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PROJECT APOLLO

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SUMMARY AND INTRODUCTION

Since the publication of reference 1, there has been a change in the lunar parking orbit of the CSM from an 80- to a 60-n. mi. circular orbit. This change necessitated a re-examination of the LM abort and CSM rescue techniques for the Hohmann Descent phase of the first lunar landing mission. It will be seen that while a LM abort can be performed at any time up to 90 minutes following DOI, areas exist in which it is not desirable to do so.

The preliminary data contained in this internal note will illustrate the present thinking for rescue and abort techniques for the Hohmann descent phase of the lunar mission. Aborts and rescues during the powered descent phase will be documented at a later date. Except for total loss of propulsion capability by the LM, there was no attempt to identify the failure source which caused the mission to be aborted. Likewise, a dispersion analysis was not considered at this time.

As used in this report, a LM abort implies that the LM is capable of terminating the mission and returning to the CSM without assistance from the CSM. A CSM rescue implies that the LM is completely passive after performing the DOI burn, requiring the CSM to perform all the rendezvous maneuvers. A CSM assist implies that the LM is able to perform one or more, but not all, of the rendezvous maneuvers.

SYMBOLS

DOI	descent orbit initiation
CSI	coelliptic sequence initiation
CDH	constant differential height maneuver
LM	lunar module

CSM	command and service modules
TPI	terminal phase initiation
LOI	lunar orbit insertion
PDI	powered descent initiation
Δh	coelliptic differential altitude

HOHMANN DESCENT PHASE

At the present time, the LM is scheduled to perform the DOI maneuver (approximately 71 fps, horizontal and retrograde) about 22 hours following LOI. This maneuver changes the LM orbit from a 60-n.mi. circular orbit (i.e., that of the CSM) to a 60-n. mi. by 50 000-ft descent orbit. The DOI maneuver is performed at a longitude 195° prior to the landing site, thus pericynthion is 15° east of the landing site.

The phasing relationship between the CSM and the LM is shown in figure 1. As can be seen, the CSM pulls ahead of the LM and stays ahead for about 25 minutes, after which the LM starts going ahead. For a landing site at 42° W longitude, DOI occurs approximately 14 minutes prior to MSFN contact; for a landing site at 34° E longitude, DOI occurs about 40 minutes prior to MSFN contact.

Nominally, about 57 minutes after DOI (approximately at pericynthion) the LM initiates powered descent. However, for this report, it was assumed the LM cannot perform the PDI.

LM ABORT FROM HOHMANN DESCENT

Generally, the technique for a LM abort from Hohmann descent is the CSI/CDH maneuver sequence, in which the CSI maneuver is the abort maneuver. The CSI maneuver is targeted to achieve a 26.6° elevation angle at TPI; this targeting allows for a line-of-sight burn if the LM is 15 n. mi. below the CSM. The CDH maneuver occurs behind the moon about one revolution following DOI. (The particular apsis number to be used is a function of the position of the CSI maneuver point in the descent orbit.) The TPI is positioned to occur about 20 minutes prior to darkness; for a 10° sun elevation angle at touchdown, TPI will occur approximately 30° east of the landing site either 1.5 or 2.5 revolutions following DOI. The TPI time is used to control the Δh to be within 10 to 20 n. mi., which is considered to be an acceptable range at the present time.

Figure 2 illustrates the LM-active technique for aborts during the Hohmann descent. It can be seen that an abort is feasible from 10 minutes to at least 90 minutes following DOI using the CSI/CDH sequence although it is doubtful that an abort as late as 90 minutes after DOI ever need be considered. The latest time at which an abort situation would be realized should be the time of PDI, in which case the LM would not initiate powered descent and would prepare for an abort without prior aid from the ground. About the only activity that appears to be required is going into the prethrust program and then executing the abort maneuver; since no maneuver was performed at PDI, no tracking is required. It is not known why the abort could not be initiated within about 15 minutes after the nominal PDI time. However, an abort should not occur after approximately 18 to 20 minutes after the nominal time of PDI (75 to 77 minutes from DOI) because of rescue considerations, which are discussed later.

Figure 2 also indicates that the coelliptic sequence is not suitable for aborts earlier than 10 minutes following DOI because of the low Δh's that occur. At the 10-minute point, the slant range between the vehicles is 6.5 to 7 n. mi., and the vehicles are separating at about 65 fps (fig. 3). This situation gives rise to two alternatives - either delay the abort until at least 10 minutes after DOI and use the coelliptic sequence or attempt to use manual control and fly the LM back to the CSM. It is likely that a lighting problem may exist with this technique.

Figure 4 illustrates a simulated manual rendezvous using range-rate and line-of-sight control; the data were generated from a limited and simplified study. It should be mentioned that the limits were assumed to be functions of one another and arbitrary. The conditions were such that if the range rate was outside either the upper or lower boundary (shown on the figure), thrusting occurred until a range rate between the two boundaries was achieved. However, it is obvious that since at abort initiation the two vehicles are separating, thrusting should continue until closure is obtained. It is seen from the figure that the longer the delay in abort initiation, the more propellant and time a manual rendezvous will require. Therefore, if an abort situation occurs almost immediately after the DOI maneuver, the astronauts could reorient the LM and immediately initiate manual control; otherwise, it would be best to wait at least 10 minutes to initiate the coelliptic sequence.

A possible situation that might arise is that the LM may attempt to abort but cannot burn the DPS. This brings up the question whether to stage the DPS (thereby jettisoning the DPS consumables) and attempt the abort with the APS or save the descent stage consumables and set up a CSM rescue at least to TPI where the LM could then stage the DPS and, if able, perform TPI and braking from below. A ground rule should be made with regard to this situation.

CSM RESCUE DURING HOHMANN DESCENT

As seen from figure 1, after about 25 minutes from DOI, the CSM begins trailing the LM and at PDI is about 7° behind. In order to rendezvous, the CSM must catchup. However, it cannot rendezvous from below because of the low LM pericynthion of 50 000 ft, and thus the CSI/CDH sequence cannot be used. The procedure recommended for CSM rescue during the Hohmann descent phase is the six-impulse sequence (ref. 2); the CSM maneuvers to a 20-n. mi. circular orbit, the CSI maneuver is performed over the longitude of LM pericynthion, CDH occurs one revolution later, and TPI occurs approximately 345° from CDH. This sequence results in a Δh of about 12 n. mi. and the CSM rendezvous from above. The CSI maneuver occurs either 1.5 or 2.5 revolutions from DOI, depending on when the rescue is initiated. (This is based on not allowing the CSI maneuver to be retrograde.)

The first two maneuvers, a Hohmann transfer and a circularization maneuver, are computed and sent from the ground on the last pass prior to DOI. The CSI and CDH maneuvers could then either be computed by the LM or the ground for the CSM. The six-impulse procedure is standard throughout the Hohmann descent; TPI time and CSI time are the only variables and they would only vary by one revolution.

Using the six-impulse sequence, the crew transfer time is within about 8 to 10 hours after DOI, which corresponds to TPI being between 6.6 and 8.5 hours from DOI. At present, it is assumed that 8 to 10 hours is within the lifetime of the LM ascent stage. However, if the descent stage is attached, the crew transfer time is well within the available lifetime. This should be considered in making the decision whether to stage the DPS for a LM abort in event of a DPS failure.

Figure 5 illustrates the six-impulse technique, and figure 6 illustrates the capability of the technique. It should be noted that the theoretical total ΔV is constant, independent of when the initial Hohmann maneuver occurs. For aborts up to about 32 minutes from DOI, the CSI maneuver occurs about 2.8 hours from DOI and TPI, 6.6 hours from DOI. For aborts between 32 and about 77 minutes, CSI occurs 4.7 hours from DOI and TPI 8.5 hours from DOI.

