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FEB 77 J T SHAFFER, R M LETSCHER
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SUBLETHAL INJURY PATTERNS IN THE BABOON RESTRAINED WITH A THREE-POINT HARNESS (-Gx IMPACT)

Contract No. DOT-HS-017-1-017-1A

February 1977

Final Report

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16. Abstract

Tests were conducted with adult male baboon subjects restrained in a three-point restraint harness designed to provide impact protection in the $-G_x$ direction. The objective of this research was to identify the first modes of injury with variations of the webbing properties of this harness and not the maximum G level that can be tolerated. The tests revealed the first modes of injury associated with the lap belt portion of the restraint and the first modes associated with the shoulder strap. Pathology was rated using the Abbreviated Injury Scale. Impact levels were 30, 40 and 50 G at velocities ranging from 47.3 to 67.5 feet per second. Five types of harness materials were used. Suggestions were made for improving the harness configuration and the need to develop new response measures was identified.

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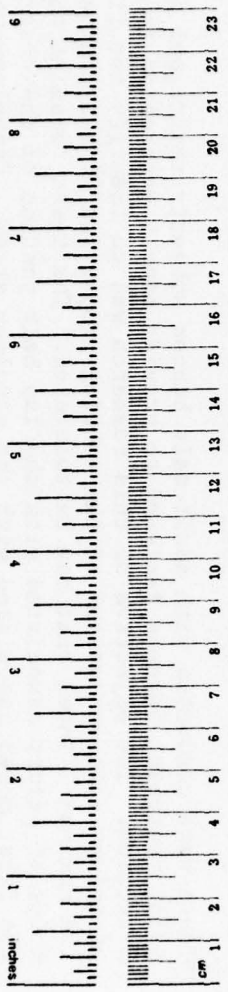
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

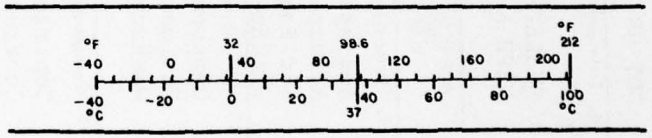
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	*meters*	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	*kilograms*	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	*millimeters*	0.04	*inches*	*in*
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	*hectares* (10,000 m^2)	2.5	*acres*	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic *meters*	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



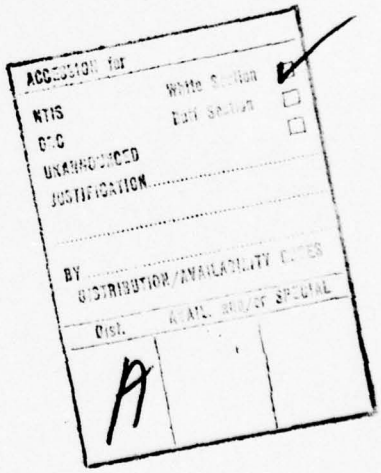
PREFACE

This study, "Sublethal Injury Patterns in the Baboon Restrained with a Three-Point Harness ($-G_x$ Impact)", was conducted by the Impact Branch, Biodynamics and Bionics Division, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, under Project 7231, "Biomechanic of Aerospace Operations", Task 723106, "Impact Exposure Limits and Protection Criteria". The research was accomplished as a collaborative effort with the National Highway Traffic Safety Administration, Department of Transportation, under Interagency Agreement DOT-HS-017-1-017-IA.

Mr. James W. Brinkley was the Air Force program manager and Mr. Thomas Glenn was the Technical Monitor for the National Highway Traffic Safety Administration.

Operation and maintenance of the test facility used in this research program was accomplished by the associated personnel of Dynalectron Corporation under Contract Number F33615-74-C-4050. Data processing was accomplished by the associated personnel of the University of Dayton Research Institute under Contract Number F33615-73-C-4157.

This report has been identified by the Aerospace Medical Research Laboratory as AMRL-TR-76-76.



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SUBLETHAL INJURY PATTERNS IN THE THREE-POINT HARNESS

INTRODUCTION

The Aerospace Medical Research Laboratory has been conducting research into the types and mechanisms of injury associated with aircraft crashes and emergency escapes, as well as investigating techniques to use in preventing or reducing the severity of these injuries. To date, success in terms of information usable to aircraft designers has been accomplished in the pure $+G_z$ acceleration direction only. A major reason for the success in this direction is that the first mode of injury is very well defined: fracture of a vertebral body in the spine. However, in all other acceleration directions encountered, this first mode of injury is not known. The lack of this information makes it very difficult to effectively protect crewmen subjected to these conditions.

The majority of past work in this area has been directed towards identifying the acceleration or force level in a given direction which is not survivable (Reference 1). Little attention has been paid to the injuries produced at lower than fatal acceleration levels. This knowledge is vital if aircraft ejection seats and aircraft and automotive crash restraints are to provide effective injury prevention. In recent years, impact injury and restraint effectiveness studies by AMRL have been conducted with support from the National Highway Traffic Safety Administration, an organization with similar responsibilities in protecting automotive occupants. This report describes a joint research investigation of one aspect of the crash injury problem. Specifically, it addresses the $-G_x$ impact direction (the one most often encountered in crashes) and the dynamic responses and injuries associated with the use of a three-point restraint harness.

PROGRAM OBJECTIVES

The primary objective of this test program was to determine the sublethal injury patterns produced in adult male baboons restrained by a three-point harness system in simulated crash tests. Secondarily, the program was intended to evaluate simulation, scaling and instrumentation techniques used in this type of impact testing. The experimental work was confined to the $-G_x$ impact direction with the three-point harness. Similar test programs with other type restraints have been accomplished (Reference 2) or are being planned.

After the patterns of injuries had been established with the three-point restraint harness and configurations chosen for this research, the data were examined closely to establish if there were differences due to the belt material type or if there was a relationship between the

measured environmental parameters (loads, accelerations, photo displacements) and the injuries produced.

TEST CONFIGURATION

All tests were conducted on the AMRL Impulse Accelerator facility (Reference 3). This is a linear, horizontal acceleration track using a 24-inch HYGE machine manufactured by Bendix Corporation for propulsion. Figure 1 shows the facility. Test impacts are produced by releasing high pressure air against a thrust piston which in turn accelerates the impact sled and test article. By controlling the manner in which the air is metered into the thrust chamber, the stroke length and the initial pressure level, the acceleration waveform can be altered and controlled. After the initial high acceleration profile is produced, the sled coasts to a stop along the track rails. The deceleration level used to stop the sled is in the range of 0.3 to 0.5. All test functions are performed under automatic control and monitoring. These include photo coverage, electronic data collection and actuator firing.

The seat used for the testing is pictured in Figure 2. The included angle between the seat pan and seat back was 97 degrees. The seat pan was inclined 6 degrees above the horizontal. This seat configuration has been used for other $-G_x$ baboon testing (Reference 1, 2). The seat itself provides no restraint function other than to preposition the test subjects.

Harness tiedown points were modeled after the tiedown positions in an automobile. Because the baboon is smaller than a man, the positions were changed to reflect the baboon's smaller size. Relationships between a large baboon and a 95th percentile man are given in Table 1. The various scale factors these dimensions produce are given in the table also. The variation is considerable. They basically point out that besides being considerably lighter than man, the baboon's torso is long and narrow compared to that of a man.

Very little guidance is available for selecting one of these scale factors or even if one is necessary. The one which was chosen was the shoulder height relation. This measure kept the restraint tiedown angles close to those for the human. The tiedown points used are shown in Figure 3 relative to a coordinator axis esrablished through the center of the seat and the hip-point of the baboon.

During the testing several types of harness materials were used to investigate the effects of the injuries produced. The static properties of the five harness materials used are given in Table 2. The range of properties represented by these materials are high versus low elongation, material width and energy absorbing capability. With this wide range of material properties, the injury pattern analysis becomes somewhat independent of the belt material and only dependent on the basic harness configuration.

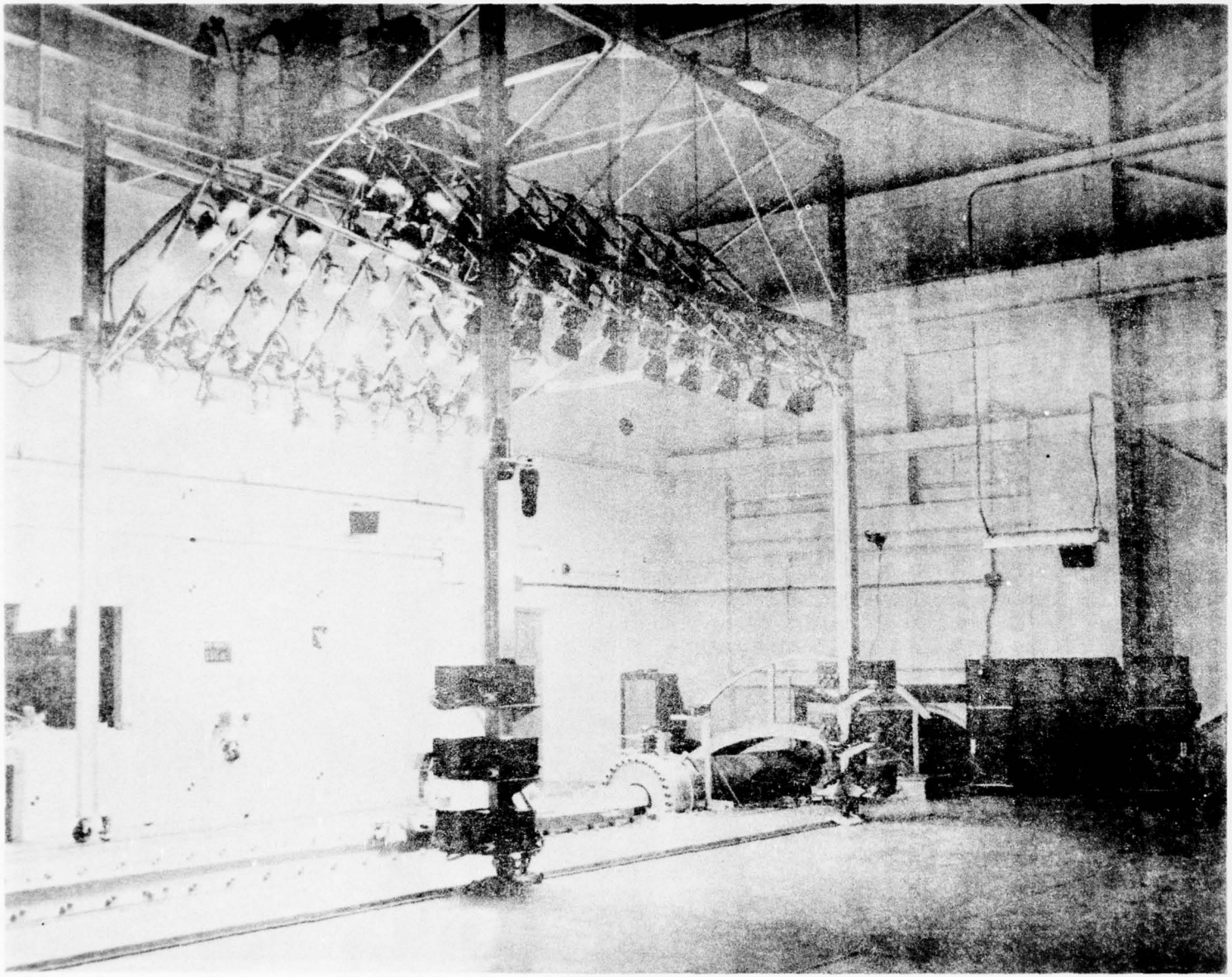


FIGURE 1 - Impulse Accelerator Facility

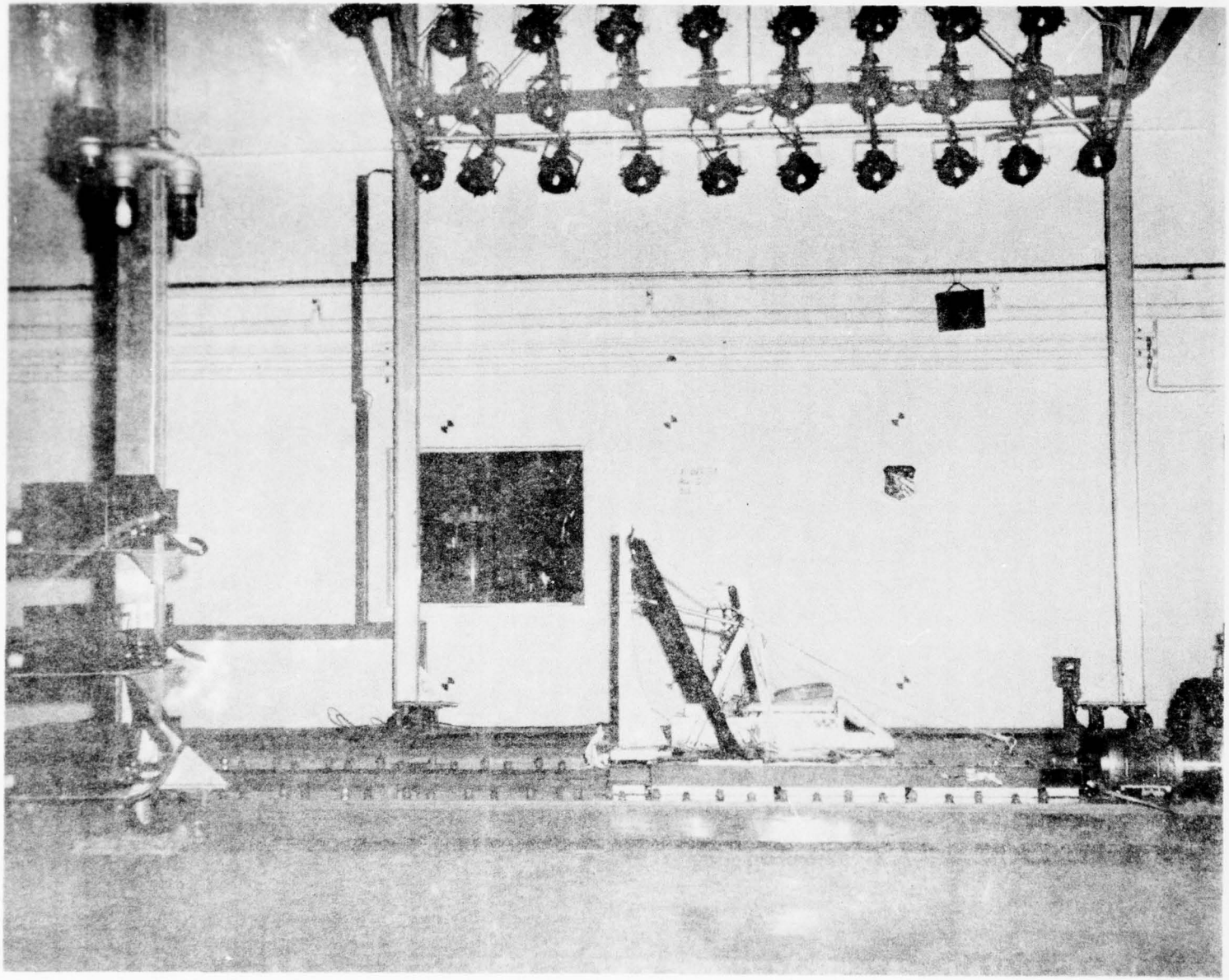


FIGURE 2 - Test Seat

TABLE 1: SCALING RELATIONSHIPS

BASIS	BABOON ①	95%tile MAN ②	SCALE FACTOR
Sitting Height	65 cm	96.6 cm	.673
Shoulder Height	49 cm	63.8 cm	.768
Hip Width	22 cm	39.2 cm	.561
Chest Width	18 cm	34.1 cm	.528
Shoulder Width	25 cm	49.3 cm	.507
Weight	65 lb	200 lb	.325

① - Measurements from baboon D56; used as subject in Test 384

② - Measurements derived from Reference 4

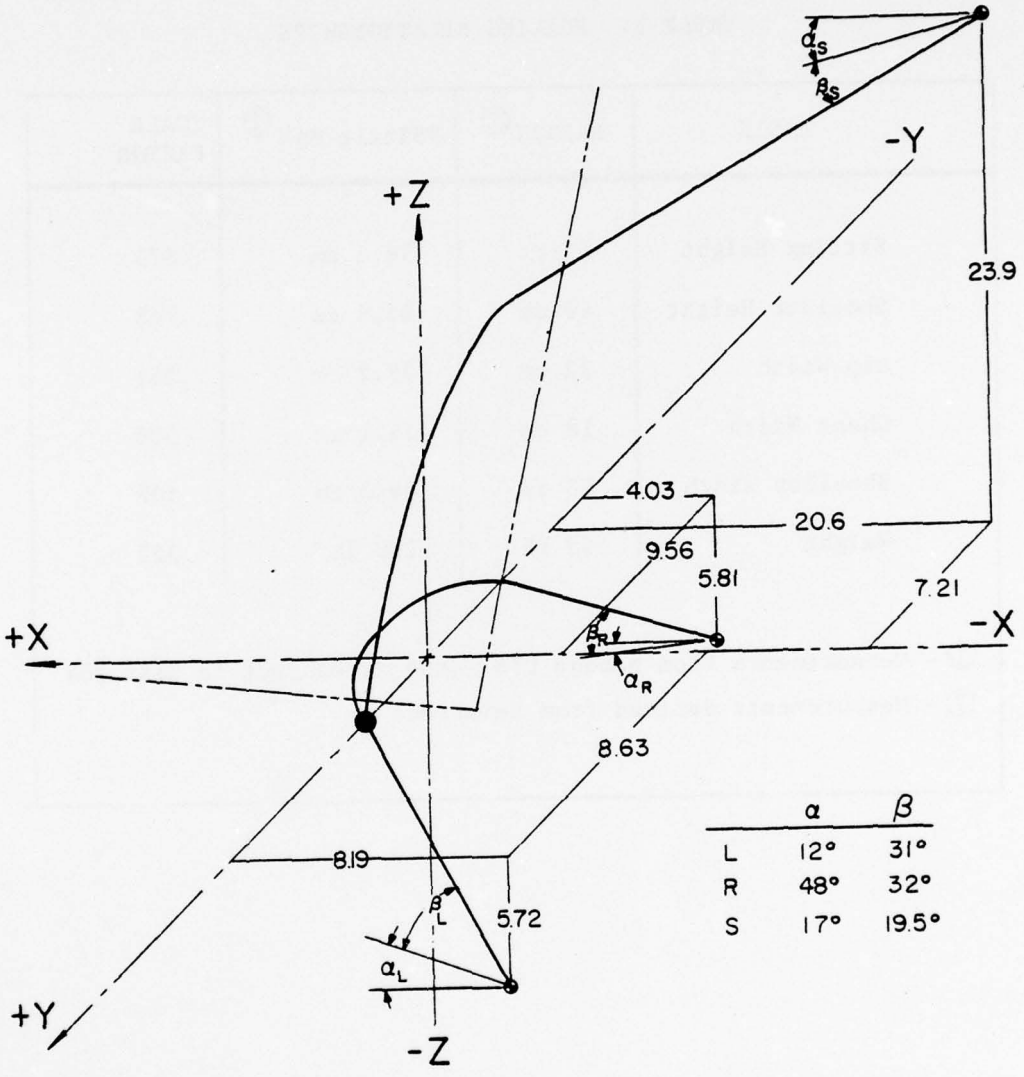


FIGURE 3 - Three Point Harness Geometry

TABLE 2: HARNESS MATERIALS

TYPE	WIDTH	ULTIMATE STRENGTH	YIELD POINT	ELONGATION AT 1200#
1-Dacron	1 inch	4520 lb	--	6 %
2-Nylon	1 inch	5440 lb	--	13 %
3-Nylon	1 15/16 inch	6500 lb	--	13 %
4-Takata ① Type A	1 inch	2200 lb	380 lb	40 %
5-Takata ① Type B	1 inch	1650 lb	188 lb	66 %
Takata Lap ①	1 inch	4600 lb	--	16 3/4 %

① - Materials supplied by Takata Kojyo Company, LTD
Type A and Type B energy absorbing materials used in shoulder strap only

INSTRUMENTATION

In addition to the injury data to be collected on this program, data was required on other responses of the subject to the test impacts. This data consisted of the belt loads, head and chest accelerations and kinematic displacements encountered during the tests.

The primary parameter to be measured was the impact environment. Three independent measurements were made of the acceleration waveform. Two accelerometers were mounted on the sled and one on the thrust column of the Impulse Accelerator. Their basic characteristics are tabulated below.

TABLE 3: ENVIRONMENT ACCELEROMETERS

ACCELEROMETER	TYPE	MFG-MODEL	RANGE	NATURAL FREQUENCY
Sled Primary	Piezoresistive	Endevco 2260	$\pm$250 G	14,000 H_z
Sled Secondary	Strain Gage	Statham A52	$\pm$100 G	970 H_z
Ram	Piezoresistive	Endevco 2262C	$\pm$200 G	3,800 H_z

In addition to the accelerometers, a tach-generator was mounted on the sled to give a continuous velocity recording. Data tabulated for each test were peak acceleration from the sled primary accelerometer and terminal velocity from the peak of the tach-generator output. Other accelerometers were checked for possible discrepancies.

The belt loads measuring system consisted of Strainsert Universal Load Cells attached at the ends of the belts. These load cells were mounted on special swivels so that they would maintain axial alignment with the belt at all times during the impact. They measured the belt load at the tiedown points.

The chest accelerometer packs consisted of three orthogonally oriented accelerometers attached to a special mounting block and sewn to a velcro strap. This strap was tightened around the chest of the baboon.

The head accelerometer pack also consisted of three orthogonally oriented accelerometers. These accelerometers were attached to an angular accelerometer to produce a package which measured x, y and z linear accelerations and x-z plane angular acceleration. This package

was then secured to a mounting post which was attached to the baboon's skull via bone screws. This provided a very rigid mount for these acceleration measurements. The accelerometer grouping is shown in Figure 4.

The characteristics of the accelerometers used in the chest and head packages are shown in Table 4.

TABLE 4: SUBJECT ACCELEROMETERS

ACCELEROMETER	TYPE	MFG-MODEL	RANGE	NATURAL FREQUENCY
Linear	Piezoresistive	Endevco 2264	$\pm$150 G	3,400 H_z
Angular	Piezoelectric	Endevco 7301	50 to 50,000 rad/sec^2	10,000 H_z

High speed color motion pictures were taken of each test using Milliken Model DBM 55 cameras operating at 500 frames per second. Three orthogonally oriented cameras were used to track various points on the subject. The normal three-cameras system with reference points is shown in Figure 5. The cameras were automatically started with the facility control system. Timing marks were placed on the film so that photo frame events could be correlated with acceleration and loading conditions.

TEST VARIABLES

Very few variables were allowed to exist during the test program as the objective was to collect data on injuries produced by this restraint type alone. As mentioned earlier, five different harness material configurations were used. However, this was to insure that the injuries would be independent of the belt material parameter and the geometry was maintained identical for all tests.

The impact level was not a variable in these tests. It was, however, necessary to do some testing at various G levels to discover where the injuries were severe enough to be classified but below lethal levels. The level chosen was a nominal 40 G at a 40 MPH velocity change. This impact profile is shown in Figure 6. Tests at 30 G produced very little injury and tests at 50 G produced too massive and extensive trauma. The data from these 30 G and 50 G tests are included in the report but very little discussion of the data is included.

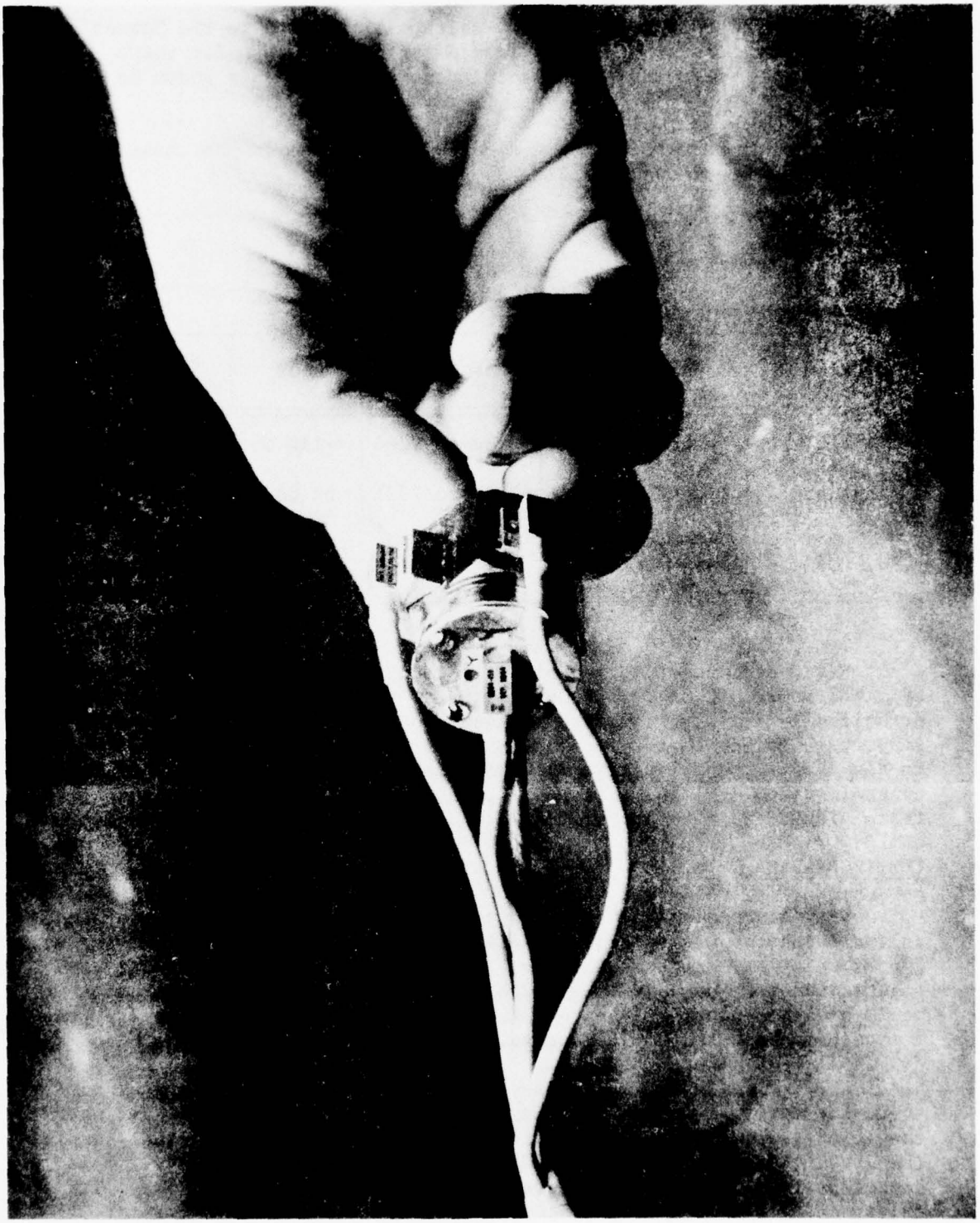
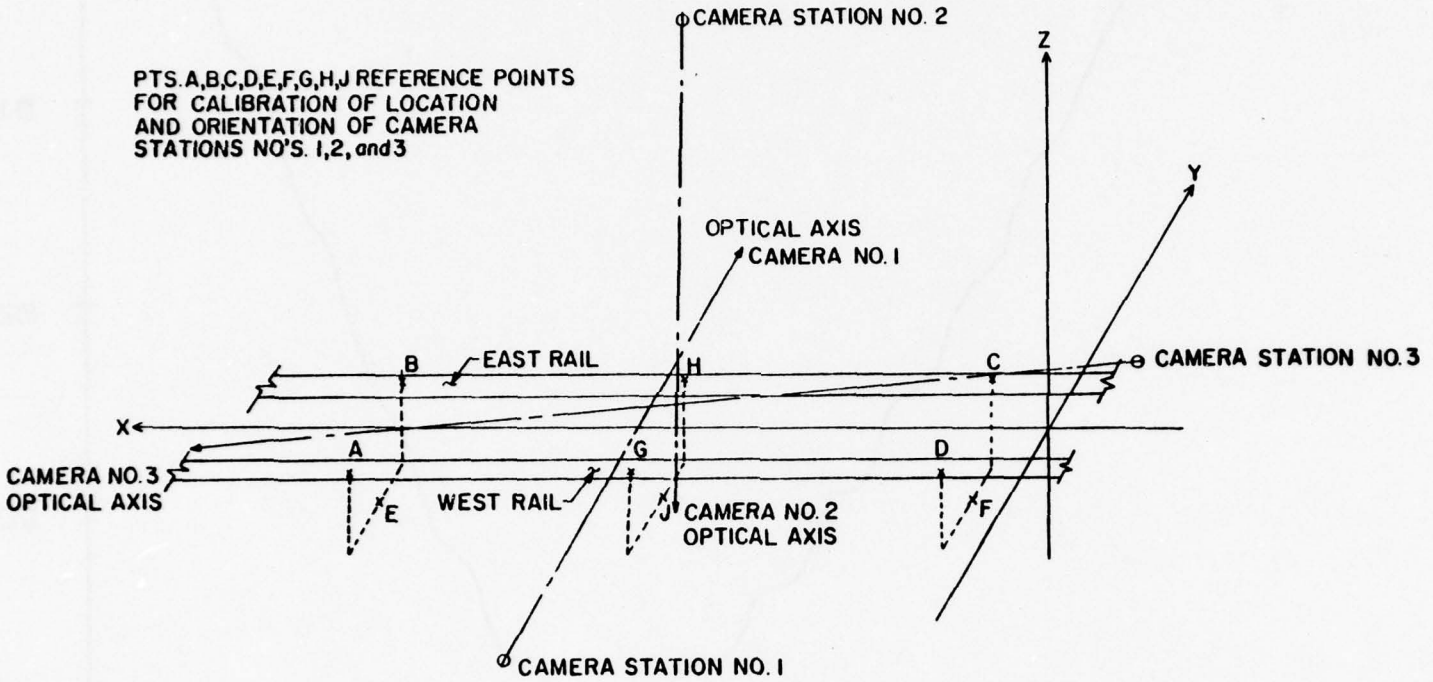


FIGURE 4 - Head Accelerometer Pack



RANGE COORDINATE SYSTEM AND CAMERA LAYOUT
HORIZONTAL IMPACT FACILITY, AMRL/BBI
BLD. 824, WRIGHT PATTERSON A.F.B., OHIO

FIGURE 5 - Range Coordinate System

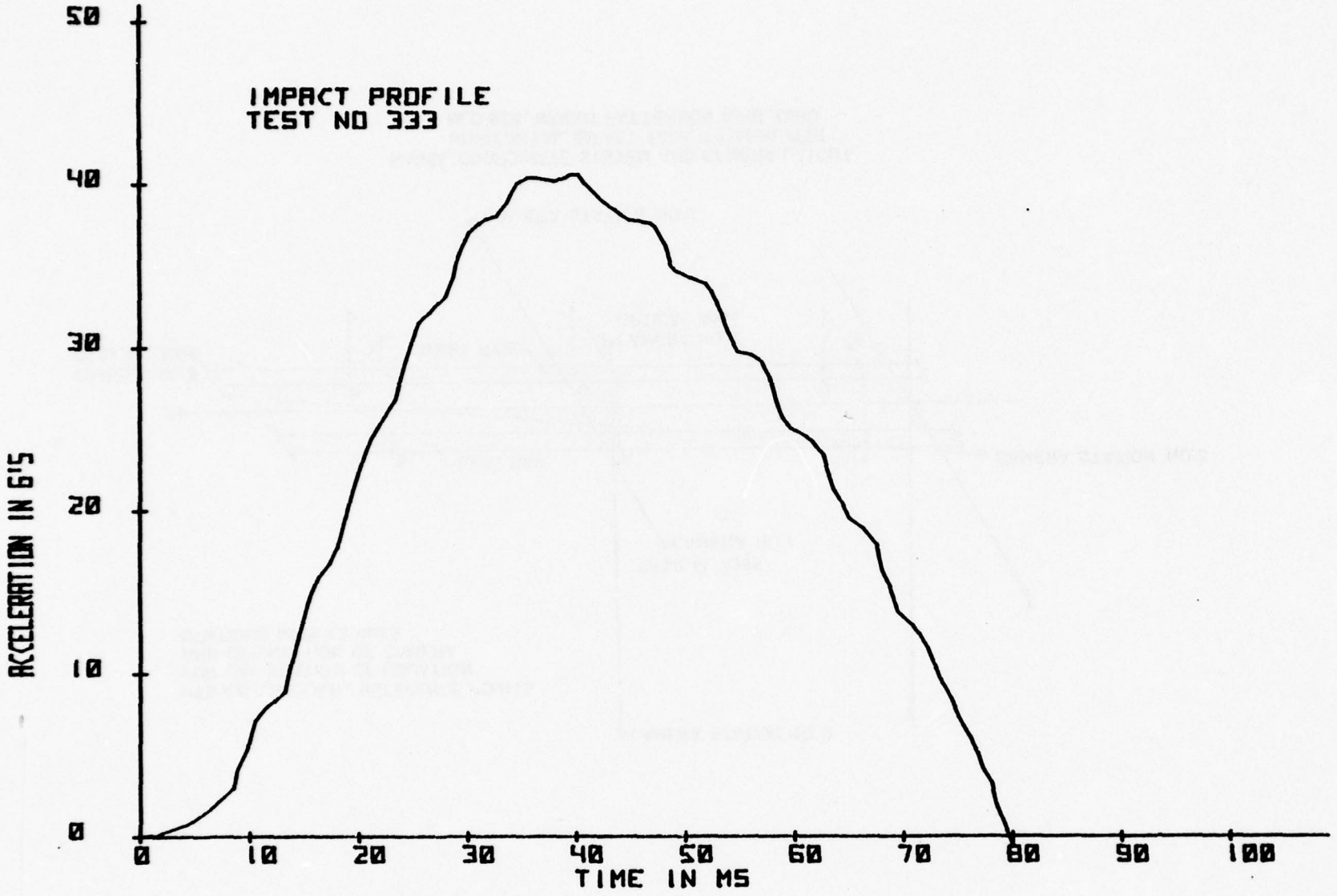


FIGURE 6 - G Impact Profile

TEST PROCEDURES

Adult male baboons (Papio cynocephalus; P. anubis) weighing between 36.5 to 75 pounds were used as test subjects. All subjects exhibited normal spinal columns via radiography prior to use in the program.

The test animals were fasted 6-24 hours before impact. Phencyclidene hydrochloride (1-1.5 mg/kg) or ketamine hydrochloride (7-10 mg/kg) was given intramuscularly to provide initial subject immobilization and an indwelling catheter was placed in a peripheral vein. Hair was clipped from the subject's body to allow adequate visualization of the subject's kinematics during the impact. Pentobarbital sodium was given intravenously to effect surgical anesthesia and the specially constructed aluminum accelerometer mounting post was surgically attached to the midline of the subject's skull (supra-optic area) via six bone screws.

In a number of animals cardiac catheters were placed in the heart to monitor cardiovascular functions during impact. Such cardiovascular data are not discussed in this paper, but are treated in Reference 7.

Following the above preparation, the subject was positioned on the sled seat and restrained in the test harness. The harness belts were pretensioned to between 10 and 15 pounds per belt. The wrists were taped together, as were the ankles, to minimize limb flailing at impact. The mouth was taped closed to avoid tongue lacerations during the impact. The head accelerometer package was attached to the cranial mounting post. Additional increments of pentobarbital sodium were given intravenously just prior to impact to maintain the surgical plane of anesthesia. In some tests it was necessary to use low-strength tape which broke at impact to maintain the subject's position in the test seat.

Following impact, the subject was euthanatized via exsanguination and an autopsy examination was conducted within one to four hours. Detailed autopsy reports were prepared to allow later grading of the injuries observed. Photographic recording of visible injuries was performed at autopsy on several occasions.

DATA HANDLING

Quick look data analysis on this program consisted of checking the test environment acceleration and velocity and examination of all data channels for peaks and form. This insured that all data channels were functioning and that the impacts were within the range desired.

Analysis of all load and acceleration data was conducted on data filtered beyond 100 H_z.

The belt loads data was digitized via an A/D converter and the individual belt loads summed algebraically to determine the peak total load. The individual belt loads at this point were tabulated so that the load distribution could be studied.

The head and chest accelerations were digitized similarly using an A/D converter. The three linear accelerations were resolved to produce the resultant acceleration of the head and chest points. The peaks were determined from this data. Severity Indices (S.I.) and Head Injury Criteria (H.I.C.) were determined for the head and S.I. were also computed for the chest.

Motion picture film, after processing, was digitized using a Producers Service Corporation Semi-Automatic Film Reader. After digitization the data were processed to determine time-displacement histories of the point being tracked. The absolute sled motion was subtracted from all subject data points to give the trajectories of the points relative to the sled. For all tests this was done with the y axis camera. This resulted in trajectory plots in the x-z plane.

The injury data obtained from the autopsies were graded according to a system patterned after the Abbreviated Injury Sclae (AIS) of the American Medical Association Committee on the Medical Aspects of Automotive Safety (Reference 5). Details of the rating system are given in Appendix A. In general, this scale rates injuries numerically according to their severity. Table 5 outlines the correlation between the injury number and its severity. No injury on this program was rated higher than 5 using this system. Injury ratings were made individually for seven different body areas. They were (1) head and neck, (2) chest, (3) spine, (4) abdominal contents, (5) abdominal wall, (6) pelvis or sublumbar muscles, and (7) extremities or shoulders. This classification allowed the injuries to be attributed to that portion of the harness which produced them. It also allowed ready comparison to be made of the traumatic injuries observed in the different impact tests.

RESULTS

Table 6 summarizes the test parameters of the 36 tests accomplished during this program. Data from test numbers 319 and 352 were eliminated from any analysis made. A lap belt failure occurred on test number 319 and the animal struck the sled producing abnormal accelerations which contributed greatly to the injuries received. Test number 352 was conducted normally; however, a brake system failure on the sled produced a high deceleration level immediately after the impact. Data will be given for all tests except 319. Data from 352 should be regarded suspiciously because of the abnormal impact environment. The injury analysis will be restricted to the tests in the 40 G range; however, loading, acceleration and autopsy information is given for all tests. The differences, upon examination, would seem to be primarily one of degree.

TABLE 5: ABBREVIATED INJURY SCALE ①

INJURY NUMBER	-	SEVERITY
0	-	No Injury
1	-	Minor
2	-	Moderate
3	-	Severe (Not Life-threatening)
4	-	Serious (Life-threatening, survival probable)
5	-	Critical (Survival uncertain)
6-9	-	Fatal

① - After Reference 4

TABLE 6: TEST RUN SUMMARY

TEST NUMBER	HARNESS MATERIAL	SUBJECT WEIGHT, LB.	TEST G LEVEL	PEAK VELOCITY, FPS	DATE
302	1" Dacron	44.0	43.6	59.9	10/10/73
307	1" Dacron	64.0	44.8	61.3	11/02/73
309	1" Dacron	54.5	43.0	57.0	11/06/73
312	1" Dacron	36.5	42.3	60.1	11/08/73
317	1" Dacron	41.0	42.7	62.6	11/13/73
319 *	1" Dacron	66.0	43.9	64.1	11/15/73
328	1" Nylon	67.5	41.3	59.6	11/20/73
330	1" NYlon	43.0	42.8	60.4	11/27/73
333	1" Nylon	40.0	42.4	58.9	11/29/73
338	1" Nylon	46.0	42.6	61.6	12/04/73
342	1" Nylon	59.0	43.3	62.0	12/06/73
346	1" Nylon	60.0	30.7	47.3	12/11/73
348	1" Nylon	44.0	52.1	67.2	12/13/73
350	1" Nylon	52.0	52.6	66.9	12/18/73
352 **	1" Nylon	45.5	53.0	68.2	12/20/73
380	2" Nylon	50.5	43.5	62.1	02/14/74
382	2" nylon	62.5	42.4	58.7	02/19/74
384	2" Nylon	65.0	41.9	58.8	02/21/74
386	2" Nylon	56.0	41.1	58.3	02/26/74
389	2" Nylon	73.0	40.9	58.5	02/28/74
397	2" Nylon	60.0	41.9	59.7	03/07/74
401	2" Nylon	65.0	53.2	67.4	03/19/74
403	2" Nylon	57.0	52.5	67.5	03/21/74
405	2" Nylon	67.0	52.5	66.9	03/26/74
410	2" Nylon	54.0	30.1	48.9	03/28/74
417	Takata A	69.0	42.4	60.3	04/09/74
419	Takata B	65.0	42.8	60.4	04/11/74
421	Takata A	65.5	42.5	57.7	04/15/74
423	Takata B	65.0	41.9	60.5	04/18/74
434	Takata A	56.0	42.4	59.7	05/02/74
439	Takata B	58.0	42.2	59.7	05/14/74
441	Takata B	57.0	41.2	60.0	05/16/74
443	Takata A	59.0	41.5	58.3	05/21/74
445	Takata B	57.0	42.7	60.0	05/23/74
447	Takata A	62.0	42.7	59.1	05/28/74
449	Takata B	61.5	42.1	59.1	05/30/74

* Lap belt failure.

** High deceleration level.

The mean G level for the nominal 40 G impacts was 42.4 G (δ=.84 G) at a velocity change of 59.8 feet per second (δ=1.4 fps). All of the belt systems are included together in this analysis.

Table 7 lists the peak belt loads encountered during the program and also the percentage of this peak load being carried by each belt. In order to compare these loads correctly they need to be normalized by the subject weight. When this is done it can be seen that the energy absorbing type harness system produced lower peak loads than the elastic harnesses. Typical data plots are presented in Appendix E.

Table 8 lists the acceleration data for each test. Table 8a gives the average values of this acceleration data for the 30, 40 and 50 G levels.

Table 9 gives the injury ratings assigned to each of the selected body areas by test. These ratings were given based upon the autopsy information in Appendix B. As the assignment of a rating number requires some subjective judgments to be made as to the severity of the injury, all ratings were made by the same individual. There could be disagreements on some of the severities assigned; however, the information contained in Table 9 should be consistent and comparable for each test.

Table 9 shows that the most severe and frequent injuries occur to the abdominal contents and to the shoulder and extremity areas. Frequent injuries also occur to the chest and abdominal wall areas. Injuries to the head and neck or the spine occur less frequently. Of course, we are talking only about grossly observable injuries and injury to the nervous system cannot be fully assessed by this method. Had the subjects been allowed to regain consciousness, more complete clinical evaluation might have revealed such injuries although such evaluation would be difficult with these subjects.

Virtually all of the injuries observed can be attributed to the presence of the belts and the forces which they apply to the various body areas. While many types of injuries were noticed throughout the tests, the most frequent, reoccurring injuries were right clavicle fractures, colon contusions and lacerations to the muscles in the abdominal area. The clavicle fractures are attributable to the shoulder strap, while the colon and abdominal muscle injuries are due to the lap belt. It should be pointed out that, with the exception of an obvious broken bone, external evidence of injury was lacking in most cases. Contusions, abrasions and minor lacerations were all that was evident externally. Only upon autopsy could the full extent of the injuries be seen.

