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MSC INTERNAL NOTE NO. 67-FM-105

July 26, 1967

USE OF REAL-TIME GEMINI RENDEZVOUS LOGIC FOR LM RESCUE

By Jerome W. Kahanek
Rendezvous Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
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PROJECT APOLLO

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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HOUSTON, TEXAS

Approved: Edgar C. Lineberry
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John P. Mayer, Chief
Mission Planning and Analysis Division

USE OF THE REAL-TIME GEMINI RENDEZVOUS LOGIC FOR LM RESCUE

By Jerome W. Kahanek

SUMMARY

A study has been made to determine if the Gemini real-time rendezvous logic (DKI logic) can be used for lunar module (LM) rescue by the command and service modules (CSM) in lunar orbit anytime the LM lifts off from the lunar surface.

Two maneuver sequences were investigated for rendezvous counters of 3, 4, 5, 6, and 7. The first sequences consisted of a height maneuver at maneuver point 0.5, a phasing maneuver at maneuver point 1.0 and a coelliptic maneuver one revolution before the rendezvous counter. The second sequence consisted of a phasing maneuver at maneuver point 1.0, a height maneuver at maneuver point 1.5, and the coelliptic maneuver one revolution before the rendezvous counter.

The study shows that the DKI logic can effect LM rescue within the lifetime of the LM for all phase angles at insertion from -10° to -360° and from 0.0° to approximately +9.0°. The CSM orbits were allowed a minimum altitude of 8.0 n. mi. The DKI logic could effect rendezvous for phase angles 0° to -10° if the logic was changed to permit phase angles greater than -360°, that is if -10° could be called -370°.

INTRODUCTION

LM rescue utilizing the Gemini rendezvous logic (DKI) used in the real-time Gemini rendezvous program (ref. 1) has been studied to determine the capability of the DKI logic for LM lift-off occurring anytime. The advantage of the DKI logic is that both the time of rendezvous and the differential altitude can be specified.

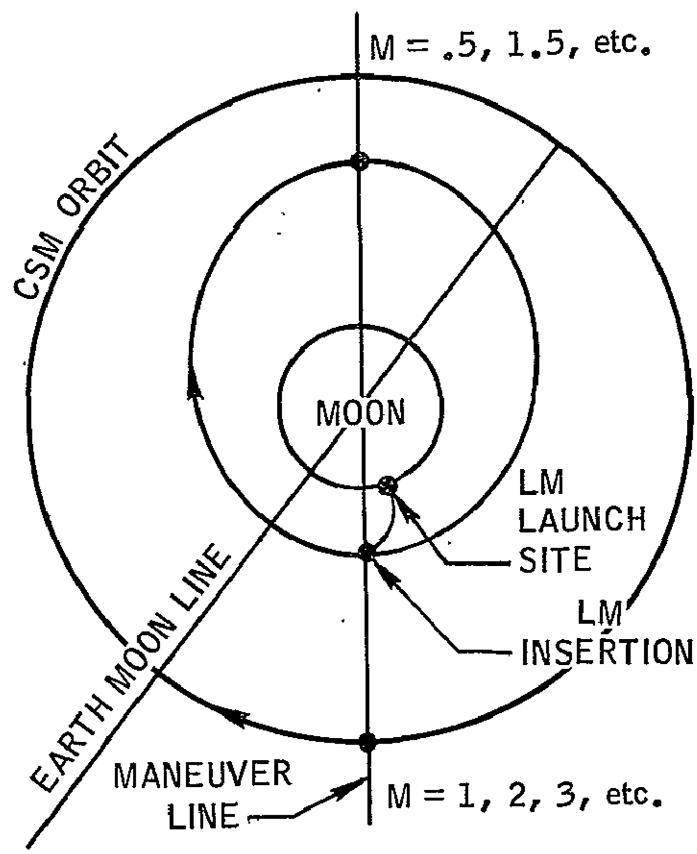
In the study many assumptions were made, such as the minimum altitude the CSM orbit would be allowed and the amount of time required between sending the CSM a maneuver and the actual execution of the maneuver. Consequently, the data should not be used as specific planning data.

CSM ΔV cutoff lines and LM lifetime lines are not included on the figures presented since the values are not yet firm.

