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PRELIMINARY ABORT AND RESCUE PROCEDURES FOR APOLLO MISSION F

VOLUME III

TIME-CRITICAL PROCEDURES

Orbital Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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PROJECT APOLLO

PRELIMINARY ABORT AND RESCUE PROCEDURES FOR APOLLO MISSION F VOLUME III - TIME-CRITICAL PROCEDURES

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CONTENTS

FIGURES

Figure		Page

PRELIMINARY ABORT AND RESCUE PROCEDURES FOR APOLLO MISSION F

VOLUME III - TIME-CRITICAL PROCEDURES

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1.0 SUMMARY

A preliminary LM-active abort procedure that requires only 70 minutes from failure through crew transfer is presented for the Apollo F mission time-critical rendezvous situations. The abort procedures, standardized for all cases, are initiated by a two-impulse transfer maneuver to an offset position either ahead of or behind the CSM. The rendezvous is then completed by initiation of a manual braking sequence.

The 70-minute constraint from failure through crew transfer can be met in most cases. However, because of the large vehicle-to-vehicle ranges in the area from DOI plus 50 minutes to phasing plus 35.5 minutes (DOI plus 90 minutes) and from phasing plus 70.5 minutes to insertion plus 50 minutes (DOI plus 135 minutes to DOI plus 240 minutes), greater times are required or an abort cannot be accomplished within elliptical velocity limits. Although this procedure provides short rendezvous times, it has the following inherent disadvantages: requirements for extremely large ΔV's which extend in some cases to approximately 5000 fps total and approximately 2500 fps for one of the two-impulse maneuvers; no control over the lighting at the maneuver points or during the final braking; transfer orbits with pericynthions that eventually intersect the moon (although safe altitudes exist between the two-impulse maneuvers); and no ground assistance available. If the 70-minute constraint must be met for time-critical aborts, then serious consideration will have to be given to the problems identified in this preliminary plan before the operational LM time-critical abort plan is formulated. The problems associated with the 70-minute constraint may also have an impact on the vehicle-to-vehicle maneuver ranges in the nominal plan.

2.0 INTRODUCTION

A time-critical LM abort requirement similar to the one identified by ASPO for the Apollo 9 mission was considered still valid for the Apollo F mission. The single-point failure involves a malfunction of the suit fan onboard the LM which forces a time constraint for the abort of approximately 70 minutes from the time of the failure through crew transfer. It was apparent from the differences between vehicle-to-vehicle relative ranges in the nominal rendezvous plans for the two missions that this 70-minute requirement would be more difficult to realize for the F mission. Therefore, the purpose of this report is to identify the trajectory-related procedures and problems associated with meeting the 70-minute constraint for a LM abort during Mission F.

In addition to the guidelines and assumptions, a two-impulse technique is described which places the LM at an offset position either ahead of or behind the CSM, based on the phase angle at the time of the failure. Data are presented which are based on use of this technique for a time-critical abort initiated anytime between DOI and approximately the nominal TPI time. The basic objective of the data is to identify the type of trajectory situations (ΔV requirements, pericynthion altitudes, etc.) that result from the two-impulse maneuver technique.

LM rescue procedures which use the CSM as the active vehicle have not been considered because that situation would arise only after at least a double failure on the LM, such as a systems failure and a LM propulsion failure. Also, because the ΔV's required for a CSM rescue will be essentially the same as the LM abort ΔV's, these required ΔV's will probably be larger than the CSM rescue budget (approximately 790 fps) in most areas.

The nominal profile assumed for this report is not the most current profile, but the changes do not decrease significantly the usefulness of the procedure or the data presented in this report.

3.0 SYMBOLS AND DEFINITIONS

ASPO	Apollo Spacecraft Program Office
APS	ascent propulsion system
CDH	constant differential height (coelliptic) maneuver
CSI	coelliptic sequence initiation
CSM	command and service modules
ΔV	velocity increment
DOI	descent orbit insertion
DPS	descent propulsion system
F.T.	full throttle
LGC	LM guidance computer
LM	lunar module
PC	plane change
RCS	reaction control system
SM	service module
SPS	service propulsion system
TPF	terminal phase finalization
TPI	terminal phase initiation
ωt	transfer angle
abort	nonnominal rendezvous procedure for which the LM is the maneuvering vehicle
final braking phase	the section of the rendezvous procedure from the stable offset position to the stationkeeping distance of approximately 100 ft from the CSM

insertion	insertion maneuver in the nominal profile
offset	a position at the same altitude as the CSM but displaced ahead of or behind the CSM
phasing	phasing maneuver in the nominal profile
pressurized RCS	regular LM RCS system which uses the propellant in the RCS tanks
RCS interconnect	system which burns APS propellant through the +X-axis RCS thrusters
rescue	nonnominal rendezvous procedure for which the CSM is the maneuvering vehicle
theoretical ΔV	Keplerian impulsive ΔV, for example, the TPF ΔV for the impulsive intercept velocity match
time-critical situation	situation for which the time from failure to the completion of crew transfer is considerably shorter than the normal LM lifetime, usually less than 2 to 3 hours
two-impulse transfer	the interval of the rendezvous procedure from abort initiation to the stable offset position

4.0 NOMINAL PROFILE, GROUND RULES, AND ASSUMPTIONS

4.1 Nominal Profile Description

The time-critical LM abort plan presented in this document is based on the nominal rendezvous profile used in the preliminary nontime-critical abort and rescue document and is explained in detail in reference 1. The nominal LM-active rendezvous profile which is assumed for this report (fig. 1) has the following characteristics.

1. The profile begins with a Hohmann descent (DOI) as in the lunar landing mission, but the powered descent at pericynthion is not initiated.

2. A DPS phasing maneuver (193 fps, posigrade) is applied approximately 8° past the pseudolanding site to place the LM into a phasing orbit 215 n. mi. by 10 n. mi. Thus, at the resultant pericynthion (just less than one revolution later, approximately over the pseudolanding site), the relative positions of the vehilces would be the same as they would be for a nominal insertion after powered ascent for the lunar landing mission.

3. At the insertion point, an APS insertion maneuver (232 fps, retrograde) is performed to place the LM in the standard insertion orbit (30 n. mi. by 10 n. mi.); staging is executed at the beginning of insertion.

4. A CSI maneuver, which is an RCS posigrade maneuver with a ΔV of approximately 50 fps, is performed essentially at apocynthion of the insertion orbit, half a revolution after insertion; the post-CSI orbit is 45 n. mi. by 30 n. mi.

5. Although it is not indicated for any of the abort or rescue procedures, a nominally-zero plane change would actually be scheduled between CSI and CDH (approximately 90° from each). If the CSI and CDH maneuvers are one or two revolutions apart, the PC would be scheduled either 90° after CSI or 90° prior to CDH, or at both of these points.

6. A CDH maneuver, which is an RCS posigrade maneuver with a ΔV of approximately 20 fps, is performed half a revolution after CSI, approximately at the insertion longitude; the post-CDH orbit is 45 n. mi. circular and the coelliptic Δh = 15 n. mi.

7. A TPI maneuver, which is an RCS line-of-sight maneuver with a ΔV of approximately 25 fps, is performed at the midpoint of darkness about 34 minutes after CDH.

8. A TPF maneuver, which is an RCS maneuver with a theoretical ΔV of approximately 31 fps, is performed after the CSM has traveled 130° from TPI.

4.2 Ground Rules

The ground rules used in this report provide the basis for generation of the time-critical LM abort plan. The following ground rules were used.

1. The resultant two-impulse transfer maneuver must not exceed approximately 26 minutes or approximately an 80° transfer angle to stay within the 70-minute total time constraint.

2. Minimum acceptable altitude between the two-impulse maneuvers is 35 000 ft (5.76 n. mi.) above the mean lunar radius.

3. Unsafe pericynthions are acceptable if they do not occur between the two-impulse maneuvers.

4. The capability exists in the LGC to compute solutions for the two-impulse maneuvers to an offset position technique.

5. The LM abort procedure must be applicable to all acceptable earth launch times and lunar landing sites.

6. The procedure must be consistent with system, crew, and operational constraints.

7. Onboard independence from ground assistance is required.

8. The LM will be staged when the use of the APS is necessary.

9. Staging will occur immediately prior to the first attempted APS burn.

10. Pressurized RCS can be used when required.

11. The RCS interconnect can be used after an APS burn or after an ullage maneuver sufficient to settle the APS propellant.

12. No dispersions or LM errors were considered.

13. Out-of-plane situations were not considered.

14. CSM failures were not considered.

15. Detailed braking procedures will not be defined.

4.3 Assumptions

Vehicle weights	
CSM, lb	36 600
LM unstaged, based on half-loaded APS, lb	30 500
LM ascent stage, lb	8 200
ΔV capabilities	
SPS, fps	790
SM RCS, fps	130
LM RCS, pressurized, fps	415
DPS, fps	6 000
APS, fps	3 000
Timeline for abort sequence	
Total time, excluding variable transfer time, min	44
From failure to abort initiation, min	10
From abort initiation to second impulse	Variable
From second impulse to rendezvous, min	14
From rendezvous to docking, min	10
From docking through crew transfer, min	10
Maximum continuous ±X RCS thruster burn limits	
+X, unstaged, sec	15
+X, staged, sec	90 to 100
-X, sec	30

5.0 DISCUSSION OF THE TECHNIQUE

The technique involved for all cases is a two-impulse transfer of the LM to a stable offset position which is at the same altitude as the CSM (60 n. mi. above the mean lunar radius) but which is displaced approximately 2 to 3 n. mi. either ahead of or behind the CSM. If the LM is at a phase angle ahead of the CSM, then the offset position will be ahead of the CSM; if the LM is at a phase angle behind the CSM, then the offset position will be behind the CSM. For convenience in data presentation, it was assumed that the offset position was ahead of the CSM from DOI to insertion and was behind the CSM from insertion to TPI. No significant ΔV or time savings result from the use of one offset rather than the other. The transfer angle (ωt) varies from 10° to 340°, with transfer time variations between 3 and 113 minutes.

The use of an offset position was chosen to insure adequate spacing between the two vehicles while the LM reduced the extremely high relative velocities of up to approximately 2000 fps that can occur at the second impulse. The presented data are based on an offset position of approximately 3 n. mi.

