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ATD BIODYNAMIC RESPONSE DURING LATERAL IMPACT USING THE HORIZONTAL IMPULSE ACCELERATOR

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14. ABSTRACT Research was conducted involving a series of impact tests on the HIA in a lateral impact orientation as part of a collaboration between AFIT and the 711th Human Performance Wing under AFRL. The purpose of the tests was to conduct an assessment of the biodynamic response of a ATD for the development of neck injury criteria. Testing was completed using a 50th male Hybrid III aerospace ATD. A specially designed test matrix was developed to assess ATD response as a function of various seat configurations which were an approximation of the seat configurations used by MCW for lateral impact tests of PMHS subjects. The lateral seat configurations were a rigid seat with a 5 pt harness and a padded seat with a 3 pt harness, and the input acceleration pulses were trapezodial in shape and varied in peak magnitude from 8.5 to 17 G. The rigid and padded seat configurations both had the assessed parameters generate fairly linear responses across the input acceleration range. The rigid seat had small standard deviations and the padded seat had larger standard deviations for the assessed parameters. The ATD's response with the padded seat and the 3 pt restraint was greater than the ATD's response with the rigid seat and the 5 pt. restraint by a factor or 2, and the upper neck My torque showing the greatest increase from the rigid seat configuration to the padded seat configuration. This highlights the importance of a proper restraint and the importance of controlling the motion of the torso since it could reduce the loads and torques of the unrestrained head and neck resulting in a lower probability of injury. Injury risk as determined by MANICy exceeded the AFRL limit at input accelerations of 12.5 G and greater. The lateral testing of the ATD will provided critical impact data to fill data gaps and continue the development of the MANICy neck injury criteria, and will also be used to support the development of the critical ATD-to-human transfer functions for the MANIC neck injury calculations.

15. SUBJECT TERMS AFIT, Lateral Impact Response, Horizontal Impulse Accelerator, 50th Male Hybrid III Aerospace ATD, Rigid Seat, Padded Seat, 5 pt. Restraint, 3 pt. Restraint, Head Biodynamics, Neck Injury Criteria, MANICy

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1.0 OVERVIEW

The Aircrew Biodynamics and Protection (ABP) team under the Applied Neuroscience Branch (711 HPW/RHCP), and their in-house technical support contractor, Infoscitex, recently conducted a series of impacts on the Air Force Research Laboratory (AFRL) Horizontal Impulse Accelerator (HIA). The purpose of the tests was to conduct a technical assessment of the biodynamic response of an instrumented anthropomorphic test device (ATD) subjected to lateral impact in various seat configurations. The effort will support current ABP research focused on the development of injury criteria for airmen exposed to impact in extreme operational environments.

The experimental effort was conducted using a lateral or +Y axis impact configuration and a generic rigid seat structure mounted on the HIA sled. A 50th Hybrid III Aerospace instrumented ATD was used in this test program to simulate human response. Data collection on the HIA consisted of sled accelerations, seat accelerations, restraint loads, ATD head, chest, and lumbar/pelvis accelerations, ATD neck loads and moments, lumbar loads and moments, and high speed video. The data will be used to support the development of the Multi-Axial Neck Injury Criteria (MANIC) in collaboration with AFIT, as well as support the efforts developing ATD computational models.

This effort is an internal research program funded by the USAF, Air Force Research Lab, 711th Human Performance Wing, Airman Systems Directorate. The horizontal impact facility is located in Building 824, Area B, Wright-Patterson Air Force Base, Ohio, and was operated by the Aircrew Biodynamics and Protection team and it's technical support contractor, IST, under the Aerospace Physiology & Performance Section, Applied Neuroscience Branch, Warfighter Interface Division, 711th Human Performance Wing (711 HPW/RHCPT).

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2.0 BACKGROUND

In the early design of escape systems and other pilot safety related technology, emphasis was placed on reducing the acceleration imparted to the lower back of the pilot during the catapult phase of ejection. This was accomplished through the development of injury criteria known as the Dynamic Response Index or DRI (Stech & Payne, 1969; Brinkley & Shaffer., 1970). The risk of spinal injury calculated using the DRI is based on describing the biodynamic response of the human torso in terms of the displacement of the mass of a simple lumped-parameter, mass-spring-damper mechanical system. The system can be represented by a second order differential equation, which can be used to calculate the magnitude of deflection in the human spinal column. The maximum value of the deflection relates the tolerance of the human spine to an impact acceleration pulse. Typically, the DRI was restricted to a value of 18 or less which equated to a probability of spinal injury of 5% or less.

With the push for helmet mounted technology in the late 1980's, it became necessary to develop some form of a neck injury criterion to limit the risk of injury during ejection if a Helmet Mounted Device (HMD) was being used. In 1993, the US Air Force Research Laboratory (AFRL) developed an Interim Neck Injury Criteria which limited the total head supported weight and the resultant head/helmet center of gravity relative to the head's anatomical axis origin. This was developed using a combination of data from literature reviews, and data collected during an extensive series of vertical impacts at AFRL with instrumented human subjects and special helmet that was designed to allow varying weight and center-of-gravity configurations. The AFRL research conducted in the 1990's and early 2000's focused on studies performed with human subjects in accelerative environments which repeatedly demonstrated significant increases in neck loads when the subjects were wearing an HMD when exposed to the same input acceleration pulse without wearing an HMD (Buhrman & Perry, 1994; Perry & Buhrman, 1995, Perry & Buhrman, 1996; Perry, 1998). Research on heavy helmet systems with an off-axis center of gravity (CG) produced increased neck loading which in an ejection environment could lead to injuries that could range from low severity strains and muscle tears to high severity cervical spine fractures and ligament ruptures (Buhrman & Perry, 1994; Perry, Buhrman, Doczy, & Mosher, 2003; Doczy, Mosher & Buhrman, 2004).

In addition to the laboratory testing, dynamic loading of the cervical spine observed by AFRL in ATD necks during simulated pilot ejections, parachute deployment, and other scenarios conducted in the late 1990's, indicated very large values of tensile load as referenced to current criteria in the literature. These tests indicated tensile loading rates from 5,000-10,000 lb per second with peak loads in excess of 300 lb for the ADAM (Hybrid III) neck. Despite the potential for serious and even fatal injuries due to dynamic tensile loading of the cervical spine, little has been reported on the failure limits of the human neck under these conditions. As a result, AFRL developed a Tensile Neck Injury Criteria in 2000 that related a measured tensile neck load to the probability of a serious injury using a logistic curve (Carter, Pellettiere, Perry & Wilson, 2000). The AFRL curve was based on human volunteer impact test data and cadaver data properly scaled for age and tissue type (cadaver vs live). The curve was then scaled again to account for size differences. Also at that time, the currently accepted neck injury risk criteria were the Mertz Criteria for automotive ATDs used by the Society of Automotive Engineers (SAE), and the Nij Neck Injury Risk Criteria developed by National Highway Transportation and

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Safety Administration (NHTSA). These criteria have limitations. The Mertz criteria were based on a load duration function related to a single probability of injury or a "pass/fail criteria." The Nij criterion combined only axial neck loading and flexion and extension measurements, and was developed primarily as a risk factor for automotive airbag deployments.

As a result of these limitations, AFRL initiated a multi-faceted program in 2001 to provide criteria to design safe and comfortable crew protection systems for the head and neck. The program addressed multi-axial neck loading in terms of tensile loads, compressive loads, shear loads, and neck torques associated with head yaw, pitch, and roll. It was proposed to develop a series of probability of risk curves to address these different loading modes using non-failure human impact response data, and cadaver test data from impacts conducted on specimens until their failure (ligamentous rupture or bony failure).

In order to make sense of the multi-axial response of the neck in a dynamic environment, AFRL developed an injury risk indicator similar to the Nij used by the NHTSA, but involved all the modes of response and not just axial loading and torques resulting from pitching motion of the head. The new AFRL neck injury risk indicator was called the Neck Multi-axial Dynamic Response Criteria or NMDRC, and would combine all modes of neck loading.

$$NMDRC = \sqrt{\left(\frac{Fx}{Fxcrit}\right)^2 + \left(\frac{Fy}{Fycrit}\right)^2 + \left(\frac{Fz}{Fzcrit}\right)^2 + \left(\frac{Mx}{Mxcrit}\right)^2 + \left(\frac{My}{Mycrit}\right)^2 + \left(\frac{Mz}{Mzcrit}\right)^2} \quad (1)$$

Critical response values below each measured force and torque are taken from the probability risk curves for each individual loading method that are being developed using non-failure and cadaver failure data. Acceptable values of the NMDRC indicator would be determined through calculation of values using non-injury multi-axial neck loads resulting from human volunteer impact tests, and from injurious multi-axial neck loads resulting from whole cadaver or cadaver head-neck-torso segment impact tests. Calculation of the failure and non-failure NMDRC indicator values would result in a final probability of risk function relating probability of risk to the NMDRC indicator similar to the DRI value for the lower spine.

More recently, the new Joint Strike Fighter (JSF) F-35 aircraft will use a Martin-Baker Mk-US16E ejection seat which is expected to accommodate the full range of aircrew (103-245 lb). However, preliminary rocket sled qualification tests of this seat have shown that the neck forces and head rotations as measured in instrumented ATDs may be unacceptably high for small human occupants.

As a result, AFRL and AFIT initiated a collaboation in 2013 to re-energize the development of new criteria with a primary goal to emphasize research to develop an acceptable method to improve aviation-specific, neck injury criteria for aircraft ejection, as well as applicable metrics for the criteria. The initial efforts by AFIT (Parr, Miller, Pellettiere, & Erich, 2013; Parr, 2014; Zinck et al., 2016) laid the groundwork for the development of new USAF neck injury criteria identified as AFRL Multi-Axial Neck Injury Criteria or MANIC which is the new term used for the NMDRC.

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One of the results of this research collaboration was the identification of several gaps in the data required to develop and implement the MANIC criteria, and one such gap was the requirement for additional ATD lateral impact tests (Gy). The results of these Gy tests will be analyzed and used in conjunction with human, Post Mortem Human Subject (PMHS), Hybrid III ATD, and EuroSid 2 (ES2) ATD lateral impact data to establish the ATD-to-human transfer equations for the lateral impact portion of the MANIC injury criteria model.

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3.0 OBJECTIVES

The primary purpose of this effort was to conduct instrumented ATD tests to collect lateral impact response data to fill a gap in neck load and angular head acceleration data required for MANIC. A secondary objective was to collect ATD biodynamic response data for development of computational models.

The critical questions to be addressed by the test data were:

a. What is the response of the ATD as a function of impact level, restraint configuration, and lateral seat configuration? Is the response linear?
b. Can linear and angular head/neck acceleration data from the Hybrid III Aerospace 50^{th} ATD be used to complete the gap in the Gy MANIC model?
c. Can Hybrid III 50^{th} Aerospace data collected under identical conditions be used to finalize the lateral response of the current Aerospace 50^{th} ATD FE model?

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4.0 TEST FACILITY AND EQUIPMENT

4.1 Horizontal Impulse Accelerator

The Horizontal Impulse Accelerator or HIA (Shaffer, 1976; Strzelecki, 2006) was used to conduct the lateral impact tests to evaluate ATD acceleration response and ATD neck and spine loading during the variouis acceleration exposures. The ATD was restrained in a rigid 90-90-90 seat with lateral support plates that was developed for high-energy impact testing.

The HIA, shown in Figure 1, consists of a thrust pistion, a test sled, and track rails. The 4x8 ft sled is positioned on 160 feet of twin-rail track and the sled was accelerated from a stationary position by the thrust piston housed in a pneumatic actuator. The HIA actuator operates on the principle of differential gas pressures acting on both surfaces of the thrust piston in the actuator (24 inch diameter cylinder). The impact acceleration occurs at the beginning of the experiment as stored high-pressure air is allowed to impinge on the back-side surface of the thrust piston in-side the actuator. The thrust piston is held in place in-side the actuator by a lock-yoke. At t=0 sec following a count-down, the lock-yoke is released causing the high-pressure air to move the thrust piston and accelerate the sled down the track. As the sled breaks contact with the thrust piston, the sled coasts to a stop due to friction, or is stopped with a pneumatic brake system mounted beneath the sled. The acceleration pulse imparted to the sled depends on the pressure differential within the actuator (set pressure and load pressure), the volumes of the pressure chambers within the actuator (set length and load length), and the shape of the metering pin. HIA metering Pin #4 was used for this test program. It is also possible to increase the onset rate of the acceleration pulse by applying glide brakes from the start of impact.

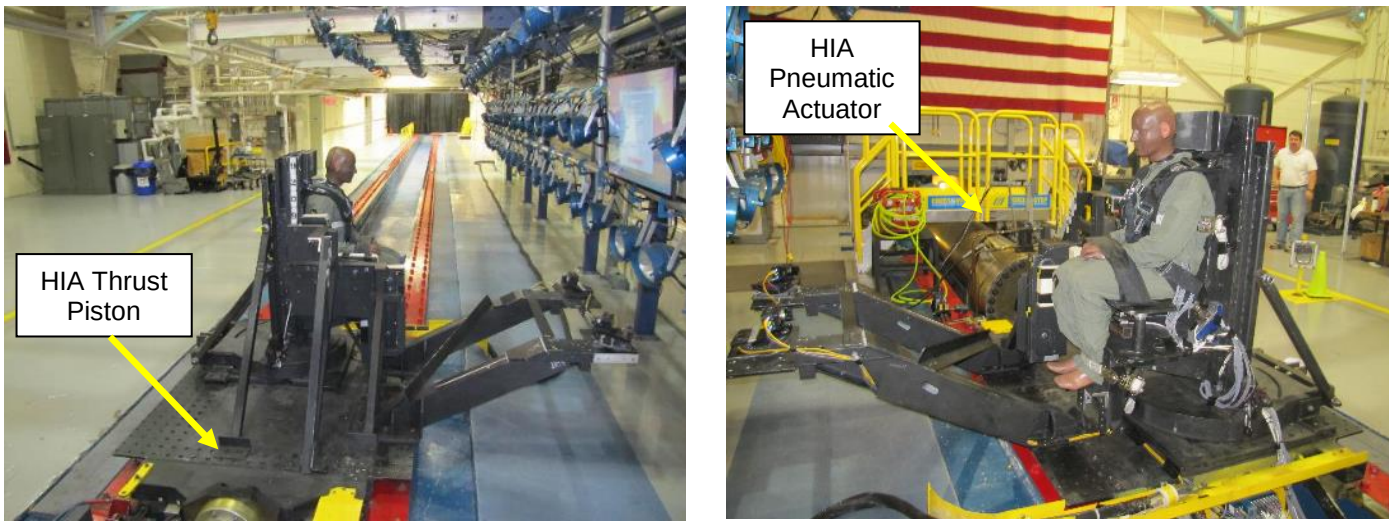

Figure 1. 711 HPW Horizontal Sled Facility

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4.2 HIA Configuration

A specially designed test fixture to hold the rigid 90-90-90 seat was mounted to the front of the HIA multi-axial test buck attached to the top of the HIA sled. The test buck allows any seat to be positioned at multiple angles in both yaw (0° to 180°) and pitch (0° to 90°) relative to the thrust piston at the front of the sled. The test buck pitch was set at 0° such that the seat was in a pure vertical or upright orientation, and the test buck yaw was set at 90° relative to the thrust pistion such that the seat was oriented to be perpendicular to the light rack and the sled-mounted cameras. This seat orientation is shown in Figure 2.

The positive axis of the coordinate system for the test configuration for this program was defined with respect to the plane of the seatback of the seat fixture mounted on test buck on the top of the HIA sled. Therefore, the coordinate system moves with respect to the test buck as the seat is positioned in yaw or pitch. The coordinate system for this test series is also shown in Figure 2.

Figure 2. Orientation of Rigid Seat Mounted on HIA Test Buck

4.3 Rigid Seat

The test program used a specially designed 90-90-90 rigid seat fixture (angle between seat back plane and seat pan plane is 90°, and angle between seat pan plane and lower leg/foot support is 90°). The seat back was composed of three rigid plates (including the headrest plate) that could be adjusted up or down in the vertical plane. Each seat back plate also provided an adjustable

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position in the horizontal plane using a stackable puck system. The seat pan was a single plate with a center access to allow for termination of a center crotch strap while using a 5pt restraint configuration. The seat pan provided adjustable positioning in the vertical plane using a stackable puck system or rigid structures of variable length. The lower leg support provided a single foot support bar that could be positioned up or down in the vertical plane. The rigid seat fixture is shown in Figure 3.

A rigid plate was positioned on the right side of the seat fixture (towards the HIA piston) to provide lateral support for the ATD during impact. The back side of the rigid plate was supported by three seperate beam structures to prevent translational motion of the rigid lateral plate and the rigid seat structure during the lateral impacts. This set-up is also shown in Figure 3.

Figure 3. Rigid Seat (Left) and Lateral Support Structure (Right) on HIA Sled

- The test seat fixture was set-up in two different configurations for this test program. The first configuration was defined as the "Rigid Seat" configuration and consisted of the seat back and seat pan with no padding or cushions, and the rigid lateral plate with very high density felt padding at four different locations on plate. The high density felt was 2.0 inch thick, 32S1 felt from Bacon Felt Company in Rochester, NH (32 lb density was defined by Bacon Felt as the density for a 3x3 sq. ft. sample at 1.0 inch thickness) which was positioned at four different locations on the lateral plate to prevent side-slip of the ATD: knee, upper leg, hip, and upper arm. The felt was attached to plates that were adjusted to allow contact with ATD at the defined points when the ATD was restrainted in the seat fixture. The rigid felt padding was used instead of bare aluminum plates to

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prevent damage to the ATD during impact. The felt padding is shown in Figure 4 (note: unable to see hip location).

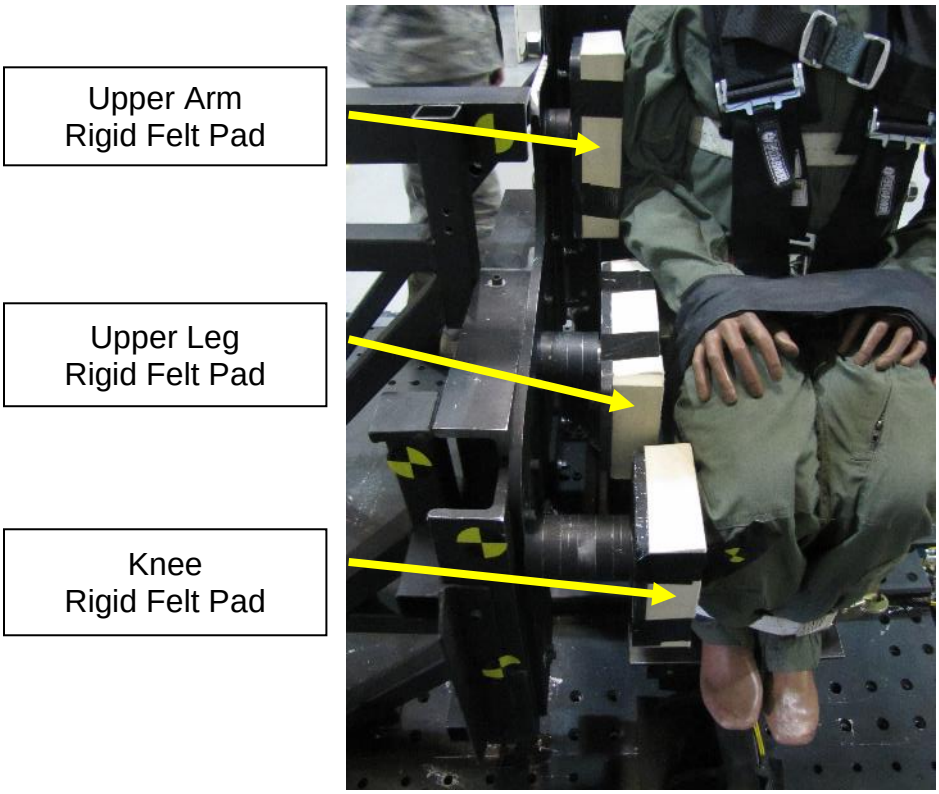

Figure 4. Seat Fixture in "Rigid Seat" Configuration Showing High Density Felt Pads

The second seat configuration was defined as the “Padded Seat” configuration, and consisted of the seat back with a 2.5 inch thick pad, the seat pan with a 5 inch thick seat cushion, and the rigid lateral plate with very low density foam pad cut to fit the approximate shape of the lateral side plate. The very low density foam pad was approximately 4 inch thick, and was to provide as much contact area as possible on the ATD from ankle up to the shoulder area. The cushions and foam padding are shown in Figures 5 and 6.

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Figure 5. Seat Fixture in "Padded Seat" Configuration Showing Seat Cushions

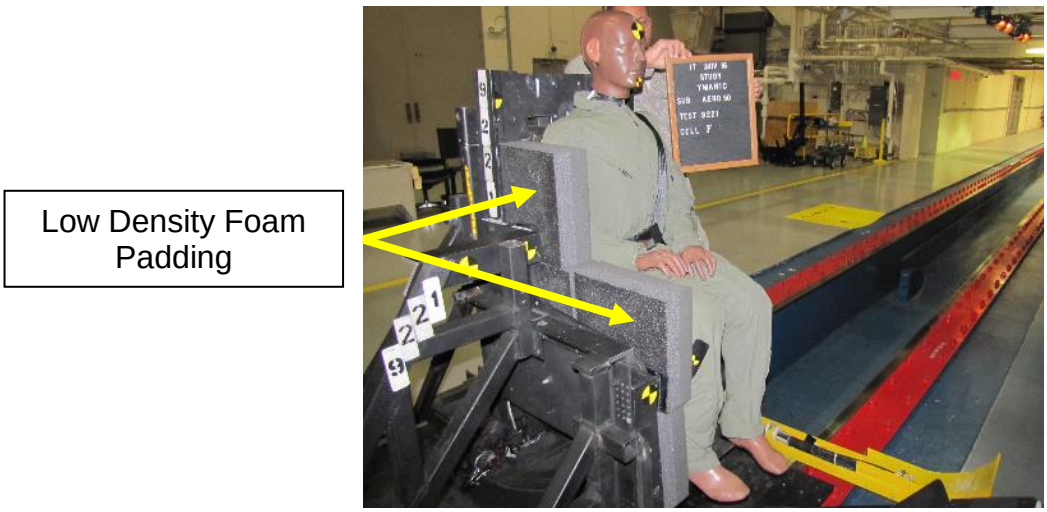

Figure 6. Seat Fixture in "Padded Seat" Configuration Showing Lateral Foam Padding

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4.4 ATD and Flight Equipment

All tests were conducted with an instrumented 50th Hybrid III aerospace ATD. The ATD was dressed in a standard USAF flight suit, and did not wear flight boots. The instrumented ATD had an approximate test weight of 161 lb. A few tests were also conducted with the ATD wearing an HGU-55/P flight helmet with a MBU-20/P oxygen mask, and which increased the approximate test weight up to 164 lb.

4.5 Restraint Systems

The test ATD was restrained using a different restraint configuration based on the seat configuration. The "Rigid Seat" configuration used a 5 pt. restraint harness manufactured by ProArmor with each 3 inch webbing strap having its own adjustor, and with each strap terminating at rigidly mounted load cells on the seat structure. In addition to the ProArmor restraint, the ATD's upper torso and lower legs were also restrained by cargo straps, and the arms were restrained to the upper legs using an industrial Velcro strap. The "Rigid Seat" restraint set-up is shown in Figure 7.

The "Padded Seat" configuration used a 3 pt. restraint harness which consisted of standard automotive 2 inch webbing straps with the shoulder strap positioned over the shoulder of the ATD that was opposite or away from the point of impact on the sled (ATD's left shoulder for this study). The 3 pt. restraint also had each strap terminating at rigidly mounted load cells on the seat structure. The "Padded Seat" configuration did not use additional cargo or Velcro straps. The "Padded Seat" configuration is shown in Figure 8.

For all tests, the seat pan was adjusted such that the shoulder straps were parallel to the horizontal (or close to parallel) and the ATD's head was approximately centered in the headrest. After all the restraint straps were adjusted to remove excess slack, the facility technician tightened the lap belts securely with pre-tension levels of 20 ± 5 lb measured by the restraint termination load cells attached to each strap/belt. The facility technician then tightened the shoulder strap(s) to obtain 20 ± 5 lb of tension as measured on each strap by the restraint termination load cells.

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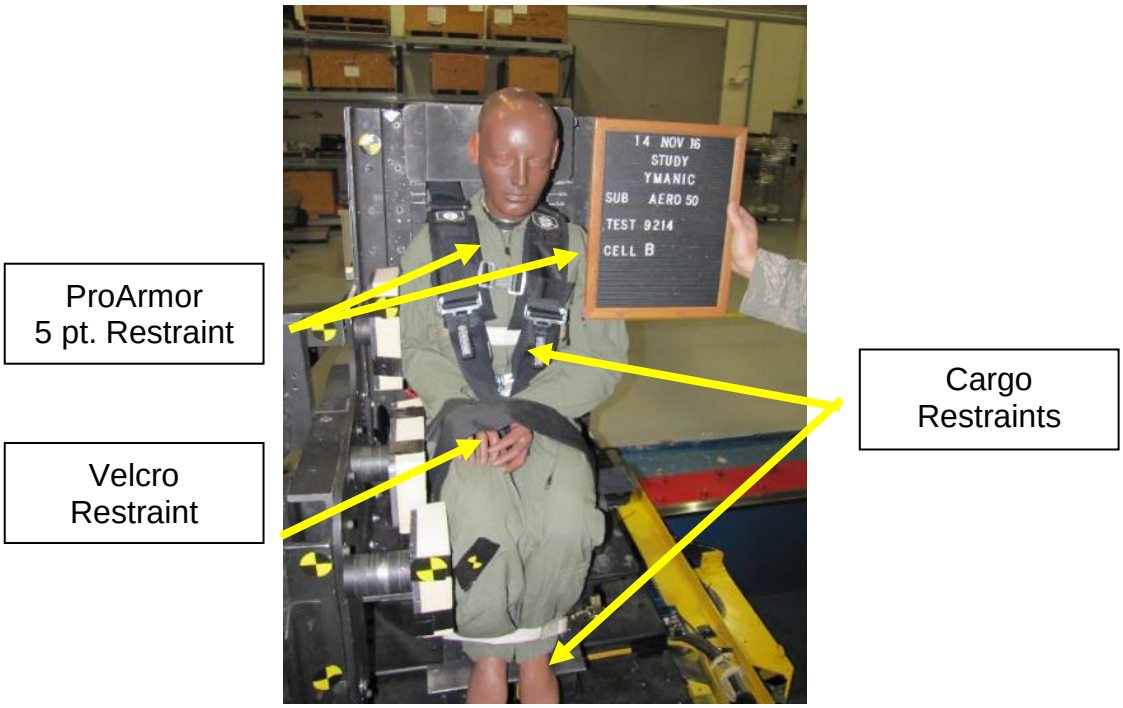

Figure 7. Restraint System used for "Rigid Seat" Configuration

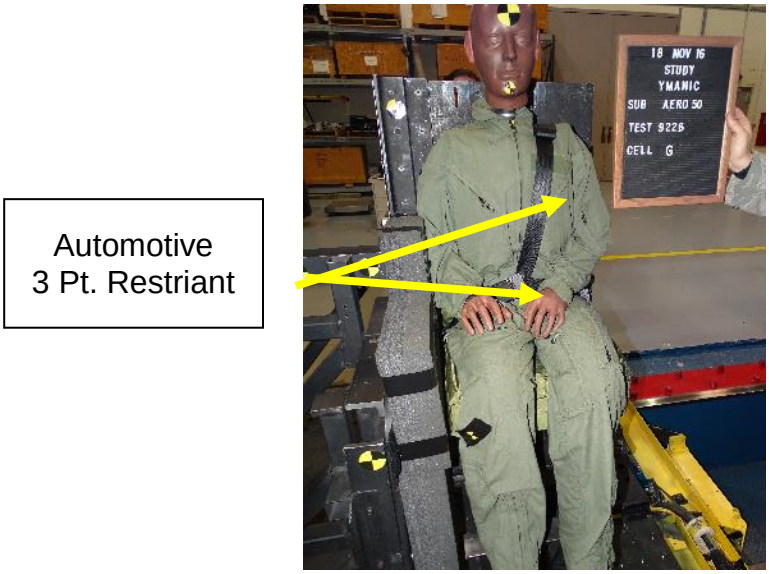

Figure 8. Restraint System used for "Padded Seat" Configuration

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5.0 INSTRUMENTATION AND DATA COLLECTION

Transducers were chosen to provide the optimum resolution over the expected test acceleration ranges. Full-scale data ranges were selected to provide the expected full-scale range plus 50% to assure the capture of peak signals. All transducer bridges were balanced for optimum output prior to the start of the program. The appropriate accelerometers were adjusted with software for the effect of gravity by adding the component of a 1 G vector in-line with the force of gravity along the accelerometer axis (z-axis or combined z-axis/x-axis depending on seat back angle).

This research effort used the Right-Hand Rule coordinate system (shown in Figure 1) with the z-axis parallel to the seat back and perpendicular to the top of the HIA sled. The x-axis is perpendicular to the z-axis and points out away from the seat fixture. The y-axis is perpendicular to the x- and z-axes according to the right-hand rule. The linear accelerometers were wired to provide a positive output voltage when the acceleration experienced by the accelerometer was applied in the +x, +y and +z directions.

The ATD coordinate system used was the standard AFRL impact facility system with positive z-axis acceleration up. The following critical parameters were measured as follows: Neck tension load was measured as positive, neck compression load was measured as negative, flexion (head rotation forward) was measured as positive, and extension (head rotation rearward) was measured as negative.

5.1 Facility Instrumentation

The HIA sled was instrumented with a tri-axial linear accelerometer package mounted on the bottom of the sled deck. The tri-axial accelerometer package consisted of three Measurement Specialties (MEAS SPEC) EGCS-S425-250 accelerometers. A tri-axial accelerometer package was also mounted on the seat pan close to the seat reference point, and consisted of three Entran Model EGV3-F-250 accelerometers.

The restraint configuration was instrumented with five specially designed three-axis load cells mounted at the termination points of the shoulder straps and the lap belts, and at the termination point of the crotch strap. Each load cell was a Michigan Scientific Model TR3D-B-3K.

5.2 ATD Instrumentation for 50th Hybrid III Aerospace

The ATD was instrumented with tri-axial accelerometer packages located in the head, chest, and pelvis, a tri-axial angular rate sensor in the head, a single axis angular accelerometer in the chest, and with 6-axis load cells (3 orthogonal linear forces, 3 orthogonal moments) in the upper neck and the lumbar spine/pelvis junction. The critical accelerations for this effort were the head z-axis acceleration, head x-axis acceleration, and the head angular rates (Rx, Ry, and Rz). The critical bending moment for this effort was the bending moment that measured lateral flexion of the head on the neck (Mx), and the bending moment that measured flexion and extension of the head on the neck (My).

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The ATD's head was instrumented with a tri-axial linear accelerometer package and a tri-axial angular rate sensor package measuring rotational rate around the head x, y, and z-axis. The tri-axial accelerometer package was composed of three MEAS SPEC Model EGCS-S425-250 linear accelerometers. The tri-axial angular rate sensor package was composed of three Diversified Technical Systems (DTS) Model ARS-8K angular rate sensors.

The ATD's chest and lumbar/pelvis junction were instrumented with a tri-axial accelerometer package composed of linear accelerometers. The chest tri-axial package was composed of three MEAS SPEC Model EGCS-S425-250 linear accelerometers. The lumbar tri-axial package was also composed of three Entran Model EGV3-F-250 linear accelerometers.

The ATD's upper neck was instrumented with a Denton Model 1716A 6-axis load cell which measured the axial loads and angular torques in the three orthogonal axes. In addition, the lower neck was instrumented with a Denton Model 1794AJTF 6-axis load cell. The ATD's lumbar spine was instrumented with a Denton Model 1914A 6-axis load cell.

5.3 Transducer Calibration

On-site personnel from Infoscitex, Inc., conducted pre- and post-calibrations on all sensors used on the carriage and seat fixture. Calibration records of individual transducers as well as the Standard Practice Instructions are maintained in the biodynamic facility's Impact Information Center. For this test program, a record was made identifying the data channel, transducer manufacturer, model number, serial number, date and sensitivity of pre-calibration, date and sensitivity of post-calibration, and percentage change. Pre- and post-calibration information is maintained with the program data. The instrumentation used in this study is listed in the Electronic Instrumentation Data Sheets (See Appendix A).

5.4 Data Acquisition Control

The Master Instrumentation Control Unit in the Instrumentation Room located between the HIA and the Vertical Deceleration Tower (VDT) impact facilities controlled the data acquisition. A test was initiated when the countdown clock reached zero using a comparator. The comparator was set to start data collection at a pre-selected time based on a positive reading of multiple safety inter-lock sensors used by the facility to protect the facility operators and for when human test subjects were used. Data were recorded to establish a zero reference for all transducers prior to restraining the ATD to the seat fixture. The reference data were stored separately from the test data and were used in the processing of the test data. A reference mark pulse was generated to mark the electronic data at a pre-selected time after test initiation to place the reference mark close to the impact point. The reference mark time was used as the start time for data processing of the electronic data.

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5.5 Data Acquisition System

This research program used two Test Data Analysis System (TDAS) G5 Data Acquisition Systems (DAS) manufactured by DTS Inc., to collect all the facility, seat fixture and ATD data for each test as defined by the test matrix. Each TDAS G5 was a 32 channel DAS, and was mounted on-board the HIA at the back of the sled (Figure 9). The TDAS G5 is a ruggedized, DC powered, fully programmable signal conditioning and recording systems for transducers and events. The TDAS G5 was designed to withstand a 100 G shock.

The signal conditioning accepts a variety of transducers including full and partial bridges, voltage, and piezo-resistive sensors. Transducer signals were amplified, filtered, digitized and recorded in onboard solid-state memory. The data acquisition system was controlled through an Ethernet interface using the Ethernet instruction language. A desktop Personal Computer (PC) with an Ethernet board configures the TDAS G5 before testing and retrieves the data after each test. For this program, the Data Acquisition System (DAS) collected data at a 1K sample rate and filtered at 120 Hz.

Figure 9. Location of TDAS G5 Data Collection Systems Mounted on HIA Sled

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5.6 Quick Look Data Plots

After each test, the filtered data were graphically plotted in a portrait format of 4-6 plots per page, and grouped with similar channels. The spreadsheet of plots also contained pertinent maxima, minima, and respective times of each occurrence. For all data, time = 0 was at initial carriage motion. The plots arranged in this fashion included: displacement versus time, force (load) versus time, and acceleration versus time.

5.7 High Speed Video and Photography

Two Phantom Miro-3 High-Speed digital cameras (Figure 10) were used to collect video of each test. Two cameras were mounted on-board the HIA sled in a test fixture relative to the frontal plane of the ATD (in-line with, and at an oblique angle relative to the x-axis of the ATD) to record the ATD motion. These locations are shown in Figure 11.

The Phantom Micro line is a compact, light-weight, rugged family of cameras targeted at industrial applications ranging from biometric research to automotive crash testing. Rated to survive 100g acceleration this rugged camera can take 512 x 512 images at up to 2200 frames-per-second (fps). Frame rates greater than 95,000 fps can be achieved with a reduction of the resolution to 32 x 32. The Miro-3 has a number of external control signals allowing for external triggering, camera synchronization, and time-stamping. The camera has both dynamic Random Access Memory (RAM) and internal flash memory for non-volatile storage. Internal battery power allows the camera to be used in an un-tethered mode and ensures data survivability in both RAM and flash memory in case of loss of power.

The images for this study were collected at 500 fps. The video files were downloaded and converted to either a MP4 or AVI format, and stored in the Collaborative Biomechanics Data Bank (CBDN). Photographs were taken of the test set-up prior to each test. Photographic and video data were stored on an internal network for downloads as requested. Selected photos used to document each test are shown in Appendix B.

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Figure 10. Phantom Miro-3 High-Speed Digital Camera

Figure 11. Phantom Miro-3 Cameras Mounted On-board HIA Sled

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6.0 EXPERIMENTAL DESIGN

6.1 Test Matrix

A specially designed test matrix was developed addressing the program requirement to conduct an assessment of lateral impact response of the 50th Hybrid III Aerospace ATD. The test matrix was developed to approximate the two test configurations that were used by the Medical College of Wisconsin (MCW) during lateral impact tests of both an EuroSID-2 lateral impact ATD and PMHS subjects (Philippens, Forbes, Wismans, DeWesse, & Moorcroft, 2011), and where the PMHS subjects developed injuries. The test matrix is shown in Table 1 showing the pulse configurations generated by the MCW test facility. An additional test cell was included to provide response data from the ATD with a standard USAF helmet and mask which will support the development of both injury and computational models.

One MCW configuration was a rigid seat with full thorax restraint using a 5 pt. harness, additional straps, and lateral support brackets. The second MCW configuration was an "aircraft seat" set-up with seat pan and seat back cushions, a 3 pt. restraint system, and lateral support foam. These are shown in Figure's 12 and 13 (Philippens, et al., 2011). The MCW tests had peak G levels that ranged from 8.5 to 17 G, velocity changes that ranged from 8.7 to 18 m/s (28.5 to 59.0 ft/s), and pulse durations that averaged around 100 ms. The AFRL input acceleration pulses were developed to produce similar peak G levels and velocity changes as the MCW pulses, and was also able to produce trapezoidal or rectangular pulses that were a close match to the MCW pulses. The sled pulses using HIA Pin 4 are shown in Figure 14 for each impact level.

Table 1. HIA Lateral Impact Test Matrix

Cell	Impact Level (G)	Velocity Change (ft/s)	Restraint Configuration	Seat	Side Support	Helmet
A	8.5	28.5	5-point	Rigid	Rigid Plates	None
A1	8.5	28.5	5-point	Rigid	Rigid Plates	HGU-55/P
B	10.5	37.4	5-point	Rigid	Rigid Plates	None
C	12.5	41.0	5-point	Rigid	Rigid Plates	None
D	15.5	59.0	5-point	Rigid	Rigid Plates	None
E	17.0	59.0	5-point	Rigid	Rigid Plates	None
F	8.5	28.5	3-point	Padded	Full Padded	None
G	10.5	37.4	3-point	Padded	Full Padded	None
H	12.5	41.0	3-point	Padded	Full Padded	None

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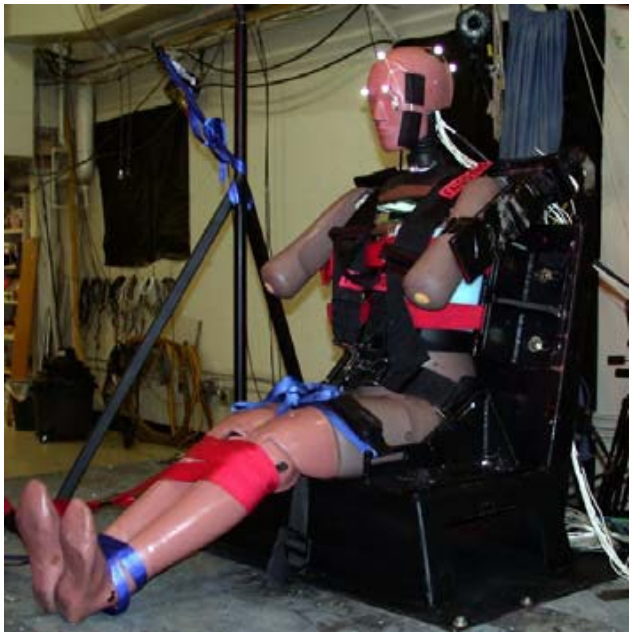

Figure 12. Setup for MCW Tests with Rigid Seat Showing Lateral Rigid Arm Support

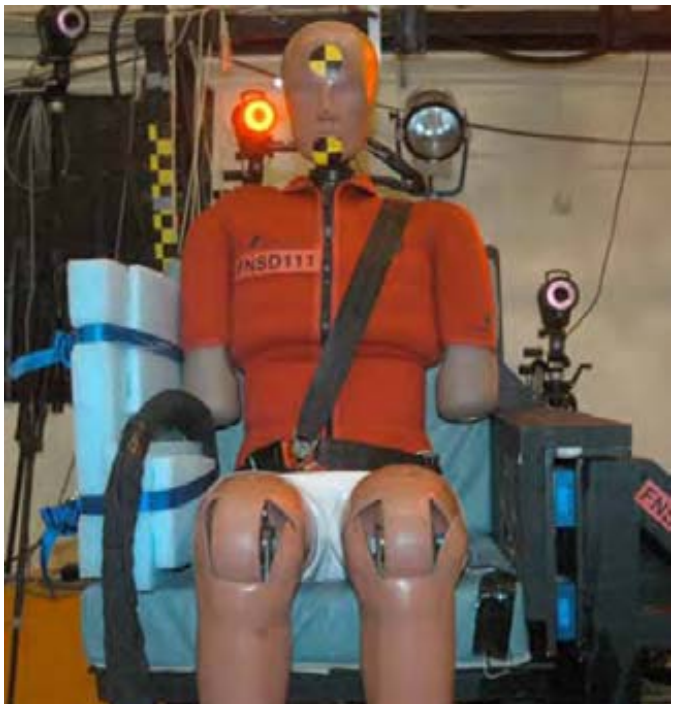

Figure 13. Setup for MCW Tests with Aircraft Seat Showing Lateral Foam Support

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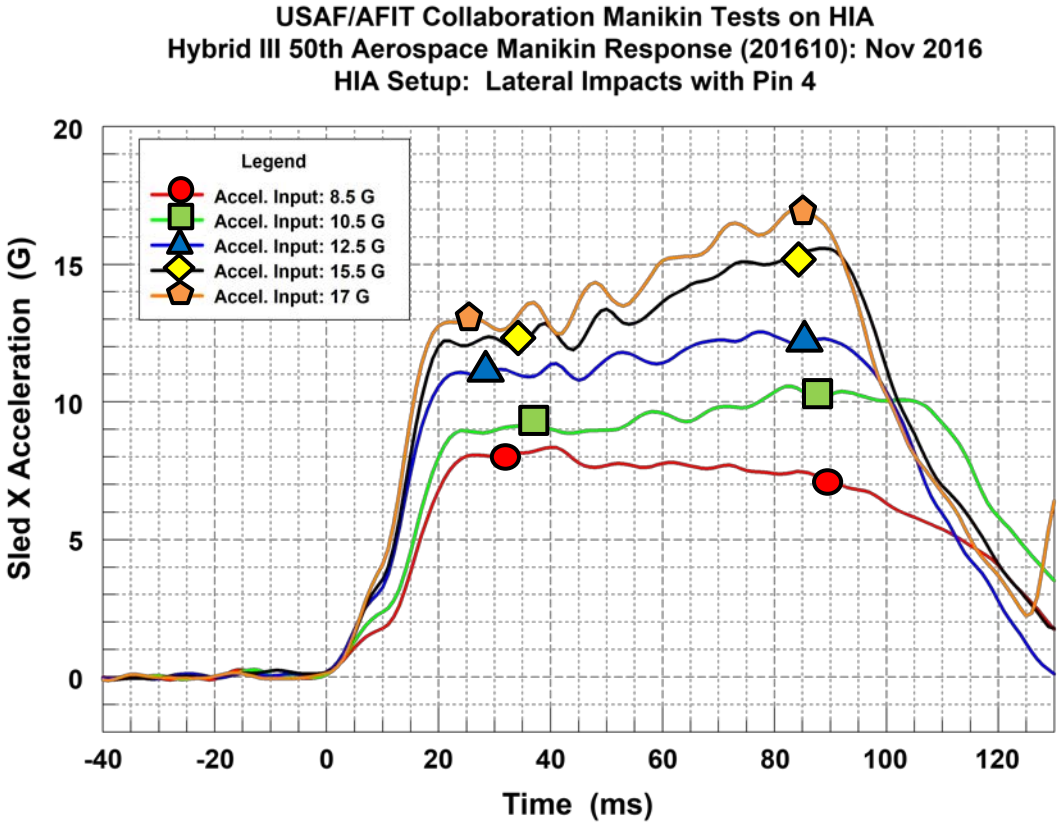

Figure 14. HIA Sled Pulses using Pin 4 for 50th Hybrid III Aerospace ATD Impacts

6.2 Risk Assessment Methodology

An initial assessment of head accelerations, neck loads & moments, lumbar loads and moments, and mask and helmet system interaction were conducted at the conclusion of each test. Analysis of the effect of head accelerations and neck and lumbar loads and moments on injury risk was conducted at the end of the test program.

An analysis of potential neck injury due to imparted loads and torques during the impact acceleration was assessed for some of the data using a neck injury risk assessment tool known as the Multi-Axial Neck Injury Criteria for lateral or y-axis input or MANICy. The MANICy is based on the Nij Neck Injury Criteria developed by National Highway Traffic Safety Administration (NHTSA), and the MANIC neck injury criteria currently being developed through a collaboration between AFRL and AFIT. The combined cervical force and neck moment limits are expressed as the MANICy, and calculated using measured loads and moments from the special six-axis load cell (3 orthogonal axial loads, and 2 of the 3 orthogonal rotational moments) mounted in the neck of the ATDs. Axial tension and compression loads are measured in the z-axis of the neck (inferior/superior direction). Flexion and extension moments of the neck are measured about the y-axis of the head/neck junction (flexion is forward motion of the head towards the chest, extension is rearward rotation of the head towards the back or shoulder

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blades). The y-axis of the head runs from right ear canal to the left ear canal with positive towards the left. This is shown in Figure 15.

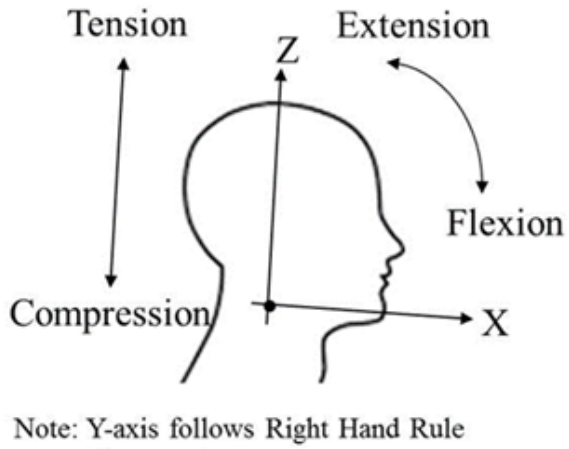

Figure 15. Neck Load and Torque Sign Convention

The combined cervical-force-and-moment value was calculated for each impact test. The peak AFRL MANICy limit for risk of injury in aerospace applications is 0.47 (Parr et al., 2013; Parr, 2014 for an Abbreviated Injury Scale (AIS) 2 injury at a probability level less than or equal to 5% (limit is 0.53 for AIS 3). The MANICy value was calculated throughout the time history of the impact test according to the following formula:

$$MANICy = \sqrt{\left(\frac{Fx}{Fxcrit}\right)^2 + \left(\frac{Fy}{Fycrit}\right)^2 + \left(\frac{Fz}{Fzcrit}\right)^2 + \left(\frac{My}{Mycrit}\right)^2 + \left(\frac{Mz}{Mzcrit}\right)^2} \quad (2)$$

where:

Fx = observed x direction shear loading
Fxcrit = critical intercept value for x direction shear loading
Fy = observed y direction shear loading
Fycrit = critical intercept value for y direction shear loading
Fz = observed axial loading (+*Fz* = tension, -*Fz* = compression)
Fzcrit = critical intercept value for axial loading (different for tension/compression)
My = observed moment about the anatomical y axis (sagittal plane anterior/posterior bending, +*My* = flexion, -*My* = extension)
Mycrit = critical intercept value for sagittal plane moments (different for flexion/extension)
Mz = observed moment about the anatomical z axis (neck twisting)
Mzcrit = critical intercept value for neck twisting

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The critical intercept values for MANICy calculation at C0-C1 for this program were based on the use of the male Hybrid III type ATD neck (Table 2).

Table 2. Critical Intercept Values for MANICy Calculation at C0-C1

	Critical Value
+ Fz Tension / -Fz Compression (lb)	1530 / 1385
Fx Shear (lb)	625
Fy Lateral Shear (lb)	625
+My Extension / -My Flexion (in-lb)	2744 / 1195
Mz Neck Twisting (in-lb)	1195

6.3 Test Procedures

The following test procedures were used for all the ATD tests on the HIA.

a. Zeros were taken for channel calibration prior to each test.

b. After the ATD was properly dressed and configured with the correct garment (suit, helmet as determined by test matix), mechanical checks were performed, the ATD was placed in the lateral seat mounted on the sled.

c. The ATD was positioned to make contact with lateral contact points, pads, plates on the lataeral seat configuration. Care was taken to align the sagittal plane of the ATD in the sagittal plane of the seat fixture (center line of headrest and seat pan). Pads and/or plates were adjusted as needed to provide firm support of the different areas on the right side of the manikn.

d. The ATD's hands were placed on its lap, and the upper arms were parallel to the seat back. As required, additional restraint (load straps, etc.) was positioned on the ATD's torso and lower legs to minimize motion. The restriants were then tightened starting with the lap belt (and crotch strap if present) followed by the shoulder belts.

e. Final checks were conducted to ensure that proper restraint fit and positioning were completed.

f. Still photographs were taken from the side and frontal views. Special photos were also taken of any specific changes from the previous test.

g. The test area around the HIA was evacuated and the Safety Officer checked all safety systems and assured that the test area is secured and ready for facility operation.

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h. The load chamber of the HIA cylinder was then pressured to a pre-determined pressure level to provide the proper impact level.

i. If all safety systems continued to be satisfactory, the Test Conductor instructed the HIA operator to start the automatic countdown and activate the release of the HIA thrust column at t = 0, and propelling the sled down the track.

j. After sled came to a stop, pictures were taken of the seat and ATD, and then the sled was pulled back to the starting position (the stationay position that has the sled in contact with the front of the thrust column).

k. As required, the ATD was removed from the seat. The the seat, restraint system, and all other flight equipment were inspected prior to the next test.

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7.0 RESULTS

Thirty five impact tests (including proof tests) were completed in support of this effort to characterize the biodynamic response of the 50th Hybrid III aerospace ATD to acceleration pulses in a lateral impact configuration. Data assessment will focus on affects of impact level and seat configuration on the biodynamic response of the ATD's head/neck.

7.1 HIA Repeatability

Two tests per test cell were conducted at a minimum to evaluate repeatability. The repeatability of the HIA impacts is shown below in Table 3 as a function of the impact level, time to peak impact level, and the velocity change. Even though there were two seat fixture configurations, it was determined based on previous experience that the minor wieght difference between them would have little affect on the sled pulse; therefore, the repeatability data includes the data from both seat configurations.

The peak acceleration level and velocity change summaries indicated that the HIA facility and impact environment were well controlled during the duration of the program with variation of less than 2.0 % and 4.0 %. The velocity changes achieved by the HIA were very close to the velocity changes achieved by the MCW facility, and this is shown in Table 4.

The rise time data sets demonstrated the most variability which is due to the shape of the pulse and the intrinsic noise on the signal due to the design of the HIA system (thrust pin shape and surface, internal wall friction, fluid friction and dynamics, etc.) beyond control. It should be noted that the 8.5 G impacts had the time-to-peak value towards the beginning of the pulses, and the 10.5 G through 17 G impacts had the time-to-peak values towards the end of the pulses, even though all the pulses were rectangular/trapezoidal in shape.

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Table 3. HIA Repeatability for +Y Seat Configuration

Test Cell	Seat Fixture Configuration	Peak Sled Acceleration (G)	Time-to-Peak Accel. (ms)	Velocity Change (ft/s)
A	Rigid	8.35	40.00	25.89
A	Rigid	8.33	36.00	26.52
A1	Rigid	8.59	37.00	26.56
A1	Rigid	8.41	35.00	26.68
B	Rigid	10.57	83.00	37.86
B	Rigid	10.66	83.00	38.97
C	Rigid	12.54	77.00	37.17
C	Rigid	12.64	78.00	36.90
D	Rigid	15.44	86.00	54.49
D	Rigid	15.58	89.00	55.92
E	Rigid	17.02	84.00	60.66
E	Rigid	16.99	85.00	60.58
F	Padded	8.54	39.00	28.06
F	Padded	8.70	40.00	27.70
G	Padded	10.42	88.00	38.43
G	Padded	10.52	93.00	38.97
H	Padded	12.43	74.00	37.77
H	Padded	12.46	82.00	38.77
8.5 G Impacts		8.49 ± 0.15	37.83 ± 2.14	26.90 ± 0.81
10.5 G Impacts		10.54 ± 0.10	86.75 ± 4.79	38.56 ± 0.53
12.5 G Impacts		12.52 ± 0.09	77.75 ± 3.30	37.65 ± 0.83
15.5 G Impacts		15.51 ± 0.10	87.50 ± 0.71	55.21 ± 1.01
17.0 G Impacts		17.01 ± 0.02	84.50 ± 0.71	60.62 ± 0.06

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Table 4. Velocity Change Comparison for AFRL and MCW Sled Facilities

Impact Level	AFRL Peak Sled Acceleration (G)	AFRL Sled Velocity Change (ft/s)	MCW Sled Velocity Change (ft/s)
8.5 G Impacts	8.49 ± 0.15	26.90 ± 0.81	28.5
10.5 G Impacts	10.54 ± 0.10	38.56 ± 0.53	37.4
12.5 G Impacts	12.52 ± 0.09	37.65 ± 0.83	41.0
15.5 G Impacts	15.51 ± 0.10	55.21 ± 1.01	59.0
17.0 G Impacts	17.01 ± 0.02	60.62 ± 0.06	59.0

7.2 Test by Test Summary

A review of the specific test configuration for each of the impact tests conducted on the HIA with the 50th Hybrid III aerospace ATD is documented with a test-by-test summary of the test conditions and a brief summary of the key data. Test numbers 9195 through 9208 were Proof tests conducted to determine the key facility parameters to meet the required pulses with HIA Pin 4. The remaining tests were conducted to address the test matrix. The test-by-test summary is shown in Appendix B.

7.3 Select Data Analysis: Rigid Seat Configuration

Immediately following each test, the "quick look" data was evaluated to determine the adequacy of the test. These data consisted of all acceleration and load measurement except those data that were computed (MANIC injury risk values, etc.). No further tests were performed until the quick-look data from the previous test had been printed out and given to the Test Conductor for review. Analysis of head accelerations, neck loads & moments, and injury risk assessment were conducted at the conclusion of the test program.

Data analysis focused on impact response of the ATD head's linear accelerations, rotational velocities, shear loads, and axial torques. The ATD loads and torques were modified by the software program ANALYZETEST (Version 1.1.5) which accounts for the offset of the head/neck load cell from the pivot point on the neck. ANALYZETEST also computed neck injury risk values. A summary of these selected acceleration and neck load metrics are shown below in Tables 5 and 6. Plots of these selected data sets are shown in Figures 16 and 17.

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Table 5. Rigid Seat: Head and Neck Acceleration Data

Test Cell	Impact Level (G)	Head Y-Axis Accel (G)	Head Z-Axis Accel (G)	Head Rx Angular Vel. (Rad/S)	Head Rz Angular Vel. (Rad/S)
A	8.5	13.08 ± 0.04	9.65 ± 1.84	16.95 ± 0.93	4.76 ± 0.42
A1	8.5	12.14 ± 0.67	8.67 ± 0.30	17.28 ± 0.42	4.57 ± 0.24
B	10.5	15.54 ± 0.90	12.58 ± 0.11	18.73 ± 0.32	5.16 ± 0.56
C	12.5	18.97 ± 0.06	16.69 ±0.01	23.57 ± 0.17	7.36 ± 0.20
D	15.5	21.77 ± 0.83	21.47 ± 1.57	26.20 ± 1.90	8.67 ± 0.70
E	17	23.02 ± 0.48	24.40 ± 0.91	28.07 ± 1.06	9.69 ± 0.72

Table 6. Rigid Seat: Neck Load and Torque Data

Test Cell	Impact Level (G)	Y-Axis Shear Load (lb)	Z-Axis Tension Load (lb)	Upper Neck +Mx Torque (in-lb)	Upper Neck +My Torque (in-lb)	Lower Neck Mx Torque (in-lb)
A	8.5	114.5 ± 1.5	83.3 ± 22.9	302.9 ± 11.0	53.7 ± 13.9	1339 ± 30.5
A1	8.5	130.4 ± 4.5	86.06 ± 2.2	370.6 ± 9.5	75.8 ± 1.8	1569 ± 48.5
B	10.5	131.8 ± 3.5	106.6 ± 4.6	356.6 ± 16.9	49.6 ± 4.1	1677 ± 46.2
C	12.5	163.2 ± 1.7	147.6 ± 0.30	454.0 ± 5.2	87.8 ± 2.2	2146 ± 14.5
D	15.5	183.0 ± 7.5	204.6 ± 13.1	521.9 ± 28.6	71.1 ± 3.3	2512 ± 112
E	17	198.9 ± 6.0	229.5 ± 0.5	581.8 ± 30.9	54.5 ± 1.2	2755 ± 59.3

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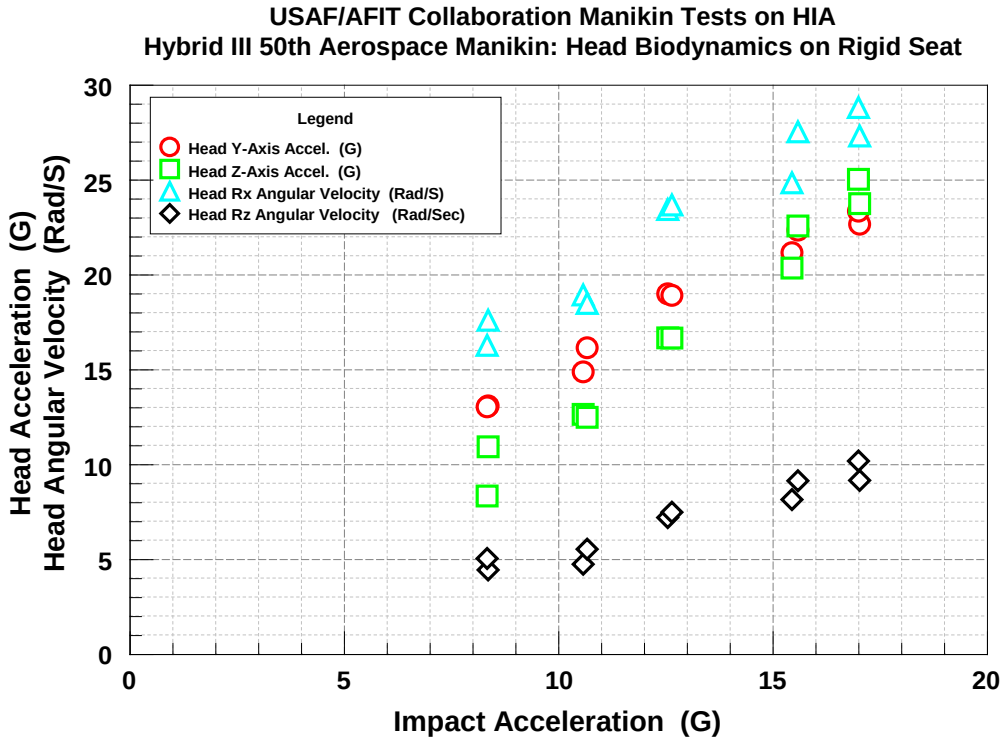

Figure 16. Rigid Seat ATD Response: Head Biodynamics

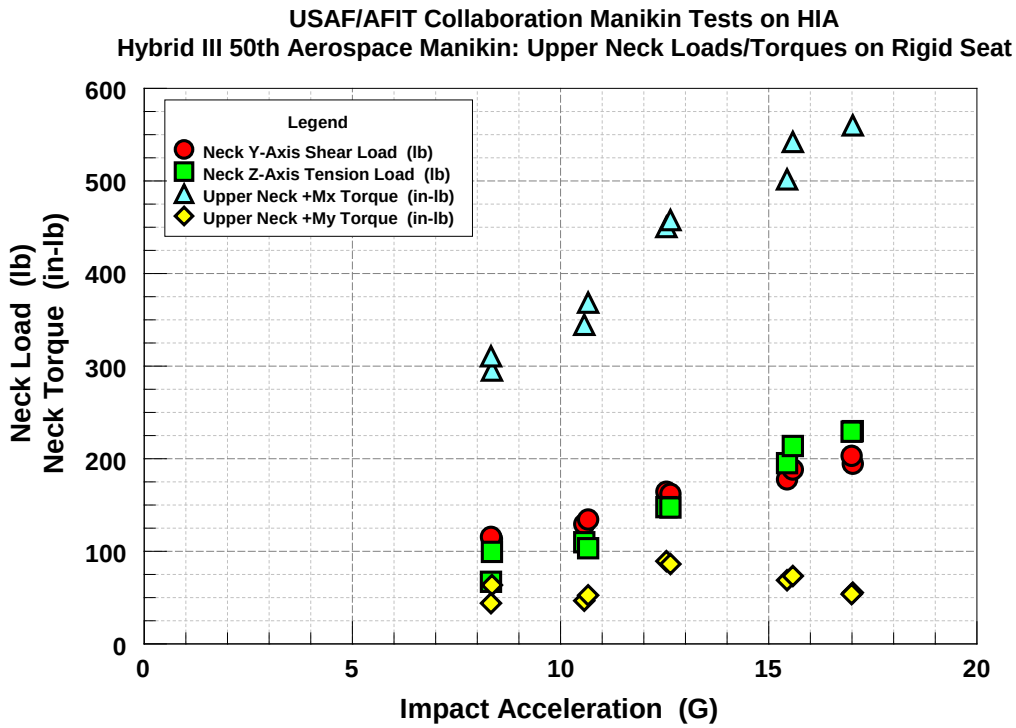

Figure 17. Rigid Seat ATD Response: Neck Loads and Torques

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The effect of the peak G level on the ATD head's biodynamic acceleration response indicated an expected step-wise increase in accelerations and rotational velocities as the impact level increased from 8.5 to 17 G. The variation in the data sets was small and averaged less than 10% for the majority of the data sets that were analyzed. The primary linear acceleration response appears to transition from a lateral response in the y-axis to an axial response in the z-axis as the input acceleration increased, and occurred at input accelerations greater than 15 G. This transition was most likely due to the ATDs head rotating into the direction of the impact. The rotation of the ATD head around the x-axis (lateral flexion or lateral bending) was primary compared to the other axes as indicated by the greater head Rx angular velocity values compared to the head Ry and Rz. The head Rz angular velocity did double its response as the input acceleration increased (approximately 5 rad/s up to 10 rad/s), but the head Ry velocity response did not change relative to the its initial response at 8.5 G, and never exceeded 5 rad/s. All the ATD biodynamic response variables that were analyzed inicated a general linear increase out to the 17 G input acceleration. A summary of the curve fitting response using a linear model is shown in Table 7. The Correlation Value or *"r"* is defined as the strength and direction of a linear relationship between the dependent and independent variables, and the Coefficient of Determination (COD) or *"r^2"* is defined as the proportion of the variance in the dependent variable that is predictable from the independent variable. All Correlation values were in the range from 0.96 to 0.99, and all COD values were in the range from 0.85 to 0.93.

The effect of the peak G level on the ATD upper neck loads and torques indicated an expected step-wise increase as the impact level increased from 8.5 to 17 G. The variation in the data was small and similar to the accelerations and rotational velocities, averaging less than 10% for the majority of the data sets that were analyzed. Similar to the head acceleration response, the primary linear force response appears to transition from a lateral shear force in the y-axis to an axial tension force in the z-axis as the input acceleration increased, and again occurred at the input accelerations greater than 15 G. The Mx torque was primary compared to the My and Mz torques. It should be noted that the head biodynamic resopnse data indicated a greater increase in the head Rx angular velocity relative to the Ry and the Rz velocity, and the torque data indicated a greater increase in Mx torque relative to the My (and Mz) torque. In addition to the torques measured by the upper neck load cell, the Mx torque measuerd by the lower neck load was also analyzed. The lower neck Mx torque data had similar characteristics to the upper neck Mx torque data relative to a step-wise increase as a function of the input acceleration. It is interesting to note that the lower neck Mx torque had peak values that exceeded the upper neck Mx torque values by a factor of 5 or greater, and the lower neck My torque was not as dominant in the response as the upper neck My torque. All the ATD load and torque variables that were analyzed inicated a general linear increase out to the 17 G input acceleration except for the My torque which changed very little out to 17 G. A summary of the curve fitting response using a linear model is shown in Table 8. All Correlation values were in the range from 0.98 to 0.99, and all Coefficient of Determination values were in the range from 0.88 to 0.97 excluding the My torque variable.

The data set for the test series with the ATD wearing a helmet was compared to the data set without the helmet at the 8.5 G input acceleration. The head linear acceleration data did not indicate much of a difference between the two data sets, but the upper neck loads and torques all indicated a greater response with the helmet than without. The neck y-axis shear load, the upper

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neck Mx and My torques, and the lower neck Mx torque all indicated an increase based on simple difference betweeen means; however it should be noted that the value of n was 2 for both data sets.

Table 7. Rigid Seat: ATD Head Biodynamics Linear Models

Biodynamic Parameter	Linear Model (y=a*x)	Correlation	COD
Head Y-Axis Acceleration	y = 1.4267 * x	0.99	0.93
Head Z-Axis Acceleration	y = 1.3465 * x	0.99	0.93
Head Rx Angular Velocity	y = 1.7468 * x	0.97	0.85
Head Rz Angular Velocity	y = 0.5587 * x	0.96	0.92

Table 8. Rigid Seat: ATD Upper Neck Loads and Torques Linear Models

Biodynamic Parameter	Linear Model (y=a*x)	Correlation	COD
Neck Y-Axis Shear Load	y = 12.21 * x	0.99	0.92
Neck Z-Axis Tension Load	y = 12.36 * x	0.98	0.88
Upper Neck Mx Torque	y = 34.48 * x	0.98	0.97
Upper Neck My Torque	y = 4.72 * x	0.22	-0.58

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7.4 Select Data Analysis: Padded Seat Configuration

Data analysis for the padded seat configuration focused on impact response of the ATD head's linear accelerations, rotational velocities, shear loads, and axial torques. A summary of these selected acceleration and neck load metrics are shown below in Tables 9 and 10. Plots of these selected data sets are shown in Figures 16 and 17.

Table 9. Padded Seat: Head and Neck Acceleration Data

Test Cell	Impact Level (G)	Head Y-Axis Accel (G)	Head Z-Axis Accel (G)	Head Rx Angular Vel. (Rad/S)	Head Rz Angular Vel. (Rad/S)
F	8.5	10.97 ± 0.23	20.01 ± 4.15	29.40 ± 1.44	4.35 ± 2.66
G	10.5	14.03 ± 2.50	27.48 ± 2.69	34.50 ± 2.31	8.91 ± 0.37
H	12.5	15.36 ± 2.95	32.91 ± 3.37	37.33 ± 1.98	7.23 ± 1.05

Table 10. Padded Seat: Neck Load and Torque Data

Test Cell	Impact Level (G)	Y-Axis Shear Load (lb)	Z-Axis Tension Load (lb)	Upper Neck +Mx Torque (in-lb)	Upper Neck +My Torque (in-lb)	Lower Neck Mx Torque (in-lb)
F	8.5	100.9 ± 1.1	178.1 ± 36.4	315.1 ± 5.7	101.6 ± 13.2	1327 ± 52.4
G	10.5	122.8 ± 19.8	247.7 ± 22.0	363.9 ± 44.5	114.7 ± 21.2	1708 ± 162
H	12.5	132.7 ± 23.9	293.4 ± 25.9	417.1 ± 58.0	132.9 ± 61.3	1852 ± 291

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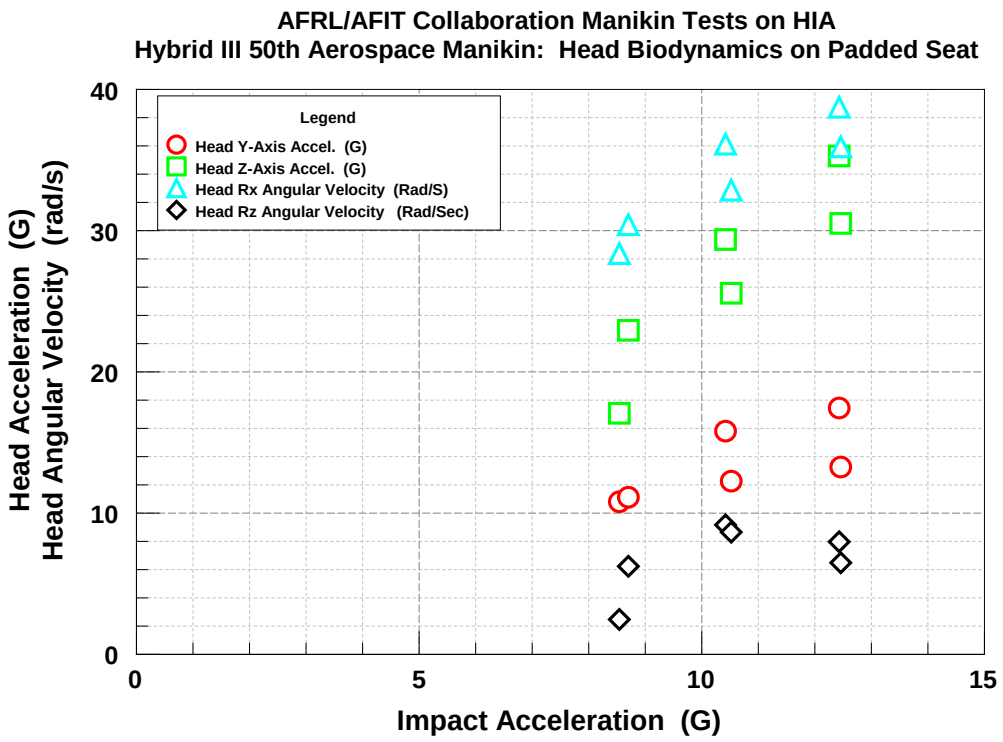

Figure 18. Padded Seat ATD Response: Head Biodynamics

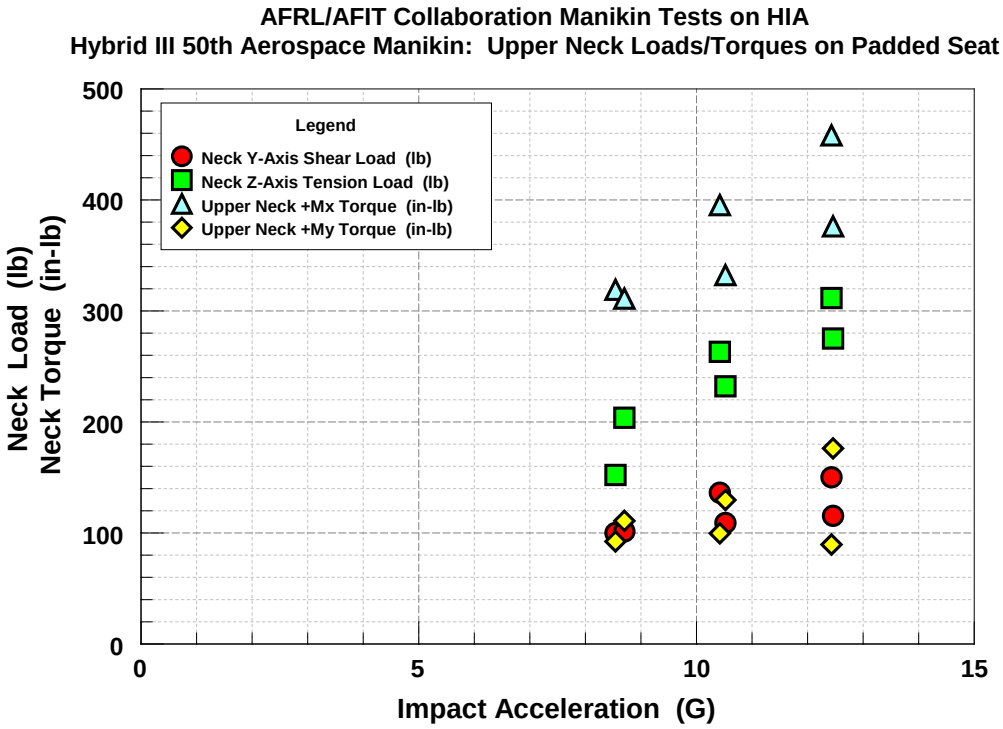

Figure 19. Padded Seat ATD Response: Neck Loads and Torques

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The effect of the peak G level on the ATD head's biodynamic response with the padded seat configuration indicated an expected step-wise increase in accelerations and rotational velocities as the impact level increased from 8.5 to 12.5 G. The variation in the data was larger than what was shown with the rigid seat data, and ranged from less than 5% to approximately 20% for the majority of the data sets that were analyzed. The primary linear acceleration response was in the z-axis for all the acceleration inputs when compared to the y-axis lateral acceleration. This indicates the ATD's head was rotating into the direction of impact much quicker than what was shown with the rigid seat configuration. The rotation of the ATD head around the x-axis was primary compared to the other axes as indicated by the greater head Rx angular velocity values compared to the head Ry and Rz, which is what was shown with the rigid seat. The head Rz angular velocity did double its response as the input acceleation increased (approximately 4 rad/s upto 8 rad/s), but the head Ry velocity response did not change relative to the its initial response at 8.5 G, and never exceeded 5 rad/s. All the ATD biodynamic response variables that were analyzed inicated a general linear increase out to the 12.5 G input acceleration. A summary of the curve fitting response using a linear model is shown in Table 11. All Correlation values (r) were in the range from 0.53 to 0.91 (three values exceeded 0.7), and all Coefficient of Determination values (r^2) were in the range from 0.28 to 0.71 (three values exceeded 0.5). This data indicates the padded seat configuration with the 3 pt harness generated head responses that did not follow a linear model as well as the data from the rigid seat with the 5 pt harness.

The effect of the peak G level on the ATD upper neck loads and torques indicated an expected step-wise increase as the impact level increased from 8.5 to 12.5 G. The variation in the data was larger than shown with the rigid seat, and ranged from 5% to approximately 10% for the majority of the data sets that were analyzed. The neck torque data sets had the highest variation in data with variations that ranged from approximately 20% to as high as 50%. Similar to the head acceleration response, the primary linear force response was the axial load in the z-axis when compared to the lateral shear force in the y-axis. This again indicates the ATD's head was rotating into the direction of impact much quicker than what was shown with the rigid seat configuration. The torque generated around the x-axis was primary compared to the other axes as indicated by the greater Mx torque values compared to the My and Mz torques. In addition, the measured Mx and My torques with the padded seat configuration were much more random, and both were greater than the Mx and My torque measured with the rigid seat. As with the rigid seat configuration, the Mx torque measured by the lower neck load was also analyzed , and had similar characteristics to the upper neck Mx torque data relative to a step-wise increase as a function of the input acceleration. The lower neck Mx torque had peak values that exceeded the upper neck Mx torque values, similar to the data from the rigid seat, but with a factor of approximately 4. The upper neck Z-axis load, upper neck Y-axis shear load, and upper neck Mx torque variables that were analyzed inicated a generally linear increase out to the 12.5 G input acceleration; however, the upper neck My torque did not indicate a tread to increase as a function of the input acceleration. A summary of the curve fitting response using a linear model is shown in Table 12. All Correlation values were in the range from 0.44 to 0.91 (three values exceeded 0.69), and all the Coefficient of Determination values were in the range from greater than 0.18 to 0.79 (two values exceeded 0.5). Similar to the head biodynamics data, this data indicates the padded seat with the 3 pt harness generated neck load and torque responses that did not follow a linear model as well as the data from the rigid seat with the 5pt harness.

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Table 11. Padded Seat: ATD Head Biodynamics Linear Models

Biodynamic Parameter	Linear Model (y=a*x)	Correlation	COD
Head Y-Axis Acceleration	y = 1.2762 * x	0.73	0.52
Head Z-Axis Acceleration	y = 2.5669 * x	0.91	0.77
Head Rx Angular Velocity	y = 3.1851 * x	0.91	0.57
Head Rz Angular Velocity	y = 0.6519 * x	0.53	0.28

Table 12. Padded SeatL ATD Upper Neck Loads and Torques Linear Models

Biodynamic Parameter	Linear Model (y=a*x)	Correlation	COD
Neck Y-Axis Shear Load	y = 11.22 * x	0.70	0.42
Neck Z-Axis Tension Load	y = 22.96 * x	0.91	0.79
Upper Neck + Mx Torque	y = 34.57 * x	0.80	0.58
Upper Neck + My Torque	y = 11.02 * x	0.44	0.18

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7.5 Select Data Analysis: Seat Configuration Comparison

A comparison was made for select head biodynamic parameters and neck force and torque parameters based on the three input accelerations that overlapped the two different seat configurations that were assessed during this program. These overlapping acceleration levels were 8.5, 10.5, and 12.5 G. The head biodynamic parameters that were selected for comparison were head z-axis acceleration and head Rx angular velocity, and the neck force and torque parameters that were selected for comparison were neck Z-axis tension force and upper neck Mx torque. The mean response values for the parameters (from the data tables), and the parameter's linear models are shown to emphasize the comparison. The mean values and linear models are shown in Figures 18 through 21.

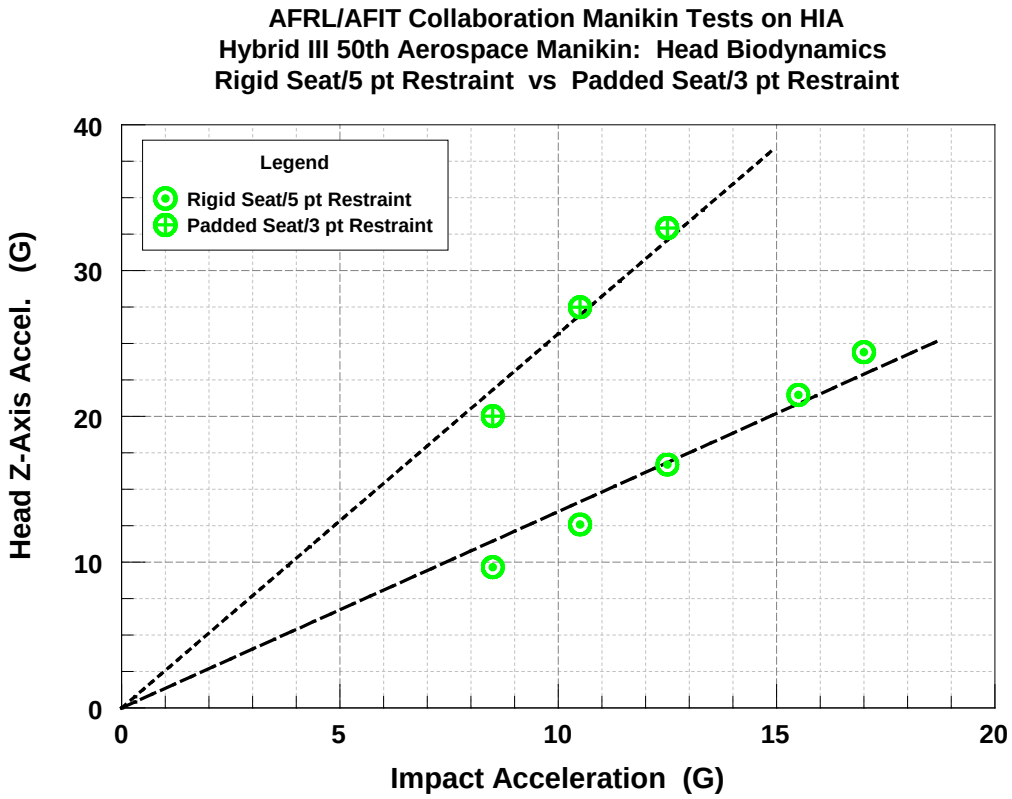

Figure 20. Seat and Restraint Comparison: Head Z-axis Acceleration

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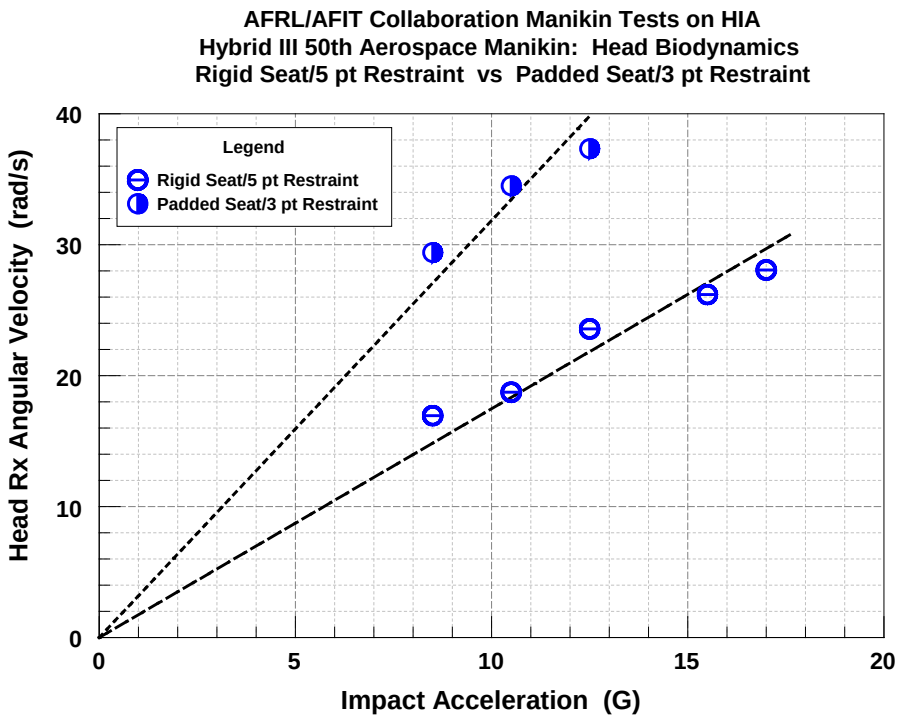

Figure 21. Seat and Restraint Comparison: Head Rx Angular Velocity

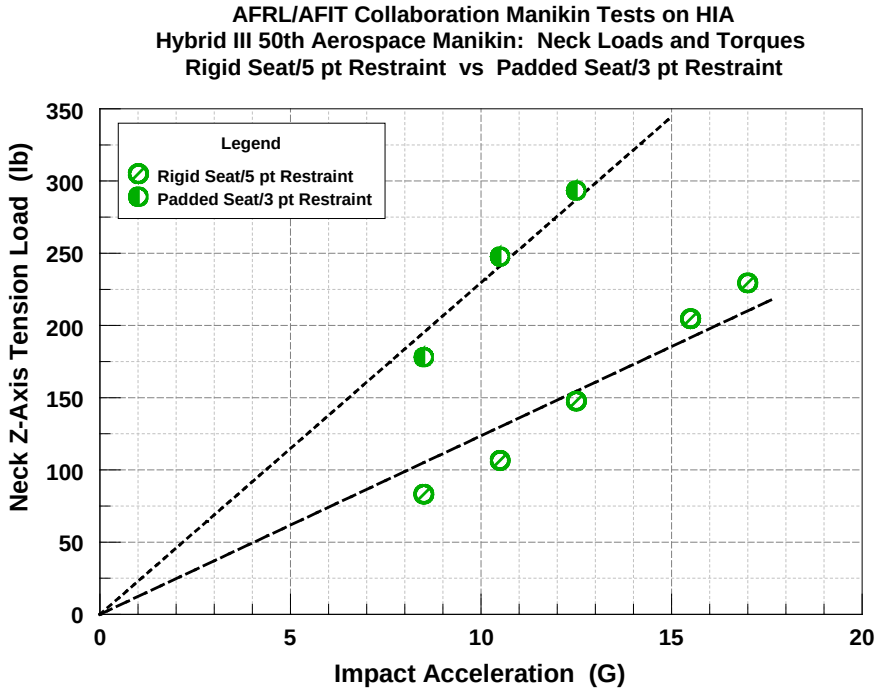

Figure 22. Seat and Restraint Comparison: Neck Z-axis Tension Load

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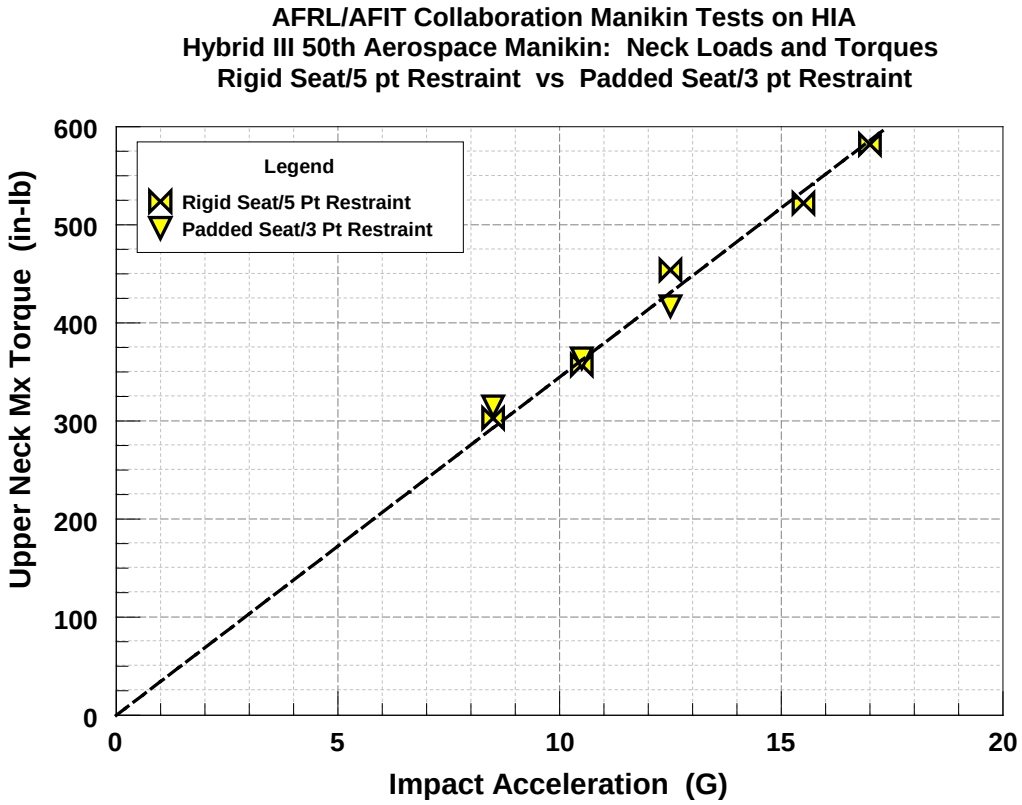

Figure 23. Seat and Restraint Comparison: Upper Neck Mx Torque

The plots in Figures 18 through 20 all consistantly show that the ATD's response with the padded seat and the 3 pt restraint is approximately 1.5 to 3 times greater than the ATD's response with the rigid seat and the 5 pt. restraint based on the analysis of these four response parameters. However, the upper neck Mx torque showed almost no difference between the rigid seat configuration to the padded seat configuration. Additional analysis of the ATD responses was expanded to the upper neck My torque, as shown in Figure 22, which shows the padded seat configuration generated greater My torque than the rigid seat by a factor of around 2. This indicates the importance of controlling the motion of the torso, and that control of the torso can reduce most of the loads and torques of the unrestrained head and neck which could result in a lower probability of injury.

