JRS Dynamic Rollover Test

2008 Toyota Highlander Limited Hybrid

Sponsored By:

Automotive Safety Research Institute
Charlottesville, VA.

Vehicle Loaned by:
State Farm Insurance Company
Chicago, IL.

Introduction

The Center for Injury Research conducted a JRS dynamic rollover test consisting of two rolls of a 2008 Toyota Highlander Hybrid (HV) on January 16th and 17th. This test report is organized in sections containing test information, data tables and photographs as follows:

Section 1 – Test Procedures and Summaries

Section 2 – Test Results, Data Tables and Selected Comparison Photographs for Roll 1.

Section 3 – Test Results, Data Tables and Selected Comparison Photographs for Roll 2.

Section 4 – Data Graphs

Section 5 – All Test Photographs

Enclosed with this report is a DVD of the video of both rolls.

2008 Toyota Highlander Limited HV

Executive Summary

The test was a two roll event. The planned difference between the rolls was the pitch of the vehicle; 5 degrees in Roll 1 and 10 degrees in Roll 2 and the position of the Hybrid III dummy. For Roll 1, the dummy was located "out of position;" leaning towards the passenger side approximately 45° in order to simulate approximately 1g of lateral acceleration. For Roll 2, the dummy was left in the resting position from the previous roll. Table 1 describes the impact conditions of each test. Table 2 shows the injury assessment reference values for the low durometer neck that was used. Values from Roll 1 were found from analysis of the high speed video.

Table 1 Summary of Test Conditions

Roll	Pitch	Road Speed	Contact Angle	Roll Rate	Yaw
1	5 deg	15 mph	140 deg	175 deg/sec	10 deg
2	10 deg	15 mph	137 deg	176 deg/sec	10 deg

Table 2 Lower Neck IARV's for 10% Probability of an AIS ≥ 3 Injury

Neck Type	My (Nm) Flexion	My (Nm) Extension	Mx (Nm)	Axial Fz (N)
Production	380	−156	268	4000
Low Durometer	90-110	−38-−46	59-90	1640-2000
Human/Cadaver	58			1500

In Roll 1, the dummy data was lost due to an electrical short. The peak intrusion speed at the top of the A-Pillar was 3.4 mph with a peak crush of 2.0 inches.

In Roll 2, the peak lower neck compressive load was 827 N and the peak lower neck moment was 98 Nm in flexion and 38 Nm in extension. The peak intrusion speed at the top of the A-Pillar was 7.1 mph with a peak crush of 5.0 inches.

1. Test Procedure and Summaries

For each roll of the test, the following steps are performed as necessary:

1. Inspect the test vehicle for prior damage, rust or other factors that might influence the outcome of the test
2. Prepare the test equipment
3. Install and prepare the instrumentation and video cameras
4. Install the test vehicle in test fixture
5. Perform pre-test measurements
6. Photograph the vehicle
7. Conduct the impact test
8. Perform post test measurements
9. Photograph the vehicle following the test

The set up of the test vehicle in the fixture and the instrumentation in the vehicle was the same for Rolls 1 and 2 with the exception of the pitch angle; Roll 1 = 5.0° and Roll 2 = 10.0°.

The test weight of the vehicle was 4,479 pounds. The initial weight of the vehicle was 4,531 pounds. The test roll moment of inertia was approximately 737.2 lb-ft-sec^2 for a referenced value of 771.3 lb-ft-sec^2.

The vehicle was suspended on mounts at the rear and at the front in a manner that allowed it to roll freely and be dropped, passenger side (near side) leading.

Three string potentiometer mounts were placed approximately on the longitudinal roll axis of the vehicle at the cg of the vehicle. The sensors measured the roof dynamics at the top of the driver's side A-pillar, at the header inboard of the A-pillar and at the top of the passenger's side A-pillar. An instrumented, restrained Hybrid III 50th percentile male test dummy was placed in the driver's seat. The dummy was instrumented with upper and lower neck load cells as well as a triaxial head accelerometer. In addition, seat belt load cells were utilized at the lap and shoulder belt.

The Hybrid III dummy was equipped with a more biofidelic (low durometer) neck, located in the driver's seat which was positioned in the mid seat position. The dummy was restrained using the vehicle's standard 3 point harness. The vehicle also had a side curtain airbag and a belt pretensioner which were fired at 30 degrees of roll during the first impact test. The dummy's head was chalked before each roll to locate impact marks during the tests. The lower neck mounting block was replaced with a block that increased the neck angle forward 30 degrees from the nominal position.

For the first roll the dummy was tethered "out of position" with a small cable that electronically disconnected at approximately 30° of roll. The "out of position" location of the dummy was found by rotating the vehicle by 90° toward the passenger side. This orientation simulated the dummy accelerating toward the passenger side door at 1 g. For the second roll the dummy was left in the same position from the end of the first roll, held in place by the belt in tension.

Six vertical and two lateral load cells were placed in the moving roadway to record the impact characteristics of the test.

Two string potentiometers were placed on the fixture support towers to record vehicle vertical motion characteristics during the test. One string potentiometer was located in the front drop tower and the other was located in the rear drop tower.

A roll encoder was placed on the cable pulley which pulls the moving roadway to record the roadway velocity throughout the test. In addition, a roll rate sensor was placed inside the vehicle.

The equipment used in the conduct of this test is listed in Table 3 and the test vehicle identification data is shown in Table 4 below.

Table 3 Equipment and Instrumentation

Item	MFR./Model
String Potentiometer – Driver's Side A-Pillar	Space Age Control – 301432
String Potentiometer – Driver's Side B-Pillar	Space Age Control – 301432
String Potentiometer – Roof Header	Space Age Control – 301432
String Potentiometer – Passenger's Side A-Pillar	Space Age Control – 301432
String Potentiometer – Front Fixture Support Tower	Space Age Control – 4332-01
String Potentiometer – Rear Fixture Support Tower	Space Age Control – 4332-01
Upper Neck Load Cell	RA Denton 1716A
Lower Neck Load Cell	RA Denton 1794A
Triaxial Head Accelerometer	Endevco, 7264C-2KTZ-2-240
Belt Load Cell - Lap	RADenton 3255
Belt Load Cell - Torso	RADenton 3255
Roll Rate Sensor	DTS ARS
Hybrid III, 50th Percentile Male	Denton 50th Male
Vertical Load Cell 1	Transducer Techniques, SWP-20k – 173372
Vertical Load Cell 2	Transducer Techniques, SWP-20k – 176138
Vertical Load Cell 3	Transducer Techniques, SWP-20k – 176139
Vertical Load Cell 4	Transducer Techniques, SWP-20k – 176140
Vertical Load Cell 5	Transducer Techniques, SWP-20k – 176141
Vertical Load Cell 6	Transducer Techniques, SWP-20k – 176142
Lateral Load Cell 1	Transducer Techniques, DSM-8k – 149806
Lateral Load Cell 2	Transducer Techniques, DSM-8k – 149807
Roadway Velocity Roll Encoder	Contelec – RSC 2201 236 111 106
Vehicle Data Acquisition System	Diversified Technical Systems, TDAS PRO SIM
Roadway Data Acquisition System	Diversified Technical Systems, TDAS PRO SIM
JRS Fixture Acquisition System	Measurement Computing, USB – 1608FS

Table 4 General Test Vehicle Data Test Vehicle: 2008 Toyota Highlander HV

Test Vehicle Information:	
Manufacturer: Toyota	VIN: JTEEW44A682003849
Gross Weight: 6000 lb	Curb Weight: 4571 lb
Sunroof: No	2WD/4WD: 4WD
Equivalent Years: 2008- Present	Body Type: 4 Door Mid-Size SUV

2. Test Results, Data Tables and Selected Comparison Photographs for Roll 1.

The results of the first roll of the JRS Dynamic Rollover Test are presented in this section. In the roll, the vehicle dropped as planned and contacted the vehicle's roof structure.

Roll 1 – 01/16/12

Summary of Results

Instrument	Peak Value	Residual Intrusion (inches)	Peak Velocity (mph)
Sum of Vertical Load Cells (near side contact)	20,277 lb		
Sum of Vertical Load Cells (far side contact)	22,436 lb		
Sum of Lateral Load Cells (near side contact)	1443 lb		
Sum of Lateral Load Cells (far side contact)	1516 lb		
Driver's Side A-Pillar String Potentiometer	-2.0 in	-1.5 in	-3.4
Roof Header String Potentiometer	*	*	*
Passenger's Side A-Pillar String Potentiometer	*	*	*

Instrument	Maximum Value	Minimum Value
Lap Belt Load	*	*
Shoulder Belt Load	*	*
Dummy Head Acceleration Ax	*	*
Dummy Head Acceleration Ay	*	*
Dummy Head Acceleration Az	*	*
Lower Neck Load Cell Fx	*	*
Lower Neck Load Cell Fy	*	*
Lower Neck Load Cell Fz	*	*
Lower Neck Load Cell Mx	*	*
Lower Neck Load Cell My	*	*
Upper Neck Load Cell Fz	*	*
HIC	*	

*Data from the vehicle instrumentation and roadway towers was lost due to a power short. Values have been derived from the high-speed cameras when possible.

The vertical load cells mounted on the roadway platform show the near and far side impacts. For the first roll, the vehicle struck the roadway on the near side at approximately 1.73 seconds. The entire roll sequence was completed by approximately 2.5 seconds.

During the first roll there was very little deformation and, due to high elasticity, an over 25% recovery from peak deformation. The sunroof did not break and the windshield experienced localized cracking but did not fail completely.

Pull tests were conducted on both the driver side doors of the vehicle after the first roll. Each door required less than 15 lb-f to open.

Roll 1 Comparison Photographs

Figure 1: Vehicle Pre Roll 1

Figure 2: Vehicle Post Roll 1

3. Test Results, Data Tables and Selected Comparison Photographs for Roll 2.

The results of the second roll of the JRS Dynamic Rollover Test are presented in this section. In the roll, the vehicle dropped as planned and contacted the moving roadbed.

Roll 2 – 01/17/12

Summary of Results

Instrument	Peak Value	Residual Intrusion (inches)	Peak Velocity (mph)
Sum of Vertical Load Cells (near side contact)	14,181 lb		
Sum of Vertical Load Cells (far side contact)	23,705 lb		
Sum of Lateral Load Cells (near side contact)	961 lb		
Sum of Lateral Load Cells (far side contact)	1094 lb		
Driver's Side A-Pillar String Potentiometer	-5.0	-2.3	-7.1
Roof Header String Potentiometer	-1.6	-0.6	-2.2
Passenger's Side A-Pillar String Potentiometer	-4.0	-2.1	-4.3

Instrument	Maximum Value	Minimum Value
Lap Belt Load	346 lb	-46 lb
Shoulder Belt Load	159 lb	-5 lb
Dummy Head Acceleration Ax	26 g	-9 g
Dummy Head Acceleration Ay	13 g	-3 g
Dummy Head Acceleration Az	31 g	-3 g
Lower Neck Load Cell Fx	915 N	-134 N
Lower Neck Load Cell Fy	64 N	-313 N
Lower Neck Load Cell Fz	262 N	-827 N
Lower Neck Load Cell Mx	21 N-m	-26 N-m
Lower Neck Load Cell My	98 N-m	-38 N-m
Upper Neck Load Cell Fz	227 N	-1,536 N
HIC	43	

The vertical load cells mounted on the roadway platform show the near and far side impacts. The vehicle struck the roadway on the near side at approximately 1.72 seconds. The entire roll sequence was completed by approximately 2.05 seconds.

The string potentiometers located on the fixture support towers show the vertical vehicle motion throughout the test. The front of the vehicle dropped 4.34 inches and the rear dropped 3.83 inches prior to initial touch down. The vehicle was pitched at 10 degrees at contact.

The roll encoder located on the cable pulley shows the roadway velocity throughout the roll. During the second roll, the roadway was traveling at 14.97 mph at contact. A roll rate sensor in the vehicle was used to determine the roll angle and roll rate at impact. The roll angle of the vehicle was 137 degrees and the roll rate was 176 degrees per second at the roadway impact.

During the second roll the windshield fractured further. No other windows broke during this roll.

Pull tests were conducted on both the driver side doors of the vehicle after the second roll. The two rear doors required less than 15 lb-f to open. The front two doors were stuck behind the top front corners of the two rear doors due to deformation and could not be opened without the rear doors opened first. Once the two rear doors were open the front doors required less than 15 lb-f each to open.

