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ALTERNATE LUNAR MISSION PROFILES FOR APOLLO 17 LAUNCHED DECEMBER 6, 1972, C.S.T.

(DECEMBER 7, 1972, G.M.T.)

Mission Analysis Branch

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1.0 SUMMARY

This document describes the alternate lunar mission profiles which have been designed for Apollo 17 (mission J-3). These profiles include alternate missions initiated early in translunar coast (both CSM alone and CSM plus LM) and alternate missions initiated after lunar orbit insertion (LOI).

The data presented provide a detailed sequence of major events for each of the alternate profiles described. These major event sequences are based on the Apollo 17 mission launched December 7, 1972, at 2 hours 53 minutes Greenwich mean time (G.m.t.), on a 72.1° launch azimuth (first opportunity TLI). The data also show the variation of the CSM-alone alternate mission profile as a function of launch azimuth, launch day, and midcourse maneuver time.

The effect of translunar injection (TLI) underburns on the alternate mission profiles is discussed; in addition, specific data are presented which relate attainable lunar parking orbit (LPO) inclination and node, required midcourse correction (MCC), LOI ΔV's, and so forth, to apogee altitude at TLI cutoff. These data dealing with TLI underburns are based on a launch at 2:53 G.m.t. on December 7, 1972, 72.1° launch azimuth, first TLI opportunity.

This document does not include earth orbit alternate missions or alternate lunar landing missions; these topics are covered by references 1 and 2, respectively.

2.0 INTRODUCTION

The objective of alternate mission design is to select mission profiles which will optimize the return (scientific information and operational experience) from a mission when the primary goal, in this case a lunar landing, cannot be achieved.

The Apollo 17 spacecraft carries in one quadrant of the service module a package of scientific experiments designed to study the moon from lunar orbit. This package of scientific experiments is known as the scientific instrument module (SIM). The SIM package on Apollo 17 (fig. 1) is different from the Apollo 15 and 16 SIM packages (which were identical; see ref. 3, fig. 1) in that the particles and fields subsatellite, gamma-ray spectrometer, alpha and x-ray spectrometer, and mass spectrometer experiments have been replaced by the ultraviolet (UV) spectrometer, infrared (IR) scanning radiometer, and lunar sounder experiments. To gain the information from this SIM package is the primary reason for flying a lunar orbit mission, even if a lunar landing is no longer possible.

The basic guidelines used in designing the alternate mission profiles for Apollo 17 remain the same as for Apollo 16 (ref. 3); they are the following:

a. Increase return from the CSM experiments package within the constraints imposed by the remaining guidelines.

b. Minimize impact on overall premission planning.

c. Lunar orbit planning will be based on a 60-n. mi. circular orbit and nominal 6-day stay time in lunar orbit.

d. Maintain any-revolution service propulsion system (SPS) transearth injection (TEI) capability while in lunar orbit.

e. The descent propulsion stage (DPS) may be used for a lunar orbit plane change (LOPC) maneuver, or for LOI when required to achieve a lunar orbit mission.

f. Use standard LOI and TEI techniques (i.e., no multi-impulse).

g. Free-return translunar trajectories will be used for CSM-alone missions.

h. Translunar trajectories for CSM-plus-LM missions will be maintained within DPS capability to return to earth after a LOI failure.

Although the guidelines indicate that a DPS LOPC maneuver is allowed, no requirement for such a maneuver has been identified in alternate mission design for Apollo 17.

Alternate lunar mission design can be divided into two major categories based on when during the mission the decision to abandon the lunar landing is made. First are the alternate mission profiles designed to deal with a no-go for lunar landing in earth orbit or early in translunar coast. Second are the alternate mission profiles designed for those cases in which no-go for landing is after LOI. These two categories of alternate mission profiles are treated in sections 4 and 5 of this document.

3.0 ABBREVIATIONS AND SYMBOLS

a	semimajor axis (orbital element)
APS	ascent propulsion system (LM)
CSM	command and service module
c.s.t.	central standard time
DOI	descent orbit insertion
DPS	descent propulsion system (LM)
EMP	earth-moon plane (coordinate system)
e.s.t.	eastern standard time
FCUA	fuel critical unspecified area (return to earth trajectory mode)
fps	feet per second
g.e.t.	ground elapsed time
G.m.t.	Greenwich mean time
h_{ph}	perilune altitude of translunar trajectory
i	inclination (orbital element)
IR_{MAX}	maximum allowed geocentric inclination of return
I_{sp}	specific impulse
LM	lunar module
LLS	lunar landing site
LOI	lunar orbit insertion
LOPC	lunar orbit plane change
LPO	lunar parking orbit
MCC	midcourse correction
MPL	mid-Pacific line
PDI	powered descent initiation
RTG	radioisotope thermoelectric generator

SG	selenographic (coordinate system)
SIM	scientific instrument module
SPS	service propulsion system (CSM)
TD&E	transposition, docking, and extraction
$TEFT_{MAX}$	maximum allowed transearth flight time
TEI	transearth injection
TLC	translunar coast
TLI	translunar injection
Ω	right ascension of ascending node (orbital element)

4.0 NO-GO FOR LANDING EARLY IN TRANSLUNAR COAST

In designing alternate mission profiles to deal with the contingency of a no-go for lunar landing early in translunar coast the problem can be further divided into the following two categories based on consideration of vehicle configuration.

a. CSM-alone configuration

b. CSM-plus-LM configuration

The first category, the CSM-alone configuration, could result from the inability to extract the LM from the S-IVB, or from some other condition which makes it necessary to leave the LM behind; in either event, such a configuration in itself rules out a landing mission. [It should be noted, however, that there is no situation in which transposition, docking, and extraction (TD&E) will not be attempted solely in order to be able to execute a particular alternate mission profile.] The CSM-alone configuration also restricts (by virtue of the guidelines listed in section 2.0) alternate mission profiles for this case to be constrained to free-return translunar trajectories.

The second category covers the case where the configuration is CSM plus LM. The no-go for landing in this instance could be the result of spacecraft systems problems; or it could result from a TLI burn dispersion of such magnitude that the spacecraft fuel reserves are not sufficient to permit correction of the TLI burn error and completion of a landing mission.

In considering the case of the CSM-plus-LM configuration, a question must be asked concerning the status of the DPS: Can the DPS be used for docked (CSM-plus-LM) maneuvers? If the DPS is not usable, then the alternate mission profiles for this situation must again be constrained to free-return translunar trajectories. In this case a real-time decision will be required on whether to retain the LM for life support systems backup or to jettison the LM and revert to the CSM-alone configuration. Retaining the LM and flying a free-return translunar trajectory will greatly reduce the obtainable LPO inclination and TLI underburn coverage.

The following subsections present in detail the alternate mission philosophy and profiles for the CSM-alone and the CSM-plus-LM configurations. They also consider the effects of TLI underburns on these profiles.

4.1 CSM-Alone Configuration

As mentioned previously, the data return from the CSM SIM experiments package provides the primary motivation for flying an alternate lunar orbit mission. The major objective of alternate mission planning is to select mission profiles which maximize the return from the mission under certain contingency situations. For the case of an Apollo 17 CSM-alone contingency, it was determined (ref. 4) that this objective (maximizing mission return) could best be accomplished by maintaining the nominal LPO inclination and shifting the ascending node as far east of nominal as possible. (Note: To fly a CSM-alone mission to the nominal LPO is not possible because of the free-return constraint on CSM-alone translunar trajectories.) The nominal LPO inclination is approximately 20° (20° is the acute angle between the LPO plane and the lunar equatorial plane; measured in the usual sense, the inclination is 160°). The ascending node of the nominal LPO is approximately 130.5° on rev 3.

4.1.1 Nominal TLI.- In selecting the alternate LPO to yield maximum easterly node shift, it was important to ensure that the selected LPO would be accessible across the entire Apollo 17 quarterly launch window (December 6, 7, 1972; January 4, 5, 6, 1973; and February 3, 4, 1973; ref. 5). Therefore, a study was conducted to determine the range of ascending nodes which would be accessible across the quarterly launch window for an LPO with 20° inclination. The study results show this ascending node range to be approximately 171.4° to 188° referenced to rev 3 (about 5.3 hr after LOI). The constraint which imposes these limits is the 40-n. mi. minimum acceptable perilune altitude (h_{ph}) of the required free-return translunar trajectory. The 188° limit corresponds to the December T+24 (December 7, e.s.t.) launch opportunity, and the 171.4° limit corresponds to the February T-0 (February 4, e.s.t.) opportunity. These limits were computed by using the opening of the corresponding daily launch windows, and, because there is typically some variation in h_{ph} across the daily window, the alternate LPO ascending node selected was 185° versus the maximum possible 188°. The 185° (rev 3) ascending node represents approximately 55° easterly shift with respect to the nominal mission LPO.

A comparison of the selected alternate lunar orbit groundtrack with the nominal Apollo 17 lunar groundtrack is shown in figure 2. For CSM-alone missions, this alternate LPO is defined by the following set of pseudo lunar landing site targets which are used in computing the required MCC and LOI maneuvers:

Radius at lunar landing site, R_{LLS}	938.4935 n. mi.
Latitude of lunar landing site, ϕ_{LLS}	0°
Longitude of lunar landing site, λ_{LLS}	5°E
Azimuth at lunar landing site, ψ_{LLS}	250°
Time from LOI to first pass, Δt_{LLS}	≈5.3 hr

In outline form, the basic alternate mission profile for the case of a no-go for landing early in translunar coast with the CSM-alone configuration is as follows:

a. An SPS midcourse maneuver at TLI plus 9 hours to establish the required free-return trajectory.

b. An SPS LOI to a 60-n. mi. by 170-n. mi. orbit having the desired lunar groundtrack.

c. After two revs in the 60 by 170 LPO, perform an SPS maneuver to circularize the orbit at about 60 n. mi.

d. Stay approximately 6 days in lunar orbit to gather data with the SIM experiments package.

e. Perform an SPS TEI on rev 80 to return to the mid-Pacific line (MPL) at approximately 304 hours g.e.t. with an inclination of return less than or equal to 70°.

A more detailed description of this alternate mission profile is provided by table I, which presents the sequence of major events for the CSM-alone mission corresponding to a December 7, 1972, G.m.t. launch at 72.1° launch azimuth, first

opportunity nominal TLI. This case represents the opening of the December 1972 launch window for Apollo 17. One item noted in table I and not mentioned previously in the profile outline is a possible trim burn in lunar orbit. The purpose of this maneuver (if performed) will be to maintain the LPO perilune altitude at no less than 52 n. mi. for lunar sounder operation without changing the period of the orbit. To make the trim burn and leave the orbit period unchanged requires that the semimajor axis (a) remain constant. One method of doing this is to circularize the orbit at a radius equal to the current semimajor axis magnitude. The LPO as presented in table I starts out (after circularization) approximately 60-n. mi. circular, and without a trim burn the orbit perturbs to approximately 44.3 n. mi. by 75.2 n. mi. at TEI with perilune about 47°E longitude. The LPO perilune crosses the 52-n. mi. lunar sounder operation limit about 146 hours g.e.t. Performing a trim burn approximately 145:43 g.e.t. to circularize the LPO without changing the period would cost about 35 fps ΔV and would ensure a perilune altitude greater than 52 n. mi. for the remainder of lunar orbit stay time.

Table I presents detailed information for the CSM alternate mission profile for the particular case corresponding to the opening of the Apollo 17 December 1972 launch window. Figure 3 shows how some of the important parameters of this alternate mission profile vary across the December launch window for both first and second TLI opportunities with constant time from TLI to MCC of 9 hours.

The variation of required midcourse (MCC) ΔV versus launch azimuth is given in figure 3(a) for the December 7 and 8 (G.m.t.) launch opportunities. The figure shows that the required MCC ΔV decreases almost linearly (from 642 fps to 478 fps for first TLI opportunity) across the December 7 launch window, and on the December 8 launch window the required MCC ΔV is considerably smaller and remains nearly constant (97 fps to 122 fps) across the launch window. This difference in magnitude and behavior of required MCC ΔV is caused by the different translunar flight times for these two launch dates with respect to the required free-return flight time. On December 7, TLI is targeted to provide an essentially constant G.m.t. of LOI; thus, the nominal translunar flight time decreases from approximately 85.6 hours to 82.1 hours across the window. In contrast, the translunar flight time of the required free-return is approximately 74 hours and remains almost constant across the launch window. However, for December 8, TLI is targeted to provide an essentially constant translunar flight time of approximately 69 hours across the launch window, and again the required free-return flight time remains almost constant at about 71 hours across the window. The required free-return midcourse ΔV is a direct function of the difference in translunar flight time between the nominal and the desired free-return trajectory. The effect of this translunar flight time difference is also reflected in the difference in the initial terminator longitudes shown in figure 2.

Figure 3(b) shows the change in LOI ΔV versus launch azimuth and the associated variation of LOI plane change (Δ azimuth of LOI) is shown by figure 3(f). For December 7 the LOI ΔV range is from approximately 4000 fps to 4076 fps, and the associated Δ azimuth range is approximately 22.8° to 23.63°. On December 8, the LOI ΔV varies from about 3822 fps to 3890 fps and the corresponding variation in Δ azimuth is about 19.97° to 20.7°. These variations across the daily launch windows are functions of the launch azimuth and TLI opportunity. The differences in LOI ΔV and Δ azimuth between the two launch days (December 7 and 8) are caused by the change in earth-moon geometry and its effect on the selenographic locus of free-return trajectories.

The range of postcircularization SPS ΔV available for the CSM-alone alternate mission across the December 1972 launch window is presented by figure 3(c). Postcircularization SPS ΔV available is the SPS ΔV remaining after LOI and circularization. It represents the total SPS ΔV capability for TEI and transearth midcourses. The figure shows that the minimum postcircularization ΔV available is approximately 4485 fps. This minimum occurs at the opening of the launch window (December 7, 1972, G.m.t., launch at 72.1° launch azimuth, first TLI opportunity). The range of SPS ΔV available postcircularization is approximately 4485 fps to 4740 fps on December 7 and approximately 5155 fps to 5240 fps on December 8. The difference between December 7 and 8 in postcircularization SPS ΔV available is the result of the previously discussed differences in MCC and LOI ΔV's for these launch dates. One further note about postcircularization SPS ΔV available is that computations of these ΔV reserves for the CSM-alone alternate mission profile are based on a post-TD&E CSM/SPS ΔV available of 9297 fps as given in reference 6, nominal engine performance, and no allowance has been made for expendables weight loss.

Figures 3(d) and (e) show the variation in perilune altitude of the translunar trajectory and the G.m.t. of perilune, respectively, for the CSM-alone alternate mission profile across the December 1972 launch window. The range on perilune altitude is approximately 49.2 n. mi. to 51 n. mi. for December 7 and approximately 45.3 n. mi. to 47.8 n. mi. for December 8. The perilune altitudes are referenced to the mean lunar radius (938.4935 n. mi.) and the small variations seen across the launch window result from the optimization process, which seeks to minimize the sum (MCC ΔV + LOI ΔV) with perilune altitude as one of the degrees of freedom. The G.m.t. of perilune shows a nearly linear increase across the window for both launch days. This is due to the fact that the translunar flight times of the required free-return trajectories remain essentially constant across the launch window while of course the G.m.t. of TLI increases linearly.

Figure 3 has presented data showning how some of the important CSM-alone mission parameters vary across the launch window for a constant time from TLI to MCC. Figure 4 shows the behavior of these same parameters as functions of the time from TLI to MCC while holding launch azimuth and TLI opportunity constant. The curves in figure 4 were generated based on the opening of the daily launch windows (72.1° launch azimuth, first TLI opportunity) for the December 7 and 8 (G.m.t.) launch days. They concern MCC maneuver times in the range from TLI + 1 hour to TLI + 60 hours.

Figure 4(a) shows required MCC ΔV as a function of the time from TLI to the midcourse maneuver. For both launch days the magnitude of the required MCC ΔV exhibits a marked decrease for the first few hours after TLI and then almost a linear increase until several hours before LOI. The substantial decrease in required MCC ΔV for the first few hours following TLI results from the tradeoff in magnitude of velocity vector direction change necessary versus the magnitude of the velocity vector. The variation in LOI ΔV as a function of midcourse maneuver time is presented in figure 4(b), and figure 4(f) shows the corresponding behavior of LOI Δ azimuth. For December 7 the required LOI ΔV increases from about 4000 fps for a MCC at TLI + 1 hour to about 4136 fps for a MCC time of TLI + 60 hours; for December 8 LOI ΔV decreases as a function of MCC time from about 3855 fps for MCC at TLI + 1 hour to about 3693 fps for MCC at TLI + 60 hours. Figure 4(c) shows the effect of midcourse maneuver time on postcircularization SPS ΔV available. On December 7 MCC maneuver time has a very definite effect on postcircularization SPS ΔV reserves with the best ΔV reserves (≈4488 fps) corresponding to MCC at TLI + 8.5 hours. However, on December 8 the postcircularization SPS ΔV reserves show

only a small variation as a function of MCC maneuver time. (December 8 range of ΔV reserves approximately 5170 fps to 5270 fps). These differences between December 7 and 8 are due in major part to the difference in nominal translunar trajectories between these two launch days. Again, the SPS ΔV reserves presented here are based on a nominal post-TD&E CSM/SPS ΔV available of 9297 fps, nominal engine performance, and no allowance for expendables weight loss. Figure 4(d) shows the influence of MCC maneuver time upon perilune altitude of the resulting free-return trajectory, and the corresponding G.m.t. of perilune is presented in figure 4(e).

The range of postcircularization SPS ΔV available for the CSM-alone alternate mission across the Apollo 17 December 1972 launch window has been presented in figure 3(c), and figure 4(c) has shown the expected variation in postcircularization SPS ΔV available as a function of MCC maneuver time. Figure 5 shows postcircularization ΔV required for TEI as a function of LPO rev number for the CSM-alone alternate lunar orbit. Figure 5(a) corresponds to the opening of the window for a December 7 (G.m.t.) launch and figure 5(b) corresponds to the opening of the December 8 (G.m.t.) launch window. In selecting an alternate mission lunar orbit, one of the guidelines (section 2.0) imposed is the requirement to maintain any-revolution SPS TEI capability. In applying this guideline, acceptable TEI solutions are usually constrained to provide a landing on the MPL with return inclination $\leq 70°$; an additional requirement is that the CSM/SPS maintain at least a 500-fps post-TEI ΔV reserve to allow for weather avoidance and 3σ low engine performance. Comparison of figures 5(a) and 5(b) shows that the TEI ΔV requirements are slightly greater on December 7 than on December 8. This difference is due to the change in earth-moon geometry between the two days. Furthermore, analysis of figure 5(a) indicates that 4300 fps is about the minimum postcircularization SPS ΔV capability required to provide any-revolution TEI with 500 fps post-TEI SPS ΔV reserves and transearth flight times not exceeding 5 days. As noted previously, the lowest expected postcircularization SPS ΔV reserve across the December launch window is approximately 4485 fps, corresponding to the opening of the window on December 7 [fig. 3(c)]. This is well above the minimum requirement of 4300 fps, and, in addition, reference to figure 4(c) shows that the time of the MCC maneuver could be delayed to TLI + 47 hours before the 4300 fps postcircularization SPS ΔV limit is reached.

4.1.2 TLI underburns.- The major effect of an underburn in TLI is to cause a decrease in the apogee altitude at cutoff. This decrease must be compensated for in the midcourse maneuver. Figure 6 shows the effect upon apogee altitude of TLI underburns in the range 0 to 36 seconds. The larger the TLI underburn, the larger the midcourse ΔV required to compensate becomes and the less SPS ΔV there is available for LOI and TEI. Therefore, in order to maintain a post-TEI SPS ΔV reserve of 500 fps, it is necessary to counter the increased expenditure of SPS fuel in MCC with an equal reduction of SPS fuel required for LOI plus TEI. The objective is to obtain the required reduction in LOI ΔV and TEI ΔV while maintaining the most favorable combination of LPO inclination and ascending node. The effect of varying LPO inclination and node upon the required LOI ΔV is easily determined; however, its effect upon TEI ΔV requirements is considerably more difficult to evaluate. The difficulty in determining the TEI ΔV requirement arises because the TEI ΔV of interest is not necessarily the nominal end of mission TEI, but rather the maximum ΔV required to meet the any-revolution TEI constraint.

Figure 7 presents TEI ΔV requirements as a function of lunar orbit inclination and ascending node. It has been shown (ref. 7) that the TEI ΔV required is directly related to the earth-moon plane inclination (i_{EMP}) and ascending node (Ω_{EMP}) of the LPO. Figure 7 shows this relationship for LPO inclinations in the range 154° EMP to 170° EMP for ascending nodes from 0° EMP to 360° EMP. The TEI ΔV curves shown represent the cheapest TEI solution (in terms of ΔV required) within the constraints that transearth flight time be $\leq$ 100 hours and inclination of return be $\leq$ 70°. The curves presented in figure 7 make it possible to obtain a good estimate of the maximum TEI ΔV requirement to be expected for a given LPO without the need of computing numerous rev-by-rev TEI solutions to various MPL landing days, as was done for figure 5. For example the CSM-alone alternate LPO has an EMP inclination of about 154° and an initial (rev 3) EMP ascending node of about 183°. During the LPO stay the ascending node regresses to the west (decreases) at the rate of approximately 1° per rev. Reference to the 154° EMP inclination curve of figure 7 shows that TEI ΔV required reaches a maximum of approximately 3810 fps as the ascending node passes through 160° EMP. Adding 500 fps pad for weather avoidance and 3σ low engine performance would yield 4310 fps as the minimum postcircularization SPS ΔV required to provide any-revolution TEI capability. This compares very closely with the 4300 fps as determined from analysis of figure 5(a). Note that the 3810 fps ΔV maximum for the 154° EMP inclination curve in figure 7 corresponds almost exactly with the ΔV maximum of the 100-hour flight time contour in figure 5(a).

To maintain maximum LPO inclination in the presence of TLI underburns it is necessary to allow the LPO ascending node to be free. However, for Apollo 17 it was determined (ref. 8) that from the standpoint of science return the most favorable approach was not to maximize inclination but rather to maintain the LPO groundtrack as close as possible to the nominal CSM-alone LPO. It was found that this objective could best be achieved by holding the LPO selenographic ascending node, Ω_{SG} (rev 3), constant at the nominal 175°W and reducing the LPO selenographic inclination, i_{SG}, as required to maintain satisfactory ΔV reserves. Holding Ω_{SG} constant at 175°W and decreasing i_{SG} shifts the initial Ω_{EMP} westward and causes i_{EMP} to decrease; however, Ω_{EMP} does not move far enough west to miss the peak ΔV region (Ω_{EMP} = 160° to 170°) shown in figure 7. Therefore, the maximum TEI ΔV requirements during LPO stay are dictated by the peak ΔV's shown in this region of figure 7 (Ω_{EMP} = 160° to 170°). Figure 8 is a plot of the peak TEI ΔV's required as a function i_{EMP}. It also shows i_{EMP} versus i_{SG} for fixed Ω_{SG} = 175°W. From this figure it is possible to cross plot (for rev 3 Ω_{SG} = 175°W) maximum TEI ΔV required versus i_{SG} of the LPO. Figure 9 shows this crossplot of required TEI ΔV versus LPO inclination (i_{SG}) and also shows postcircularization SPS ΔV available as a function of both LPO inclination (i_{SG}) and apogee altitude at TLI cutoff. Figure 9(a) presents these data for a MCC maneuver time of TLI + 1 hour, and figure 9(b) for a MCC maneuver time of TLI + 3 hours. The intersection points of the postcircularization SPS ΔV available curves with the TEI ΔV required + 500 fps curve define the maximum LPO inclination (for Ω_{SG} = 175°W, rev 3) available as a function of apogee altitude at TLI cutoff.

