Analysis of Crash Data from the MATAI Conference Exhibition Crashes:

May 20th, 1997 at the Ingham County Fairgrounds

June 17, 1997

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ABSTRACT:

The study of accidents and accident reconstruction requires the analyst to apply the theory of motion, friction, and energy dissipation to real world impacts. It is often the case that these impacts occur in a short, violent and unexpected manner. There is no handy way to quantitatively measure the forces involved. The data is preserved in several forms: The qualitative observations of witnesses that sometimes conflict one another, the qualitative condition of the post-impact vehicle(s), and the quantitative measurement of the accident scene.

The practice of crash testing offers the accident investigator the opportunity to witness in a controlled manner the real-world application of accident theory. The investigator can employ many different tools to directly measure the kinematics involved in the impact. High-speed cameras, RADAR, LASER, and accelerometer-based systems can all be used to verify theory-based investigative methods.

This document deals with the application of triaxial crash recorders in several staged crashes. The Michigan Association of Traffic Accident Investigators (MATAI) staged these crash tests on May 20, 1997. The three tests occurred during the MATAI conference at the Ingham County Fairgrounds in Mason, Michigan.

Table of Contents:

Test Description:

IST provided three separate data recorders for the test. These recorders recorded the energy transfer in the form of acceleration from one vehicle to the next. One of the recorders was mounted in the chest cavity of a crash test dummy to examine the dynamics of passenger interaction within the environment of the vehicle.

The three crash tests are examined within this document in varying degrees. The first test involves two vehicles in a broadside collision. This test has the most documentation and includes clips from video footage that show the movement of the crash test dummy inside the vehicle. This movement can be correlated with the acceleration data.

The second test involves two vehicles in a front-end collision. Unfortunately, two of the three systems that were installed did not have available data. This data was lost during the exchange between the lap top computer and the desktop computer used for data analysis. What is left is the data from the crash test dummy.

The third test involves two vehicles in a rear-end collision. All three systems yielded data for this test but there is no video footage with which to correlate the movement of the vehicles.

The illustrations provided in this report represent the acceleration and velocity change of the major axis involved in each crash. Each plot is discussed in the analysis of each crash. **Axis orientations can be found in figures A & B.**

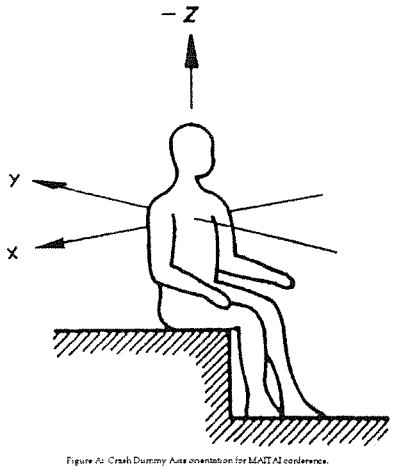


Figure A: Crash Dummy Axis orientation for MATAI conference.

Figure A: Crash dummy axis orientation

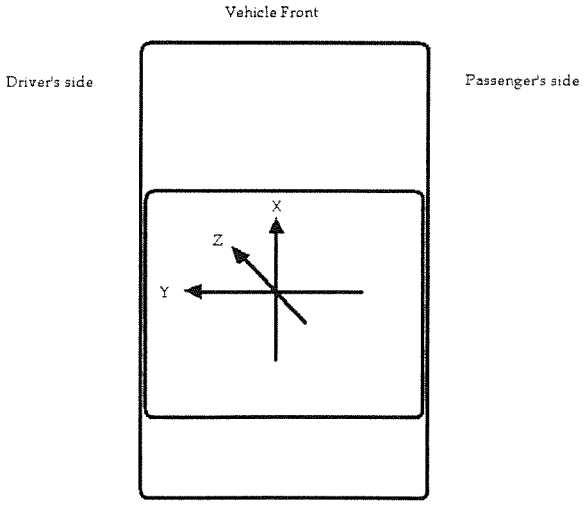


Figure B: Vehicle axis orientation

Figure B: Vehicle axis orientation

Crash test #1: Broadside collision

The broadside collision was staged with 1995 Oldsmobile Cutlass wagon and a 1995 Chevrolet Cavalier. The Cavalier was parked in the path of the wagon for a full-side impact. The crash test dummy was placed into the driver's seat of the cavalier. Seat belts were used for the impact in order to restrain the dummy.

Six video images document the crash. These images show the movement of the crash dummy inside the passenger compartment, as well as the change in attitude of the cavalier as the wagon pushes it sideways down the drive. **(See figures 1 through 6.)**

The three plot sets show the acceleration forces from the crash. Data from the systems shows that acceleration occurred for approximately 1.4 seconds, with the crash dummy coming to final rest at 1.7 seconds. These times include the length of impact, slide, and de-acceleration to rest.

Impact time: An assumption has been made as to the nature and length of the impact time. It is assumed that the impact time is the time required for the Cavalier's acceleration to proceed from zero to peak, and back to zero. After acceleration crosses the zero threshold for a second time, it is assumed that this represents the slide. Analysis of the Cavalier data shows the total acceleration time to be 92 milliseconds, at which time a change in velocity of 4.04 Meters per second (9.03 MPH) is recorded. An initial displacement during this time of 19 CM occurs during this time as well. **(Reference plots 1 - 4.)**

The impact was also observed from the Cutlass Wagon. Analysis of the data shows an impact time of 113 milliseconds, with a ΔV of 3.71 M/sec (8.29 MPH), and an initial displacement of 22 CM. This data is within twenty percent of the Cavalier data and does not take into account contributing factors such as crush of the frontal zone, doors, rotation of vehicles, and etceteras. One interesting note that one can observe in the data is a momentary decrease in acceleration during the initial impact. This occurs at approximately the time at which the crash test dummy impacts the door. This decrease in acceleration can be seen in all three data sets. It is possible that this anomaly could be the secondary impact of the vehicle with the crash dummy. **(Reference plots 5 & 6.)**

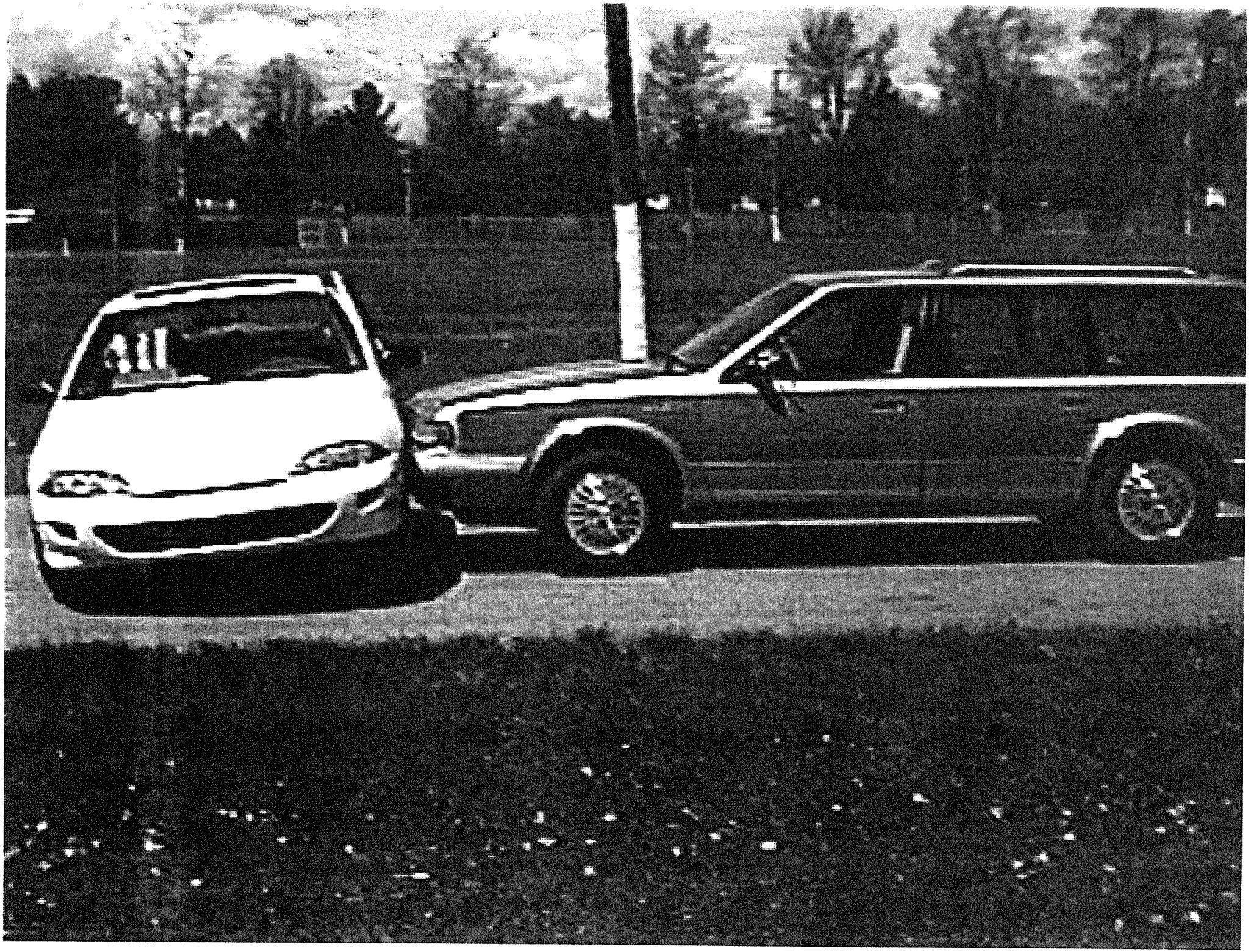
The crash dummy data shows several interesting similarities to the other two data sets. ΔT for the initial impact is 98 milliseconds, with a ΔV of 4.3 M/second (9.6 MPH). Both of these statistics corroborate the data from the vehicle recorders. Plots of the crash dummy data also show acceleration from the impact as well as rebound of the dummy from the seat belt. These motions can be graphically seen on the video sequence photos in **figures 1 through 6. (Reference plots 7 - 9.)** The video sequence shows the dummy's head striking the driver's window, then rebounding across the car until the seat belt stops it's motion when the head is approximately above the center console. At this time, the dummy is violently pulled back into the driver's seat, and the baseball cap that was mounted on the dummy is flung off against the passenger window. This action can be seen at approximately 100 milliseconds after impact in the crash data, in **plot 5.**