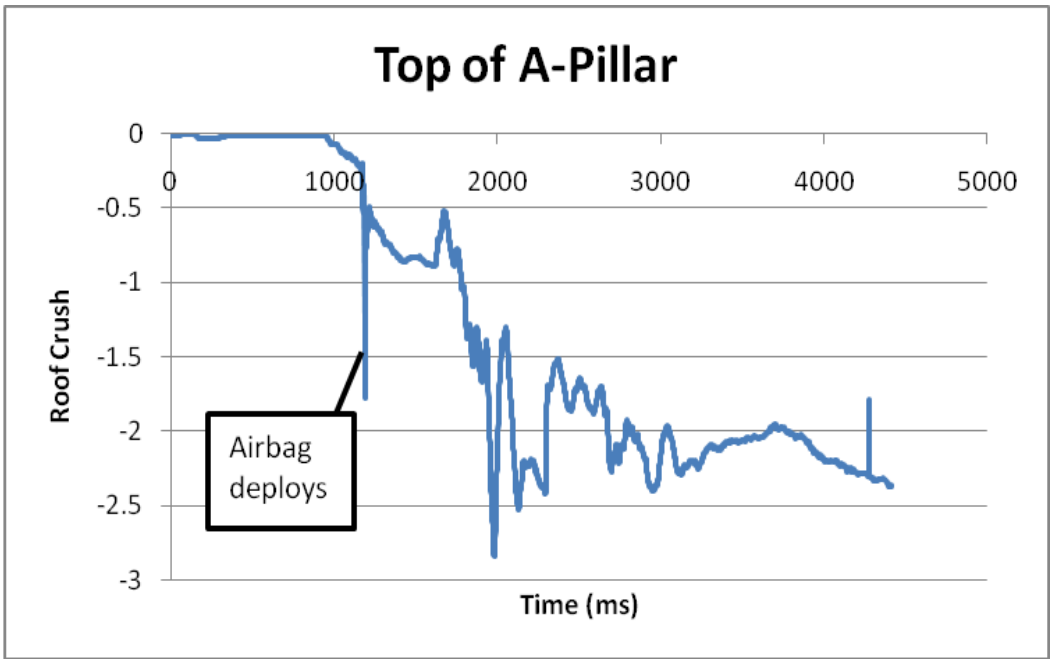
Roll 2 Comparison Photographs

Figure 3: Vehicle Pre Roll 2

Figure 4: Vehicle Post Roll 2

4. Data Graphs

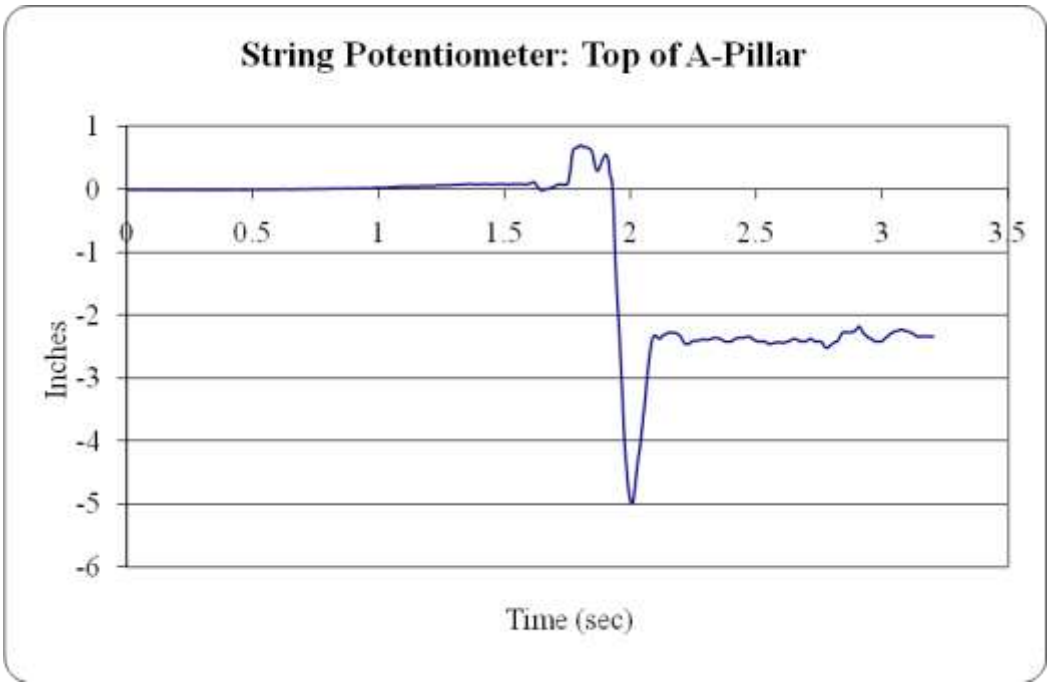
Roll 1 Data Plots – 01/16/12



Plot 1: Top of Driver's Side A-Pillar Displacement v. Time

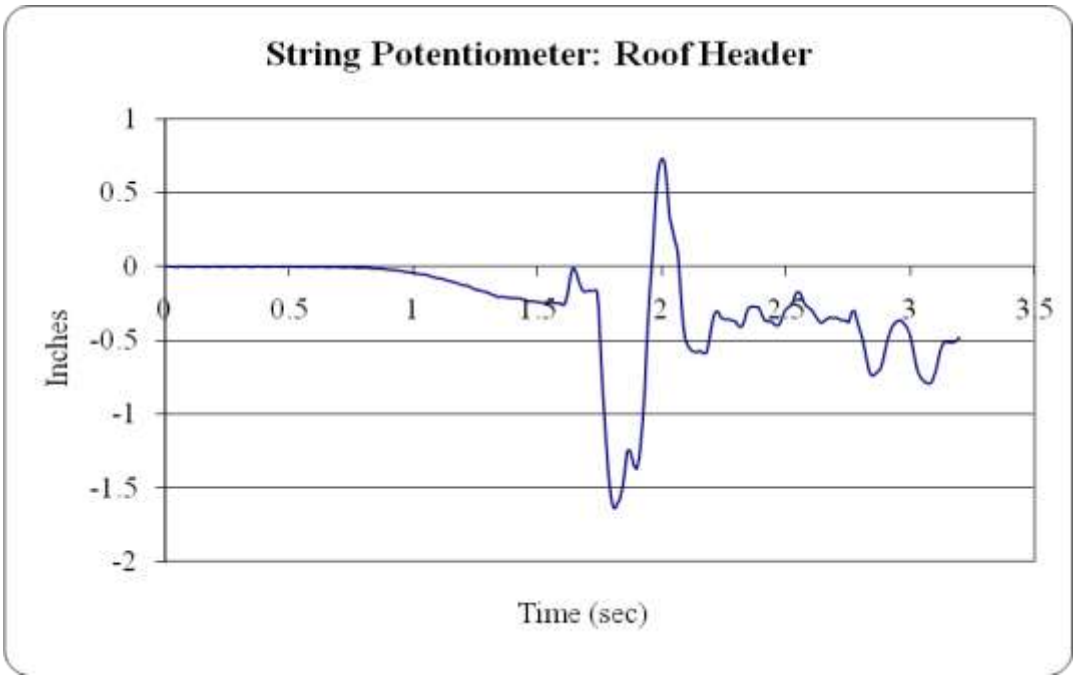
Data Sampling Rate: 10 kHz

Roll 2 Data Plots – 01/17/12



Plot 2: String Potentiometer Driver's Side A-Pillar Displacement v. Time

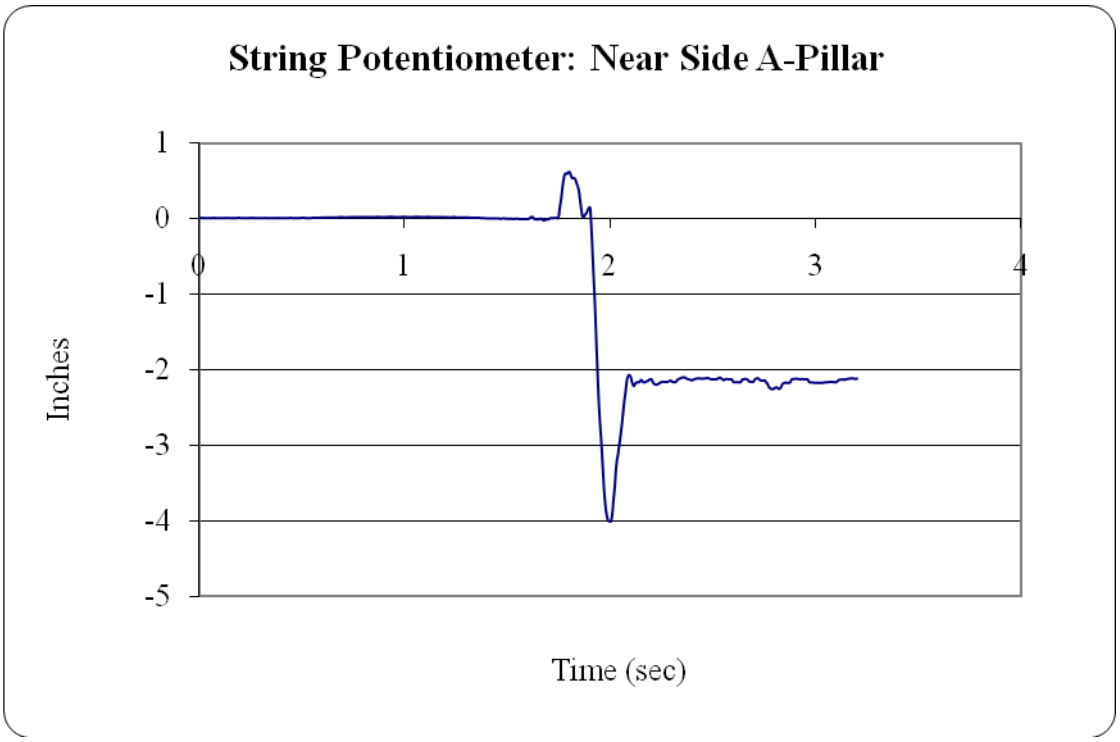
Data Sampling Rate: 10 kHz



Plot 3: String Potentiometer Driver's Side Roof Header Displacement v. Time

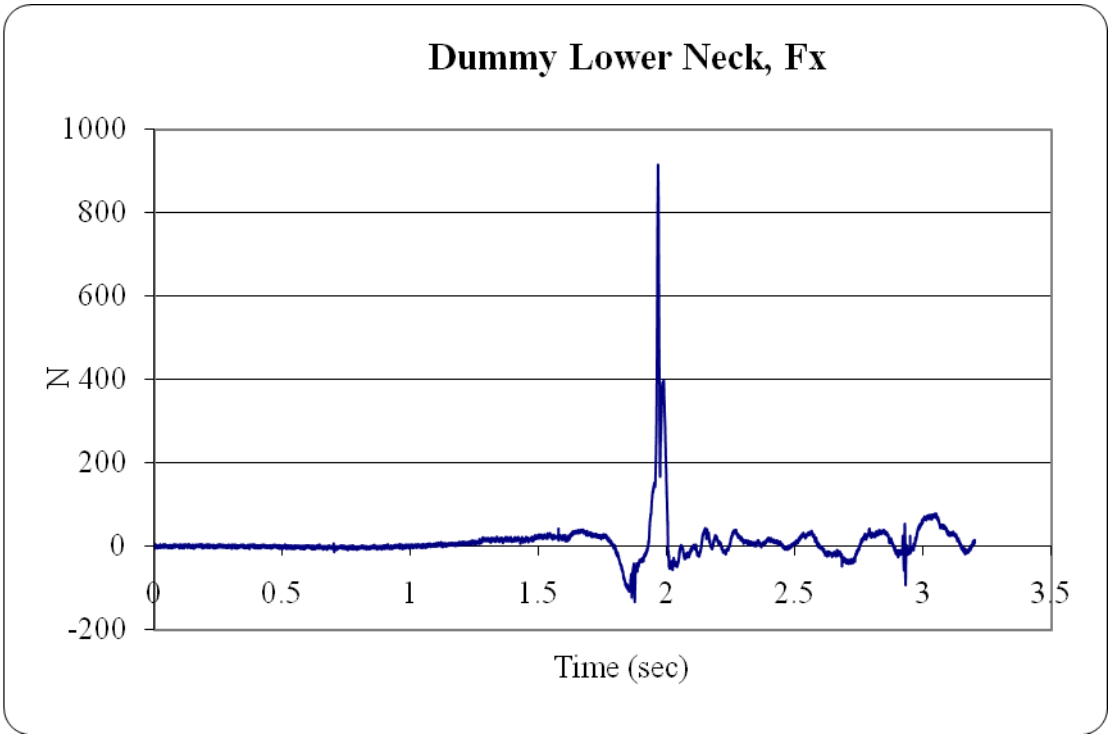
Data Sampling Rate: 10 kHz

Roll 2



Plot 4: String Potentiometer Passenger's Side A-Pillar Displacement v. Time

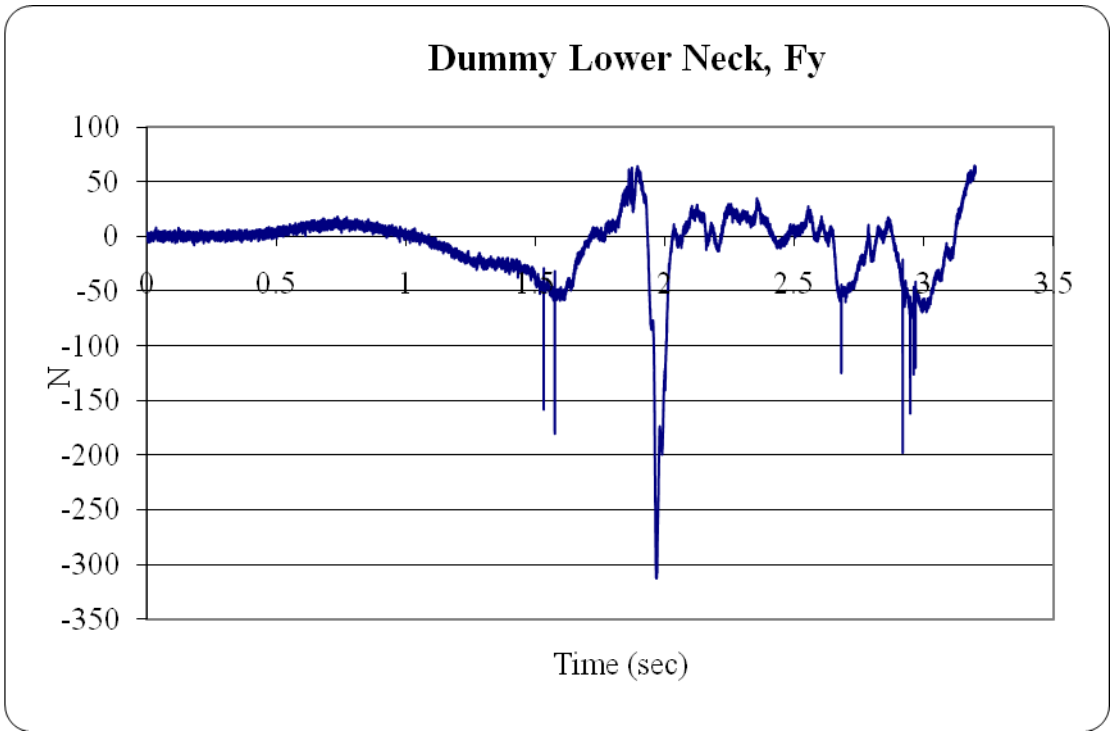
Data Sampling Rate: 10 kHz



Plot 5: Lower Neck Load, Fx, v. Time