Figure 10 presents the important parameters for the CSM-alone alternate mission as defined by the intersection points in figures 9(a) and (b). Figure 10(a) shows selenographic inclination (i_{SG}) as a function of apogee altitude at TLI cutoff, and figure 10(b) shows the corresponding postcircularization SPS ΔV available. These figures show that for apogee altitudes (h_a) at TLI cutoff in the range 242 000 n. mi. to approximately 203 000 it is possible to maintain the nominal 160° i_{SG} by moving the MCC maneuver time from TLI + 9 hours (for h_a = 242 000 n. mi.) to TLI + 3 hours (for h_a = 203 000 n. mi.). At h_a = 203 000 n. mi. the postcircularization SPS ΔV reserve reaches the 4300 fps limit set for the nominal CSM-alone LPO. In the 203 000 n. mi. to approximately 147 000 n. mi. apogee altitude range, maximum LPO inclination can be achieved by performing the MCC maneuver at TLI + 3 hours, and for apogee altitudes less than 147 000 n. mi. the best LPO inclination can be obtained by shifting the MCC to TLI + 1 hour. The minimum acceptable postcircularization CSM/SPS ΔV available (for low inclination LPO's) is considered to be approximately 3300 fps, 2800 fps for TEI plus 500 fps pad for weather avoidance and 3σ low engine performance. Figure 10(b) shows that the minimum apogee altitude at TLI cutoff for a CSM-alone mission is about 71 000 n. mi. for a MCC maneuver time of TLI + 3 hours and about 57 000 n. mi. for a MCC maneuver time of TLI + 1 hour. Note that these apogee altitude limits apply to an LPO with fixed selenographic ascending node (Ω_{SG} = 175°W, rev 3). The minimum allowable apogee altitude at TLI cutoff can be extended to about 52 000 n. mi. for the MCC at TLI + 1 hour case by freeing Ω_{SG} of the LPO. This minimum apogee altitude CSM-alone profile requires a TLI + 1 hour midcourse targeted to provide a minimum (in terms of required MCC ΔV) free-return lunar flyby having a 60-n. mi. perilune altitude; from the flyby trajectory a coplanar LOI maneuver is performed. The MCC ΔV for this case is about 2976 fps, the LOI ΔV (coplanar to a 60 n. mi. by 170 n. mi. LPO) is about 2875 fps, and the postcircularization SPS ΔV available is approximately 3310 fps.

Figure 10(c) shows the CSM-alone mission required MCC ΔV as a function of MCC maneuver time and the apogee altitude at TLI cutoff. The important thing to note in this figure is that for small TLI underburns the earliest possible MCC maneuver time does not yield the cheapest MCC ΔV. Figure 10(d) shows the variation in perilune altitude with apogee altitude at TLI, which results from targeting for the LPO inclinations specified in figure 10(a). Figure 10(e) presents azimuth at the pseudo lunar landing site (ψ_{LLS}) as a function of apogee altitude at TLI cutoff. The required LOI ΔV and corresponding plane change in LOI (Δ azimuth LOI) are shown in figures 10(f) and 10(g), respectively.

The data which have been presented in this section dealing with the CSM-alone alternate mission profile in the presence of TLI underburns were all generated for the particular case corresponding to the opening of the December 1972 launch window. As noted previously [section 4.1.1, fig. 3(c)], from the standpoint of postcircularization SPS ΔV reserves this is the worst case for the December launch window, and, particularly, the postcircularization SPS ΔV situation is much better on December 8 than December 7. It is therefore reasonable to expect that the LPO inclinations specified in figure 10(a) will remain attainable for corresponding TLI underburns on December 8.

4.2 CSM-Plus-LM Configuration

When the spacecraft configuration is CSM plus LM and a no-go for lunar landing occurs early in translunar coast, then the alternate mission profile to be followed depends upon both the usability of the DPS and the apogee altitude at TLI cutoff. If the DPS cannot be used for docked DPS maneuvers then the alternate mission profile reverts to the case of the CSM-alone configuration. In this situation a real-time decision will be required on whether or not to retain the LM as a life support systems backup. If the LM is retained through LOI, then at the opening of the window on December 7 it would just be possible to fly a minimum CSM-alone lunar orbit mission; the postcircularization SPS ΔV reserves for this case would be in the range 2950 fps to 3050 fps. The situation on December 8 is considerably better because of the greatly reduced MCC ΔV requirement.

4.2.1 Nominal TLI.- For the case of a nominal TLI burn and a usable DPS, the alternate mission plan is to follow the nominal landing mission profile through LOI and then proceed as in the case of a no-go for landing which occurs after LOI (section 5.0 of this document). The reason for remaining on the nominal profile through LOI is twofold. First, staying on the nominal LPO groundtrack provides the opportunity of conducting the nominal mission orbital science plan. Second, remaining on the nominal profile retains the capability to achieve a landing in the event that the problem causing the no-go contingency can be cleared up or circumvented.

4.2.2 TLI underburns.- As mentioned previously the major problem associated with TLI underburns is the resulting increase in required MCC ΔV, which must be compensated for by a corresponding reduction in one or more of the subsequent maneuvers (LOI, DOI, LOPC, and TEI). For small TLI underburns it is still possible from a performance standpoint to achieve a lunar landing provided certain modifications are made to the mission profile to yield the required reduction in LOI, LOPC, and TEI ΔV. Reference 2 presents a description of these modified mission profiles for Apollo 17 and shows the applicable range (in terms of apogee altitude at TLI cutoff) of each profile for the case of a launch at the opening of the December 7, G.m.t. launch window. Figure 1 of reference 2 shows that a landing mission can be maintained for apogee altitudes (h_a) at TLI cutoff $\geq$ 118 000 n. mi., but for h_a less than 170 000 n. mi., it is necessary to give up the nominal lunar groundtrack. The minimum landing mission profile associated with h_a equal 118 000 n. mi. at TLI cutoff is presented in more detail in reference 9.

For the case of CSM plus LM usable DPS configuration and TLI underburns resulting in apogee altitudes in the range 242 000 n. mi. to 118 000 n. mi., the alternate mission plan is to follow (at least through LOI) the landing mission profiles as specified in reference 2. The reasons for remaining on a landing mission through LOI are the same for this case as noted previously for the nominal TLI case. If the apogee altitude at TLI cutoff is $\geq$ 170 000 n. mi., the post-LOI groundtrack remains nominal and essentially the nominal lunar orbit science plan can be executed for these cases. When apogee altitude at TLI cutoff is less than 170 000 n. mi., the post-LOI lunar groundtracks as specified in reference 2 are nonnominal; however, for these cases, there exists the option of performing a DPS LOPC maneuver to re-establish the nominal groundtrack.

For apogee altitudes at TLI cutoff (h_a) less than 118 000 n. mi., it is no longer possible to conduct a lunar landing mission, and for these cases there exist essentially two alternate mission options. The first option is to perform a DPS LOI

to achieve the nominal lunar groundtrack (i_{SG} = 160°; Ω_{SG} = 130.5° - rev 3). The second option is to continue with an SPS LOI profile by accepting a reduced inclination groundtrack (i_{SG} = 170°; Ω_{SG} = 130.5° - rev 3). By selecting the option of reduced LPO inclination and performing the circularization maneuver with the DPS, it is possible to retain an SPS LOI profile down to an h_a of approximately 101 000 n. mi. The DPS LOI option, however, makes it possible to maintain the nominal lunar groundtrack for h_a as low as about 41 000 n. mi., and with DPS LOI the reduced inclination groundtrack can be extended to h_a of approximately 33 000 n. mi. To fly a lunar orbit mission for h_a less than 33 000 n. mi., it is necessary to give up LPO ascending node location as well as to reduce LPO inclination. Reference 10 defines the minimum h_a for December 7, G.m.t., launch to be about 28 000 n. mi. and presents an outline of the required mission profile. The LPO inclination and node for this case are i_{SG} of 174° and Ω_{SG} of about 80.5°W on rev 3.

One of the most important differences from a performance standpoint between CSM-plus-LM and CSM-alone alternate missions is in the constraints on the translunar trajectories and the effects which these constraints have on the required MCC ΔV's. As stated in the alternate mission guidelines (section 2.0) translunar trajectories for the CSM-plus-LM (usable DPS) configuration will be maintained within the usual DPS capability to return to earth after an LOI failure. To be more precise the translunar trajectory should be constrained so that the abort ΔV required, in the event of a failure to perform LOI, is less than the minimum of docked DPS ΔV available and CSM/SPS ΔV available. In general, this translunar trajectory constraint results in considerably lower required MCC ΔV than does the corresponding free-return constraint for CSM-alone missions. However, there is an added complication for the CSM-plus-LM case; namely, both the ΔV required for an abort and the ΔV available are functions of the MCC maneuver which is performed.

Figure 11 presents docked DPS ΔV available and CSM/SPS ΔV available as a function of docked SPS ΔV expended. Use of this figure permits determination of the abort ΔV available as a function of MCC maneuver ΔV (assuming an SPS MCC). Figure 12 presents the important CSM-plus-LM alternate mission parameters as functions of the apogee altitude at TLI cutoff. Figure 12(a) shows required MCC ΔV (MCC maneuver time TLI + 1 hr) for both fixed and unconstrained translunar flight time, and for both the nominal and the reduced inclination LPO's. Figure 12(b) shows the resulting perilune-plus-2-hour (PC + 2 hr) abort ΔV required and the corresponding docked DPS ΔV available. The PC-plus-2-hour abort requirement presents no problem when targeting to the nominal LPO but, for the reduced inclination LPO and h_a at TLI cutoff less than 76 000 n. mi., the PC-plus-2-hour abort ΔV required will exceed the docked DPS ΔV available if translunar flight time is unconstrained. The resulting g.e.t. of perilune with unconstrained translunar flight time for both the nominal and reduced inclination LPO is shown in figure 12(c) as a function of h_a at TLI cutoff. Figure 13 shows the relationship between PC-plus-2-hour abort ΔV required and the g.e.t. of perilune for the nominal and reduced inclination LPO mission profiles.

A comparison of the LOI ΔV required versus docked DPS ΔV available for both the nominal and the reduced inclination groundtracks is presented in figure 12(a) as a function of the h_a at TLI cutoff. These data show that the docked DPS ΔV available is never sufficient to complete an LOI to a 60-n. mi. by 170-n. mi. LPO for either the nominal or reduced inclination groundtrack. To perform a DPS LOI for such cases, it is necessary to accept an initial LPO apolune altitude greater than 170 n. mi. and a corresponding increase in the circularization ΔV required. Figure 12(e) shows the minimum apolune altitude which can be achieved and also the corresponding circularization ΔV required for varying apogee altitude at TLI cutoff. Note in this figure that the minimum apolune altitude curves shown result from constraining the DPS LOI maneuver to perform all of the plane change required to establish the desired lunar groundtrack. Lower apolune altitudes could be obtained by giving up the lunar groundtrack. Another constraint which must be considered in the case of a DPS LOI is the requirement that the first SPS maneuver following a long docked DPS burn (such as DPS LOI) must be at least 40 seconds long. However, this constraint does not affect the curves in figure 12(e) except the reduced inclination LPO curves for h_a less than approximately 45 000 n. mi.

Figure 12(f) summarizes the postcircularization CSM/SPS ΔV reserves for the various CSM-plus-LM alternate mission options as a function of apogee altitude at TLI cutoff. It also shows what are considered to be the acceptable minimum postcircularization CSM/SPS ΔV reserves for the nominal and reduced inclination lunar groundtracks. The intersections of the ΔV available curves with the respective ΔV reserve limits define for each alternate mission profile the minimum h_a which were discussed earlier. For the DPS LOI reduced inclination LPO, figure 12(f) indicates a minimum h_a of about 30 500 n. mi., whereas the minimum h_a stated previously for this profile was approximately 33 000 n. mi. The reason for this discrepancy is that the low h_a portion (h_a less than approximately 45 000 n. mi.) of this curve is in violation of both the PC-plus-2-hour abort ΔV constraint and the 40-second SPS burn time constraint. It is believed that the enforcement of these constraints would shift the intersection point of the ΔV available curve to about 33 000 n. mi.

5.0 NO-GO FOR LANDING AFTER LOI

The contingency situation of a no-go for landing after LOI can be subdivided into three categories based on whether the no-go occurs prior to DOI, after DOI, or results from a PDI abort. However, for Apollo 17 the alternate mission plan is essentially the same for all three cases, namely, fly the nominal lunar orbit groundtrack and conduct as nearly as possible the nominal lunar orbit science plan. It is assumed that, unless the no-go contingency involves an SPS failure, DOI will be performed and the nominal mission plan will be continued as long as possible. The following is an outline of the basic alternate mission plan for the case of a no-go for landing which occurs after LOI:

a. Follow the nominal mission profile as long as possible.

b. Circularize the LPO at approximately 60 n. mi.

c. Stay in lunar orbit approximately 6 days and conduct as nearly as possible the nominal mission science plan.

d. Deorbit and impact LM on lunar surface.

e. Perform an SPS TEI on rev 75 to return to the MPL at about 304 hours g.e.t. with inclination of return $\leq 70°$.

Table II provides a more detailed description of this alternate mission profile for the case of a December 7, 1972, G.m.t., launch at 72.1° launch azimuth, first TLI opportunity. This case represents the opening of the December 1972 launch window for Apollo 17. The time specified in the table for the circularization maneuver (123:26:34.3 hr:min:sec g.e.t.) corresponds to approximately 6-1/2 revs past the nominal time of PDI. This does not represent from a performance (ΔV reserve) standpoint the maximum wave-off capability; however, by 7 revs after nominal PDI all 210-foot antenna coverage of a landing would be lost, and, more important, by this time the crew will have been awake for almost 24 hours. For these reasons, 6 to 7 revs after nominal PDI time is considered to be a reasonable time frame in which to initiate an alternate mission profile. Also, table II indicates that the circularization maneuver is a docked SPS burn; this assumes that the nominal CSM circularization prior to PDI was not performed. If nominal CSM circularization was performed, then the circularization maneuver specified in the table would probably be replaced by a DPS active rendezvous.

The alternate mission profile as outlined previously and detailed in table II indicates that the LM is to be deorbited. However, the real-time option still remains to retain the LM and perform a DPS TEI. Two problems arise if this latter option is selected. First, if the DPS is being saved for TEI, the stay time in lunar orbit must be reduced because of the LM SHe (supercritical helium) constraint. For a December 7, G.m.t., launch, this constraint limits the total stay time in lunar orbit to about 68 hours, and for a December 8 launch the orbit stay time would be limited to about 58 hours. Second, if the DPS is retained for TEI or until just prior to TEI, the LM structure causes interference with the lunar sounder antenna patterns, and degrades the results of this experiment.

One final note with regard to the alternate mission profile detailed in table II concerns the possible lunar orbit trim burn. As in the case of the CSM-alone alternate mission (section 4.1.1) the purpose of this maneuver (if performed) will be to maintain the LPO perilune altitude $\geq$ 52 n. mi. for lunar sounder operation. Again the approximate maneuver times given in the table correspond to a maneuver which circularizes the orbit without changing the orbital period. The ΔV cost for this maneuver is again approximately 35 fps.

6.0 CONCLUSIONS

Alternate lunar orbit mission profiles and guidelines for Apollo 17 (mission J-3) have been presented and discussed. These profiles have been designed to cover no-go for landing situations which occur either during translunar coast or after LOI for both CSM-alone and CSM-plus-LM configurations.

A CSM-alone alternate mission lunar groundtrack which is accessible across the entire Apollo 17 quarterly launch window has been selected. Data are presented which show in detail the performance of this alternate mission profile across the December 1972 launch window and which show how this profile must be modified in the presence of TLI underburns.

The CSM-plus-LM alternate mission lunar groundtrack for Apollo 17 is essentially the same as that of the nominal mission. Data are presented which show the effect of TLI underburns on this profile and the modifications required to maintain a lunar orbital mission despite these underburns.

TABLE I. - SEQUENCE OF MAJOR EVENTS - CSM ALONE MISSION

[DECEMBER 7, 1972 (G.M.T.), LAUNCH; 72.1° LAUNCH AZIMUTH; FIRST OPPORTUNITY TLI]

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary	
Post-TLI events[a]				
MCC-1	12:25:27.9 (TLI plus 9 hr)	Dec. 7, 1972 09:18:27.9	ΔV, fps	645.5
			Inclination free-return, deg	42.2
			Latitude free-return, deg:min	18:20N
			Longitude free-return, deg:min	28:43W
			Landing time free-return, hr:min, g.e.t.	146:00
SIM door jettison	72:39:07.0 (LOI minus 4.5 hr)	Dec. 9, 1972 21:32:07.0	Average ΔV imparted to door, fps	13.7
Lunar orbit insertion (LOI)				
Burn initiation	77:09:07.0	Dec. 10, 1972 02:02:07.0	Mass, lb	62 513.0
			Altitude[b], n. mi.	100.29
			Selenographic latitude, deg	2.24
			Selenographic longitude, deg	-164.15
			Selenographic inclination, deg	176.56
			Selenographic ascending node, deg	-24.85
			Velocity, fps	8247.7
			Flight-path angle, deg	-13.96
Burn termination	77:14:17.5	02:07:17.5	Altitude[b], n. mi.	59.59
			Selenographic latitude, deg	4.16
			Selenographic longitude, deg	176.15
			Selenographic inclination, deg	159.99
			Selenographic ascending node, deg	-172.33
			Velocity, fps	5481.4
			Flight-path angle, deg	0.04
			Burn duration, sec	310.55

[a]Events prior to and including TLI are the same as in table 1-I of the Apollo 17 Operational Trajectory (ref. 4).

[b]Altitude above mean lunar radius (938.4935 n. mi.).

TABLE I. - SEQUENCE OF MAJOR EVENTS - CSM ALONE MISSION

[DECEMBER 7, 1972 (G.M.T.), LAUNCH; 72.1° LAUNCH AZIMUTH; FIRST OPPORTUNITY TLI] - Continued

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary	
		Dec. 10, 1972	Plane change, deg	22.98
			ΔV, fps	4033.2
			Perilune altitude[b], n. mi.	59.58
			Apolune altitude[b], n. mi.	169.95
			Orbital period, hr:min:sec	2:08:50.8
Circularization Burn initiation	81:31:48.8	06:24:48.8	Mass, lb	41 950.3
			Altitude[b], n. mi.	59.44
			Selenographic latitude, deg	4.19
			Selenographic longitude, deg	173.84
			Velocity, fps	5482.2
			Flight-path angle, deg	0.0
Burn termination	81:31:57.4	06:24:57.4	Altitude[b], n. mi.	59.44
			Selenographic latitude, deg	4.34
			Selenographic longitude, deg	173.42
			Selenographic inclination, deg	159.99
			Selenographic ascending node, deg	-174.55
			Velocity, fps	5344.7
			Flight-path angle, deg	0.02
			Burn duration, sec	8.66
			Plane change, deg	0.00
			ΔV, fps	137.5
			Perilune altitude[b], n. mi.	59.33
			Apolune altitude[b], n. mi.	60.34
			Orbital period, hr:min:sec	1:58:53.9
CSM pass over pseudo-landing site	82:27:09.2	07:20:09.2	Altitude[b], n. mi.	59.57
			Selenographic latitude, deg	0.00
			Selenographic longitude, deg	5.00
			Selenographic azimuth, deg	250.00

[b]Altitude above mean lunar radius (938.4935 n. mi.).

TABLE I.- SEQUENCE OF MAJOR EVENTS - CSM ALONE MISSION

[DECEMBER 7, 1972 (G.M.T.), LAUNCH; 72.1° LAUNCH AZIMUTH; FIRST OPPORTUNITY TLI] - Continued

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
Trim burn	~145:43	Dec. 12, 1972 ~22:36	To be defined: The purpose of this maneuver (if performed) will be to maintain the LPO perilune altitude ≥ 52 n. mi. for Lunar Sounder operation without changing the LPO period.
Transearth injection (TEI) Burn initiation[c]	235:28:27.0	Dec. 16, 1972 16:21:27.0	
			Mass, lb: 40 750.0
			Altitude[b], n. mi.: 71.35
			Selenographic latitude, deg: -19.88
			Selenographic longitude, deg: -176.23
			Selenographic inclination, deg: 159.55
			Selenographic ascending node, deg: 107.91
			Velocity, fps: 5281.0
			Flight-path angle, deg: -0.59
			Perilune altitude[b], n. mi.: 44.30
			Apolune altitude[b], n. mi.: 75.20
			Orbital period, hr:min:sec: 1:58:53.0

[b]Altitude above mean lunar radius (938.4935 n. mi.).

[c]These data would be changed slightly by the trim burn.

TABLE I. - SEQUENCE OF MAJOR EVENTS - CSM ALONE MISSION

[DECEMBER 7, 1972 (G.M.T.), LAUNCH; 72.1° LAUNCH AZIMUTH; FIRST OPPORTUNITY TLI] - Concluded

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary	
Burn termination[c]	235:31:24.1	16:24:24.1	Altitude[b], n. mi.	81.67
			Selenographic latitude, deg	-20.09
			Selenographic longitude, deg	172.06
			Selenographic inclination, deg	159.36
			Selenographic ascending node, deg	68.26
			Velocity, fps	8303.1
			Flight-path angle, deg	7.52
			Burn duration, sec	177.13
			Plane change, deg	13.66
			ΔV, fps	3477.9
Transearth coast		Dec. 19, 1972		
Entry interface	304:11:15.7	13:04:15.7	Transearth coast time, hr.	68.66
			Velocity (inertial), fps	36 085.9
			Flight-path angle (inertial), deg	-6.49
			Altitude (geodetic), n. mi.	65.81
			Latitude (geodetic), deg	11.45
			Longitude, deg	189.00
			Inclination, deg (descending)	70.00
CM Landing	304:19:12.5	13:12:12.5	Latitude (geodetic); deg:min	17:51S
			Longitude, deg: min	165:00W

[b]Altitude above mean lunar radius (938.4935 n. mi.).

[c]These data would be changed slightly by the trim burn.

TABLE II.- SEQUENCE OF MAJOR EVENTS - NO-GO FOR LANDING IN LUNAR ORBIT

[DECEMBER 7, 1972 (G.M.T.), LAUNCH; 72.1° LAUNCH AZIMUTH; FIRST OPPORTUNITY TLI]

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary	
Post-DOI events[a]				
Circularization				
Burn initiation	123:26:34.3	Dec. 12, 1972 00:19:34.3	Configuration - docked (SPS burn)	
			Mass, lb	74 829.1
			Altitude[b], n. mi.	58.64
			Selenographic latitude, deg	-19.98
			Selenographic longitude, deg	-163.20
			Velocity, fps	5280.3
			Flight-path angle, deg	0.01
Burn termination	123:26:41.7	00:19:41.7	Altitude[b], n. mi.	56.64
			Selenographic latitude, deg	-19.96
			Selenographic longitude, deg	-163.60
			Selenographic inclination, deg	159.80
			Selenographic ascending node, deg	115.61
			Velocity, fps	5346.4
			Flight-path angle, deg	0.00
			Burn duration, sec	7.45
			Plane change, deg	0.00
			ΔV, fps	66.1
			Perilune altitude[b], n. mi.	58.64
			Apolune altitude[b], n. mi.	59.10
			Orbital period, hr:min:sec	1:58:43.6

[a]Events prior to and including DOI are the same as in table 1-I of the Apollo 17 Operational Trajectory (ref. 4).

[b]Altitude referenced to the mean lunar radius (938.4935 n. mi.).

TABLE II.- SEQUENCE OF MAJOR EVENTS - NO-GO FOR LANDING IN LUNAR ORBIT

[DECEMBER 7, 1972 (G.M.T.), LAUNCH; 72.1° LAUNCH AZIMUTH; FIRST OPPORTUNITY TLI] - Continued

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary
CSM/LM separation			To be defined.
LM deorbit and impact			To be defined.
Trim burn	~188:44	Dec. 14, 1972 ~17:37	To be defined: The purpose of this maneuver (if performed) will be to maintain the LPO perilune altitude ≥ 52 n. mi. for Lunar Sounder operation without changing the LPO period.
Transearth injection (TEI) Burn initiation[c]	235:53:08.4	Dec. 16, 1972 16:46:08.4	Configuration - undocked (SPS burn) Mass, lb 37 500.0 Altitude[b], n. mi. 65.55 Selenographic latitude, deg -15.64 Selenographic longitude, deg -169.12 Selenographic inclination, deg 159.80 Selenographic ascending node, deg 60.43 Velocity, fps 5309.6 Flight-path angle, deg -0.46 Perilune altitude[b], n. mi. 48.46 Apolune altitude[b], n. mi. 69.36 Orbital period, hr:min:sec 1:58:44.0
Burn termination[c]	235:55:31.3	16:48:31.3	Altitude[b], n. mi. 67.29 Selenographic latitude, deg -17.63 Selenographic longitude, deg -178.33 Selenographic inclination, deg 158.69 Selenographic ascending node, deg 56.23 Velocity, fps 8274.7 Flight-path angle, deg 2.96 Burn duration, sec 142.95 Plane change, deg 1.85 ΔV, fps 2980.0

[b]Altitude referenced to the mean lunar radius (938.4935 n. mi.).

