technique, except that procedural changes were necessary to accommodate the variable altitude differential.

Gemini XI

The third primary rendezvous conducted during the program was the first-orbit technique used for Gemini XI (figs. 2-7 and 2-8). The limited time available to conduct the first-orbit rendezvous prohibited the multicorrection catchup phase and coelliptical approach used on other missions. Instead, a correction was made at spacecraft insertion to remove out-of-plane motion and to adjust

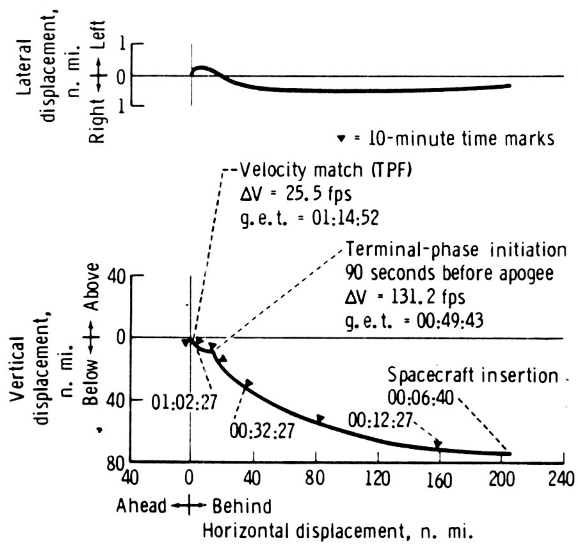

FIGURE 2-7.—Relative trajectory. Gemini XI mission.

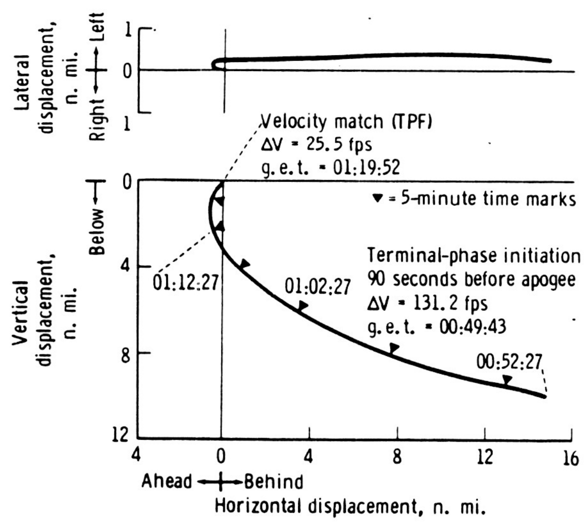

FIGURE 2-8.—Relative trajectory, terminal phase. Gemini XI mission.

apogee height and phasing. This correction was based upon onboard navigation information obtained from the spacecraft guidance system. At 90° after insertion, a second out-of-plane correction, also based upon onboard information, was performed. Terminal-phase initiation occurred just prior to first spacecraft apogee with the spacecraft 10 nautical miles below and 15 nautical miles behind the target vehicle. A 120° transfer was used with two vernier corrections at 12-minute intervals after the terminal-phase initiation. After a manual braking and line-of-sight phase, rendezvous was completed within the first orbit.

Description of Re-Rendezvous and Dual Rendezvous Operations

The first of three re-rendezvous techniques was an optical rendezvous from an equiperiod orbit and was conducted on the Gemini IX–A mission (fig. 2–9). The purpose of this rendezvous was to evaluate the optical rendezvous procedures, and particularly the terminal-phase lighting, required for the dual rendezvous scheduled for Gemini X. An upward radial velocity change was used to separate the spacecraft from the target vehicle into an equiperiod orbit. Approximately one-half orbit after separation, a correction