For the stable offset position, a closing rate of approximately 50 fps will initiate a manual braking sequence that will complete the rendezvous. The final approach will take approximately 14 minutes to complete rendezvous (i.e., to reach a stationkeeping position approximately 100 ft from the CSM) and will require a theoretical ΔV of approximately 80 fps. Therefore, the final approach will require a theoretical ΔV of 130 fps (an actual operational ΔV cost of approximately 200 fps) in addition to that required for the two-impulse maneuvers.

Although parametric data for this technique is included for all points from DOI to approximately the nominal TPI time, the two-impulse maneuver to an offset position will probably not be used from DOI to DOI plus 20 minutes. The technique that is used will probably be some type of direct return similar to what is recommended in reference 2 for the interval from DOI to DOI plus 5 minutes.

6.0 RESULTS AND DISCUSSION OF THE DATA

Although the rendezvous procedure is the same for all cases, the results and discussion of the data have been divided into sections which represent the areas between the major maneuvers in the nominal profile excluding the plane-change maneuver and the terminal phase maneuvers. Parametric data are presented in figures 2 through 6 for transfer angles of up to 340° with abort points that occur within each section.[a] The figures indicate the required total ΔV for the two-impulse phase of the transfer as well as the pericynthion altitudes for the transfer orbits as a function of the transfer angle. The ΔV curves are terminated either because the altitudes along the transfer trajectory are unsafe or because the transfer orbits are parabolic or hyberbolic. Representative relative motion diagrams are presented in figures 7 through 11 for a typical abort in each interval.

It is assumed that any attempted nominal maneuver will be nominally performed; that is, a propulsion failure in combination with the time-critical failure is not considered. The final braking phase for this technique is similar in all cases. For this reason, only one plot has been included that shows the relative motion during this final phase for the offset positions ahead of the CSM and behind the CSM (fig. 12). The final phase begins with a closing maneuver of approximately 50 fps and requires a theoretical total braking ΔV of approximately 80 fps. Thus, the phase required approximately 130 fps to complete (an actual operational ΔV cost of approximately 200 fps) and takes approximately 14 minutes from the offset position to attain the stationkeeping distance of 100 feet.

In figure 13 is shown a breakdown of the ΔV's required to complete the two-impulse portion of the technique as a function of time from DOI. A transfer angle of 80° was chosen because it represents a transfer time of approximately 26 minutes which, when combined with the 44 minutes necessary for crew procedures and final braking, is the maximum allowable transfer time that still meets the 70-minute constraint caused by the suit-fan failure.

Although some of the two-impulse burns shown in figure 13 are very large, they fall within the ΔV capability of the DPS and the APS. However, in the regions between approximately 50 to 90 minutes and approximately 135 to 240 minutes after DOI (i.e., DOI plus 50 minutes to phasing plus 35.5 minutes and phasing plus 70.5 minutes to insertion plus 50 minutes), the 70-minute constraint cannot be met because either altitudes along the transfer trajectory are unsafe or because the transfer

[a]The appendix presents sample cases and instructions for interpretation of figures 2 through 6.

orbits are parabolic or hyperbolic. A successful abort can be accomplished within the first region and during approximately the first 10 minutes of the second region if the allowable time is increased beyond 70 minutes (i.e., a longer transfer time is allowed). A two-impulse maneuver to the required offset position is not possible from approximately 145 minutes to 240 minutes after DOI, regardless of the transfer time. Therefore, during the nominal profile, there is a combined time-span of approximately 150 minutes in which the 70-minute limit cannot be met and a time-span of approximately 90 minutes in which no two-impulse-type abort can be accomplished. Because the main objective of this analysis was to define abort procedures for time-critical situations that require less than approximately 70 minutes from failure to crew transfer completion, attempts were not made to design three-impulse or four-impulse techniques which might work in this final interval. Such techniques would probably require nearly as long to complete rendezvous as the corresponding nontime-critical techniques.

6.1 Between DOI and Phasing

In the interval between DOI and phasing, the two-impulse maneuver to an offset position probably will not be used for the area between DOI and DOI plus 20 minutes. For the remainder of the interval, a successful abort theoretically can be accomplished if enough time is allowed. However, the 70-minute constraint dictated by the suit-fan failure cannot be met for aborts initiated between approximately DOI plus 50 minutes and the nominal time of the phasing maneuver.

In figure 2, it is also shown that the total necessary ΔV can become large for small ωt's and for aborts initiated close to phasing. Many of the transfer orbits have pericynthions as low as 200 n. mi. below the moon's surface. A representative relative motion diagram for an abort initiated in the interval between DOI and phasing is presented in figure 7.

6.2 Between Phasing and Insertion

Aborts can be accomplished between the phasing maneuver and phasing plus 80 minutes if enough time is allowed between failure and completion of crew transfer (fig. 3). However, the 70-minute constraint cannot be met in the interval between phasing and phasing plus 30 minutes and between phasing plus 70 minutes and phasing plus 80 minutes. An abort cannot be accomplished with this technique in the interval between phasing plus 80 minutes and insertion.

The results presented in figure 3 also indicate that the total ΔV necessary for an abort after phasing is considerably higher than what is necessary for aborts after DOI for the smaller ωt's. Again, many of the transfer orbits have pericynthions as low as 200 n. mi. below the moon's surface. A representative relative motion diagram for an abort initiated in the interval between phasing and insertion is presented in figure 8.

6.3 Between Insertion and CSI

In the interval between insertion and CSI, aborts can be accomplished between insertion plus 40 minutes and CSI if enough time is allowed between failure and completion of crew transfer. The interval during which the 70-minute constraint can be met is limited between insertion plus 50 minutes and CSI. For most of the interval from insertion to insertion plus 40 minutes, the two-impulse maneuver to the offset position abort cannot be accomplished with this technique.

In the interval between insertion and CSI, completion of the two-impulse maneuvers requires large total ΔV's (fig. 4). Also in this interval, the pericynthions of the transfer orbits rarely get below the minimum acceptable altitude of 5.76 n. mi., and only a few are below the lunar surface. A representative relative motion diagram for an abort initiated in this region is presented in figure 9.

6.4 Between CSI and CDH

Theoretically, aborts can be accomplished within the entire interval between CSI and CDH, probably because the LM and the CSM are relatively close together. Data presented in figure 5 indicate that large ΔV's are necessary for the smaller transfer angles. However, all the transfer orbits have safe pericynthion altitudes. A representative relative motion diagram for an abort initiated within the interval between CSI and CDH is presented in figure 10.

6.5 Between CDH and Approximately the Nominal TPI Time

Data presented in figure 6 show that an abort initiated at all points in the interval between CDH and approximately the nominal TPI time theoretically can meet the 70-minute time constraint and also that the transfer orbits have safe pericynthions. However, the total ΔV's required are about half of those required for the previous interval. A representative relative motion diagram of an abort initiated in the interval between CDH and approximately the nominal TPI time is presented in figure 11.

7.0 CONCLUSIONS

The procedure discussed in this report was chosen because there is no other known workable procedure available that can produce usable results for the time-critical situations considered; that is, in most cases, time-critical aborts theoretically can be accomplished by use of the assumed procedure. However, this procedure is not only unable to meet the 70-minute constraint in all intervals, but also cannot always provide a time-critical abort capability regardless of transfer time.

The 70-minute time duration from the failure to completion of crew transfer theoretically can be met for the intervals from DOI to DOI plus 50 minutes, from phasing plus 35.5 minutes to phasing plus 70.5 minutes (DOI plus 90 minutes to DOI plus 135 minutes), and from insertion plus 50 minutes (DOI plus 240 minutes) to the nominal TPI time. The following conditions must be accepted if the 70-minute time constraint is maintained: high ΔV's (up to approximately 5000 fps); high closing rates at the second impulse; no lighting control during maneuvers and the final braking phase; transfer orbits that impact the moon outside the two-impulse transfer interval; and, transfer times less than about 26 minutes (i.e., an ωt of less than approximately 80°).

Theoretically, a time-critical abort also can be accomplished from DOI plus 50 minutes to phasing plus 35.5 minutes (DOI plus 90 minutes) and from phasing plus 70.5 minutes to phasing plus 80.5 minutes (DOI plus 135 minutes to DOI plus 145 minutes) if longer transfers are used. Within these intervals, the 70-minute time constraint cannot be met.

For the interval between phasing plus 80.5 minutes and insertion plus 50 minutes (DOI plus 145 minutes to DOI plus 240 minutes), aborts which use this time-critical procedure cannot be accomplished significantly earlier than the corresponding nontime-critical procedure listed in reference 2. A summary of the described intervals is presented in figure 14.

A CSM rescue is not considered in this document because a double failure on the LM is required to obtain a rescue situation. However, if a rescue were involved, the resultant ΔV's probably would be similar to those for the LM procedure. Therefore, the fuel budget for rescue (approximately 790 fps) makes rescue impossible within the required time for most of the intervals considered.

In summary, the time-critical procedure presented in this document is the only procedure known to accomplish time-critical aborts. However, it is not known if this procedure is acceptable from an operational viewpoint. Therefore, it is recommended that attempts be made to develop a procedure for reducing or eliminating the time-critical situation. If that is not possible, the procedure recommended in this document will have to be developed further, prior to use.