Right clavicle fractures or joint luxations, depending upon when they occurred and how much energy they had absorbed in failure, allowed other injuries such as muscle lacerations, sternum and rib involvement, lung contusions and heart muscle involvement to show up. It might be

TABLE 7: BELT LOADS

TEST NUMBER	LH BELT LOAD % OF TOTAL	RH BELT LOAD % OF TOTAL	SHOULDER BELT LOAD % OF TOTAL	PEAK TOTAL LOAD LB
302	37.4	27.7	35.5	3,777
307	38.0	26.8	35.2	4,882
309	41.0	27.9	31.4	3,840
312	39.2	25.9	34.9	2,865
317	39.0	28.3	34.2	3,476
319	NO DATA - BELT SYSTEM FAILURE			
328	41.4	27.7	31.3	5,187
330	41.3	25.7	35.4	3,030
333	38.9	26.3	36.1	2,957
338	42.4	27.6	31.1	3,290
342	42.2	22.5	35.8	4,325
346	37.1	27.5	36.3	2,820
348	41.9	26.4	31.7	4,071
350	43.8	26.2	30.1	4,622
352	44.3	26.8	30.1	4,575
380	40.6	26.5	32.8	3,989
382	41.7	26.0	32.2	4,679
384	38.6	28.9	32.5	4,537
386	41.6	27.9	31.2	4,473
389	41.8	25.4	33.5	5,296
397	40.6	28.3	31.6	4,480
401	43.1	26.0	30.9	5,801
403	43.9	27.5	29.8	5,481
405	41.5	27.0	31.5	5,753
410	41.4	27.3	32.5	2,744
417	43.3	32.5	25.6	3,654
419	44.9	30.0	25.4	4,159
421	46.3	29.7	26.8	3,920
423	44.0	31.6	26.1	3,701
434	45.4	29.7	26.8	3,266
439	44.2	32.9	25.1	3,613
441	45.2	34.1	20.7	3,708
443	43.5	33.3	27.5	3,887
445	46.0	36.3	22.9	3,443
447	45.5	31.9	25.7	3,971
449	43.9	33.9	22.2	4,081

TABLE 8: ACCELERATION DATA

TEST NUMBER	HEAD			CHEST	
	PEAK RESULT.	S.I.	H.I.C.	PEAK RESULT.	S.I.
302	143.0 G	5,016	3,559	94.4 G	1,764
307	220.7	11,622	8,453	61.5	995
309	171.8	8,762	6,358	58.9	1,006
312	167.2	7,449	5,628	68.2	999
317	184.8	5,561	4,287	75.1	1,025
319		NO DATA - BELT SYSTEM FAILURE			
328	180.1	9,266	6,899	71.8	1,092
330	185.8	7,416	5,008	70.9	1,212
333	179.6	9,574	5,755	66.9	1,266
338	174.7	8,224	4,237	67.2	1,029
342	189.9	9,484	6,829	76.3	1,138
346	154.2	5,594	3,619	53.9	694
348	178.3	9,354	6,901	72.2	1,699
350	195.4	5,710	3,501	93.3	1,884
352	207.8	6,749	5,310	73.0	1,220
380	223.7	11,279	3,791	71.7	1,470
382	177.4	10,488	7,341	68.8	1,331
384	114.8	5,840	3,962	105.4	2,172
386	197.5	9,877	6,883	69.7	1,408
389	170.1	9,417	5,549	61.5	964
397	244.6	15,060	8,939	67.0	1,085
401	166.2	11,839	7,584	85.9	1,849
403	166.0	11,136	8,794	86.8	1,496
405	212.8	15,530	9,352	100.6	2,997
410	134.0	3,812	1,925	46.8	584
417	224.3	10,845	5,729	69.6	1,261
419	211.7	7,438	4,672	73.9	1,277
421	238.6	11,934	7,490	89.0	1,383
423	224.8	13,278	8,274	75.6	1,238
434	109.7	4,070	2,834	NO DATA	
439	208.3	6,371	3,769	74.8	1,110
441	161.0	7,547	5,628	58.5	1,095
443	150.3	5,129	3,145	80.8	1,207
445	181.4	6,553	4,237	62.1	1,322
447	146.1	4,934	2,689	64.1	1,163
449	143.1	5,586	3,786	55.6	1,187

TABLE 8a: AVERAGE ACCELERATION DATA

G LEVEL	NUMBER OF TESTS	HEAD			CHEST	
		RESULTANT	S.I.	H.I.C.	RESULTANT	S.I.
30	2	144.1 G s = 14.3	4703 s = 1260	2772 s = 1198	50.4 G s = 5.0	639 s = 78
40	27	182.4 G s = 35.0	8260 s = 3134	5397 s = 1786	71.5 G s = 11.2	1200 s = 305
50	6	187.8 G s = 20.6	10,086 s = 3559	6907 s = 2198	86.1 G s = 10.2	1858 s = 610

S = Standard Deviation

TABLE 9: INJURY RATINGS BY TEST

NUMBER	HEAD/NECK	CHEST	SPINE	ABDOMINAL CONTENTS	ABDOMINAL WALL	PELVIS OR SUBLUMBAR MUSCLES	EXTREMITIES OR SHOULDERS
302	0	1	0	4	1	0	3
307	1	3	0	4	3	2	3
309	0	2	0	3	3	1	3
312	0	2	0	3	1	1	1
317	0	1	0	4	1	0	1
319			NO DATA	- BELT SYSTEM FAILUE			
328	0	3	0	3	3	1	4
330	1	2	0	3	1	0	3
333	0	2	0	4	1	0	2
338	0	2	0	4	2	0	3
342	0	1	0	4	3	0	3
346	0	1	0	2	1	0	2
348	0	2	2	5	3	1	4
350	0	2	0	4	1	2	4
352	0	2	0	4	2	1	2
380	0	3	0	3	2	1	4
382	0	3	0	4	3	0	4
384	0	3	0	3	1	2	4
386	0	3	0	5	1	0	3
389	0	3	0	5	4	1	4
397	0	1	0	4	1	0	2
401	0	3	2	4	3	1	5
403	0	2	3	5	1	0	4
405	0	4	3	4	2	0	3
410	0	1	0	4	1	0	2
417	0	3	0	5	3	3	3
419	0	2	0	5	4	3	2
421	0	2	2	5	4	4	2
423	0	2	0	3	4	4	3
434	0	1	0	5	3	1	3
439	0	1	0	5	4	0	2
441	0	1	0	5	2	0	2
443	0	1	0	4	3	2	4
445	0	1	0	5	3	3	2
447	0	1	2	4	4	4	3
449	0	3	0	4	3	1	2

postulated that if the clavicle failures did not occur many of the other shoulder strap injuries would also have been avoided. In test numbers 312, 317 and 330 where the clavicle did support the impact load, these other injuries were absent or minor in nature.

As mentioned, injuries due to the lap belt most frequently encountered were colon damage and muscle lacerations in the caudal abdominal area. Other injuries were present, but not as frequently nor as repeatedly as these. It would appear that the lap belt did not apply its major force to the bony structures in the pelvic area. This indicates that the belt loads were applied directly to the soft areas of the abdomen. The specific organ injury involvement would depend on the exact place the load was applied. The abdominal muscles would be involved no matter where the force application was made. Likewise, colon involvement, because of the large area it covers, would also be independent of the belt placement. Other organ injuries did occur (spleen, bladder, liver) but not as regularly.

CONCLUSIONS

The three-point restraint harness produces injuries in $-G_x$ impacts which are related to its configuaration. With this harness system, the clavicle is the primary structure preventing injury to the chest and shoulder areas. Once this structure has failed, severe injuries to deeper shoulder/axillary tissues can occur. Likewise, the thorasic viscera (heart, great vessels, lungs) become more exposed to direct or indirect force application. If clavicle fracture, not a severe injury in itself, can be prevented then these other more severe injuries may also be prevented. The dual shoulder harness configuration would be a logical choice for distributing the loads on both clavicles, thereby decreasing the injury severity.

Injuries due to the lap belt appear first to the abdominal musculature and to the colon. These may be very severe injuries in and of themselves. A severe first mode such as this indicates a need to find a different way to load the body in the lap area. Possibly by insuring that the lap belt loaded against the pelvic girdle, the severe abdominal wall and visceral injuries could be avoided or minimized. To do this the placement of the lap belt needs to be controlled precisely. This would involve careful control of the tiedown points and angles as they relate to the subject position and/or the addition of a crotch strap to keep the belt from migrating cranially above the pelvis during impact.

All of this indicates a need for more research to be conducted on harness configurations. The dual shoulder harness work has been done (Reference 2) but at higher G levels than here. The implication is that it indeed has produced an improvement in the $-G_x$ tolerance levels. However, this dual shoulder harness system also produced severe abdominal injuries. Work needs to be done to improve the lap belt restraint efficiency.

This work has also produced some insight into the effects of the material types on injury locations and severities. The data to make these comparisons is contained in this report. The results of this type analysis were recently reported to the 46th Annual Scientific Meeting of the Aerospace Medical Association (Reference 6).

A final note on this work is that environmental measures of loads, accelerations and photo displacements (Appendix C) cannot be correlated to the specific injuries which occurred. Now that the first and critical modes have been identified for this harness, a means of predicting when these injuries will occur needs to be developed. This will require developing new and different measurement methods to allow predictions of probability of injury from specific impact levels.

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APPENDICES

A. Baboon Injury Rating System

B. Summary of More Significant Injuries

C. Detailed Necropsy Protocols

D. Photo Trajectory Plots

E. Typical Data Plots

BABOON INJURY RATING SYSTEM*

Severity Code 0

No grossly evident injury.

Severity Code 1

[1]Head/Neck - mild subdural hemorrhage; mild/moderate cranial contusion/laceration.

[2]Chest - minor contusions, chest wall.

Abdominal Wall - mild/moderate abrasions or contusions, abdominal muscles.

Abdominal Contents - mild/moderate contusion or hemorrhage, abdominal mesentery or fat depots.

Pelvis/Sublumbar Region - mild/moderate contusion, regional musculature.

[3]Extremity/Shoulder Regions - mild/moderate contusion, shoulder/pectoral regions.

Severity Code 2

Head/Neck - mild/moderate subdural/meningeal hemorrhage.

Spine - fracture of spinous or transverse processes; mild/moderate avulsion, ligaments between vertebral arches.

Chest - simple rib or sternal fractures; minor lung contusions.

Abdominal Wall - severe contusion or very mild laceration/avulsion, abdominal musculature.

Abdominal Contents - mild/moderate laceration, abdominal mesentery or peritoneum.

Pelvis/Sublumbar Region - severe contusion or very mild laceration, regional musculature; ilial wing fracture.

Extremity/Shoulder Regions - subluxation, scapulo-humeral joints, with ligamentous damage; clavicular fractures; minor scapular fractures (acromial or coracoid process); acromio-clavicular luxation; minor laceration, pectoral or ventrolateral neck musculature in shoulder region.

Severity Code 3

Spine - fracture of C3-C7, without cord damage; thoracic or lumbar vertebral fractures without cord damage.

Chest - moderate lung contusion; displaced sternal fractures; multiple rib fractures.

Abdominal Wall - moderate laceration/avulsion, abdominal musculature (may include complete transection or avulsion of one or more muscles, with incomplete transection or no damage to other abdominal muscles; may also include multiple incomplete muscle lacerations).

Abdominal Contents - very minor liver laceration; intestinal contusion, including rupture of teniae coli and overlying serosa; transection of ureter; extraperitoneal bladder rupture; contusion of other abdominal organs.

Pelvis/Sublumbar Region - moderate laceration of iliopsoas musculature, involving as much as half of its thickness.

Extremity/Shoulder Regions - displaced simple long bone fracture (e.g. humerus); multiple lacerations of pectoral or ventrolateral neck musculature near attachments to humerus or scapula.

Severity Code 4

Spine - thoracic or lumbar spine fracture with cord damage.

Chest - Flail chest.

Abdominal Wall - near complete laceration/avulsion of abdominal musculature beneath lap belt.

Abdominal Contents - intestinal contusion accompanied by laceration of outer muscular layers and/or mucosal lacerations; mild/moderate liver lacerations; intraperitoneal bladder rupture.

Pelvis/Sublumbar Region - laceration of more than half the thickness of the iliopsoas musculature.

Extremity/Shoulder Regions - multiple transections and extensive lacerations of pectoral and ventrolateral neck musculature medial to shoulder joint.

Severity Code 5

Abdominal Wall - complete transection/avulsion of abdominal musculature.

Abdominal Contents - severe laceration of abdominal organs (e.g. liver); laceration of intestine with exposure of lumen.

Extremity/Shoulder Regions - multiple severe muscle transections medial to shoulder joint, with resultant exposure of axillary vessels and brachial plexus.

Severity Code 6

[4]Fatal injury in any region.

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[1]Includes head injuries and C1 or C2 injuries.

[2]Cardiac injuries observed (subendocardial, epicardial, or valvular hemorrhage) not included in rating.

[3]Damage to ventrolateral neck musculature due to shoulder harness included here.

[4]Although fatal injuries were seen only in the "Head/Neck" region, multiple fatal injuries are possible and would be rated separately.

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*Coccygeal injuries are not considered. Only grossly observable injuries are rated. The most severe injury in a region is rated. Other injuries which might be observed would be assigned severity codes by using Abbreviated Scale, AMA Committee on Medical Aspects of Automotive Safety, as a guide. However each of the seven regions would be considered separately; no values of 7, 8 or 9 would be assigned.

SUMMARY OF MORE SIGNIFICANT INJURIES *

Test Number	Necropsy Findings
302	Bladder laceration. Minor colon contusion. Pectoralis muscle laceration.
307	Bladder laceration. Minor colon contusion. Fracture, right clavicle, with moderate/severe laceration of adjacent musculature. Multiple rib fractures, right side; sternal fracture. Moderate laceration/avulsion, caudal abdominal muscle. Bilateral ilial wing fractures. Several minor subendocardial hemorrhages, left ventricle.
309	Mild/moderate colon contusion. Fracture, right clavicle, with moderate/severe associated muscle lacerations. Sternal luxation. Moderate lacerations, caudal abdominal muscles.
312	Mild/moderate colon contusion. Several minor subendocardial hemorrhages, left ventricle.
317	Moderate colon contusion. Several minor subendocardial hemorrhages, left ventricle.
328	Minor avulsion, splenic capsule. Multiple chondrosternal luxations, right side. Moderate/severe avulsion, caudal abdominal muscles, right side. Fracture, right clavicle, with rather severe laceration of adjacent musculature. Mild/moderate rectal contusion.
330	Minor colon contusions. Multiple subendocardial hemorrhages, left ventricle. Fracture, right humerus.

* Hemorrhages observed in the heart muscle were not, in the author's opinion, significant injuries. They are listed because of a special interest in these injuries expressed by others.

Test Number	Necropsy Findings
333	Severe colon contusions. Several minor, focal, subendocardial hemorrhages, left ventricle. Fracture, right clavicle.
338	Bladder laceration. Mild/moderate colon contusion. Luxation, right acromio-clavicular joint, with minor laceration of adjacent musculature. Minor laceration, right caudal abdominal muscle.
342	Moderate liver lacerations. Two mild colon contusions. Multiple mild, focal, subendocardial hemorrhages, left ventricle. Fracture, right clavicle, with moderate/severe laceration of adjacent musculature. Moderate avulsion, right caudal abdominal muscles.
346	Fracture, right clavicle.
348	Three colon transections. Minor avulsion, splenic capsule. Fracture, right clavicle, with rather severe lacerations of adjacent musculature. Moderate/severe lacerations, right caudal abdominal muscles. Incomplete fracture, base of transverse process, T9. Two rib fractures, right side.
350	Three moderate/severe colon contusions. Moderate liver laceration. Fracture, right clavicle, with rather severe lacerations of adjacent musculature. Incomplete fracture, body of right scapula. Fracture, left clavicle.
352	Moderate/severe colon contusion. Mild/moderate liver laceration. Minor lung contusion, right side. Several minor focal subendocardial hemorrhages, left ventricle. Subluxation, right acromio-clavicular joint, with associated acromial and corocoid fractures. Fracture, left clavicle Minor avulsion, right caudal abdominal muscle.

Test Number	Necropsy Findings
380	Moderate colon contusion. Fracture, right clavicle, with moderate/severe lacerations of associated musculature. Sternal and chondrosternal luxations.
382	Moderate colo-rectal contusion. Moderate lung contusion, right middle lobe. Mild myocardial contusion; several focal subepicardial hemorrhages. Fracture, right clavicle, with moderate/severe lacerations of adjacent musculature. Sternal and chondrosternal luxations. Rib fractures multiple. Moderate laceration, right rectus abdominis muscle.
384	Minor colon contusion. Minor hepatic subcapsular hemorrhage. Fracture, right clavicle, with rather severe associated muscle lacerations, shoulder/chest area. Fractures, right scapula, right ilial wing. Complete sternal luxation, with displacement. Lung contusions, right side, moderate.
386	Severe colon contusions; one colon perforation. Fracture, right clavicle, with minor associated muscle laceration. Laceration, left pectoralis major, moderate. Sternal luxation, complete.
389	Severe colon contusions; one colon perforation. Moderate/severe small intestine contusion. Minor subcapsular hepatic hemorrhage. Fracture, right clavicle, with rather severe associated muscle lacerations. Rather severe lacerations, caudal abdominal musculature, right side. Sternal luxation, with displacement.
397	Severe colon contusion; moderate small intestine contusions. Minor avulsion, splenic capsule. Fracture, right clavicle; subluxation acromioclavicular joint.

Test Number	Necropsy Findings
401	Severe colon contusion. Moderate subcapsular renal hemorrhage, left side. Moderate avulsion, hepatic capsule, left lobe. Fracture, right clavicle, with severe associated muscle lacerations. Fracture, right scapula. Multiple rib fractures, right side. Fracture, left transverse processes, L1-5. Laceration, right rectus abdominis. Focal subpleural hemorrhage, hilum of right middle lobe. Minor focal (5/10 mm) subepicardial hemorrhage, ventral cardiac surface, near apex.
403	Multiple colon contusions, moderate/severe. Two contusions, small intestine, moderate. Moderate/severe liver lacerations, with major intraperitoneal hemorrhage. Luxation, left elbow joint. Luxation, right acromio-clavicular joint, with rather severe associated muscular lacerations/contusions. Moderate avulsion, intercostal muscles, right side. Fracture, left transverse processes, L4 and L5. Fracture, vertebral arch, T11. Minor subpleural hemorrhages, costal surfaces, right lung.
405	Animal died, respiratory arrest following impact. Two rather severe lacerations in subcutis underlying restraint harness. Bladder laceration, intraperitoneal. Moderately severe colon contusion. Minor avulsion, liver capsule and adjacent parenchyma. Minor avulsion, splenic capsule. Fracture, right clavicle, with rather severe laceration of adjacent musculature. Major lacerations, caudal abdominal muscles. Multiple rib fractures, left side. Three rib fractures, right side. Fracture, spinous processes, C6 and C7. Fracture, vertebral arches, T1 and T2, with associated ligamentous avulsion. Moderate focal lung contusions, right side. Minor subepicardial hemorrhage, caudal surface of left ventricle.

Test Number	Necropsy Findings
410	Three rather severe colon contusions. Fracture, right clavicle.
417	Severe colon contusions; one colon transection. Minor hepatic laceration; moderate subcapsular hemorrhage. Fracture, right clavicle, with moderate/severe laceration of adjacent musculature. Sternal fracture and luxation, with displacement. Fracture, right 3rd rib. Chondrosternal luxations, 4th ribs. Rather severe lacerations, right caudal abdominal wall. Moderate laceration, right subpelvic musculature. Minor focal right lung contusion.
419	Severe colon contusion; two colon transections. Minor hepatic lacerations. Avulsion, right acromial process. Minor laceration, right pectoralis minor. Severe contusion, right trapezius. Subluxations, chondrosternal joints, right side. Severe lacerations, caudal abdominal muscles; subpelvic muscles. Minor lung contusion. Several subendocardial petechiae (possibly catheter induced).
421	Moderate subcutaneous lacerations and contusions. Three severe colon contusions, with perforation. Mild/moderate subcapsular hepatic hemorrhages. Avulsion, acromial process of right scapula, with minor laceration of associated musculature. Subluxation, right shoulder joint. Chondrosternal luxations, right side. Rather severe laceration, caudal abdominal muscles. Contusion/laceration, moderate, subpelvic muscles. Fracture, left transverse process, L5. Minor lung contusion, right side. Very mild scattered subendocardial hemorrhage, left ventricle.
423	Moderate subcutaneous lacerations. Minor colon contusion. Minor subcapsular hepatic hemorrhage. Fracture, right clavicle and scapula, with rather severe laceration of adjacent musculature. Sternal luxation.

Test Number	Necropsy Findings
423 (continued)	Right 5th rib fracture. Severe laceration, caudal abdominal muscles. Fracture, ilial wings, with moderate/severe subpelvic muscle laceration. Minor contusion, right lung. Minor subendocardial hemorrhage, left ventricle and aortic valve (possibly catheter induced).
434	Severe intestinal contusions, with exposure of gut lumen. Considerable intraperitoneal hemorrhage. Moderate subcapsular hepatic hemorrhage, with minor liver lacerations. Minor gastric contusion. Fracture, right clavicle, with moderate/severe laceration of associated musculature. Moderate contusions/lacerations, caudal abdominal muscles. Several minor hemorrhages, aortic valve and left interventricular septum (possibly catheter induced).
439	Severe colon contusions/transections, with intraperitoneal hemorrhage. Luxation, right clavicle. Rather severe lacerations, caudal abdominal muscles. Minor subpleural hemorrhage, right lung. Minor hemorrhage, right A-V valve.
441	Two colon transections, one severe contusion, rather massive accompanying hemorrhage. Minor subcapsular hepatic hemorrhage. Fracture, right clavicle. Minor separation, caudal abdominal muscles. Minor petechiae, left ventricle (possibly iatrogenic).
443	Rather severe rectal contusion. Rather mild subcapsular renal hemorrhage, left side. Fracture, right clavicle, with moderately severe lacerations of associated musculature. Fracture, right scapula. Moderate/severe lacerations, caudal abdominal musculature. Fracture, left ilial wing.
445	Two transections, small intestine; one severe colon contusion. Fracture, right clavicle. Moderately severe lacerations, caudal abdominal musculature, right side. Moderate laceration, right subpelvic musculature.

Test Number	Necropsy Findings
447	Moderate contusion/laceration, abdominal subcutis. Rupture, urinary bladder. Colon laceration, with considerable abdominal hemorrhage. Moderate/severe laceration, caudal abdominal musculature. Moderate/severe laceration, sublumbar musculature. Fracture, right clavicle, with moderate laceration of associated musculature of shoulder.
449	Severe colon contusion. Luxation, right acromio-clavicular joint. Sternal luxation, with displacement. Moderate/severe laceration, caudal abdominal musculature.

Veterinary Necropsy Protocol

Experimental History

This animal was subjected to approximately 40 G load, $-G_x$ direction, on the BBI Impulse Accelerator, 10 Oct 73, Run 302. Dacron harness material was used and adjusted to 6-9 lb. tension prior to impact. A "three point" restraint system was used for subject protection.

Identification

Baboon D28, adult male, 44 lbs., Papio sp.

Gross Observations

The animal survived impact and was exsanguinated via bilateral femoral arterotomy prior to autopsy.

External: Rather mild contusions/abrasions present overlying the inguinal/caudal abdominal area and from the right shoulder to just caudal to the left axilla, underlying the restraint harness. The left pectoral muscle was obviously ruptured beneath the linear skin - contusions/abrasions present.

Mild hemorrhage present in the mouth due to a small tongue laceration present.

Subcutis: Very mild petechial and ecchymotic hemorrhages present in subcutis and epimuscular fascia underlying the skin contusions noted above.

Abdominal Cavity: Considerable bloody urine present in the caudal abdominal cavity and in the retroperitoneal fascial and areolar tissue ventral and lateral to the bladder. There was a laceration in the ventral surface of the bladder, running longitudinally from near the neck to the fundus. This laceration nearly encircled the neck of the bladder at its caudal extreme, with only the dorsal wall of the neck intact.

The visceral peritoneum adjacent to the internal inguinal rings was torn bilaterally for 1-2 cm.

Considerable hemorrhage was present in the retroperitoneal areolar and adipose tissues adjacent to the bladder and in the subpelvic areas.

A colon contusion was present, near its caudal limits. Here the teniae were ruptured and moderate associated intramural hemorrhage was present.

Musculoskeletal System: The left pectoralis major muscle was lacerated through its belly as noted above.

Slight foci of hemorrhage were present overlying the lateral limits of the inguinal ligaments.

Thoracic Cavity: A focus of moderate hemorrhage was noted in the septal cusp of the right A-V valve.

Rather mild petechial and ecchymotic hemorrhage present scattered over the lung surface in the hilar areas; all lobes seemed equally affected.

More Significant Lesions

1. Bladder laceration.

2. Left Pectoralis muscle laceration.

3. Colon contusion, with rupture of the teniae.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 2 Nov 73, Run 307. Dacron harness material (new) was used and adjusted to 8-12 lbs. tension prior to impact. A "three-point" automotive type restraint system was used for subject protection.

Identification

Baboon D30, adult male, 64 lbs., Papio sp.

Gross Observations

The animal survived impact and was euthanized via exsanguination prior to autopsy.

External: Moderate hemorrhage occurred from the mouth following impact due to several puncture wounds in the tongue (teeth punctures).

A rather short laceration, approximately 2 cm, present through the skin, subcutis and fascia overlying the lateral extreme of the left inguinal ligament.

Rather mild contusions and abrasions present in the skin underlying the restraint harness (caudal abdominal wall, overlying right shoulder and chest).

Subcutis: Considerable subcutaneous and epimuscular hemorrhage present in the area of the right caudal abdominal wall. Similar hemorrhage present overlying the right shoulder extending to the midpoint of the sternum.

The right clavicle was obviously fractured near midshaft.

Abdominal Cavity: The bladder was lacerated longitudinally on the ventral surface near the fundus, 1 cm in length. Considerable bloody urine was present in the retroperitoneal tissues adjacent to the bladder and in the abdominal cavity. Two peritoneal lacerations were present, 2-4 cm in length, one at the right internal inguinal ring and the other just cranial to the left internal inguinal ring. Considerable hemorrhage/contusion was present in the adipose and areolar tissues adjacent to the bladder.

A colon contusion was present at its caudal limit. The teniae were ruptured at this point and some subserosal/intramural hemorrhage was present. A slight tear in the mesocolon had occurred at this point also.

The sublumbar adipose tissues were very hemorrhagic.

Musculoskeletal System: The pectoralis major and minor were ruptured near their insertions, adjacent (medial) to the shoulder joint. The clavicular fracture was noted above.

The right omohyoideus muscle was separated near the fracture site.

The 4th sternebra was fractured obliquely at its cranial end, and the 4th right rib had separated at this point. Considerable hemorrhage occurred with these injuries, and was evident on the subpleural surface of the sternum and in the adjacent mediastinal tissues.

The 6th right rib was fractured approximately 2-1/2 cm from the costachondral junction.

Ribs 7 through 11 were fractured on the right side, 1-2 cm from their vertebral attachments.

The right rectus abdominis muscle was separated near the pubis.

The transversus abdominis muscle was separated from the inguinal ligament on the right side.

Some superficial fibers of the right iliacus muscle were separated also, with moderate associated hemorrhage.

There was a focal hemorrhage overlying the lateral limit of the left inguinal ligament.

Bilateral fracture of the ilial wings occurred at their craniolateral extremities. Some associated hemorrhage was present.

There was considerable hemorrhage present underlying the right trapezius muscle, medial to the shoulder joint and scapular spine.

Central Nervous System: Some mild subdural hemorrhage was present overlying the dorsal surface of the spinal cord at the foramen magnum.

Thoracic Cavity: A small 1 mm subendocardial hemorrhage was present at the junction of the septal and ventrolateral cusps of the right A-V valve.

Four focal 2-3 mm subendocardial hemorrhages were present on the septal wall of the left ventricle.

More Significant Lesions

1. Clavicle fracture.
2. Rib fractures.
3. Sternal fracture.
4. Muscle lacerations, abdominal and pectoral.
5. Ilial wing fractures.
6. Bladder rupture.
7. Colon contusion.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 6 Nov 73, Run 309. New dacron harness material was used and adjusted to 7-10 lbs. tension prior to impact. A "three-point" automotive type restraint system was used for subject protection.

Identification

Baboon D36, adult male, Papio sp., 54-1/2 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination prior to autopsy.

External: A moderate hemorrhagic contusion, 3x4 cm, was present in the left inguinal area; a similar but milder lesion was present on the right side. A linear contusion/abrasion extended from just medial to the point of the right shoulder caudally over the chest and sternum. These areas were underlying the harness at impact.

Subcutis: There was a 2-3 cm rent in the subcutis on the caudal abdominal midline, 4 cm anterior to the pubis. A similar 4-5 cm rent was present overlying the sternum. Rather mild hemorrhage was associated with these injuries.

Abdominal Cavity: Rather mild scattered petechiae present in the suspensory ligaments of the spleen and liver. Scattered mild subcapsular hemorrhage was present over the diaphragmatic surface of the liver near its ligamentous attachments also.

A moderate colon contusion was present, near the level of the pubis. The teniae were ruptured here, and moderate intramural and subserosal hemorrhage was present.

The sublumbar retroperitoneal fat depots were moderately hemorrhagic, as were the fat depots adjacent to the bladder and pelvic cavity.

The peritoneum was lacerated bilaterally in the areas of the internal inguinal rings, 3-4 cm in length.

Musculoskeletal System: The right clavicle was fractured near midshaft. The adjacent pectoralis major muscle belly was entirely separated near this point also. The right sternomastoideus was also separated at this area. There was minor separation of the cranial portion of the right trapezius just medial to the shoulder. Moderate hemorrhage was associated with these injuries.

A sternum luxation was present at S4 and S5, with moderate associated subpleural hemorrhage.

Additional subpleural hemorrhage, rather mild, was noted about the shafts of ribs 3 through 6, 3-6 cm from their vertebral extremeties.

The right rectus abdominis muscle was transected through the lateral half of its belly, 3-4 cm cranial to the pubis.

The right internal oblique and transversus were separated from their attachments to the lateral fourth of the inguinal ligament.

Rather mild hemorrhage was present in the right iliacus muscle.

Central Nervous System: The vessels of the parietal dura appeared congested.

More Significant Lesions

1. Clavicle fracture.

2. Muscle lacerations, abdominal and shoulder region.

3. Sternal luxation.

4. Colon contusion.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 8 Nov 73, Run 312. New dacron harness material was used and adjusted to 5-6 lbs. tension prior to impact. A "three-point" automotive type harness was used for subject protection.

Identification

Baboon D24, young adult male, Papio sp., 36.5 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination prior to autopsy.

External: Mild contusions were present under the lateral limits of the lap belt; a moderate linear contusion was present from the right shoulder to the sternum (underlying the shoulder harness).

Subcutis: Rather mild subcutaneous and epimuscular hemorrhage present along the caudal abdominal wall and medial to the right shoulder; moderate such lesions were present over the sternum.

Abdominal Cavity: Rather mild hemorrhagic contusion present in sublumbar fat depots.

Rather moderate colon contusion present, near level of pubis; two teniae ruptured here with associated subserosal and intramural hemorrhage.

Mild petechiae present, splenic and hepatic suspensory ligaments. Very mild subcapsular petechial hemorrhage present scattered over liver surface adjacent to suspensory ligaments.

Thoracic Cavity: Mild subpleural focal hemorrhage, approximately 5 mm in diameter, adjacent to the rib shafts of ribs 4, 5 and 6, near midshaft, right side.

Four mild parallel linear subpleural hemorrhages, 1x10 mm, present on the costal surfaces of the diaphragmatic and apical lung lobes, right side.

A linear, mild subendocardial hemorrhage was present, approximately 1x3 mm, on the trabeculae carnae near the apex, at the junction of the septum and left wall of the left ventricle. Several similar focal, mild subendocardial hemorrhages were present on a papillary muscle in the left ventricle. These hemorrhages were approximately 1x1 mm and affected the left-most papillary muscle, which supplied chordae tendinae to both A-V cusps.

Musculoskeletal System: A mild focus of hemorrhage was present in the attachments of the abdominal muscles to the lateral end of the right inguinal ligament.

A minor focus of hemorrhage was present superficially on the right iliacus muscle.

More Significant Lesions

1. Colon contusion.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 13 Nov 73, Run 317. New dacron harness material was used and adjusted to 6-9 lbs. tension prior to impact. A "three-point" automotive type harness was used for subject protection.

Identification

Baboon D26, young adult male, Papio sp., 41 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination prior to autopsy.

External: Very mild contusions/abrasions underlying the lateral limits of the lap belt. Mild such linear lesion present from right shoulder to sternum.

Subcutis: Very mild scattered subcutaneous hemorrhages over caudal abdominal wall; moderate such lesions from right shoulder to sternum. A slight 2 cm rent in subcutis longitudinally overlying the sternum.

Abdominal Cavity: Slight intra-abdominal hemorrhage present, caudal abdominal cavity, from colon contusion. This moderate contusion was present at the level of the pubis, with moderate associated subserosal and intramural hemorrhage. The mesocolon was lacerated perhaps 1.5 cm adjacent to the contusion, and the serosa was lacerated perhaps 1 cm along the mesenteric attachment also. The teniae were ruptured at this locus as well. Rather minor separation of the outermost layer of the colon wall had occurred for approximately 1 cm along its mesenteric attachment.

Rather mild hemorrhage was present in the sublumbar fat depots.

Some scattered petechiae were present in the suspensory ligaments of the spleen and liver. Some scattered minor subcapsular hemorrhage was present on the liver surface at its ligamentous attachments to the diaphram.

Thoracic Cavity: Several scattered subendocardial petechia noted over the septal wall of the left ventricle. A minor focal 1x1 mm hemorrhage was also present beneath the parietal cusp of the left A-V valve.

Occasional focal 1x1 mm subpleural hemorrhages noted over the lung surfaces; few were present. Similar lesions noted over the ventral thymic surface also.

Mild, rather diffuse subpleural hemorrhage noted along the shafts of ribs 4 through 7, right side. Similar focal hemorrhage present at the costochondral junctions of these ribs.

More Significant Lesions

Colon contusion.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 20 Nov 73, Run 328. New black nylon harness material was used and adjusted to 8-12 lbs. tension prior to impact. A "three-point" automotive type harness was used for subject protection.

Identification

Baboon D50, adult male, Papio sp., 67.5 lbs.

Gross Observations

External: Mild contusions/abrasions present underlying the lateral limits of the lap belt and the shoulder harness from the right shoulder to the sternum.

Subcutis: Very mild subcutaneous scattered focal hemorrhages were present beneath the skin lesions noted above. A 2 cm rent was present in the subcutis overlying the caudal sternal segments.

Abdominal Cavity: Slight intraperitoneal hemorrhage present, left cranial quadrant, due to separation of the splenic capsule from the spleen surface at the attachments of the splenic ligaments. The area involved was perhaps 5x10 mm.

Mild petechiae were present in the suspensory ligaments of the liver, diaphragmatic surfaces.

The subpelvic fat depots were moderately hemorrhagic. A rectal contusion was present near the level of the pubis. Incomplete separation of the teniae had occurred at this level and moderate associated intramural and subserosal hemorrhage was present.

A very mild contusion was present in the small intestine also. Scattered petechiae were present subserosally.

Thoracic Cavity: Mild/moderate hemorrhage present in the ventral mediastinal tissues underlying sternal luxations to be noted below.

Musculoskeletal System: Focal intramuscular hemorrhage present overlying the left sternoclavicular joint and sternal extreme of clavicle.

The transversus abdominis muscle was separated from its attachments to the left side of the xiphoid. (The torso accelerator package was mounted externally in this area.)

There were chondrosternal luxations of ribs 5, 6, 7, and 8, right side, with considerable associated hemorrhage.

The internal oblique and transversus abdominis muscles were nearly completely separated from their attachments to the lateral portion of the right inguinal ligament.

There was rather extensive trauma present medial to the right shoulder joint. The pectoralis major was separated near its sternal attachments. The pectoralis minor was incompletely separated medial to the shoulder joint. The right clavicle was fractured near midshaft. The right trachelo-acromialis was ruptured near the shoulder joint also. The trapezius at this point was partially separated as well, as was the omohyoideus. Considerable hemorrhage was associated with these lesions.

Focal epimuscular hemorrage, approximately 3x4 cm, was present overlying the trapezius at the posterior border of the left scapula.

Rather diffuse, mild hemorrhage present along the shafts of ribs 4 through 6, right side, visible from the pleural surfaces.

Mild hemorrhage present in the right iliacus muscle.

More Significant Lesions

1. Rectal contusion.

2. Splenic capsular laceration.

3. Muscle ruptures, abdominal and shoulder muscles.

4. Fracture, right clavicle.

5. Chondrosternal luxations.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 27 Nov 73, Run 330. New black nylon harness material, 1 inch wide, was used and adjusted to approximately 10 lbs. tension prior to impact. A "three-point" automotive type harness was used for subject protection.

Identification

Baboon D34, young adult male, Papio sp., 43 lbs.

Gross Observations

External: Mild contusions/abrasions present in the skin underlying the restraint harness at impact. These occurred from the right shoulder to mid-sternum and in the lateral inguinal areas.

Subcutis: Moderate epimuscular and subcutaneous hemorrhage present overlying the sternum; mild, scattered, occasional echymotic hemorrhages in the lateral inguinal/caudal abdominal areas.

Abdominal Cavity: A rather mild colon contusion was present, just cranial to the pubis. Here the mesenteric tenia was ruptured with rather minor associated intramural and subserosal hemorrhage.

A second very minor colon contusion was present approximately 25 cm proximal to the first. Here a focal 3 mm subserosal hemorrhage was present.

Mild scattered petechiae present in the suspensory ligaments of the hepatic flexure of the colon and the splenic ligaments also.

Rather mild subcapsular hemorrhage present at the base of the fissure separating the cental and right liver lobes. A 1 mm tear was present in the serosa at the base of this fissure.

Moderate subserosal hemorrhage was present longitudinally along the body of the gall bladder, on its ventral hepatic surface.

Rather mild hemorrhage was present in the subpelvic fat depots.

Minor scattered petechiae present scattered over the caudal abdominal pariental peritoneum.

Thoracic Cavity: Rather mild diffuse hemorrhage present along the shafts of ribs 5 through 9, right side, visible from the pleural surface of the chest wall. Some very mild, linear, subpleural hemorrhage was also visible on the lung surfaces adjacent to several of these ribs.

Two petechiae were present on the dorsal-most papillary muscle in the right ventricle (which supplied chordae tendinae to the dorso-lateral A-V cusp). In the left ventricle both papillary muscles contained linear, subendocardial hemorrhages. Scattered, patchy, mild subendocardial hemorrhages were also present scattered over the septal wall and several traheculae cornae.

Musculoskeletal System: Rather mild focal hemorrhage noted about the left acromio-clavicular joint. Here the coraco-clavicular ligament had separated from its clavicular attachments.

Moderate hemorrhage was present about the right shoulder joint. The source of this hemorrhage was a transverse fracture of the shaft of the humerus, several centimeters from the head. Considerable hemorrhage was associated with this fracture.

A moderate focus of hemorrhage, perhaps 1.5 cm in diameter, was present in the right temporalis muscle, just anterior to the nuchal (lambdoid) crest near midline.

Focal moderate hemorrhage was present along the lateral limits of the right inguinal ligament; very mild such hemorrhage present on the left side.

Mild deep focal hemorrhage present at the origins of the anterior thigh muscles to the left ilial shaft.

More Significant Lesion

Fractured right humerus.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 29 Nov 73, Run 333. New black nylon harness material, 1 inch wide, was used and adjusted to approximately 10 lbs. tension prior to impact. A "three-point" automotive type harness configuration was used for subject protection.

Identification

Baboon D46, young adult male, Papio sp., 40 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: A moderate linear contusion was present from the right shoulder to the caudal sternal segments. Rather minor such lesions in the lateral inguinal areas.

Subcutis: Moderate subcutaneous and epimuscular hemorrhage present from the right shoulder to the sternum.

Abdominal Cavity: Some rather minor free hemorrhage present in the caudal abdominal cavity. The source of this hemorrhage was a rather severe colon contusion, just cranial to the pubis. Here the serosa, teniae and some underlying outer layers of colon wall were lacerated. Moderate associated intramural hemorrhage was present, visible from the mucosal surface, involving perhaps 2 cm of colon length. Several scattered minor mucosal lacerations were present also, with some free hemorrhage in the colon lumen. The adjacent mesocolon was moderately hemorrhagic also.

A few scattered petechiae were present in the splenic ligaments.

Some minor subcapsular hemorrhage was present at the base of the fissure separating the central and right liver lobes. Similar hemorrhage was also present at the base of the umbilical fissure of the central lobe.

Thoracic Cavity: Several minor rather linear subpleural hemorrhages, parallel to the ribs, were present in the apical and cardiac lobes of the right lung.

Heart: A focal 1x2 mm hemorrhage was present in the ventrolateral cusp of the right A-V valve. A focal 1x3 mm subendocardial hemorrhage was present perhaps 2 mm dorsal to the midpoint to the dorsolateral cusp of the right A-V valve, in the right atria. (Perhaps these two hemorrhages resulted from the cardiac catheter?)

Several petechiae were present beneath the dorsal cusp of the left A-V valve. The distal tips of the two papillary muscles supporting this cusp have minor, diffuse subendocardial hemorrhage present.

Musculoskeletal System: Moderate hemorrhage present about the acromial end of the right clavicle due to a transverse clavicular fracture present at this locus.

Moderate intramuscular hemorrhage present in the third and fourth interspace, right side, adjacent to the costochondral junction of rib 4. Mild such hemorrhage present in these same interspaces 3-4 cm from the vertebral column.

Focal, minor, intramuscular hemorrhage present at the lateral extremity of the left inguinal ligament.

More Significant Lesions

1. Moderate/severe colon contusion.

2. Fracture, right clavicle.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 4 Dec 73, Run 338. Black nylon harness material, 1 inch wide, in a "three-point" automotive type configuration was used for subject protection, Harness tension was adjusted to approximately 10 lbs. prior to impact.

Identification

Baboon C96, adult male, Papio sp., 46 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: A moderate linear skin contusion was present, from the point of the right shoulder to the caudal sternum area. Very mild contusions present in the lateral inguinal areas.

Subcutis: Considerable rent in subcutis overlying right pectoral muscle and sternum, associated with rather mild hemorrhage.

Abdominal Cavity: Bladder rupture present, longitudinal laceration along ventral body and encircling perhaps 180 degrees of the neck. Much bloody urine present in the retroperitoneal space adjacent to the bladder and in the abdominal cavity also.

A mild colon contusion was present, anterior to the pubis, with rupture of the mesenteric tenia and mild focal associated subserosal and intramural hemorrhage. Several minor 1-3 mm mucosal lacerations were present at this locus also with very minor associated hemorrhage into colon lumen.

Slight tearing of the omental attachments to one colon band near the hepatic flexure of the colon had occurred.

Rather mild subcapsular hemorrhage was present at the base of the fissure separating the right and central liver lobes. Similar such hemorrhage present on the visceral surface of the right lobe also, near the hilus.

Thoracic Cavity: Several mild, focal, subpleural hemorrhages present over the costal surfaces of the right lung lobes.

Heart: A linear 1x2 mm subendocardial hemorrhage present near the tip of the lateral-most papillary muscle, right ventricle. Several petechial hemorrhages present, septal cusp, right A-V valve; one 1x1 mm

hemorrhage present here also. A 1x2 mm subendocardial hemorrhage present on the ventral right atrial wall, 6-8 mm above the ventrolateral cusp of the A-V valve. (Cardiac catheter damage?)

Musculoskeletal System: Luxation of the right acromio-clavicular joint was present; moderate associated hemorrhage in area.

The right trachelo-acromialis muscle was nearly completely transected 5-7 cm from its origin on the atlas.

The right transversus abdominis muscle was partially separated at the craniolateral limit of the inguinal ligament. On the contralateral side there was minor deep intramuscular hemorrhage at this locus.

More Significant Lesions

1. Acromio-clavicular luxation.

2. Lateral neck muscle laceration.

3. Abdominal muscle separation.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, Run 342, 6 Dec 73. New black nylon harness material, 1 inch wide, in a three-point automotive type configuration was used for subject protection. Harness tension was adjusted to approximately 10 lbs. prior to impact.

