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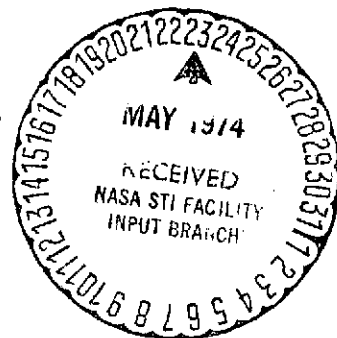
STI

STATISTICAL TRAJECTORY ESTIMATION PROGRAM

(STEP) IMPLEMENTATION FOR BLDT POST

FLIGHT TRAJECTORY SIMULATION

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NAS1

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## Introduction

During the summer of 1972 four tests were conducted to provide flight conditions for qualifying the Viking Decelerator System in a simulated Mars environment. Because of uncertainties in the Martian atmosphere, it was necessary to test the decelerator at supersonic, transonic and subsonic conditions. A Balloon Launched Decelerator Test (BLDT) vehicle which has an external shape similar to the actual Mars Viking Lander Capsule was used so that the decelerator would be deployed in the wake of a blunt body. The BLDT vehicle and inflated decelerator are shown in Figure 1. A detailed account of the flights is given in References (1), (2), (3) and (4).

As part of the post-flight analysis an effort was made to simulate the BLDT vehicle flights from the time they were dropped from the balloon, through decelerator deployment, until stable decelerator conditions were reached. The purpose of this paper is to outline the procedure used to simulate these flights using the Statistical Trajectory Estimation Program (STEP). Using primarily ground-based position radar and vehicle onboard rate gyro and accelerometer data, the STEP produces a minimum variance solution of the vehicle trajectory (position and velocity) and calculates vehicle attitude histories (Euler angles). Using film from cameras in the vehicle along with the computer program described in Reference (5), attitude histories for portions of the flight before and after decelerator deployment were calculated independent of the STEP simulation. With the assumption that the vehicle motions derived from camera data are accurate, a comparison reveals that STEP was able to simulate vehicle motions for all flights both before and after decelerator deployment.

## Tools

The primary tool for simulation of the BLDT vehicle flights was the Statistical Trajectory Estimation Program (STEP); more specifically, STEP 2. A formulation report, Reference (6), presents the equations, theory, and numerical techniques used in the STEP. A utilization report, Reference (7), presents the computer program listing, input and output information, and general user information. These reports should be obtained and reviewed before attempting to run the STEP. This paper does not attempt to replace these reports, but is a complementary work presenting program utilization for a specific task.

No basic modifications were made to the STEP for the BLDT simulations. Output changes were made so that an output tape could be generated in a format compatible with an existing plotting program. A total angle of attack calculation was also added during the output phase of the program.

A complete listing and flow chart of the STEP is given in Reference (7). A listing of the control cards necessary to retrieve the STEP, which is on a data cell at Langley, and the changes which were made to the program are presented in the Appendix. The control cards as listed enable running STEP, program TAPES, and a plot program BRUTUS, as one input job. Program TAPES separates the STEP output tape into two tapes, one containing the forward integration, the other the backward smoothing pass. This program properly formats the data for the plotting program. BRUTUS, the plotting program, plots designated parameters on the CALCOMP plotter. Listings of these two routines along with the necessary information for using BRUTUS are given in the Appendix. The listings present the STEP, TAPES, and BRUTUS as they were input for the AV-4 example simulation.

A smoothing program, SMOOTH, was utilized to smooth telemetry data before it was used in the STEP. This program uses a least square polynomial curve fit with a walking second degree mid-point filter. It incorporates the Langley computer facility subroutine LSQPOL which is documented in Reference (8).

### Implementation

The transonic and supersonic flights were simulated in two parts. The first part is from vehicle drop until the decelerator is deployed (i.e., mortar fire). The second starts at mortar fire and simulates the vehicle motions with the decelerator deployed. The simulations were divided at mortar fire primarily because the rates and accelerations after mortar fire have greater amplitudes and higher frequencies than those prior to mortar fire. A secondary reason is that inaccuracies in telemetry data or initial conditions are partially additive in STEP because of the integration and, therefore, errors may increase with time.

The basic simulation process is the same for before or after mortar fire. Any exceptions are discussed as they arise. The actual simulation process begins by accumulating all necessary input data. First, a binary tape containing time histories of slant range, azimuth and elevation angle from the primary radar along with corresponding standard deviations for these parameters is prepared in the manner described in the utilization report. This is called a FIT tape. Little difficulty was encountered in preparing the FIT tapes since the radar data is not conditioned before being used in STEP. Time histories of slant range, azimuth and elevation angle are shown in Figures (2), (3), and (4). A second binary tape, the PQR tape, containing the vehicle telemetry rate gyro and accelerometer data must also be prepared. This data must be conditioned and a discussion explaining how this can be accomplished is given in the appendix of Reference (7). In this instance, the wild points were removed by a difference technique similar to that in Reference (7) or, in areas of high non-linearity, they were visually recognized and replaced individually. The data were then smoothed using the smoothing program already discussed. In some cases, especially those simulations from drop up to mortar fire, as many as 29 points of data were used in the smoothing filter and as many as three smoothing passes were made. Some cases dealing with data after mortar fire were not smoothed because of the rapid oscillation of the data. In these instances only the wild points were removed. It should be remembered the primary objective of the data conditioning is to obtain a time history for each parameter that most accurately reproduces the rates and accelerations actually encountered in flight. The order in which the PQR data are written on tape is given in Reference (7). Time histories of the pitch, yaw and roll rates and X, Y, Z accelerations for the period from drop to mortar fire are shown in Figures (5) through (10). Figures (11) through (16) show the rate and acceleration inputs for the period after mortar fire.

The remaining data are submitted on punched cards. The formats along with an explanation of the parameters are given in the utilization report. A sample listing of the card input is shown in the Appendix. A brief discussion of each input card as it pertains to this project follows.

The first card is a comment card used to label the run. The second card contains 10 control parameters. The first parameter, NPC (1) determines the mode of operation. The filtering mode was used for this work because it was designed for post flight simulation. The second parameter NPC (2) indicates whether English or metric units are to be used. NPC (3) determines the form of the input and output variables. NPC (3) was set equal to one so that the initial attitude as well as the vehicle attitude histories would be in Euler angles.

NPC (4) determines whether the reference trajectory as defined by radar will be updated or not during the forward integration. Both methods were tried, but only the updated mode would give satisfactory results. NPC (5) was set equal to zero so the radar data would be printed. NPC (6) is also a print-control to indicate whether or not the covariance and correlation matrices are to be printed. NPC (7) indicates the number of iterations. As many as three iterations were attempted, but the best results were obtained on the first iteration. NPC (8) was set equal to 3 to smooth the state variables and covariances and calculate residuals and loss function. The residuals were used to determine the difference between the original and final STEP radar data. NPC (9) set to zero processes radar slant range, azimuth and elevation angle data by the vector process which is most efficient. NPC (10) was set equal to zero to prevent a STATE tape from being generated. Instead, a tape of output data compatible with the plotting program was written in the output portion of the program. Most control options were exercised to determine exactly what effect their operation had on the STEP. Those given in the sample proved to be the best combination for the BLDT simulations.

The next nine cards set the initial state parameter values and their standard deviations. For the simulations initiated at drop, values for velocity, altitude, flight path angle, azimuth, latitude and longitude were obtained from radar data. Of the three Euler angles, Psi (vehicle azimuth) was established using data from the magnetometer on the load bar. Theta (vehicle pitch attitude) and Phi (vehicle roll attitude) were obtained from preflight measurements. For those simulations initiated at mortar fire, the initial state variables were derived from the final conditions of the best STEP simulations which were terminated at mortar fire. The standard deviations of the state variables were obtained either from the accuracy of the radar data or, in the case of the Euler angles, by engineering judgement. The varying of the initial conditions and their standard deviations influenced the trajectory simulation. Those shown in the sample are typical of what were necessary to obtain a good simulation.

The next twelve cards of the sample input are examples of the biases and scale factors of the rates and accelerations. Their model parameter number and the proper units are shown in the sample listing as well as in the utilization report.

The next three cards identify the latitude, longitude, and altitude of the radar site.

The next card specifies initial time, printout frequency, computing interval, and final time. The computing interval should be small enough to accurately define the rate and acceleration time histories. In the simulations before mortar fire a computing interval of .1 second was used. For simulations after mortar fire the computing interval was .02 second.

The next card specifies geophysical and gravitational data. In all the simulations the polar and equatorial radii were equal to the local earth radius at White Sands. This was done to bypass a suspected problem with the oblate earth subroutine.

The next to last input card identifies the type of tracking data; in this case radar. It specifies the initial and final time to process the radar data, and the processing interval. It also specifies processing of all three radar components and an incremental standard deviation for each component. These standard deviations are added to those on the FIT tape to produce a total standard deviation. This completes all card input data. The last card has only the number 20 beginning in Column 1.

The program should now be ready to run. The primary objective is to simulate the BLDT flights by matching vehicle attitude time histories derived from on-board camera data while still comparing favorably with the radar parameters. After the initial STEP run is made, using nominal or default biases and scale factors, an attempt is made to match the roll attitude time history obtained from the STEP with that from camera data. This was accomplished by adjusting the scale factor or bias on the roll rate data or, in the simulations after mortar fire, by adjusting the initial roll angle,  $\Phi$ . As in the example of the drop to mortar fire portion, the roll attitude at mortar fire was approximately 75 degrees larger than it should have been when the default scale factor of 1.0 was used. By looking at the roll rate telemetry data, the average spin rate during the approximately 30 seconds the vehicle is spinning is 150 degrees/second. It can then be calculated that a scale factor of .9835 will decrease the total roll by 75 degrees. The program is rerun with the new input and compared again. This process continues until the camera roll attitude data compare favorably with the backward smoothing simulation of the STEP. Next, the pitch and yaw attitude histories are compared to determine if a bias or scale factor adjustment is necessary. As these iterations proceed, make sure the roll attitude does not change appreciably due to changes in pitch or yaw. Furthermore, as the attitude histories begin to compare favorably, the radar parameters derived from the STEP (i.e., altitude, velocity, flight path angle, and azimuth) should be checked against the actual radar data. Discrepancies in the radar data may also be adjusted with a bias or scale factor or by a change in initial conditions. Changes in biases, scale factors, or initial conditions should be within the accuracy of the telemetry or radar data. Any large changes that seem necessary would indicate a problem on either the FIT or PQR tape or possibly an incorrect initial condition. The iteration process continues until the STEP attitude histories compare favorably with those derived from camera data and the STEP radar data checks with actual radar data.

Figures (17) through (19) show the difference between the STEP attitude histories and camera data from drop until mortar fire. The comparisons of flight path angle and azimuth with radar are also shown in Figures (17) and (18). Comparisons of the STEP velocity and altitude histories with radar data are shown in Figures (20) and (21). Figures (22) through (26) present similar comparisons for the period after mortar fire.

These comparisons reveal that the STEP was able to simulate the BLDT vehicle dynamics and trajectory parameters successfully. It should be remembered that an iterative process was used to obtain these results and the steps described above are for a specific simulation. For simulation of other vehicles and trajectories the order or possibly the necessity of some steps will probably be different. This example does, however, provide insight on how the iterative process was able to produce good results for this particular problem.

## References

1. Dickinson, D.; Schlemmer, J.; Hicks, F.; Michel, F.; and Moog, R. D.: Balloon Launched Decelerator Test Program Post Flight Test Report BLDT Vehicle AV-1. Martin Marietta Corporation TR-3720289, September 1972.
2. Dickinson, D.; Schlemmer, J.; Hicks, F.; Michel, F.; and Moog, R. D.: Balloon Launched Decelerator Test Program Post Flight Test Report BLDT Vehicle AV-2. Martin Marietta Corporation TR-3720291, December 1972.
3. Dickinson, D.; Schlemmer, J.; Hicks, F.; Michel, F.; and Moog, R. D.: Balloon Launched Decelerator Test Program Post-Flight Test Report BLDT Vehicle AV-3. Martin Marietta Corporation TR-3720293, January 1973.
4. Dickinson, D.; Schlemmer, J.; Hicks, F.; Michel, F.; Moog, R. D.: Balloon Launched Decelerator Test Program Post-Flight Test Report BLDT Vehicle AV-4. Martin Marietta Corporation TR-3720295, October 1972.
5. Renfroe, P. G.: Transmittal of Draft of Working Paper on Vehicle Attitude Program. LTV Aerospace Corporation V-19000/3NASA-279, May 1973.
6. Wagner, William E.; and Serold, Arno C.: Formulation on Statistical Trajectory Estimation Programs. NASA CR-1482, 1970.
7. Wagner, William E.; and Serold, Arno C.: Utilization of Statistical Trajectory Estimation Programs. NASA CR-66837, 1969.
8. Anon.: Computer Programming Manual, Langley Research Center, Vol. I.