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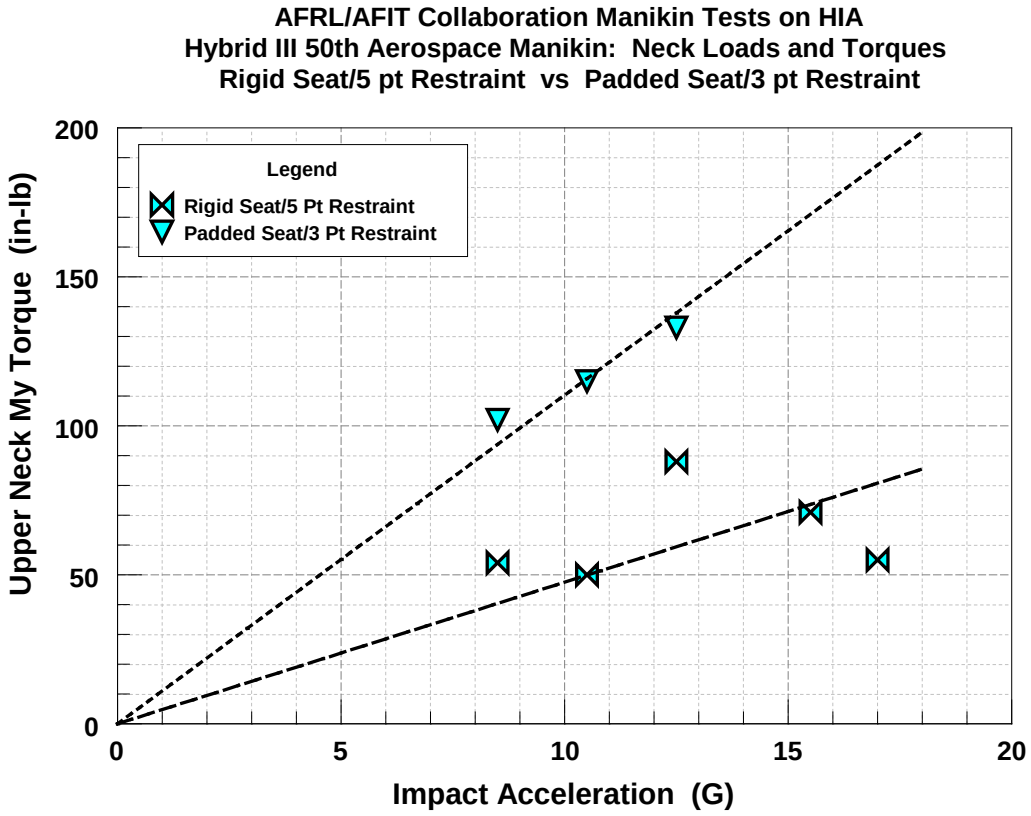

Figure 24. Seat and Restraint Comparison: Upper Neck My Torque

7.6 Neck Injury Risk Assessment

The calculation of an estimated neck injury risk was conducted using the neck loads and moments measured in the ATD during each test. The analysis of potential neck injury due to these imparted loads and torques using the neck injury risk assessment tool known as the MANICy. A summary of MANICy for each seat configuration is shown below in Tables 13 and 14.

The MANICy was calculated using the five-factor equation shown in Equation 2 from Section 6.2. The MANICy value as determined by the collected ATD data was corrected to an estimated human MANICy value using correction value of 1.783 which is the current estimated conservative correction value based on the ATD-to-human MANICy transfer function developed by the ABP team. The transfer function is based on linear models of the MANICy ATD response data and the MANICy human/PMHS response data. Values highlighted in RED exceed the maximum acceptable value of 0.47.

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Table 13. Rigid Seat: Neck Injury Risk

Test Cell	Impact Level (G)	ATD Upper Neck MANICy	Estimated Human MANICy (Corrected ATD)
A	8.5	0.32 ± 0.01	0.57
A1	8.5	0.39 ± 0.01	0.70
B	10.5	0.38 ± 0.01	0.68
C	12.5	0.48 ± 0.01	0.86
D	15.5	0.55 ± 0.02	0.98
E	17	0.60 ± 0.03	1.07

Table 14. Padded Seat: Neck Injury Risk

Test Cell	Impact Level (G)	ATD Upper Neck MANICy	Estimated Human MANICy (Corrected ATD)
F	8.5	0.34 ± 0.01	0.61
G	10.5	0.40 ± 0.04	0.71
H	12.5	0.43 ± 0.07	0.77

The rigid seat configuration indicates that the MANICy values increase as a function of the impact level as expected. The affect of wearing a helmet increased the neck injury probability by approximately 16% at the 8.5 G input, but neither MANICy value at 8.5 G nor did the value at 10.5 G exceeded the AFRL MANICy limit of 0.47 for AIS 2 injury or greater. However, the MANICy values at impact levels from 12.5 to 17 G did exceed the limit of 0.47. The padded seat configuration showed similar results at 8.5 and 10.5 G impacts, but the 12.5 G impact

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acceleration did not predict an exceedance of the AFRL MANICy limit. This was most likely due to the increased variability of the ATD data with the padded seat, and also because the five-factor MANICy calculation did not include the ATD Mx torque data which showed the highest increase when comparing the the rigid seat to the padded seat configuration.

The estimated human MANICy for the rigid seat exceeded the AFRL limit for all of the input G levels from 8.5 to 17 G. These estimated human neck injury values indicates an overall neck injury risk greater than 5%, and ranged from approximately 10% to 70% for an AIS 2 neck injury at input accelerations from 8.5 to 17 G respectively. The estimated human MANICy for the padded seat configuration also exceeded the AFRL limit for all of the input G levels from 8.5 to 12.5 G. These estimated human neck injury values indicates an overall neck injury risk that was also greater than 5%, and ranged from approximately 10% to 30% for an AIS 2 neck injury at an input acceleration from 8.5 to 12.5 G respectively. The probability of injury ranges for each seat configuration are based on the current MANICy risk curve developed by Parr et al, 2013.

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8.0 SUMMARY AND CONCLUSIONS

Research was conducted involving a series of impact tests on the HIA in a lateral impact orientation as part of a collaboration between AFIT and the 711th Human Performance Wing under AFRL. The purpose of the tests was to conduct an assessment of the biodynamic response of a ATD for the development of neck injury criteria. Testing was completed using a 50th male Hybrid III aerospace ATD.

A specially designed test matrix was developed to assess ATD response as a function of various seat configurations which were an approximation of the seat configurations used by MCW for lateral impact tests of PMHS subjects. The independent variables consisted of the direction of impact to the seat configuration, the peak impact acceleration level, and the seat configuration. The lateral seat configurations consisted of either a rigid seat with a 5 pt harness or a padded seat with a 3 pt harness, and the input acceleration pulses were trapezodial in shape and varied in peak magnitude from 8.5 to 17 G. AFRL conducted an independent assessment of potential neck injury due to imparted loads and torques during the lateral impact accelerations using a neck injury risk assessment tool known as the MANICy Neck Injury Criteria, which is based on the Nij Neck Injury Criteria developed by NHTSA.

The greater number of impact tests were conducted with the rigid seat configuration which also included one test series with a helmet. The assessed parameters generated fairly linear responses from the 8.5 to the 17 G input acceleration range. The responses had generally small standard deviations, and the head Rx angular velocity and the neck Mx torque were the dominant acceleration/velocity and force responses respectively. It should be noted that as the acceleration input increased beyond 10.5 G, the primary linear acceleration and force responses shift from the y-axis to the z-axis. In addition, the risk of neck injury based on MANICy exceeded the AFRL 5% risk limit as the acceleration inputs increased beyond 10.5 G. The effect of the helmet was not apparent when analyzing just the head accelerations and rotations from the 8.5 G input accelerations and velocities, but the helmet did increase the neck loads and torques which subsequently increased the probability of neck injury by 16% based on the ATD MANICy.

There were only three input accelerations (8.5, 10.5, 12.5 G) for the tests conducted with the padded seat configuration, and no tests were conducted with a helmet. The assessed parameters generated fairly linear responses from the 8.5 to the 17 G input acceleration range which was similar to the rigid seat configuration; however, the responses had larger standard deviations than what was observed with the rigid seat. The head Rx angular velocity was still a dominant response parameter, and with the padded seat, the neck Mx torque was still the dominant torque over the head My and Mz torques. The z-axis accelerations and forces were greater than the y-axis shear forces at all the input accelerations which was not observed with the rigid seat configuration. The risk of neck injury based on MANICy did not exceed the AFRL 5% risk limit at the tested accelerations inputs up to 10.5 G, which was similar to the rigid seat; however, the MANICy still did not exceed the AFRL risk limit at the 12.5 G input acceleration, which it did for the rigid seat configuration. It is theorized that this occurred due to the inceased variation in the data, and due to the fact that the neck My torque response was greater for the padded seat configuration than for the rigid seat. The current MANICy calculation is a five-factor MANICy calculation and does not include Mx torque because it was not calculated for the human subjects

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due to the lack of head angular acceleration term during human subject impact data collection. Therefore, the current probability of injury calculation is based on the five-factor MANICy (no Mx torque) versus a six-factor MANICy (includes the Mx torque term) currently in development.

A comparison of the ATD's impact response with the rigid seat configuration versus the padded seat configuration was completed using four response parameters: head z-axis acceleration, head Rx angular velocity, neck z-axis tension load, and neck Mx torque. The ATD's response with the padded seat and the 3 pt restraint was greater than the ATD's response with the rigid seat and the 5 pt. restraint by approximately a factor of 2. This highlights the importance of a proper restraint and the importance of controlling the motion of the torso since it could reduce the loads and torques of the unrestrained head and neck resulting in a lower probability of injury.

AFRL neck injury criteria was developed using probability of injury or risk curves composed of human and PMHS data sets. The risk curves are plots of an injury metric (MANIC for example) versus the probability of injury where typically PMHS data is used for failure points (100% probability of injury) and human volunteer subject data is used for non-injury points (0% probability of injury). The USAF uses instrumented ATDs to collect response data during escape system and component testing which is used to calculate the injury metric, and which is then used to determine the risk of injury using the risk curves. Recent collaboration between AFIT and ABP has determined that transfer functions should be developed to relate these calculated ATD injury metrics to predicted human injury metrics, and that this should be accomplished prior to determination of probability of injury to the pilot using risk curves which are based on human response data. As shown in this report, initial calculations of human MANICy and the associated injury risk compared to that shown with the ATD MANICy highlights this point. It should also be noted that the current MANICy does not include Mx torque data which was a dominant response for the ATD data sets with both seat configurations, and this highlights the need for additional research to investigate including this parameter in the MANICy calculations to become the MANICy Six Factor or MANICy-6F injury criteria.

The successful completion of this recent lateral testing of a ATD will provided critical impact data to fill data gaps and continue the development of the MANICy neck injury criteria. The data will also be used to support the continuing development of the critical ATD-to-human transfer functions for the MANIC neck injury calculations, which will provide the best estimate of neck injury for the assessment of escape systems and helmet configurations. The data will also be used to support the continuing development of computational models of ATD biodynamic response both in-house and through collaboration with external organizations.

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BIBLIOGRAPHY

Brinkley, J.W. and Shaffer, J.T. (1970). Dynamic Simulation Techniques for the Design of Escape Systems: Current Applications and Future Air Force Requirements, Aerospace Medical Research Laboratory Symposium on Biodynamic Models and Their Applications, Report No. AMRL-TR-71-29, Wright-Patterson Air Force Base, OH, Oct 1970.

Buhrman, J.R. and Perry, C.E. (1994). "Human and Manikin Head/Neck Response to +Gz Acceleration When Encumbered by Helmets of Various Weights." *Aviation, Space, and Environmental Medicine*: 1086-1090.

Carter, L.A., Pellettiere, J.A., Perry, C.E., Wilson, D. (2000). Tensile Neck Injury Criterion Development, SAFE Association 38th Annual Symposium Proceedings, Reno NV, October 2000.

Doczy, E., Mosher, S., and Buhrman, J. (2004). "The Effects of Variable Helmet Weight and Subject Bracing on Neck Loading During Frontal -Gx Impact." Proceedings of the 42nd Annual SAFE Symposium, 186-192.

Parr, J.C., Miller, M.E., Kabban, C.M., Pellettiere, J.A., Perry, C.E. (2014). Development of an Updated Tensile Neck Injury Criteria. Aviation, Space, and Environmental Medicine, Vol. 85 (10), October 2014, pp. 1026 – 1032.

Parr, J.C. (2014). A Method to Develop Neck Injury Criteria to Aid Design and Test of Escape Systems Incorporting Helmet Mounted Displays. USAF Air Force Institute of Technology Dissertation: AFIT/DS/ENV/1401, September 2014.

Parr, J.C., Miller, M.E., Pellettiere, J.A., and Erich, R.A. (2013). Neck Injury Criteria Formulation and Injury Risk Curves for the Ejection Environment: A Pilot Study. Aviation, Space, and Environmental Medicine, 84(12), Dec 2013.

Perry, C. (1998). "The Effect of Helmet Inertial Properties on Male and Female Head Response During +Gz Impact Accelerations." SAFE Journal: 28(1): 32-38.

Perry, C. and Buhrman, J. (1996). "Effect of Helmet Inertial Properties on the Biodynamics of the Head and Neck During +Gz Impact Accelerations." SAFE Journal: 26(2): 34-41.

Perry, C. and Buhrman, J. (1995). "Effect of Helmet Intertial Properties on Head and Neck Response During +Gz Impact Accelerations." *Journal of Gravitational Physiology*: 2(1): 88-92.

Perry, C. (1994). "Vertical Impact Testing of Two Helmet-Mounted Night Vision Systems." Air Force Research Laboratory Technical Report #AL/CF-SR-1994-0013. Wright-Patterson AFB, Ohio.

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

Perry, C., Buhrman, J., Doczy, E., & Mosher, S. (2003). “The Effects of Variable Helmet Weight on Head Response and Neck Loading During Lateral +Gy Impact.” Proceedings of the 41st Annual SAFE Symposium.

Philippens, M., Forbes, P., Wismans, J., DeWesse, R., and Moorcroft, D. (2011). Neck Injury Criteria for Side-Facing Aircraft Seats. Department of Transportationa and Federal Aviation Administration Technical Report: DOT/FAA/AR-09/41. United States Department of Transportation, Federal Aviation Administration, Air Traffic Organization NextGen & Operations Planning, Office of Research and Technology Development, Washington, DC.

Shaffer, J.T. (1976). The Impulse Accelerator: An Impact Sled Facility for Human Research and Safety Systems Testing. USAF Technical Report: AMRL-TR-76-08. Wright-Patterson AFB: Biodynamics and Bionics Division, Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command.

Strzelecki, J.P. (2006). Characterization of Horizontal Impulse Accelerator Pin Profiles. USAF Technical Report: AFRL-HE-WP-SR-2006-0057. Wright-Patterson AFB: Human Effectiveness Directorate, Air Force Research Laboratory.

Stech, E.L. and Payne, P.R. (1969). Dynamic Models of the Human Body, Aerospace Medical Research Laboratory Report No. AMRL-TR-66-157, Wright-Patterson Air Force Base, OH Nov 1969

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LIST OF SYMBOLS, ABBREVIATIONS AND ACRONYMS

711 HPW	711th Human Performance Wing
ABP	Aircrew Biodynamics and Protection
ABW	Air Base Wing
ACES	Advanced Crew Escape Suit
AFRL	Air Force Research Laboratory
AIS	Abbreviated Injury Scale
ATD	Anthropomorphic Test Device
CEV	Crew Exploration Vehicle
DAS	Data Acquisition System
DTS	Diversified Technical Systems
EuroSID	European Side Impact Dummy
FE	Finite Element
fps	frames-per-second
HGU	Head Gear Unit
HIA	Horizontal Impulse Accelerator
HSIR	Human Systems Integration Requirements
HYGE	Hydraulically Controlled, Gas Energized
in-lb	symbol for inch-pounds: unit of torque
lb	symbol for pound; unit of weight
ISO	International Organization for Standardization
ms	symbol for milliseconds; unit of time
MANIC	Multi-Axial Neck Injury Criteria
MBU	Mask Breathing Unit
MPCV	Multi-Purpose Crew Vehicle
My	Moment about Y-Axis
NASA	National Aeronautics and Space Administration
NESC	NASA Engineering and Safety Center
NHTSA	National Highway Traffic Safety Administration
PC	Personnel Computer
PCU	Protective Combat Uniform
RAM	Random Access Memory
Ry	Rotational Acceleration about Y-Axis
SAE	Society of Automotive Engineers
TDAS	Test Data Analysis System
THOR	Test device for Human Occupant Restraint
USAF	United States Air Force
VDT	Vertical Deceleration Tower

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APPENDIX A. ELECTRONIC DATA CHANNEL DESCRIPTIONS: STUDY 201610

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PROGRAM: Measurement of Head/Neck Acceleration during Lateral Impact Tests on the Horizontal Impulse Accelerator (+GyMANIC)						TEST DATES: 7 - 9 Nov 2016; 14 - 18 Nov 2016						
STUDY NUMBER: 201610						TEST NUMBERS: 9195 - 9208; 9209 - 9229						
FACILITY: HIA						SAMPLE RATE: 1KHz						
DATA COLLECTION SYSTEM: TDAS G5 (2)						FILTER FREQUENCY: 120 Hz						
						TRANSDUCER RANGE (VOLTS): +/- 5V						
DATA CHANNEL	DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% Δ	DAS SENSITIVITY	BRIDGE	FULL SCALE	NOTES
				DATE	SENS	DATE	SENS					
1	SLED X ACCEL (G)	MEAS SPEC EGCS-S425-250	A013008	17-Jun-16	2.8566 mv/g at 10V exc	21-Nov-16	2.8789 mv/g at 10V exc	0.8	.28566 mv/v/g	FULL	50 G	
2	SLED Y ACCEL (G)	MEAS SPEC EGCS-S425-250	A013013	26-Jan-16	2.8942 mv/g at 10V exc	21-Nov-16	2.9128 mv/g at 10V exc	0.6	.28942 mv/v/g	FULL	25 G	
3	SLED Z ACCEL (G)	MEAS SPEC EGCS-S425-250	A013009	26-Jan-16	2.9114 mv/g at 10V exc	21-Nov-16	2.9281 mv/g at 10V exc	0.6	.29114 mv/v/g	FULL	25 G	
4	SEAT X ACCEL (G)	ENTRAN EGV3-F-250	95F95F 30PT06 (X)	26-Jan-16	.8968 mv/g at 10V exc	21-Nov-16	.9115 mv/g at 10V exc	1.6	.08968 mv/v/g	FULL	250 G	
5	SEAT Y ACCEL (G)	ENTRAN EGV3-F-250	95F95F 30PT06 (Y)	26-Jan-16	.9004 mv/g at 10V exc	21-Nov-16	.9199 mv/g at 10V exc	2.2	.09004 mv/v/g	FULL	250 G	
6	SEAT Z ACCEL (G)	ENTRAN EGV3-F-250	95F95F 30PT06 (Z)	26-Jan-16	.8620 mv/g at 10V exc	21-Nov-16	.8747 mv/g at 10V exc	1.5	.08620 mv/v/g	FULL	250 G	
7	LEFT LAP X FORCE (LB)	MICH SCI TR3D-B-3K	447 (Z)	13-Oct-16	10.91 uv/lb at 10V exc	22-Nov-16	10.99 uv/lb at 10V exc	0.7	.001091 mv/v/lb	FULL	1500 LBS	
8	LEFT LAP Y FORCE (LB)	MICH SCI TR3D-B-3K	447 (Y)	13-Oct-16	13.60 uv/lb at 10V exc	22-Nov-16	13.56 uv/lb at 10v exc	-0.3	.001360 mv/v/lb	FULL	1500 LBS	
9	LEFT LAP Z FORCE (LB)	MICH SCI TR3D-B-3K	447(X)	13-Oct-16	13.73 uv/lb at 10V exc	22-Nov-16	13.64 uv/lb at 10V exc	-0.7	.001373 mv/v/lb	FULL	1500 LBS	
10	RIGHT LAP X FORCE (LB)	MICH SCI TR3D-B-3K	2 (Z)	13-Oct-16	10.89 uv/lb at 10V exc	22-Nov-16	11.04 uv/lb at 10V exc	1.7	.001389 mv/v/lb	FULL	1500 LBS	
11	RIGHT LAP Y FORCE (LB)	MICH SCI TR3D-B-3K	2 (Y)	13-Oct-16	13.53 uv/lb at 10V exc	22-Nov-16	13.61 uv/lb at 10V exc	0.6	.001353 mv/v/lb	FULL	1500 LBS	
12	RIGHT LAP Z FORCE (LB)	MICH SCI TR3D-B-3K	2 (X)	13-Oct-16	13.79 uv/lb at 10V exc	22-Nov-16	13.71 uv/lb at 10V exc	-0.6	.001379 mv/v/lb	FULL	1500 LBS	
13	LEFT SHOULDER X FORCE (LB)	MICH SCI TR3D-B-3K	5 (Z)	13-Oct-16	10.92 uv/lb at 10V exc	22-Nov-16	10.93 uv/lb at 10V exc	0.1	.001092 mv/v/lb	FULL	1500 LBS	
14	LEFT SHOULDER Y FORCE (LB)	MICH SCI TR3D-B-3K	5 (Y)	13-Oct-16	13.49 uv/lb at 10V exc	22-Nov-16	13.42 uv/lb at 10V exc	-0.5	.001349 mv/v/lb	FULL	1500 LBS	
15	LEFT SHOULDER Z FORCE (LB)	MICH SCI TR3D-B-3K	5 (X()	13-Oct-16	13.59 uv/lb at 10V exc	22-Nov-16	13.50 uv/lb at 10V exc	-0.7	.001359 mv/v/lb	FULL	1500 LBS	
16	RIGHT SHOULDER X FORCE (LB)	MICH SCI TR3D-B-3K	381 (Z)	13-Oct-16	10.83 uv/lb at 10V exc	22-Nov-16	10.93 uv/lb at 10V exc	0.9	.001083 mv/v/lb	FULL	1500 LBS	

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17	RIGHT SHOULDER Y FORCE (LB)	MICH SCI TR3D-B-3K	381 (Y)	13-Oct-16	12.88 uv/lb aat 10V exc	22-Nov-16	12.81 uv/lb at 10V exc	-0.5	.001288 mv/v/lb	FULL	1500 LBS	
18	RIGHT SHOULDER Z FORCE (LB)	MICH SCI TR3D-B-3K	381 (X)	13-Oct-16	12.66 uv/lb at 10V exc	22-Nov-16	12.60 uv/lb at 10V exc	-0.5	.001266 mv/v/lb	FULL	1500 LBS	
19	CROTCH STRAP X FORCE (LB)	MICH SCI TR3D-B-3K	4 (X)	1-Apr-16	13.17 uv/lb at 10V exc	22-Nov-16	13.38 uv/lb at 10v exc	1.6	.001317 mv/v/lb	FULL	1500 LBS	
20	CROTCH STRAP Y FORCE (LB)	MICH SCI TR3D-B-3K	4 (Y)	1-Apr-16	13.07 uv/lb at 10V exc	22-Nov-16	13.29 uv/lb at 10v exc	1.7	.001307 mv/v/lb	FULL	1500 LBS	
21	CROTCH STRAP Z FORCE (LB)	MICH SCI TR3D-B-3K	4 (Z)	1-Apr-16	10.77 uv/lb at 10V exc	22-Nov-16	10.98 uv/lb at 10V exc	1.9	.001077 mv/v/lb	FULL	1500 LBS	
22	INT HEAD X ACCEL (G)	MEAS SPEC EGCS-S425-250	R130NY	29-Mar-16	.5778 mv/g at 10V exc	22-Nov-16	.5823 mv/g at 10v exc	0.8	.05778 mv/v/g	FULL	100 G	
23	INT HEAD Y ACCEL (G)	MEAS SPEC EGCS-S425-250	R13087	28-Mar-16	.5696 mv/g at 10V exc	17-Jan-16	.5694 mv/g at 10V exc	0	.05696 mv/v/g	FULL	100 G	
24	INT HEAD Z ACCEL (G)	MEAS SPEC EGCS-S425-250	R130NX	29-Mar-16	.5862 mv/g at 10V exc	22-Nov-16	.5905 mv/g at 10v exc	0.7	.05862 mv/v/g	FULL	100 G	
25	INT HEAD Rx Ang Velocity (RAD/SEC)	DTS ARS-8K	11653	17-Oct-16	10.9497 mv/rad/sec at 5 V exc	22-Nov-16	10.9541 mv/rad/sec at 5V exc	0	2.8990 mv/v/rad/sec	FULL	139 RAD/SEC	
26	INT HEAD Ry Ang Velocity (RAD/SEC)	DTS ARS-8K	11672	17-Oct-16	11.1429 mv/rad/sec at 5V exc	22-Nov-16	11.1721 mv/rad/sec at 5V exc	0.3	2.2286 mv/v/rad/sec	FULL	139 RAD/SEC	
27	INT HEAD Rz Ang Velocity (RAD/SEC)	DTS ARS-8K	11683	17-Oct-16	10.9108 mv/rad/sec at 5V exc	22-Nov-16	10.9153 mv/rad/sec at 5V exc	0	2.1822 mv/v/rad/sec	FULL	139 RAD/SEC	
28	INT NECK X FORCE (LB)	DENTON 1716A	625	19-May-16	8.16 uv/lb at 10V exc	22-Feb-17	8.14 uv/lb at 10V exc	-0.3	.000816 mv/v/lb	FULL	2000 LB	
29	INT NECK Y FORCE (LB)	DENTON 1716A	625	19-May-16	8.42 uv/lb at 10V exc	22-Feb-17	8.54 uv/lb at 10V exc	1.4	.000842 mv/v/lb	FULL	2000 LB	
30	INT NECK Z FORCE (LB)	DENTON 1716A	625	19-May-16	3.98 uv/lb at 10V exc	22-Feb-17	3.93 uv/lb at 10V exc	-1.3	.000398 mv/v/lb	FULL	3000 LB	
31	INT NECK Mx TORQUE (IN-LB)	DENTON 1716A	625	19-May-16	6.63 uv/in-lb at 10V exc	22-Feb-17	6.72 uv/in-lb at 10V exc	1.4	.000663 uv/v/in-lb	FULL	2500 IN-LB	
32	INT NECK My TORQUE (IN-LB)	DENTON 1716A	625	19-May-16	6.71 uv/in-lb at 10V exc	22-Feb-17	6.79 uv/in-lb at 10V exc	1.2	.000671 mv/v/in-lb	FULL	2500 IN-LB	
33	INT NECK Mz TORQUE (IN-LB)	DENTON 1716A	625	19-May-16	9.02 uv/in-lb at 10V exc	22-Feb-17	9.04 uv/in-lb at 10V exc	0.2	.000902 mv/v/in-lb	FULL	2500 IN-LB	
34	INT LOWER NECK X FORCE (LB)	DENTON 1794AJTF	282	04-Aug-16	6.31 uv/lb at 10V exc	NA	NA	NA	.000631 mv/v/lb	FULL	3000 LB	customer did not want post cal done.
35	INT LOWER NECK Y FORCE (LB)	DENTON 1794AJTF	282	04-Aug-16	6.30 uv/lb at 10V exc	NA	NA	NA	.000630 mv/v/lb	FULL	1500 LB	customer did not want post cal done.
36	INT LOWER NECK Z FORCE (LB)	DENTON 1794AJTF	282	04-Aug-16	3.17 uv/lb at 10V exc	NA	NA	NA	.000317 mv/v/lb	FULL	3000LB	customer did not want post cal done.

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37	INT LOWER NECK Mx TORQUE (IN-LB)	DENTON 1794AJTF	282	04-Aug-16	4.39 uv/in-lb at 10V exc	NA	NA	NA	.000439 mv/v/in-lb	FULL	1500 LB	customer did not want post cal done.
38	INT LOWER NECK My TORQUE (IN-LB)	DENTON 1794AJTF	282	04-Aug-16	4.26 uv/in-lb at 10V exc	NA	NA	NA	.000426 mv/v/in-lb	FULL	3000 LB	customer did not want post cal done.
39	INT LOWER NECK Mz TORQUE (IN-LB)	DENTON 1794AJTF	282	04-Aug-16	7.76 uv/in-lb at 10V exc	NA	NA	NA	.000776 mv/v/in-lb	FULL	2000 LB	customer did not want post cal done.
40	INT CHEST X ACCEL (G)	MEAS SPEC EGCS-S425-250	R1307Z	28-Mar-16	.6185 mv/g at 10V exc	22-Nov-16	.6233 mv/g at 10V exc	0.8	.06185 mv/v/g	FULL	100 G	
41	INT CHEST Y ACCEL (G)	MEAS SPEC EGCS-S425-250	R150VG	28-Mar-16	.5240 mv/g at 10V exc	22-Nov-16	.5271 mv/g at 10V exc	0.6	.05240 mv/v/g	FULL	100 G	
42	INT CHEST Z ACCEL (G)	MEAS SPEC EGCS-S425-250	T13131	29-Mar-16	.5676 mv/g at 10V exc	22-Nov-16	.5690 mv/g at 10v exc	0.2	.05676 mv/v/g	FULL	100 G	
43	INT CHEST Ry ANG ACCEL (RAD/SEC2)	ENDEVCO 7302BM4	10214	18-May-16	3.64 uv/rad/sec at 10V exc	22-Nov-16	3.66 uv/rad/sec2 at 10V exc	0.5	.000364 uv/at/sec	FULL	5000 RAD/SEC2	
44	INT LUMBAR X ACCEL (G)	ENTRAN EGV3-F-250	95F95F 30PT03 (X)	26-Jan-16	.9103 mv/g at 10V exc	22-Nov-16	.9259 mv/g art 10V exc	1.7	.09103 mv/v/g	FULL	100 G	
45	INT LUMBAR Y ACCEL (G)	ENTRAN EGV3-F-250	95F95F 30PT03 (Y)	26-Jan-16	.9035 mv/g at 10V exc	22-Nov-16	.9160 mv/g at 10V exc	1.4	.09035 mv/v/g	FULL	100 G	
46	INT LUMBAR Z ACCEL (G)	ENTRAN EGV3-F-250	95F95F 30PT03 (Z)	26-Jan-16	.8965 mv/g at 10V exc	22-Nov-16	.9084 mv/g at 10V exc	1.3	.08965 mv/v/g	FULL	100 G	
47	INT LUMBAR X FORCE (LB)	DENTON 1914A	438	19-May-16	6.67 uv/lb at 10V exc	22-Feb-17	6.66 uv/lb at 10V exc	-0.2	.000667 mv/v/lb	FULL	3000 LB	
48	INT LUMBAR Y FORCE (LB)	DENTON 1914A	438	19-May-16	6.62 uv/lb at 10V exc	22-Feb-17	6.70 uv/lb at 10V exc	1.1	.000662 mv/v/lb	FULL	3000 LB	
49	INT LUMBAR Z FORCE (LB)	DENTON 1914A	438	19-May-16	2.80 uv/lb at 10V exc	22-Feb-17	2.80 uv/lb at 10V exc	0	.000280 mv/v/lb	FULL	5000 LB	
50	INT LUMBAR Mx TORQUE (IN-LB)	DENTON 1914A	438	19-May-16	5.28 uv/in-lb at 10V exc	22-Feb-17	5.31 uv/in-lb at 10V exc	0.6	.000528 mv/v/in-lb	FULL	3000 IN-LB	
51	INT LUMBAR My TORQUE (IN-LB)	DENTON 1914A	438	19-May-16	5.20 uv/in-lb at 10V exc	22-Feb-17	5.21 uv/in-lb at 10V exc	0.2	.000520 mv/v/in-lb	FULL	3000 IN-LB	
52	INT LUMBAR Mz TORQUE (IN-LB)	DENTON 1914A	438	19-May-16	8.86 uv/in-lb at 10V exc	22-Feb-17	8.72 uv/in-lb at 10V exc	-1.6	.000886 mv/v/in-lb	FULL	3000 IN-LB	

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APPENDIX B. HIA TEST-BY-TEST DESCRIPTION SUMMARY: STUDY 201610

Study: ATD Biodynamic Response during Lateral Impact using the Horizontal Impulse Accelerator

Study Number: 201610

Date(s): November 2016

The following is a review of the test configuration for each of the impact tests conducted on the HIA sled with a test-by-test summary documenting test conditions and a brief summary of the key data. All tests were conducted with a 50th Hybrid III Aerospace ATD except the Proof tests which were conducted with a ballast weight attached to the sled. The review covers test numbers 9195 through 9229.

HIA 9195 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 8.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.

Input summary: Sled X Accel. = 7.96 G, Sled Velocity = 26.34 ft/s, Time-to-Peak = 42.0 ms.

No Test –Desired impact level was not achieved

HIA 9196 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 8.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.

Input summary: Sled X Accel. = 8.15 G, Sled Velocity = 26.60 ft/s, Time-to-Peak = 43.0 ms.

No Test –Desired impact level was not achieved

HIA 9197 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 8.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.

Input summary: Sled X Accel. = 8.88 G, Sled Velocity = 27.90 ft/s, Time-to-Peak = 41.0 ms.

No Test –Desired impact level was not achieved

HIA 9198 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 8.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.

Input summary: Sled X Accel. = 8.26 G, Sled Velocity = 27.32 ft/s, Time-to-Peak = 37.0 ms.

No Test –Desired impact level was not achieved

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HIA 9199 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 8.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 8.47 G, Sled Velocity = 27.29 ft/s, Time-to-Peak = 41.0 ms.
Successful Test –Desired impact level was achieved

HIA 9200 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 10.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 9.02 G, Sled Velocity = 32.29 ft/s, Time-to-Peak = 95.0 ms.
No Test –Desired impact level was not achieved

HIA 9201 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 10.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 9.81 G, Sled Velocity = 33.90 ft/s, Time-to-Peak = 87.0 ms.
No Test –Desired impact level was not achieved

HIA 9202 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 10.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 10.72 G, Sled Velocity = 36.82 ft/s, Time-to-Peak = 85.0 ms.
No Test –Desired impact level was not achieved

HIA 9203 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 10.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 10.55 G, Sled Velocity = 36.06 ft/s, Time-to-Peak = 84.0 ms.
Successful Test –Desired impact level was achieved

HIA 9204 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 12.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 12.37 G, Sled Velocity = 36.96 ft/s, Time-to-Peak = 80.0 ms.
Successful Test –Desired impact level was achieved

HIA 9205 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 15.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 14.97 G, Sled Velocity = 54.90 ft/s, Time-to-Peak = 86.0 ms.
No Test –Desired impact level was not achieved

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HIA 9206 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 15.5 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 15.61 G, Sled Velocity = 55.14 ft/s, Time-to-Peak = 84.0 ms.
Successful Test –Desired impact level was achieved

HIA 9207 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 17.0 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 16.42 G, Sled Velocity = 59.92 ft/s, Time-to-Peak = 76.0 ms.
No Test –Desired impact level was not achieved

HIA 9208 – Proof Test, HIA Pin 4; SUBJECT: Ballast; IMPACT: 17.0 G; CONFIGURATION: Gy Lateral Impact; RESTRAINT: None; HELMET/MASK: None.
Input summary: Sled X Accel. = 16.91 G, Sled Velocity = 61.22 ft/s, Time-to-Peak = 76.0 ms.
Successful Test –Desired impact level was achieved

HIA 9209 – Cell A, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 8.5 G; CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support; RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 8.35 G, Sled Velocity = 25.89 ft/s, Time-to-Peak = 40.0 ms.
Successful Test –Desired impact level was achieved

HIA 9210 – Cell A, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 8.5 G; CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support; RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 8.33 G, Sled Velocity = 26.52 ft/s, Time-to-Peak = 36.0 ms.
Successful Test –Desired impact level was achieved

HIA 9211 – Cell A1, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 8.5 G; CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support; RESTRAINT: 5 pt; HELMET/MASK: HGU-55/P, MBU-20/P.
Input summary: Sled X Accel. = 8.59 G, Sled Velocity = 26.56 ft/s, Time-to-Peak = 37.0 ms.
Successful Test –Desired impact level was achieved

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HIA 9212 – Cell A1, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 8.5 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: HGU-55/P, MBU-20/P.
Input summary: Sled X Accel. = 8.41 G, Sled Velocity = 26.68 ft/s, Time-to-Peak = 35.0 ms.
Successful Test –Desired impact level was achieved

HIA 9213 – Cell B, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 10.5 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 10.57 G, Sled Velocity = 37.86 ft/s, Time-to-Peak = 83.0 ms.
Successful Test –Desired impact level was achieved

HIA 9214 – Cell B, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 10.5 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 10.66 G, Sled Velocity = 38.97 ft/s, Time-to-Peak = 83.0 ms.
Successful Test –Desired impact level was achieved

HIA 9215 – Cell C, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 12.5 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 12.54 G, Sled Velocity = 37.17 ft/s, Time-to-Peak = 77.0 ms.
Successful Test –Desired impact level was achieved

HIA 9216 – Cell C, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 12.5 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 12.64 G, Sled Velocity = 36.90 ft/s, Time-to-Peak = 78.0 ms.
Successful Test –Desired impact level was achieved

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HIA 9217 – Cell D, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 15.5 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 15.44 G, Sled Velocity = 54.49 ft/s, Time-to-Peak = 86.0 ms.
Successful Test –Desired impact level was achieved

HIA 9218 – Cell D, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 15.5 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 15.58 G, Sled Velocity = 55.92 ft/s, Time-to-Peak = 89.0 ms.
Successful Test –Desired impact level was achieved

HIA 9219 – Cell E, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 17.0 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 17.02 G, Sled Velocity = 60.66 ft/s, Time-to-Peak = 84.0 ms.
Successful Test –Desired impact level was achieved

HIA 9220 – Cell E, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 17.0 G;
CONFIGURATION: Gy Lateral Impact with Rigid Seat and Rigid Side Support;
RESTRAINT: 5 pt; HELMET/MASK: None.
Input summary: Sled X Accel. = 16.99 G, Sled Velocity = 60.58 ft/s, Time-to-Peak = 85.0 ms.
Successful Test –Desired impact level was achieved

HIA 9221 – Cell F, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 8.5 G;
CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support;
RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 8.57 G, Sled Velocity = 28.06 ft/s, Time-to-Peak = 39.0 ms.
No Test – Neck load cell wire broke

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HIA 9222 – Cell F, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 8.5 G;
CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support;
RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 8.54 G, Sled Velocity = 27.70 ft/s, Time-to-Peak = 40.0 ms.
Successful Test –Desired impact level was achieved

HIA 9223 – Cell F, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 8.5 G;
CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support;
RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 8.70 G, Sled Velocity = 28.02 ft/s, Time-to-Peak = 40.0 ms.
Successful Test – Desired impact level was achieved (slightly high but test was accepted as sufficiently close due to time constraints)

HIA 9224 – Cell G, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 10.5 G;
CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support;
RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 10.23 G, Sled Velocity = 38.14 ft/s, Time-to-Peak = 75.0 ms.
No Test – Desired impact level was not achieved (considered slightly too low)

HIA 9225 – Cell G, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 10.5 G;
CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support;
RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 10.42 G, Sled Velocity = 38.43 ft/s, Time-to-Peak = 88.0 ms.
Successful Test – Desired impact level was achieved

HIA 9226 – Cell G, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 10.5 G;
CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support;
RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 10.52 G, Sled Velocity = 38.97 ft/s, Time-to-Peak = 93.0 ms.
Successful Test – Desired impact level was achieved

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HIA 9227 – Cell H, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 12.5 G; CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support; RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 12.15 G, Sled Velocity = 37.43 ft/s, Time-to-Peak = 66.0 ms.
No Test – Desired impact level was not achieved

HIA 9228 – Cell H, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 12.5 G; CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support; RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 12.43 G, Sled Velocity = 37.77 ft/s, Time-to-Peak = 74.0 ms.
Successful Test – Desired impact level was achieved

HIA 9229 – Cell H, HIA Pin 4; SUBJECT: 50th Hybrid III Aero; IMPACT: 12.5 G; CONFIGURATION: Gy Lateral Impact with Seat Back/Pan Cushions and Foam Side Support; RESTRAINT: 3 pt with left shoulder belt distal from impact; HELMET/MASK: None.
Input summary: Sled X Accel. = 12.46 G, Sled Velocity = 38.77 ft/s, Time-to-Peak = 82.0 ms.
Successful Test – Desired impact level was achieved

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APPENDIX C. SAMPLE DATA SHEETS OF TEST PROGRAM PROCESSED DATA QUICK-LOOKS

The following are examples of the post-test processed data for each test cell. One test is shown for each test cell for the impact accelerations from 8.5 to 17 G, and are summarized below.

HIA Test # 9209 Cell A	**8.5 G Impact**	**Rigid Seat/5 pt Restraint**
HIA Test # 9213 Cell B	**10.5 G Impact**	**Rigid Seat/5 pt Restraint**
HIA Test # 9215 Cell C	**12.5 G Impact**	**Rigid Seat/5 pt Restraint**
HIA Test # 9218 Cell D	**15.5 G Impact**	**Rigid Seat/5 pt Restraint**
HIA Test # 9219 Cell E	**17 G Impact**	**Rigid Seat/5 pt Restraint**
HIA Test # 9222 Cell F	**8.5 G Impact**	**Padded Seat/3 pt Restraint**
HIA Test # 9226 Cell G	**10.5 G Impact**	**Padded Seat/3 pt Restraint**
HIA Test # 9229 Cell H	**12.5 G Impact**	**Padded Seat/3 pt Restraint**

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9209 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 8.5 Cell: A

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				16.0	
Impact Rise Time (Ms)				40.0	
Impact Duration (Ms)				144.0	
Velocity Change (Ft/Sec)		25.89			
SLED X ACCEL (G)	0.03	8.35	-0.50	40.0	175.0
SLED Y ACCEL (G)	-0.01	0.62	-0.55	59.0	68.0
SLED Z ACCEL (G)	-0.99	-0.38	-2.02	69.0	49.0
SLED RESULTANT	0.99	8.41	0.59	40.0	138.0
INTEGRATED ACCEL (FT/SEC)	0.01	25.89	0.04	144.0	0.0
SEAT X ACCEL (G)	-0.06	2.68	-3.24	69.0	153.0
SEAT Y ACCEL (G)	-0.11	2.21	-10.42	144.0	54.0
SEAT Z ACCEL (G)	0.95	3.42	-0.25	51.0	62.0
SEAT RESULTANT	1.00	10.71	0.54	54.0	224.0
LEFT LAP X FORCE (LB)	66.97	173.55	30.48	56.0	226.0
LEFT LAP Y FORCE (LB)	-6.48	-6.17	-74.74	2.0	60.0
LEFT LAP Z FORCE (LB)	11.93	25.81	3.91	51.0	167.0
LEFT LAP RESULTANT (LB)	68.34	189.98	31.61	56.0	228.0
RIGHT LAP X FORCE (LB)	27.19	48.76	3.38	201.0	40.0
RIGHT LAP Y FORCE (LB)	7.40	9.59	-9.17	192.0	45.0
RIGHT LAP Z FORCE (LB)	1.78	6.99	-2.21	204.0	54.0
RIGHT LAP RESULTANT (LB)	28.24	50.01	8.62	203.0	34.0
LEFT SHOULDER X FORCE (LB)	31.16	110.08	19.92	71.0	177.0
LEFT SHOULDER Y FORCE (LB)	1.05	16.59	-24.88	246.0	67.0
LEFT SHOULDER Z FORCE (LB)	-4.01	-0.23	-14.54	49.0	246.0
LEFT SHOULDER RESULTANT (LB)	31.44	112.80	20.15	71.0	177.0
RIGHT SHOULDER X FORCE (LB)	24.65	52.15	12.49	228.0	169.0
RIGHT SHOULDER Y FORCE (LB)	1.11	16.14	-26.98	241.0	51.0
RIGHT SHOULDER Z FORCE (LB)	-6.87	-3.96	-11.07	171.0	60.0
RIGHT SHOULDER RESULTANT (LB)	25.62	54.66	13.47	228.0	170.0
CROTCH STRAP X FORCE (LB)	3.98	7.74	-3.05	96.0	60.0
CROTCH STRAP Y FORCE (LB)	-1.46	0.31	-42.06	227.0	64.0
CROTCH STRAP Z FORCE (LB)	0.06	94.63	-5.98	63.0	159.0
CROTCH STRAP RESULTANT (LB)	4.26	103.37	4.32	63.0	0.0

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201610 Test: 9209 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 8.5 Cell: A

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT HEAD X ACCEL (G)	-0.08	1.32	-1.98	143.0	83.0
INT HEAD Y ACCEL (G)	0.08	6.02	-13.10	222.0	97.0
INT HEAD Z ACCEL (G)	1.06	10.95	-0.47	68.0	41.0
INT HEAD RESULTANT (G)	1.13	14.56	0.58	98.0	26.0
INT HEAD HIC		22.20		85.0	115.0
INT HEAD Rx ANG VELOCITY (RAD/SEC)	-0.01	17.61	-15.38	70.0	187.0
INT HEAD Ry ANG VELOCITY (RAD/SEC)	0.02	1.25	-3.07	106.0	174.0
INT HEAD Rz ANG VELOCITY (RAD/SEC)	-0.02	3.27	-4.46	61.0	111.0
INT HEAD ANG VELOCITY RESULTANT	0.07	17.84	0.04	70.0	13.0
INT NECK X FORCE (LB)	6.74	19.80	-11.26	179.0	85.0
INT NECK Y FORCE (LB)	-0.24	52.00	-113.40	227.0	94.0
INT NECK Z FORCE (LB)	5.31	99.45	-3.35	67.0	26.0
INT NECK RESULTANT (LB)	8.66	129.39	7.38	104.0	22.0
INT NECK Mx TORQUE (IN-LB)	0.81	104.12	-215.99	222.0	104.0
INT NECK My TORQUE (IN-LB)	-4.17	30.55	-37.17	95.0	163.0
INT NECK Mz TORQUE (IN-LB)	2.20	26.21	-32.80	134.0	78.0
INT NECK TORQUE RES (IN-LB)	4.83	217.61	2.56	103.0	25.0
INT LOWER NECK X FORCE (LB)	3.35	25.70	-13.28	180.0	85.0
INT LOWER NECK Y FORCE (LB)	3.80	60.55	-166.94	220.0	101.0
INT LOWER NECK Z FORCE (LB)	4.86	99.75	-22.90	65.0	93.0
INT LOWER NECK RESULTANT (LB)	7.04	179.65	4.06	66.0	13.0
INT LOWER NECK Mx TORQUE (IN-LB)	0.80	544.31	-1317.24	225.0	101.0
INT LOWER NECK My TORQUE (IN-LB)	8.73	186.77	-176.80	92.0	186.0
INT LOWER NECK Mz TORQUE (IN-LB)	1.51	92.73	-275.33	221.0	68.0
INT LOWER NECK TORQUE RES (IN-LB)	8.99	1350.43	10.41	101.0	2.0
INT CHEST X ACCEL (G)	-0.01	1.53	-1.76	174.0	73.0
INT CHEST Y ACCEL (G)	-0.04	1.26	-16.17	246.0	56.0
INT CHEST Z ACCEL (G)	1.00	4.14	-0.64	67.0	90.0
INT CHEST RESULTANT (G)	1.01	16.27	0.42	56.0	149.0
INT CHEST Rx ANG ACCEL (RAD/SEC2)	0.73	27.98	-50.00	44.0	166.0
INT LUMBAR X ACCEL (G)	0.00	3.56	-1.20	71.0	53.0
INT LUMBAR Y ACCEL (G)	-0.10	2.04	-18.65	157.0	66.0
INT LUMBAR Z ACCEL (G)	1.03	4.10	-0.81	68.0	46.0
INT LUMBAR RESULTANT (G)	1.03	19.12	0.79	66.0	226.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9209 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 8.5 Cell: A

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT LUMBAR X FORCE (LB)	2.61	24.08	-51.33	236.0	70.0
INT LUMBAR Y FORCE (LB)	2.82	64.32	-60.07	167.0	49.0
INT LUMBAR Z FORCE (LB)	-32.28	233.17	-63.59	64.0	246.0
INT LUMBAR FORCE RES (LB)	32.52	237.83	12.64	64.0	211.0
INT LUMBAR Mx TORQUE (IN-LB)	-16.38	243.07	-185.29	168.0	41.0
INT LUMBAR My TORQUE (IN-LB)	-44.33	206.91	-135.32	71.0	239.0
INT LUMBAR Mz TORQUE (IN-LB)	-8.99	15.95	-60.01	237.0	89.0
INT LUMBAR TORQUE RESULTANT (IN-LB)	48.11	247.08	46.51	168.0	4.0
NIJ SHEAR (LB)		19.80	-11.26	179.0	85.0
NIJ TENSION (LB)		99.45		67.0	
NIJ COMPRESSION (LB)		-3.35		26.0	
NIJ FLEXION (IN-LB)		35.27		96.0	
NIJ EXTENSION (IN-LB)		47.16		163.0	
NIJ NTF	0.0000	0.0692	0.0000	69.0	0.0
NIJ NTE	0.0109	0.0654	0.0000	62.0	23.0
NIJ NCF	0.0000	0.0022	0.0000	41.0	0.0
NIJ NCE	0.0000	0.0080	0.0000	26.0	0.0
NIJ NTF AIS >= 2		0.12			
NIJ NTF AIS >= 3		0.04			
NIJ NTF AIS >= 4		0.07			
NIJ NTF AIS >= 5		0.02			
NIJ NTE AIS >= 2		0.12			
NIJ NTE AIS >= 3		0.04			
NIJ NTE AIS >= 4		0.07			
NIJ NTE AIS >= 5		0.02			
NIJ NCF AIS >= 2		0.11			
NIJ NCF AIS >= 3		0.04			
NIJ NCF AIS >= 4		0.06			
NIJ NCF AIS >= 5		0.02			
NIJ NCE AIS >= 2		0.11			
NIJ NCE AIS >= 3		0.04			
NIJ NCE AIS >= 4		0.06			
NIJ NCE AIS >= 5		0.02			
NMIx	0.0007	0.1807	0.0000	104.0	3.0
NMIz	0.0018	0.0274	0.0000	78.0	111.0

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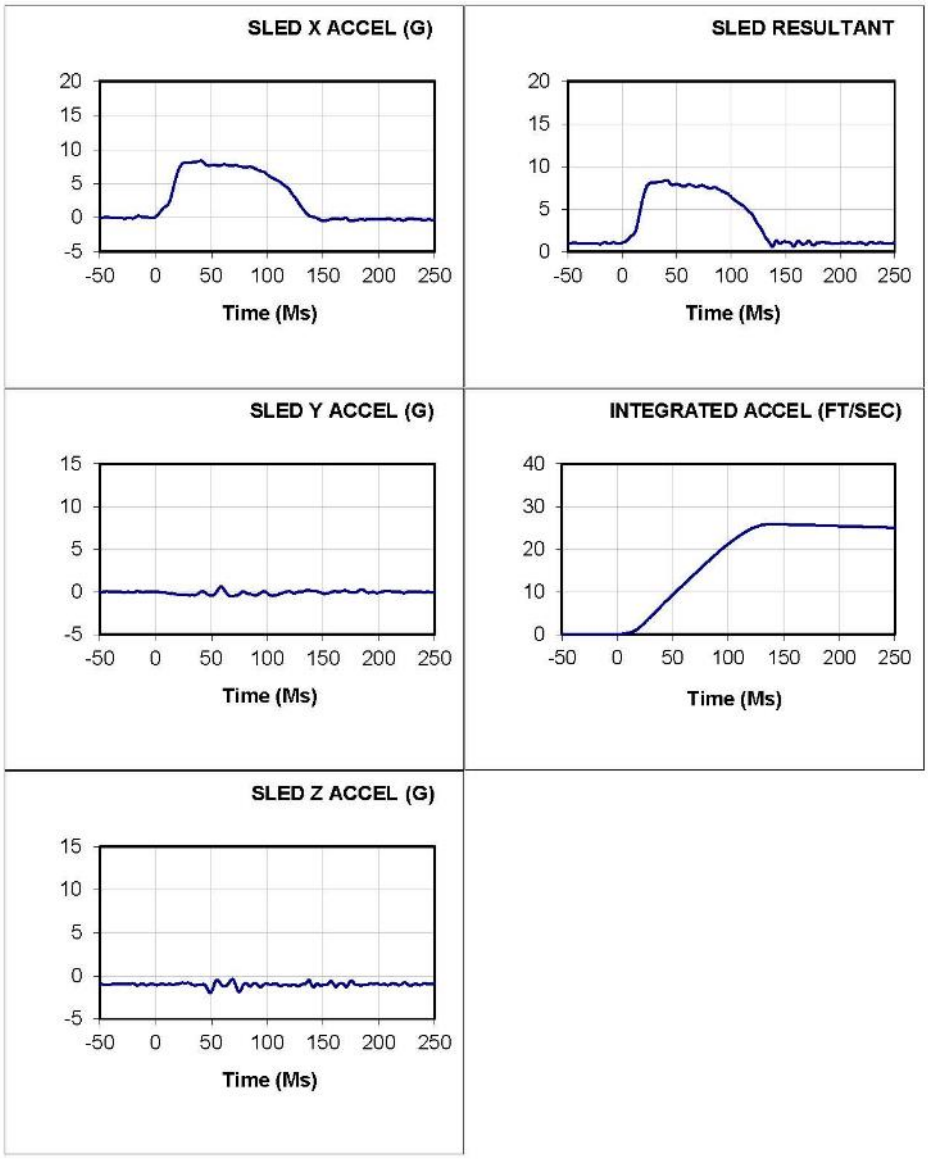
201610 Test: 9209 Test Date: 161114 Subj: AERO50 Cell: A



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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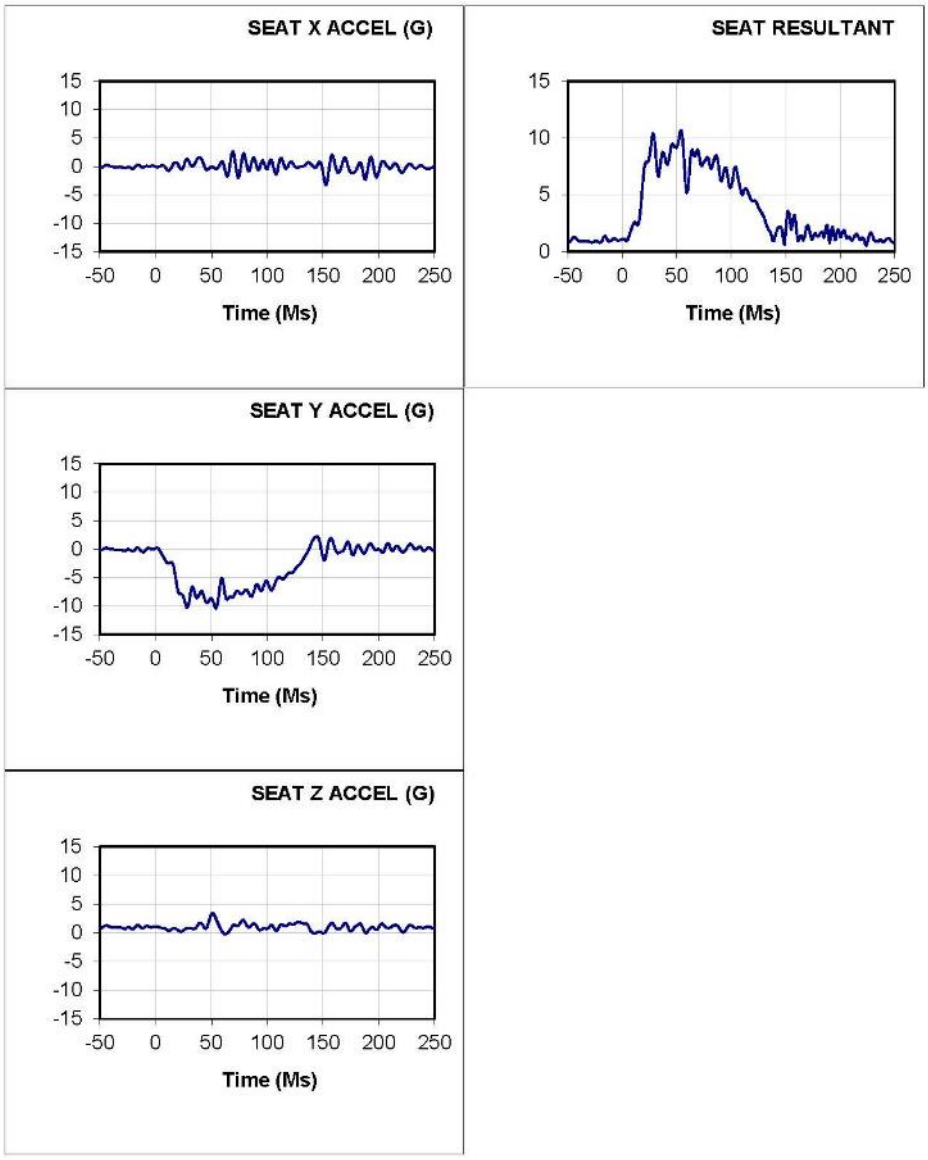

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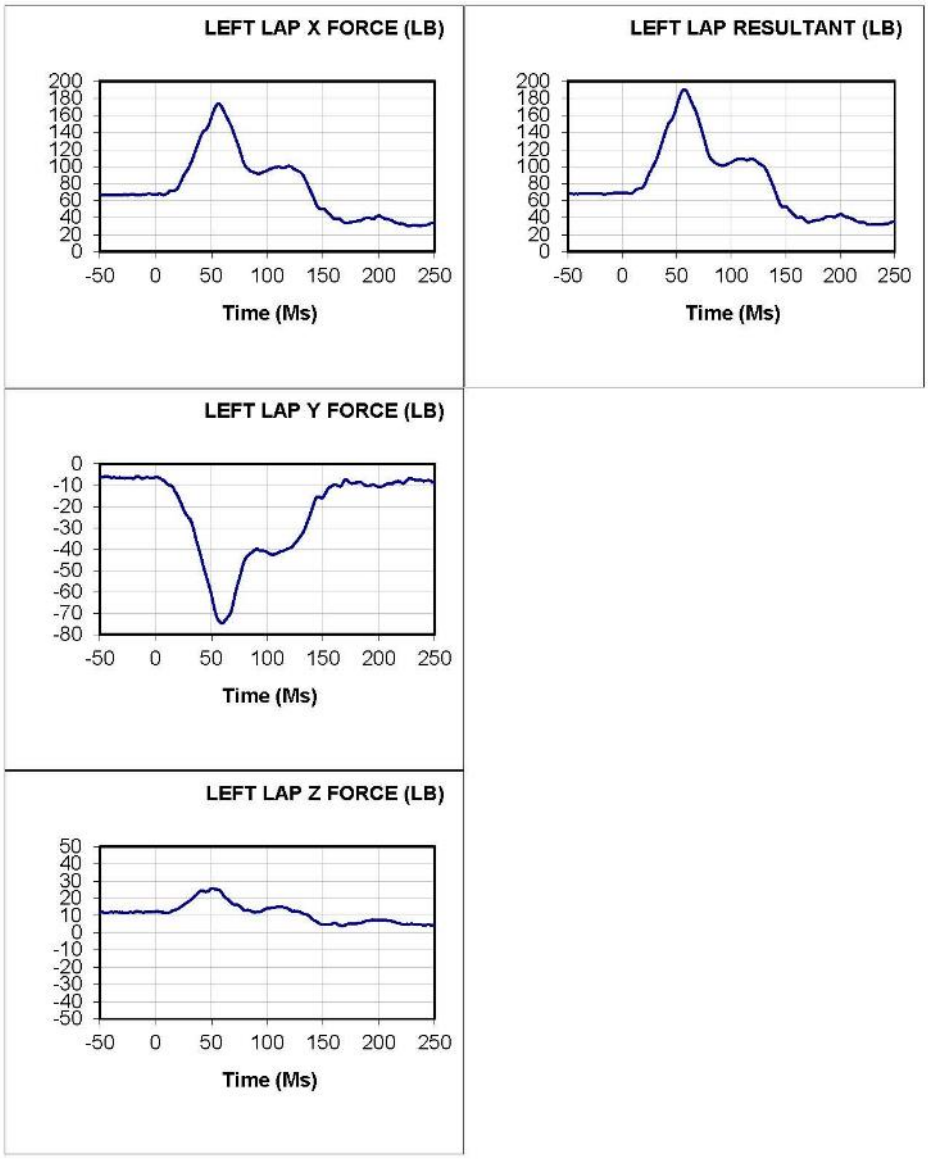

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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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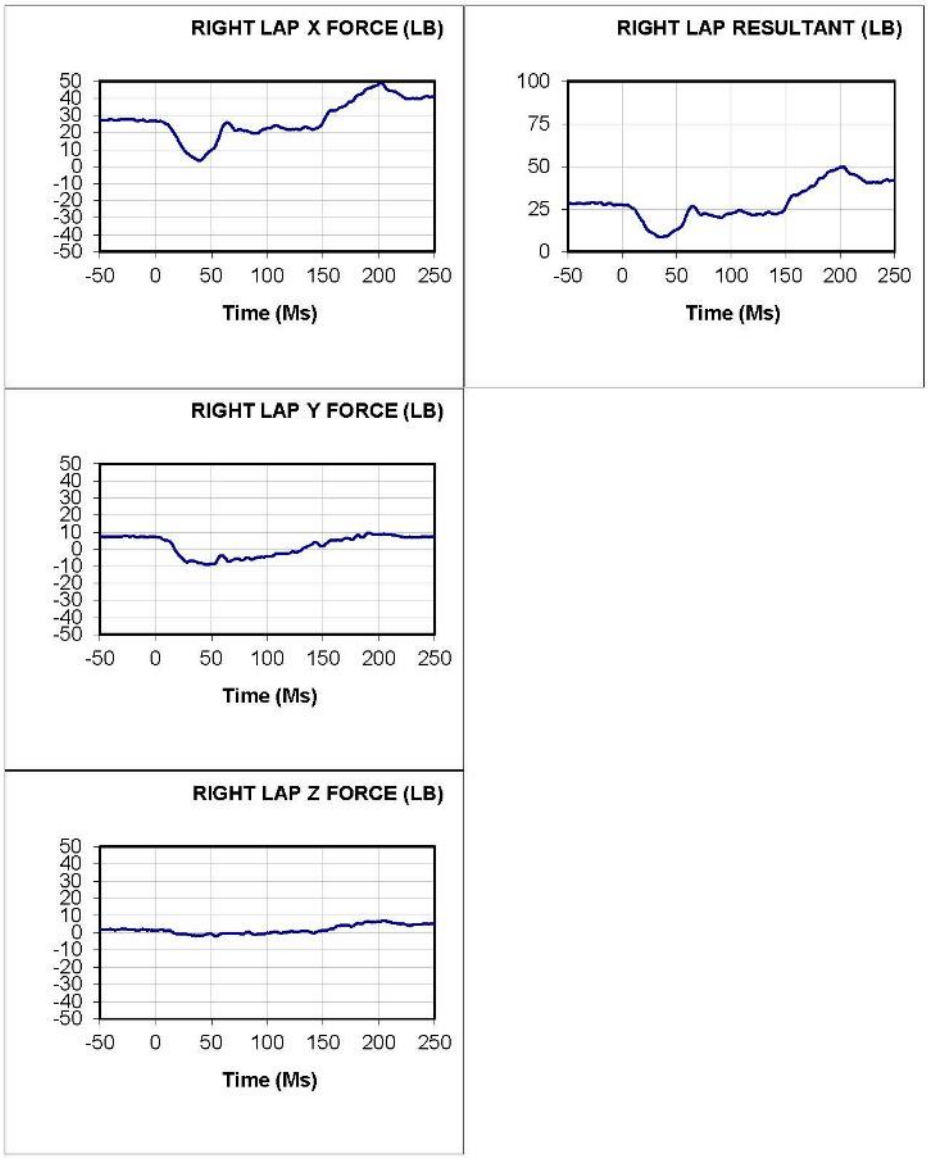

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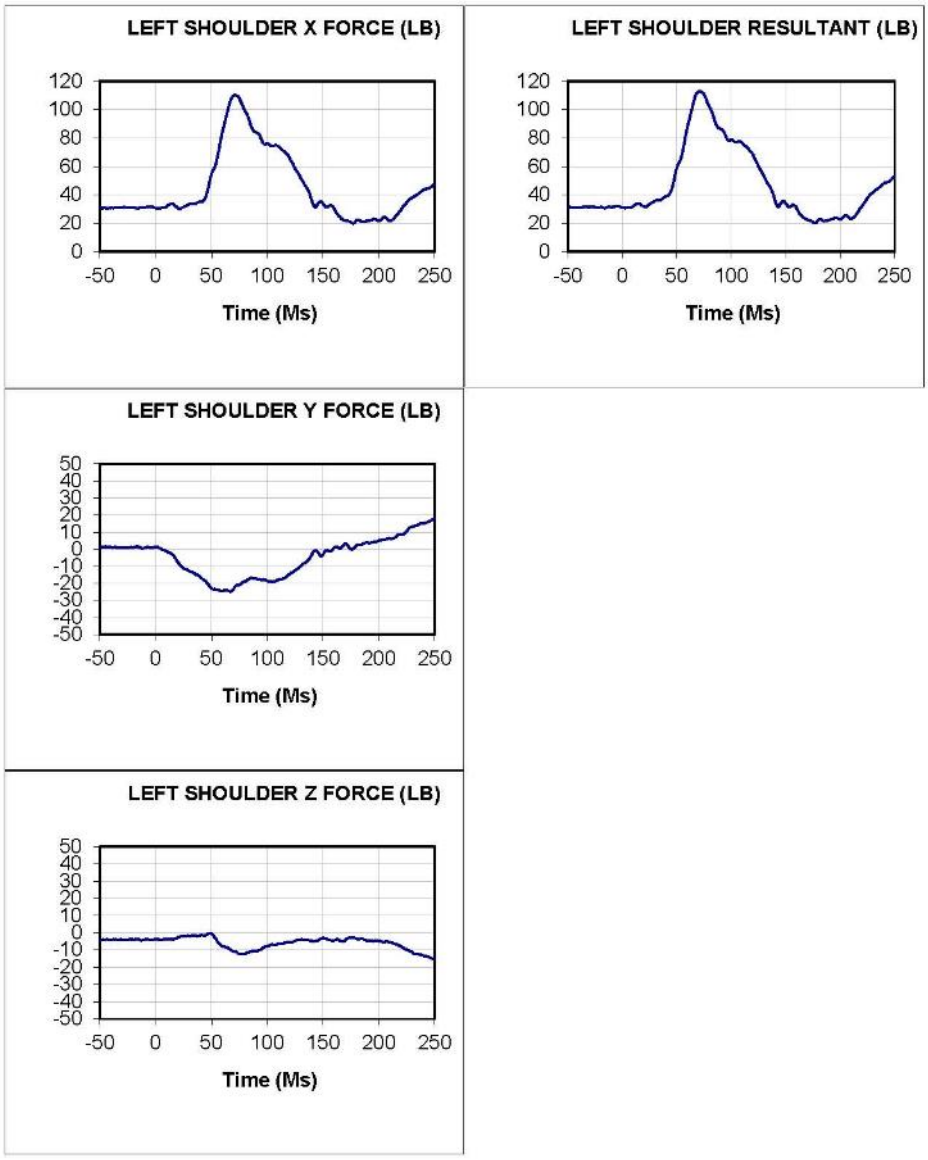

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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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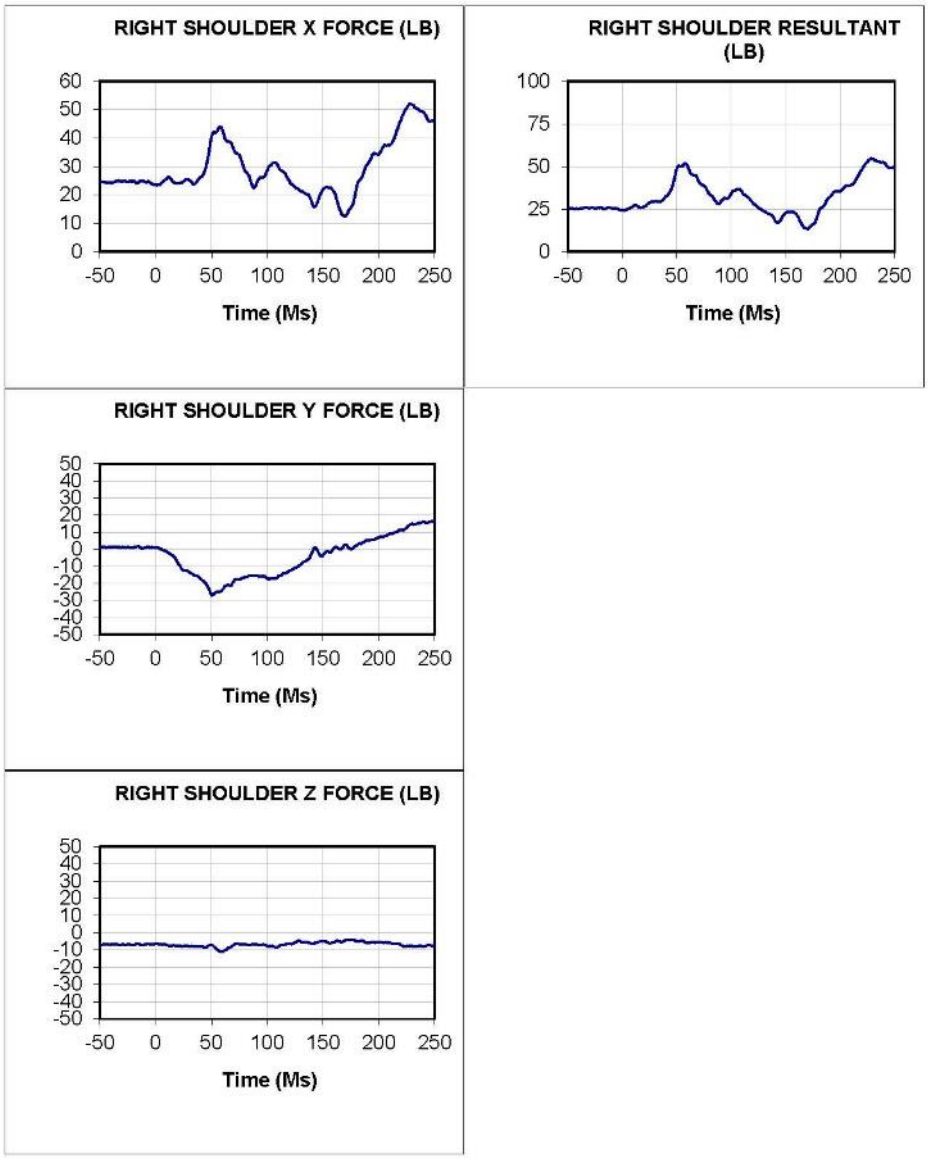

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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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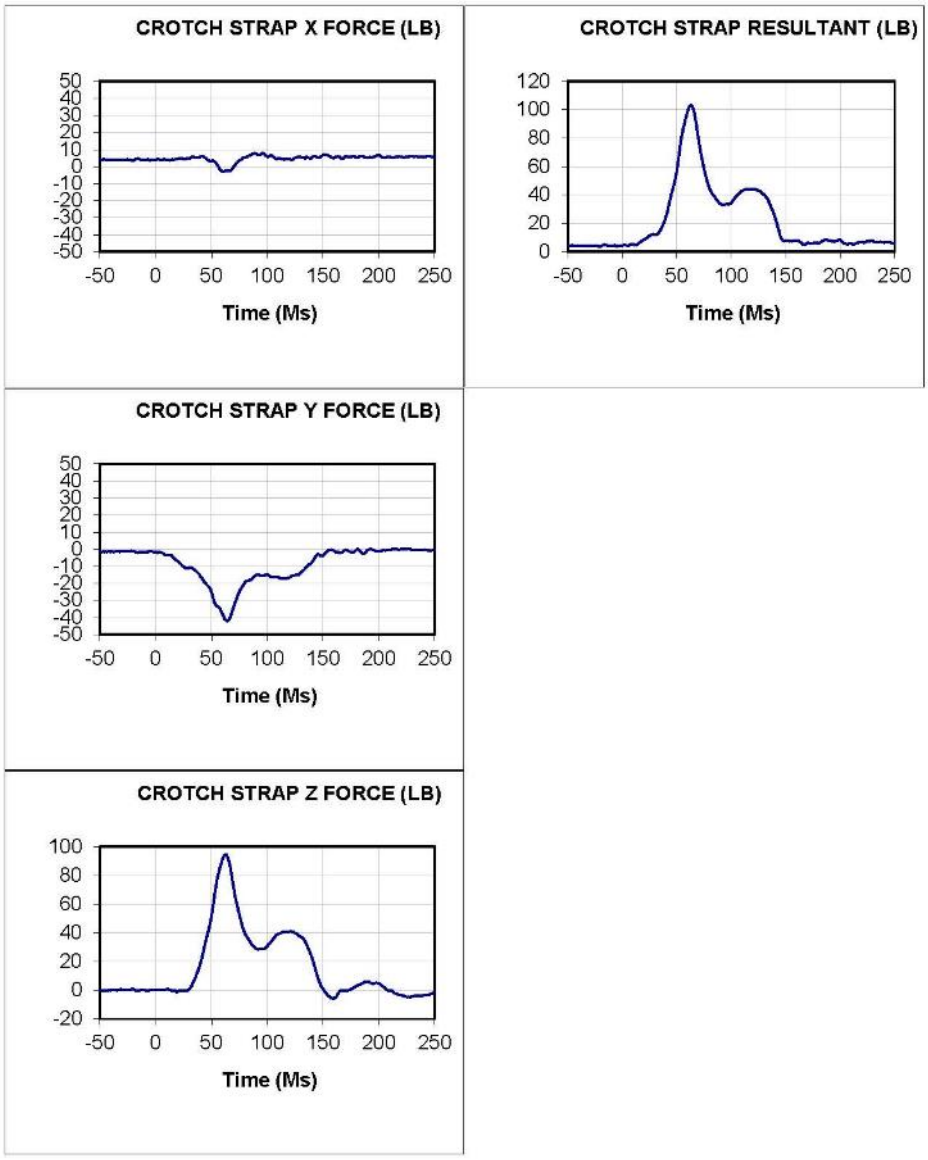

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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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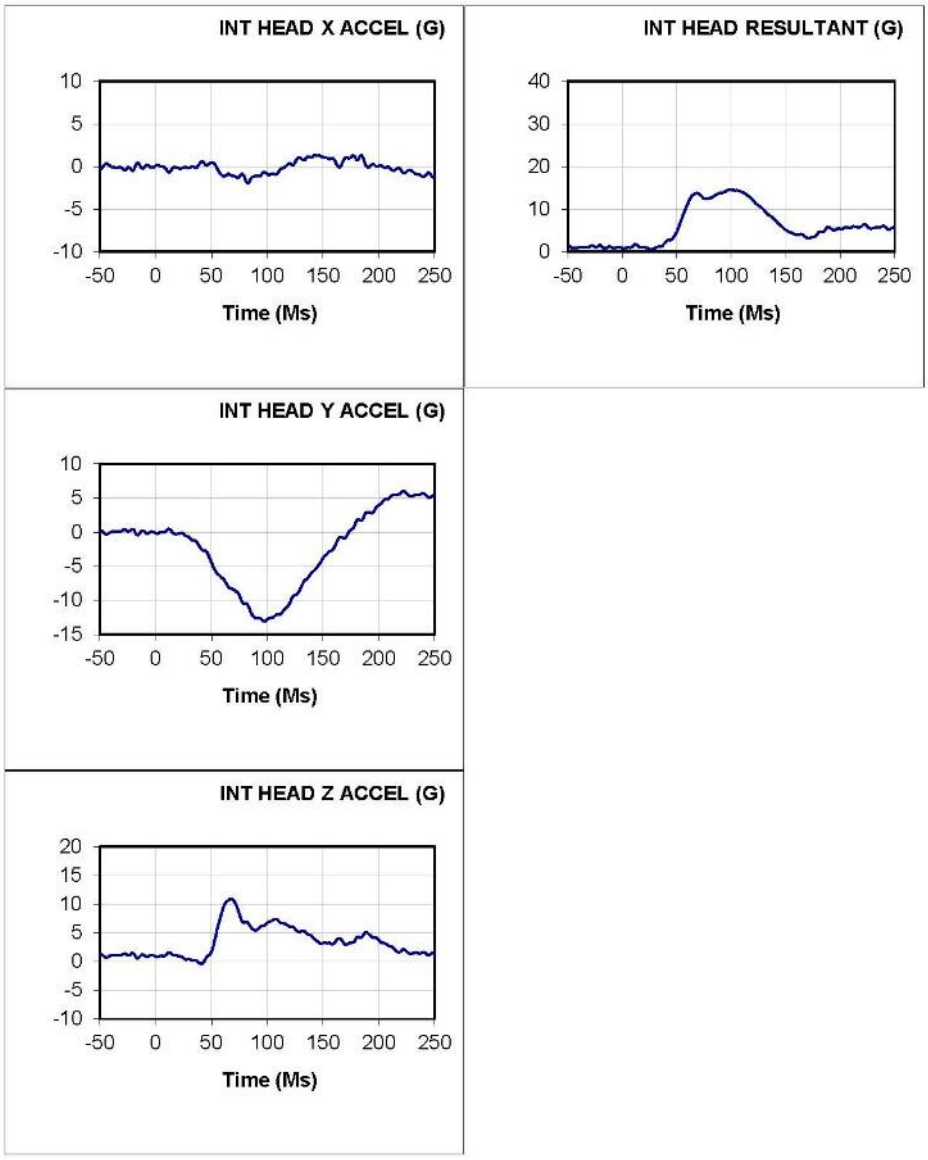

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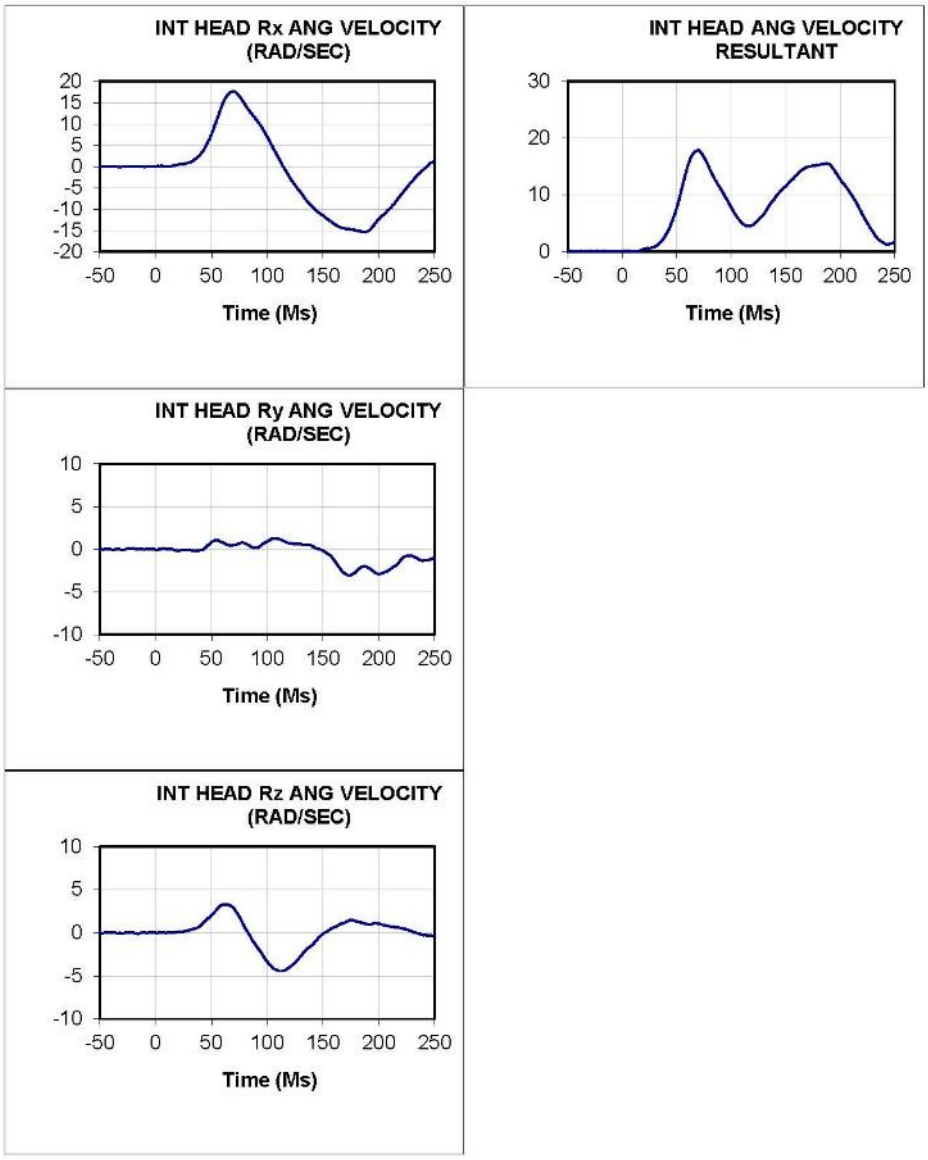
201610 Test: 9209 Test Date: 161114 Subj: AERO50 Cell: A