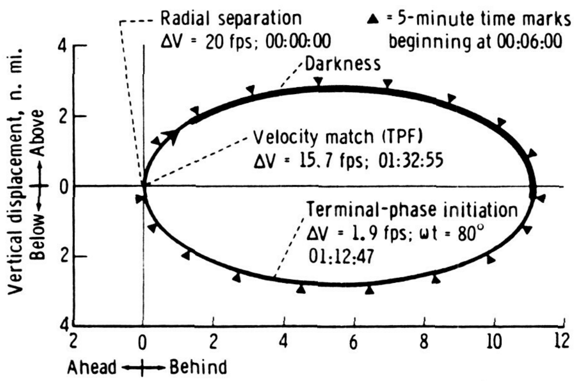

FIGURE 2–9.—Relative trajectory of spacecraft for (equiperiod) re-rendezvous in target vehicle curvilinear coordinate system. Gemini IX–A mission.

was applied based upon the time the line of sight to the target vehicle crossed the local horizontal. The time and the magnitude of the terminal-phase-initiation maneuver were determined from visual angle observations, and an 80° transfer was initiated when the Sun was nearly overhead. Two vernier corrections also based upon visual angle measurements were applied, and rendezvous occurred just prior to sunset. It was a requirement that the spacecraft be in a station-keeping mode prior to entering darkness with a passive target.

A second re-rendezvous technique (figs. 2–10 and 2–11) was developed to evaluate a terminal-phase condition with an Earth background. Two midcourse maneuvers were used to insert the spacecraft into a coelliptical orbit 7.5 nautical miles above the target vehicle. Except for a reversal in approach direction, the terminal phase was identical to that employed on the earlier coelliptical approach from below. Experience gained during this rendezvous indicates that the probability of success would be very low in case of a radar guidance system failure because of the extremely poor target visibility.

During the Gemini XI mission, a third re-rendezvous exercise was performed. This rendezvous was ground controlled except that the terminal braking and line-of-sight control phases were performed by the crew using visual observations (no radar). After the initial separation maneuver, the spacecraft was in a nearly circular orbit at the same altitude as the target vehicle, but with a trailing displacement of approximately 25 nautical miles. Since the relative motion of the vehicles in this configuration was approximately zero, the rendezvous was referred to as a stable-orbit rendezvous (fig. 2–12). A ground-computed maneuver was performed which placed the spacecraft on a trajectory to intercept the target vehicle in 292° of target orbital travel. With 34° of orbital travel remaining, a second and final ground-computed maneuver was applied. The rendezvous was then completed by the flight crew using visual cues. The terminal-phase portion of