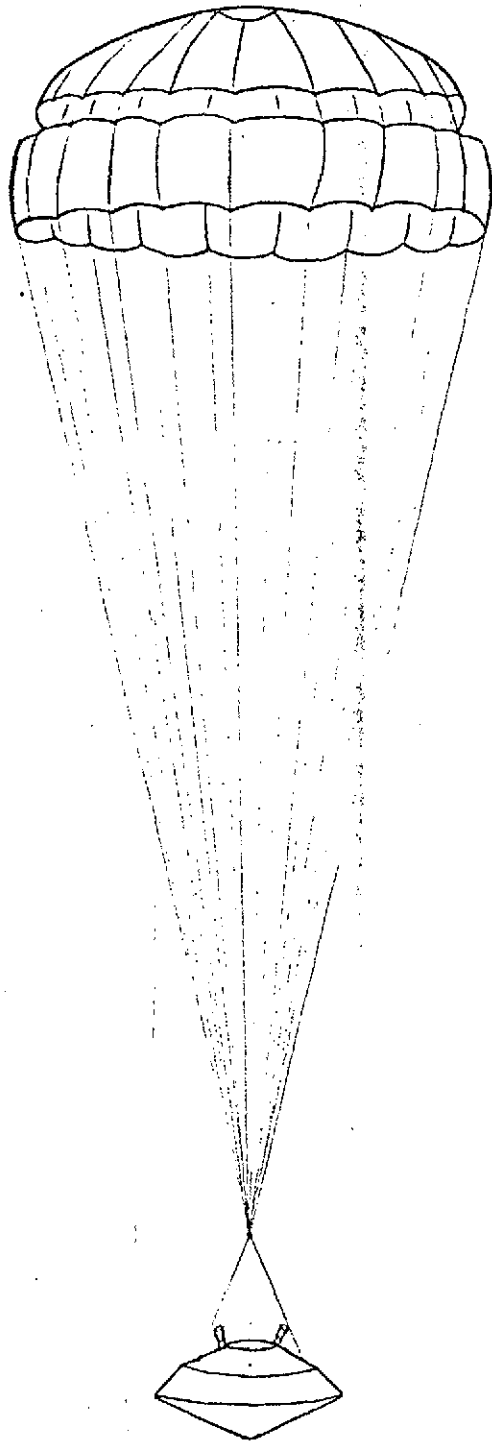


Figure 1 BLDT Vehicle and Decelerator



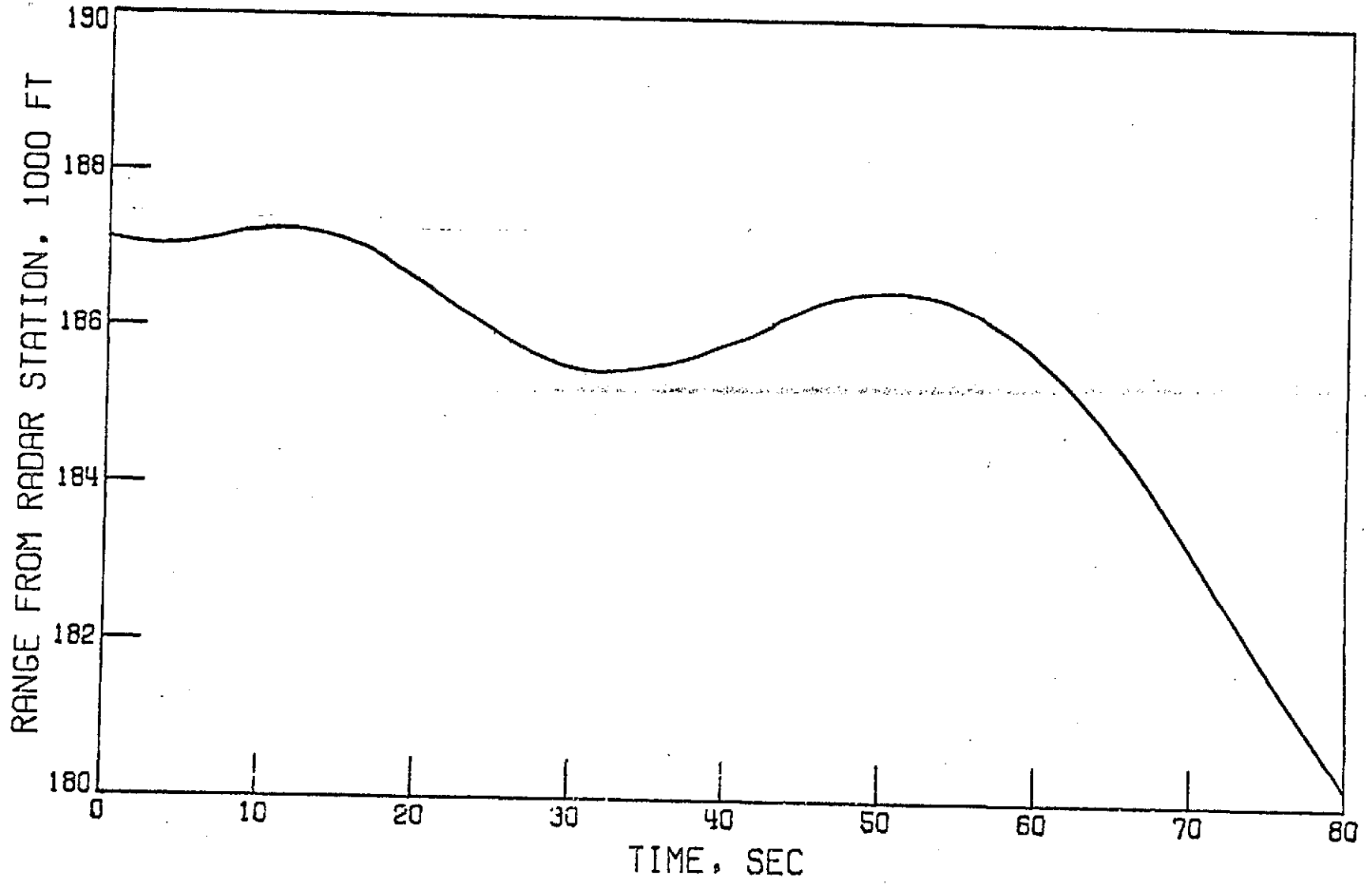


Figure 2. Slant Range Time History

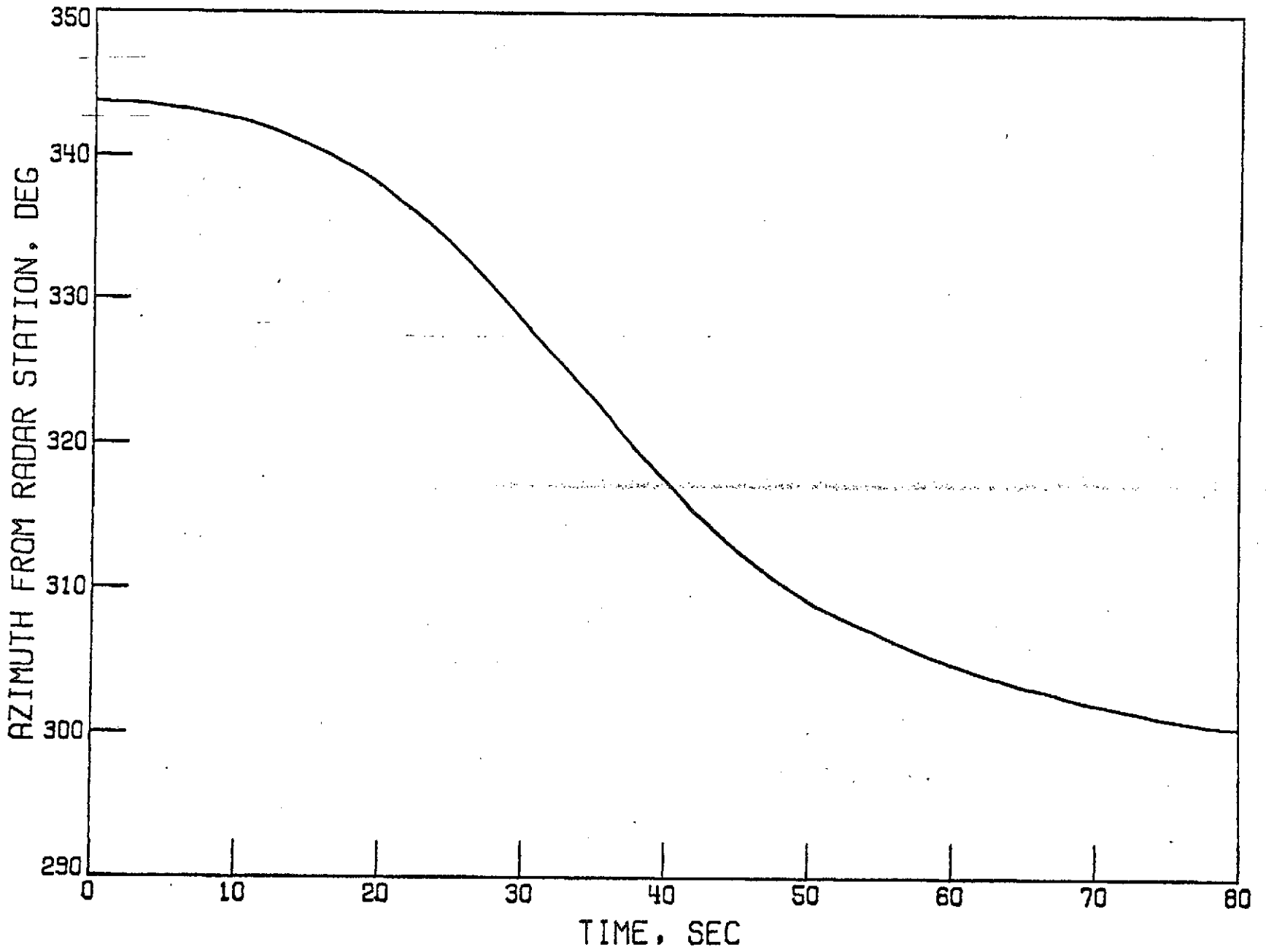
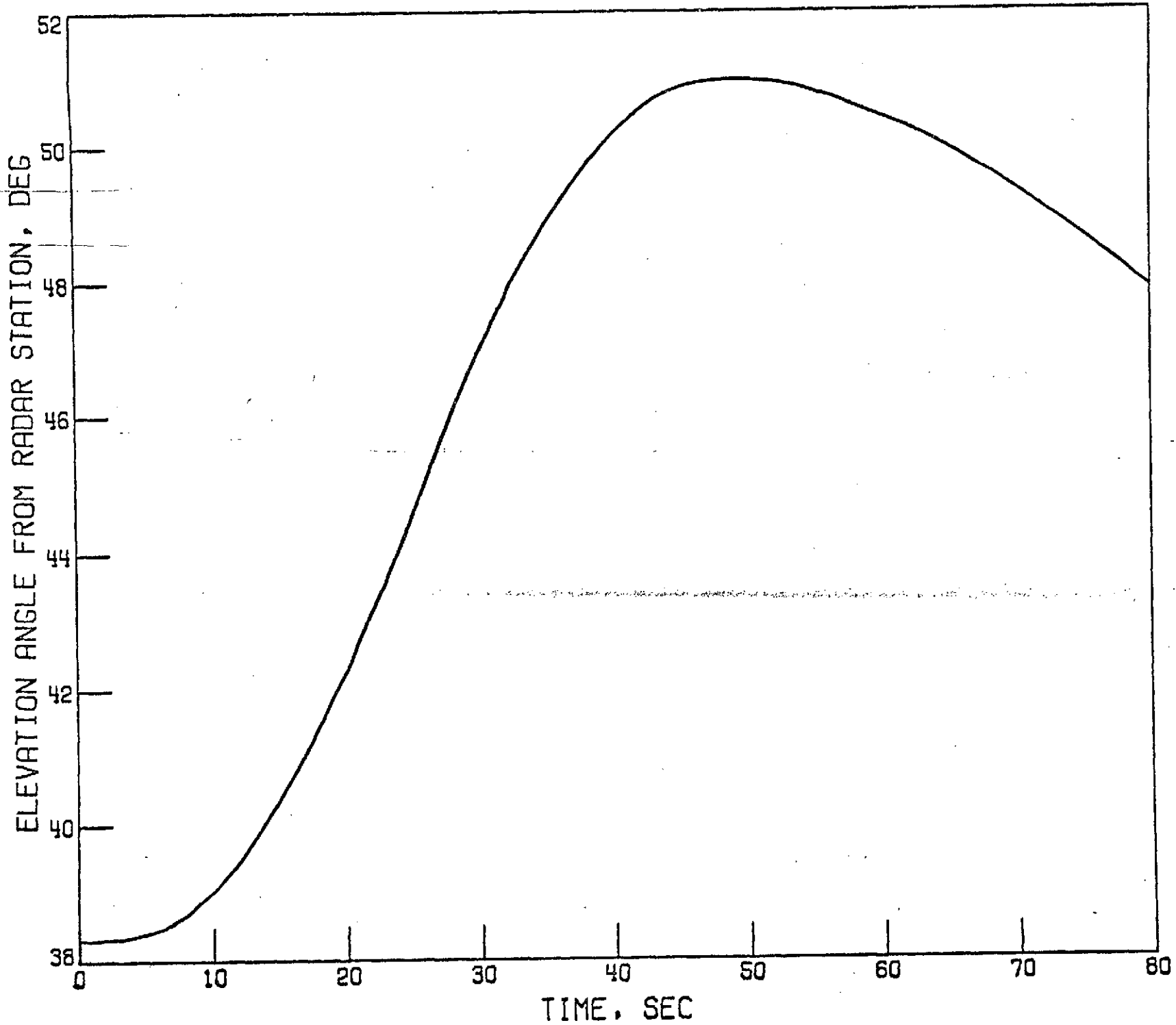


