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TECHNICAL REPORT BRL-TR-3001

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A LIBRARY OF DIGITIZED FLIGHTPATHS

JOSEPH K. WALD

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## TABLE OF CONTENTS

	Page
LIST OF FIGURES.....	5
I. INTRODUCTION.....	9
II. METHODOLOGY DESCRIPTION.....	9
III. THE FLIGHTPATHS.....	10
DISTRIBUTION LIST .....	107

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## LIST OF FIGURES

	Page
1. Flightpath 1: Low Angle View.....	11
2. Flightpath 1: High Angle View.....	12
3. Flightpath 1: Position.....	13
4. Flightpath 1: Velocity.....	14
5. Flightpath 1: Acceleration.....	15
6. Flightpath 1: Attitude Angles .....	16
7. Flightpath 2: Low Angle View.....	17
8. Flightpath 2: High Angle View.....	18
9. Flightpath 2: Position.....	19
10. Flightpath 2: Velocity.....	20
11. Flightpath 2: Acceleration.....	21
12. Flightpath 2: Attitude Angles .....	22
13. Flightpath 3: Low Angle View.....	23
14. Flightpath 3: High Angle View.....	24
15. Flightpath 3: Position.....	25
16. Flightpath 3: Velocity.....	26
17. Flightpath 3: Acceleration.....	27
18. Flightpath 3: Attitude Angles .....	28
19. Flightpath 4: Low Angle View.....	29
20. Flightpath 4: High Angle View.....	30
21. Flightpath 4: Position.....	31
22. Flightpath 4: Velocity.....	32
23. Flightpath 4: Acceleration.....	33
24. Flightpath 4: Attitude Angles .....	34
25. Flightpath 5: Low Angle View.....	35
26. Flightpath 5: High Angle View.....	36
27. Flightpath 5: Position.....	37
28. Flightpath 5: Velocity.....	38
29. Flightpath 5: Acceleration.....	39
30. Flightpath 5: Attitude Angles .....	40
31. Flightpath 6: Low Angle View.....	41

## LIST OF FIGURES (Cont'd)

	Page
32. Flightpath 6: High Angle View.....	42
33. Flightpath 6: Position.....	43
34. Flightpath 6: Velocity.....	44
35. Flightpath 6: Acceleration.....	45
36. Flightpath 6: Attitude Angles .....	46
37. Flightpath 7: Low Angle View.....	47
38. Flightpath 7: High Angle View.....	48
39. Flightpath 7: Position.....	49
40. Flightpath 7: Velocity.....	50
41. Flightpath 7: Acceleration.....	51
42. Flightpath 7: Attitude Angles .....	52
43. Flightpath 8: Low Angle View.....	53
44. Flightpath 8: High Angle View.....	54
45. Flightpath 8: Position.....	55
46. Flightpath 8: Velocity.....	56
47. Flightpath 8: Acceleration.....	57
48. Flightpath 8: Attitude Angles .....	58
49. Flightpath 9: Low Angle View.....	59
50. Flightpath 9: High Angle View.....	60
51. Flightpath 9: Position.....	61
52. Flightpath 9: Velocity.....	62
53. Flightpath 9: Acceleration.....	63
54. Flightpath 9: Attitude Angles .....	64
55. Flightpath 10: Low Angle View.....	65
56. Flightpath 10: High Angle View.....	66
57. Flightpath 10: Position.....	67
58. Flightpath 10: Velocity.....	68
59. Flightpath 10: Acceleration.....	69
60. Flightpath 10: Attitude Angles .....	70
61. Flightpath 11: Low Angle View.....	71
62. Flightpath 11: High Angle View.....	72

## LIST OF FIGURES (Cont'd)

	Page
63. Flightpath 11: Position.....	73
64. Flightpath 11: Velocity.....	74
65. Flightpath 11: Acceleration.....	75
66. Flightpath 11: Attitude Angles .....	76
67. Flightpath 12: Low Angle View.....	77
68. Flightpath 12: High Angle View.....	78
69. Flightpath 12: Position.....	79
70. Flightpath 12: Velocity.....	80
71. Flightpath 12: Acceleration.....	81
72. Flightpath 12: Attitude Angles .....	82
73. Flightpath 13: Low Angle View.....	83
74. Flightpath 13: High Angle View.....	84
75. Flightpath 13: Position.....	85
76. Flightpath 13: Velocity.....	86
77. Flightpath 13: Acceleration.....	87
78. Flightpath 13: Attitude Angles .....	88
79. Flightpath 14: Low Angle View.....	89
80. Flightpath 14: High Angle View.....	90
81. Flightpath 14: Position.....	91
82. Flightpath 14: Velocity.....	92
83. Flightpath 14: Acceleration.....	93
84. Flightpath 14: Attitude Angles .....	94
85. Flightpath 15: Low Angle View.....	95
86. Flightpath 15: High Angle View.....	96
87. Flightpath 15: Position.....	97
88. Flightpath 15: Velocity.....	98
89. Flightpath 15: Acceleration.....	99
90. Flightpath 15: Attitude Angles .....	100
91. Flightpath 16: Low Angle View.....	101
92. Flightpath 16: High Angle View.....	102
93. Flightpath 16: Position.....	103

LIST OF FIGURES (Cont'd)

	Page
94. Flightpath 16: Velocity.....	104
95. Flightpath 16: Acceleration.....	105
96. Flightpath 16: Attitude Angles .....	106

# A Library Of Digitized Flightpaths

Dr. Joseph K. Wald

## I. INTRODUCTION

Digitized flightpaths are required input to detailed simulation models for a number of air defense weapon systems, both guns and missiles. Generally speaking, the more detailed and extensive the modeling of the fire control in such models, the more detailed and realistic the flightpaths should be. Sometimes mathematically generated flightpaths are used, but unless these are constructed in a rather sophisticated way, they lack the proper frequency content and plant noise reflected in flightpaths flown by real pilots in real aircraft.

In this report we present pictures of a variety of flightpaths we have collected over the last few years from a number of Army field tests of air defense weapon systems. After undergoing a smoothing process, these flightpaths have been used in simulation validation efforts and effectiveness analyses.

## II. METHODOLOGY DESCRIPTION

The raw data for the flightpaths contained in this collection were recorded in tests conducted at Ft. Bliss, Texas and Ft. Hunter Liggett, California. The rotary wing aircraft were typically UH1s and the fixed wing aircraft were typically A7s with an occasional F100 or A10. The equipment used to collect the raw target position data was usually radar or cinetheodolites. To remove the "measurement noise" from the raw data, we used a double sweep optimal smoothing technique<sup>1</sup> that simultaneously produces position, velocity, and acceleration estimates in the x, y, and z coordinates. For each flightpath, the time interval between successive data points is 0.05 seconds.

There were typically no attitude sensors on board the aircraft during these tests, so we had to calculate the aircraft attitude angles (roll, pitch, and yaw) analytically. For the fixed wing aircraft, we added the target attitude angles under the assumption that the longitudinal axis of the aircraft coincided with its velocity vector - i.e., there was no angle of attack. For the aircraft and flight profiles under consideration, this was generally a good assumption. We made the same assumption in those cases in which the helicopter had a significant forward velocity. For the hovering helicopters, we made the assumption that the helicopter had no pitch or roll, and that the aircraft would orient itself to present a "nose-on" view to its target, which was presumed to be at the origin of the coordinate system.

<sup>1</sup>Scheder, Robert A., A Computer Program For Double Sweep Optimal Smoothing (U), U.S. Army Materiel Systems Analysis Activity Technical Report No. 246, January, 1979. UNCLASSIFIED.

### III. THE FLIGHTPATHS

There are sixteen flightpaths in this collection, nine flown by fixed wing aircraft and seven by helicopters. A number of different ground attack maneuvers are represented in this collection. These are summarized in Table 1.

TABLE 1. Flightpath Summary.		
Flightpath	Aircraft	Maneuver
1	fixed wing	"pop-up, turn, and dive"
2	fixed wing	"pop-up, turn, and dive"
3	fixed wing	"straight and level"
4	fixed wing	"constant g turn"
5	fixed wing	"jink"
6	fixed wing	"pop-up, turn, and dive"
7	fixed wing	"straight and level"
8	fixed wing	"constant g turn"
9	helicopter	"hover"
10	helicopter	"hover"
11	helicopter	"hover"
12	helicopter	"hover"
13	helicopter	"straight and level"
14	helicopter	"constant g turn"
15	helicopter	"pop-up and shallow dive"
16	fixed wing	"turn and dive"

The flightpaths are depicted in figures 1 through 96. For each flightpath, there are two three dimensional views and time histories for each of the nine state variables and the attitude angles. In the three dimensional pictures, the x, y, and z axes are denoted by "east", "north", and "up" respectively, and the origin of the coordinate system lies at the center of the small rectangular box depicted in the ground plane. The small arrows indicate the direction of aircraft motion. Due to scaling problems in the case of the hovering helicopters, we have presented a close-up high angle view in which the solid circles represent the location of the "center" of the helicopter at one second intervals. This was done to give the reader a feel for the extent of both vertical and lateral motion of the helicopters when hovering.

The resolution of the data is one centimeter for the state variables and one tenth of a milliradian for the attitude angles. This causes some time histories to appear as "step functions" (see e.g., figure 53). Also, the restriction that the values of the FORTRAN ATAN2 function lie in the interval  $(-\pi, \pi)$  gives rise to the apparent instantaneous 360 degree "jump" that appears in some of the time histories of the attitude angles (see e.g., figure 6).

As data from future field tests becomes available, this library of flightpaths will be updated and expanded to include new aircraft and new maneuvers.