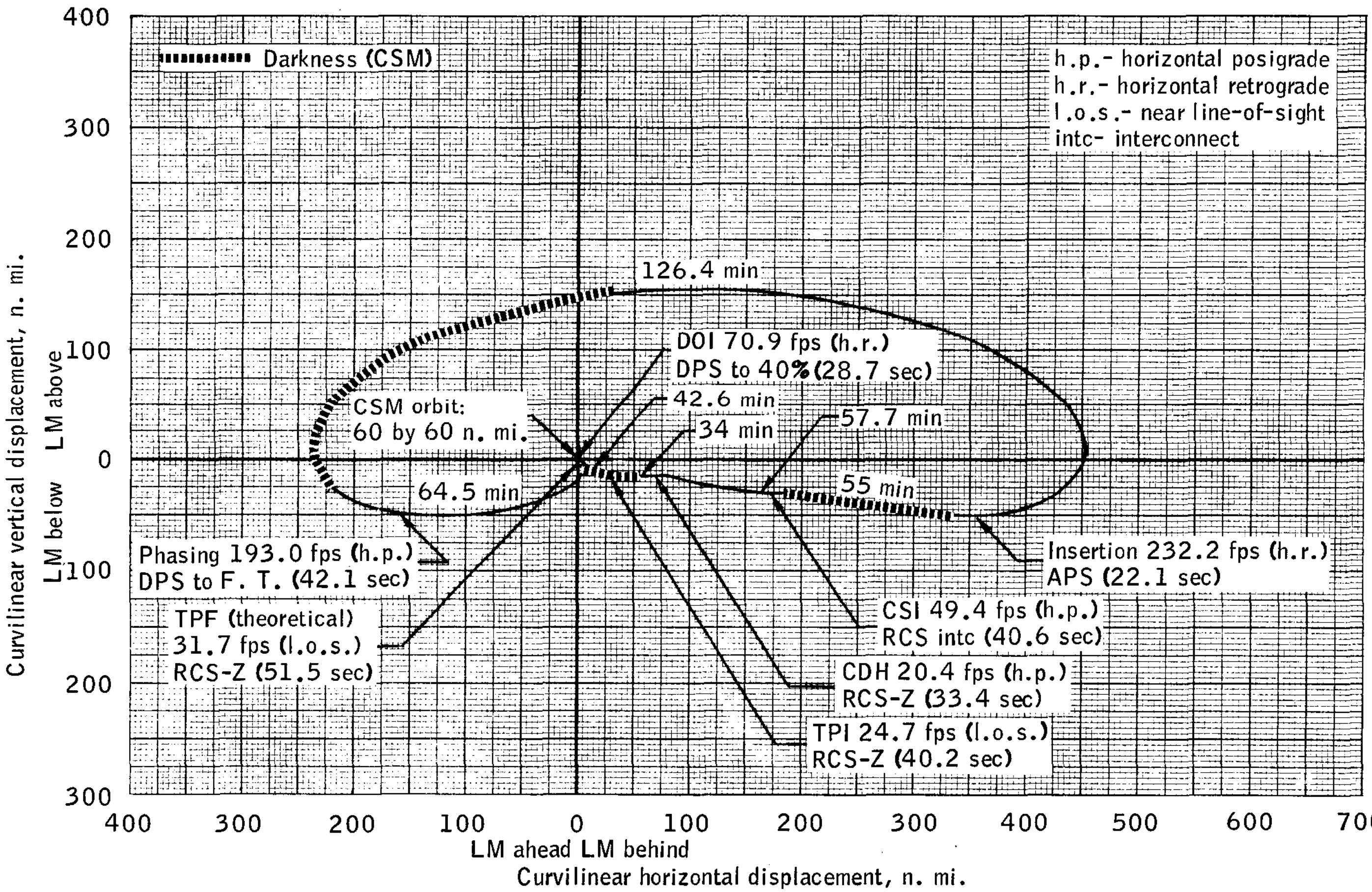


Figure 1.- Relative motion (curvilinear, CSM-centered) for nominal LM-active phase of Mission F.

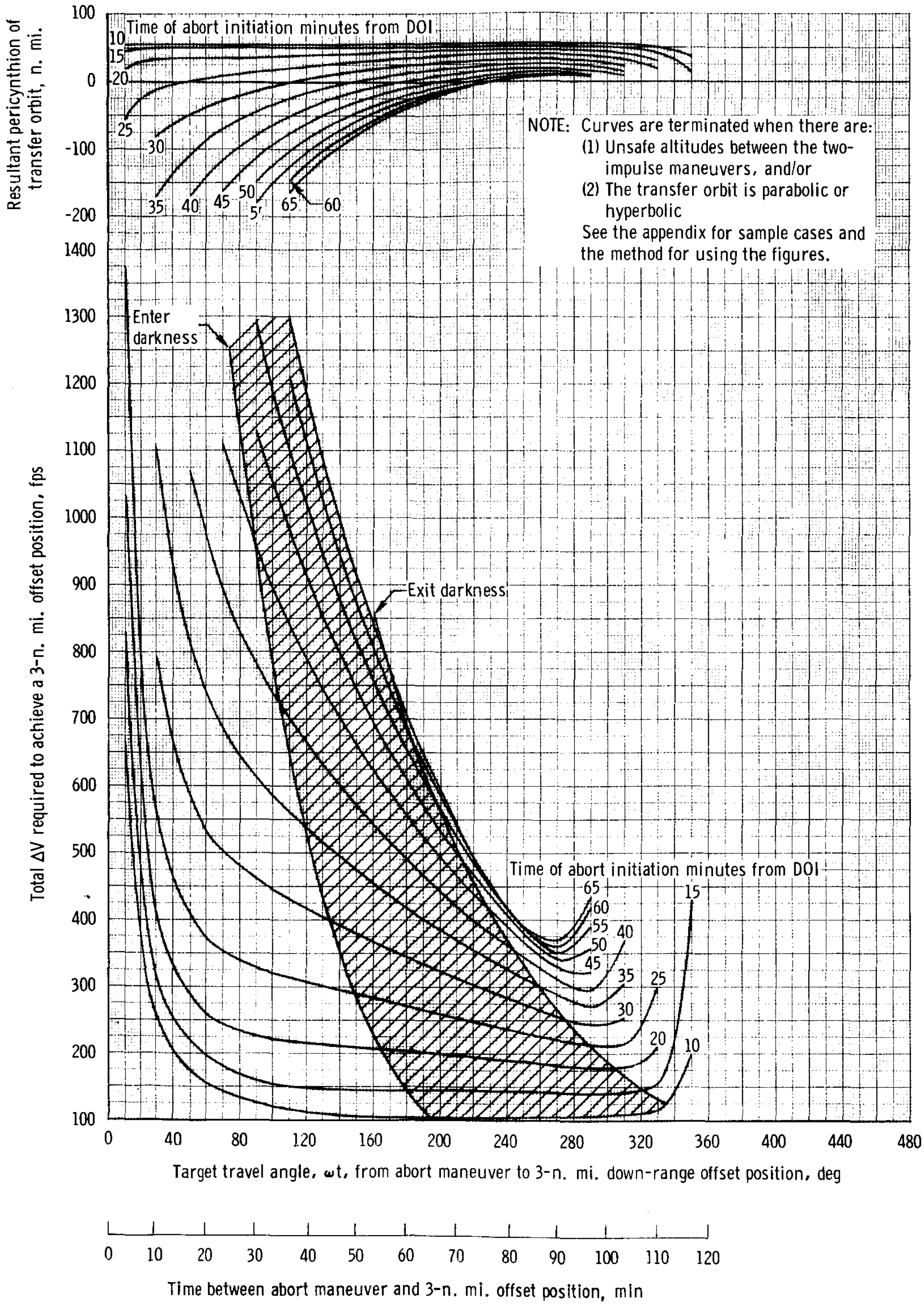


Figure 2.- Time-critical abort during Hohmann descent by maneuvering LM to 3-nautical mile offset position ahead of CSM.

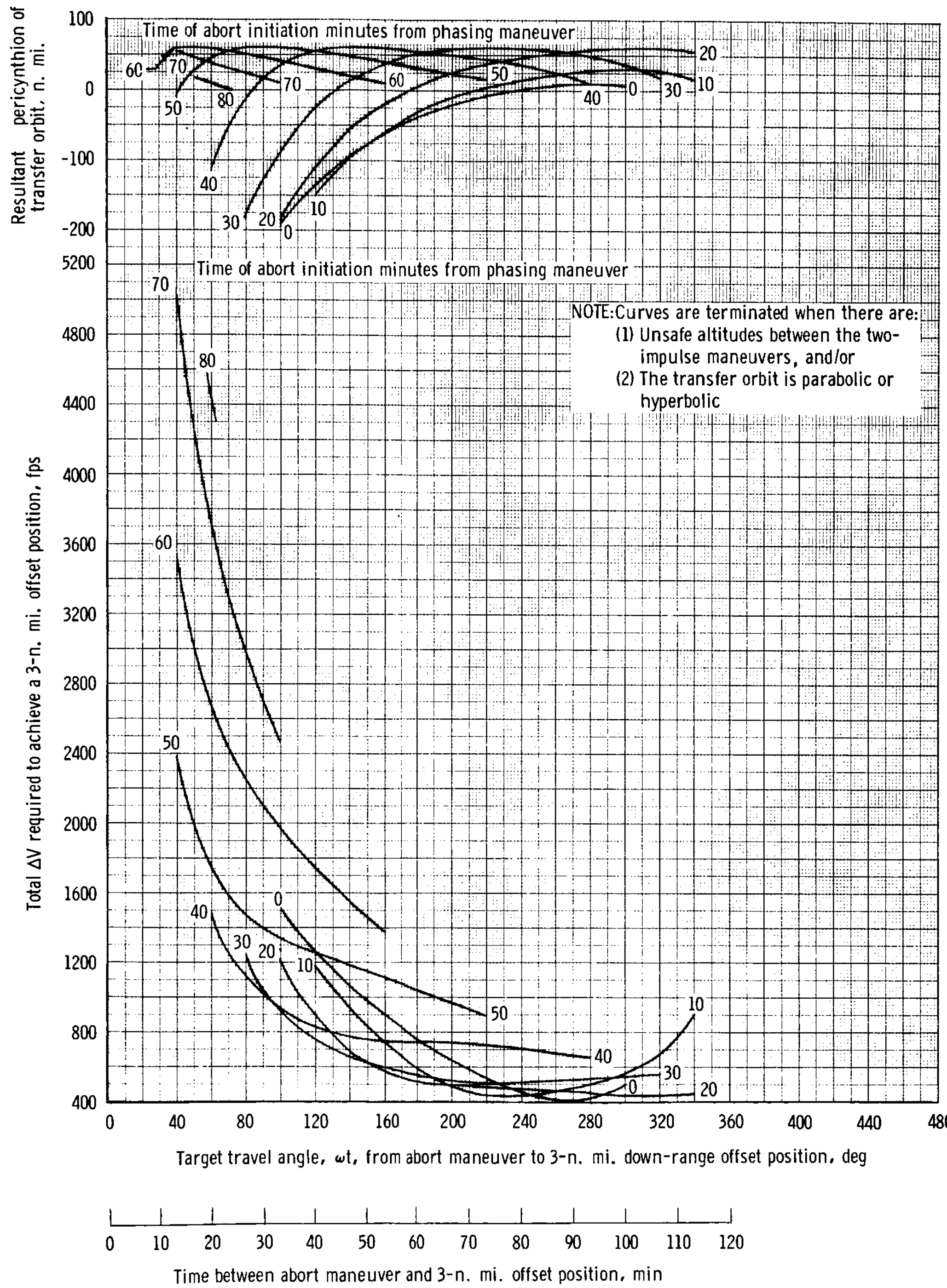


Figure 3. - Time-critical abort following phasing maneuver by maneuvering LM to 3-nautical mile offset position ahead of CSM.