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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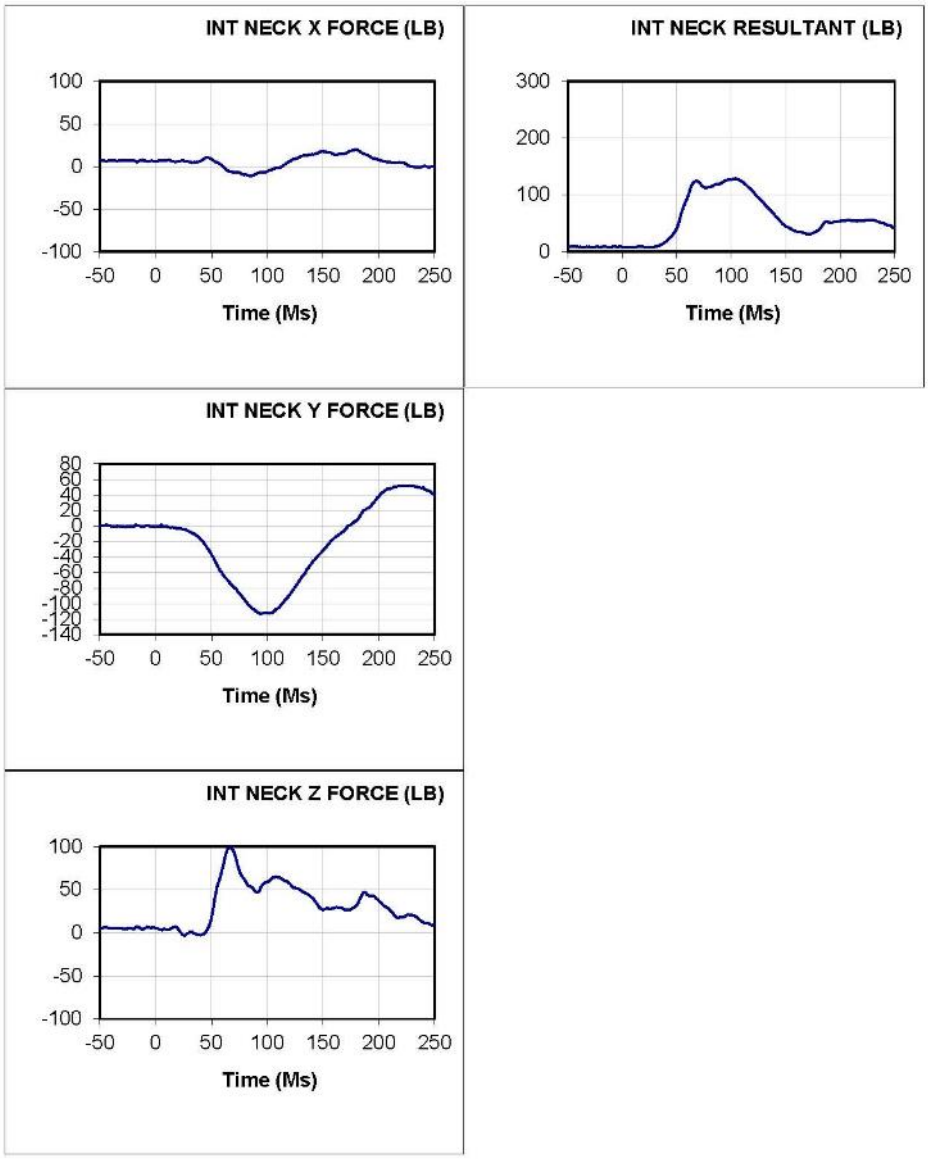

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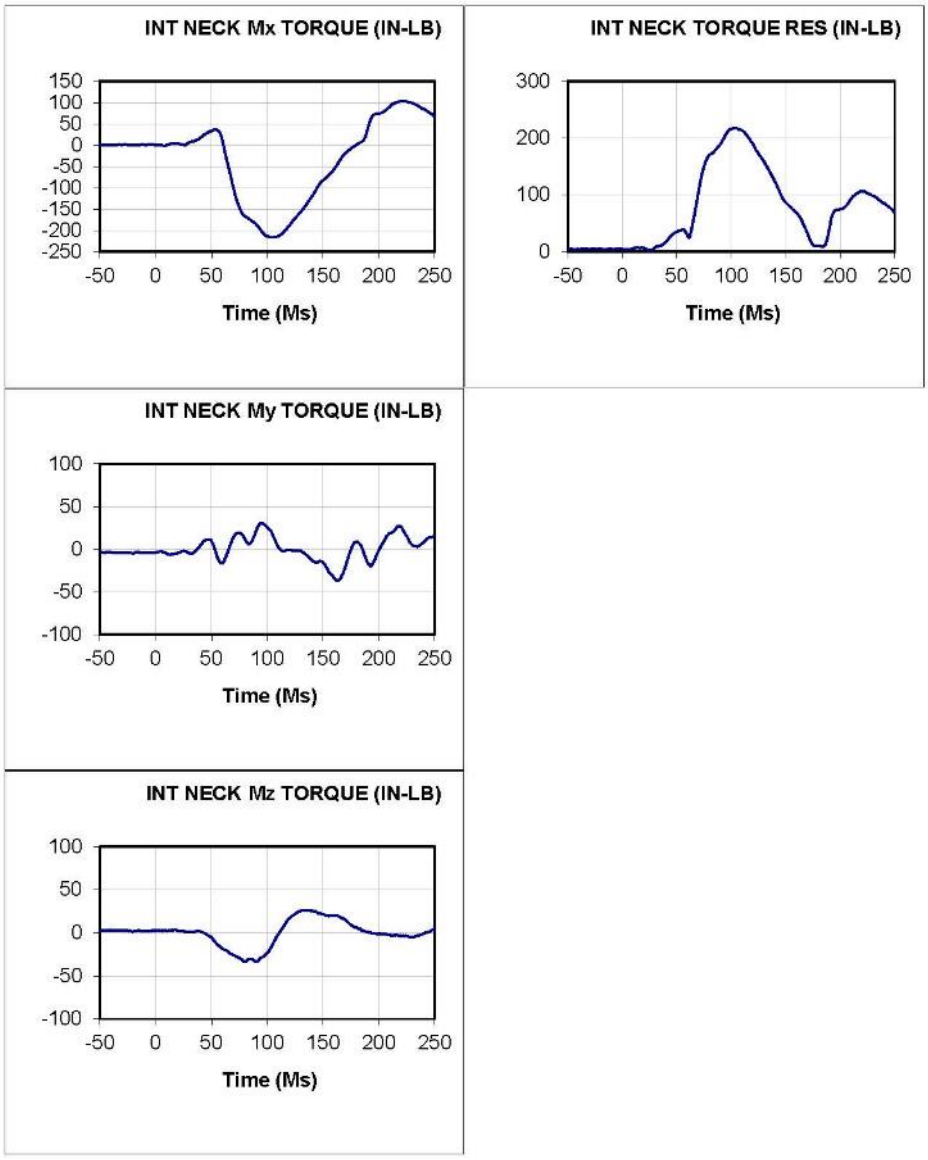

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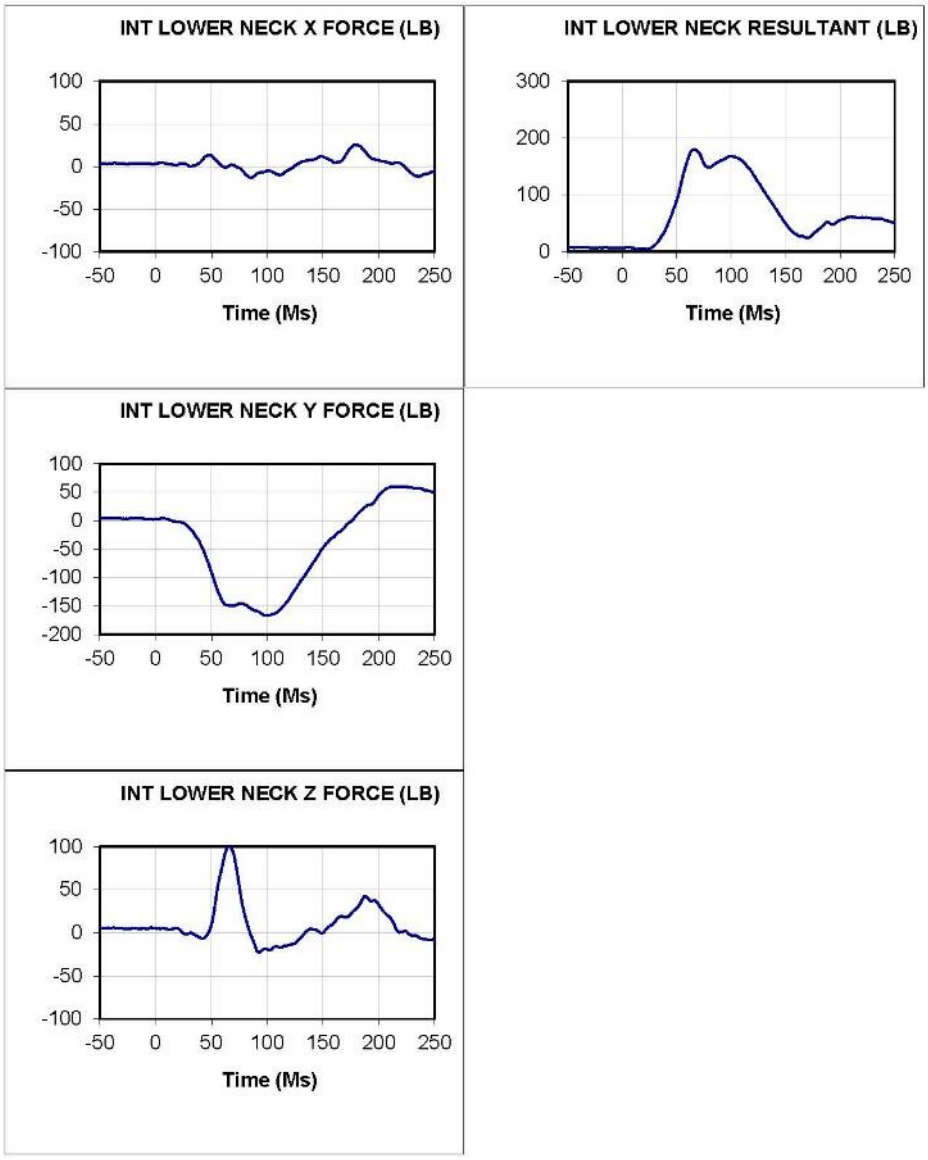

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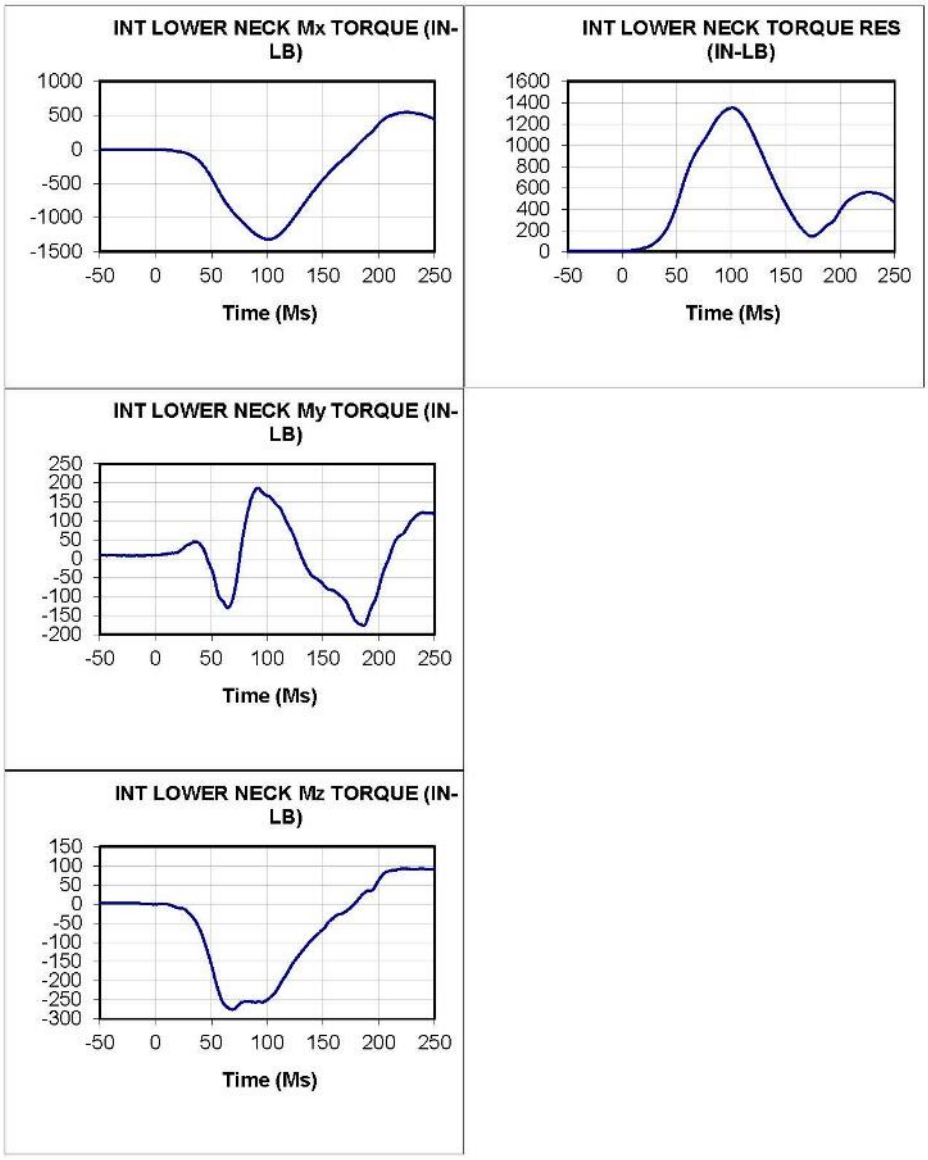

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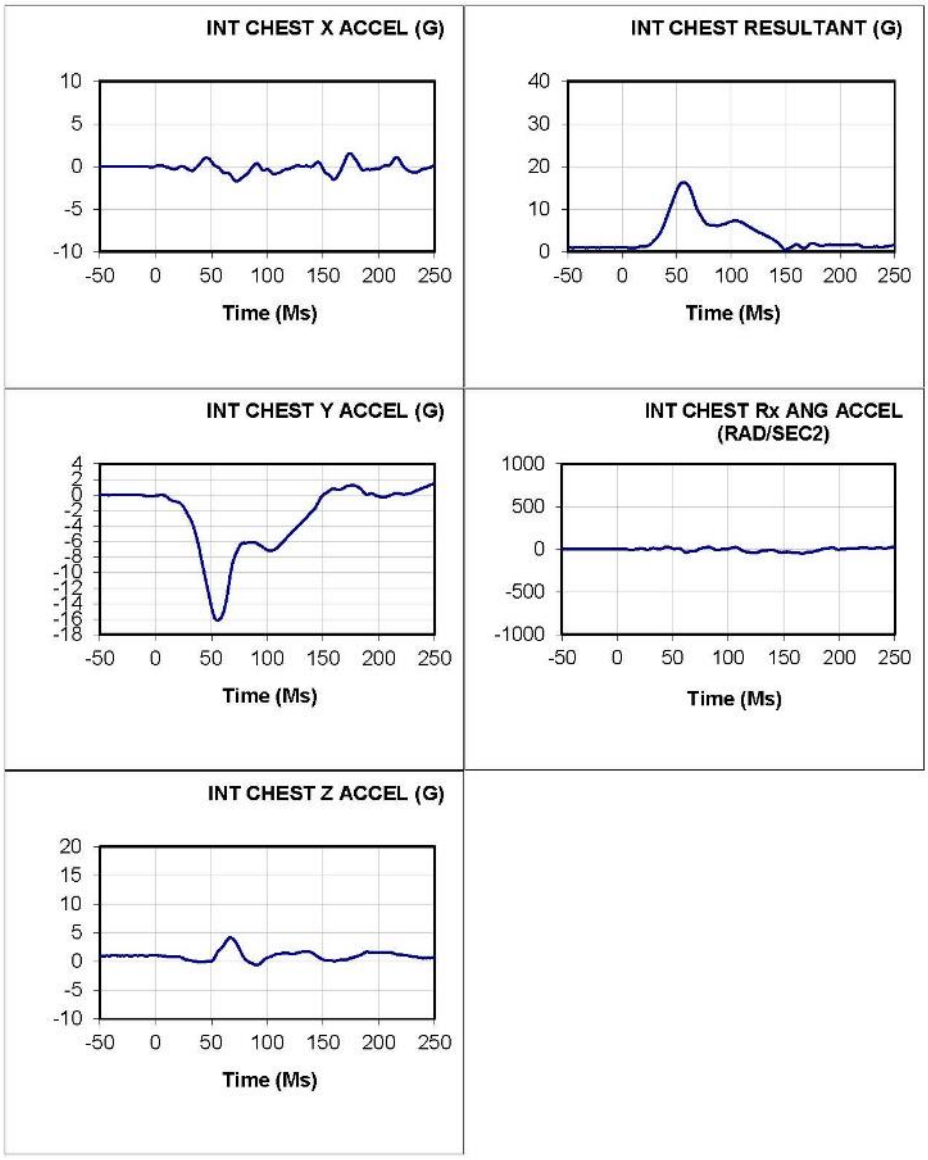

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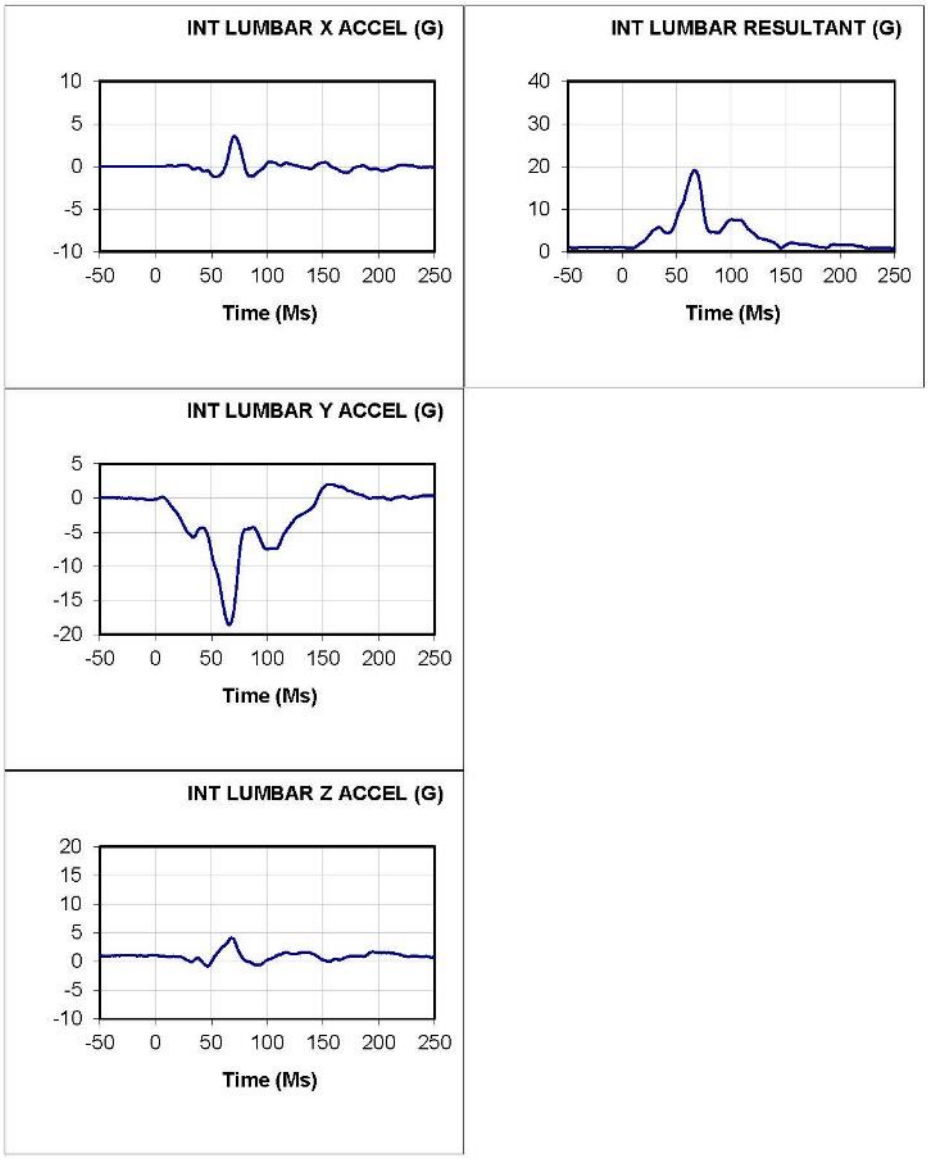

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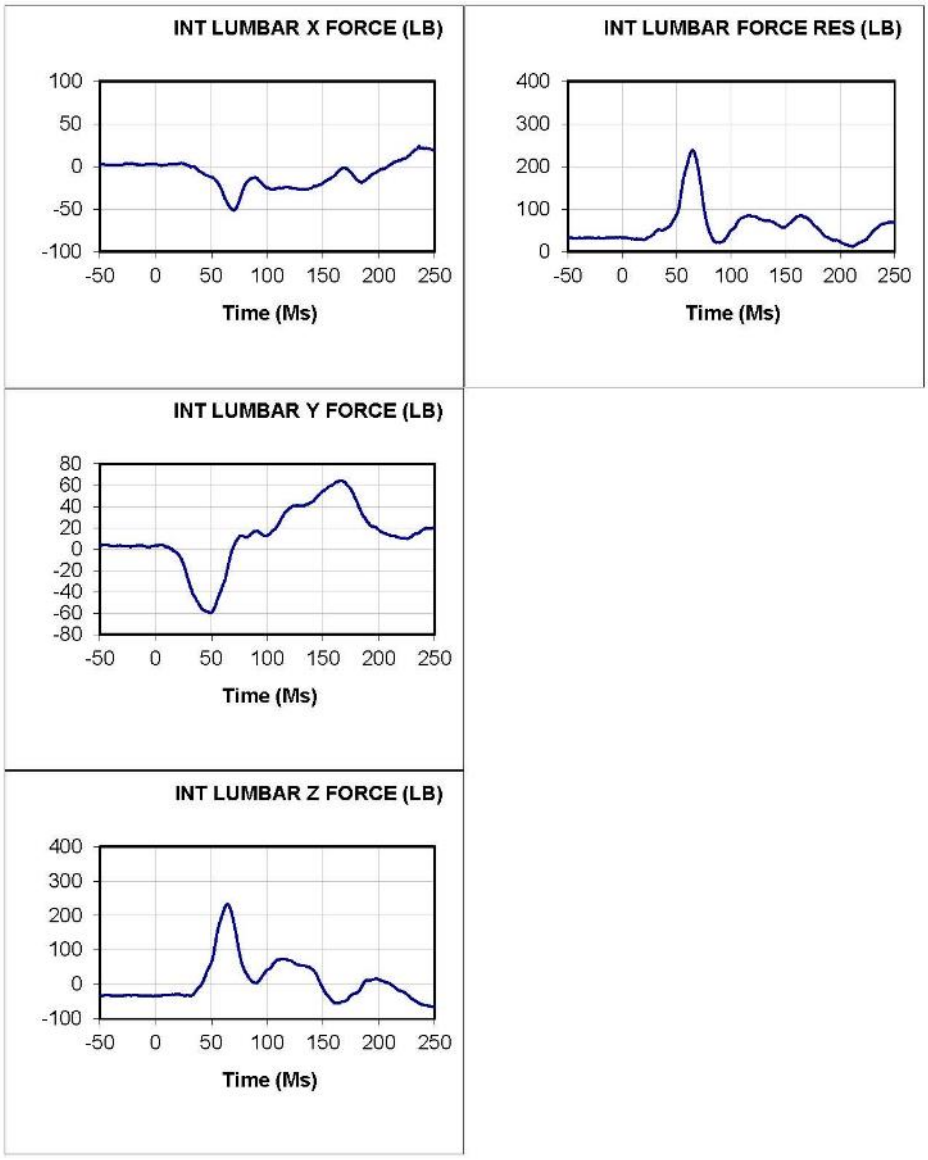
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9209 Test Date: 161114 Subj: AERO50 Cell: A



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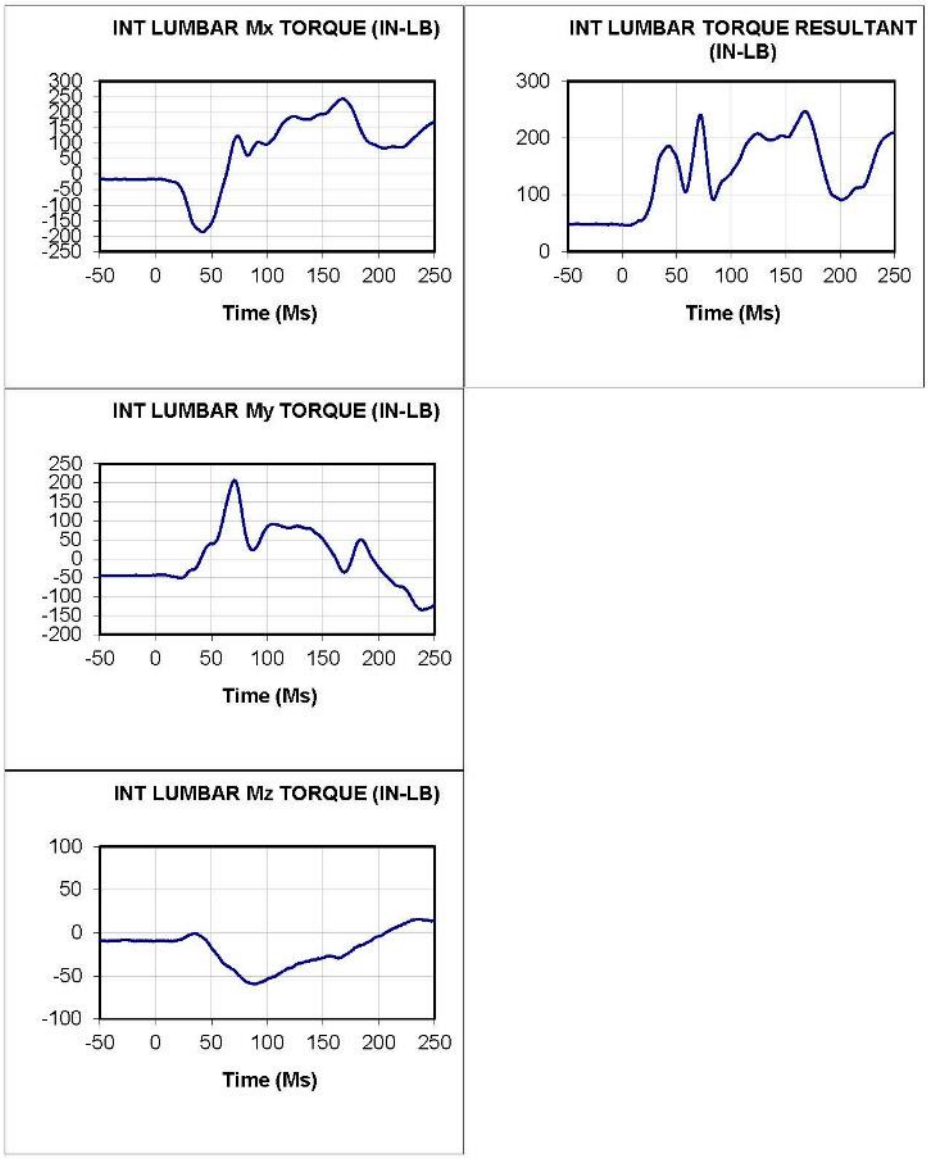
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9209 Test Date: 161114 Subj: AERO50 Cell: A



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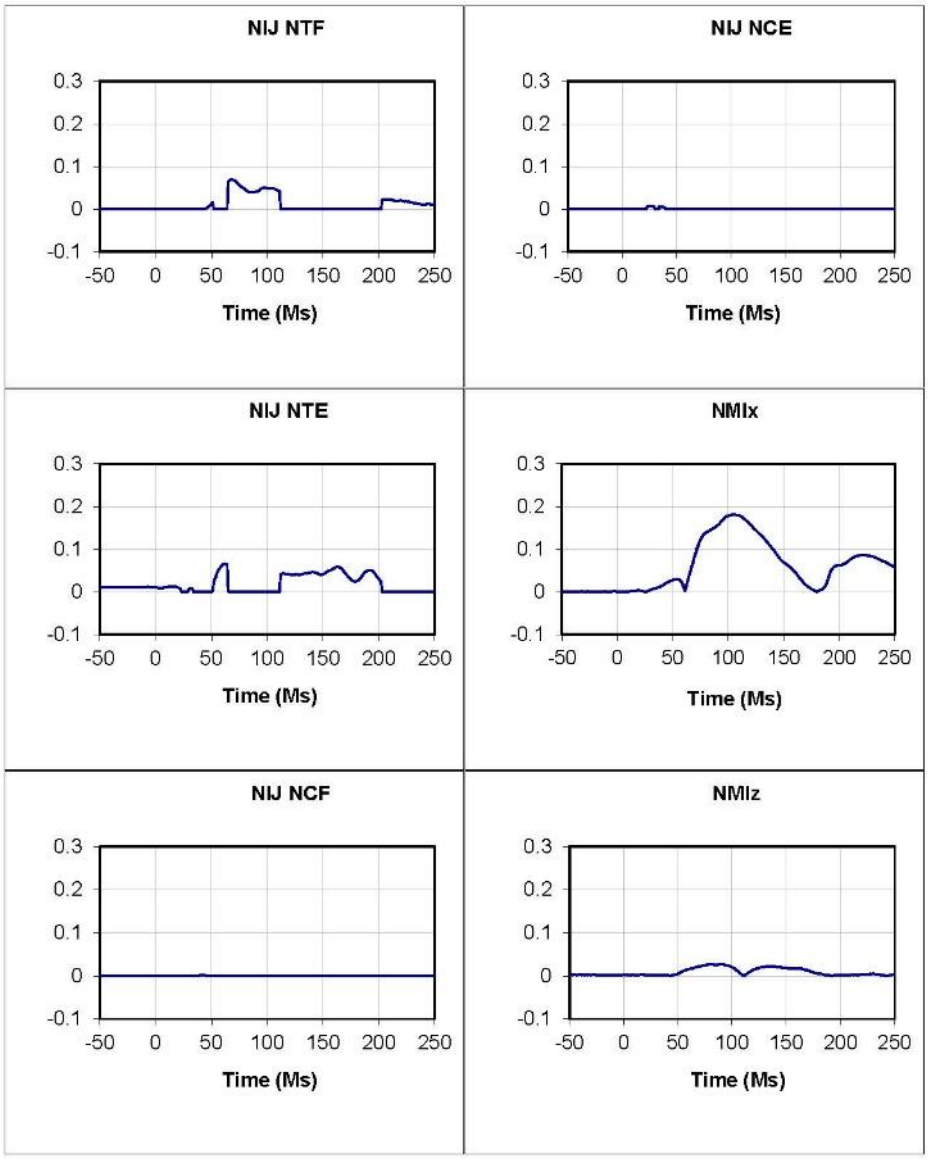
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9209 Test Date: 161114 Subj: AERO50 Cell: A



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 10.5 Cell: B

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				15.0	
Impact Rise Time (Ms)				83.0	
Impact Duration (Ms)				155.0	
Velocity Change (Ft/Sec)		37.86			
SLED X ACCEL (G)	0.05	10.57	-0.55	83.0	206.0
SLED Y ACCEL (G)	0.00	0.79	-0.74	55.0	46.0
SLED Z ACCEL (G)	-1.00	0.26	-2.11	165.0	70.0
SLED RESULTANT	1.01	10.65	0.57	82.0	147.0
INTEGRATED ACCEL (FT/SEC)	0.01	37.86	0.04	202.0	0.0
SEAT X ACCEL (G)	-0.01	4.37	-4.18	75.0	70.0
SEAT Y ACCEL (G)	-0.07	4.03	-13.72	154.0	49.0
SEAT Z ACCEL (G)	0.99	3.79	-1.25	47.0	150.0
SEAT RESULTANT	1.02	14.08	0.69	49.0	169.0
LEFT LAP X FORCE (LB)	86.52	226.65	48.49	54.0	243.0
LEFT LAP Y FORCE (LB)	-19.60	-14.36	-112.32	228.0	57.0
LEFT LAP Z FORCE (LB)	13.73	27.38	6.60	53.0	160.0
LEFT LAP RESULTANT (LB)	89.77	253.57	51.27	54.0	228.0
RIGHT LAP X FORCE (LB)	41.97	58.22	15.02	164.0	32.0
RIGHT LAP Y FORCE (LB)	10.16	10.25	-7.75	1.0	64.0
RIGHT LAP Z FORCE (LB)	7.30	11.60	1.57	171.0	39.0
RIGHT LAP RESULTANT (LB)	43.79	59.27	16.39	164.0	33.0
LEFT SHOULDER X FORCE (LB)	30.26	85.33	14.99	66.0	175.0
LEFT SHOULDER Y FORCE (LB)	0.01	7.43	-26.42	241.0	98.0
LEFT SHOULDER Z FORCE (LB)	-3.93	1.05	-8.85	45.0	75.0
LEFT SHOULDER RESULTANT (LB)	30.51	89.26	15.85	66.0	174.0
RIGHT SHOULDER X FORCE (LB)	28.62	59.50	15.87	55.0	183.0
RIGHT SHOULDER Y FORCE (LB)	0.52	8.59	-29.64	240.0	46.0
RIGHT SHOULDER Z FORCE (LB)	-5.41	-2.33	-11.13	181.0	55.0
RIGHT SHOULDER RESULTANT (LB)	29.14	66.64	17.29	54.0	177.0
CROTCH STRAP X FORCE (LB)	1.44	3.79	-14.12	160.0	55.0
CROTCH STRAP Y FORCE (LB)	-3.20	-1.84	-44.57	154.0	58.0
CROTCH STRAP Z FORCE (LB)	0.00	87.68	-9.78	57.0	157.0
CROTCH STRAP RESULTANT (LB)	3.53	99.07	3.63	58.0	1.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 10.5 Cell: B

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT HEAD X ACCEL (G)	-0.02	2.21	-1.85	123.0	77.0
INT HEAD Y ACCEL (G)	0.02	4.50	-14.90	217.0	105.0
INT HEAD Z ACCEL (G)	1.02	12.66	-0.46	103.0	39.0
INT HEAD RESULTANT (G)	1.07	19.52	0.77	104.0	11.0
INT HEAD HIC		43.72		89.0	119.0
INT HEAD Rx ANG VELOCITY (RAD/SEC)	0.00	18.95	-18.19	67.0	183.0
INT HEAD Ry ANG VELOCITY (RAD/SEC)	0.03	2.49	-4.97	122.0	180.0
INT HEAD Rz ANG VELOCITY (RAD/SEC)	0.03	3.08	-4.76	203.0	106.0
INT HEAD ANG VELOCITY RESULTANT	0.07	19.06	0.04	67.0	12.0
INT NECK X FORCE (LB)	0.94	20.10	-12.62	159.0	78.0
INT NECK Y FORCE (LB)	0.52	42.83	-129.35	212.0	101.0
INT NECK Z FORCE (LB)	-1.05	109.81	-11.71	104.0	27.0
INT NECK RESULTANT (LB)	1.67	169.53	0.93	104.0	0.0
INT NECK Mx TORQUE (IN-LB)	-3.01	99.61	-255.10	200.0	112.0
INT NECK My TORQUE (IN-LB)	0.41	35.63	-44.78	89.0	130.0
INT NECK Mz TORQUE (IN-LB)	1.88	24.03	-35.27	131.0	86.0
INT NECK TORQUE RES (IN-LB)	3.63	255.11	2.96	112.0	1.0
INT LOWER NECK X FORCE (LB)	4.07	32.72	-15.25	186.0	103.0
INT LOWER NECK Y FORCE (LB)	3.53	48.66	-234.87	234.0	103.0
INT LOWER NECK Z FORCE (LB)	2.39	93.60	-40.22	60.0	120.0
INT LOWER NECK RESULTANT (LB)	5.93	235.43	3.09	103.0	10.0
INT LOWER NECK Mx TORQUE (IN-LB)	5.08	433.16	-1644.14	213.0	105.0
INT LOWER NECK My TORQUE (IN-LB)	10.08	157.82	-248.78	96.0	186.0
INT LOWER NECK Mz TORQUE (IN-LB)	1.24	55.52	-338.23	244.0	99.0
INT LOWER NECK TORQUE RES (IN-LB)	11.46	1683.22	10.71	104.0	5.0
INT CHEST X ACCEL (G)	-0.01	1.41	-1.98	178.0	67.0
INT CHEST Y ACCEL (G)	-0.06	1.39	-17.40	165.0	54.0
INT CHEST Z ACCEL (G)	1.00	3.11	-0.62	60.0	39.0
INT CHEST RESULTANT (G)	1.00	17.58	0.42	54.0	173.0
INT CHEST Rx ANG ACCEL (RAD/SEC2)	-0.11	111.46	-69.83	185.0	212.0
INT LUMBAR X ACCEL (G)	0.00	3.20	-2.37	63.0	52.0
INT LUMBAR Y ACCEL (G)	-0.07	3.10	-17.99	160.0	56.0
INT LUMBAR Z ACCEL (G)	1.03	3.25	-0.64	61.0	83.0
INT LUMBAR RESULTANT (G)	1.03	18.19	0.70	56.0	167.0

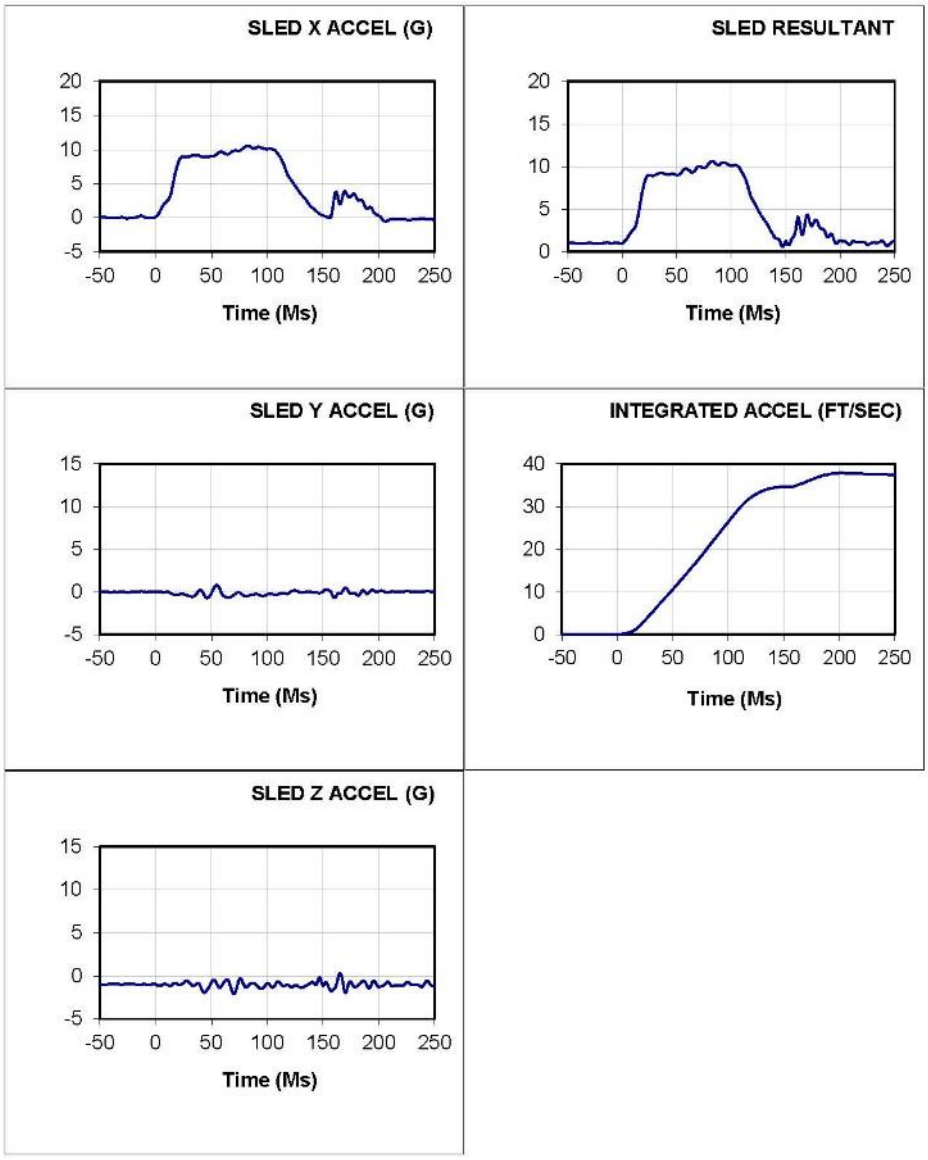
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 10.5 Cell: B

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT LUMBAR X FORCE (LB)	2.21	13.63	-24.20	245.0	184.0
INT LUMBAR Y FORCE (LB)	6.34	54.17	-87.81	164.0	52.0
INT LUMBAR Z FORCE (LB)	-33.40	249.82	-87.71	59.0	226.0
INT LUMBAR FORCE RES (LB)	34.07	257.57	8.34	59.0	202.0
INT LUMBAR Mx TORQUE (IN-LB)	19.91	207.23	-269.85	165.0	52.0
INT LUMBAR My TORQUE (IN-LB)	-15.42	113.94	-73.93	186.0	77.0
INT LUMBAR Mz TORQUE (IN-LB)	-11.75	-3.40	-43.54	32.0	78.0
INT LUMBAR TORQUE RESULTANT (IN-LB)	27.80	271.00	22.64	52.0	18.0
NIJ SHEAR (LB)		20.10	-12.62	159.0	78.0
NIJ TENSION (LB)		109.81		104.0	
NIJ COMPRESSION (LB)		-11.71		27.0	
NIJ FLEXION (IN-LB)		40.80		89.0	
NIJ EXTENSION (IN-LB)		55.32		130.0	
NIJ NTF	0.0000	0.0697	0.0000	99.0	0.0
NIJ NTE	0.0000	0.0825	0.0000	130.0	0.0
NIJ NCF	0.0002	0.0119	0.0000	227.0	8.0
NIJ NCE	0.0009	0.0033	0.0000	14.0	0.0
NIJ NTF AIS >= 2		0.12			
NIJ NTF AIS >= 3		0.04			
NIJ NTF AIS >= 4		0.07			
NIJ NTF AIS >= 5		0.02			
NIJ NTE AIS >= 2		0.12			
NIJ NTE AIS >= 3		0.04			
NIJ NTE AIS >= 4		0.07			
NIJ NTE AIS >= 5		0.02			
NIJ NCF AIS >= 2		0.12			
NIJ NCF AIS >= 3		0.04			
NIJ NCF AIS >= 4		0.06			
NIJ NCF AIS >= 5		0.02			
NIJ NCE AIS >= 2		0.11			
NIJ NCE AIS >= 3		0.04			
NIJ NCE AIS >= 4		0.06			
NIJ NCE AIS >= 5		0.02			
NMIx	0.0025	0.2135	0.0001	112.0	183.0
NMIz	0.0016	0.0295	0.0000	86.0	22.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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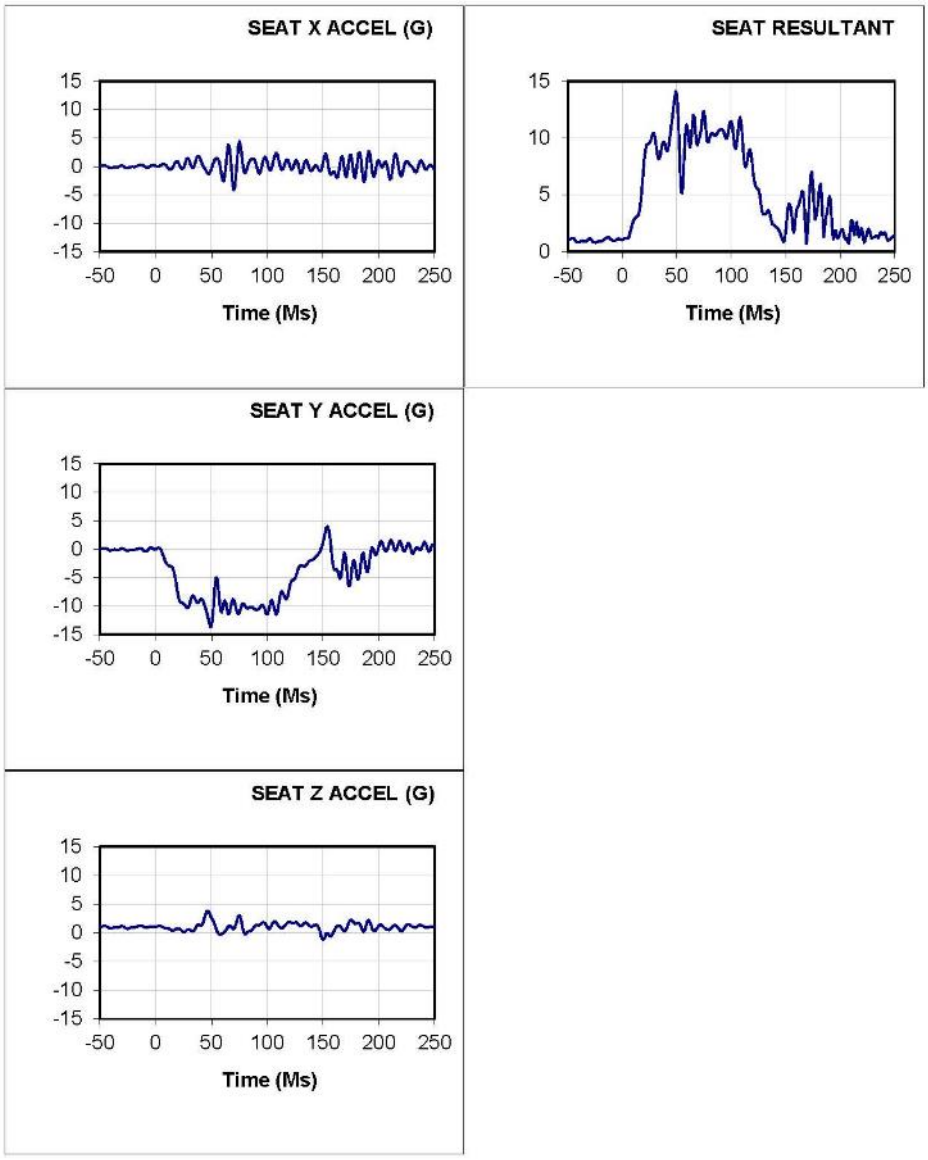
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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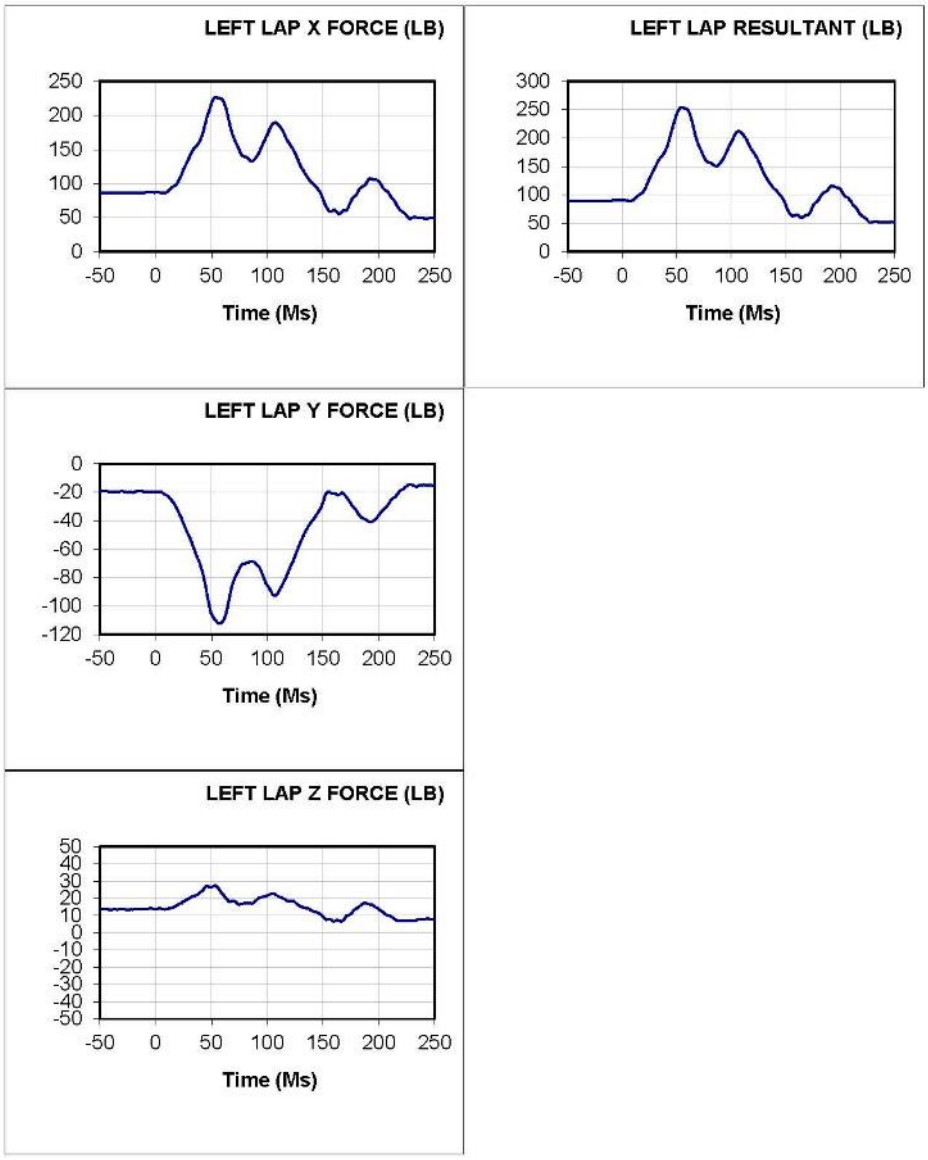
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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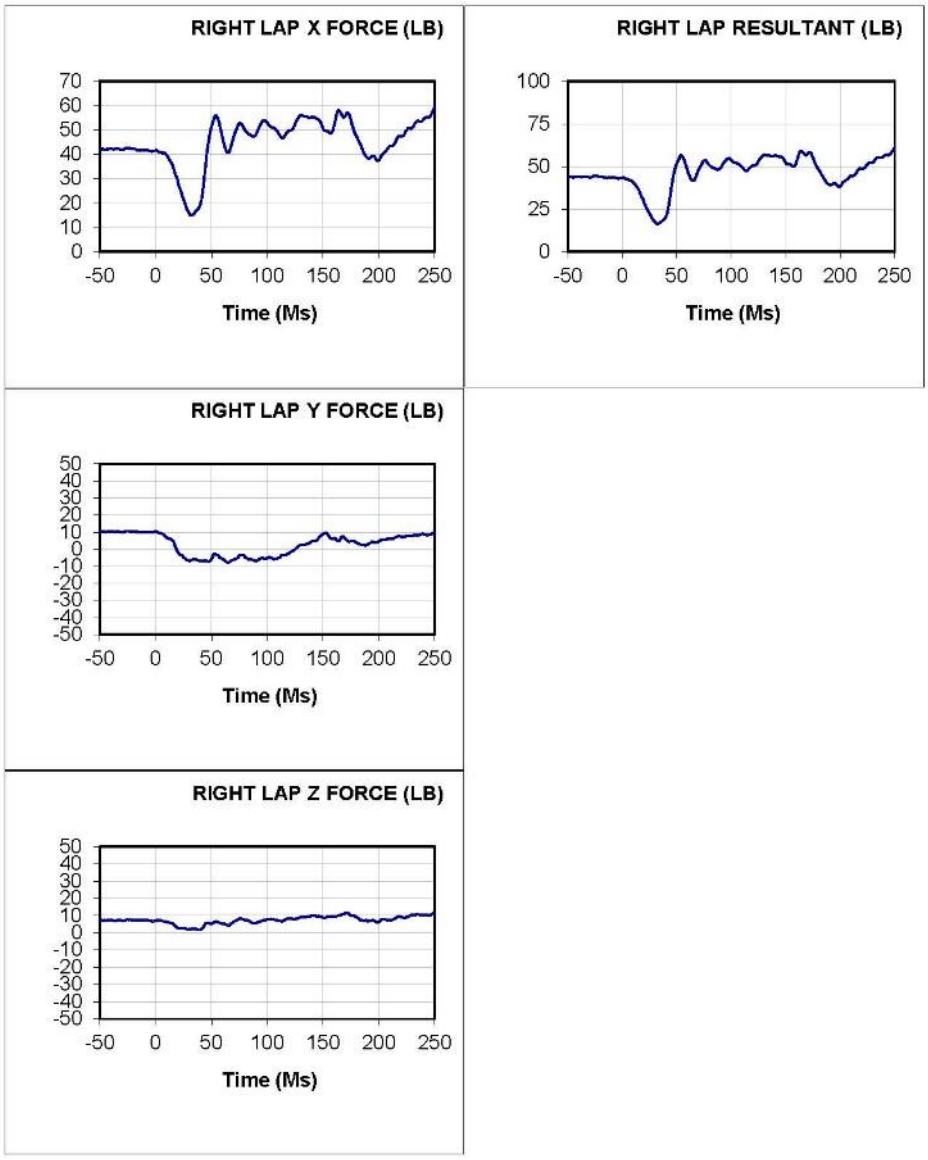
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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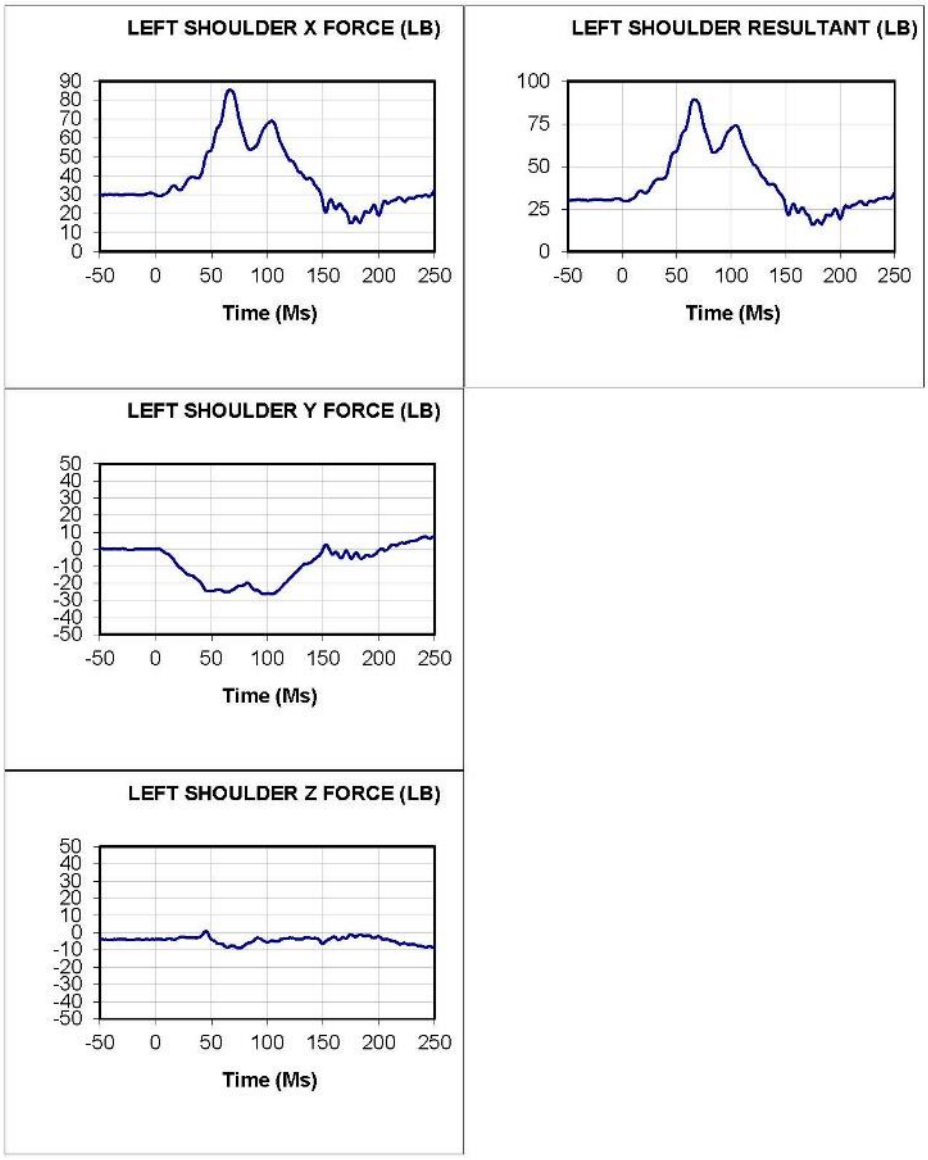
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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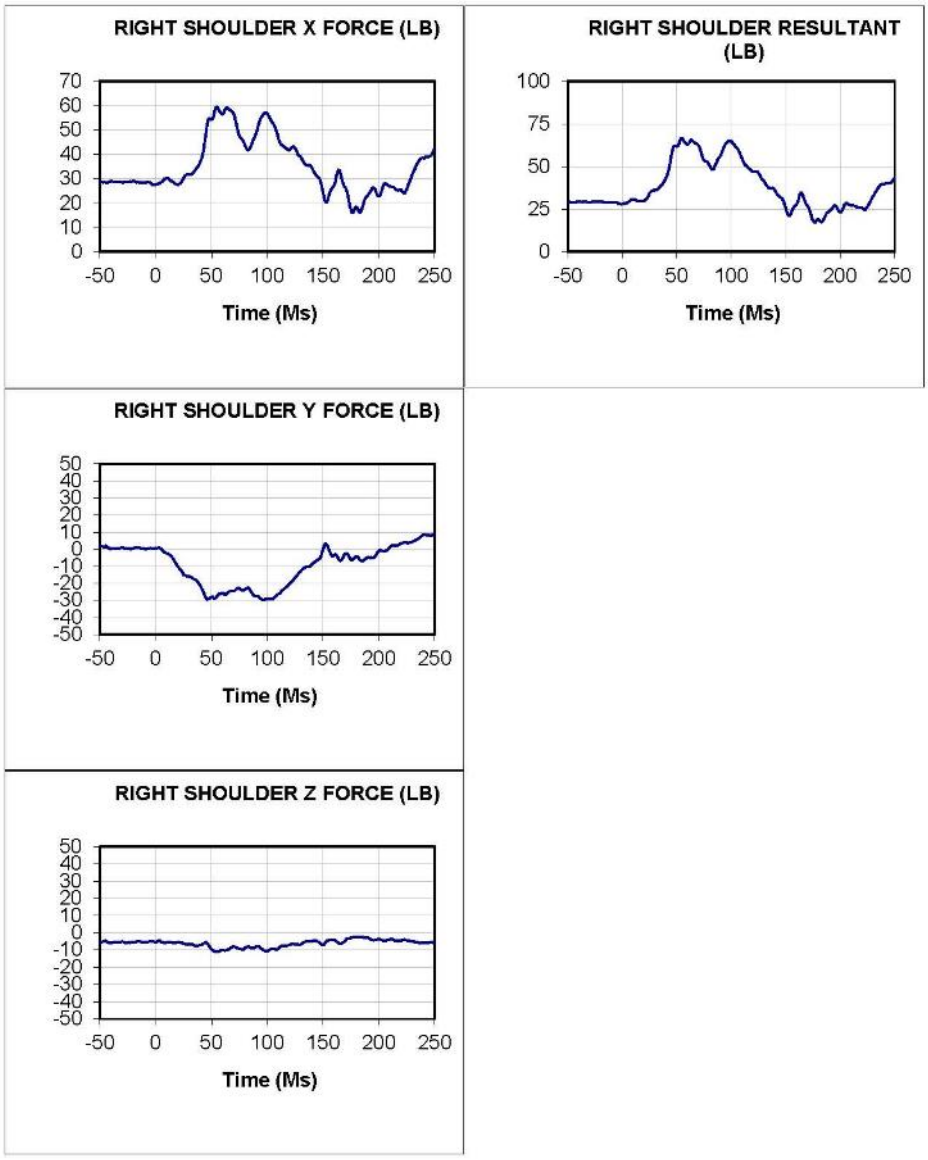
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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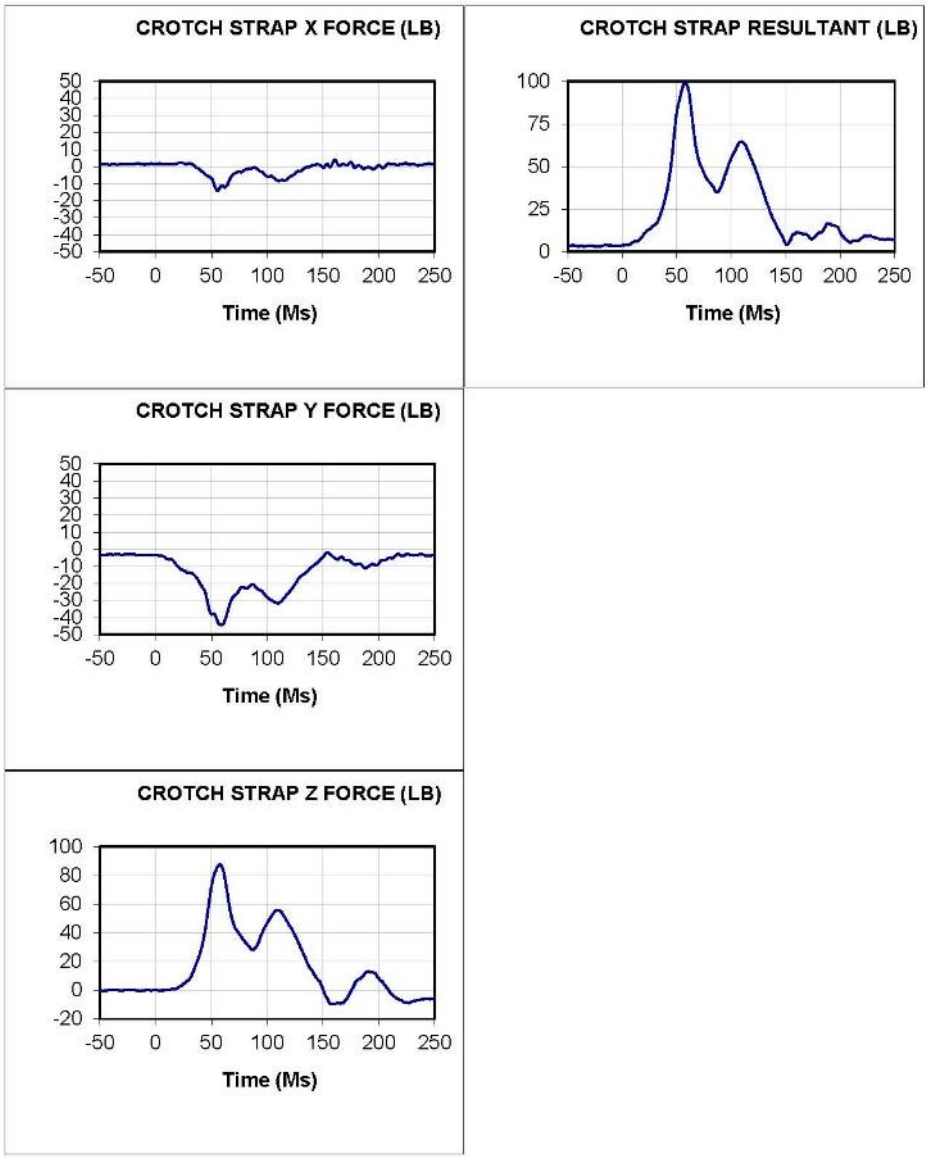
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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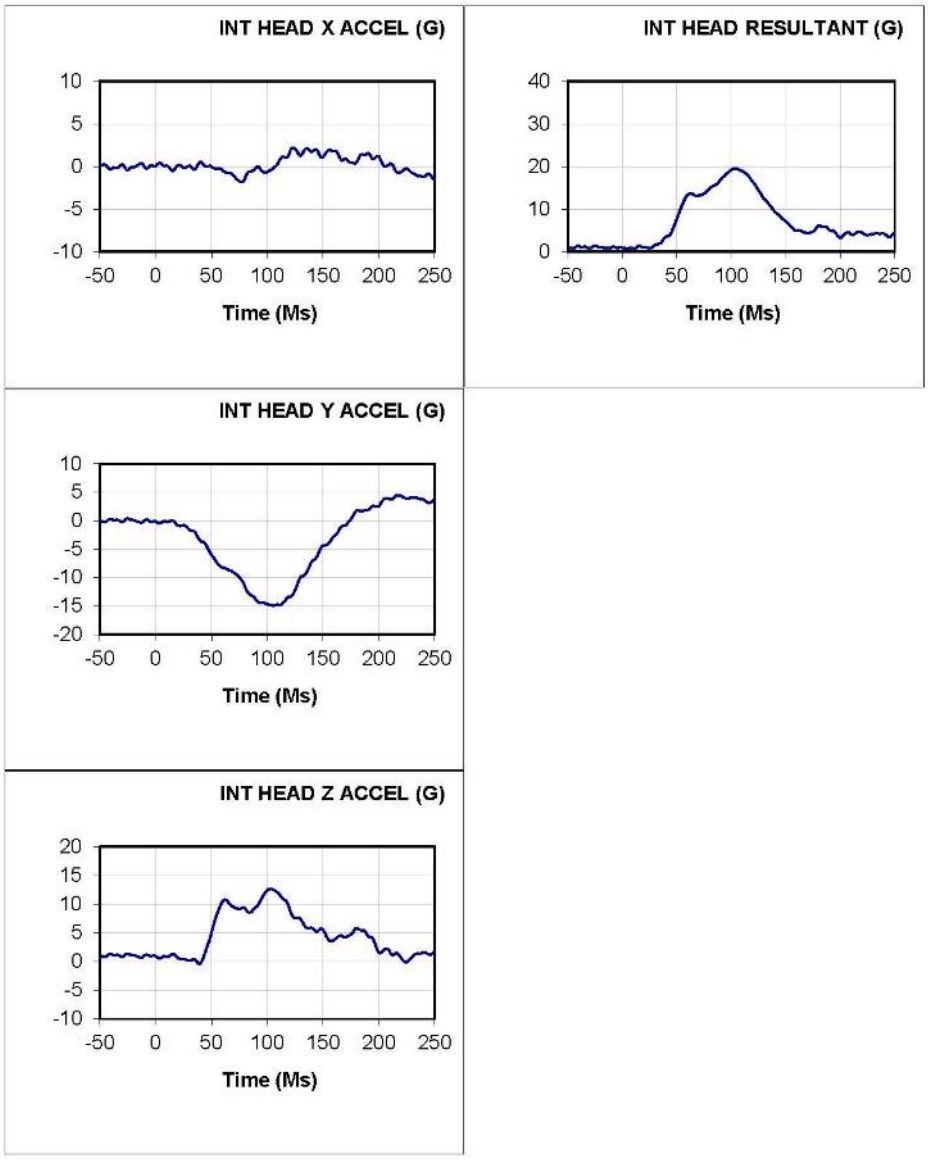
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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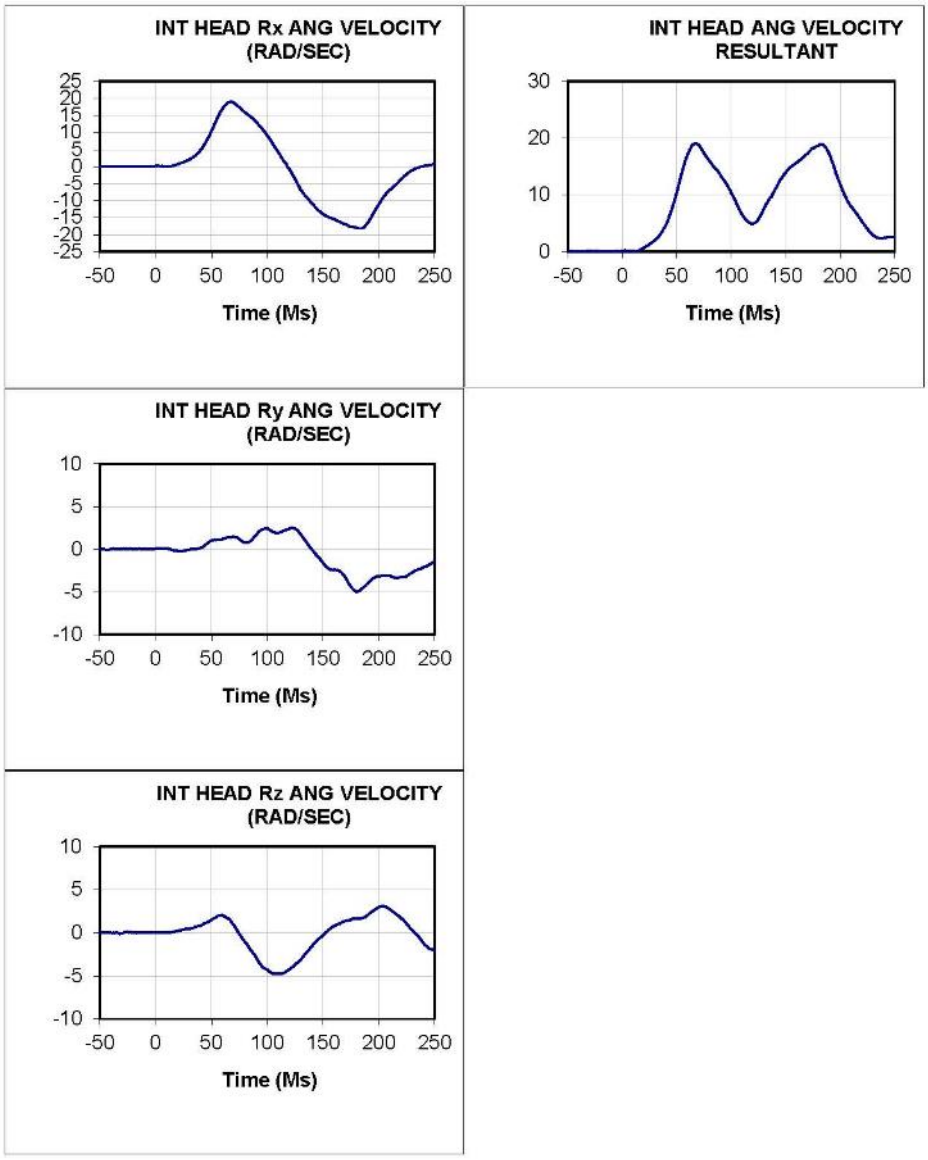
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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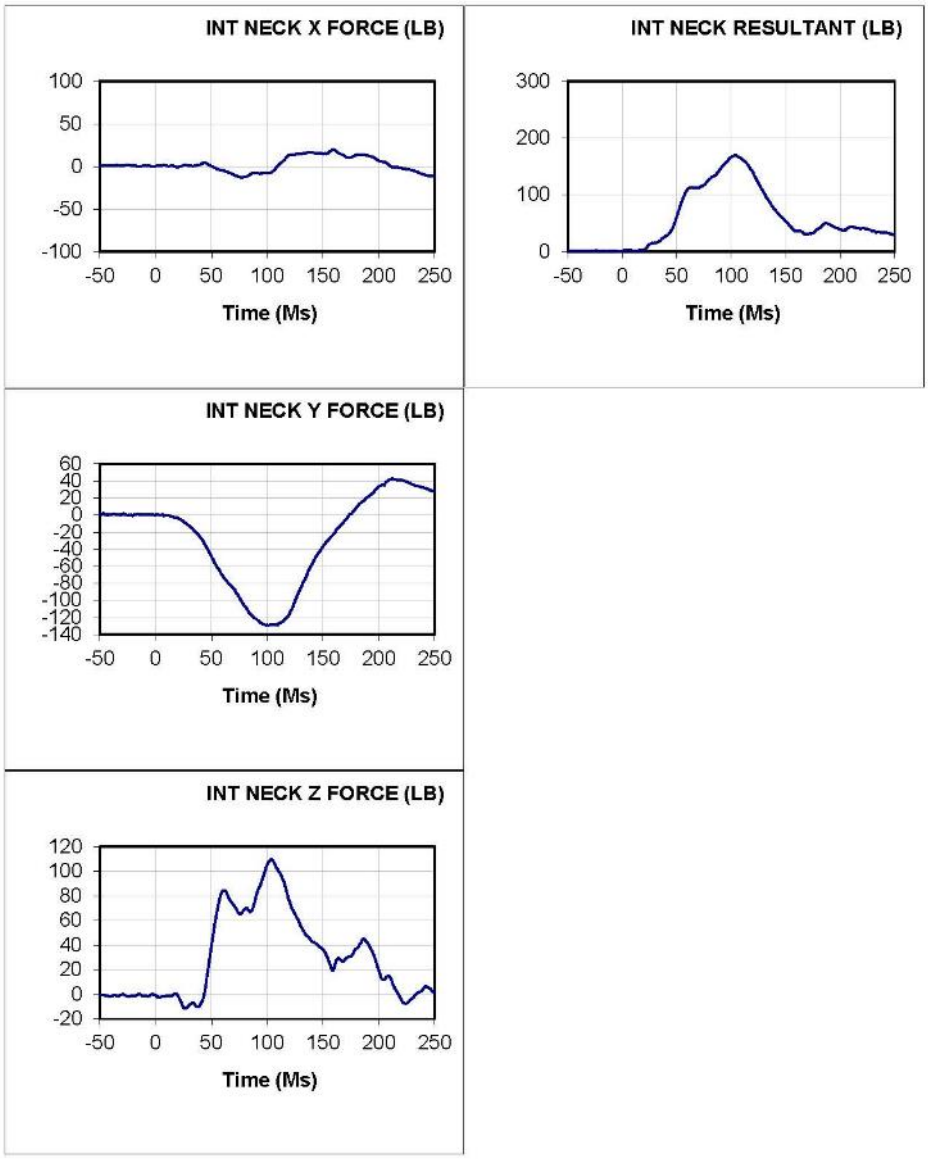
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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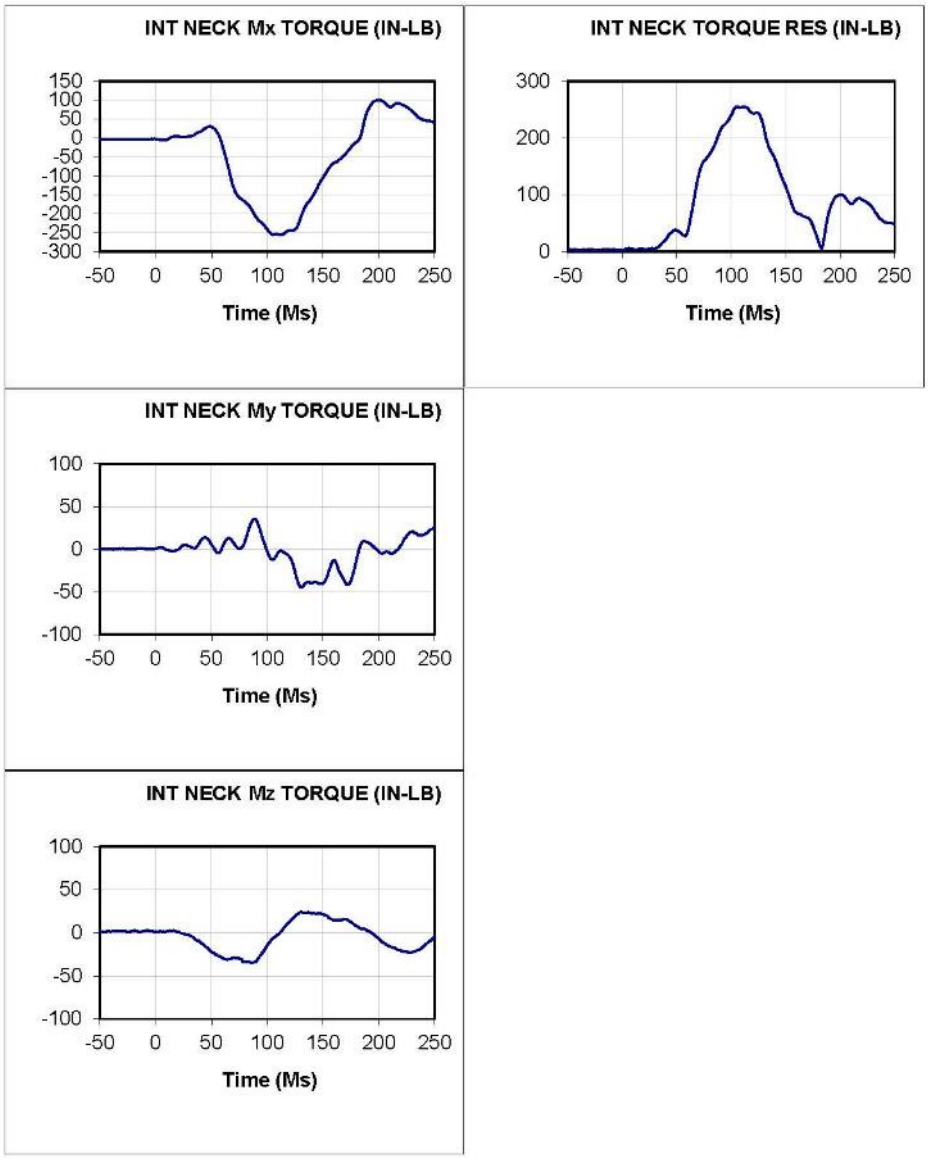
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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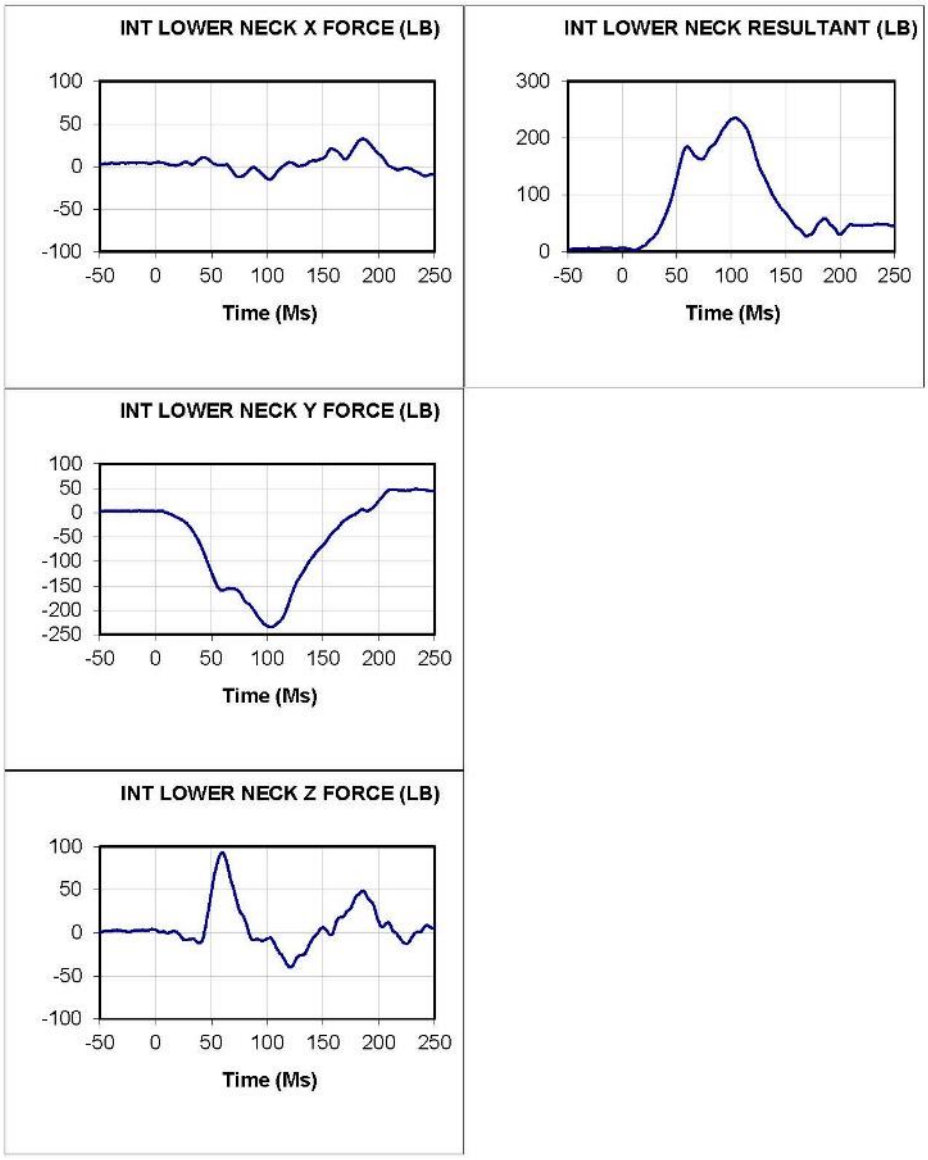
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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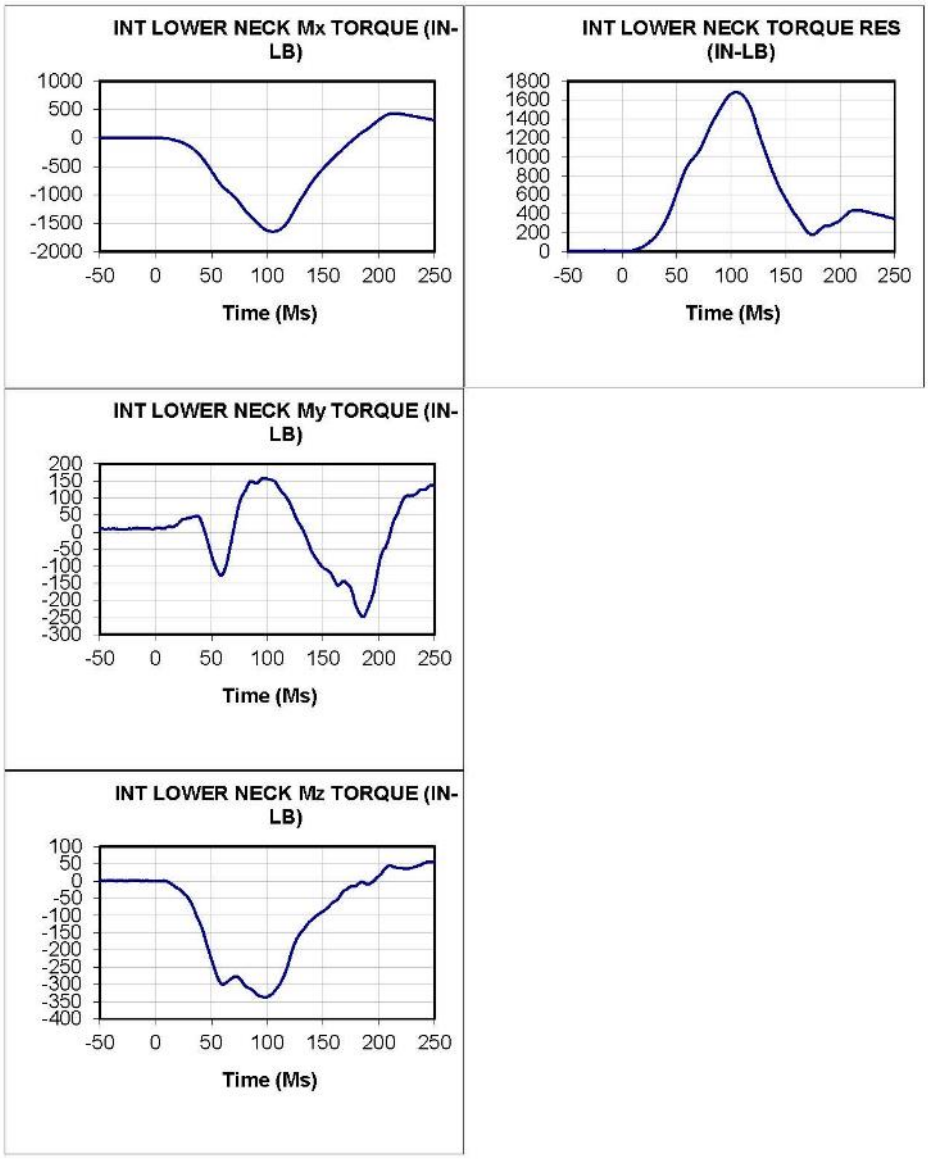
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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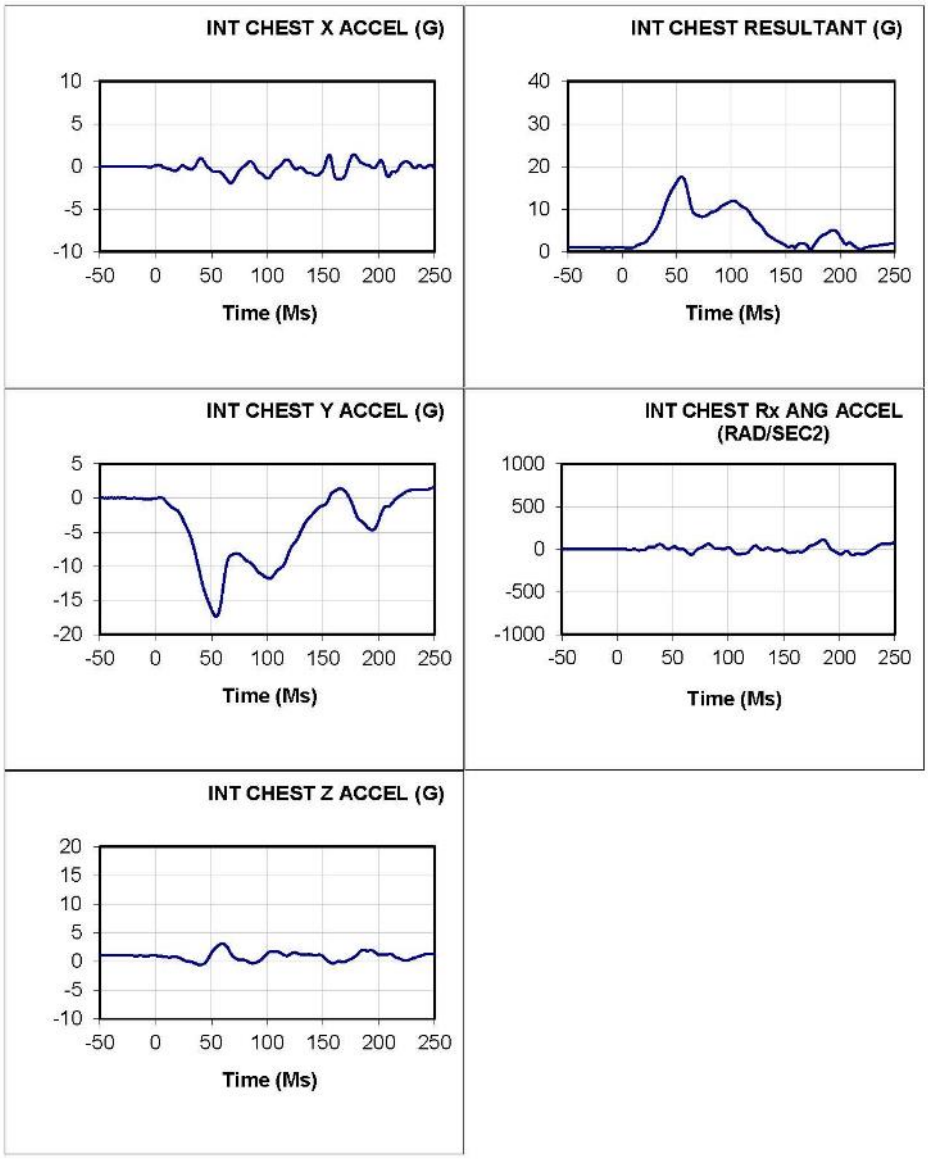
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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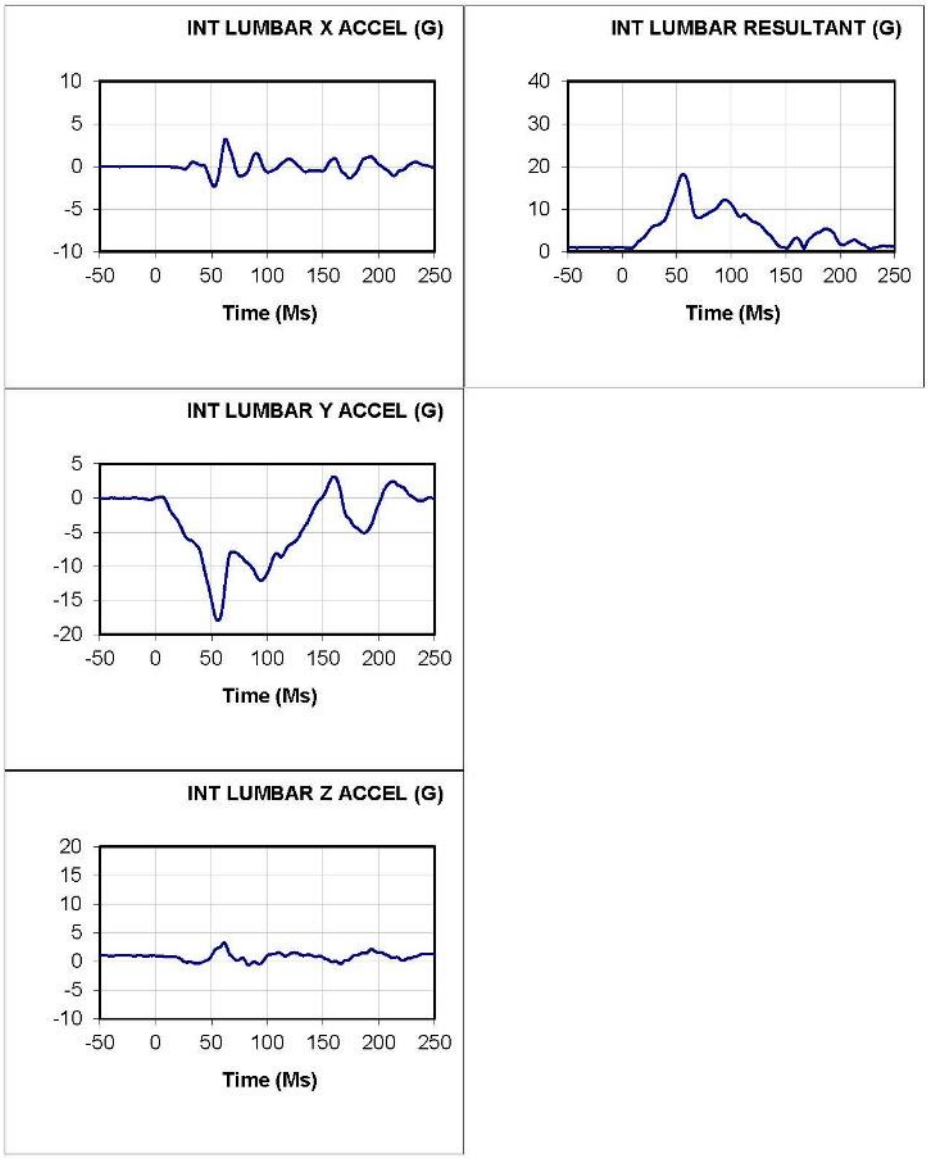
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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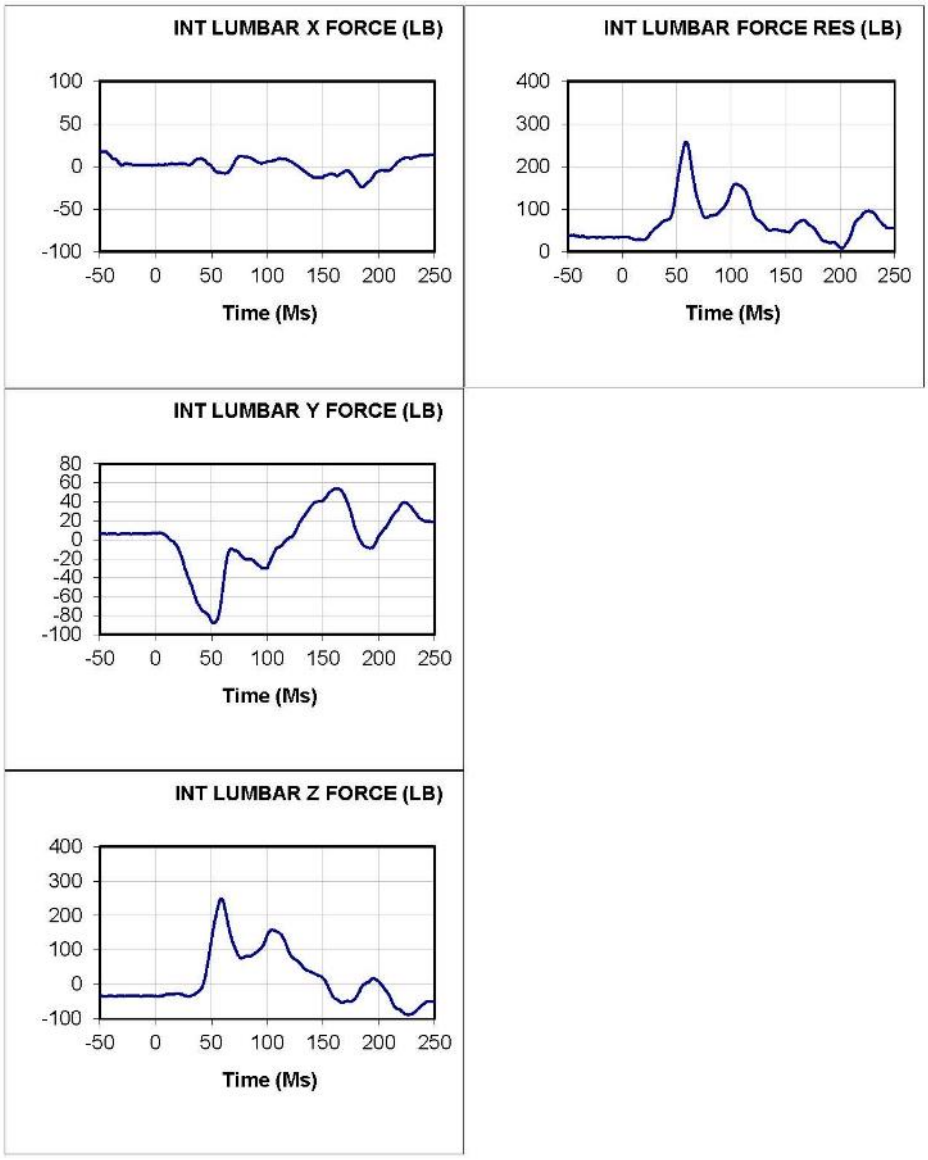
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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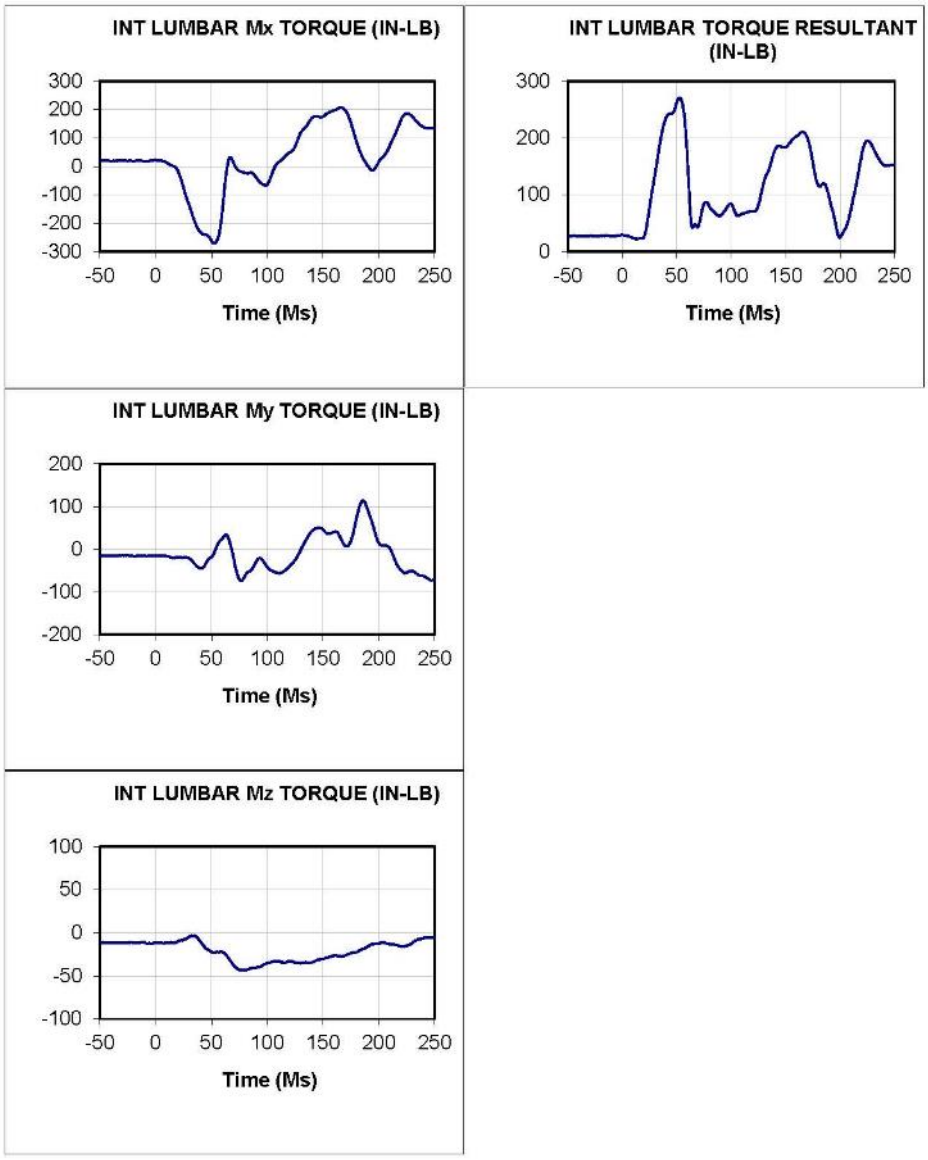
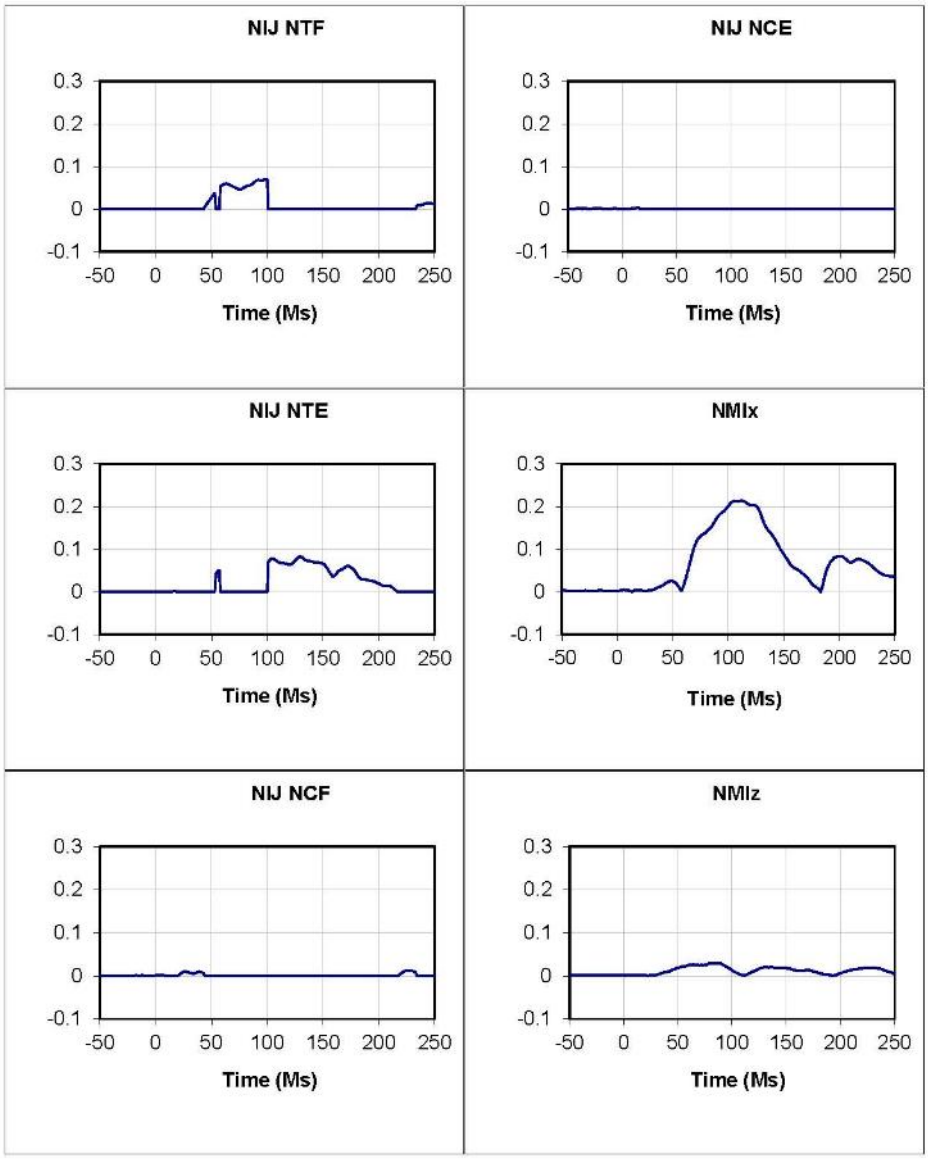
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9213 Test Date: 161114 Subj: AERO50 Cell: B