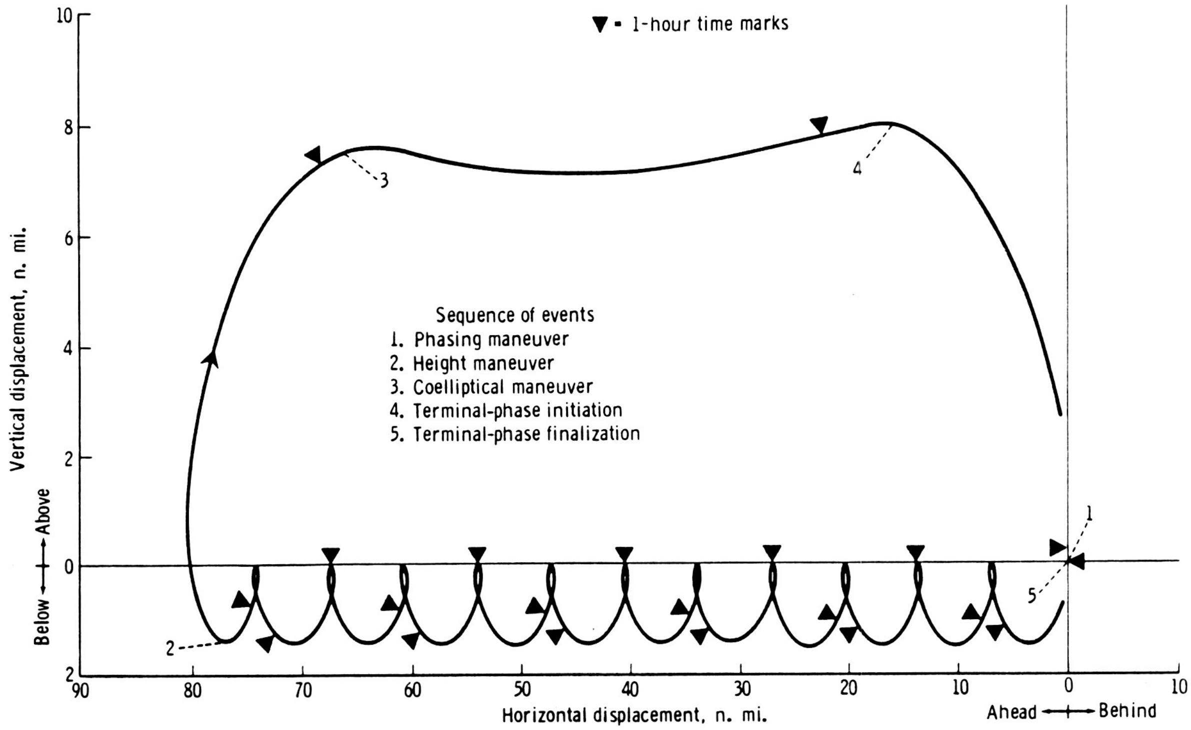

FIGURE 2-10.—Relative trajectory profile for re-rendezvous from above. Gemini IX-A mission.

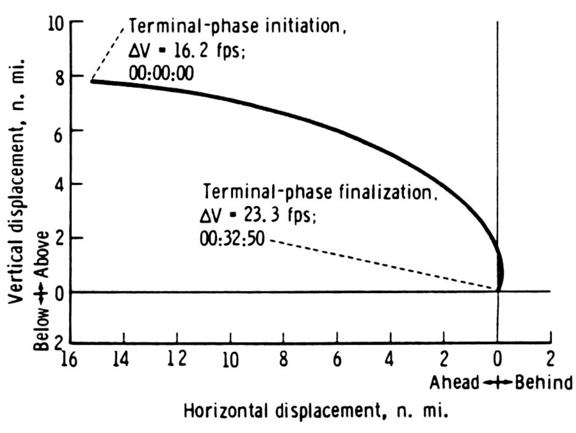

FIGURE 2-11.—Relative trajectory re-rendezvous from above. Gemini IX-A mission.

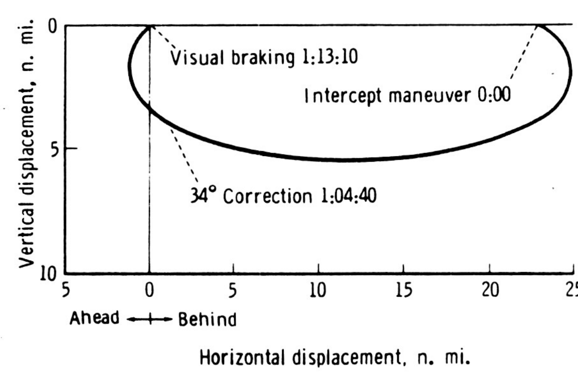

FIGURE 2-12.—Gemini XI stable orbit re-rendezvous.

this rendezvous had the same characteristics as the tangential concept previously described. Theoretically, the propellant required is small when compared with the coelliptical approach; however, with minor dispersions at the intercept maneuver point, the lighting conditions, approach angles, and propellant consumption for the braking phase can vary widely. The reason is that, for most cases, the spacecraft will end up approaching the target from above, resulting in poor target visibility. This type of rendezvous generated considerable interest in its application to certain rendezvous operations, particularly where a highly precise ground-tracking system is used to provide the terminal-phase maneuvers. The commitment to conduct such a rendezvous reflected the confidence that was established during Gemini in the capabilities of the ground-tracking, computation, and control facilities.