Figure 3. Azimuth Time History



--- 4 Elevation Angle Time History

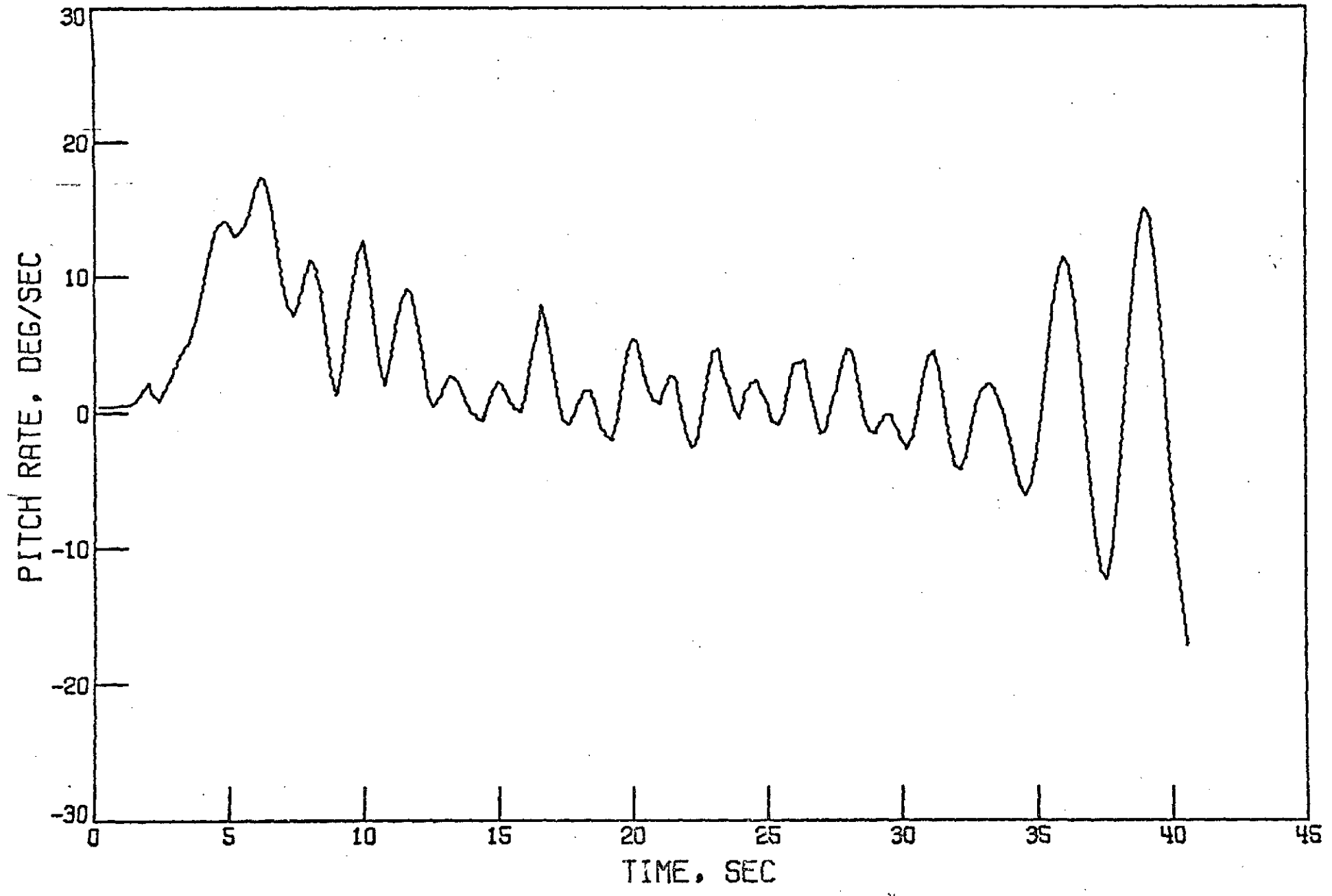


Figure 5. Telemetered Pitch Rate from Drop to Mortar Fire

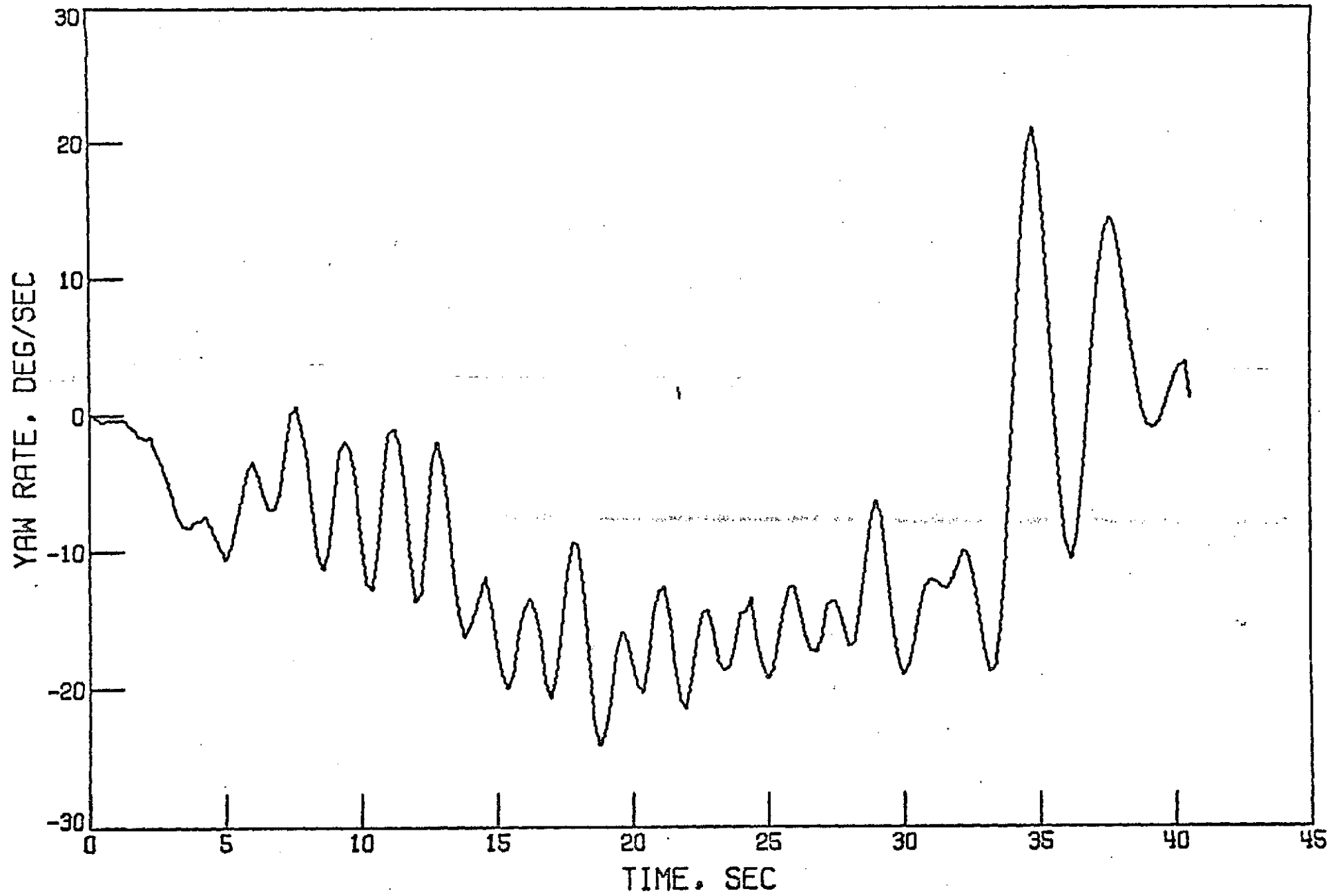


Figure 6. Telemetered Yaw Rate from Drop to Mortar Fire

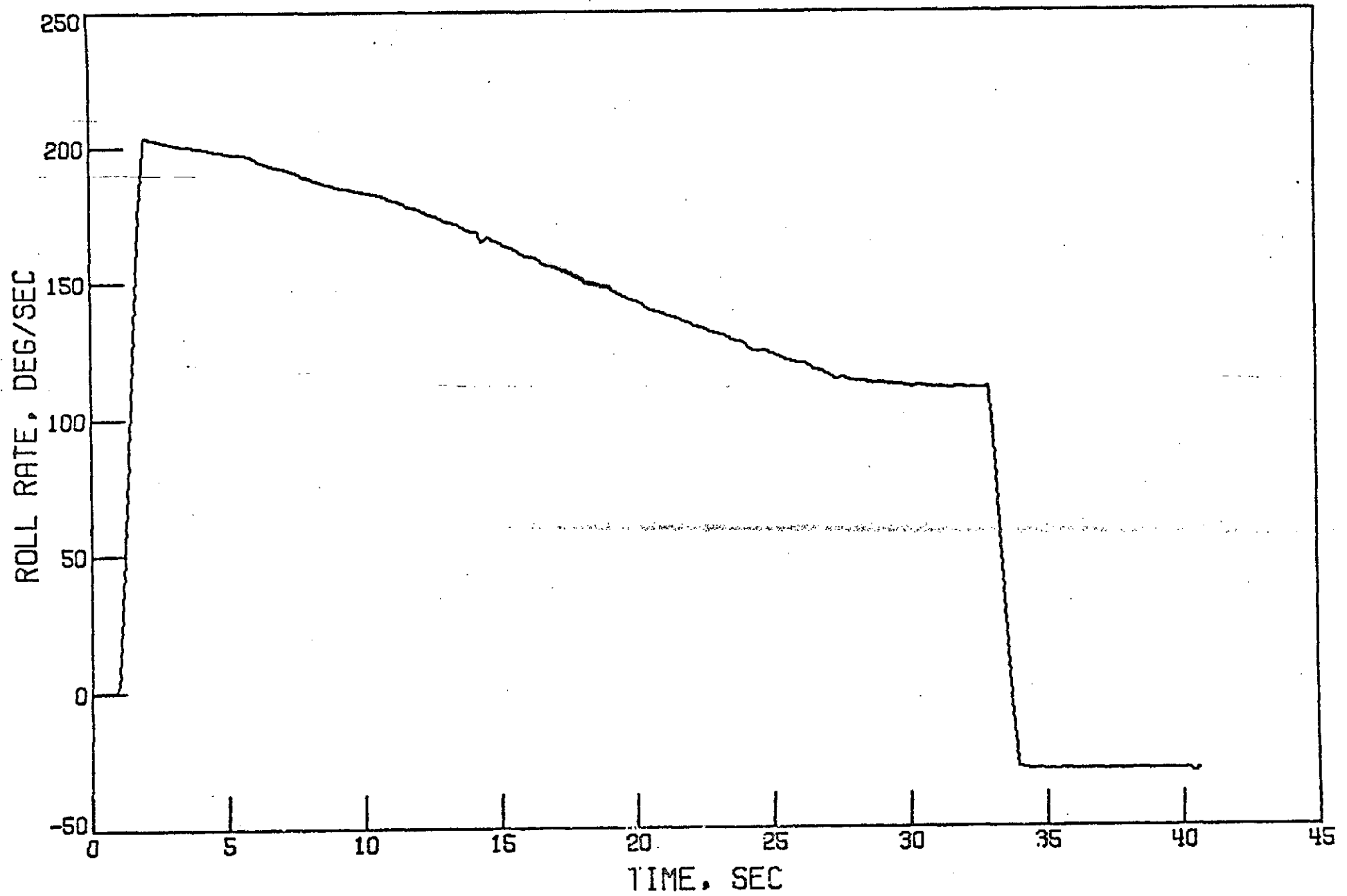


Figure 7. Telemetered Roll Rate from Drop to Mortar Fire

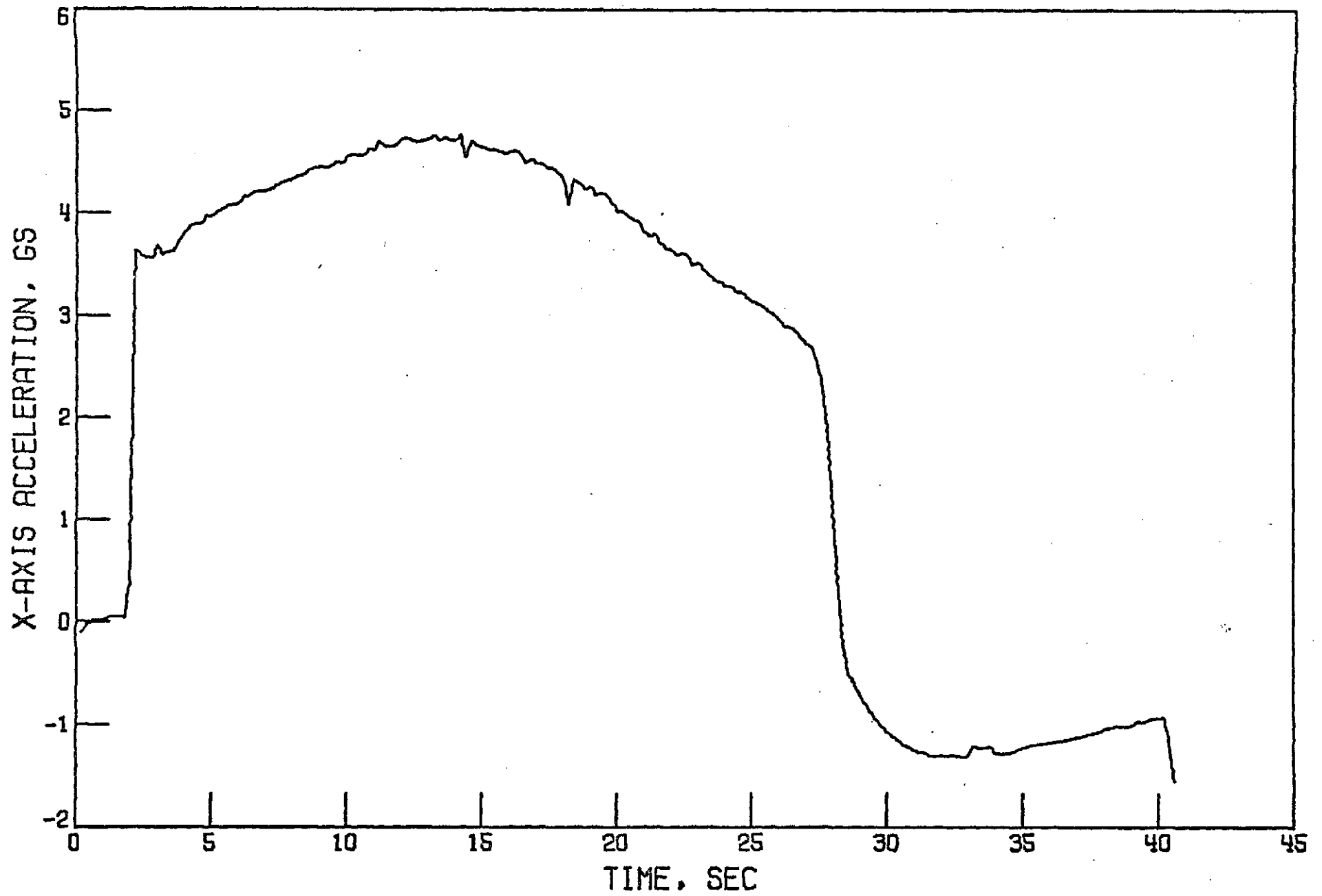


Figure 8. Telemetered X-Axis Acceleration from Drop to Mortar Fire

