CPSC Staff Statement on SEA, Ltd. Report "Repeatability of J-Turn Testing of Four Recreational Off-Highway Vehicles"[1]
September 2013

The report titled, "Repeatability of J-Turn Testing of Four Recreational Off-Highway Vehicles," presents the findings of dynamic tests conducted by SEA, Ltd. under Contract CPSC-D-11-0003, Task Orders 0003 and 0004. SEA performed the repeatability tests in support of CPSC's advance notice of proposed rulemaking (ANPR) to address the rollover hazard associated with recreational off-highway vehicles (ROVs). Specifically, the repeatability tests were performed in response to comments made by the Recreational Off-Highway Vehicle Association (ROHVA) at a public meeting that questioned the repeatability of J-turn tests conducted on ROVs.[2]

SEA conducted nearly 650 J-turn tests on four ROVs at the Vehicle Dynamics Area (VDA) at the Transportation Research Center (TRC) located in East Liberty, Ohio. The repeatability study consists of four sets of ten test runs that were conducted in the left and right directions and in the Northbound (upgrade) and Southbound (downgrade) directions of the 1% grade VDA. The report contains three main sections and six appendices. The three report sections are Overview, Dynamic Testing, and Discussion of Test Results. Appendix A contains tables listing the test vehicle weight conditions, Appendix B contains graphical results from the repeatability test runs, Appendix C contains results from the comparison methods used to measure and compute the lateral acceleration at the threshold of vehicle rollover, Appendix D contains a discussion of how the data was processed, Appendix E contains a log of all the test runs conducted, and Appendix F contains a listing of the weather conditions during the testing that was conducted on April 8 – 10, 2013.

The results of the repeatability tests indicate that the lateral acceleration at the threshold of vehicle rollover, indicated by two-wheel lift of the inside wheels in a J-turn, can be measured with good repeatability. The standard deviation for the sets of 10 runs (Northbound Right Turns, Northbound Left Turns, Southbound Right Turns, and Southbound Left Turns) ranged from 0.002 g to 0.013 g. The average of the standard deviations from all of the 10 run sets is 0.006 g.

[1] This statement was prepared by the CPSC staff, and the attached report was produced by SEA for CPSC staff. The statement and report have not been reviewed or approved by, and do not necessarily represent the views of, the Commission.
[2] Meeting log of July 19, 2012. http://www.cpsc.gov/Global/Newsroom/Public-Calendar/Meeting-Logs/2012/071912MtgLogROHVACPSC.pdf.

Repeatability of J-Turn Testing of Four Recreational Off-Highway Vehicles

for:
Consumer Product Safety Commission

September 2013

Vehicle Dynamics Division
7349 Worthington-Galena Rd.
Columbus, Ohio 43085

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"These comments are those of S-E-A, Ltd. staff, and they have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission."

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1. OVERVIEW

This report contains results from measurements made by S-E-A, Ltd., for the U.S. Consumer Product Safety Commission (CPSC), under Contract CPSC-D-11-0003, Task Orders 0003 and 0004. The objective of this testing was:

- To conduct repeatability testing on four ROV's.

Two previous reports, both published in 2011, titled *Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles*[1] and *Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles – Additional Results for Vehicle J*,[2] contain numerous laboratory and dynamic (test track) measurement results for 10 Recreational Off-Highway Vehicles (ROVs). These reports contain results listing the lateral acceleration levels (thresholds) at the point of two wheel lift during 30 mph, dropped-throttle J-Turn tests for each of the 10 vehicles tested. For each vehicle, the threshold accelerations were determined for right J-Turns and left J-Turns, and the average of these two values was also calculated.

The process used to achieve threshold acceleration involves increasing maneuver severity by incrementally increasing the J-Turn steering magnitude to the point of two-wheel lift. The data from previous tests conducted in the loading configuration that represented the weight of the Operator and Passenger loading configuration, showed that for some of the vehicles, the lateral acceleration values achieved in tests leading up to the point of two-wheel lift were often times very close to threshold values. However, the threshold runs were not repeated as part of the previous testing. This latest series of tests addresses the repeatability of multiple test runs of the same maneuver.

Four of the 10 vehicles tested previously, Vehicles D, E, G, and J, were selected by CPSC for 30 mph, dropped-throttle J-Turn maneuver repeatability testing.

During all of these previous tests, during the straight lead in to the J-Turns, the vehicles were driven up the 1% grade of the Vehicle Dynamics Area (VDA) at the Transportation Research Center (TRC). The upgrade direction on the VDA is close to north-northwest; so upgrade runs are further referred to as "Northbound" in this document. Downgrade runs are referred to as "Southbound". This latest series of tests includes conducting repeated runs of the same maneuver in two opposite directions, both Northbound and Southbound on the VDA.

For the previous testing, the threshold lateral acceleration values were manually selected by visual inspection of the filtered lateral acceleration traces. The values were selected to the nearest 0.01 g of lateral acceleration. The process to determine threshold lateral acceleration levels for the current repeatability tests includes a systematic procedure that provides a definite

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[1] *Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles*, CPSC Contract CPSC-S-10-0014, S-E-A, Ltd. Report to CPSC, April 2011. **http://www.cpsc.gov/library/foia/foia11/os/rov.pdf**.

[2] *Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles – Additional Results for Vehicle J*, CPSC Contract CPSC-S-10-0014, S-E-A, Ltd. Report to CPSC, August 2011. **http://www.cpsc.gov/PageFiles/93928/rovj.pdf**.

value that does not rely on visual, subjective analysis. The procedure includes selecting the absolute maximum lateral acceleration from test data filtered using a 2.0 Hz low pass filter.

For the testing conducted on Vehicle D, a second sensor unit that records chassis body-fixed tri-axial accelerations and tri-axial angular rates was used. The purpose of using this second sensor was to compare methods used to compute ground plane (corrected) lateral accelerations at the center-of-gravity (CG) location of the vehicle.

This report contains three main sections and six appendices. The three report sections are Overview, Dynamic Testing, and Discussion of Test Results. Appendix A contains tables listing the test vehicle weight conditions, Appendix B contains graphical results from the repeatability test runs, Appendix C contains results from the comparison of methods used to measure and compute corrected lateral acceleration at the CG location of the vehicle, Appendix D contains a discussion regarding using a 2 Hz low pass filter to filter data used to select peak lateral acceleration values during dropped throttle J-Turn tests, Appendix E contains a log of the tests conducted, and Appendix F contains a listing of the wind and temperature conditions during the testing conducted on April 8-10, 2013.

2. DYNAMIC TESTING

The tests on Vehicle D were conducted on April 8, 2013; tests on Vehicle E and Vehicle G were conducted on April 9, 2013; and the tests on Vehicle J were conducted on April 10, 2013. Vehicle D was first tested using the tires that were used for all previous tests on Vehicle D preformed in May 2010. Vehicle D was then tested using new tires, and the other three vehicles were all tested with new tires only.

All of the dynamic tests were performed in one loading configuration, the “Operator, Instrumentation, and Outriggers” loading configuration as used in previous CPSC testing and described in detail in the previous CPSC reports. The same test driver, test instrumentation, and CPSC outriggers that were used for previous testing were used for this repeatability testing. The total weight of the driver, instrumentation, and safety outriggers is nominally 426 lb, which is the same weight as two 213 lb occupants. Table 1 lists the instrumentation used on all of the vehicles during the dynamic testing. An additional transducer, a Crossbow Model H6X Dynamic Measurement Unit (DMU) was also used during tests conducted on Vehicle D. The test equipment was adjusted so that the lateral and longitudinal center-of-gravity (CG) positions of the vehicles would be close to their positions during previous dynamic testing with outriggers. The heights of the safety outriggers were set to the same levels as those used for previous testing, in an effort to position the vertical CG heights of the vehicles close to where they were during previous tests. The tables in Appendix A list the vehicle test weights used during the April 2013 repeatability tests, as well as the weights used for previous testing. The odometer (mileage) readings of each test vehicle, after the repeatability tests were completed, are also listed on the tables.

Table 1: Instrumentation Used During Dynamic Testing

Transducer	Measurement	Range	Accuracy*
Oxford Technical Solutions RT3002 Inertial and GPS Navigation System	Longitudinal, Lateral, and Vertical Accelerations	$\pm$ 100 m/s^2 ($\pm$ 10 g)	0.01 m/s^2 (0.001 g)
	Roll, Pitch, and Yaw Rates	$\pm$ 100 deg/s	0.01 deg/s
	Speed	No Limit Specified	0.05 km/h (0.03 mph)
	Roll and Pitch Angles	-180 to +180 deg	0.03 deg
	Vehicle Heading	0 to 360 deg	0.1 deg
Encoder on S-E-A, Ltd. ASC	Steering Wheel Angle	No Limit Specified	$\pm$ 0.25 deg

*The accuracy specifications for the RT3002 listed above are from the product website manual (**http://www.oxts.com/default.asp?pageRef=14**). These specifications are more straightforward and somewhat different from RT3002 specifications provided in previous SEA reports presented to CPSC regarding ROV testing.

The RT3002 was mounted in the cargo area of each vehicle, and its longitudinal, lateral, and vertical offsets to the actual vehicle CG location were measured and entered into the RT3002 system software. This information was used to translate the measured quantities to those at the CG of the vehicle.

Table 2 contains a list of variables measured during the testing. The units and description for each variable are also provided in Table 2. Variables 1 through 21 were measured for tests on all four vehicles, while variable 22 through 27 (which are signals from the Crossbow H6X transducer) were only measured for Vehicle D. CPSC has made the data from the repeatability testing available to the public in two different formats: Matlab data files (mat file) and space delimited text files (asc files). The variable names listed in Table 2 are the variable names used in the Matlab files. The column numbers listed in the table show the column order of the variables in the text files.

Lateral acceleration threshold at rollover is determined from tests that produce visually verified two-wheel lift. Visual verification of two-wheel lift is achieved when light is simultaneously visible beneath both lift-side tires of the vehicle.

In total, nearly 650 J-Turn tests were conducted, and a test log for each vehicle is provided in Appendix E. The test logs list the data file number, test description, and test comments. The "100" data series is for Vehicle D with worn tires, while the "200", "300", "400", and "500" data series are for Vehicles D, E, G and J, respectively; all with new tires. The test logs contain a listing of all of the tests conducted, including tests that did not result in two-wheel lift. Only those tests for which two-wheel lift was definitely visually observed at the time of the tests include the phrase "2 Wheel Lift" in the test comments. All of the two-wheel lift tests that were used in the repeatability study analysis include the phrase "2 Wheel Lift – Used in Repeatability Study" in the test comments.

Video was recorded for all of the J-Turn tests conducted with new tires on the vehicles, and CPSC has made video files from the repeatability testing available to the public. Each time the video camera was set to record, a new video file with a new video file number was generated. These video numbers are also included in the test logs. Most of the test maneuvers include two video segments, one with video of the data file number shown on a flip chart, and one with video of the actual maneuver. The video file numbers listed in the test logs are those showing the actual maneuvers. For any given run, the video numbers and data file numbers do not match.

Table 2: Variables Measured During Dynamic Testing			
Column	**Variable**	**Units**	**Description**
1	Time	sec	Time
2	RollRate	deg/sec	Roll Rate
3	PitchRate	deg/sec	Pitch Rate
4	YawRate	deg/sec	Yaw Rate
5	Ax	g	Longitudinal Acceleration in the Road Plane at Vehicle CG
6	Ay	g	Lateral Acceleration in the Road Plane at Vehicle CG
7	Az	g	Vertical Acceleration Perpendicular to the Road Plane at Vehicle CG
8	Body_Fixed_Ax	g	Body-Fixed Longitudinal Acceleration at Vehicle CG
9	Body_Fixed_Ay	g	Body-Fixed Lateral Acceleration at Vehicle CG
10	Body_Fixed_Az	g	Body-Fixed Vertical Acceleration at Vehicle CG
11	RollAngle	deg	Vehicle Roll Angle
12	PitchAngle	deg	Vehicle Pitch Angle
13	Heading	deg	GPS Heading Angle
14	E	m	GPS East Coordinate
15	N	m	GPS North Coordinate
16	HWA_Desired	deg	Desired Steering Wheel Angle (ASC Commanded)
17	HWA_Actual	deg	Actual Steering wheel Angle (ASC Output)
18	Beta	deg	Vehicle Side Slip Angle
19	Vtotal	mph	Vehicle Total Velocity
20	Vx	mph	Vehicle Longitudinal Velocity (Forward Speed)
21	Vy	mph	Vehicle Lateral Velocity
22	CrossBow_RollRate	deg/sec	Roll Rate from Body-Fixed Crossbow Sensor
23	CrossBow_PitchRate	deg/sec	Pitch Rate from Body-Fixed Crossbow Sensor
24	CrossBow_YawRate	deg/sec	Yaw Rate from Body-Fixed Crossbow Sensor
25	CrossBow_Ax	g	Body-Fixed Longitudinal Acceleration at Crossbow Sensor Location
26	CrossBow_Ay	g	Body-Fixed Lateral Acceleration at Crossbow Sensor Location
27	CrossBow_Az	g	Body-Fixed Vertical Acceleration at Crossbow Sensor Location

3. DISCUSSION OF TEST RESULTS

All of the tests were conducted on TRC's VDA. TRC's measurement of peak braking coefficient and sliding skid numbers were 97.7 and 88.8, respectively, on March 27, 2013. The tests on Vehicle D were conducted on April 8, 2013; tests on Vehicle E and Vehicle G were conducted on April 9, 2013; and the tests on Vehicle J were conducted on April 10, 2013. Vehicle D was first tested using the tires that were used for all previous tests on Vehicle D preformed in May 2010. Vehicle D was then tested using new tires, and the other three vehicles were all tested with new tires only.

Appendix B contains graphical results from the 30 mph dropped-throttle, J-Turn tests that resulted in two-wheel lift. There are two pages of graphs for each of the five vehicle configurations tested (Vehicle D – Worn Tires, Vehicle D – New Tires, Vehicle E – New Tires, Vehicle G – New Tires, and Vehicle J – New Tires). A total of 40 maneuvers resulting in two-wheel lift were performed for each vehicle configuration. The first page for each vehicle configuration contains results for the 20 Northbound runs (10 right turns and 10 left turns) and the second page for the 20 Southbound runs (10 right turns and 10 left turns).

The top half of each page in Appendix B contains time domain plots of Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate. The bottom half of each page shows a plot of the ground plane lateral acceleration for all of the runs. All of the dynamic test data are sampled at 100 Hz. Except for the steer angle (which is not filtered), all of the data shown were digitally low-pass filtered to 2.0 Hz using a phaseless, eighth-order, Butterworth filter. An S-E-A Automated Steering Controller (ACS) was used to precisely trigger the start of the J-Turn steering input when the vehicle speed reached 30 mph. The rate used for the steering ramp input for all of the tests was 500 deg/s. The time domain data shown for each vehicle contain data from 0.5 seconds prior to the time the steering was ramped to the desired test steering magnitude (the Threshold Steering Input), until 5.0 seconds after the start of the steering input. The steering magnitude was held by the ASC for 4.0 seconds, after which it was returned to zero at a rate of 250 deg/s.

Ultimately, it is the repeatability of the threshold lateral acceleration that is of interest in this case, and not the amount of steering magnitude used during the test. Test data from this current repeatability study and from previous testing indicate that the peak ground plane (corrected) lateral acceleration at the center-of-gravity location of the vehicle does not vary significantly when the steering magnitude is varied by 5 degrees in maneuvers that are near the point of two-wheel lift.

A general method to determine the Threshold Steering Input value is:

- Start with a steering magnitude (that is a an integer multiple of 10 degrees) that will not result in a two-wheel lift outcome
- Increase the steering magnitude on subsequent runs by 10 degrees until the test results in a two-wheel lift outcome
- Decrease the steering magnitude by 5 degrees and repeat the test
    - If two-wheel lift occurs, use this steering magnitude as the Threshold Steering Input
    - If two-wheel lift does not occur, use the steering magnitude from the previous test that

resulted in two-wheel lift outcome as the Threshold Steering Input

For the repeatability testing, the above procedure was generally followed, but in some cases knowledge from previous tests conducted on the vehicles was used to help establish the Threshold Steering Input values. The steering magnitudes used for all of the repeatability testing, including all tests that did not result in two-wheel lift outcome, are listed in the test logs contained in Appendix E. Table 3 contains a list of test numbers for all of the runs with two-wheel lift used for the repeatability study. The test numbers are also the numbers used in the data file names for the particular tests.

For Vehicle D, the vehicle tested on the first day of testing with both worn tires and new tires, for each heading and turn direction tests were conducted until four two-wheel lift events occurred. Then additional tests were conducted in each heading and turn directions until a total of 10 two-wheel lift events in each heading and turn direction. For Vehicle D with new tires, in the case of the southbound left turns, the two-wheel lift events began to produce higher two-wheel lift using 130 degrees of steering input, so the steering was reduced to 125 degrees and tests were run until 10 two-wheel lift events occurred using 125 degrees of steering. It is possible that tire break-in wear and/or wind speed contributed to the fact that Vehicle D with new tires tipped up at a lower steering magnitude of 125 degrees at a later time and after additional left turns were made. In going forward with the testing, a decision was made to augment the test process to allow for adjusting the steering input up or down (in five degree increments) in the event that the two-wheel lift events starting generating much higher wheel lift or in the event that the steering magnitude used no longer generated two-wheel lift. The goal of the testing is to determine the threshold lateral acceleration at tip-up, not the steering magnitude required to generate tip-up. As mentioned, testing has indicated that the lateral acceleration does not vary significantly when the steering magnitude is varied by 5 degrees in maneuvers that are near the point of two-wheel lift, so this procedure is adequate to provide a consistent measure of threshold lateral acceleration at the point of tip-up defined by two-wheel lift.

Vehicle G was tested first on the second day of testing. In the first series for both the right turn and left turn directions, less steering magnitude was required to generate two-wheel lift events after several tip-up events were conducted. This was attributed to tire break-in wear including wearing off the tire mold sheen. Vehicle E was tested after Vehicle G on the second day of testing, and Vehicle J was tested on the third day of testing. In an effort to minimize new tire break-in wear issues for Vehicles E and J, prior to conducting the official test protocol, a minimum of four runs were made in both the right turn and left turn directions that generated two-wheel lift. The listings of the tire break-in runs (Runs 1401-1416 for Vehicle E and Runs 1501-1516 for Vehicle J) are contained in Appendix E.

The first page of Appendix B contains graphical results from the 20 Northbound tip-up runs of Vehicle D with worn tires. The bottom half of this page is a graph of the lateral accelerations for all of the runs. Figure 1 contains this same graph as well as two expanded views of the 10 right turn and 10 left turn peak lateral accelerations.

Table 3: Test Numbers (and Data File Numbers) for Runs with Two-Wheel Lift		
Vehicle D Worn Tires	Northbound Right Turns	123 124 125 126 150 151 152 153 154 155
	Northbound Left Turns	132 133 134 135 158 159 160 161 162 163
	Southbound Right Turns	139 140 141 142 165 166 167 168 169 170
	Southbound Left Turns	144 145 146 147 172 173 176 178 181 186
Vehicle D New Tires	Northbound Right Turns	211 212 213 214 234 235 236 237 238 239
	Northbound Left Turns	216 218 219 220 240 241 242 243 245 246
	Southbound Right Turns	221 223 224 225 248 249 250 251 252 253
	Southbound Left Turns	261 262 264 265 266 267 268 269 270 271
Vehicle E New Tires	Northbound Right Turns	404 406 409 410 411 412 413 414 415 416
	Northbound Left Turns	419 421 423 425 426 427 428 431 432 434
	Southbound Right Turns	442 445 447 448 449 450 451 453 454 455
	Southbound Left Turns	459 460 467 469 470 471 472 476 479 481
Vehicle G New Tires	Northbound Right Turns	312 313 314 315 316 317 318 319 320 321
	Northbound Left Turns	330 332 333 334 335 336 337 338 339 340
	Southbound Right Turns	342 344 349 350 351 352 353 354 355 356
	Southbound Left Turns	357 360 361 362 363 364 365 366 367 368
Vehicle J New Tires	Northbound Right Turns	504 505 506 507 508 509 510 511 512 513
	Northbound Left Turns	517 518 519 520 521 522 523 524 525 526
	Southbound Right Turns	531 532 533 534 535 536 537 538 539 540
	Southbound Left Turns	544 545 548 549 550 552 553 554 555 556

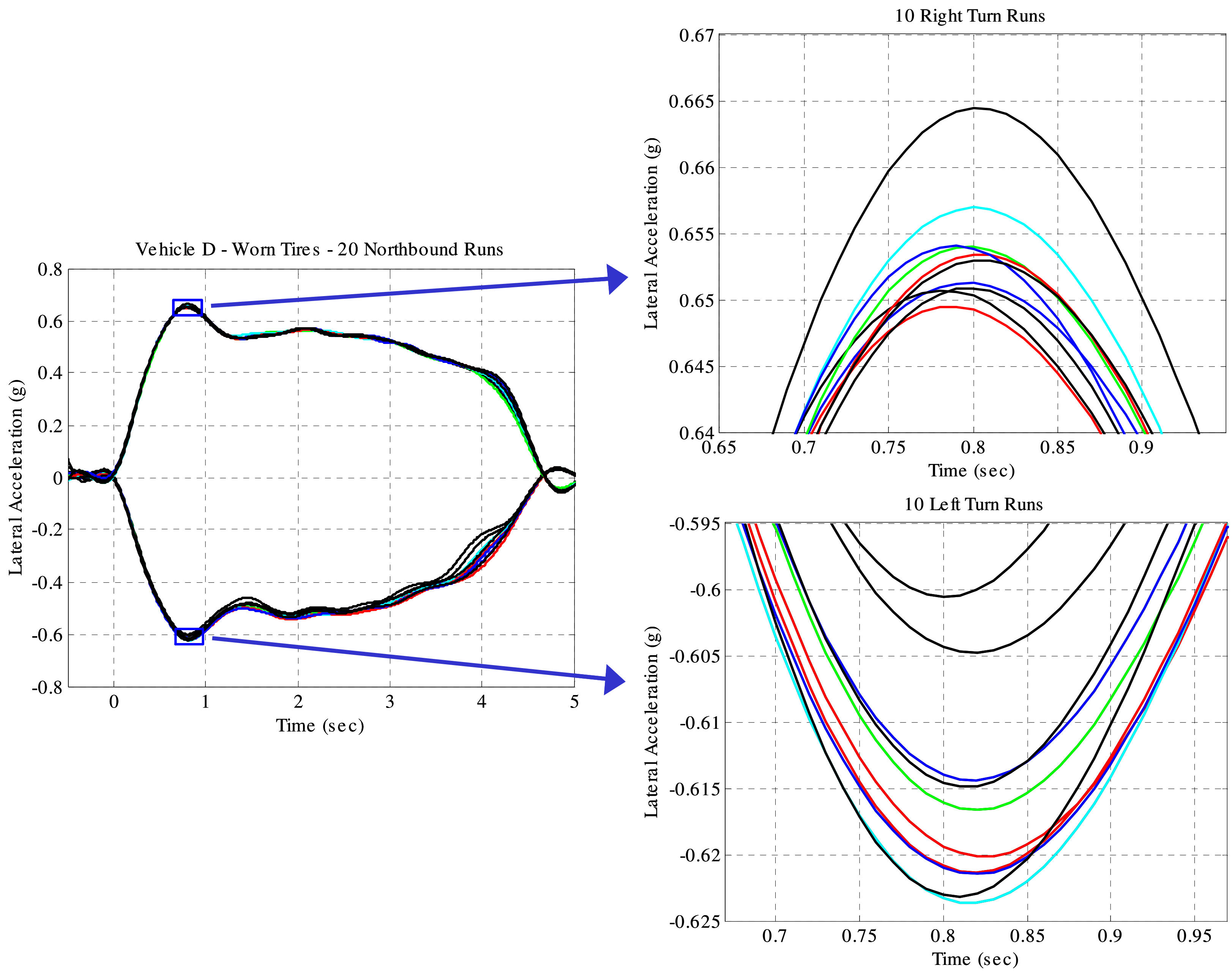


Figure 1: Expanded Views of 10 Right Turn and 10 Left Turn Peak Lateral Accelerations
Northbound Runs of Vehicle D with Worn Tires

Table 4 contains a listing of the peak lateral acceleration at tip-up for the 40 threshold tip-up runs made for Vehicle D with worn tires. The values of the peak lateral accelerations for the 10 right turn and 10 left turn northbound runs correspond to the absolute peaks values shown in the expanded views on Figure 1. The mean values and standard deviations of the lateral accelerations for each of the four sets (Northbound Right Turns, Northbound Left Turns, Southbound Right Turns, and Southbound Left Turns) of 10 runs are shown on Table 4. The average values of all 20 northbound runs, all 20 southbound runs, and all 40 runs are also shown on Table 4.

