FEB 4 1969

FEB 3 1969

Internal Note 69-FM-15

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC INTERNAL NOTE NO. 69-FM-15

January 27, 1969

OPERATIONAL ABORT PLAN FOR THE APOLLO 9 MISSION VOLUME I - LAUNCH PHASE

AUG 13 1969

Technical Library, Bellcomm, Inc.

Flight Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

(NASA-TM-X-70041) OPERATIONAL ABORT PLAN FOR THE APOLLO 9 MISSION. VOLUME 1: LAUNCH PHASE (NASA) 62 p

N74-72495

Unclas

00/99 16870

MSC INTERNAL NOTE NO. 69-FM-15

PROJECT APOLLO

OPERATIONAL ABORT PLAN FOR THE APOLLO 9 MISSION
VOLUME I - LAUNCH PHASE

By Edward M. Henderson
Flight Analysis Branch

January 27, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

Approved: Charlie C. Allen
Charlie C. Allen, Acting Chief
Flight Analysis Branch

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

CONTENTS

Section		Page
1.0	SUMMARY	1
2.0	INTRODUCTION	1
3.0	INPUT DATA	2
4.0	LAUNCH TRAJECTORY MONITORING	2
	4.1 Ground Monitoring	2
	4.2 Onboard Monitoring	4
5.0	DISCUSSION OF LAUNCH ABORT TRAJECTORY DATA	5
	5.1 General Trajectory Data	5
	5.2 Suborbital Aborts	6
	5.3 Contingency Orbit Insertion	8
6.0	CONCLUDING REMARKS	9
	REFERENCES	57

TABLES

Table		Page
I	LAUNCH SEQUENCE AND EVENT TIME FOR APOLLO 9 LAUNCH	10
II	SC CONSTANTS USED FOR APOLLO 9 LAUNCH ABORT STUDIES	12
III	COMMAND MODULE AERODYNAMICS USED FOR APOLLO 9 LAUNCH ABORT STUDIES	13
IV	TYPICAL DSKY PARAMETERS DURING LAUNCH FOR THE APOLLO 9 MISSION	14
V	TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE II ABORTS FOR THE APOLLO 9 MISSION	
	(a) Entry parameters	19
	(b) Event times	22
VI	TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE III ABORTS FOR THE APOLLO 9 MISSION	
	(a) Burn parameters	24
	(b) Entry parameters	27
VII	TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE IV ABORTS FOR THE APOLLO 9 MISSION	
	(a) Without ΔV pad	30
	(b) With 100 fps pad	33

FIGURES

Figure		Page
1	Apollo 9 launch timeline and contingency capability	36
2	Launch abort and capability limits	37
3	Near-insertion abort mode overlap	38
4	S-IVB early staging to orbit capability	39
5	SPS contingency orbital insertion capability	40
6	AGC display keyboard and display parameters	41
7	No-voice crew chart for launch phase	42
8	Inertial velocity and inertial flight-path angle along the nominal launch trajectory	
	(a) Complete launch	43
	(b) Near insertion	44
9	Downrange distance and altitude along the nominal launch trajectory	
	(a) Complete launch	45
	(b) Near insertion	46
10	Spacecraft IMU gimbal angle readouts along the nominal launch trajectory	47
11	Mode II abort parameters for aborts from the nominal launch trajectory	48
12	Entry orientation following no burn aborts from the nominal launch trajectory	49
13	Mode III burn orientation following aborts from the nominal launch trajectory	50
14	Mode III abort parameters for aborts from the nominal launch trajectory	51

Figure		Page
15	Constant mode III ΔV contours required to land at the Atlantic discrete recovery area	52
16	Entry orientation following mode III aborts from the nominal launch trajectory	53
17	Mode IV burn orientation following aborts from the nominal launch trajectory	54
18	Mode IV abort parameters for aborts from the nominal launch trajectory	55
19	Constant mode IV ΔV contours required to achieve a 75-nautical mile perigee altitude	56

OPERATIONAL ABORT PLAN FOR THE APOLLO 9 MISSION

VOLUME I - LAUNCH PHASE

By Edward M. Henderson

1.0 SUMMARY

A continuous method of returning the flight crew safely to earth for the Apollo 9 mission - with or without ground control help - has been defined. This volume contains the rationale and supporting data for the launch phase. Volume II will contain the abort data for the orbit phase. These abort studies were conducted for the command and service modules (CSM) - 104 spacecraft and the AS-504 launch vehicle. The abort trajectory data presented provides information on abort monitoring, abort maneuver requirements, and abort results.

2.0 INTRODUCTION

The abort studies contained in this document were conducted for the CSM-104 Apollo spacecraft (SC) and AS-504 Saturn V launch vehicle (LV). Specific trajectory data resulting from a launch escape vehicle abort, mode I, are not presented because of a change in launch pads (39B to 39A) since the publication of the operational launch trajectory (ref. 1). The launch pad coordinates have a negligible effect on subsequent abort modes, and the data presented will be very representative for the Apollo 9 mission. Representative mode I data can be obtained directly from reference 2.

The data presented is primarily an update to previous studies based on specific Apollo 9 characteristics. The basic launch abort philosophy and abort mode definitions are essentially unchanged from the previous Apollo missions. General information, along with dispersion trends, can be obtained directly from reference 3. The current launch abort techniques are presented in reference 4.

The SC trajectory data shown in this document were based on computer simulations of the recommended abort procedures. These studies were conducted by TRW Systems Group, Houston Operations, under MSC/TRW Task A-162 (ref. 5).

The launch abort capability is best illustrated by figure 1, which indicates the primary and backup abort methods for the nominal launch timeline. The LV and SC abort event times are presented on table I for the nominal launch profile.

This document presents information that could be used by ground controllers and the crew to provide safe abort capability in the event of a contingency during the launch phase. Volume II will contain the abort data for the orbit phase.

3.0 INPUT DATA

Pertinent SC constants and performance characteristics for CSM-104 were obtained from references 6 and 7. The SC constants are summarized in table II, and the SC aerodynamics for launch aborts are shown in table III. table III. The initial state vectors used for abort initiation were based on the AS-504 operational launch trajectory (ref. 1). Note these studies are based on a launch from pad 39B. Since the generation of these studies, the launch pad has changed to 39A. This change has a negligible effect on the enclosed trajectory data.

The multi-vehicle N stage (MVNS) computer program, reference 8, was used to simulate the abort trajectories studied. The inertial measurement unit (IMU) reference system used in this report to define the attitude angles is a right-handed orthogonal coordinate system centered at the launch site. The positive X-axis extends down range along the flight azimuth (72°) and lies in the horizontal plane. The positive Z-axis is directed downward along the astronomical vertical at lift-off. The positive Y-axis completes the right-handed system.

4.0 LAUNCH TRAJECTORY MONITORING

4.1 Ground Monitoring

The ground Mission Control Center in Houston (MCC-H) flight controllers have the prime responsibility of monitoring the trajectory during the launch phase. The ground is prime for determining abort trajectory limit violations, abort mode decisions, and GO - NO-GO orbit insertion status. The flight dynamics displays are the trajectory monitoring displays used by the ground controllers. These consist of the launch digitals and projection plotters displayed on cathode ray tubes (TV) and analog plotboards. The displays are driven by real-time computer computations based on the actual flight data received

from the Manned Space Flight Network (MSFN). The Flight Dynamics displays currently being used in Apollo 9 simulation are presented in reference 9.

The launch abort trajectory limits are summarized on figure 2. These limits include a structural breakup limit, 16g limit, a 100-second free-fall time (t_{ff}) limit, and an exit heating limit (still under arbitration). Note that the exit heating limit is invalid for engine out or low thrust trajectories. These limits define a launch corridor that is acceptable for safe SC abort capability. In addition to the limits and the nominal trajectory, the S-IVB early staging and service propulsion system (SPS) contingency orbital insertion (COI) capability lines are shown. The latter two lines define, respectively, when the S-II has progressed sufficiently for the S-IVB to direct stage into a parking orbit (100 n. mi., circular) and when the S-IVB has progressed enough for the SPS (mode IV) to insert the SC in a contingency orbit ($h_p > 75$ n. mi.).

Comparing the COI capability with the suborbital capability for the near-insertion region, the abort mode overlays can be determined. This is shown on figure 3 and, as can be seen, the mode IV COI capability overlaps the end of mode II and all of mode III along the nominal trajectory. Also shown are the dispersed S-IVB cutoff conditions that would require an apogee kick or a mode III maneuver. The 75-n. mi. perigee altitude line is shown to indicate when the S-IVB has achieved a GO orbit and a 8.5-second line indicates an S-IVB overspeed condition. Note that mode III capability is limited by 100-seconds t_{ff} and 16g constraints. Therefore, mode III burns initiated beyond these constraints would require lift modulation to avoid a land landing or to reduce g. Increased insertion ranges would further restrict the mode III capability.

The trajectory lines shown on figures 2 and 3 are analogous to the plotboard information being displayed to the flight controllers in real time. Comparing the actual launch trace with this trajectory information will aid the flight controllers in determining the trajectory status during launch and to determine the appropriate abort mode, if necessary. The S-IVB early staging and the SPS COI capabilities depend on current altitude. Therefore, console plots, such as figures 4 and 5, will be required to determine these capabilities for off-nominal altitude histories. The ground will keep the crew informed on the trajectory status by voice communications and request abort action by both voice and the abort light upon abort confirmation.

4.2 Onboard Monitoring

During launch, the crew has command module computer (CMC) program P-11 and its corresponding DSKY displays, and the flight director attitude indicator (FDAI) displays to facilitate trajectory monitoring. P-11 is automatically initiated upon lift-off (or manually by V75E) and is available until the ground or crew commands program 00. Normally the ground will inform the crew of their trajectory status. However, if voice communications were lost during the launch, the crew would have to depend on P-11 displays for this information. Table IV shows the values of the DSKY parameters for a nominal launch, which were computed with the COLOSSUS guidance equations (ref. 10) for Apollo 9. The nominal FDAI attitudes during the launch are shown on figure 10. The DSKY displays are updated every 2 seconds and displayed to the crew. Any time the ground should rule the SC guidance NO-GO, the computer would be commanded to program 00, and these DSKY displays would no longer be available.

In conjunction with the DSKY displays associated with P-11 (fig. 6), an onboard chart (fig. 7) is proposed for use in the event of voice communications loss during the launch. The basic DSKY displays for launch monitoring are the inertial velocity, V_i, altitude rate, $\dot{h}$, and altitude, h, parameters. Therefore, these are the parameters used to govern the chart. The chart with the DSKY is to be used to help determine when and what abort action is necessary. These functions would normally be conducted by the ground when voice communications exist. Once the abort decision has been made, the crew would use the DSKY parameters to monitor the abort burn. The mode III and IV SPS burn ignition times are for 125 seconds after S-IVB cutoff; other ignition times would be incompatible with the COI capability shown on the onboard chart and with burn verification runs made by the ground. If t_{ff} becomes equal to 100 seconds and is decreasing during a burn, the burn must be terminated and immediate entry preparation initiated. Caution should be employed during the mode IV burn. If anytime during the burn perigee altitude starts decreasing, the burn should be terminated; and if terminated with $h_p < 75$ n. mi., a mode III abort should be initiated when $\dot{h} \leq 0$ or $h_a < 75$ n. mi., and an apogee kick should be initiated when $\dot{h} > 0$.

The onboard chart is divided into two parts and plotted on one chart for operational ease. The first part, shown on figure 7, shows the nominal altitude rate versus velocity trace and the current abort trajectory limits. Should the actual flight trace violate the booster breakup line, the exit heating limit, or the maximum entry load limit line (16g), an abort is required. Note the exit heating limit is invalid for engines out or low thrust trajectories. If the trace

approaches the t_{ff} limit line, V82E and N50E should be called and abort action taken when t_{ff} equals 100 seconds and is decreasing. Note that even if voice communications were lost, the ground might still be able to command abort action by using the abort light. Because of the sensitivity of the 16g limit line to altitude, this limit is shown for several different altitudes, and the current altitude displayed on the DSKY would govern which abort limit to use.

The second part, shown on figure 7, shows the nominal altitude rate versus velocity trace for approximately the last 2 minutes of the launch. This chart expands the region where abort capability starts varying rapidly. The primary use of this chart is to show for what S-IVB cutoff conditions COI capability exists. Therefore, the COI boundary is defined for different altitudes. Since the altitude is fairly static near insertion, the crew could choose the appropriate COI boundary and determine when the S-IVB trace crosses into the COI capability region. Note if the S-IVB cutoff point is outside the appropriate mode IV evelope and beyond the 2 minutes 5 seconds to apogee line, then it is recommended that the COI maneuver be postponed until apogee (apogee kick). The other abort capabilities can be determined directly from the DSKY. Once tower jettison has occurred, mode II capability extends until ΔR[a] becomes greater than -400 n. mi., which corresponds to a full-lift landing at 3200 n. mi. S-IVB cutoff conditions resulting in a ΔR of between -400 and 0 n. mi. when a suborbital abort is required indicate a no-burn, half-lift entry abort procedure; for $\Delta R > 0$, a mode III burn is required. A GO orbit is achieved when perigee altitude is greater than or equal to 75 n. mi.

Note whenever the t_{ff} is 59 minutes 59 seconds, the ΔR computation is invalid. This is true once the perigee altitude becomes greater than 300 000 ft. If a mode III burn is required in this region, ΔR will become valid when the burn has progressed enough to decrease perigee altitude below 300 000 ft.

5.0 DISCUSSION OF LAUNCH ABORT TRAJECTORY DATA

5.1 General Trajectory Data

The ascent profile is governed by the launch trajectory as defined in reference 1. A list of the key events during launch is presented in table I. The spacecraft abort data uses this trajectory as a basis

---

[a] ΔR, or SPLERROR, is the difference between the onboard predicted landing point and the mode III target point.

for initial abort conditions and a monitoring guide. The spacecraft abort capability is primarily a function of the inertial velocity, inertial flight-path angle, altitude, and down-range distance. These critical parameters are shown on figures 8 and 9 for the nominal launch timeline. The spacecraft IMU gimbal angles are presented on figure 10 for the nominal launch. These are used to monitor the attitudes during launch and to establish initial SC orientations for abort conditions. Note that a tumbling abort could result in any attitude at abort initiation and would require a manual correction, but this additional sequence will have a negligible effect on data presented in this document.

If initial abort conditions can be related to the velocity, flight-path angle, altitude, and down range distance, then the resulting SC abort trajectory data is representative from mission to mission. This is because of the similarities inherent in the Apollo SC design. Therefore, plots such as those shown on figures 8 and 9 can be used to correlate data from other launch abort studies to this mission by adjusting the times to the state conditions.

5.2 Suborbital Aborts

Suborbital aborts are defined as aborts that occur in the launch phase prior to COI capability, where entry is eminent, or aborts which occur near insertion that require immediate return to the earth. These suborbital aborts are subdivided into three abort modes:

1. Mode I aborts which require use of the launch escape tower (LET) to perform a safe abort.

2. Mode II aborts which require separation from the LV and a full-lift entry.

3. Mode III aborts which require separation from the LV and then a maneuver to avoid land landing.

The possibility of mode I aborts from the Saturn V vehicle exists from the time the launch escape vehicle (LEV) is armed until nominal tower jettison at approximately 3 minutes 16 seconds ground elapsed time (g.e.t.). The LEV is designed to accelerate the CM and the crew away from the LV to a safe separation distance and far enough down range from the launch pad for a safe water landing. Mode I aborts are divided into three categories: mode IA (low altitude), mode IB (medium altitude), and mode IC (high altitude).

Since the generation of the LV operational trajectory (ref. 1) the launch pad has been changed from 39B to 39A. Because of the sensitivity of mode I trajectory data to the pad location, no mode I

trajectory data is presented for this LV trajectory. However, the data presented for Apollo 8 in reference 2 is considered to be very representative of the Apollo 9 mode I trajectory characteristics and can be used until the LV trajectory is revised for the new pad location.

The mode II abort procedures are designed for contingencies occurring from LET jettison (196 seconds g.e.t.) until a safe orbit can be achieved with the SPS (562 seconds g.e.t.) or until the resulting landings threaten the west coast of Africa (R_{ip} = 3200 n. mi.). Because these aborts can result in high entry loads (g) and/or time critical entries, no range control maneuvers are considered. A full-lift entry is used to minimize g, and a simple separation technique is established for rapid entry orientation. The mode II sequence requires at least a 100-second t_{ff} from S-IVB cutoff to 300 000-ft altitude for orientation to proper atmospheric capture attitude (blunt end forward).

A list of the pertinent trajectory parameters for mode II aborts from the nominal launch trajectory are presented in table V. The resulting t_{ff}, g, and landing range following a mode II abort are plotted on figure 11. The SC IMU pitch gimbal angle corresponding to the proper CM entry orientation attitude is presented in figure 12. A more detailed analysis of the mode II aborts for the Saturn V launches is presented in reference 3.

The mode III abort procedures are required for contingencies occurring beyond mode II (R_{ip} > 3200 n. mi.) when a safe orbit cannot be achieved or when SC systems malfunctions dictate immediate landings. The first mode III requirement is unlikely because of the large COI region and S-IVB cutoff conditions would have to be greatly dispersed from the nominal launch trajectory (fig. 3). The second is unlikely because if such a malfunction had occurred during launch, the abort would more probably be initiated prior to entering mode III, and failures occurring after entering mode III would be almost impossible to confirm in sufficient time to recommend a mode III abort. System failures would have to be such that landing must occur in less than about 30 minutes versus about 2 hours for landing in Area 2-1. These types of system failures are currently undefined.

Mode III abort capability begins at the end of mode II when the full-lift landing range (R_{ip}) exceeds 3200 n. mi. (571 seconds g.e.t.). Since mode III entries are half-lift (RL55) and the SPS retrograde burn is only required to achieve a landing range of 3350 n. mi., there exists a period (between 571 and 594 seconds g.e.t.) which requires no-burn and landings would be west of 3350-n. mi. landing target (ADRA). Should the mode III burn violate t_{ff} (100 seconds) or g (16) during the burn, the burn must be terminated and the appropriate lift profile flown to avoid land and/or reduce g.

A list of the pertinent trajectory parameters for mode III aborts from the nominal launch trajectory is presented on table VI. The SC IMU pitch gimbal angle corresponding to the horizon monitor (31.7° window sribe mark) retrograde SPS burn attitude is presented on figure 13 for mode III aborts from the nominal trajectory. The required ΔV and the resulting t_{ff} and g for the mode III aborts are plotted on figure 14. The mode III ΔV requirements to achieve landings at the Atlantic Discrete Recovery Area (ADRA) are shown on figure 15 for deviations from the nominal flight-path angle. Note from this figure that the mode III region is bounded by the end of mode II, 16g entry load limit, and the 100-second t_{ff} limit. The SC IMU pitch gimbal angle corresponding to the proper CM entry orientation attitude at 0.05g is presented on figure 16. Additional mode III abort definition and trajectory data can be obtained from reference 3.