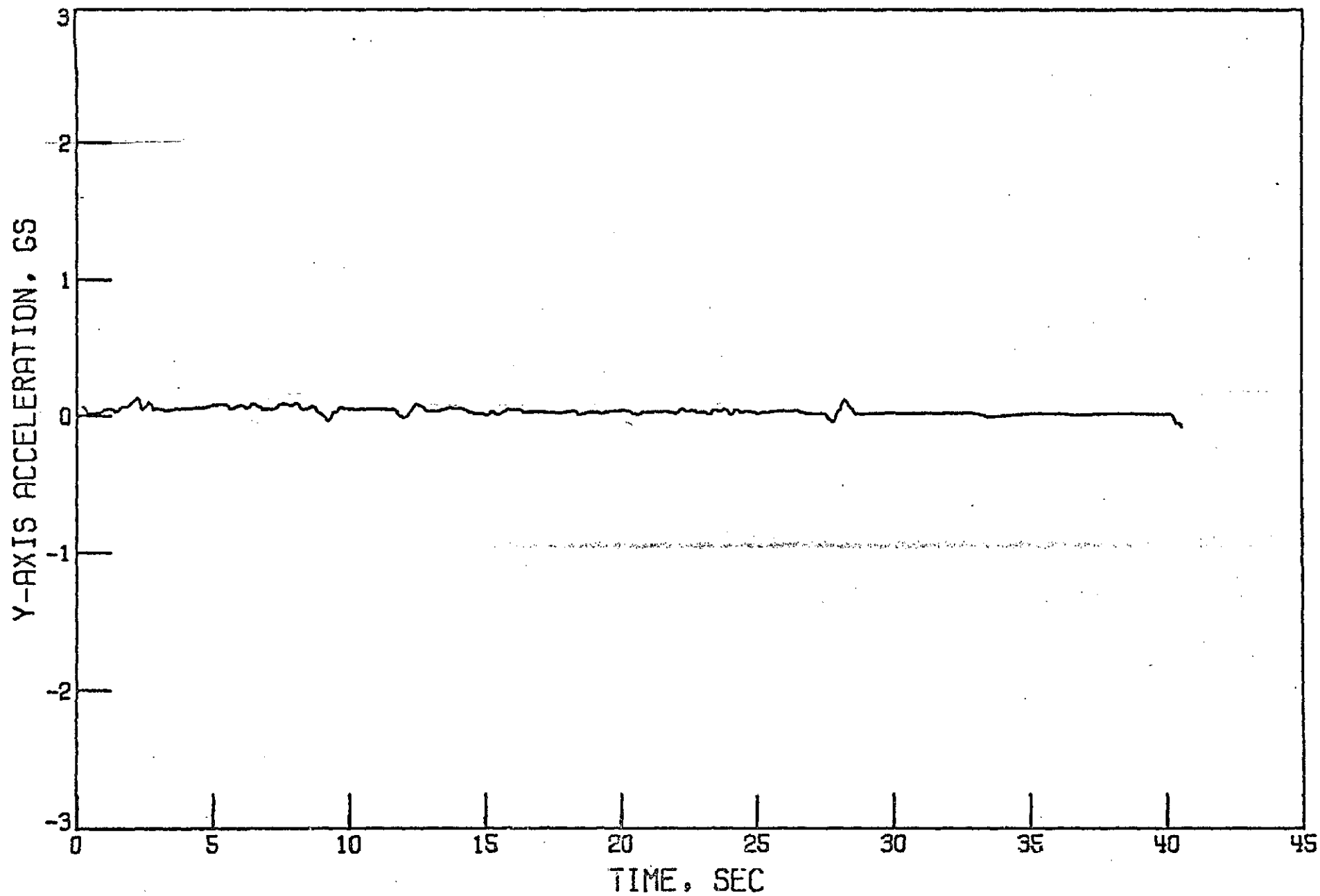


Figure 9. Telemetered Y-Axis Acceleration from Drop to Mortar Fire



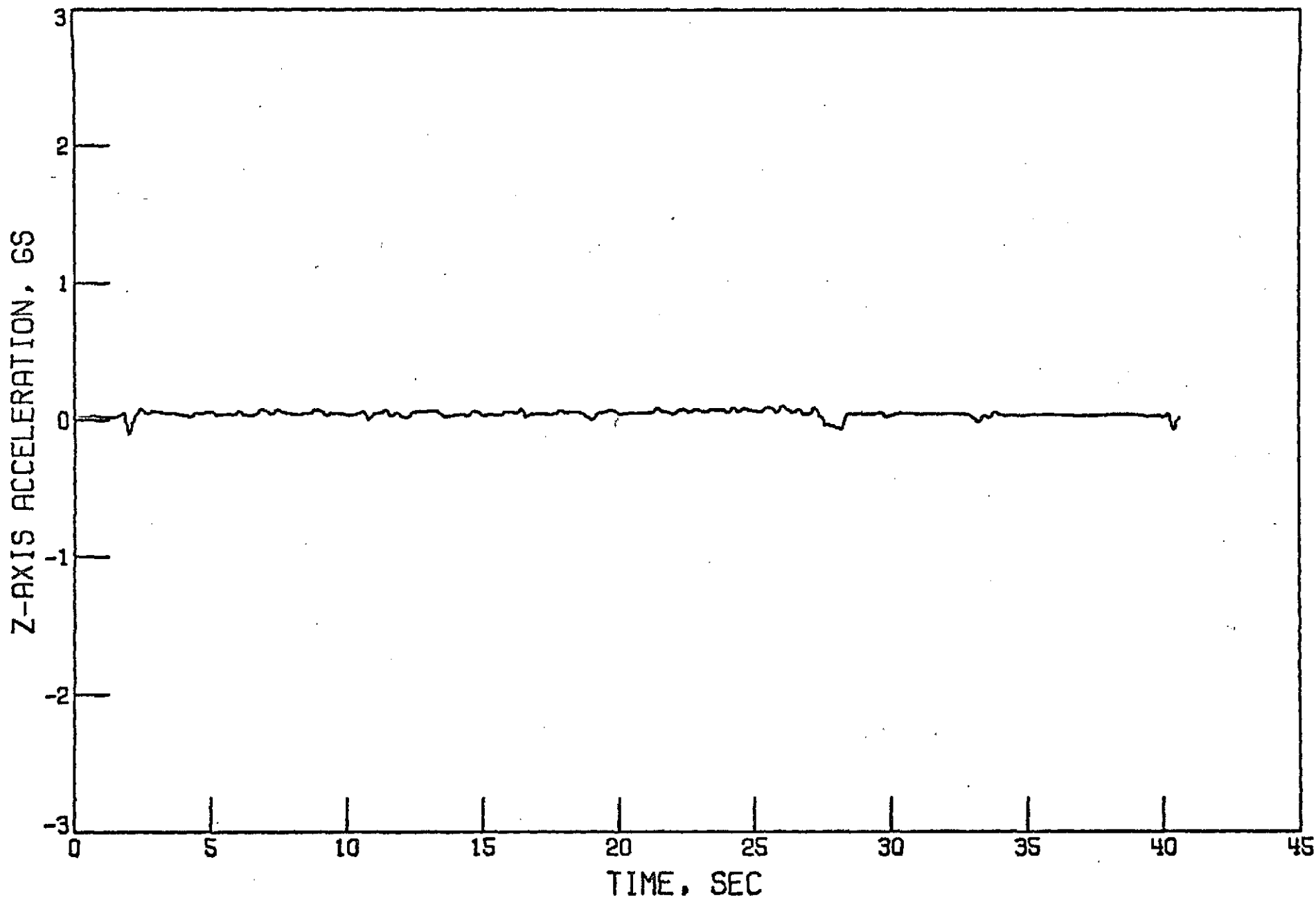


Figure 10. Telemetered Z-Axis Acceleration from Drop to Mortar Fire

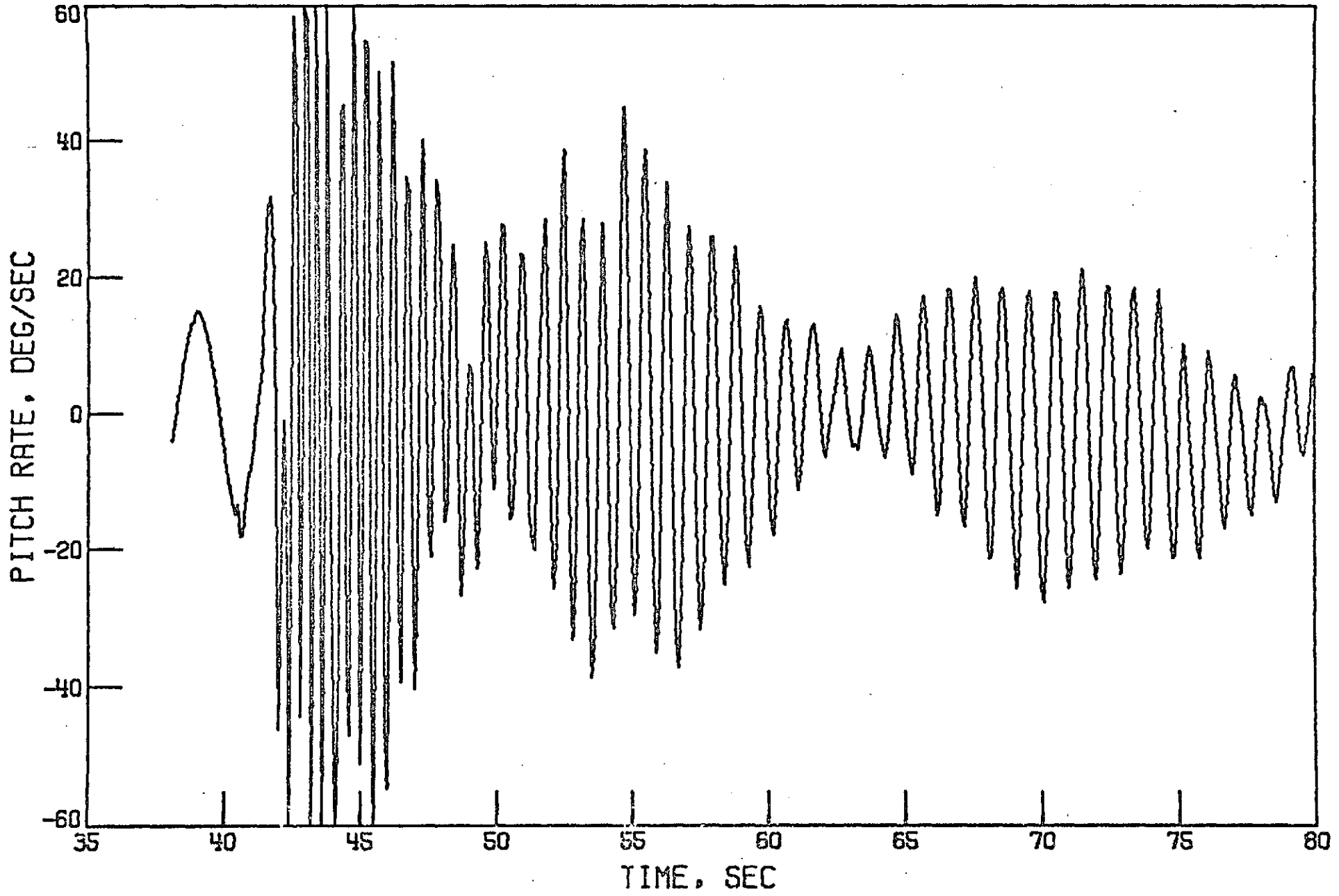


Figure 11. Telemetered Pitch Rate after Mortar Fire

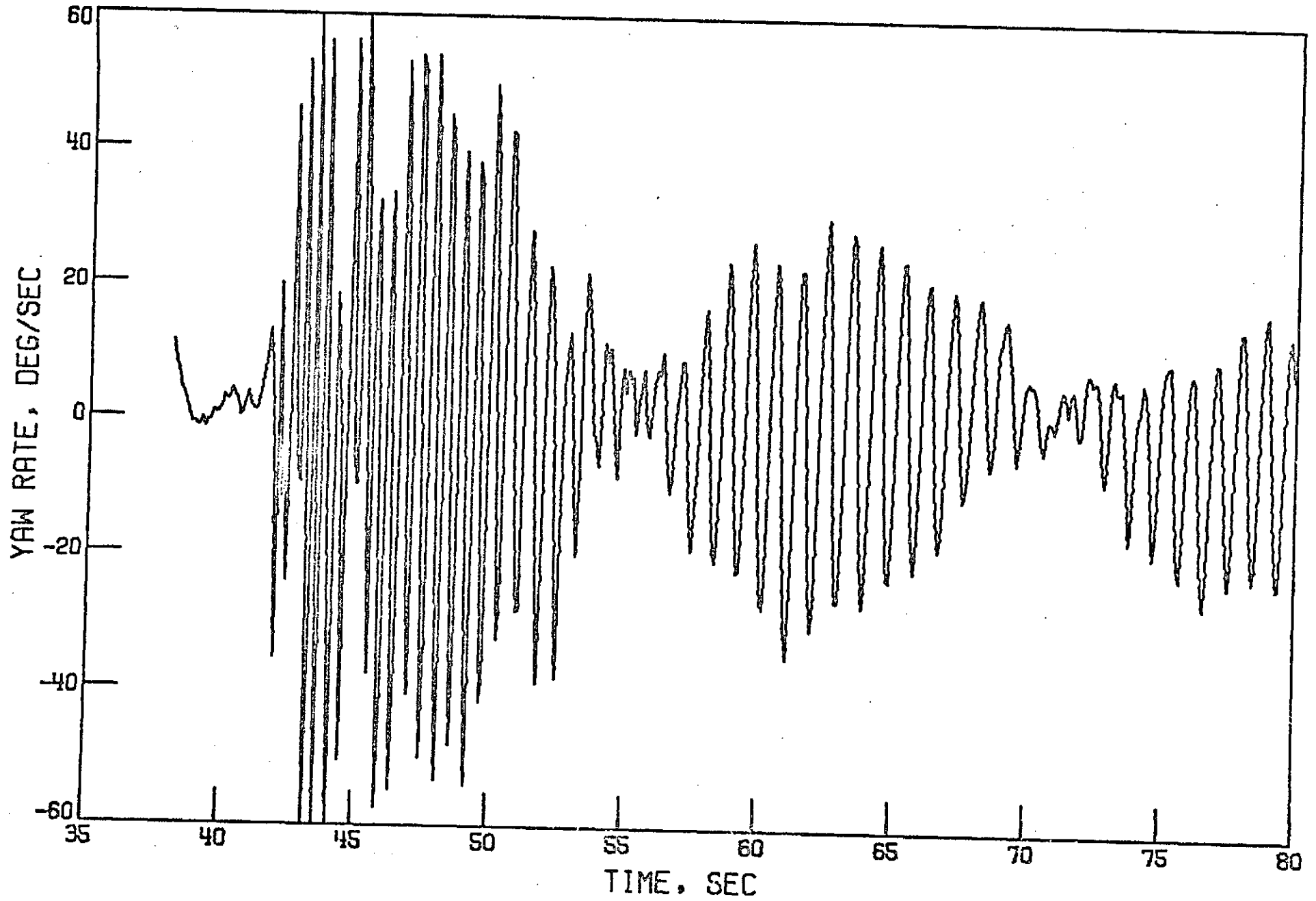


Figure 12. Telemetered Yaw Rate after Mortar Fire

