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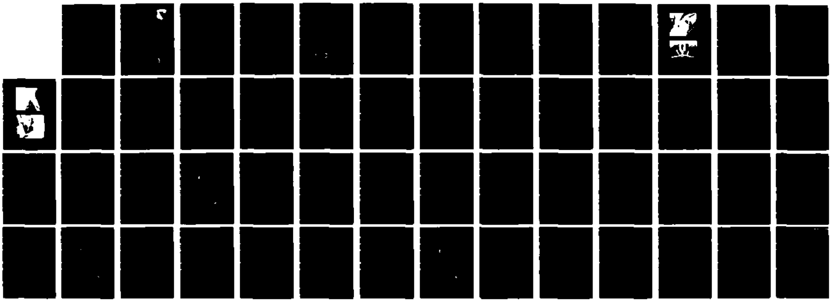

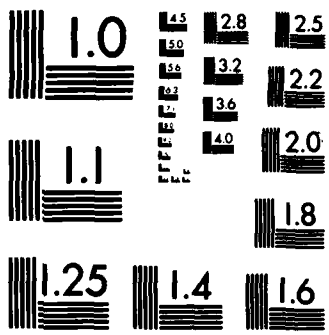

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AFAMRL-TR-84-053

AD-A148 021

IMPACT TESTS OF ADJUSTERS FOR THE HBU-12 LAP BELT

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AUGUST 1984

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AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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NOTICES

TECHNICAL REVIEW AND APPROVAL

AFAMRL-TR-84-053

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

HENNING E. VON GIERKE, Dr Ing
Director
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Air Force Aerospace Medical Research Laboratory

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PREFACE

This report was prepared by the Biomechanical Protection Branch, Biodynamics and Bioengineering Division of the Air Force Aerospace Medical Research Laboratory. The tests described herein were conducted in response to a request from San Antonio Air Logistics Center under whose auspices the tests were accomplished. Mr Darryl Powers (SA-ALC/MMIRCC) was the program manager for the San Antonio Air Logistics Center.

The impact facilities, data acquisition equipment, and data processing system were operated by the Scientific Services Division of the Dynalectron Corporation under Air Force Contract F33615-70-C-0523. Photographic data and documentation services were provided by the Technical Photographic Division of the 4950th Test Wing.

The authors are grateful to the many personnel of the Biomechanical Protection Branch who participated in the planning, accomplishment, and documentation of this test and evaluation effort.

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SECTION 1

INTRODUCTION

A. BACKGROUND

Impact tests conducted during the HBU-X Automatic Lap Belt Acquisition Program disclosed numerous structural and functional deficiencies in off-the-shelf restraint hardware as well as the hardware developed for the program (Brinkley and Schimmel, 1982). These tests and subsequent tests also conducted by the Air Force Aerospace Medical Research Laboratory (Brinkley and Schimmel, 1984) provided the technology base necessary to select lap belt hardware that would function under high acceleration conditions representative of those expected during aircraft crash or high-speed emergency escape. The resulting lap belt configuration has been designated the HBU-12 automatic lap belt.

The impact tests performed during the HBU-X Automatic Lap Belt Acquisition also served to provide to restraint system hardware manufacturers information that could be useful in redesigning restraint hardware. H. Koch and Sons modified the lap belt adjuster that they had manufactured for the HBU-X program based on the test results. The modification was intended to prevent the slippage of the lap belt webbing that had been previously observed.

In order to verify the adequacy of the modification and thereby increase the availability of an alternative source of belt adjuster for the HBU-12 lap belt, the San Antonio Air Logistics Center requested that impact tests be conducted using the adjuster manufactured by H. Koch and Sons. This report describes the results of the tests that were conducted for the San Antonio Air Logistics Center.

B. TEST OBJECTIVES

The primary objective of the tests was to demonstrate the adequacy of Koch webbing adjusters under high-energy impact conditions. The secondary objective of the test program was to evaluate the benefits of using an automotive crash test dummy for USAF restraint system tests.

C. EVALUATION CRITERIA

The adequacy of the adjusters was evaluated on the basis of the following factors:

a. Ability to carry test loads without structural failure.

b. Capacity to limit slippage of lap belt webbing to no more than one-half inch through either belt adjuster.

SECTION 2

TEST METHODS

A. APPROACH

The tests were performed in accordance with the HBU-12 Lap Belt Adjuster test plan, dated 8 December 1982. The planned acceleration level was 40 G with an impact velocity of 80 ft/sec and a time to peak G of 30 msec. The adjusters were incorporated into an HBU-12 lap belt and tested as part of a restraint harness configuration consisting of two shoulder straps, the lap belt, and a crotch strap. The harness was used to restrain a 95th percentile male-sized dummy to a test seat that simulated the dimensions of a typical ejection seat designed to meet USAF specification MIL-S-9479B.

B. IMPACT FACILITY

The impact conditions were produced using the AFAMRL Horizontal Decelerator Facility. This impact test facility consists of a low-G launch system, a two-rail track, a sled, and a hydraulic decelerator. The launch system is used to accelerate the sled along the track toward the decelerator. The length of the launch phase is approximately 75 ft. After the sled is accelerated, it glides on the track for approximately 135 ft until a five-foot-long piston attached to the front of the sled enters the hydraulic decelerator. The decelerator consists of a water-filled cylinder. As the sled piston enters the cylinder it forces the water through orifices encircling the sides of the cylinder. The arrangement and diameters of the orifices installed in the cylinder walls determine the acceleration-time profile for any given set of impact velocity and sled mass. The sled velocity is measured throughout the launch and glide phases and may be adjusted during the glide phase by a computer-controlled brake mounted on the sled.

During this test program the peak acceleration ranged from 41.8 to 43.7 G. The impact velocity was 84.9 to 86.7 ft/sec and the acceleration pulse duration ranged from 0.12 to 0.15 sec.

C. ELECTRONIC INSTRUMENTATION

The electronic data collected during the test program included triaxial translational acceleration of the sled, sled velocity, triaxial loads measured at the tie-down points of the lap belt, shoulder harness, and the load measured at the tie-down point of the crotch strap. Detailed descriptions of the transducers, their mounting positions, and calibrations are provided in Appendix A. Fourteen channels of data were recorded using the Automatic Data Acquisition and Control System (ADACS) also described in Appendix A. The ADACS equipment mounted on the sled amplified, provided anti-aliasing filtering, and encoded signals from the acceleration, load, and velocity measuring transducers used in the test program. The data were transmitted in digital format (pulse code modulated) by cable to a word formatter at the central data collection and processing area of the ADACS.

The data were then reformatted from serial to parallel form and transmitted to a DEC PDP-11/34 computer for recording and analysis.

D. PHOTOGRAMMETRIC DATA COLLECTION

Motion pictures were recorded on the sled using two 16-mm high-speed cameras (Photosonics Model 16mm-1B). These cameras were operated at 500 frames per second. One camera was mounted to provide a side view of the seat and dummy and the second camera provided an oblique view. A third motion picture camera (Teledyne Millikin Model DBM45) was mounted at the side of the track to provide overall documentation of the test. The cameras were started at a preset time in the test sequence and were synchronized with the electronic data by a pulse code and an electronic flash.

A video camera was used to allow the investigators to evaluate the overall impact response of the dummy and the restraint system immediately after each test. The video camera and a magnetic tape video recorder used with it recorded images at a rate of 120 frames per second with an effective shutter speed of 10 microseconds or less.

E. ANTHROPOMORPHIC DUMMIES

Two test dummies were used in this program. The first dummy that was used was a VIP-95 model manufactured by Alderson Research Laboratories, Inc. Use of this type of dummy was discontinued after its failure. The VIP-95 dummy is designed for automotive crash tests. The second dummy was a C-95 dummy also manufactured by Alderson Research Laboratories, Inc. The C-95 dummy is designed for ejection seat tests. The torso of the C-95 dummy is not articulated and the joints of the extremities are simple pin-and-clevis mechanisms. Prior to each test, the dummy's joints were adjusted to a one-G torque value in accordance with Federal Motor Vehicle Safety Standard No. 208 (U.S. Department of Transportation, 1972). Each dummy weighed 210 lbs and represented the 95th percentile adult male flying personnel in general body size.

F. TEST ARTICLES, TEST PREPARATIONS AND PROCEDURES

The lap belt adjuster tested, P/N 015-12231-5, manufactured by H. Koch and Sons, is shown in Figure 1. The lap belt adjusters were tested as part of a restraint harness consisting of a lap belt, two shoulder straps, and a crotch strap. The lap belt was constructed of two lap belt adjusters, 1 3/4-inch wide Type XIII nylon (MIL-W-4088), a non-opening dummy lap belt buckle, and two lap belt anchor fittings (P/N 549035-10) as shown in Figure 2. The shoulder harness was an MB-6 double shoulder harness (MIL-H-5364D) constructed of 1 3/4-inch wide Type I polyester webbing (MIL-W-25361C). The crotch straps were fabricated using 1 3/4-inch wide Type I polyester (MIL-W-25361C). The lap belt, shoulder harness, and crotch strap attachment locations are contained within Appendix A.

Prior to each test the lap belt and shoulder harness were pretensioned to create a force of ± 10 pounds measured at each of the restraint load cells. The

Figure 1. Koch Adjuster.

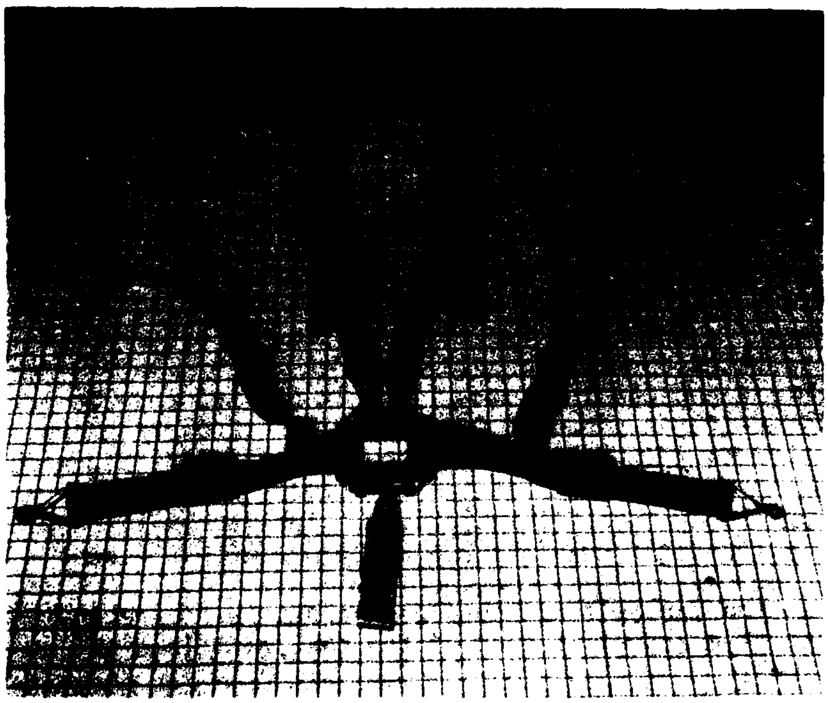


Figure 2. Restraint Harness Configuration.

configuration of the test fixture, harness attachment points, and the symmetry of the restraint harness were identical for all tests. After all adjustments to the lap belt and shoulder harness were completed, each lap belt and shoulder harness was marked at the adjuster to allow measurement of belt slippage. After each test the belts were removed from the test fixture and any belt slippage was measured.

G. DATA PROCESSING

Data from each test were reduced in a standardized format. Reduced electronic data are available for review within Appendix B. Computer summaries provide relevant maxima and minima from a total of 14 recorded signals. Relevant sums and times were also computed. The sums of the measured forces are the maximum values of continuously summed measurements. Scaled plots of selected signals and computer resultants were produced. Time integrals of sled acceleration signals were compared with velocity determined from displacement measurements.

SECTION 3

FINDINGS

A. TEST-BY-TEST NARRATIVES

Test 1441 - The maximum sled deceleration was 43.3 G, the sled velocity at impact was 86.7 ft/sec, and the duration of the deceleration pulse was 158 milliseconds. There was no measurable lap belt slippage through the adjusters. The shoulder harness attachment link (P/N 6384009) failed as shown in Figure 3. The VIP-95 dummy incurred extensive damage. Both left and right shoulder clavicle castings broke, and the outer covering of the upper torso, lower arms, and head was torn as shown in Figure 4. Subsequent tests were accomplished using the C-95 dummy.

Test 1442 - The maximum sled deceleration was 43.7 G, the sled velocity at impact was 86.7 ft/sec, and the duration of the deceleration pulse was 126 milliseconds. The right-hand lap belt adjuster slipped 1/8 inch. The left-hand lap belt adjuster slipped 3/16 inch. Neither lap belt adjuster would release until all lap belt tension was removed.

Test 1444 - The maximum sled deceleration was 41.8 G, the sled velocity at impact was 84.9 ft/sec, and the duration of the deceleration pulse was 125 milliseconds. The right-hand lap belt slipped 3/8 inch. The left-hand lap belt slipped 1/8 inch. Neither lap belt adjuster would release until all lap belt tension was removed.

Test 1445 - The maximum sled deceleration was 42.5 G, the sled velocity at impact was 85.1 ft/sec, and the duration of the deceleration pulse was 138 milliseconds. The right-hand lap belt slipped 1/8 inch. The left-hand lap belt slipped 1/4 inch. Neither lap belt adjuster would release until all lap belt tension was removed.

B. SUMMARY OF DATA

The test data collected from each test are summarized in tables 1 through 4. These tables provide sled deceleration maximums, sled impact velocity, the maximum restraint strap loads in three axes, the maximum magnitude of the resultant restraint strap load impact vectors, and the maximum crotch strap loads.

Figures 2 through 4 contain graphs of the data collected from each of the above-mentioned channels for Test 1441. The data from tests 1442, 1444, and 1445 are provided in Appendix B.

Figure 3. Shoulder Harness Clevis Breakage.

Figure 4. VIP - 95 Dummy Damage.

Table 1. Summary of the Electronically Measured and Computed Data from Test 1441.

Maximum Sled Deceleration (G)	
X Axis	-43.28
Y Axis	- 3.24
Z Axis	- 1.74
Sled Velocity at Impact (ft/sec)	
	86.7
Maximum Shoulder Harness Load (lbs)	
X Axis	4159
Y Axis	126
Z Axis	201
Resultant	4160
Maximum Left Lap Belt Load (lbs)	
X Axis	4369
Y Axis	781
Z Axis	2910
Resultant	5307
Maximum Right Lap Belt Load (lbs)	
X Axis	4180
Y Axis	785
Z Axis	2900
Resultant	5148
Maximum Crotch Strap Load (lbs)	
	1274

Table 2. Summary of the Electronically Measured and Computed Data from Test 1442.

Maximum Sled Deceleration (G)	
X Axis	-43.65
Y Axis	- 1.51
Z Axis	- 0.56
Sled Velocity at Impact (ft/sec)	
	86.7
Maximum Shoulder Harness Load (lbs)	
X Axis	4490
Y Axis	116
Z Axis	80
Resultant	4490
Maximum Left Lap Belt Load (lbs)	
X Axis	5047
Y Axis	1728
Z Axis	3816
Resultant	6552
Maximum Right Lap Belt Load (lbs)	
X Axis	4637
Y Axis	1850
Z Axis	3938
Resultant	6352
Maximum Crotch Strap Load (lbs)	
	1280

Table 3. Summary of the Electronically Measured and Computed Data from Test 1444.

Maximum Sled Deceleration (G)	
X Axis	-41.81
Y Axis	- 3.05
Z Axis	- 1.66
Sled Velocity at Impact (ft/sec)	
	84.9
Maximum Shoulder Harness Load (lbs)	
X Axis	4089
Y Axis	141
Z Axis	65
Resultant	4090
Maximum Left Lap Belt Load (lbs)	
X Axis	4670
Y Axis	1886
Z Axis	3968
Resultant	6559
Maximum Right Lap Belt Load (lbs)	
X Axis	4631
Y Axis	1959
Z Axis	3958
Resultant	6399
Maximum Crotch Strap Load (lbs)	
	177

Table 4. Summary of the Electronically Measured and Computed Data from Test 1445.