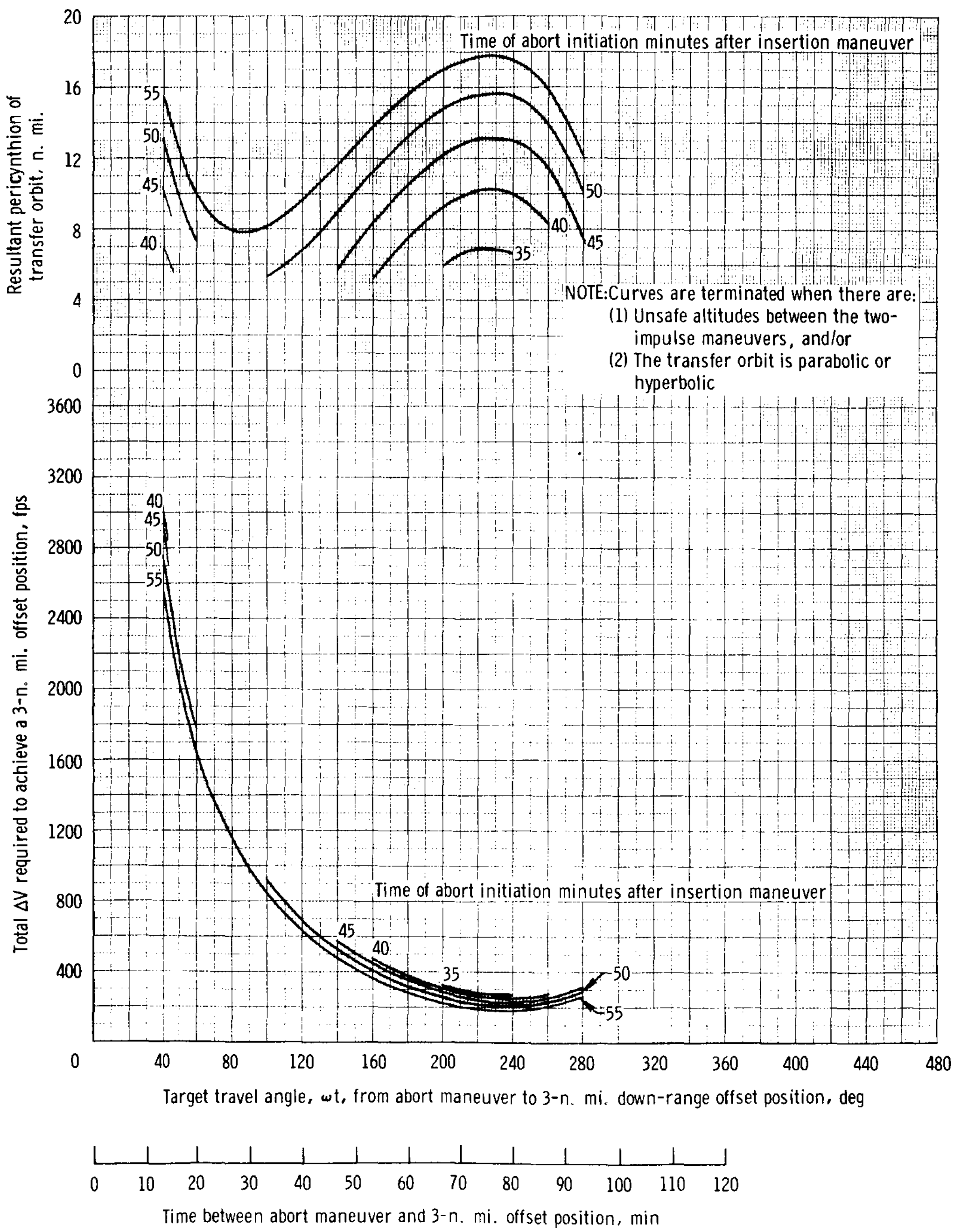


Figure 4. - Time-critical abort following insertion maneuver by maneuvering LM to 3-nautical mile offset position behind CSM.

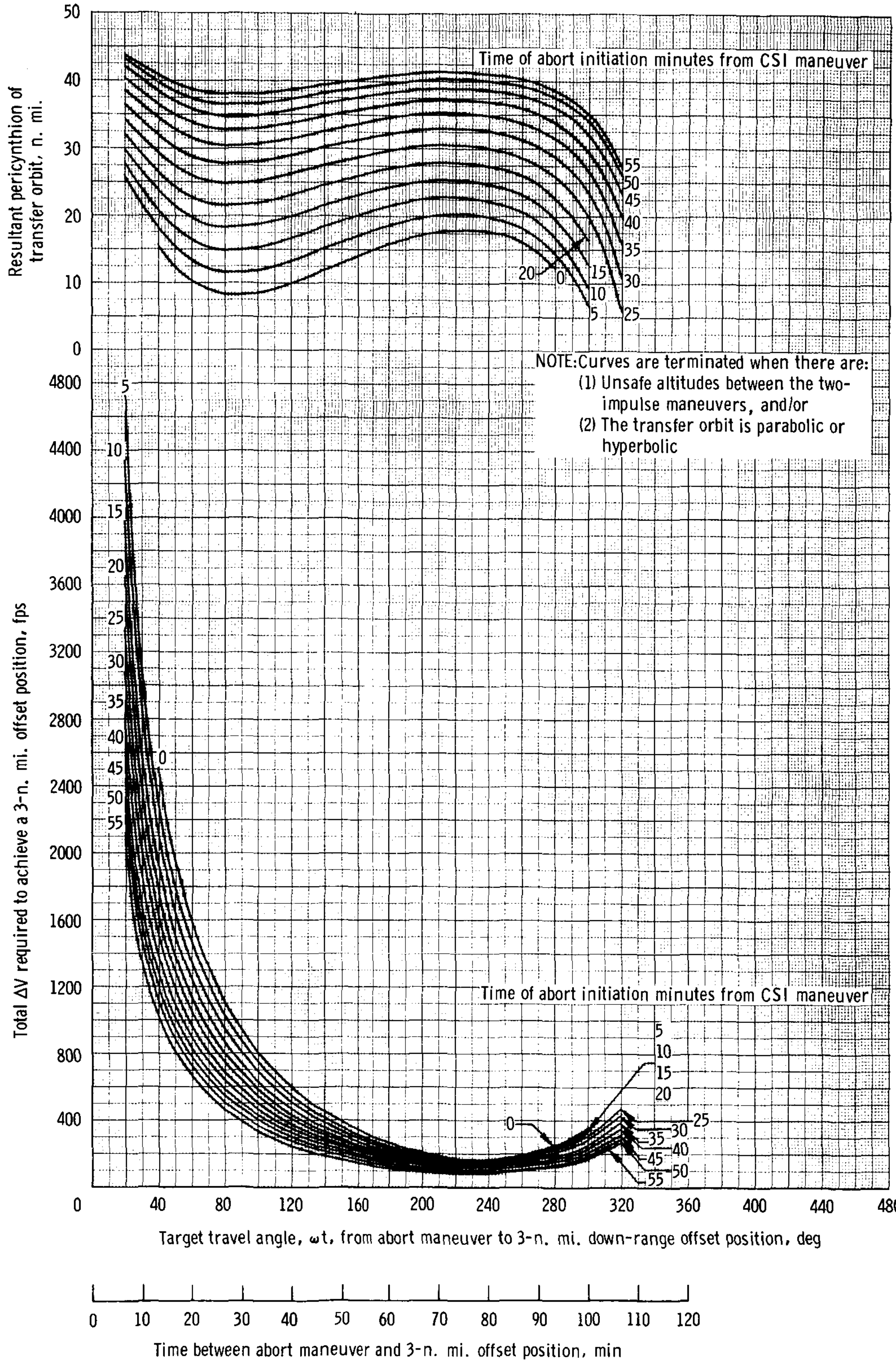


Figure 5. - Time-critical abort following CSI maneuver by maneuvering LM to 3-nautical mile offset position behind CSM.

