CR-151289

MCDONNELL DOUGLAS TECHNICAL SERVICES CO.
HOUSTON ASTRONAUTICS DIVISION

DESIGN NOTE NO. 1.4-7-52

QUICK LOOK ANALYSIS OF AN EMERGENCY SEPARATION FOR ALT CAPTIVE-INERT FLIGHT #1

MISSION PLANNING, MISSION ANALYSIS AND SOFTWARE FORMULATION

31 MARCH 1977

This Design Note is Submitted to NASA Under Task Order No. D0608, Task Assignment A, in Partial Fulfillment of Contract NAS 9-14960.

PREPARED BY: ______________________
G. M. Glenn
488-5660, Ext. 281 or 282

PREPARED BY: ______________________
R. H. Seale
488-5660, Ext. 281 or 282

APPROVED BY: ______________________
C. L. Colwell
ALT Separation
Task Manager
488-5660, Ext. 281 or 282

APPROVED BY: ______________________
T. H. Wenglinski
Powered Flight, Separation and
Consumables Analysis
Technical Manager
488-5660, Ext. 229

APPROVED BY: ______________________
W. E. Hayes
Project Manager
Mission Planning, Mission
Analysis and Software
Formulation
488-5660, Ext. 266

(NASA-CR-151289) QUICK LOOK ANALYSIS OF AN EMERGENCY SEPARATION FOR ALT CAPTIVE-INERT FLIGHT 1 (McDonnell-Douglas Technical Services) 34 p HC A03/MF A01 CSCL 22A
N77-21174
G3/16 Unclas 24347

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 SUMMARY

Previous analyses determined emergency separation procedures for ALT free flight configurations for a range of airspeeds between 180 KEAS and 260 KEAS. This supplementary analysis investigates emergency separation capability for the landing configuration of ALT Captive Inert Flight Number One. The quick look analysis documented herein confirms emergency separation capability under nominal conditions for the ALT landing configuration. The recommended emergency separation procedure under those conditions is not applicable to all ALT configurations. The emergency separation procedure documented herein was informally provided to JSC MPAD (FM4) for transmittal to JSC EAD (EX32) prior to the ALT Captive Inert Flight Number One.

2.0 INTRODUCTION

A quick look analysis of emergency separation capability during ALT Captive Inert Flight Number One is required to support JSC MPAD inputs to the ALT flight test planning. Previous analyses (see Reference 1) have been performed to determine emergency ALT Separation procedures for an ALT free flight configuration in an airspeed range between 180 KEAS and 260 KEAS. This analysis is supplemental to that of Reference 1 in that emergency separation capability is investigated for the ALT Captive Inert Flight Number One landing configuration at an initial airspeed of 140 KEAS.

3.0 DISCUSSION

The SCA landing configuration for ALT Captive Inert Flight Number One consists of landing flaps at position 30, landing gear down, and spoilers retracted. Vehicle mass properties documented in Reference 2 were assumed although orbiter weight was adjusted to 142,390 lbs. The aerodynamic increments (supplemental to those documented in Reference 3) for the SCA landing flaps are tabulated in Table 2 (see Reference 4). The corresponding initial conditions for straight and level flight at an airspeed of 140 KEAS and an altitude (above MSL) of 16,000 ft are tabulated in column one of Table 1.

A quick look feasibility analysis of the separation capability of the ALT Captive Inert Flight Number One landing configuration is performed using The Mated Trim Program (see Reference 5). Relative normal acceleration between vehicle cg's increases as angle of attack decreases. An extreme SCA angle of attack condition of -4 deg is considered for the SCA configuration of landing flaps positioned at 30, landing gear down, and spoilers extended (45 deg). (This would be difficult to attain and maintain via a pushover limited to 0.3g as recommended in Reference 1.) The moment trim conditions at 140 KEAS for a -4 deg SCA angle of attack is tabulated in column two of Table 1. The negative relative normal acceleration between the two vehicle CG's precludes separation capability for that configuration even at a -4 deg SCA angle of attack. Separation capability with SCA landing flaps at position 30 is thereby eliminated from further consideration. The landing flap retraction rate capability is tabulated in Table 3. The landing flap full retraction time of 45.5 sec is also undesirable from a standpoint of expediency in an emergency separation. However, landing flaps may be retracted from position 30 to position 5 in 14 sec. The moment trim conditions at 140 KEAS for a 0.3g mated normal load factor for SCA landing flaps at position 5, landing gear down, and spoilers at 45 deg are tabulated in column three of Table 1. The 0.12g relative normal acceleration between the two vehicles is indicative of potential separation capability. Further analysis via Space Vehicle Dynamics Simulation (see Reference 6) is thereby warranted.

The trial emergency separation sequence is tabulated in Table 4. Landing flap repositioning is initiated immediately in order to expedite separation. A pushover is also initiated immediately in order to build up airspeed and moderate angle of attack buildup. Pitch attitude is limited to -10 deg in order to moderate the steepness of the flight path angle. The throttle chop is timed to allow five seconds for thrust decay before separation. Spoilers are simultaneously deployed for consistency with the nominal separation sequence. The second pushover is calibrated to approximate a .3g pushover (recommended by Reference 1). Separation is timed for the near simultaneous attainment of flap position 5 and the .3g pushover. Pitch attitude hold is initiated at separation in order to moderate the steepness of the SCA flight path angle. The SCA roll steering is executed to effect the evasive maneuver. Only nominal conditions are considered in this quick look analysis.

4.0 RESULTS

The results of the Space Vehicle Dynamics Simulation are illustrated in Figures 1 through 19. The effectiveness of the pitch attitude steering (response shown in Figure 1) in enabling separation capability is evident in Figures 2 through 6. Figure 2 shows an SCA angle of attack attainment of approximately 1.5 deg at separation (14 sec). The corresponding mated vehicle normal load factor is approximately .42g (see Figure 3). Normal load factor of each vehicle (see Figure 4) is thereby managed to yield a relative normal acceleration of approximately +0.175g's at separation (see Figure 5). The relative axial acceleration of the two vehicles (see Figure 6) is acceptable.

Relative normal displacement, relative normal velocity, and relative normal acceleration of each of the three attach point pairs is shown in Figures 7, 8, and 9, respectively. Avoidance of attach point recontact of all three pairs is evident from Figures 7 through 9.

Compliance with the 20 deg design target cone angle is illustrated in Figures 10 and 11. Figure 10 is the displacement of the orbiter mid aft attach point relative to the carrier mid aft attach point. Figure 11 is the projection of the relative position of the two vehicles in the carrier pitch plane.

Success of the carrier evasive maneuver is illustrated in Figures 12 through 14. Figure 12 shows the carrier CG moving to the left and behind the orbiter CG. Figure 13 shows the carrier cg moving below and behind the orbiter CG. Figure 14 also illustrates acceptable wing tip clearance of the respective vehicles.

Acceptable post separation dynamic responses are illustrated in Figure 15 through 19. Figure 15 shows the carrier roll response which effects the successful evasive maneuver. Figure 16 illustrates the carrier turn coordination. Figure 17 shows the carrier airspeed buildup to be within carrier overspeed limits. Figure 18 shows carrier altitude sufficient for carrier pull out to straight and level flight. Flight 19 shows the carrier flight path angle to be sufficiently shallow for carrier pull out to straight and level flight.

5.0 CONCLUSIONS AND RECOMMENDATIONS

It is concluded that emergency separation capability exists for ALT Captive Inert Flight Number One landing configuration under nominal flight conditions. It is therfore recommended that the separation sequence of events tabulated in Table 4 be used to accommodate the specified emergency separation contingency.

6.0 REFERENCES

1) TBC Document No. D180-18407-5, "ALT Launch Simulation No. 3 and Captive Flight Test Simulation No. 1 - 30 Day Report."

2) MDTSCO Design Note No. 1.4-7-51, "ALT Separation Reference Trajectories For Tailcone On Orbiter Forward and Aft CG Configurations," 31 March 1977.

3) MDTSCO TM No. 1.4-7-403, "Update of ALT Separation Aerodynamic Data Base," 31 March 1977.

4) TBC Document No. D180-18402-4, "747/Orbiter CAM Aerodynamic Characteristics - Approach and Landing Test Configuration Tailcone On, Volume IV."

5) MDTSCO Design Note No. 1.4-7-19, "ALT 747/Orbiter Mated Trim Computer Program," 17 November 1975.

6) JSC Internal Note No. 76-FM-26, "Space Vehicle Dynamics Simulation (SVDS) Program Description," 6 May 1976.

Table 1

ALT Captive Inert Flight #1 Trial Separation Initial Conditions

	Equilibrium Glide	Moment Trim Conditions for Landing Flap Position	
		30.0	5.0
Carrier Configuration			
Landing Flap Position (-)	30.0	30.0	5.0
Spoiler Position (deg)	0.0	45.0	45.0
Landing Gear (deg)	90.0	90.0	90.0
Incidence Angle (deg)	6.0	6.0	6.0
Orbiter Elevon Setting (deg)	-1.0	-1.0	-1.0
MSL Altitude (ft)	16,000.0	16,000.0	16,000.0
Airspeed (KEAS)	140.0	140.0	140.0
Mach (-)	0.287	0.287	0.287
Flight Path Angle (deg)	0.000	0.000	0.000
Carrier Angle of Attack (deg)	2.98	-4.0	2.0
Carrier Pitch Attitude (deg)	2.98	-4.0	2.0
Relative Normal Accelerations (g's)	-0.854	-0.295	0.122
Orbiter Initial Post Separation Pitch Acceleration (deg/sec^2	1.64	1.54	1.40

Table 2

SCA Landing Flap Aerodynamics

$$\Delta C_{L_{FLAP}} = \left[.89 + \frac{.04}{6}\alpha_{747}\right] \times \frac{\delta_{FLAP}}{30}$$

$$\Delta C_{D_{FLAP}} = \left[.159 + \frac{.042}{6}\alpha_{747}\right] \times \frac{\delta_{FLAP}}{30}$$

$$\Delta C_{M_{FLAP}} = -\left[.22 + \frac{.032}{6}\alpha_{747}\right] \times \frac{\delta_{FLAP}}{30}$$