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 12.5 Cell: C

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				12.0	
Impact Rise Time (Ms)				77.0	
Impact Duration (Ms)				131.0	
Velocity Change (Ft/Sec)		37.17			
SLED X ACCEL (G)	0.07	12.54	-0.73	77.0	135.0
SLED Y ACCEL (G)	0.01	0.90	-1.13	48.0	60.0
SLED Z ACCEL (G)	-1.02	0.41	-2.99	49.0	36.0
SLED RESULTANT	1.02	12.62	0.39	78.0	155.0
INTEGRATED ACCEL (FT/SEC)	0.01	37.17	0.05	131.0	0.0
SEAT X ACCEL (G)	0.05	5.13	-5.48	156.0	161.0
SEAT Y ACCEL (G)	0.00	5.65	-18.86	156.0	43.0
SEAT Z ACCEL (G)	1.05	5.91	-1.04	40.0	146.0
SEAT RESULTANT	1.09	19.24	0.61	43.0	195.0
LEFT LAP X FORCE (LB)	66.78	197.17	44.08	62.0	158.0
LEFT LAP Y FORCE (LB)	-19.30	-11.13	-106.46	155.0	61.0
LEFT LAP Z FORCE (LB)	11.28	26.97	5.43	49.0	147.0
LEFT LAP RESULTANT (LB)	70.42	225.08	46.82	61.0	158.0
RIGHT LAP X FORCE (LB)	48.52	83.71	13.22	192.0	33.0
RIGHT LAP Y FORCE (LB)	9.21	18.11	-11.56	191.0	41.0
RIGHT LAP Z FORCE (LB)	7.27	16.21	2.67	169.0	33.0
RIGHT LAP RESULTANT (LB)	49.92	86.95	16.48	192.0	33.0
LEFT SHOULDER X FORCE (LB)	31.85	120.75	14.12	66.0	174.0
LEFT SHOULDER Y FORCE (LB)	4.35	24.60	-28.21	238.0	46.0
LEFT SHOULDER Z FORCE (LB)	-5.30	3.92	-22.73	39.0	239.0
LEFT SHOULDER RESULTANT (LB)	32.58	124.32	15.26	66.0	174.0
RIGHT SHOULDER X FORCE (LB)	31.77	60.92	19.32	58.0	140.0
RIGHT SHOULDER Y FORCE (LB)	1.71	17.62	-36.55	238.0	47.0
RIGHT SHOULDER Z FORCE (LB)	-5.29	-1.70	-11.51	40.0	46.0
RIGHT SHOULDER RESULTANT (LB)	32.26	68.96	19.88	57.0	165.0
CROTCH STRAP X FORCE (LB)	-0.35	4.33	-21.76	149.0	58.0
CROTCH STRAP Y FORCE (LB)	-4.20	0.18	-54.07	156.0	60.0
CROTCH STRAP Z FORCE (LB)	0.01	115.66	-14.29	54.0	155.0
CROTCH STRAP RESULTANT (LB)	4.23	128.63	4.23	54.0	1.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 12.5 Cell: C

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT HEAD X ACCEL (G)	0.07	2.39	-2.76	147.0	74.0
INT HEAD Y ACCEL (G)	-0.08	8.45	-19.01	220.0	96.0
INT HEAD Z ACCEL (G)	0.94	16.69	-1.73	92.0	35.0
INT HEAD RESULTANT (G)	1.01	25.25	0.64	96.0	12.0
INT HEAD HIC		79.27		80.0	110.0
INT HEAD Rx ANG VELOCITY (RAD/SEC)	0.00	23.45	-22.96	62.0	169.0
INT HEAD Ry ANG VELOCITY (RAD/SEC)	0.03	2.19	-5.93	96.0	170.0
INT HEAD Rz ANG VELOCITY (RAD/SEC)	0.01	3.68	-7.22	57.0	103.0
INT HEAD ANG VELOCITY RESULTANT	0.05	23.75	0.05	169.0	11.0
INT NECK X FORCE (LB)	1.29	21.55	-24.36	144.0	75.0
INT NECK Y FORCE (LB)	0.35	78.68	-164.60	215.0	100.0
INT NECK Z FORCE (LB)	-2.25	147.78	-22.24	95.0	35.0
INT NECK RESULTANT (LB)	2.66	221.10	2.55	96.0	13.0
INT NECK Mx TORQUE (IN-LB)	-2.69	161.74	-340.54	210.0	107.0
INT NECK My TORQUE (IN-LB)	1.34	65.34	-45.72	85.0	124.0
INT NECK Mz TORQUE (IN-LB)	3.96	40.67	-58.88	125.0	83.0
INT NECK TORQUE RES (IN-LB)	5.00	340.61	4.35	107.0	1.0
INT LOWER NECK X FORCE (LB)	4.46	40.71	-26.07	179.0	99.0
INT LOWER NECK Y FORCE (LB)	1.91	83.84	-304.97	207.0	94.0
INT LOWER NECK Z FORCE (LB)	1.57	108.78	-68.58	59.0	111.0
INT LOWER NECK RESULTANT (LB)	5.13	307.88	3.97	95.0	9.0
INT LOWER NECK Mx TORQUE (IN-LB)	-0.20	802.36	-2156.37	210.0	97.0
INT LOWER NECK My TORQUE (IN-LB)	4.70	318.12	-282.43	98.0	174.0
INT LOWER NECK Mz TORQUE (IN-LB)	3.79	113.26	-460.27	193.0	90.0
INT LOWER NECK TORQUE RES (IN-LB)	6.25	2220.73	7.64	97.0	0.0
INT CHEST X ACCEL (G)	-0.02	2.46	-3.02	177.0	66.0
INT CHEST Y ACCEL (G)	-0.06	2.14	-21.68	156.0	49.0
INT CHEST Z ACCEL (G)	1.00	2.37	-2.12	58.0	37.0
INT CHEST RESULTANT (G)	1.01	21.73	0.78	49.0	137.0
INT CHEST Rx ANG ACCEL (RAD/SEC2)	0.45	94.72	-123.58	29.0	61.0
INT LUMBAR X ACCEL (G)	0.00	3.39	-2.70	61.0	50.0
INT LUMBAR Y ACCEL (G)	-0.05	3.42	-20.08	145.0	53.0
INT LUMBAR Z ACCEL (G)	1.00	2.95	-1.06	56.0	32.0
INT LUMBAR RESULTANT (G)	1.01	20.21	0.54	54.0	209.0

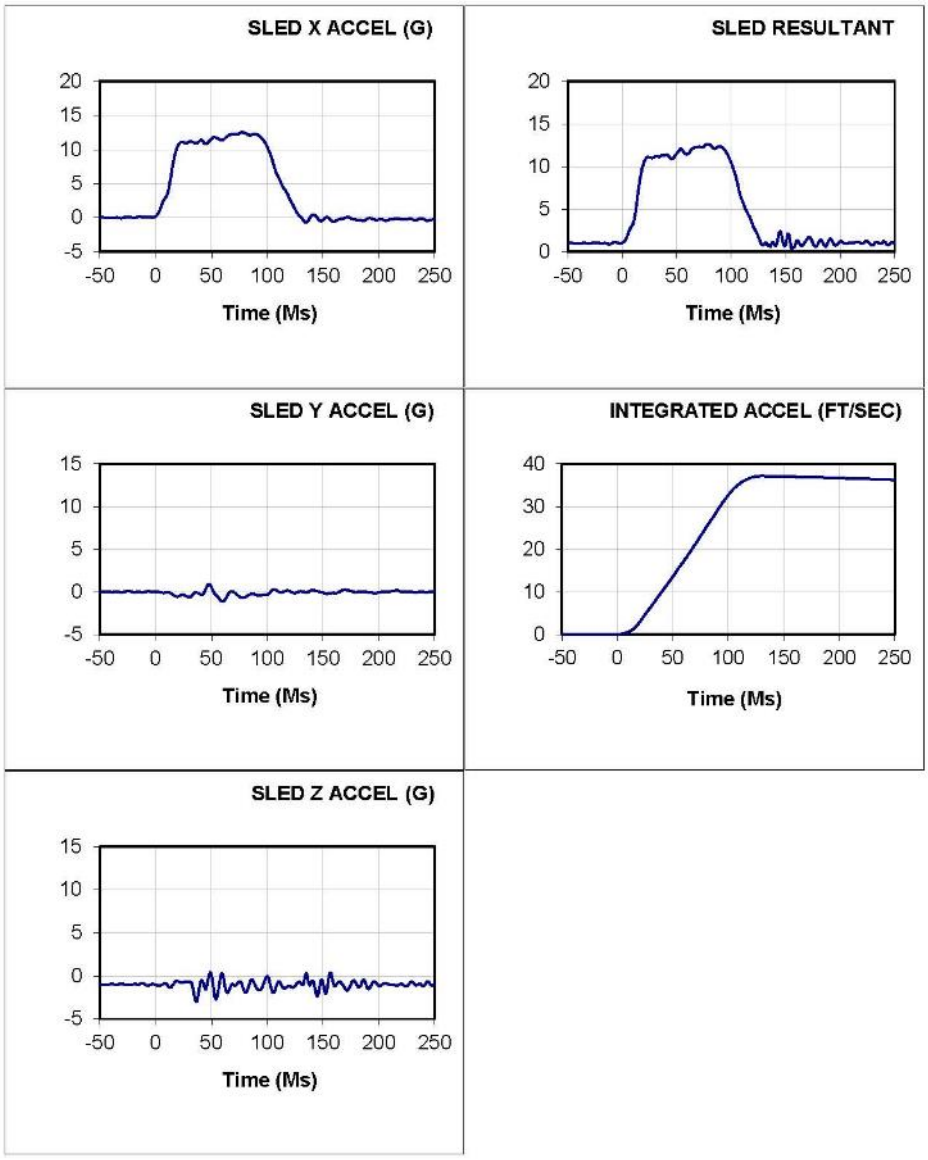
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Wt: 161.0
Nom G: 12.5 Cell: C

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT LUMBAR X FORCE (LB)	8.63	30.31	-27.49	36.0	182.0
INT LUMBAR Y FORCE (LB)	-1.74	35.17	-106.81	156.0	40.0
INT LUMBAR Z FORCE (LB)	-15.34	261.45	-68.79	57.0	223.0
INT LUMBAR FORCE RES (LB)	17.70	272.95	12.72	53.0	10.0
INT LUMBAR Mx TORQUE (IN-LB)	-30.16	91.55	-367.38	157.0	41.0
INT LUMBAR My TORQUE (IN-LB)	-51.51	133.15	-150.90	182.0	36.0
INT LUMBAR Mz TORQUE (IN-LB)	-5.83	21.31	-55.96	234.0	72.0
INT LUMBAR TORQUE RESULTANT (IN-LB)	59.98	386.13	38.58	40.0	61.0
NIJ SHEAR (LB)		21.55	-24.36	144.0	75.0
NIJ TENSION (LB)		147.78		95.0	
NIJ COMPRESSION (LB)		-22.24		35.0	
NIJ FLEXION (IN-LB)		80.28		85.0	
NIJ EXTENSION (IN-LB)		56.87		124.0	
NIJ NTF	0.0000	0.1189	0.0000	89.0	0.0
NIJ NTE	0.0000	0.0875	0.0000	123.0	0.0
NIJ NCF	0.0013	0.0214	0.0000	36.0	8.0
NIJ NCE	0.0005	0.0037	0.0000	20.0	0.0
NIJ NTF AIS >= 2		0.13			
NIJ NTF AIS >= 3		0.05			
NIJ NTF AIS >= 4		0.07			
NIJ NTF AIS >= 5		0.02			
NIJ NTE AIS >= 2		0.12			
NIJ NTE AIS >= 3		0.05			
NIJ NTE AIS >= 4		0.07			
NIJ NTE AIS >= 5		0.02			
NIJ NCF AIS >= 2		0.12			
NIJ NCF AIS >= 3		0.04			
NIJ NCF AIS >= 4		0.06			
NIJ NCF AIS >= 5		0.02			
NIJ NCE AIS >= 2		0.11			
NIJ NCE AIS >= 3		0.04			
NIJ NCE AIS >= 4		0.06			
NIJ NCE AIS >= 5		0.02			
NMIx	0.0023	0.2850	0.0002	107.0	13.0
NMIz	0.0033	0.0493	0.0001	83.0	204.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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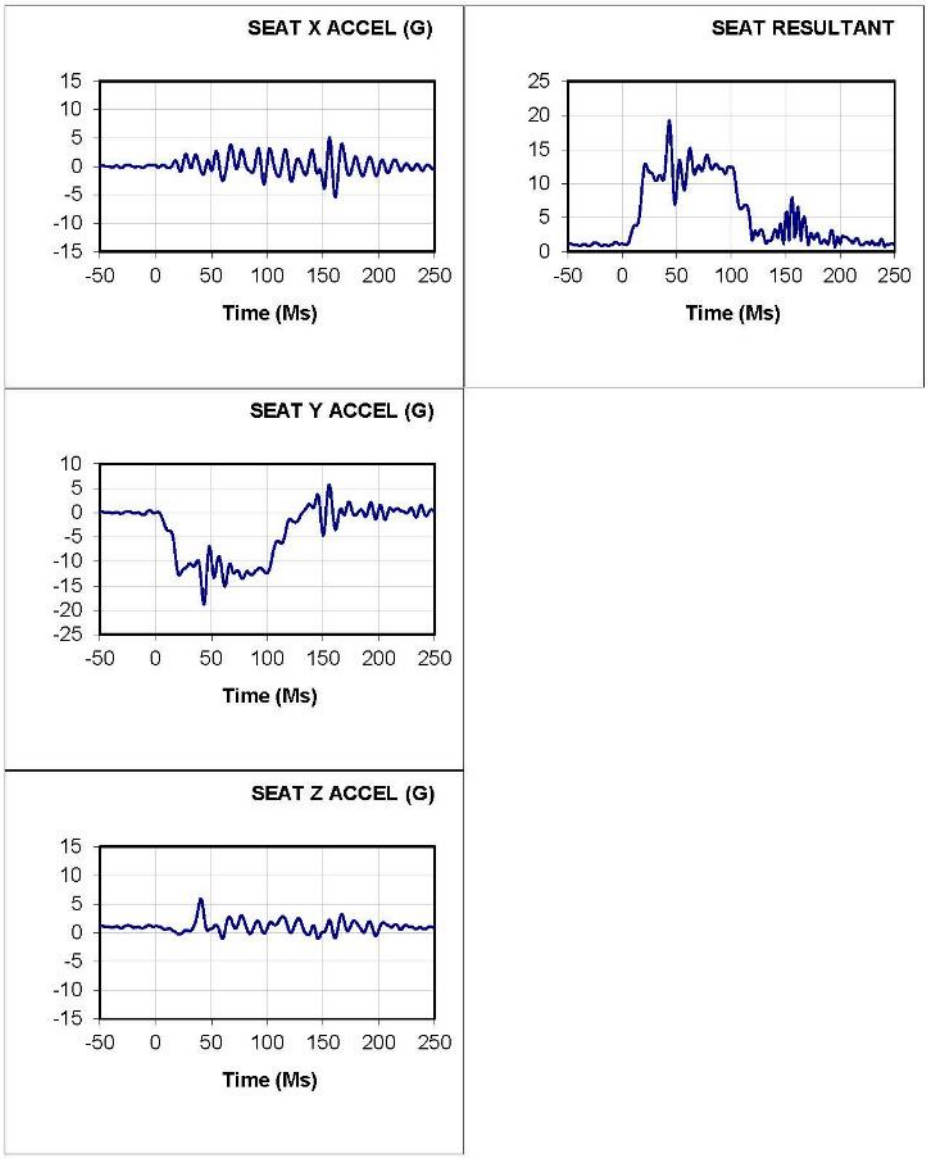
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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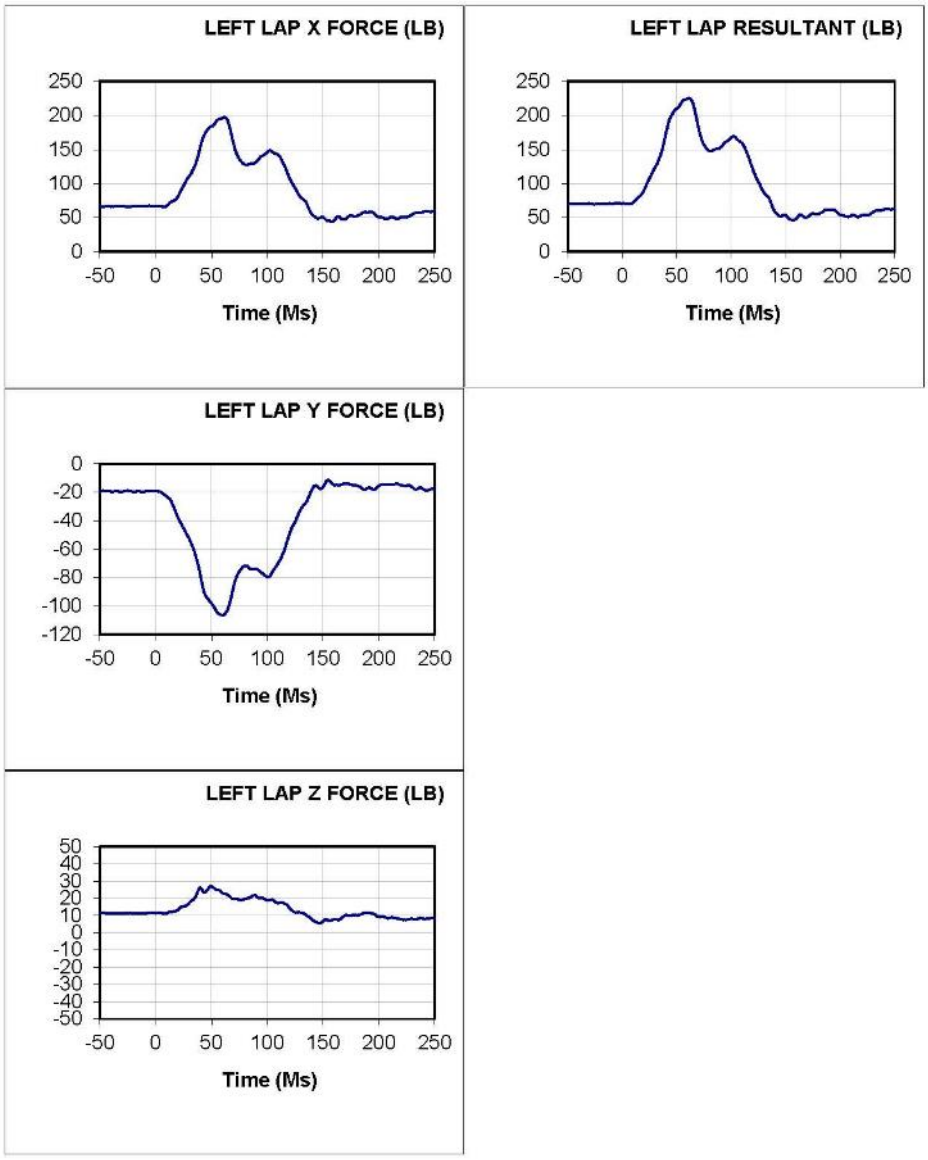
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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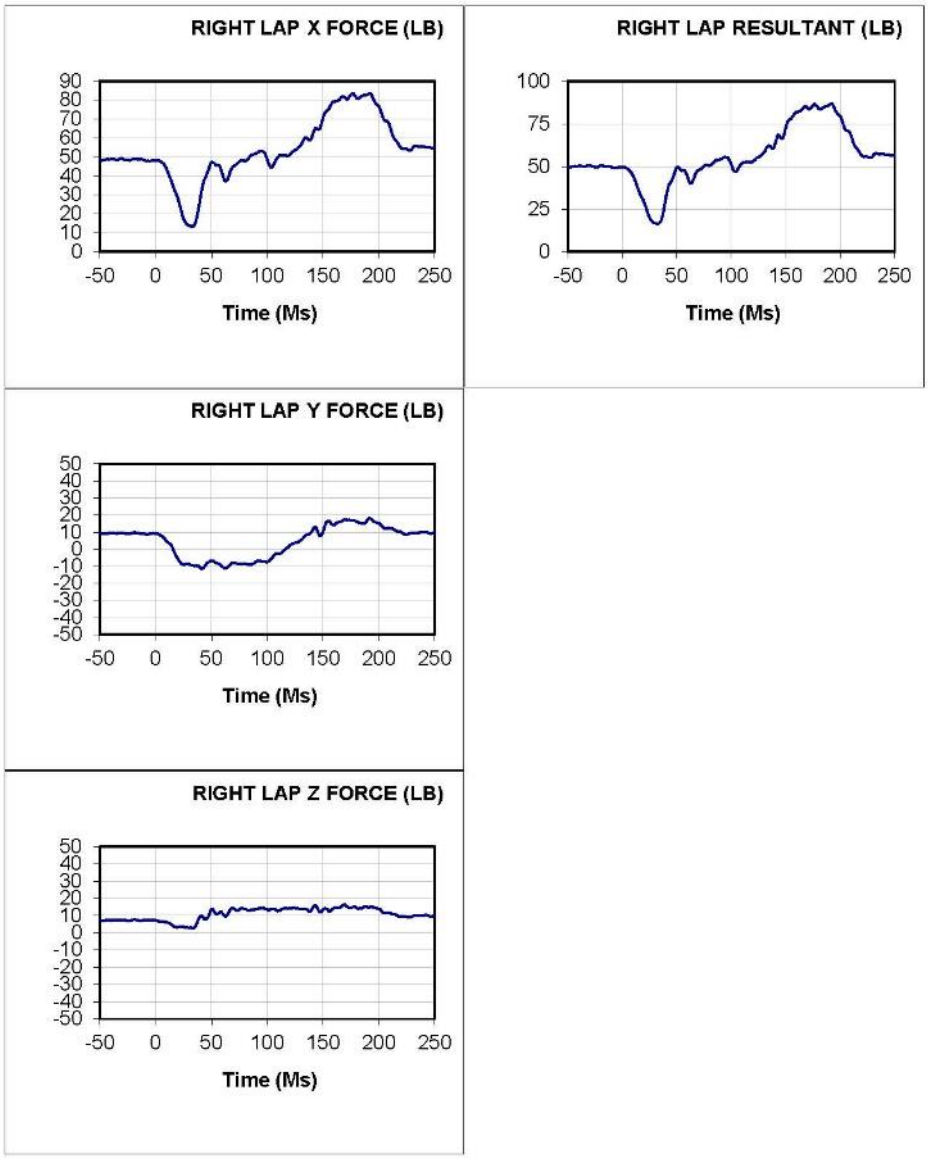
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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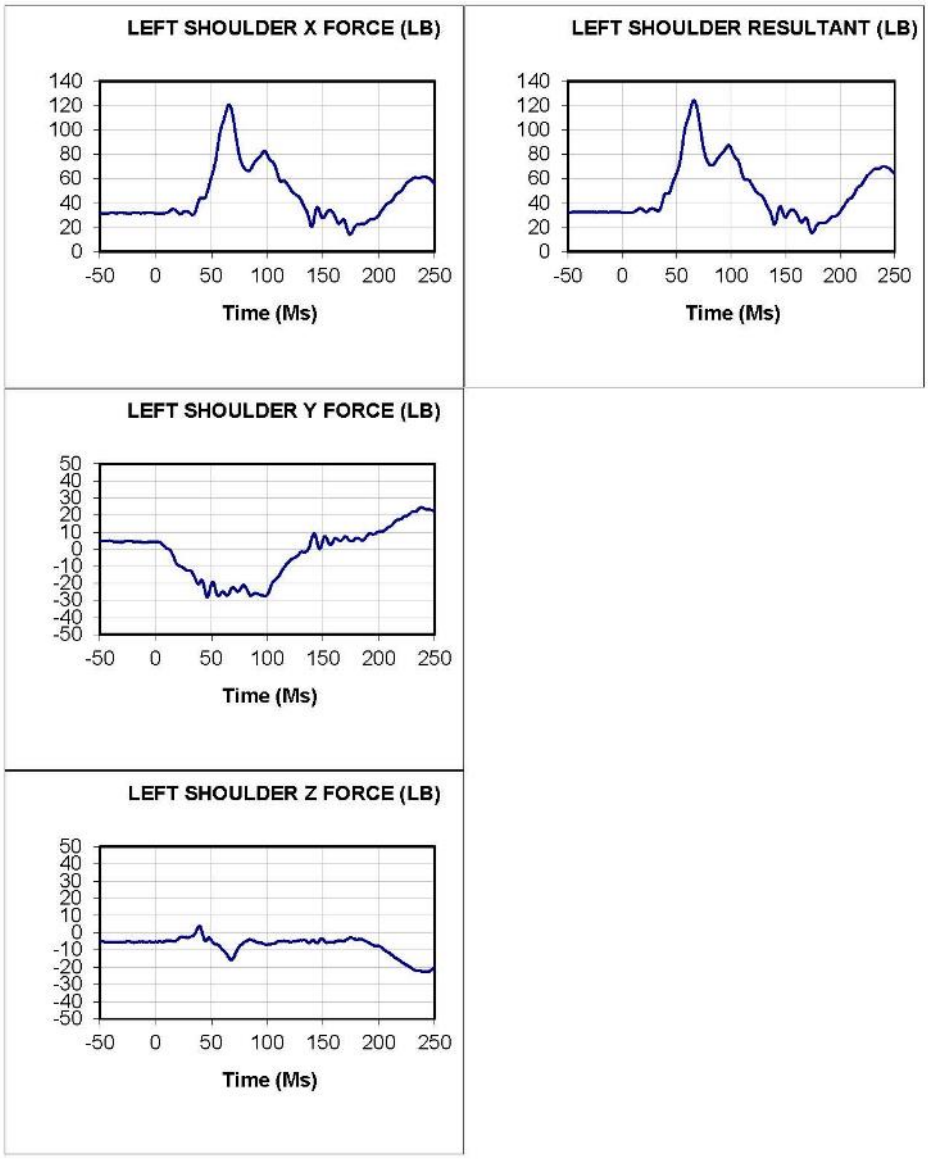
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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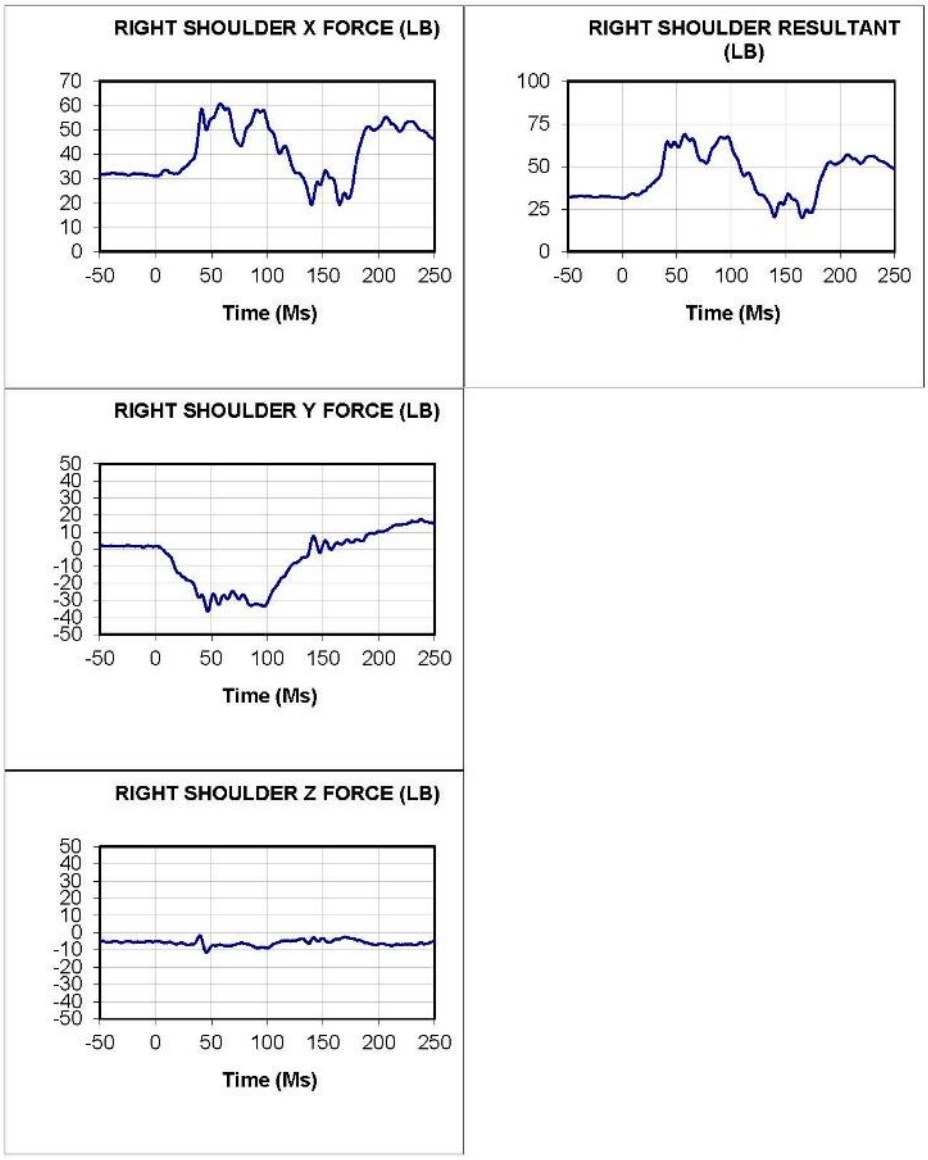
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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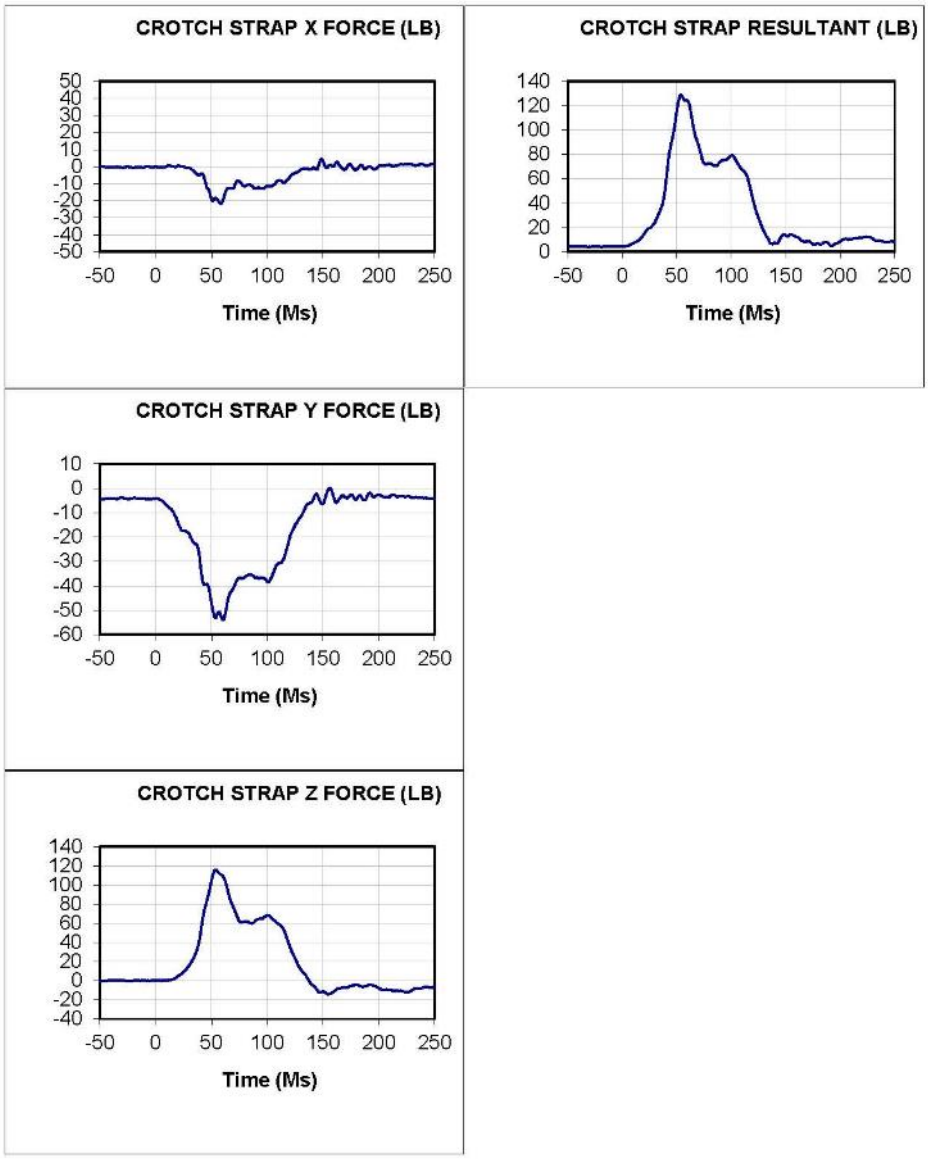
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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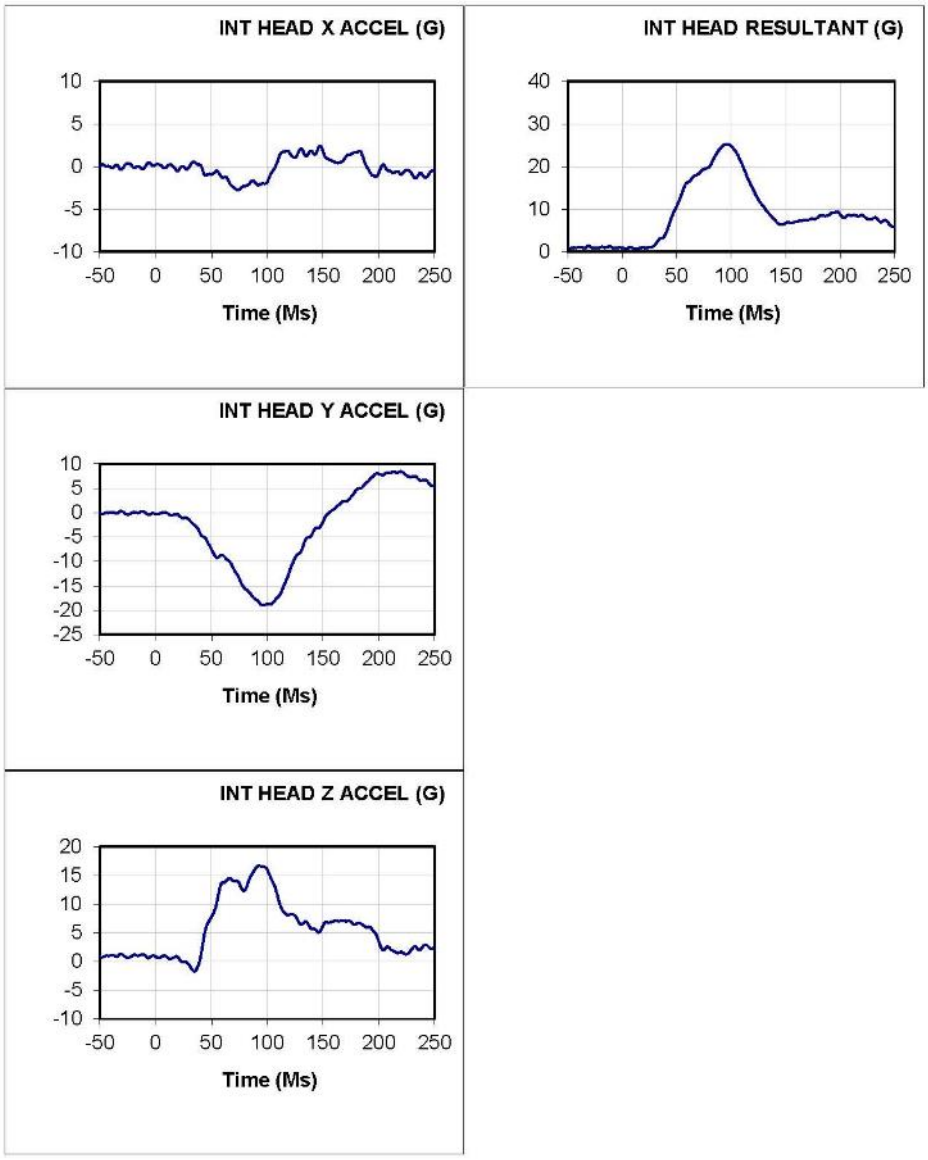
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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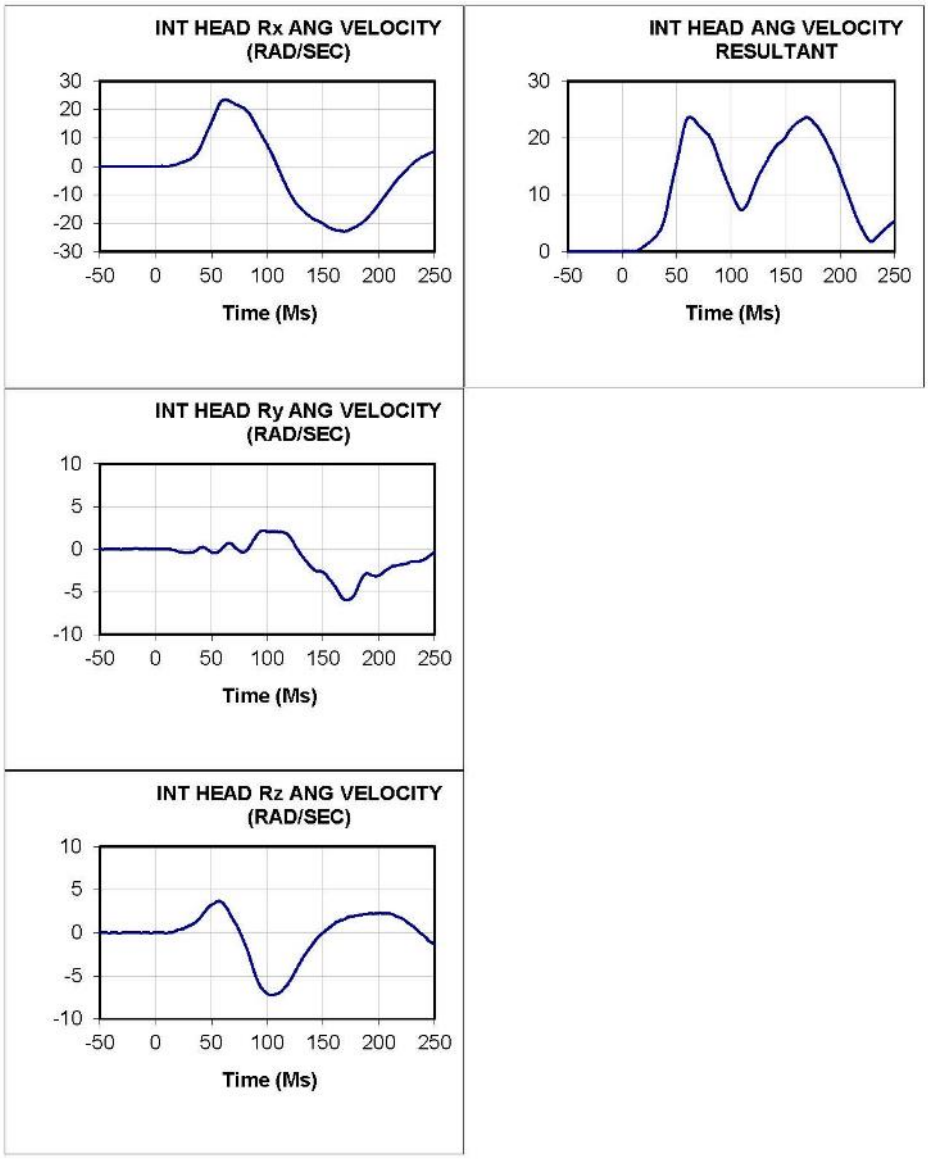
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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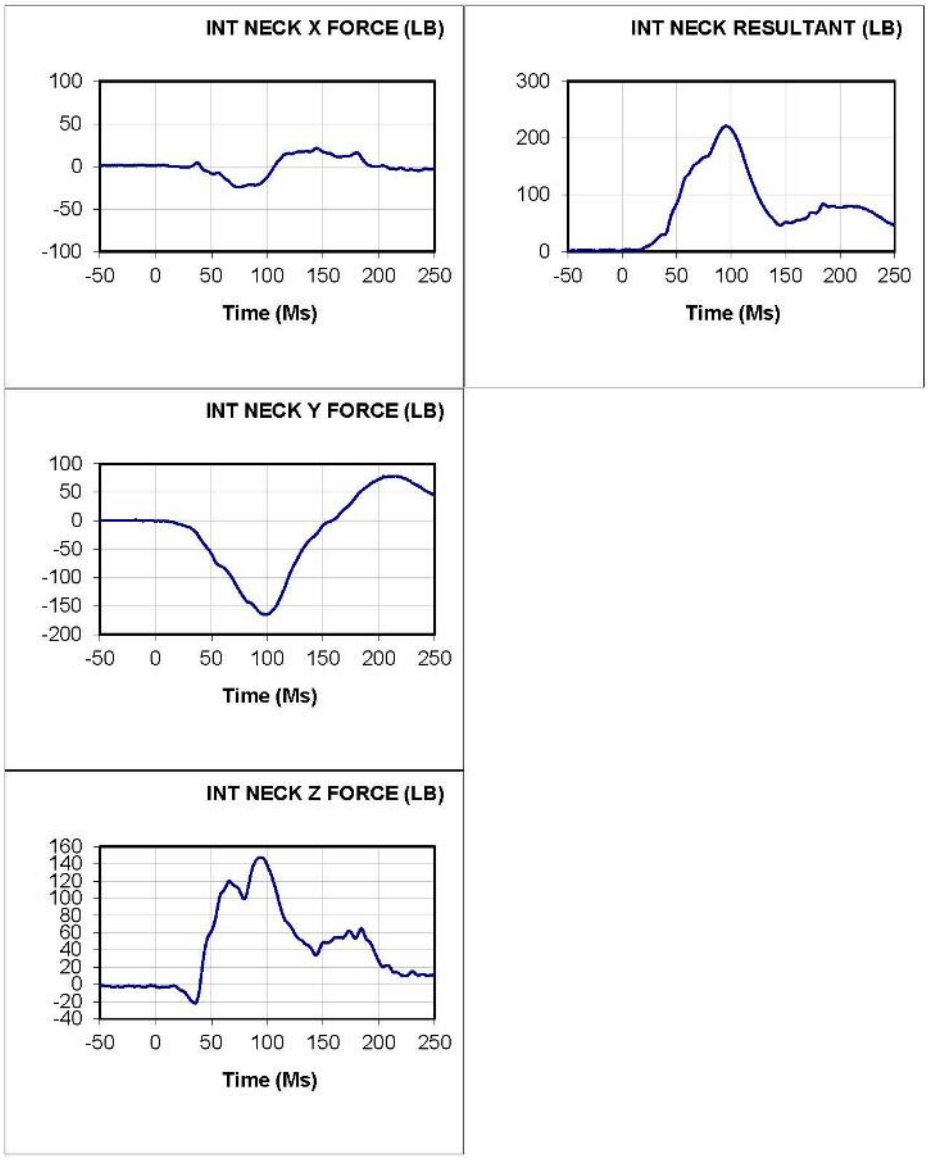
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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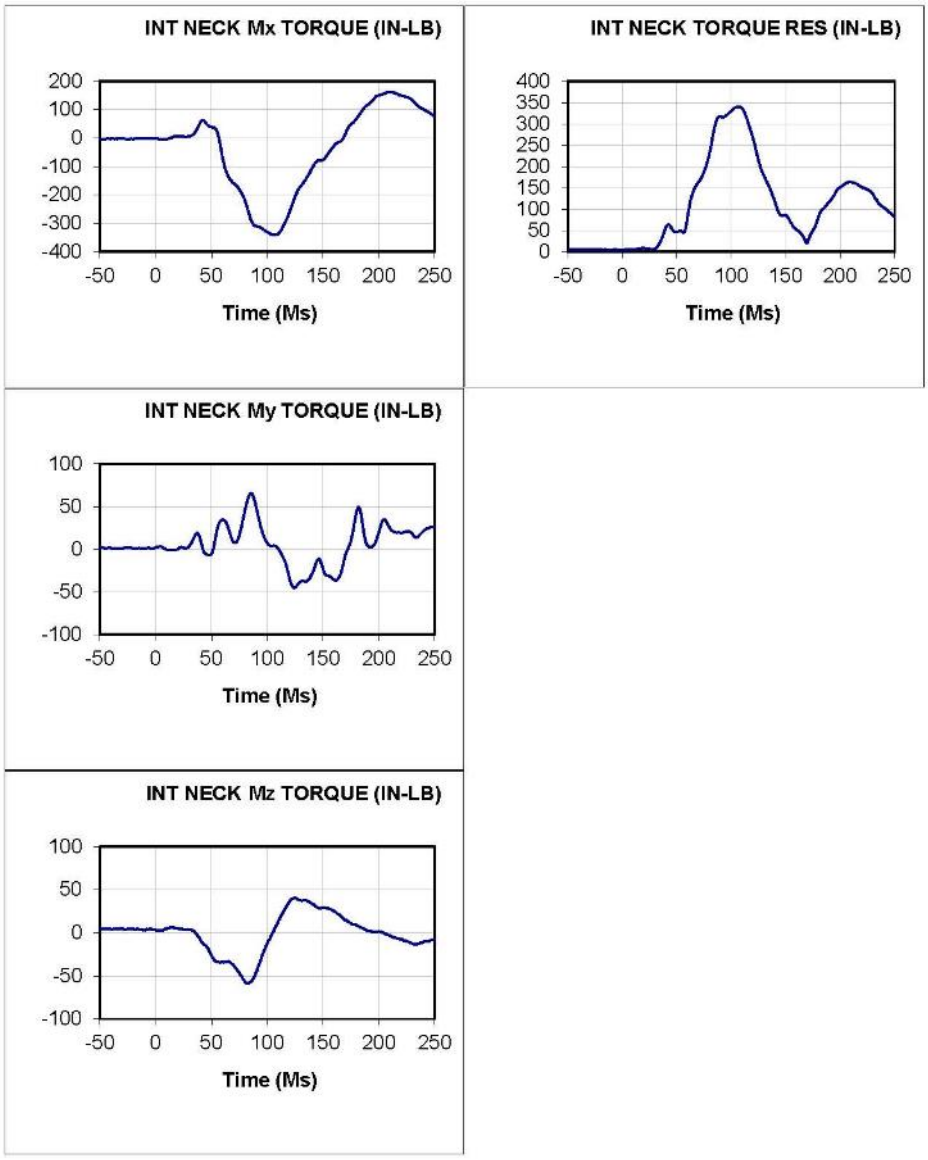
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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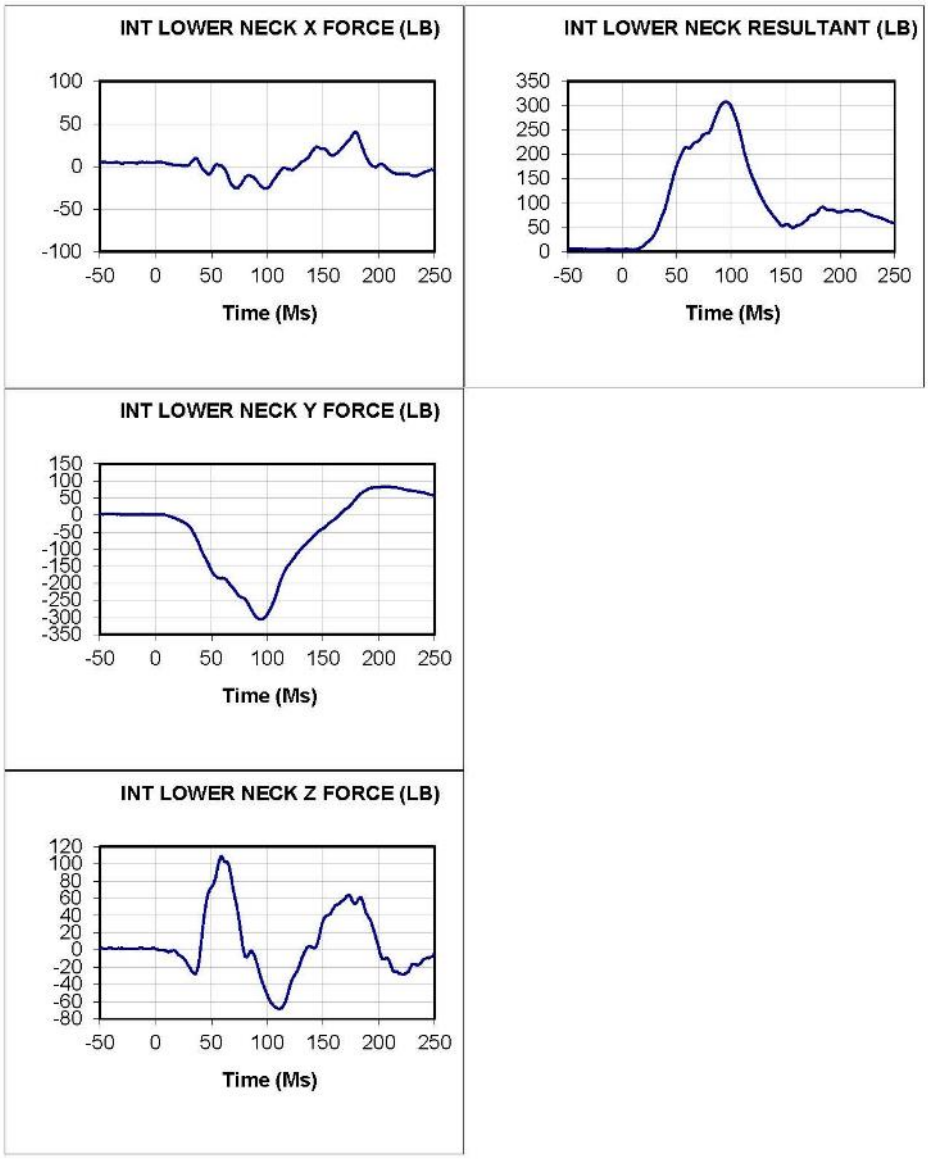
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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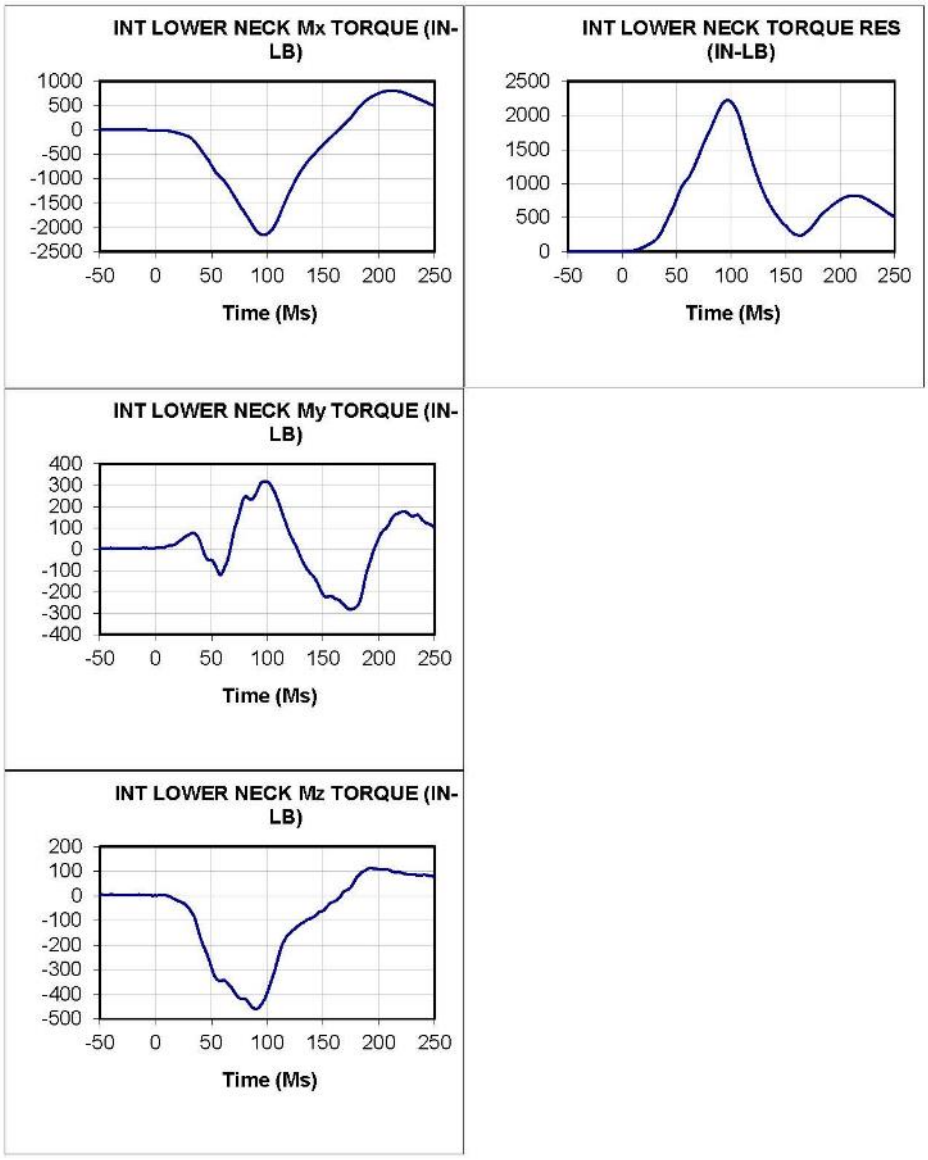
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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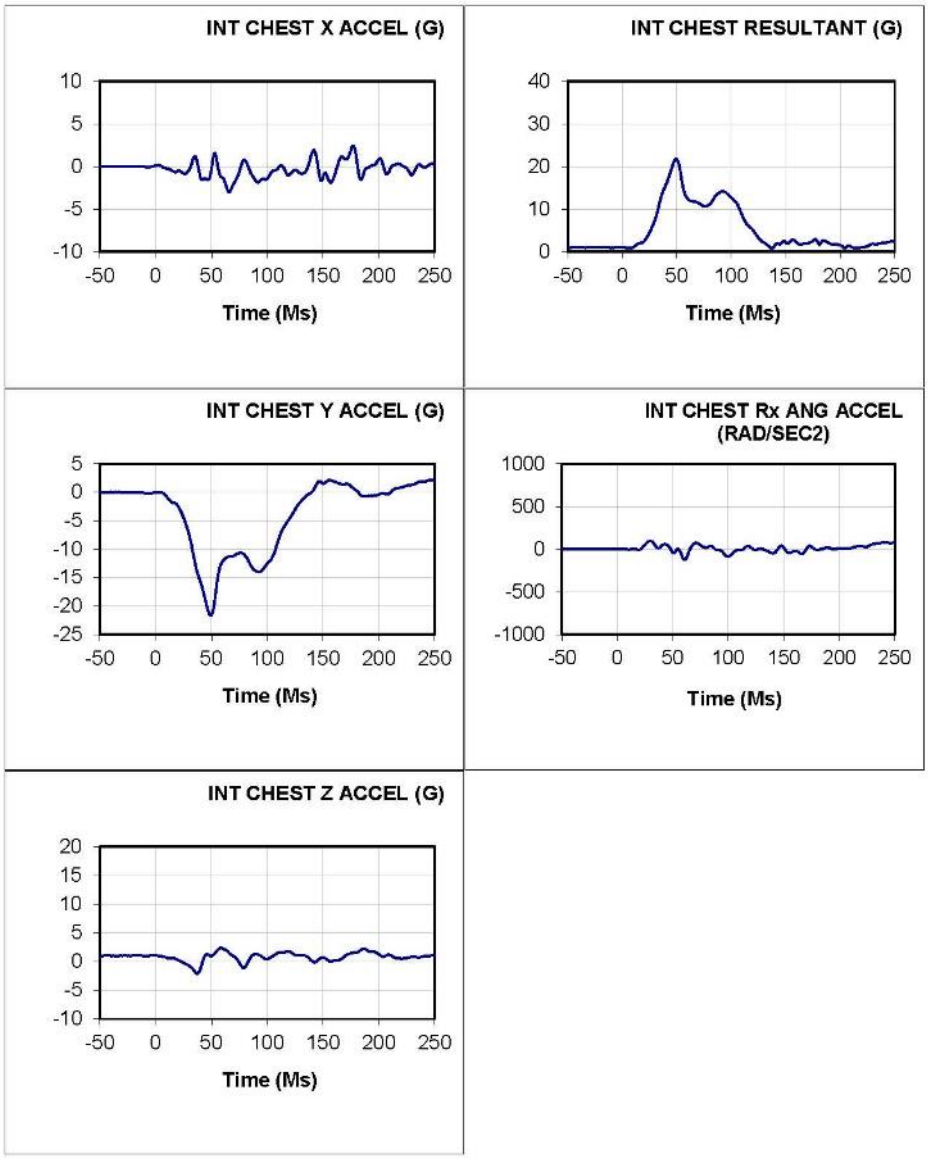
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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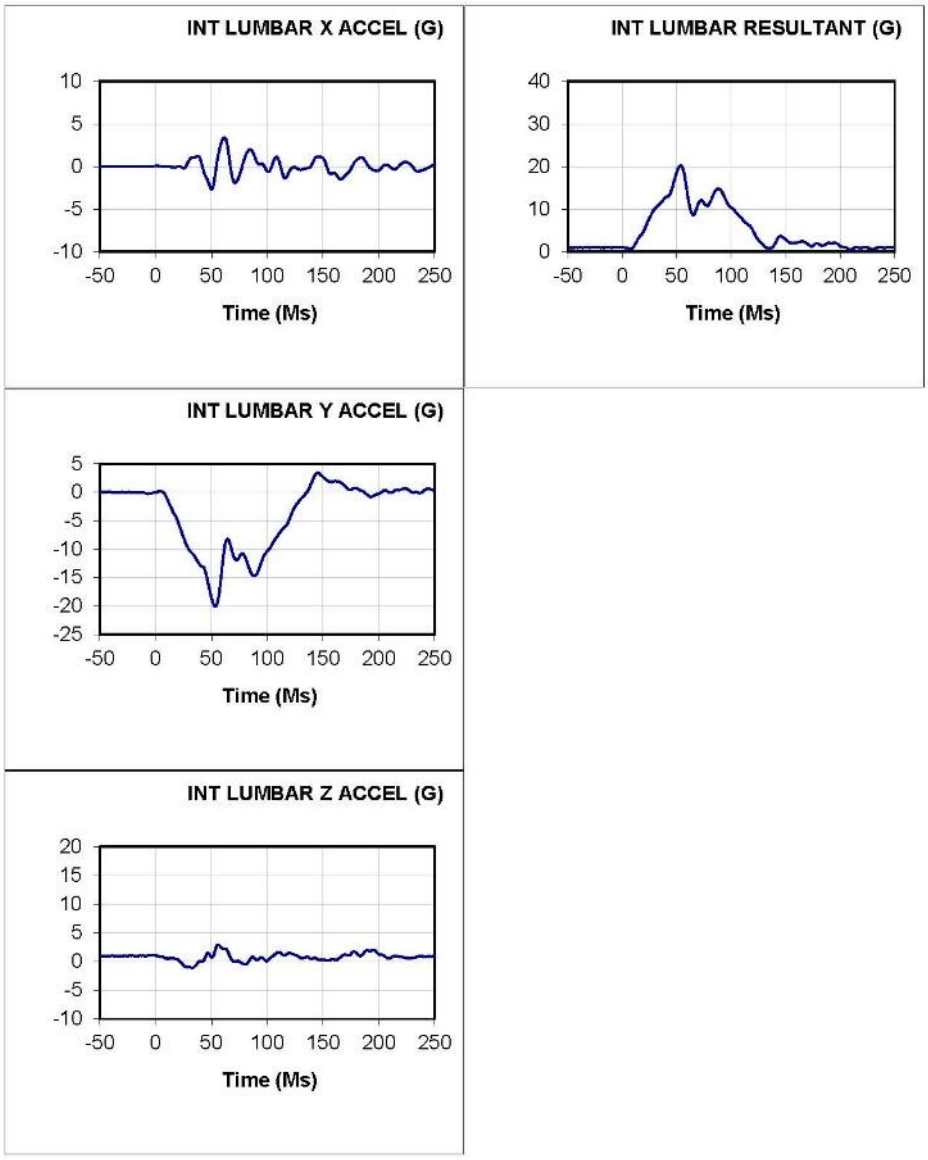
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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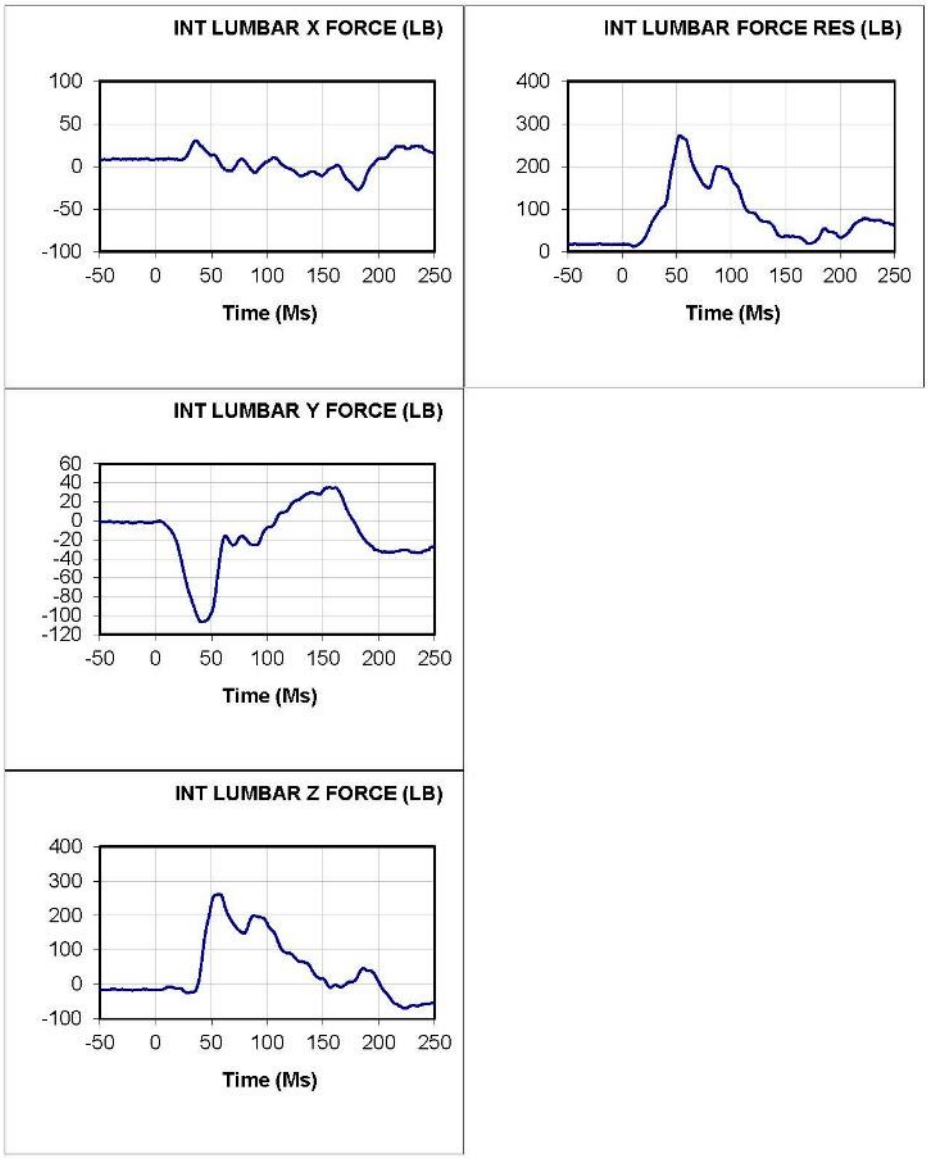
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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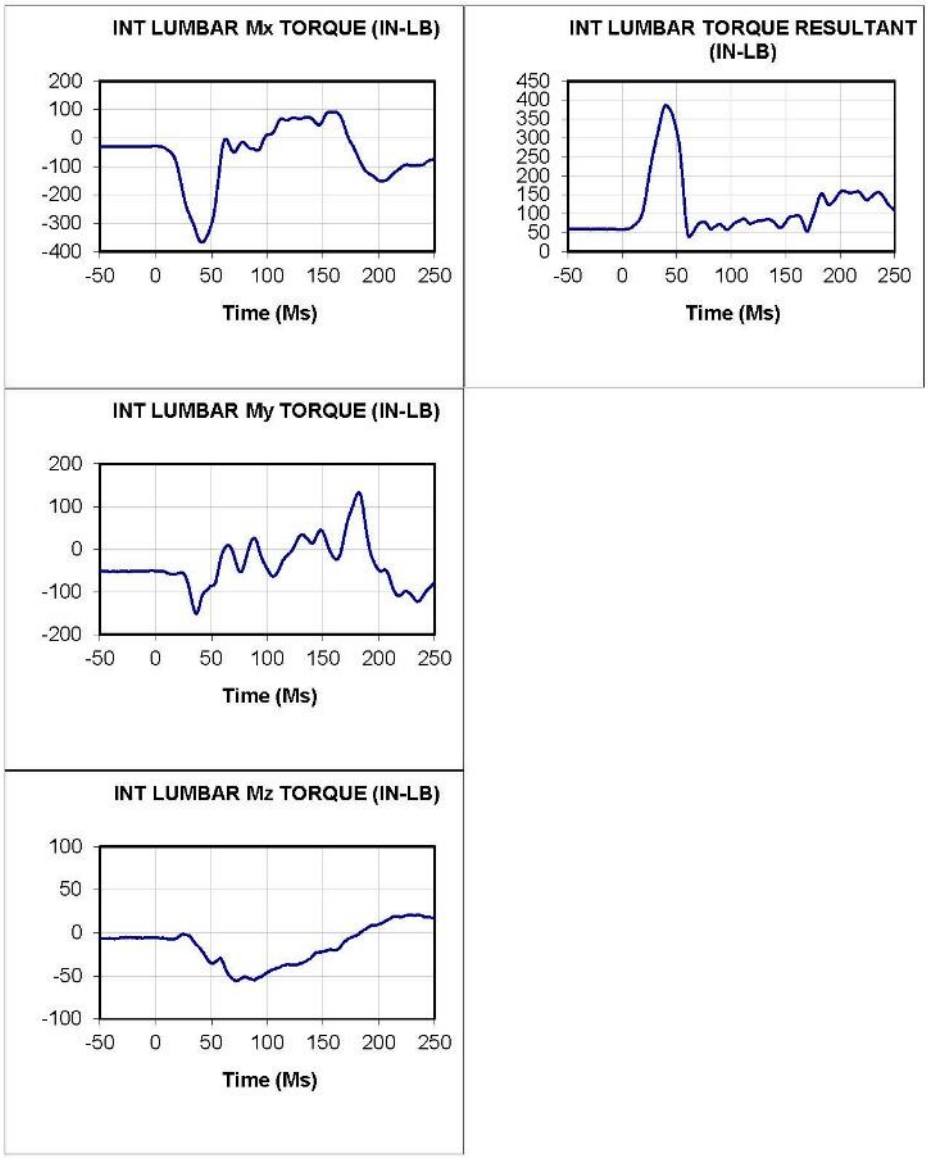
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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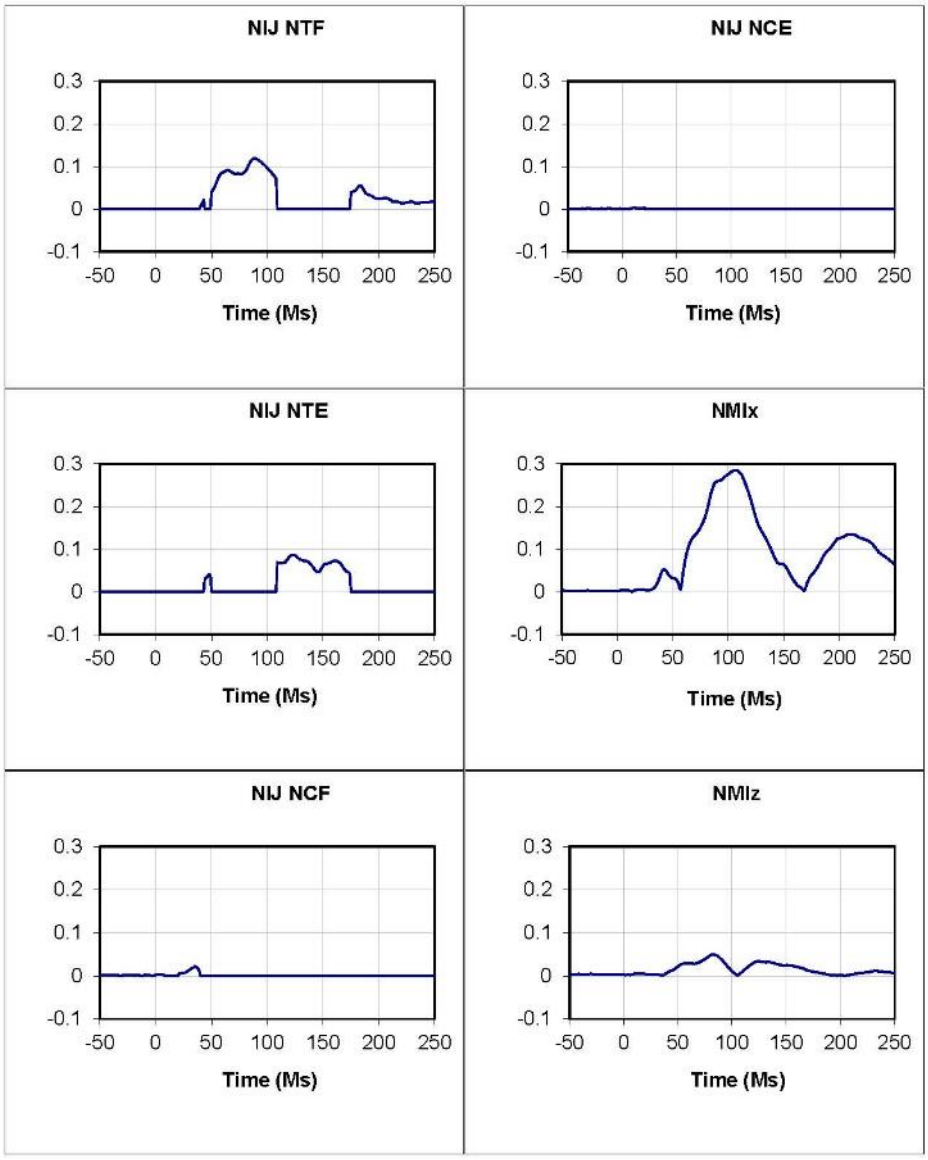
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9215 Test Date: 161114 Subj: AERO50 Cell: C