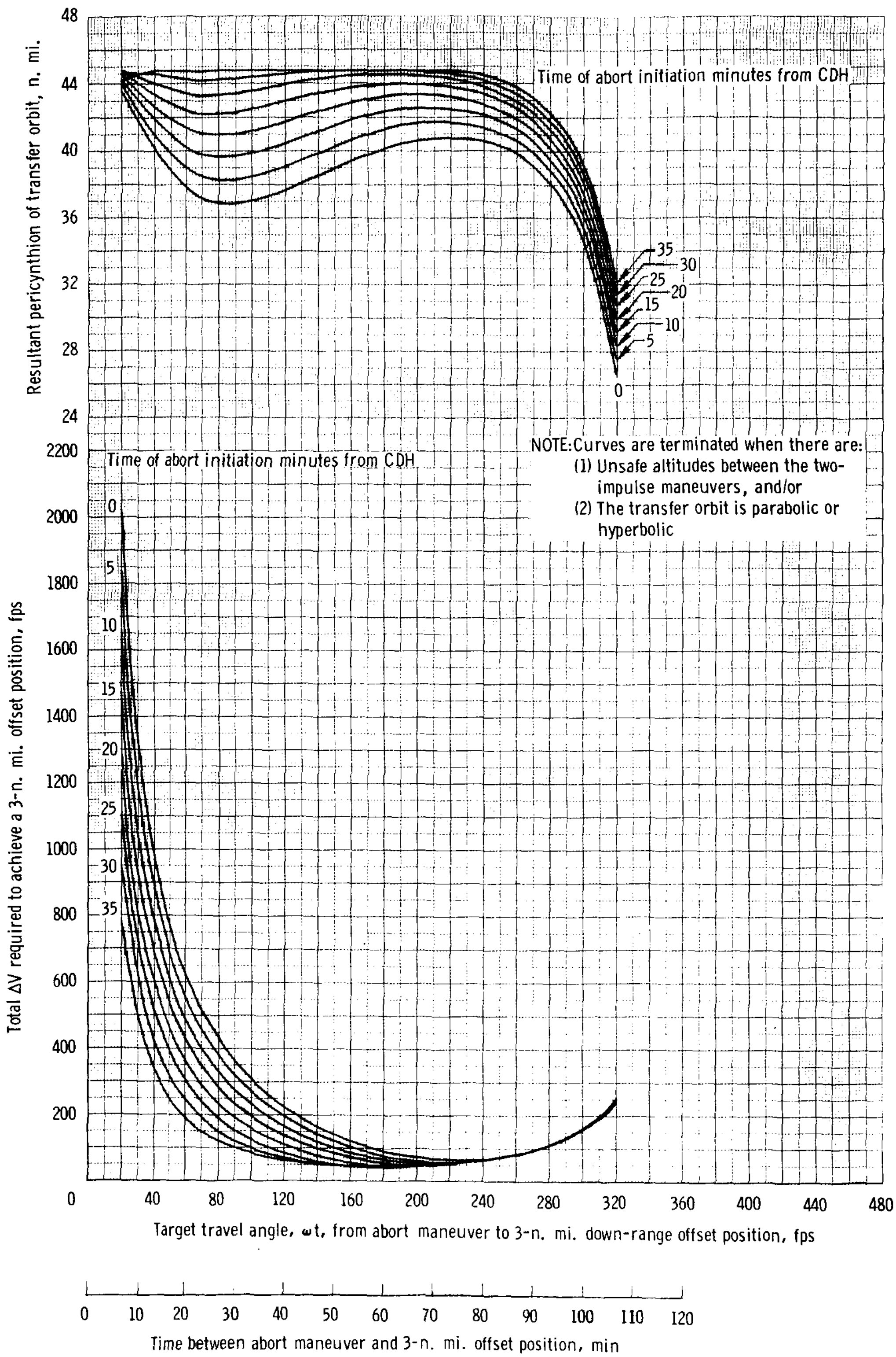


Figure 6. - Time-critical abort following CDH maneuver by maneuvering LM to 3-nautical mile offset position behind CSM.

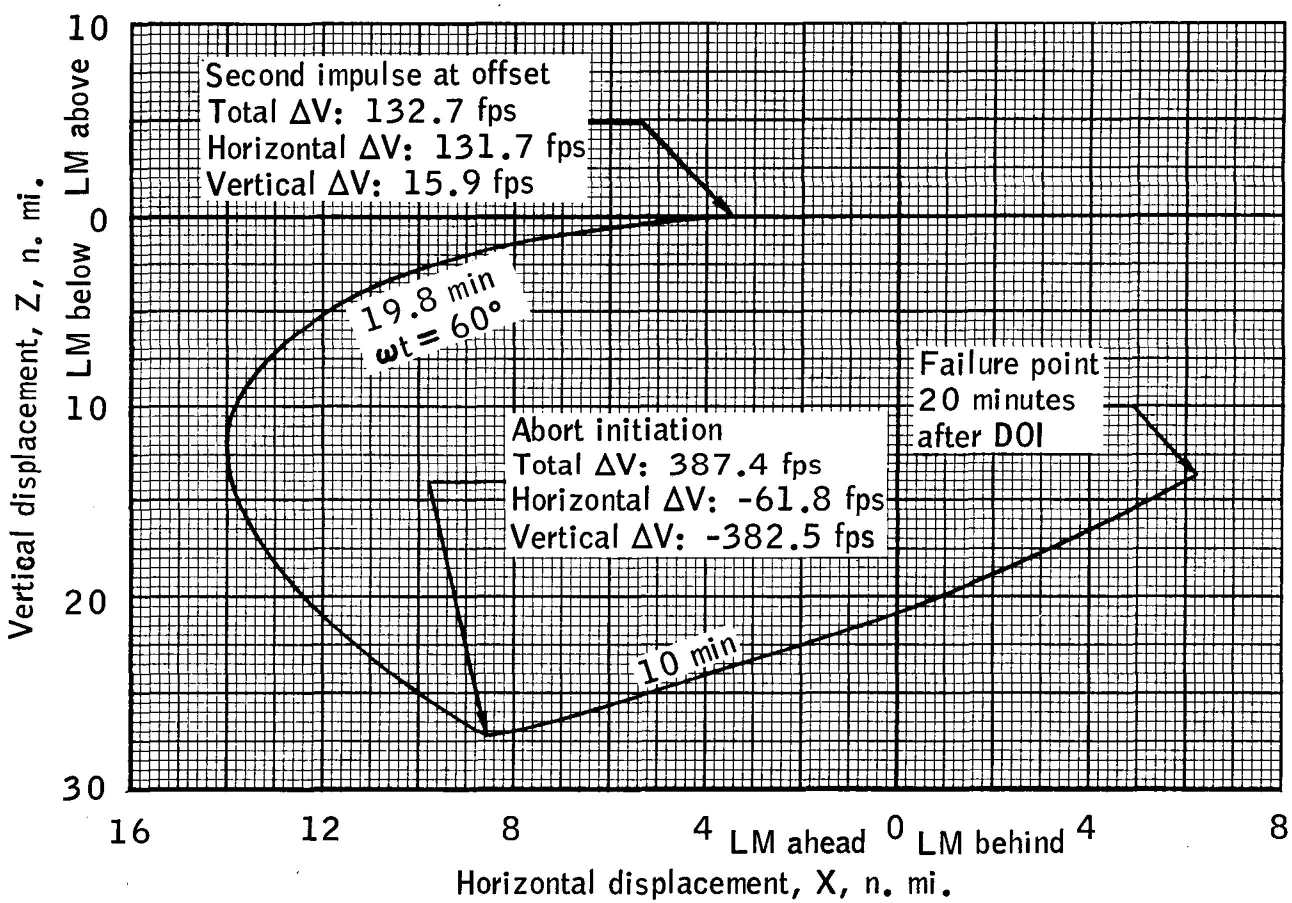


Figure 7.- Representative relative motion (curvilinear, CSM-centered) of an abort initiated 30 minutes after DOI to an offset position 3 nautical miles ahead of the CSM.

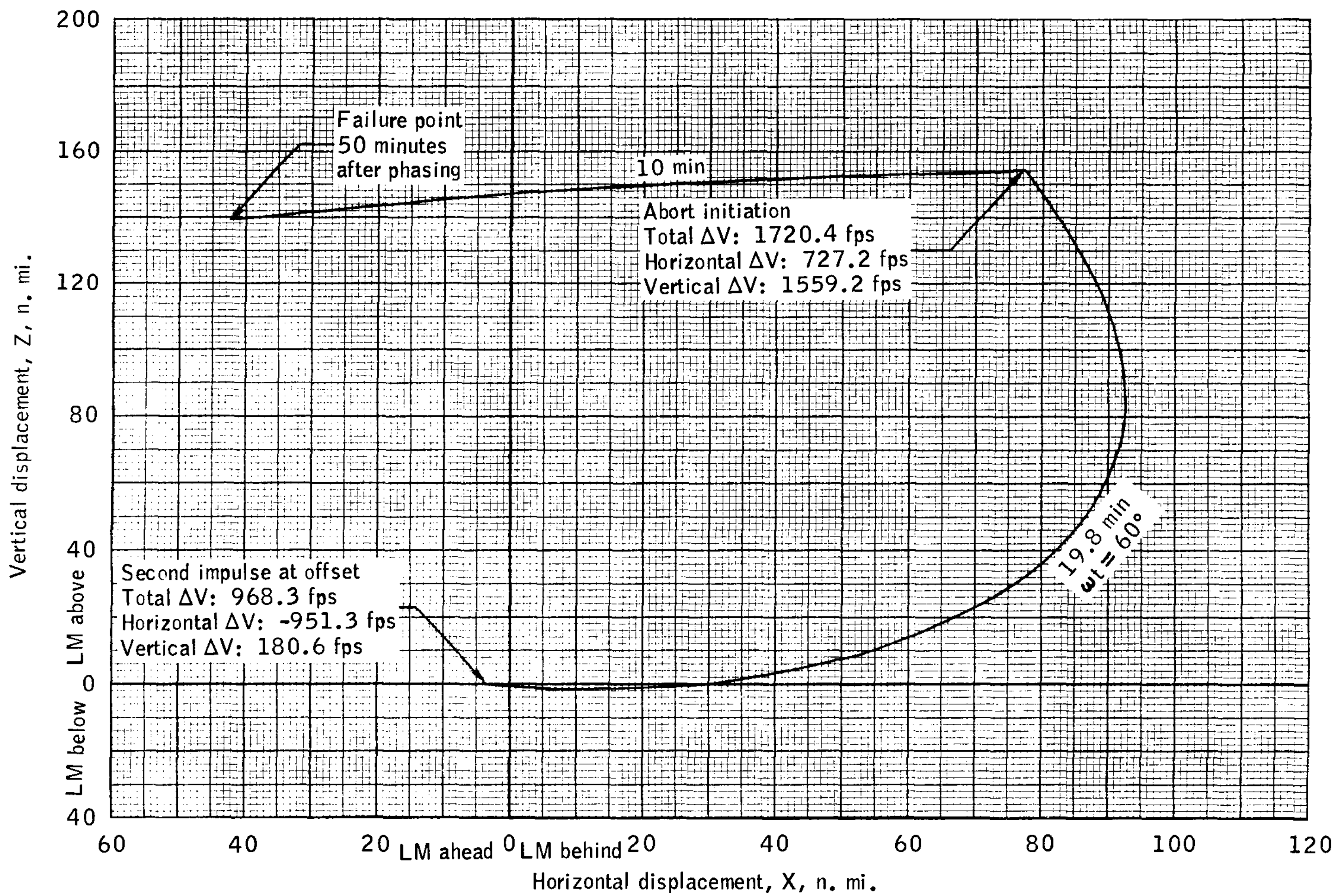


Figure 8.- Representative relative motion (curvilinear, CSM-centered) of an abort initiated 60 minutes after the phasing maneuver to an offset position 3 nautical miles ahead of the CSM.

