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By Donald L. Dietrick,
Flight Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

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Approved: C. R. Hicks, Jr.
C. R. Hicks, Jr., Chief
Flight Analysis Branch

Approved: Carl R. Huss
for John P. Mayer, Chief
Mission Planning and Analysis Division

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[a]Figure 5 is repeated on page 141 for use with figure 22.

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THE EFFECTS OF WIND FORCES ON A THRUSTING LAUNCH VEHICLE AND LAUNCH ESCAPE SYSTEM FOR APOLLO MODE I ABORTS

By Donald L. Dietrick

SUMMARY

The effect of wind forces on a launch vehicle (LV) trajectory and launch escape system (LES) trajectory of a thrusting vehicle was investigated up to and during mode I aborts. The effect of wind forces on the command module (CM) landing points computed by the mode-I-abort CM-landing-point-prediction program was studied to verify the current real-time mode-I-abort landing-prediction technique employed by the Real-Time Auxiliary Computing Facility (RTACF). Six-degrees-of-freedom (DOF) computer programs for the LV and mode I abort simulations were used to generate data for this study.

It was found that wind forces do affect the position and body attitudes of a thrusting vehicle. When these effects are not considered in the mode-I-abort CM-landing-point predictions, accuracy is degraded.

INTRODUCTION

The effect of wind forces upon the attitude of a thrusting LV and on the powered phase of the LES has in the past been considered negligible for unmanned Apollo missions when predicting the mode I abort CM landing location. The Manned Spacecraft Center real-time mode-1-abort landing-prediction program used by the RTACF currently ignores the effect of the wind forces during the thrusting phases of both the LV and the LES. Actual measured winds are applied to the canard phase and subsequent phases of the mode I abort sequence to impact.

The real-time mode-I-abort landing prediction program is used to predict the landing location of the CM in the event of a mode I abort, to determine if a land landing is possible under current wind conditions, and to position the recovery forces in the launch site area. The requirement of land landing prediction to support future Apollo missions has received a mandatory priority and necessitated a reevaluation of present methods and procedures. Thus, the purpose of the study presented here was to obtain the effects of wind forces (1) during the thrust phase of the LV, and (2) during the thrust phase of the LES. This note compares and analyzes the LV trajectory data, LES trajectory data, and predicted mode-I-abort landing-location data generated by six DOF computer programs.

The purpose of the comparison and analysis is to determine the effects of wind forces on the LV and the LES thrust phase, verify the current real-time mode-I-abort landing-prediction technique employed by the RTACF, and recommend method and procedural changes where applicable.

ANALYSIS

Computer Programs

Six DOF computer programs were used to generate data for this study. A three DOF mode-I-abort landing-location prediction program that computes results identical to similar phases of the six DOF mode-I-abort landing-location prediction program is mentioned below since it is the program that has been in use by the RTACF. These programs are modifications that have been made by the Computation and Analysis Division to the GE-MASS (General Electric, Missile and Satellite Systems Program for the IBM 7090) computer program (ref. 1).

Launch vehicle simulation computer program.- The LV simulation computer program was used to generate a basic Saturn IB nominal launch profile. It is a quasi six DOF GE-MASS computer program with the capability of applying winds. The state vector quantities generated by this simulation program define the position, velocity, and orientation of the LV and the LES at descrete times of abort, t_a, necessary for input to the six DOF mode-I-abort landing-location prediction program. Since the total effect of winds was desired, in this study, a non-wind-biased trajectory was generated to eliminate pitch program corrections for wind drifts.

Six-degree-of-freedom (six DOF) mode-I-abort landing-location prediction program.- The six DOF mode-I-abort landing-location prediction program is a six DOF GE-MASS program which simulates the LES sequence of events from t_a to the drogue chute deploy and switches by exercising a program option to a three DOF simulation at drogue chute deploy to CM landing. This program is initiated with a state vector from the LV simulation computer program or a Marshall Space Flight Center (MSFC) operational flight trajectory and has the provision to allow winds to be applied to the entire abort trajectory calculations.

Three-degree-of-freedom (three DOF) mode-I-abort landing-location prediction program.- The three DOF mode-I-abort landing-location prediction program is the three DOF GE-MASS program and real-time mode I abort simulation that has been in use by the RTACF. It is a point mass program which simulates the LES abort sequence of events from t_a + 11 seconds to CM landing.

This program is initiated with a vector from the six DOF mode I abort simulation defining the position, velocity, and orientation of the LES at 11 seconds after the beginning of the launch escape motor thrusting (t_a + 11 seconds). It uses aerodynamic data generated by the six DOF mode I abort simulation as input to the canard phase (see sequence of events for mode I aborts). These aerodynamic data cause results to be computed in the three DOF program similar to the related flight phase of the six DOF simulation.

For the real-time simulation and mission support by the RTACF, state vector conditions for each mission are obtained from the six DOF mode I abort simulation that was initiated with a vector from the MSFC Operational Flight Trajectory. Wind forces in the three DOF program are applied to the trajectory calculations at the beginning of the canard phase to CM landing.

Sequence of Events for Mode I Aborts

The sequence of events for mode I aborts considered in this study are the same as those for the Apollo 5 Mission (AS-204 - ref. 2) and are as follows:

(a) Mode 1a - low altitude LES aborts (pad abort through 61 seconds g.e.t.)

Time	Event
t_a	Fire launch escape motor and pitch control motor
t_a + 11 sec	Deploy canards
t_a + 14 sec	Jettison tower
t_a + 14.4 sec	Jettison apex cover
t_a + 16 sec	Deploy drogue chutes
2800-ft altitude	Deploy main chutes

(b) Mode 1b - Medium altitude LES aborts (62 through 68 seconds g.e.t.)

Time	Event
t_a	Fire launch escape motor
t_a + 11 sec	Deploy canards
t_a + 14 sec	Jettison tower
t_a + 14.4 sec	Jettison apex cover
t_a + 16 sec	Deploy drogue chutes
10 200-ft altitude	Deploy main chutes

(c) Mode 1b - Medium altitude LES aborts (69 through 90 seconds g.e.t.).

Time	Event
t_a	Fire launch escape motor
t_a + 11 sec	Deploy canards
23 300-ft altitude	Jettison tower
$t_{23\ 300\ ft}$ + .4 sec	Jettison apex cover
$t_{23\ 330\ ft}$ + 2 sec	Deploy drogue chutes
10 200-ft altitude	Deploy main chutes

More information concerning the sequence of events is given in figure 1 and reference 3.

Wind Profile

The wind imposed on the LV and the LES for this study, illustrated in figure 2 and taken from reference 4, is referred to a wind with a 95 percent probability of occurrence. This means that 95 percent of the time the winds at Cape Kennedy will be of the magnitude shown, or less.

To manufacture a representative daily wind profile is unrealistic since wind magnitude and direction are unpredictable at any time; therefore, a probability of occurrence approach best solved the problem. The maximum value or the limit wind condition is used to provide the worst case situation. The value for surface winds was changed slightly (see fig. 2) to reflect mission launch restrictions due to excessive winds.

To obtain various wind effects on the LV and the LES, winds from four directions were considered: (1) a headwind, (2) a tailwind, (3) right crosswind, and (4) left crosswind. The flight azimuth for the LV was 72°, which serves as the basis for selecting the wind directions. The SW wind (252°) causes the headwind effect; the NE wind (72°) causes the tailwind effect; the SE wind (162°) causes the right crosswind effect; and the NW wind (342°) causes the left crosswind effect. For clarification the wind directions NE, SE, SW, and NW refer to the directions to which the wind blows.

Wind Effects Computed

In this study the effect of wind forces was investigated by comparing the resulting (1) LV trajectory data, (2) LES trajectory data, and (3) the CM mode-I-abort landing point data. The first was generated with the quasi-six-DOF LV simulation computer program and the last two by the six-DOF mode-I-abort landing-location prediction program. It was not necessary to use the three-DOF mode-I-abort landing-location prediction program since it produces results identical to the related phases of the six DOF simulation.

The effects of wind forces on the LV and the LES were analyzed by imposing winds on the LV and on the subsequent phases of the LES in various combinations and comparing the computed results. Computed results are presented here as parametric data and CM landing points. Wind effects on the LV and the LES were studied by comparisons of the CM landing points of the following cases.

1. Case 1 - Winds on LV and LES to landing.

2. Case 2 - Winds on LES at canard deploy to landing.

3. Case 3 - Winds on thrust phase of LES.

4. Case 4 - Winds on LV and LES, no wind on chutes.

5. Case 5 - No winds.

6. Case 6 - Winds on LV and LES thrust phase.

RESULTS

Wind Effects on the LV

The effect of wind forces imposed on the LV trajectory is shown in figures 3(a) through 3(j). Different wind directions are shown to influence the trajectory by varying degrees. The LV at any time up to 90 seconds after lift-off is changed from a no-wind case to four wind cases by applying winds from four directions (headwind, tailwind, right and left crosswind).

Figure 3(a) indicates how the down-range values are affected by wind forces. The maximum and minimum down-range values, as may be expected, are for a headwind and tailwind, respectively. As an example of the effect on range, the difference between maximum and minimum range for an altitude of 45 000 ft is approximately 8000 ft, or 1.3 n. mi.; at 60 000-ft altitude, the difference is approximately 13 000 ft, or 2.5 n. mi.

The relative flight azimuth shown in figure 3(c) indicates that the LV, from lift-off to 20 seconds g.e.t., is actually blown in the direction of each wind (NE, SE, SW, NW). The relative flight azimuth changes rapidly to the mission flight azimuth as the LV pitch program begins and the LV's velocity and thrust increases.

Figures 3(b) and 3(d) through 3(g) present comparisons of the no-wind case with the various winds on the LV and show the effects on altitude, flight-path angle, relative velocity, latitude, and longitude.

Figures 3(h) through 3(j) present comparisons of no wind with the various winds on the LV and give the differences in distance on the X, Y, Z planes caused by the wind forces.

Comparison of Case 1 and Case 2

When comparing the data of case 1, winds on LV and LES to landing (fig. 5), and case 2, winds on LES at canard deploy to landing (fig. 4), the values for the impact point locations varied for common aborts (those having the same time of abort, t_a, and same wind direction). This comparison shows the effect of applying winds on the LV and during the thrusting phase of the launch escape motor (see sequence of events for mode I aborts). The variations of common impact points for a pad abort through the 61-second abort were appreciable but small compared to those experienced from 62 through 90 seconds. Aborts resulting in a land landing in the vicinity of the launch pad occurred in both cases with a headwind for aborts from 30 through 68 seconds. The apogee altitudes for these aborts range from 10 584 ft to 40 034 ft, respectively. The higher the altitude from which the CM descends, the greater the effect of wind forces on the landing location. This fact is not only true because of higher velocity winds usually associated with high altitude, such as used in this study, but because of total time on the chutes. Parametric data for these two cases are included as figures 6 through 21.

Comparison of Case 1 and Case 4

When comparing the data of case 1, winds on LV and LES to landing (fig. 5), and case 4, winds on LV and LES, no winds on chutes, (fig. 22), the common impact points indicate that the largest effect of wind forces is due to winds on the chutes. Case 4 (fig. 22) shows that only the 68-second abort with headwinds will cause a land landing. Also, it may be noted here that the impacts for other times of abort for case 4 are between those impacts with the no-wind condition, case 5 (fig. 24), and the impacts of case 1 (fig. 5).

Comparison of Case 3 and Case 5

Case 3, winds on thrust phase of LES (fig. 25), and case 5, no winds (fig. 24), when compared show that there is an effect due to winds on the LES thrust phase. For example, with a headwind the differences in range were found to vary from 19 ft (t_a of 40 seconds) to 3000 ft (t_a of 67 seconds).

Comparison of Case 3 and Case 6

Case 3, winds on thrust phase of LES (fig. 25), and case 6, winds on LV and LES thrust phase (fig. 23), support the fact that wind forces imposed on the LV and thrust phase of the LES produce a larger effect on the landing points of the CM than wind forces imposed only on the thrust phase of the LES. Comparison of figure 25 and figure 23 shows that the wind's major effect is on aborts from 50 seconds through 90 seconds and that the winds cause case 6 landing points to diverge from those of case 3. The distance between landing points increased from 1 mile for aborts at 50 seconds to 3 miles for aborts at 90 seconds.

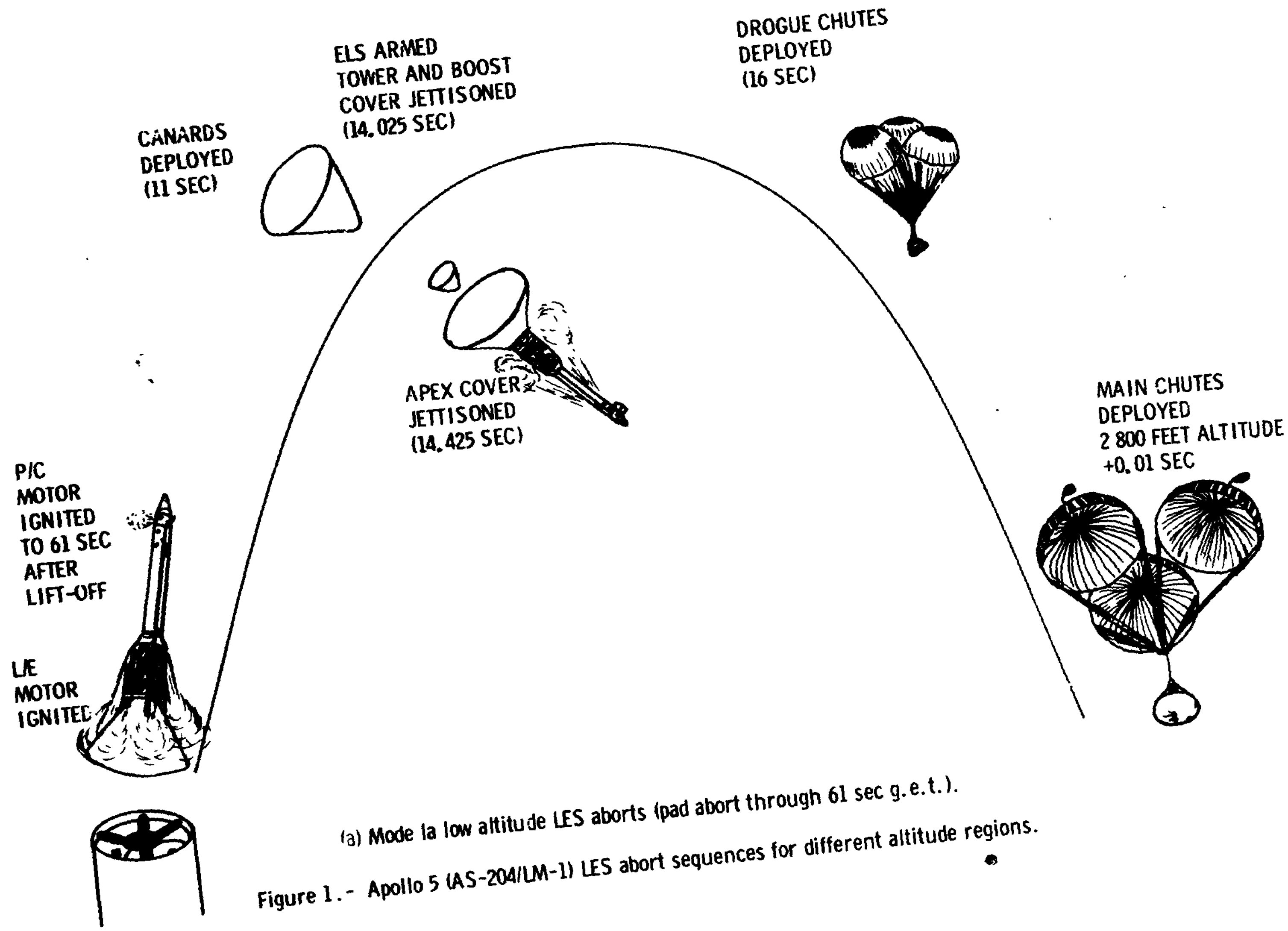
CONCLUSIONS

The conclusions listed below are based on the analysis of data from the six DOF LV simulation computer program and six DOF mode I abort CM impact point prediction program.

1. The LV and LES trajectory and CM landing point data presented herein make it evident that wind forces affect the position and body attitudes of a thrusting vehicle. A sufficient change between the no-wind case and various wind case data is realized and thus provides an area for improvement of the techniques used in the mode-I-abort CM-landing-location prediction program.

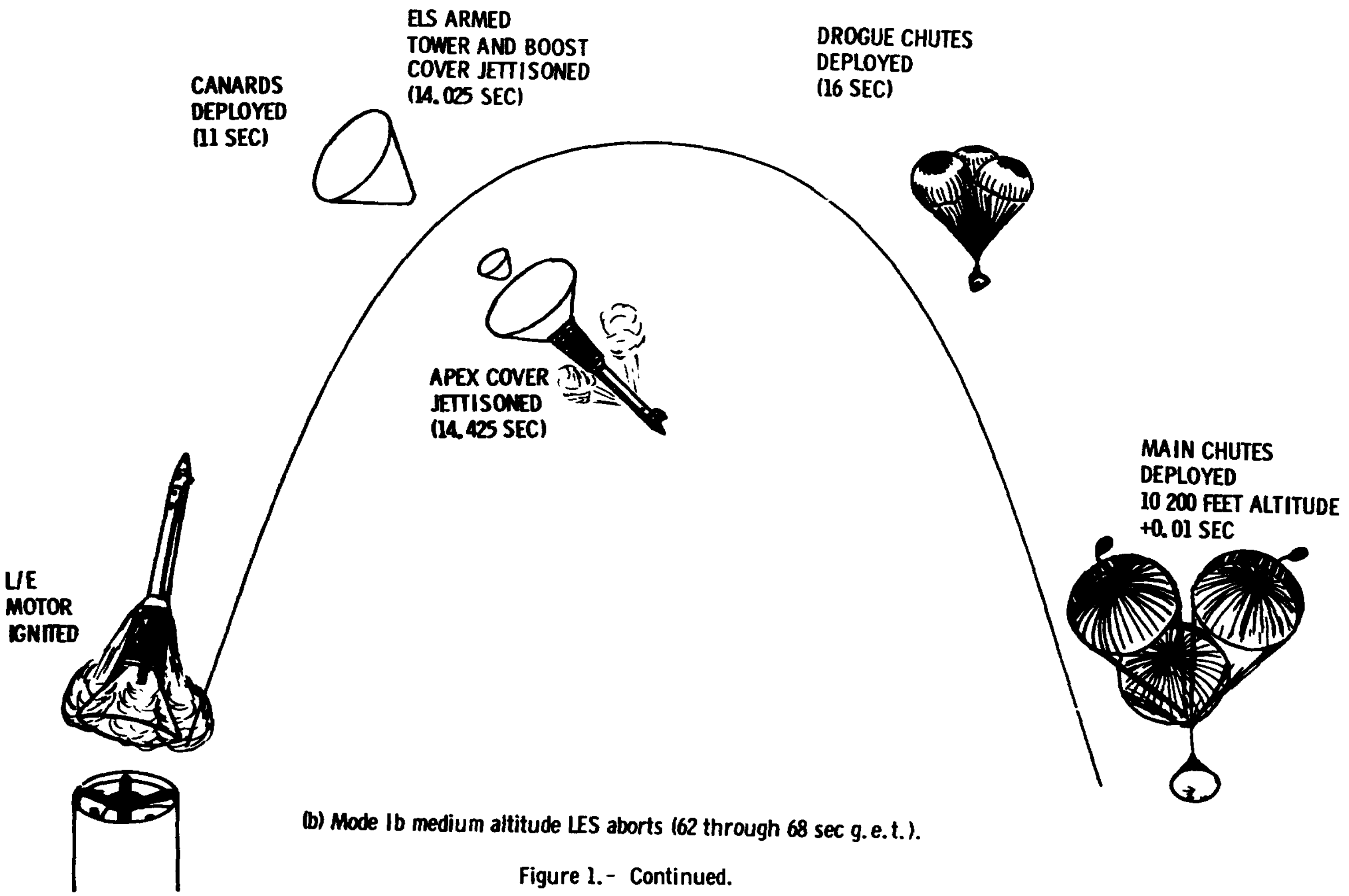
2. The effect of wind forces on the LV and LES should by some method be considered by the RTACF real-time mode-I-abort CM-impact-point prediction program. The techniques used should be modified by implementing a six DOF program in place of the three DOF program, which would allow wind effects to be considered on the launch trajectory and the entire abort trajectory.

3. The largest effect of wind forces realized by the LES is on the drogue and main parachutes. The length of time on the parachutes and surface areas to be affected aerodynamically causes drift distances and directions to be a major concern, specifically when considering land landings.



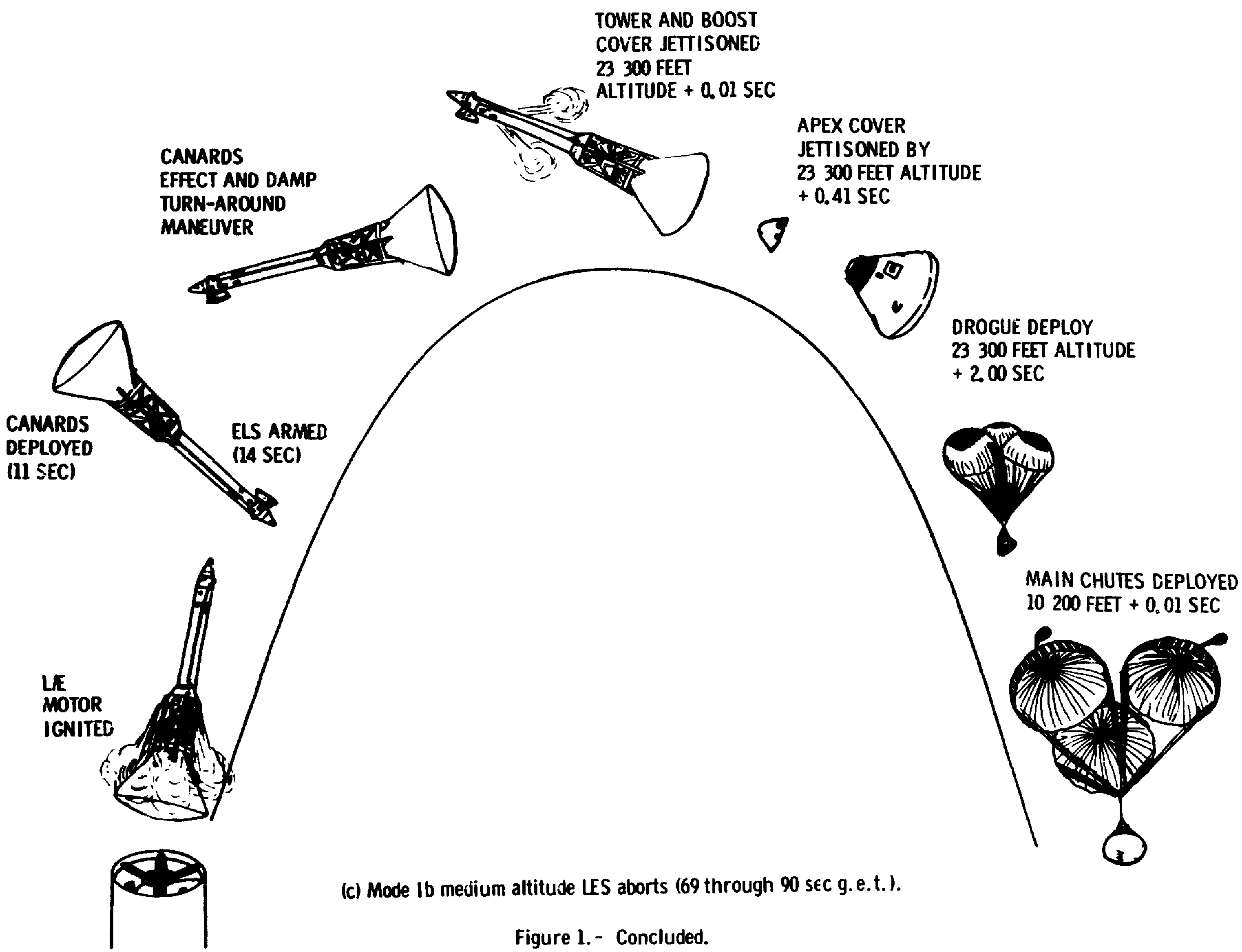
(a) Mode Ia low altitude LES aborts (pad abort through 61 sec g.e.t.).

Figure 1.- Apollo 5 (AS-204/LM-1) LES abort sequences for different altitude regions.



(b) Mode Ib medium altitude LES aborts (62 through 68 sec g.e.t.).

Figure 1.- Continued.



(c) Mode Ib medium altitude LES aborts (69 through 90 sec g.e.t.).

Figure 1.- Concluded.

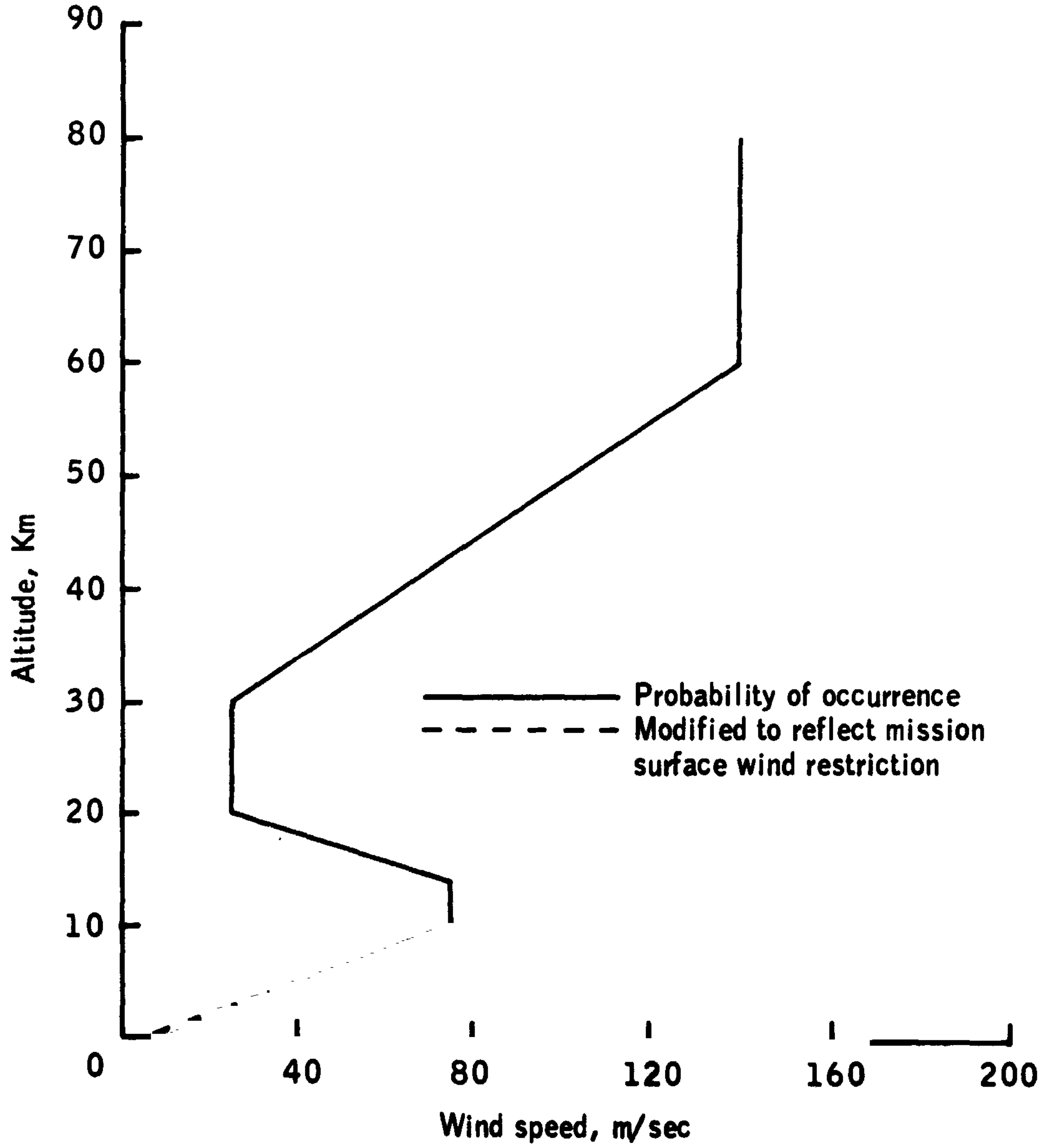
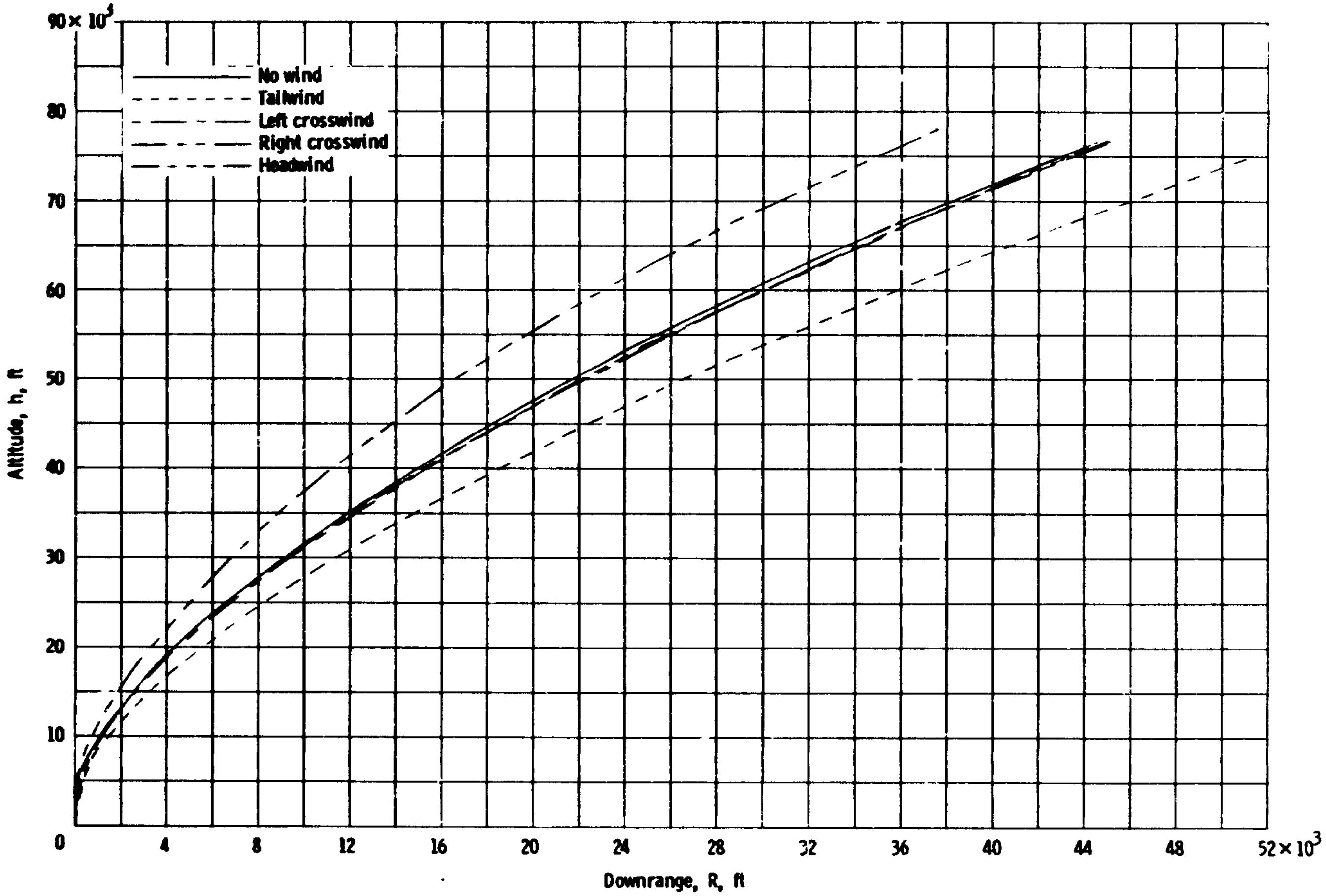
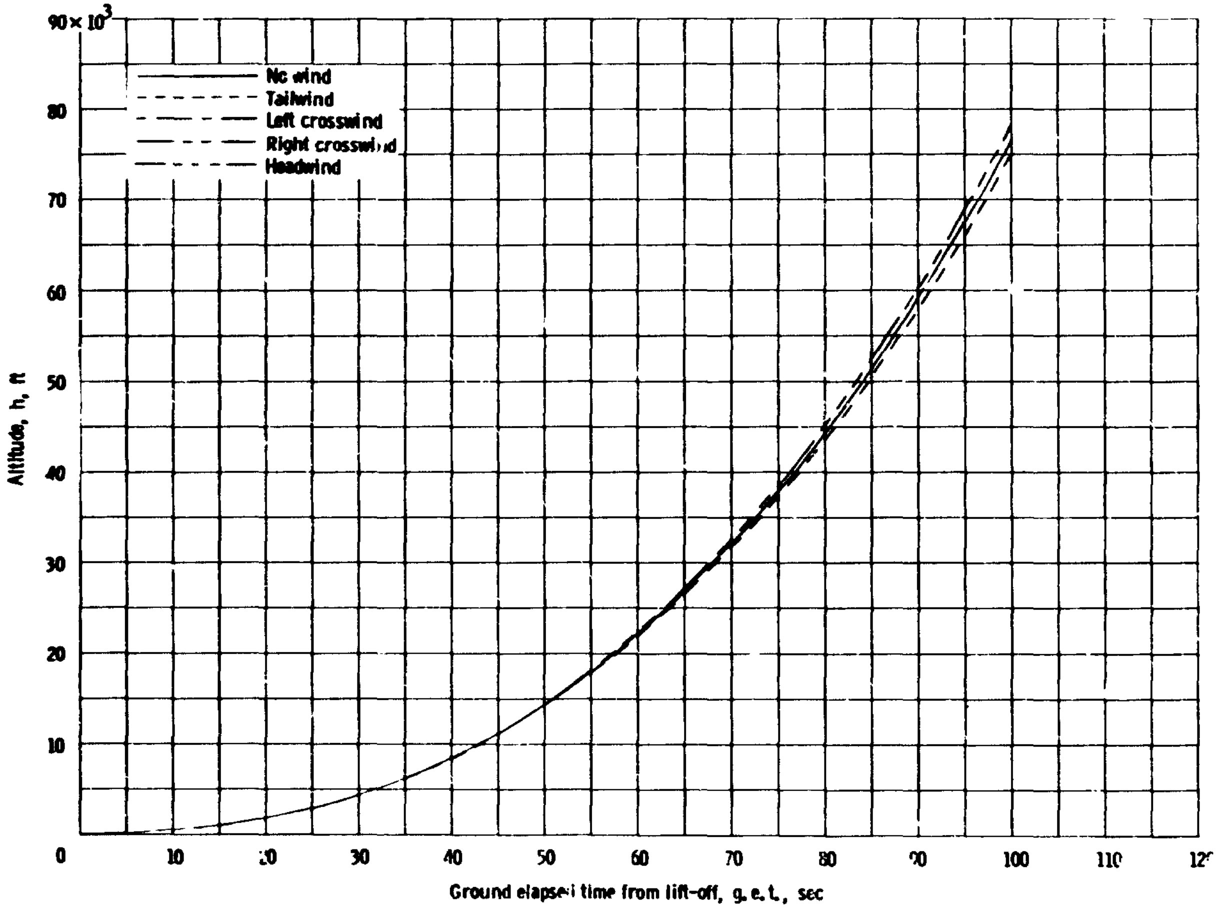


Figure 2.- Ninety-five-percent-probability-of-occurrence wind speed profile envelope for Cape Kennedy, Florida.



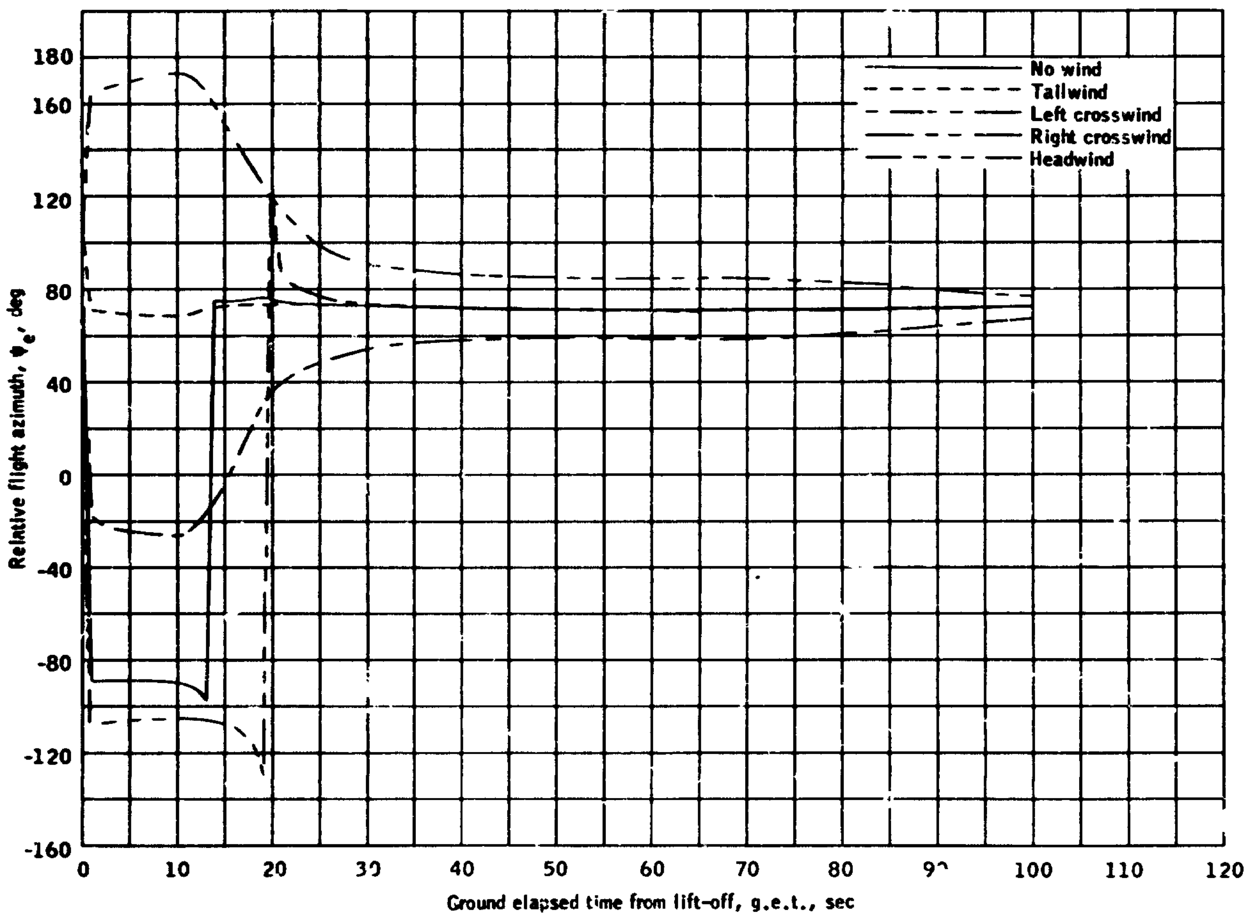
(a) Altitude versus downrange.

Figure 3. - Wind effects on launch vehicle.



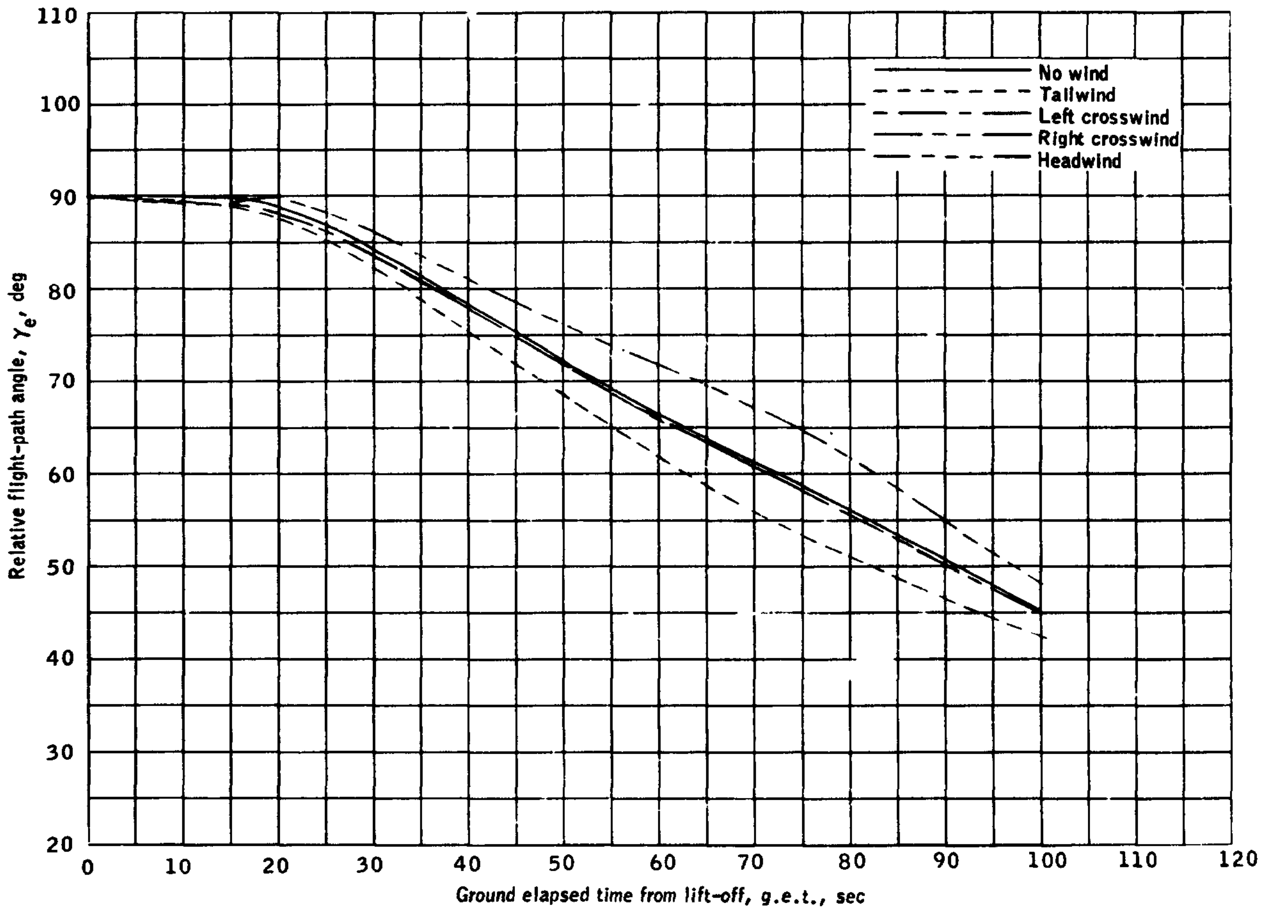
(b) Altitude versus time.

Figure 3.- Continued.



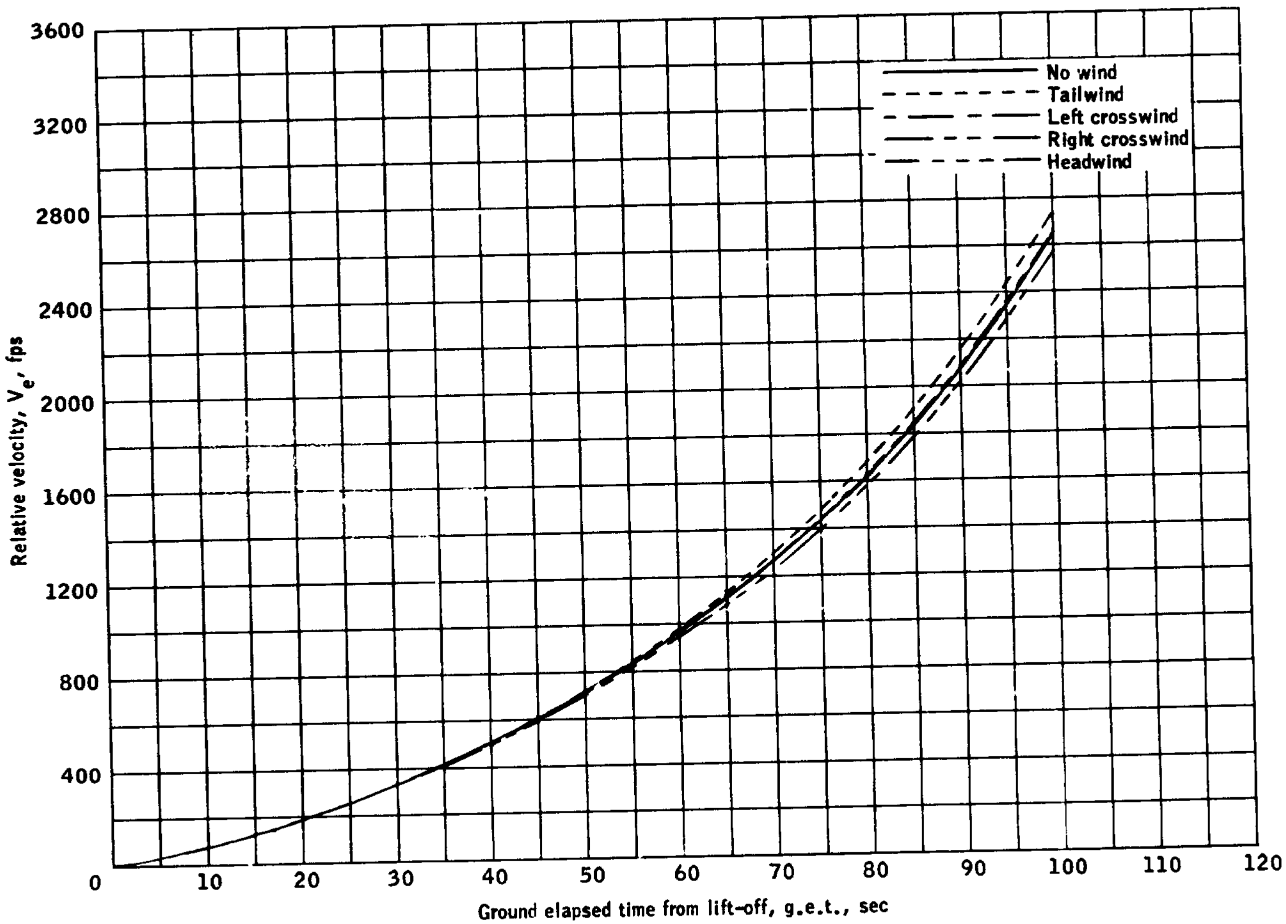
(c) Relative flight azimuth versus time.

Figure ? - Continued.



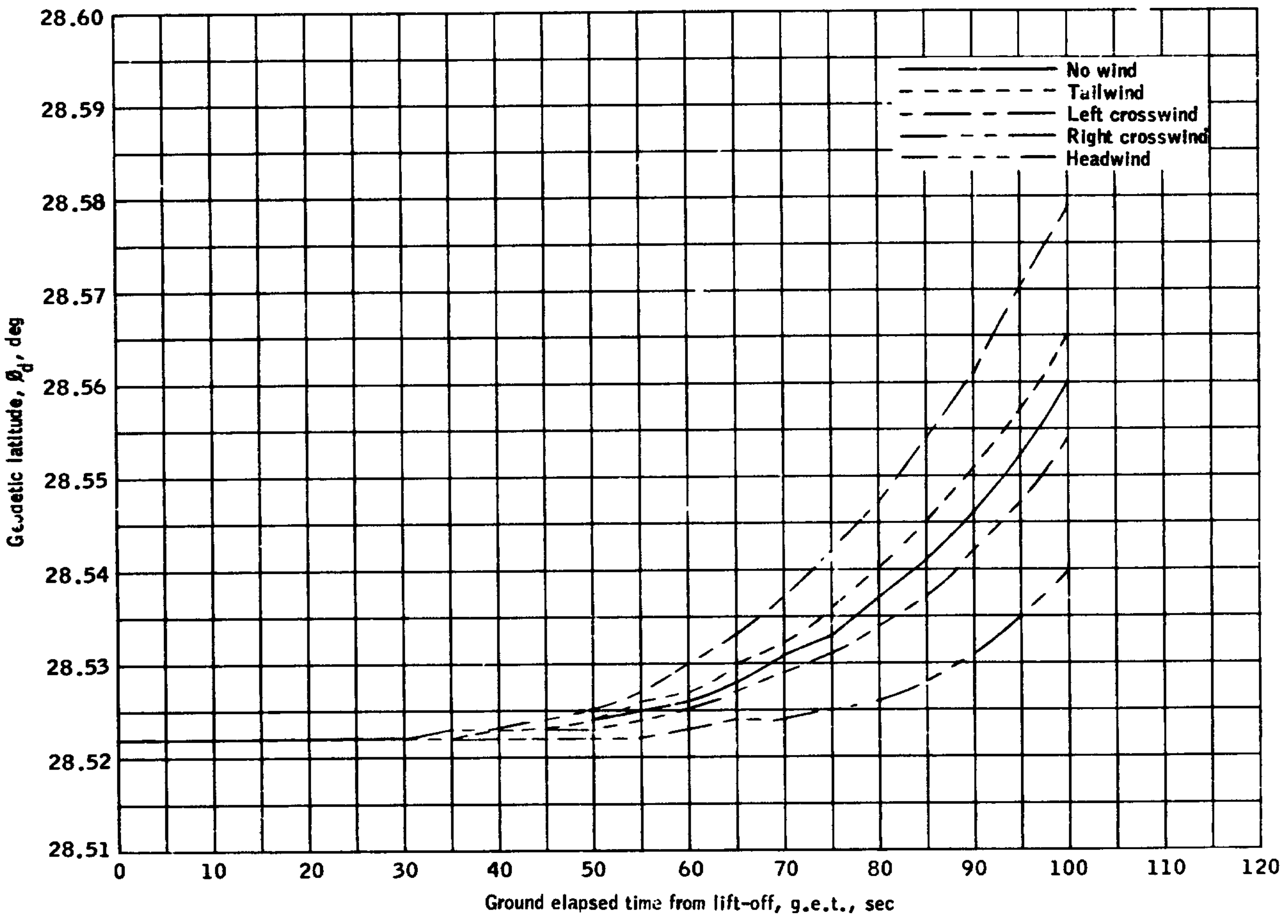
(d) Relative flight-path angle versus time.

Figure 3.- Continued.



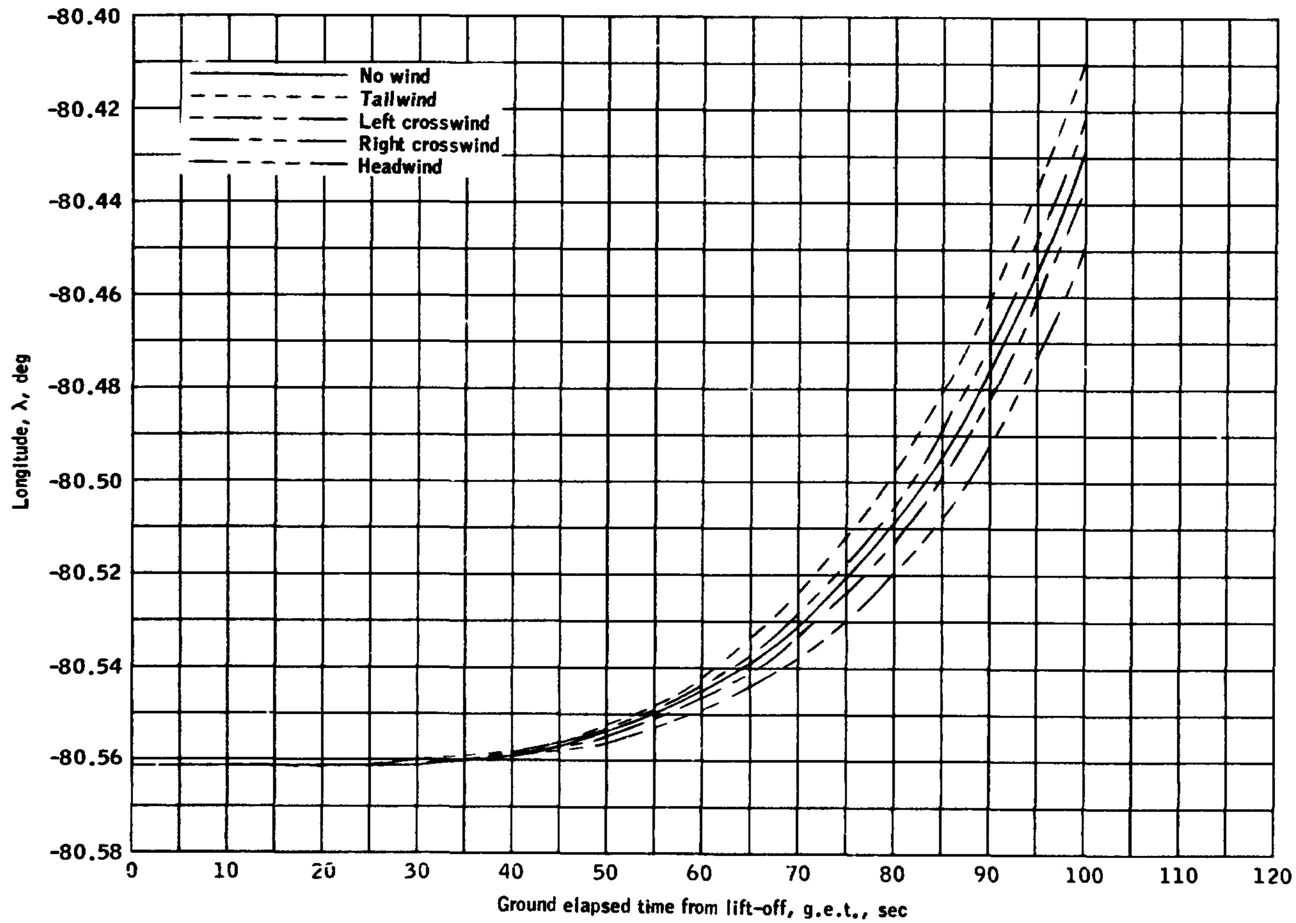
(e) Relative velocity versus time.

Figure 3.- Continued.



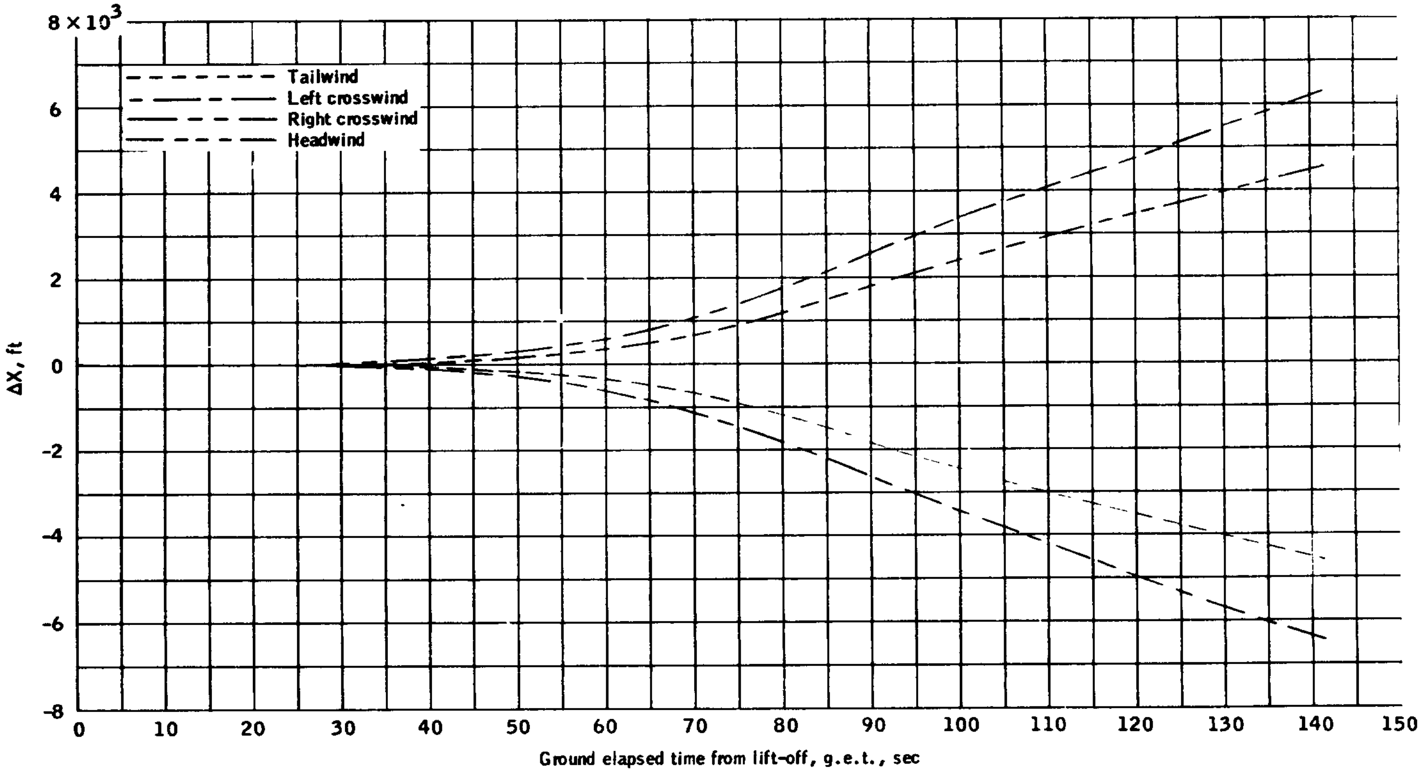
(f) Geodetic latitude versus time.

Figure 3.- Continued.



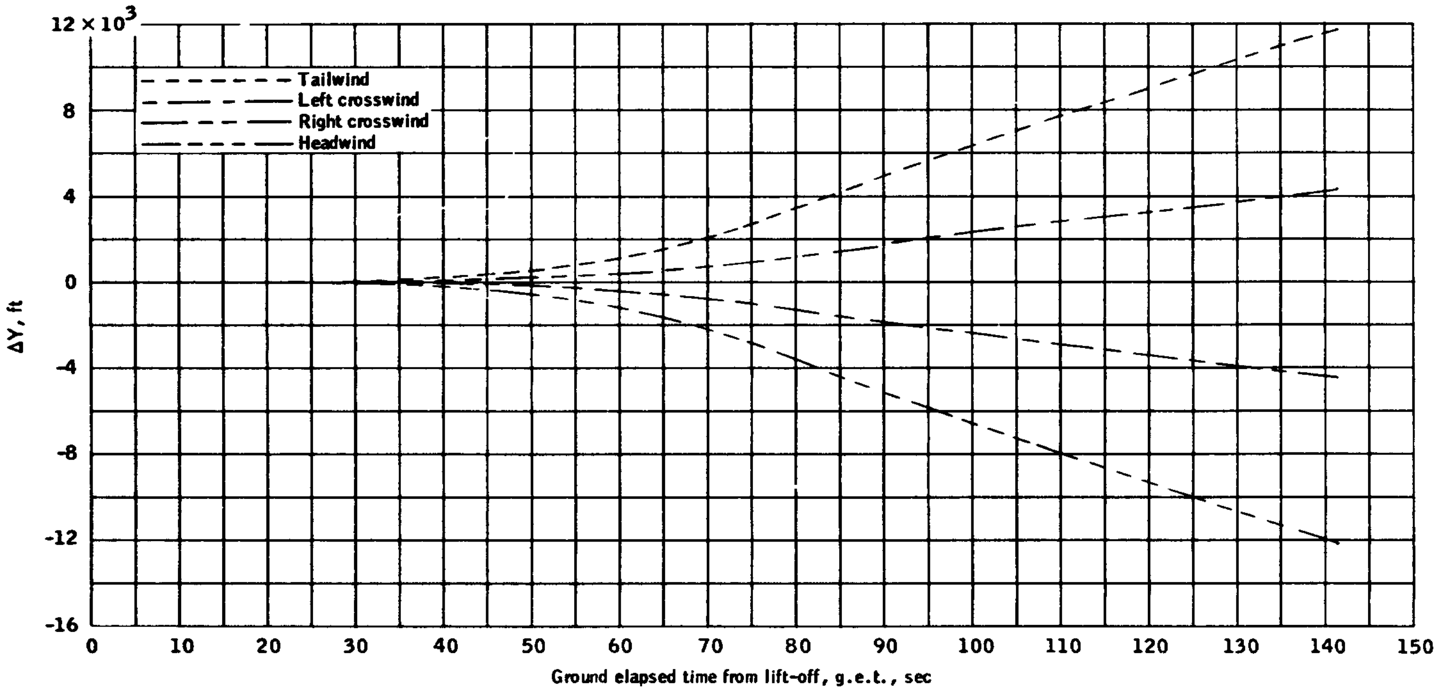
(g) Longitude versus time.

Figure 3.- Continued.



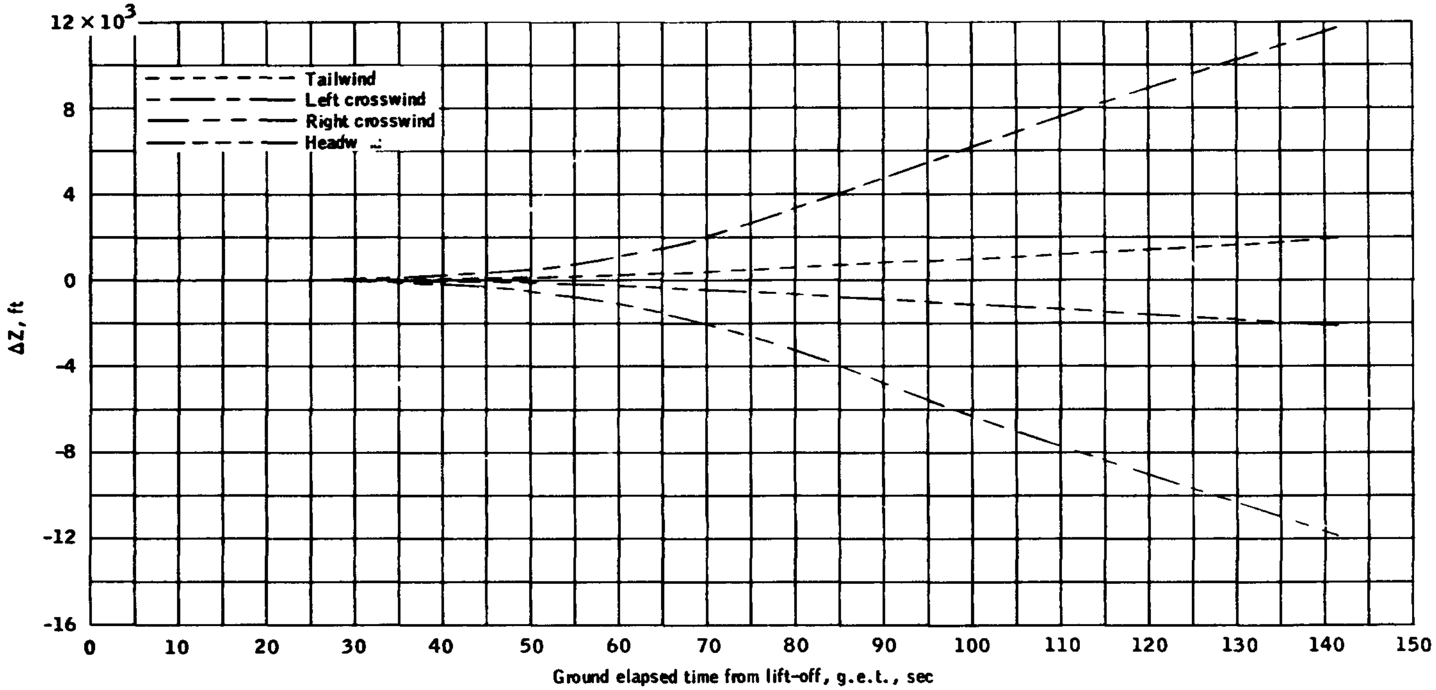
(h) Δx (x geocentric position for winds on launch vehicle minus x geocentirc position for no winds on launch vehicle) versus time.

Figure 3.- Continued.



(i) Δy (y geocentric position for winds on launch vehicle minus y geocentric position for no winds on launch vehicle) versus time.