Identification

Baboon C90, adult male, Papio sp., 59 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: Rather mild cutaneous abrasions/contusions present, right shoulder to caudal sternum and in lateral inguinal areas.

Subcutis: Rather mild subcutaneous and epimuscular hemorrhage present underlying the skin lesions noted above. A slight rent in the subcutis was present overlying the caudal sternum.

Abdominal Cavity: Considerable abdominal fat depots present; those adjacent to the bladder were moderately hemorrhagic. The peritoneum was lacerated bilaterally along the cranial base of these fat depots for 3-4 cm.

Some free hemorrhage present in the abdominal cavity (50 ml?). Source of this hemorrhage was two liver lacerations. Both were present on the visceral surface of the central lobe, were 2.5-3 cm in length, and 6 mm deep at their deepest points. One originated at about the midpoint of the body of the gall bladder and the other near the hilus. Some mild subcapsular hemorrhage present at the attachments of the suspensory ligaments to the cranial surface of the right liver lobe.

Two colon contusions present, perhaps 16 cm apart. One rather mild contusion was at the distal colon. Here all three teniae were ruptured with mild associated subserosal hemorrhage. The proximal lesion was milder. Here only the mesenteric tenia was ruptured, with limited associated hemorrhage.

Slight petechial hemorrhage present, splenic ligaments.

Heart: A focal 1x1 mm subendocardial hemorrhage present in the right atrial wall, 6-8 mm above the midpoint of the ventro-lateral cusp, right A-V valve (possibly due to atrial catheter?).

There were numerous mild, focal, subendocardial hemorrhages scattered over the left ventricular surfaces and the base of the papillary muscles. Most of these hemorrhages were approximately 1x1 mm; some were more linear, perhaps 1x3 mm.

Musculoskeletal System: Mild, diffuse, intramuscular hemorrhage present in the 4th and 5th interspaces, right side, approximately midshaft of the ribs.

There was considerable trauma adjacent to the right shoulder. Here the clavicle was fractured, near midshaft. The right pectoralis major and minor were ruptured through perhaps half their bellies just medial to the right shoulder joint. The right trapezius muscle was lacerated through perhaps 4 cm of its cranial limit medial to the shoulder joint also. Here the trachelo-acromialis and perhaps one-half of the belly of the atlantoscapularis muscle were lacerated as well.

The internal oblique and transversus muscles, right side, were nearly completely separated from the craniolateral third of the inguinal ligament. A moderate, deep intramuscular contusion was present at this locus on the left side.

More Significant Lesions

1. Liver lacerations.

2. Muscle lacerations, right shoulder area and caudal abdominal area.

3. Right clavicular fracture.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 30 G, $-G_x$ direction, on the Impulse Accelerator, 11 Dec 73, Run 346. New black harness material, 1 inch wide, in a three-point automotive type configuration was used for subject protection. Harness tension was adjusted to approximately 10 lbs. prior to impact.

Identification

Baboon D16, adult male, Papio sp., 60 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: Mild linear cutaneous contusion present, medial to right shoulder to sternum. Similar very mild such lesions present in lateral inguinal areas.

Subcutis: Mild epimuscular and subcutaneous hemorrhage present overlying the caudal third of the sternum; a 2 cm rent in the subcutis was present here also.

Mild diffuse epimuscular hemorrhage present overlying the dorsal lumbar area.

Abdominal Cavity: A mild, focal, 1 cm hemorrhage present in the terminal mesocolon perhaps 3-4 cm from the colon wall. Several scattered petechiae were present at this locus of the mesocolon also.

Some slight petechiae present in the splenic ligaments.

The globular fat depots adjacent to the urinary bladder were moderately hemorrhagic. There were bilateral lacerations in the peritoneum, 2-3 cm in length, at the base of these fat depots.

Musculoskeletal System: Slight rather diffuse intramuscular hemorrhage present in interspace 3 and 4, right side, about midshaft of the ribs. Similar slight focal hemorrhage present about the right third costochondral joint.

The right clavicle was fractured transversely near midshaft; mild/moderate associated hemorrhage present.

Rather mild localized contusion of the muscular tissues adjacent to the craniolateral limits of the left inguinal ligament was present.

More Significant Lesion

Fracture, right clavicle.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 50 G, $-G_x$ direction, on the Impulse Accelerator, 13 Dec 73, Run 348. New black nylon harness material, 1 inch wide, in a three-point automotive type configuration, was used for subject protection. Harness tension was adjusted to approximately 10 lbs. prior to impact.

Identification

Baboon C84, adult male, Papio sp., 44 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: Mild/moderate linear contusion from medial to right shoulder to just across the caudal sternum. Mild such lesions present overlying the inguinal/groin areas.

Subcutis: Moderate subcutaneous and epimuscular hemorrhage present from the right shoulder to the sternum. Very mild scattered such hemorrhages across the caudal abdomen, 2-3 cm caudal to the umbilicus. There was a short 2 cm rent in the subcutis on the caudal abdominal midline and 5-6 cm rent over the sternum/right chest wall.

A rather mild focal subcutaneous hemorrhage present overlying T6-T9 on the dorsal midline.

Abdominal Cavity: Considerable free hemorrhage present in the peritoneal cavity (perhaps 100 ml?). The source of this hemorrhage was three colon transections. Two colon transections were spaced approximately 3 cm apart at the terminal colon. The 3 cm colon segment was free floating in the abdominal cavity, devoid of mesenteric attachments. The mesocolon at this locus was torn 6-8 cm.

The most proximal colon transection was approximately 20 cm distal to the hepatic flexure. Here the adjacent mesocolon was lacerated 4 cm.

Rather mild subperitoneal hemorrhage present linearly along the falciform ligament (which contained considerable adipose tissue). This hemorrhage was located along the abdominal wall cranial to the umbilicus.

Approximately 1 cm^2 of splenic ligament and capsule was separated from the caudal end of the spleen. Little associated hemorrhage was present.

Minor subcapsular hemorrhage was present along the attachments of the left liver lobe to the diaphragm.

Bilateral 2 cm lacerations present in the peritoneum at the base of the globular sublumbar fat depots. These fat depots are rather severely hemorrhagic.

Multiple lacerations present in the greater omentum, 1-15 cm in length.

Thoracic Cavity: Two mild lung contusions present, right apical and cardiac lobes, costal surfaces. Only superficial lung parenchyma involved.

Musculoskeletal System: Bilateral lacerations/separations present in the aponeurosis of the transversus abdominis muscles adjacent and roughly parallel to the falciform ligaments. These lacerations were 4-6 cm in length and located caudal to the xiphoid cartilage.

Mild focal intramuscular hemorrhage present, chondrosternal joints of the left 4th and right 5th ribs.

Mild diffuse intramuscular hemorrhage present, 3rd, 4th and 5th interspaces, right side, 4-6 cm from costochondral junctions. The right 5th and 6th ribs were fractured 3-4 cm from the costochondral junctions.

Rather severe trauma medial to the right shoulder joint and to adjacent chest musculature. The cranial two-thirds of the pectoralis major and the cranial one-fourth of the pectoralis minor were lacerated 2-4 cm lateral to the sternum. The right clavicle was fractured 1.5 cm from the sternoclavicular joint. The right atlanto-scapularis, trachelo-acromialis, and omohyoideus muscles were ruptured medial to the shoulder joint. The right trapezius muscle was lacerated through its cranial 4-5 cm. The underlying supraspinatus muscle belly was lacerated 1-2 cm deep in its cranial border. Moderate hemorrhage was associated with these injuries.

Some rather moderate trauma occurred over the caudal abdominal wall. The right rectus abdominis muscle belly 2cm caudal to the umbilicus was half transected. The right internal oblique and transversus muscles were partially separated from their attachments to the craniolateral fourth of inguinal ligament. Rather mild focal intramuscular hemorrhage/contusions present bilaterally at the craniolateral borders of the ilial crests.

Rather mild contusions present in the iliacus muscles 3-4 cm from the ilial crests.

The spinous process of T8 was fractured diagonally from its tip to its base. The fracture fragment, perhaps one-third of the spinous process, remained attached to the spinous process of T9 by muscular and ligamentous tissues. An incomplete fracture line extended from the vertebral foramen at the cranial end of the base of the right transverse process of T9 out toward the costovertebral joint. The flexibility of the vertebral column appeared normal in all respects. (I feel these vertebral injuries to be the result of rebound against the seat back after harness loading had occurred.)

More Significant Lesions

1. Colon transections.

2. Fracture, right clavicle.

3. Severe muscle lacerations, right pectoral and right shoulder areas.

4. Moderate trauma, caudal abdominal musculature.

5. Rib fractures, ribs 5 and 6, right side.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 50 G, $-G_x$ direction, on the Impulse Accelerator, 18 Dec 73, Run 350. New black nylon harness material, 1 inch wide, in a three-point automotive type configuration was used for subject protection. Harness tension was adjusted to approximately 10 lbs. prior to impact.

Identification

Baboon D40, adult male, 52 lbs., Papio sp.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: Moderate linear cutaneous contusion present, from right shoulder to caudal sternum. Rather mild focal such lesions located at lateral inguinal areas, overlying ilial shafts.

Subcutis: Moderate subcutaneous and epimuscular hemorrhage, right shoulder to caudal sternum. Mild such lesions scattered across caudal abdominal wall approximately 4 cm cranial to pubis and overlying ilial shafts.

A focal subcutaneous hemorrhage, 4 cm in diameter, present on the dorsal midline, overlying the mid-thoracic vertebrae (rebound injury).

Abdominal Cavity: A rather minor amount of free hemorrhage present in the abdominal cavity (20-30 ml?). The source of this hemorrhage was several colon contusions and a liver laceration.

Three colon contusions were present, 10 cm apart; the distal contusion was perhaps 20 cm cranial to the rectum. These contusions were approximately equal in severity. At each locus the teniae and the overlying serosa were ruptured and the adjacent mesocolon was torn 4-5 cm. The outermost colon layers appeared separated underlying several of the teniae ruptures. At each of these contused sites there was minimal hemorrhage on the mucosal surface and scattered minor mucosal lacerations, 1-3 cm in length. Moderate intramural hemorrhage occurred at these sites as well.

The liver laceration was present on the visceral surface of the central lobe. It extended from the base of the umbilical fissure 2.5 cm toward the hilus. It was 1.5 cm deep at its deepest point.

A mild focal contusion was present on the proximal small intestine. Petechiae and scattered ecchymoses were present subserosally at this locus.

Rather mild subcapsular hemorrhage present overlying the right kidney.

Moderate hemorrhage present in the sublumbar adipose tissues.

Several 8-16 cm lacerations present in the greater omentum.

Thoracic Cavity: Several mild linear contusions present on the lung surfaces. These were present on the costal surfaces of the apical and diaphragmatic lobes, right lung, where they were parallel to the ribs. One similar contusion was present on the left diaphragmatic lobe, adjacent and parallel to the vertebral column. Minor subpleural hemorrhage occurred at these locations, not involving deeper lung tissue. These contusions were 10-15 mm in length on the collapsed lungs.

Musculoskeletal System: Rather severe trauma present involving the right shoulder/chest area. The cranial 4 cm of the pectoralis major and 2 cm of the pectoralis minor were lacerated just medial to the shoulder joint. The ventral edge of the detoid was lacerated 1-2 cm adjacent to the major pectoral laceration. The clavicle was fractured transversely near midshaft. The atlanto-scapularis/trachelo-acromialis muscles were lacerated near the shoulder joint. The omohyoideus and the cranial 3 cm of the trapezius were lacerated at this locus also. There was an incomplete fracture of the scapula. The fracture line extended from the base of the coracoid process 5 cm along the base of the scapular spine. Rather moderate hemorrhage associated with these shoulder injuries.

The left clavicle was incompletely fractured near midshaft. The ventral (superficial) cortex wall was fractured at this locus. The coracoclavicular ligament was separated from its clavicular attachments. The tip of the coracoid process was fractured from its base. Focal mild/moderate hemorrhage associated with these lesions.

Mild scattered, rather diffuse intramuscular hemorrhage in the right 3rd, 4th, and 5th interspaces.

Very minor separation of a few superficial muscle fibers of the right iliacus muscle present; rather mild associated hemorrhage.

More Significant Lesions

1. Liver laceration.

2. Colon contusions.

3. Rather severe trauma, musculature of right shoulder and chest.

4. Fractures, bilateral, clavicles, scapulae.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 50 G, $-G_x$ direction, on the Impulse Accelerator, 20 Dec 73 Run 352. New black nylon harness material, 1 inch wide, in a three-point automotive type configuration was used for subject protection. Harness tension was adjusted to approximately 10 pounds prior to impact. The emergency brake was activated following acceleration and the sled stopped prematurely.

Identification

Baboon D32, adult male, Papio sp., 45.5 pounds.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: Mild/moderate linear skin contusion from right shoulder to caudal sternum. Rather mild rather focal such lesions present in lateral inguinal areas.

Subcutis: Moderate subcutaneous and epimuscular hemorrhage present over right shoulder and chest; mild such lesions scattered across caudal abdominal wall 3-4 cm caudal to umbilicus.

Abdominal Cavity: Some free hemorrhage present in peritoneal cavity, perhaps 15-25 ml, mainly in the caudal abdomen. The major source of this hemorrhage was a moderately severe colon contusion; a rather minor liver laceration provided some hemorrhage.

The major 3 cm colon contusion was approximately 20 cm proximal to the rectum. Here the teniae, the overlying serosa, and some superficial colon wall tissue underlying the teniae were lacerated. Multiple minor mucosal lacerations were present at this locus also, 1-2 mm in length, with scanty hemorrhage into the colon lumen. Rather considerable intramural colon hemorrhage present, associated with this contusion. The mesocolon was separated from 1 cm of colon surface as well.

A second rather minor colon contusion was present approximately 8 cm proximal to the major contusion. Here the mesenteric tenia was separated and a minor 2 mm mucosal tear was present, with rather mild, focal subserosal and intramural hemorrhage.

The liver laceration was present at the base of the umbilical fissure on the viseral surface of the central lobe. It extended perhaps 10 mm and was 5 mm deep.

The sublumar adipose tissue, overlying the iliopsoas musculature, was moderately hemorrhagic.

Thoracic Cavity: Several mild lung contusions present, right lung, involving apical, cardiae, and diaphragmatic lobes. These patchy contusions involved only the most superficial lung tissue on the costal surfaces of these lobes. Total area of contusion was perhaps 2-3 cm^2.

Heart: Four or five subendocardial petechiae present, septal wall of left ventricle. Two ecchymotic such hemorrhages present at the tip of the medial papillary muscle, left ventricle.

Musculoskeletal System: Subluxation of the right acromio-clavicular joint was present. The opposing tips of the coracoid process and acromium were fractured/avulsed from their origins on the right scapula. Moderate hemorrhage was associated with these injuries.

The left clavicle was fractured transversely 1 cm from the acromioclavicular joint. The free end of the longer clavicular segment was wedged into deeper tissues medial to the shoulder joint. Rather mild hemorrhage associated with this fracture.

Rather mild diffuse intramuscular hemorrhage present in the 3rd and 4th interspaces, right side, 2-4 cm from the vertebral column.

Minor laceration/separation of the right internal abdominal oblique muscle present, involving only a few muscle fibers. Moderate associated intramuscular hemorrhage present. This injury occurred overlying the craniolateral border of the right ilial wing.

There was rather minor superficial contusion of the right iliacus muscle.

More Significant Injuries

1. Moderately severe colon contusion.
2. Minor liver laceration.
3. Minor lung contusion.
4. Right scapular fractures.
5. Left clavicle fracture.
6. Minor laceration, right internal oblique muscle.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 14 February 74, Run 380. Subject was protected by a three-point automotive harness of white nylon, 1.75 inches wide through the shoulder strap. The lap belt overlying the animal's abdomen was double thickness nylon, 1 inch wide, and was rather stiff due to the stitching present.

Animal Identification

Baboon D52, 50.5 lbs., adult male, Papio anubis.

Gross Observations

The animal survived impact and was exsanguinated and autopsied approximately an hour after impact.

External: Rather mild cutaneous linear contusion present, right shoulder and chest wall; similar such lesions present in the lateral flank areas overlying the ilial shafts.

Subcutis: Rather mild subcutaneous and epimuscular hemorrhage present underlying the cutaneous lesions noted above.

Abdominal Cavity: Moderate contusion present on the terminal colon. Here the teniae were ruptured and a minor serosal tear was present overlying one tenia. Moderate associated subserosal hemorrhage and minor intramural hemorrhage were associated with this contusion.

Scattered petechiae and minor ecchymoses present in the distal portion of the greater omentum. Similar such hemorrhage present in the hepatic suspensory ligaments.

A moderate focus of hemorrhage present in the retroperitoneal tissues between the splenic body and the pancreas (perhaps 2x2 cm). (The source of this hemorrhage was not identified.)

The adipose tissue adjacent to the distended bladder was moderately hemorrhagic.

Heart: A minor focus of subendocardial hemorrhage was present near the middle of the right atrial wall, above the junction of the dorso- and ventrolateral cusps of the A-V valve. A petechial hemorrhage was present in the ventrolateral cusp of this valve. (These lesions were possibly catheter induced.)

Musculoskeletal System: There was a 1.5 cm laceration in the transversus just to the left of the xiphoid. (The torso accelerometer was mounted near this locus externally.)

There was rather extensive trauma of the right shoulder area. The clavicle was fractured near it sternal end. The cranial 3/4 of the pectoralis major was lacerated just medial to the shoulder joint. The cranial border of the trapezuis was lacerated perhaps 2 cm just cranial to the scapular spine. The trachelo-acromialis/atlanto-scapularis muscle complex was lacerated in this area also. The supraspinatus was moderately contused. Rather moderate subfascial hemorrhage present overlying the shoulder joint itself.

Sternal segments 4 and 5 were luxated, as was the 5th right chondrosternal joint.

Minor diffuse hemorrhage was present in the 2nd - 5th interspaces, right side.

Minor contusion of the left iliacus was present.

Minor contusions of the caudal abdominal muscles along the cranial ends of the inguinal ligaments were present.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 19 February 74, Run 382. New white nylon, 1.75 inches wide, was used as subject protection in a three-point automotive configuration. The lap belt for perhaps 3 inches across the abdominal wall was double-layered and stitched, thus being rather stiff. Harness tension was adjusted to approximately 10 lbs. prior to impact.

Identification

Baboon D54, adult male, Papio anubis, 62.5 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination approximately one hour post impact.

External: Some hemorrhage occurred from the mouth following impact due to a tongue laceration present (tooth puncture).

Rather mild linear contusion present over right shoulder and chest; similar lesions present in lateral flank areas, overlying ilial wings.

Subcutis: Rather mild subcutaneous hemorrhage underlying the above noted skin contusions. Moderate subcutaneous and subfascial hemorrhage present at the external inguinal rings and in the spermatic cords at these loci.

Abdominal Cavity: A moderate contusion, perhaps 5 cm in length, present at the terminal colon/proximal rectum. Here there were minor serosal and mucosal tears, rather considerable subserosal hemorrhage, and rather minor intramural hemorrhage.

Rather mild linear retroperitoneal hemorrhage present along the tail of the pancreas, gastric surface, for 3-4 cm.

The globular fat depots adjacent to the bladder and in the sublumbar area were moderately hemorrhagic.

There were mild petechiae and ecchymoses in the hepatic suspensory ligaments and in the tendinous diaphragmatic surface.

Thoracic Cavity: Mild/moderate hemorrhage present in the mediastinum underlying the sternal luxation to be noted below.

A moderate lung contusion present in the right middle lobe, costal surface. The contusion is rather linear, 1.5 x 3 cm and 5 mm in depth.

The lungs were poorly collapsed, mottled and fluidous. The tracheobronchial tree was filled with frothy mucus containing some small clots of fresh blood (aspirated from tongue laceration).

Heart: A focal subepicardial hemorrhage, 1.5 cm diameter, present overlying the ventral interventricular groove near the cardiac apex. A superficial myocardial contusion was present underlying this lesion, perhaps 1-2 cm in depth. A second subepicardial hemorrhage, perhaps 1 cm in diameter, was present near the origin of the ventral interventricular groove, adjacent to the left auricle. Scattered subepicardial petechiae and ecchymoses present over the ventral surface of the right ventricle, rather numerous. Similar such lesions were scattered over the surface of the right auricle and aortic root.

Within the right ventricle a focal mild subendocardial hemorrhage was located at the tip of the left papillary muscle. Three scattered ecchymotic subendocardial hemorrhages were present on the ventral surface of the right ventricular wall (possibly due to catheter trauma).

Three mild ecchymotic subendocardial hemorrhages were present on the surface of adjacent trabeculae carnae at the junction of the septal and ventral walls of the right ventricle, left side, near the conus arteriosus.

Several very mild patchy subendocardial hemorrhages present on the septal wall of the left ventricle, perhaps 1 cm below the aortic valve. (Catheter trauma?)

Musculoskeletal System: Rather severe trauma to the right shoulder area present. The right clavicle was fractured 1-2 cm from the sternal end. The cranial three-fourths of the pectoralis major was lacerated medial to the shoulder joint. The cranial border of the trapezius was lacerated perhaps 3 cm. The atlanto-scapularis/acromialis muscle complex was completely lacerated at this level also. The ventral 1 cm of the deltoideus was lacerated at the acromial end of the clavicle.

There was complete luxation of the joint between sternebrae 3 and 4, with ventro-cranial displacement of the caudal sternal segment. Subluxations of the 2nd - 4th chondrosternal joints, right side, were present also.

Ribs 6 through 9, left side, were fractured perhaps 2-3 cm from their chondral ends.

Rib 3, right side, was fractured 2 cm from its vertebral attachment.

Moderate intramuscular hemorrhage, diffuse, present in interspaces 1-3, right side.

Very superficial laceration present, peritoneal surface of left rectus abdominis muscle, 4-5 cm cranial to pubis. The right rectus at this location was perhaps one-fourth lacerated.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 21 February 74, Run 384. New white nylon, 1.75 inches wide, was used as harness material in an automotive configuration. The harness was double-layered across most of the abdominal surface of the lap belt. Harness tension was adjusted to approximately 10 pounds prior to impact.

Identification

Baboon D56, adult male, Papio cynocephalus, 65 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination and examined one hour post impact.

External: Minor external skin contusions present, over right shoulder and in lateral flank areas.

Subcutis: Moderate hemorrhage present in subcutis and epimuscular fascia overlying right shoulder and chest; similar lesions present overlying ilial shafts and wings.

Abdominal Cavity: Rather minor terminal colon contusion present. Two teniae were ruptured and mild subserosal and intramural hemorrhage were present.

Minor subcapsular hemorrhage present at the junction of the hepatic suspensory ligaments and the diaphragmatic surfaces of the right and left liver lobes. Minor scattered petechiae and ecchymoses present in the hepatic suspensory ligaments.

A minor focal hemorrhage present in the mesentery adjacent to the small intestine, perhaps 7-8 mm in diameter.

Moderate hemorrhage present in the globular fat depots adjacent to the urinary bladder as well as in the sublumbar area.

Musculoskeletal System: Rather severe trauma present in the right shoulder/chest area. Here the clavicle was fractured near midshaft and the cranial two-thirds of the pectoralis major was lacerated. There was also a 1 cm laceration in the cranial margin of the pectoralis minor. The deltoideus was lacerated perhaps 1.5 cm through its ventral border at its clavicular attachment. The atlanto-scapularis/trachelo-acromialis muscle complex was nearly completely lacerated near the shoulder joint.

The supraspinatus was rather severely contused. The ventral border of the trapezuis was lacerated 2 cm near the scapular spine. There was an incomplete scapular fracture, extending roughly parallel to the scapular spine and originating near the base of the coracoid process. This fracture line extended perhaps 6-8 cm.

Considerable trauma present to the thoracic cage itself. There was a complete sternal luxation between S4 and S5, with cranioventral displacement of the caudal sternal segment. Considerable hemorrhage associated with this injury, into the adjacent soft tissue, including the ventral mediastinum. Considerable intramuscular hemorrhage present in the 4th and 5th interspaces on the left side, near the sternum. There was a ragged, incomplete 1.5 cm laceration of the intercostal muscles, right 4th interspace, near the costochondral junctions.

A moderate contusion was present in the right iliacus muscle. There was a fracture of the underlying ilial wing, with a 6-8 cm fracture line extending roughly parallel to the lumbar spine.

There was a moderate contusion of the abdominal musculature adjacent to the right inguinal ligament.

Thoracic Cavity: The mediastinal hemorrhage was noted above.

The right middle lung lobe contained two contusions, 1-1.5 cm in diameter on the collapsed lung. These contusions radiated deeply into the lung tissue.

Heart: A focal, mild subendocardial ecchymotic hemorrhage present on the right ventricular septal wall. A similar very mild and rather diffuse lesion was present on the left ventricular septal wall (possibly catheter trauma).

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, -Gx direction, on the Impulse Accelerator, 26 February 74, Run 386. New white nylon harness material, 1.75 inches wide, was used in an automotive configuration for subject protection. The harness was double-layered over most of the abdominal surface of the lap belt. Harness tension was adjusted to approximately 10 lbs. prior to impact.

Identification

Baboon D58, adult male, Papio anubis, 56 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination and autopsied two hours post impact.

External: Mild linear contusion over right shoulder and chest wall; very mild focal contusions overlying ilial wings.

Subcutis: Moderate subcutaneous and epimuscular hemorrhage present overlying right shoulder. Similar focal lesion present, moderately severe, caudomedial to left shoulder joint on chest wall, 3-4 cm in diameter.

Abdominal Cavity: Some free hemorrhage present in abdominal cavity, perhaps 50-75 ml. The source of this hemorrhage was three colon contusions. One contusion was at the terminal colon. Here the teniae were ruptured, mild/moderate hemorrhage in adjacent mesacolon, moderate subserosal and intramural hemorrhage, and several 1-2 mm mucosal tears were present. The serosa was lacerated 2-3 mm overlying the teniae.

The other two colon contusions were more severe. At these loci, located approximately 15 cm apart and 25 cm from the terminal colon, the serosa and outer colon layers were lacerated about the circumference of the gut wall. Multiple short 1-3 mm mucosal tears, with minor associated hemorrhage onto the mucosal surface, were present also. Rather severe subserosal and intramural hemorrhage were present. At the proximal contusion, a 3 mm laceration into the gut lumen was present.

Slight, rather diffuse hemorrhage present along the gastric border of the tail of the pancreas, 1-2 cm segment.

Musculoskeletal System: Moderate trauma to right shoulder area. The right clavicle was fractured near midshaft. The pectoralis major muscle belly was incompletely lacerated adjacent to this fracture, perhaps 1-2 cm. Considerable hemorrhage associated with these injuries.

The left pectoralis major was incompletely lacerated for 3-4 cm caudomedial to the shoulder joint. This laceration extended nearly completely through the muscle belly parallel to the muscle fibers.

A complete displaced sternal luxation present, between S4 and S5. Considerable hemorrhage associated with this lesion, some into the ventral mediastinum. The right 6th chondrosternal joint was subluxated also.

Minor focal intramuscular hemorrhage present in the internal oblique muscles at the craniolateral borders of the ilial wings.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 28 February 74, Run 389. New white nylon harness material, 1.75 inches wide, was used for subject protection in an automotive configuration. Harness tension was adjusted to approximately 10 pounds prior to impact.

Identification

Baboon D62, adult male, Papio anubis, 73 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination four hours post impact. Autopsy examination was conducted 21 hours after impact.

External: Moderate cutaneous linear contusion present, over right shoulder and chest wall. Minor focal contusions present over the ilial shafts.

Subcutis: A 4-5 cm laceration present in the subcutis on the right chest wall. Moderate subcutaneous hemorrhage over right shoulder and chest wall; minor such hemorrhage over caudal abdominal wall.

Abdominal Cavity: Some free hemorrhage present in the abdominal cavity, perhaps 50 ml. The source of this hemorrhage was two rather severe colon contusions.

Three colon and two small intestine contusions were present. One contusion was at the terminal colon; the other contusions resulted when loops of bowel were trapped beneath the lap belt.

The terminal colon contusion was rather moderate. The three teniae were ruptured, a short serosal tear was present, and rather minor subserosal and intramural hemorrhage were present.

The two major colon contusions were perhaps 40-50 cm proximal to the terminal colon. They were 8-10 cm apart and the adjacent mesacolon was nearly completely lacerated between these contusions. The seromuscular layers were lacerated at these loci, and a 1.5 mm laceration was present on the mesenteric surface of the distal contusion, exposing the bowel lumen. Multiple mucosal lacerations were present at these loci, 1-3 mm in length, with minor hemorrhage into the lumen. Considerable intramural hemorrhage also present at these loci.

The two small intestine contusions were perhaps 18 cm apart. A transverse contusion was present in the adjacent mesentery between these contusions, as evidenced by multiple focal hemorrhages. One small intestine contusion was more severe. Here a 1 cm serosal laceration was present and several 1-2 mm mucosal tears. Moderate subserosal and intramural hemorrhage was also present. The second small intestine contusion presented multiple subserosal ecchymoses.

Very minor focal subcapsular hemorrhages present at the attachments of the suspensory ligaments to the diaphragmatic surfaces of the right and left liver lobes.

The subilial fat depots were rather severely hemorrhagic, and the overlying peritoneum was lacerated bilaterally 4-5 cm.

Musculoskeletal System: Rather severe trauma to the right shoulder area present. The clavicle was fractured near the sternal end. The adjacent pectoralis major was lacerated perhaps 4 cm. The trachelo-acromialis/atlanto-scapularis muscle complex was lacerated near the right shoulder joint. The trapezius was lacerated 1.5 cm at this level also. Minor incomplete laceration of the supraspinatus was present.

The transversus abdominis was lacerated bilaterally near its aponeurosis adjacent to the xiphoid, perhaps 8 cm on each side.

The sternum was luxated at S4-S5, with cranioventral displacement of the caudal segment. Considerable hemorrhage was associated with this injury, some into the ventral mediastinum.

Mild/moderate intramuscular hemorrhage, diffuse, present in the 3rd - 5th interspace, right side.

The right rectus abdominis was lacerated 4-5 cm cranial to the pubis. Also on the right side the internal oblique and transversus were nearly completely separated from the inguinal ligament adjacent to the rectus injury.

There was a moderate deep muscular contusion present overlying the left ilial shaft.

The iliacus muscles were moderately contused.

Heart: Two petechial subendocardial hemorrhages were present on the septal wall of the left ventricle, just below the aortic valve (catheter trauma?).

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 7 March 74, Run 397. New white nylon harness material, 1.75 inches wide, was used for subject protection in an automotive configuration. Harness tension was approximately 10 pounds prior to impact.

Identification

Baboon D64, adult male, Papio cynocephalus, 60 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination and autopsied two hours after impact.

External: Mild linear cutaneous contusion present over right shoulder and chest wall. Similar mild focal lesions overlying ilial wings.

Subcutis: Minor scattered subcutaneous hemorrhages present, underlying the cutaneous lesions noted above; such lesions also extended across the caudal abdominal wall. A 4-5 cm laceration in the subcutis was present over the sternum.

Abdominal Cavity: Rather severe colon contusion present perhaps 18 cm from the rectum. Here the three teniae and the seromuscular layers adjacent to the two antimesenteric teniae were lacerated. Multiple 2-4 mm mucosal lacerations were also present with minor luminal hemorrhage. Moderate hemorrhage present in colon wall. Several mesocolic hemorrhages present extending radially from this lesion.

Two mild/moderate small intestine contusions present also, approximately 10-12 cm apart. (The loop of gut was caught beneath the lap belt.) Moderate focal intramural and subserosal hemorrhages were present at these loci.

Minor scattered focal hemorrhages present in caudal omentum.

Minor separation of splenic capsule from spleen surface, 5x10 mm, caudal end of spleen. Minor associated intraperitoneal hemorrhage.

Musculoskeletal System: The right clavicle was fractured 2 cm from sternal end. The acromio-clavicular joint was subluxated.

Moderate deep intramuscular hemorrhage present overlying the cranio-lateral aspect of the right ilial wing.

Minor diffuse intramuscular and subpleural hemorrhage, 3rd-5th interspaces, right side, near midshaft of ribs.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 50 G, $-G_x$ direction, on the Impulse Accelerator, 19 March 74, Run 401. New white nylon harness material, 1.75 inches wide, was used for subject protection in an automotive configuration. Harness tension was approximately 10 lbs. prior to impact.

Identification

Baboon D66, adult male, Papio cynocephalus, 65 lbs.

Gross Observations

The animal left the seat during impact and twisted to the right although the harness remained about the torso. The animal survived impact and was euthanized via exsanguination and autopsied two hours after impact.

External: Moderately severe linear cutaneous present, right shoulder and chest wall. Mild focal such lesions present overlying the ilial shafts and caudal abdominal wall.

Abdominal Cavity: Severe colon contusion present 18-20 cm proximal to the rectum. The serosa teniae and outer colon muscular wall were lacerated at this locus. The mucosa contained multiple lacerations. Considerable intramural hemorrhage was present. A transverse laceration, 6-8 cm long, present in the adjacent mesacolon. Some minor hemorrhage from this contusion present in the caudal abdominal cavity.

An area of hepatic capsule, approximately 4x4 cm, was separated from the lateral diaphragmatic surface of the left lobe. A short 1 cm laceration was present in the lateral extreme of the capsular surface. Perhaps 30-50 ml hemorrhage present in the left cranial abdominal quadrant from this injury.

There was minor subcapsular hemorrhage present over the left kidney. The kidney capsule was separated from the kidney surface but intact.

Mild scattered ecchymoses present, caudal omentum.

Musculoskeletal System: There was rather severe trauma to the right shoulder area. The right clavicle was fractured near midshaft. The right pectoralis major and minor were lacerated from the caudal sternum to the point of the shoulder. The ventral border of the

deltoideus was lacerated 2-3 cm near the shoulder joint. The atlanto-scapularis/trachelo-acromialis muscle complex was lacerated near the shoulder joint. The cranio-ventral edge extreme of the trapezuis was lacerated transversely for 4-5 cm adjacent to the scapula. The supra-spinatus was lacerated near its midpoint. A scapular fracture, comminuted, was present. The major fracture line was incomplete, extending from the base of the coracoid process parallel and cranial to the scapular spine for 4-5 cm.

Ribs 3 and 4 were fractured near the costo-chondral junction. Ribs 9 and 10 were fractured 2-4 cm from their vertebral attachments. These fractures were on the right side and considerable intramuscular hemorrhage accompanied them.

The transverse processes of L1-5, left side, were fractured. L1-3 were fractured near their tips, L4 and 5 were fractured near their bases. Considerable hemorrhage present into adjacent musculature.

The psoas musculature, left side, was moderately contused.

The right rectus abdominis was nearly completely lacerated, 4-6 cm cranial to the pubis.

Lungs: There was moderate focal subpleural hemorrhage at the hilus of the right middle lobe.

Two focal superficial contusions present, perhaps 8-10 mm in diameter on the collapsed lung, costal surface, right diaphragmatic lobe, opposite the rib fractures (9 and 10) noted above.

Heart: A minor focal subepicardial hemorrhage, 5x10 mm, present adjacent to the interventricular branch of the left coronary artery near the apex, ventral cardiac surface.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 50 G, $-G_x$ direction, on the Impulse Accelerator, 21 March 74, Run 403. New white nylon harness material, 1.937 inches wide, was used for subject protection in an automotive configuration. Harness tension was approximately 10 lbs. prior to impact.

Identification

Baboon D68, adult male, Papio anubis, 57 lbs.

Gross Observations

The animal survived impact and was euthanized via exsanguination and autopsied two hours after impact.

External: Moderately severe cutaneous linear contusion present, right shoulder and chest wall. Mild such lesion in lateral flank areas.

Subcutis: A laceration present in subcutis, 3-4 cm, overlying sternum. Rather severe hemorrhage in subcutis over right chest wall. Mild hemorrhage scattered over caudal abdomen. Focal hemorrhage overlying the spermatic cord/external inguinal ring areas.

Abdominal Cavity: Considerable free hemorrhage in peritoneal cavity (500 ml?). The major source of this hemorrhage was multiple liver lacerations involving the left and central lobe. These lacerations extended from the ligamentous attachments of the liver, diaphragmatic surface, for 3-4 cm over the liver surface. Those involving the left lobe were 5-7 mm deep; those in the left portion of the central lobe were 2-3 cm long and extended completely through the lobe.

Four colon contusions were present. The one present at the terminal colon and the one adjacent to the ileo-colic junction were rather moderate, with laceration of the teniae and considerable subserosal and intramural hemorrhage.

The two major contusions were 18-20 cm apart, the distal lesion being located 6-8 cm from the terminal colon contusion. It appeared that a loop of colon was trapped beneath the lap belt, resulting in the two major contusions. At these sites the teniae, overlying serosa, and underlying superficial colon layers were lacerated focally. Multiple mucosal lacerations, 1-3 mm, were present also. The mesocolon adjacent to these contusions was moderately hemorrhagic for 3-4 cm.

Two small intestine contusions were present also, 6-8 cm apart (apparently a loop of gut trapped again). Moderate focal subserosal and intramural hemorrhages present.

Musculoskeletal System: There was luxation of the left elbow joint, with lateral displacement of the radius and ulna and disruption of the associated ligamentous attachments. Considerable hemorrhage present locally.

Rather severe trauma to right shoulder area. The pectoralis major was split between its fibers for 4-6 cm from its midsternal origin. However, near its insertion it was completely lacerated, perhaps 5 mm from the humerus. Considerable local hemorrhage present.

The pectoralis minor was severely contused near the midpoint of its length, with some slight laceration of its fibers. The acromioclavicular joint was luxated, with laceration/avulsion of the acromioclavicular ligament and tip of the coracoid process. The deep surface of the trapezius, overlying the scapular spine, was rather severely contused with minor lacerations of deep fibers. Considerable hemorrhage present about the shoulder joint due to these injuries.

Considerable hemorrhage present, with some separation of muscle fibers, in interspaces 4, 5 and 6, right side, near vertebral column.

Most of the vertebral arch of T11 was fractured from the vertebral body, leaving just the cranial portion of the arch (the cranial articular processes) intact. There was minimal displacement of the fragment, however, as the intervertebral joint between T11 and T12 was intact. Very scanty hemorrhage associated with this lesion. There was a minor contusion on the dorsal midline overlying this area of the vertebral column.

The left transverse processes of L4 and L5 were fractured near their bases; minor hemorrhage present.

Some deep hemorrhage present overlying the ilial shafts/inguinal ligaments.

Lungs: Minor linear subpleural hemorrhages present on apical, middle, and diaphragmatic lobes, costal surfaces, right lung. These hemorrhages were about 1-2 x 4-5 mm on the collapsed lung surface, perhaps 4 or 5 present.

Heart: Three petechial subendocardial hemorrhages present, left (lateral) papillary muscle tip, left ventricle.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 50 G, $-G_x$ direction, on the Impulse Accelerator, 26 March 74, Run 405. New white nylon harness material, 1.937 inches wide, was used for subject restraint in an automotive configuration.

Identification

Baboon D70, adult male, 67 lbs., Papio cynocephalus.

Gross Observations

The animal suffered respiratory arrest following impact and died within minutes.

External: The left chest wall was obviously depressed. A moderately severe linear cutaneous contusion present, right shoulder and chest wall. Moderate such lesion present over caudal abdominal wall.

Subcutis: A 4-5 cm laceration present over the sternum. A similar laceration present underlying the cutaneous abdominal contusion, from right ilial shaft to near the left ilial shaft, 4-6 cm cranial to pubis. Considerable contusion of subcutis over caudal abdominal wall.

Abdominal Cavity: Considerable dark bloody urine present in peritoneal cavity (200 ml?). Much fat droplets present in the fluid.

Bladder laceration present, 2-3 cm, right fundic area. The bladder wall was rather severely contused as well, and the mesenteric attachments were avulsed from most of its surface. The abundant globular fat depots adjacent to the bladder and in the sublumbar area were rather severely hemorrhagic. The peritoneum overlying these depots were lacerated extensively.

A rather severe contusion present at the terminal colon. Several 2-3 mm serosal lacerations present and considerable intramural hemorrhage. The mucosa was lacerated nearly 360° about the colon wall.

There was avulsion of a 1x1 cm segment of liver capsule from the dorsal edge of the left lobe, gastric surface. A small 4x4 mm segment of liver parenchyma was avulsed with the capsule, perhaps 2 mm thick.

A slight 1x3 mm avulsion of the splenic capsule was present at the tail of the spleen, omental attachments.

Musculoskeletal System: There was considerable trauma to the area of the right shoulder. The clavicle was fractured near midshaft and the adjacent subclavius muscle belly was completely lacerated. The trachelo-acromialis/atlanto-scapularis muscle complex was severed near the scapula. The trapezius was lacerated for 4 cm overlying the scapula. The supra-spinatus was moderately contused and slightly lacerated.

The right rectus abdominis was severed 5-6 cm cranial to the pubis; the left rectus was nearly severed. The aponeurosis of the external oblique, right side, was lacerated for 6-8 cm along the caudal muscle border. The transversus abdominis, right side, sustained minor separation of its fibers along the ilial shaft.

Multiple rib fractures present, left side. Ribs 3-10 were fractured near midshaft. Ribs 6-8 were fractured adjacent to their costochondral junctions. The chest wall between these fracture lines was markedly depressed.

Three rib fractures were present on the right side. Rib 4 was fractured near midshaft. Ribs 8 and 9 were fractured near the vertebral column. Rather severe focal hemorrhage present in the interspaces adjacent to these fractures. Some minor muscle lacerations present, interspaces 2-4, right side.

The spinous processes of C6 and C7 were fractured near their bases. The caudal portions of the vertebral arches of T1 and T2 were fractured transversely. These two fractures were nearly identical, extending through the base of the spinous processes and along the caudal edge of the vertebral arches. There was rupture of the ligamentum flavum between C7-T1, and T1-T2. There was a slight displacement of the fracture fragments and minor associated hemorrhage. Some eipdural hemorrhage was present between C6-T2.

Lungs: Several moderate focal contusions present, costal surface of right lung, opposite the rib fractures noted above. These contusions were 8-10 mm in diameter and 3-5 mm deep on the collapsed lung.

Heart: A slight focal 1x2 mm subepicardial hemorrhage present, caudal surface of left ventricle, adjacent to a marginal branch of the left circumflex artery.

Cause of Death: Combination of trauma of impact and depth of anesthesia; this animal was in a relatively deep plane of anesthesia prior to impact and sustained a multitude of serious injuries. However, no single injury was thought to be lethal in itself.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 30 G, $-G_x$ direction, on the Impulse Accelerator, 28 March 74, Run 410. New white nylon harness, 1.937 inches wide, was used for subject protection in an automotive configuration. Static harness tension was approximately 10 pounds.

Animal Identification

Baboon D72, Papio cynocephalus, adult male, 54 pounds.

Gross Observations

The animal survived impact and was euthanized via exsanguination and autopsied two hours after impact.

External: Mild focal cutaneous contusions present overlying ilial shafts.

Subcutis: Rather mild focal, 2 cm hemorrhage, in subcutis over mid-sternum. Similar lesions over ilial shafts.

Abdominal Cavity: Some slight free hemorrhage in abdominal cavity. The source of this hemorrhage was three widely separated colon contusions. The distal lesion was perhaps 25 cm from the rectum. Here there was considerable intramural hemorrhage involving a 3-4 cm segment. Two more proximal lesions were nearly equal in severity. The teniae were ruptured at these loci, and the overlying serosa and underlying outer colon layers were focally lacerated. The mucosal surfaces at these loci sustained multiple 1-5 mm lacerations also. Minor hemorrhage present on the mucosal surfaces.

The subiliac fat depots were moderately contused.

Musculoskeletal System: The right clavicle was fractured near midshaft. Moderate associated hemorrhage.

Focal intramuscular hemorrhage, mild, right 4th interspace, adjacent to sternum; similar lesion, 3rd interspace, near midshaft.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, Run 417, 9 April 74. Takata Type A harness material was used in an automotive configuration. Static harness tension was approximately 10 pounds.