Table 3

SCA Landing Flap Retraction Rate

Time (Sec)	Flap Position
0	30
5.0	20
10.0	10
14.0	5
44.0	1
45.5	0

Table 4

ALT Captive Inert Flight #1 Emergency Separation Sequence of Events

TIME (SEC)	EVENT
0	Start flap retraction (see schedule from Table 3)
0	Begin -2 deg/sec pushover
$\simeq$ 6.5	Attitude hold @ $\theta \simeq -10$ deg
9	Chop throttle to idle
9	Deploy spoilers
11	Begin -4.3 deg/sec pushover (approximate .3g pushover)
14	Separate
14	Attitude hold (pitch)
19	Start -10 deg/sec roll maneuver to -30 deg bank angle

FIGURE 1

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

PITCH ATTITUDE TIME HISTORIES

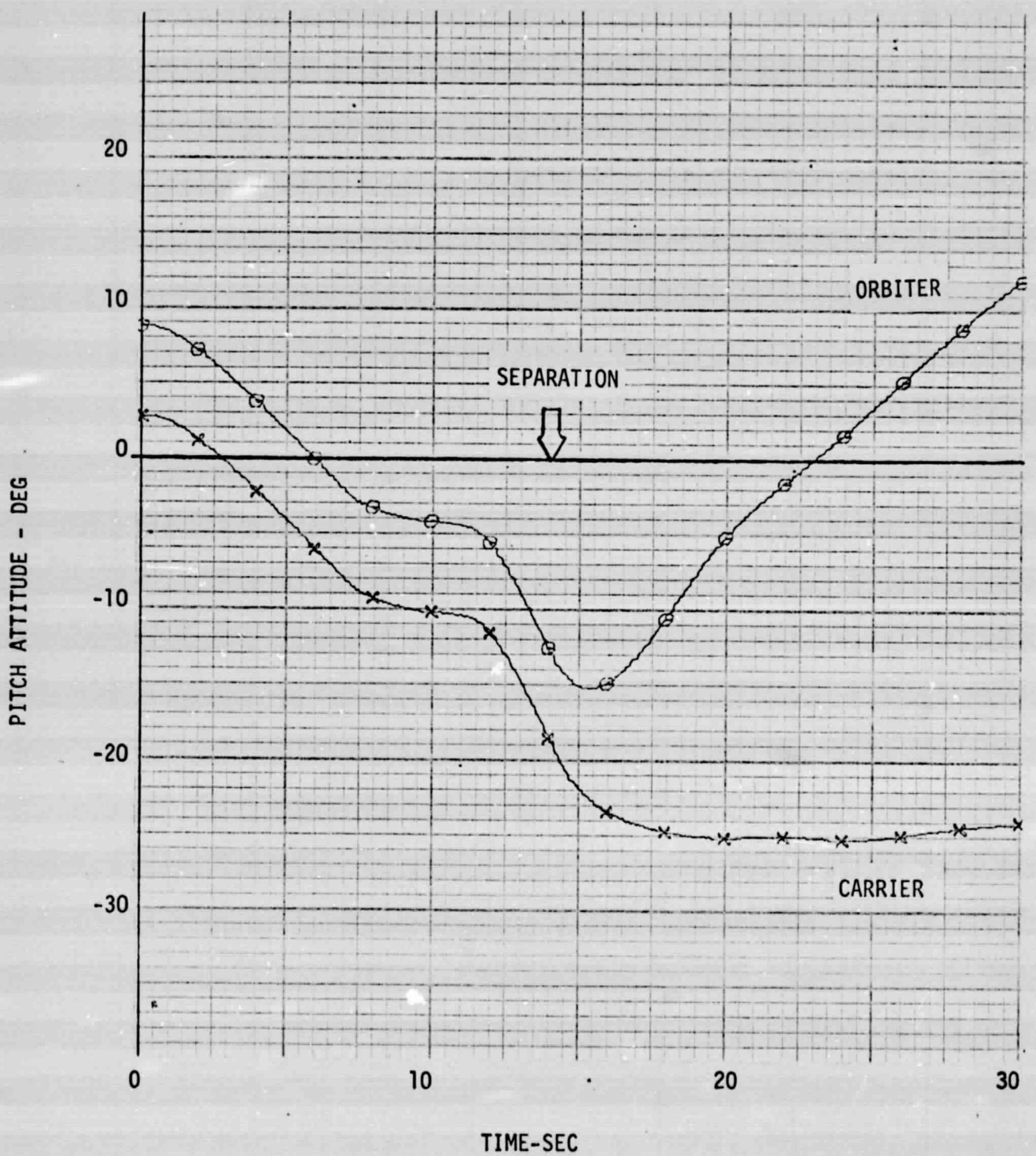

FIGURE 2

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

ANGLE OF ATTACK TIME HISTORIES

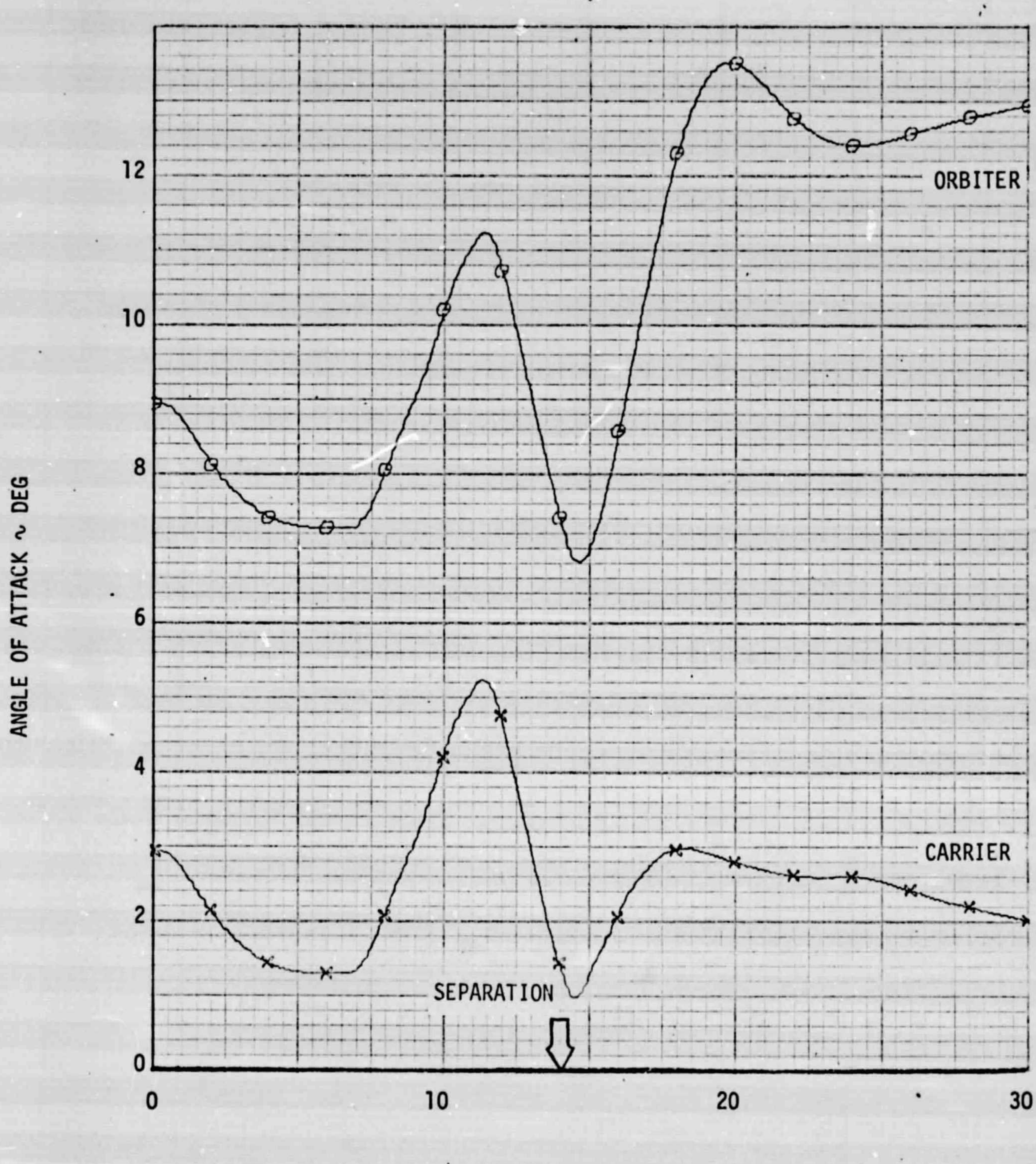

FIGURE 3

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

MATED VEHICLE NORMAL LOAD FACTOR TIME HISTORY

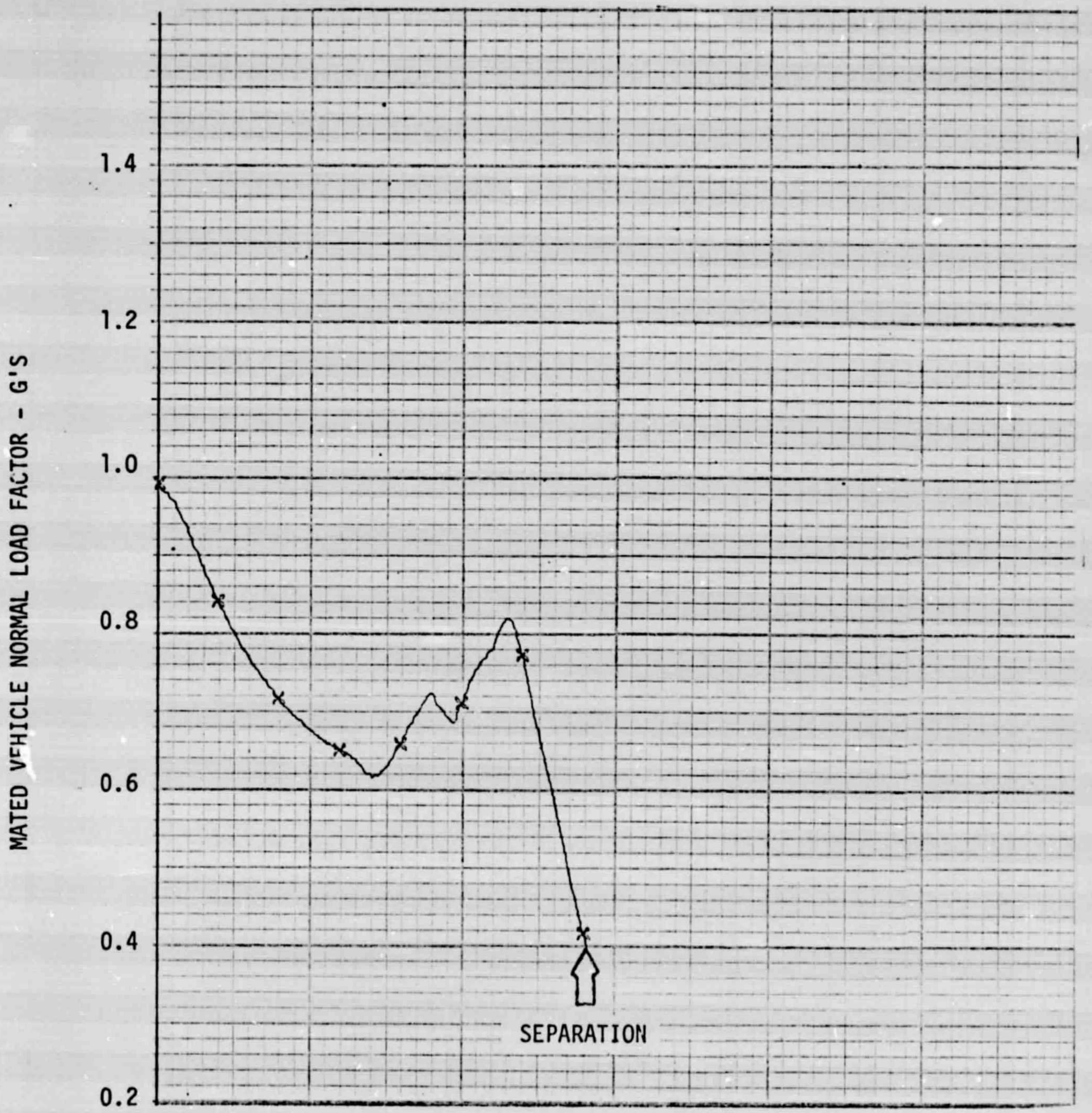

FIGURE 4

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