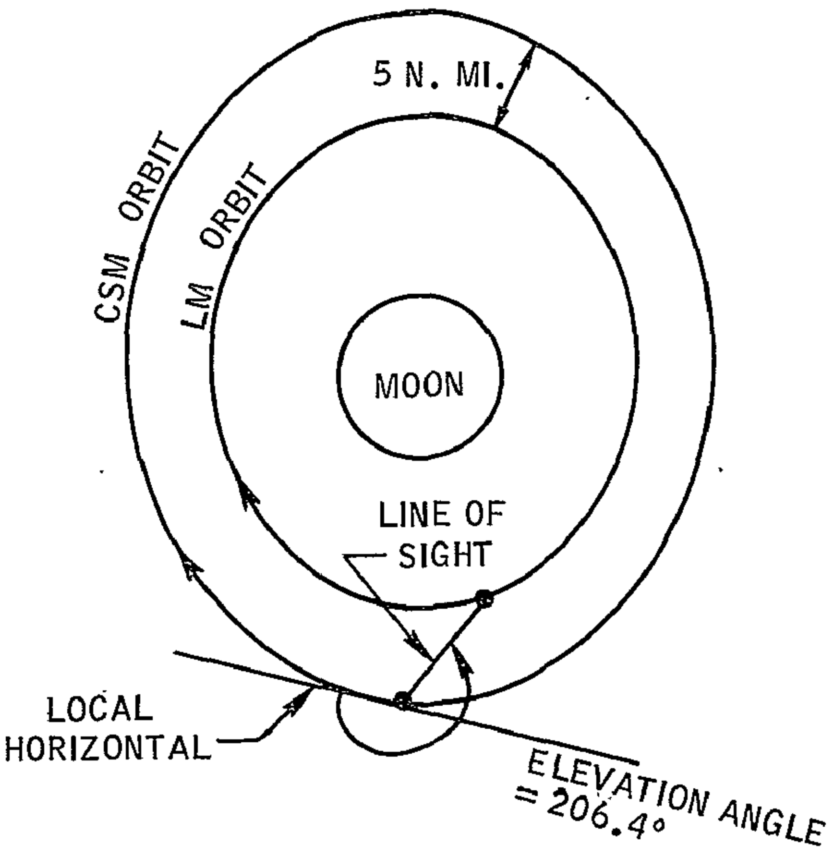
ANALYSIS AND RESULTS

The CSM lunar orbit used was an 80.0-n. mi. circular orbit. The LM was launched into an 8.0-n. mi. by 28.5-n. mi. orbit. The maneuvers used to effect rendezvous are a height maneuver, N_H, a phasing maneuver N_{C1}, and a coelliptic maneuver, N_{SR}. Two sequences were studied: N_H, N_{C1}, and N_{SR}; and N_{C1}, N_H, and N_{SR}. 5 impulse

Maneuvers were performed at a maneuver point, or counter, as illustrated below. The point which occurs 180° around from nominal LM insertion is defined as maneuver point 0.5. (Nominal LM insertion is assumed to occur when the CSM is 20.6° past the LM insertion point.) The rendezvous counter, M, refers to the value of the counter nearest the point of rendezvous.



Phase angle, θ, measures the angle from the CSM radius vector to the LM radius vector, positive in the direction of motion and negative in the opposite direction. The phasing and height maneuvers set a phase angle of -1.3° (CSM in front) and a height difference, ΔH, of 5.0 miles (CSM above) at the coelliptic maneuver point. The coelliptic maneuver put the CSM in an orbit 5.0 miles above the LM. The two-impulse processor was used to compute the terminal phase solution. The first impulse was initiated with a CSM elevation angle of 206.4° measured as shown below.



Sequences 1 and 2 are discussed below. Figure 1 describes both sequences from M = 3, 4, 5, and 6. In figure 1(a) through (d), negative phase angle (CSM ahead) is plotted versus the total ΔV cost of the LM rescue and the pericynthion of the CSM orbit after the phasing maneuver. Figure 1(e) shows the same information for the second sequence for M = 6 and 7 and illustrates the rendezvous possibilities for an early LM lift-off or extremely late lift-off where the LM inserts a few degrees ahead of the CSM.

