CPSC Staff Statement on SEA, Ltd. Report "Vehicle Characteristics Measurements Of Recreational Off-Highway Vehicles Results from Tests on Thirteen 2014-2015 Model Year Vehicles"[1]
September 2015

The report titled, "Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles Results from Tests on Thirteen 2014-2015 Model Year Vehicles," presents the findings of static and dynamic tests conducted by SEA, Ltd., under Contract CPSC-D-11-0003, Task Orders 0005 and 0006. CPSC staff purchased 13 recreational off-highway vehicles (ROVs) that represent the range of recreational- and utility-oriented vehicles currently available in the U.S. market and contracted SEA to perform static and dynamic tests to measure the vehicles' characteristics.

The report contains four main sections and six appendices. The four report sections are Overview, Laboratory Testing, Dynamic Testing, and Discussion of Test Results. Appendix A contains tabular results of laboratory measurements; Appendix B contains bar chart and graphical summaries of all tests for each vehicle; Appendix C contains graphical results of the constant radius tests; Appendix D contains graphical results of the constant speed slowly increasing steer tests; Appendix E contains graphical results of the dropped throttle J-turn tests; and Appendix F contains graphical results of the steering ratio tests.

The report is a follow-up to a study of ROV characteristics that was conducted in 2010, "Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles."[2]

[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] Heydinger, G. (2011) Vehicle Characteristics Measurements of Recreational Off-Highway Vehicles. Retrieved from http://www.cpsc.gov/PageFiles/96037/rov.pdf.

Vehicle Characteristics Measurements Of Recreational Off-Highway Vehicles

Results from Tests on Thirteen 2014-2015 Model Year Vehicles

for:
Consumer Product Safety Commission

September 2015

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

Vehicle Characteristics Measurements Of Recreational Off-Highway Vehicles

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

Report prepared by Gary J. Heydinger, Ph.D., P.E.,
with primary support from Ron Bixel, Joe Yapp, Anmol Sidhu,
Jon Coyle, and Hank Jebode

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

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1. OVERVIEW

This report contains results from measurements made by SEA, Ltd. for the Consumer Product Safety Commission (CPSC) under contract CPSC-D-11-0003. The objectives of contract CPSC-D-11-0003 are:

- To obtain vehicle characteristic data that is accurate and repeatable using measurement and test methods that are proven and accepted in the academic and industrial communities.

- To document, study, and compare the dynamic performance characteristics of commonly available recreational off-highway vehicles (ROV's).

This report contains test results for measurements made on thirteen 2014-2015 model year vehicles. The vehicles are designated Vehicle A15 through Vehicle M15. Vehicles I15, K15, L15 and M15 are model year 2015 vehicles, and the other nine vehicles are model year 2014 vehicles. Table 1 lists the front and rear tire make, tire size, and tire pressure for each test vehicle.

All of the vehicles were selected by CPSC. Vehicle D15 is a four-passenger vehicle, Vehicle G15 is a single-passenger vehicle, and all of the other vehicles have side-by-side front seating for either two or three passengers. All of the vehicles use a steering wheel, brake pedal, and throttle pedal for operator control inputs.

The vehicles were evaluated using both laboratory measurements and dynamic tests. The laboratory measurements were made by SEA, Ltd. in Columbus, Ohio using their Vehicle Inertia Measurement Facility (VIMF) and other laboratory equipment. The dynamic tests were performed by SEA on numerous dates between September 25, 2014 and July 1, 2015, at the Transportation Research Center, Inc. (TRC) in East Liberty, Ohio. The dynamic test evaluations included steering maneuvers on the flat dry asphalt surface of TRC's Vehicle Dynamics Area (VDA).

This report contains four main sections: Overview, Laboratory Testing, Dynamic Testing, and Discussion of Test Results. There are also six appendices containing test results.

Table 1: Test Vehicle Tire Specifications		
Vehicle A15	Front Tires	Rear Tires
Tire Make	Maxxis Bighorn 2.0	Maxxis Bighorn 2.0
Tire Size	25X8.00-12 NHS 2PR	25X10.00-12 NHS 4PR
Tire Pressure (psi)	11	13
Vehicle B15	Front Tires	Rear Tires
Tire Make	Maxxis Bighorn 2.0	Maxxis Bighorn 2.0
Tire Size	26X9.00R12 NHS	26X11.00R12 NHS
Tire Pressure (psi)	11.4	16
Vehicle C15	Front Tires	Rear Tires
Tire Make	Maxxis	Maxxis
Tire Size	25X8.00-12	25X10.00-12
Tire Pressure (psi)	10	14
Vehicle D15	Front Tires	Rear Tires
Tire Make	Maxxis Bighorn 2.0	Maxxis Bighorn 2.0
Tire Size	27X9.00R14 NHS	27X11.00R14 NHS
Tire Pressure (psi)	14	14
Vehicle E15	Front Tires	Rear Tires
Tire Make	Duro Kaden	Duro Kaden
Tire Size	26X9.00R14	26X11.00R14
Tire Pressure (psi)	12	16
Vehicle F15	Front Tires	Rear Tires
Tire Make	Carlisle Trail Pro	Carlisle Trail Pro
Tire Size	25X8.00-12 NHS 78D	25X10.00-12 NHS 84D
Tire Pressure (psi)	14	14
Vehicle G15	Front Tires	Rear Tires
Tire Make	Carlisle AT489	Carlisle AT489
Tire Size	25X8.00-12	25X10.00-12
Tire Pressure (psi)	7	7

Table 1 (Continued): Test Vehicle Tire Specifications		
Vehicle H15	Front Tires	Rear Tires
Tire Make	Maxxis Bighorn 2.0	Maxxis Bighorn 2.0
Tire Size	26X8.00R14	26X10.00R14
Tire Pressure (psi)	14	14
Vehicle I15	Front Tires	Rear Tires
Tire Make	Maxxis Bighorn 2.0	Maxxis Bighorn 2.0
Tire Size	27X9.00R12 NHS	27X11.00R12 NHS
Tire Pressure (psi)	13	16
Vehicle J15	Front Tires	Rear Tires
Tire Make	Blackstone	Blackstone
Tire Size	25X8.00-12	25X10.00-12
Tire Pressure (psi)	10	12
Vehicle K15	Front Tires	Rear Tires
Tire Make	Dirt Commander	Dirt Commander
Tire Size	27X9.00R12	27X11.00R12
Tire Pressure (psi)	10	14
Vehicle L15	Front Tires	Rear Tires
Tire Make	Carlisle AT489	Carlisle AT489
Tire Size	25X10.00-12	25X11.00-12
Tire Pressure (psi)	10	12
Vehicle M15	Front Tires	Rear Tires
Tire Make	Ancia	Ancia
Tire Size	25X8.00-12	25X10.00-12
Tire Pressure (psi)	8	10

2. LABORATORY TESTING

This section describes the laboratory measurements made as well as computations made to compute various rollover resistance metrics and other vehicle characteristics. This section is divided into two parts, one covering the vehicle characteristics and metrics determined from Vehicle Inertia Measurement Facility (VIMF) testing and one covering the other miscellaneous laboratory measurements made. Tabular results from all of the measurements and metrics discussed in this section are contained in Appendix A.

2.1 Vehicle Characteristics and Rollover Resistance Metrics Determined from VIMF Testing

Laboratory measurements of vehicle weight (including the four corner weights); vehicle center-of-gravity (CG) position (longitudinal, lateral, and vertical (CG height)); vehicle pitch, roll, and yaw moments of inertia; and roll/yaw product of inertia were made by SEA using their Vehicle Inertia Measurement Facility (VIMF)[1]. Measurements of front track width, rear track width, and wheelbase were also made. SEA conducts measurements of vehicle CG height, average track width, and Static Stability Factor (SSF) for the National Highway Traffic Safety Administration (NHTSA) New Car Assessment Program (NCAP). Where applicable, the same protocols and equipment used for the NCAP testing were used during this CPSC testing.

The VIMF tests were conducted on all test vehicles, except Vehicle G15, in the following loading conditions:

1. **Operator and Passenger**
   This loading condition was specified to be the vehicle curb condition plus two occupants, one in the Operator's seating position and one in the front Passenger's seating position. For this loading condition Hybrid II test dummies weighing 164 lb were used and ballast was added to their laps to bring the weight for each occupant up to nominally 213 lb. The vehicle weight for this loading is nominally 426 lb more than the vehicle curb weight.

2. **Operator, Instrumentation, and Outriggers**
   This loading condition was specified to be the vehicle curb condition plus the weight of the actual test driver, test instrumentation (including measurement transducers, data acquisition computer, SEA's Automated Steering Controller (ASC), ASC controller box, and ASC battery box), and safety outriggers. This is the loading condition that was used during the dynamic testing phase of this project, and it was designed to represent the Operator and Passenger loading condition (Loading Condition #1). The total vehicle weight of Loading Condition #2 was set to match as closely as possible the total weight of Loading Condition #1. Also, for Loading Condition #2, the vehicles' lateral, longitudinal, and vertical CG positions were made to match those of Loading Condition #1 as closely as practically possible. The vehicle weight for this loading is nominally 426 lb more than the vehicle curb weight.

[1] *The Design of a Vehicle Inertia Measurement Facility*, Heydinger, G.J., Durisek, N.J., Coovert, D.A., Guenther, D.A., and Novak, S.J., SAE Paper No. 950309, February, 1995.

For the single-passenger Vehicle G15, VIMF tests were conducted in an Operator Only loading condition, with the operator weighing 213 lb. For Vehicle G15 dynamic tests, SEA's lightest test driver drove and SEA used its lightest set of outriggers, and the total weight added to the vehicle was 264 lb (over the curb weight). This was the Operator, Instrumentation, and Outriggers loading condition used for the second VIMF test of Vehicle G15.

The vehicle CG longitudinal position is expressed as a distance from the front axle. The vehicle CG lateral position is expressed as a lateral distance from the vehicle centerline; CG positions to the right (passenger's side) of the centerline are positive. The vehicle CG height is expressed as the distance of the vehicle center of gravity above the road plane. The CG height test results are determined from five separate VIMF sub-tests. The first test finds the nominal zero angle of the platform/vehicle system, and the remaining four are the actual CG height tests. Two tests are performed with the vehicle tilted forward, and two are performed with the vehicle tilted rearward. Results from the four tests are then averaged together. Based on detailed error analyses and supported by the results of actual repeat testing, the repeatability of VIMF center of gravity height measurements is within ±0.5% of the measured values.

The moments and product of inertia for a vehicle are computed relative to the vehicle's center of gravity, using an orthogonal coordinate system with its origin at the vehicle center of gravity. The X-axis of the coordinate system is directed forward and parallel to the road plane, the Y-axis is directed to the driver's right and is also parallel to the road plane, and the Z-axis is directed downward. By definition, all moments of inertia are positive, but the roll/yaw product of inertia can take on positive and negative values. The moment of inertia tests are repeated three times each and the results averaged.

In addition to the direct measurements provided by the VIMF, two other metrics that are used to characterize vehicle rollover resistance were computed, namely, the Static Stability Factor (SSF) and the lateral stability coefficient (KST).

SSF is a fundamental rollover resistance metric which equals the lateral acceleration in g's at which rollover begins in the most simplified rollover analysis of a vehicle represented by a rigid body without suspension movement or tire deflections. NHTSA uses SSF, measured with vehicles loaded in a Driver Only configuration, to evaluate passenger vehicle rollover resistance for NCAP. SSF is given by:

$$SSF = \frac{T_{AVE}}{2 \times H_{CG}}$$

where: T_{AVE} is the Average Track Width, and
H_{CG} is the Vehicle CG Height.

KST is similar to SSF in that it represents the acceleration in g's at which rollover begins in the most simplified rollover analysis of a vehicle with different front and rear track widths represented by a rigid body without suspension movement or tire deflections. For vehicles with equal front and rear track widths, KST and SSF are equal. KST is given by:

$$\mathrm{KST} = \frac{L \times T_R + L_{CG} \times (T_F - T_R)}{2 \times L \times H_{CG}}$$

where: L is the Vehicle Wheelbase,
T_F is the Front Track Width,
T_R is the Rear Track Width, and
L_{CG} is the Longitudinal Distance from the Rear Axle to the CG, and
H_{CG} is the Vehicle CG Height.

2.2 Other Laboratory Measurements

Two additional types of laboratory measurements were made: the vehicles' ground clearances and steering ratios. These measurements were made with the vehicles loaded in the Operator and Passenger loading condition.

Front and rear ground clearance measurements were made using a tape measure with the vehicles on the flat, level VIMF platform. At both the front and rear suspension locations of each vehicle, the vertical distance between the platform (road) surface and the lowest object along the centerline of the vehicle were measured to the nearest 0.05 inches. The lowest points on the vehicles in these locations are typically skid plates or driveline components.

The steering ratio tests consisted of placing the front tires on commercial low friction wheel alignment pads and placing the rear tires on blocks of the same thickness as the alignment pads. The steering wheel angle and roadwheel angles are measured using SEA's steering ratio measurement equipment, a rotary potentiometer for the steering wheel angle measurements and a series of string potentiometers for the roadwheel angle measurements. To conduct the tests, the steering wheel was moved incrementally from zero degrees, to its full lock position to the right, to its full lock position to the left, and returned back to zero degrees. The steering wheel angle increments used were 0°, ±45°, ±90°, ±135°, ±180°, ±270°, ±360°, and full lock in both directions. Both the right side and left side roadwheel angles were recorded at all steering positions. Linear curve fits of the measured data in the range of ±180° of steering wheel angle were used to compute the overall steering ratios. Graphical results from these tests are contained in Appendix F.

3. DYNAMIC TESTING

This section describes the dynamic testing conducted at TRC between September 25, 2014 and July 1, 2015. The dynamic test evaluations included steering maneuvers on the flat dry asphalt surface of TRC's Vehicle Dynamics Area (VDA).

For 11 of the vehicles, triangulated aluminum safety outriggers that extend on both sides of vehicles were used. These outriggers mount to the ROPS/OPS structures on the ROV's. Vehicle F15 has a narrow ROPS/OPS section above the passenger compartment, so mounting the triangulated aluminum outriggers was not possible using typical fastening methods. Therefore, for Vehicle F15, SEA used its light-vehicle underbody steel outriggers, a steel tube outrigger with adjustable height pucks on both sides of the vehicle. SEA used their All Terrain Vehicle (ATV) aluminum outriggers for the single-passenger Vehicle G15, in an effort to minimize the total weight added to the vehicle during dynamic testing.

All of the dynamic tests were performed in one loading configuration, namely:

Operator, Instrumentation, and Outriggers
This dynamic testing loading condition was specified to be the vehicle curb condition plus the weight of the actual test driver, test instrumentation (including measurement transducers, data acquisition computer, SEA's Automated Steering Controller (ASC), ASC controller box, and ASC battery box), and safety outriggers.

Table 2 lists the nominal weights of the test instrumentation, test driver and outriggers for all of the test vehicles except the single-passenger Vehicle G15. The total weight of the driver, instrumentation, and safety outriggers is nominally 426 lb, which is the same weight as two 213 lb occupants. As mentioned previously, this dynamic loading condition was designed to match as closely as possible the total weight of the Operator and Passenger (each weighing nominally 213 lb) loading condition used during the laboratory testing. The test equipment and safety outriggers were adjusted so that the vertical, lateral and longitudinal CG positions of the dynamic loading configurations would match those of Operator and Passenger loading configurations as closely as practically possible.

Table 3 lists the nominal weights of the test instrumentation, test driver and outriggers for Vehicle G15. The total weight of the driver, instrumentation, and safety outriggers is nominally 264 lb, which is greater than the weight of 213 lb used to represent passengers in all other cases. For this vehicle, the Operator, Instrumentation, and Outriggers loading condition is nominally 51 lb greater than the Operator only loading condition.

Table 2: Weights of Instrumentation, Driver and Outriggers (All Vehicles Except Vehicle G15)	
Object	**Weight (lb)**
ASC Handwheel Unit	34
ASC Electronics Box and Cables	25
ASC Battery Box	27
SEA Data Acquisition Computer	10
Auxiliary 12V Battery	25
RT3002 GPS/IMU, Antenna, and Cables	10
SEA Power Distribution Box and Misc. Straps	7
Fire Extinguisher	5
Test Driver, Safety Outriggers and Ballast	283
Total Nominal Weight	**426**

Table 3: Weights of Instrumentation, Driver and Outriggers (Vehicle G15 – Single-Passenger Vehicle)	
Object	**Weight (lb)**
ASC Handwheel Unit	34
ASC Electronics Box and Cables	25
ASC Battery Box	27
SEA Data Acquisition Computer	10
RT3002 GPS/IMU, Antenna, and Cables	5
SEA Power Distribution Box and Misc. Straps	7
Fire Extinguisher	5
Test Driver, Safety Outriggers and Ballast	151
Total Nominal Weight	**264**

Table 4 lists the instrumentation used during the dynamic testing.

The RT3002 was mounted as near as conveniently possible to the CG of each vehicle. Nonetheless, for each vehicle, the longitudinal, lateral, and vertical offsets from the center of the RT3002 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 loaded vehicle. The lateral accelerations measured and reported herein are accelerations parallel to the road plane, as opposed to vehicle body-fixed accelerations.

Table 4: Instrumentation Used During Dynamic Testing

Transducer	Measurement	Range	Accuracy*
Oxford Technical Solutions RT3002 Inertial and GPS Navigation System	Longitudinal, Lateral, and Vertical Accelerations	± 100 m/s^2 (± 10 g)	0.01 m/s^2 (0.001 g)
	Roll, Pitch, and Yaw Rates	± 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	± 0.25 deg

In total, over 650 dynamic tests were performed on the 13 vehicles. The following suite of three different types of dynamic tests was performed using each test vehicle:

- **Constant Radius (100 ft) Circle Tests**
- **Constant Speed (30 mph) Slowly Increasing Steer Tests**
- **Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 30 mph)**

3.1 Constant Radius (100 ft) Circle Tests

Constant radius circle tests were used to evaluate the vehicles' understeer characteristics[2]. A constant radius circle test involves driving a vehicle on a circular path of constant radius (100 ft in this case). The test vehicles were driven in the clockwise and counterclockwise directions. For this testing, the vehicles were driven from a very low speed up to their maximum speeds. Most of the vehicles tipped up on to the safety outriggers during the higher speed portions of these tests.

The slowly increasing speed method as opposed to a discrete speed method was used for these tests. It is more efficient to conduct slowly increasing speed circle tests than discrete speed circle tests, and the data reduction process is more straightforward.

The constant radius circle tests were used to determine steering wheel angle gradients. The steering wheel angle gradients are the slopes of the tests' characteristic curves of steering wheel angle versus lateral acceleration. The circle tests were also used to determine if the vehicles transitioned from understeer to oversteer during the tests. Finally, roll gradients, vehicle roll angle response as a function of lateral acceleration, were computed from these tests.

Detailed results from the circle tests are contained in Appendix C.

3.2 Constant Speed (30 mph) Slowly Increasing Steer Tests

Constant speed slowly increasing steer (SIS) tests were also used to evaluate the vehicles' understeer characteristics[3]. During these SIS tests, the driver tried to maintain a constant speed of 30 mph and the ASC was programmed to apply a slow steering input at the rate of 5 deg/sec. Many of the vehicles tipped up on to the safety outriggers during the higher steering angle portions of these tests.

Using methods appropriate for SIS tests, these tests were also used to determine if the vehicles transitioned from understeer to oversteer during the tests.

Detailed results from the slowly increasing steer tests are contained in Appendix D.

3.3 Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 30 mph)

J-turn tests, often referred to as step steer tests, involve imparting a rapid steering input up to a fixed magnitude while the vehicle is traveling along a straight path. For the dropped throttle J-turn tests, the test driver drove each vehicle along a straight-line path at a speed slightly above 30 mph. He then dropped the throttle and triggered the ASC to initiate the steering input precisely when the vehicle speed reached 30 mph.

The following Test Procedure and Verification protocols, provided by CPSC, were used for this test program:

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[2] SAE Surface Vehicle Recommended Practice - Steady-State Directional Control Test Procedures For Passenger Cars and Light Trucks, SAE J266, 1996.
[3] Ibid

Test Procedure - While recording data and starting with a relatively low steering angle to produce a right turn, conduct 30 mph drop throttle J-turns, holding steering angles for a minimum of 4 seconds before returning steering to zero. The steering rate when returning to zero may be less than 500 degrees per second. Conduct additional J-turns, increasing the steering angle in 10 degree increments as required until a two wheel lift event is achieved. Then, decrease the test steering angle in 5 degree increments to find the lowest steering angle that will produce a two wheel lift event. Repeat for left turns.

Verification – While recording data, conduct trials in two opposite directions on the test surface using the minimum steering angle for left or right determined in the Test Procedure to verify that the steering angle produces two wheel lift events in both directions on the test surface. Conduct five trials with visually verified, successful tip-up in each direction, while recording data for each trial. All data for each trial should be reviewed to detect trials that were not executed correctly. Any trials that do not produce tip-up should be diagnosed for cause. If a cause is identified, the data may be discarded and the trial should be repeated to replace the data. If no cause can be identified, repeat Test Procedure, to assure that the correct steering angle has been determined. A minimum of five trials yielding two-wheel lift must be recorded for each turn direction in each direction on the test surface, which will result in twenty (20) total J-turns to complete the minimum data set. Addition J-turns may be added to the minimum data set in groups of four with one for each turn direction in each direction on the test surface.

For this testing, tip-up events were considered those that produced visual two-wheel lift. These tests provided a measure of the minimum peak lateral acceleration (Threshold Ay) and minimum steering wheel angle (Threshold Steering) required to cause two-wheel lifts during the tests.

4. DISCUSSION OF TEST RESULTS

Table 5 lists the appendices that contain test results. Appendix A contains tables with all of the results from the laboratory testing, with the exception of the graphs from the steering ratio tests conducted in the laboratory, which are contained in Appendix F. Detailed results from all of the dynamic testing are contained in Appendix C through Appendix E. Appendix B contains a collection of bar charts, graphs, and tables summarizing selected results from both laboratory and dynamic testing.

Table 5: List of Appendices Containing Test Results	
Appendix	**Title**
Appendix A	Laboratory Test Results
Appendix B	Summary Bar Charts, Graphs, and Tables
Appendix C	Constant Radius (100 ft) Circle Test Results
Appendix D	Constant Speed (30 mph) Slowly Increasing Steer Test Results
Appendix E	Dropped Throttle J-Turn (Step Steer) Test Results (30 mph)
Appendix F	Steering Ratio Test Results

4.1 Discussion of Appendix A: Laboratory Test Results

Appendix A contains tabular results of laboratory measurements made by SEA. There are 13 pages of results, one page for each vehicle. The first 19 rows of each table contain quantities related to the mass (weight), center-of-gravity location, and inertia measurements, as well as static rollover propensity calculations, based on measurements made using the VIMF. The final three rows contain measured values for the front and rear ground clearances and steering ratios.

VIMF tests were conducted on all vehicles in their Operator and Passenger configurations and their Operator, Instrumentation and Outriggers configurations. For the Curb configurations only the vehicle weight was measured (i.e. no VIMF tests were conducted for this loading configuration). The ground clearance and steering ratios were measured only for the Operator and Passenger loading configuration.

4.2 Discussion of Appendix B: Summary Bar Charts, Graphs, and Tables

All of the results presented in Appendix B are for the vehicles in their Operator, Instrumentation and Outriggers configurations.

The first 20 pages of Appendix B contain bar charts of Weight, Wheelbase, CG Height, Average Track Width, SSF, KST, Roll Gradient, Steering Ratio, Threshold Ay, and Threshold Steering.

Pages 21 and 22 contain circle test characteristic curves of steering wheel angle versus lateral acceleration in the range of 0.01 to 0.50 g for all 13 vehicles. The lateral accelerations shown on these graphs (and throughout this report) are the lateral accelerations parallel to the road plane, not the vehicle body-fixed lateral accelerations. Pages 23 and 24 show the same results but they are shifted along the vertical axis by subtracting out the Ackermann angles.

Pages 25 and 26 contain values for the slopes of the circle test characteristic curves (the steering wheel angle gradients) at selected lateral accelerations ranging from 0.0 to 0.5 g.

Pages 27-31 contain slope values for the individual vehicles in the CW direction, CCW direction, and Average of the two directions. (The average values are the quantities used on Pages 25 and 26.)

Page 32 contains a table listing the CW, CCW, and Average values for the lateral accelerations at which the vehicles that transitioned from understeer to oversteer during the circle tests did so. "NA" in the table indicates that no transition to oversteer occurred.

Page 33 contains a table listing the Right Turn, Left Turn, and Average values for the lateral accelerations at which the vehicles that transitioned from understeer to oversteer during the SIS tests did so. "NA" in the table indicates that no transition to oversteer occurred.

Page 34 contains a table summarizing the average steering wheel angles (Threshold Steering values) and average minimum peak lateral accelerations (Threshold Ay values) during the dropped throttle J-turn tests.

4.3 Discussion of Appendix C: Constant Radius (100 ft) Circle Test Results

Constant radius circle test results are contained in Appendix C.

For each vehicle there are four pages showing results from both the clockwise (CW) and counterclockwise (CCW) circle tests. The first page shows time domain plots of Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate. All of the dynamic test data is sampled at 200 Hz. For the circle test results, the data shown was digitally low-pass filtered to 1.0 Hz using a phaseless, eighth-order, Butterworth filter. The time domain data shown for each vehicle contains all of the data from the time the test driver started the data acquisition (prior to starting to move on the circle) to the time the test driver ended the data acquisition at the end of the test. The thin black lines for the CW and CCW tests show this full range of data. The thicker lines (red for CW and blue for CCW) indicate the range of data from the time the vehicle attained a speed of 4.0 mph, which is a lateral acceleration of 0.01 g on a 100 ft radius circle, until the vehicle attained a speed of 27.4 mph, which is a lateral acceleration of 0.50 g on a 100 ft radius circle. This range of data, from 0.01 g to 0.50 g, was selected because it provided a consistent range of lateral accelerations over which meaningful curve fits of the data could be made without weighting the spurious data that can occur at the beginning and end of a circle test taken to the limits of a vehicle's response. The speed plots show that the circle tests were conducted using a very slow rate of increase in speed during the circle tests. Regarding conducting circle tests for passenger vehicles, SAE J266[4] states: "If speed is steadily increased, the rate of increase shall not

[4] SAE Surface Vehicle Recommended Practice - Steady-State Directional Control Test Procedures For Passenger Cars and Light Trucks, SAE J266, 1996.

exceed 1.5 km/h per second (0.93 mph per second), and data shall be recorded continuously, so long as the vehicle remains on radius." The rates of speed increase during the circle tests conducted are many times less than the J266 recommended maximum rate.

The second page for each vehicle shows graphs of Handwheel Steer Angle versus Ay (lateral acceleration). The CW test results are in the upper right quadrants of the graphs and the CCW test results are in the lower left quadrants of the graphs. The thin red lines show data in the range of vehicle speeds from 4.0 mph to full speed achieved during each test. For both the CW and CCW data, there are two thicker lines for indicating second-order polynomial curve fits to two different ranges of the data. The thick black lines are curve fits of the data in the range of vehicle speeds from 4.0 mph to maximum speed achieved during each test. The thick blue lines are curve fits of the data in the range of vehicle speeds from 4.0 mph (0.01 g) to 27.4 mph (0.50 g). The red circles on these graphs are the geometric Ackermann steer angles, a function of the steering ratio (K) times the wheelbase (L) divided by the circle radius (R), given by:

$$\delta_{SW\ (\mathrm{Geometric\ Ackermann})} = \frac{(180/\pi)\times K\times L}{R}$$

The geometric Ackermann steer angles are not the same as the actual steer angles required to negotiate the circles at very low speed, with Ay close to zero. The actual steer angles, which can be referred to as the measured Ackermann steer angles, are generally greater than the geometric Ackermann steer angles due primarily to compliance and lash in the steering system, and compliance in the suspension systems and tires.

The third page for each vehicle in Appendix C shows graphs of Handwheel Steer Angle minus (measured) Ackermann Angle versus Ay (lateral acceleration). For these graphs, the signs of the CCW data are reversed so that the CW and CCW results can be directly compared. The thin lines show data in the range of vehicle speeds from 4.0 mph (0.01 g) to 27.4 mph (0.50 g). The thick lines are the second-order polynomial curve fits to the data. Notice that the measured Ackermann steer angles are the abscissae of the curve fits taken at Ay equal to zero, so the curve fits tend to zero as Ay goes to zero. For a circle test: understeer can be defined as the condition when the steering wheel input required to maintain the circular path increases as the vehicle speed increases, neutral steer can be defined as the condition when the steering wheel input required to maintain the circular path does not change as the vehicle speed increases, and oversteer can be defined as the condition when the steering wheel input required to maintain the circular path decreases as the vehicle speed increases. The second-order polynomial curve fits do a good job of representing the underlying data whether the particular test vehicle exhibits understeer, neutral steer, or oversteer characteristics during the circle tests.

Several of the vehicles tested exhibit understeer at low levels of lateral acceleration and then transition to oversteer at higher levels of lateral acceleration. The points of transition from understeer to oversteer are indicated on the graphs by black circles, and they are mathematically the points where the slopes of the curve fits change from being positive to negative. For circle tests where the vehicles exhibited a transition from understeer to oversteer, the values of the lateral acceleration at the points of transition are indicated on the graphs.

The fourth page for each vehicle in Appendix C shows graphs of Roll Angle versus Ay (lateral acceleration). The CW test results are in the lower right quadrants of the graphs and the CCW test results are in the upper left quadrants of the graphs. The thin lines show data in the range of vehicle speeds from 4.0 mph to full speed achieved during each test. The thick lines are linear curve fits to the CW and CCW data in the range of vehicle speeds from 4.0 mph (0.01 g) to 27.4 mph (0.50 g). For each vehicle configuration, the average of the CW and CCW curve fit slopes are listed on the graphs as the Roll Gradient.