Identification

Baboon D74, Papio cynocephalus, adult male, 69 pounds.

Gross Observations

The animal left the sled seat during impact and fell to the sled floor on the right of the seat. The animal was euthanized via exguination and autopsied 1.5 hours after impact.

External: Minor linear contusion over right shoulder and chest wall; similar focal lesions overlying ilial shafts in flank areas.

Subcutis: Rather minor subcutaneous contusion over right chest wall; minimal focal hemorrhages in lateral extremes of caudal abdominal wall.

Abdominal Cavity: Rather severe contusion of terminal colon, 5-6 cm in length. Here there was extensive subserosal and intramural hemorrhage, and several 1 mm mucosal tears.

A loop of colon had been entrapped beneath the lap belt, resulting in severe trauma at two sites 9-10 cm apart. The distal lesion was perhaps 25 cm from the terminal colon. At this site the colon was transected. At the more proximal lesion there was separation of the outer seromuscular layers about the colon wall and a longitudinal 2 cm laceration into the lumen on the mesenteric side. The mesocolon between these two lesions was lacerated transversely for 6-7 cm. There was considerable hemorrhage into the abdominal cavity from these lesions, perhaps 200-300 ml.

There was an area, perhaps 3x4 cm, of subcapsular hemorrhage on the diaphragmatic surface of the left liver lobe. A short 2-3 mm hepatic laceration, near the suspensory ligaments, was the source of this hemorrhage. Similar hemorrhage was present in an area perhaps 1.5x1.5 cm, visceral surface, left central lobe, and 1x2 cm, diaphragmatic surface, right lobe. No hepatic lacerations were noted underlying these hemorrhages.

Musculoskeletal System: Considerable trauma to right shoulder area. Here the clavicle was fractured near midshaft and the adjacent omohyoideus and subclavius were transected. The trapezius was lacerated 4-6 cm craniomedial to the scapular spine and the trachelo-acromialis/atlanto-scapularis muscle complex was transected here also. The supraspinatus was moderately contused.

There was a sternal luxation between S3 and S4, with longitudinal fracture of the shaft of S4. The fourth pair of ribs were luxated at this point also. The caudal sternal segment was displaced cranio-dorsally.

The right third rib was fractured near midshaft. There was moderate associated intramuscular hemorrhage in the third interspace; similar hemorrhage present in the first interspace also, near the vertebral column.

The right rectus abdominis muscle was approximately half lacerated, lateral side, 6-7 cm cranial to the pubis. The adjacent internal oblique and transversus were nearly completely transected at this level also, extending to the ilial shaft, right side.

There was a deep intramuscular contusion in the abdominal wall, left side, overlying the ilial shaft.

The right iliacus was perhaps a third lacerated, with considerable associated hemorrhage.

Lungs: There was a rather mild, focal 1 cm diameter contusion opposite the third right rib fracture noted above.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, Run 419, 11 April 74. Black Takata type B harness material, 1 inch wide, was used in an automotive configuration for subject protection. Static harness tension was approximately 10 pounds prior to impact.

Identification

Baboon D76, adult male, Papio cynocephalus, 65 pounds.

Gross Observations

The animal survived impact and was euthanized via exsanguination and autopsied 1.5 hours after impact.

External: A rather deep 1-2 cm laceration present in the dorsum of the tongue (bite injury); hemorrhage, moderate associated.

A very mild linear contusion present in the skin over the right shoulder and chest wall. Moderate cutaneous contusions and abrasions present over caudal abdominal wall, particularly overlying the ilial wing areas.

Subcutis: Rather mild scattered hemorrhages present across the caudal abdominal wall. A moderate focal area of epimuscular hemorrhage present, 4-6 cm in diameter, over the midsternal area. The subcutis was lacerated 4-5 cm here.

Abdominal Cavity: Considerable free hemorrhage present due to severe colon trauma present. A severe 4-5 cm contusion 3-4 cm from the rectum present. The outer seromuscular layers and teniae were lacerated at this locus, and the adjacent mesocolon was torn 1-2 cm. The mucosal surface was encircled by a laceration also.

A loop of colon 25-30 cm from the hepatic flexure had been entrapped by the lap belt and severed at two points 6-8 cm apart. The mesocolon between these lacerations was torn 4-5 cm also.

There were two minor 2-3 mm hepatic lacerations present, perhaps 1 mm deep, on the visceral surface of the left central lobe, near the suspensory ligaments. A small 1x2 mm focus of subcapsular hemorrhage was present on the diaphragmatic surface of the right central lobe.

Musculoskeletal System: Rather moderate trauma of the right shoulder area present. The tip of the acromial process of the scapular spine was avulsed, with moderate associated hemorrhage about the acromioclavicular joint. The cranial edge of the pectoralis minor adjacent to this joint was lacerated 1 cm. The trapezius overlying the scapular spine near the shoulder joint was severely contused. The supraspinatus muscle was moderately contused.

The 6th, 7th and 8th chondrosternal joints were subluxated, right side, with moderate focal associated hemorrhage.

The 3rd, 4th and 5th interspaces, right side, contained rather diffuse intramuscular hemorrhage.

Rather severe trauma present underlying the lap belt. The rectus abdominis muscles were severed bilaterally, 6-8 cm cranial to the pubis. The right internal oblique and transversus were lacerated from the rectus to the craniolateral aspect of the ilial wing. The left internal oblique and transversus were lacerated 3-4 cm at the ilial wing.

The right iliacus was lacerated through half of its thickness; the right iliacus was a fourth lacerated.

Lungs: A mild linear 1x10 mm subpleural hemorrhage present on the costal surface of the right apical lobe.

Heart: Two petechiae present in the ventrolateral cusp of the right A-V valve.

One petechia present in the septal cusp of the left A-V valve. A minor 1x2 mm subendocardial hemorrhage present in the left ventricular septal wall, just beneath the aortic valve.

(All these cardiac lesions were possibly catheter induced.)

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 44 G, $-G_x$ direction, on the Impulse Accelerator, 15 April 74, Run 421. New Takata Type A harness material, 1 inch wide, was used for subject protection in an automotive configuration. Static harness tension was approximately 10 lbs.

Identification

Baboon D78, Papio cynocephalus, adult male, 65.5 lbs.

Gross Observations

The animal slipped off the seat to the right at impact. Impact was survived and the animal was euthanized via exsanguination and autopsied two hours after impact.

External: Minor linear contusion present over right shoulder and chest wall. Mild/moderate linear contusion present over caudal abdominal wall.

Subcutis: A 4-5 cm rent in subcutis overlying midsternum; a 3-4 cm such lesion on midline of caudal abdominal wall. Rather severe subcutaneous contusion present, caudal abdominal wall. Focal 4-5 cm hemorrhage in subcutis near midsternum. The outer fascial layer at the lateral border of the right rectus abdominis was lacerated 3-4 cm, 7-9 cm from pubis.

Abdominal Cavity: Considerable free hemorrhage present (300-400 ml). The source of this hemorrhage was several severe colon contusions. The distal lesion was located at the terminal colon. Here the teniae and outer servomuscular colon layers were lacerated completely about the colon wall, and the adjacent mesocolon was lacerated 2-3 cm. Considerable intramural hemorrhage was present for 3-4 cm. There were multiple mucosal lacerations here also.

Two severe colon contusions present approximately 40 cm from the hepatic flexure. Here a loop of colon had been entrapped by the lap belt. At the proximal lesion the teniae and seromuscular layers were lacerated about the colon wall with perforation into the lumen for 2 cm along the mesenteric border. At the more distal lesion, 8-10 cm from the first, similar lesions were present except the colon perforation was 1-2 mm. Multiple mucosal lacerations were present at each locus. The mesocolon between these lesions was nearly completely lacerated longitudinally.

The subpelvic fat depots were severely contused.

Focal 2x2 cm subcapsular hemorrhage present on the left lobe, at the base of the fissure dividing the left and central lobes. A similar hemorrhage was present on the right lobe, between the right and central lobes. Here the overlying capsule was torn 4-5 mm.

Musculoskeletal System: Rather moderate trauma present to the right shoulder area. There was avulsion of the tip of the acromial process with moderate associated hemorrhage. The underlying cranio-ventral edge of the atlanto-scapularis/trachelo-acromialis muscle complex was lacerated 1 cm. The adjacent trapezius overlying the scapular spine was severely contused.

There was subluxation of the right scapulo-humeral joint, with some disruption of the soft tissue attachments along the dorsal/posterior surface of the neck of the humerus.

The right 5th, 6th and 7th chondrosternal joints were subluxated, with moderate associated hemorrhage.

Severe trauma present underlying the lap belt. The rectus abdominis was severed bilaterally, 7-9 cm from the pubis. The internal and external fascial layers were lacerated 3-4 cm at the lateral border of the right rectus; the underlying peritoneum was intact. The caudal edge of the external oblique and its aponeurosis was lacerated bilaterally at the level of the ilial crests. The right transversus was lacerated at this level also; the internal oblique incompletely so. The left internal oblique was moderately contused adjacent to the ilial crest.

The right iliacus was three-fifths lacerated, near the ilial crest. The left iliacus was moderately contused.

The left transverse process of the 5th lumbar vertebra was fractured near its base; minimal associated hemorrhage present.

Lungs: Minor contusion, linear, 10x2 mm, present on caudal costal surface of the right apical lobe, 2 mm deep on the collapsed lung.

Heart: Very mild, barely visible subendocardial hemorrhage present in the left ventricle. This hemorrhage was located linearly along the prominances by several trabeculae carnae at the ventricular apex, and was rather diffuse and poorly defined.

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Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, Run 423, 18 April 74. New 1 inch Takata Type B harness material, in an automotive configuration, was used for subject protection. Static harness tension was approximately 10 pounds.

Identification

Baboon D80, Papio cynocephalus, adult male, 65 pounds.

Gross Observations

The animal survived impact, was euthanized via exsanguination, and was examined 1.5 hours after impact.

External: Very mild linear cutaneous contusion present over right shoulder. Focal contusion present, lateral inguinal areas, moderate/severe on right side, mild/moderate on left. A 3 mm skin laceration present, right caudal abdominal wall, near contusion previously noted.

Subcutis: A 3-4 cm rent in subcutis near midsternum, within a 5-6 cm rather severe contusion. Rather mild such contusion over right shoulder. A 4-5 cm rent in subcutis on caudal midabdominal wall. The external fascial layers of the abdominal wall near the midshaft of the right ilium were lacerated 3-4 cm; the deeper muscle tissue was lacerated as well. Considerable subfascial and subcutaneous hemorrhage adjacent to this laceration.

Abdominal Cavity: Rather mild 1-2 cm contusion present at terminal colon; mild associated subserosal and intramural hemorrhage present.

A focal 1x1 cm area of subcapsular hemorrhage present at the right lateral extreme of the central lobe, at the base of the fissure separating the right and central lobes.

The areolar tissue about the ventral urinary bladder was avulsed from the bladder surface. The adjacent fat depots were rather severely hemorrhagic. Considerable bloody urine present within the bladder, as well as multiple small fresh clots. The bladder mucosa was intact.

Bilateral 3-4 cm lacerations in the peritoneum overlying the subpelvic musculature.

Musculoskeletal Sytem: Moderate/severe trauma to right shoulder area. The clavicle was fractured near midshaft. The trachelo-acromialis/atlanto-scapularis muscle complex was severed near its scapular

attachments. The trapezius was lacerated 4-5 cm along the scapular spine. The supraspinatus was moderately contused. The underlying scapula was incompletely fractured 4-6 cm along its cranial margin. Considerable hemorrhage associated with these lesions.

A sternal luxation was present between S4-S5, with moderate displacement. The right 5th rib was fractured near midshaft. Considerable hemorrhage associated with these lesions, particularly the sternal lesion. The hemorrhage here extended into the ventral mediastinum.

Rather severe trauma present due to the lap belt. The rectus abdominis muscles were severed bilaterally, 4-6 cm cranial to the pubis. The internal oblique and transversus muscles adjacent to this were also lacerated to the ilial wings, completely so on the right side, and nearly completely on the left.

The iliacus muscles were lacerated, nearly completely on the right side, rather minor on the left.

The ilial wings were fractured longitudinally bilaterally, along their craniolateral borders. The right fracture was incomplete, extending 5-6 cm; the left was complete, extending 6-8 cm.

Lungs: Several minor 1x8-10 mm subpleural hemorrhages present on caudal costal surface of right apical lobe. Rather focal contusion/hemorrhage present at the hilus of the right apical and middle lobes, dorsal surfaces, extending 3-4 mm into the collapsed lung parenchyma at the origin of these lobes.

Heart: A single petechia present in the leaflet of the aortic valve adjacent to the right coronary artery origin. The left ventricular wall below this leaflet displayed a focus of ecchymotic subendocardial hemorrhage. (I feel these are catheter-induced lesions.)

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 2 May 74, Run 434. New Takata Type A harness material, 1 inch wide, was used for subject restraint in an automotive configuration. Static harness tension was approximately 10 pounds.

Identification

Baboon D84, Papio cynocephalus, adult male, 56 pounds.

Gross Observations

The animal survived impact, was euthanized via exsanguination, and autopsied two hours after impact.

External: Minor linear cutaneous contusion over right shoulder; similar focal lesions in lateral inguinal areas.

Subcutis: Moderate subcutaneous and epimuscular hemorrhage present over right shoulder; mild/moderate such lesions over caudal abdominal wall.

Abdominal Cavity: Considerable hemorrhage present (200-250 ml) due to the gut lesions present. A severe colon contusion was present 8 cm cranial to the rectum. Here a severe seromuscular laceration encircled the colon, with extensive associated mucosal lacerations. The adjacent mesocolon was lacerated transversely for 8-10 cm.

A loop of small intestine had been entrapped by the lap belt also. The two contusions were 7-8 cm apart and the adjoining mesocolon was contused also. The intestinal lumen was exposed at both loci, along the mesenteric border of the gut. The lacerations were longitudinal and 1-2 cm in length.

An area of subcapsular hepatic hemorrhage was present, perhaps 3x5 cm, on the left lobe adjacent to the fissure separating the left and central lobes. Two minor 1x2-3 mm liver lacerations were the source of this hemorrhage.

A rather mild linear contusion present over the ventral (abdominal) surface of the stomach, extending from near the esophageal entrance to the greater curvature. Rather mild intramural and subserosal hemorrhage associated with this contusion.

Musculoskeletal System: Considerable trauma to the right shoulder area present. The clavicle was fractured near midshaft; the adjacent subclavius muscle presented a minor laceration. The omohyoideus muscle was half lacerated at this level. The atlanto-scapularis/trachelo-acromialis muscle complex was two-thirds lacerated along the cranial border of the scapular spine. The trapezius was lacerated 3-4 cm here also. The underlying supraspinatus was moderately/severely contused.

Both rectus abdominis muscles were moderately contused 6-8 cm from the pubis. There was incomplete laceration of the internal obliques and transversus muscles for 3-5 cm along the cranial portions of the inguinal ligaments.

The iliopsoas musculature was bilaterally moderately contused.

Heart: Several petechiae present in the cusps of the aortic valve. An ecchymotic hemorrhage was present on the interventricular septum just beneath this valve. (These are probably iatrogenic lesions.)

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 14 May 74, Run 439. New Takata Type B harness material, 1 inch wide, was used for subject restraint in an automotive configuration. Static harness tension was approximately 10 pounds.

Identification

Baboon D88, Papio anubis, adult male, 58 pounds.

Gross Observations

The animal survived impact and was euthanized via exsanguination and autopsied two hours following impact.

External: Mild linear cutaneous contusion present, right ventral chest wall adjacent to the shoulder; similar focal lesions present in lateral inguinal areas.

Subcutis: Moderate linear subcutaneous contusion/hemorrhage present, right chest wall to midsternum. Rather mild focal such lesions over caudal abdominal wall.

Abdominal Cavity: Mild/moderate free hemorrhage present in abdominal cavity, perhaps 150-200 ml. The source of this hemorrhage was severe colon lesions. A loop of colon, perhaps 30 cm from the rectum, had been entrapped by the lap belt, resulting in two colon transections 8-10 cm apart. The mesocolon between the transections was nearly completely transected longitudinally also. A third colon lesion was present 4-5 cm from the rectum. Here the seromuscular layers were lacerated focally adjacent to the ruptured teniae. Multiple short mucosal lacerations were present also.

The caudal omentum was severely contused and lacerated in several places.

Musculoskeletal System: The right acromio-clavicular joint was luxated with rupture of the associated ligamentous tissue. Moderate associated focal hemorrhage present.

The right internal oblique and transversus abdominis muscles were transected from the craniolateral aspect of the ilial wing to the rectus abdominis muscle, 5-6 cm cranial to the pubis. The right rectus was nearly transected at this level also. The left rectus was moderately contused, as were the abdominal muscles along the inguinal ligament, left side.

Lungs: There was a minor linear subpleural hemorrhage 1x15 mm on the right caudal apical lobe, costal surface.

Heart: There was a 1x2 mm focal hemorrhage in the dorsal (medial) cusp of the right A-V valve.

There was a linear endocardial roughening (possible laceration), perhaps 2 mm in length, on the left interventricular septal wall, just beneath the aortic valve (catheter induced?).

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, Run 441, 16 May 74. New Takata Type B harness material, 1 inch wide, was used for subject restraint in an automotive configuration. Static harness tension was approximately 10 pounds.

Identification

Baboon D86, Papio anubis, adult male, 57 pounds.

Gross Observations

The animal rotated to his right at impact, left the sled seat, and landed in right lateral recumbancy on the sled floor to the right of the seat, his head toward the rear of the sled.

External: Very mild linear cutaneous contusions present, over right shoulder and in lateral inguinal areas.

Subcutis: Mild subcutaneous contusions present beneath the cutaneous lesions noted above.

Abdominal Cavity: Rather massive hemorrhage present in abdominal cavity due to colon lesions present. A loop of descending colon had been entrapped by the lap belt, resulting in two colon transections 20-22 cm apart. The mesocolon between the lesions was nearly transected also. A third severe colon contusion was present perhaps 16 cm cranial to the pubis. Here the teniae were lacerated with extensive seromuscular lacerations encircling the colon. Multiple mucosal lacerations present also. The adjacent mesocolon was lacerated 8-9 cm transversely.

Minor subcapsular hemorrhage, perhaps 1x1 cm, present on the left liver lobe, at the base of the fissure separating the left and central lobes.

The caudal omentum was severely contused.

Musculoskeletal System: The right clavicle was fractured near midshaft, with moderate focal hemorrhage.

The rectus abdominis muscles were moderately contused 5-8 cm from the pubis.

The internal obliques exhibited minor separation along the cranial inguinal ligaments.

Lungs: Several scattered subpleural petechiae present in a linear pattern over the costal surface of the right apical lobe, perhaps 8-10 mm in length.

Heart: Two subendocardial petechiae present on the left interventricular septum. One was located just below the aortic valve; the other was 1 cm lower on the septum (possibly catheter induced).

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, Run 443, 21 May 74. New Takata Type A harness material, 1 inch wide, was used for subject protection in an automotive configuration. Static harness tension was approximately 10 pounds.

Identification

Baboon D90, Papio anubis, adult male, 59 pounds.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: Mild linear cutaneous contusion present over right chest wall; very mild such lesions present at lateral inguinal areas.

Subcutis: Mild hemorrhage present, over caudal abdomen and right shoulder area.

Abdominal Cavity: The globular fat depots adjacent to the bladder were rather severely contused.

A rather severe contusion present on the proximal rectum. Here most of the teniae were ruptured as were the underlying muscular layers in several places. Several minor mucosal lacerations were present as well.

There was mild/moderate subcapsular hemorrhage present over the left kidney.

Musculoskeletal System: The right clavicle was fractured near midshaft and the adjacent subclavius muscle was transected. The pectoralis major was perhaps one-third lacerated at this level (3-4 cm from sternum). The cranial border of the underlying pectoralis minor was lacerated 1 cm. The trapezius was lacerated 5-6 cm along the scapular spine. The trachelo-acromialis/atlanto-scapularis muscle complex was transected at this level also. A complete scapular fracture was present, with the fracture line roughly parallel and cranial to the spine, originating near the coracoid process. The supraspinatus was moderately contused.

The right rectus abdominis muscle was transected 4-6 cm cranial to the pubis; the left rectus was two-thirds transected. There was minor separation of the internal oblique and transversus abdominis muscles, right side, at the cranial end of the inguinal ligament. These muscles were moderately contused on the left side at this locus.

There was moderate contusion of the musculature adjacent to the left transverse processes of the lumbar vertebrae.

There was a complete fracture of the craniolateral aspect of the left ilial wing.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, Run 445, 23 May 74. New Takata Type B harness material, 1 inch wide, was used in an automotive configuration. Static harness tension was approximately 10 pounds.

Identification

Baboon D92, Papio cynocephalus, adult male, 57 pounds.

Gross Observations

The animal survived impact and was euthanized via exsanguination.

External: Mild linear cutaneous contusion over right shoulder and chest wall; very mild focal such lesions in lateral inguinal areas.

Subcutis: Focal moderate epimuscular hemorrhage, 5 cm in diameter, overlying midsternum. Minor scattered hemorrhages over right shoulder and caudal abdomen.

Abdominal Cavity: Considerable hemorrhage present in abdominal cavity (500 ml?) due to gut lesions present. A loop of small intestine (ileum) had been entrapped by the lap belt and two transections were present 4-5 cm apart. The adjacent mesentery was nearly transected also.

A severe colon contusion was present also, 20-22 cm cranial to the pubis. Here the teniae were ruptured and a seromuscular laceration, 1-2 cm wide, encircled the colon wall. Extensive mucosal lacerations were also present. The adjacent mesocolon was lacerated 8-10 cm transversely.

The caudal omentum was rather severely contused and exhibited several short lacerations (3-6 cm).

The globular fat depots in the subpelvic region and adjacent to the urinary bladder were rather severely contused.

Musculoskeletal System: The right clavicle was fractured near midshaft. The adjacent subclavius muscle was transected.

The right rectus abdominis muscle was nearly completely transected 6-7 cm cranial to the pubis. The adjacent internal oblique and transversus abdominis muscles were nearly completely lacerated over to the cranial end of the right inguinal ligament. The left rectus abdominis was moderately contused; minor separation of the left internal oblique was present along the cranial end of the left inguinal ligament.

The right iliopsoas musculature was perhaps one-third lacerated.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, 28 May 74, Run 447. Takata Type A harness material, 1 inch wide, was used in an automotive configuration. Static harness tension was approximately 10 pounds.

Identification

Baboon D94, Papio anubis, adult male, 62 pounds.

Gross Observations

The animal survived impact and was euthanized via exsanguination. and autopsied one hour after impact.

External: Mild linear cutaneous contusion over right shoulder and chest wall; mild focal such lesion in left lateral inguinal area.

Subcutis: A 5-6 cm transverse rent present in subcutis on caudal abdominal midline, 4-6 cm cranial to the pubis. Underlying this rent was a 2-3 cm laceration through the abdominal wall, just to the left of the midline, exposing the abdominal cavity; the left rectus abdominis muscle was obviously transected.

A rather extensive moderate contusion of the subcutis was present on the left caudal and lateral aspects of the abdominal wall.

There were rather minor scattered hemorrhages over right shoulder area.

Abdominal Cavity: Considerable blood present in abdominal cavity (200-300 ml) due to colon trauma present. Much fat droplets present in this hemorrhage.

There was a 2 cm laceration present in the fundus of the urinary bladder; some bloody urine remained in the bladder.

The peritoneum overlying the left subpelvic and sublumbar area was lacerated 8-10 cm. The subpelvic fat depots were rather severely contused. Considerable retroperitoneal hemorrhage present in the sublumbar area due to the muscle contusions present.

A severe colon contusion present 4-5 cm cranial to the pubis. There was a 1-2 cm laceration into the colon lumen and rather severe seromuscular laceration encircling the colon. The adjacent mesocolon was lacerated 7-8 cm transversely.

Musculoskeletal System: The rectus abdominis muscles were transected bilaterally 4-6 cm cranial to the pubis. The associated internal and external fascial layers, and peritoneum, were also torn on the left side.

There were mild/moderate contusions of the abdominal muscles along the cranial ends of the inguinal ligaments.

The iliopsoas muscles were three-fifths lacerated on the left side and one-half lacerated on the right side, just cranial to the ilial wings.

There was rupture of the interspinous ligaments between L3 and L4; the adjacent ligamentum flavum was partially torn.

There was fracture of the right clavicle, near midshaft, with laceration of the adjacent subclavius muscle. The trapezius was lacerated 7-8 cm along the cranial border of the scapular spine; the trachelo-acromialis/atlanto-scapularis muscle complex was transected at this level also.

Veterinary Necropsy Protocol

Experimental History

This animal was impacted at approximately 40 G, $-G_x$ direction, on the Impulse Accelerator, Run 449, 30 May 74. Black Takata Type B harness material, 1 inch wide, was used for subject restraint in an automotive configuration. Static harness tension was approximately 10 pounds.

Identification

Baboon D96, Papio anubis, adult male, 61.5 pounds.

Gross Observations

The animal survived impact and was euthanized via exsanguination and autopsied two hours after impact.

External: Mild linear cutaneous contusion over right shoulder and chest wall; similar lesion over caudal abdominal wall, 10-12 cm cranial to pubis.

Subcutis: Moderate linear contusion of subcutis over caudal abdominal wall. Focal hemorrhagic lesion, 1 cm diameter, present over midsternum.

Abdominal Cavity: The caudal omentum was rather severely contused and exhibited several short lacerations.

Rather minor hemorrhage present in abdominal cavity due to a severe colon contusion present. This contusion was located 20-25 cm from the rectum. Here the teniae and seromuscular layers were lacerated about the colon wall, involving a 2 cm colon segment. The mucosal surface at this locus presented multiple short lacerations also. The adjacent mesocolon was lacerated transversely 8-10 cm.

The subpelvic and sublumbar adipose and aerolar tissues were rather severely contused.

Musculoskeletal System: There was luxation of the right acromio-clavicular joint with focal associated hemorrhage and separation of the acromio-clavicular ligament.

Sternal luxation was present between S5 and S6, with craniodorsal displacement of the caudal segment. The adjacent pair of ribs was luxated also at this locus. Considerable associated hemorrhage present.

The rectus abdominis muscles were transected 10-12 cm cranial to the pubis. There was mild/moderate contusion of the abdominal muscles along the cranial ends of the inguinal ligaments. The caudal extreme (2 cm) of the right external oblique muscle were transected.

There was a minor laceration of the superficial portion of the right iliopsoas musculature just cranial to the ilial wing.

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APPENDIX D

PHOTO TRAJECTORY PLOTS

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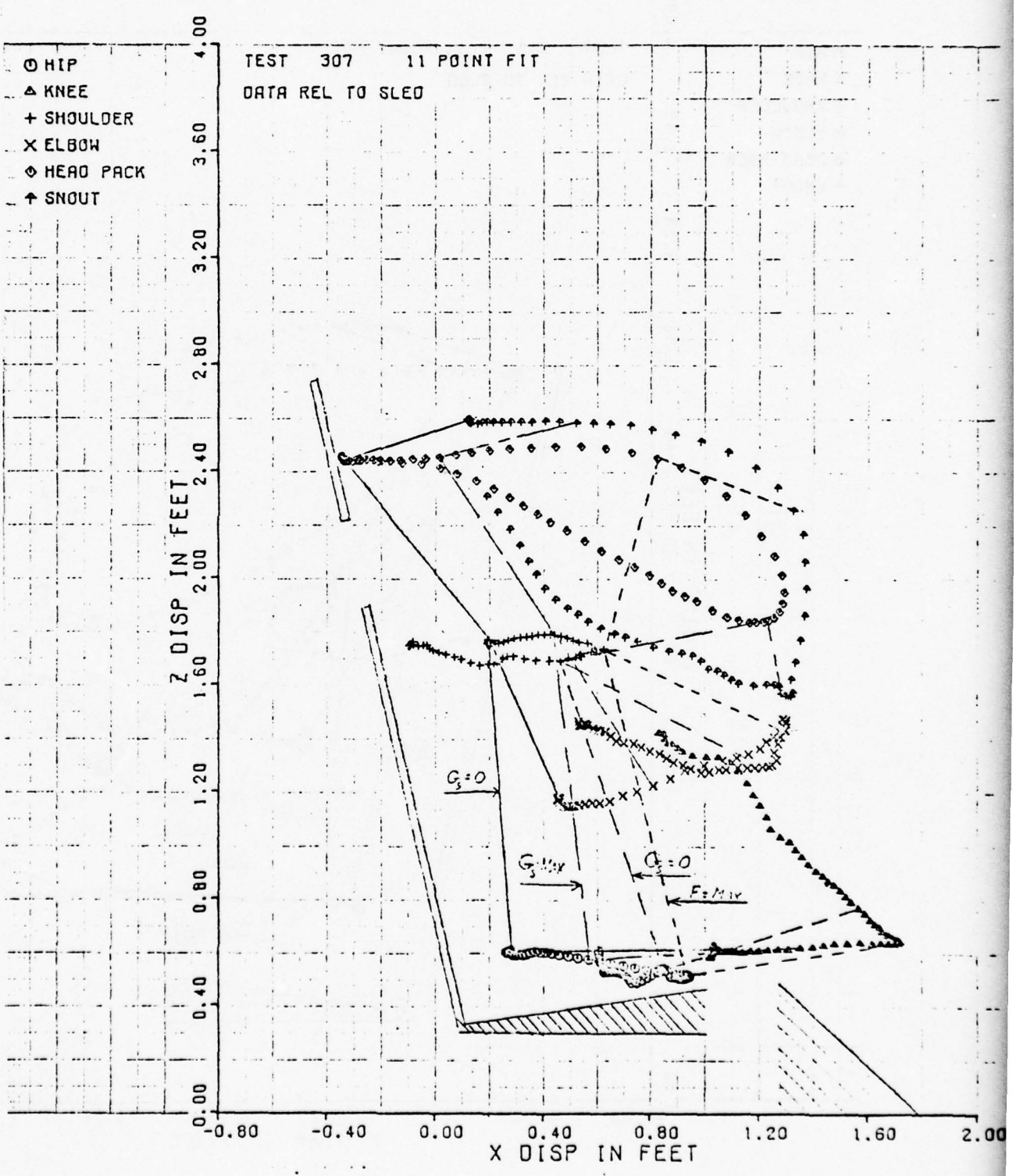

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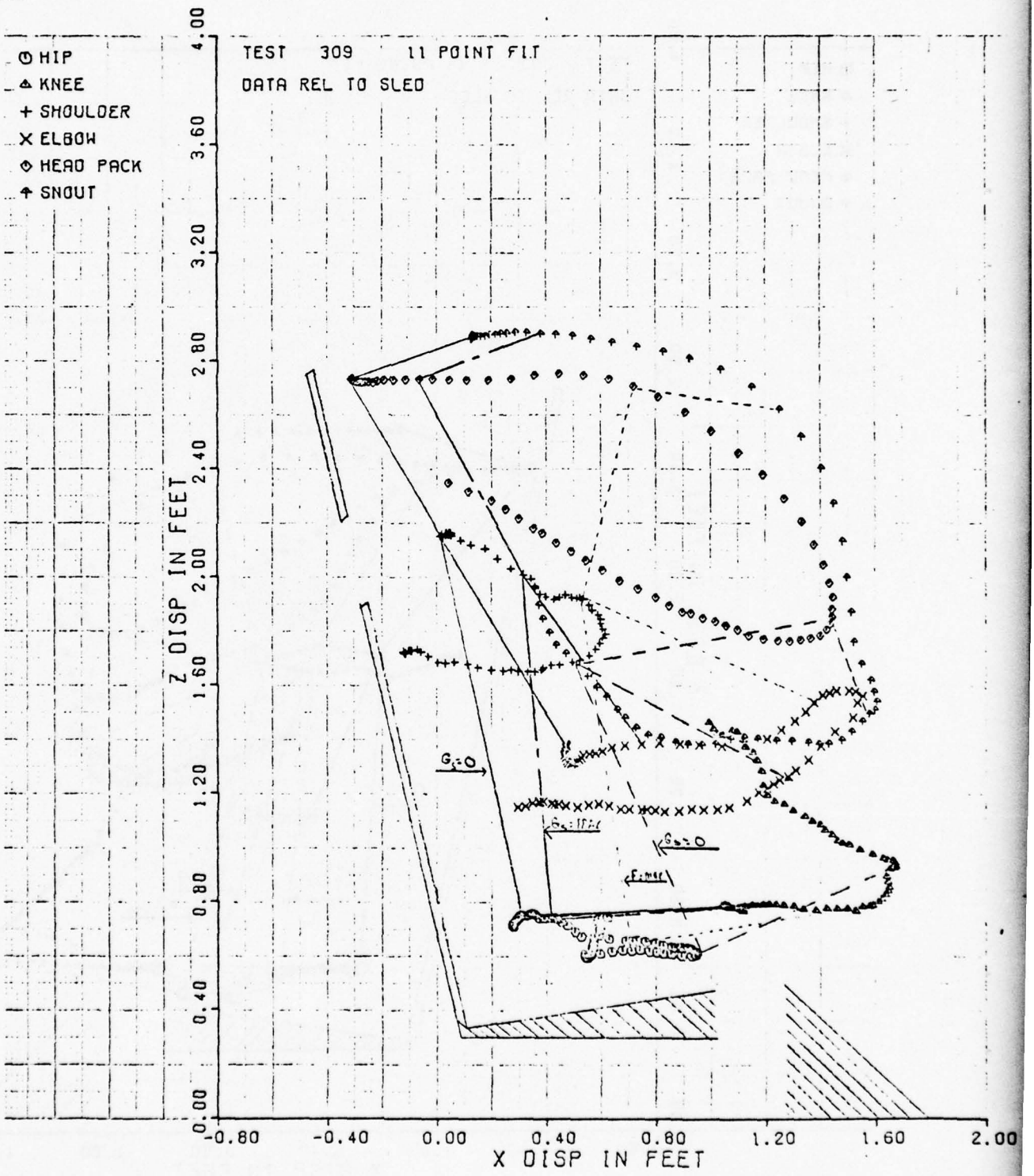

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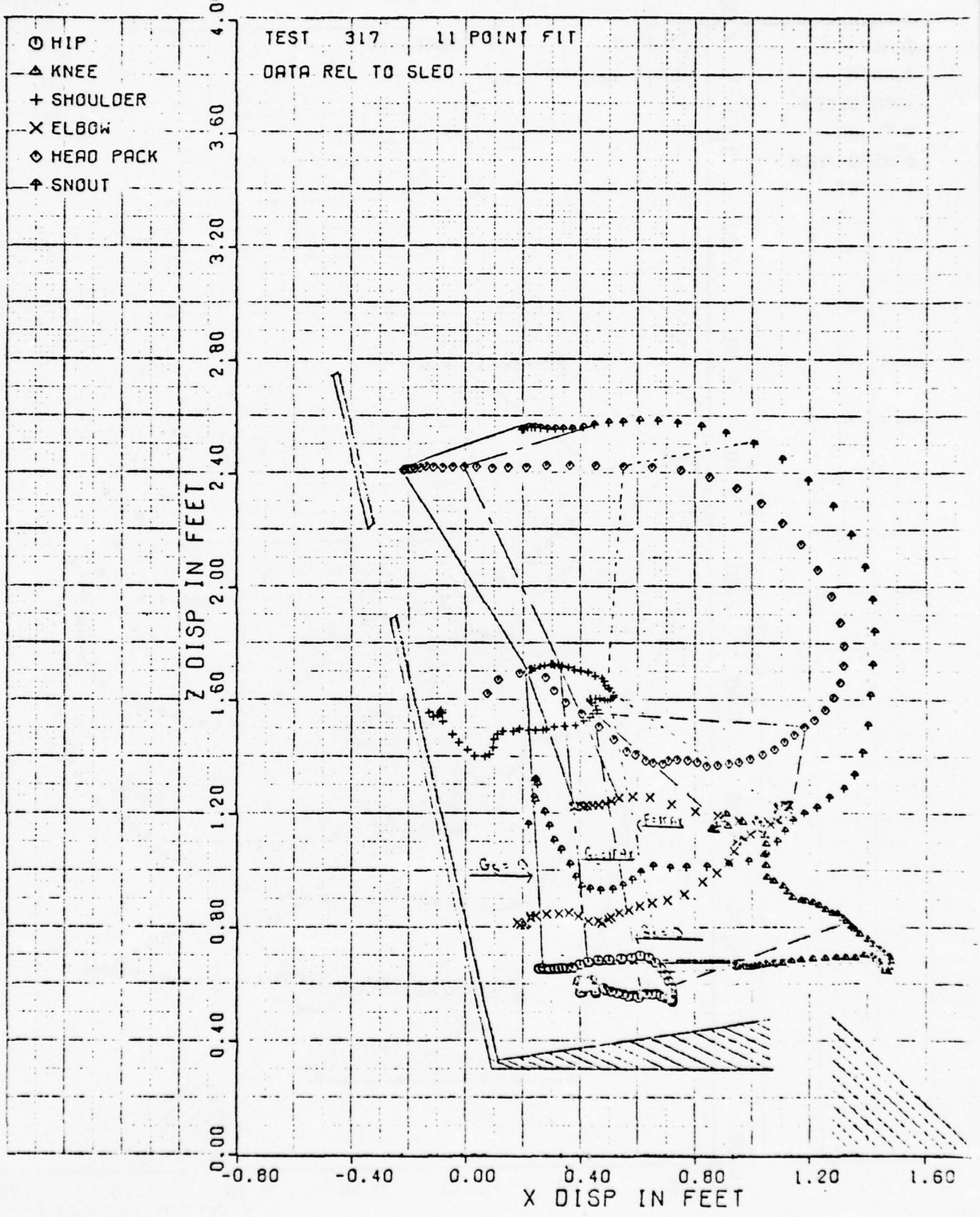

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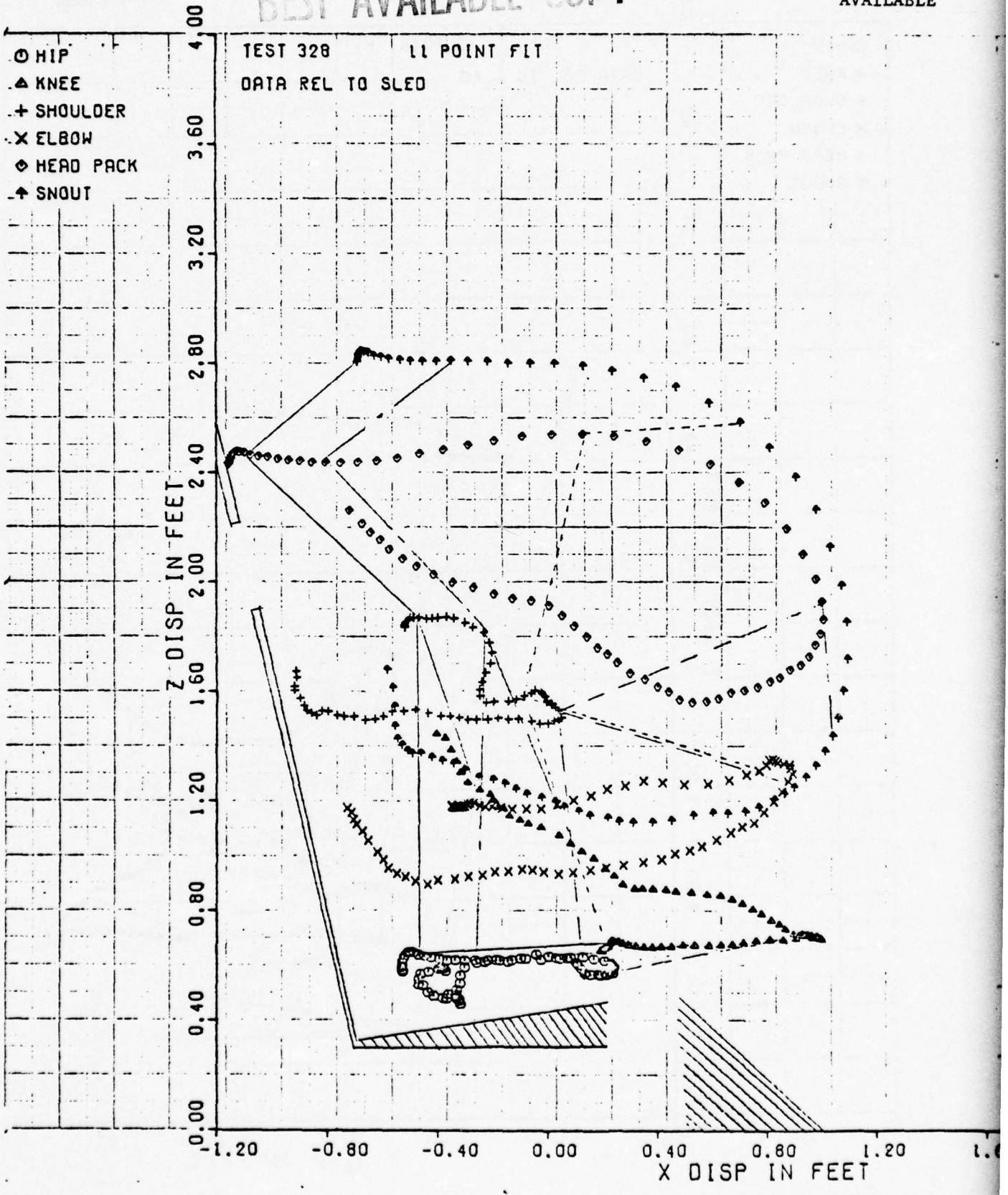

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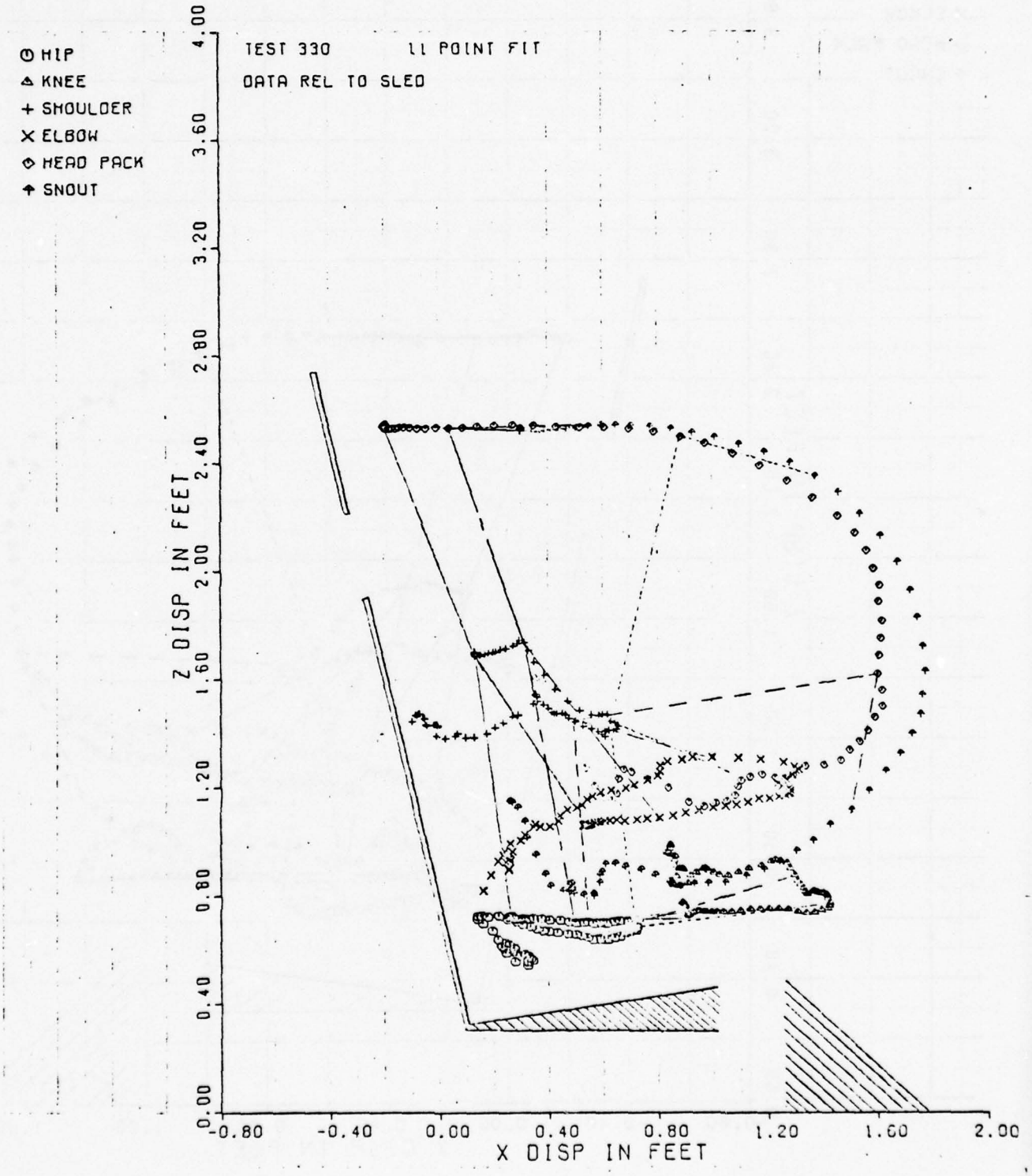