SEQUENCE 1 - HEIGHT, PHASING, COELLIPTIC MANEUVERS

In maneuver sequence 1 the height maneuver is performed 180° around from LM insertion. This maneuver point 0.5, is behind the moon so the CSM must be informed to perform the maneuver before losing contact with the earth. Whether contact can be made or not depends on the LM landing site and the phase angle at insertion. Assuming landing sites from 45° W to 45° E and loss of CSM-earth contact at 22° past the line perpendicular to the earth-moon line, the CSM will have earth contact at LM insertion phase angles up to -69° or up to -157°, depending on the location of the landing site. Negative phase angle indicates that the LM is behind the CSM. If the positive phase angle is used, meaning the LM is ahead of the CSM, the DKI logic will try to make the CSM catch up by going down to a lower orbit. For all positive phase angles, using maneuver sequence 1, the CSM must go too low or below the lunar surface in order to catch the LM.

If the LM inserts within the phase angle constraints, less than -69° or -157° depending on landing site, the CSM can be informed to perform the height maneuver behind the moon. The phasing maneuver is then performed on the front side of the moon approximately over the launch site. The CSM will remain in this orbit until the coelliptic maneuver which occurs approximately one revolution prior to rendezvous. The only constraint on the rendezvous counter crossing number is the LM lifetime. Figure 1 shows that rendezvous counters 3, 4, and 5 are well within nominal LM lifetime. Rendezvous counter 6 is also presented; however, the time required from the LM lift-off to the terminal phase finalization (TPF) maneuver is very near the currently assumed LM lifetime.

SEQUENCE 2 - PHASING, HEIGHT, COELLIPTIC MANEUVERS

If the CSM is out of earth contact prior to LM insertion or already past the 0.5 maneuver point, the height maneuver must be delayed one revolution and sequence 2 is used. In this case the CSM will perform the phasing maneuver first as it comes across the launch site or maneuver point 1.0. After the phasing maneuver, the CSM will perform the height maneuver behind the moon at maneuver point 1.5, to set up the proper height differential at the coelliptic maneuver point.

Using maneuver sequence 2, the CSM can rescue the LM over a range of insertion phase angles from -10° to -360°, depending on the value of the rendezvous counter M. The minimum phase angle for each rendezvous counter depends on the height of pericynthion after the phasing maneuver. For example, if the CSM is not allowed to go below 8.0 n. mi., the minimum phase angle allowed is -10° for M = 6. At present the DKI logic only permits phase angles from -360° to +360°. If the logic were changed to permit larger negative phase angles, say -370°, then the DKI logic could effect LM rescue for any given phase angle using either M = 3, 4, 5, or 6 and the maximum time to rendezvous would be 10 hours 36 minutes 42 seconds. As the rendezvous counter increases, the phase angle corresponding to a minimum pericynthion altitude of 8.0 n. mi. decreases, and the total ΔV requirement for any given phase angle decreases. Of course, the time to rendezvous also increases as the rendezvous counter increases.