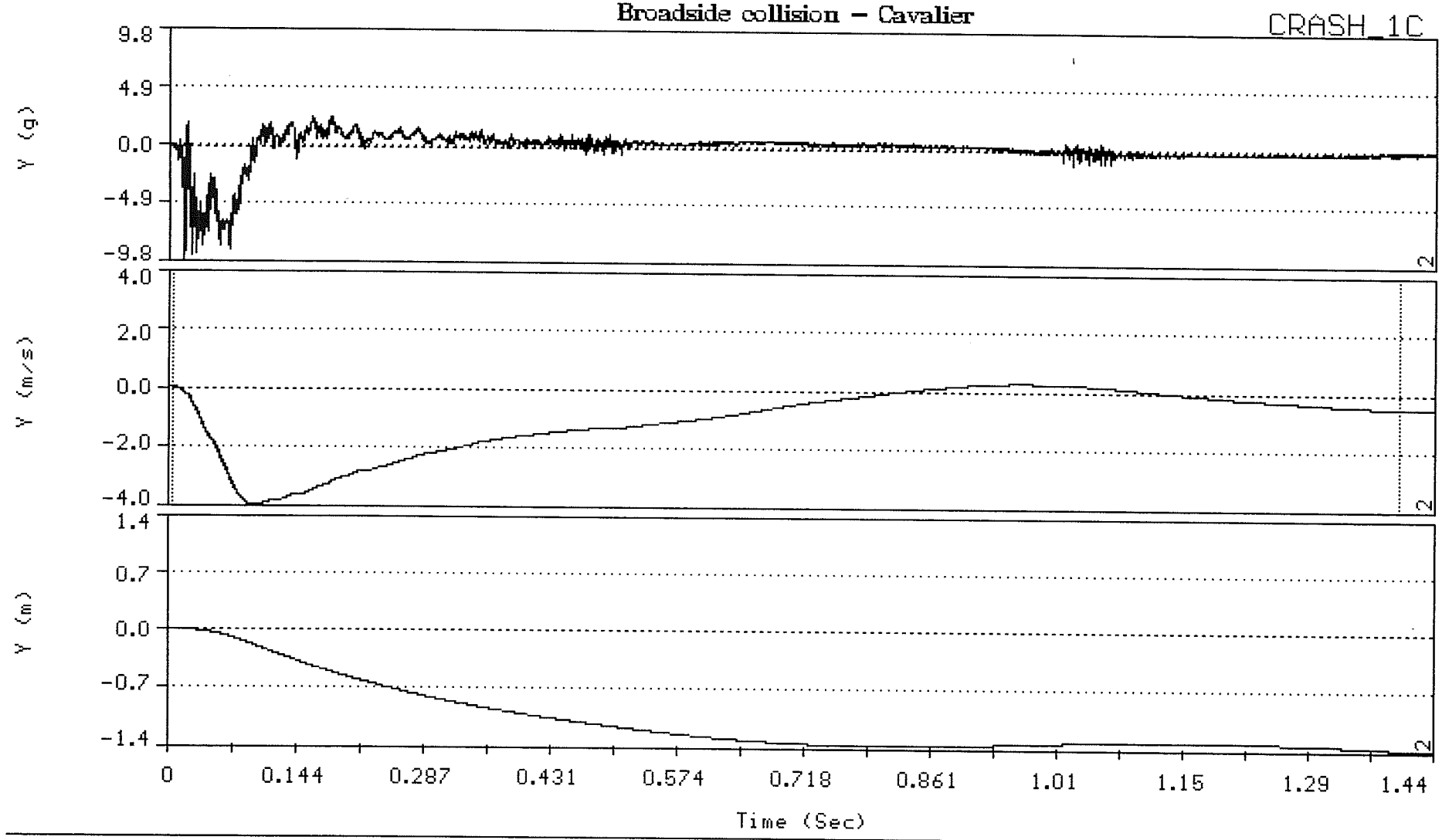
Crash 2: Head-on collision

Unfortunately, no data is available for this event from either vehicle recorder. Technical problems with the recorders and the lap top computer caused this data to be lost. Data was recovered from the crash test dummy, however.

The crash dummy data shows considerable rotation relative to the Y and Z axis. Gravitational forces have influenced the data to make analysis rather difficult. Acceleration has therefore been illustrated as a **resultant,** which is a vector addition of acceleration forces from all three axis.

The initial impact event length was derived from the Y axis, which showed the most acceleration. The impact length was 142 msec, with a corresponding change in velocity of 3.7 M/sec (8.2 MPH). This velocity is derived from the resultant vector. **(See plot #10)**

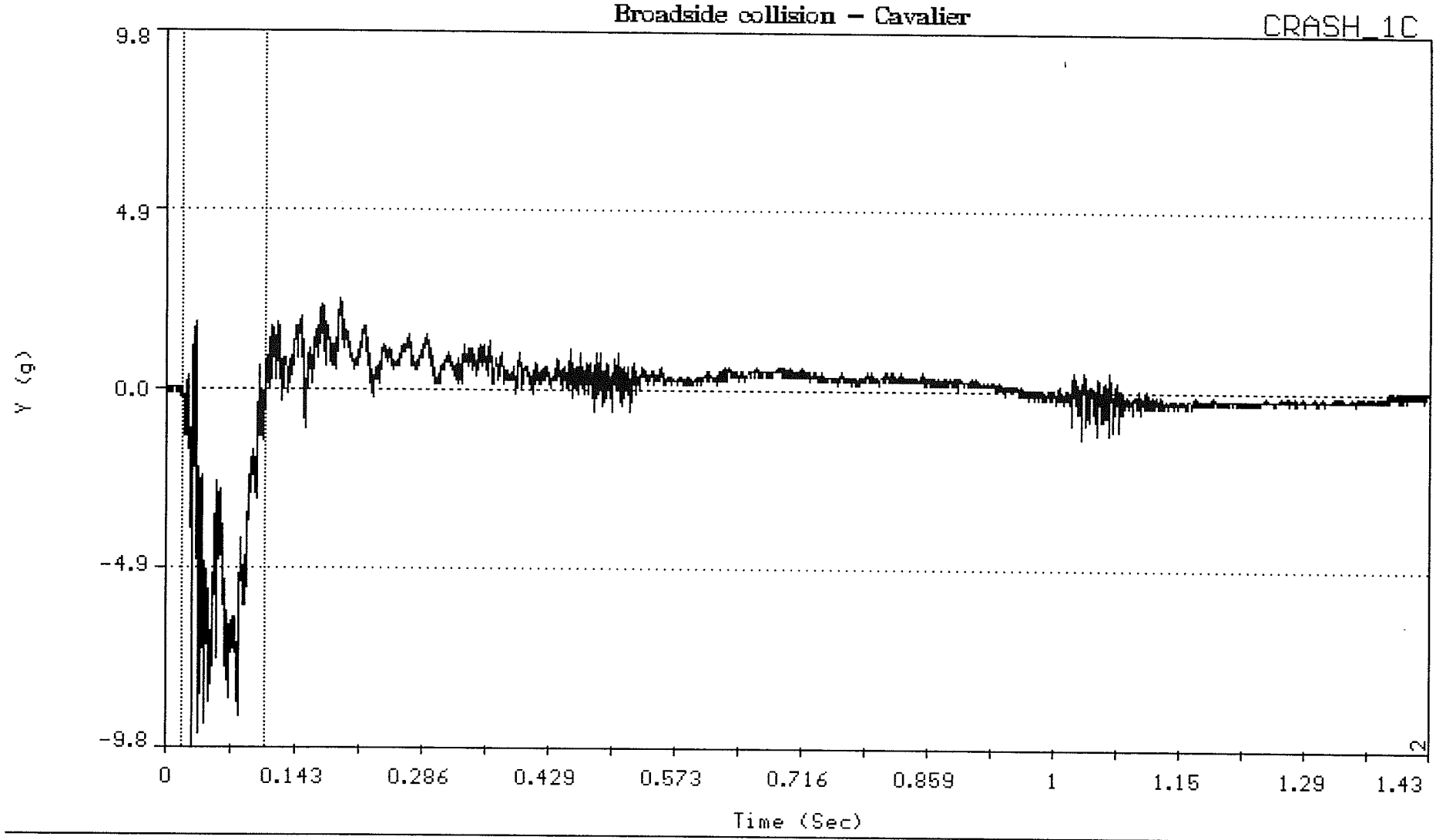




Cursor in window #2 Total points: 4432 1.436 sec
event 2 point 994 0.042 m/s | event 2 point 5286 -0.466 m/s
Delta T: 1.3901 sec 1/T: 0.7193 Hz Delta D: -1.357 m