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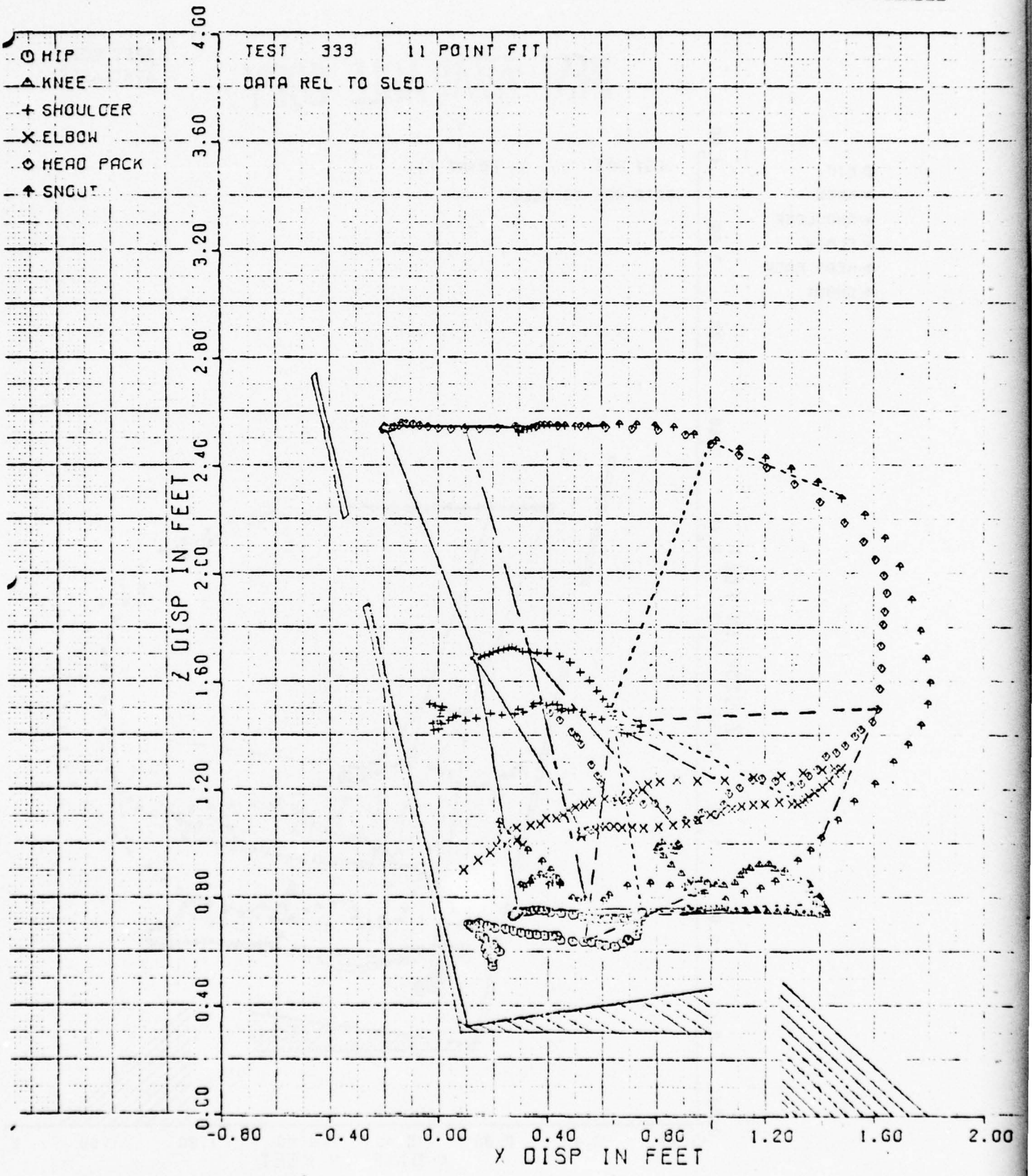

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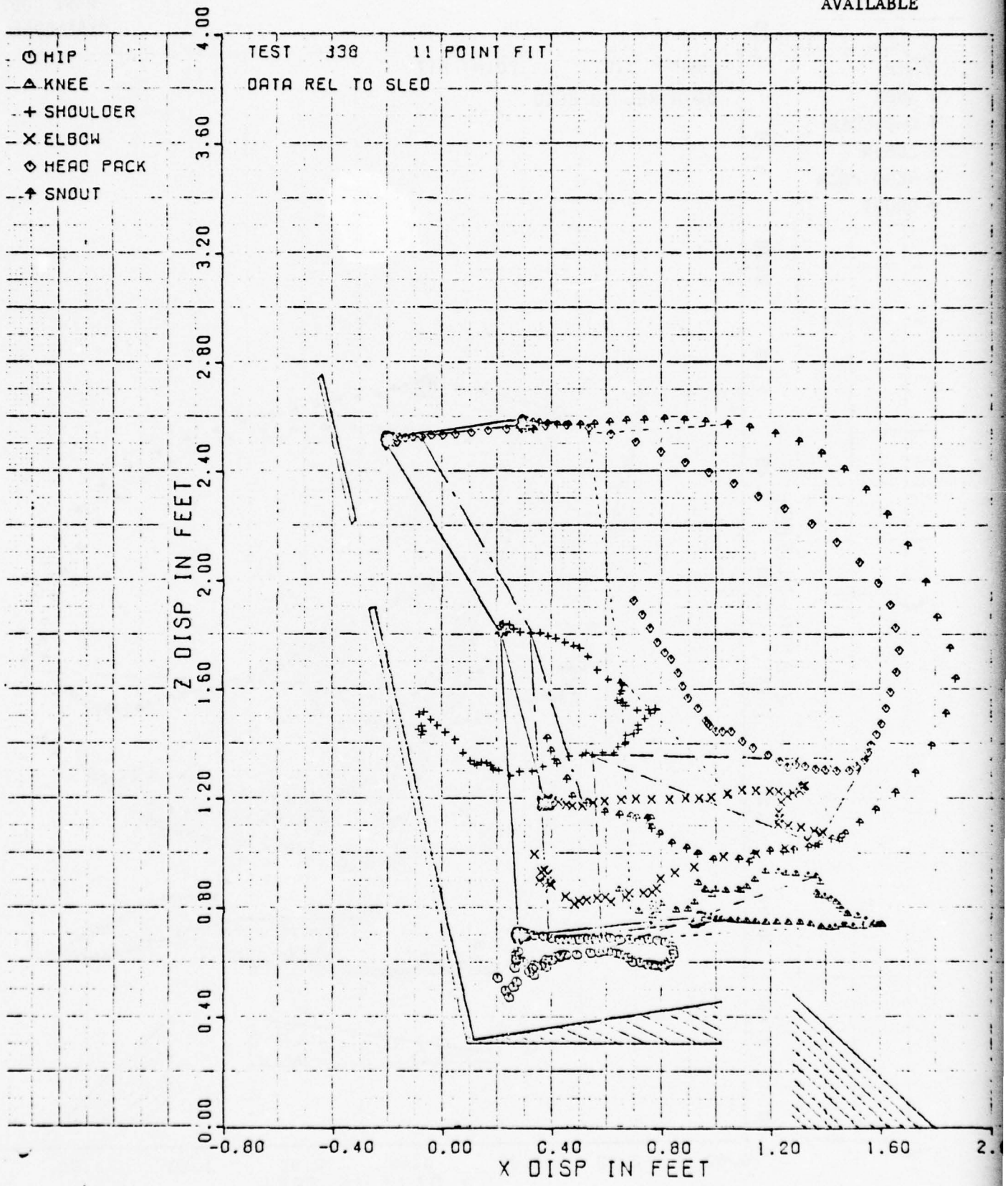

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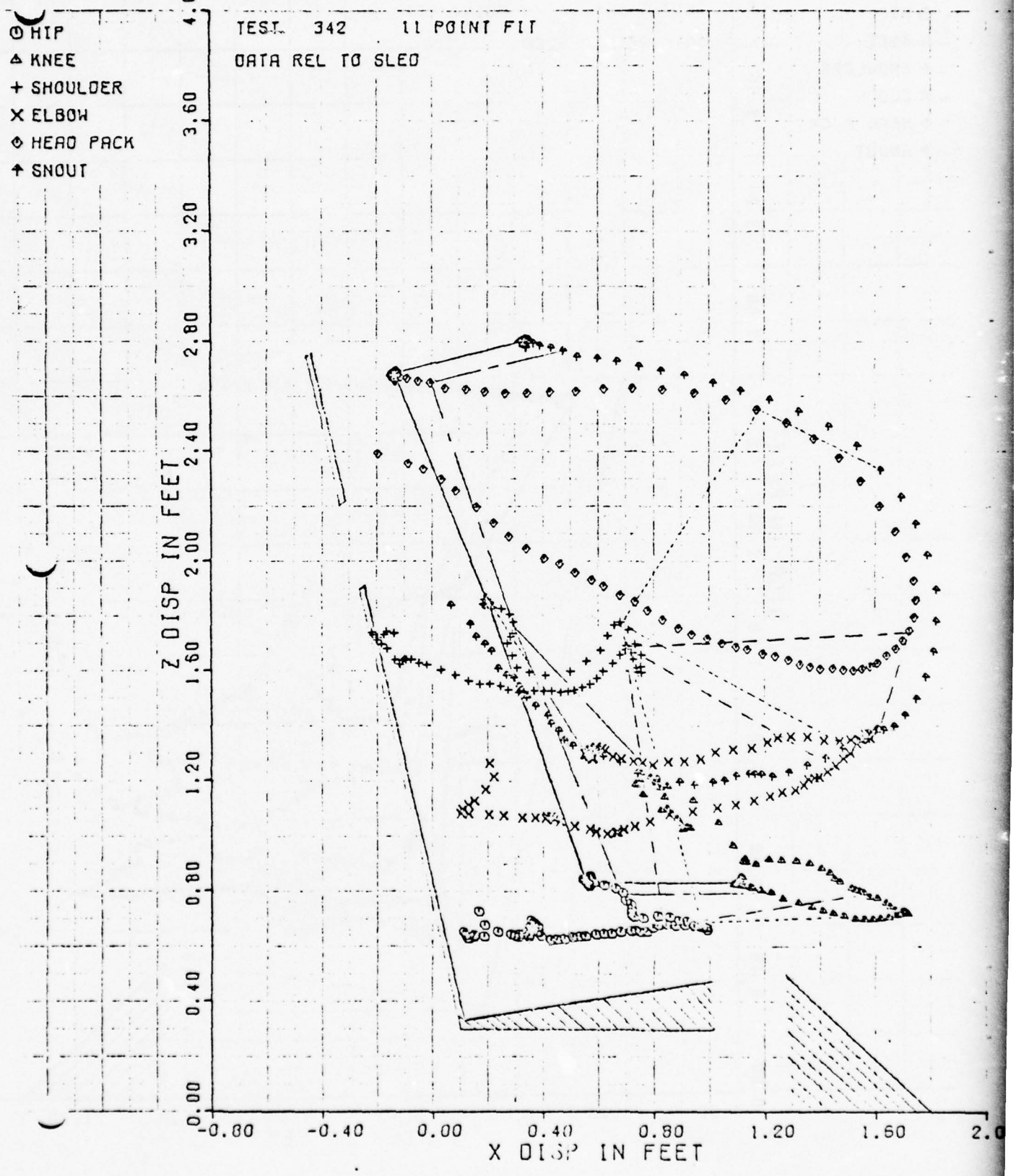

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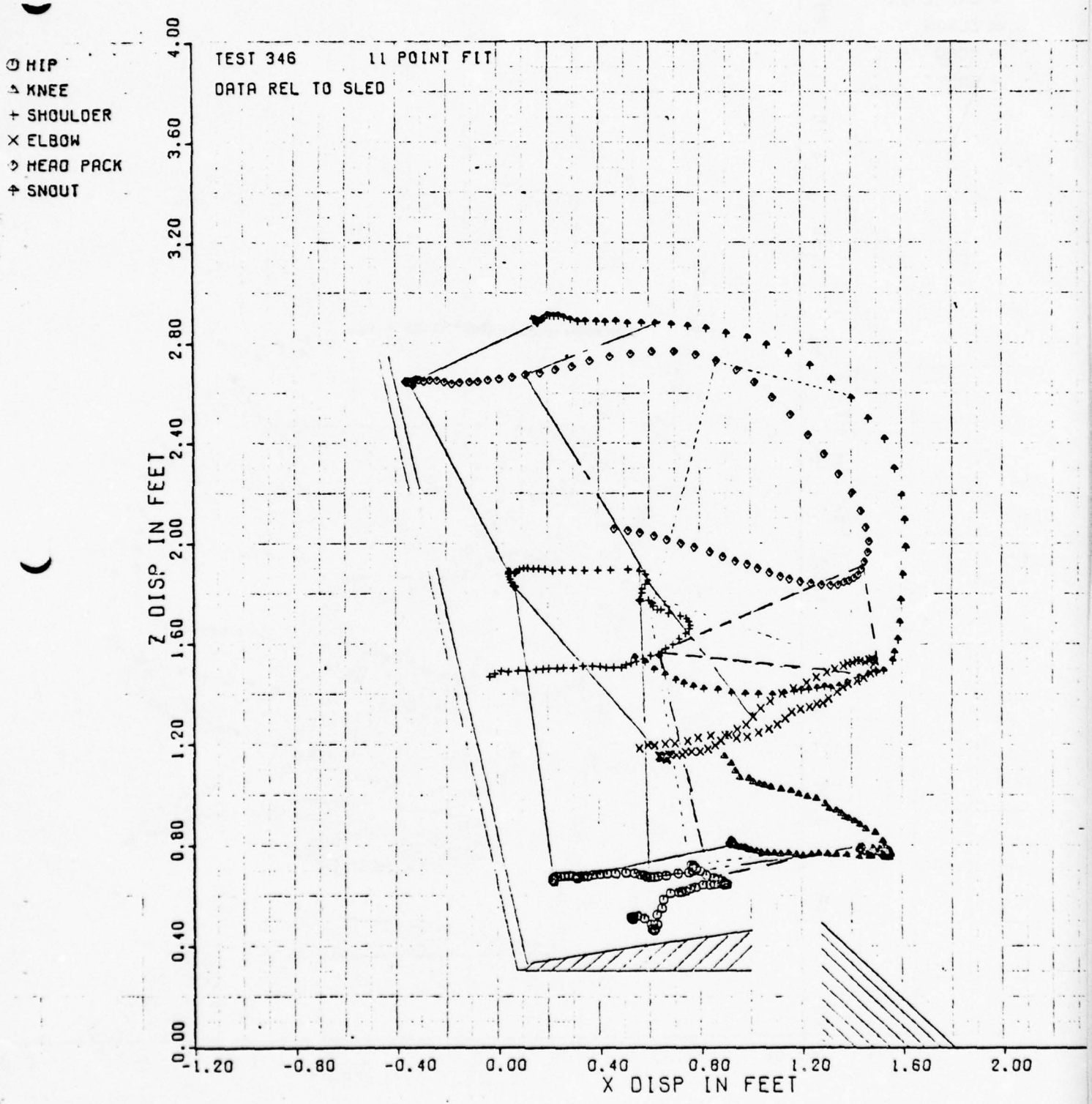

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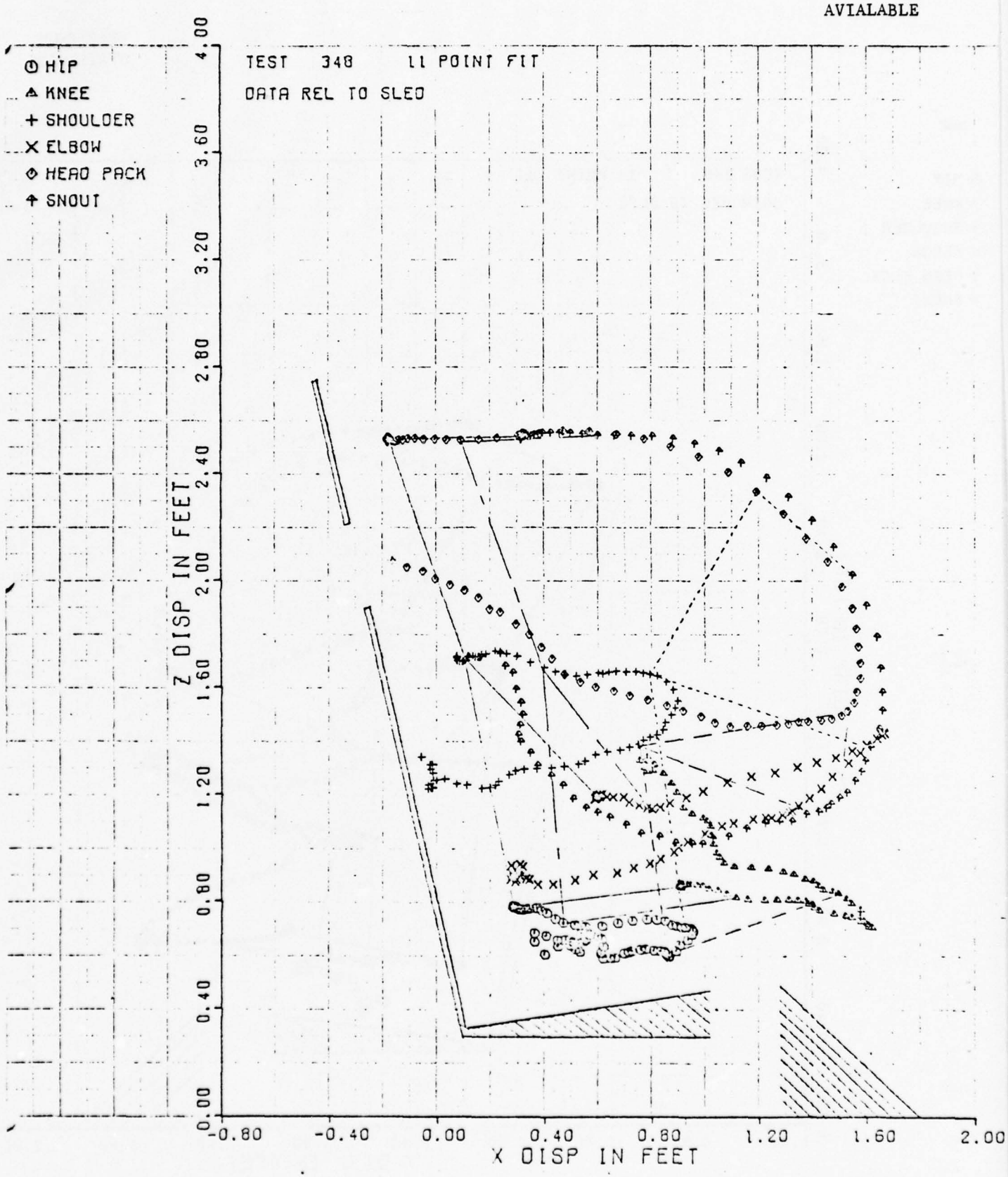

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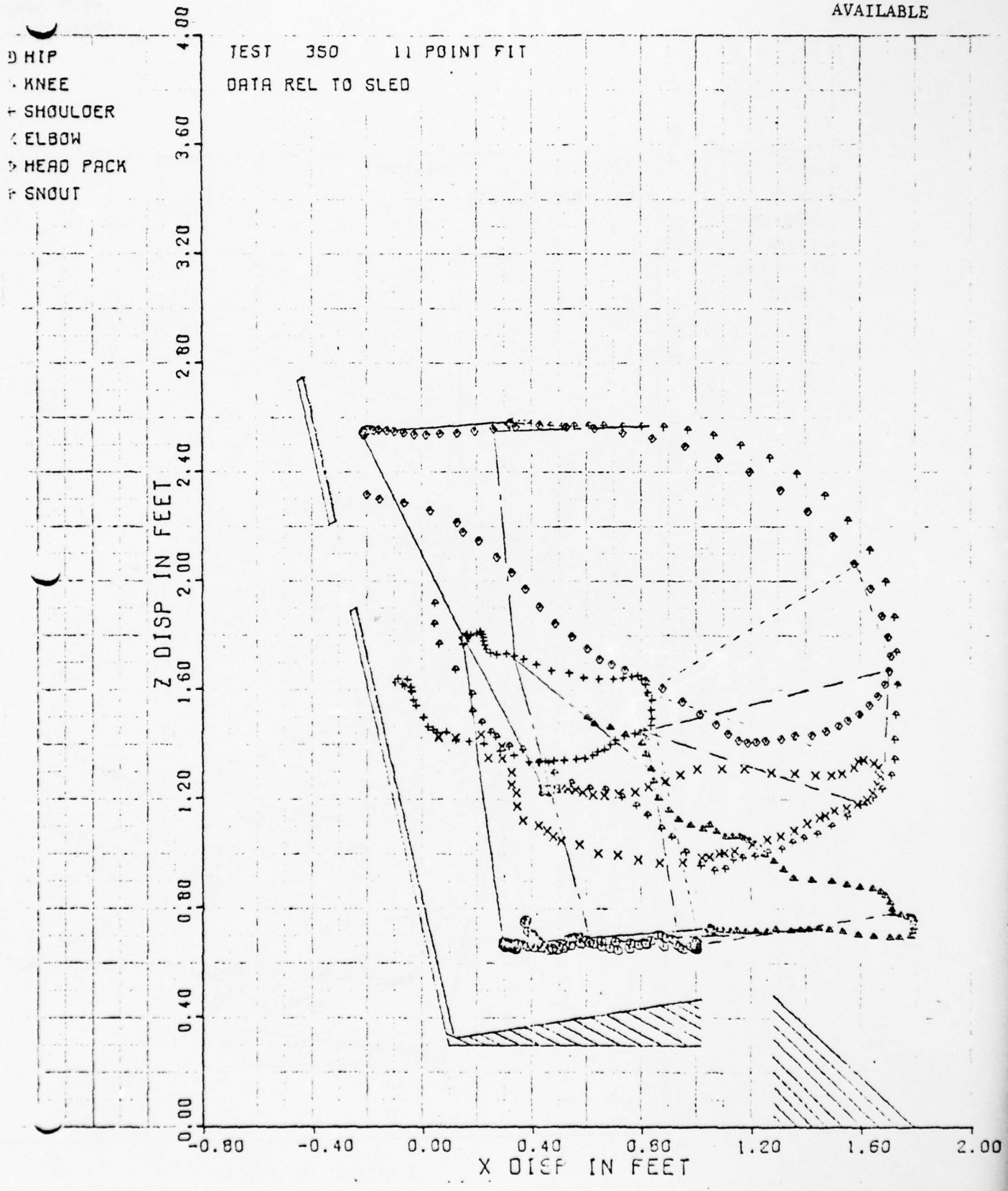

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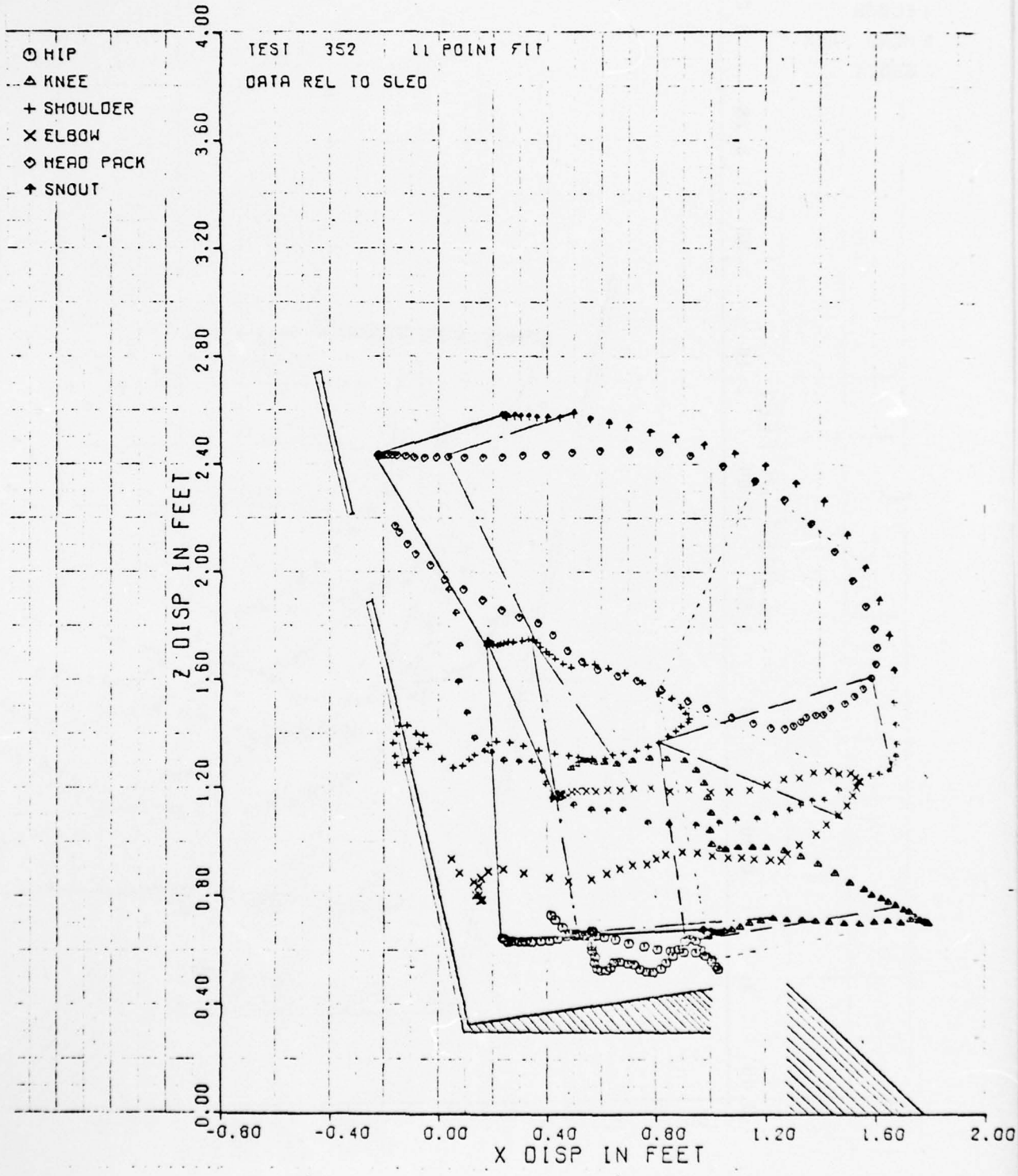

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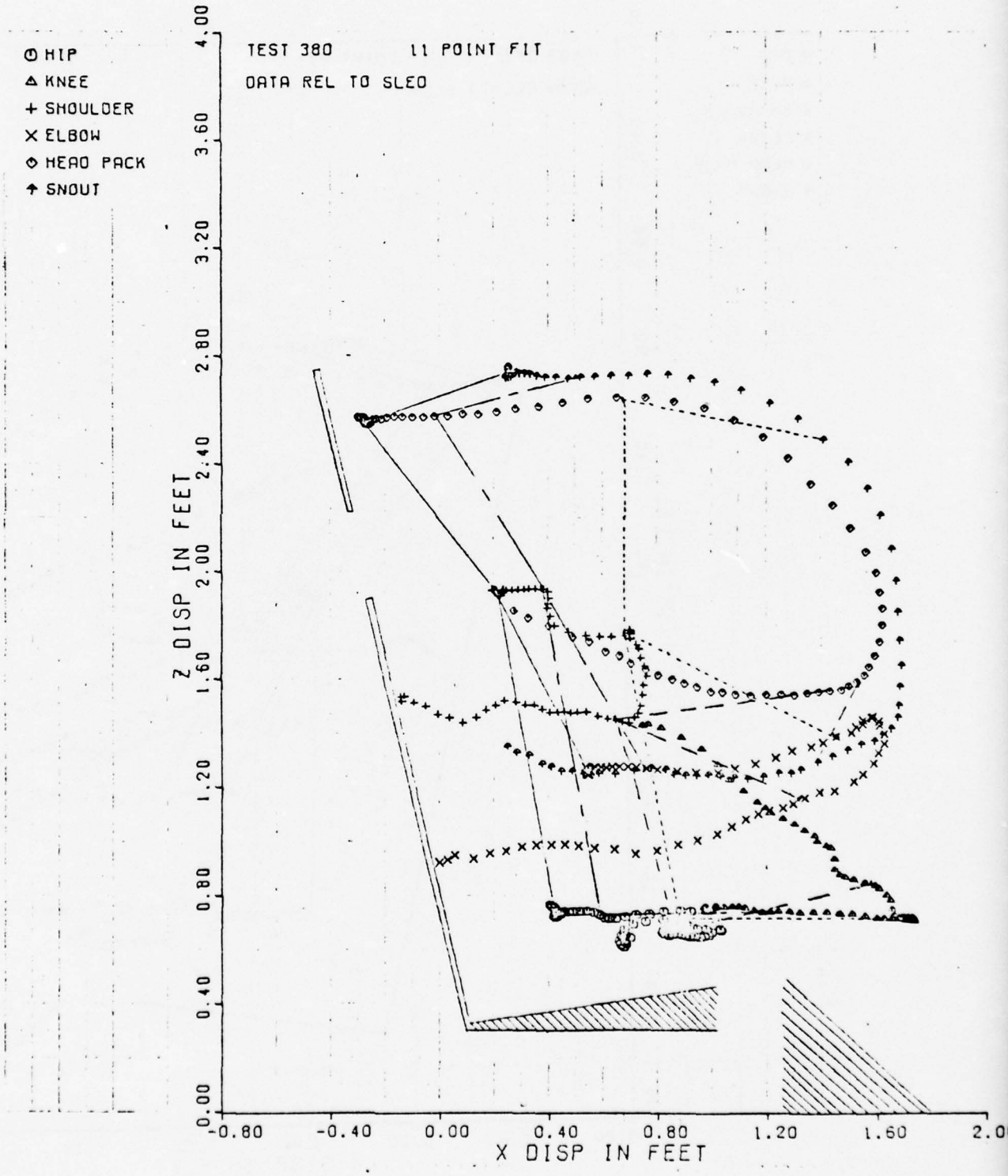

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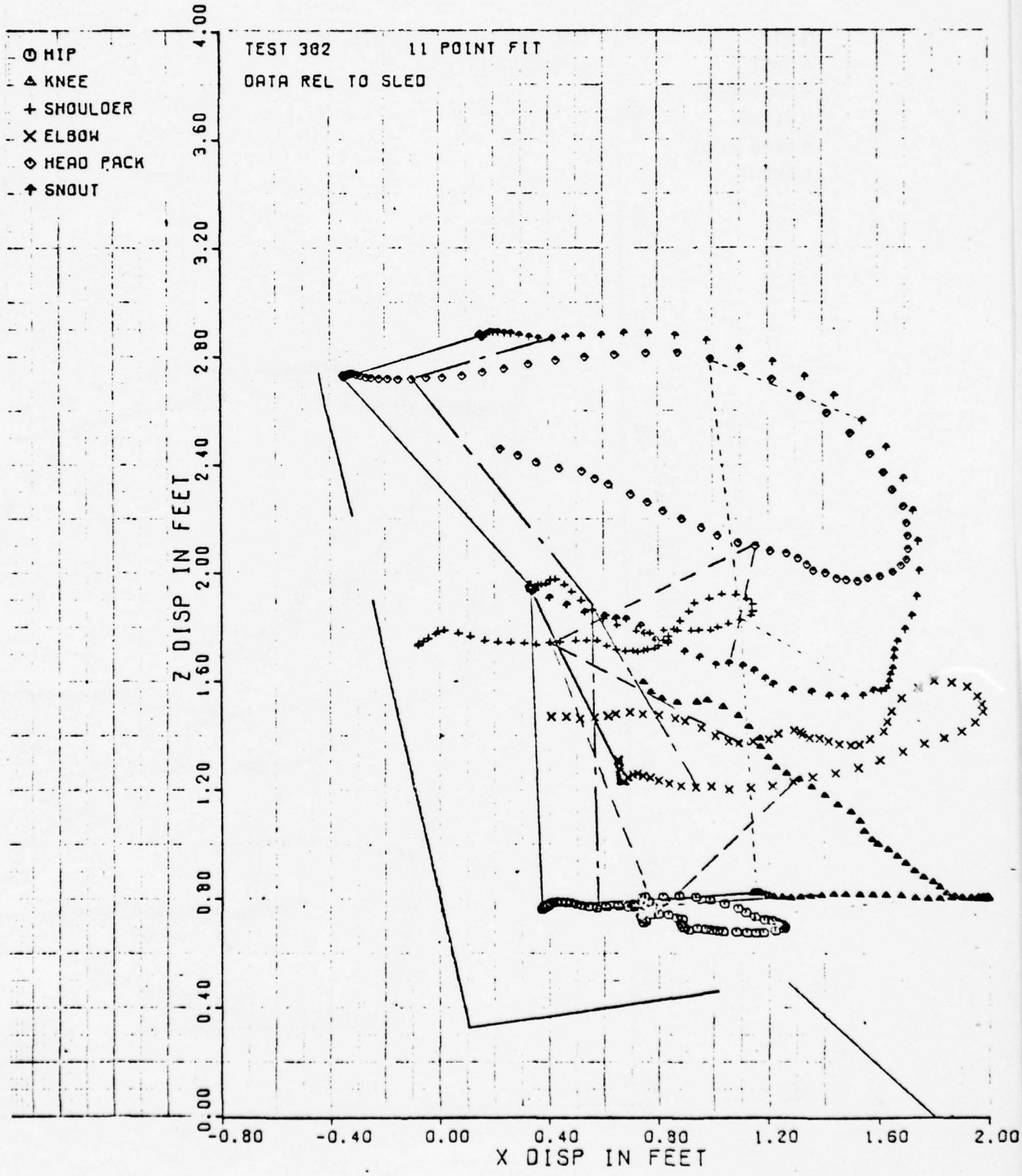

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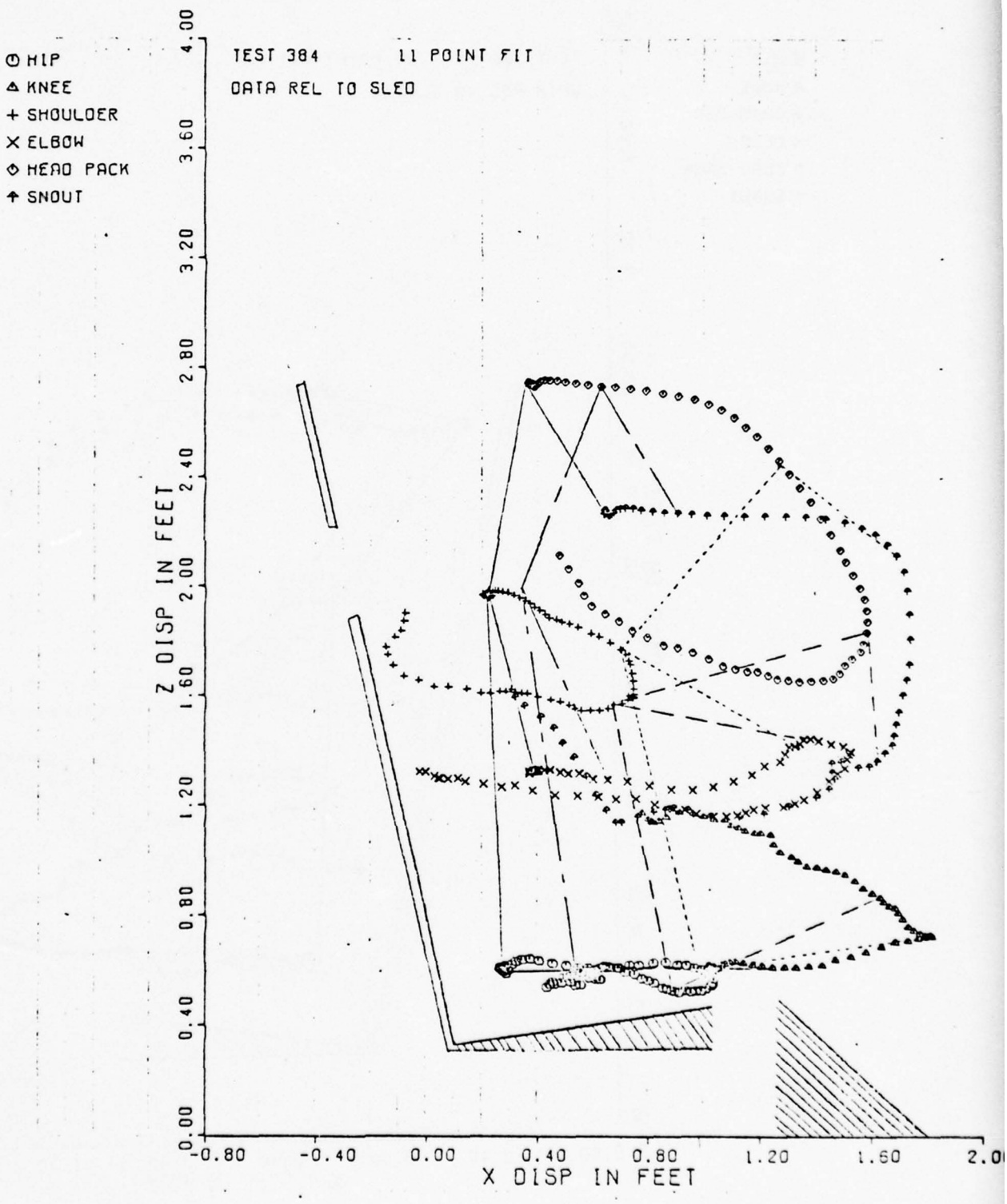

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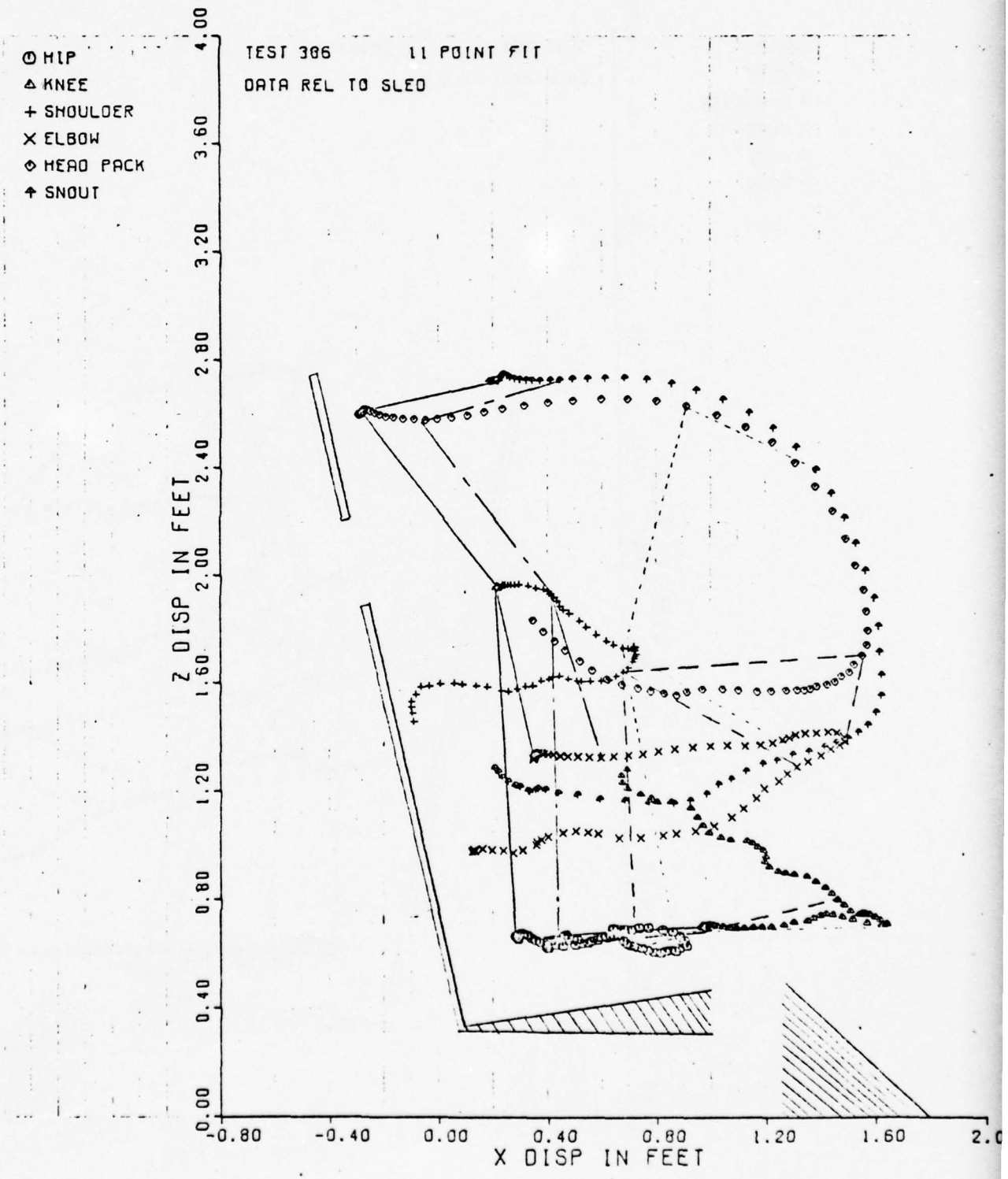