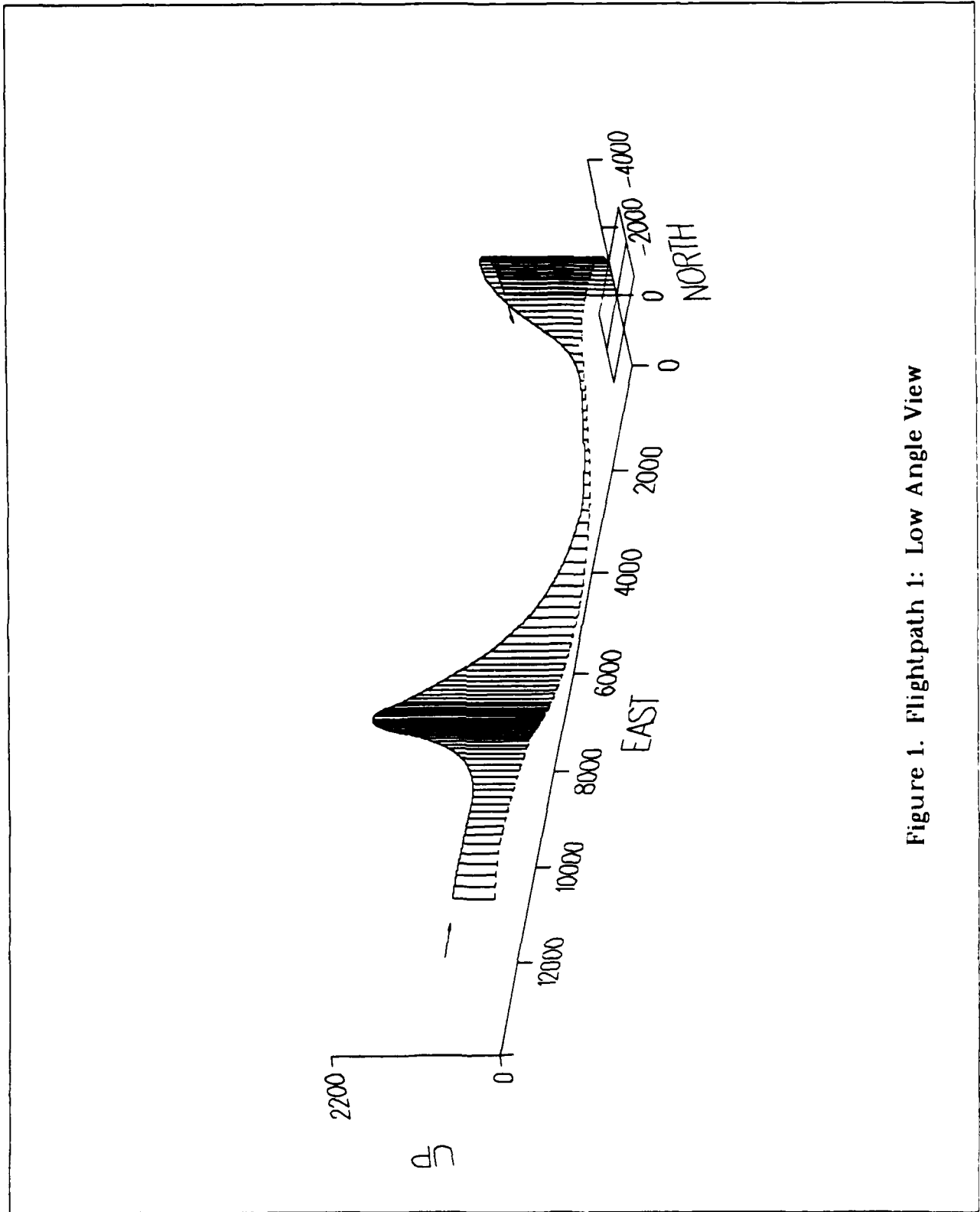


Figure 1. Flightpath 1: Low Angle View

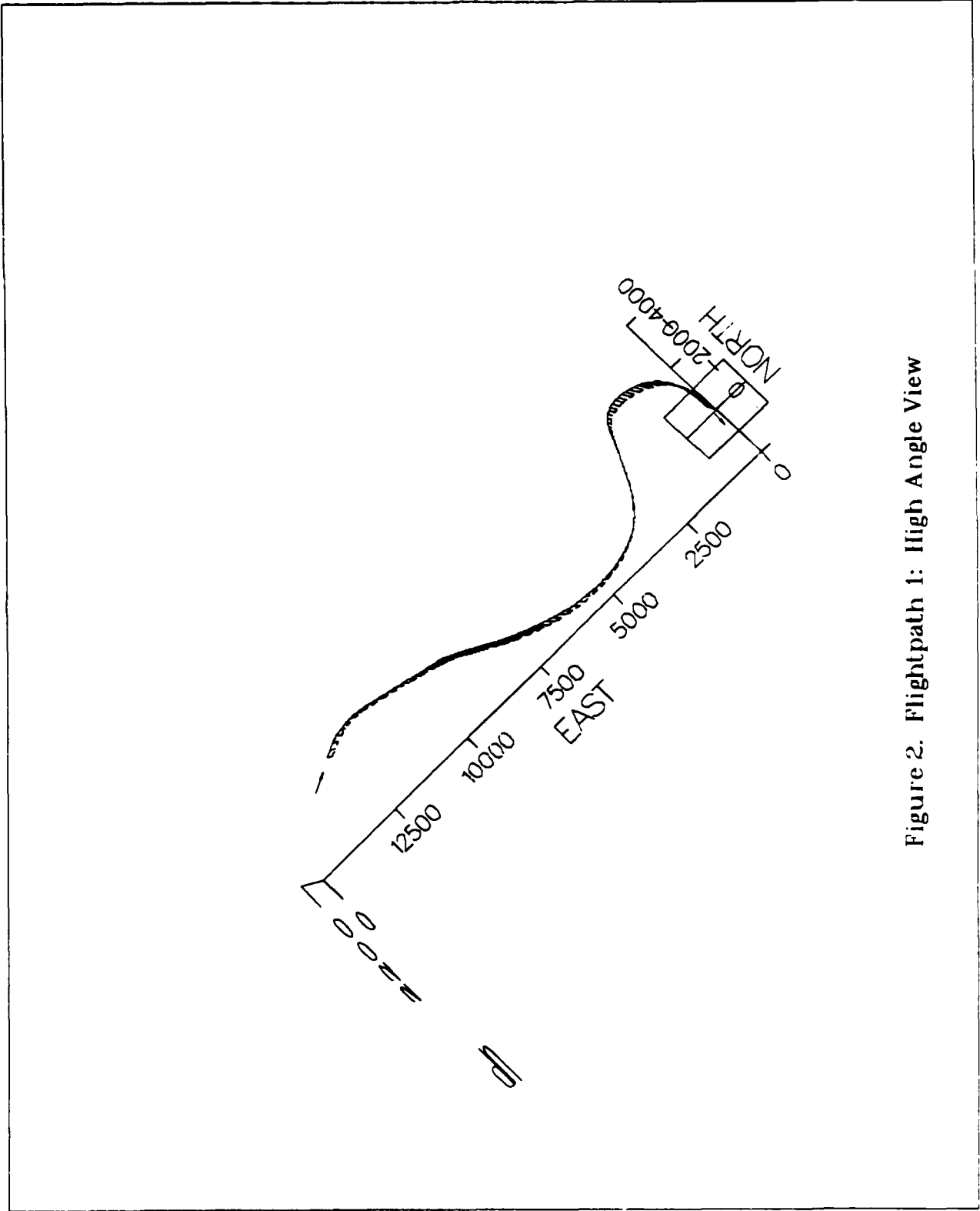


Figure 2. Flightpath 1: High Angle View

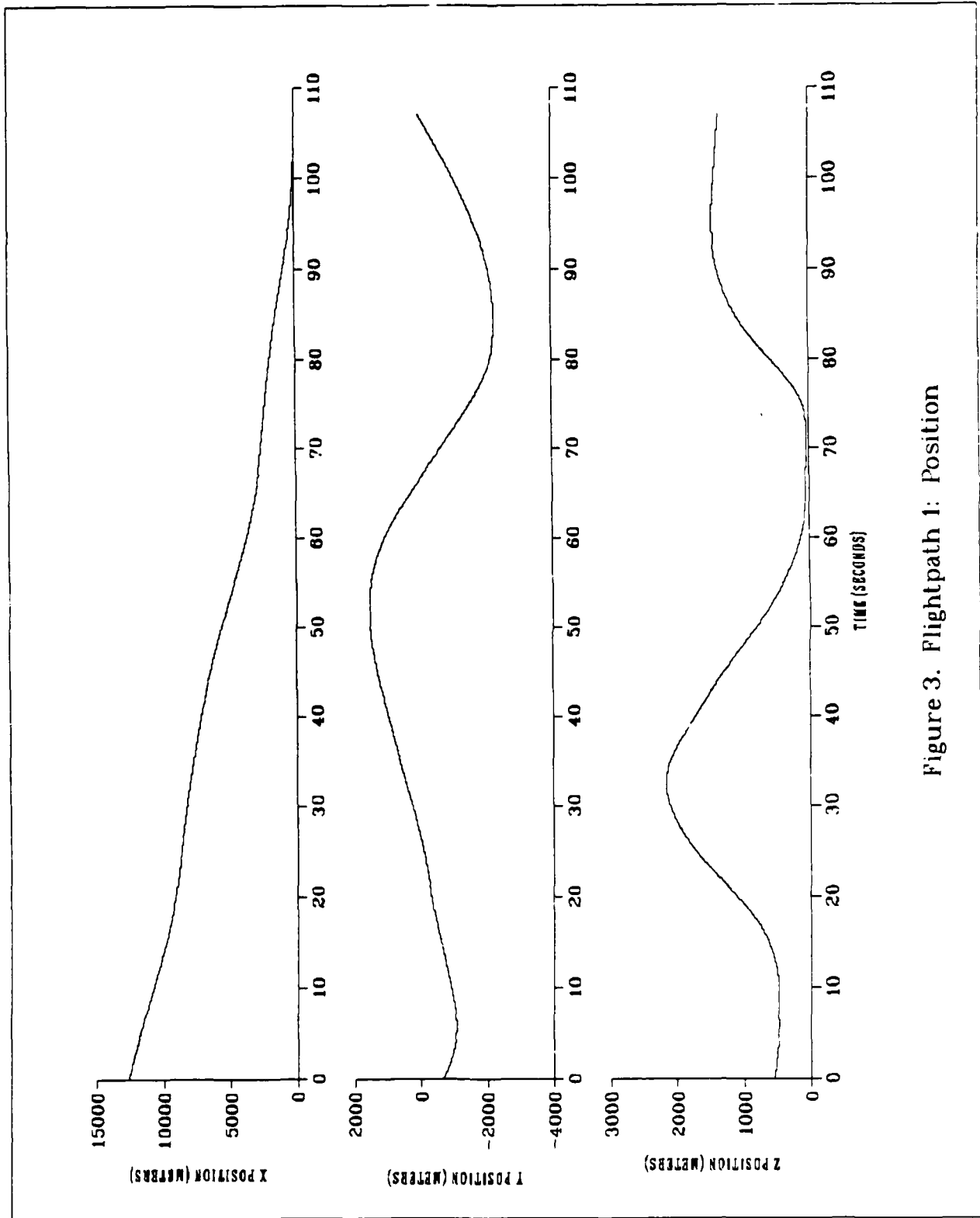


Figure 3. Flightpath 1: Position

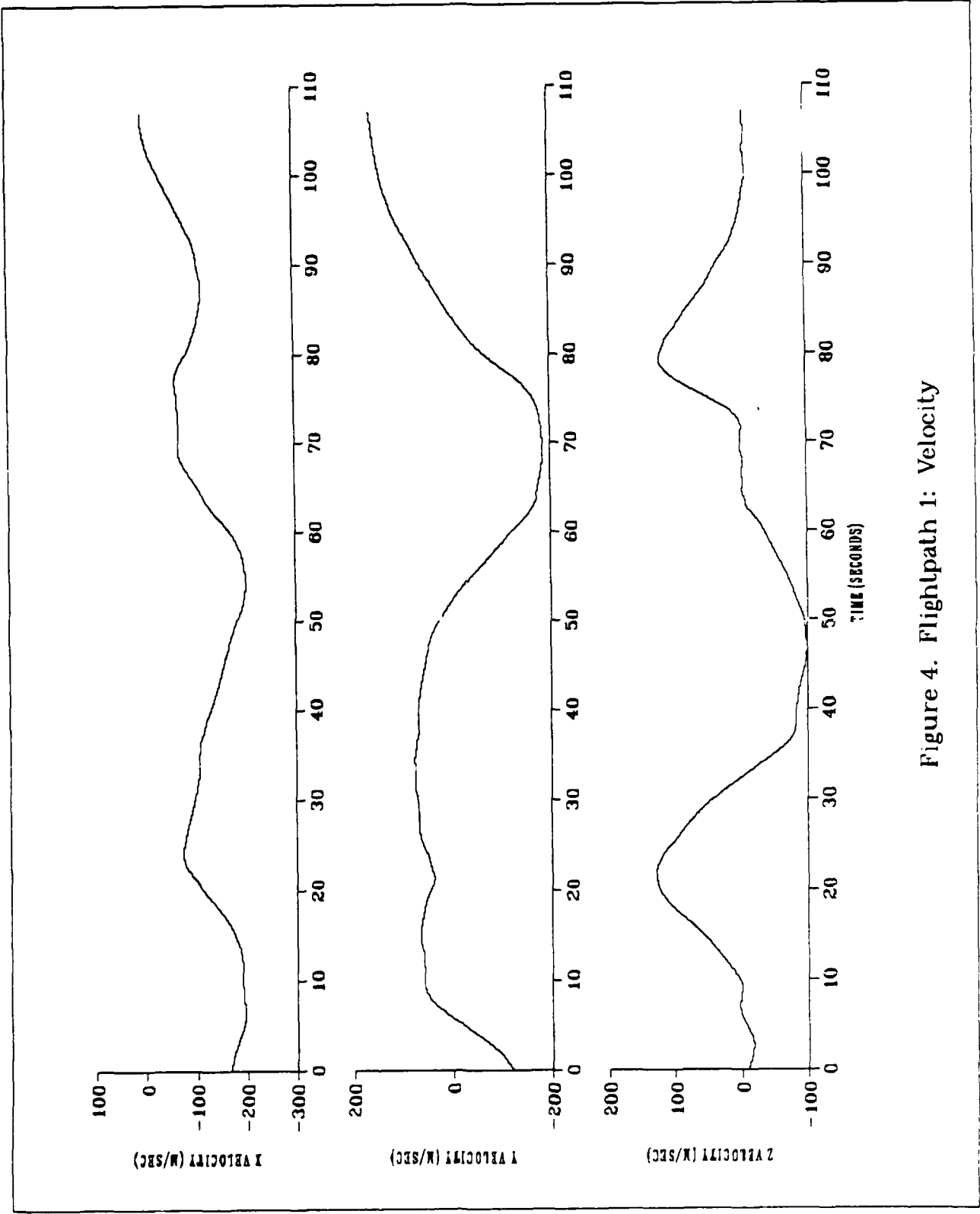


Figure 4. Flightpath 1: Velocity

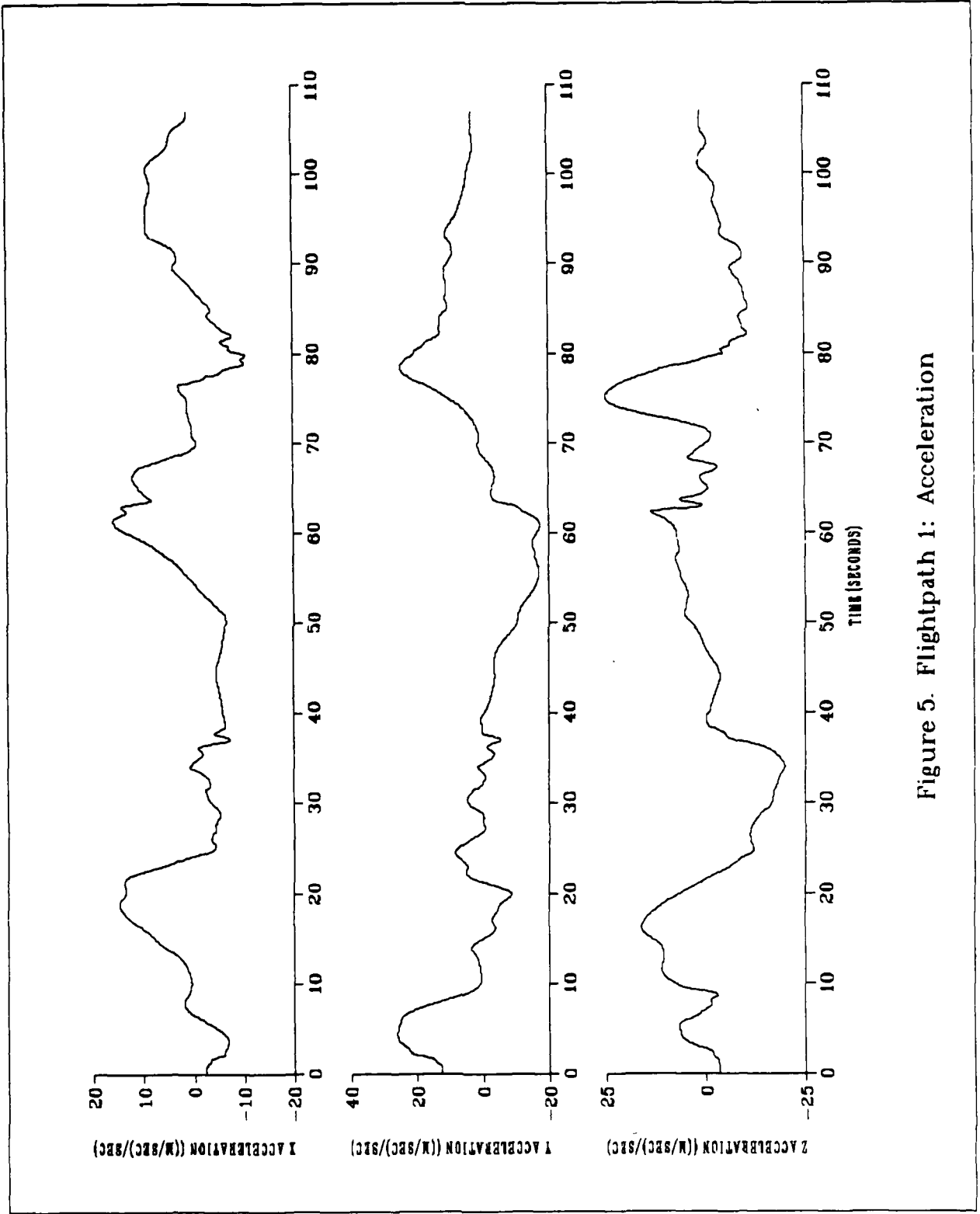


Figure 5. Flightpath 1: Acceleration

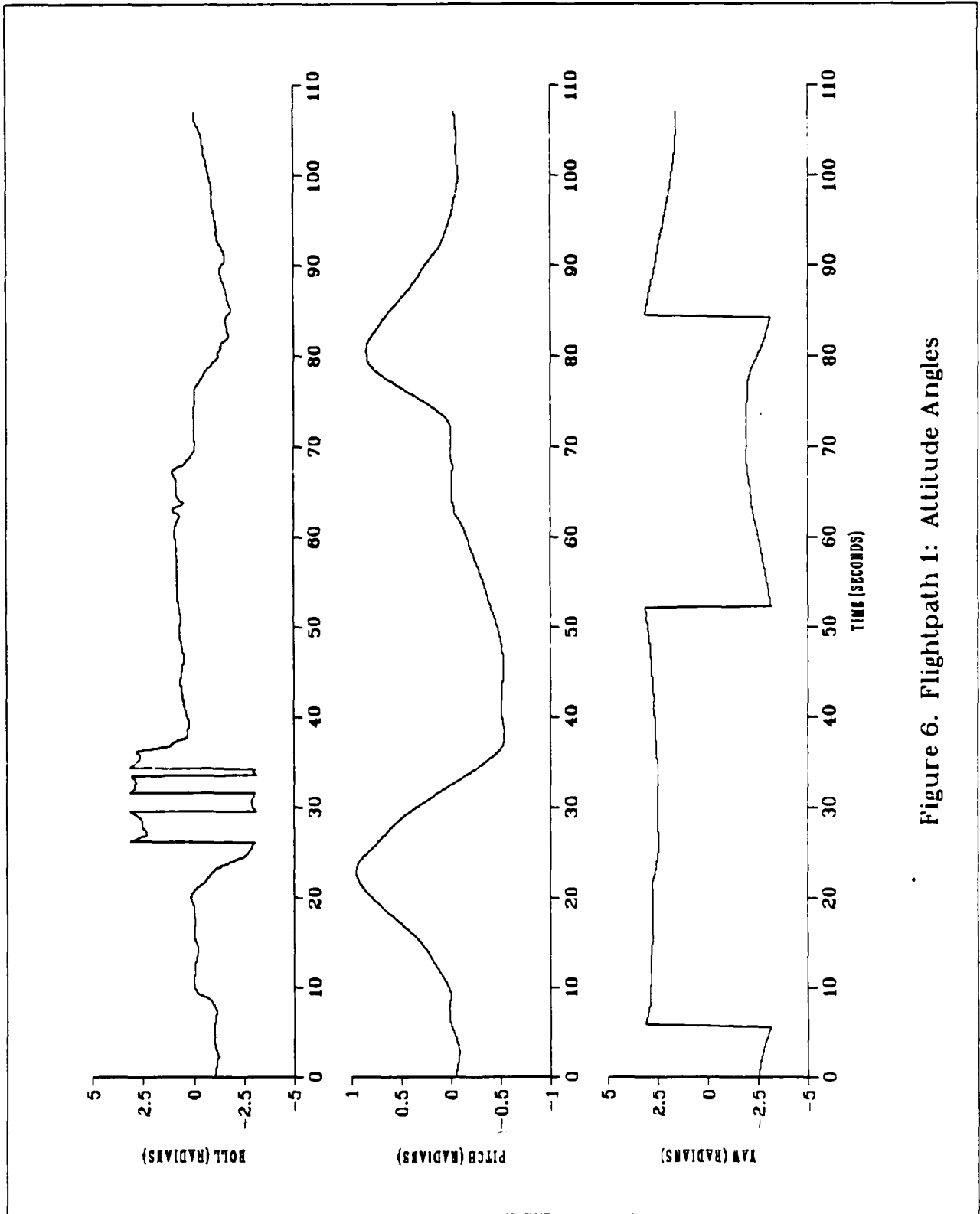


Figure 6. Flightpath 1: Altitude Angles

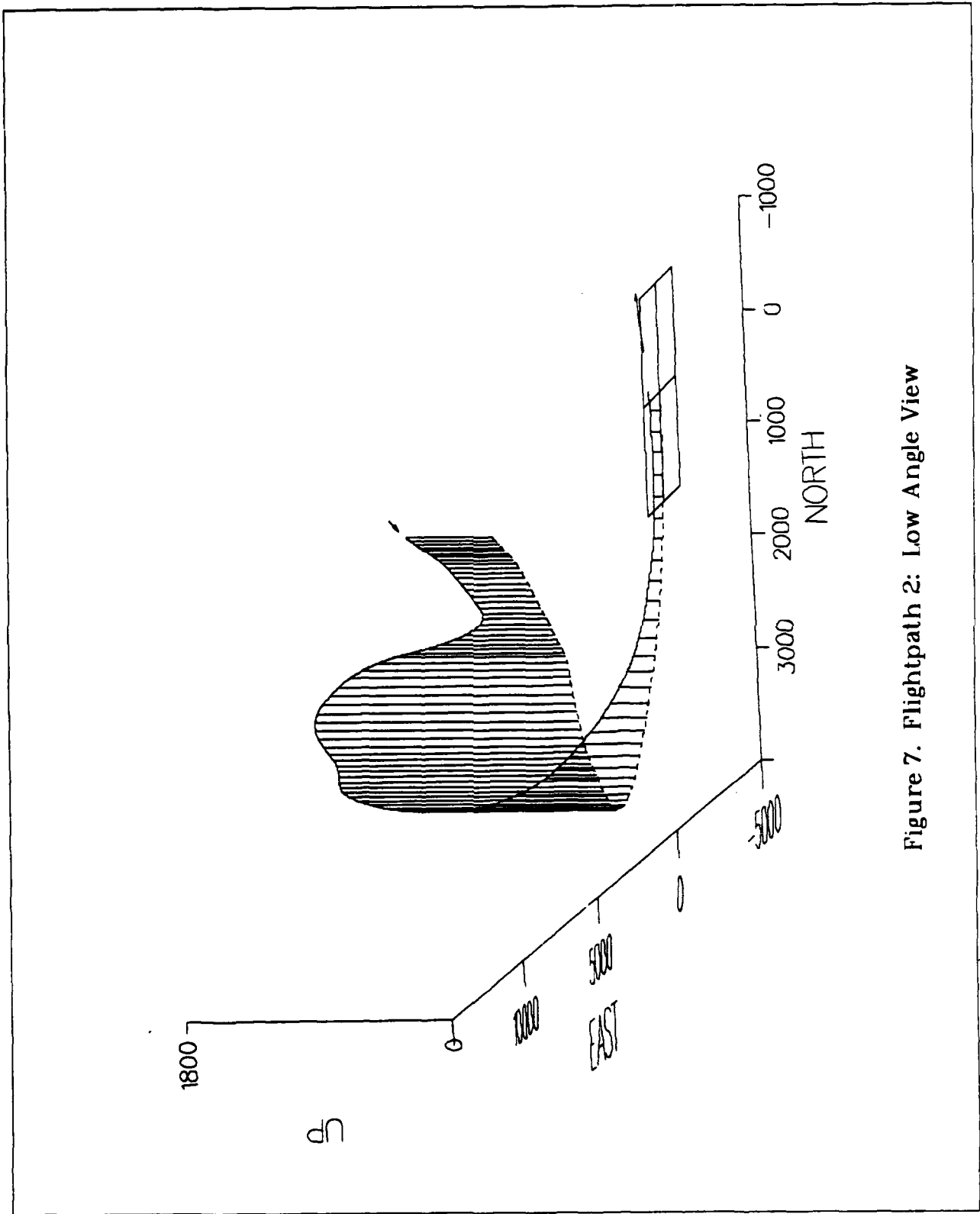


Figure 7. Flightpath 2: Low Angle View

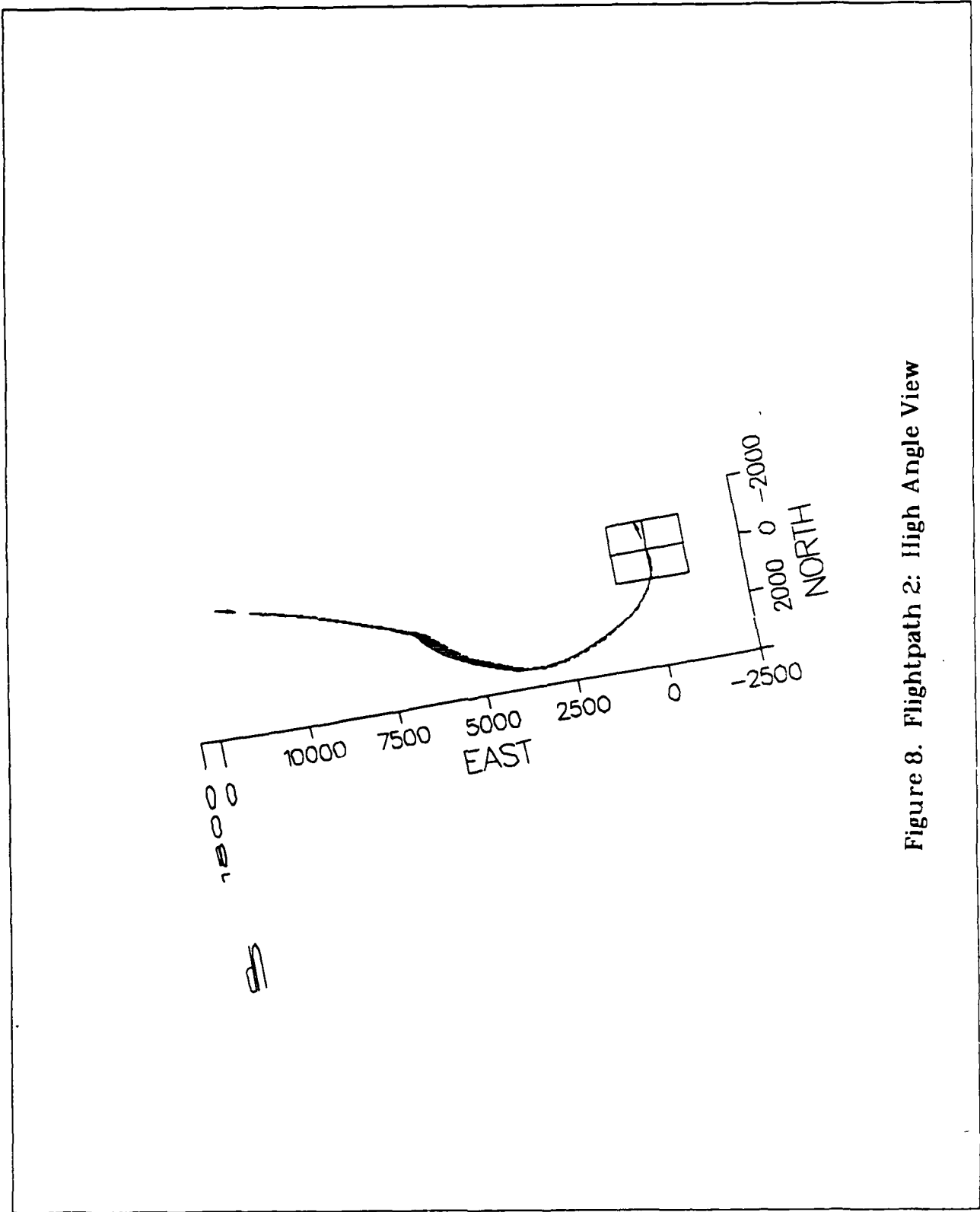


Figure 8. Flightpath 2: High Angle View

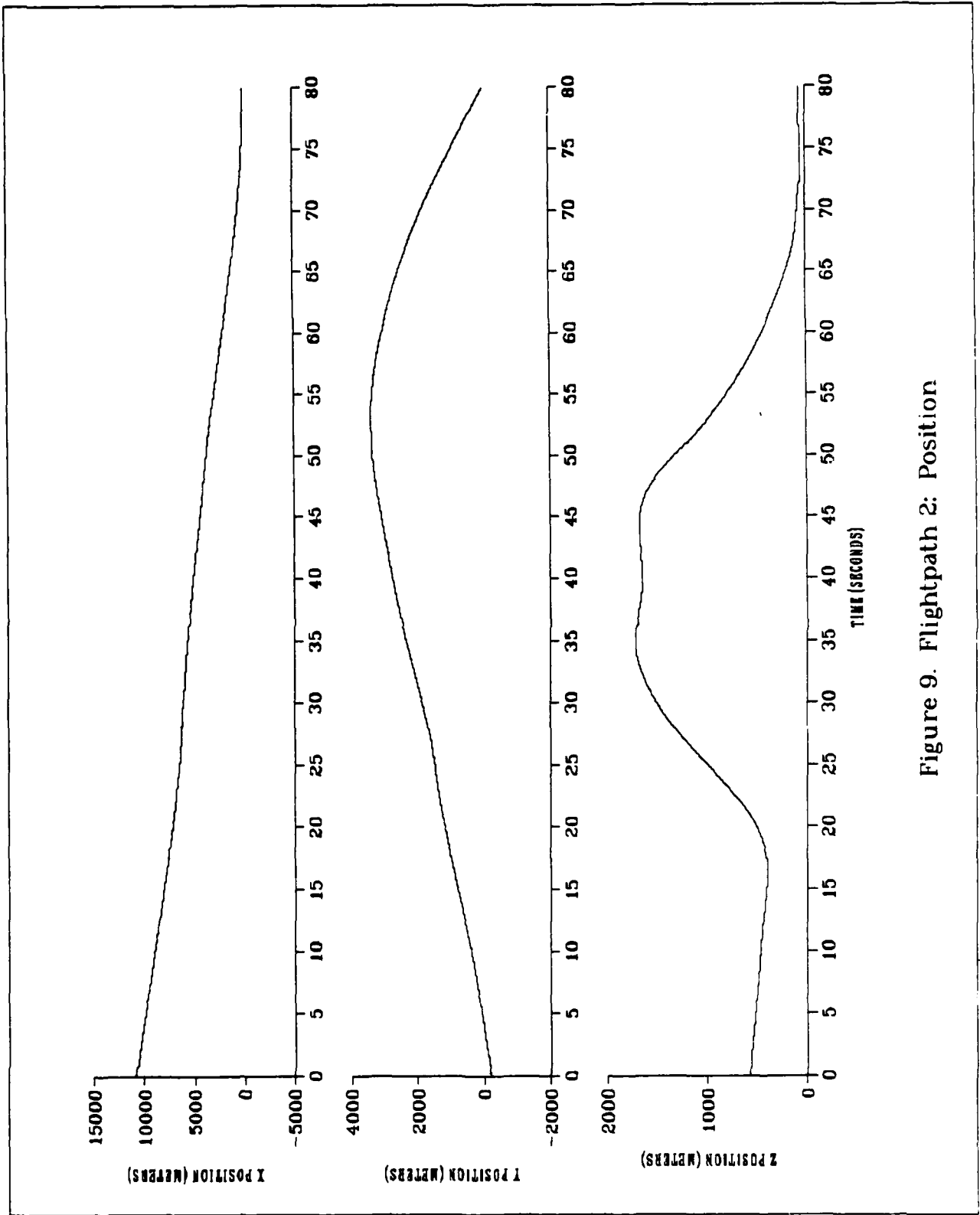


Figure 9. Flightpath 2: Position

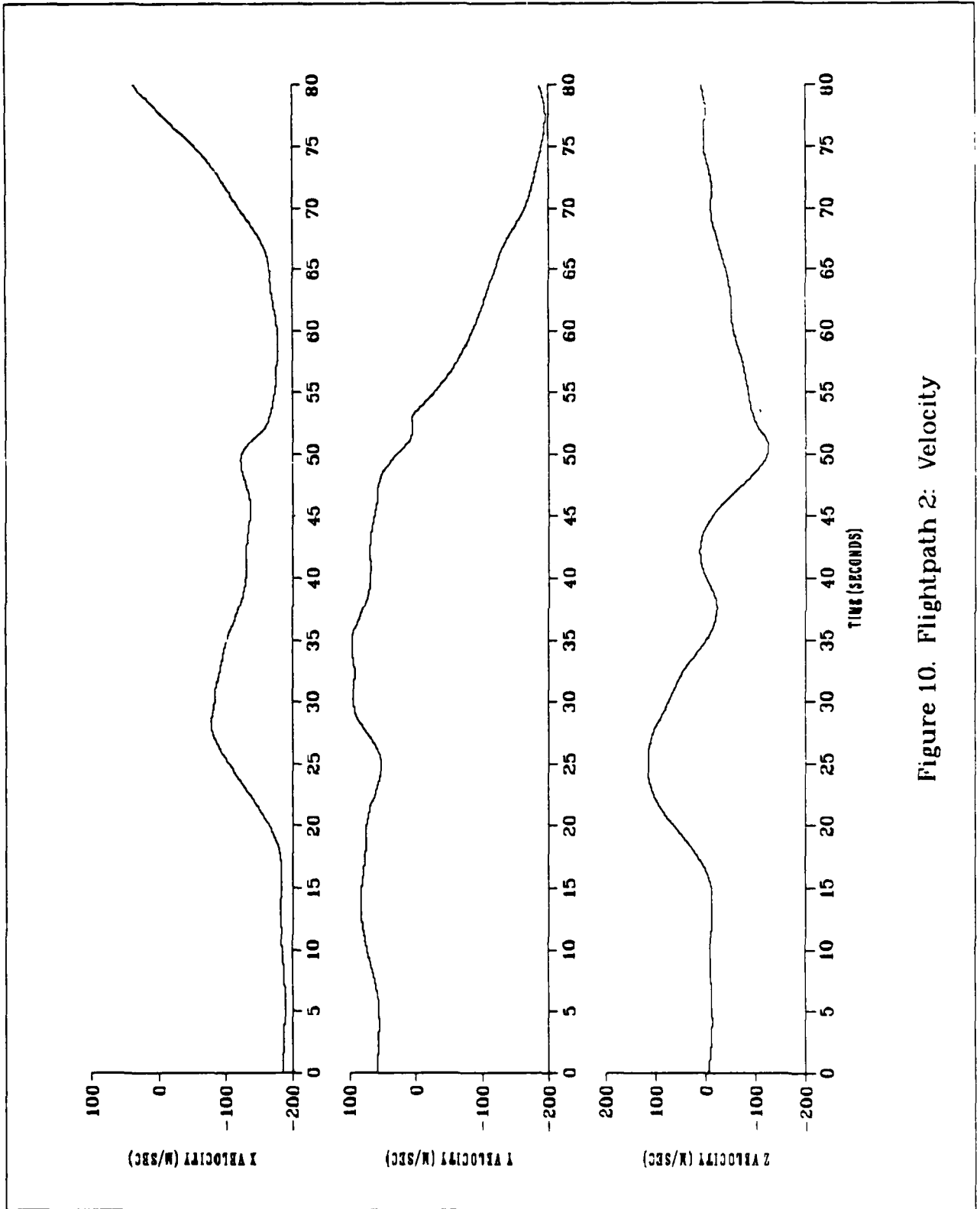


Figure 10. Flightpath 2: Velocity

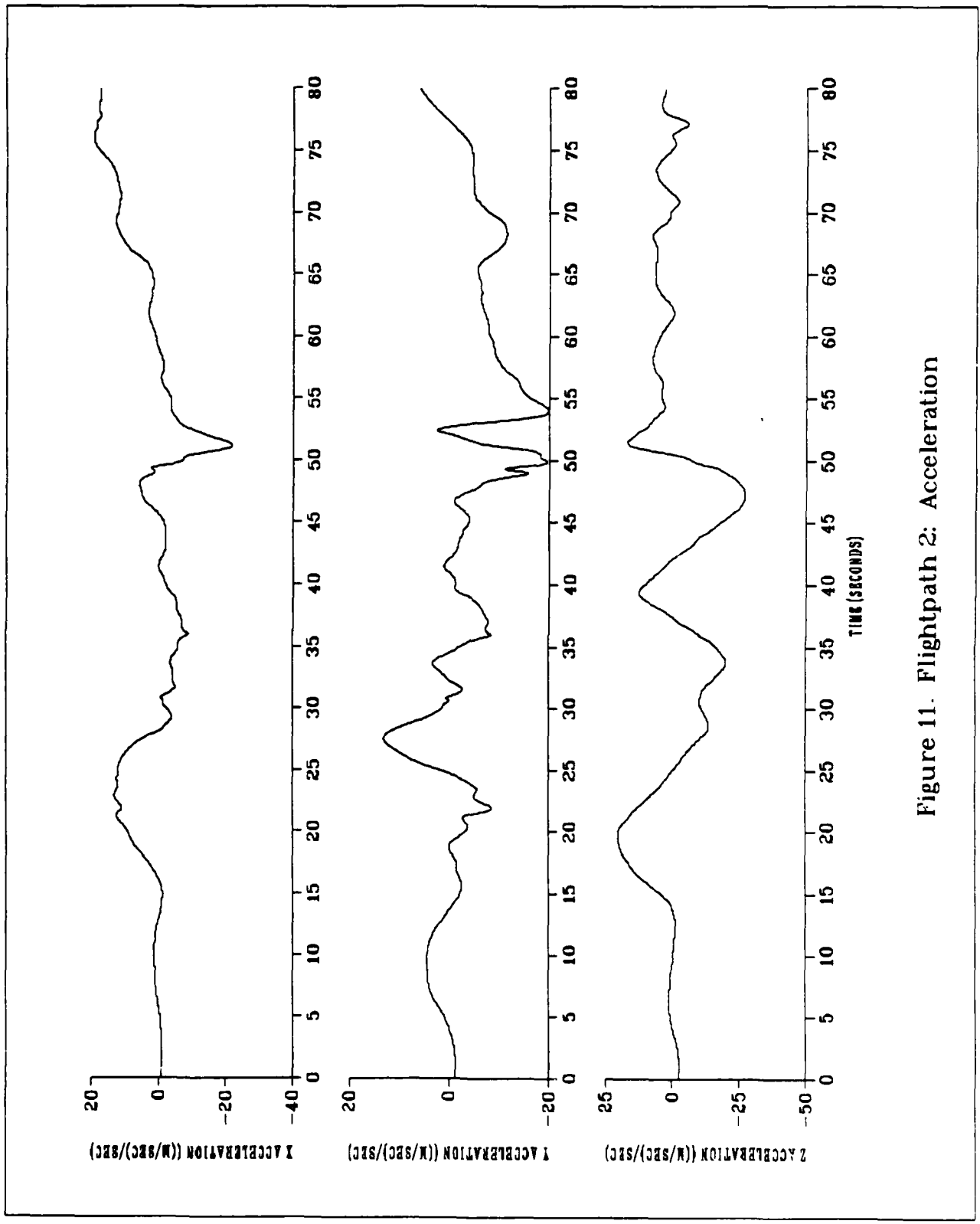


Figure 11. Flightpath 2: Acceleration

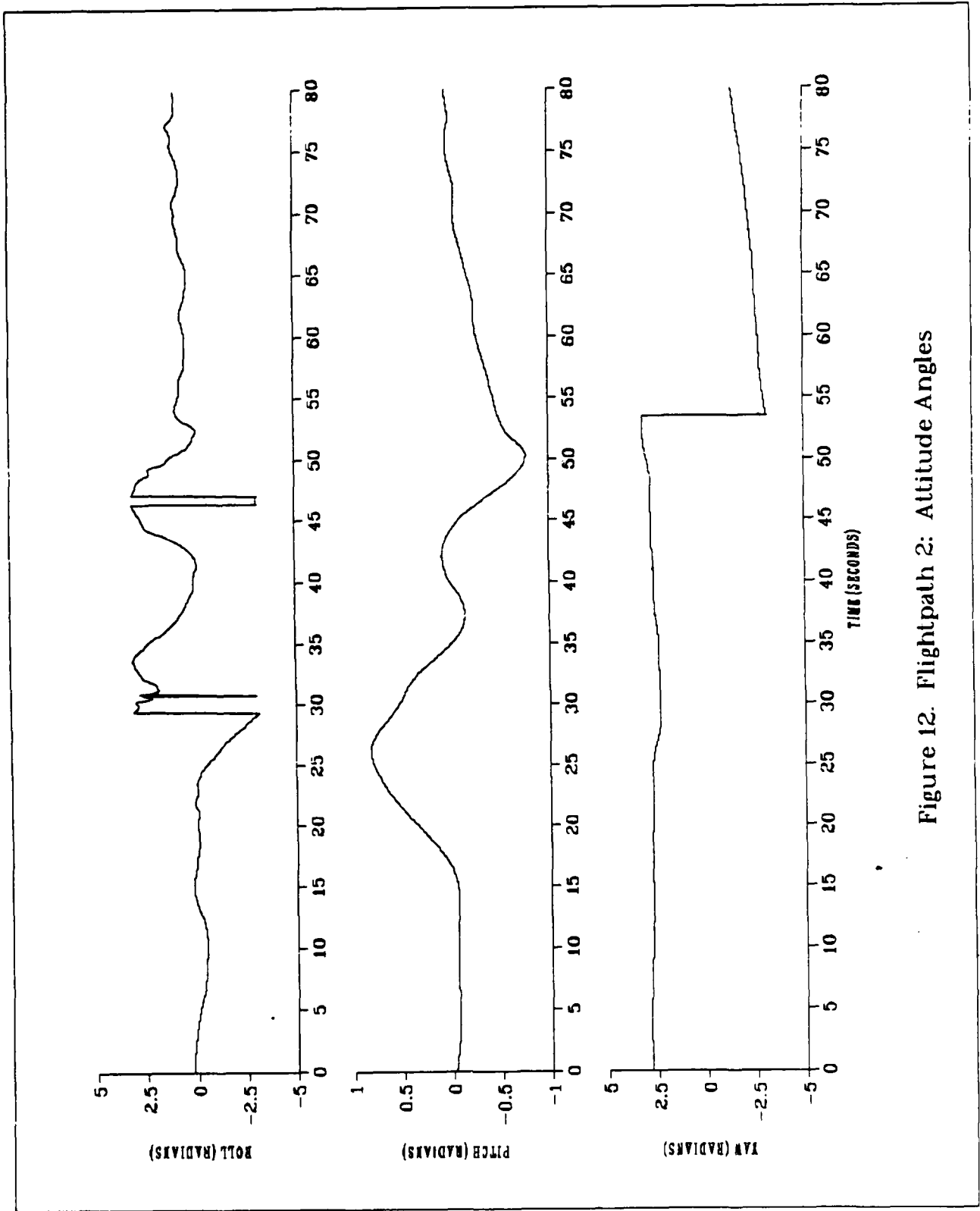


Figure 12. Flightpath 2: Attitude Angles

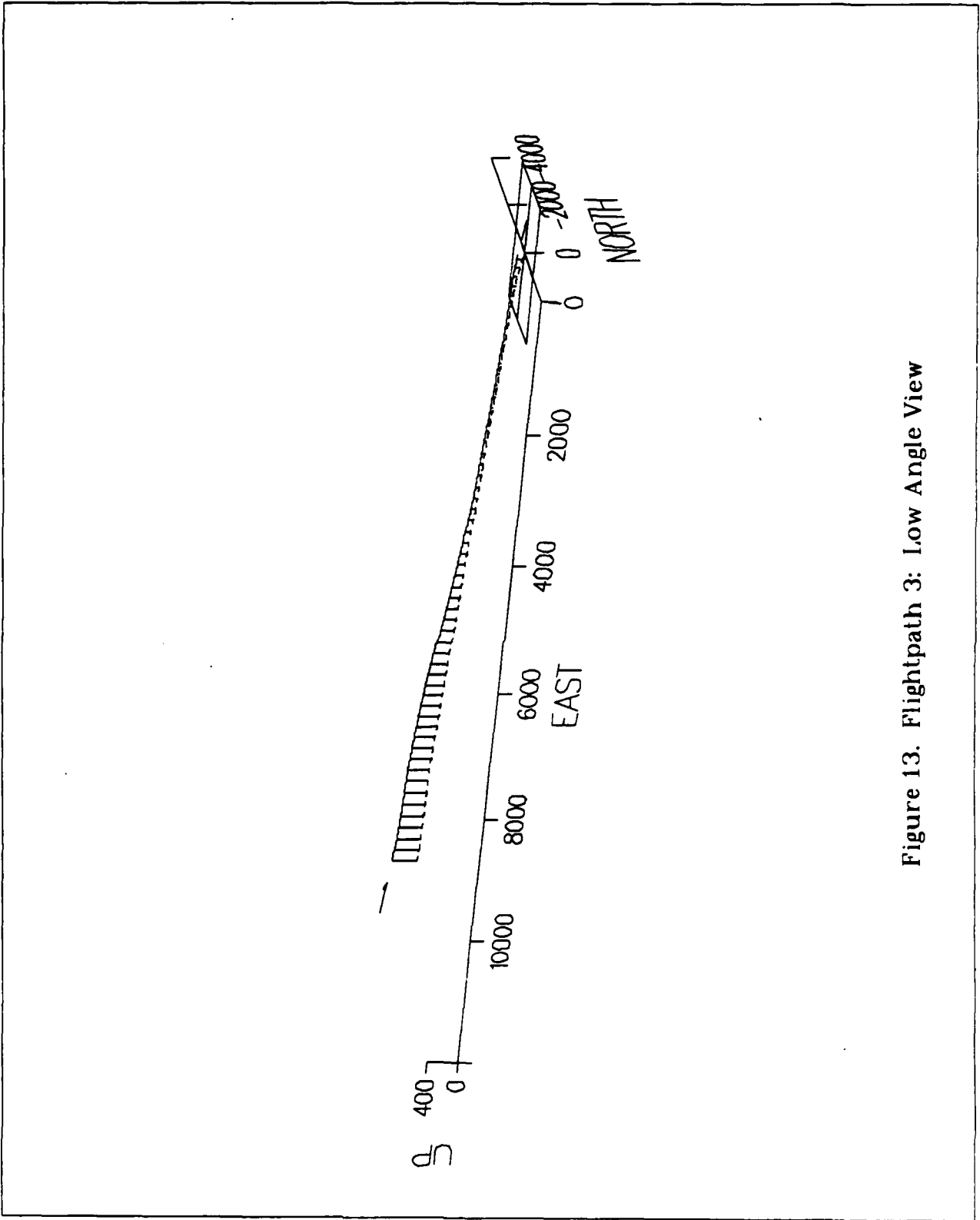


Figure 13. Flightpath 3: Low Angle View