Events in file: 1
Sample freq: 3087
Samples per event: 8192

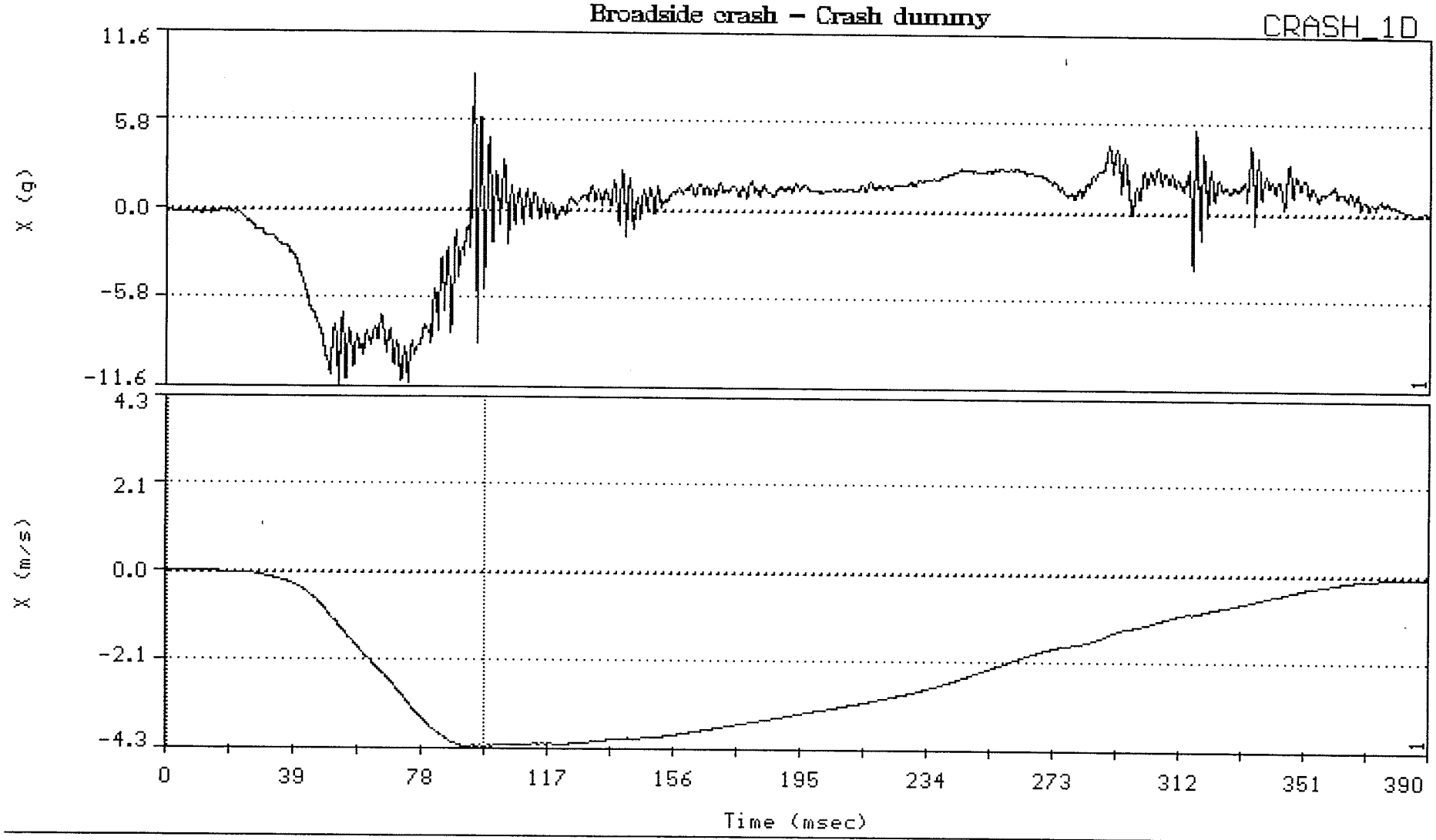
PLOT 1: TOTAL MOVEMENT LENGTH = 1.4 SECONDS



Cursor in window #1 Total points: 4419 1.432 sec
event 2 point 997 -0.061 g | event 2 point 1280 -0.183 g
Delta T: 0.0917 sec 1/T: 10.9097 Hz Delta V: -4.040 m/s

PLOT 2: INITIAL IMPACT. Δt = 92 msec. ΔV = 4.04 m/s

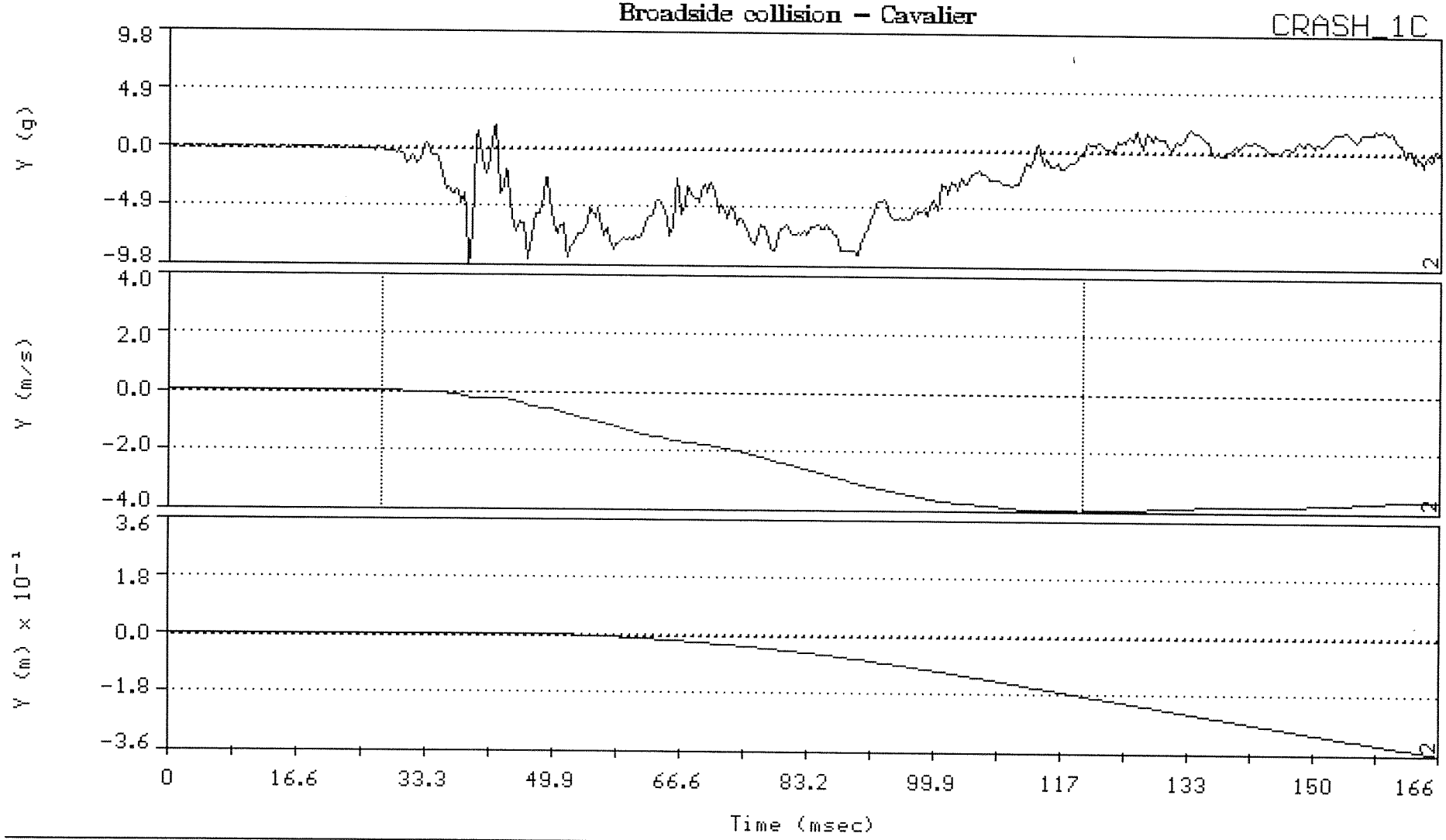
Events in file: 1
Sample freq: 3087
Samples per event: 8192