NORMAL LOAD FACTOR TIME HISTORIES

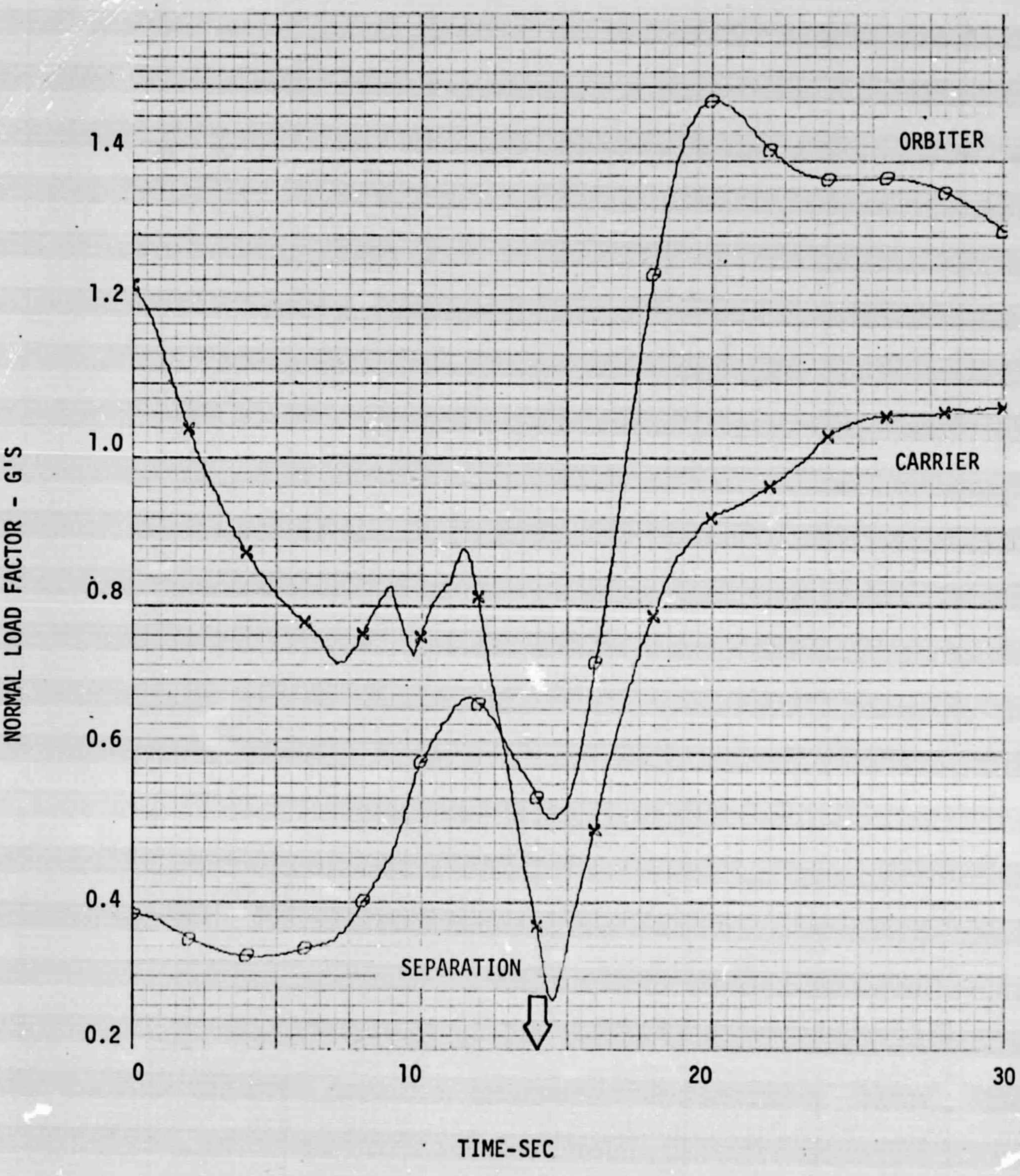

FIGURE 5

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

RELATIVE NORMAL LOAD FACTOR TIME HISTORY

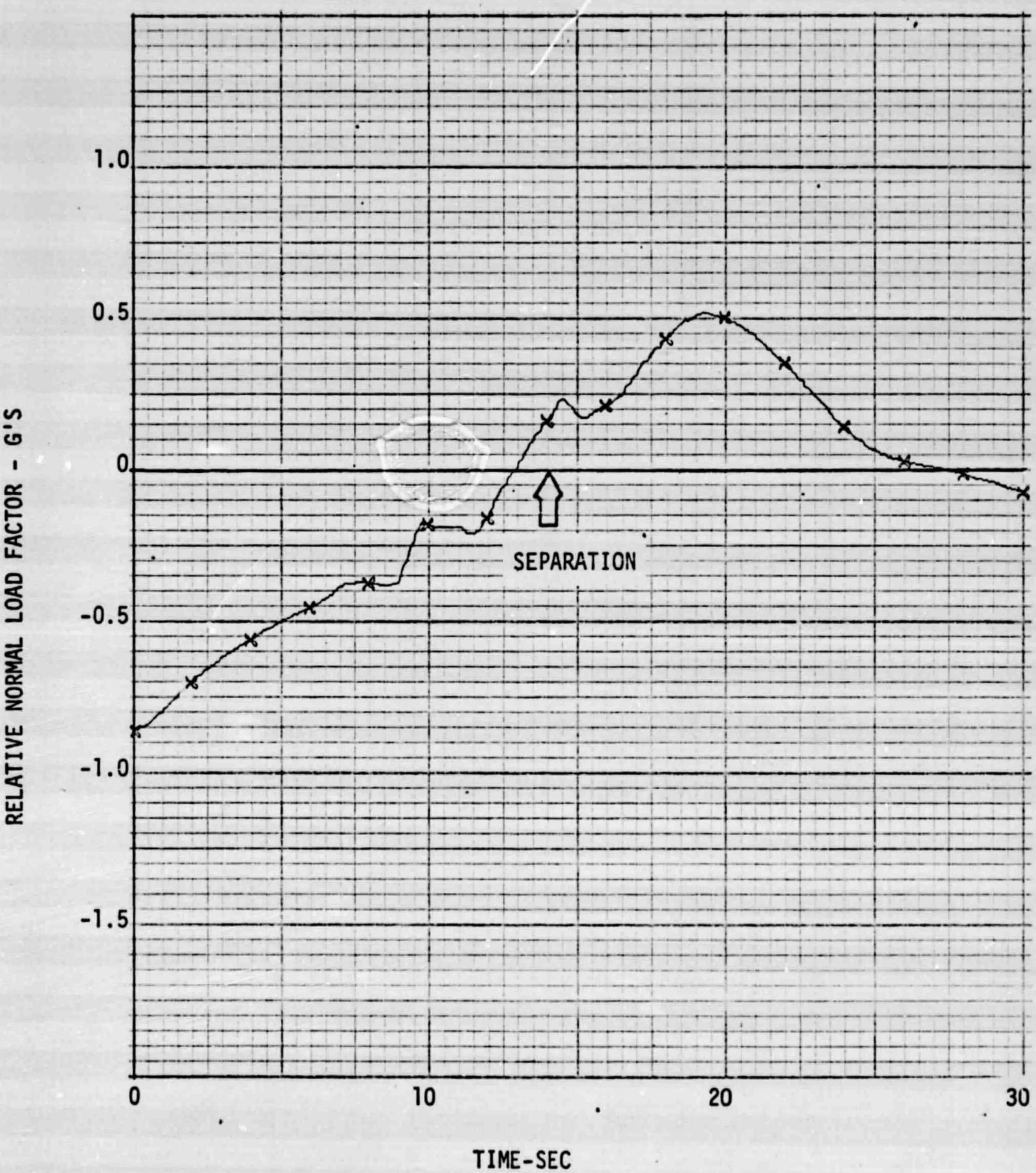

FIGURE 6

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

RELATIVE AXIAL LOAD FACTOR TIME HISTORY

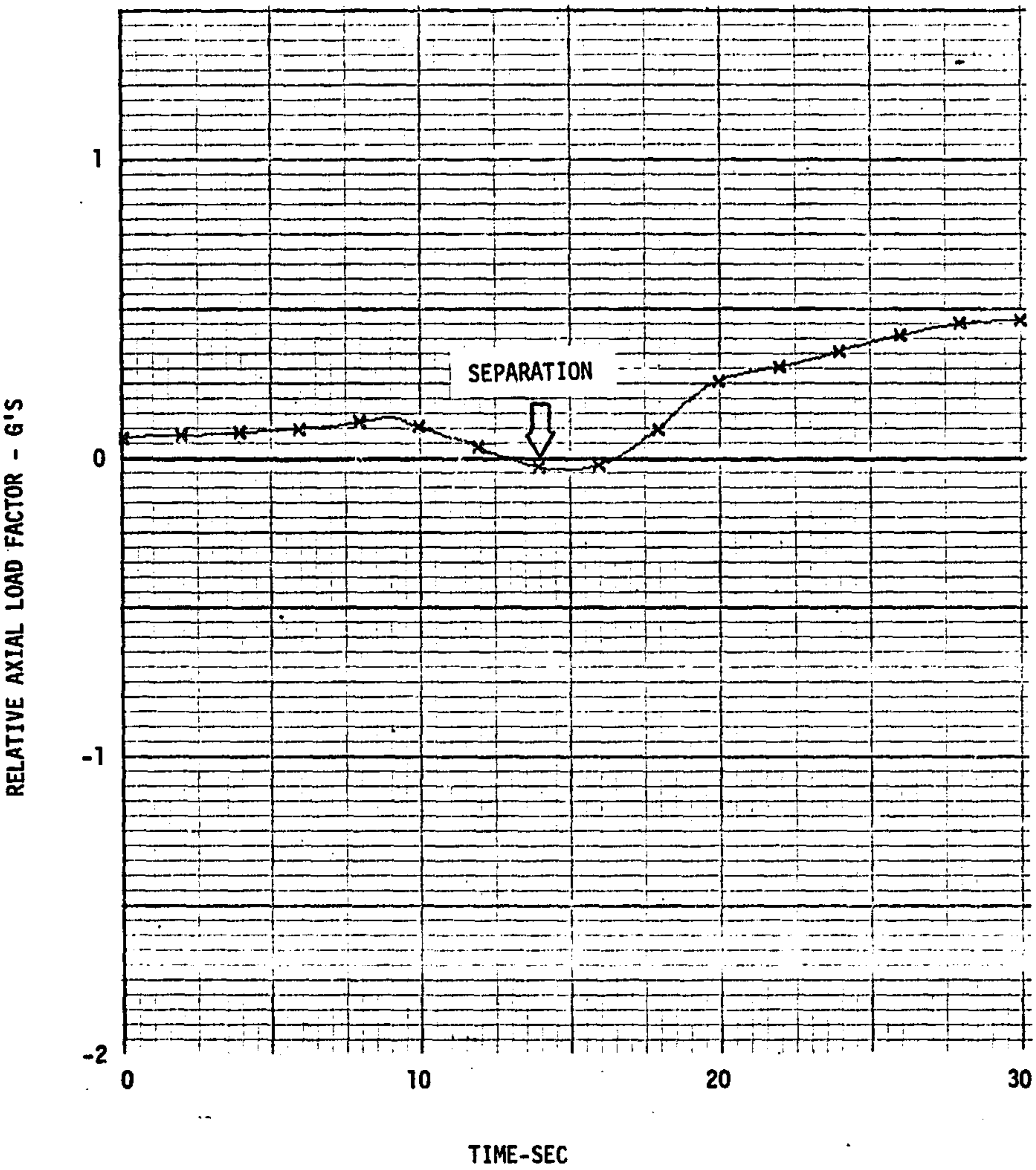

FIGURE 7

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

ATTACH POINT RELATIVE NORMAL DISPLACEMENT TIME HISTORIES