5.3 Contingency Orbit Insertion

The COI procedure is selected for contingencies once the SPS can insert the SC into a safe orbit (h_p > 75 n. mi.) and deorbit from any place in the resulting orbit. This capability is divided into two regions: (1) mode IV which requires an SPS burn as soon as practical, and (2) apogee kick which requires delaying the SPS burn until apogee is achieved. COI is the prime selection whenever the capability exists because it is the safest and has potential alternate mission capability. It allows the ground and crew ample time in earth orbit to determine the SC's trajectory state and system's status, and the ground can compute a precise deorbit maneuver for a planned landing area.

The initial mode IV capability is not dependent upon the amount of SPS propellant loaded for this mission, but is based on the SPS performance with the fixed burn attitude to achieve orbital velocity prior to premature entry. In addition, this capability is extremely sensitive to pitch errors during the maneuver. Therefore, the capability is defined for a ±2° pitch error bias during the burn.

Mode IV COI capability begins at 562 seconds g.e.t. and ends once the S-IVB has achieved a safe perigee, 648 seconds g.e.t., or about 1 second prior to the nominal S-IVB cutoff signal. A list of the pertinent trajectory parameters for mode IV maneuvers performed from the nominal trajectory are presented on table VII. The SC IMU pitch gimbal angle corresponding to SPS ignition (125 seconds after abort) using horizon monitor (31.7° window scribe mark) for the mode IV is shown on figure 17 for burns initiated for S-IVB shutdowns along the nominal trajectory. The ground-computed ΔV is that required to achieve a h_p = 75 n. mi. This ΔV will be padded approximately 100 fps prior

to being relayed to the crew. These ΔV's along with the resulting orbital parameters are plotted on figure 18. The mode IV ΔV requirements to achieve a h_p = 75 n. mi. are shown on figure 19 for deviations from the nominal flight-path angle.

The apogee kick capability begins once the S-IVB cutoff conditions would locate the apogee favorably for such a maneuver. Previous studies have indicated this to be true when apogee occurs greater than 125 seconds from S-IVB cutoff and for S-IVB cutoff velocities in excess of 23 500 fps. Even though the apogee kick is nearer optimum than the mode IV for the COI maneuver, current mission rules stipulate that this maneuver will only be recommended for S-IVB cutoffs beyond the mode IV capability. This is because of an inherent delay in the ground's computation of the apogee kick maneuver, whereas the mode IV solution is readily available. Additional COI trajectory information can be obtained from reference 3 and can be used to supplement the information presented in this document.

6.0 CONCLUDING REMARKS

This document plus previous Saturn V launch abort studies demonstrate that an adequate abort plan exists for the launch phase of the Apollo 9 mission. In addition, it presents information that could be used by ground controllers and the crew to provide safe abort capability. The data presented is primarily an update based on specific Apollo 9 characteristics. The basic launch abort philosophy and abort mode definitions are essentially unchanged from the previous Apollo missions. Past studies, such as the launch abort studies presented in references 2 and 3, can be used to supplement the enclosed data with reasonable agreement.

Mode I launch abort studies will be conducted upon receipt of the revised launch trajectory (pad 39A). If these studies indicate an appreciable change from the Apollo 8 data, then these will be published as an amendment to this document.

The primary objective if contingencies occur during launch is to continue into orbit whenever possible. These studies show that the existing launch abort procedures and techniques used to define, execute, and monitor abort trajectories are adequate for contingencies which could develop during the launch phase for the planned Apollo 9 mission.

TABLE I.- LAUNCH SEQUENCE AND EVENT

TIME FOR APOLLO 9 LAUNCH

g.e.t., min:sec	Event description
-20:00	arm the LEV, begin mode IA
00:00	first motion
00:42	begin mode IB
01:45	fixed time abort 1 (mode IB)
01:54	100 000 ft altitude, begin mode IC
02:14	S-IC center-engine cutoff (TB2)
02:39.7	S-IC onboard-engine cutoff (TB3)
02:40.5	S-IC/S-II separation
02:42.1	S-II ignition
03:00	fixed time abort 2 (mode IC)
03:10.2	jettison S-II after interstage
03:15.9	jettison launch escape tower, begin mode II
04:30	fixed time abort 3 (mode II)
05:50	S-IVB early staging orbit capability
08:53.6	S-II engine cutoff (TB4)
08:57.6	S-IVB engine ignition
09:10	fixed time abort 4 (mode II)
09:22	begin mode IV, COI
09:30	begin no voice/no G&N mode III Procedure $t_b = 2(t_a - 570)$

TABLE I.- LAUNCH SEQUENCE AND EVENT

TIMES FOR APOLLO 9 LAUNCH - Concluded

g.e.t., min:sec	Event description
09:31	begin mode III (no burn)
09:54	begin mode III (w/burn)
10:49.3	S-IVB first guidance cutoff
10:59.3	insertion

TABLE II.- SC CONSTANTS USED FOR APOLLO 9

LAUNCH ABORT STUDIES

Launch pad	39B
Launch pad geodetic latitude, deg N	28.626536
Launch pad longitude, deg W	-80.620811
CSM weight at insertion, lb	58 962
CM weight (launch), lb	12 319
SPS propellant (nominal deliverable), lb	35 730.9
SPS thrust, lb	20 626
SPS I_{sp}, sec	313
SPS thrust vector pitch offset (c.g. at launch), deg	3.684
SM/RCS thrust, lb	102.8
SM/RCS I_{sp}, sec	277.3
SM/RCS quad thrust offset, deg	10
Mode III landing target range ($\Delta R = 0$), n. mi.	3350
Mode III target geodetic latitude, deg N	26.30
Mode III target latitude, deg W	-17.14
Mode IV (COI) minimum target perigee altitude, n. mi.	75

TABLE III.- COMMAND MODULE AERODYNAMICS USED

FOR APOLLO 9 LAUNCH ABORT STUDIES

Mach no.	Alpha	C_L	C_D	C_L/C_D
0.20	170.85	0.23471	0.82516	0.28445
0.40	167.22	0.24291	0.85330	0.28467
0.70	164.08	0.26673	0.98340	0.27123
0.90	161.27	0.32675	1.06167	0.30777
1.10	154.15	0.50448	1.16099	0.43453
1.20	154.50	0.48861	1.14844	0.42545
1.35	153.41	0.57346	1.27104	0.45118
1.65	152.42	0.55997	1.25543	0.44604
2.00	152.11	0.54083	1.25152	0.43214
2.40	152.53	0.51634	1.21981	0.42330
3.00	153.11	0.48762	1.19417	0.40833
4.00	155.30	0.45019	1.19920	0.37541
10.00	156.02	0.43694	1.20867	0.36150
29.50	159.41	0.39649	1.27650	0.31060

Note: Begin mission aerodynamics

XCG = 1042.41

YCG = -0.10

ZCG = 6.08

Bank angle bias = -0.94°

TABLE IV.- TYPICAL DSKY PARAMETERS DURING LAUNCH FOR THE APOLLO 9 MISSION

Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Altitude (n mi)	Altitude Rate (ft/sec)	SPLERROR (n mi)	Predicted Perigee (n mi)	Predicted Apogee (n mi)	Predicted Time of Free Fall to 300,000 Feet (min:sec)
00:00	1,342	0.0	0	-3350.0*	-3436.7	0.0	-59:59**
00:10	1,344	0.1	78	-3350.0*	-3436.7	0.1	-59:59**
00:20	1,356	0.3	179	-3350.0*	-3436.7	0.4	-59.59**
00:30	1,403	0.7	305	-3350.0*	-3436.5	0.9	-59:59**
00:40	1,505	1.3	457	-3349.9*	-3436.1	1.8	-59:59**
00:50	1,671	2.2	635	-3349.6*	-3435.2	3.2	-59:59***
01:00	1,911	3.4	839	-3349.1*	-3433.8	5.2	-59:59**
01:10	2,224	5.0	1,058	-3348.3*	-3431.5	7.8	-59:59**
01:20	2,621	6.9	1,293	-3347.0*	-3427.9	11.2	-59:59**
01:30	3,113	9.3	1,543	-3345.1*	-3422.4	15.4	-59:59**
01:40	3,710	12.0	1,787	-3342.4*	-3413.9	20.3	-59:59**
01:50	4,412	15.1	2,024	-3338.6*	-3401.2	26.0	-59:59**
02:00	5,224	18.7	2,261	-3333.7*	-3383.0	32.3	-59:59**
02:10	6,163	22.6	2,511	-3327.4*	-3357.3	39.8	-59:59**
02:20	7,098	26.9	2,709	-3319.5*	-3325.9	47.3	-59:59**

*SPLERROR = R_{TO-GO} (distance from current position to target - apogee less than 300,000 feet)

**Time of free fall = POSMAX (-59:59) - display for apogee less than 300,000 feet)

TABLE IV.- TYPICAL DSKY PARAMETERS DURING LAUNCH FOR THE APOLLO 9 MISSION - Continued

Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Altitude (n mi)	Altitude Rate (ft/sec)	SPLERROR (n mi)	Predicted Perigee (n mi)	Predicted Apogee (n mi)	Predicted Time of Free Fall to 300,000 Feet (min:sec)
02:30	8,043	31.5	2,868	-2990.6	-3287.9	55.0	-3:05
02:40	9,121	36.4	3,049	-2969.5	-3237.2	63.8	-3:05
02:40.474*	9,127	36.6	3,041	-2968.6	-3236.7	63.9	-3:05
02:50	9,197	41.3	2,838	-2948.3	-3228.9	65.1	-3:05
03:00	9,364	45.8	2,664	-2927.0	-3216.3	67.0	-3:05
03:10	9,542	50.0	2,495	-2905.0	-3203.0	68.8	-3:05
03:15.904**	9,654	52.4	2,398	-2892.8	-3194.8	69.9	-3:05
03:20	9,735	54.0	2,333	-2884.2	-3188.9	70.6	-3:05
03:30	9,937	57.7	2,189	-2862.2	-3174.2	72.4	-3:05
03:40	10,136	61.3	2,085	-2837.7	-3160.0	74.7	-3:07
03:50	10,346	64.6	1,985	-2812.5	-3144.8	76.9	-3:09
04:00	10,567	67.8	1,883	-2786.6	-3128.4	79.0	-3:11
04:10	10,801	70.8	1,782	-2760.1	-3110.9	80.9	-3:12
04:20	11,046	73.7	1,681	-2732.9	-3092.0	82.7	-3:13
04:30	11,303	76.4	1,581	-2704.9	-3071.8	84.5	-3:14

*S-IC/S-II Staging

**Launch Escape Subsystem Jettison

TABLE IV.- TYPICAL DSKY PARAMETERS DURING LAUNCH FOR THE APOLLO 9 MISSION - Continued

Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Altitude (n mi)	Altitude Rate (ft/sec)	SPLERROR (n mi)	Predicted Perigee (n mi)	Predicted Apogee (n mi)	Predicted Time of Free Fall to 300,000 Feet (min:sec)
04:40	11,571	78.9	1,483	-2676.0	-3050.1	86.1	-3:15
04:50	11,852	81.3	1,387	-2646.1	-3026.7	87.6	-3:16
05:00	12,145	83.5	1,292	-2615.3	-3001.6	89.1	-3:16
05:10	12,450	85.6	1,199	-2583.3	-2974.6	90.4	-3:17
05:20	12,768	87.5	1,108	-2550.2	-2945.5	91.6	-3:17
05:30	13,100	89.3	1,020	-2515.7	-2914.1	92.8	-3:18
05:40	13,445	90.9	934	-2479.7	-2880.1	93.8	-3:18
05:50	13,804	92.4	851	-2442.1	-2843.4	94.8	-3:19
06:00	14,177	93.7	771	-2402.7	-2803.5	95.7	-3:19
06:10	14,566	94.9	694	-2361.3	-2760.1	96.5	-3:20
06:20	14,970	96.0	621	-2317.5	-2712.9	97.3	-3:21
06:30	15,391	97.0	553	-2271.0	-2661.3	98.0	-3:22
06:40	15,829	97.9	488	-2221.4	-2604.9	98.6	-3:24
06:50	16,285	98.7	429	-2168.2	-2542.8	99.1	-3:26
07:00	16,761	99.3	374	-2110.6	-2474.4	99.6	-3:29
07:10	17,257	99.9	326	-2047.9	-2398.7	100.0	-3:32

TABLE IV.- TYPICAL DSKY PARAMETERS DURING LAUNCH FOR THE APOLLO 9 MISSION - Continued

Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Altitude (n mi)	Altitude Rate (ft/sec)	SPLERROR (n mi)	Predicted Perigee (n mi)	Predicted Apogee (n mi)	Predicted Time of Free Fall to 300,000 Feet (min:sec)
07:20	17,773	100.4	284	-1978.8	-2314.6	100.4	-3:36
07:30	18,307	100.9	248	-1902.7	-2221.8	100.8	-3:42
07:40	18,829	101.3	213	-1822.4	-2124.6	101.1	-3:48
07:50	19,348	101.6	179	-1736.2	-2021.2	101.4	-3:54
08:00	19,877	101.9	149	-1640.2	-1908.0	101.6	-4:02
08:10	20,420	102.2	126	-1530.8	-1783.1	101.8	-4:12
08:20	20,979	102.4	115	-1414.6	-1644.0	102.0	-4:25
08:30	21,563	102.6	116	-1276.2	-1486.2	102.2	-4:44
08:40	22,177	102.8	124	-1100.7	-1305.1	102.4	-5:10
08:50	22,813	103.0	139	-867.0	-1098.4	102.7	-5:47
08:54.4896*	23,055	103.1	144	-755.7	-1013.7	102.9	-6:05
09:00	23,070	103.3	115	-748.2	-1008.3	102.9	-6:01
09:10	23,271	103.4	86	-645.6	-935.2	103.0	-6:11
09:20	23,484	103.6	50	-534.4	-855.2	103.0	-6:23
09:30	23,701	103.6	19	-407.6	-770.9	103.0	-6:37
09:40	23,922	103.7	-7	-259.1	-681.9	103.0	-6:56

*S-II/S-IVB Staging

TABLE IV.- TYPICAL DSKY PARAMETERS DURING LAUNCH FOR THE APOLLO 9 MISSION - Concluded

Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Altitude (n mi)	Altitude Rate (ft/sec)	SPLERROR (n mi)	Predicted Perigee (n mi)	Predicted Apogee (n mi)	Predicted Time of Free Fall to 300,000 Feet (min:sec)
09:50	24,147	103.6	-27	-78.2	-587.7	103.0	-7:21
10:00	24,375	103.6	-41	150.8	-488.4	103.0	-7:56
10:10	24,608	103.5	-47	458.3	-383.0	102.9	-8:46
10:20	24,845	103.5	-47	905.8	-271.2	102.9	-10:05
10:30	25,086	103.4	-41	1,660.3	-152.5	102.8	-12:26
10:40	25,330	103.4	-24	3,508.6	-26.0	102.7	-18:38
10:49.295***	25,561	103.3	-1	-2,091.5*	99.0	102.6	-59:59**
10:50	25,567	103.3	0	-2,088.7*	102.3	102.6	-59:59**
10:59.295****	25,568	103.3	0	-2,052.7*	102.6	102.7	-59:59**

*SPLERROR = R_{TO-GO} (distance from current position to target - perigee greater than 300,000 feet)

**Time of free fall = POSMAX (-59:59) - perigee greater than 300,000 feet

***Guidance cutoff signal

****Insertion

TABLE V.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE II ABORTS FOR THE APOLLO 9 MISSION

(a) Entry parameters

Ground Elapsed Time of Abort (min:sec)	Inertial Velocity at Abort (ft/sec)	Maximum Entry Load Factor (g's)	Inertial Velocity at 400,000 Feet (ft/sec)	Inertial Flight-path Angle at 400,000 Feet (deg)	Geodetic Latitude at Landing (deg north)	Longitude at Landing (deg west)	Range at Landing (n mi)
3:15.904*	9,654.20	9.15	9,398.72	-7.25	30.58	72.45	442.92
3:20	9,734.88	9.28	9,531.69	-7.73	30.61	72.29	451.65
3:30	9,936.70	9.58	9,792.45	-8.78	30.69	71.87	473.96
3:40	10,136.17	9.92	10,061.41	-9.83	30.78	71.40	498.53
3:50	10,345.76	10.31	10,334.51	-10.62	30.87	70.92	523.86
4:00	10,567.39	10.64	10,613.64	-11.19	30.96	70.43	549.82
4:10	10,800.90	10.93	10,898.85	-11.61	31.04	69.92	576.48
4:20	11,046.05	11.22	11,190.45	-11.89	31.13	69.40	603.93
4:30	11,302.78	11.48	11,488.43	-12.08	31.22	68.86	632.25
4:40	11,571.28	11.78	11,793.40	-12.19	31.31	68.30	661.51
4:50	11,851.82	12.04	12,105.93	-12.23	31.40	67.72	691.77
5:00	12,144.68	12.30	12,426.58	-12.20	31.49	67.12	723.09
5:10	12,450.08	12.52	12,755.86	-12.12	31.58	66.49	755.60
5:20	12,768.30	12.75	13,094.33	-11.99	31.67	65.84	789.41
5:30	13,099.68	12.94	13,442.58	-11.82	31.75	65.16	824.64
5:40	13,444.64	13.06	13,801.32	-11.62	31.84	64.45	861.45
5:50	13,803.64	13.13	14,171.24	-11.38	31.93	63.70	900.02

*Launch Escape Tower Jettison

TABLE V.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE II ABORTS FOR THE APOLLO 9 MISSION - Continued