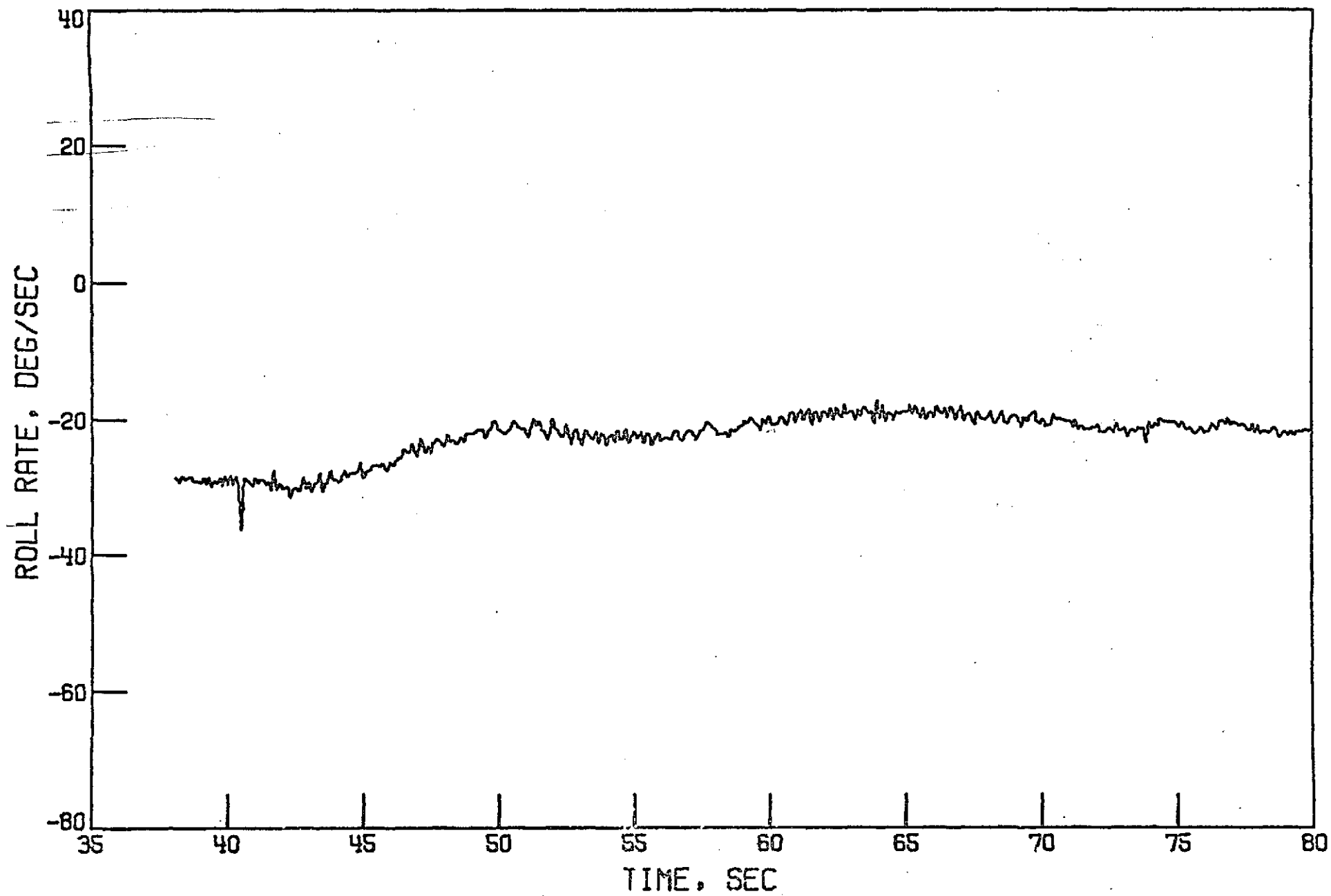


Figure 13, Telemetered Roll Rate after Mortar Fire

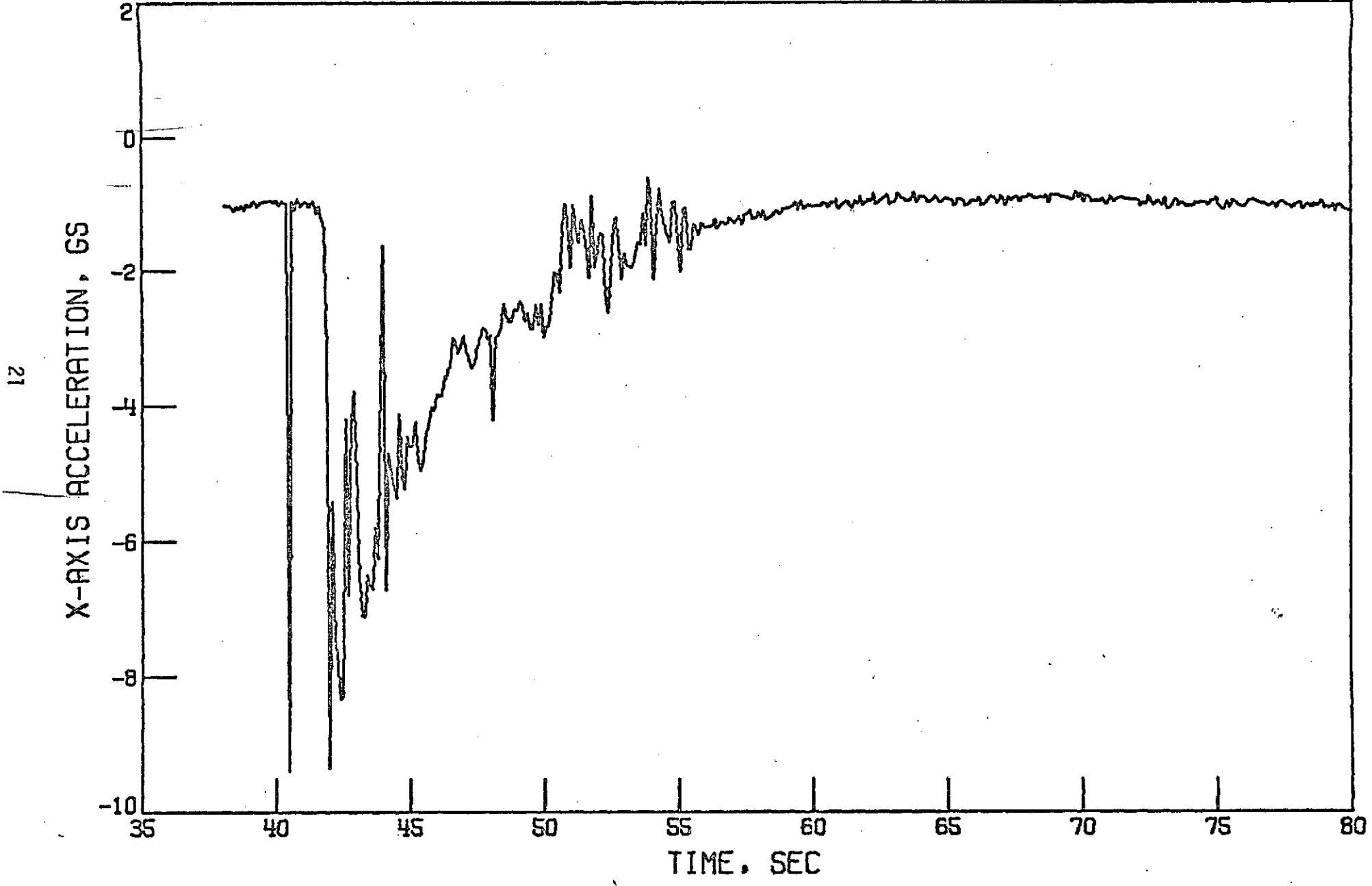


Figure 14. Telemetered X-Axis Acceleration after Mortar Fire

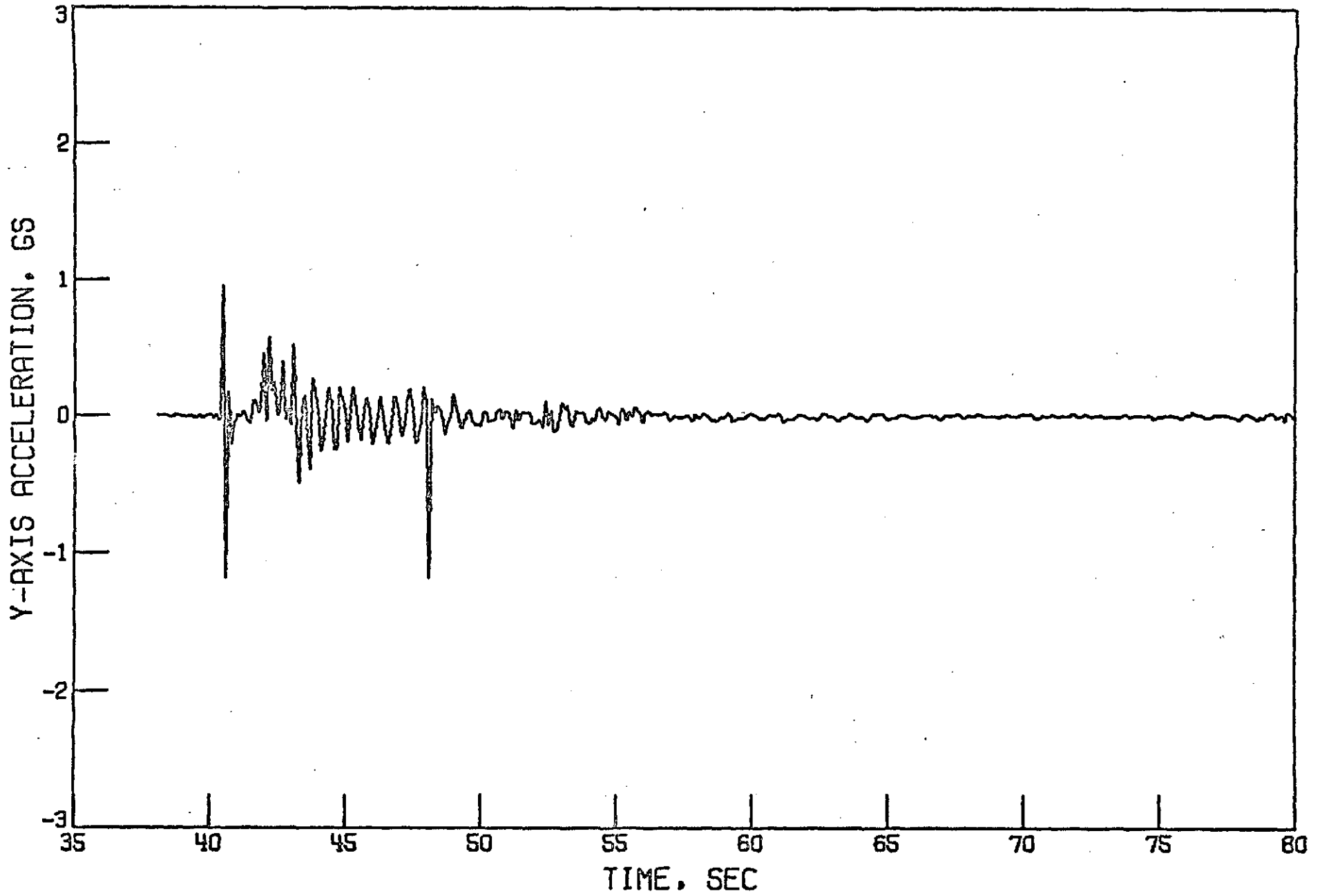


Figure 15. Telemetered Y-Axis Acceleration after Mortar Fire

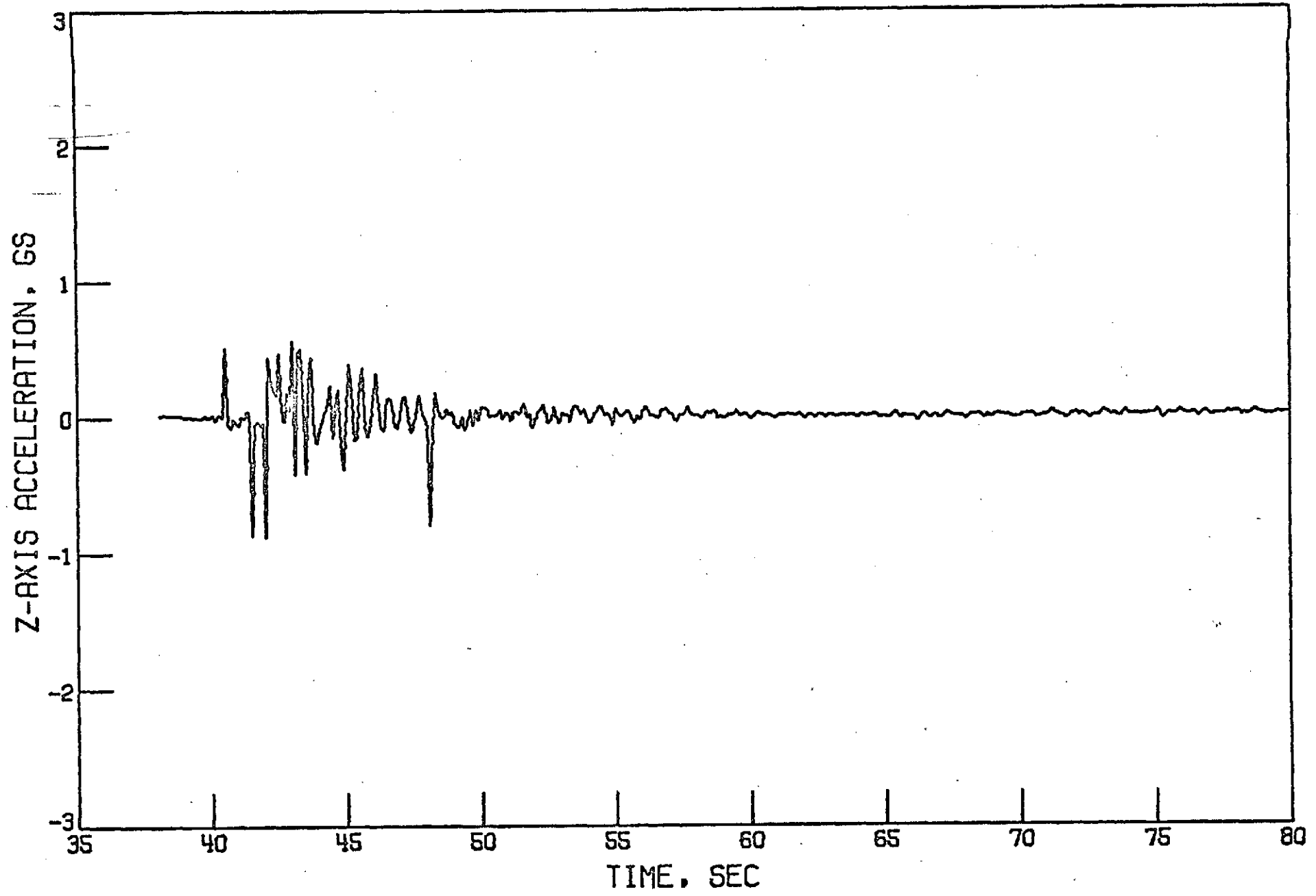


Figure 16. Telemetered Z-Axis Acceleration after Mortar Fire

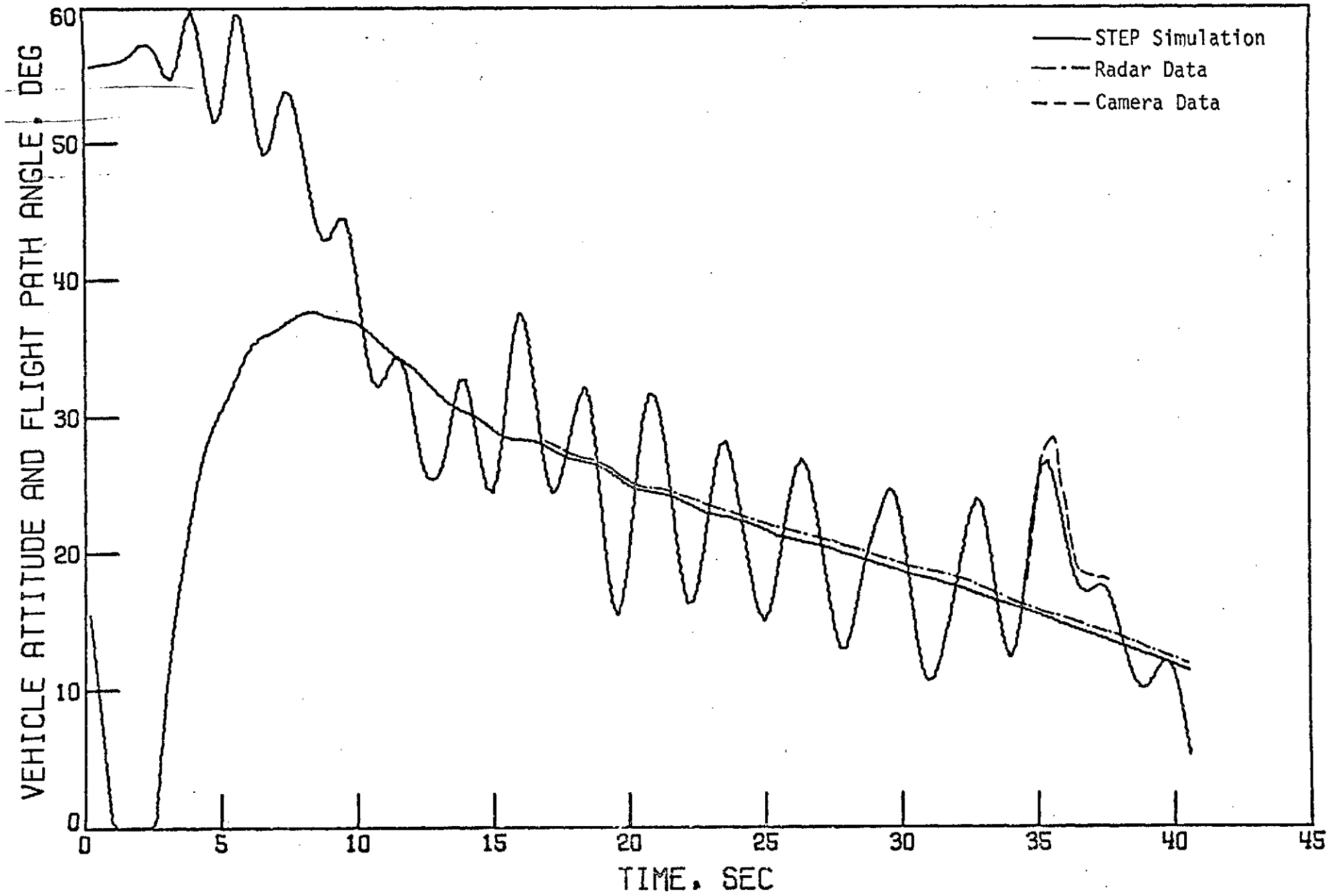