CSM ASSIST DURING HOHMANN DESCENT

The maneuvers involved in a CSM assist can be divided into planned and unplanned maneuvers. An example of the planned CSM maneuvers if the setting up of the proper conditions at TPI and then allowing the LM to execute the terminal phase maneuvers. This would save both LM and

CSM RCS propellant. A good representation of an assist has been mentioned previously - whether to stage the DPS if it could not be fired. If the decision were not to stage at that time, then the CSM could initiate the six-impulse sequence and perform maneuvers through the CDH maneuver. After the CDH maneuver is completed, the LM could then stage and prepare to do the terminal phase maneuvers. If the LM is still unable to maneuver, nothing is lost; however, if it can maneuver, a savings in CSM propellant would result in addition to being able to rendezvous from below.

Unplanned CSM maneuvers would be required if a LM failure occurred at scheduled maneuver points other than the initial maneuver. (It was previously stated that if the LM cannot perform the initial maneuver, the CSM activity is classified as a rescue and not as an assist.) Therefore, there are two places in the Hohmann descent phase that an unplanned CSM maneuver could occur (excluding a failure after TPI) - after either the CSI or the CDH maneuvers. If a failure occurs after the LM performed CDH, the CSM could initiate the terminal phase maneuver at the same time the LM would have. However, if the failure occurs following the CSI maneuver, difficulties arise. The remainder of this section is devoted to a discussion of this situation.

Figure 7 illustrates the orbital geometry at the time of CDH resulting from LM execution of the CSI maneuver. Although the apocynthion altitude (e.g., the altitude at CDH) varies between about 68 and 80 n. mi., the pericynthion altitude may be as high as 41 n. mi. or as low as 8.23 n. mi. (50 000 ft), depending on when the LM abort occurred. For all abort times, the CSM lags the LM at CDH - between about 3.5° and 12.8°. Also, the time of CDH can vary about 25 minutes, again depending on when the abort occurred.

In the analysis of this situation it was assumed there was no knowledge of a LM propulsion problem until the LM attempted CDH. It is also assumed that the CSM would require at least 1 minute after the CDH time to prepare to execute the required maneuvers.

Three different rendezvous techniques were investigated. Although other techniques will be investigated, these techniques were selected on the basis of operational simplicity, uniformity (that is, keeping the technique as similar as possible to those required for the other phases of the mission), ΔV requirements, and time. The three techniques require the CSM to perform one of the three following sequences.

1. Coelliptic maneuver plus terminal phase.

2. CSI/CDH sequence (two maneuvers) plus terminal phase.

3. Six impulse sequence (four maneuvers) plus terminal phase.

It will be shown that for LM abort times between 23 and 40 minutes following DOI, unfavorable rendezvous trajectories caused by Δh and pericynthion altitude result. Hence, it is recommended that an abort not be made during this time except for a catastrophic type failure. If such a procedure were adopted, the technique employed for an assist would be fairly simple. For LM aborts during the first 23 minutes following DOI, the CSM could execute a coelliptic maneuver immediately after the nominal LM CDH time. For abort times between 40 and 75 minutes, the CSM could employ the six-impulse technique, initiating the first maneuver immediately after the nominal LM CDH time.

CSM Performs A Coëlliptic Maneuver

This technique is the simplest to execute and requires the least amount of propellant and time to rendezvous. It also achieves a Δh close to that which the LM would have achieved had it been able to execute the CDH maneuver. Since the CSM cannot compute the coelliptic maneuver, this maneuver would have to come from either the ground or the LM. (The maneuver could also be the reverse of the LM CDH maneuver, but this would not result in the orbits being coelliptic. Therefore, this study only considered ground- or LM-computed maneuvers resulting in coelliptic orbits.) Since it was assumed that (1) the LM was not aware of a problem until it reached CDH, and (2) the CSM initiated the CDH maneuver 1 minute after the nominal LM maneuver time, the LM could not have had time to compute the CDH maneuver for the CSM. Therefore, the maneuver would have to be computed by the ground. It should be noted that, regardless of the location of the landing site, the CSM will always have some contact with the MSFN after the CSI maneuver and prior to CDH. Therefore, it is assumed that MSFN would compute this maneuver for the CSM - whether or not it is required.

Problems do exist with this technique. Because the LM is above the CSM at CDH and the desired Δh is between 10 and 20 n. mi., the CSM pericynthion after the CDH maneuver will be about 10 to 20 n. mi. below the LM pericynthion. (See fig. 7.) For an early abort, the LM pericynthion is high enough that the CSM will maintain a safe pericynthion after CDH; however, for later aborts, the LM pericynthion decreases, requiring an unsafe CSM orbit.

The capability of this technique is shown in figure 8. It can be seen that for aborts later than approximately 23 minutes after DOI, the resultant CSM pericynthion is below 10 n. mi.

CSM Performs A CSI/CDH Sequence

This technique produces uncertainties in the Δh at CDH because of its inability to control the differential altitude; therefore, obtaining a safe CSM orbit is also uncertain. Two particular situations were considered: in the first case, the CSM initiates a CSI maneuver 1 minute after the LM CDH time and TPI occurs about 4.8 hours following DOI; the second case delays both CSI and TPI one revolution. In both cases CDH is performed 180° from DOI.

The source of the maneuvers should be considered here also, since the CSM cannot compute them. For the first case, the ground will provide the maneuvers for the reasons mentioned in the preceding section; however, for the second case where CSI is delayed one revolution, the LM, being aware of this situation, could then have time to compute the maneuvers for the CSM. The CSM will then have made a full pass in view of MSFN and can alert the ground to the situation. Therefore, for the second case, the CSM should then have two maneuver sources available.

Figure 9 illustrates the capability of the CSI/CDH sequence to rendezvous from this situation. Figure 9(a) shows the result of an immediate rendezvous initiation, and figure 9(b) shows the result of a delayed rendezvous initiation. It can be seen from figure 9(a) that the Δh's obtained from a safe pericynthion region are no greater than 6 n. mi., and figure 9(b) illustrates that the Δh could be between 6 and 12 n. mi. for the areas of safe pericynthion. It is also seen from figure 9(b) that safe pericynthion and an acceptable Δh are no longer obtained for aborts beyond 25 minutes from DOI.

CSM Performs The Six-Impulse Sequence

Although the six-impulse sequence requires the longest time to rendezvous and is unable to control the Δh for the entire abort region, it does provide an acceptable rendezvous profile for aborts near pericynthion of the LM descent orbit and guarantees a safe CSM orbit. This technique is identical to that described for CSM rescue. It is assumed that the initial maneuver occurs 1 minute beyond the nominal LM CDH time, and CSI occurs over the longitude of LM pericynthion. Figure 10 illustrates the capability of this technique. Note that the Δh varies from about 20 n. mi. below the LM orbit to about 12 n. mi. above the LM orbit. This variation occurs because the CSM is in a 20-n. mi. circular orbit, and the LM pericynthion altitude varies from 41 n. mi. to 50 000 ft. Other altitudes could have been chosen according to the LM pericynthion altitude; however, the ground would have to determine the proper maneuver. By using a 20-n. mi. circular orbit, the procedure is identical to that for a CSM rescue.

It should be noted that:

(a) The ΔV required to rendezvous from below with this technique is much greater than with the other techniques.

(b) For LM aborts between 40 and 70 minutes from DOI, the Δh and ΔV are about constant at 12 n. mi. from above and 228 fps, respectively.

(c) The Δh is not acceptable (less than 10 n. mi.) for LM aborts between 18 and 40 minutes following DOI.

CONCLUDING REMARKS

It has been shown that the LM can abort at any time during the descent and successfully accomplish the rendezvous. Also, the CSM can initiate a rescue any time during the descent (up to about 75 minutes) and successfully accomplish a rescue. However, if the LM were to abort and not be able to complete the rendezvous, problems could result. Thus, it is felt that the LM should not abort at any time during the descent, but only at times which allow a CSM assist if required.