[c]These data would be changed slightly by the trim burn.

TABLE II.- SEQUENCE OF MAJOR EVENTS - NO-GO FOR LANDING IN LUNAR ORBIT

[DECEMBER 7, 1972 (G.M.T.), LAUNCH; 72.1° LAUNCH AZIMUTH; FIRST OPPORTUNITY TLI] - Concluded

Event	Time, hr:min:sec, g.e.t.	Time, hr:min:sec, c.s.t.	Data summary	
Transearth coast Entry interface	304:13:27.0	Dec. 19, 1972 13:06:27.0	Transearth coast time, hr Velocity (inertial), fps Flight-path angle (inertial), deg Altitude (geodetic), n. mi. Latitude (geodetic), deg Longitude, deg Inclination, deg	68.30 36 086.7 -6.49 65.77 -4.09 180.66 43.88
CM Landing	304:21:30.7	13:14:30.7	Latitude (geodetic), deg:min Longitude, deg:min	18:02S 165:00W

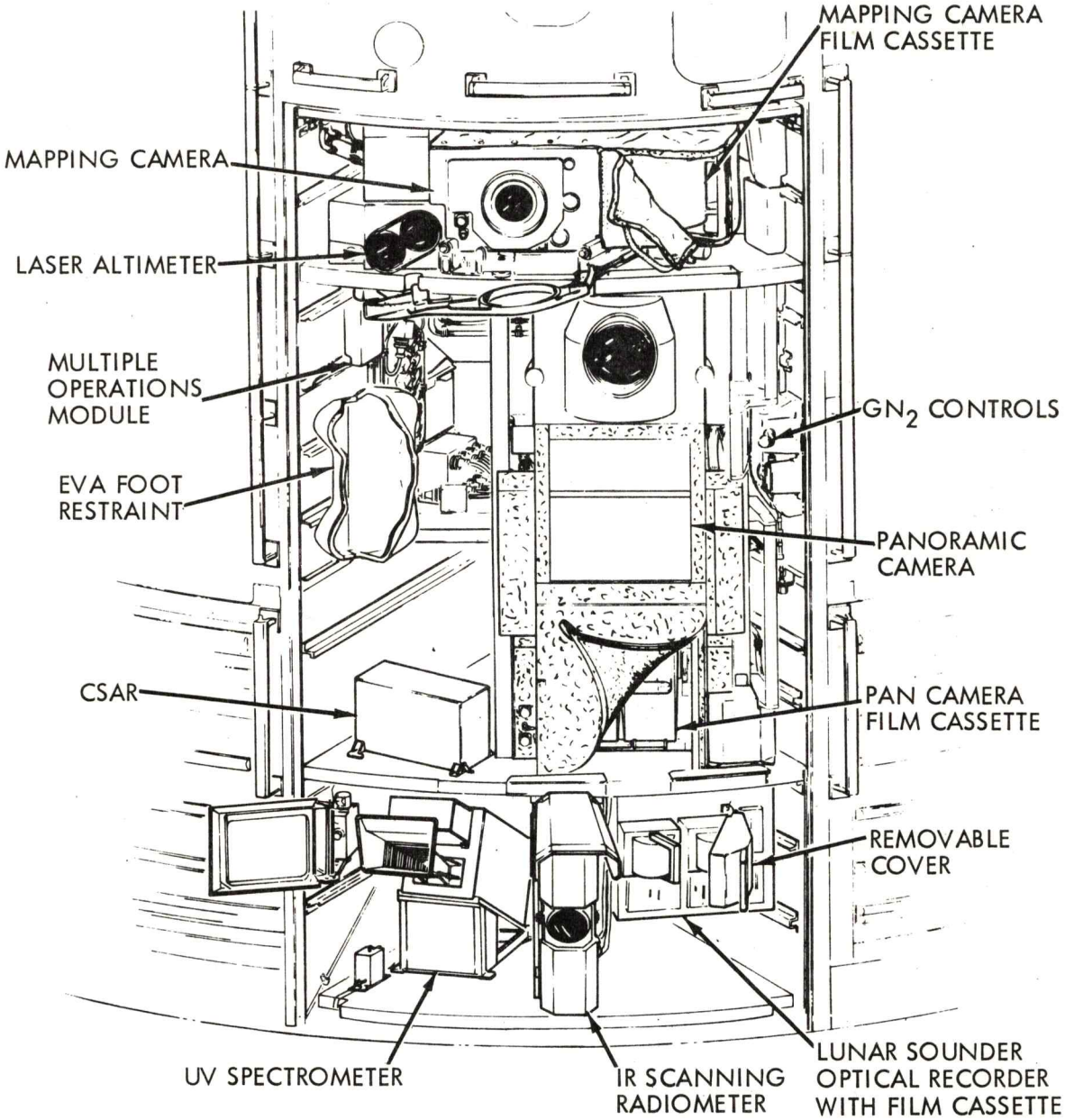


Figure 1.- SIM experiment complement.

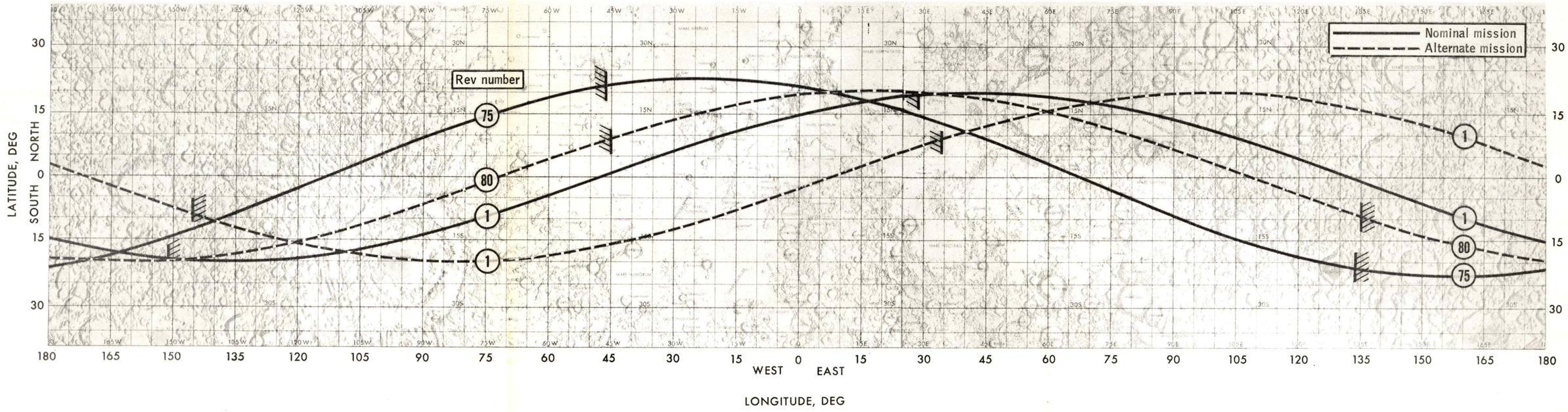
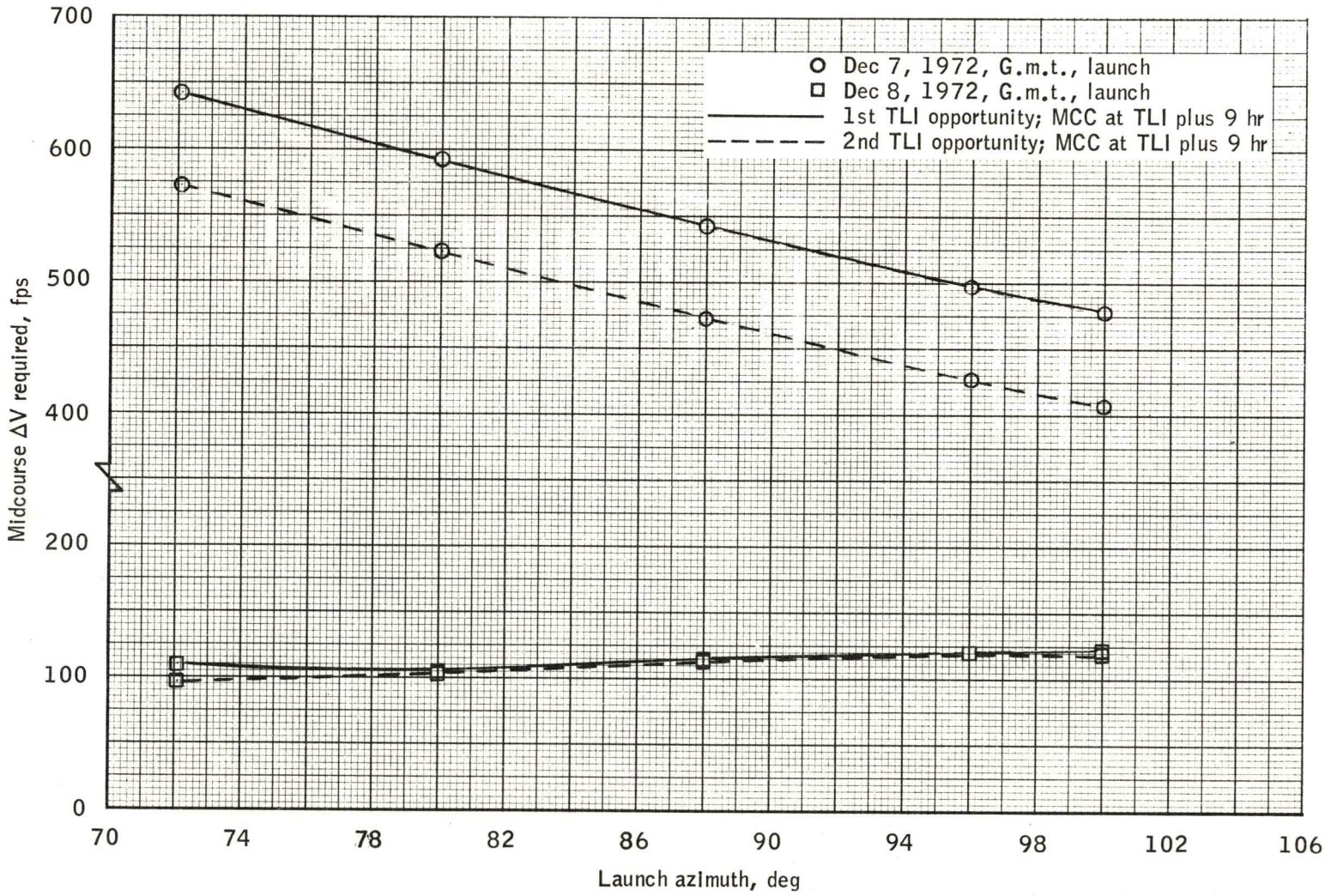
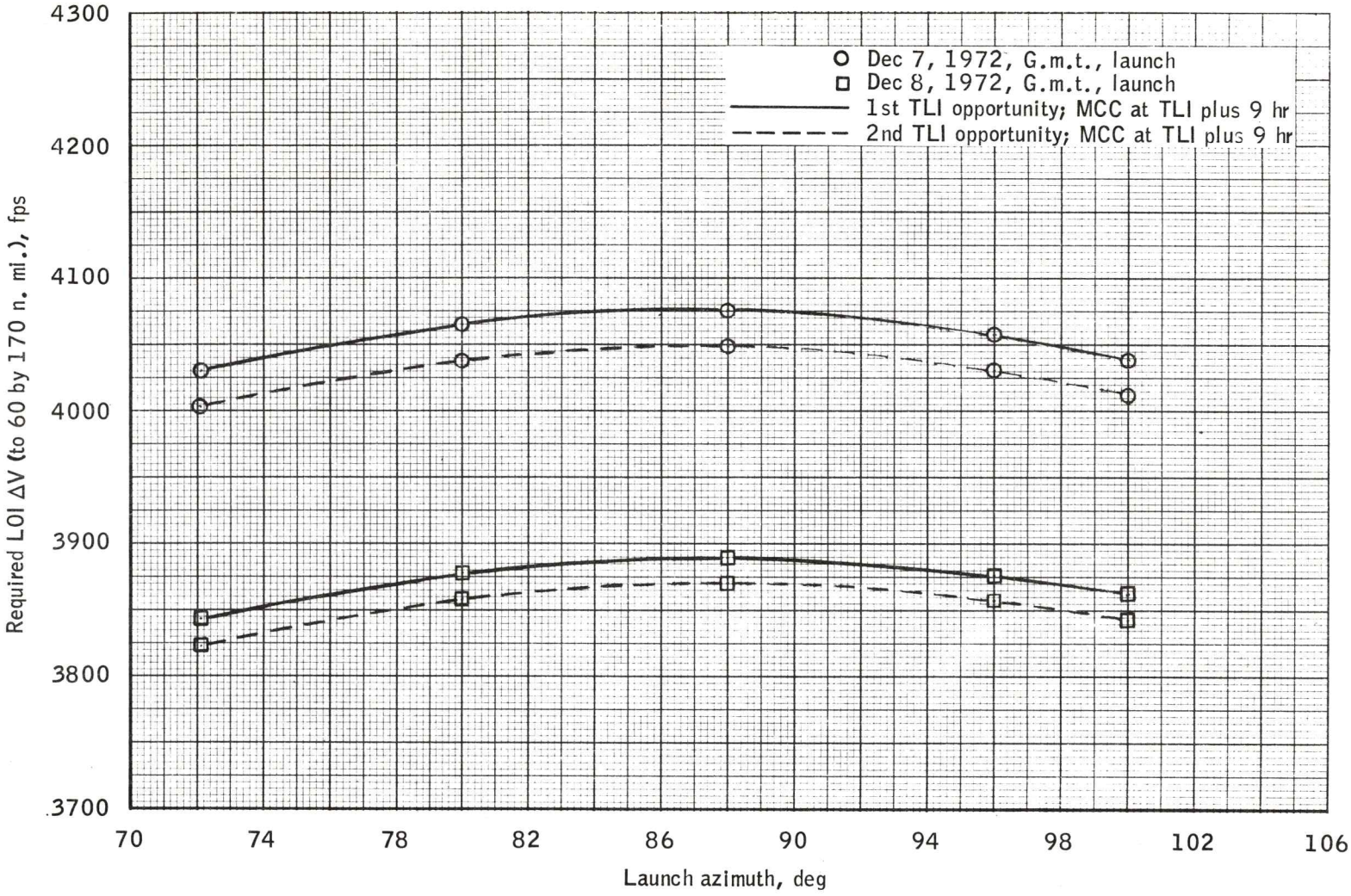


Figure 2.- Apollo 17 nominal lunar orbit groundtrack compared with alternate mission groundtrack.



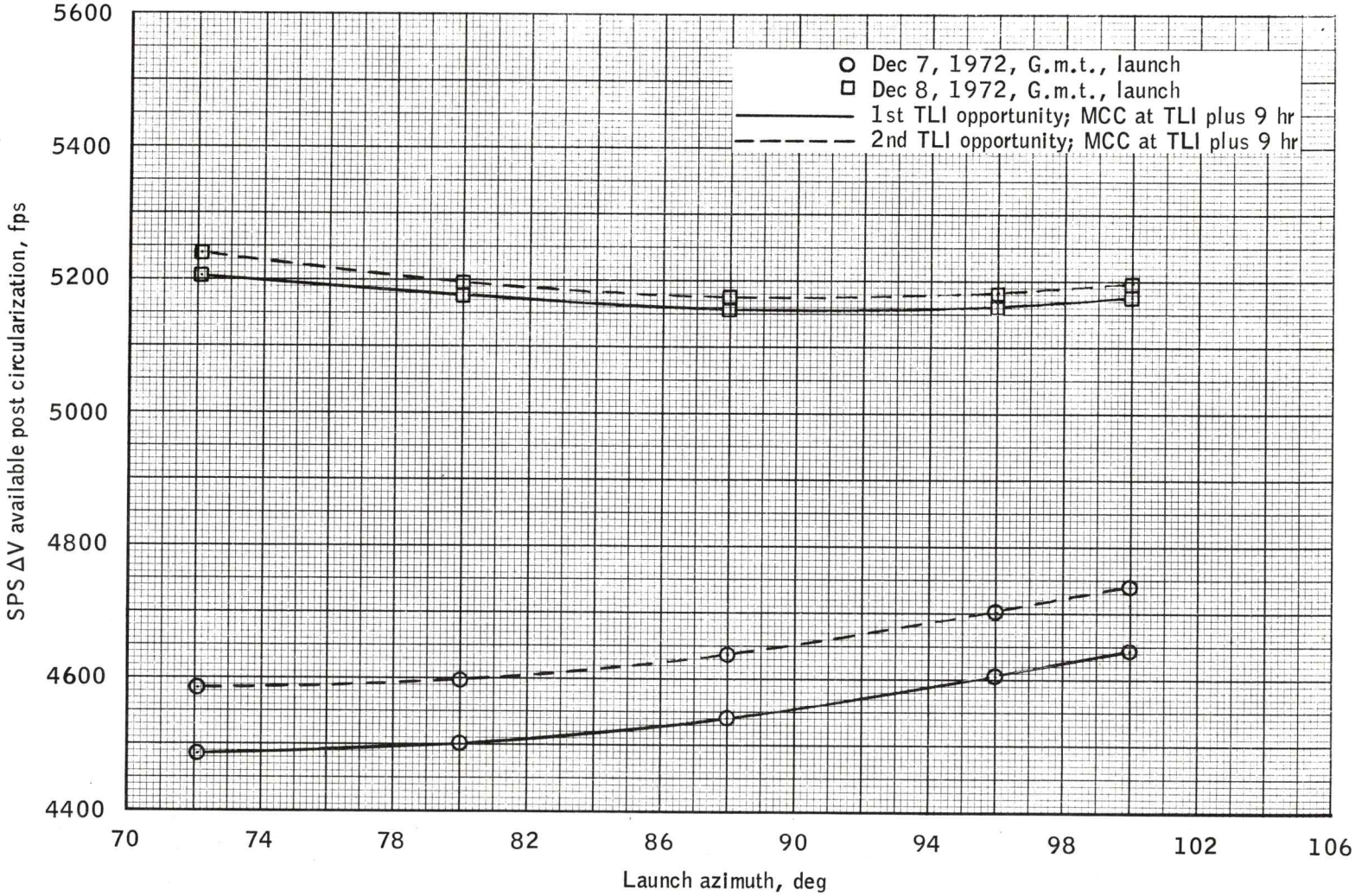
(a) Midcourse ΔV required.

Figure 3.- CSM-alone mission: flight parameters versus launch azimuth.



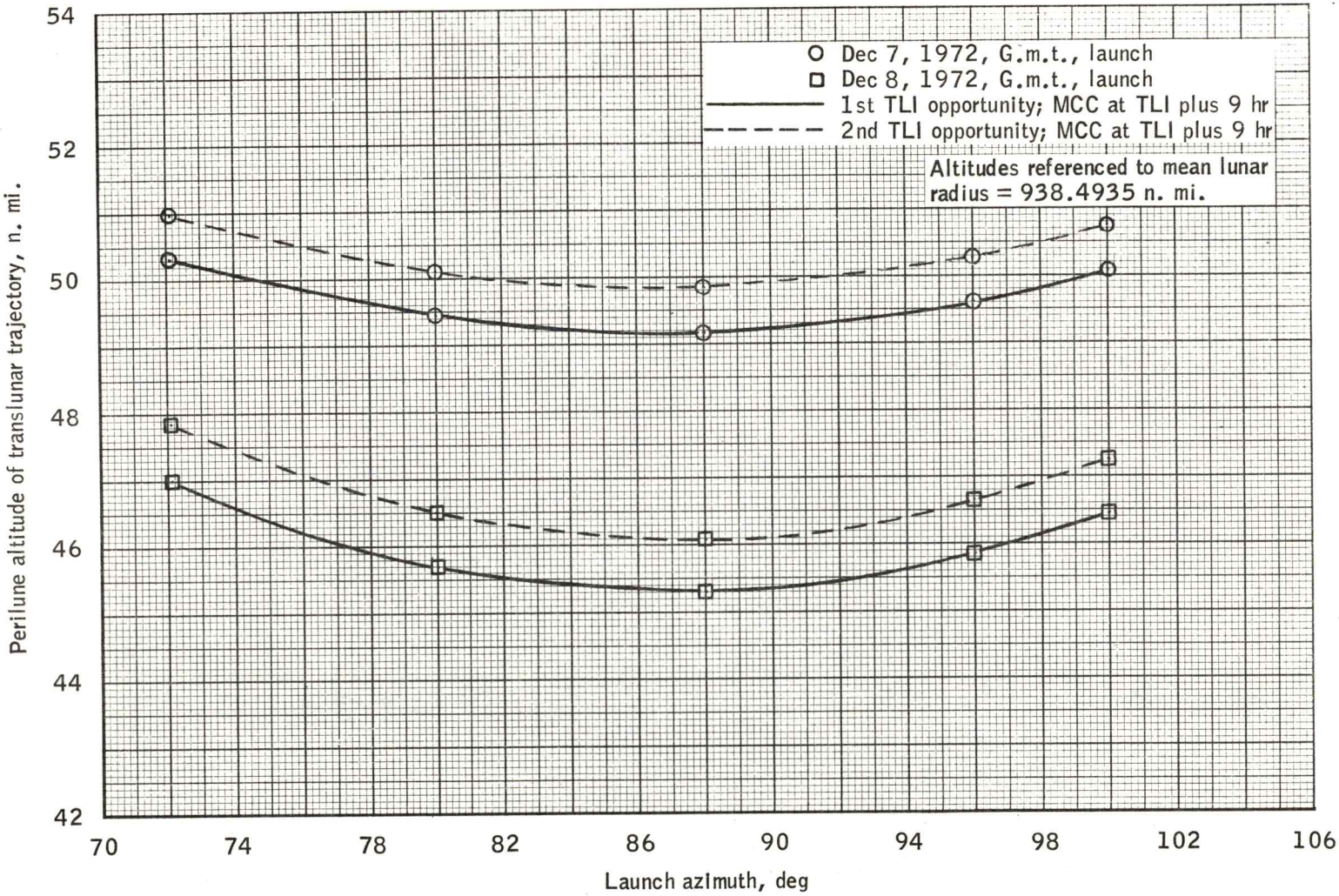
(b) Required LOI ΔV.

Figure 3.- Continued.