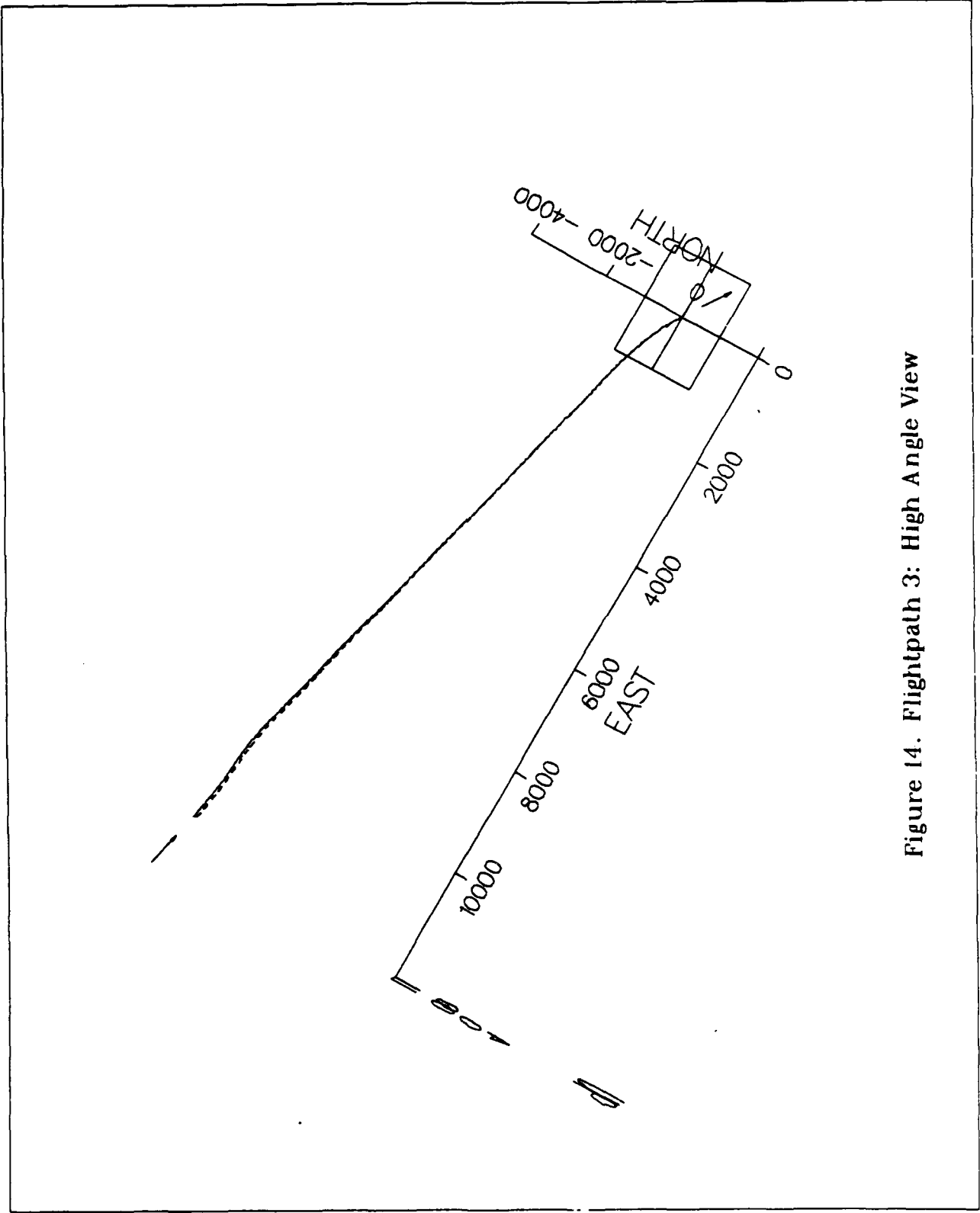


Figure 14. Flightpath 3: High Angle View

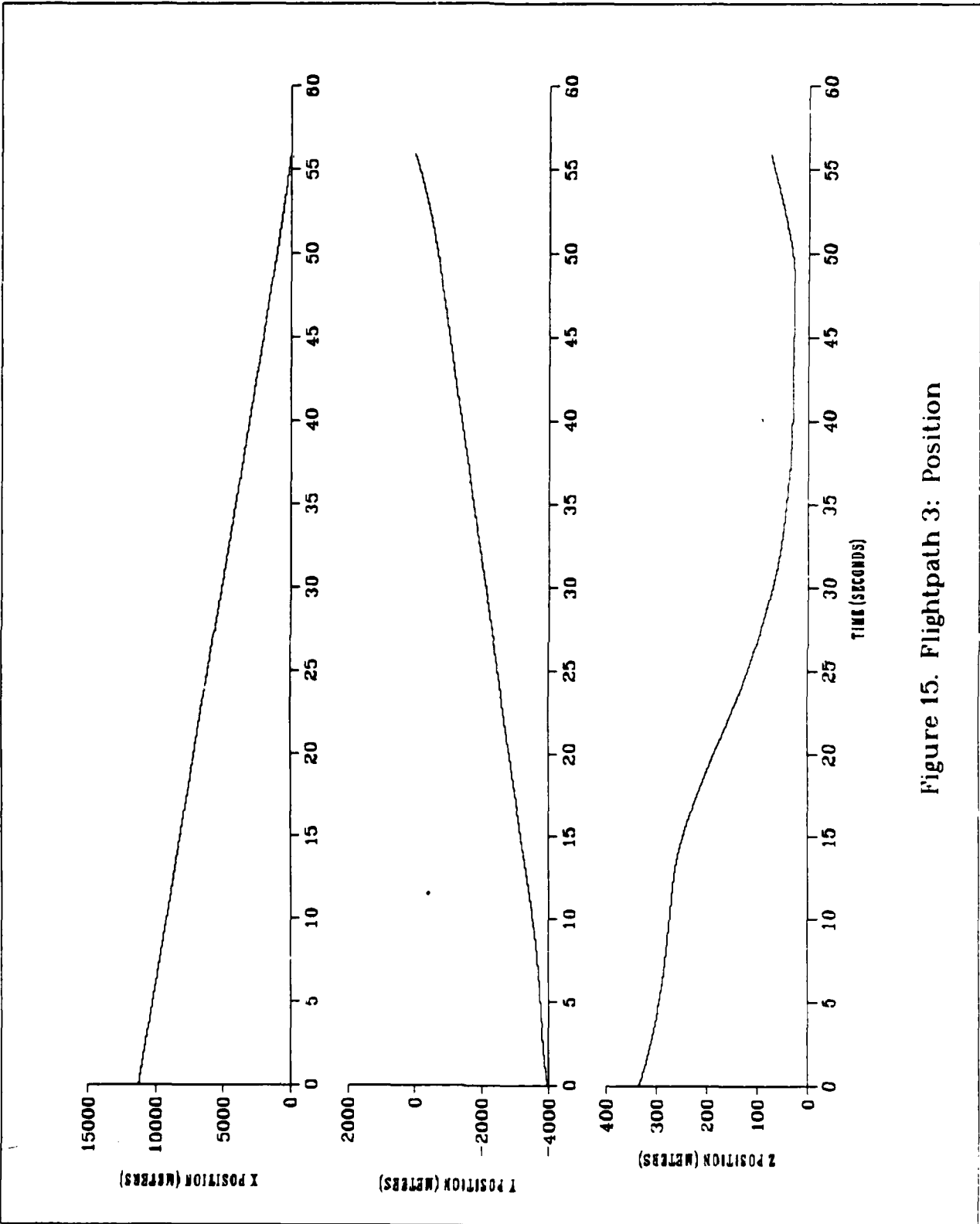


Figure 15. Flightpath 3: Position

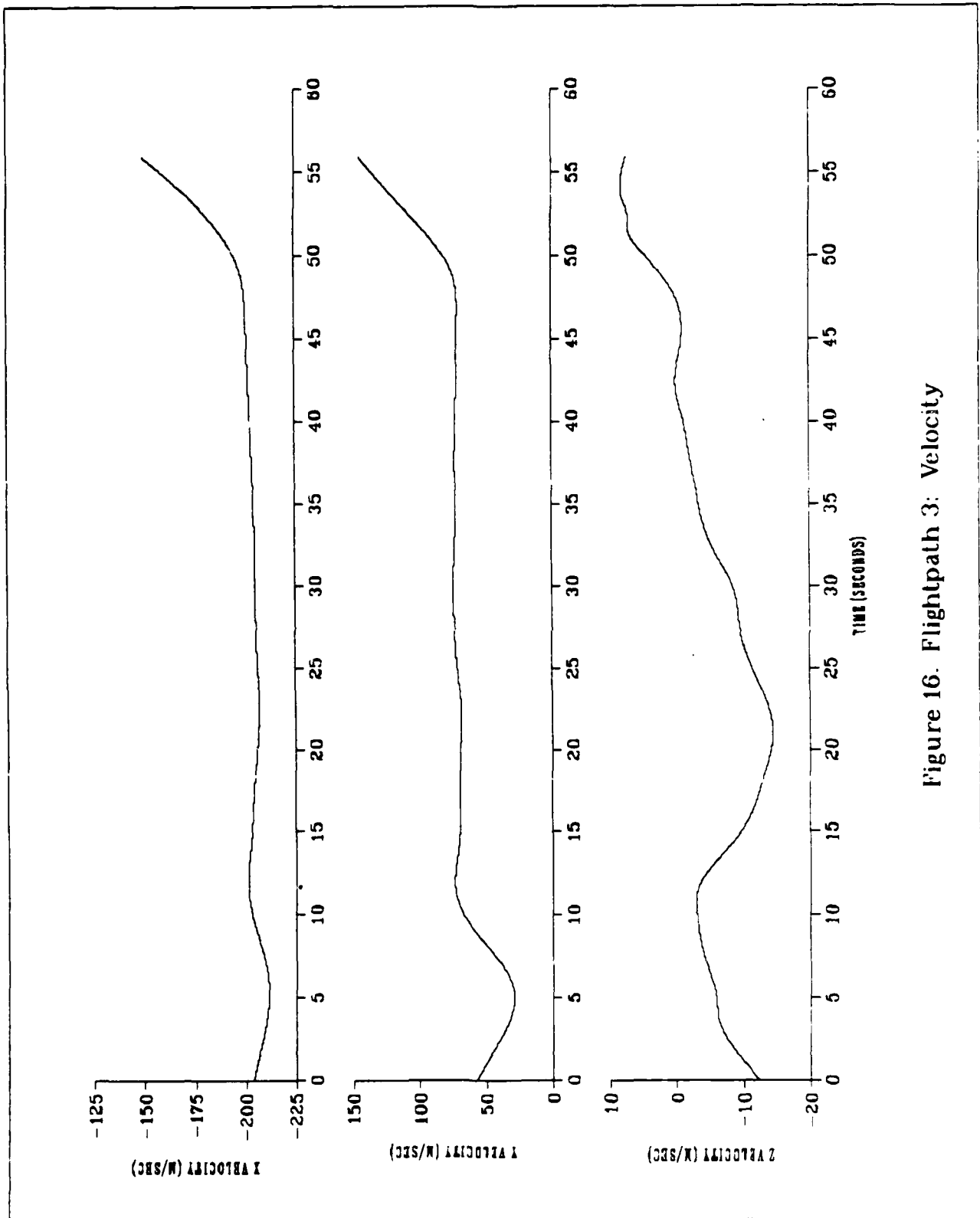


Figure 16. Flightpath 3: Velocity

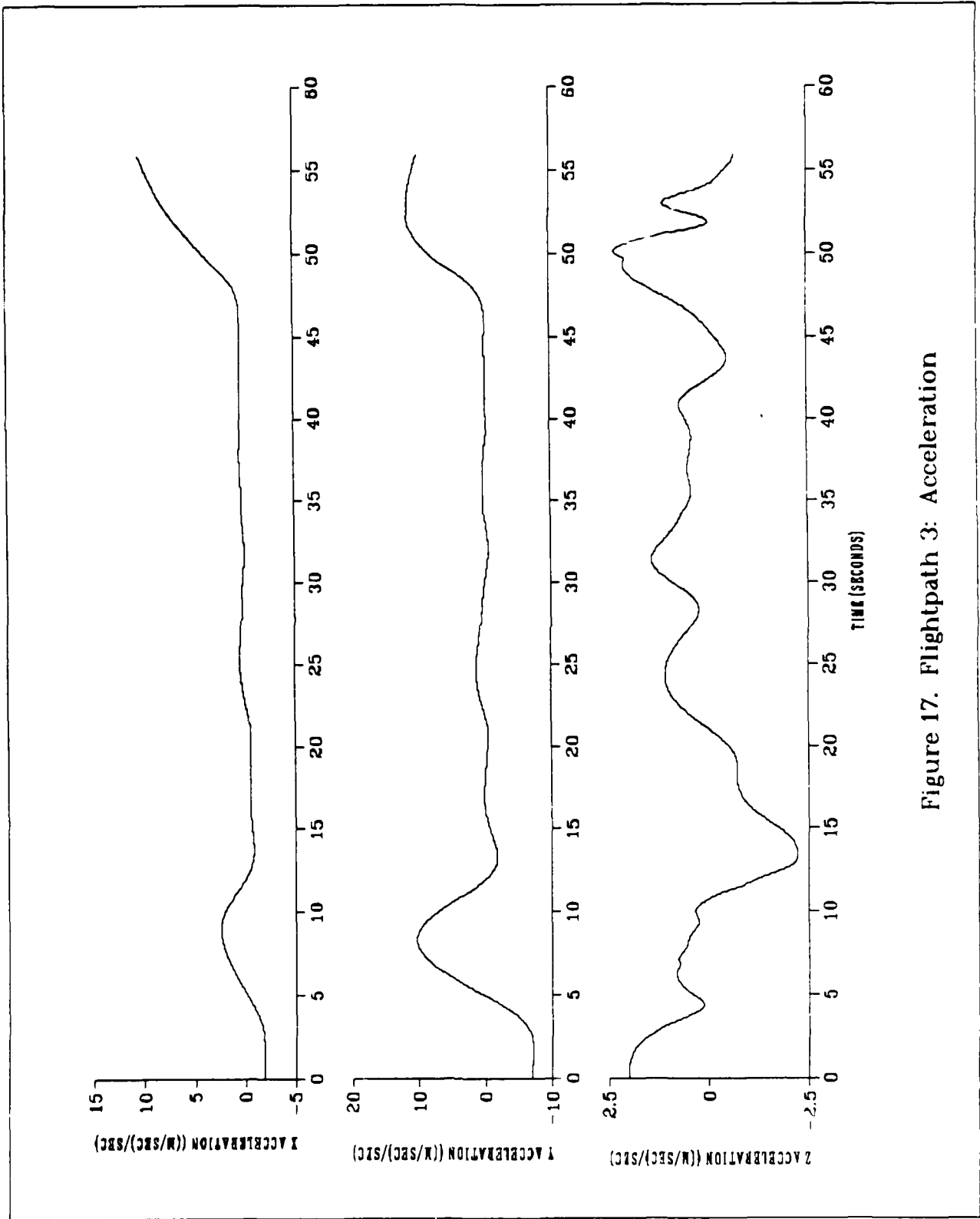


Figure 17. Flightpath 3: Acceleration

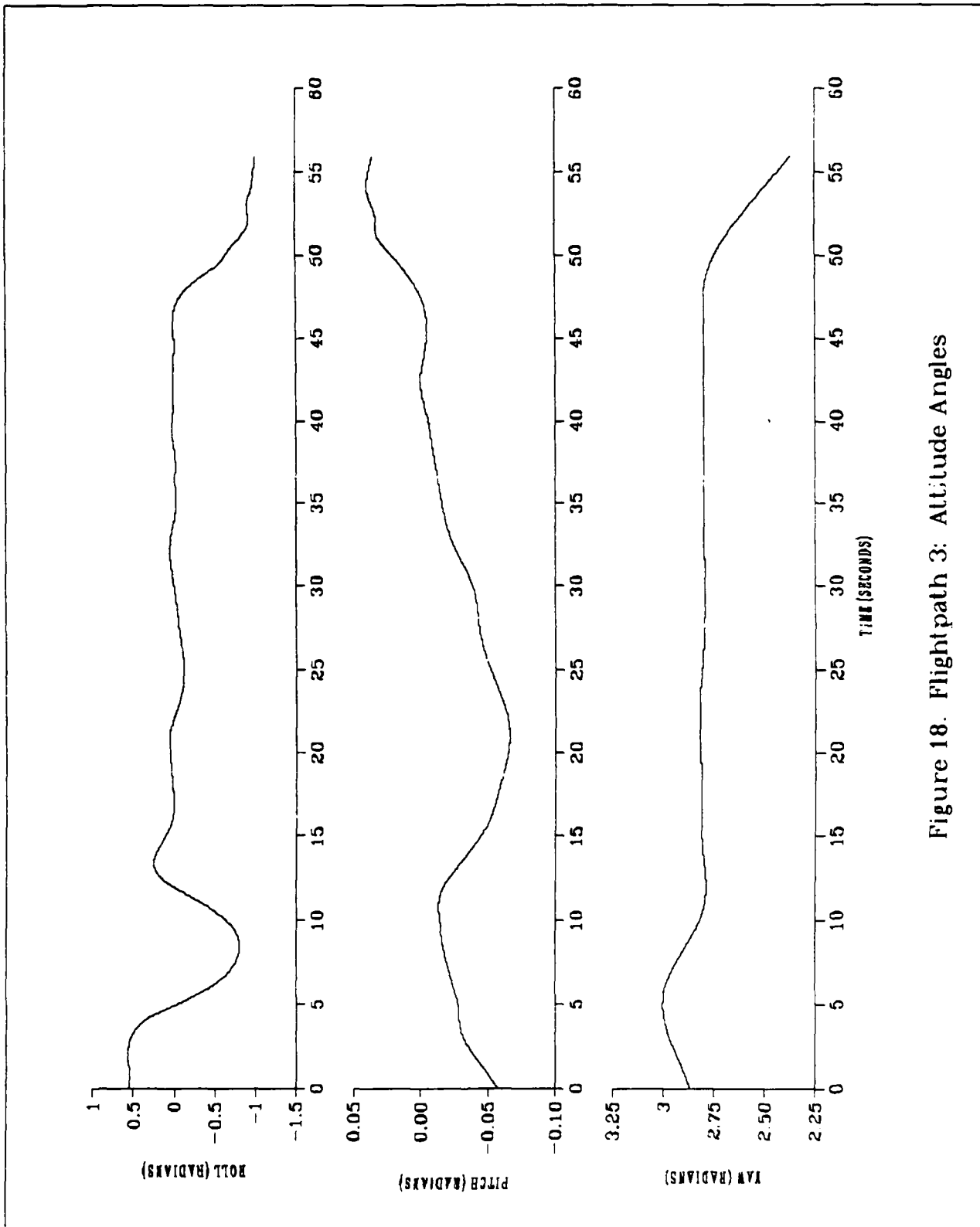


Figure 18. Flightpath 3: Altitude Angles

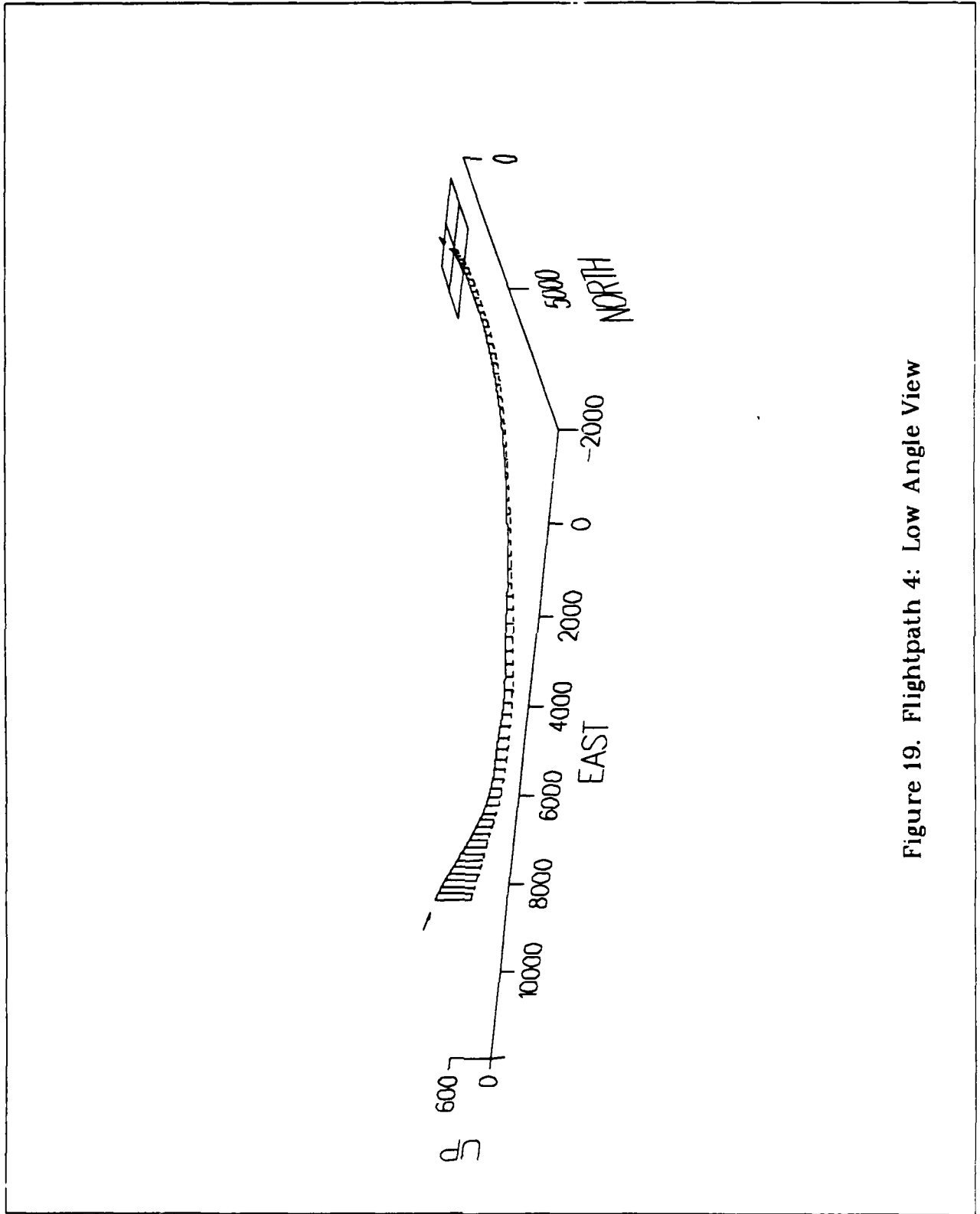


Figure 19. Flightpath 4: Low Angle View

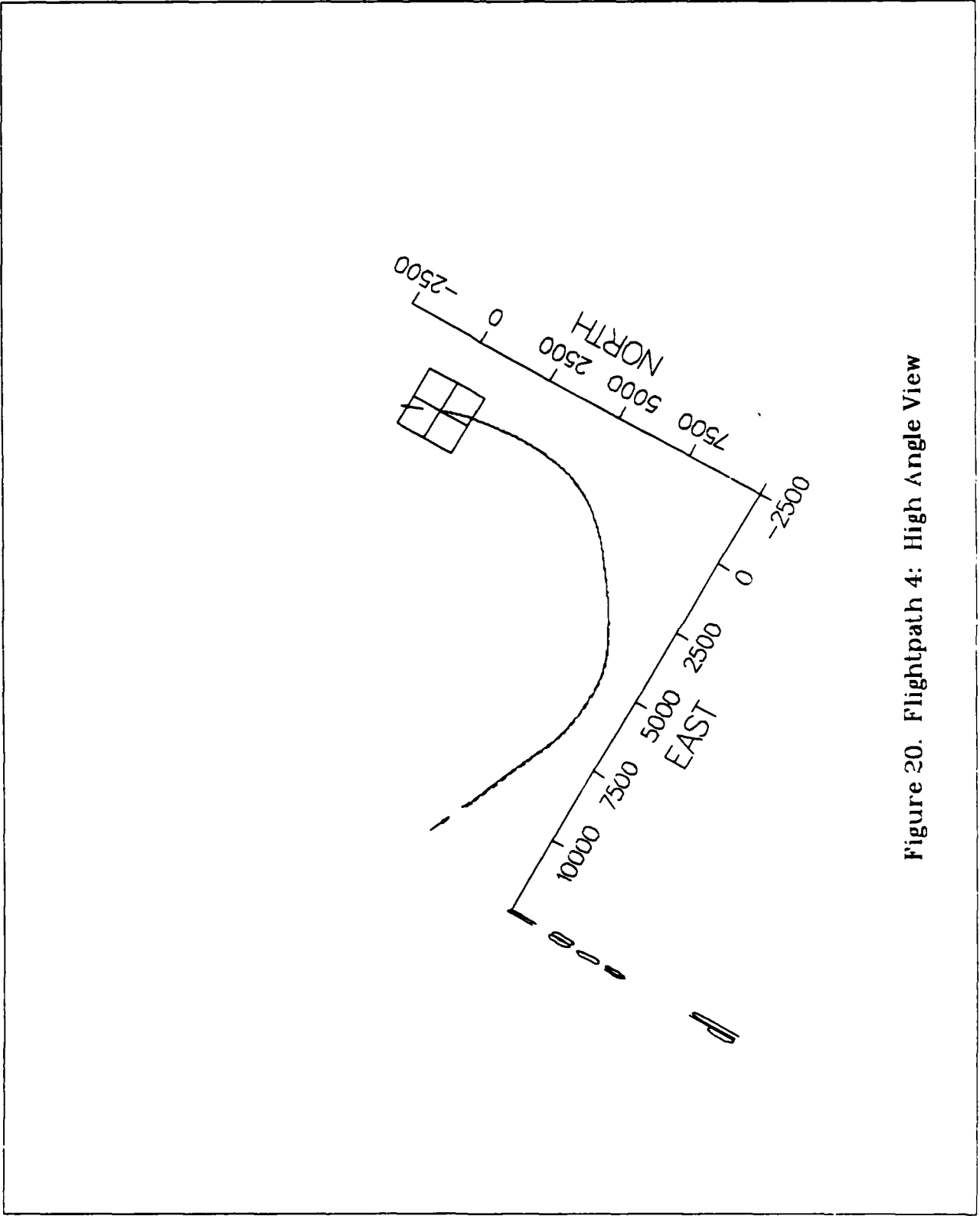


Figure 20. Flightpath 4: High Angle View

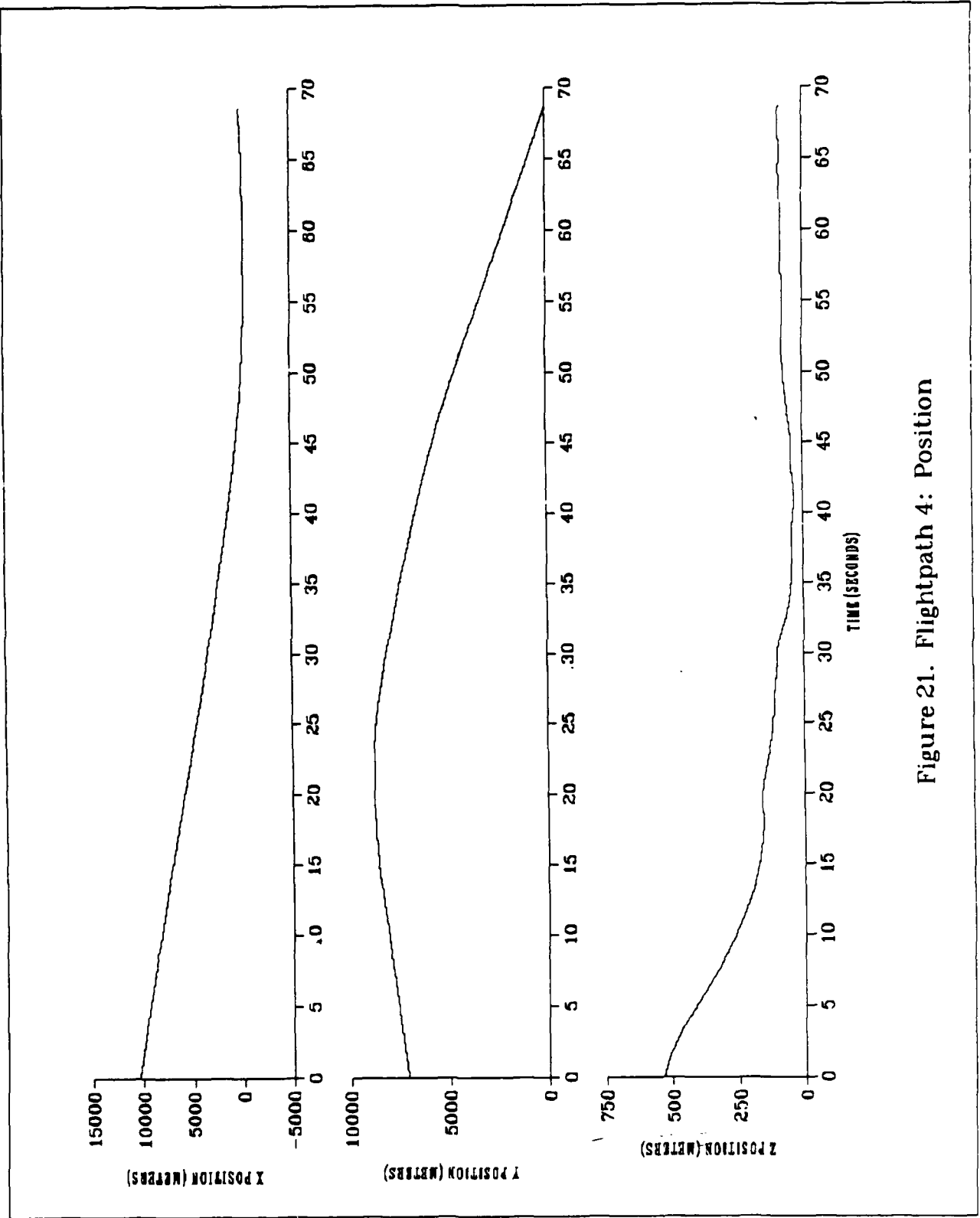


Figure 21. Flightpath 4: Position

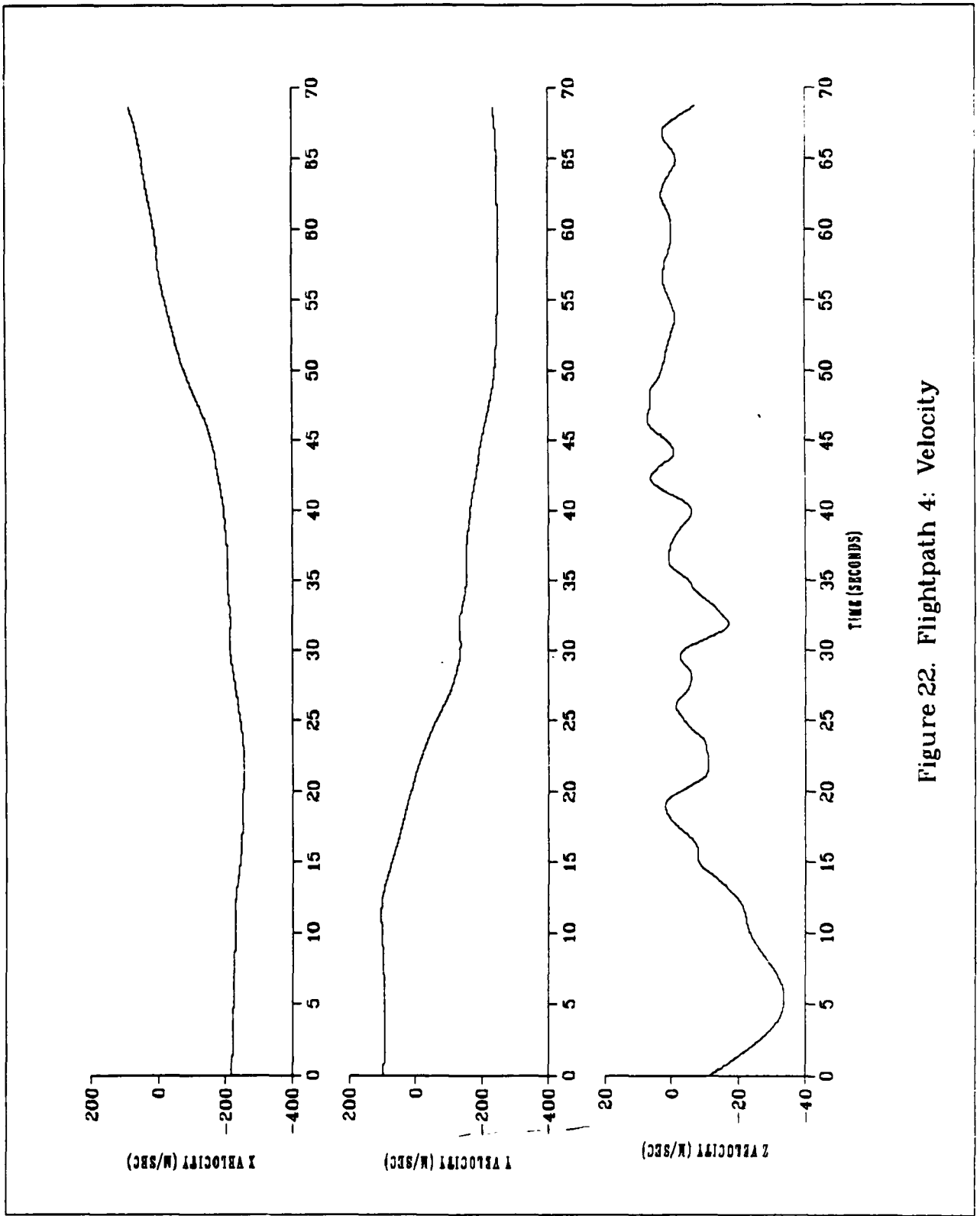


Figure 22. Flightpath 4: Velocity

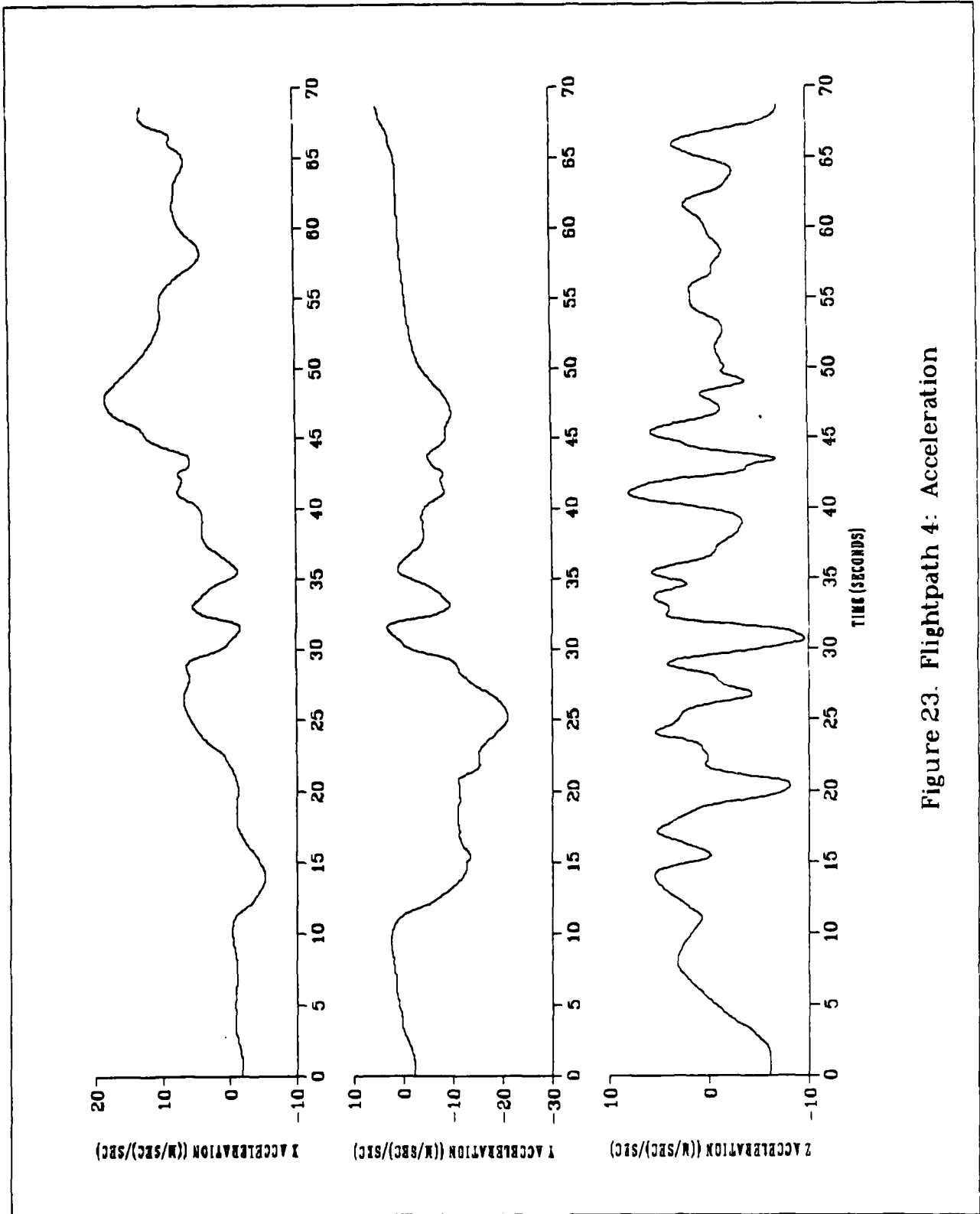


Figure 23. Flightpath 4: Acceleration

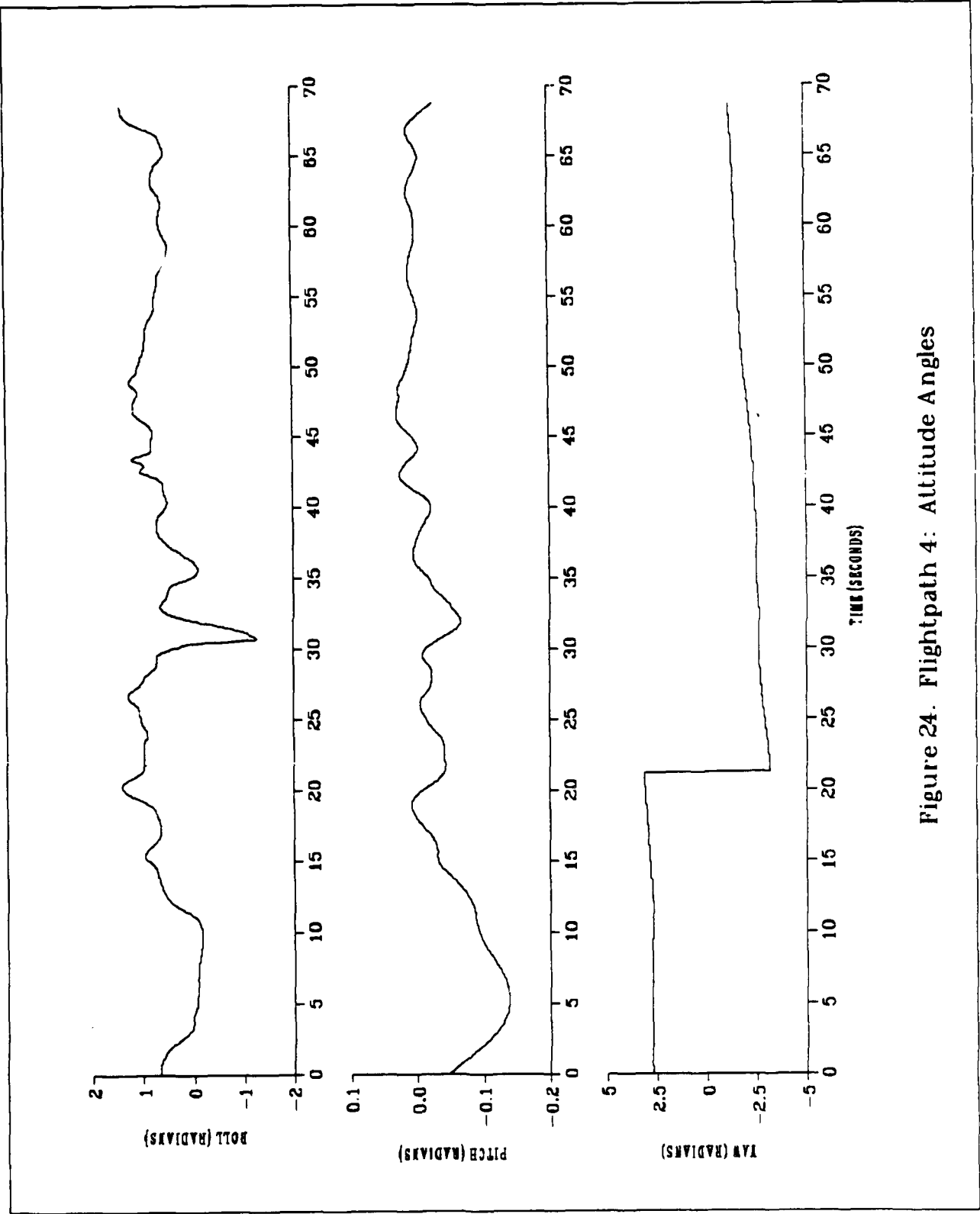


Figure 24. Flightpath 4: Attitude Angles

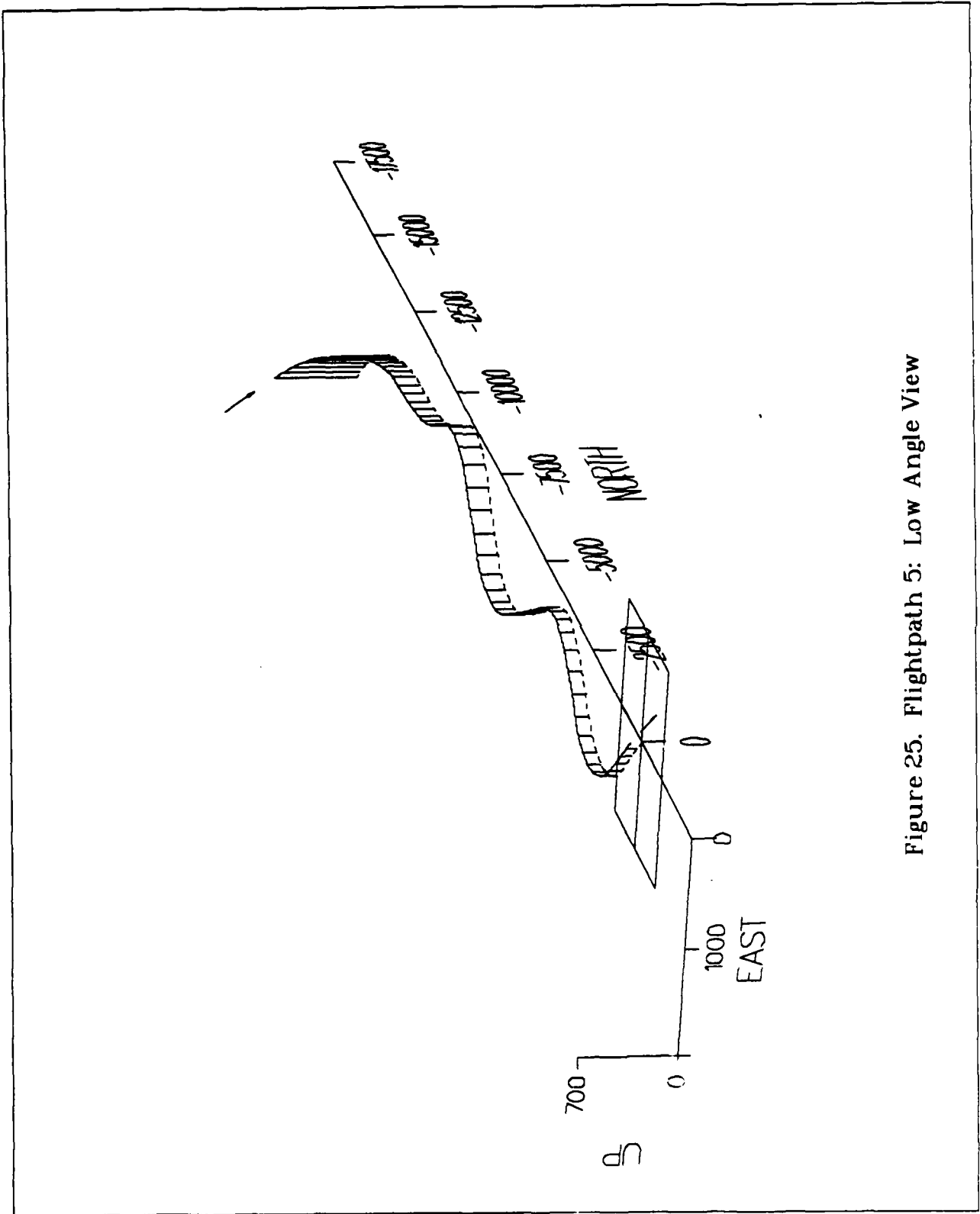


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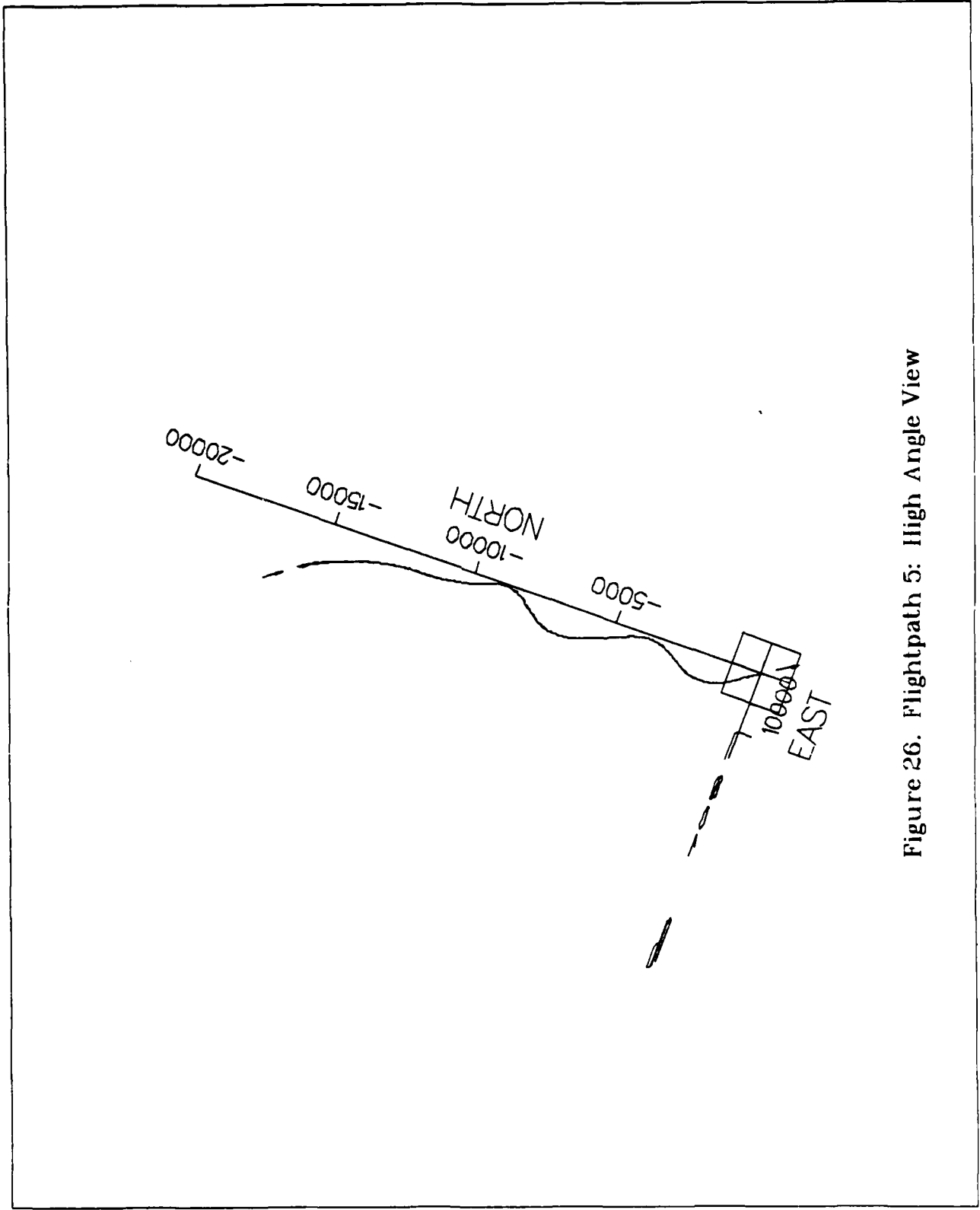