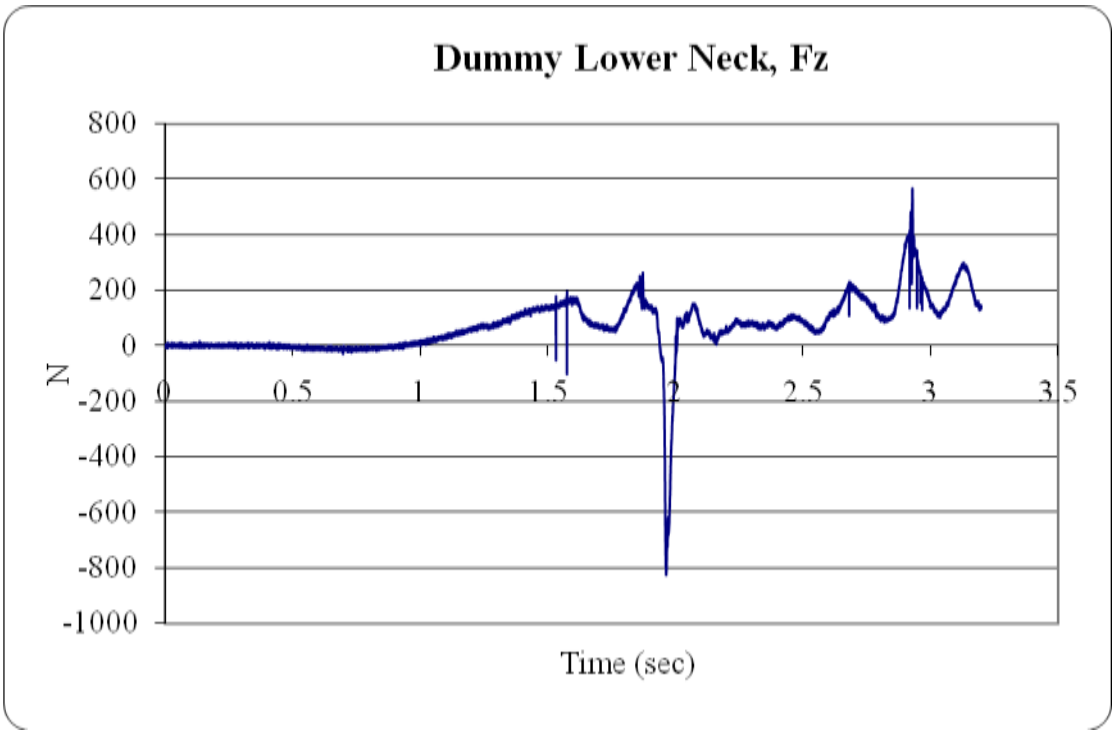
Data Sampling Rate: 10 kHz

Roll 2



Plot 6: Lower Neck Load, Fy, v. Time

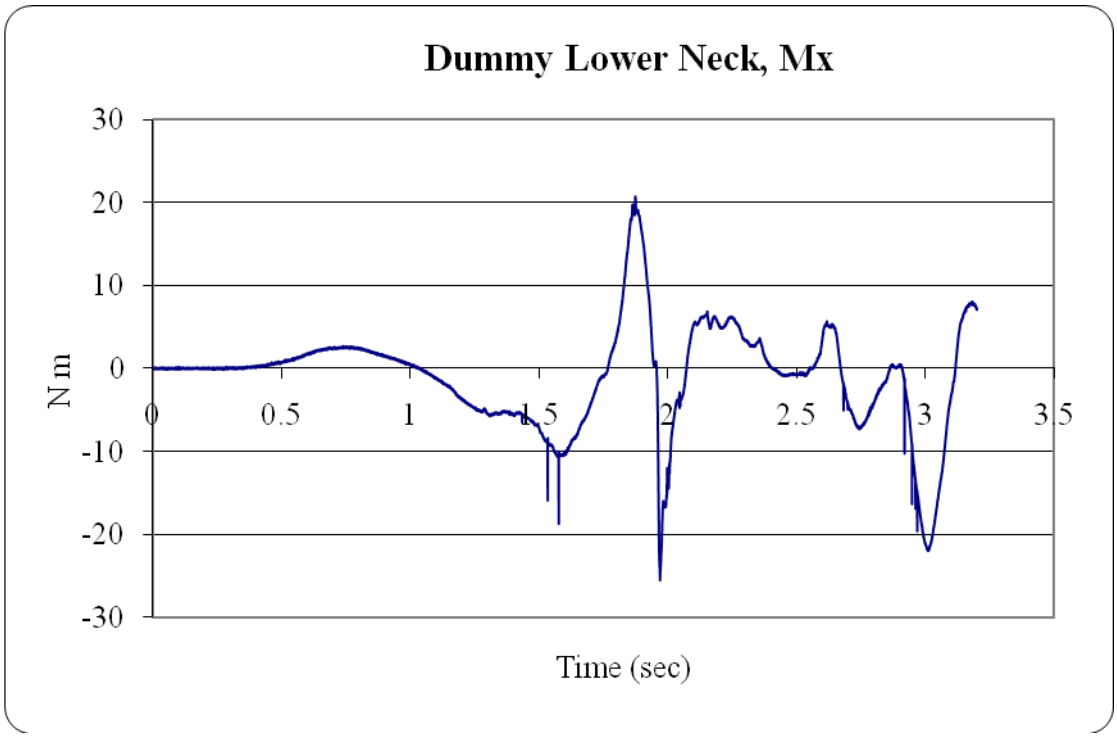
Data Sampling Rate: 10 kHz



Plot 7: Lower Neck Load, Fz, v. Time

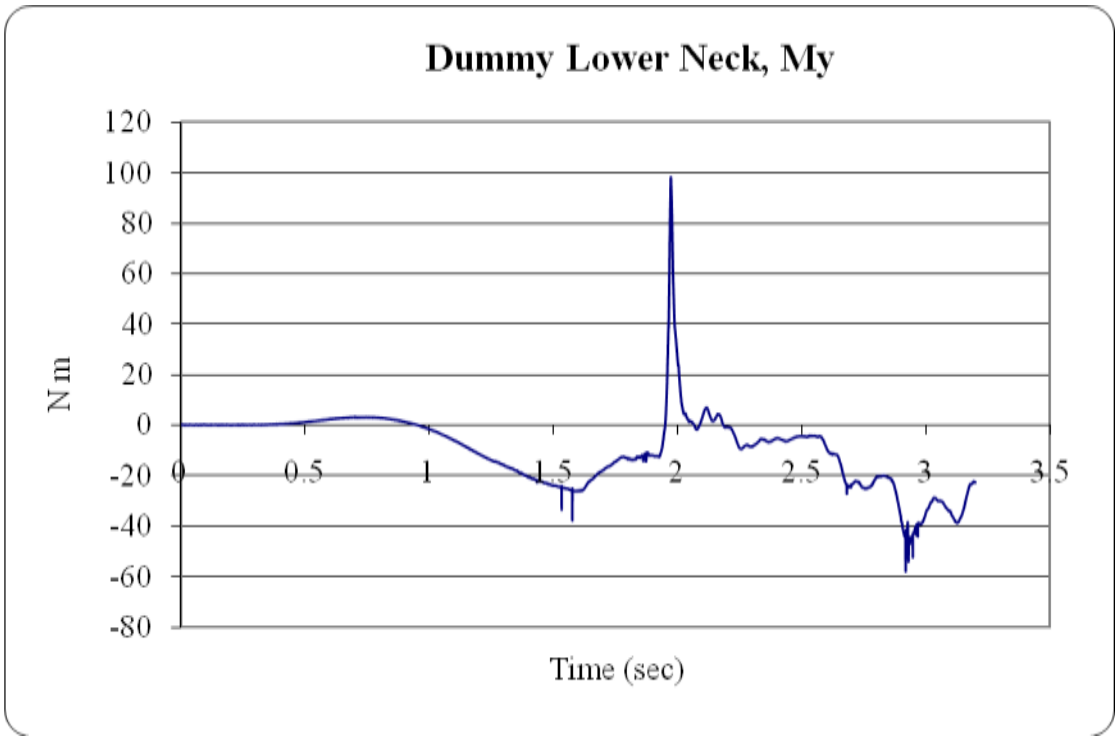
Data Sampling Rate: 10 kHz

Roll 2



Plot 8: Lower Neck Load, Mx, v. Time

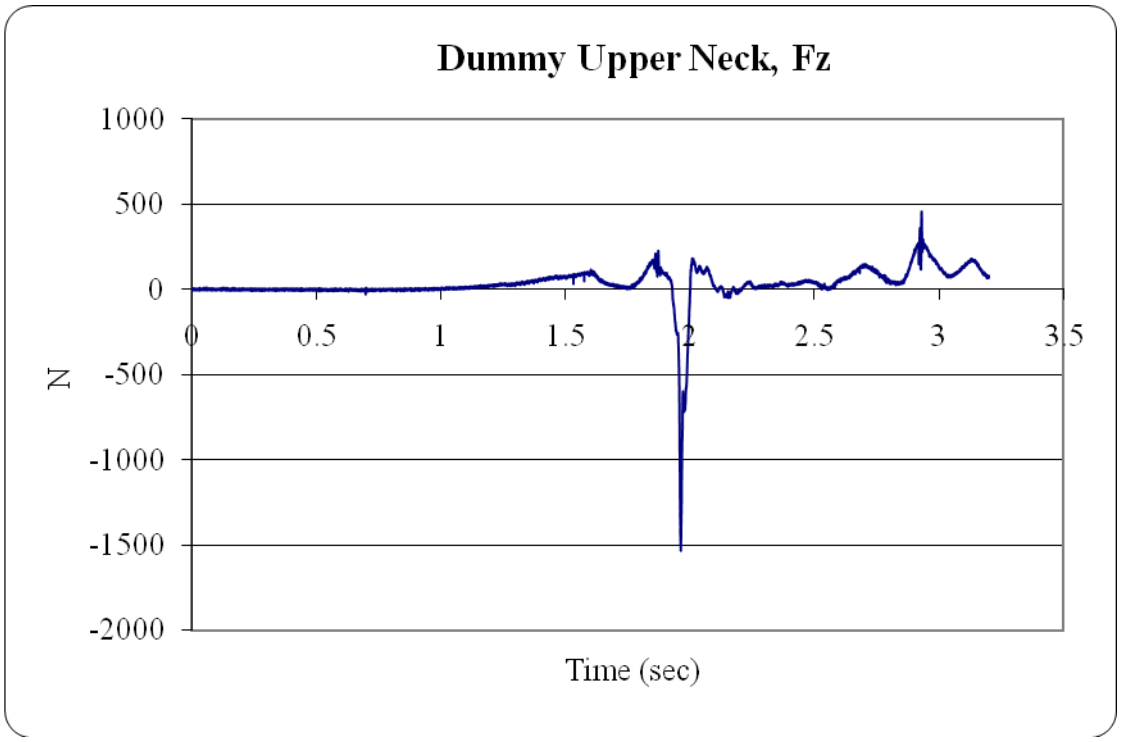
Data Sampling Rate: 10 kHz



Plot 9: Lower Neck Load, My, v. Time

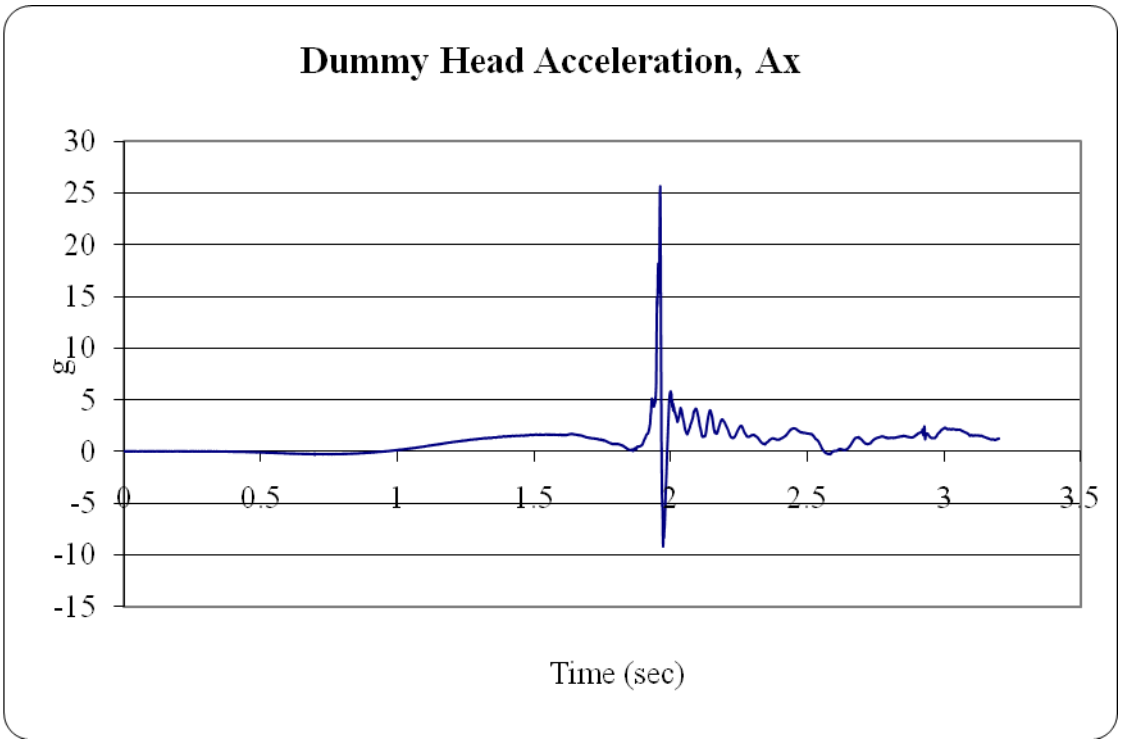
Data Sampling Rate: 10 kHz

Roll 2



Plot 10: Upper Neck Load, Fz, v. Time

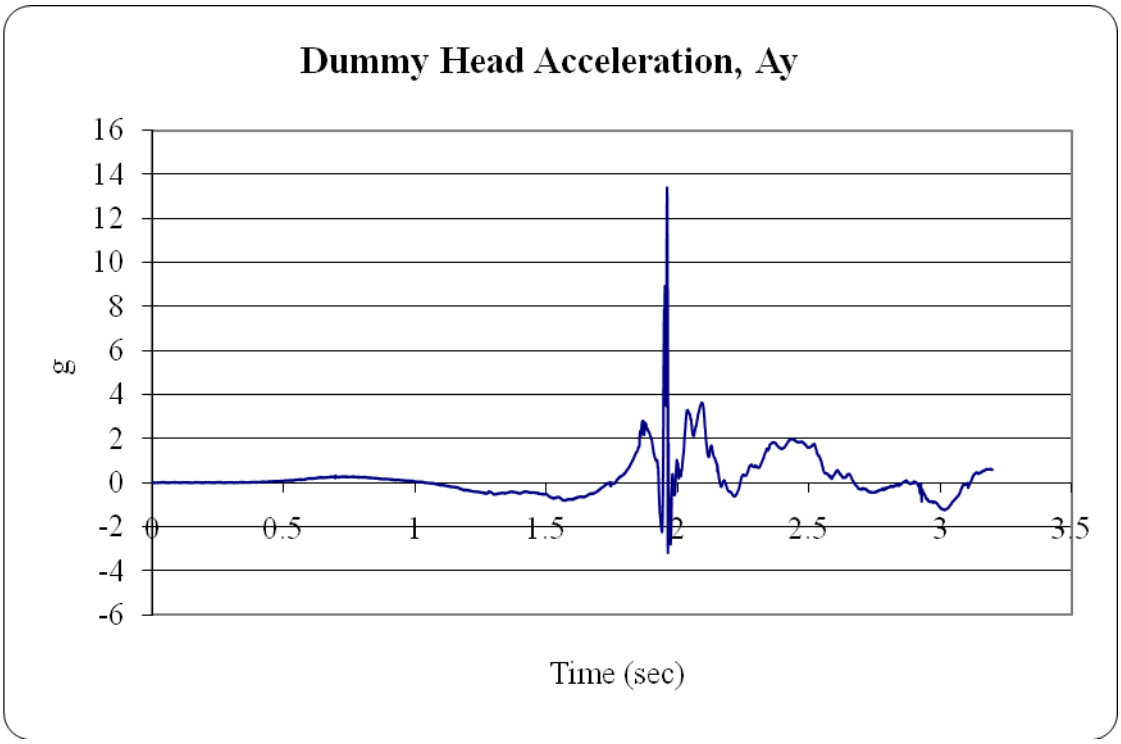
Data Sampling Rate: 10 kHz



Plot 11: Head Acceleration, Ax, vs. Time

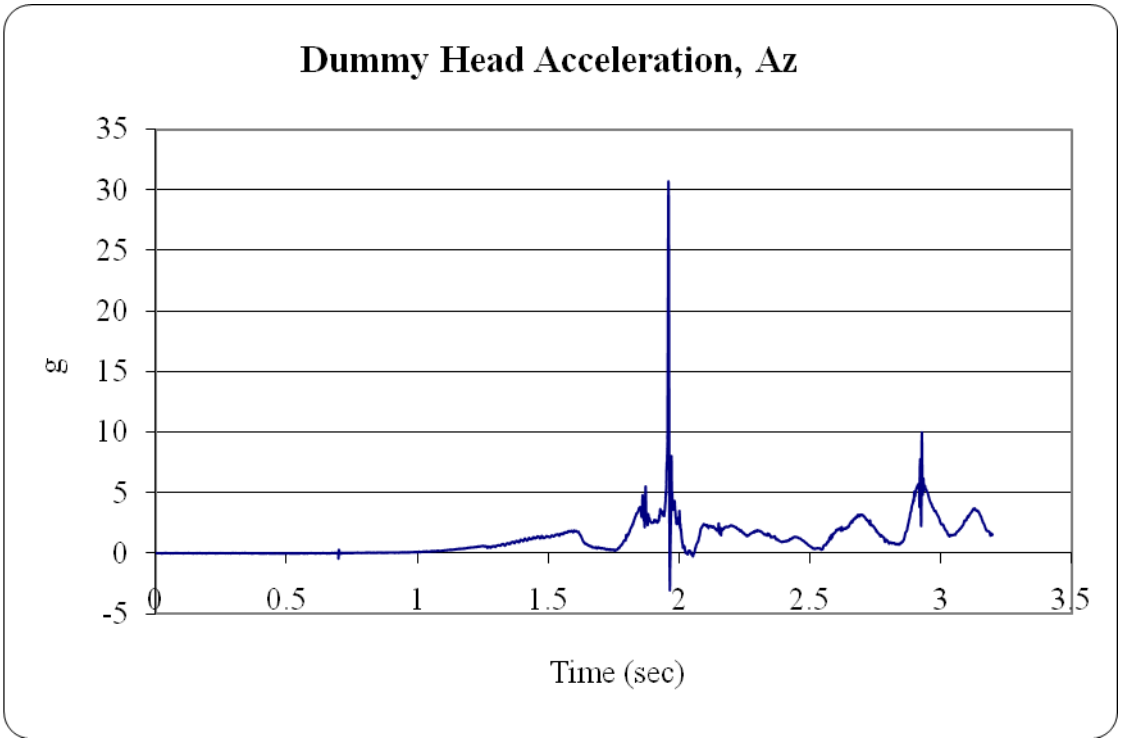
Data Sampling Rate: 10 kHz

Roll 2



Plot 12: Head Acceleration, Ay, vs. Time

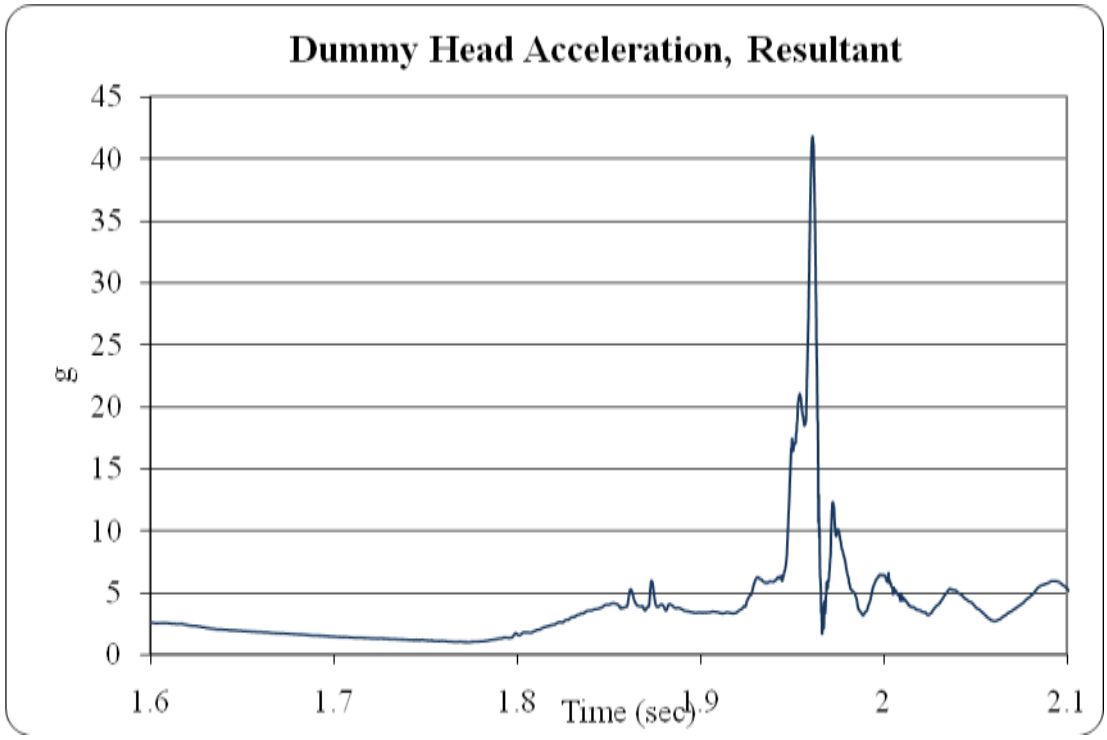