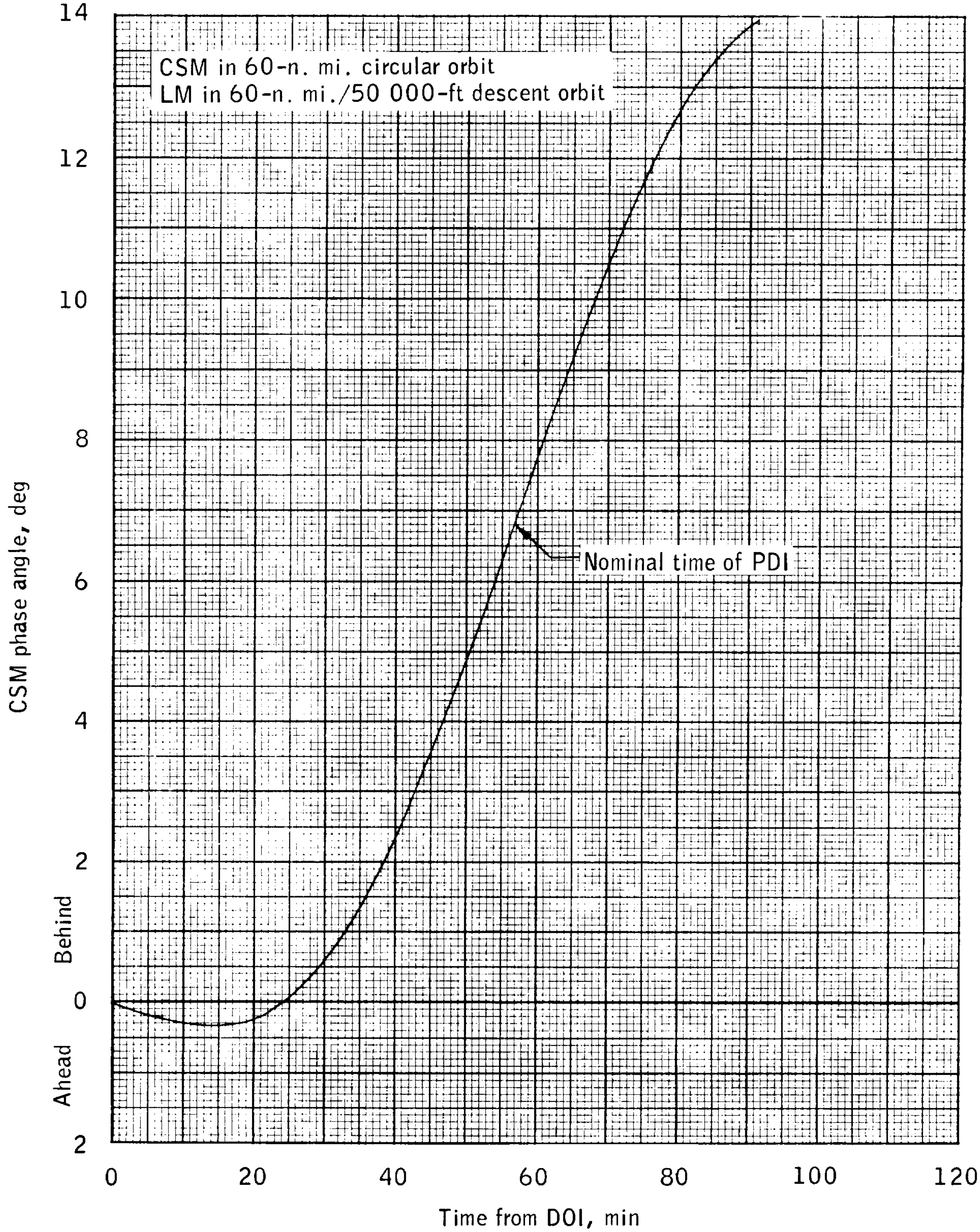


Figure 1.- Phase angle profile following descent orbit initiation.

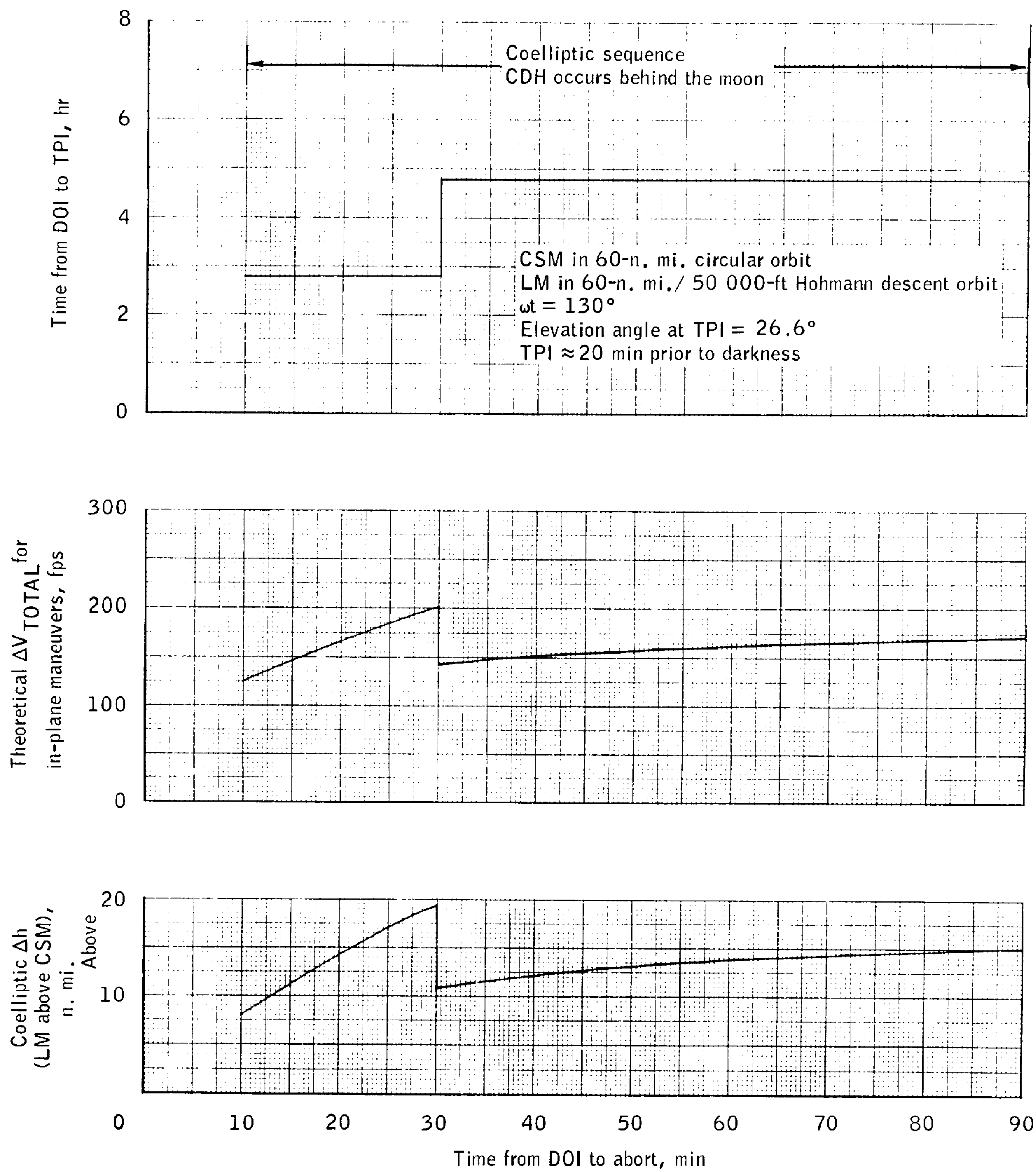


Figure 2.- LM active rendezvous techinque for aborts from Hohmann descent.