The mean values listed for the sets of 10 runs are simply the average of the ten values. The standard deviations listed are calculated using the nonbiased method for computing the standard deviation, *s*, from a sample of a population (in this case the sample size, *N*, is 10):

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Where, x_i, is the lateral acceleration value for each individual run and, $\bar{x}$, is the mean value of the 10 runs.

Tables 5-8 contain listings of the peak lateral accelerations at tip-up for the 40 threshold tip-up runs made for Vehicles D, E, G and J, respectively (all tested with new tires). The same information that is provided on Table 4 is provided on Tables 5-8.

The standard deviations for the sets of 10 runs ranged from 0.002 g to 0.013 g. The average of the standard deviations from all of the 10 run sets is 0.006 g.

Table 9 contains a summary of the various average lateral acceleration values contained in Tables 4-8. For all vehicle configurations tested, the average lateral acceleration values determined from the 20 northbound runs are very close to the values determined from the 20 southbound runs. The differences between the northbound and southbound runs ranged from 0.001 g for Vehicle J to 0.007 g for Vehicle D with worn tires, and the average difference between the northbound and southbound averages is less than 0.004 g.

The average values for each of the four sets (Northbound Right Turns, Northbound Left Turns, Southbound Right Turns, and Southbound Left Turns) of 10 runs ranged from 0.020 g for Vehicle G to 0.078 g for Vehicle J. The fact that the range of variation among the 10 set runs with different heading and steering directions is much greater than the range of variation among the average northbound and southbound runs can be explained by a number of reasons. This is typical for J-Turn test tip-up results, and this is the reason why it is a usual practice to conduct both right turn and left turn maneuvers, and then average the values (as was done in previous ROV testing conducted for CPSC and presented in previous reports).

The right to left differences in lateral acceleration needed to achieve tip-up can be attributed to such things as lateral offset of the CG of the vehicle; vehicle steering and suspension asymmetries; magnitude and direction of the prevailing wind; and slope of the test surface. Appendix F contains a summary of the weather conditions (average wind speed, maximum wind speed, and average temperature) for ten-minute intervals throughout the three-day duration of the testing. In spite of any wind effects, CG lateral offsets, and vehicle asymmetries; when the 10 right turn and 10 left turn average values are averaged together, the resulting averages are quite consistent for the northbound and southbound runs. These results indicate that the lateral acceleration at the threshold of tip-up indicated by two-wheel lift can be measured with good repeatability.

The 40-run average lateral acceleration for Vehicle D with worn tires (0.639 g) is close to the 40-run average for Vehicle D with new tires (0.631 g). This indicates that the wear on the tires from all of the dynamic testing done on Vehicle D in 2010 (results contained in the 2011 CPSC report) did not have a significant influence on the corrected lateral acceleration at the point of two-wheel lift in the 30 mph dropped-throttle J-Turn maneuvers. In both cases, worn and new, the tires were able to provide sufficient lateral cornering force capability for the vehicle to tip-up during the maneuvers. This suggests that determining lateral acceleration threshold using this method is not dependent on tire wear; and likely not dependent on tire/surface friction, so long as the tire to surface friction is high enough to allow for the generation of lateral forces high enough to result in vehicle tip-up.

Lateral Acceleration (g) at Tip-Up – Vehicle D – Worn Tires

	Northbound Right Turns	Northbound Left Turns	
1	0.6495	-0.6202	
2	0.6512	-0.6144	
3	0.6507	-0.6048	
4	0.6540	-0.6167	
5	0.6569	-0.6237	
6	0.6534	-0.6214	
7	0.6540	-0.6215	
8	0.6509	-0.6232	
9	0.6644	-0.6006	
10	0.6529	-0.6149	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6538	-0.6161	**0.6350**
Standard Deviation of 10 Runs	0.004	0.008	

	Southbound Right Turns	Southbound Left Turns	
1	0.6352	-0.6425	
2	0.6338	-0.6567	
3	0.6340	-0.6460	
4	0.6394	-0.6469	
5	0.6323	-0.6501	
6	0.6333	-0.6482	
7	0.6347	-0.6579	
8	0.6183	-0.6536	
9	0.6394	-0.6570	
10	0.6291	-0.6570	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6330	-0.6516	**0.6423**
Standard Deviation of 10 Runs	0.006	0.006	

Average of All 40 Runs **0.639**

Table 4: Lateral Acceleration at Tip-Up – Vehicle D with Worn Tires

Lateral Acceleration (g) at Tip-Up – Vehicle D – New Tires

	Northbound Right Turns	Northbound Left Turns	
1	0.6404	-0.6141	
2	0.6387	-0.6059	
3	0.6379	-0.6071	
4	0.6358	-0.5970	
5	0.6487	-0.6064	
6	0.6500	-0.6134	
7	0.6488	-0.6156	
8	0.6482	-0.6142	
9	0.6473	-0.6214	
10	0.6536	-0.6201	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6450	-0.6115	**0.6282**
Standard Deviation of 10 Runs	0.006	0.007	

	Southbound Right Turns	Southbound Left Turns	
1	0.6229	-0.6391	
2	0.6171	-0.6373	
3	0.6225	-0.6348	
4	0.6164	-0.6378	
5	0.6246	-0.6415	
6	0.6309	-0.6368	
7	0.6395	-0.6457	
8	0.6294	-0.6447	
9	0.6279	-0.6419	
10	0.6344	-0.6376	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6266	-0.6397	**0.6332**
Standard Deviation of 10 Runs	0.007	0.004	

Average of All 40 Runs **0.631**

Table 5: Lateral Acceleration at Tip-Up – Vehicle D with New Tires

Lateral Acceleration (g) at Tip-Up – Vehicle E – New Tires

	Northbound Right Turns	Northbound Left Turns	
1	0.6976	-0.7074	
2	0.6942	-0.7048	
3	0.6948	-0.7207	
4	0.6940	-0.7084	
5	0.6951	-0.7182	
6	0.6917	-0.7000	
7	0.6923	-0.7033	
8	0.6944	-0.7030	
9	0.6905	-0.7114	
10	0.6964	-0.7106	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6941	-0.7088	**0.7014**
Standard Deviation of 10 Runs	0.002	0.007	

	Southbound Right Turns	Southbound Left Turns	
1	0.6562	-0.7328	
2	0.6600	-0.7441	
3	0.6776	-0.7508	
4	0.6648	-0.7358	
5	0.6735	-0.7415	
6	0.6643	-0.7368	
7	0.6750	-0.7378	
8	0.6828	-0.7330	
9	0.6758	-0.7298	
10	0.6752	-0.7322	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6705	-0.7374	**0.7040**
Standard Deviation of 10 Runs	0.009	0.006	

Average of All 40 Runs **0.703**

Table 6: Lateral Acceleration at Tip-Up – Vehicle E with New Tires

Lateral Acceleration (g) at Tip-Up – Vehicle G – New Tires

	Northbound Right Turns	Northbound Left Turns	
1	0.7639	-0.7731	
2	0.7781	-0.7686	
3	0.7613	-0.7702	
4	0.7658	-0.7508	
5	0.7702	-0.7734	
6	0.7643	-0.7575	
7	0.7669	-0.7776	
8	0.7624	-0.7792	
9	0.7655	-0.7695	
10	0.7651	-0.7772	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.7663	-0.7697	**0.7680**
Standard Deviation of 10 Runs	0.005	0.009	

	Southbound Right Turns	Southbound Left Turns	
1	0.7713	-0.7495	
2	0.7650	-0.7620	
3	0.7892	-0.7549	
4	0.7779	-0.7630	
5	0.7630	-0.7599	
6	0.8003	-0.7744	
7	0.7812	-0.7662	
8	0.7973	-0.7481	
9	0.7776	-0.7608	
10	0.7725	-0.7593	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.7795	-0.7598	**0.7697**
Standard Deviation of 10 Runs	0.013	0.008	

Average of All 40 Runs **0.769**

Table 7: Lateral Acceleration at Tip-Up – Vehicle G with New Tires

Lateral Acceleration (g) at Tip-Up – Vehicle J – New Tires

	Northbound Right Turns	Northbound Left Turns	
1	0.6341	-0.6549	
2	0.6244	-0.6529	
3	0.6303	-0.6623	
4	0.6328	-0.6589	
5	0.6303	-0.6562	
6	0.6282	-0.6558	
7	0.6399	-0.6576	
8	0.6267	-0.6615	
9	0.6349	-0.6405	
10	0.6367	-0.6582	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6318	-0.6559	**0.6439**
Standard Deviation of 10 Runs	0.005	0.006	

	Southbound Right Turns	Southbound Left Turns	
1	0.6064	-0.6812	
2	0.6036	-0.6771	
3	0.6016	-0.6832	
4	0.6071	-0.6929	
5	0.5934	-0.6814	
6	0.6010	-0.6757	
7	0.6034	-0.6827	
8	0.5976	-0.6819	
9	0.6099	-0.6787	
10	0.6126	-0.6849	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6037	-0.6820	**0.6428**
Standard Deviation of 10 Runs	0.006	0.005	

Average of All 40 Runs **0.643**

Table 8: Lateral Acceleration at Tip-Up – Vehicle J with New Tires

Table 9: Summary Lateral Accelerations for Runs with Two-Wheel Lift							
	Average 10 Northbound Right Turns (g)	**Average 10 Northbound Left Turns (g)**	**Average 20 Northbound Runs (g)**	**Average 10 Southbound Right Turns (g)**	**Average 10 Southbound Left Turns (g)**	**Average 20 Southbound Runs (g)**	**Average All 40 Runs (g)**
Vehicle D Worn Tires	0.654	-0.616	**0.635**	0.633	-0.652	**0.642**	**0.639**
Vehicle D New Tires	0.645	-0.612	**0.628**	0.627	-0.640	**0.633**	**0.631**
Vehicle E New Tires	0.694	-0.709	**0.701**	0.671	-0.737	**0.704**	**0.703**
Vehicle G New Tires	0.766	-0.770	**0.768**	0.780	-0.760	**0.770**	**0.769**
Vehicle J New Tires	0.632	-0.656	**0.644**	0.604	-0.682	**0.643**	**0.643**

Comparison of Current and Previously Reported Peak Lateral Acceleration Values

Vehicles D, E, G, and J were previously tested by SEA for CPSC, and results of peak lateral accelerations measured during 30 mph, dropped-throttle J-Turn tests that resulted in two-wheel lift were reported in the 2011 test reports.

The dates on which each of the vehicles was previously tested are contained on Table 10, as are the previously reported peak lateral acceleration values. The previously reported lateral acceleration values are based on averaging a single right turn value and a single left turn value. The previous tests were all run in the Northbound direction on the VDA. Also, the method used to select the previous peak values was to manually (visually) select the peak value to the nearest 0.01 g from a plot of lateral acceleration data filtered using a 5 Hz low pass filter.

Table 10 also lists the current values of the peak lateral accelerations determined from the April 2013 vehicle testing with new tires on the test vehicles (the same values listed in Table 9). These peak values are from the 40 test averages determined by selecting the absolute peak values from lateral acceleration data filtered using a 2 Hz low pass filter. The differences between the previously reported and current lateral acceleration values are list in blue on the right column of Table 10. The differences for Vehicles D and E are small, with the current values being less than 0.01 g higher than the previously reported values. The current value for Vehicle G is 0.016 g lower than the previously reported value, and for Vehicle J the current value is 0.027 g lower than the previously reported.

The current and previously reported values compare fairly well given that two different methods were used to select the peak lateral acceleration values, with the current method offering better resolution in selecting the peak values than the previous method when the peaks were selected to nearest 0.01 g. Also, the current tests were conducted between 22 to 34 months after the previous tests, and some differences could be attributed to vehicle aging.

The previously reported values were based on a two-test average, one right turn and one left turn. The current values are based on a 40-test average (20 right turns and 20 left turns). Certainly, using repeated test runs in both turn directions to determine the peak lateral acceleration value is better than using only one run in each turn direction, as averaging multiple runs diminishes the affects of run-to-run variability. Also, conducting multiple runs in two opposite heading directions (e.g Northbound and Southbound) can mitigate bias effects that could be present on some test surfaces and also help mitigate effects of wind.

Table 11 lists the values for peak braking coefficient (PBC) and sliding skid number (SN) measured by TRC on March 27, 2013, and on the dates closest to the dates of the previous testing. There is no significant correlation between surface friction measurements and the peak lateral accelerations measured on different dates. As mentioned previously, the determination of peak lateral acceleration during dropped-throttle J-Turn tests is likely not dependent on tire/surface friction, so long as the tire to surface friction is high enough to allow for the generation of lateral forces high enough to result in vehicle tip-up.

Table 10: Current Lateral Acceleration Values Compared to Previously Report Values				
Vehicle	**Previous Test Date**	**Previously Reported Peak Ay (g)**	**Current Peak Ay (g) (April 2013)**	**Differences Between Current and Previous Peak Ay (g)**
Vehicle D	5/20/2010	0.625	0.631	**0.006**
Vehicle E	5/25/2010	0.700	0.703	**0.003**
Vehicle G	8/17/2010	0.785	0.769	**-0.016**
Vehicle J	5/20/2011	0.670	0.643	**-0.027**

Table 11: TRC Skid Number Measurements		
Location	VDA	
Pad #	V-5, dry	
Pavement	Asphalt	
Surface	Untreated	
Condition	Dry	
Date	Peak PBC	Slide SN
5/5/2010	92.5	82.2
6/1/2010	98.1	84.7
8/23/2010	93.3	83.5
5/11/2011	92.7	85.0
3/27/2013	97.7	88.8

Appendix A:

Vehicle Test Weights Used During April 2013 Repeatability Tests

Vehicle D

	Curb	Operator	Operator & Passenger	Operator, Inst & Outriggers	Operator, Inst, Outriggers Repeat Tests April 2013
Mileage					118
VIMF Test Number		4190	4191	4193	
Total Vehicle Weight (lb)	1294.9	1508.2	1720.9	1728.6	1733
Left Front Weight (lb)	280.3	351.3	384.1	398.9	397
Right Front Weight (lb)	304.5	331.1	395.8	390.4	395
Left Rear Weight (lb)	341.6	451.7	448.3	460.5	470
Right Rear Weight (lb)	368.5	374.1	492.7	478.8	471
Front Track Width (in)	51.65	51.65	52.18	52.18	52.18
Rear Track Width (in)	48.28	48.28	49.23	49.23	49.23
Average Track Width (in)	49.96	49.96	50.70	50.70	50.70
Wheelbase (in)	75.80	75.80	75.80	75.80	75.80
CG Longitudinal (in)	41.57	41.50	41.45	41.19	41.16
CG Lateral (in)	0.99	-1.62	0.83	0.14	-0.01
CG Height (in)		26.11	27.07	26.91	
Roll Inertia - I_{XX} (ft-lb-s^2)		162	185	219	
Pitch Inertia - I_{YY} (ft-lb-s^2)		319	333	353	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		340	353	399	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	11	10	
SSF		0.957	0.937	0.942	
KST		0.960	0.939	0.944	
CSV (mph)		8.14	7.99	8.23	
Front Ground Clearance (in)			9.30		
Rear Ground Clearance (in)			10.75		
Steering Ratio (deg/deg)			18.0		

Vehicle E

	Curb	Operator	Operator & Passenger	Operator, Inst & Outriggers	Operator, Inst, Outriggers Repeat Tests April 2013
Mileage					72
VIMF Test Number		4200	4201	4203	
Total Vehicle Weight (lb)	1402.2	1615.3	1827.9	1831.4	1829
Left Front Weight (lb)	300.4	375.6	394.5	406.5	393
Right Front Weight (lb)	317.9	329.2	395.8	382.7	397
Left Rear Weight (lb)	397.4	502.3	512.7	526.3	543
Right Rear Weight (lb)	386.5	408.2	524.9	515.9	496
Front Track Width (in)	49.38	49.38	50.10	50.10	50.10
Rear Track Width (in)	48.50	48.50	48.93	48.93	48.93
Average Track Width (in)	48.94	48.94	49.51	49.51	49.51
Wheelbase (in)	75.90	75.90	75.90	75.90	75.90
CG Longitudinal (in)	42.43	42.78	43.08	43.19	43.12
CG Lateral (in)	0.12	-2.13	0.18	-0.46	-0.58
CG Height (in)		24.73	25.55	25.66	
Roll Inertia - I_{XX} (ft-lb-s^2)		147	173	201	
Pitch Inertia - I_{YY} (ft-lb-s^2)		326	341	352	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		351	363	403	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	16	13	
SSF		0.989	0.969	0.965	
KST		0.991	0.970	0.966	
CSV (mph)		8.18	8.08	8.21	
Front Ground Clearance (in)			10.40		
Rear Ground Clearance (in)			10.80		
Steering Ratio (deg/deg)			14.9		

Vehicle G

	Curb	Operator	Operator & Passenger	Operator, Inst & Outriggers	Operator, Inst, Outriggers Repeat Tests April 2013
Mileage					112
VIMF Test Number		4224	4225	4227	
Total Vehicle Weight (lb)	1753.4	1966.8	2179.2	2188.5	2181
Left Front Weight (lb)	375.1	458.3	497.8	500.7	480
Right Front Weight (lb)	373.4	413.1	494.5	491.3	500
Left Rear Weight (lb)	499.3	567.2	580.8	598.8	619
Right Rear Weight (lb)	505.6	528.2	606.1	597.7	582
Front Track Width (in)	50.20	51.45	51.73	51.73	51.73
Rear Track Width (in)	51.40	51.53	51.75	51.75	51.75
Average Track Width (in)	50.80	51.49	51.74	51.74	51.74
Wheelbase (in)	79.15	79.15	79.15	79.15	79.15
CG Longitudinal (in)	45.36	44.08	43.11	43.27	43.59
CG Lateral (in)	0.07	-1.10	0.26	-0.12	-0.20
CG Height (in)		24.45	25.33	25.10	
Roll Inertia - I_{XX} (ft-lb-s^2)		168	187	210	
Pitch Inertia - I_{YY} (ft-lb-s^2)		465	482	496	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		486	503	540	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		3	-2	0	
SSF		1.053	1.021	1.031	
KST		1.053	1.021	1.031	
CSV (mph)		8.74	8.50	8.69	
Front Ground Clearance (in)			9.60		
Rear Ground Clearance (in)			9.80		
Steering Ratio (deg/deg)			14.7		

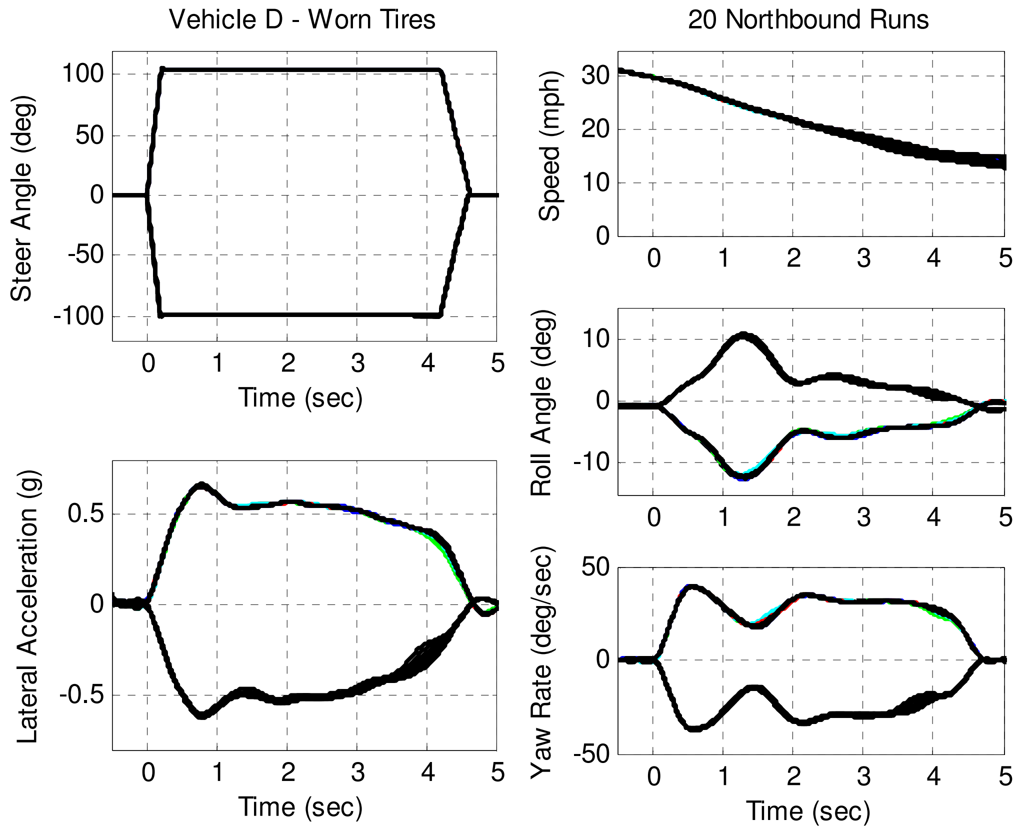
Vehicle J

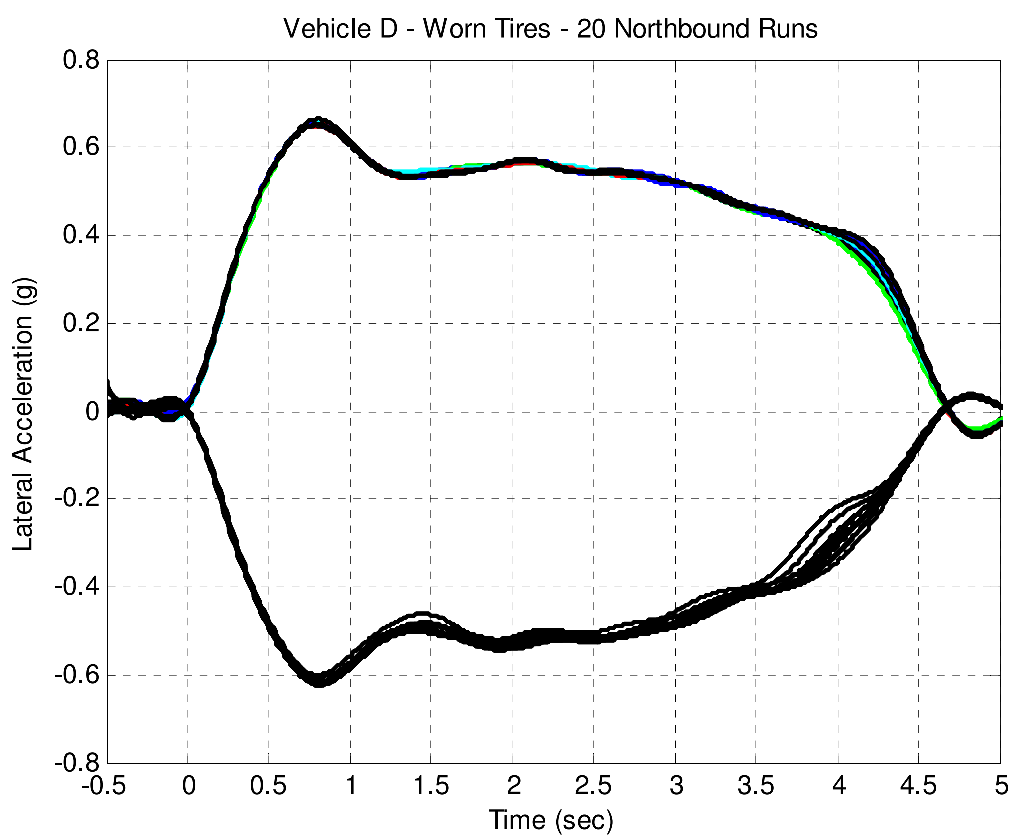
	Curb	Operator	Operator & Passenger	Operator, Inst & Outriggers	Operator, Inst, Outriggers Repeat Tests April 2013
Mileage					103
VIMF Test Number		4366	4367	4368	
Total Vehicle Weight (lb)	1417.2	1631.0	1841.9	1848.8	1845.0
Left Front Weight (lb)	312.5	349.5	390.2	394.9	385
Right Front Weight (lb)	313.1	356.5	394.9	389.2	395
Left Rear Weight (lb)	381.4	524.7	519.4	550.7	563
Right Rear Weight (lb)	410.2	400.3	537.4	514.0	502
Front Track Width (in)	49.65	49.65	50.38	50.38	50.38
Rear Track Width (in)	48.33	48.33	48.33	48.33	48.33
Average Track Width (in)	48.99	48.99	49.35	49.35	49.35
Wheelbase (in)	76.05	76.05	76.20	76.20	76.20
CG Longitudinal (in)	42.48	43.13	43.72	43.88	43.99
CG Lateral (in)	0.51	-1.76	0.30	-0.57	-0.68
CG Height (in)		24.98	25.46	25.66	
Roll Inertia - I_{XX} (ft-lb-s^2)		159	187	208	
Pitch Inertia - I_{YY} (ft-lb-s^2)		332	345	362	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		356	370	403	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	16	14	
SSF		0.981	0.969	0.962	
KST		0.982	0.972	0.965	
CSV (mph)		8.19	8.15	8.21	
Front Ground Clearance (in)			10.25		
Rear Ground Clearance (in)			8.10		
Steering Ratio (deg/deg)			13.2		