Pages 53-58 of Appendix C contain graphs summarizing the 0.01 g to 0.50 g curve fit data for each vehicle. Pages 53-54 contain graphs of Steering Wheel Angle versus Ay, Pages 55-56 contain graphs of Handwheel Steer Angle minus (measured) Ackermann Angle versus Ay, and Pages 57-58 contain graphs of Ay versus Handwheel Steer Angle minus (measured) Ackermann Angle. The graphs on Pages 55-56 and 57-58 contain the same information, but different organizations prefer one presentation to the other.

Pages 59-60 contain summary bar charts of the average of the CW and CCW curve fit slopes at lateral acceleration of 0.0 g through 0.5 g. These slopes have dimension of "deg/g". For a circle test, these slopes or gradients of the characteristic curve of Handwheel Steer Angle versus Ay are often referred to as Steering Wheel Angle Gradients or Understeer Gradients[5]. However, the slopes presented on Pages 59-60 should not be confused with the linear range Understeer Gradients that are often used to characterize vehicles in their low lateral acceleration linear range of response.

Pages 61-65 in Appendix C contain bar charts of the CW, CCW, and average slopes for the individual vehicles at all lateral accelerations evaluated.

Page 66 contains a summary table of the CW, CCW, and average lateral acceleration levels at which the vehicles that transitioned from understeer to oversteer did so. "NA" in the table indicates that no transition to oversteer occurred.

4.4 Discussion of Appendix D: Constant Speed (30 mph) Slowly Increasing Steer Test Results

Results from the 30 mph constant speed slowly increasing steer (SIS) tests are contained in Appendix D.

For each vehicle there are three pages showing results from both the right turn and left turn slowly increasing steer tests. The first page shows time domain plots of Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate. For the SIS test results, the data shown was digitally low-pass filtered to 5.0 Hz using a phaseless, eighth-order, Butterworth filter. The time domain data shown for each vehicle contains data from 0.5 seconds before the ASC steering input was applied until the time the test driver ended the test. The thin black lines for the right turn and left turn tests show the range of data collected. During these SIS tests, the driver tried to maintain a constant speed of 30 mph and the ASC was programmed to apply a slow steering

[5] The slopes or gradients presented are degrees of steering wheel angle per g of lateral acceleration. Understeer Gradients are oftentimes expressed in degrees of roadwheel angle per g of lateral acceleration, wherein the roadwheel angle is taken as the steering wheel angle divided by the steering ratio.

input at the rate of 5.0 deg/sec. The thicker lines (red for right turns and blue for left turns) indicate the range of data from time equal zero to the time the vehicle speed fell below 28.0 mph.

The second page for each vehicle shows graphs of handwheel Steer Angle versus Lateral Acceleration (Ay). The right turn test results are in the upper right quadrants of the graphs and the left turn test results are in the lower left quadrants of the graphs. The red and blue lines show data in the range of vehicle speeds from 0.0 mph to 28.0 mph. For both the right turn and left turn data, there are black lines indicating fifth-order polynomial curve fits to the data in the range from time (and Ay) equal to zero to the time when the lateral acceleration reached 0.5 g. This range of data, from 0.0 g to 0.5 g, was selected because it provided a consistent range of lateral accelerations over which meaningful curve fits of the data could be made without weighting the spurious data that can occur at the end of an SIS test taken to the limits of a vehicle's response. The fifth-order polynomial curve fits do a good job of representing the underlying data from the SIS tests.

The green lines on the second page graphs are the Ackermann steer angle gradients, a function of the steering ratio (K) times the wheelbase (L) divided by the vehicle speed (V) squared, given by:

$$\text{Ackermann Steer Angle Gradient} = \frac{g \times (180/\pi) \times K \times L}{V^2}$$

where "g" is the Gravitational Constant.

When plotted on the graphs of data from a constant speed SIS test, Ackermann steer angle gradients represent neutral steer. Conditions when the slope of the characteristic curve is greater than the Ackermann steer angle gradient represent understeer and conditions when the slope of the characteristic curve is less than the Ackermann steer angle gradient represent oversteer. For vehicles that transitioned to Oversteer, the points during the tests where the vehicles transitioned (the points where the slope of the characteristic curve equals the slope of the Ackermann steer angle gradient) are indicated on the graphs by a black circle. Also, the lateral accelerations where the transition to oversteer occurred are listed on the graphs.

The third page for each vehicle in Appendix D shows graphs of Lateral Acceleration versus handwheel Steer Angle. These graphs contain the same underlying data as the second page graphs, but different organizations prefer one presentation to the other.

Page 40 in Appendix D contains a summary table of the right turn, left turn, and average lateral acceleration levels at which the vehicles transitioned from understeer to oversteer. "NA" in the tables indicate that no transition to oversteer occurred.

4.5 Discussion of Appendix E: Dropped Throttle J-Turn (Step Steer) Test Results (30 mph)

Results from the dropped throttle J-turn tests are contained in Appendix E.

For each vehicle there are five pages of results. The first four pages show time domain plots for the tests. The first and third pages for each vehicle show plots of Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate; for the 10 Northbound and 10 Southbound runs respectively. The second and forth pages for each vehicle show larger plots of Lateral Acceleration; for the 10 Northbound and 10 Southbound runs respectively. For the J-turn test results, the data shown was digitally low-pass filtered to 2.0 Hz using a phaseless, eighth-order, Butterworth filter. The time domain data shown for each vehicle contains data from 0.5 seconds before the ASC steering input was applied until 5.0 seconds after it was applied.

For each vehicle, the plots contain results from five Northbound right steer J-turns, five Northbound left steer J-turns, five Southbound right steer J-turns, and five Southbound left steer J-turns. In all cases, the plots contain results for tests that resulted in visual two-wheel lift. An SAE standard sign convention is used, with Steer Angle, Lateral Acceleration, and Yaw Rate being positive and Roll Angle being negative for right turns.

The fifth page shown for each vehicle contains a summary of the peak lateral accelerations measured in each test. These values are the maximum values of lateral acceleration shown on the plots, which contain data that has been filtered to 2.0 Hz.

The summary pages show the peak lateral accelerations for the five runs conducted in the Northbound right steer direction, Northbound left steer direction, Southbound right steer direction, and Southbound left steer direction. The mean values and standard deviations from each of the five sample runs are shown on the summary pages. Also, the average of the ten Northbound and Southbound runs is shown, as is the average of all 20 runs, which is the Threshold Ay value.

Page 66 of Appendix E contains a table listing the average right and average left steering angles, and average right and average left peak lateral accelerations for all Northbound and Southbound runs. The right two columns of the table on Page 66 contain Average Steering and Average Peak Lateral Acceleration for all 20 runs for each vehicle. These values are the Threshold Steering and Threshold Ay.

4.6 Discussion of Appendix F: Steering Ratio Test Results

Results from the steering ratio tests are contained in Appendix F.

There is one page of steering ratio results provided for each vehicle. The top figure on each page plots data taken from the right wheel and the bottom figure data from the left wheel. The plots also show blue linear curve fits to the data in the range of ±180° of steering wheel angle. The right steering ratio, the left steering ratio, and the average steering ratio are presented on the plots.

Vehicle A15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5430	5431
Total Vehicle Weight (lb)	1371.3	1796.9	1796.6
Left Front Weight (lb)	291.8	388.0	397.6
Right Front Weight (lb)	295.9	395.5	384.6
Left Rear Weight (lb)	372.4	488.1	510.0
Right Rear Weight (lb)	411.2	525.3	504.4
Front Track Width (in)	52.10	52.75	52.75
Rear Track Width (in)	52.00	52.69	52.69
Average Track Width (in)	52.05	52.72	52.72
Wheelbase (in)	83.93	83.75	83.75
CG Longitudinal (in)	47.96	47.23	47.29
CG Lateral (in)	0.81	0.66	-0.27
CG Height (in)		26.20	26.20
Roll Inertia - I_{XX} (ft-lb-s^2)		225	262
Pitch Inertia - I_{YY} (ft-lb-s^2)		397	416
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		438	483
Roll/Yaw - I_{XZ} (ft-lb-s^2)		6	-1
SSF		1.006	1.006
KST		1.006	1.006
Front Ground Clearance (in)		10.60	
Rear Ground Clearance (in)		9.80	
Steering Ratio (deg/deg)		13.7	

Vehicle B15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5433	5437
Total Vehicle Weight (lb)	1537.1	1962.6	1963.1
Left Front Weight (lb)	373.0	484.7	490.6
Right Front Weight (lb)	385.9	492.2	486.6
Left Rear Weight (lb)	378.0	479.9	495.9
Right Rear Weight (lb)	400.2	505.8	490.0
Front Track Width (in)	50.40	51.34	51.34
Rear Track Width (in)	50.48	51.16	51.16
Average Track Width (in)	50.44	51.25	51.25
Wheelbase (in)	85.85	85.85	85.85
CG Longitudinal (in)	43.46	43.12	43.12
CG Lateral (in)	0.58	0.44	-0.13
CG Height (in)		26.30	26.02
Roll Inertia - I_{XX} (ft-lb-s^2)		216	245
Pitch Inertia - I_{YY} (ft-lb-s^2)		434	448
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		457	499
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	4
SSF		0.974	0.985
KST		0.974	0.985
Front Ground Clearance (in)		8.55	
Rear Ground Clearance (in)		8.50	
Steering Ratio (deg/deg)		15.2	

Vehicle C15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5446	5459
Total Vehicle Weight (lb)	1263.2	1689.2	1691.2
Left Front Weight (lb)	264.6	349.0	365.1
Right Front Weight (lb)	276.6	371.5	357.2
Left Rear Weight (lb)	338.5	463.6	492.8
Right Rear Weight (lb)	383.5	505.1	476.1
Front Track Width (in)	48.56	50.78	50.78
Rear Track Width (in)	48.65	50.29	50.29
Average Track Width (in)	48.61	50.53	50.53
Wheelbase (in)	75.30	75.35	75.35
CG Longitudinal (in)	43.04	43.21	43.17
CG Lateral (in)	1.10	0.96	-0.37
CG Height (in)		25.71	25.50
Roll Inertia - I_{XX} (ft-lb-s^2)		178	200
Pitch Inertia - I_{YY} (ft-lb-s^2)		307	320
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		320	362
Roll/Yaw - I_{XZ} (ft-lb-s^2)		11	6
SSF		0.983	0.991
KST		0.983	0.992
Front Ground Clearance (in)		9.23	
Rear Ground Clearance (in)		10.08	
Steering Ratio (deg/deg)		14.0	

Vehicle D15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5457	5458
Total Vehicle Weight (lb)	1703.2	2129.0	2129.5
Left Front Weight (lb)	358.2	468.2	491.2
Right Front Weight (lb)	388.0	516.4	495.1
Left Rear Weight (lb)	472.2	569.5	585.7
Right Rear Weight (lb)	484.8	574.9	557.5
Front Track Width (in)	49.61	50.38	50.38
Rear Track Width (in)	47.44	48.34	48.34
Average Track Width (in)	48.53	49.36	49.36
Wheelbase (in)	105.85	105.90	105.90
CG Longitudinal (in)	59.48	56.92	56.85
CG Lateral (in)	0.61	0.63	-0.27
CG Height (in)		25.71	25.94
Roll Inertia - I_{XX} (ft-lb-s^2)		243	288
Pitch Inertia - I_{YY} (ft-lb-s^2)		691	716
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		708	757
Roll/Yaw - I_{XZ} (ft-lb-s^2)		7	5
SSF		0.960	0.951
KST		0.961	0.953
Front Ground Clearance (in)		9.75	
Rear Ground Clearance (in)		8.70	
Steering Ratio (deg/deg)		13.6	

Vehicle E15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5461	5462
Total Vehicle Weight (lb)	1338.6	1763.8	1767.1
Left Front Weight (lb)	294.6	381.8	402.7
Right Front Weight (lb)	308.0	387.1	373.2
Left Rear Weight (lb)	372.0	491.1	515.8
Right Rear Weight (lb)	364.0	503.8	475.4
Front Track Width (in)	50.79	51.15	51.15
Rear Track Width (in)	48.70	49.30	49.30
Average Track Width (in)	49.74	50.23	50.23
Wheelbase (in)	74.95	74.85	74.85
CG Longitudinal (in)	41.21	42.22	41.98
CG Lateral (in)	0.11	0.25	-0.99
CG Height (in)		27.76	27.69
Roll Inertia - I_{XX} (ft-lb-s^2)		203	247
Pitch Inertia - I_{YY} (ft-lb-s^2)		344	356
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		347	374
Roll/Yaw - I_{XZ} (ft-lb-s^2)		28	21
SSF		0.905	0.907
KST		0.907	0.909
Front Ground Clearance (in)		8.83	
Rear Ground Clearance (in)		8.80	
Steering Ratio (deg/deg)		12.5	

Vehicle F15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5480	5481
Total Vehicle Weight (lb)	1077.0	1503.9	1504.8
Left Front Weight (lb)	223.5	323.6	322.5
Right Front Weight (lb)	224.1	315.9	315.8
Left Rear Weight (lb)	290.5	397.4	421.5
Right Rear Weight (lb)	338.9	467.0	445.0
Front Track Width (in)	41.70	42.33	42.33
Rear Track Width (in)	39.65	40.53	40.53
Average Track Width (in)	40.68	41.43	41.43
Wheelbase (in)	84.65	84.30	84.30
CG Longitudinal (in)	49.47	48.45	48.54
CG Lateral (in)	0.90	0.83	0.22
CG Height (in)		21.98	22.20
Roll Inertia - I_{XX} (ft-lb-s^2)		114	114
Pitch Inertia - I_{YY} (ft-lb-s^2)		290	310
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		291	318
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	10
SSF		0.942	0.933
KST		0.946	0.936
Front Ground Clearance (in)		8.70	
Rear Ground Clearance (in)		7.90	
Steering Ratio (deg/deg)		11.5	

Vehicle G15

	Curb	Operator	Operator, Instrumentation & Outriggers
VIMF Test Number		5496	5497
Total Vehicle Weight (lb)	879.9	1092.2	1146.1
Left Front Weight (lb)	183.7	235.3	241.7
Right Front Weight (lb)	178.8	226.5	241.9
Left Rear Weight (lb)	266.5	321.9	336.4
Right Rear Weight (lb)	250.9	308.5	326.1
Front Track Width (in)	41.00	41.20	41.35
Rear Track Width (in)	40.51	40.90	41.40
Average Track Width (in)	40.76	41.05	41.38
Wheelbase (in)	61.58	61.73	61.65
CG Longitudinal (in)	36.21	35.63	35.64
CG Lateral (in)	-0.47	-0.42	-0.18
CG Height (in)		22.48	22.44
Roll Inertia - I_{XX} (ft-lb-s^2)		70	75
Pitch Inertia - I_{YY} (ft-lb-s^2)		173	182
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		148	162
Roll/Yaw - I_{XZ} (ft-lb-s^2)		2	1
SSF		0.913	0.922
KST		0.914	0.922
Front Ground Clearance (in)		9.00	
Rear Ground Clearance (in)		8.40	
Steering Ratio (deg/deg)		14.1	

Vehicle H15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5545	5546
Total Vehicle Weight (lb)	1549.8	1975.5	1975.1
Left Front Weight (lb)	351.1	446.2	469.8
Right Front Weight (lb)	345.8	443.5	415.6
Left Rear Weight (lb)	438.6	556.0	561.4
Right Rear Weight (lb)	414.3	529.8	528.3
Front Track Width (in)	48.53	48.85	48.85
Rear Track Width (in)	46.40	46.25	46.25
Average Track Width (in)	47.46	47.55	47.55
Wheelbase (in)	76.70	76.75	76.75
CG Longitudinal (in)	42.21	42.18	42.34
CG Lateral (in)	-0.45	-0.34	-1.06
CG Height (in)		24.16	24.16
Roll Inertia - I_{XX} (ft-lb-s^2)		178	196
Pitch Inertia - I_{YY} (ft-lb-s^2)		393	411
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		404	436
Roll/Yaw - I_{XZ} (ft-lb-s^2)		10	7
SSF		0.984	0.984
KST		0.987	0.987
Front Ground Clearance (in)		8.75	
Rear Ground Clearance (in)		8.60	
Steering Ratio (deg/deg)		15.6	

Vehicle I15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5526	5527
Total Vehicle Weight (lb)	1404.5	1830.7	1830.3
Left Front Weight (lb)	302.4	396.4	395.4
Right Front Weight (lb)	324.3	386.0	386.3
Left Rear Weight (lb)	385.5	509.6	557.2
Right Rear Weight (lb)	392.3	538.7	491.4
Front Track Width (in)	55.23	56.23	56.23
Rear Track Width (in)	53.83	54.46	54.46
Average Track Width (in)	54.53	55.34	55.34
Wheelbase (in)	84.40	84.50	84.50
CG Longitudinal (in)	46.74	48.39	48.41
CG Lateral (in)	0.56	0.27	-1.12
CG Height (in)		26.17	26.21
Roll Inertia - I_{XX} (ft-lb-s^2)		199	241
Pitch Inertia - I_{YY} (ft-lb-s^2)		352	367
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		376	418
Roll/Yaw - I_{XZ} (ft-lb-s^2)		24	21
SSF		1.057	1.056
KST		1.060	1.058
Front Ground Clearance (in)		10.50	
Rear Ground Clearance (in)		10.00	
Steering Ratio (deg/deg)		12.0	

Vehicle J15

	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5574	5575
Total Vehicle Weight (lb)	1272.1	1697.7	1698.5
Left Front Weight (lb)	301.2	415.8	415.1
Right Front Weight (lb)	307.7	407.4	406.5
Left Rear Weight (lb)	306.0	400.2	431.4
Right Rear Weight (lb)	357.2	474.3	445.5
Front Track Width (in)	51.50	52.43	52.43
Rear Track Width (in)	49.65	50.20	50.20
Average Track Width (in)	50.58	51.32	51.32
Wheelbase (in)	76.88	76.75	76.75
CG Longitudinal (in)	40.08	39.53	39.62
CG Lateral (in)	1.13	0.97	0.08
CG Height (in)		27.17	27.09
Roll Inertia - I_{XX} (ft-lb-s^2)		185	229
Pitch Inertia - I_{YY} (ft-lb-s^2)		334	344
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		333	372
Roll/Yaw - I_{XZ} (ft-lb-s^2)		15	7
SSF		0.944	0.947
KST		0.945	0.948
Front Ground Clearance (in)		9.15	
Rear Ground Clearance (in)		10.20	
Steering Ratio (deg/deg)		15.1	

Vehicle K15

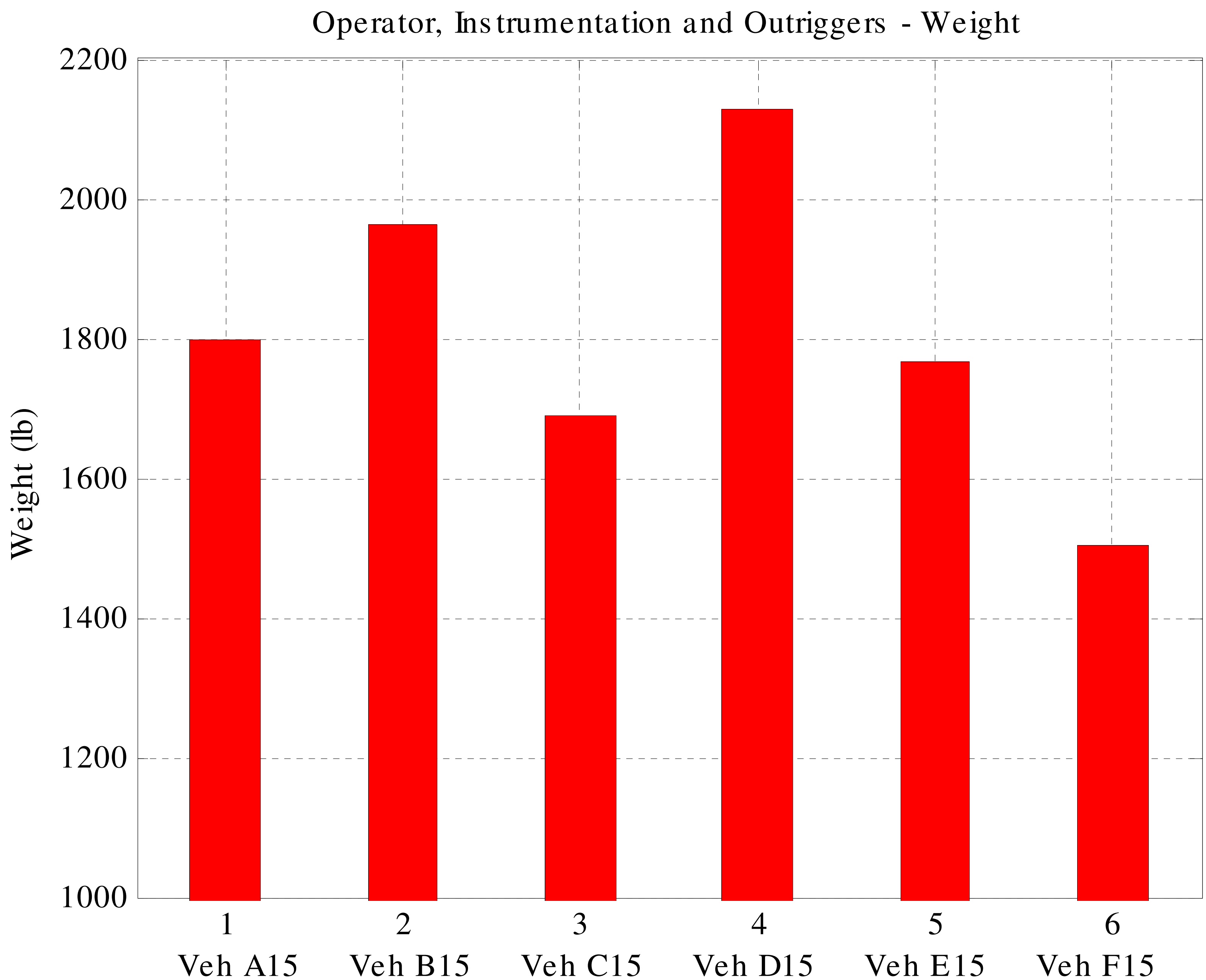
	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5571	5572
Total Vehicle Weight (lb)	1298.1	1724.6	1723.8
Left Front Weight (lb)	274.1	360.9	370.7
Right Front Weight (lb)	273.2	374.1	364.6
Left Rear Weight (lb)	360.3	486.0	503.9
Right Rear Weight (lb)	390.5	503.6	484.6
Front Track Width (in)	52.84	53.70	53.70
Rear Track Width (in)	51.38	51.94	51.94
Average Track Width (in)	52.11	52.82	52.82
Wheelbase (in)	79.10	78.88	78.88
CG Longitudinal (in)	45.75	45.26	45.23
CG Lateral (in)	0.58	0.47	-0.39
CG Height (in)		24.83	24.77
Roll Inertia - I_{XX} (ft-lb-s^2)		149	185
Pitch Inertia - I_{YY} (ft-lb-s^2)		325	339
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		337	375
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	0
SSF		1.064	1.066
KST		1.066	1.069
Front Ground Clearance (in)		10.25	
Rear Ground Clearance (in)		9.80	
Steering Ratio (deg/deg)		10.6	

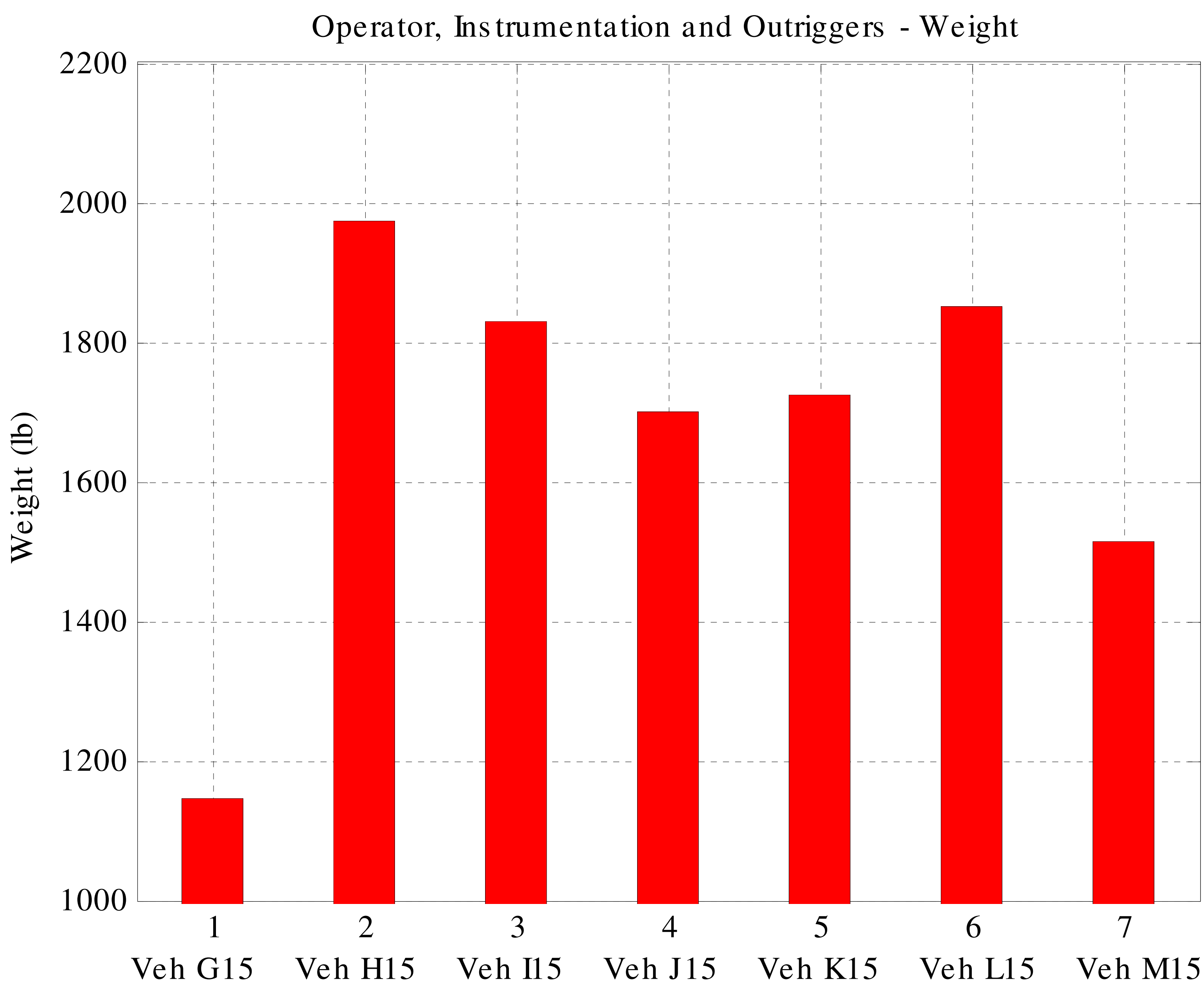
Vehicle L15

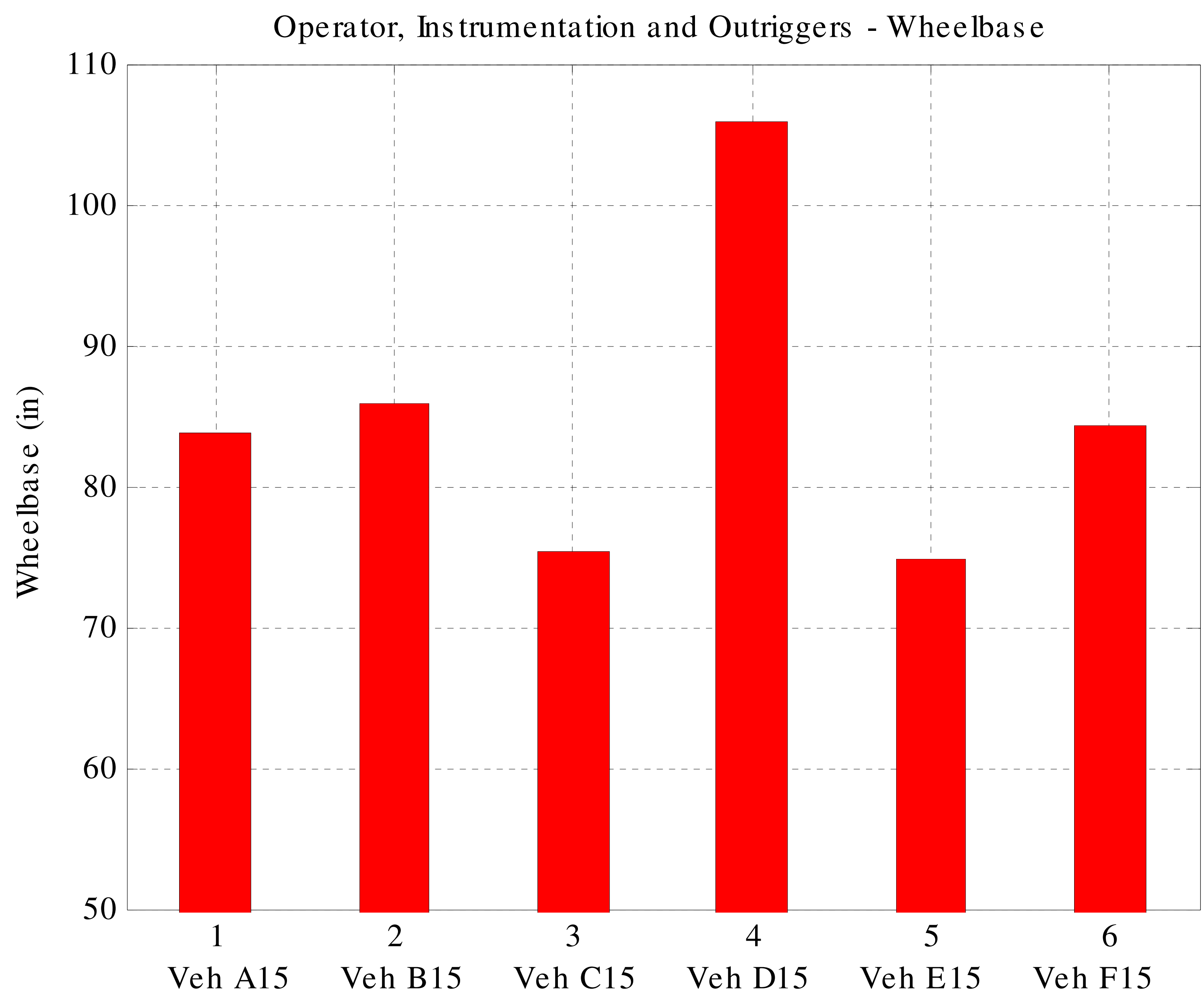
	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5542	5543
Total Vehicle Weight (lb)	1425.4	1851.1	1850.9
Left Front Weight (lb)	319.8	430.4	433.2
Right Front Weight (lb)	308.0	408.1	401.8
Left Rear Weight (lb)	394.6	500.1	528.6
Right Rear Weight (lb)	403.0	512.5	487.3
Front Track Width (in)	52.08	52.50	52.50
Rear Track Width (in)	50.55	50.85	50.85
Average Track Width (in)	51.32	51.68	51.68
Wheelbase (in)	80.70	80.55	80.55
CG Longitudinal (in)	45.16	44.06	44.21
CG Lateral (in)	-0.07	-0.15	-1.01
CG Height (in)		26.89	26.91
Roll Inertia - I_{XX} (ft-lb-s^2)		201	239
Pitch Inertia - I_{YY} (ft-lb-s^2)		390	407
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		401	441
Roll/Yaw - I_{XZ} (ft-lb-s^2)		7	4
SSF		0.961	0.960
KST		0.962	0.962
Front Ground Clearance (in)		9.50	
Rear Ground Clearance (in)		9.35	
Steering Ratio (deg/deg)		18.3	

