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GEMINI PROGRAM MISSION REPORT

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GEMINI IV

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this date Sept 30, 1974 D.M. Smith

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION ☐ MANNED SPACECRAFT CENTER

4.3.1.3 Station keeping.- Time histories of separation range, azimuth, and elevation during the first revolution between the spacecraft and the second stage of the launch vehicle are shown in figure 4-5. Relative motion between the spacecraft and stage II is shown in figure 4-6. These parameters were calculated by simulating each vehicle's trajectory, utilizing the corrected IGS insertion vector as shown in section 5.1.5.2.1. An initial spacecraft - launch-vehicle separation velocity of 6 to 7 ft/sec was established through simulations during postflight evaluation. A 4.1-ft/sec velocity increment was applied to the spacecraft using the aft-firing thrusters, and a 2 to 3 ft/sec velocity increment was applied to the launch vehicle which may have been a result of the shaped-charge firing or the effect of the OAMS aft-firing thrusters impinging on the launch vehicle or a combination of both. If uncompensated, this velocity difference would build up to give a separation of approximately 17 nautical miles at the end of the first revolution. The relative trajectory for this situation is shown in figure 4-7. The trajectory obtained from the simulation appears to be compatible with the following information available from the flight crew and from ground orbit determination.

(a) At Canary Island (22 min g.e.t.), the crew was almost directly above stage II.

(b) Stage II was never above the horizon (as viewed from the spacecraft).

(c) Prior to Carnarvon (52 min g.e.t.) the two vehicles came back together within a minimum range of 0.3 nautical mile.

(d) After darkness, stage II was well below and in front of the spacecraft.

(e) At the time of the last maneuver, stage II was well below and in front of the spacecraft.

(f) The final orbit obtained from the simulation agreed within 1.3 nautical miles of the actual orbit determined by ground tracking. A detailed list of all thrusts and attitudes is contained in table 4-IV, and a summary list of all maneuvers for each thruster is presented in table 4-V.

Two retrograde maneuvers were completed by 00:09:23 g.e.t. using the aft-firing thrusters and with the spacecraft in the BEF orientation (fig. 4-8). Prior to platform alinement, one additional small thrust was made with the aft-firing thrusters and a second with the up-firing thrusters. These four thrusts, totaling 5.1 ft/sec, were applied to reduce the separation rate and were greater than the separation velocity applied by the crew.

Figure 4-9 shows the principal velocity increments applied during the first 60 minutes of the station-keeping exercise. Also shown is the spacecraft attitude at the time of these thrusts.

During the station-keeping exercise, the critical nature of rate determination was demonstrated. After separation, following the four thrusts back toward the launch vehicle, a rate of 1.5 ft/sec away from the stage II existed, whereas, a rate toward it should have been established. The range was approximately 1800 feet at this time. Later, at the point of closest approach, an 8-ft/sec rate existed, normal to the line of sight, which should have been removed. The range at this time was also 1800 feet; however, both vehicles were in darkness. The ability of a flight crew member to determine rates of the target even in daylight is considerably impaired without a stable background or familiar objects in the foreground. At night, the ability to determine rates depends on the relative distance between two reference lights if they are both visible. If only one light is visible, the flight crew member's judgement depends on his ability to measure the intensity of the light, and, if this one light is flashing, the task becomes very difficult. Therefore, it appears necessary to follow a procedure which requires that perceptible rates be established. In addition, the data from this flight confirm that a limit of separation for maintaining a close-up station-keeping exercise should be established which provides that relative rates remain low, yet perceptible. At the same time, total fuel consumption must stay reasonable. Figure 4-7 shows that the maneuvers conducted after 32 minutes on this flight were less successful than those before that time in maintaining a close-up station with the second stage of the launch vehicle. The data also indicate that any attempt after that time to achieve a close-up station would have required a significant period of time and a number of thrust periods.