Data Sampling Rate: 10 kHz



Plot 13: Head Acceleration, Az, vs. Time

Data Sampling Rate: 10 kHz

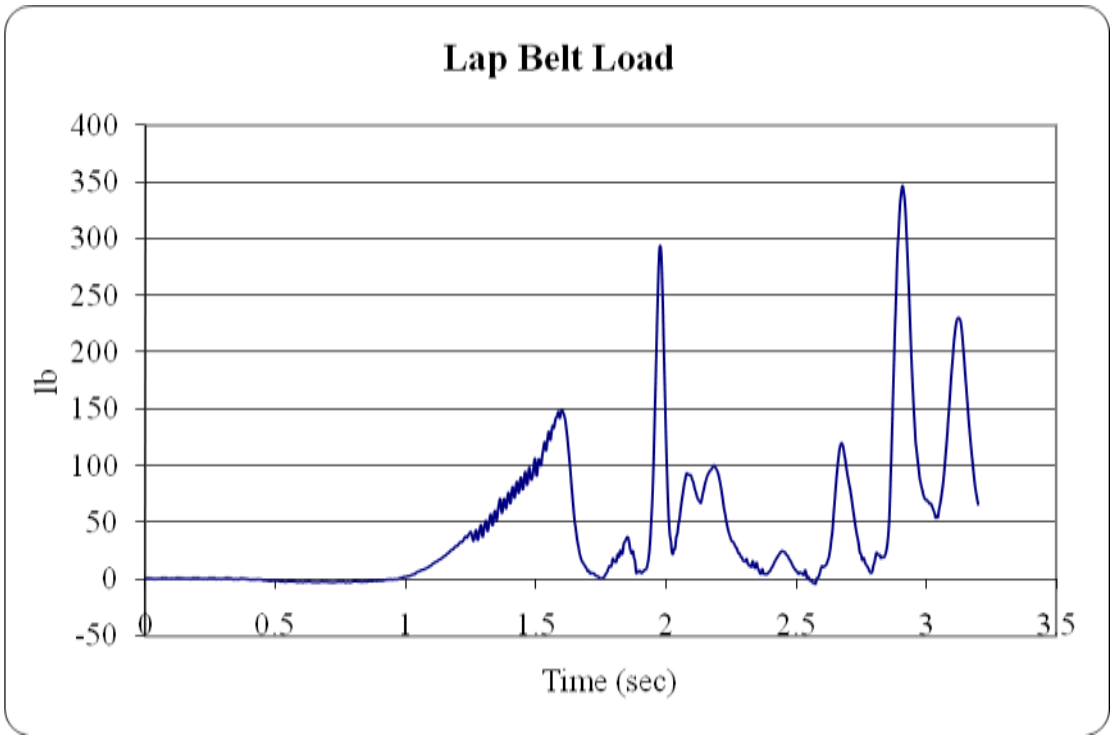
Roll 2



Plot 14: Resultant Head Acceleration vs. Time

HIC = 37

Data Sampling Rate: 10 kHz

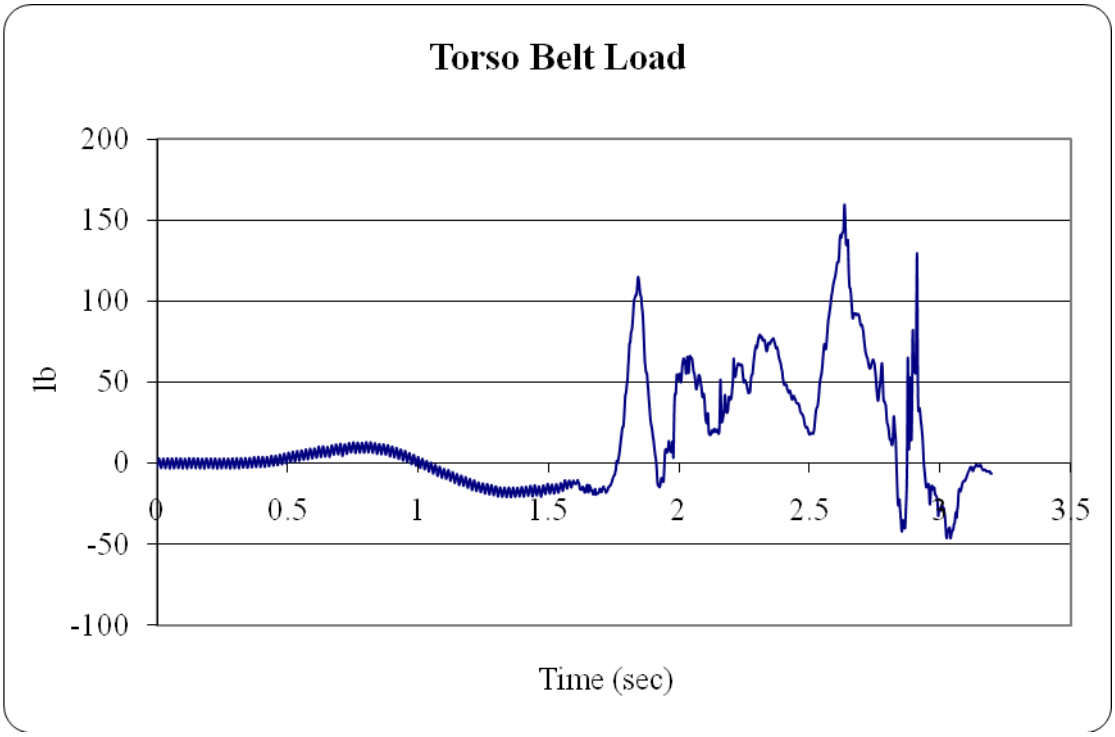


Plot 15: Lap Belt Load* vs. Time

*Measured on one side of the belt

Data Sampling Rate: 10 kHz

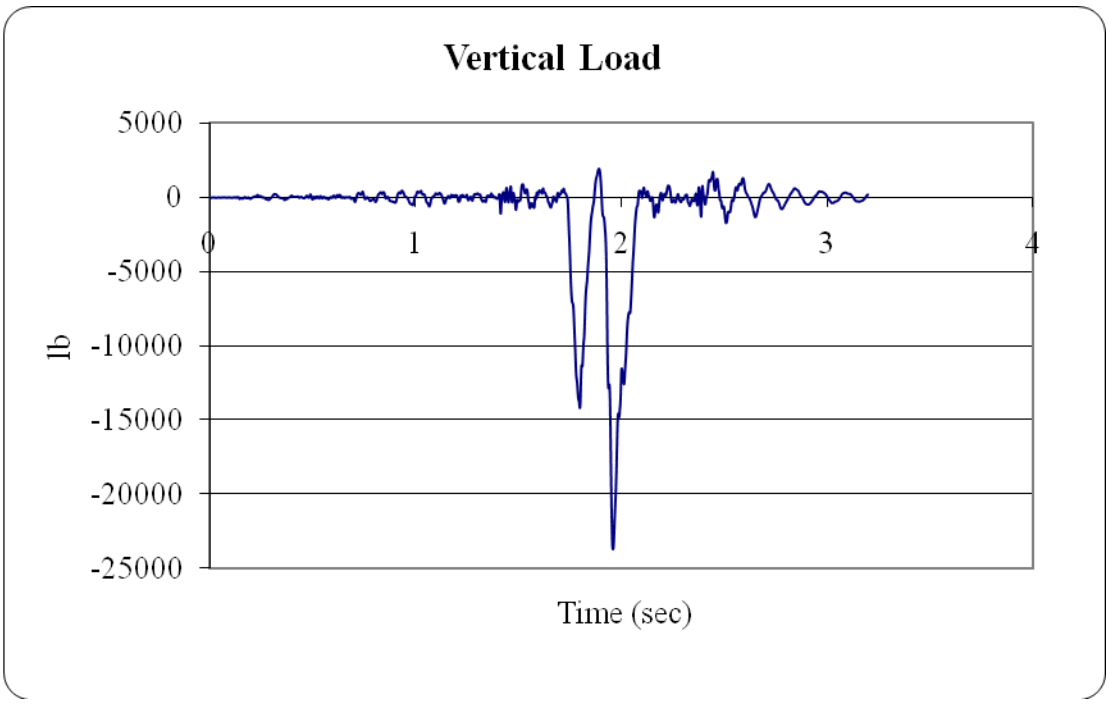
Roll 2



Plot 16: Torso Belt Load* vs. Time

*Measured on one side of the belt

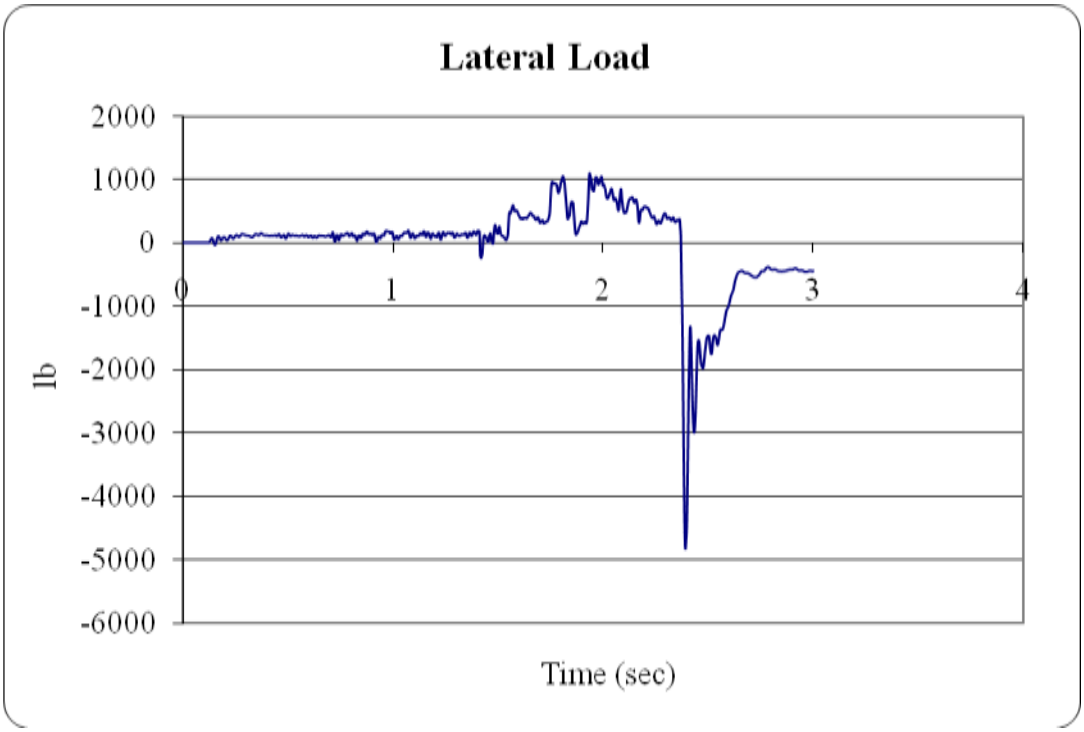
Data Sampling Rate: 10 kHz



Plot 17: Total Vertical Load v. Time

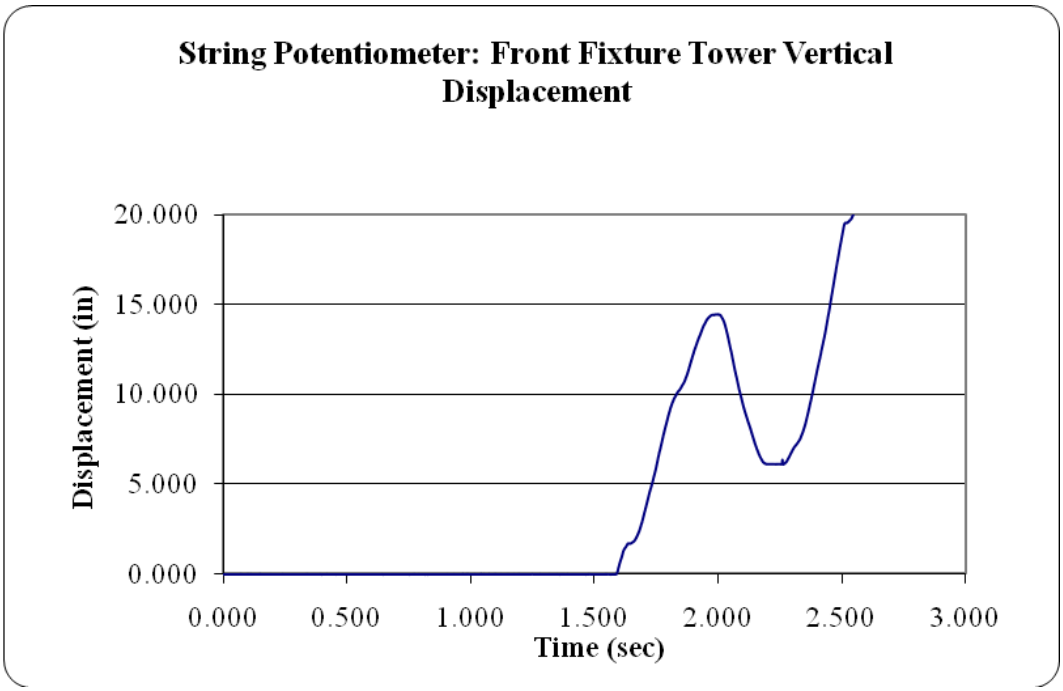
Data Sampling Rate: 10 kHz

Roll 2



Plot 18: Total Lateral Load v. Time

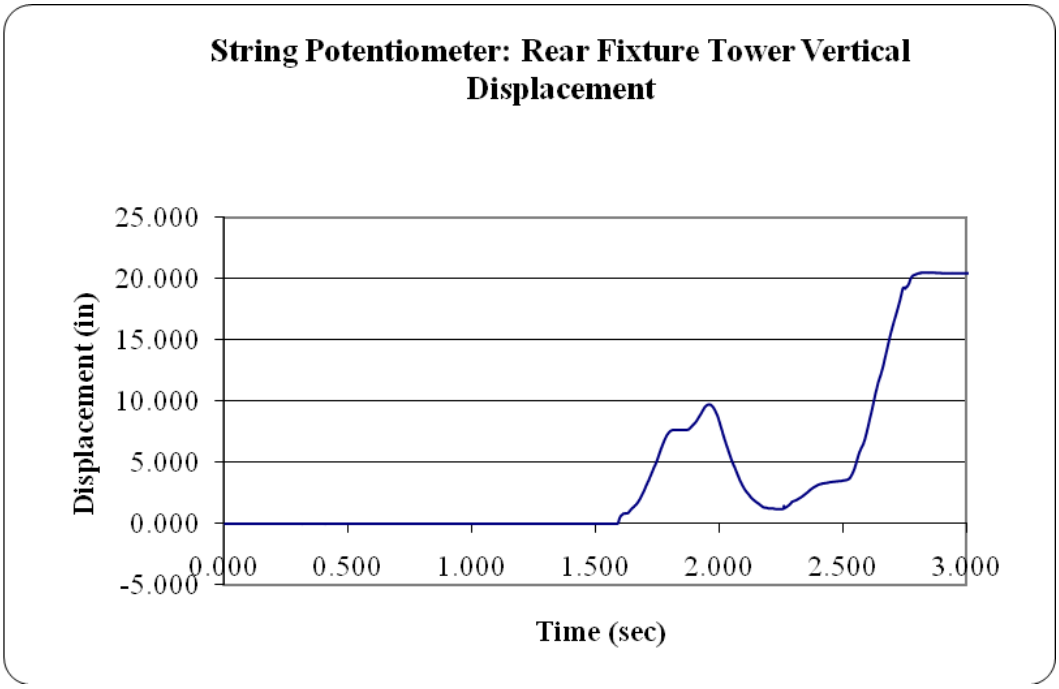
Data Sampling Rate: 10 kHz



Plot 19: String Potentiometer Front Fixture Support Tower Displacement vs. Time