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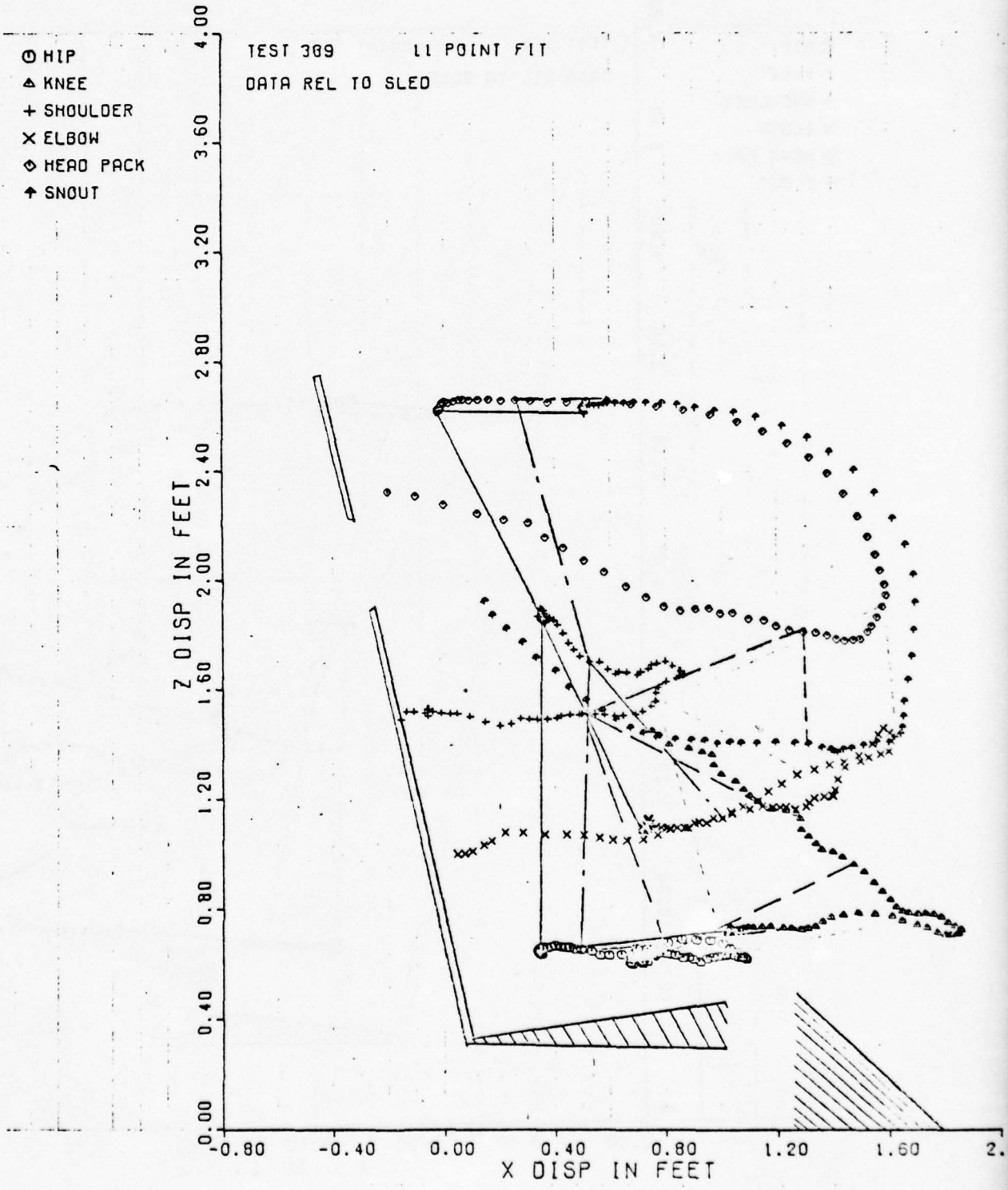

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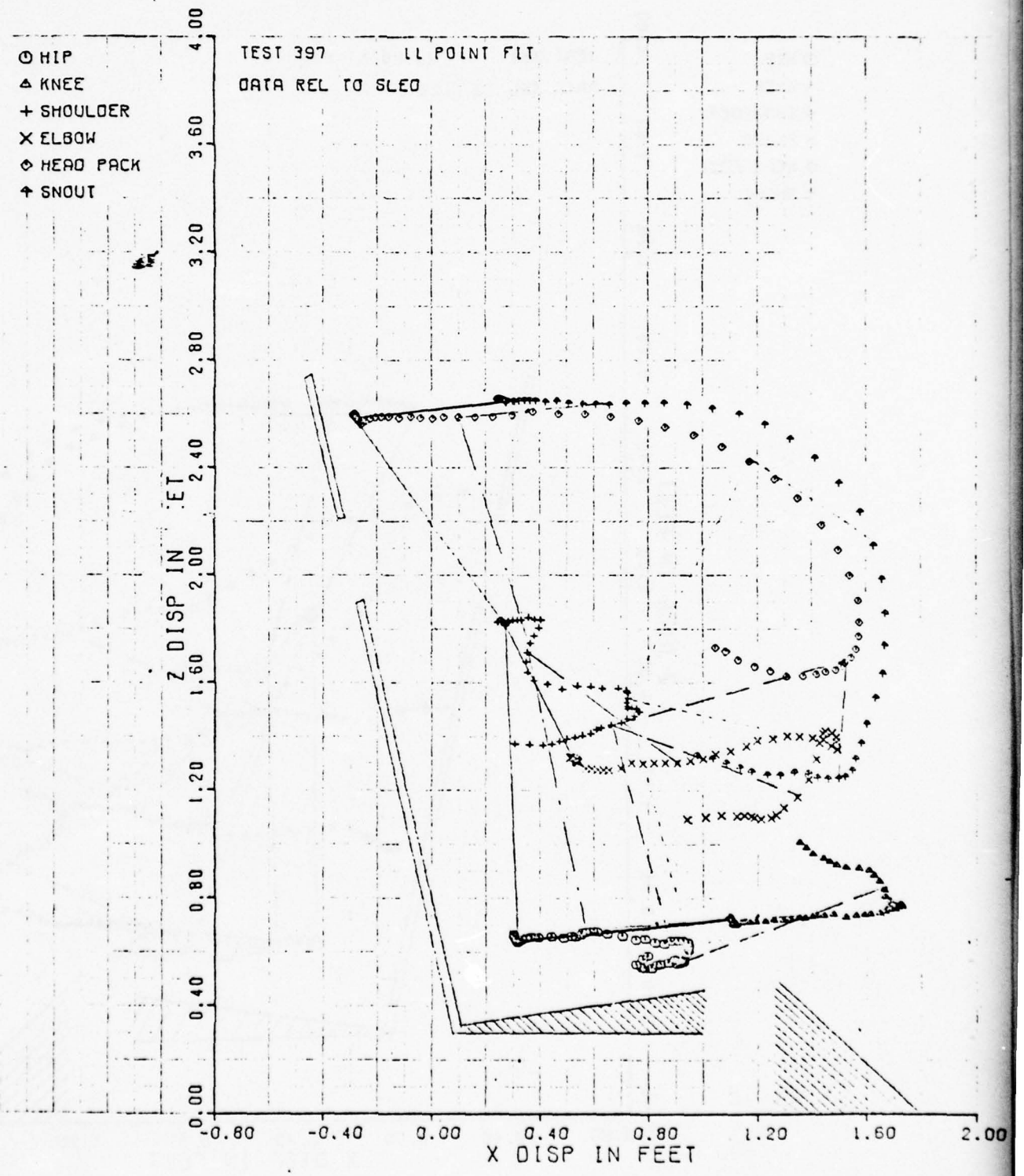

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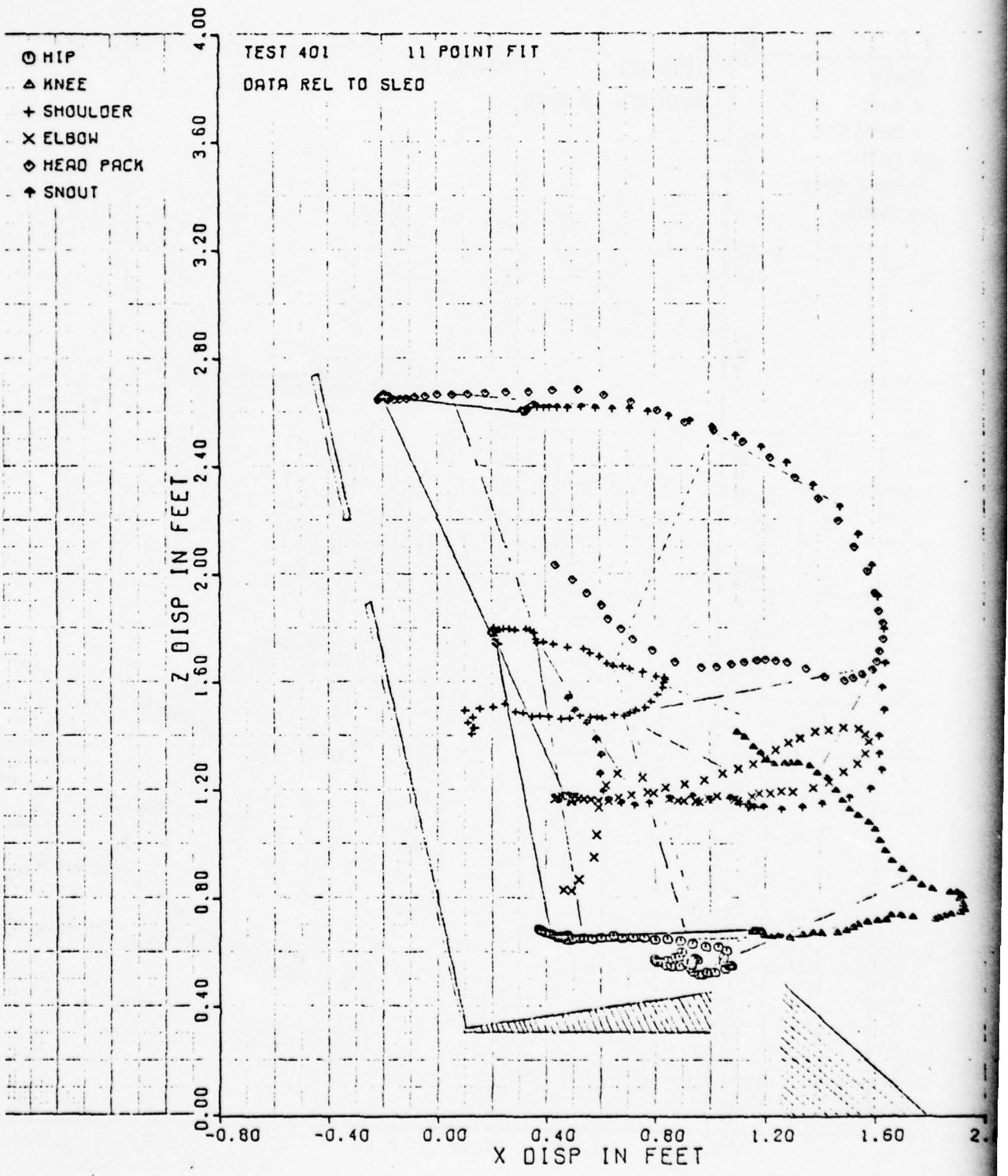

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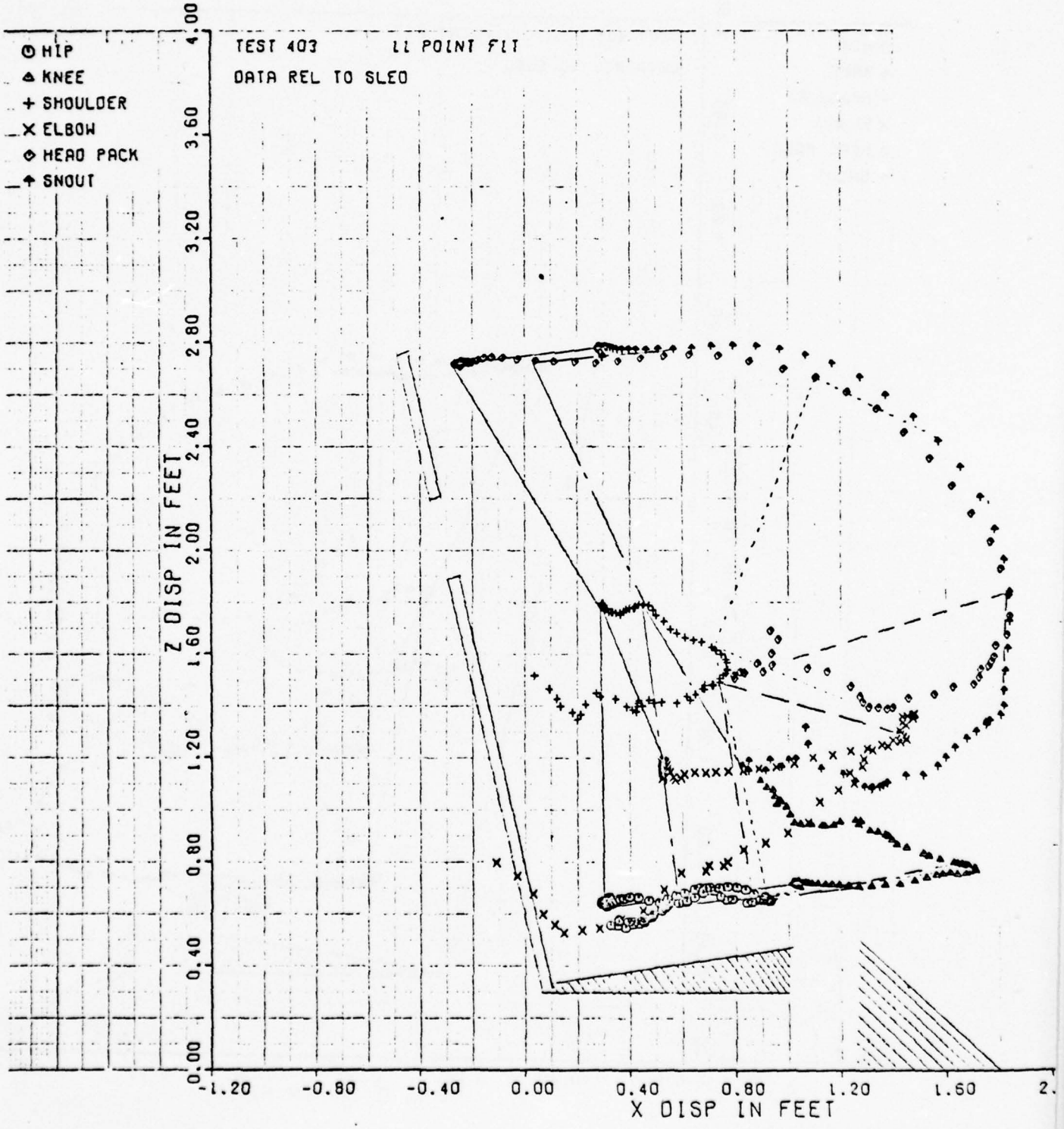

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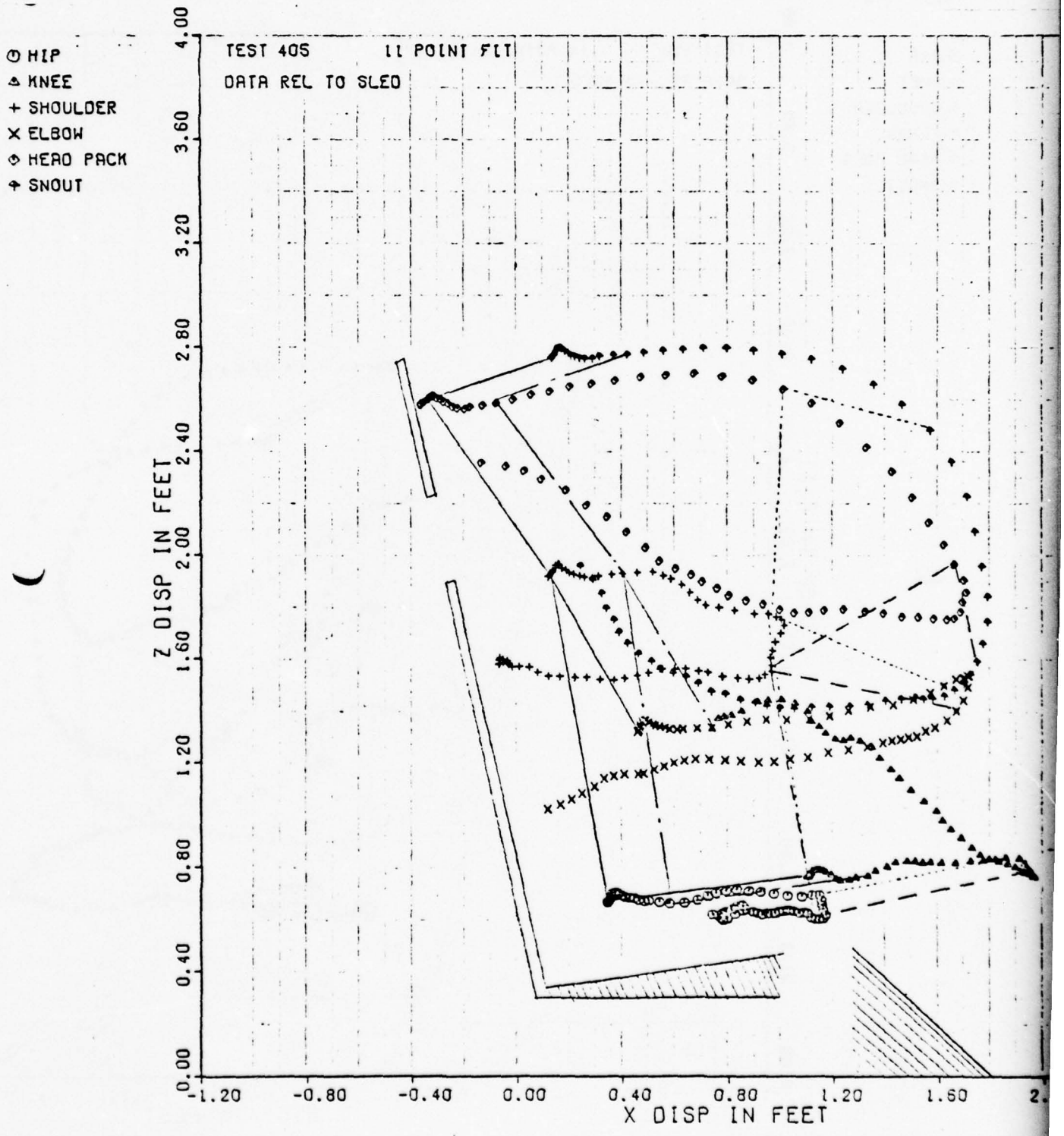

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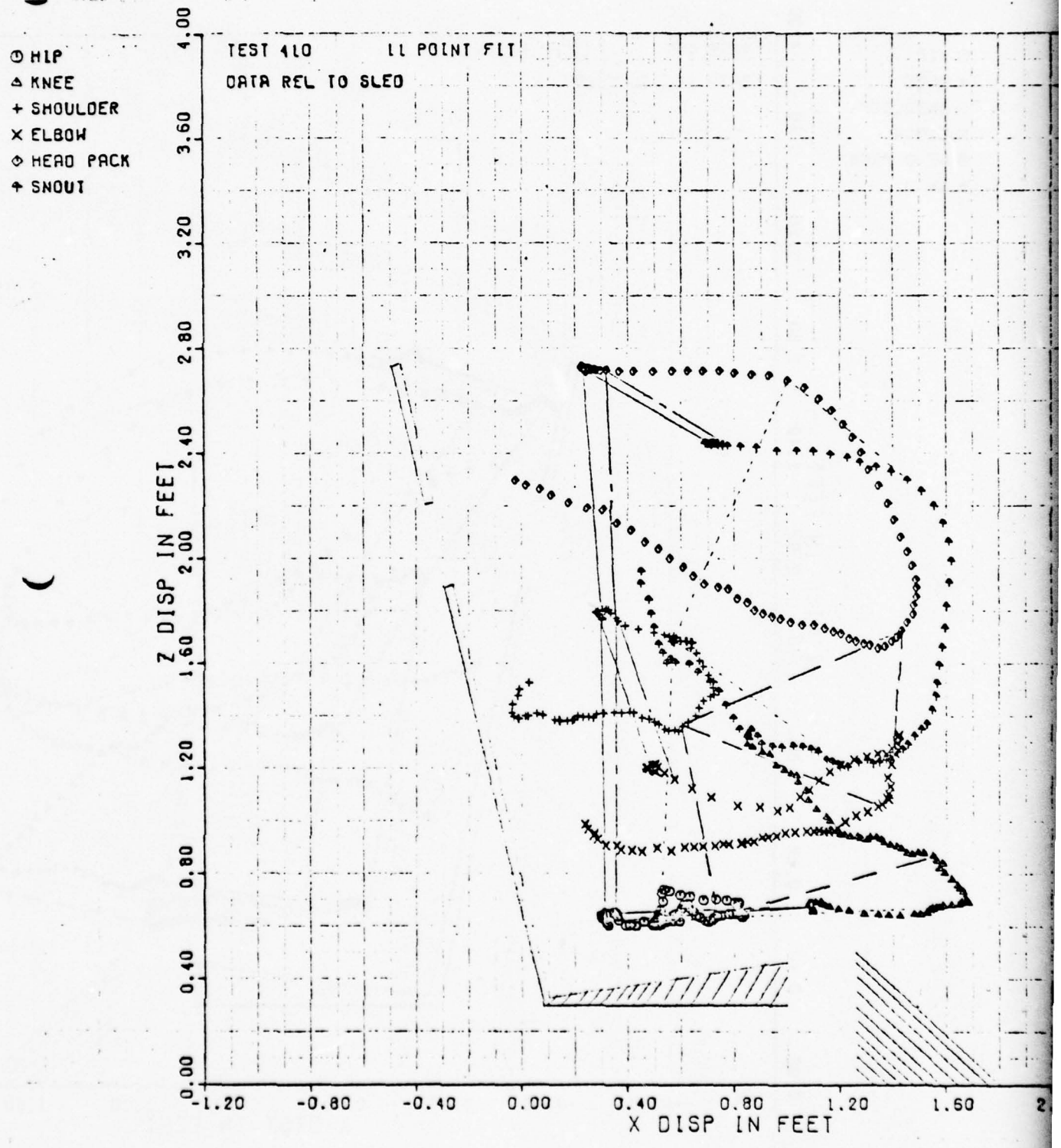

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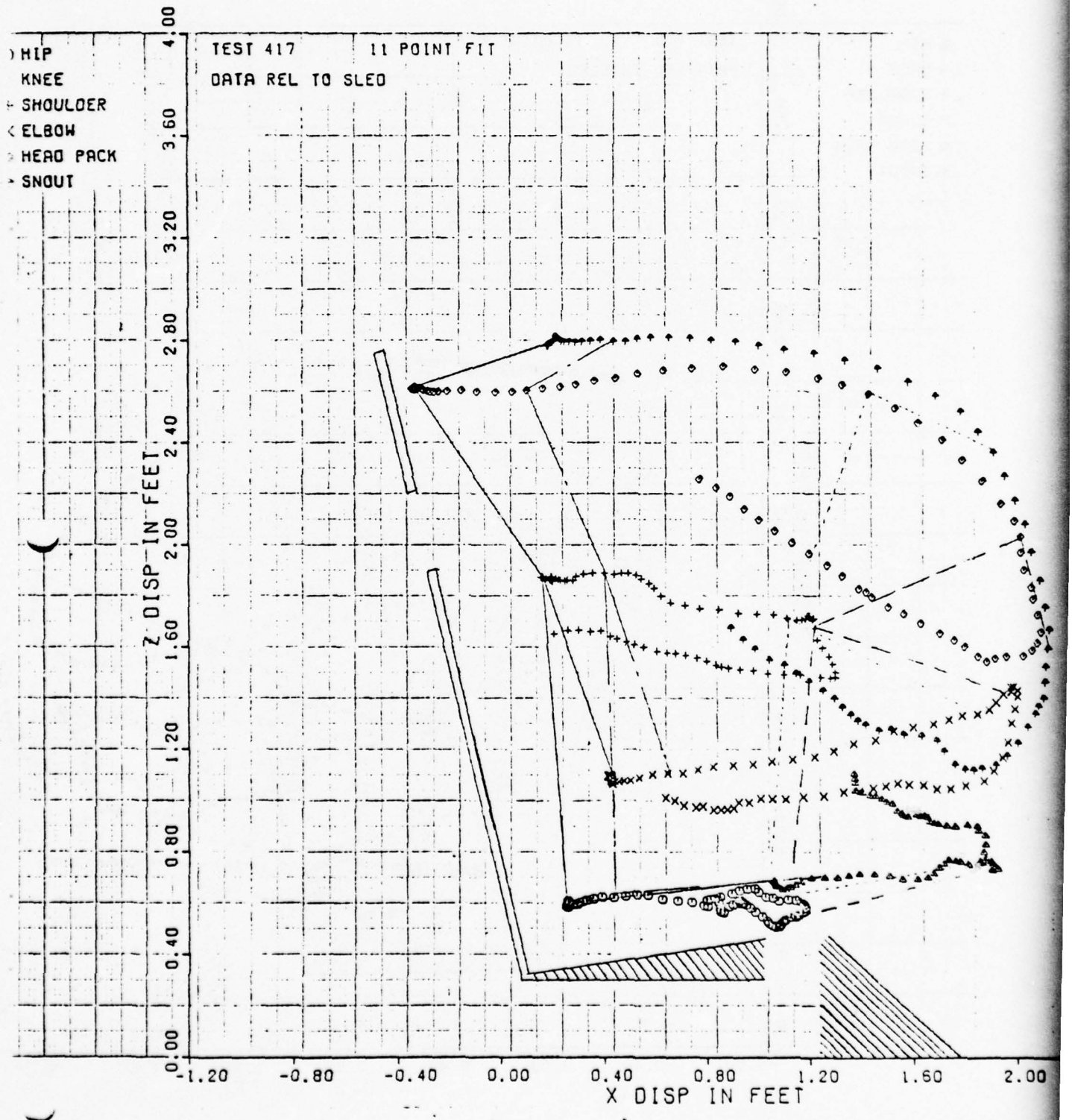

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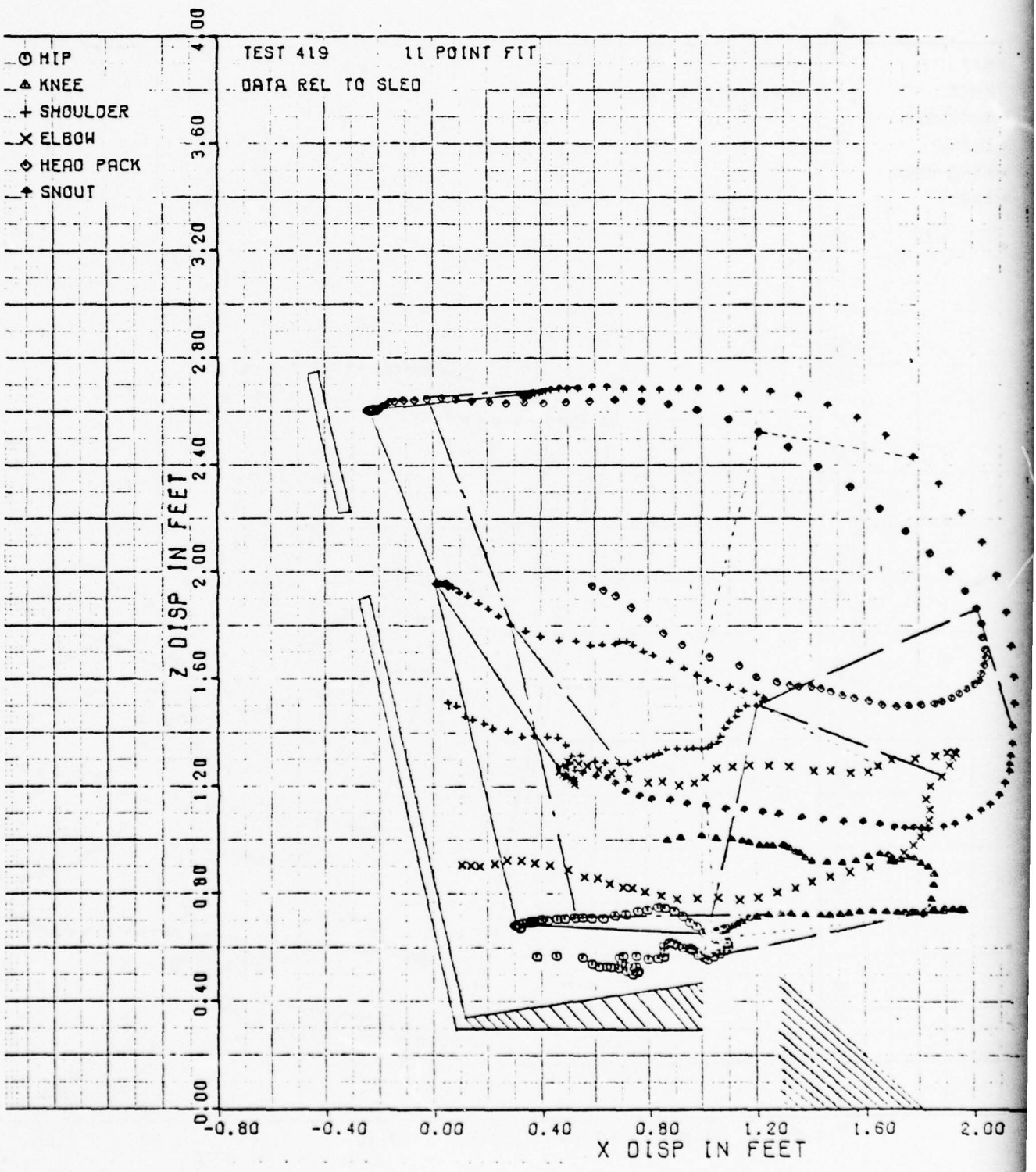

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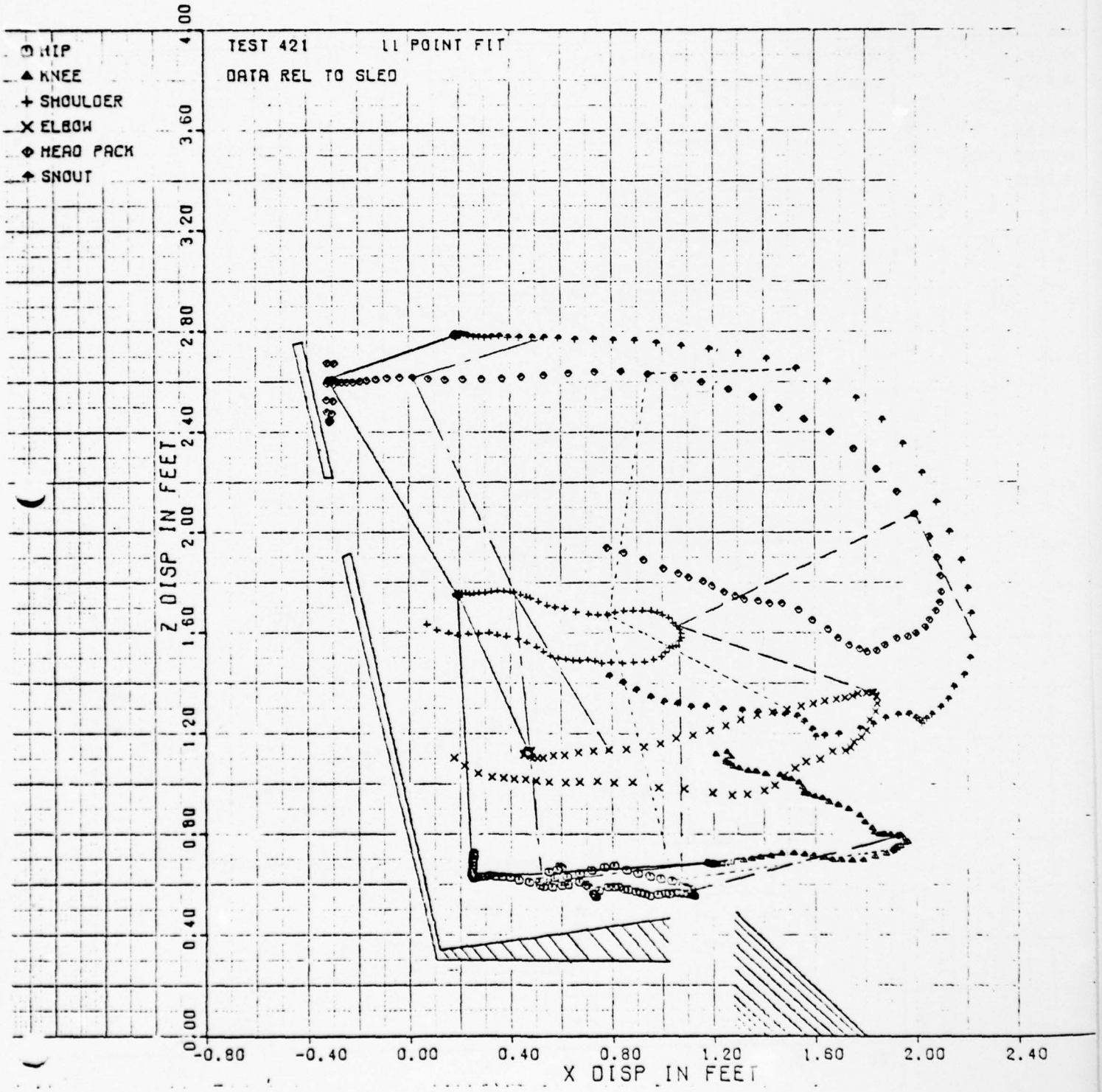

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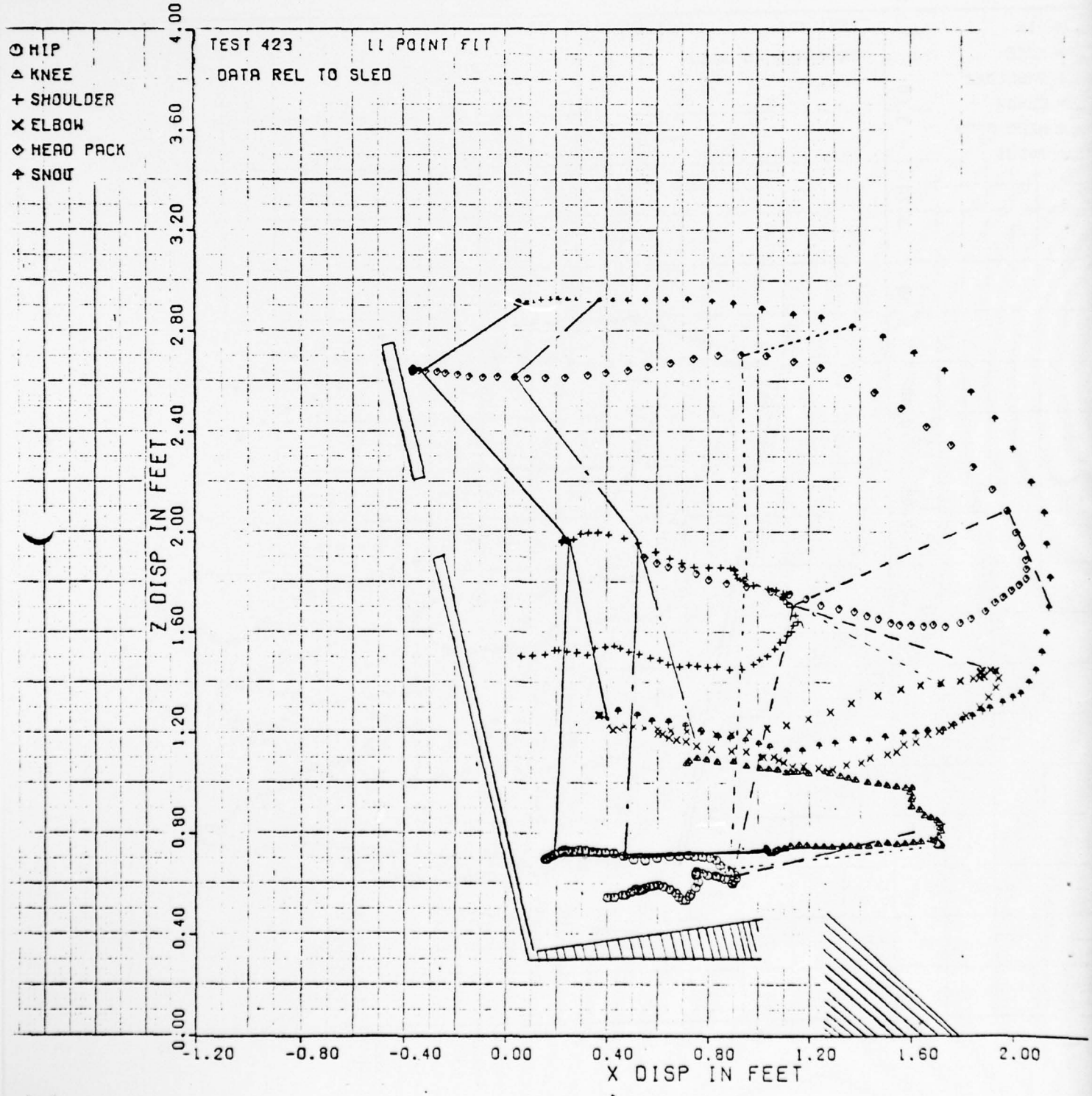

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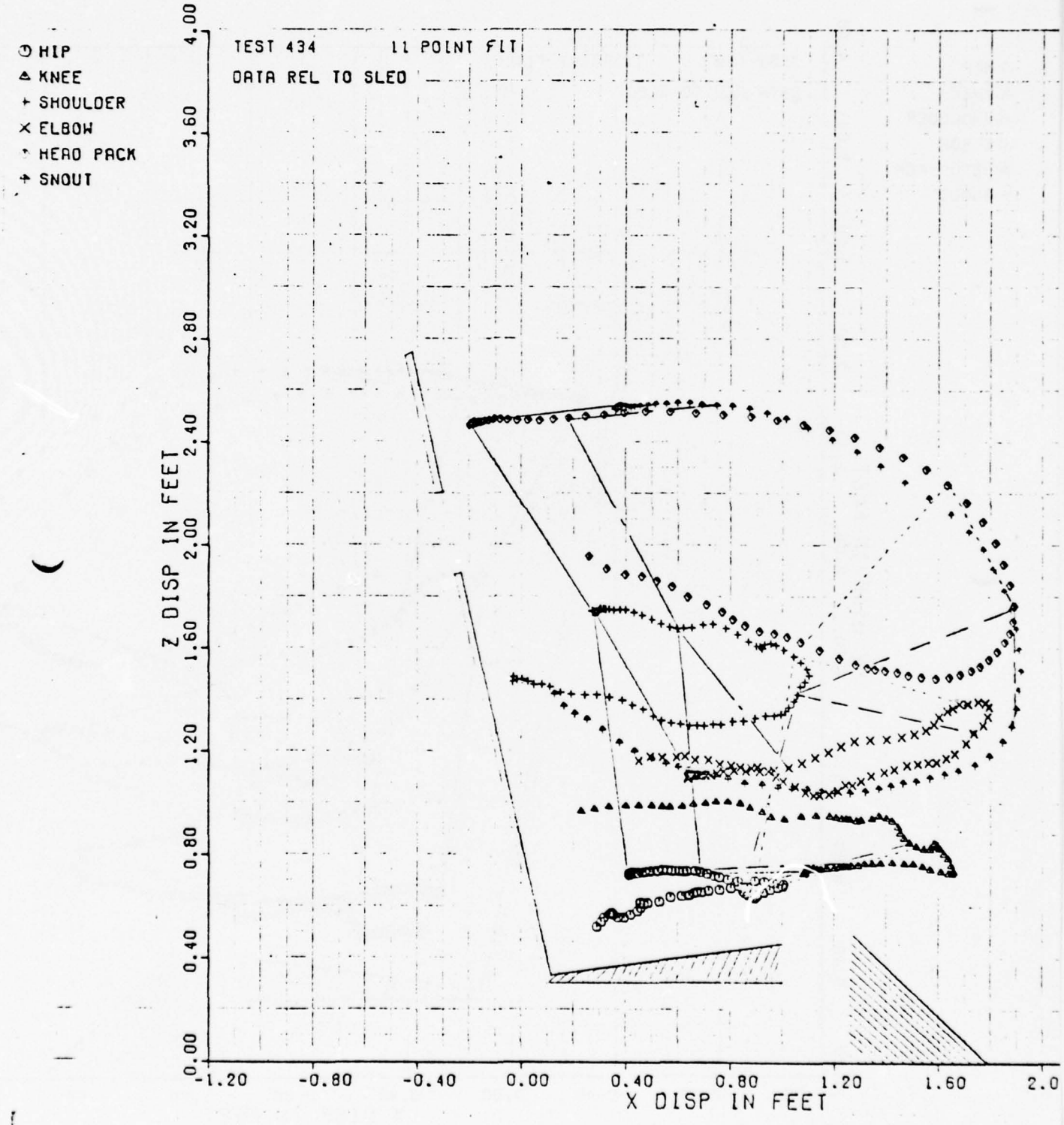

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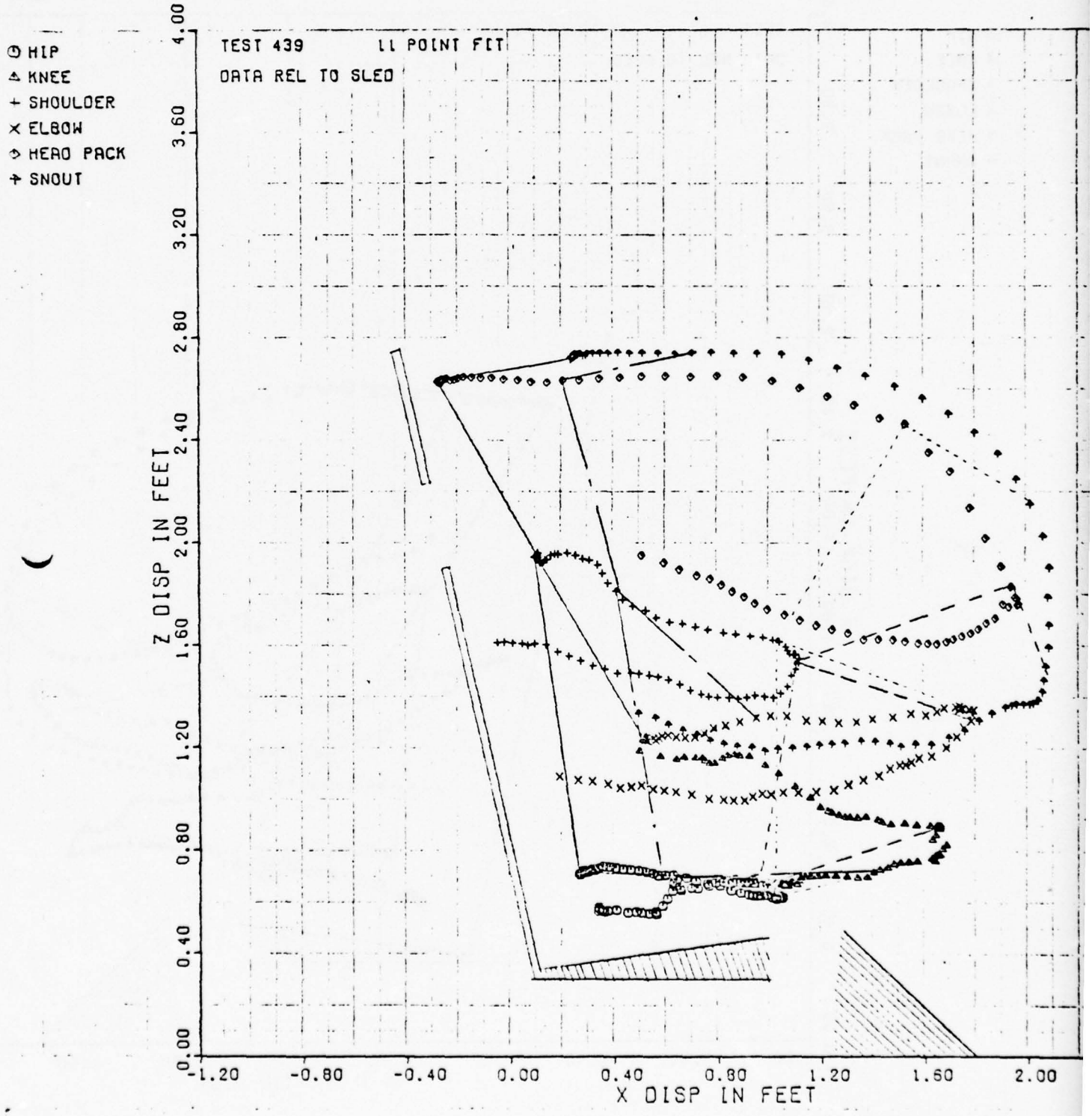