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Wt: 161.0
Nom G: 15.5 Cell: D

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				12.0	
Impact Rise Time (Ms)				89.0	
Impact Duration (Ms)				200.0	
Velocity Change (Ft/Sec)		55.92			
SLED X ACCEL (G)	0.10	15.58	-0.90	89.0	220.0
SLED Y ACCEL (G)	0.03	1.37	-1.21	47.0	57.0
SLED Z ACCEL (G)	-1.04	2.20	-3.83	165.0	160.0
SLED RESULTANT	1.05	15.70	0.20	88.0	211.0
INTEGRATED ACCEL (FT/SEC)	0.02	55.92	0.09	200.0	0.0
SEAT X ACCEL (G)	0.15	6.24	-7.76	228.0	233.0
SEAT Y ACCEL (G)	0.06	5.30	-19.93	227.0	43.0
SEAT Z ACCEL (G)	1.14	6.64	-2.15	39.0	210.0
SEAT RESULTANT	1.17	20.05	0.82	42.0	133.0
LEFT LAP X FORCE (LB)	83.84	271.04	44.82	54.0	227.0
LEFT LAP Y FORCE (LB)	-26.10	-12.55	-144.56	227.0	54.0
LEFT LAP Z FORCE (LB)	14.72	31.70	6.60	47.0	219.0
LEFT LAP RESULTANT (LB)	89.04	308.48	47.64	54.0	227.0
RIGHT LAP X FORCE (LB)	38.73	69.23	21.51	236.0	26.0
RIGHT LAP Y FORCE (LB)	5.52	11.32	-14.36	242.0	42.0
RIGHT LAP Z FORCE (LB)	2.96	9.95	-3.20	215.0	43.0
RIGHT LAP RESULTANT (LB)	39.23	70.50	23.78	236.0	26.0
LEFT SHOULDER X FORCE (LB)	34.62	98.92	16.89	63.0	211.0
LEFT SHOULDER Y FORCE (LB)	4.88	10.87	-31.92	214.0	93.0
LEFT SHOULDER Z FORCE (LB)	-6.11	3.52	-12.83	37.0	64.0
LEFT SHOULDER RESULTANT (LB)	35.49	102.08	18.78	63.0	211.0
RIGHT SHOULDER X FORCE (LB)	42.06	84.24	26.22	55.0	211.0
RIGHT SHOULDER Y FORCE (LB)	6.23	13.20	-41.16	242.0	93.0
RIGHT SHOULDER Z FORCE (LB)	-5.72	-2.51	-14.78	161.0	43.0
RIGHT SHOULDER RESULTANT (LB)	42.90	91.08	27.95	56.0	211.0
CROTCH STRAP X FORCE (LB)	1.75	5.30	-23.78	219.0	48.0
CROTCH STRAP Y FORCE (LB)	-4.61	0.55	-59.59	228.0	51.0
CROTCH STRAP Z FORCE (LB)	-0.20	125.48	-12.63	51.0	227.0
CROTCH STRAP RESULTANT (LB)	4.96	140.29	4.74	51.0	1.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Wt: 161.0
Nom G: 15.5 Cell: D

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT HEAD X ACCEL (G)	0.21	2.32	-3.26	146.0	86.0
INT HEAD Y ACCEL (G)	-0.18	1.20	-22.36	241.0	98.0
INT HEAD Z ACCEL (G)	0.81	22.58	-2.22	92.0	215.0
INT HEAD RESULTANT (G)	0.96	31.15	0.61	92.0	13.0
INT HEAD HIC		129.61		77.0	107.0
INT HEAD Rx ANG VELOCITY (RAD/SEC)	-0.01	27.54	-21.65	60.0	149.0
INT HEAD Ry ANG VELOCITY (RAD/SEC)	-0.01	3.53	-4.98	105.0	171.0
INT HEAD Rz ANG VELOCITY (RAD/SEC)	0.00	6.41	-9.16	179.0	104.0
INT HEAD ANG VELOCITY RESULTANT	0.05	27.75	0.08	60.0	3.0
INT NECK X FORCE (LB)	-0.58	21.46	-33.41	126.0	88.0
INT NECK Y FORCE (LB)	1.69	10.58	-188.41	242.0	96.0
INT NECK Z FORCE (LB)	-0.51	213.83	-30.84	90.0	215.0
INT NECK RESULTANT (LB)	2.10	282.23	0.90	92.0	204.0
INT NECK Mx TORQUE (IN-LB)	-4.15	90.35	-415.63	174.0	103.0
INT NECK My TORQUE (IN-LB)	1.78	66.09	-56.10	78.0	119.0
INT NECK Mz TORQUE (IN-LB)	2.29	38.74	-61.86	120.0	79.0
INT NECK TORQUE RES (IN-LB)	5.12	415.79	3.50	103.0	14.0
INT LOWER NECK X FORCE (LB)	3.76	39.60	-24.60	178.0	90.0
INT LOWER NECK Y FORCE (LB)	1.15	15.08	-390.84	242.0	92.0
INT LOWER NECK Z FORCE (LB)	1.94	131.45	-89.05	56.0	107.0
INT LOWER NECK RESULTANT (LB)	4.41	392.57	4.30	92.0	10.0
INT LOWER NECK Mx TORQUE (IN-LB)	-1.41	68.65	-2591.83	242.0	96.0
INT LOWER NECK My TORQUE (IN-LB)	0.80	325.30	-299.56	94.0	166.0
INT LOWER NECK Mz TORQUE (IN-LB)	0.32	52.94	-585.01	242.0	90.0
INT LOWER NECK TORQUE RES (IN-LB)	1.84	2666.04	6.78	95.0	1.0
INT CHEST X ACCEL (G)	-0.01	3.40	-3.13	172.0	221.0
INT CHEST Y ACCEL (G)	-0.04	2.01	-26.81	230.0	48.0
INT CHEST Z ACCEL (G)	0.98	2.73	-2.41	57.0	36.0
INT CHEST RESULTANT (G)	0.99	26.83	0.86	48.0	9.0
INT CHEST Rx ANG ACCEL (RAD/SEC2)	-0.41	111.91	-134.82	165.0	181.0
INT LUMBAR X ACCEL (G)	0.00	4.68	-2.54	56.0	46.0
INT LUMBAR Y ACCEL (G)	-0.03	4.27	-23.78	218.0	47.0
INT LUMBAR Z ACCEL (G)	0.97	3.79	-1.91	55.0	34.0
INT LUMBAR RESULTANT (G)	0.98	23.90	0.77	47.0	9.0

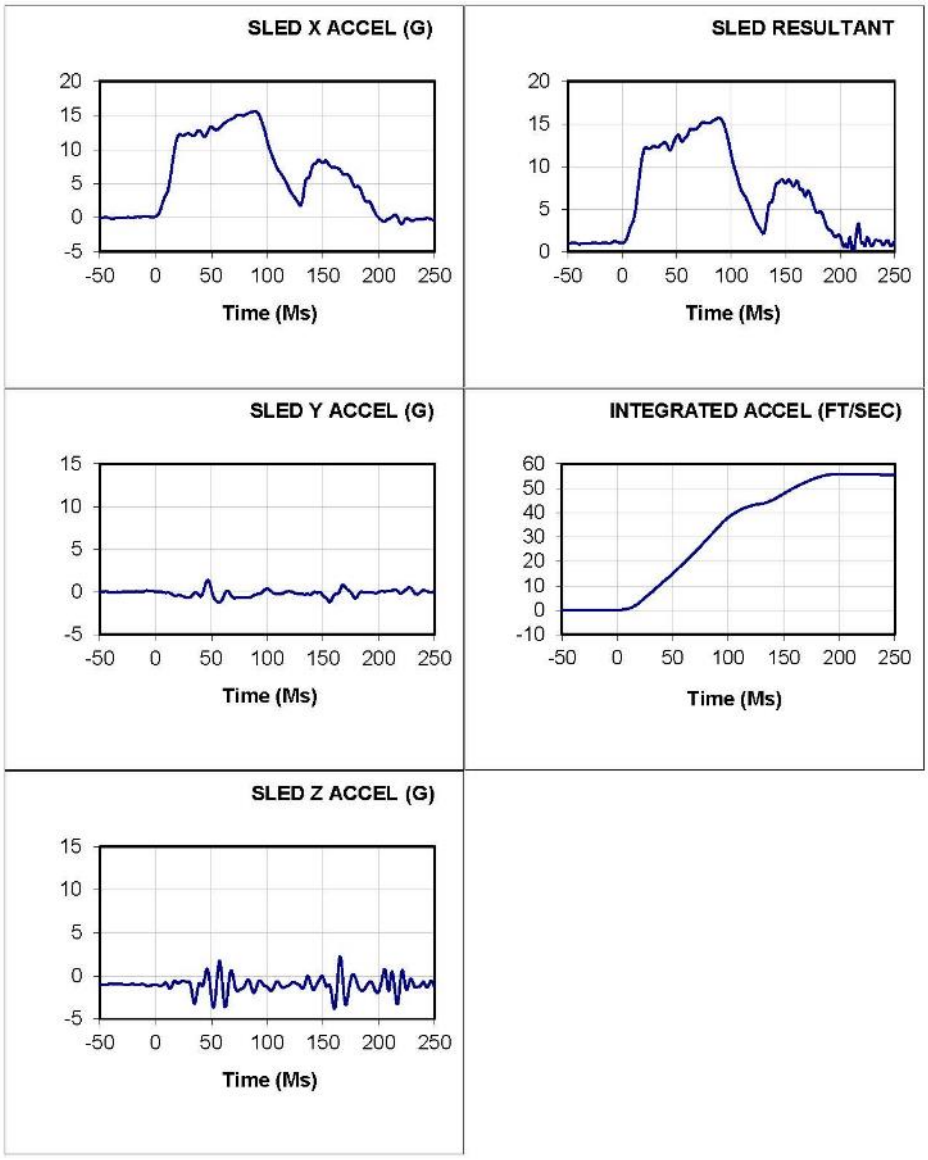
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Wt: 161.0
Nom G: 15.5 Cell: D

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT LUMBAR X FORCE (LB)	-12.27	16.45	-33.73	38.0	134.0
INT LUMBAR Y FORCE (LB)	2.66	38.60	-221.20	228.0	47.0
INT LUMBAR Z FORCE (LB)	-34.63	333.61	-75.87	52.0	218.0
INT LUMBAR FORCE RES (LB)	36.85	383.96	19.17	50.0	196.0
INT LUMBAR Mx TORQUE (IN-LB)	-12.34	148.37	-887.16	230.0	48.0
INT LUMBAR My TORQUE (IN-LB)	-31.51	55.74	-162.72	137.0	37.0
INT LUMBAR Mz TORQUE (IN-LB)	-9.34	-3.01	-41.85	28.0	76.0
INT LUMBAR TORQUE RESULTANT (IN-LB)	35.11	896.72	18.79	48.0	200.0
NIJ SHEAR (LB)		21.46	-33.41	126.0	88.0
NIJ TENSION (LB)		213.83		90.0	
NIJ COMPRESSION (LB)		-30.84		215.0	
NIJ FLEXION (IN-LB)		86.01		79.0	
NIJ EXTENSION (IN-LB)		70.17		119.0	
NIJ NTF	0.0003	0.1601	0.0000	90.0	1.0
NIJ NTE	0.0000	0.1175	0.0000	115.0	0.0
NIJ NCF	0.0010	0.0405	0.0000	215.0	0.0
NIJ NCE	0.0000	0.0102	0.0000	204.0	0.0
NIJ NTF AIS >= 2		0.13			
NIJ NTF AIS >= 3		0.05			
NIJ NTF AIS >= 4		0.08			
NIJ NTF AIS >= 5		0.03			
NIJ NTE AIS >= 2		0.13			
NIJ NTE AIS >= 3		0.05			
NIJ NTE AIS >= 4		0.07			
NIJ NTE AIS >= 5		0.02			
NIJ NCF AIS >= 2		0.12			
NIJ NCF AIS >= 3		0.04			
NIJ NCF AIS >= 4		0.07			
NIJ NCF AIS >= 5		0.02			
NIJ NCE AIS >= 2		0.11			
NIJ NCE AIS >= 3		0.04			
NIJ NCE AIS >= 4		0.06			
NIJ NCE AIS >= 5		0.02			
NMIx	0.0035	0.3478	0.0000	103.0	219.0
NMIz	0.0019	0.0518	0.0000	79.0	174.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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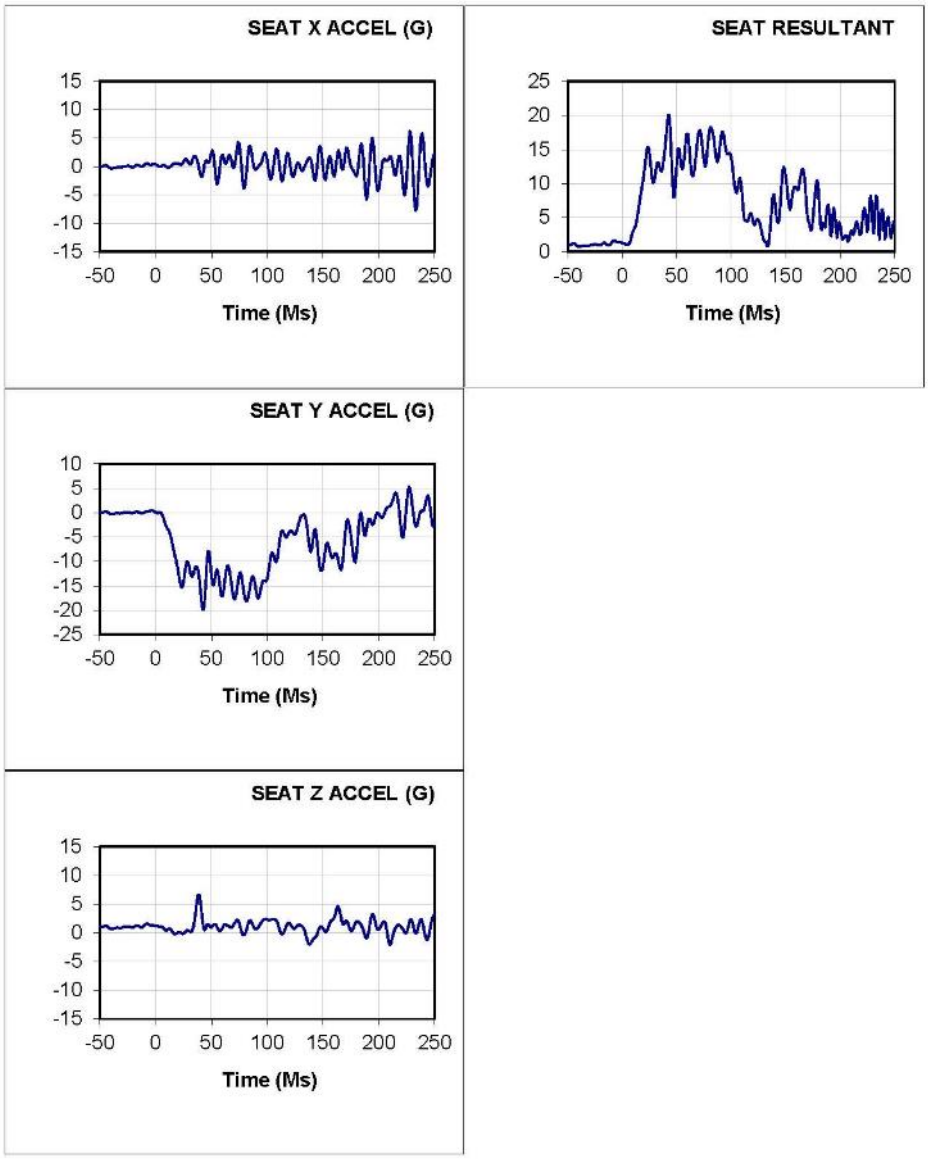
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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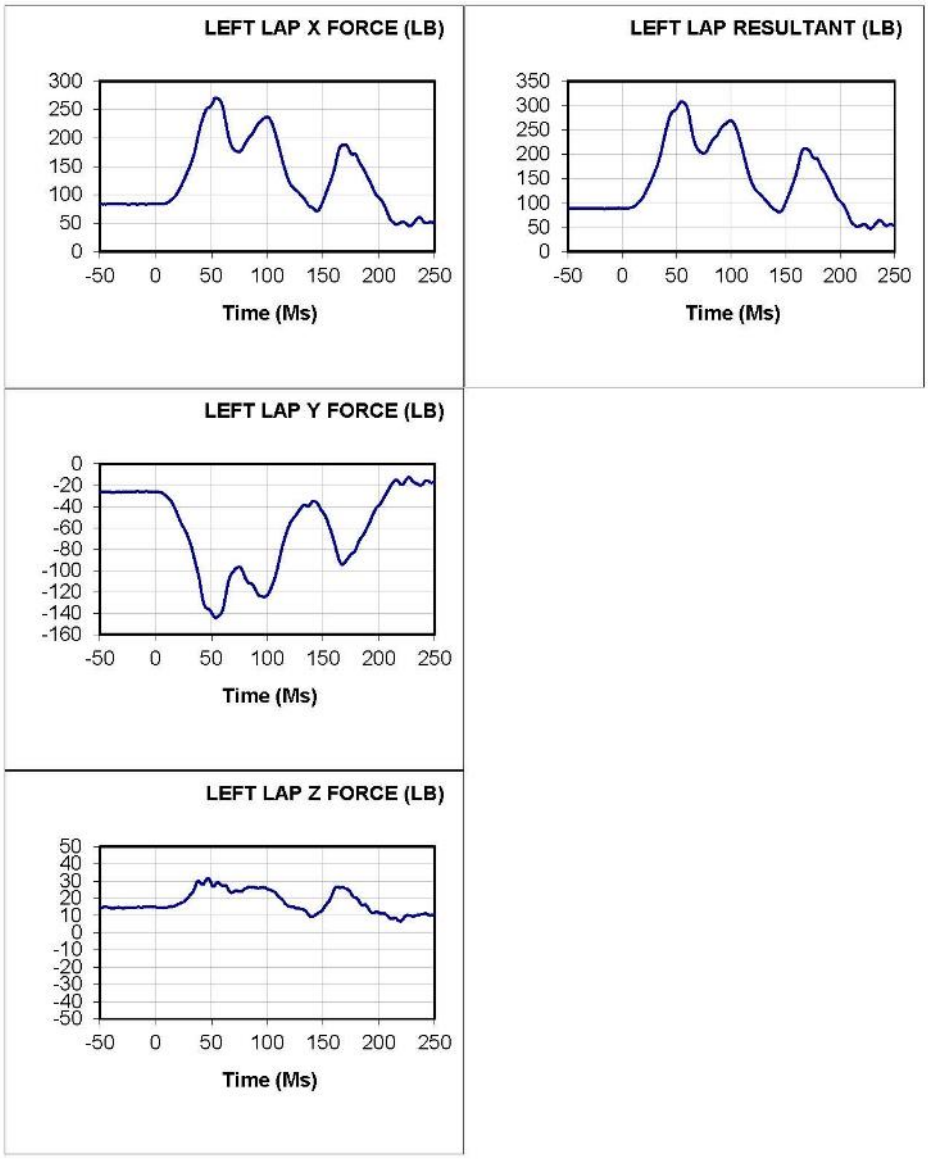
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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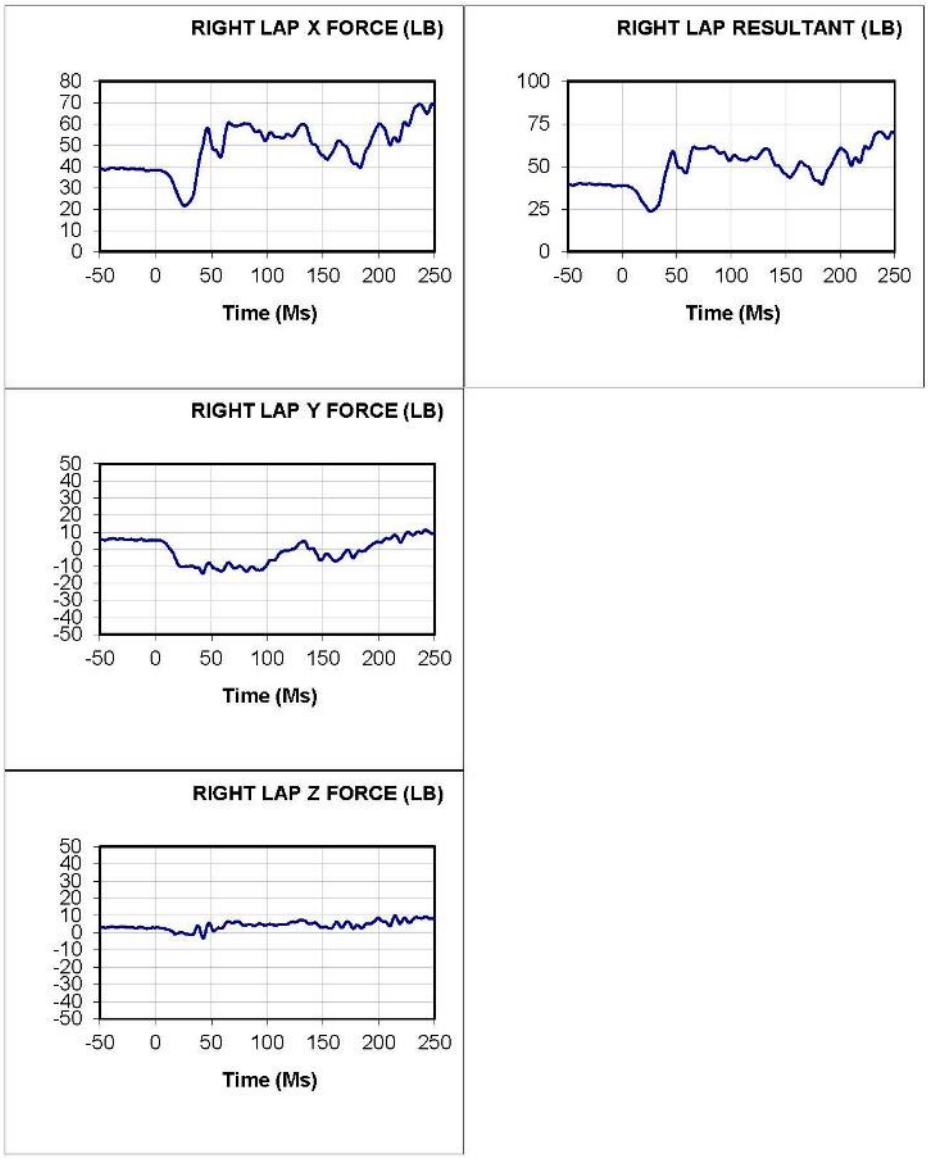
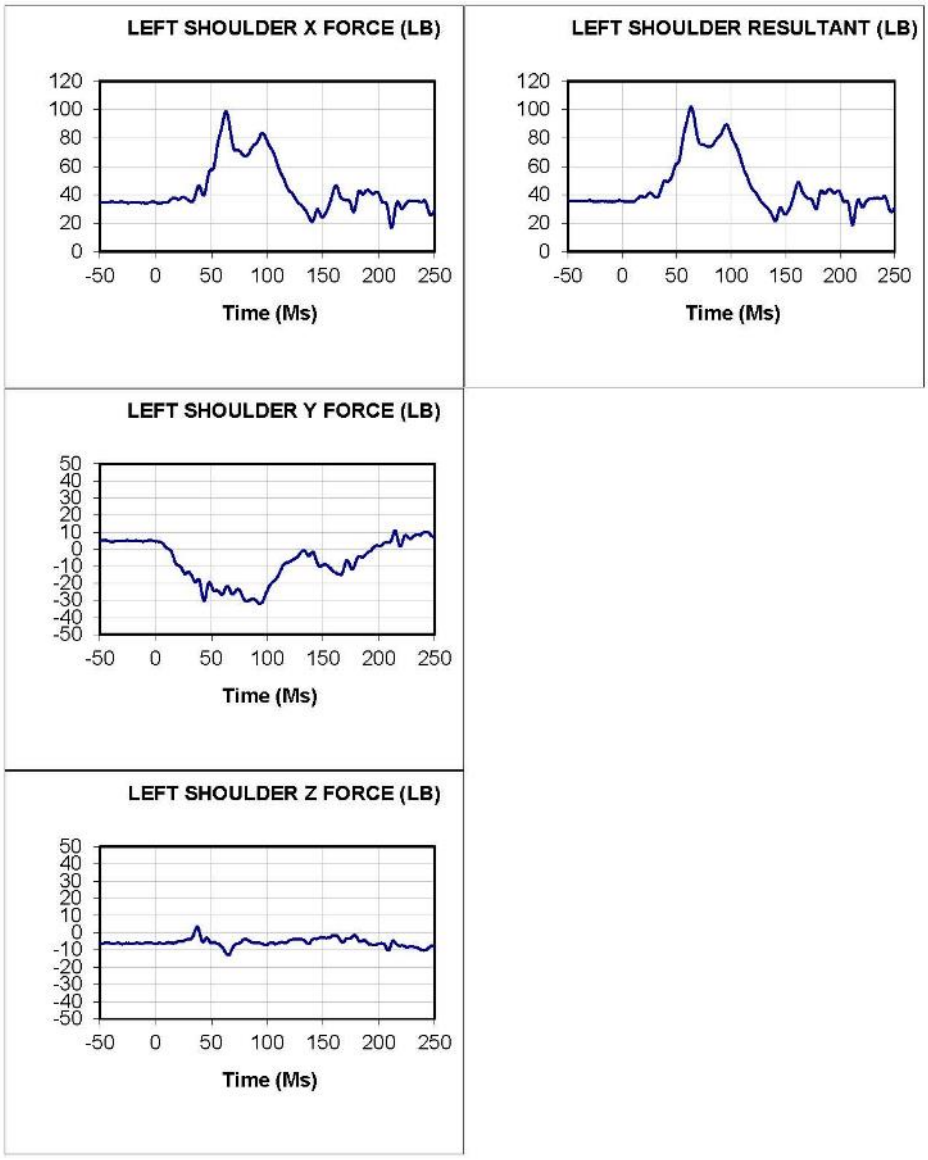
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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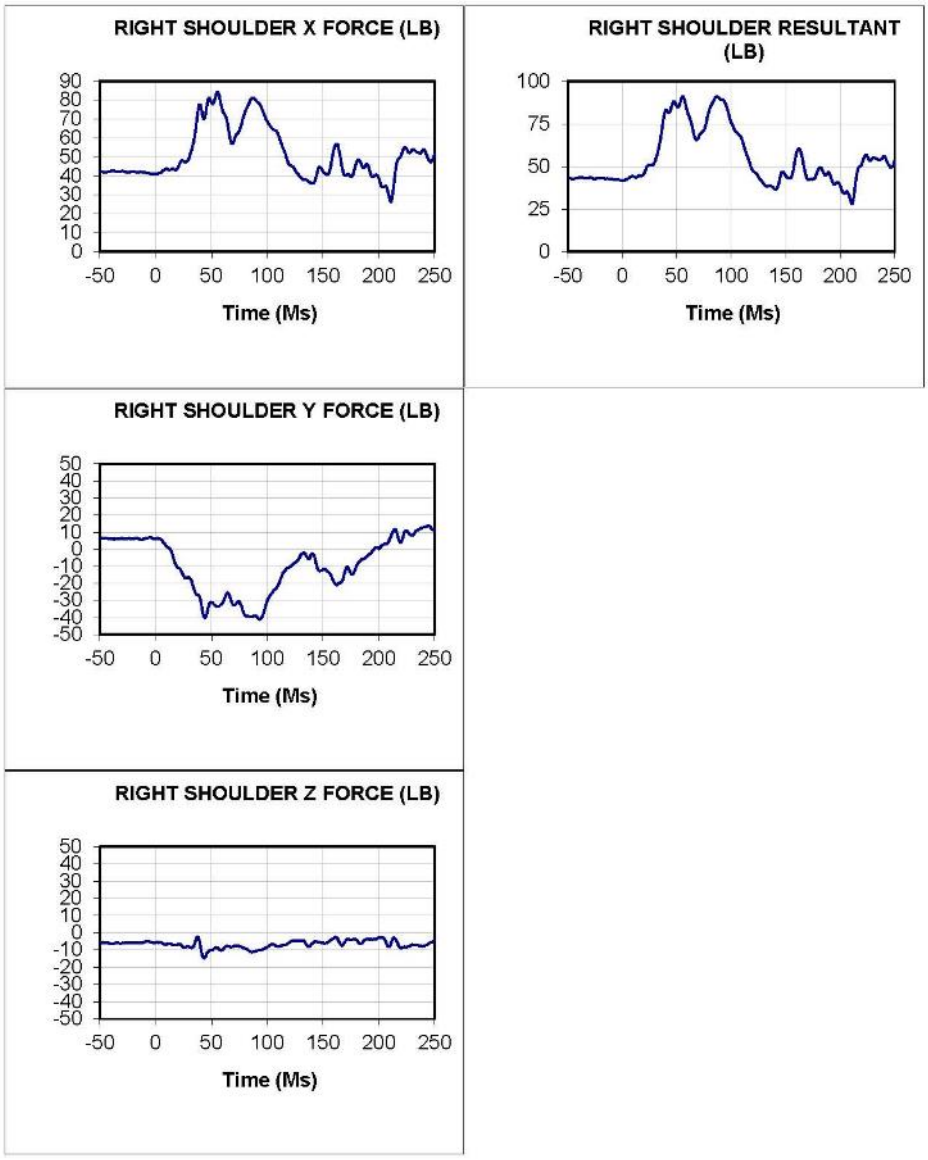
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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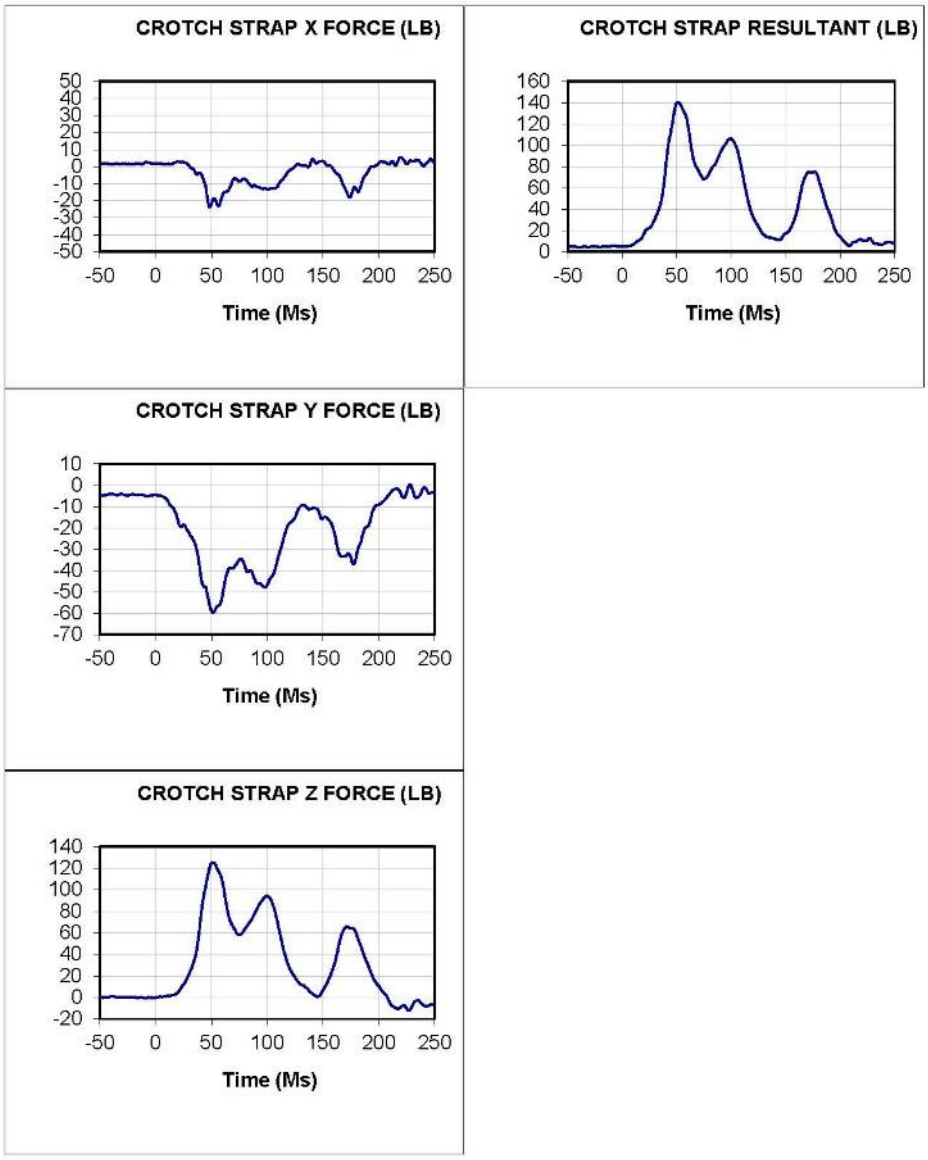
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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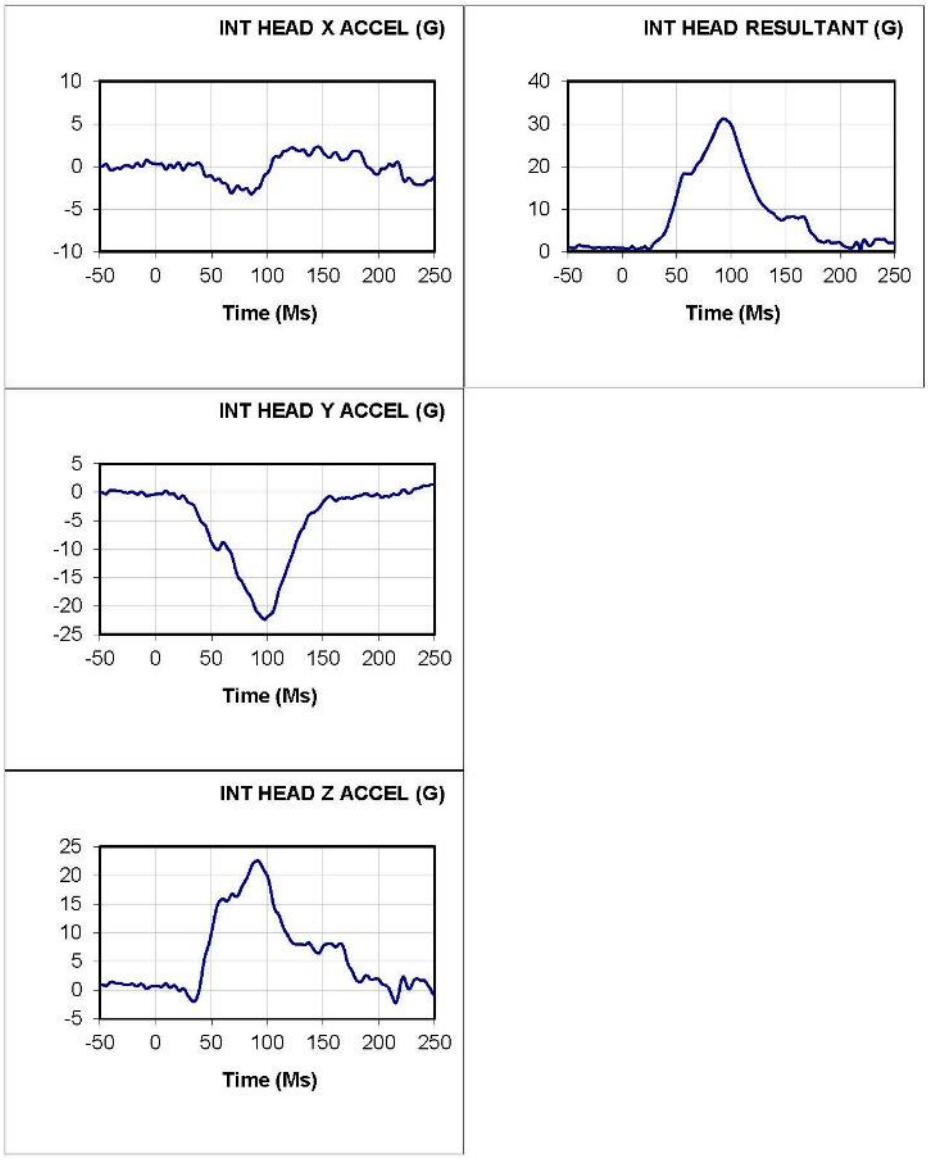
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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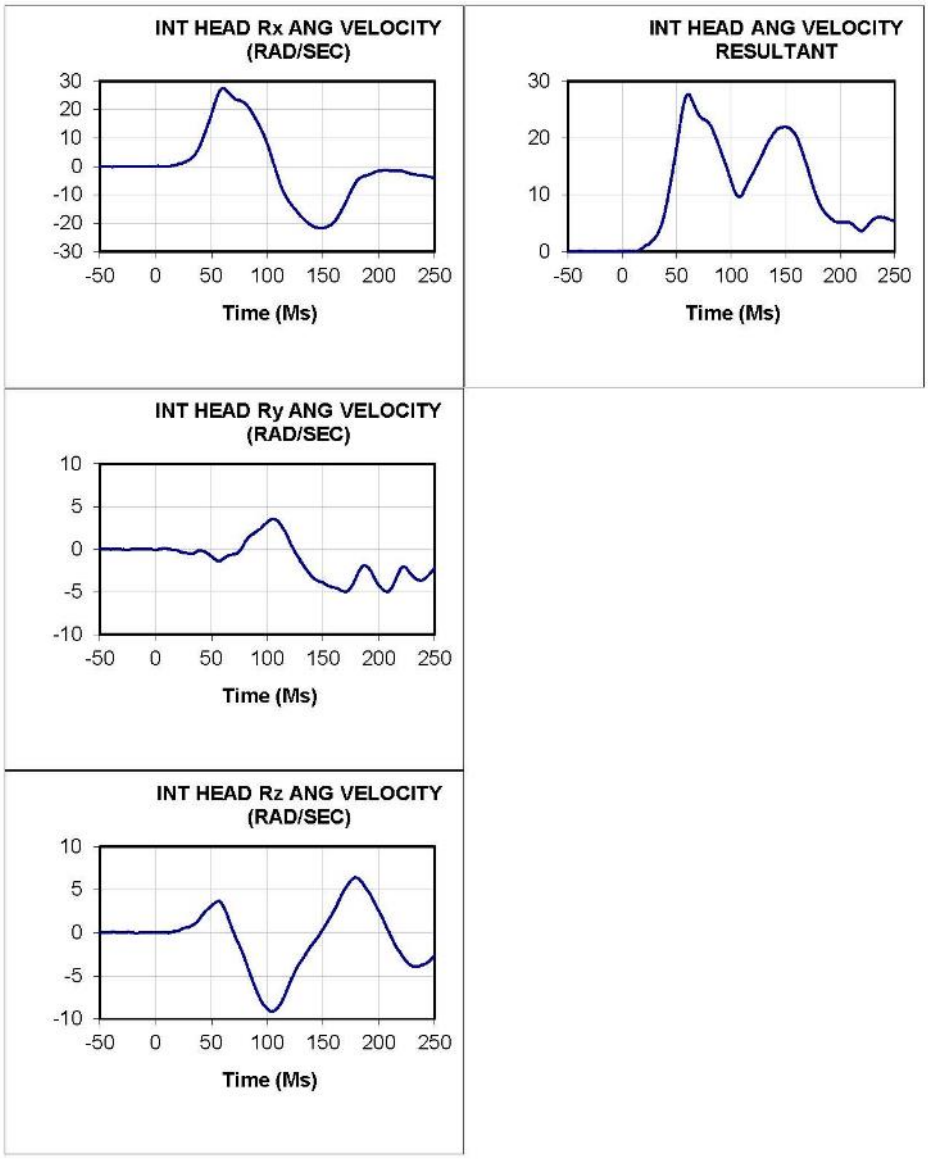
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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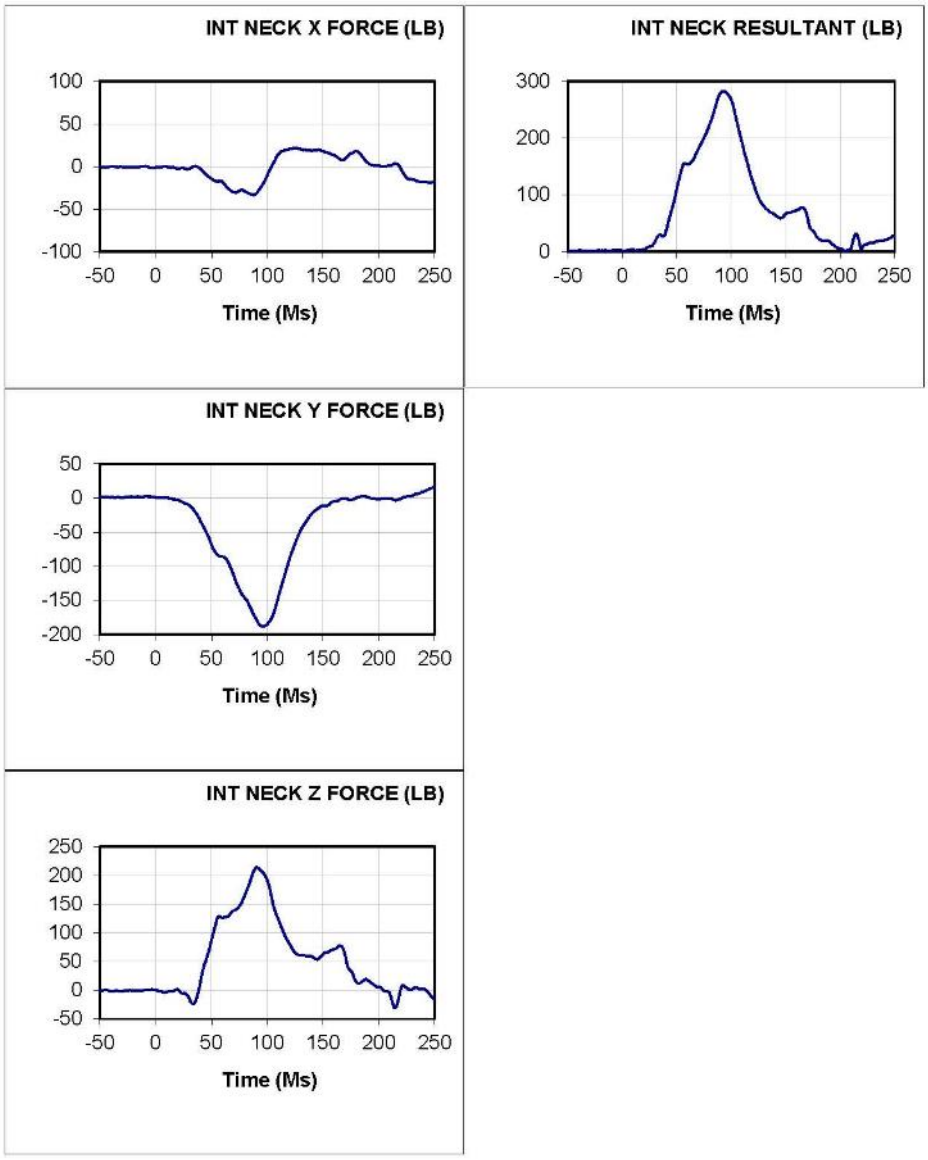
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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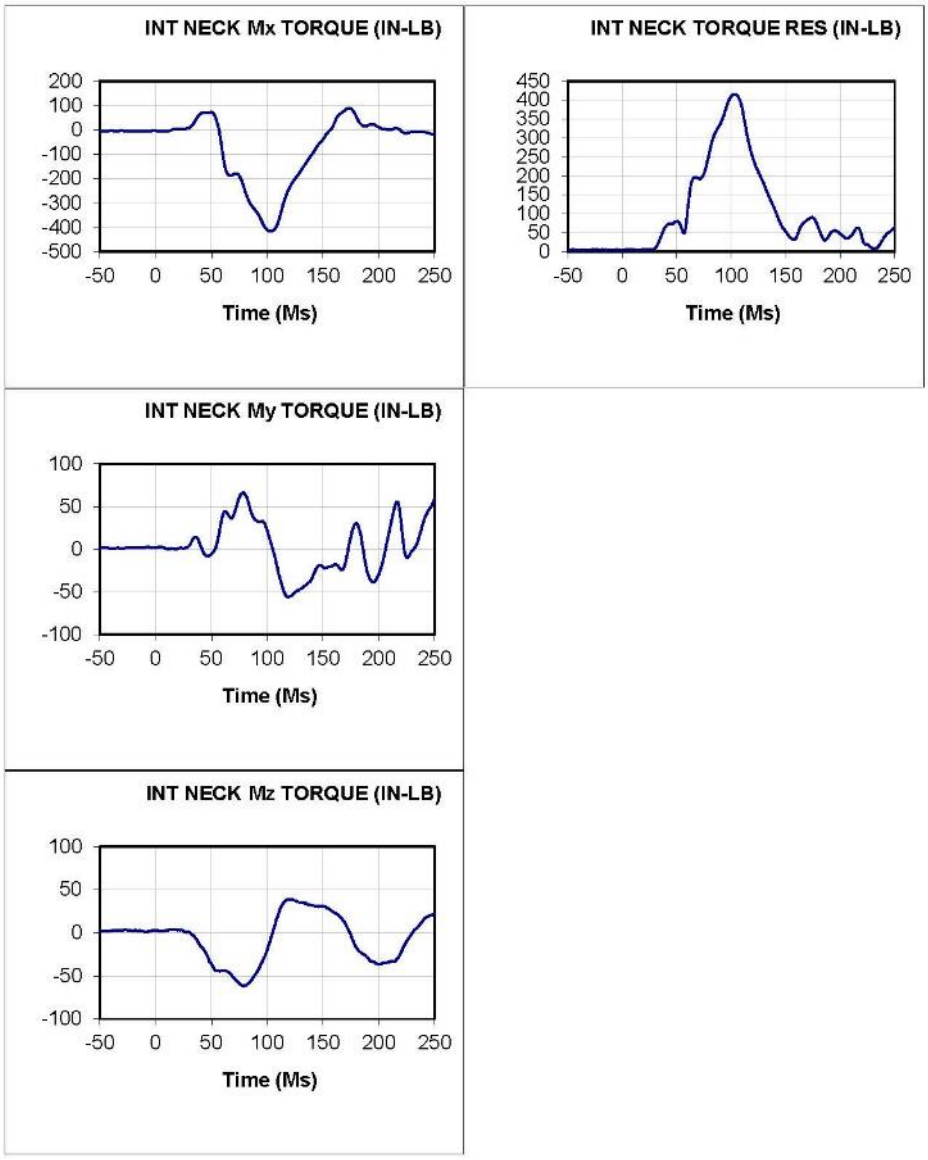
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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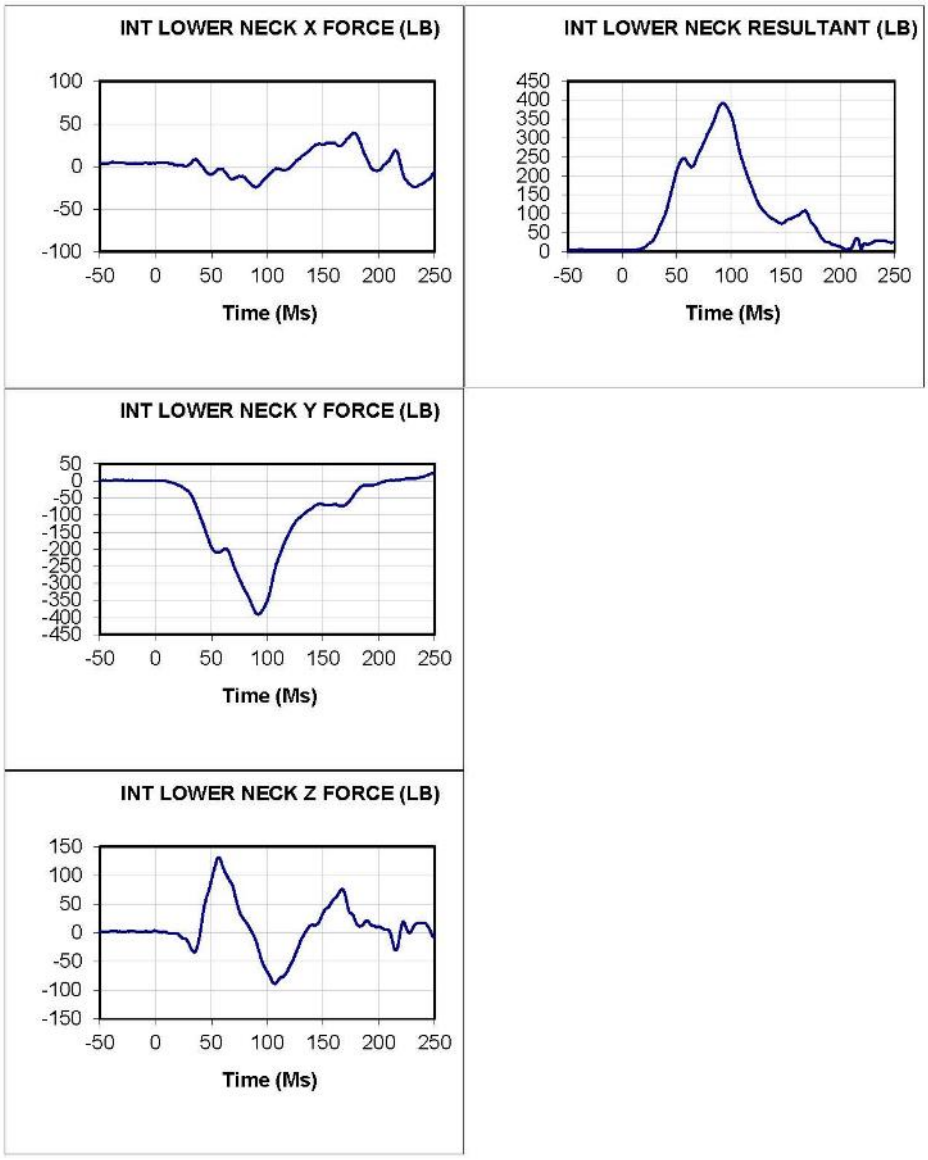
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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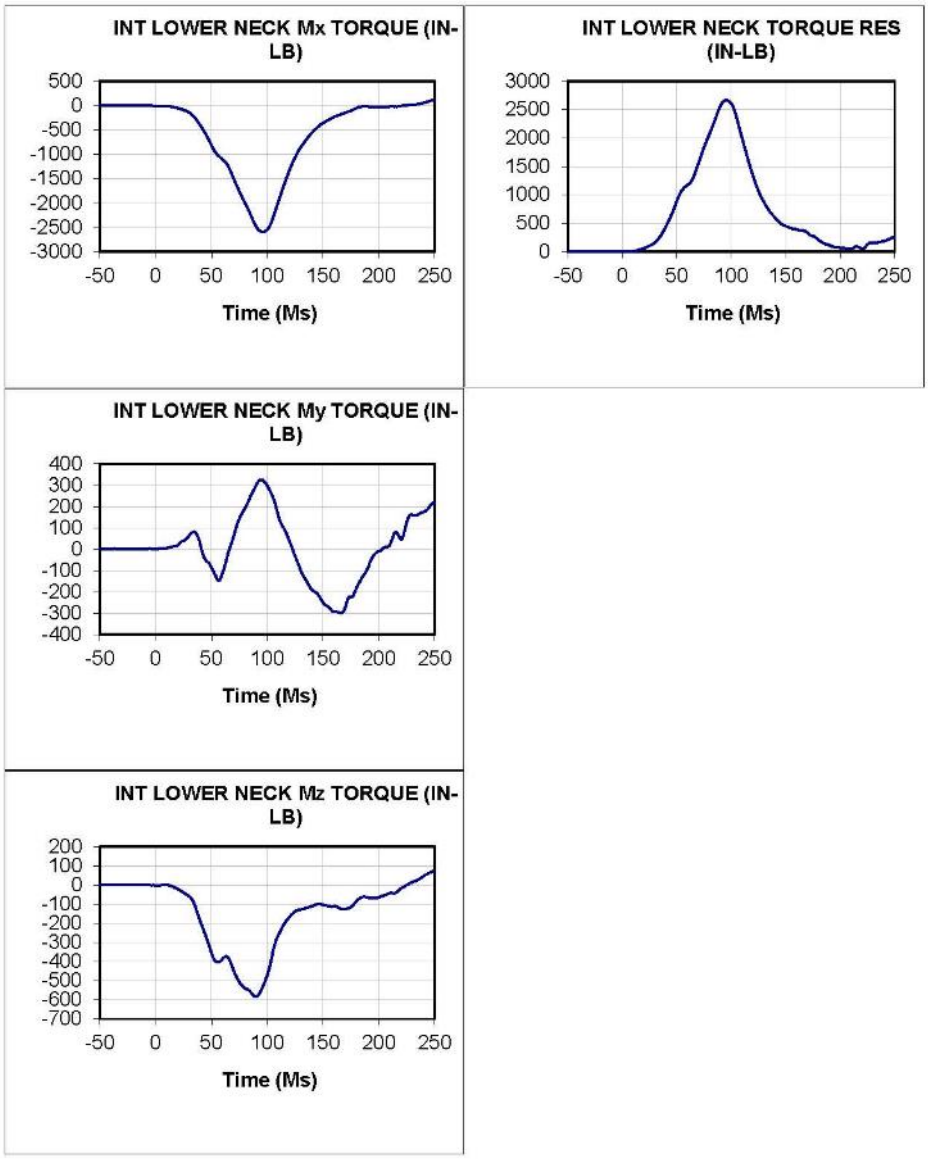
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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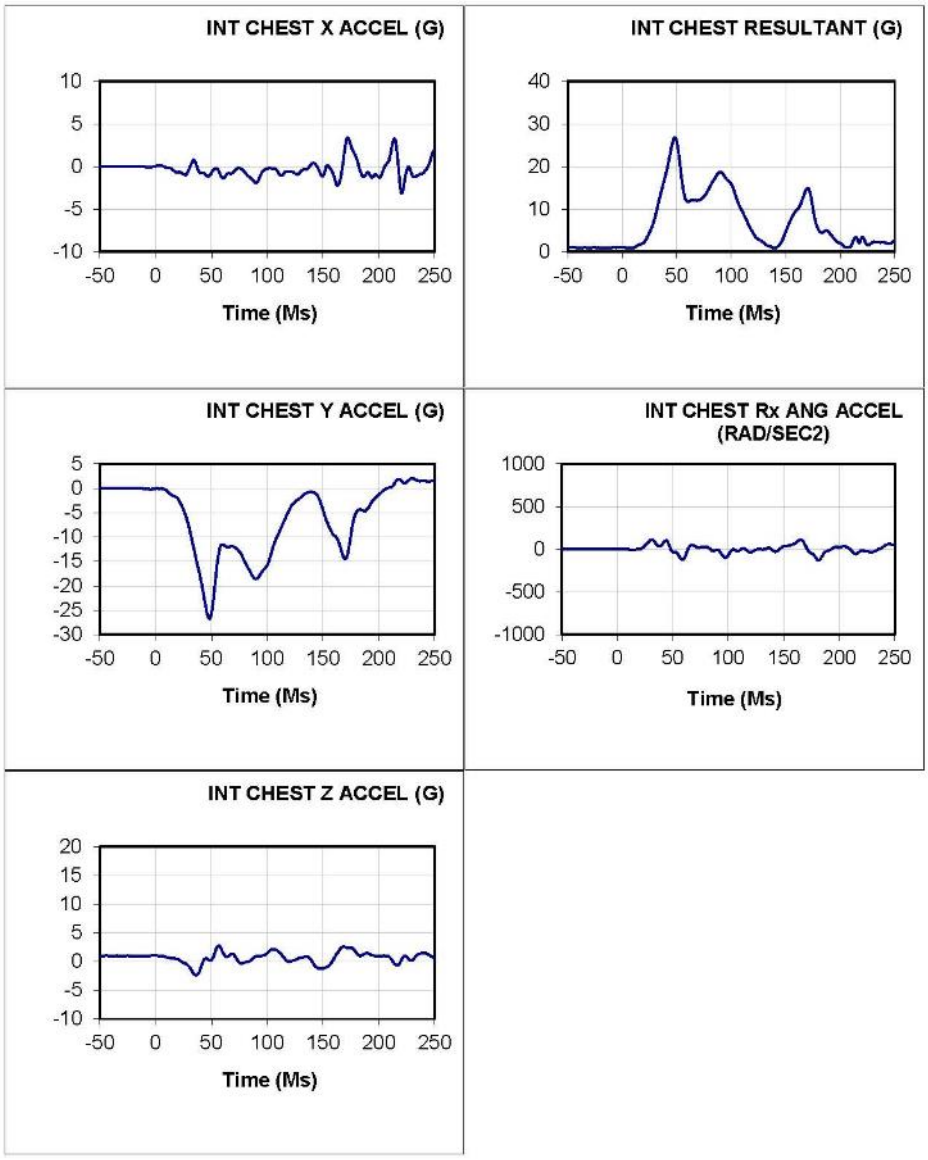
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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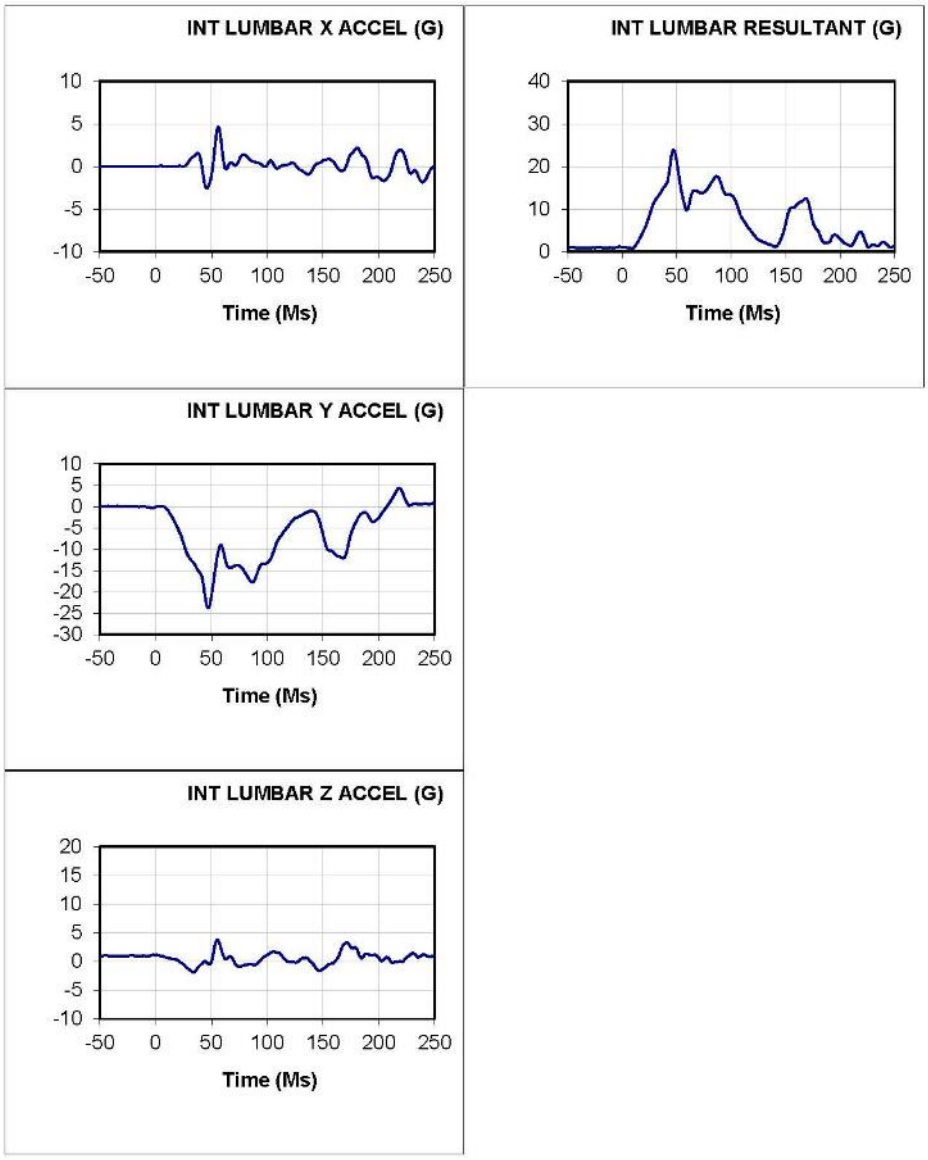
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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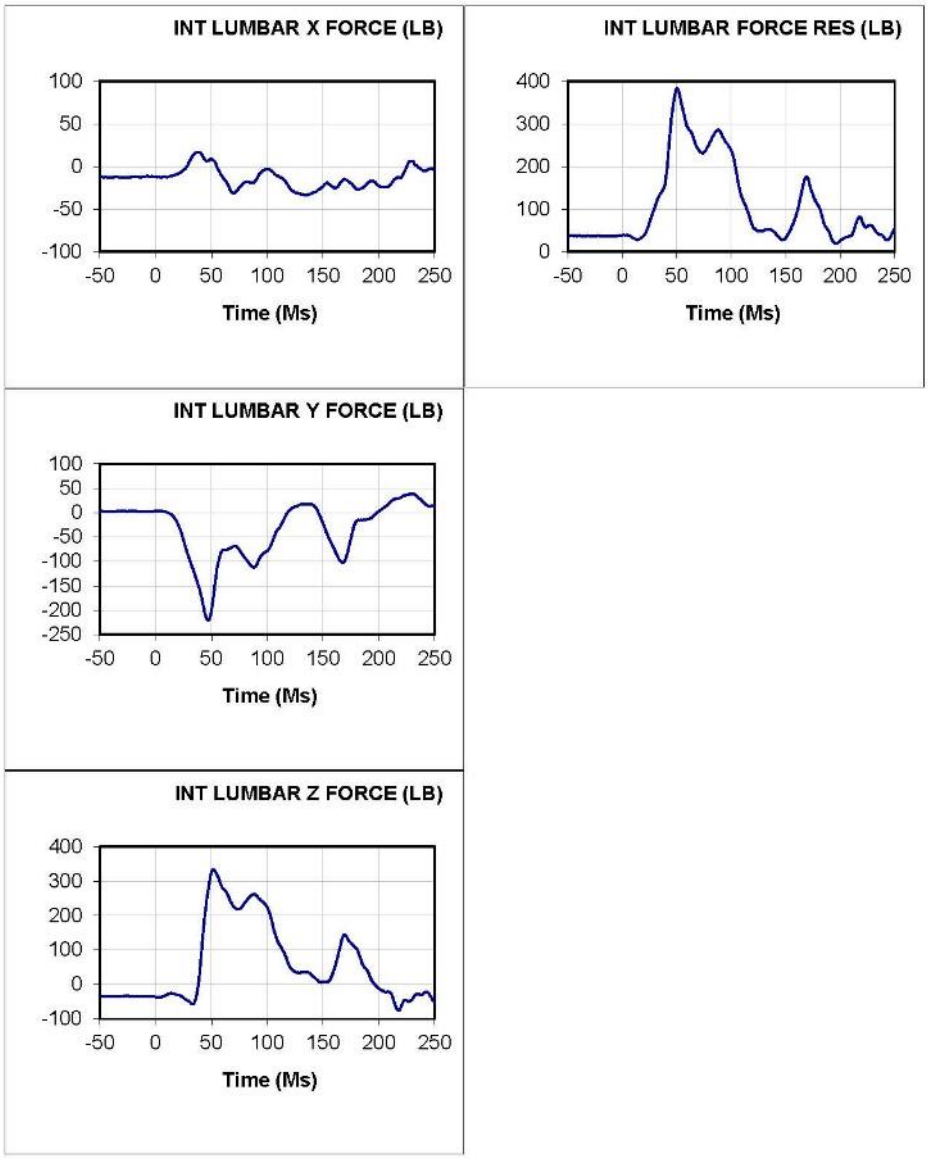
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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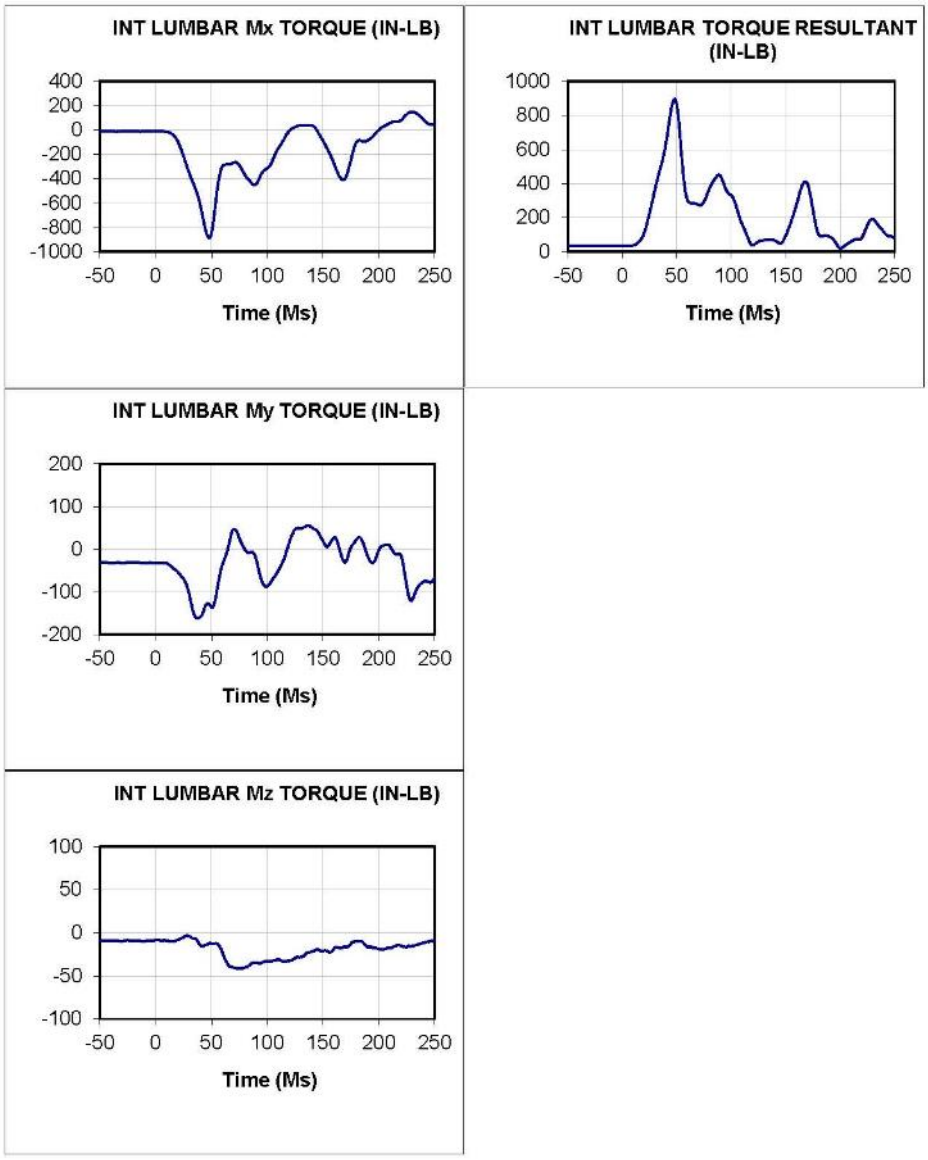
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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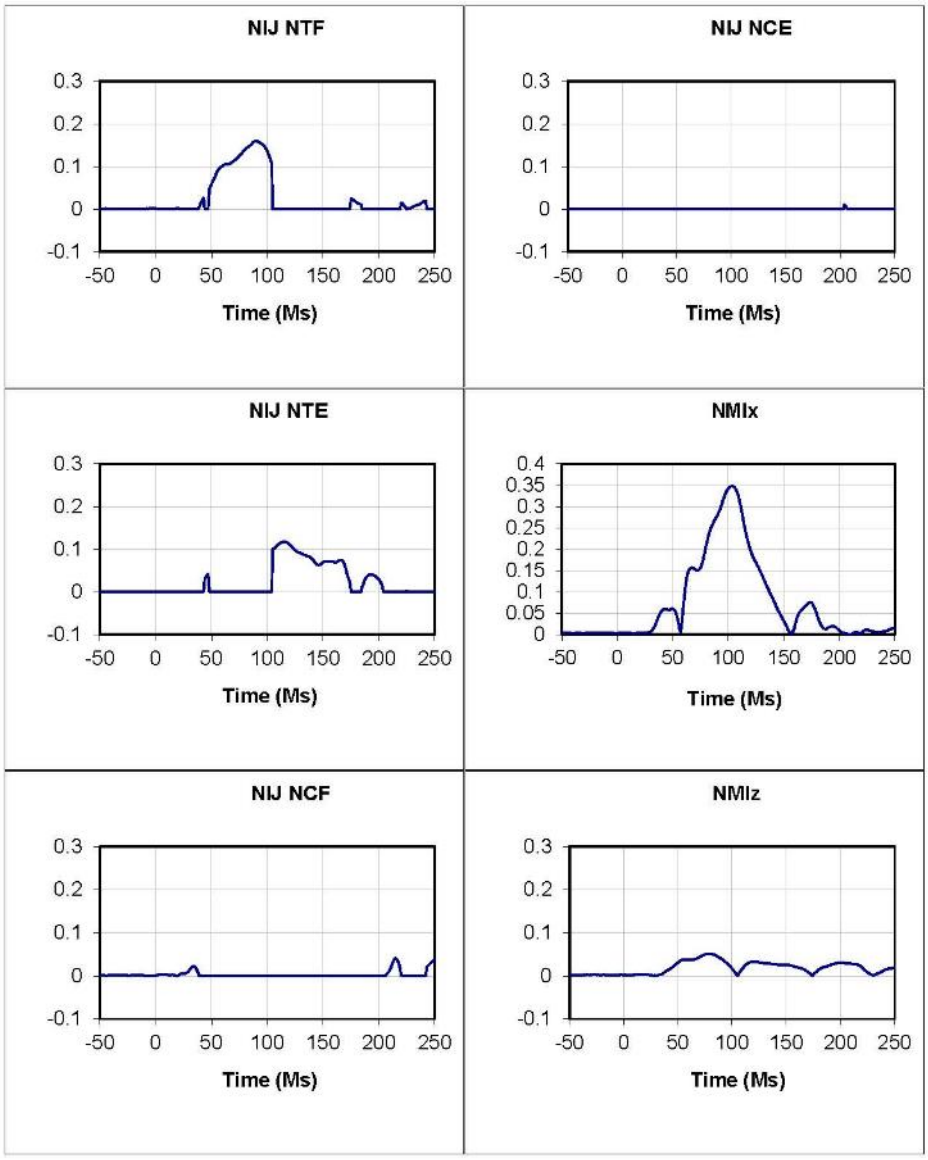
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9218 Test Date: 161115 Subj: AERO50 Cell: D



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Wt: 161.0
Nom G: 17.0 Cell: E

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				10.0	
Impact Rise Time (Ms)				84.0	
Impact Duration (Ms)				202.0	
Velocity Change (Ft/Sec)		60.66			
SLED X ACCEL (G)	0.00	17.02	-1.00	84.0	220.0
SLED Y ACCEL (G)	-0.03	1.38	-1.17	44.0	54.0
SLED Z ACCEL (G)	-0.98	2.68	-4.61	55.0	60.0
SLED RESULTANT	0.98	17.23	0.40	85.0	229.0
INTEGRATED ACCEL (FT/SEC)	0.03	60.66	0.05	201.0	0.0
SEAT X ACCEL (G)	-0.08	7.66	-8.49	228.0	234.0
SEAT Y ACCEL (G)	-0.13	5.73	-23.81	228.0	41.0
SEAT Z ACCEL (G)	0.91	6.60	-2.09	36.0	209.0
SEAT RESULTANT	0.94	23.85	0.71	41.0	220.0
LEFT LAP X FORCE (LB)	78.13	292.37	46.50	53.0	240.0
LEFT LAP Y FORCE (LB)	-27.48	-17.18	-170.23	227.0	52.0
LEFT LAP Z FORCE (LB)	8.59	28.43	5.78	45.0	219.0
LEFT LAP RESULTANT (LB)	83.27	339.28	50.19	53.0	240.0
RIGHT LAP X FORCE (LB)	34.93	56.11	18.61	234.0	25.0
RIGHT LAP Y FORCE (LB)	4.56	8.93	-18.10	227.0	40.0
RIGHT LAP Z FORCE (LB)	3.76	8.74	-3.26	215.0	41.0
RIGHT LAP RESULTANT (LB)	35.43	57.17	21.78	235.0	26.0
LEFT SHOULDER X FORCE (LB)	26.90	120.88	7.10	62.0	211.0
LEFT SHOULDER Y FORCE (LB)	2.21	9.70	-38.13	214.0	91.0
LEFT SHOULDER Z FORCE (LB)	-5.71	1.81	-18.32	35.0	64.0
LEFT SHOULDER RESULTANT (LB)	27.59	124.58	9.34	62.0	211.0
RIGHT SHOULDER X FORCE (LB)	26.52	61.99	12.78	86.0	211.0
RIGHT SHOULDER Y FORCE (LB)	1.90	9.40	-40.54	213.0	91.0
RIGHT SHOULDER Z FORCE (LB)	-5.91	-1.82	-13.08	214.0	41.0
RIGHT SHOULDER RESULTANT (LB)	27.24	73.04	15.25	89.0	211.0
CROTCH STRAP X FORCE (LB)	1.87	5.80	-30.60	221.0	54.0
CROTCH STRAP Y FORCE (LB)	-3.07	2.02	-65.51	228.0	51.0
CROTCH STRAP Z FORCE (LB)	0.21	139.80	-9.85	50.0	227.0
CROTCH STRAP RESULTANT (LB)	3.61	156.50	3.41	51.0	2.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Wt: 161.0
Nom G: 17.0 Cell: E

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT HEAD X ACCEL (G)	-0.14	2.13	-4.21	121.0	77.0
INT HEAD Y ACCEL (G)	0.11	0.58	-22.68	239.0	96.0
INT HEAD Z ACCEL (G)	1.13	23.76	-2.83	87.0	214.0
INT HEAD RESULTANT (G)	1.15	32.55	0.55	92.0	12.0
INT HEAD HIC		146.89		74.0	104.0
INT HEAD Rx ANG VELOCITY (RAD/SEC)	0.02	27.32	-22.55	58.0	142.0
INT HEAD Ry ANG VELOCITY (RAD/SEC)	0.00	2.40	-4.51	103.0	202.0
INT HEAD Rz ANG VELOCITY (RAD/SEC)	0.02	6.62	-9.18	173.0	104.0
INT HEAD ANG VELOCITY RESULTANT	0.05	27.58	0.04	58.0	5.0
INT NECK X FORCE (LB)	5.10	23.98	-33.58	177.0	86.0
INT NECK Y FORCE (LB)	0.12	0.19	-194.94	6.0	95.0
INT NECK Z FORCE (LB)	0.40	229.86	-30.00	88.0	214.0
INT NECK RESULTANT (LB)	5.17	300.62	4.03	92.0	14.0
INT NECK Mx TORQUE (IN-LB)	0.58	72.63	-433.86	160.0	102.0
INT NECK My TORQUE (IN-LB)	-4.91	82.10	-45.08	83.0	193.0
INT NECK Mz TORQUE (IN-LB)	3.23	37.32	-71.15	119.0	79.0
INT NECK TORQUE RES (IN-LB)	5.92	434.28	4.10	102.0	0.0
INT LOWER NECK X FORCE (LB)	3.87	35.67	-30.26	176.0	92.0
INT LOWER NECK Y FORCE (LB)	3.38	10.18	-405.43	240.0	89.0
INT LOWER NECK Z FORCE (LB)	4.77	138.86	-81.61	53.0	106.0
INT LOWER NECK RESULTANT (LB)	7.06	407.84	2.94	90.0	11.0
INT LOWER NECK Mx TORQUE (IN-LB)	-1.69	-1.95	-2713.28	240.0	94.0
INT LOWER NECK My TORQUE (IN-LB)	9.18	412.93	-276.50	94.0	159.0
INT LOWER NECK Mz TORQUE (IN-LB)	1.01	42.23	-626.23	240.0	85.0
INT LOWER NECK TORQUE RES (IN-LB)	9.56	2800.73	9.24	93.0	4.0
INT CHEST X ACCEL (G)	-0.01	3.83	-3.45	213.0	220.0
INT CHEST Y ACCEL (G)	-0.07	1.88	-26.13	240.0	46.0
INT CHEST Z ACCEL (G)	0.99	3.56	-2.44	54.0	34.0
INT CHEST RESULTANT (G)	1.00	26.14	0.92	46.0	8.0
INT CHEST Rx ANG ACCEL (RAD/SEC2)	0.16	116.33	-155.98	64.0	57.0
INT LUMBAR X ACCEL (G)	0.00	4.81	-3.19	56.0	46.0
INT LUMBAR Y ACCEL (G)	-0.03	2.80	-23.14	217.0	47.0
INT LUMBAR Z ACCEL (G)	0.99	4.15	-2.16	167.0	31.0
INT LUMBAR RESULTANT (G)	1.00	23.36	0.80	47.0	209.0

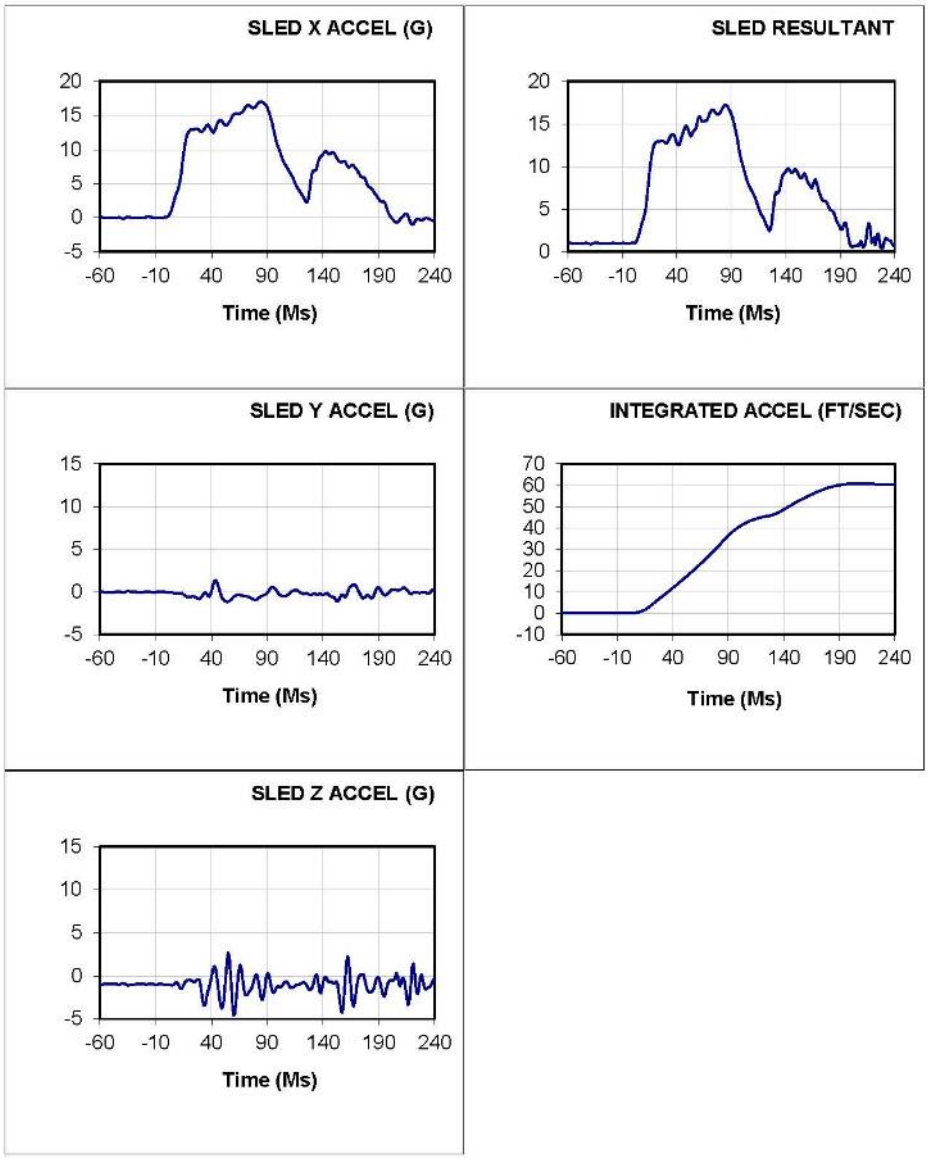
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Wt: 161.0
Nom G: 17.0 Cell: E