Maximum Sled Deceleration (G)	
X Axis	-42.53
Y Axis	- 2.07
Z Axis	- 1.36
Sled Velocity at Impact (ft/sec)	
	85.1
Maximum Shoulder Harness Load (lbs)	
X Axis	4193
Y Axis	139
Z Axis	56
Resultant	4195
Maximum Left Lap Belt Load (lbs)	
X Axis	5097
Y Axis	1822
Z Axis	4015
Resultant	6739
Maximum Right Lap Belt Load (lbs)	
X Axis	4603
Y Axis	1902
Z Axis	3788
Resultant	6257
Maximum Crotch Strap Load (lbs)	
	440

Table 5. Summary of Test Results

Test No.	Planned G Level	Measured G Level	Test Results	Remarks
1441	40	43.3	Inadequate test	Shoulder harness clevis broke
1442	40	43.7	Success	
1444	40	41.8	Success	
1445	40	42.5	Success	

C. CONCLUSIONS

On the basis of the data collected during the four impact tests, it is concluded that the modified lap belt adjusters manufactured by H. Koch and Sons functioned satisfactorily when subjected to 40 G test conditions.

The benefits of using an automotive test dummy could not be evaluated. The test dummy failed in the first test due to loads incurred subsequent to failure of the attaching link of the MB-6 shoulder harness.

The MB-6 shoulder harness attachment link (P/N 6384009) failed at a load of 4160 lbs. The link has failed on previous 40 G impact tests (Brinkley and Schimmel, 1984), but the failure has occurred at higher load levels. Redesign of the attachment link is recommended.

APPENDIX A

DATA ACQUISITION EQUIPMENT AND METHODS

INSTRUMENTATION

Data collected during the HBU-12 lap belt adjuster program consisted of impact sled acceleration, velocity and restraint harness loads. Sled acceleration was measured using three miniature piezoresistive accelerometers mounted to the sled structure. Loads in the restraint systems were measure by load cells mounted to the restraint harness attachment fittings. The measurement transducers used in the test program are listed in Table A-I and Table A-II. These tables designate the manufacturer, type, serial number, sensitivity and other specifications on each transducer utilized. The instrumentation coordinate system and the locations of the load cells in the x, y, and z axis are shown in Figure A-1.

Three accelerometers were positioned to measure the acceleration of the sled in the x, y, and z axis. The package consisted of two Endevco Model 2264 and one Endevco Model 2262 accelerometers mounted to a 3/4 x 1 x 1 inch aluminum block which was mounted to the under surface of the sled.

Pre-program and post-program calibrations were made to check the accuracy of the data-measuring transducers. The calibration of the accelerometers was performed by the Dynalectron Corporation using the reciprocity method (Ensor, 1970). A laboratory standard accelerometer, calibrated on a yearly basis by Endevco with standards traceable to the National Bureau of Standards, and a test accelerometer were mounted on a shake table. The frequency response and phase shift of the test accelerometer were determined by driving the shake table with a random noise generator and analyzing the outputs of the accelerometers with a PDP 11/15 minicomputer and 1923 Time Data Unit using Fourier analysis. The natural frequency and damping factor of the test accelerometers were determined, recorded, and compared to previous calibration data for that test accelerometer.

Calibrations were made at a frequency of 100 Hz and acceleration of 40 G. The sensitivity of the test accelerometer was determined by comparing its output to the output of the laboratory standard accelerometer.

The negative G strap was attached to a Strainsert load cell. The calibration of the Strainsert load cell was performed by the Precision Measurement Equipment Laboratory (PMEL), Wright-Patterson Air Force Base. PMEL calibrated this load cell on a periodic basis and provided current sensitivity and linearity data.

Three triaxial GM load cells were used to measure the shoulder strap load and the right and left lap belt loads. These load cells were calibrated to a laboratory standard load cell in a special test fixture by the Dynalectron Corporation. The sensitivity and linearity of each load cell were obtained by comparing the output of the test load cell to the output of the laboratory

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM: HBU-12 LAP BELT ADJUSTER   DATE: 7DEC82   THRU: 13DEC82

FACILITY: HORIZONTAL DECELERATOR   RUN: 1428   THRU: 1445

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	FILTER S/N	AMP GAIN	AMP S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
1	SLED X	ENDEVCO 2262-200	FR42	4.136 mv/g	10.00	1	60	1	10	28	1K	1	60.4g	120	2.5	+5.0 -0.0	375K -IN TO GND	-	
2	SLED Y	ENDEVCO 2264-200	BX49	2.595 mv/g	10.00	2	60	2	50	21	1K	1	19.27g	120	2.5	+5.0 -0.0	82K IN TO GND	1.47K	
3	SLED Z	ENDEVCO 2264-150	BB11	2.364 mv/g	10.00	3	60	3	50	16	1K	1	21.15g	120	2.5	+5.0 -0.0	43K IN TO GND	1.58K	
15	LEFT LAP LOAD X	GM 3D-SW	15X	5.03 uv/LB	10.00	15	60	15	100	22	1K	1	4970LB	120	2.5	+5.0 -0.0	15K IN TO GND	-	
16	LEFT LAP LOAD Y	"	15Y	5.30 uv/LB	10.00	16	60	16	201	4	1K	1	2347LB	120	2.5	+5.0 -0.0	16K IN TO GND	-	
17	LEFT LAP LOAD Z	"	15Z	6.14 uv/LB	10.00	17	60	17	100	16	1K	1	4072LB	120	2.5	+5.0 -0.0	28K IN TO GND	-	
18	RIGHT LAP LOAD X	"	21X	4.90 uv/LB	10.00	18	60	18	100	19	1K	1	5102LB	120	2.5	+5.0 -0.0	13.5K IN TO GND	-	
19	RIGHT LAP LOAD Y	"	21Y	4.83 uv/LB	10.00	19	60	19	201	15	1K	1	2575LB	120	2.5	+5.0 -0.0	6.8K IN TO GND	-	
20	RIGHT LAP LOAD Z	"	21Z	6.05 uv/LB	10.00	20	60	20	100	25	1K	1	4132LB	120	2.5	+5.0 -0.0	90K IN TO GND	-	
21	SHOULDER LOAD Z	"	20X	5.55 uv/LB	10.00	21	60	21	201	14	1K	1	2241LB	120	2.5	+5.0 -0.0	30K IN TO GND	-	USE LOAD CELL X AXIS CAL.
22	SHOULDER LOAD Y	"	20Y	5.76 uv/LB	10.00	22	60	22	402	3	1K	1	1080LB	120	2.5	+5.0 -0.0	800K IN TO GND	-	
23	SHOULDER LOAD X	"	20Z	6.21 uv/LB	10.00	23	60	23	100	5	1K	1	4026LB	120	*1.9	+5.0 -0.0	48K IN TO GND	-	* TEST 1442 AND SUBSEQUENT BIAS CHANGED FROM 2.5V to 1.9V. TO PROVIDE APPROX. 5000 LB F.S.
29	VELOCITY	GLOBE 22A672	2	.2664V/FPS 10.25" WHEEL	-	29	30	1	1	-	1K	1	117.2	60	0	+5.0 -0.0	-	-	SIGNAL ATTENUATED BY 6.242 PRIOR TO SIG. COND. AMP. INPUT - SENS.=.2664VFPS/6.242 =.04268 VOLT FPS
30	N-G STRAP	STRAIN-SERT FL1U-2SG	207	19.81 uv/LB	10.00	30	60	30	50	28	1K	1	2524LB	120	2.5	+5.0 -0.0	-	-	TEST 1428-1443 AMP GAIN @100,F.S. = 1262LB.

PAGE 1 OF 2

Table A-I. Instrumentation Transducers and Channel Specifications.

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM HBU-12 LAP BELT ADJUSTER DATE 7DEC82 THRU 13DEC82

FACILITY HORIZONTAL DECELERATOR RUN 1428 THRU 1445

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	FILTER S/N	AMP GAIN	AMP S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
37	REFERENCE EVENT	-	-	-	-	37	1000	30	2.5	9	1K	1	2.5VOLTS	2000	5.0	+5.0 -0.0	-	-	
31	T1	-	-	-	-	31	1000	3	1	-	1K	1	5.0VOLTS	2000	2.5	+5.0 -0.0	-	-	
45	5 VOLT EXC.	-	-	-	-	45	180	28	1	-	1K	1	2.5VOLT	360	2.5	+5.0 -0.0	-	-	ATTENUATED BY 2
46	10 VOLT EXC.	-	-	-	-	46	180	27	1	-	1K	1	2.5VOLT	360	2.5	+5.0 -0.0	-	-	ATTENUATED BY 4
47	2.5 VOLT BIAS	-	-	-	-	47	180	14	1	-	1K	1	2.5VOLT	360	2.5	+5.0 -0.0	-	-	

PAGE 2 OF 2

Table A-II. Instrumentation Specifications

HBU-12	Point No.	Axis X Inches (Centimeters)	Axis Y Inches (Centimeters)	Axis Z Inches (Centimeters)
Center Reference	1	0	0	0
Load Cell	2	+15.00 (+38.1)	0	-3.00 (-7.62)
Triaxial Load Cell	3	0	+9.00 (+22.86)	-1.77 (-4.50)
Triaxial Load Cell	4	0	-9.00 (-22.86)	-1.77 (-4.50)
Triaxial Load Cell	5	-11.83 (-30.00)	0	+26.78 (+68.00)

<u>LOAD CELL 2</u> PROVIDES A POSITIVE (+) OUTPUT VOLTAGE WHEN THE N-G STRAP IS PULLED IN THE +Z DIRECTION.

<u>TRIAXIAL LOAD CELL 5</u> PROVIDES A POSITIVE (+) OUTPUT VOLTAGE FOR X, Y AND Z WHEN THE HARNESS IS PULLED IN THE +X, -Y AND -Z DIRECTIONS RESPECTIVELY.

<u>TRIAXIAL LOAD CELLS 3, 4</u> PROVIDE A POSITIVE (+) OUTPUT VOLTAGE WHEN THE HARNESS IS PULLED TOWARDS THE CENTER REFERENCE.

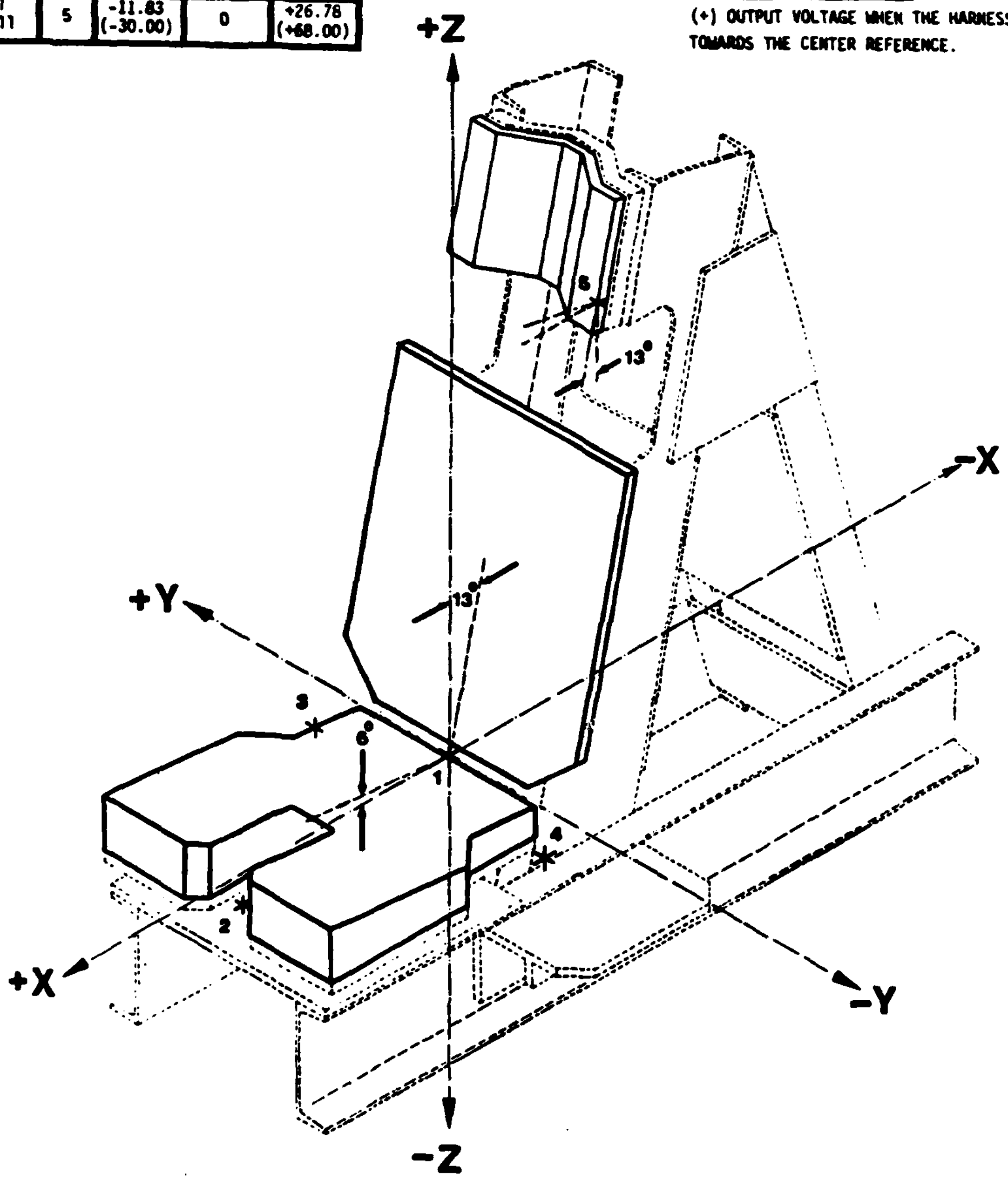


Figure A-1. Test Seat and Instrumentation Coordinate System.

standard under identical loading conditions. The laboratory standard load cell, in turn, is calibrated by PMEL on a periodic basis.

A Globe Industries tachometer, mounted in a special fixture, was used to measure sled velocity. The fixture consisted of an aluminum wheel, with a rubber O ring around its circumference to assure good rail contact, that was attached to the rotor of the tachometer. The tachometer was calibrated by rotating the wheel at various revolutions per minute (RPMs) and recording both the output voltage and the RPM. The sensitivity was dynamically checked out with a VS 300 velocity measuring system manufactured by GHI Systems, Rancho Palos Verdes, California. The VS 300 system consists of a timing unit and an optical sensor mounted near the track rails. As the sled travels along the track rails, a metal blade on the sled interrupts the optical sensor beam. The timing unit displays a time which may be correlated to a velocity.

AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM (ADACS)

The Automatic Data Acquisition and Control System (ADACS) is composed of 48 separate data channels and was designed by the Physical Science Laboratory of the University of New Mexico. The ADACS provides excitation, amplifier gains and filtering in addition to digitizing the analog signal from the transducers. This system, which is rigidly mounted to the sled, can transfer the digitized electronic data via a seven-wire whip cable to the digital computer interface.

The seat-mounted portion of the ADACS consists of three major components: the power conditioner, the signal conditioner, and the encoder. This configuration of the ADACS is outlined in Figure A-2. The power conditioner receives 28 VDC via the whip cable and provides six regulated voltages. The signal conditioner contains 48 modules capable of processing transducer data. Each module has an amplifier and filter section. Each amplifier can be programmed for one of seven gains by use of external gain plugs. Each filter can be programmed for one of four filter frequencies by use of external filter plugs.

Each module provides +5 and +10 VDC for transducer excitation and +2.5 VDC for output signal offset, if necessary. Bridge completion and balance resistors can be added to the module input connector, if necessary. The 48 module output signals are digitized via the pulse code modulation (PCM) encoder into 48 eleven-digit words. Two additional 11-bit synchronization (sync) words are added to the data frame. This 50-word data frame is then sampled at a rate of 1000 samples per second. Three synchronization pulse trains (bit sync, word sync, and frame sync) are added to the word frame and sent to the computer via the junction box and whip cable.