In addition to the primary and re-rendezvous missions, a dual rendezvous was performed by the Gemini X crew. The target vehicle launched during the Gemini VIII mission was left in orbit and was the passive target for the dual operation. One problem encountered during the development of the Gemini X mission was obtaining precise state vectors for the passive target vehicle, and making accurate predictions far enough in advance to find acceptable launch windows. Because of the inaccuracies in drag prediction, it was necessary for launch date, lift-off time, and catchup sequence to be flexible. The catchup sequence included a series of maneuvers by the docked Gemini X spacecraft and Gemini X target vehicle for gross catchup, and another series of maneuvers by the undocked spacecraft for fine catchup. The capability for large changes in altitude during the gross catchup sequence allowed an acceptable wide variation in the initial-phase angle. The terminal approach was coelliptical with an altitude differential of 7 nautical miles; the terminal-phase guidance employed was the same as for the optical rendezvous conducted on Gemini IX–A.

Rendezvous Considerations and Flight Results

In developing the rendezvous missions, many factors were considered, primarily launch procedures, system requirements, and crew procedures.

Launch Procedures

Development of the launch procedures required extensive analyses to define methods of controlling out-of-plane displacement, establishing launch-window length, and developing a countdown method.

Selecting a target orbit inclination slightly above the latitude of the launch site makes the out-of-plane displacement relatively small for a long period of time (fig. 2–13). By varying the launch azimuth so that the spacecraft would be inserted parallel to the target-vehicle orbital 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. The out-of-plane displacement could also be minimized by using the variable launch-azimuth technique with guidance in yaw during second-stage powered flight. This is accomplished by biasing the launch azimuth of the spacecraft so that the launch azimuth is at an optimum angle directed toward the target-vehicle orbital plane (fig. 2–14). As a result, the out-of-plane distance would be reduced prior to the initiation of closed-loop guidance during the second-stage flight. This technique would effectively use the launch-vehicle performance capability to control the out-of-plane displacement. Sufficient performance capability existed in the Gemini Launch Vehicle to control the out-of-plane displacement to within ±0.55° (table 2–II). The maximum allowable wedge angle of ±0.55° was not needed on any of the rendezvous missions. By selecting an inclination of

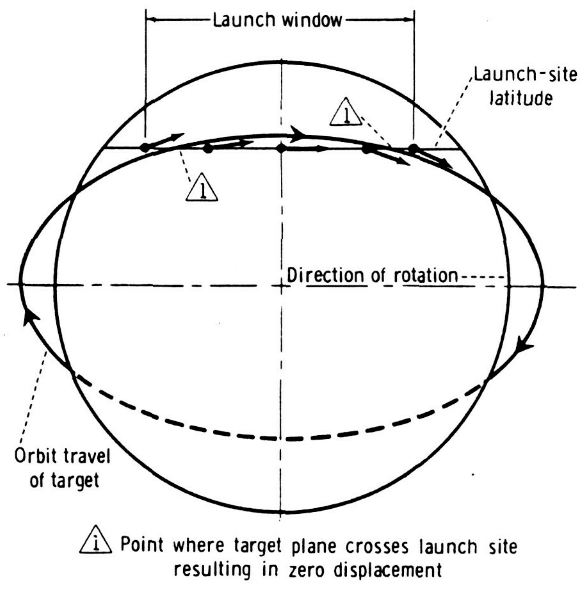

FIGURE 2–13.—Variable azimuth launch technique.

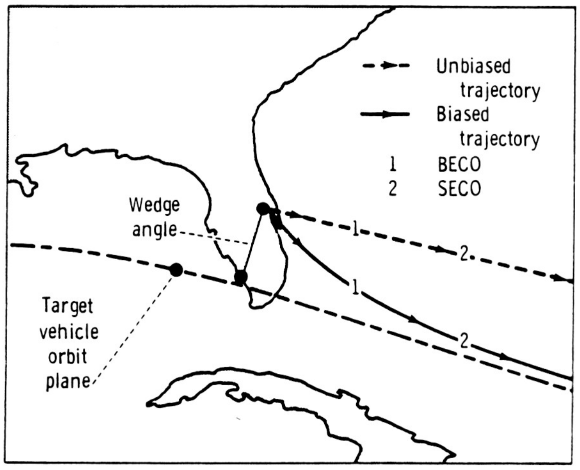

FIGURE 2-14.—Typical Gemini rendezvous launch. Biased launch azimuth and Stage II yaw steering.