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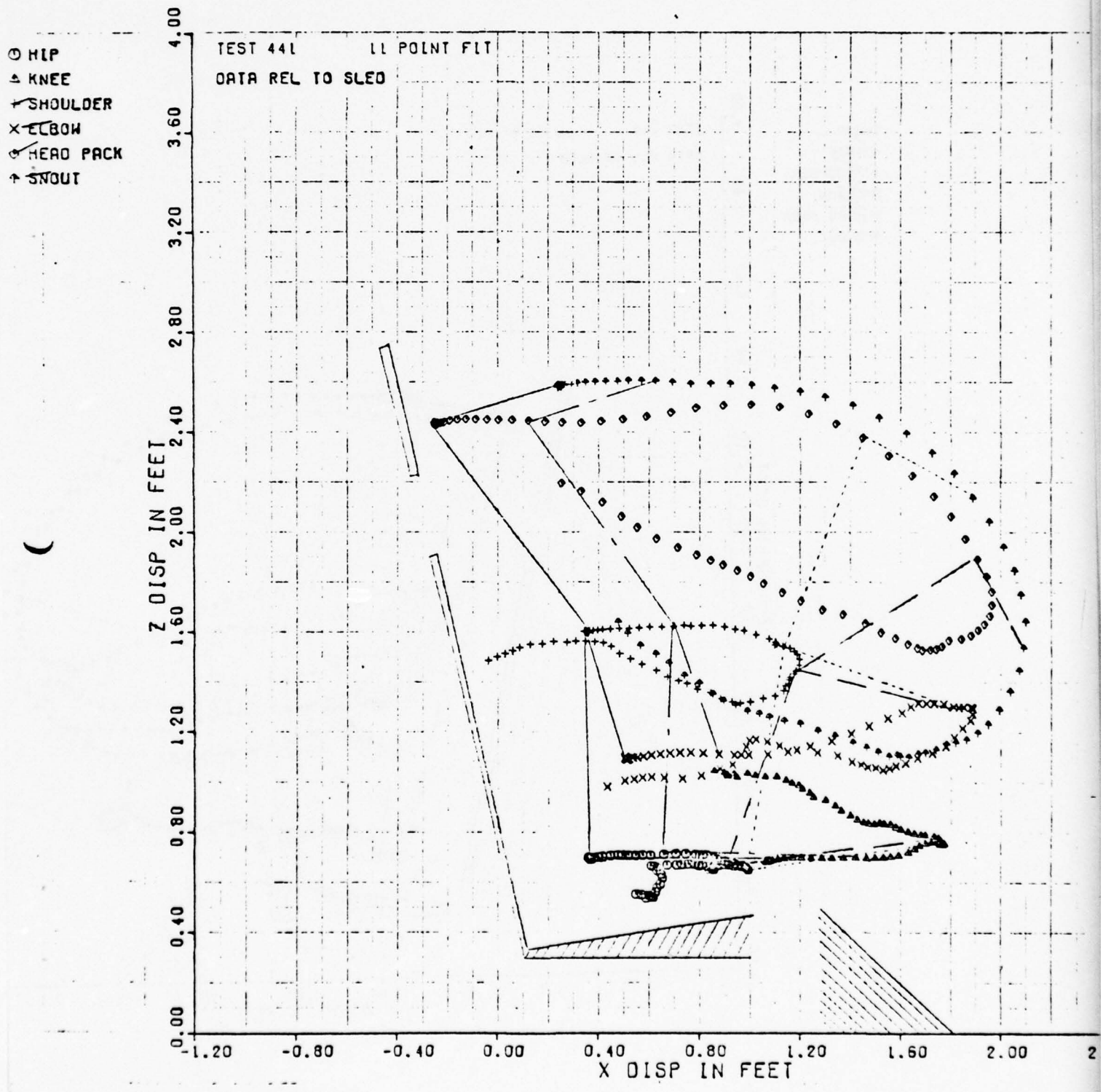

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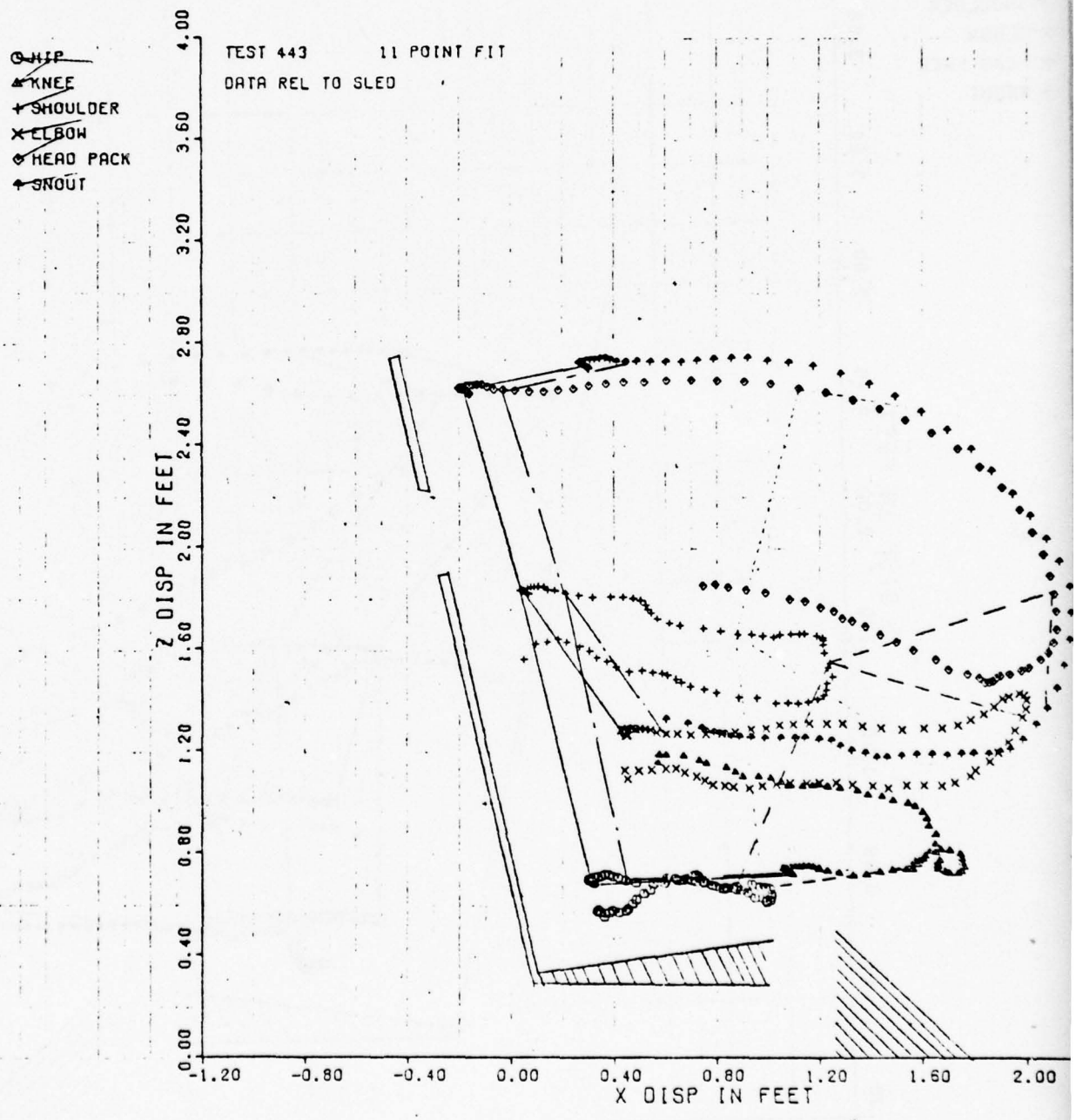

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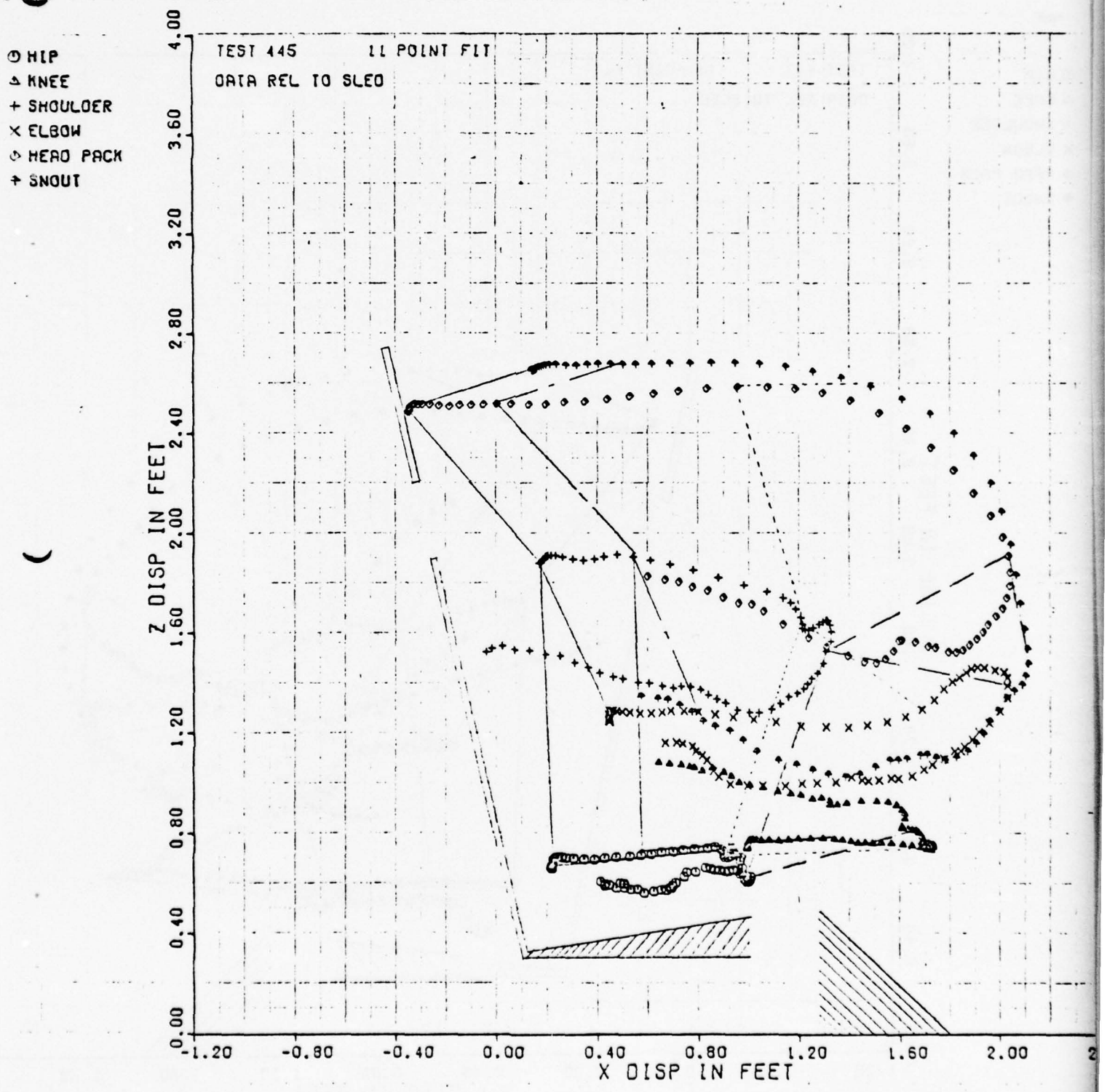

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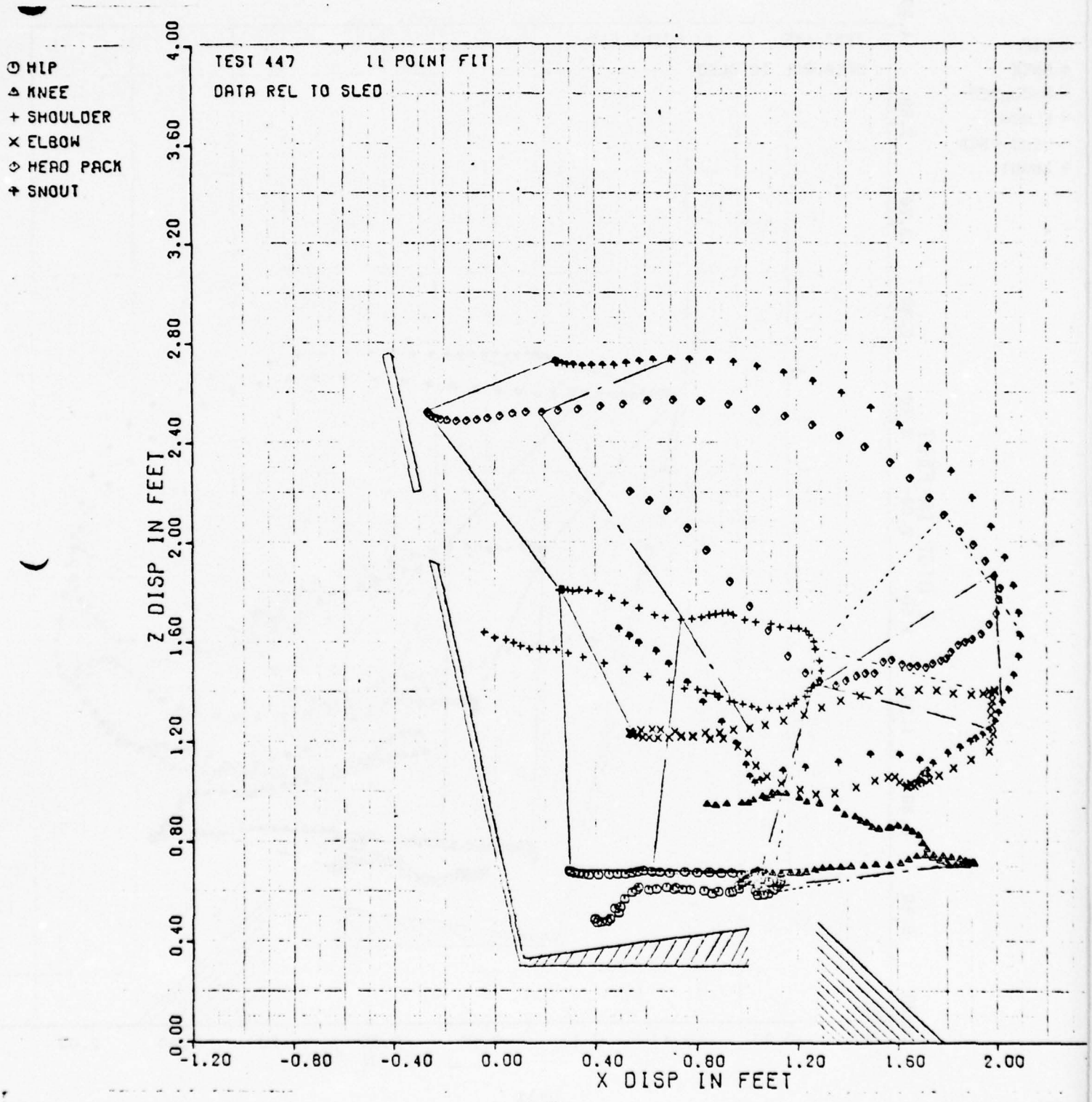

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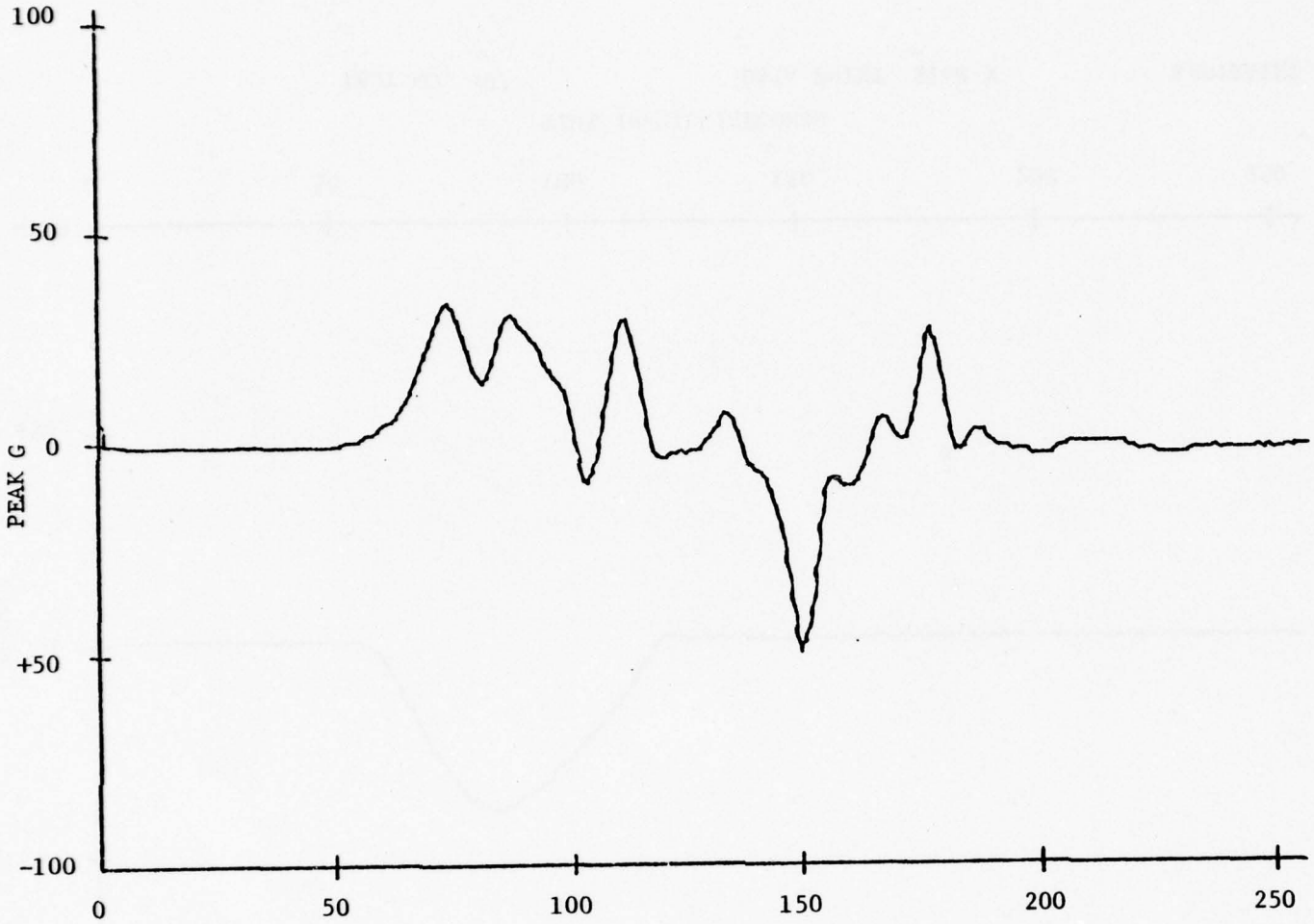

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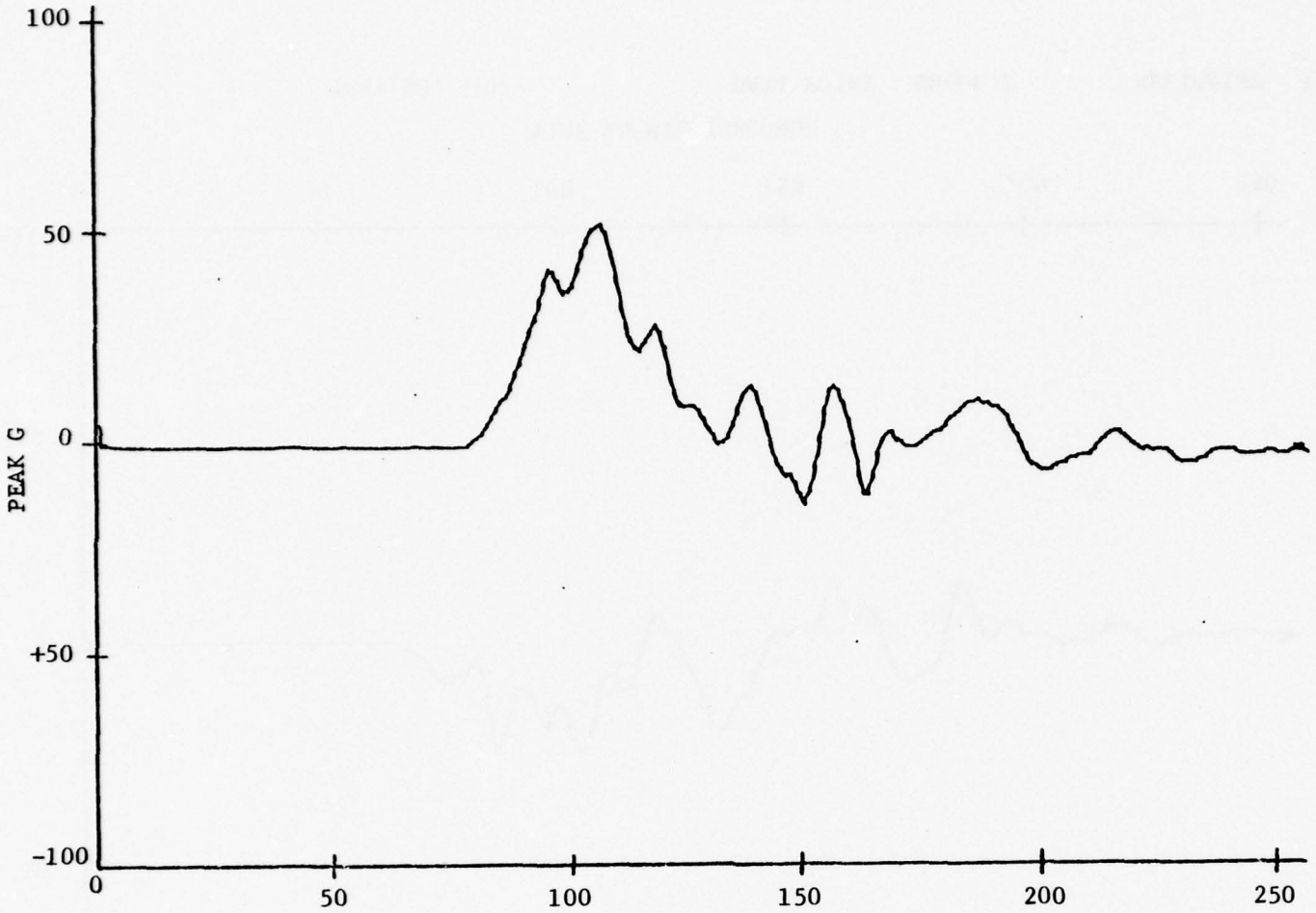

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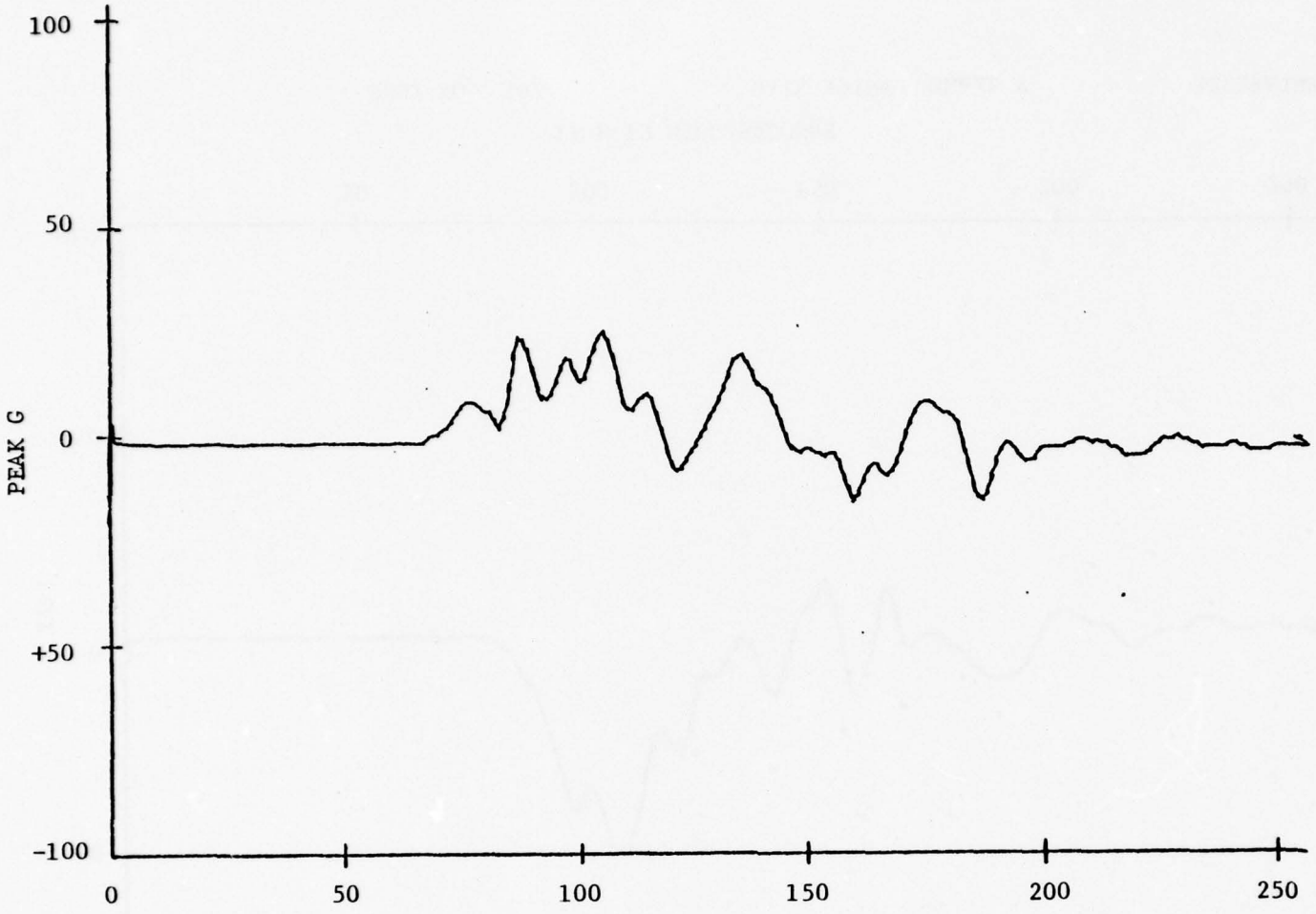

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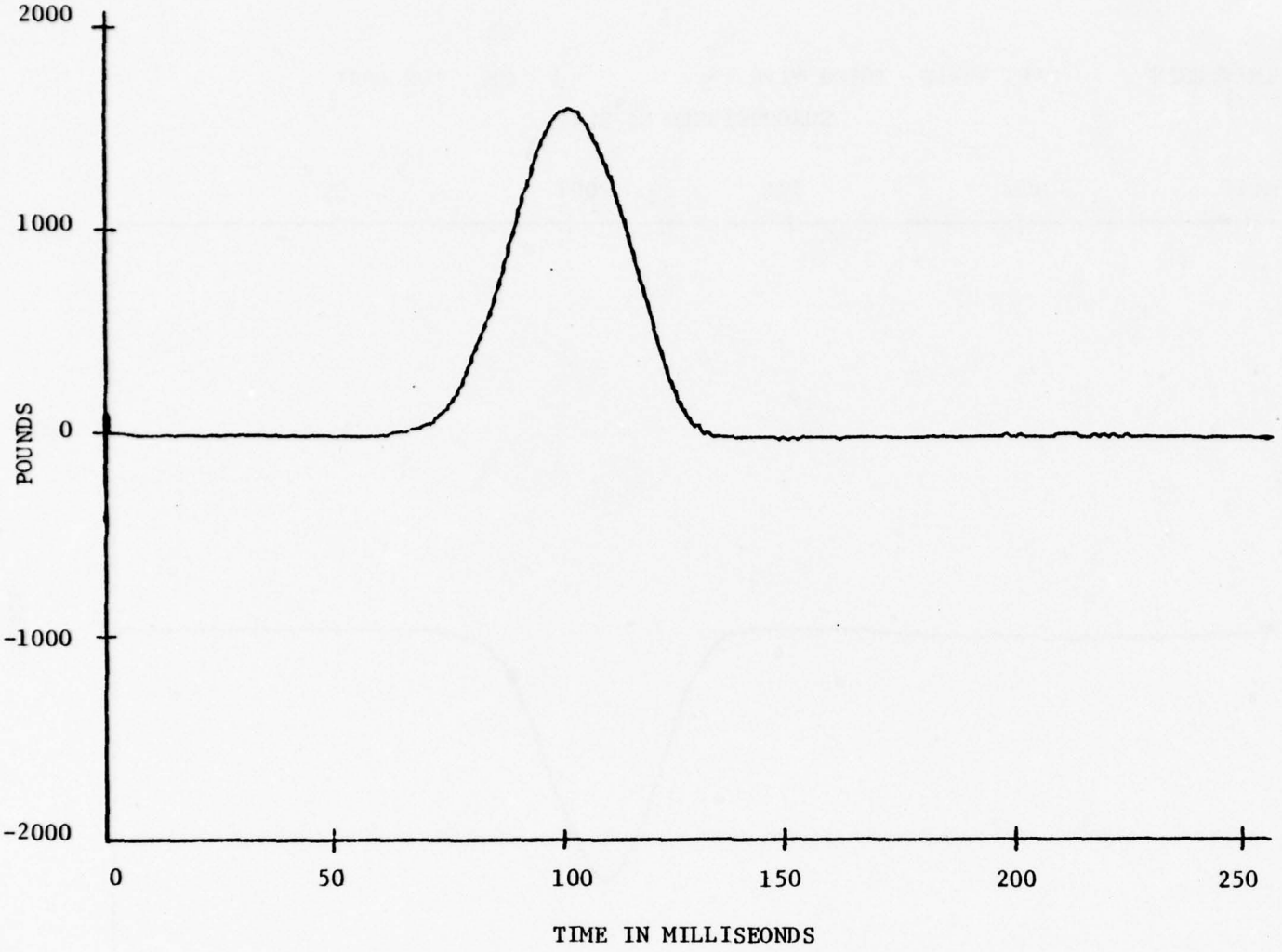

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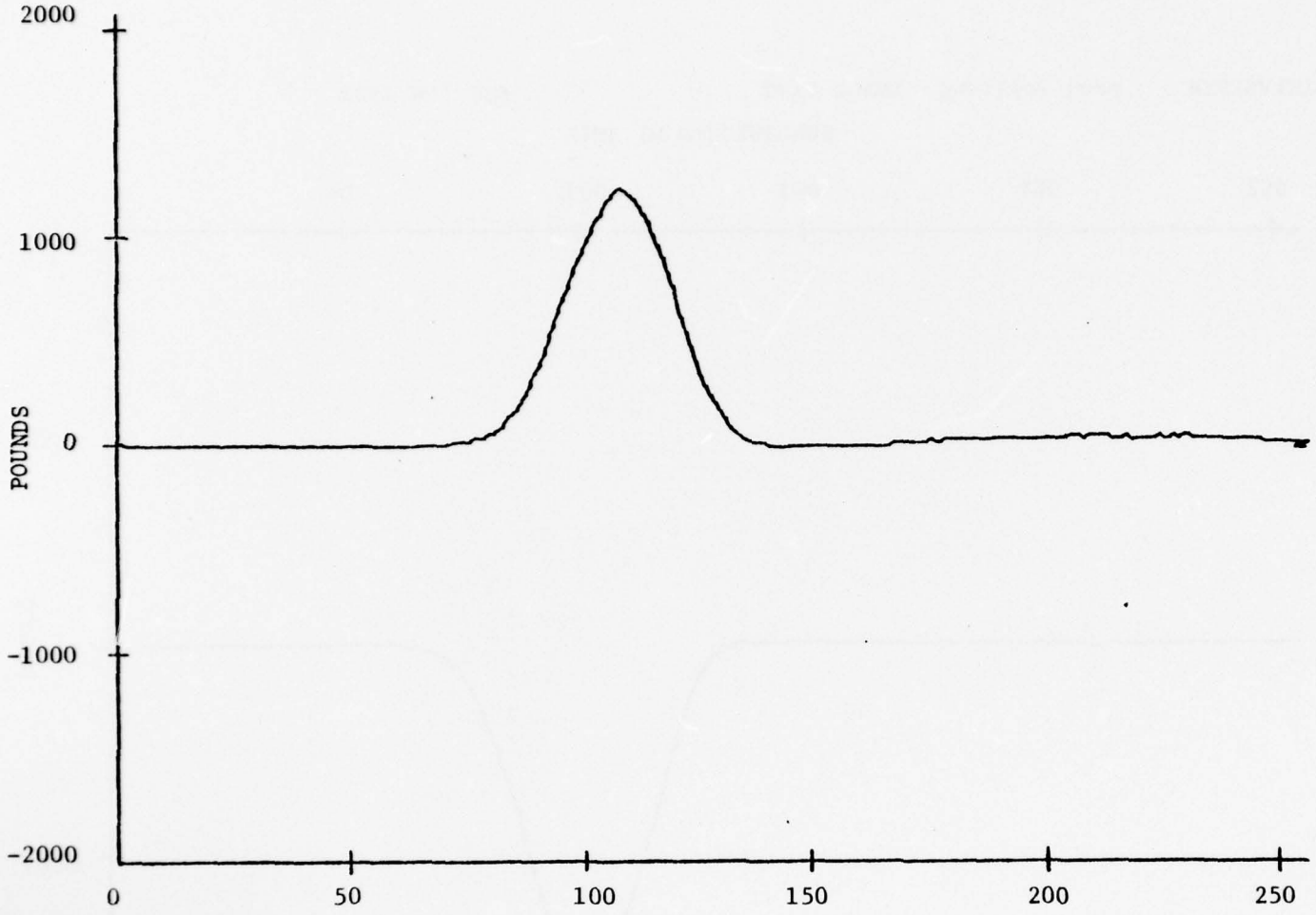

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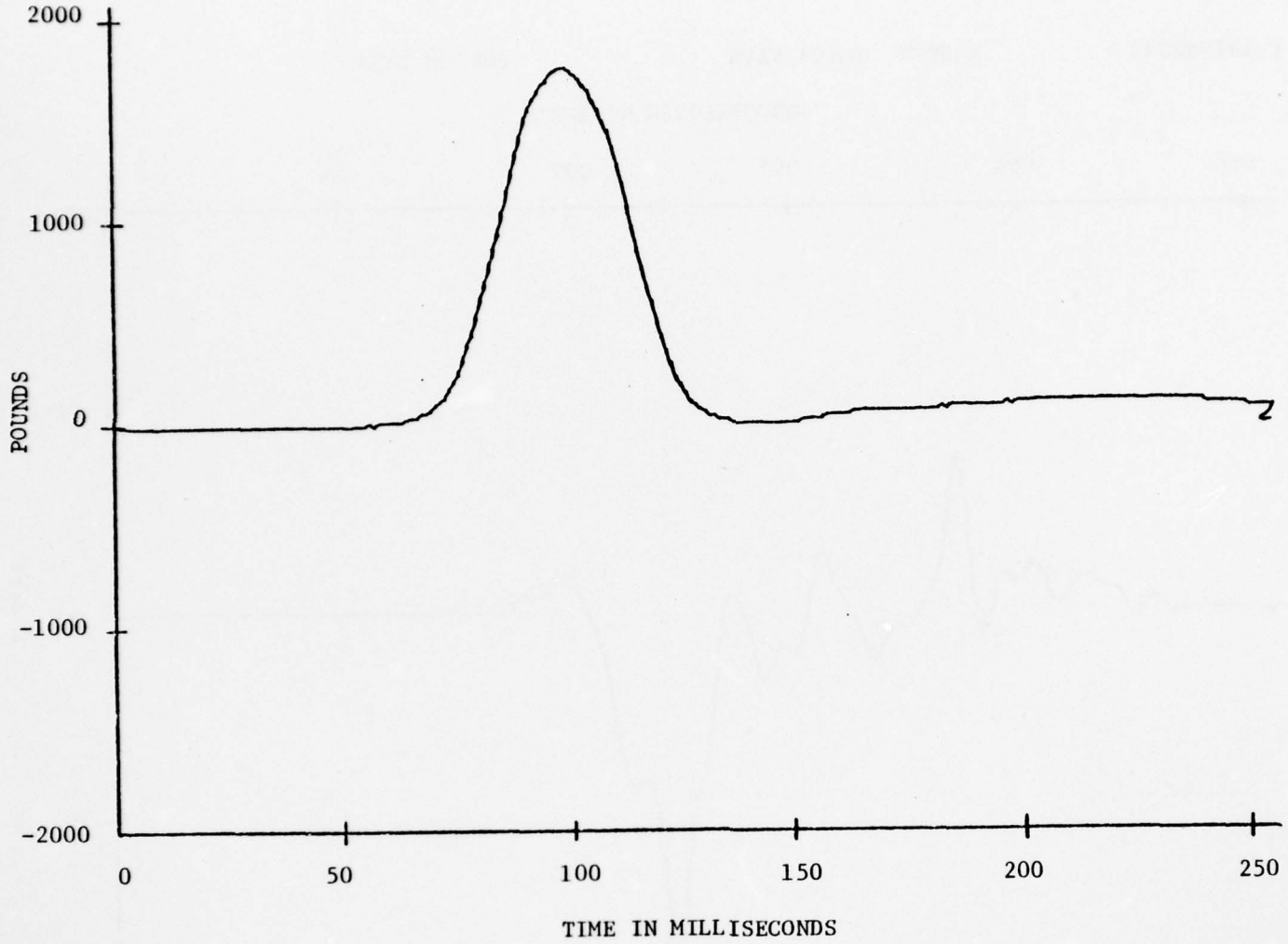

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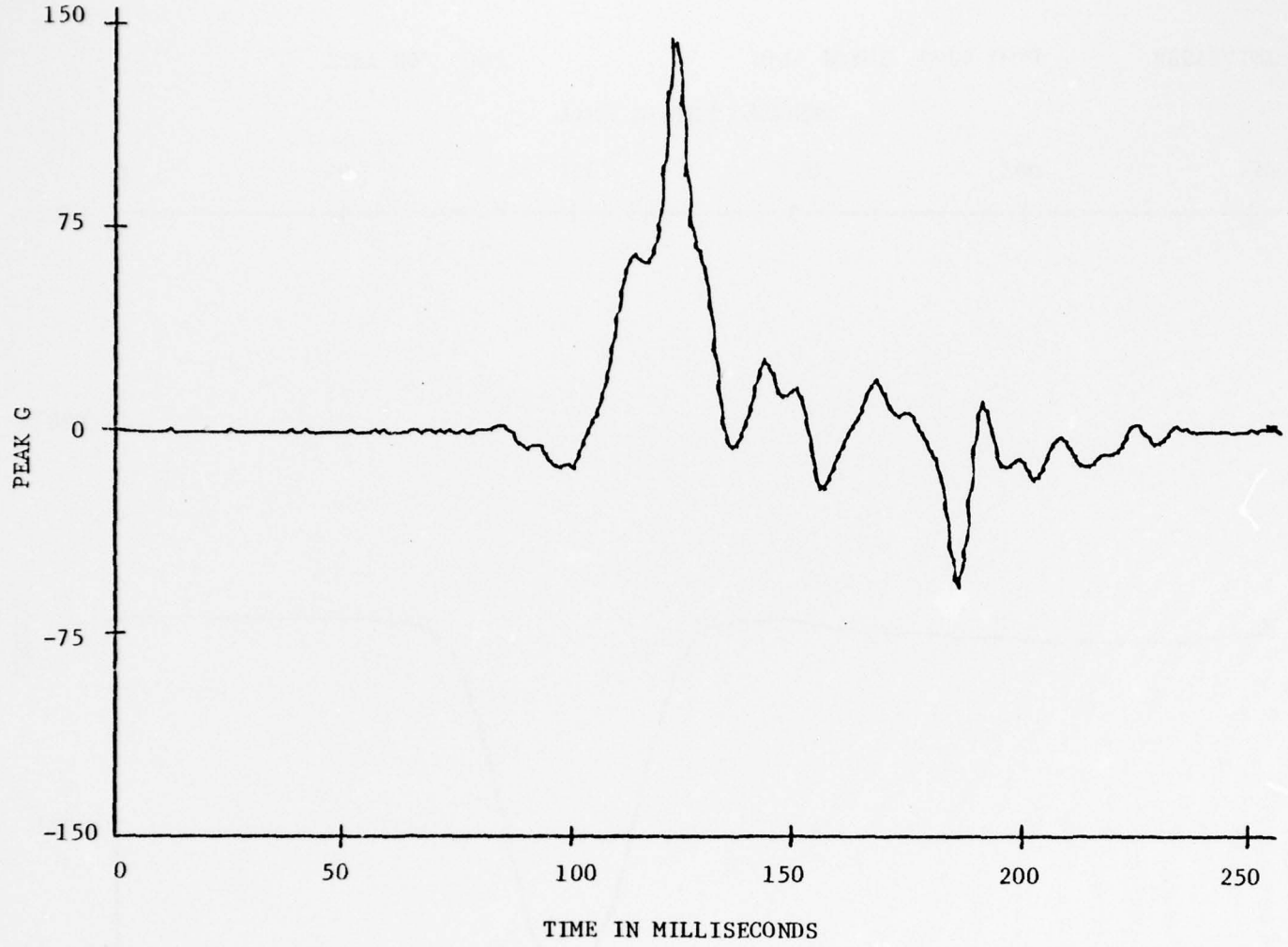

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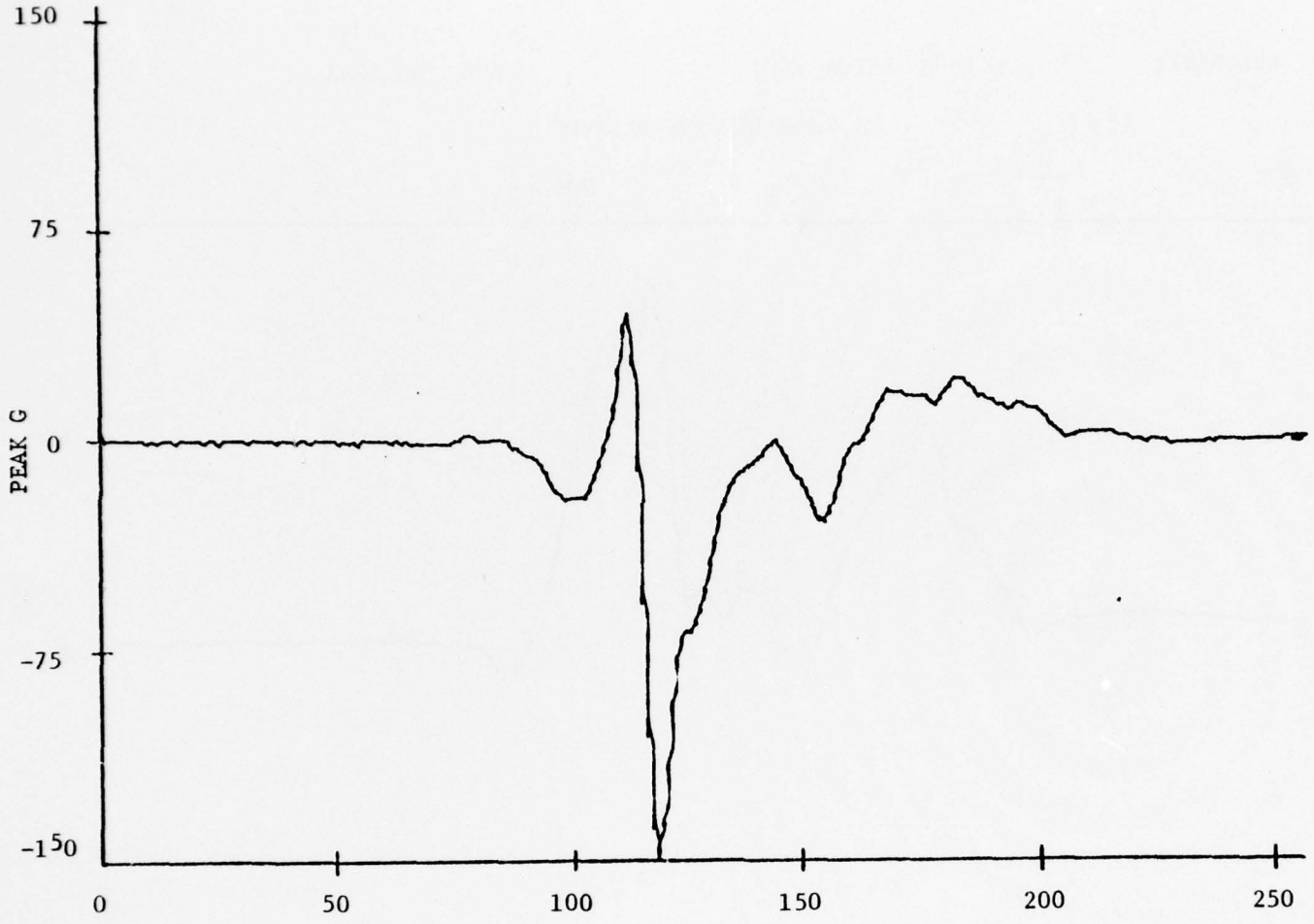