The PDP 11/34 minicomputer receives serial data from the ADACS. The serial data coming from the sled are converted to parallel data in the data formatter. The data formatter deposits data by direct momory access (DMA) into the computer memory via the buffered data channel where data are stored on disk temporarily to be later transferred to magnetic tape for permanent storage. The

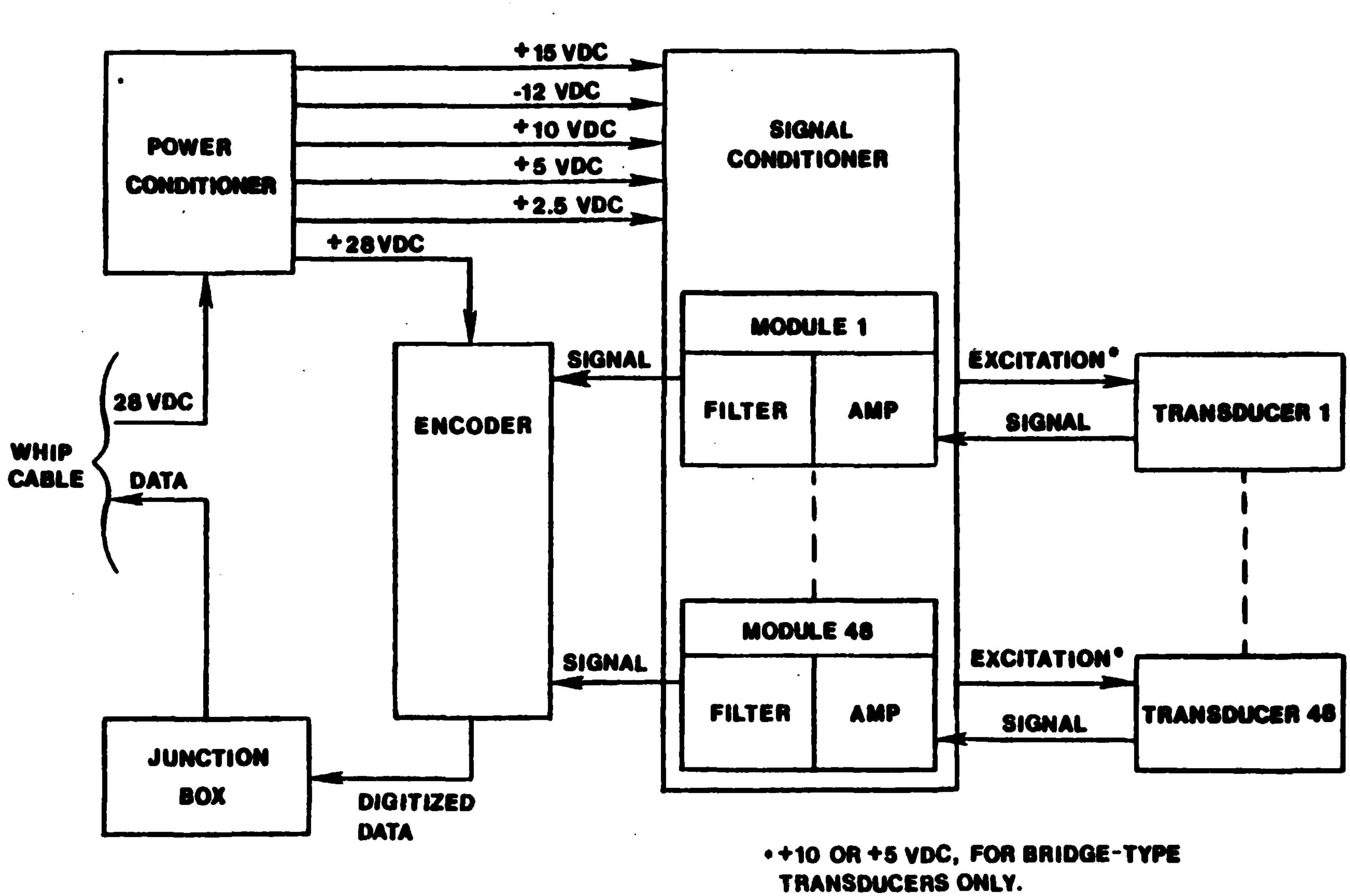


Figure A-2. Onboard ADACS Configuration.

inter-relationships among the data acquisition and storage equipment are shown in Figure A-3.

Test data were reviewed immediately after each test by using the "Quick-Look" CHAN routine. CHAN may be used to produce a plot of the data stored on any channel as a function of time. The routine determines the minimum and maximum values of any data plot. It may also be used to calculate velocity by integrating sled acceleration.

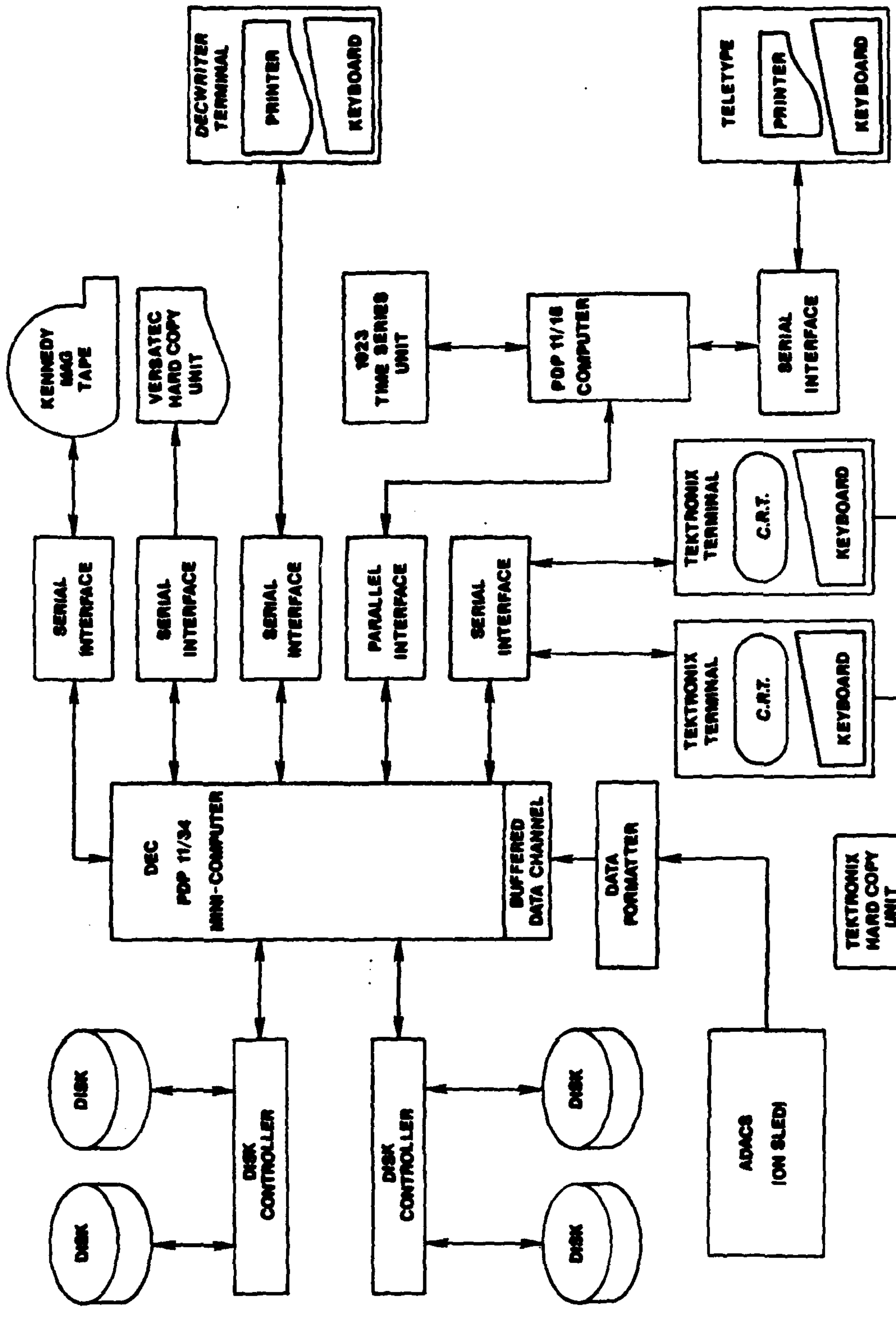


Figure A-3. ADACS Configuration.

APPENDIX B

DATA SUMMARIES AND GRAPHS

This appendix contains the data collected from each test accomplished in this test series. These data are summarized in a table of maximum and minimum values with corresponding times of maximum and minimum values and in graphs of sled accelerations, sled velocity, and loads measured at the restraint tie-down points.

The data printed out in tabular form are identified by an abbreviated title. The data are listed in four columns titled max (the maximum value), min (the minimum value), I1 (the time the maximum valued occurred), and T2 (the time the minimum value occurred). A fifth column identifies the data channel number. The values of time are specified in milliseconds. An event mark is used to synchronize the electronic and photometric data. The event time is the first data value specified on each table. To correlate a time value form one test to another, the reader must calculate the values of T1 and T2 with respect to the common time event mark. For example, if the event mark time is 160 milliseconds and the max value of the resultant shoulder harness load occurs at 300 milliseconds, subtraction of the event mark time from the time of the max resultant shoulder harness load yields the correlated time value, 140 milliseconds.

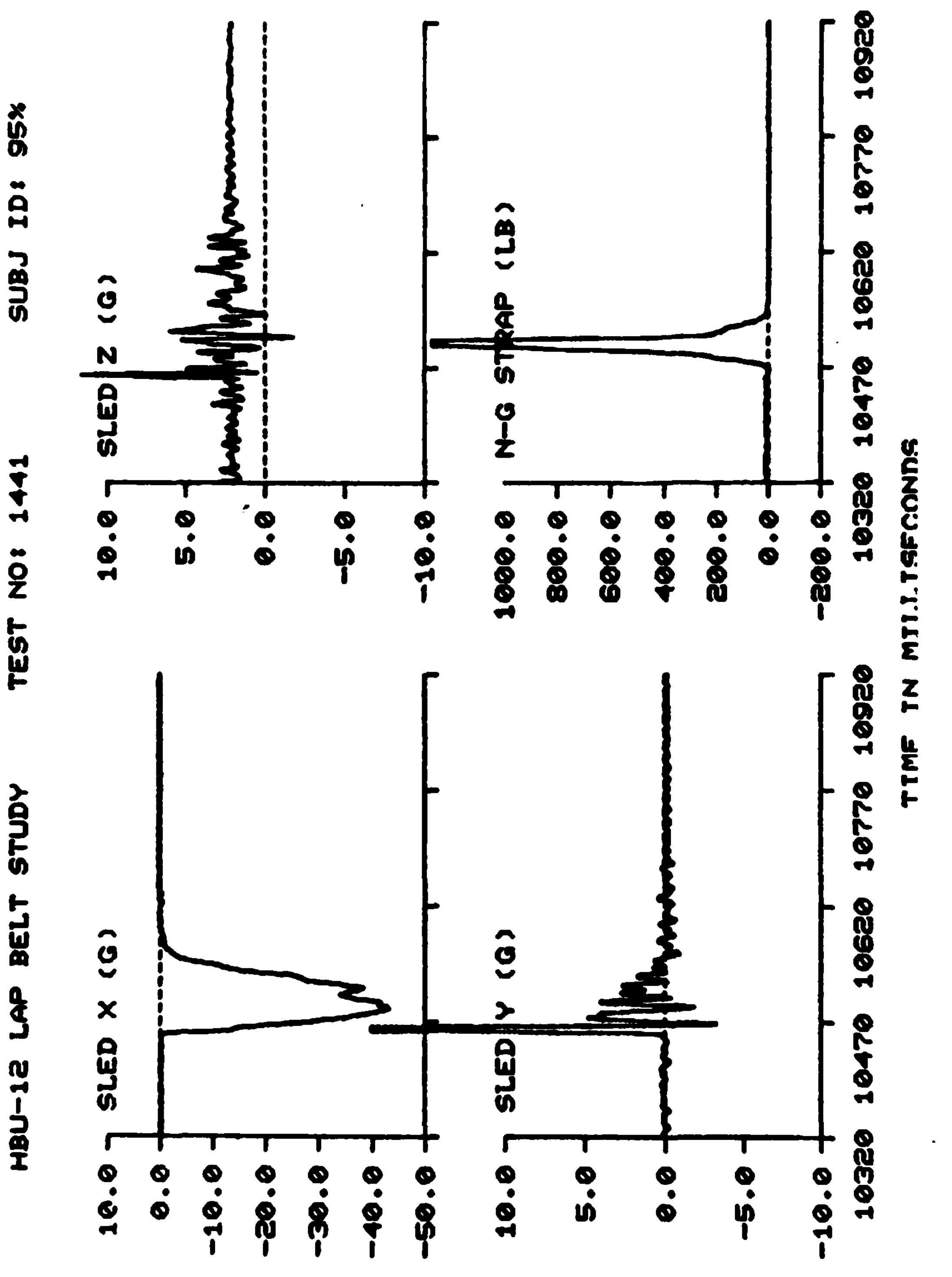
The data titles are defined as follows:

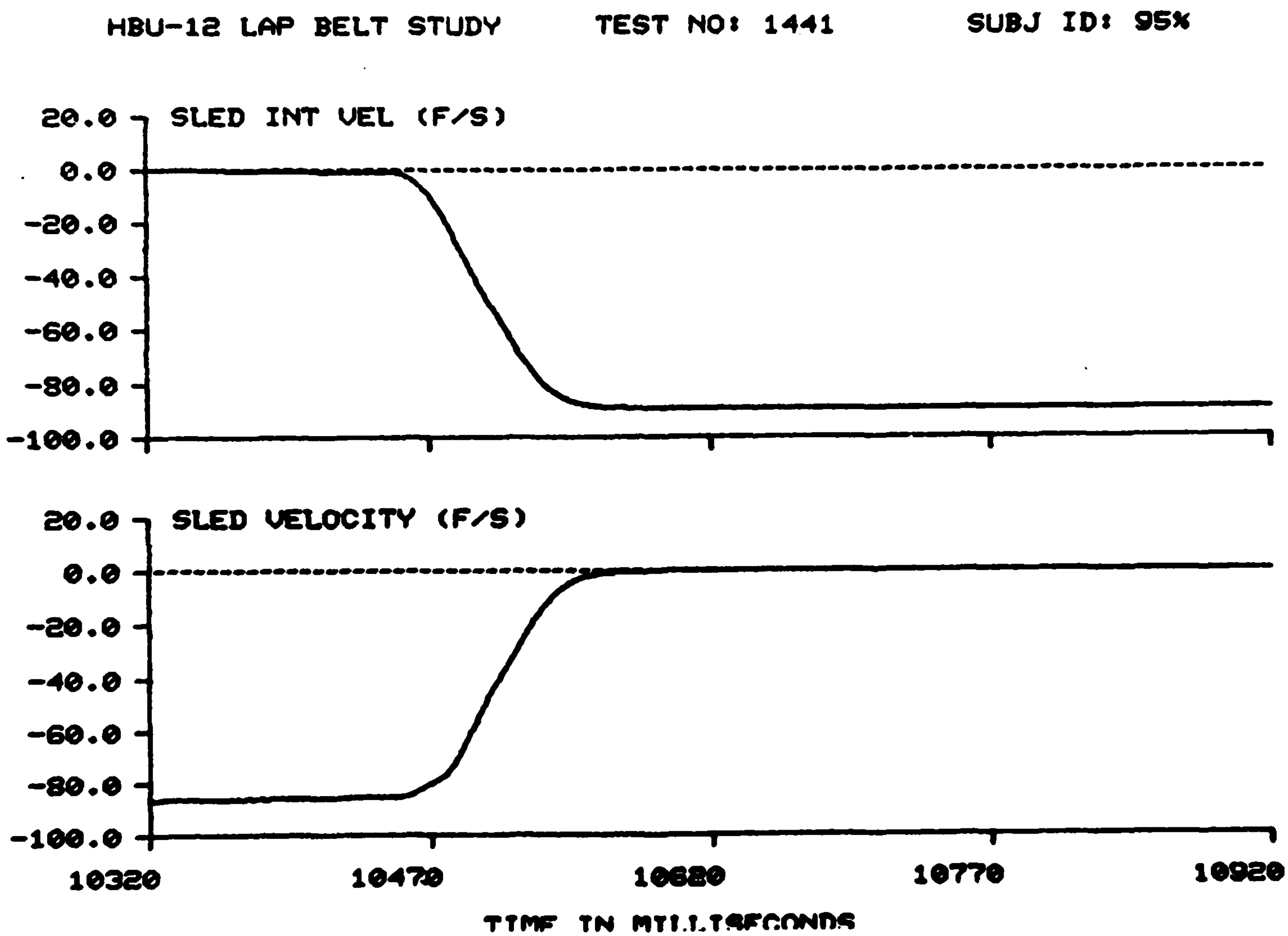
TIME OF EVENT	= Time of event correlation mark
2.5V EXT PWR	= Monitor of 2.5 volt power
10V EXT PWR	= Monitor of 10 volt power
SHD PLD PRIOR EVENT	= Shoulder harness preload prior to impact
LF LAP PLD PRIOR EVENT	= Left lap belt preload prior to impact
RT LAP PLD PRIOR EVENT	= Right lap belt preload prior to impact
SLED X ACCEL	= Sled acceleration in the X axis
SLED X ACCEL (SM)	= Sled X acceleration smoothed using a point-moving average method
SLED Y ACCEL	= Sled acceleration in the Y axis
SLED Z ACCEL	= Sled acceleration in the Z axis
N-G STRAP	= The load acting at the crotch strap tie-down point