Figure 3.- Continued.



(j) Δz (z geocentric position for winds on launch vehicle minus z geocentric position for no winds on launch vehicle) versus time.

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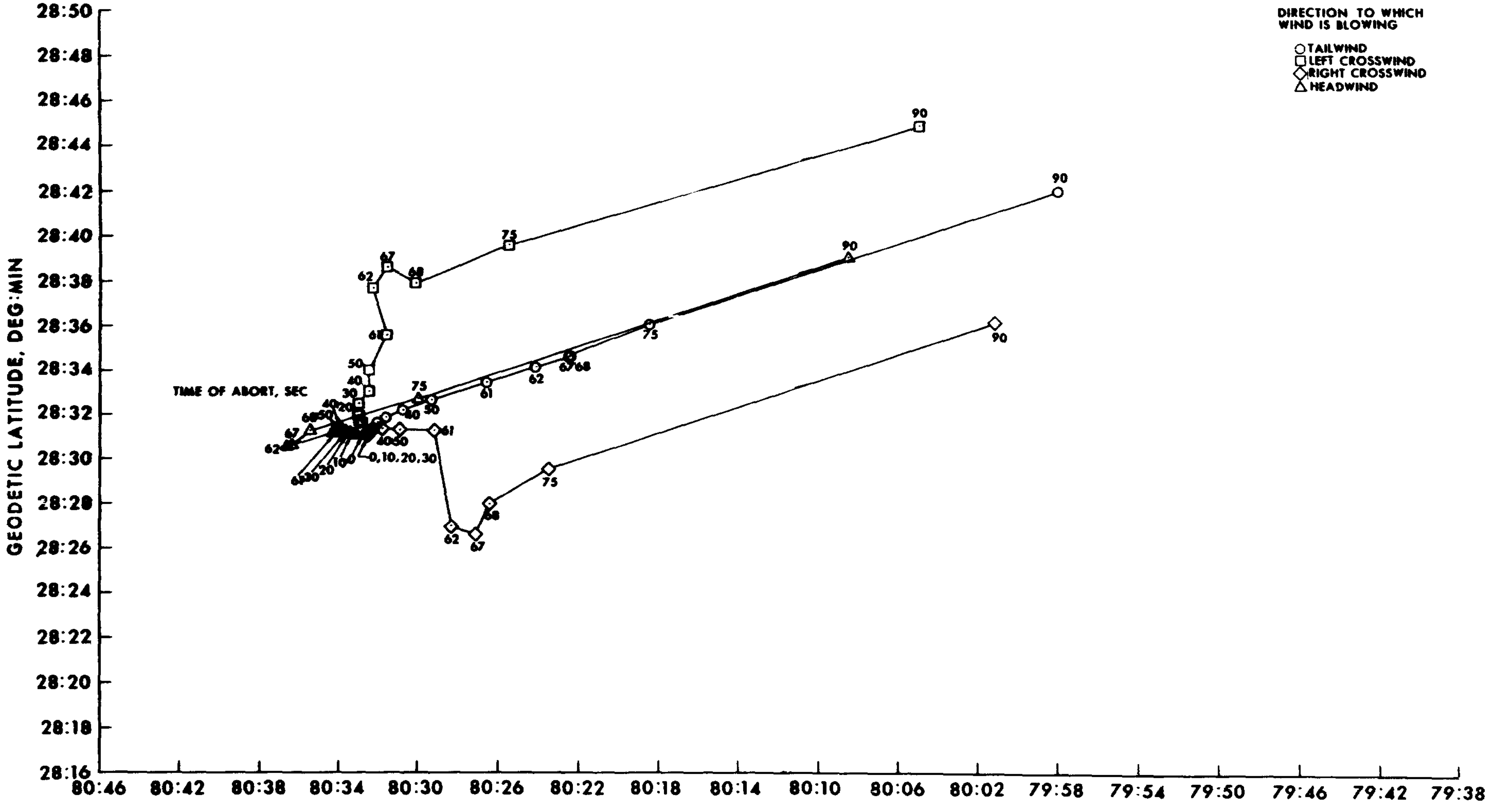

FIGURE 4.- COMMAND MODULE IMPACT POINTS FOR WINDS ON THE LES AT CANARD DEPLOY TO LANDING.

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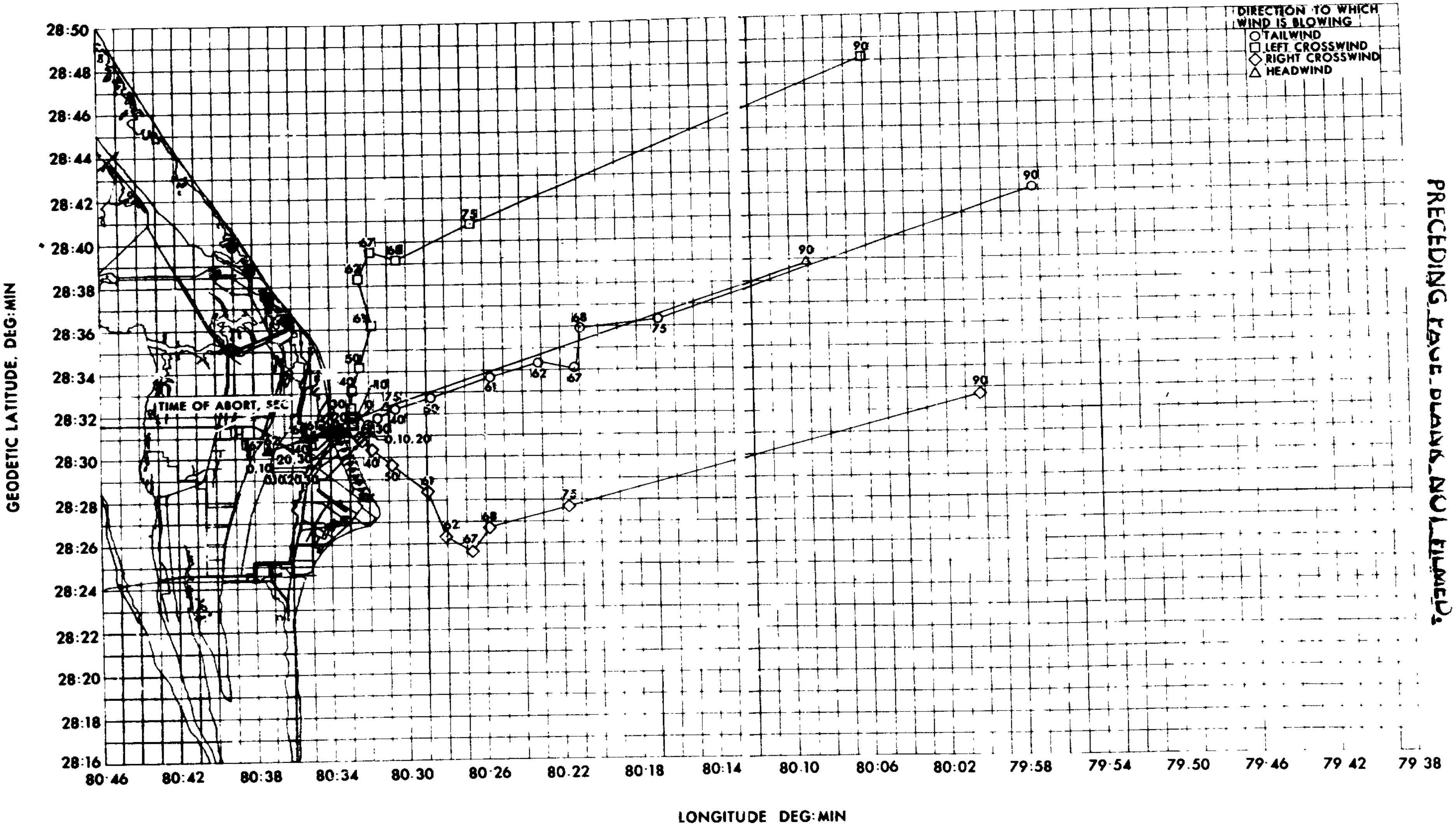
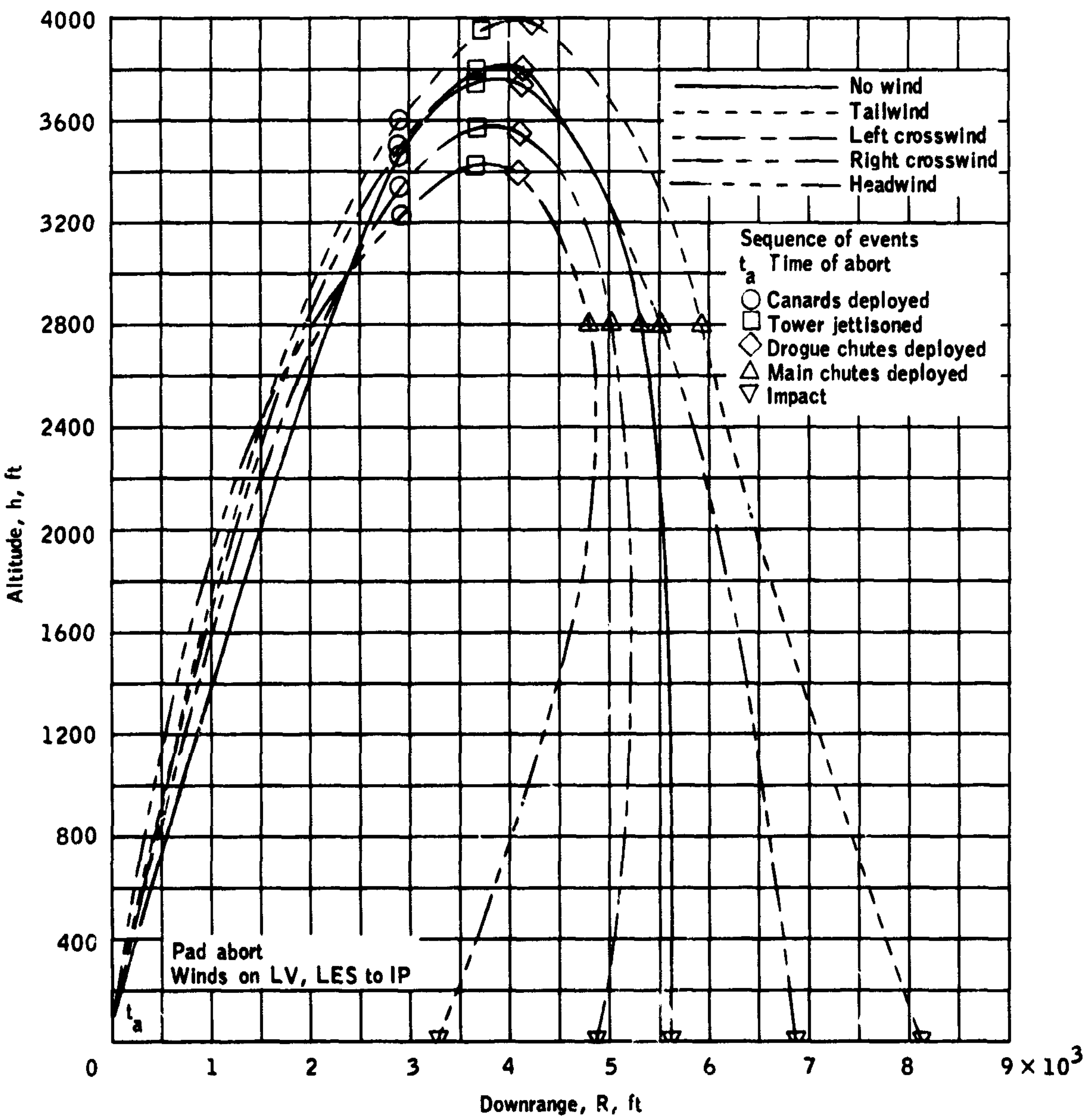
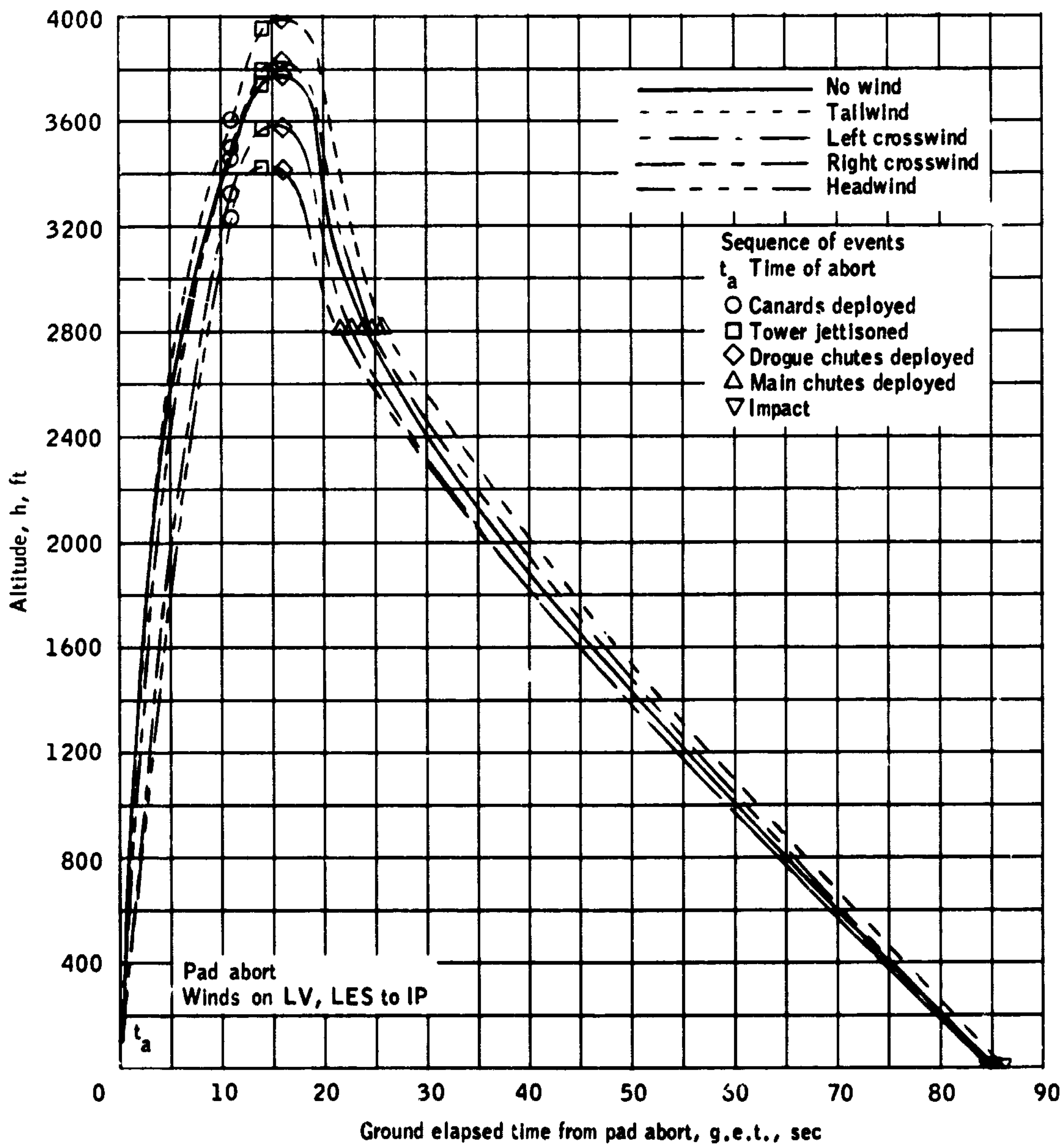


FIGURE 5 - COMMAND MODULE IMPACT POINTS FOR WINDS ON THE LV AND LES TO LANDING.



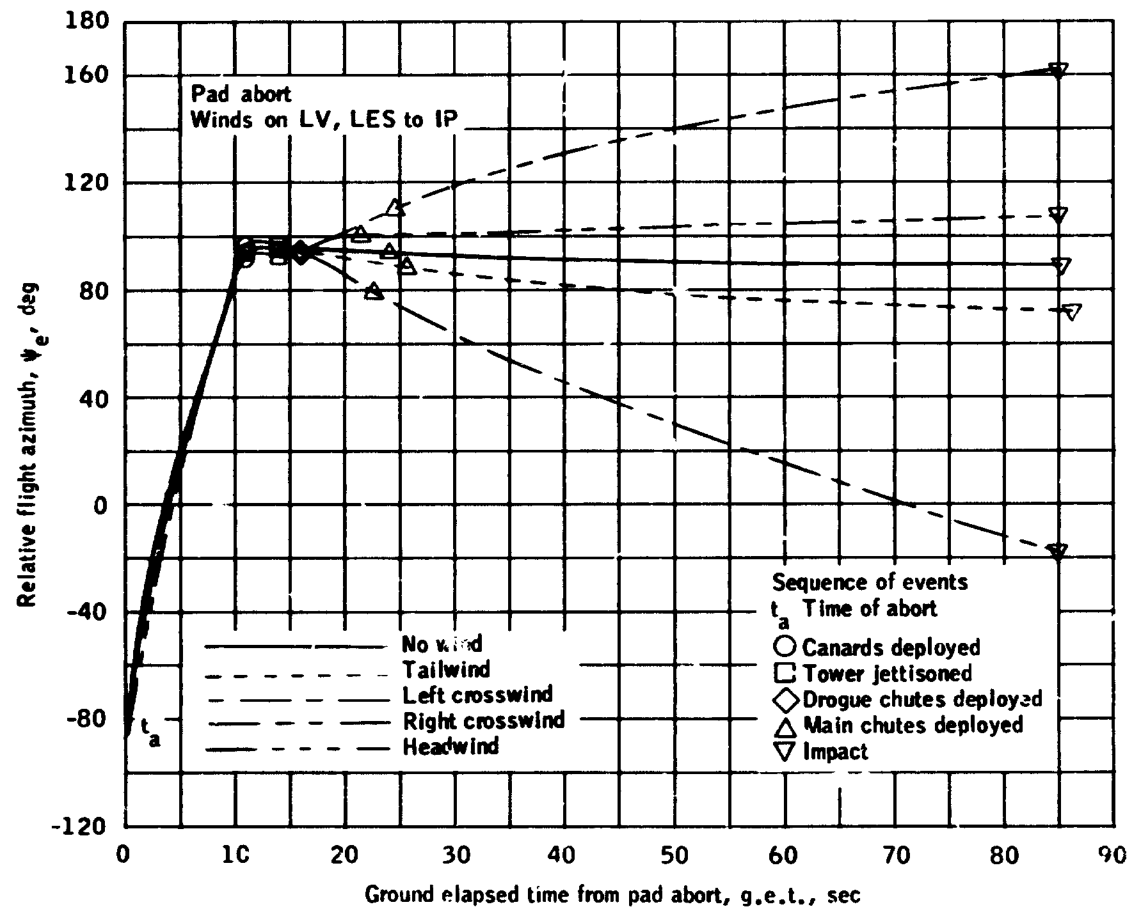
(a) Altitude versus downrange.

Figure 6.- Winds on the LV and LES to landing for a pad abort.



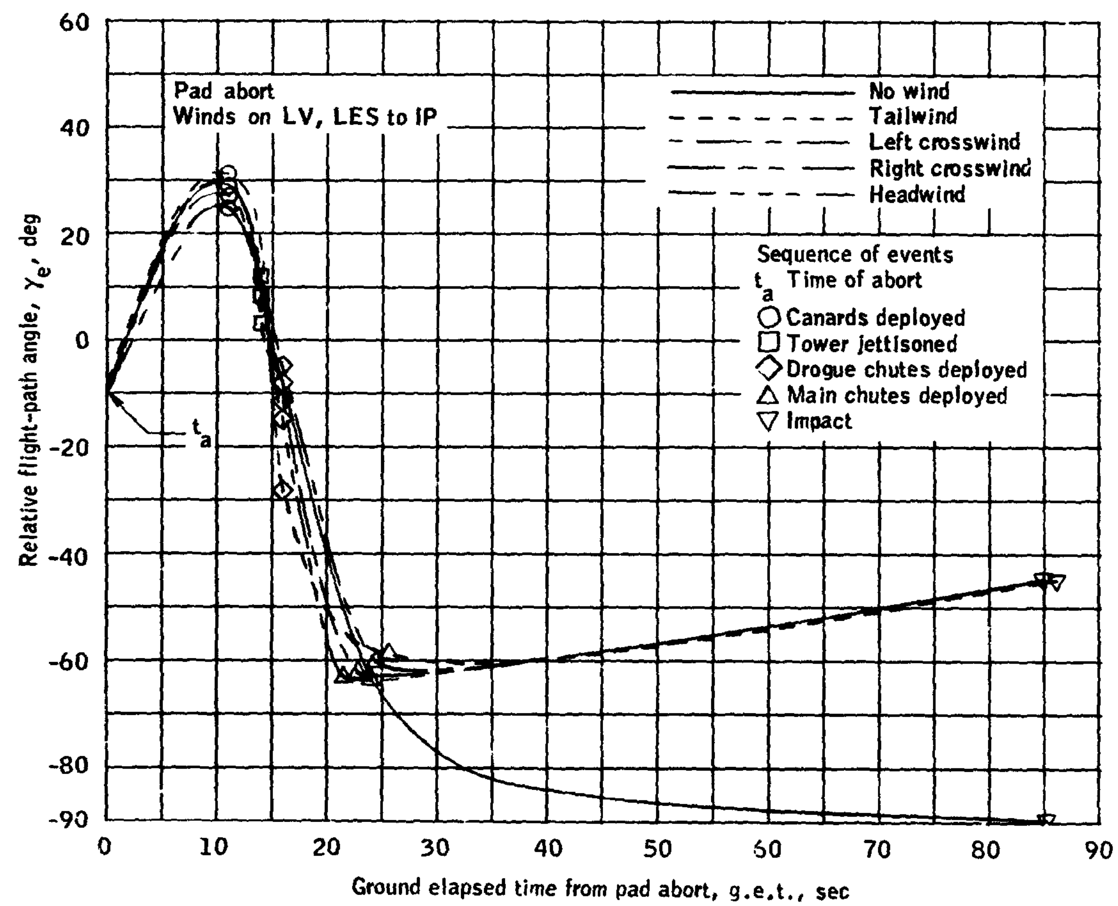
(b) Altitude versus time.

Figure 6.- Continued.



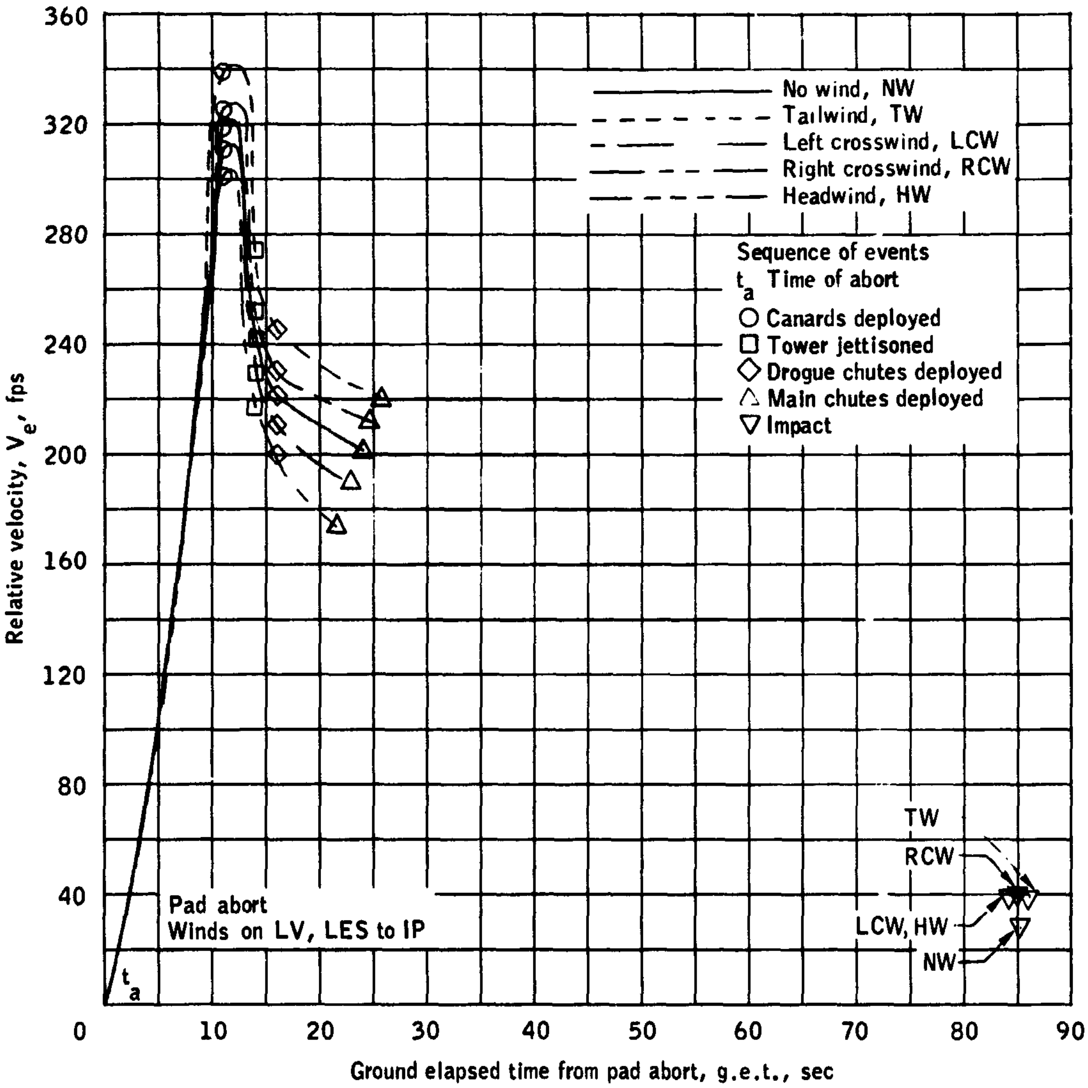
(c) Relative flight azimuth versus time.

Figure 6.- Continued.



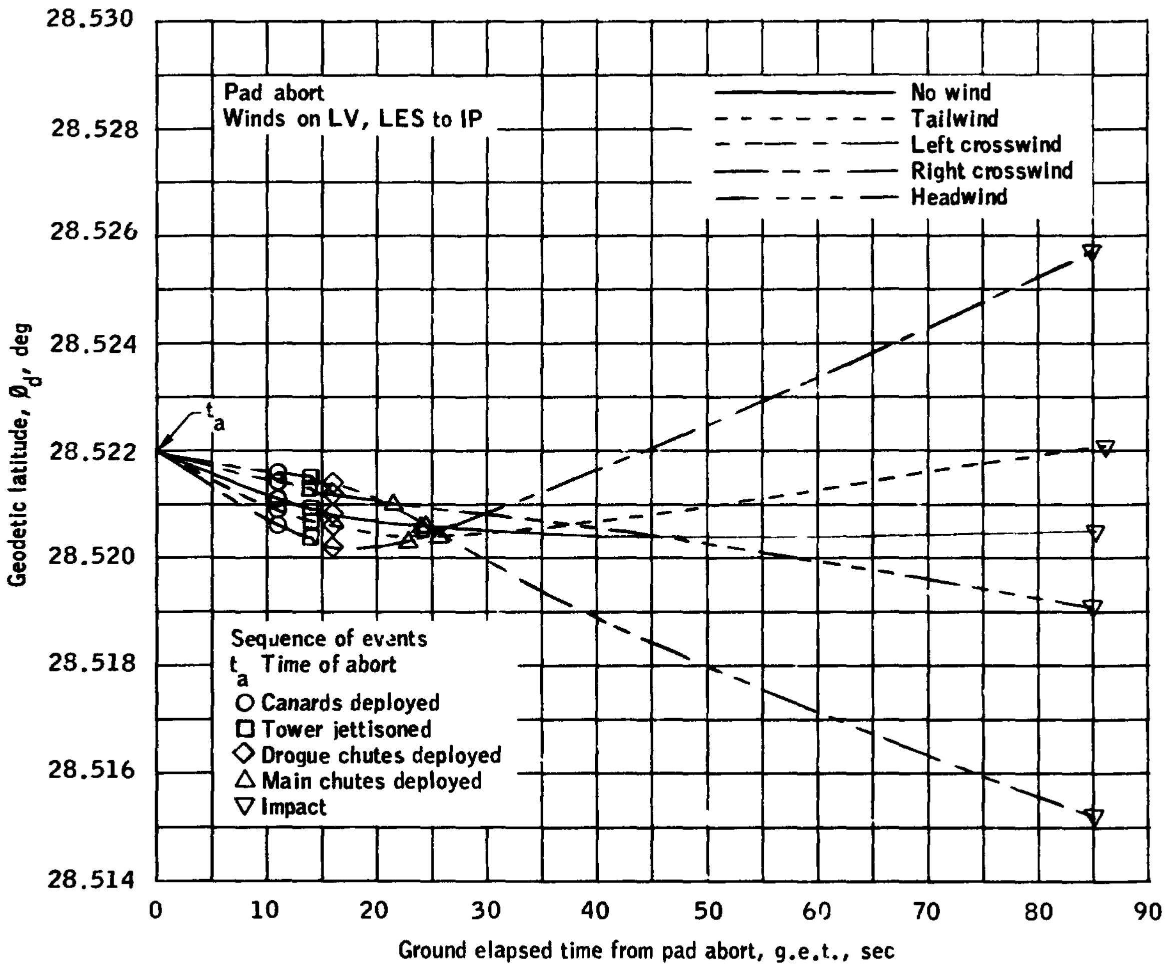
(d) Relative flight-path angle versus time.

Figure 6.- Continued.



(e) Relative velocity versus time.

Figure 6.- Continued.



(f) Geodetic latitude versus time.

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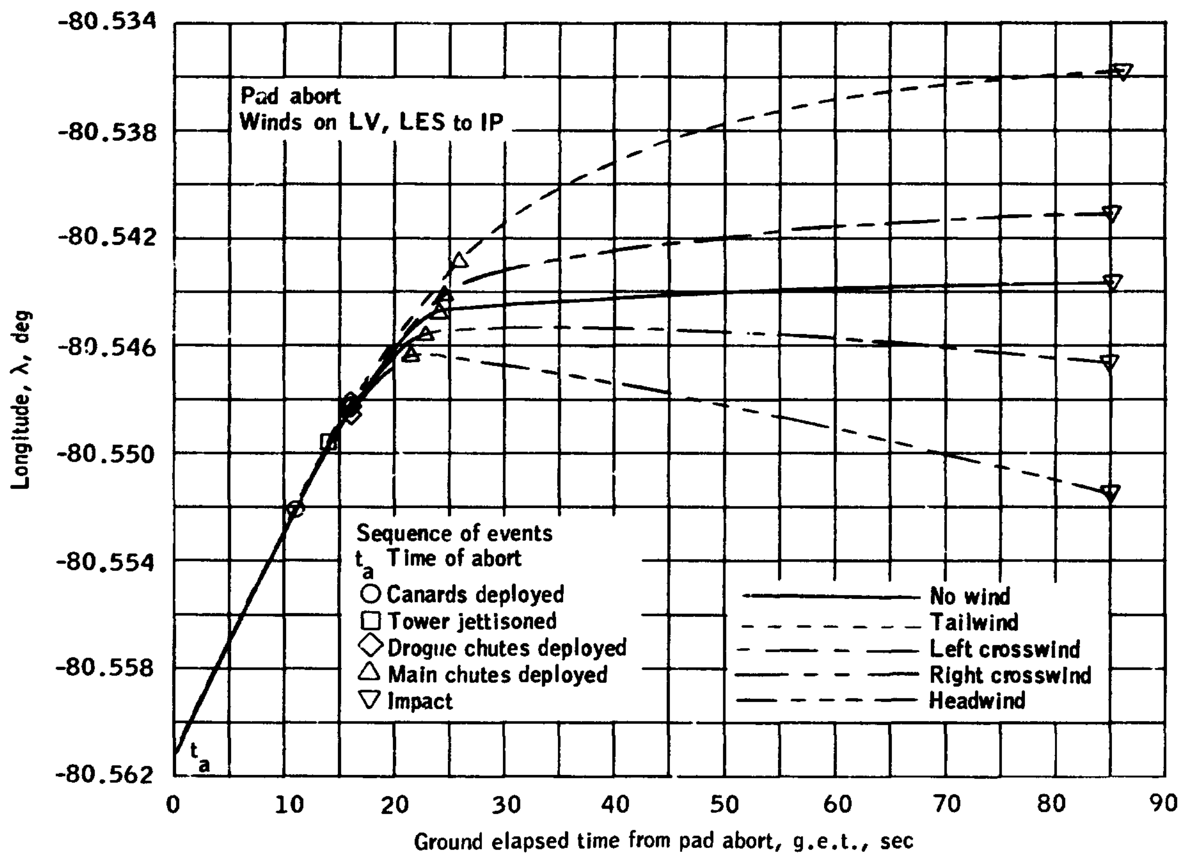

(g) Longitude versus time.

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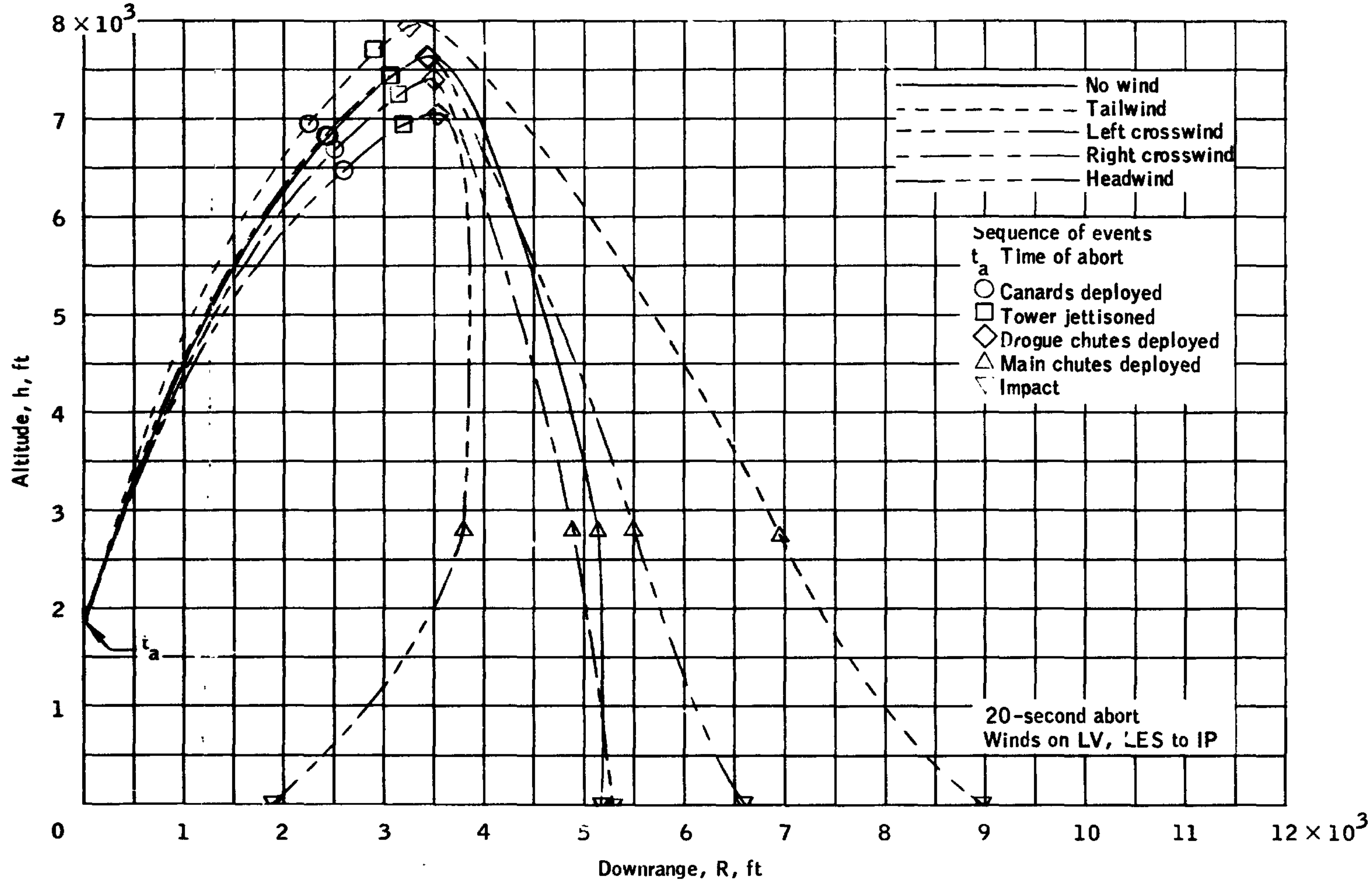
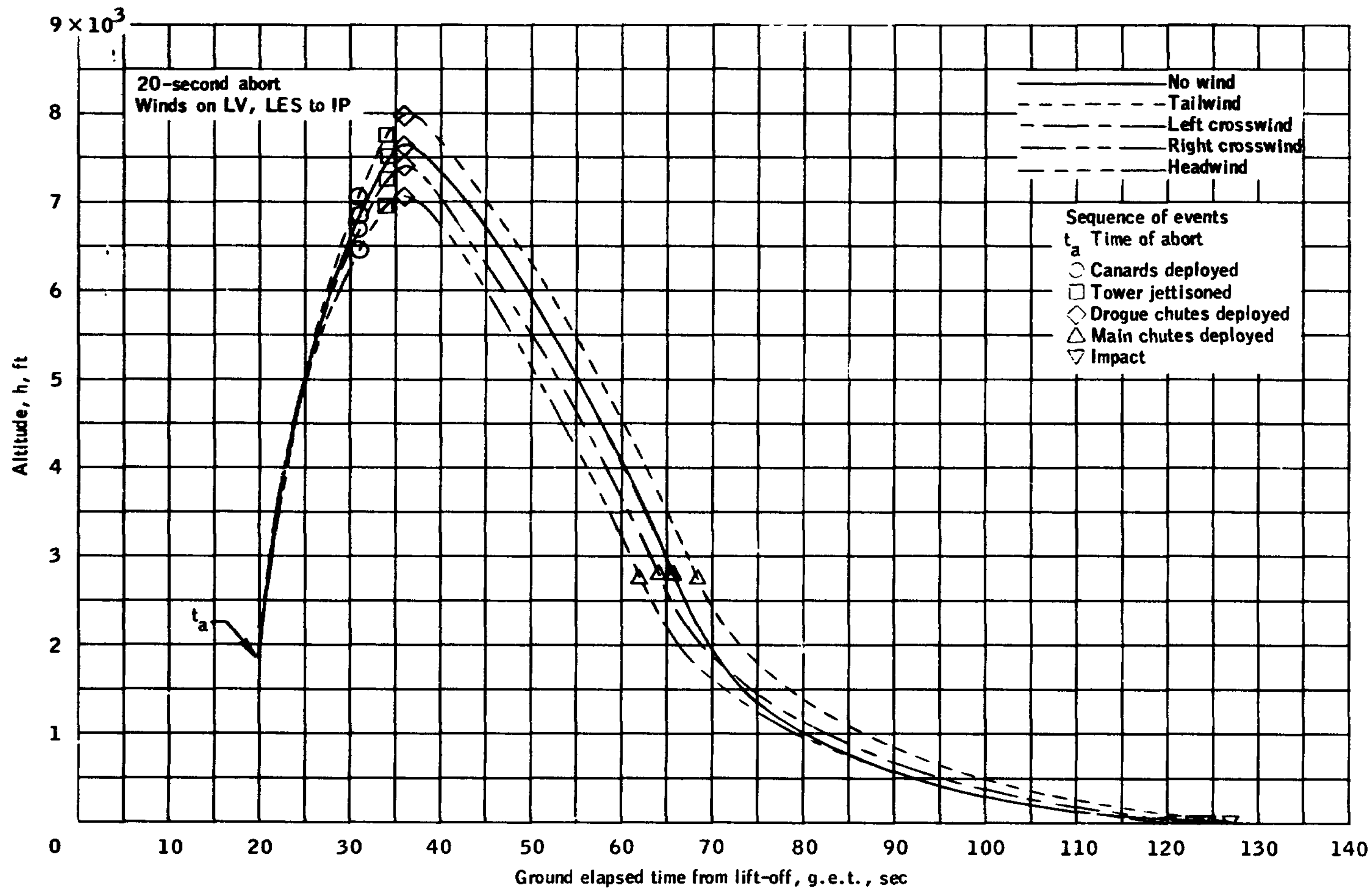


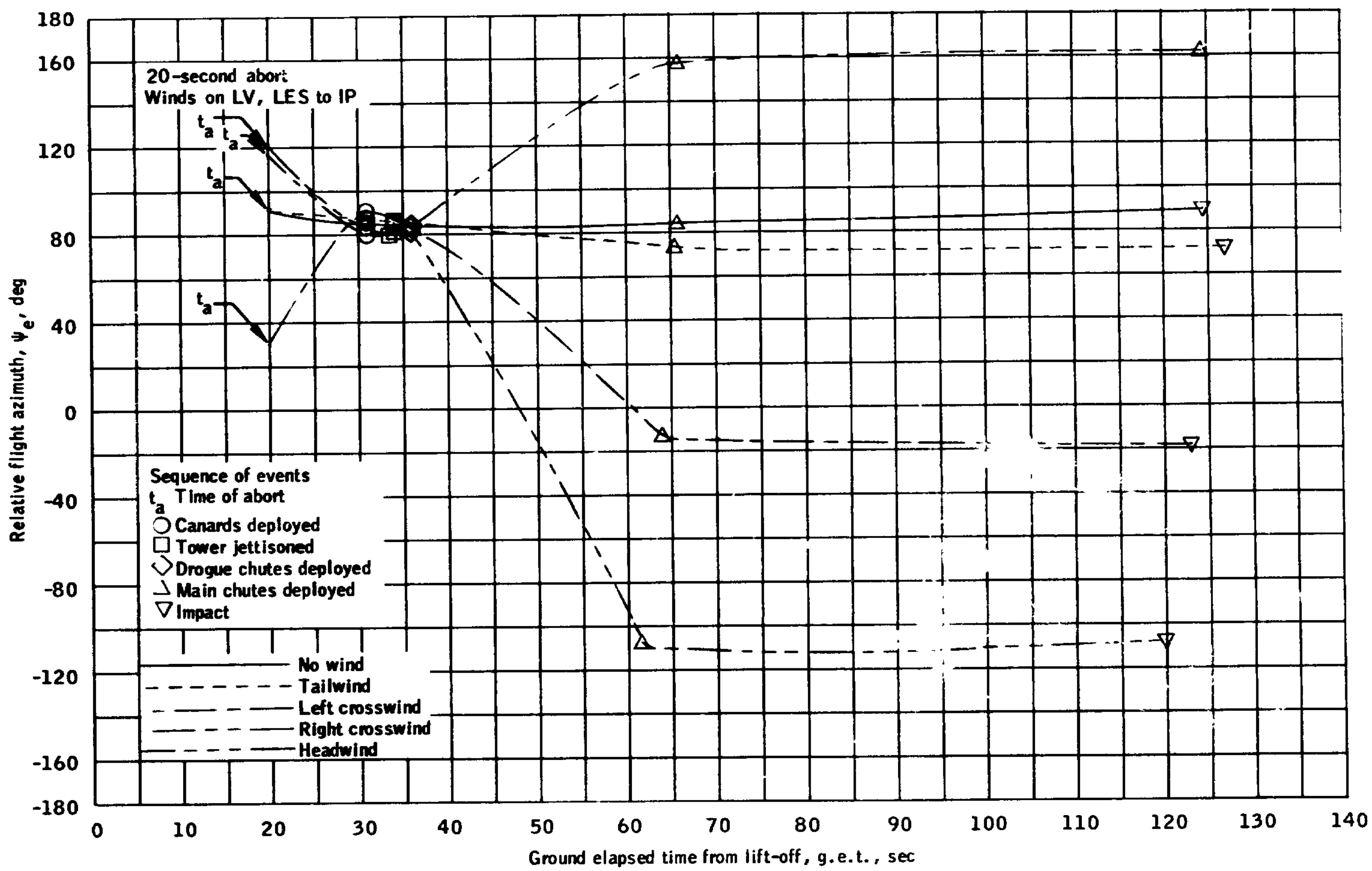
(a) Altitude versus downrange.

Figure 7.- Winds on the LV and LES to landing for a 20-second g.e.t. abort.



(b) Altitude versus time.

Figure 7.- Continued.



(c) Relative flight azimuth versus time.

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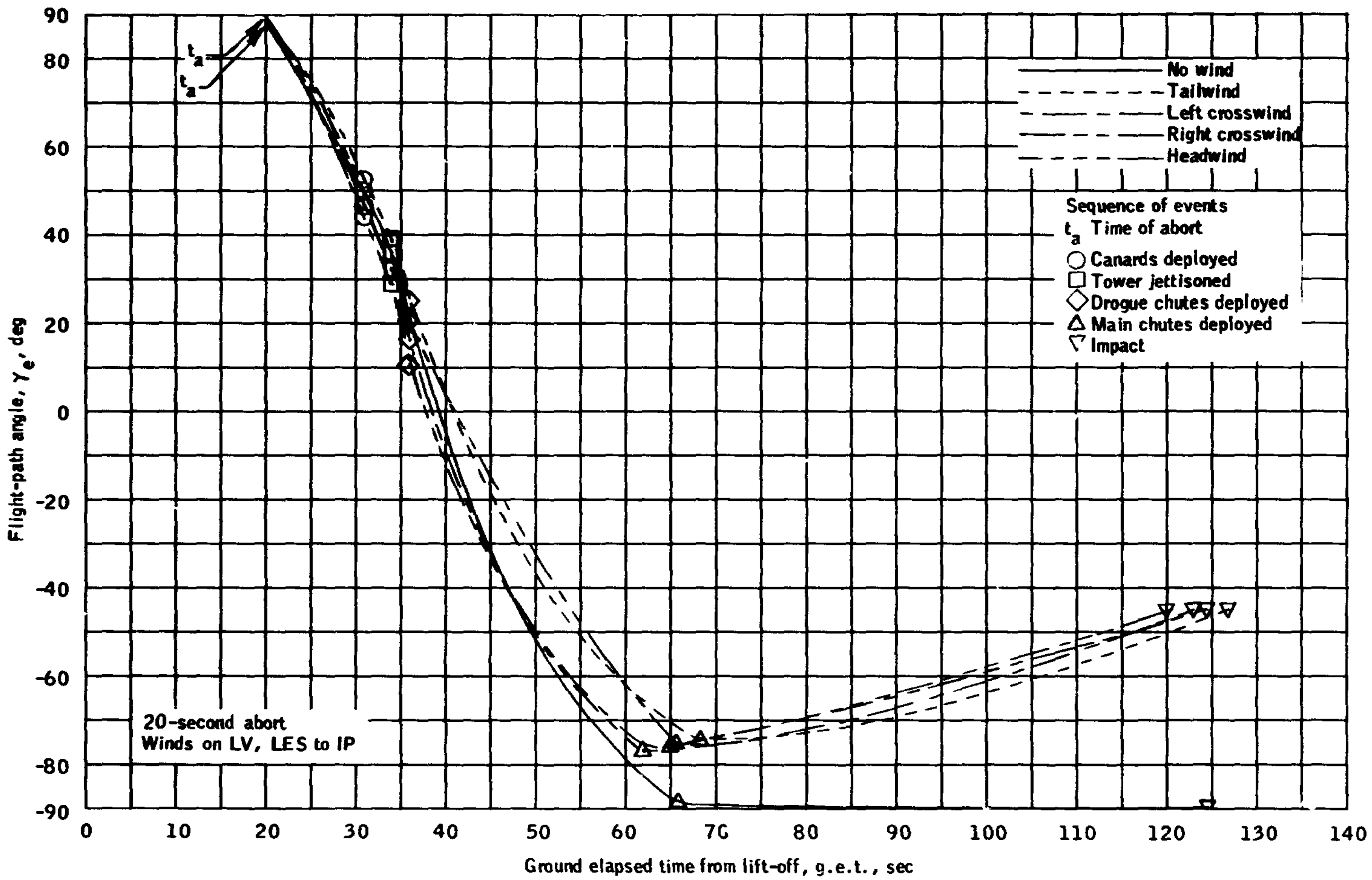
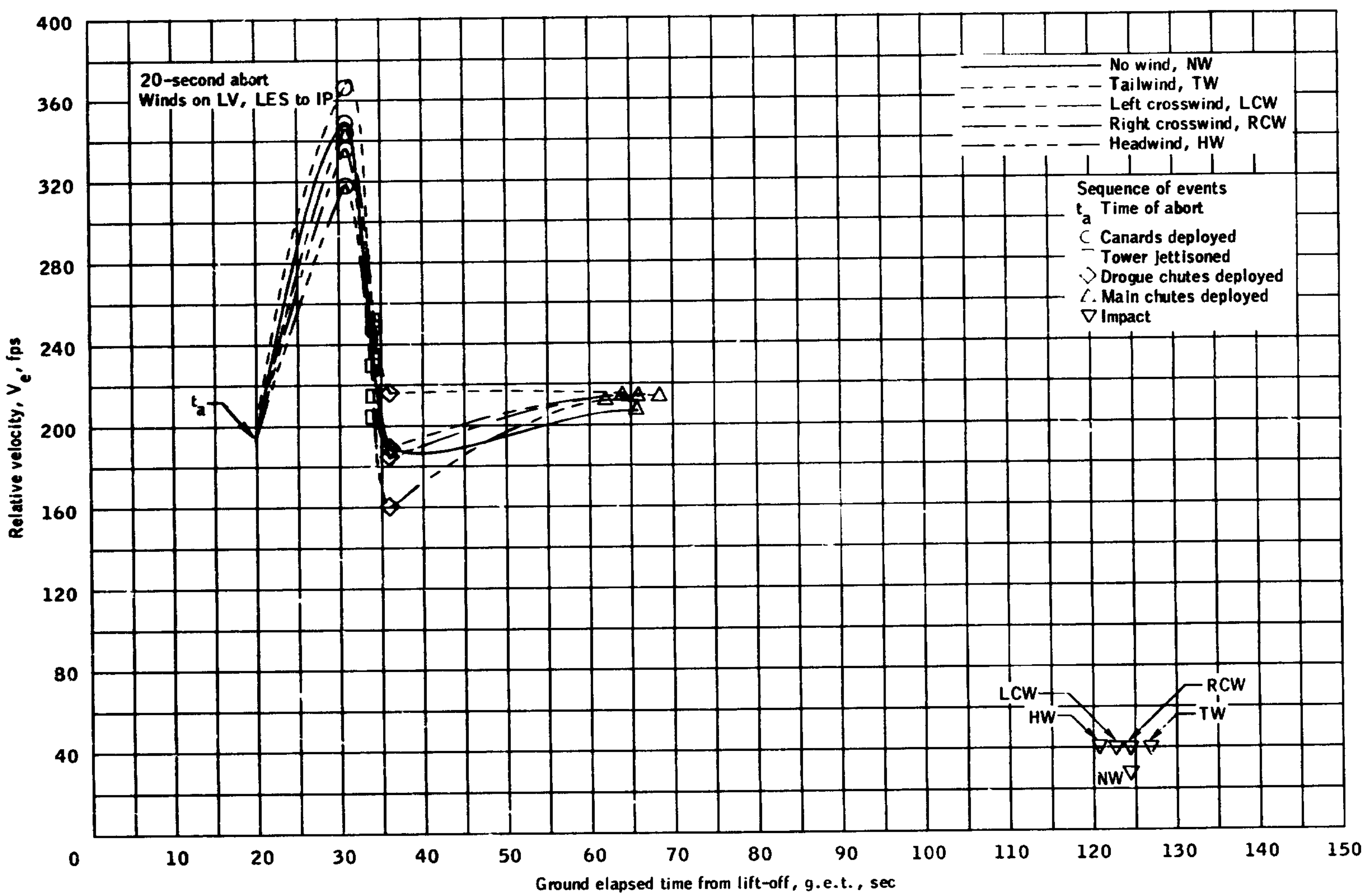


(d) Relative flight-path angle versus time.

Figure 7.- Continued.



(e) Relative velocity versus time.

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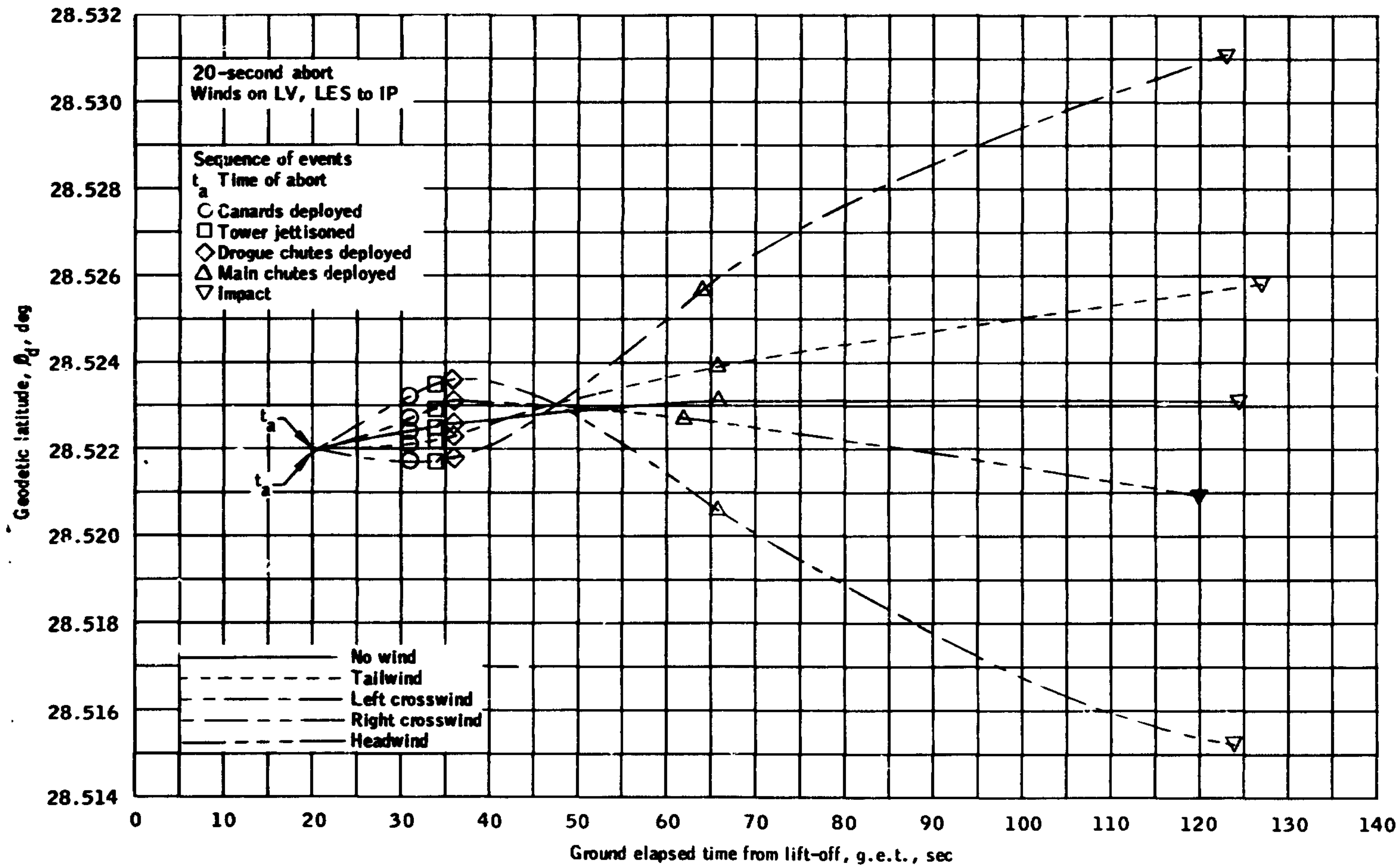
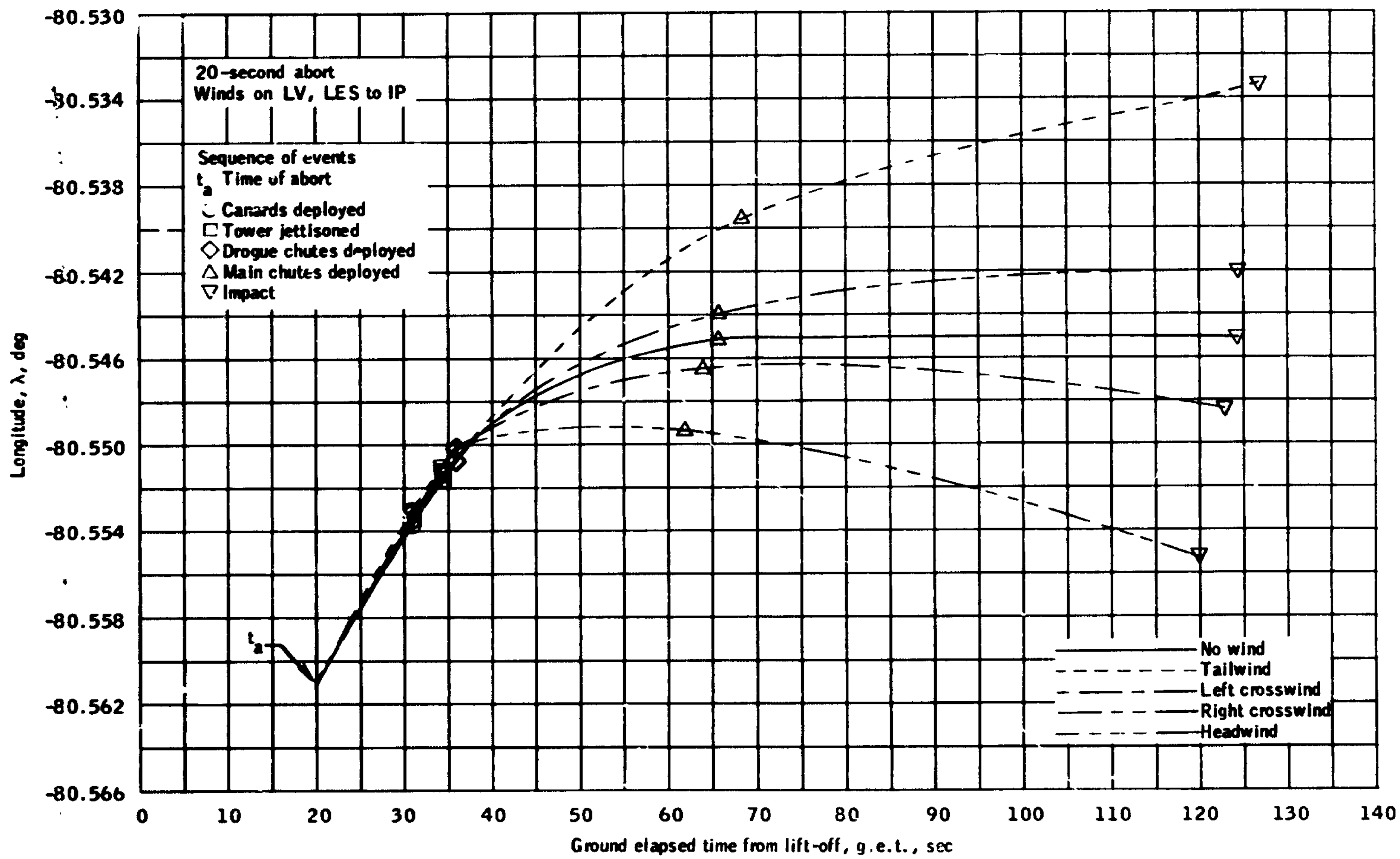


(f) Geodetic latitude versus time.

Figure 6.- Continued.



(g) Longitude versus time.