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT LUMBAR X FORCE (LB)	23.70	52.76	5.17	33.0	120.0
INT LUMBAR Y FORCE (LB)	7.48	35.77	-186.26	231.0	46.0
INT LUMBAR Z FORCE (LB)	-1.53	329.07	-31.60	54.0	215.0
INT LUMBAR FORCE RES (LB)	24.92	342.40	21.40	53.0	205.0
INT LUMBAR Mx TORQUE (IN-LB)	4.60	130.45	-714.01	228.0	47.0
INT LUMBAR My TORQUE (IN-LB)	-41.94	43.06	-167.73	63.0	34.0
INT LUMBAR Mz TORQUE (IN-LB)	-5.55	-1.96	-53.23	24.0	66.0
INT LUMBAR TORQUE RESULTANT (IN-LB)	42.57	719.74	39.51	47.0	140.0
NIJ SHEAR (LB)		23.98	-33.58	177.0	86.0
NIJ TENSION (LB)		229.86		88.0	
NIJ COMPRESSION (LB)		-30.00		214.0	
NIJ FLEXION (IN-LB)		105.34		83.0	
NIJ EXTENSION (IN-LB)		56.21		129.0	
NIJ NTF	0.0000	0.1851	0.0000	85.0	0.0
NIJ NTE	0.0063	0.1002	0.0000	109.0	0.0
NIJ NCF	0.0000	0.0351	0.0000	214.0	0.0
NIJ NCE	0.0012	0.0292	0.0000	198.0	4.0
NIJ NTF AIS >= 2		0.14			
NIJ NTF AIS >= 3		0.05			
NIJ NTF AIS >= 4		0.08			
NIJ NTF AIS >= 5		0.03			
NIJ NTE AIS >= 2		0.13			
NIJ NTE AIS >= 3		0.05			
NIJ NTE AIS >= 4		0.07			
NIJ NTE AIS >= 5		0.02			
NIJ NCF AIS >= 2		0.12			
NIJ NCF AIS >= 3		0.04			
NIJ NCF AIS >= 4		0.07			
NIJ NCF AIS >= 5		0.02			
NIJ NCE AIS >= 2		0.12			
NIJ NCE AIS >= 3		0.04			
NIJ NCE AIS >= 4		0.07			
NIJ NCE AIS >= 5		0.02			
NMIx	0.0005	0.3631	0.0000	102.0	10.0
NMIz	0.0027	0.0595	0.0001	79.0	29.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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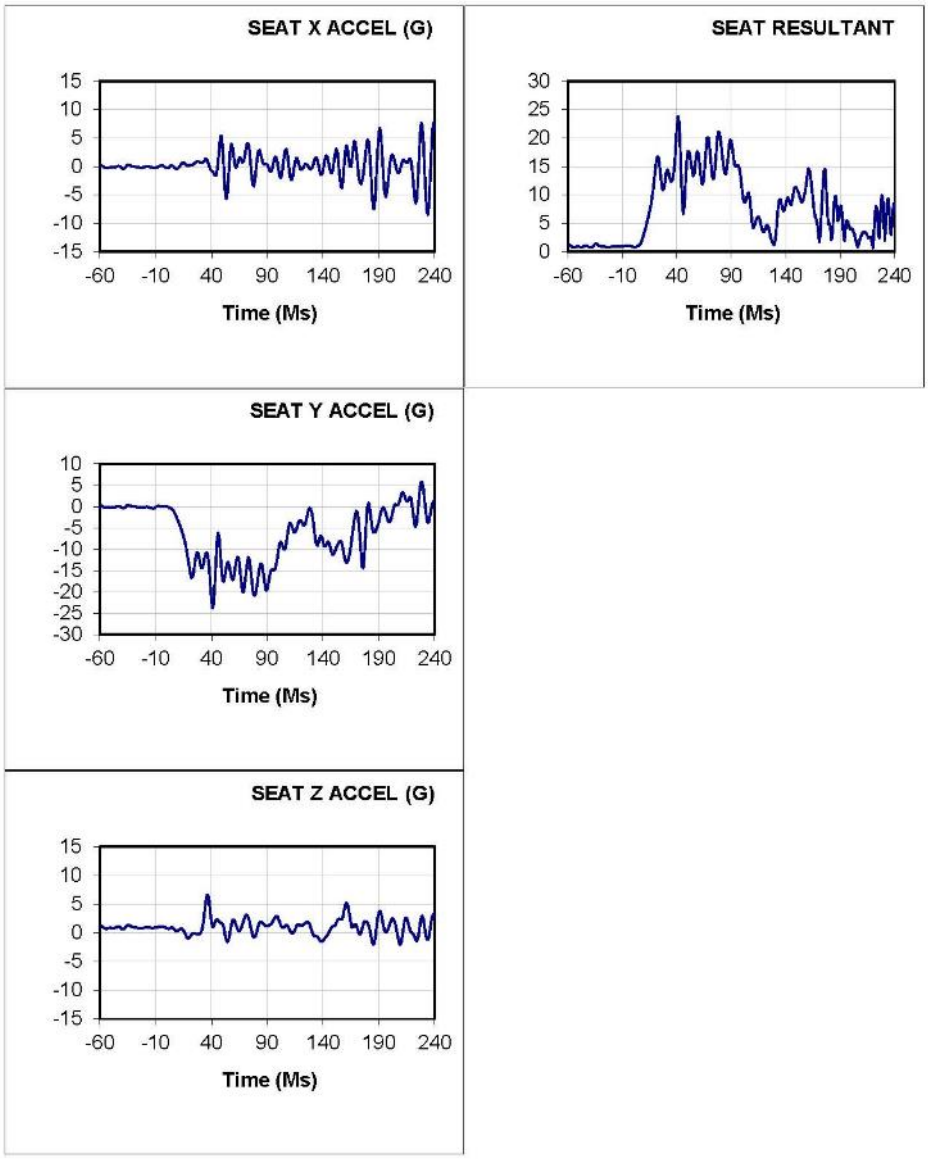
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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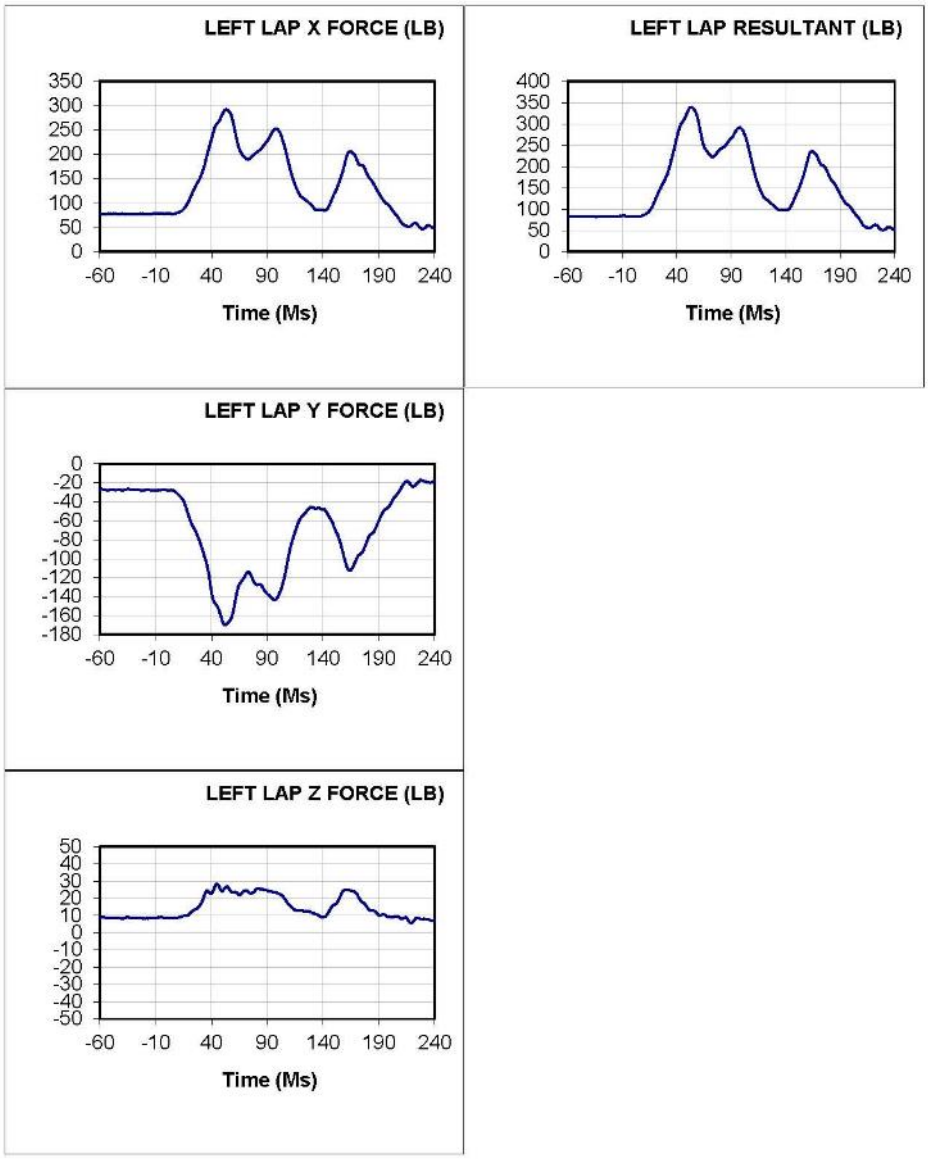
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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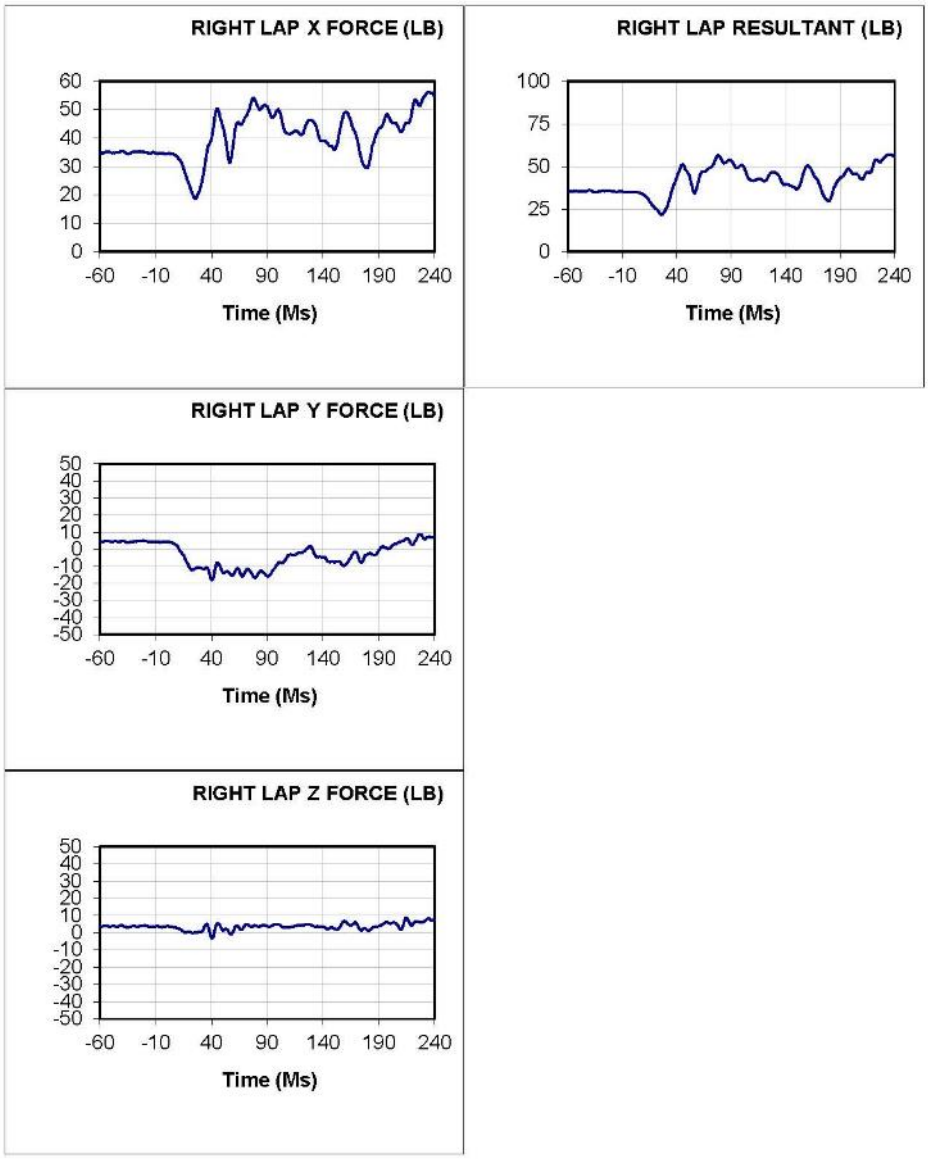
201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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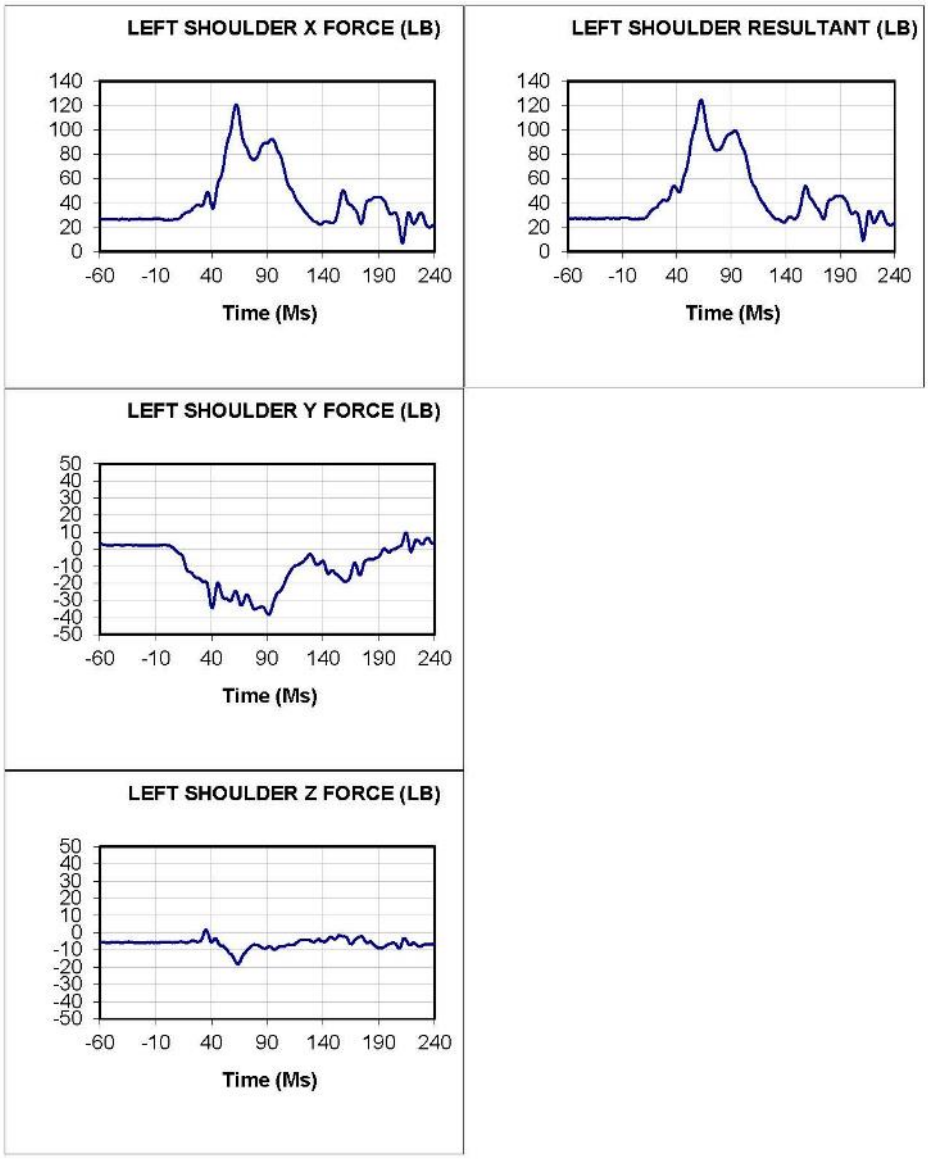
201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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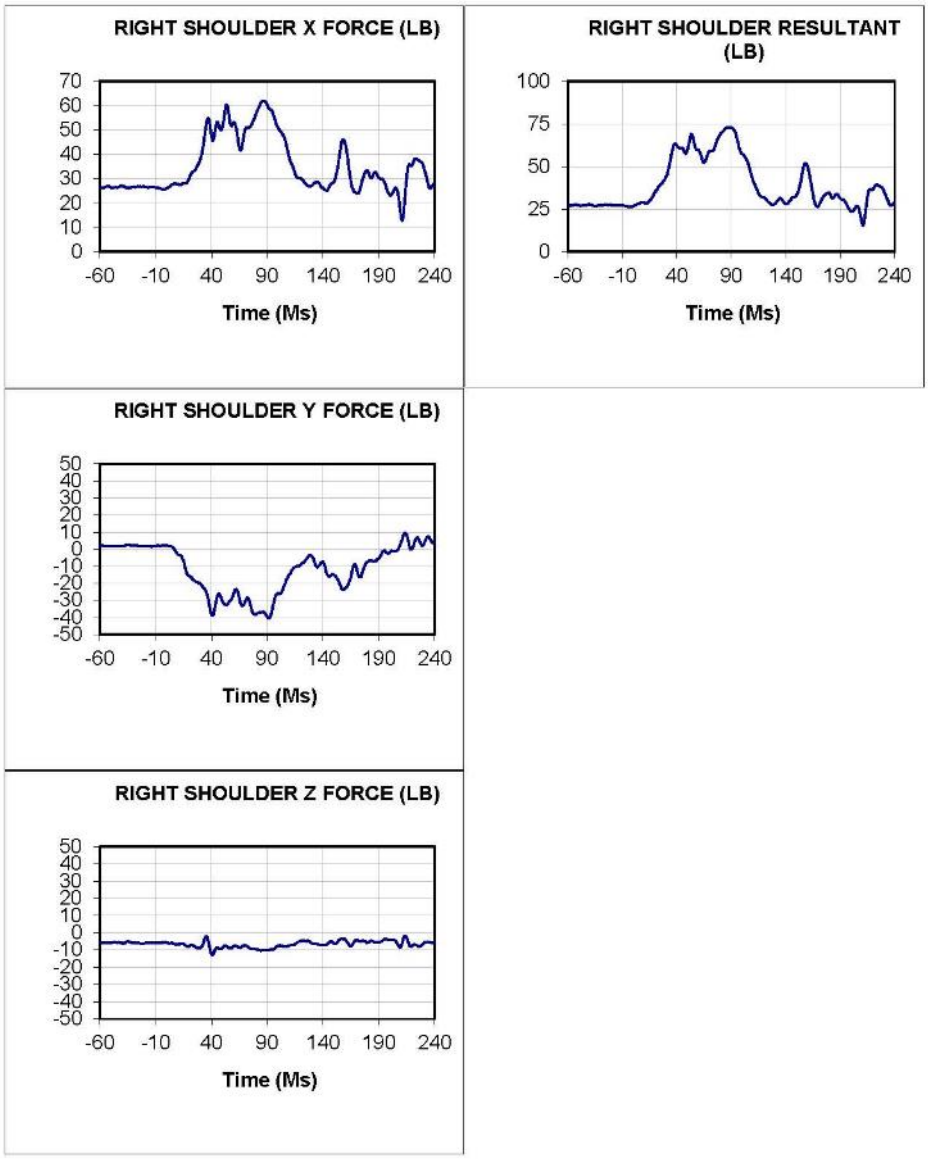
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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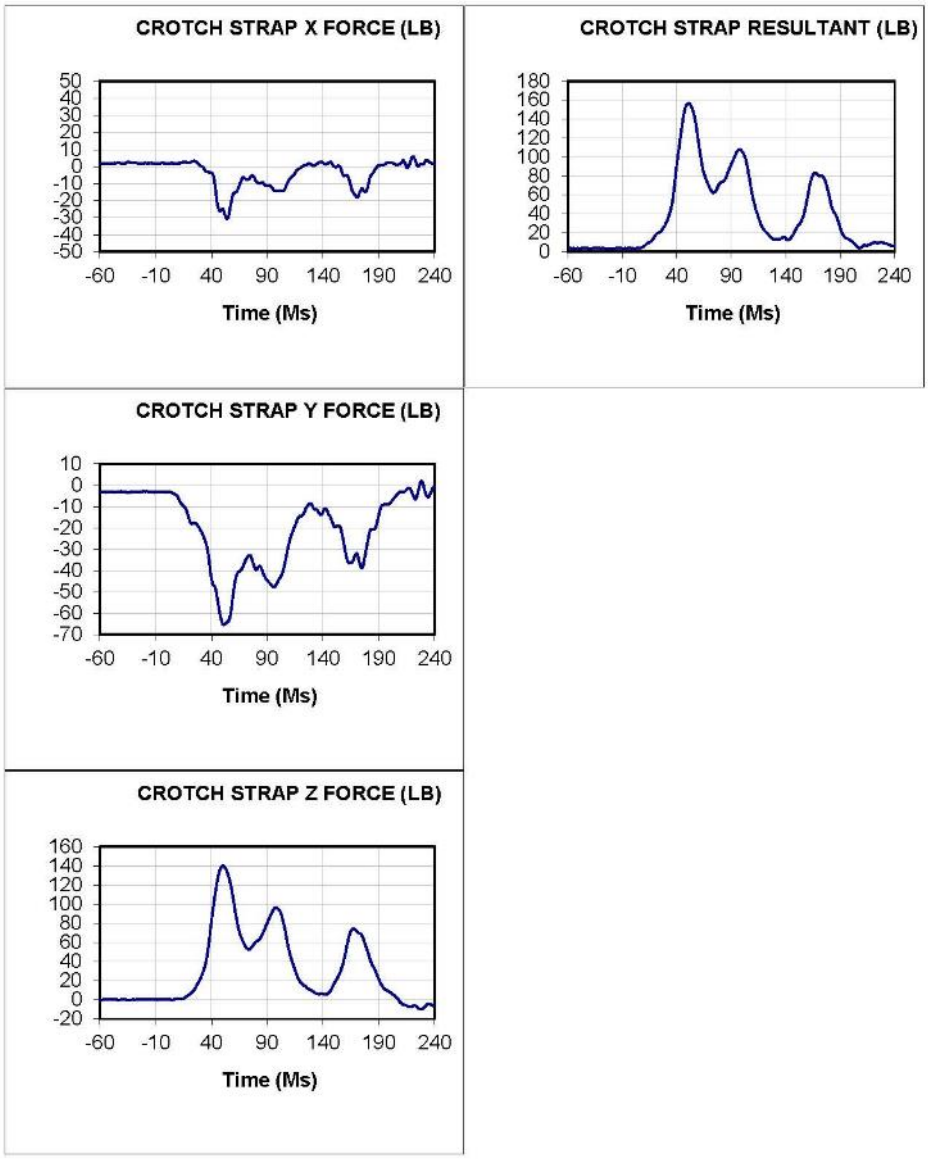
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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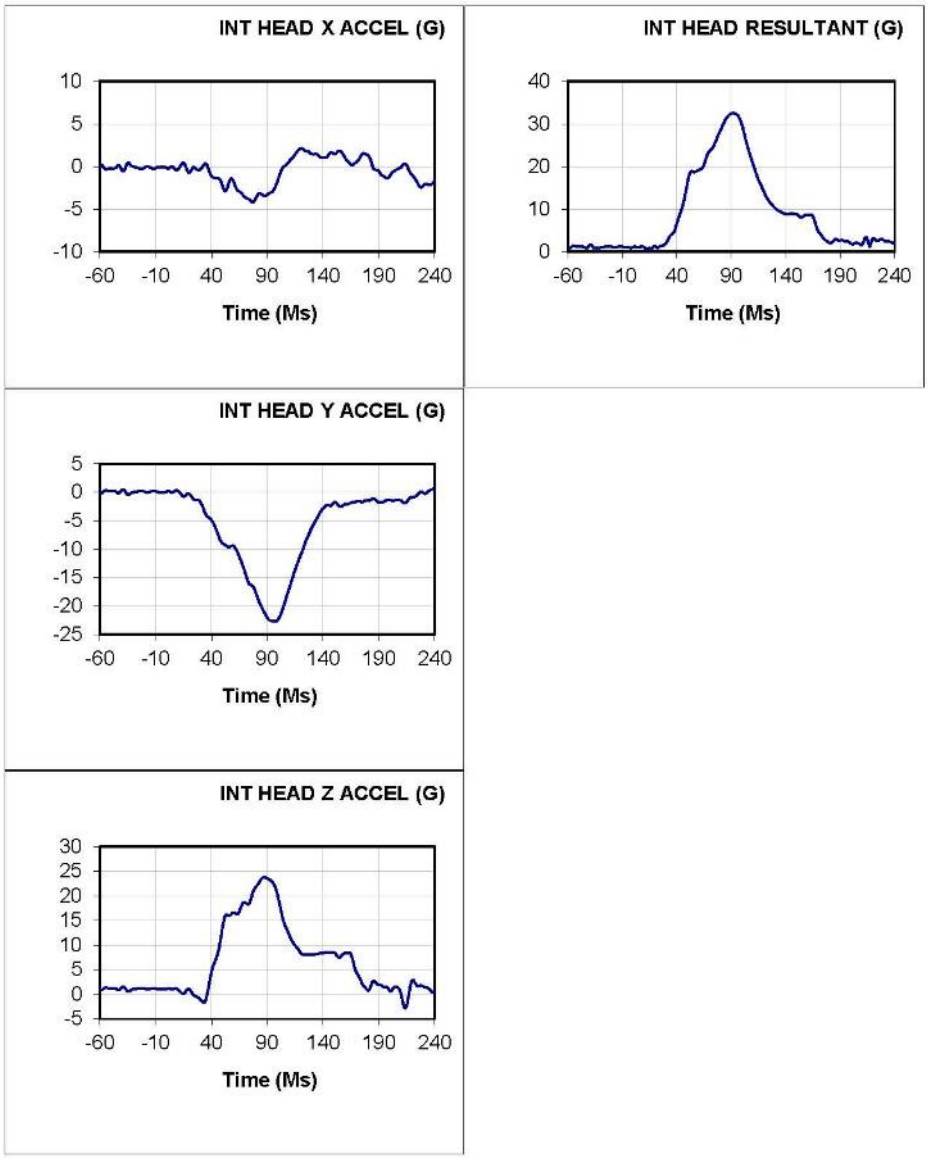
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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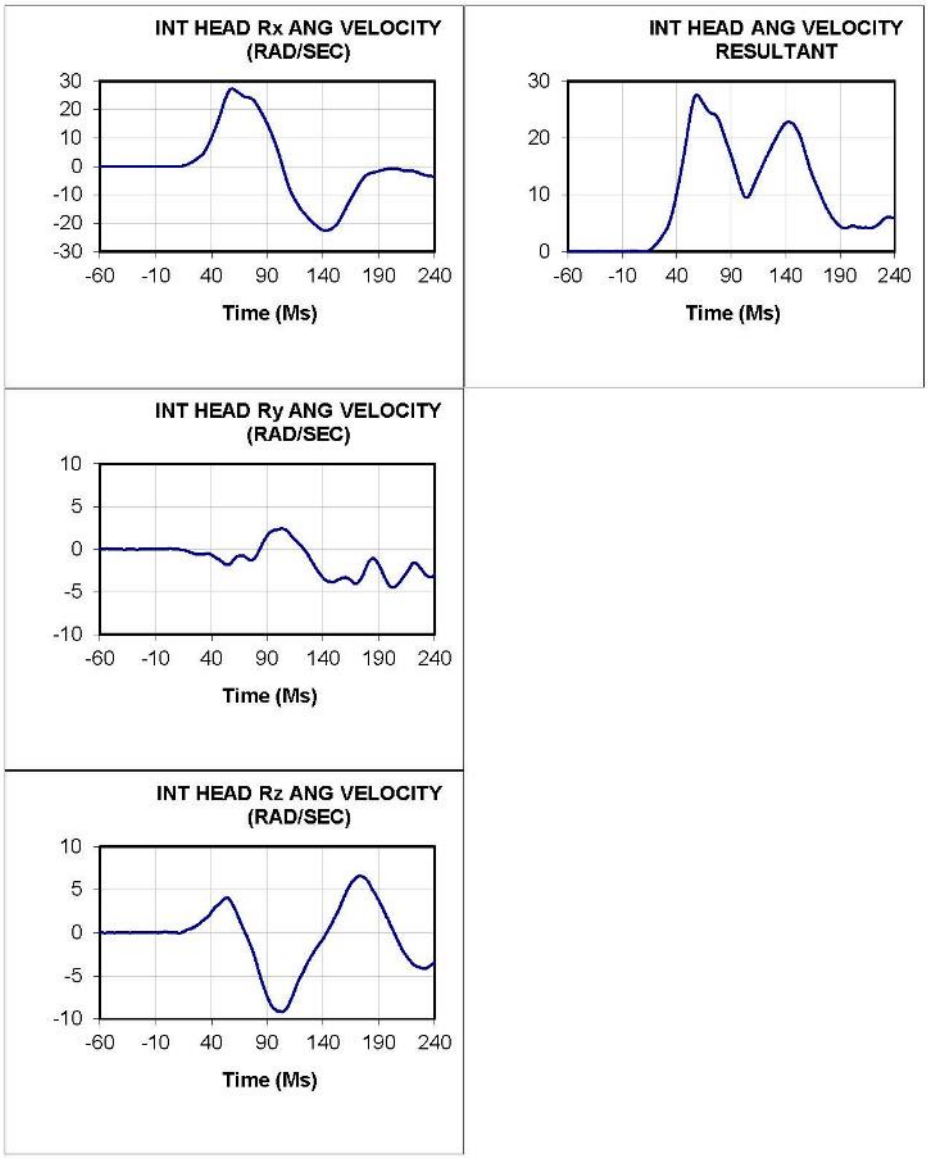
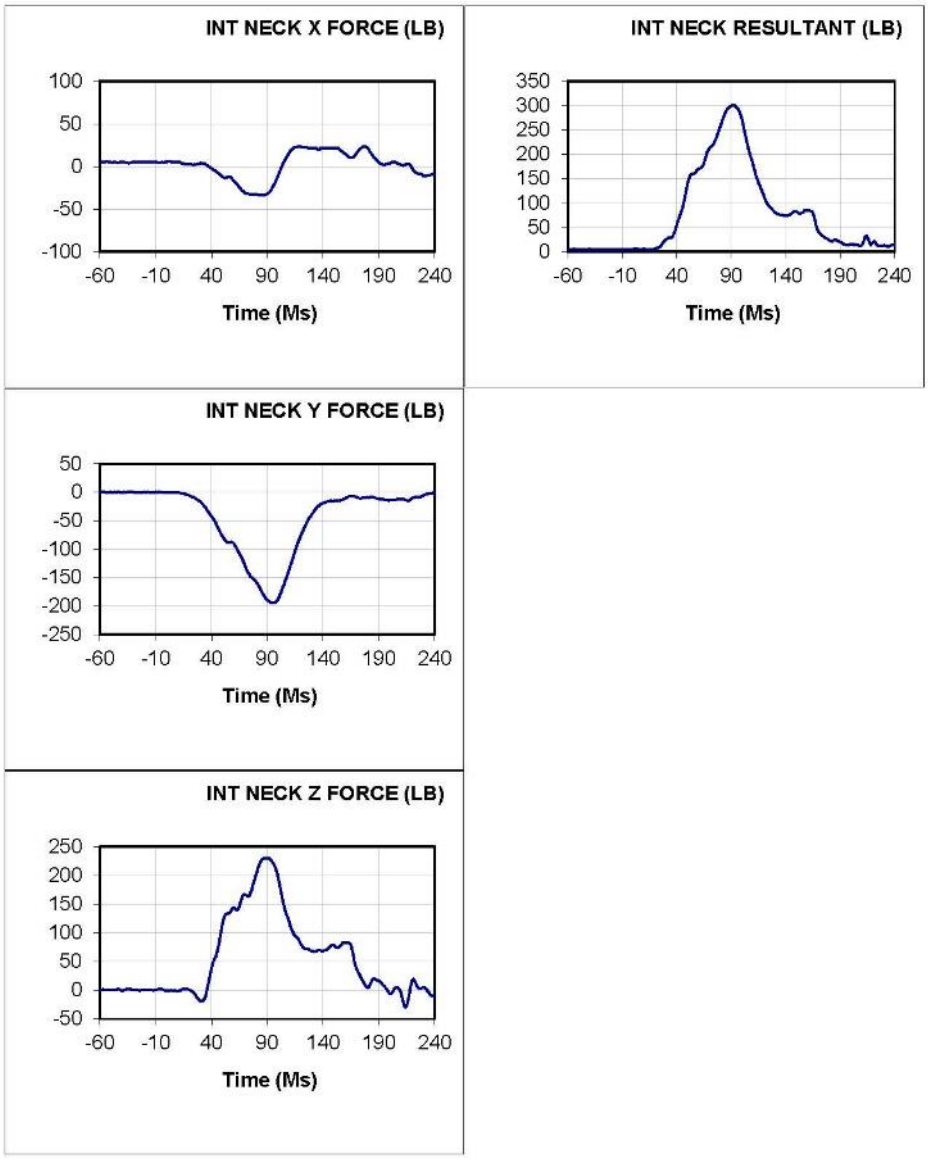
201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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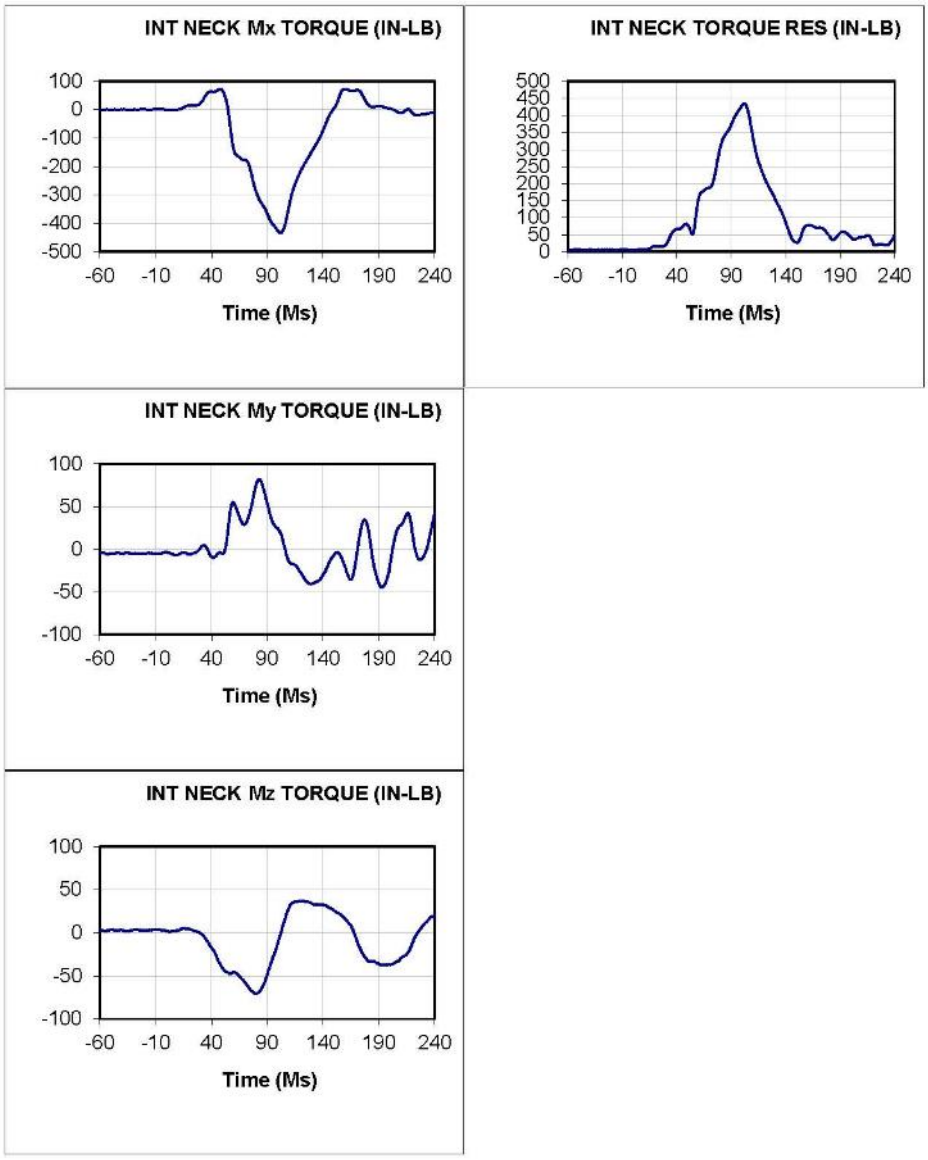

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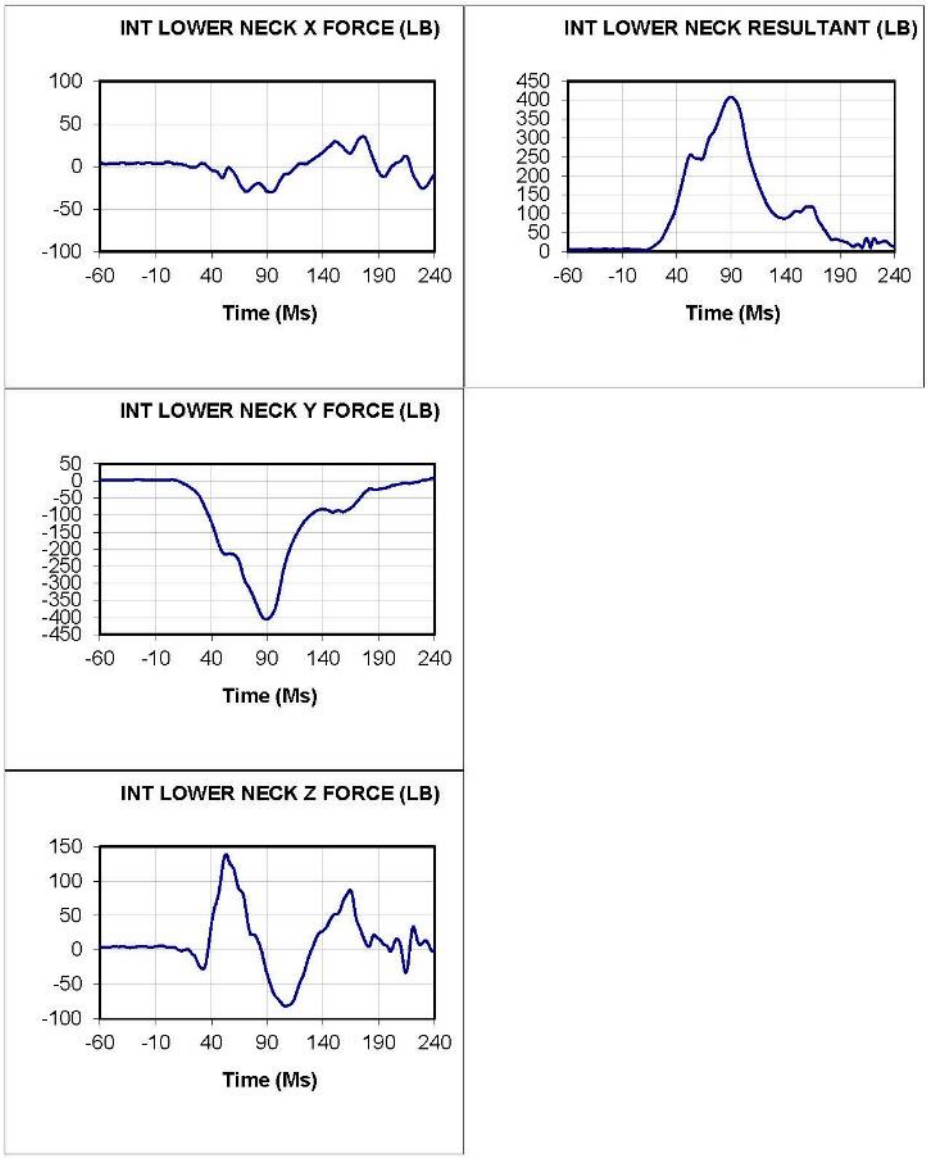
201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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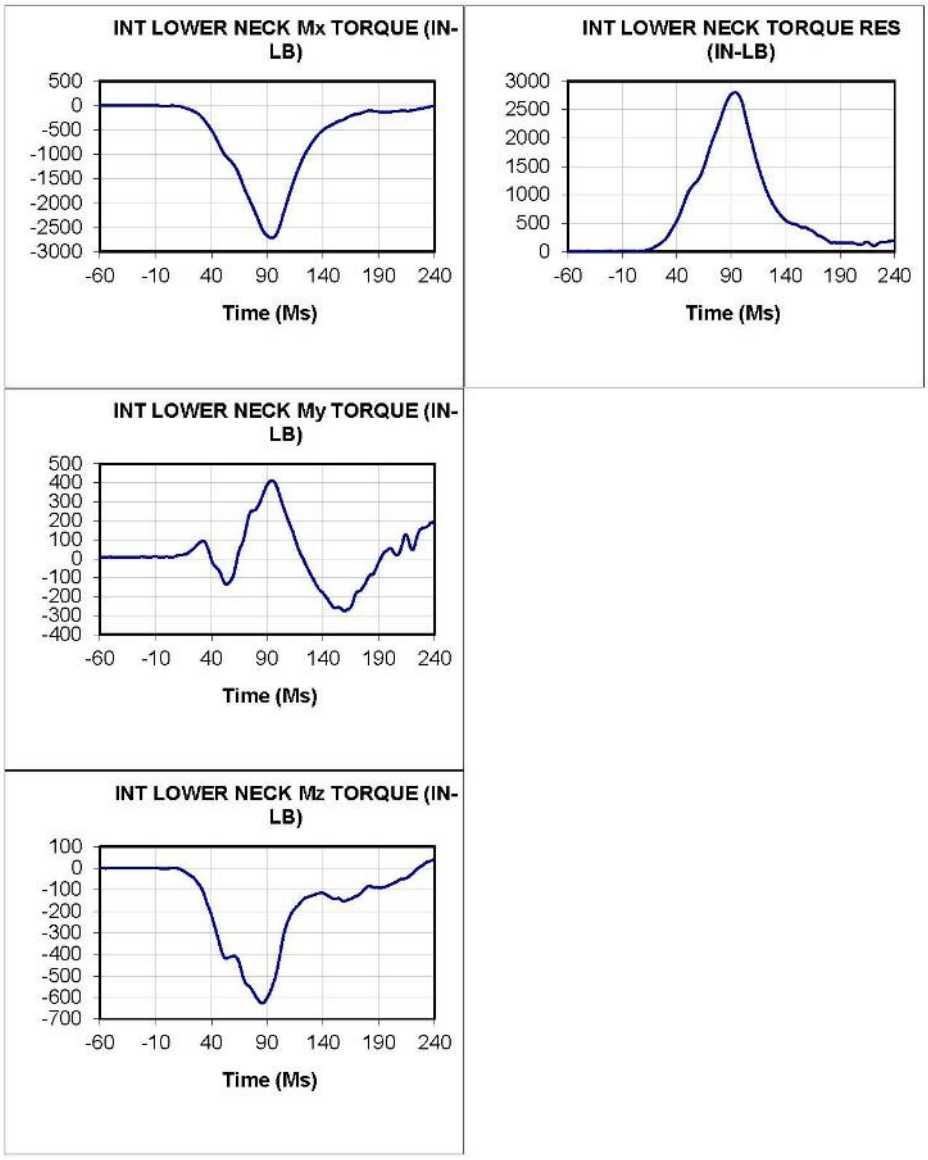
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019



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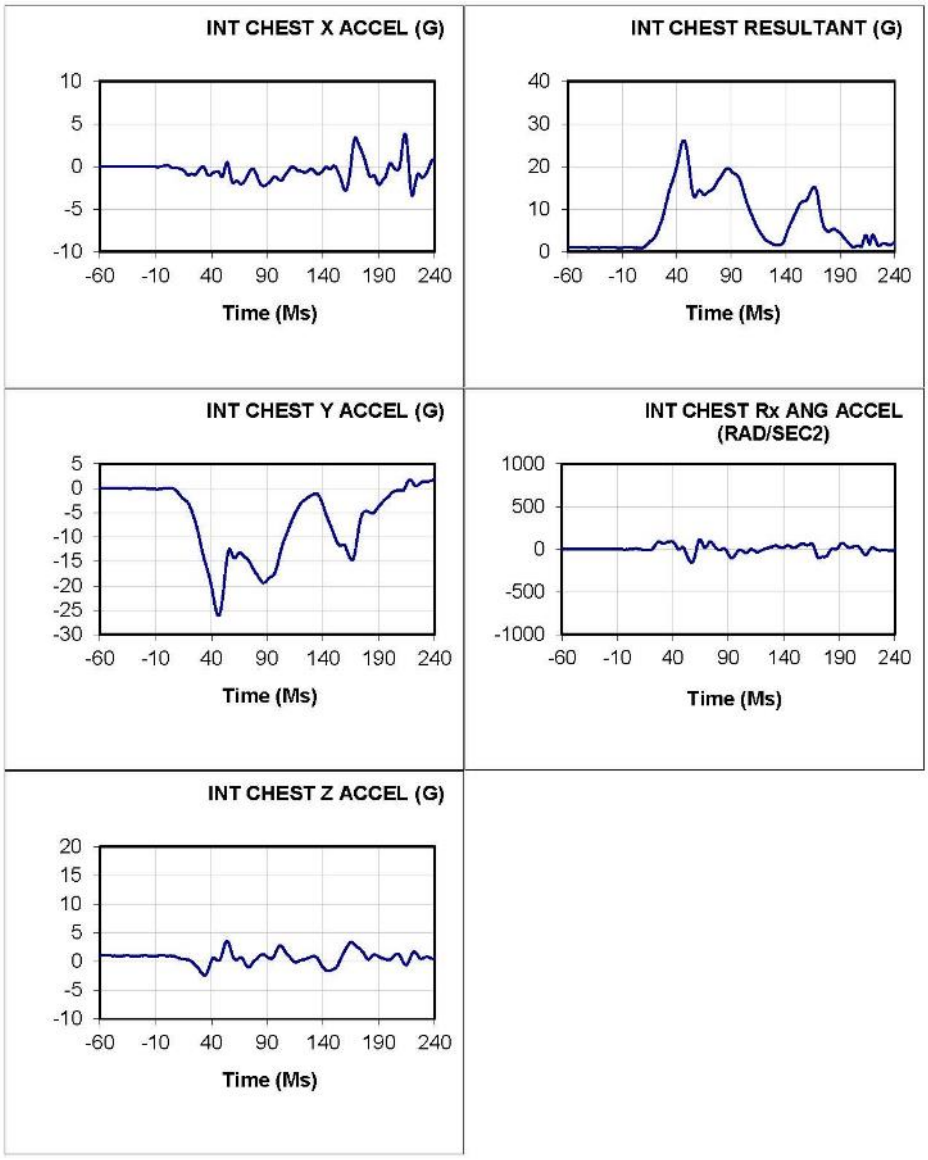
201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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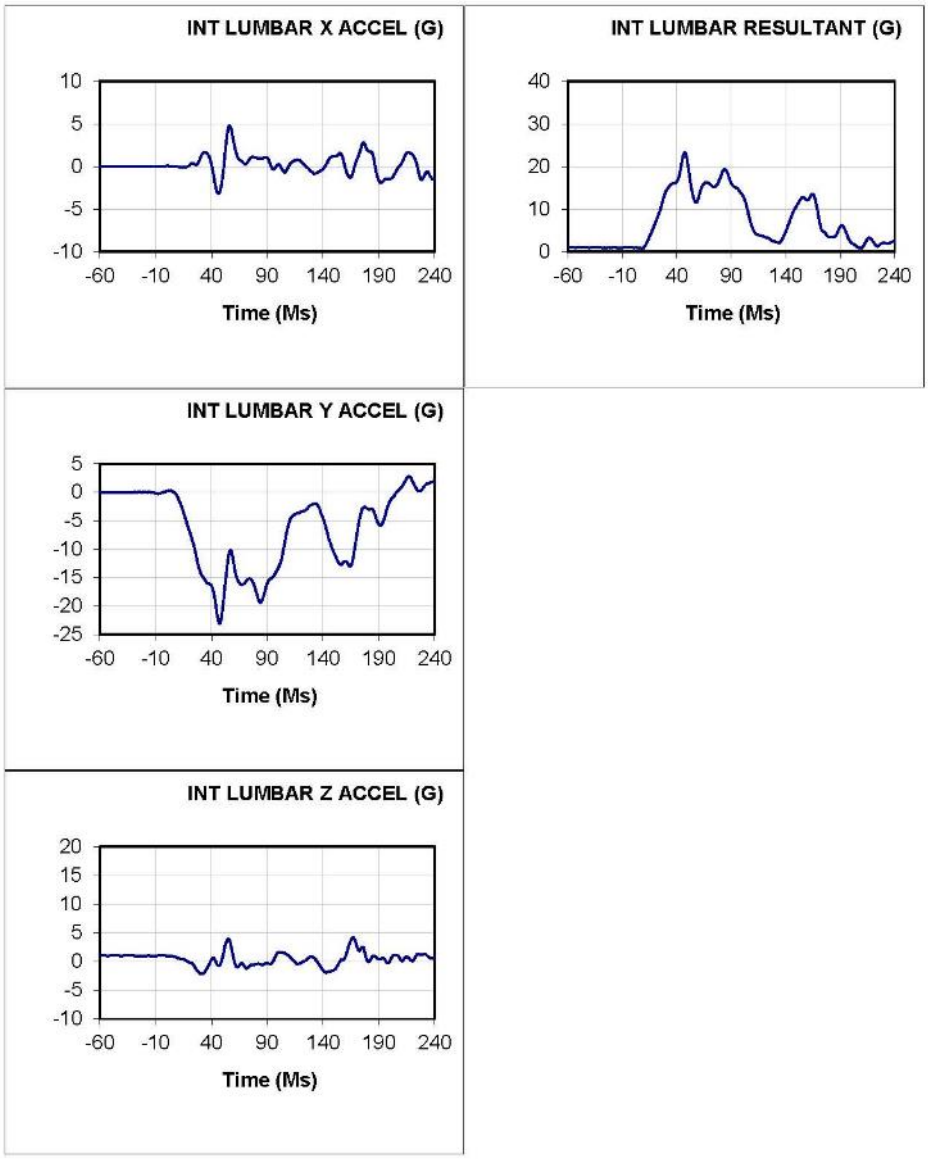

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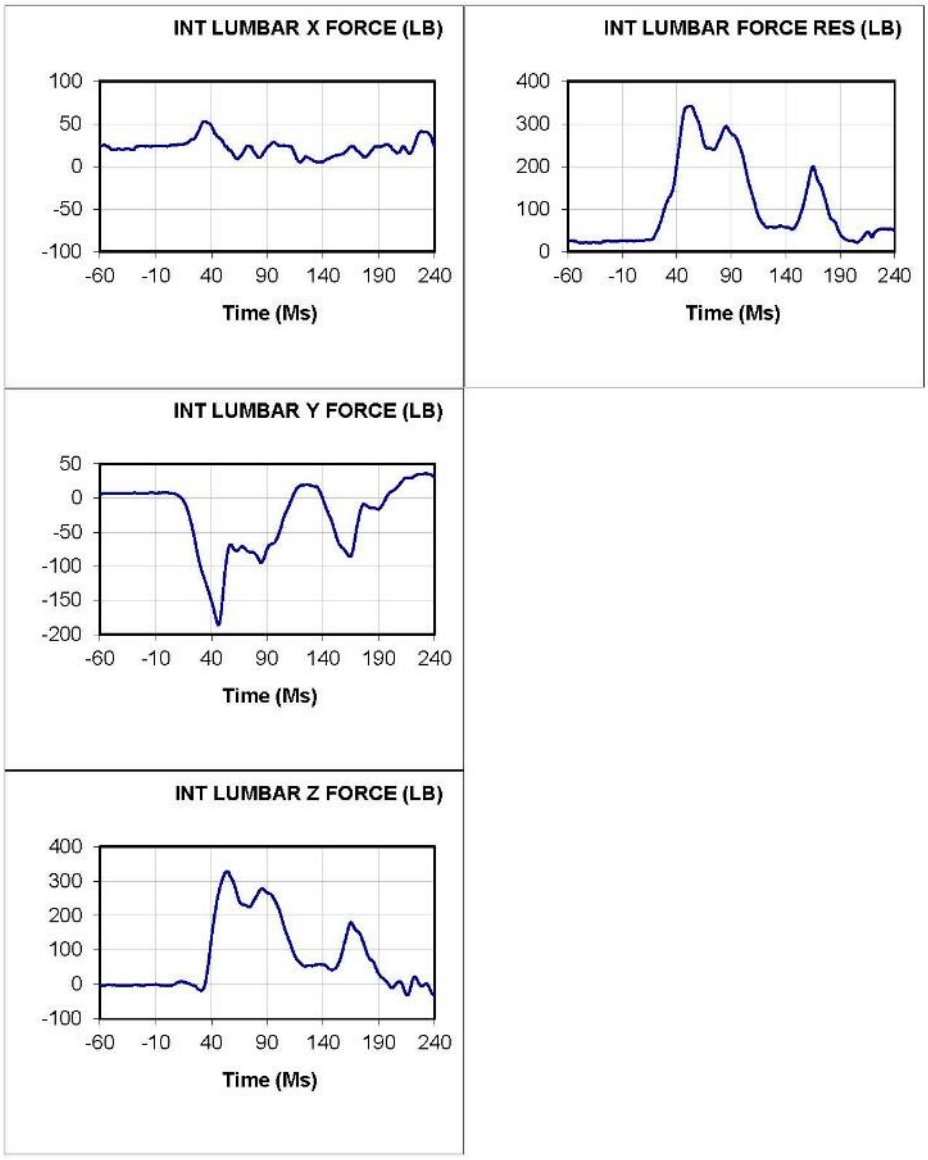
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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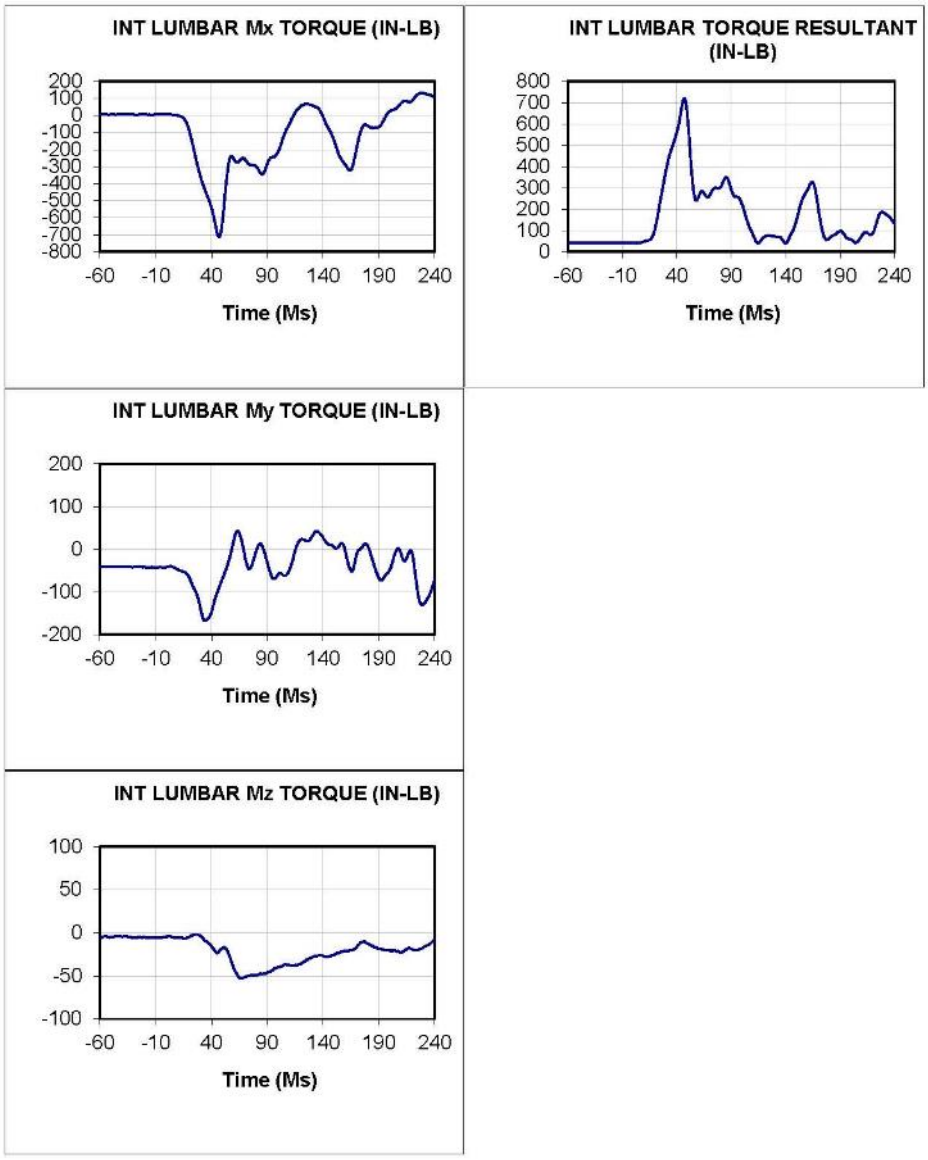
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9219 Test Date: 161116 Subj: AERO50 Cell: E



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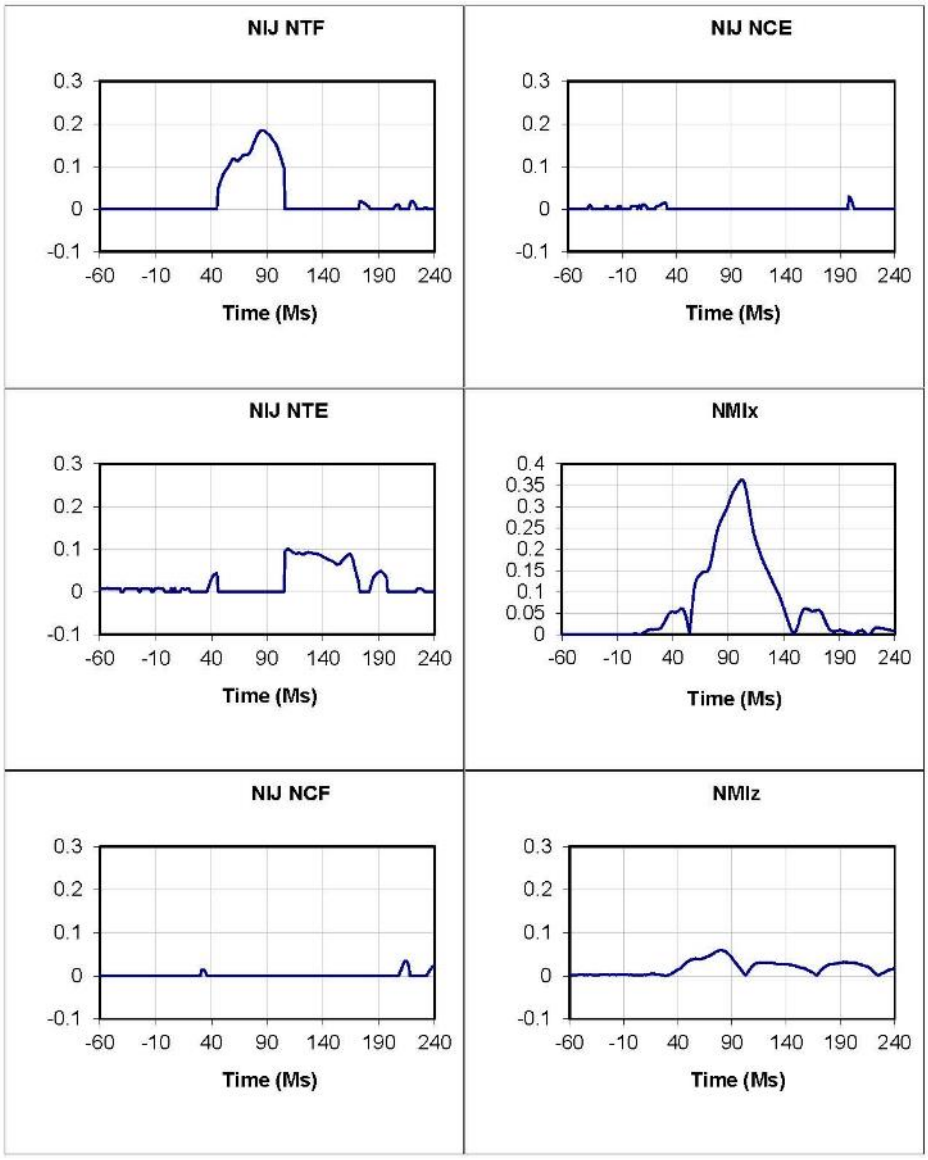

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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9222 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 8.5 Cell: F

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				15.0	
Impact Rise Time (Ms)				40.0	
Impact Duration (Ms)				140.0	
Velocity Change (Ft/Sec)		27.70			
SLED X ACCEL (G)	0.04	8.54	-0.61	40.0	143.0
SLED Y ACCEL (G)	0.00	0.25	-0.45	199.0	51.0
SLED Z ACCEL (G)	-1.00	0.31	-2.52	103.0	97.0
SLED RESULTANT	1.01	8.61	0.41	40.0	141.0
INTEGRATED ACCEL (FT/SEC)	0.00	27.70	0.06	139.0	0.0
SEAT X ACCEL (G)	0.02	4.24	-3.10	108.0	183.0
SEAT Y ACCEL (G)	-0.03	4.80	-10.19	150.0	104.0
SEAT Z ACCEL (G)	1.00	3.64	-1.19	100.0	79.0
SEAT RESULTANT	1.04	10.51	0.38	104.0	144.0
LEFT LAP X FORCE (LB)	12.18	315.54	1.62	134.0	244.0
LEFT LAP Y FORCE (LB)	5.91	8.30	-56.62	176.0	129.0
LEFT LAP Z FORCE (LB)	2.87	93.76	2.34	132.0	30.0
LEFT LAP RESULTANT (LB)	13.84	333.35	6.97	134.0	244.0
RIGHT LAP X FORCE (LB)	20.41	289.61	4.85	142.0	39.0
RIGHT LAP Y FORCE (LB)	1.51	7.39	-33.83	244.0	84.0
RIGHT LAP Z FORCE (LB)	5.11	88.99	-1.22	142.0	39.0
RIGHT LAP RESULTANT (LB)	21.09	303.55	9.51	142.0	33.0
LEFT SHOULDER X FORCE (LB)	9.11	138.82	-1.23	144.0	102.0
LEFT SHOULDER Y FORCE (LB)	-1.32	15.42	-86.18	245.0	76.0
LEFT SHOULDER Z FORCE (LB)	6.75	15.88	-19.51	82.0	141.0
LEFT SHOULDER RESULTANT (LB)	11.42	149.65	6.61	77.0	109.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9222 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 8.5 Cell: F

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT HEAD X ACCEL (G)	0.01	3.39	-3.23	97.0	243.0
INT HEAD Y ACCEL (G)	-0.01	1.58	-10.80	244.0	131.0
INT HEAD Z ACCEL (G)	0.99	17.07	0.25	110.0	48.0
INT HEAD RESULTANT (G)	1.06	18.95	0.37	111.0	48.0
INT HEAD HIC		41.40		102.0	132.0
INT HEAD Rx ANG VELOCITY (RAD/SEC)	-0.05	28.38	-12.05	108.0	198.0
INT HEAD Ry ANG VELOCITY (RAD/SEC)	0.00	7.54	-12.17	103.0	207.0
INT HEAD Rz ANG VELOCITY (RAD/SEC)	-0.02	2.47	-1.51	105.0	135.0
INT HEAD ANG VELOCITY RESULTANT	0.08	29.30	0.02	108.0	3.0
INT NECK X FORCE (LB)	0.50	29.71	-31.36	153.0	245.0
INT NECK Y FORCE (LB)	0.64	17.95	-100.10	245.0	127.0
INT NECK Z FORCE (LB)	1.76	152.33	-5.74	110.0	53.0
INT NECK RESULTANT (LB)	2.08	173.07	0.63	111.0	16.0
INT NECK Mx TORQUE (IN-LB)	-0.88	60.39	-250.05	96.0	131.0
INT NECK My TORQUE (IN-LB)	1.13	116.89	-105.81	96.0	158.0
INT NECK Mz TORQUE (IN-LB)	4.26	26.09	-25.06	147.0	97.0
INT NECK TORQUE RES (IN-LB)	4.54	250.29	3.29	131.0	0.0
INT LOWER NECK X FORCE (LB)	4.51	70.60	-29.89	95.0	243.0
INT LOWER NECK Y FORCE (LB)	5.46	20.23	-188.56	245.0	105.0
INT LOWER NECK Z FORCE (LB)	4.77	128.42	-14.62	107.0	161.0
INT LOWER NECK RESULTANT (LB)	8.56	228.22	1.78	106.0	37.0
INT LOWER NECK Mx TORQUE (IN-LB)	7.37	166.59	-1290.32	245.0	130.0
INT LOWER NECK My TORQUE (IN-LB)	-6.75	336.52	-346.85	245.0	99.0
INT LOWER NECK Mz TORQUE (IN-LB)	2.59	25.64	-346.75	244.0	101.0
INT LOWER NECK TORQUE RES (IN-LB)	10.35	1327.11	1.69	127.0	17.0
INT CHEST X ACCEL (G)	0.00	10.59	-3.55	93.0	153.0
INT CHEST Y ACCEL (G)	0.00	-0.06	-25.61	4.0	93.0
INT CHEST Z ACCEL (G)	0.98	150.81	-1.01	194.0	99.0
INT CHEST RESULTANT (G)	0.99	150.82	0.96	194.0	11.0
INT CHEST Rx ANG ACCEL (RAD/SEC2)	-0.12	7271.23	-875.72	217.0	147.0
INT LUMBAR X ACCEL (G)	0.01	61.65	-137.29	148.0	238.0
INT LUMBAR Y ACCEL (G)	-0.03	355.49	-20.42	150.0	87.0
INT LUMBAR Z ACCEL (G)	1.00	5.10	-4.38	137.0	99.0
INT LUMBAR RESULTANT (G)	1.01	380.25	0.93	219.0	1.0

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201610 Test: 9222 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 8.5 Cell: F

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT LUMBAR X FORCE (LB)	-16.62	34.08	-150.29	245.0	138.0
INT LUMBAR Y FORCE (LB)	-3.17	13.69	-341.87	245.0	94.0
INT LUMBAR Z FORCE (LB)	0.14	698.71	-43.86	103.0	53.0
INT LUMBAR FORCE RES (LB)	16.95	767.82	15.96	102.0	12.0
INT LUMBAR Mx TORQUE (IN-LB)	-19.02	-19.22	-1509.24	7.0	94.0
INT LUMBAR My TORQUE (IN-LB)	7.51	502.37	-139.47	140.0	245.0
INT LUMBAR Mz TORQUE (IN-LB)	8.26	13.34	-67.22	56.0	138.0
INT LUMBAR TORQUE RESULTANT (IN-LB)	22.07	1517.37	22.27	94.0	15.0
NIJ SHEAR (LB)		29.71	-31.84	153.0	252.0
NIJ TENSION (LB)		152.33		110.0	
NIJ COMPRESSION (LB)		-6.82		254.0	
NIJ FLEXION (IN-LB)		105.47		96.0	
NIJ EXTENSION (IN-LB)		125.27		157.0	
NIJ NTF	0.0014	0.1031	0.0000	99.0	0.0
NIJ NTE	0.0001	0.1452	0.0000	155.0	1.0
NIJ NCF	0.0000	0.0386	0.0000	245.0	0.0
NIJ NCE	0.0000	0.0000	0.0000	0.0	0.0
NIJ NTF AIS >= 2		0.13			
NIJ NTF AIS >= 3		0.05			
NIJ NTF AIS >= 4		0.07			
NIJ NTF AIS >= 5		0.02			
NIJ NTE AIS >= 2		0.13			
NIJ NTE AIS >= 3		0.05			
NIJ NTE AIS >= 4		0.07			
NIJ NTE AIS >= 5		0.03			
NIJ NCF AIS >= 2		0.12			
NIJ NCF AIS >= 3		0.04			
NIJ NCF AIS >= 4		0.07			
NIJ NCF AIS >= 5		0.02			
NIJ NCE AIS >= 2		0.11			
NIJ NCE AIS >= 3		0.04			
NIJ NCE AIS >= 4		0.06			
NIJ NCE AIS >= 5		0.02			
NMIx	0.0007	0.2092	0.0000	131.0	31.0
NMIz	0.0036	0.0218	0.0000	147.0	57.0

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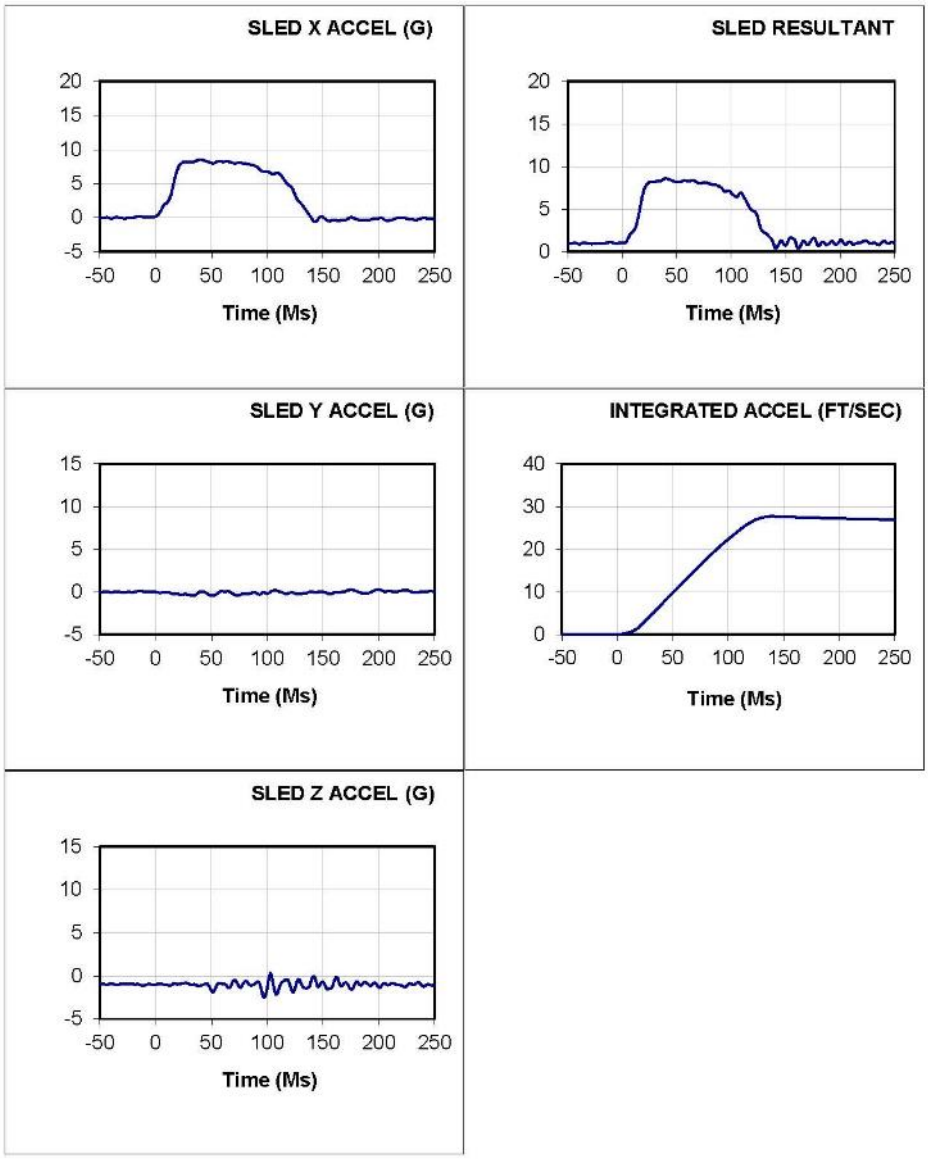

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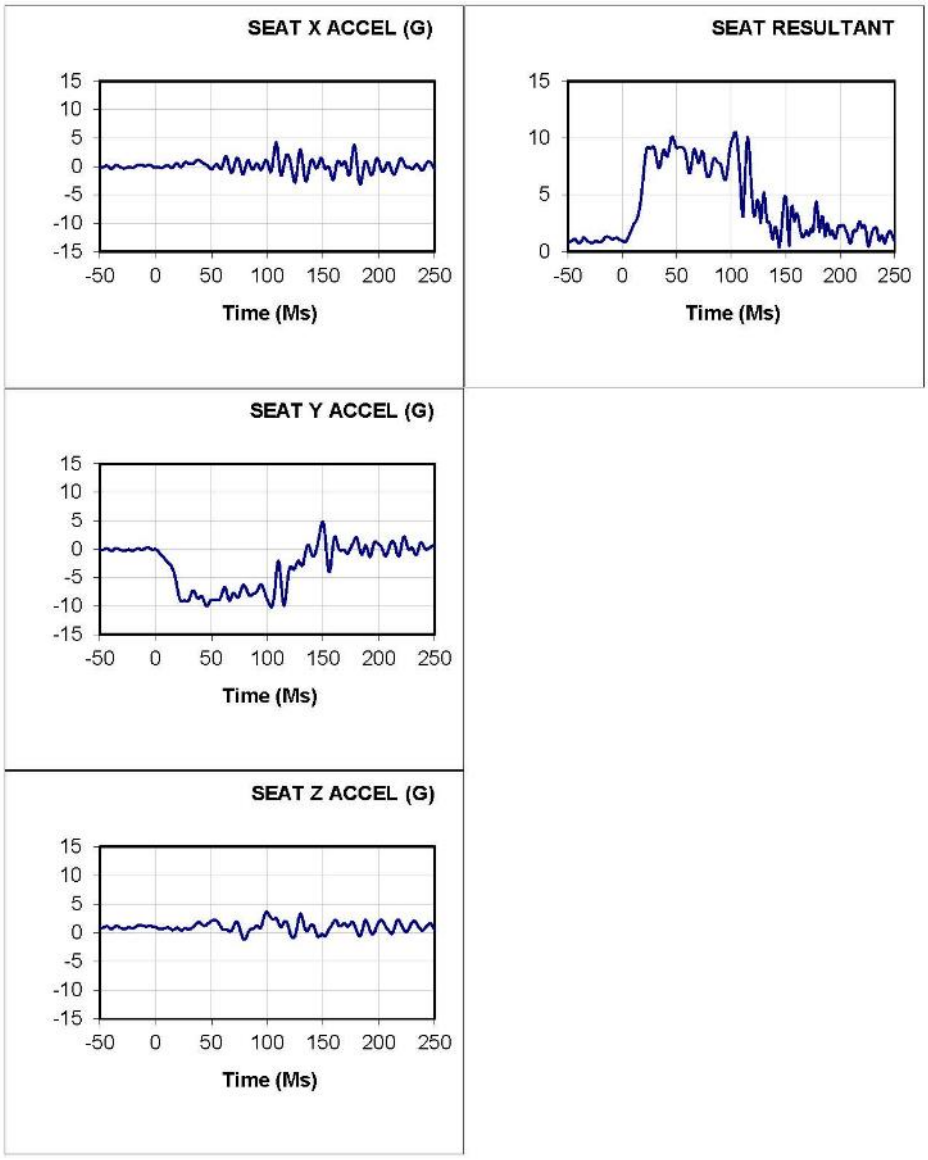

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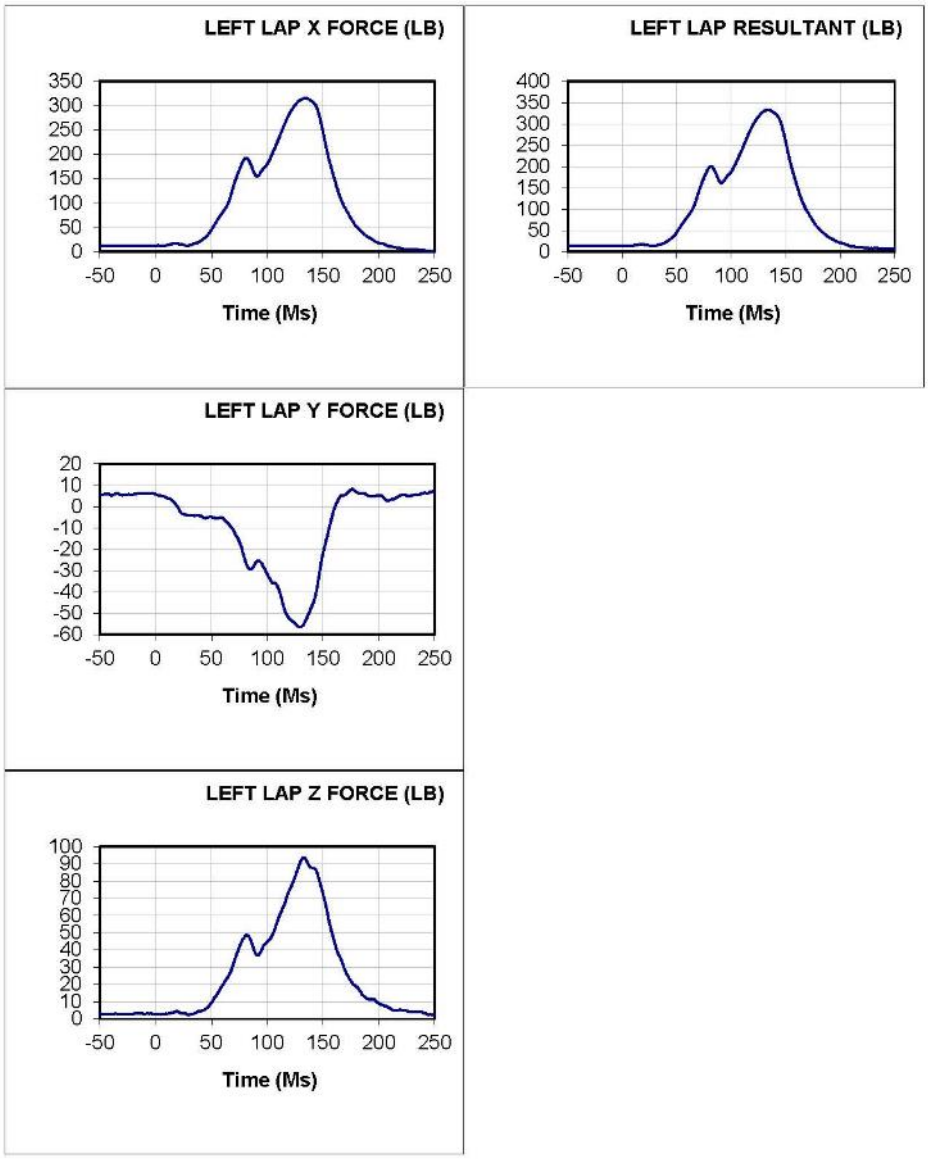

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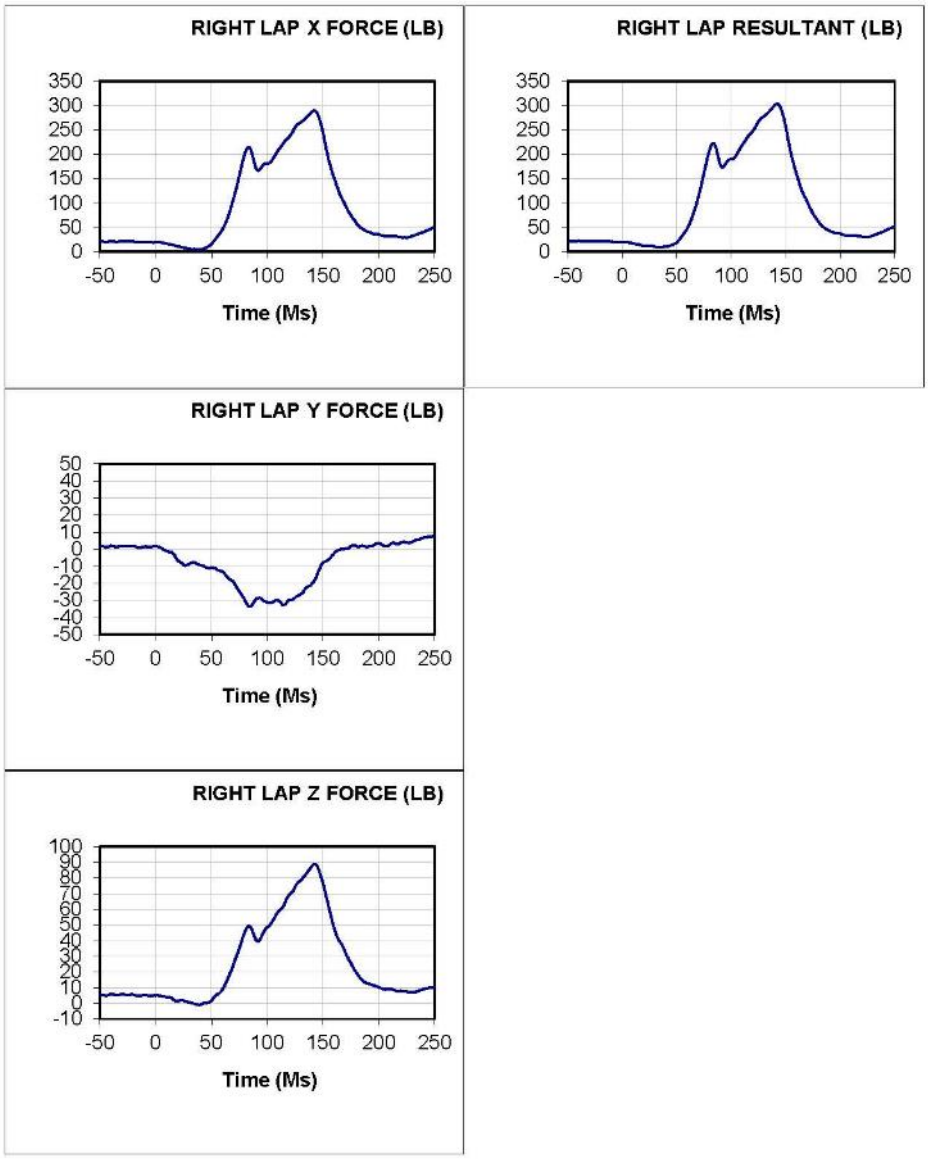