Appendix B:

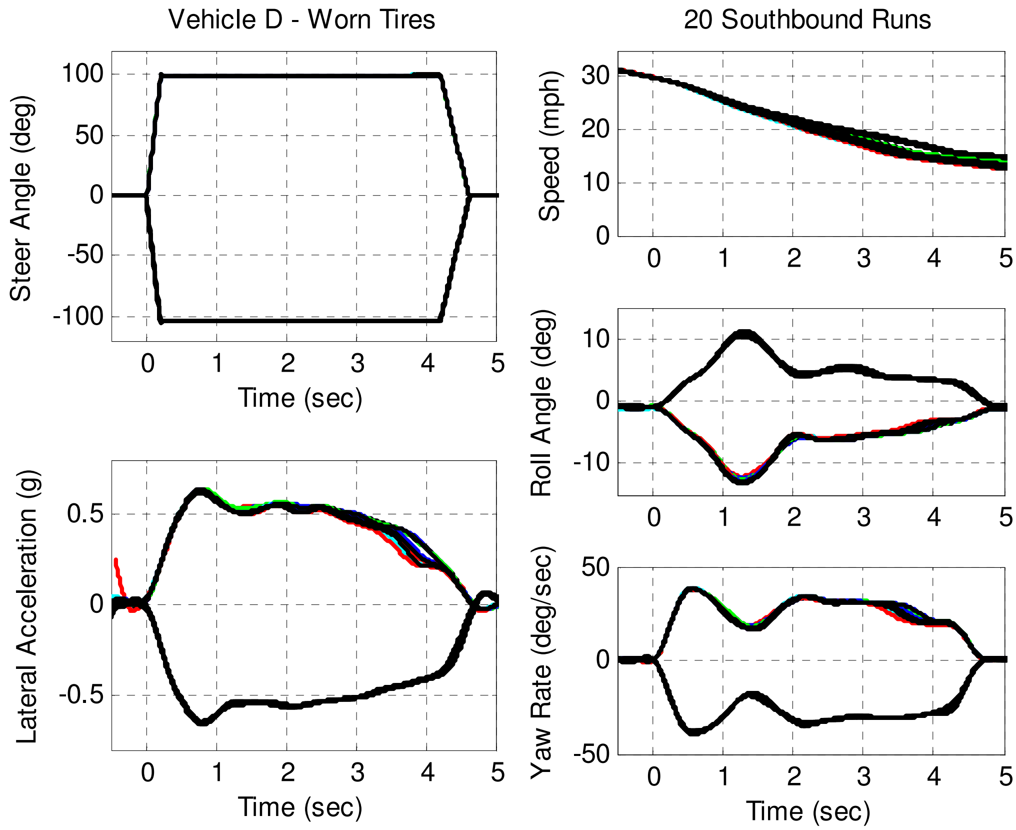
Graphical Results from 30 mph Dropped Throttle J-Turn Tests

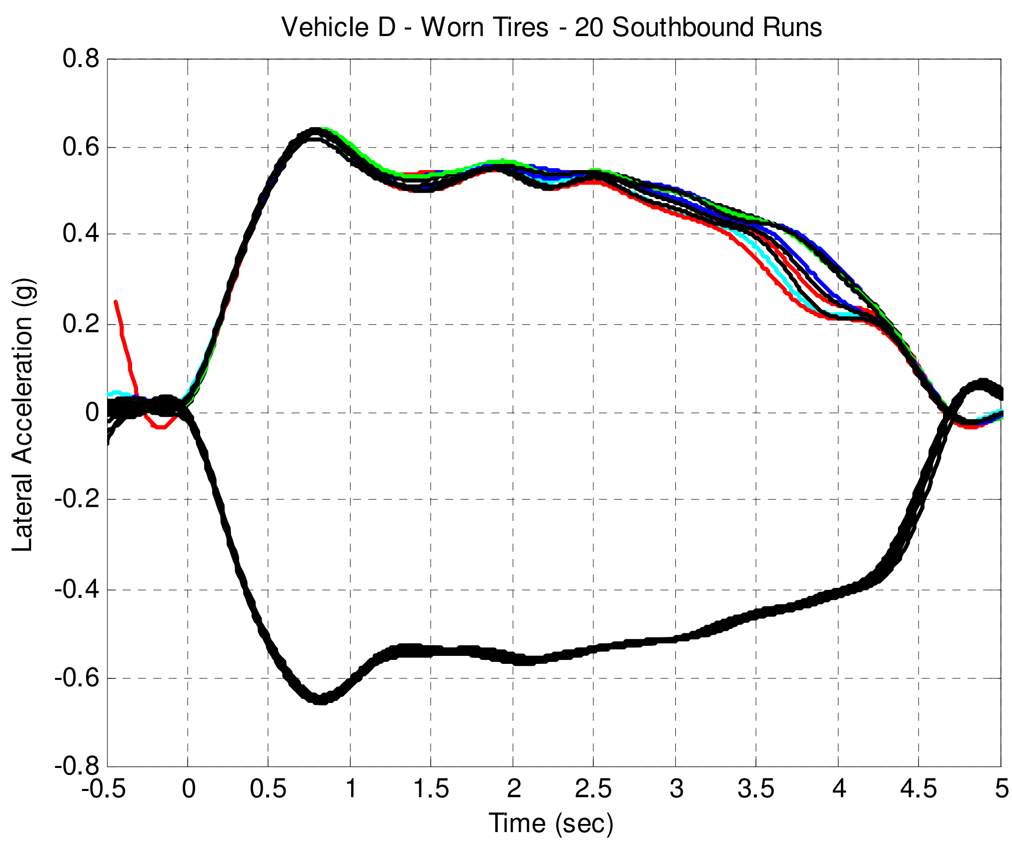
30 mph Dropped Throttle J-Turn Test Results – 20 Northbound Runs
Vehicle D – Worn Tires



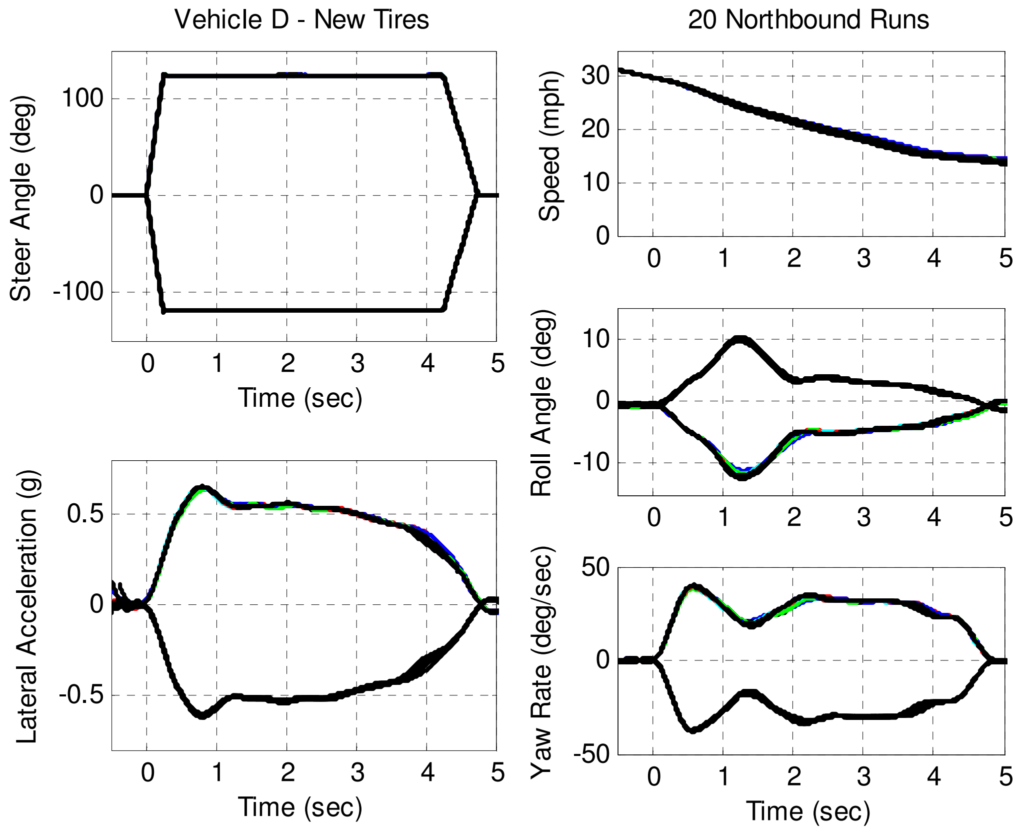


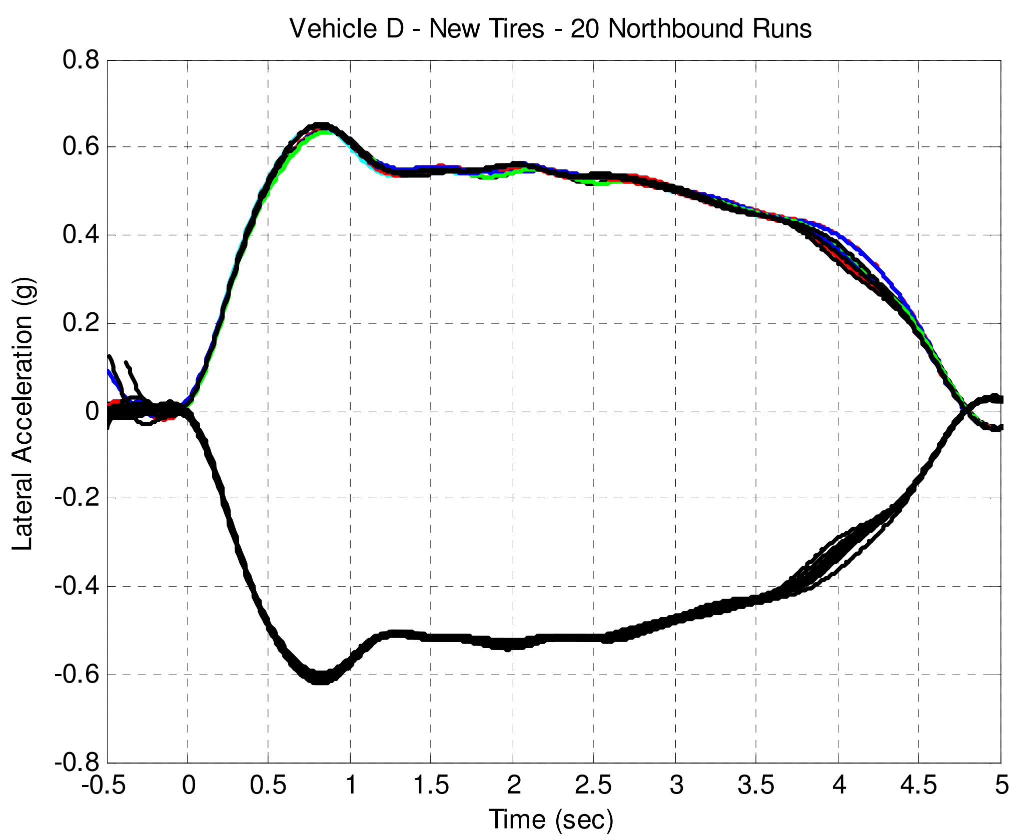
30 mph Dropped Throttle J-Turn Test Results – 20 Southbound Runs
Vehicle D – Worn Tires



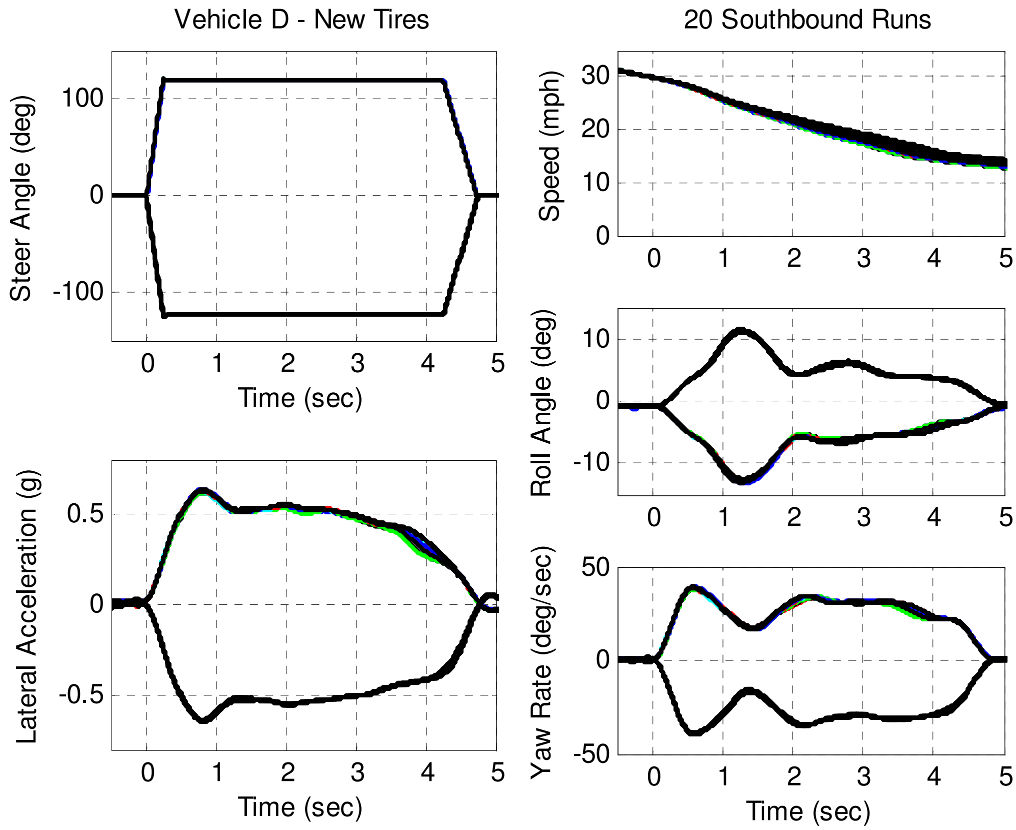


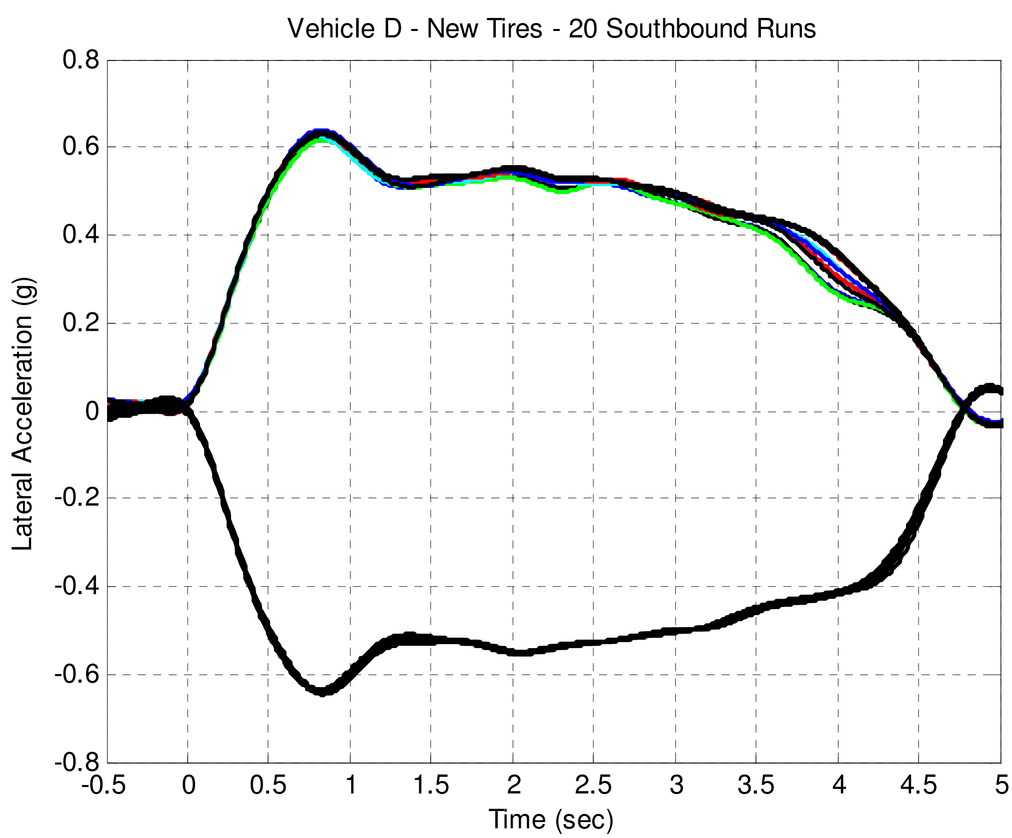
30 mph Dropped Throttle J-Turn Test Results – 20 Northbound Runs
Vehicle D – New Tires



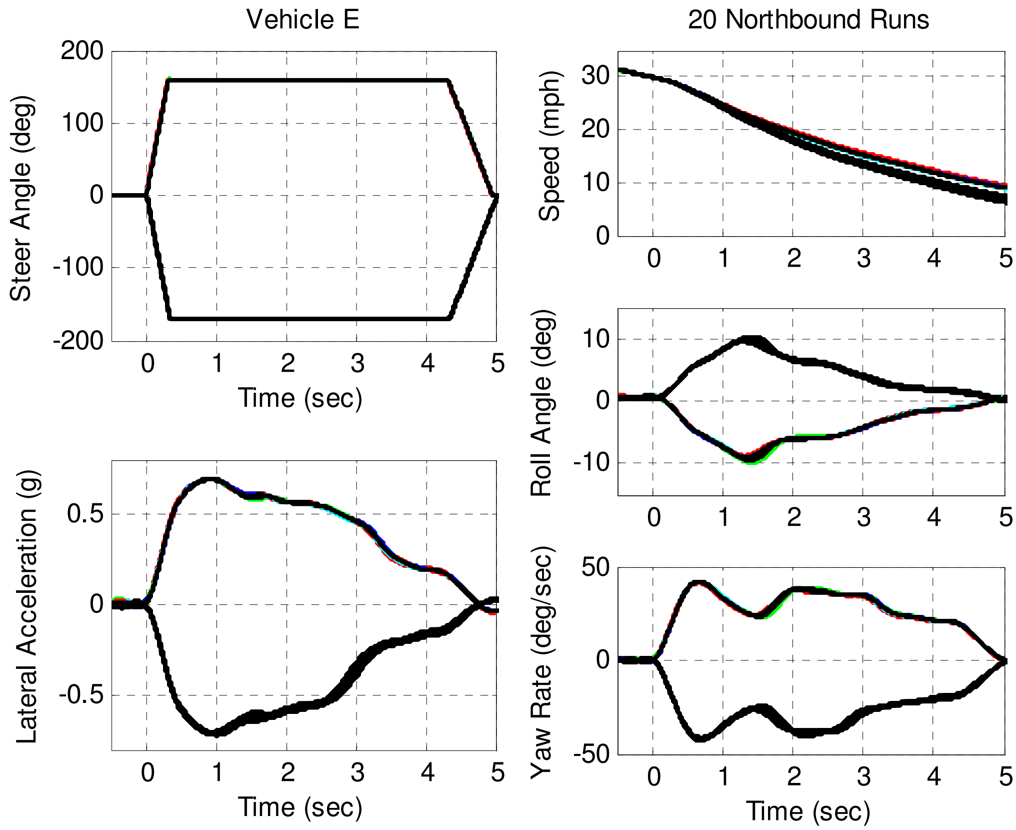


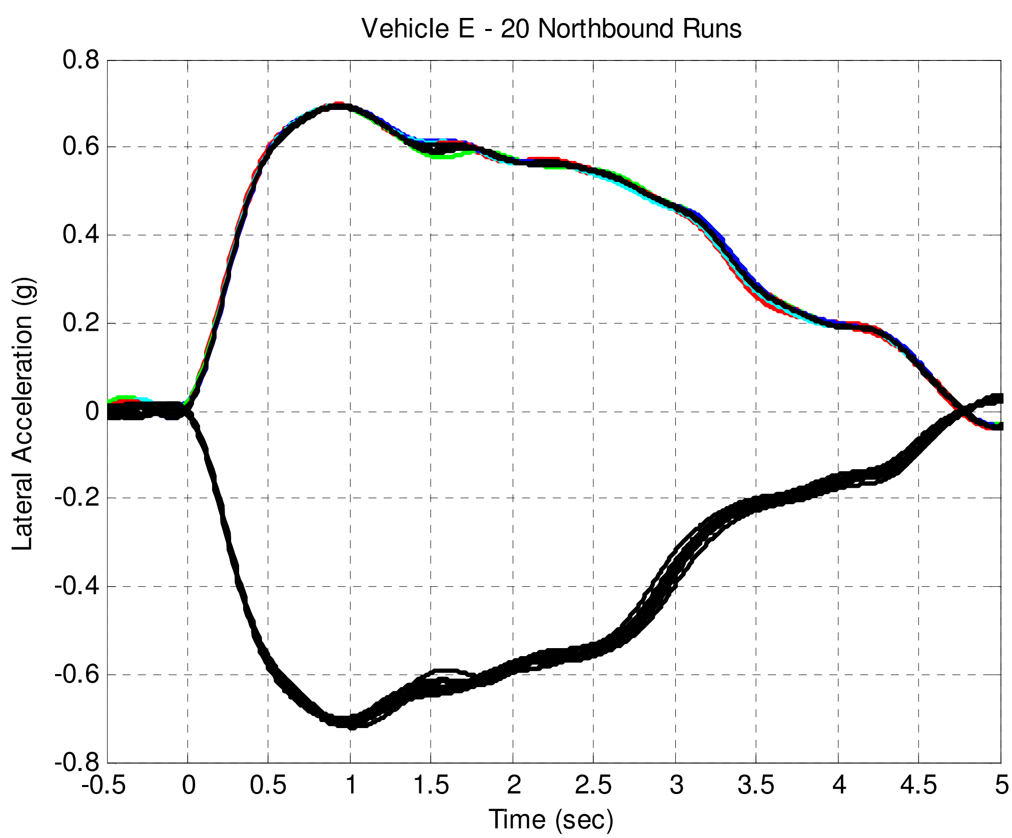
30 mph Dropped Throttle J-Turn Test Results – 20 Southbound Runs
Vehicle D – New Tires