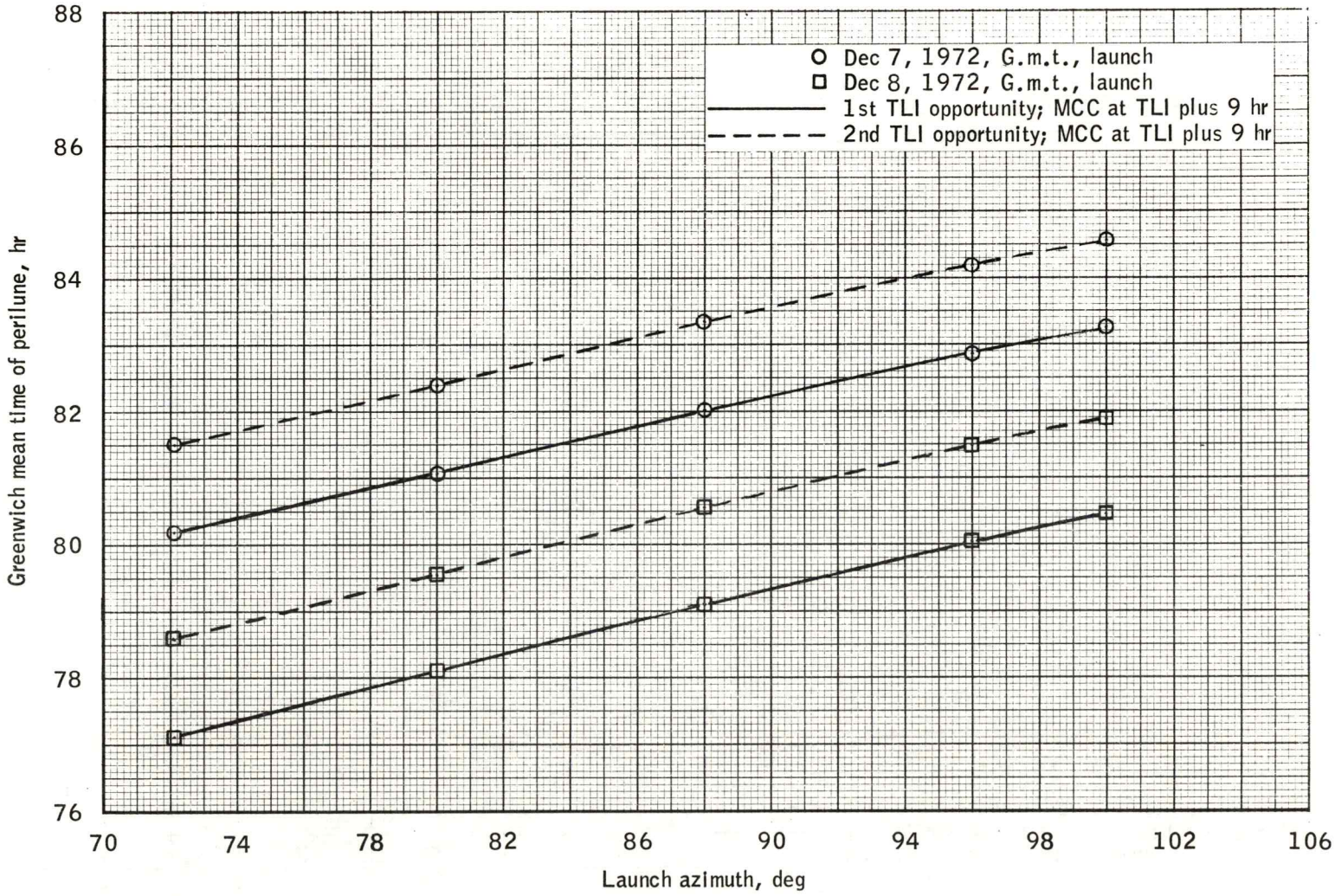
(c) SPS ΔV available postcircularization.

Figure 3.- Continued.



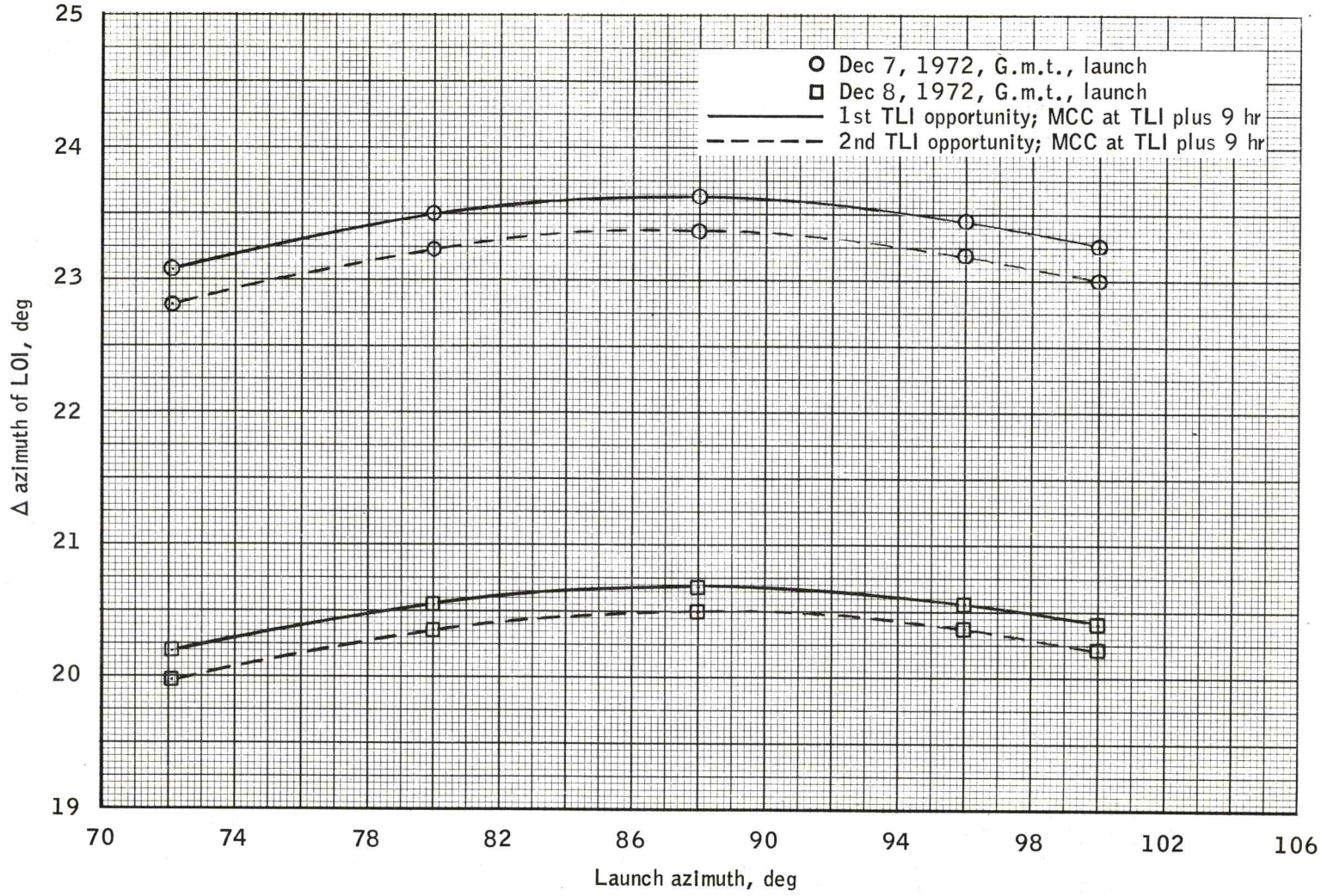
(d) Perilune altitude of translunar trajectory.

Figure 3.- Continued.



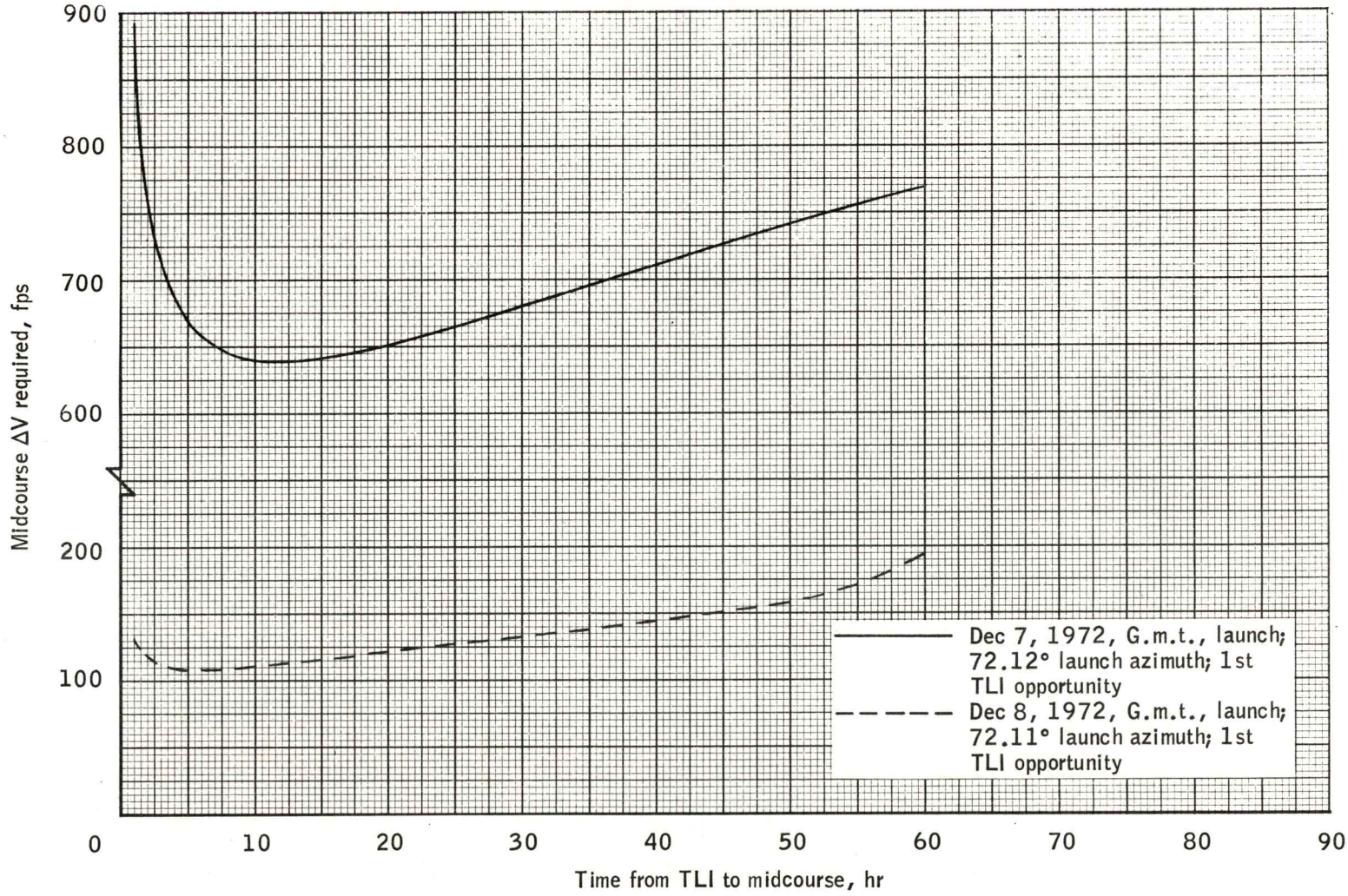
(e) Greenwich mean time of perilune.

Figure 3.- Continued.



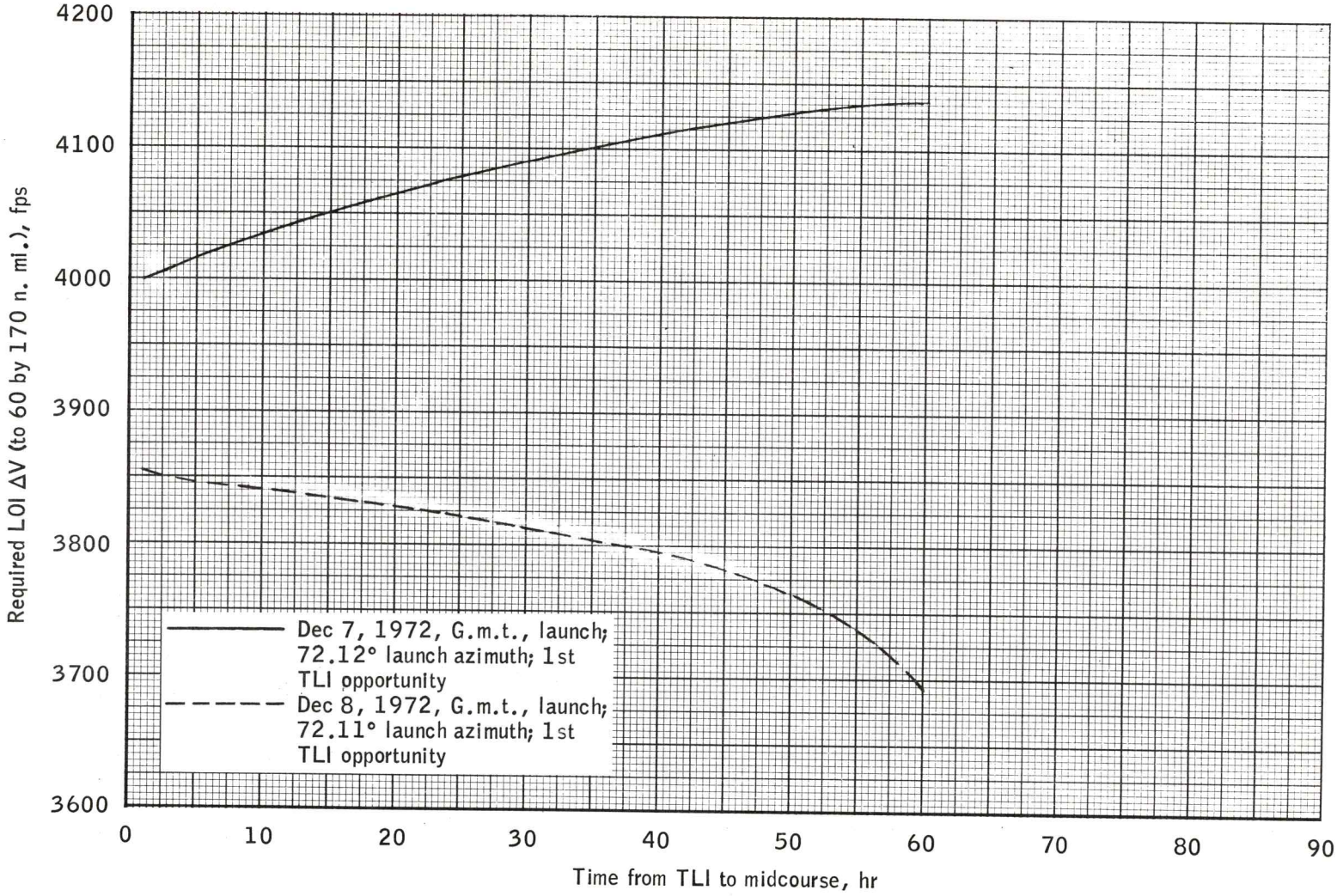
(f) Δ azimuth of LOI.

Figure 3.- Concluded.



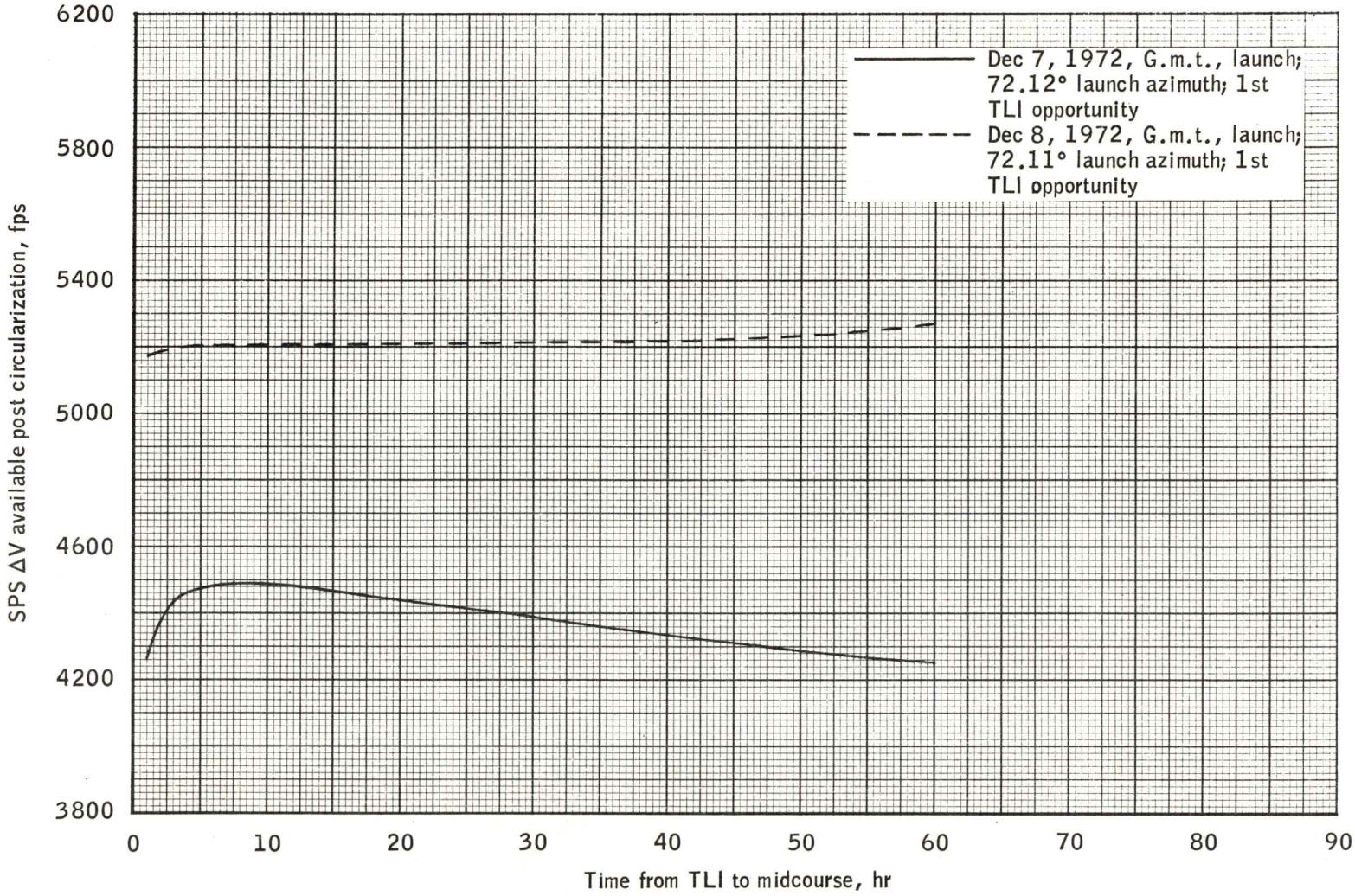
(a) Midcourse ΔV required.

Figure 4.- CSM-alone mission: flight parameters versus time from TLI to midcourse.



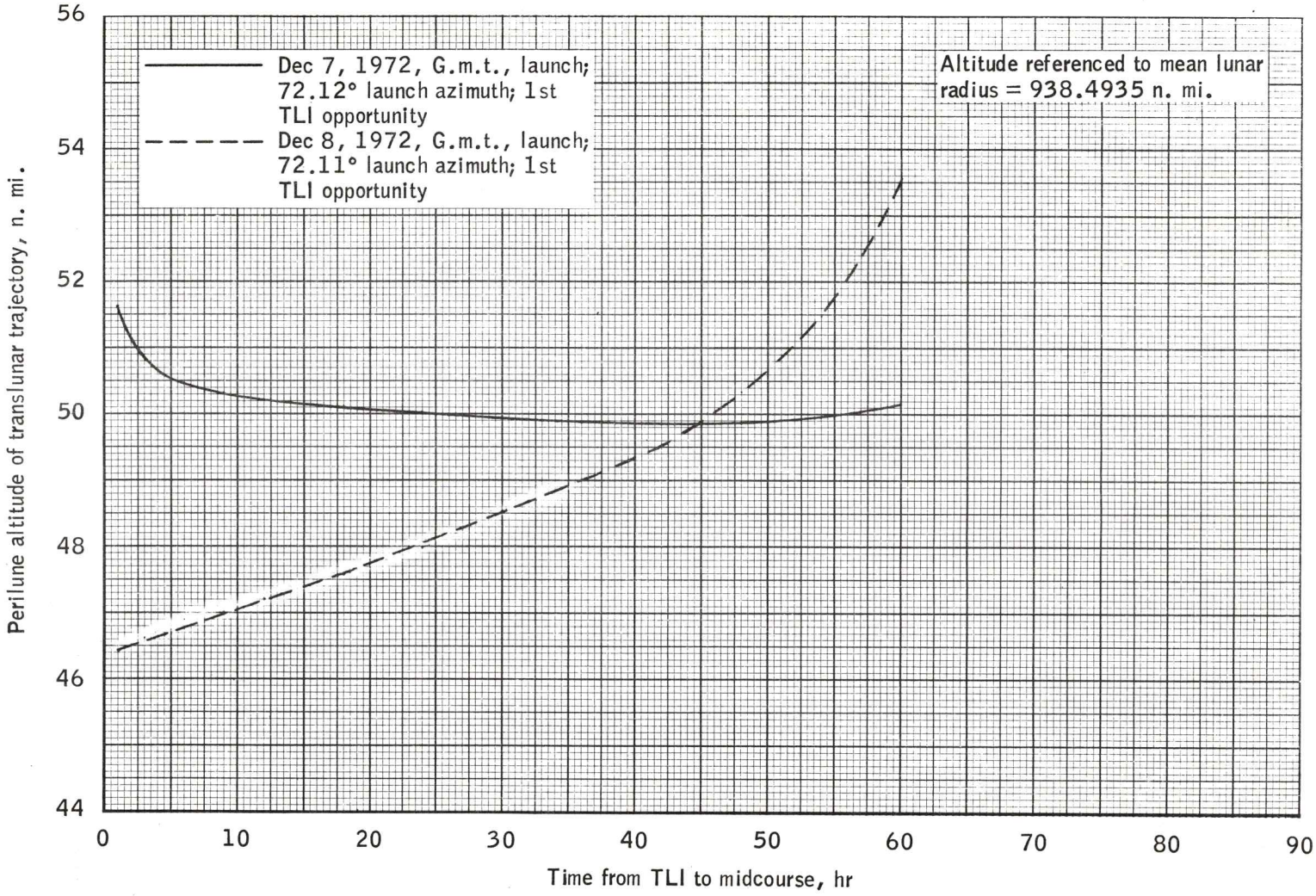
(b) Required LOI ΔV.

Figure 4.- Continued.



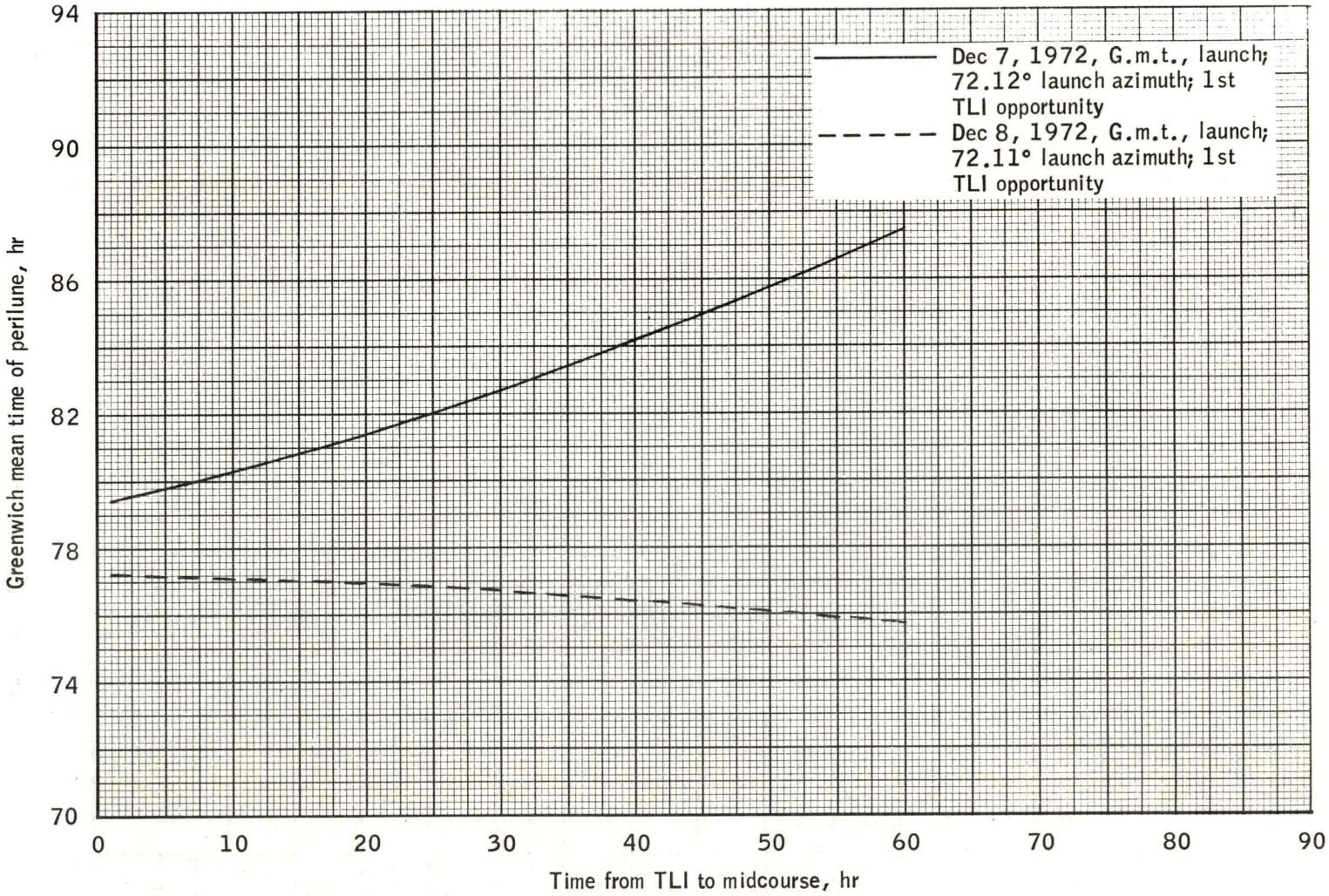
(c) SPS ΔV available postcircularization.