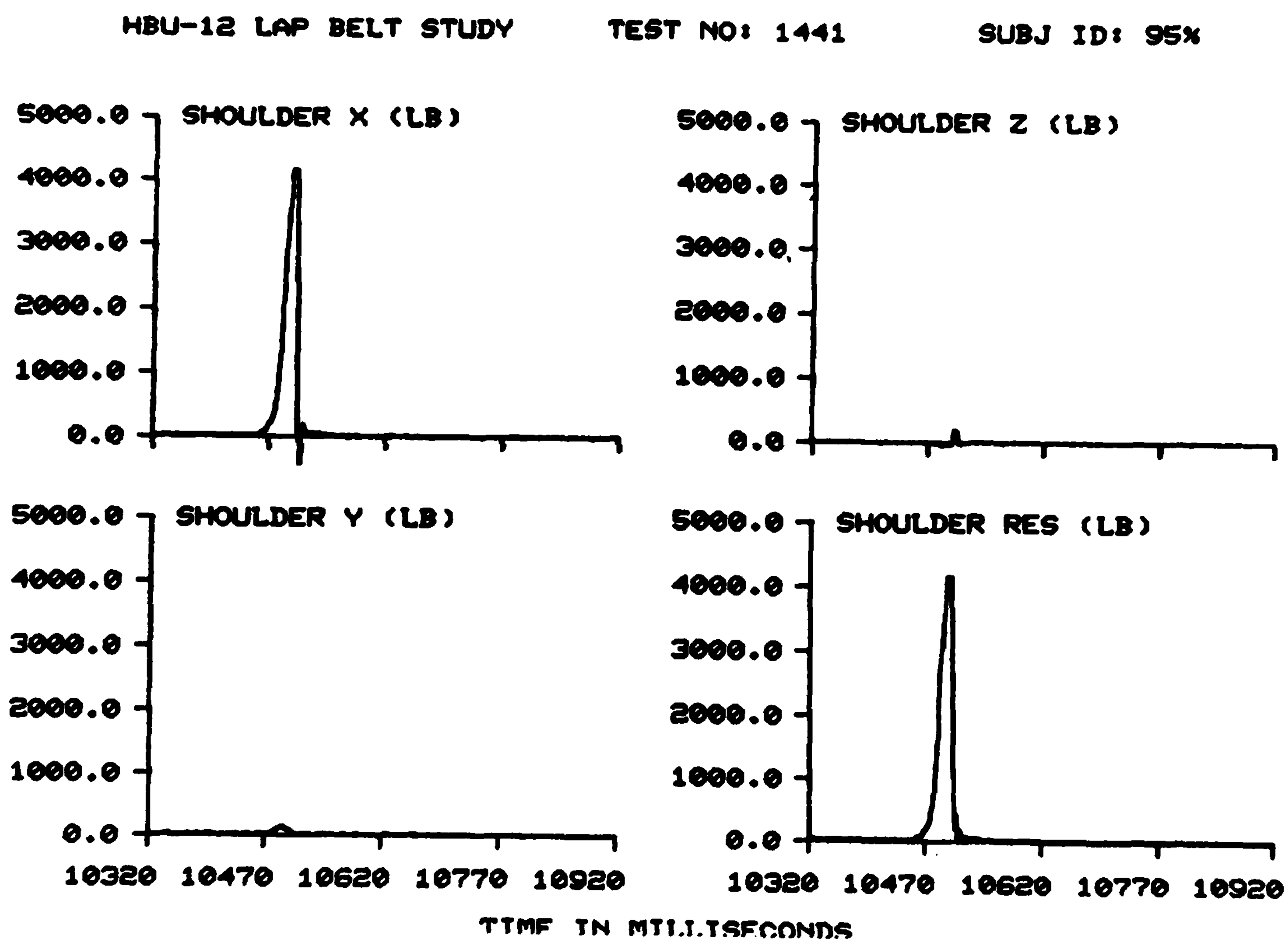
SLED VEL (INT ACCEL)	= Sled velocity computed by intergration of sled acceleration
SLED VELOCITY	= Sled velocity computed from the tachometer
VEL AT EVENT	= The velocity at event
SHOULDER LOAD X	= The X axis component of the load acting at the shoulder harness tie-down point
SHOULDER LOAD Y	= The Y axis component of the load acting at the shoulder harness tie-down point
SHOULDER LOAD Z	= The Z axis component of the load acting at the shoulder harness tie-down point
SHOULDER RESULTANT	= The resultant of the continuously summed shoulder harness load components
SHOULDER RES/WT	= The maximum resultant shoulder harness load divided by the total weight of the subject
LF LAP LOAD X	= The X axis component of the load acting at the left lap belt tie-down point
LF LAP LOAD Y	= The Y axis component of the load acting at the left lap belt tie-down point
LF LAP LOAD Z	= The Z axis component of the load acting at the left lap belt tie-down point
LF LAP RESULTANT	= The resultant of the continuously summed left lap belt load components
RT LAP LOAD X	= The X axis component of the load acting at the right lap belt tie-down point
RT LAP LOAD Y	= The Y axis component of the load acting at the right lap belt tie-down point
RT LAP LOAD Z	= The Z axis component of the load acting at the right lap belt tie-down point
RT LAP RESULTANT	= The resultant of the continuously summed right lap belt load components

MBU-12 LAP BELT STUDY TEST: 1441 SUBJ: 95% WT: 208.0 NOM G: 40.0 CELL: X

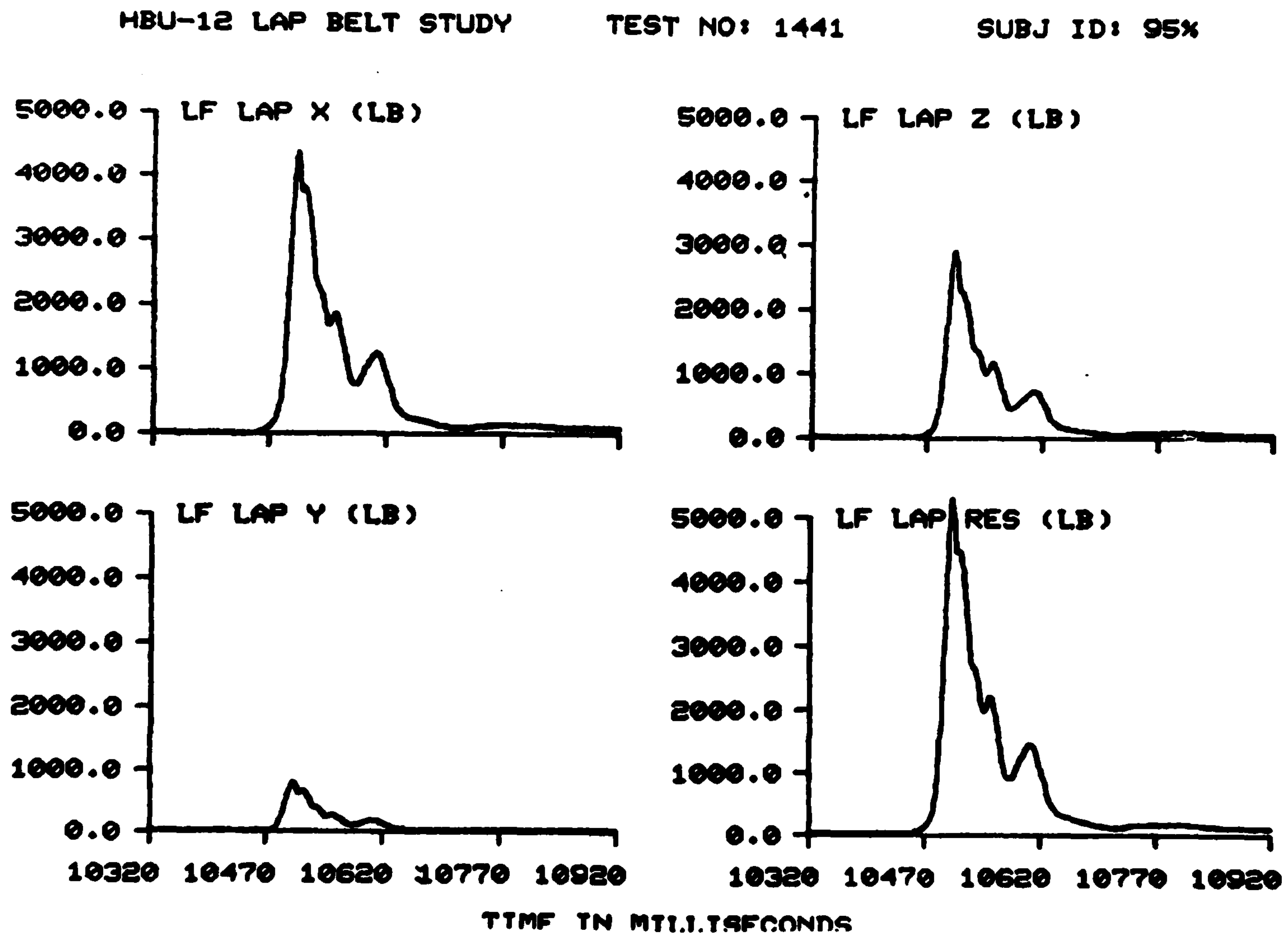
DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			10320.00		37
2.5V EXT PWR	2.50	2.49	18.00	253.00	47
10V EXT PWR	10.00	10.00	0.00	0.00	48
SHD PLD PRIOR EVENT	13.33		10220.00	10320.00	
LF LAP PLD PRIOR EVENT	12.62		10220.00	10320.00	
RT LAP PLD PRIOR EVENT	12.75		10220.00	10320.00	
SLED X ACCEL	0.29	-43.28	10645.00	10487.00	1
SLED X ACCEL (SM)	0.17	-42.46	10646.00	10488.00	
SLED Y ACCEL	18.40	-3.24	10458.00	10467.00	2
SLED Z ACCEL	11.73	-1.74	10460.00	10510.00	3
N-G STRAP	1273.75	-5.40	10499.00	10467.00	30
SLED VEL (INT ACCEL)	0.00	-89.57	10320.00	10920.00	
SLED VELOCITY	0.23	-86.66	10637.00	10322.00	29
VEL AT EVENT		-86.66		10322.00	
SHOULDER LOAD X	4159.20	-424.31	10498.00	10509.00	23
SHOULDER LOAD Y	126.21	-7.62	10490.00	10507.00	22
SHOULDER LOAD Z	200.85	-47.81	10506.00	10489.00	21
SHOULDER RESULTANT	4160.19	1.93	10498.00	10634.00	
LF LAP LOAD X	4369.03	-12.92	10505.00	10353.00	15
LF LAP LOAD Y	781.25	-9.29	10505.00	10355.00	16
LF LAP LOAD Z	2909.91	-0.16	10505.00	10337.00	17
LF LAP RESULTANT •	5307.20	6.96	10505.00	10427.00	
RT LAP LOAD X	4179.65	-12.55	10505.00	10416.00	18
RT LAP LOAD Y	785.25	-7.57	10505.00	10470.00	19
RT LAP LOAD Z	2900.41	-3.39	10505.00	10439.00	20
RT LAP RESULTANT	5147.67	7.89	10505.00	10323.00	


HBU-12 LAP BELT STUDY
TEST NO: 1441
SUBJ ID: 95%
SLED X (G)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
SLED Y (G)
10.0
5.0
0.0
-5.0
-10.0
SLED Z (G)
10.0
5.0
0.0
-5.0
-10.0
N-G STRAP (LB)
1000.0
800.0
600.0
400.0
200.0
0.0
-200.0
10320 10470 10620 10770 10920
TIME IN MILLISECONDS

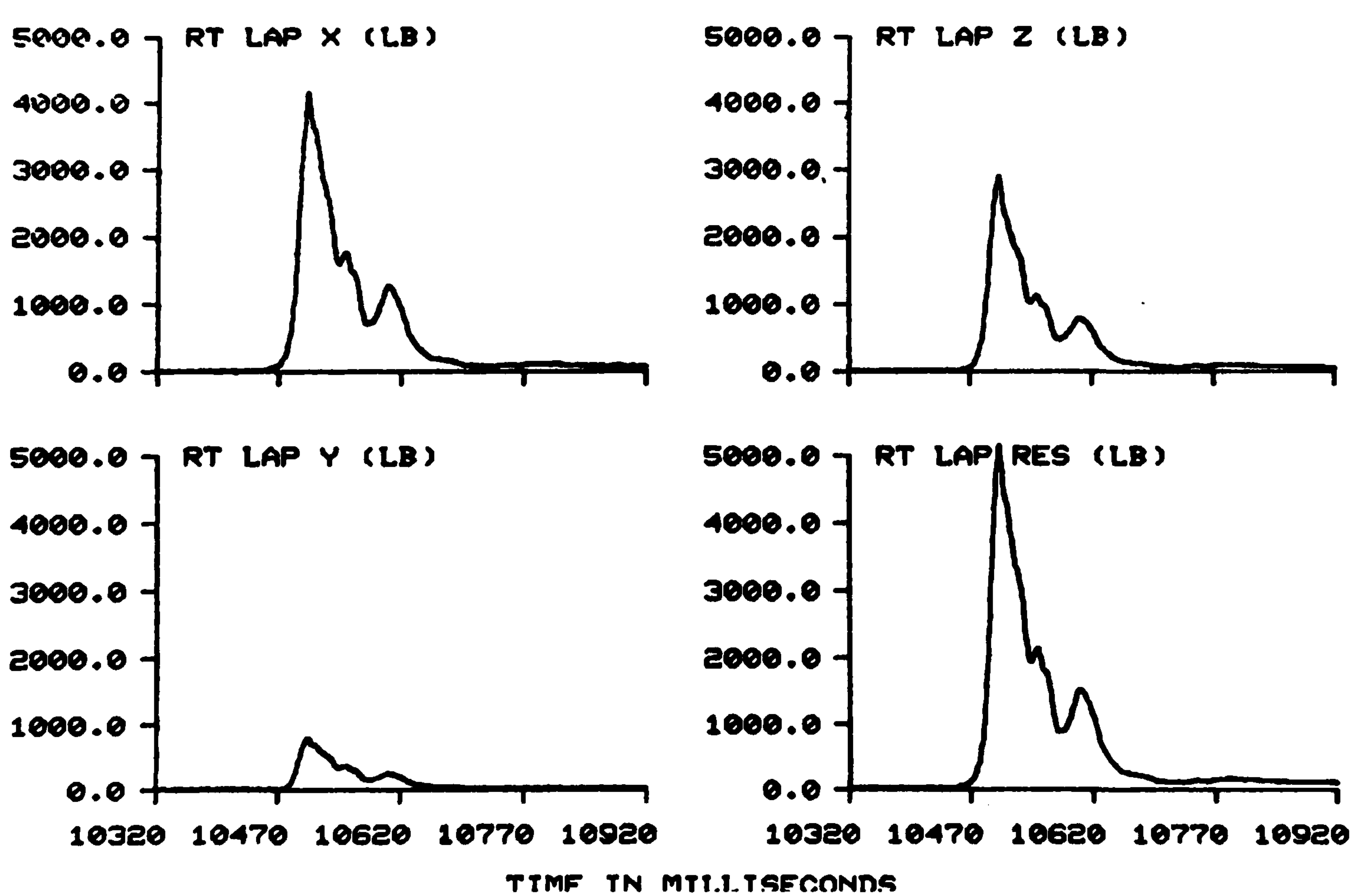

HBU-12 LAP BELT STUDY
TEST NO: 1441
SUBJ ID: 95%
SLED INT VEL (F/S)
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
SLED VELOCITY (F/S)
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
10320
10470
10620
10770
10920
TIME IN MILLISECONDS



HBU-12 LAP BELT STUDY
TEST NO: 1441
SUBJ ID: 95%
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
10320
10470
10620
10770
10920
TIME IN MILLISECONDS