Cursor in window #2 Total points: 1204 0.390 sec
event 1 point 932 0.029 m/s | event 1 point 1232 -4.251 m/s
Delta T: 0.0972 sec 1/T: 10.2915 Hz Delta D: -0.154 m

PLOT 7: INITIAL IMPACT. $\Delta t = 97$ msec
$\Delta V = 4.3$ m/sec
$\Delta D = 15.4$ cm

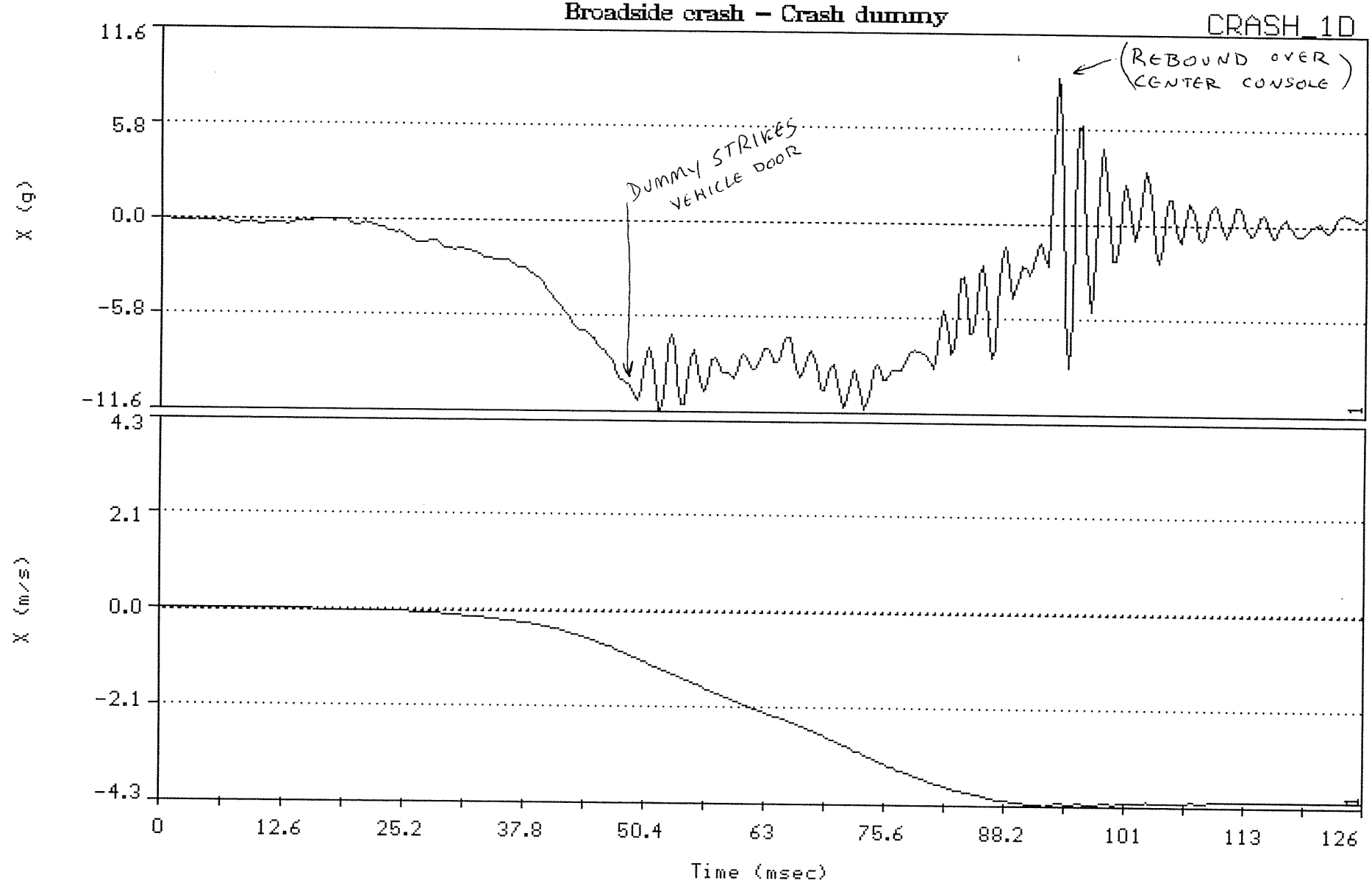
Events in file: 1
Sample freq: 3087
Samples per event: 8192



Cursor in window #2 Total points: 514 0.166 sec
event 2 point 997 0.042 m/s | event 2 point 1280 -3.998 m/s
Delta T: 0.0917 sec 1/T: 10.9097 Hz Delta D: -0.186 m

PLOT 3: INITIAL IMPACT. $\Delta V = 4.04\ m/s$, $\Delta D = 0.186\ M$

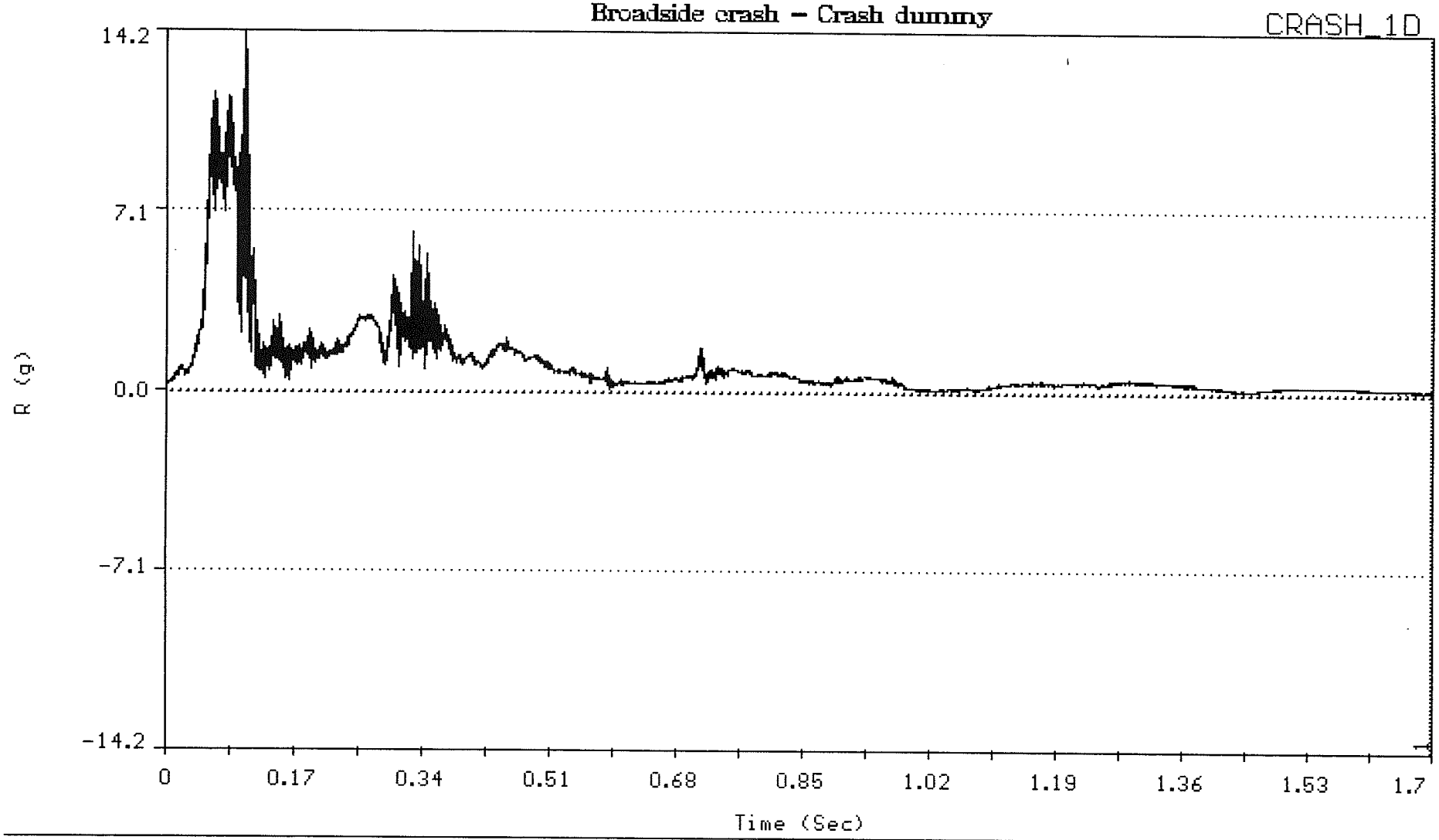
Events in file: 1
Sample freq: 3087
Samples per event: 8192



PLOT 8: INITIAL IMPACT AND REBOUND.