Referenced to the computer coordinate system, the IVI indicated total ΔV expenditure from the time of entering the catch-up mode to the close of the station-keeping exercise was:

$$\left|\Delta V_X\right| = 44 \text{ ft/sec} + +4 \text{ ft/sec} = 48 \text{ ft/sec}$$

$$\left|\Delta V_Y\right| = 75 \text{ ft/sec} + -9 \text{ ft/sec} = 66 \text{ ft/sec}$$

$$\left|\Delta V_Z\right| = 21 \text{ ft/sec} + +11 \text{ ft/sec} = 32 \text{ ft/sec}$$

The first term for each component is the sum of the magnitudes of the applied ΔV's along the respective axis. The second term is the accumulated ΔV over 4700 seconds due to accelerometer drift, resulting from a difference between input accelerometer bias terms and actual accelerometer bias.

Figure 4-7 illustrates the effectiveness of the thrusting history by showing the relative trajectory that would have resulted if thrusting had been terminated after several of the principal thrust periods. The range and range-rate time history for this period is shown in figure 4-10.

Review of these figures shows that the velocity increments applied through 00:09:21 g.e.t. succeeded in reducing the separation rate, but left a residual rate of 1.5 ft/sec away from the launch vehicle. As a result, the range from spacecraft to launch vehicle increased to 0.84 nautical mile and the range-rate increased to 6.5 ft/sec by 00:30:2[illegible] g.e.t. when corrective action was initiated. From 00:30:2[illegible] g.e.t. to 00:3[illegible] g.e.t., thrusts were applied which cancelled the separation rate and produced a range rate of 2.[illegible] ft/sec towards the launch vehicle. The resulting orbit would have passed within 2700 feet of the launch vehicle if no further thrusts had been applied.

Further thrusting was applied at 00:44:30 g.e.t. and at 00:55:55 g.e.t., which resulted in reducing the closest approach distance to 1800 feet. At this point (00:52:00 g.e.t.) a relative velocity of 8 ft/sec normal to the line of sight existed. This velocity propagated into a separation distance of 1.6 nautical miles and a separation rate of 17 ft/sec by the time corrective action was initiated at 01:05:30 g.e.t. The corrective thrust applied was insufficient and the separation distance continued to increase throughout the remainder of the first revolution as shown by figure 4-6. The application of velocity changes was further complicated during this time (01:04:00 g.e.t. through the end of revolution 1) because of the apparent failure of an aft-firing thruster. It appears that if a procedure had been followed that required the crew (1) to initially establish a clearly perceptible closing rate with the target at all times and (2) to again establish a perceptible closing rate any time the range became larger than several stage II lengths, then the closeup station-keeping goal could perhaps have been achieved. If these procedures had been followed for the thrusts applied in the first 24 minutes after separation, it appears that closeup station keeping would have been achieved using less fuel than that actually expended in attempting the task. The values of rates needed to be perceptible are very sensitive to the lighting conditions and can cause high propellant consumption if these lighting conditions are inadequate. The lighting conditions also limit how close to the target station keeping can be maintained with safety.

Figure 4-9 shows the effect of applying a correction which establishes a closing rate such that the target is intercepted. This plot shows how one thrust correction could theoretically achieve closure; however, in a flight case a number of successive thrusts approaching the one shown would be required because of the sensitivity of the trajectory to small corrections. This trajectory would in this case have placed the spacecraft below and behind the target which is desirable to allow nulling of the translation rates against an inertial background and provide effective corrections during closure with the target.

7.1 FLIGHT CREW PERFORMANCE

7.1.1 Activities

The crew activities outlined in the flight plan were tailored to mission objectives which were ambitious during the early revolutions. In order to accomplish extravehicular activity (EVA) and rendezvous maneuvers in the vicinity of the launch vehicle, it was necessary to plan this activity early in the flight because of the predicted differential orbital decay rates of the two vehicles. It was decided to perform station keeping with the launch vehicle during the first two revolutions rather than separate during the first revolution and perform visual rendezvous maneuvers during the second revolution concurrent with spacecraft systems tests and the EVA preparation.

The separation and maneuver and subsequent rendezvous maneuver were planned after EVA on the third and fourth revolutions, respectively.

Crew performance is discussed in the following paragraphs and crew training summary is included at the end of this section.

7.1.1.1 Prelaunch.- Prelaunch preparations proceeded smoothly, and the crew was ready for ingress at the scheduled time of T-100 minutes. The erector problem and resultant launch delay had no noticeable effect on crew readiness. During this period, the crew performed all required countdown functions and was waiting for lift-off.