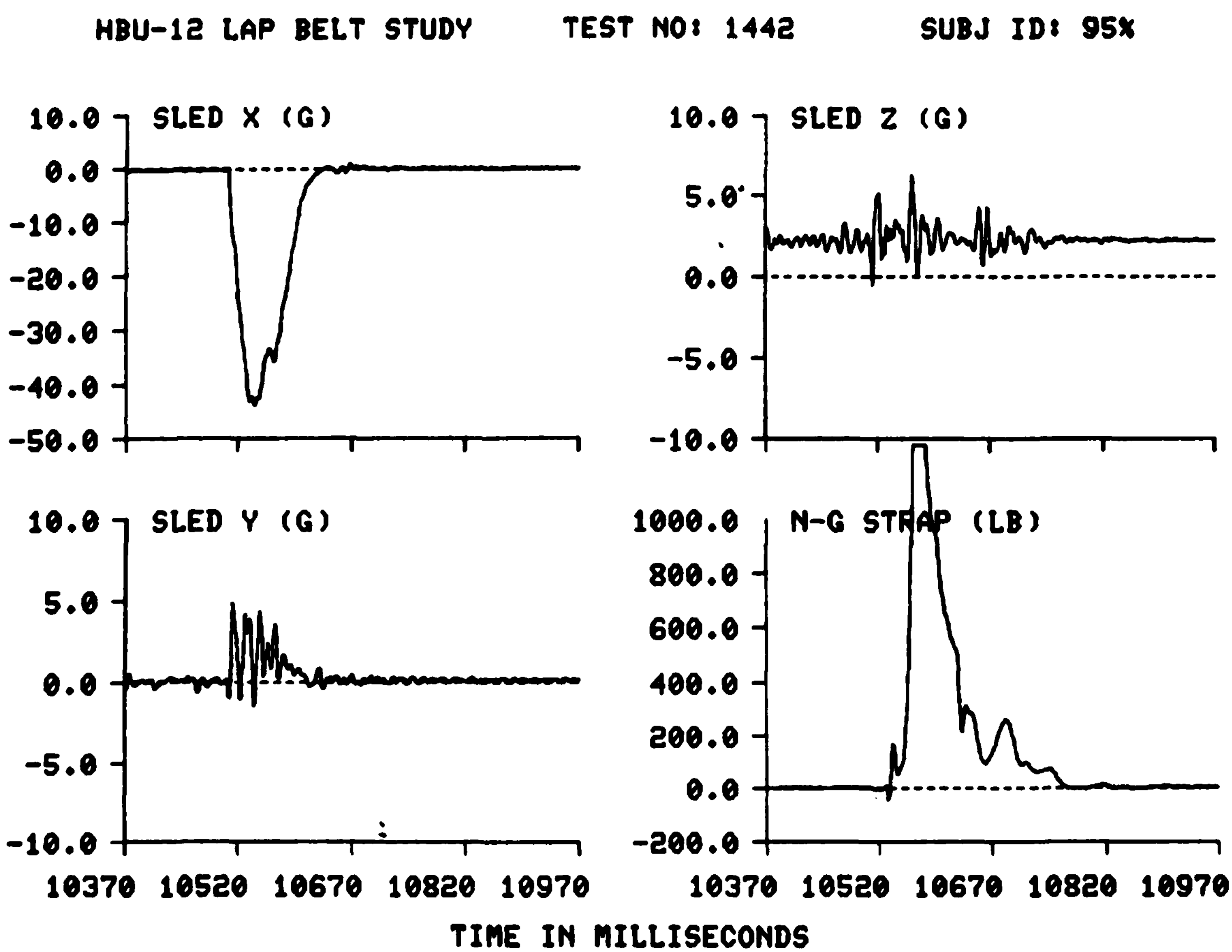

HBU-12 LAP BELT STUDY
TEST NO: 1441
SUBJ ID: 95%
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
10320
10470
10620
10770
10920
TIME IN MILLISECONDS

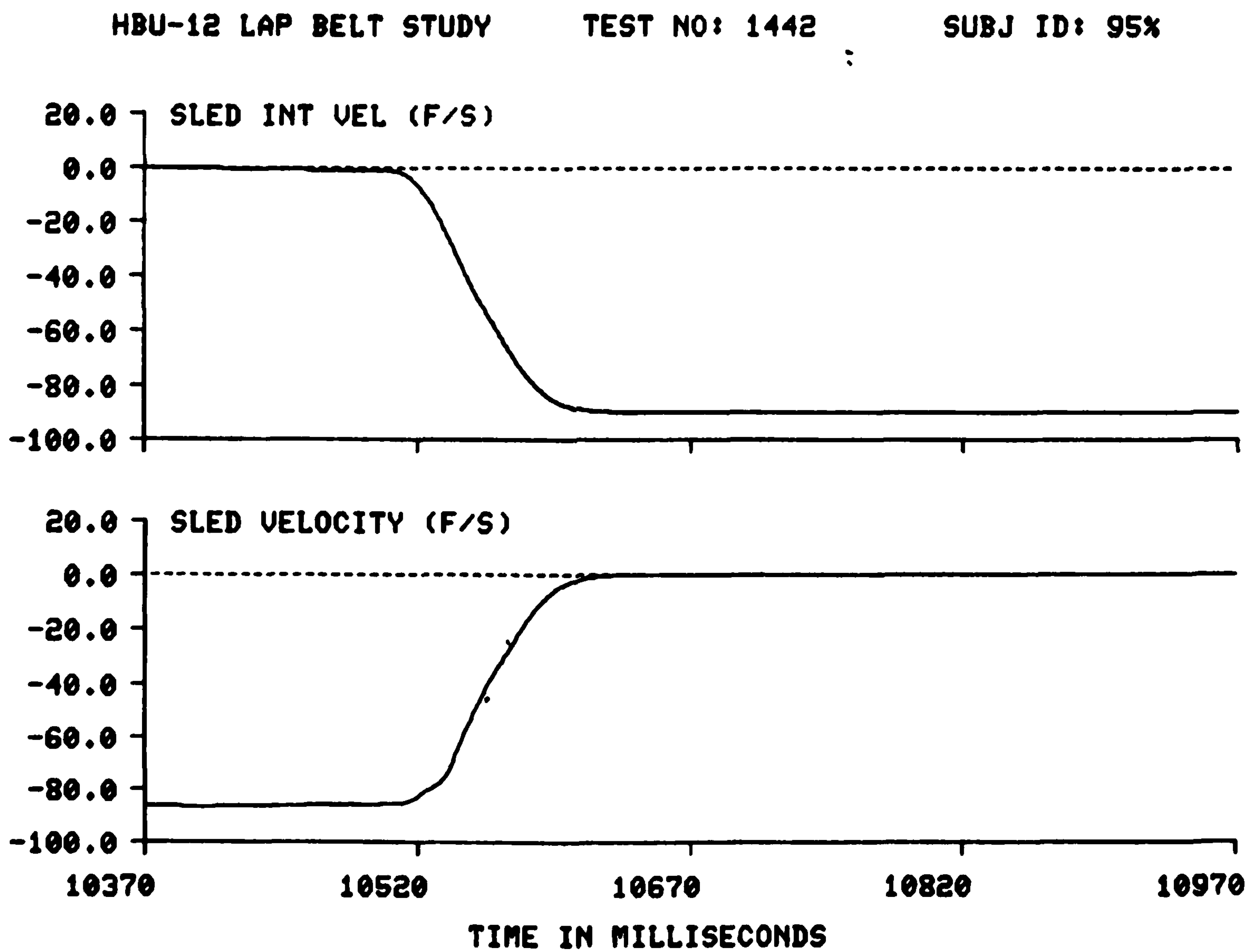
HBU-12 LAP BELT STUDY TEST NO: 1441 SUBJ ID: 95%

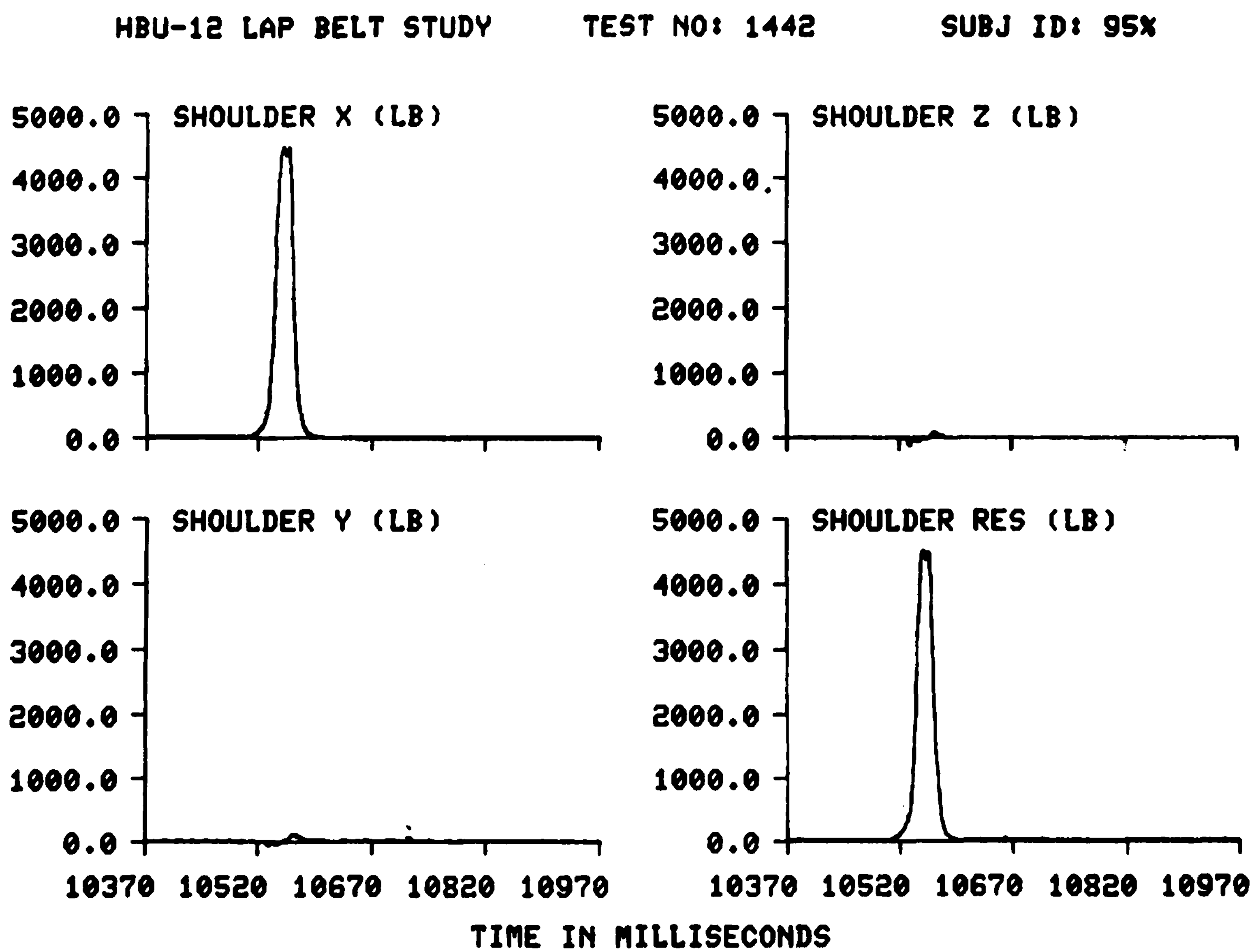


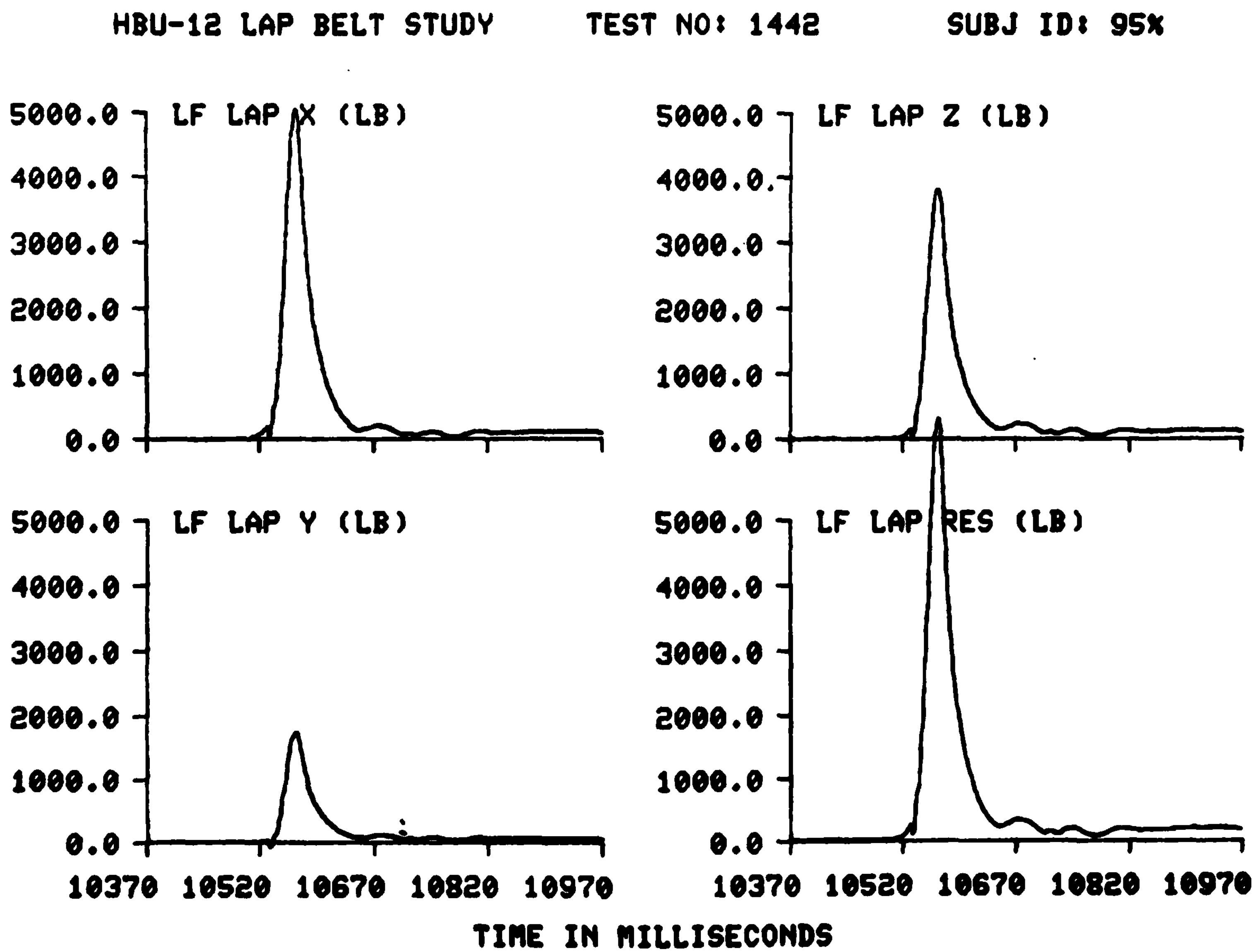
HBU-12 LAP BELT STUDY   TEST: 1442   SUBJ: 95%   WT: 210.0   NOM G: 40.0   CELL: X

DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			10372.00		37
2.5V EXT PWR	2.55	2.15	162.00	180.00	47
10V EXT PWR	10.00	10.00	0.00	0.00	48
SHD PLD PRIOR EVENT	12.80		10270.00	10370.00	
LF LAP PLD PRIOR EVENT	8.38		10270.00	10370.00	
RT LAP PLD PRIOR EVENT	8.90		10270.00	10370.00	
SLED X ACCEL	0.82	-43.65	10667.00	10541.00	1
SLED X ACCEL (SM)	0.34	-43.06	10667.00	10541.00	
SLED Y ACCEL	4.86	-1.51	10513.00	10542.00	2
SLED Z ACCEL	6.25	-0.56	10586.00	10513.00	3
N-C STRAP	1279.02	-40.49	10567.00	10532.00	30
SLED VEL (INT ACCEL)	0.00	-89.89	10370.00	10664.00	
SLED VELOCITY	0.24	-86.71	10640.00	10393.00	29
VEL AT EVENT		-86.71		10393.00	
SHOULDER LOAD X	4490.23	-40.97	10552.00	10680.00	23
SHOULDER LOAD Y	115.87	-68.68	10566.00	10533.00	22
SHOULDER LOAD Z	80.42	-121.19	10566.00	10533.00	21
SHOULDER RESULTANT	4490.25	1.03	10552.00	10478.00	
LF LAP LOAD X	5046.59	-20.97	10566.00	10436.00	15
LF LAP LOAD Y	1728.02	-85.29	10587.00	10533.00	16
LF LAP LOAD Z	3815.90	-9.93	10565.00	10375.00	17
LF LAP RESULTANT	6552.01	4.53	10566.00	10388.00	
RT LAP LOAD X	4636.51	-19.79	10562.00	10455.00	18
RT LAP LOAD Y	1649.53	-68.16	10571.00	10539.00	19
RT LAP LOAD Z	3938.09	-14.87	10562.00	10407.00	20
RT LAP RESULTANT	6352.23	2.21	10562.00	10375.00	