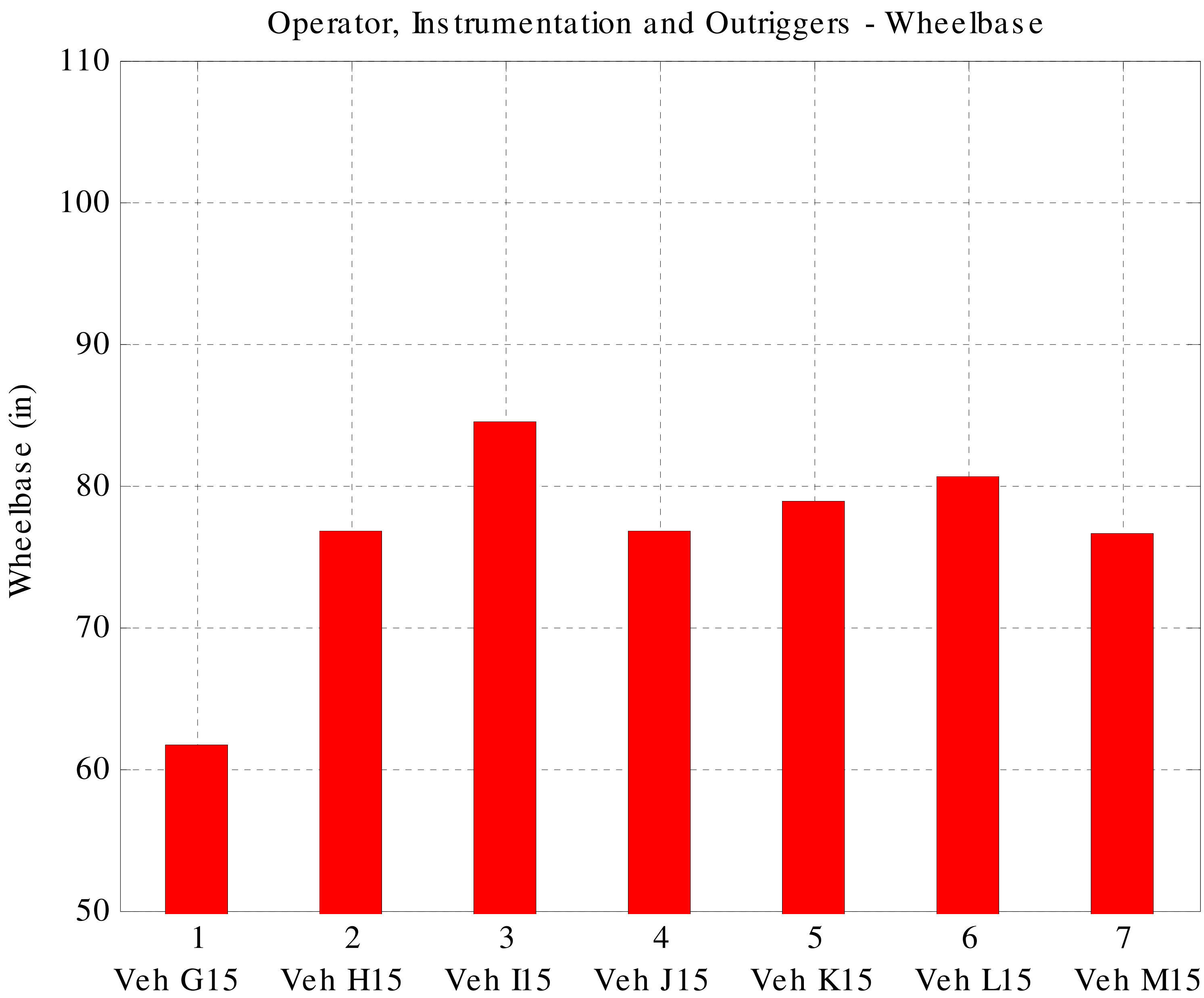
Vehicle M15

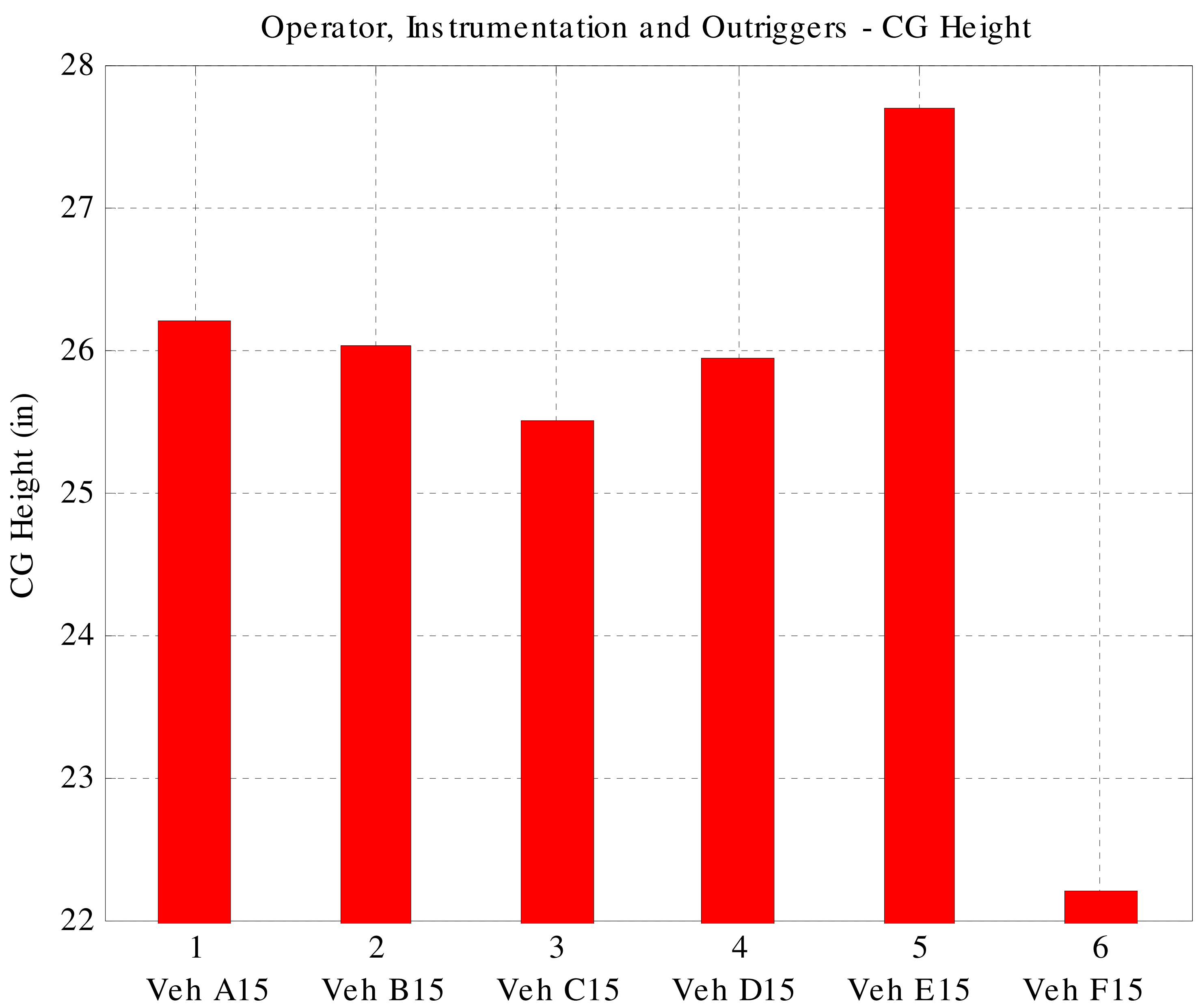
	Curb	Operator & Passenger	Operator, Instrumentation & Outriggers
VIMF Test Number		5725	5726
Total Vehicle Weight (lb)	1087.0	1512.7	1512.6
Left Front Weight (lb)	213.3	307.6	310.5
Right Front Weight (lb)	229.7	320.9	317.4
Left Rear Weight (lb)	319.6	434.4	453.3
Right Rear Weight (lb)	324.4	449.8	431.4
Front Track Width (in)	41.90	42.73	42.73
Rear Track Width (in)	40.61	40.85	40.85
Average Track Width (in)	41.26	41.79	41.79
Wheelbase (in)	76.70	76.60	76.60
CG Longitudinal (in)	45.44	44.77	44.80
CG Lateral (in)	0.41	0.40	-0.20
CG Height (in)		22.65	22.66
Roll Inertia - I_{XX} (ft-lb-s^2)		119	158
Pitch Inertia - I_{YY} (ft-lb-s^2)		283	312
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		279	310
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	0
SSF		0.922	0.922
KST		0.926	0.926
Front Ground Clearance (in)		7.60	
Rear Ground Clearance (in)		7.80	
Steering Ratio (deg/deg)		14.8	

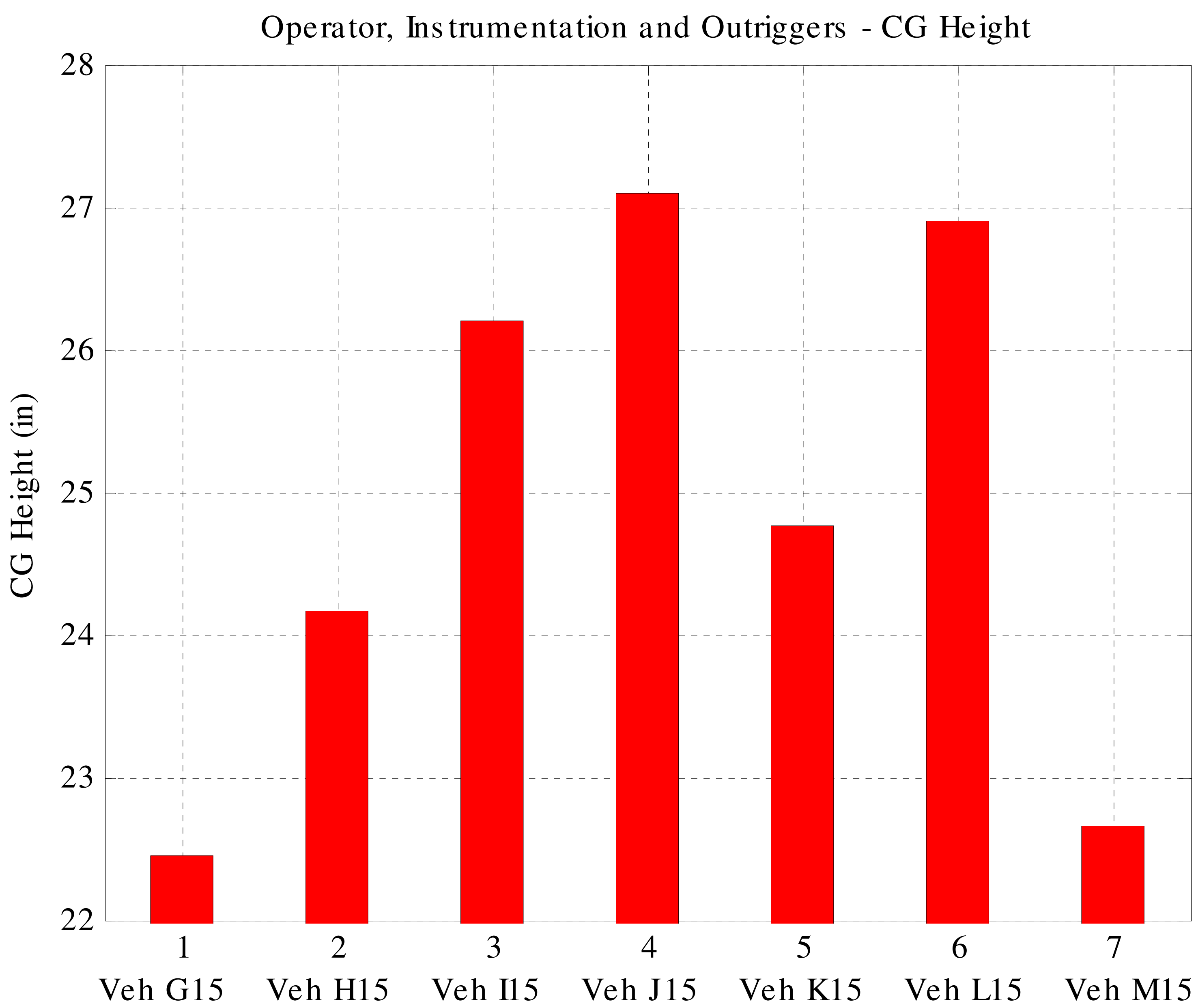

Operator, Instrumentation and Outriggers - Weight
2200
2000
1800
1600
1400
1200
1000
Weight (lb)
1
Veh A15
2
Veh B15
3
Veh C15
4
Veh D15
5
Veh E15
6
Veh F15

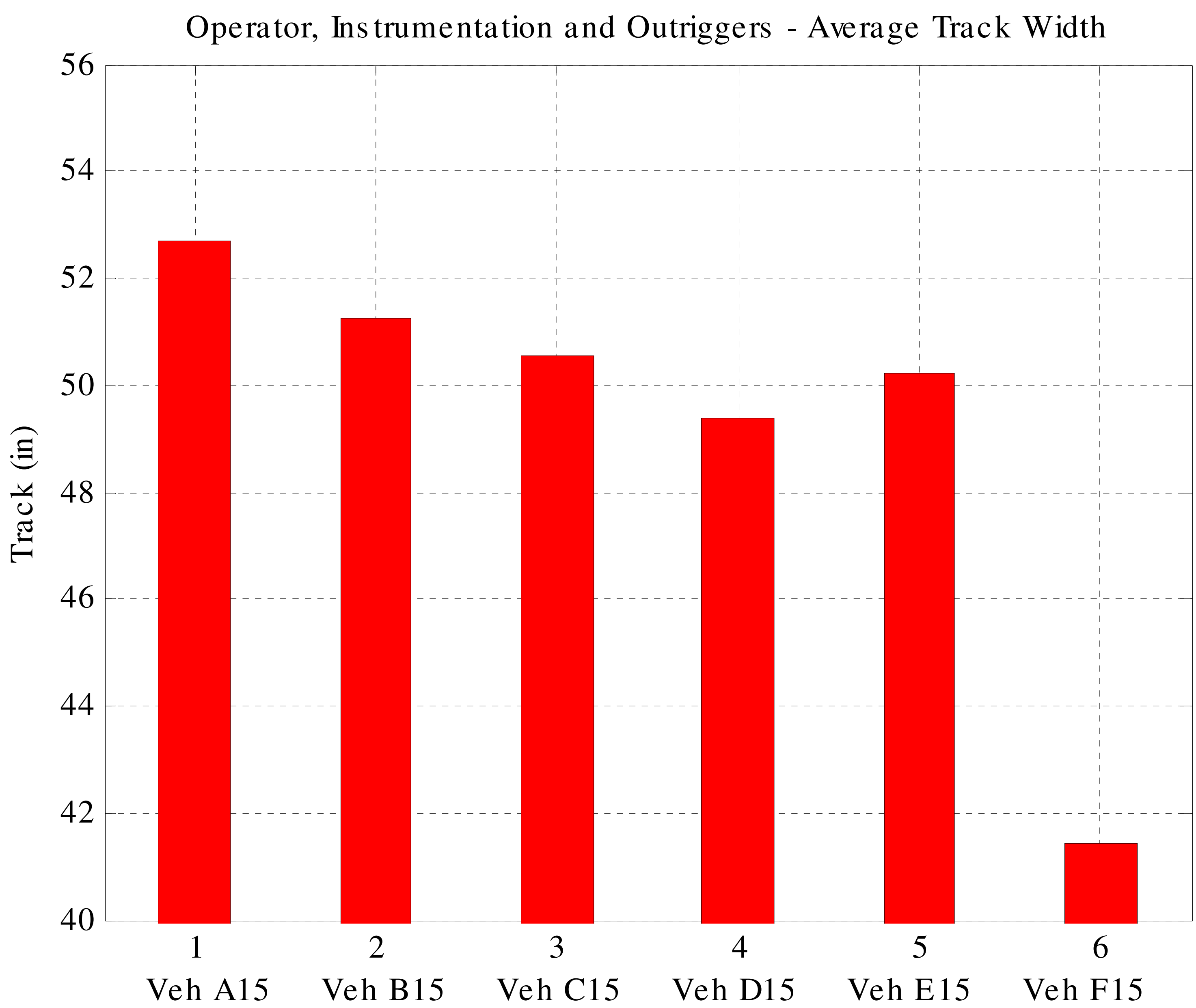

Operator, Instrumentation and Outriggers - Weight
Weight (lb)
2200
2000
1800
1600
1400
1200
1000
1
2
3
4
5
6
7
Veh G15
Veh H15
Veh I15
Veh J15
Veh K15
Veh L15
Veh M15

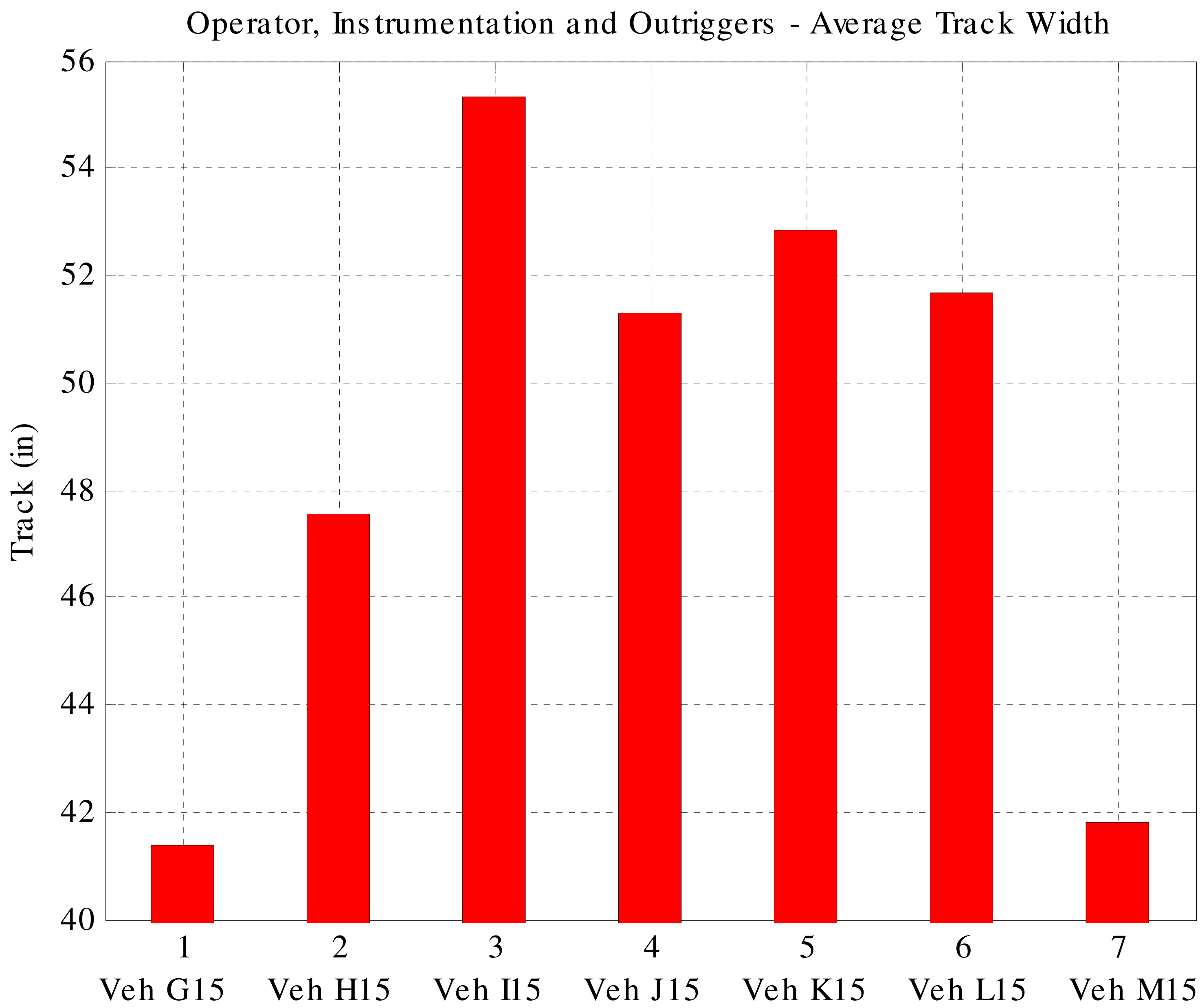

Operator, Instrumentation and Outriggers - Wheelbase
Wheelbase (in)
110
100
90
80
70
60
50
1
Veh A15
2
Veh B15
3
Veh C15
4
Veh D15
5
Veh E15
6
Veh F15

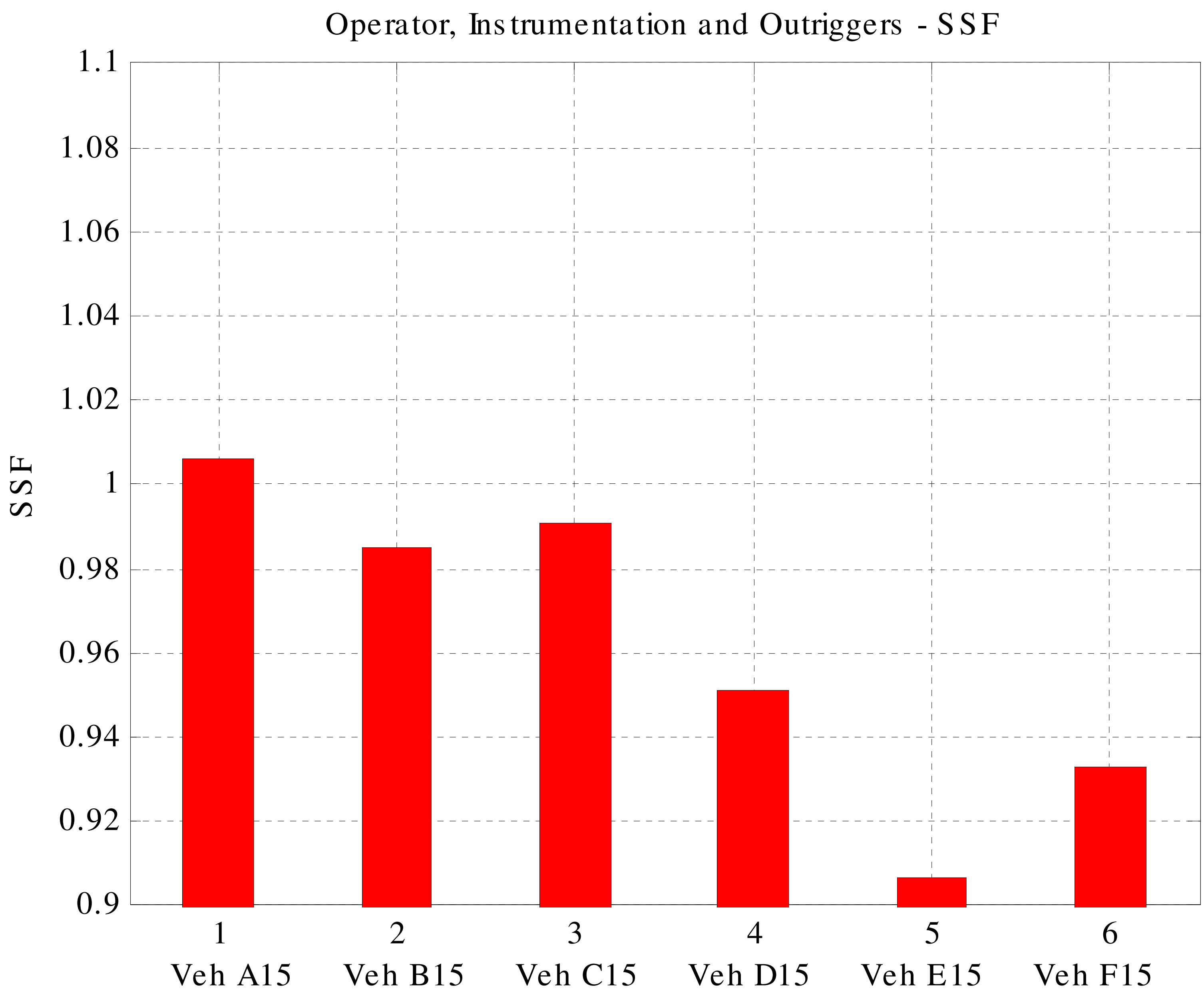

Operator, Instrumentation and Outriggers - Wheelbase
Wheelbase (in)
110
100
90
80
70
60
50
1
Veh G15
2
Veh H15
3
Veh I15
4
Veh J15
5
Veh K15
6
Veh L15
7
Veh M15

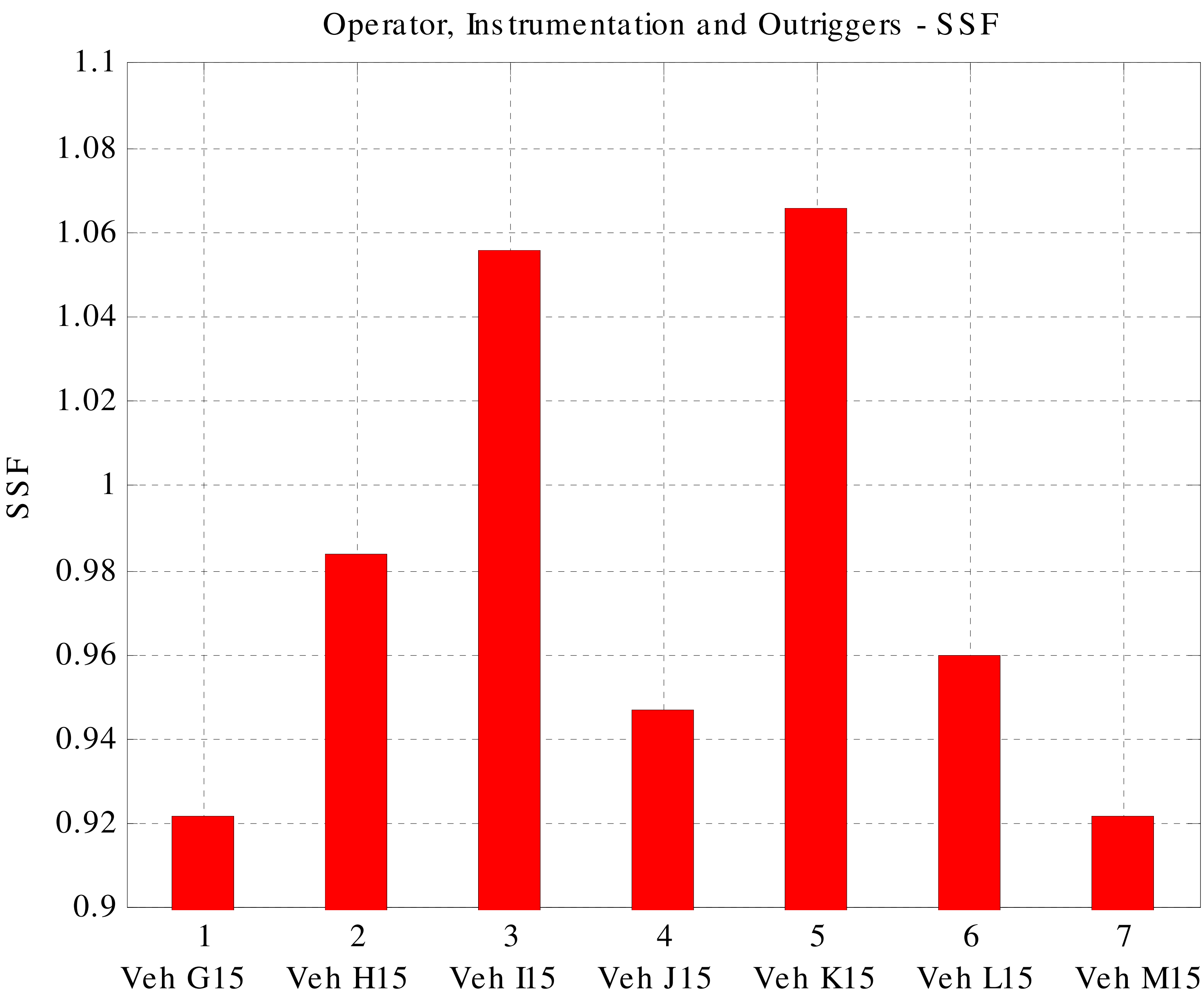

Operator, Instrumentation and Outriggers - CG Height
CG Height (in)
28
27
26
25
24
23
22
1
Veh A15
2
Veh B15
3
Veh C15
4
Veh D15
5
Veh E15
6
Veh F15