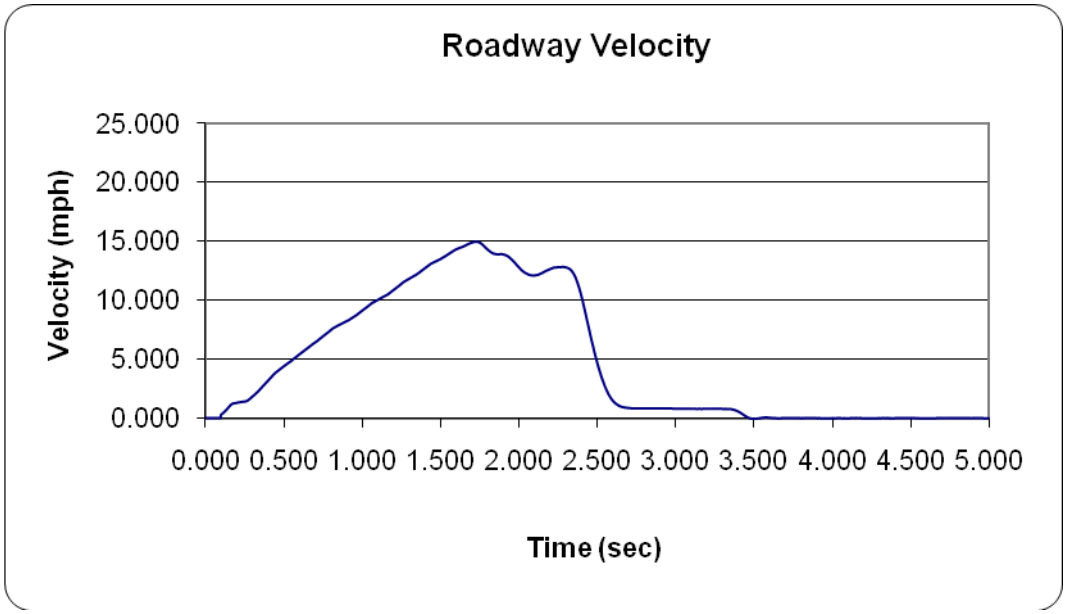
Data Sampling Rate: 1 kHz

Roll 2



Plot 20: String Potentiometer Rear Fixture Support Tower Displacement vs. Time

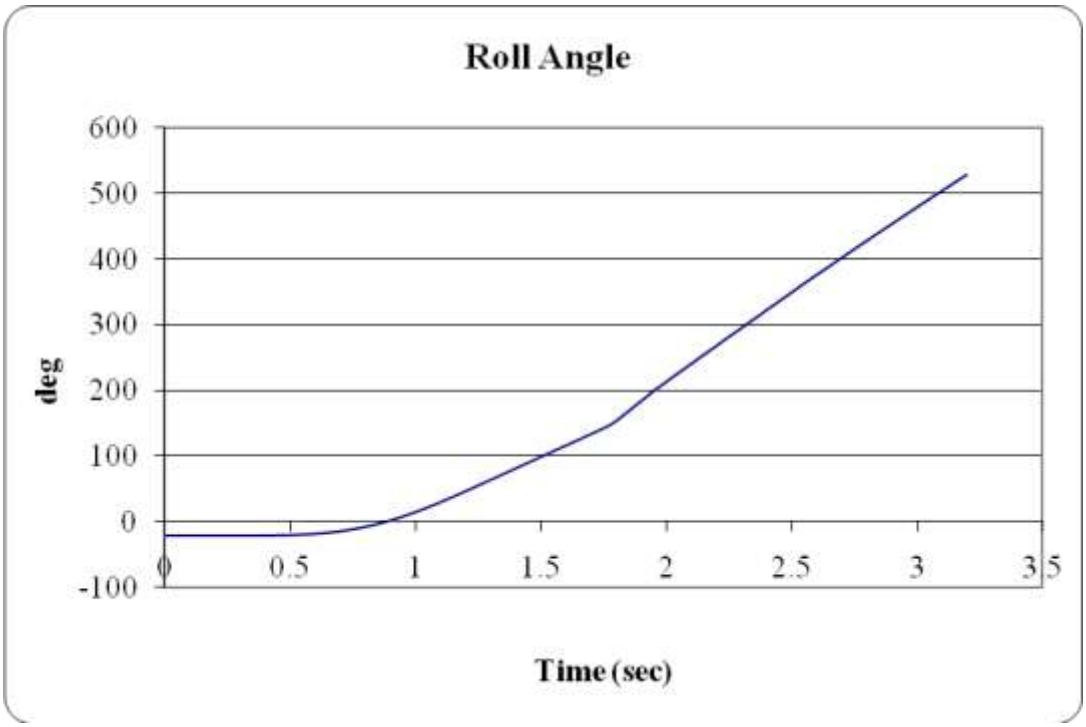
Data Sampling Rate: 1 kHz



Plot 21: Roll Encoder on Roadway Velocity vs. Time

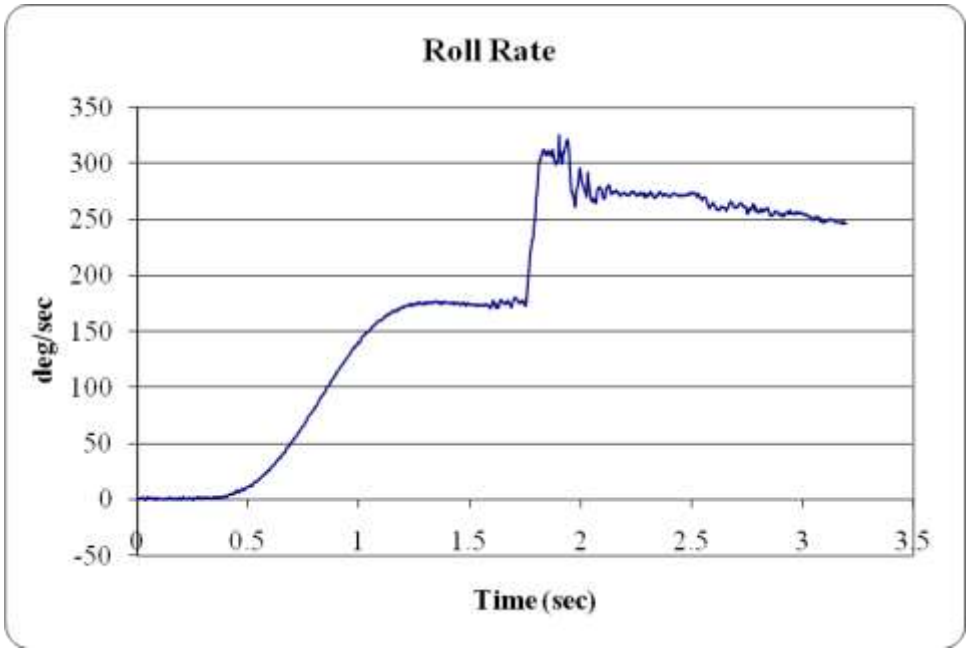
Data Sampling Rate: 1 kHz

Roll 2



Plot 22: Roll Angle vs. Time

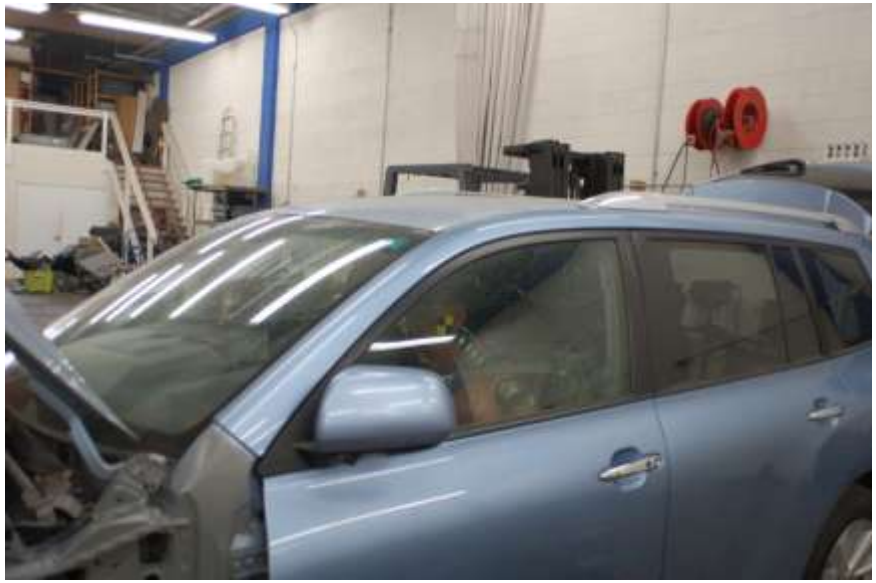
Data Sampling Rate: 10 kHz



Plot 23: Roll Rate vs. Time

Data Sampling Rate: 10 kHz

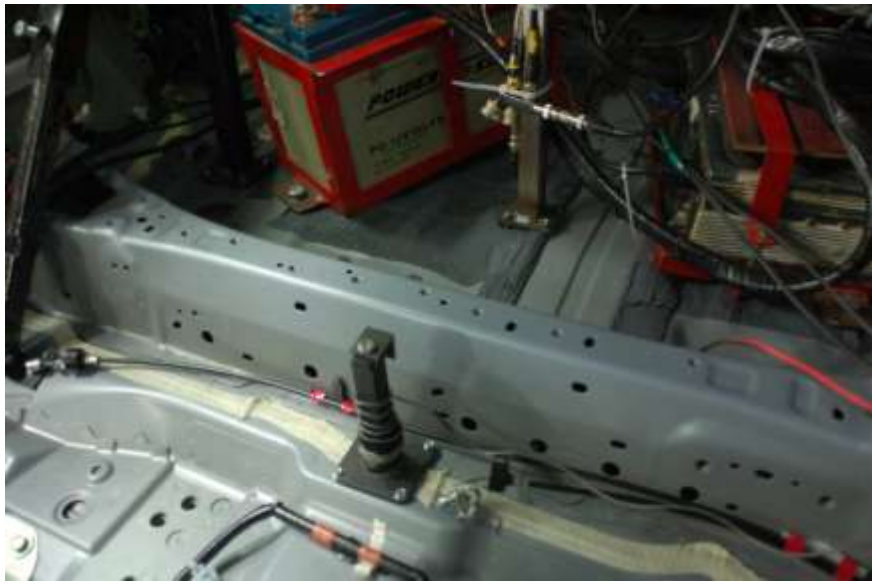
5. All Test Photographs – Test Setup



Vehicle Instrumentation

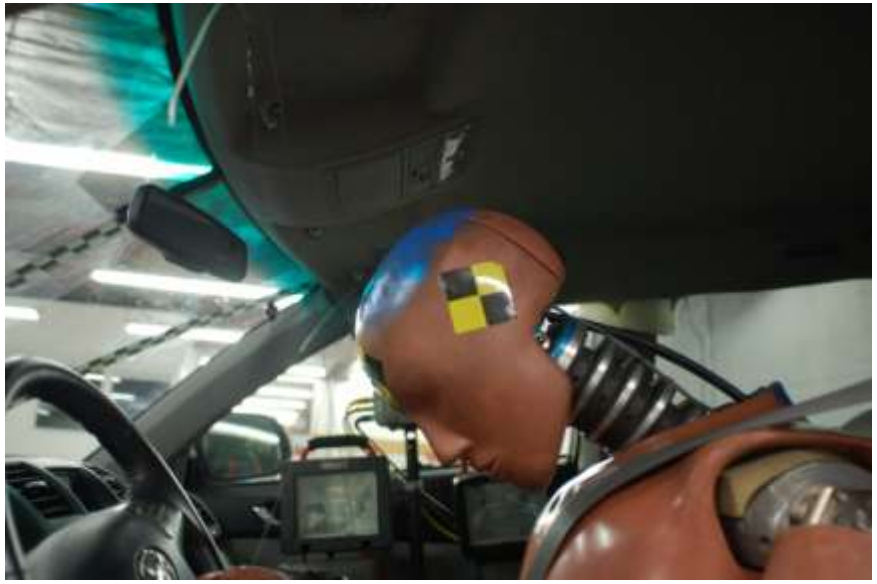



Vehicle Instrumentation



Vehicle Instrumentation

Roll 1 Photographs – 01/16/2012 – Dummy Inspection

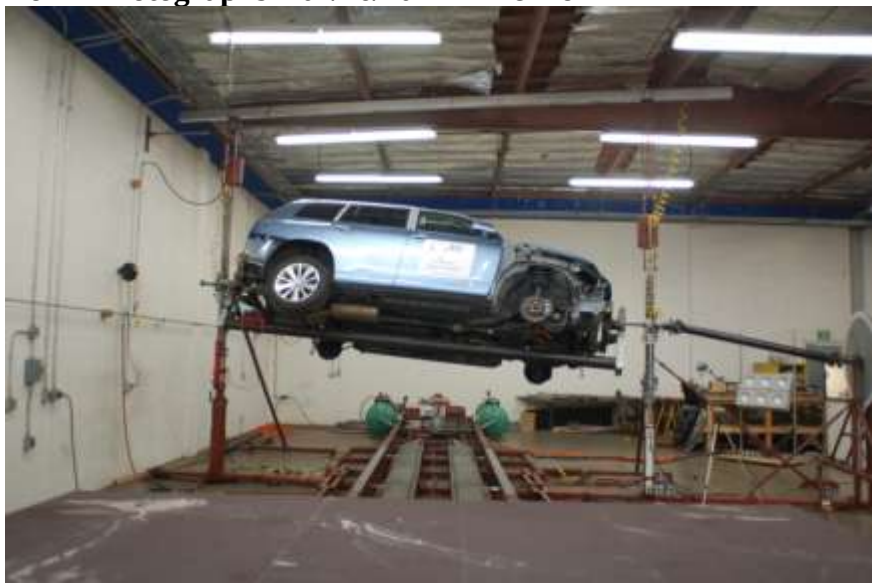
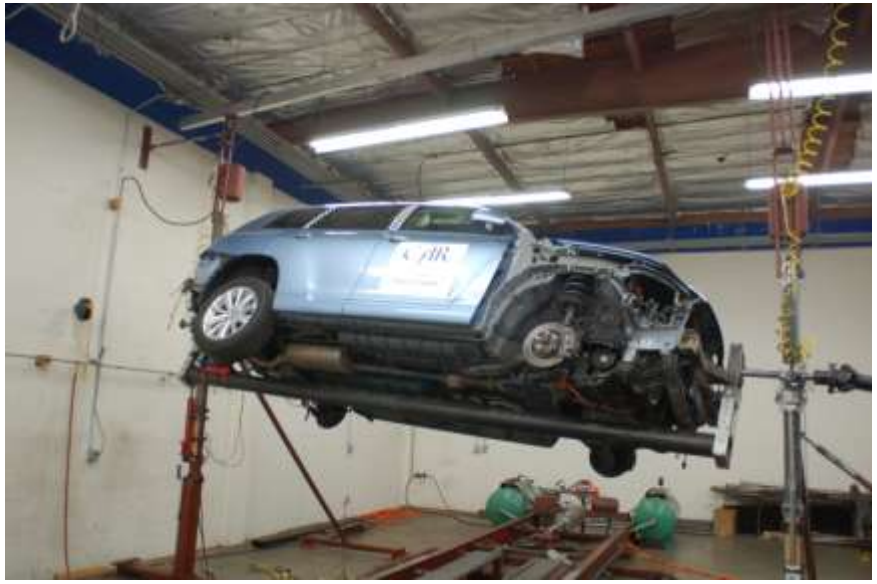