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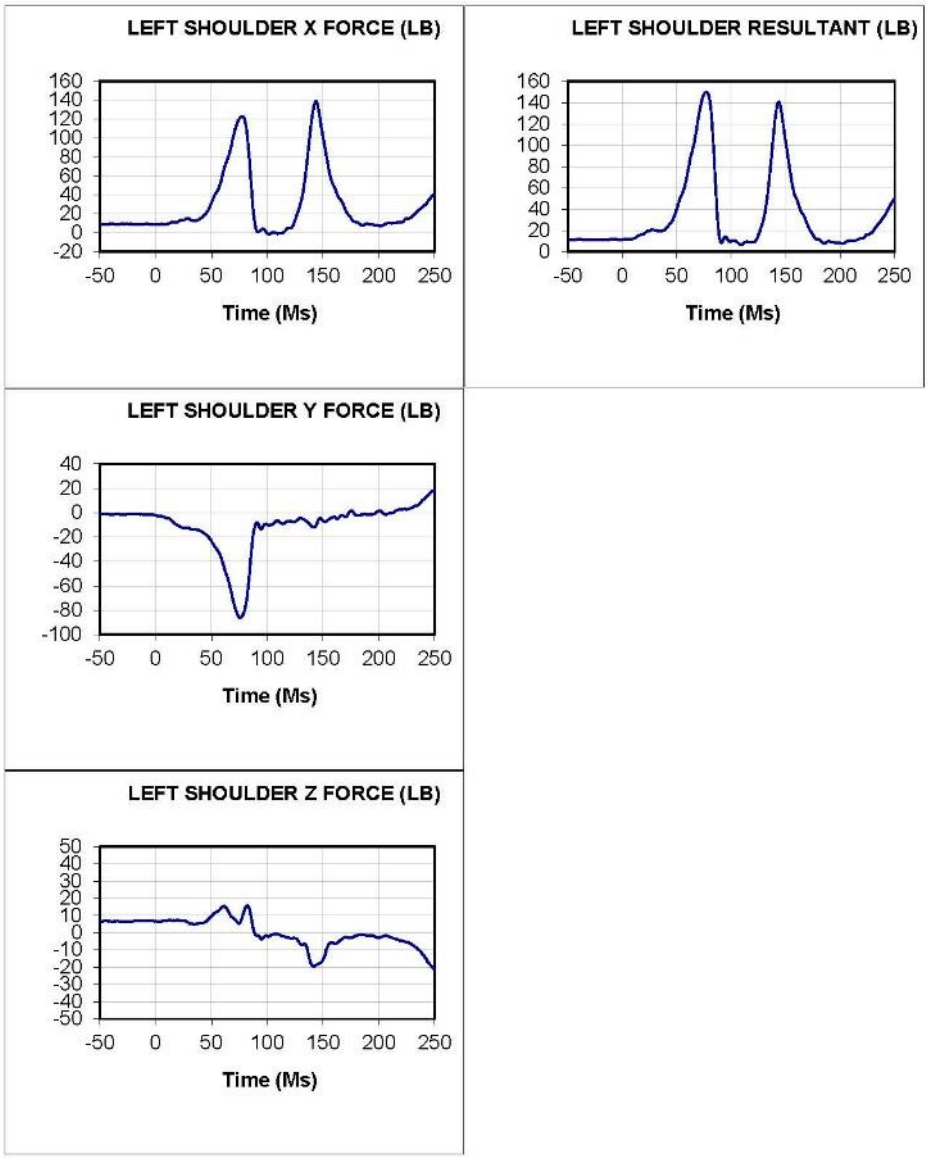

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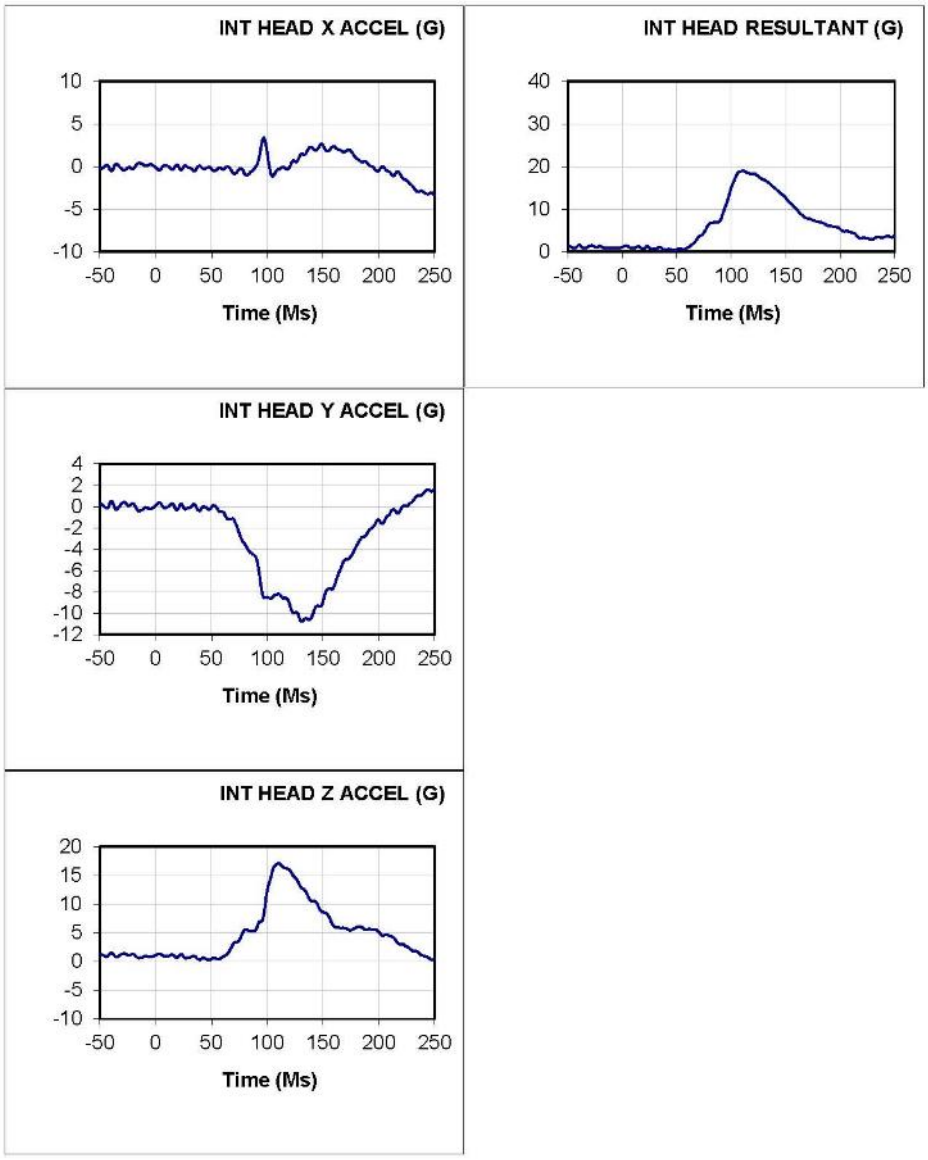

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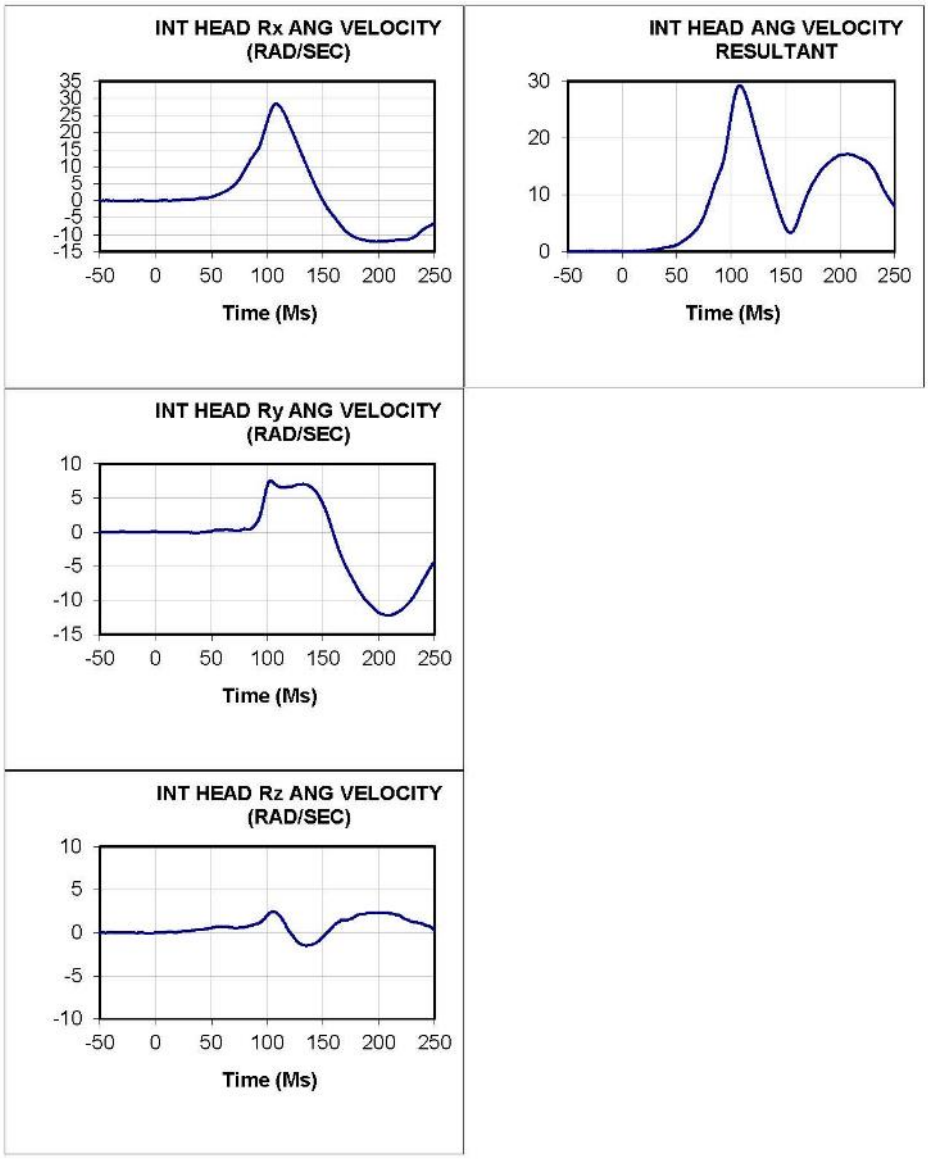

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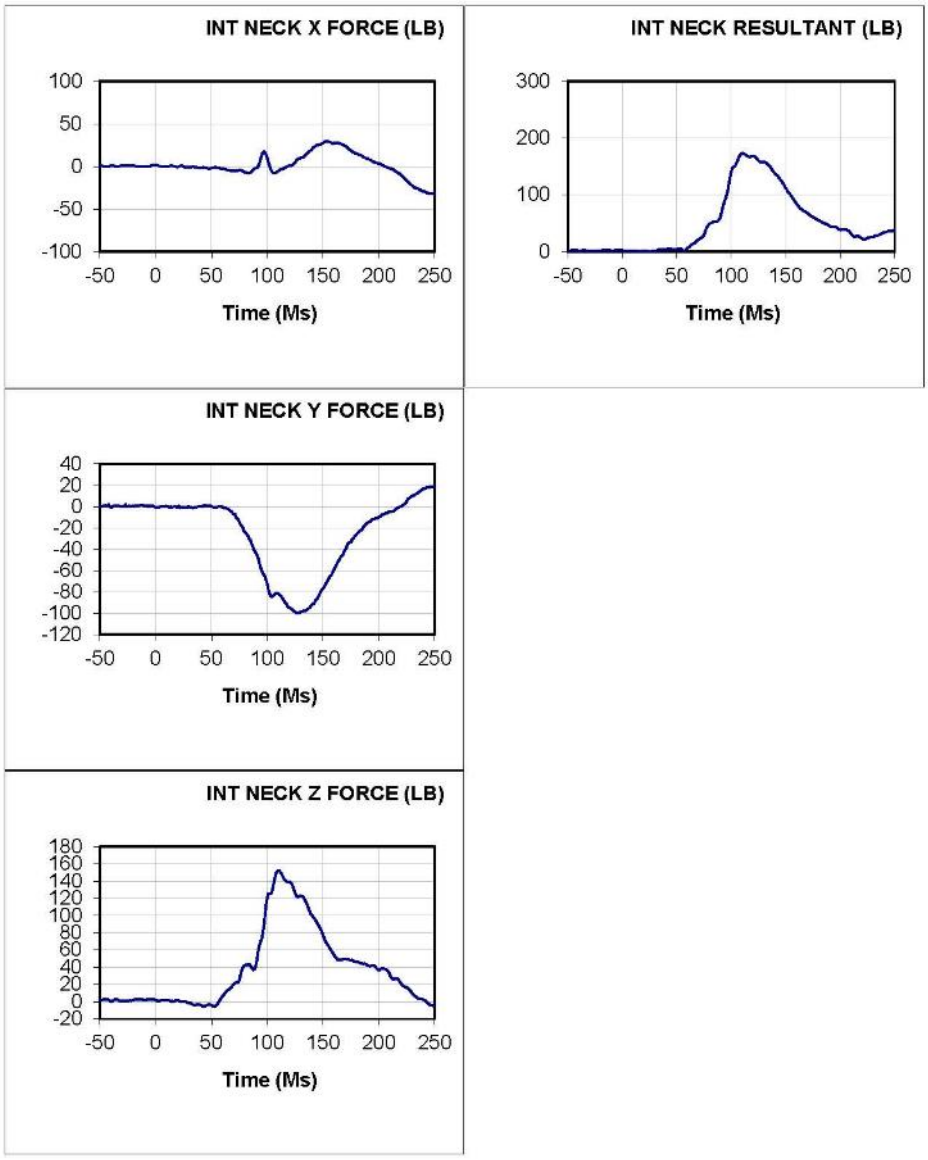

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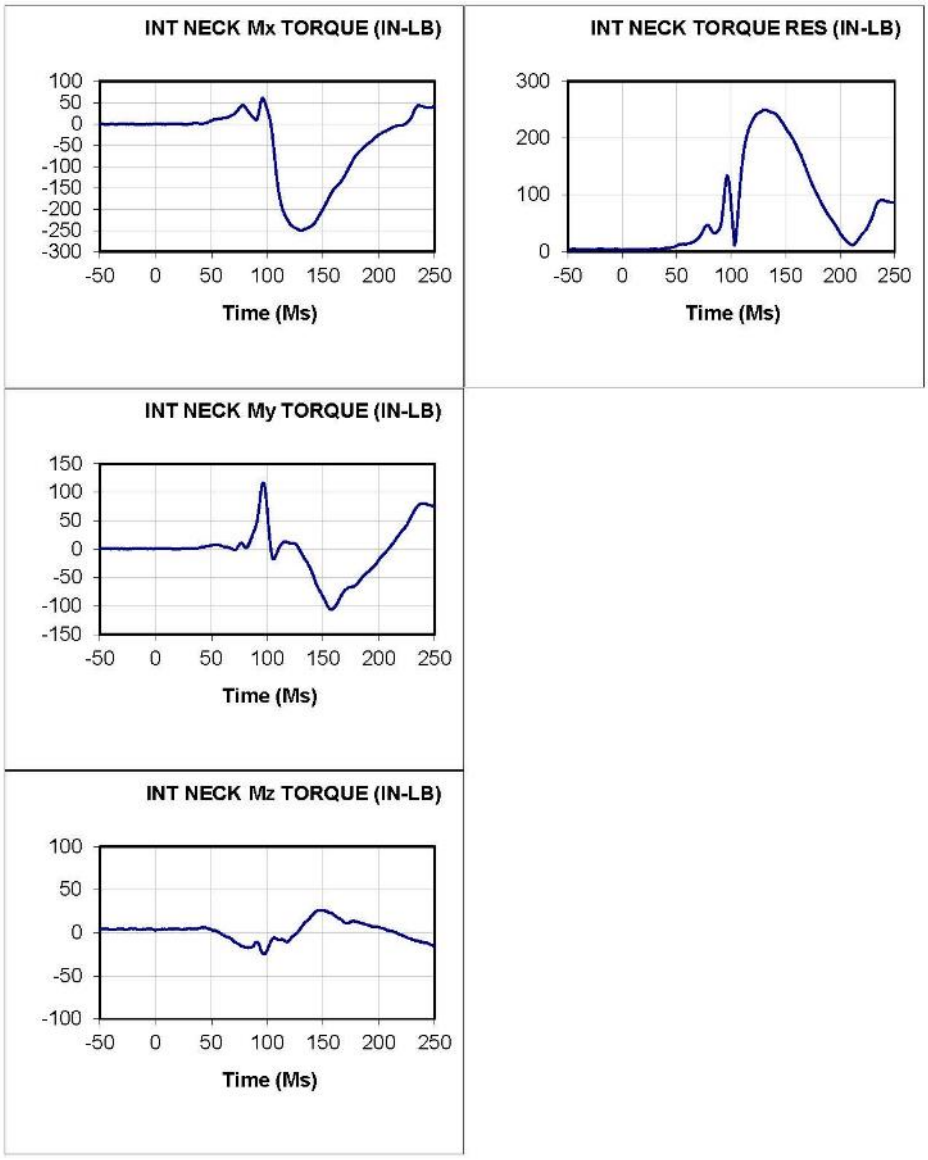

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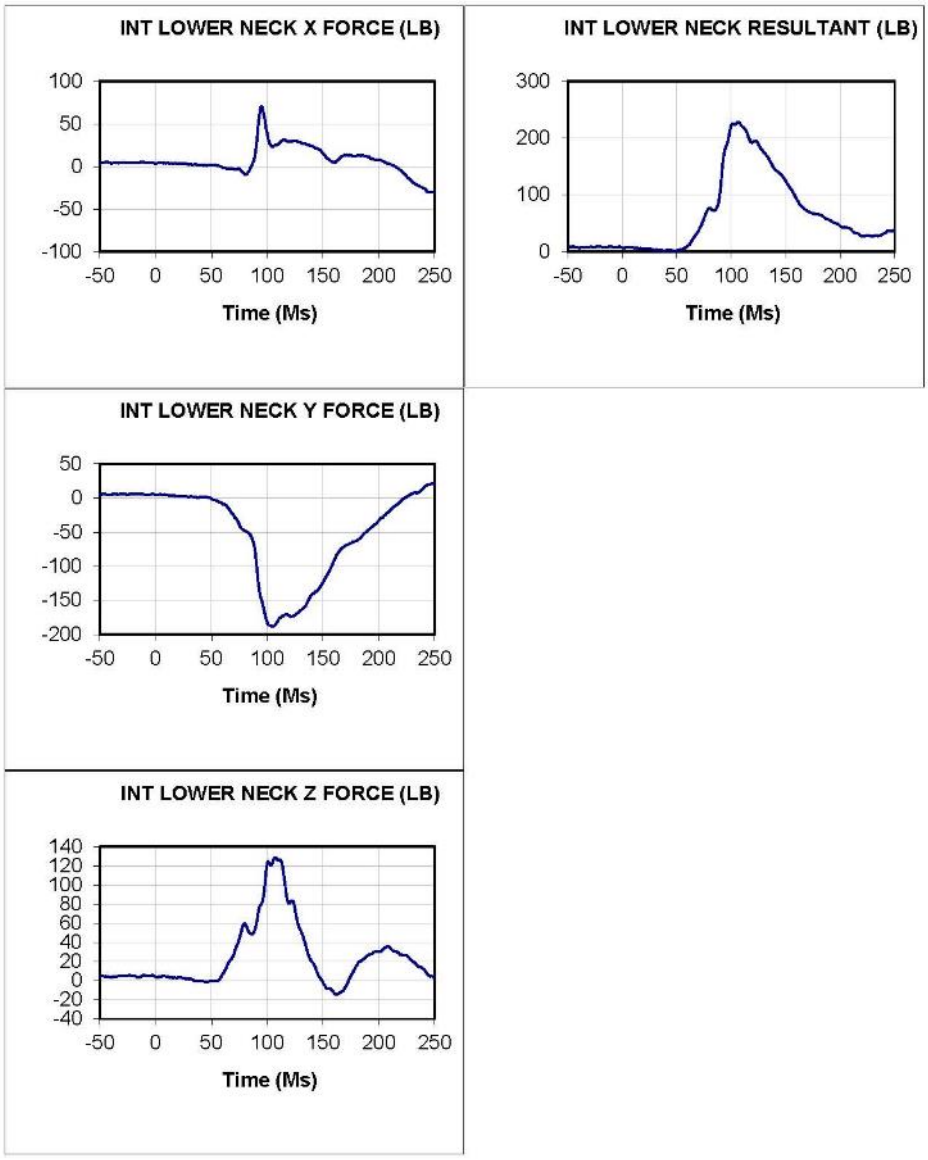

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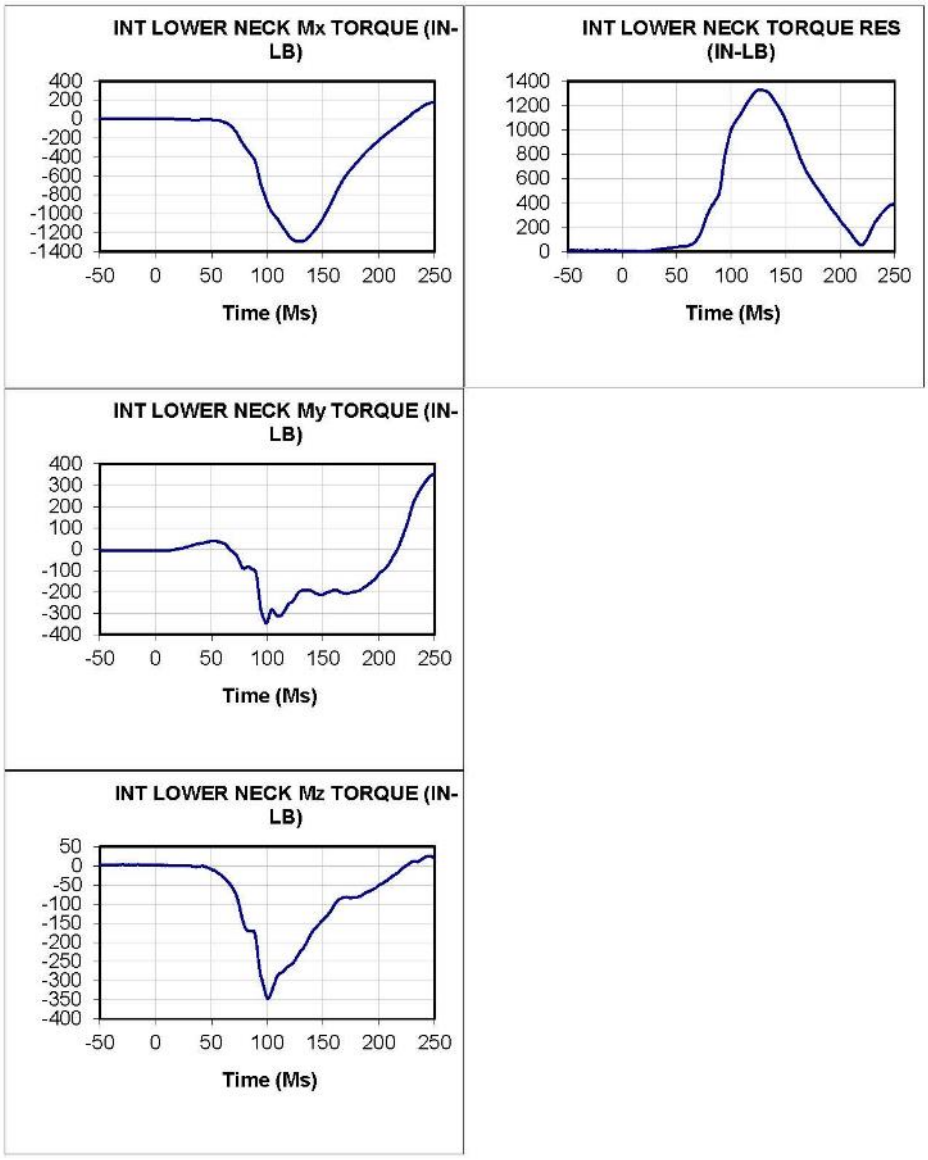
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9222 Test Date: 161118 Subj: AERO50 Cell: F



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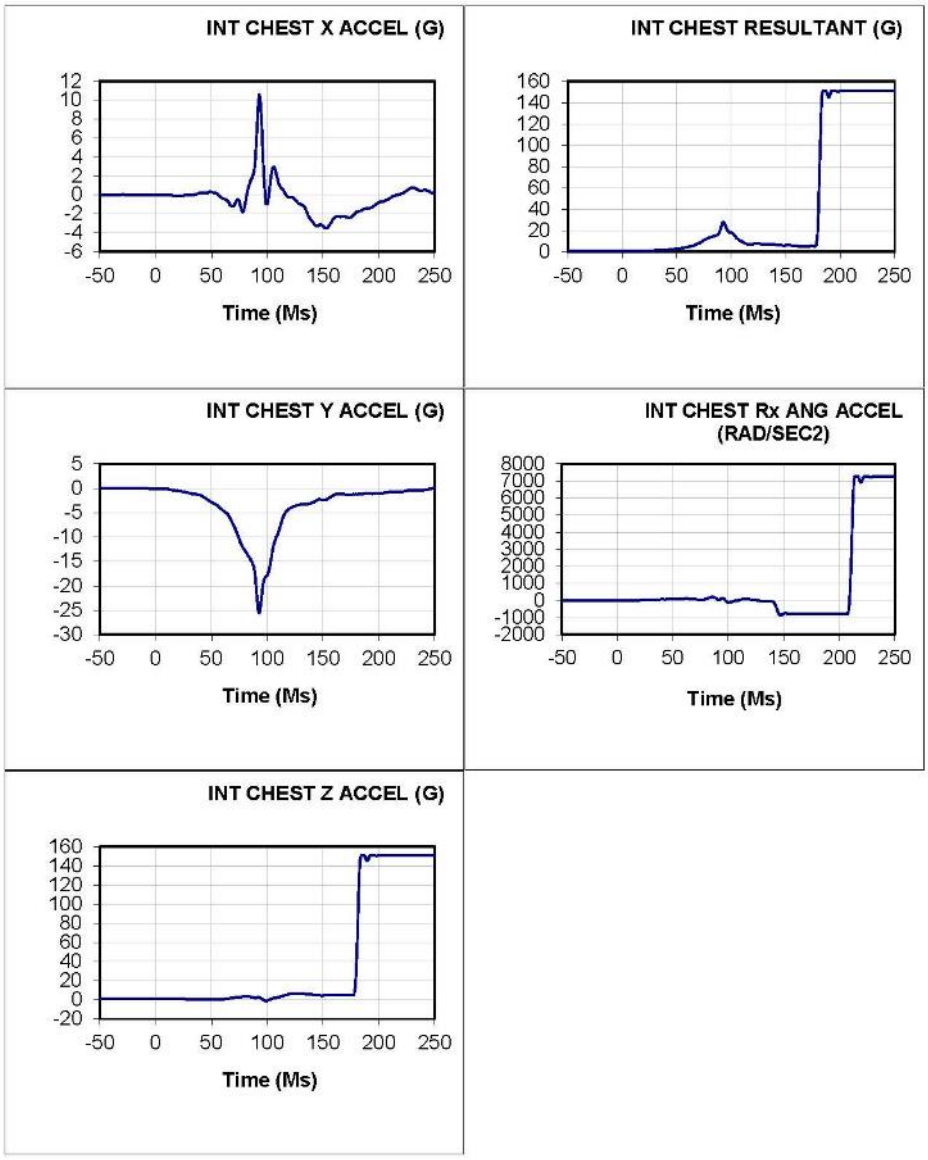
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9222 Test Date: 161118 Subj: AERO50 Cell: F



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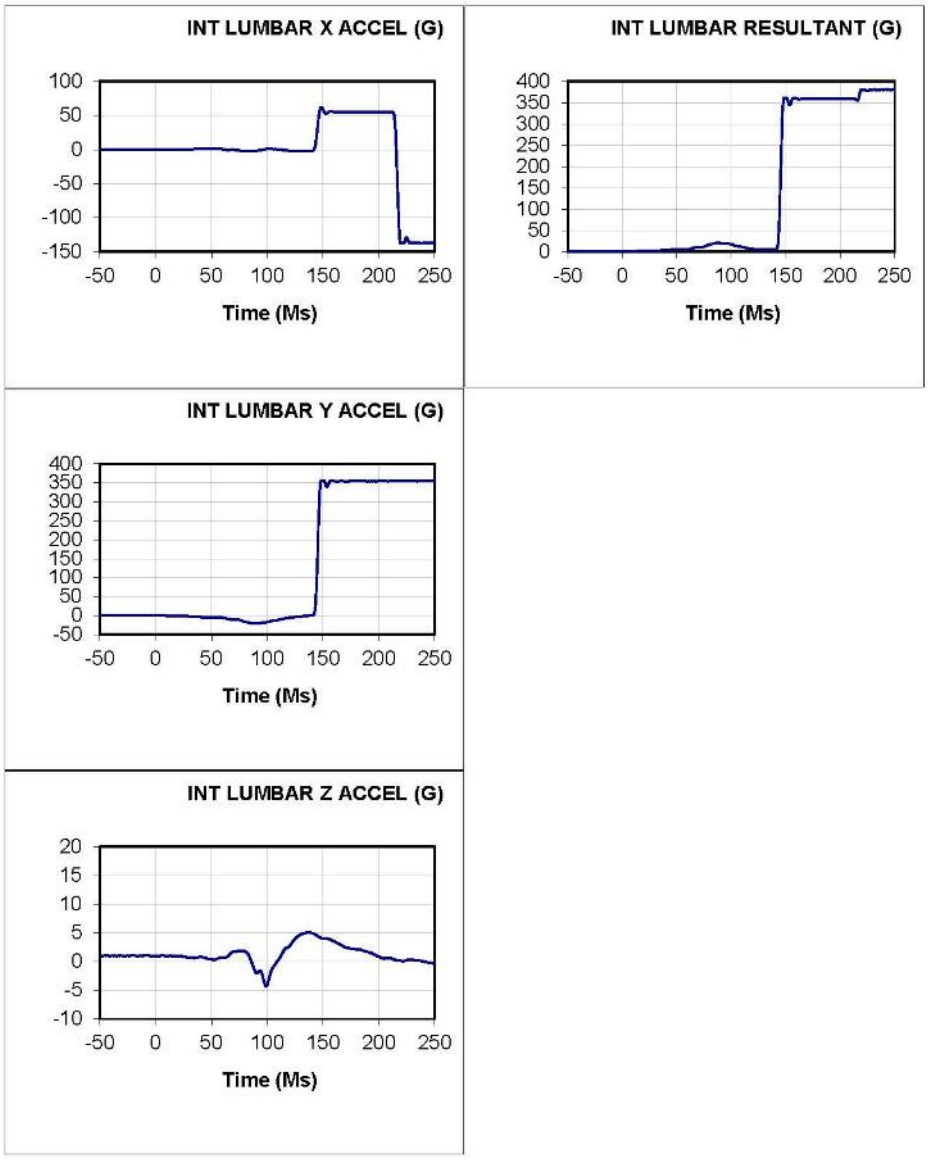
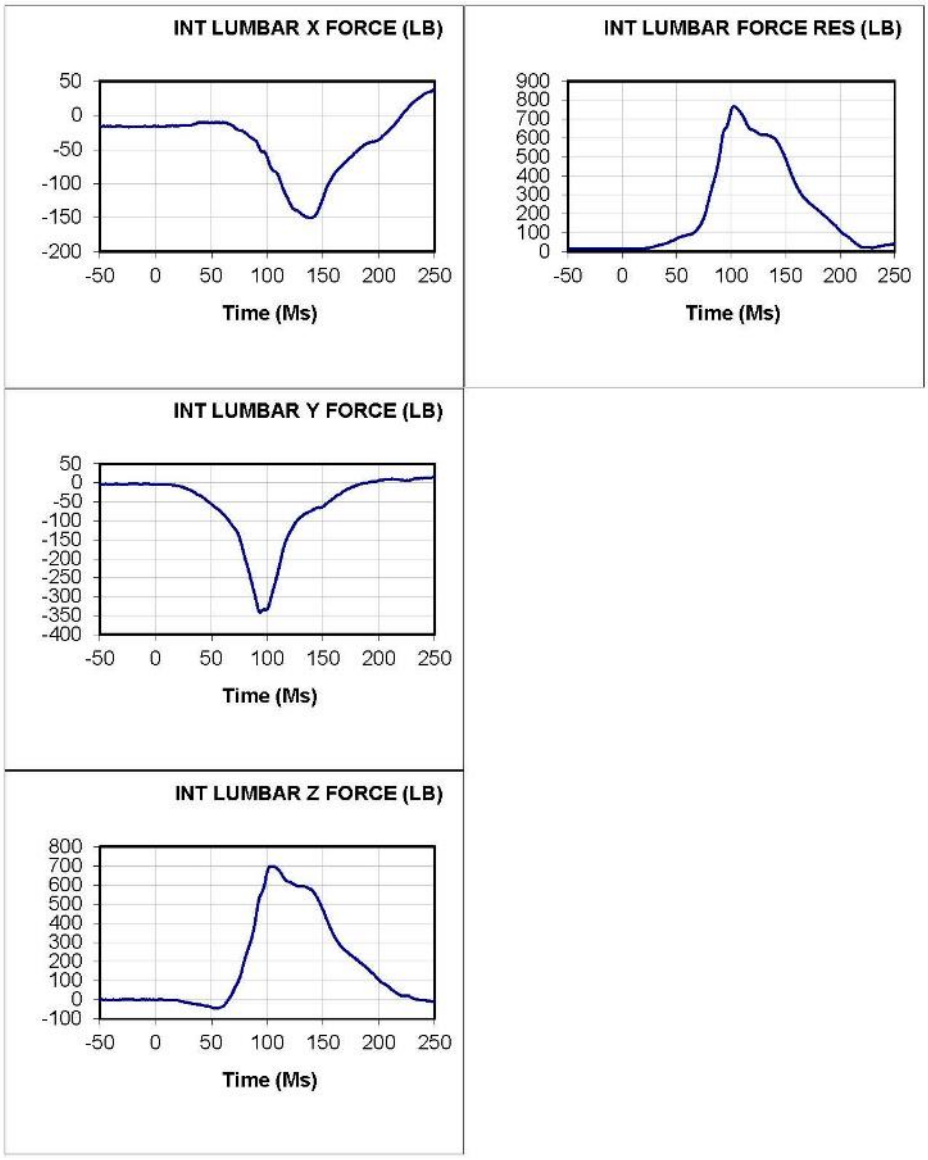
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9222 Test Date: 161118 Subj: AERO50 Cell: F



Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9222 Test Date: 161118 Subj: AERO50 Cell: F



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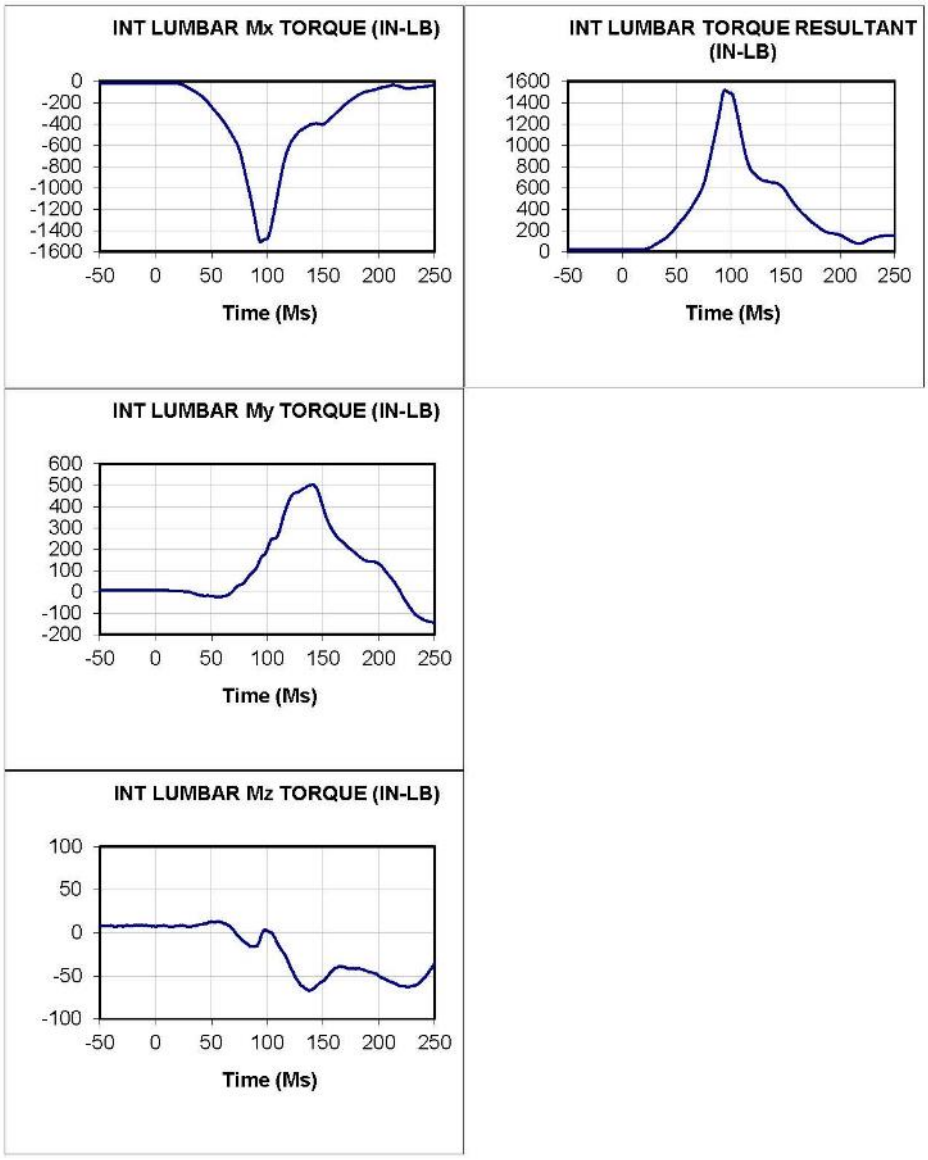
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9222 Test Date: 161118 Subj: AERO50 Cell: F



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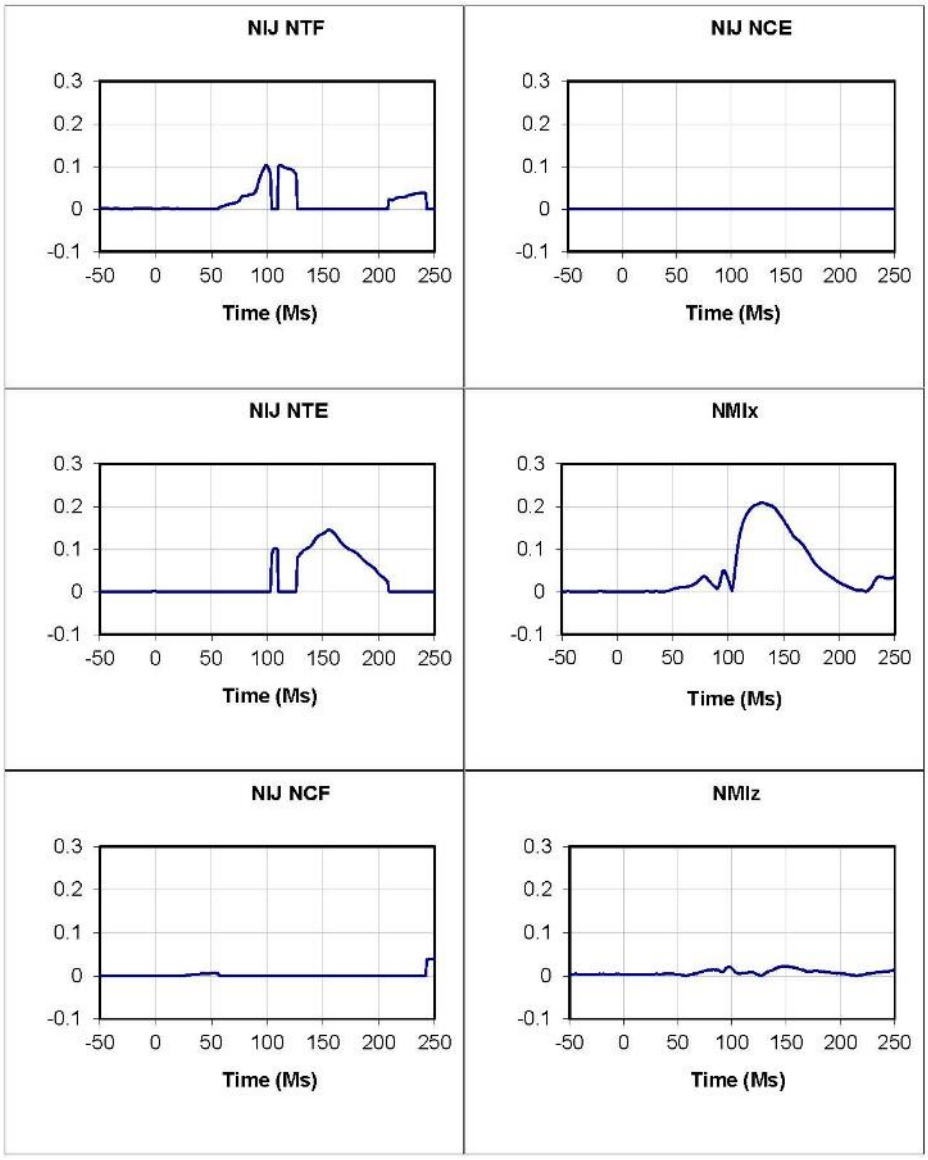
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9222 Test Date: 161118 Subj: AERO50 Cell: F



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 10.5 Cell: G

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				12.0	
Impact Rise Time (Ms)				93.0	
Impact Duration (Ms)				146.0	
Velocity Change (Ft/Sec)		38.97			
SLED X ACCEL (G)	0.03	10.52	-0.81	93.0	200.0
SLED Y ACCEL (G)	-0.03	0.46	-0.68	181.0	67.0
SLED Z ACCEL (G)	-0.97	0.60	-2.31	221.0	80.0
SLED RESULTANT	0.98	10.57	0.30	93.0	220.0
INTEGRATED ACCEL (FT/SEC)	-0.01	38.97	0.05	196.0	0.0
SEAT X ACCEL (G)	-0.12	4.29	-4.38	235.0	216.0
SEAT Y ACCEL (G)	-0.17	4.09	-15.83	207.0	89.0
SEAT Z ACCEL (G)	0.89	4.04	-1.55	45.0	158.0
SEAT RESULTANT	0.95	15.95	0.54	90.0	201.0
LEFT LAP X FORCE (LB)	26.16	597.38	26.38	127.0	6.0
LEFT LAP Y FORCE (LB)	6.74	6.94	-192.22	4.0	120.0
LEFT LAP Z FORCE (LB)	5.45	167.37	5.25	134.0	10.0
LEFT LAP RESULTANT (LB)	27.56	646.16	27.65	127.0	7.0
RIGHT LAP X FORCE (LB)	31.91	527.30	6.69	122.0	36.0
RIGHT LAP Y FORCE (LB)	1.34	1.61	-82.16	1.0	112.0
RIGHT LAP Z FORCE (LB)	6.88	163.74	-1.63	125.0	36.0
RIGHT LAP RESULTANT (LB)	32.67	556.36	12.00	122.0	31.0
LEFT SHOULDER X FORCE (LB)	18.44	163.68	-2.97	132.0	91.0
LEFT SHOULDER Y FORCE (LB)	0.04	4.73	-99.32	206.0	68.0
LEFT SHOULDER Z FORCE (LB)	6.86	27.48	-37.39	72.0	132.0
LEFT SHOULDER RESULTANT (LB)	19.68	178.11	2.49	68.0	192.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 10.5 Cell: G

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT HEAD X ACCEL (G)	-0.17	5.14	-3.40	86.0	98.0
INT HEAD Y ACCEL (G)	0.15	4.52	-12.26	240.0	146.0
INT HEAD Z ACCEL (G)	1.15	25.57	-0.08	103.0	46.0
INT HEAD RESULTANT (G)	1.21	26.58	0.23	104.0	44.0
INT HEAD HIC		88.14		95.0	125.0
INT HEAD Rx ANG VELOCITY (RAD/SEC)	-0.02	32.86	-22.51	101.0	216.0
INT HEAD Ry ANG VELOCITY (RAD/SEC)	-0.01	8.62	-10.99	92.0	190.0
INT HEAD Rz ANG VELOCITY (RAD/SEC)	-0.01	8.65	-0.02	231.0	0.0
INT HEAD ANG VELOCITY RESULTANT	0.08	33.23	0.03	101.0	1.0
INT NECK X FORCE (LB)	2.44	33.71	-19.14	87.0	99.0
INT NECK Y FORCE (LB)	-0.19	44.01	-108.82	242.0	141.0
INT NECK Z FORCE (LB)	1.85	232.10	-5.14	104.0	37.0
INT NECK RESULTANT (LB)	3.17	244.59	1.29	104.0	23.0
INT NECK Mx TORQUE (IN-LB)	-1.40	180.25	-258.01	86.0	151.0
INT NECK My TORQUE (IN-LB)	-2.36	175.39	-111.23	86.0	146.0
INT NECK Mz TORQUE (IN-LB)	3.95	37.84	-41.33	203.0	85.0
INT NECK TORQUE RES (IN-LB)	4.86	278.16	4.74	149.0	9.0
INT LOWER NECK X FORCE (LB)	5.70	109.21	-26.69	84.0	158.0
INT LOWER NECK Y FORCE (LB)	2.47	42.42	-251.43	239.0	136.0
INT LOWER NECK Z FORCE (LB)	1.46	218.79	-27.29	103.0	160.0
INT LOWER NECK RESULTANT (LB)	6.41	306.81	2.89	103.0	52.0
INT LOWER NECK Mx TORQUE (IN-LB)	-3.73	454.67	-1593.56	242.0	138.0
INT LOWER NECK My TORQUE (IN-LB)	-12.12	140.04	-561.26	163.0	86.0
INT LOWER NECK Mz TORQUE (IN-LB)	0.73	75.25	-343.24	231.0	85.0
INT LOWER NECK TORQUE RES (IN-LB)	12.72	1622.06	2.14	138.0	25.0
INT CHEST X ACCEL (G)	0.00	16.26	-5.69	81.0	140.0
INT CHEST Y ACCEL (G)	0.00	-0.06	-34.49	2.0	82.0
INT CHEST Z ACCEL (G)	0.99	10.85	-0.22	114.0	92.0
INT CHEST RESULTANT (G)	0.99	38.41	0.90	82.0	21.0
INT CHEST Rx ANG ACCEL (RAD/SEC2)	-0.25	536.18	-295.19	85.0	134.0
INT LUMBAR X ACCEL (G)	0.00	2.62	-2.80	163.0	74.0
INT LUMBAR Y ACCEL (G)	0.00	5.19	-30.25	144.0	87.0
INT LUMBAR Z ACCEL (G)	0.98	7.56	-7.87	143.0	88.0
INT LUMBAR RESULTANT (G)	0.98	31.26	0.98	87.0	6.0

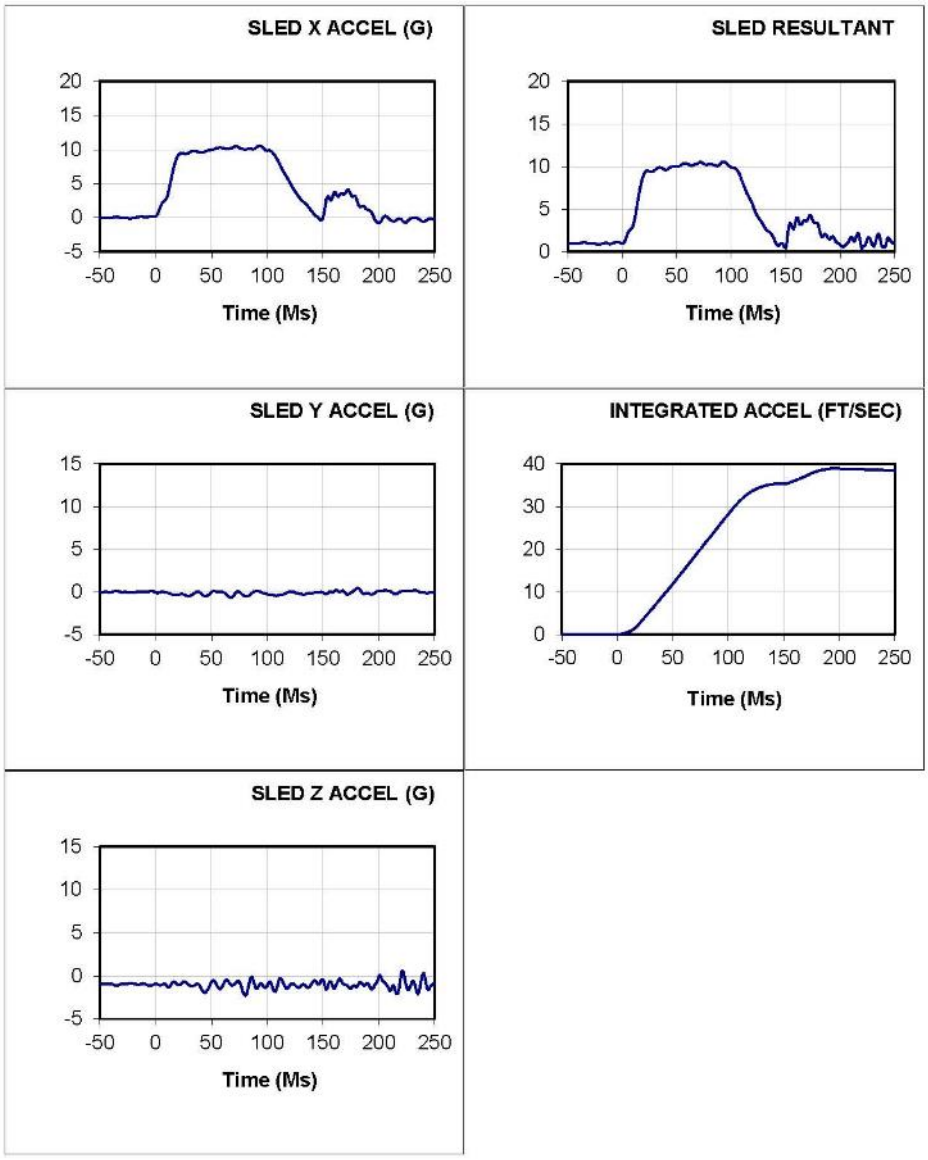
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 10.5 Cell: G

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT LUMBAR X FORCE (LB)	-11.18	102.57	-36.54	88.0	177.0
INT LUMBAR Y FORCE (LB)	-2.17	-3.30	-588.75	2.0	90.0
INT LUMBAR Z FORCE (LB)	-23.65	1025.70	-55.29	116.0	40.0
INT LUMBAR FORCE RES (LB)	27.37	1132.76	25.54	98.0	0.0
INT LUMBAR Mx TORQUE (IN-LB)	-58.45	-60.86	-2613.86	0.0	92.0
INT LUMBAR My TORQUE (IN-LB)	-61.47	122.60	-476.59	180.0	88.0
INT LUMBAR Mz TORQUE (IN-LB)	-5.12	69.83	-70.22	90.0	176.0
INT LUMBAR TORQUE RESULTANT (IN-LB)	84.98	2647.21	86.01	92.0	2.0
NIJ SHEAR (LB)		33.71	-19.14	87.0	99.0
NIJ TENSION (LB)		232.10		104.0	
NIJ COMPRESSION (LB)		-5.14		37.0	
NIJ FLEXION (IN-LB)		152.61		86.0	
NIJ EXTENSION (IN-LB)		119.45		146.0	
NIJ NTF	0.0000	0.1705	0.0000	112.0	0.0
NIJ NTE	0.0046	0.1985	0.0000	98.0	24.0
NIJ NCF	0.0000	0.0019	0.0000	45.0	0.0
NIJ NCE	0.0000	0.0068	0.0000	37.0	0.0
NIJ NTF AIS >= 2		0.14			
NIJ NTF AIS >= 3		0.05			
NIJ NTF AIS >= 4		0.08			
NIJ NTF AIS >= 5		0.03			
NIJ NTE AIS >= 2		0.14			
NIJ NTE AIS >= 3		0.06			
NIJ NTE AIS >= 4		0.08			
NIJ NTE AIS >= 5		0.03			
NIJ NCF AIS >= 2		0.11			
NIJ NCF AIS >= 3		0.04			
NIJ NCF AIS >= 4		0.06			
NIJ NCF AIS >= 5		0.02			
NIJ NCE AIS >= 2		0.11			
NIJ NCE AIS >= 3		0.04			
NIJ NCE AIS >= 4		0.06			
NIJ NCE AIS >= 5		0.02			
NMIx	0.0012	0.2159	0.0000	151.0	30.0
NMIz	0.0033	0.0346	0.0000	85.0	58.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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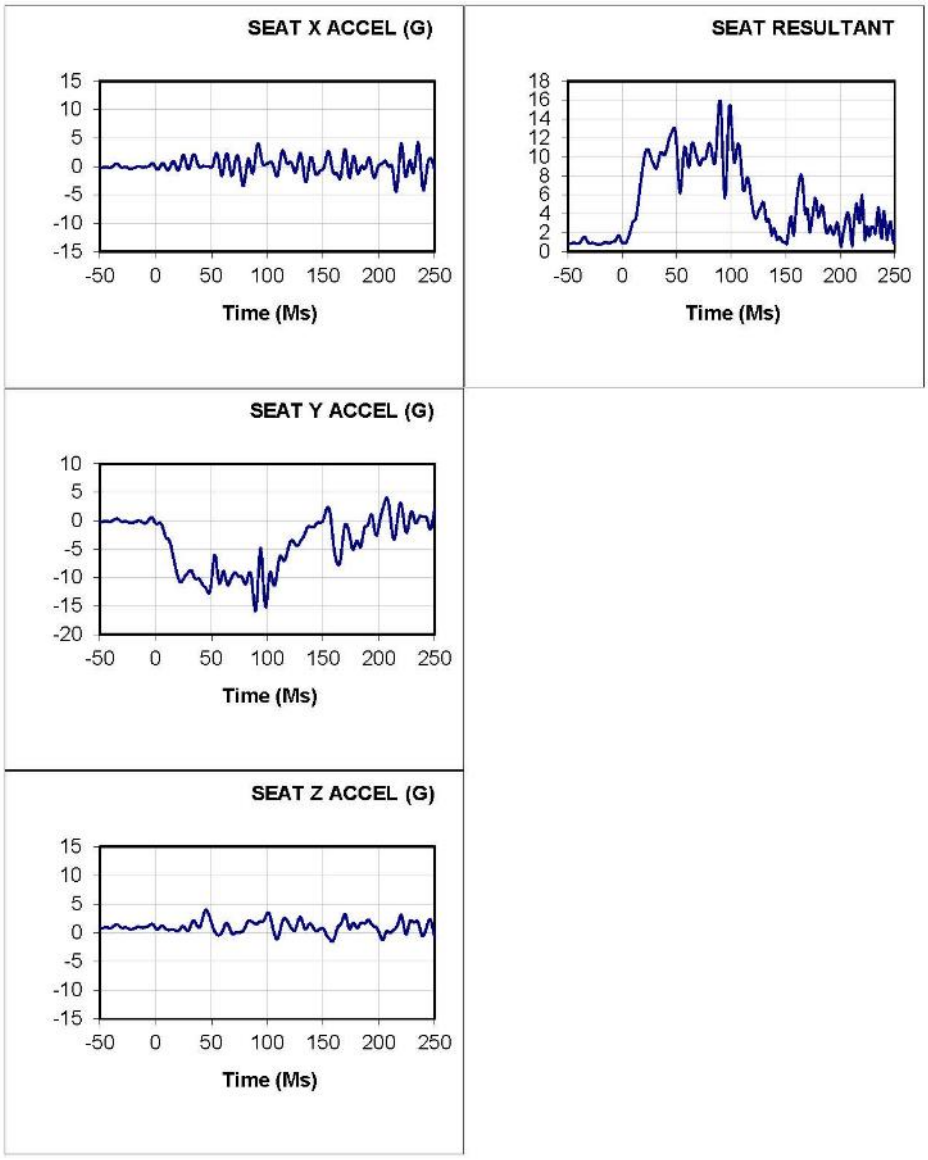
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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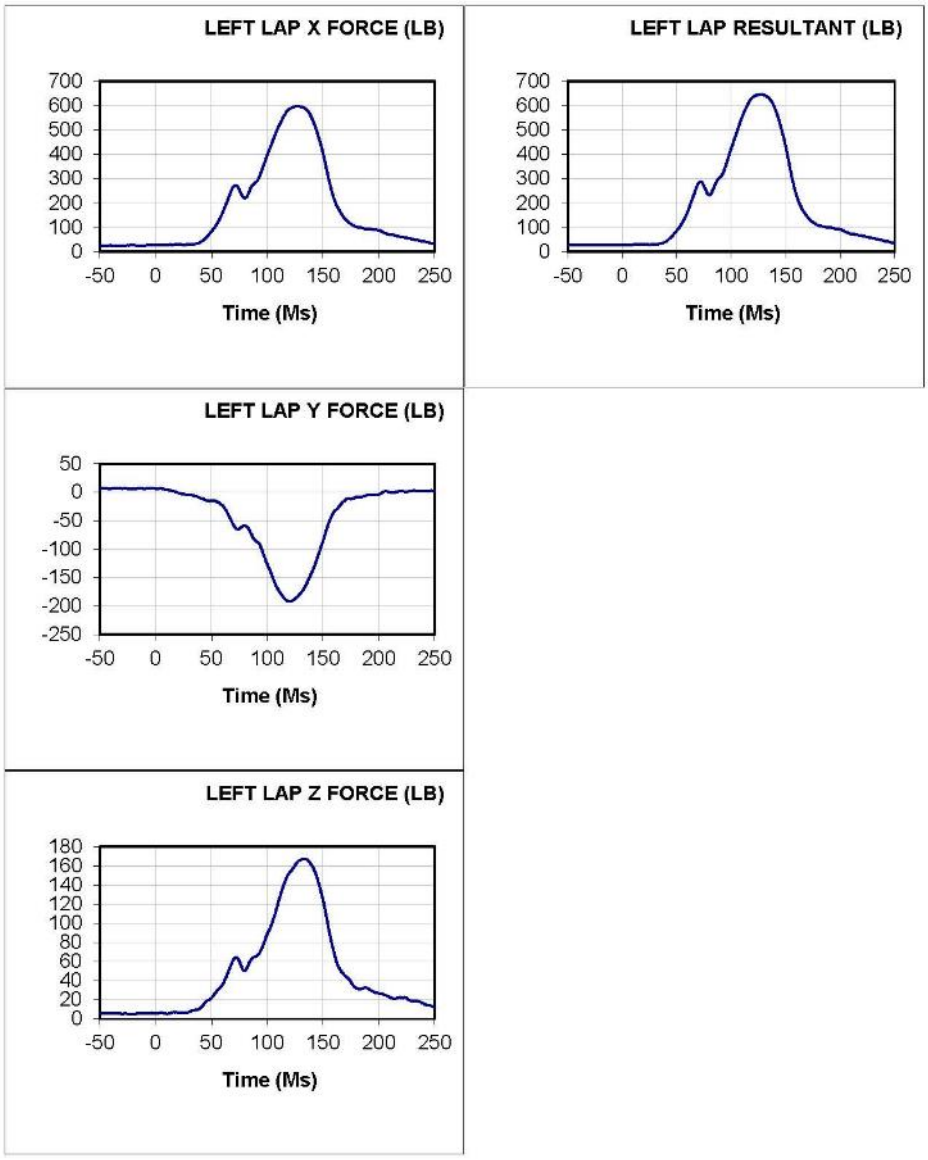
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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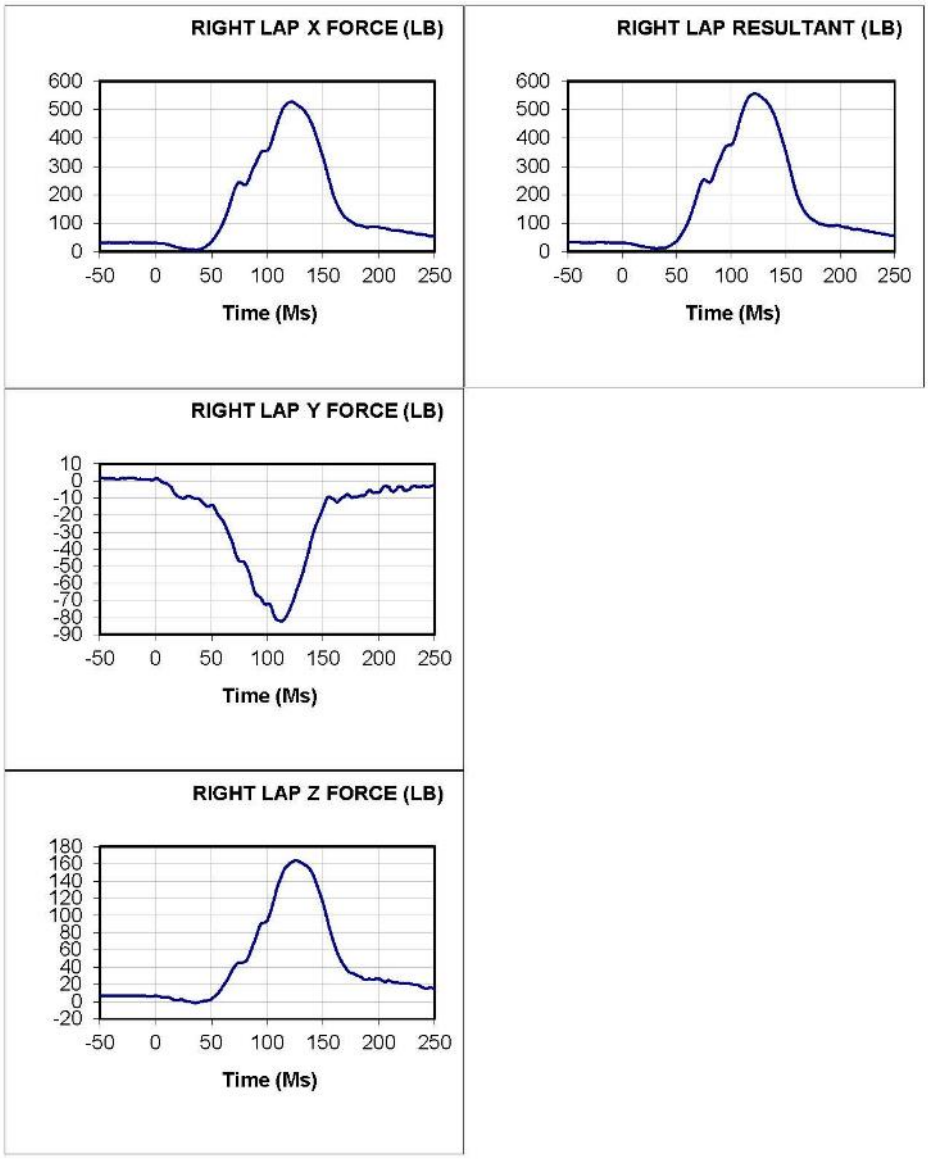
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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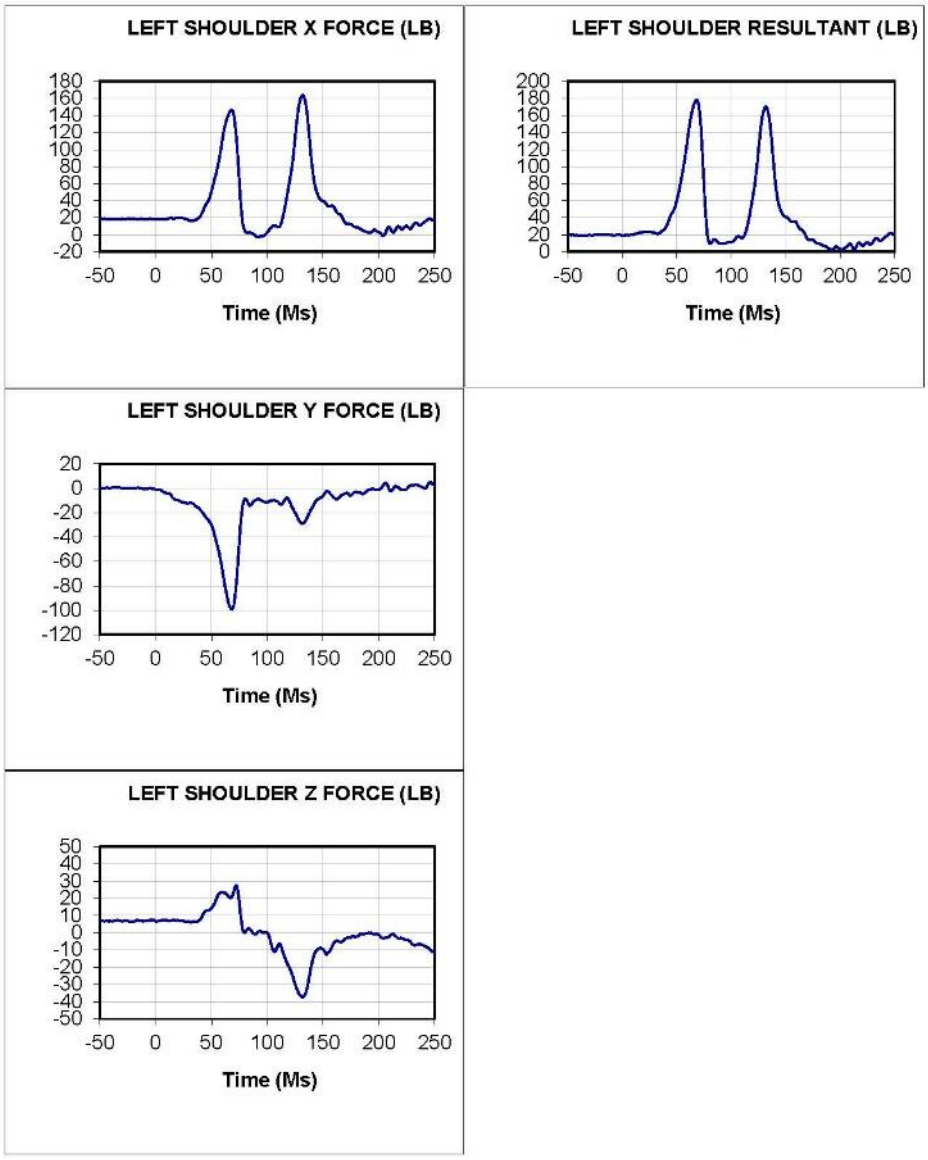
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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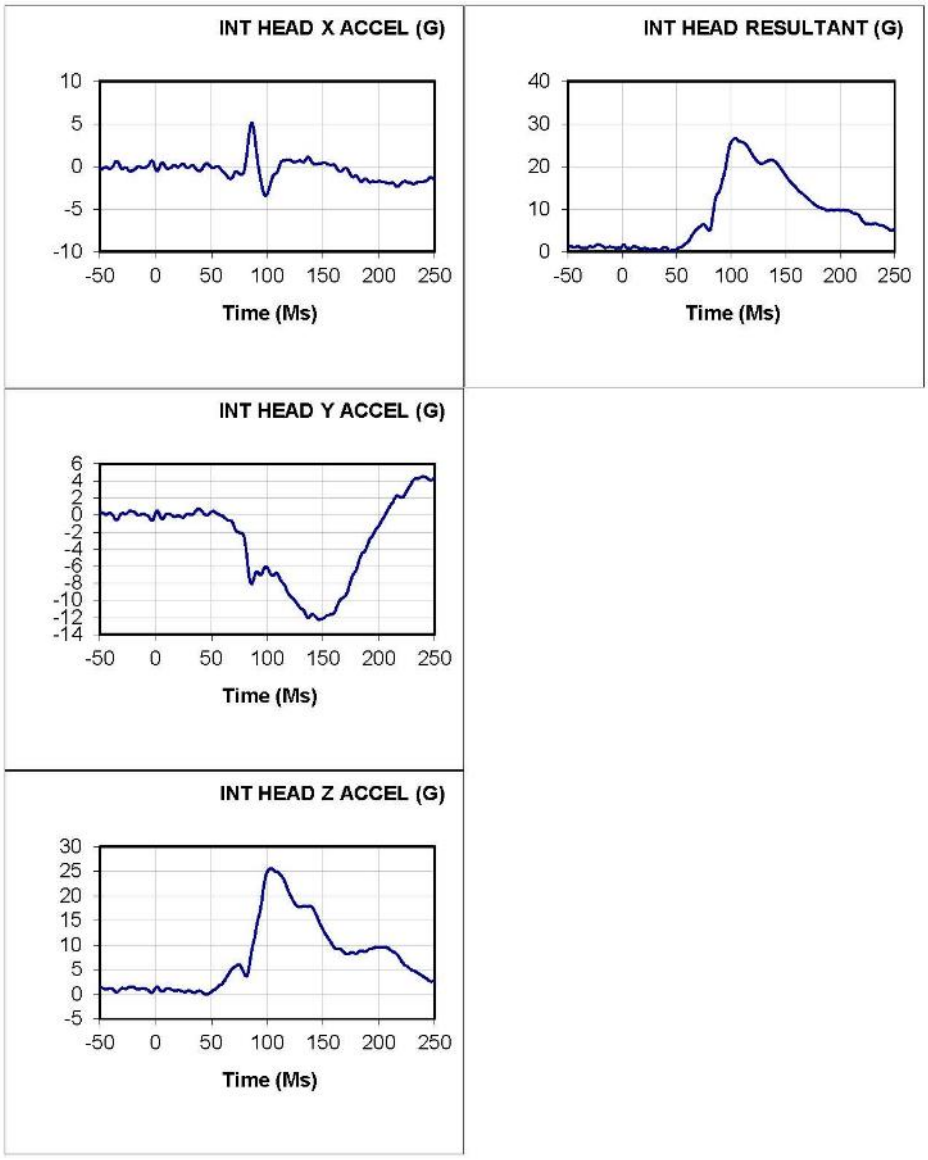
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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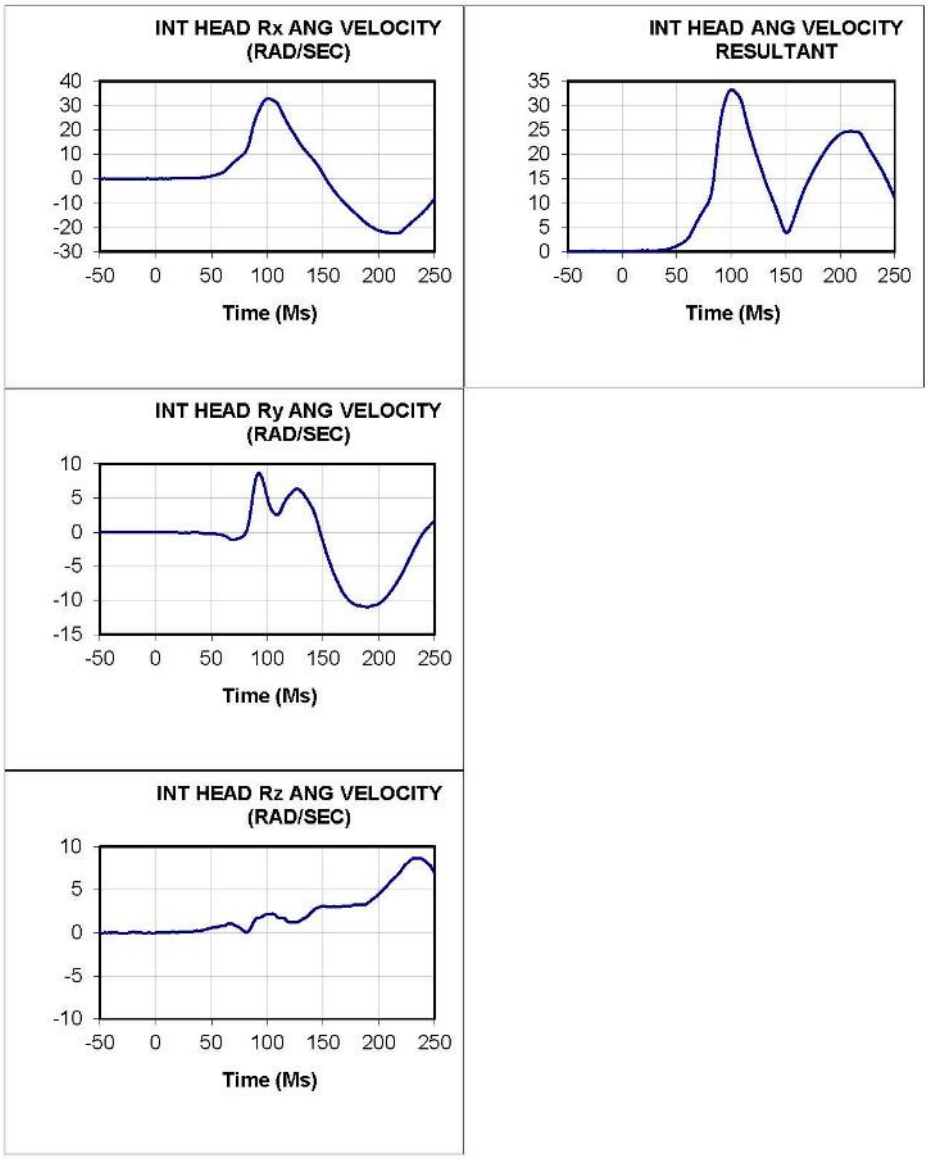
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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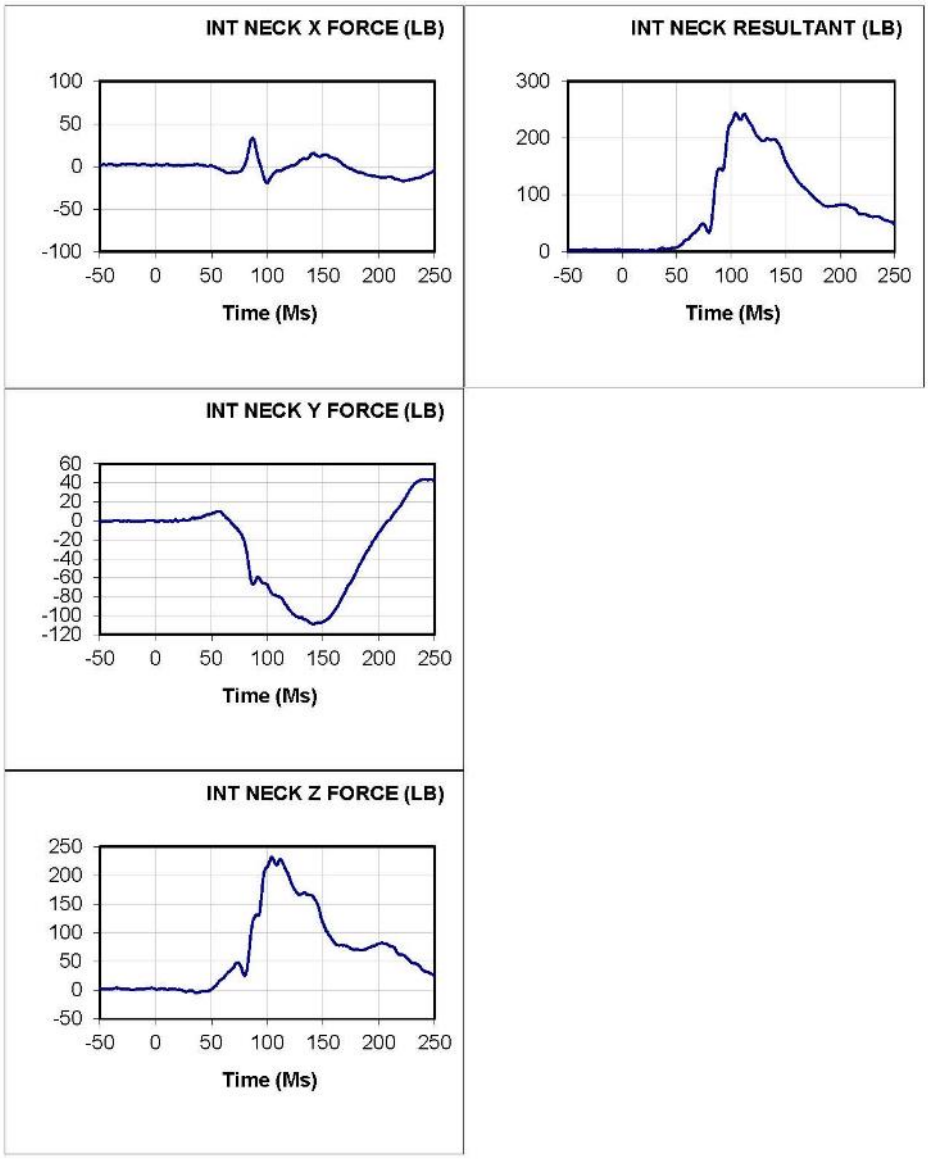
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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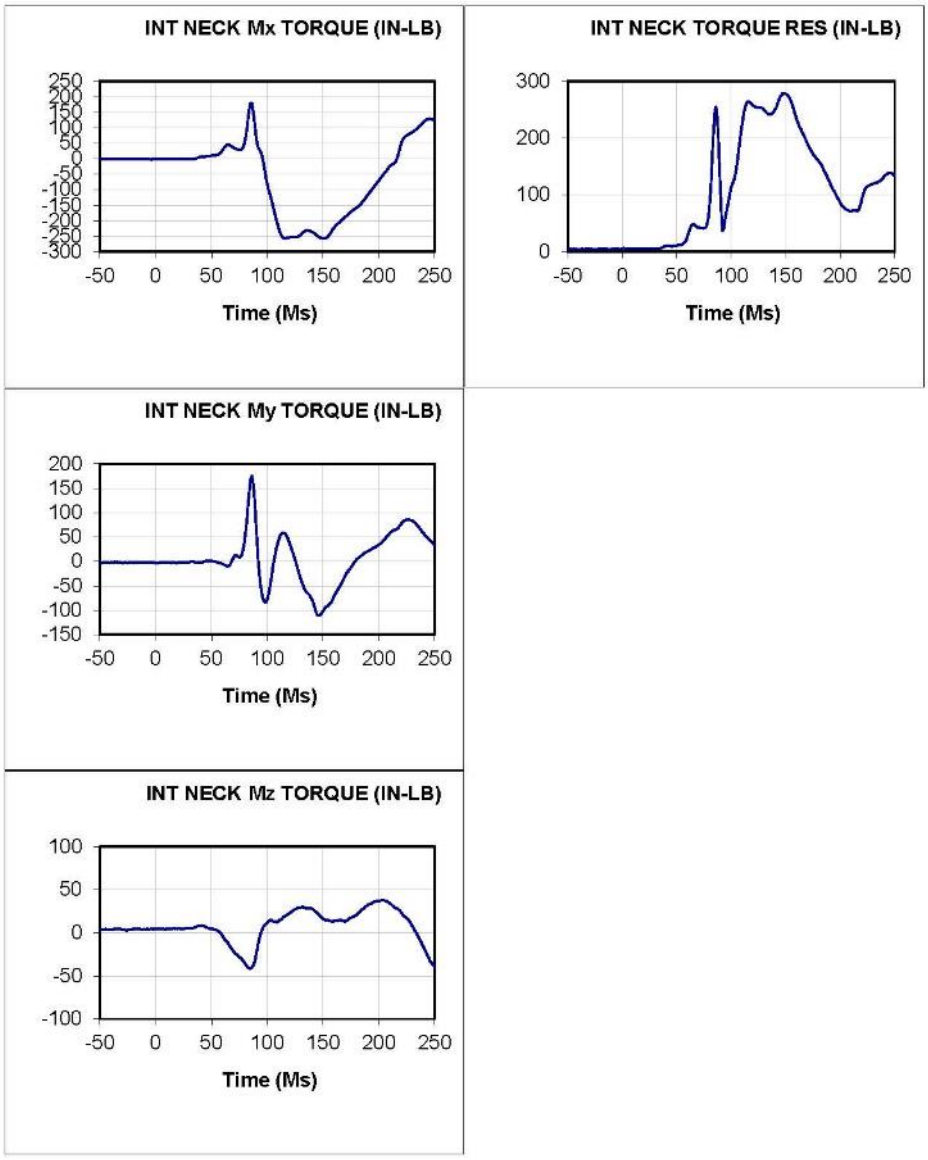
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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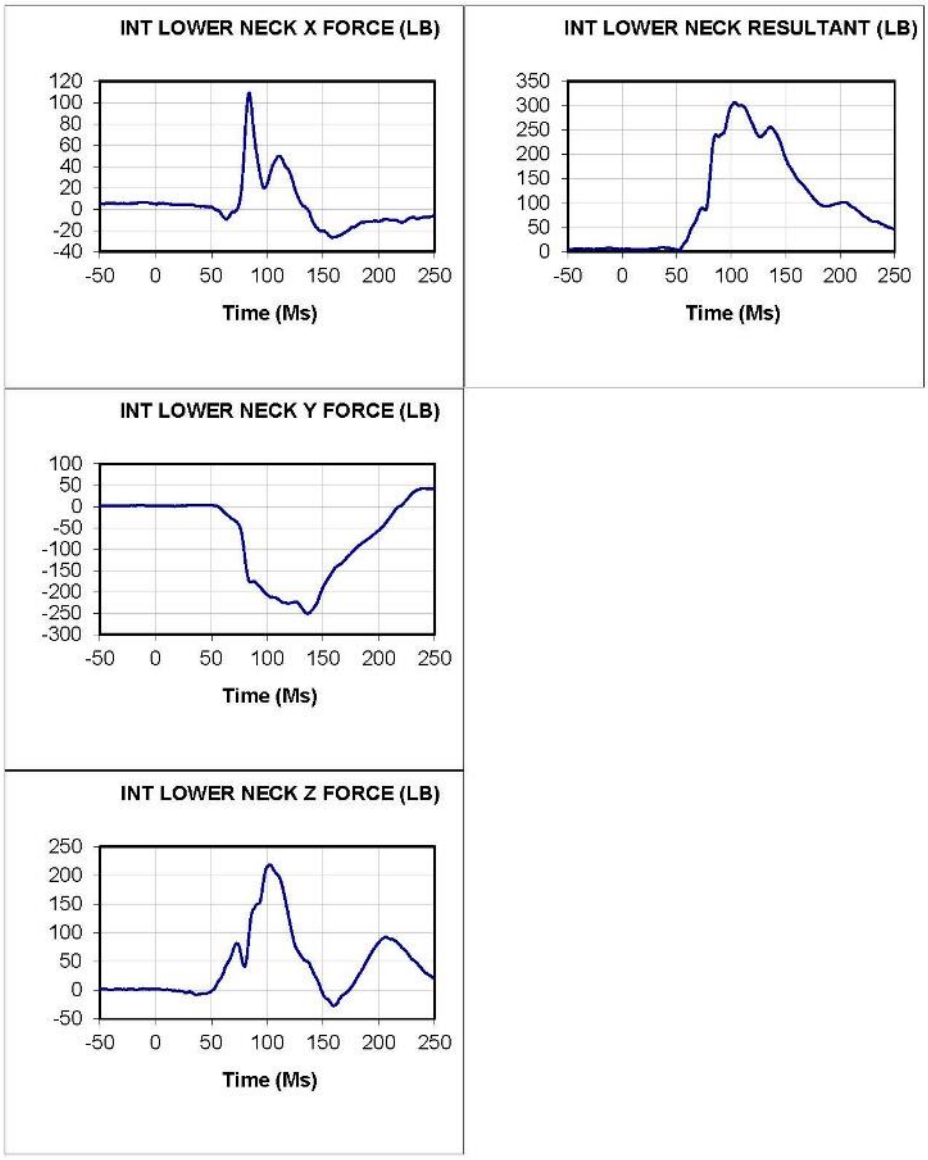
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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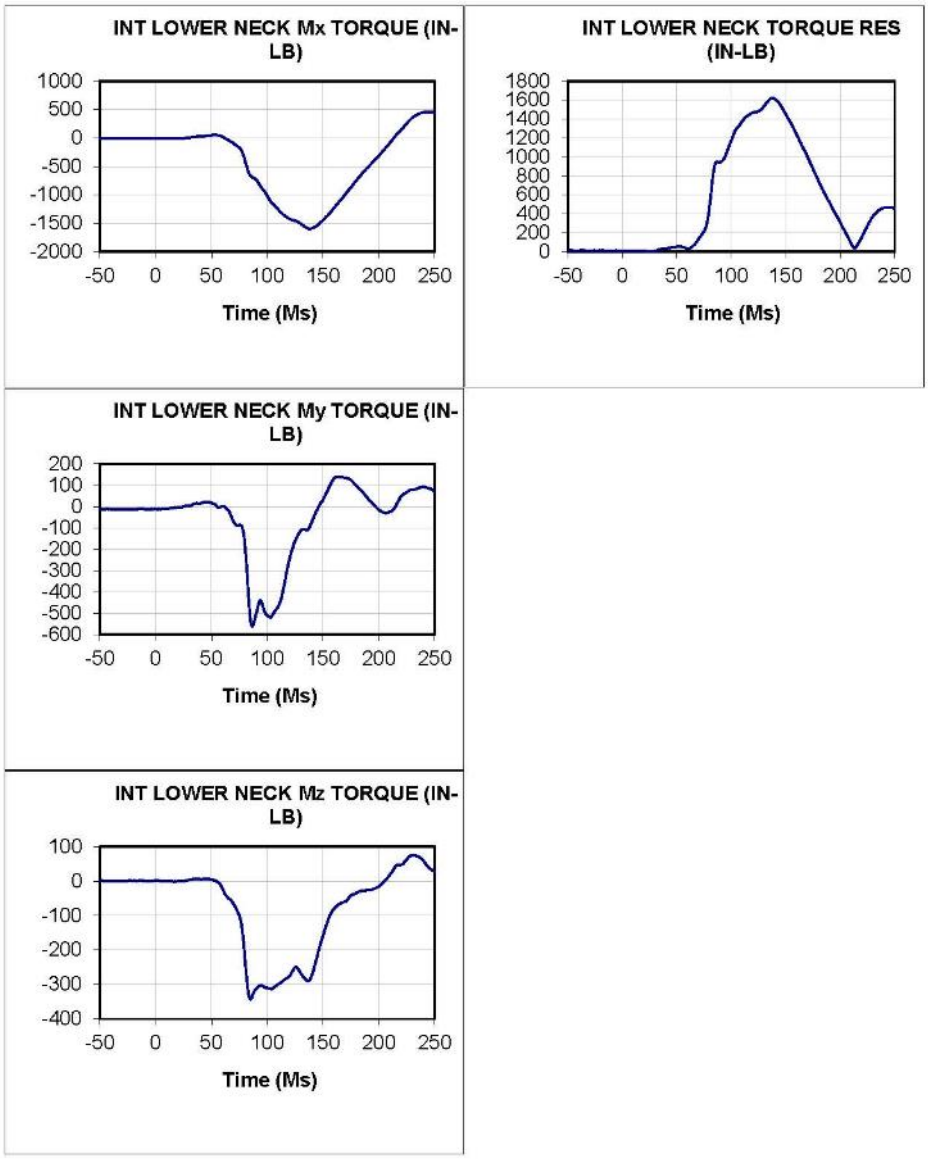
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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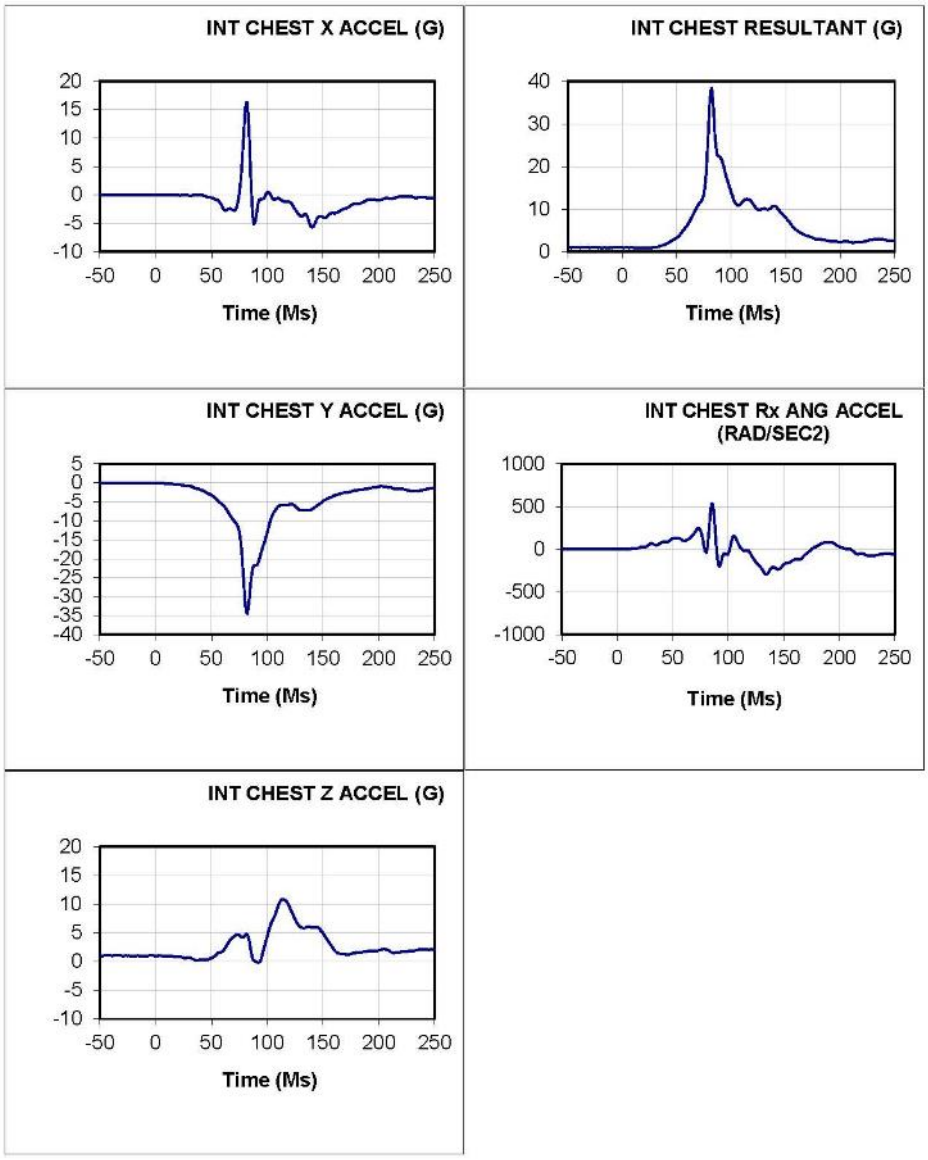
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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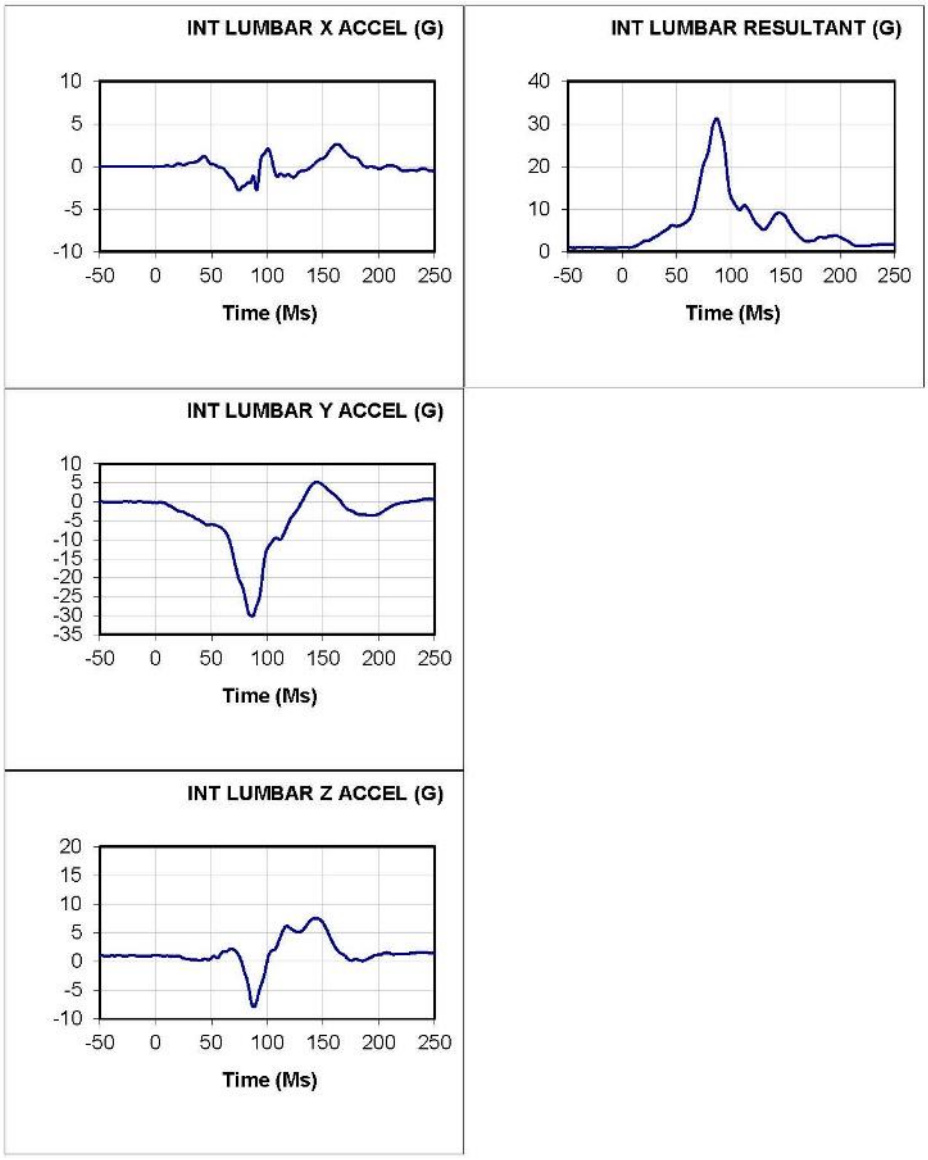
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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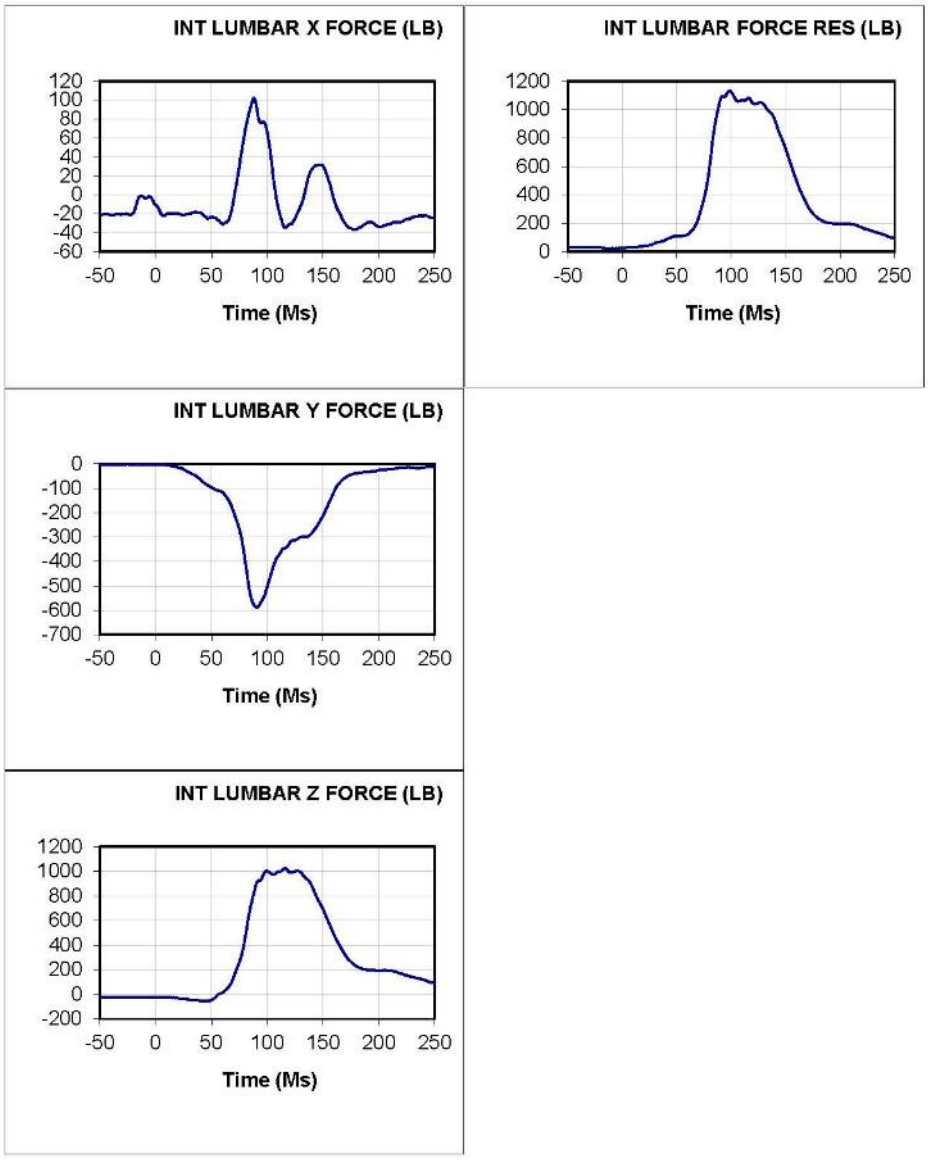
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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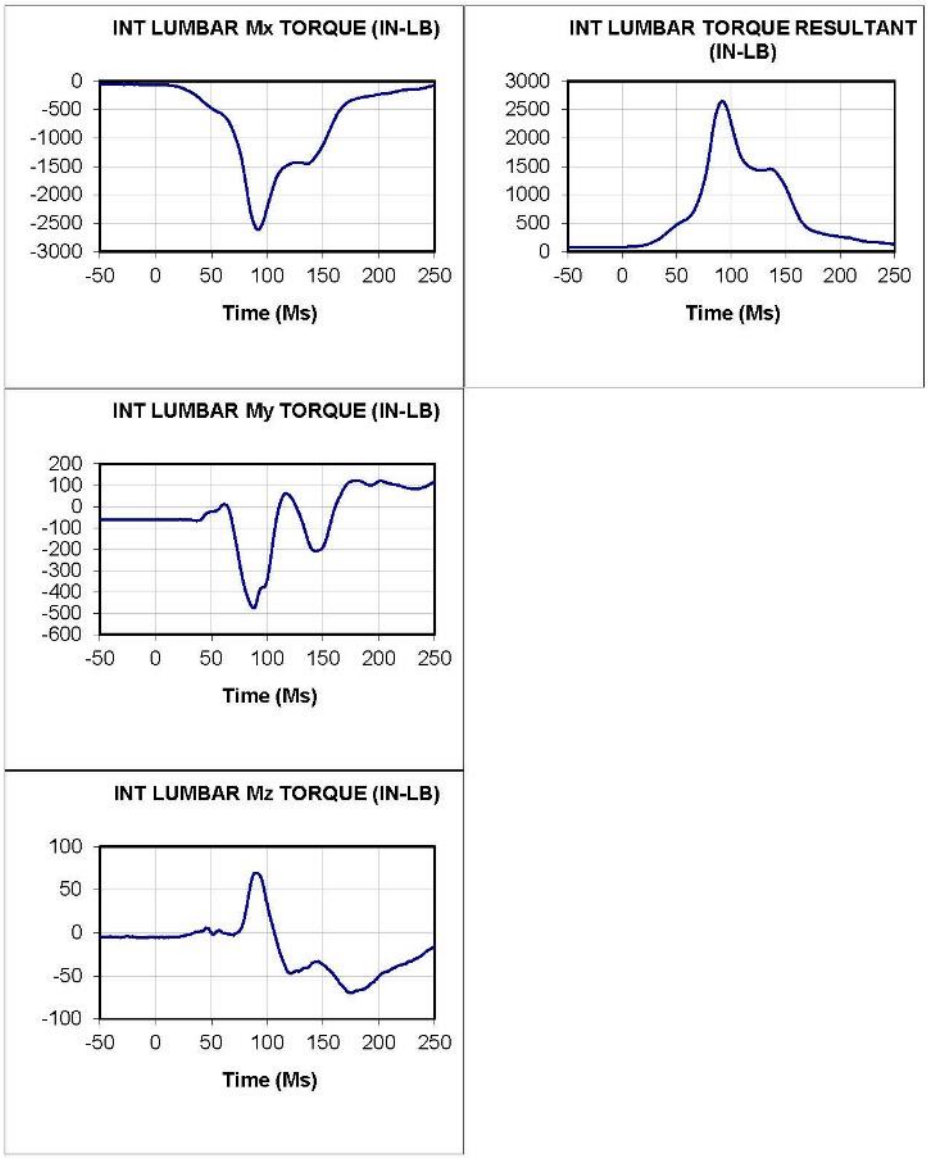
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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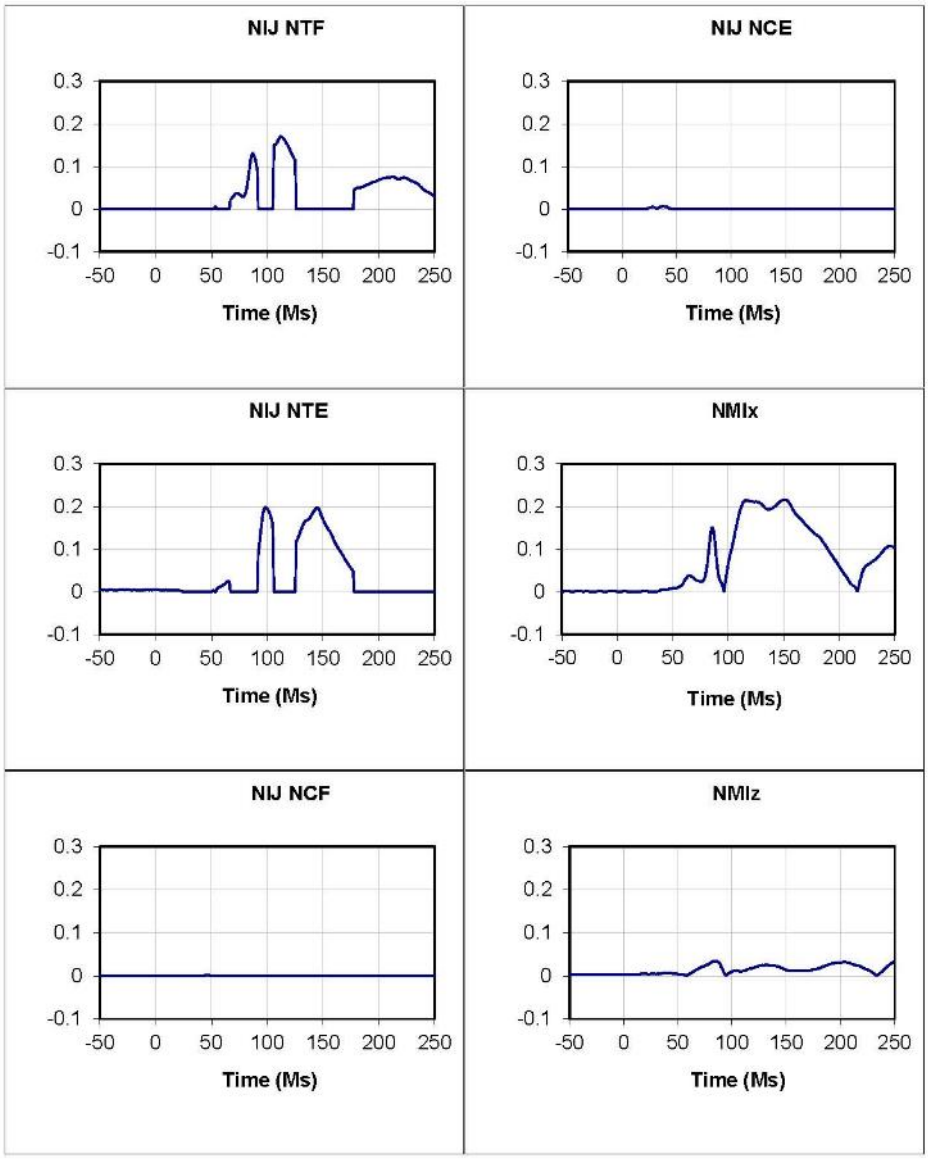
Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9226 Test Date: 161118 Subj: AERO50 Cell: G