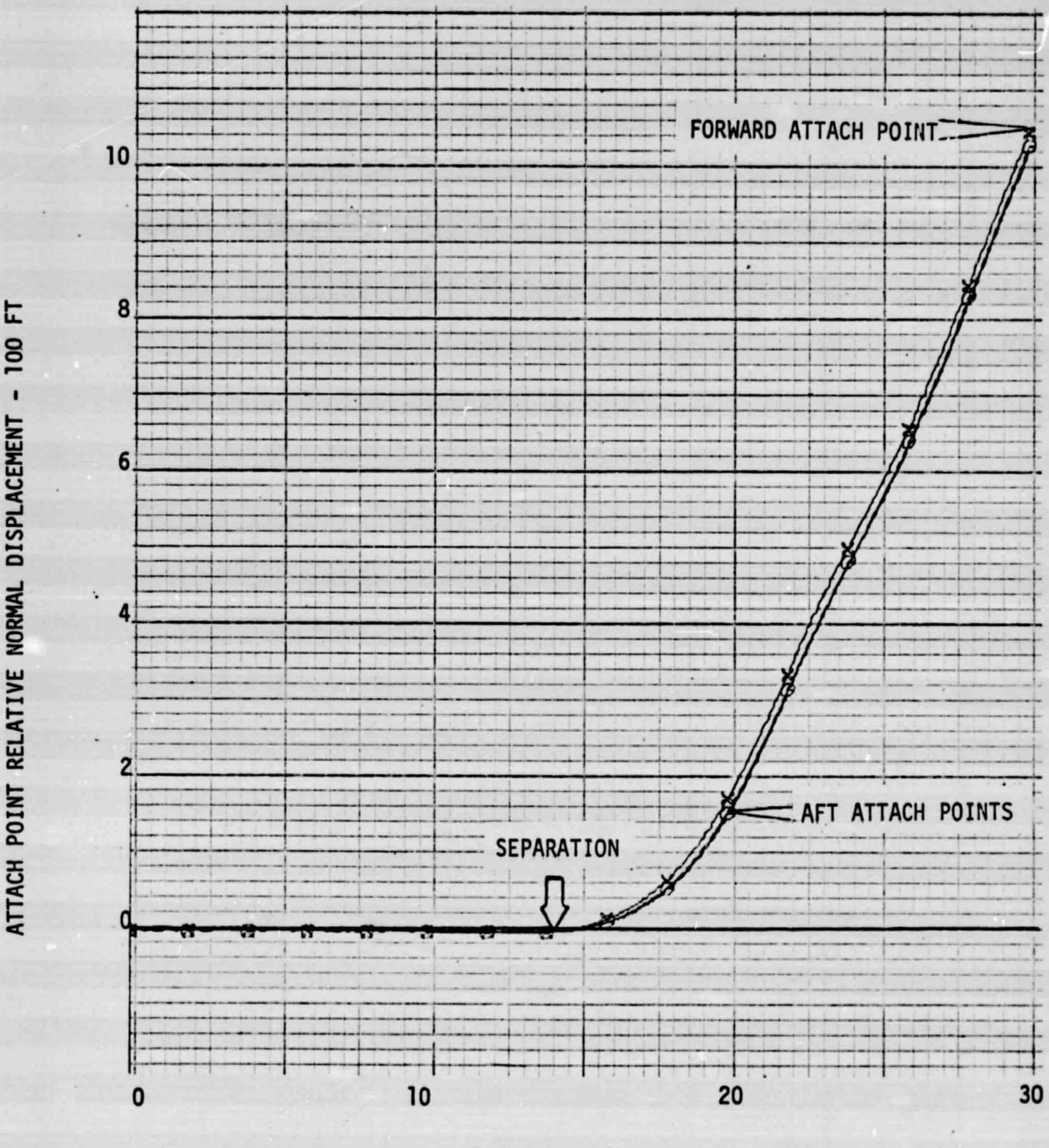

FIGURE 8

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

ATTACH POINT RELATIVE NORMAL VELOCITY TIME HISTORIES

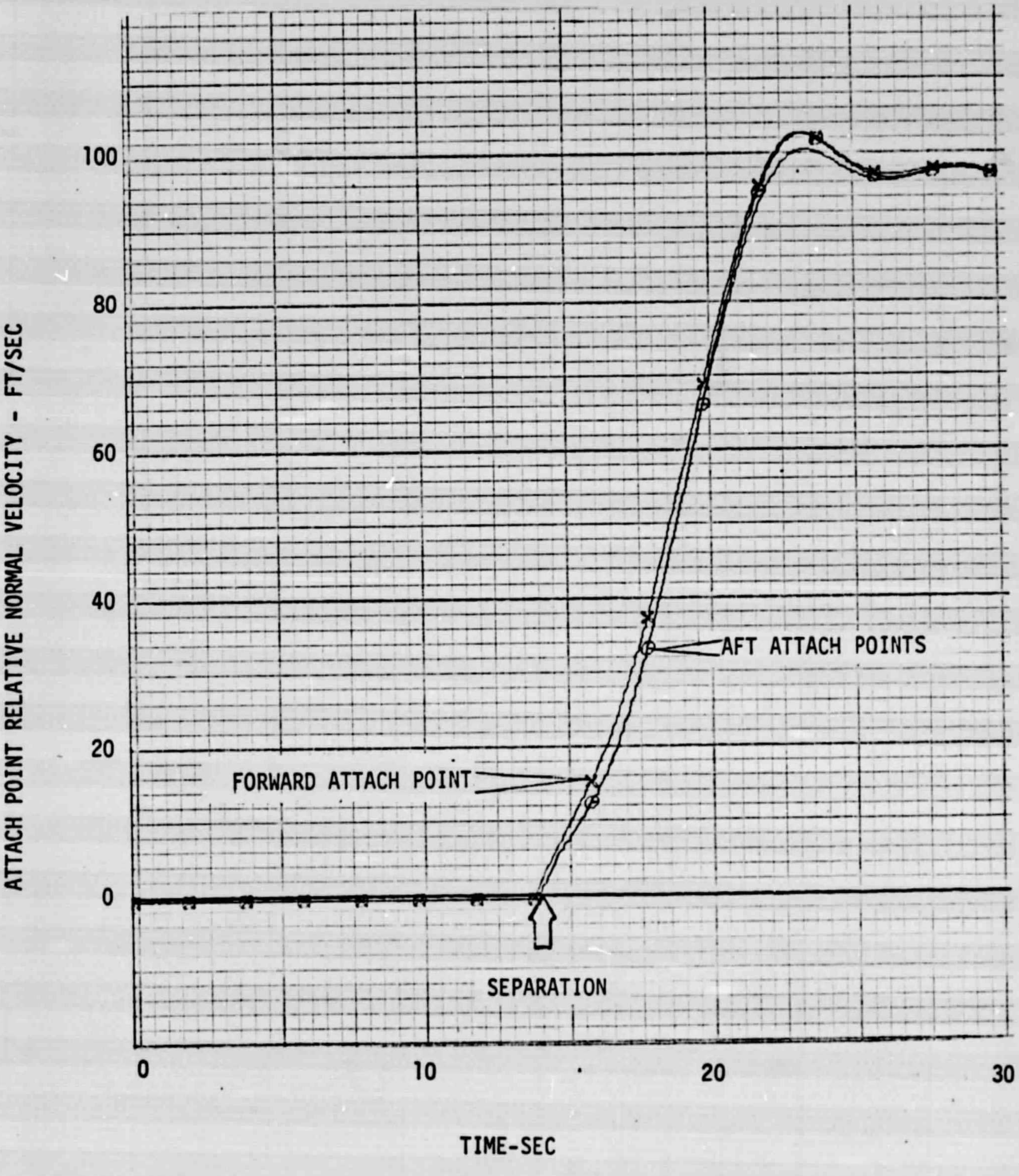

FIGURE 9

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

ATTACH POINT RELATIVE NORMAL ACCELERATION TIME HISTORIES

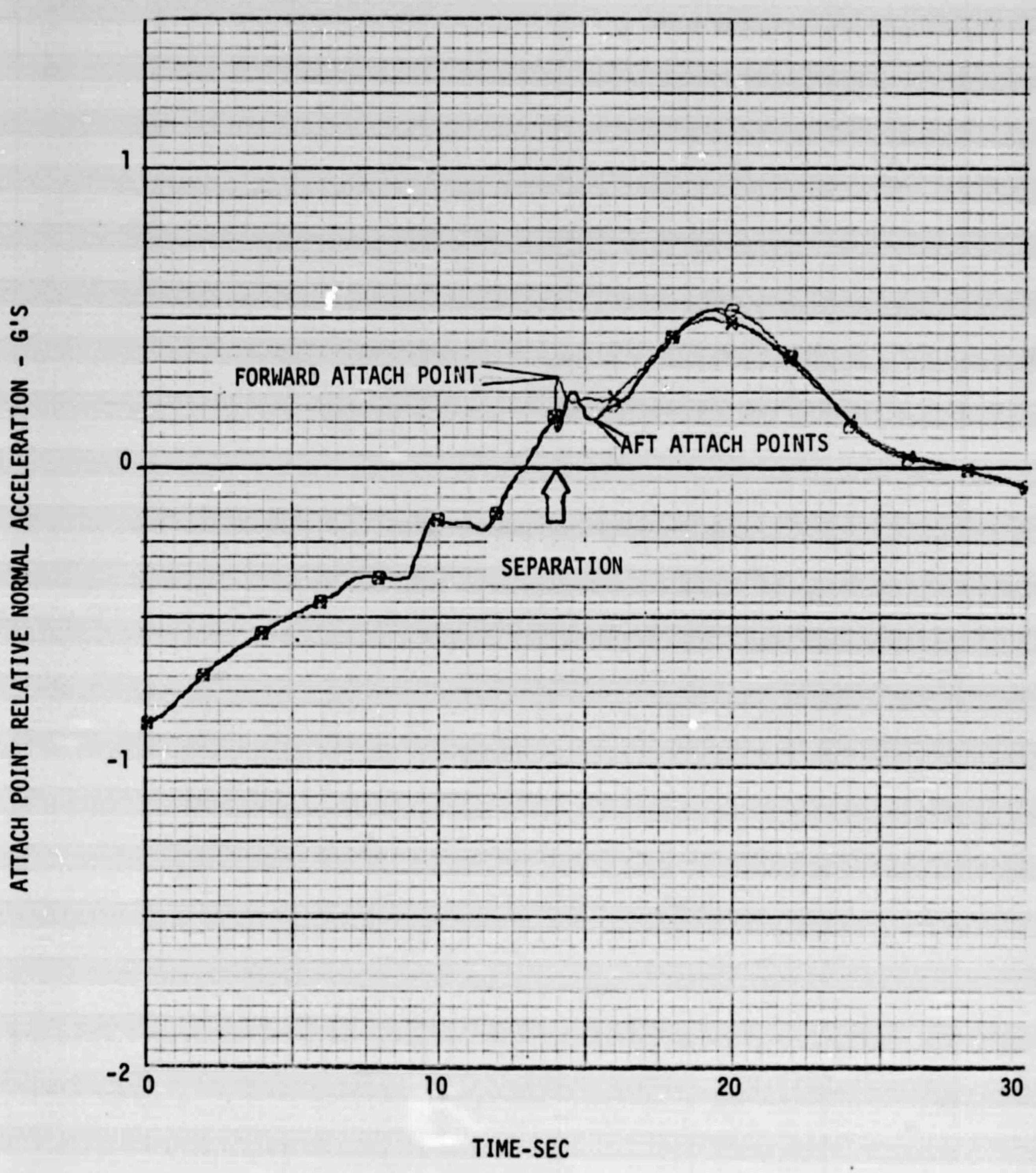

FIGURE 10

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

NORMAL CLEARANCE VERSUS LONGITUDINAL CLEARANCE

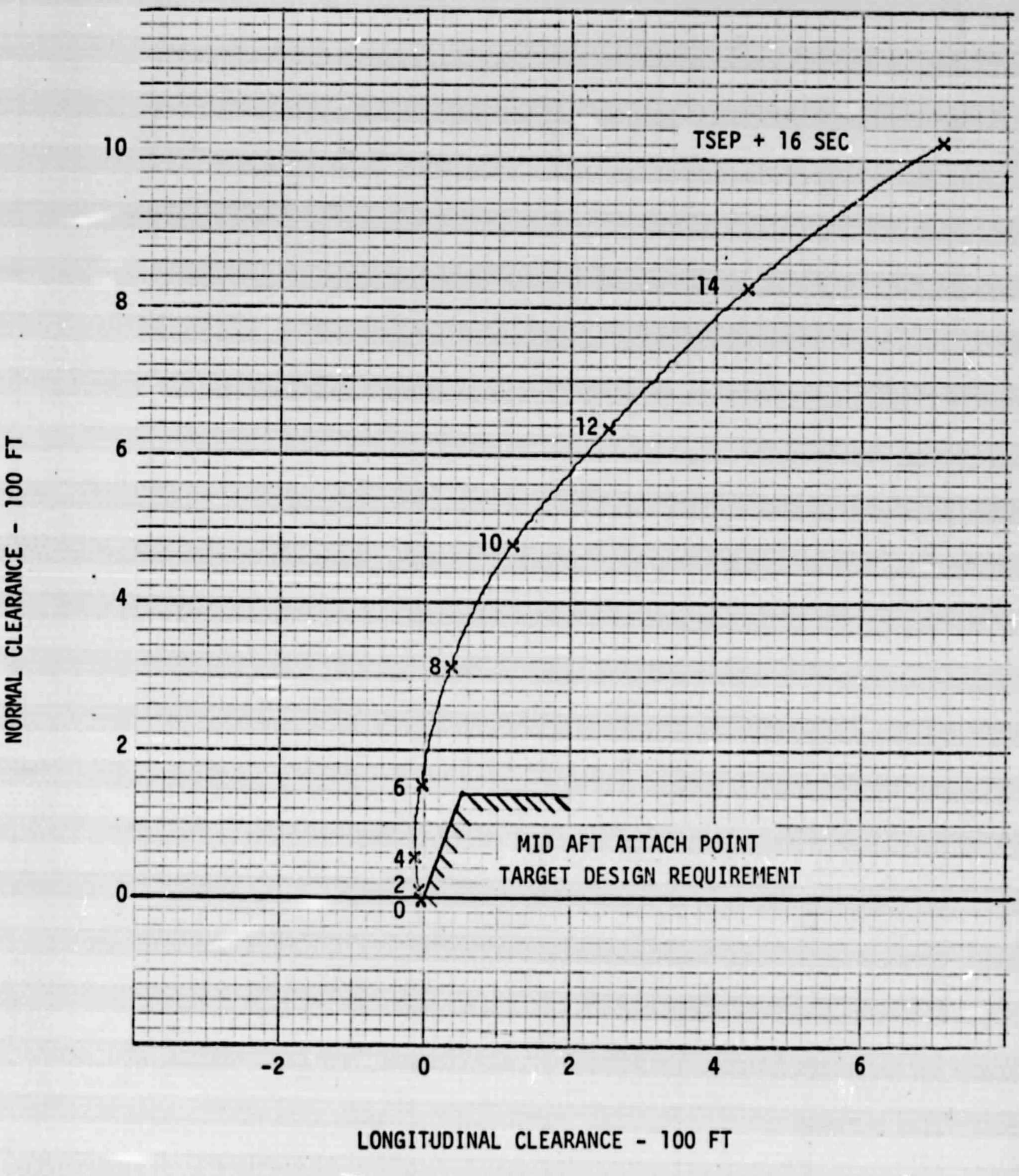