(a) Entry parameters - Continued

Ground Elapsed Time of Abort (min:sec)	Inertial Velocity at Abort (ft/sec)	Maximum Entry Load Factor (g's)	Inertial Velocity at 400,000 Feet (ft/sec)	Inertial Flight-path Angle at 400,000 Feet (deg)	Geodetic Latitude at Landing (deg north)	Longitude at Landing (deg west)	Range at Landing (n mi)
6:00	14,177.14	13.28	14,553.04	-11.12	32.01	62.91	940.58
6:10	14,565.78	13.24	14,947.61	-10.83	32.10	62.08	983.36
6:20	14,970.16	13.32	15,355.76	-10.52	32.19	61.20	1,028.68
6:30	15,391.02	13.30	15,778.46	-10.18	32.27	60.25	1,076.93
6:40	15,829.15	13.23	16,216.71	-9.83	32.35	59.24	1,128.61
6:50	16,285.45	13.09	16,671.61	-9.45	32.43	58.15	1,184.32
7:00	16,760.93	12.95	17,144.38	-9.07	32.50	56.96	1,244.82
7:10	17,256.67	12.74	17,636.29	-8.66	32.56	55.66	1,311.01
7:20	17,773.27	12.46	18,148.12	-8.24	32.61	54.22	1,384.07
7:30	18,306.72	12.12	18,675.87	-7.81	32.66	52.63	1,464.76
7:40	18,829.01	11.70	19,191.99	-7.39	32.66	50.94	1,550.01
7:50	19,347.63	11.26	19,704.72	-6.98	32.65	49.14	1,641.61
8:00	19,877.09	10.73	20,228.01	-6.55	32.60	47.12	1,743.72
8:10	20,419.74	10.13	20,764.25	-6.12	32.50	44.83	1,859.92
8:20	20,979.07	9.43	21,317.10	-5.67	32.33	42.14	1,997.09
8:30	21,563.35	8.61	21,894.96	-5.20	32.03	38.87	2,164.44
8:40	22,176.77	7.66	22,501.97	-4.69	31.52	34.79	2,375.34
8:50	22,812.73	6.55	23,131.23	-4.14	30.64	29.51	2,652.45

TABLE V.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE II ABORTS FOR THE APOLLO 9 MISSION - Continued

(a) Entry parameters - Concluded

Ground Elapsed Time of Abort (min:sec)	Inertial Velocity at Abort (ft/sec)	Maximum Entry Load Factor (g's)	Inertial Velocity at 400,000 Feet (ft/sec)	Inertial Flight-path Angle at 400,000 Feet (deg)	Geodetic Latitude at Landing (deg north)	Longitude at Landing (deg west)	Range at Landing (n mi)
8:54.4896*	23,055.46	6.11	23,360.26	-3.93	30.17	27.19	2,776.15
9:00	23,069.86	6.07	23,378.41	-3.92	30.13	26.99	2,786.56
9:10	23,270.76	5.70	23,578.87	-3.73	29.63	24.78	2,905.54
9:20	23,483.73	5.29	23,790.05	-3.52	29.05	22.40	3,035.12
9:30	23,700.70	4.86	24,004.75	-3.30	28.32	19.71	3,183.59
9:31	23,722.63	4.82	24,026.36	-3.28	28.23	19.42	3,199.68

*SII/SIVB Separation

TABLE V.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE II ABORTS FOR THE APOLLO 9 MISSION - Continued

(b) Event times

Ground Elapsed Time of Abort (min:sec)	Predicted Time of Free Fall from Abort to 300,000 Feet (min:sec)	Ground Elapsed Time at 400,000 Feet (min:sec)	Ground Elapsed Time at Landing (min:sec)	Ground Elapsed Time at S-band Blackout Entry (min:sec)	Ground Elapsed Time at S-band Blackout Exit (min:sec)	Ground Elapsed Time at Drogue Chute Deployment (min:sec)
3:15.904*	3:05.14	5:29.12	14:53.32	-----	-----	9:45.32
3:20	3:04.90	5:34.78	14:57.84	-----	-----	9:49.84
3:30	3:05.01	5:48.78	15:08.15	-----	-----	10:00.15
3:40	3:07.31	6:04.64	15:20.50	-----	-----	10:12.50
3:50	3:09.40	6:19.36	15:32.96	-----	-----	10:24.96
4:00	3:11.06	6:33.01	15:45.43	-----	-----	10:37.43
4:10	3:12.39	6:45.91	15:57.93	-----	-----	10:49.93
4:20	3:13.47	6:58.26	16:10.53	-----	-----	11:02.53
4:30	3:14.37	7:10.19	16:23.26	-----	-----	11:15.26
4:40	3:15.12	7:21.80	16:36.17	-----	-----	11:28.17
4:50	3:15.75	7:33.12	16:49.25	-----	-----	11:41.25
5:00	3:16.28	7:44.22	17:02.52	-----	-----	11:54.52
5:10	3:16.75	7:55.14	17:16.04	-----	-----	12:08.04
5:20	3:17.18	8:05.93	17:29.83	-----	-----	12:21.83
5:30	3:17.61	8:16.64	17:43.95	-----	-----	12:35.95
5:40	3:18.08	8:27.30	17:58.43	9:43	9:49	12:50.43
5:50	3:18.62	8:37.96	18:13.33	9:52	10:01	13:05.33
6:00	3:19.27	8:48.65	18:28.72	10:01	10:12	13:20.72
6:10	3:20.07	8:59.43	18:44.65	10:11	10:24	13:36.65
6:20	3:21.09	9:10.34	19:01.22	10:21	10:36	13:53.22
6:30	3:22.38	9:21.45	19:18.53	10:31	10:49	14:10.53
6:40	3:24.02	9:32.83	19:36.72	10:42	11:01	14:28.72
6:50	3:26.11	9:44.58	19:55.97	10:54	11:15	14:47.97

*Launch Escape Tower Jettison

TABLE V.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE II ABORTS FOR THE APOLLO 9 MISSION - Concluded

(b) Event times - Concluded

Ground Elapsed Time of Abort (min:sec)	Predicted Time of Free Fall from Abort to 300,000 Feet (min:sec)	Ground Elapsed Time at 400,000 Feet (min:sec)	Ground Elapsed Time at Landing (min:sec)	Ground Elapsed Time at S-band Blackout Entry (min:sec)	Ground Elapsed Time at S-band Blackout Exit (min:sec)	Ground Elapsed Time at Drogue Chute Deployment (min:sec)
7:00	3:28.77	09:56.81	20:16.47	11:06	11:29	15:08.47
7:10	3:32.16	10:09.66	20:38.45	11:19	11:44	15:30.45
7:20	3:36.47	10:23.30	21:02.24	11:32	12:00	15:54.24
7:30	3:41.81	10:37.83	21:25.96	11:47	12:18	16:17.96
7:40	3:47.60	10:52.68	21:54.59	12:02	12:36	16:46.59
7:50	3:54.08	11:08.07	22:22.66	12:19	12:55	17:14.66
8:00	4:01.97	11:24.66	22:53.36	12:37	13:16	17:45.36
8:10	4:11.91	11:43.03	23:27.64	12:57	13:40	18:19.64
8:20	4:25.35	12:04.54	24:07.38	13:20	14:08	18:59.38
8:30	4:43.81	12:30.54	24:54.92	13:50	14:42	19:46.92
8:40	5:09.51	13:02.93	25:53.57	14:26	15:26	20:45.57
8:50	5:46.76	13:45.56	27:09.06	15:15	16:24	22:01.06
8:54.4896*	6:04.88	14:04.92	27:42.34	15:37	16:50	22:34.34
9:00	6:00.89	14:06.54	27:45.15	15:39	16:52	22:37.15
9:10	6:11.49	14:24.82	28:16.94	16:00	17:17	23:08.94
9:20	6:22.81	14:43.27	28:51.25	16:23	17:44	23:43.25
9:30	6:37.28	15:04.30	29:30.36	16:48	18:14	24:22.36
9:31	6:38.95	15:06.57	29:34.59	16:51	18:17	24:26.59

*SII/SIVB Separation

TABLE VI.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE III ABORTS FOR THE APOLLO 9 MISSION

(a) Burn parameters

Ground Elapsed Time of Abort (min:sec)	Inertial Velocity at Abort (ft/sec)	Ground Elapsed Time at SPS Ignition (min:sec)	SPS Burn Time (min:sec)	SPS ΔV (ft/sec)	Predicted Time of Free Fall From SPS Cutoff to 300,000 Feet (ft/sec)	Inertial Velocity at 400,000 Feet (ft/sec)	Inertial Flight-path Angle at 400,000 Feet (deg)
9:31	23,722.6	----	0	0	06:37.10*	24,026.3	-3.28
9:32	23,744.6	----	0	0	06:40.66*	24,048.1	-3.26
9:34	23,788.6	----	0	0	06:44.22*	24,091.6	-3.21
9:36	23,822.9	----	0	0	06:47.99*	24,135.3	-3.16
9:38	23,877.2	----	0	0	06:51.96*	24,179.1	-3.12
9:40	23,921.8	----	0	0	06:56.17*	24,223.1	-3.07
9:42	23,966.5	----	0	0	07:00.62*	24,267.2	-3.02
9:44	24,011.4	----	0	0	07:05.34*	24,311.5	-2.97
9:46	24,056.4	----	0	0	07:10.35*	24,356.0	-2.92
9:48	24,101.6	----	0	0	07:15.67*	24,400.6	-2.87
9:50	24,147.0	----	0	0	07:21.34*	24,445.2	-2.82
9:52	24,192.4	----	0	0	07:27.36*	24,490.0	-2.77
9:54	24,237.9	----	0	0	07:33.79*	24,534.9	-2.71
9:54	24,237.9	11:59.00	00:01.56	17.55	05:24.52	24,523.8	-2.74
9:56	24,283.6	12:01.00	00:05.33	60.05	05:17.63	24,541.8	-2.74
9:58	24,329.5	12:03.00	00:09.10	102.70	05:10.97	24,560.0	-2.74

*Time of free fall at abort

TABLE VI.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE III ABORTS FOR THE APOLLO 9 MISSION - Continued

(a) Burn parameters - Continued

Ground Elapsed Time of Abort (min:sec)	Inertial Velocity at Abort (ft/sec)	Ground Elapsed Time at SPS Ignition (min:sec)	SPS Burn Time (min:sec)	SPS ΔV (ft/sec)	Predicted Time of Free Fall From SPS Cutoff to 300,000 Feet (ft/sec)	Inertial Velocity at 400,000 Feet (ft/sec)	Inertial Flight-path Angle at 400,000 Feet (deg)
10:00	24,375.5	12:05.00	00:12.94	146.34	05:04.28	24,578.0	-2.75
10:02	24,421.7	12:07.00	00:16.86	191.05	04:57.57	24,595.7	-2.76
10:04	24,468.2	12:09.00	00:20.83	236.57	04:50.89	24,613.3	-2.77
10:06	24,514.7	12:11.00	00:24.87	283.11	04:44.21	24,630.6	-2.79
10:08	24,561.5	12:13.00	00:29.87	330.98	04:37.44	24,647.4	-2.80
10:10	24,608.4	12:15.00	00:33.14	379.12	04:30.90	24,664.4	-2.82
10:12	24,655.5	12:17.00	00:37.39	428.78	04:24.26	24,680.9	-2.84
10:14	24,702.7	12:19.00	00:41.72	479.68	04:17.61	24,697.1	-2.87
10:16	24,750.1	12:21.00	00:46.14	531.79	04:10.99	24,712.9	-2.89
10:18	24,797.5	12:23.00	00:50.59	584.60	04:04.48	24,728.6	-2.92
10:20	24,845.1	12:25.00	00:55.10	638.43	03:57.95	24,744.2	-2.95
10:22	24,892.9	12:27.00	00:59.68	693.40	03:51.47	24,759.5	-2.98
10:24	24,940.8	12:29.00	01:04.38	750.00	03:45.00	24,774.4	-3.02
10:26	24,988.9	12:31.00	01:09.24	809.02	03:38.37	24,788.3	-3.06
10:28	25,037.1	12:33.00	01:14.19	869.38	03:31.84	24,801.9	-3.10
10:30	25,085.6	12:35.00	01:19.29	932.04	03:25.22	24,814.9	-3.15

TABLE VI.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE III ABORTS FOR THE APOLLO 9 MISSION - Continued

(a) Burn parameters - Concluded

Ground Elapsed Time of Abort (min:sec)	Inertial Velocity at Abort (ft/sec)	Ground Elapsed Time at SPS Ignition (min:sec)	SPS Burn Time (min:sec)	SPS ΔV (ft/sec)	Predicted Time of Free Fall From SPS Cutoff to 300,000 Feet (ft/sec)	Inertial Velocity at 400,000 Feet (ft/sec)	Inertial Flight-path Angle at 400,000 Feet (deg)
10:32	25,134.2	12:37.00	01:24.48	996.17	03:18.71	24,827.7	-3.20
10:34	25,183.0	12:39.00	01:29.77	1,061.95	03:12.27	24,840.0	-3.25
10:36	25,232.0	12:41.00	01:35.22	1,130.18	03:05.76	24,851.7	-3.31
10:38	25,281.1	12:43.00	01:40.84	1,200.94	02:59.20	24,862.6	-3.37
10:40	25,330.3	12:45.00	01:46.60	1,274.14	02:52.63	24,872.9	-3.44
10:42	25,379.8	12:47.00	01:52.55	1,350.15	02:46.01	24,882.5	-3.51
10:44	25,429.4	12:49.00	01:58.69	1,429.37	02:39.30	24,891.1	-3.59
10:46	25,479.0	12:51.00	02:04.97	1,510.95	02:32.64	24,899.3	-3.67
10:48	25,528.8	12:53.00	02:11.44	1,595.71	02:25.95	24,906.7	-3.76
10:49.295*	25,561.1	12:54.29	02:15.76	1,652.58	02:21.56	24,911.0	-3.82
10:50	25,567.1	12:55.00	02:16.32	1,659.99	02:20.66	24,909.0	-3.83
10:52	25,567.6	12:57.00	02:17.45	1,675.03	02:18.47	24,902.2	-3.86
10:54	25,567.7	12:59.00	02:18.53	1,689.41	02:16.36	24,895.4	-3.89
10:56	25,567.7	13:01.00	02:19.71	1,705.02	02:14.10	24,888.1	-3.92
10:58	25,567.7	13:03.00	02:20.88	1,720.62	02:11.87	24,880.8	-3.96
10:59.295**	25,567.7	13:04.30	02:21.64	1,730.73	02:10.44	24,876.1	-3.98

*Guidance cutoff signal

**Insertion

TABLE VI.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE III ABORTS FOR THE APOLLO 9 MISSION - Continued

(b) Entry parameters

Ground Elapsed Time of Abort (min:sec)	Ground Elapsed Time at S-Band Blackout Entry (min:sec)	Ground Elapsed Time at S-Band Blackout Exit (min:sec)	Ground Elapsed Time at Drogue Chute Deployment (min:sec)	Geodetic Latitude at Landing (Deg North)	Longitude at Landing (Deg West)	Maximum Load Factor
9:31	16:51	18:12	22:05.40	28.41	24.31	6.88
9:32	16:54	18:16	22:09.62	28.34	24.05	6.82
9:34	17:00	18:23	22:17.55	28.19	23.50	6.70
9:36	17:06	18:30	22:25.46	28.04	22.94	6.58
9:38	17:12	18:38	22:34.26	27.88	22.35	6.45
9:40	17:19	18:46	22:43.08	27.70	21.74	6.33
9:42	17:26	18:54	22:52.23	27.52	21.12	6.20
9:44	17:33	19:03	23:01.74	27.33	20.47	6.07
9:46	17:40	19:11	23:11.64	27.13	19.79	5.94
9:48	17:48	19:21	23:21.96	26.91	19.09	5.81
9:50	17:56	19:30	23:32.73	26.68	18:36	5.67
9:52	18:05	19:41	23:43.97	26.44	17.60	5.54
9:54	18:13	19:51	23:55.77	26.17	16.81	5.40
9:54	18:09	19:46	23:50.5	26.29	17.15	5.45
9:56	18:08	19:46	23:50.0	26.29	17.16	5.43
9:58	18:07	19:45	23:49.6	26.28	17.15	5.42

TABLE VI.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE III ABORTS FOR THE APOLLO 9 MISSION - Continued

(b) Entry parameters - Continued

Ground Elapsed Time of Abort (min:sec)	Ground Elapsed Time at S-Band Blackout Entry (min:sec)	Ground Elapsed Time at S-Band Blackout Exit (min:sec)	Ground Elapsed Time at Drogue Chute Deployment (min:sec)	Geodetic Latitude at Landing (Deg North	Longitude at Landing (Deg West)	Maximum Load Factor
10:00	18:06	19:44	23:49.19	26.28	17.15	5.40
10:02	18:05	19:44	23:48.72	26.28	17.15	5.40
10:04	18:04	19:43	23:48.26	26.28	17.15	5.39
10:06	18:04	19:42	23:47.78	26.28	17:15	5.39
10:08	18:03	19:42	23:47.18	26.28	17.16	5.39
10:10	18:02	19:41	23:46.78	26.28	17.15	5:40
10:12	18:02	19:41	23:46.3	26.28	17.15	5:41
10:14	18:01	19:40	23:45.7	26.28	17.15	5.42
10:16	18:01	19:39	23:45.1	26.28	17.16	5.44
10:18	18:00	19:38	23:44.6	26.28	17.15	5.46
10:20	18:00	19:38	23:44.0	26.29	17.15	5.49
10:22	18:00	19:38	23:43.5	26.29	17.14	5.53
10:24	17:59	19:37	23:43.0	26.29	17.14	5.56
10:26	17:59	19.37	23:42.2	26.29	17.15	5.61
10:28	17:59	19.36	23:41.5	26.30	17.15	5.67
10:30	17:59	19:36	23:40.8	26.30	17.15	5.73

TABLE VI.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE III ABORTS FOR THE APOLLO 9 MISSION - Concluded

(b) Entry parameters - Concluded

Ground Elapsed Time of Abort (min:sec)	Ground Elapsed Time at S-Band Blackout Entry (min:sec)	Ground Elapsed Time at S-Band Blackout Exit (min:sec)	Ground Elapsed Time at Drogue Chute Deployment (min:sec)	Geodetic Latitude at Landing (Deg North	Longitude at Landing (Deg West	Maximum Load Factor
10:32	17:59	19:35	23:40.1	26.31	17.15	5.79
10:34	18:00	19:35	23:39.4	26.31	17.14	5.87
10:36	18:00	19:35	23:38.7	26.31	17.14	5.96
10:38	18:00	19:34	23:37.9	26.32	17.14	6.05
10:40	18:02	19:34	23:37.1	26.32	17.13	6.17
10:42	18:02	19.34	23:36.3	26.33	17.13	6.29
10:44	18.02	19:33	23:35.3	26.34	17.13	6.42
10:46	18:03	19:33	23:34.4	26.35	17.13	6.57
10:48	18:04	19:33	23:33.4	26.36	17.12	6.73
10:49.295*	18:05	19:33	23:32.8	26.36	17.12	6.85
10:50	18:05	19:33	23:32.7	26.36	17.12	6.87
10:52	18:06	19:33	23:32.5	26.37	17.12	6.94
10:54	18:06	19:33	23:32.4	26.37	17.12	7.01
10:56	18:07	19:34	23:32.1	26.38	17.12	7.08
10:58	18:08	19:34	23:31.8	26.38	17.12	7.15
10:59.295**	18:09	19:34	23:31.7	26.38	17.12	7.19