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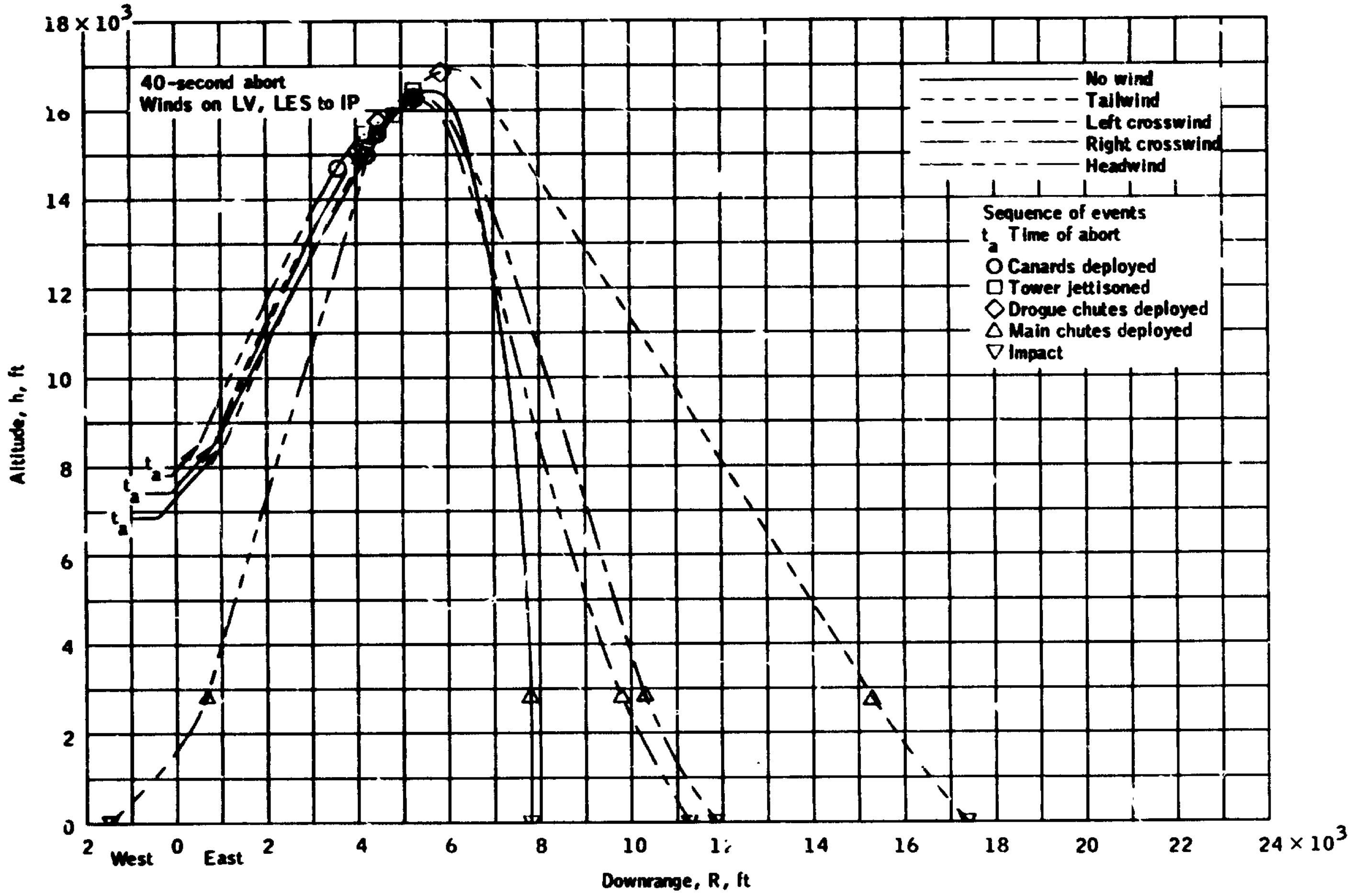
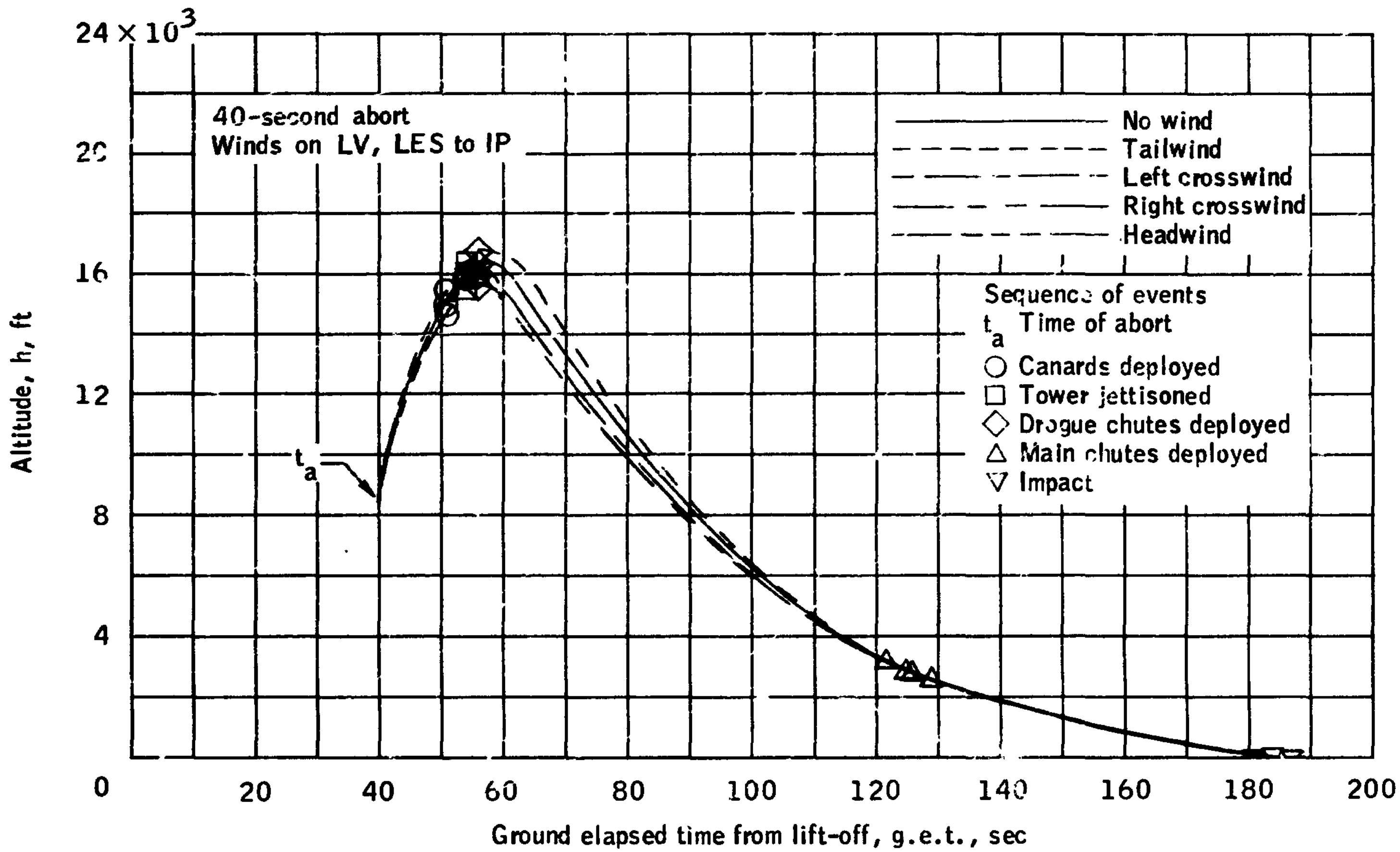


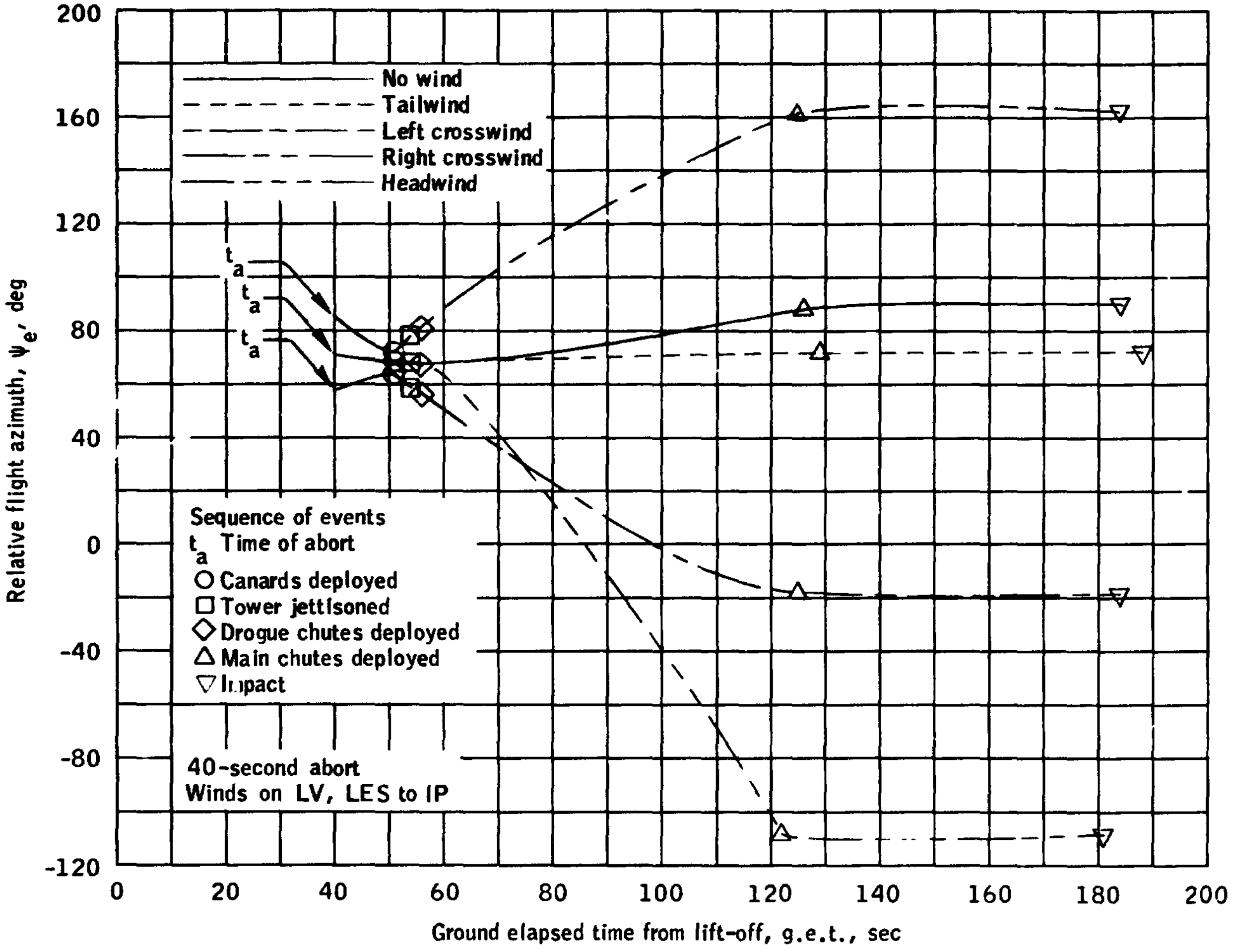
(a) Altitude versus downrange.

Figure 8.- Winds on the LV and LES to landing for a 40-second g.e.t. abort.



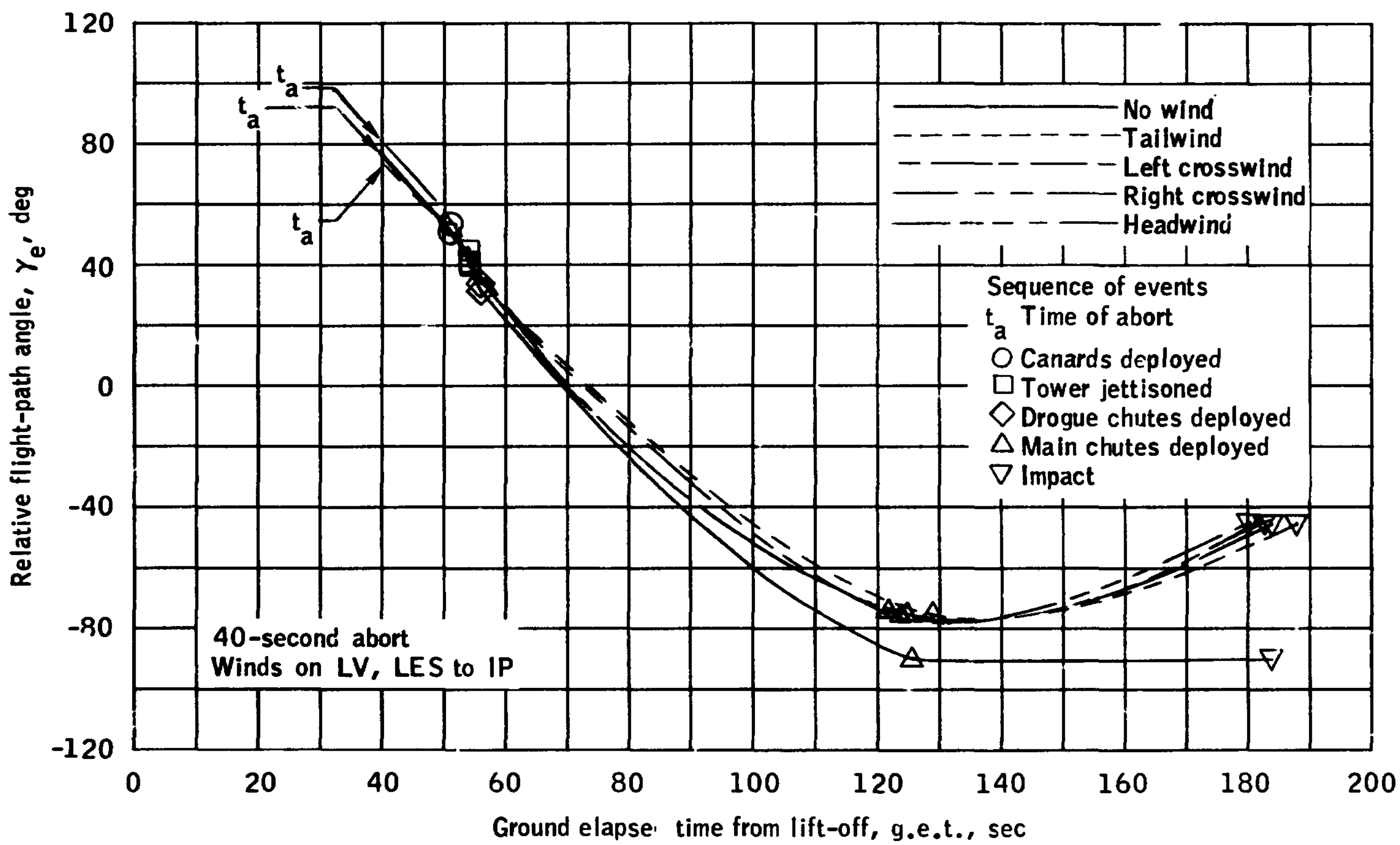
(b) Altitude versus time.

Figure 8.- Continued.



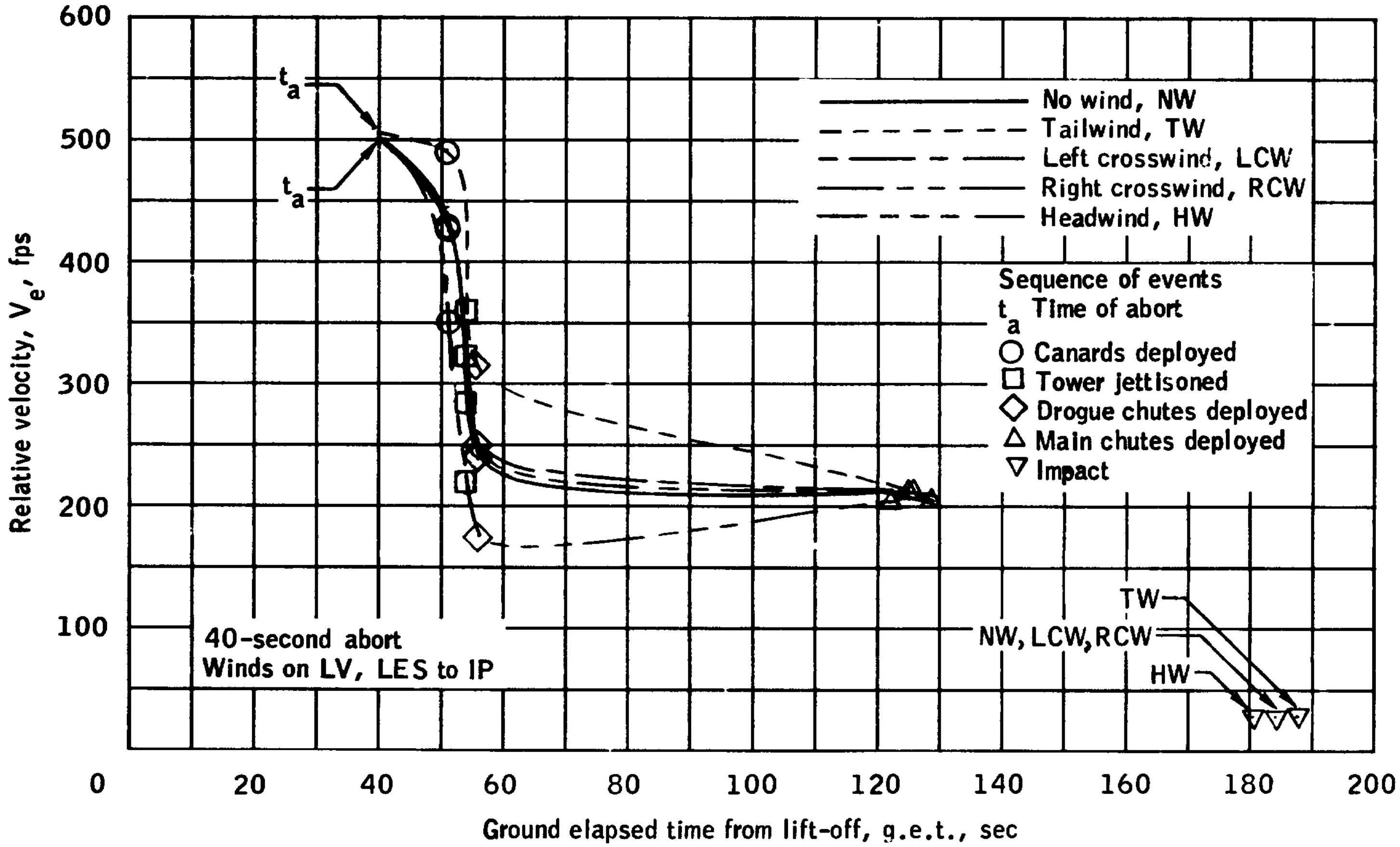
(c) Relative flight azimuth versus time.

Figure 8.- Continued.



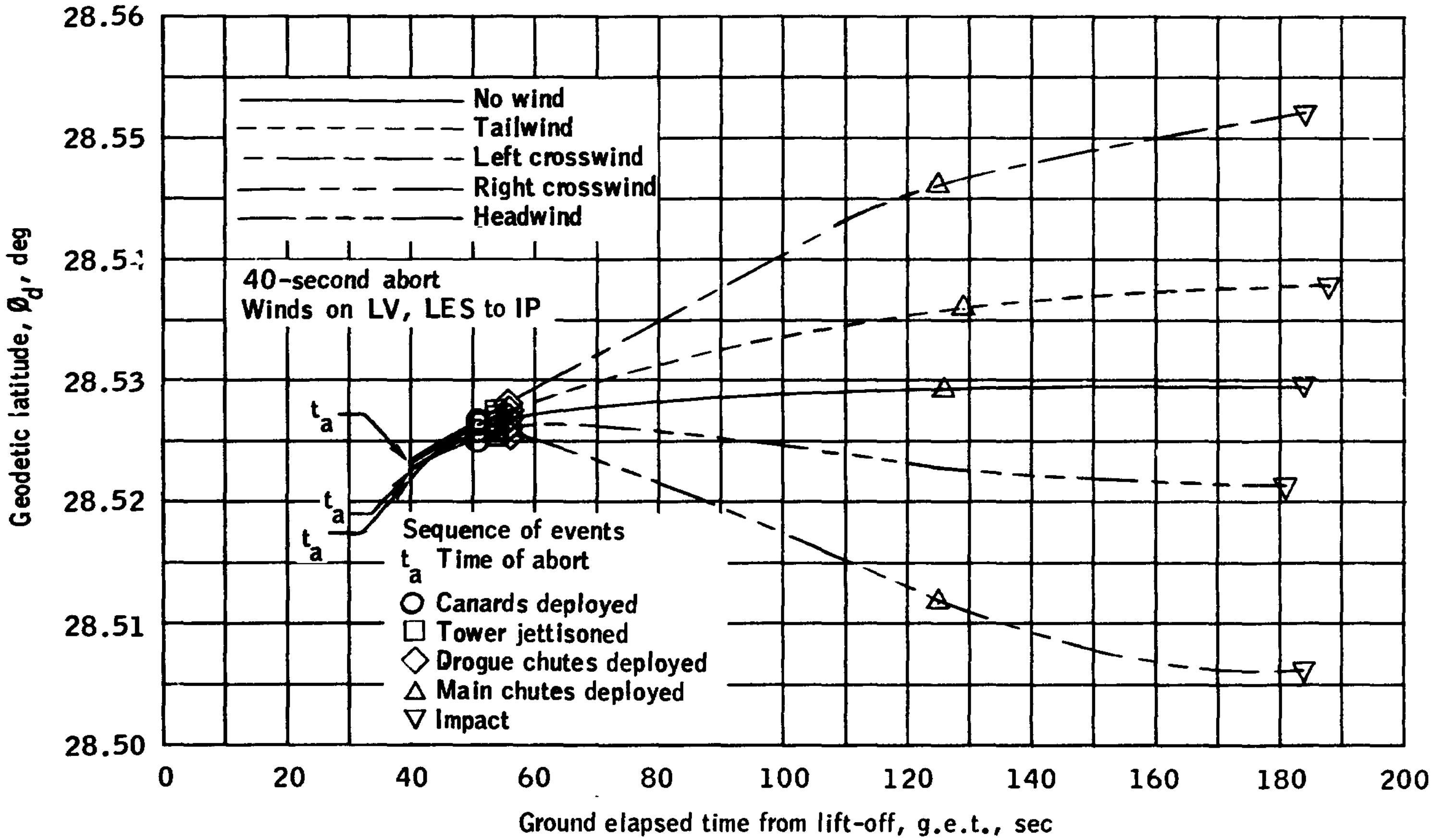
(d) Relative flight-path angle versus time.

Figure 8.- Continued.



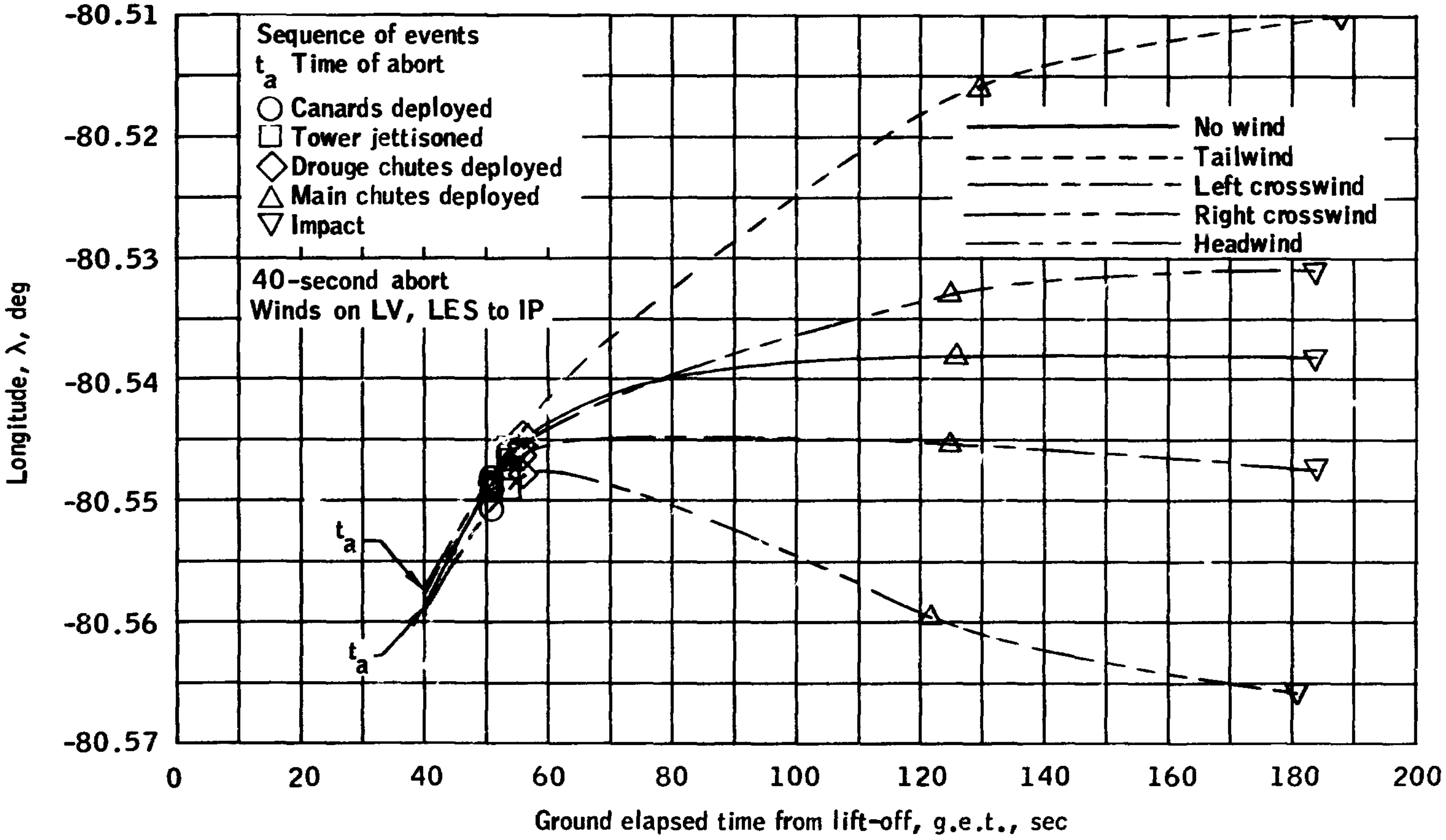
(e) Relative velocity versus time.

Figure 8.- Continued.



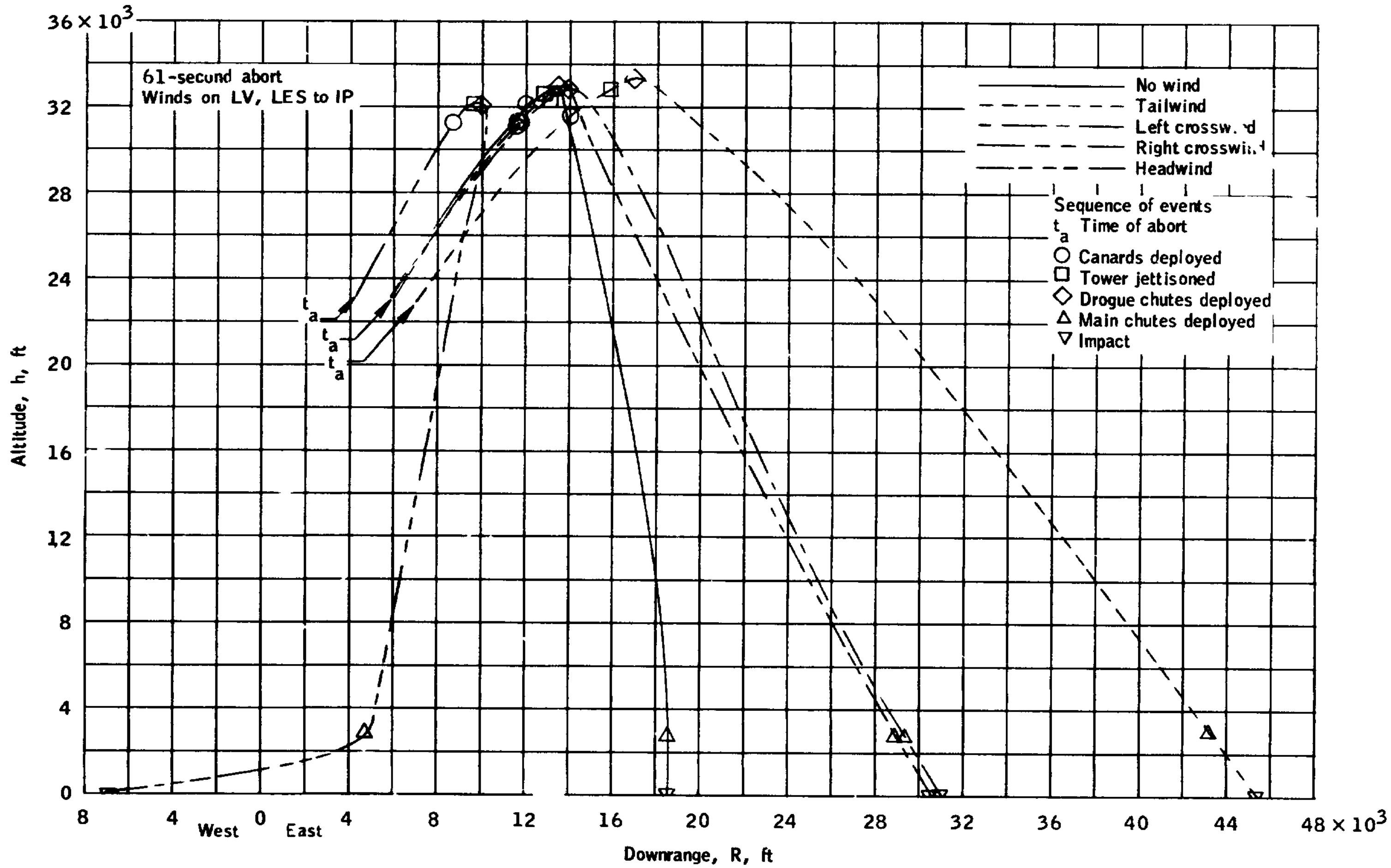
(f) Geodetic latitude versus time.

Figure 8.- Continued.



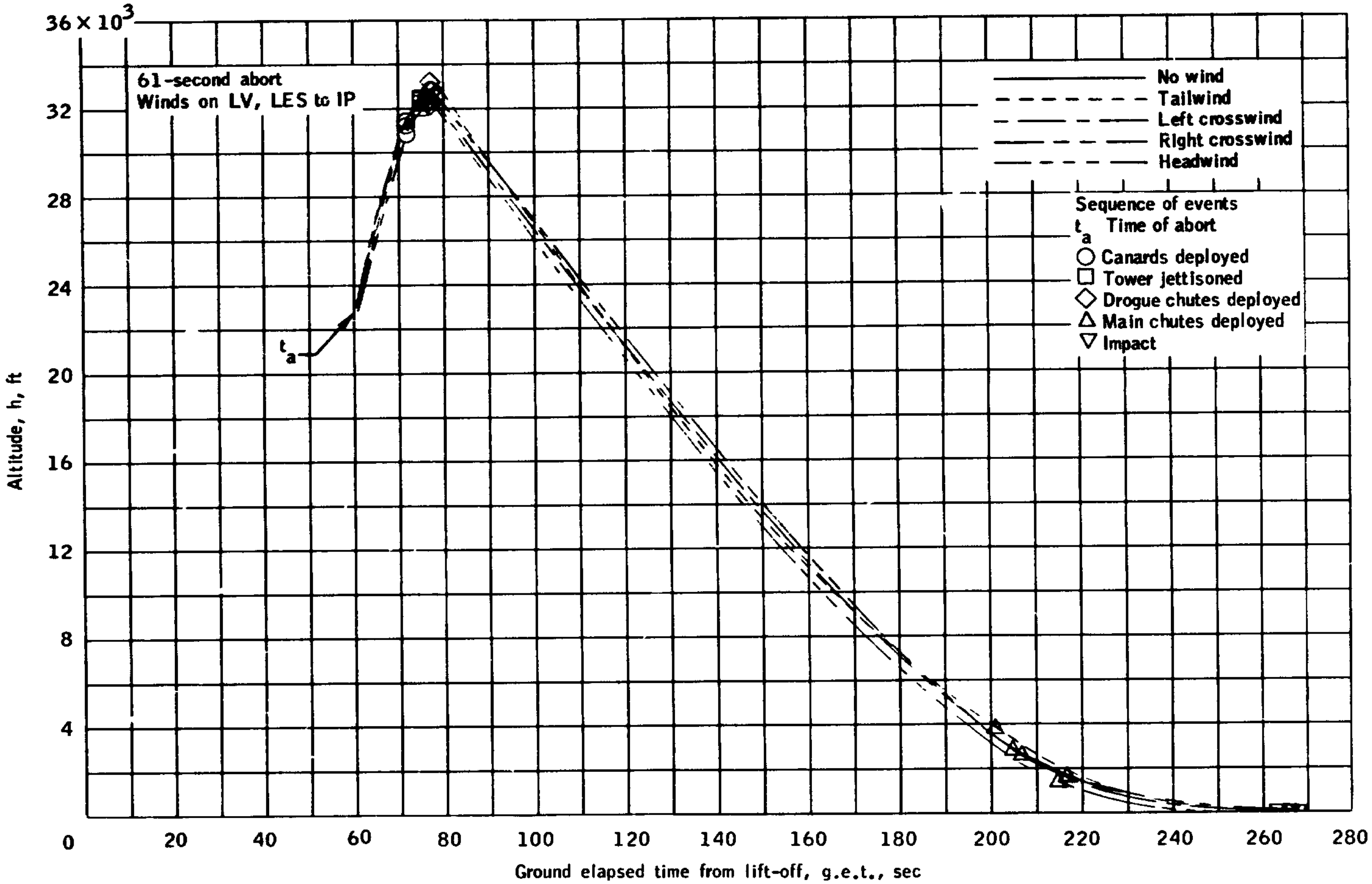
(g) Longitude versus time.

Figure 8.- Concluded.



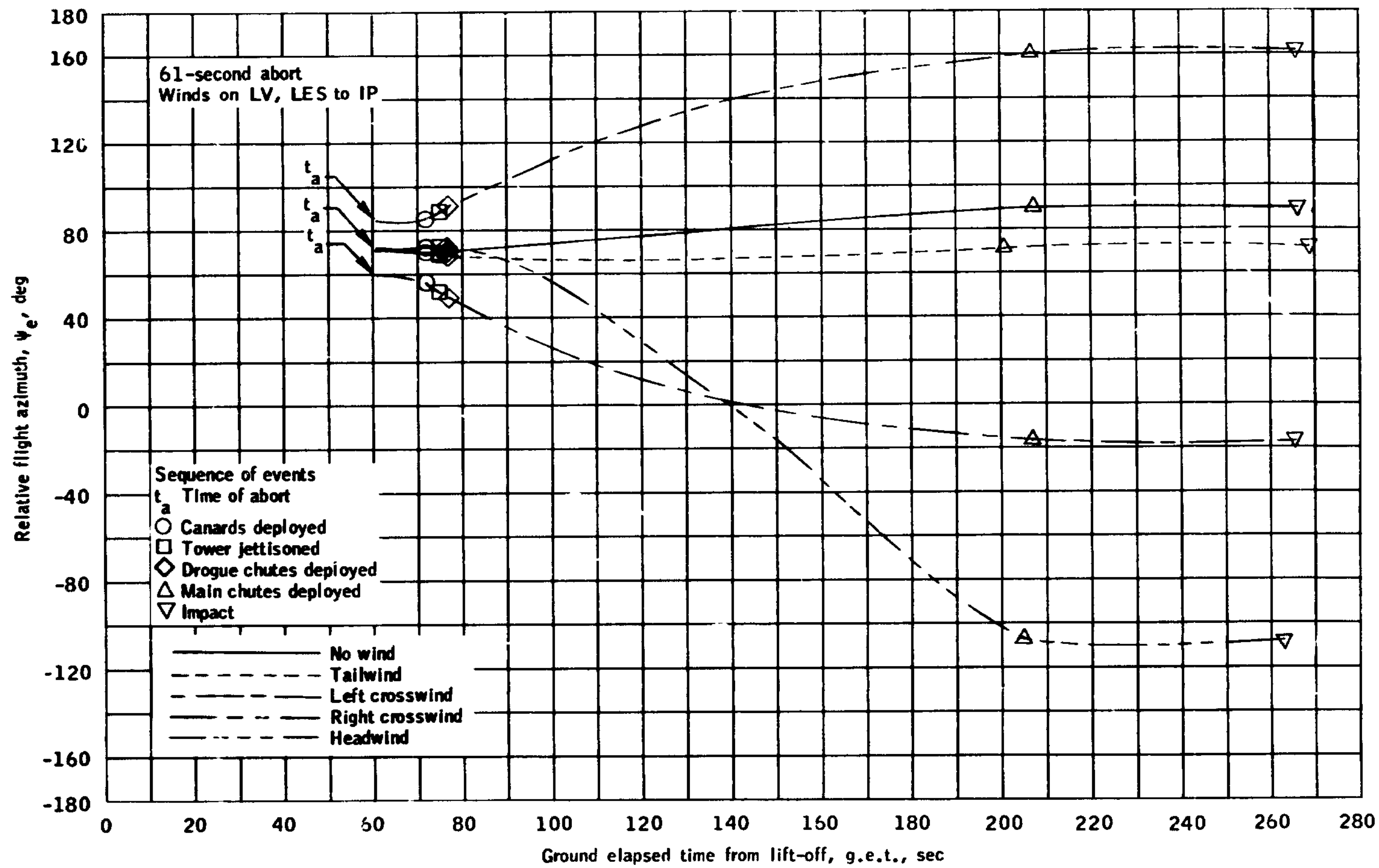
(a) Altitude versus downrange.

Figure 9.- Winds on the LV and LES to landing for a 61-second g.e.t. abort.



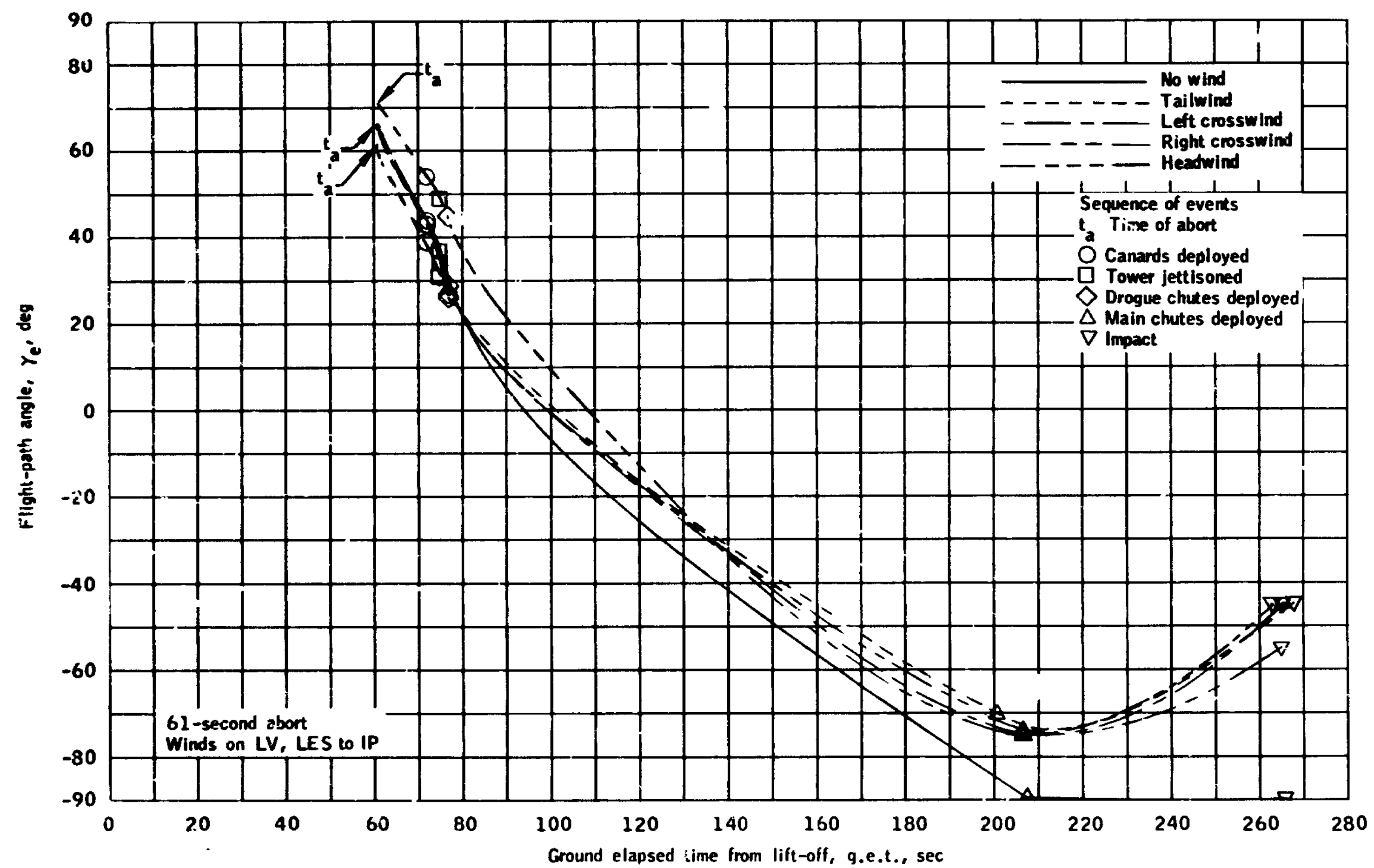
(b) Altitude versus time.

Figure 9.- Continued.



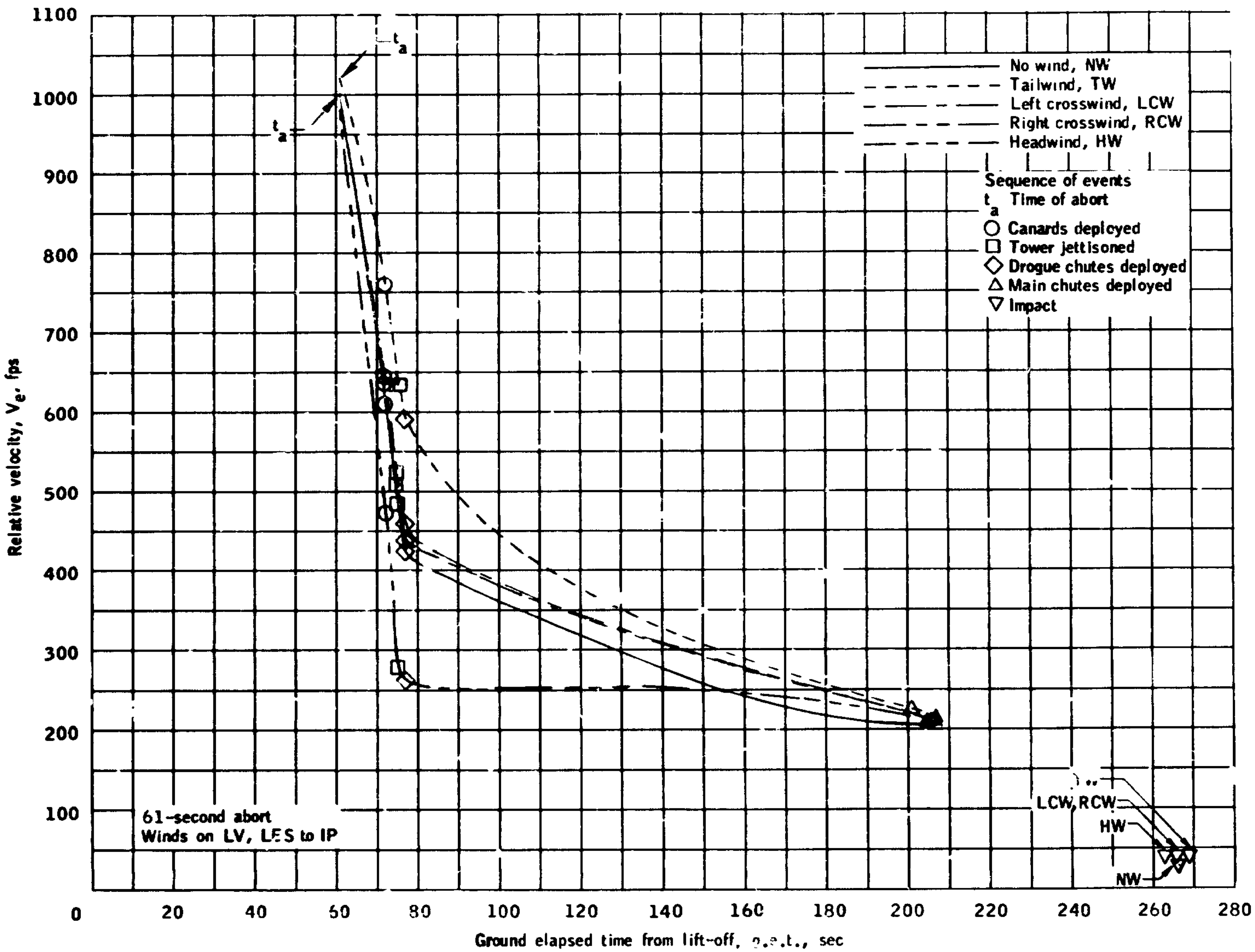
(c) Relative flight azimuth versus time.

Figure 9.- Continued.



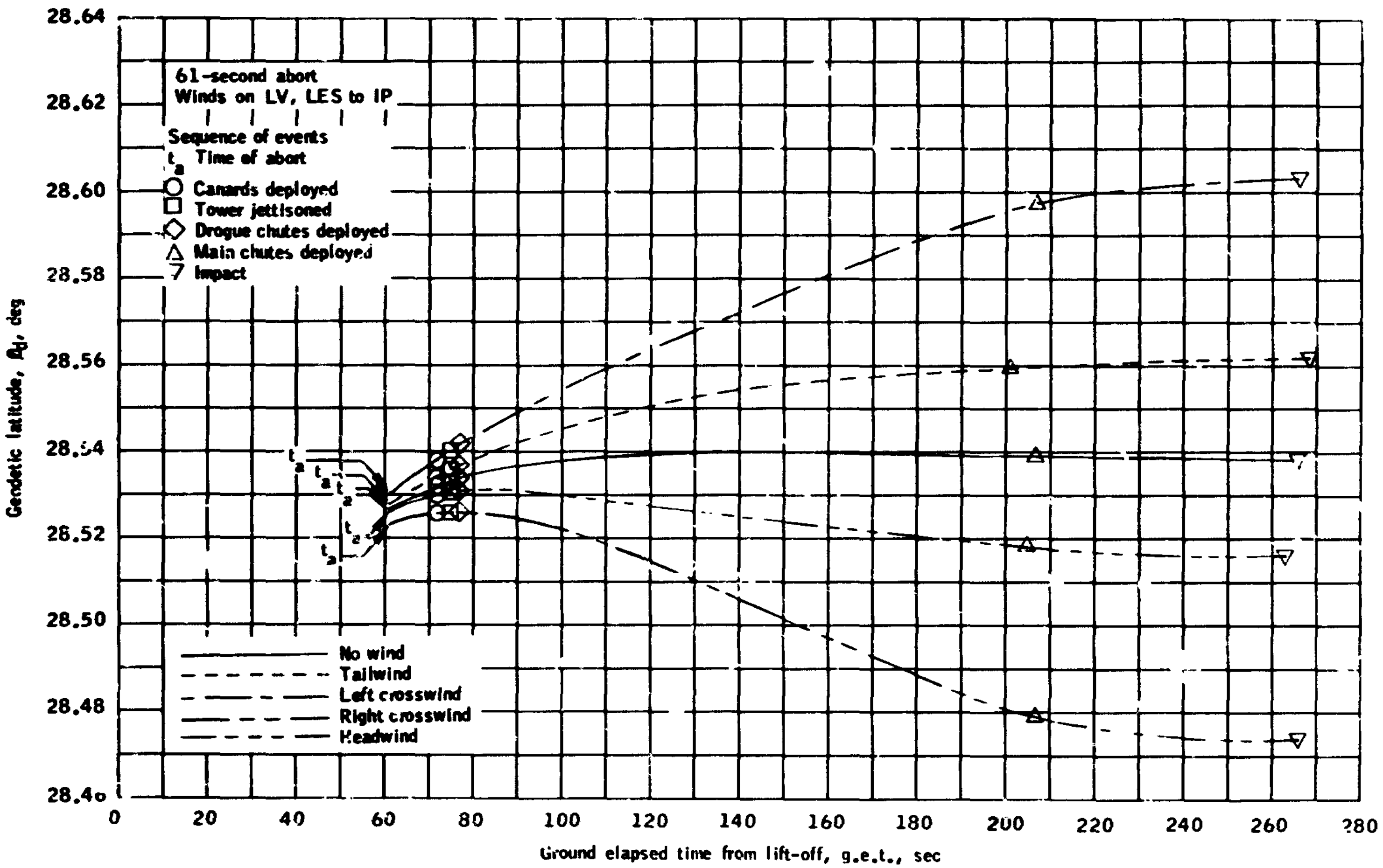
(d) Relative flight-path angle versus time.

Figure 9.- Continued.



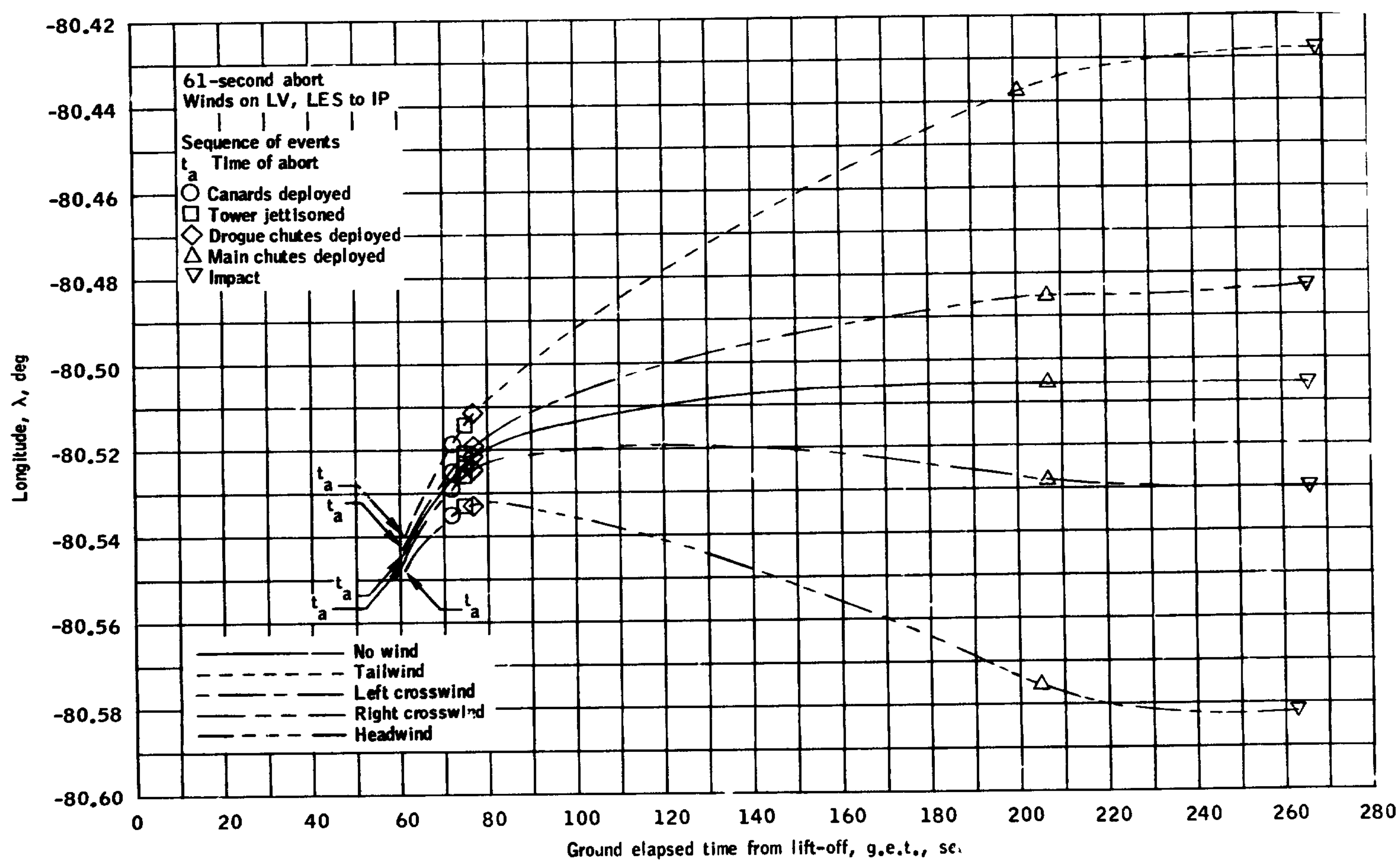
(e) Relative velocity versus time.

Figure 9.- Continued.



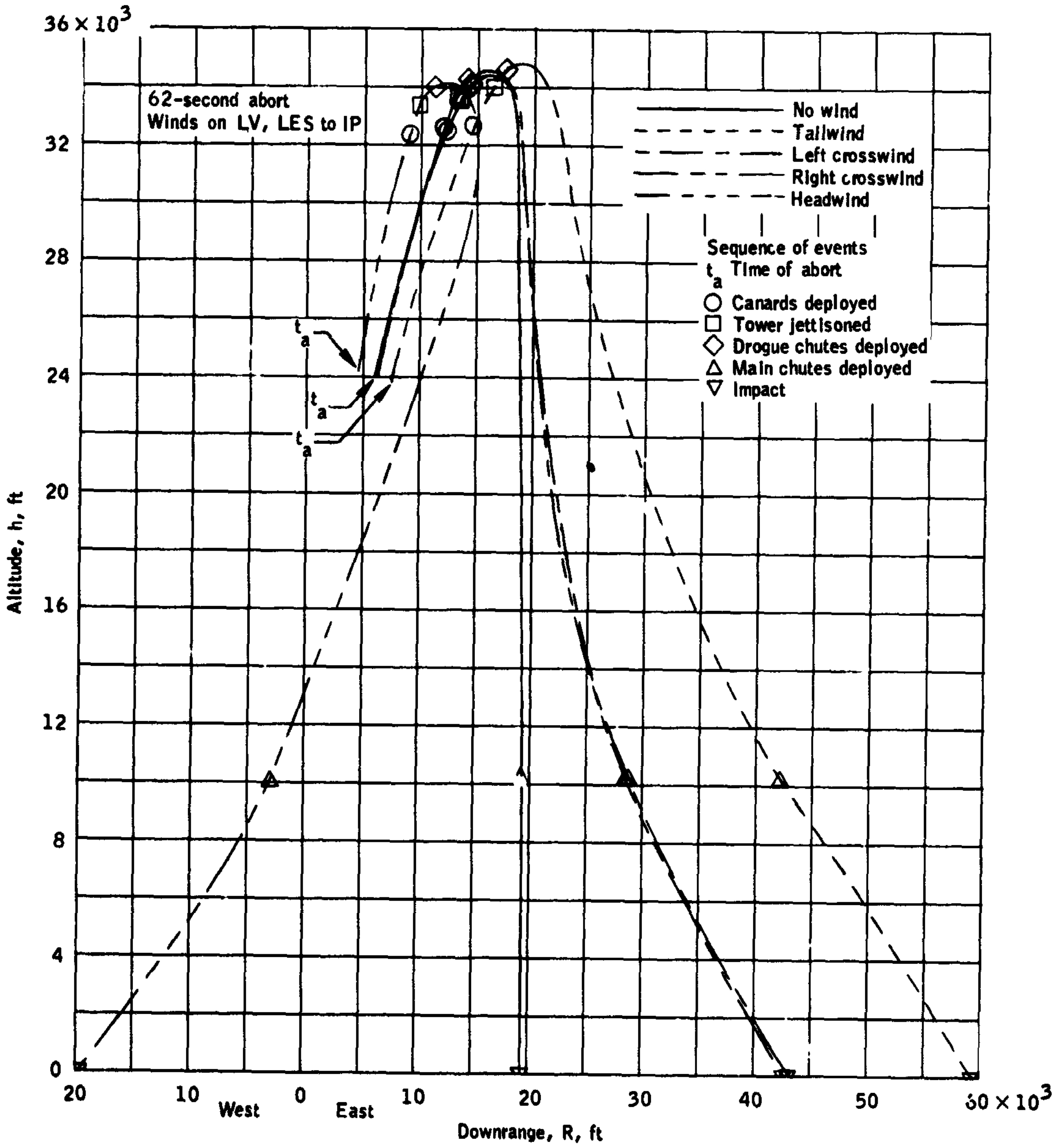
(f) Geodetic latitude versus time.

Figure 9.- Continued.



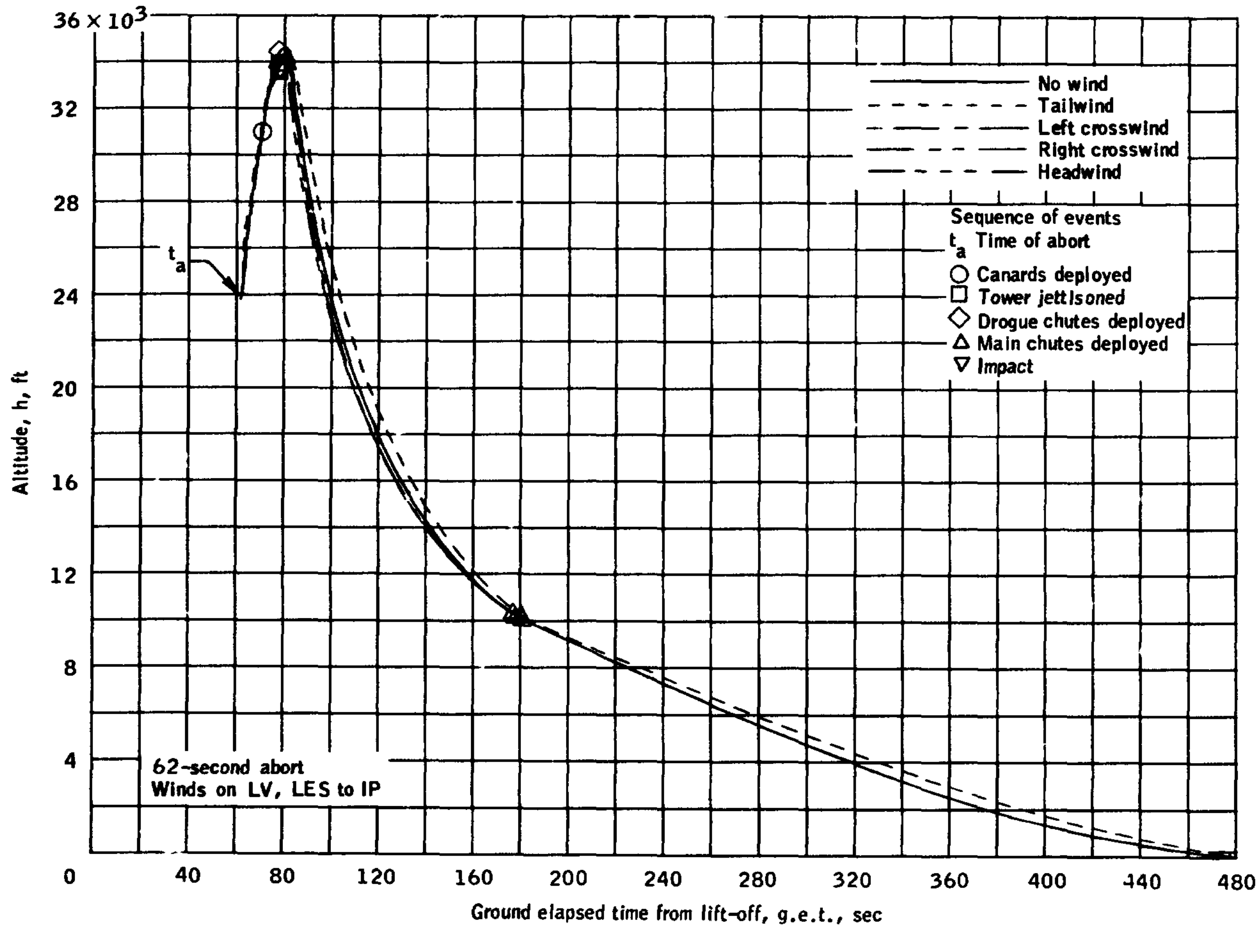
(g) Longitude versus time.

Figure 9.- Concluded.



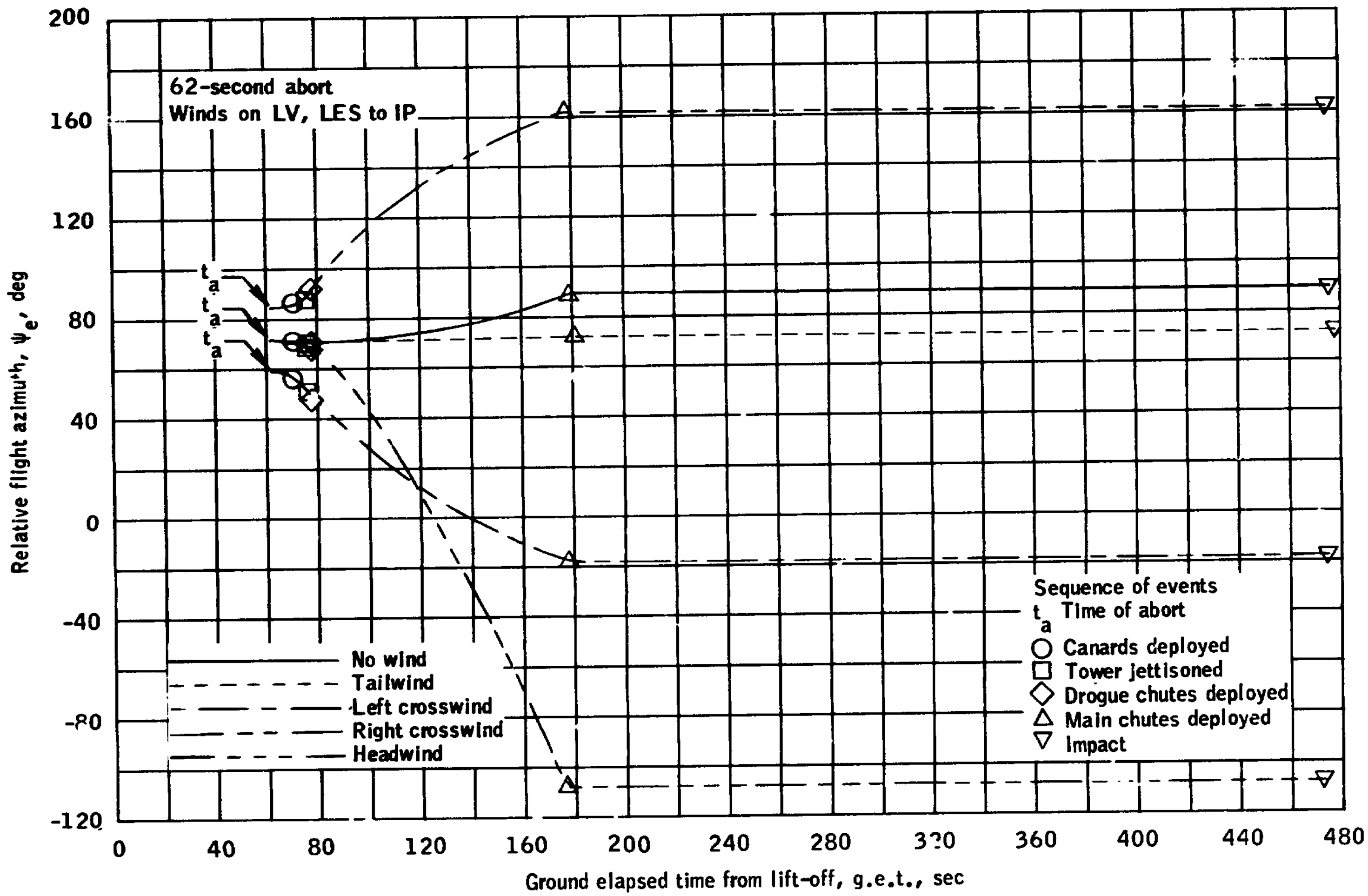
(a) Altitude versus downrange.

Figure 10.- Winds on the LV and LES to landing for a 62-second g.e.t. abort.



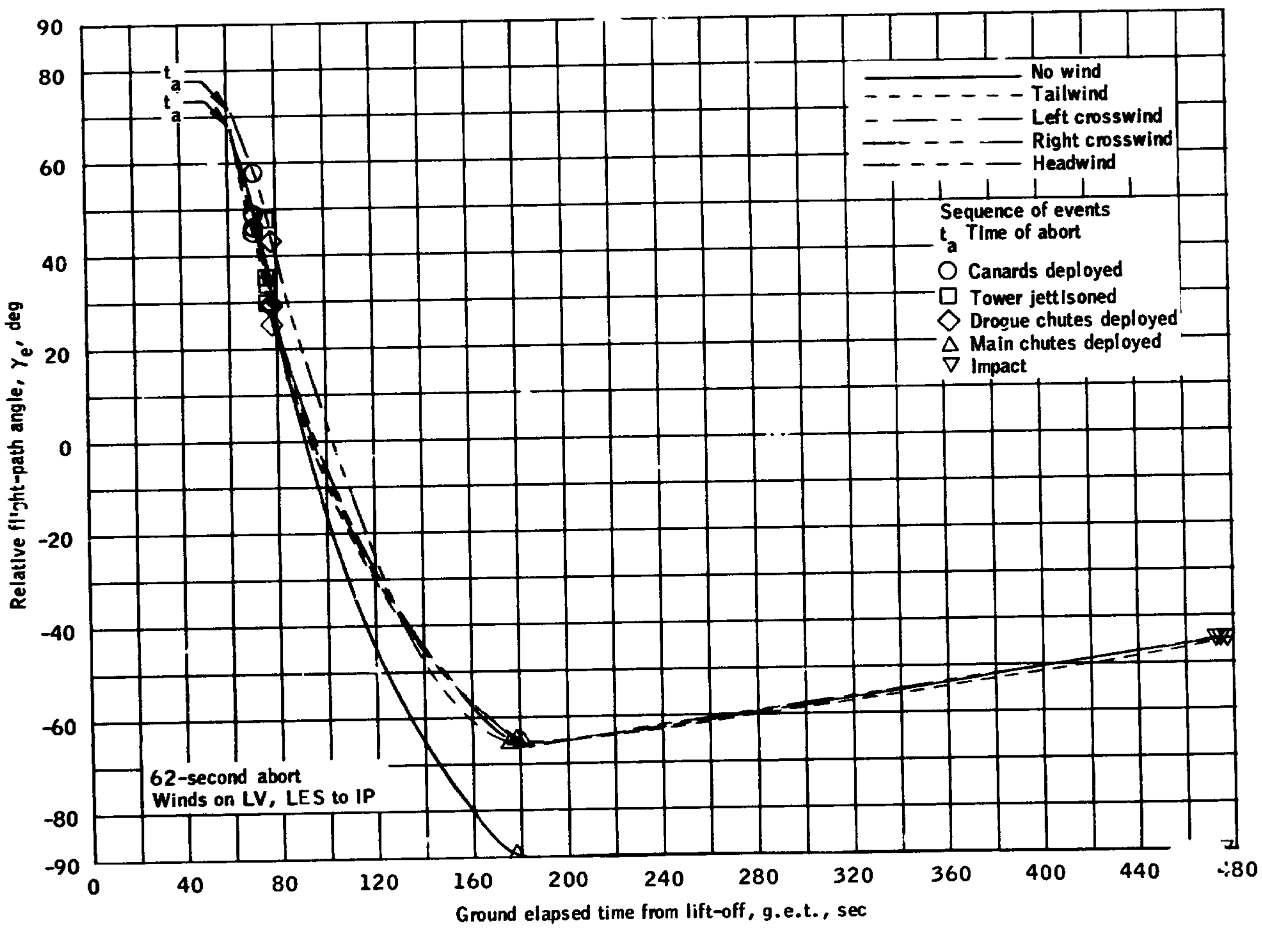
(b) Altitude versus time.

Figure 10. Continued.