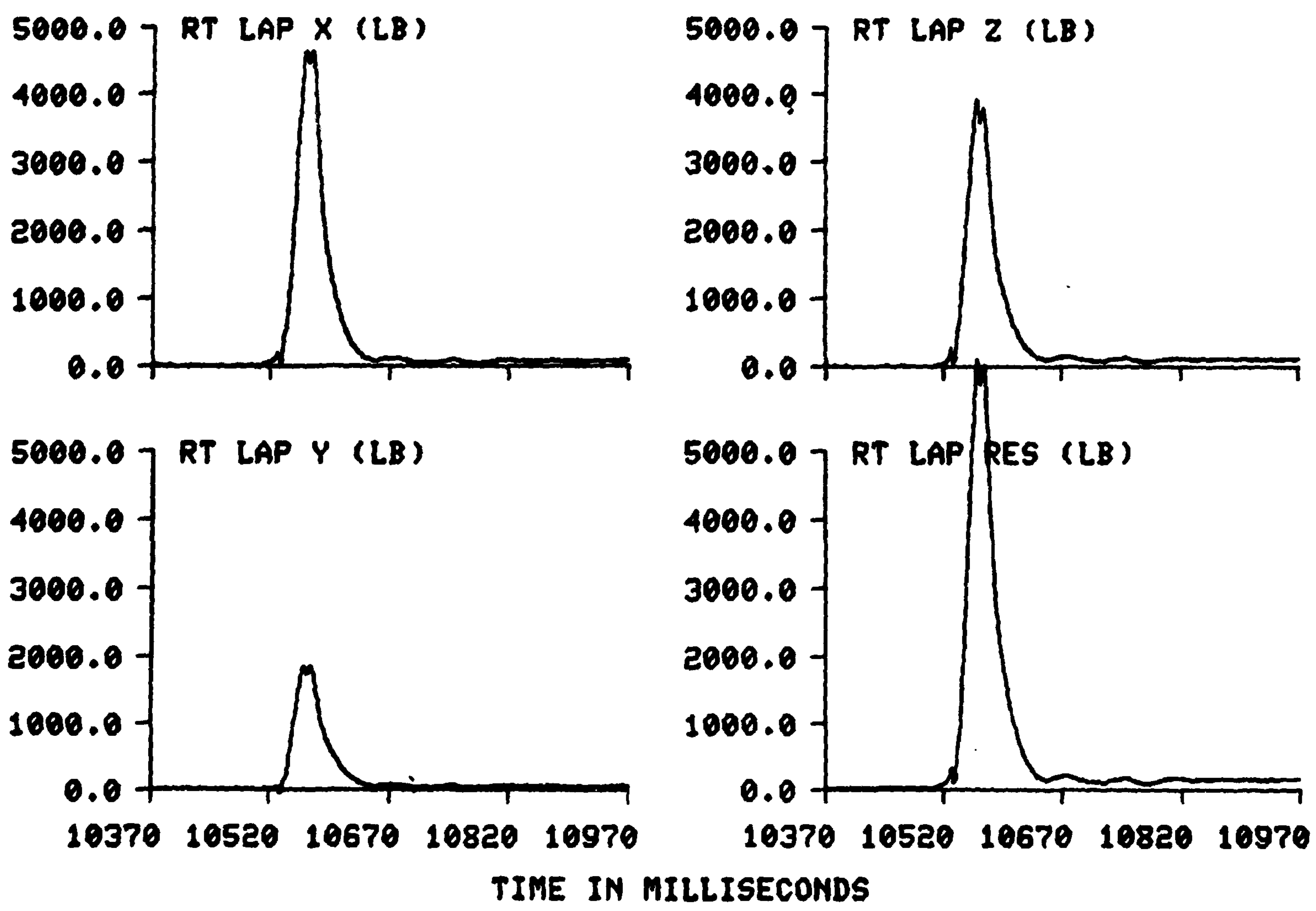

HBU-12 LAP BELT STUDY
TEST NO: 1442
SUBJ ID: 95%
SLED X (G)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
SLED Z (G)
10.0
5.0
0.0
-5.0
-10.0
SLED Y (G)
10.0
5.0
0.0
-5.0
-10.0
N-G STRAP (LB)
1000.0
800.0
600.0
400.0
200.0
0.0
-200.0
10370 10520 10670 10820 10970
10370 10520 10670 10820 10970
TIME IN MILLISECONDS


HBU-12 LAP BELT STUDY
TEST NO: 1442
SUBJ ID: 95%
SLED INT VEL (F/S)
SLED VELOCITY (F/S)
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
10370
10520
10670
10820
10970
TIME IN MILLISECONDS


HBU-12 LAP BELT STUDY
TEST NO: 1442
SUBJ ID: 95%
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
10370 10520 10670 10820 10970
TIME IN MILLISECONDS


HBU-12 LAP BELT STUDY
TEST NO: 1442
SUBJ ID: 95%
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
10370
10520
10670
10820
10970
TIME IN MILLISECONDS

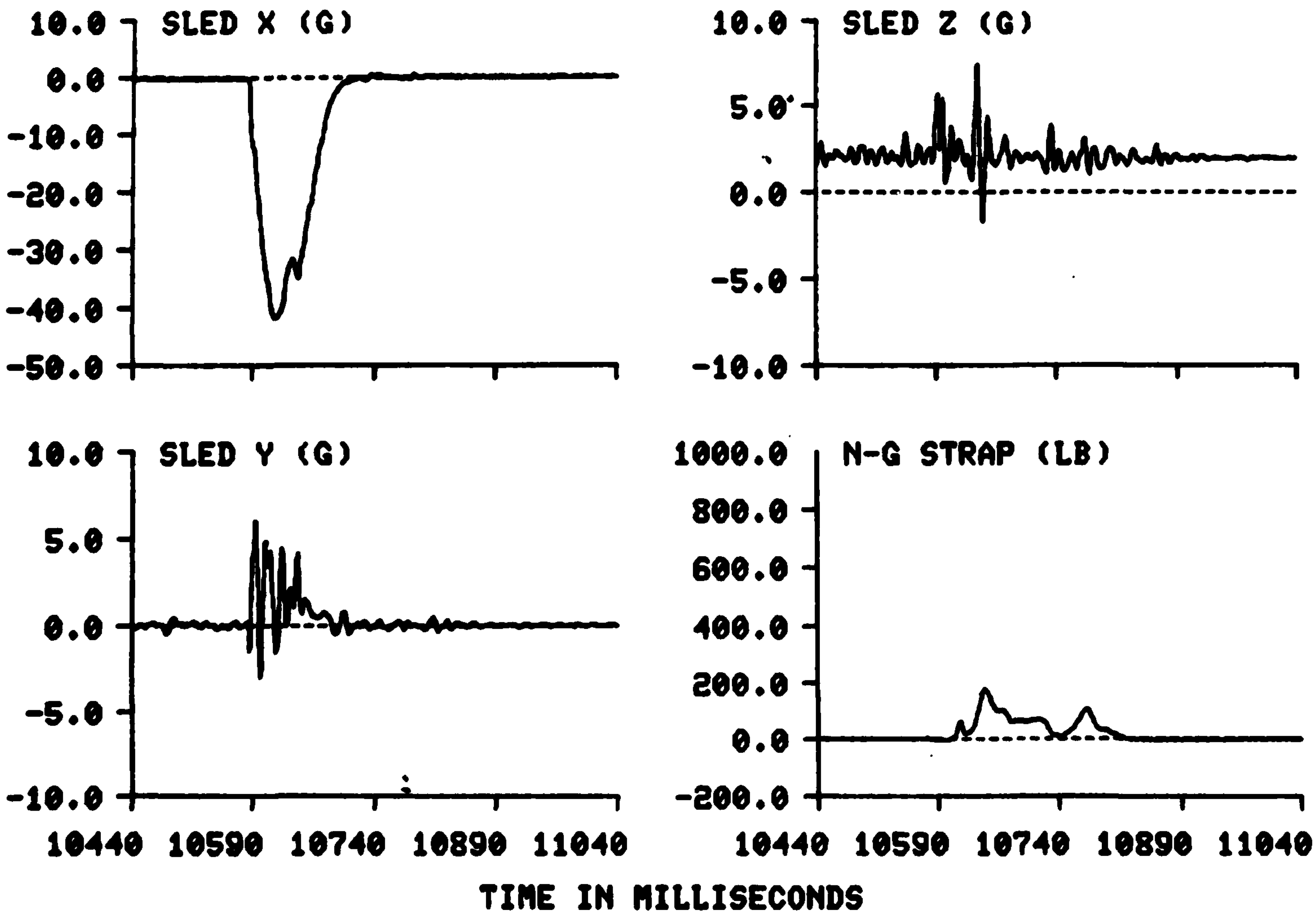
HBU-12 LAP BELT STUDY   TEST NO: 1442   SUBJ ID: 95%



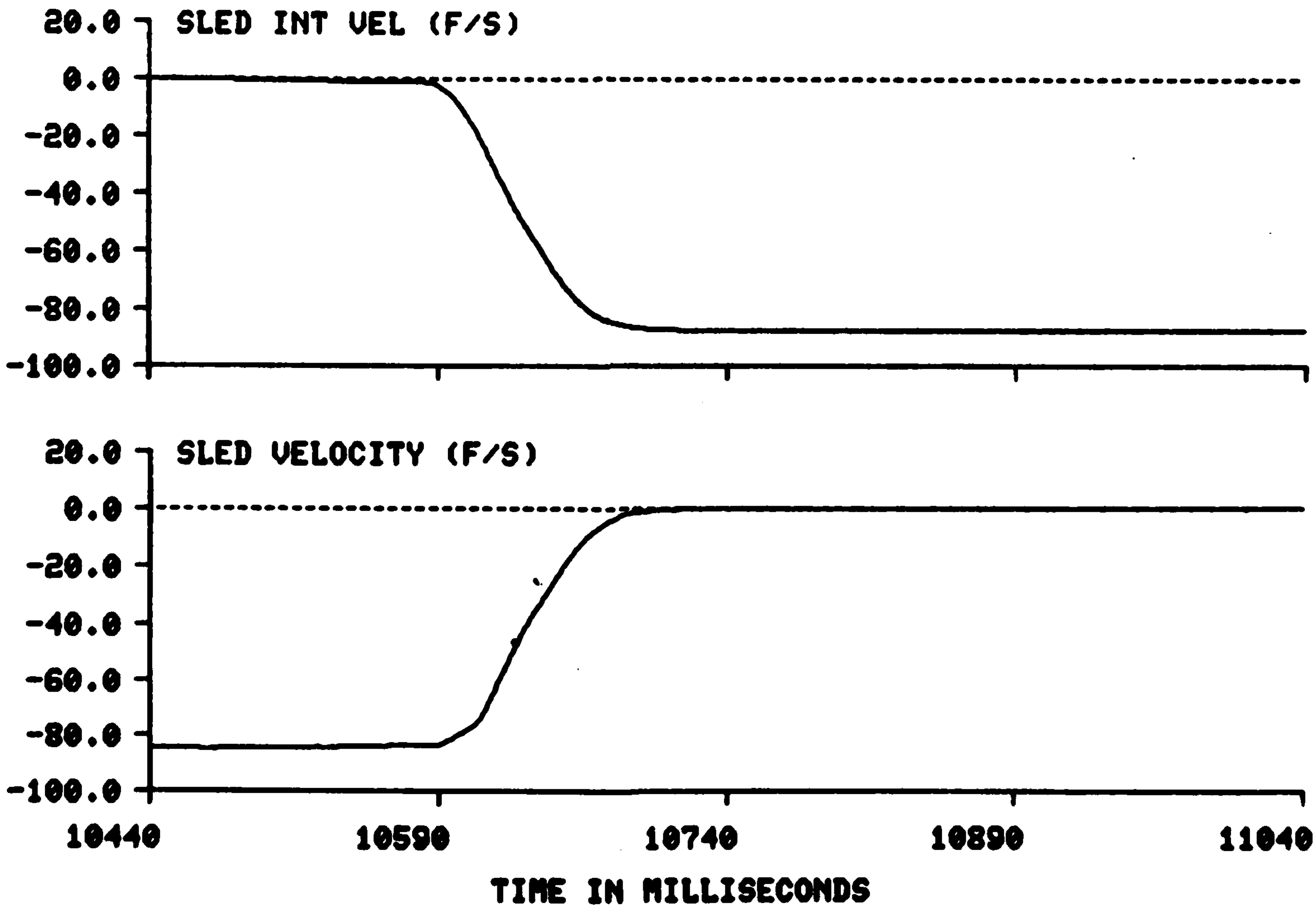
HBU-12 LAP BELT STUDY TEST: 1444 SUBJ: 95% WT: 210.0 NOM G: 40.0 CELL: X

DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			10444.00		37
2.5V EXT PWR	2.50	2.49	22.00	537.00	47
10V EXT PWR	10.00	10.00	0.00	0.00	48
SHD PLD PRIOR EVENT	15.06		10340.00	10440.00	
LF LAP PLD PRIOR EVENT	12.34		10340.00	10440.00	
RT LAP PLD PRIOR EVENT	15.82		10340.00	10440.00	
SLED X ACCEL	0.48	-41.81	10743.00	10618.00	1
SLED X ACCEL (SM)	0.33	-41.48	10744.00	10619.00	
SLED Y ACCEL	5.98	-3.05	10593.00	10600.00	2
SLED Z ACCEL	7.39	-1.66	10642.00	10649.00	3
N-G STRAP	176.78	-4.87	10648.00	10597.00	30
SLED VEL (INT ACCEL)	0.00	-87.47	10440.00	10733.00	
SLED VELOCITY	0.21	-84.86	10795.00	10468.00	29
VEL AT EVENT		-84.86		10468.00	
SHOULDER LOAD X	4089.35	-15.29	10636.00	10702.00	23
SHOULDER LOAD Y	141.01	-7.92	10622.00	10779.00	22
SHOULDER LOAD Z	85.19	-53.54	10643.00	10619.00	21
SHOULDER RESULTANT	4089.63	0.91	10636.00	10739.00	
LF LAP LOAD X	4869.92	-8.84	10642.00	10457.00	15
LF LAP LOAD Y	1886.46	-1.92	10643.00	10523.00	16
LF LAP LOAD Z	3967.79	-4.56	10643.00	10490.00	17
LF LAP RESULTANT	6558.83	3.77	10643.00	10556.00	
RT LAP LOAD X	4631.00	-4.89	10641.00	10555.00	18
RT LAP LOAD Y	1958.78	-10.40	10645.00	10480.00	19
RT LAP LOAD Z	3957.67	-7.68	10641.00	10446.00	20
RT LAP RESULTANT	6398.92	5.88	10645.00	10468.00	