Figure 26. Flightpath 5: High Angle View

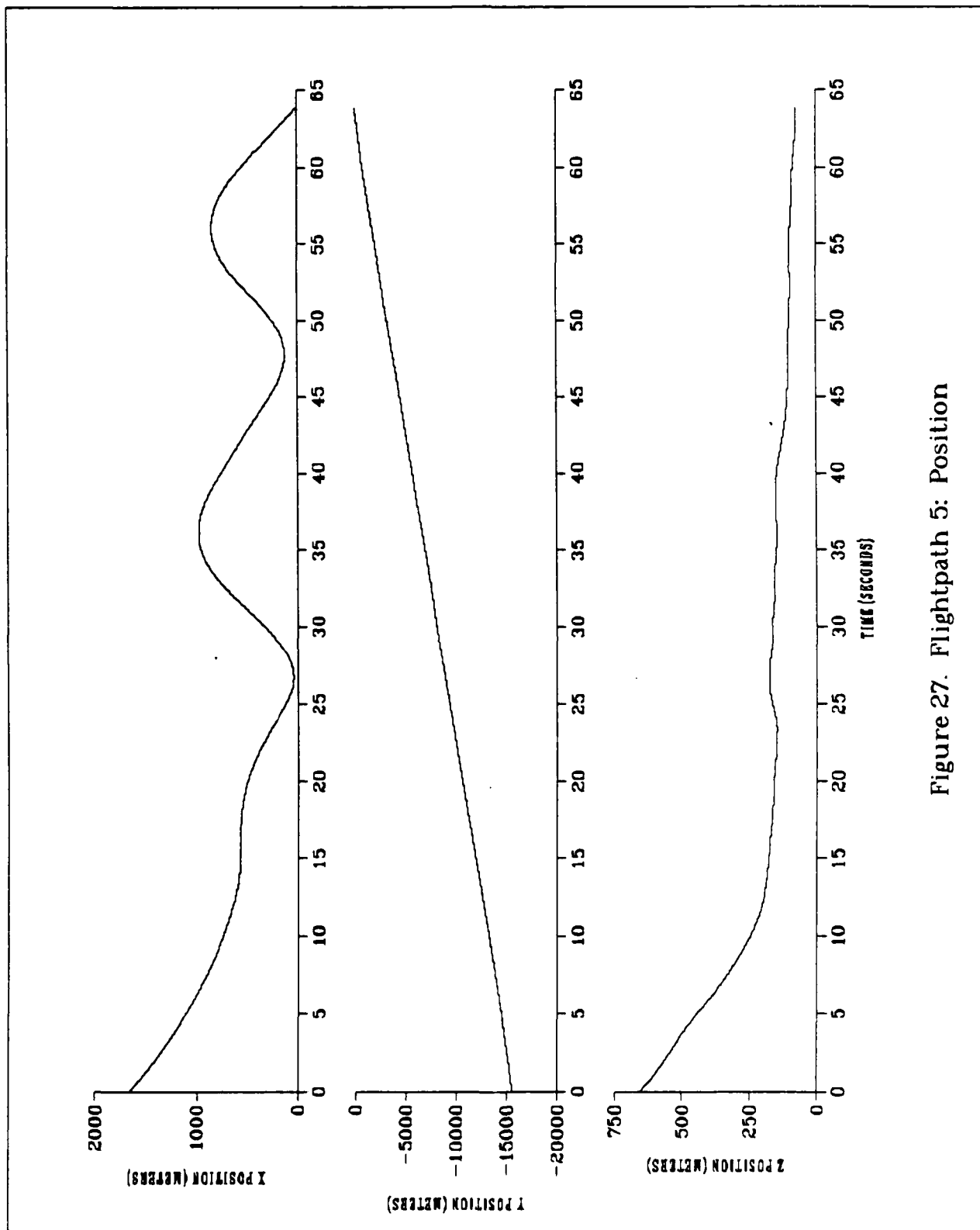


Figure 27. Flightpath 5: Position

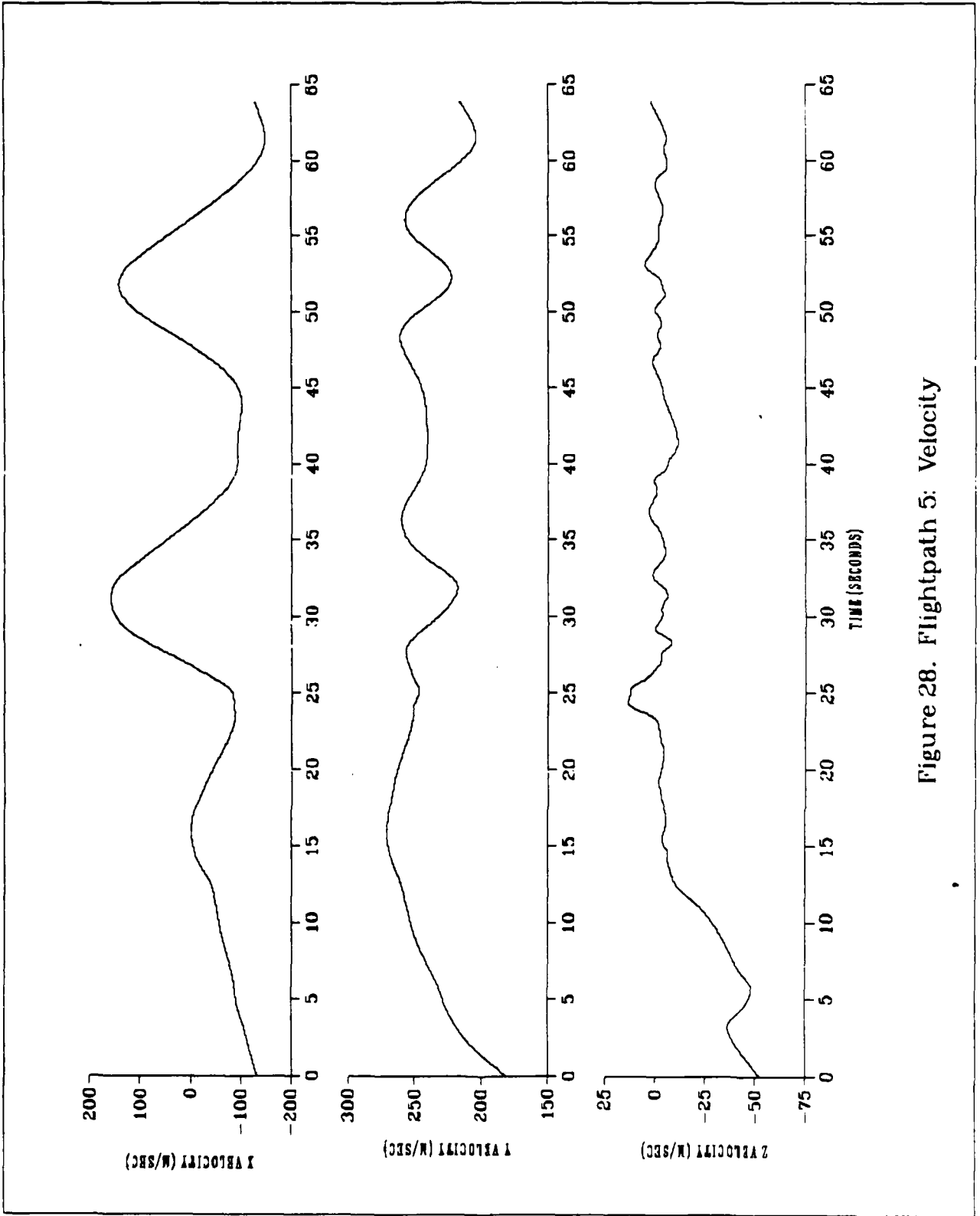


Figure 28. Flightpath 5: Velocity

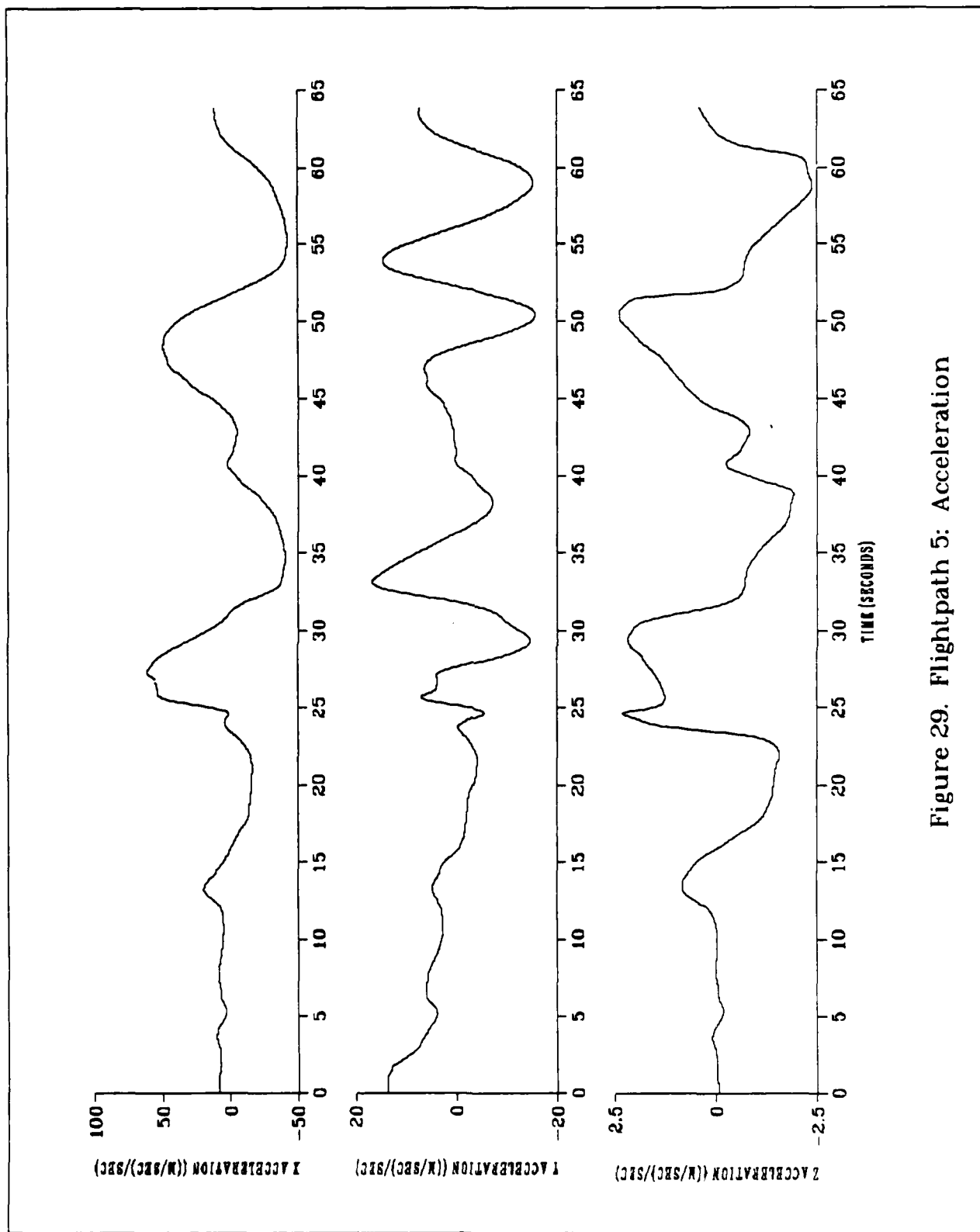


Figure 29. Flightpath 5: Acceleration

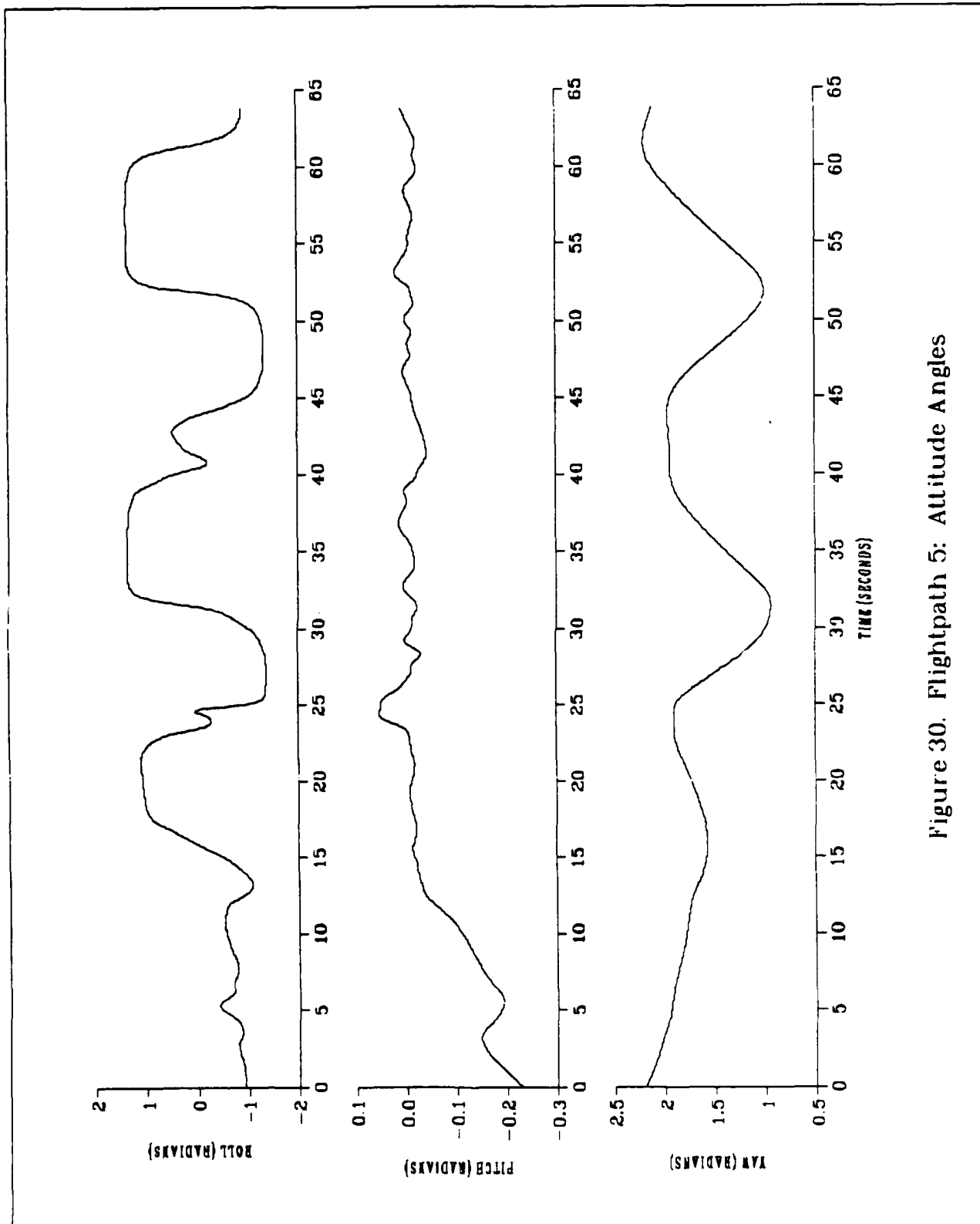


Figure 30. Flightpath 5: Attitude Angles

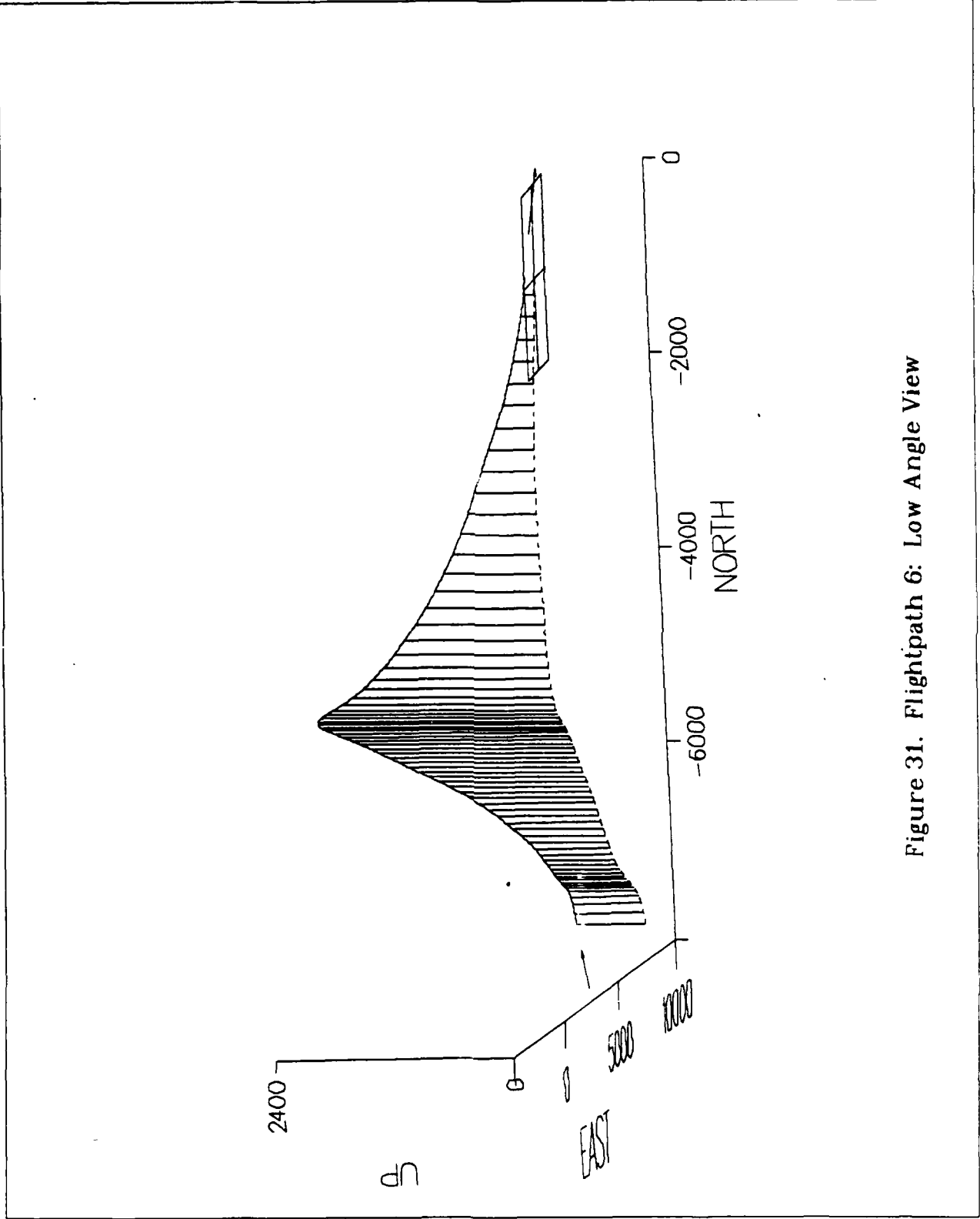


Figure 31. Flightpath 6: Low Angle View

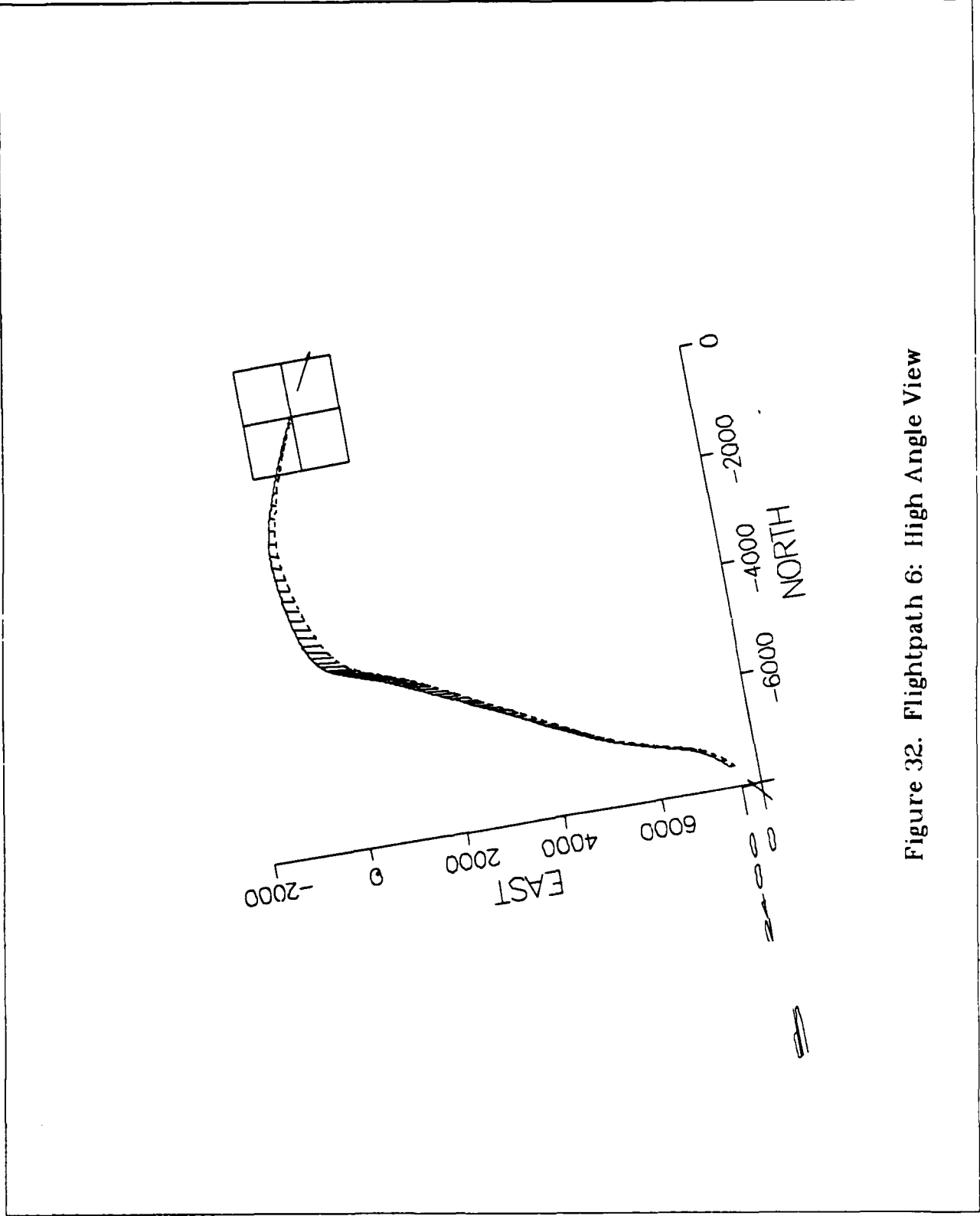


Figure 32. Flightpath 6: High Angle View

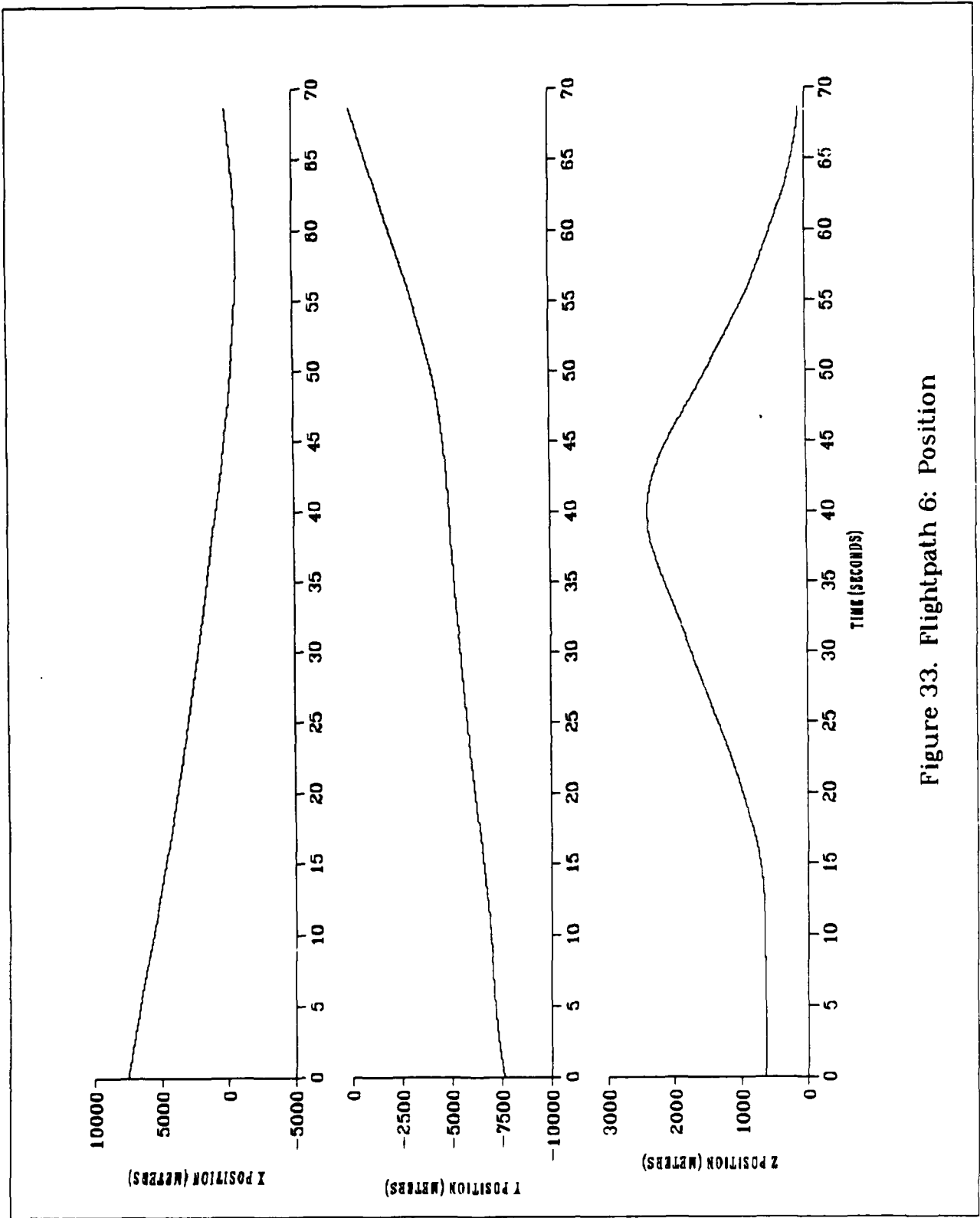


Figure 33. Flightpath 6: Position

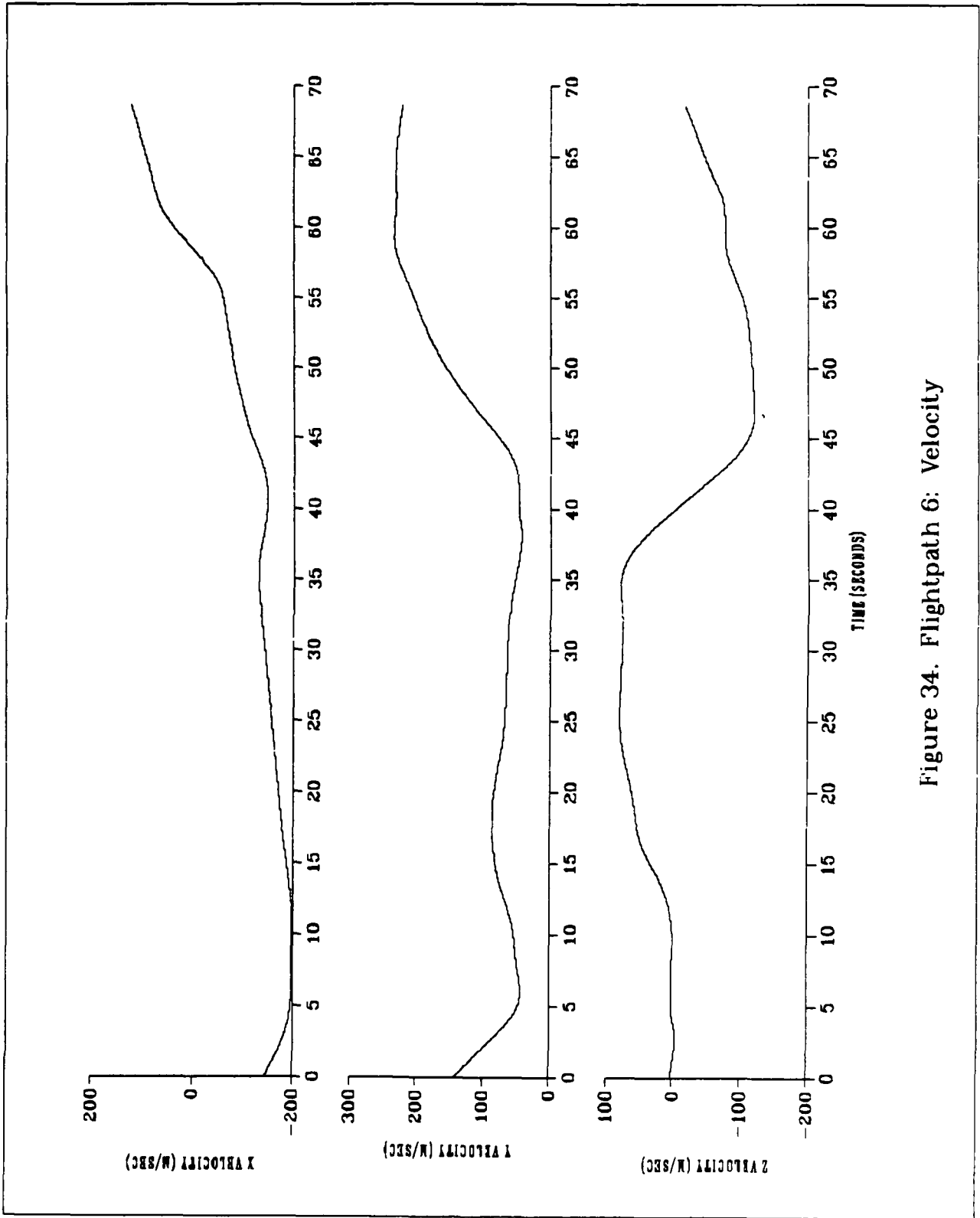


Figure 34. Flightpath 6: Velocity

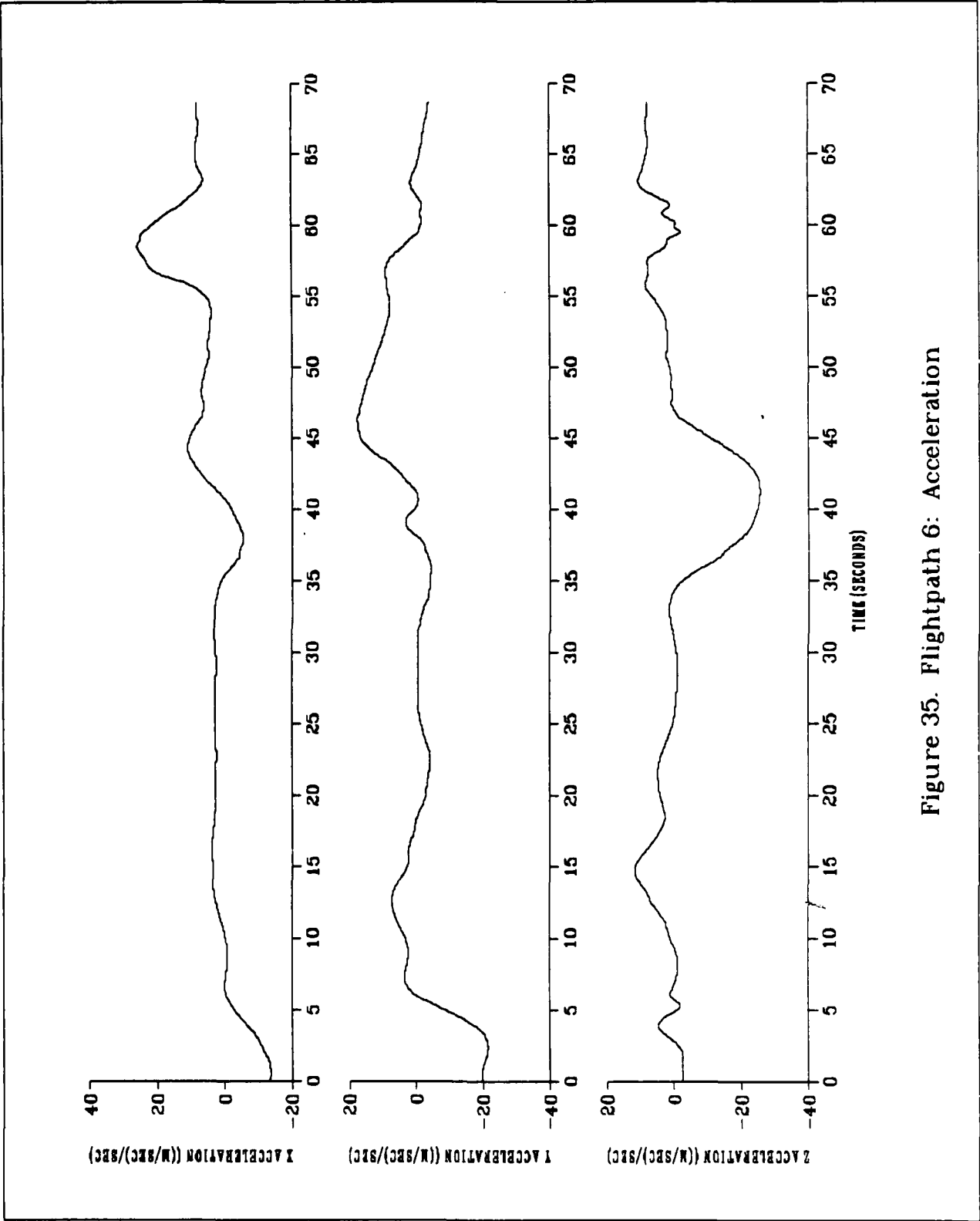


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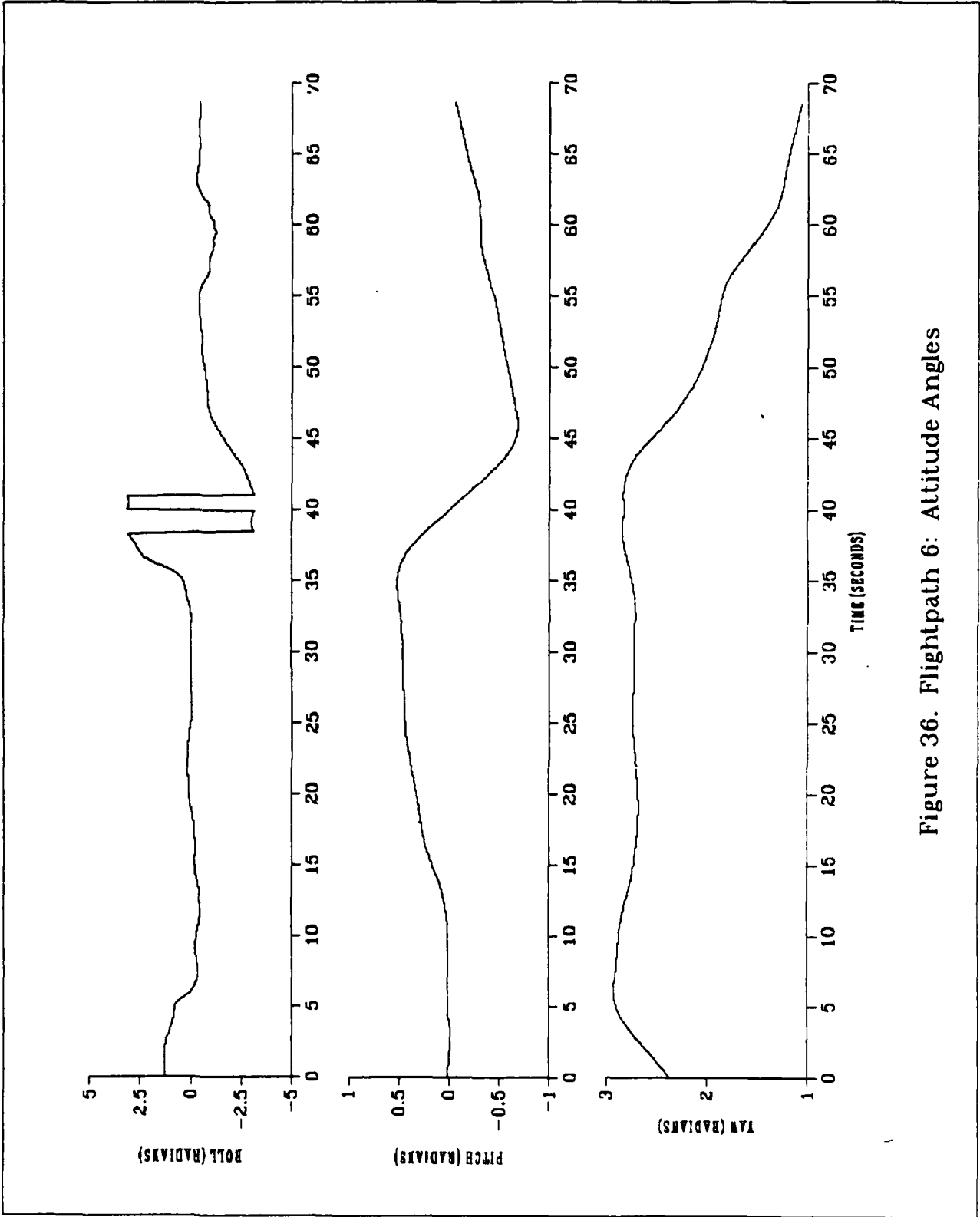


Figure 36. Flightpath 6: Altitude Angles

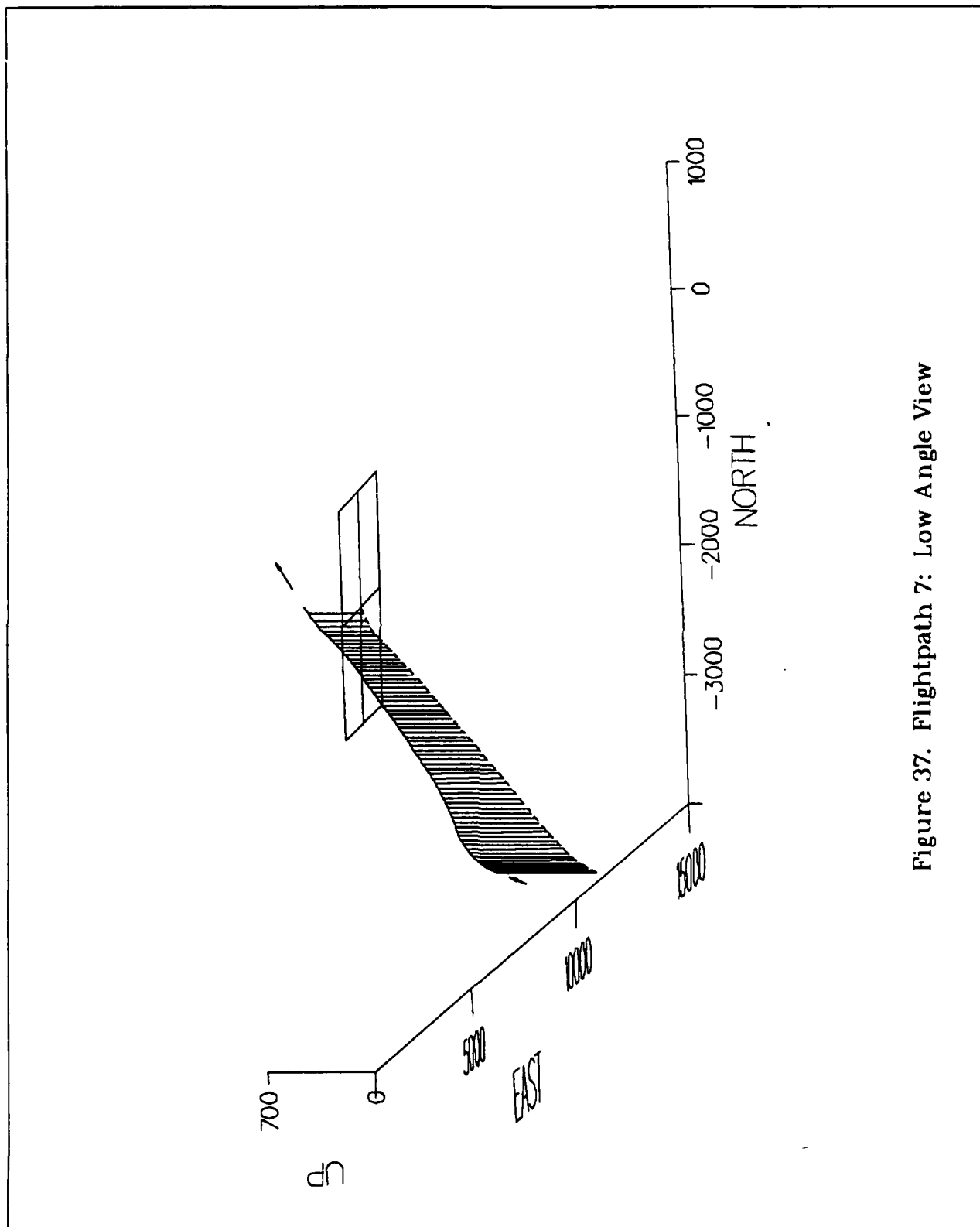


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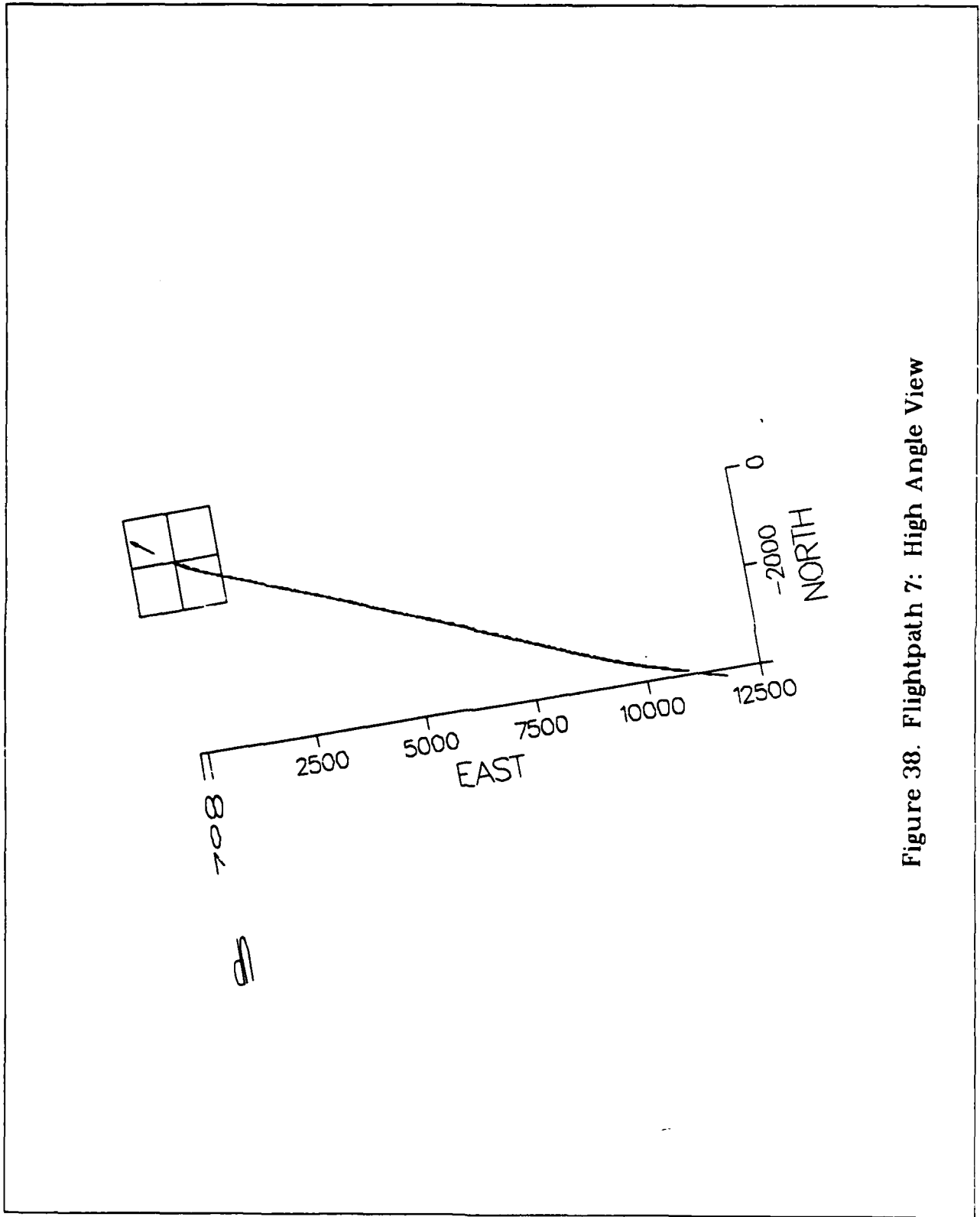


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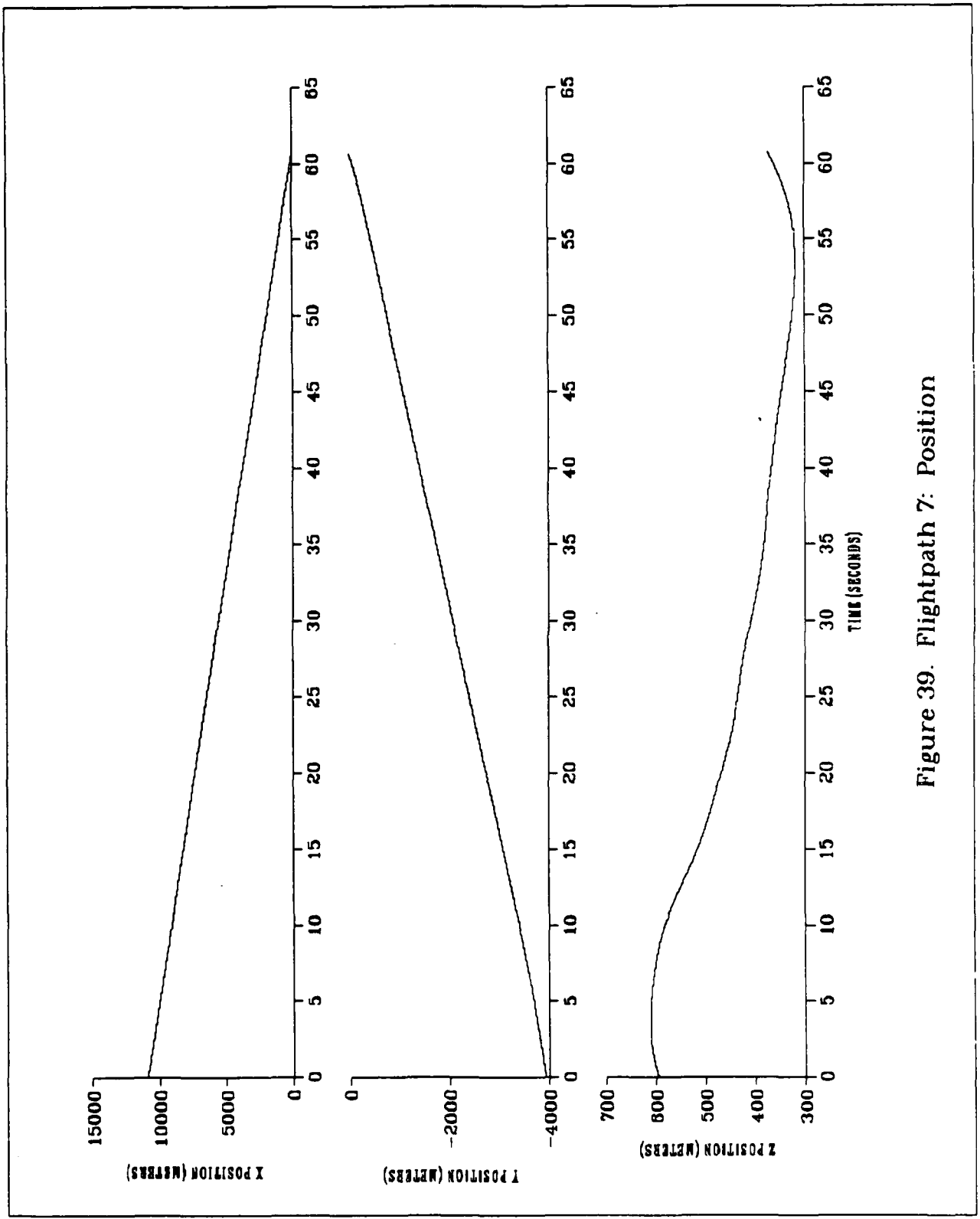


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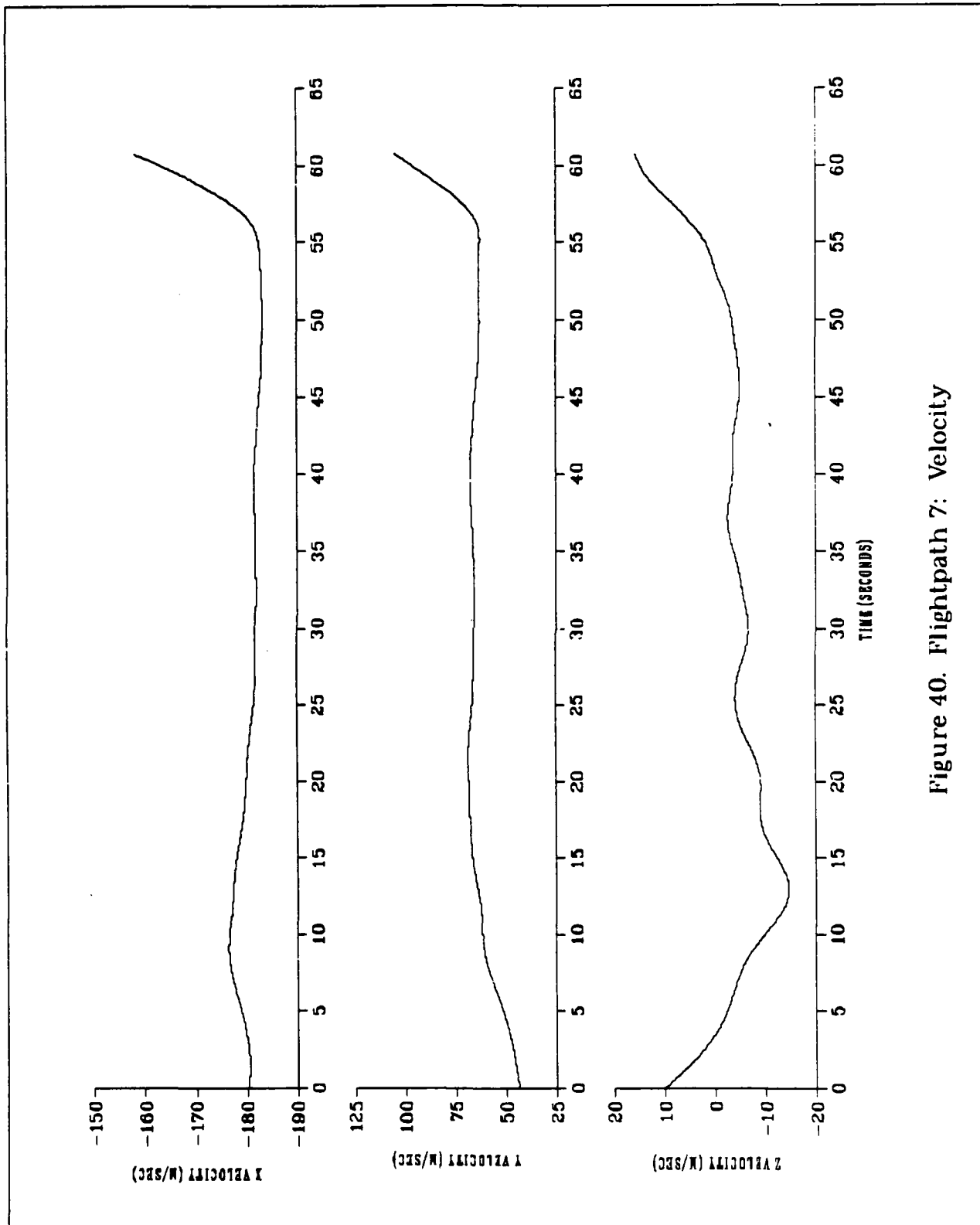


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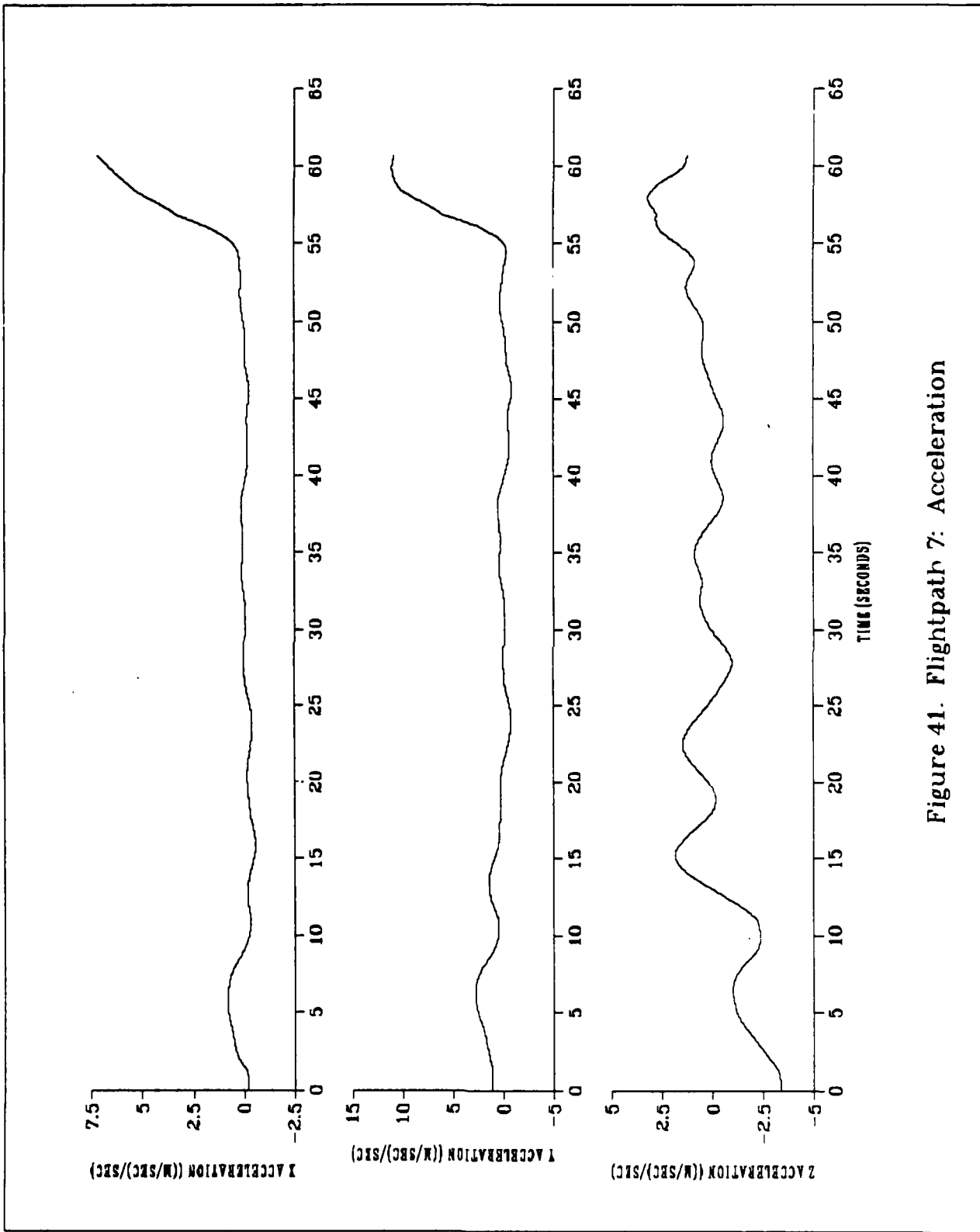


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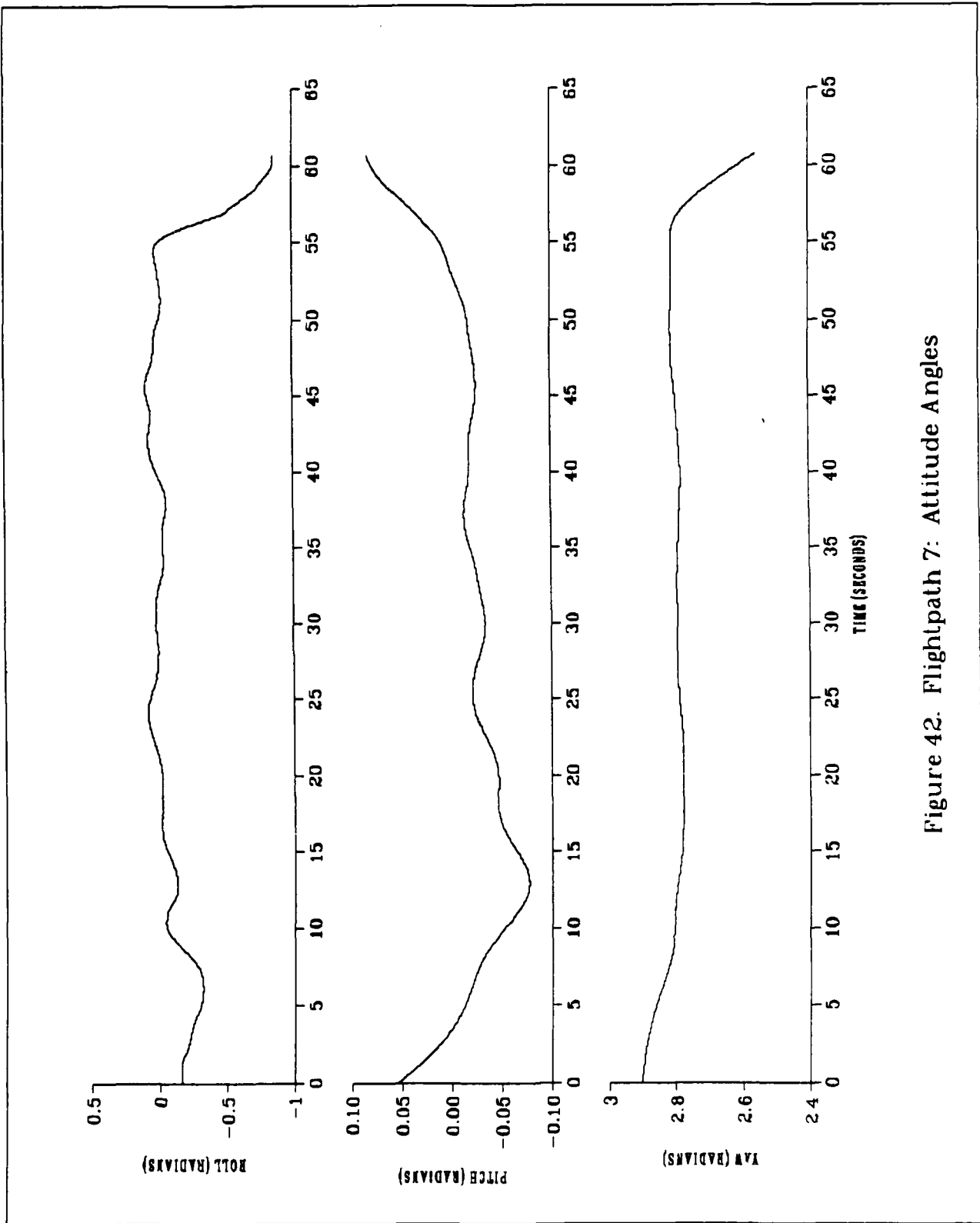


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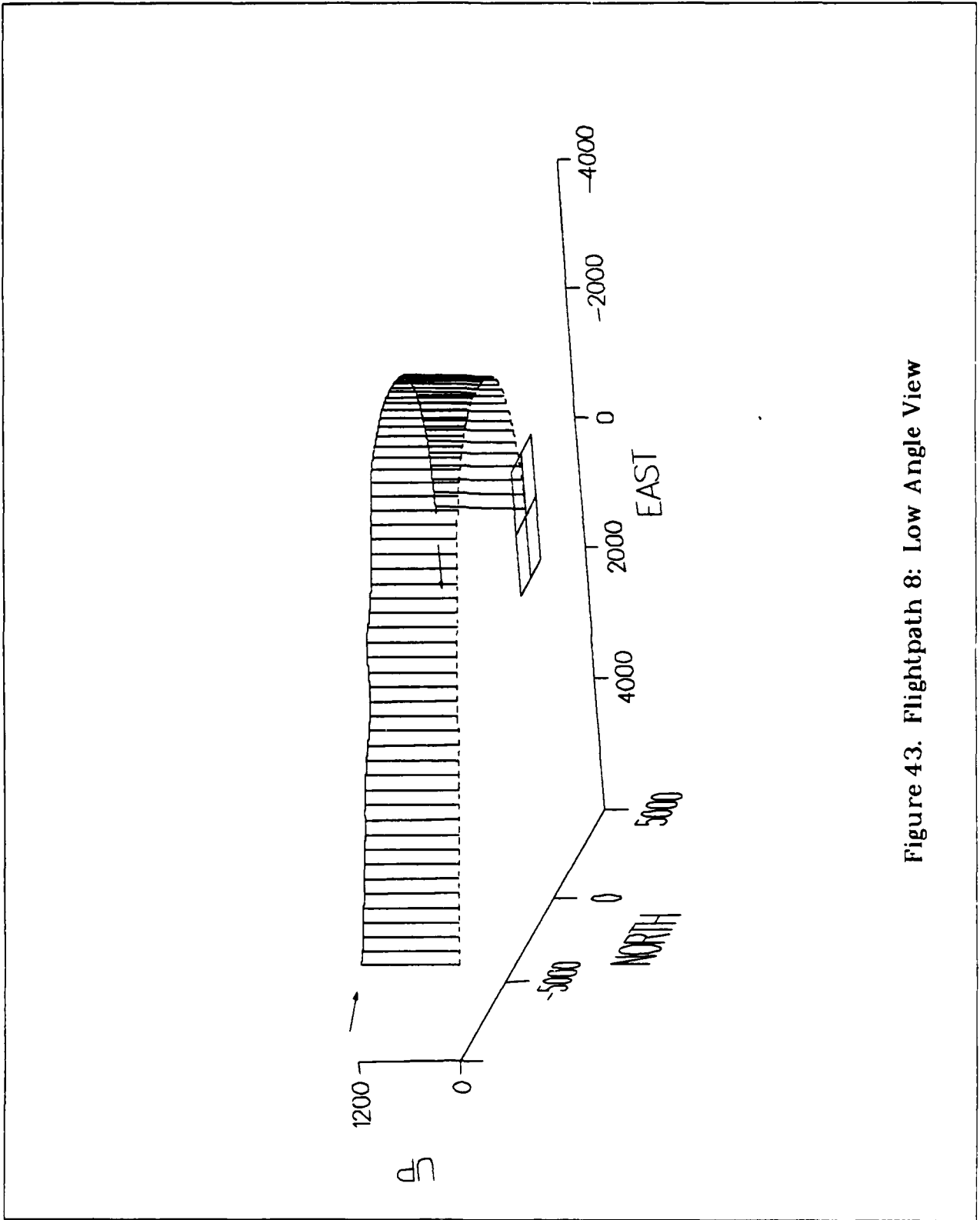


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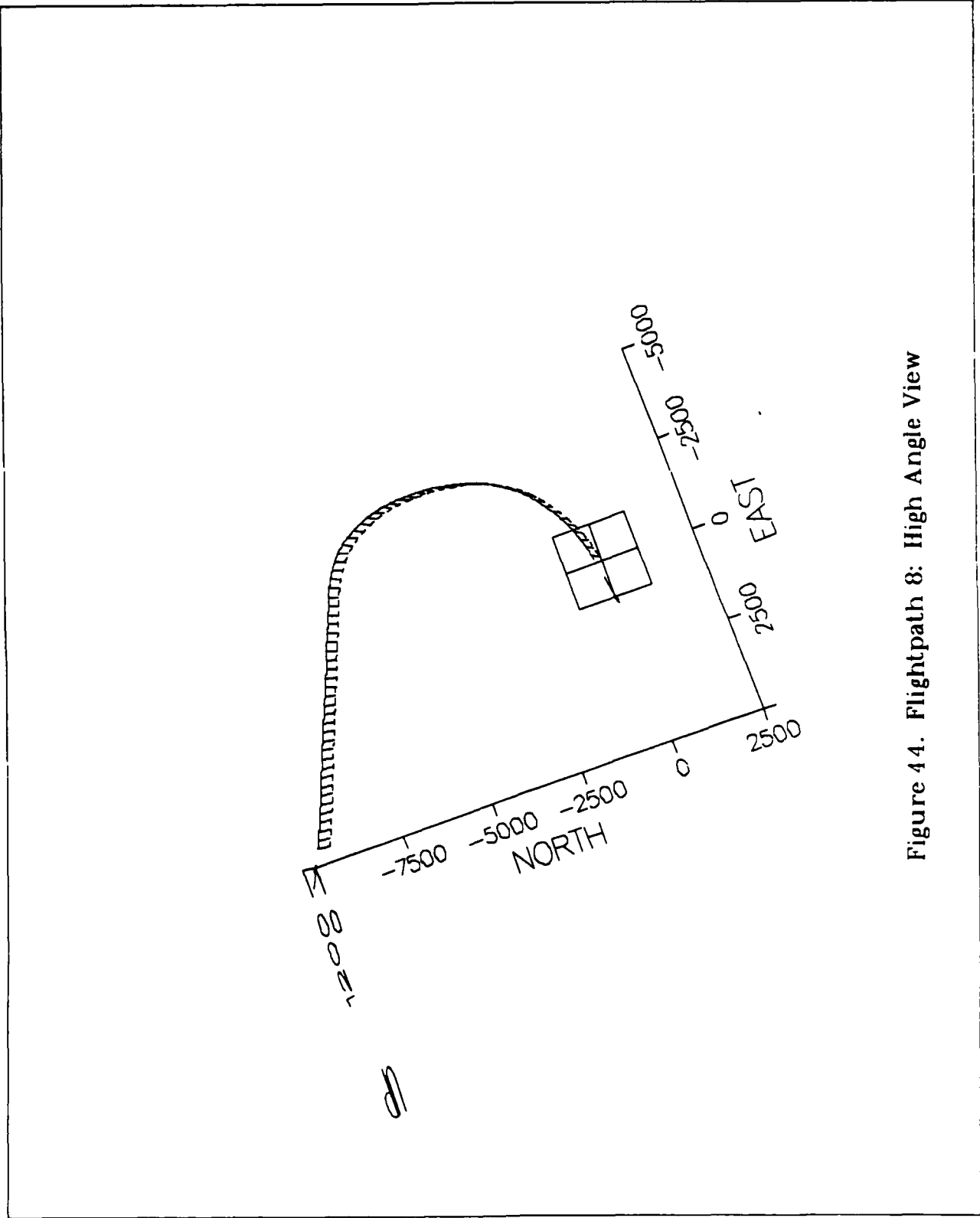


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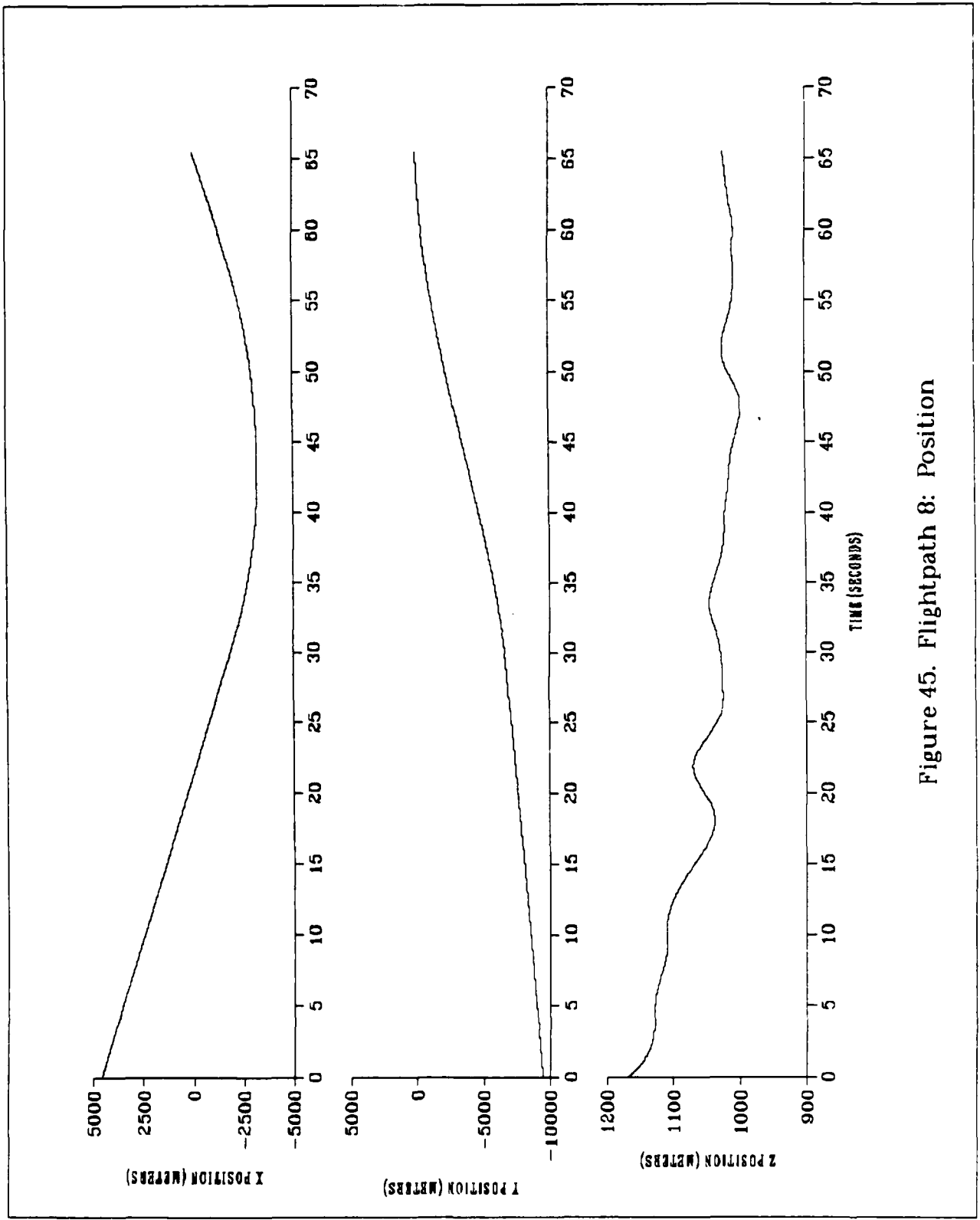


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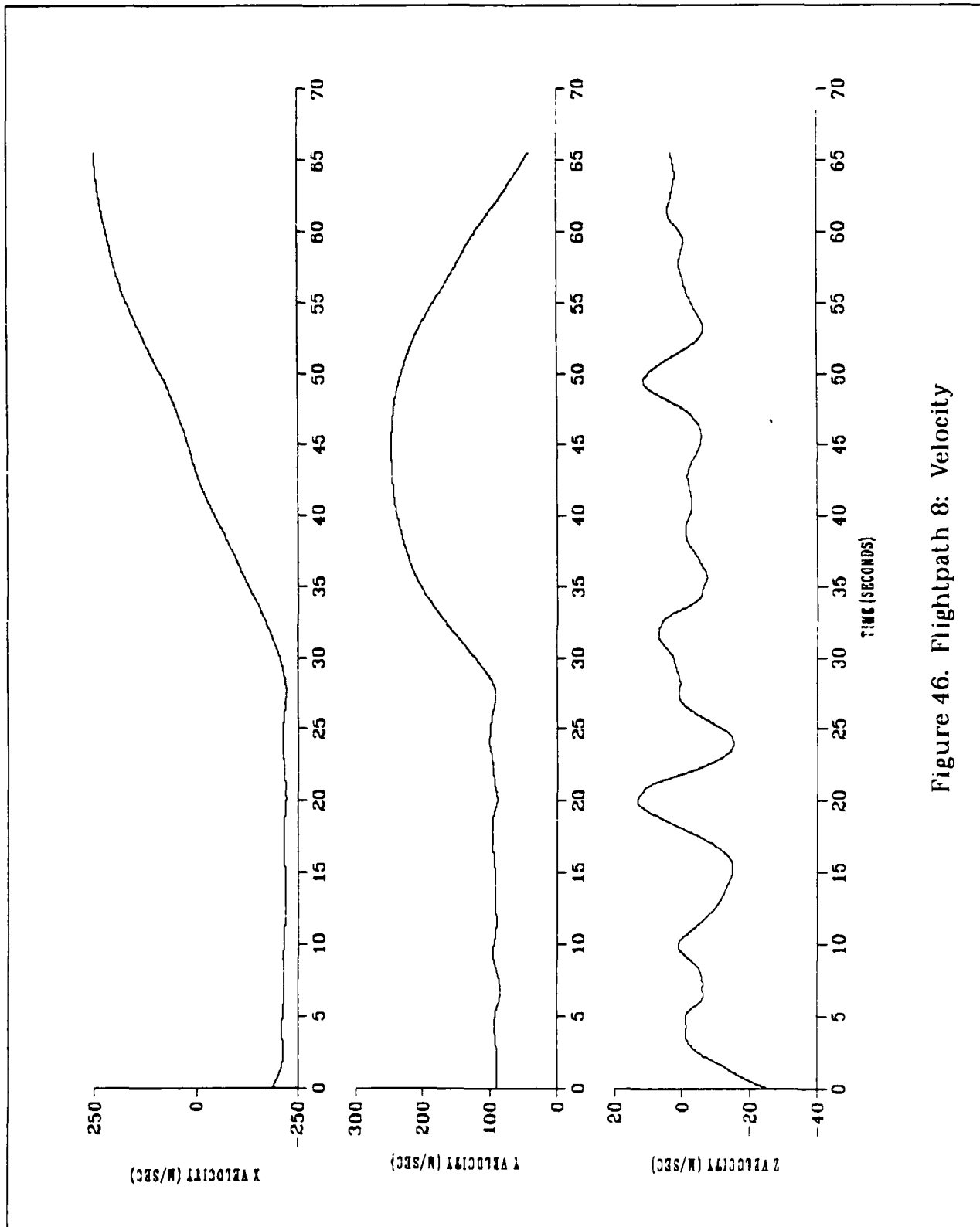