FIGURE 11

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

MOTION OF ORBITER RELATIVE TO 747 AFTER SEPARATION

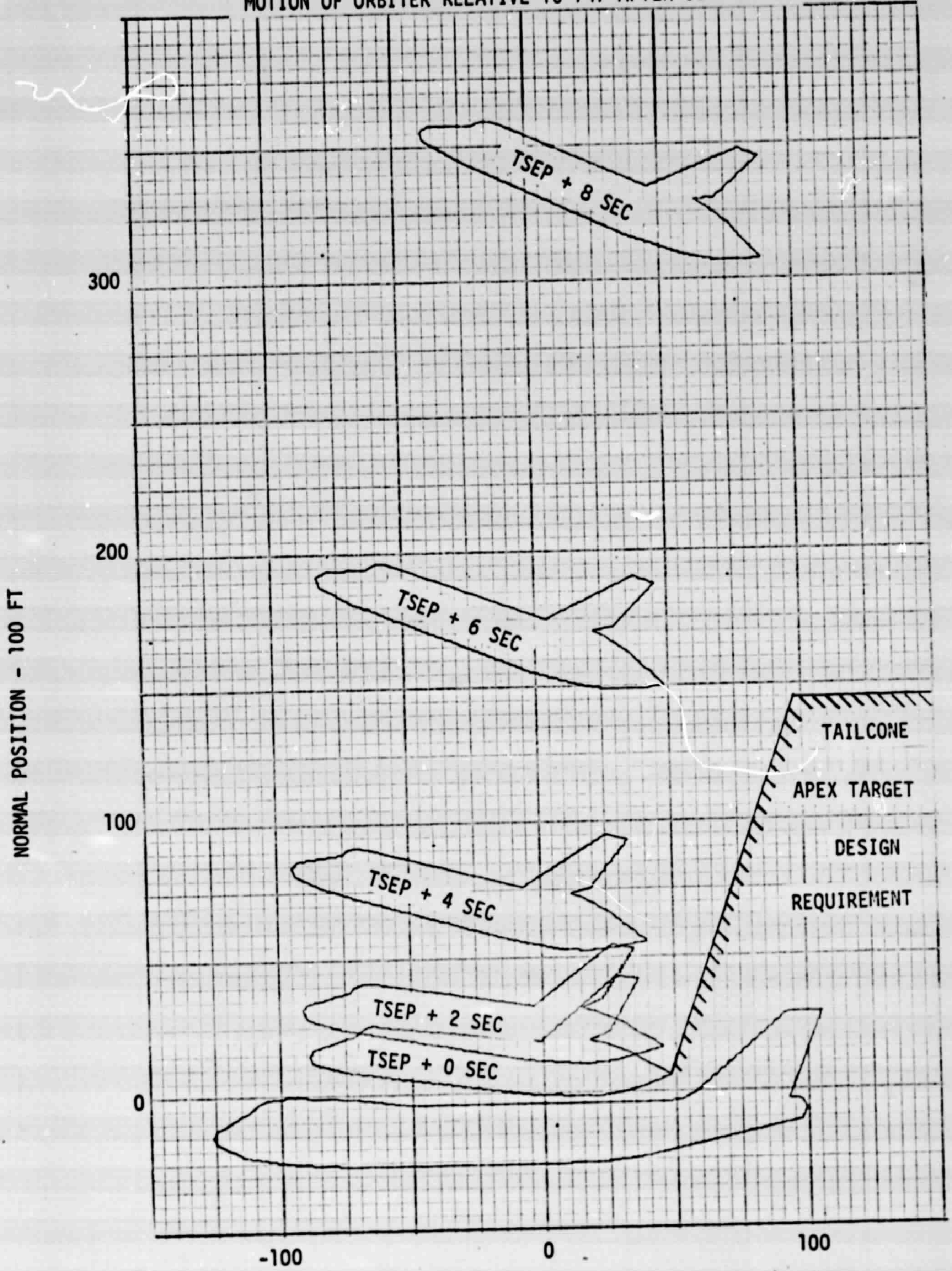

FIGURE 12

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

RELATIVE DOWNRANGE VERSUS RELATIVE CROSSRANGE

VIEW LOOK DOWN (+z)

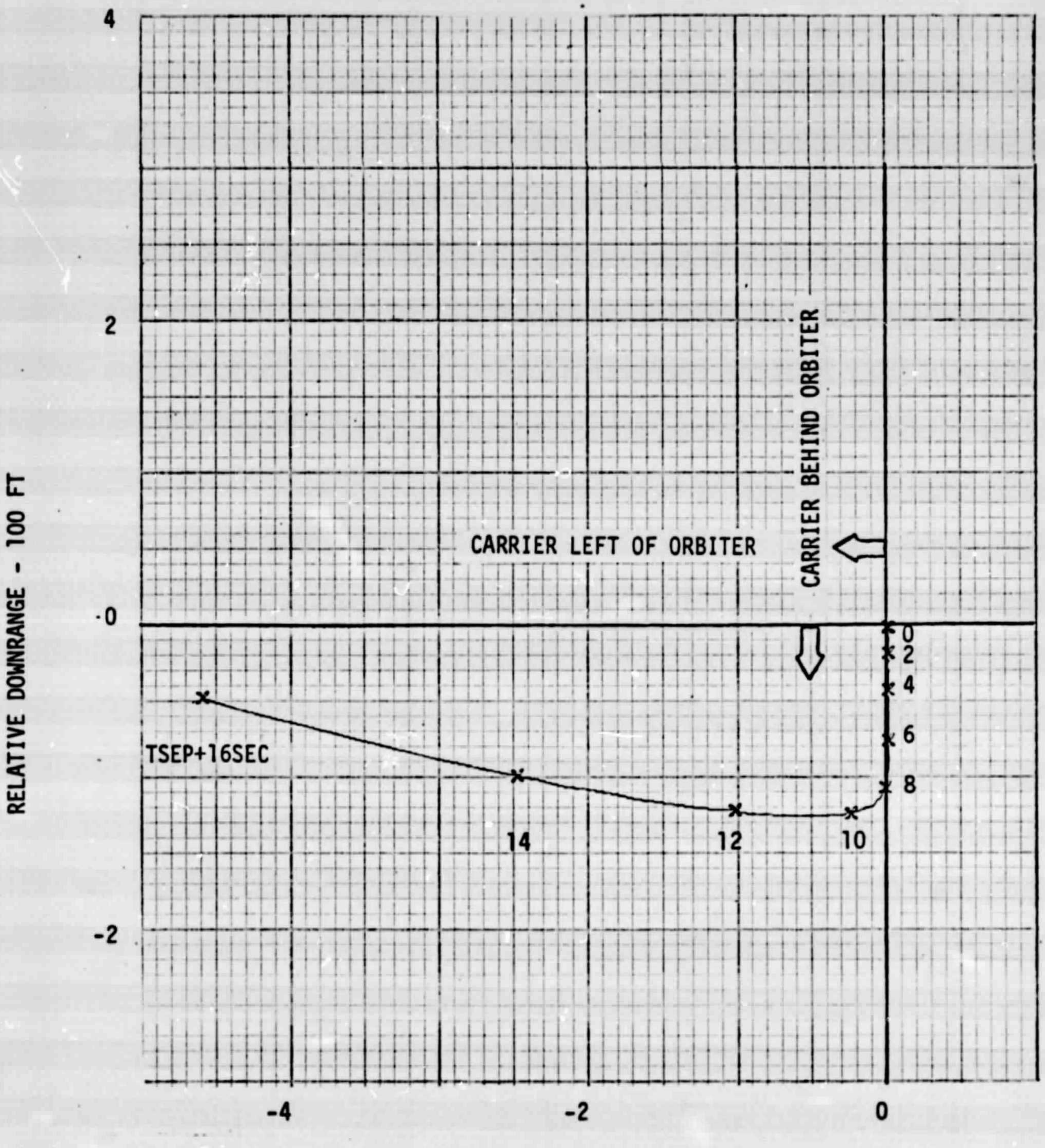

FIGURE 13

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

RELATIVE VERTICAL RANGE VERSUS RELATIVE DOWNRANGE

VIEW LOOKING LEFT CROSSRANGE (-Y)