Events in file: 1
Sample freq: 3087
Samples per event: 8192

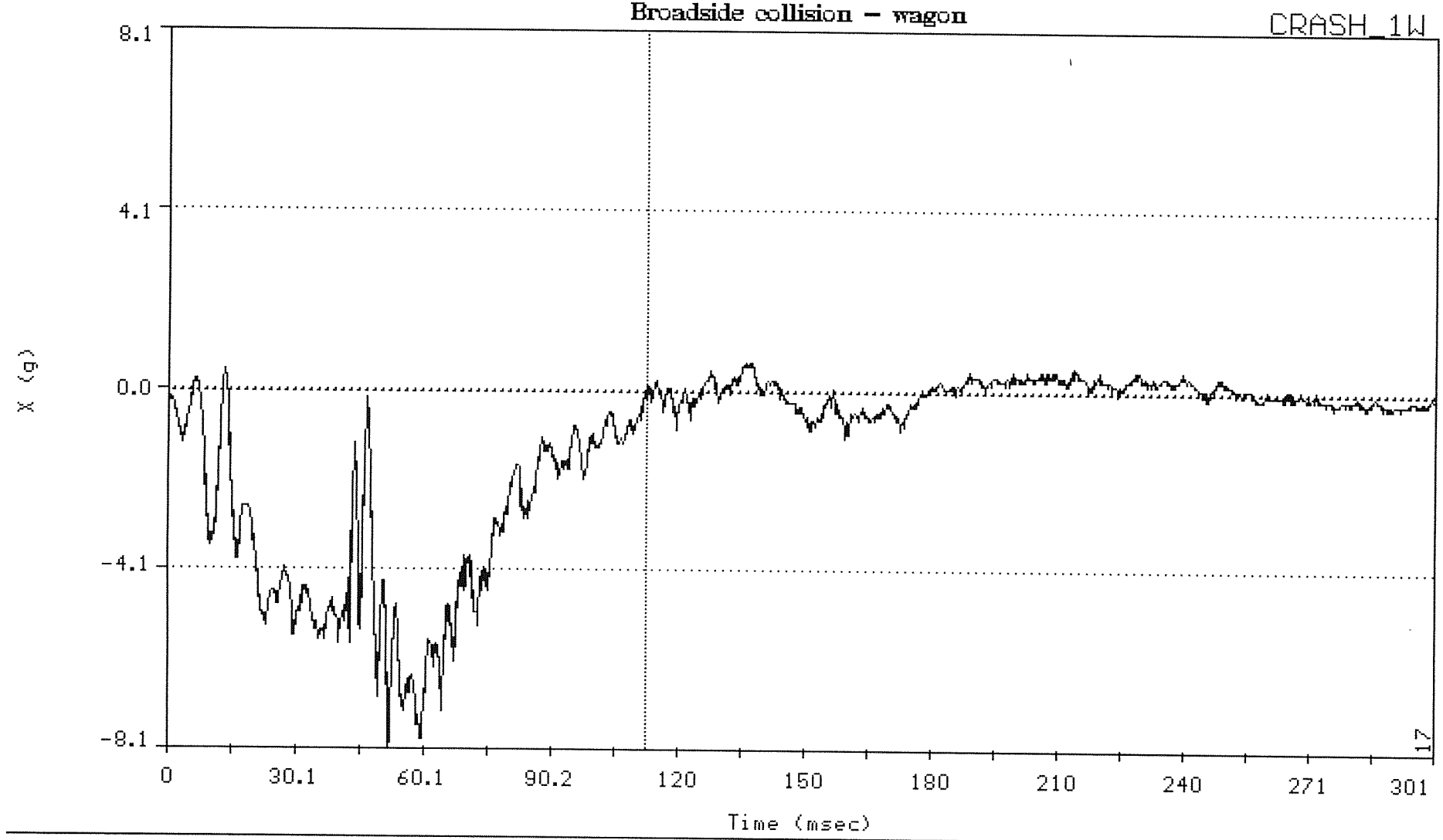
Resultant.



Cursor in window #1 Total points: 5245 1.699 sec
event 1 point 895 0.085 g | event 1 point 6140 0.162 g
Delta T: 1.6988 sec 1/T: 0.5886 Hz ~~Delta V: 17.259 m/s~~ NOT VALID FOR THIS PLOT.

Events in file: 1
Sample freq: 3087
Samples per event: 8192

PLOT 9: RESULTANT OF X Y & Z AXIS TO ILLUSTRATE THE VECTOR OF ACCELERATION AND OVERALL LENGTH OF MOVEMENT.



Cursor in window #1 Total points: 1385 0.301 sec
event 17 point 919 -0.051 g | event 17 point 1439 -0.153 g
Delta T: 0.1128 sec 1/T: 8.8615 Hz Delta V: -3.707 m/s

Events in file: 1
Sample freq: 4608
Samples per event: 4608

PLOT 6: INITIAL IMPACT. NOTE DECEL AT 50 msec. CRASH DUMMY, or SUSPENSION LOADING?

Rear end collision:

Plots 11 through 13 show the data that was collected from this collision. Details such as time of initial impact, ΔV, and ΔD are listed on these plots. Due to time constraints, no analysis is provided in this document.

Appendix A: List of figures and plots:

Figure A: Axis orientation of EDR3 as installed in crash dummy

Figure B: Axis orientation of EDR3 as installed in vehicle

Figure 1: Broadside collision; Beginning of initial impact

Figure 2: Broadside collision; Crash dummy strikes door

Figure 3: Broadside collision; Cavalier suspension loads, Dummy rebounds across compartment.

Figure 4: Broadside collision; Crash dummy strikes center console / seat belt limit

Figure 5: Broadside collision; Crash dummy returns to driver's seat

Figure 6: Broadside collision; Post impact, Cavalier suspension unloads.

Plot 1: Broadside collision; Cavalier Y axis acceleration, velocity, displacement

Plot 2: Broadside collision; Cavalier Y axis acceleration initial impact

Plot 3: Broadside collision; Cavalier Y axis acceleration, velocity, displacement, initial impact.

Plot 4: **No plot 4 exists.**

Plot 5: Broadside collision; Cutlass Wagon X axis: Accel, Velocity, Displacement: Initial Impact.

Plot 6: Broadside collision; Cutlass Wagon X axis: Accel Initial Impact.

Plot 7: Broadside collision; Crash Dummy X axis Accel, Velocity: Initial Impact.

Plot 8: Broadside collision; Crash Dummy X axis Initial Impact and rebound

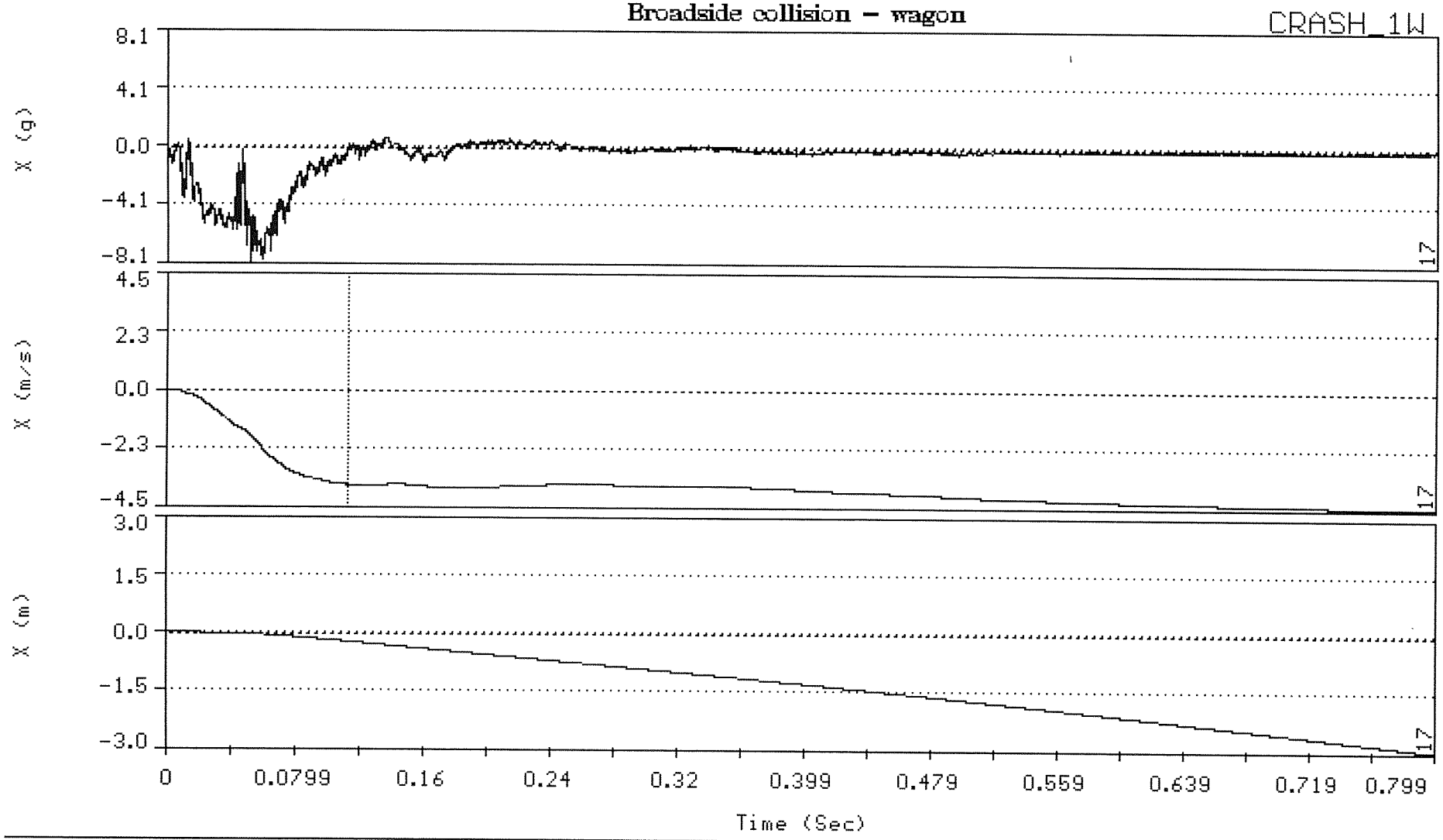
Plot 9: Broadside collision; Crash Dummy resultant of acceleration.