Figure 46. Flightpath 8: Velocity

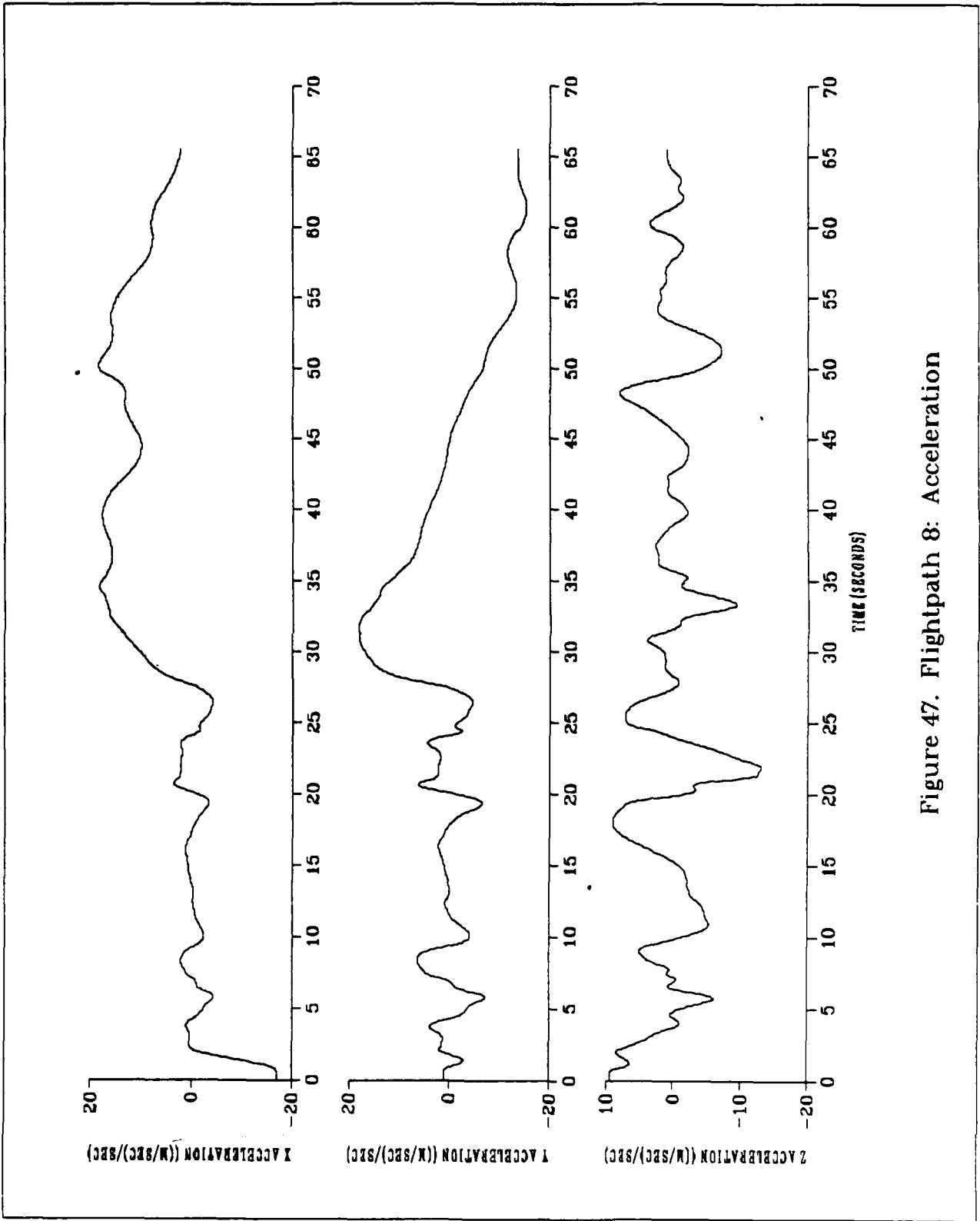


Figure 47. Flightpath 8: Acceleration

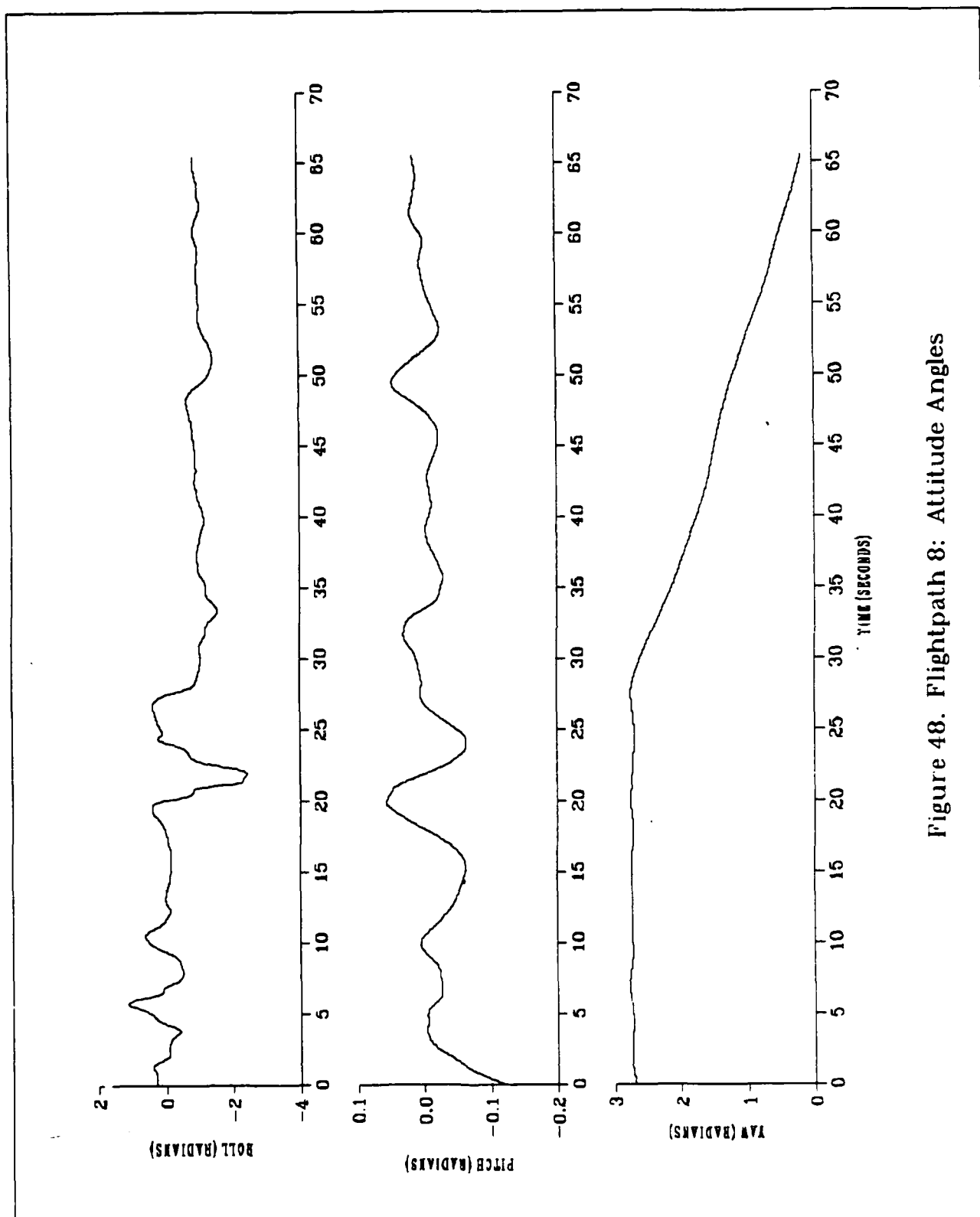


Figure 48. Flightpath 8: Attitude Angles

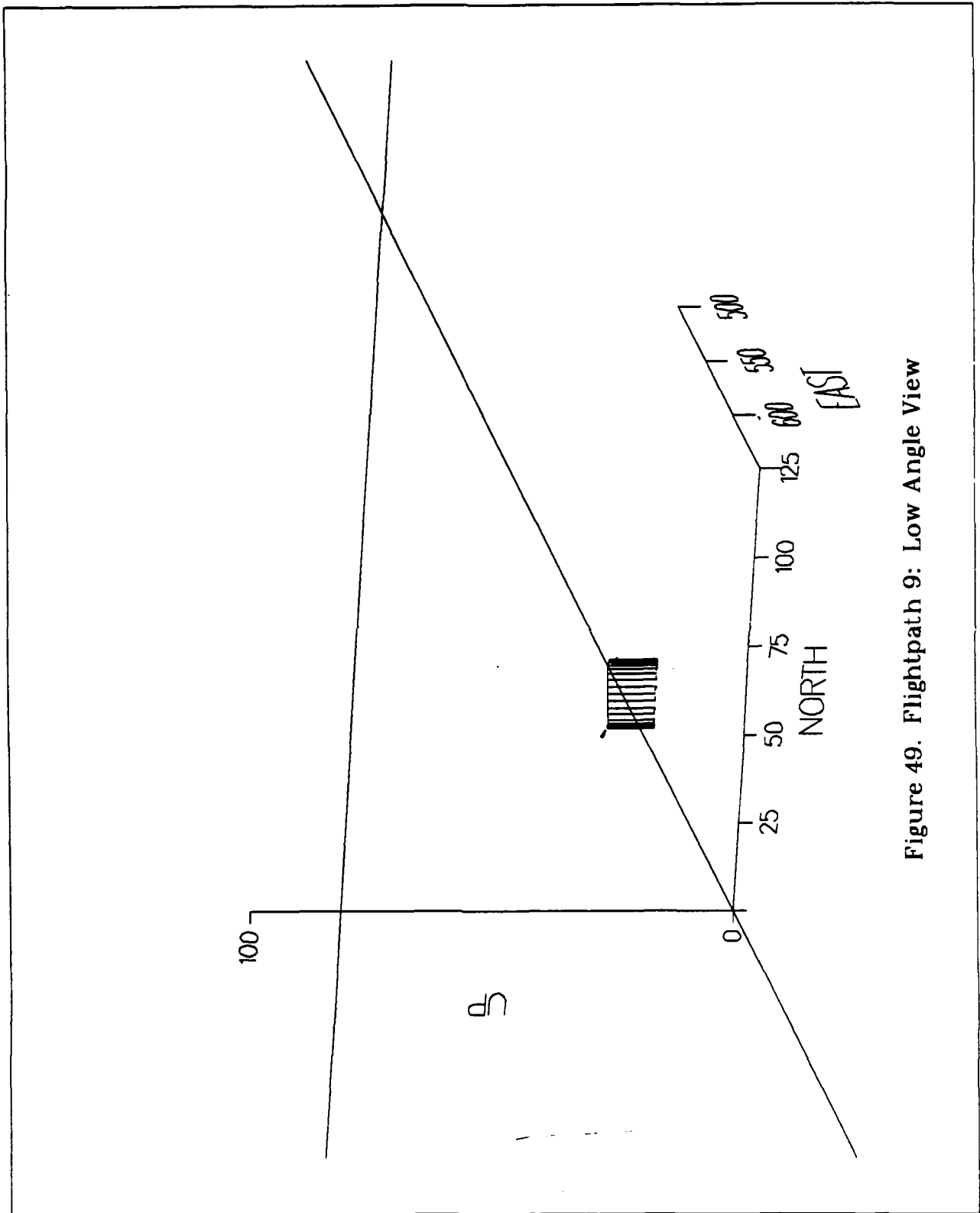


Figure 49. Flightpath 9: Low Angle View

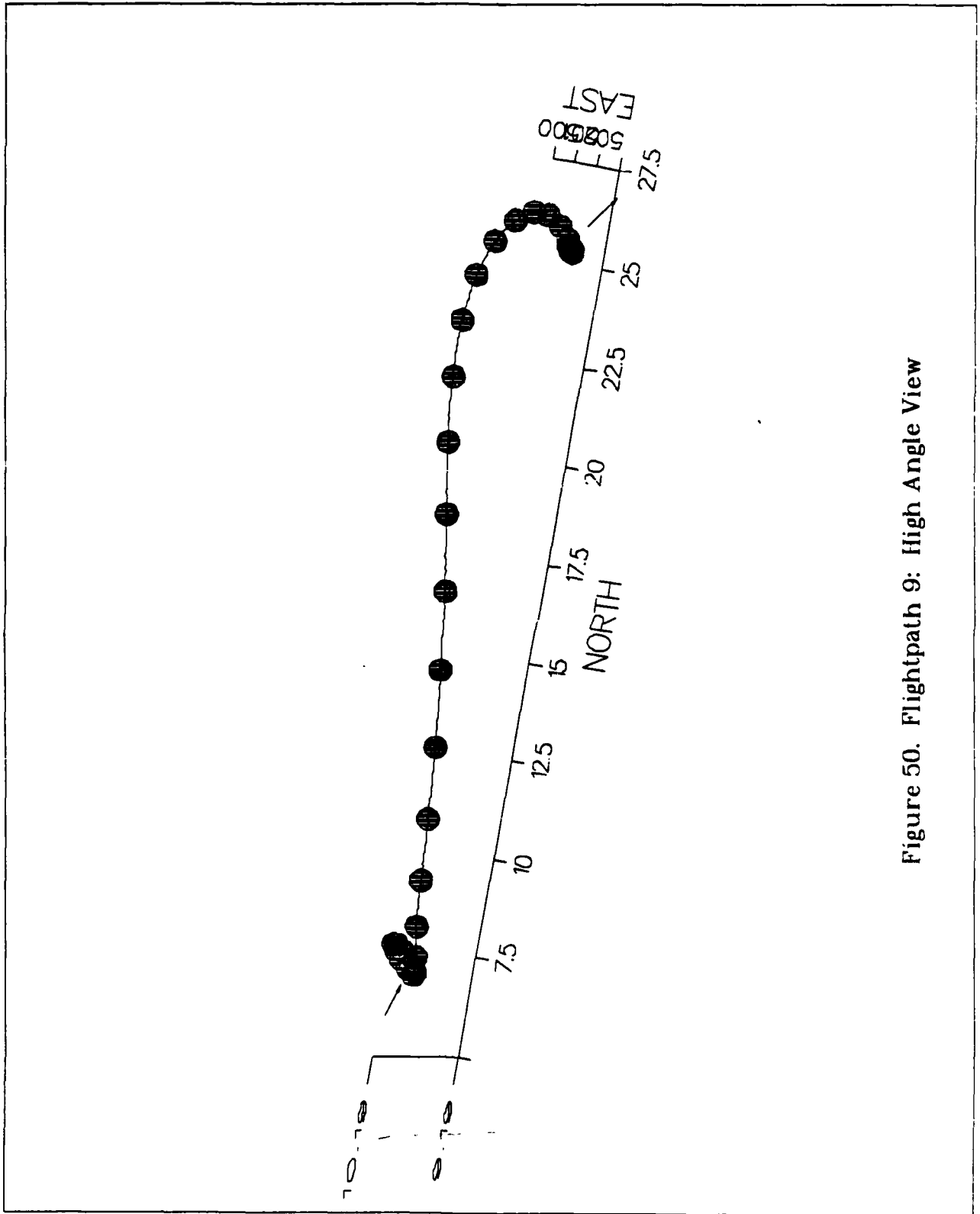


Figure 50. Flightpath 9: High Angle View

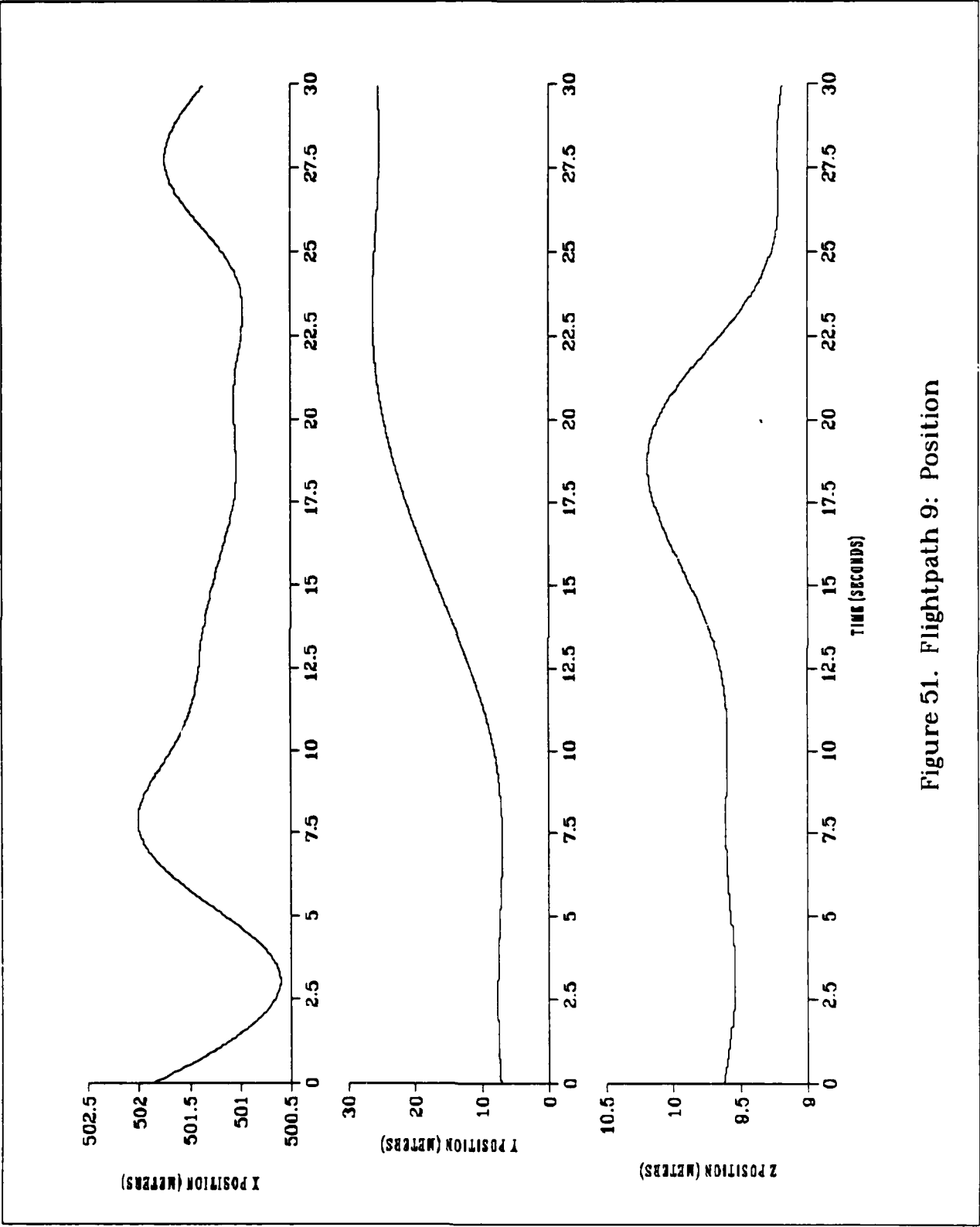


Figure 51. Flightpath 9: Position

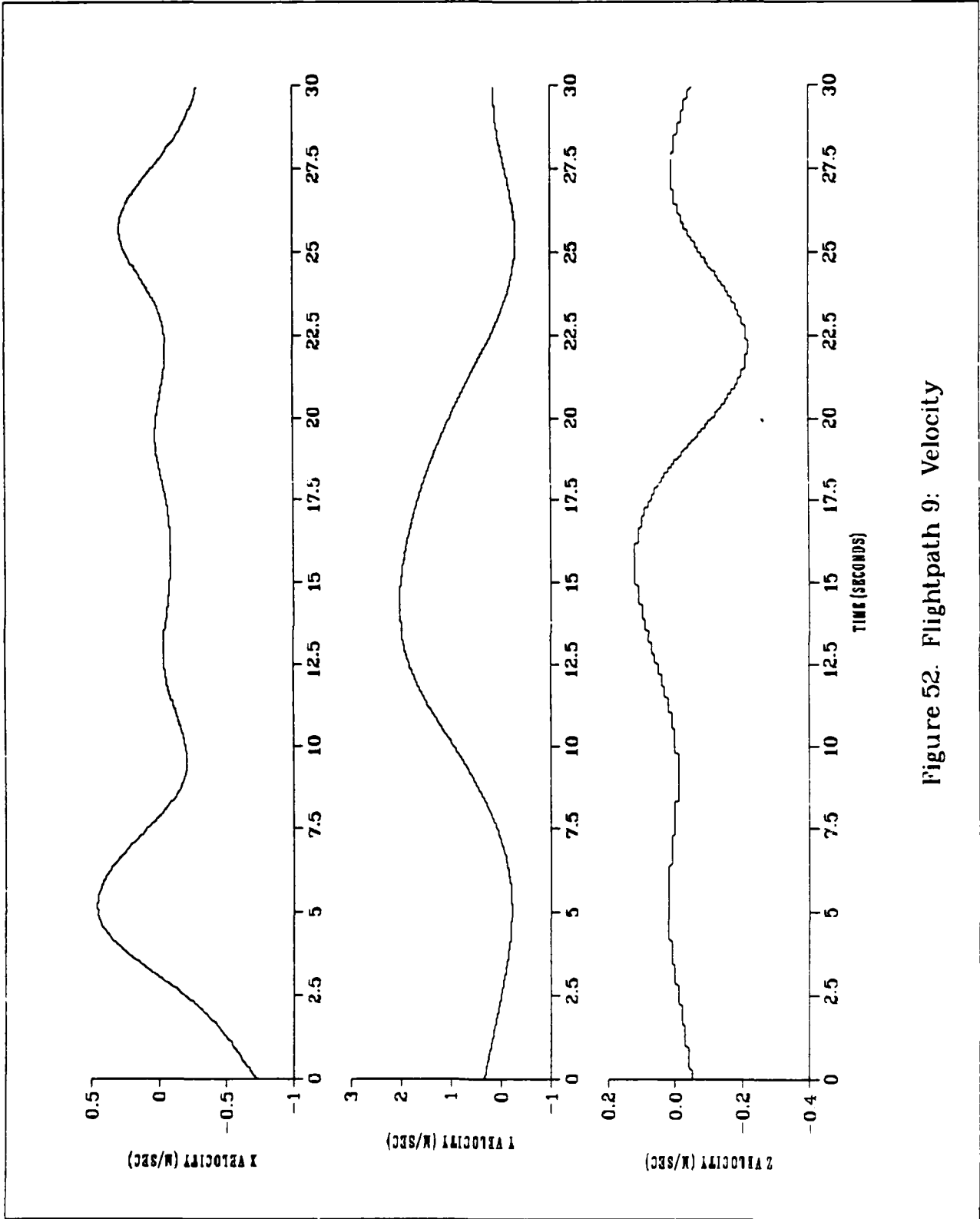


Figure 52. Flightpath 9: Velocity

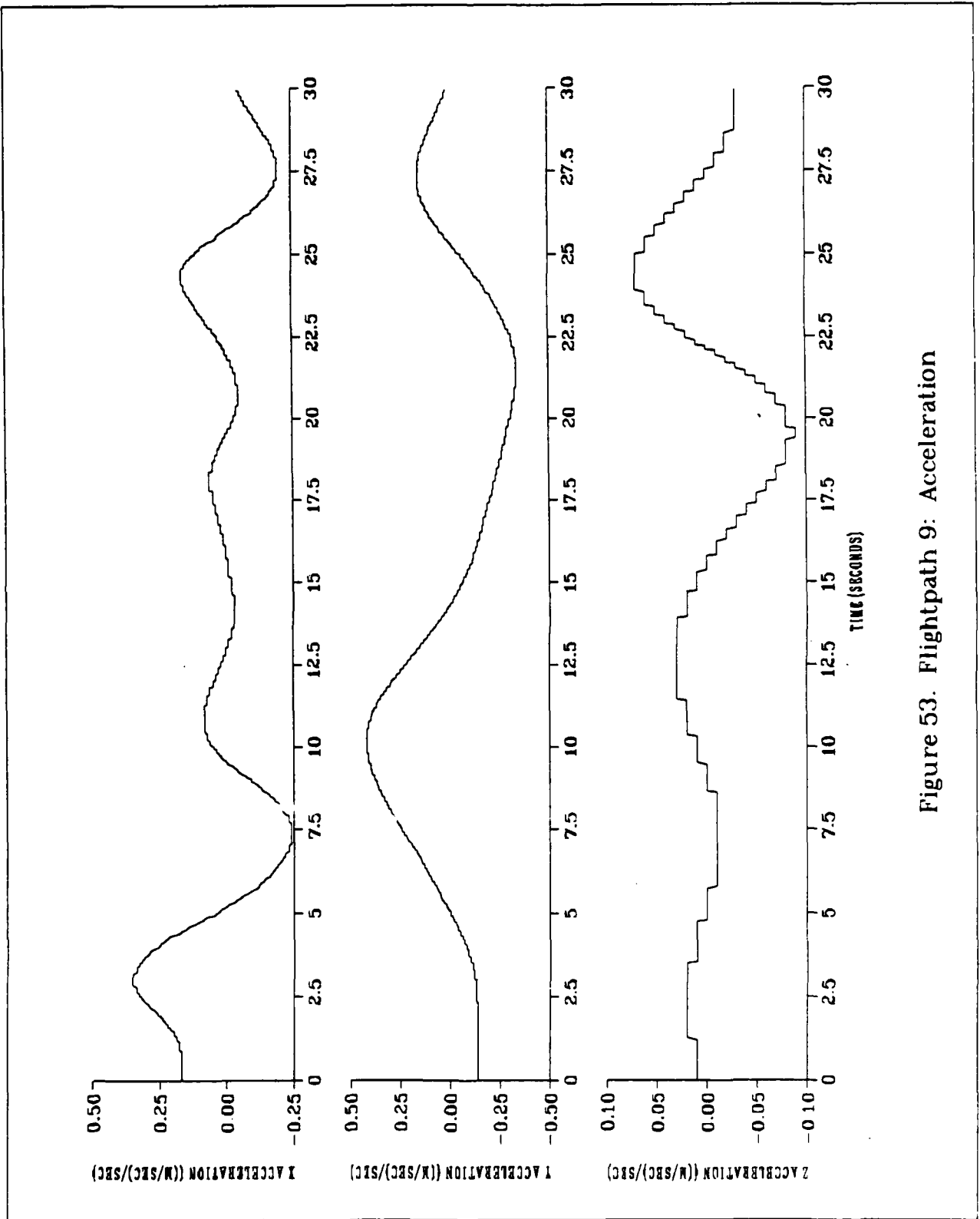


Figure 53. Flightpath 9: Acceleration

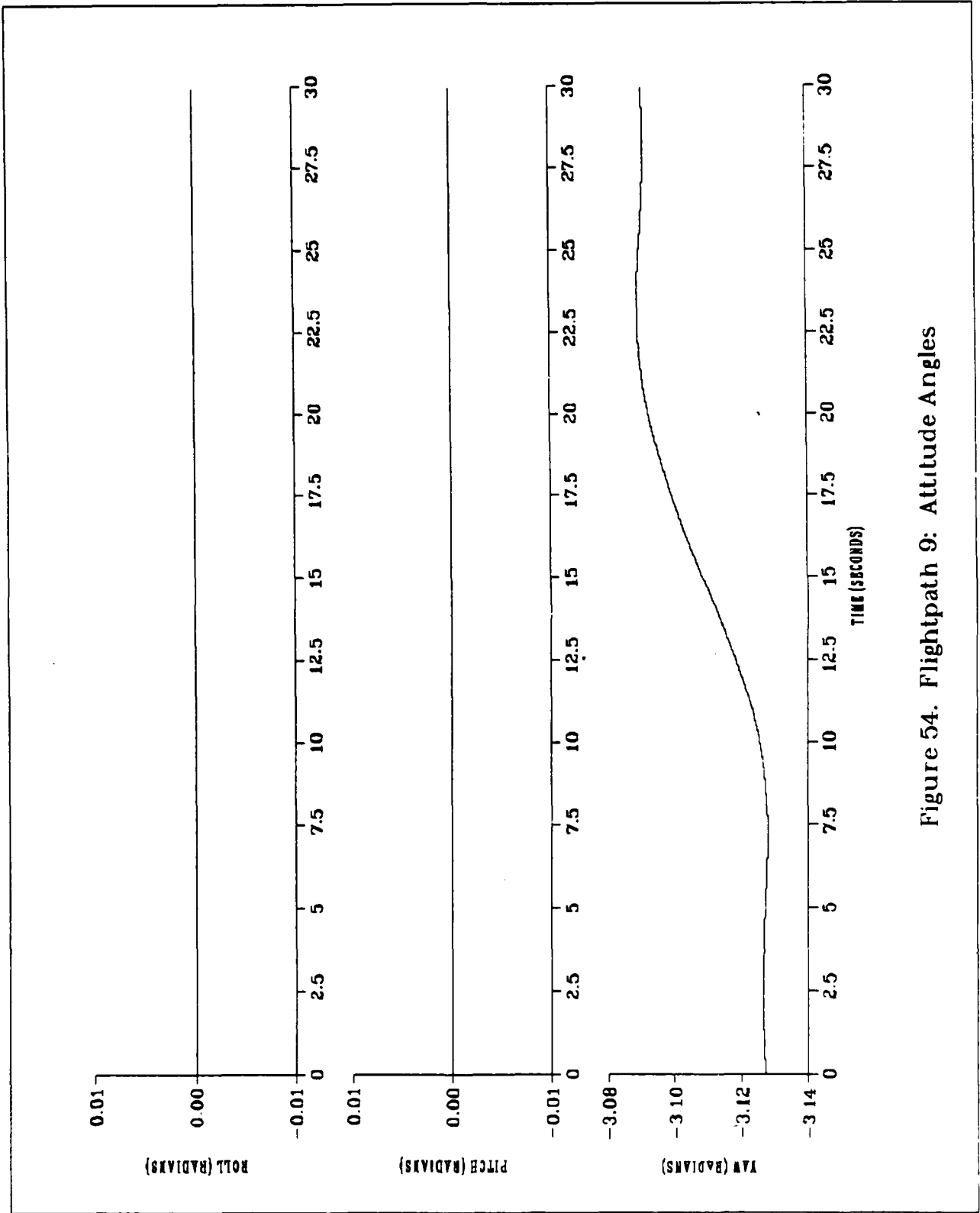


Figure 54. Flightpath 9: Attitude Angles

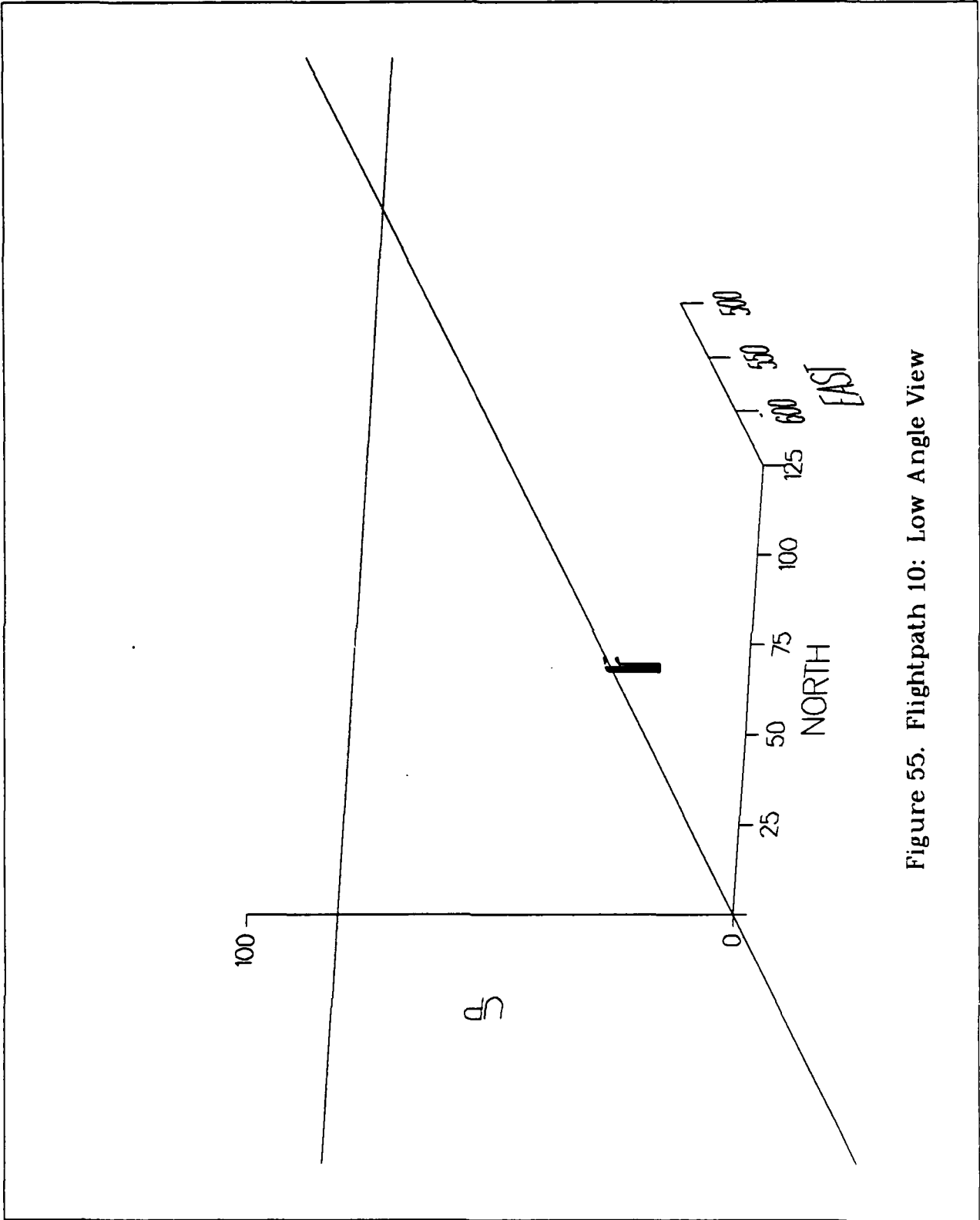


Figure 55. Flightpath 10: Low Angle View



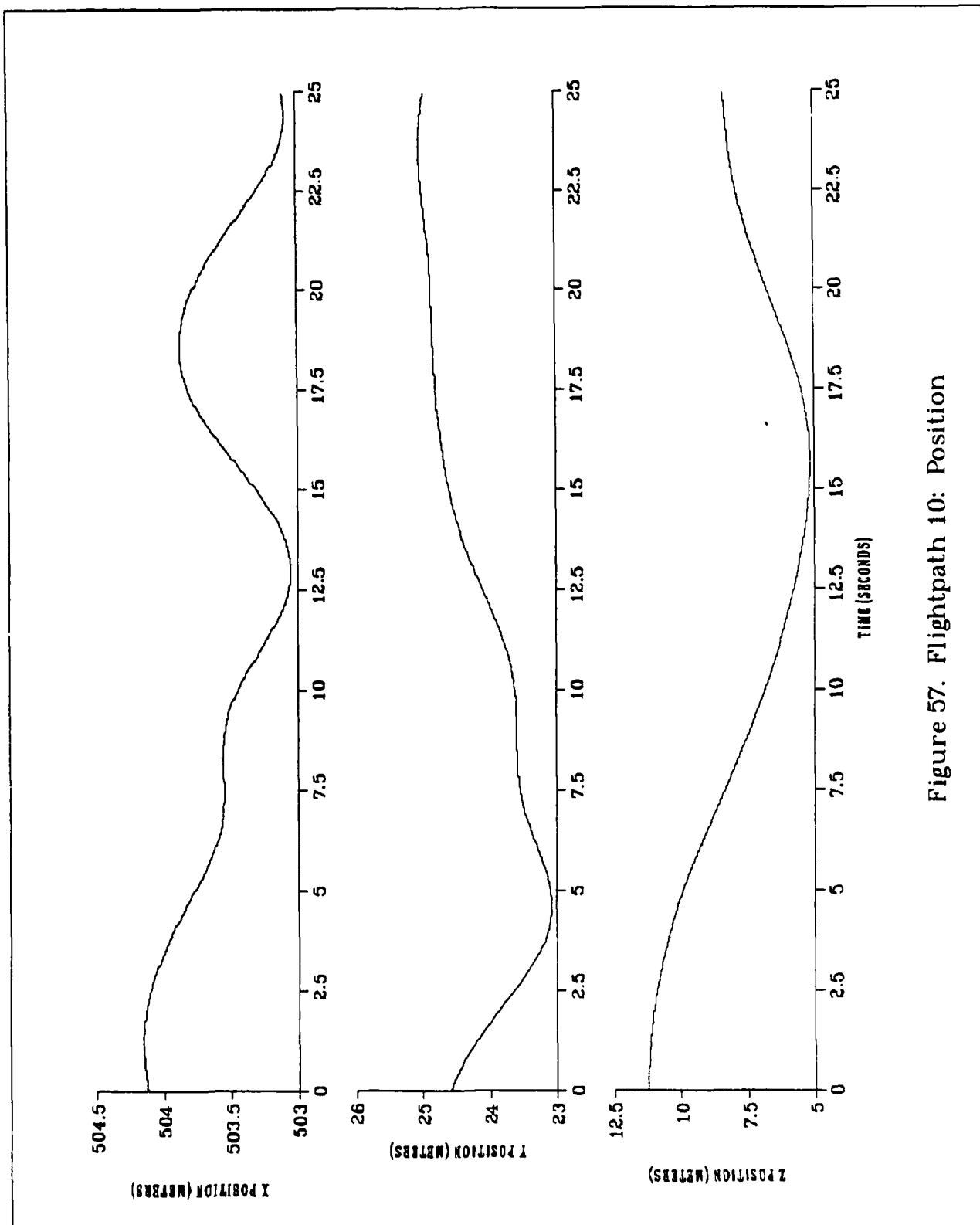


Figure 57. Flightpath 10: Position

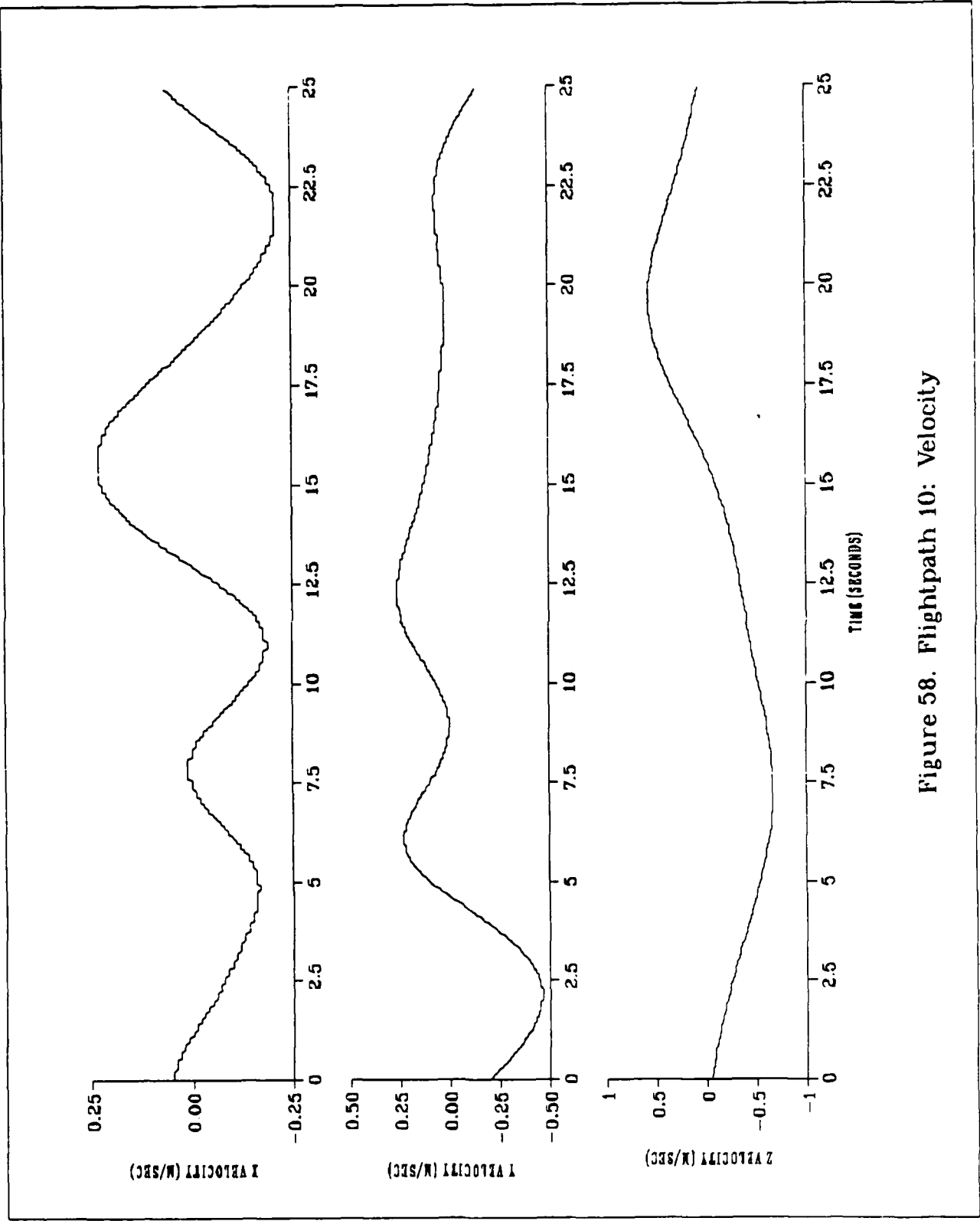


Figure 58. Flightpath 10: Velocity

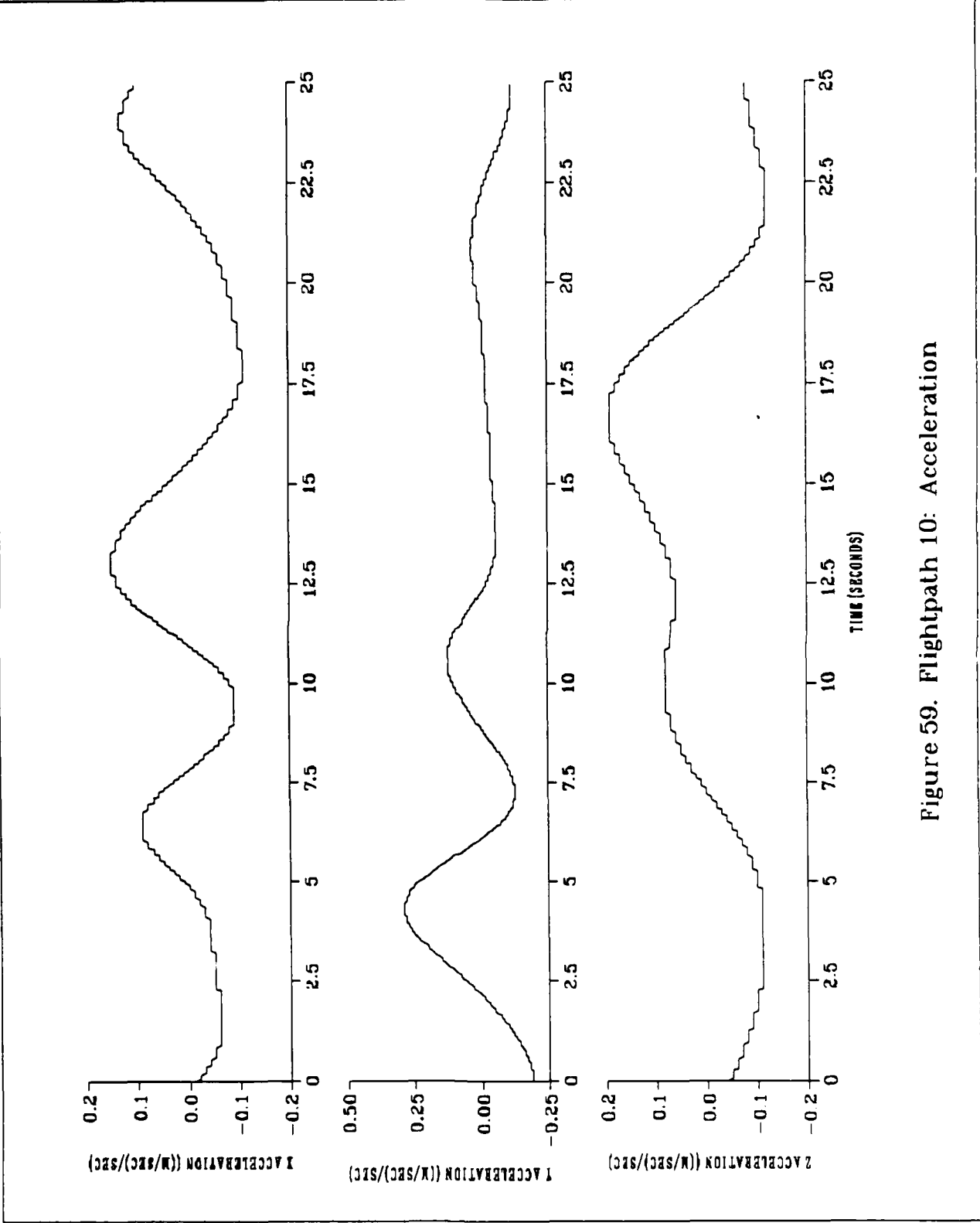


Figure 59. Flightpath 10: Acceleration

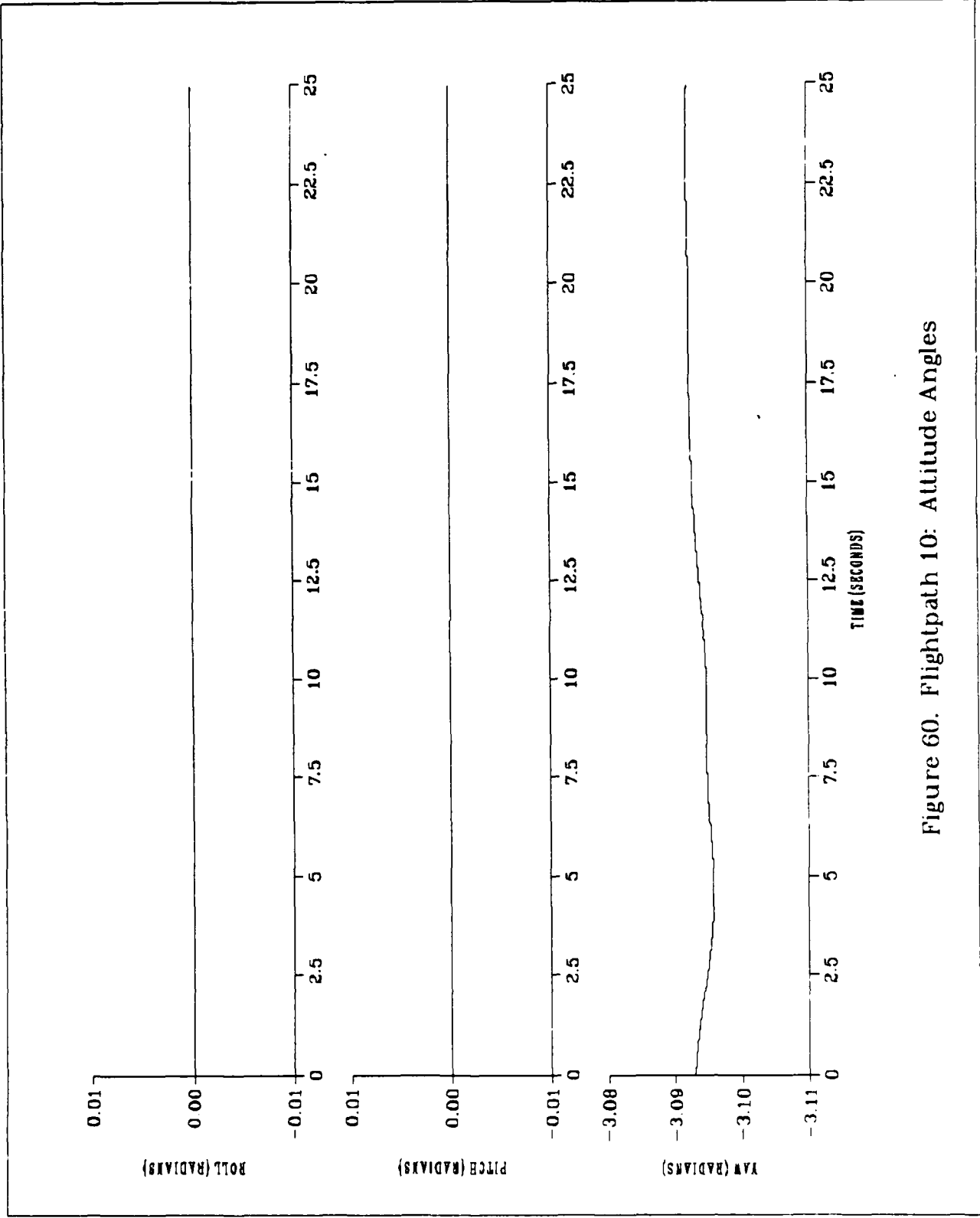


Figure 60. Flightpath 10: Attitude Angles

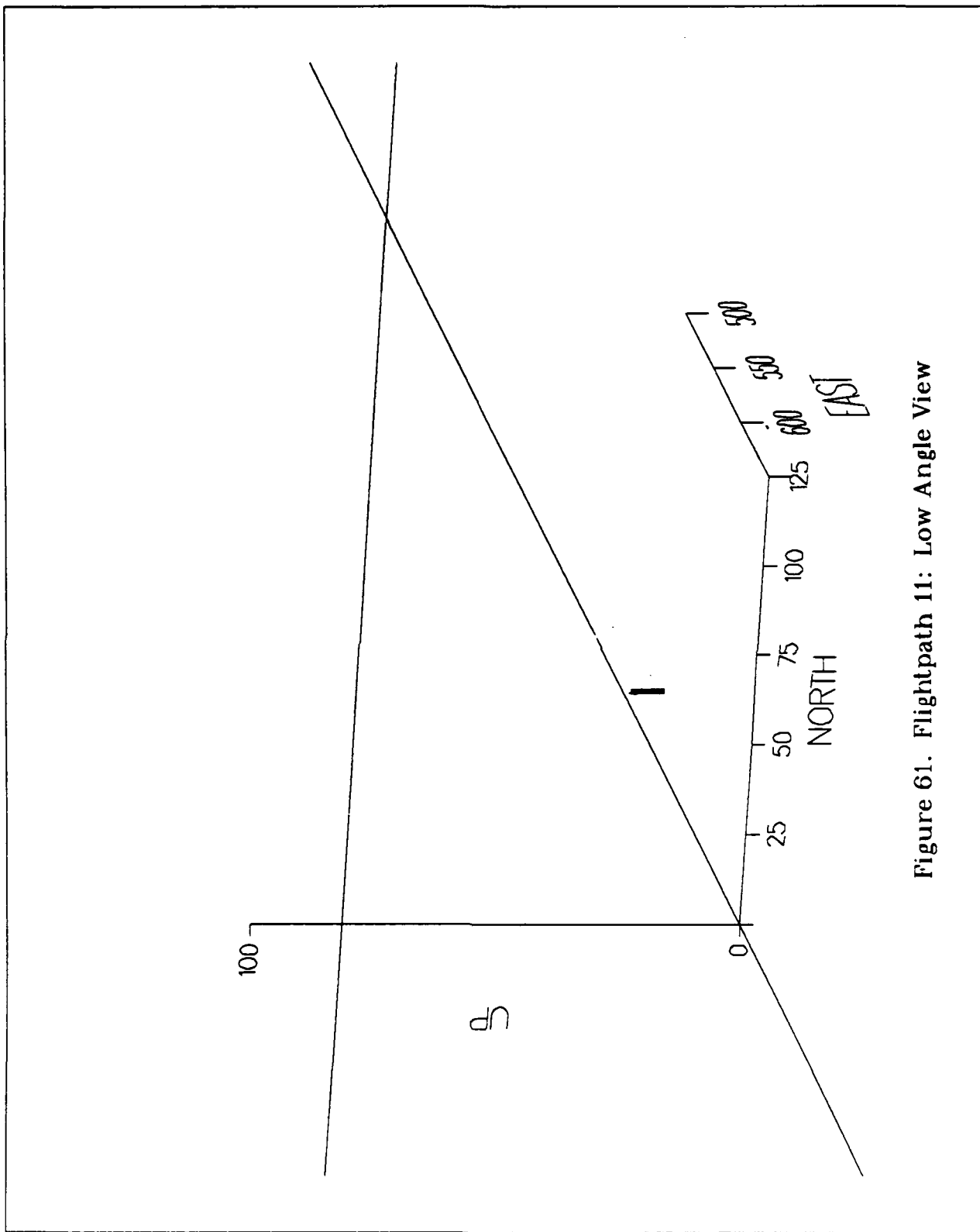


Figure 61. Flightpath 11: Low Angle View