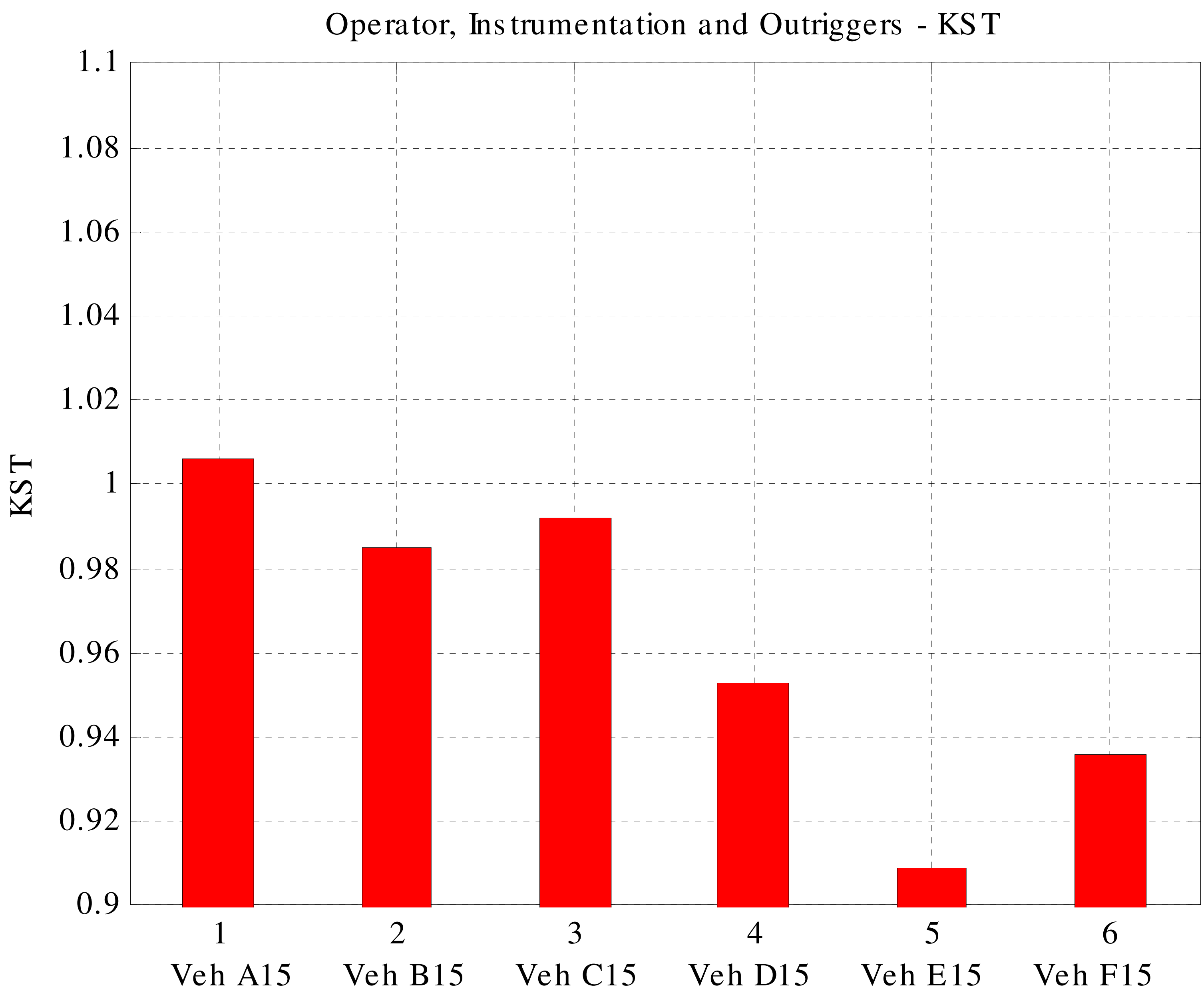

Operator, Instrumentation and Outriggers - CG Height
CG Height (in)
28
27
26
25
24
23
22
1
2
3
4
5
6
7
Veh G15
Veh H15
Veh I15
Veh J15
Veh K15
Veh L15
Veh M15

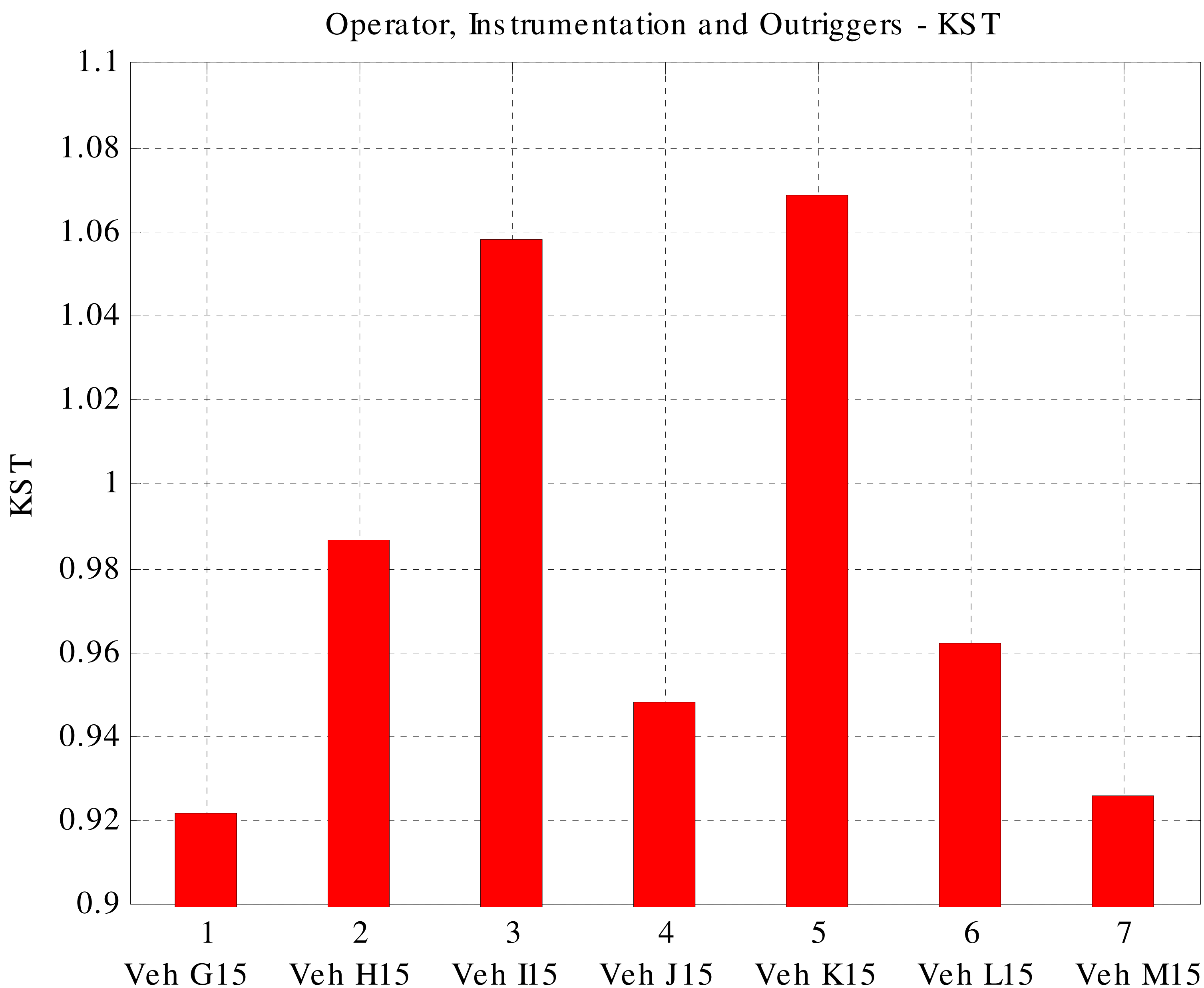

Operator, Instrumentation and Outriggers - Average Track Width
Track (in)
56
54
52
50
48
46
44
42
40
1
2
3
4
5
6
Veh A15
Veh B15
Veh C15
Veh D15
Veh E15
Veh F15

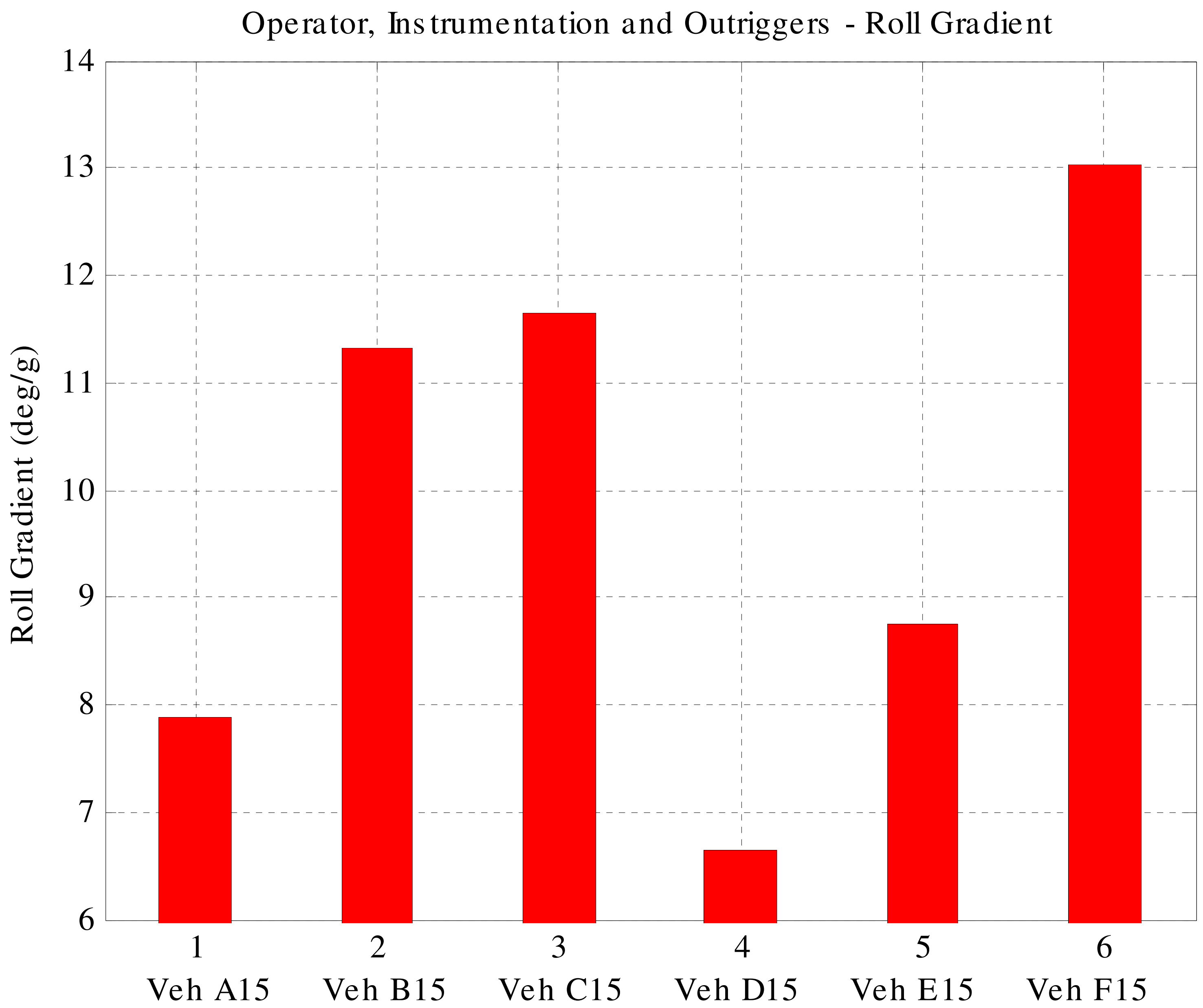

Operator, Instrumentation and Outriggers - Average Track Width
Track (in)
56
54
52
50
48
46
44
42
40
1
Veh G15
2
Veh H15
3
Veh I15
4
Veh J15
5
Veh K15
6
Veh L15
7
Veh M15


Operator, Instrumentation and Outriggers - SSF
SSF
1.1
1.08
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
1
Veh A15
2
Veh B15
3
Veh C15
4
Veh D15
5
Veh E15
6
Veh F15

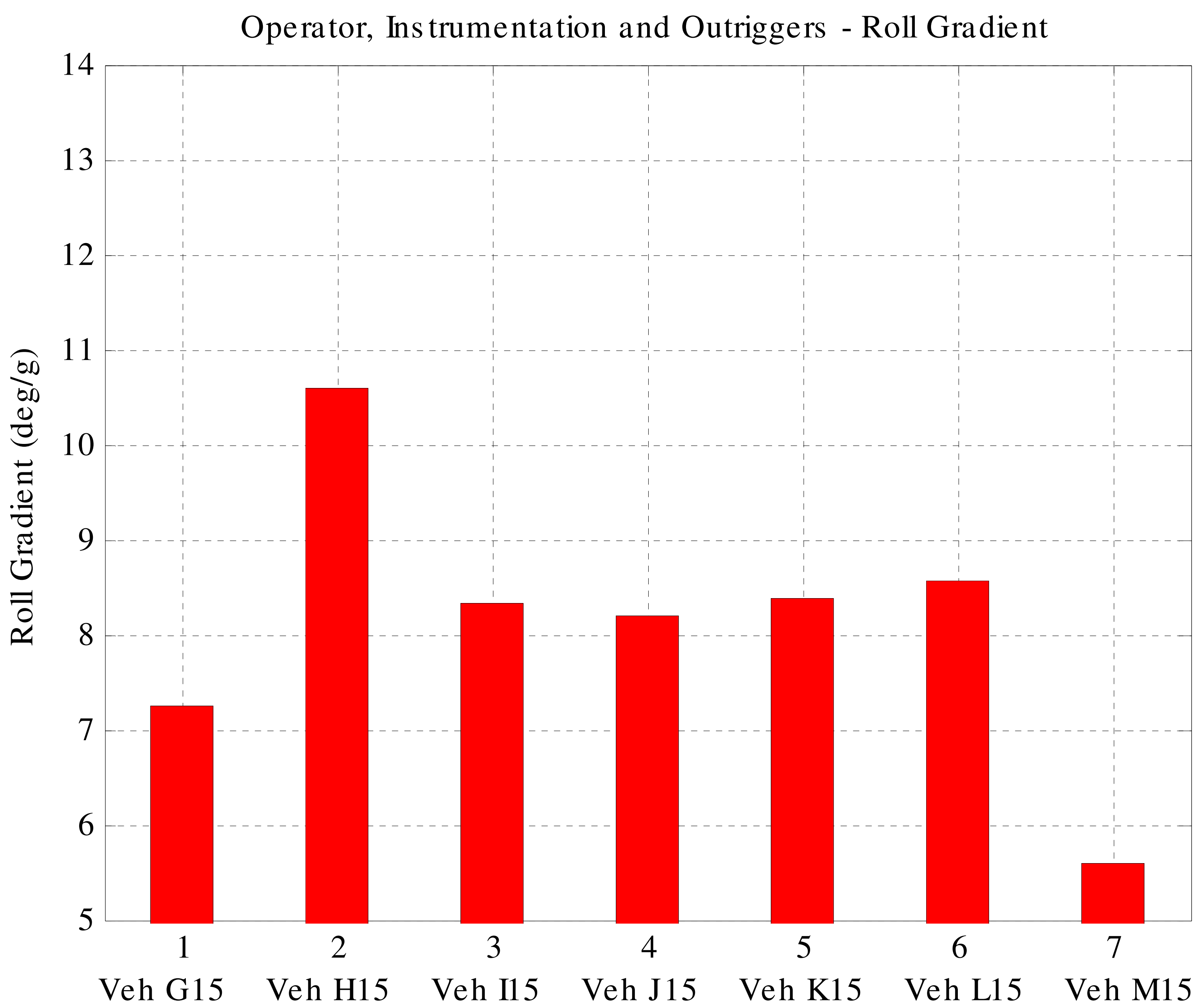

Operator, Instrumentation and Outriggers - SSF
SSF
1.1
1.08
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
1
2
3
4
5
6
7
Veh G15
Veh H15
Veh I15
Veh J15
Veh K15
Veh L15
Veh M15

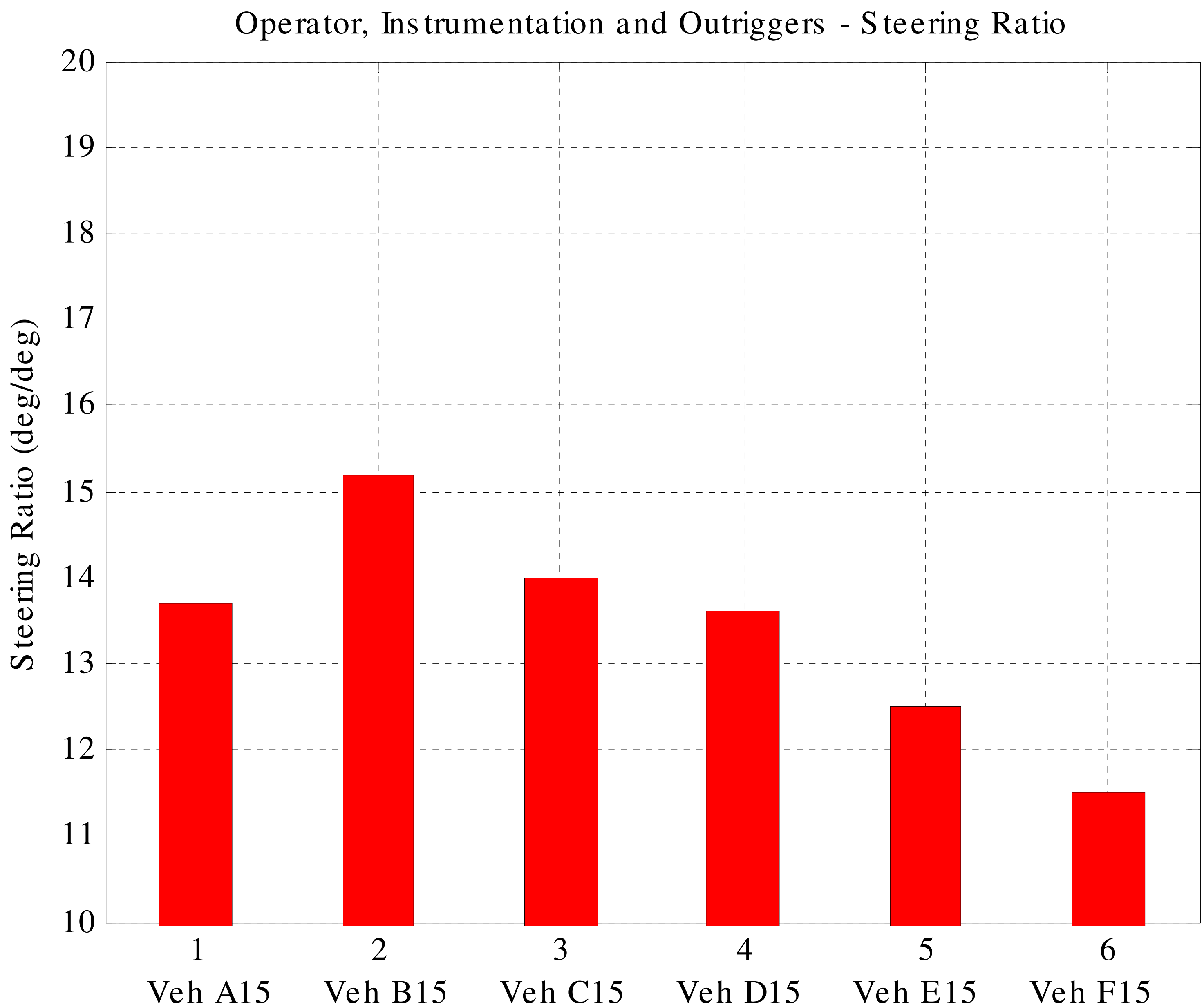

Operator, Instrumentation and Outriggers - KST
KST
1.1
1.08
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
1
Veh A15
2
Veh B15
3
Veh C15
4
Veh D15
5
Veh E15
6
Veh F15


Operator, Instrumentation and Outriggers - KST
KST
1.1
1.08
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
1
Veh G15
2
Veh H15
3
Veh I15
4
Veh J15
5
Veh K15
6
Veh L15
7
Veh M15

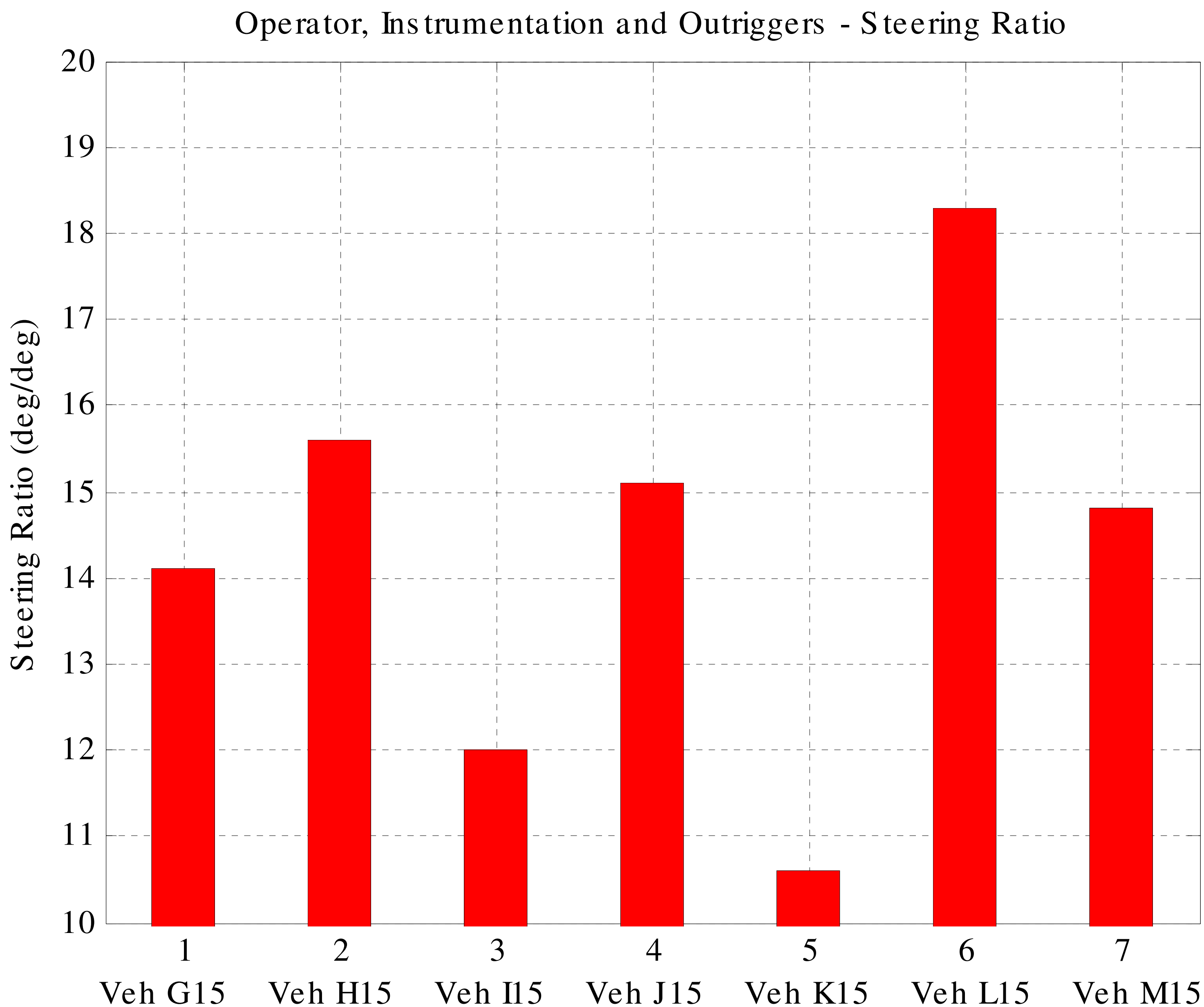


Operator, Instrumentation and Outriggers - Roll Gradient
Roll Gradient (deg/g)
14
13
12
11
10
9
8
7
6
1
Veh A15
2
Veh B15
3
Veh C15
4
Veh D15
5
Veh E15
6
Veh F15

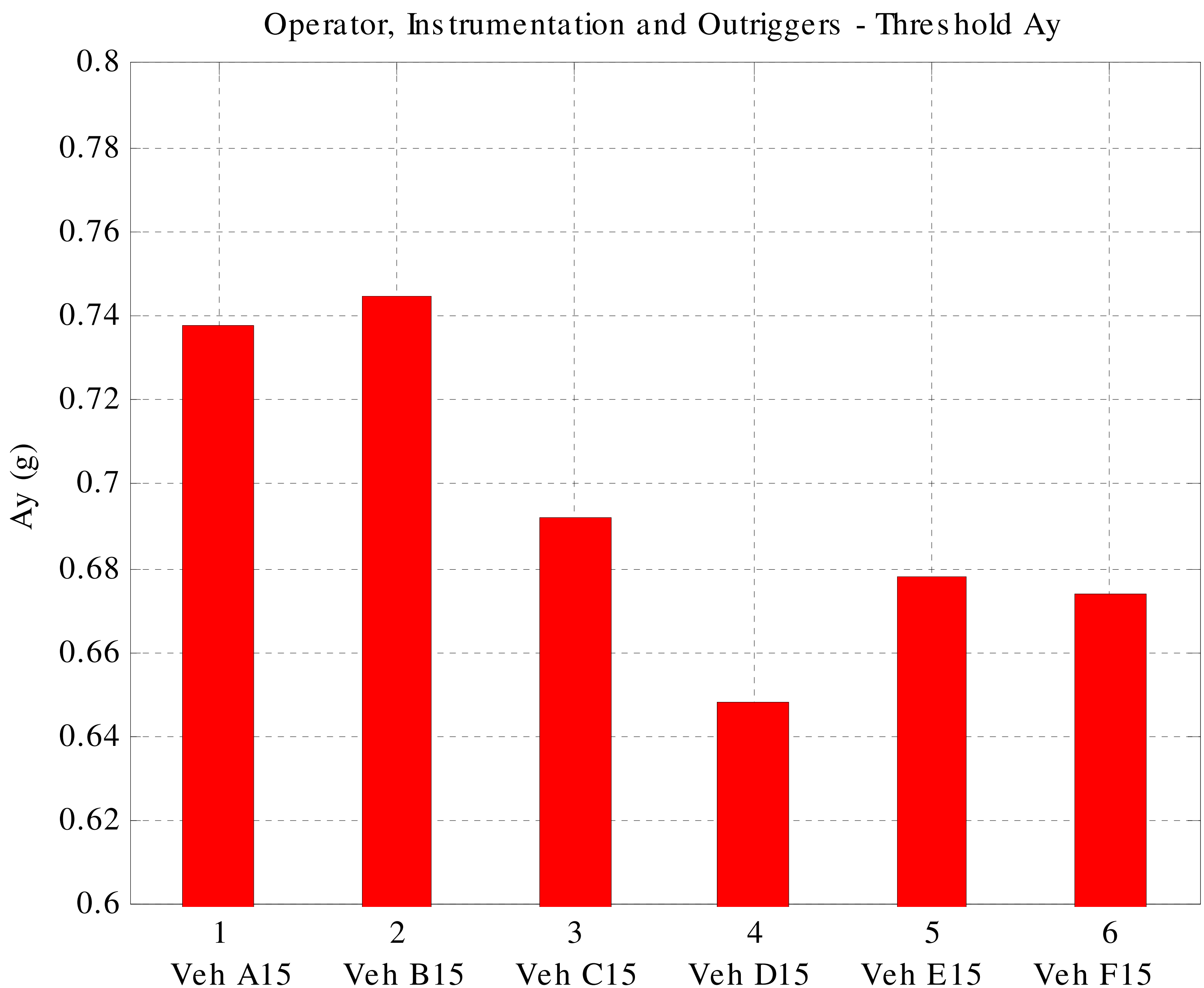

Operator, Instrumentation and Outriggers - Roll Gradient
Roll Gradient (deg/g)
14
13
12
11
10
9
8
7
6
5
1
2
3
4
5
6
7
Veh G15
Veh H15
Veh I15
Veh J15
Veh K15
Veh L15
Veh M15