*Guidance cutoff signal

**Insertion

TABLE VII.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE IV ABORTS FOR THE APOLLO 9 MISSION

(a) Without ΔV pad

At Abort Initiation		At SPS ignition	After Nominal SPS Burn*			
Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Ground Elapsed Time (min:sec)	SPS Burn Duration (min:sec)	SPS Sensed Velocity Change (ft/sec)	True Anomaly (deg)	Predicted Apogee Altitude (n mi)
9:22	23,526.8	11:27	2:58.28	2,231.4	103.78	95.33
9:24	23,570.0	11:29	2:54.37	2,176.9	110.67	94.14
9:26	23,613.4	11:31	2:50.50	2,123.0	117.32	93.25
9:28	23,657.0	11:33	2:46.64	2,069.6	123.71	92.60
9:30	23,700.7	11:35	2:42.78	2,016.6	129.80	92.13
9:32	23,744.6	11:37	2:38.92	1,963.8	135.58	91.82
9:34	23,788.6	11:39	2:35.06	1,911.3	141.07	91.94
9:36	23,832.9	11:41	2:31.20	1,858.9	146.23	91.55
9:38	23,877.2	11:43	2:27.32	1,806.7	151.07	91.56
9:40	23,921.8	11:45	2:23.43	1,754.6	155.57	91.64
9:42	23,966.5	11:47	2:19.53	1,702.6	159.76	91.79
9:44	24,011.4	11:49	2:15.61	1,650.6	163.65	91.98
9:46	24,056.4	11:51	2:12.67	1,598.7	167.24	92.22
9:48	24,101.6	11:53	2:07.72	1,546.8	170.56	92.50
9:50	24,147.0	11:55	2:03.75	1,495.0	173.59	92.81
9:52	24,192.4	11:57	1:59.77	1,443.3	176.37	93.14
9:54	24,237.9	11:59	1:55.77	1,391.6	178.89	93.49
9:56	24,283.6	12:01	1:52.75	1,339.9	181.17	93.85
9:58	24,329.5	12:03	1:47.71	1,288.2	183.21	94:24
10:00	24,375.5	12:05	1:43.65	1,236.5	185.05	94.63
10:02	24,421.7	12:07	1:39.55	1,184.7	186.69	95.02
10:04	24,468.2	12:09	1:35.43	1,132.8	188.17	95.42
10:06	24,514.7	12:11	1:31.29	1,080.8	189.49	95.82

*Resulting predicted perigee = 75 nautical miles

TABLE VII.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE IV ABORTS FOR THE APOLLO 9 MISSION - Continued

(a) Without ΔV pad - Continued

At Abort Initiation		At SPS ignition	After Nominal SPS Burn*			
Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Ground Elapsed Time (min:sec)	SPS Burn Duration (min:sec)	SPS Sensed Velocity Change (ft/sec)	True Anomaly (deg)	Predicted Apogee Altitude (n mi)
10:10	24,608.4	12:15	1:22.92	976.8	191.75	96.62
10:12	24,655.5	12:17	1:18.70	924.8	192.66	97.02
10:14	24,702.7	12:19	1:14.45	872.6	193.46	97.41
10:16	24,750.1	12:21	1:10.18	820.5	194.10	97.80
10:18	24,797.5	12:23	1:05.89	768.3	194.71	98.18
10:20	24,845.1	12:25	1:01.57	716.1	195.46	98.55
10:22	24,892.9	12:27	0:57.23	663.9	196.11	98.92
10:24	24,940.8	12:29	0:52.85	611.6	196.56	99.28
10:26	24,988.9	12:31	0:48.46	559.3	196.82	99.63
10:28	25,037.1	12:33	0:44.03	506.9	196.96	99.97
10:30	25,085.6	12:35	0:39.57	454.3	196.96	100.30
10:32	25,134.2	12:37	0:35.07	401.7	196.82	100.61
10:34	25,183.0	12:39	0:30.55	349.0	196.57	100.92
10:36	25,232.0	12:41	0:26.00	296.2	196.22	101.21
10:38	25,281.1	12:43	0:21.42	243.4	195.74	101.50
10:40	25,330.3	12:45	0:16.81	190.5	195.15	101.77
10:42	25,379.8	12:47	0:13.16	137.5	194.45	102.03
10:44	25,429.4	12:49	0:07.49	84.5	193.65	102.28
10:46	25,479.0	12:51	0:02.80	31.5	192.79	102.52
10:48	25,528.8	12:53	0:01	11.2	193.44	102.60
10:49.295**	25,561.1	12:54.295	0:00	0.0	183.12	102.63

*Resulting predicted perigee = 75 nautical miles

TABLE VII.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE IV ABORTS FOR THE APOLLO 9 MISSION - Continued

(a) Without ΔV pad - Concluded

At Abort Initiation		At SPS ignition	After Nominal SPS Burn*			
Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Ground Elapsed Time (min:sec)	SPS Burn Duration (min:sec)	SPS Sensed Velocity Change (ft/sec)	True Anomaly (deg)	Predicted Apogee Altitude (n mi)
10:50	25,567.1	12:55	0:00	0.0	179.98	102.63
10:52	25,567.6	12:57	0:00	0.0	121.39	102.63
10:54	25,567.7	12:59	0:00	0.0	108.47	102.63
10:56	25,567.7	13:01	0:00	0.0	44.88	102.64
10:58	25,567.7	13:03	0:00	0.0	27.87	102.65
10:59.295***	25,567.7	13:04.295	0:00	0.0	20.15	102.66

*Resulting predicted perigee = 75 nautical miles

**Guidance Cutoff

***Insertion

TABLE VII.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE IV ABORTS FOR THE APOLLO 9 MISSION

(b) With 100 fps pad

At Abort Initiation		After Over Burn of 100 ft/sec				
Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Total SPS Burn Duration (min:sec)	Total SPS Sensed Velocity Change (ft/sec)	True Anomaly (deg)	Predicted Apogee Altitude (n mi)	Predicted Perigee Altitude (n mi)
9:22	23,526.8	3:05.38	2,331.4	40.76	135.48	81.18
9:24	23,570.0	3:01.52	2,276.8	40.40	133.61	81.95
9:26	23,613.4	2:57.68	2,223.0	39.91	132.06	82.72
9:28	23,657.0	2:53.85	2,169.6	39.31	130.76	83.48
9:30	23,700.7	2:50.03	2,116.6	38,60	129.66	84.22
9:32	23,744.6	2:46.22	2,063.8	37.81	128.73	84.95
9:34	23,788.6	2:42.39	2,011.3	36.93	127.94	85.66
9:36	23,832.9	2:38.56	1,958.9	35.97	127.27	86.37
9:38	23,877.2	2:34.73	1,906.7	34.95	126.71	87.05
9:40	23,921.8	2:30.88	1,854.6	33.88	126.24	87.72
9:42	23,966.5	2:27.01	1,802.6	32.75	125.85	88.38
9:44	24,011.4	2:23.13	1,750.6	31.59	125.53	89.01
9:46	24,056.4	2:19.24	1,698.7	30.40	125.27	89.63
9:48	24,101.6	2:15.32	1,646.8	29.18	125.07	90.23
9:50	24,147.0	2:11.39	1,595.0	27.95	124.91	90.82
9:52	24,192.4	2:07.45	1,543.3	26.72	124.80	91.39
9:54	24,237.9	2:03.49	1,491.6	25.49	124.72	91.94
9:56	24,283.6	1:59.51	1,439.9	24.29	124.68	92.47
9:58	24,329.5	1:55.51	1,388.2	23.11	124.67	92.99
10:00	24,375.5	1:51.48	1,336.5	21.96	124.68	93.49
10:02	24,421.7	1:47.43	1,284.7	20.84	124.72	93.98
10:04	24,468.2	1:43.35	1,232.8	19.74	124.77	94.45
10:06	24,514.7	1:39.35	1,180.8	18.69	124.84	94.91

TABLE VII.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE IV ABORTS FOR THE APOLLO 9 MISSION - Continued

(b) With 100 fps pad - Continued

At Abort Initiation		After Over Burn of 100 ft/sec				
Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Total SPS Burn Duration (min:sec)	Total SPS Sensed Velocity Change (ft/sec)	True Anomaly (deg)	Predicted Apogee Altitude (n mi)	Predicted Perigee Altitude (n mi)
10:08	24,561.5	1:35.12	1,128.9	17.64	124.91	95.36
10:10	24,608.4	1:30.96	1,076.8	16.64	125.00	95.80
10:12	24,655.5	1:26.79	1,024.8	15.70	125.10	96.22
10:14	24,702.7	1:22.58	972.6	14.79	125.20	96.64
10:16	24,750.1	1:18.35	920.5	13.97	125.31	97.04
10:18	24,797.5	1:14.10	868.3	13.14	125.43	97.43
10:20	24,845.1	1:09.83	816.1	12.15	125.55	97.81
10:22	24,892.9	1:05.52	763.9	11.21	125.67	98.18
10:24	24,940.8	1:01.20	711.6	10.41	125.80	98.54
10:26	24,988.9	0:56.84	659.3	9.76	125.92	98.90
10:28	25,037.1	0:52.46	606.9	9.20	126.04	99.24
10:30	25,085.6	0:48.04	544.3	8.77	126.16	99.58
10:32	25,134.2	0:43.59	501.7	8.46	126.57	99.91
10:34	25,183.0	0:39.11	449.0	8.26	126.38	100.23
10:36	25,232.0	0:34.61	396.2	8.17	126.48	100.55
10:38	25,281.1	0:30.07	343.4	8.22	126.58	100.86
10:40	25,330.3	0:25.50	190.5	8:38	126.68	101.16
10:42	25,379.8	0:20.91	137.5	8.69	126.77	101.45
10:44	25,429.4	0:16.28	184.5	9.12	126.86	101.73

TABLE VII.- TRAJECTORY CHARACTERISTICS FOLLOWING NOMINAL MODE IV ABORTS FOR THE APOLLO 9 MISSION - Concluded

(b) With 100 fps pad - Concluded

At Abort Initiation		After Over Burn of 100 ft/sec				
Ground Elapsed Time (min:sec)	Inertial Velocity (ft/sec)	Total SPS Burn Duration (min:sec)	Total SPS Sensed Velocity Change (ft/sec)	True Anomaly (deg)	Predicted Apogee Altitude (n mi)	Predicted Perigee Altitude (n mi)
10:46	25,479.0	0:11.64	131.5	9.65	126.96	102.00
10:48	25,528.8	0:09.85	100.0	10.92	144.27	102.09
10:49.295*	25,561.1	0:08.87	100.0	11.33	156.59	102.14
10:50	25,567.1	0:08.86	100.0	11.35	157.47	102.14
10:52	25,567.6	0:08.86	100.0	11.36	157.66	102.14
10:54	25,567.7	0:08.86	100.0	11.35	157.67	102.14
10:56	25,567.7	0:08.86	100.0	11.35	157.69	102.14
10:58	25,567.7	0:08.86	100.0	11.35	157.71	102.14
10:59.295**	25,567.7	0:08.87	100.0	11.36	157.72	102.14

*Guidance cutoff

**Insertion

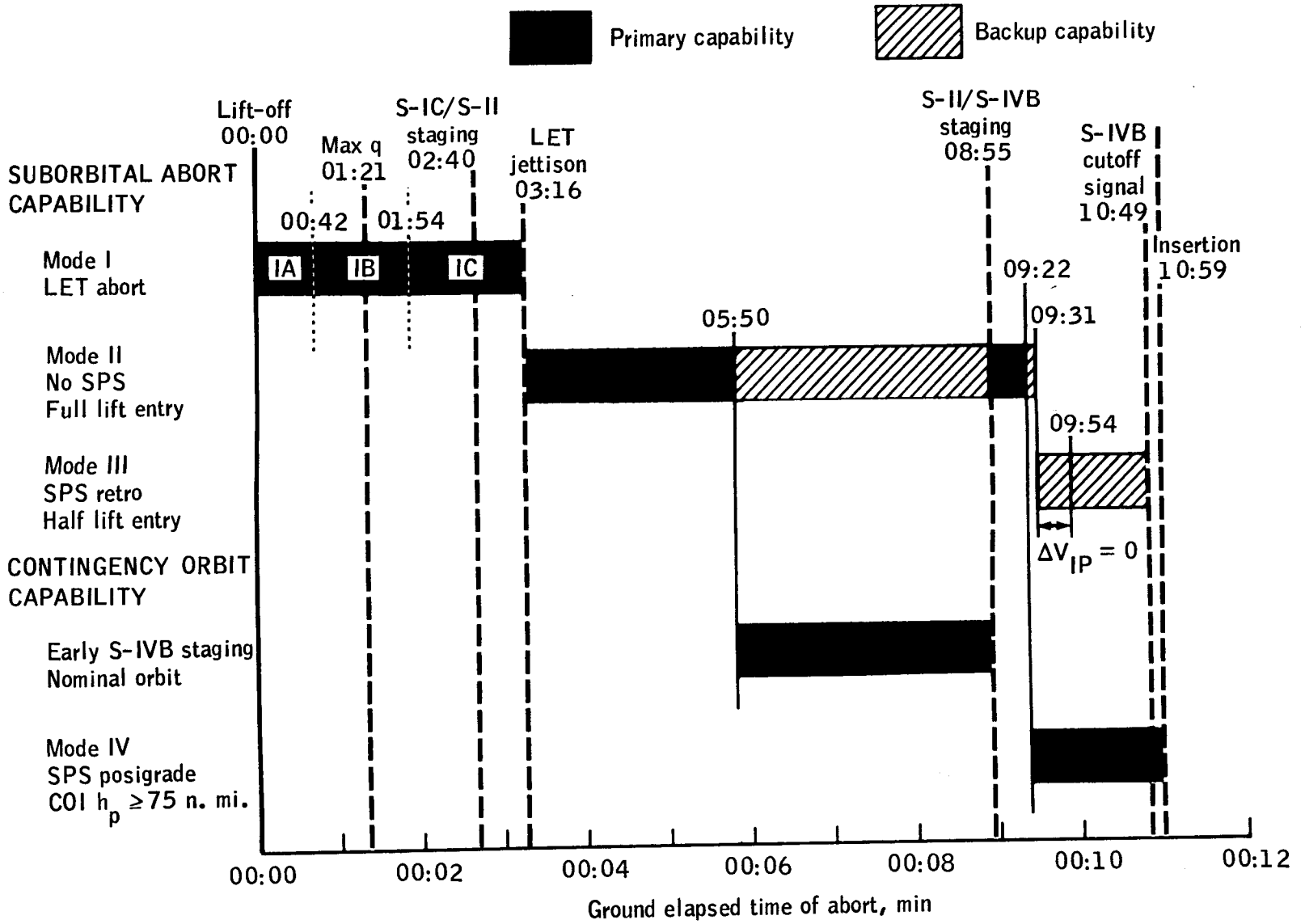


Figure 1.- Apollo 9 launch timeline and contingency capability.

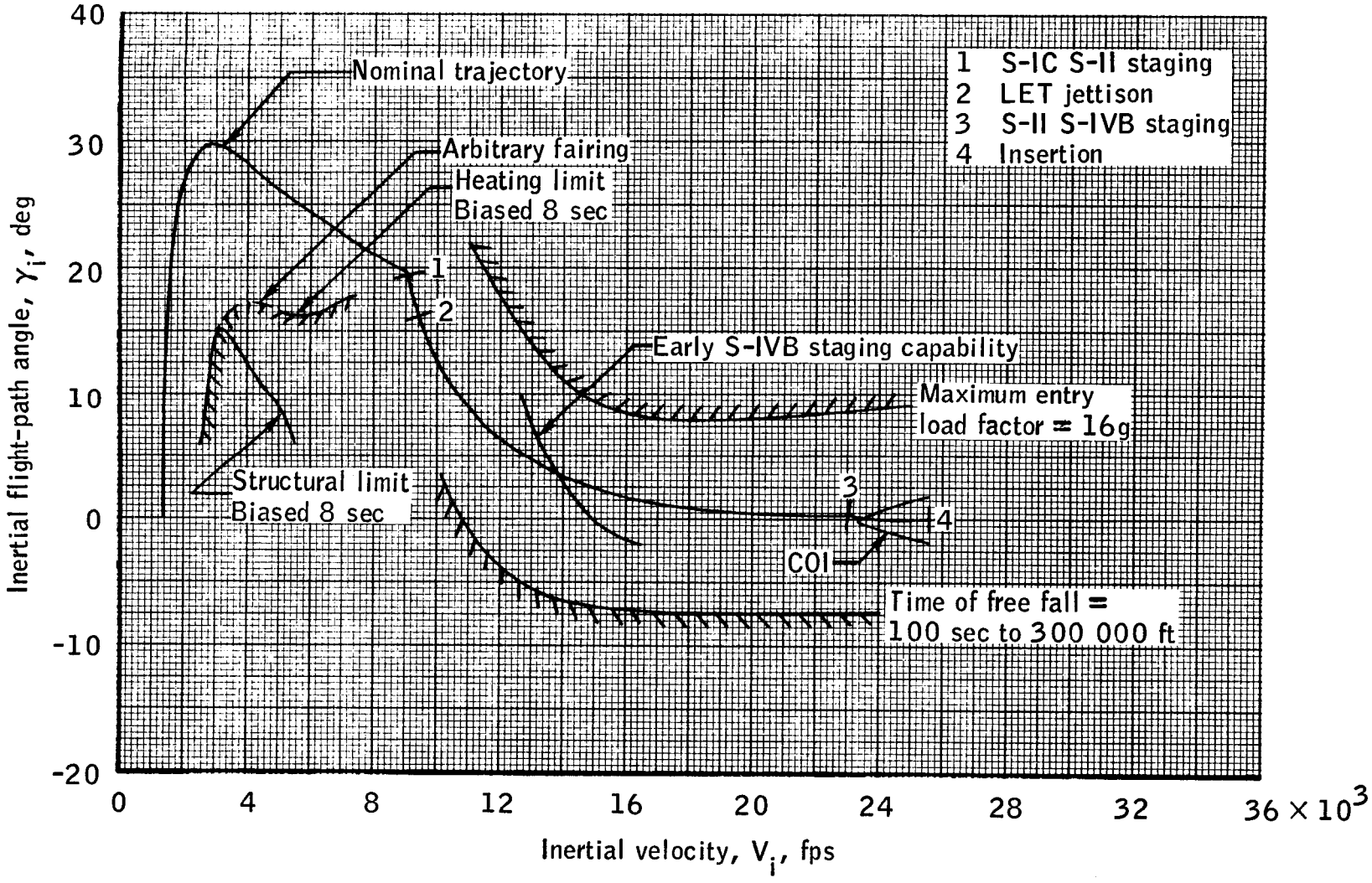


Figure 2.- Launch abort and capability limits.