Figure 4.- Continued.



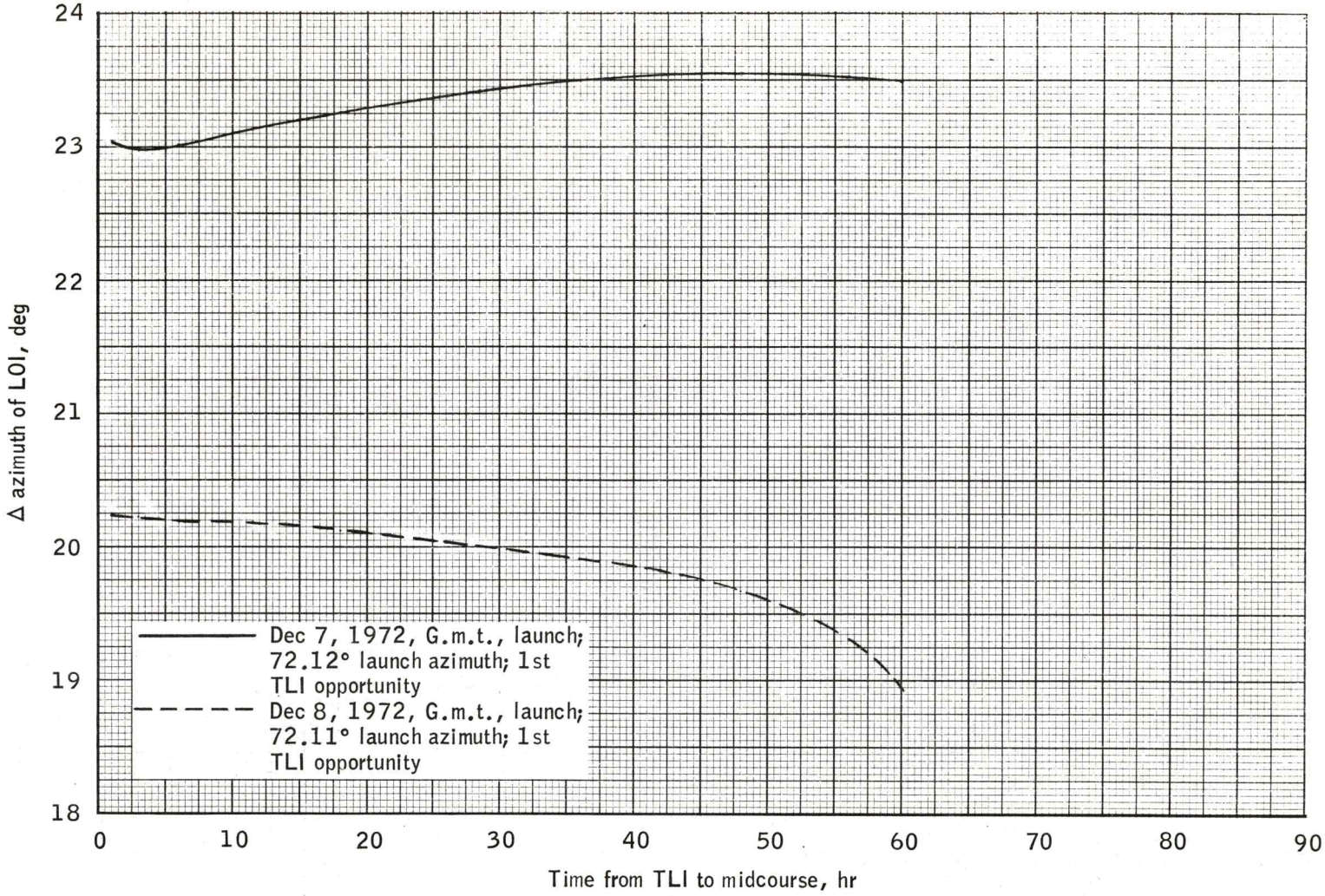
(d) Perilune altitude of translunar trajectory.

Figure 4.- Continued.



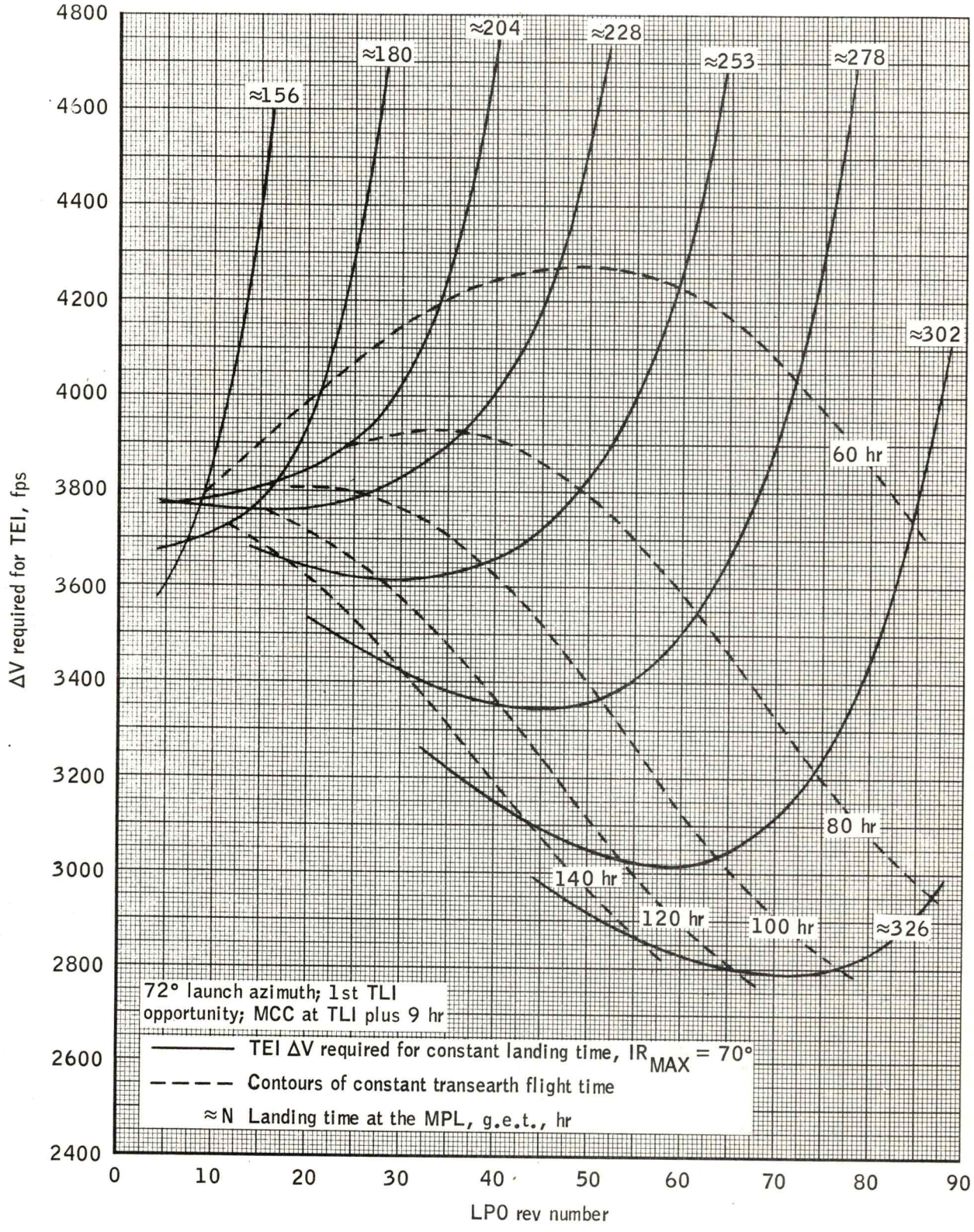
(e) Greenwich mean time of perilune.

Figure 4.- Continued.



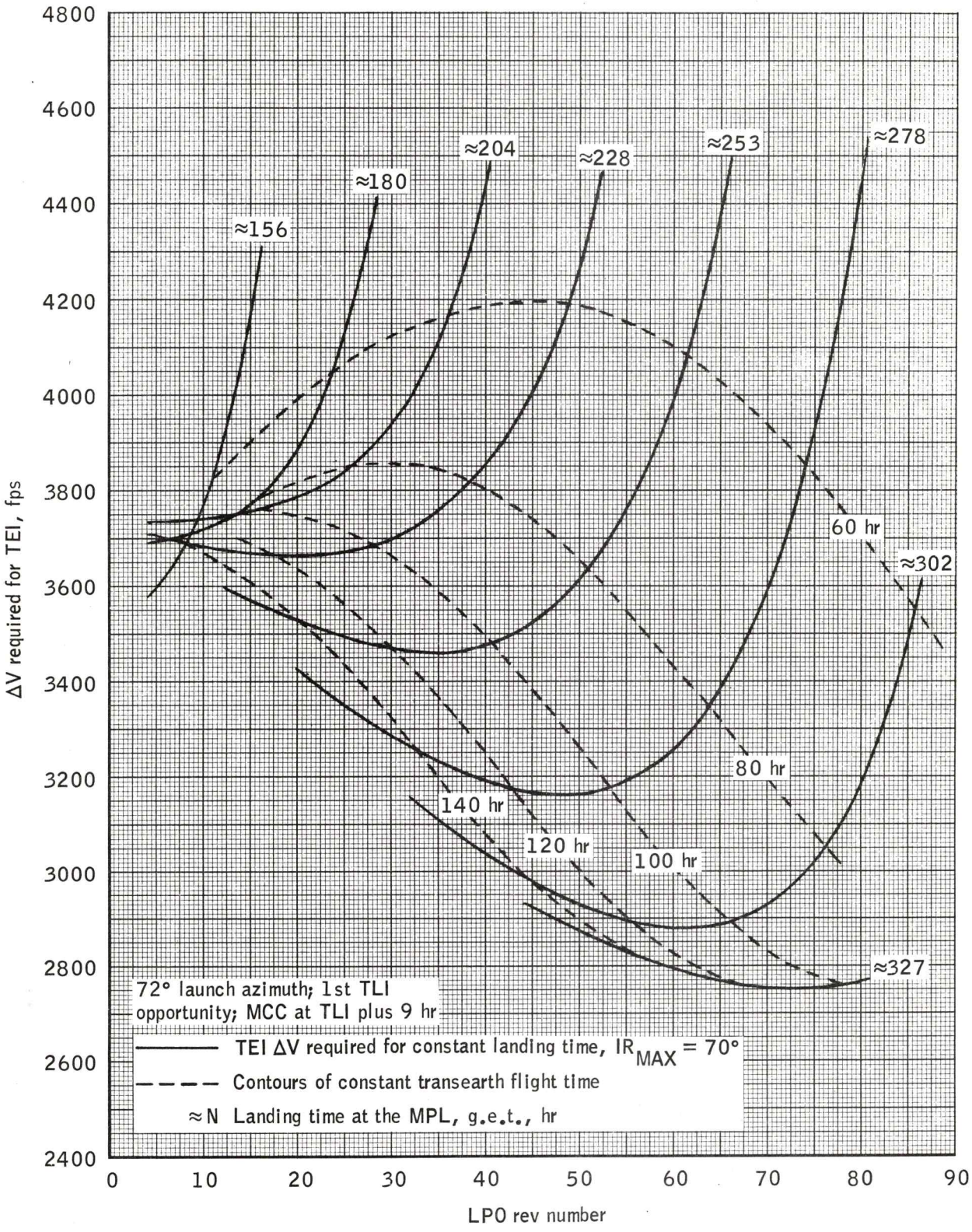
(f) Δ azimuth of LOI.

Figure 4.- Concluded.



(a) December 7, 1972, G.m.t., launch.

Figure 5.- CSM-alone mission: ΔV required for TEI versus LPO rev number.



(b) December 8, 1972, G.m.t., launch.

Figure 5.- Concluded.

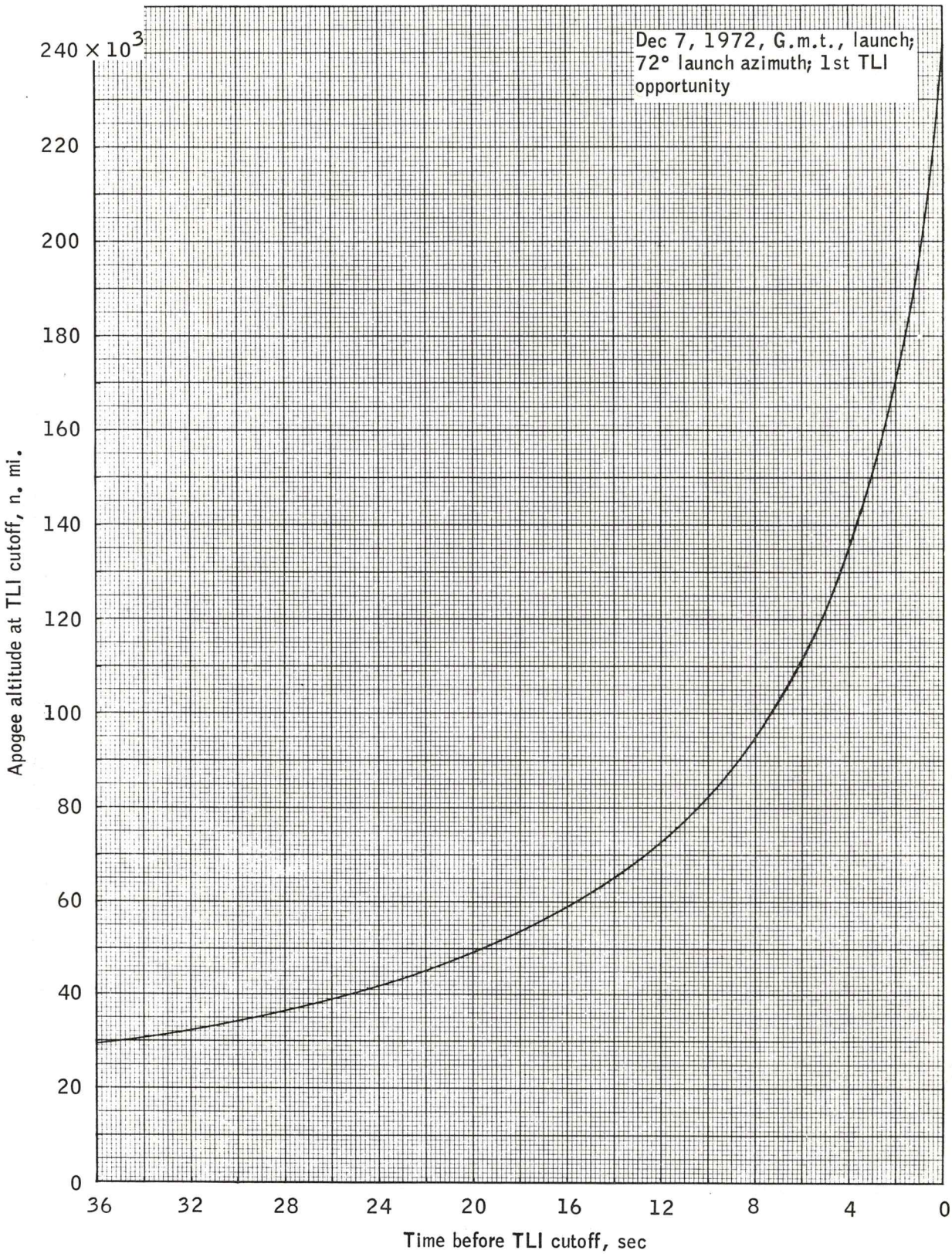


Figure 6.- Apogee altitude at TLI cutoff versus time from nominal TLI engine cutoff.

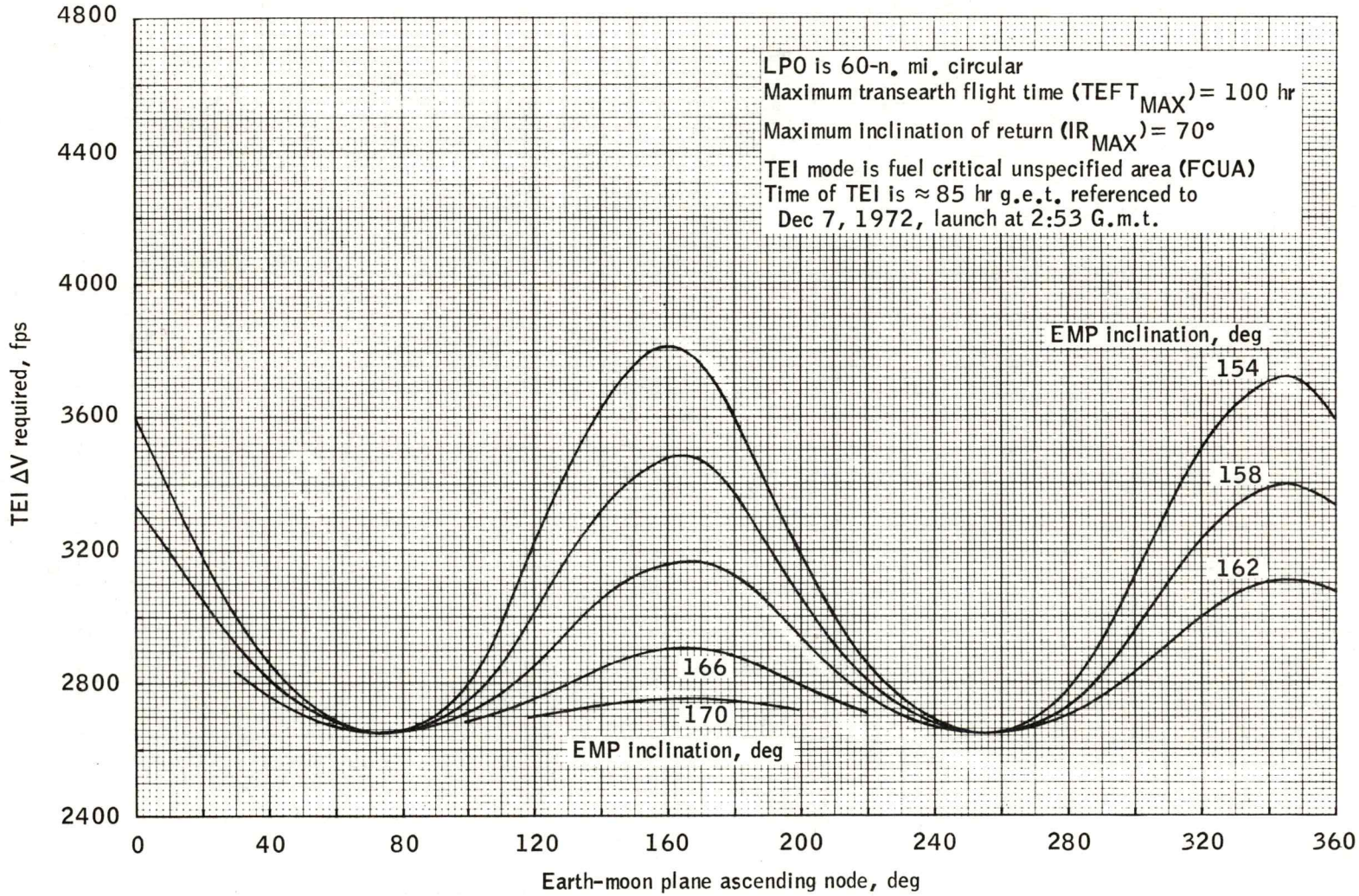


Figure 7.- TEI ΔV required (FCUA) versus earth-moon plane (EMP) inclination and node.