Roll 1 Photographs – 01/16/2012 – Dummy Inspection

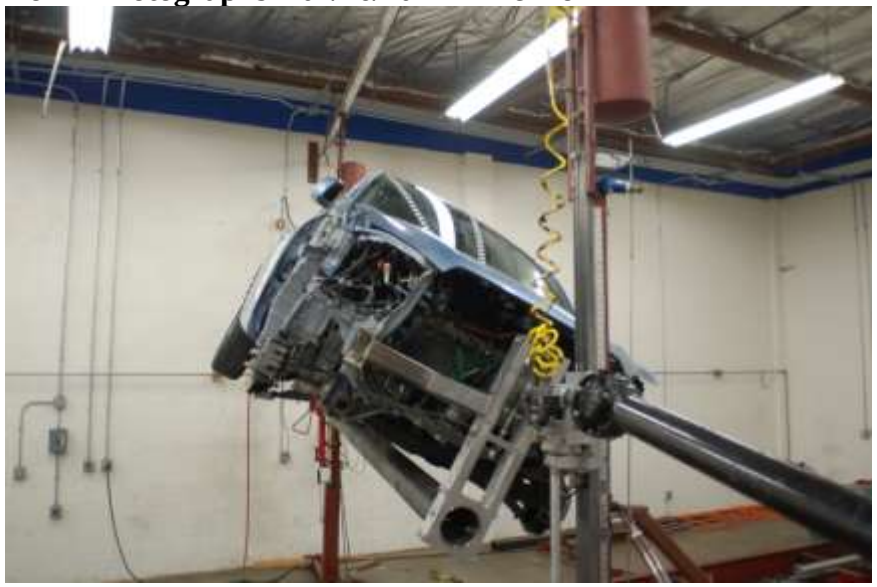


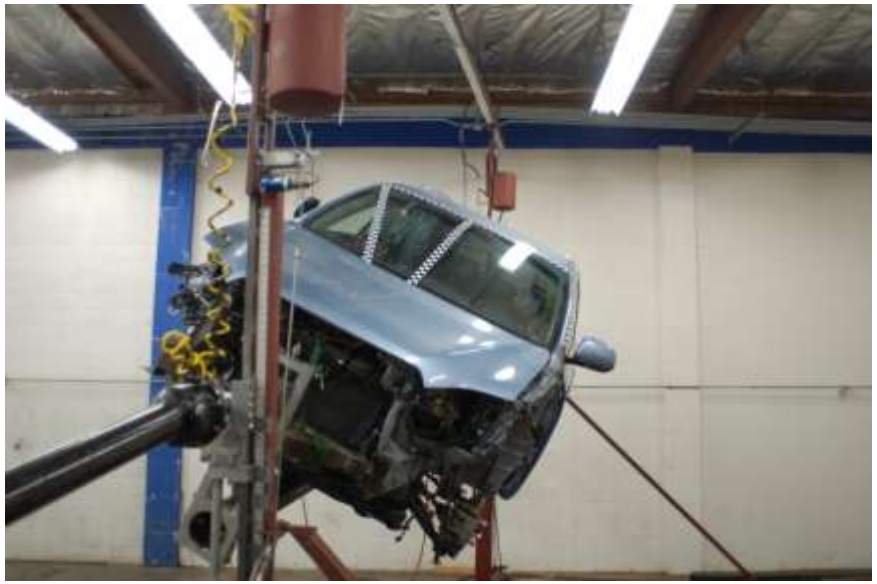

Roll 1 Photographs – 01/16/2012 – Dummy Inspection

Roll 1 Photographs – 01/16/2012 – Pre-Roll

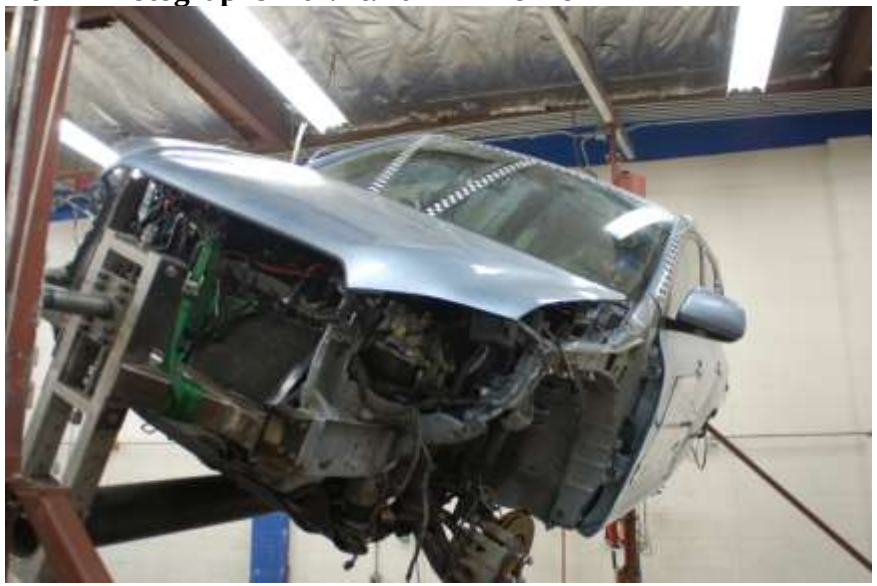



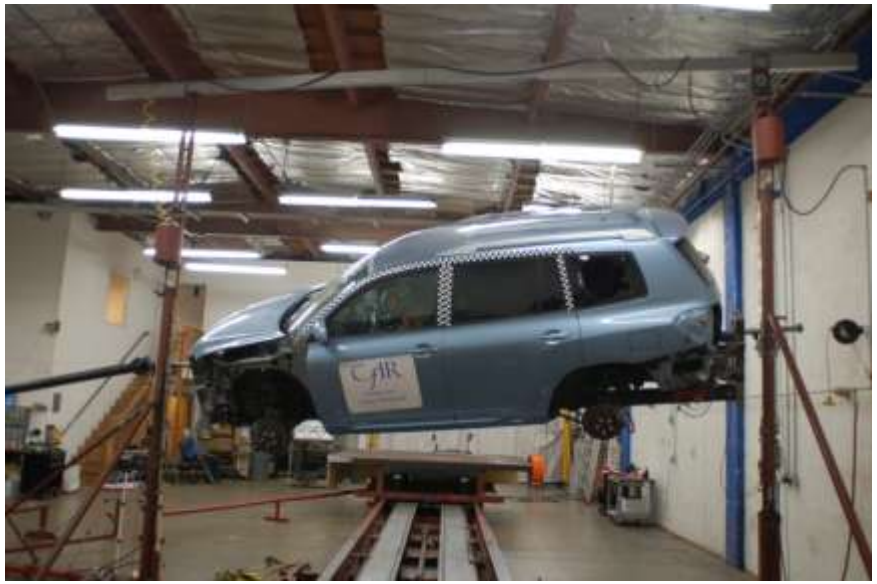
Roll 1 Photographs – 01/16/2012 – Pre-Roll





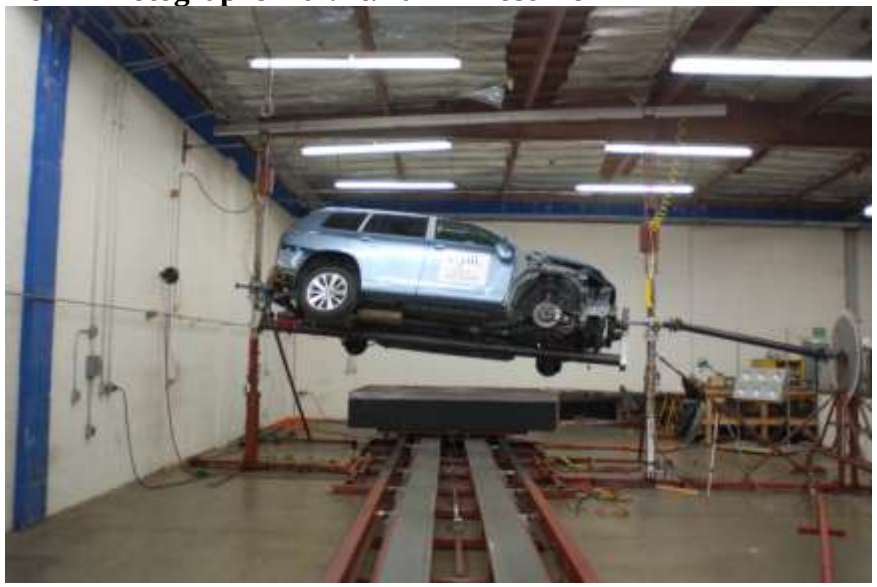
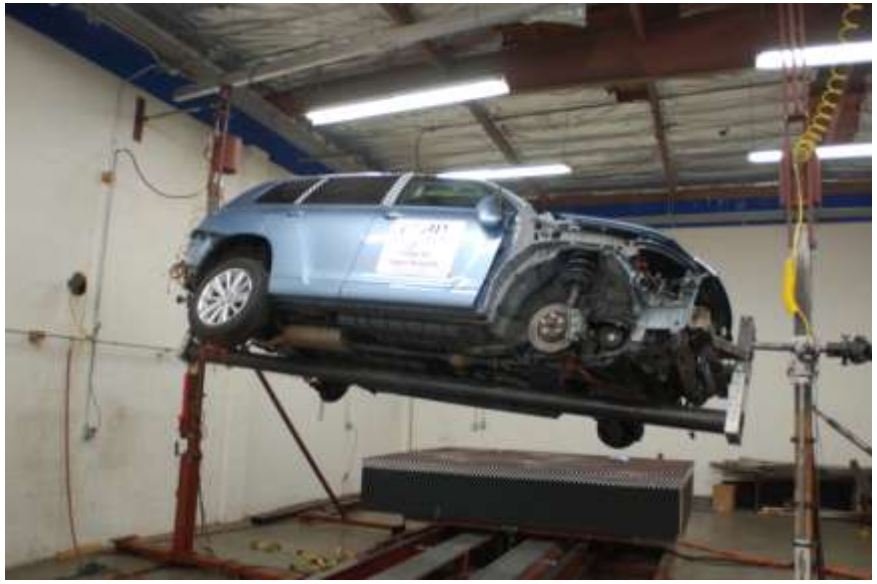
Roll 1 Photographs – 01/16/2012 – Pre-Roll



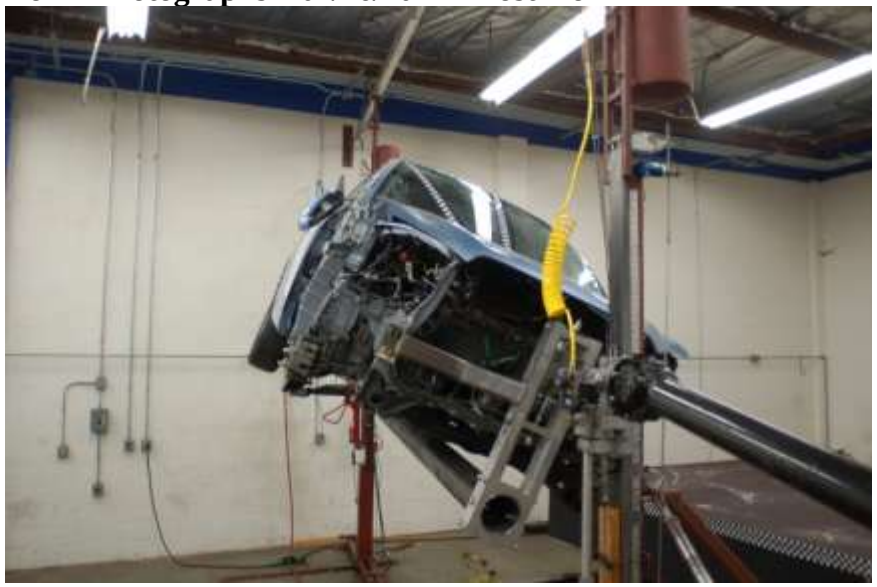


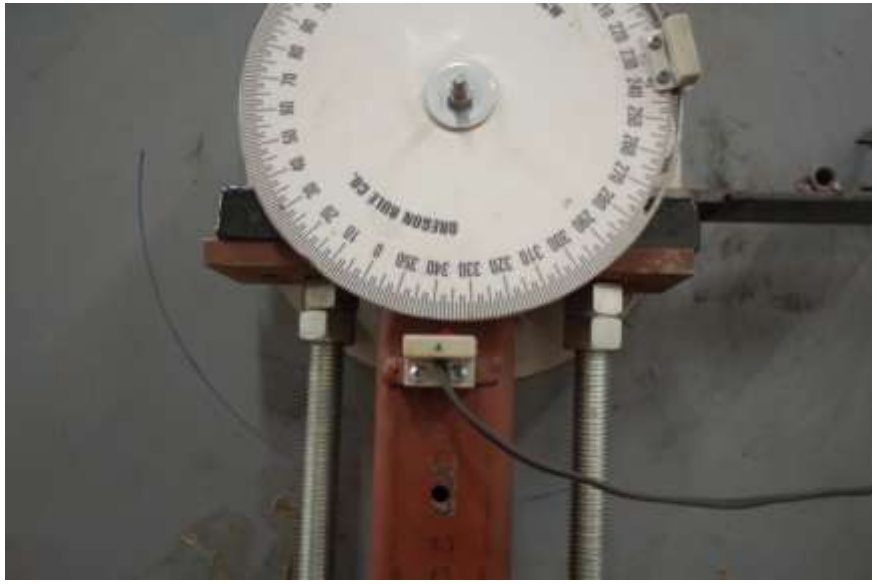
Roll 1 Photographs – 01/16/2012 – Pre-Roll

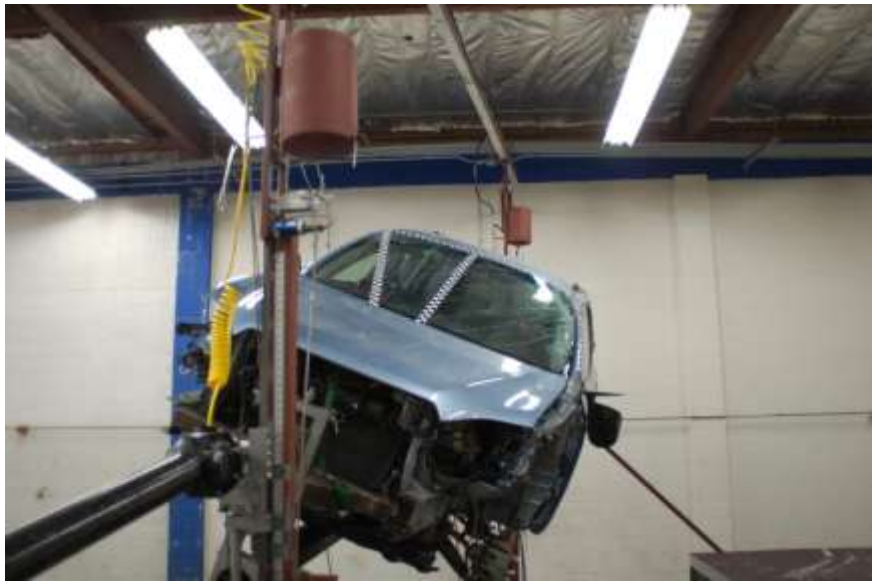
Roll 1 Photographs – 01/16/2012 – Post-Roll

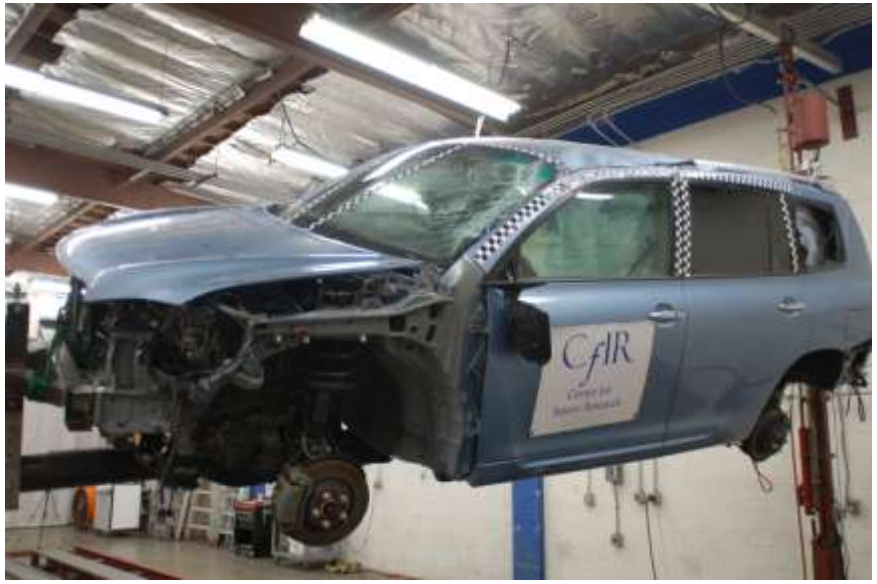
Roll 1 Photographs – 01/16/2012 – Post-Roll