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9229 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 12.5 Cell: H

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
Reference Mark Time (Ms)				12.0	
Impact Rise Time (Ms)				82.0	
Impact Duration (Ms)				130.0	
Velocity Change (Ft/Sec)		38.77			
SLED X ACCEL (G)	0.09	12.46	-2.31	82.0	166.0
SLED Y ACCEL (G)	0.02	0.45	-0.90	166.0	63.0
SLED Z ACCEL (G)	-1.03	0.83	-2.92	173.0	169.0
SLED RESULTANT	1.04	12.52	0.38	65.0	172.0
INTEGRATED ACCEL (FT/SEC)	0.04	38.77	0.11	164.0	0.0
SEAT X ACCEL (G)	0.10	6.03	-6.70	79.0	154.0
SEAT Y ACCEL (G)	0.02	11.44	-24.24	170.0	78.0
SEAT Z ACCEL (G)	1.10	6.42	-2.48	87.0	97.0
SEAT RESULTANT	1.15	25.18	0.78	78.0	134.0
LEFT LAP X FORCE (LB)	15.42	676.62	12.71	121.0	241.0
LEFT LAP Y FORCE (LB)	5.53	6.86	-224.53	180.0	113.0
LEFT LAP Z FORCE (LB)	2.77	198.40	2.57	123.0	10.0
LEFT LAP RESULTANT (LB)	16.62	735.70	14.51	120.0	242.0
RIGHT LAP X FORCE (LB)	24.76	547.50	0.95	121.0	33.0
RIGHT LAP Y FORCE (LB)	1.40	6.73	-89.16	242.0	104.0
RIGHT LAP Z FORCE (LB)	4.93	173.86	-2.74	123.0	32.0
RIGHT LAP RESULTANT (LB)	25.29	577.40	10.87	121.0	29.0
LEFT SHOULDER X FORCE (LB)	18.56	170.43	-10.36	123.0	80.0
LEFT SHOULDER Y FORCE (LB)	0.59	9.92	-76.22	240.0	61.0
LEFT SHOULDER Z FORCE (LB)	10.40	33.58	-29.94	59.0	120.0
LEFT SHOULDER RESULTANT (LB)	21.29	175.85	0.70	123.0	207.0

Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

201610 Test: 9229 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 12.5 Cell: H

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT HEAD X ACCEL (G)	0.14	8.15	-3.55	74.0	89.0
INT HEAD Y ACCEL (G)	-0.12	5.10	-13.27	238.0	140.0
INT HEAD Z ACCEL (G)	0.85	30.52	-0.06	95.0	38.0
INT HEAD RESULTANT (G)	0.96	31.63	0.16	95.0	34.0
INT HEAD HIC		123.61		88.0	118.0
INT HEAD Rx ANG VELOCITY (RAD/SEC)	-0.05	35.93	-24.73	96.0	209.0
INT HEAD Ry ANG VELOCITY (RAD/SEC)	-0.01	9.93	-7.09	81.0	164.0
INT HEAD Rz ANG VELOCITY (RAD/SEC)	0.01	6.49	-0.03	222.0	3.0
INT HEAD ANG VELOCITY RESULTANT	0.08	36.30	0.04	96.0	6.0
INT NECK X FORCE (LB)	2.71	53.51	-18.26	74.0	94.0
INT NECK Y FORCE (LB)	2.52	51.98	-115.85	232.0	137.0
INT NECK Z FORCE (LB)	1.88	275.16	-9.56	102.0	38.0
INT NECK RESULTANT (LB)	4.25	287.27	2.94	102.0	21.0
INT NECK Mx TORQUE (IN-LB)	-5.64	363.36	-302.40	74.0	117.0
INT NECK My TORQUE (IN-LB)	2.35	234.88	-124.66	74.0	88.0
INT NECK Mz TORQUE (IN-LB)	3.74	25.31	-35.77	189.0	242.0
INT NECK TORQUE RES (IN-LB)	7.18	433.90	6.16	74.0	19.0
INT LOWER NECK X FORCE (LB)	6.12	142.45	-45.51	72.0	149.0
INT LOWER NECK Y FORCE (LB)	4.11	55.54	-263.72	235.0	105.0
INT LOWER NECK Z FORCE (LB)	1.67	283.85	-23.88	94.0	153.0
INT LOWER NECK RESULTANT (LB)	7.57	381.85	5.58	94.0	22.0
INT LOWER NECK Mx TORQUE (IN-LB)	7.21	524.74	-1645.89	239.0	130.0
INT LOWER NECK My TORQUE (IN-LB)	-15.71	296.60	-755.17	152.0	75.0
INT LOWER NECK Mz TORQUE (IN-LB)	2.56	72.09	-401.90	226.0	72.0
INT LOWER NECK TORQUE RES (IN-LB)	17.51	1670.17	3.25	131.0	23.0
INT CHEST X ACCEL (G)	0.00	26.17	-9.13	71.0	75.0
INT CHEST Y ACCEL (G)	0.00	0.29	-57.19	199.0	71.0
INT CHEST Z ACCEL (G)	0.99	10.83	-0.08	106.0	87.0
INT CHEST RESULTANT (G)	0.99	63.40	0.77	71.0	25.0
INT CHEST Rx ANG ACCEL (RAD/SEC2)	-0.35	812.20	-1077.87	76.0	71.0
INT LUMBAR X ACCEL (G)	0.01	3.41	-2.64	90.0	82.0
INT LUMBAR Y ACCEL (G)	-0.02	7.03	-40.41	137.0	75.0
INT LUMBAR Z ACCEL (G)	0.99	7.72	-7.61	130.0	79.0
INT LUMBAR RESULTANT (G)	1.00	40.56	0.56	75.0	200.0

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201610 Test: 9229 Test Date: 161118 Subj: AERO50 Wt: 161.0
Nom G: 12.5 Cell: H

Data ID	Immediate Preimpact	Maximum Value	Minimum Value	Time Of Maximum	Time Of Minimum
INT LUMBAR X FORCE (LB)	-12.62	159.89	-20.21	90.0	50.0
INT LUMBAR Y FORCE (LB)	-1.79	32.82	-704.01	191.0	84.0
INT LUMBAR Z FORCE (LB)	1.97	32.43	-35.13	106.0	110.0
INT LUMBAR FORCE RES (LB)	12.94	718.26	2.66	84.0	228.0
INT LUMBAR Mx TORQUE (IN-LB)	-15.33	133.82	-2981.49	204.0	85.0
INT LUMBAR My TORQUE (IN-LB)	-20.67	207.70	-572.30	242.0	90.0
INT LUMBAR Mz TORQUE (IN-LB)	13.59	120.70	-74.54	84.0	167.0
INT LUMBAR TORQUE RESULTANT (IN-LB)	29.11	3030.13	29.67	85.0	1.0
NIJ SHEAR (LB)		53.51	-18.26	74.0	94.0
NIJ TENSION (LB)		275.16		102.0	
NIJ COMPRESSION (LB)		-9.56		38.0	
NIJ FLEXION (IN-LB)		197.42		74.0	
NIJ EXTENSION (IN-LB)		115.96		88.0	
NIJ NTF	0.0012	0.1999	0.0000	103.0	7.0
NIJ NTE	0.0003	0.2440	0.0000	92.0	0.0
NIJ NCF	0.0000	0.0085	0.0000	38.0	0.0
NIJ NCE	0.0000	0.0008	0.0000	8.0	0.0
NIJ NTF AIS >= 2		0.14			
NIJ NTF AIS >= 3		0.06			
NIJ NTF AIS >= 4		0.08			
NIJ NTF AIS >= 5		0.03			
NIJ NTE AIS >= 2		0.15			
NIJ NTE AIS >= 3		0.06			
NIJ NTE AIS >= 4		0.08			
NIJ NTE AIS >= 5		0.03			
NIJ NCF AIS >= 2		0.11			
NIJ NCF AIS >= 3		0.04			
NIJ NCF AIS >= 4		0.06			
NIJ NCF AIS >= 5		0.02			
NIJ NCE AIS >= 2		0.11			
NIJ NCE AIS >= 3		0.04			
NIJ NCE AIS >= 4		0.06			
NIJ NCE AIS >= 5		0.02			
NMIx	0.0047	0.3041	0.0002	74.0	45.0
NMIz	0.0031	0.0299	0.0000	242.0	61.0

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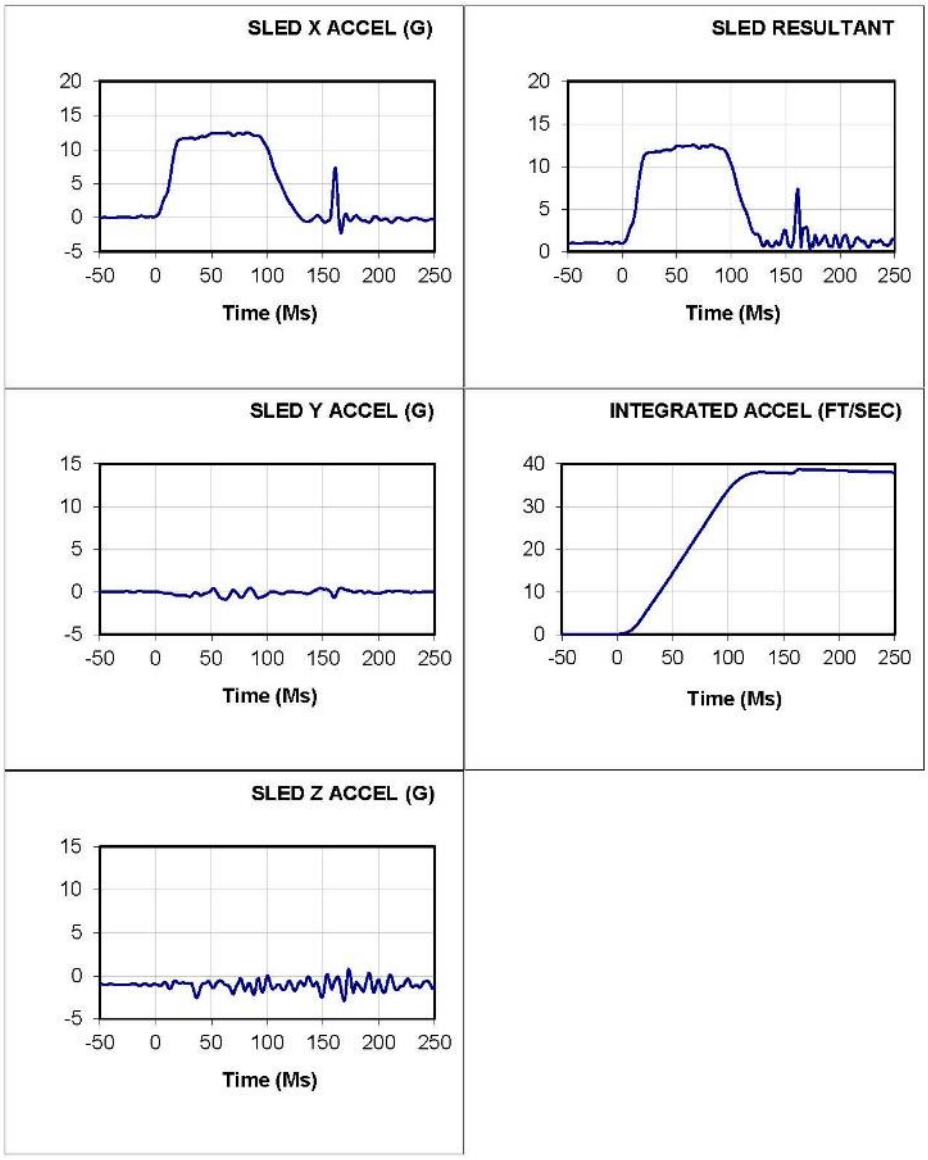
201610 Test: 9229 Test Date: 161118 Subj: AERO50 Cell: H



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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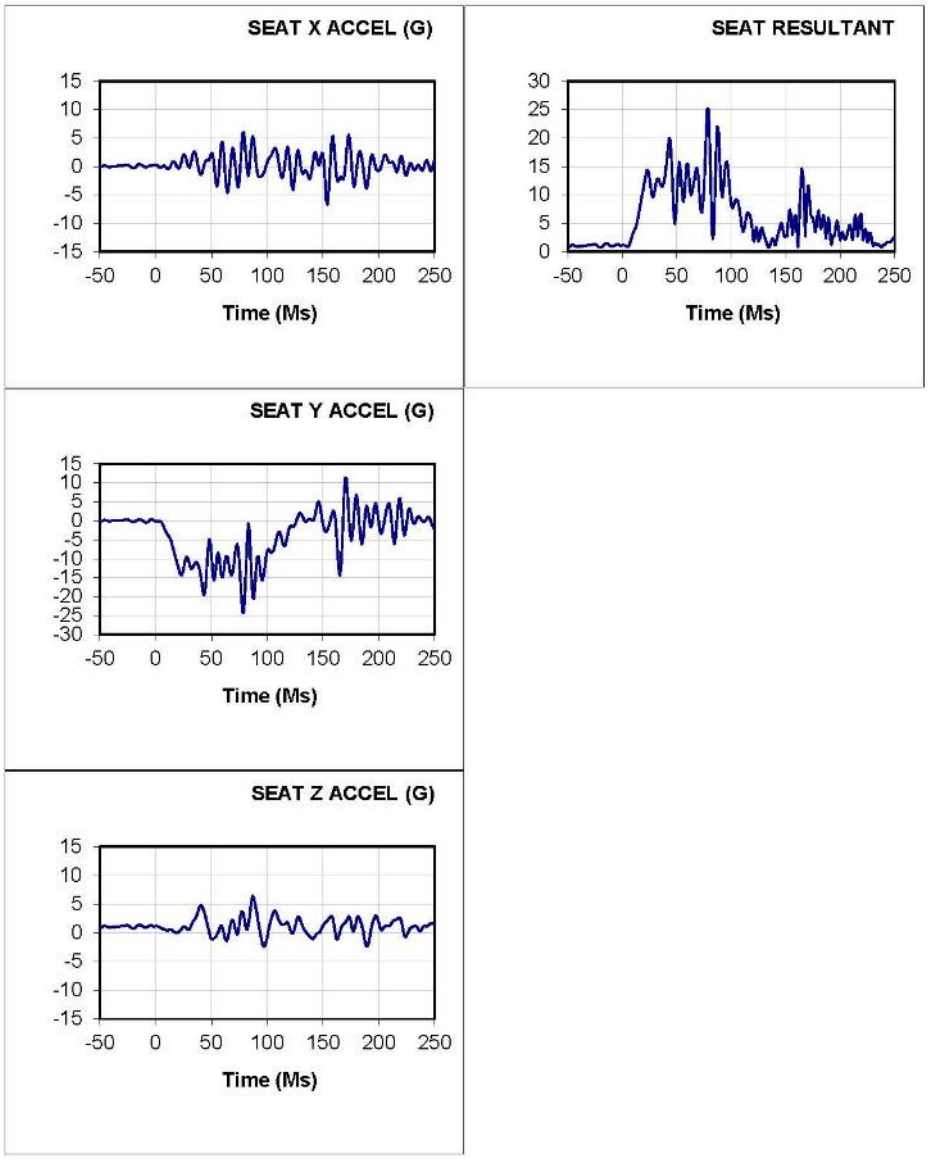

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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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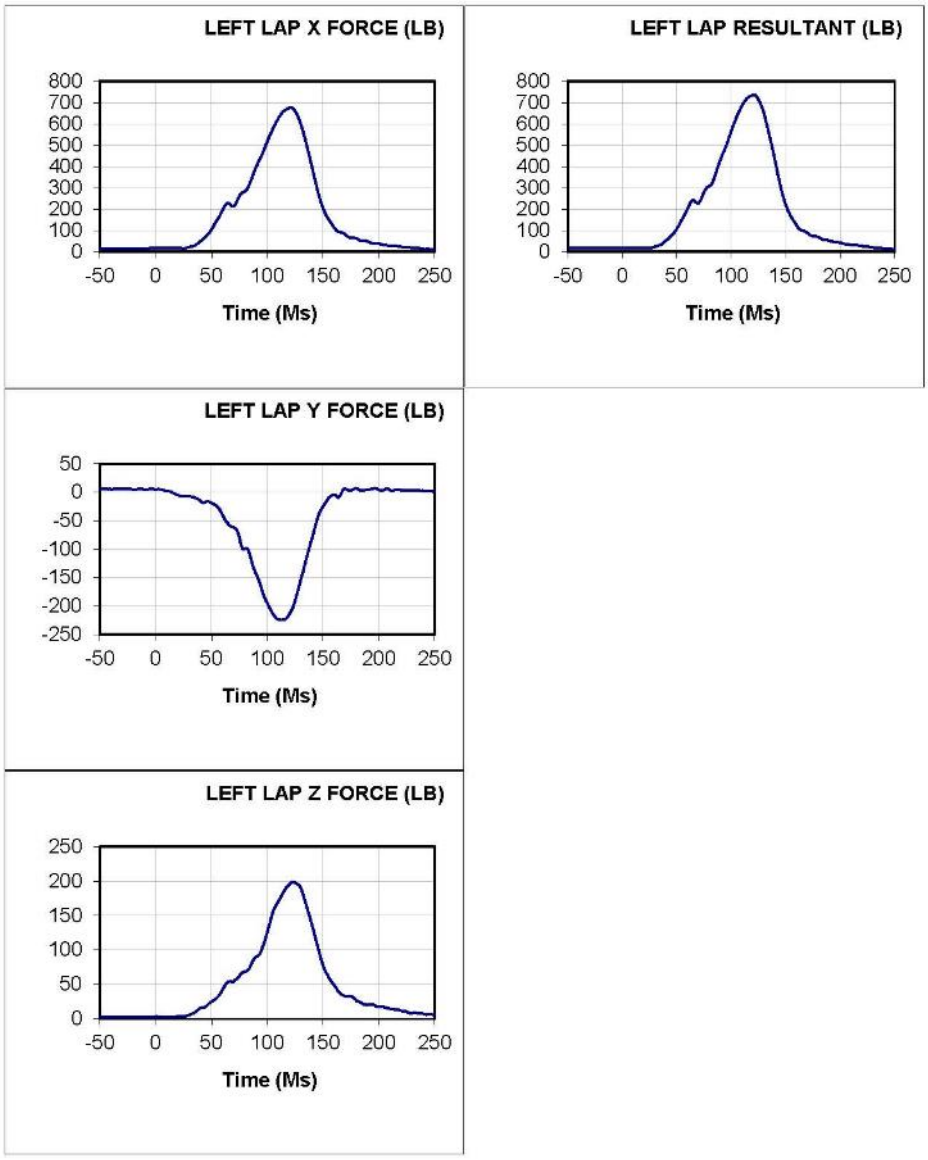

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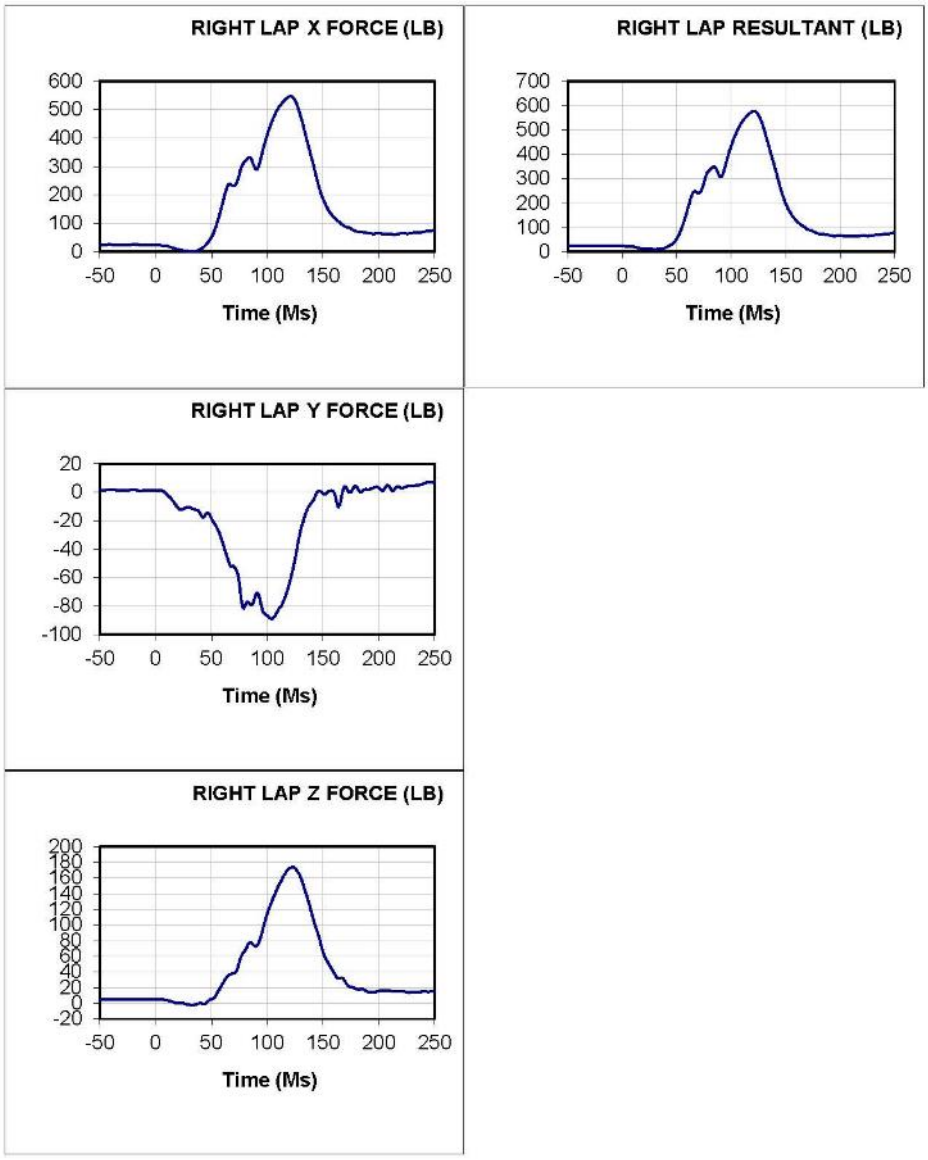
201610 Test: 9229 Test Date: 161118 Subj: AERO50 Cell: H



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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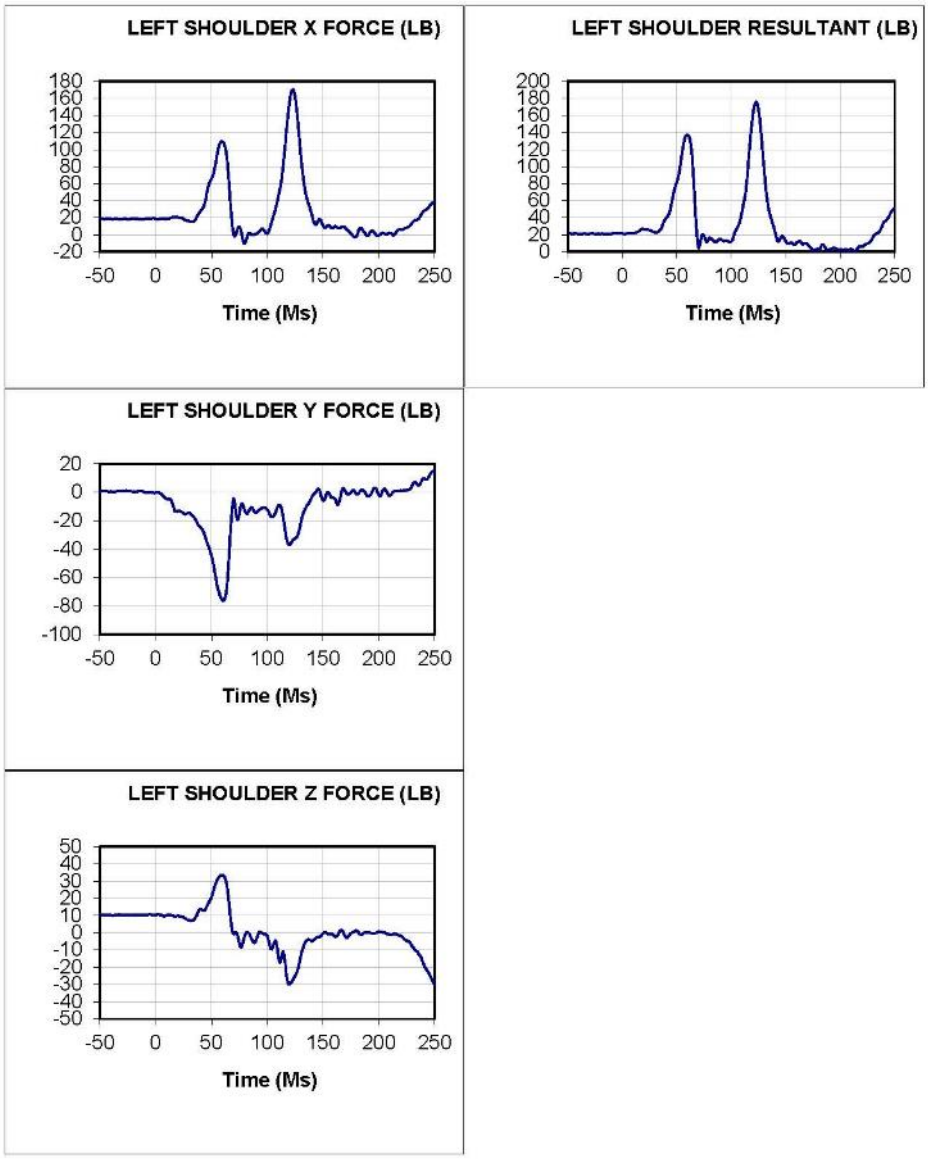

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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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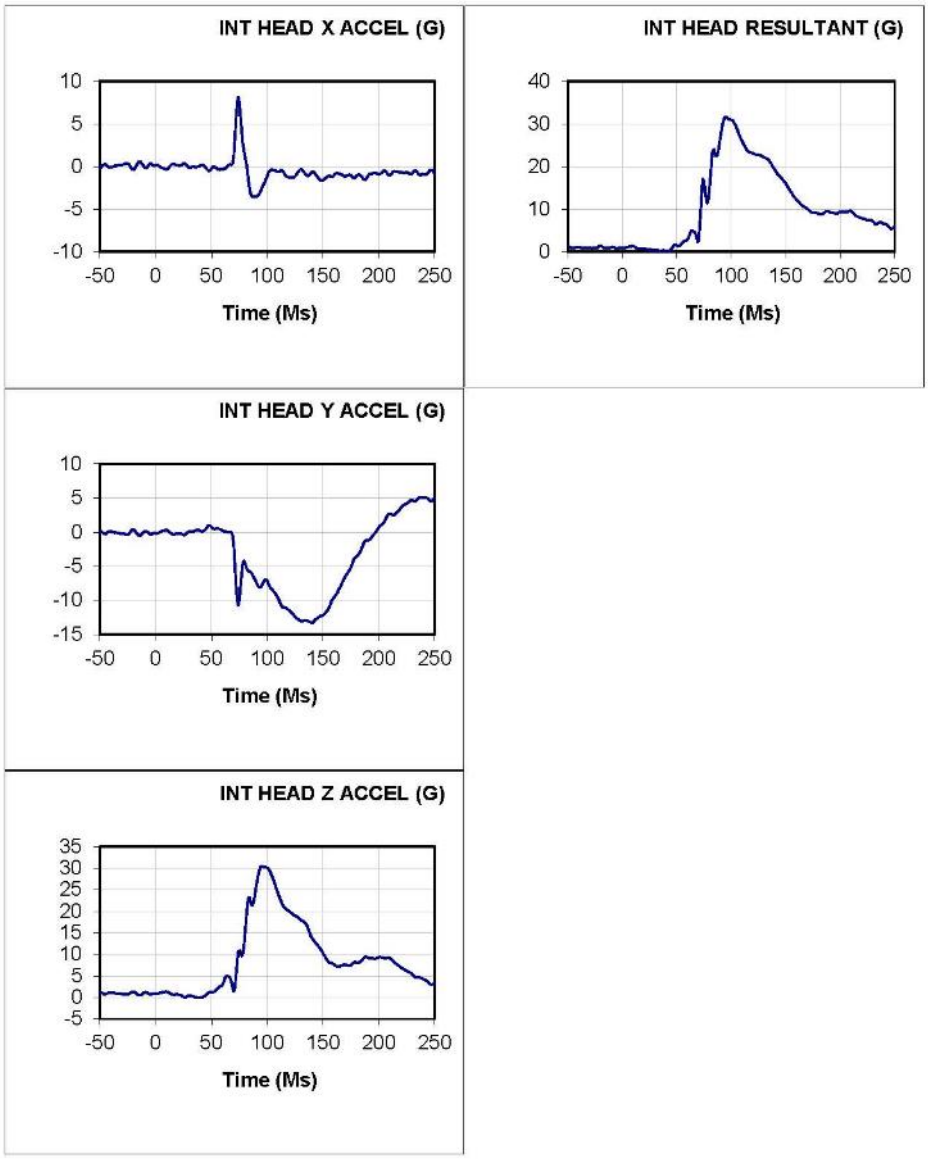

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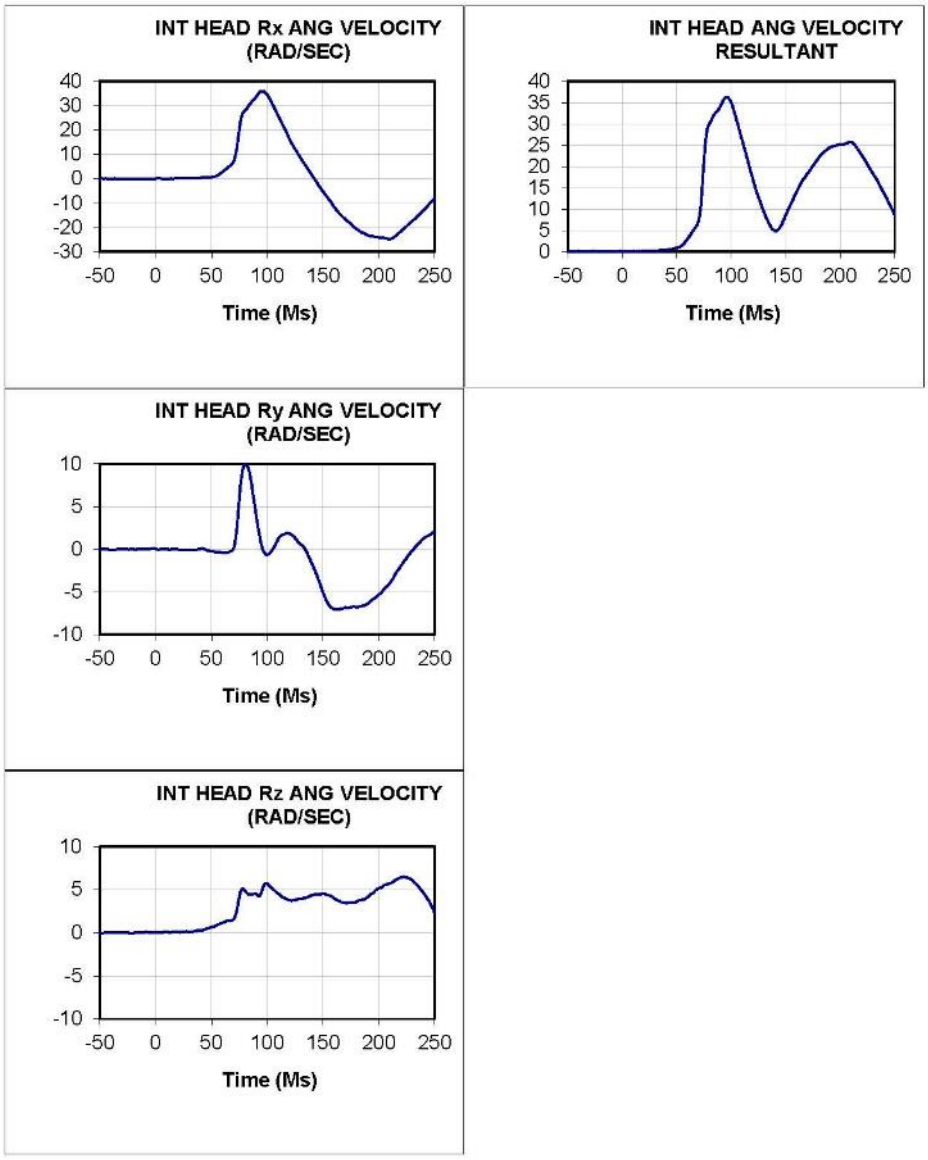
201610 Test: 9229 Test Date: 161118 Subj: AERO50 Cell: H



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Distribution A: Approved for public release. 88ABW-2019-2220; Cleared: 8 May 2019

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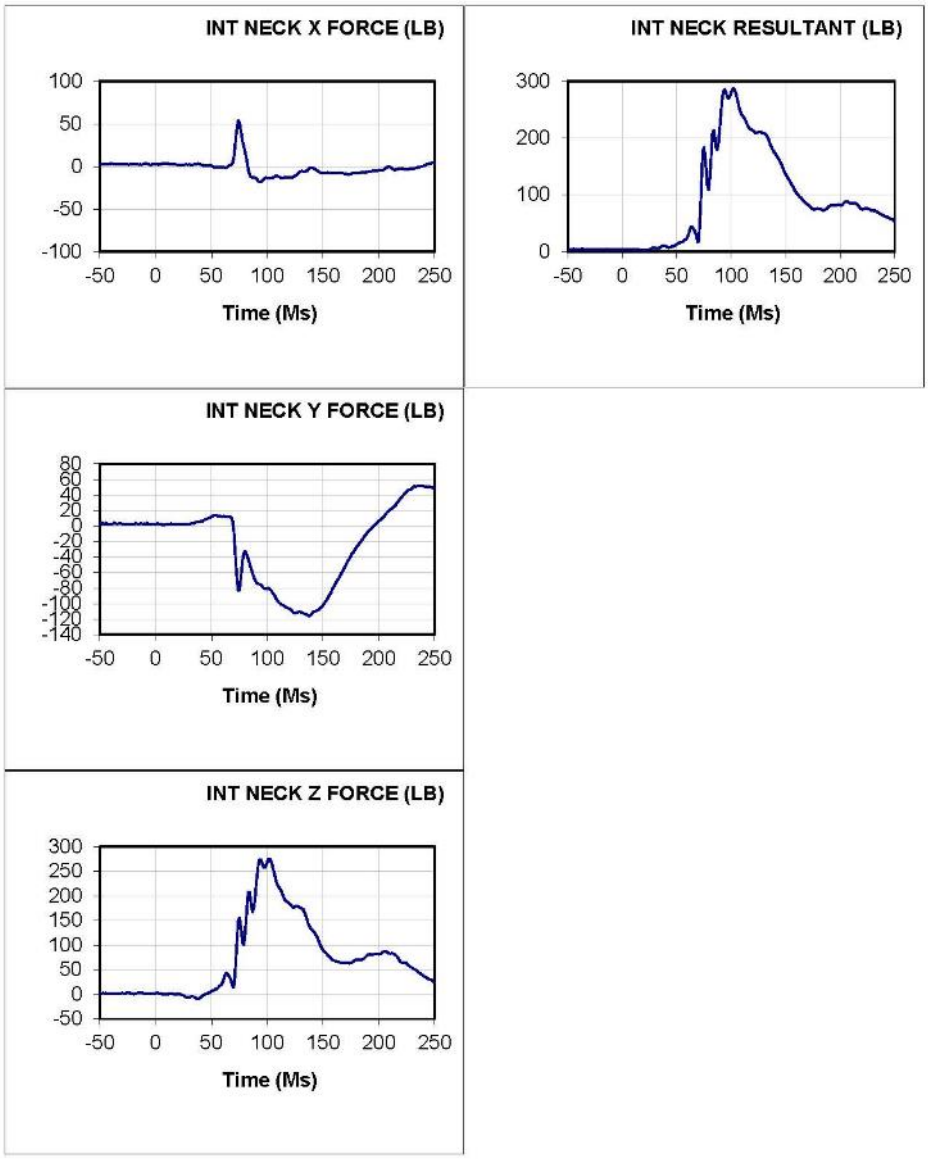

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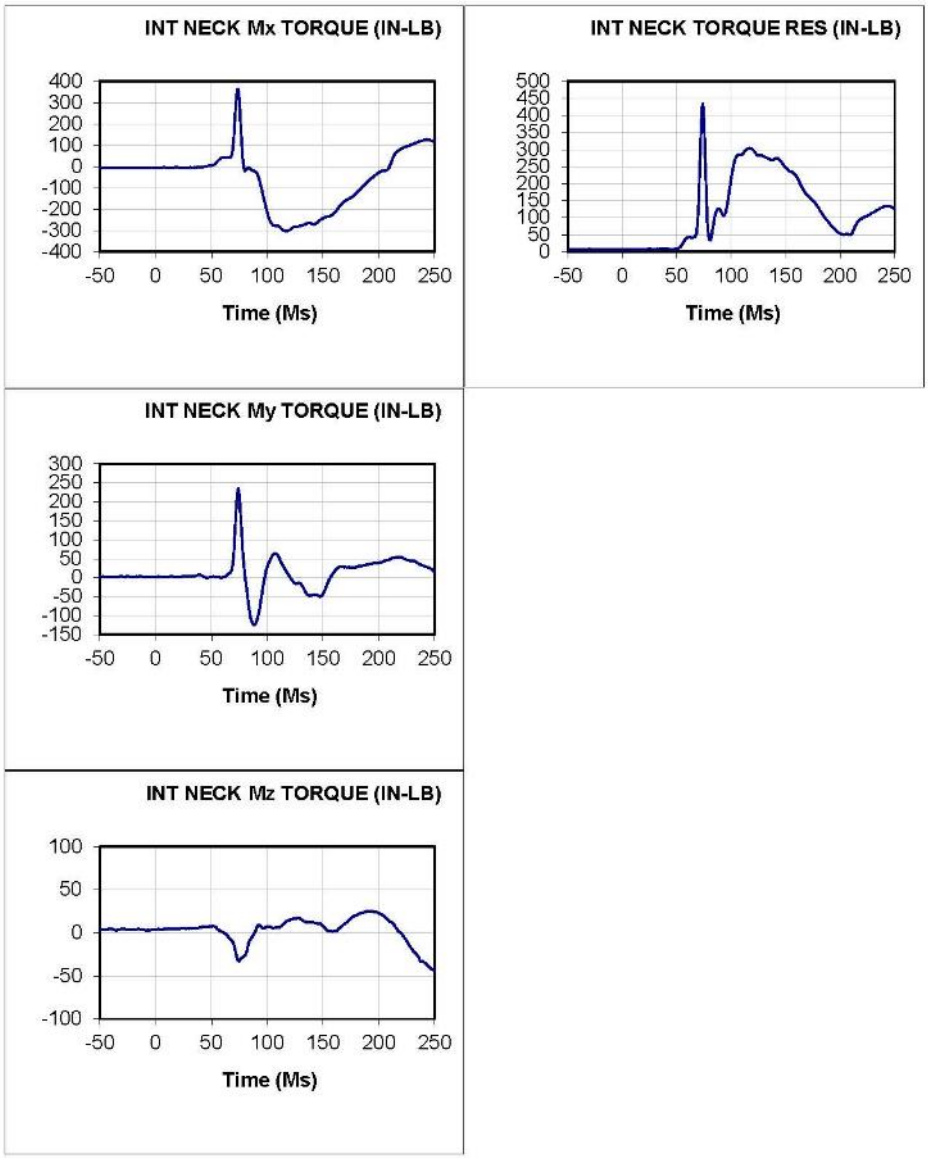

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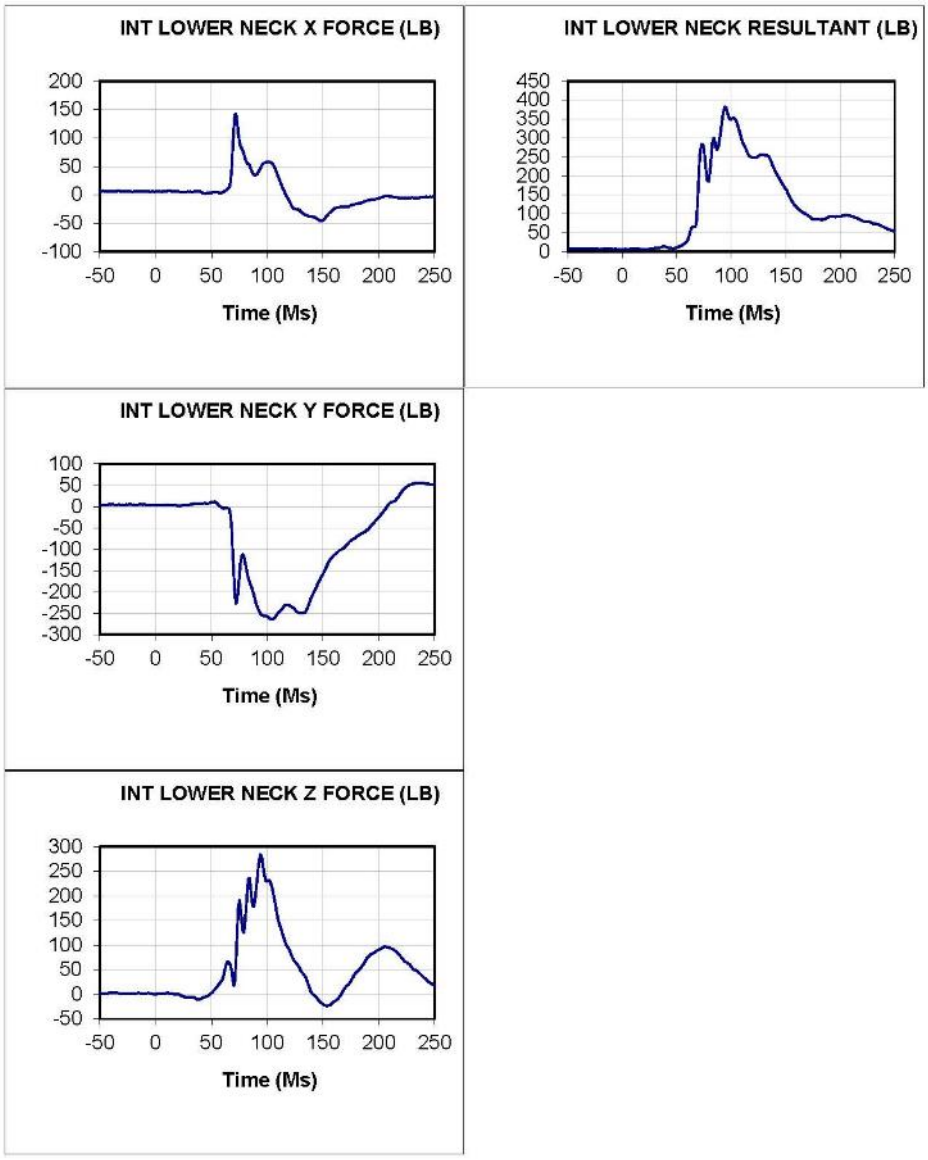

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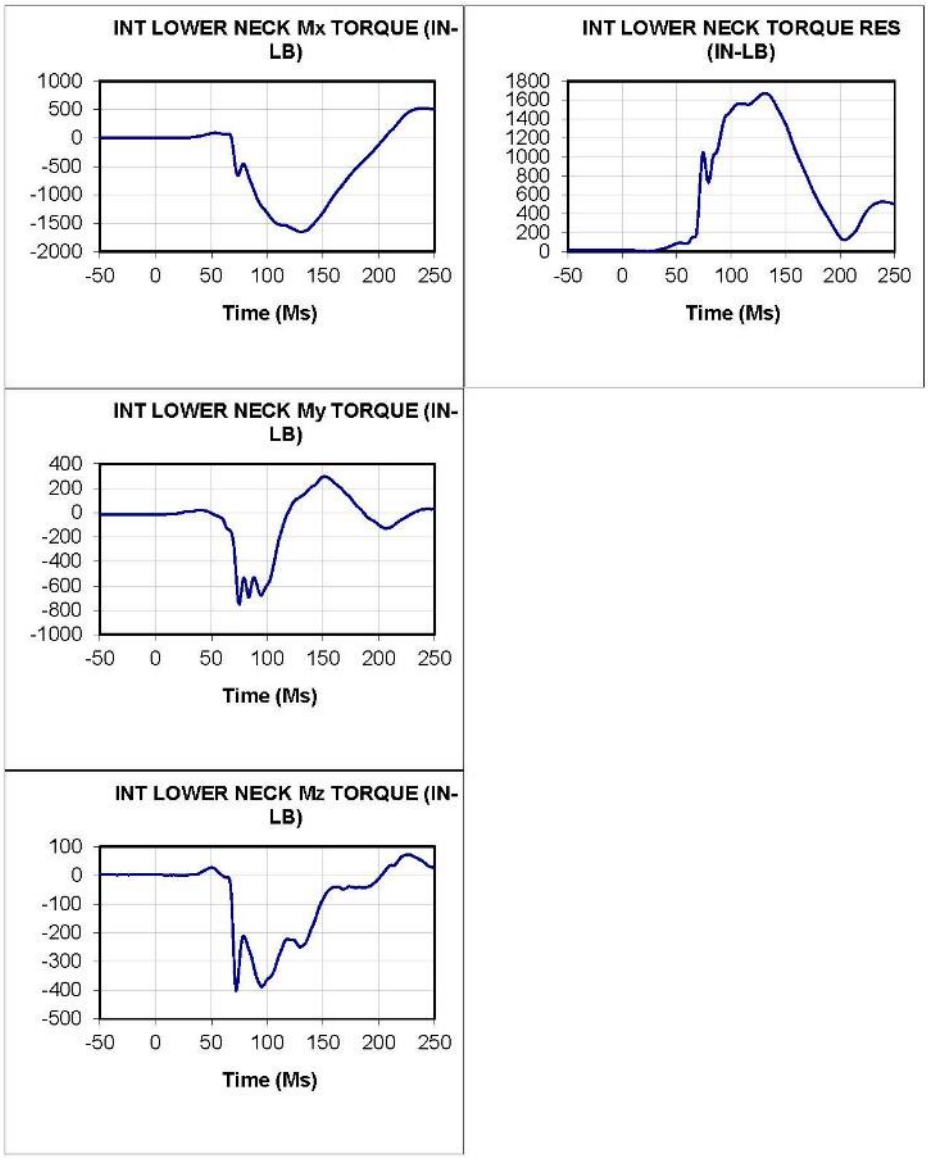

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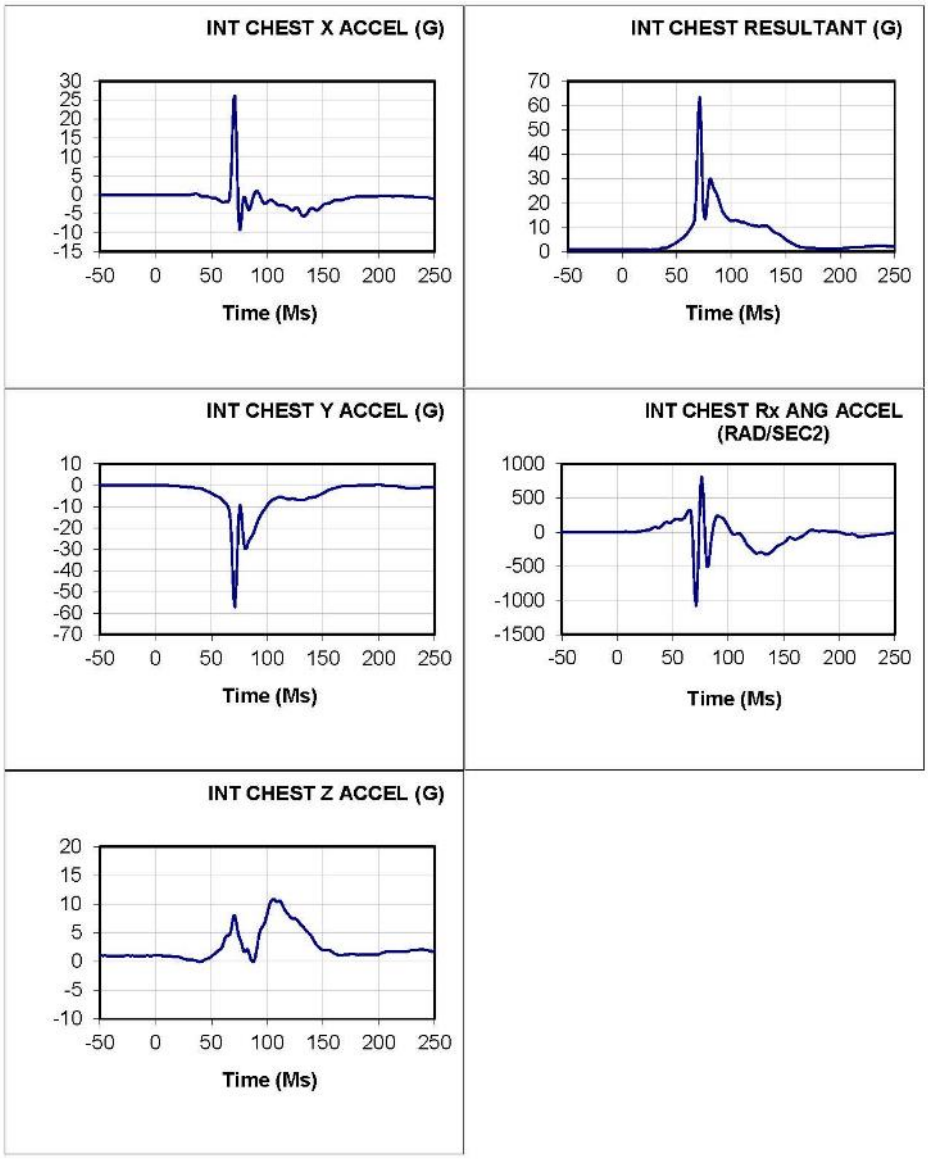

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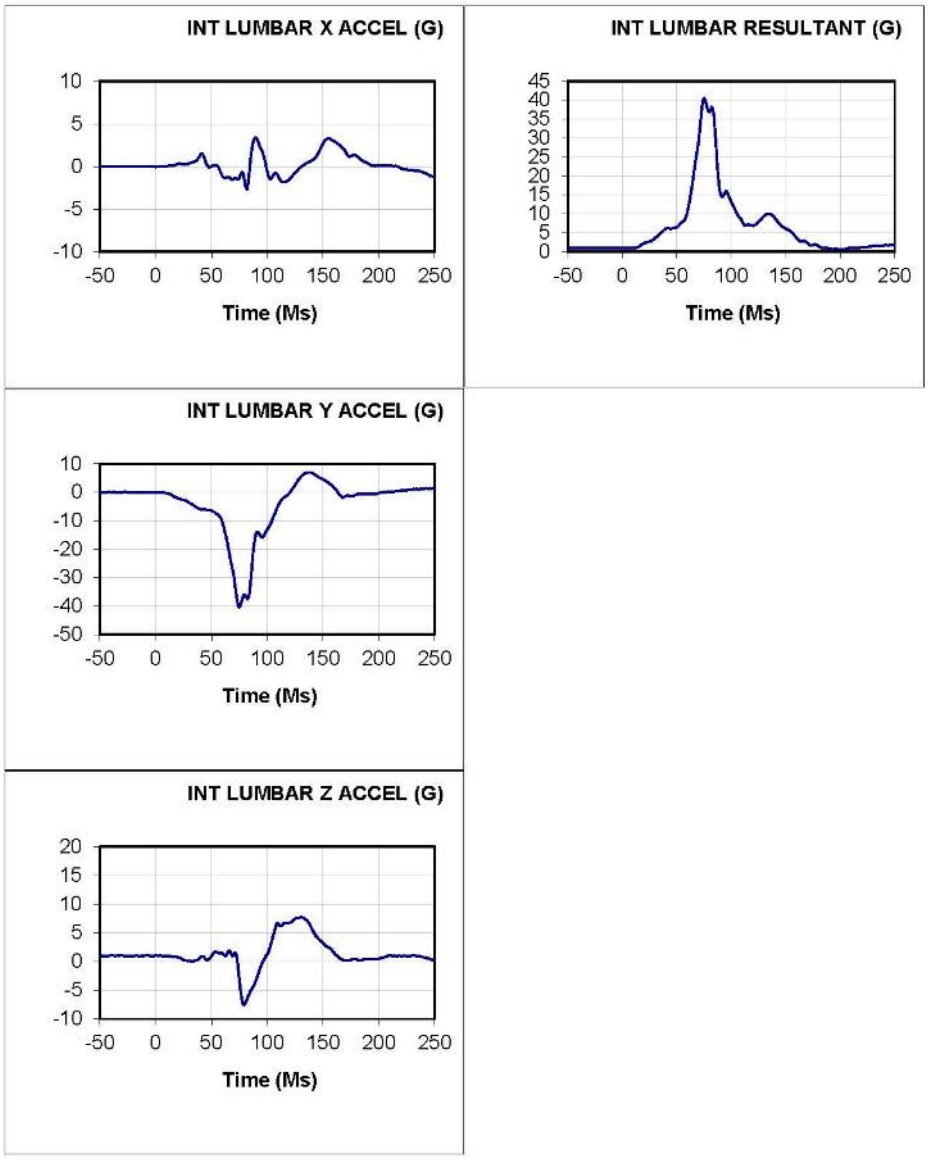

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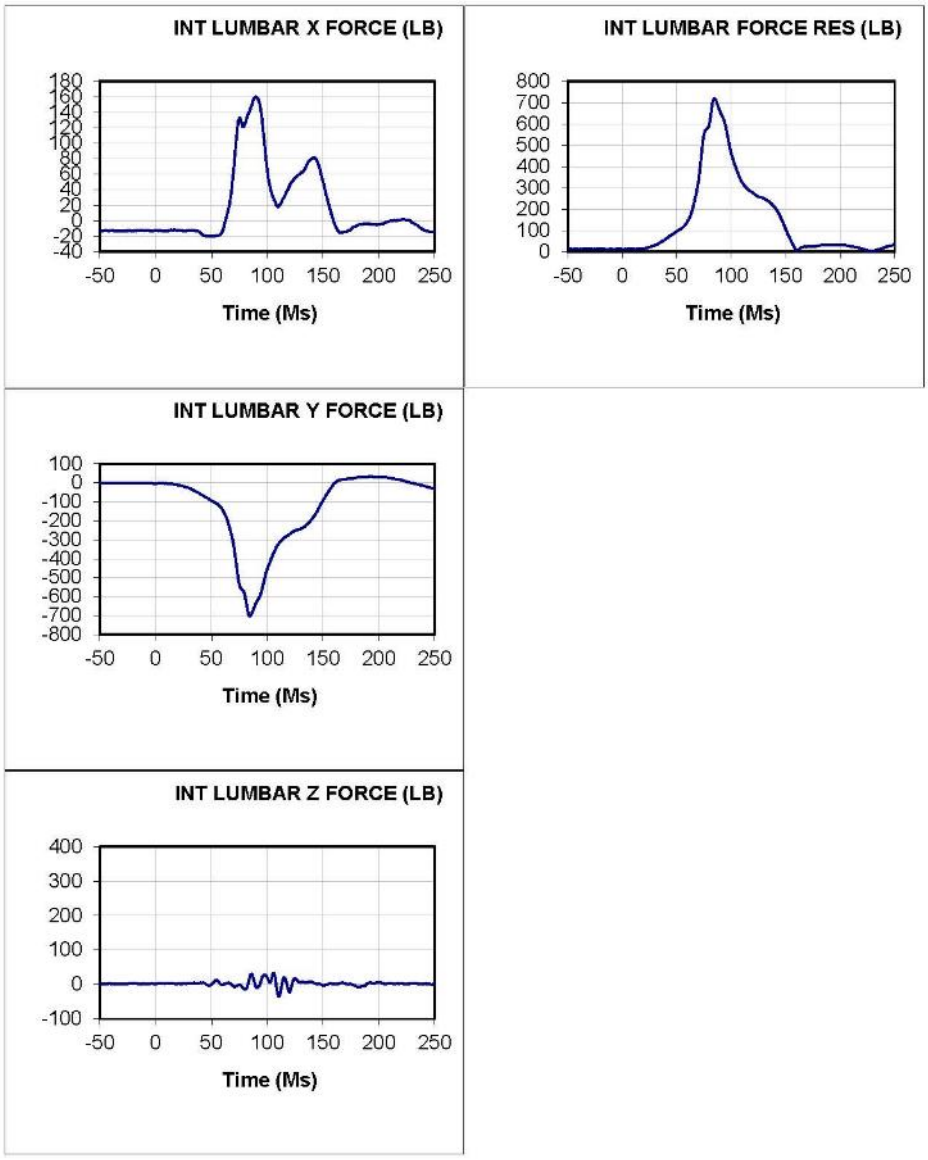

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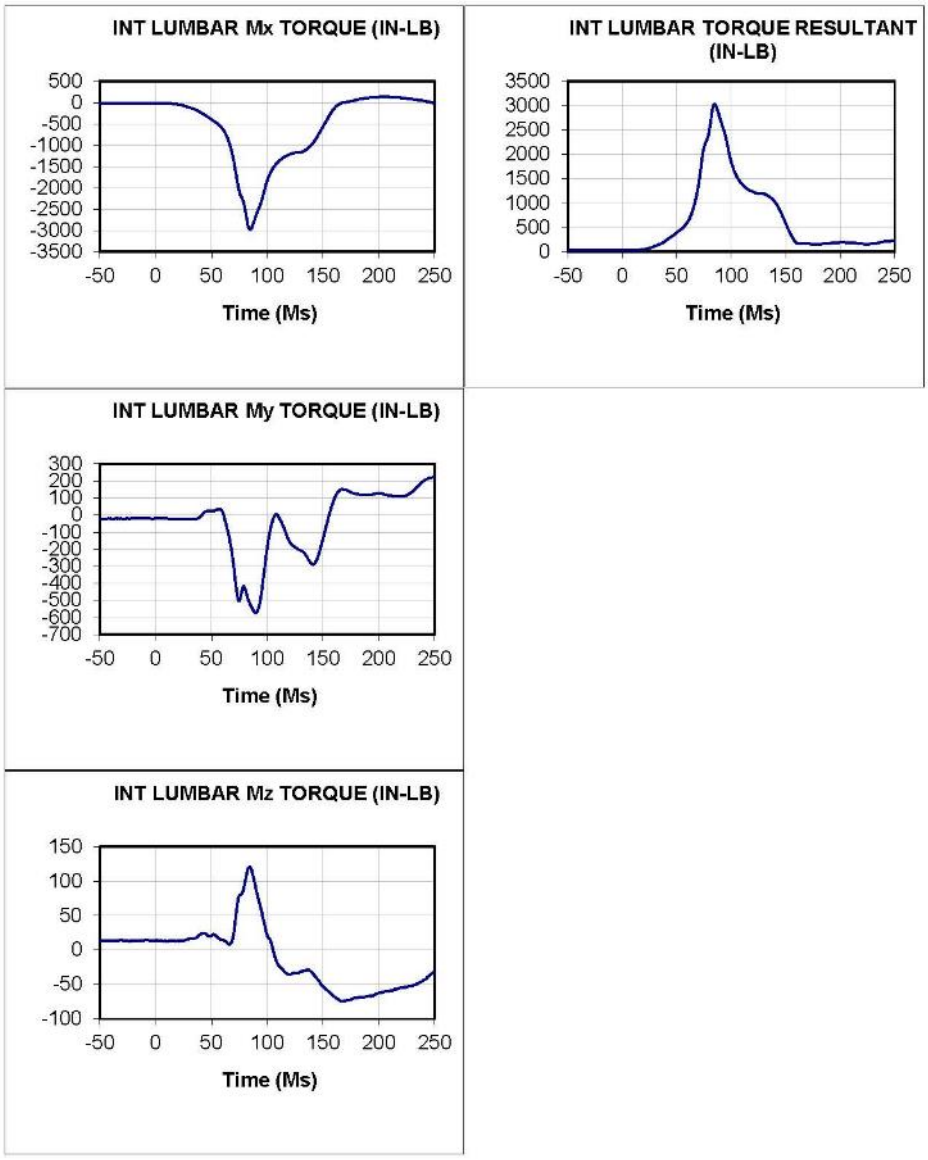

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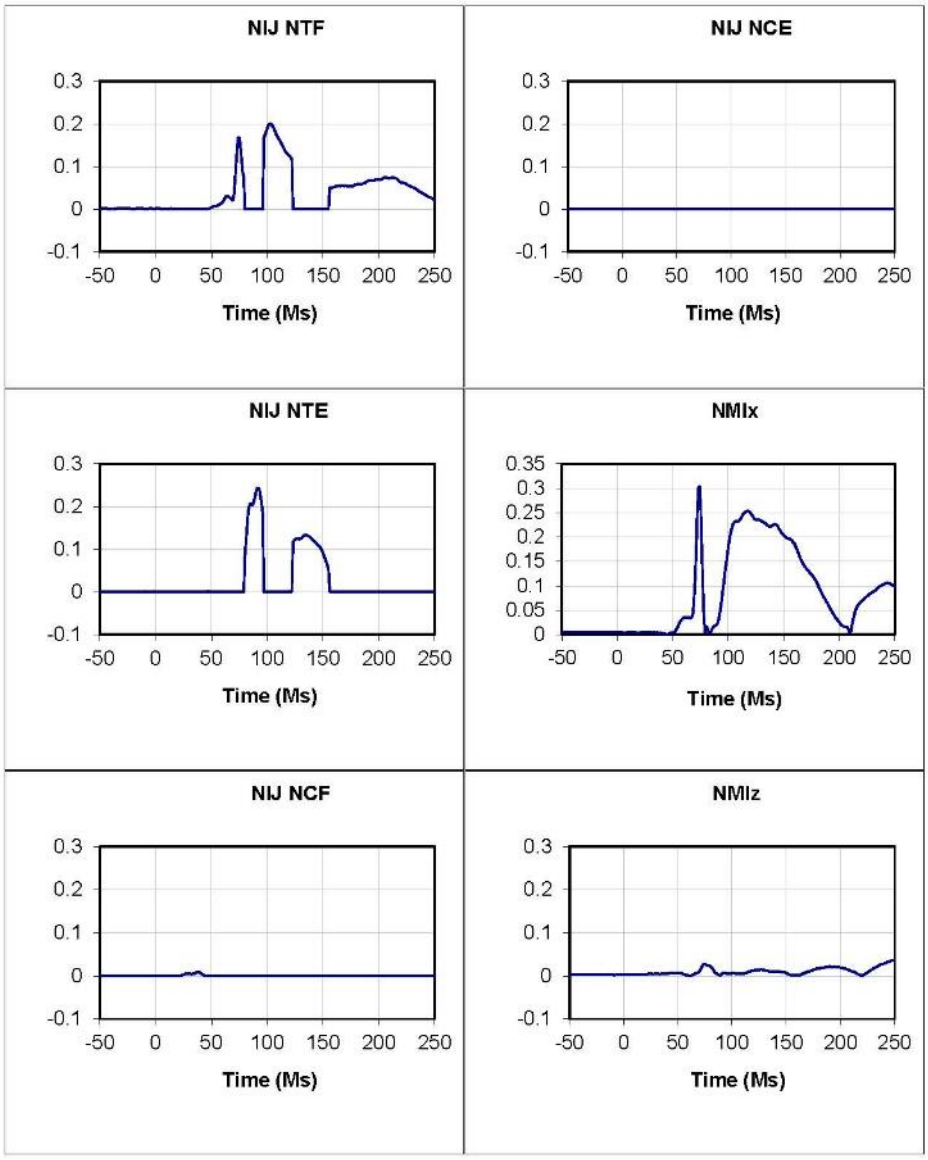

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