TABLE 2-II—*Yaw Steering Summary*

Gemini mission	Targeted out-of-plane displacement, deg
VI-A	0.20
VIII	−.21
IX-A	−.50
X	−.077
XI	−.131
XII	−.16

28.87°, 0.53° above the launch-site latitude, and by using a variable launch-azimuth technique, the out-of-plane displacement could be controlled to within 0.53° for 135 minutes.

During the early planning phases of the Gemini Program, a relatively large launch window (table 2-III) was considered mandatory; however, later experience indicated that reliable countdown procedures could be developed, and it is now the general opinion that large launch windows are not required. Since Gemini V, the launches have either been essentially on time, or the launch has been scrubbed. By suitable planning, minor launch delays can be easily absorbed in the count, and if major problems occur, large launch-window lengths are not particularly helpful. An on-time launch capability provides a tremendous potential in planning operational rendezvous missions and indicates that rendezvous operations, booster performance permitting, are operationally feasible at any orbital inclination.

TABLE 2-III.—*Gemini Launch Performance*

Mission	Launch attempts	Launch date	Launch-time deviation
I	1	Apr. 8, 1964	On time
II	2	Jan. 19, 1965	−4 min
III	1	Mar. 23, 1965	−24 min
IV	1	June 3, 1965	−16 min
V	2	Aug. 21, 1965	On time
VI	1	(a)	—
VI-A	2	Dec. 15, 1965	On time
VII	1	Dec. 4, 1965	On time
VIII	2	Mar. 16, 1966	On time
IX	1	(b)	—
IX-A	2	June 3, 1966	On time
X	1	July 18, 1966	On time
XI	3	Sept. 12, 1966	On time
XII	3	Nov. 11, 1966	On time

[a] Target-vehicle failure.
[b] Target launch-vehicle failure.

Initial analyses of countdown methods indicated that the highest probability of mission success could be achieved by simultaneously counting down both vehicles. Even though simultaneous countdowns have been used extensively in Gemini, nothing in the results clearly indicates that this is a necessity.

Systems Requirements

A primary consideration in the development of the rendezvous operations was the area of systems requirements. The requirements for the systems design were based upon design-reference missions. As the designs became established, however, the operational missions were developed to exploit the systems capabilities, and, of course, the missions were ultimately limited by the systems capabilities. For example, a desired objective during the Gemini XII mission planning was to complete a rendezvous during the second orbit ($M=2$). Accomplishing this objective within acceptable dispersions would have required a trajectory correction based on radar range at a point outside the spacecraft radar-range capability. As a result, the second-apogee rendezvous plan was eliminated.

Crew Procedures

Further requirements were imposed to achieve workable crew procedures. The major requirements in this area were the following:

(1) Sufficient time for the crew to complete the necessary activities

(2) Approach trajectories which are reasonably insensitive to insertion dispersion and to errors in midcourse maneuvers

(3) Lighting conditions which are compatible with backup procedures

(4) Low terminal-approach velocities and line-of-sight angular rates

(5) Backup procedures for guidance-systems failures

The requirement to allow sufficient time for crew procedures had an effect on several of the Gemini missions. For example, the first orbits of the Gemini VI–A and VIII missions were free of rendezvous maneuvers, allowing the crew sufficient time to verify the satisfactory operation of all spacecraft systems. The Gemini X primary rendezvous was changed from a third-orbit to a fourth-orbit rendezvous to allow the crew sufficient time to conduct the heavy procedural workload required by the star-horizon onboard orbit determination.

The second procedural requirement, approach trajectories which are reasonably insensitive to insertion dispersion and errors in midcourse maneuvers, was also important in the development of the fourth-orbit rendezvous. An objective was to develop a mission which could effect a near-nominal terminal-approach trajectory notwithstanding insertion dispersions, spacecraft equipment degradation, or ground tracking and computation errors. This objective established the need for the development of backup terminal-phase procedures in the event of a guidance-component failure.