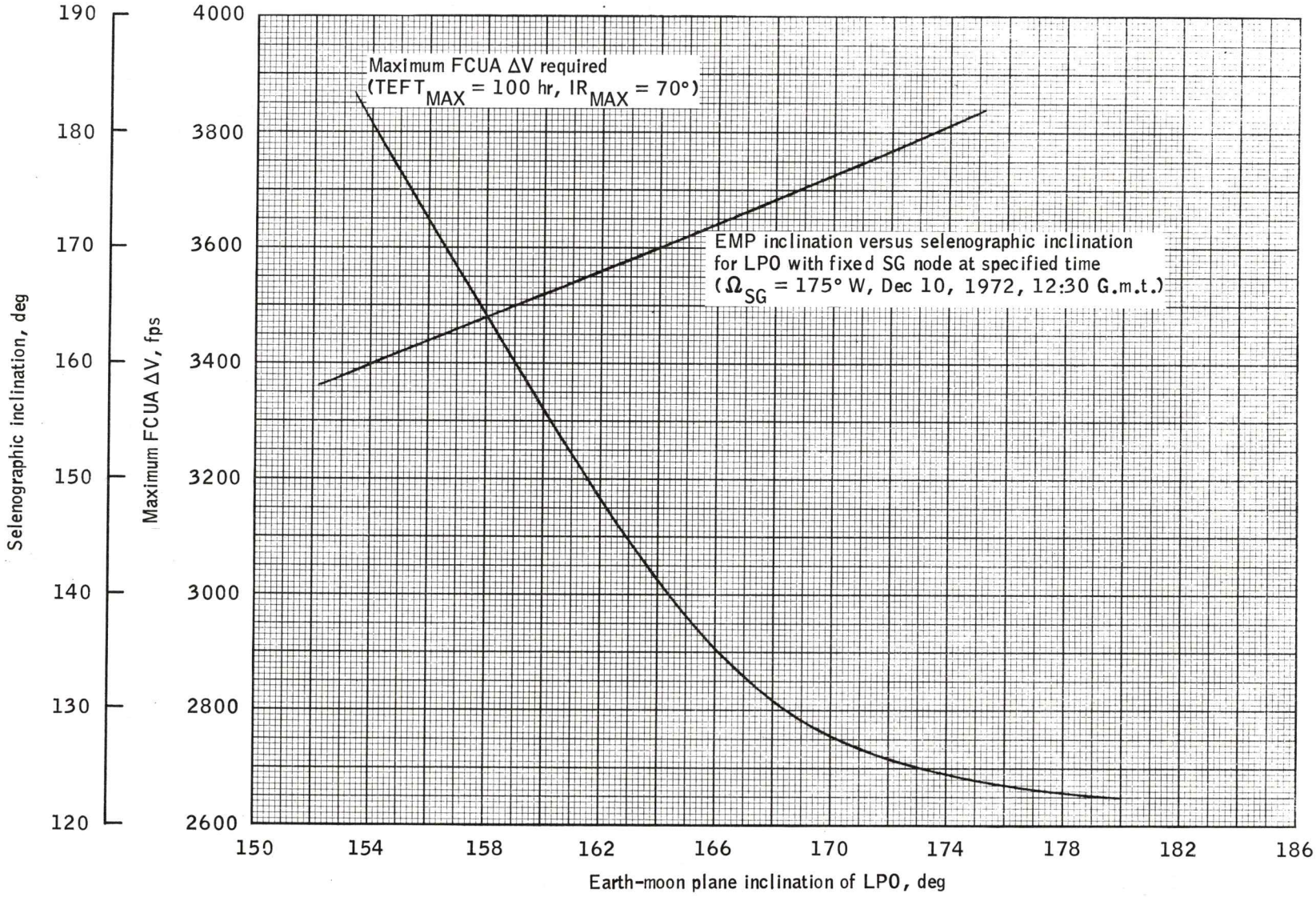
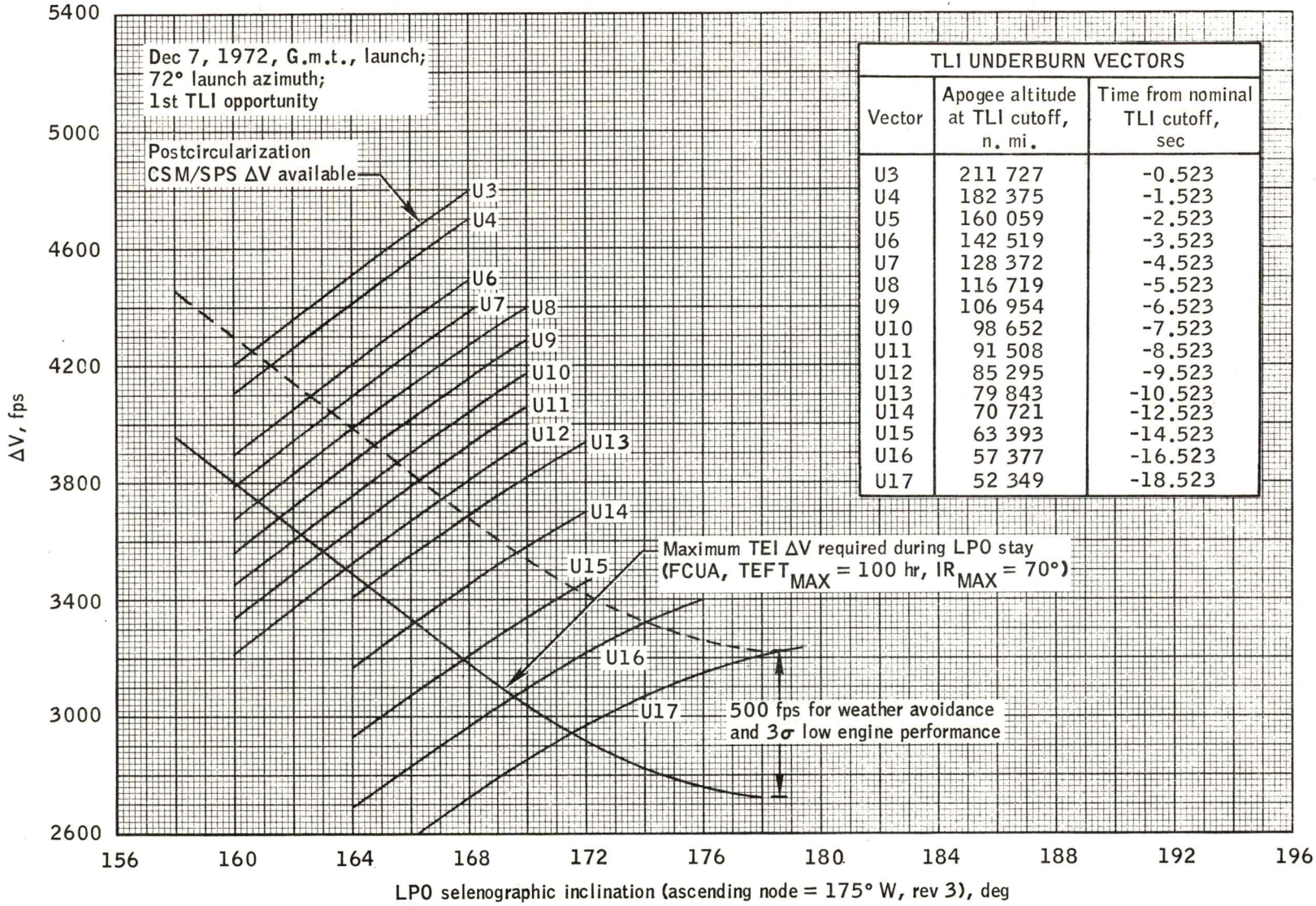


Figure 8.- LPO selenographic inclination and maximum FCUA ΔV required versus earth-moon plane inclination of LPO.

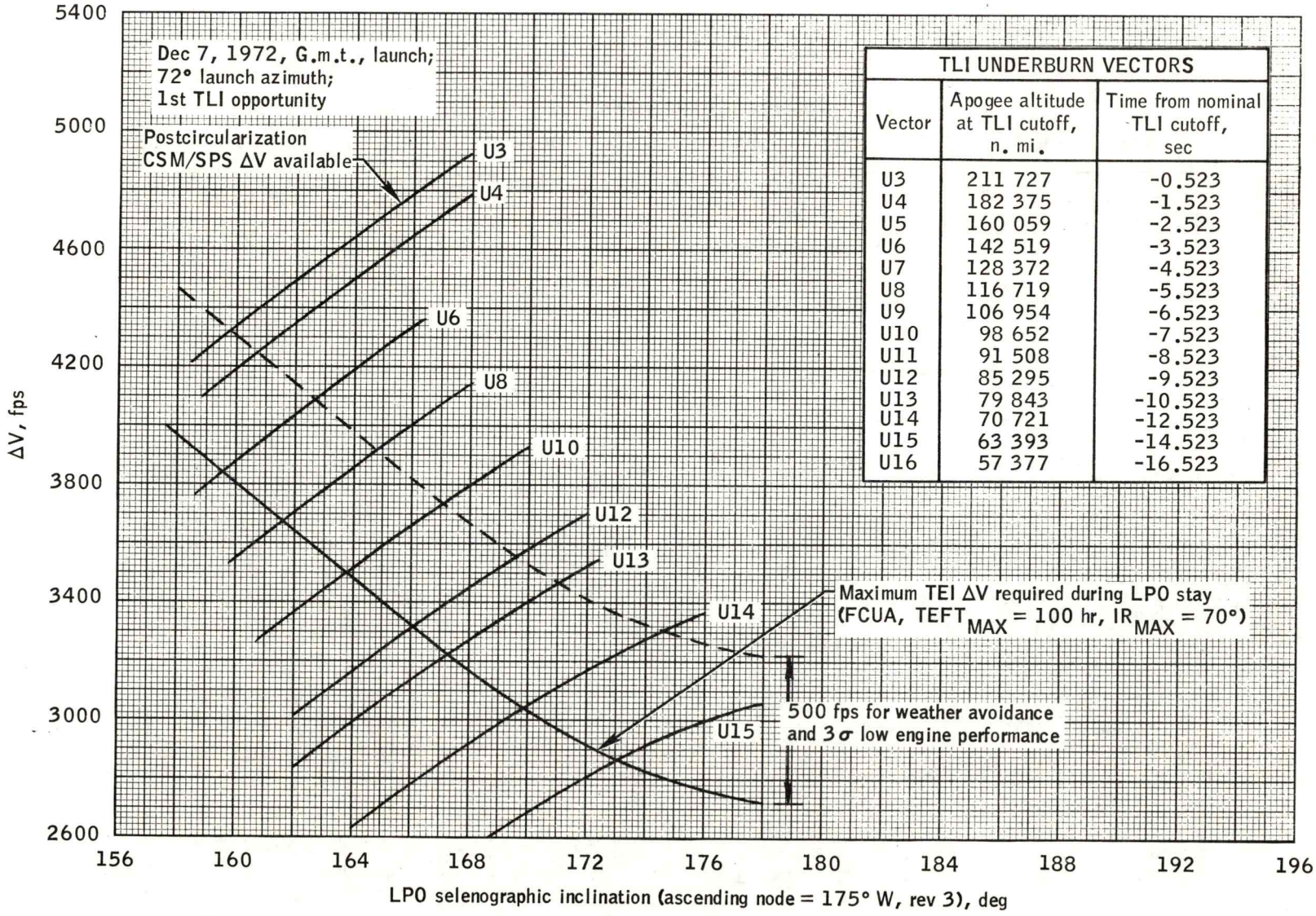


TLI UNDERBURN VECTORS

Vector	Apogee altitude at TLI cutoff, n. mi.	Time from nominal TLI cutoff, sec
U3	211 727	-0.523
U4	182 375	-1.523
U5	160 059	-2.523
U6	142 519	-3.523
U7	128 372	-4.523
U8	116 719	-5.523
U9	106 954	-6.523
U10	98 652	-7.523
U11	91 508	-8.523
U12	85 295	-9.523
U13	79 843	-10.523
U14	70 721	-12.523
U15	63 393	-14.523
U16	57 377	-16.523
U17	52 349	-18.523

(a) MCC at TLI plus 1 hour.

Figure 9.- CSM-alone mission: postcirculariza tion CSM/SPS ΔV available versus LPO inclination.



TLI UNDERBURN VECTORS

Vector	Apogee altitude at TLI cutoff, n. mi.	Time from nominal TLI cutoff, sec
U3	211 727	-0.523
U4	182 375	-1.523
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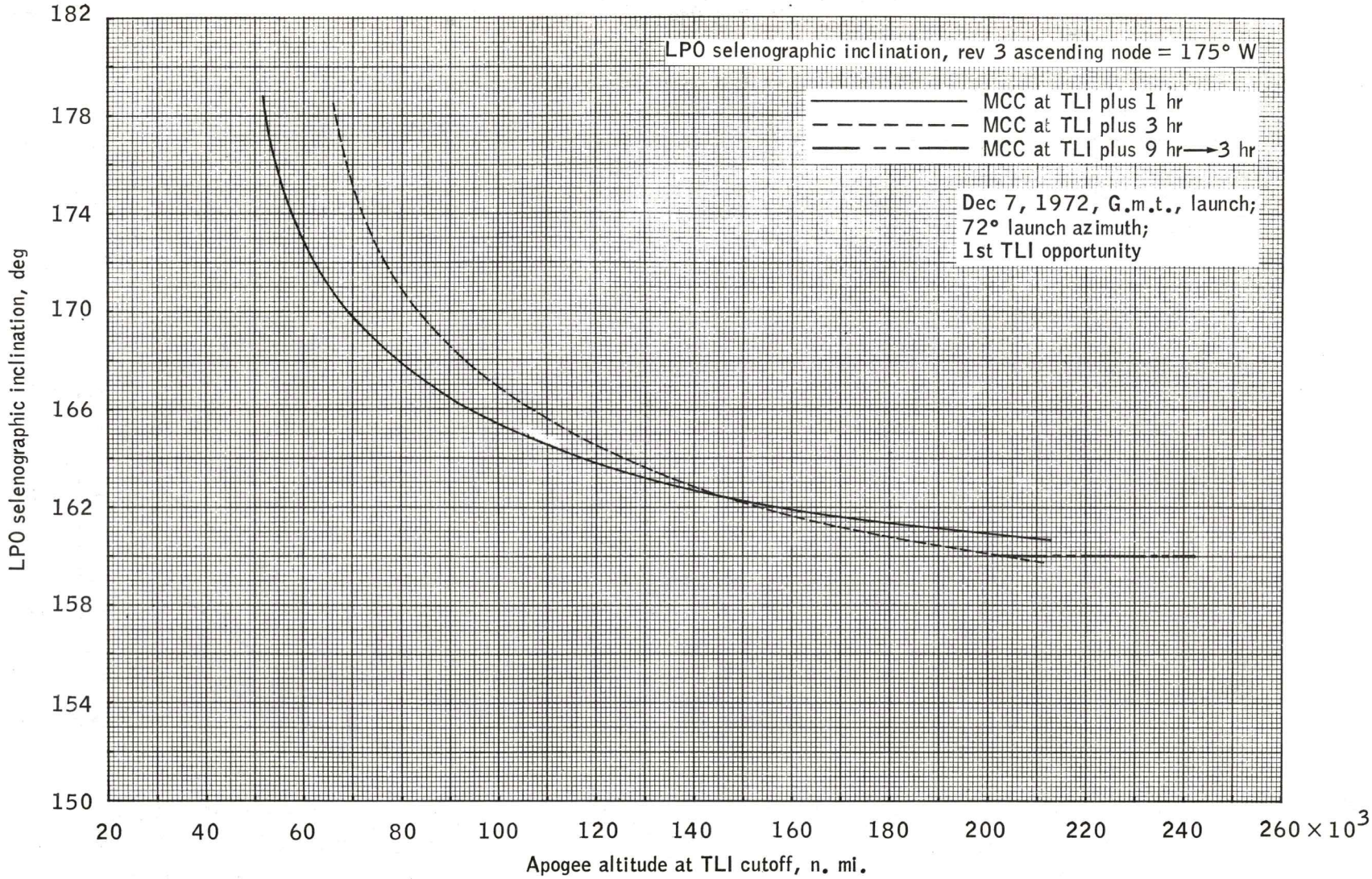
U6	142 519	-3.523
U7	128 372	-4.523
U8	116 719	-5.523
U9	106 954	-6.523
U10	98 652	-7.523
U11	91 508	-8.523
U12	85 295	-9.523
U13	79 843	-10.523
U14	70 721	-12.523
U15	63 393	-14.523
U16	57 377	-16.523

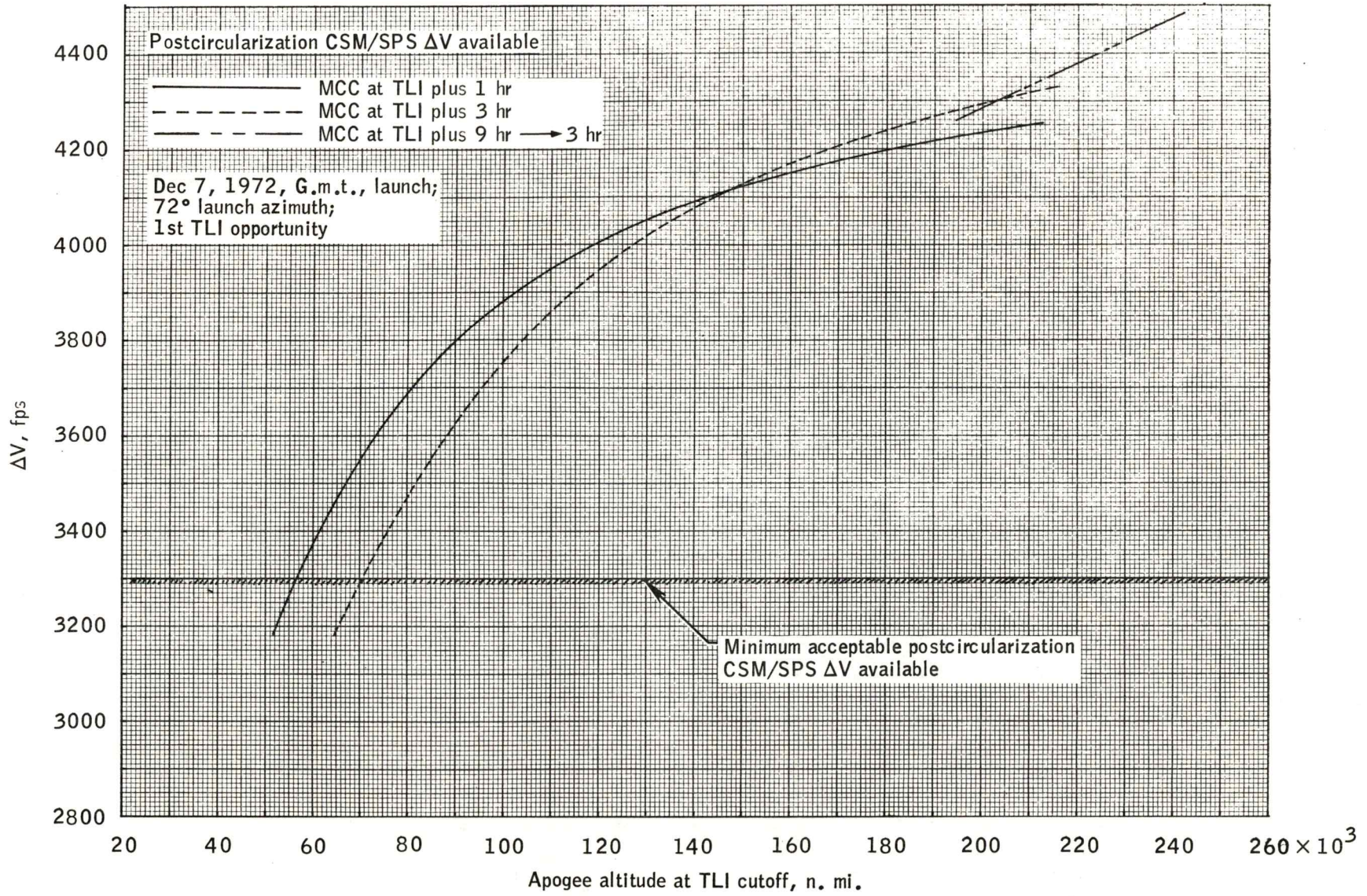
(b) MCC at TLI plus 3 hours.

Figure 9.- Concluded.



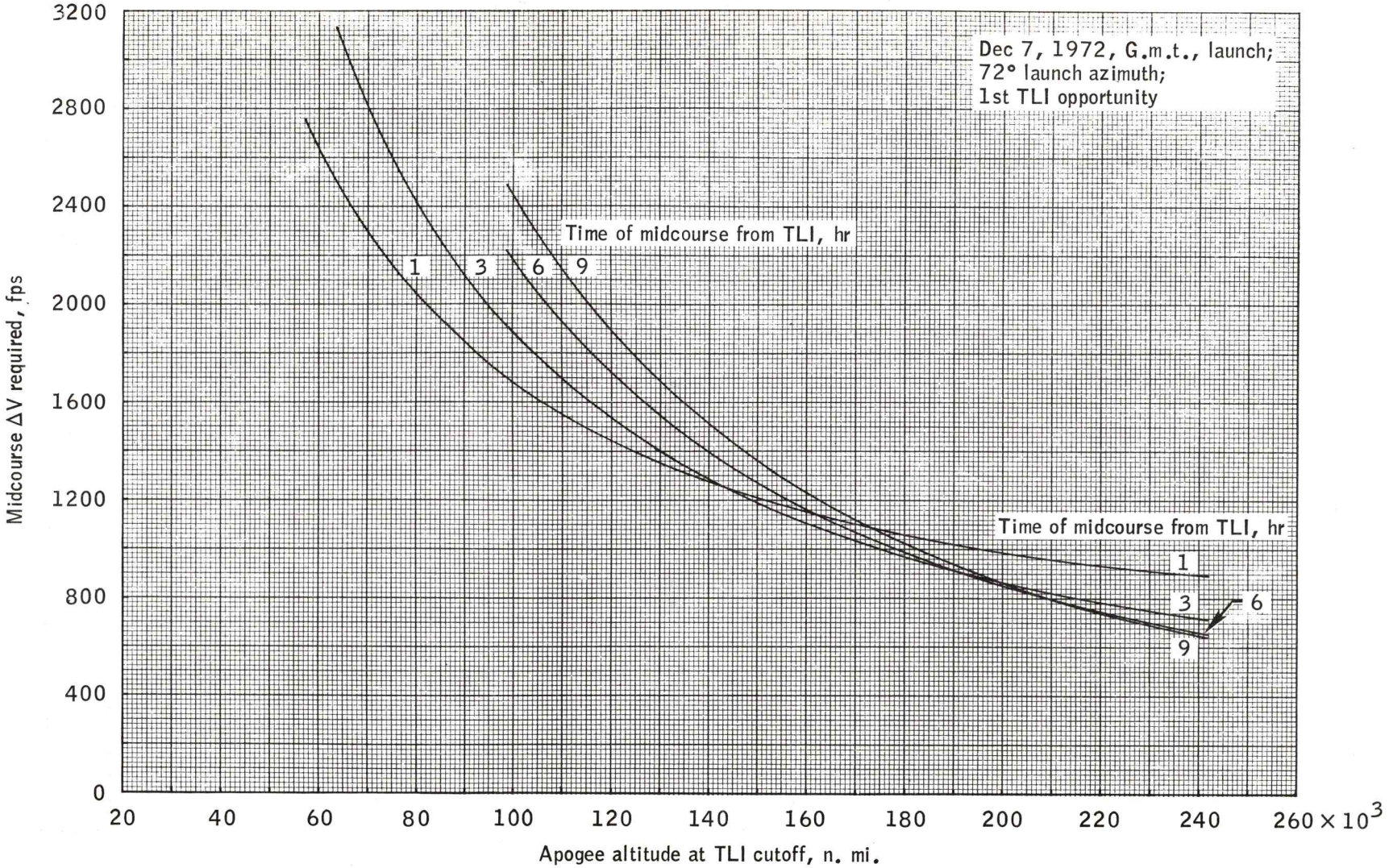
(a) LPO inclination.

Figure 10.- CSM-alone mission: flight parameters versus apogee altitude at TLI cutoff.



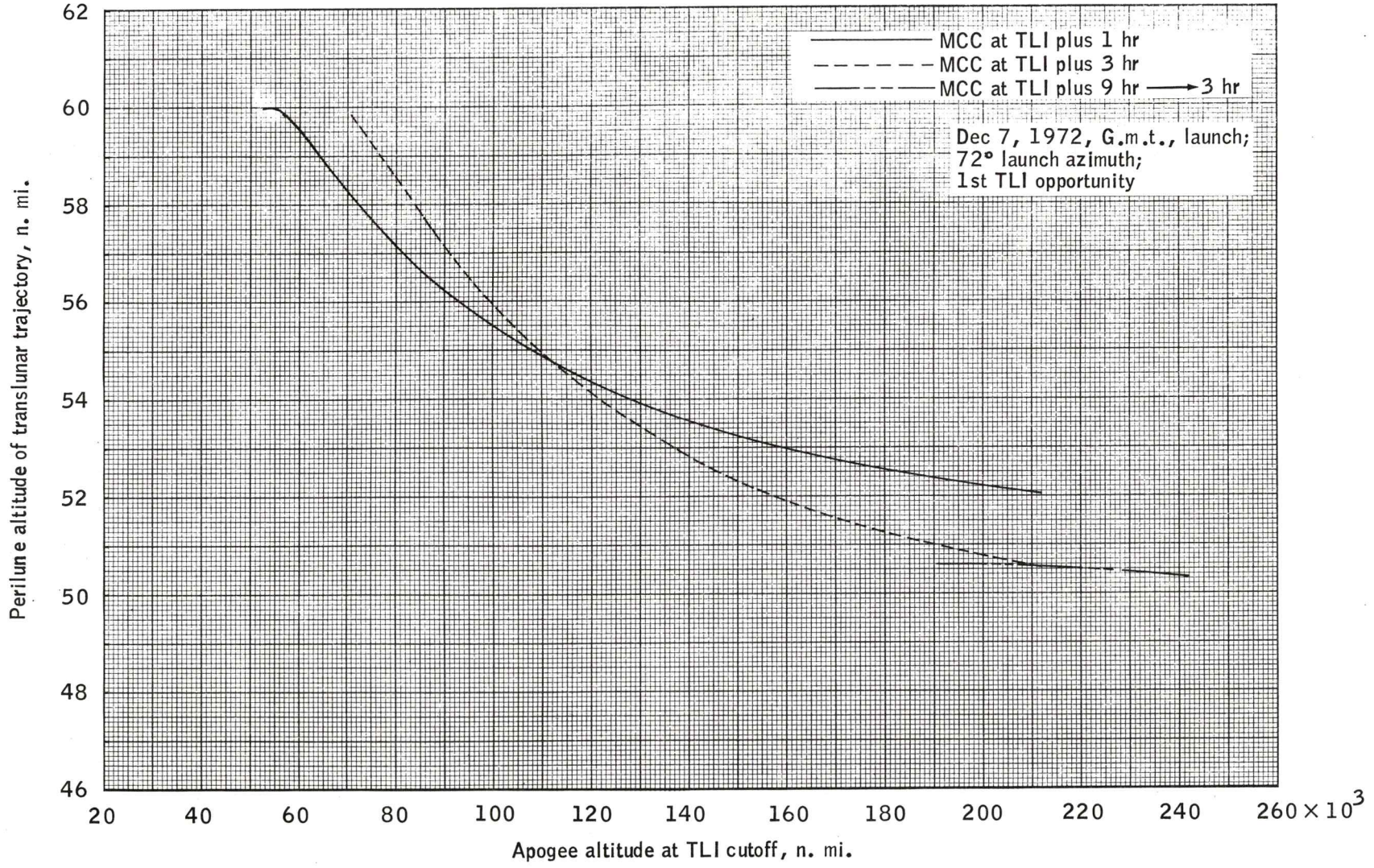
(b) Postcircularization CSM/SPS ΔV available.