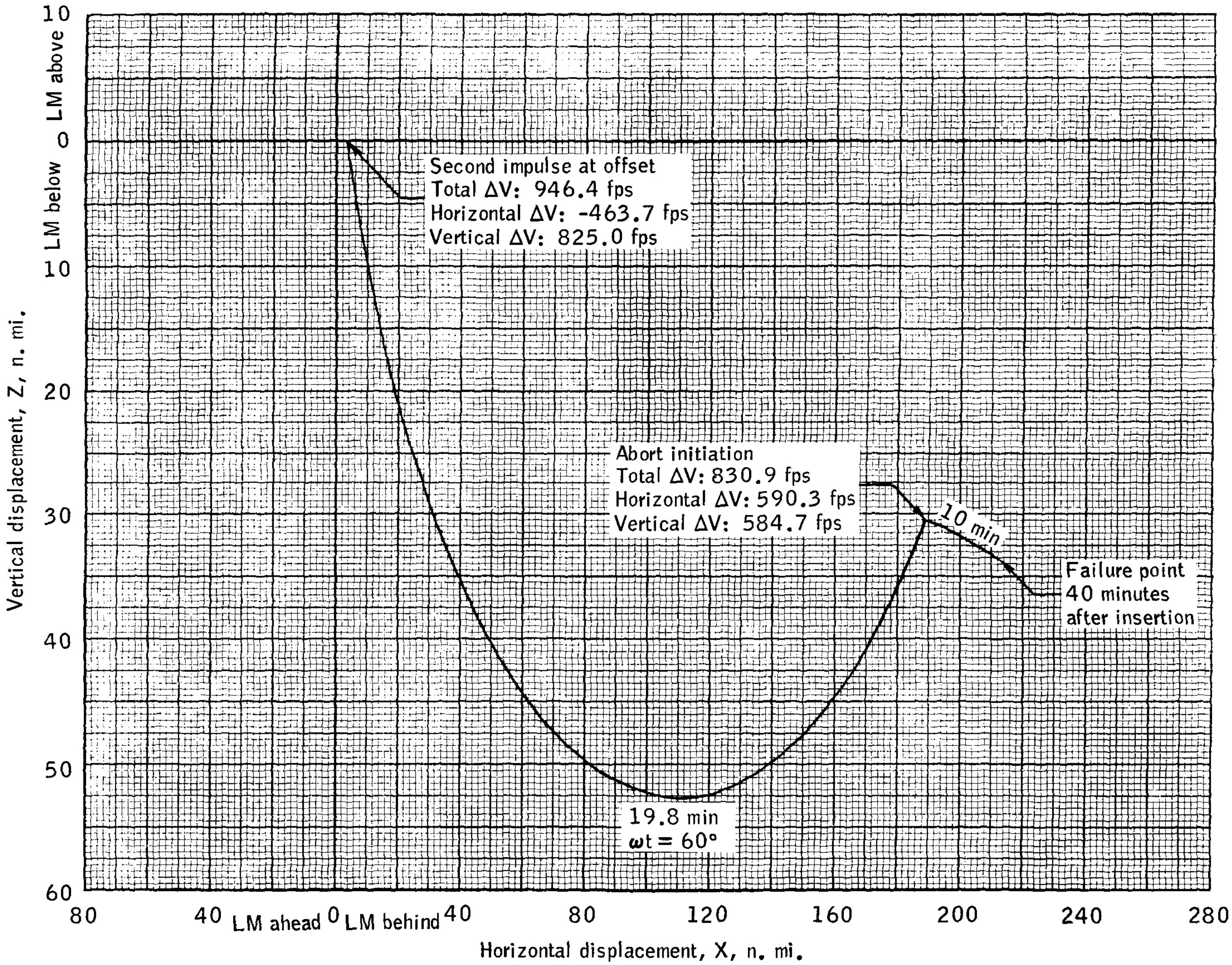


Figure 9.- Representative relative motion (curvilinear, CSM-centered) of an abort initiated 50 minutes after the insertion maneuver to an offset position 3 nautical miles behind the CSM.

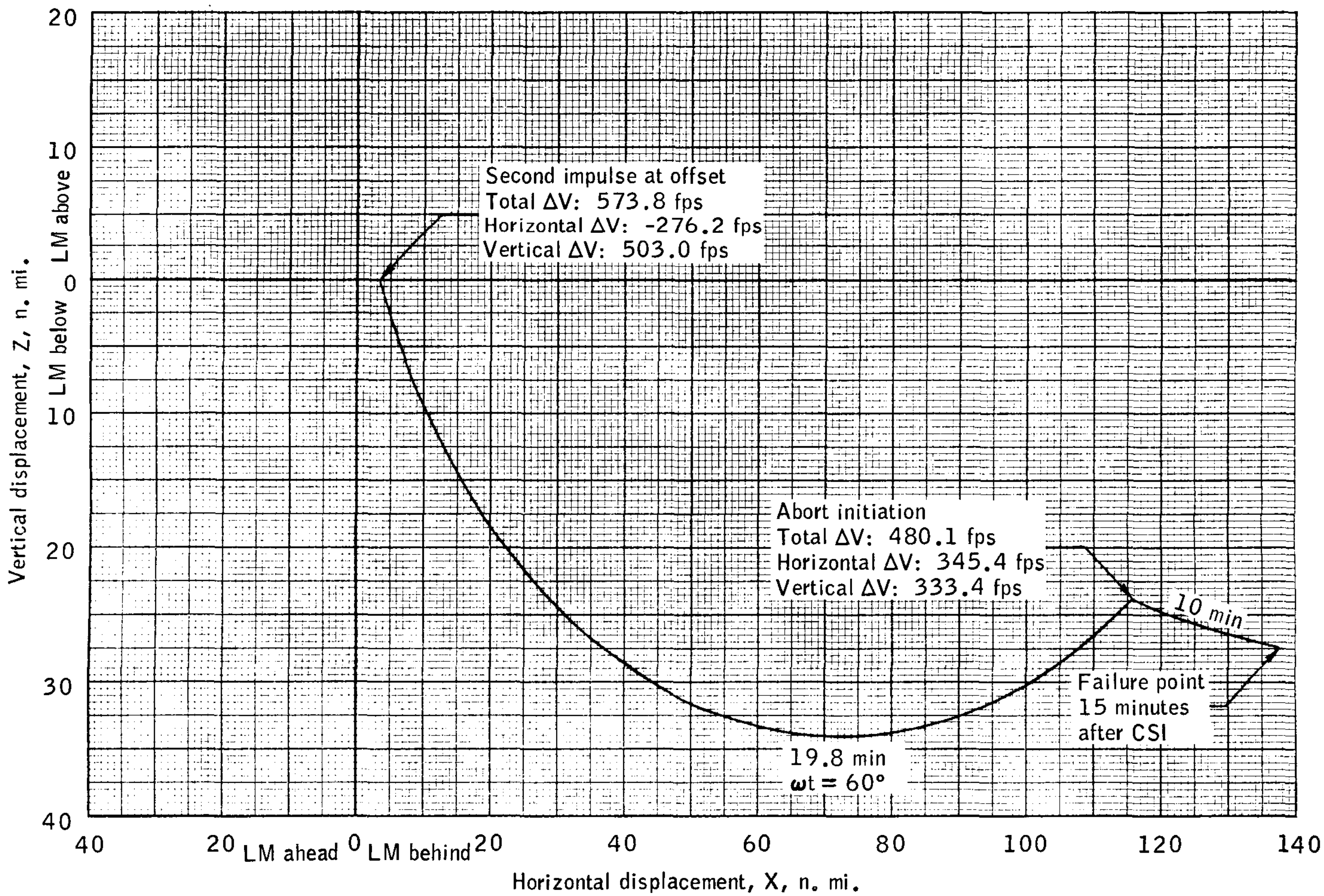


Figure 10.- Representative relative motion (curvilinear, CSM-centered) of an abort initiated 25 minutes after CSI to an offset position 3 nautical miles behind the CSM.

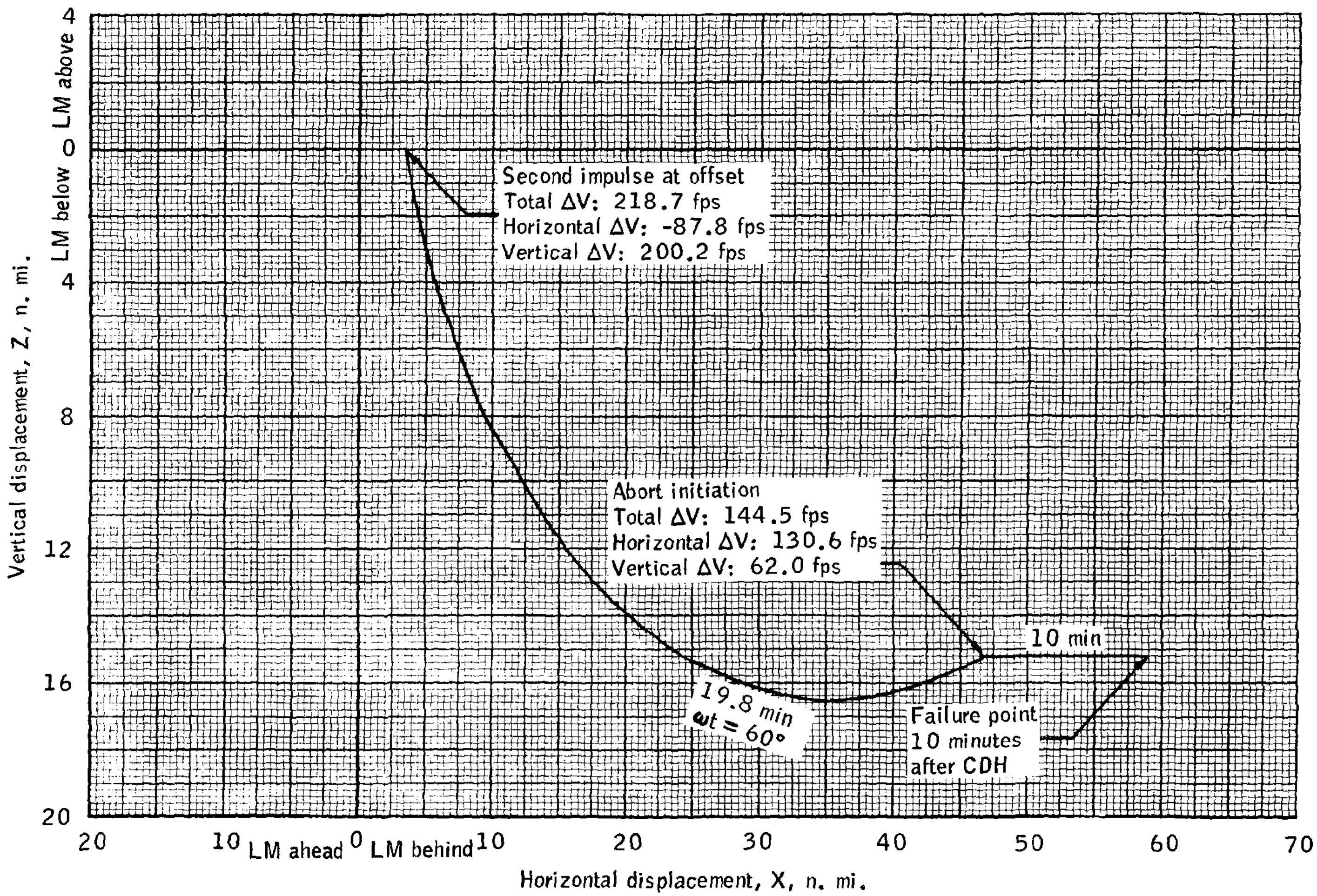


Figure 11.- Representative relative motion (curvilinear, CSM-centered) of an abort initiated 20 minutes after CDH to an offset position 3 nautical miles behind the CSM.