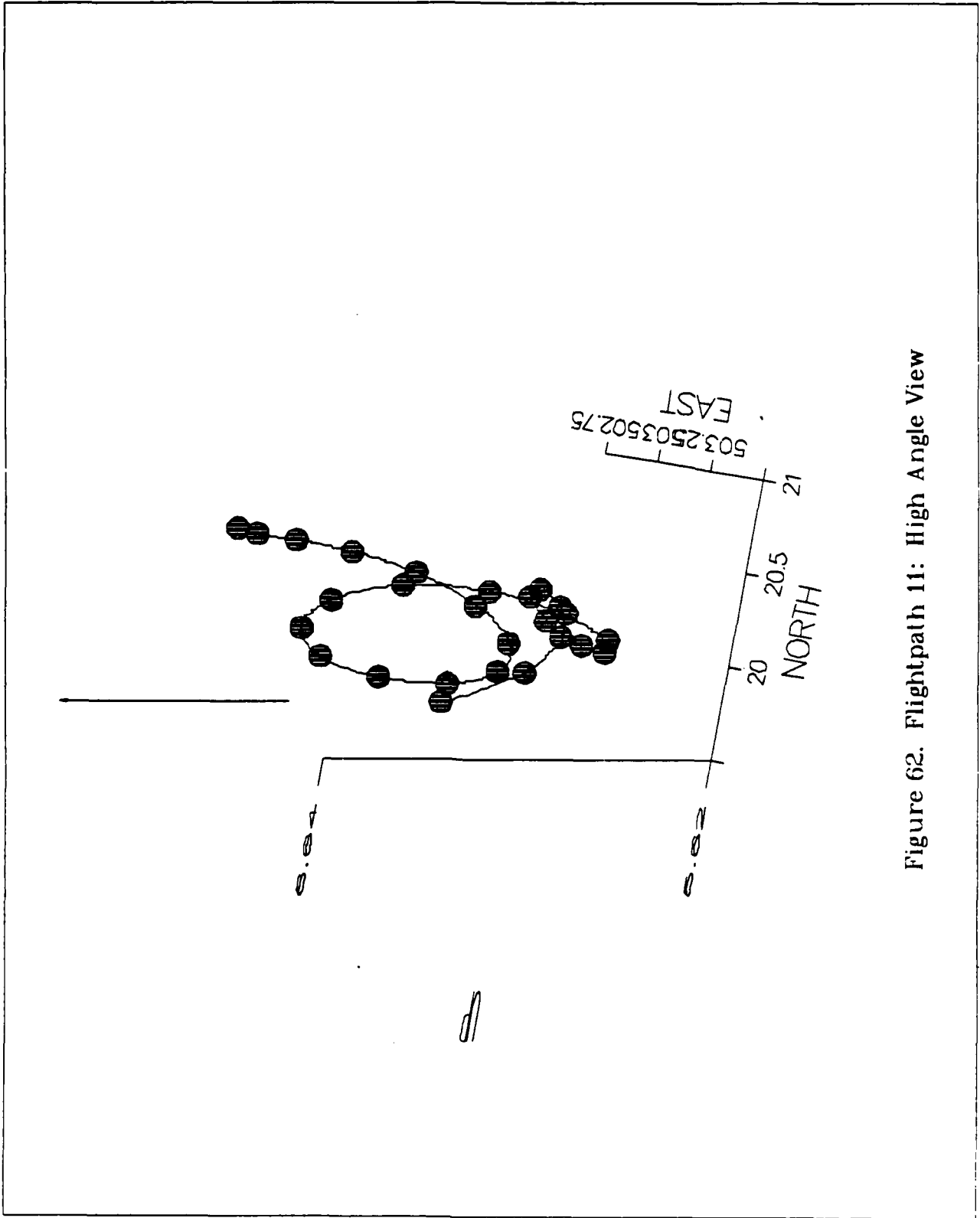


Figure 62. Flightpath 11: High Angle View

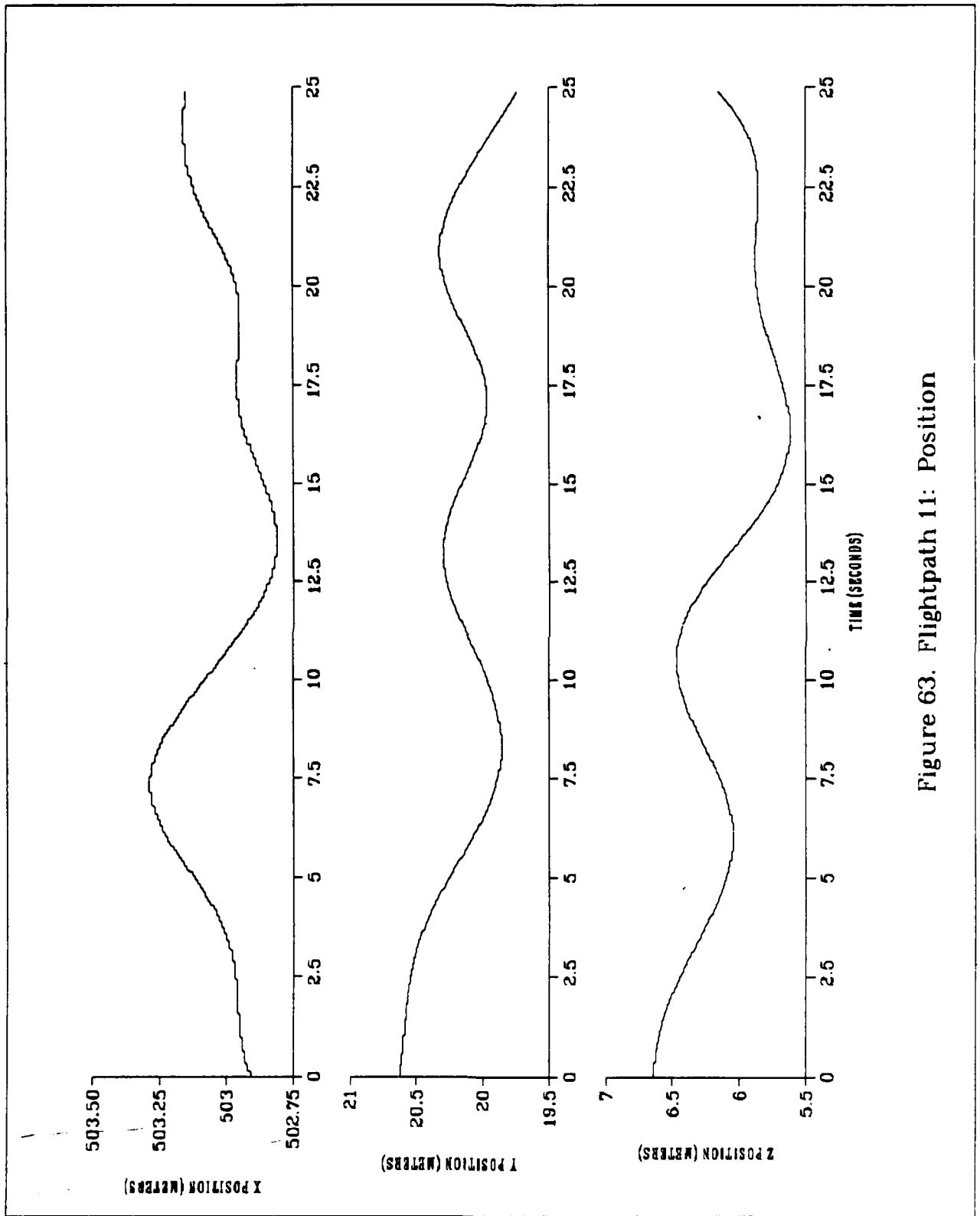


Figure 63. Flightpath 11: Position

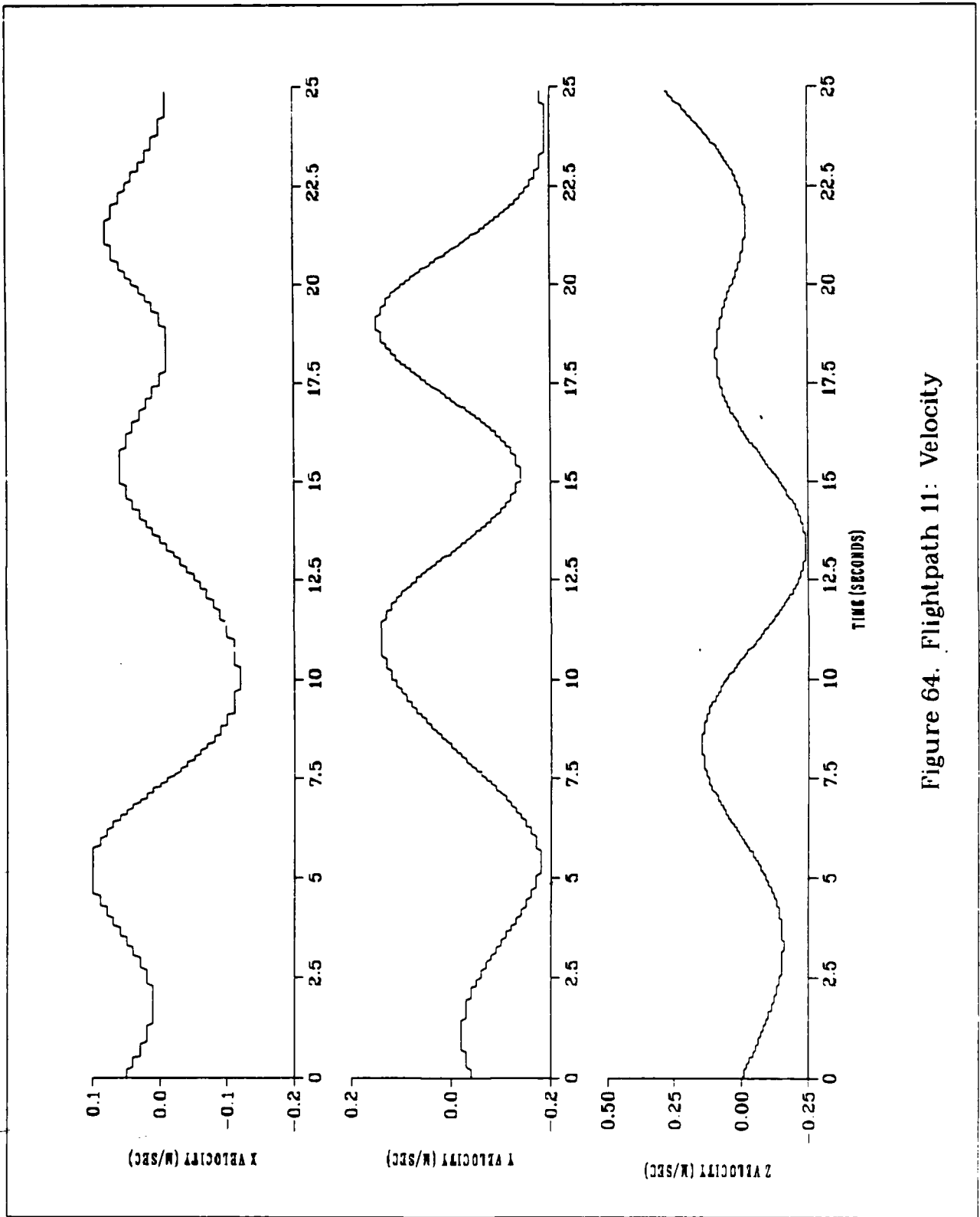


Figure 64. Flightpath 11: Velocity

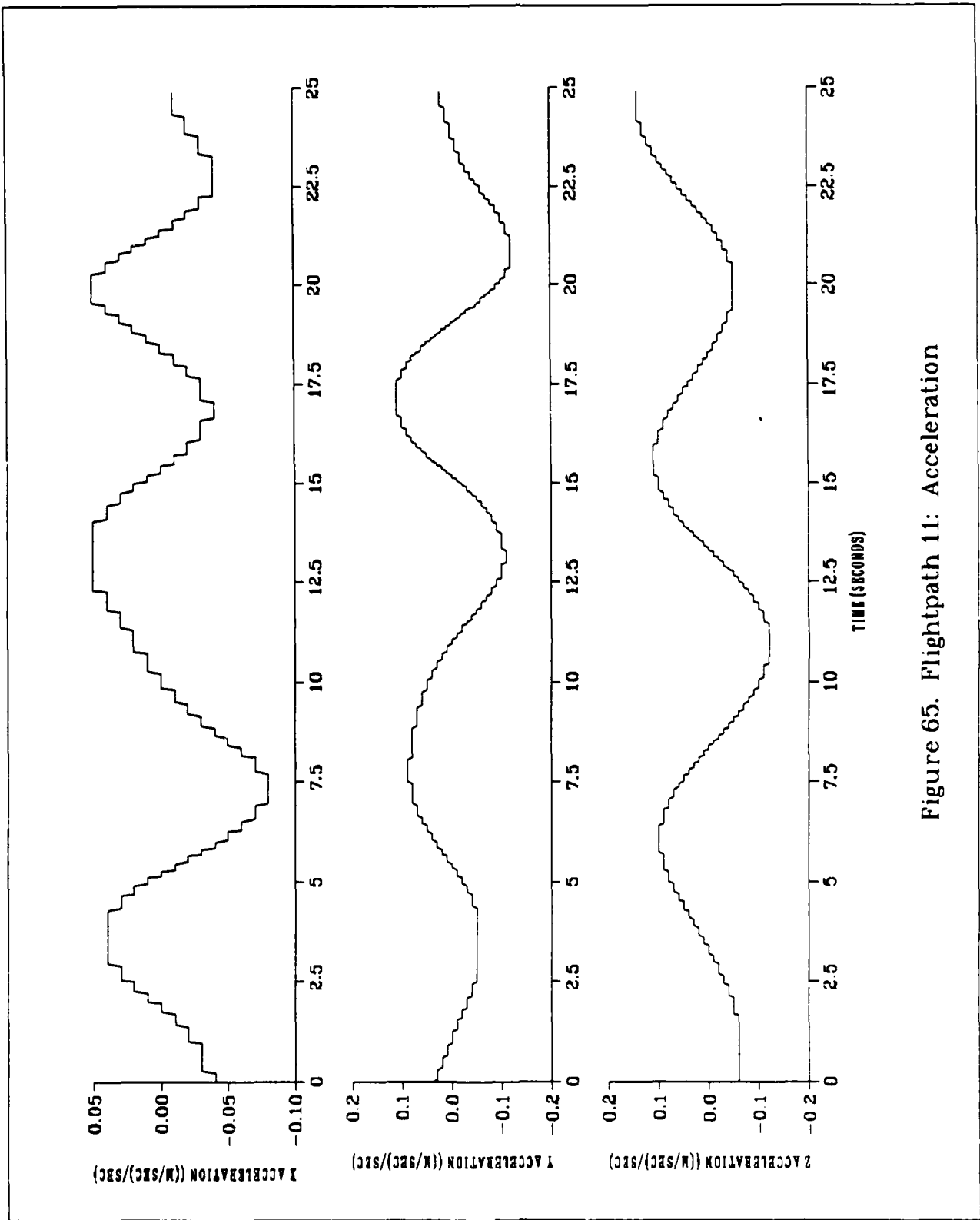


Figure 65. Flightpath 11: Acceleration

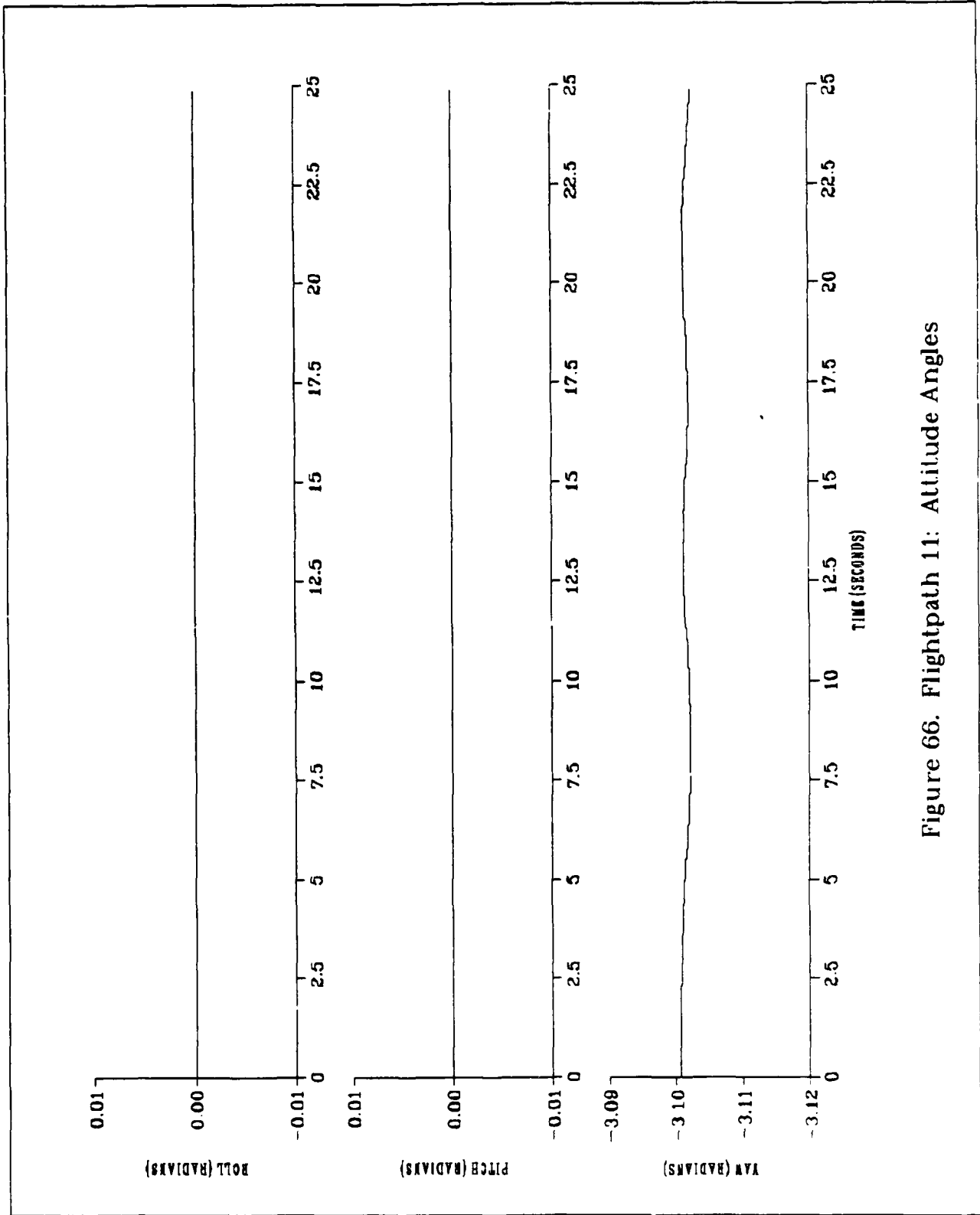


Figure 66. Flightpath 11: Attitude Angles

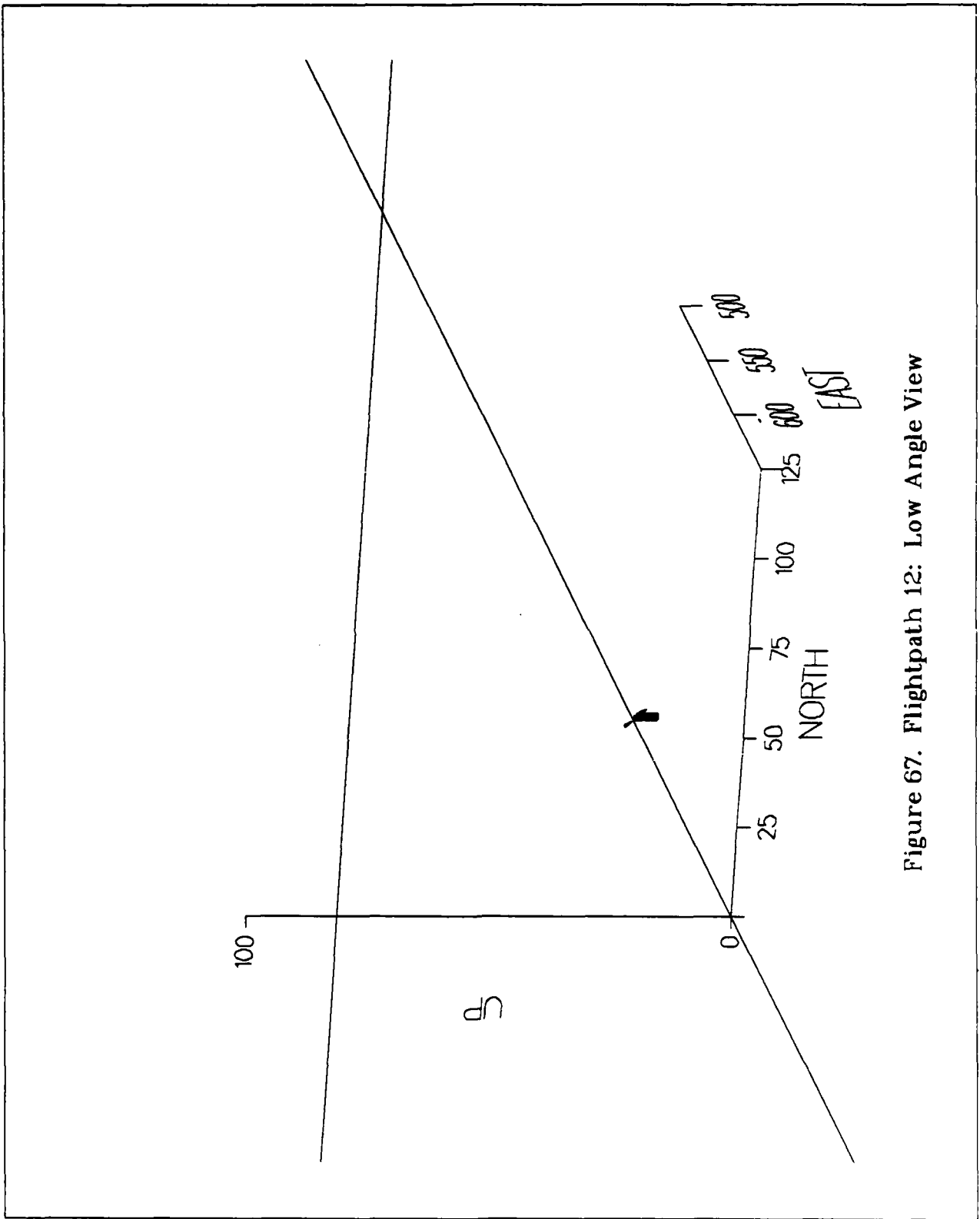


Figure 67. Flightpath 12: Low Angle View

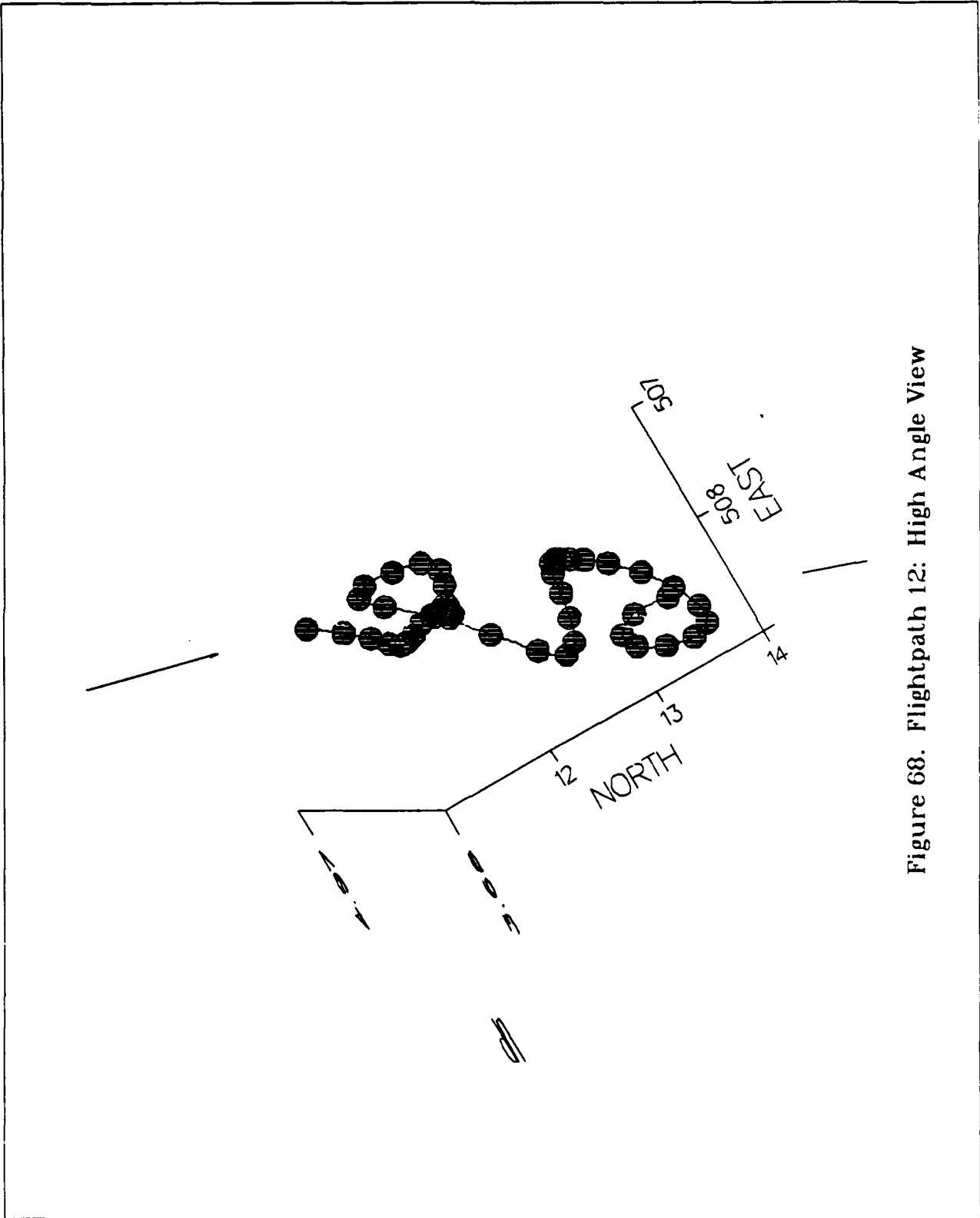


Figure 68. Flightpath 12: High Angle View

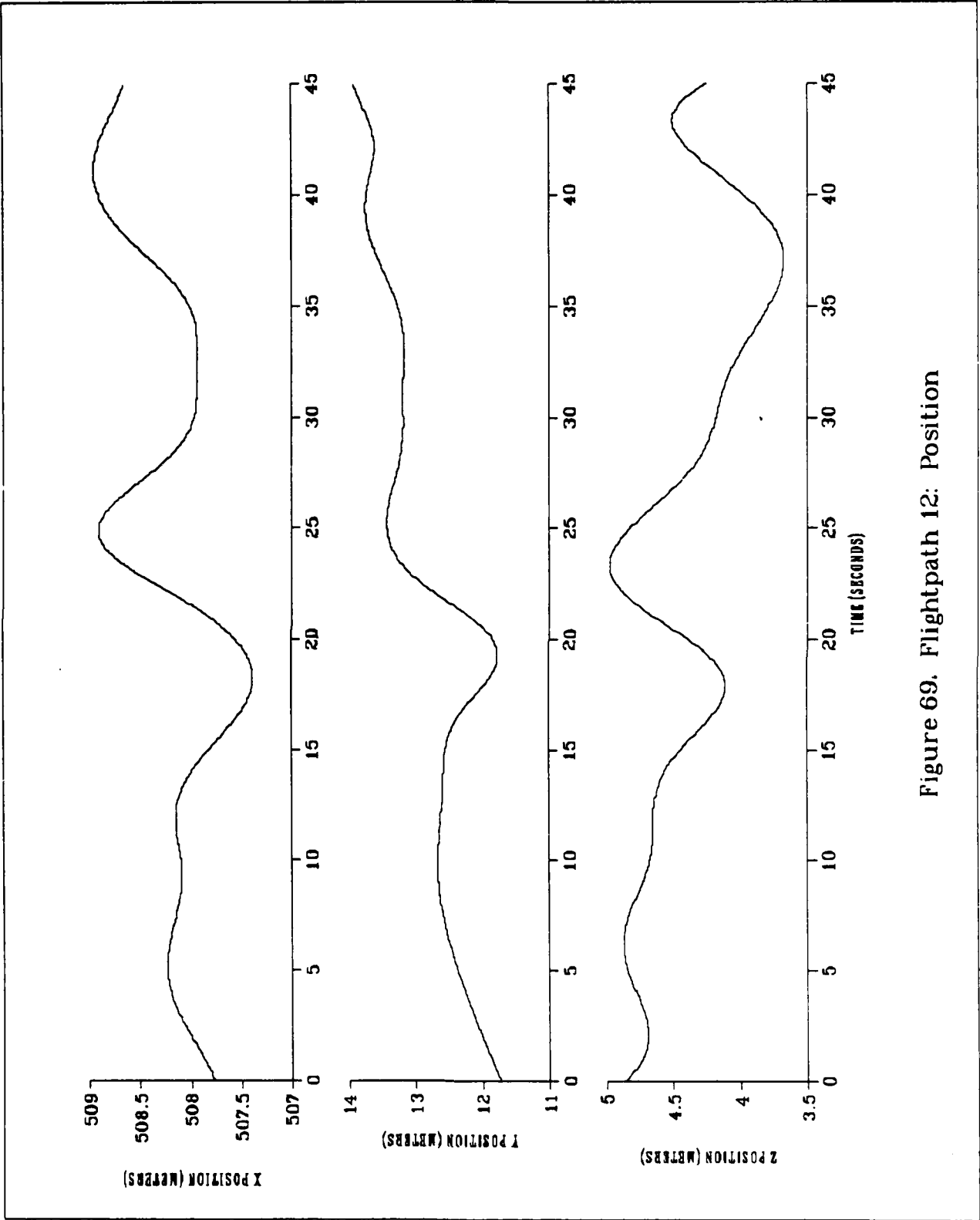


Figure 69. Flightpath 12: Position

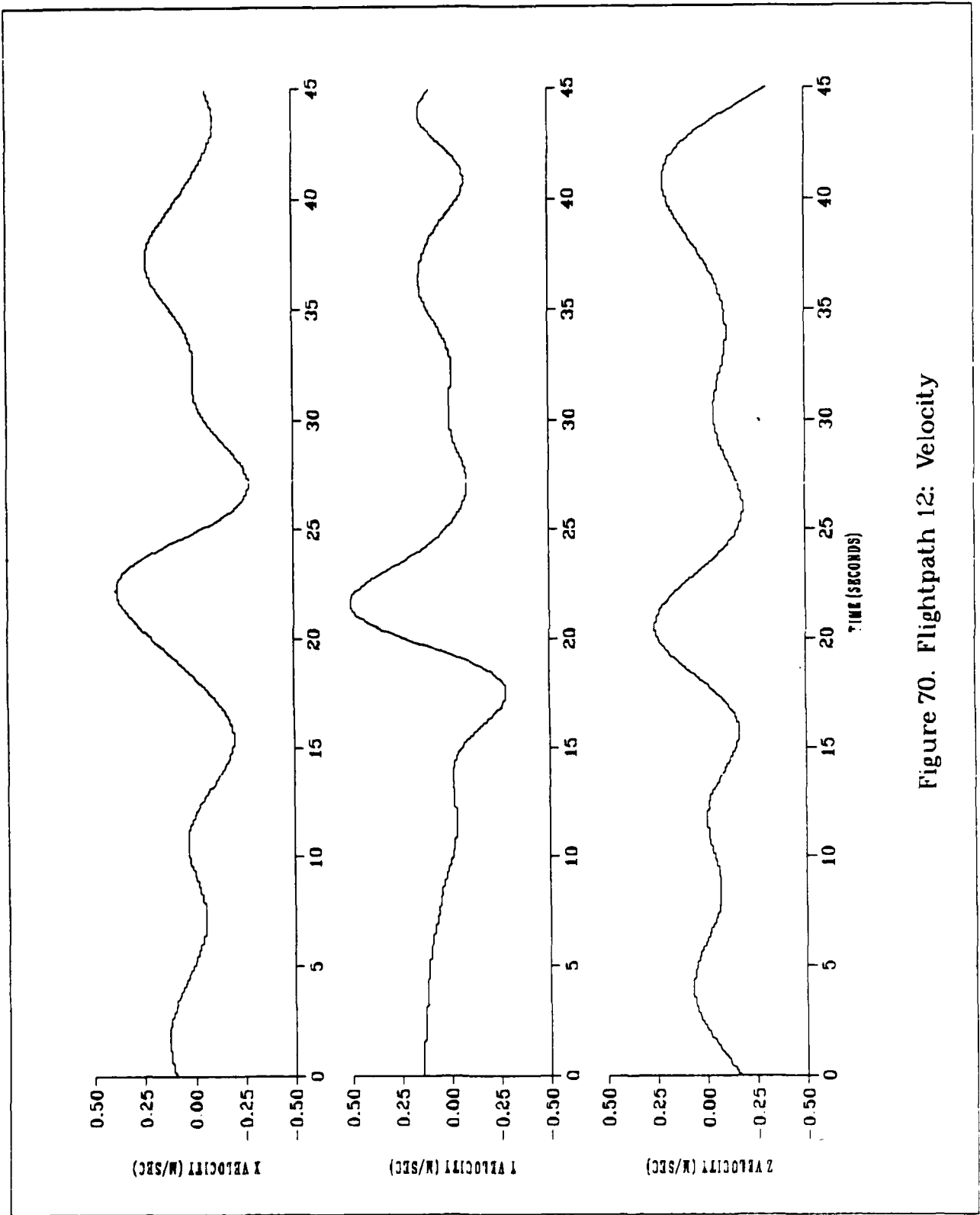


Figure 70. Flightpath 12: Velocity

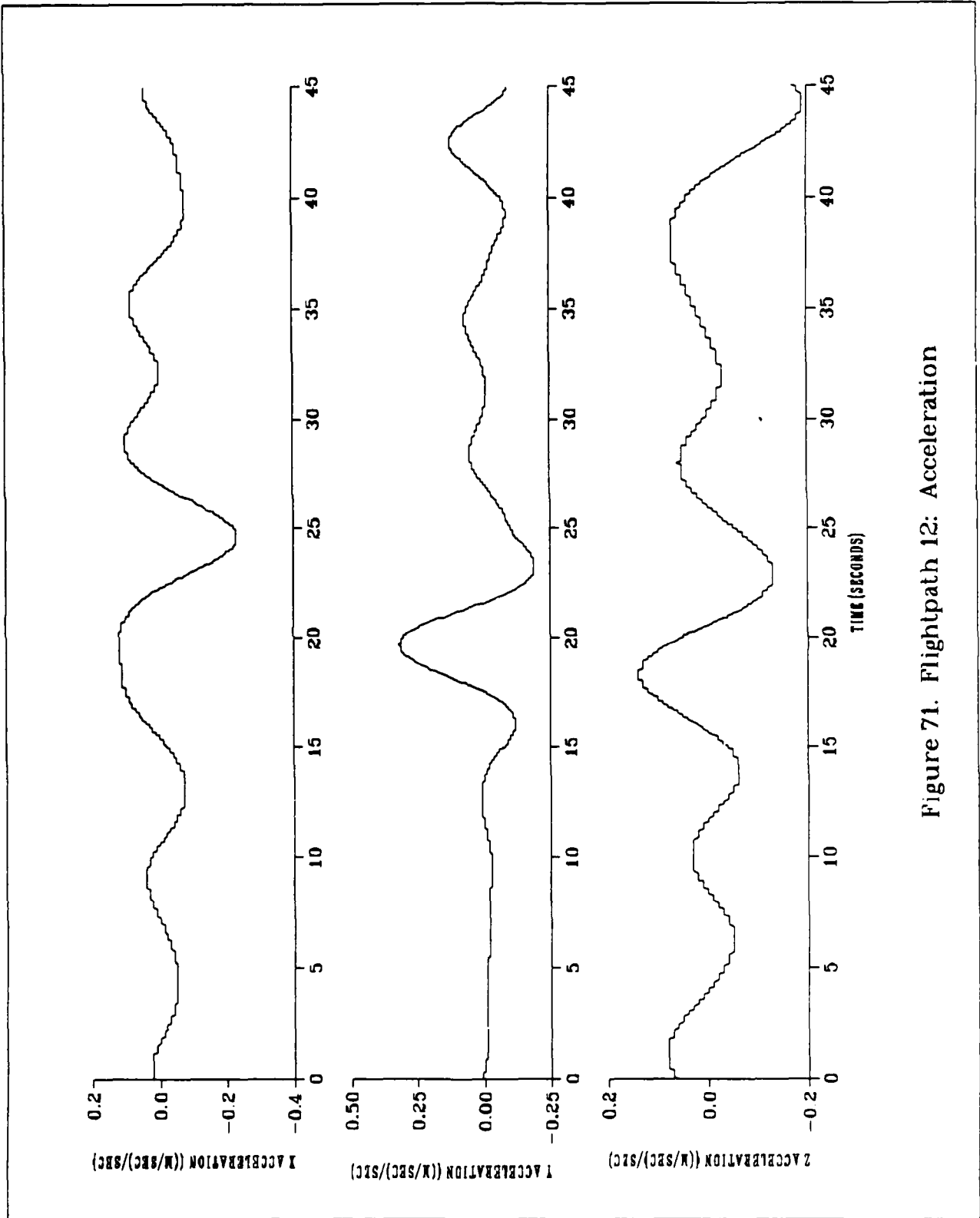


Figure 71. Flightpath 12: Acceleration

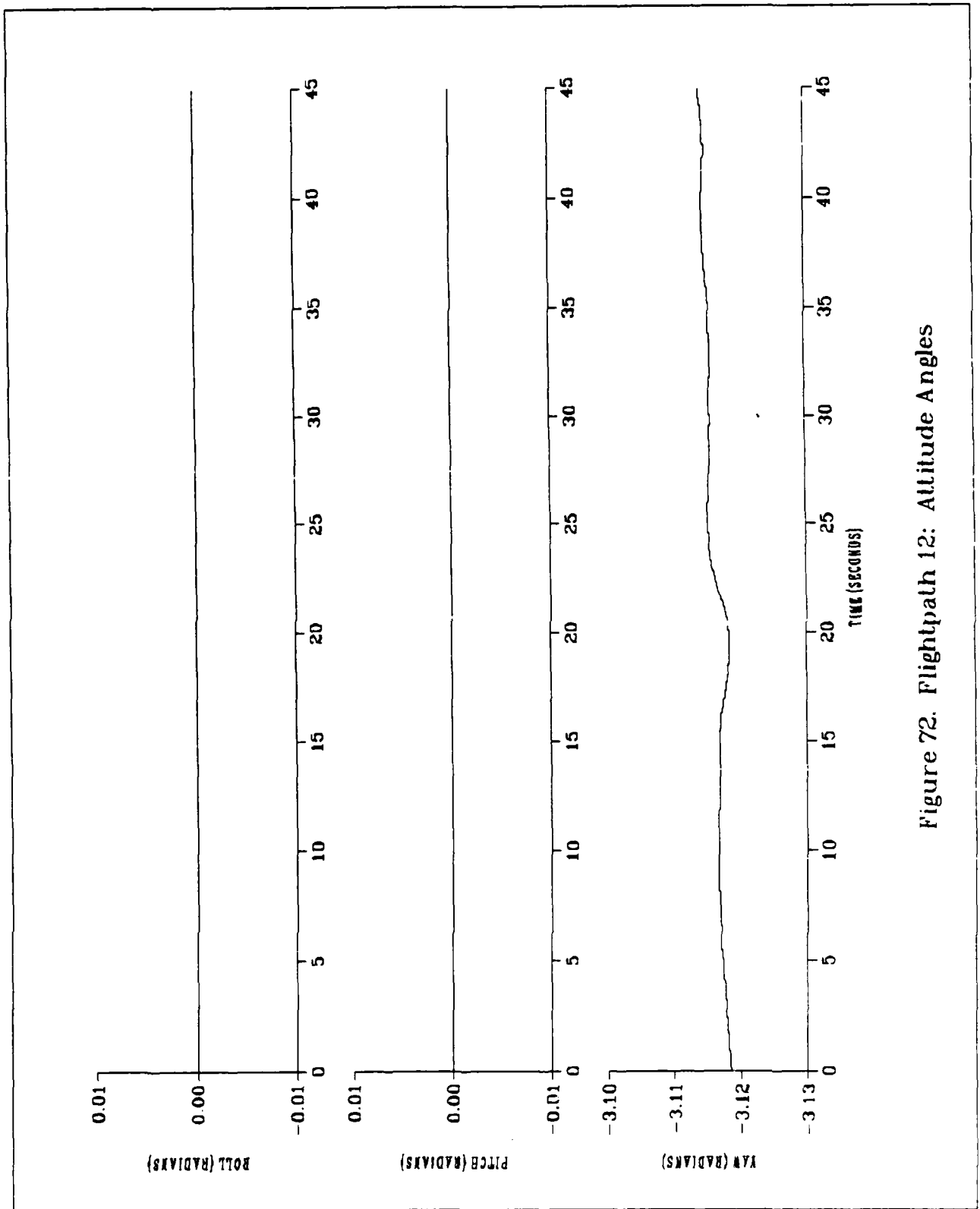


Figure 72. Flightpath 12: Attitude Angles

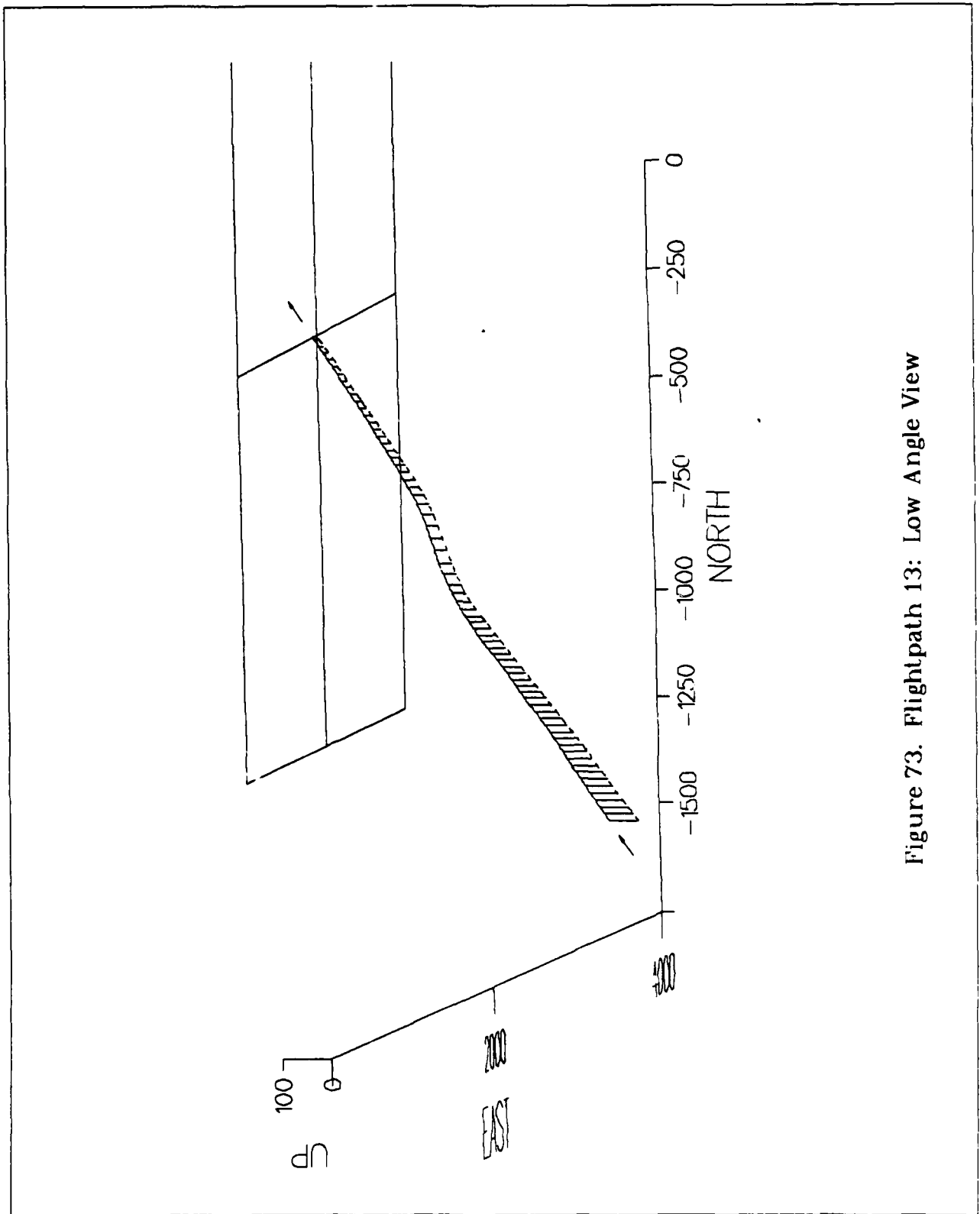


Figure 73. Flightpath 13: Low Angle View

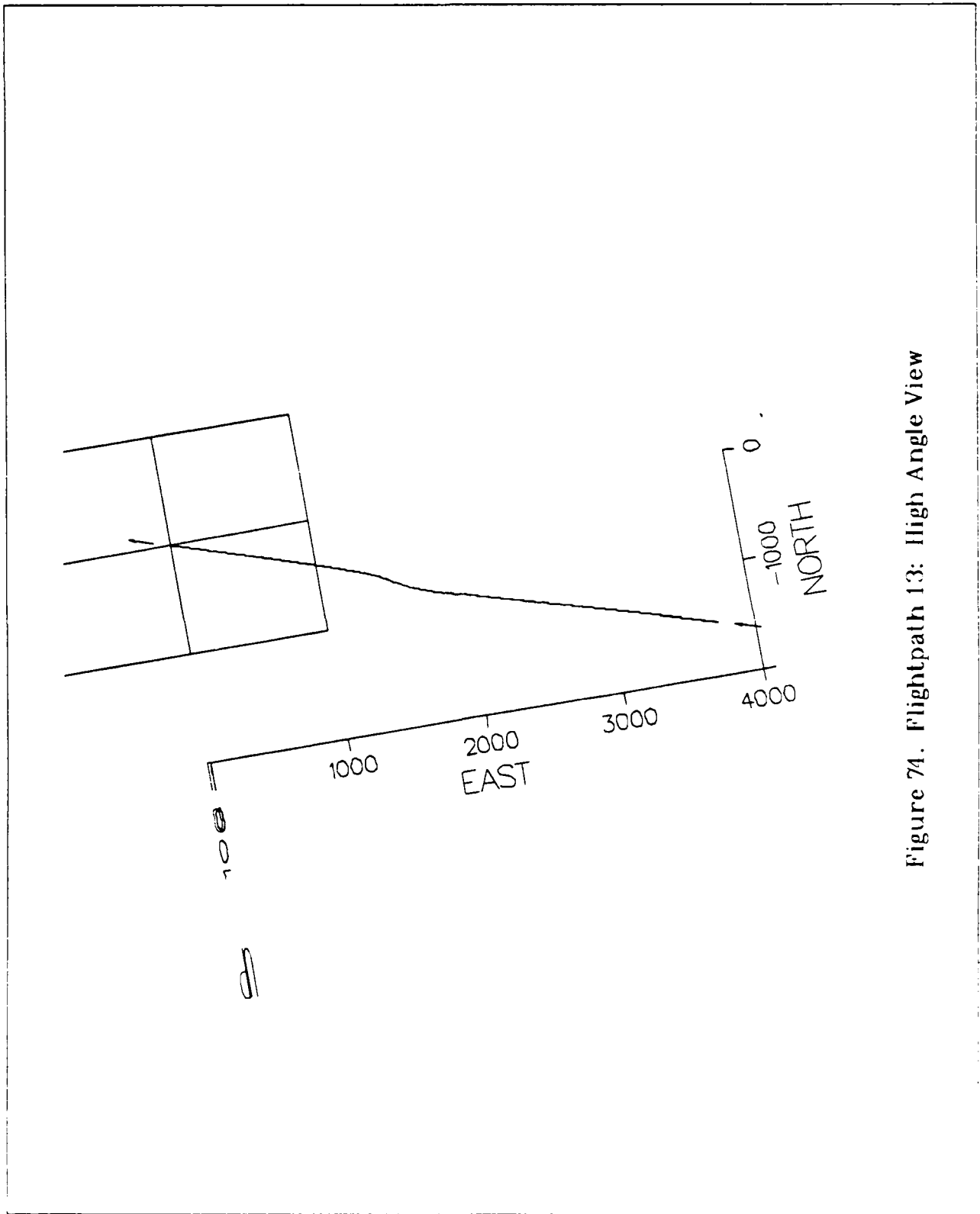


Figure 74. Flightpath 13: High Angle View

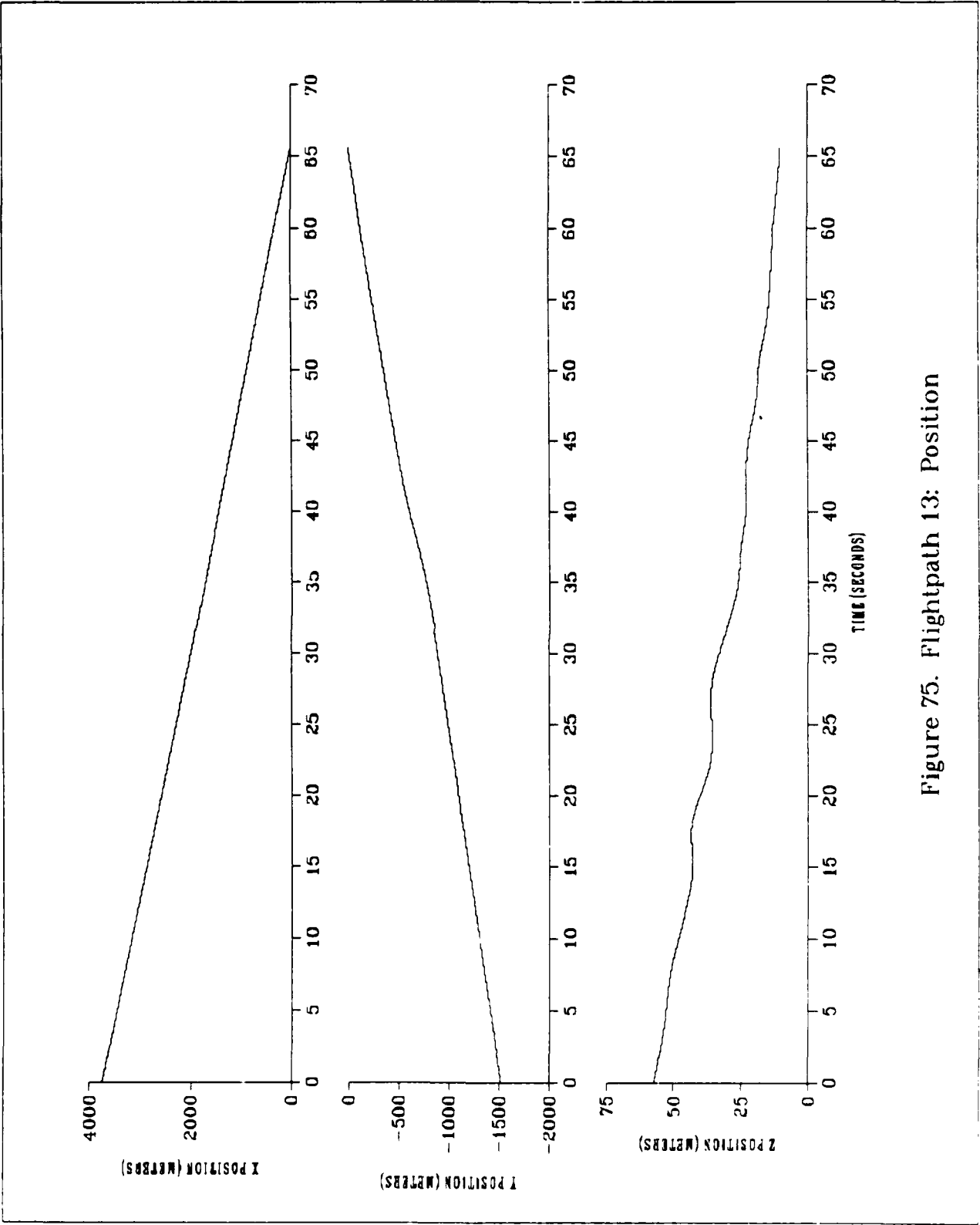


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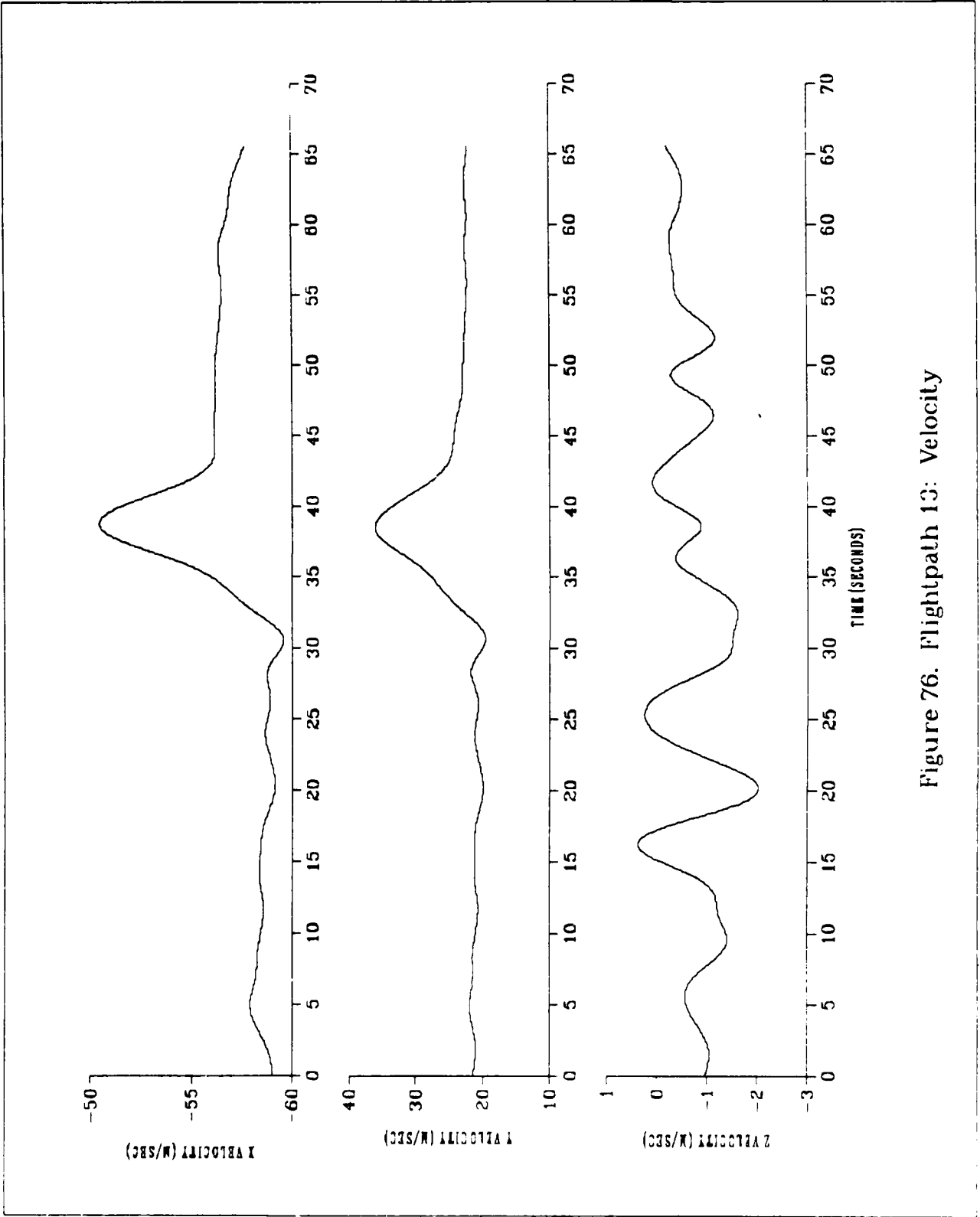