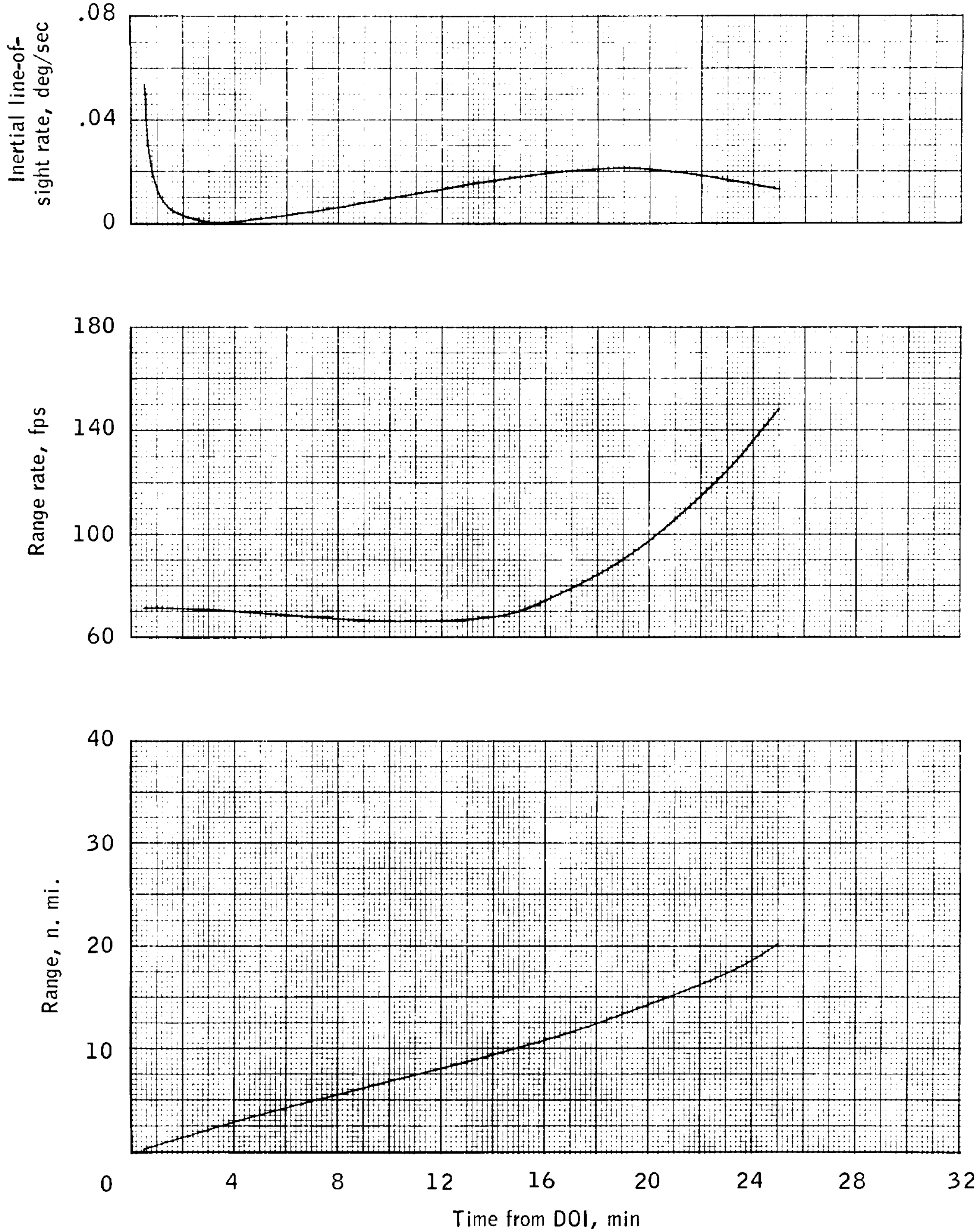


Figure 3.- Braking parameters following descent orbit initiation.

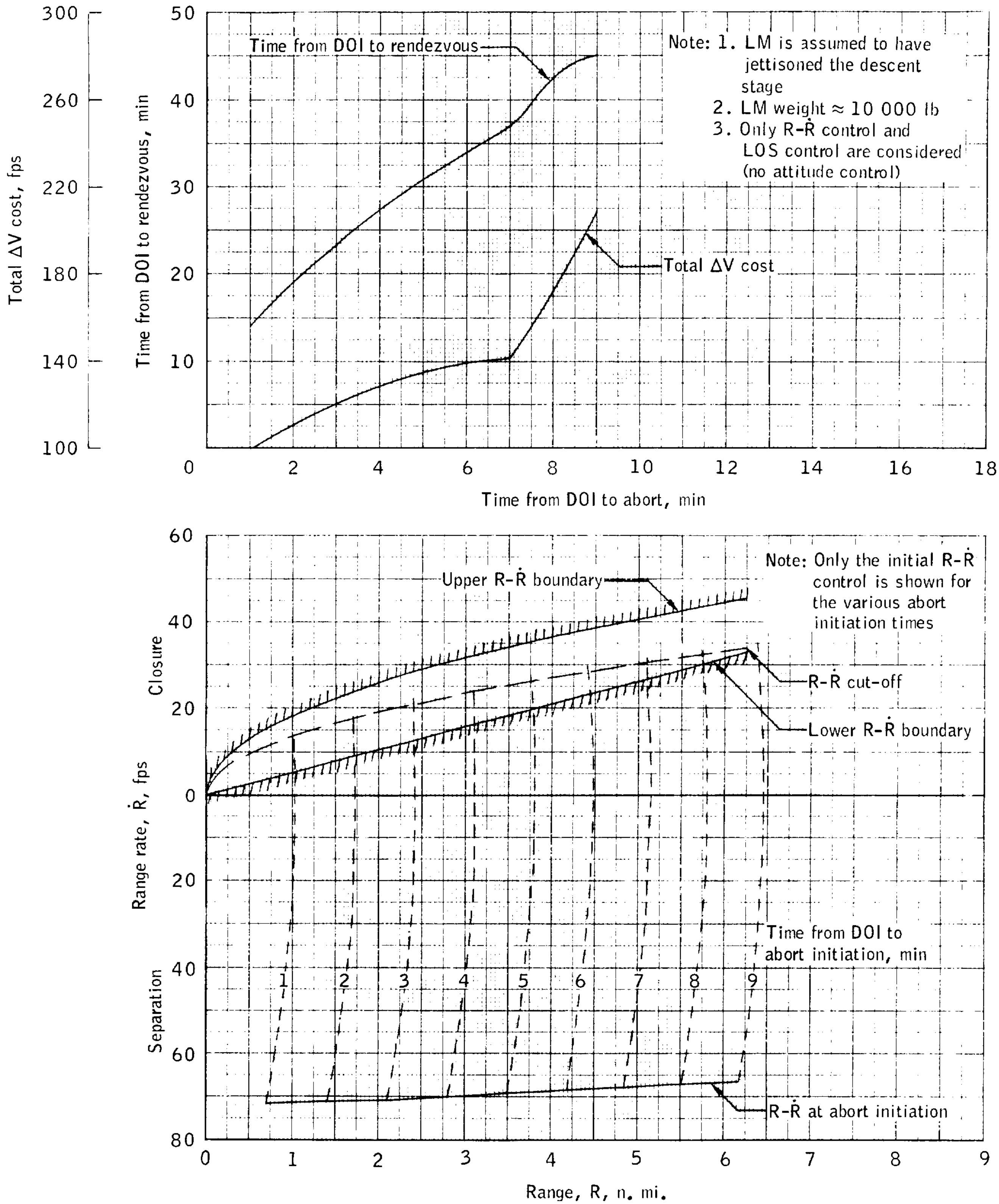


Figure 4.- Typical LM-active rendezvous capabilities utilizing simulated manual control following a LM abort from Hohmann descent up to 9 minutes after DOI.