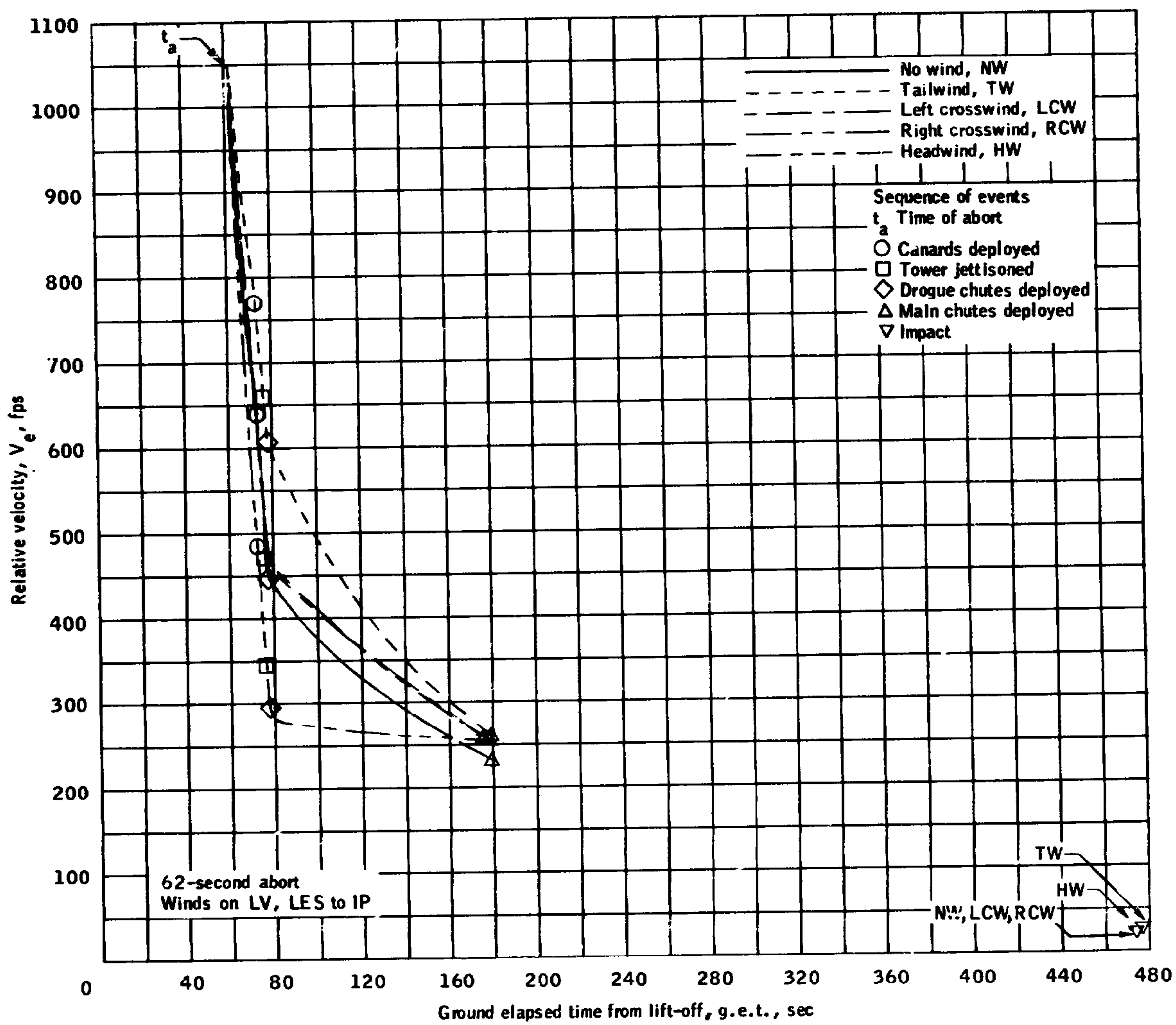
(c) Relative flight azimuth versus time.

Figure 10.- Continued.



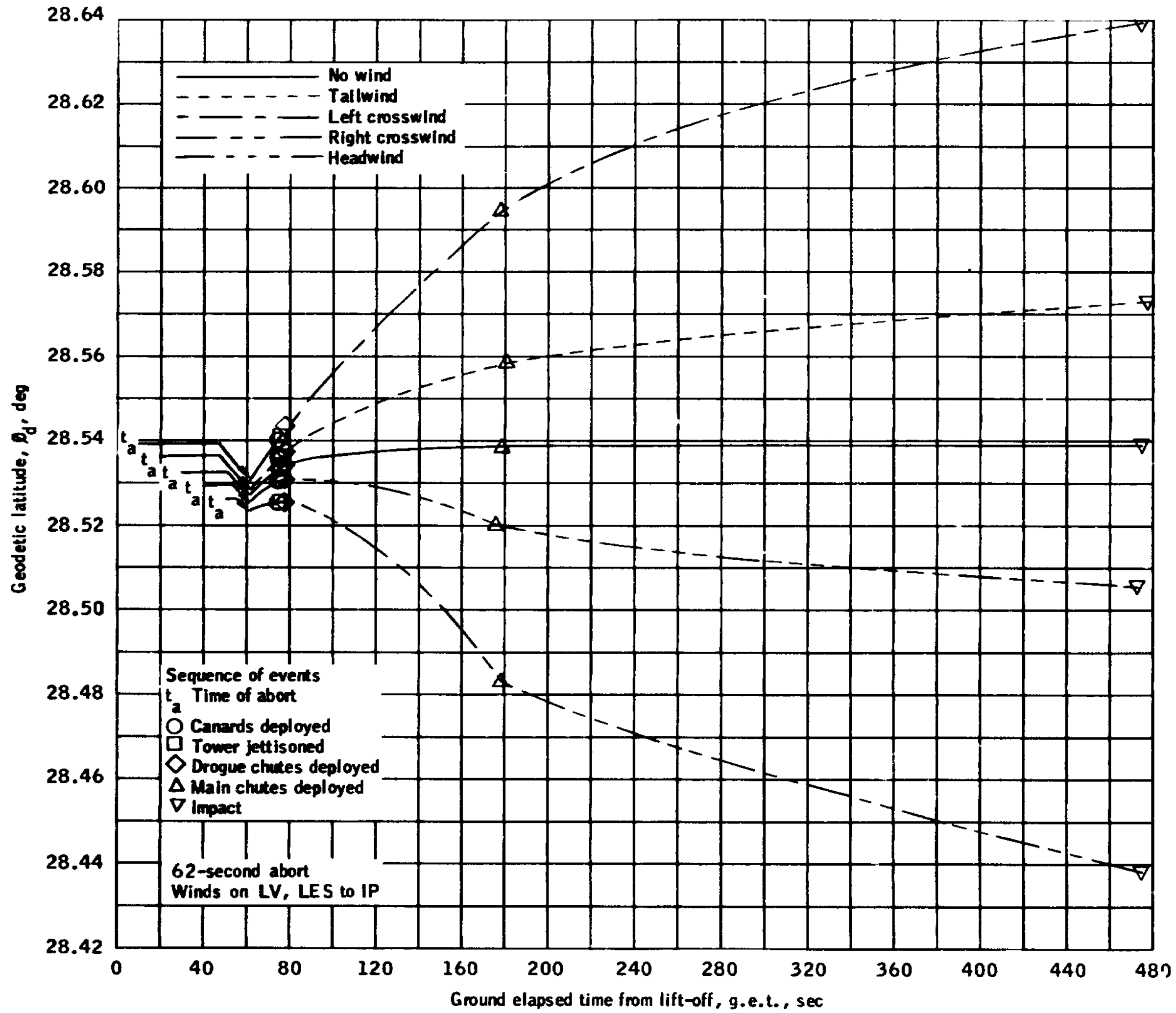
(d) Relative flight-path angle versus time.

Figure 10.- Continued.



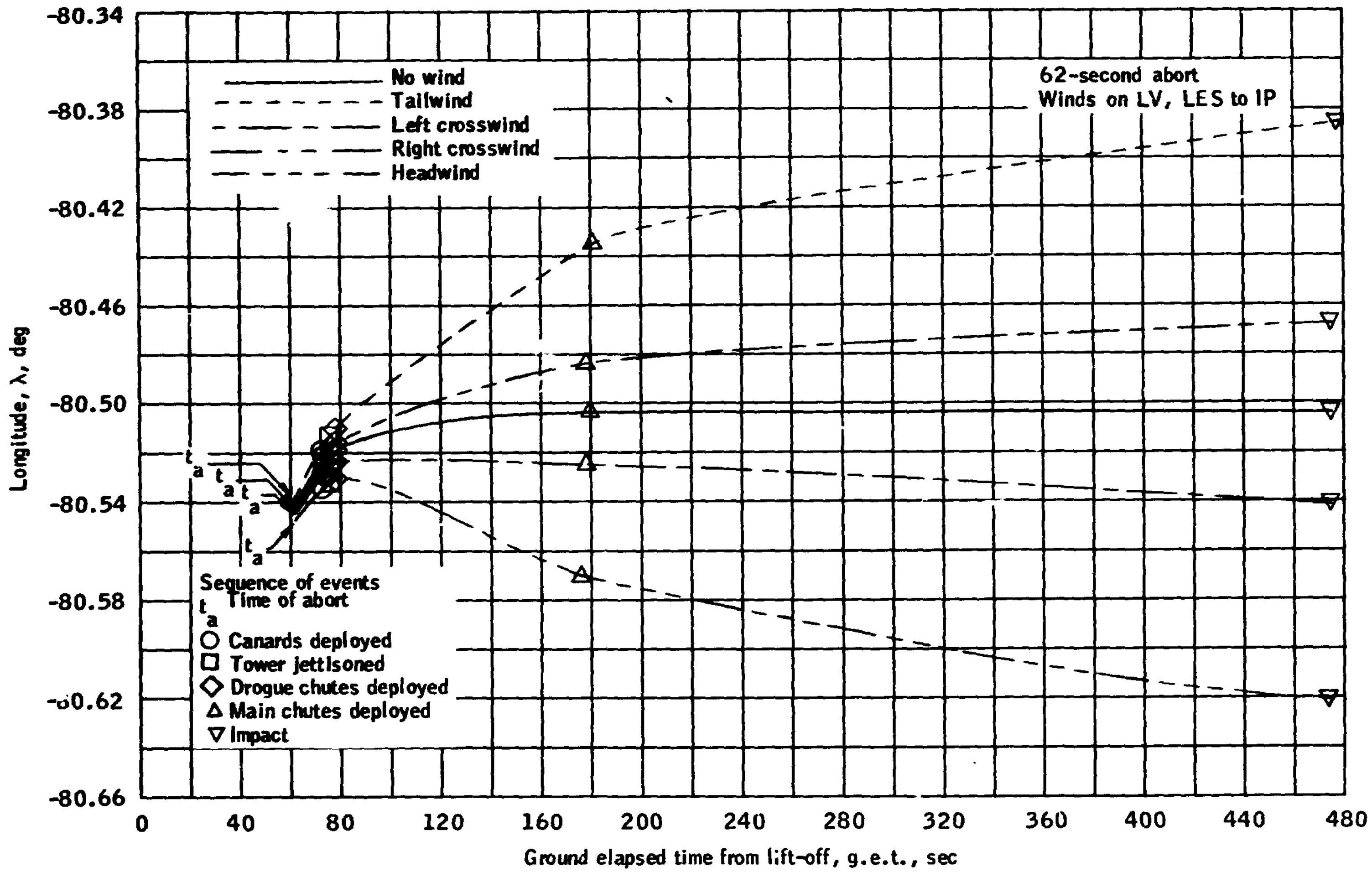
(e) Relative velocity versus time.

Figure 10.- Continued.



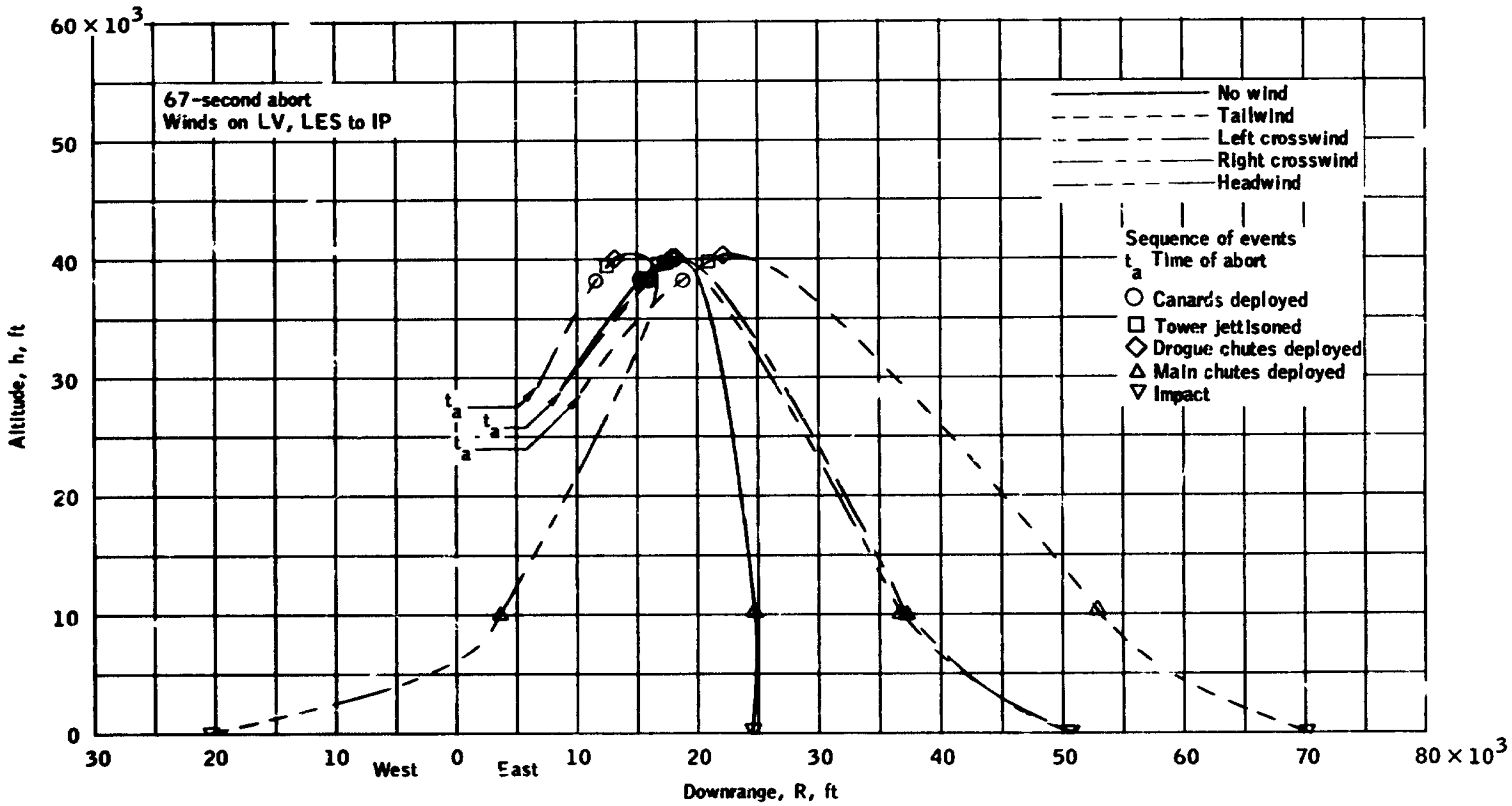
(f) Geodetic latitude versus time.

Figure 10.– Continued.



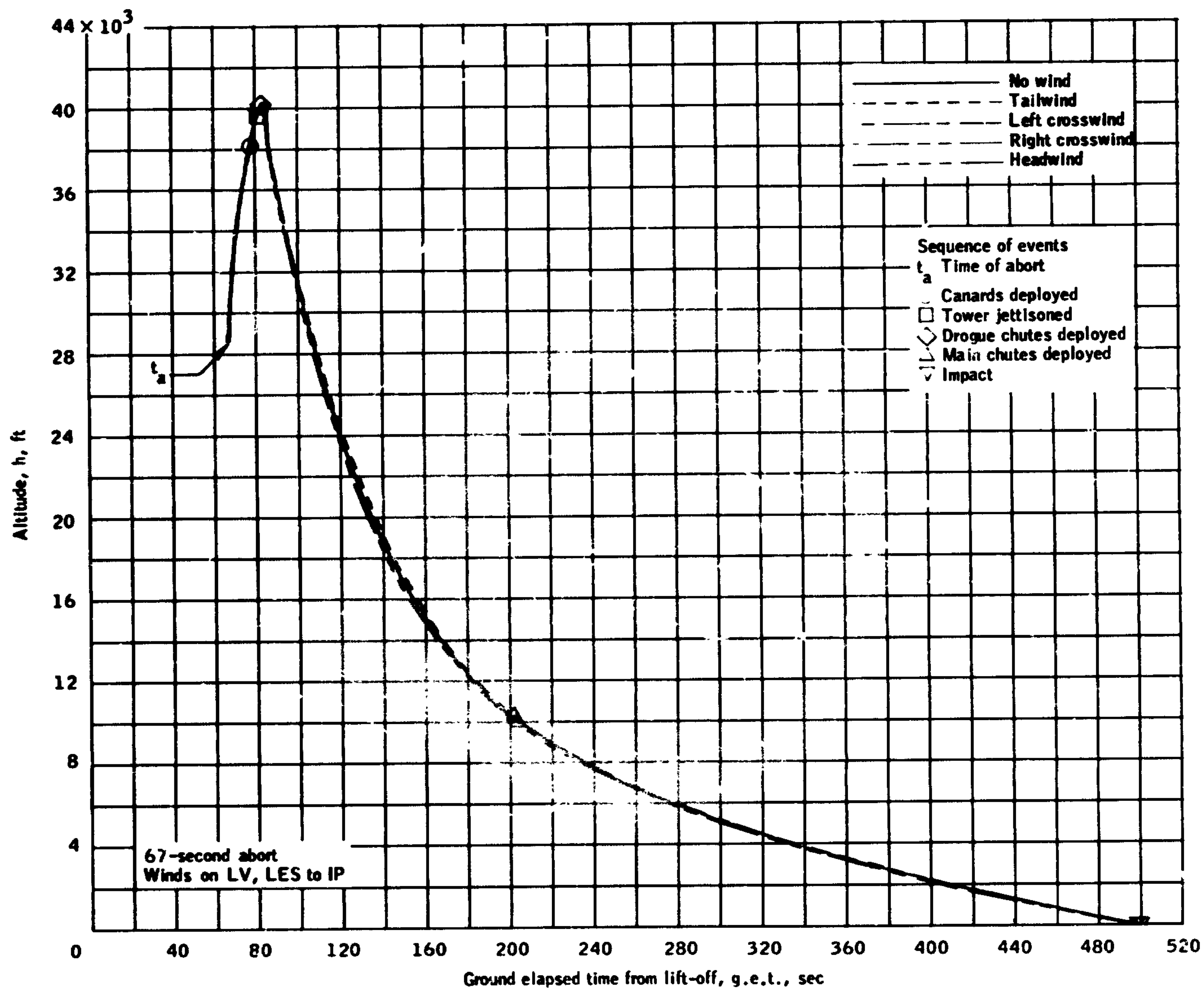
(g) Longitude versus time.

Figure 10.- Concluded.



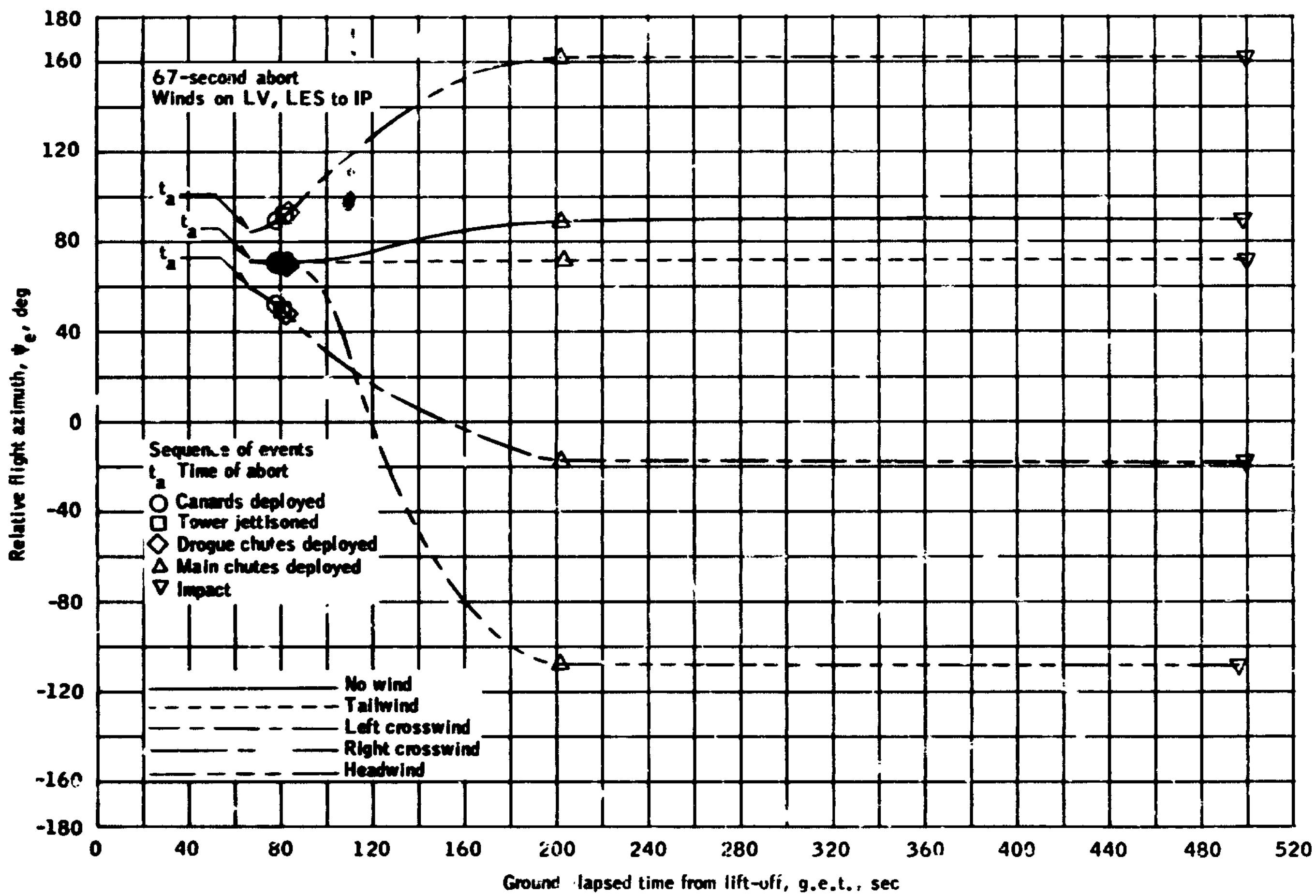
(a) Altitude versus downrange.

Figure 11.- Winds on the LV and LES to landing for a 67-second g.e.t. abort.



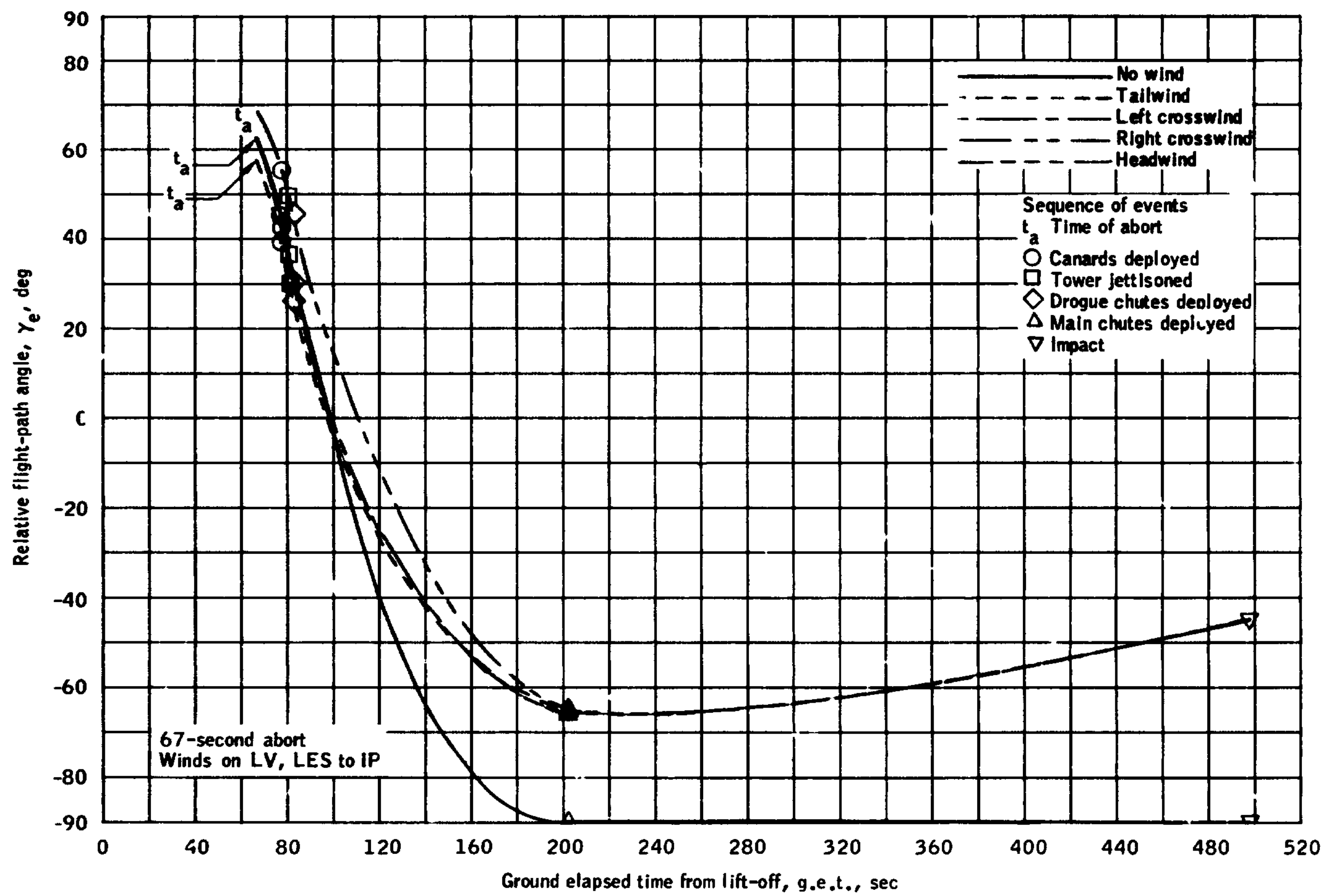
(b) Altitude versus time.

Figure 11.- Continued.



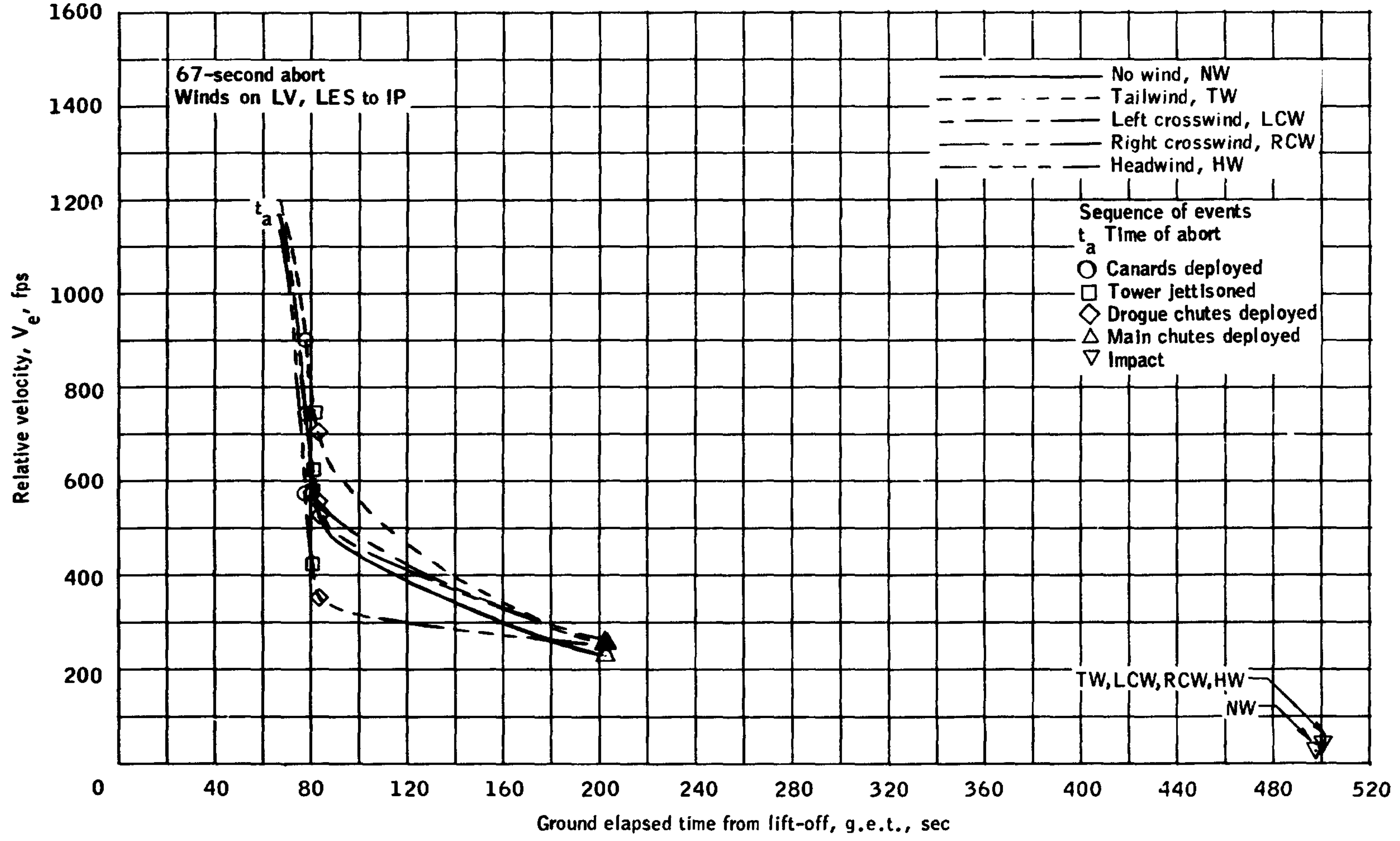
(c) Relative flight azimuth versus time.

Figure 11.- Continued.



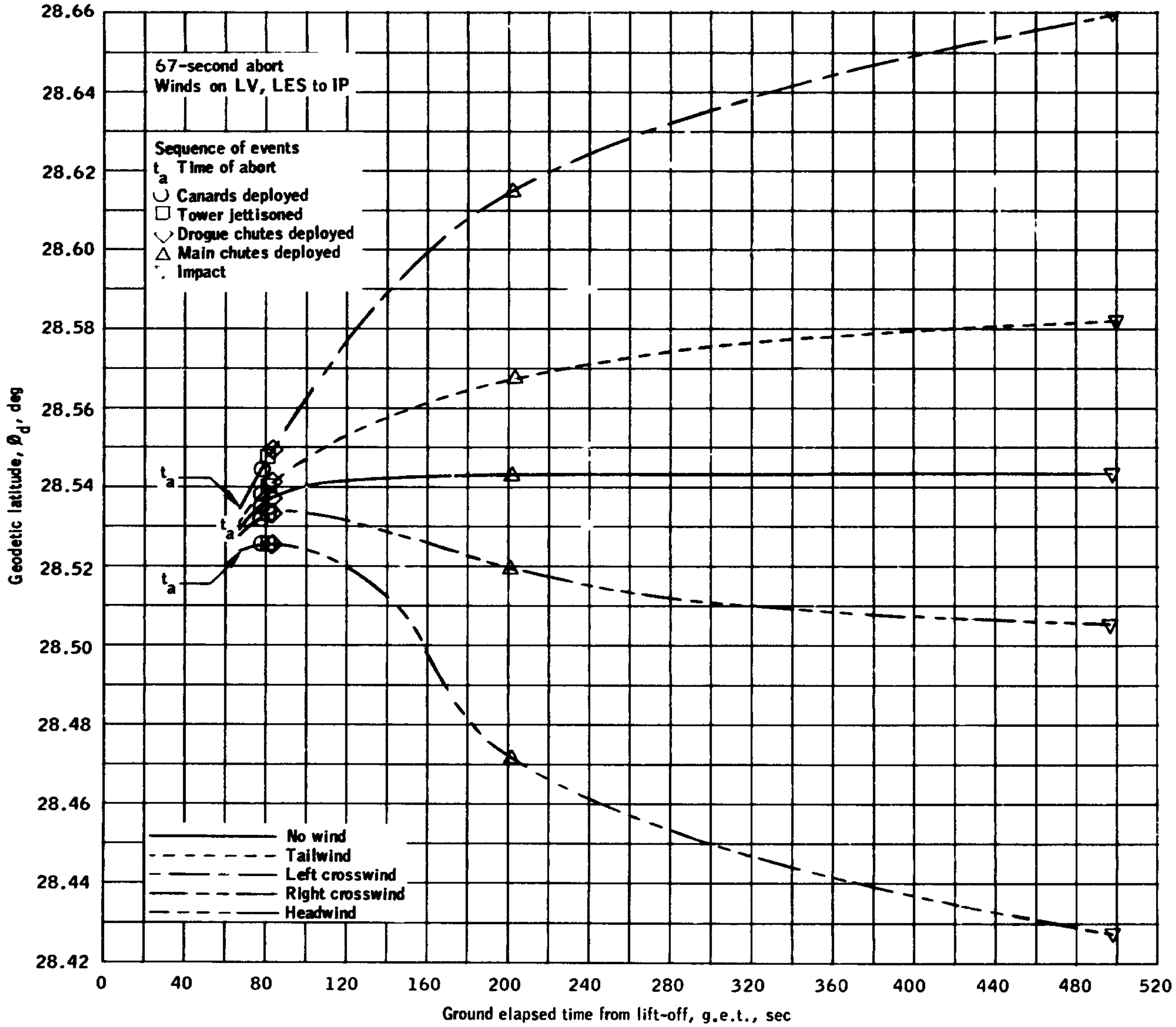
(d) Relative flight-path angle versus time.

Figure 11.- Continued.



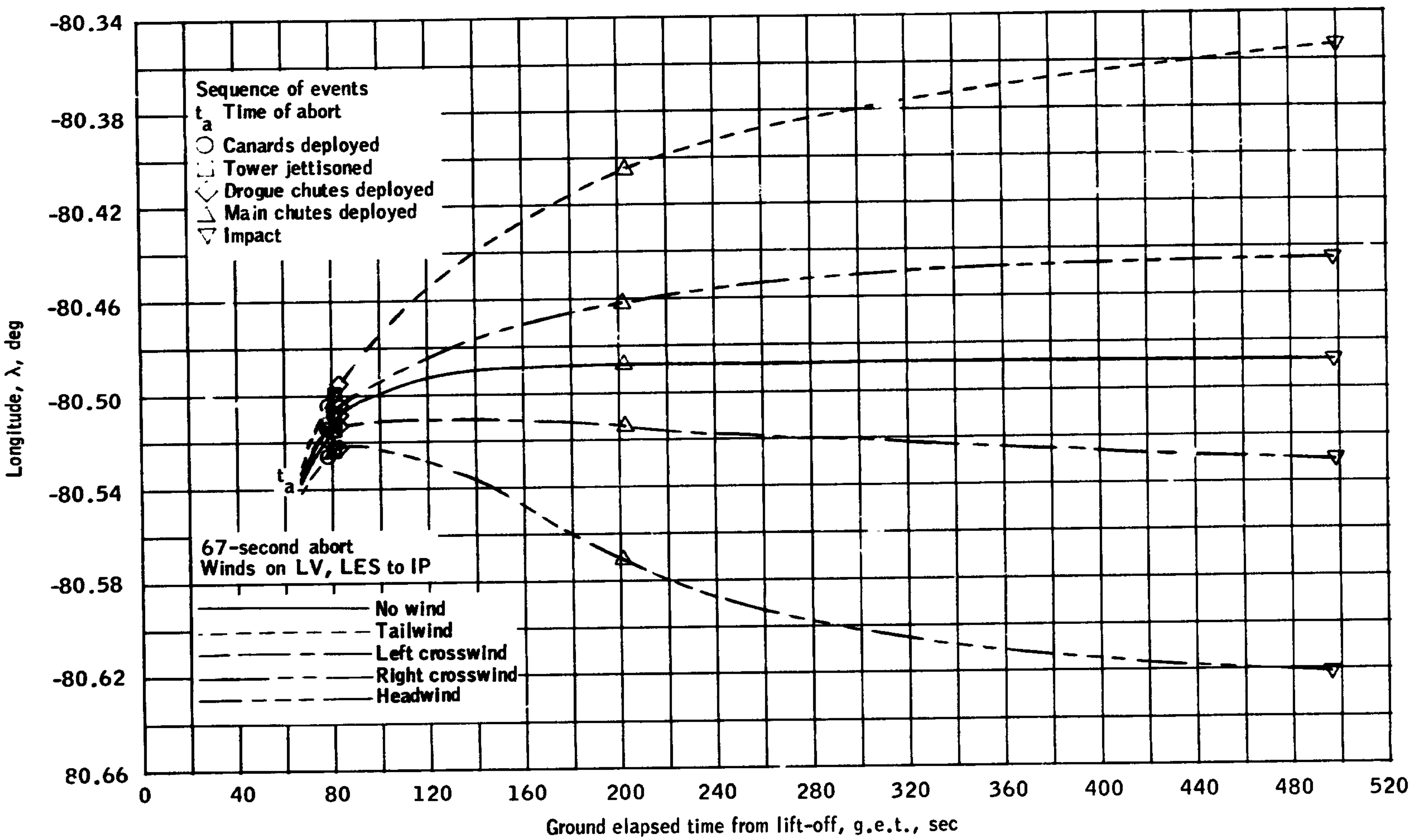
(e) Relative velocity versus time.

Figure 11.- *Continued.*



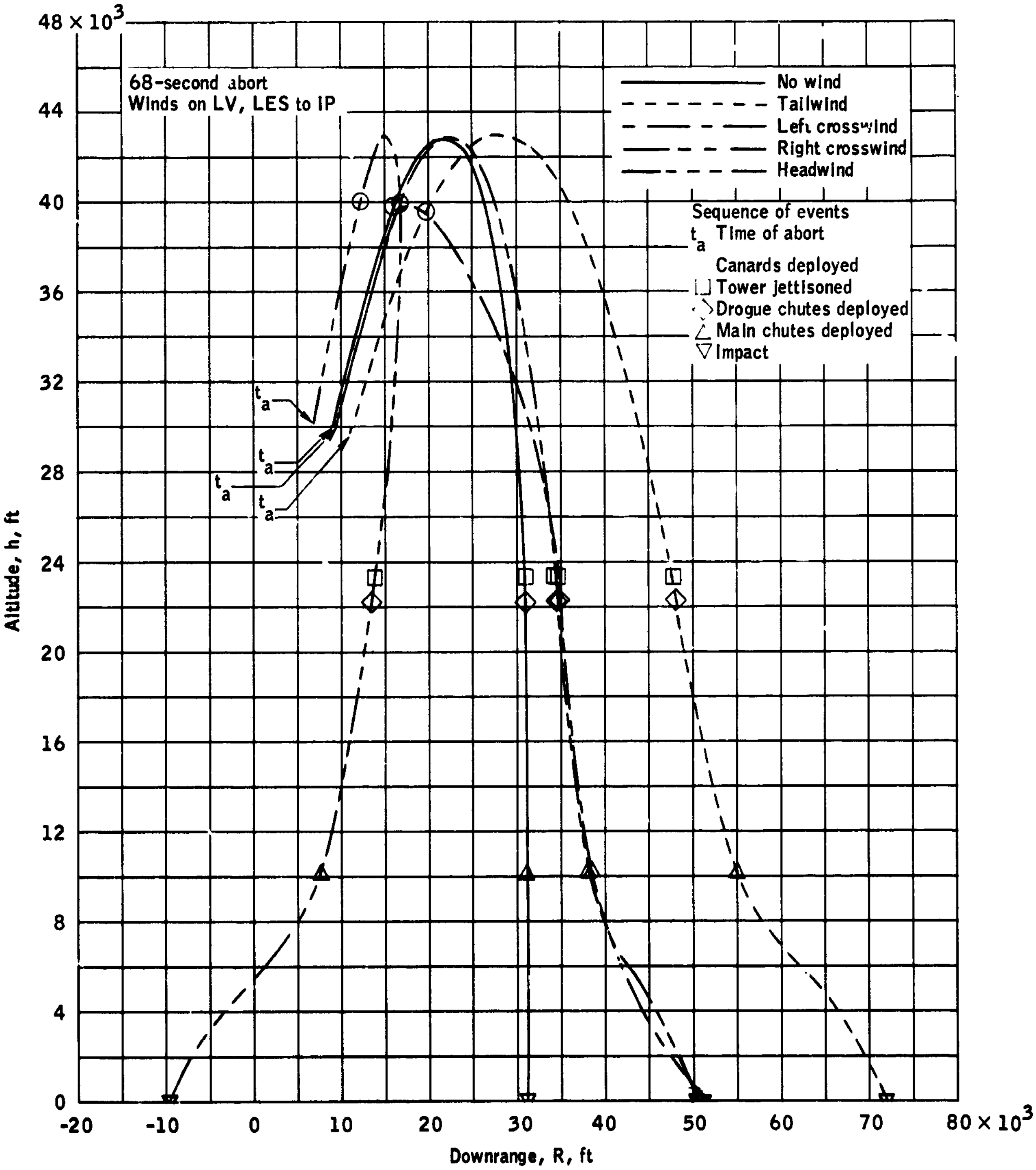
(f) Geodetic latitude versus time.

Figure 11.- Continued.



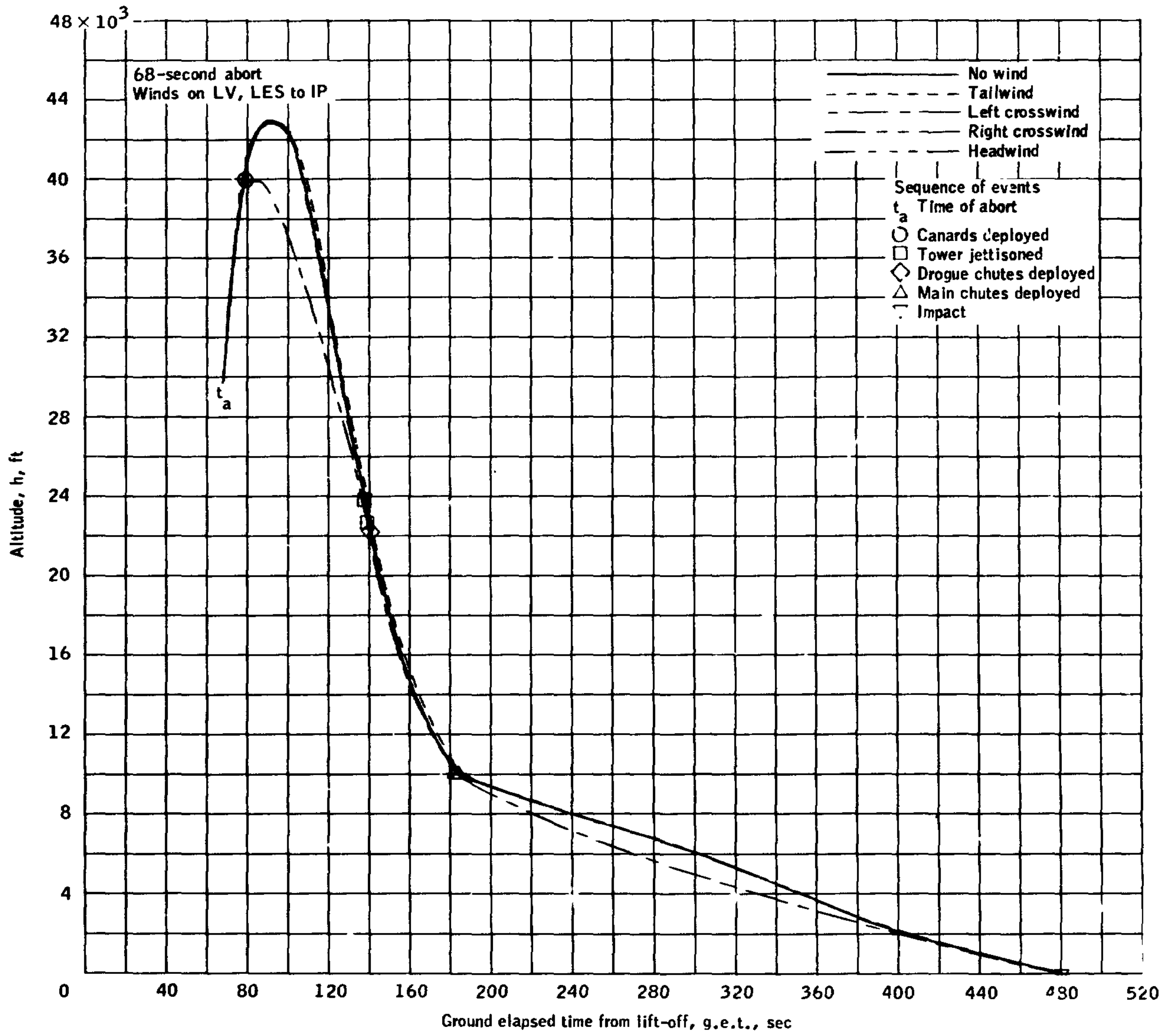
(g) Longitude versus time.

Figure 11.- Concluded.



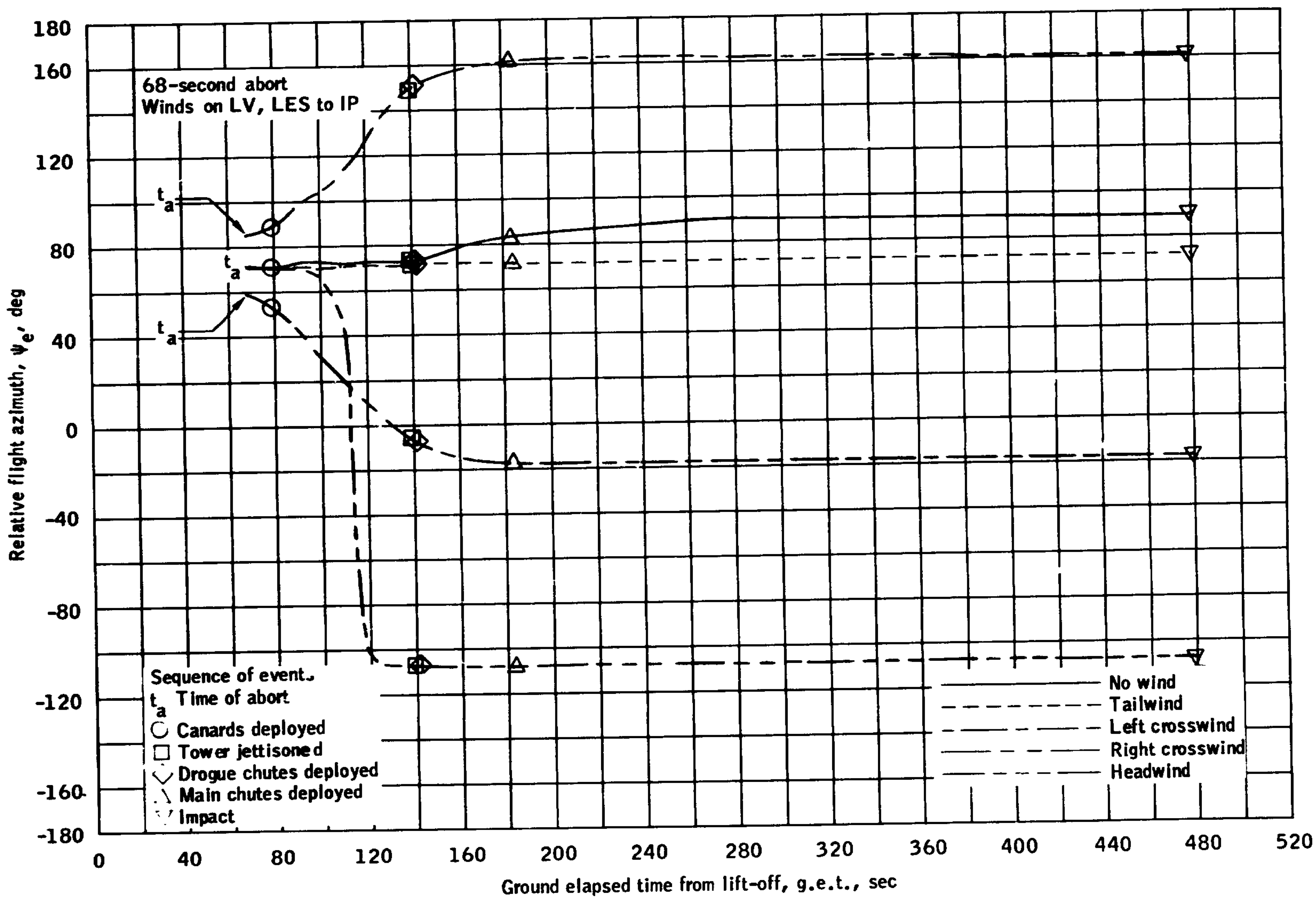
(a) Altitude versus downrange.

Figure 12.- Winds on the LV and LES to landing for a 68-second g.e.t. abort.



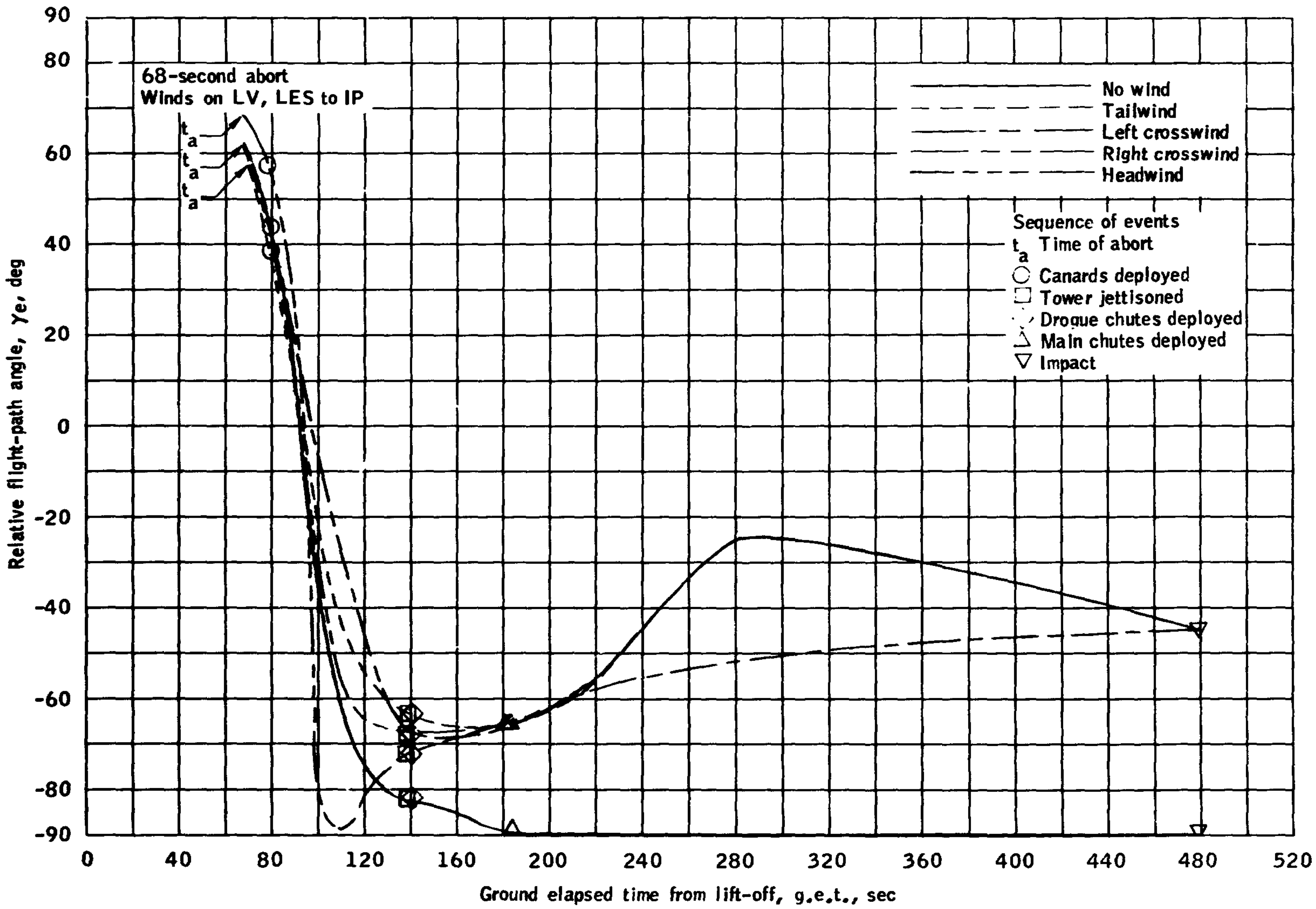
(b) Altitude versus time.

Figure 12.- Continued.



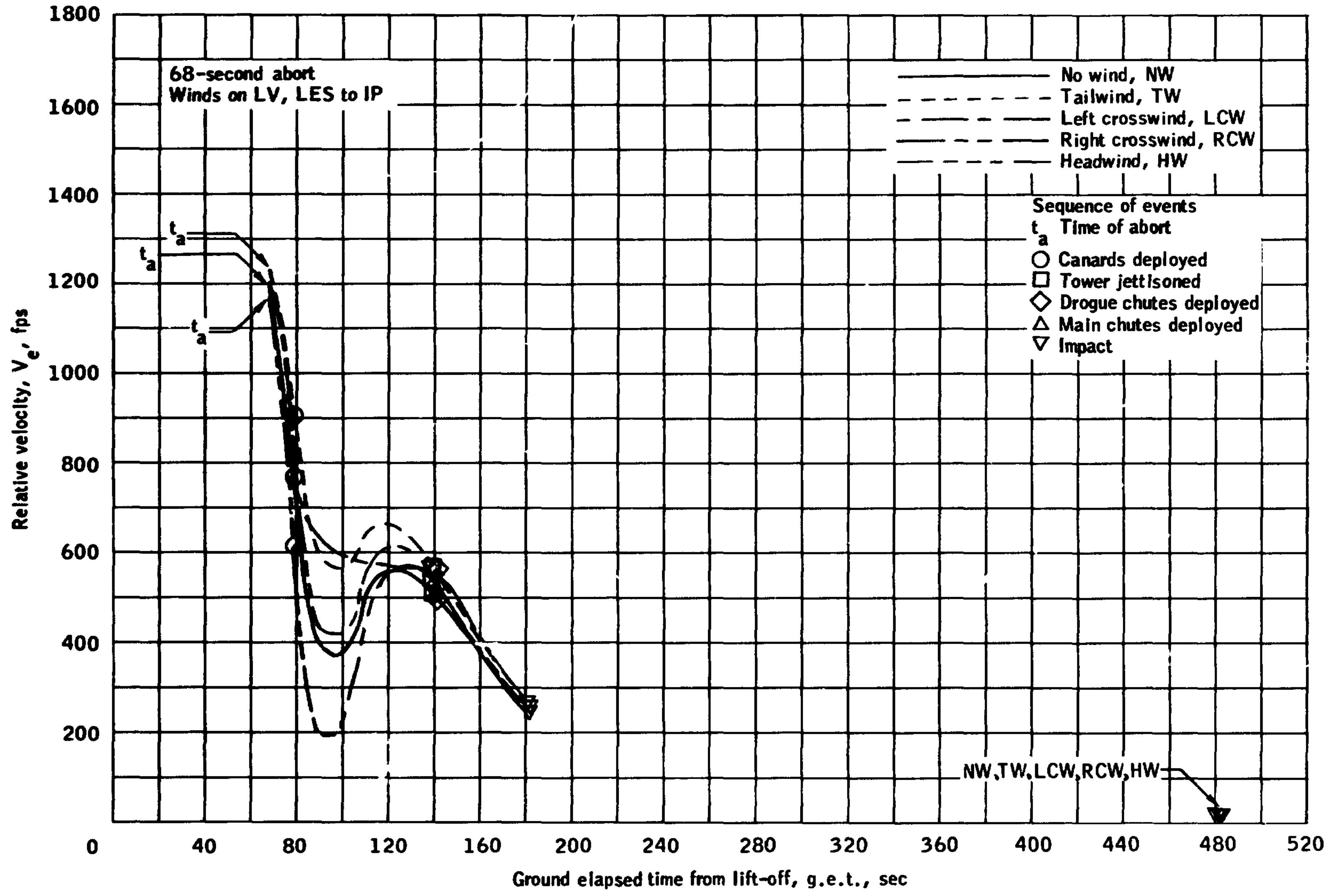
(c) Relative flight azimuth versus time.

Figure 12.- Continued.



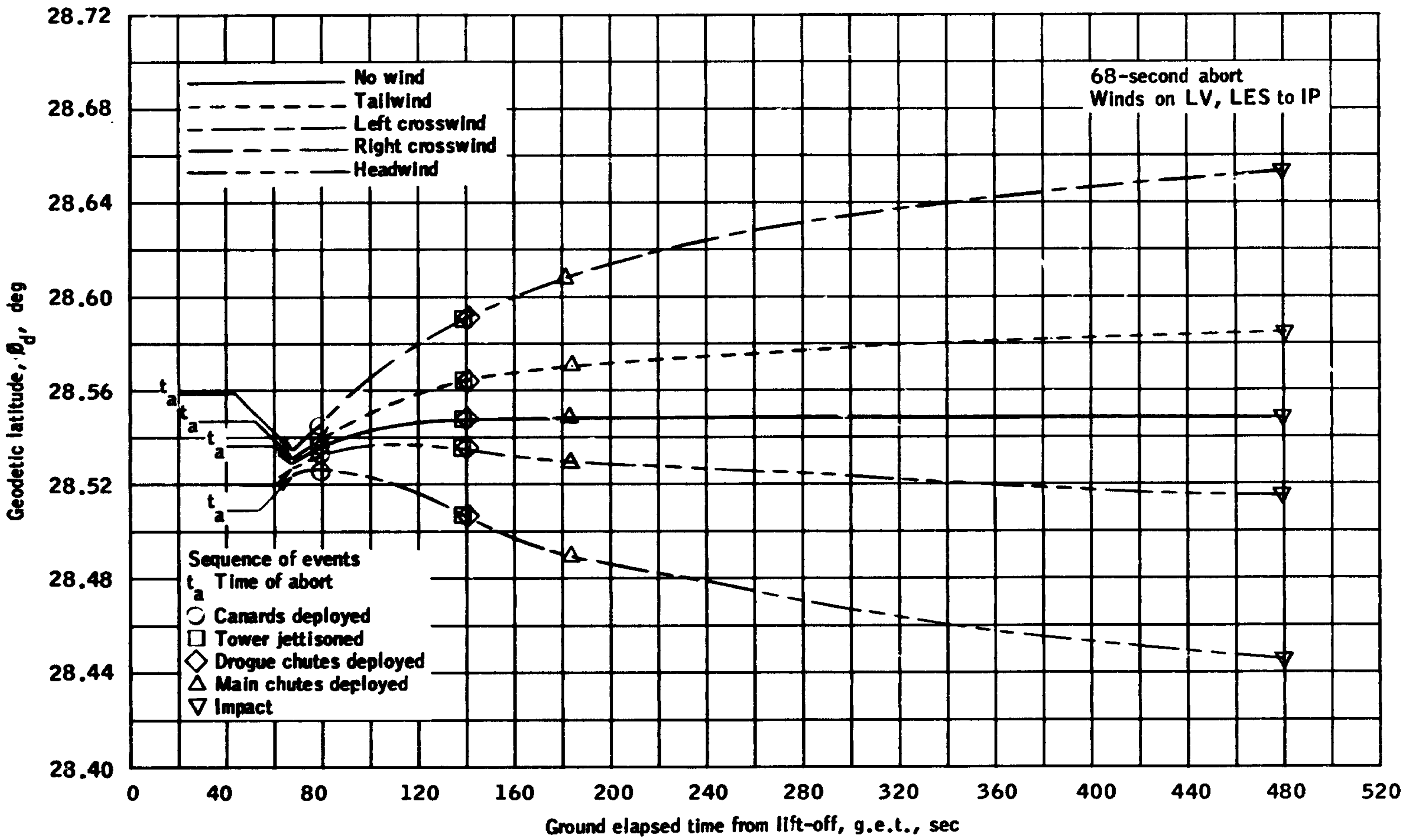
(d) Relative flight-path angle versus time.

Figure 12.- Continued.



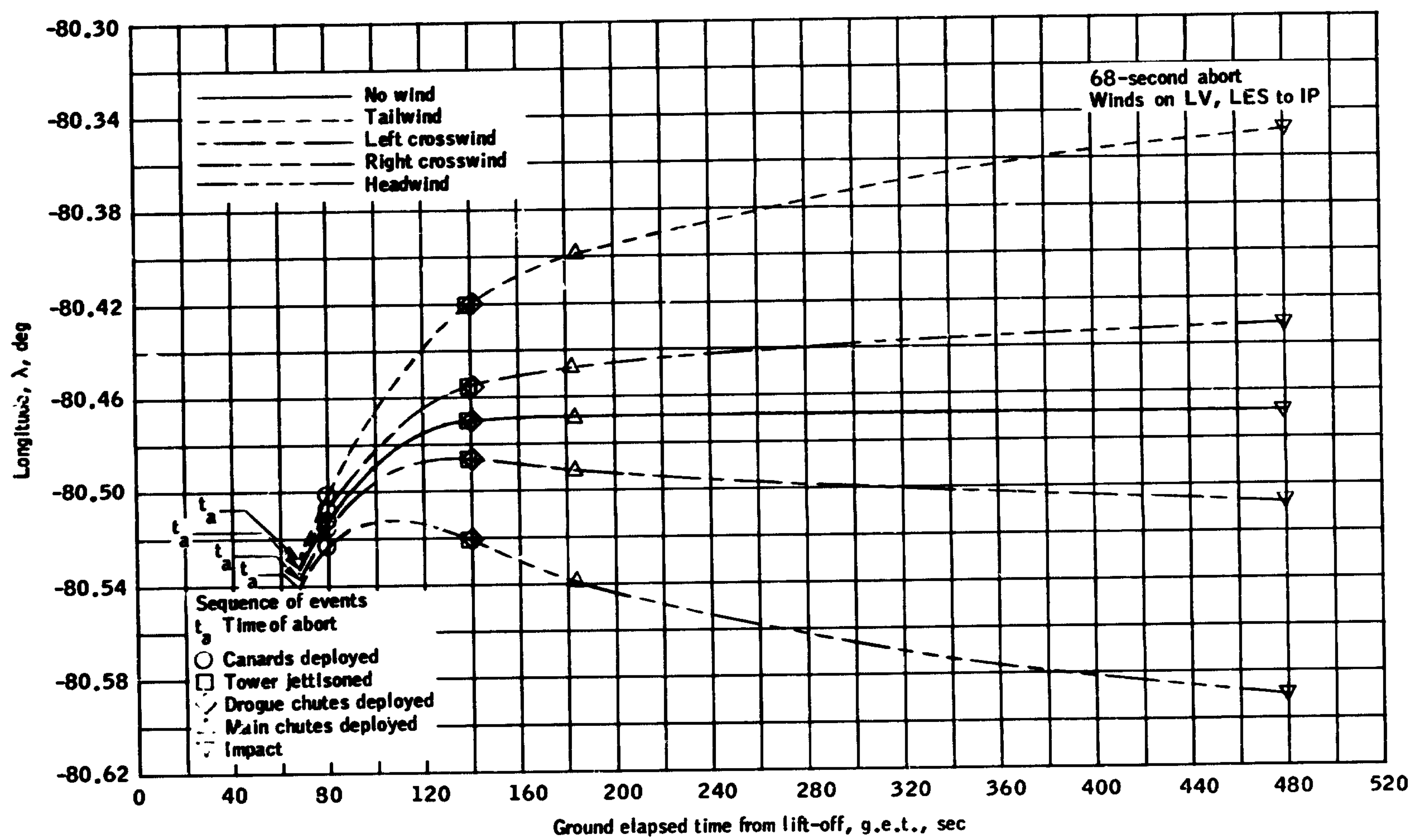
(e) Relative velocity versus time.

Figure 12.- Continued.