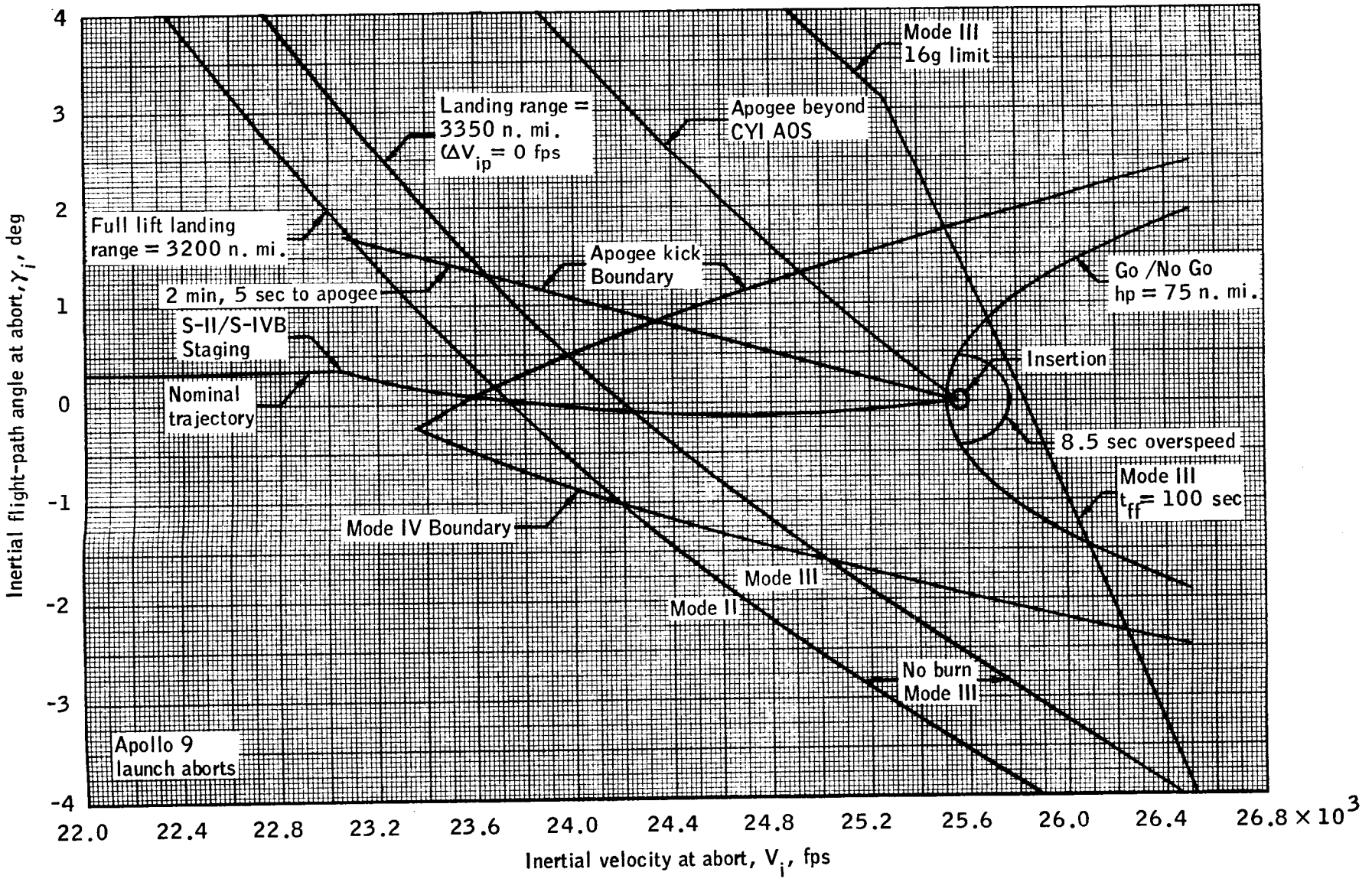


Figure 3.- Near-insertion abort mode overlap.

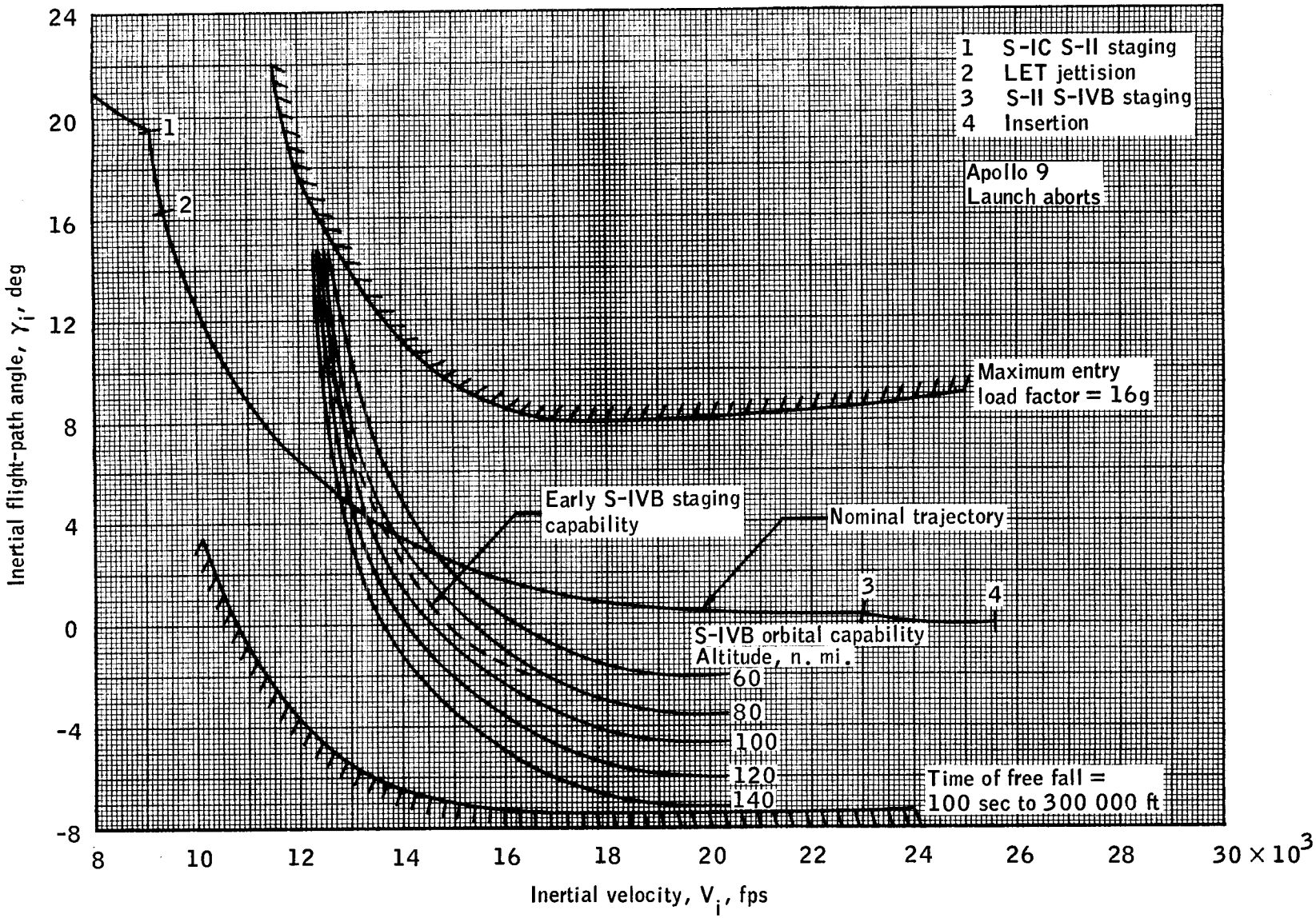


Figure 4.- S-IVB early staging to orbit capability.

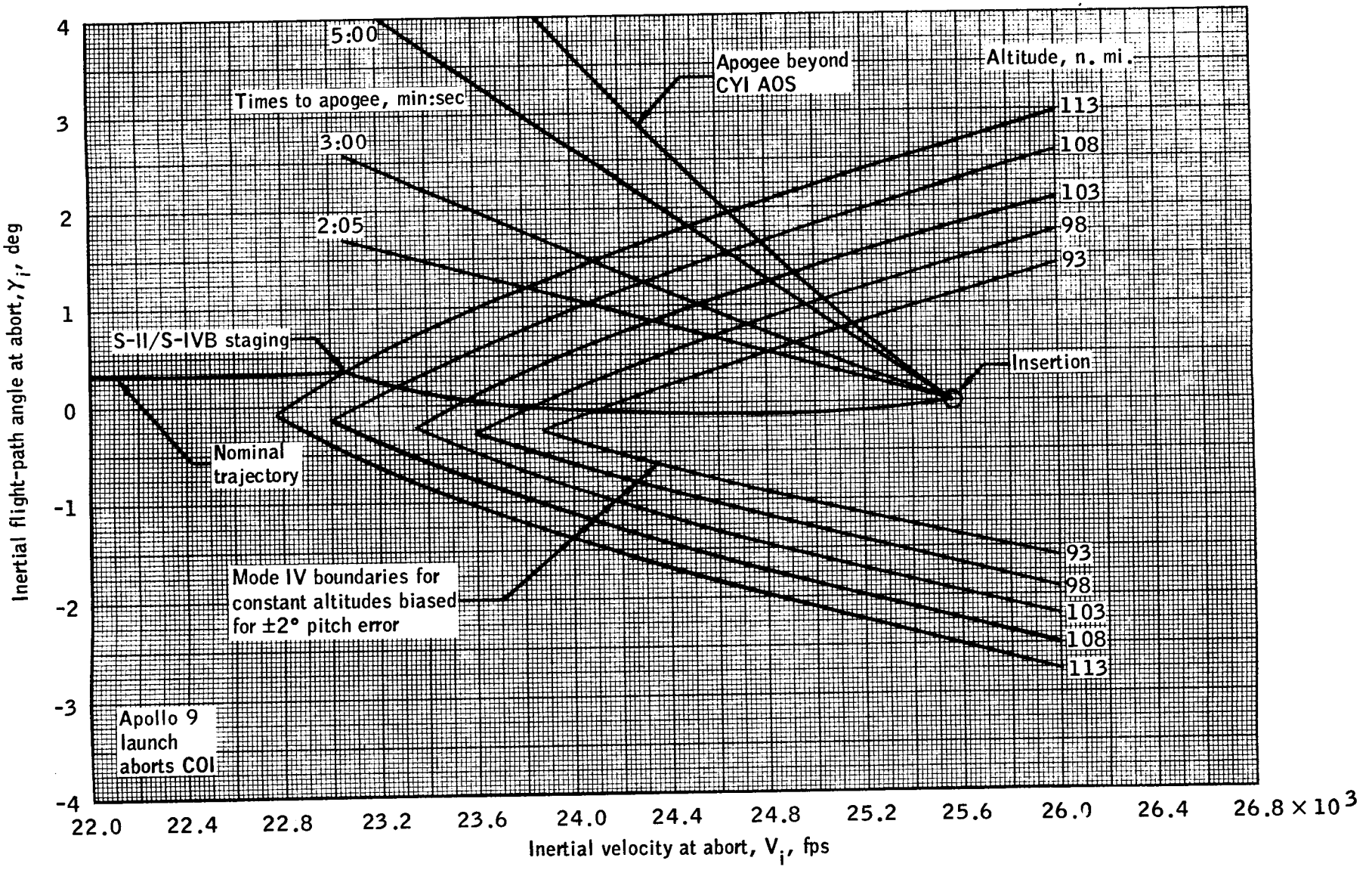


Figure 5.- SPS contingency orbital insertion capability.

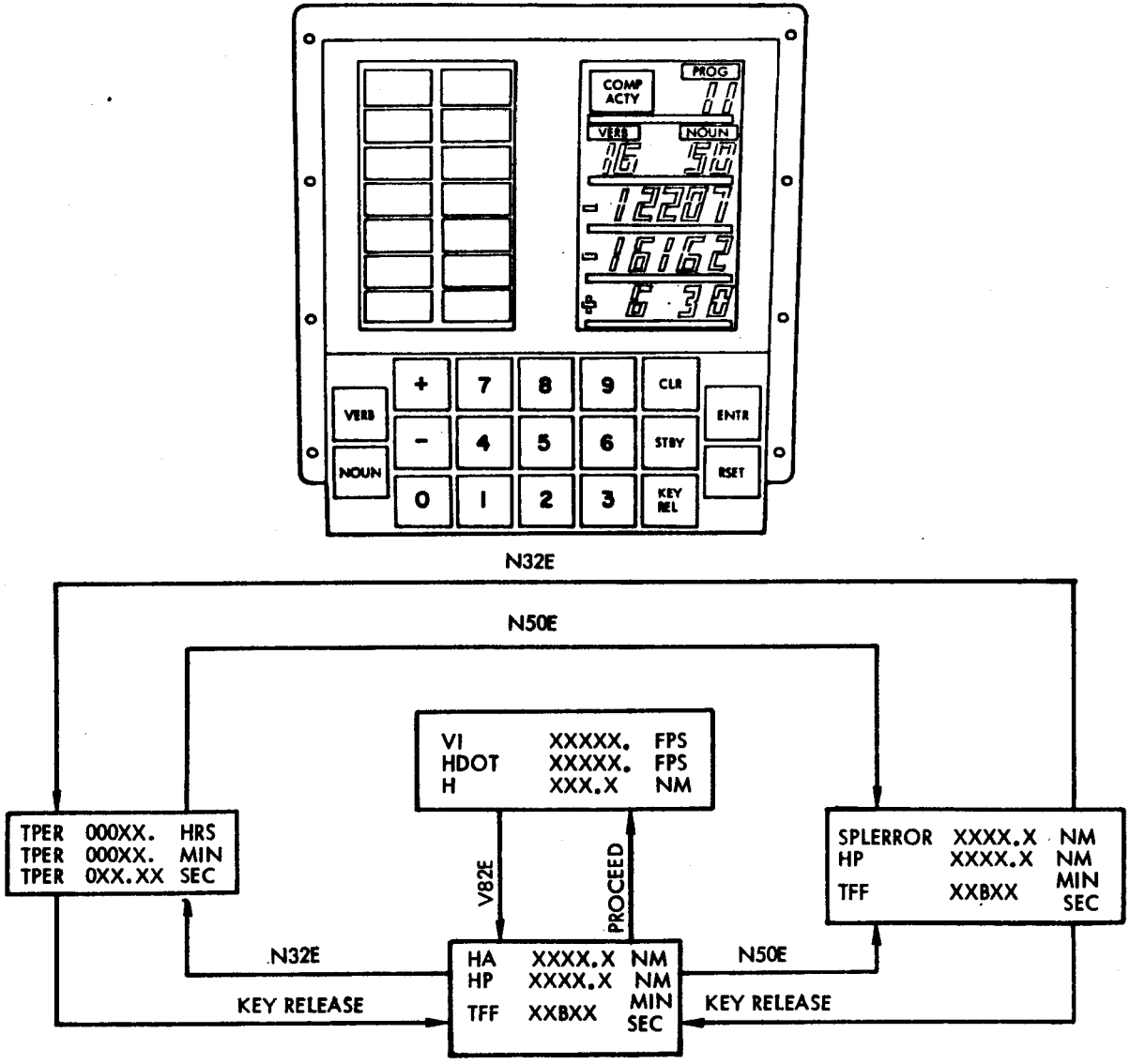


Figure 6.- AGC display keyboard and display parameters.