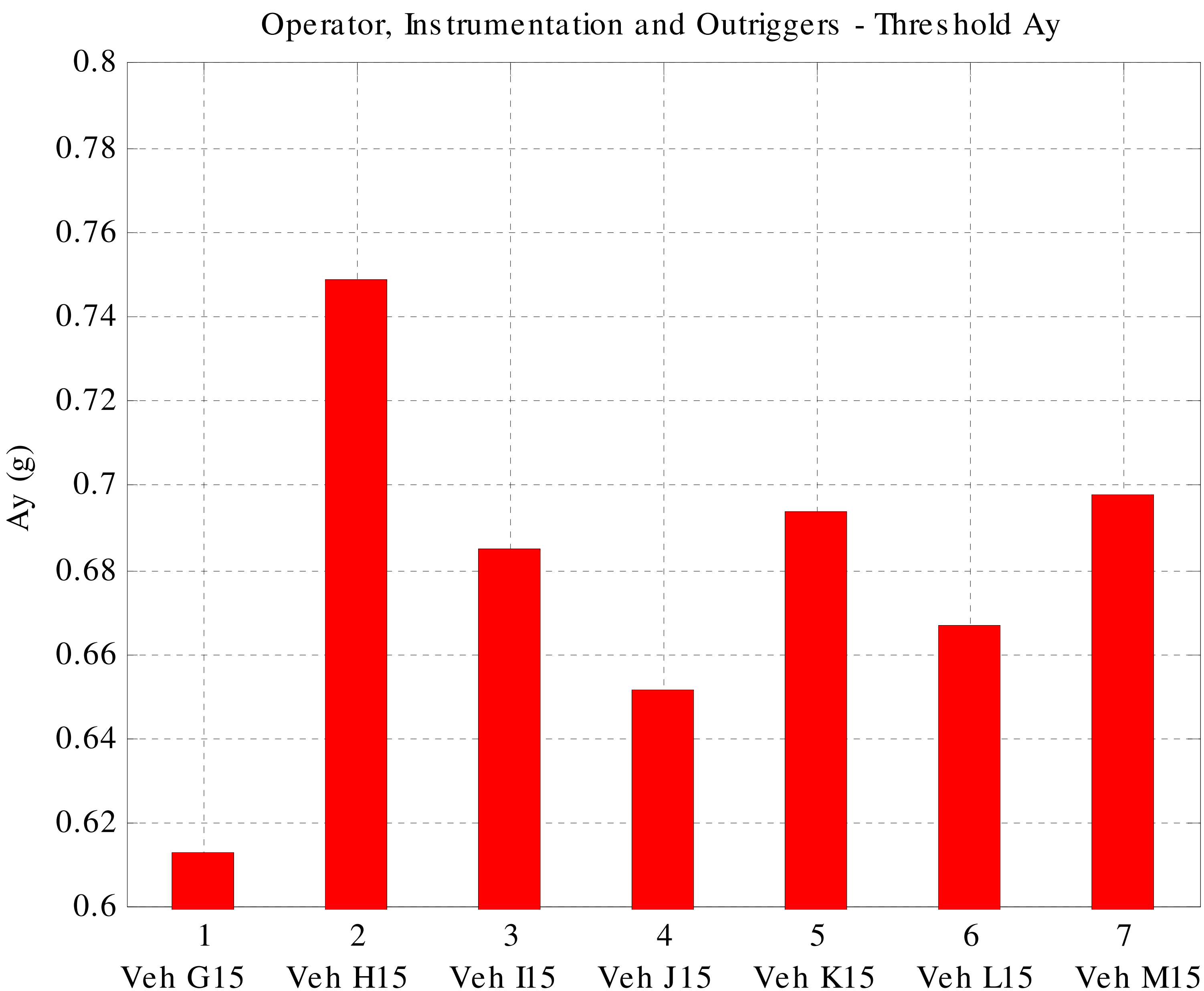


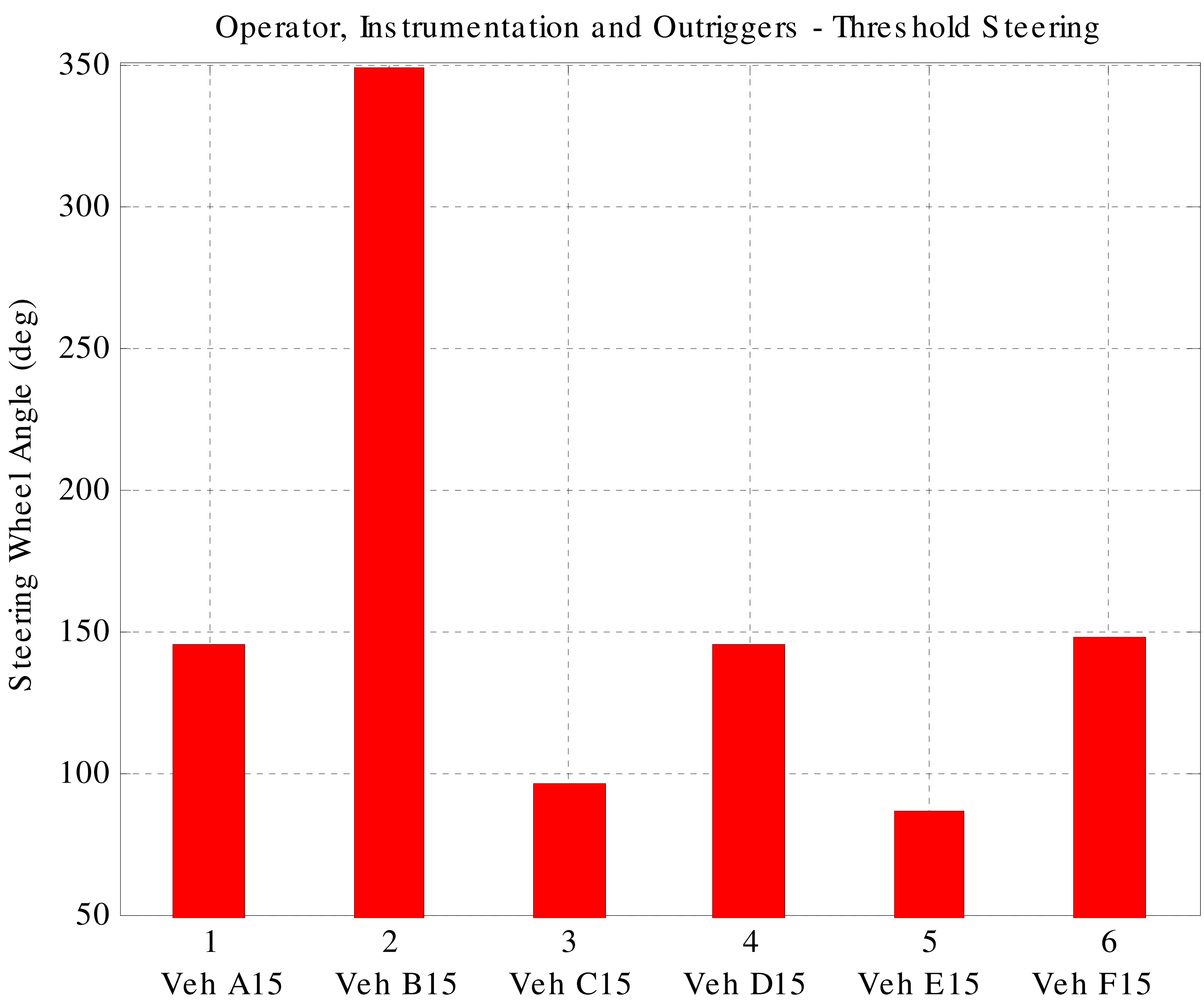
Operator, Instrumentation and Outriggers - Steering Ratio
Steering Ratio (deg/deg)
20
19
18
17
16
15
14
13
12
11
10
1
Veh A15
2
Veh B15
3
Veh C15
4
Veh D15
5
Veh E15
6
Veh F15

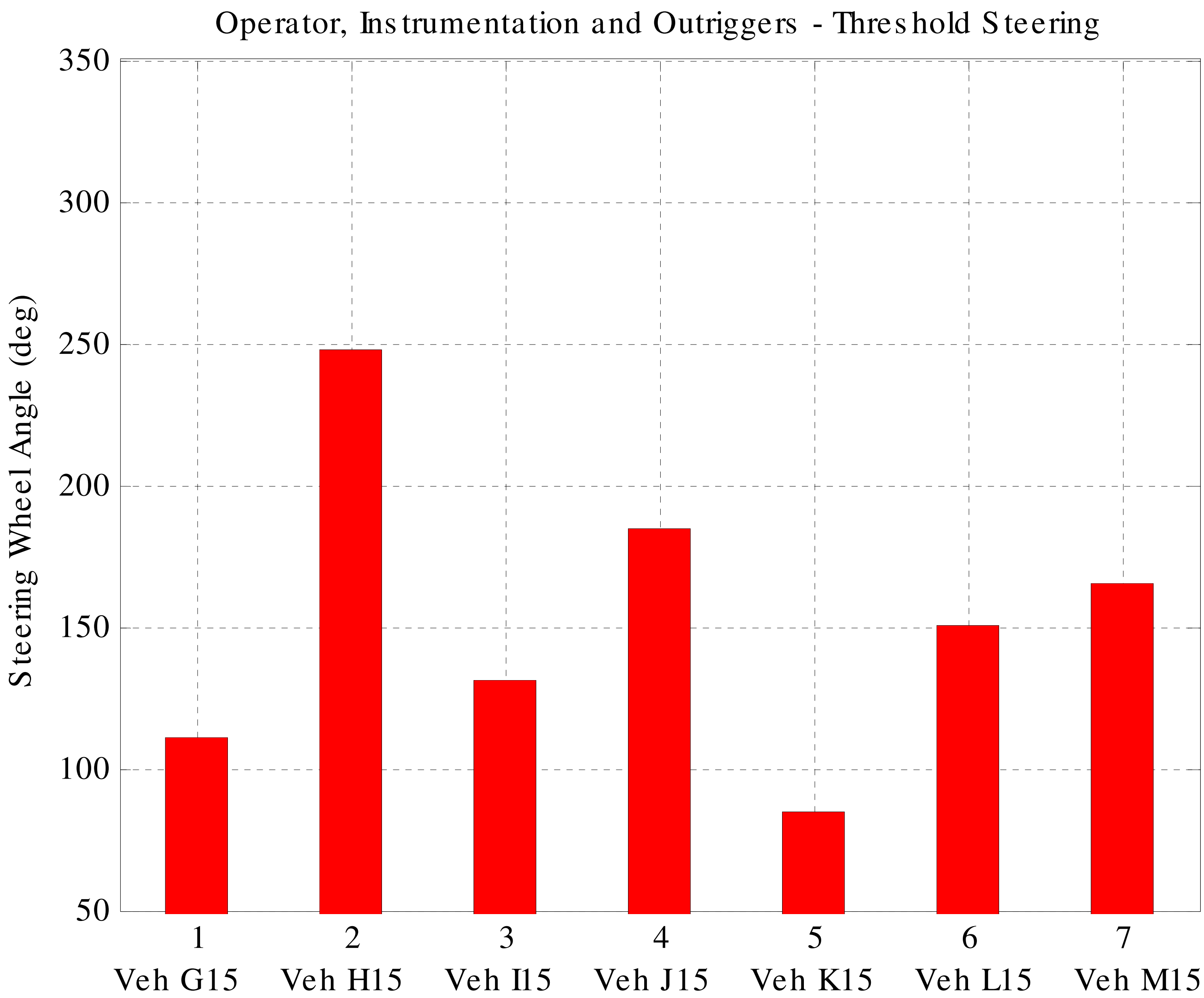


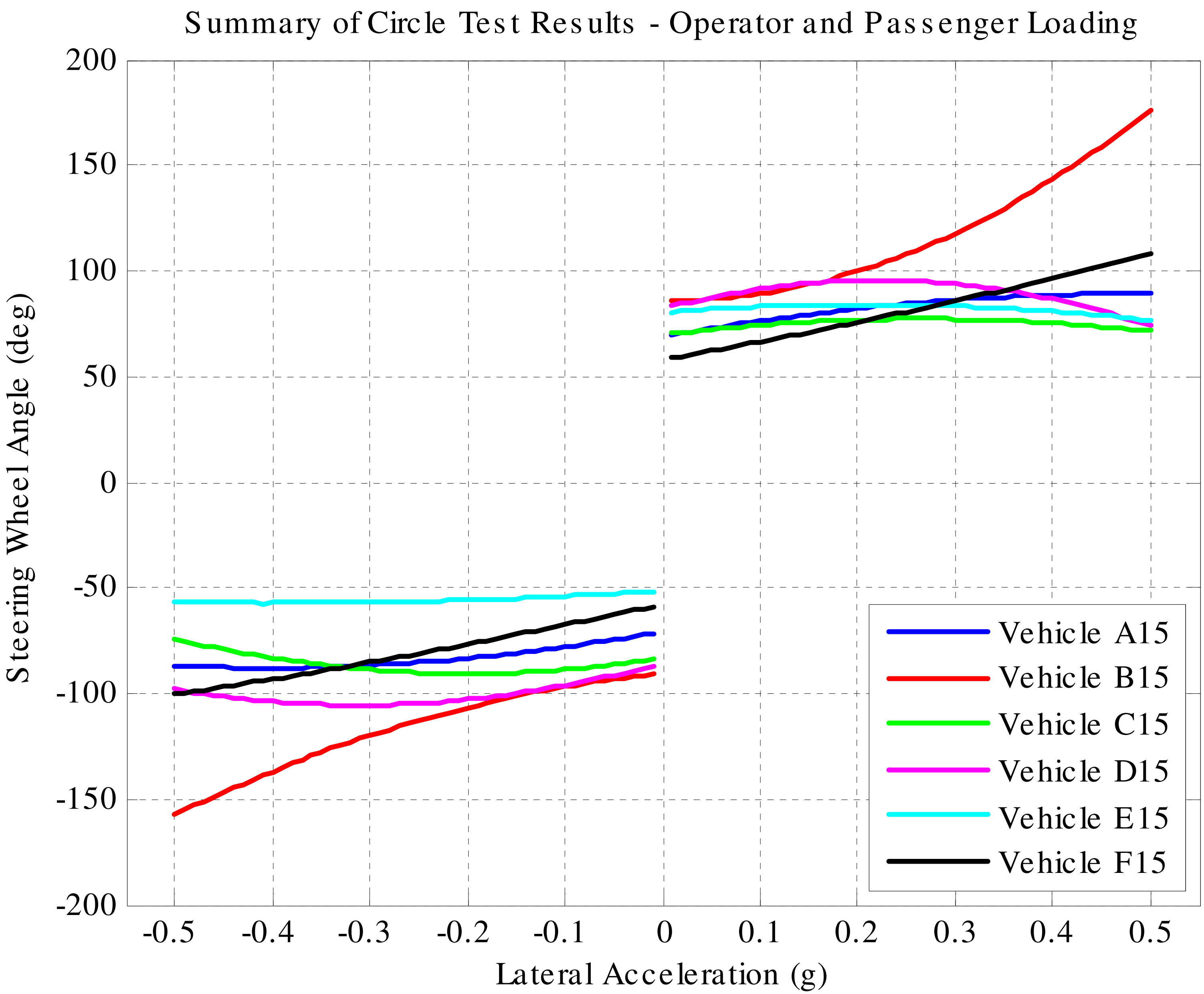
Operator, Instrumentation and Outriggers - Steering Ratio
Steering Ratio (deg/deg)
20
19
18
17
16
15
14
13
12
11
10
1
Veh G15
2
Veh H15
3
Veh I15
4
Veh J15
5
Veh K15
6
Veh L15
7
Veh M15

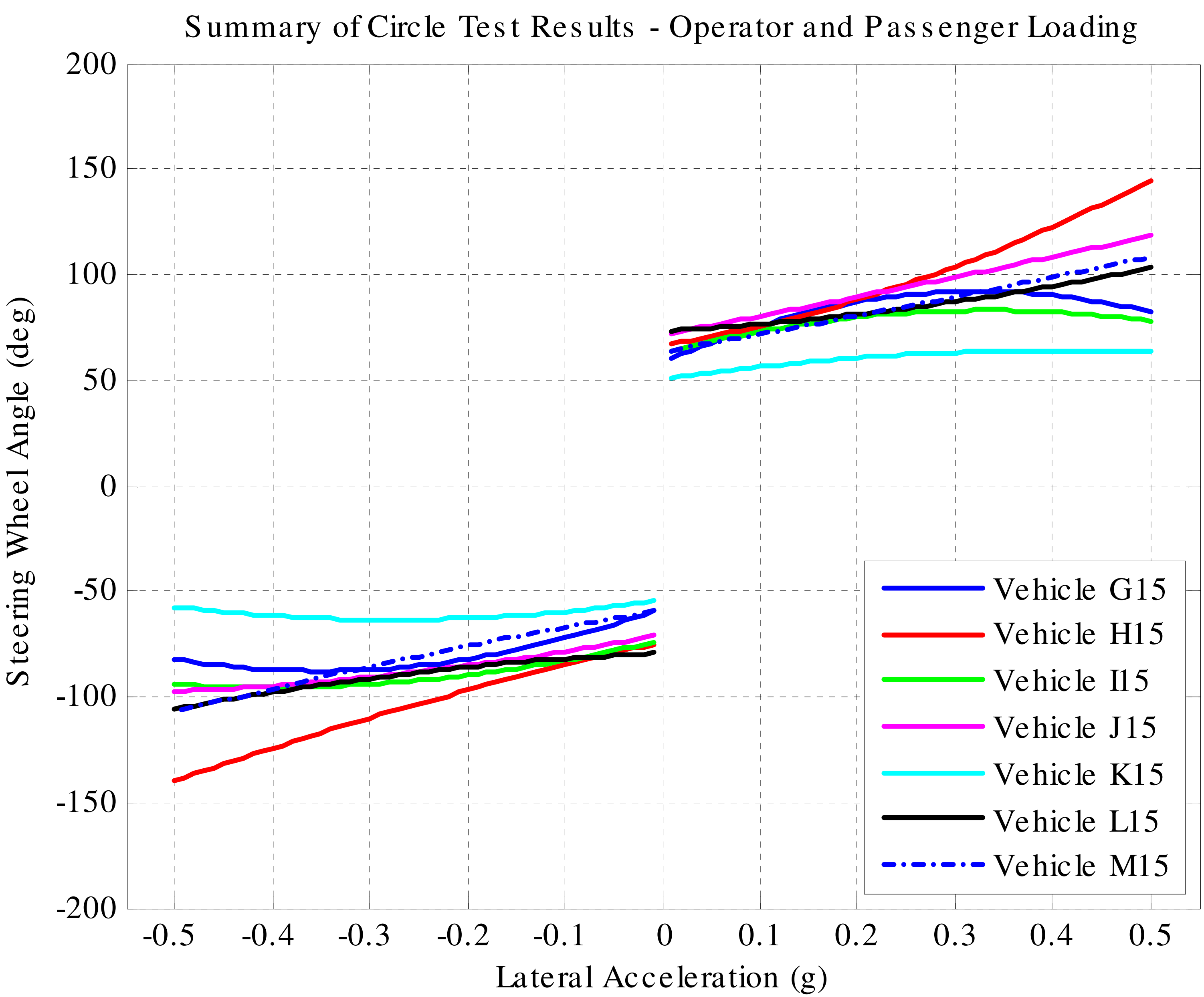

Operator, Instrumentation and Outriggers - Threshold Ay
0.8
0.78
0.76
0.74
0.72
0.7
0.68
0.66
0.64
0.62
0.6
Ay (g)
1
Veh A15
2
Veh B15
3
Veh C15
4
Veh D15
5
Veh E15
6
Veh F15

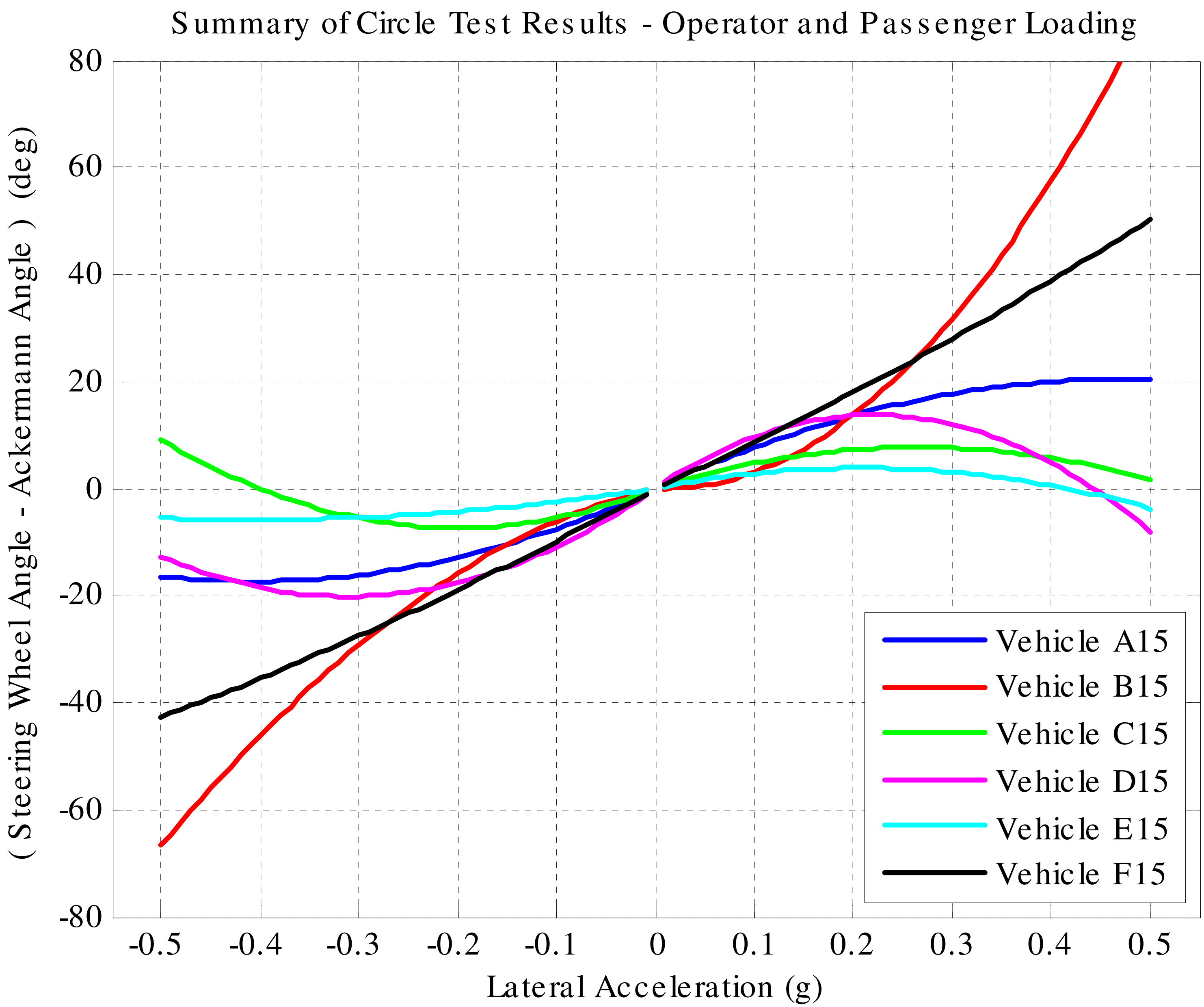

Operator, Instrumentation and Outriggers - Threshold Ay
Ay (g)
0.8
0.78
0.76
0.74
0.72
0.7
0.68
0.66
0.64
0.62
0.6
1
Veh G15
2
Veh H15
3
Veh I15
4
Veh J15
5
Veh K15
6
Veh L15
7
Veh M15

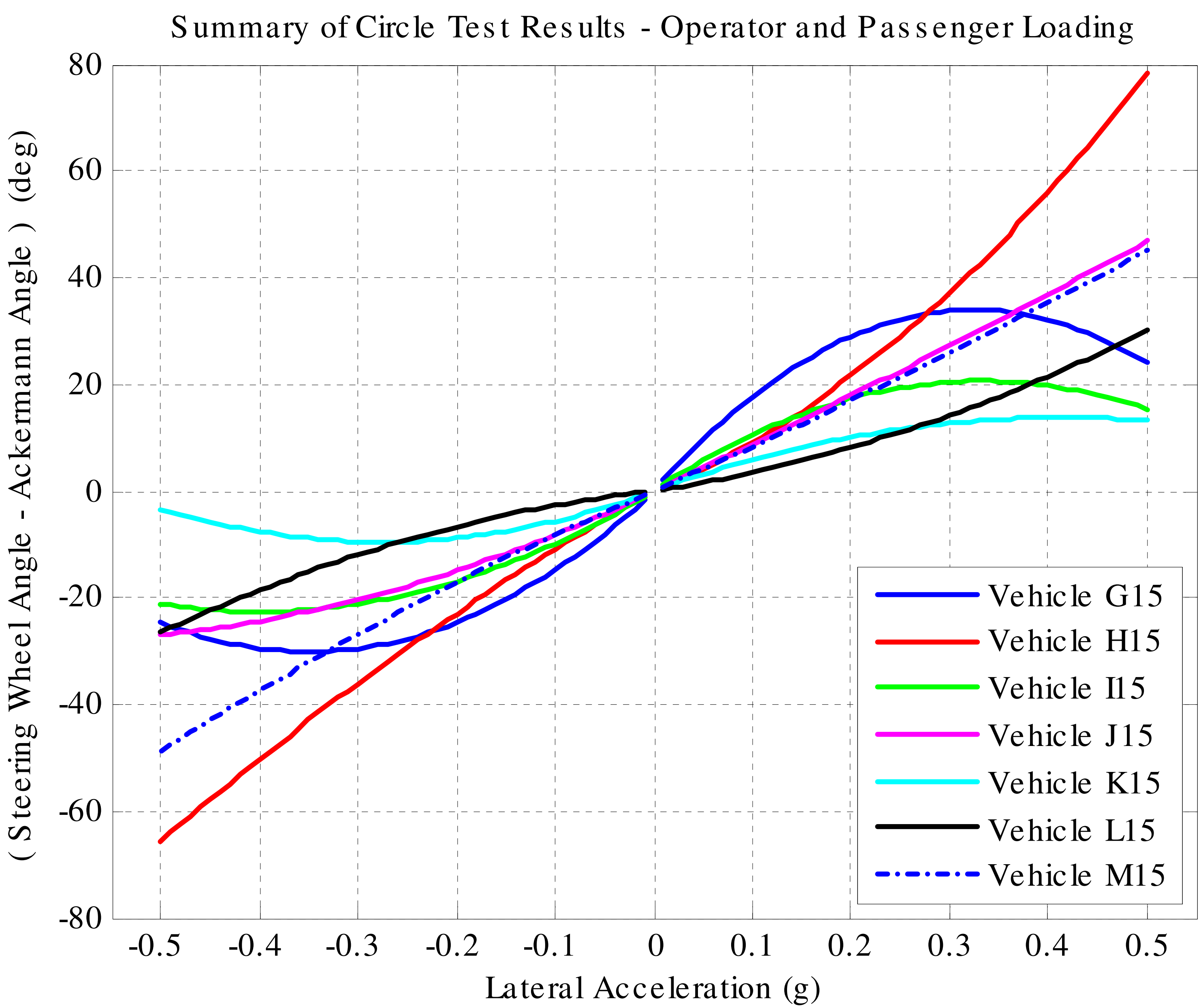

Operator, Instrumentation and Outriggers - Threshold Steering
Steering Wheel Angle (deg)
350
300
250
200
150
100
50
1
2
3
4
5
6
Veh A15
Veh B15
Veh C15
Veh D15
Veh E15
Veh F15

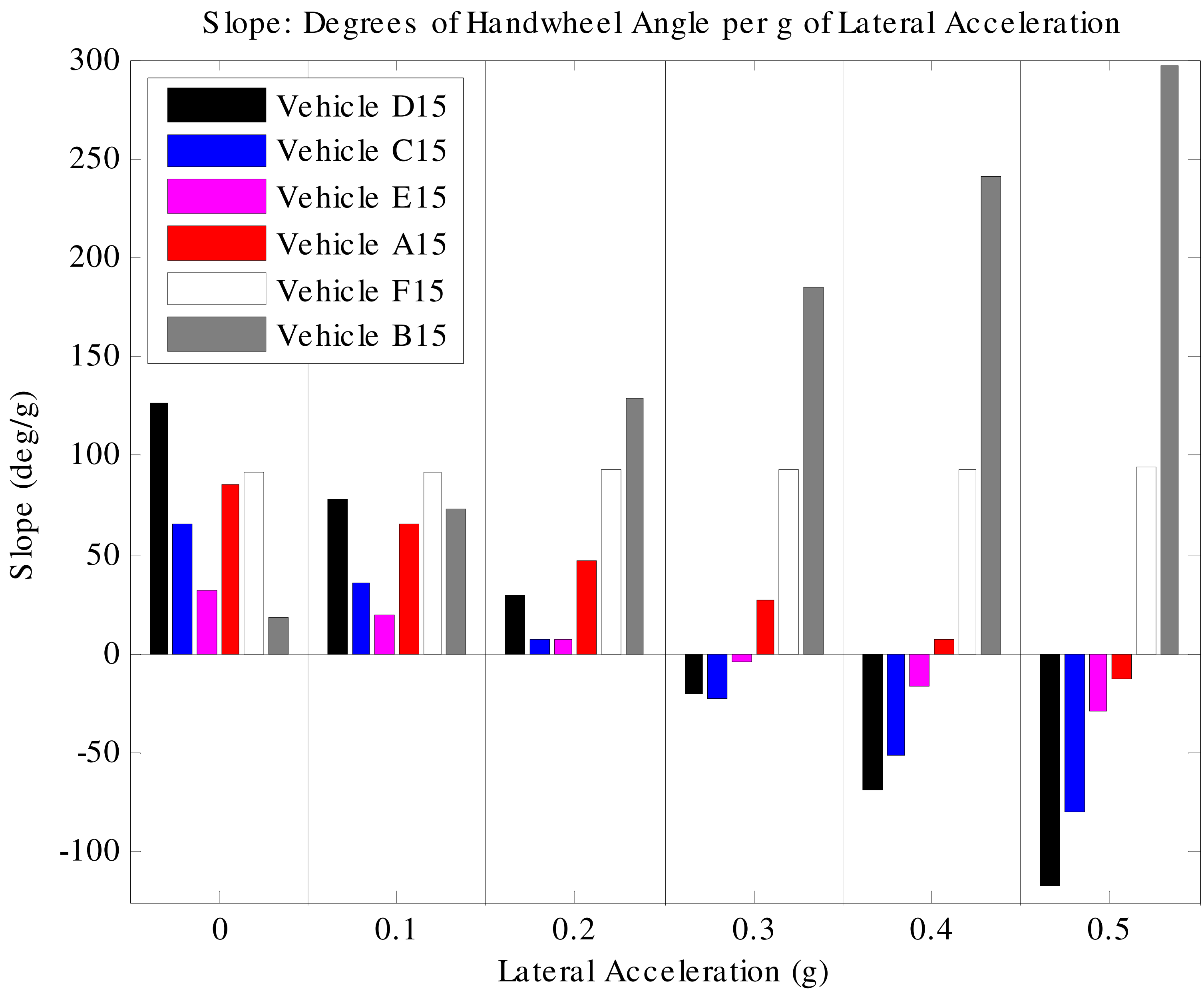

Operator, Instrumentation and Outriggers - Threshold Steering
Steering Wheel Angle (deg)
350
300
250
200
150
100
50
1
Veh G15
2
Veh H15
3
Veh I15
4
Veh J15
5
Veh K15
6
Veh L15
7
Veh M15