7.1.1.2 Launch and insertion.- The flight crew verified lift-off by calling out that the event timer was "counting." Powered-flight events occurred on schedule and were confirmed by the crew as required. The crew was well prepared for launch, and no unexpected events occurred during this phase of the mission.

7.1.1.3 Station-keeping maneuvers.- The crew members' account of the station-keeping maneuvers is contained in section 7.1.2 of this report, and a detailed evaluation of the exercise is included in section 4.3.1.3. Therefore, the chronology will not be repeated here. The command pilot did not achieve close-up station keeping with the second stage of the launch vehicle, initially as a result of insufficient translation thrust application to effect a zero relative velocity or a closing velocity immediately after separation. The difficulty in nulling relative velocity was increased as a result of the earth's being viewed as a background rather than the sky. Also, a 3 ft/sec retrograde velocity which was not predicted prior to the flight was imparted to the launch vehicle as a result of the separation maneuvers. The difficulty in estimating range rate of a tumbling vehicle was an additional factor in the difficulty encountered in achieving close-up station keeping. In addition, the crew was required to perform this complex task immediately after insertion before they became accustomed to the new environment, and they were also required to aline the platform which diverted their attention from the station-keeping tasks. All of these factors contributed to the failure of the close-up ~~of the~~ station-keeping exercise.

7.1.2.4.1 Station keeping: After separation and turnaround, the launch-vehicle second stage came into view at 200 to 500 feet behind the spacecraft and to the left of a line pointing back along the spacecraft track. The second stage was clearly visible against the dark sky, and the flashing lights were also clearly visible. The engine skirt was visible and appeared to be intact. The flight crew pointed the spacecraft at the second stage and thrusted for about 6 seconds. The crew did not have time to place the computer in catch-up mode before starting to thrust, but managed to place it there after about 2 or 3 seconds of thrust. The IVI's then counted up to 3 ft/sec. It appeared that the spacecraft and second stage were still separating; therefore, the crew thrusted for an additional 4 or 5 seconds. At that time, it appeared that the relative velocity was zero, or that the spacecraft was closing slightly. The spacecraft was then approximately 600 or 700 feet from the launch vehicle, and the crew started to aline the platform. Shortly after the crew began the alinement, the launch vehicle started to drop down below the spacecraft and finally went out of sight. The crew then thrusted down with the top thruster and waited about a minute more in the alining attitude. They then pitched down to sight the launch vehicle and found that it had dropped much further below than they had expected. It was difficult to see the launch vehicle against the earth background. The crew quickly returned to the alining attitude and placed the platform in orbit rate. The crew then retrothrusted for about 3 seconds and pitched the spacecraft down again to reacquire the launch vehicle, which was approximately 1000 feet below the spacecraft. At this point, two choices were available: One choice was to retrothrust to a different orbit and to attempt a rendezvous; the other was to force the spacecraft toward the launch vehicle by using the orbital attitude and maneuver system (OAMS) to overcome the relative velocities resulting from the now different orbits. Because of the time constraints of the flight plan, the brute force method was selected. The launch vehicle stayed below the spacecraft at a range of approximately 1200 feet as the spacecraft entered darkness. The launch vehicle disappeared in seconds as it entered darkness, and the flashing lights became visible. The crew continued to thrust both at the launch vehicle and in retrograde with most of the thrusting being at the launch vehicle. Just prior to Carnarvon, the crew had finally forced the spacecraft to an altitude approximately the same as the launch vehicle at a close range. Both flashing lights were intermittently visible throughout the maneuvers, and the distance between these lights gave some reference for judging range and range rate. The spacecraft was obviously getting close to the launch vehicle, and the crew fired a short burst to decrease the closing velocities. At about that time, the launch vehicle tumbling, which had reached a rate of 40 to 50 deg/sec, caused one of the lights to disappear. After that time, the crew was forced to judge range and range rate by the brightness of the single visible flashing light. This was extremely difficult to do, and the crew did not have a good estimate of range until the launch vehicle passed into sunlight. At that time, the launch vehicle was approximately 2 miles away, and its outline was visible below the spacecraft. During this daylight phase, the launch vehicle passed over a background of water, clouds, and land and was difficult to see at ranges greater than 1 mile. In thrusting toward it, the crew found that they could not close on it with a reasonable amount of fuel, and the range appeared to increase. The crew reported to the flight controllers that they could only close on the launch vehicle by a major expenditure of fuel; therefore, they recommended abandoning the station-keeping activity. Shortly thereafter, the crew was told to abandon the exercise. At that time, the launch vehicle was below and ahead of the spacecraft at a range of approximately 3 miles.