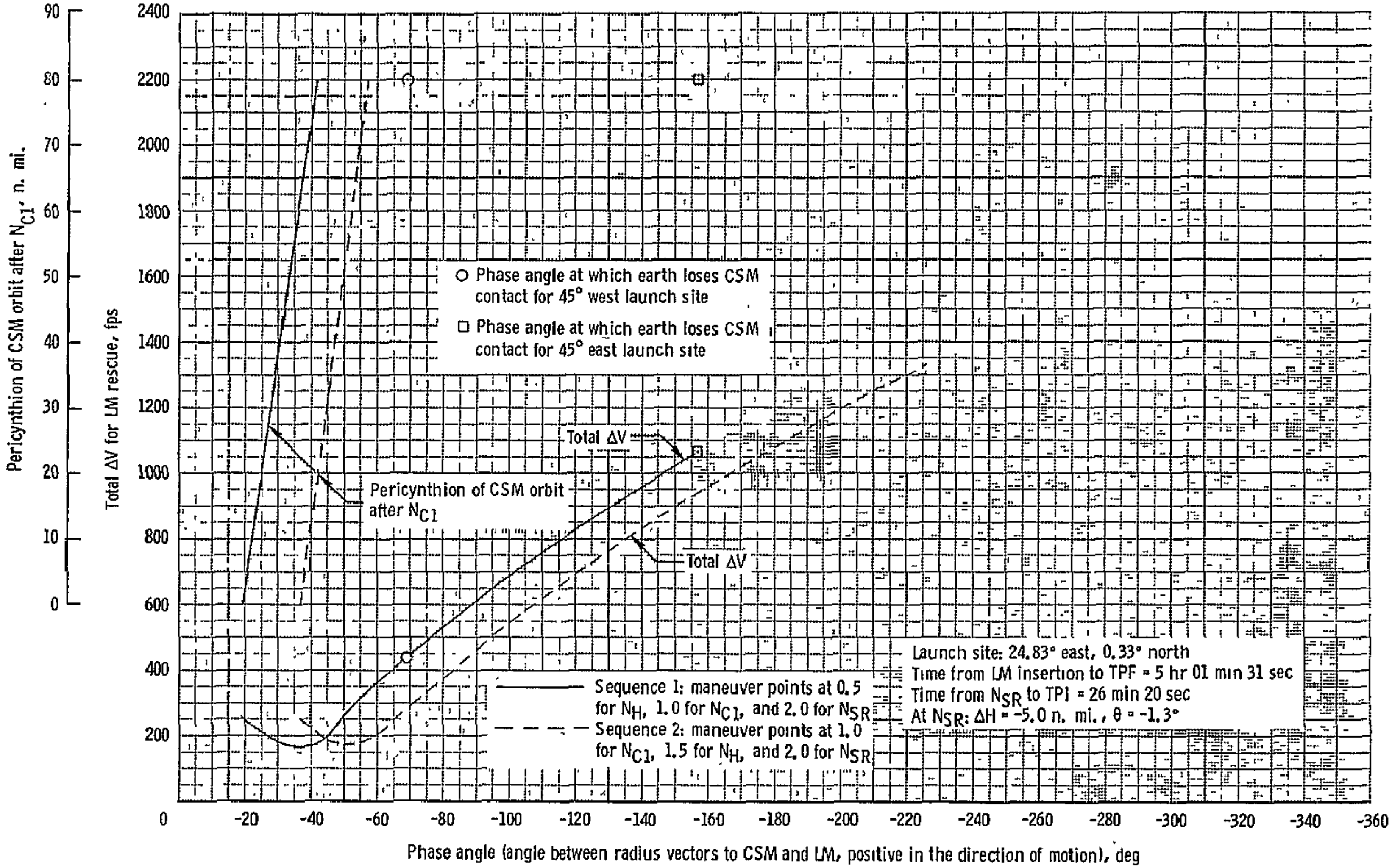
If the LM lifts off early or extremely late such that the LM is ahead of the CSM at insertion, the phase angle can be defined as a positive angle and if the CSM does the phasing maneuver as it crosses the maneuver line over the launch site, the DKI logic, using sequence 2, can effect rendezvous for counter crossings M = 6 and 7 by taking the CSM into a lower orbit.

The amount of phase angle that can be taken out, corresponding to a perigee height of 8.0 n. mi., after the phasing maneuver, and the total time to rendezvous, are 0.0° to +5° and 8 hours 45 minutes 21 seconds for M = 6 and 0.0° to +9° and 10 hours 36 minutes 55 seconds for M = 7. If the LM is delayed so long that the CSM passes the 1.0 counter before LM insertion, the maneuver points and rendezvous counter can be shifted one revolution and the above maneuver sequences can be repeated.