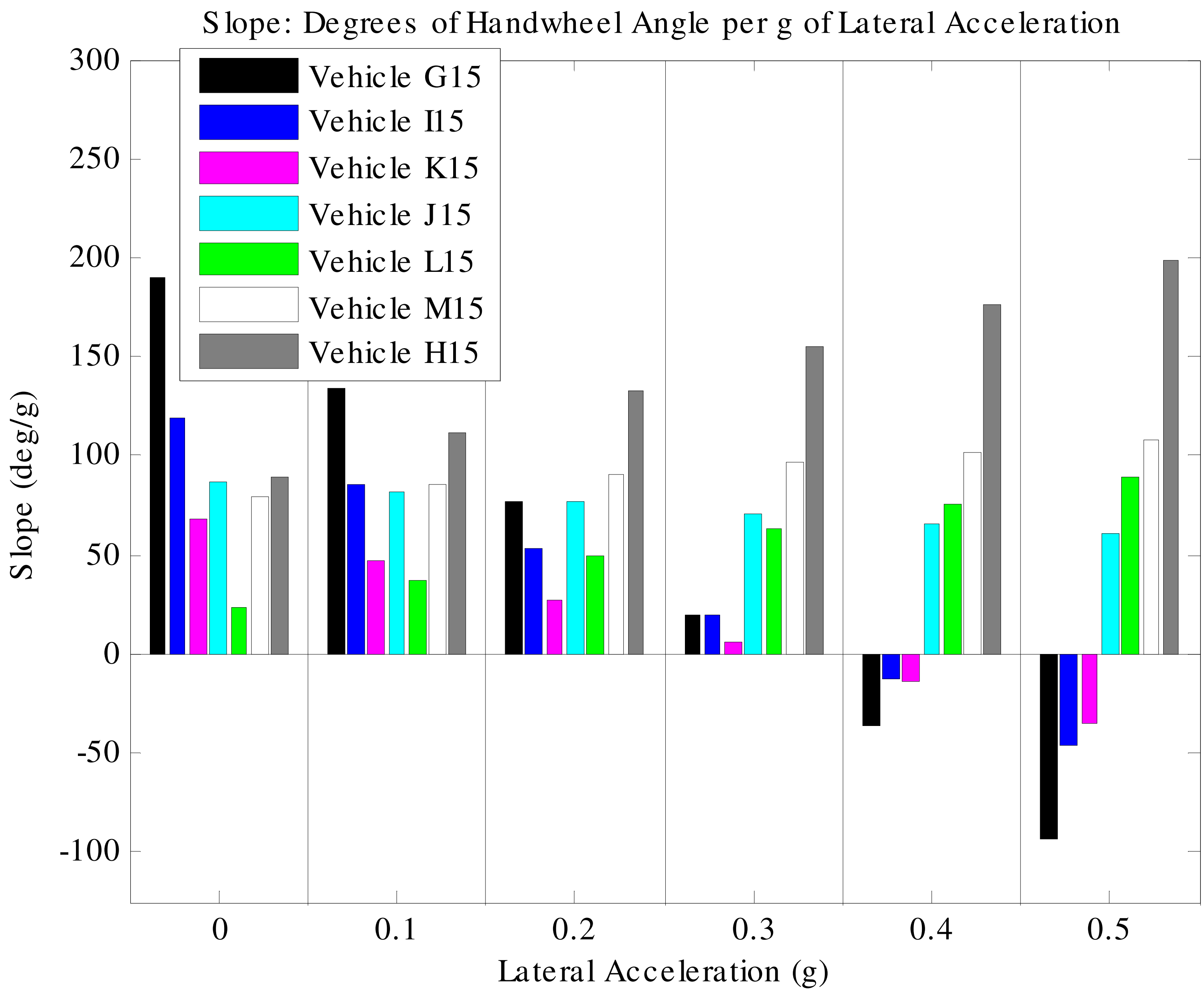

Summary of Circle Test Results - Operator and Passenger Loading
Steering Wheel Angle (deg)
200
150
100
50
0
-50
-100
-150
-200
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle A15
Vehicle B15
Vehicle C15
Vehicle D15
Vehicle E15
Vehicle F15

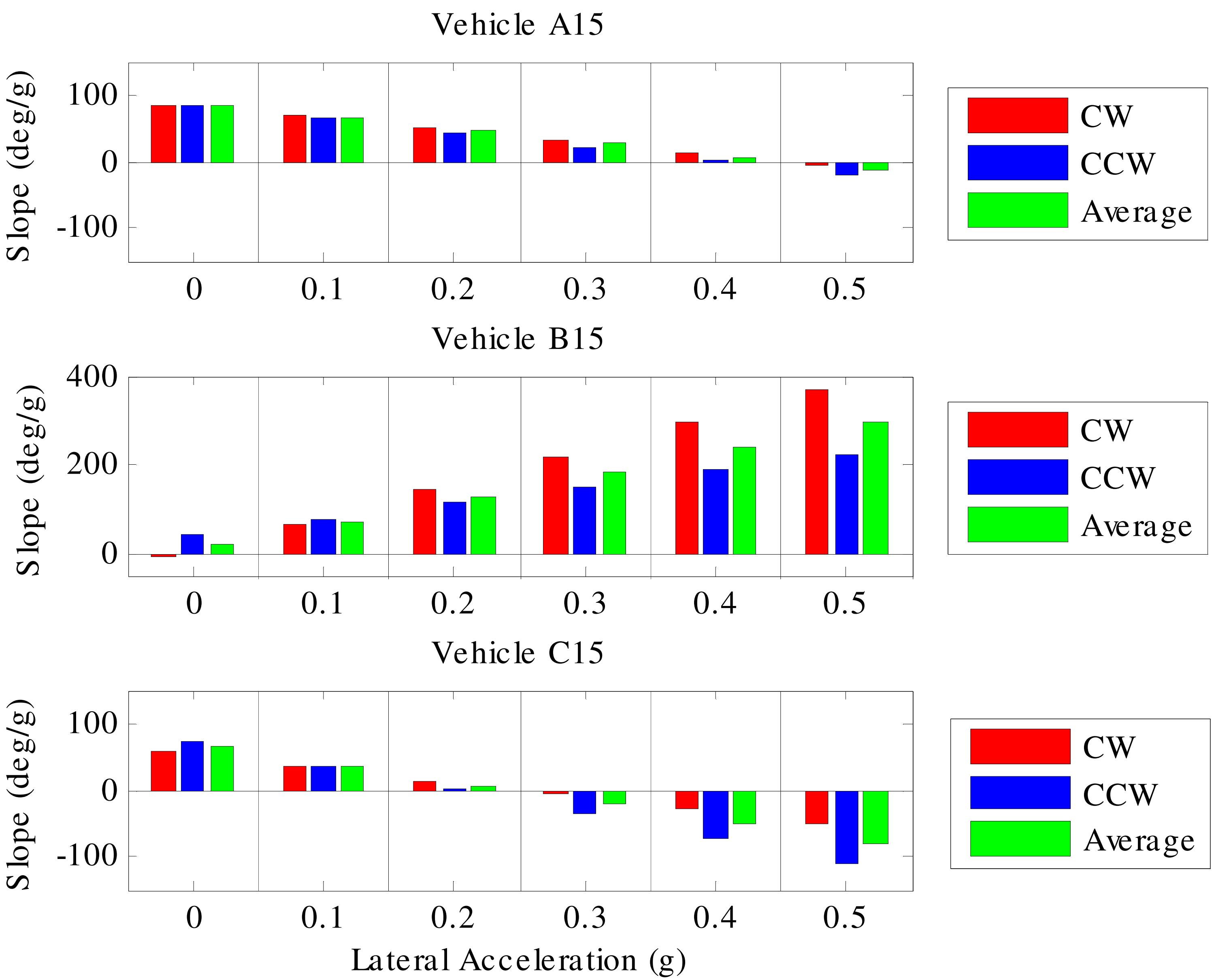

Summary of Circle Test Results - Operator and Passenger Loading
200
150
100
50
0
-50
-100
-150
-200
Steering Wheel Angle (deg)
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle G15
Vehicle H15
Vehicle I15
Vehicle J15
Vehicle K15
Vehicle L15
Vehicle M15

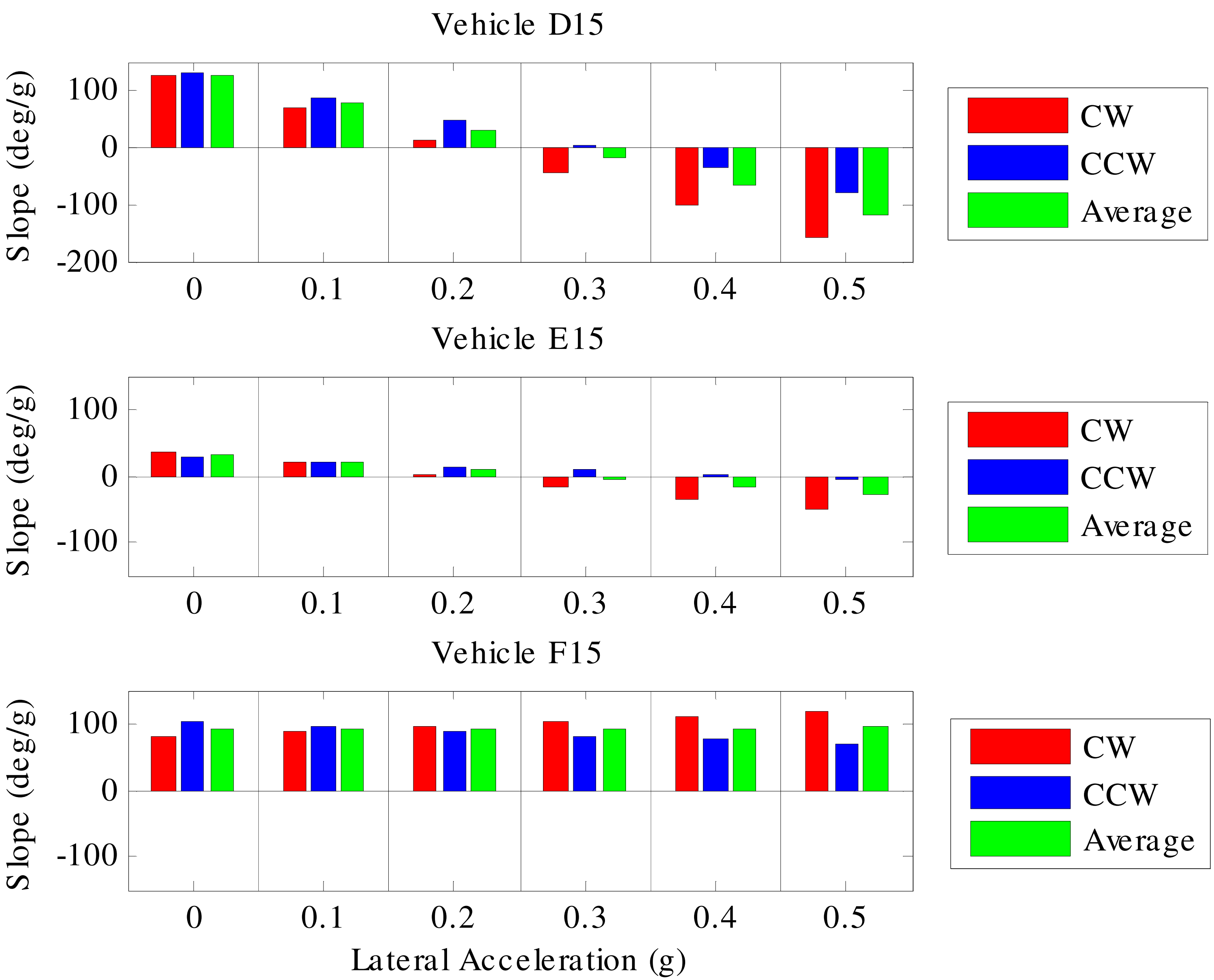

Summary of Circle Test Results - Operator and Passenger Loading
(Steering Wheel Angle - Ackermann Angle) (deg)
Lateral Acceleration (g)
80
60
40
20
0
-20
-40
-60
-80
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Vehicle A15
Vehicle B15
Vehicle C15
Vehicle D15
Vehicle E15
Vehicle F15

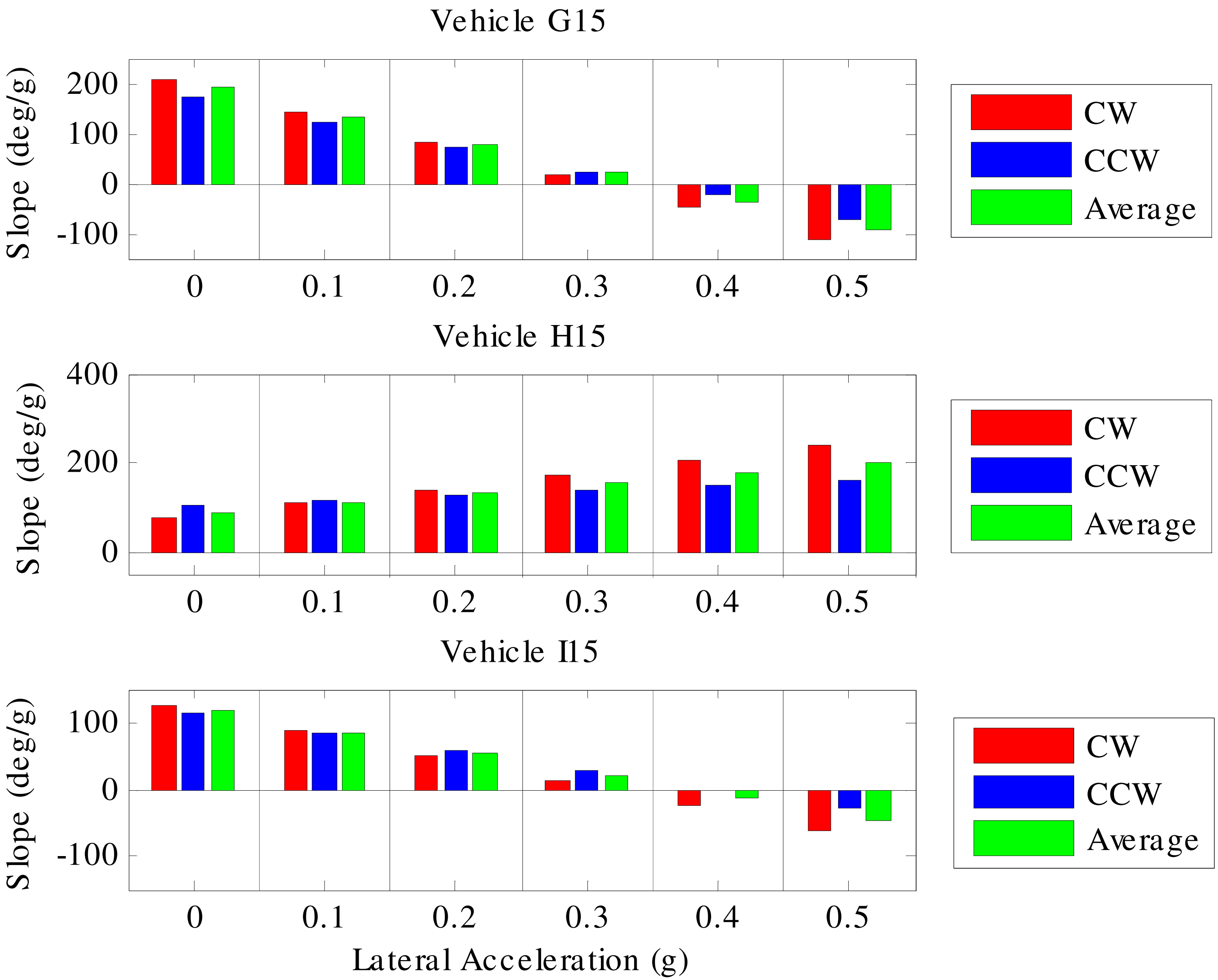

Summary of Circle Test Results - Operator and Passenger Loading
(Steering Wheel Angle - Ackermann Angle) (deg)
80
60
40
20
0
-20
-40
-60
-80
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle G15
Vehicle H15
Vehicle I15
Vehicle J15
Vehicle K15
Vehicle L15
Vehicle M15


Slope: Degrees of Handwheel Angle per g of Lateral Acceleration
Vehicle D15
Vehicle C15
Vehicle E15
Vehicle A15
Vehicle F15
Vehicle B15
Slope (deg/g)
300
250
200
150
100
50
0
-50
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)

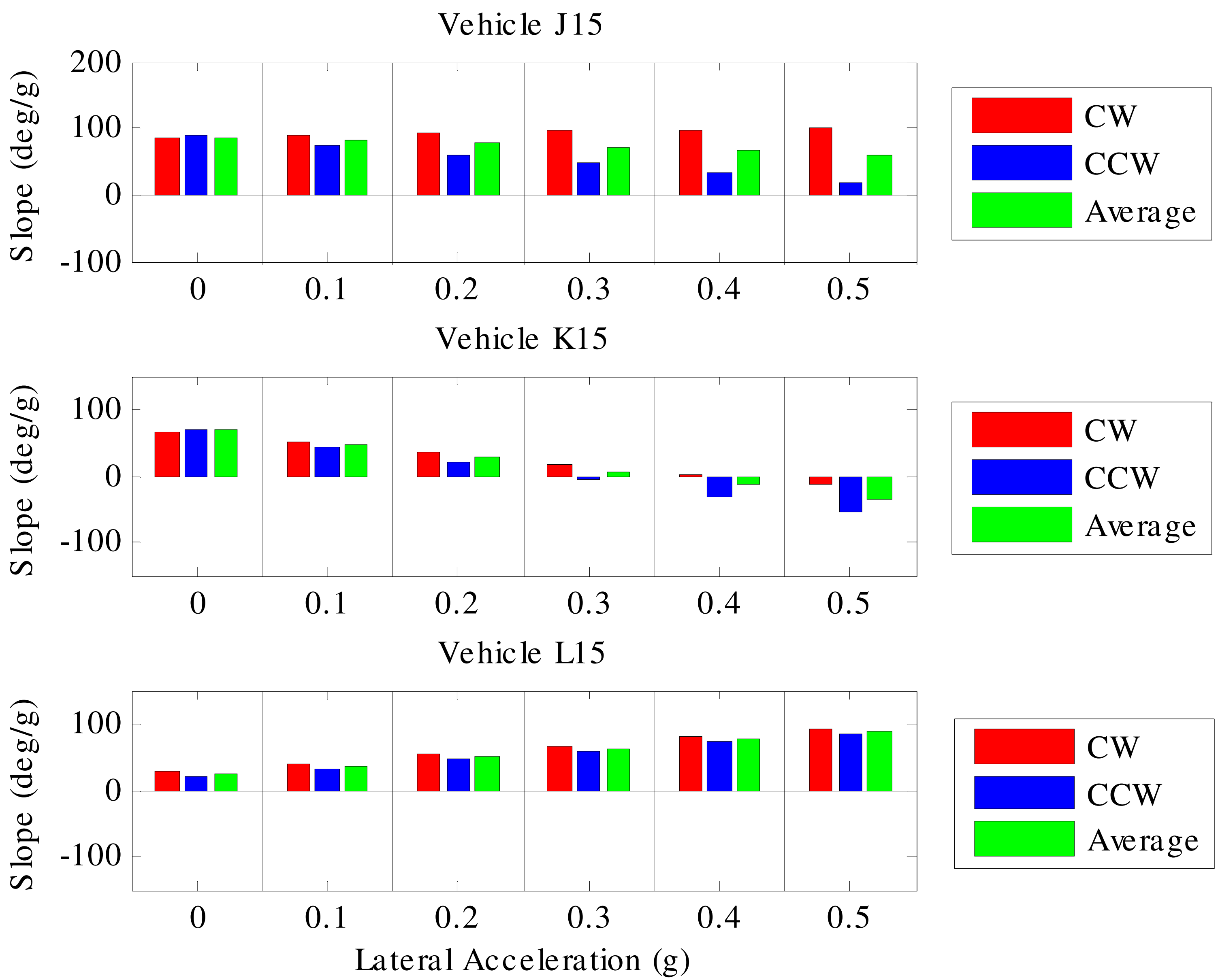

Slope: Degrees of Handwheel Angle per g of Lateral Acceleration
Vehicle G15
Vehicle I15
Vehicle K15
Vehicle J15
Vehicle L15
Vehicle M15
Vehicle H15
Slope (deg/g)
300
250
200
150
100
50
0
-50
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)

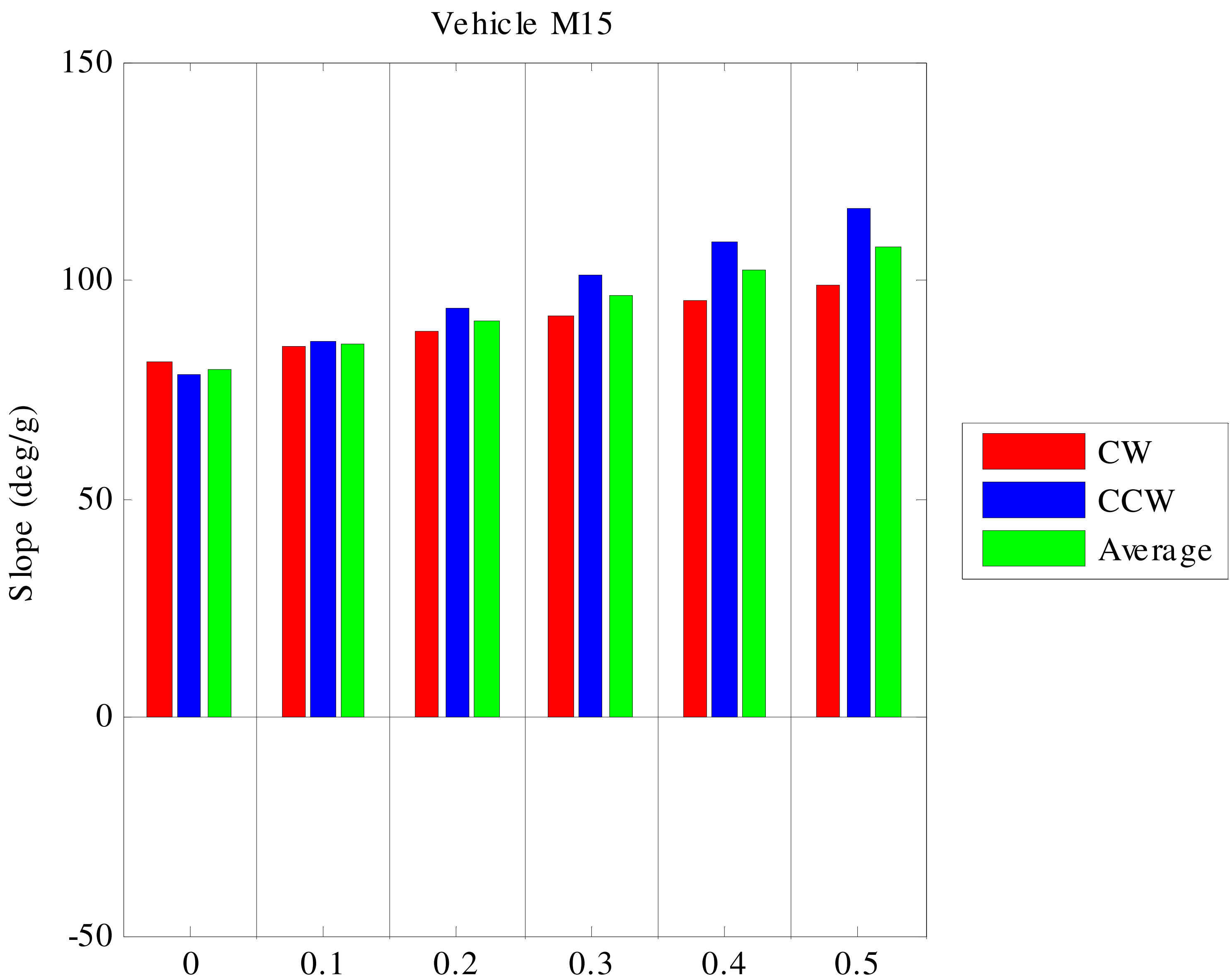

Vehicle A15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle B15
Slope (deg/g)
400
200
0
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle C15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)


Vehicle D15
Slope (deg/g)
100
0
-100
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle E15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle F15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)



Vehicle G15
Slope (deg/g)
200
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle H15
Slope (deg/g)
400
200
0
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle I15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)

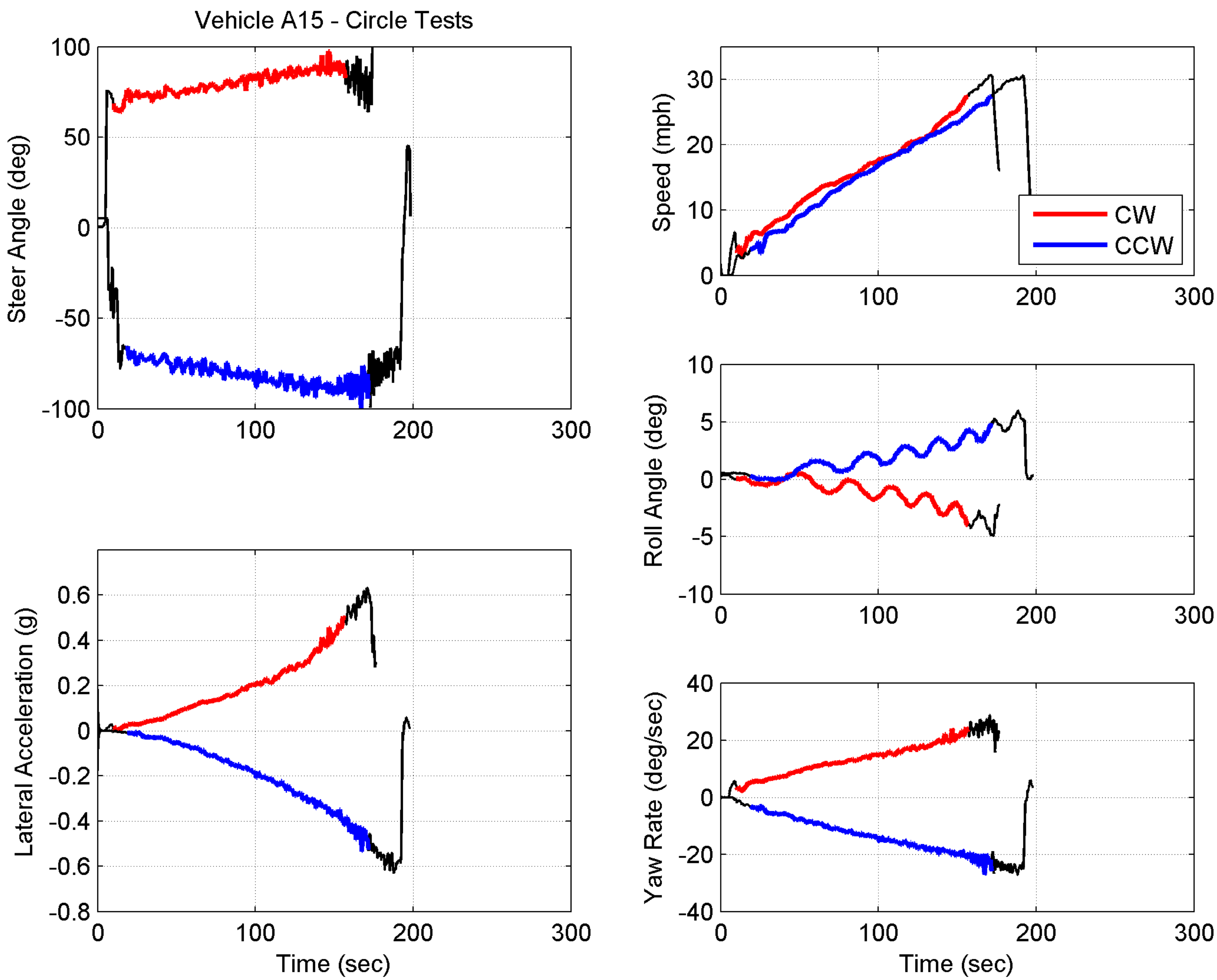

Vehicle J15
Vehicle K15
Vehicle L15
Slope (deg/g)
200
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