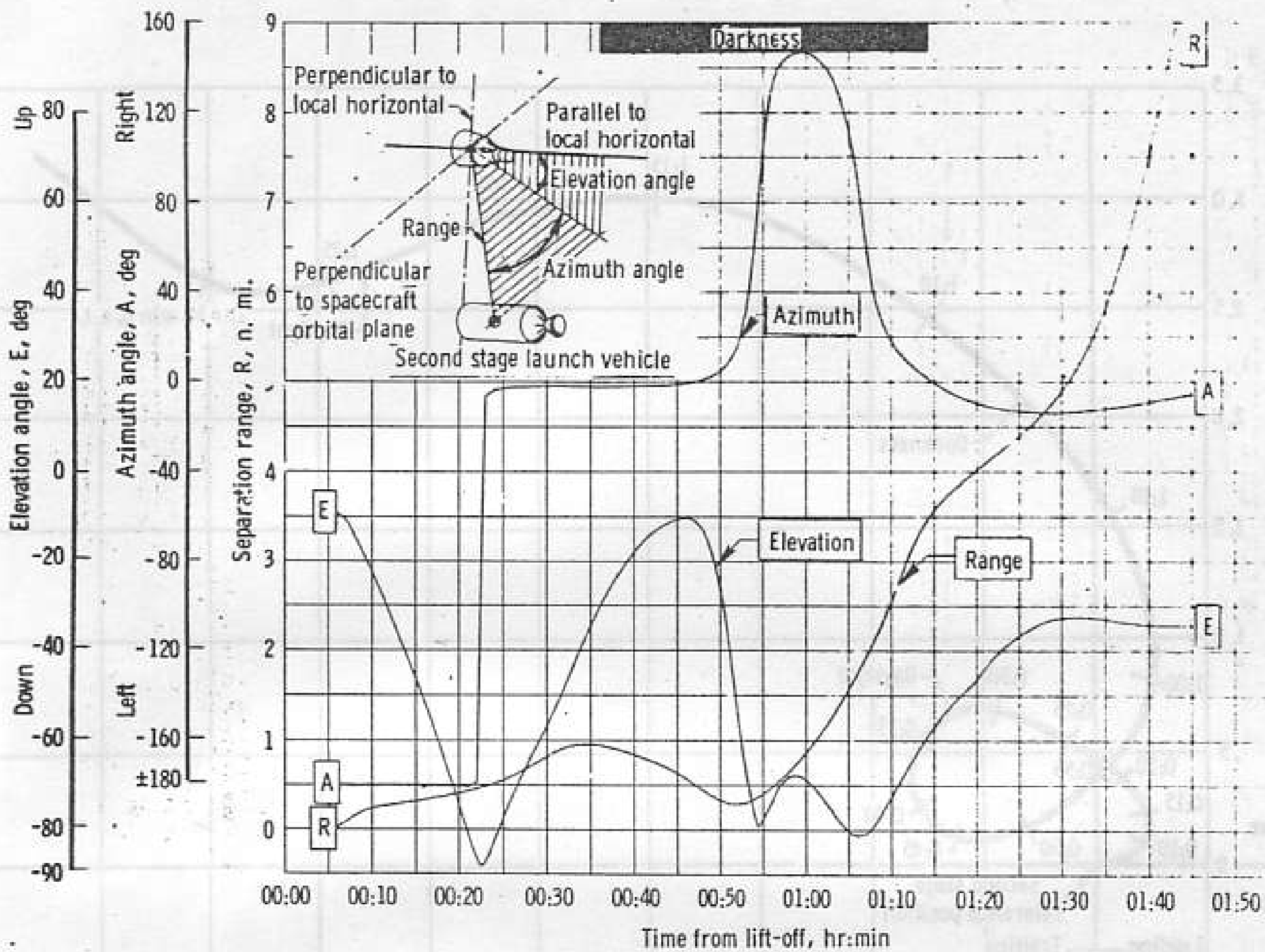

Figure 4-5. - Time history of separation range, azimuth, and elevation between the spacecraft and the second stage during the station keeping maneuvers.