CONCLUSION

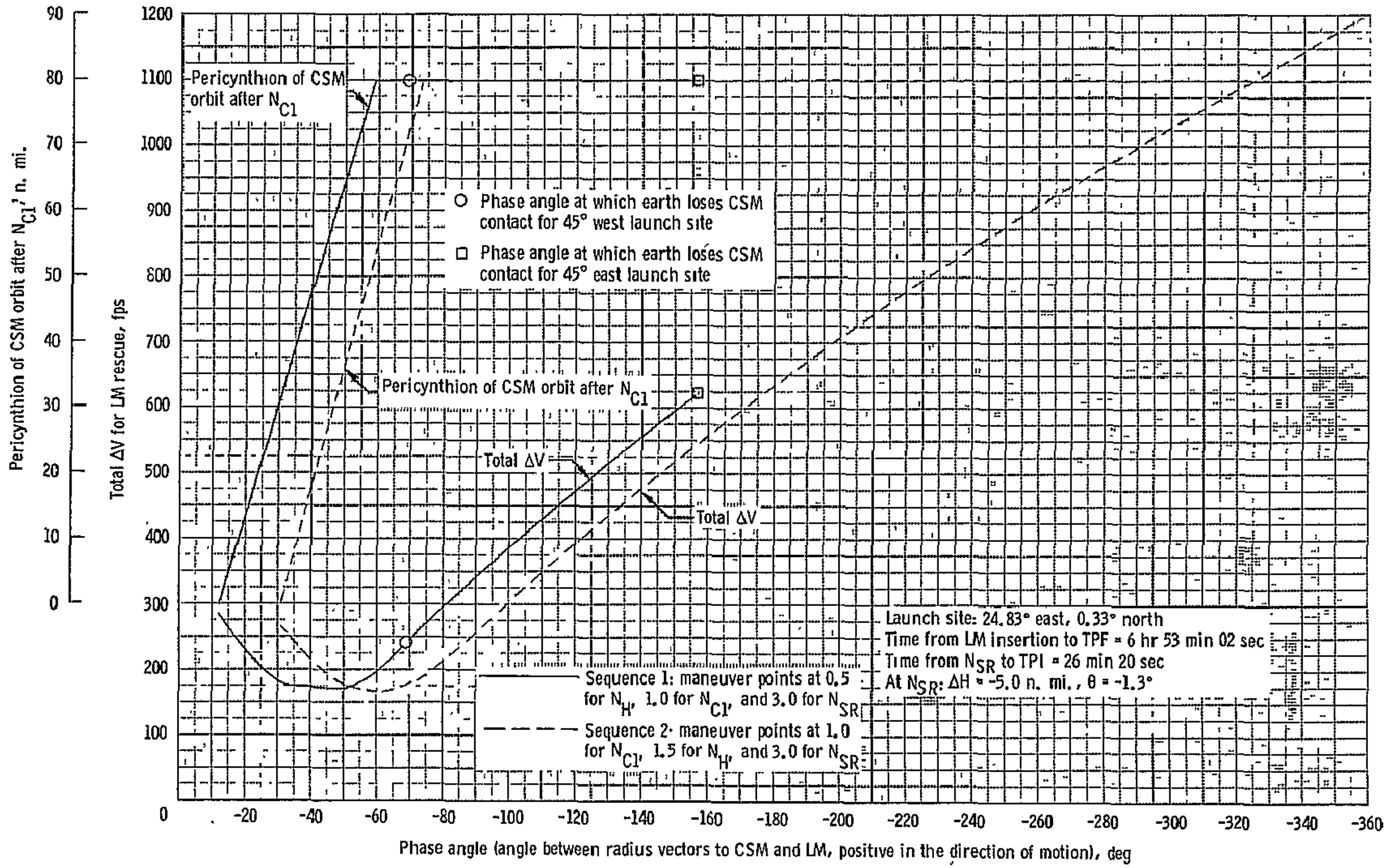
The results of using the DKI logic for LM rescue for lift-off occurring anytime show that rendezvous can be effected for all possible phase angles (0° to -360°). Maneuver sequence 1 can effect rendezvous for phase angles of -10° to -69° or -157°, depending on the location of the launch site. Maneuver sequence 2 can effect rendezvous for all phase angles from -25° to -360°. Sequence 2 can handle all cases that sequence 1 can handle except for those involving phase angles from -10° to -25°. If phase angles from -360° to -370° were permitted, phase angles 0° to -10° could be handled by maneuver sequence 2. Sequence 2 has the advantage of providing ample time to notify the CSM to perform the phasing maneuver as it crosses the launch site.

The only constraint on utilizing higher rendezvous counter crossings is the LM lifetime. If the LM lifetime is increased, the DKI logic could effect rendezvous for phase angles larger than +9° which means that the DKI logic could cover a larger time span of early LM lift-offs, where the LM inserts ahead, or in front, of the CSM.