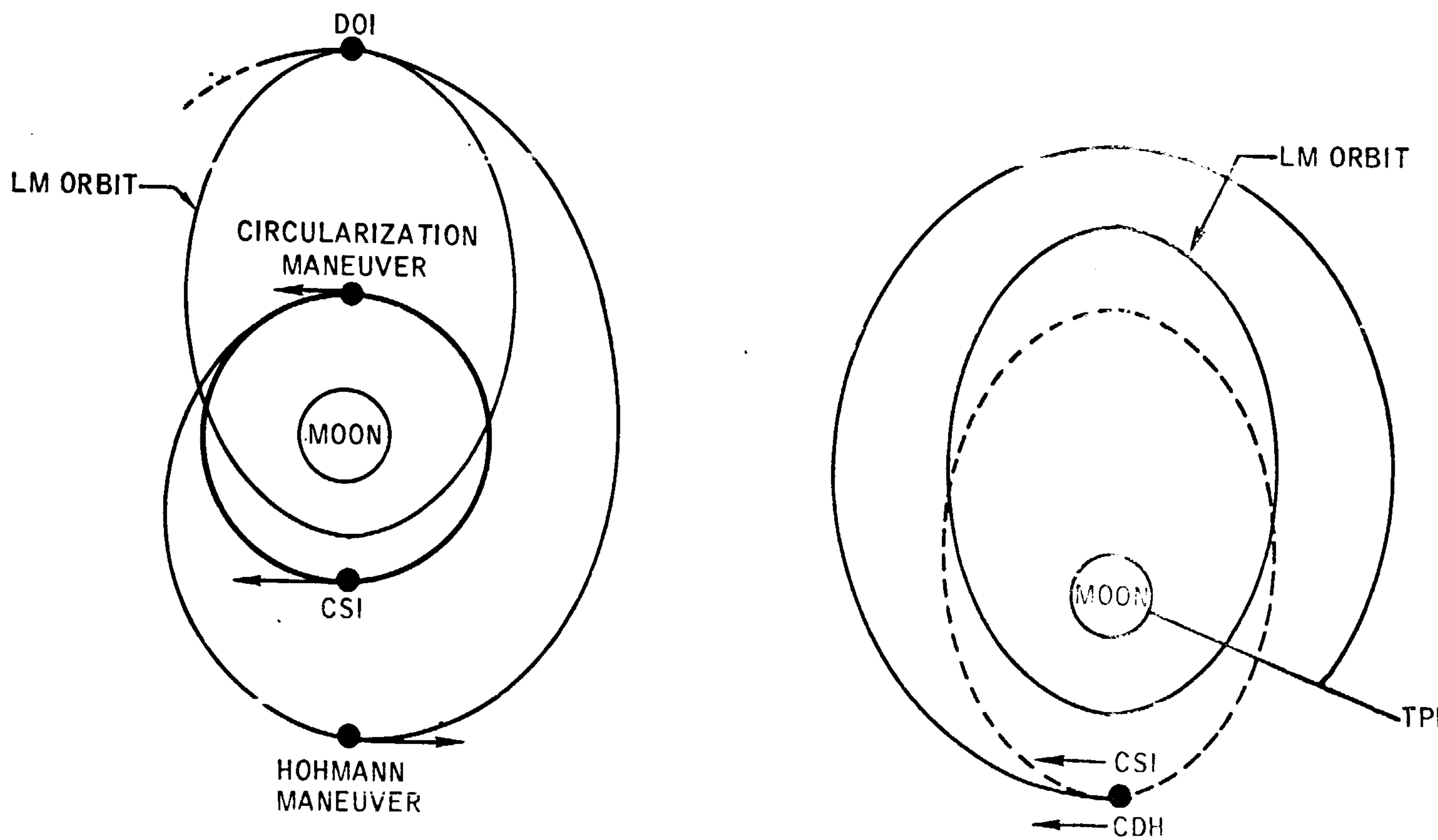


Figure 5.- CSM rescue during Hohmann descent using six-impulse technique.

Reference: MPAD 3377V

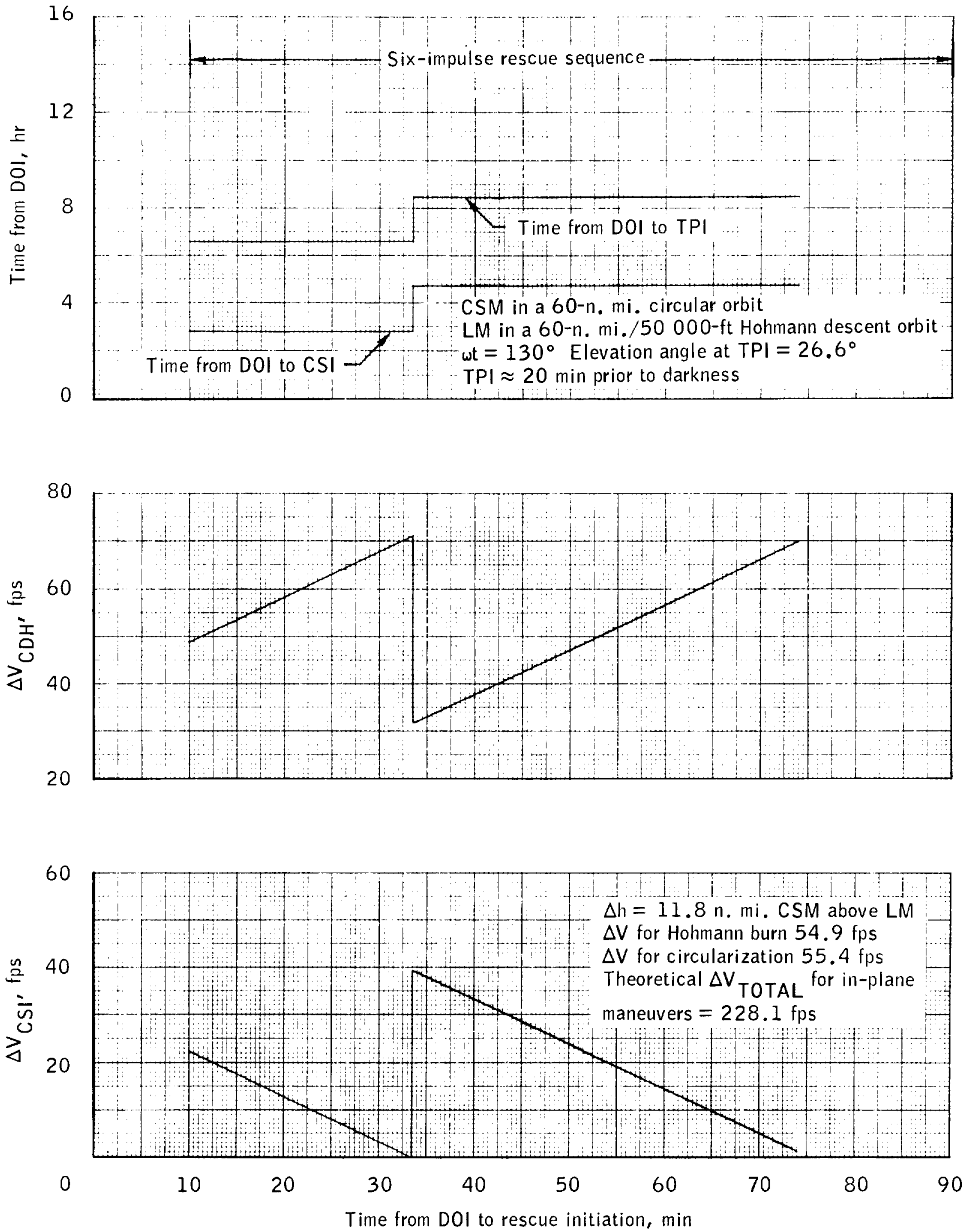


Figure 6.- CSM-active rendezvous technique for rescue during Hohmann descent.