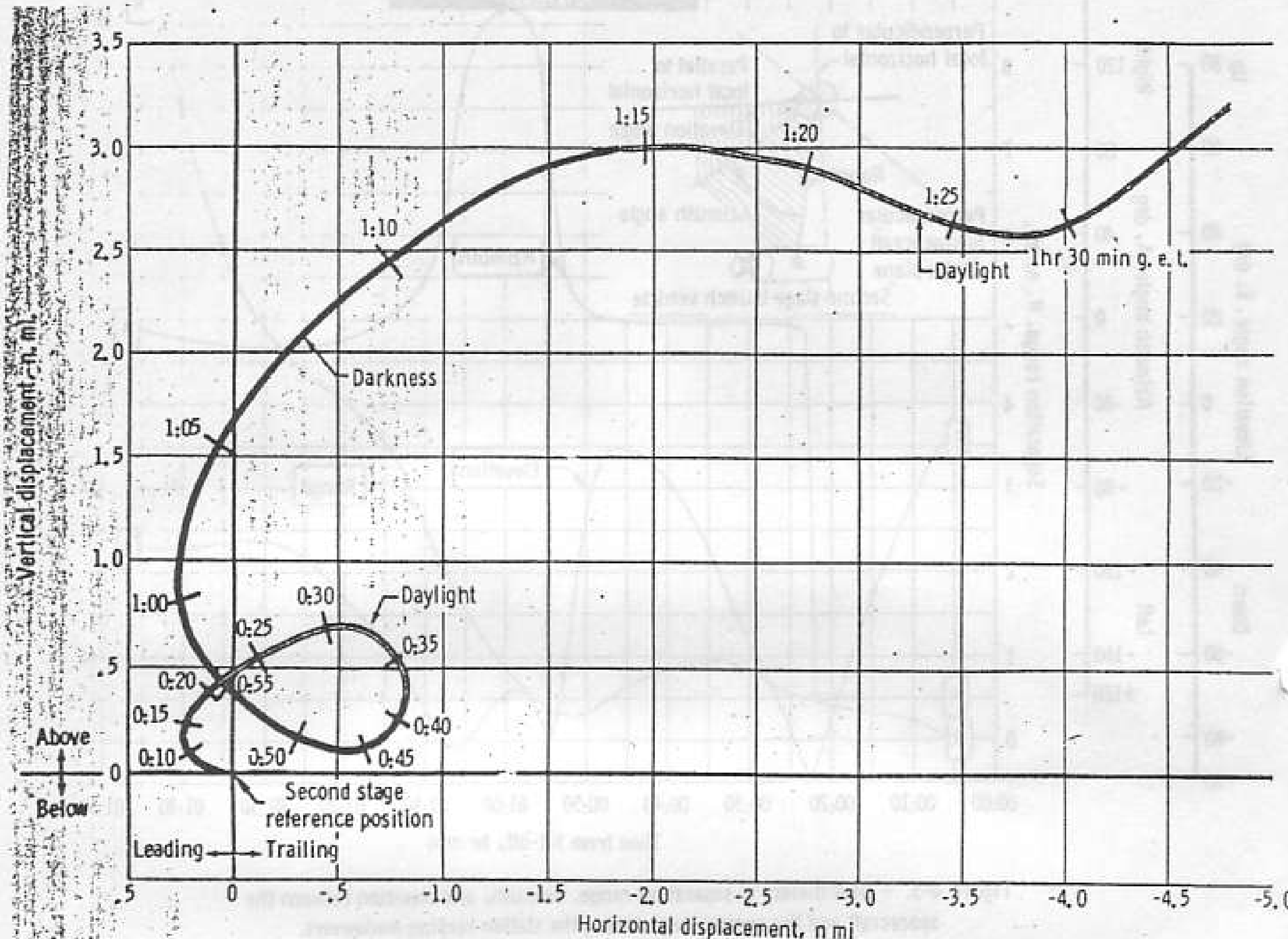

Figure 4-6. - Relative motion between the spacecraft and the second stage during station keeping maneuvers.