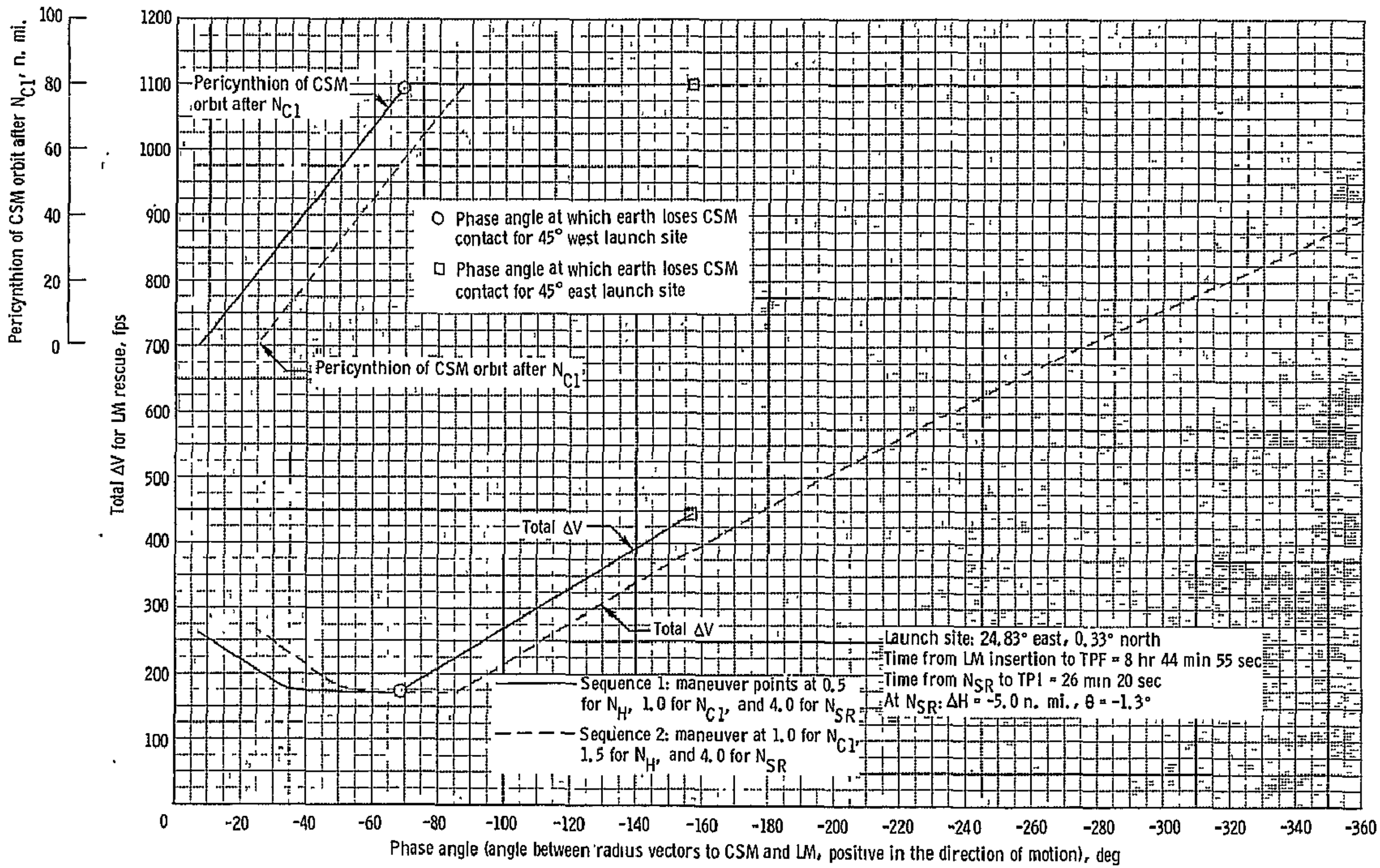
(a) Rendezvous counter, M, is 3.

Figure 1. - Total ΔV for LM rescue and pericynthion of the CSM orbit after N_{C1} as functions of phase angle (obtained with DKI logic).