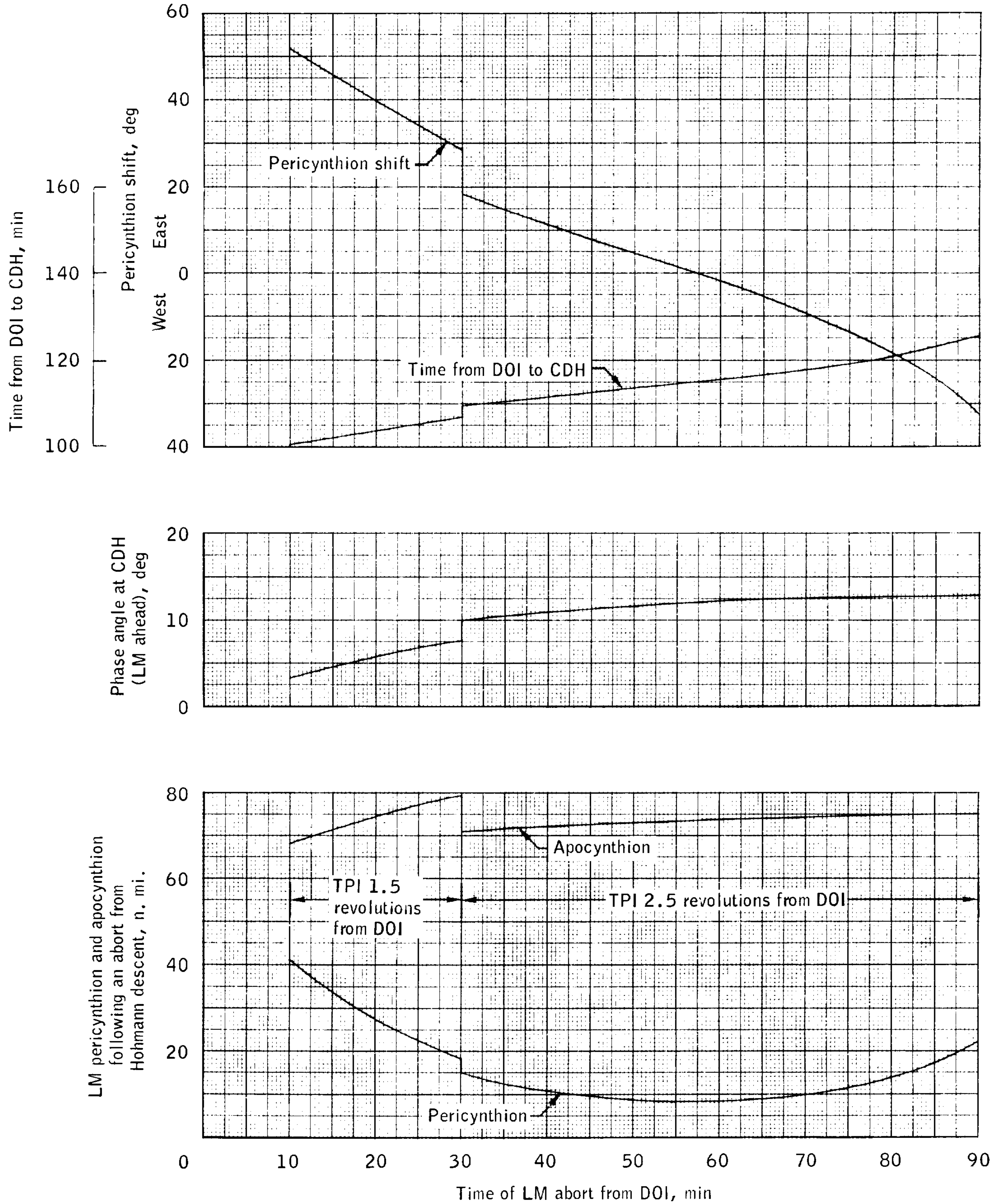


Figure 7.- Effect of the LM CSI maneuver on the LM orbit prior to the CDH maneuver.