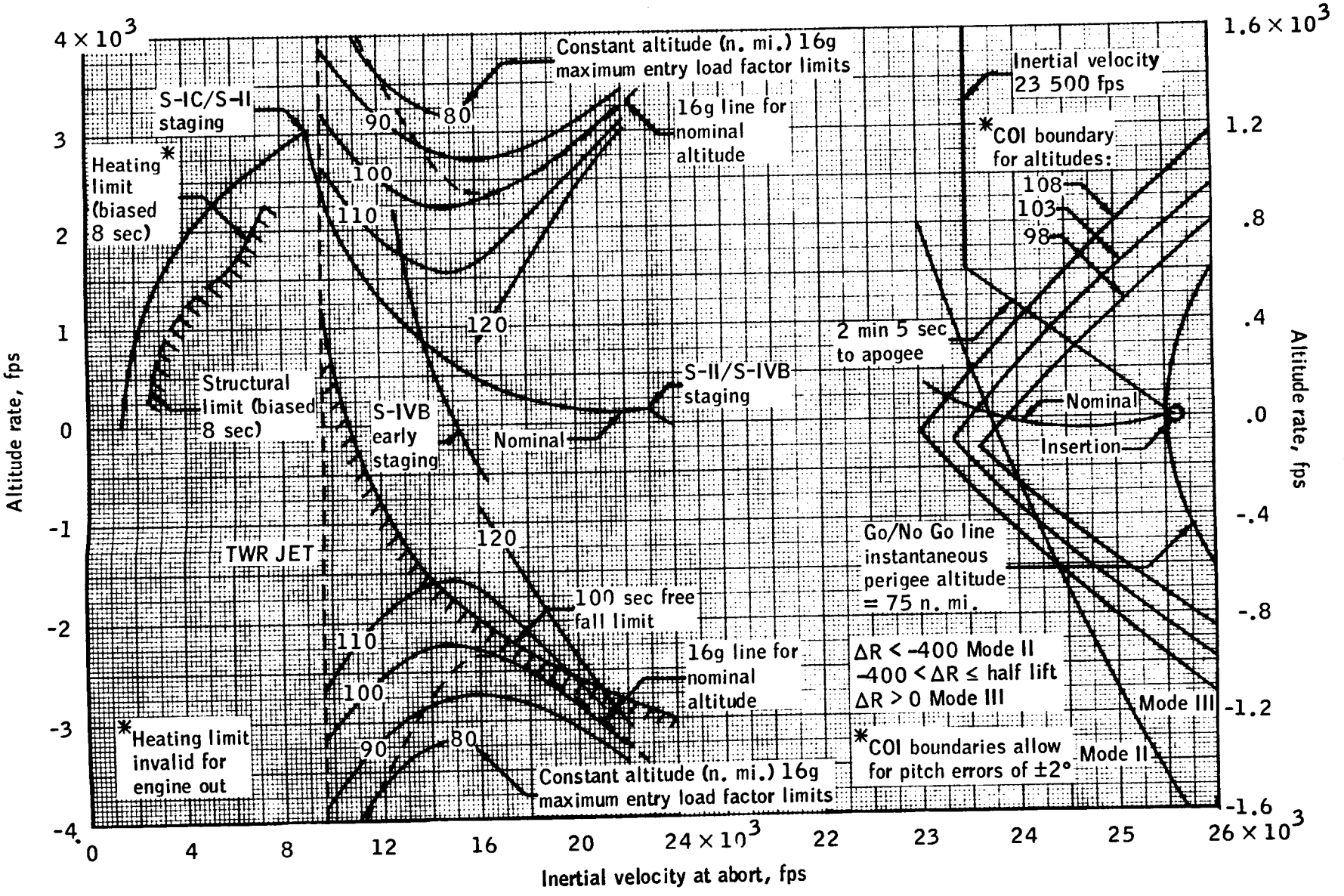
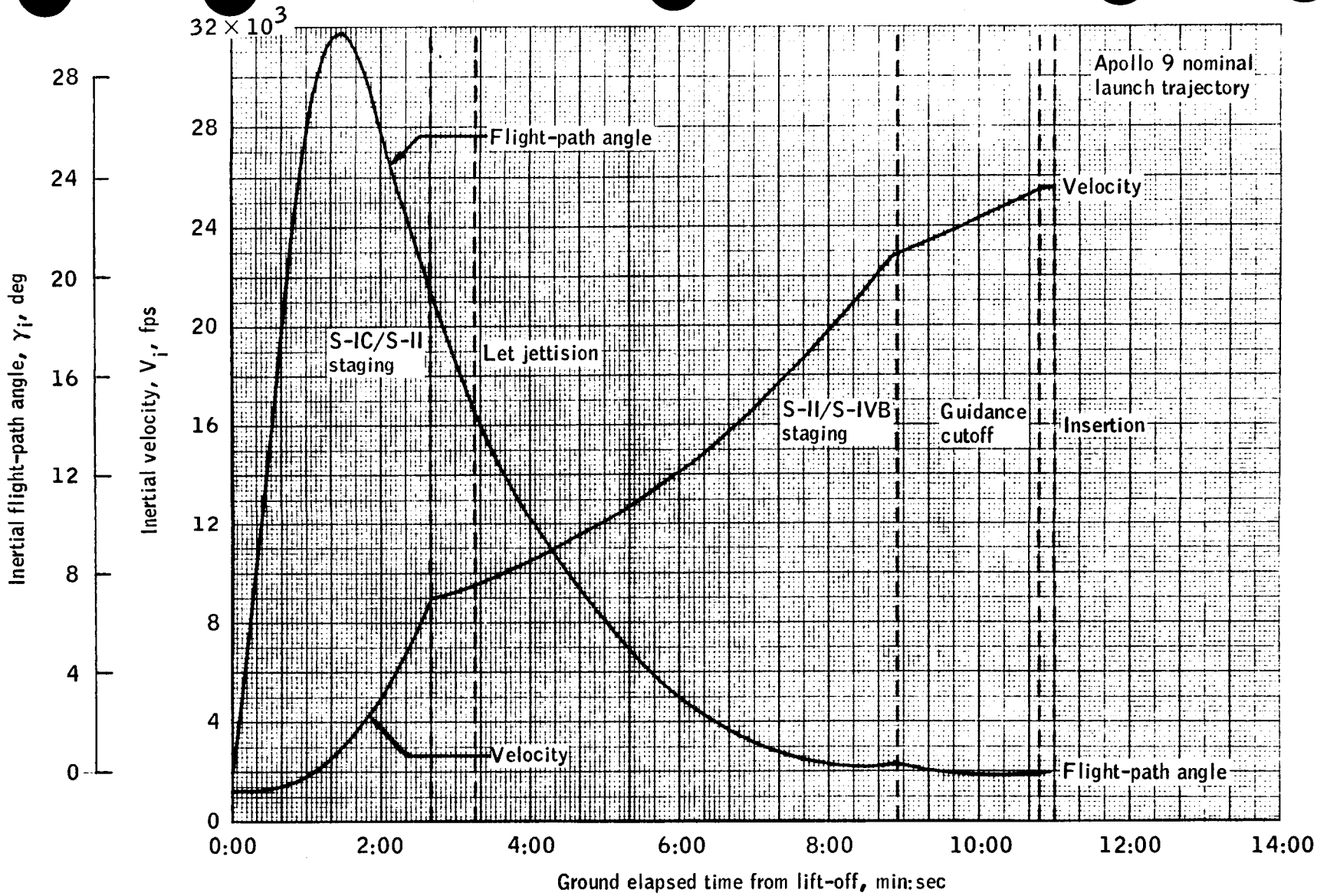
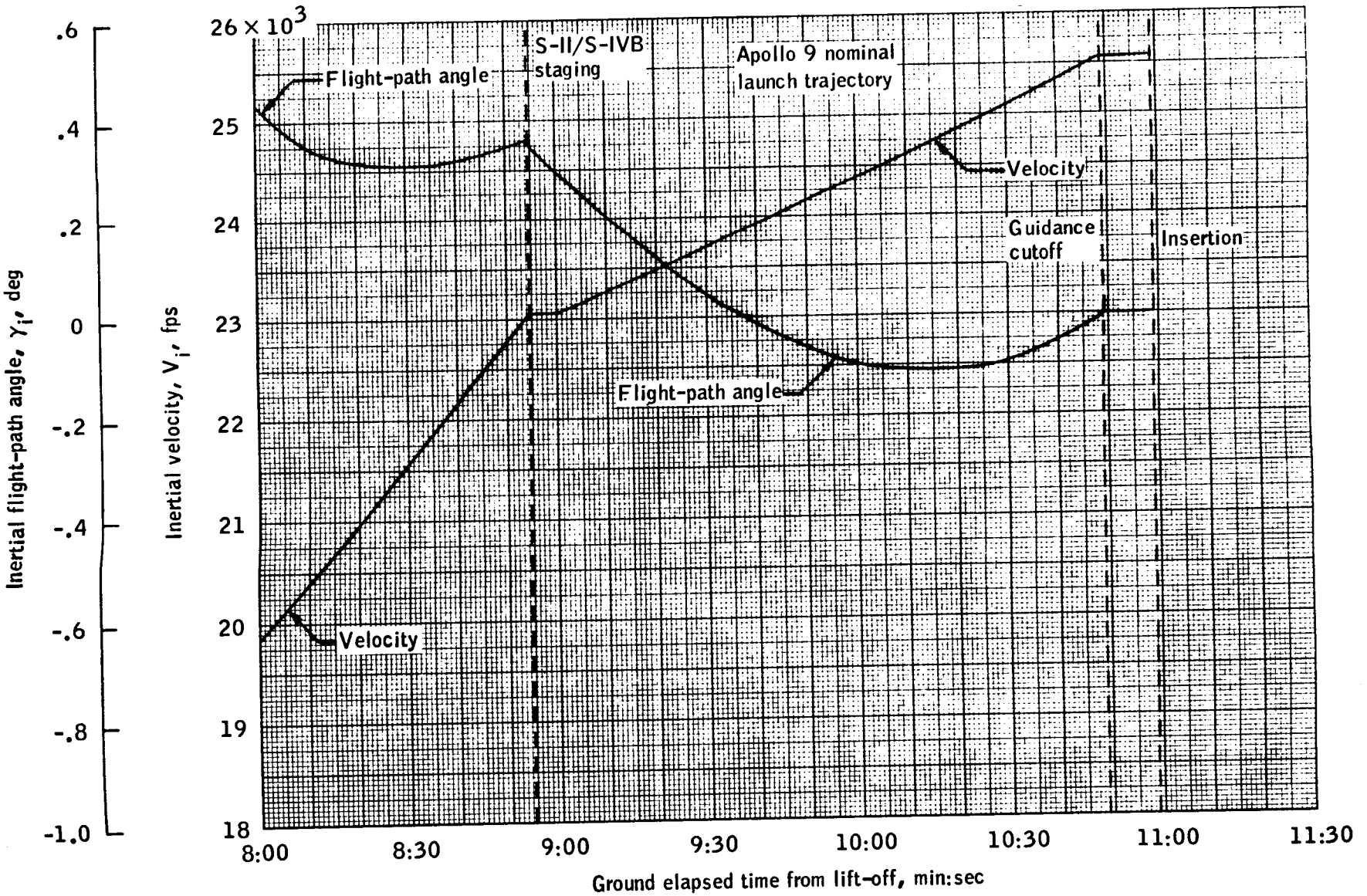


Figure 7.- No-voice crew chart for launch phase.



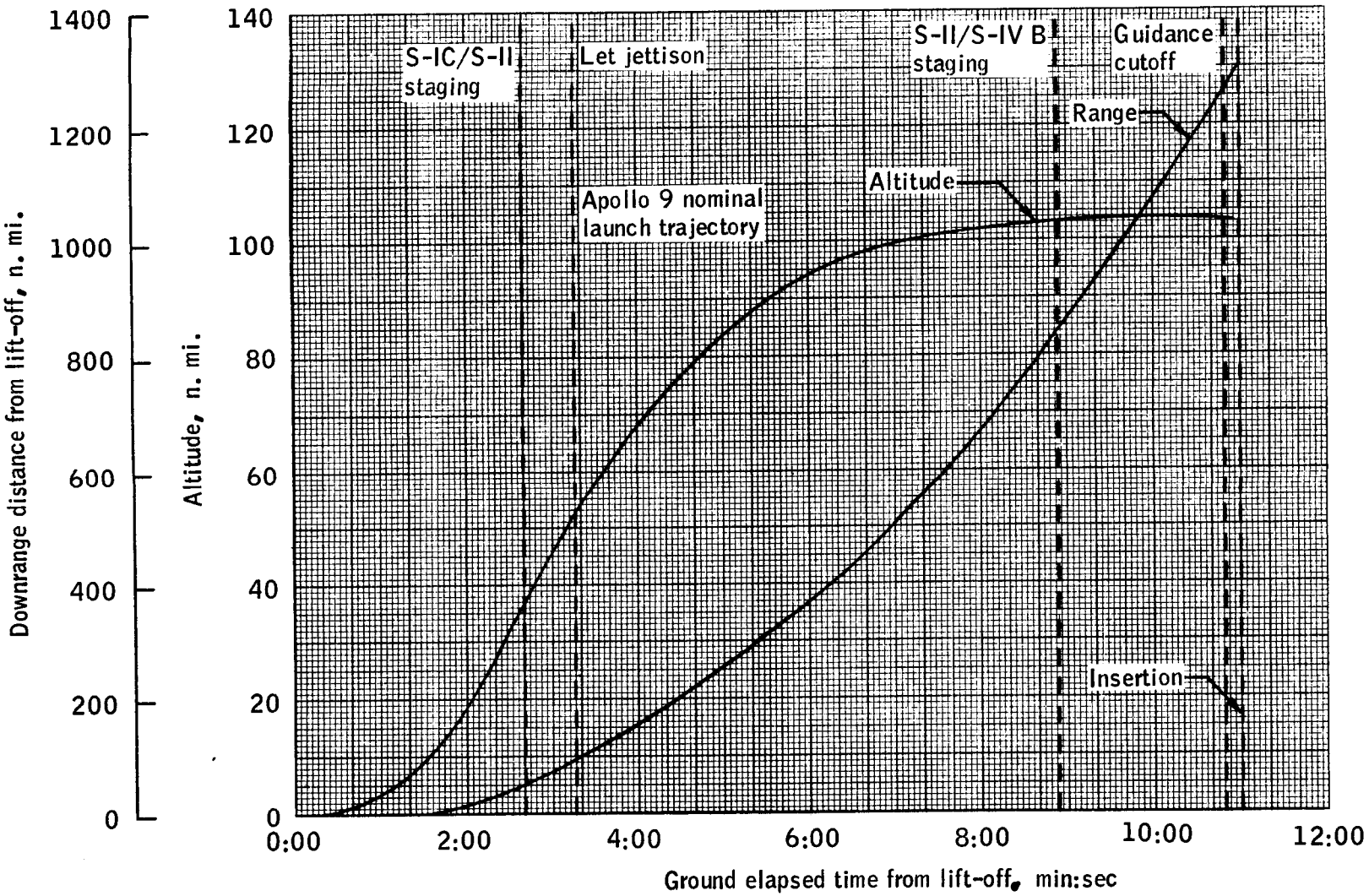
(a) Complete launch.

Figure 8.- Inertial velocity and inertial flight-path angle along the nominal launch trajectory.



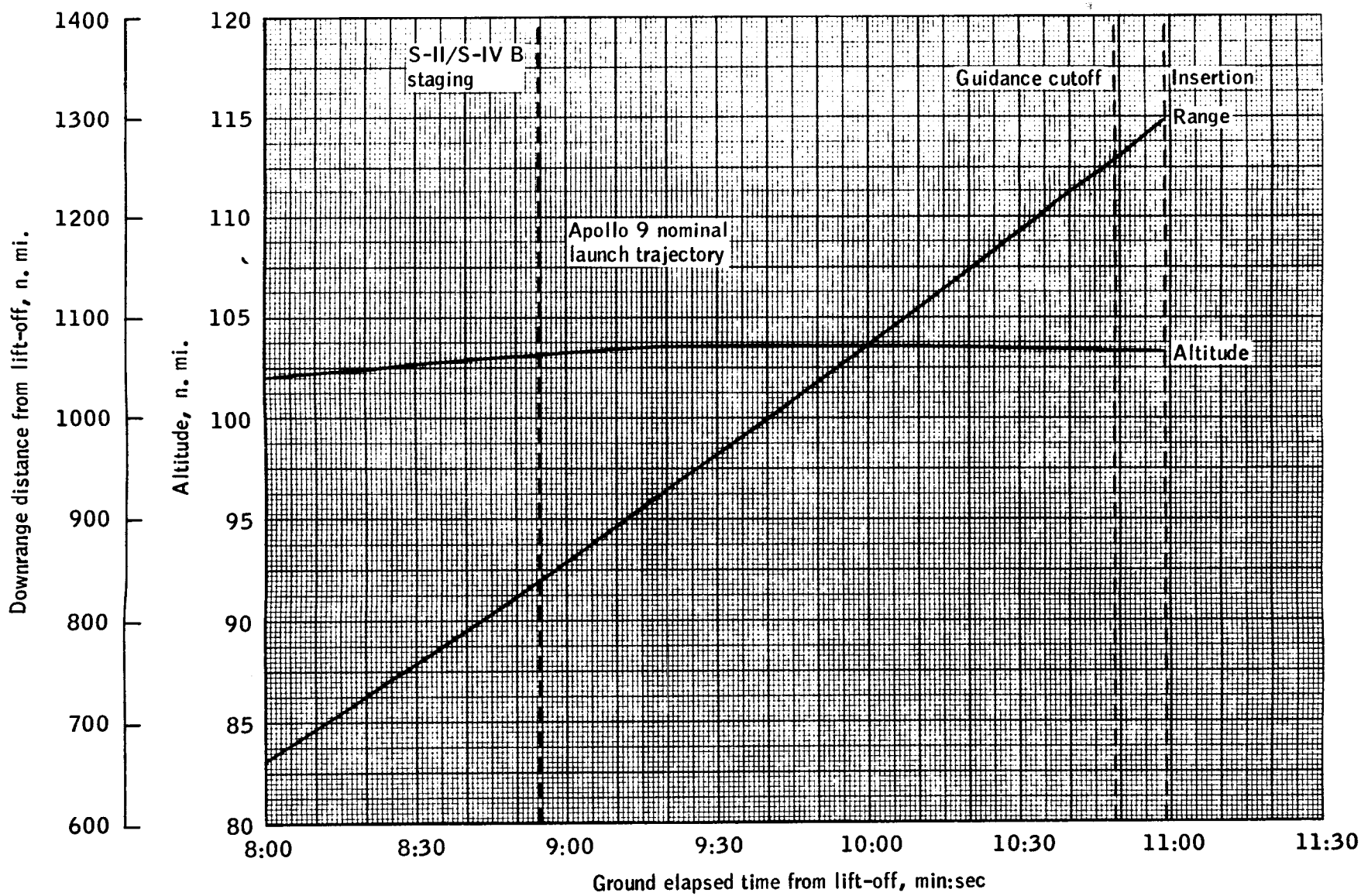
(b) Near insertion.

Figure 8.- Concluded.



(a) Complete launch.

Figure 9.- Downrange distance and altitude along the nominal launch trajectory.



(b) Near insertion.

Figure 9.- Concluded.

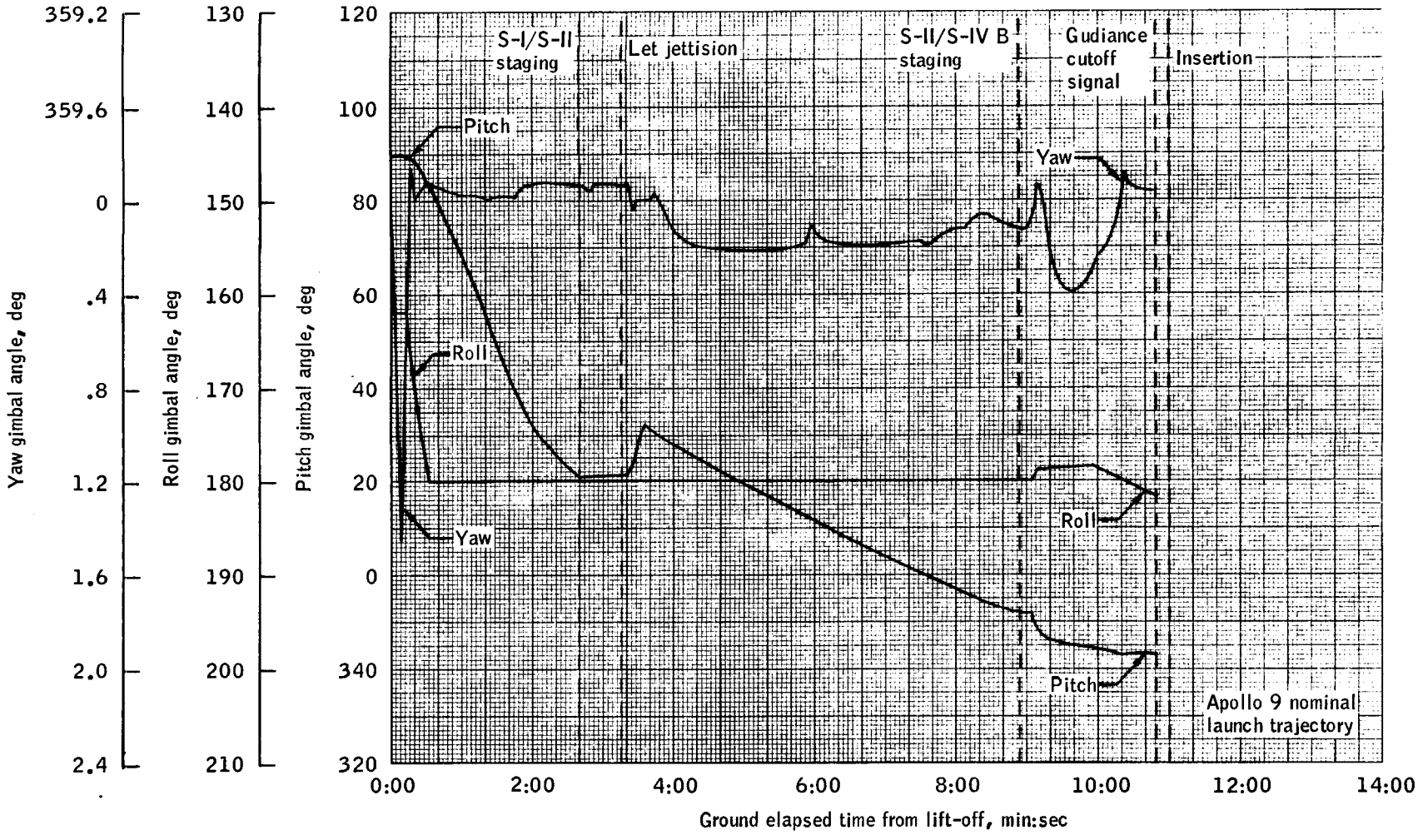


Figure 10.- Spacecraft IMU gimbal angle readouts along the nominal launch trajectory.