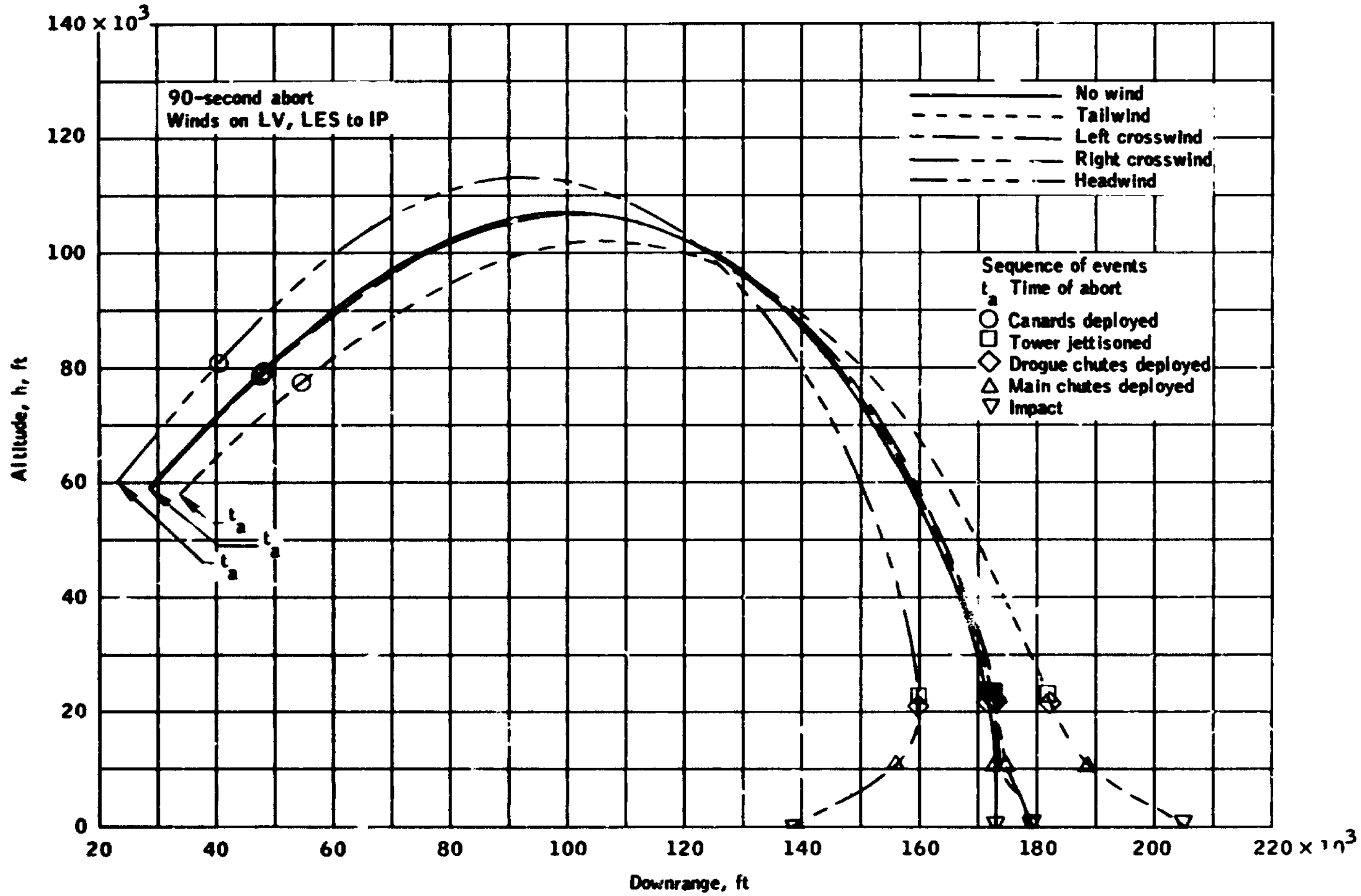
(f) Geodetic latitude versus time.

Figure 12.- Continued.



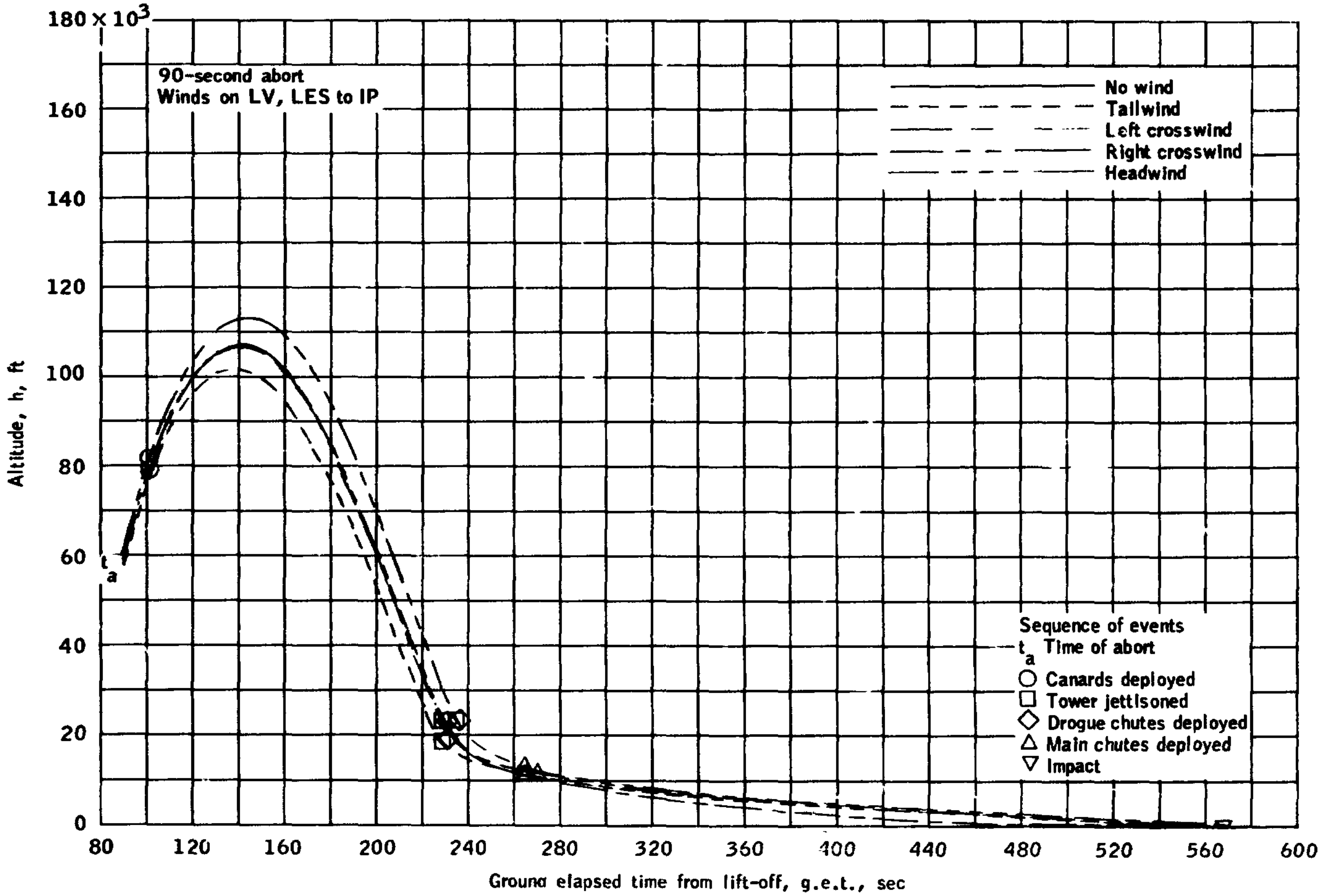
(g) Longitude versus time.

Figure 12.- Concluded.



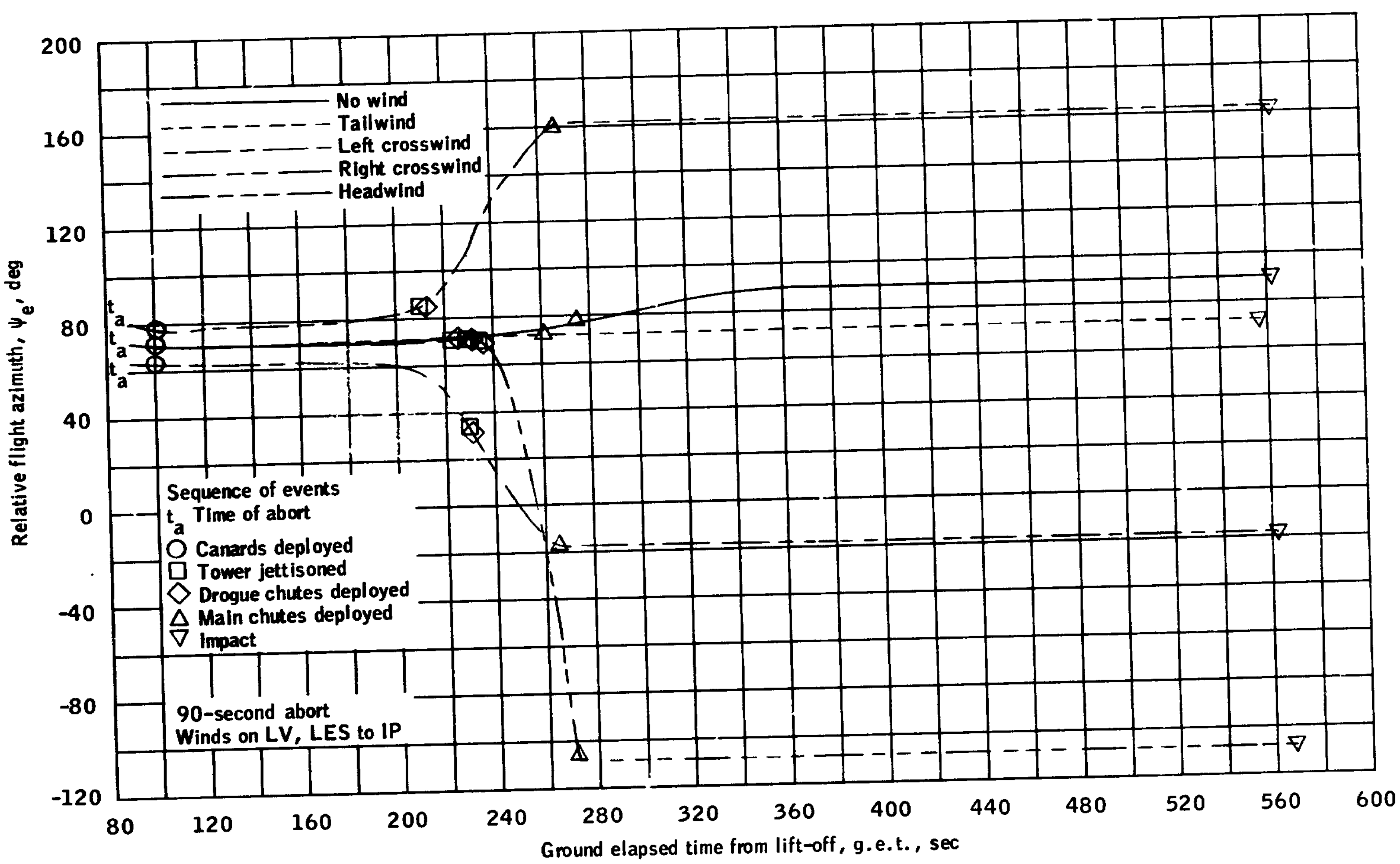
(a) Altitude versus downrange.

Figure 13.- Winds on the LV and LES to landing for a 90-second g.e.t. abort.



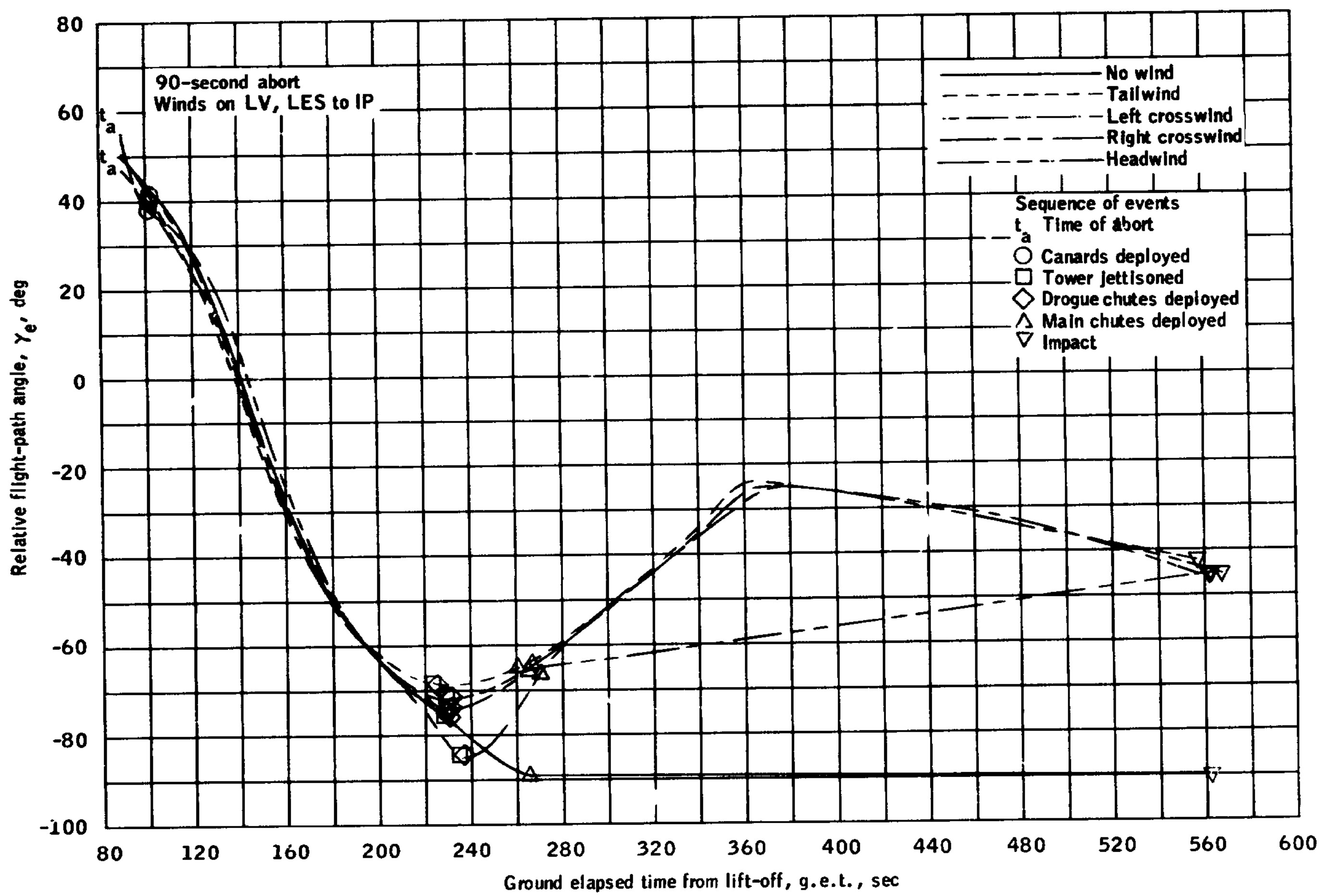
(b) Altitude versus time.

Figure 13.- Continued.



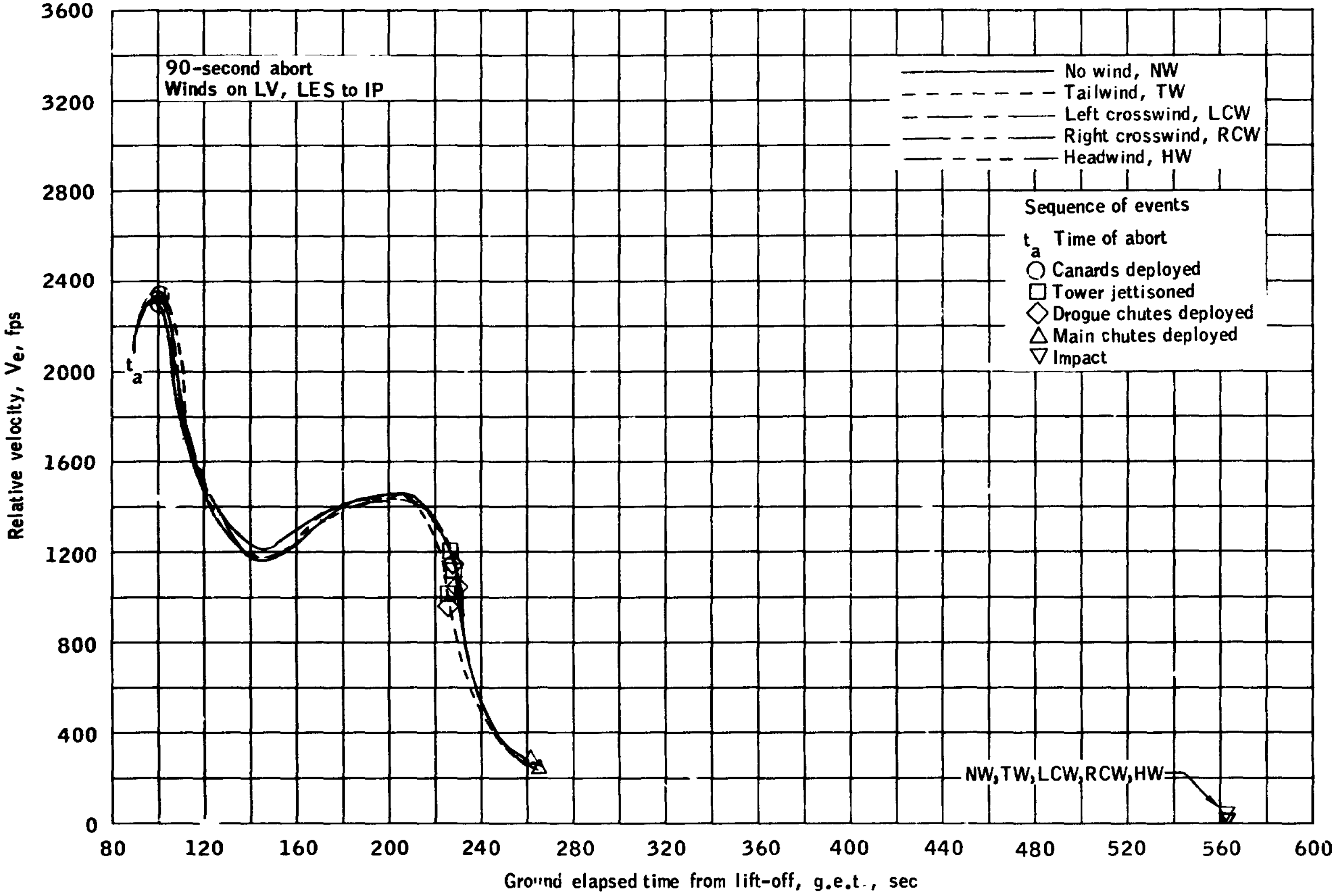
(c) Relative flight azimuth versus time.

Figure 13.- Continued.



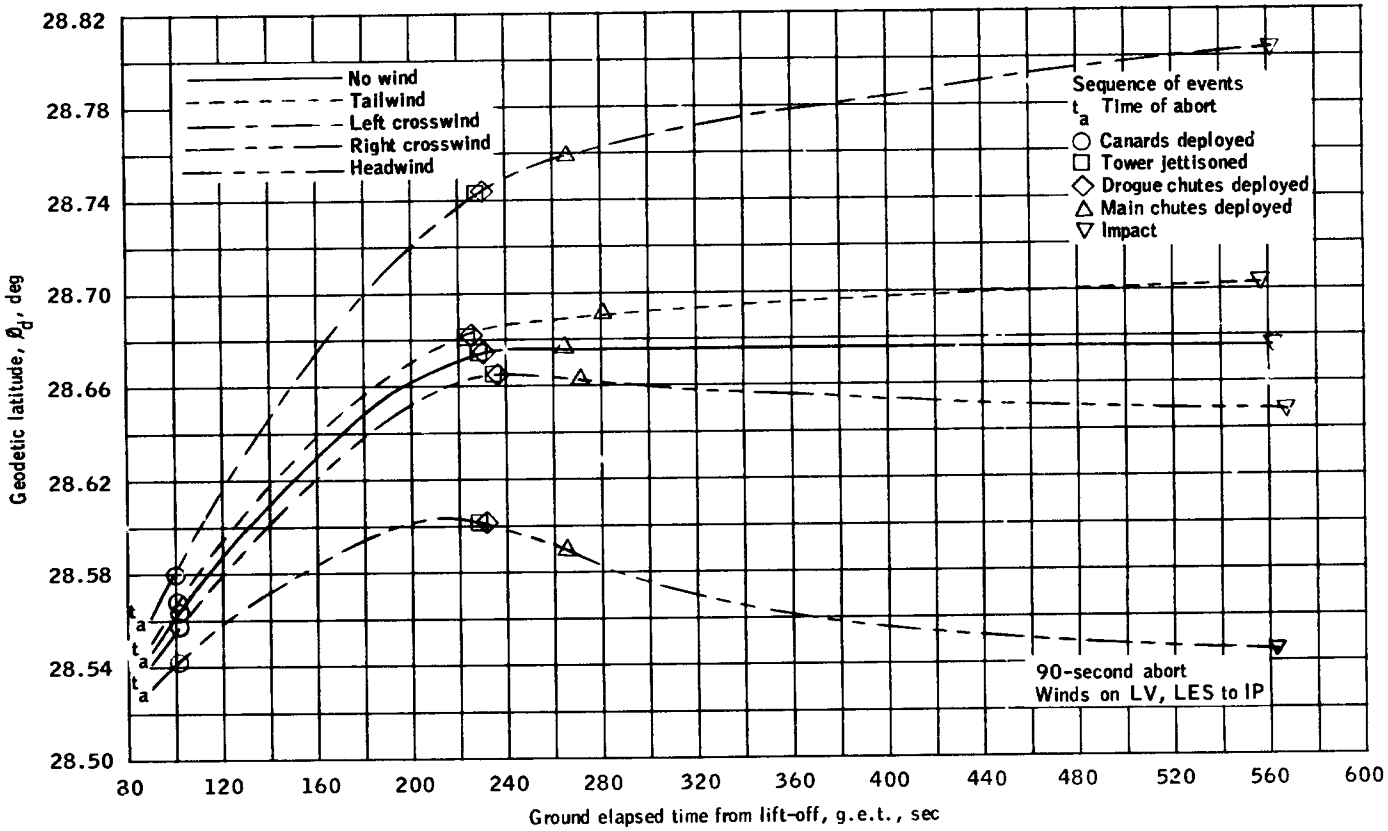
(d) Relative flight-path angle versus time.

Figure 13.- Continued.



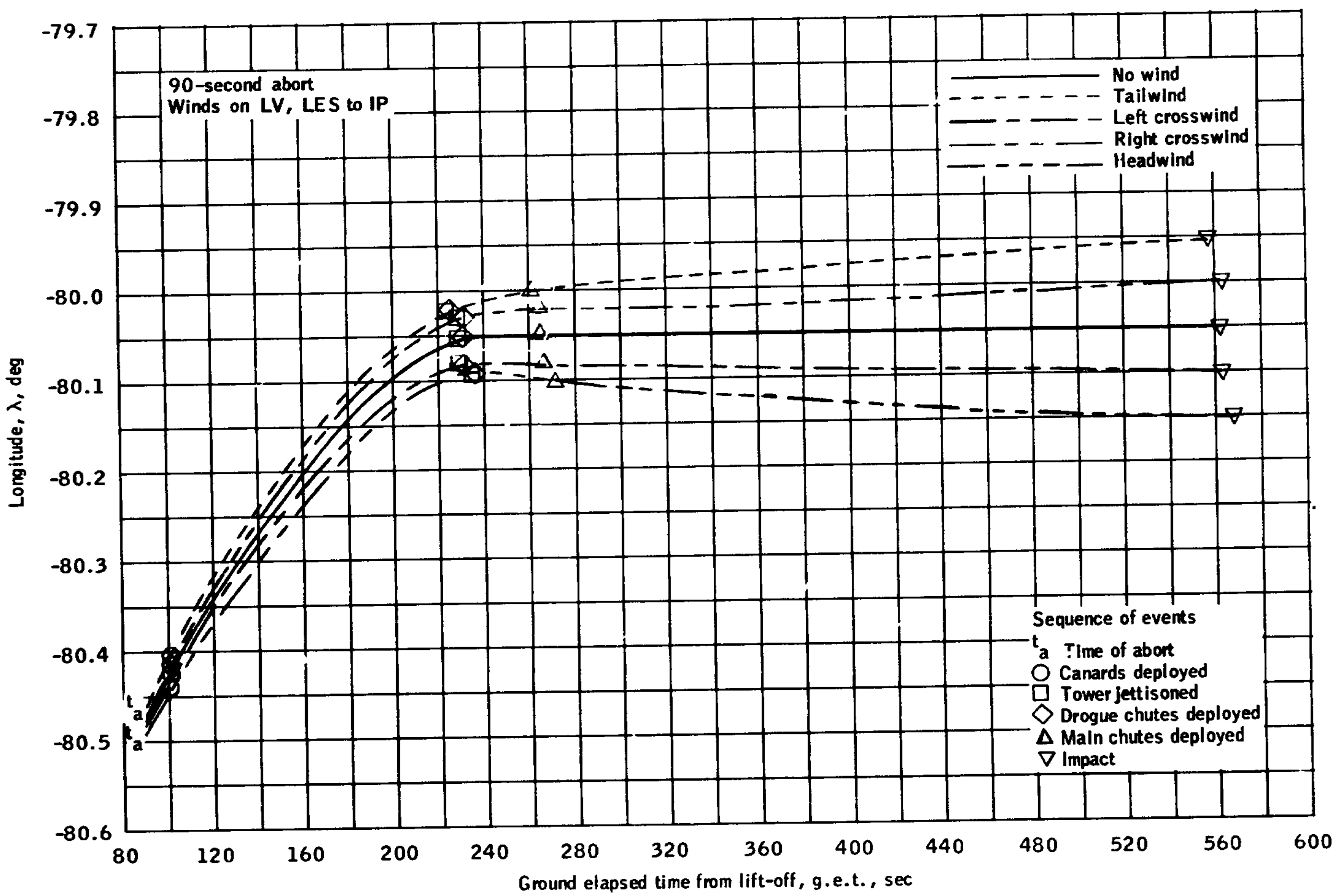
(e) Relative velocity versus time.

Figure 13.- Continued.



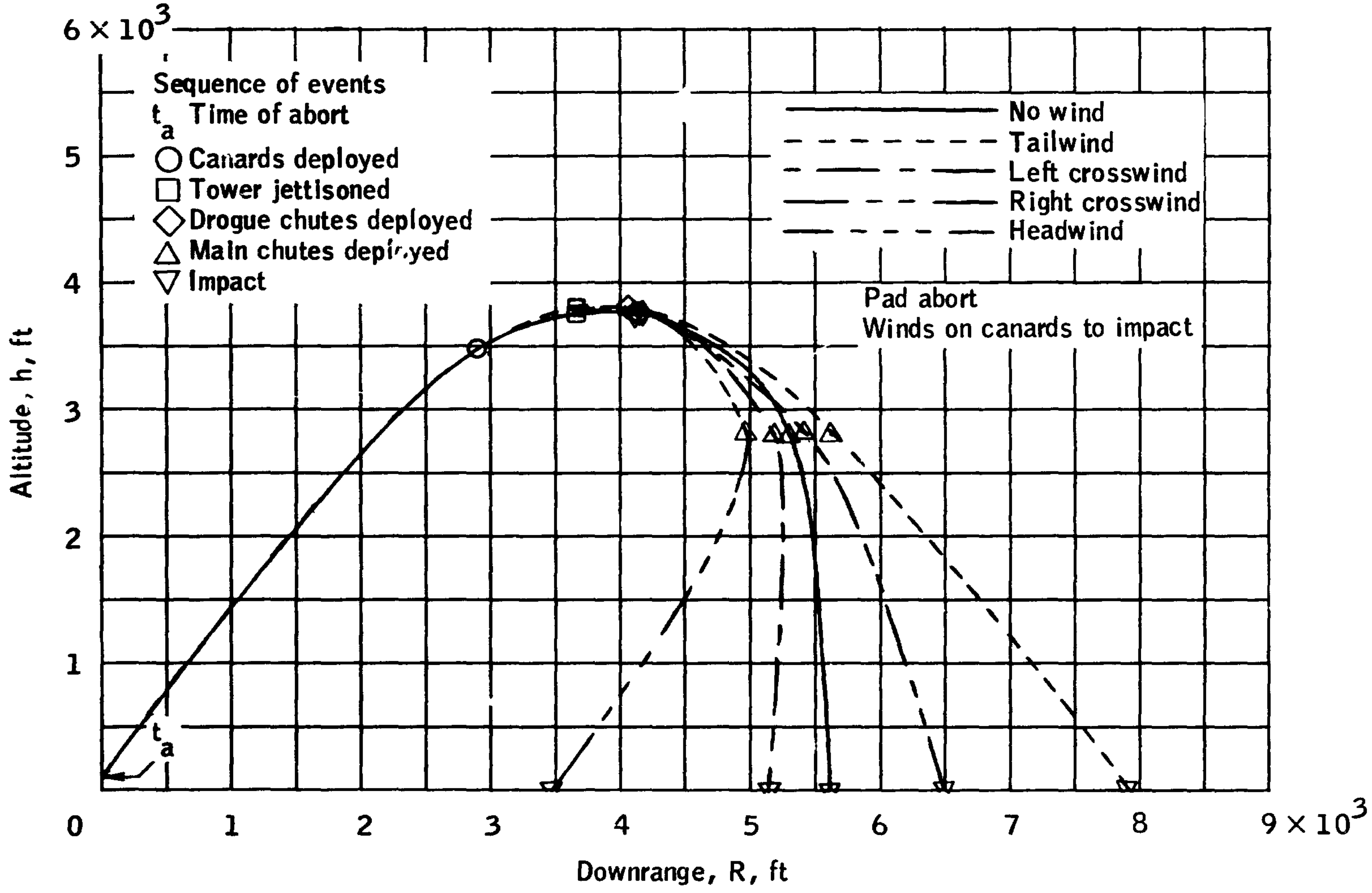
(f) Geodetic latitude versus time.

Figure 13.- Continued.



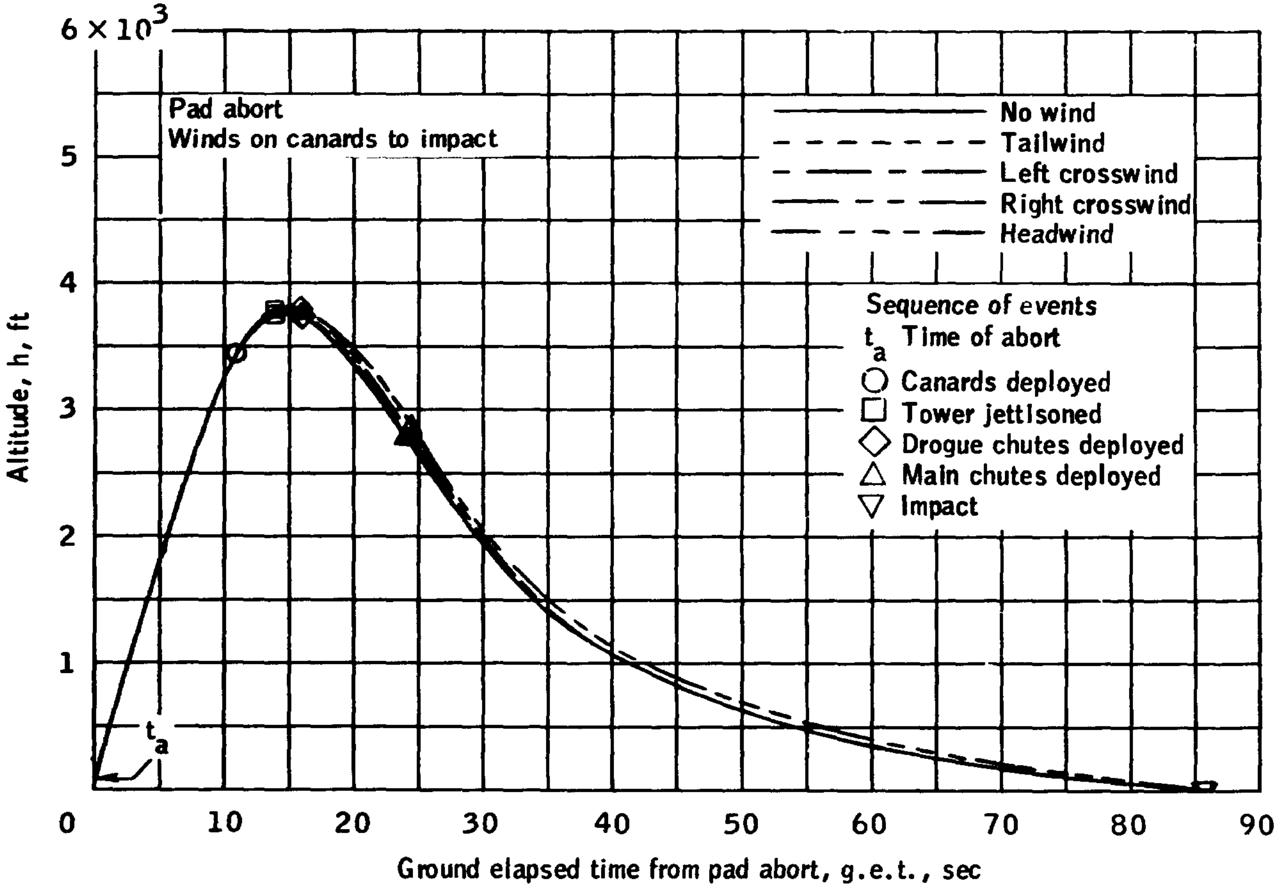
(g) Longitude versus time.

Figure 13.- Concluded.



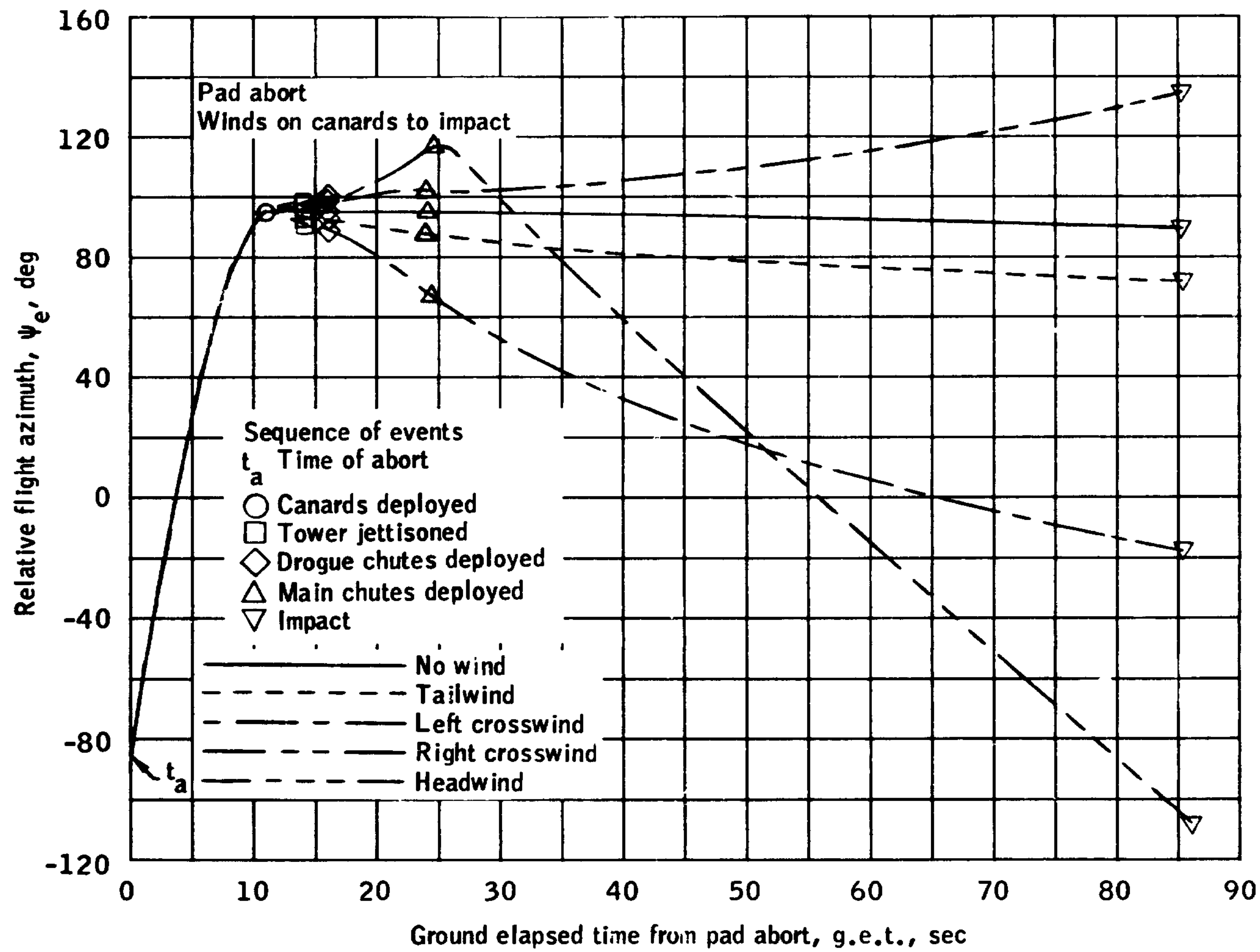
(a) Altitude versus downrange.

Figure 14.- Winds on canards to landing for a pad abort.



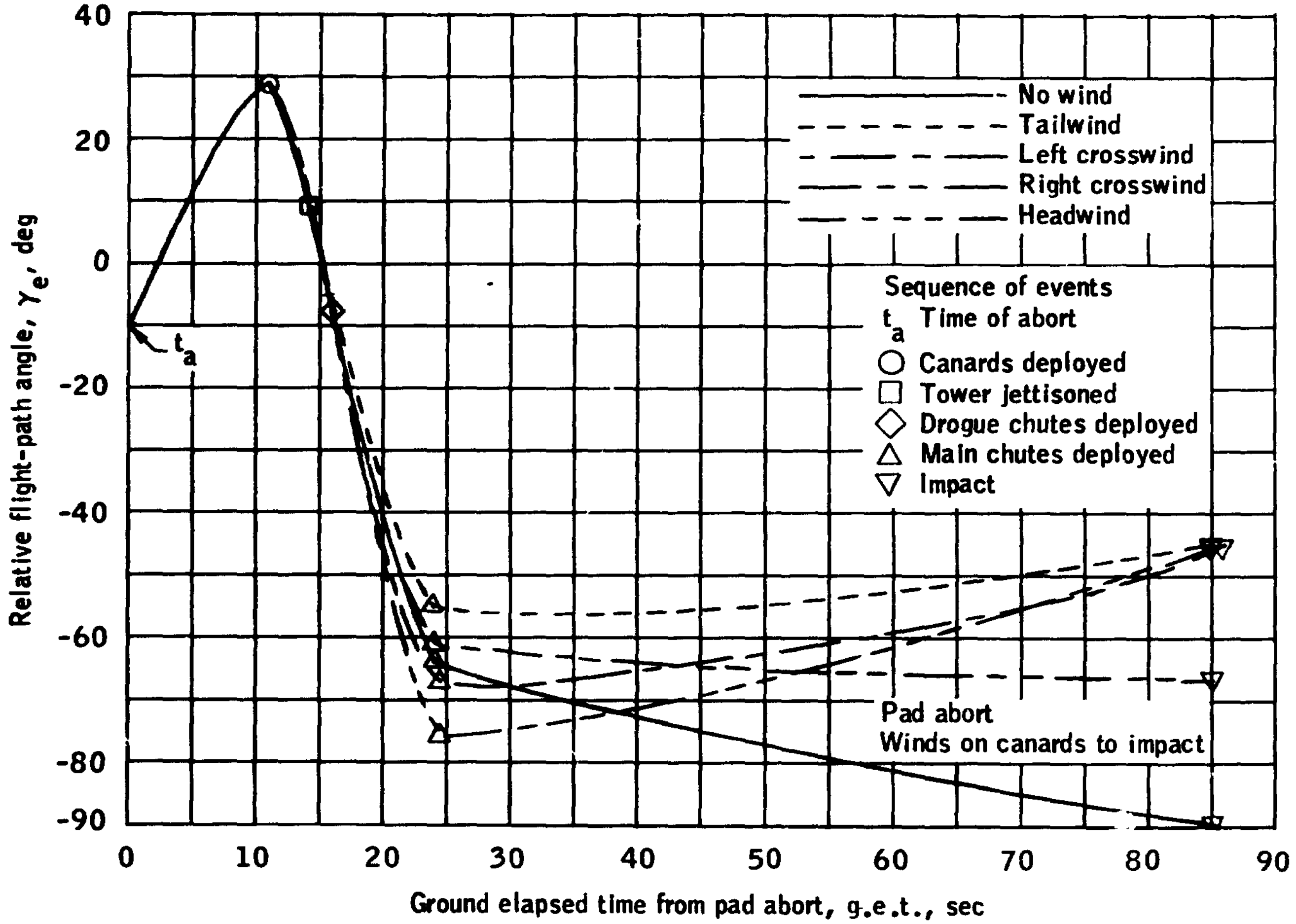
(b) Altitude versus time.

Figure 14.- Continued.



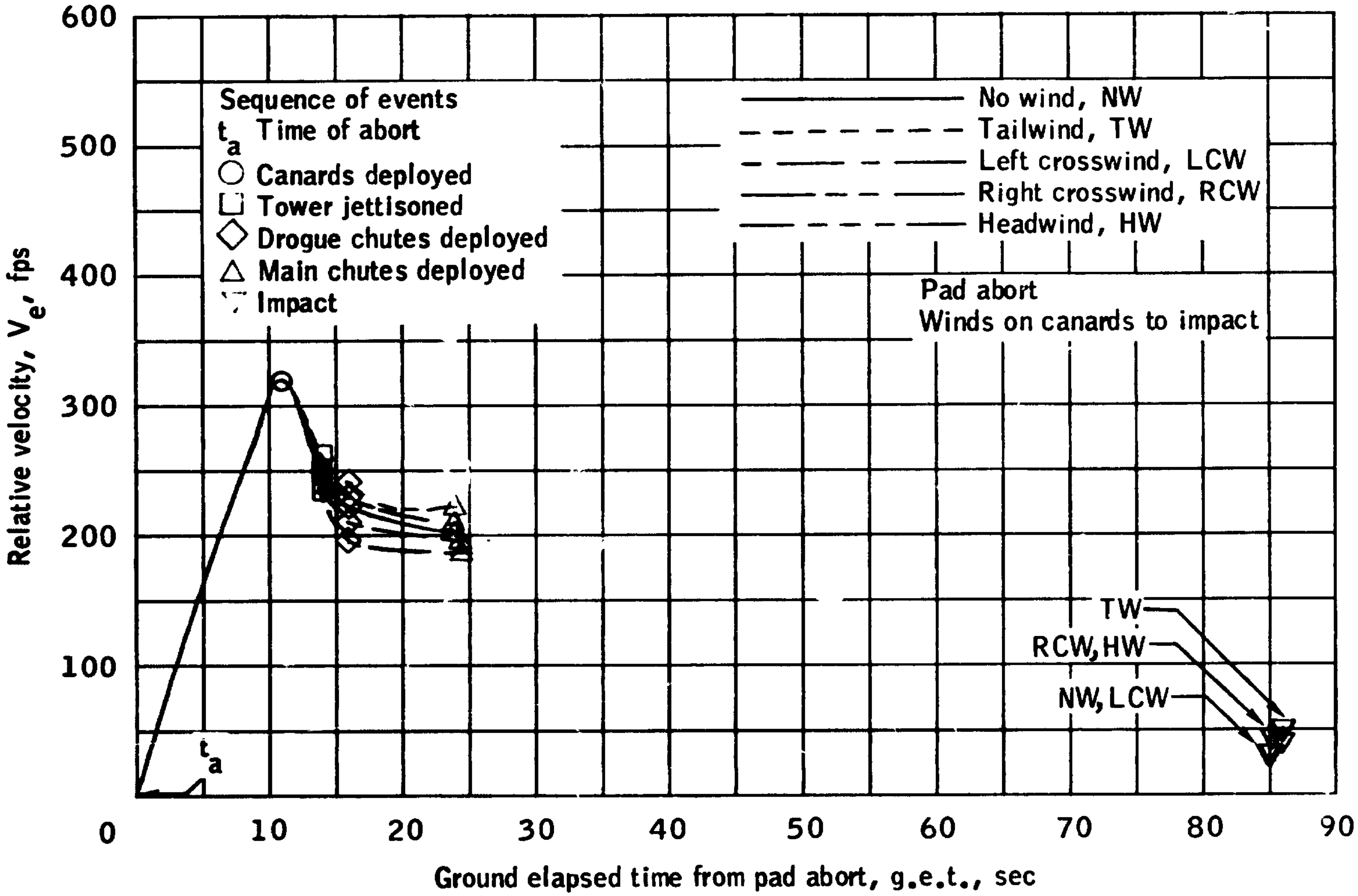
(c) Relative flight azimuth versus time.

Figure 14.- Continued.



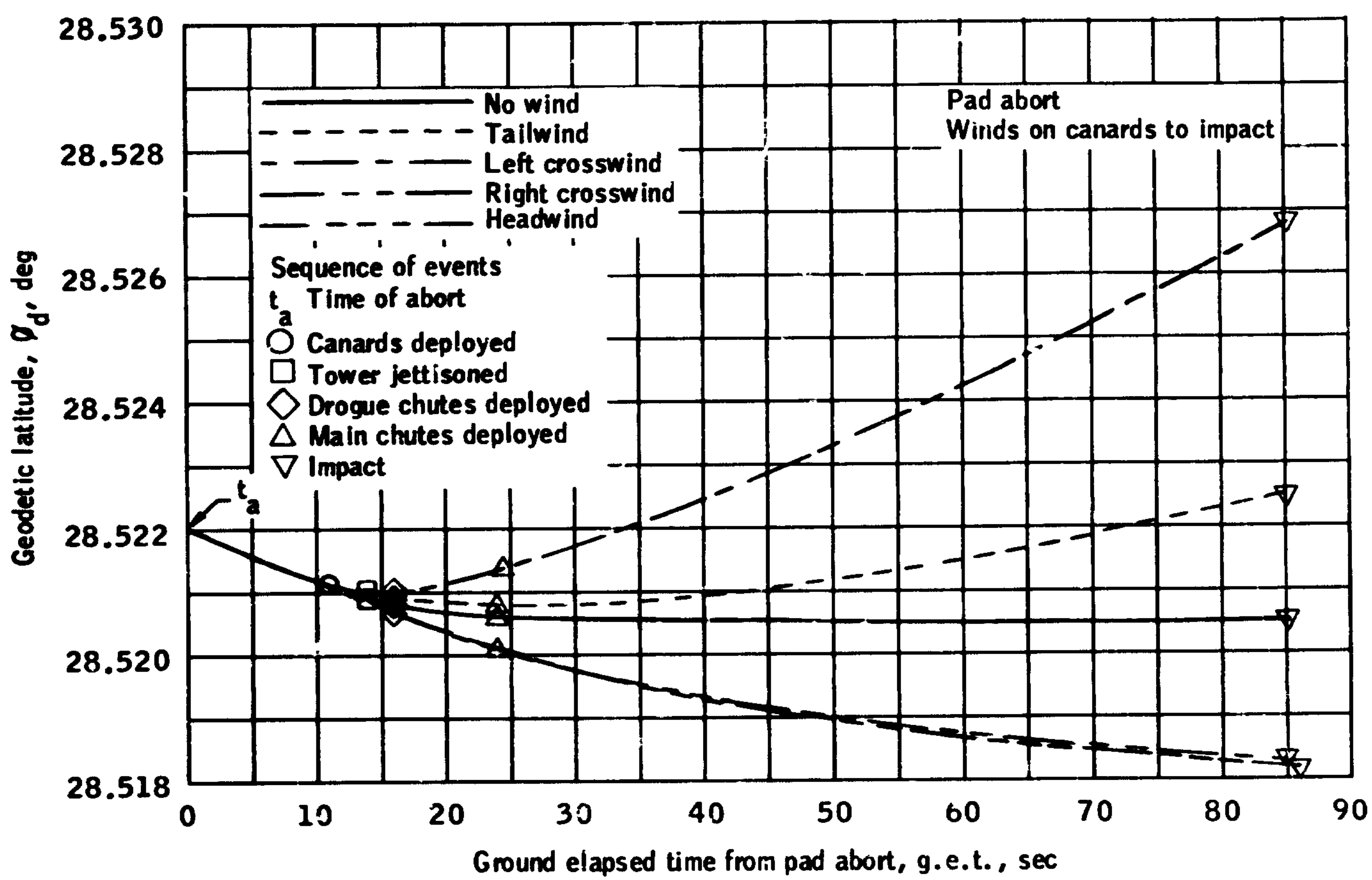
(d) Relative flight-path angle versus time.

Figure 14.- Continued.



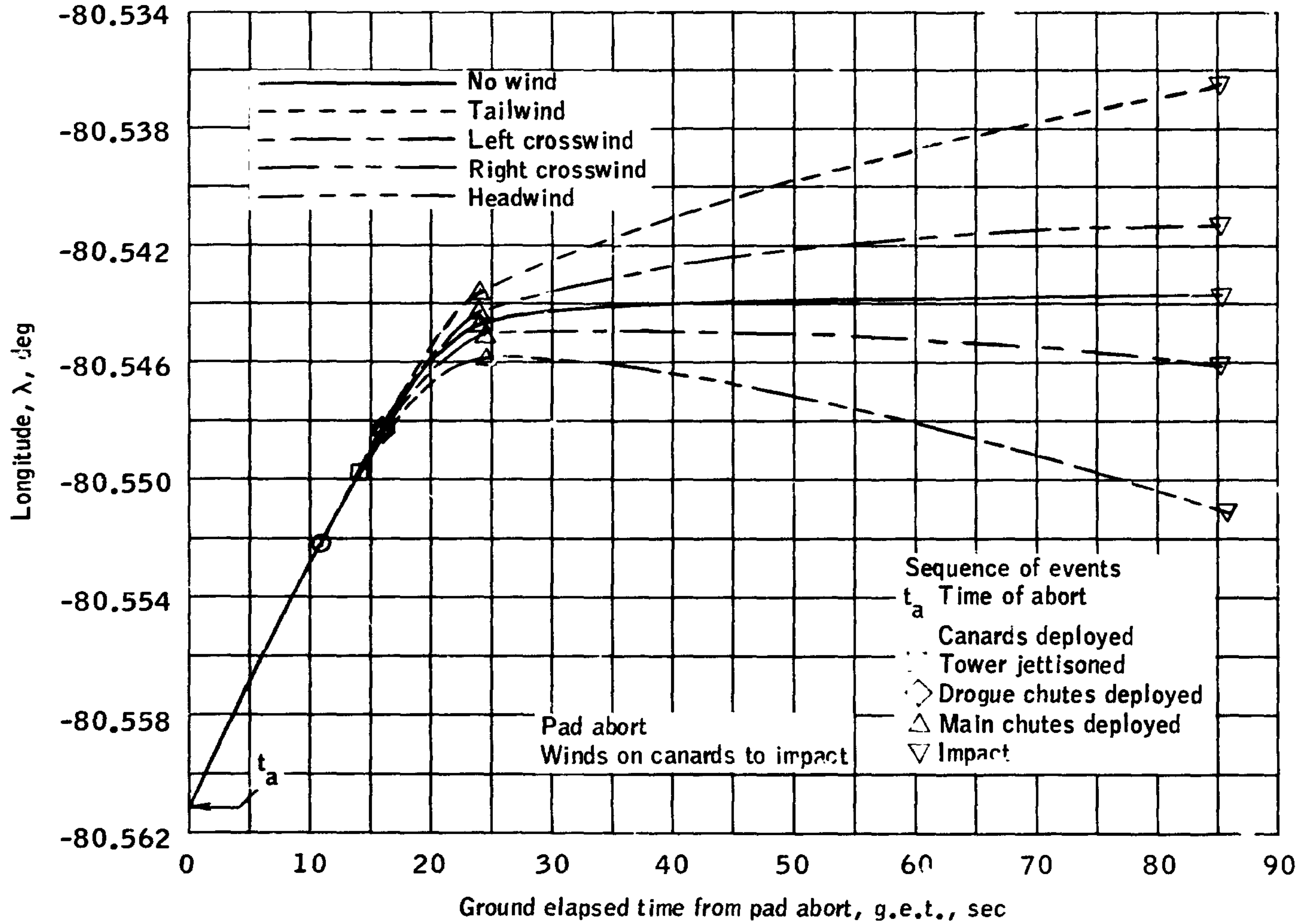
(e) Relative velocity versus time.

Figure 14.- Continued.



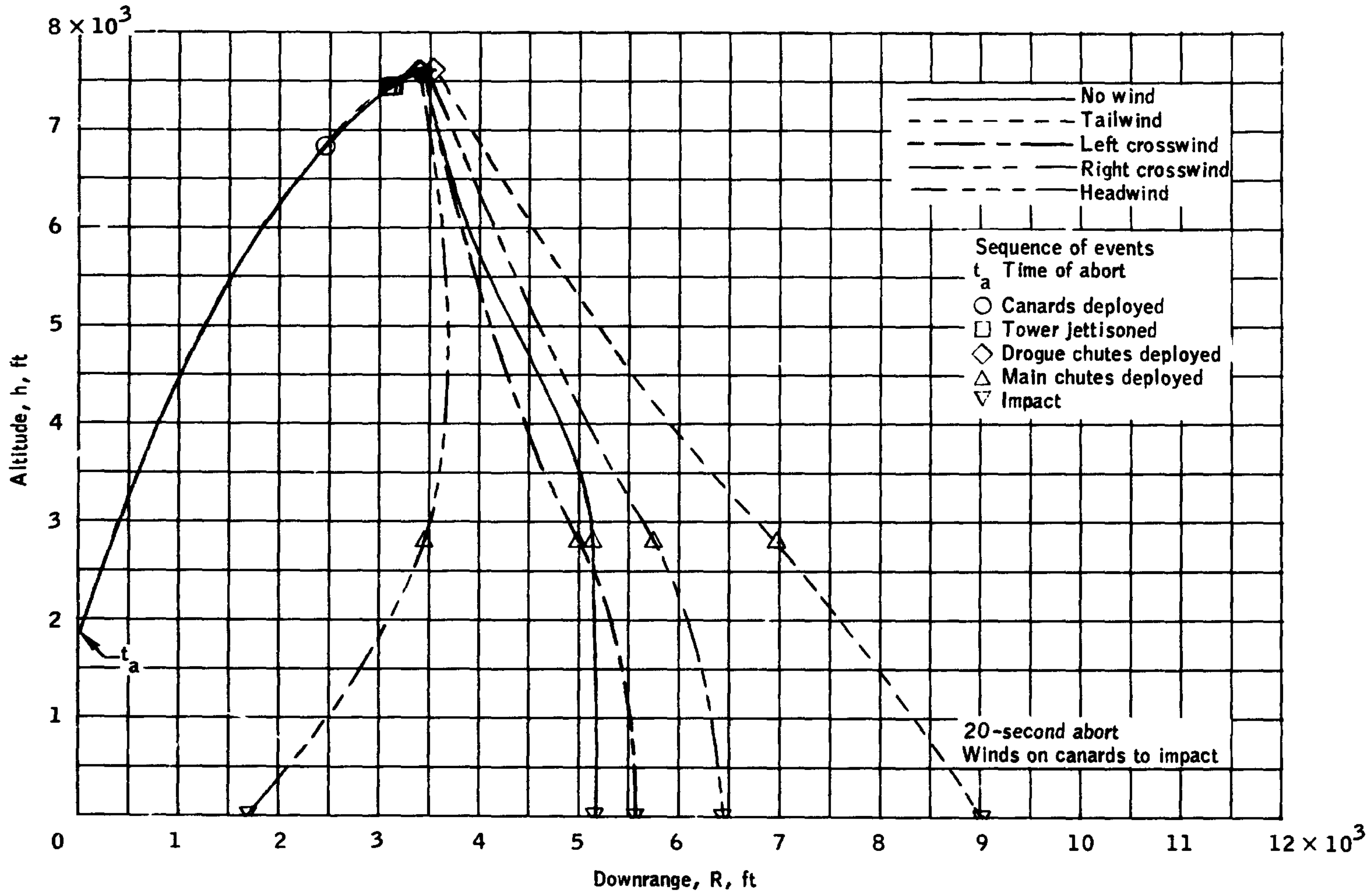
(f) Geodetic latitude versus time.

Figure 14.- Continued.



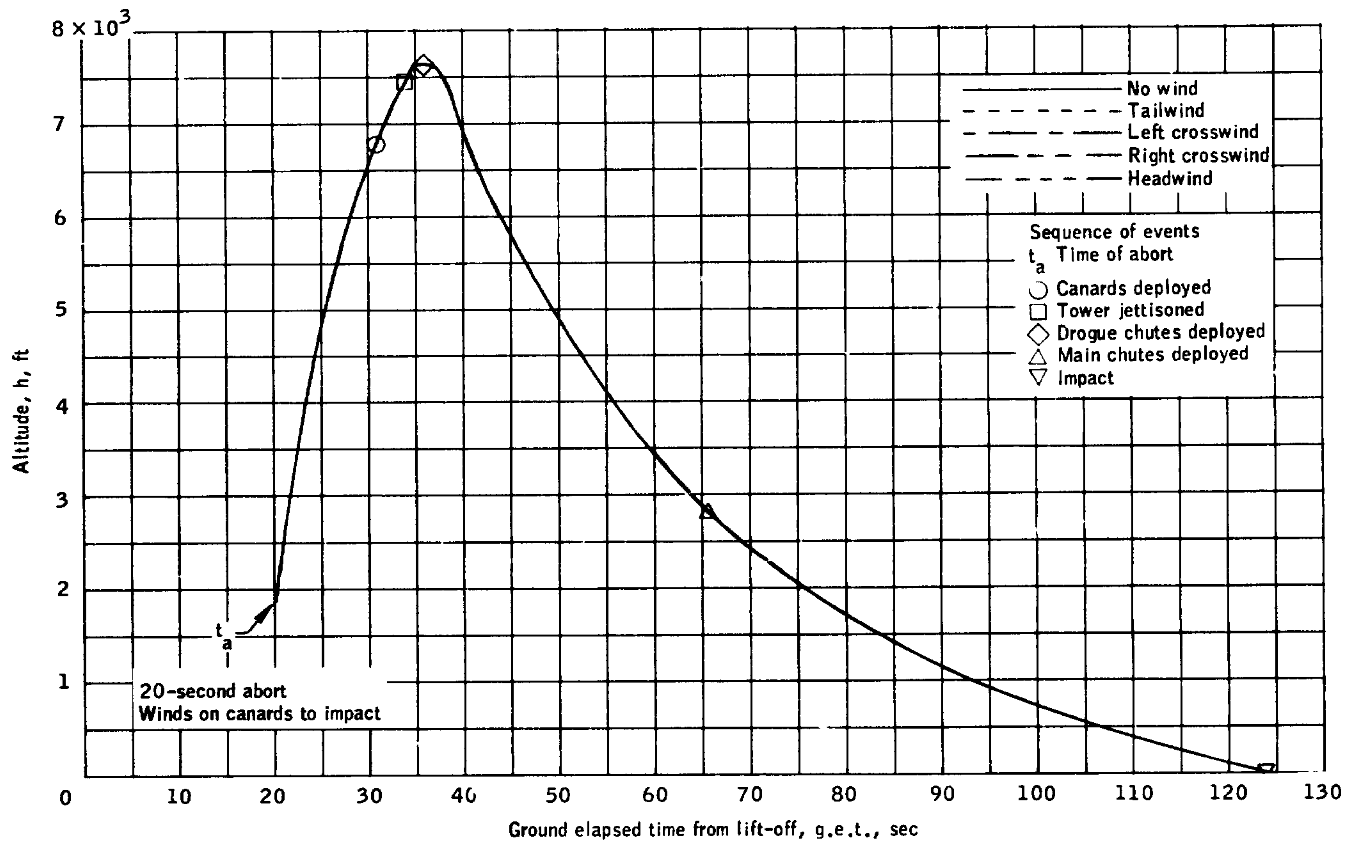
(g) Longitude versus time.

Figure 14.- Concluded.



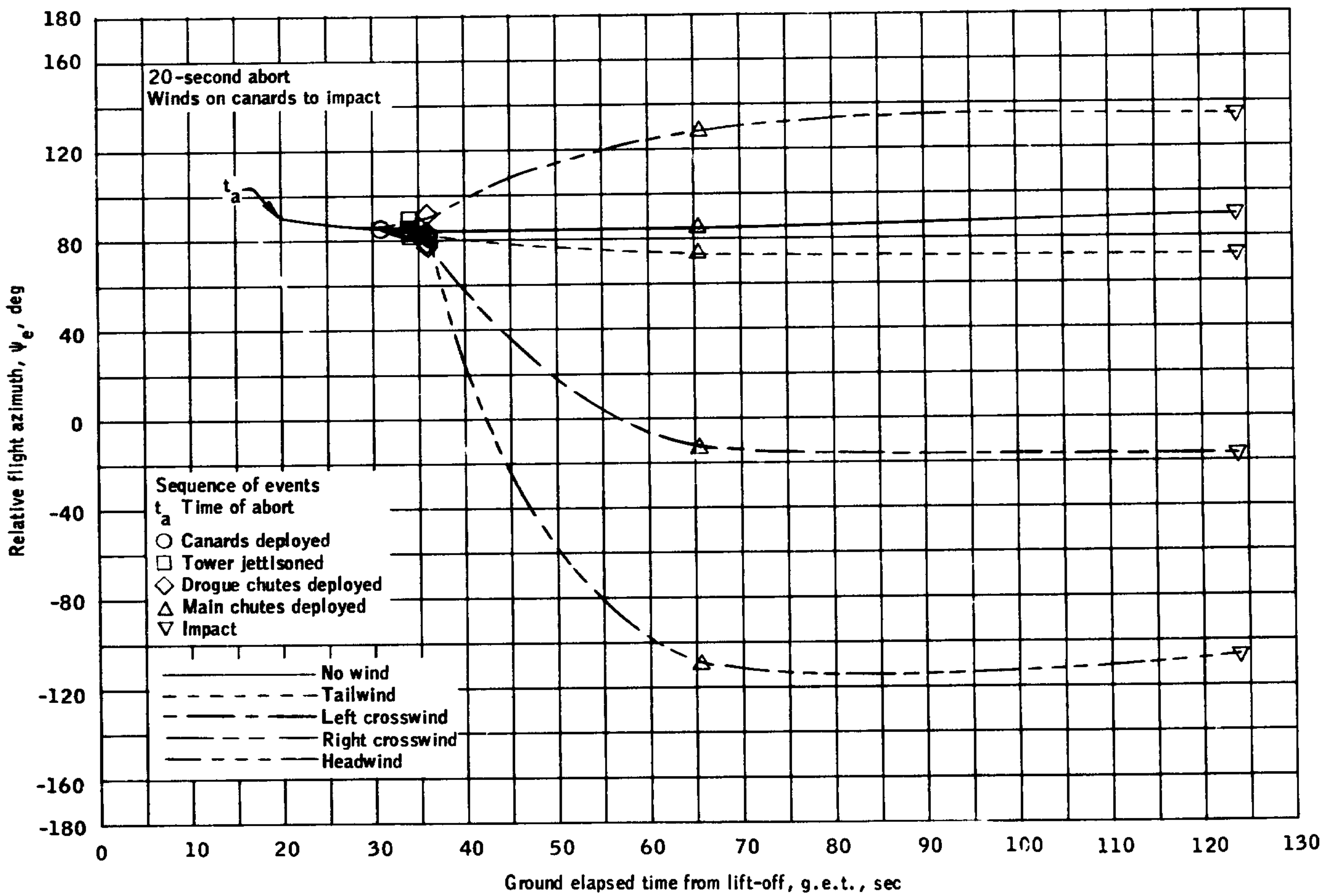
(a) Altitude versus downrange.

Figure 15.- Winds on canards to landing for a 20-second g.e.t. abort.