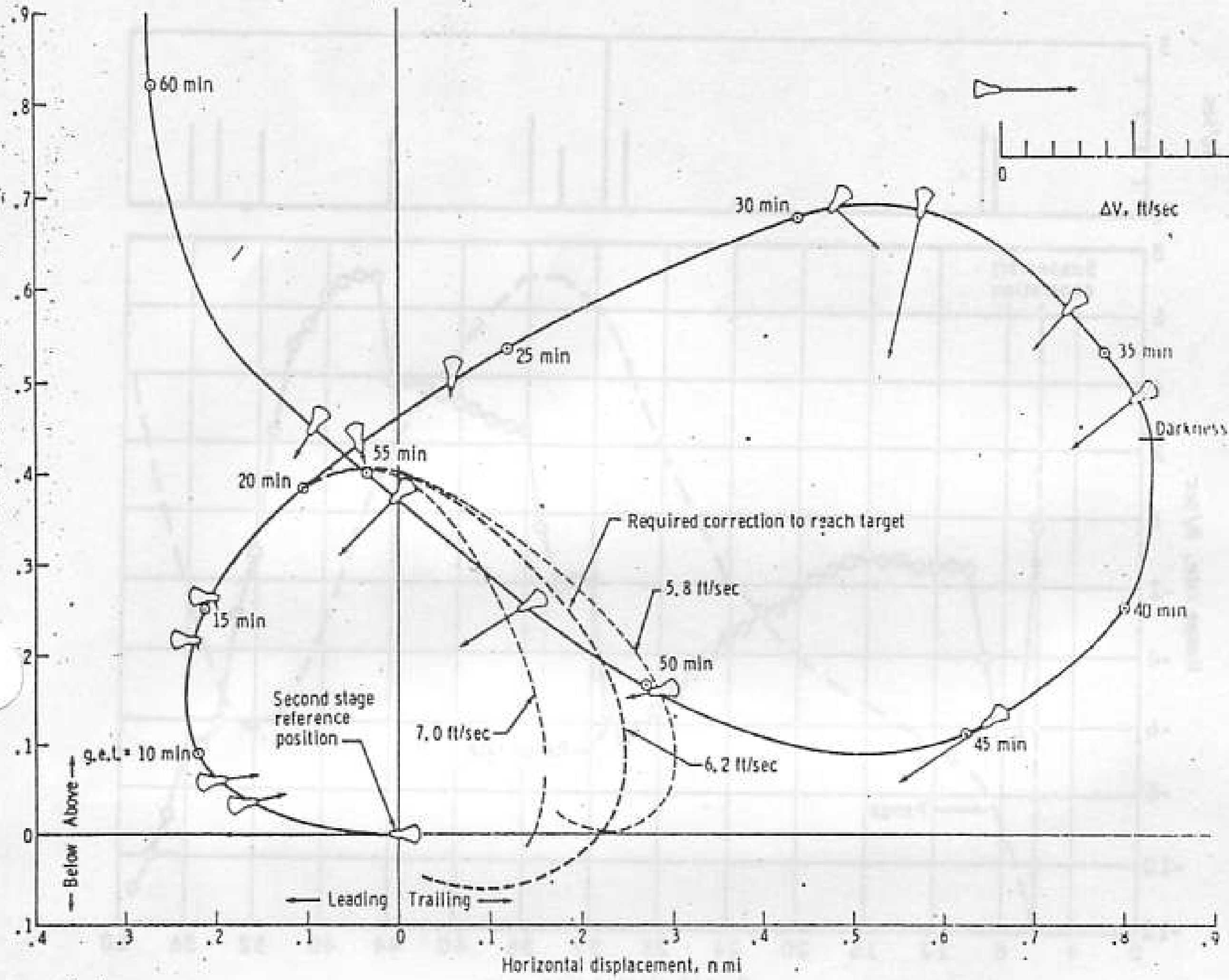

Figure 4-9. - Spacecraft-second stage relative position.