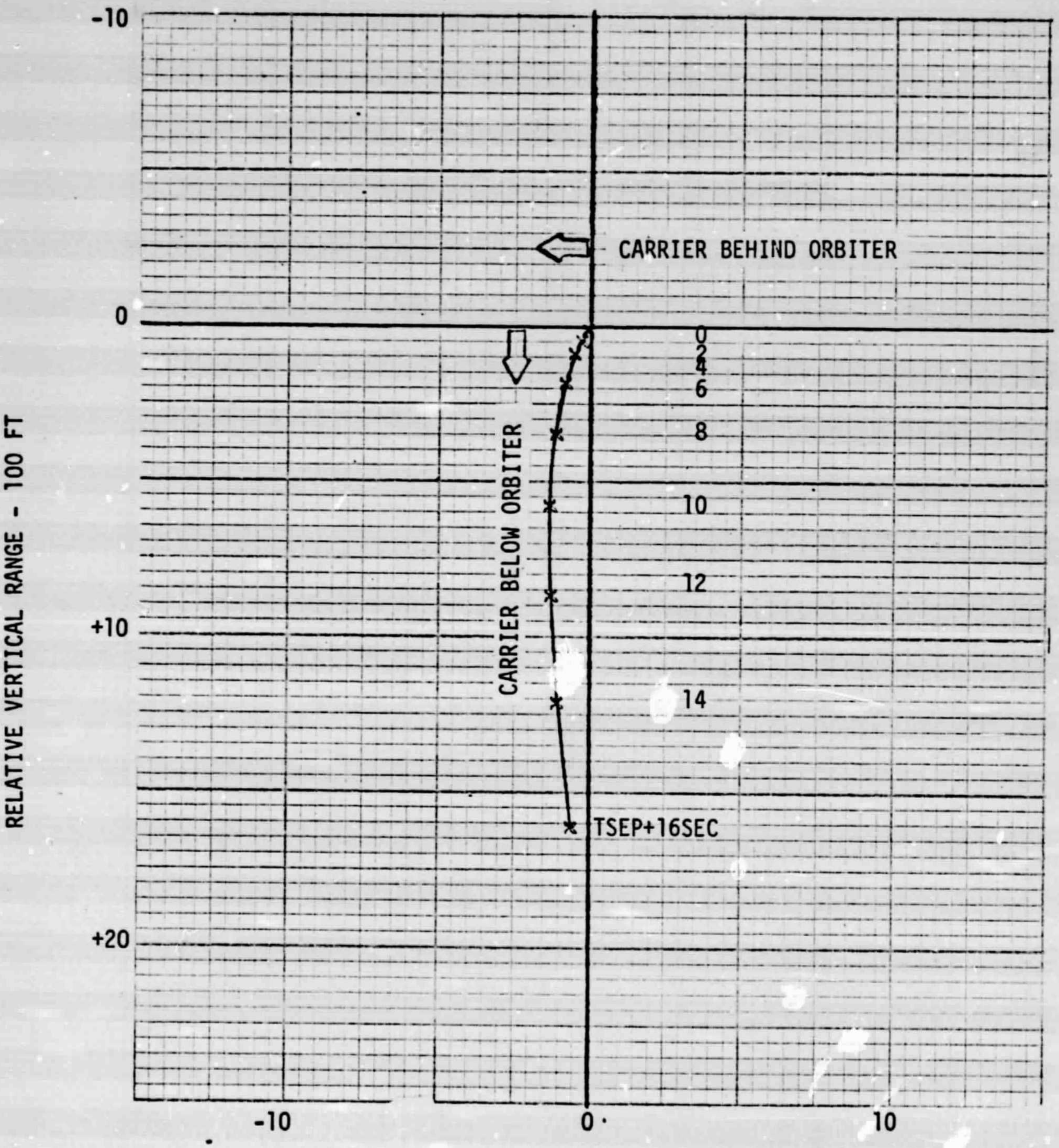

FIGURE 14

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION
RELATIVE VERTICAL RANGE VERSUS RELATIVE CROSSRANGE

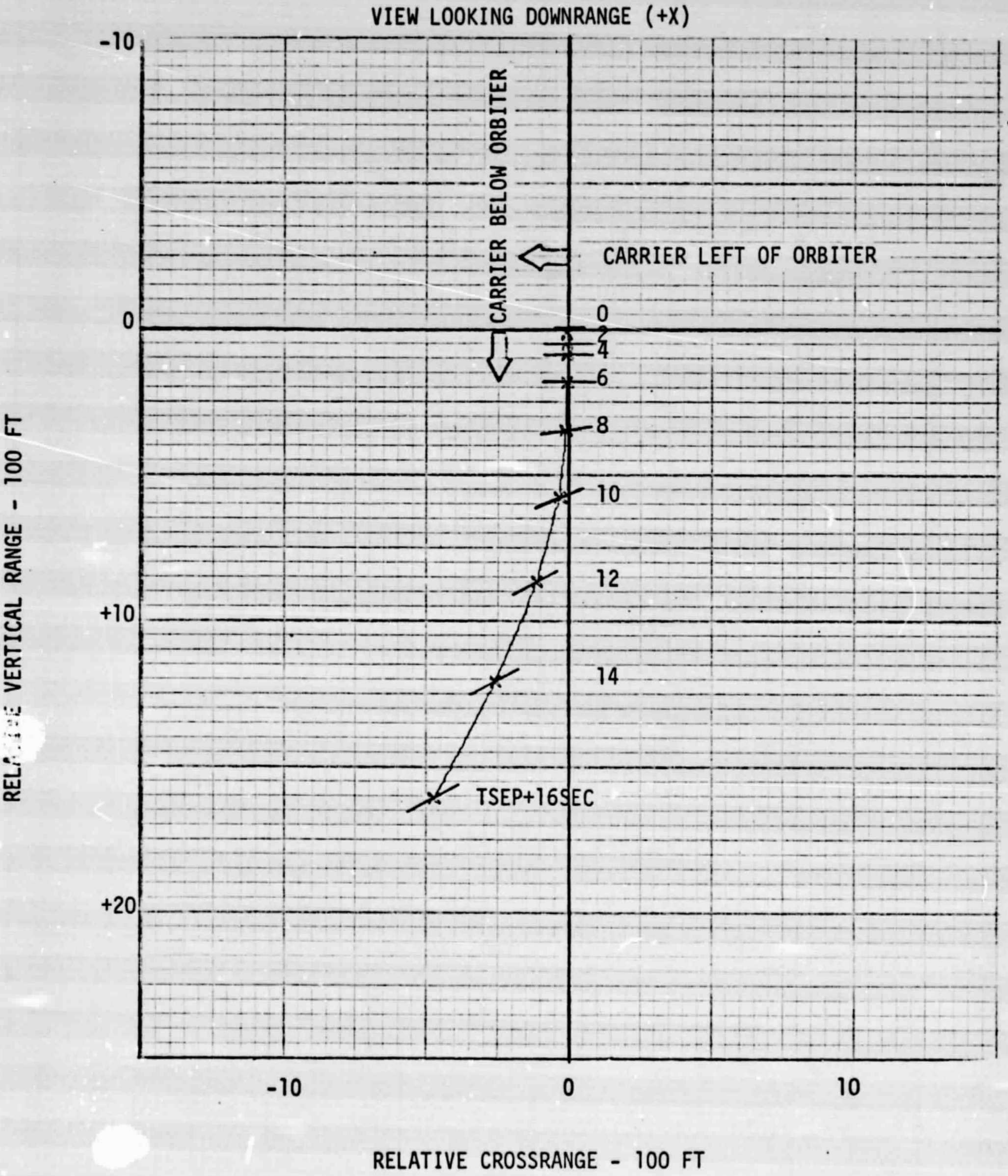

FIGURE 15

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

ROLL ATTITUDE TIME HISTORIES

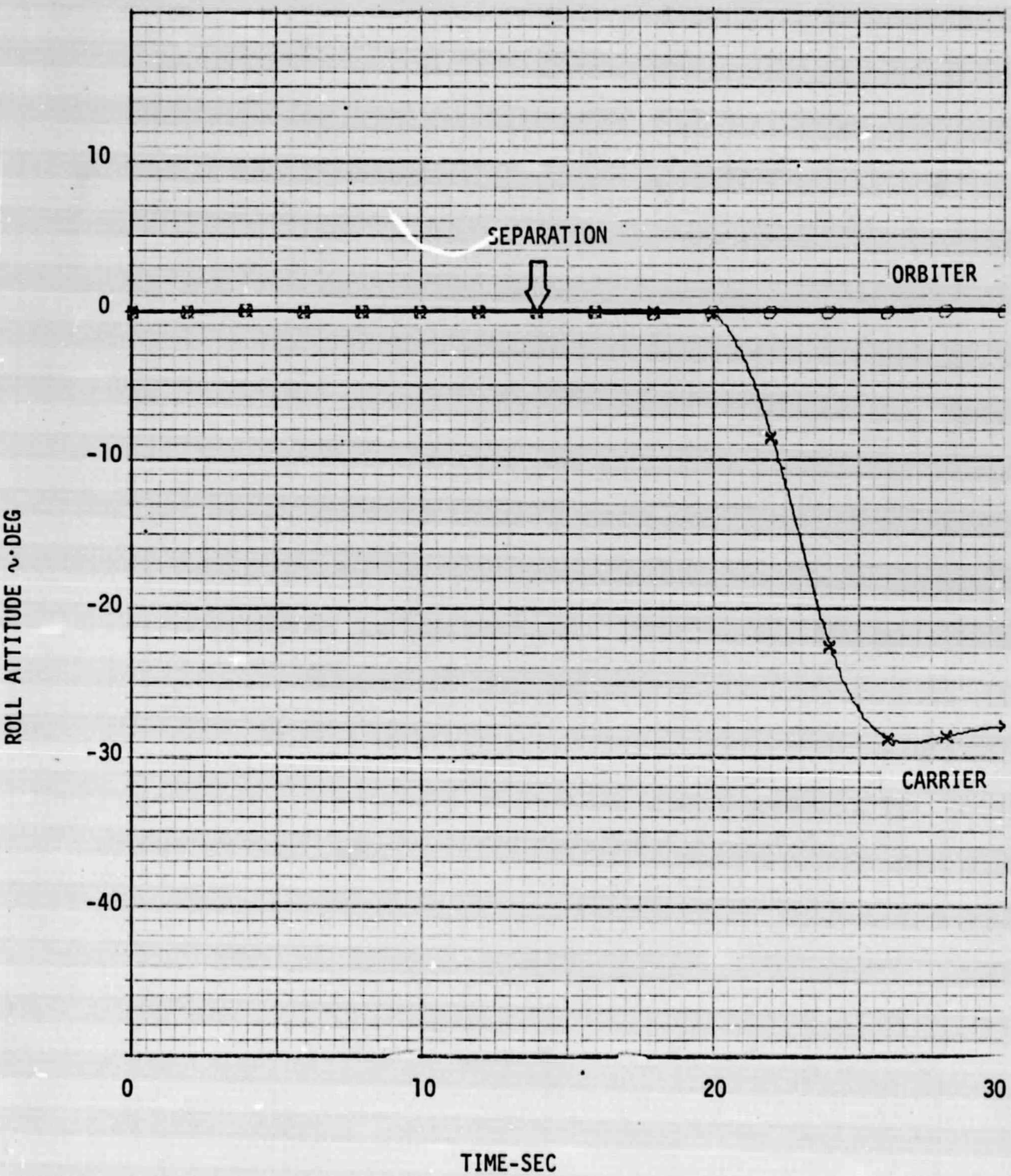

FIGURE 16

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

SIDESLIP ANGLE TIME HISTORIES