Plot 10: Frontal collision – Crash Dummy

Plot 11: Rear end collision: Grand Am, Accel, Velocity, Displacement.

Plot 12: Rear end collision: Jimmy, Accel, Velocity, Displacement.

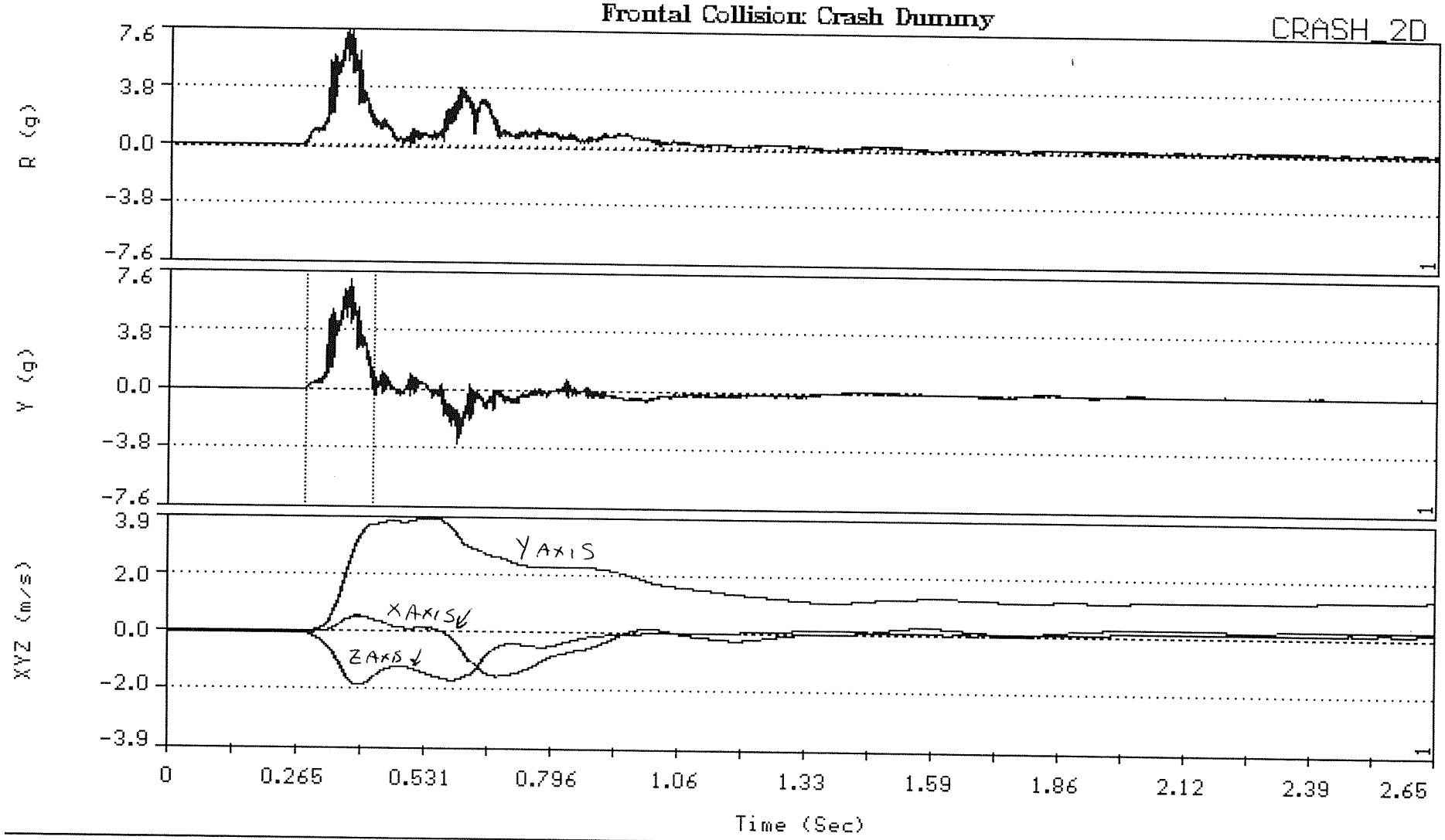
Plot 13: Rear end collision: Crash dummy, Accel, Velocity, Displacement.



Cursor in window #2 Total points: 3681 0.799 sec
event 17 point 919 0.025 m/s | event 17 point 1439 -3.682 m/s
Delta T: 0.1128 sec 1/T: 8.8615 Hz Delta D: -0.223 m

Events in file: 1
Sample freq: 4608
Samples per event: 4608

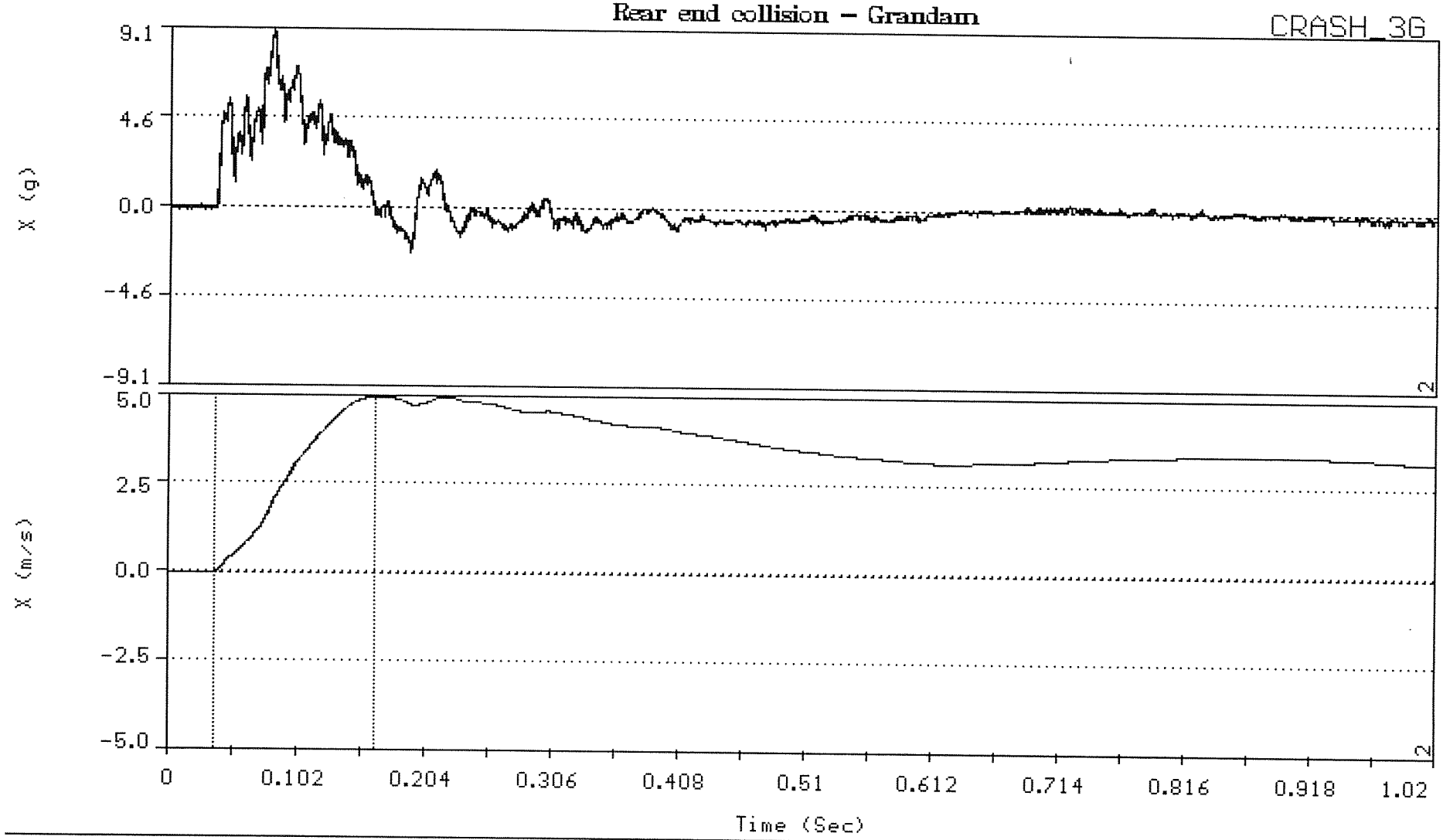
PLOT 5 - INITIAL IMPACT. Δt = 112.8 msec, ΔV = 3.71 m/sec
ΔD = .223 m