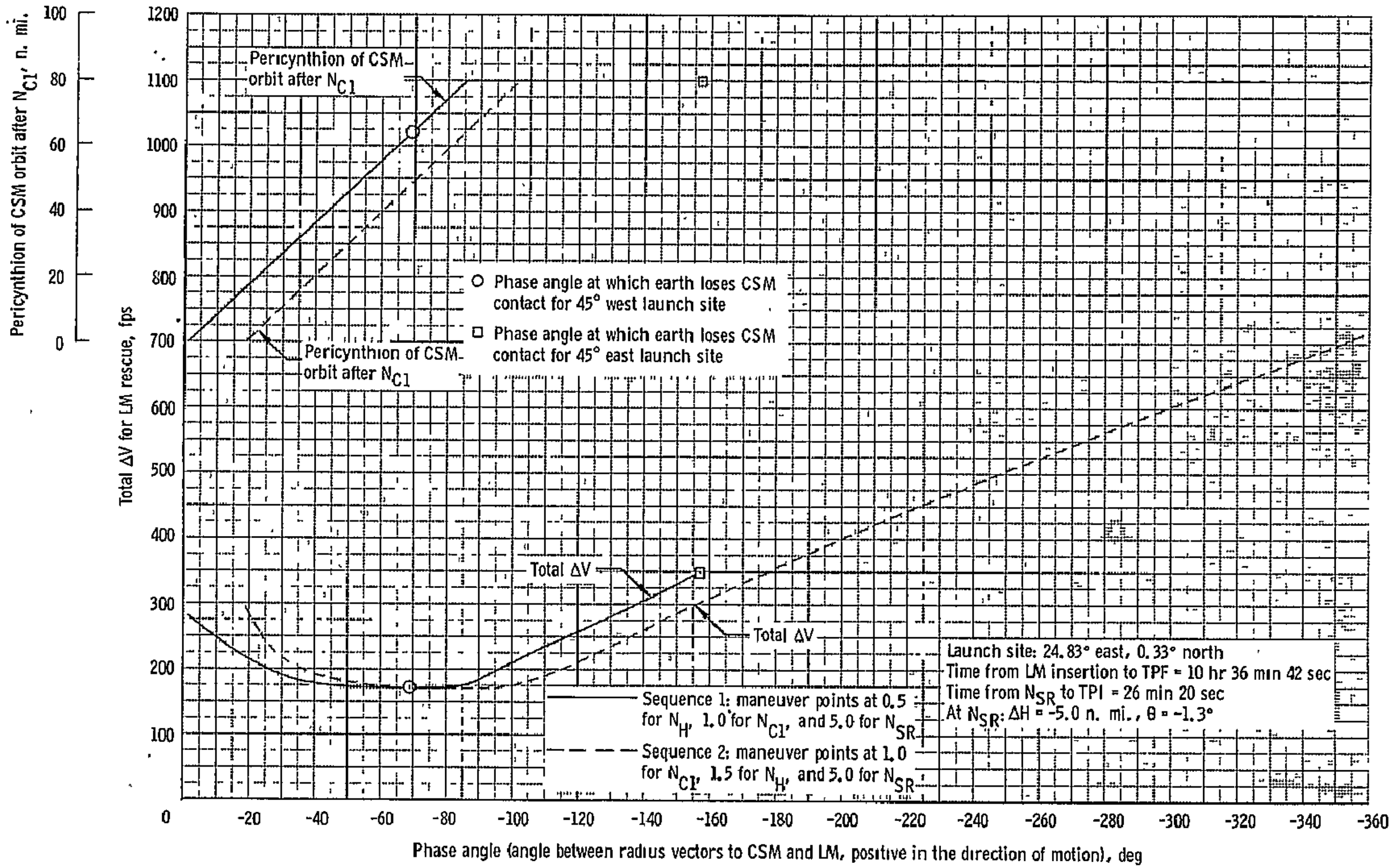
(b) Rendezvous counter, M, is 4.

Figure 1. - Continued.