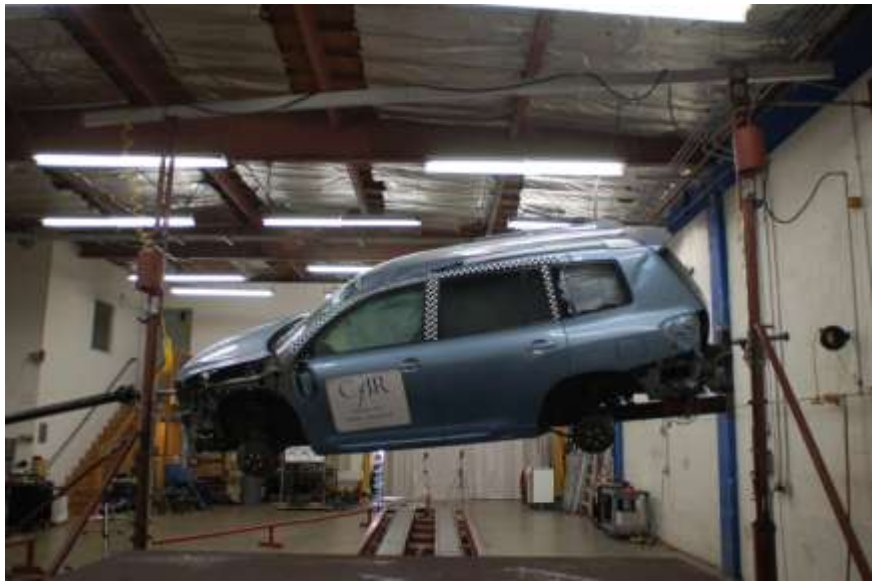






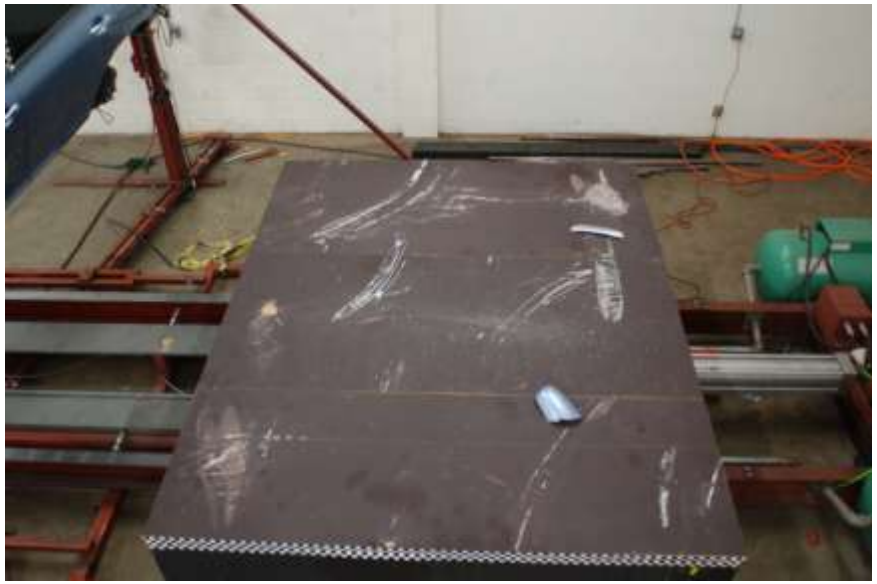
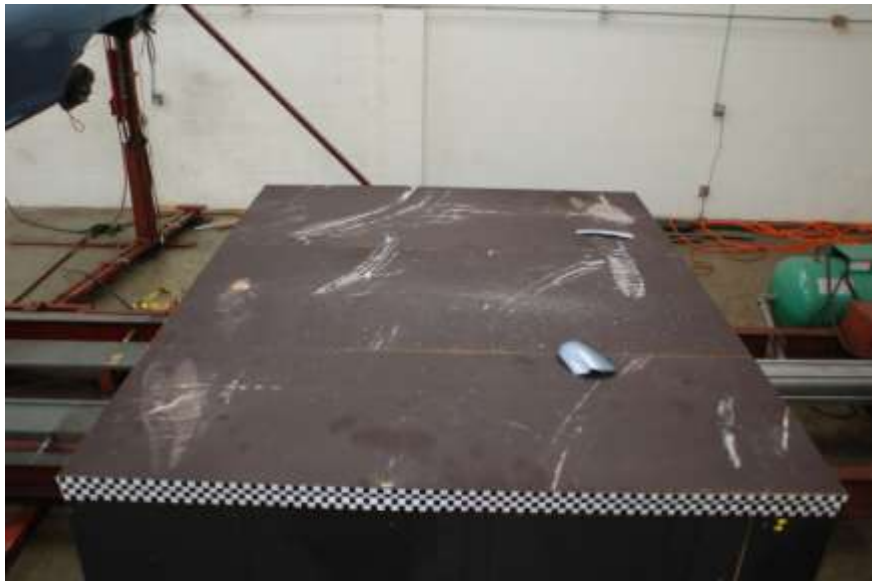
Roll 1 Photographs – 01/16/2012 – Post-Roll





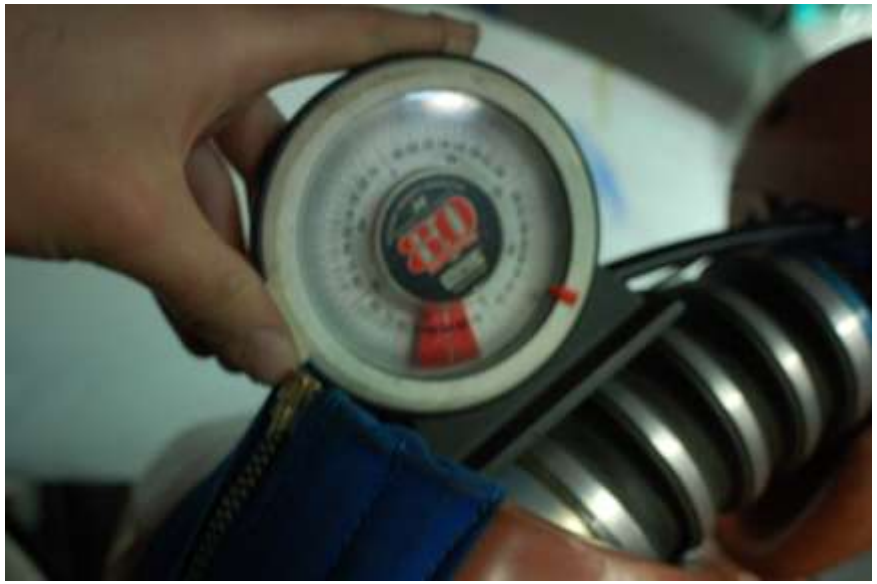
Roll 1 Photographs – 01/16/2012 – Post-Roll



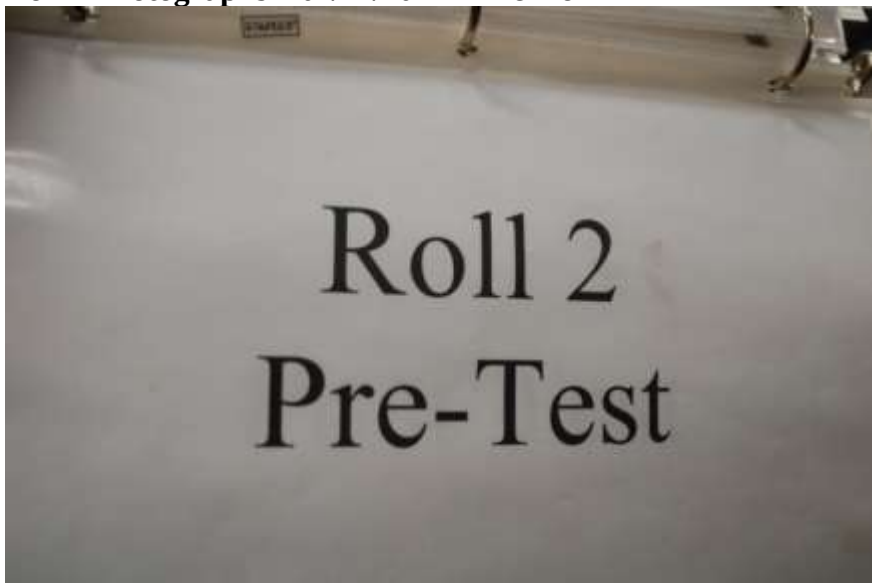
Roll 2 Photographs – 01/17/2012 – Dummy Inspection

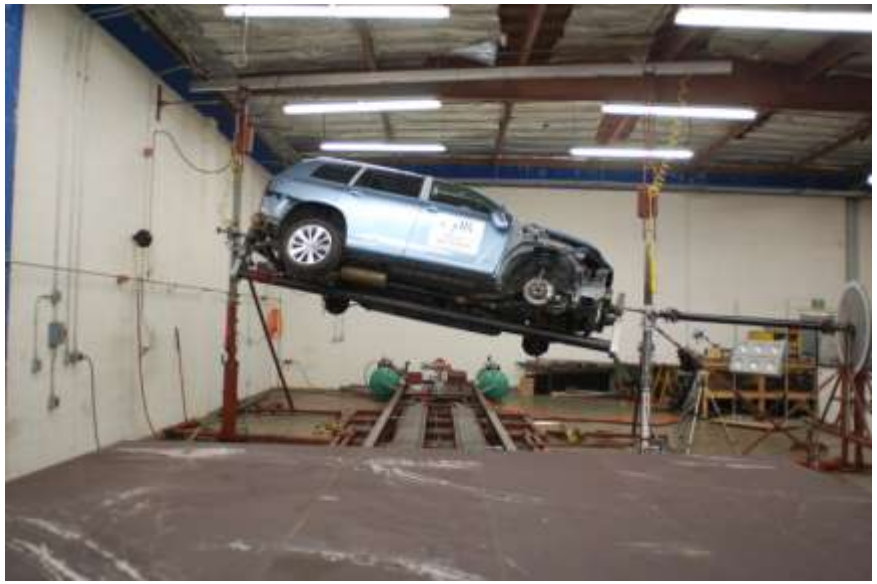




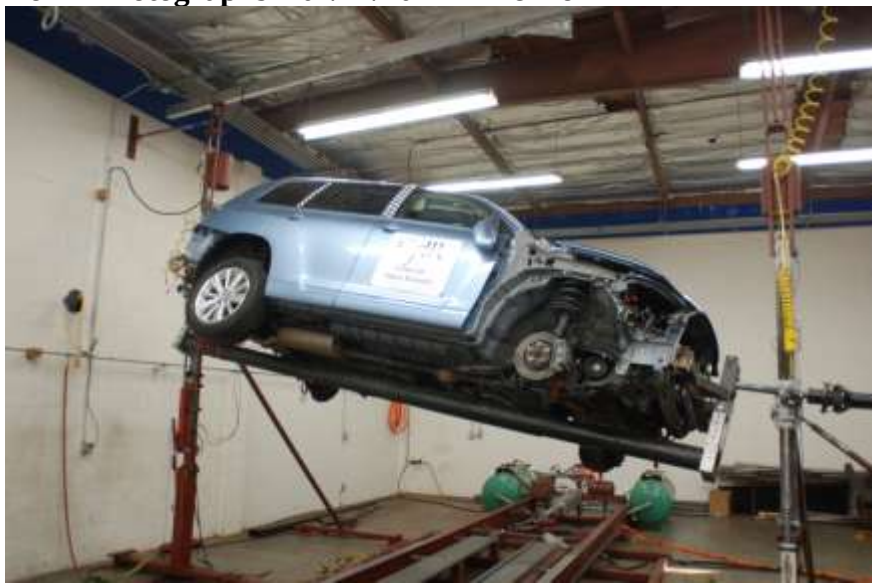
Roll 2 Photographs – 01/17/2012 – Dummy Inspection

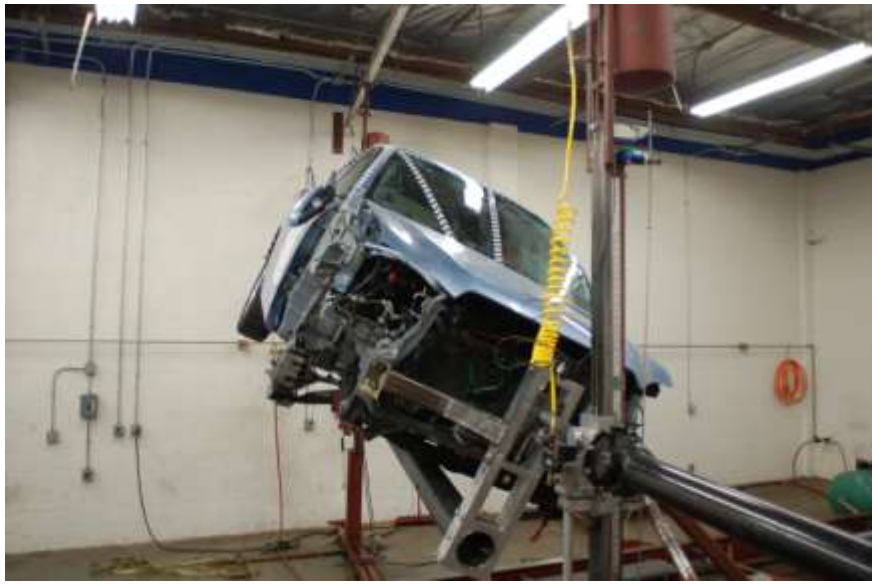
Roll 2 Photographs – 01/17/2012 – Pre-Roll



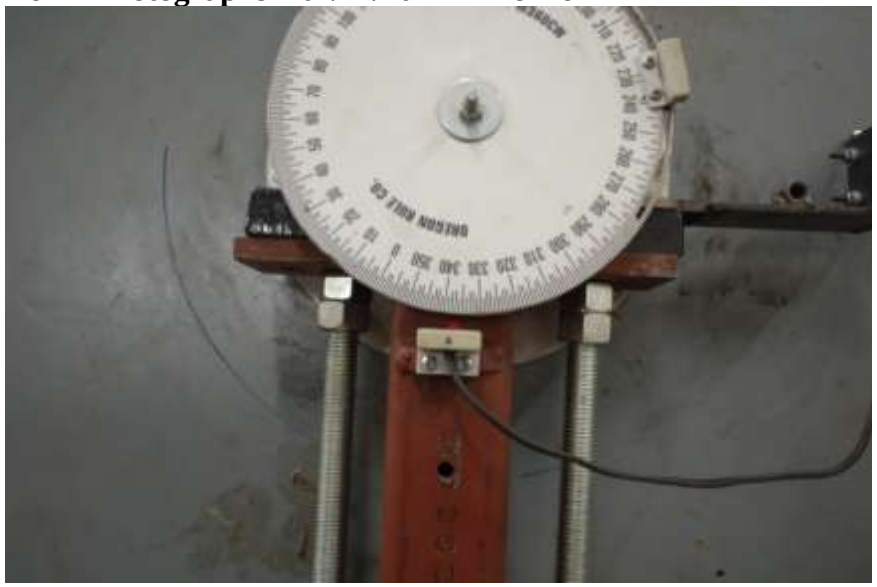
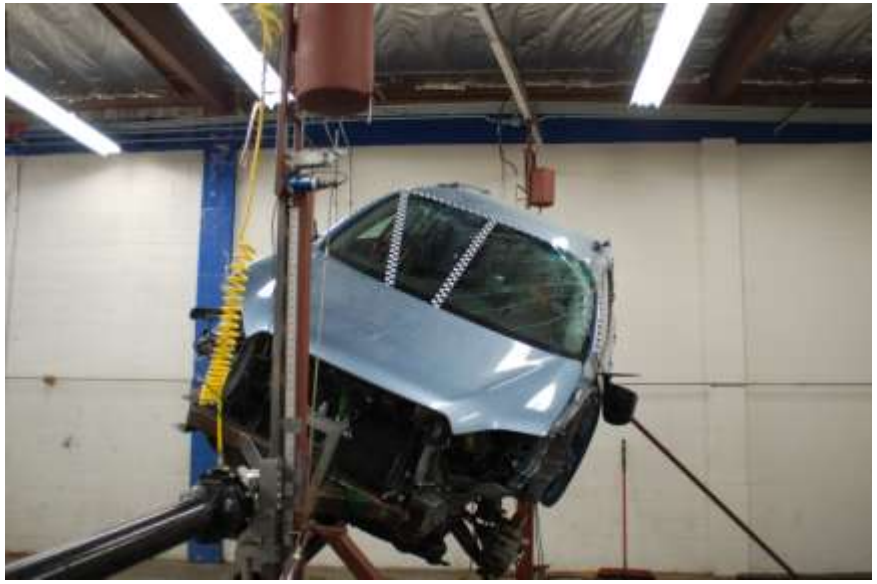