Figure 17. Vehicle Attitude and Flight Path Angle from Drop to Mortar Fire



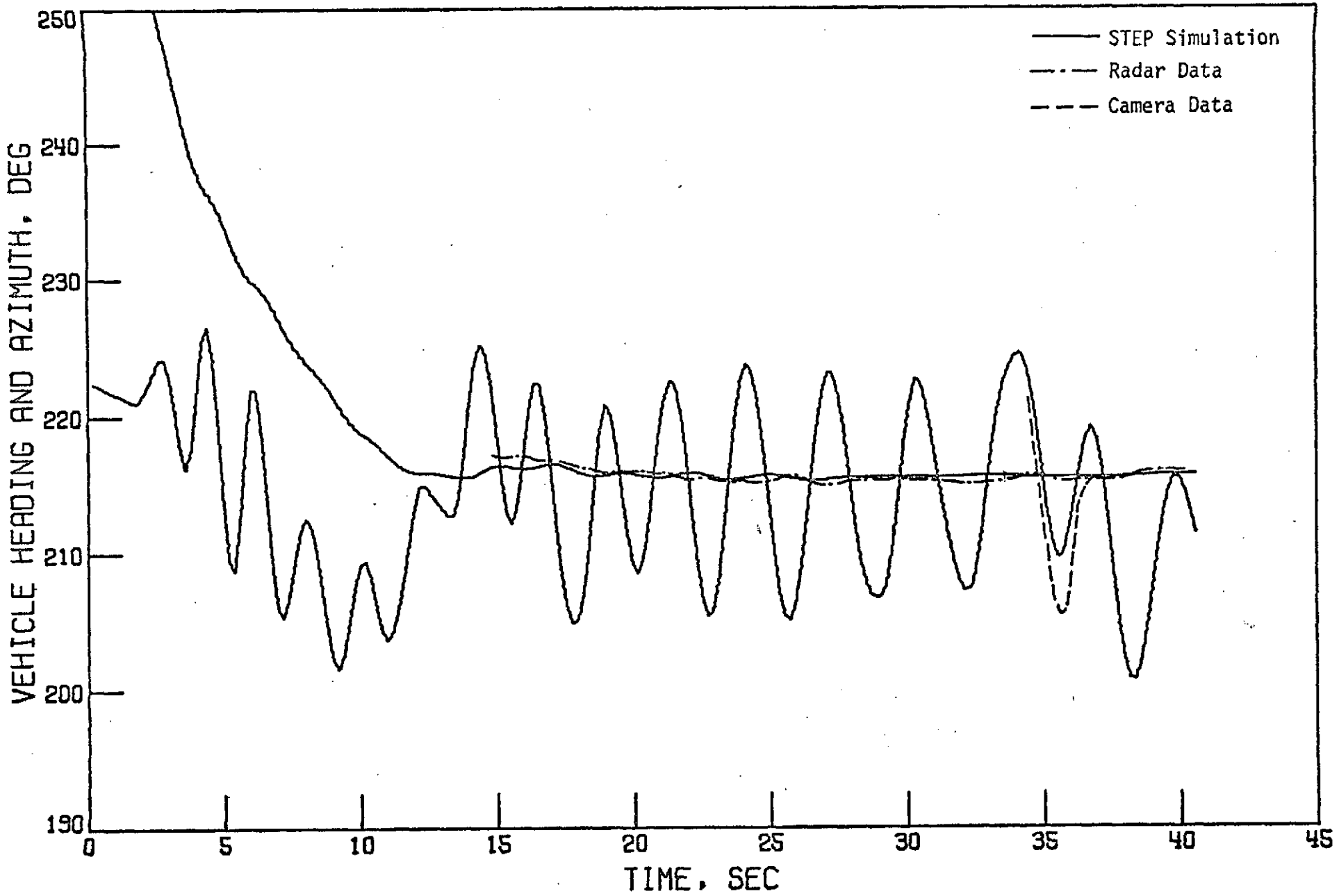


Figure 18. Vehicle Heading and Azimuth from Drop to Mortar Fire

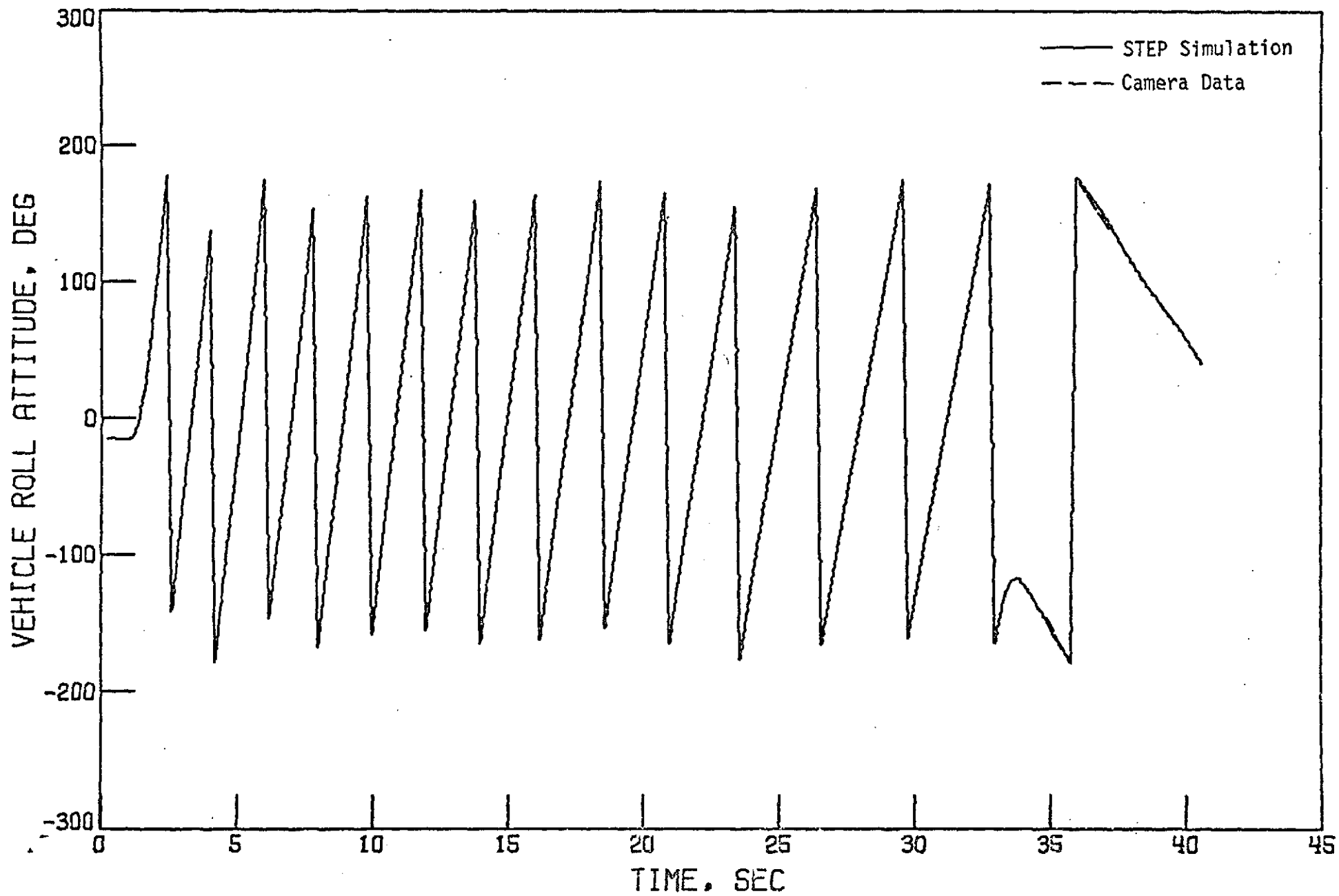


Figure 19. Vehicle Roll Attitude from Drop to Mortar Fire

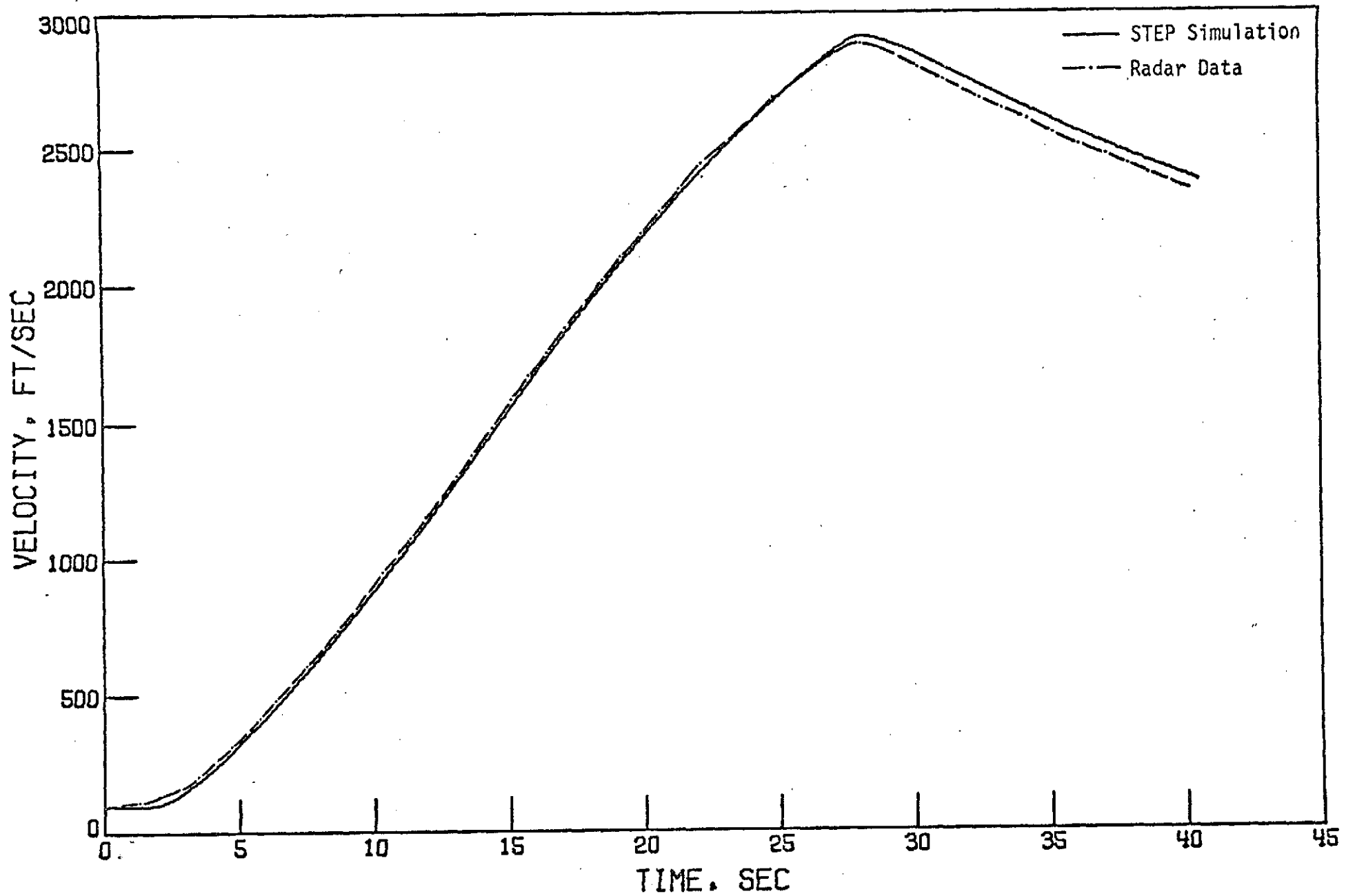


Figure 20. Velocity from Drop to Mortar Fire

28

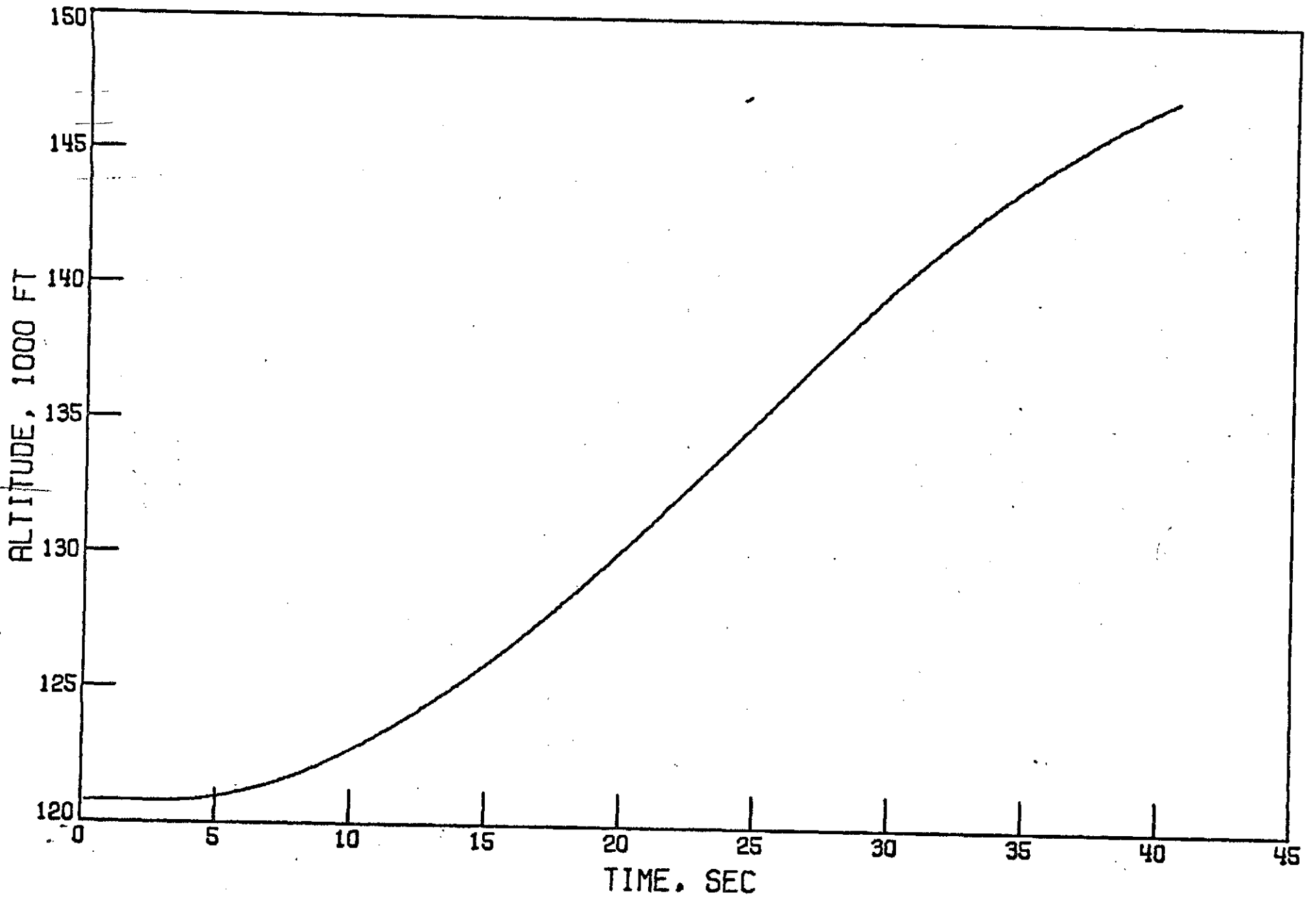
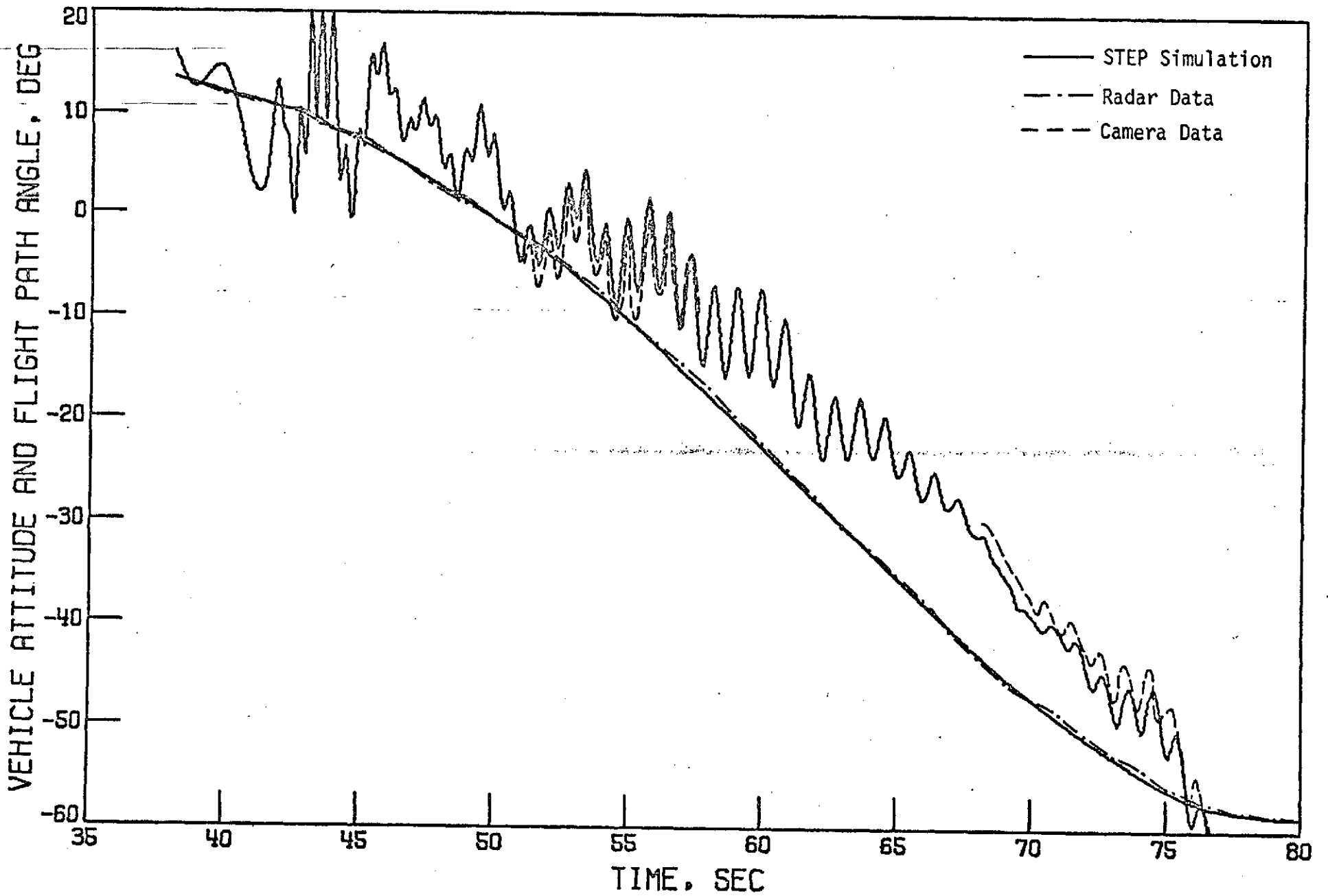