Figure 10.- Continued.



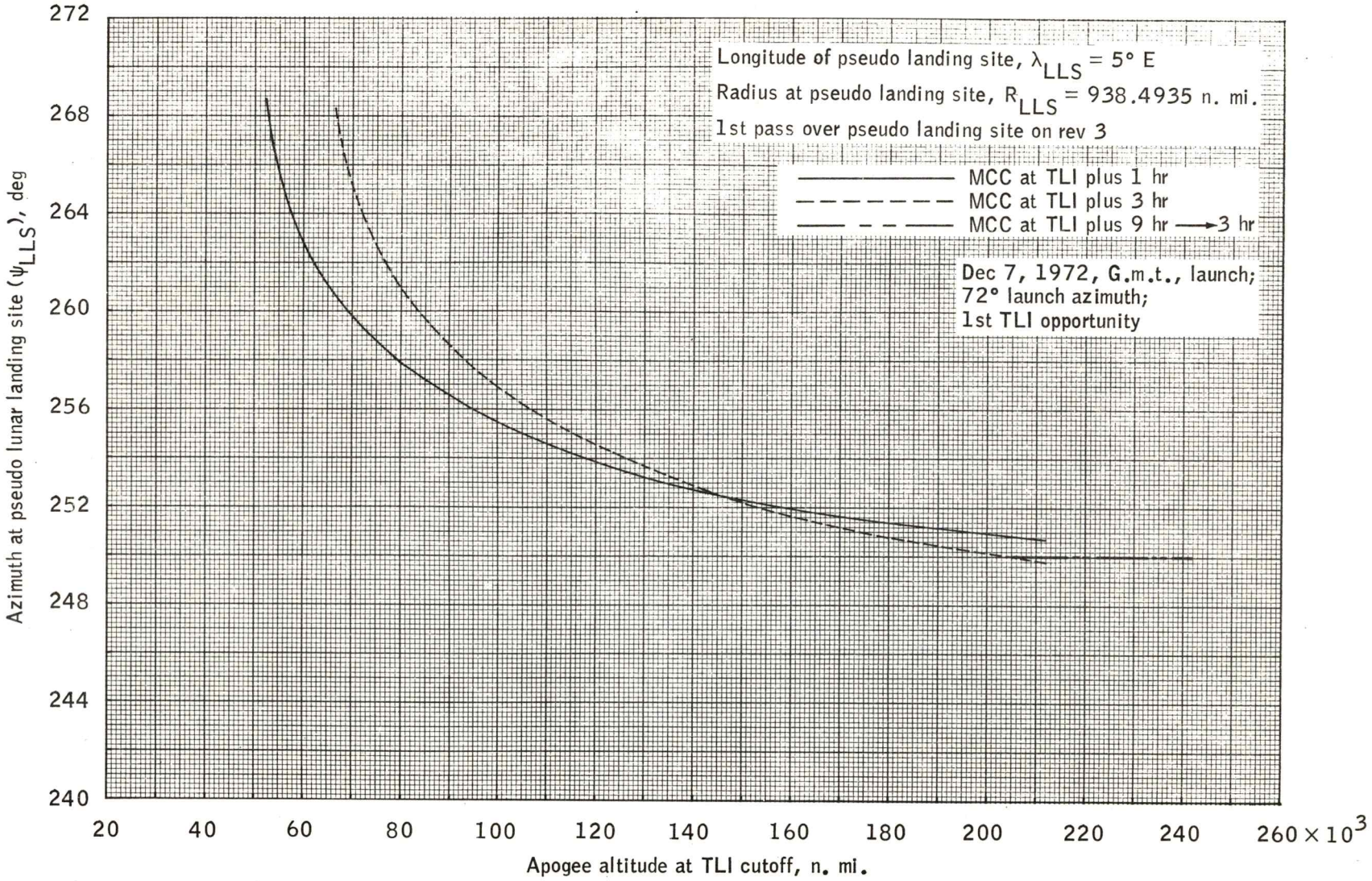
(c) Midcourse ΔV required.

Figure 10.- Continued.



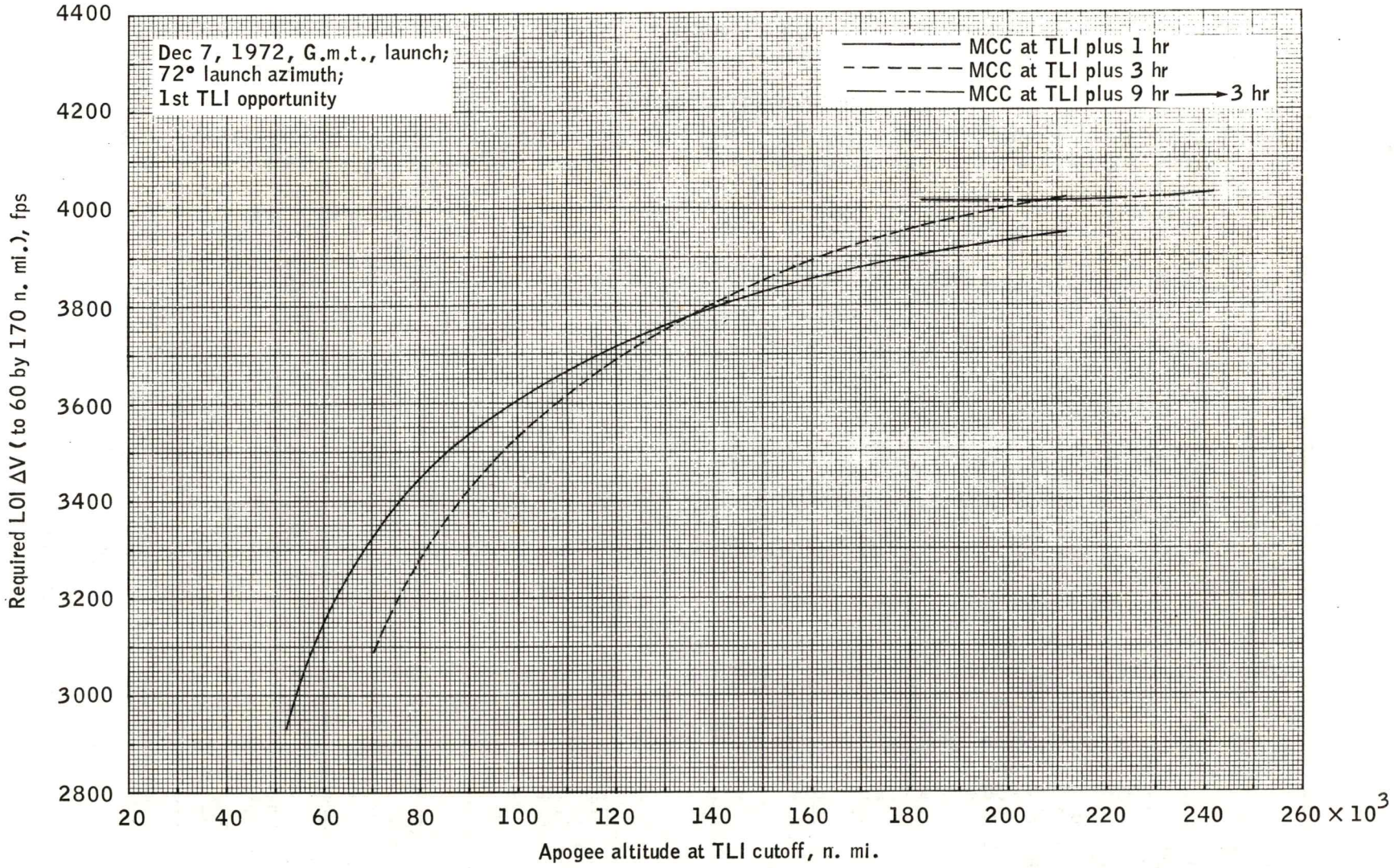
(d) Perilune altitude of translunar trajectory.

Figure 10.- Continued.



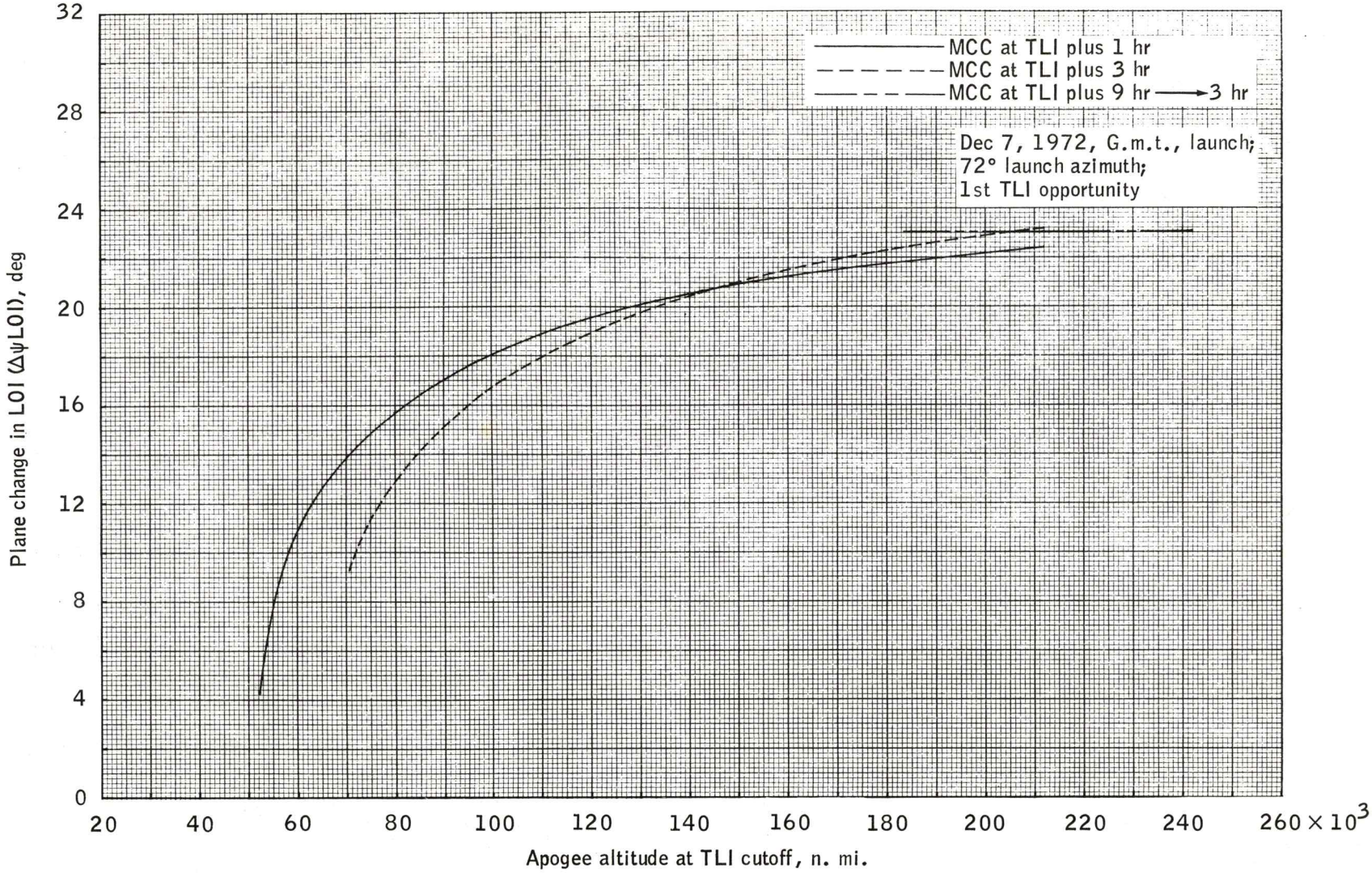
(e) Azimuth at pseudo lunar landing site.

Figure 10.- Continued.



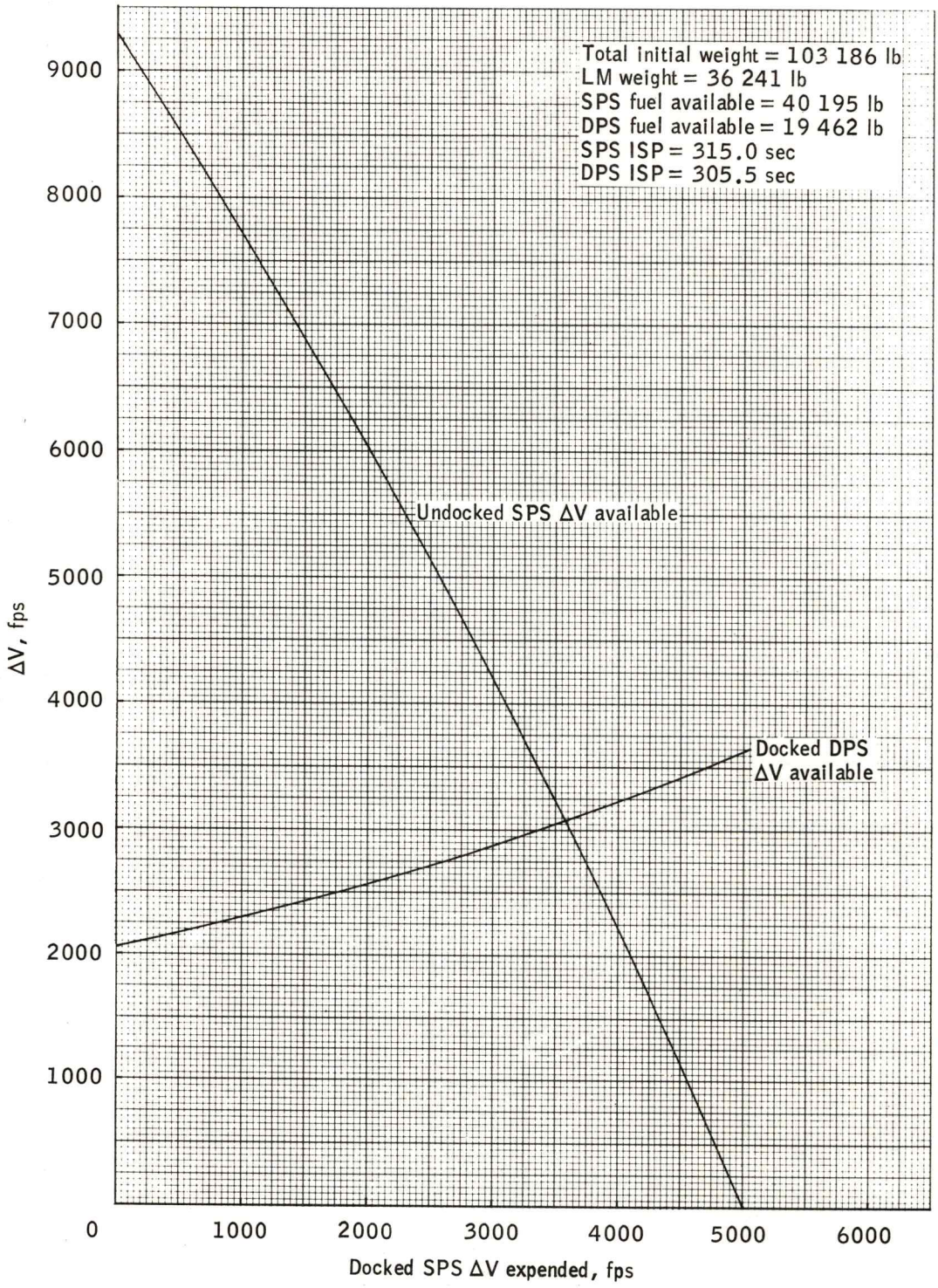
(f) Required LOI ΔV.

Figure 10.- Continued.



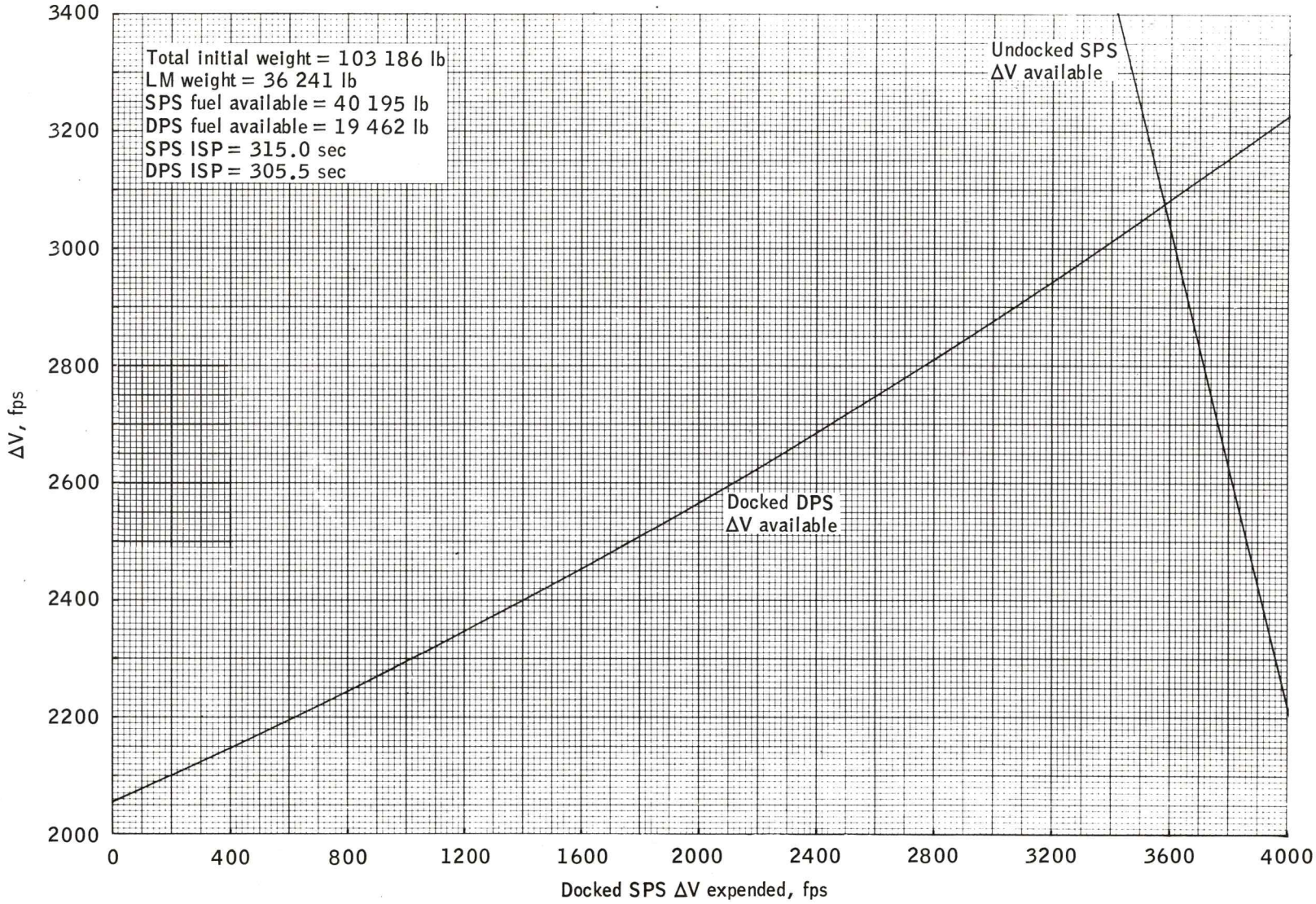
(g) Plane change in LOI.

Figure 10.- Concluded.



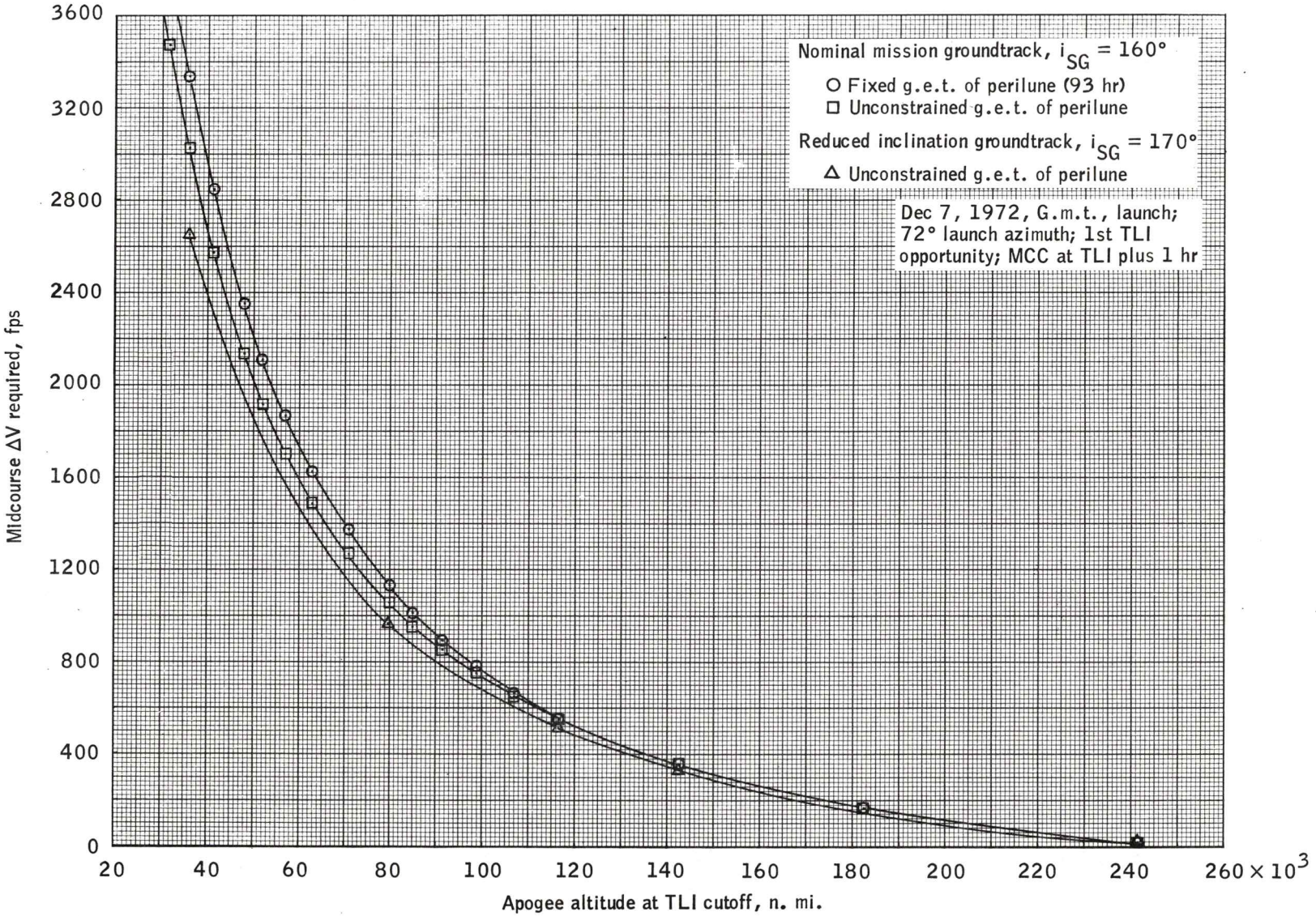
(a) Complete range.