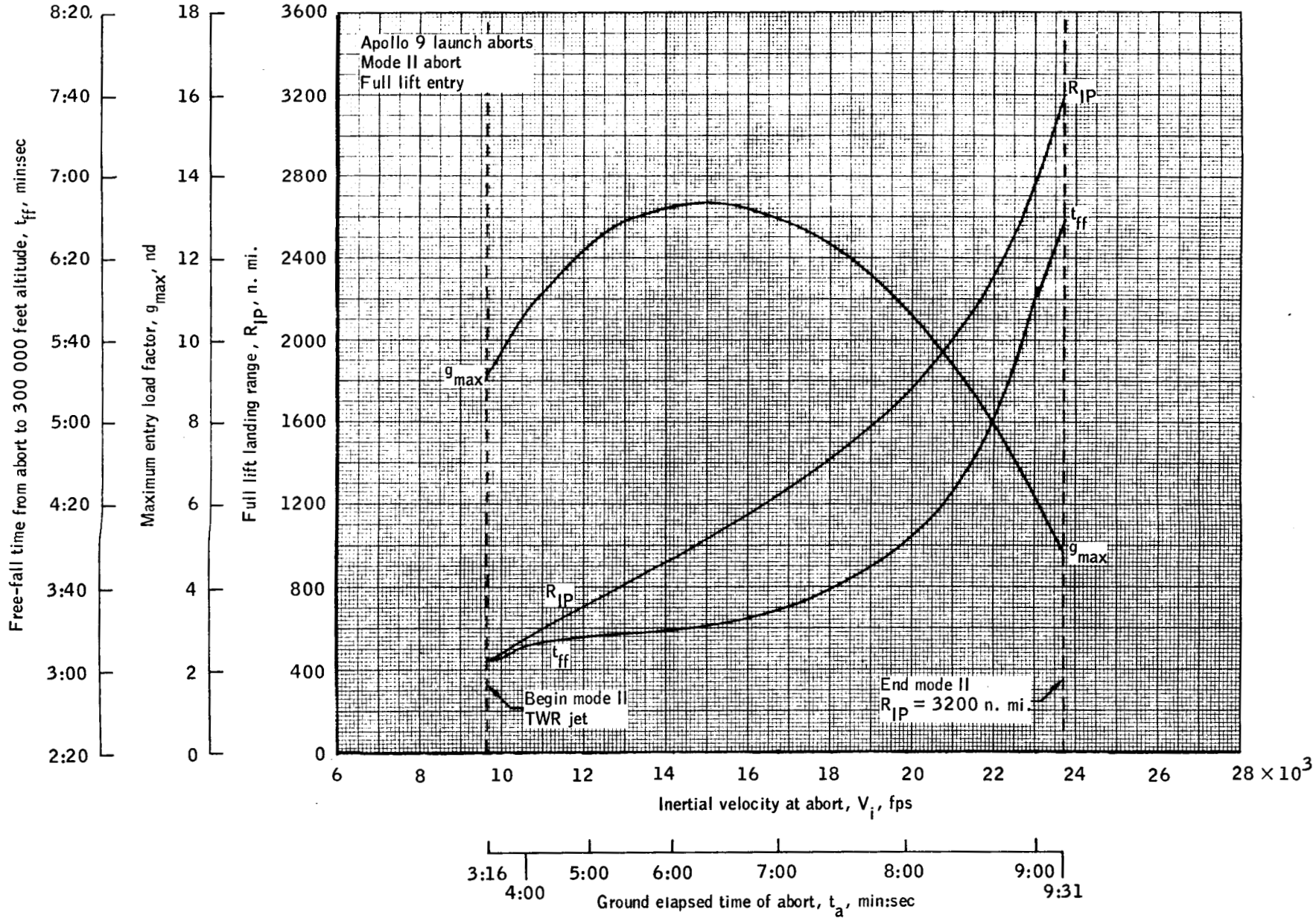


Figure 11.- Mode II abort parameters for aborts from the nominal launch trajectory.

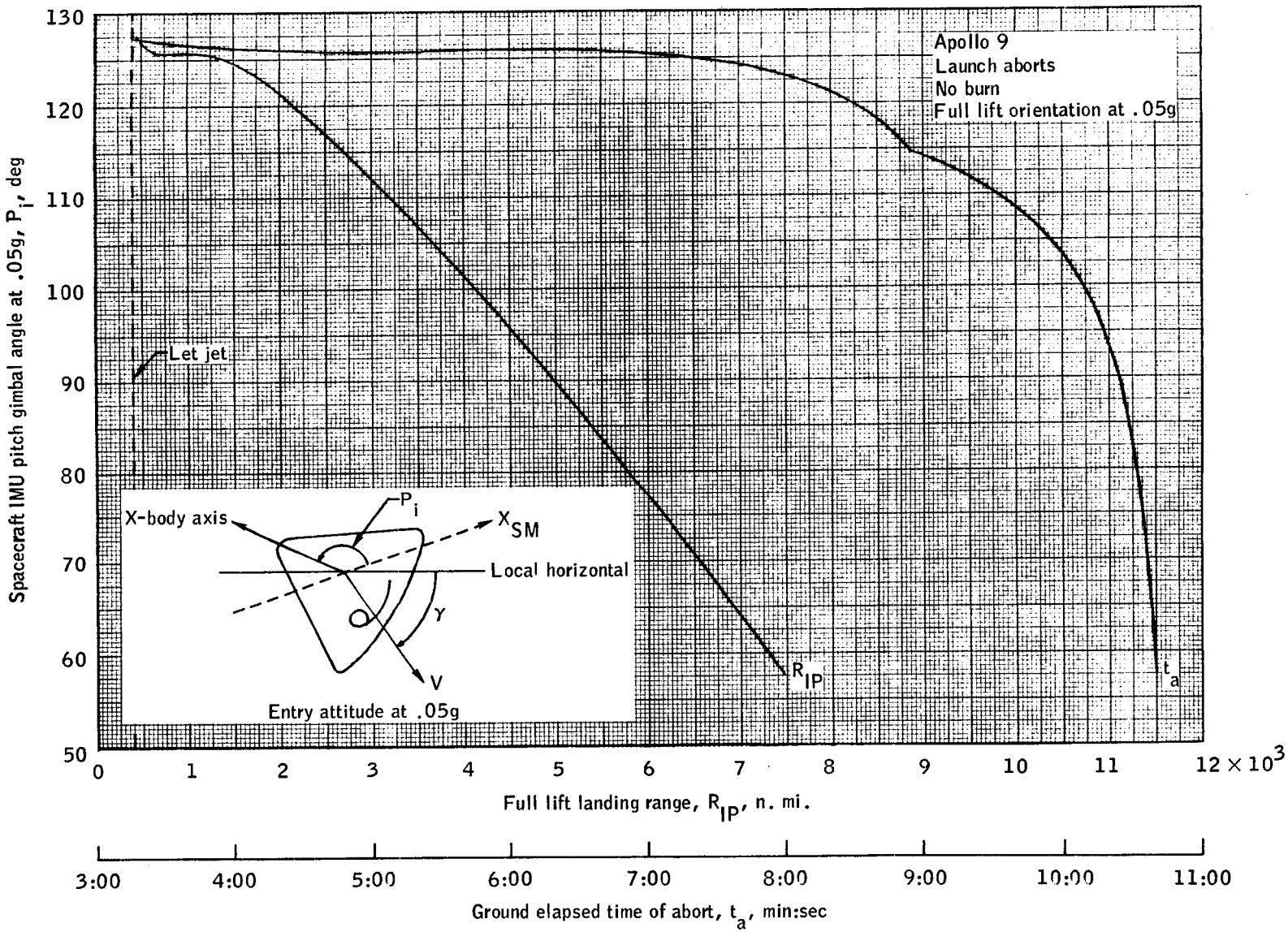


Figure 12.- Entry orientation following no burn aborts from the nominal launch trajectory.

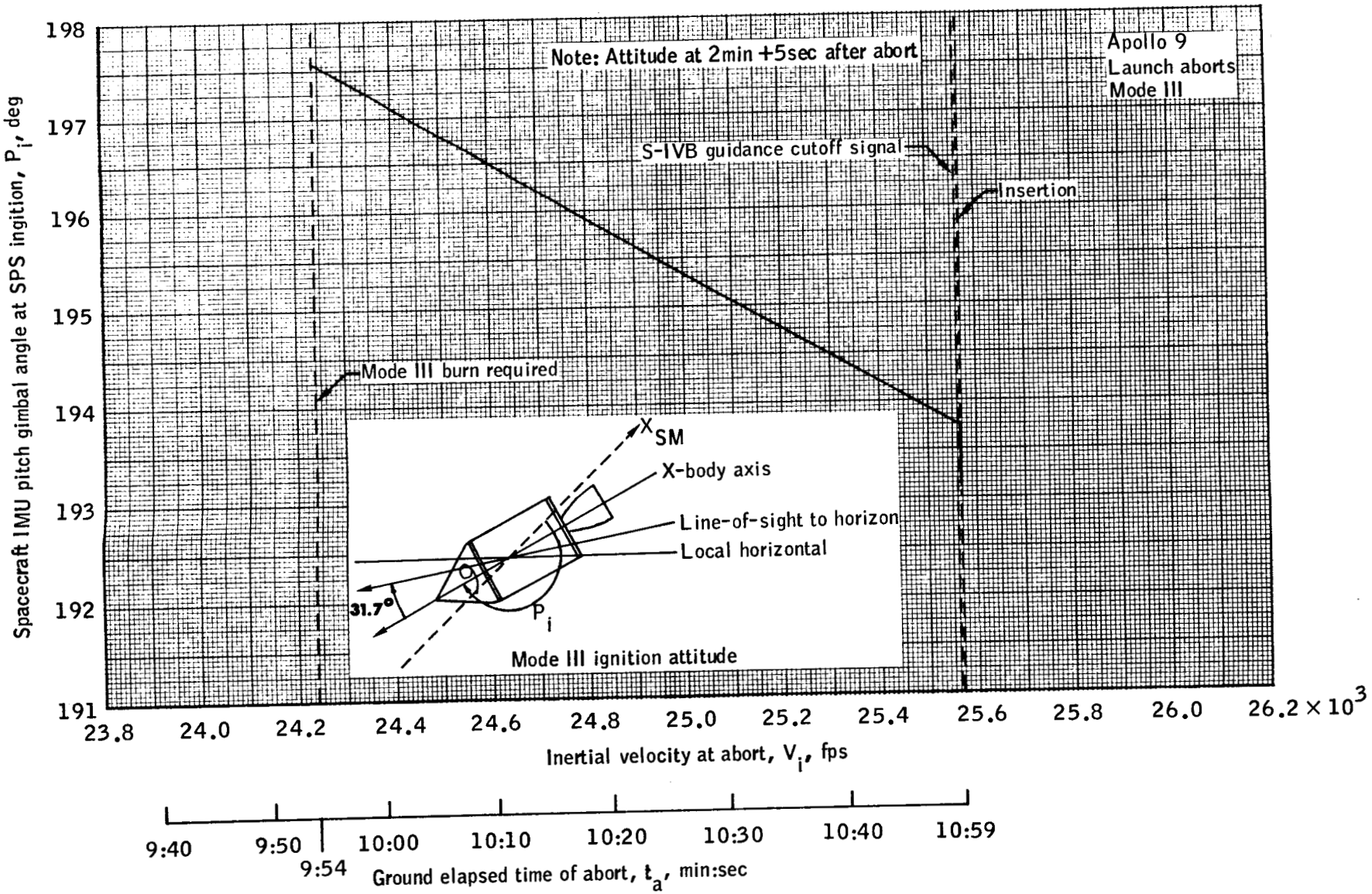


Figure 13.- Mode III burn orientation following aborts from the nominal launch trajectory.

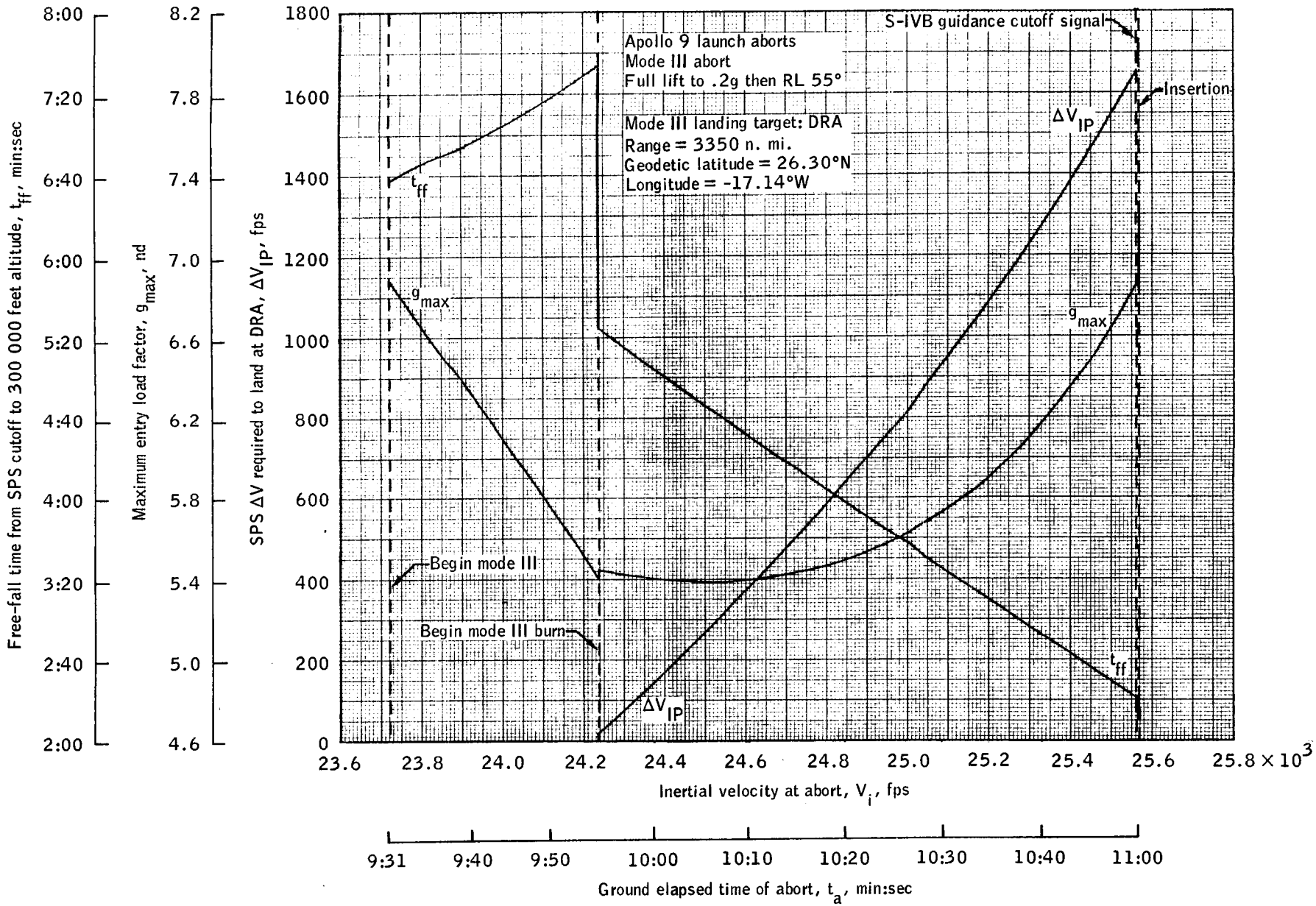


Figure 14.- Mode III abort parameters for aborts from the nominal launch trajectory.

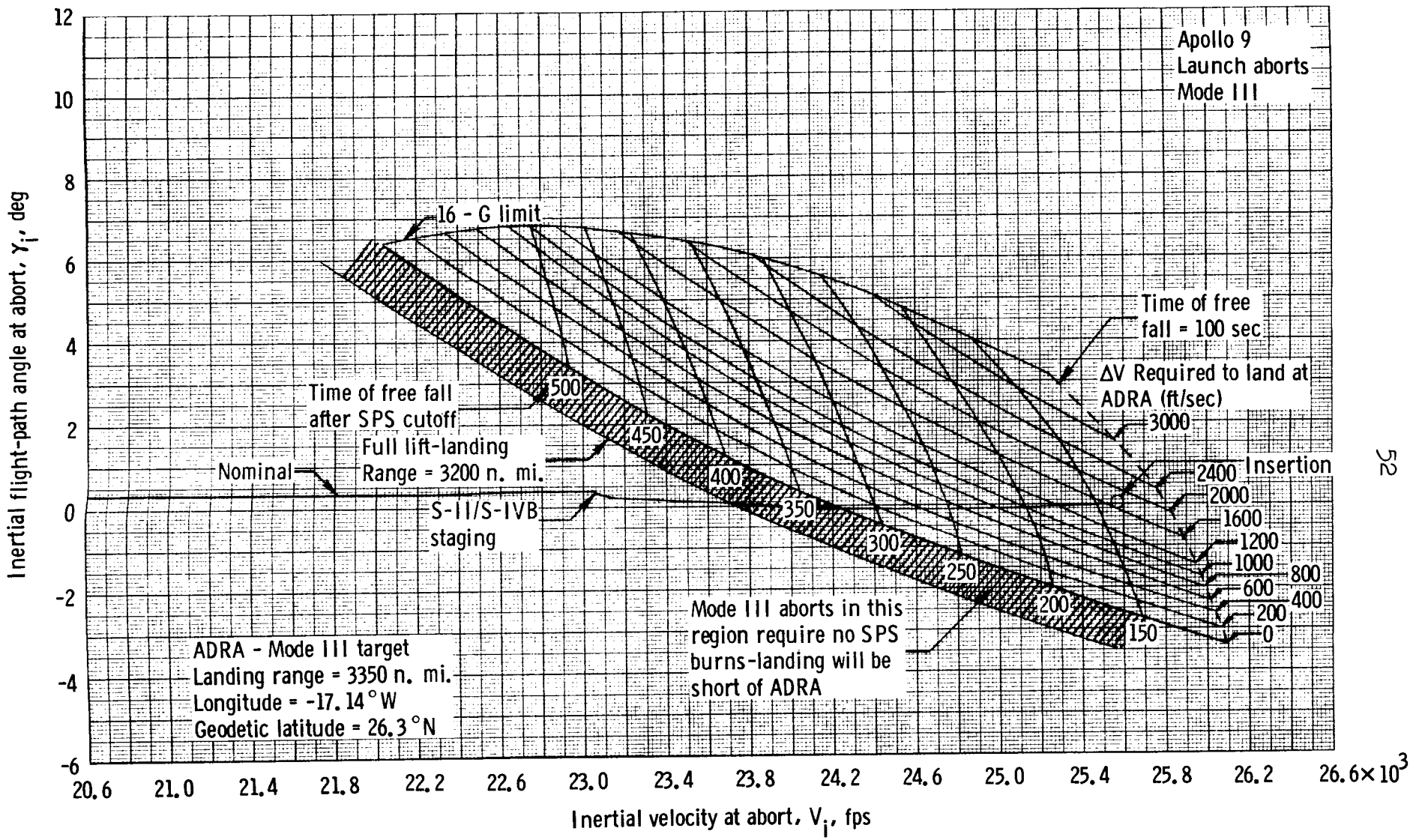


Figure 15. - Constant mode III ΔV contours required to land at the Atlantic discrete recovery area.