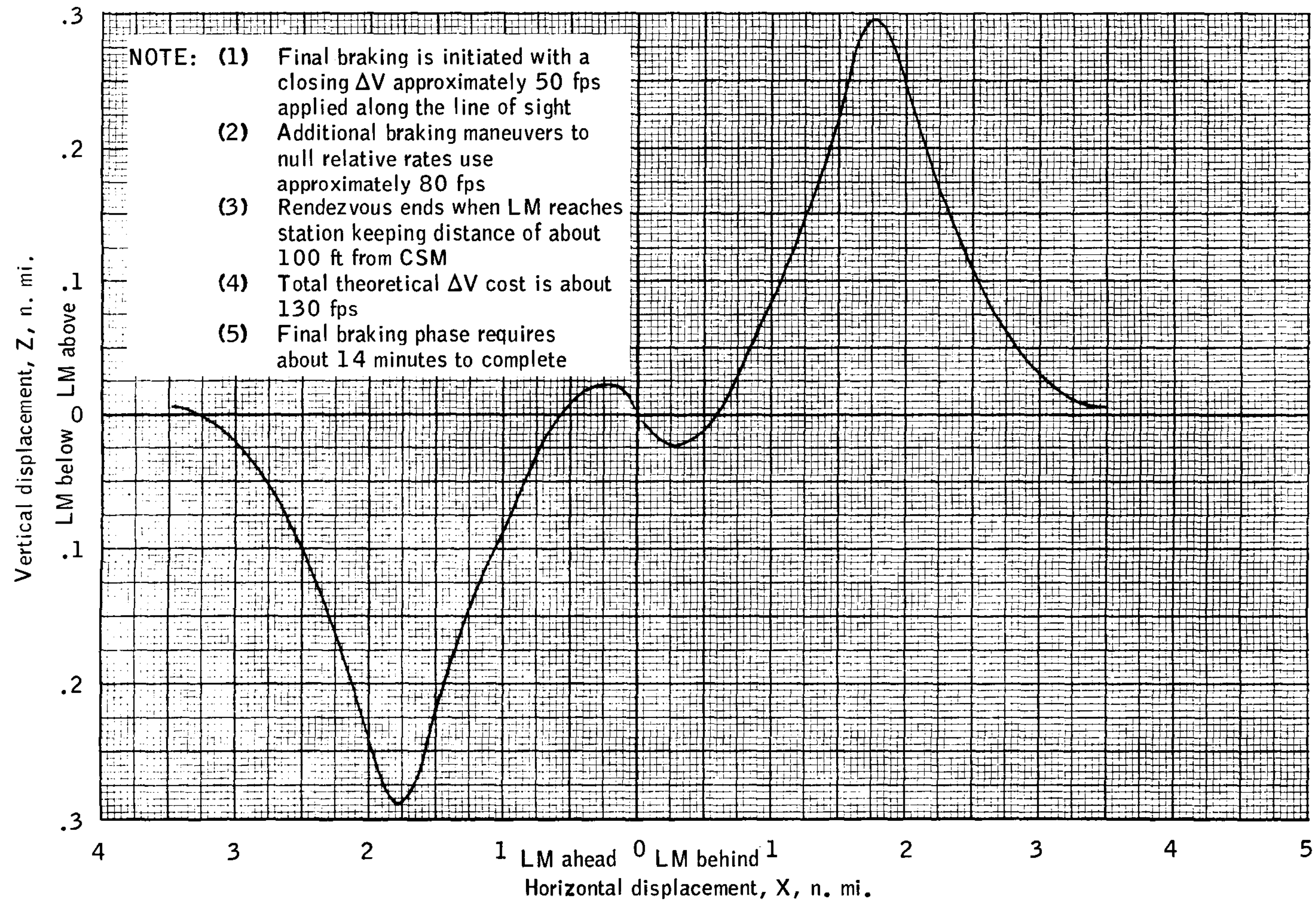


Figure 12.- Representative relative motion (curvilinear, CSM-centered) of the final braking phase from 3 nautical miles ahead of and 3 nautical miles behind the CSM.

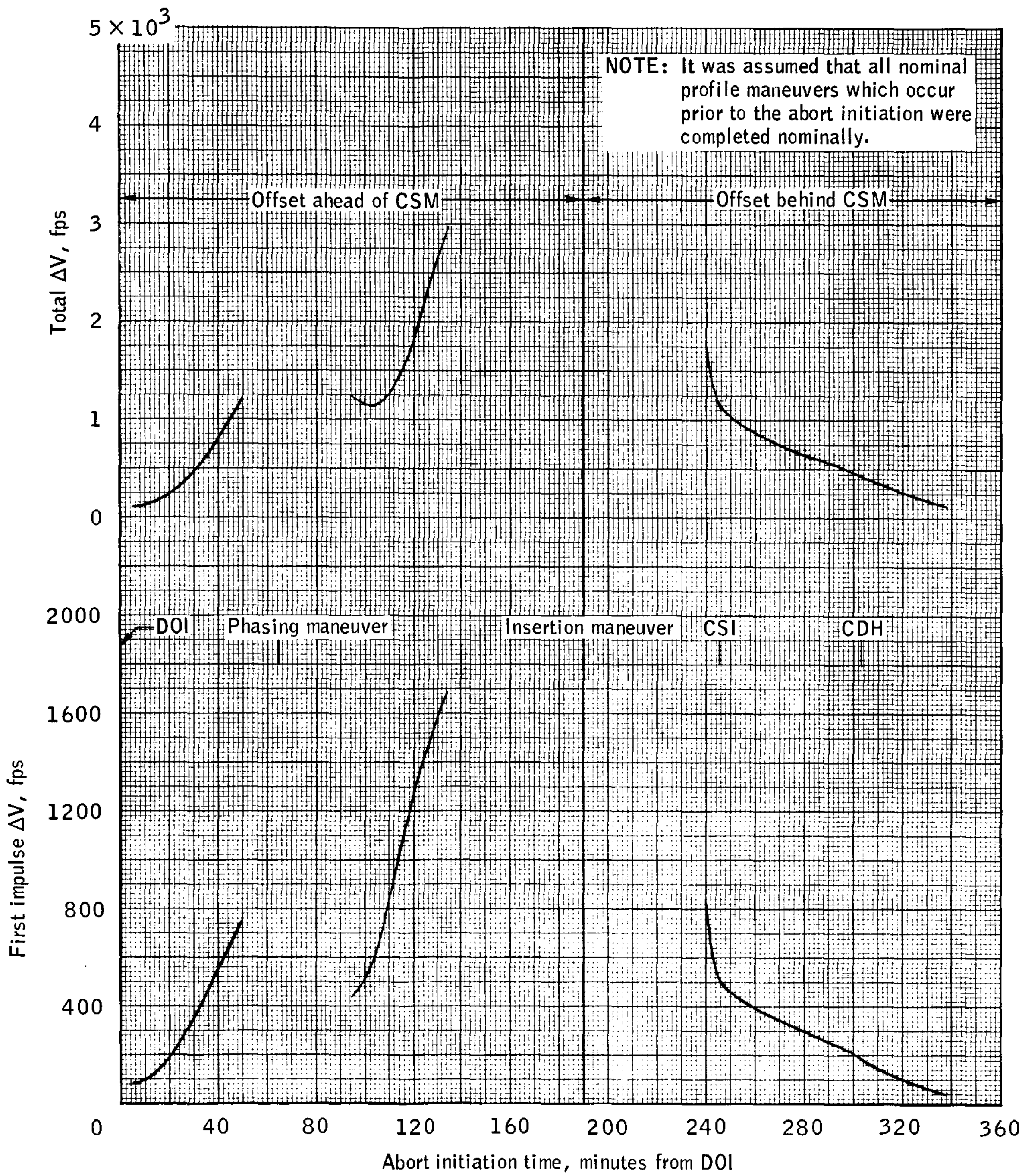


Figure 13.- Breakdown of the required ΔV for an 80-degree transfer initiated at various times after DOI.