Cursor in window #2 Total points: 8192 2.653 sec
event 1 point 876 0.046 g | event 1 point 1315 -0.244 g
Delta T: 0.1422 sec 1/T: 7.0329 Hz Delta V: 3.688 m/s

Events in file: 1
Sample freq: 3087
Samples per event: 8192

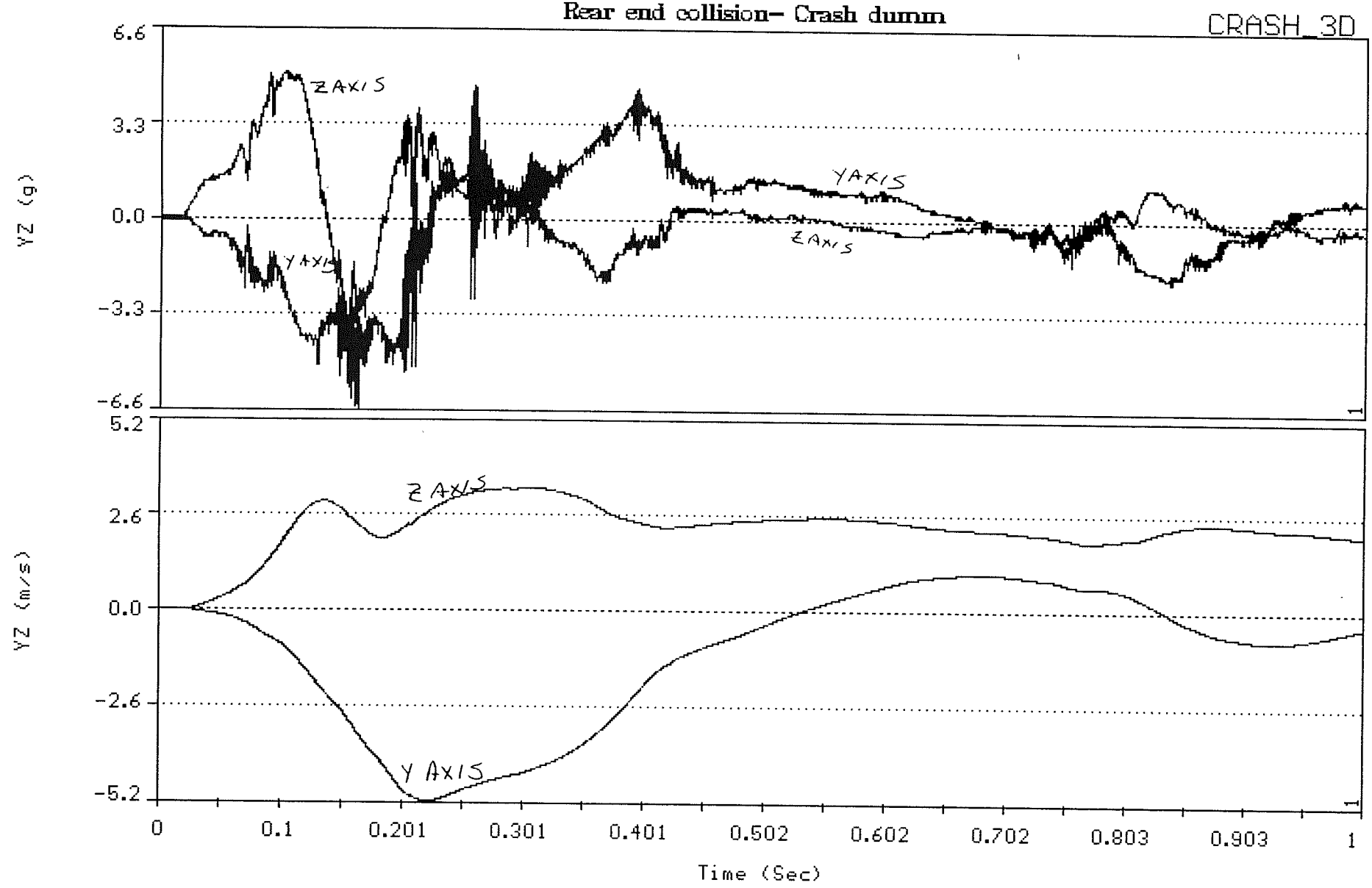
PLOT 10: INITIAL IMPACT; RESULTANT AND Y AXIS. VELOCITY FOR X, Y, & Z AXIS. NOTE THE ROTATION IN X.



Cursor in window #2 Total points: 3057 1.020 sec
event 2 point 1011 -0.013 m/s | event 2 point 1393 5.027 m/s
Delta T: 0.1275 sec 1/T: 7.8457 Hz Delta D: 0.357 m

PLOT 11: Initial impact. $\Delta t = 128$ msec
$\Delta V = 5.04$ m/sec
$\Delta D = 35.7$ cm

Events in file: 1
Sample freq: 2997
Samples per event: 8192



PLOT 13: Y & Z AXIS, INITIAL IMPACT AND SLIDE.

Events in file: 1
Sample freq: 3087
Samples per event: 8192

X AXIS

123.V99

— Calibration Certificate —

Per ISA-RP37.2

Model No. 353M194

Serial No. 30880

PO No. _____ Customer _____

Calibration traceable to NIST thru Project No. 822/255630

ICP® ACCELEROMETER
with built-in electronics

Calibration procedure is in compliance with ISO 10012-1, and former MIL-STD-45662A and traceable to NIST.

CALIBRATION DATA

* Voltage Sensitivity	9.87	mV/g
Transverse Sensitivity	1.2	%
Resonant Frequency	47.5	kHz
Output Bias Level	2.2	V
Time Constant	0.7	s

KEY SPECIFICATIONS

Range	100	±g
Resolution	0.005	g
Temp. Range	-65/+250	°F

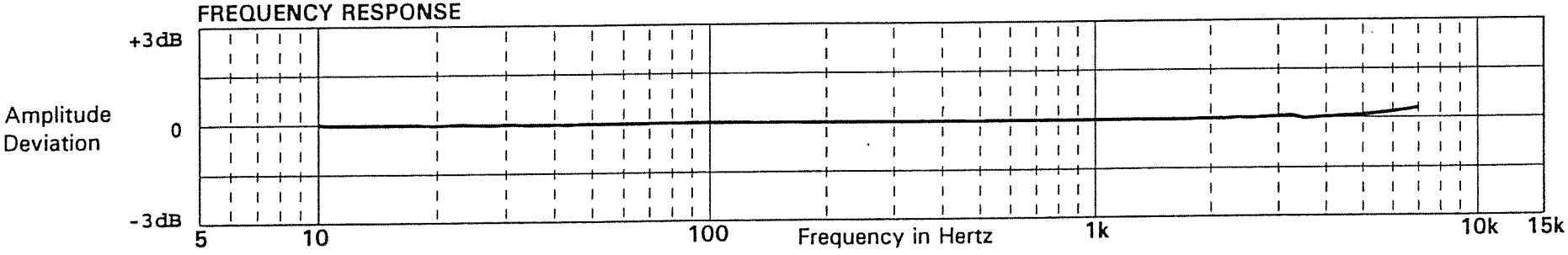
METRIC CONVERSIONS:
$ms^{-2} = 0.102\ g$
$°C = 5/9 \times (°F - 32)$

* This sensor has been calibrated with 0.560mA / 6 Volt power supply.

Reference Freq.

Frequency Hz		10	15	30	50	100	300	500	1000	3000	5000	7000			
Amplitude Deviation %		-0.0	-0.2	-0.2	-0.2	0.0	-0.2	-0.3	-0.2	0.7	1.0	3.5			

FREQUENCY RESPONSE



PCB® Piezotronics, Inc. 3425 Walden Avenue Depew, NY 14043-2495 USA
716-684-0001

Calibrated by Gary Redmond

Date 05-28-1996

Y AXIS

61.R124

— Calibration Certificate —

Per ISA-RP37.2

Model No. 353M194

Serial No. 31027

PO No. _____ Customer _____

Calibration traceable to NIST thru Project No. 822/255630

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Calibration procedure is in compliance with ISO 10012-1, and former MIL-STD-45662A and traceable to NIST.