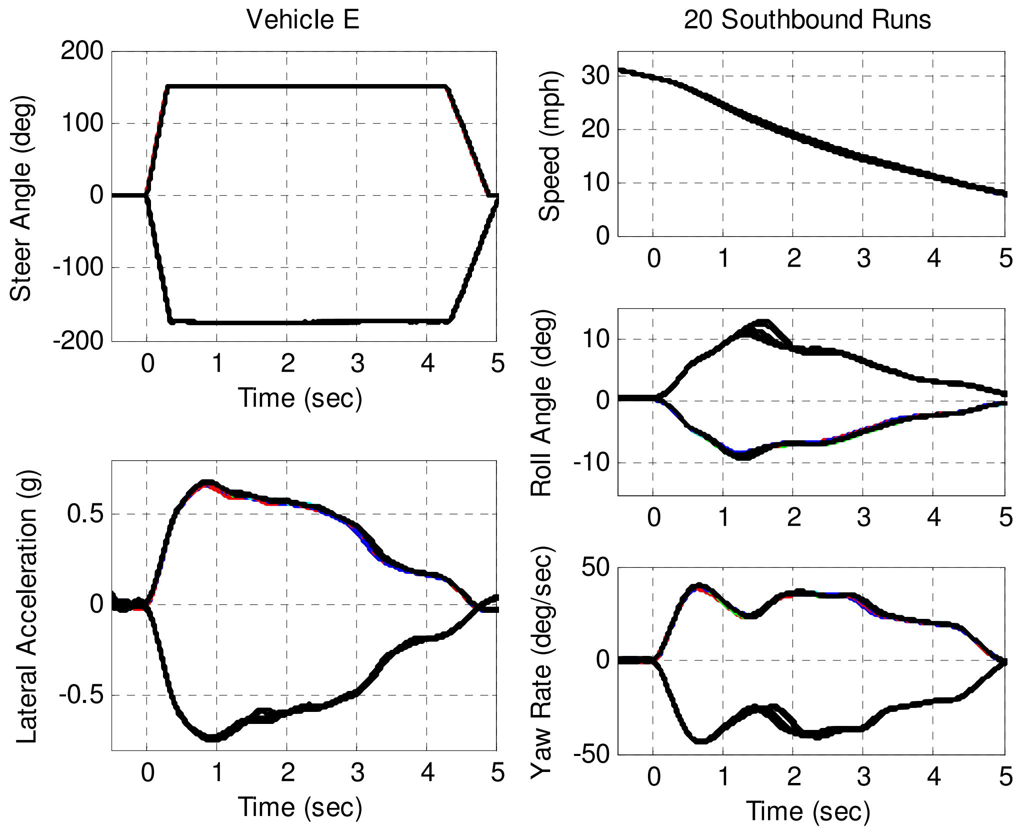


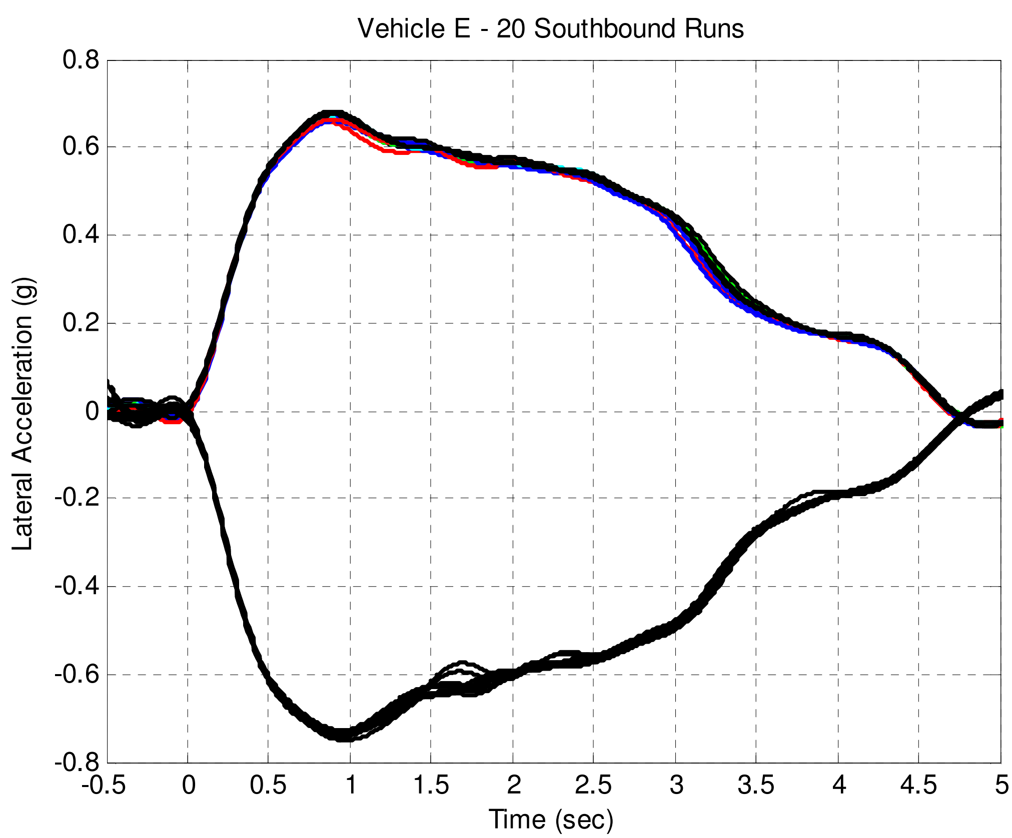
30 mph Dropped Throttle J-Turn Test Results – 20 Northbound Runs
Vehicle E – New Tires



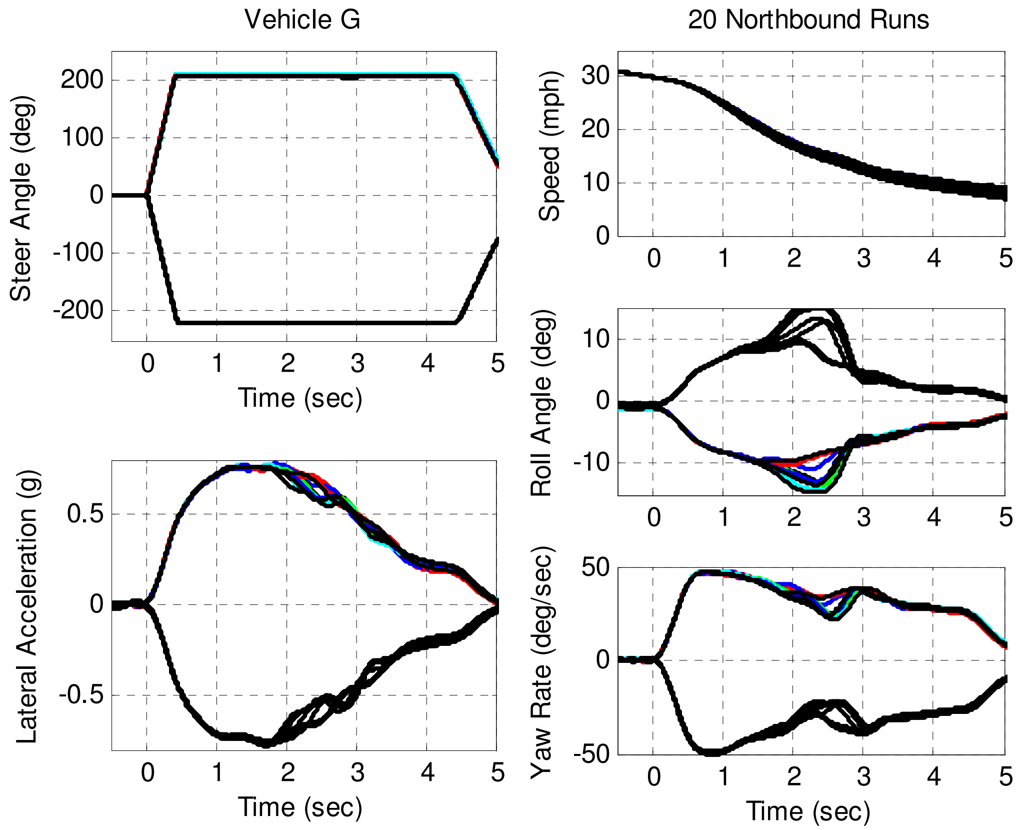


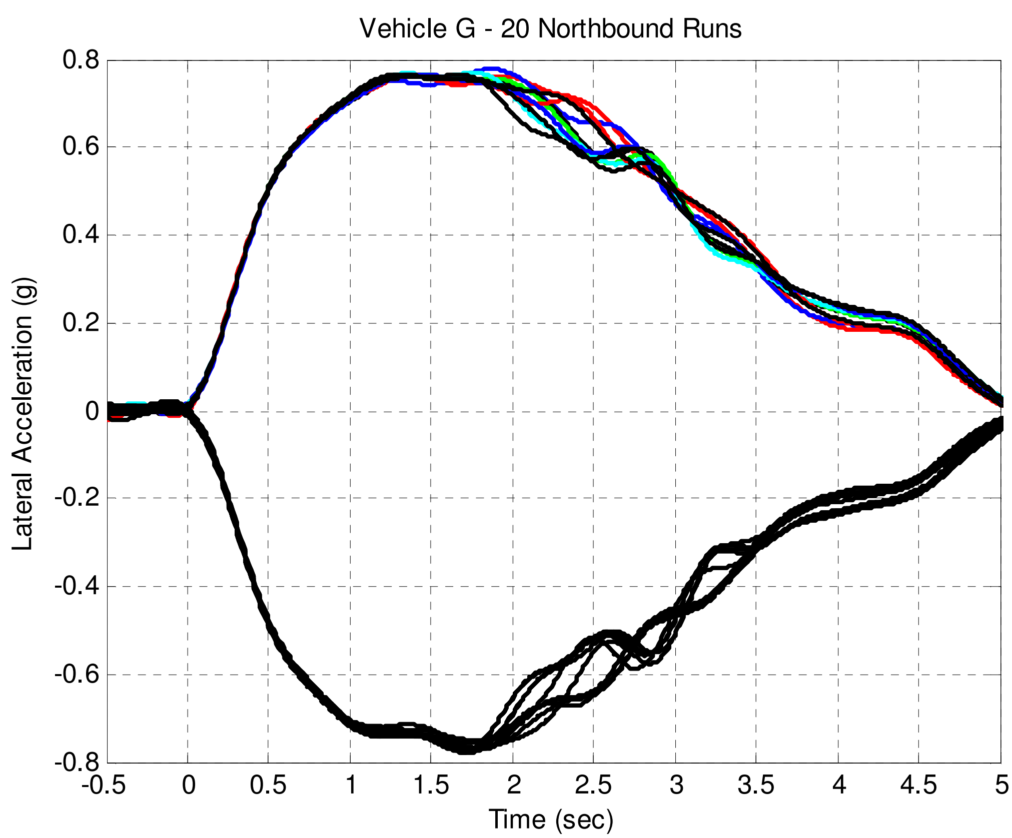
30 mph Dropped Throttle J-Turn Test Results – 20 Southbound Runs
Vehicle E – New Tires



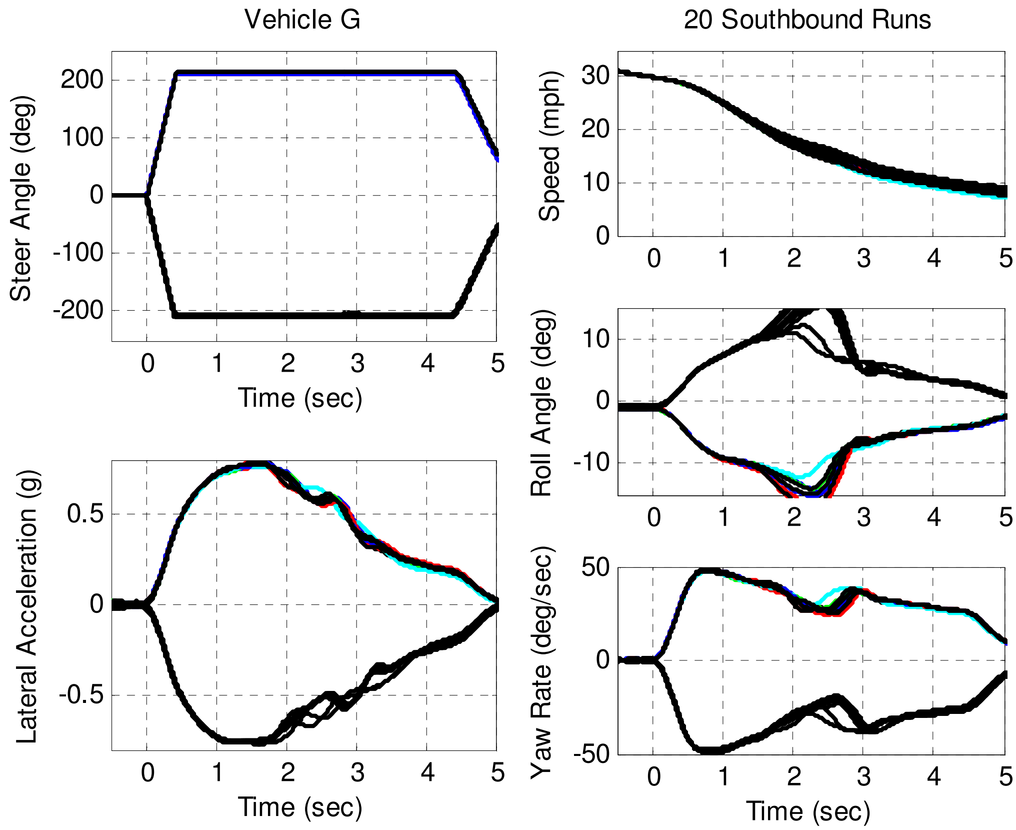


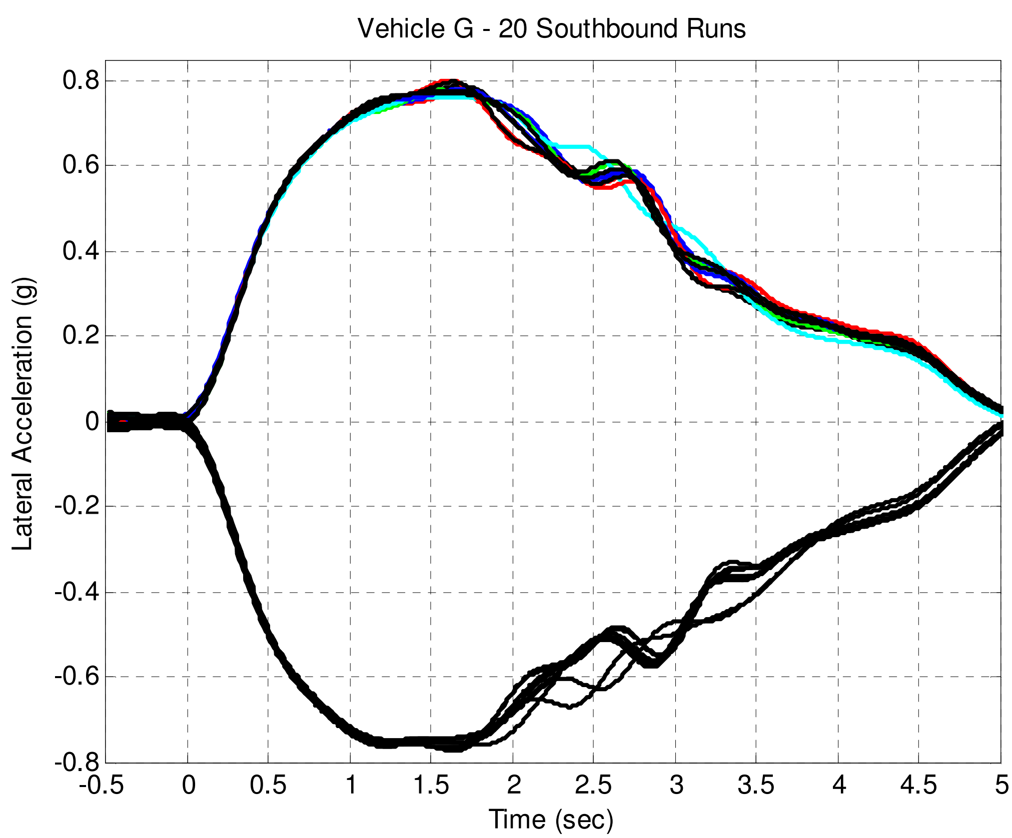
30 mph Dropped Throttle J-Turn Test Results – 20 Northbound Runs
Vehicle G – New Tires



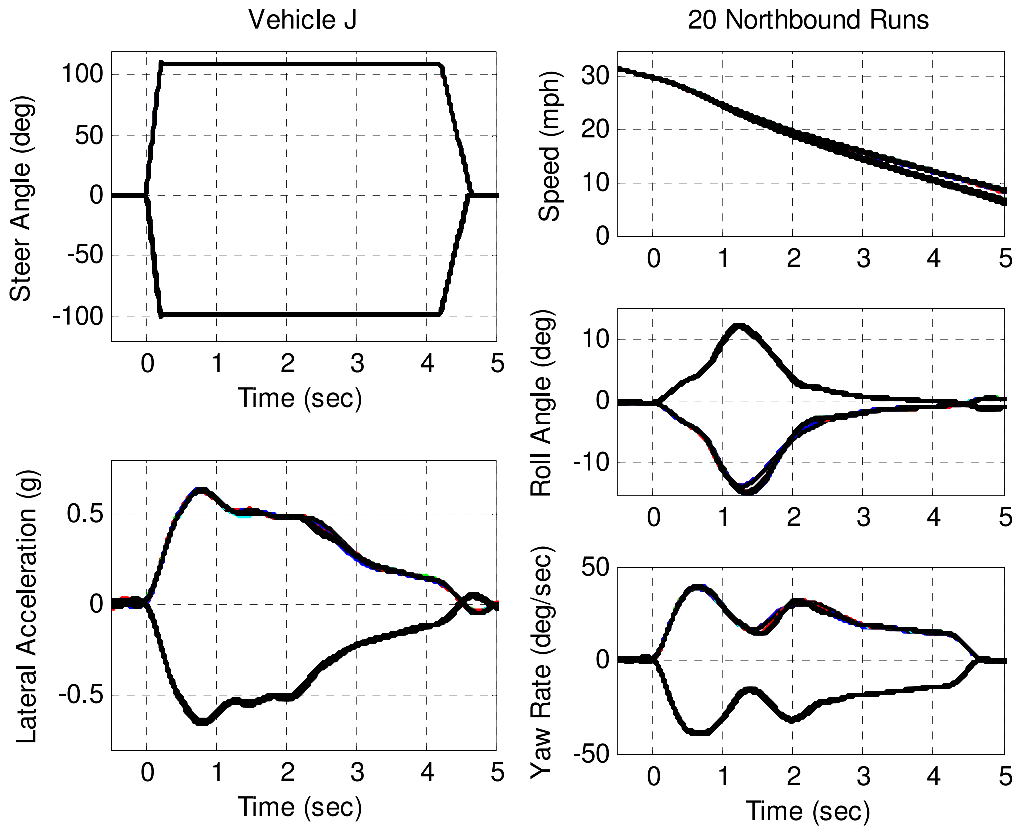


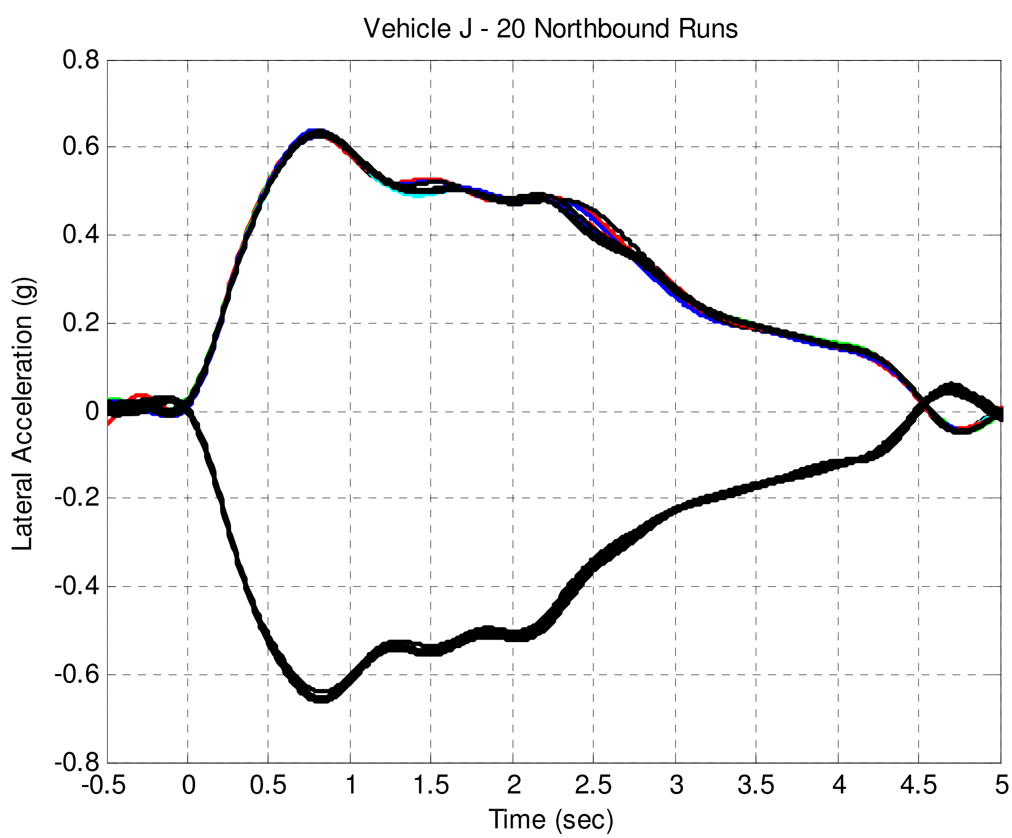
30 mph Dropped Throttle J-Turn Test Results – 20 Southbound Runs
Vehicle G – New Tires



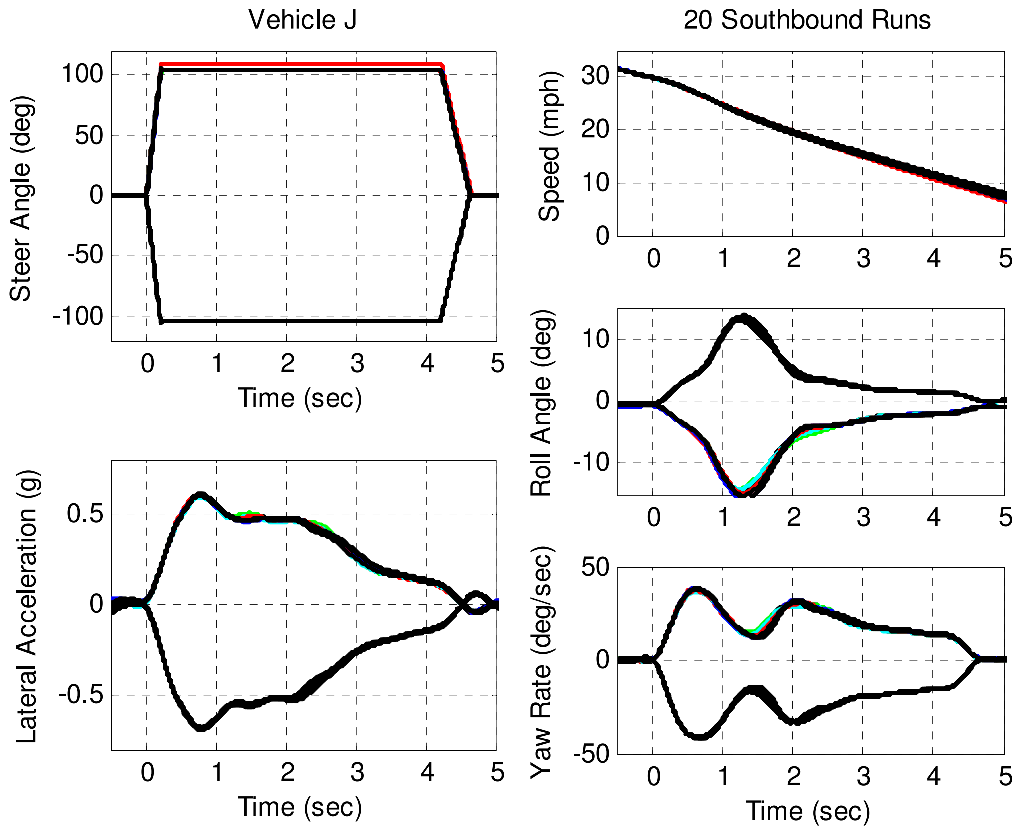


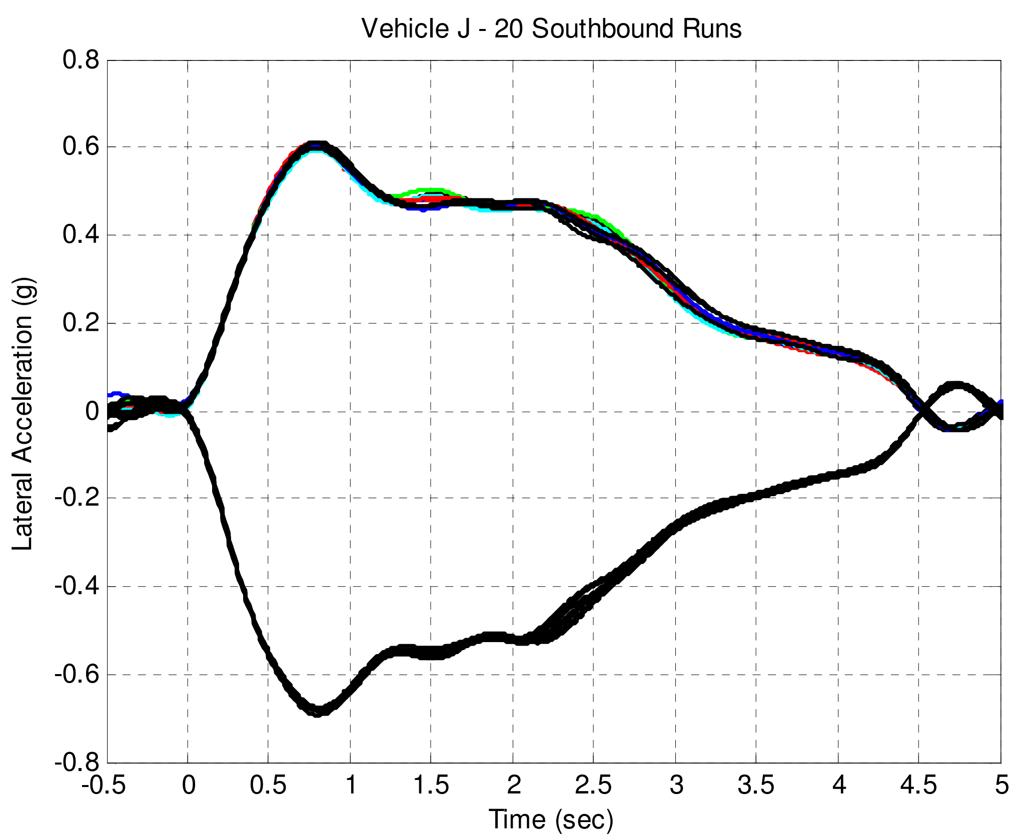
30 mph Dropped Throttle J-Turn Test Results – 20 Northbound Runs
Vehicle J – New Tires





30 mph Dropped Throttle J-Turn Test Results – 20 Southbound Runs
Vehicle J – New Tires





Appendix C:

Comparison of Methods Used to Compute Corrected Lateral Acceleration

Comparison of Methods Used to Compute Corrected Lateral Acceleration

This appendix provides an analysis of four methods used to measure and compute the roll angle corrected lateral acceleration at the CG of the vehicle, the ground plane lateral acceleration. The data shown in this appendix is all from Vehicle D, the vehicle that had two different acceleration sensors mounted onboard the vehicle during the testing. The Crossbow sensor was mounted directly on top of the RT3002 sensor. Table C1 lists the positions of the RT3002 and Crossbow sensors relative to the CG of the vehicle (using the SAE vehicle dynamics coordinate system).