Figure 21 Altitude from drop to Mortar Fire



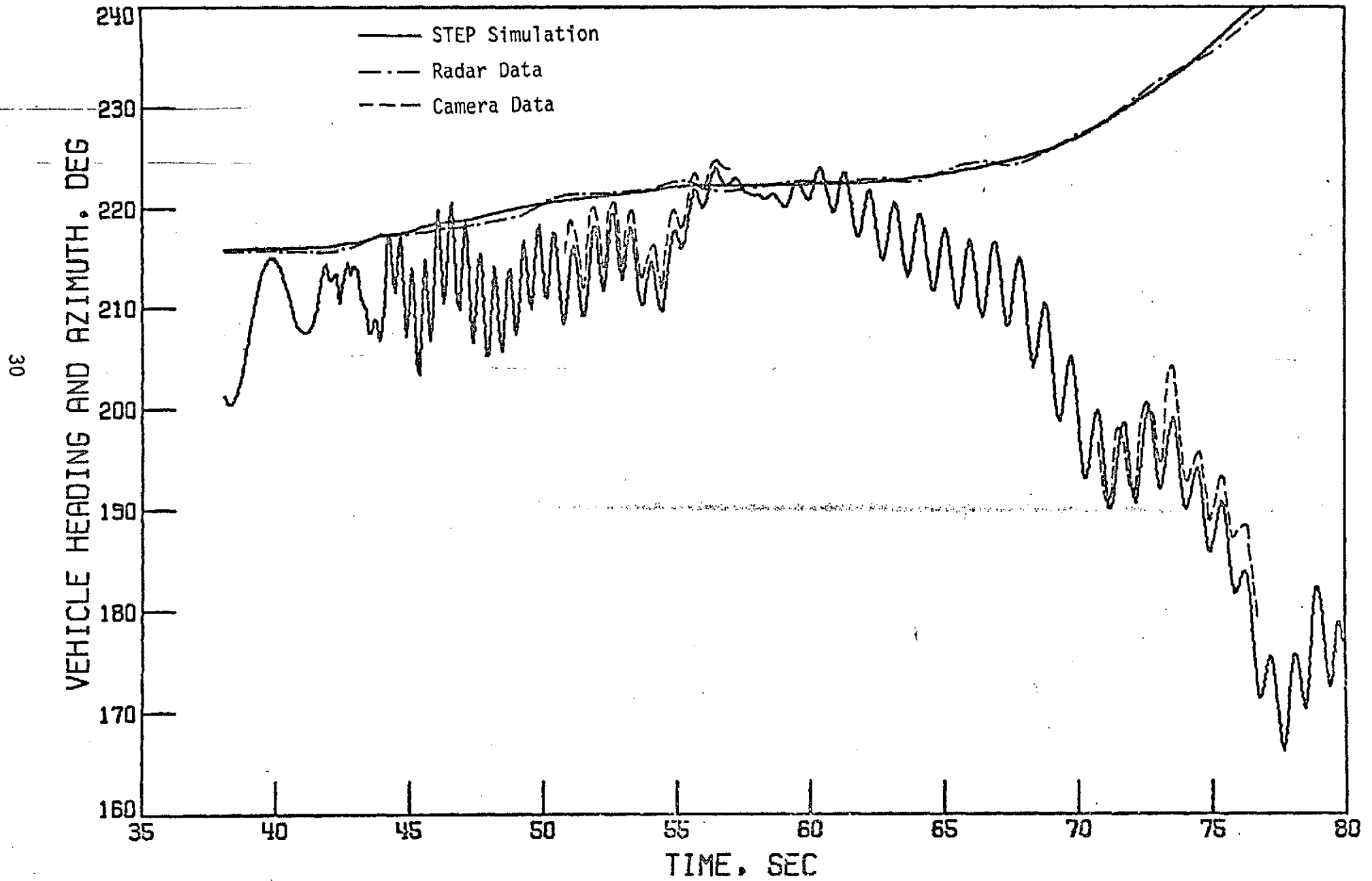


Figure 23. Vehicle Heading and Azimuth after Mortar Fire

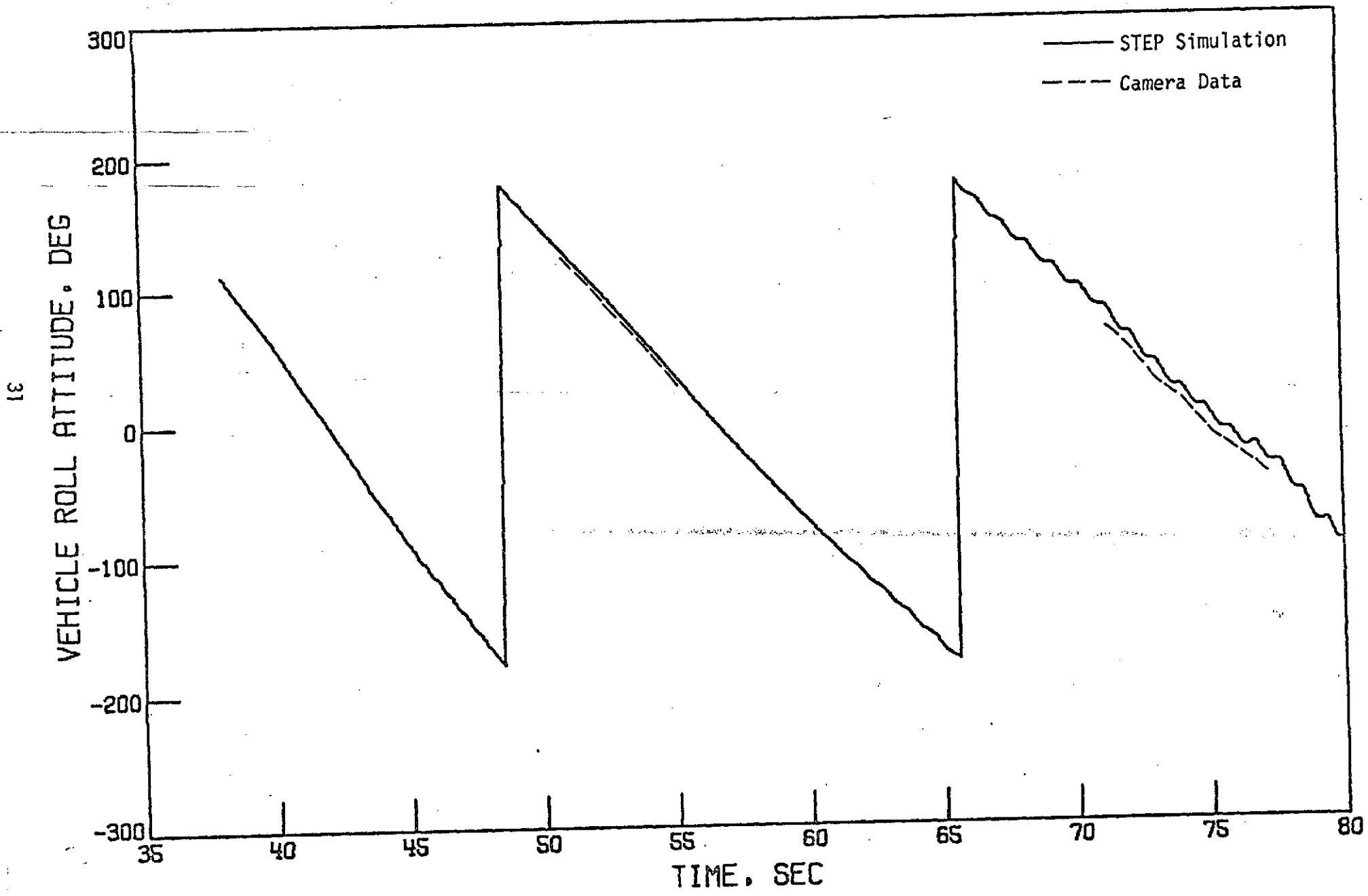


Figure 24. Vehicle Roll Attitude after Mortar Fire

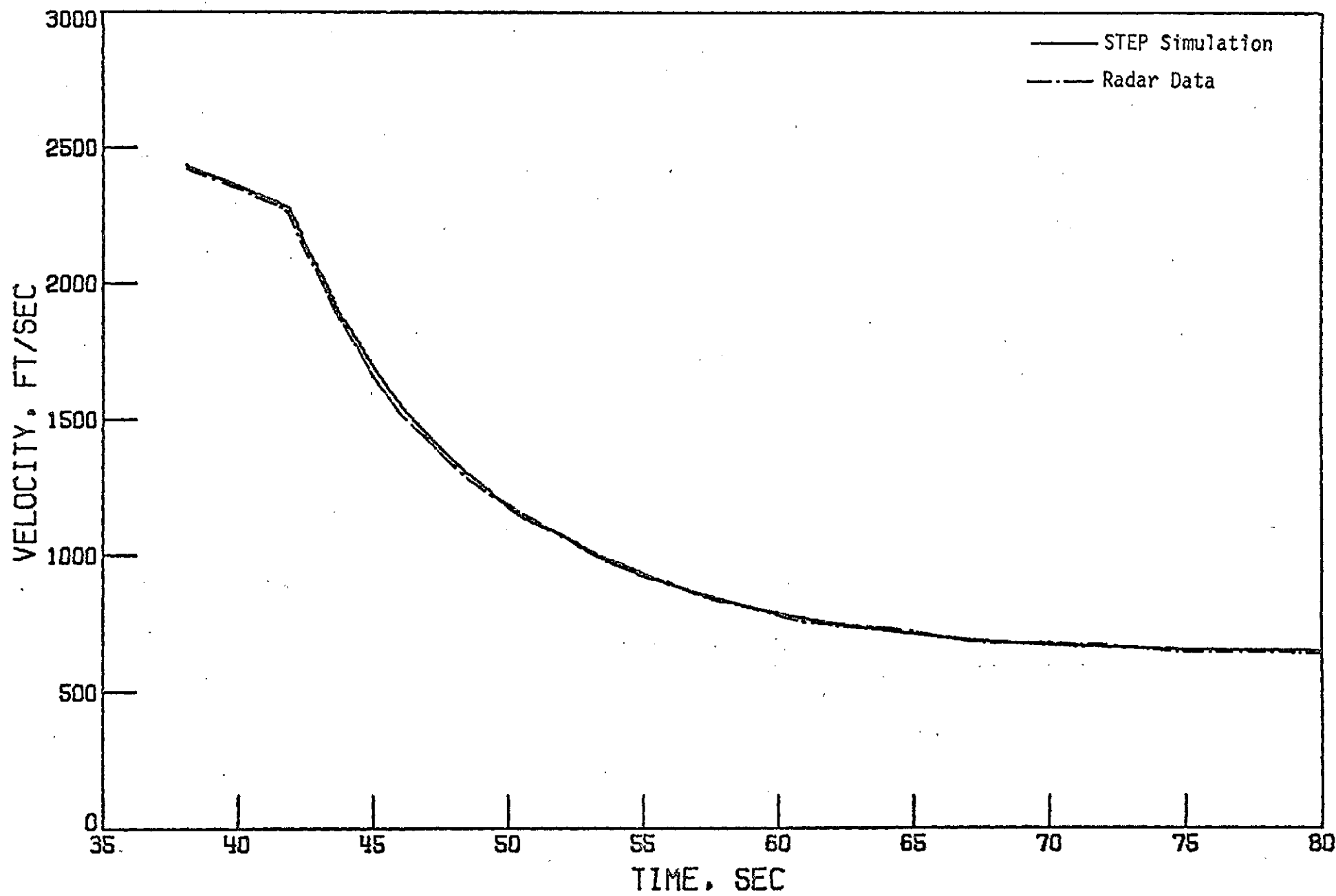


Figure 25. Velocity after Mortar Fire



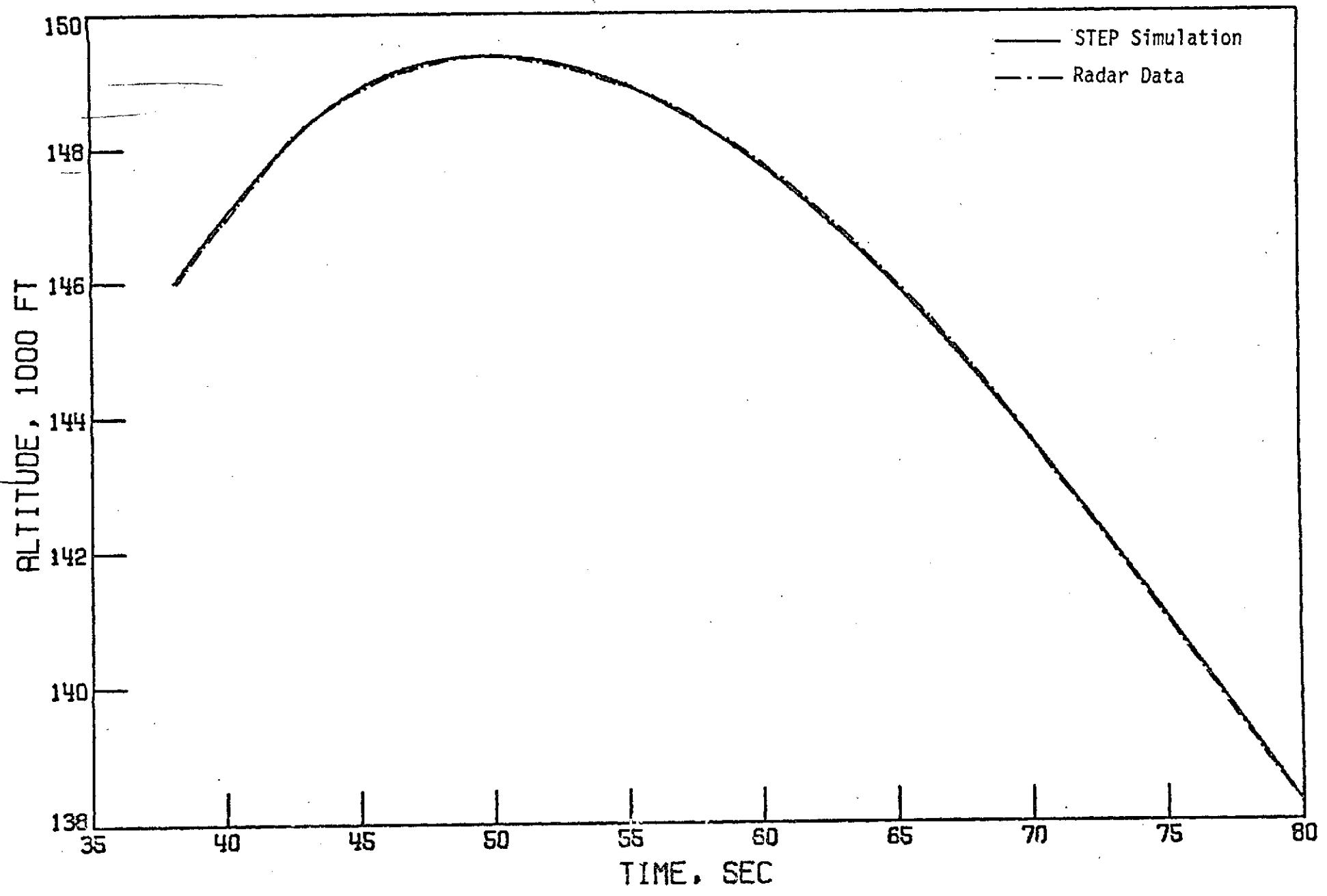


Figure 26. Altitude after Mortar Fire

## APPENDIX

SAMPLE COMPUTER INPUT

```

JOB,1,0600,100000,08000.      E1703  RYJ107      100349      BIN NO.  67
USER,DOE, J                    971561868  67200 NAS1-10900 LTV
LINECNT(10000)
REWIND(SCFILE)
FFTCH(E1719,SPRA06,SOURCE)
NORFL.
RUN(S,,,SCFILE,TRASH)
REQUEST,TAPE1,HY.              714007,ROL,TEC,RADAR-STEP FOR AV-4
REQUEST,TAPE2,HY.              413054,ROL,EWS,AV-4 STEP2 INPUT PQR
REQUEST,TAPE9,HY.              406017,RIL,EWS,STEP PLOT
REWIND(TAPE1)
REWIND(TAPE2)
REWIND(TAPE9)
SETCORE.
LGO.
DROPFIL(TAPE1)
DROPFIL(TAPE2)
RUN(S,,,,,BILLY,,,,)
REQUEST,TAPE10,HY.             404031,RIL,EWS,STEP PLOT FORWD AV-4
REQUEST,TAPE11,HY.            404039,RIL,EWS,STEP PLOT BCKWD AV-4
REWIND(TAPE9)
REWIND(TAPE10)
REWIND(TAPE11)
SFTINDF.
BILLY.
DROPFIL(TAPE9)
DROPFIL(TAPE10)
REWIND(TAPE11)
RUN(S,,,,,MIKE,,,,)
SFTINDF.
MIKE.
DROPFIL(TAPE11)
REWIND(CALTPE)
REQUEST,TAPE8,HI,X.            CALTP,RIM,EWS,STEP SIM
REWIND(TAPE8)
COPYBF(CALTPE,TAPE8)
UNLOAD(TAPE8)
EXIT.
REWIND(CALTPE)
REQUEST,TAPE8,HI,X.            CALTP,RIM,EWS,STEP SIM
REWIND(TAPE8)
COPYBF(CALTPE,TAPE8)
UNLOAD(TAPE8)
DROPFIL(TAPE11)