CALIBRATION DATA

* Voltage Sensitivity	9.81	mV/g
Transverse Sensitivity	1.5	%
Resonant Frequency	40.5	kHz
Output Bias Level	2.6	V
Time Constant	0.6	s

KEY SPECIFICATIONS

Range	100	±g
Resolution	0.005	g
Temp. Range	-65/+250	°F

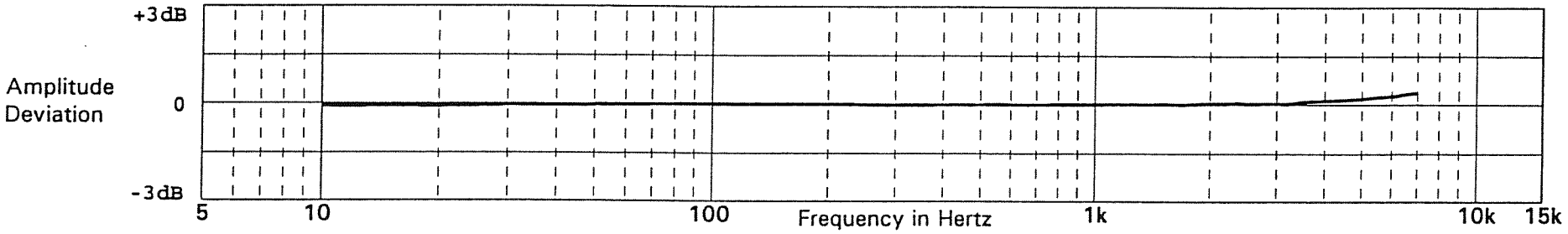
METRIC CONVERSIONS:
ms^{-2} = 0.102 g
°C = 5/9 x (°F - 32)

* This sensor has been calibrated with 0.560mA / 6 Volt power supply.

Reference Freq.

Frequency Hz		10	15	30	50	100	300	500	1000	3000	5000	7000			
Amplitude Deviation %		-0.9	-0.9	-0.5	-0.3	0.0	-0.2	-0.1	0.0	0.5	2.2	4.4			

FREQUENCY RESPONSE



PCB® **Piezotronics, Inc.** 3425 Walden Avenue Depew, NY 14043-2495 USA
716-684-0001

Calibrated by Gary Redmond

Date 06-04-1996

62.R124

— Calibration Certificate —

Per ISA-RP37.2

Model No. 353M194

Serial No. 31028

PO No. _____ Customer _____

Calibration traceable to NIST thru Project No. 822/255630

ICP® ACCELEROMETER
with built-in electronics

Calibration procedure is in compliance with ISO 10012-1, and former MIL-STD-45662A and traceable to NIST.

CALIBRATION DATA

* Voltage Sensitivity	9.86	mV/g
Transverse Sensitivity	1.2	%
Resonant Frequency	38.5	kHz
Output Bias Level	2.6	V
Time Constant	0.7	s

KEY SPECIFICATIONS

Range	100	±g
Resolution	0.005	g
Temp. Range	-65/+250	°F

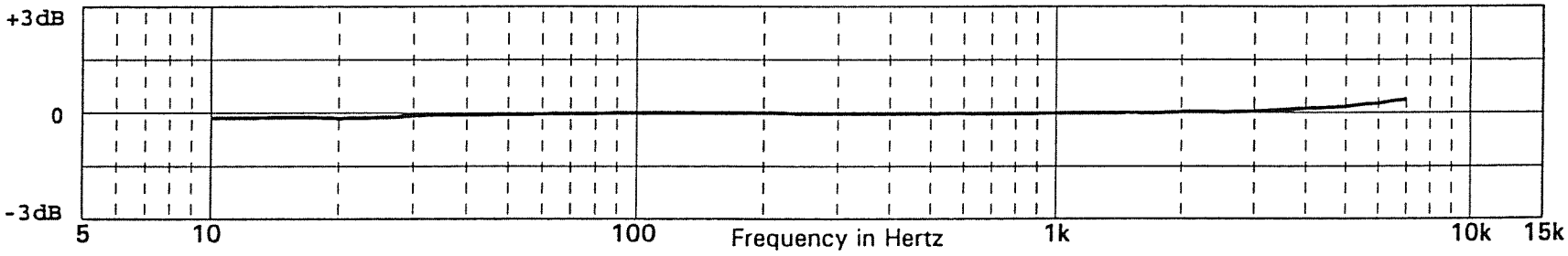
METRIC CONVERSIONS:
$ms^{-2} = 0.102\ g$
$°C = 5/9 \times (°F - 32)$

* This sensor has been calibrated with 0.560mA / 6 Volt power supply.

Reference Freq.

Frequency Hz		10	15	30	50	100	300	500	1000	3000	5000	7000			
Amplitude Deviation %		-1.6	-1.4	-0.8	-0.5	0.0	-0.2	-0.2	-0.1	0.5	2.1	4.4			

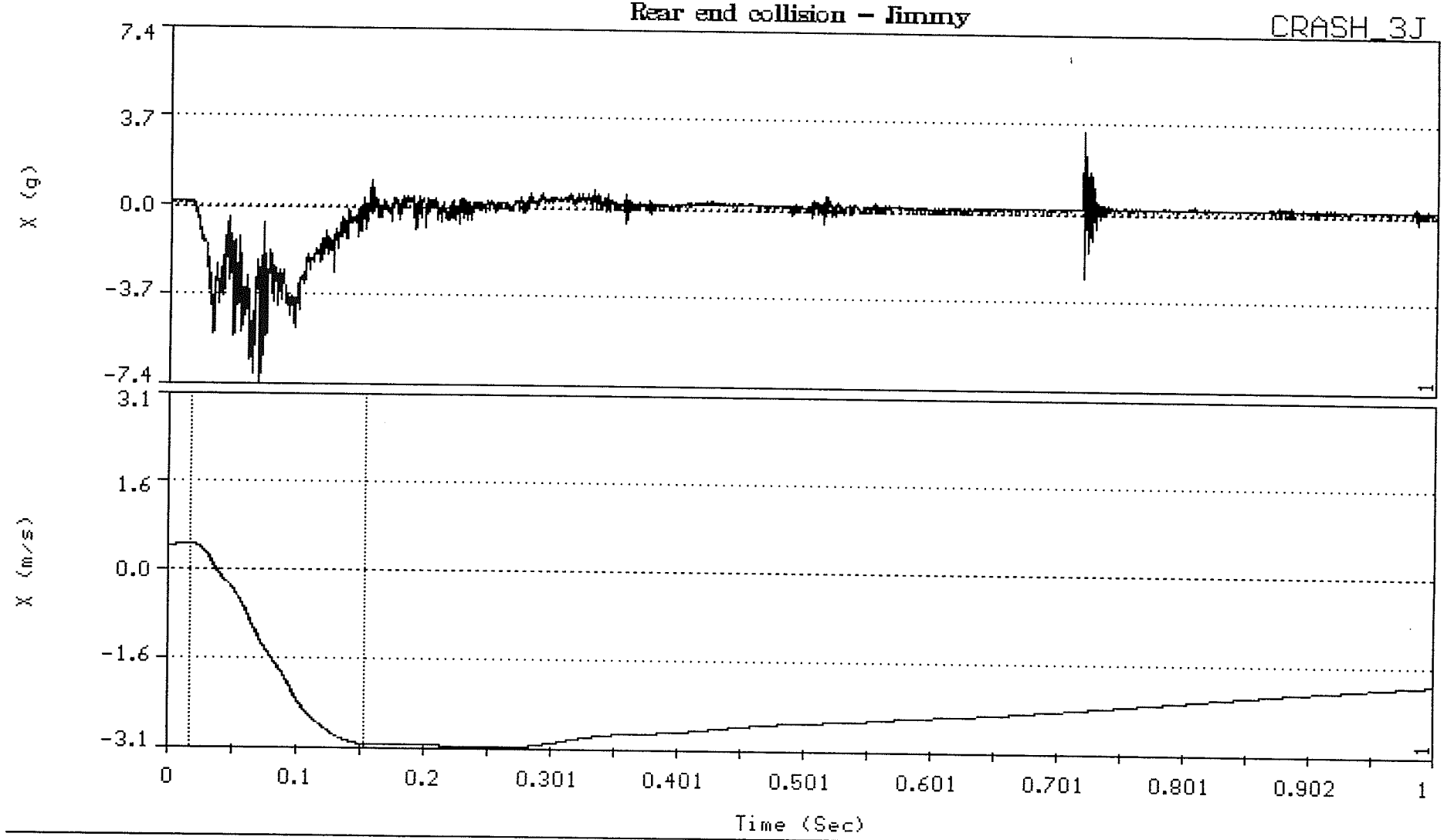
FREQUENCY RESPONSE



PCB® Piezotronics, Inc. 3425 Walden Avenue Depew, NY 14043-2495 USA
716-684-0001

Calibrated by Gary Redmond

Date 06-04-1996



Cursor in window #2 Total points: 3092 1.002 sec
event 1 point 987 0.469 m/s | event 1 point 1409 -3.063 m/s
Delta T: 0.1367 sec 1/T: 7.3162 Hz Delta D: -0.214 m

PLOT 12: INITIAL IMPACT: $\Delta t = 137$ msec
$\Delta V = -3.53$ m/sec
$\Delta D = 21$ cm

Events in file: 1
Sample freq: 3087
Samples per event: 8192