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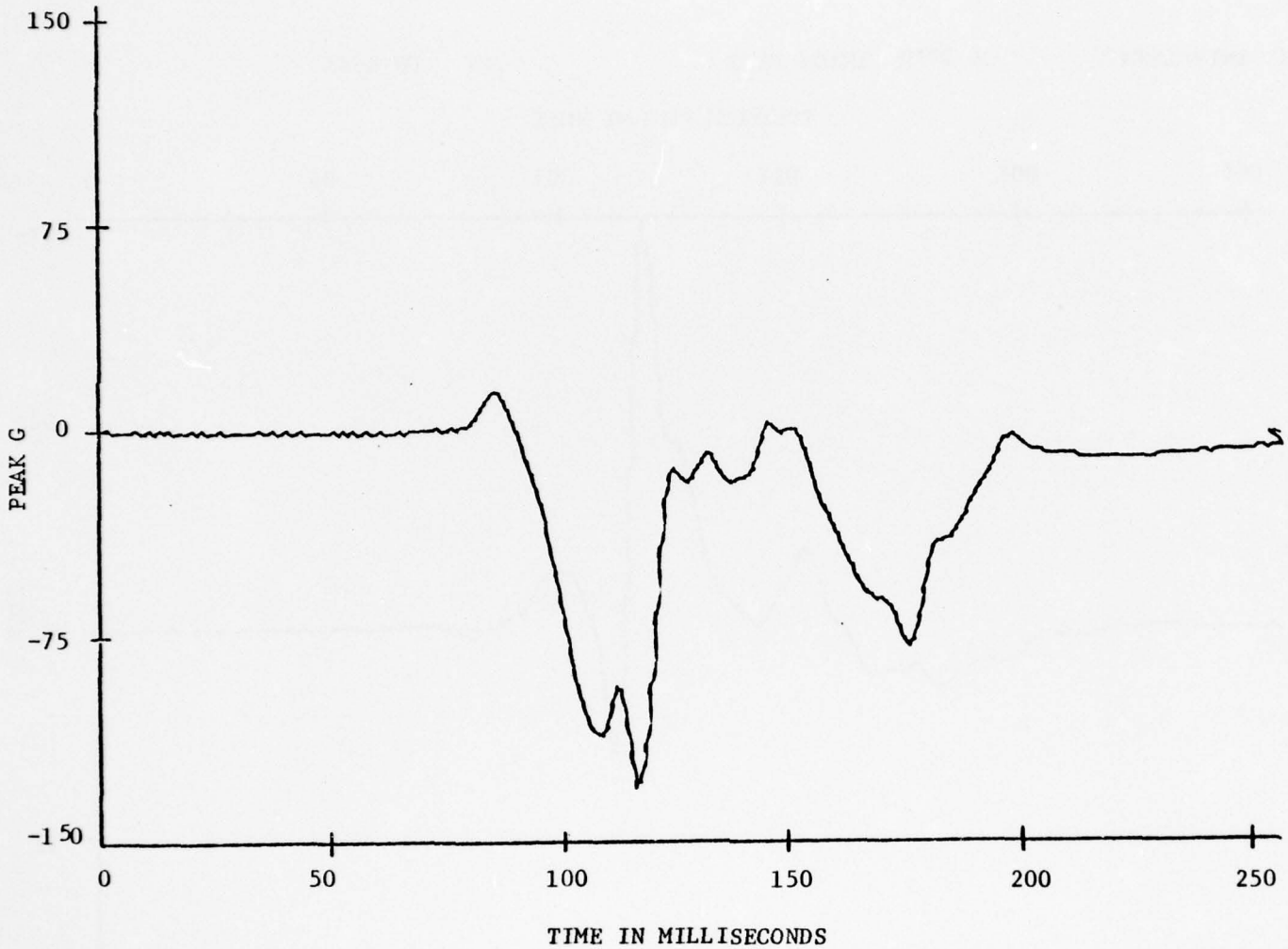

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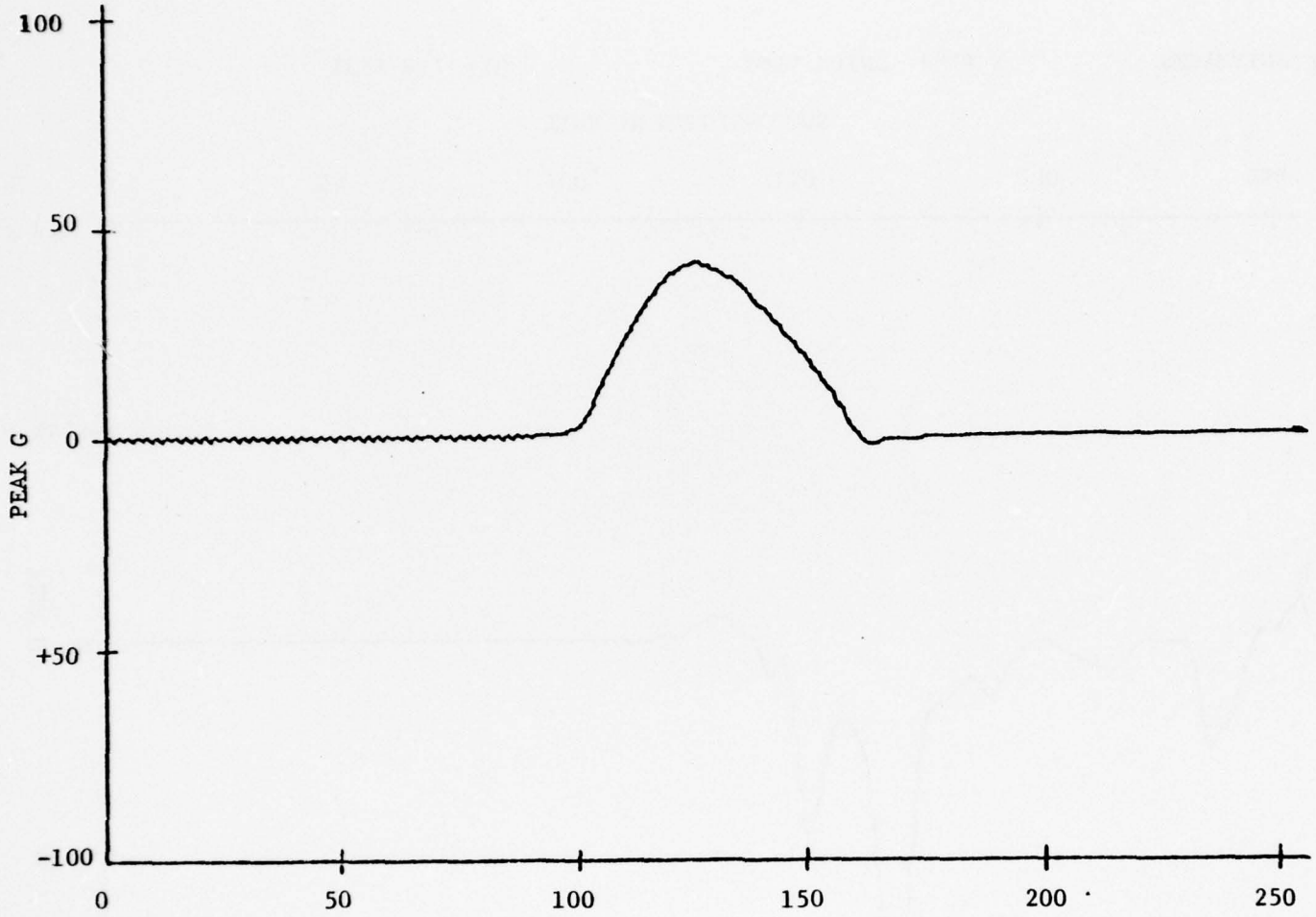

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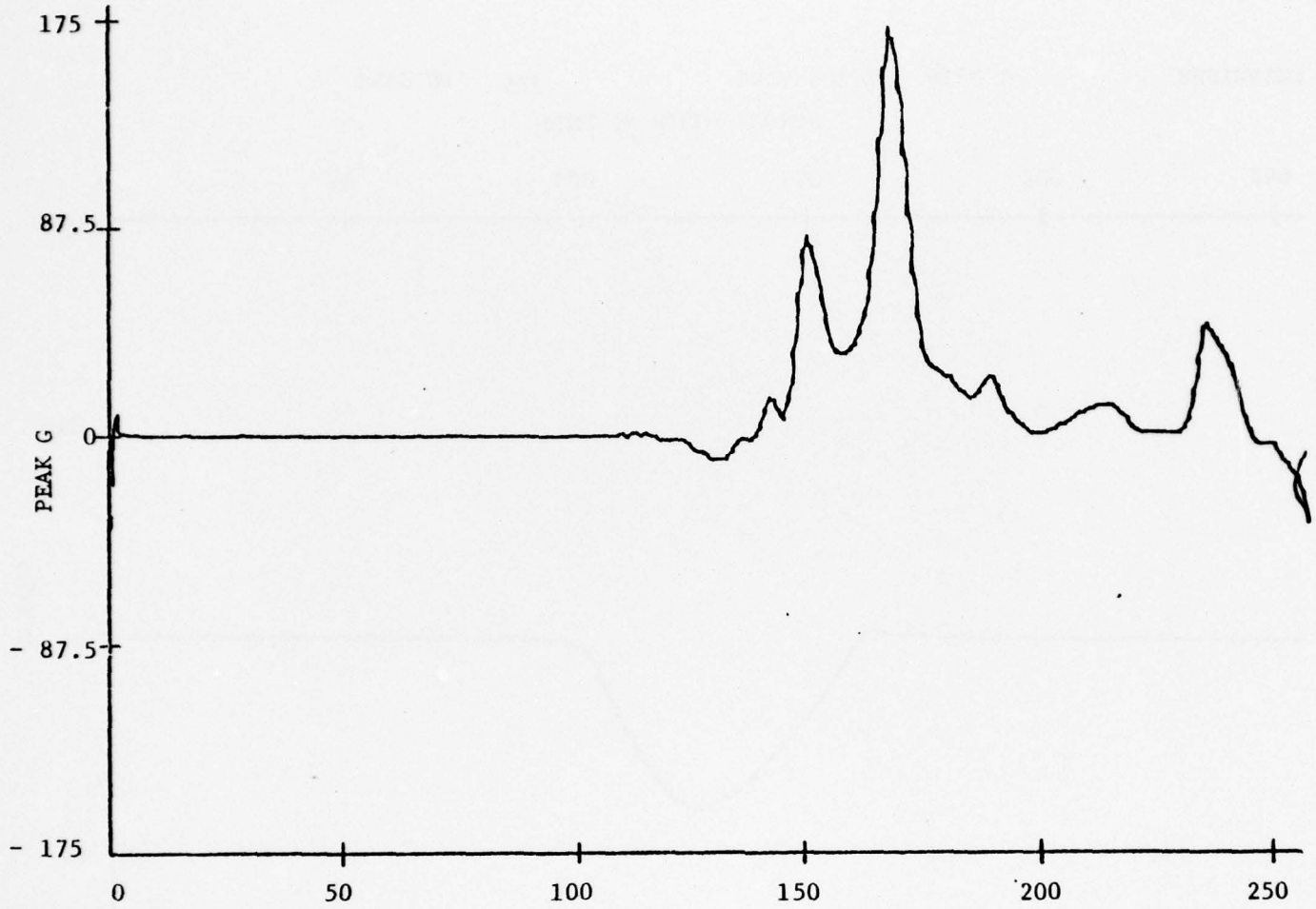
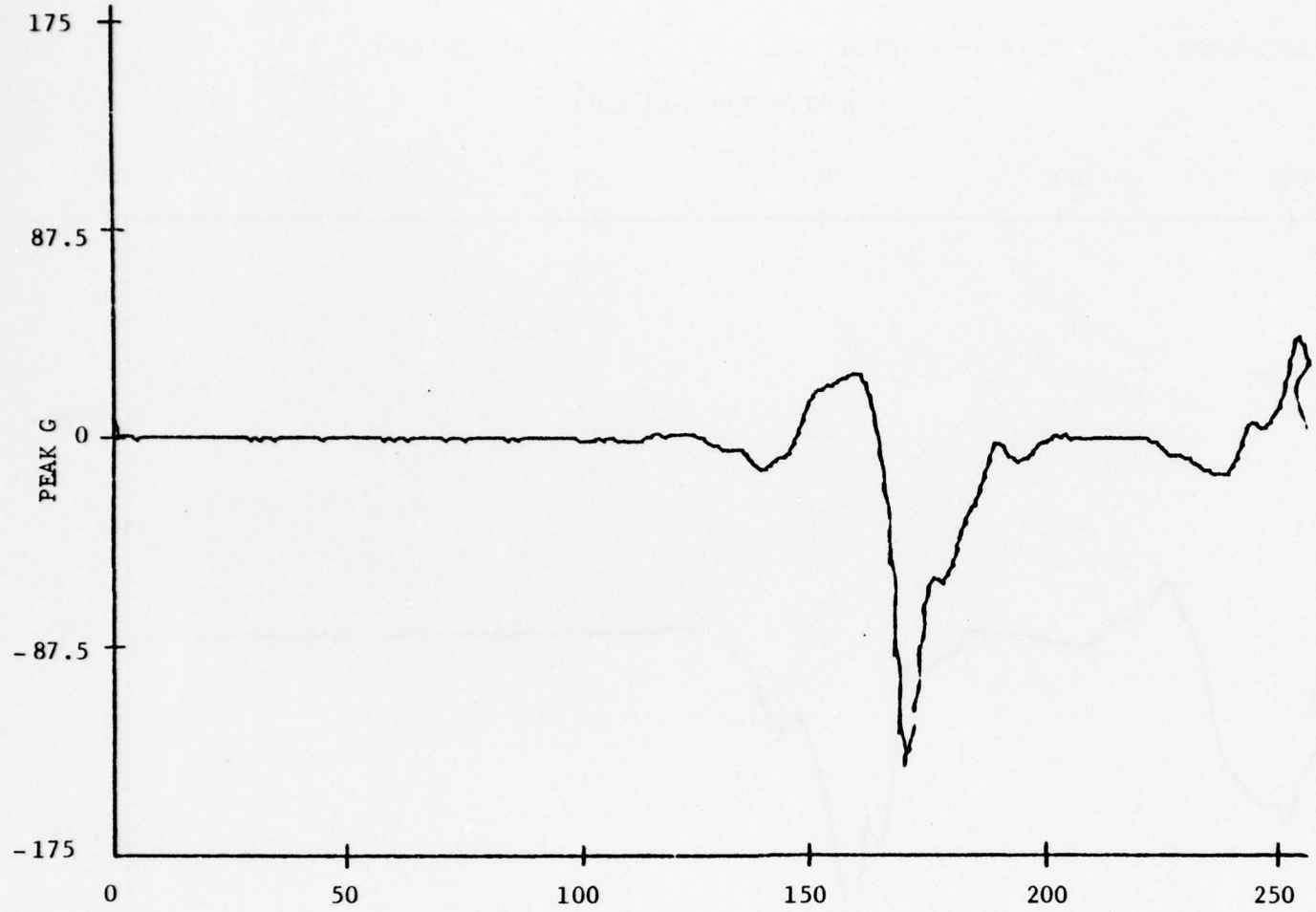
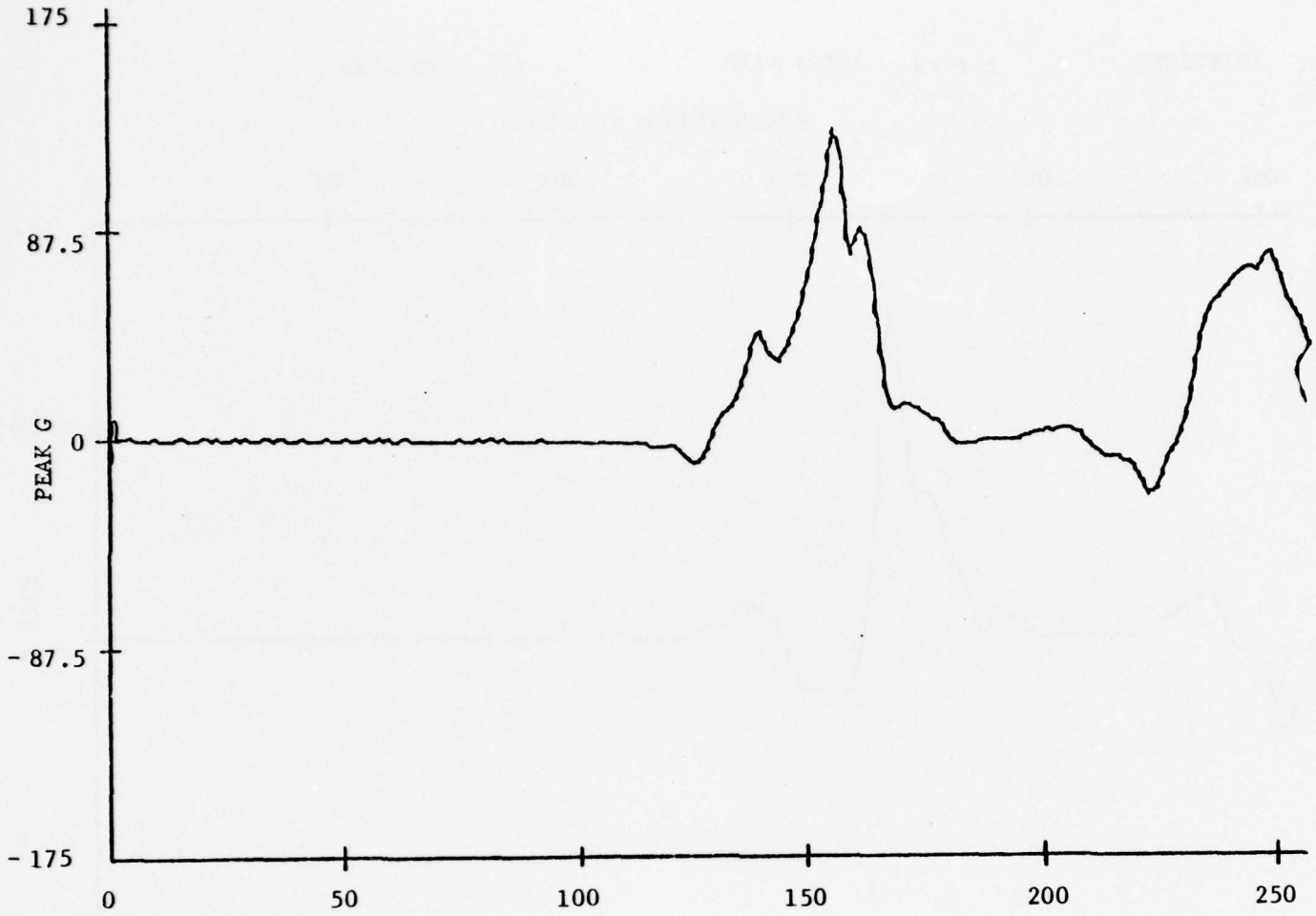


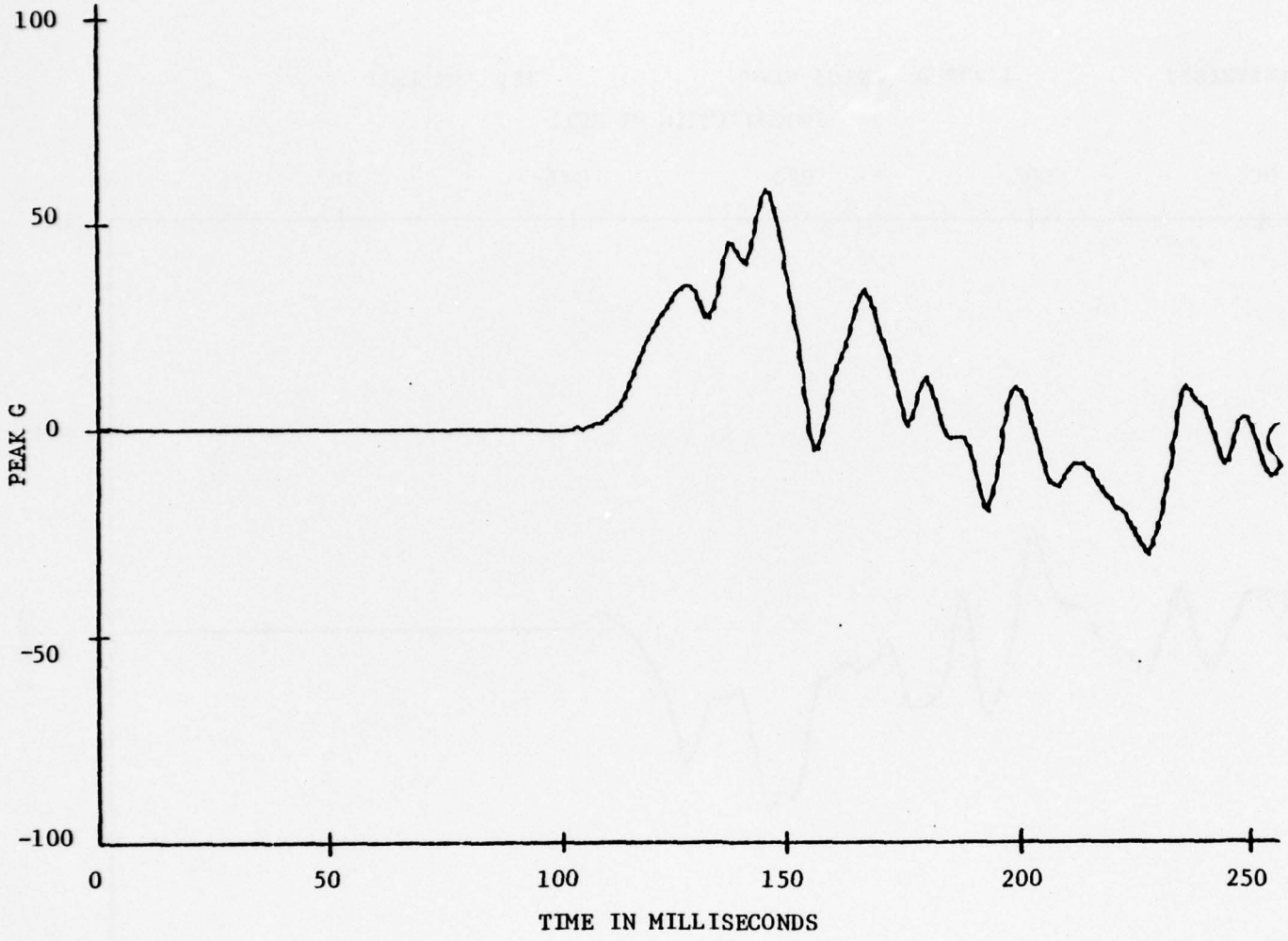
TEST NO. 421 DATA POINT Head X RESTRAINT Takata "A"



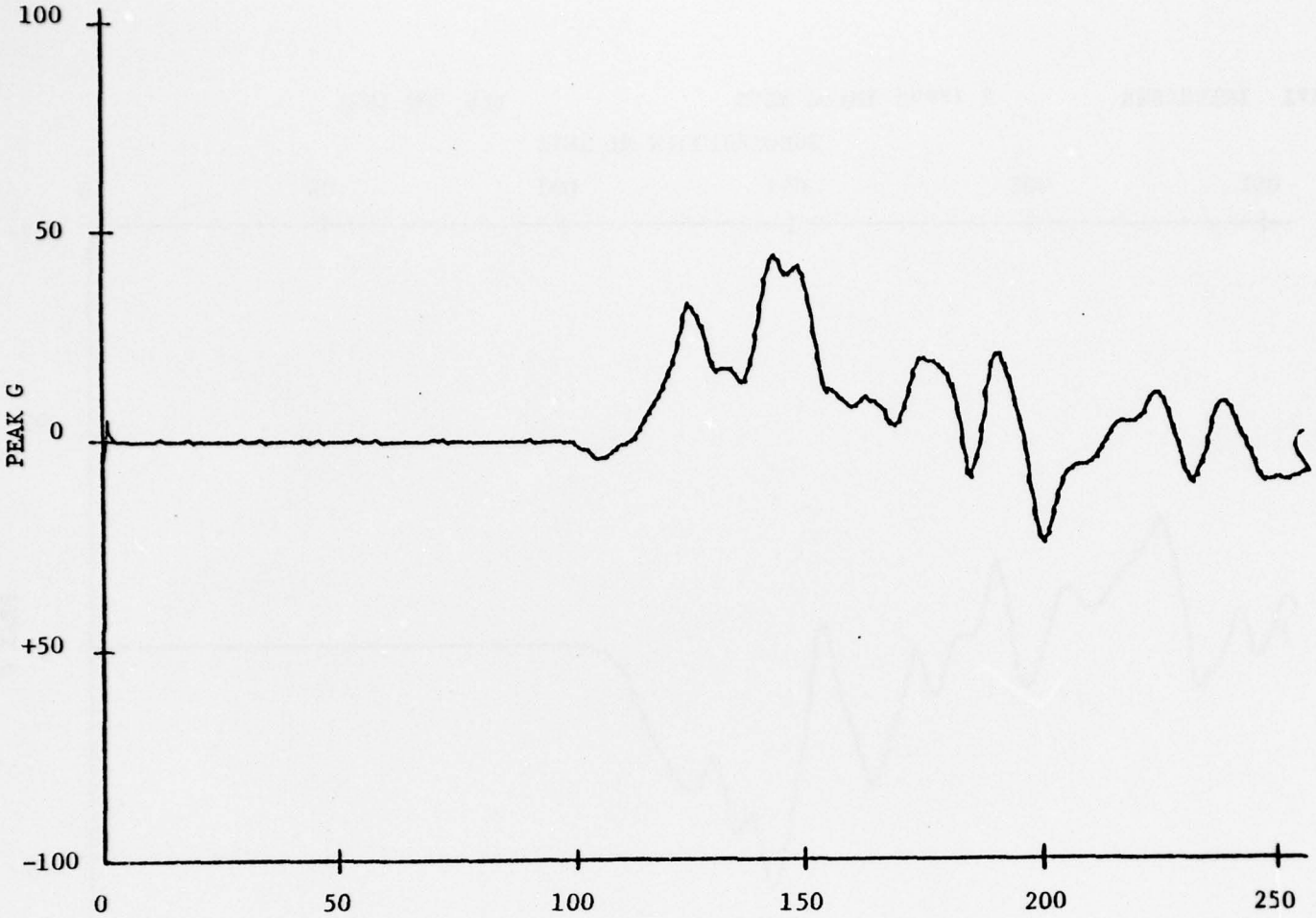
TEST NO. 421 DATA POINT Head Y RESTRAINT Takata "A"



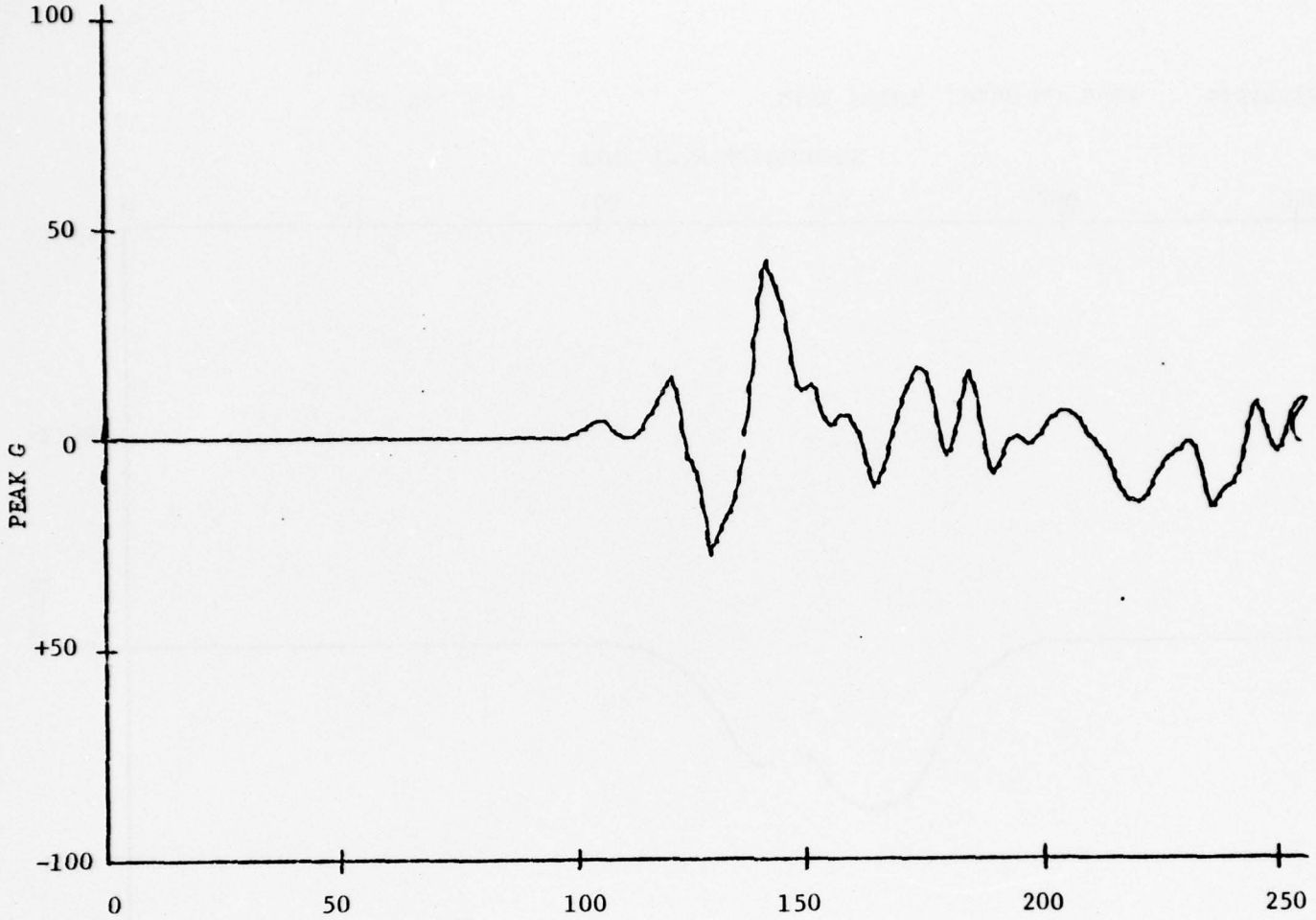
TEST NO. 421 DATA POINT Head Z RESTRAINT Takata "A"



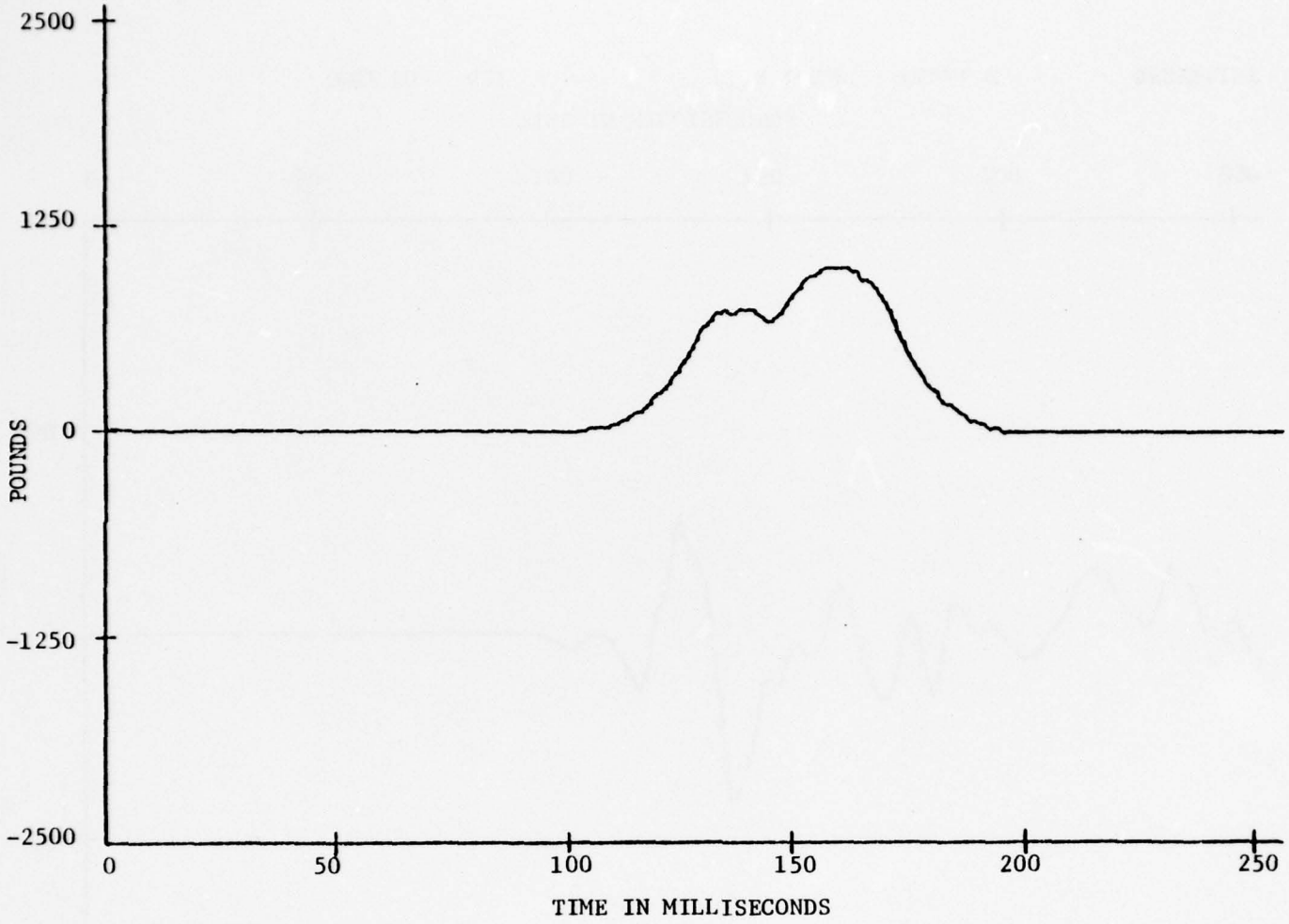
TEST NO. 421 DATA POINT Chest X RESTRAINT Takata "A"



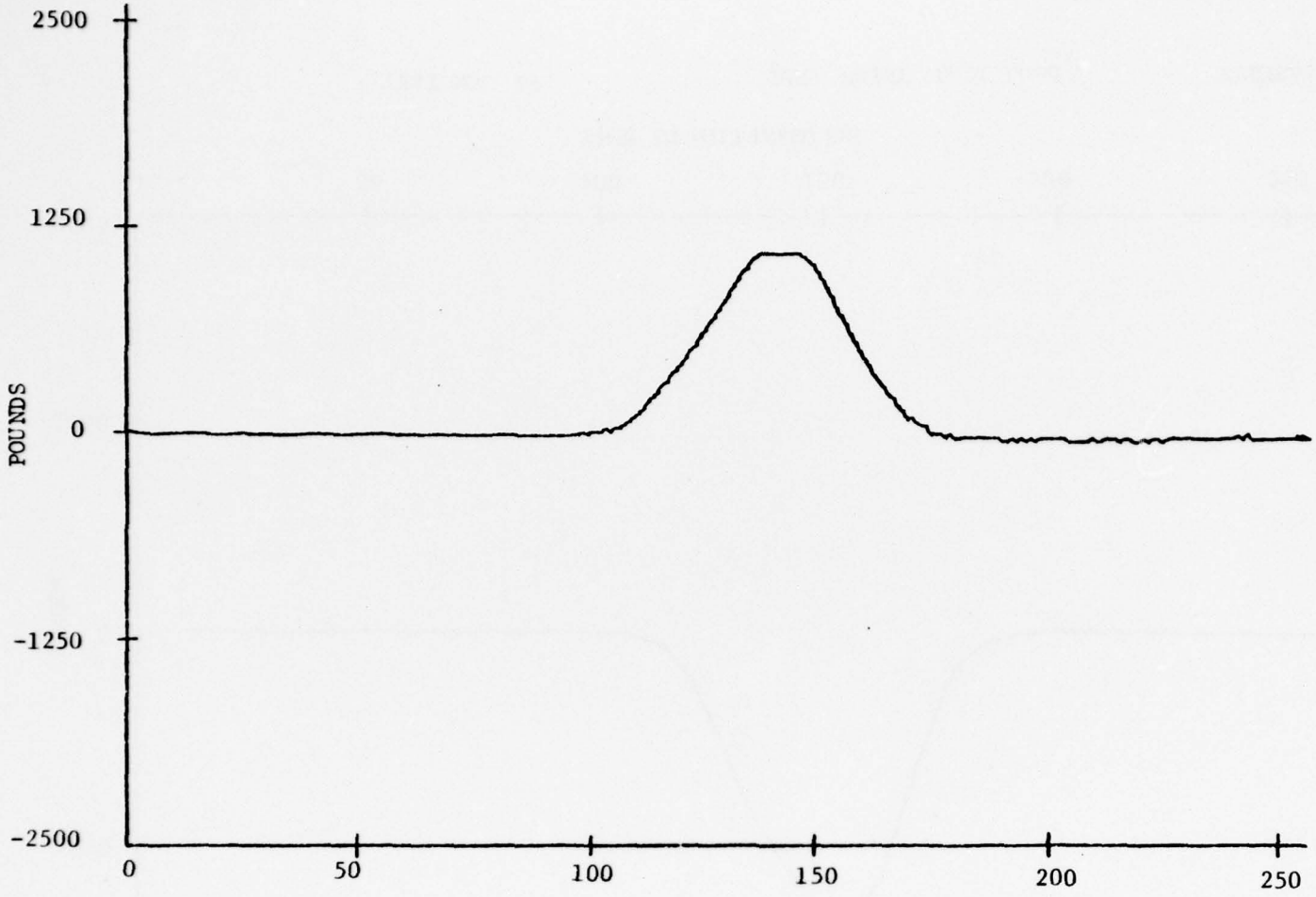
TEST NO. 421 DATA POINT Chest Y RESTRAINT Takata "A"



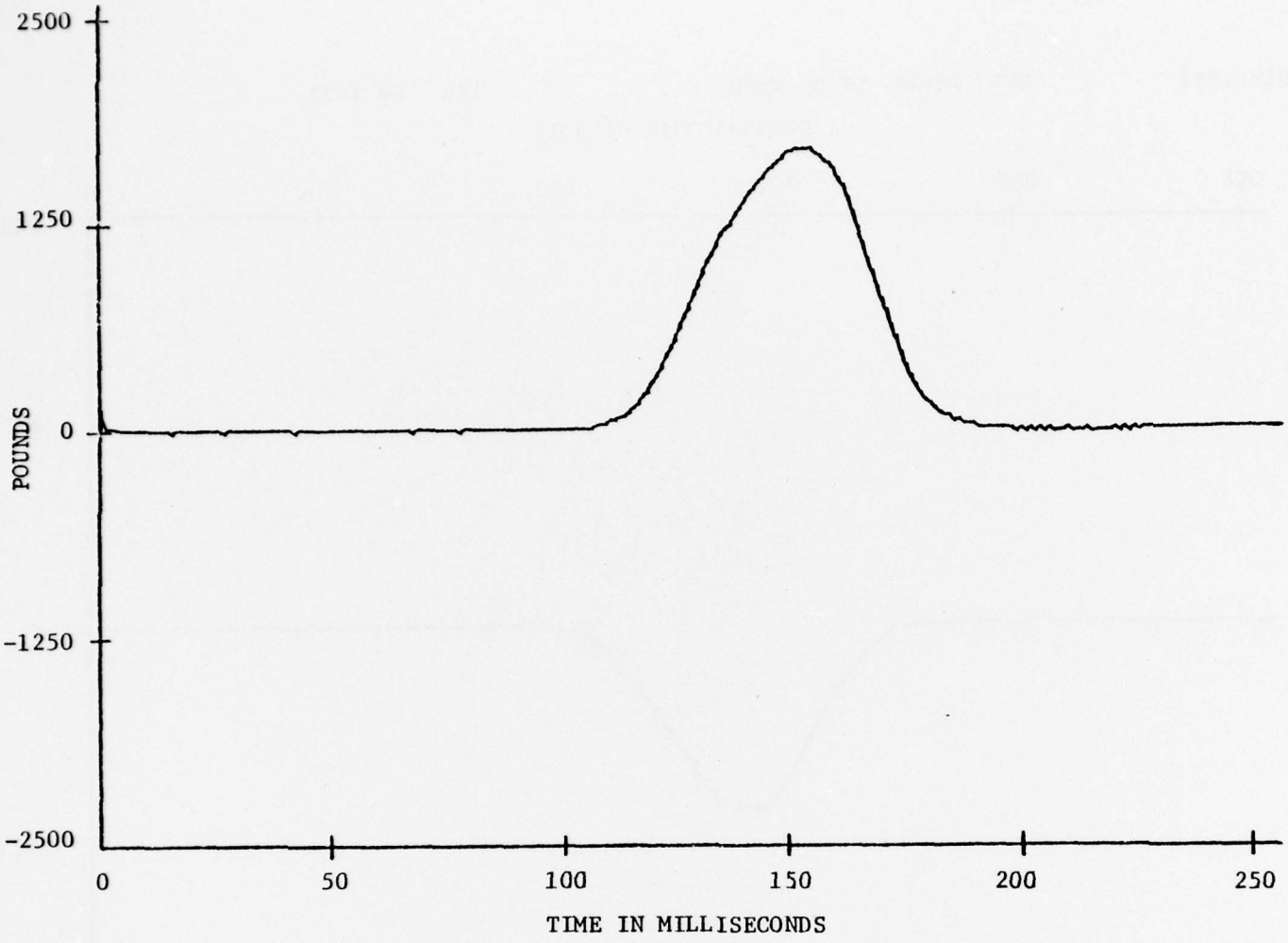
TEST NO. 421 DATA POINT Chest Z RESTRAINT Takata "A"



TEST NO. 421 DATA POINT Shoulder Load RESTRAINT Takata "A"



TEST NO. 421 DATA POINT Right Load RESTRAINT Takata "A"



TEST NO. 421 DATA POINT Left Load RESTRAINT Takata "A"