Figure 76. Flightpath 13: Velocity

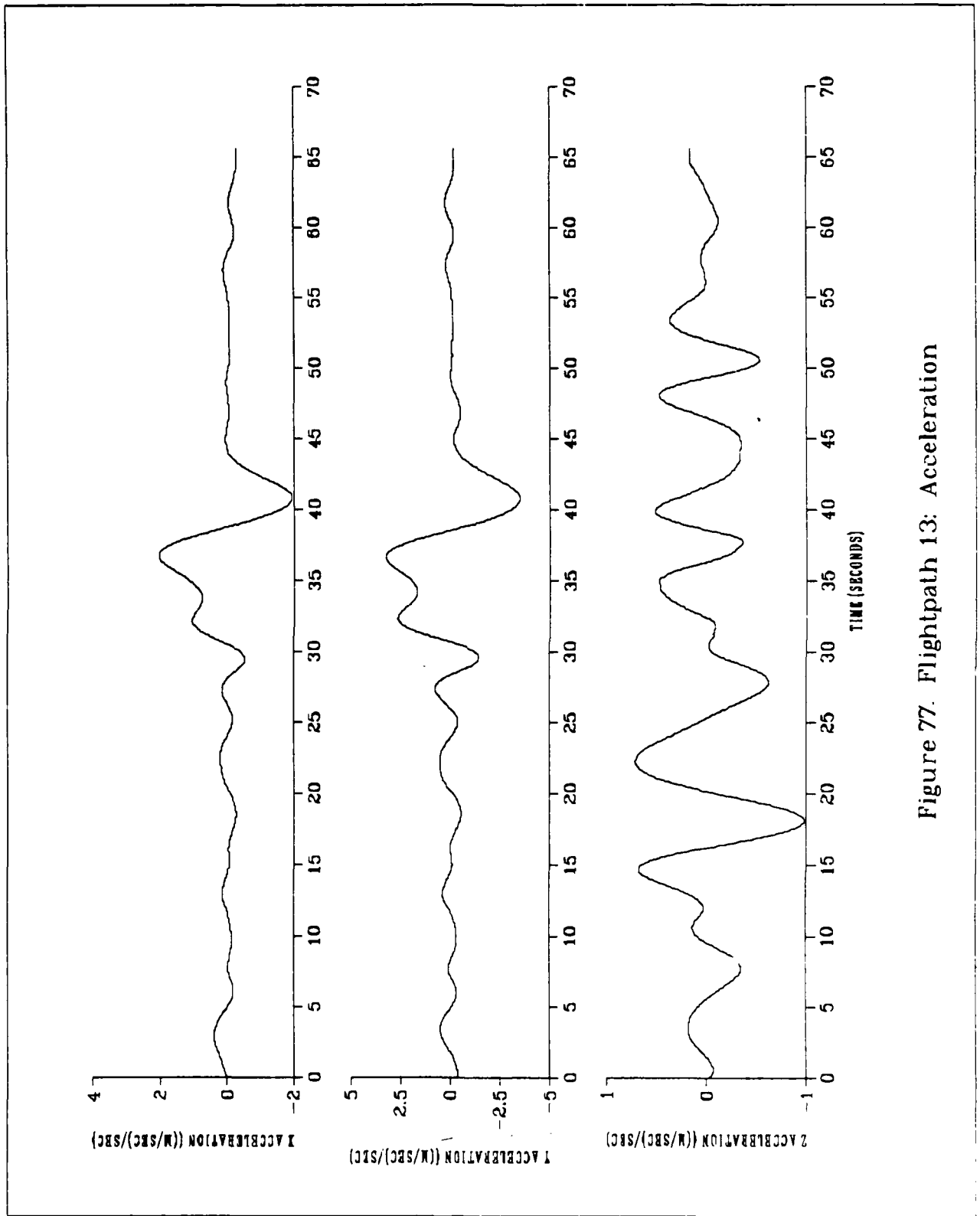


Figure 77. Flightpath 13: Acceleration

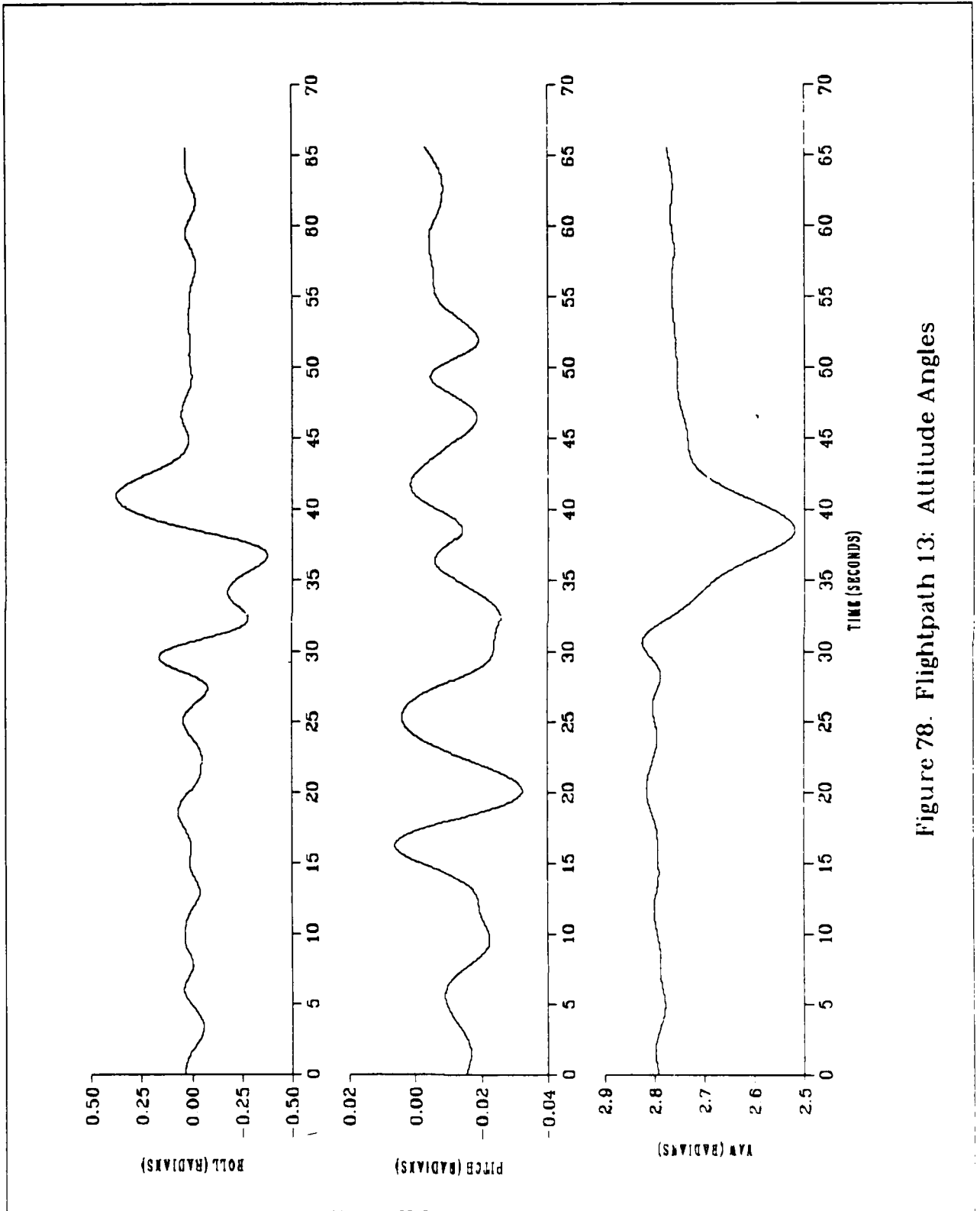


Figure 78. Flightpath 13: Attitude Angles

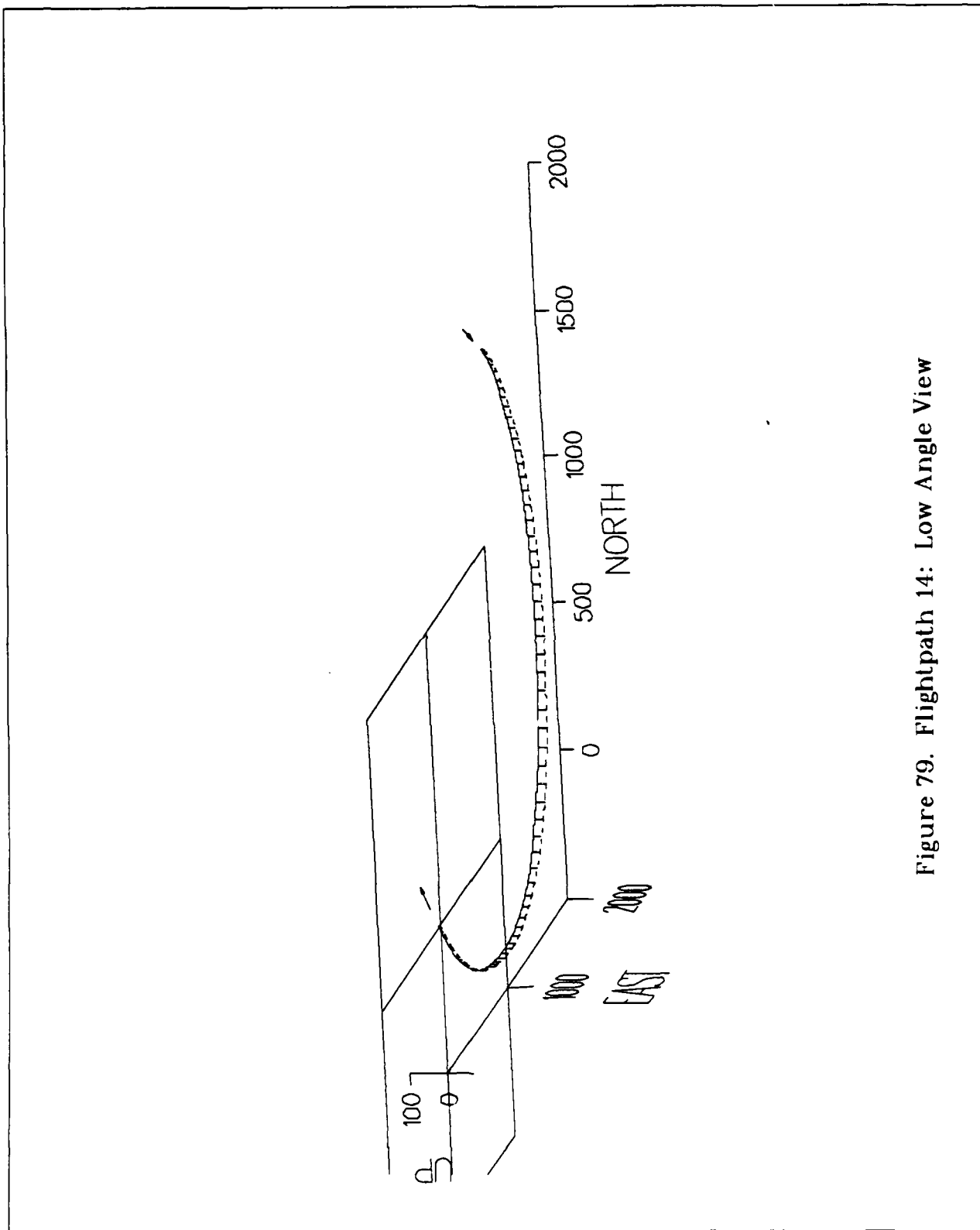


Figure 79. Flightpath 14: Low Angle View

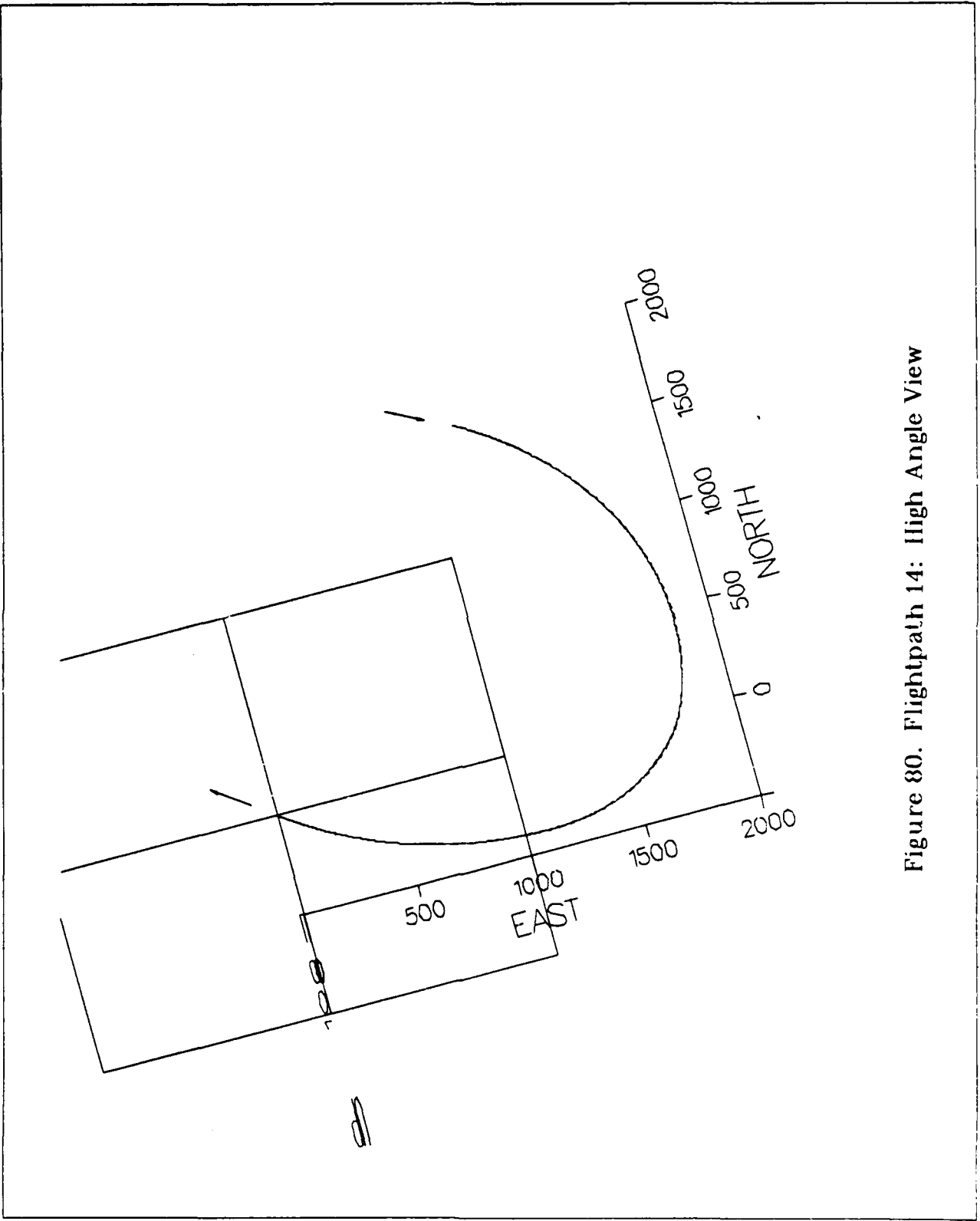


Figure 80. Flightpath 14: High Angle View

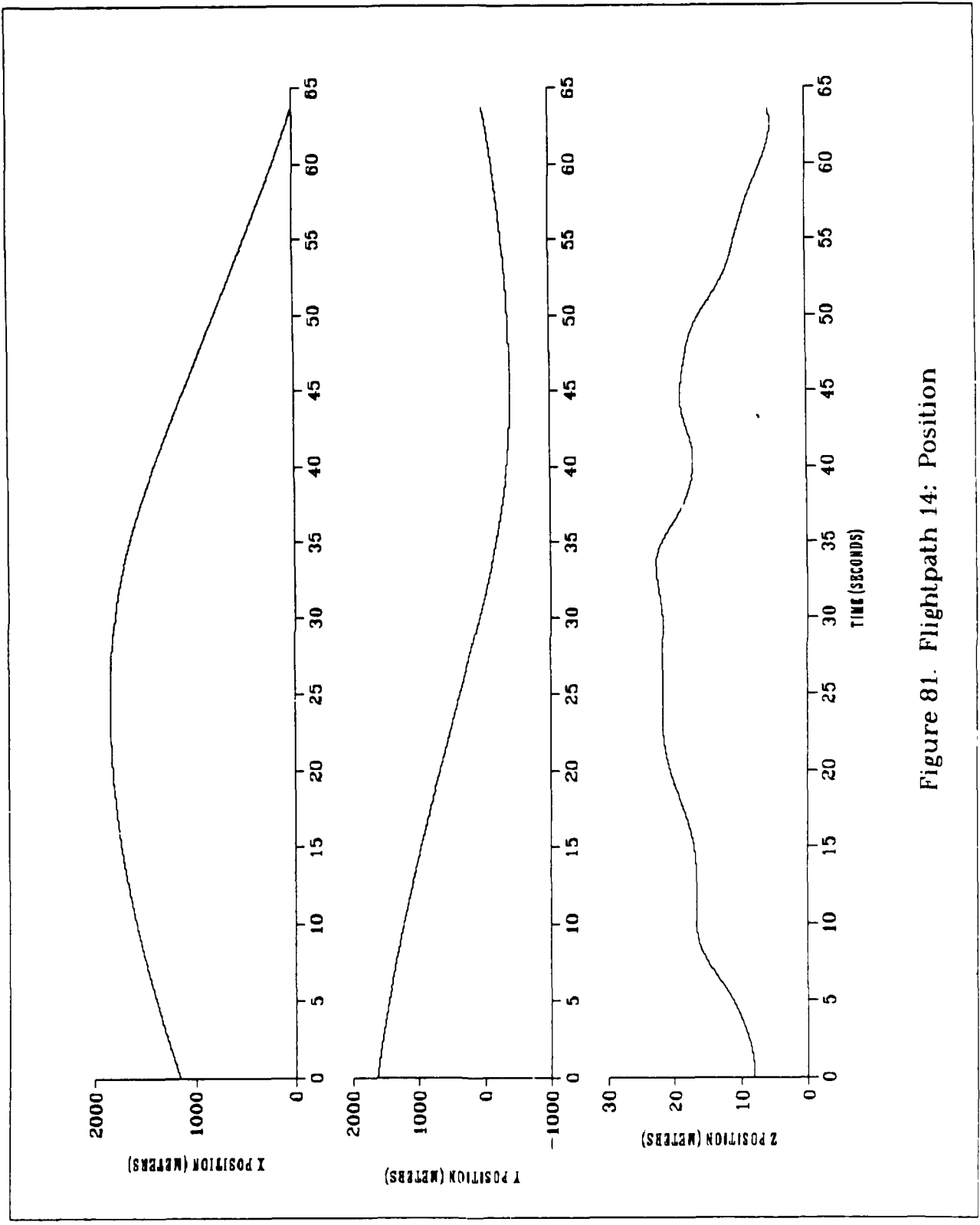


Figure 81. Flightpath 14: Position

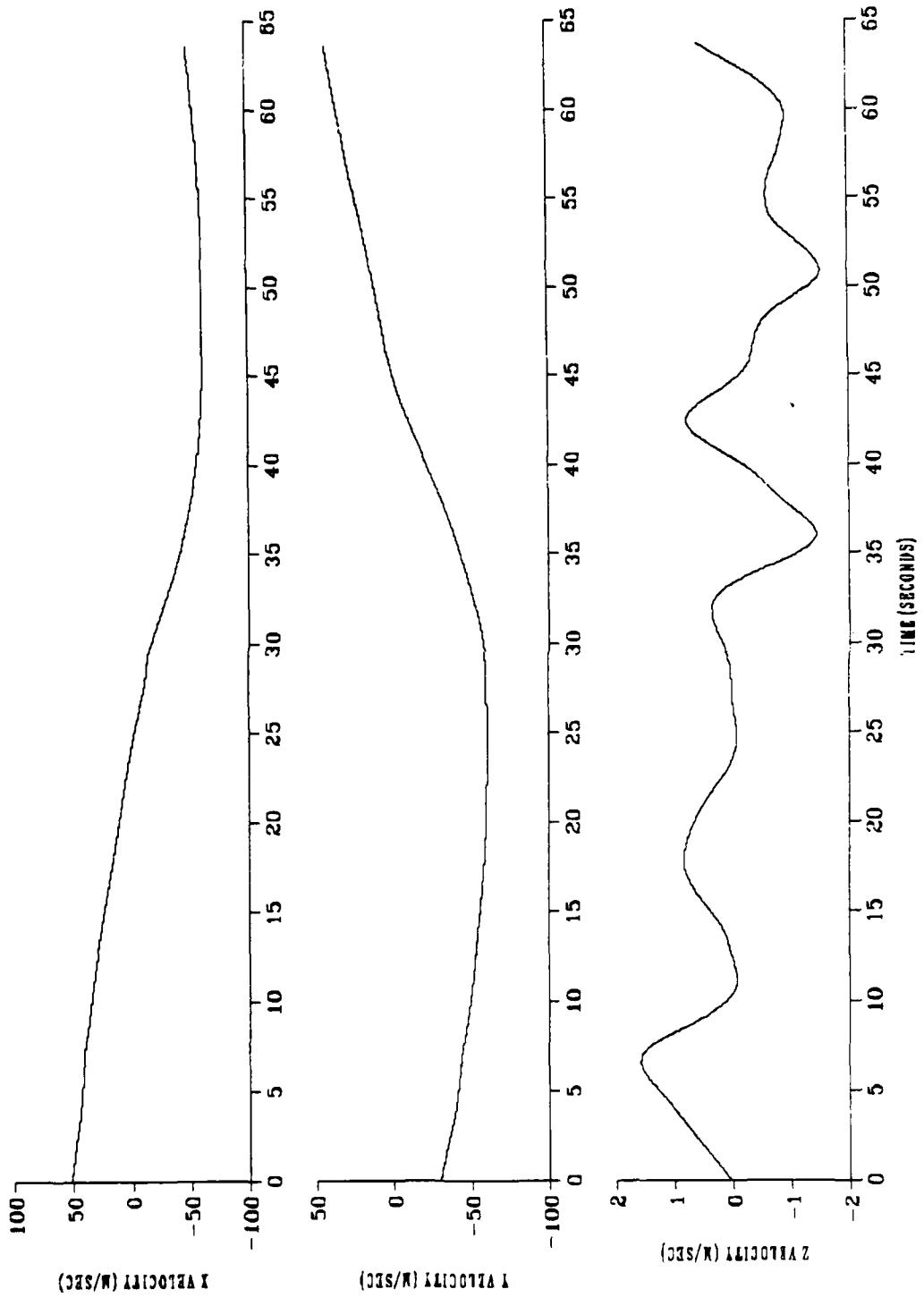


Figure 82. Flightpath 14: Velocity

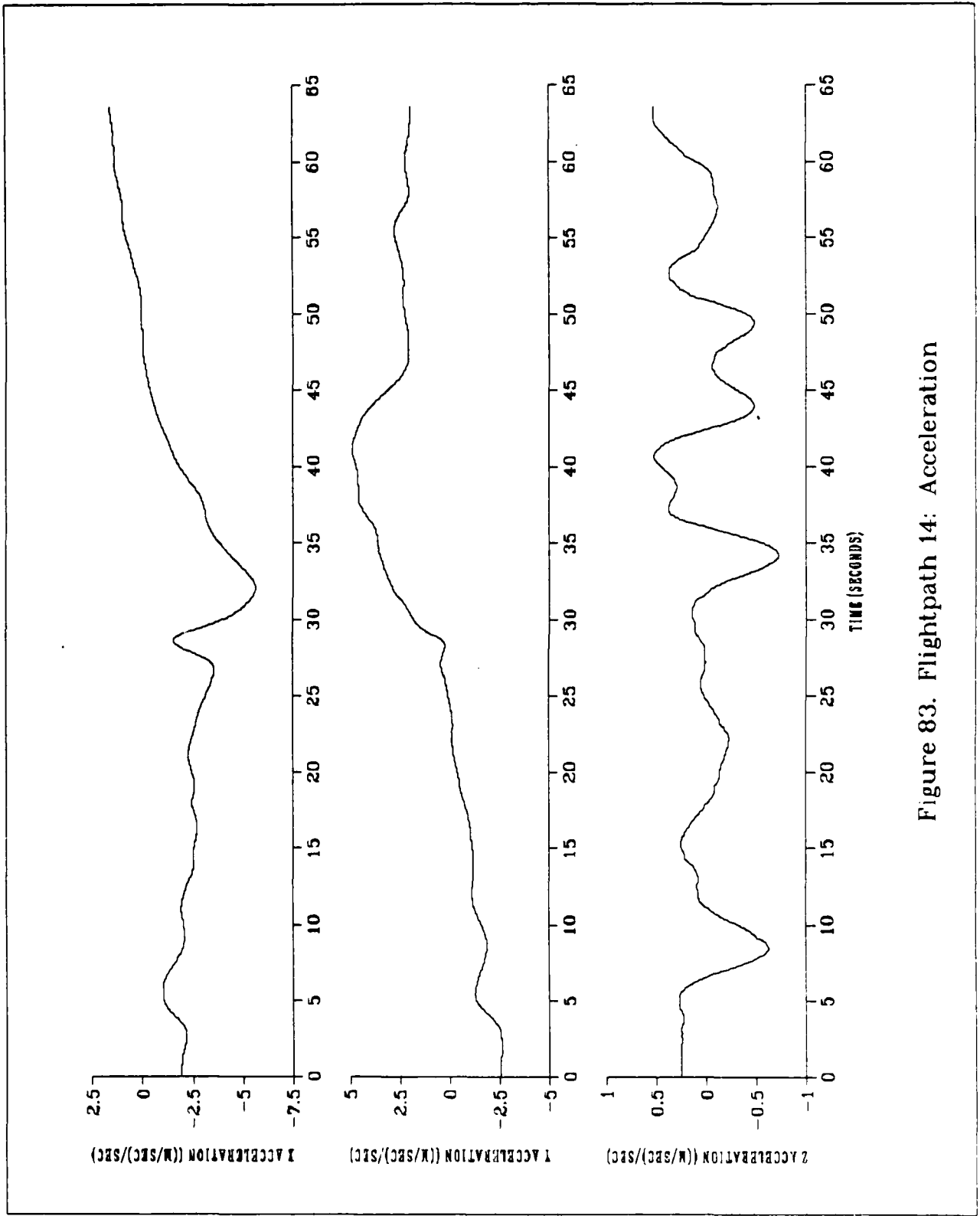


Figure 83. Flightpath 14: Acceleration

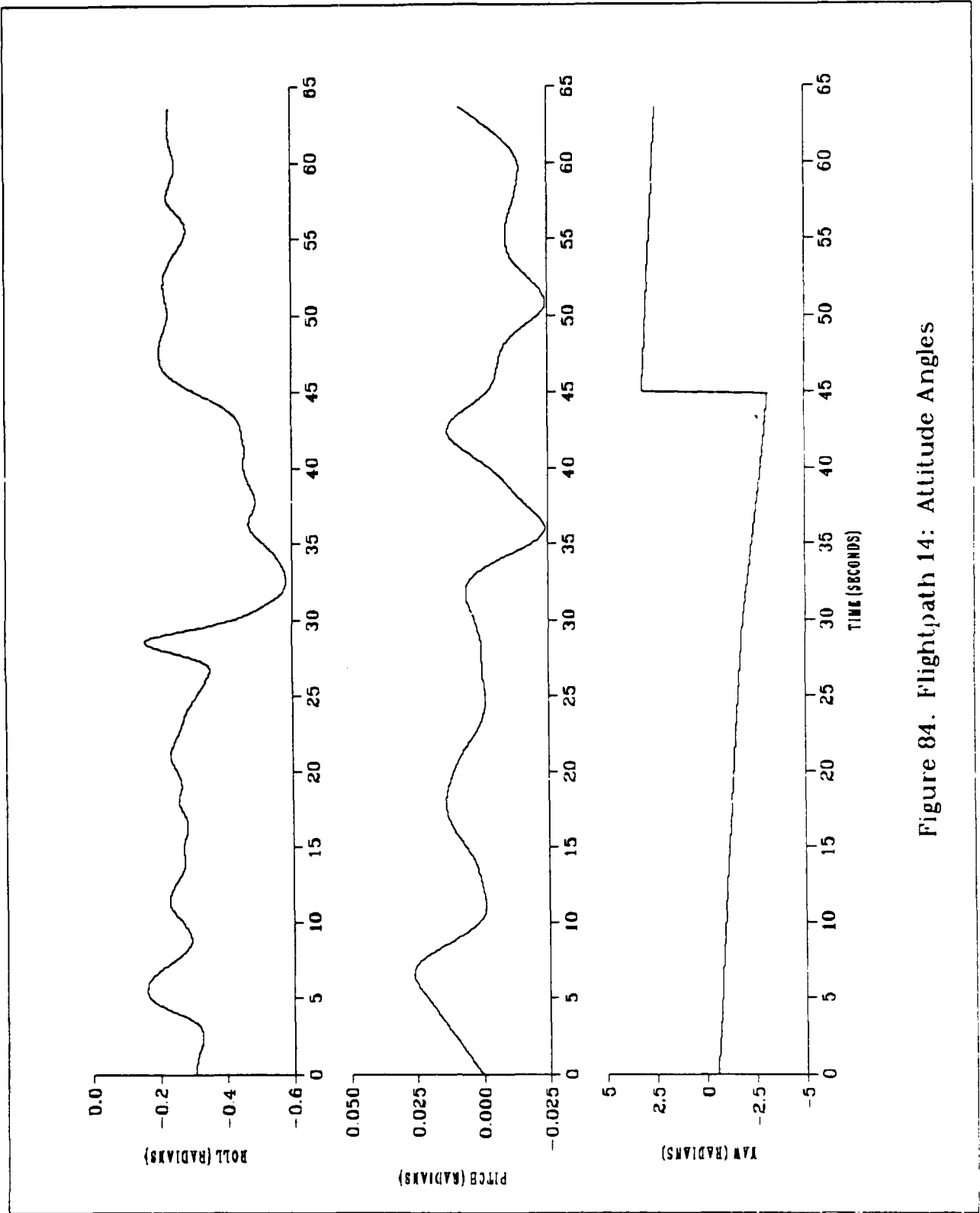


Figure 84. Flightpath 14: Attitude Angles

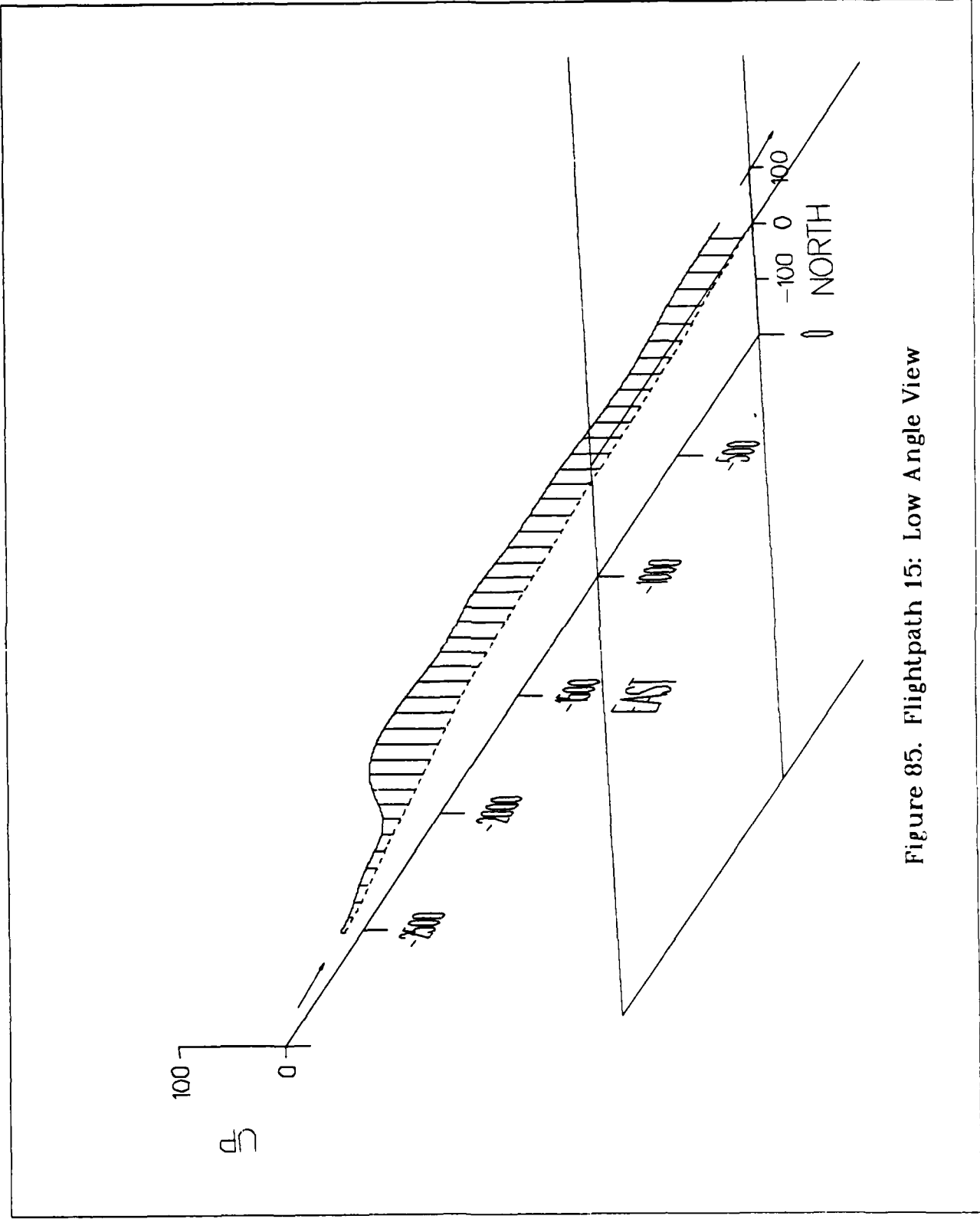


Figure 85. Flightpath 15: Low Angle View

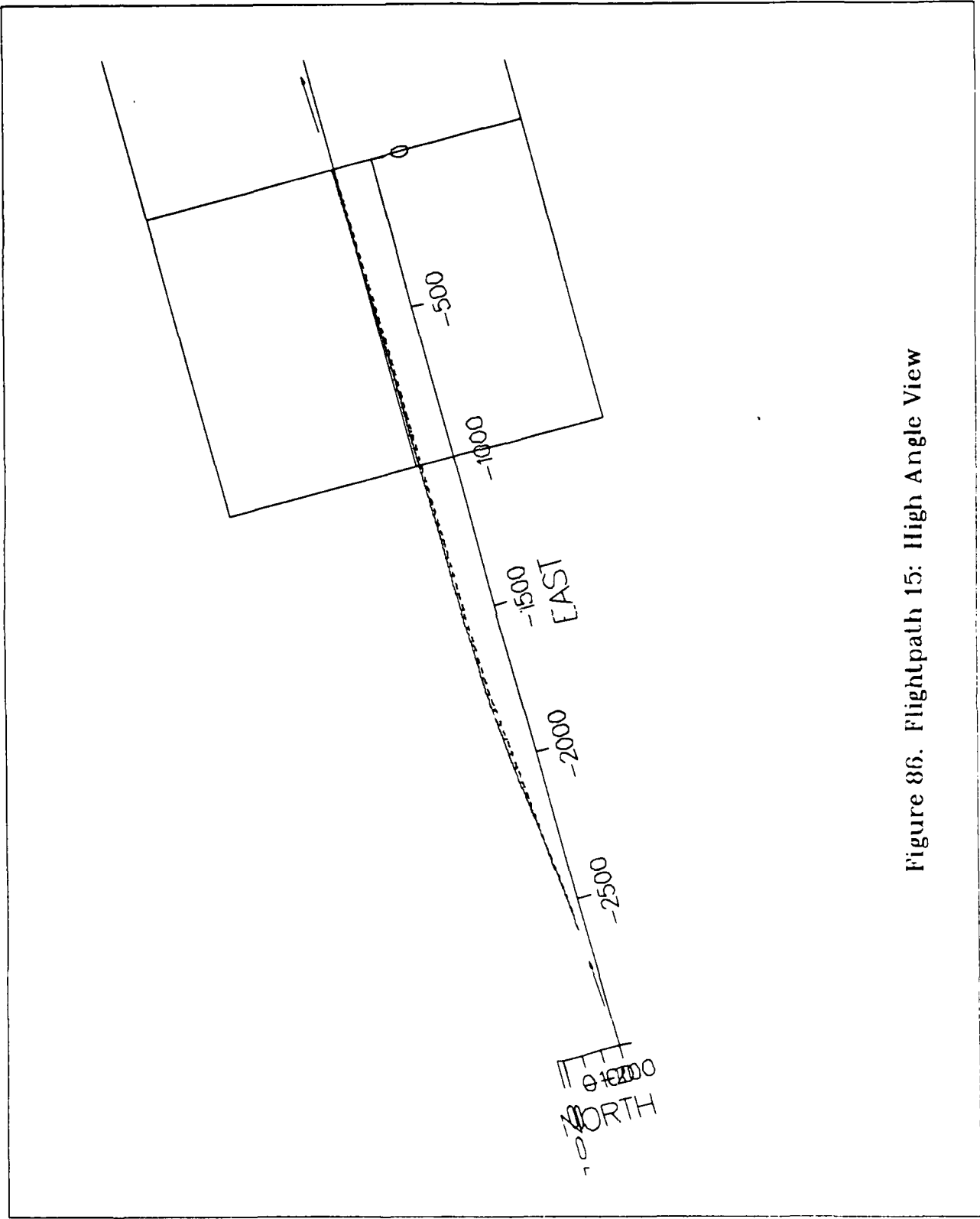


Figure 86. Flightpath 15: High Angle View

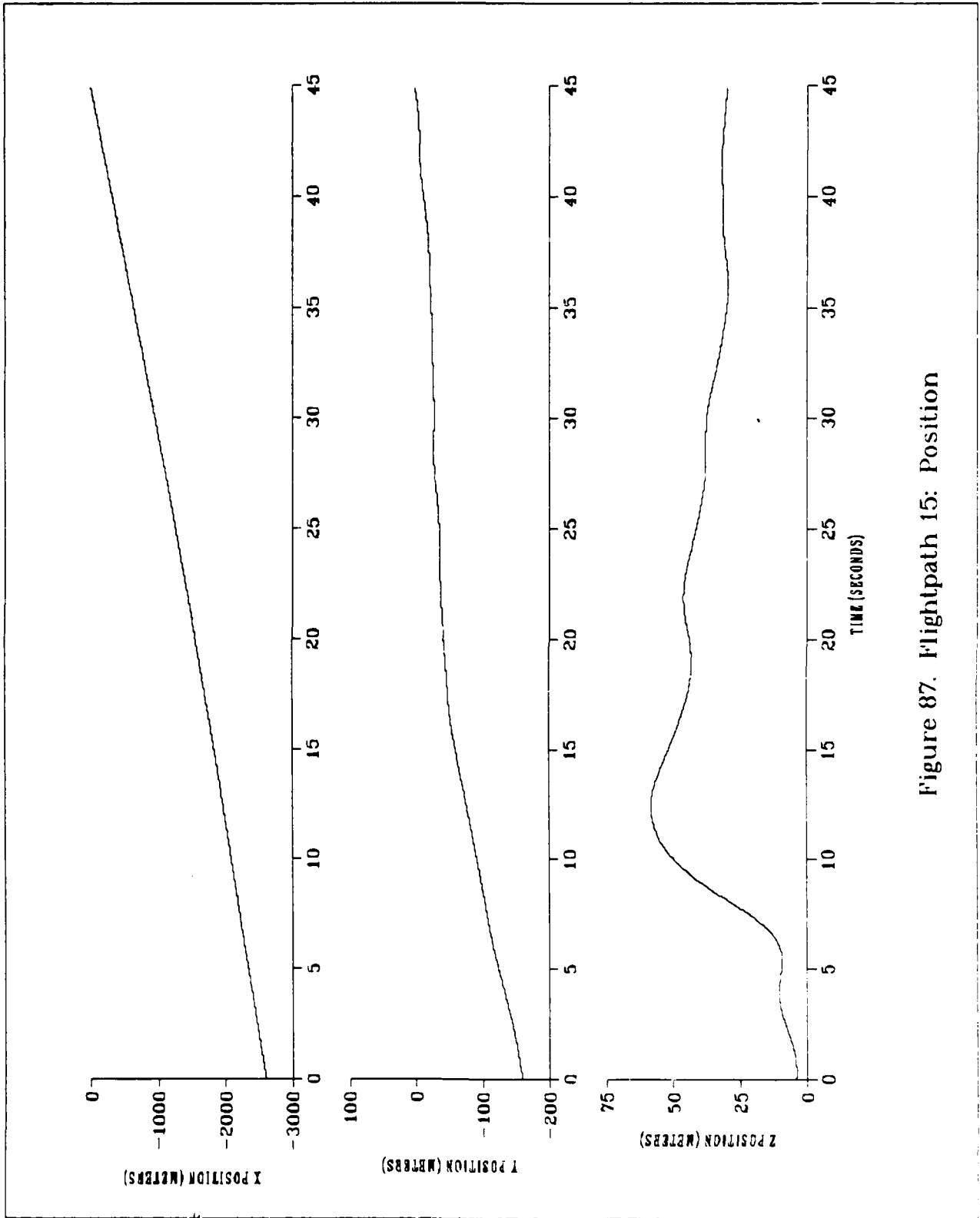