Figure 11.- Undocked SPS ΔV and docked DPS ΔV available versus docked SPS ΔV expended.



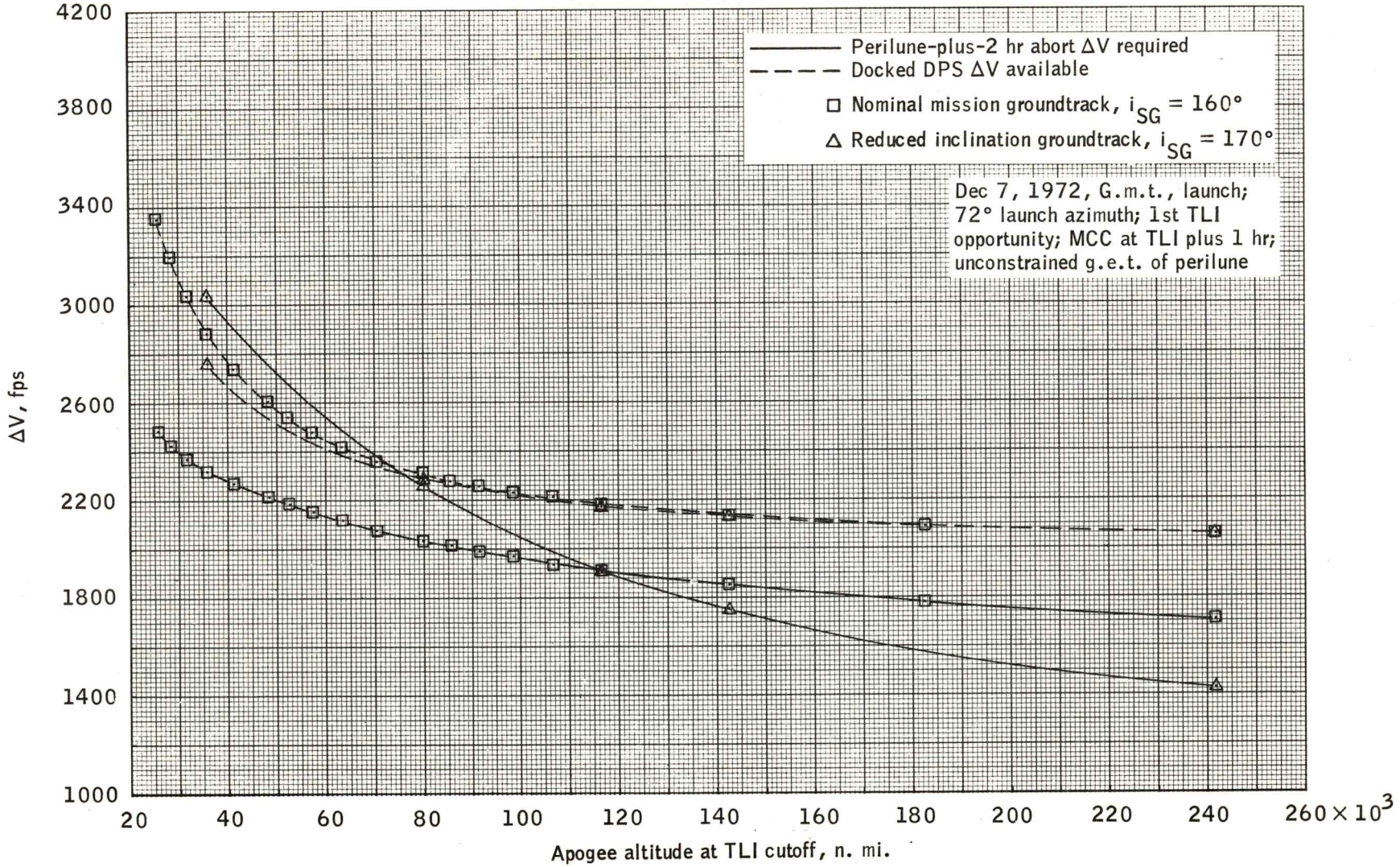
(b) Expanded ordinate scale.

Figure 11.- Concluded.



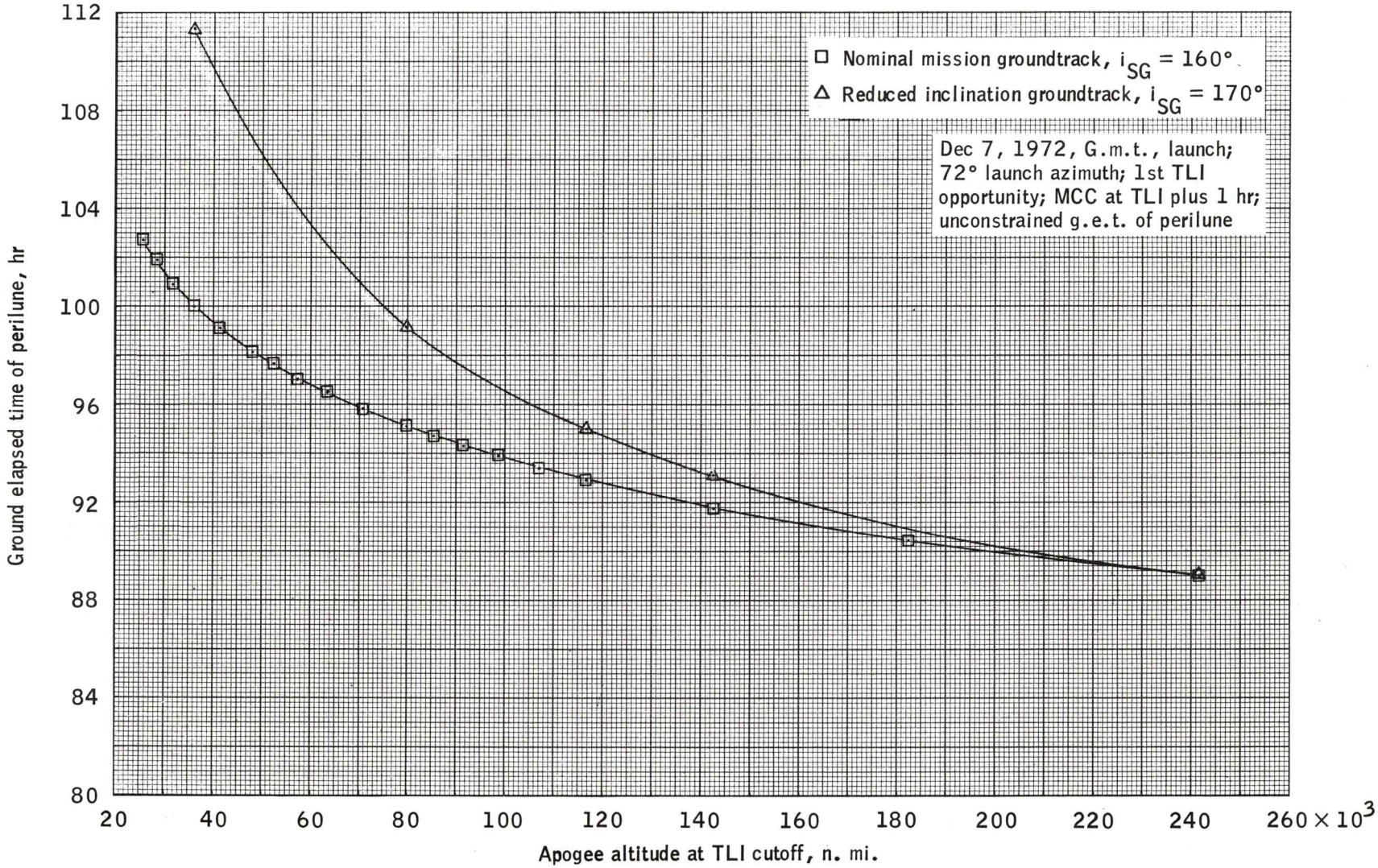
(a) Midcourse ΔV required.

Figure 12.- CSM-plus-LM mission: flight parameters versus apogee altitude at TLI cutoff.



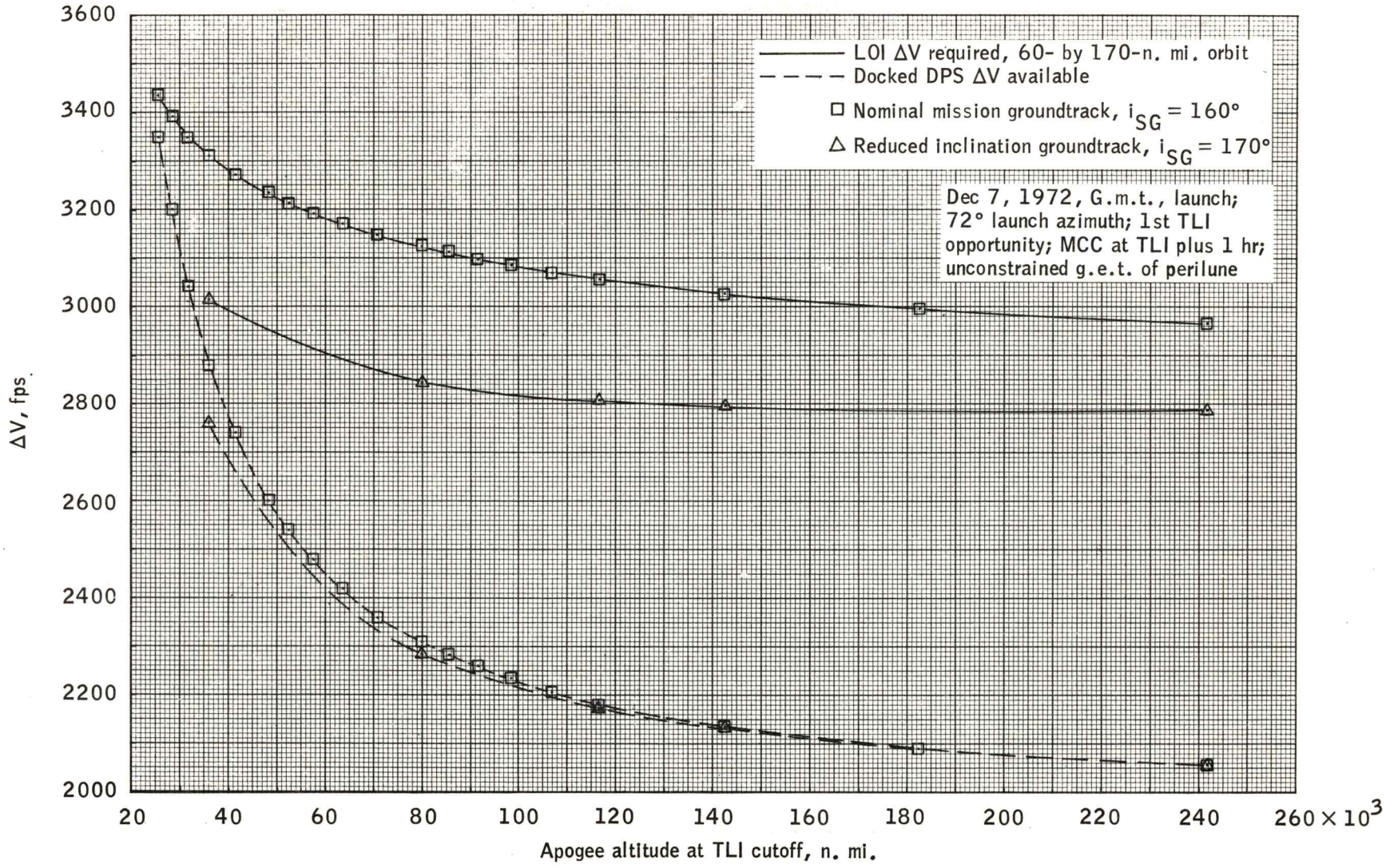
(b) Docked DPS ΔV available and perilune-plus-2 hours abort ΔV required.

Figure 12.- Continued.



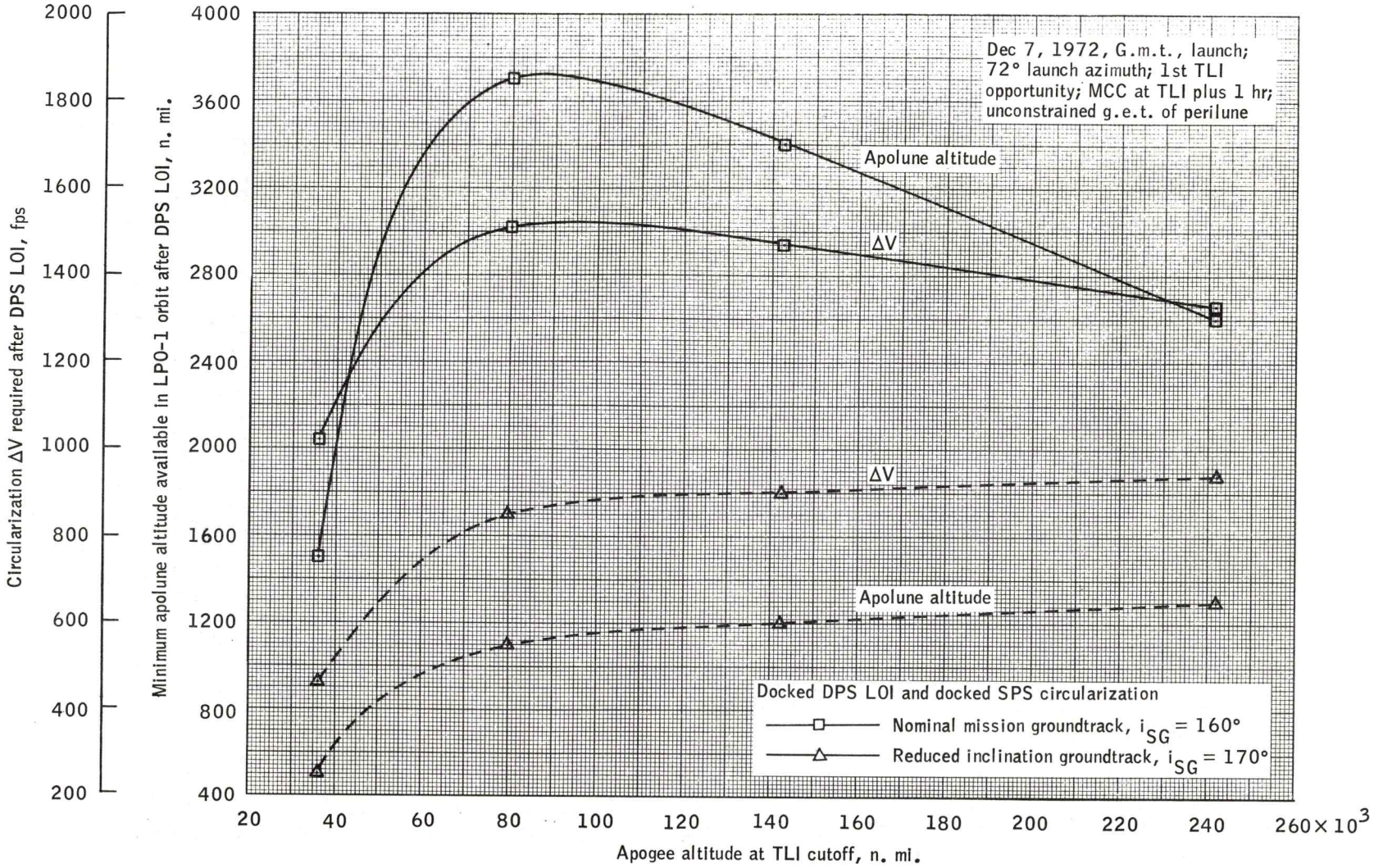
(c) Ground elapsed time of perilune.

Figure 12.- Continued.



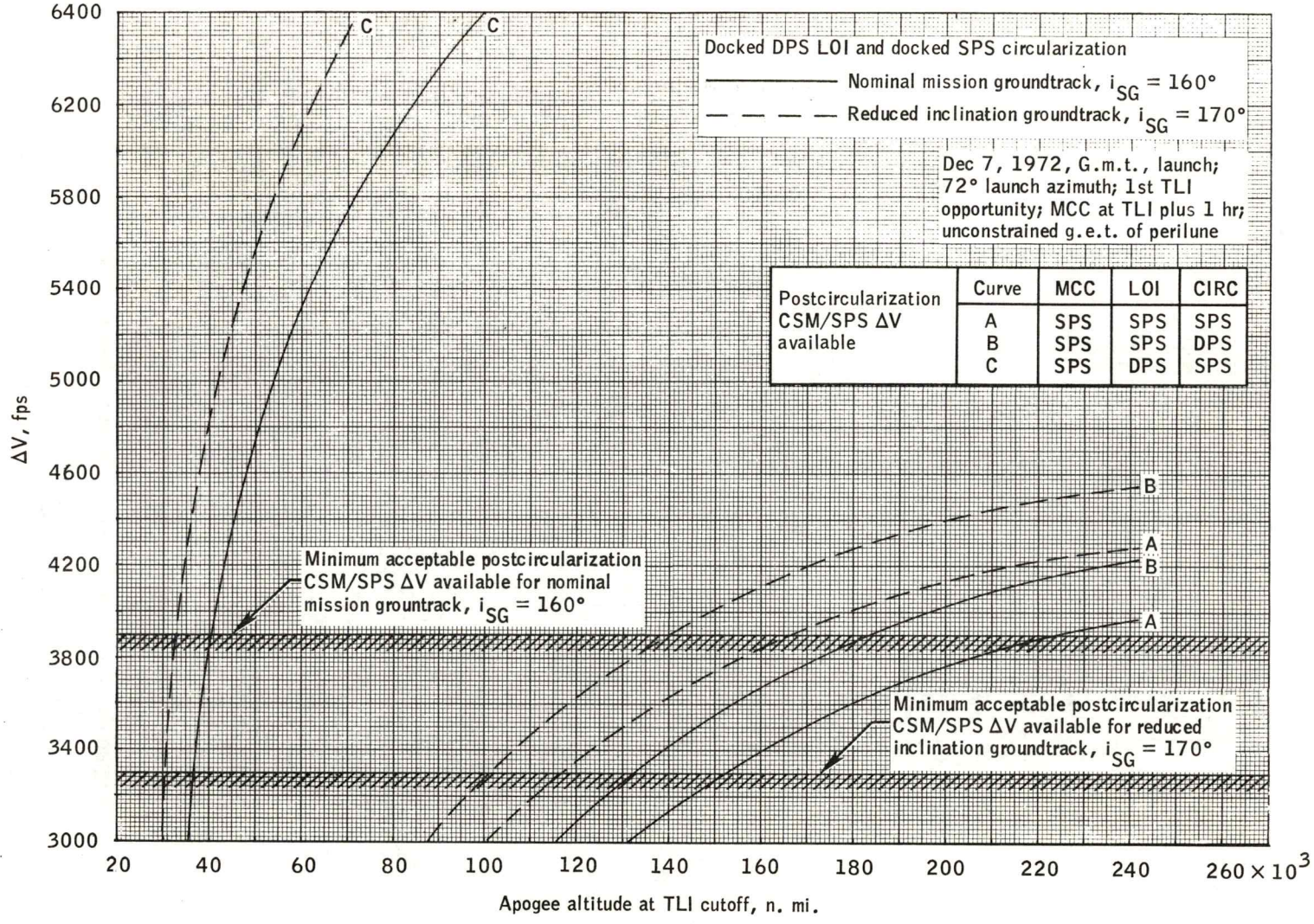
(d) Docked DPS ΔV available and LOI ΔV required.

Figure 12.- Continued.



(e) Minimum apolune altitude available in LPO-1 and circularization ΔV required after DPS LOI.

Figure 12.- Continued.



(f) Postcircularization CSM/SPS ΔV available.

Figure 12.- Concluded.

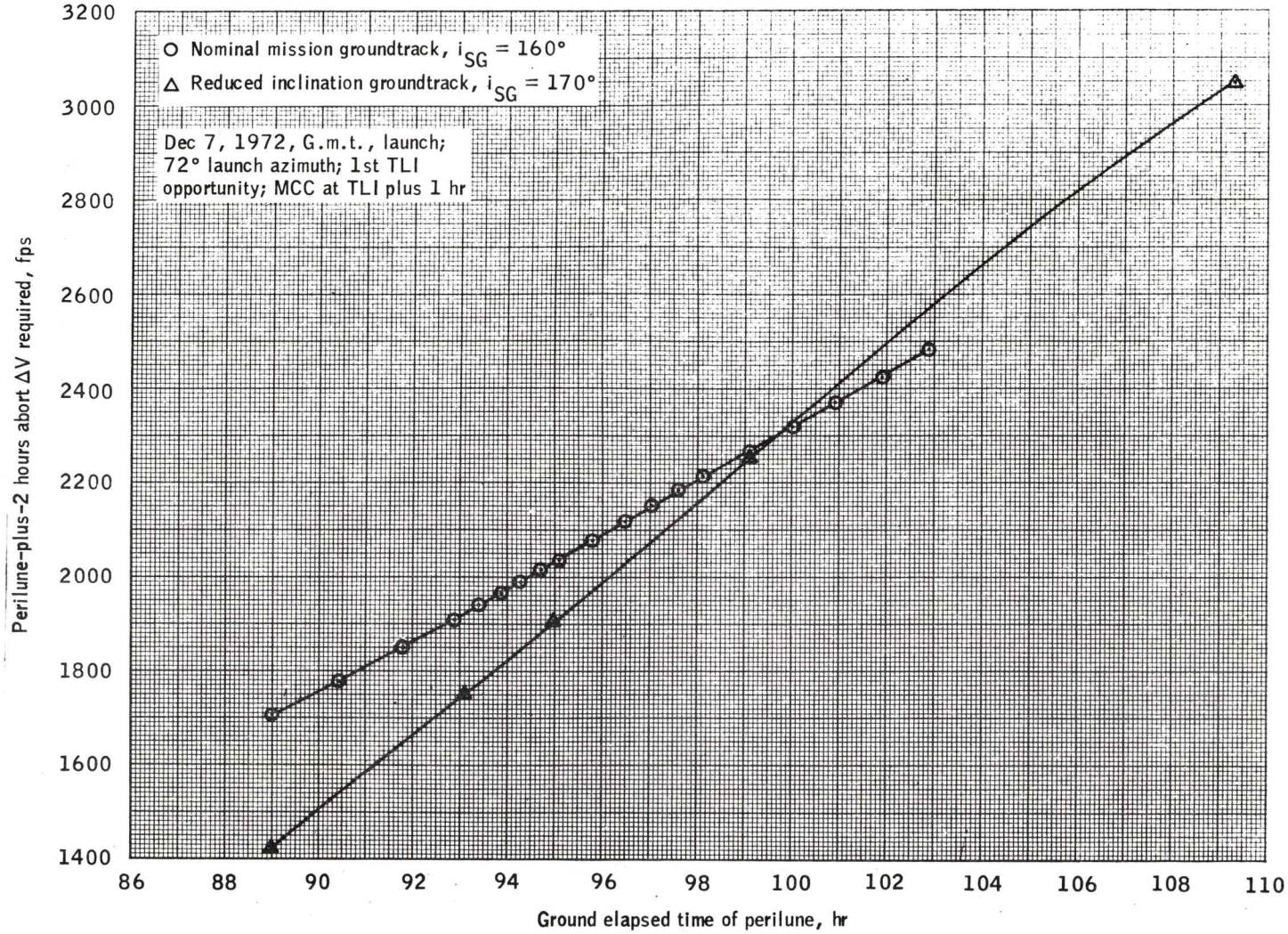


Figure 13.- CSM-plus-LM mission: perilune-plus-2 hours abort ΔV required versus ground elapsed time of perilune.

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