Roll 2 Photographs – 01/17/2012 – Pre-Roll

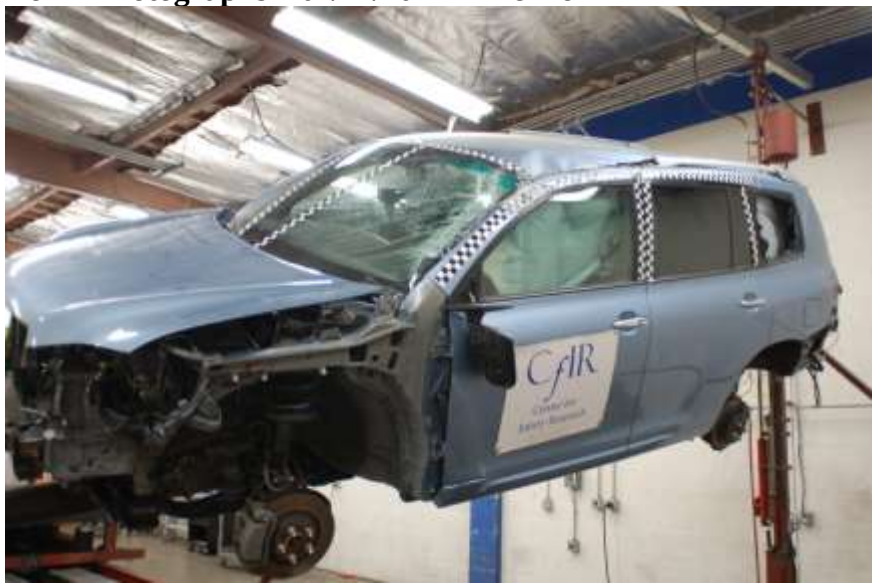


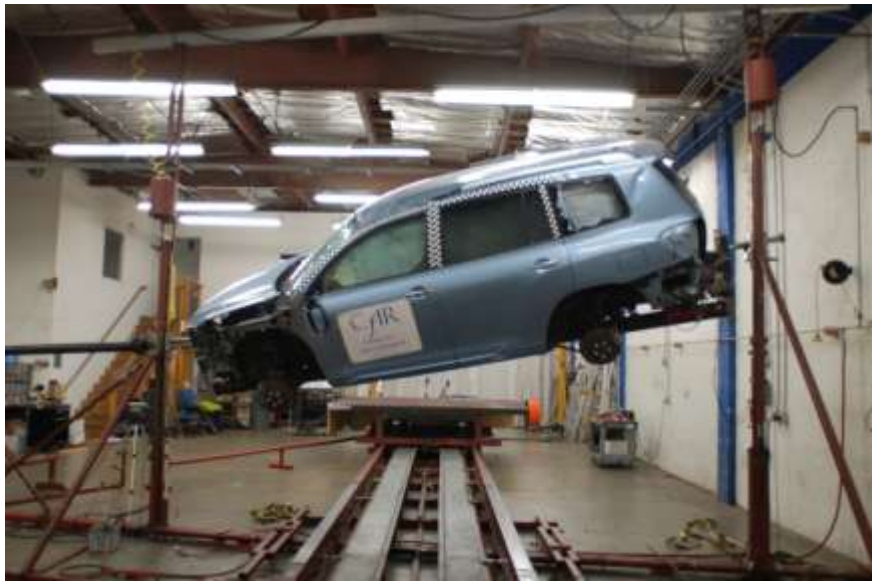



Roll 2 Photographs – 01/17/2012 – Pre-Roll

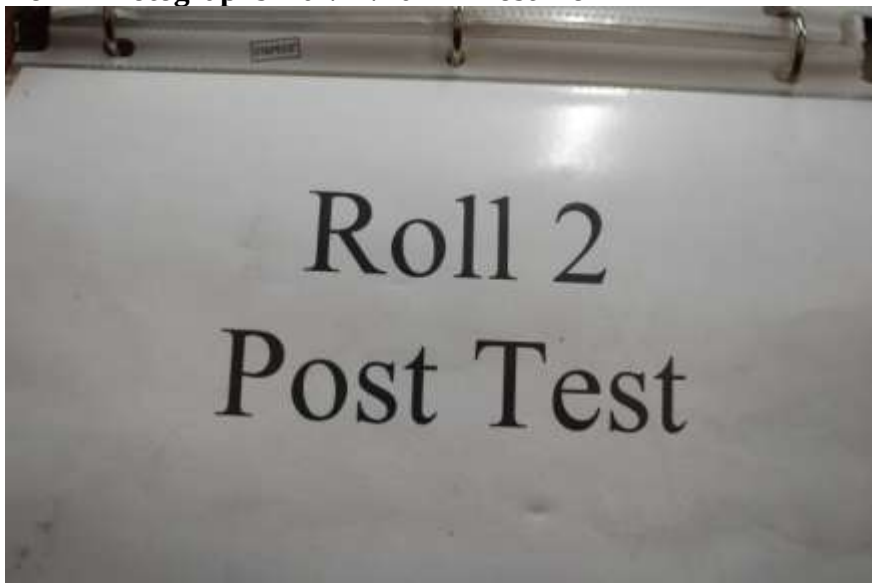



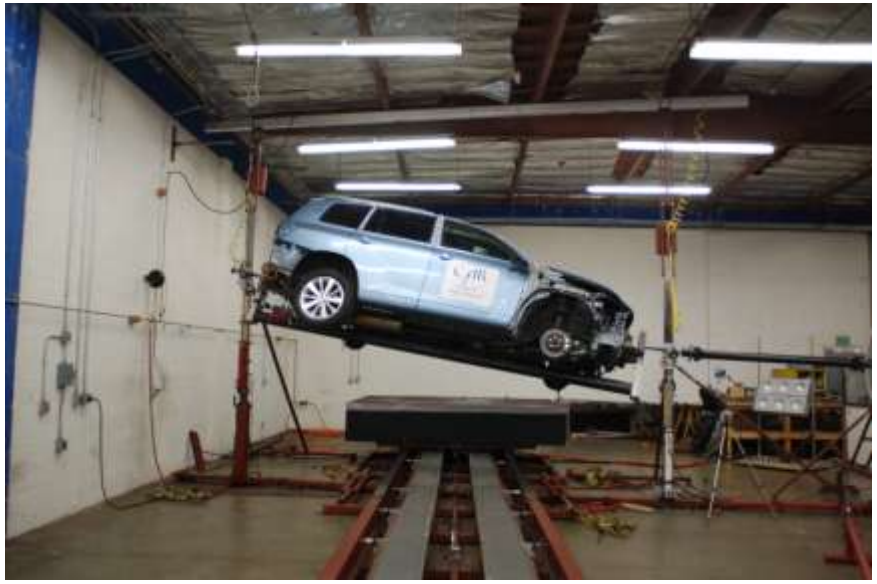
Roll 2 Photographs – 01/17/2012 – Pre-Roll

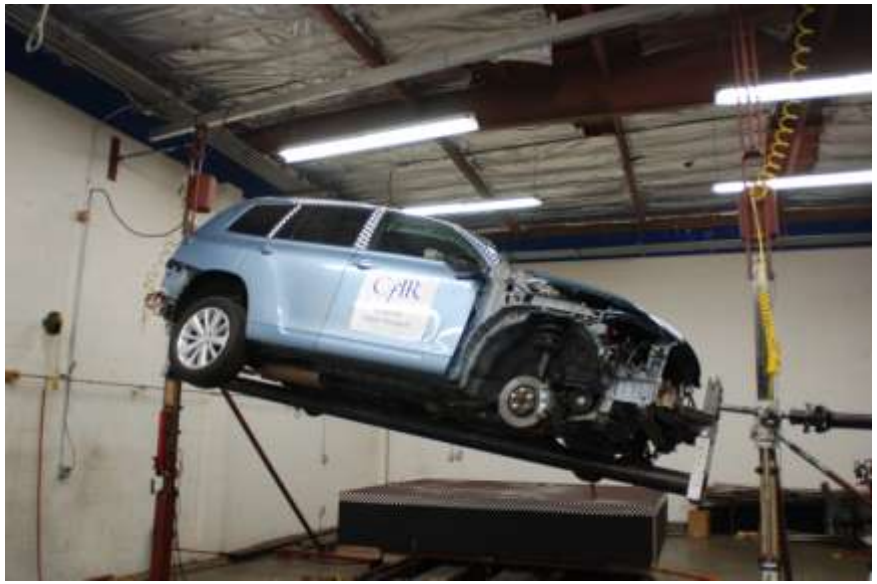





Roll 2 Photographs – 01/17/2012 – Post-Roll

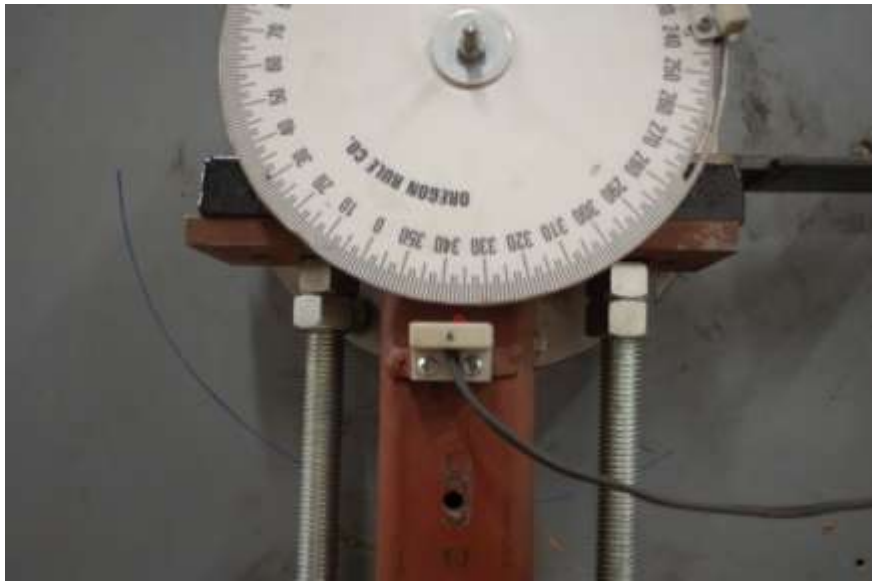






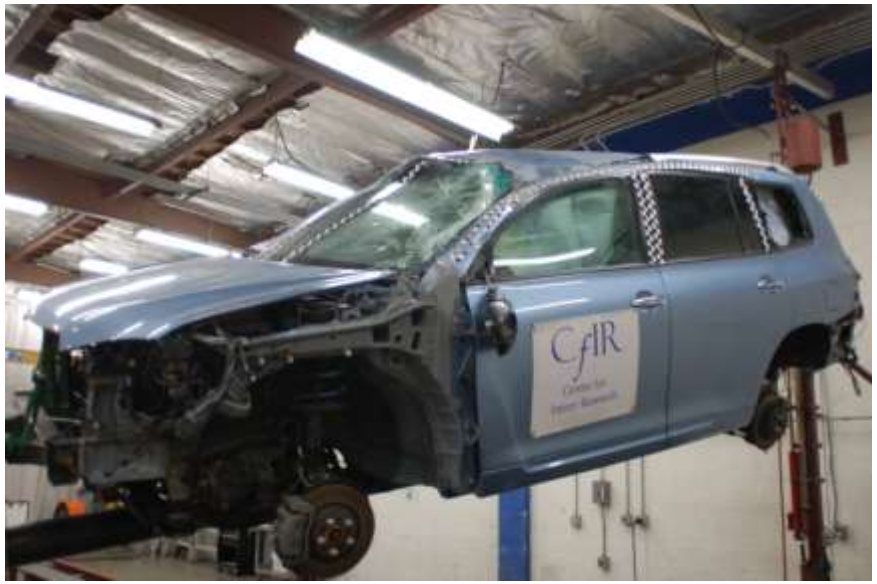
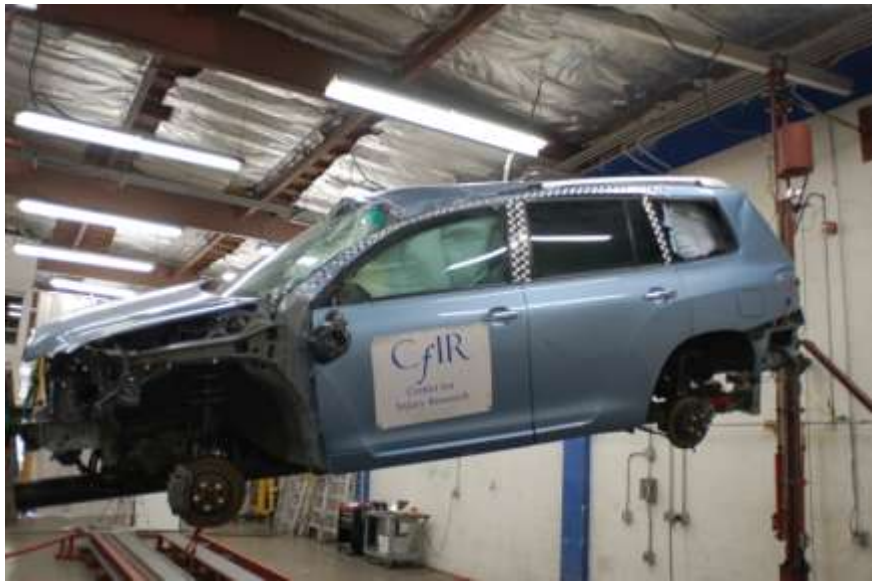
Roll 2 Photographs – 01/17/2012 – Post-Roll



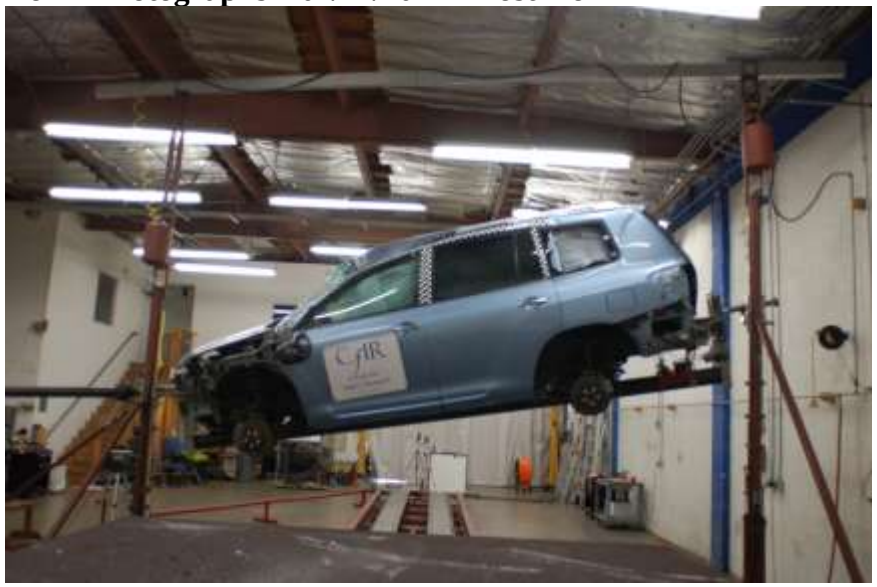



Roll 2 Photographs – 01/17/2012 – Post-Roll

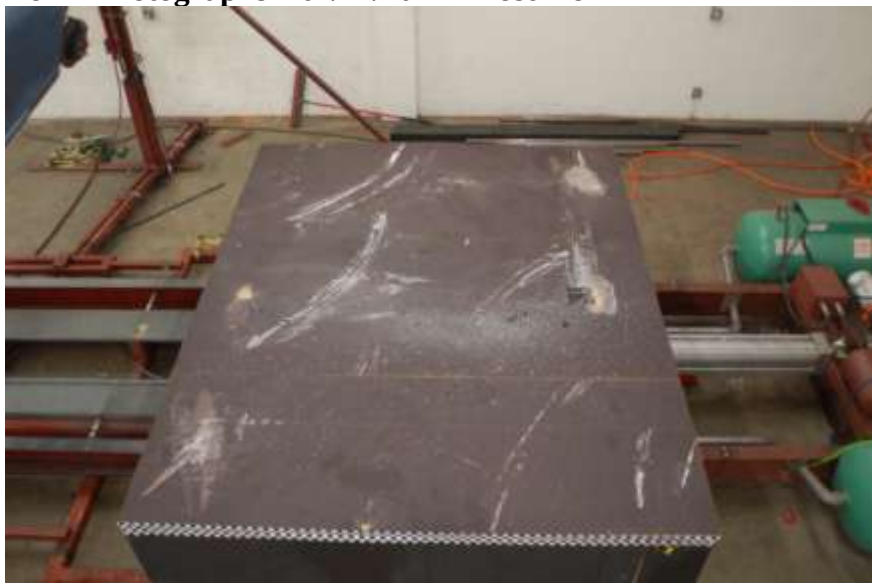
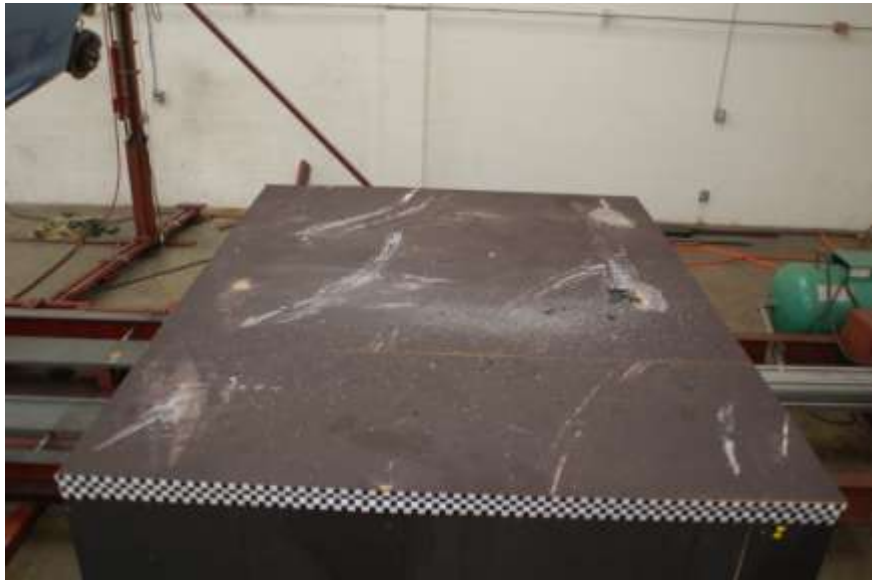


Roll 2 Photographs – 01/17/2012 – Post-Roll




Roll 2 Photographs – 01/17/2012 – Post-Roll

Roll 2 Photographs – 01/17/2012 – Post-Roll




Roll 2 Photographs – 01/17/2012 – Post-Roll

Pre-Test

Pre-Test

Pre-Test


intercomp
E-Z WEIGH Scale
LF
RF
LR
RR
1157
TOTAL:
4531 lbs
1155
BACK LIGHT
TOTAL/%
ZERO
ON/OFF


intercomp
E-Z WEIGH Scale
LF
RF
LR
RR
1156
TOTAL:
1157
1045
BACK LIGHT
TOTAL/%
ZERO
ON/OFF

Post-Test

Post-Test




Post-Test

Post-Test