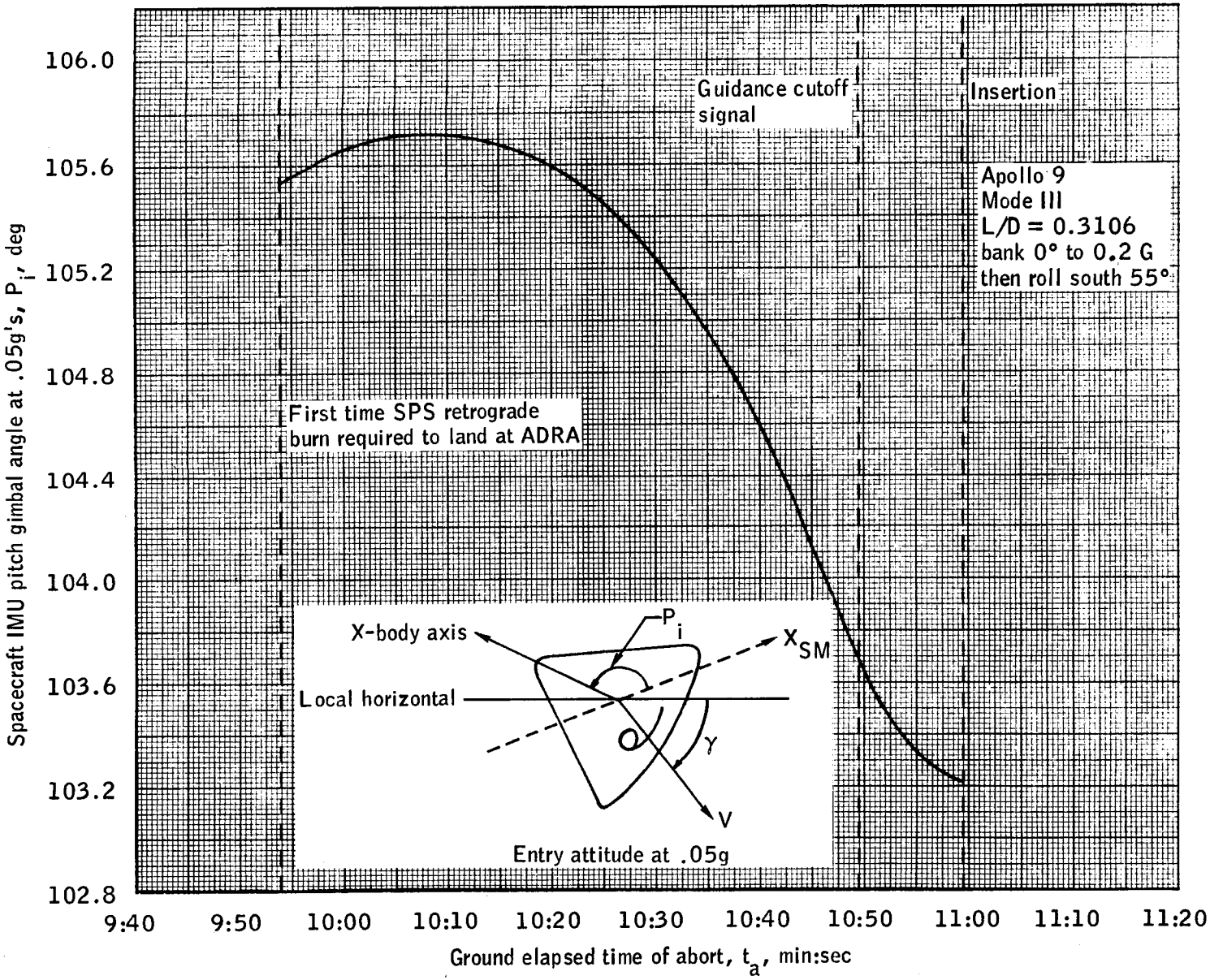


Figure 16.- Entry orientation following mode III aborts from the nominal launch trajectory.

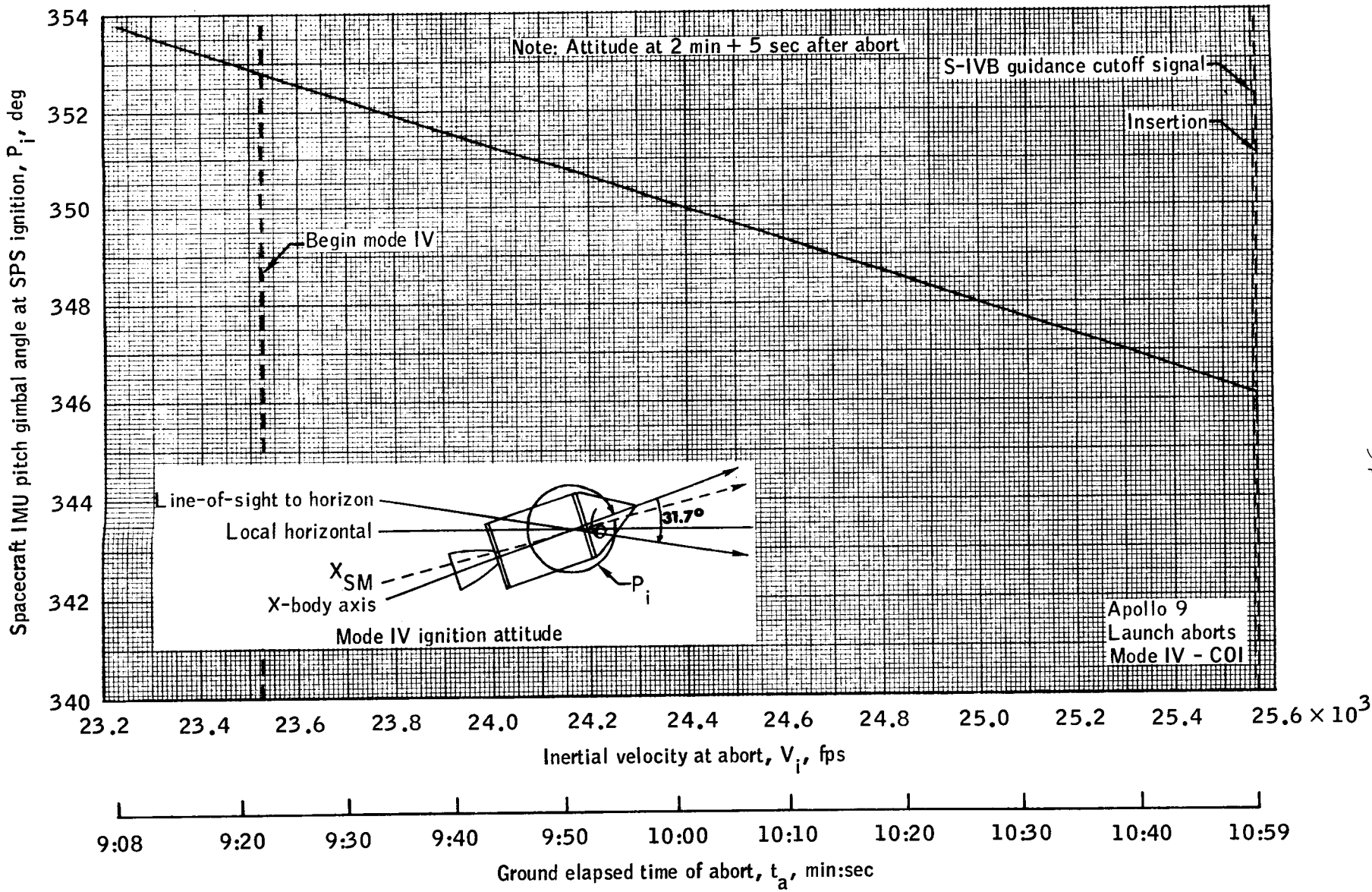


Figure 17.- Mode IV burn orientation following aborts from the nominal launch trajectory.

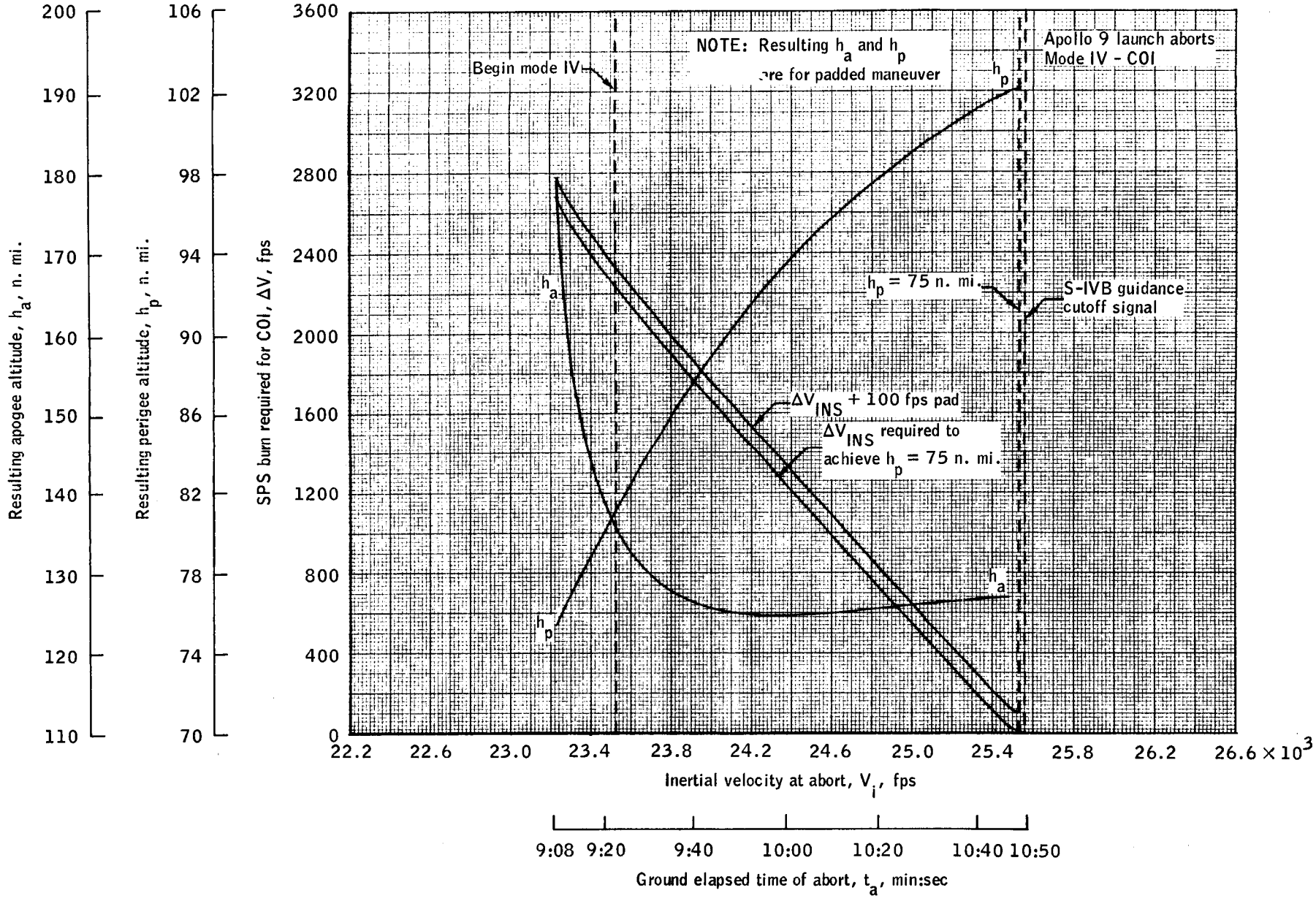


Figure 18.- Mode IV abort parameters for aborts from the nominal launch trajectory.

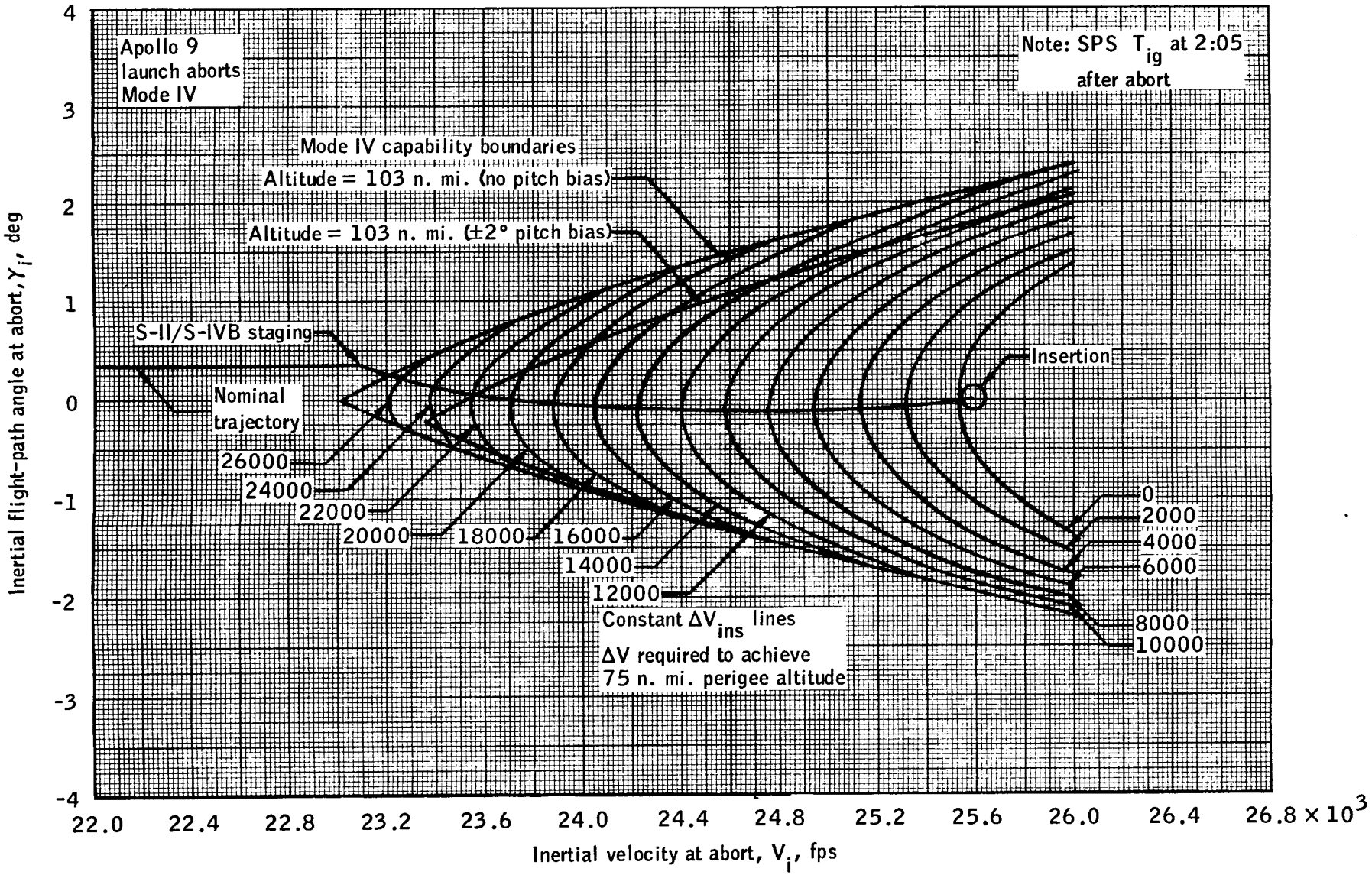


Figure 19.- Constant Mode IV ΔV contours required to achieve a 75-nautical mile perigee altitude.

REFERENCES

1. AS-504 Mission "D" Launch Vehicle Operational Trajectory. MSFC memo R-AERO-FMT-264-68, December 16, 1968.

2. Contingency Analysis Section: Operational Abort Plan for the Apollo 8 Mission. MSC IN 68-FM-209, November 26, 1968.

3. Henderson, Edward M.: General Apollo-Saturn V CSM Launch Abort Analysis. MSC IN 68-FM-232, December 4, 1968.

4. Apollo Mission Techniques Saturn V/Apollo Launch Phase Aborts, Techniques Description. MSC IN S-PA-8T-026, October 22, 1968.

5. Task Agreement Amendment for Launch Phase Operational Abort Analysis, Amenment No. 1. MSC/TRW Task A-162, October 1, 1968.

6. CSM/LM Spacecraft Operational Data Book, Volume I - CSM Data Book, Part I - Constraints and Performance. MSC IN SNA-8-D-027 (I) Rev. 1, November 1, 1968.

7. CSM/LM Spacecraft Operational Data Book, Volume III - Mass Properties. MSC IN SNA-8-D-027 (III) Rev. 1, November 1968.

8. TRW Systems Multi-Vehicle N-Stage (MVNS) Digital Computer Program. CDRC report 9830.4-23, August 2, 1965.

9. Launch Phase Flight Dynamics Displays for Mission D Simulations. MSC memo 69-FM36-5, January 13, 1969.

10. Guidance System Operations Plan for Manned CM Earth Orbital and Lunar Mission Using Program COLOSSUS, Section 5 - Guidance Equations (Rev. 1). MIT IL document, May 1968.