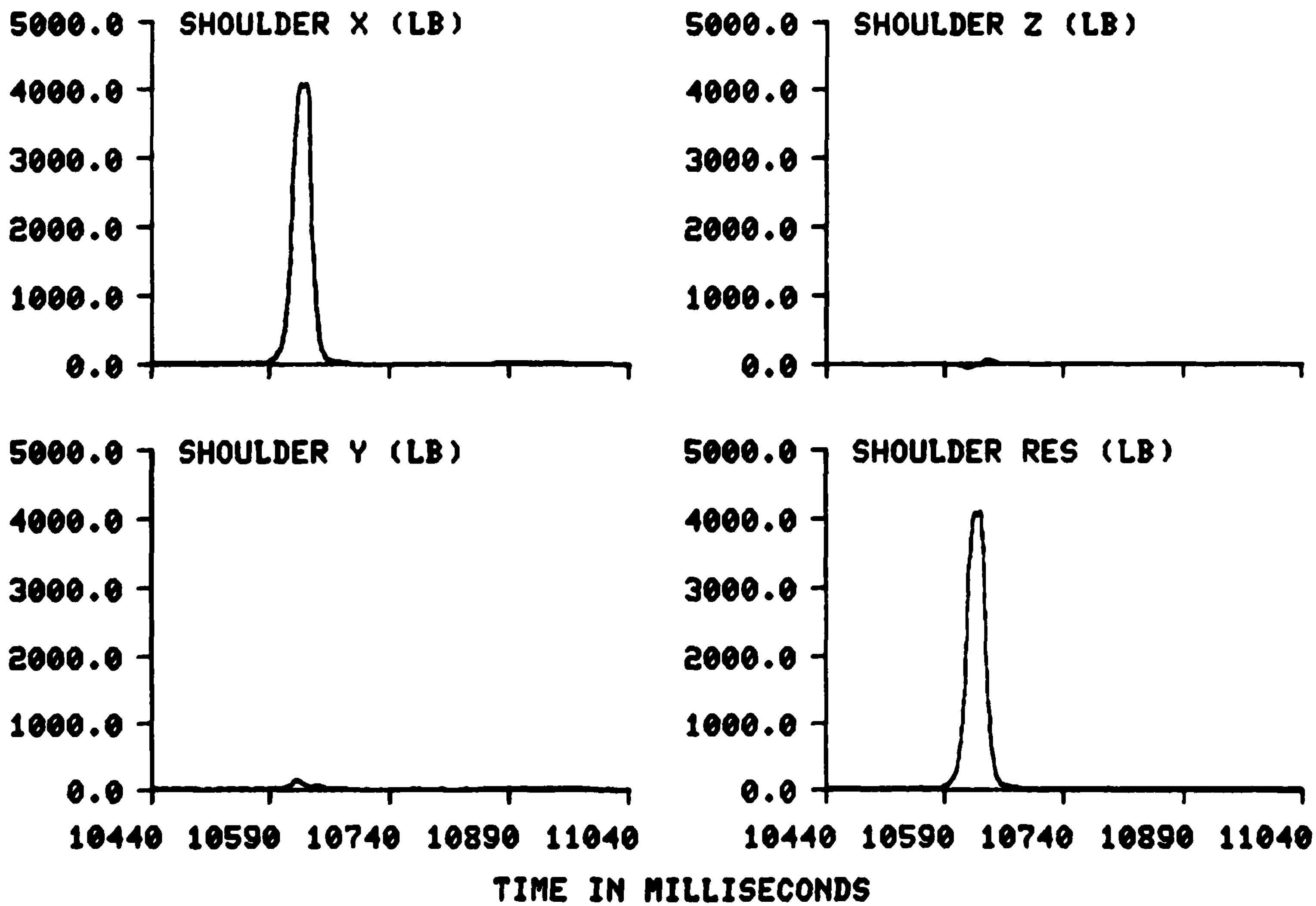
HBU-12 LAP BELT STUDY TEST NO: 1444 SUBJ ID: 95%

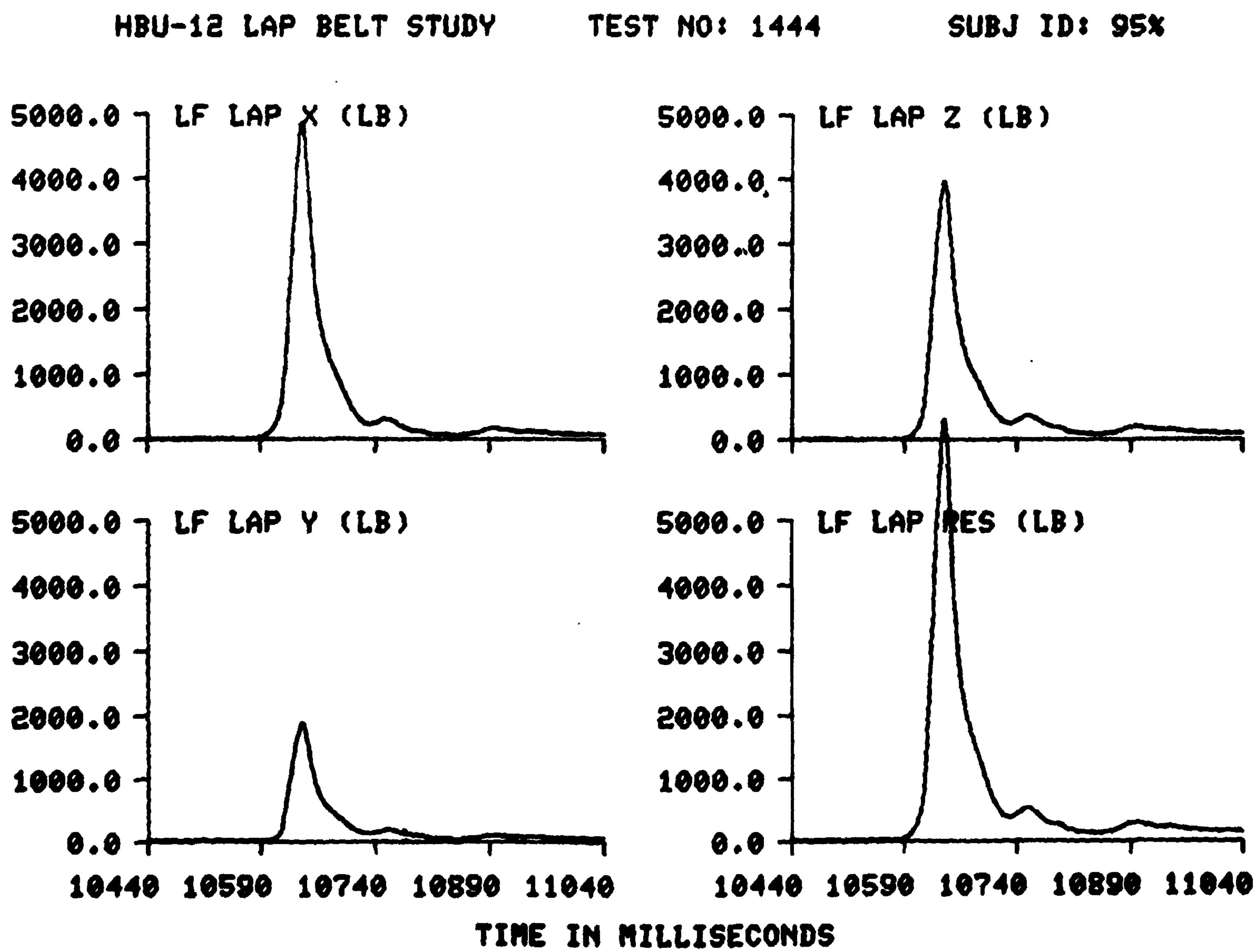


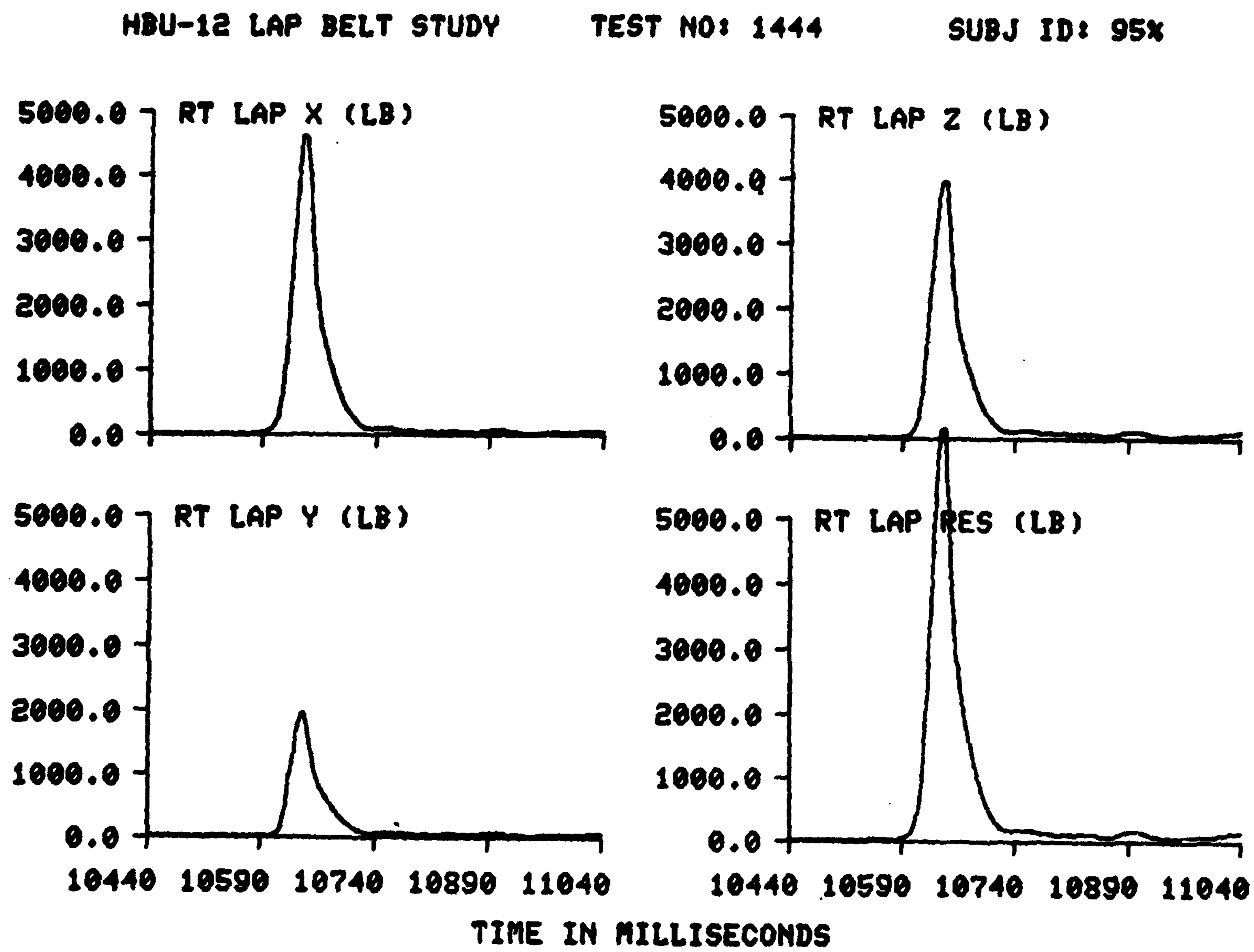
HBU-12 LAP BELT STUDY TEST NO: 1444 SUBJ ID: 95%



HBU-12 LAP BELT STUDY TEST NO: 1444 SUBJ ID: 95%



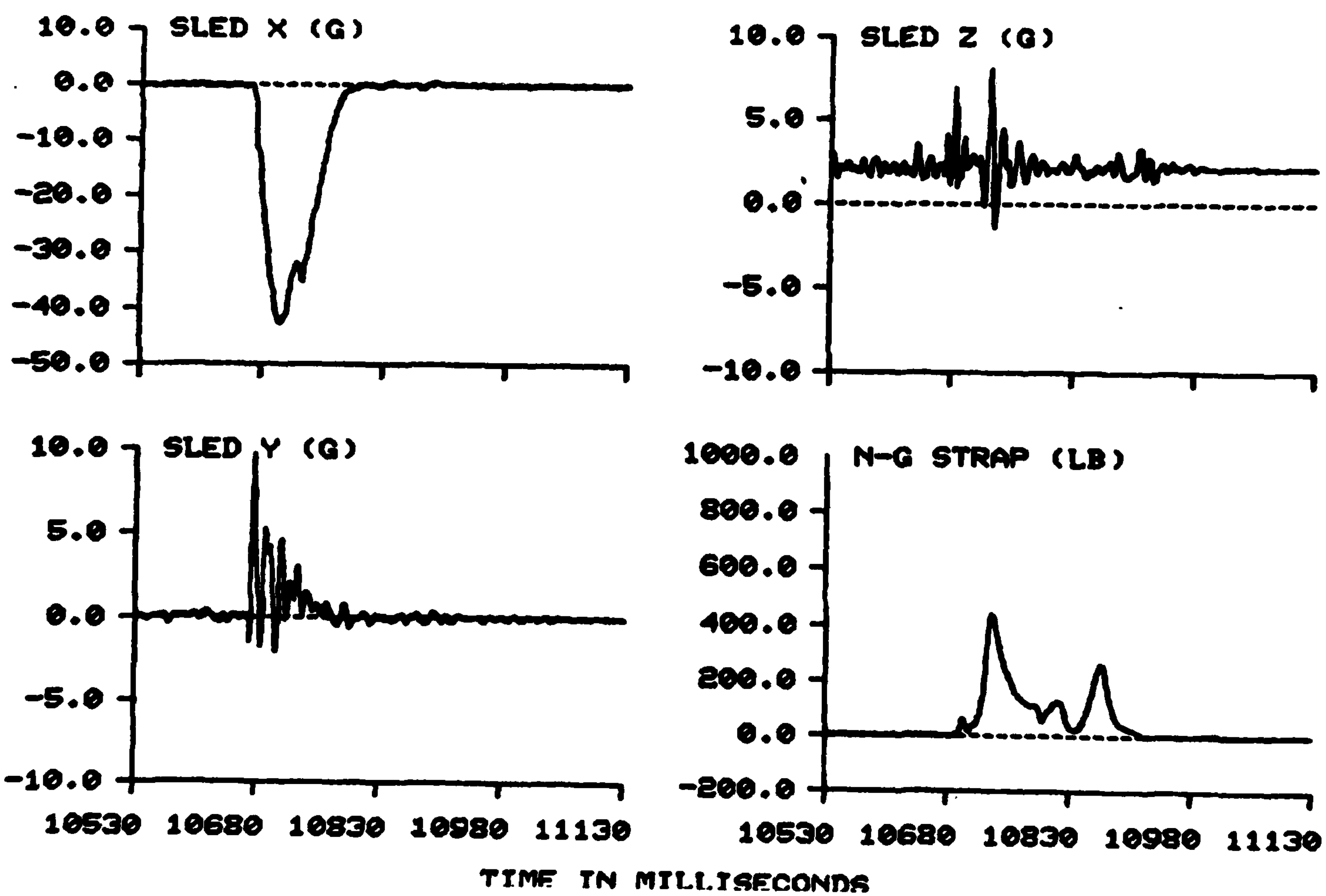

HBU-12 LAP BELT STUDY
TEST NO: 1444
SUBJ ID: 95%
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
10440 10590 10740 10890 11040
TIME IN MILLISECONDS

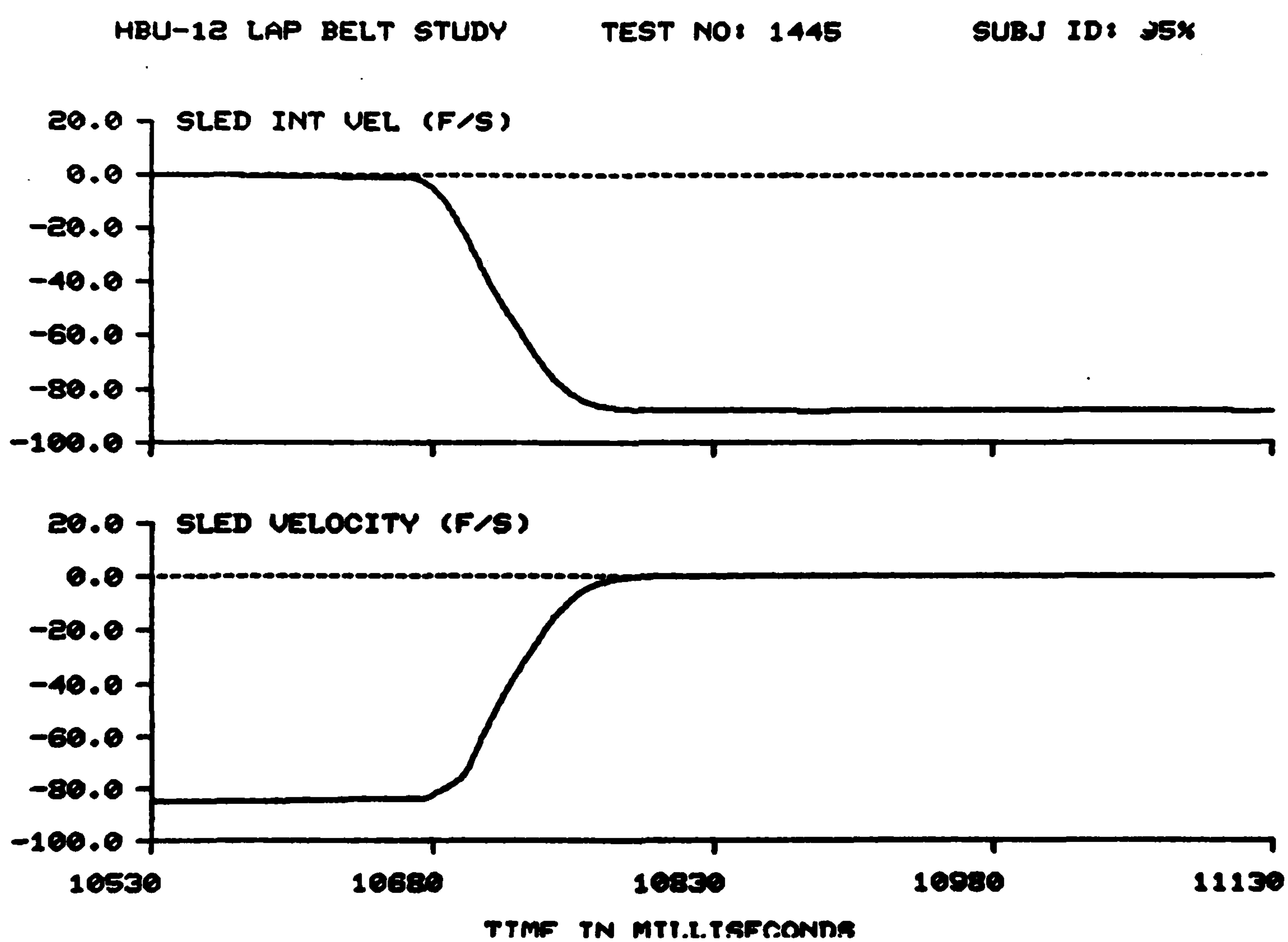

HBU-12 LAP BELT STUDY
TEST NO: 1444
SUBJ ID: 95%
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
10440
10590
10740
10890
11040
TIME IN MILLISECONDS