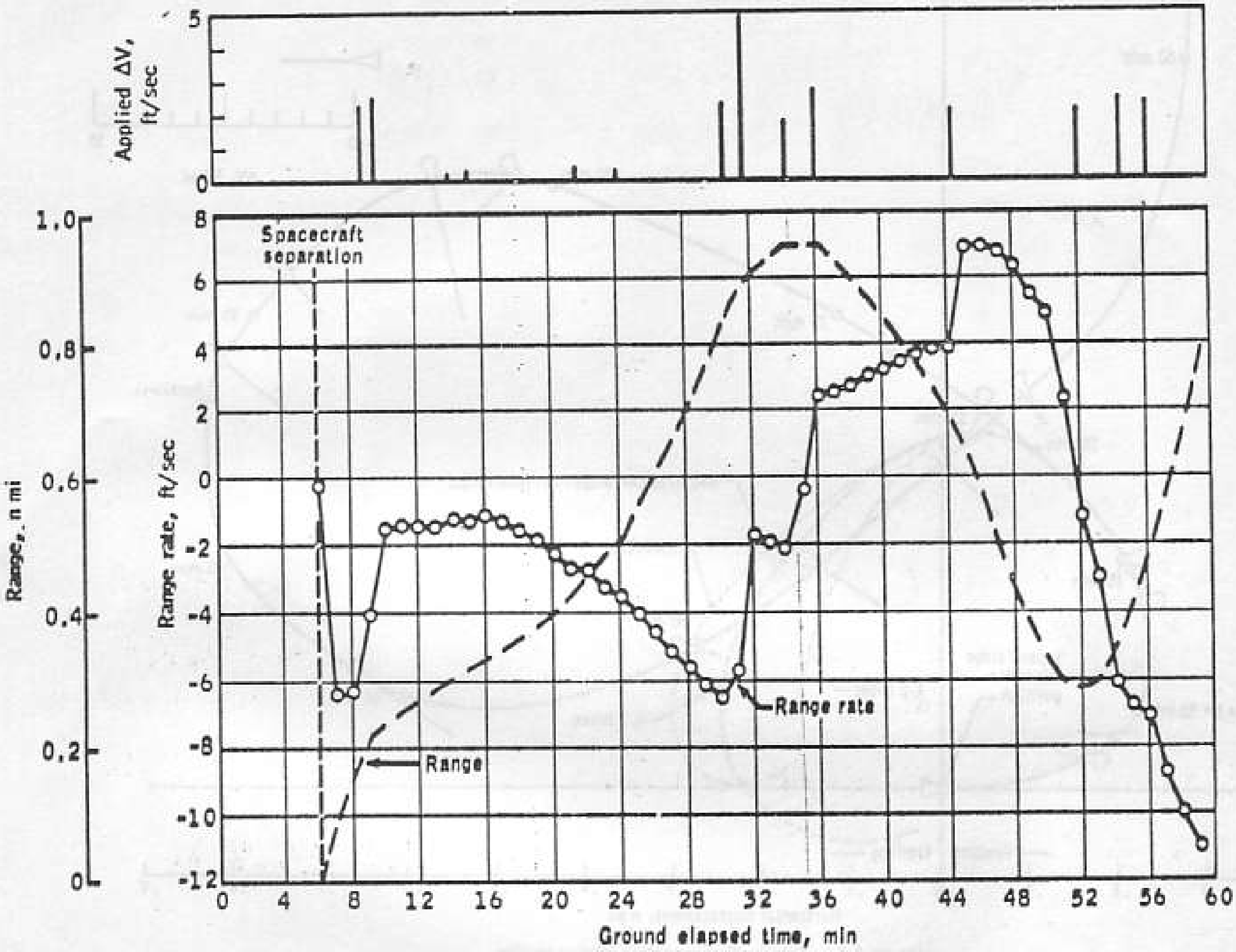

Figure 4-10. - Spacecraft - stage II range and range rate.