The need for lighting conditions (fig. 2–15) compatible with backup procedures affected all the rendezvous missions. The desired lighting situation for an active target was that the crew (1) see the target by reflected sunlight prior to and at terminal-phase initiation, (2) see the target acquisition lights against a star background during the terminal transfer, and (3) see the target by reflected sunlight for docking after exit from darkness. This lighting situation enabled the crew to maintain target visibility throughout the terminal-rendezvous operations, and established the capability for making inertial line-of-sight angle measurements in the event of a guidance platform failure. The lighting requirement was a factor in selecting the location of the terminal-phase-initiation point, the central angle of the transfer, and the terminal-approach angle. The desirable lighting conditions for rendezvous with an active target were different than for rendezvous with a passive target (fig. 2–16). Since a passive target would not

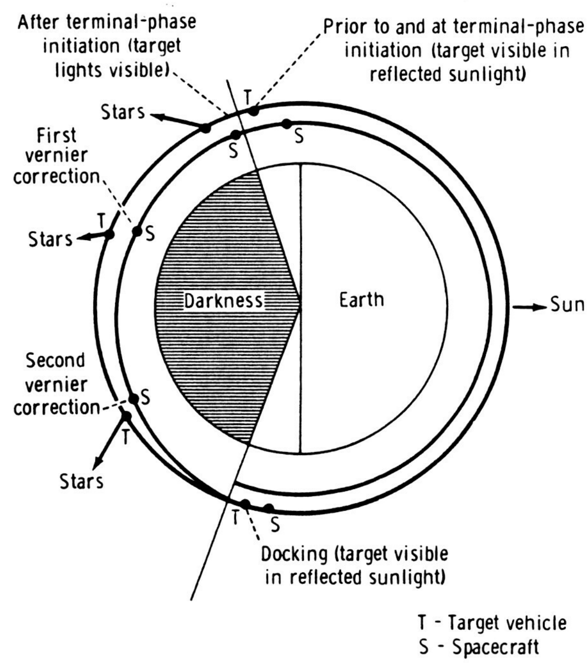

FIGURE 2–15.—Desired lighting situation for primary rendezvous.

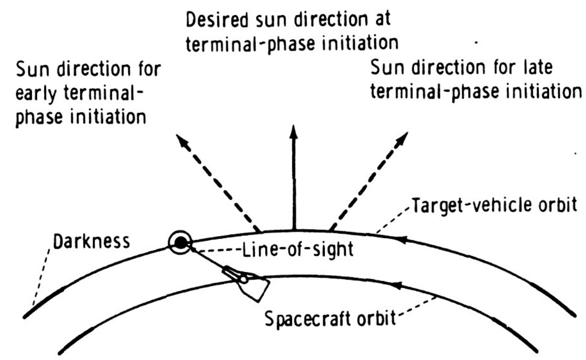

FIGURE 2-16.—Desired lighting situation for passive rendezvous.

be visible in darkness, the terminal-phase portion of the Gemini X dual optical rendezvous was conducted entirely in daylight. The desired terminal-phase initiation occurred near the midpoint of the daylight period. Earlier initiations would have placed the sunline too near the line of sight to the target, thereby obscuring target visibility. Later initiations would not have allowed adequate time in daylight for completing the rendezvous. Gemini experience has shown that lighting is not a major constraint for an active rendezvous provided the spacecraft guidance system does not fail during the terminal approach; but lighting is a major constraint for an optical rendezvous.

The fourth requirement was that the terminal trajectory allow a low terminal-approach velocity and low line-of-sight angular rate. The requirement was important in selecting the trajectory parameters for the coelliptical and the first-orbit rendezvous plans. The 130° transfer utilized on several of the missions was chosen primarily because of the low line-of-sight angular rate near intercept. The biased apogee approach was selected for Gemini XI because the direct tangential approach would have resulted in a high closing velocity.