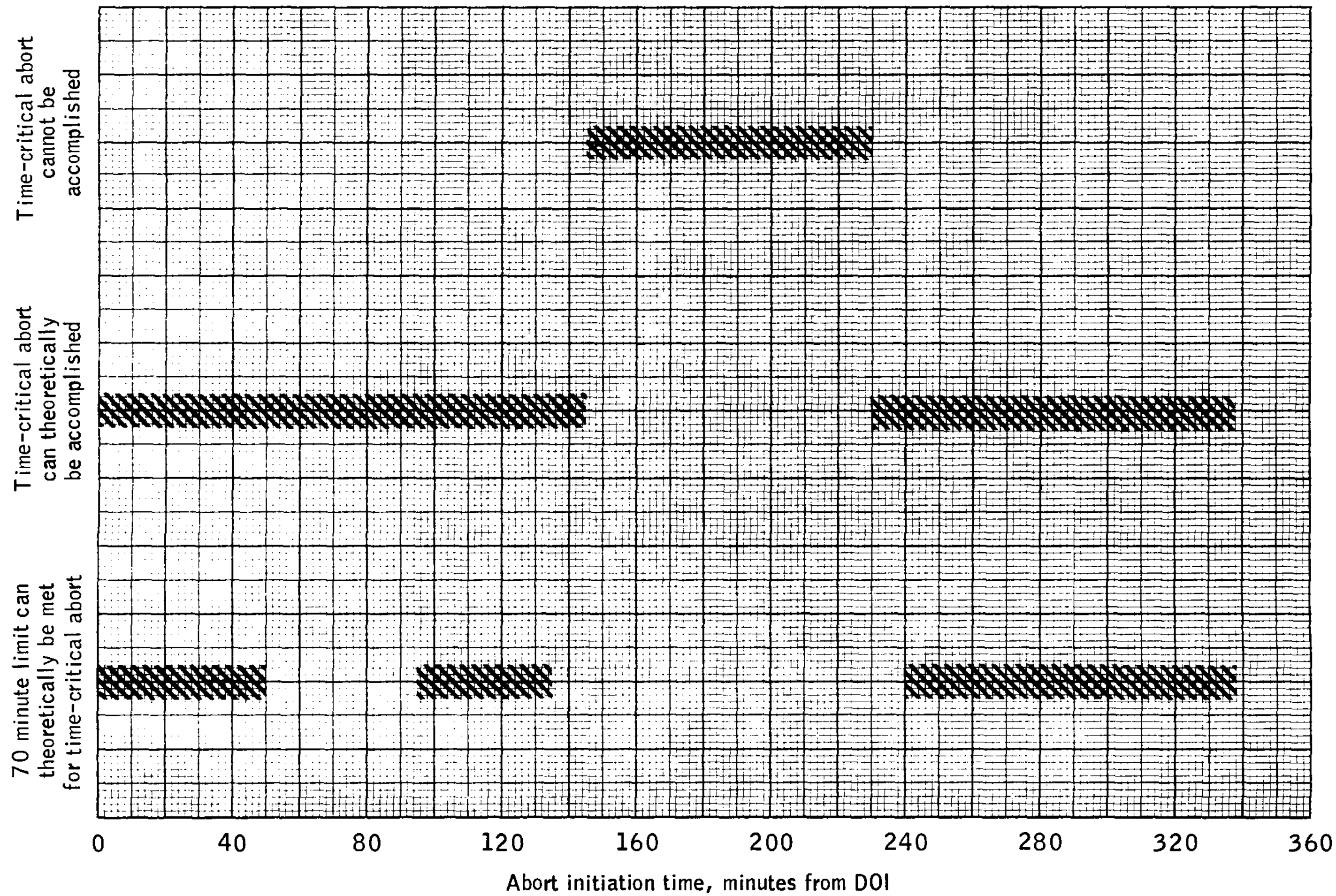


Figure 14.- Abort summary as a function of abort initiation time.

APPENDIX

SPECIFIC EXAMPLES THAT ILLUSTRATE THE USE OF THE FIGURES PRESENTED FOR THE TWO-IMPULSE TIME-CRITICAL ABORT TECHNIQUE

APPENDIX

SPECIFIC EXAMPLES THAT ILLUSTRATE THE USE OF THE FIGURES PRESENTED FOR THE TWO-IMPULSE TIME-CRITICAL ABORT TECHNIQUE

Two specific examples are presented in this apprndix to illustrate the use of the figures presented for the two-impulse maneuver to a 3-n. mi. offset position technique. Case 1 is a time-critical situation which is discovered 20 minutes after DOI and which requires crew transfer to be completed within 70 minutes from the time of the failure. The situation of case 2 has the same failure time as case 1 but requires crew transfer to be completed within the shortest time possible from the time of failure. A copy of figure 2 has been included to illustrate the pertinent data for the two cases.

CASE 1

The pertinent data are as follows for a failure that is discovered 20 minutes after DOI and that requires crew transfer to be completed within 70 minutes after the time of the failure.

1. From section 4.3, under "timeline for abort sequence", 44 minutes are required for crew procedures exclusive of the time between the two-impulse maneuvers.

2. Transfer time = total time - 44 minutes; therefore, the time between the two-impulse maneuvers is 26 minutes.

3. The solid vertical line, which indicates a transfer time of 26 minutes, corresponds to a transfer angle (ωt) of approximately 80°.

4. From section 4.3, under "timeline for abort sequence", 10 minutes are required from the time of the failure to abort initiation; therefore, abort initiation occurs at 30 minutes after DOI.

5. The point at which the solid vertical line intersects the ΔV curve for an abort initiated at DOI plus 30 minutes indicates that the total ΔV required for the two-impulse maneuvers is approximately 480 fps.

6. The point at which the solid vertical line intersects the transfer orbit pericynthion curve indicates that the pericynthion of the transfer orbit is approximately 20 n. mi. below the lunar surface.

In summary, the following trajectory data are obtained for case 1.

Time between the two-impulse maneuvers, min . . .	26
Transfer angle, deg	80
Total ΔV for the two-impulse maneuvers, fps . . .	480
Pericynthion altitude of transfer orbit, n. mi.	-20

CASE 2

The pertinent data are as follows for a failure that is discovered 20 minutes after DOI and that requires crew transfer to be completed within the shortest time possible from the time of the failure.

1. From step 2 of case 1, the theoretical minimum time occurs when the time between the two-impulse maneuvers is zero. However, the ΔV curve for an abort initiated 30 minutes after DOI reaches only to a minimum transfer angle of 30° (dashed vertical line). Therefore, the minimum time from the failure through completion of crew transfer occurs when the 30° transfer is used.

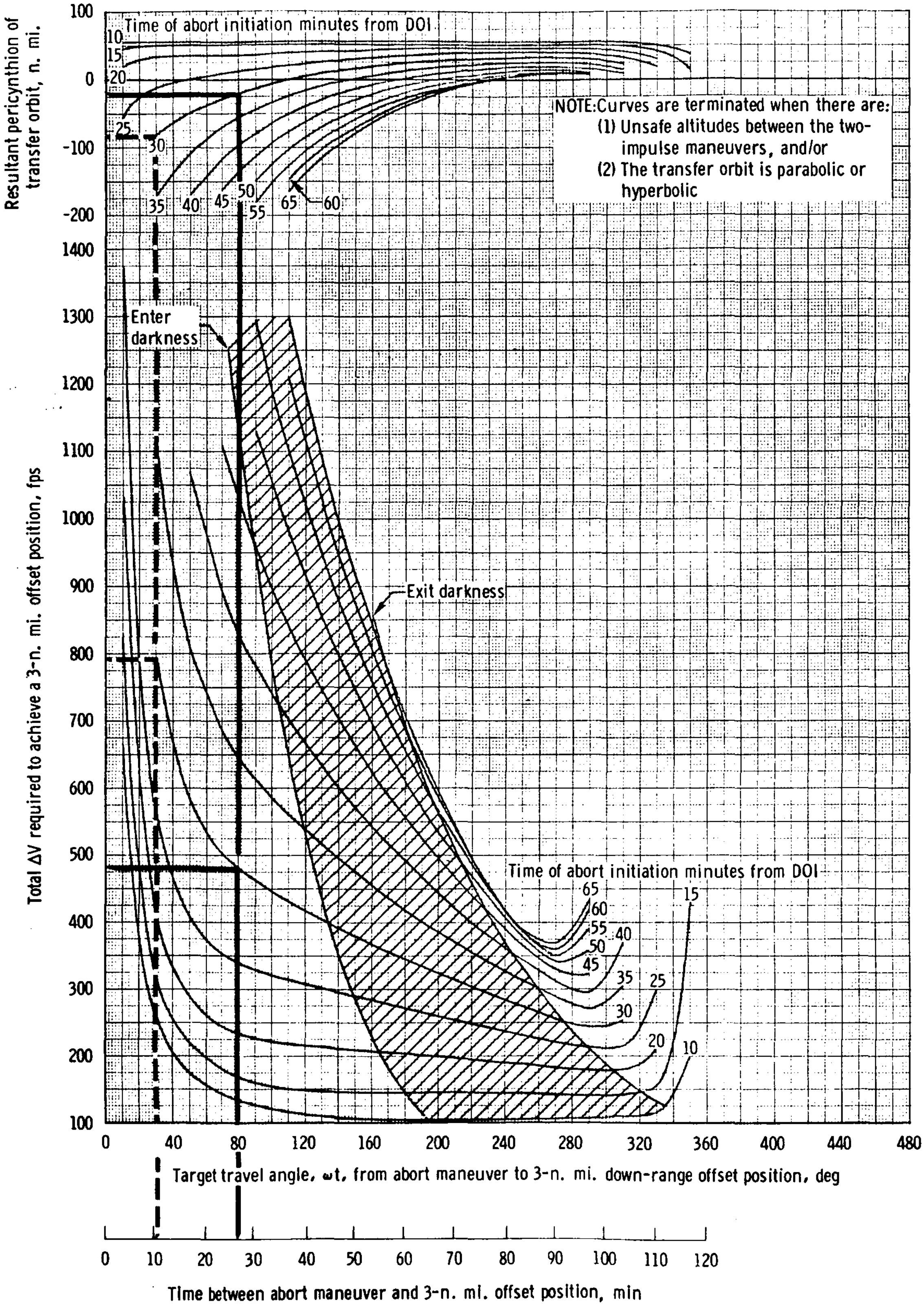
2. From the horizontal time scale, the transfer time for the 30° transfer angle is approximately 11 minutes; therefore, the total time is approximately 55 minutes.

3. The point at which the dashed vertical line intersects the ΔV curve for an abort initiated at DOI plus 30 minutes indicates that the total ΔV required for the two-impulse maneuvers is approximately 795 fps.

4. The point at which the dashed vertical line intersects the transfer orbit pericynthion curve indicates that the pericynthion of the transfer orbit is approximately 85 n. mi. below the lunar surface.

In summary, the following trajectory data are obtained for case 2.

Time between the two-impulse maneuvers, min	11
Transfer angle, deg	30
Total time, min	55
Total ΔV for two-impulse maneuvers, fps	795
Pericynthion altitude of transfer orbit, n. mi.	-80



SAMPLE FIGURE

Figure 2. - Time-critical abort during Hohmann descent by maneuvering LM to 3-nautical mile offset position ahead of CSM.

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