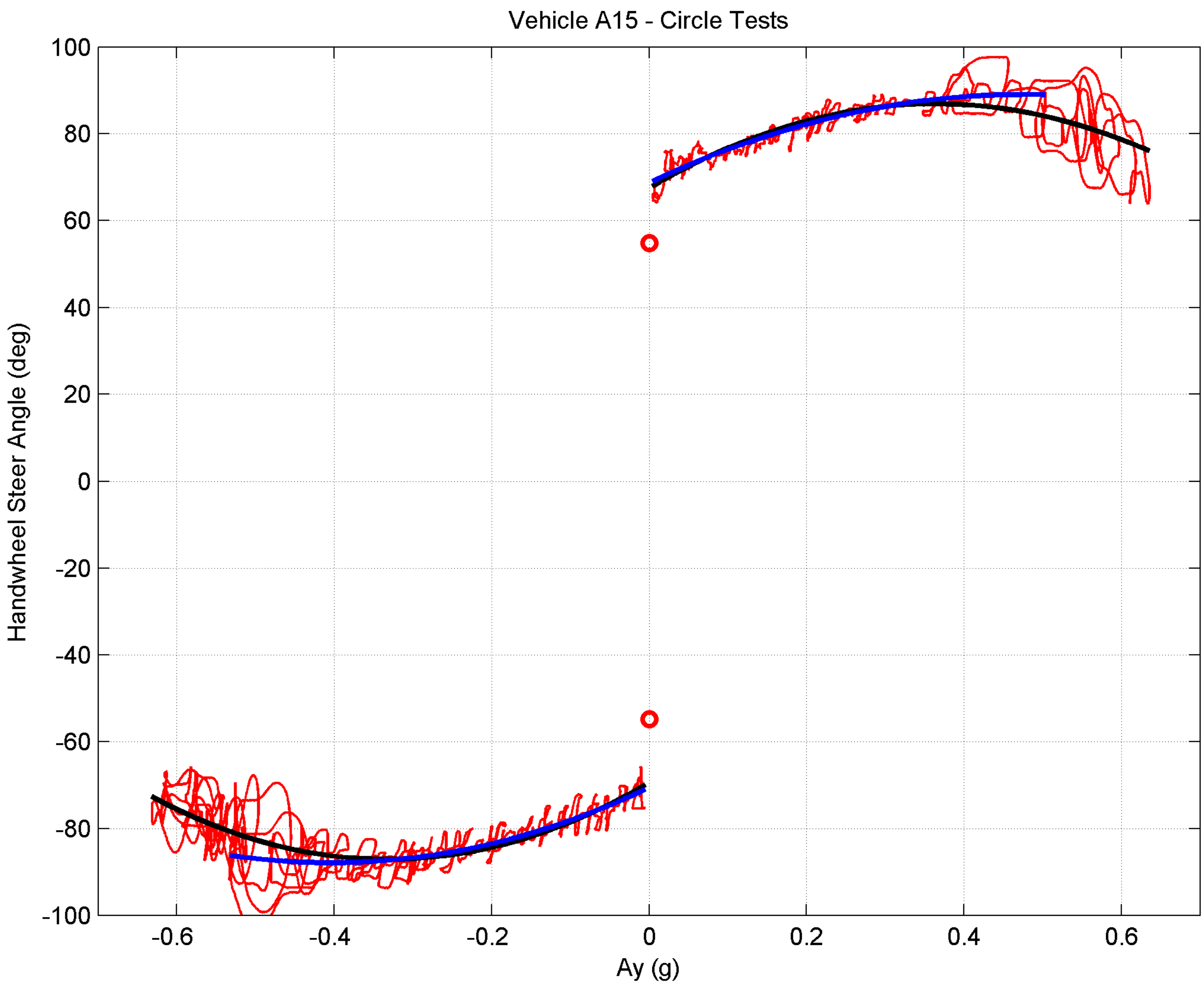

Vehicle M15
150
100
50
0
-50
Slope (deg/g)
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average

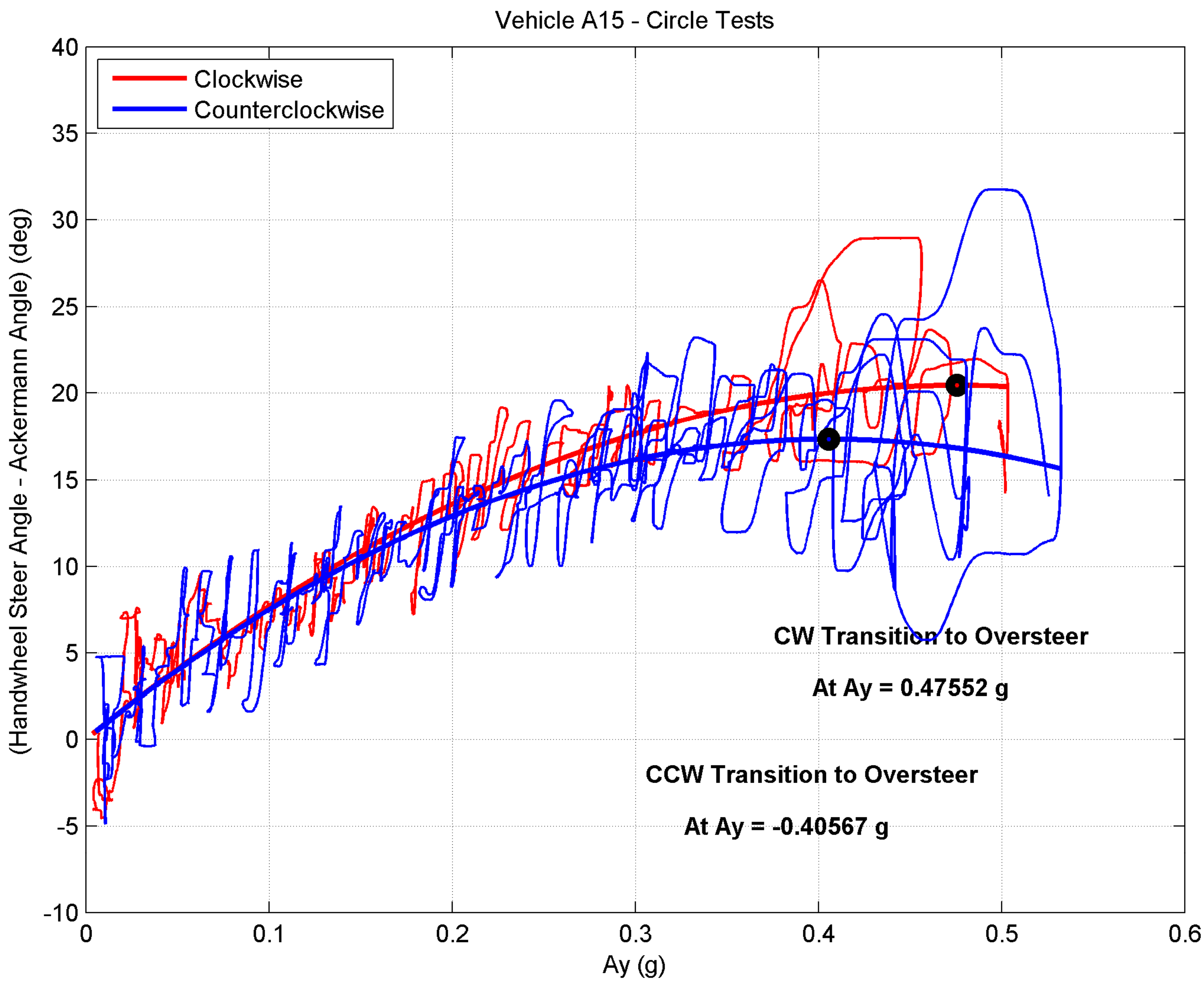
Constant Radius (100 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Operator and Passenger Loading)			
	CW (g)	CCW (g)	Average (g)
Vehicle A15	0.48	0.41	0.44
Vehicle B15	NA	NA	NA
Vehicle C15	0.27	0.20	0.23
Vehicle D15	0.22	0.31	0.27
Vehicle E15	0.21	0.41	0.31
Vehicle F15	NA	NA	NA
Vehicle G15	0.32	0.35	0.34
Vehicle H15	NA	NA	NA
Vehicle I15	0.33	0.40	0.37
Vehicle J15	NA	NA	NA
Vehicle K15	0.41	0.28	0.35
Vehicle L15	NA	NA	NA
Vehicle M15	NA	NA	NA

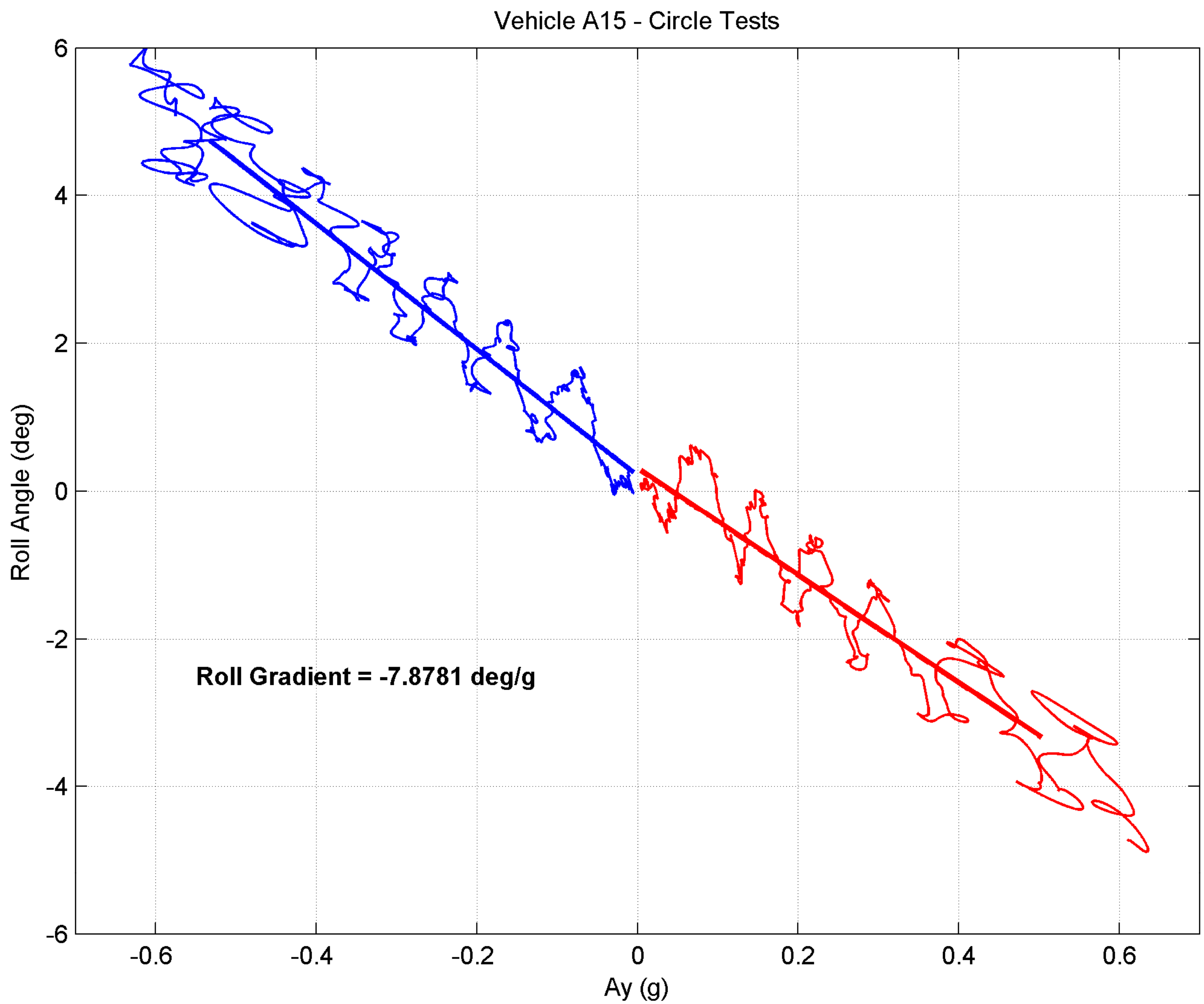
Constant Speed (30 mph) Slowly Increasing Steer Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Operator and Passenger Loading)			
	Right Turn (g)	Left Turn (g)	Average (g)
Vehicle A15	0.50	NA	NA
Vehicle B15	NA	NA	NA
Vehicle C15	0.45	0.47	0.46
Vehicle D15	0.44	0.44	0.44
Vehicle E15	0.48	0.45	0.46
Vehicle F15	NA	NA	NA
Vehicle G15	0.42	0.40	0.41
Vehicle H15	NA	NA	NA
Vehicle I15	0.45	0.48	0.47
Vehicle J15	NA	NA	NA
Vehicle K15	NA	0.44	NA
Vehicle L15	NA	NA	NA
Vehicle M15	NA	NA	NA

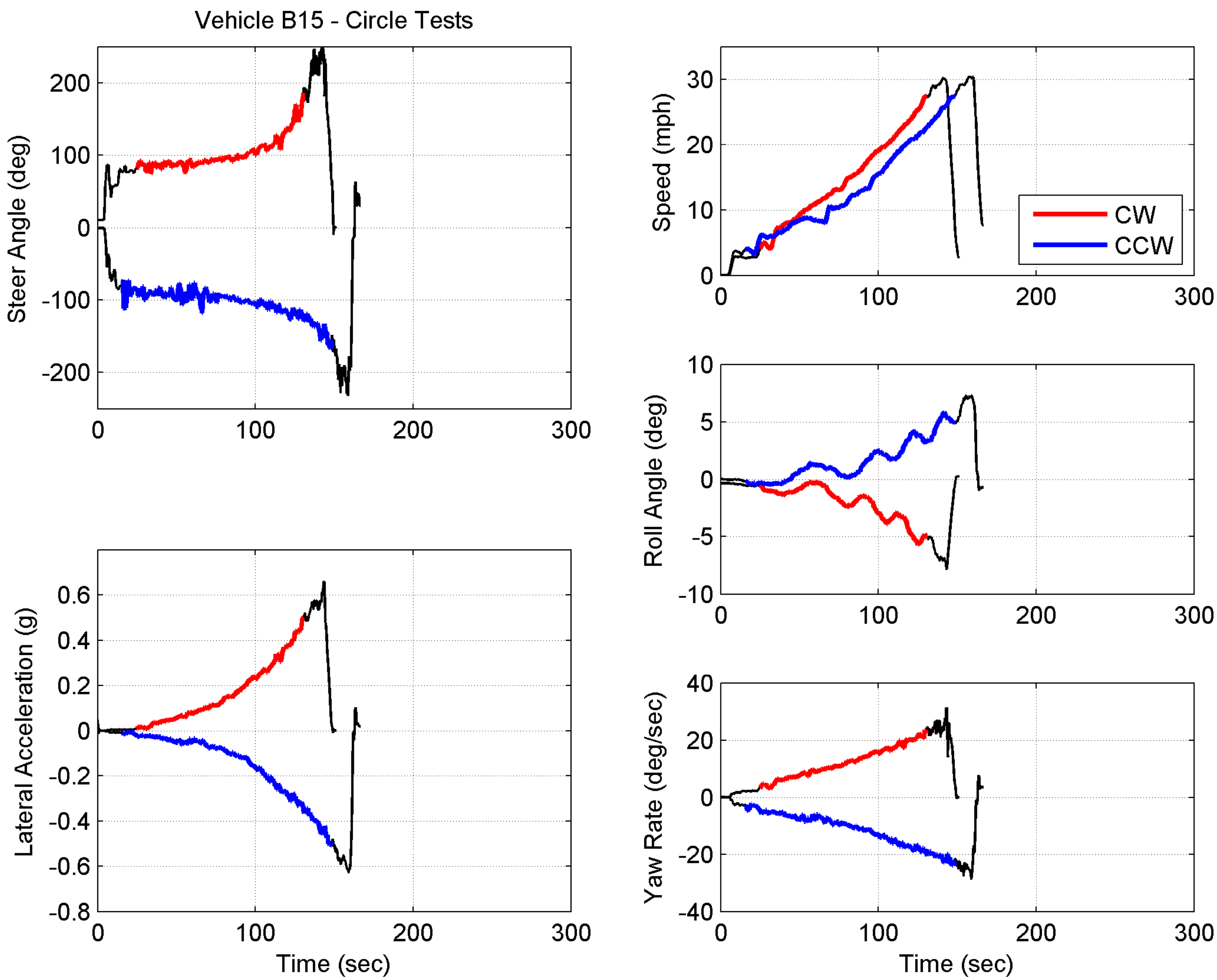
Steering Magnitudes and Threshold Lateral Accelerations During 30 mph Dropped Throttle J-Turns										
Vehicle	Northbound Runs				Southbound Runs				**Average Steering Angle (deg)**	**Average Lateral Accel. (g)**
	Right Steering Angle (deg)	Right Lateral Accel. (g)	Left Steering Angle (deg)	Left Lateral Accel. (g)	Right Steering Angle (deg)	Right Lateral Accel. (g)	Left Steering Angle (deg)	Left Lateral Accel. (g)		
Vehicle A15	145	0.7368	150	0.7508	140	0.7261	145	0.7377	**145.0**	**0.738**
Vehicle B15	355	0.7390	365	0.7592	345	0.7273	330	0.7560	**348.8**	**0.745**
Vehicle C15	95	0.6911	100	0.7035	95	0.6742	95	0.6987	**96.3**	**0.692**
Vehicle D15	140	0.6568	155	0.6562	130	0.6150	155	0.6645	**145.0**	**0.648**
Vehicle E15	95	0.6604	80	0.7074	95	0.6488	75	0.6966	**86.3**	**0.678**
Vehicle F15	155	0.6770	145	0.6768	150	0.6707	140	0.6735	**147.5**	**0.674**
Vehicle G15	120	0.6336	105	0.6065	115	0.6051	105	0.6071	**111.3**	**0.613**
Vehicle H15	215	0.7277	280	0.7746	215	0.7220	280	0.7698	**247.5**	**0.749**
Vehicle I15	130	0.6630	135	0.7084	125	0.6570	135	0.7124	**131.3**	**0.685**
Vehicle J15	200	0.6571	180	0.6603	185	0.6505	175	0.6395	**185.0**	**0.652**
Vehicle K15	75	0.6784	90	0.7001	80	0.6958	95	0.6999	**85.0**	**0.694**
Vehicle L15	155	0.6582	150	0.6847	150	0.6573	148	0.6680	**150.8**	**0.667**
Vehicle M15	155	0.6884	175	0.7172	155	0.6597	175	0.7274	**165.0**	**0.698**


Vehicle A15 - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

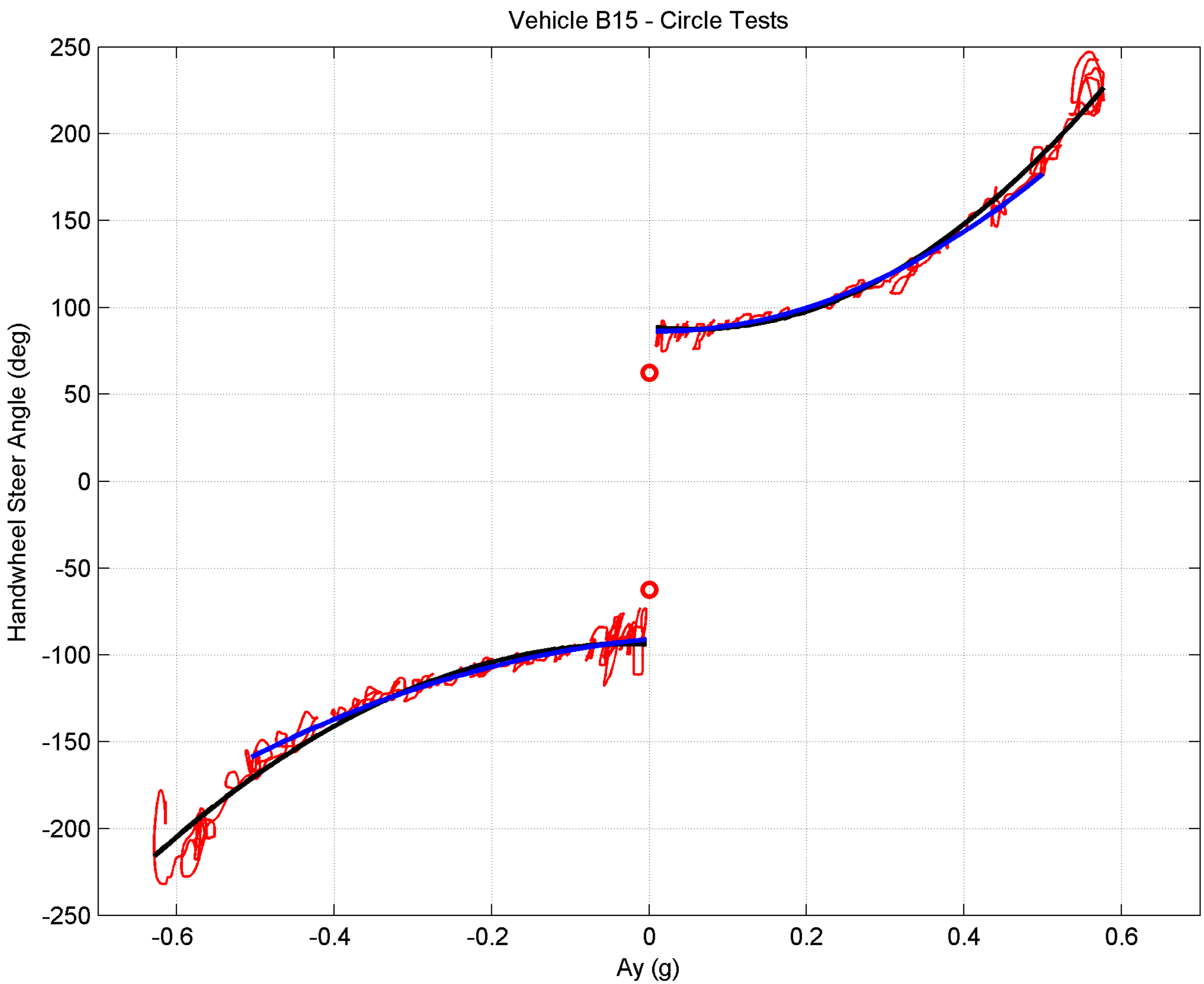

Vehicle A15 - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

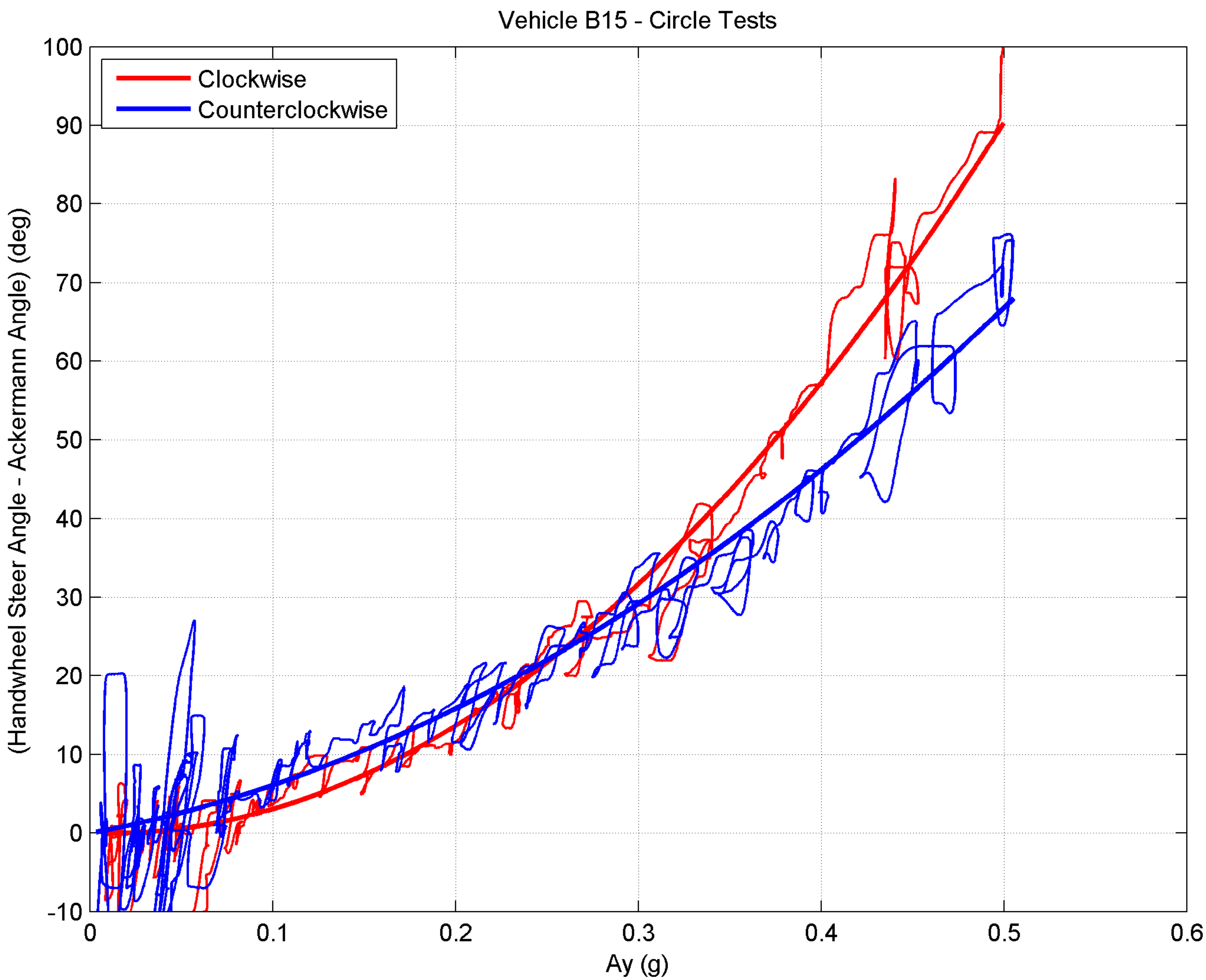

Vehicle A15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
40
35
30
25
20
15
10
5
0
-5
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
CW Transition to Oversteer
At Ay = 0.47552 g
CCW Transition to Oversteer
At Ay = -0.40567 g

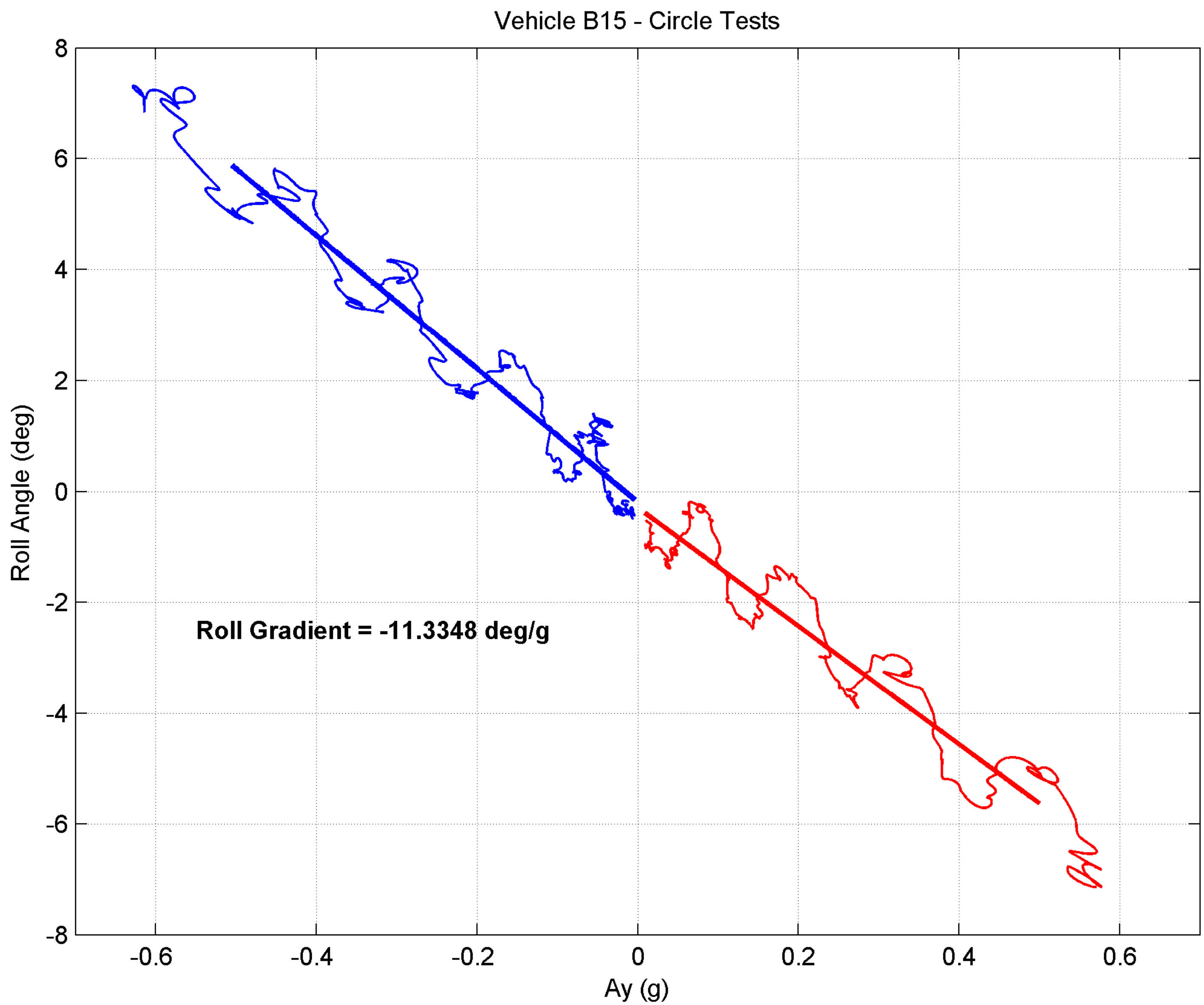

Vehicle A15 - Circle Tests
Roll Angle (deg)
Ay (g)
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Roll Gradient = -7.8781 deg/g