Table C1: Sensor Positions Relative to Vehicle CG

	RT3002	Crossbow
x_{disp}: Longitudinal Distance from Sensor to Vehicle CG	19.25 in (0.489 m)	19.25 in (0.489 m)
y_{disp}: Lateral Distance from Sensor to Vehicle CG	0.00 in (0.000 m)	0.00 in (0.000 m)
z_{disp}: Vertical Distance from Sensor to Vehicle CG	10.63 in (0.270 m)	14.09 in (0.358 m)

The methods are:

Method 1: Direct Measurement Method: Direct measurement of corrected lateral acceleration from a sensor designed to compensate for the roll angle and to translate the acceleration outputs to the CG of vehicle. This is the method that has been used by S-E-A for all ROV testing conducted for CPSC. The sensor used by S-E-A is an Oxford Technical Solutions RT3002 Inertial and GPS Navigation System (RT3002).

Method 2: NHTSA/ROHVA Calculation: Calculation from measured body-fixed lateral acceleration, body-fixed vertical acceleration, and roll angle using an equation referenced by NHTSA[3] and ROHVA[4]. A diagram constructing the derivation of the equation used is provided on Figure C1. This method has been used throughout the vehicle dynamics testing community, particularly prior to the advent/availability of sensors that have algorithms for internally compensating for the corrected lateral acceleration. This method requires that both lateral and vertical accelerations be measured, so either a tri-axial accelerator package or two individual uni-axial accelerometers are required.

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[3] *Consumer Information; New Car Assessment Program; Rollover Resistance; Final Rule,* 49 CFR Part 575, Department of Transportation, NHTSA, October 2003.

[4] *American National Standard for Recreational Off-Highway Vehicles*, ANSI/ROHVA 1 – 2011, 2011

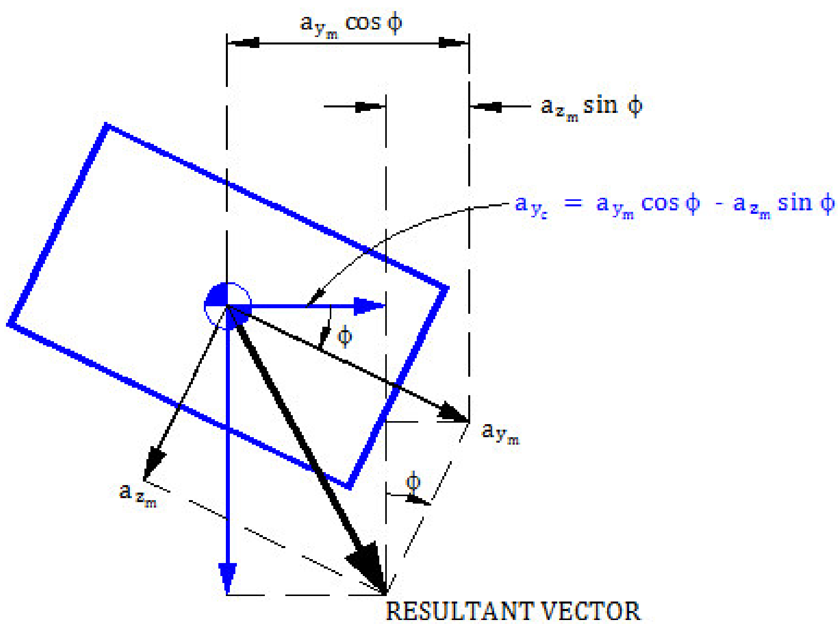
NOTE: The results presented for this method use the measured body-fixed lateral and vertical accelerations from the RT3002, and they were already translated to the CG location of the vehicle. The roll angle was also measured using the RT3002, and it is the roll angle of the vehicle body relative to a horizontal plane. The body-fixed lateral acceleration, the vertical acceleration and the roll angle were all filtered prior to making the calculation shown in Figure C1.

a_{y_m} = Measured body - fixed lateral acceleration

a_{z_m} = Measured body - fixed vertical acceleration

a_{y_c} = Corrected (Ground Plane) lateral acceleration

ϕ = Body roll angle



$$\boxed{a_{y_c} = a_{y_m} \cos\phi - a_{z_m} \sin\phi}$$

Figure C1: Method 2: NHTSA/ROHVA Calculation

Method 3: Carr Engineering, Inc. Calculation: Calculation from measured body-fixed lateral acceleration and roll angle using an equation referenced by Mr. James Walker from Carr Engineering, Inc. during his July 19, 2012 presentation made at CPSC headquarters[5]. A diagram constructing the derivation of the equation used is provided on Figure C2[5]. This method requires only lateral acceleration be measured, so only a single uni-axial accelerometer is required. According to Mr. Walker this calculation is used by some organizations, including Carr Engineering, to compute corrected lateral acceleration. He referenced an excerpt from a NHTSA standard[6] regarding Event Data Recorders (EDR) as justification for using 0 g as the vertical acceleration reference as opposed to using a reference of 1.0 g. The NHTSA standard goes on to say, "Since the acceleration data are used to compute velocity and motion relative to the other vehicle/barrier in our laboratory tests, 0 G vertical is defined with the gravity term not removed, hence 0 G vertical would be observed when the vertical accelerometer is as rest". This has nothing to do with measuring corrected lateral acceleration using the Method 3 equation listed on Figure C2. The Method 3 equation does not use vertical acceleration at all, so it is irrelevant whether the reference value for vertical acceleration is 0 g, +1 g, or –1 g.

NOTE: The results presented for this method use the measured body-fixed lateral acceleration from the RT3002, and it was already translated to the CG location of the vehicle. The roll angle was also measured using the RT3002, and it is the roll angle of the vehicle body relative to a horizontal plane. The body-fixed lateral acceleration and the roll angle were filtered prior to making the calculation shown in Figure C2.

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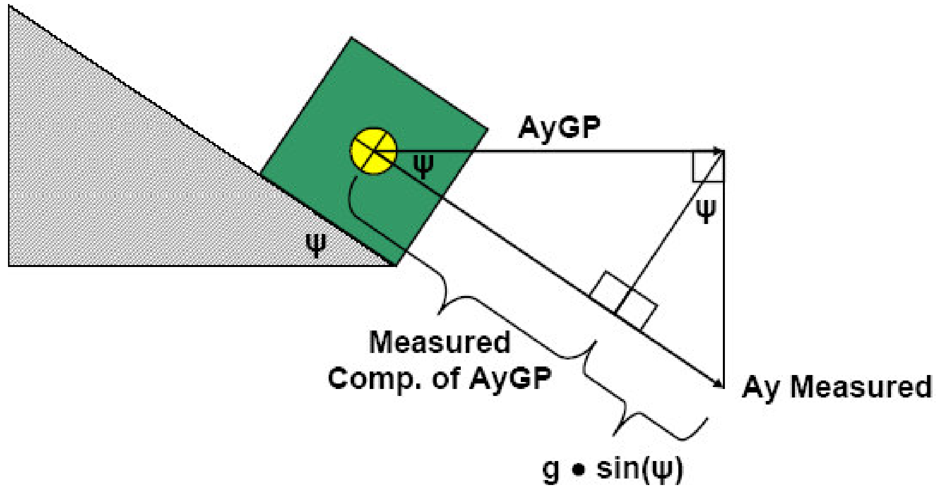
[5] *ROHVA/CPSC Technical Discussio*n, Presentation made by James Walker, Carr Engineering, Inc., at CPSC headquarters July 19, 2012.

[6] *Event Data Recorders* 49, CFR Part 563, Department of Transportation, NHTSA, Docket No. NHTSA-2006-25666, RIN 2127-AI72, August 2006



1. Measured Comp. of AyGP = (AyGP • cos(ψ))

2. Ay Measured = (AyGP • cos(ψ)) + (g • sin(ψ))

3. AyGP = (Ay Measured - sin(ψ)) / (cos(ψ)) in units of g

NOTE: In diagram and equations above: **ψ = Body roll angle**

Figure C2: Method 3: Carr Engineering, Inc. Calculation

Method 4: Measurements from Crossbow Body-Fixed Acceleration Sensor Not Mounted at the Vehicle CG using NHTSA/ROHVA Calculation: Calculation from body-fixed accelerations measured using the Crossbow sensor, which was not mounted at the CG of the test vehicle. The Crossbow sensor measures three accelerations and three angular rates. Using this information, and knowing the distances between the sensor and the vehicle CG in three dimensions (provided in Table C1), the three acceleration quantities can be translated to the CG location of the vehicle. Figure C3, taken from the NHTSA standard related to rollover resistance[7], shows the equations used to translate the quantities. Notice that the translation equations use roll, pitch, and yaw rates; and roll, pitch, and yaw accelerations. The angular rates used in reducing the data presented were the Crossbow measurements, and the angular accelerations were computed by numerically differentiating the filtered angular rates.

After the accelerations were translated to the vehicle CG location, the Method 2, NHTSA/ROHVA Calculation, was used to compute the corrected lateral acceleration.

NOTE: The roll angle used for the Method 4 calculations was measured using the RT3002, and it is the roll angle of the vehicle body relative to a horizontal plane. All

[7] *Consumer Information; New Car Assessment Program; Rollover Resistance; Final Rule,* 49 CFR Part 575, Department of Transportation, NHTSA, October 2003.

direct sensor measurements were filtered prior to computing the angular accelerations, the translation equations shown in Figure C3, and the ground plane lateral acceleration calculation shown in Figure C1.

The following equations are used to correct the accelerometer data in post-processing. They were derived from equations of general relative acceleration for a translating reference frame and use the SAE Convention for Vehicle Dynamics Coordinate Systems. The coordinate transformations are:

$$x''_{corrected} = x''_{accel} - (\Theta'^2 + \Psi'^2)x_{disp} + (\Theta'\Phi' - \Psi'')y_{disp} + (\Psi'\Phi' + \Theta'')z_{disp}$$
$$y''_{corrected} = y''_{accel} + (\Theta'\Phi' + \Psi'')x_{disp} - (\Phi'^2 + \Psi'^2)y_{disp} + (\Psi'\Theta' - \Phi'')z_{disp}$$
$$z''_{corrected} = z''_{accel} + (\Psi'\Phi' - \Theta'')x_{disp} + (\Psi'\Theta' + \Phi'')y_{disp} - (\Phi'^2 + \Theta'^2)z_{disp}$$

where

$x''_{corrected}$, $y''_{corrected}$, and $z''_{corrected}$ = longitudinal, lateral, and vertical accelerations, respectively, at the vehicle's center of gravity

x''_{accel}, y''_{accel}, and z''_{accel} = longitudinal, lateral, and vertical accelerations, respectively, at the accelerometer location

x_{disp}, y_{disp}, and z_{disp} = longitudinal, lateral, and vertical displacements, respectively, of the center of gravity with respect to the accelerometer location

Φ' and Φ'' = roll rate and roll acceleration, respectively

Θ' and Θ'' = pitch rate and pitch acceleration, respectively

Ψ' and Ψ'' = yaw rate and yaw acceleration, respectively

Figure C3: Method 4: Calculations to Translate Measured Body-Fixed Acceleration Quantities to the CG Location of the Test Vehicle

Figure C4 contains graphs showing various stages of calculations leading to the Method 4 ground plane lateral acceleration along with Method 1 direct measurement of ground plane lateral acceleration. The graphs are from two runs of Vehicle D with worn tires: the first northbound right turn tip-up (Run 123) and the first northbound left turn tip-up (Run 132). The right turn run has the positive accelerations and the left turn run has the negative accelerations. The yellow lines show the raw (unfiltered) body-fixed lateral accelerations measured using the Crossbow sensor. The red lines show the filtered (2 Hz low pass, phaseless, Butterworth filter) body-fixed lateral accelerations measured using the Crossbow sensor. The blue lines show the body-fixed lateral accelerations after they have been translated to the vehicle CG location using the calculations provided in Figure C3. The black lines (the Method 4 final results) show the ground plane lateral accelerations computed from the translated body-fixed lateral accelerations using the NHTSA/ROHVA calculation. The magenta lines are the ground plane lateral accelerations from Method 1. Notice that the magnitude of the peak ground plane lateral acceleration is greater for Method 1 in the right turn direction, and it is greater for Method 4 in the left turn direction. However, when the right turn values and left turn values are averaged together, the overall average difference between the two methods was found to be small (as will be discussed further in the following section).

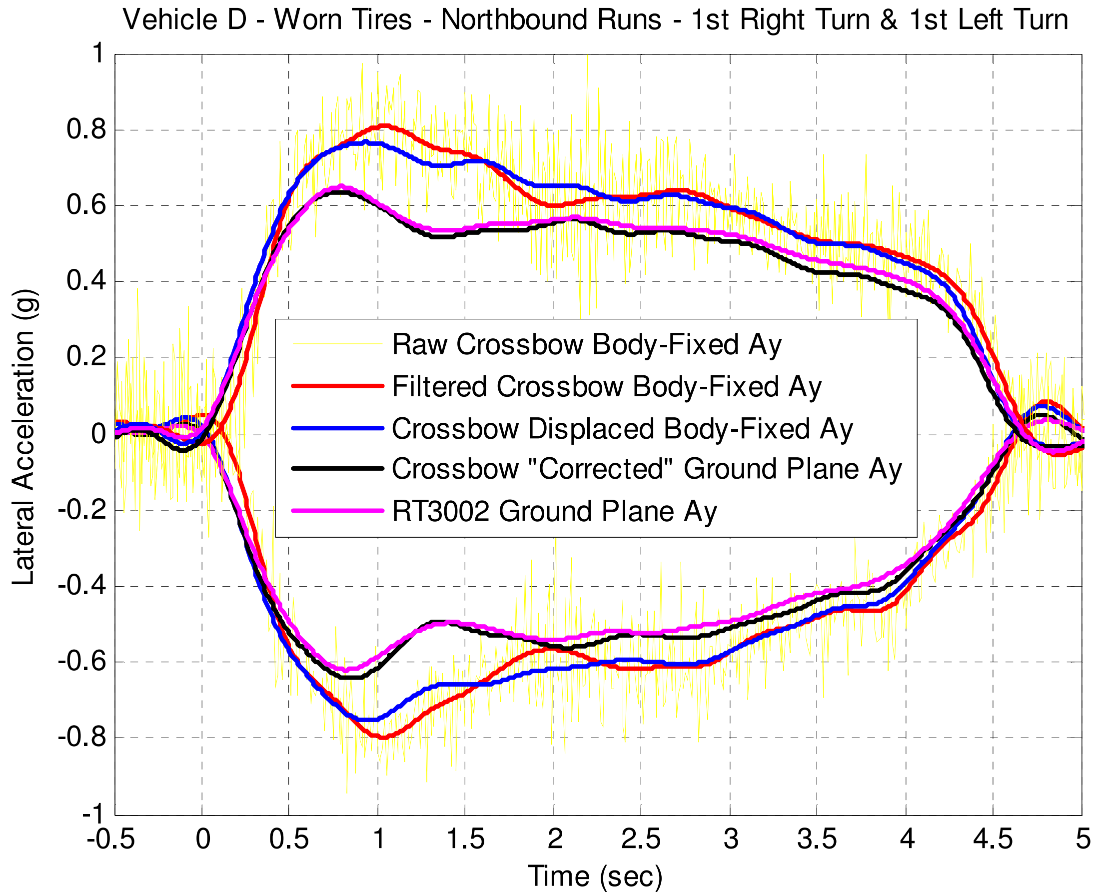


Figure C4: Graphs Showing Various Stages of Calculations Leading to the Method 4 Ground Plane Lateral Acceleration (Along with Method 1 Direct Measurement)

Discussion of Results from Using Different Methods to Compute Corrected Lateral Acceleration

The main body of this report contains the Method 1 (baseline) listing of the peak lateral acceleration at tip-up for the 40 threshold tip-up runs made for Vehicle D with worn tires (Table 4) and with new tires (Table 5). Similar listings showing the peak lateral accelerations using Methods 2, 3, and 4 for Vehicle D with worn tires are show as Tables C3, C4, and C5. For Vehicle D with new tires, results using Methods 2, 3, and 4 are shown on Tables C6, C7, and C8.

Figures C5, C6, C7, and C8 show the graphs of ground plane lateral accelerations for the 20 northbound tip-up runs of Vehicle D with worn tires using Methods 1, 2, 3, and 4, respectively.

Figures C9-C12 show similar graphs for Vehicle D with new tires.

Table C2 contains a summary of the ground plane lateral accelerations measured and computed using Methods 1, 2, 3, and 4. The table shows that Method 2 average of 40 runs gives the same ground plane lateral acceleration as Method 1. This shows that the equation and variables used in the Method 2 calculation (NHTSA/ROHVA Calculation) provides the same 40 run average ground plane lateral acceleration to the nearest 0.001 g as the direct measurements made using the internally compensated RT3002 GPS/IMU sensor. This close level agreement is as expected, given that the roll angle used in the Method 2 calculations is the same roll angle that the RT3002 uses in its internal compensation. The reported accuracy of the RT3002 roll angle measurement is 0.03 deg. If a different, less accurate method or sensor is used to measure roll angle for the Method 2 calculation, the results will not agree this well.

Table C2 indicates that the Method 3 calculation (Carr Engineering, Inc. Calculation) results in 40 run average ground plane lateral acceleration values that are 0.003 g greater in magnitude than the Method 1 and Method 2 values. For Vehicle D, not including the component of vertical acceleration in the calculation for ground plane lateral acceleration has only a small influence on the resulting peak ground plane lateral acceleration values calculated using Method 3. This is likely also true for other ROVs during 30 mph, dropped-throttle J-Turn tests. Method 3 results are computed from the same body-fixed lateral acceleration and roll angle measurements as were used in the Method 2 calculation. If a different, less accurate method or sensor is used to measure roll angle for the Method 3 calculation, the results will not agree this well.

As shown on Table C2, the 40 run average ground plane lateral acceleration values measured using the Crossbow sensor and Method 4 translations and ground plane calculations are 0.006 g different than the Method 1 values for Vehicle D with worn tires and 0.004 g different for Vehicle D with new tires. This shows that using a body-fixed acceleration sensor that is not mounted at the CG location of the test vehicle can be used to compute ground plane lateral acceleration at the CG of the vehicle with precision of less than 0.01 g, when compared to the Method 1 (direct inertia and position corrected) measurement. Method 4 used a different sensor to measure accelerations and rates, but it used the same roll angle measurement as was used in the Method 1, 2, and 3 calculations. If a different, less accurate method or sensor is used to measure roll angle for the Method 4 calculation, the results will not agree this well.

Results presented in this appendix indicate that good agreement in the peak ground plane lateral acceleration at the CG location of the vehicle (for a vehicle performing a dropped-throttle J-Turn) can be achieved using any of the four methods evaluated. In general, test-to-test repeatability was found to be good for all methods evaluated. However, adherence to exacting test methodologies is required to generate high fidelity results. Transducers must be properly calibrated; data collection systems must have low levels of noise and crosstalk that could affect signal quality; sensor location relative to the vehicle CG must be accurately measured; and methods used to measure roll angle from side height sensors or to compute roll angle from roll rate must be accurate.

The RT3002 GPS/IMU sensor provides for full three-dimensional compensation calculations of ground plane acceleration. Therefore, Method 1 (direct fully compensated sensor output) will provide accurate ground plane lateral acceleration measurements for all types of maneuvers, even ones with significant pitch motions and ones that generate any amount of roll angle. The Method 2 calculations are based on a planar analysis (the roll plane) of the dynamics of the vehicle. Any amount of significant motions out of roll plane (i.e. significant pitch motions) will cause the Method 2 results to deviate from the true ground plane lateral acceleration. The same can be said about the Method 3 calculation. The Method 3 calculation also suffers from the fact that it does not include the vertical acceleration. For maneuvers that generate greater body-fixed vertical accelerations than those studied here, the Method 3 calculated values would further deviate from the true ground plane lateral accelerations. The Method 4 equations for translating the body-fixed at the sensor location to the CG location of the vehicle are valid for all three-dimensional motions. However, the Method 4 equation for computing ground plane lateral acceleration is the same equation used in Method 2, so any significant motions out of the roll plane would also cause Method 4 results to deviate from the true ground plane lateral acceleration.

In the body of this report, it was reported that wind, lateral CG offsets, and vehicle steering and suspension asymmetries are essentially cancelled out when right turn and left turn lateral acceleration values are averaged together. Likewise, (based on several sensitivity studies performed by the author but not presented in this report) the need for stringent lateral acceleration and roll angle sensor offset removal and for tight tolerance on zeroing the roll angle transducer get essentially cancelled out if the same number of right turn and left turn corrected lateral accelerations are averaged together.