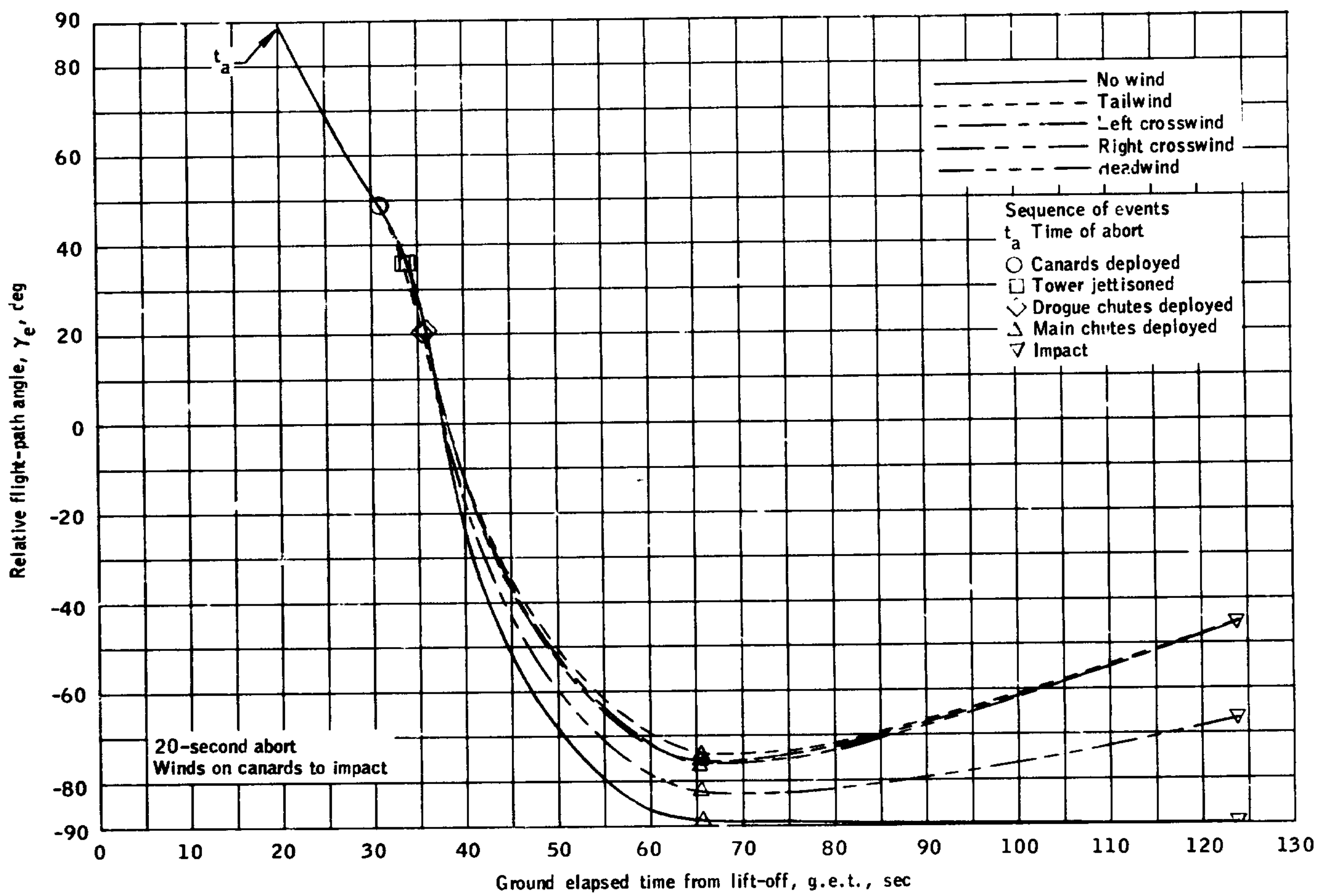
(b) Altitude versus time.

Figure 15.- Continued.



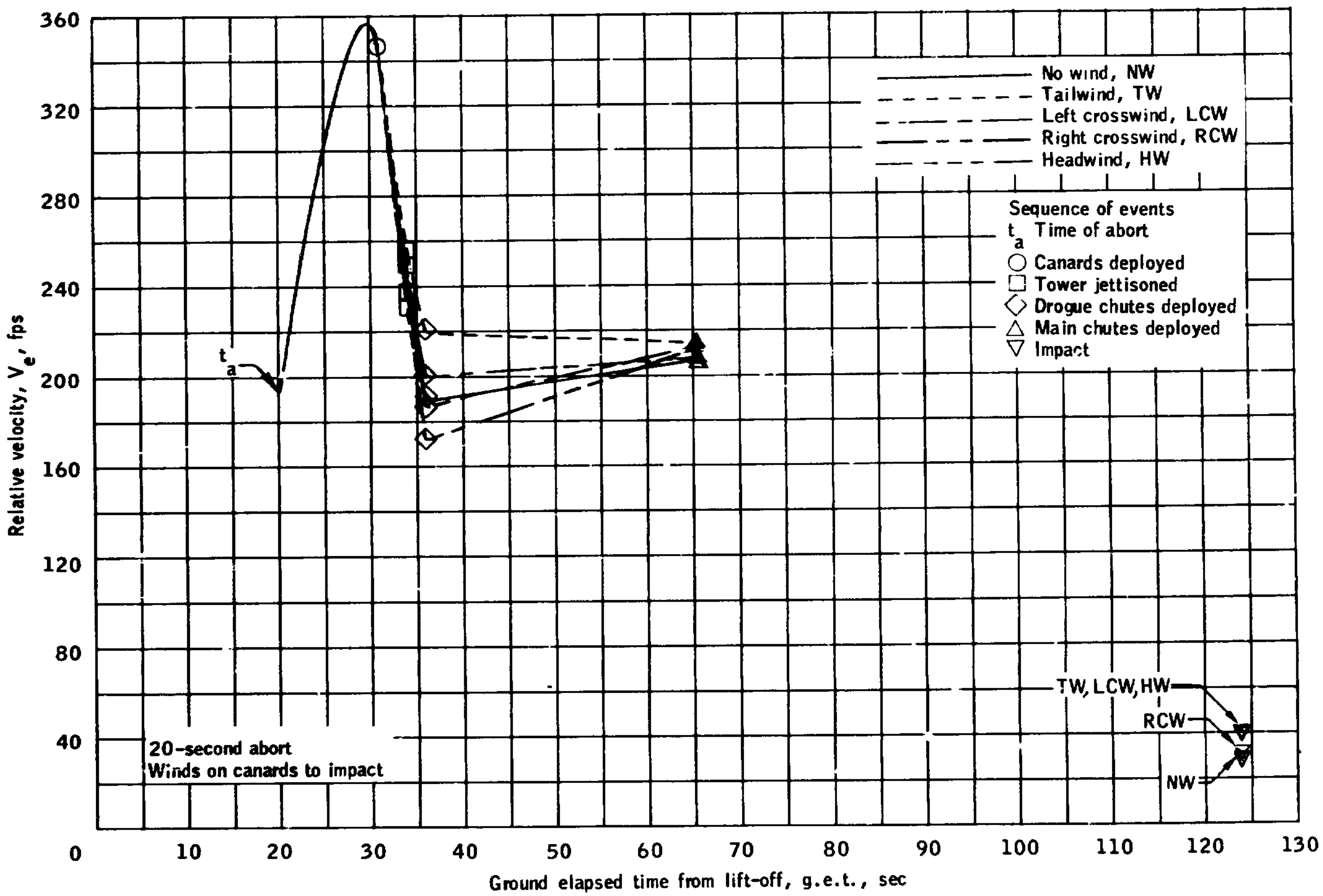
(c) Relative flight azimuth versus time.

Figure 15.- Continued.



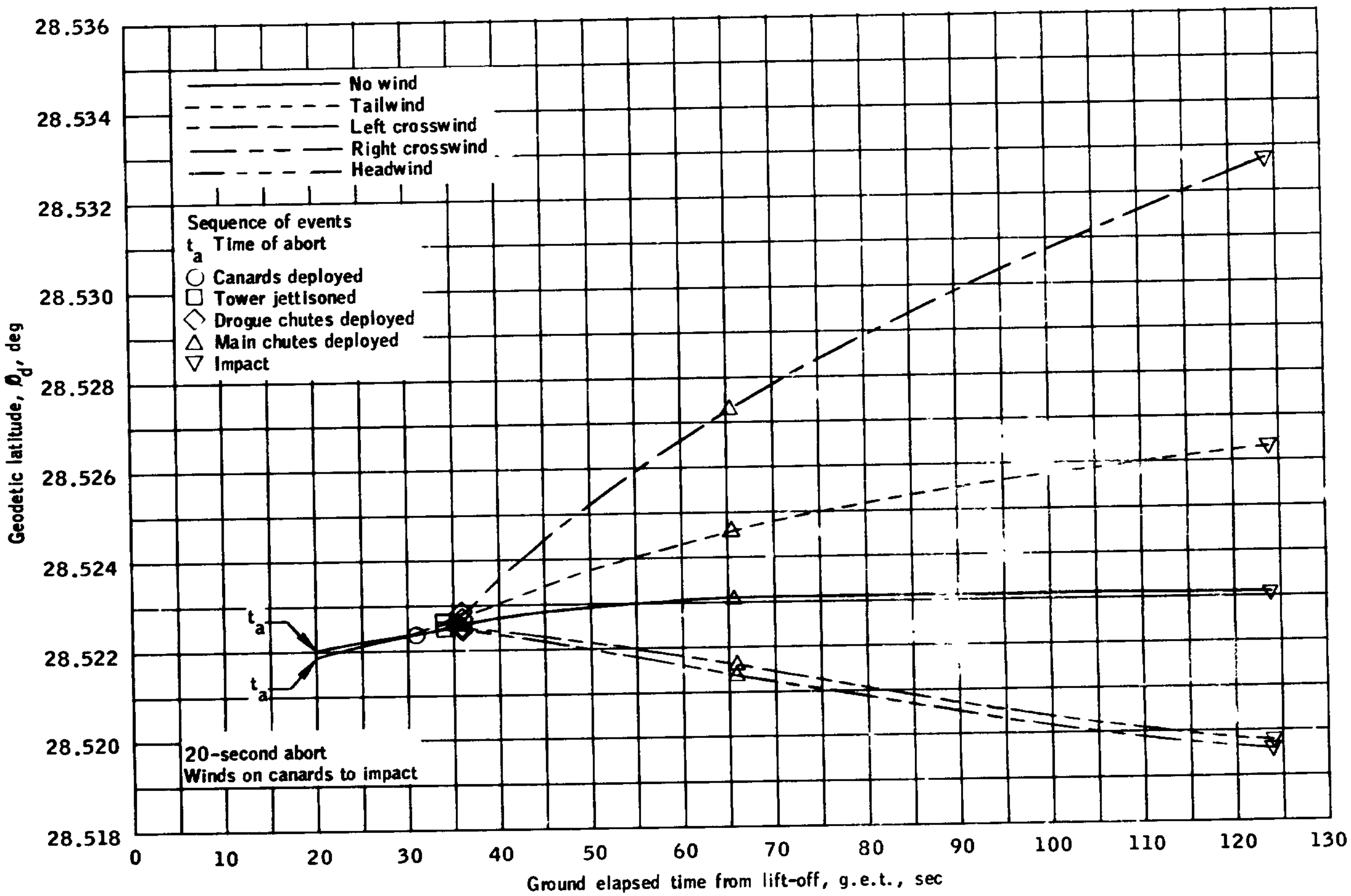
(d) Relative flight-path angle versus time.

Figure 15.- Continued.



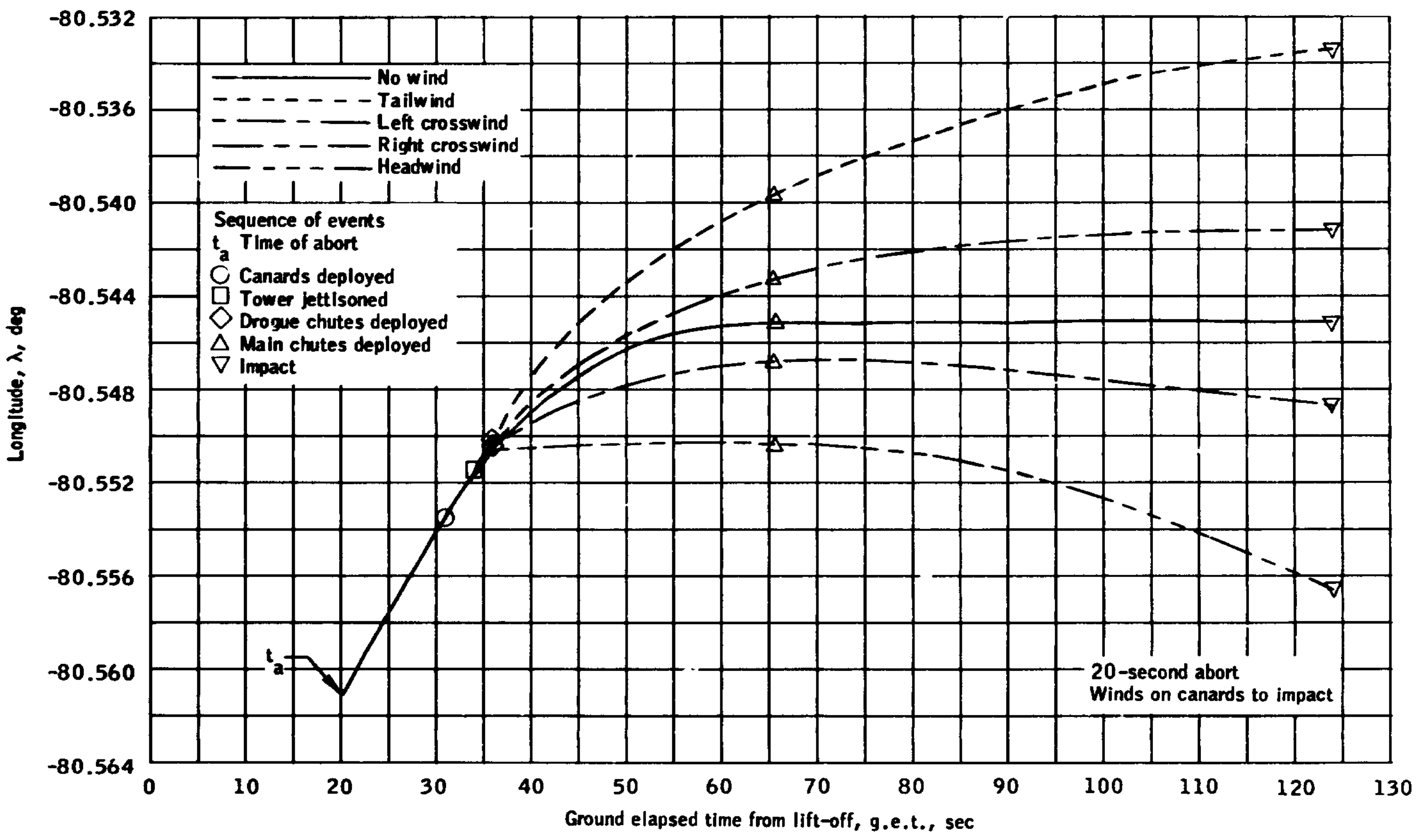
(e) Relative velocity versus time.

Figure 15.- Continued.



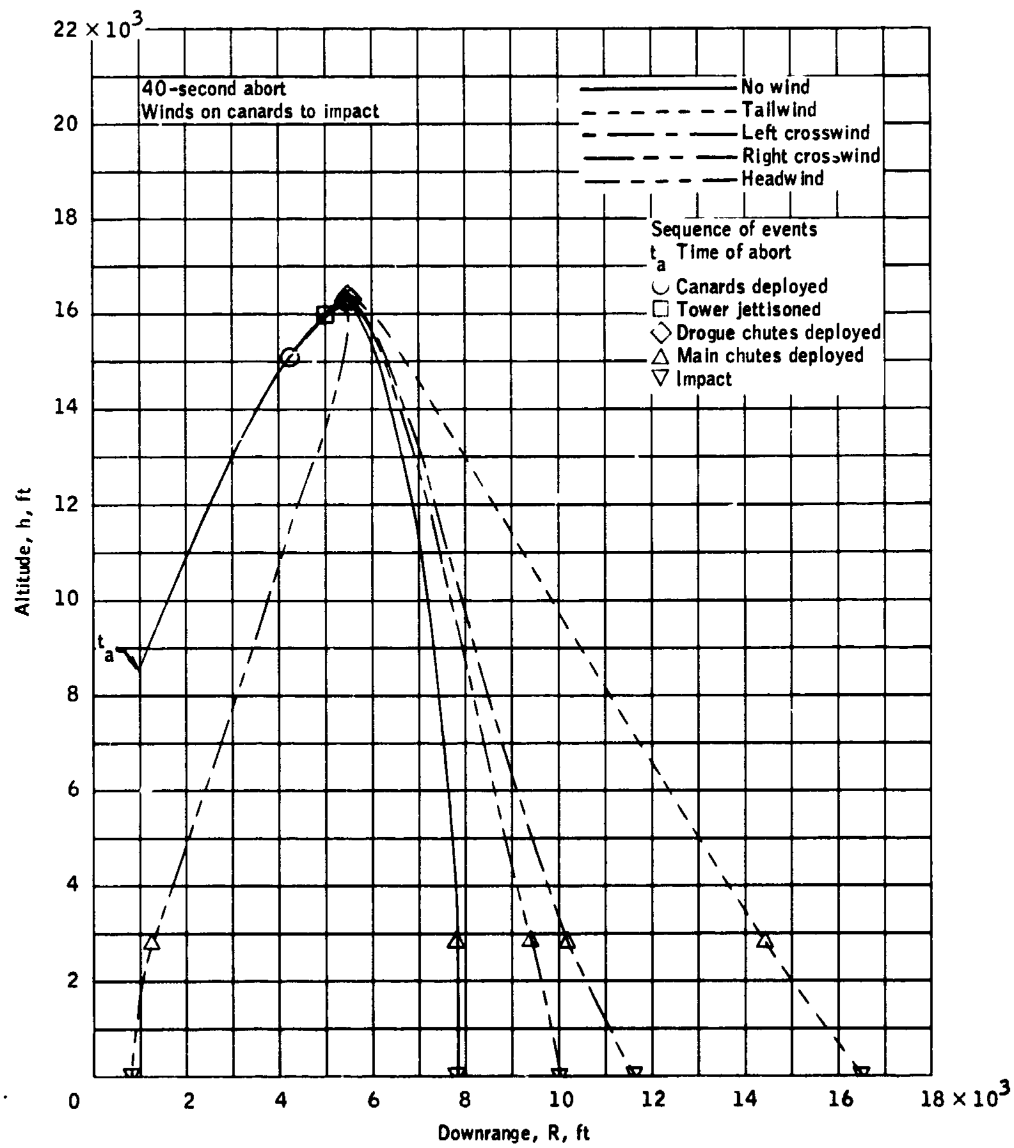
(f) Geodetic latitude versus time.

Figure 15.- Continued.



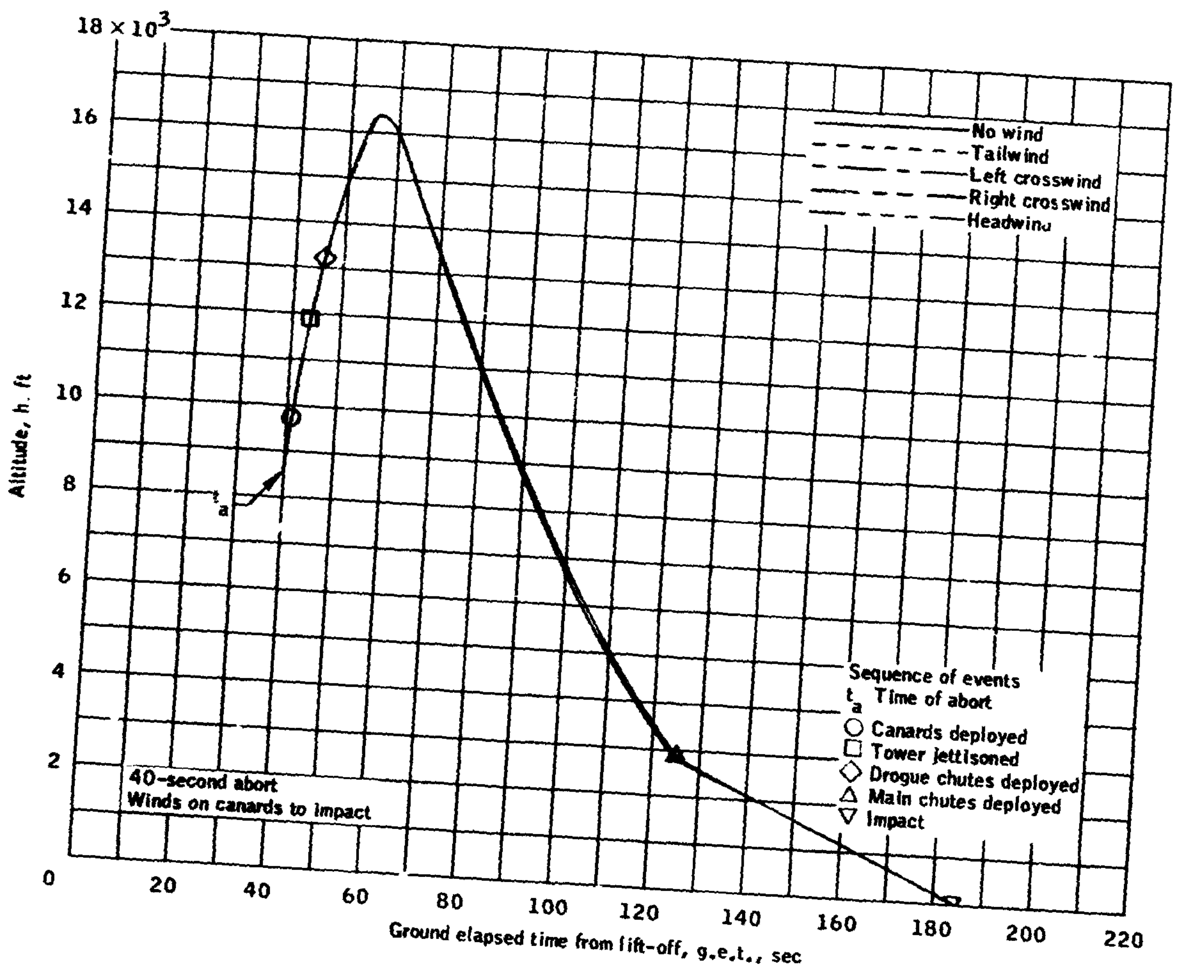
(g) Longitude versus time.

Figure 15.- Concluded.



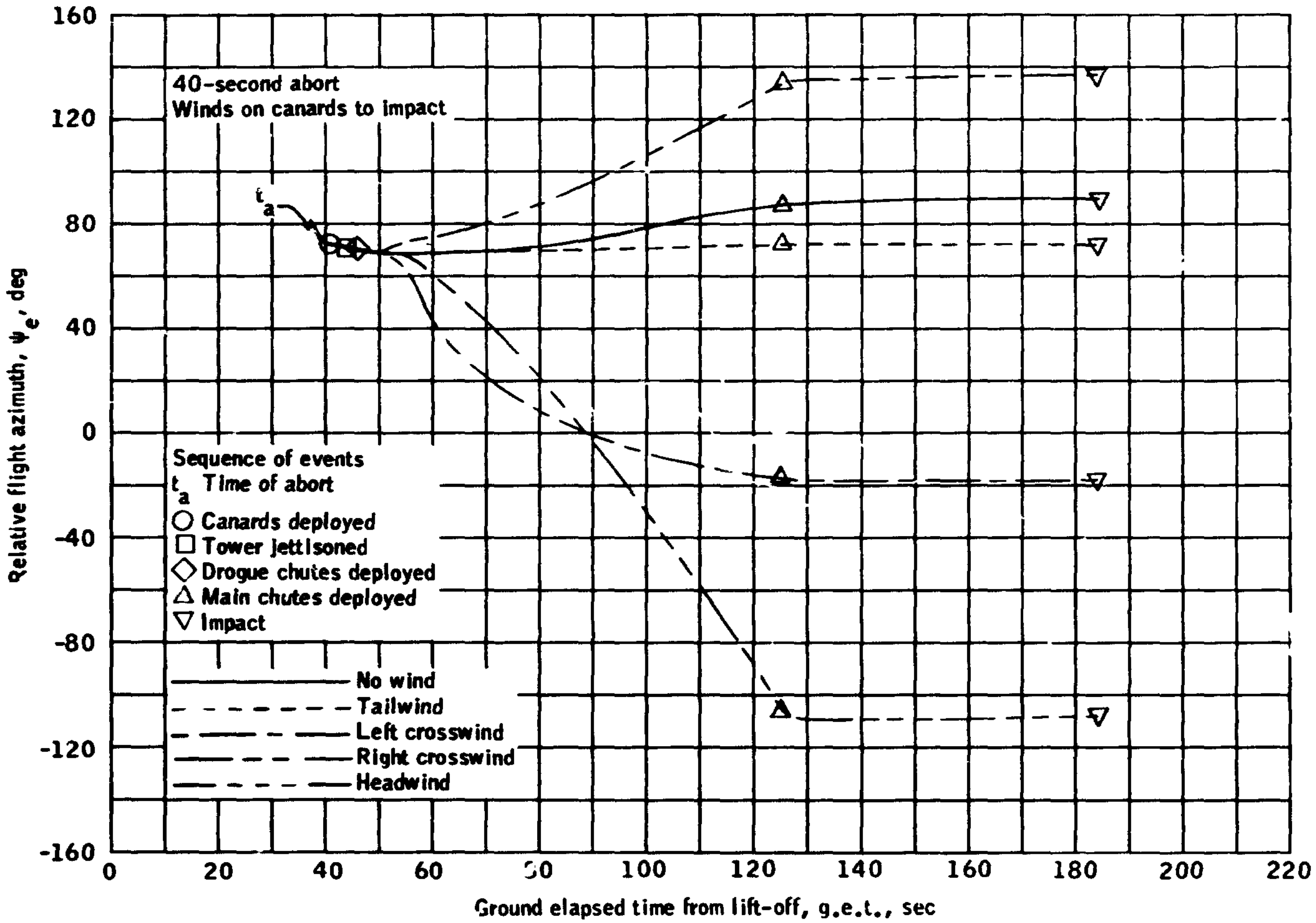
(a) Altitude versus downrange.

Figure 16.- Winds on canards to landing for a 40-second g.e.t. abort.



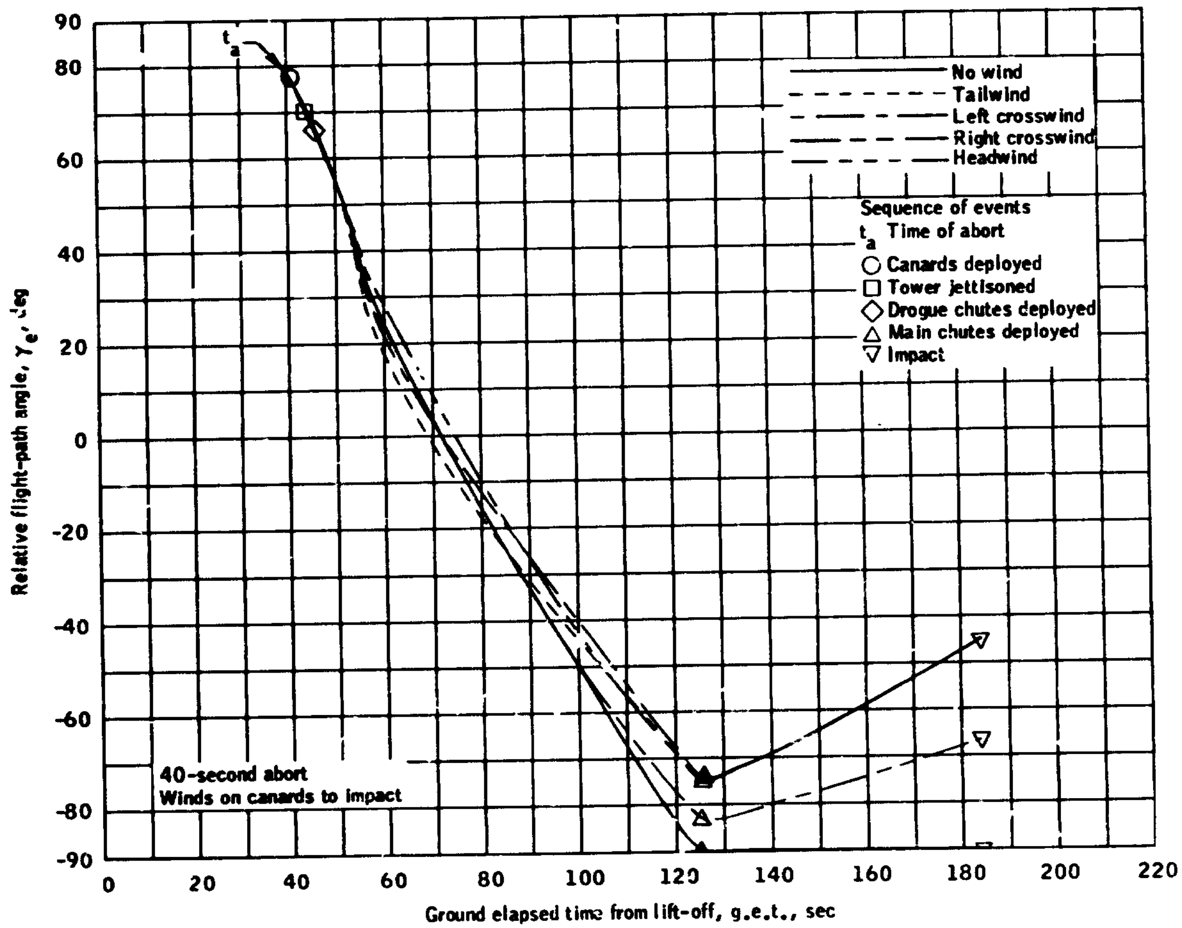
(b) Altitude versus time.

Figure 16.- Continued.



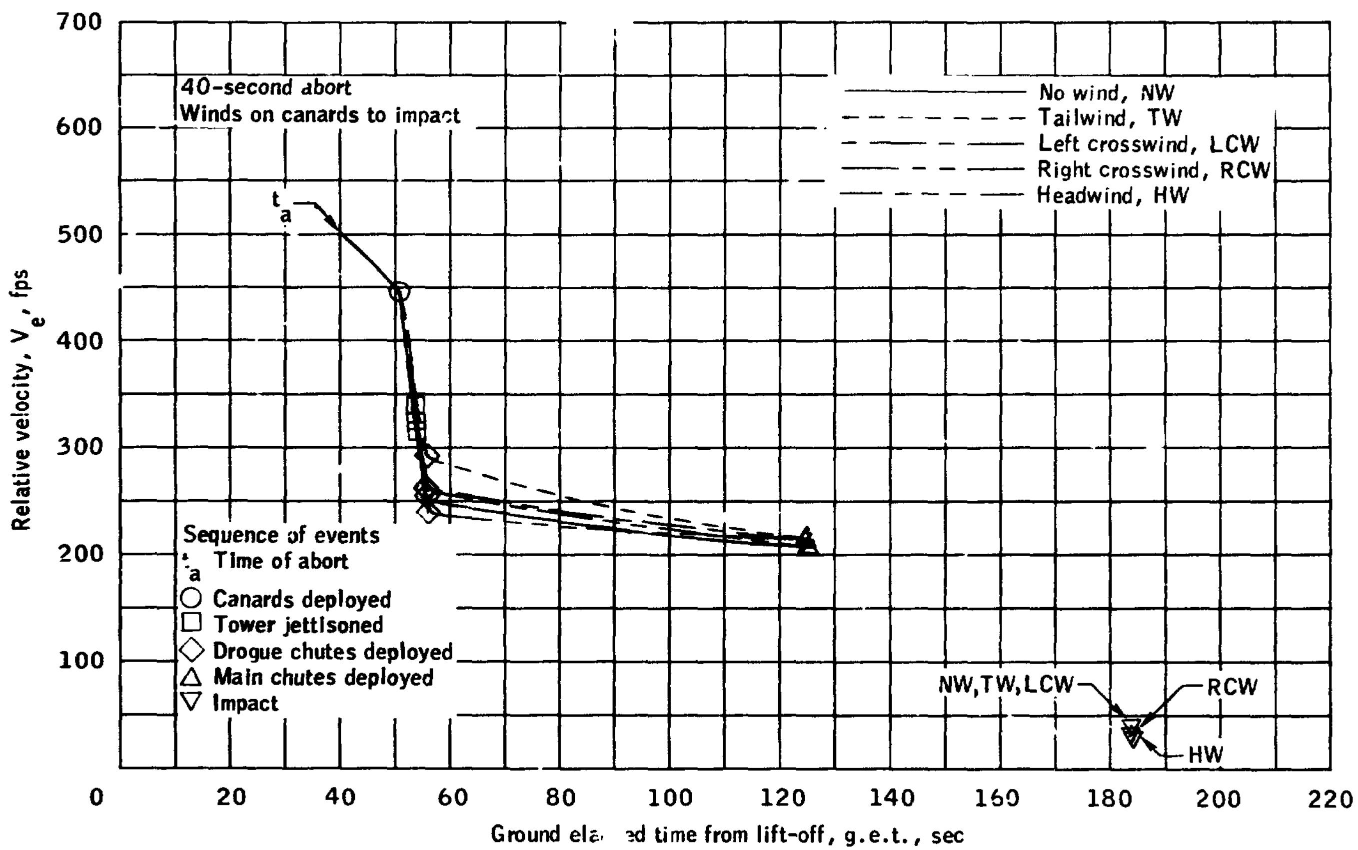
(c) Relative flight azimuth versus time.

Figure 16.- Continued.



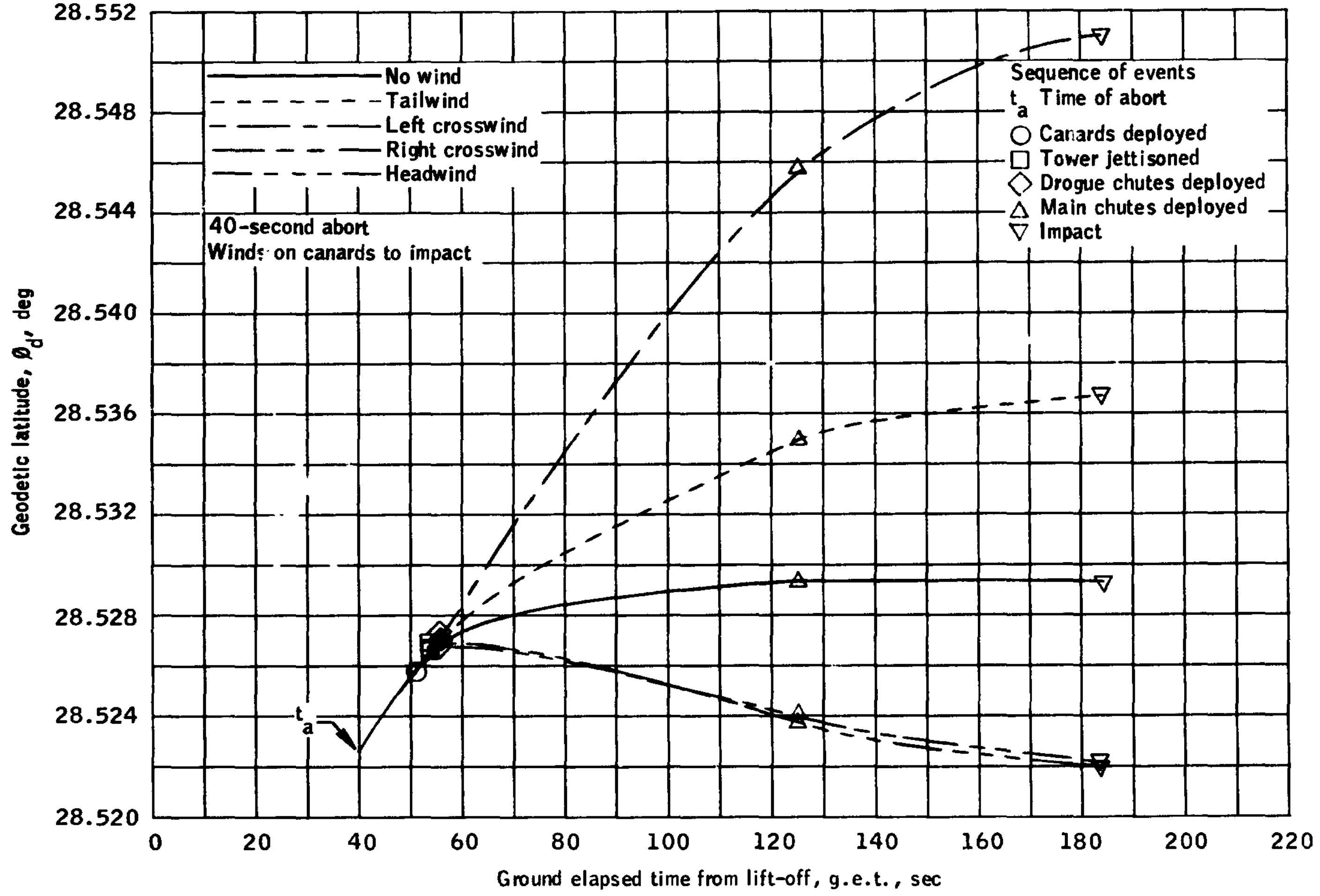
(d) Relative flight-path angle versus time.

Figure 16.- Continued.



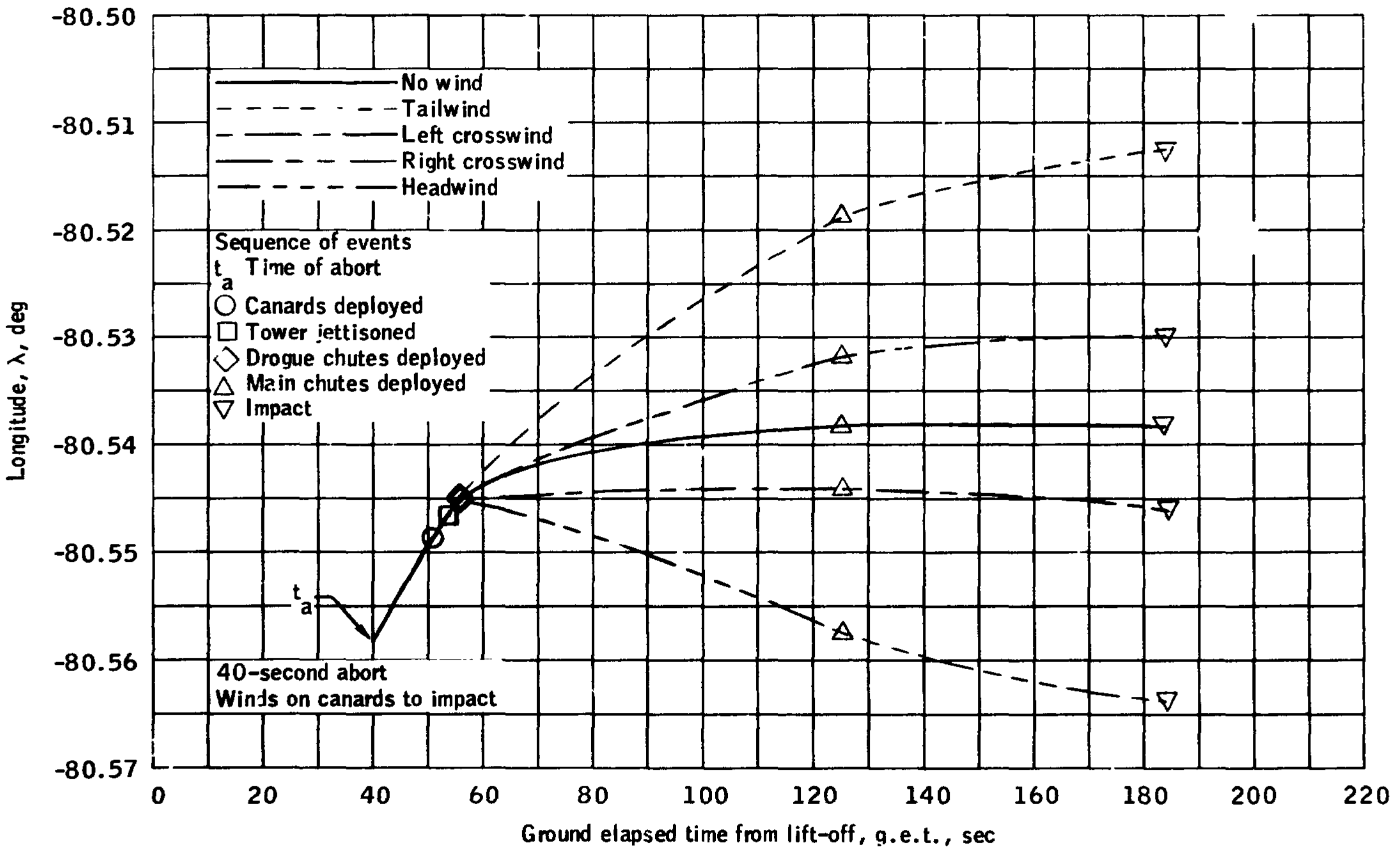
(e) Relative velocity versus time.

Figure 16.- Continued.



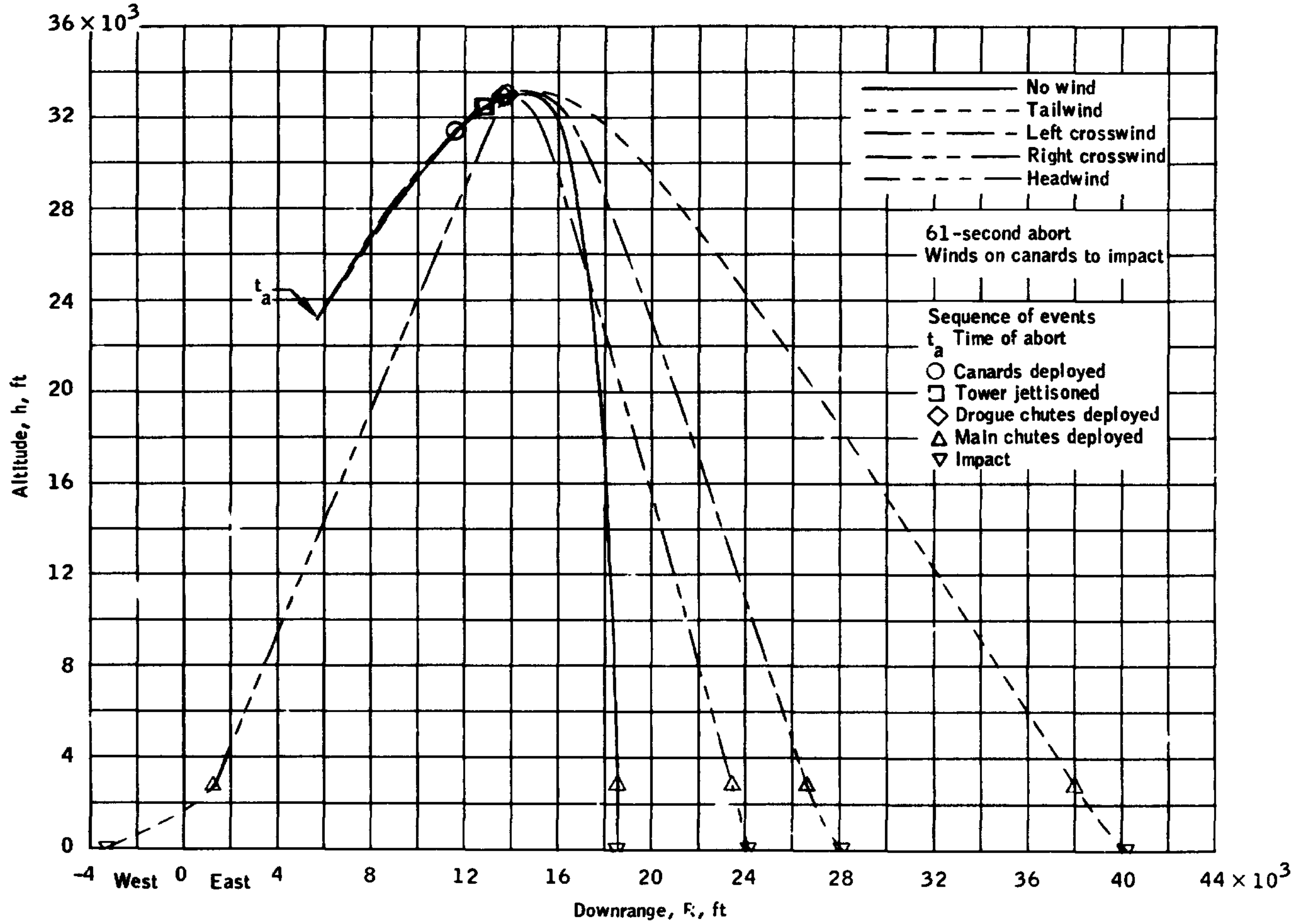
(f) Geodetic latitude versus time.

Figure 16.- Continued.



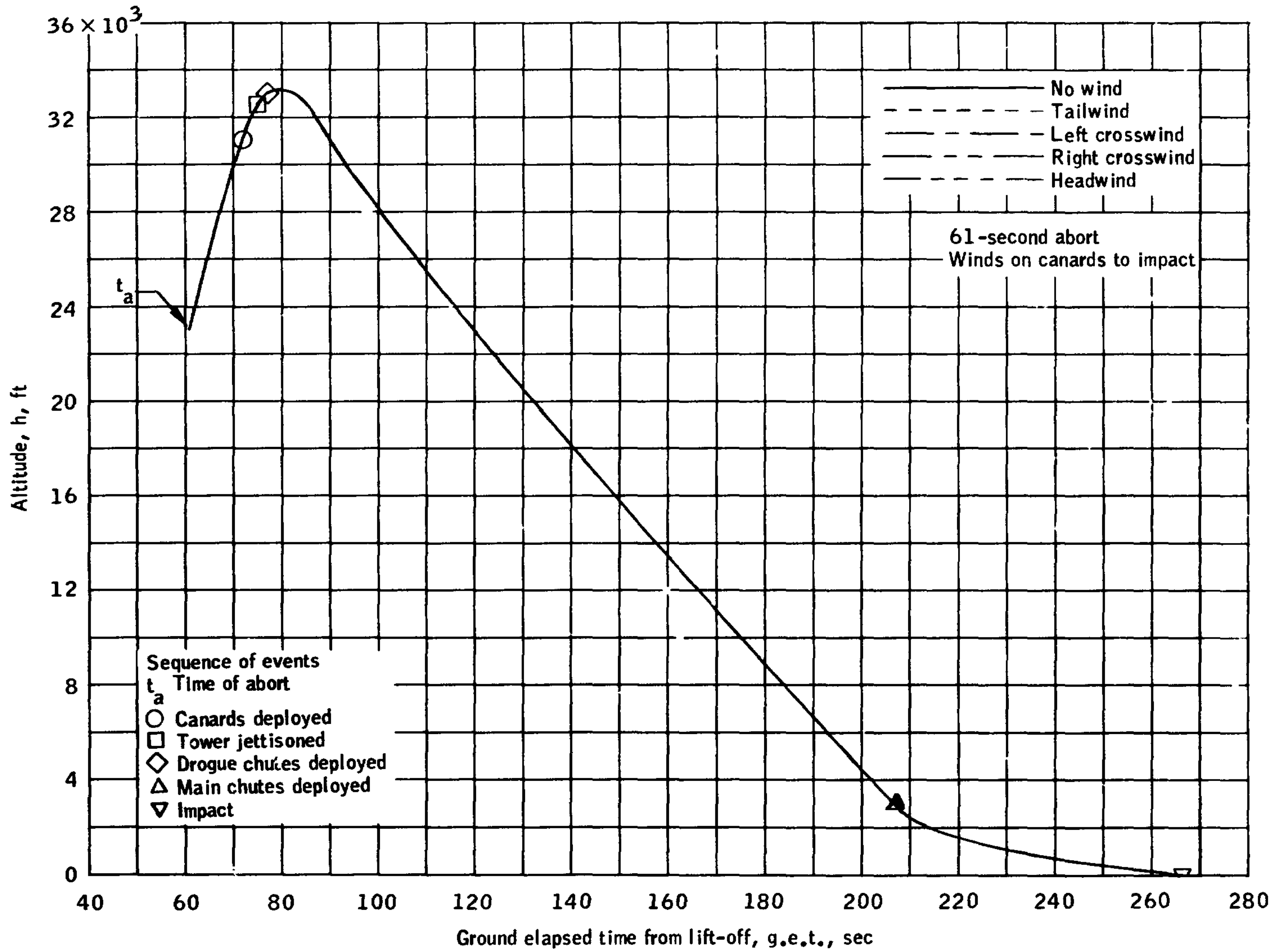
(g) Long .ude versus time.

Figure 16.- Concluded.



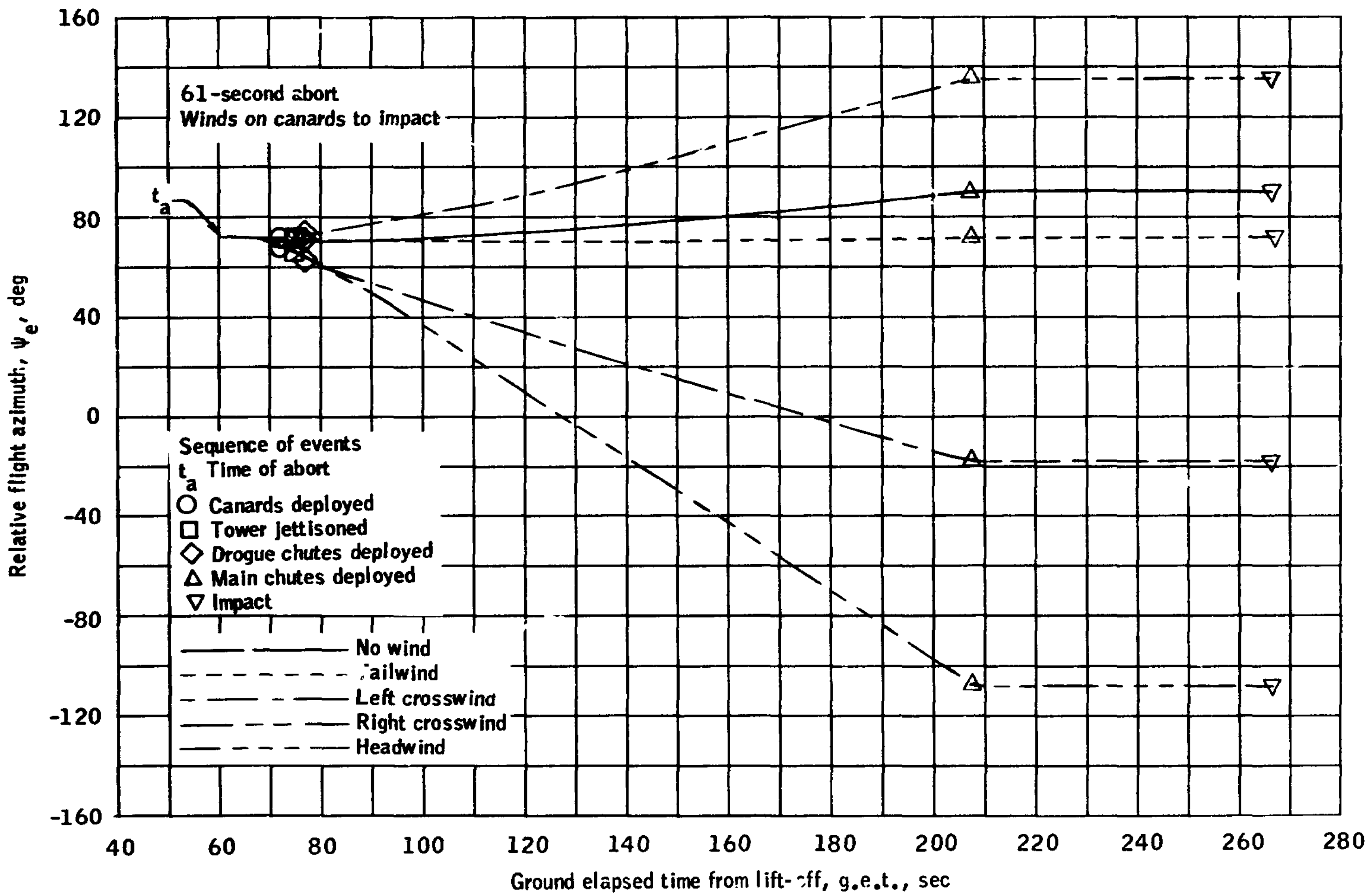
(a) Altitude versus downrange.

Figure 17.- Winds on canards to landing for a 61-second g.e.t. abort.



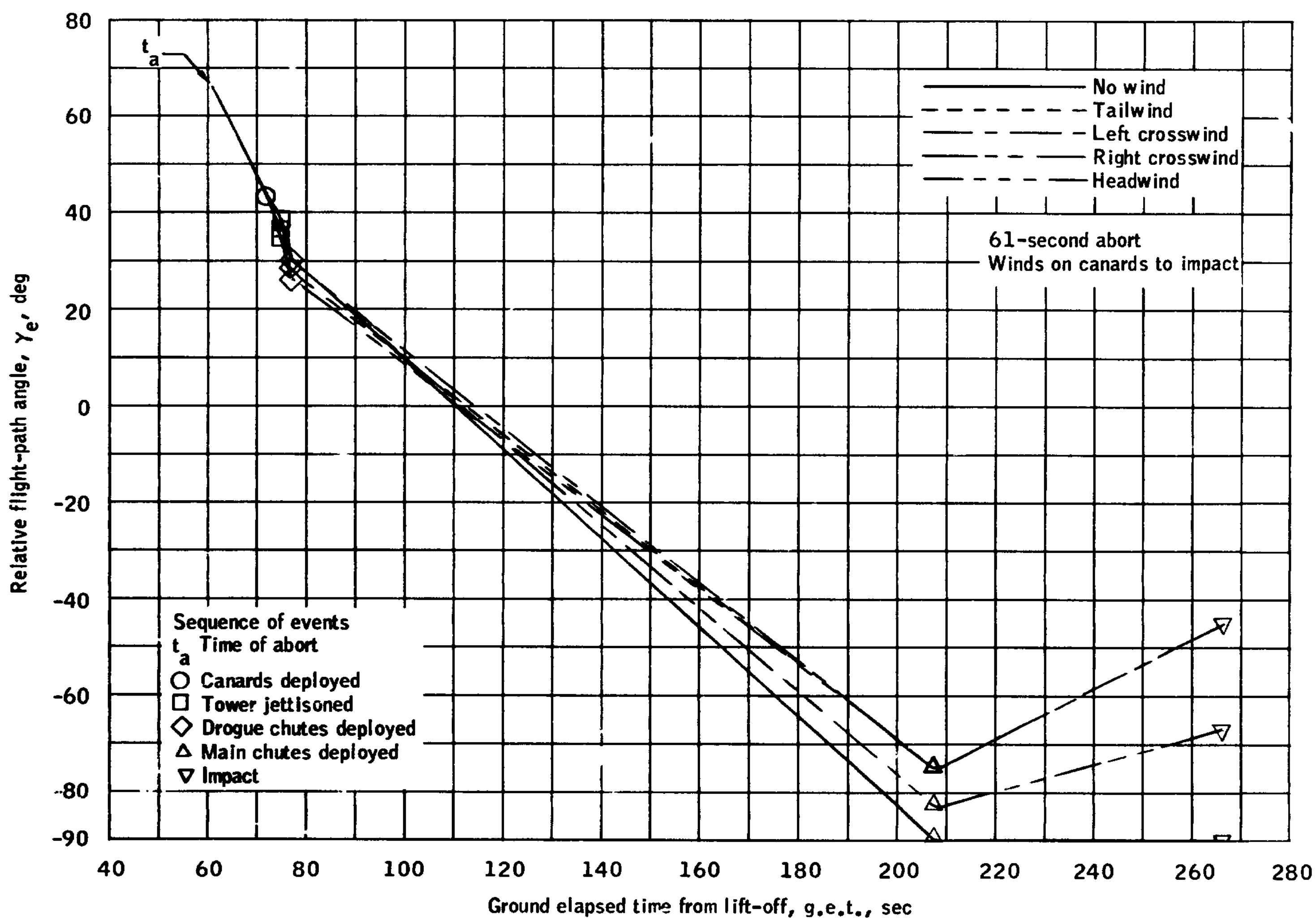
(b) Altitude versus time.

Figure 17.- Continued.



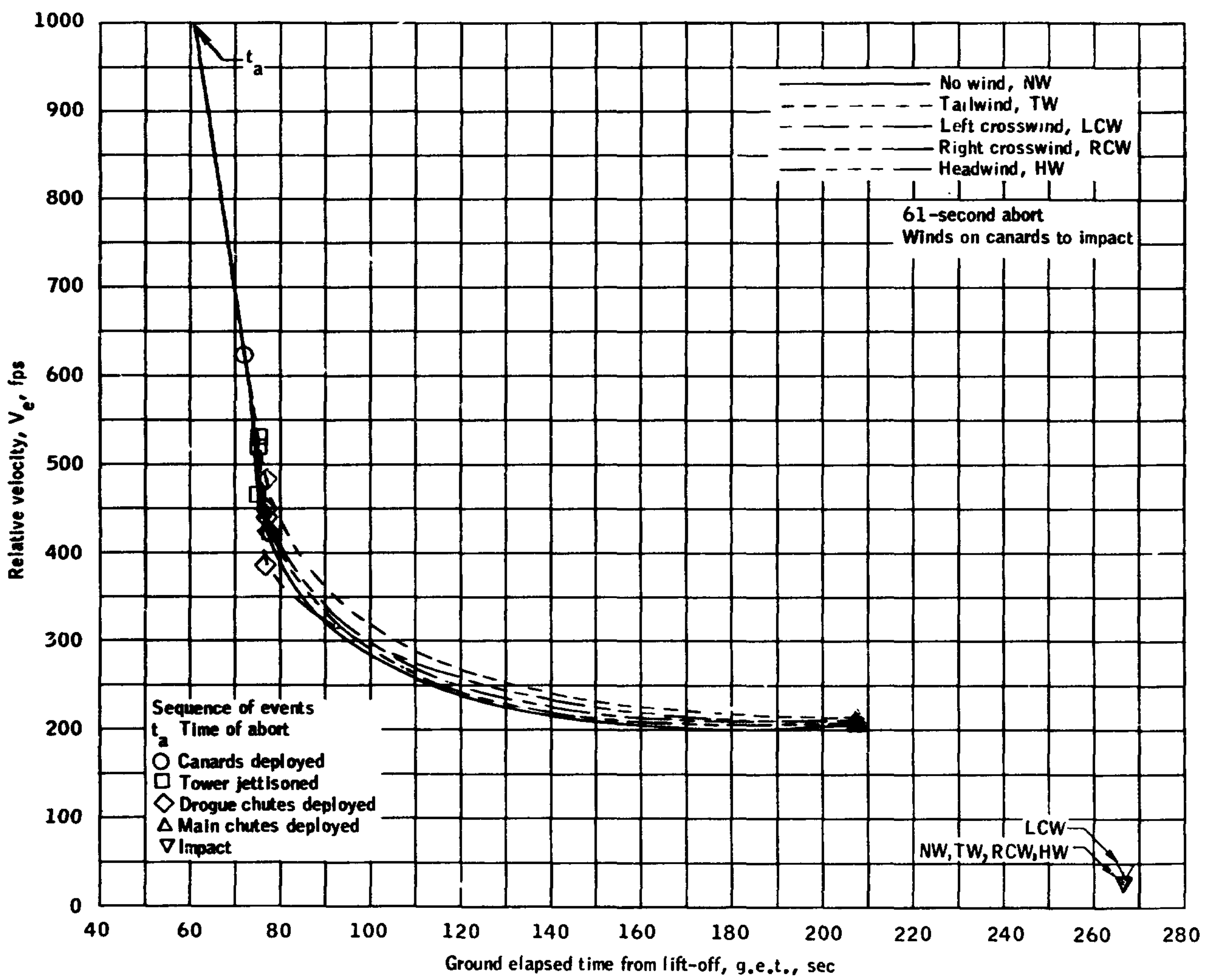
(c) Relative flight azimuth versus time.

Figure 17.- Continued.



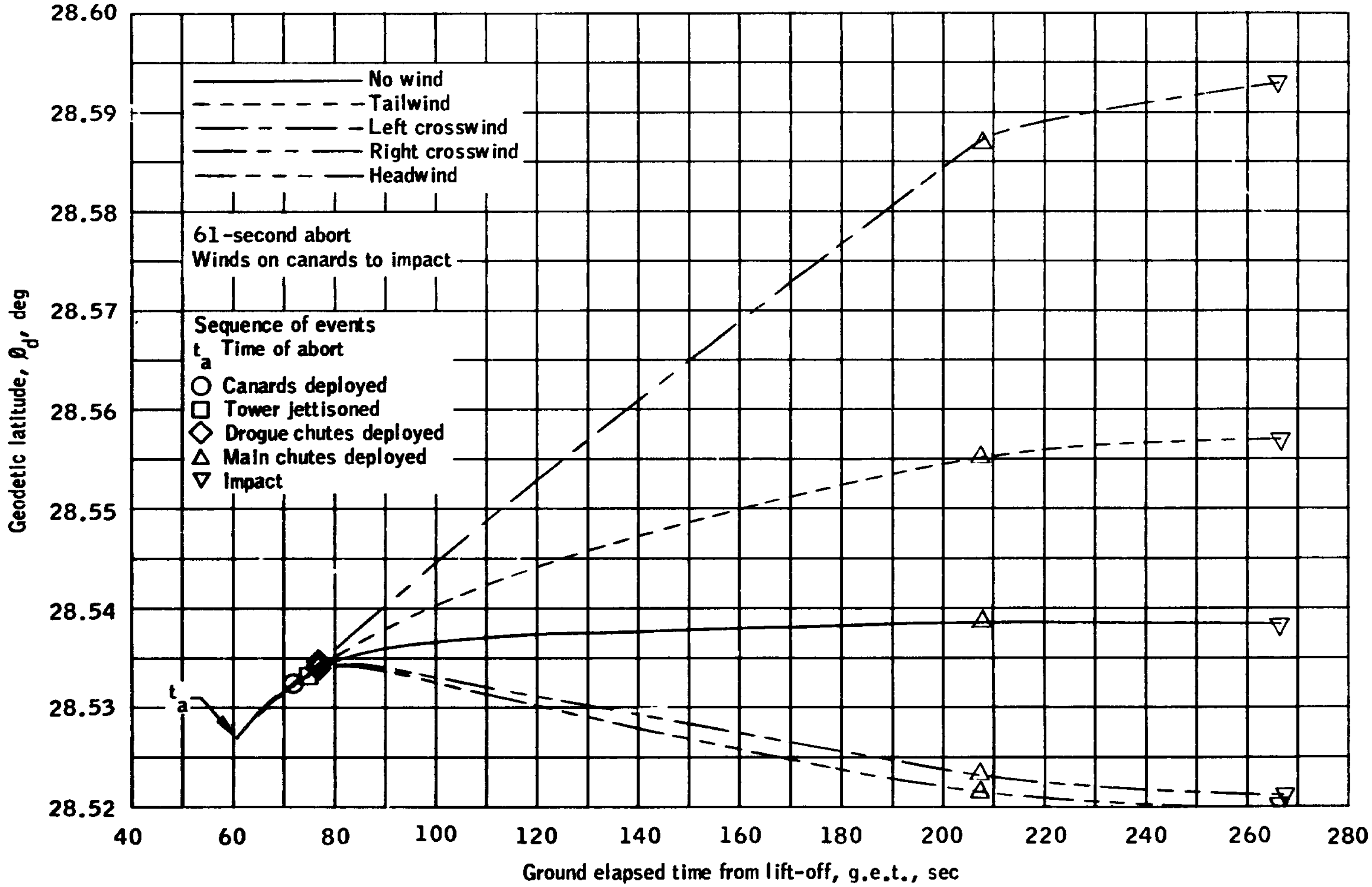
(d) Relative flight-path angle versus time.

Figure 17.- Continued.