```

A-1

```

DROPFIL(TAPE2)
DROPFIL(TAPE9)
DROPFIL(TAPE10)
DROPFIL(TAPE11)
(789 CARD)
CUTOUT      2
      2      TAPE1,TAPE2,TAPE3,TAPE4,TAPE7,TAPE9)
CUTOUT      50      51
CUTOUT      61      62
CUTOUT      78
      44 CALL OUTPT
CUTOUT      701
      IF(EOF,IN)2000,2001
      2001 WRITE(OUT,1001) KDUM,(B(I),I=1,8)
PUTIN      864
      2000 STOP
CUTOUT      1805
      SUBROUTINE OUTPT
PUTIN      1843
      IF(ST(1)+CT(1) .EQ. 0.) CT(1)=.00001
PUTIN      1847
      IF(ST(2)+CT(2) .EQ. 0.) CT(2)=.00001
PUTIN      1869
      IF(ST(4)+CT(4) .EQ. 0.) CT(4)=.00001
PUTIN      1873
      IF(ST(5)+CT(5) .EQ. 0.) CT(5)=.00001
PUTIN      1880
      IF(ST(3)+CT(3) .EQ. 0.) CT(3)=.00001
PUTIN      1882
      IF(SP(1)+VO(1) .EQ. 0.) VO(1)=.00001
CUTOUT      1896
      VO(17)=VO(17)/57.3
      VO(18)=VO(18)/57.3
      BILLE=ATAN(SQRT(TAN(VO(17))**2+TAN(VO(18))**2))
      BILLE=BILLE*57.3
      VO(17)=VO(17)*57.3
      VO(18)=VO(18)*57.3
      WRITE(OUT,1008) (XP(I),I=1,3),(SP(I),I=1,2),BILLE
PUTIN      1899
      PPPPP=PA(1)*57.296
      QQQQQ=PA(2)*57.296
      RRRRR=PA(3)*57.296
      WRITE(9)TO,VO(1),VO(2),VO(3),VO(4),VO(17),VO(18),PPPPP,QQQQQ,RRRRR
      1,AB(1),AB(2),AB(3),VO(10),VO(11),VO(12),BILLE

```

CUTOUT 2889  
24 CALL OUTPT

(789 CARD)

1 AV-4 STEP SIMULATION BEFORE MORTAR FIRE

2 0 1 1 0 0 0 0 3 0 0

3 1	1	100.1	2.	INITIAL VELOCITY	
3 1	2	1.4	.010	INITIAL FLIGHT PATH ANGLE	
3 1	3	-126.	.010	INITIAL AZIMUTH ANGLE	
3 1	4	120762.	50.	INITIAL ALTITUDE	
3 1	5	33.28710	.001	INITIAL LATITUDE	
3 1	6	-106.23220	.001	INITIAL LONGITUDE	
3 1	7	-137.	.0001	VEHICLE ROLL ATTITUDE, PSI	
3 1	8	55.	.0001	VEHICLE PITCH ATTITUDE, THETA	
3 1	9	0.	.01	VEHICLE YAW ATTITUDE, PHI	
3 5	36	.9835		ROLL SCALE FACTOR	
3 5	40	1.		PITCH SCALE FACTOR	
3 5	44	1.		YAW SCALE FACTOR	
3 5	45	-.01745		ROLL BIAS	
3 5	46	-.010646		PITCH BIAS	
3 5	47	-.06108		YAW BIAS	
3 5	61	1.		X-AXIS ACCELERATION SCALE FACTOR	
3 5	65	1.		Y-AXIS ACCELERATION SCALE FACTOR	
3 5	69	1.		Z-AXIS ACCELERATION SCALE FACTOR	
3 5	70	0.		X-AXIS ACCELERATION BIAS	
3 5	71	0.		Y-AXIS ACCELERATION BIAS	
3 5	72	0.		Z-AXIS ACCELERATION BIAS	
3 5	88	32.90139333		R-123 RADAR SITE LATITUDE	
3 5	89	-106.098614		R-123 RADAR SITE LONGITUDE	
3 5	90	4149.53		R-123 RADAR SITE ALTITUDE	
4		.2	.2	.1	40.40
5 2		20909158.8	20909158.8	.00007292116	
7 1		0.20	40.40	.10 1 1 1	6.666 .00001333 .00001333

20

(789 CARD)

```

PROGRAM TAPES(INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT,TAPE9,TAPE10,T
1APE11)
DIMENSION A(25),AA(25)
199 FORMAT(128H1 TIME VELOCITY FPA AZIMUTH ALTITUDE BETA ALP
1HA ROLL PITCH YAW AX AY AZ PSI THETA PHI
2 ETA )
299 FORMAT(128H SEC FT/SEC DEG DEG FT DEG DE
1G DEG/SECDEG/SECDEG/SEC G.S G.S G.S DEG DEG DEG
2 DEG /)
DO 10 I=1,136
READ(9)(A(L),L=1,17)
A(11)=A(11)/32.174
A(12)=A(12)/32.174
A(13)=A(13)/32.174
WRITE(10)(A(L),L=1,17)
10 CONTINUE
END FILE 10
DO 20 I=1,135
READ(9)(AA(L),L=1,17)
20 CONTINUE
DO 30 I=1,136
READ(9)(AA(L),L=1,17)
AA(11)=AA(11)/32.174
AA(12)=AA(12)/32.174
AA(13)=AA(13)/32.174
WRITE(11)(AA(L),L=1,17)
BACKSPACE 9
BACKSPACE 9
30 CONTINUE
END FILE 11
100 FORMAT(1F7.2,1F10.2,2F7.2,1F12.2,12F7.2)
STOP
END
(789 CARD)

```

```

PROGRAM BRUTUS(INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT,TAPE11,TAPE8)
DIMENSION IJ(17),A(17,300),X(300),Y(300)
DIMENSION IPH(100),BCDX(8),BCDY(8)
CALL CALCOMP
CALL LEROY
IT=0
CALL CALPLT(0.,0.,-3)
1-----
1  FORMAT(2I5)
   READ(5,2)NI,(IJ(N),N=1,NI)
2-----
2  FORMAT(16I5)
   READ(5,2)NCASES,(IPH(M),M=1,NCASES)
24  IM=1
25  IPHASE=IPH(IM)
   JI=0
   DO 27 I=1,10000
   READ(11)(A(N,I),N=1,NI)
   IF(EOF,11)28,27
28  JI=JI+1
   I=I-1
   IF(JI.GE.IPHASE) GO TO 29
27  CONTINUE
29  IT=I
   IM=IM+1
30  READ(5,2)NOW,NGO
   IF(NOW.EQ.3) GO TO 25
   IF(NOW.EQ.2)GO TO 65
4   READ(5,45)ILIM,BOTLIM,UPLIM,XNEW
45  FORMAT(1I10,3F10.5)
   READ(5,5)IX,XIN,XMIN,XMAX,XMLTPY,TMAJX
   READ(5,5)IY,YIN,YMIN,YMAX,YMLTPY,TMAJY
5   FORMAT(1I5,1F5.2,4F10.5)
   IF(NOW.EQ.4) GO TO 61
   READ(5,1)NX,NY
   MX=NX/10.+9
   MY=NY/10.+9
   READ(5,6)(BCDX(N),N=1,MX)
   READ(5,6)(BCDY(N),N=1,MY)
6   FORMAT(8A10)
61  DO 7 N=1,NI
   IF(ILIM.EQ.IJ(N))ITIME=N
   IF(IX.EQ.IJ(N))IXN=N
   IF(IY.EQ.IJ(N))IYN=N
7   CONTINUE
   YMIN=YMIN*YMLTPY

```

```

YMAX=YMAX*YMLTPY
XMIN=:MIN*XMLTPY
XMAX=XMAX*XMLTPY
DX=(XMAX-XMIN)/XIN
DY=(YMAX-YMIN)/YIN
65 K=0
DO 8 I=1,IT
IF(A(ITIME,I).LT.BOTLIM) GO TO 8
IF(A(ITIME,I).GT.UPLIM) GO TO 8
K=K+1
X(K)=A(IXN,I)*XMLTPY
Y(K)=A(IYN,I)*YMLTPY
IF(X(K).GT.XMAX) X(K)=XMAX
IF(Y(K).GT.YMAX) Y(K)=YMAX
IF(X(K).LT.XMIN) X(K)=XMIN
IF(Y(K).LT.YMIN) Y(K)=YMIN
X(K)=(X(K)-XMIN)/DX
Y(K)=(Y(K)-YMIN)/DY
8 CONTINUE
IK=K
IF(NOW.EQ.2.OR.NOW.EQ.4) GO TO 85
CALL CALPLT(XNEW,0.,-3)
TM=1./TMAJX
CALL AXES(0.,0.,0.,XIN,XMIN,DX,TMAJX,TM,BCDX,.15,-NX)
TM=1./TMAJY
CALL AXES(0.,0.,90.,YIN,YMIN,DY,TMAJY,TM,BCDY,.15,NY)
CALL CALPLT(XIN,0.,3)
CALL CALPLT(XIN,YIN,2)
CALL CALPLT(0.,YIN,2)
85 CALL CALPLT(X(1),Y(1),3)
DO 9 I=2,IK
9 CALL CALPLT(X(I),Y(I),2)
92 GO TO (25,97,10,30)NGO
97 REWIND 11
IT=0
GO TO 24
10 CALL CALPLT(0.,0.,3)
CALL CALPLT(0.,0.,999)
STOP
END
(789 CARD)
17 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114
115 116
1 1

```

A-6



1	4					
	100	0.	45.	15.00		
100	9.	0.	45.	1.	1.	
108	6.	-30.	30.	1.	1.	
9	19					
TIME, SEC						
PITCH RATE, DEG/SEC						
1	4					
	100	0.	45.	15.00		
100	9.	0.	45.	1.	1.	
109	6.	-30.	30.	1.	1.	
9	17					
TIME, SEC						
YAW RATE, DEG/SEC						
1	4					
	100	0.	45.	15.00		
100	9.	0.	45.	1.	1.	
107	6.	-50.	250.	1.	1.	
9	18					
TIME, SEC						
ROLL RATE, DEG/SEC						
1	4					
	100	0.	45.	15.00		
100	9.	0.	45.	1.	1.	
110	6.	-2.	6.	1.	.75	
9	24					
TIME, SEC						
X-AXIS ACCELERATION, GS						
1	4					
	100	0.	45.	15.00		
100	9.	0.	45.	1.	1.	
111	6.	-3.	3.	1.	1.	
9	23					
TIME, SEC						
Y-AXIS ACCELERATION, GS						
1	4					
	100	0.	45.	15.00		
100	9.	0.	45.	1.	1.	
112	6.	-3.	3.	1.	1.	
9	24					
TIME, SEC						
Z-AXIS ACCELERATION, GS						
1	4					
	100	0.	45.	15.00		

100	9.	0.	45.	1.	1.
102	6.	0.	60.	1.	1.
9	43				

TIME, SEC

VEHICLE ATTITUDE AND FLIGHT PATH ANGLE, DEG

4	4				
	100	0.	45.	0.	
100	9.	0.	45.	1.	1.
114	6.	0.	60.	1.	1.
1	4				
	100	0.	45.	15.00	
100	9.	0.	45.	1.	1.
103	6.	190.	250.	1.	1.
9	32				

TIME, SEC

VEHICLE HEADING AND AZIMUTH, DEG

4	4				
	100	0.	45.	0.	
100	9.	0.	45.	1.	1.
113	6.	190.	250.	1.	1.
1	4				
	100	0.	45.	15.00	
100	9.	0.	45.	1.	1.
115	6.	-300.	300.	1.	1.
9	26				

TIME, SEC

VEHICLE ROLL ATTITUDE, DEG

1	4				
	100	0.	45.	15.00	
100	9.	0.	45.	1.	1.
101	6.	0.	3000.	1.	1.
9	16				

TIME, SEC

VELOCITY, FT/SEC

1	3				
	100	0.	45.	15.00	
100	9.	0.	45.	1.	1.
104	6.	120000.	150000.	.001	1.
9	17				

TIME, SEC

ALTITUDE, 1000 FT

(789 CARD)

(6789) CARD

INPUT INSTRUCTIONS FOR PLOTTING PROGRAM

CARD	COLUMNS	PARAMETER	DEFINITION	UNITS	FORMAT
1	1-5	NI	Number of A-arrays on the data tape (e.g.: 3)		16I5
	6-10	IJ (1)	A-array indicies ordered as on the data tape		1
	11-15 etc.	IJ (2) etc.	(e.g.: 100 108 120)		
	51-55	IJ (10)			
2	1-5	NCASES	Number of trajectory cases on the data tape (e.g.: 25) (100)		1I5
	6-10	IPH (1)	Number of phases of each of these cases		
	11-15 etc.	IPH (2) etc.	Ordered as on the data tape (e.g.: 4)		
	76-80	IPH (15)	Use as many cards as necessary filling from the left most columns (1-5)		
3	1-5	NOW	Operation Instruction for Plotting This Data Group: = 1, Plot this data group on a new grid = 2, Plot this data group on the previous grid = 3, Skip this data group = 4, Special patch plot option		2I5
	6-10	NGØ	Operation Instruction for After This Plot: = 1, Continue to next data group = 2, Return to first data group = 3, Stop = 4, Continue with this same data group		
NOTE: If Now = 1 continue with Cards 4, 5, 6, 7, and 8 If Now = 2 or 3 repeat Card 3 for next data group If Now = 4 read only cards 4, 5 and 6					
4	1-10	ILIM	A-array index (on data tape) which is used to limit the plot range (e.g.: = 100 is time limited)		1I10
	11-20	BOTLIM	Lower limit value of ILIMIT (e.g.: 0. seconds)		1F10.5
	21-30	UPLIM	Upper limit value of ILIMIT (e.g.: 40.3 seconds)		1F10.5
	31-40	XNEW	Absissa value of origin for this grid.		1F10.5

A-9

CARD	COLUMNS	PARAMETER	DEFINITION	UNITS	FORMAT
5	1-5	IX	A-array index for abscissa		
	6-10	XIN	Length of abscissa axis (e.g.: 9 inches)		1I5
	11-20	XMIN	Origin value of abscissa (e.g.: 0. seconds)	inches	1F5.2
	21-30	XMAX	Maximum value of abscissa (e.g.: 45 seconds)		1F10.5
	31-40	XMLTPY	Abscissa multiplying factor to scale axis label between .001 and 999. (e.g.: 1.)		1F10.5
	41-50	TMAJX	Abscissa numbered label spacing (e.g.: 1. inch)	inches	1F10.5
6	1-5	IY	A-array index for ordinate		
	6-10	YIN	Length of ordinate axis (e.g.: 8 inches)		1I5
	11-20	YMIN	Origin value of ordinate (e.g.: 0. feet)	inches	1F5.2
	21-30	YMAX	Maximum value of ordinate (e.g.: 400000. feet)		1F10.5
	31-40	YMLTPY	Ordinate multiplying factor to scale axis label between .001 and 999. (e.g.: .001)		1F10.5
	41-50	TMAJY	Ordinate numbered label spacing (e.g.: 2. inches)	inches	1F10.5
7	1-5	NX	Number of digits in the abscissa axis label (e.g.: 26)		1I5
	6-10	NY	Number of digits in the ordinate axis label (e.g.: 20)		1I5
8	1-80	BCDX	Abscissa axis label identification (include scaled effects) (e.g.: TIME FROM LAUNCH SECONDS)		8A10
9	1-80	BCDY	Ordinate axis label identification (include scaled effects) (e.g.: ALTITUDE (1000 FEET) )		8A10

NOTE: If NGO = 1 return to Card 3 for the next data group on the tape  
 If NGO = 2 return to Card 3 for the first data group on the tape  
 If NGO = 3 no more input cards are required  
 If NGO = 4 return to Card 3 for the same data group