Table C2: Summary of Ground Plane Lateral Accelerations Measured and Computed Using Different Methods				
	Method 1	**Method 2**	**Method 3**	**Method 4**
	Directly From RT3002 Sensor (g)	**Computed Using RT3002 Body-Fixed Ay & Az and Using NHTSA/ROHVA Equation (g)**	**Computed Using RT3002 Body-Fixed Ay and Using Carr Eng., Inc. Equation (g)**	**Computed Using Crossbow Body-Fixed Ay and Az, by Translating to Vehicle CG and Using NHTSA/ROHVA Equation (g)**
Vehicle D Worn Tires	**0.639**	**0.639**	**0.642**	**0.645**
Vehicle D New Tires	**0.631**	**0.631**	**0.634**	**0.635**

RT3002: Ay = Body-Fixed Ay x cos(Roll Angle) - Body-Fixed Az x sin(Roll Angle)

	Northbound Right Turn	Northbound Left Turn	
1	0.6494	-0.6207	
2	0.6516	-0.6145	
3	0.6509	-0.6052	
4	0.6544	-0.6167	
5	0.6577	-0.6240	
6	0.6539	-0.6214	
7	0.6544	-0.6220	
8	0.6514	-0.6237	
9	0.6651	-0.6006	
10	0.6533	-0.6153	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6542	-0.6164	**0.6353**
Standard Deviation of 10 Runs	0.004	0.008	

RT3002: Ay = Body-Fixed Ay x cos(Roll Angle) - Body-Fixed Az x sin(Roll Angle)

	Southbound Right Turn	Southbound Left Turn	
1	0.6358	-0.6431	
2	0.6344	-0.6574	
3	0.6345	-0.6469	
4	0.6397	-0.6477	
5	0.6331	-0.6507	
6	0.6333	-0.6488	
7	0.6351	-0.6586	
8	0.6185	-0.6544	
9	0.6401	-0.6571	
10	0.6295	-0.6581	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6334	-0.6523	**0.6428**
Standard Deviation of 10 Runs	0.006	0.006	

Average of 40 Runs **0.639**

Table C3: Lateral Acceleration at Tip-Up – Vehicle D with Worn Tires
Method 2: Corrected Lateral Acceleration from RT3002 Body-Fixed Ay and Az
Using Ay = Body-Fixed Ay x cos(Roll Angle) – Body-Fixed Az x sin(Roll Angle)

RT3002: Ay = (Body-Fixed Ay + sin(Roll Angle)) / cos(Roll Angle)

	Northbound Right Turn	Northbound Left Turn	
1	0.6513	-0.6224	
2	0.6539	-0.6170	
3	0.6534	-0.6072	
4	0.6573	-0.6193	
5	0.6606	-0.6260	
6	0.6565	-0.6236	
7	0.6566	-0.6238	
8	0.6541	-0.6261	
9	0.6683	-0.6033	
10	0.6552	-0.6173	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6567	-0.6186	**0.6377**
Standard Deviation of 10 Runs	0.005	0.008	

RT3002: Ay = (Body-Fixed Ay + sin(Roll Angle)) / cos(Roll Angle)

	Southbound Right Turn	Southbound Left Turn	
1	0.6400	-0.6447	
2	0.6379	-0.6598	
3	0.6370	-0.6497	
4	0.6427	-0.6504	
5	0.6363	-0.6534	
6	0.6366	-0.6506	
7	0.6382	-0.6602	
8	0.6225	-0.6571	
9	0.6436	-0.6591	
10	0.6326	-0.6599	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6367	-0.6545	**0.6456**
Standard Deviation of 10 Runs	0.006	0.005	

Average of 40 Runs **0.642**

Table C4: Lateral Acceleration at Tip-Up – Vehicle D with Worn Tires
Method 3: Corrected Lateral Acceleration from RT3002 Body-Fixed Ay
Using Ay = (Body-Fixed Ay + sin(Roll Angle)) / cos(Roll Angle)

Crossbow: Translated to Vehicle CG and Corrected to Road Plane

	Northbound Right Turn	Northbound Left Turn	
1	0.6354	-0.6431	
2	0.6520	-0.6419	
3	0.6378	-0.6239	
4	0.6417	-0.6351	
5	0.6486	-0.6514	
6	0.6340	-0.6440	
7	0.6519	-0.6427	
8	0.6417	-0.6449	
9	0.6566	-0.6239	
10	0.6337	-0.6299	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6433	-0.6381	**0.6407**
Standard Deviation of 10 Runs	0.008	0.009	

Crossbow: Translated to Vehicle CG and Corrected to Road Plane

	Southbound Right Turn	Southbound Left Turn	
1	0.6317	-0.6629	
2	0.6356	-0.6797	
3	0.6348	-0.6617	
4	0.6369	-0.6786	
5	0.6113	-0.6667	
6	0.6380	-0.6685	
7	0.6284	-0.6649	
8	0.6195	-0.6743	
9	0.6313	-0.6683	
10	0.6217	-0.6651	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6289	-0.6691	**0.6490**
Standard Deviation of 10 Runs	0.009	0.006	

Average of 40 Runs	**0.645**

Table C5: Lateral Acceleration at Tip-Up – Vehicle D with Worn Tires
Method 4: Corrected Lateral Acceleration from Crossbow Body-Fixed Ay
after Translating Accelerations to Vehicle CG and Correcting to Ground Plane Ay

RT3002: Ay = Body-Fixed Ay x cos(Roll Angle) - Body-Fixed Az x sin(Roll Angle)

	Northbound Right Turn	Northbound Left Turn	
1	0.6412	-0.6146	
2	0.6394	-0.6063	
3	0.6385	-0.6077	
4	0.6364	-0.5979	
5	0.6494	-0.6072	
6	0.6510	-0.6145	
7	0.6492	-0.6162	
8	0.6490	-0.6147	
9	0.6478	-0.6219	
10	0.6543	-0.6204	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6456	-0.6121	**0.6289**
Standard Deviation of 10 Runs	0.006	0.007	

RT3002: Ay = Body-Fixed Ay x cos(Roll Angle) - Body-Fixed Az x sin(Roll Angle)

	Southbound Right Turn	Southbound Left Turn	
1	0.6236	-0.6399	
2	0.6176	-0.6380	
3	0.6228	-0.6355	
4	0.6167	-0.6386	
5	0.6248	-0.6423	
6	0.6313	-0.6375	
7	0.6399	-0.6464	
8	0.6303	-0.6455	
9	0.6286	-0.6428	
10	0.6347	-0.6384	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6270	-0.6405	**0.6337**
Standard Deviation of 10 Runs	0.007	0.004	

Average of 40 Runs **0.631**

Table C6: Lateral Acceleration at Tip-Up – Vehicle D with New Tires
Method 2: Corrected Lateral Acceleration from RT3002 Body-Fixed Ay and Az
Using Ay = Body-Fixed Ay x cos(Roll Angle) – Body-Fixed Az x sin(Roll Angle)

RT3002: Ay = (Body-Fixed Ay + sin(Roll Angle)) / cos(Roll Angle)

	Northbound Right Turn	Northbound Left Turn	
1	0.6438	-0.6163	
2	0.6419	-0.6077	
3	0.6415	-0.6093	
4	0.6391	-0.5994	
5	0.6518	-0.6078	
6	0.6530	-0.6162	
7	0.6526	-0.6172	
8	0.6505	-0.6161	
9	0.6498	-0.6241	
10	0.6573	-0.6221	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6481	-0.6136	**0.6309**
Standard Deviation of 10 Runs	0.006	0.007	

RT3002: Ay = (Body-Fixed Ay + sin(Roll Angle)) / cos(Roll Angle)

	Southbound Right Turn	Southbound Left Turn	
1	0.6269	-0.6426	
2	0.6217	-0.6404	
3	0.6264	-0.6379	
4	0.6202	-0.6414	
5	0.6269	-0.6447	
6	0.6347	-0.6401	
7	0.6448	-0.6487	
8	0.6334	-0.6482	
9	0.6312	-0.6459	
10	0.6380	-0.6409	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6304	-0.6431	**0.6368**
Standard Deviation of 10 Runs	0.008	0.004	

Average of 40 Runs **0.634**

Table C7: Lateral Acceleration at Tip-Up – Vehicle D with New Tires
Method 3: Corrected Lateral Acceleration from RT3002 Body-Fixed Ay
Using Ay = (Body-Fixed Ay + sin(Roll Angle)) / cos(Roll Angle)

Crossbow: Translated to Vehicle CG and Corrected to Road Plane

	Northbound Right Turn	Northbound Left Turn	
1	0.6308	-0.6224	
2	0.6369	-0.6108	
3	0.6338	-0.6259	
4	0.6309	-0.6133	
5	0.6401	-0.6181	
6	0.6367	-0.6319	
7	0.6319	-0.6293	
8	0.6447	-0.6328	
9	0.6488	-0.6384	
10	0.6531	-0.6408	**Average of 20 Northbound Runs**
Mean Value of 10 Runs	0.6388	-0.6264	**0.6326**
Standard Deviation of 10 Runs	0.008	0.010	

Crossbow: Translated to Vehicle CG and Corrected to Road Plane

	Southbound Right Turn	Southbound Left Turn	
1	0.6249	-0.6494	
2	0.6152	-0.6568	
3	0.6305	-0.6468	
4	0.6049	-0.6538	
5	0.6114	-0.6688	
6	0.6137	-0.6541	
7	0.6283	-0.6660	
8	0.6278	-0.6622	
9	0.6240	-0.6581	
10	0.6209	-0.6484	**Average of 20 Southbound Runs**
Mean Value of 10 Runs	0.6201	-0.6564	**0.6383**
Standard Deviation of 10 Runs	0.008	0.007	

Average of 40 Runs **0.635**

Table C8: Lateral Acceleration at Tip-Up – Vehicle D with New Tires
Method 4: Corrected Lateral Acceleration from Crossbow Body-Fixed Ay
after Translating Accelerations to Vehicle CG and Correcting to Ground Plane Ay

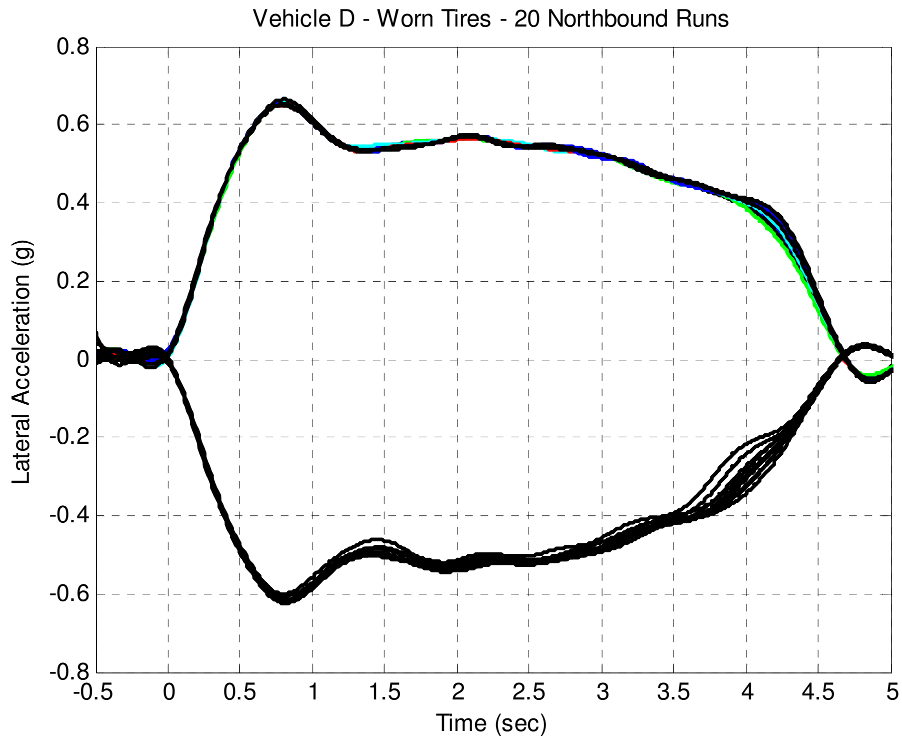


Figure C5: Results Using Method 1: Vehicle D – Worn Tires – 20 Northbound Runs

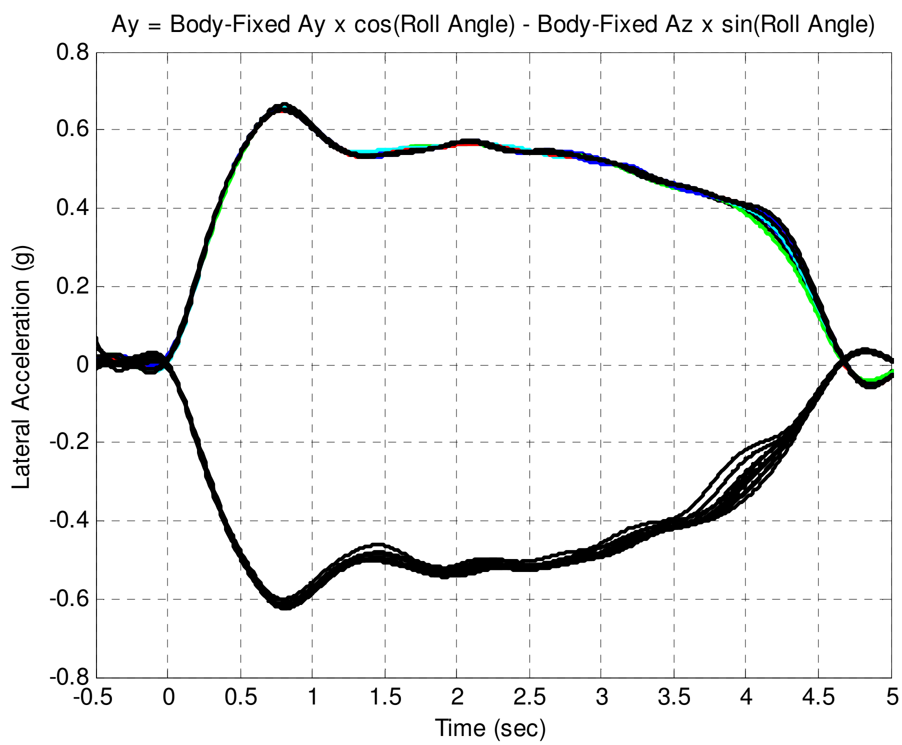


Figure C6: Results Using Method 2: Vehicle D – Worn Tires – 20 Northbound Runs

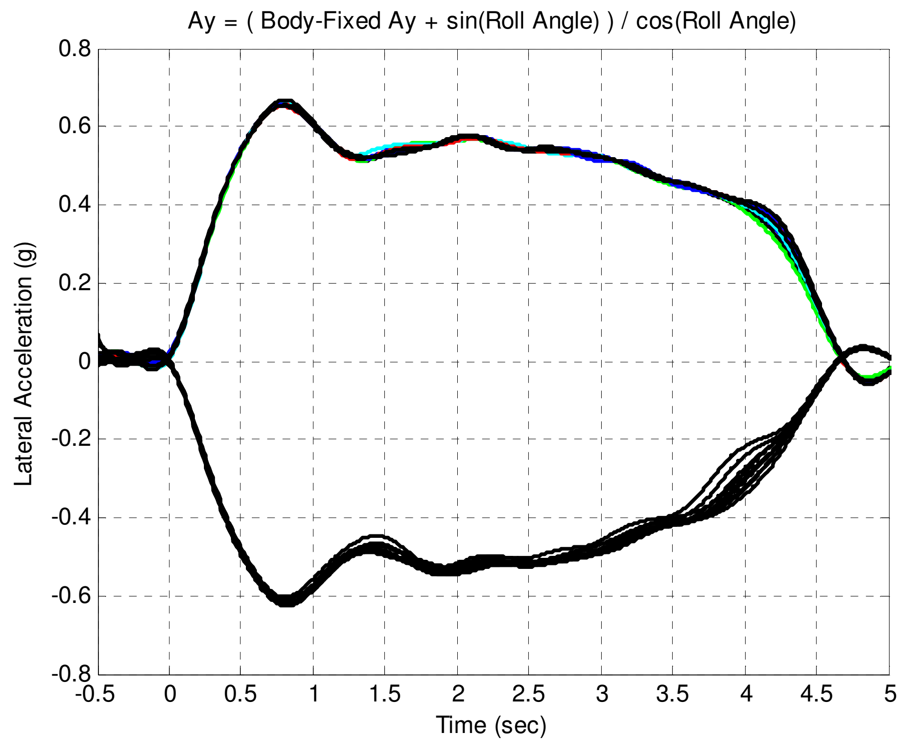


Figure C7: Results Using Method 3: Vehicle D – Worn Tires – 20 Northbound Runs

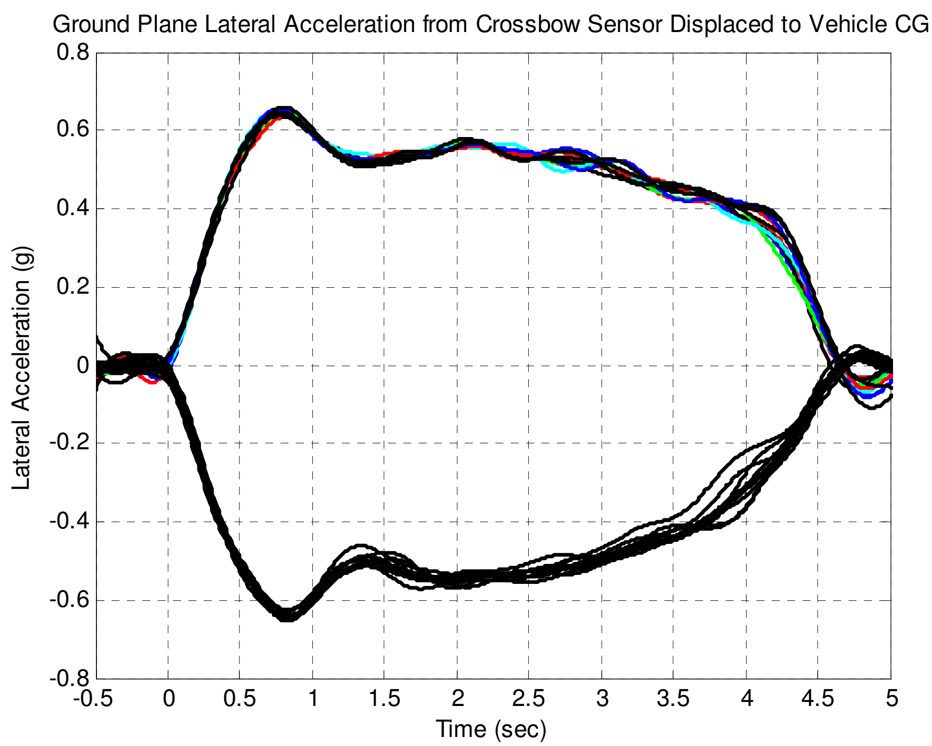


Figure C8: Results Using Method 4: Vehicle D – Worn Tires – 20 Northbound Runs

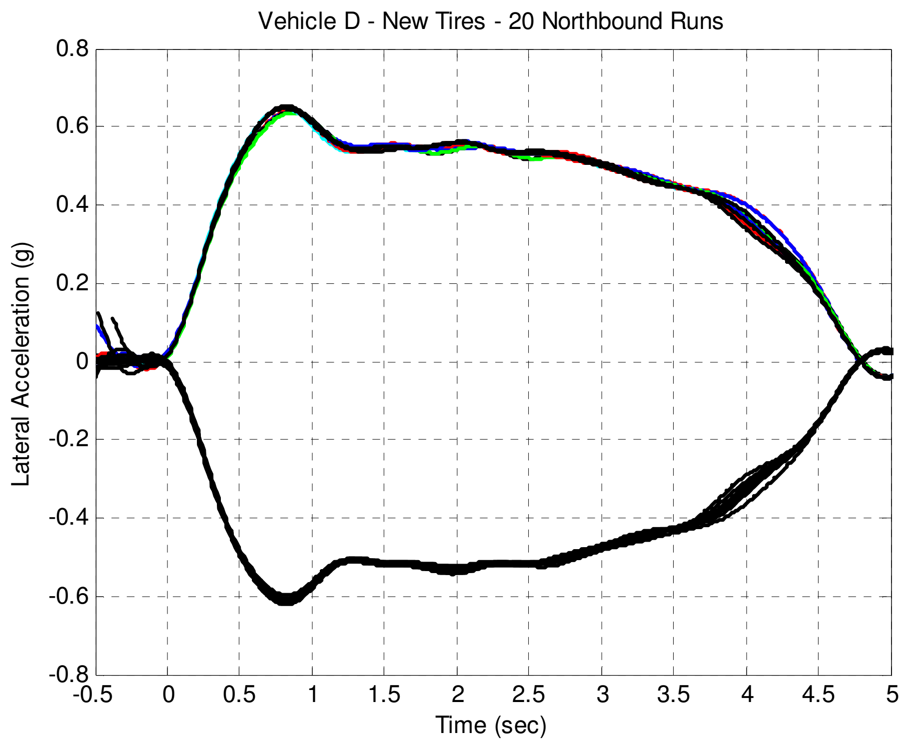


Figure C9: Results Using Method 1: Vehicle D – New Tires – 20 Northbound Runs

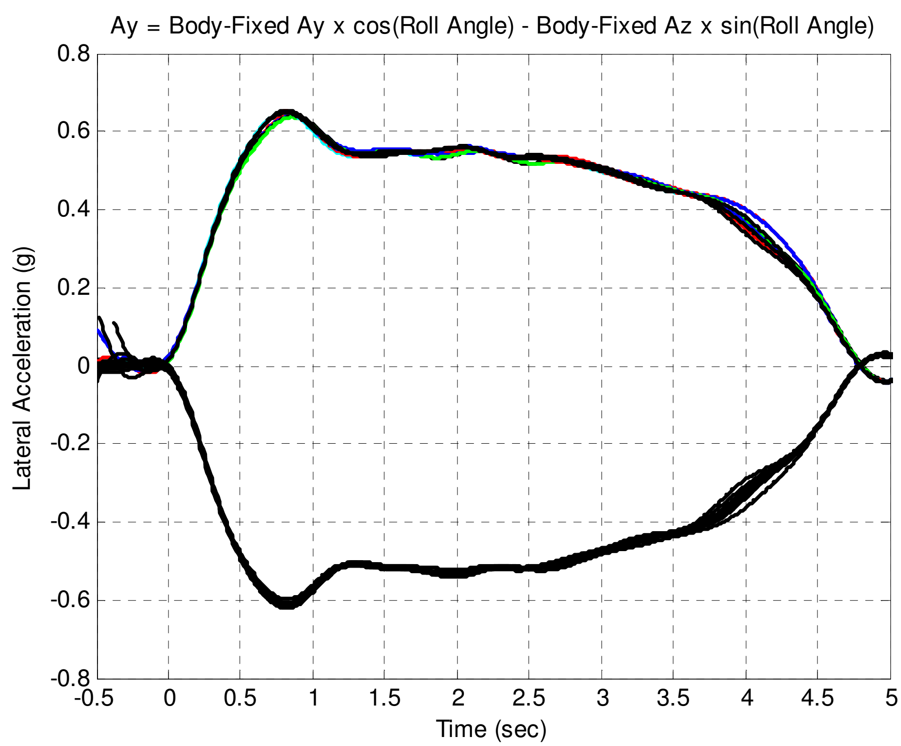


Figure C10: Results Using Method 2: Vehicle D – New Tires – 20 Northbound Runs

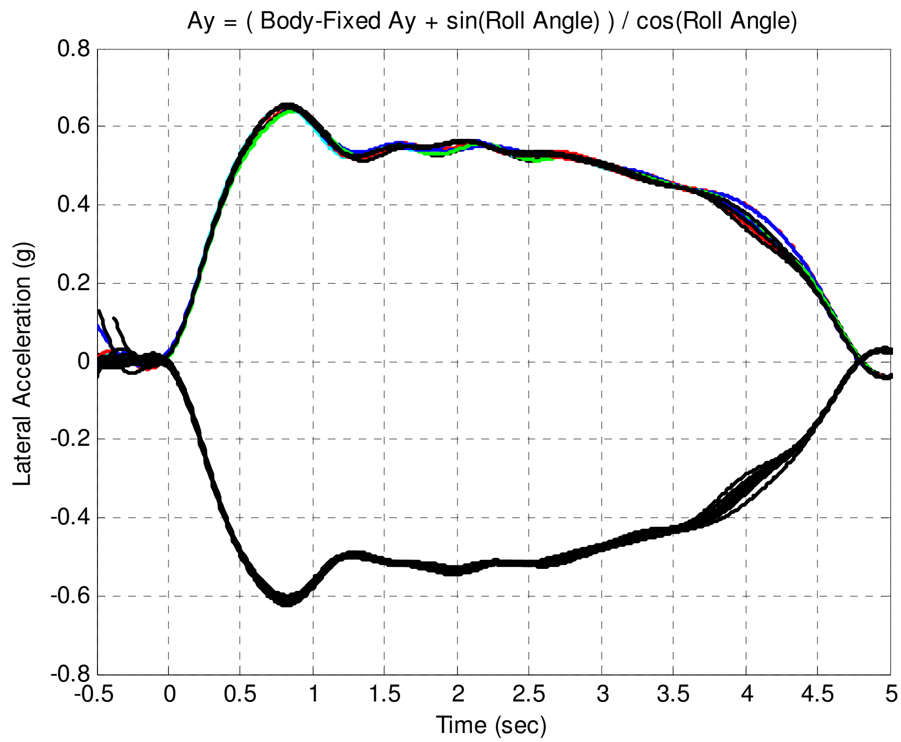


Figure C11: Results Using Method 3: Vehicle D – New Tires – 20 Northbound Runs

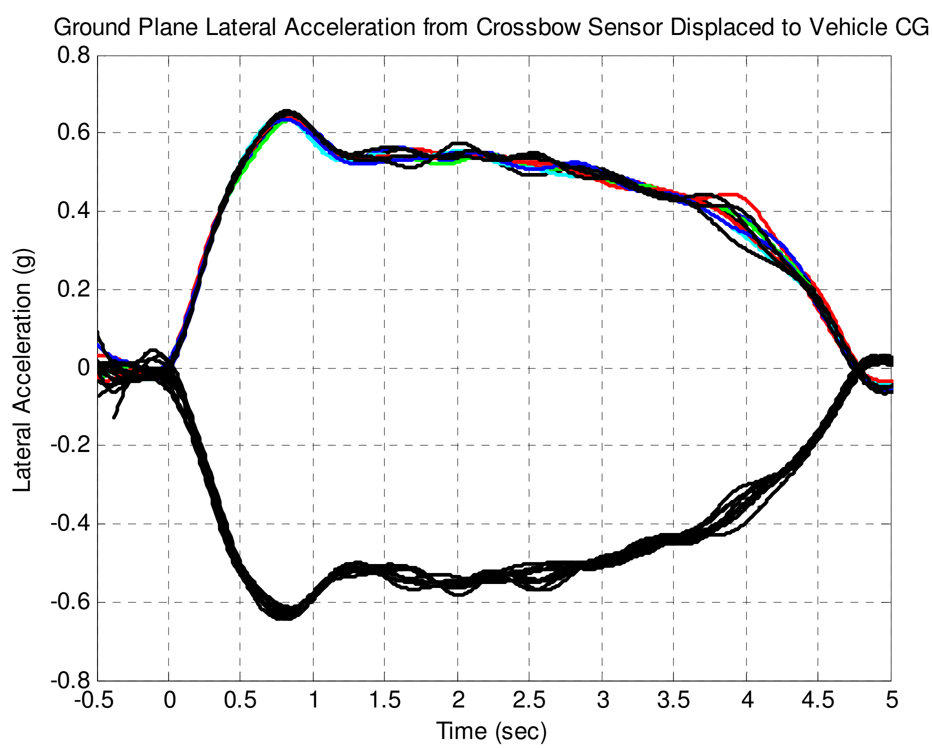


Figure C12: Results Using Method 4: Vehicle D – New Tires – 20 Northbound Runs

Appendix D:

Filtering the Test Data

Justification for Using 2 Hz Filter Low Pass Filter for Selecting Peak Magnitude

A low-pass filter is a filter that passes low-frequency signals and attenuates (reduces the amplitude of) signals with frequencies higher than the cutoff frequency. For the previous J-Turn testing done by S-E-A for CPSC, the data channels were low pass filtered using a filter with a 5 Hz cutoff frequency. Filtering vehicle response data using a 5 or 6 Hz low pass filter is not uncommon, as the natural frequencies of roll, pitch and yaw responses are generally well below 5 Hz.