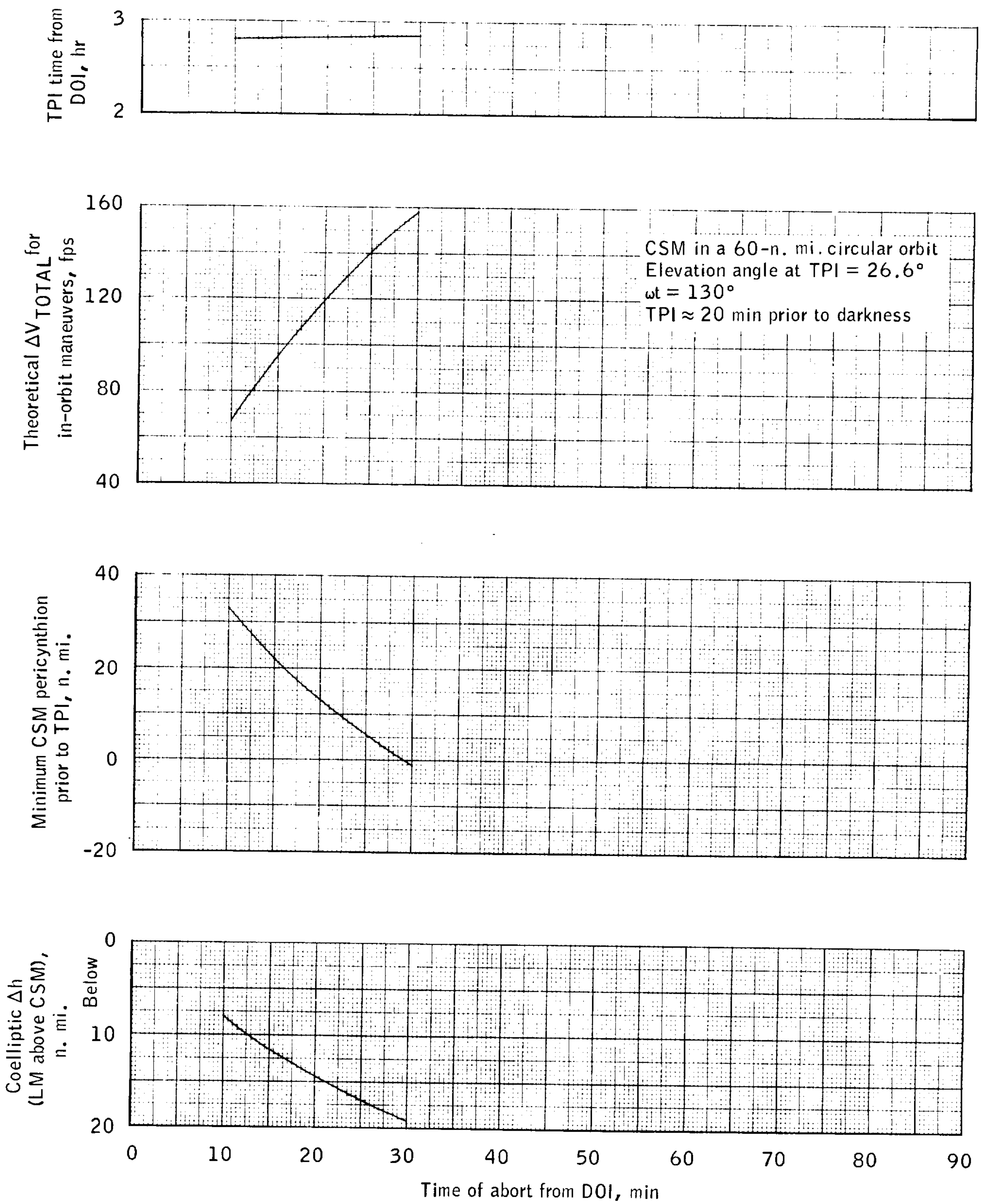
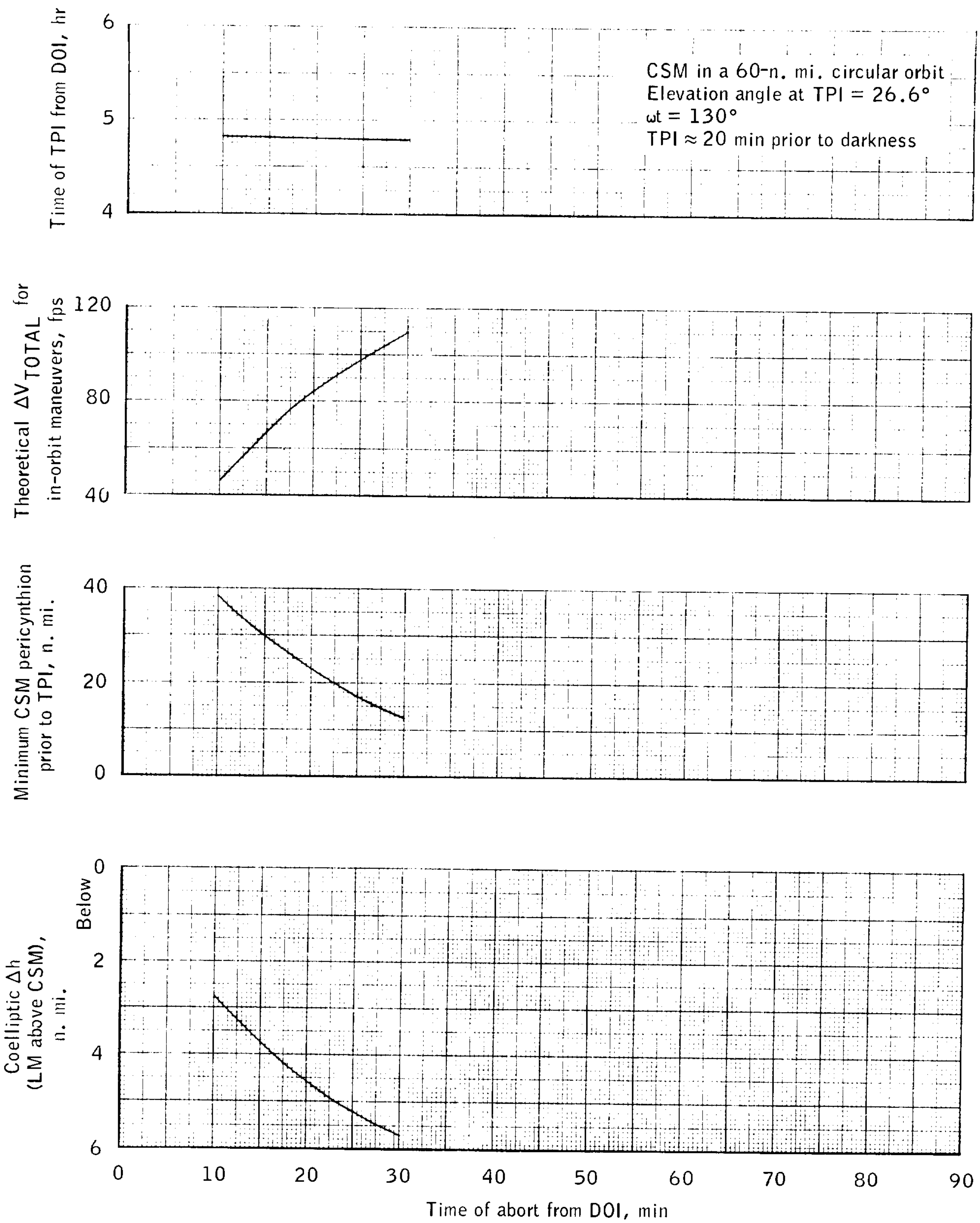
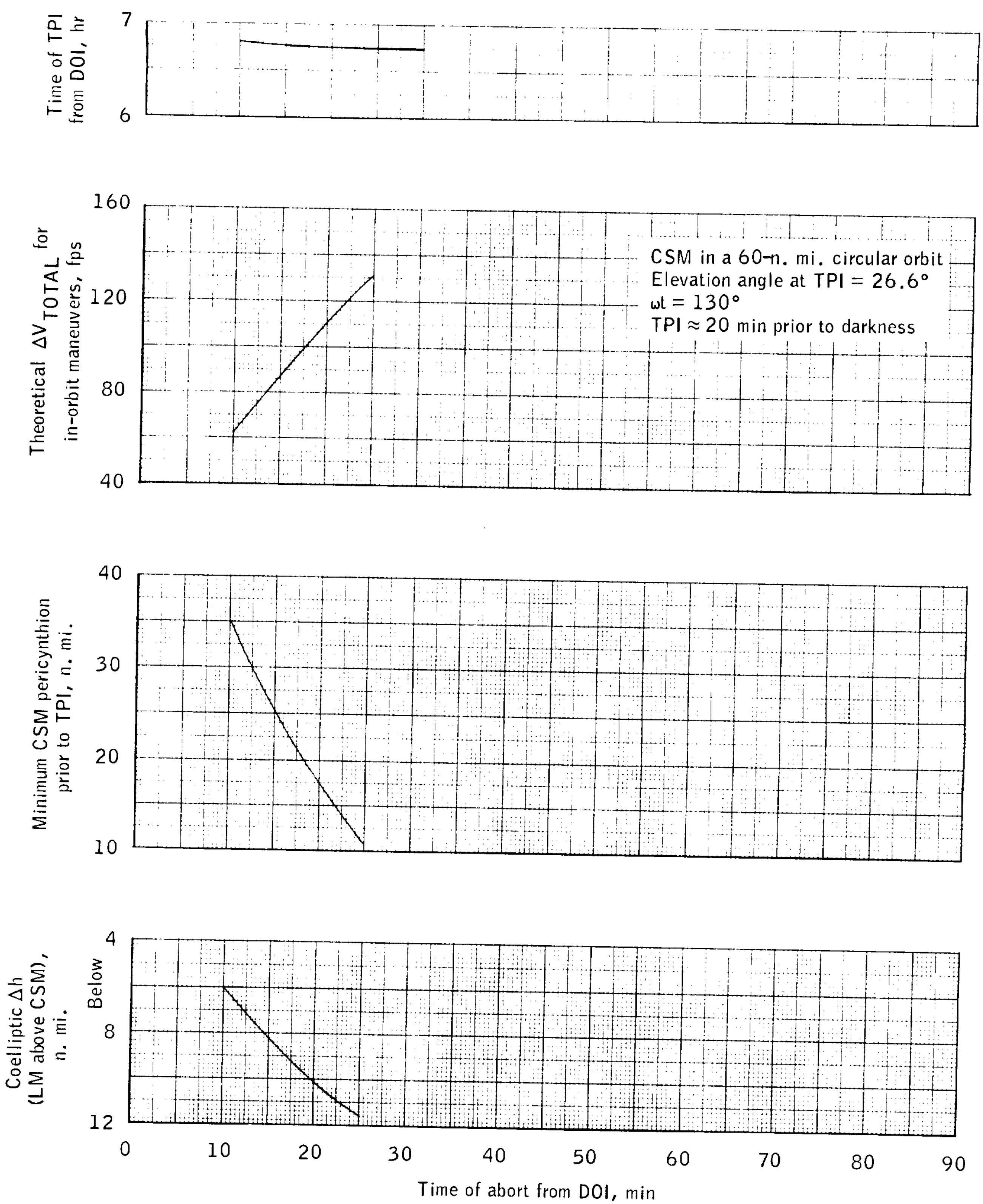


Figure 8.- Coelliptic maneuver capability for a CSM retrieval of the LM after a LM abort from the Hohmann descent orbit.



(a) CSI initiated 1 minute after nominal LM CDH time.

Figure 9.- CSI/CDH capability for a CSM retrieval of the LM after a LM abort from the Hohmann descent orbit.



(b) CSI initiated 1 revolution after nominal LM CDH time.

Figure 9.- Concluded.