Throughout the Gemini Program, there was a question of the level of effort to be applied to the development of backup procedures to accommodate guidance-system failures. During the Gemini XI first-orbit rendezvous mission, a problem with the radar system developed just prior to the final terminal-phase midcourse correction. Even though a backup solution for this maneuver was computed and applied, rendezvous could have been accomplished without the correction, since the correction required in this particular instance was small (2 ft/sec). However, on Gemini XII, a failure of a primary guidance-system component required the use of the backup procedures. The radar system failed prior to the terminal-phase-initiation maneuver on this mission, and backup procedures were employed throughout the terminal phase to complete the rendezvous.

The terminal phase of a rendezvous operation involves precision maneuvers and careful control of closing and line-of-sight rates. Table 2–IV compares fuel expenditures encountered during terminal-phase operations with the theoretical minimum. A considerable variation exists between the ratio of actual-to-minimum propellant for various types of terminal-phase conditions, and also for different flights using the same or similar terminal-phase conditions. This variation reflects the critical nature of the task, in that fairly small velocity vector errors can cascade to high propellant consumption or failure to complete the rendezvous. The braking operation is particularly critical. Braking too soon will increase line-of-sight control requirements, and require more time to control the spacecraft during the closing sequence.

An additional comparison of rendezvous performance is shown in table 2–V where the actual terminal-phase vernier corrections are compared with the preflight minimal predicted. This comparison provides an especially good measure of guidance-system performance, since the maneuvers were nominally very small and became large only with degradation of guidance-system performance or with control difficulties.

A number of terminal-phase rendezvous operations were satisfactorily completed during the Gemini Program by using optical

TABLE 2–IV.—*Rendezvous Propellant Usage*

Gemini mission	Type of rendezvous	Conditions at start of terminal phase	Propellant usage, lb		
			Actual	Minimum	Ratio
VI–A	$M = 4$	Coelliptic: $\Delta h = 15$ n. mi. $\Delta X = 25$ n. mi.	130	81	1.60
VIII	$M = 4$	Coelliptic: $\Delta h = 15$ n. mi. $\Delta X = 25$ n. mi.	160	79	2.02
IX–A	$M = 3$	Coelliptic: $\Delta h = 12$ n. mi. $\Delta X = 22$ n. mi.	113	68	1.66
IX–A	Optical	$\Delta h = 2.5$ n. mi. $\Delta X = 3.5$ n. mi.	61	20	3.05
IX–A	From above	$\Delta h = -7.5$ n. mi. $\Delta X = -10$ n. mi.	137	39	3.51
X	$M = 4$	Coelliptic: $\Delta h = 15$ n. mi. $\Delta X = 30$ n. mi.	360	84	4.28
X	Optical dual	Coelliptic: $\Delta h = 7$ n. mi. $\Delta X = 12$ n. mi.	180	73	2.46
XI	$M = 1$	Spacecraft at apogee of 87/151 orbit: $\Delta h = 10$ n. mi. $\Delta X = 15$ n. mi.	290	191	1.52
XI	Stable orbit	$\Delta h = 0$ n. mi. $\Delta X = 25$ n. mi.	87	31	2.81
XII	$M = 3$	Coelliptic: $\Delta h = 10$ n. mi. $\Delta X = 20$ n. mi.	112	55	2.04

TABLE 2–V.—*Vernier Correction Solutions for Primary Rendezvous*

Gemini mission	Actual correction, ft/sec		Nominal correction, ft/sec	
	First	Second	First	Second
VI–A	11	7	1	2
VIII	15	9	1	0
IX–A	1	3	2	3
X	20	23	2	3
XI	6	2	0	2
XII	2	5	2	3

techniques alone (no closed-loop radar-computer operation). Optical rendezvous requires careful control of lighting conditions, and a stabilized reference such as an inertial platform is highly desirable. During simulations, rendezvous have been effected without platform information; however, the probability of success is relatively low.

Concluding Remarks

The rendezvous operations conducted on Gemini have demonstrated that rendezvous is operationally feasible with an active or a passive target. It has also been demonstrated that the operation can be performed using only onboard guidance information after lift-off; using only ground-supplied information; or by using a combination of onboard and ground-supplied information.

Reference

1. ANON.: Gemini Midprogram Conference, Including Experiment Results. NASA SP-121, 1966.