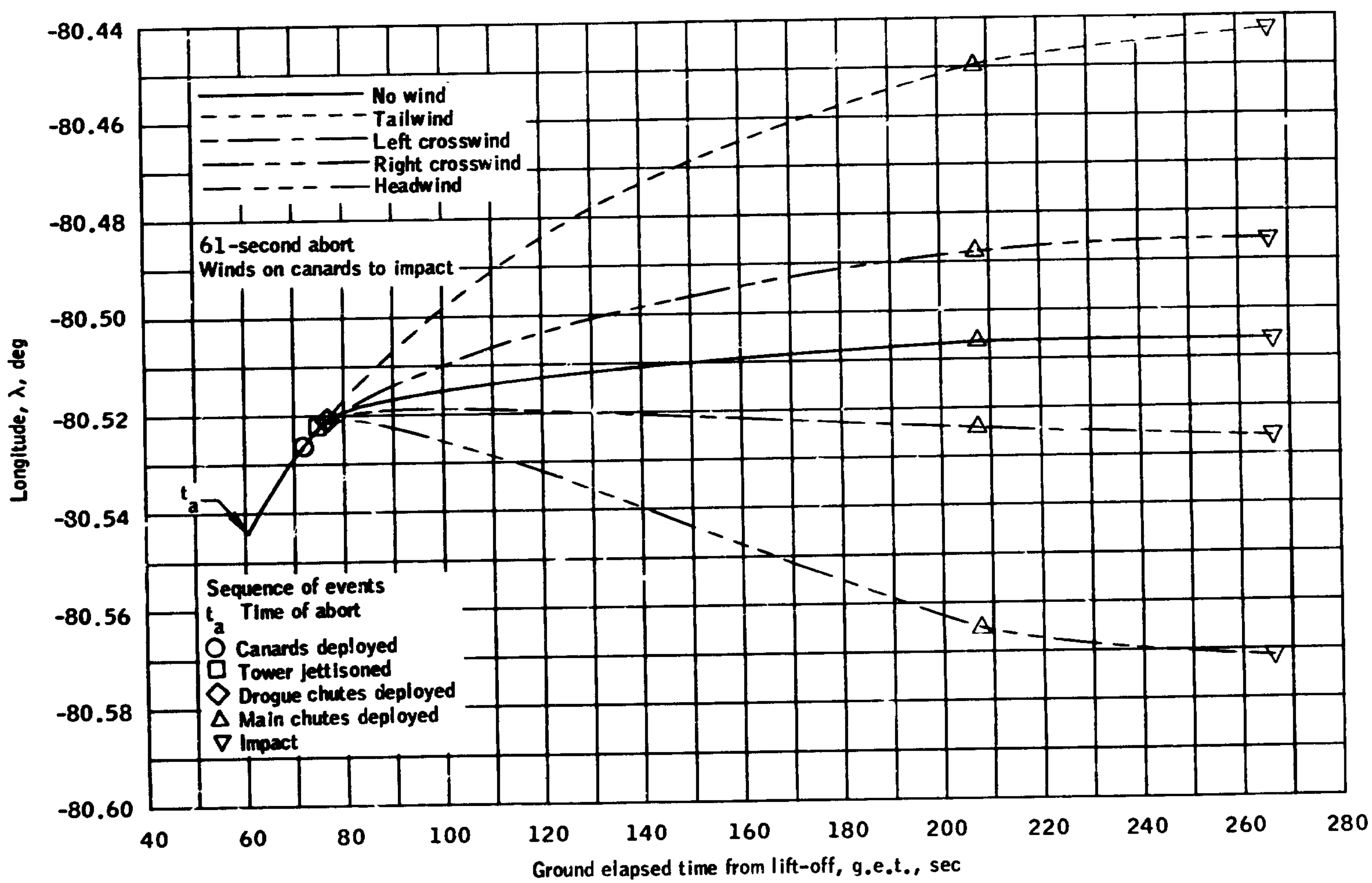
(e) Relative velocity versus time.

Figure 17.- Continued.



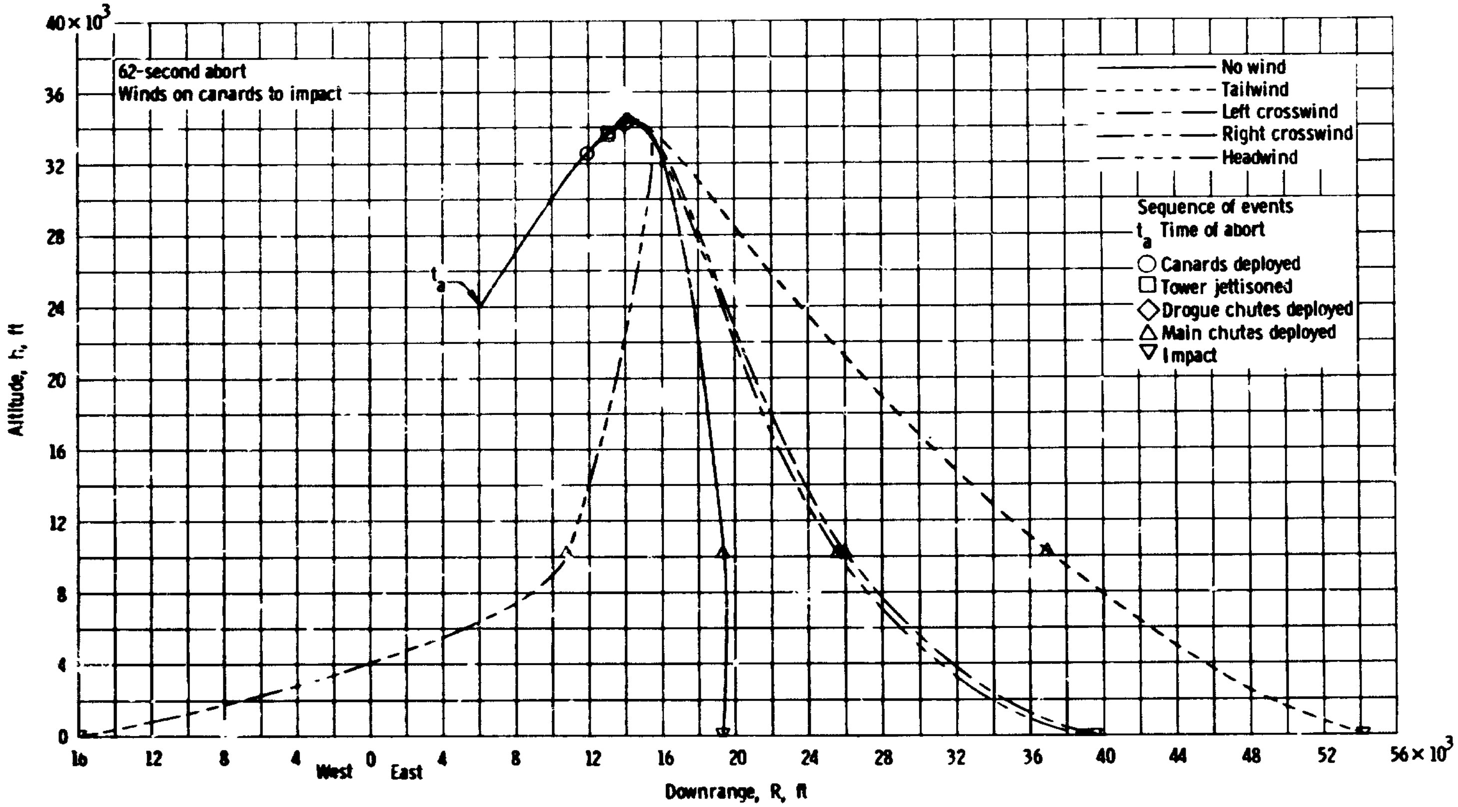
(f) Geodetic latitude versus time.

Figure 17.- Continued.



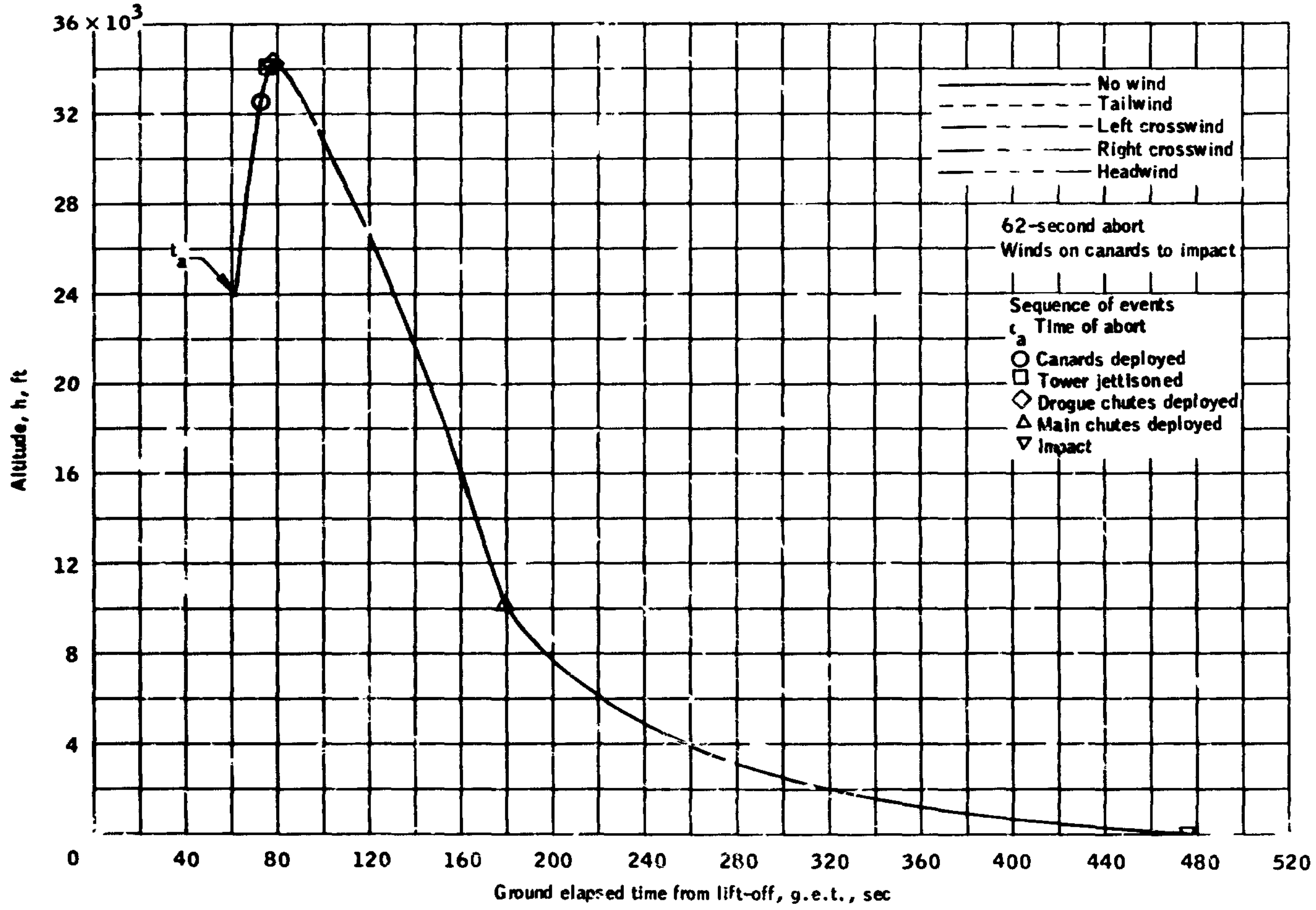
(g) Longitude versus time.

Figure 17.- Concluded.



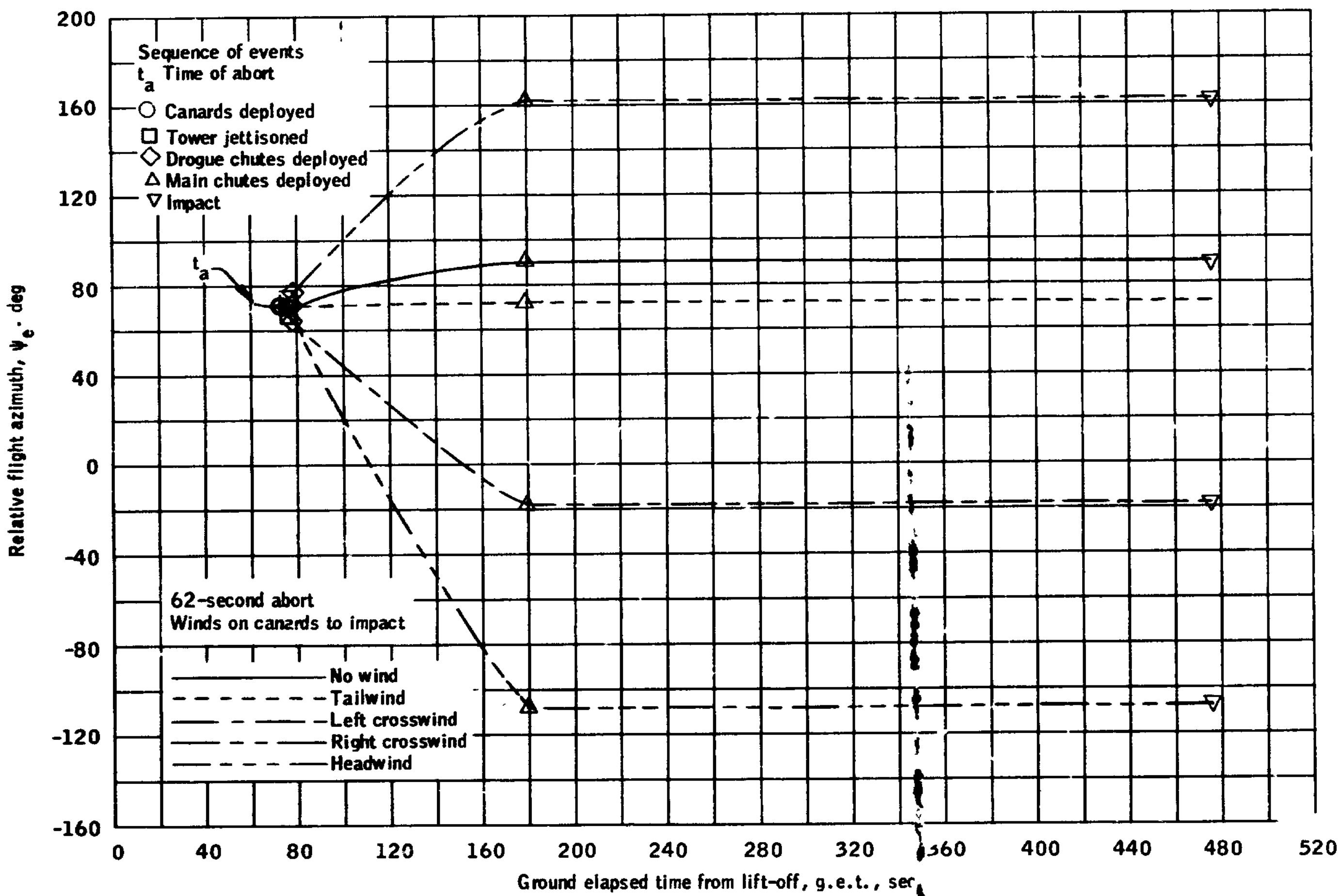
(a) Altitude versus downrange.

Figure 18.- Winds on canards to landing for a 62-second g.e.t. abort.



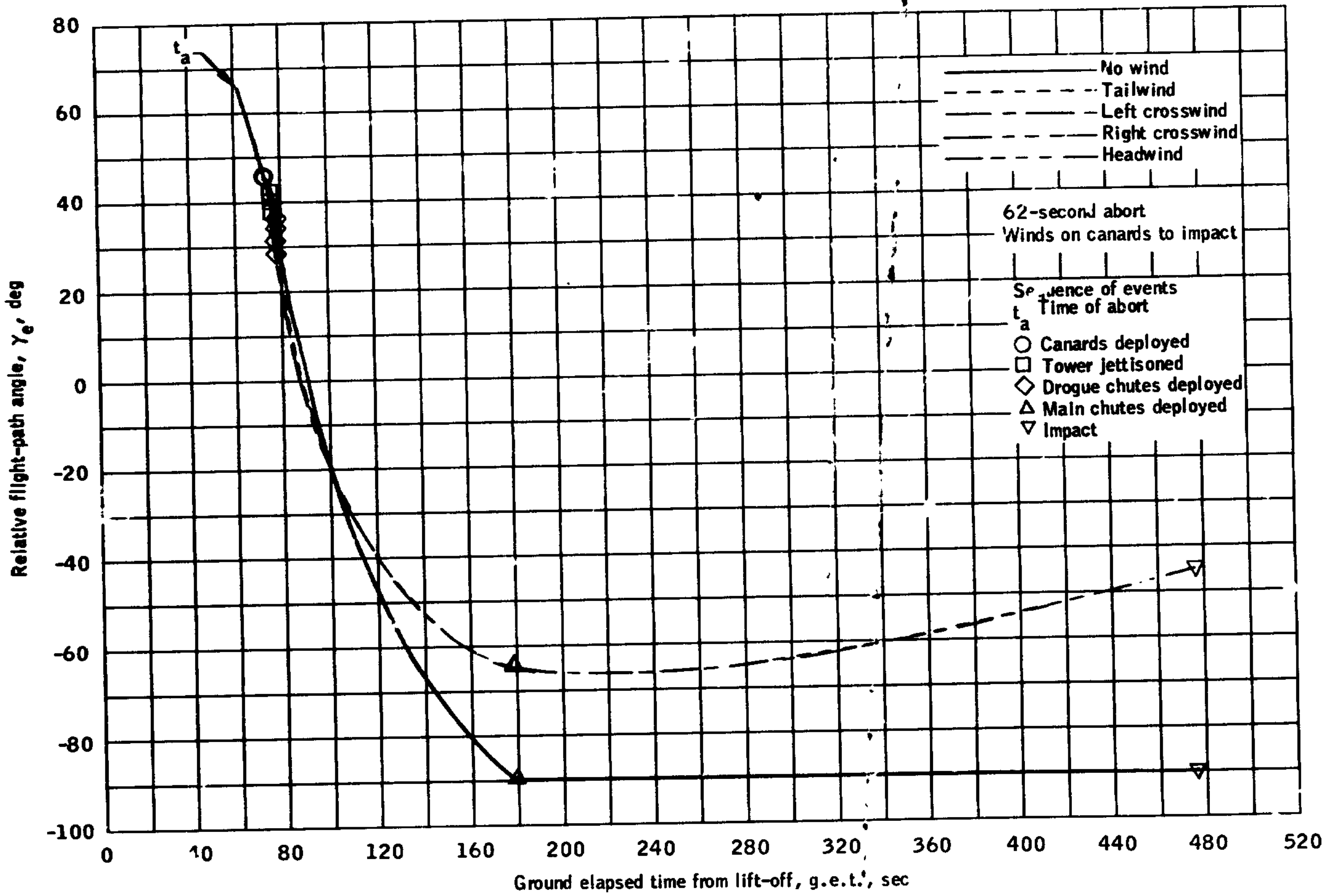
(b) Altitude versus time.

Figure 18.- Continued.



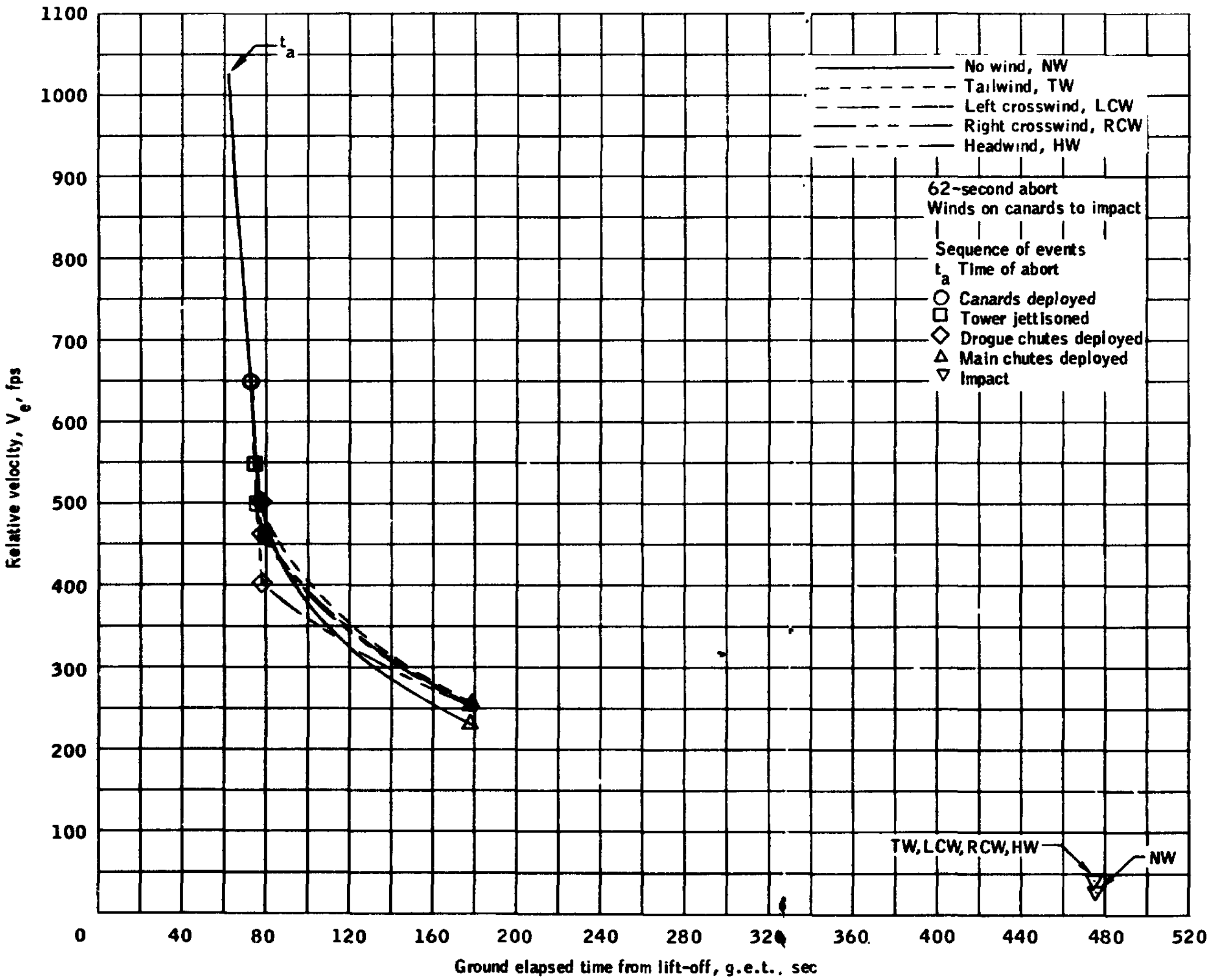
(c) Relative flight azimuth versus time.

Figure 18.- Continued.



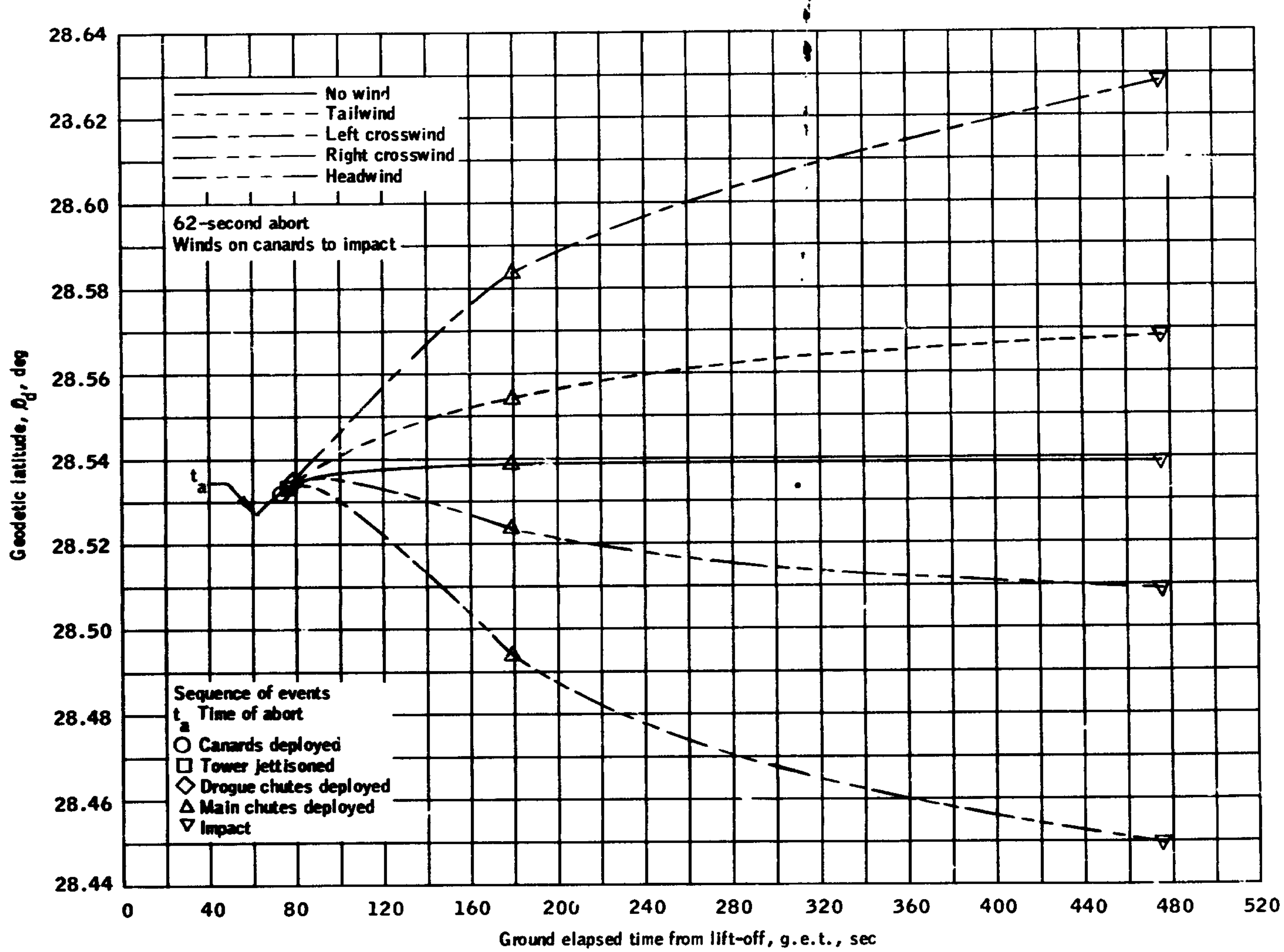
(d) Relative flight-path angle versus time.

Figure 18.- Continued.



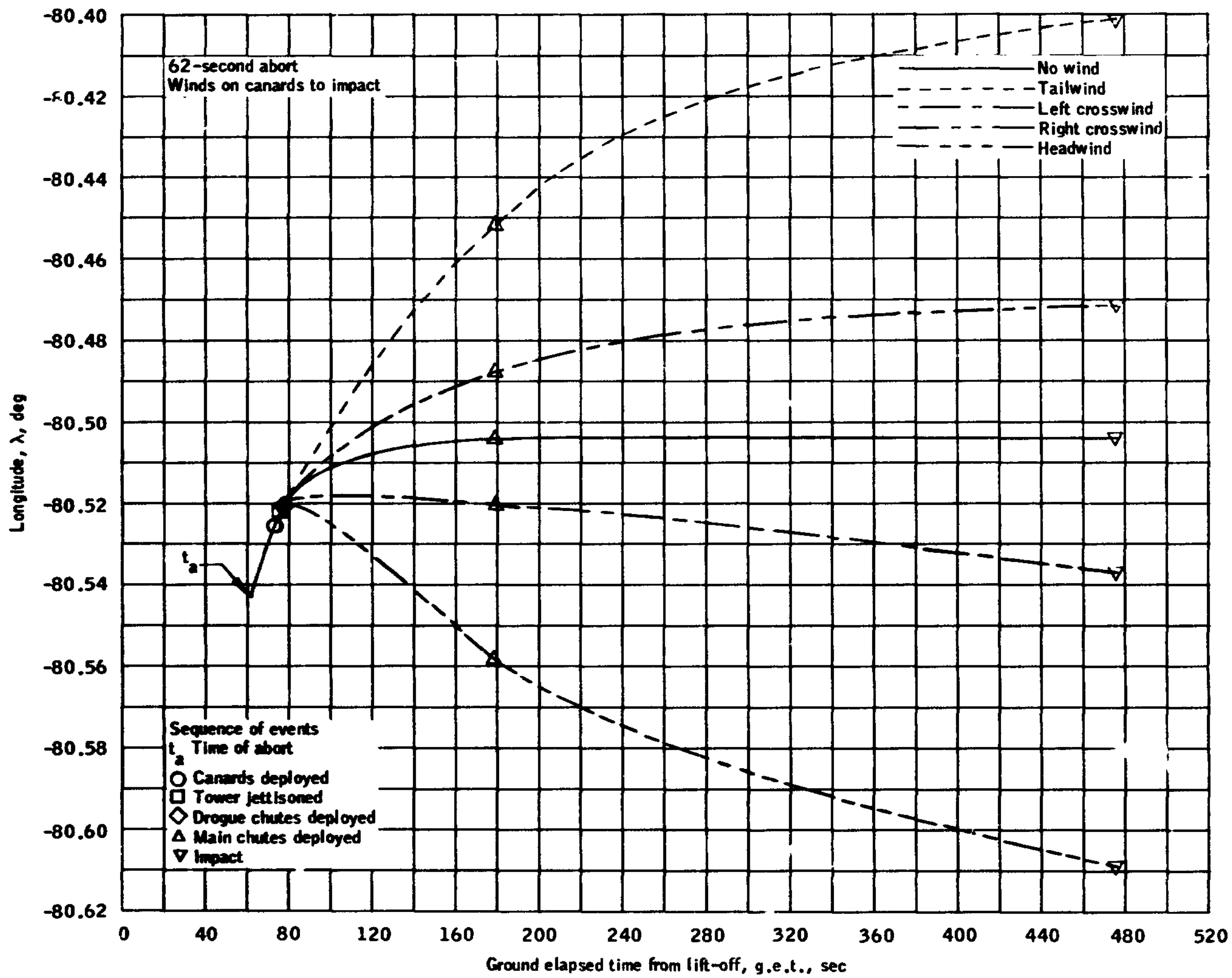
(e) Relative velocity versus time.

Figure 18.- Continued.



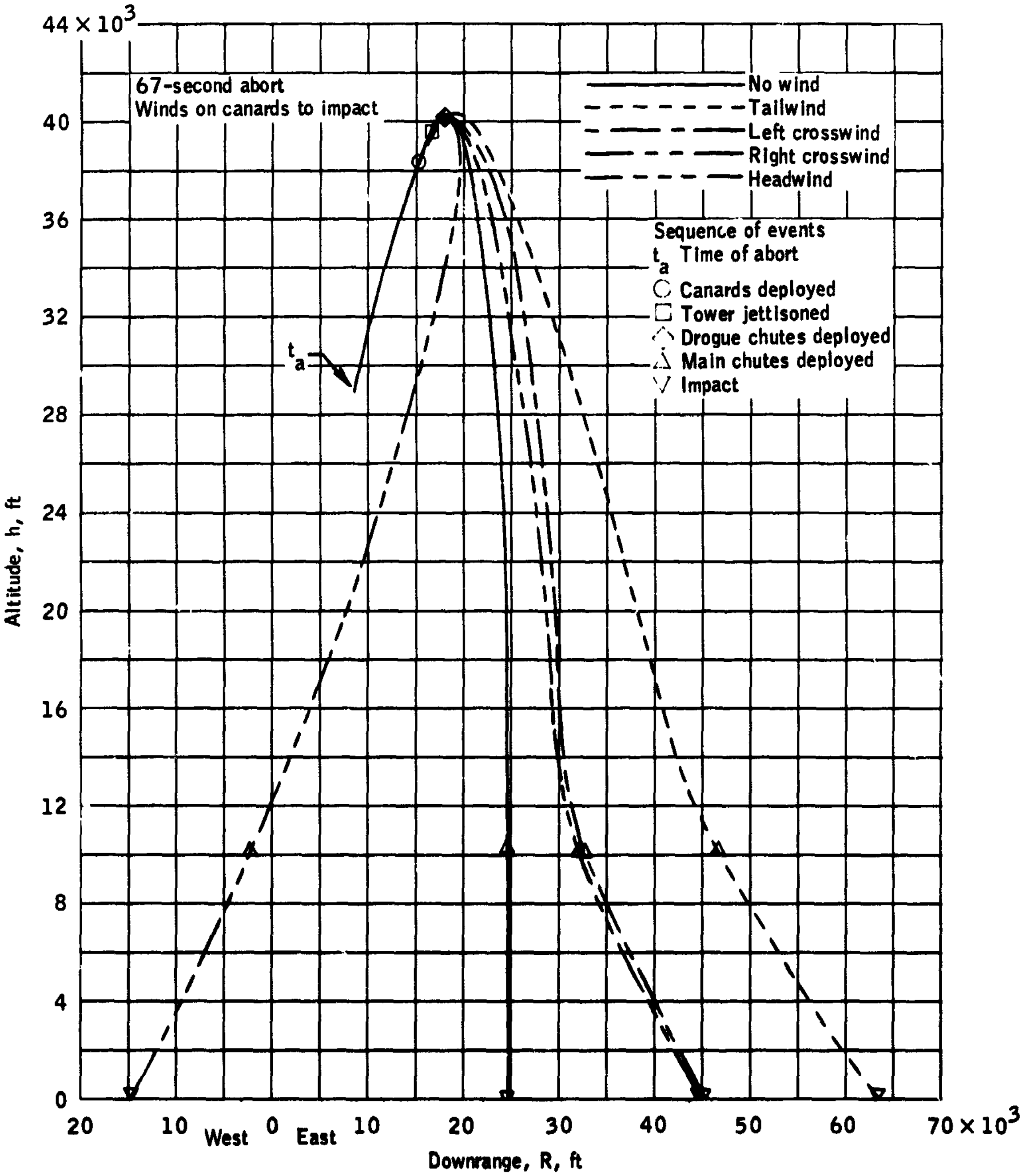
(f) Geodetic latitude versus time.

Figure 18.- Continued.



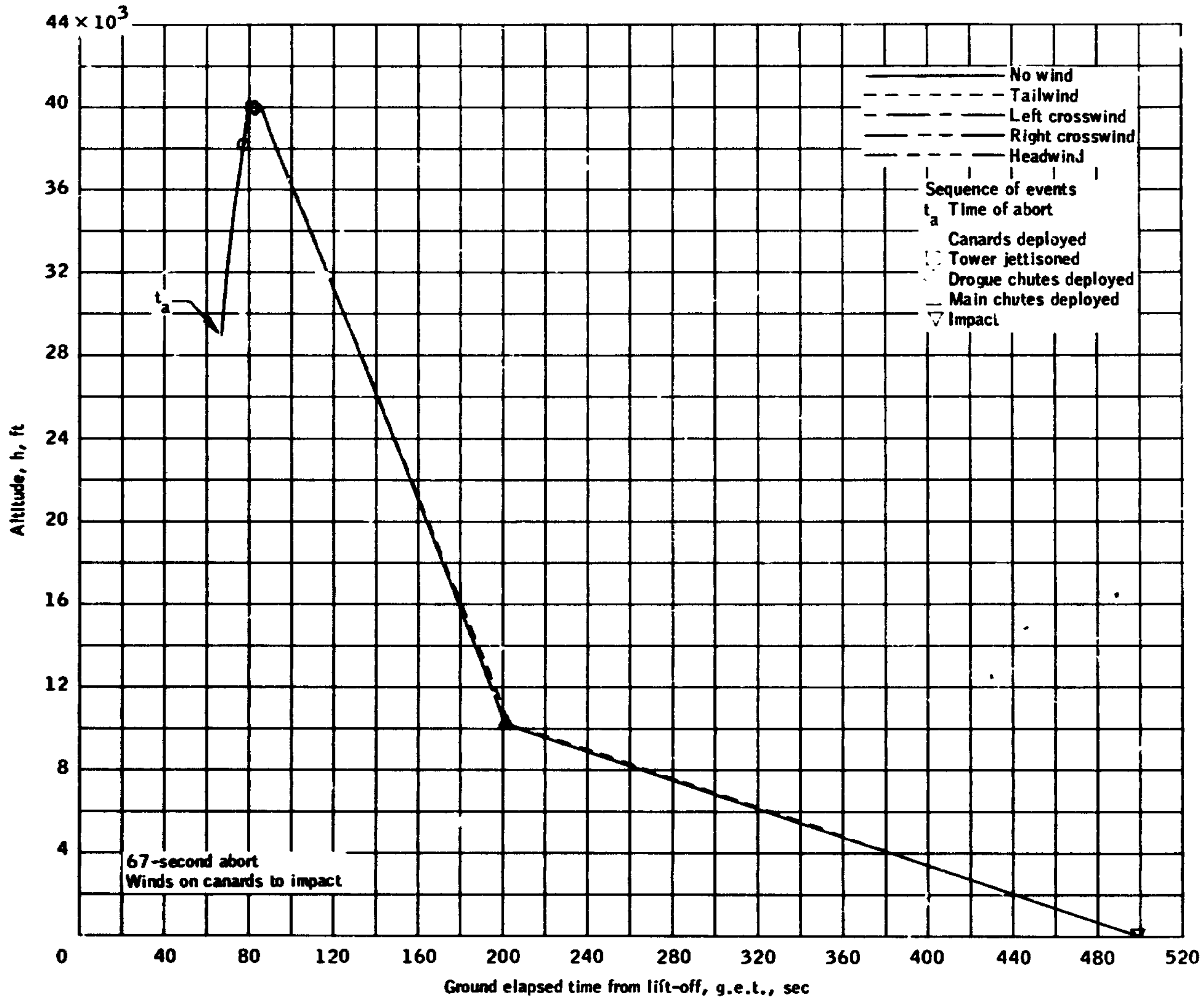
(g) Longitude versus time.

Figure 18.- Concluded.



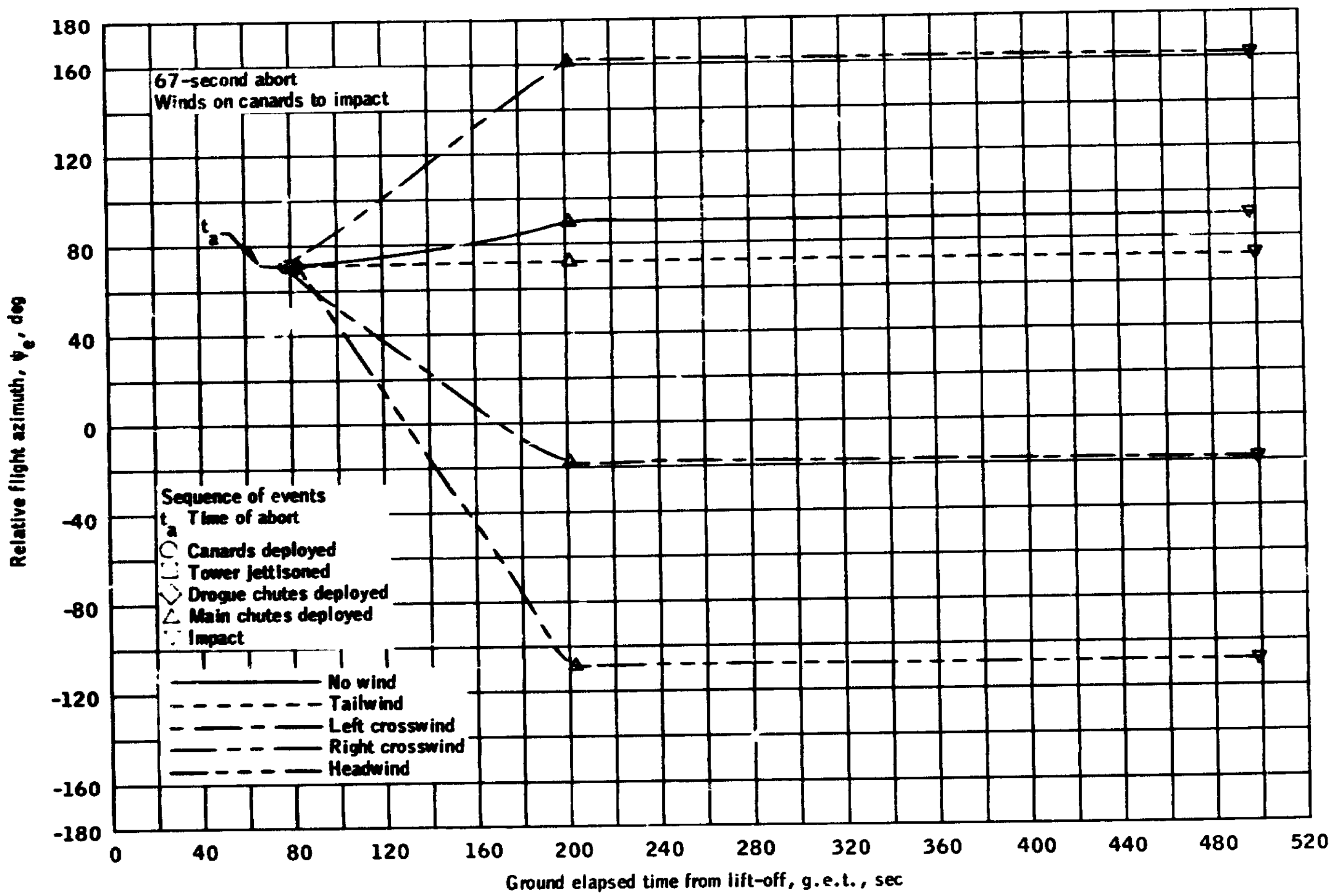
(a) Altitude versus downrange.

Figure 19.- Winds on canards to landing for a 67-second g.e.t. abort.



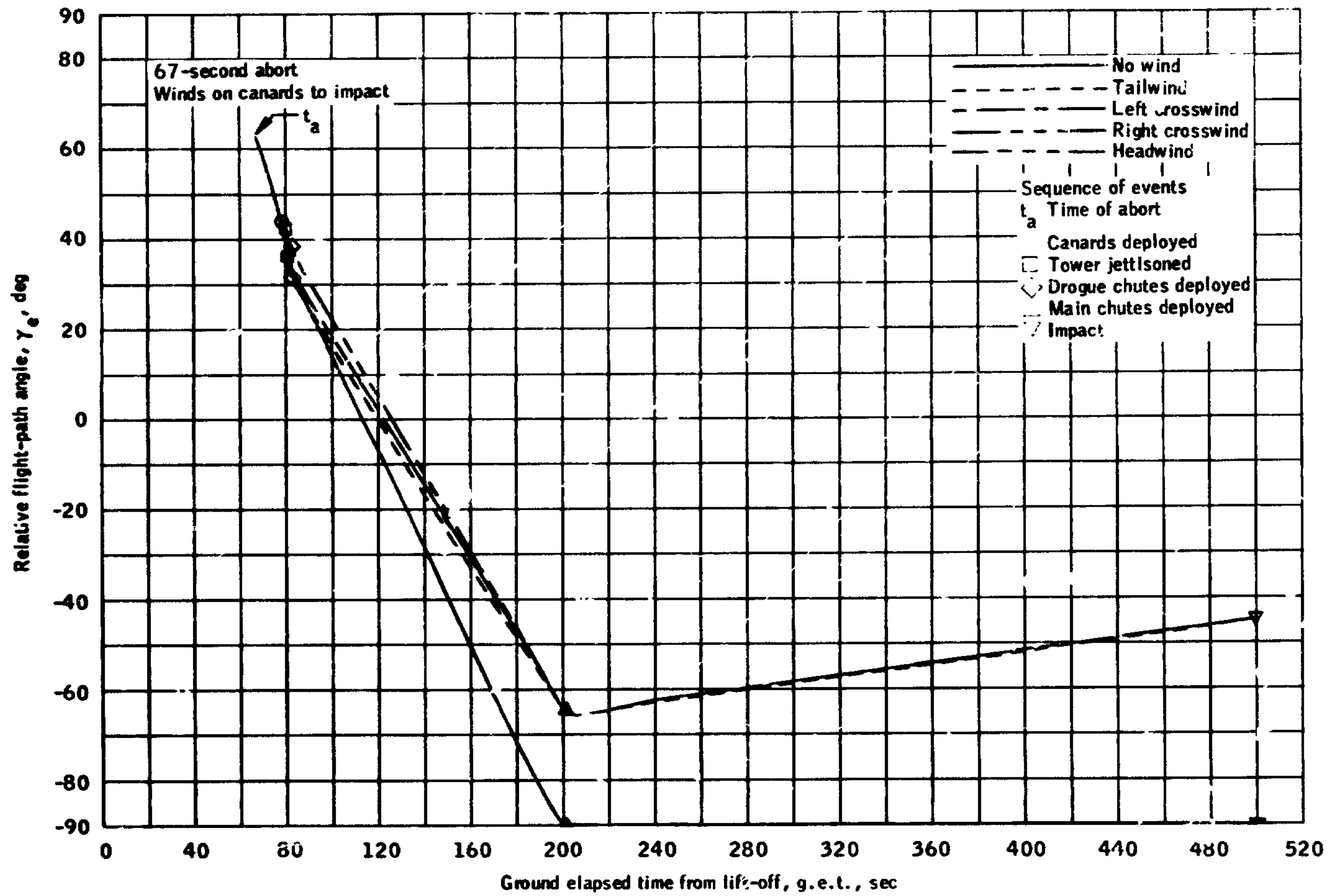
(b) Altitude versus time.

Figure 19.- Continued.



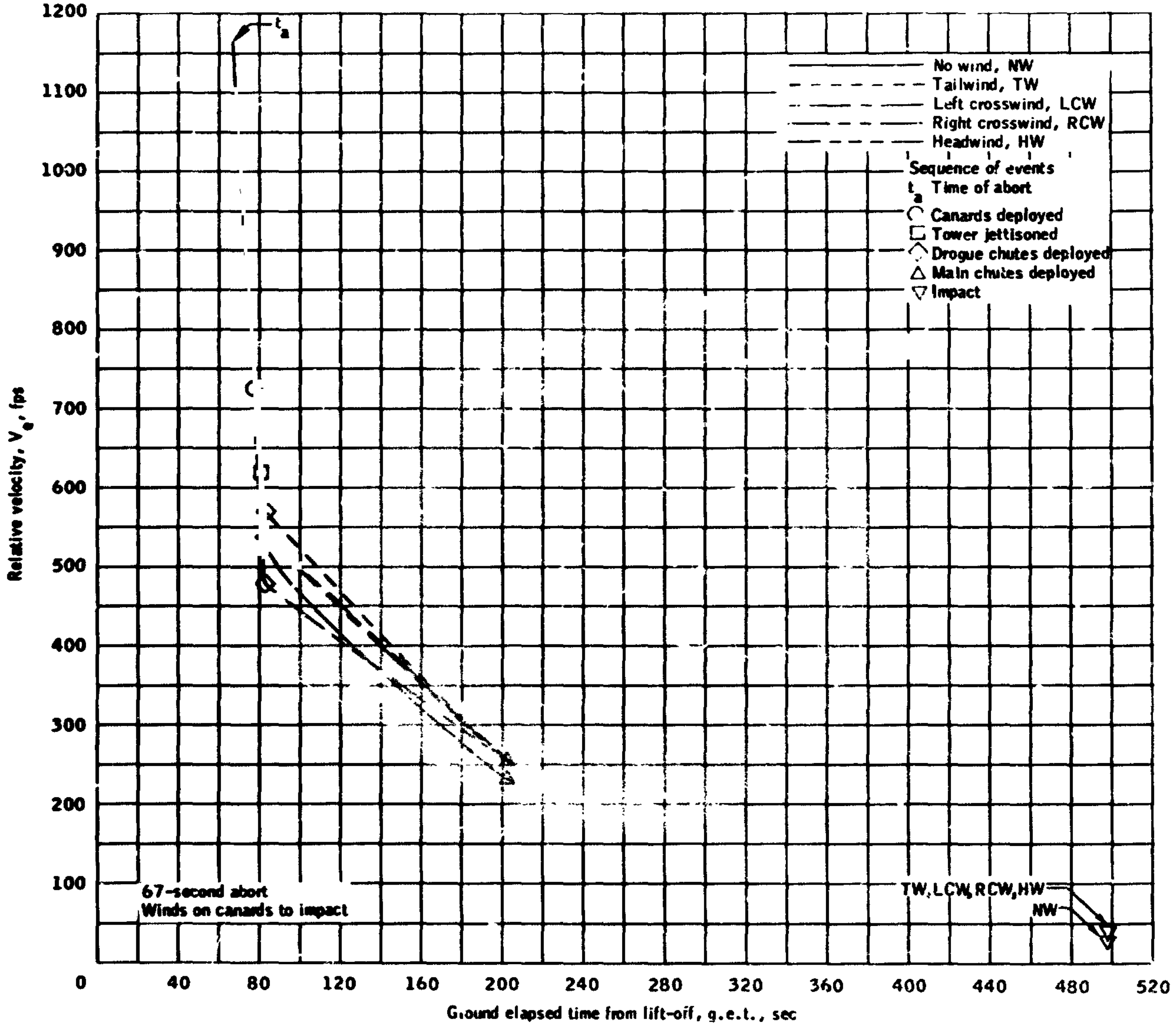
(c) Relative flight azimuth versus time.

Figure 19.- Continued.



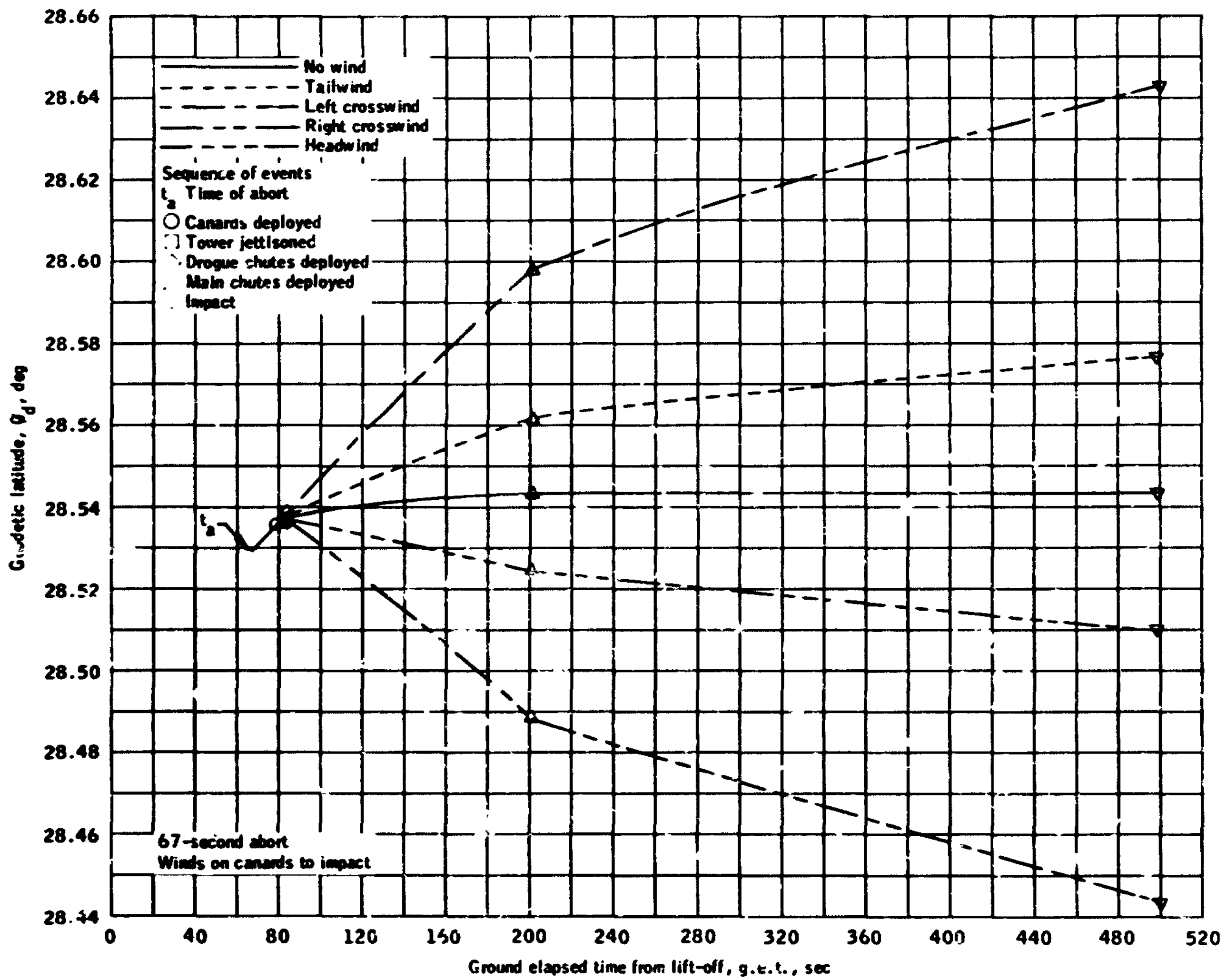
(d) Relative flight-path angle versus time.

Figure 19.- Continued.



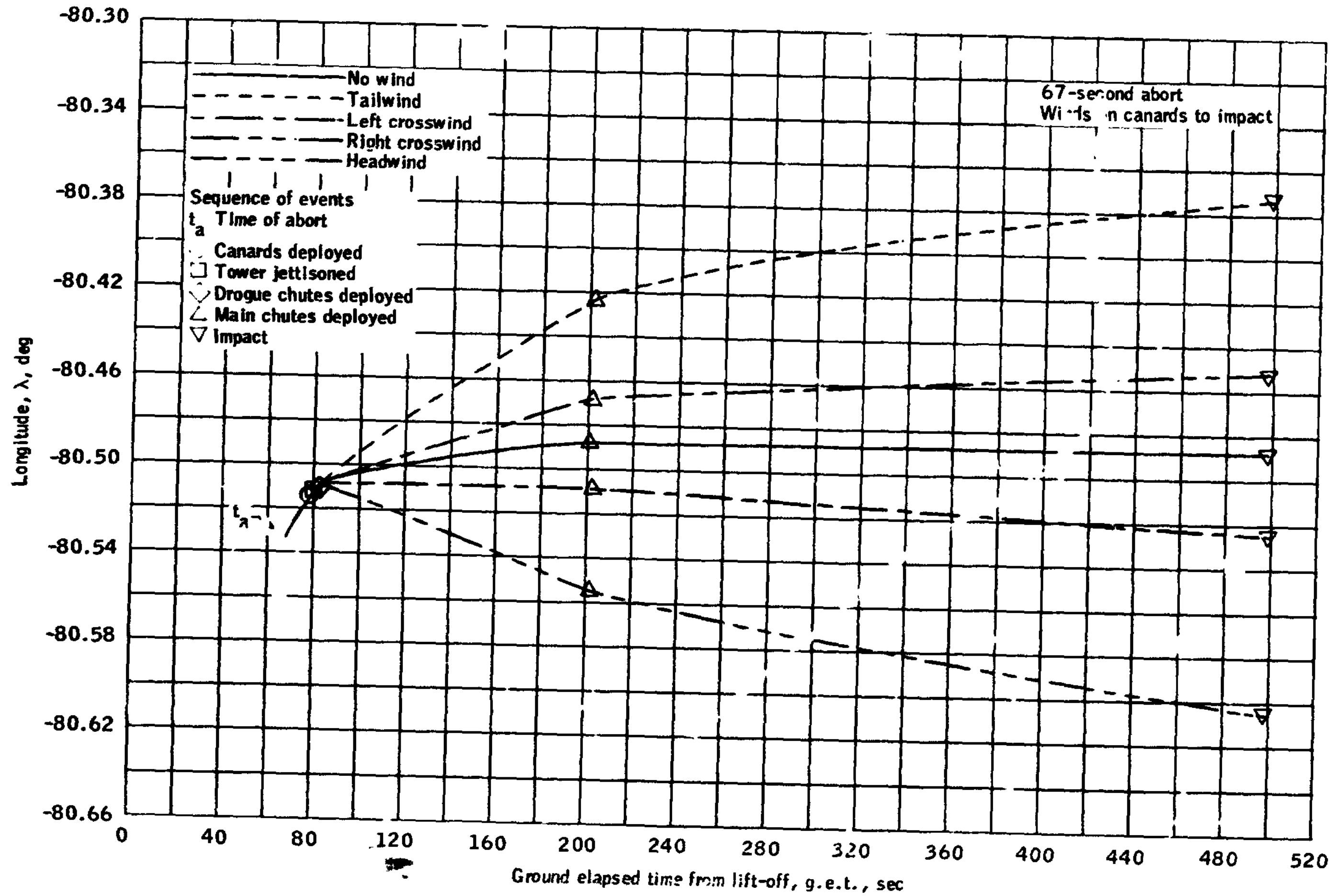
(e) Relative velocity versus time.

Figure 19.- Continued.



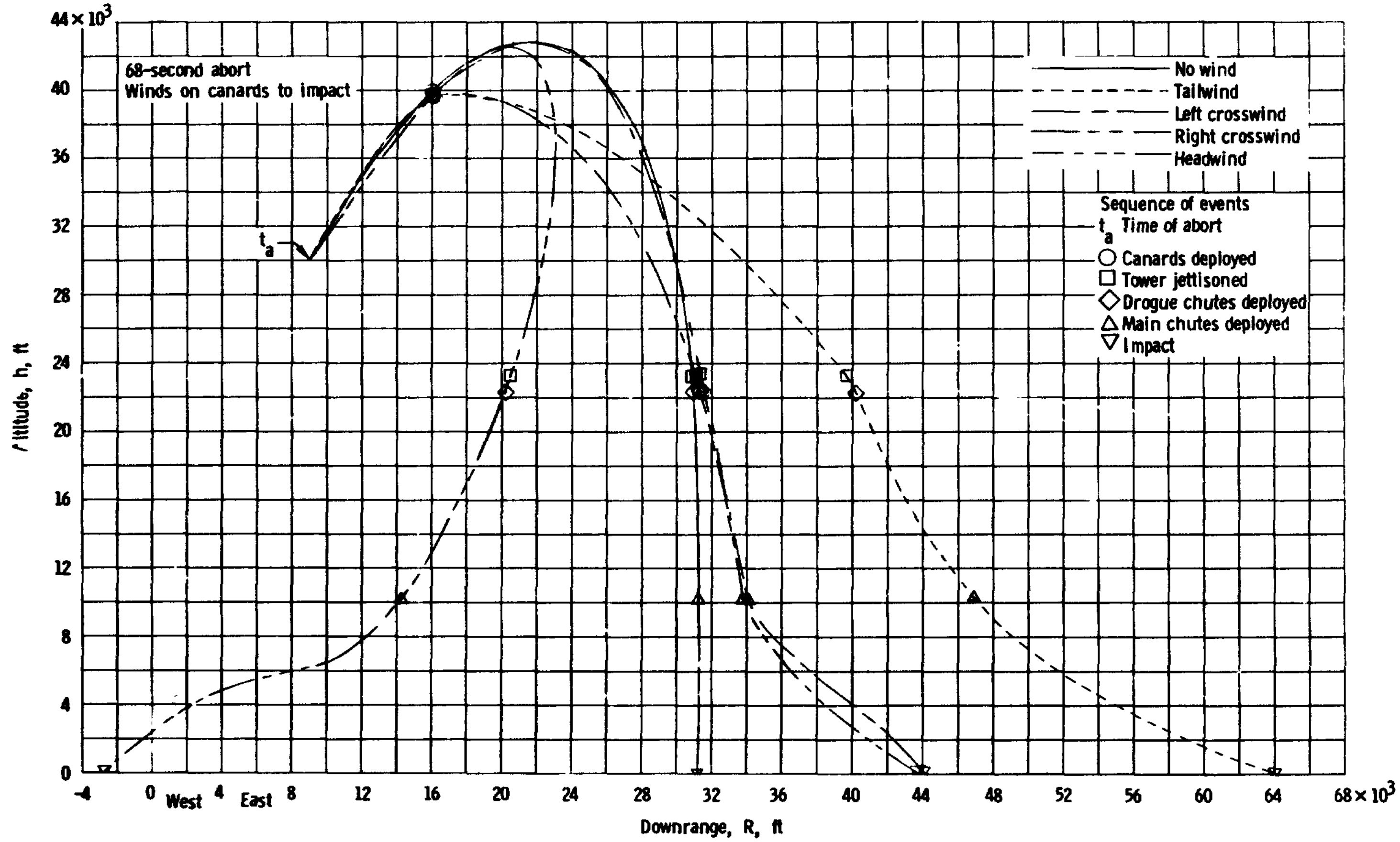
(f) Geodetic latitude versus time.

Figure 19.- Continued.



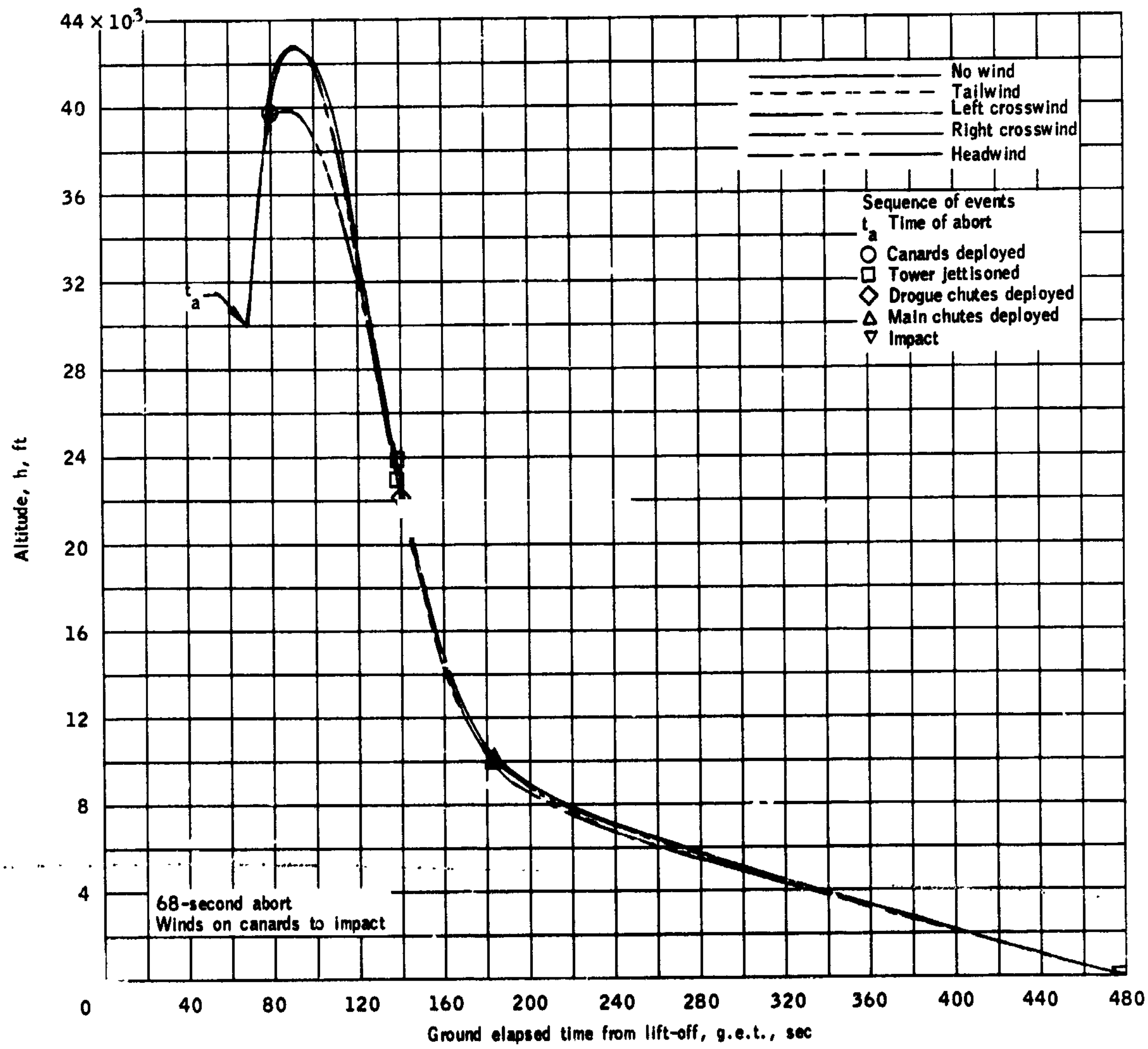
(g) Longitude versus time.

Figure 19.- Concluded.