With the exception of the acceleration signals, the raw data from the RT3002 sensor has very little signal content above 5 Hz and it would not require filtering. However, the raw (unfiltered) data from accelerometers used during vehicle testing have significant frequency content well above 5 Hz. (For example, on Figure D3 the yellow trace of a power spectral density of the lateral acceleration measured during Run 123 shows an initial significant drop in frequency content at low frequencies and then an increase starting near 10 Hz and extending to higher frequencies.) High frequency vibrations present in the test vehicle are the cause of the high frequency content sensed by an accelerometer used during a dynamic vehicle test. These high frequency vibrations come from numerous sources, such as engine vibrations, vibrations from the tires, suspension and chassis, and potentially from less than perfectly rigid sensor mounting.

Figure D1 contains various plots of ground plane lateral acceleration for Run 123 of Vehicle D with worn tires. The yellow curve shows the unfiltered data, the green curve shows the data filtered to 10 Hz, the blue curve is filtered to 5 Hz, and the red curve is filtered to 2 Hz. Figure D2 contains similar curves for Run 132. The filters used are eighth-order, Butterworth phaseless filters. The term phaseless refers to the fact that the filter used is a two-pass filter that does not cause any temporal shift in the data. The right side graphs on Figures D1 and D2 are expanded views near the peak magnitude lateral acceleration and near zero lateral acceleration. The ordinates (y-axes) of expanded view graphs have lateral acceleration grid spacings of 0.01 g.

The fundamental frequency content of the unfiltered data in the region where the peak magnitude of lateral acceleration occurs appears to be less than 1 Hz. The 10, 5 and 2 Hz filters all fit the unfiltered data well, and the filtered curves are essentially on top of each other. Nonetheless, the 10 Hz curve has some 10 Hz signal (ripple) content present in it, the 5 Hz curve has some 5 Hz content, and the 2 Hz curve has some 2 Hz content. This is most noticeable at near zero lateral acceleration (the lower right graphs on Figures D1 and D2). However, this region of the curves is not important for selecting the peak magnitude lateral acceleration.

The upper right graphs on Figure D1 and D2 detail the area of interest for selecting the peak magnitude lateral acceleration values. The 5 Hz and 2 Hz curves have very similar peak magnitude values. However, the peak on the 5 Hz curve on Figure D1 is slightly greater than the peak of the 2 Hz curve. The 5 Hz filter likely adds to the peak of the 5 Hz curve on Figure D1. The graphs suggest that the 2 Hz curve does the best job of fitting underlying lateral acceleration signal (which is less than 1 Hz in the region of interest); it neither amplifies nor attenuates the peak lateral acceleration.

Figure D3 contains various plots of the power spectral density (PSD) of the lateral acceleration for Run 123 of Vehicle D with worn tires. PSDs of the unfiltered data and the data filtered to 10 Hz, 5 Hz and 2 Hz are shown; and the same colors are used for the various filter types.

As mentioned, the yellow trace of the PSD of the unfiltered data (Figure D3) shows an initial significant drop in frequency content at low frequencies and then an increase starting near 10 Hz and extending to higher frequencies. A goal of selecting a filter cutoff frequency is to remove any unwanted frequency content while not removing any signal content that is important to the ultimate use of the filtered data – in this case selecting a peak magnitude. Notice that the 10 Hz filter (green curve) attenuates signal content above 10 Hz, the 5 Hz filter (blue curve) above 5 Hz and the 2 Hz filter (red curve) above 2 Hz. On Figure D3 the curves are plotted in order, with the yellow curve on the bottom, the green curve next, followed by the blue curve, and the red curve on top. For example, between 0 Hz and 3 Hz, the red curve lies on top of the other three curves.

For the J-Turn data analyzed, Figure D3 shows that the 2 Hz filter does not appreciably attenuate any of the signal content below about 3 Hz. Also, between about 3 Hz and 10 Hz, the power of the data signal is very low, more than 30 dB/Hz below the maximum power in the signal content (that occurs in the range of 1 Hz). Above 10 Hz, all three low pass filters attenuate the signal frequency content in the same way. The frequency domain information shown on Figure D3 supports the information shown on the time domain graph (Figure D1).

The preceding analyses and discussion provide support for an objective process that could be used to select peak lateral acceleration values from data collected during 30 mph, dropped throttle J-Turn tests conducted on ROVs. Using such a process eliminates any subjectivity in selecting a peak value by visual inspection of a graph. An objective process such as the one used here provides a means for anyone using the same raw data and process to determine the peak lateral acceleration will get the same answers as someone else analyzing the same data and process.

Selection of Peak Lateral Acceleration from Previous Tests Conducted on Vehicles A-J Using 2 Hz Low Pass Filter Method

During the April 10, 2013 public meeting with CPSC and ROHVA, a question was asked regarding how the peak lateral acceleration values selected using a 2 Hz low pass filter would differ from previous values reported by S-E-A in their reports to CPSC[8,9] which were based on using a 5 Hz low pass filter. This section provides an answer to that question.

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[8] *Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles*, CPSC Contract CPSC-S-10-0014, S-E-A, Ltd. Report to CPSC, April 2011. http://www.cpsc.gov/library/foia/foia11/os/rov.pdf.

[9] *Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles – Additional Results for Vehicle J*, CPSC Contract CPSC-S-10-0014, S-E-A, Ltd. Report to CPSC, August 2011. http://www.cpsc.gov/PageFiles/93928/rovj.pdf.

For the previous testing done by S-E-A for CPSC on Vehicle A-J, the threshold lateral acceleration values were manually selected by visual inspection of the 5 Hz low pass filtered lateral acceleration traces. The values were selected to the nearest 0.01 g of lateral acceleration. For all ten of the vehicles, only one threshold-level, two-wheel lift test was conducted in the right turn direction and one in the left turn direction. The two peak lateral acceleration magnitudes were then average, and the average values were reported to the nearest 0.005 g.

The values shown in blue on Table D1 are the previously reported average values of the peak lateral accelerations for each of the ten vehicles. Again, these values are based on single tests run in each direction and they were determined using a manual (visual) method of selecting the peaks from data filtered to 5 Hz. The values shown in red are values based on the same data, but they were determined by selecting the absolute maximum values from data filtered to 2 Hz (i.e. they are based on the current method used for selecting peak lateral acceleration values used in this report). The data in the rightmost column in bold black font show the differences in the values selected using the current method versus the previous method. For nine of the ten vehicles, the values selected using the current method are higher (from 0.002 g to 0.012 g) than the values selected using the previous method. For Vehicle F, the current method value is 0.001 g less than the previous method value.

These results show that the two methods for selecting peak values provide fairly similar values, with nine of the ten vehicles have differences of less than 0.01 g. However, the current method has several advantages over the previous method. Objectively selecting the peak value (i.e. letting the analysis routine select the peak value) offers better resolution than manually selecting the values to the nearest 0.01 g as was done in the previous method. Since the previous method values were picked by subjectively trying to isolate peak values from data that contained some level of 5 Hz ripple, it is possible that different analysts could select different values, even when selecting values to the nearest 0.01 g. Based on the analysis presented in the preceding section, the 2 Hz filter appears to better represent the underlying acceleration responses in the data ranges where the peak lateral accelerations occur in the J-Turn maneuvers. Finally, as previously mentioned, anyone using the current objective method to determine peak lateral acceleration will get the same answer as someone else using the current method.

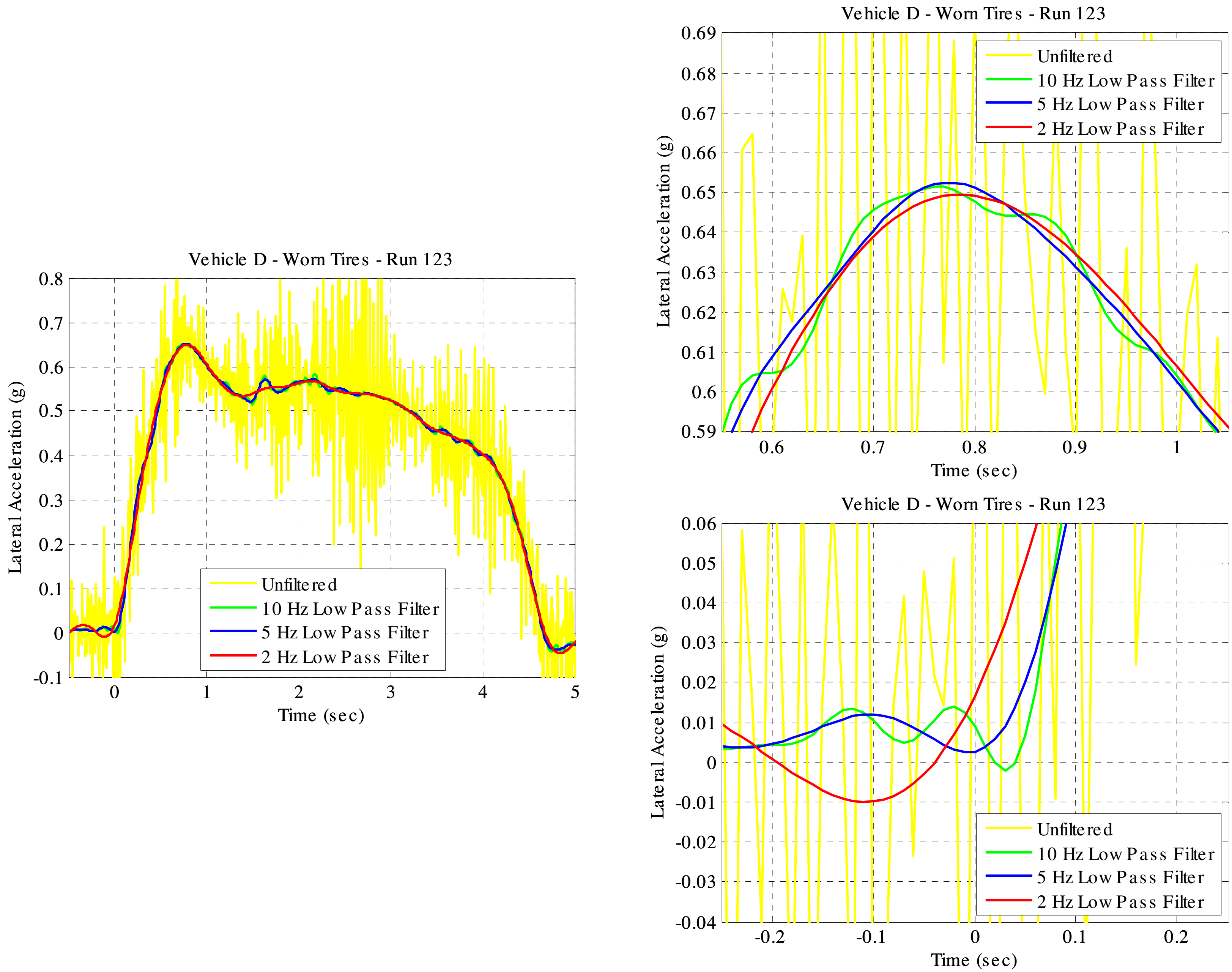


Figure D1: Vehicle D Worn Tires Run 123 – Ground Plane Ay Shown Unfiltered and with 10 Hz, 5 Hz, and 2 Hz Low-Pass Filters
Right Side Graphs are Expanded Views Near Peak Ay and Near Zero Ay

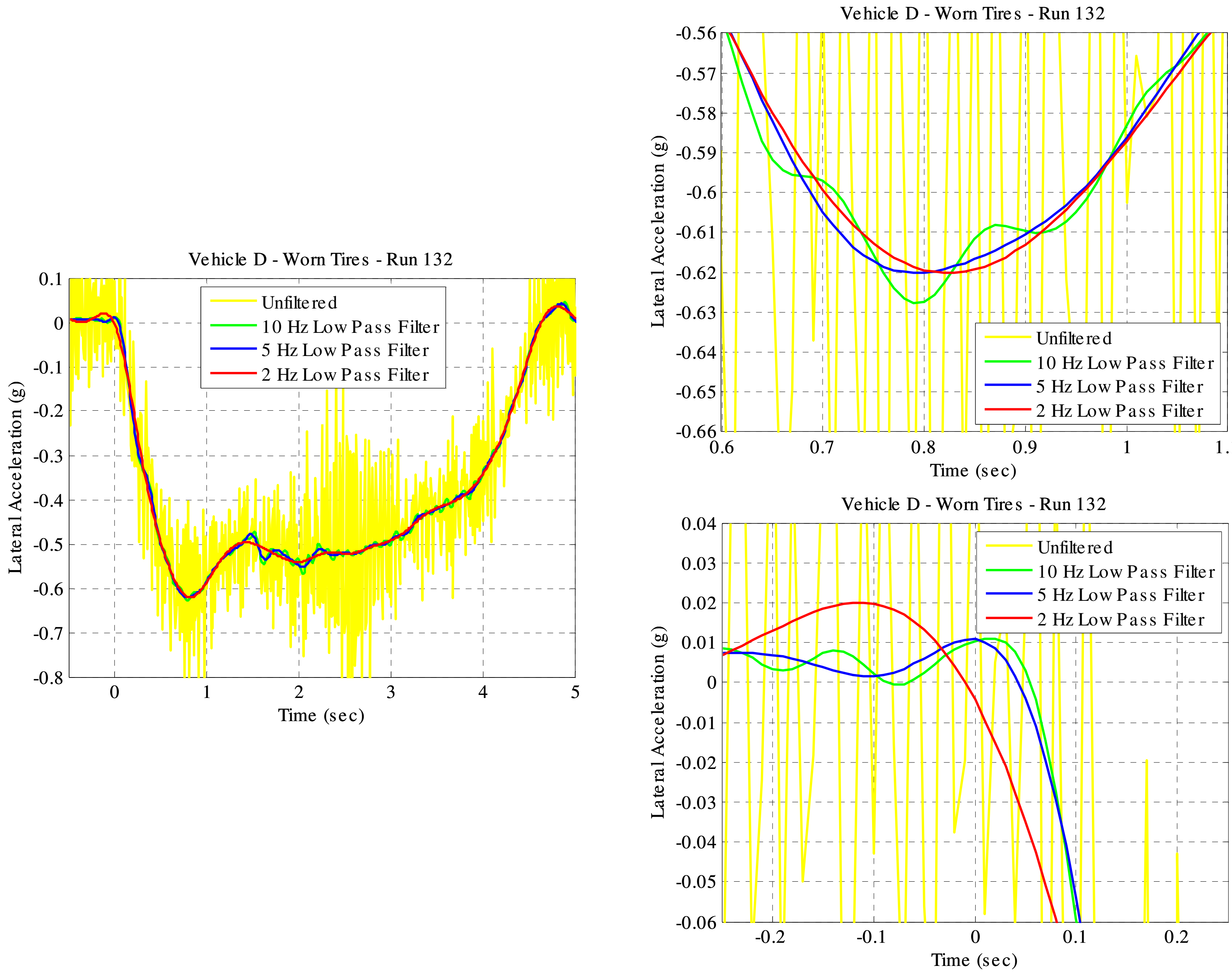


Figure D2: Vehicle D Worn Tires Run 132 – Ground Plane Ay Shown Unfiltered and with 10 Hz, 5 Hz, and 2 Hz Low-Pass Filters
Right Side Graphs are Expanded Views Near Peak Ay and Near Zero Ay

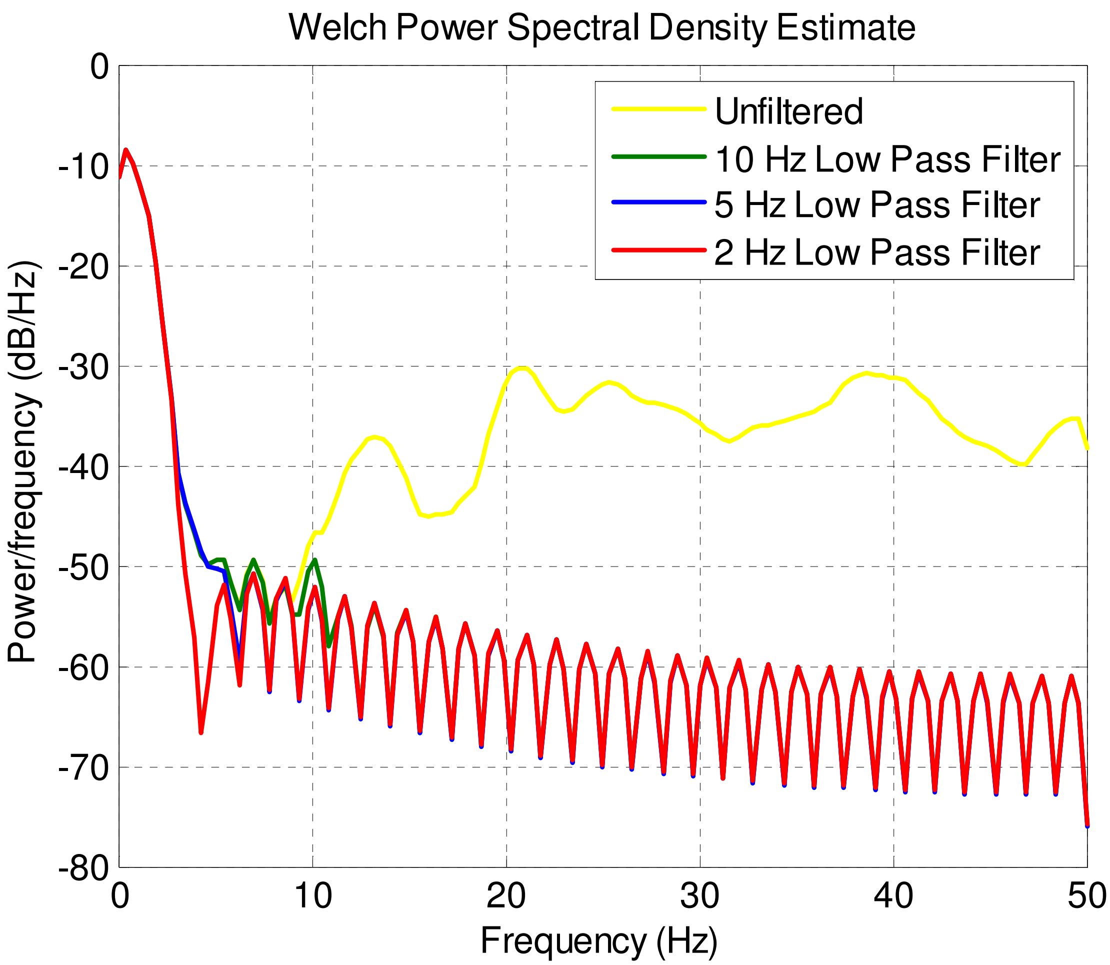


Figure D3: Vehicle D Worn Tires Run 123 – Power Spectral Density of Ground Plane Ay Shown Unfiltered and with 10 Hz, 5 Hz, and 2 Hz Low-Pass Filters

Table D1: Peak Ay Values From Previous Tests Done on Vehicle A-J Comparison of Different Methods for Selecting Peak Ay Values							
	Peaks Reported Previously Based on Manual (Visual) Method of Selecting Peak of Data Filtered Using 5 Hz Low Pass Filter			Peaks Selected Using Current Method of Using Peak Value From Data Filtered Using 2 Hz Filter			Differences in Peak Values Selected Using Current and Previous Selection Methods
Vehicle	**Right Turn Peak Ay (g)**	**Left Turn Peak Ay (g)**	**Average Ay (g)**	**Right Turn Peak Ay (g)**	**Left Turn Peak Ay (g)**	**Average Ay (g)**	**Current Method - Previous Method Ay Peak (g)**
A	0.67	-0.67	**0.670**	0.684	-0.681	**0.682**	**0.012**
B	0.67	-0.64	**0.655**	0.672	-0.647	**0.660**	**0.005**
C	0.74	-0.74	**0.740**	0.748	-0.750	**0.749**	**0.009**
D	0.62	-0.63	**0.625**	0.623	-0.636	**0.630**	**0.005**
E	0.68	-0.72	**0.700**	0.684	-0.725	**0.704**	**0.004**
F	0.67	-0.71	**0.690**	0.669	-0.710	**0.689**	**-0.001**
G	0.78	-0.79	**0.785**	0.782	-0.802	**0.792**	**0.007**
H	0.71	-0.70	**0.705**	0.710	-0.704	**0.707**	**0.002**
I	0.66	-0.69	**0.675**	0.666	-0.696	**0.681**	**0.006**
J	0.65	-0.69	**0.670**	0.655	-0.702	**0.678**	**0.008**

Appendix E:

Test Logs

Loading: Operator, Instrumentation and Outriggers
Front Tires: Carlisle AT 48925X11-12 NHS *Front Tire Pressure: 10 psi*
Rear Tires: Carlisle AT 48925X11-12 NHS *Rear Tire Pressure: 10 psi*