Figure 87. Flightpath 15: Position

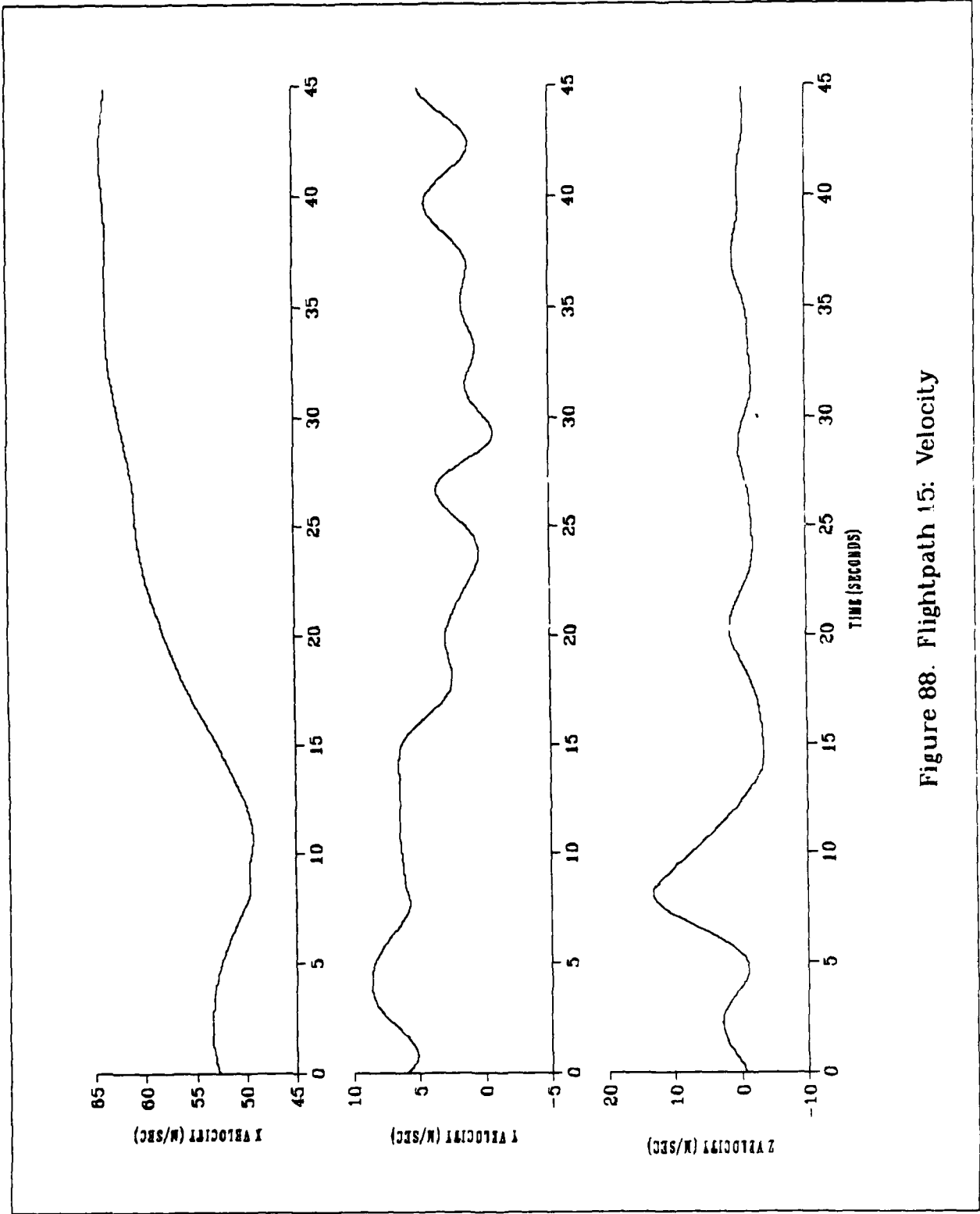


Figure 88. Flightpath 15: Velocity

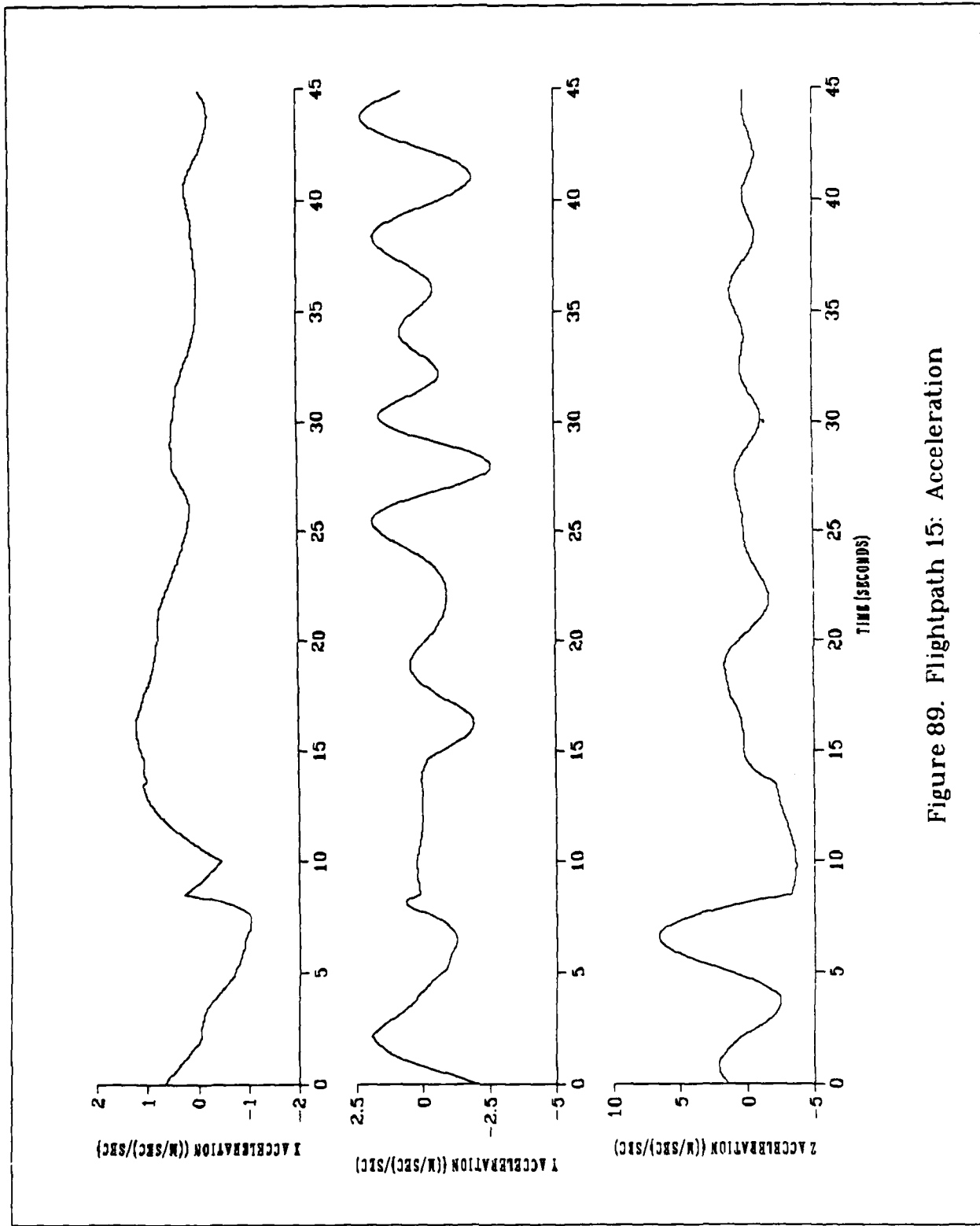


Figure 89. Flightpath 15: Acceleration

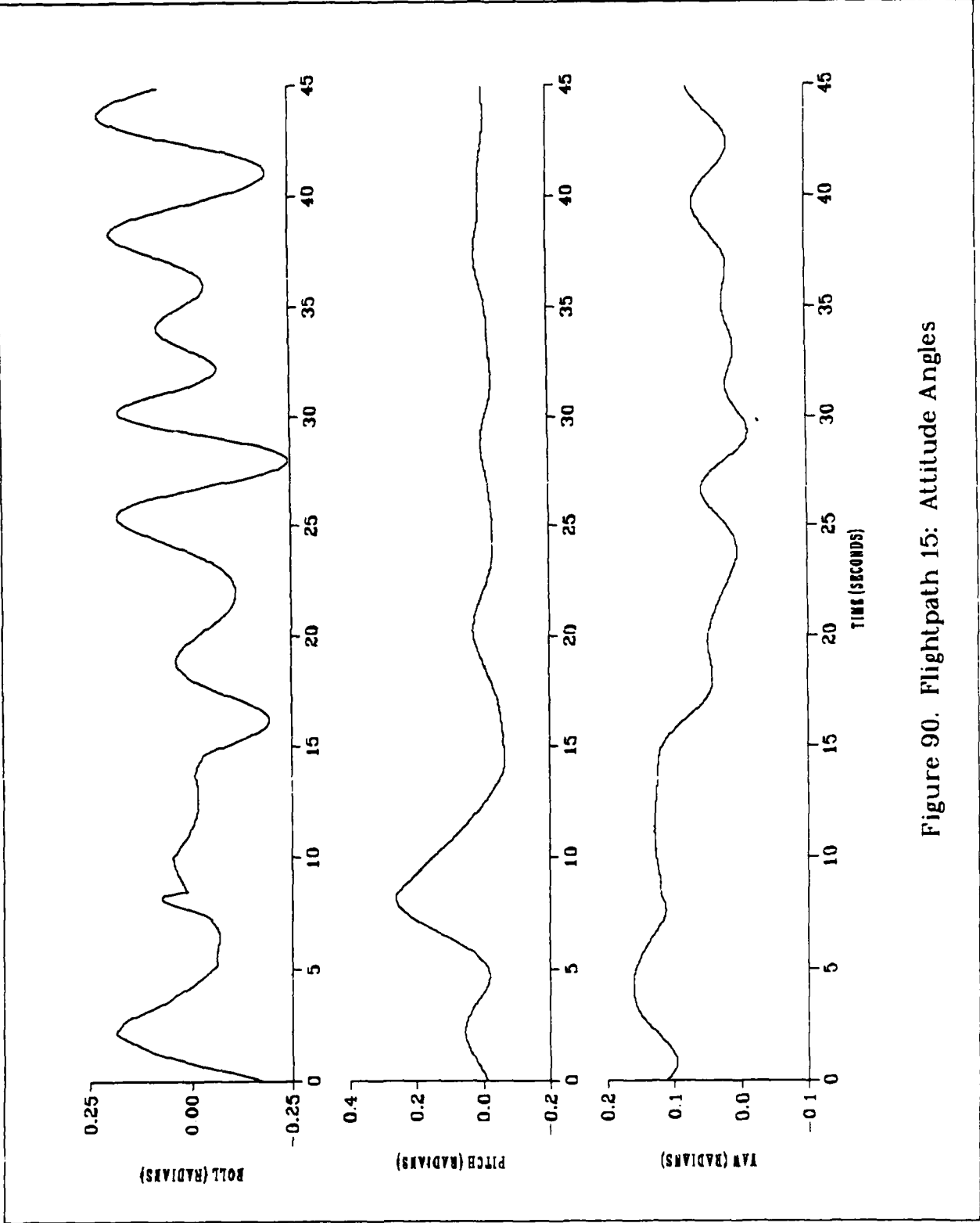


Figure 90. Flightpath 15: Attitude Angles

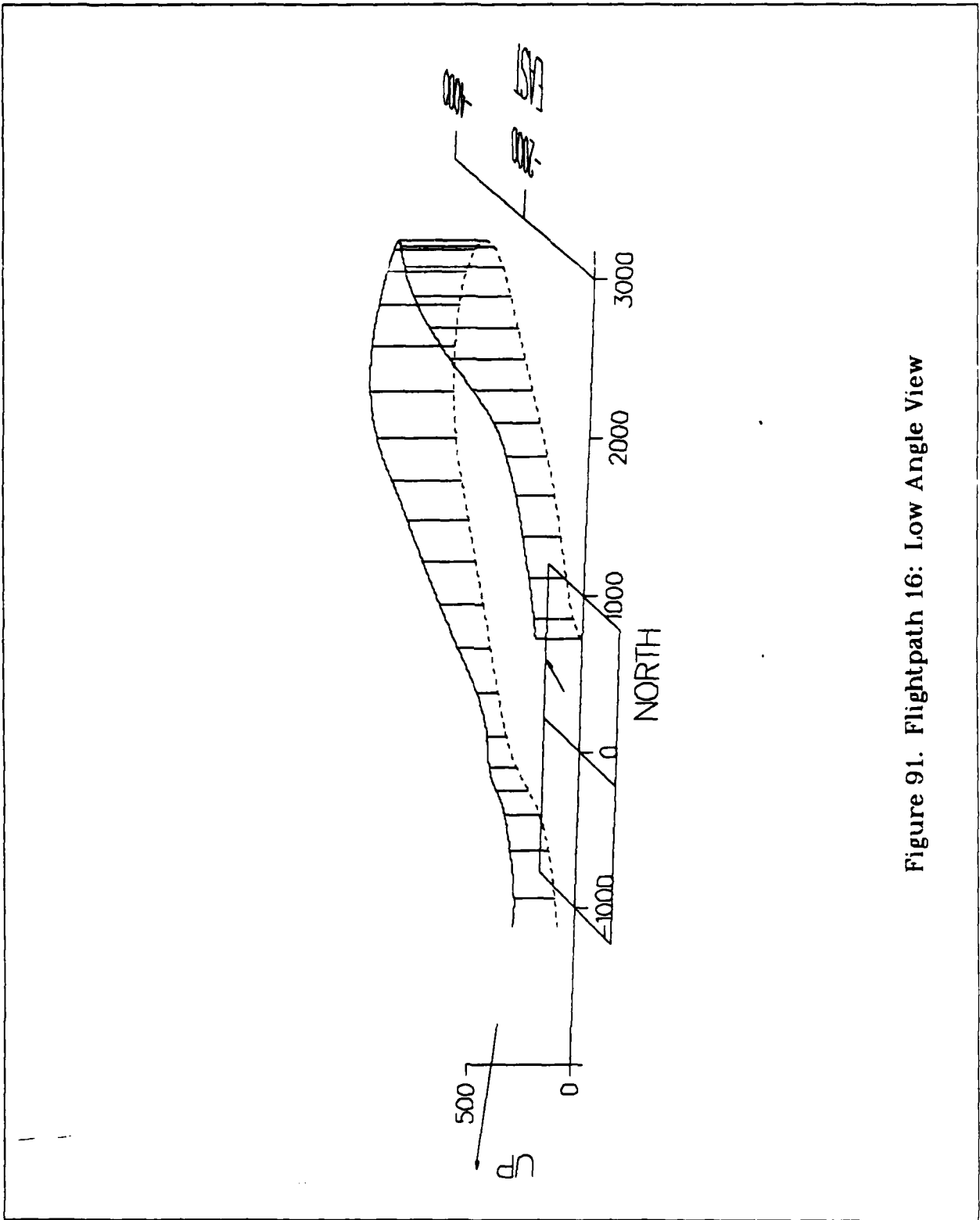


Figure 91. Flightpath 16: Low Angle View

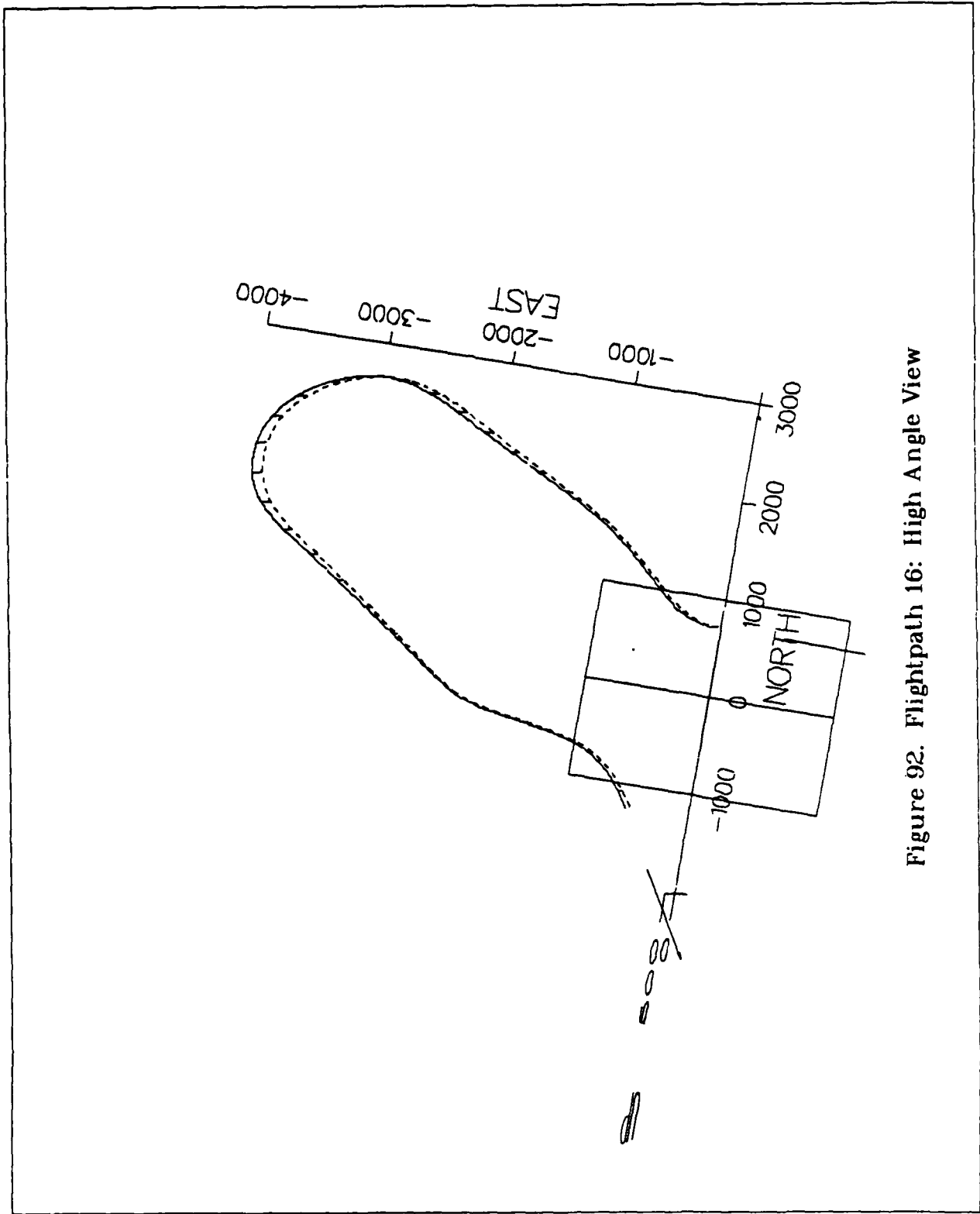


Figure 92. Flightpath 16: High Angle View

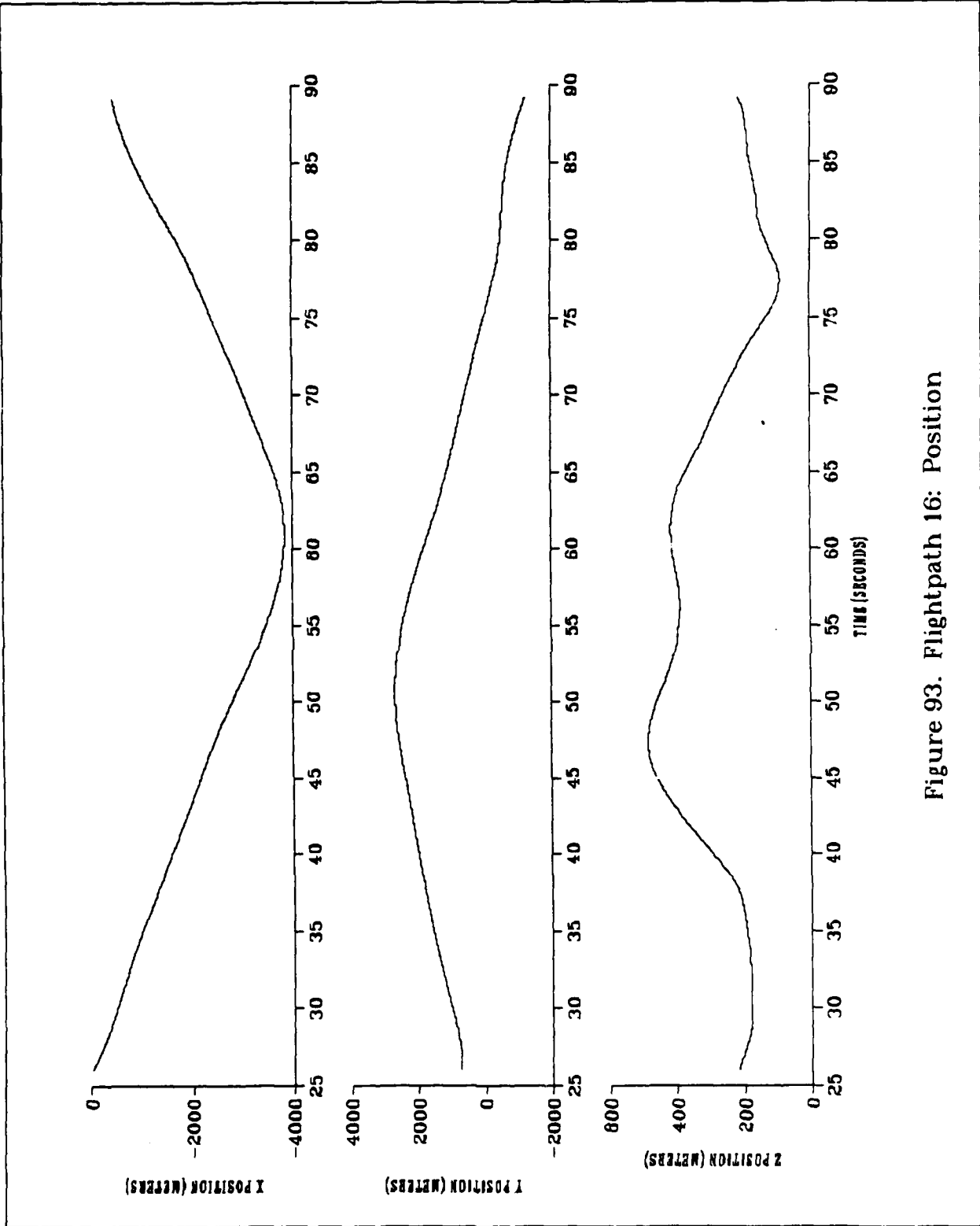


Figure 93. Flightpath 16: Position

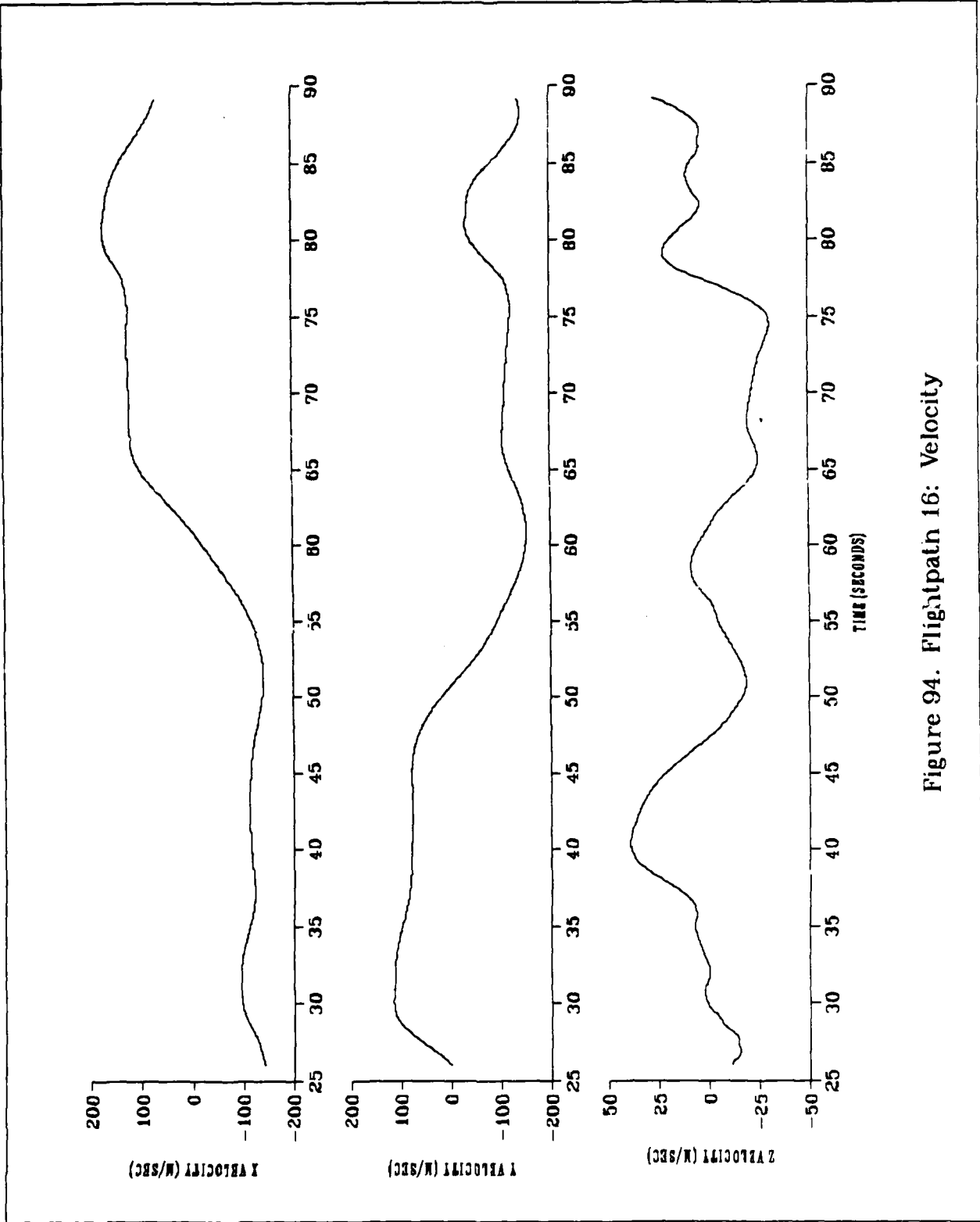


Figure 94. Flightpath 16: Velocity

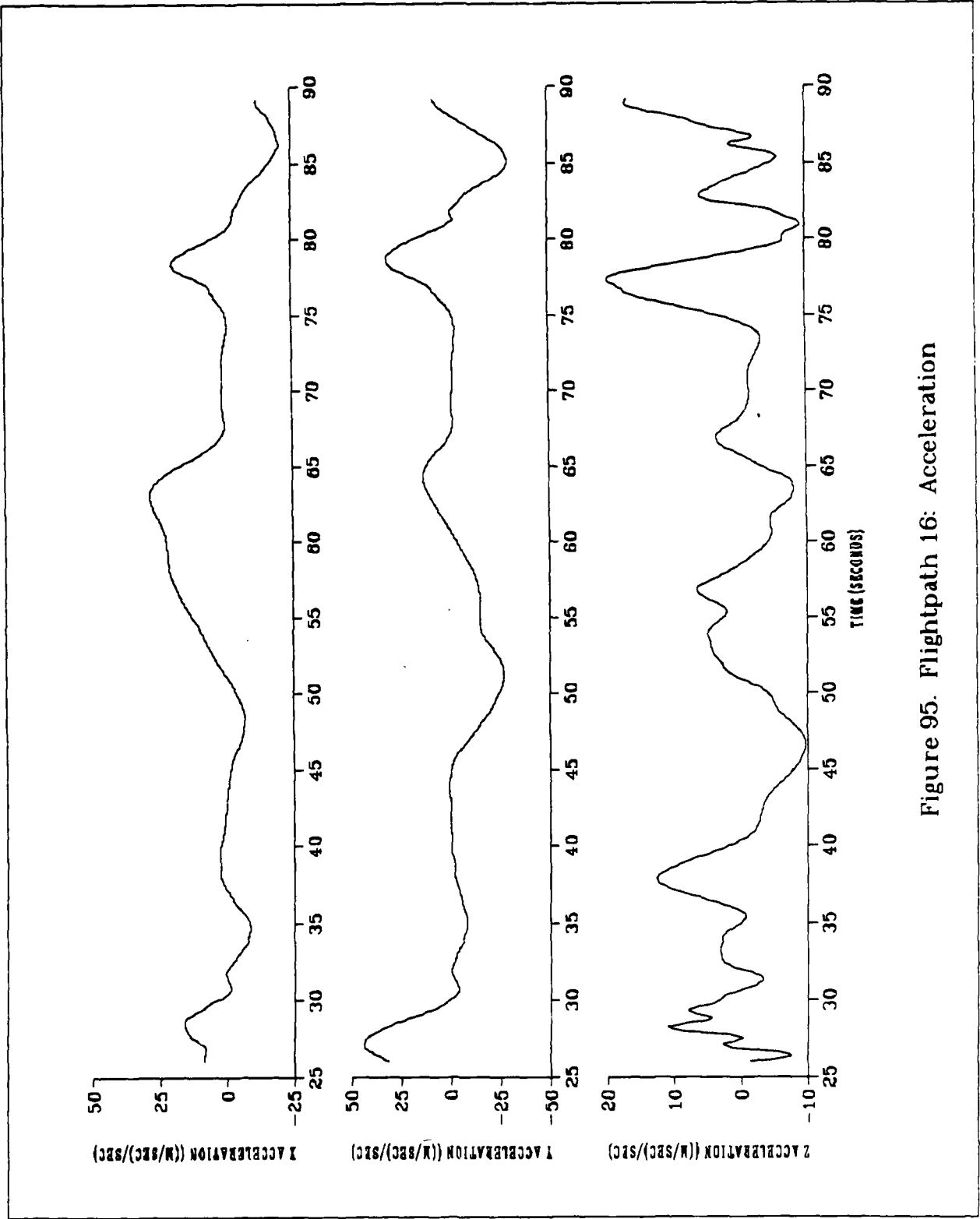


Figure 95. Flightpath 16: Acceleration

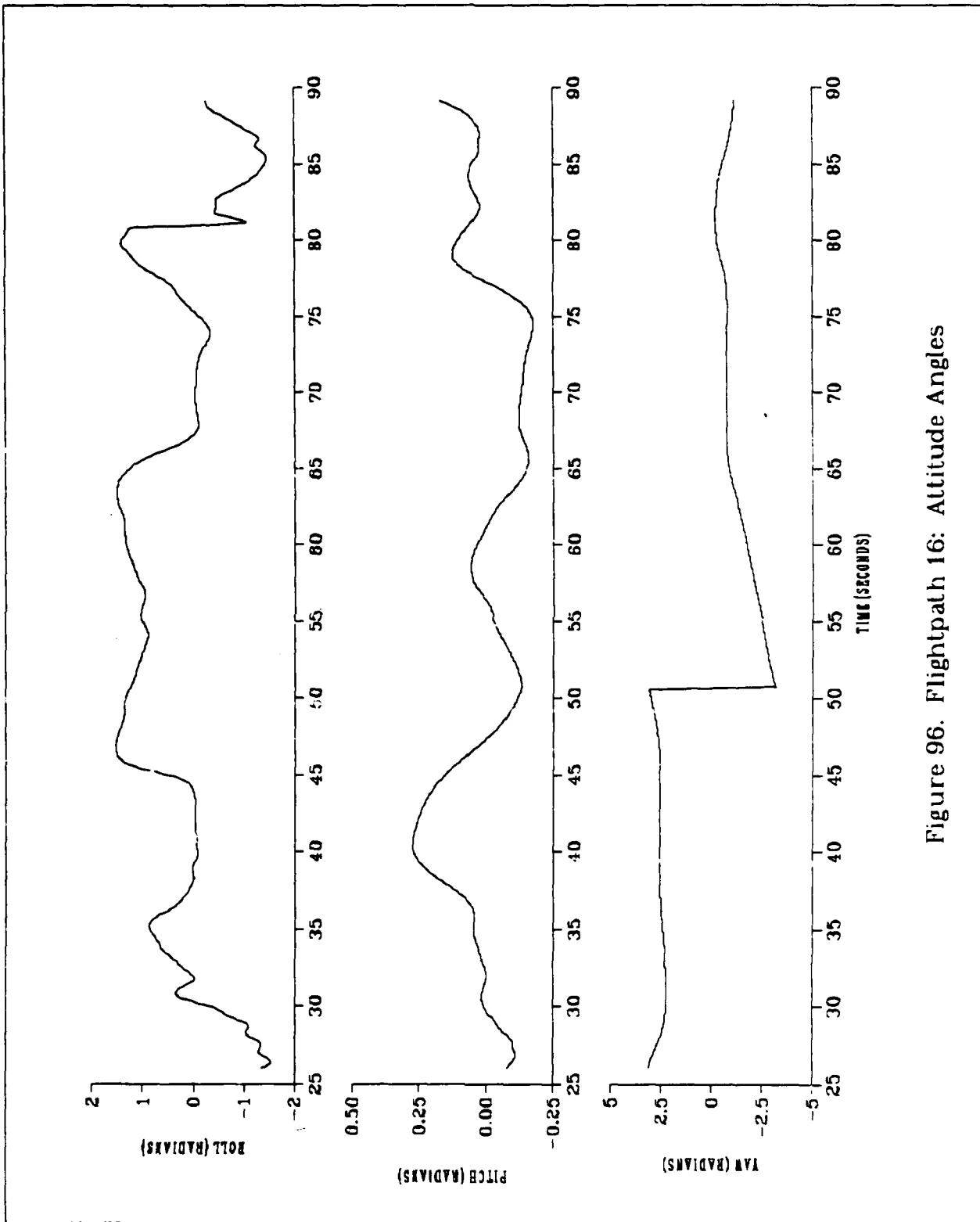


Figure 96. Flightpath 16: Attitude Angles

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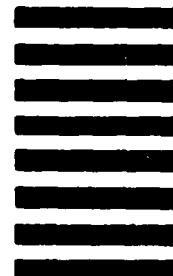


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