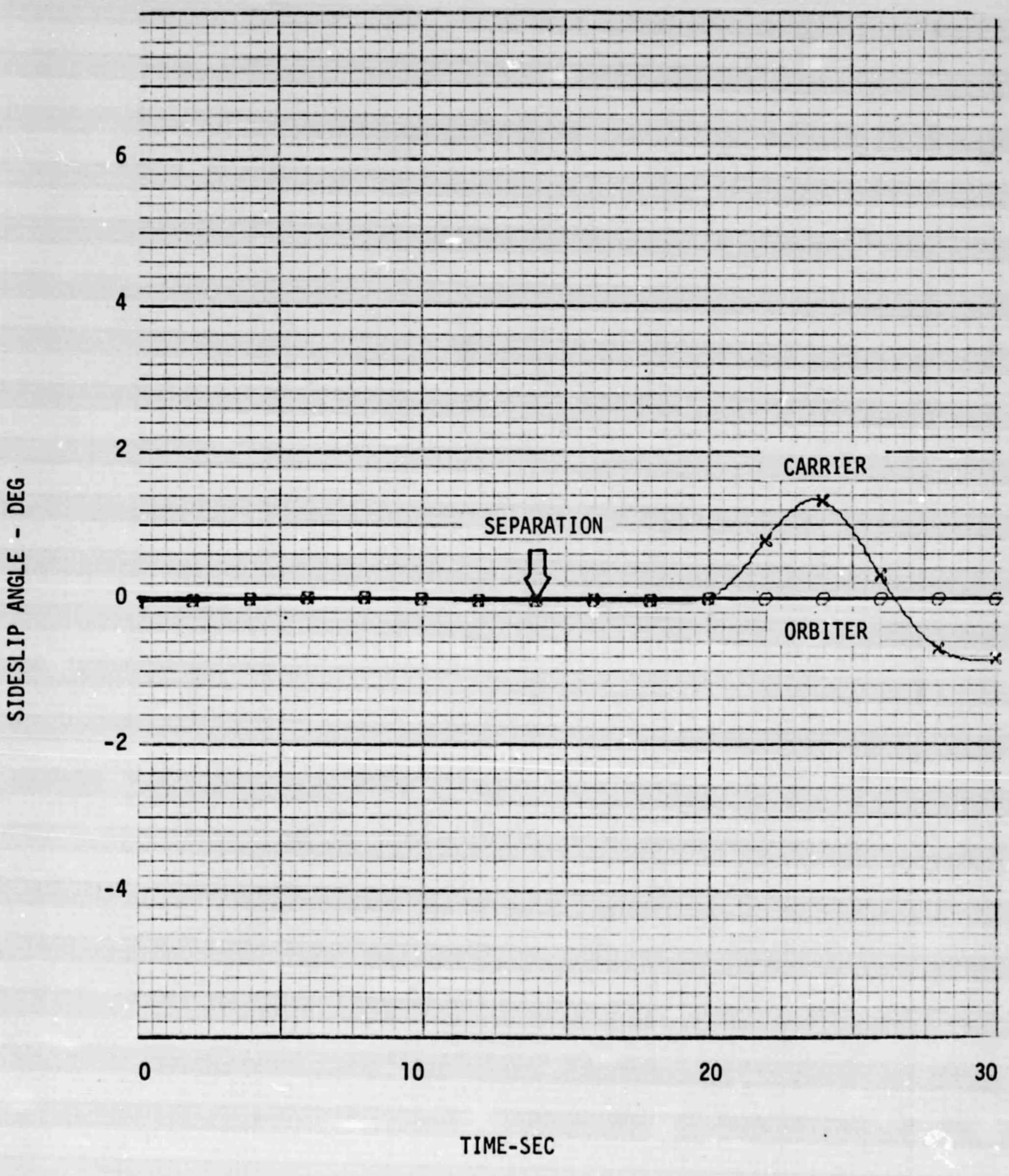

FIGURE 17

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

EQUIVALENT AIRSPEED TIME HISTORIES

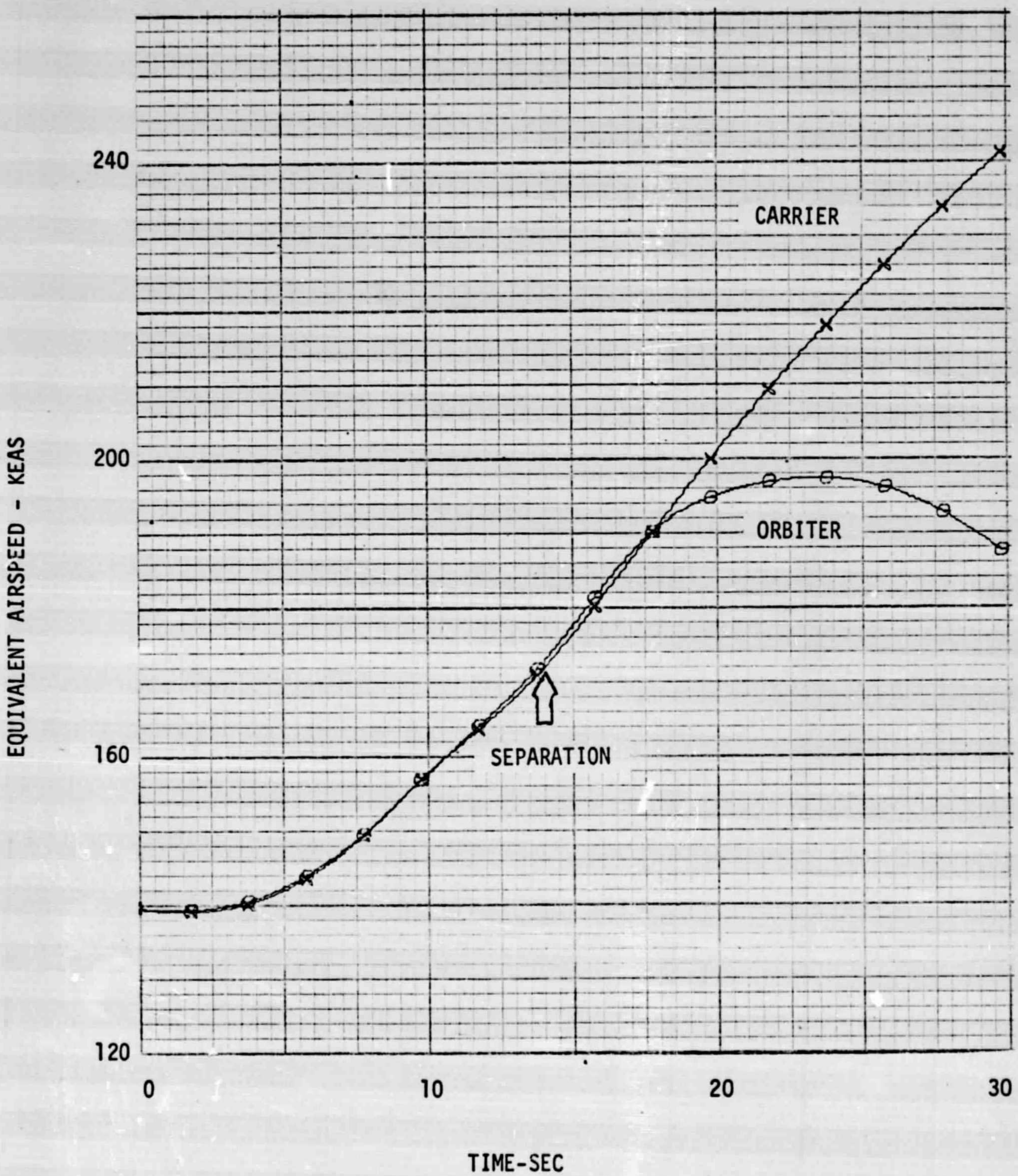

FIGURE 18

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

ALTITUDE TIME HISTORIES

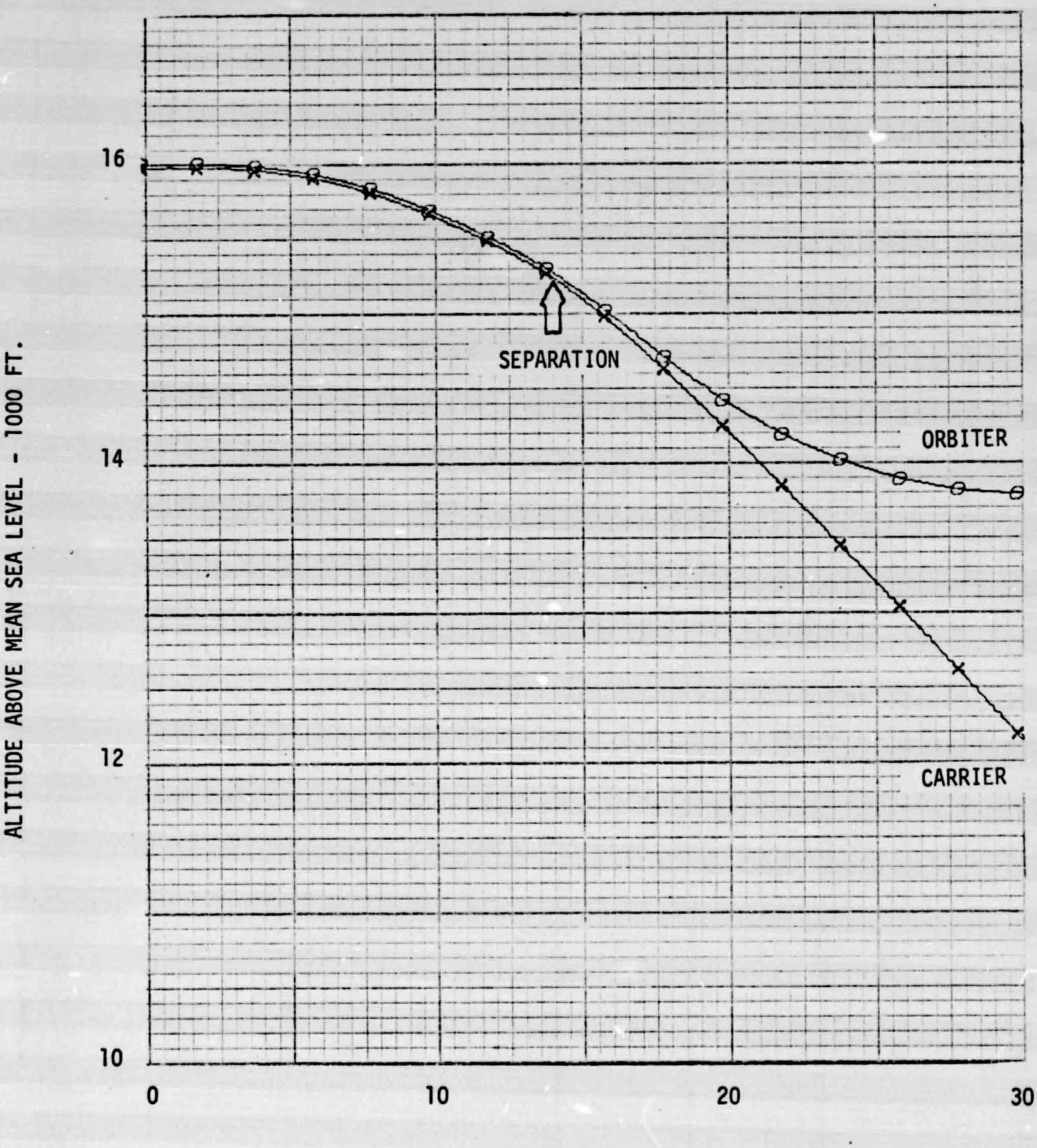

FIGURE 19

ALT CAPTIVE INERT FLIGHT NO. 1 EMERGENCY SEPARATION

FLIGHT PATH ANGLE TIME HISTORIES