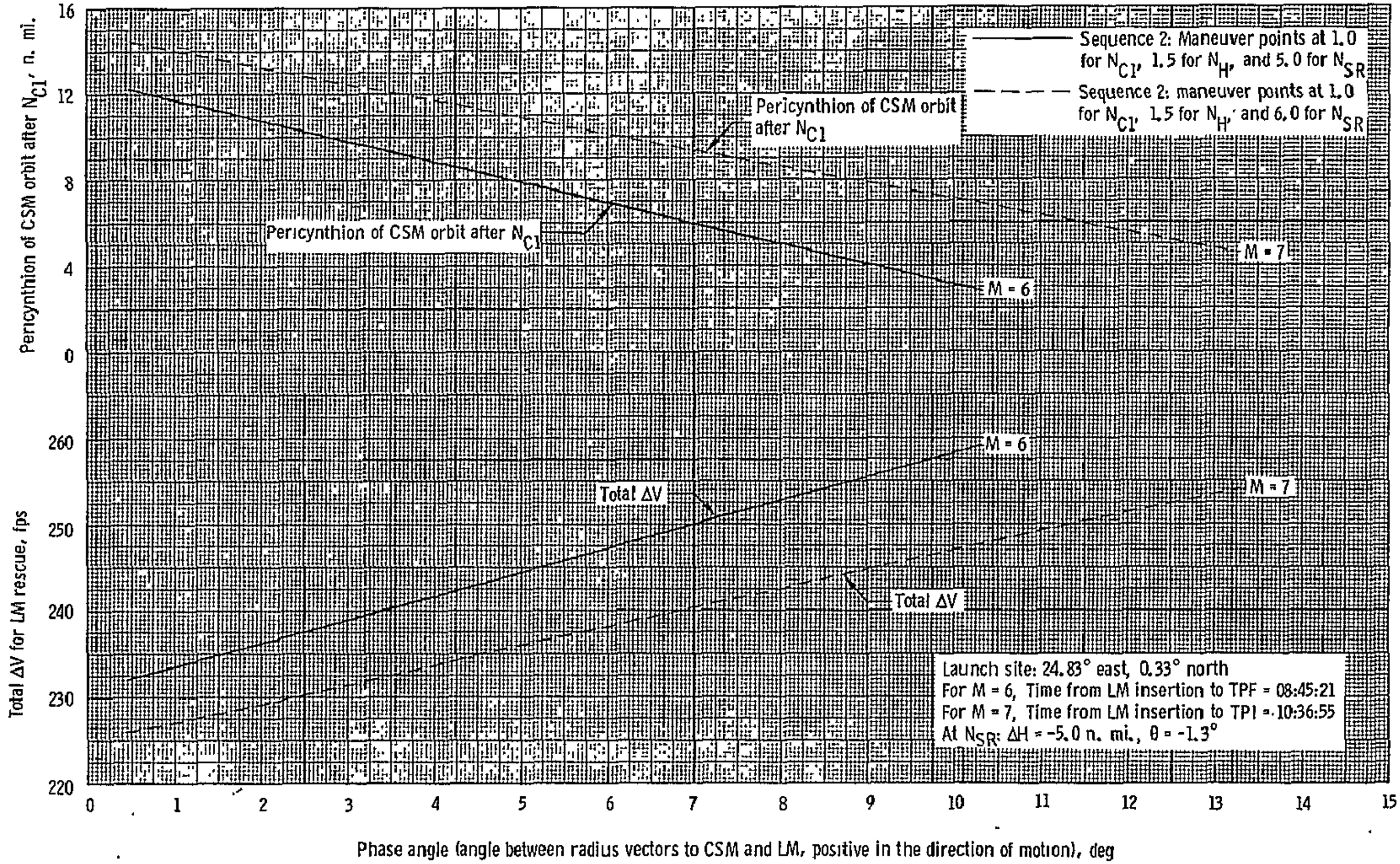
(c) Rendezvous counter, M, is 5.

Figure 1. - Continued.



(d) Rendezvous conter, M, is 6.

Figure 1. - Continued.



(e) Rendezvous counter, M, is 6 and 7.

Figure 1. - Concluded.

REFERENCE

1. Regelbrugge, Robert R.: Logic for Real Time Computation of the Docking Initiation Table Display. MSC Internal Note No. 64-FM-59, November 25, 1964.