HBU-12 LAP BELT STUDY TEST: 1445 SUBJ: 95% WT: 210.0 NOM G: 40.0 CELL: X

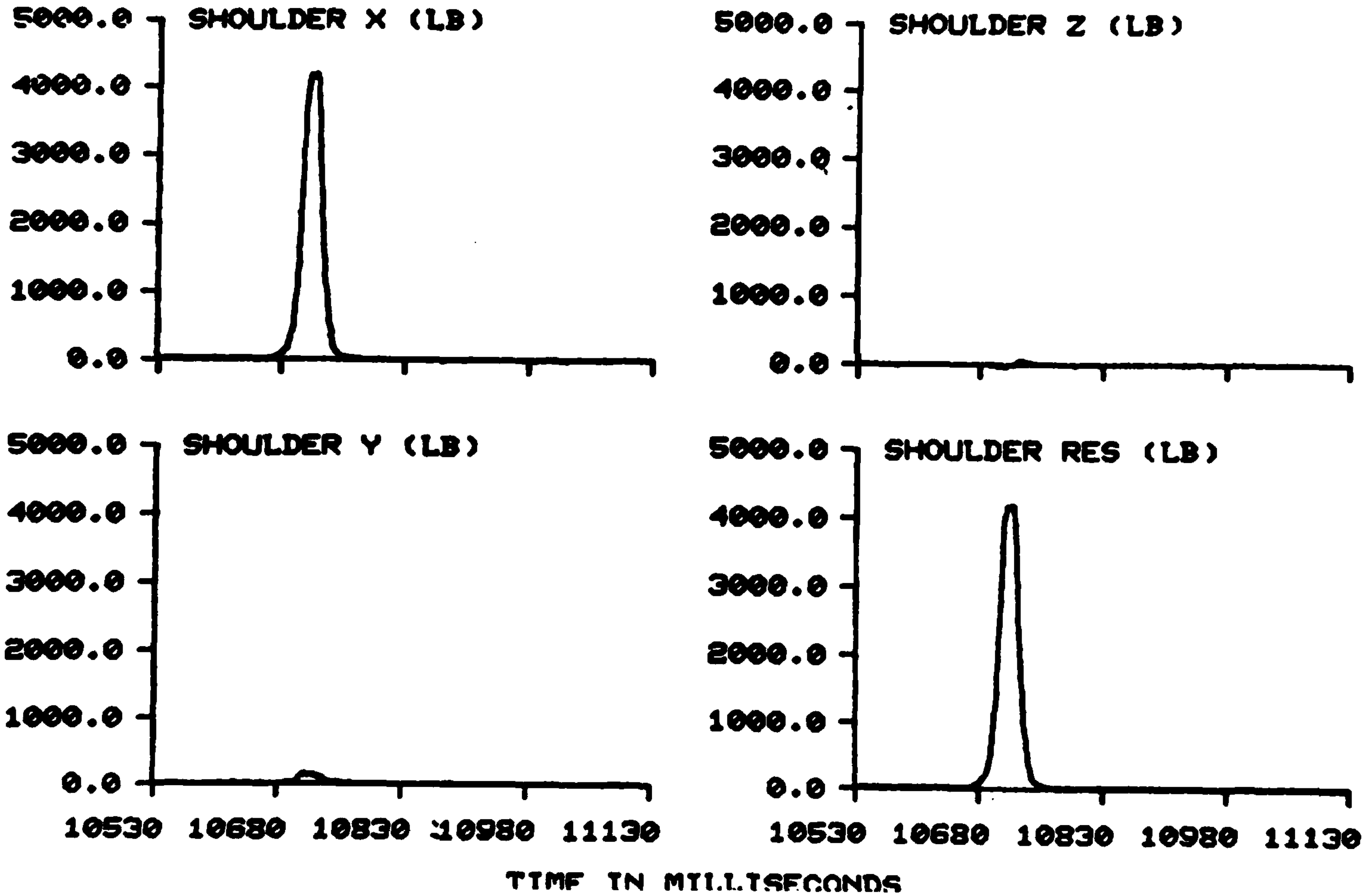
DATA ID	MAX	MIN	T1	T2	CH
TIME OF EVENT			10530.00		37
2.5V EXT PWR	2.50	2.49	4.00	280.00	47
10V EXT PWR	10.00	10.00	0.00	0.00	48
SHD PLD PRIOR EVENT	11.38		10430.00	10530.00	
LF LAP PLD PRIOR EVENT	13.87		10430.00	10530.00	
RT LAP PLD PRIOR EVENT	13.66		10430.00	10530.00	
SLED X ACCEL	0.49	-42.53	10839.00	10701.00	1
SLED X ACCEL (SM)	0.35	-42.18	10839.00	10703.00	
SLED Y ACCEL	9.69	-2.07	10675.00	10703.00	2
SLED Z ACCEL	8.14	-1.36	10727.00	10734.00	3
N-G STRAP	440.08	-2.70	10735.00	10964.00	30
SLED VEL (INT ACCEL)	0.00	-88.30	10530.00	10882.00	
SLED VELOCITY	0.24	-85.13	10837.00	10531.00	29
VEL AT EVENT		-85.13		10531.00	
SHOULDER LOAD X	4193.33	-19.96	10721.00	11074.00	23
SHOULDER LOAD Y	138.77	-9.09	10712.00	10953.00	22
SHOULDER LOAD Z	55.82	-47.22	10729.00	10706.00	21
SHOULDER RESULTANT	4195.29	0.51	10721.00	10640.00	
LF LAP LOAD X	5096.57	-10.73	10731.00	10544.00	15
LF LAP LOAD Y	1821.90	-10.18	10731.00	10597.00	16
LF LAP LOAD Z	4015.09	-2.03	10731.00	10599.00	17
LF LAP RESULTANT	6739.09	4.89	10731.00	10599.00	
RT LAP LOAD X	4602.75	-12.75	10727.00	10601.00	18
RT LAP LOAD Y	1901.94	-10.60	10727.00	10624.00	19
RT LAP LOAD Z	3788.15	-7.85	10727.00	10555.00	20
RT LAP RESULTANT	6257.22	7.99	10727.00	10612.00	

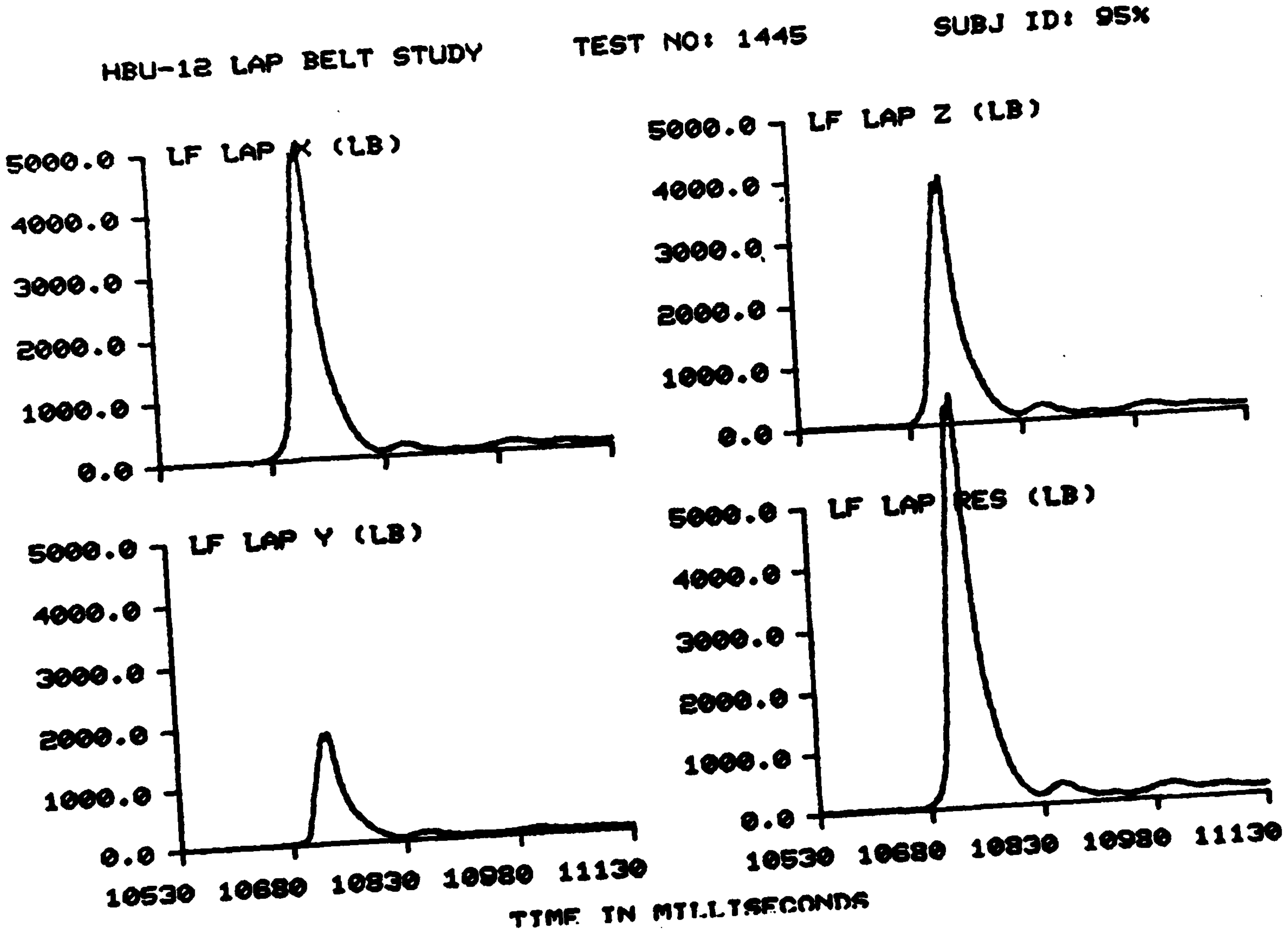
HBU-12 LAP BELT STUDY TEST NO: 1445 SUBJ ID: 95%



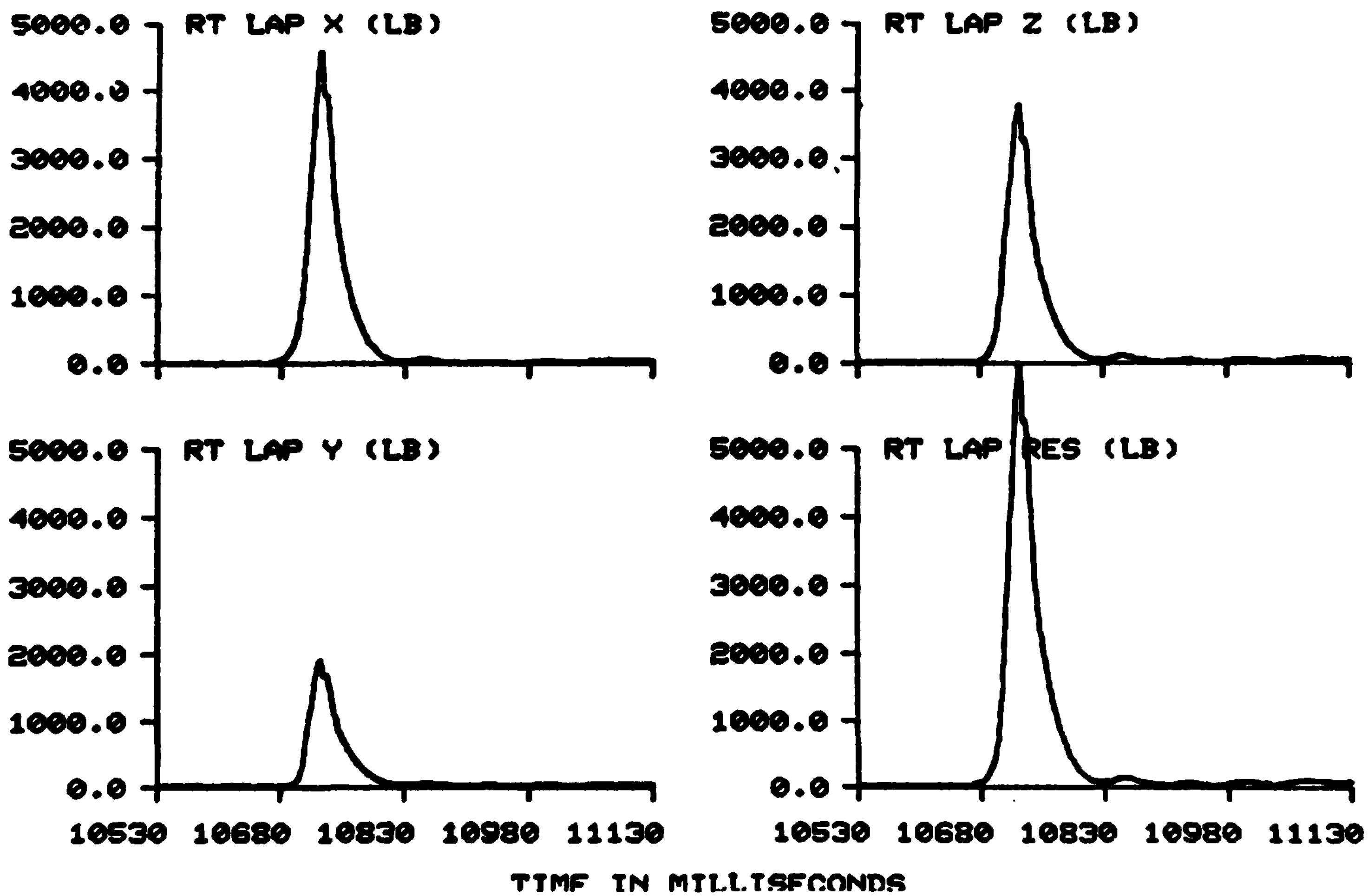

HBU-12 LAP BELT STUDY
TEST NO: 1445
SUBJ ID: J5%
SLED INT VEL (F/S)
SLED VELOCITY (F/S)
20.0
0.0
-20.0
-40.0
-60.0
-80.0
-100.0
10530
10680
10830
10980
11130
TIME IN MILLISECONDS

HBU-12 LAP BELT STUDY TEST NO: 1445 SUBJ ID: 95%




HBU-12 LAP BELT STUDY
TEST NO: 1445
SUBJ ID: 95%
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
10530
10680
10830
10980
11130
TIME IN MILLISECONDS

HBU-12 LAP BELT STUDY TEST NO: 1445 SUBJ ID: 95%



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