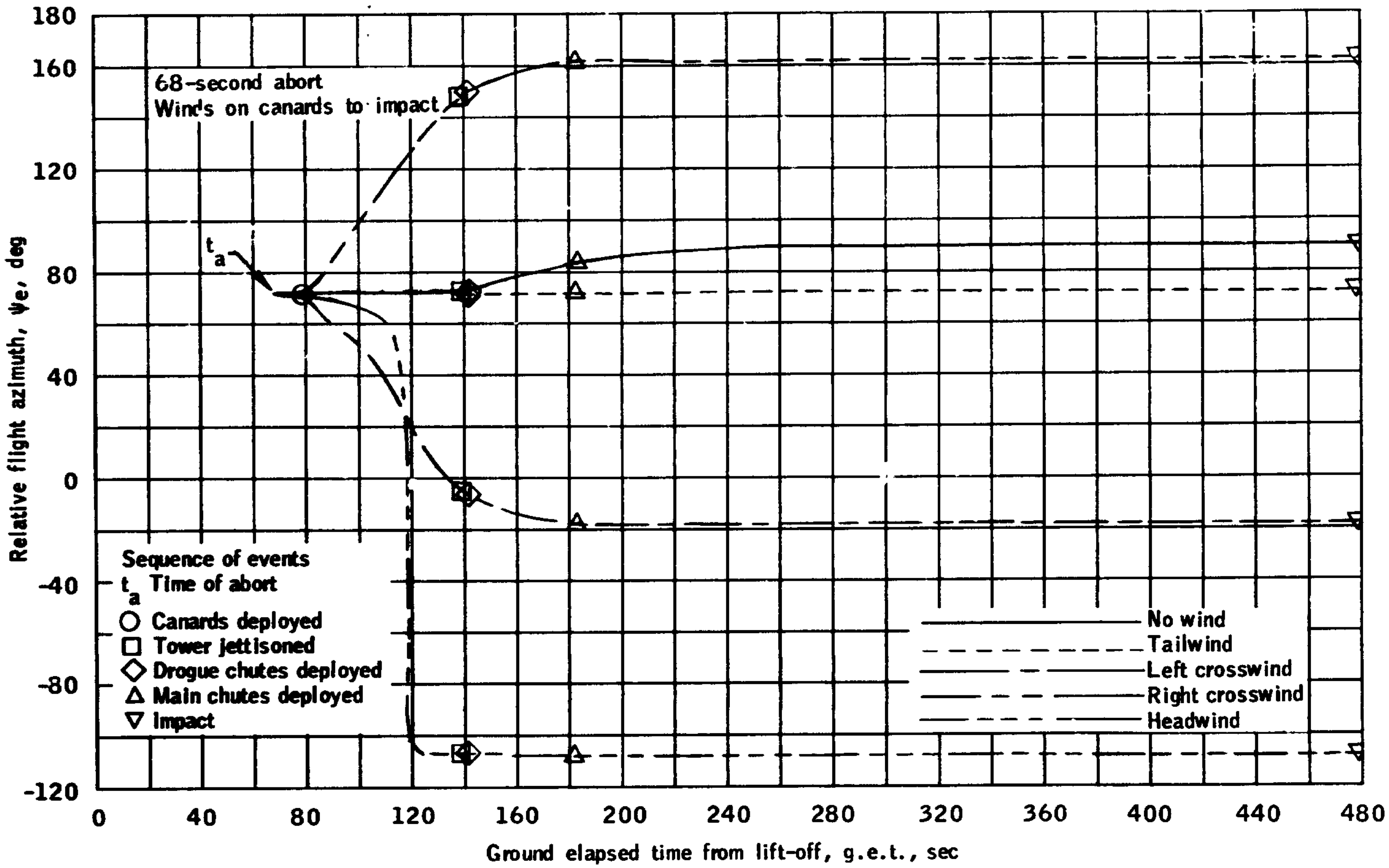
(a) Altitude versus downrange.

Figure 20. - Winds on canards to landing for a 68-second g.e.t. abort.



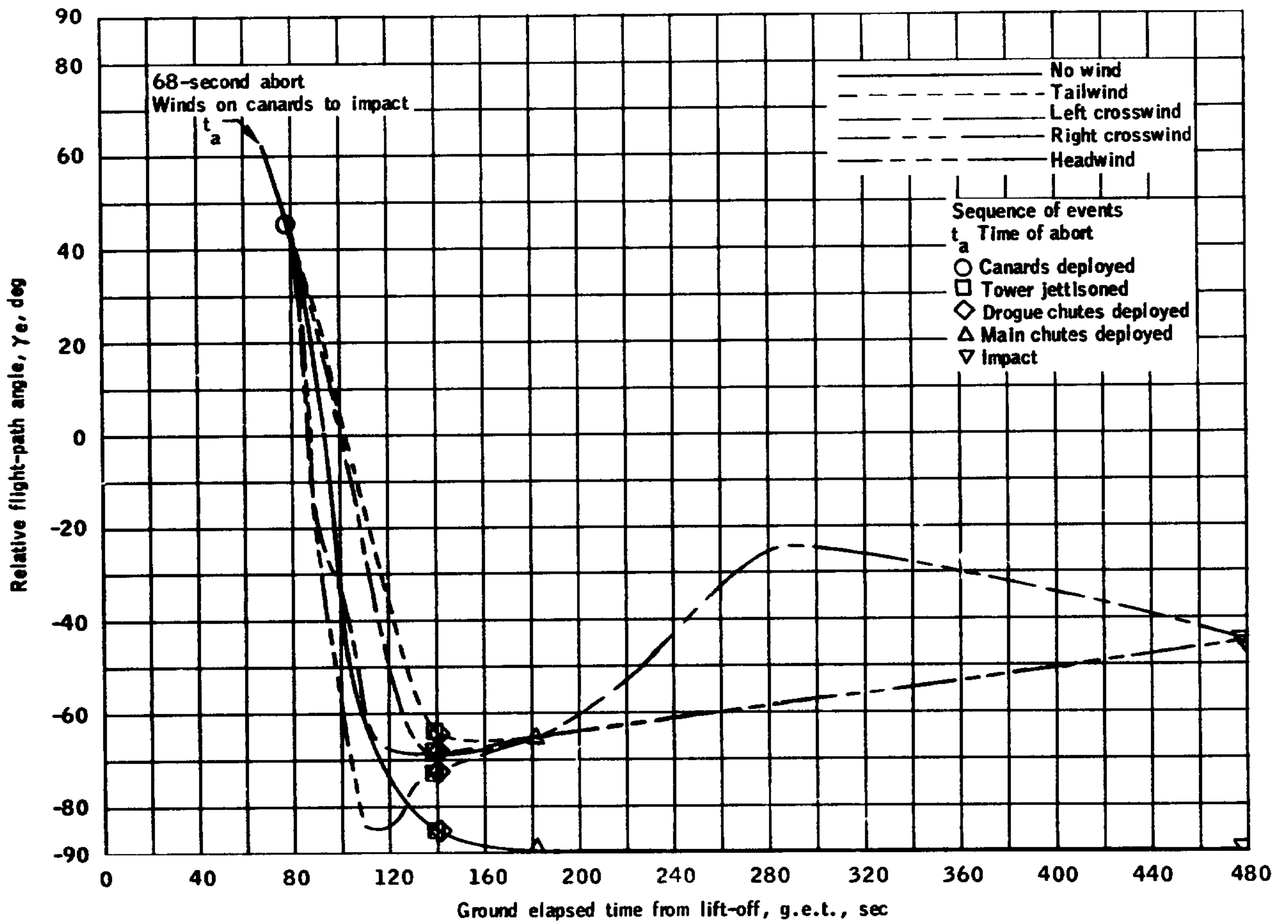
(b) Altitude versus time.

Figure 20.- Continued.



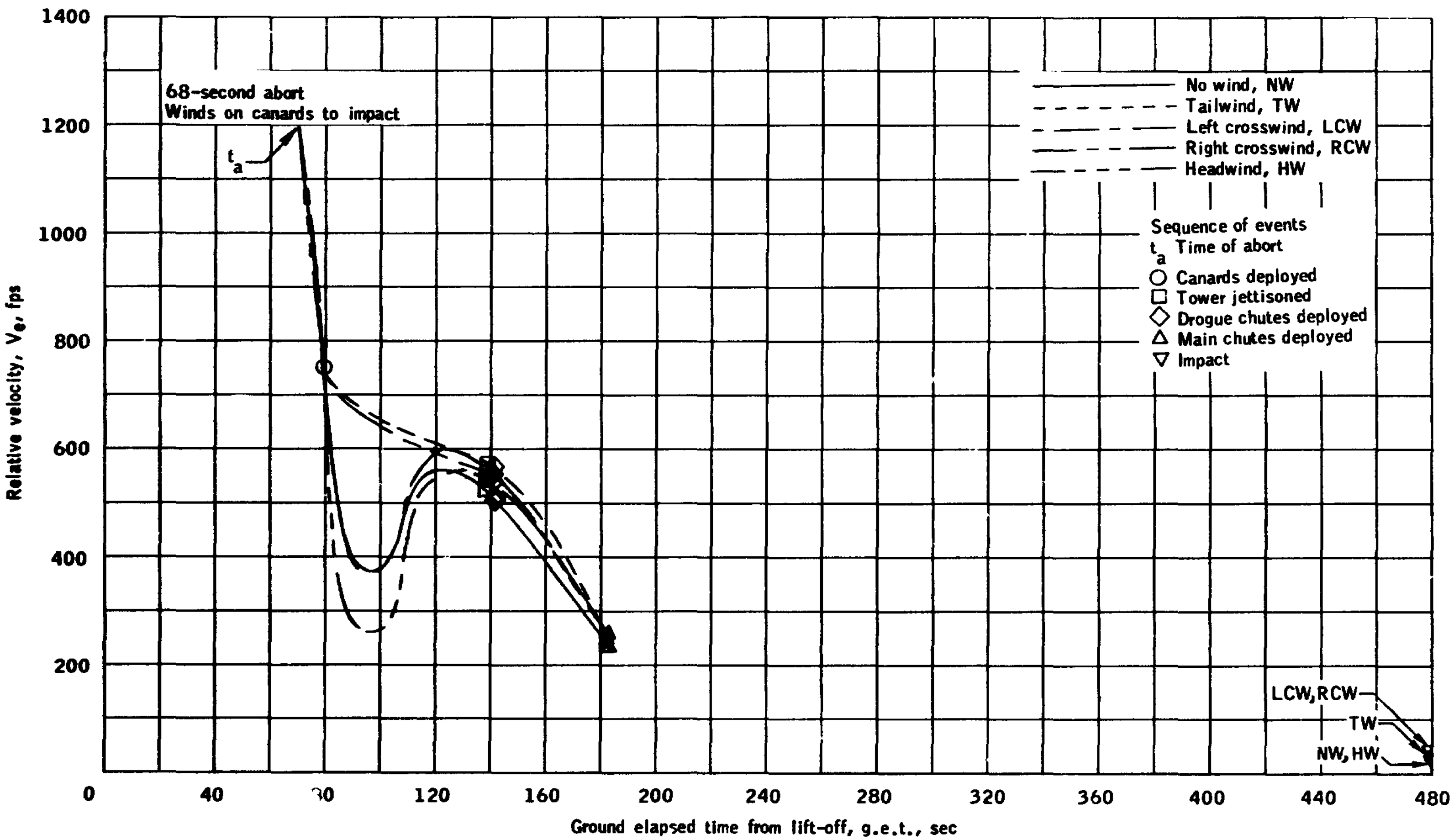
(c) Relative flight azimuth versus time.

Figure 20.- Continued.



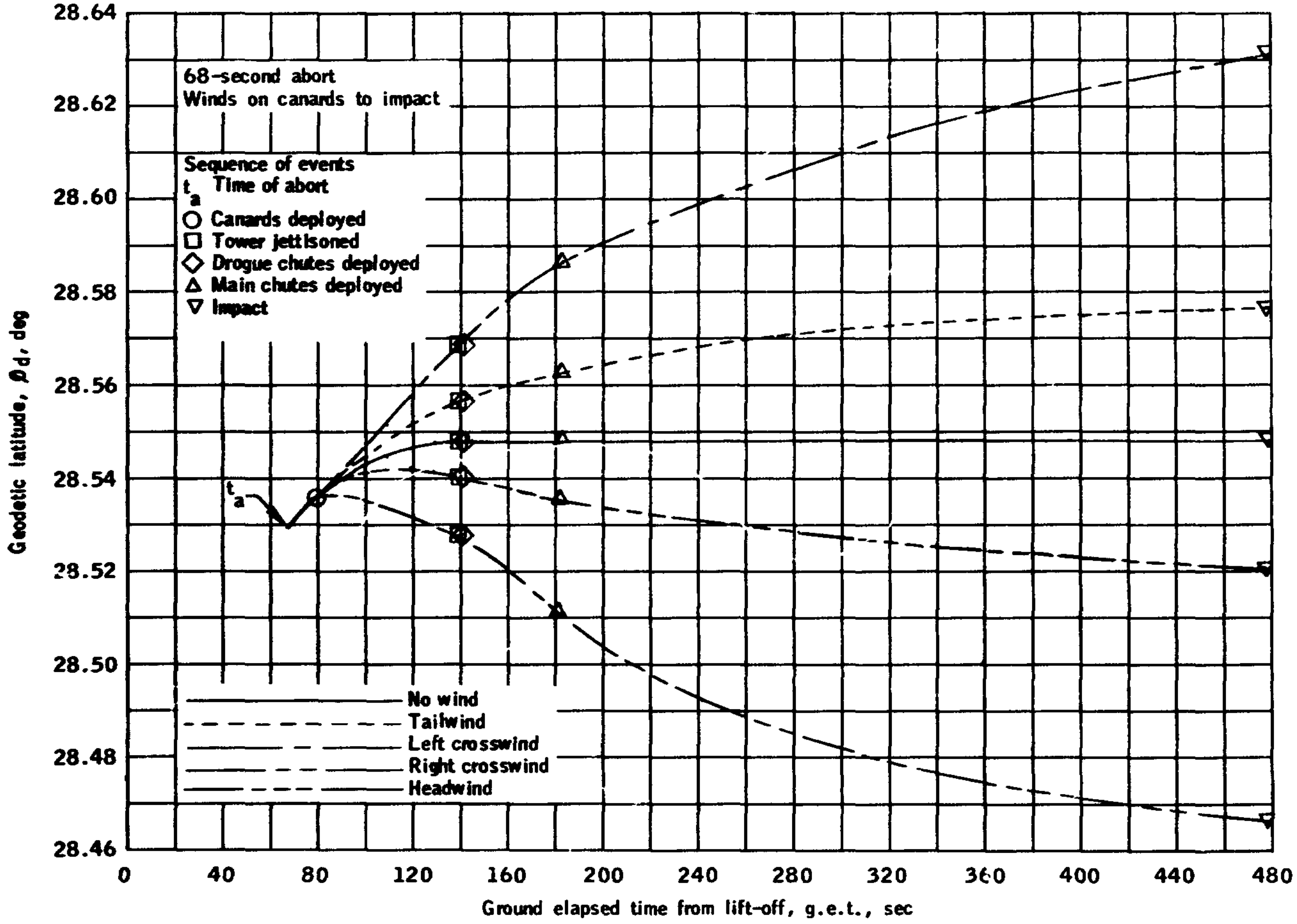
(d) Relative flight-path angle versus time.

Figure 20.- Continued.



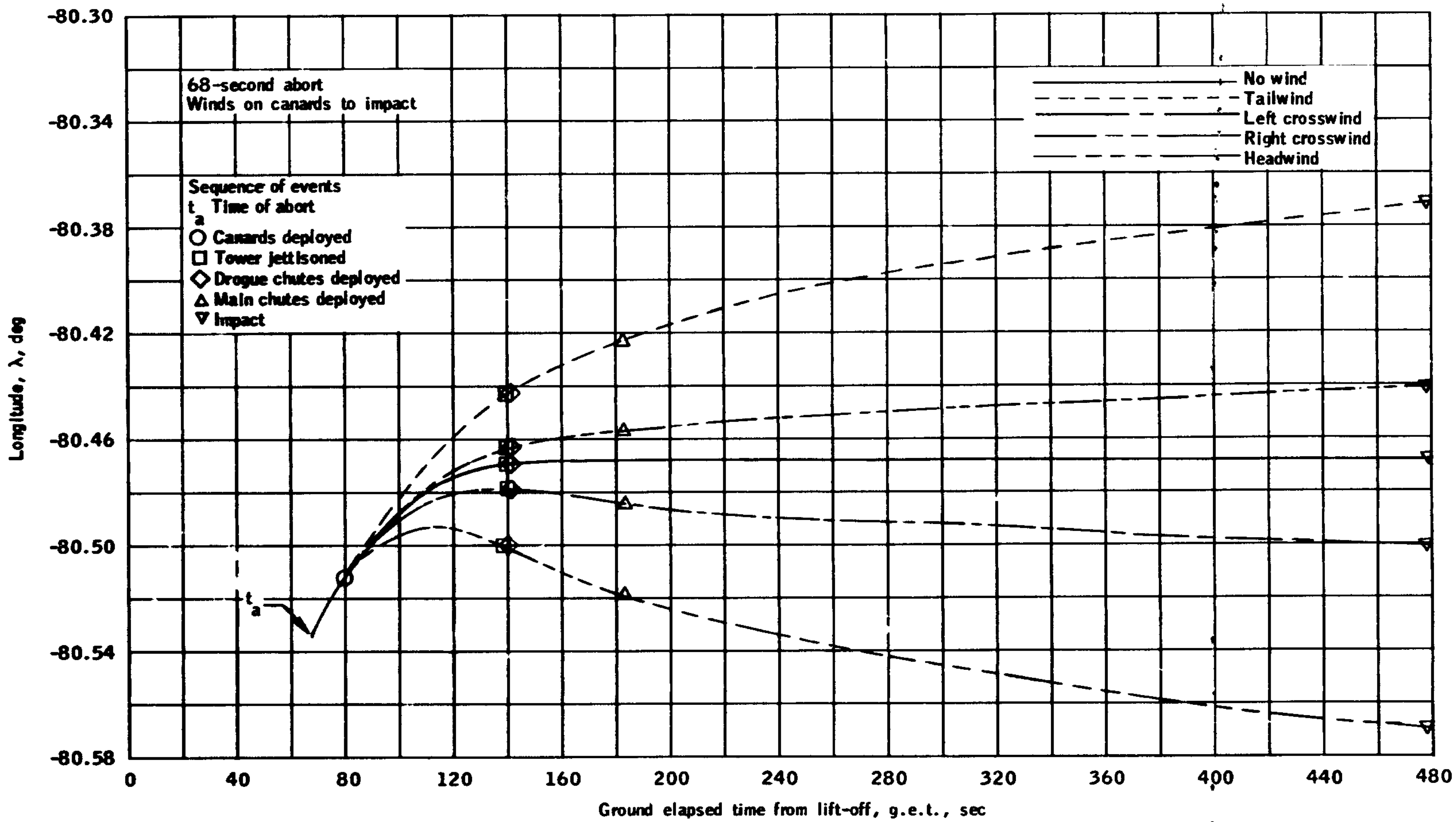
(e) Relative velocity versus time.

Figure 20.- Continued.



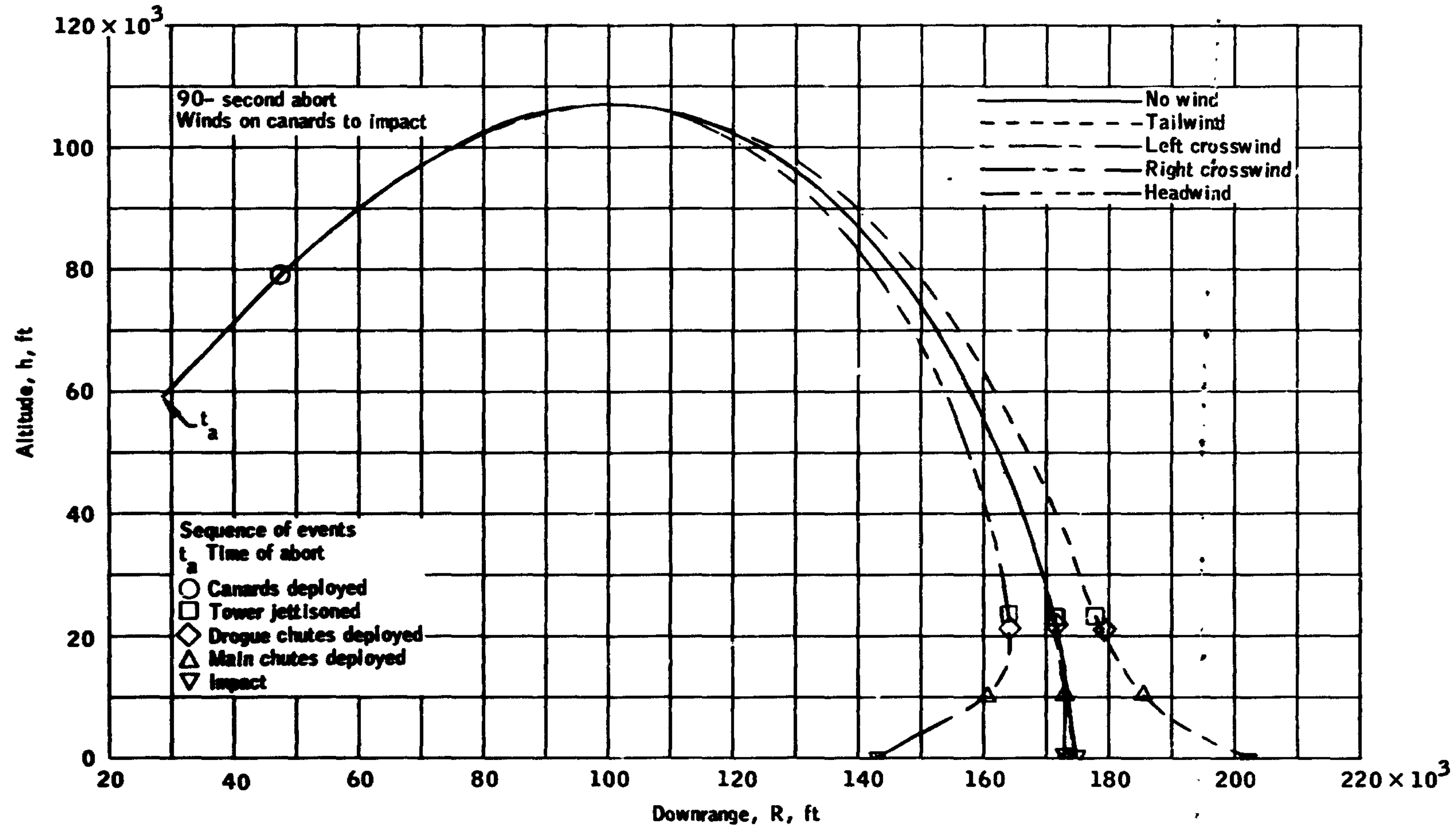
(f) Geodetic latitude versus time.

Figure 20.- Continued.



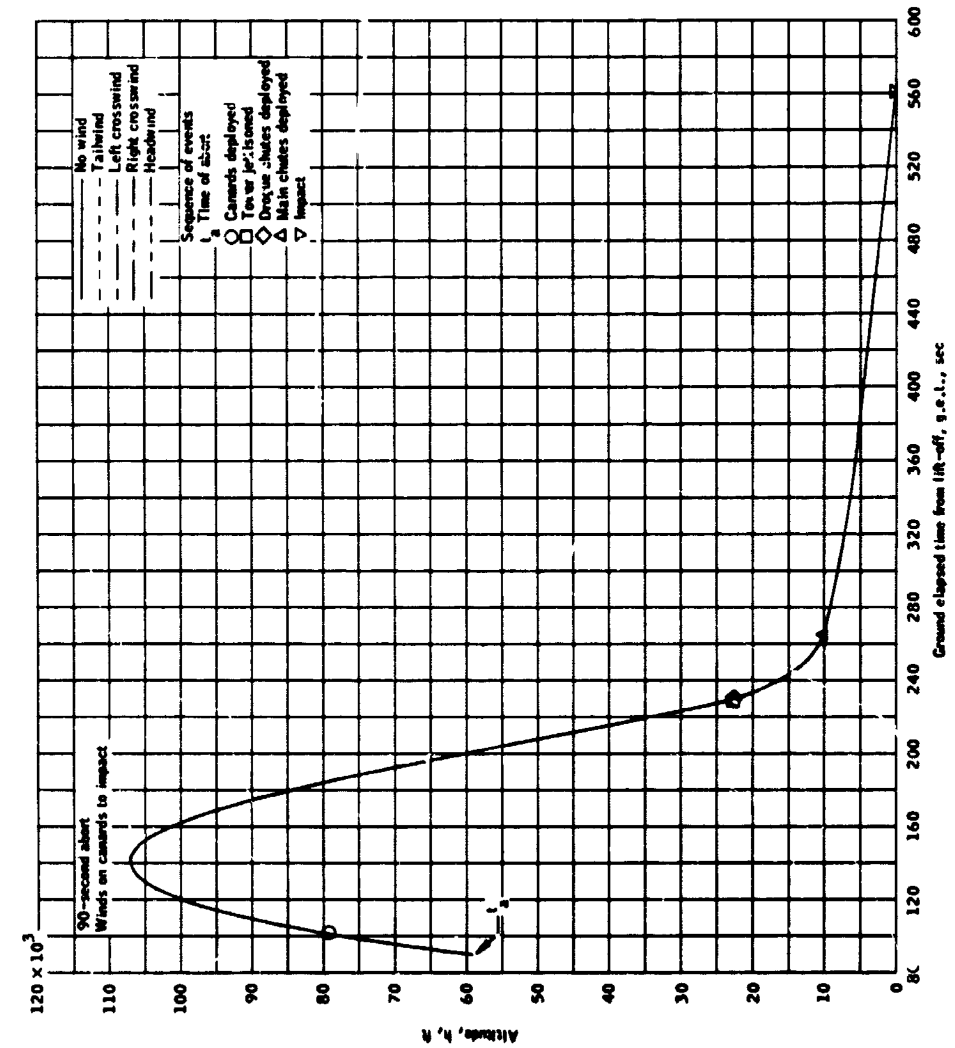
(g) Longitude versus time.

Figure 20.- Concluded.



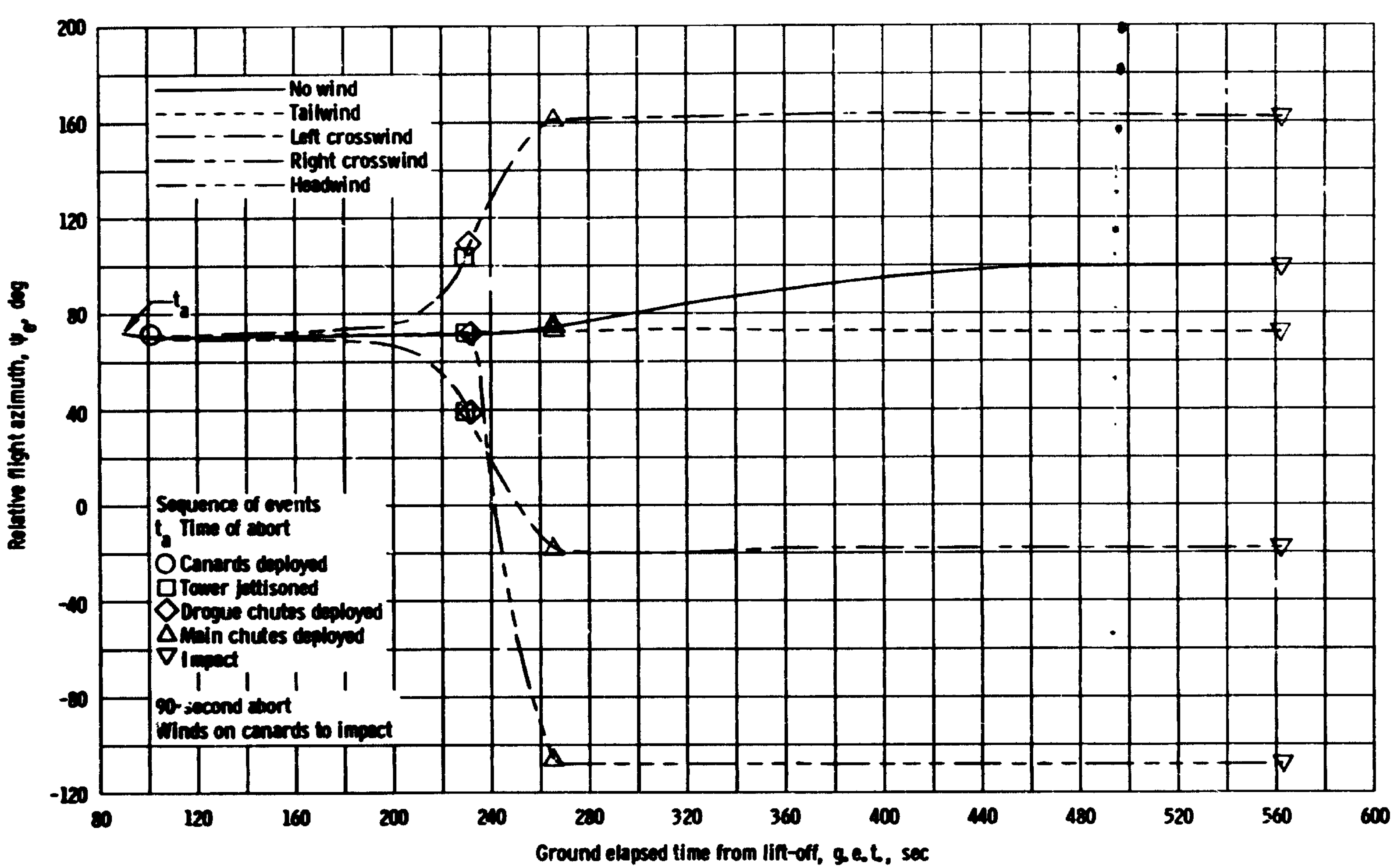
(a) Altitude versus downrange.

Figure 21.- Winds on canards to landing for a 90-second g.e.t. abort.



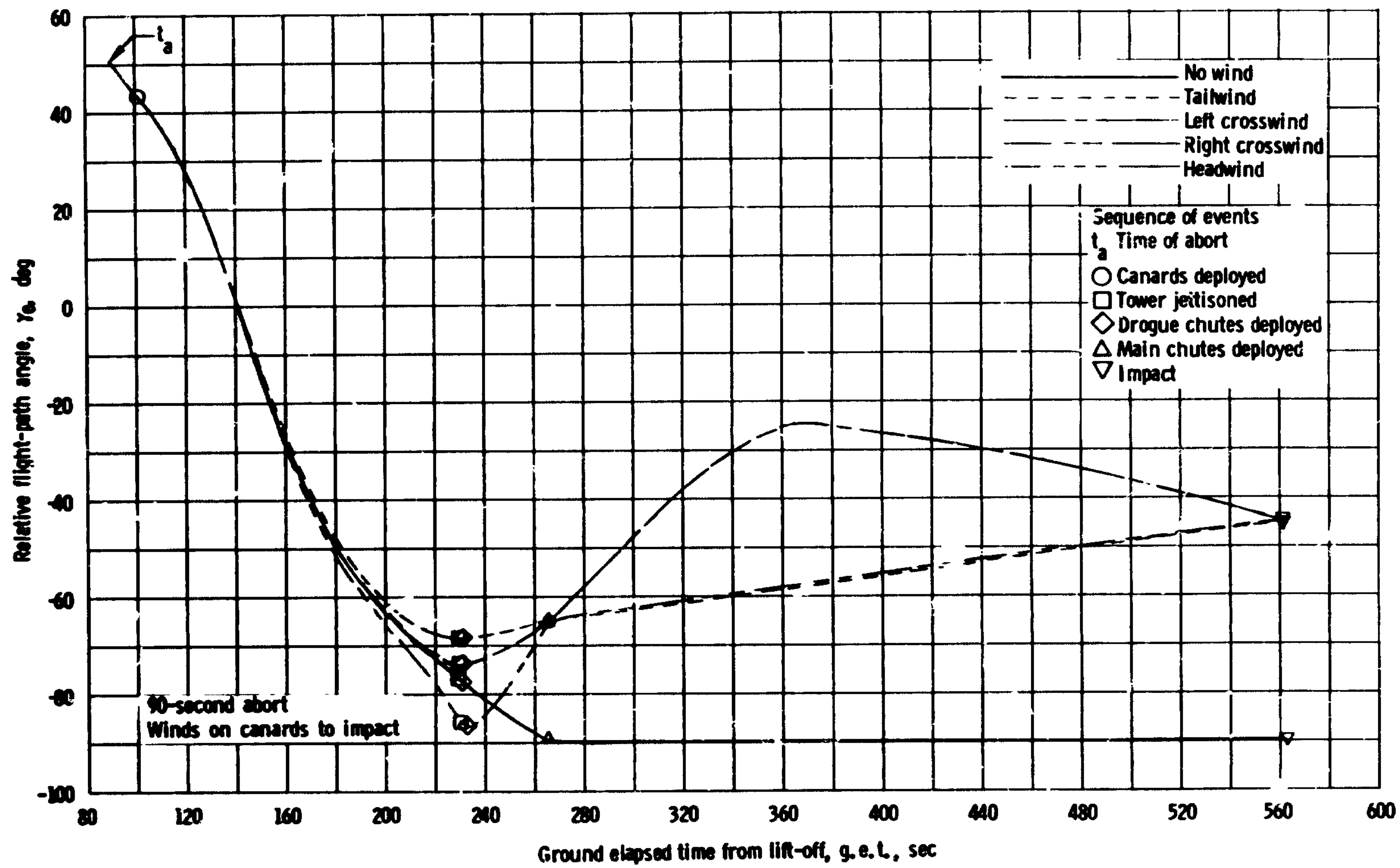
(b) Altitude versus time.

Figure 21.- Continued.



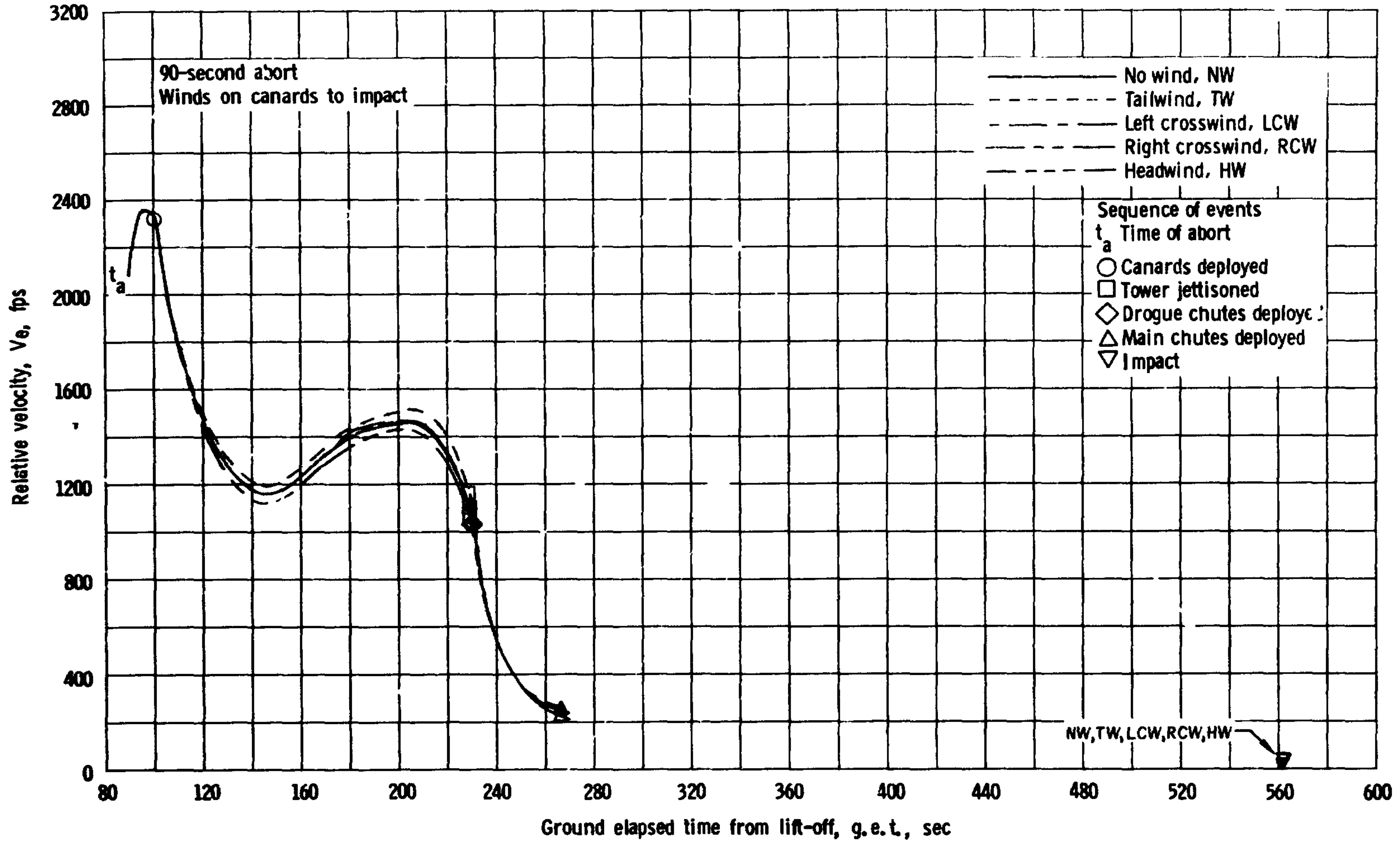
(c) Relative flight azimuth versus time.

Figure 21. - Continued.



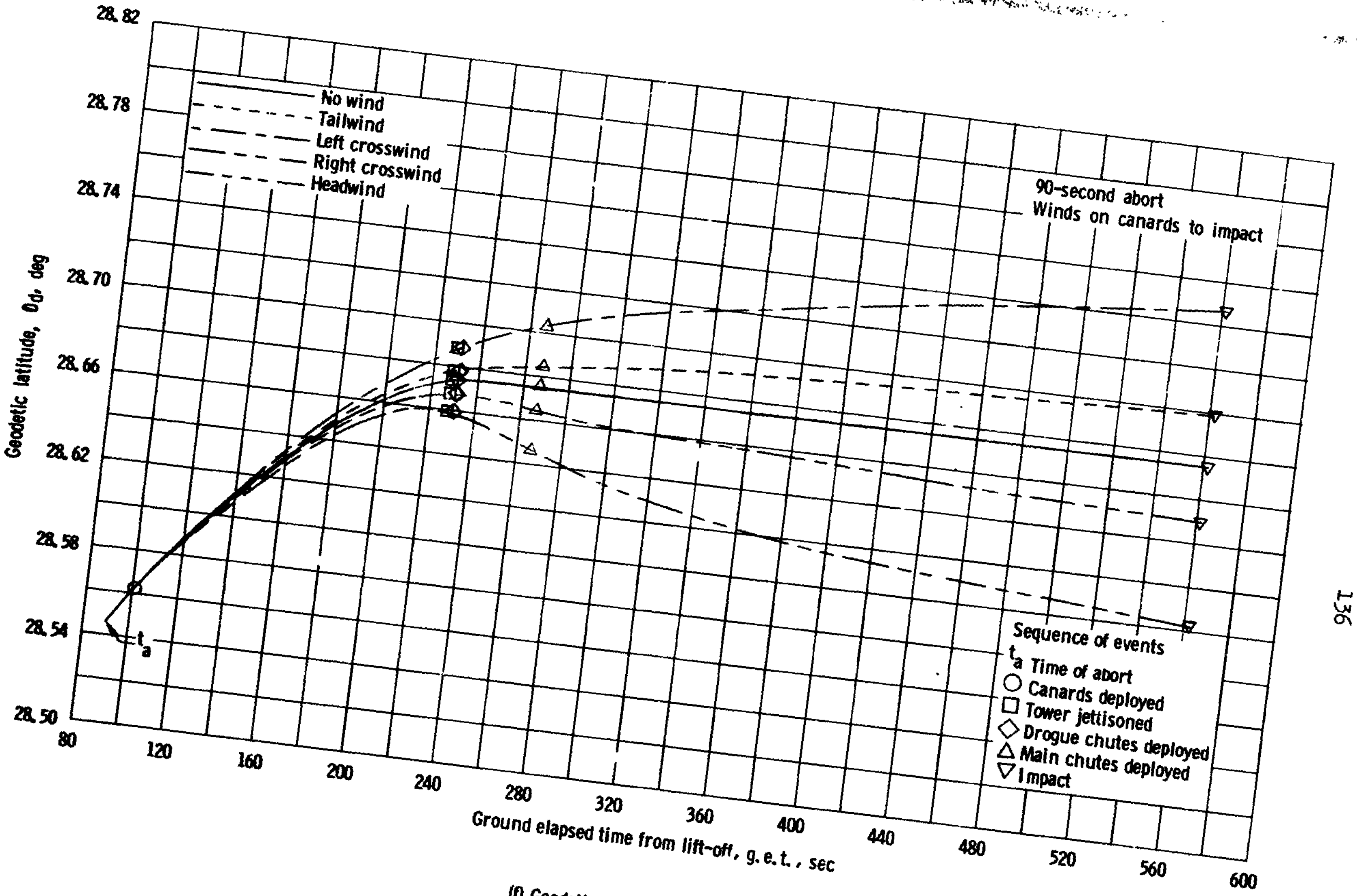
(d) Relative flight-path angle versus time.

Figure 21.- ·ntinued.



(e) Relative velocity versus time.

Figure 21. - Continued.



(f) Geodetic latitude versus time.

Figure 21.- Continued.

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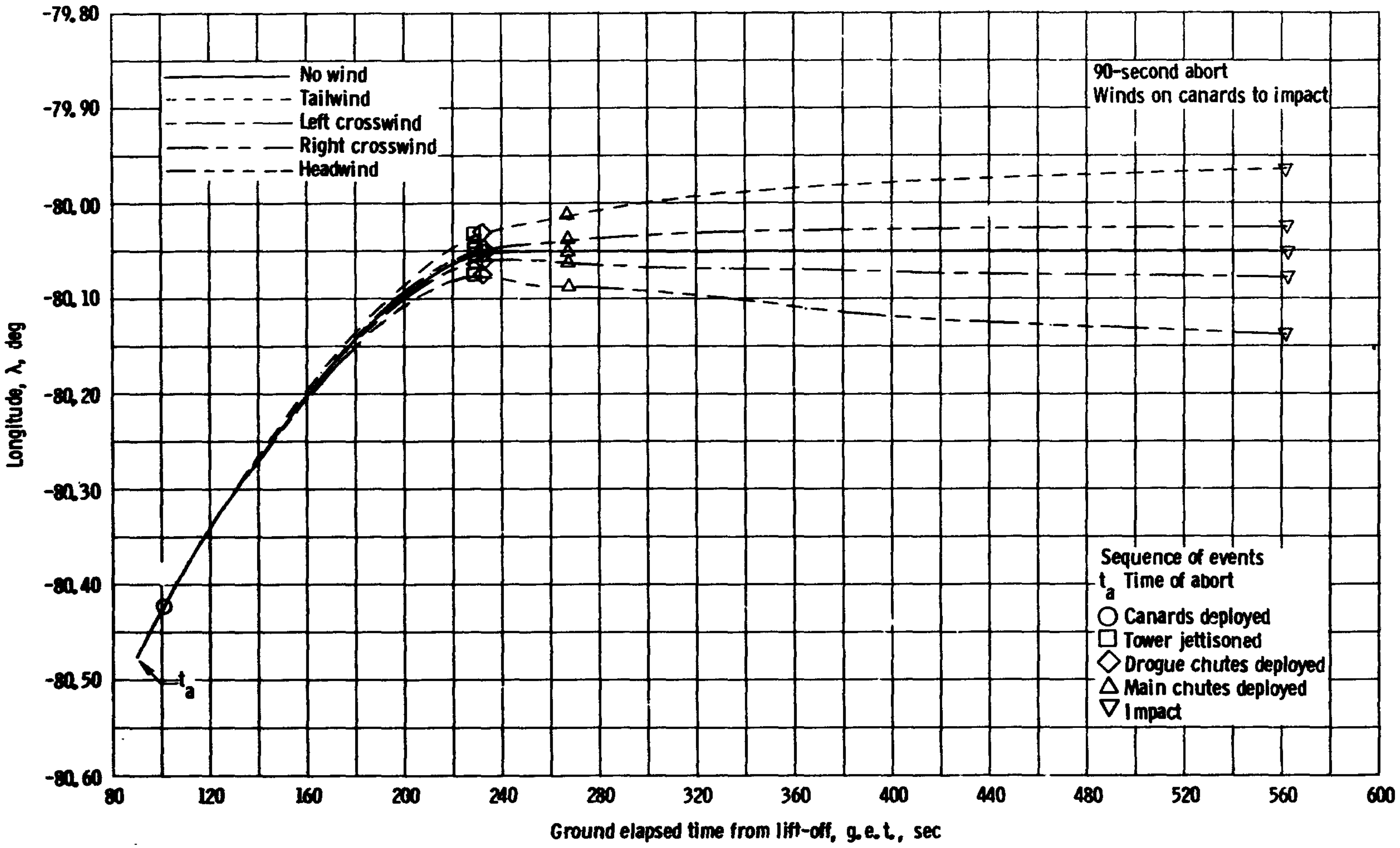

(g) Longitude versus time.

Figure 21. - Concluded.

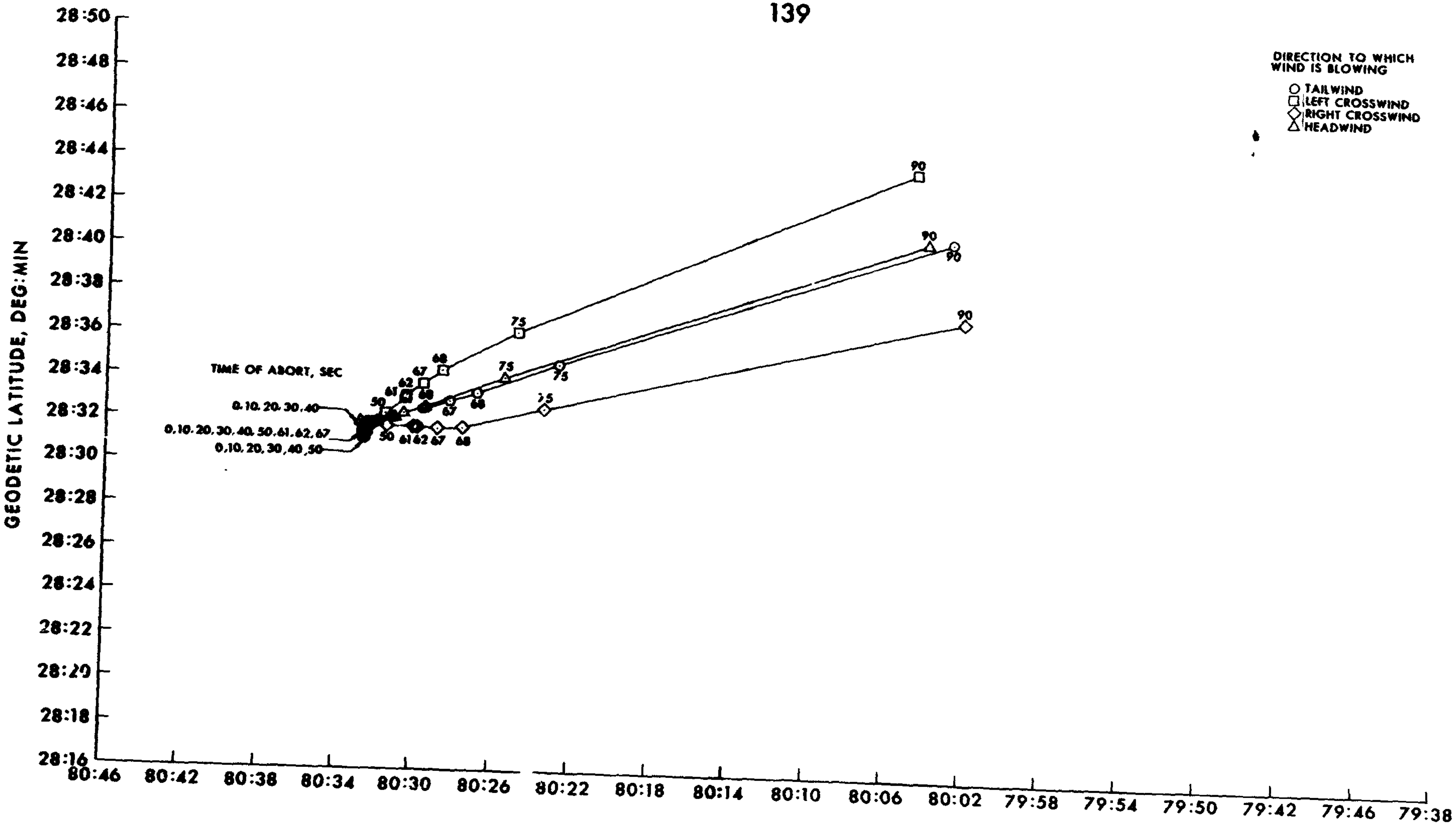

FIGURE 22.- COMMAND MODULE IMPACT POINTS FOR WINDS ON THE LV AND LES BUT NO WINDS ON CHUTES.

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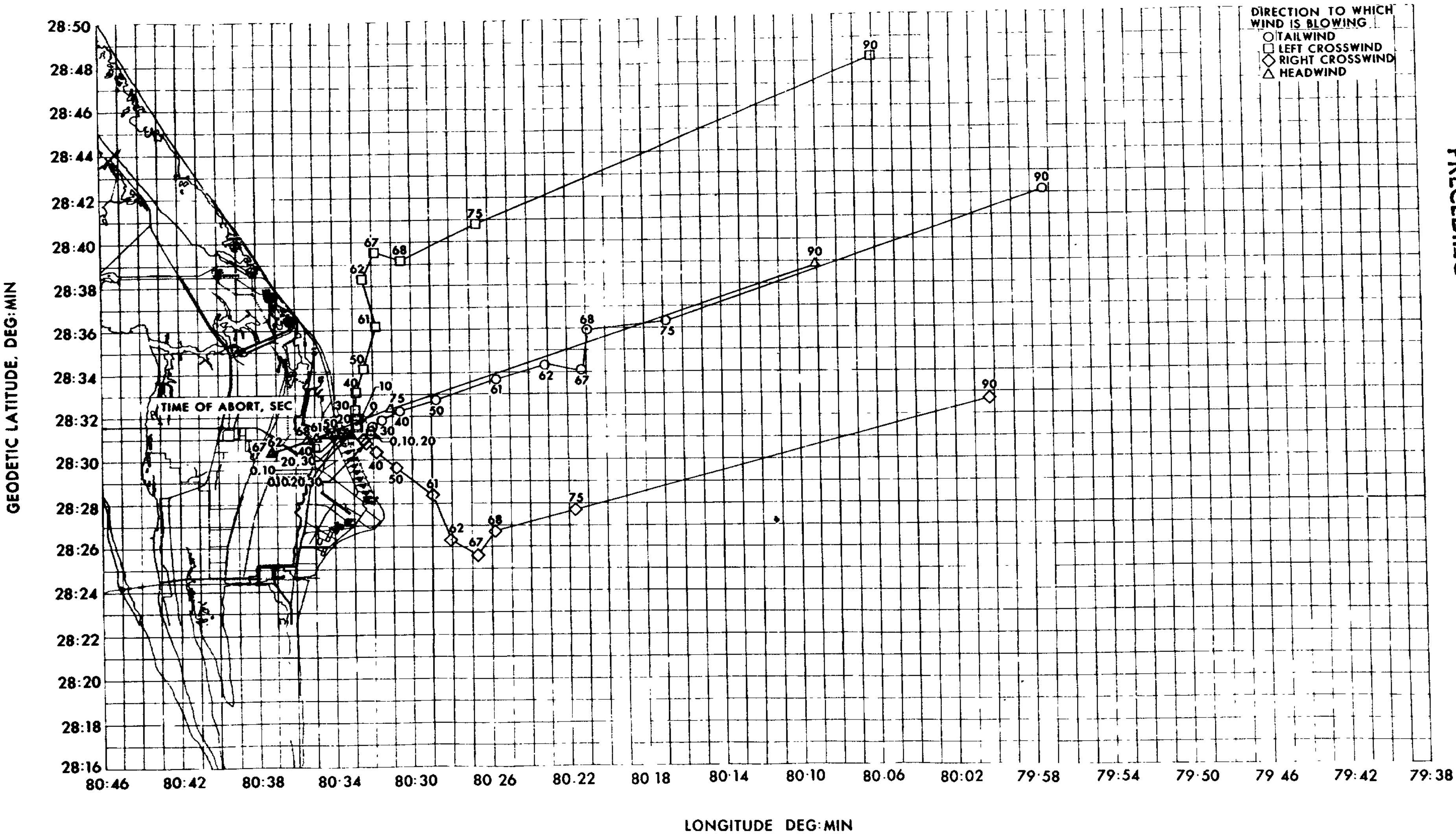

FIGURE 5.- COMMAND MODULE IMPACT POINTS FOR WINDS ON THE LV AND LES TO LANDING.

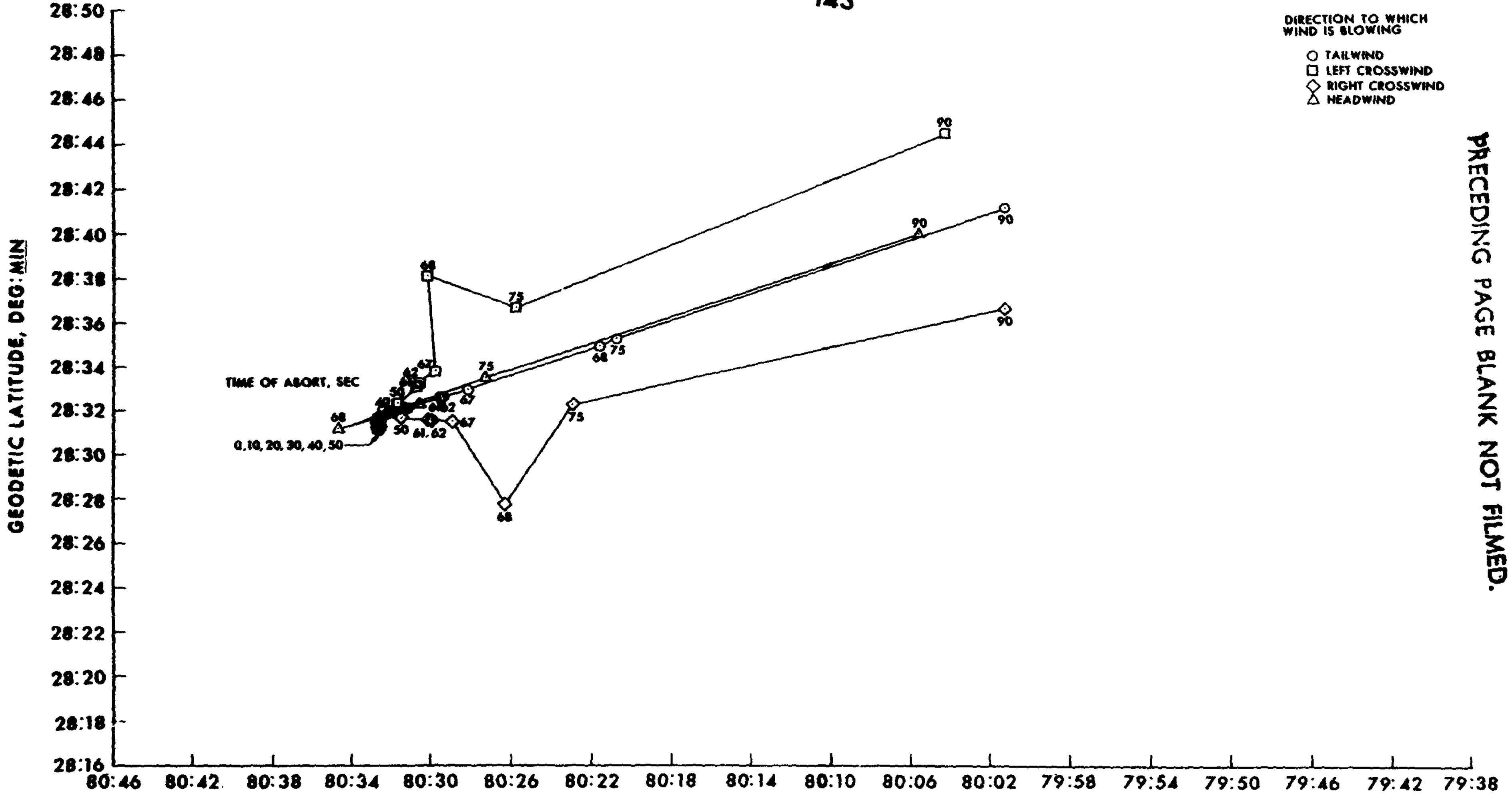

FIGURE 23.- COMMAND MODULE IMPACT POINTS FOR WINDS ON THE LV AND LES THRUST PHASE.

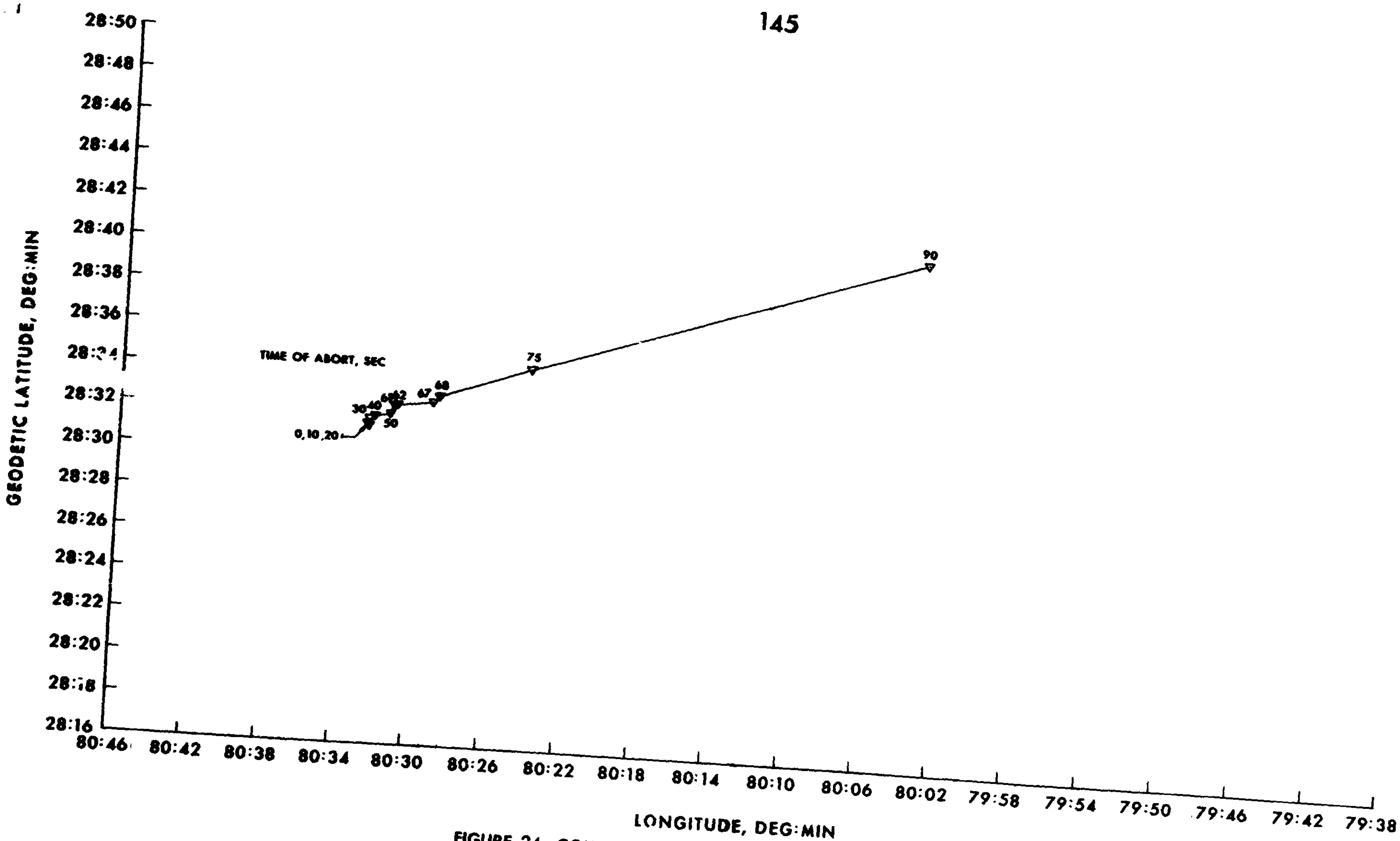

FIGURE 24.- COMMAND MODULE IMPACT POINTS FOR NO WINDS.

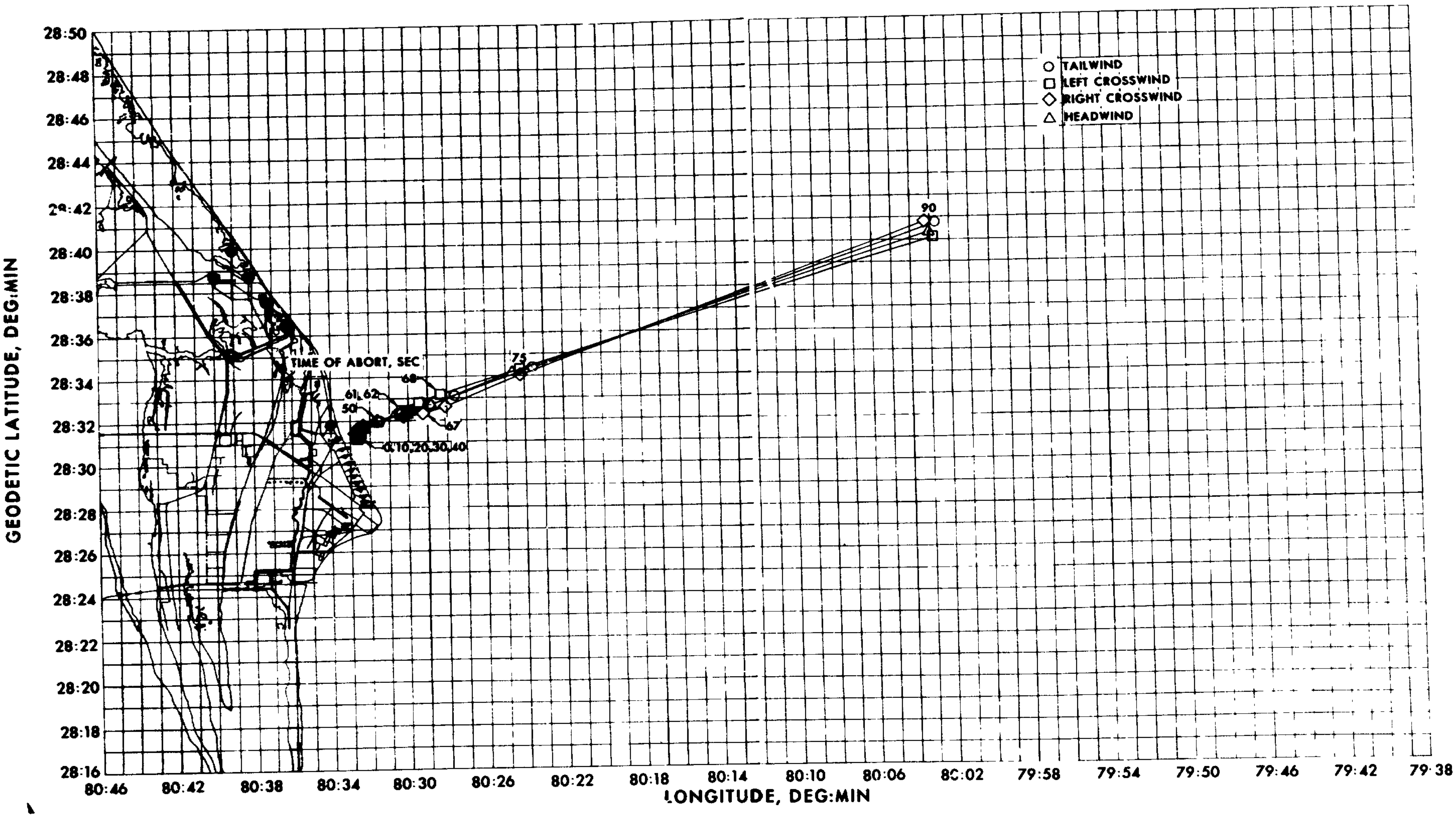

FIGURE 25.- COMMAND MODULE IMPACT POINTS FOR WINDS ON THRUST PHASE OF LES.

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