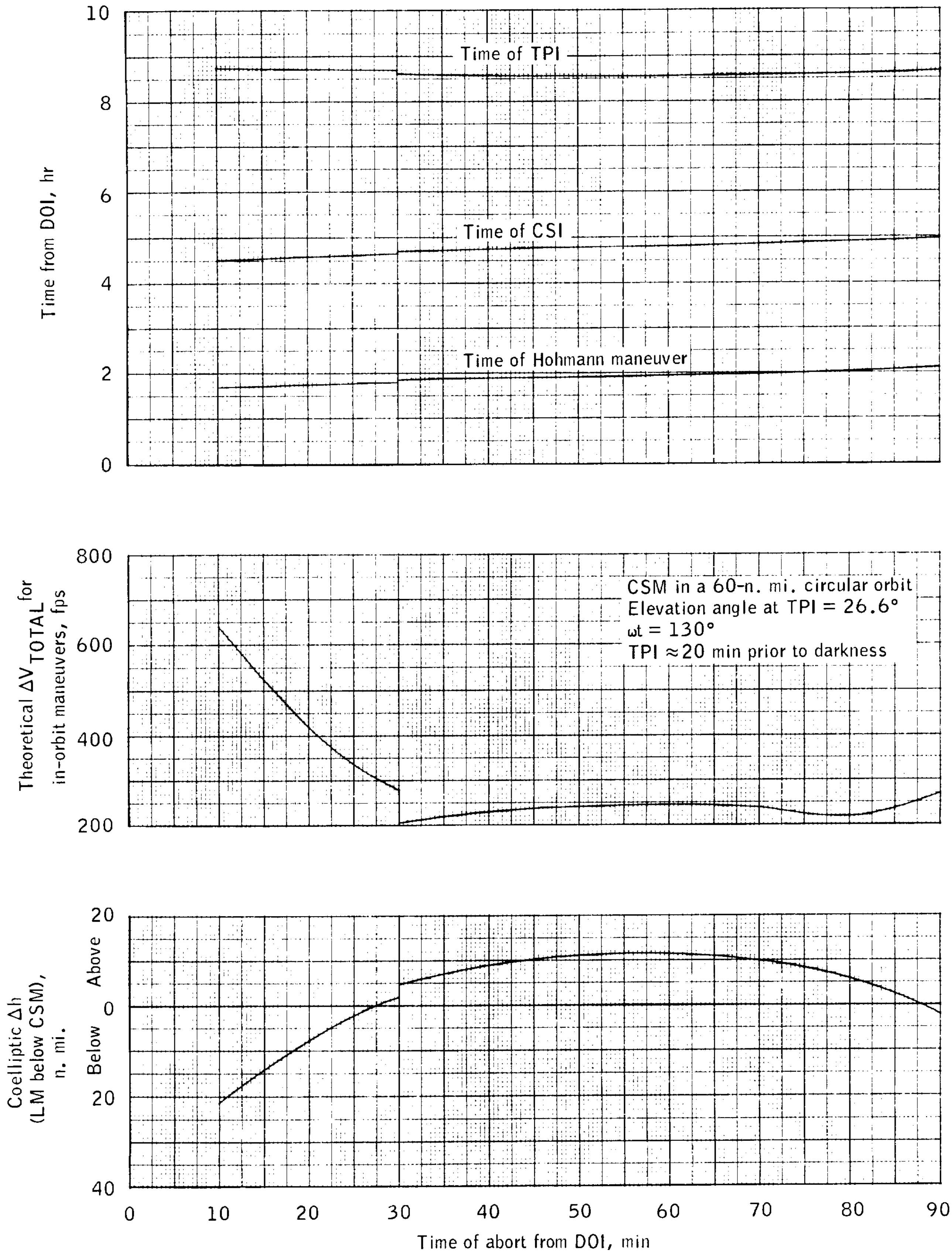


Figure 10.- Six-impulse capability for a CSM retrieval of the LM after a LM abort from the Hohmann descent orbit.

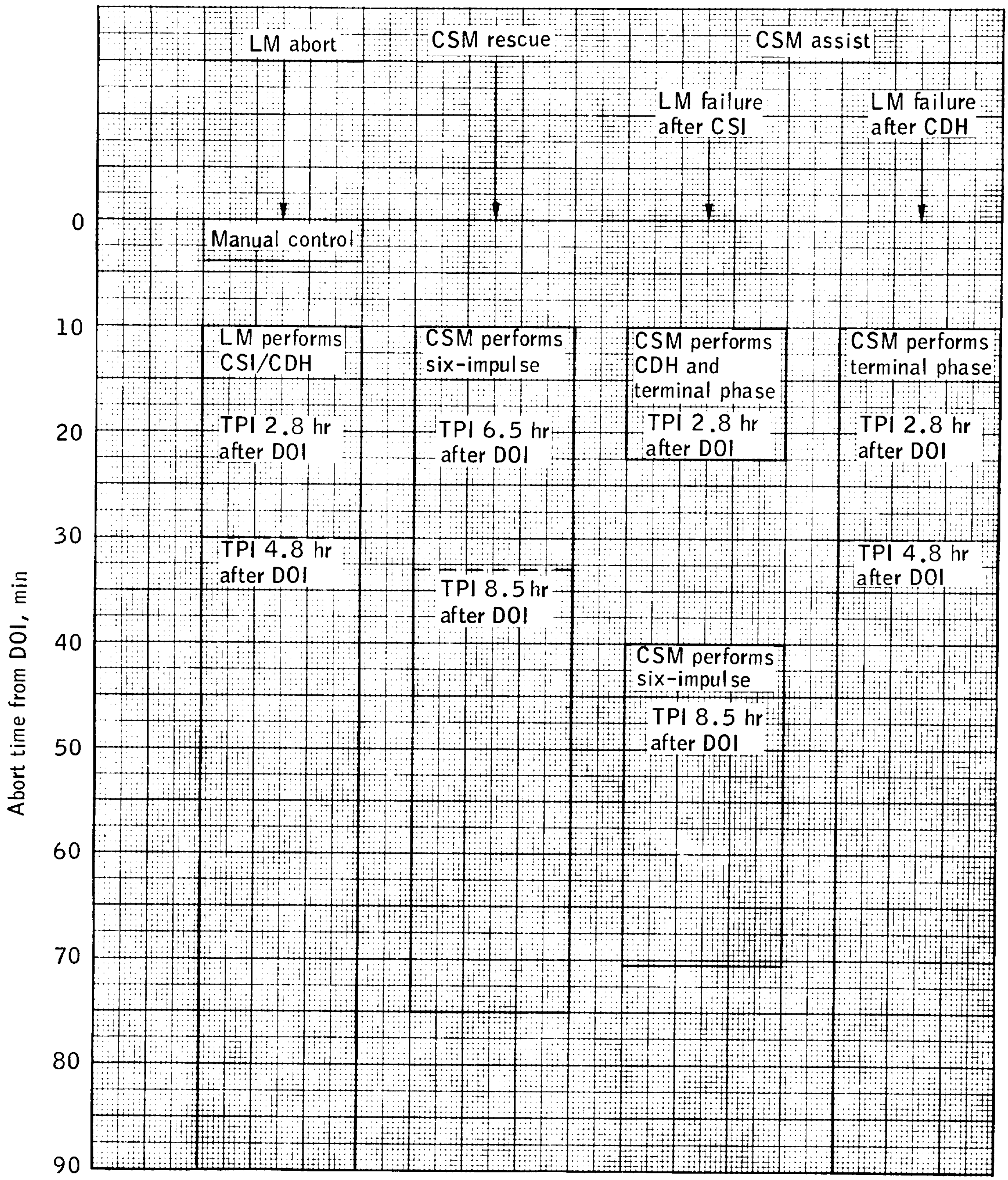


Figure 11.- Recommended abort times from DOI for various LM maneuvering capability following DOI.

REFERENCES

1. Alexander, J. D.; Bell, J. A.: Spacecraft Preliminary Abort and Alternate Mission Studies for AS-504A, Volume III - LM Abort and CSM Rescue During the Lunar Orbit Phase. MSC IN 67-FM-65, May 3, 1967.

2. Bell, J. A.: CSM Rescue of an Inactive LM from the Hohmann Descent Portion of the Lunar Mission. MSC Memorandum 66-FM63-86, October 17, 1966.