Data File Number	DESCRIPTION	COMMENTS
109	Instrumentation Zero Run - Southbound	
110	Instrumentation Zero Run - Northbound	
NORTHBOUND TESTS		
120	30.0 mph J-Turn – Right - Steering = 90° Dropped Throttle	Rear Wheel Lift
121	30.0 mph J-Turn – Right - Steering = 95° Dropped Throttle	Rear Wheel Lift
122	30.0 mph J-Turn – Right - Steering = 100° Dropped Throttle	Rear Wheel Lift
123	30.0 mph J-Turn – Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
124	30.0 mph J-Turn – Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
125	30.0 mph J-Turn – Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
126	30.0 mph J-Turn – Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
127	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift
128	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift
129	30.0 mph J-Turn - Left - Steering = 95° Dropped Throttle	Rear Wheel Lift
130	30.0 mph J-Turn - Left - Steering = 95° Dropped Throttle	Rear Wheel Lift
131	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	Test Aborted
132	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
133	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
134	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
135	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: Carlisle AT 48925X11-12 NHS *Front Tire Pressure: 10 psi*
Rear Tires: Carlisle AT 48925X11-12 NHS *Rear Tire Pressure: 10 psi*

Data File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
136	30.0 mph J-Turn – Right - Steering = 105° Dropped Throttle	2 Wheel Lift
137	30.0 mph J-Turn – Right - Steering = 100° Dropped Throttle	2 Wheel Lift
138	30.0 mph J-Turn - Right - Steering = 95° Dropped Throttle	Rear Wheel Lift
139	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
140	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
141	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
142	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
143	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	Rear Wheel Lift
144	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
145	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
146	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
147	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: Carlisle AT 48925X11-12 NHS *Front Tire Pressure: 10 psi*
Rear Tires: Carlisle AT 48925X11-12 NHS *Rear Tire Pressure: 10 psi*

Data File Number	DESCRIPTION	COMMENTS
	NORTHBOUND TESTS	
148	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	Rear Wheel Lift
149	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	Rear Wheel Lift
150	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
151	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
152	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle 1	2 Wheel Lift – Used in Repeatability Study
153	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
154	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
155	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
156	30.0 mph J-Turn - Left - Steering = 95° Dropped Throttle	Rear Wheel Lift
157	30.0 mph J-Turn - Left - Steering = 95° Dropped Throttle	Rear Wheel Lift
158	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
159	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
160	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
161	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
162	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
163	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Data File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
164	30.0 mph J-Turn - Right - Steering = 95° Dropped Throttle	Rear Wheel Lift
165	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
166	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
167	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
168	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
169	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
170	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
171	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	Rear Wheel Lift
172	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
173	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
174	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
175	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
176	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
177	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
178	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
179	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
180	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift

Data File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
181	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
182	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
183	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
184	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
185	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
186	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: Carlisle AT 48925X11-12 NHS *Front Tire Pressure: 10 psi*
Rear Tires: Carlisle AT 48925X11-12 NHS *Rear Tire Pressure: 10 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
201	Instrumentation Zero Run - Southbound	
202	Instrumentation Zero Run - Northbound	
NORTHBOUND TESTS		
203 / NA	30.0 mph J-Turn - Right - Steering = 95° Dropped Throttle	Rear Wheel Lift
204 / 013	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	Test Aborted
205 / 015	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	Rear Wheel Lift
206 / 017	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	Rear Wheel Lift
207 / 019	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	Rear Wheel Lift
208 / 021	30.0 mph J-Turn - Right - Steering = 115° Dropped Throttle	Rear Wheel Lift
209 / 023	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	Rear Wheel Lift
210 / 025	30.0 mph J-Turn - Right - Steering = 130° Dropped Throttle	2 Wheel Lift
211 / 027	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
212 / 029	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
213 / 031	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
214 / 033	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
215 / 035	30.0 mph J-Turn - Left - Steering = 110° Dropped Throttle	Rear Wheel Lift
216 / 037	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
217 / 039	30.0 mph J-Turn - Left - Steering = 115° Dropped Throttle	Rear Wheel Lift
218 / 041	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
219 / 043	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
220 / 045	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers

Front Tires: Carlisle AT 48925X11-12 NHS *Front Tire Pressure: 10 psi*

Rear Tires: Carlisle AT 48925X11-12 NHS *Rear Tire Pressure: 10 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
221 / 047	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
222 / 049	30.0 mph J-Turn - Right - Steering = 115° Dropped Throttle	Rear Wheel Lift
223 / 051	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
224 / 053	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
225 / 055	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
226 / 057	30.0 mph J-Turn - Left - Steering = 110° Dropped Throttle	Rear Wheel Lift
227 / 059	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	Rear Wheel Lift
228 / 061	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift
229 / 063	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	Rear Wheel Lift
230 / 065	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	Rear Wheel Lift
231 / 067	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift
232 / 069	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift
233 / 071	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift

Data / Video File Number	DESCRIPTION	COMMENTS
NORTHBOUND TESTS		
234 / 073	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
235 / 075	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
236 / 077	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
237 / 079	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
238 / 081	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
239 / 083	30.0 mph J-Turn - Right - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
240 / 085	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
241 / 087	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
242 / 089	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
243 / 091	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
244 / 093	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	Rear Wheel Lift
245 / 095	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
246 / 097	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Data / Video File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
247 / 099	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	Test Aborted
248 / 101	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
249 / 103	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
250 / 105	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
251 / 107	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
252 / 109	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
253 / 111	30.0 mph J-Turn - Right - Steering = 120° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
254 / 113	30.0 mph J-Turn - Right - Steering = 115° Dropped Throttle	Rear Wheel Lift

Data / Video File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
255 / 115	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift
256 / 117	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift
257 / 119	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift
258 / 121	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift
259 / 123	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift
260 / 125	30.0 mph J-Turn - Left - Steering = 130° Dropped Throttle	2 Wheel Lift – Amount of Wheel Lift has Increased, so Reduce Steering by 5°, and Check for 2 Wheel Lift
261 / 127	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
262 / 129	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
263 / 131	30.0 mph J-Turn - Left - Steering = 120° Dropped Throttle	Rear Wheel Lift
264 / 133	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
265 / 135	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
266 / 137	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
267 / 139	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
268 / 141	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
269 / 143	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
270 / 145	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
271 / 147	30.0 mph J-Turn - Left - Steering = 125° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: Maxxis 26X8.00-12NHS *Front Tire Pressure: 8.7 psi*
Rear Tires: Maxxis 26X10.00-12NHS *Rear Tire Pressure: 13.1 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
401	Instrumentation Zero Run - Southbound	
402	Instrumentation Zero Run - Northbound	
NORTHBOUND TESTS		
403 / 292	30.0 mph J-Turn - Right - Steering = 150° Dropped Throttle	Rear Wheel Lift
404 / 294	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
405 / 296	30.0 mph J-Turn - Right - Steering = 155° Dropped Throttle	Rear Wheel Lift
406 / 298	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
407 / 300	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	Rear Wheel Lift
408 / 302	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	Rear Wheel Lift
409 / 304	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
410 / 305	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
411 / 307	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
412 / 310	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
413 / 312	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
414 / 314	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
415 / 316	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
416 / 318	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Data / Video File Number	DESCRIPTION	COMMENTS
NORTHBOUND TESTS		
417 / NA	30.0 mph J-Turn - Left - Steering = 160° Dropped Throttle	Test Aborted
418 / 322	30.0 mph J-Turn - Left - Steering = 160° Dropped Throttle	Rear Wheel Lift
419 / 324	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
420 / 326	30.0 mph J-Turn - Left - Steering = 165° Dropped Throttle	Rear Wheel Lift
421 / 328	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
422 / 330	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	Rear Wheel Lift
423 / 331	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
424 / 333	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	Rear Wheel Lift
425 / 335	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
426 / 337	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
427 / 339	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
428 / 341	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
429 / 343	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	Rear Wheel Lift
430 / 346	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	Rear Wheel Lift
431 / 348	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
432 / 350	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
433 / 352	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	Rear Wheel Lift
434 / 355	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Data / Video File Number	DESCRIPTION	COMMENTS
	SOUTHBOUND TESTS	
435 / 357	30.0 mph J-Turn – Right - Steering = 160° Dropped Throttle	2 Wheel Lift
436 / 359	30.0 mph J-Turn – Right - Steering = 155° Dropped Throttle	2 Wheel Lift
437 / 361	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift
438 / 363	30.0 mph J-Turn – Right - Steering = 145° Dropped Throttle	2 Wheel Lift
439 / 365	30.0 mph J-Turn – Right - Steering = 140° Dropped Throttle	Rear Wheel Lift
440 / 367	30.0 mph J-Turn – Right - Steering = 145° Dropped Throttle	Rear Wheel Lift
441 / 370	30.0 mph J-Turn – Right - Steering = 145° Dropped Throttle	Rear Wheel Lift
442 / 372	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
443 / 374	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	Rear Wheel Lift
444 / 376	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	Rear Wheel Lift
445 / 378	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
446 / 380	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	Rear Wheel Lift
447 / 382	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
448 / 384	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
449 / 386	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
450 / 388	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
451 / 390	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
452 / 392	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	Rear Wheel Lift
453 / 394	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
454 / 396	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
455 / 398	30.0 mph J-Turn – Right - Steering = 150° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: Maxxis 26X8.00-12NHS *Front Tire Pressure: 8.7 psi*
Rear Tires: Maxxis 26X10.00-12NHS *Rear Tire Pressure: 13.1 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
456 / 400	30.0 mph J-Turn - Left - Steering = 160° Dropped Throttle	Rear Wheel Lift
457 / 402	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	Rear Wheel Lift
458 / 404	30.0 mph J-Turn - Left - Steering = 180° Dropped Throttle	2 Wheel Lift
459 / 406	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
460 / 408	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
461 / 410	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift – Data File Corrupted
462 / 412	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift – Data File Corrupted
463 / 414	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Data File Corrupted
464 / 416	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Data File Corrupted
465 / 418	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift – Data File Corrupted
466 / 420	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Data File Corrupted
467 / 422	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
468 / 424	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift
469 / 426	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
470 / 427	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
471 / 429	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
472 / 431	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
473 / NA	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift
474 / 434	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift

Data / Video File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS (Continued)		
475 / NA	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift
476 / NA	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
477 / NA	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift
478 / NA	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Test Aborted
479 / NA	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
480 / NA	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	Rear Wheel Lift
481 / NA	30.0 mph J-Turn - Left - Steering = 175° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

TIRE BREAK IN RUNS		
1401	30.0 mph J-Turn - Right - Steering = 140° Dropped Throttle	Rear Wheel Lift
1402	30.0 mph J-Turn - Right - Steering = 150° Dropped Throttle	Rear Wheel Lift
1403	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift
1404	30.0 mph J-Turn - Right - Steering = 155° Dropped Throttle	Rear Wheel Lift
1405	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift
1406	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift
1407	30.0 mph J-Turn - Right - Steering = 160° Dropped Throttle	2 Wheel Lift
1408	30.0 mph J-Turn - Left - Steering = 150° Dropped Throttle	Rear Wheel Lift
1409	30.0 mph J-Turn - Left - Steering = 160° Dropped Throttle	Rear Wheel Lift
1410	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift
1411	30.0 mph J-Turn - Left - Steering = 165° Dropped Throttle	2 Wheel Lift
1412	30.0 mph J-Turn - Left - Steering = 165° Dropped Throttle	2 Wheel Lift
1413	30.0 mph J-Turn - Left - Steering = 165° Dropped Throttle	Test Aborted
1414	30.0 mph J-Turn - Left - Steering = 165° Dropped Throttle	Test Aborted
1415	30.0 mph J-Turn - Left - Steering = 165° Dropped Throttle	Rear Wheel Lift
1416	30.0 mph J-Turn - Left - Steering = 170° Dropped Throttle	2 Wheel Lift

Loading: Operator, Instrumentation and Outriggers

Front Tires: CST Ancla 29X9-12 *Front Tire Pressure: 14 psi*

Rear Tires: CST Ancla 29X11-12 *Front Tire Pressure: 14 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
302	Instrumentation Zero Run - Southbound	
303	Instrumentation Zero Run - Northbound	
NORTHBOUND TESTS		
304 / NA	30.0 mph J-Turn - Right - Steering = 190° Dropped Throttle	
305 / NA	30.0 mph J-Turn - Right - Steering = 200° Dropped Throttle	Rear Wheel Lift
306 / 161	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	Rear Wheel Lift
307 / 163	30.0 mph J-Turn - Right - Steering = 220° Dropped Throttle	Rear Wheel Lift
308 / 165	30.0 mph J-Turn - Right - Steering = 230° Dropped Throttle	2 Wheel Lift
309 / 167	30.0 mph J-Turn - Right - Steering = 225° Dropped Throttle	2 Wheel Lift
310 / 169	30.0 mph J-Turn - Right - Steering = 220° Dropped Throttle	2 Wheel Lift
311 / 171	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift
312 / 173	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
313 / 175	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
314 / 177	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
315 / 179	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
316 / 181	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
317 / 183	30.0 mph J-Turn - Right - Steering = 205° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
318 / 185	30.0 mph J-Turn - Right - Steering = 205° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
319 / 187	30.0 mph J-Turn - Right - Steering = 205° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
320 / 189	30.0 mph J-Turn - Right - Steering = 205° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
321 / 191	30.0 mph J-Turn - Right - Steering = 205° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: CST Ancla 29X9-12 *Front Tire Pressure: 14 psi*
Rear Tires: CST Ancla 29X11-12 *Front Tire Pressure: 14 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
NORTHBOUND TESTS		
322 / 193	30.0 mph J-Turn - Left - Steering = 200° Dropped Throttle	
323 / 196	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	
324 / 198	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	
325 / 202	30.0 mph J-Turn - Left - Steering = 230° Dropped Throttle	Rear Wheel Lift
326 / 204	30.0 mph J-Turn - Left - Steering = 240° Dropped Throttle	2 Wheel Lift
327 / 206	30.0 mph J-Turn - Left - Steering = 235° Dropped Throttle	2 Wheel Lift
328 / 208	30.0 mph J-Turn - Left - Steering = 230° Dropped Throttle	2 Wheel Lift
329 / 210	30.0 mph J-Turn - Left - Steering = 225° Dropped Throttle	2 Wheel Lift
330 / 212	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
331 / 214	30.0 mph J-Turn - Left - Steering = 215° Dropped Throttle	Rear Wheel Lift
332 / 216	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
333 / 218	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
334 / 220	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
335 / 222	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
336 / 224	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
337 / 226	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
338 / 228	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
339 / 230	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
340 / 232	30.0 mph J-Turn - Left - Steering = 220° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: CST Ancla 29X9-12 *Front Tire Pressure: 14 psi*
Rear Tires: CST Ancla 29X11-12 *Front Tire Pressure: 14 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
341 / 234	30.0 mph J-Turn - Right - Steering = 200° Dropped Throttle	Rear Wheel Lift
342 / 236	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
343 / 238	30.0 mph J-Turn - Right - Steering = 205° Dropped Throttle	Rear Wheel Lift
344 / 240	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
345 / 242	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	Rear Wheel Lift
346 / 244	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	Rear Wheel Lift
347 / 246	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	Rear Wheel Lift
348 / 248	30.0 mph J-Turn - Right - Steering = 210° Dropped Throttle	Rear Wheel Lift
349 / 250	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
350 / 252	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
351 / 254	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
352 / 256	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
353 / 258	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
354 / 260	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
355 / 262	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
356 / 265	30.0 mph J-Turn - Right - Steering = 215° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: CST Ancla 29X9-12 *Front Tire Pressure: 14 psi*
Rear Tires: CST Ancla 29X11-12 *Front Tire Pressure: 14 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
357 / 267	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
358 / 269	30.0 mph J-Turn - Left - Steering = 205° Dropped Throttle	Rear Wheel Lift
359 / 271	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	Rear Wheel Lift
360 / 273	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
361 / 275	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
362 / 277	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
363 / 279	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
364 / 281	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
365 / 283	30.0 mph J-Turn - Left - Steering = 210° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
366 / 285	30.0 mph J-Turn - Left - Steering = 205° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
367 / 287	30.0 mph J-Turn - Left - Steering = 205° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
368 / 289	30.0 mph J-Turn - Left - Steering = 205° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers

Front Tires: Carlisle Blackrock 27x9.00-12 NHS *Front Tire Pressure: 10 psi*

Rear Tires: Carlisle Blackrock 27x11.00-12 NHS *Front Tire Pressure: 12 psi*

Data / Video File Number	DESCRIPTION	COMMENTS
501	Instrumentation Zero Run - Southbound	
502	Instrumentation Zero Run - Northbound	
NORTHBOUND TESTS		
503 / 437	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	Rear Wheel Lift
504 / 440	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
505 / 442	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
506 / 445	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
507 / 447	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
508 / 449	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
509 / 451	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
510 / 454	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
511 / 457	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
512 / 459	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
513 / 461	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
514 / 463	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	Rear Wheel Lift

Data / Video File Number	DESCRIPTION	COMMENTS
NORTHBOUND TESTS		
515 / 465	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift
516 / 467	30.0 mph J-Turn - Left - Steering = 95° Dropped Throttle	Rear Wheel Lift
517 / 469	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
518 / 471	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
519 / 473	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
520 / 475	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
521 / 477	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
522 / 479	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
523 / 481	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
524 / 483	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
525 / 485	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
526 / 487	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

Loading: Operator, Instrumentation and Outriggers
Front Tires: Carlisle Blackrock 27x9.00-12 NHS *Front Tire Pressure: 10 psi*
Rear Tires: Carlisle Blackrock 27x11.00-12 NHS *Front Tire Pressure: 12 psi*

Data / Video File Number	NORTHBOUND	COMMENTS
SOUTHBOUND TESTS		
527	30.0 mph J-Turn - Right - Steering = 90° Dropped Throttle	No Test / No Data
528 / NA	30.0 mph J-Turn - Right - Steering = 90° Dropped Throttle	Rear Wheel Lift
529 / NA	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	Rear Wheel Lift
530 / 491	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	Rear Wheel Lift
531 / 493	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
532 / NA	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
533 / 496	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
534 / 498	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
535 / 500	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
536 / 502	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
537 / NA	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
538 / NA	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
539 / NA	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
540 / NA	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

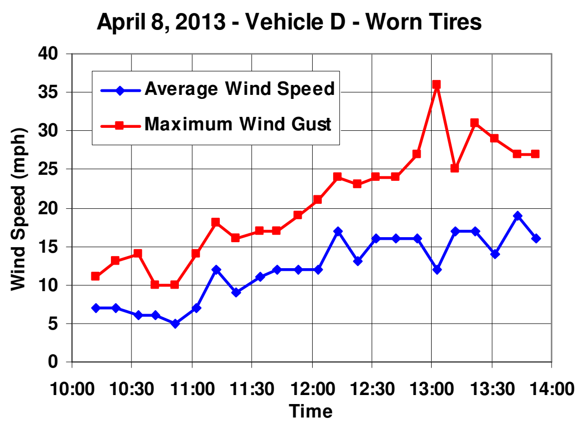
Data / Video File Number	DESCRIPTION	COMMENTS
SOUTHBOUND TESTS		
541 / 510	30.0 mph J-Turn - Left - Steering = 90° Dropped Throttle	Rear Wheel Lift
542 / 512	30.0 mph J-Turn - Left - Steering = 100° Dropped Throttle	Rear Wheel Lift
543 / 514	30.0 mph J-Turn - Left - Steering = 110° Dropped Throttle	2 Wheel Lift
544 / 516	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
545 / 518	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
546 / 520	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
547 / 522	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
548 / 525	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
549 / 527	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
550 / 529	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
551 / 531	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
552 / 533	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
553 / 535	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
554 / 537	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
555 / 539	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study
556 / 541	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	2 Wheel Lift – Used in Repeatability Study

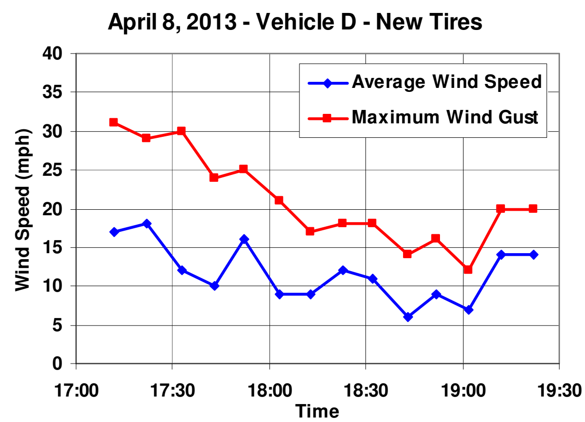
TIRE BREAK IN RUNS		
1501	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	2 Wheel Lift
1502	30.0 mph J-Turn - Right - Steering = 95° Dropped Throttle	Rear Wheel Lift
1503	30.0 mph J-Turn - Right - Steering = 100° Dropped Throttle	Rear Wheel Lift
1504	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	2 Wheel Lift
1505	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	Rear Wheel Lift
1506	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift
1507	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift
1508	30.0 mph J-Turn - Right - Steering = 110° Dropped Throttle	2 Wheel Lift
1509	30.0 mph J-Turn - Right - Steering = 105° Dropped Throttle	Rear Wheel Lift
1510	30.0 mph J-Turn - Left - Steering = 110° Dropped Throttle	Rear Wheel Lift
1511	30.0 mph J-Turn - Left - Steering = 110° Dropped Throttle	2 Wheel Lift
1512	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift – No Data
1513	30.0 mph J-Turn - Left - Steering = 105° Dropped Throttle	Rear Wheel Lift
1514	30.0 mph J-Turn - Left - Steering = 110° Dropped Throttle	2 Wheel Lift
1515	30.0 mph J-Turn - Left - Steering = 110° Dropped Throttle	2 Wheel Lift
1516	30.0 mph J-Turn - Left - Steering = 110° Dropped Throttle	2 Wheel Lift

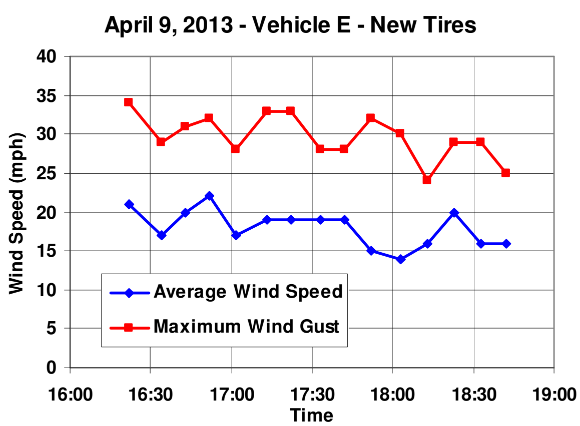
Appendix F:

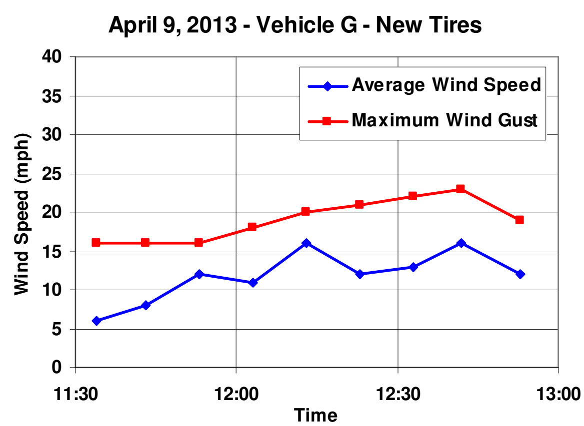
Wind Speed and Air Temperature Conditions

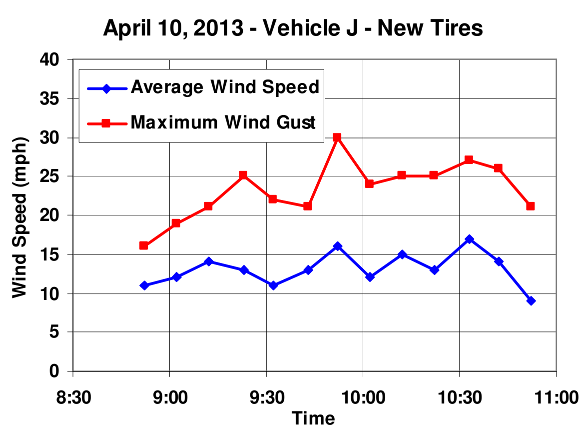
Vehicle	Data File Numbers	Date	Time Span
Vehicle D - Worn Tires	109-186	4/8/2013	10:18 AM - 1:50 PM
Vehicle D - New Tires	201-271	4/8/2013	5:18 PM - 7:16 PM
Vehicle E - New Tires	401-481	4/9/2013	4:22 PM - 6:35 PM
Vehicle G - New Tires	302-368	4/9/2013	11:35 AM - 12:54 PM
Vehicle J - New Tires	501-556	4/10/2013	8:58 AM - 10:46 AM











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