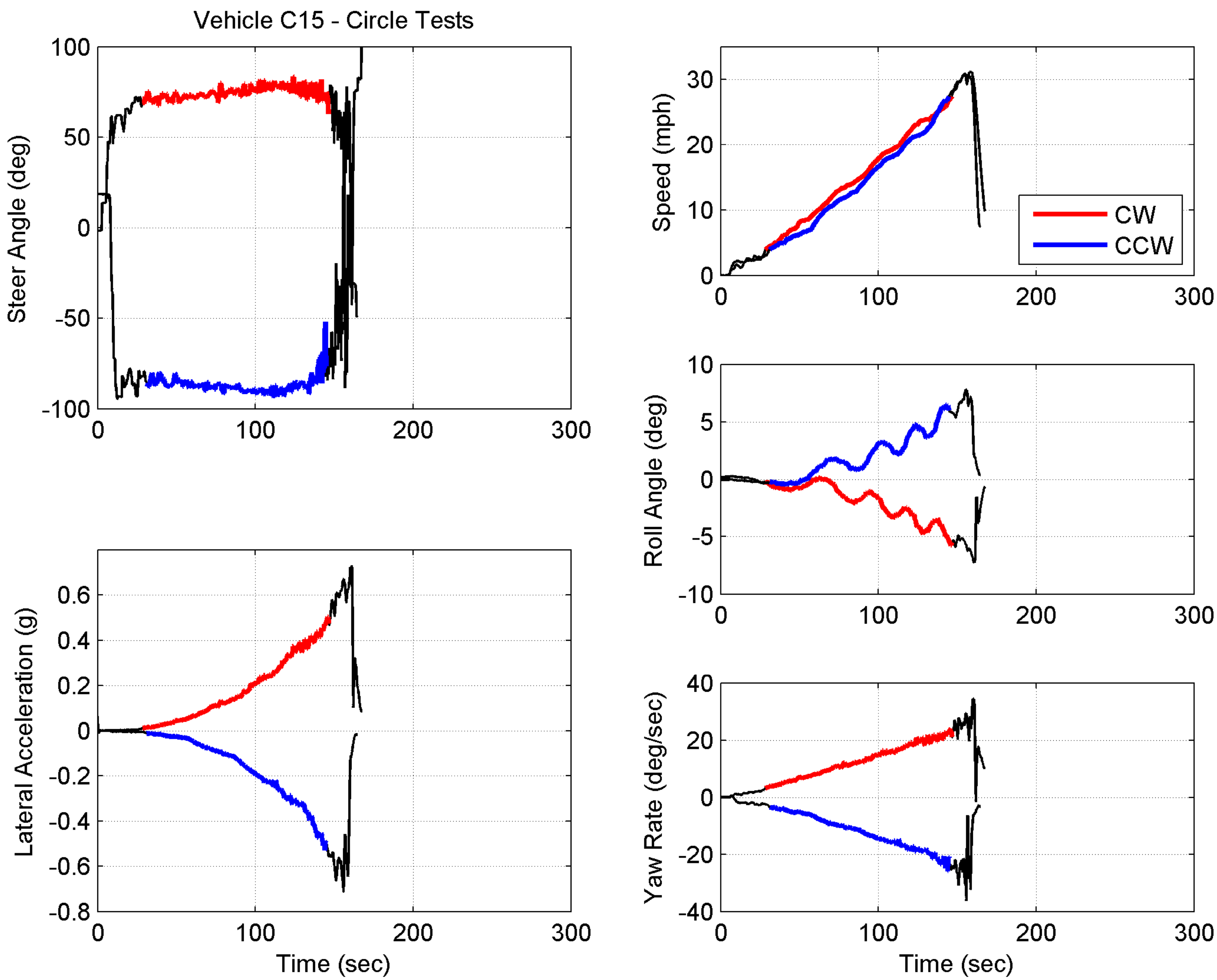


Vehicle B15 - Circle Tests
Steer Angle (deg)
200
100
0
-100
-200
0
100
200
300
Speed (mph)
30
20
10
0
CW
CCW
Roll Angle (deg)
10
5
0
-5
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

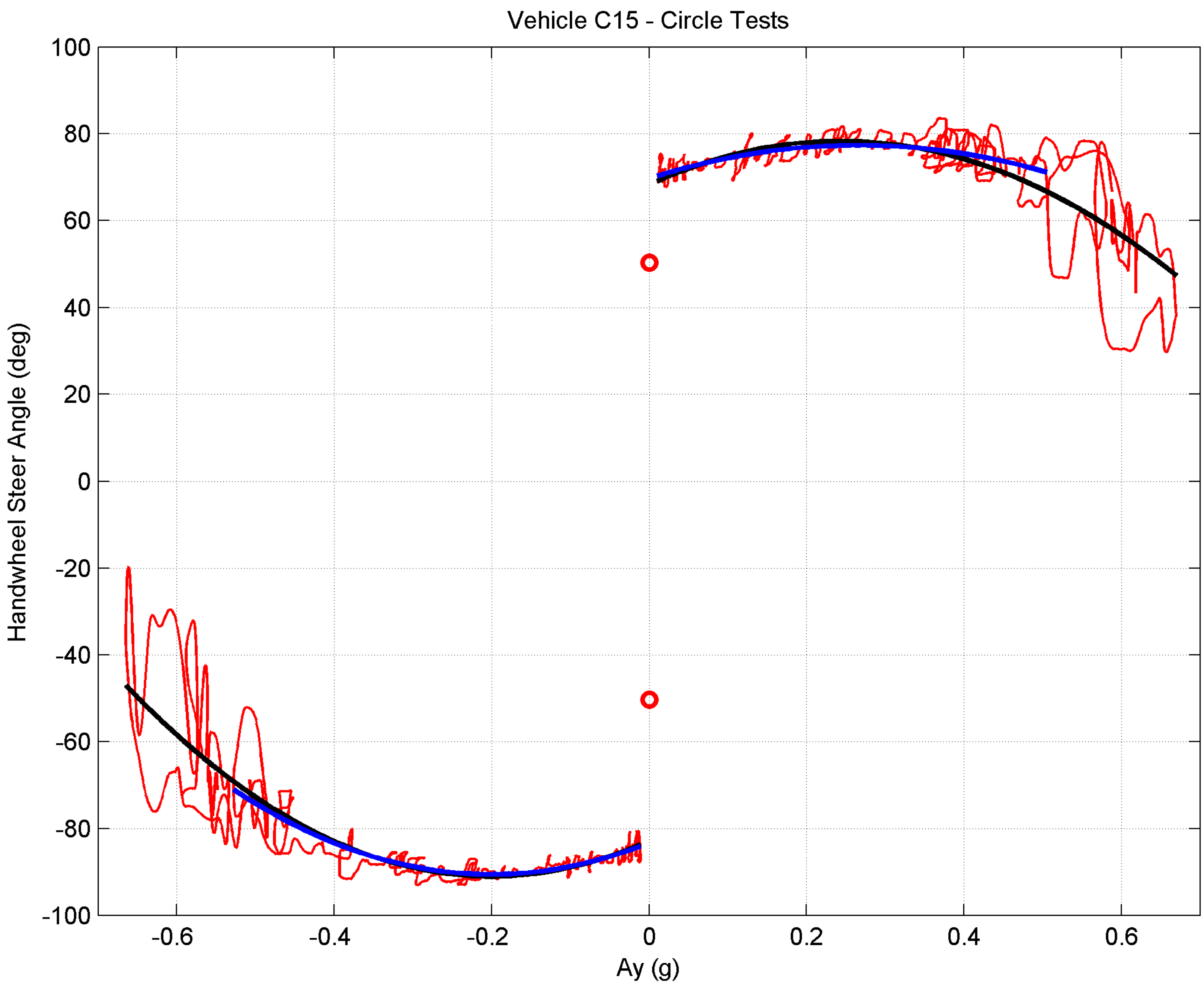

Vehicle B15 - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
250
200
150
100
50
0
-50
-100
-150
-200
-250
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

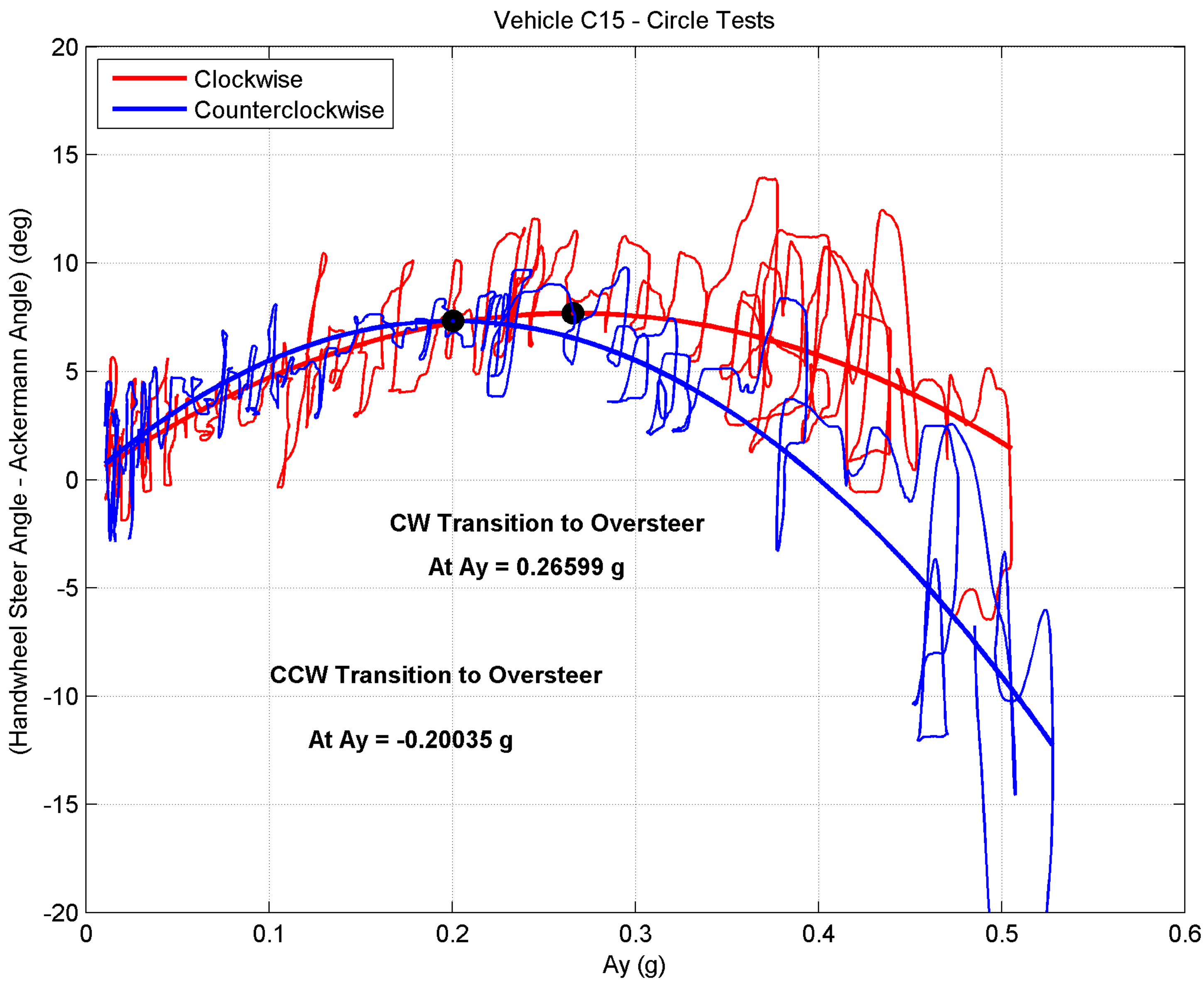

Vehicle B15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
100
90
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6


Vehicle B15 - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -11.3348 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

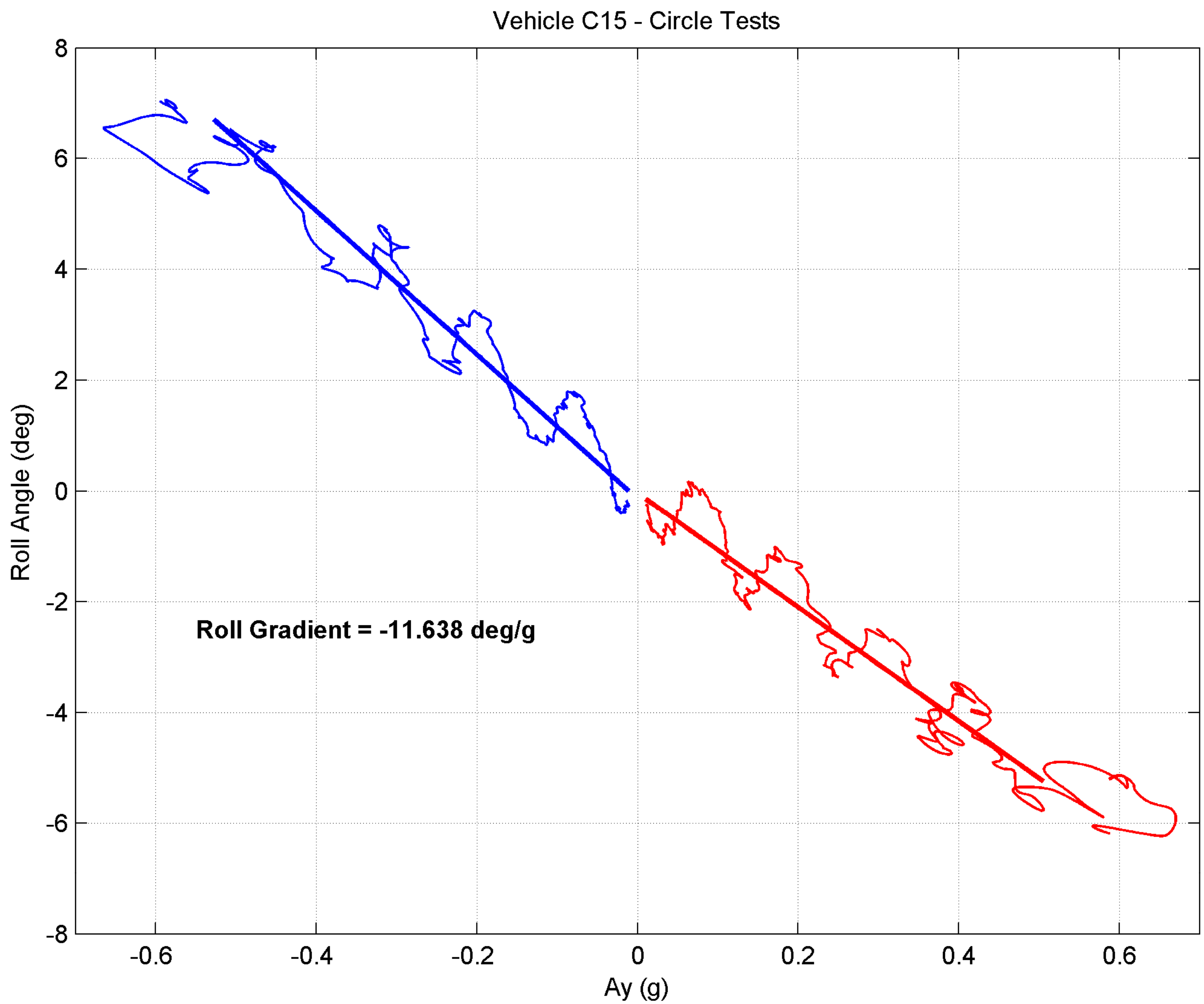


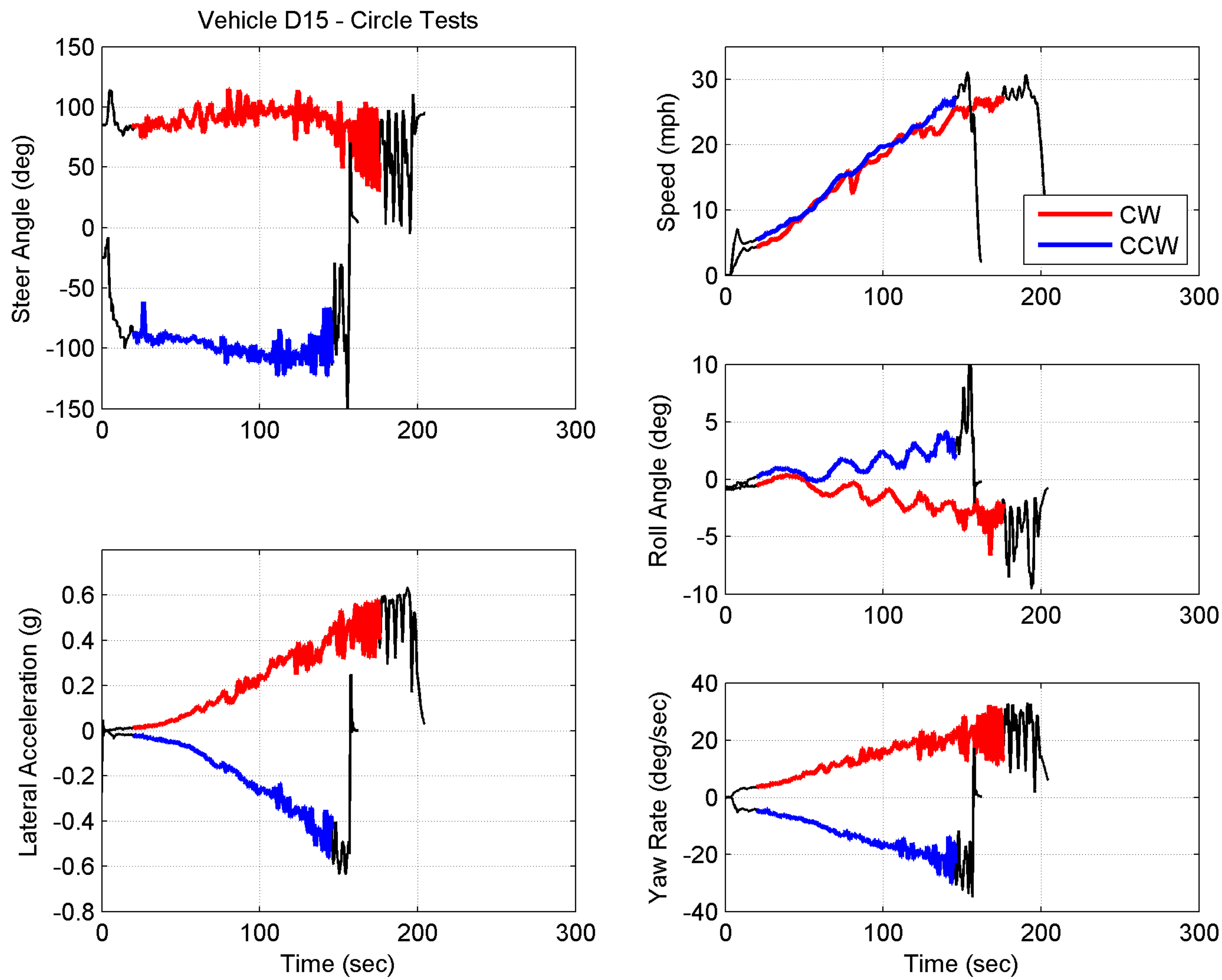
Vehicle C15 - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
30
20
10
0
CW
CCW
Roll Angle (deg)
10
5
0
-5
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)


Vehicle C15 - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

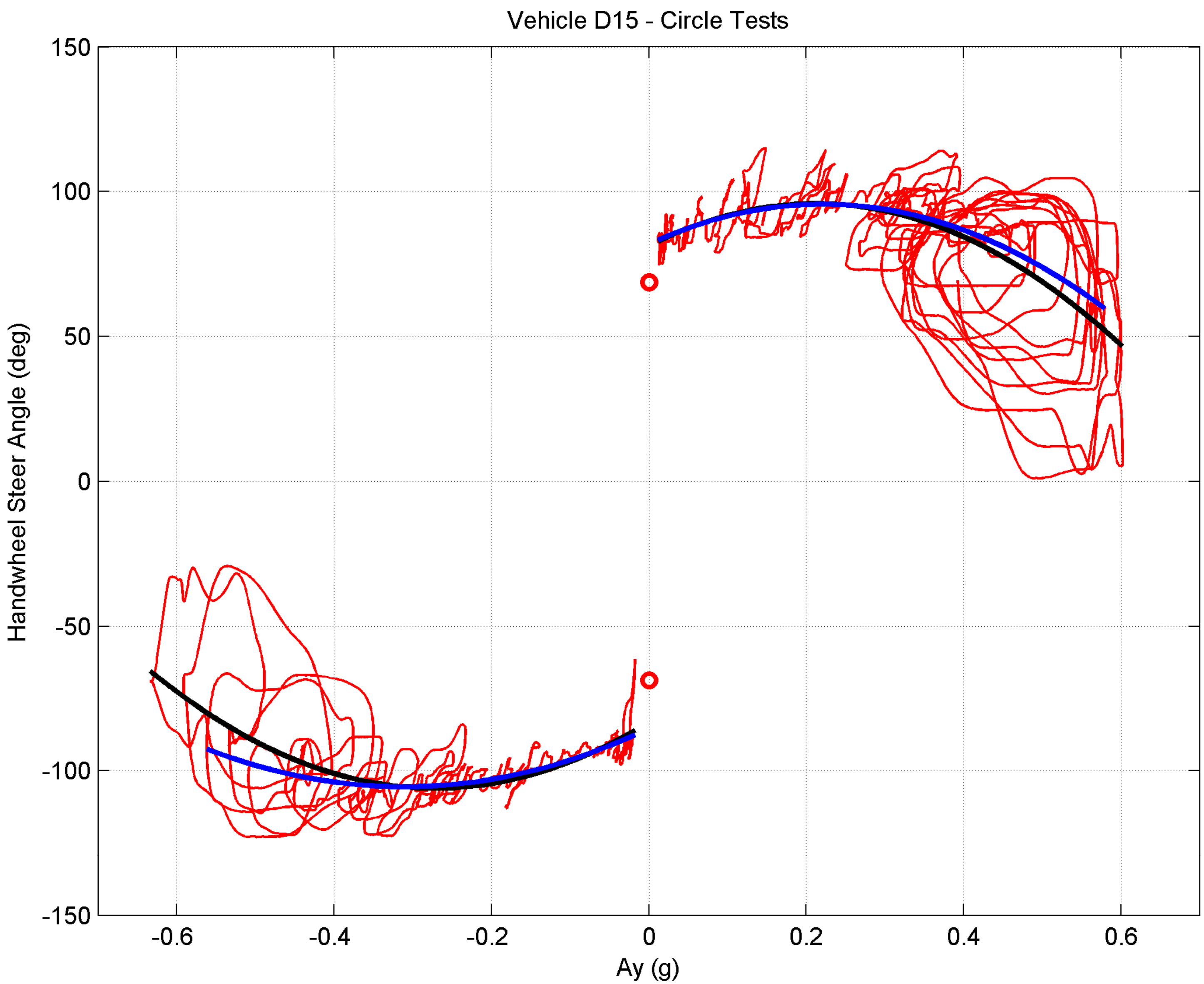


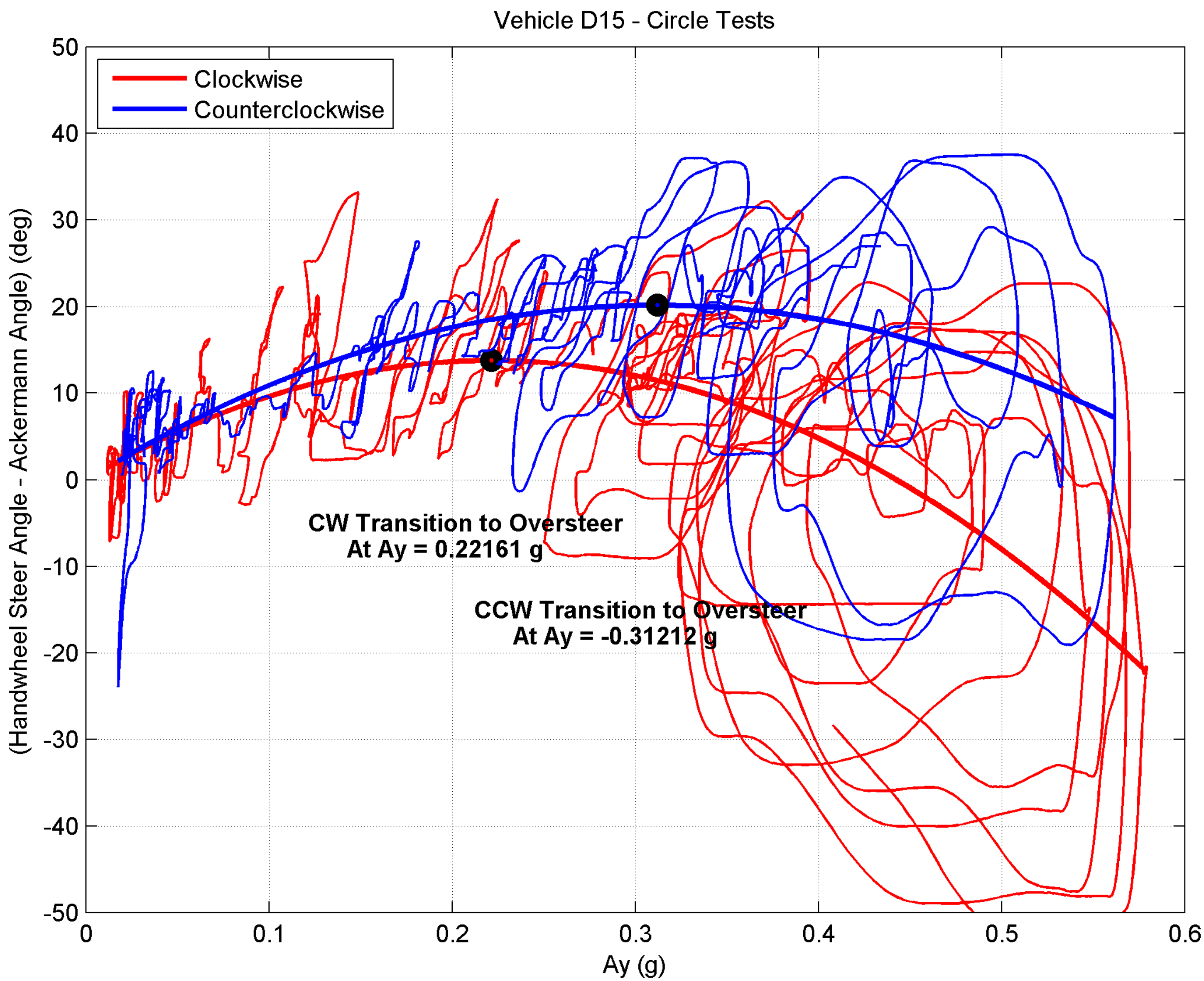
Vehicle C15 - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.26599 g
CCW Transition to Oversteer
At Ay = -0.20035 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
20
15
10
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
0.4
0.5
0.6


Vehicle C15 - Circle Tests
Roll Gradient = -11.638 deg/g
Roll Angle (deg)
Ay (g)
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

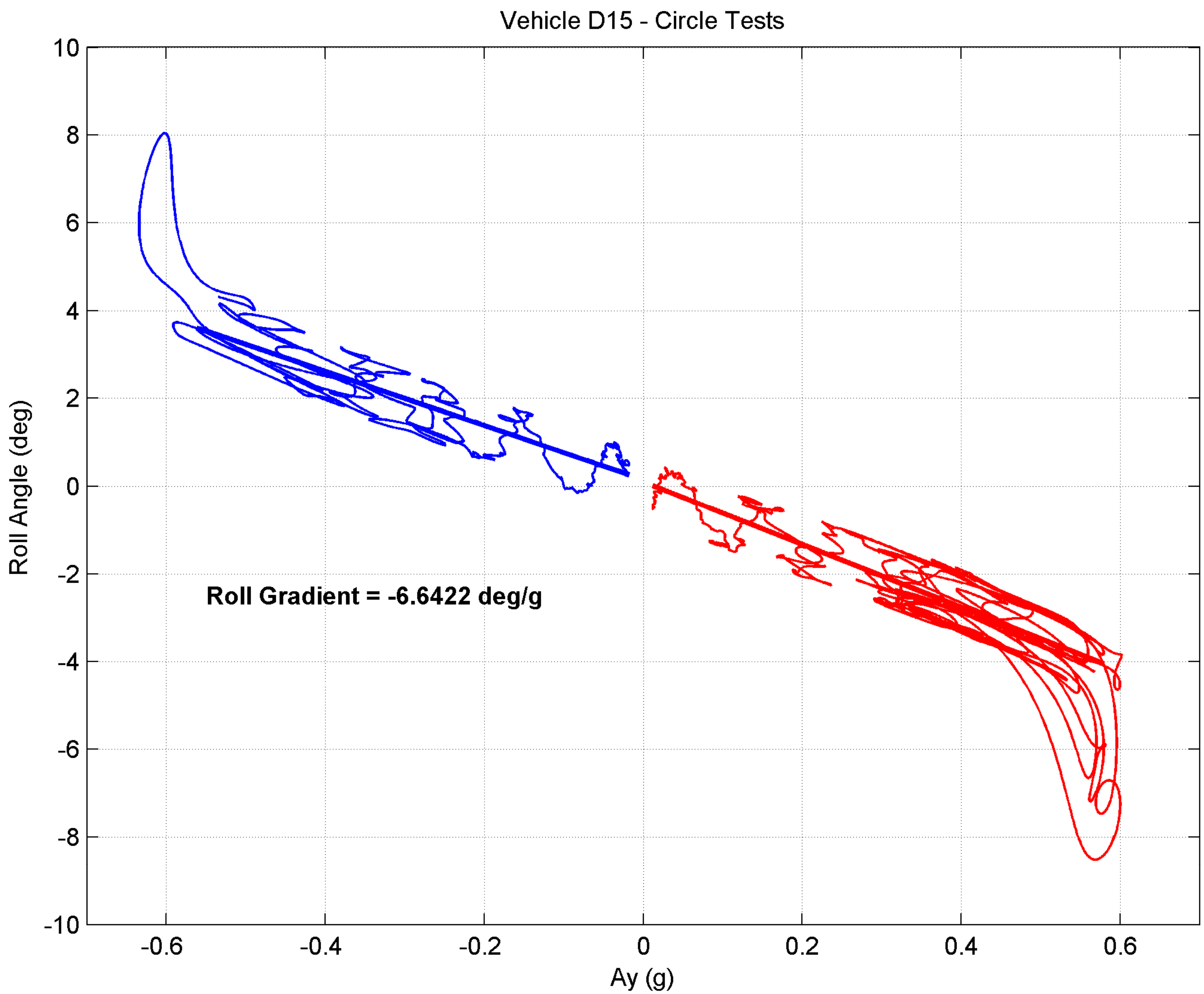


Vehicle D15 - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

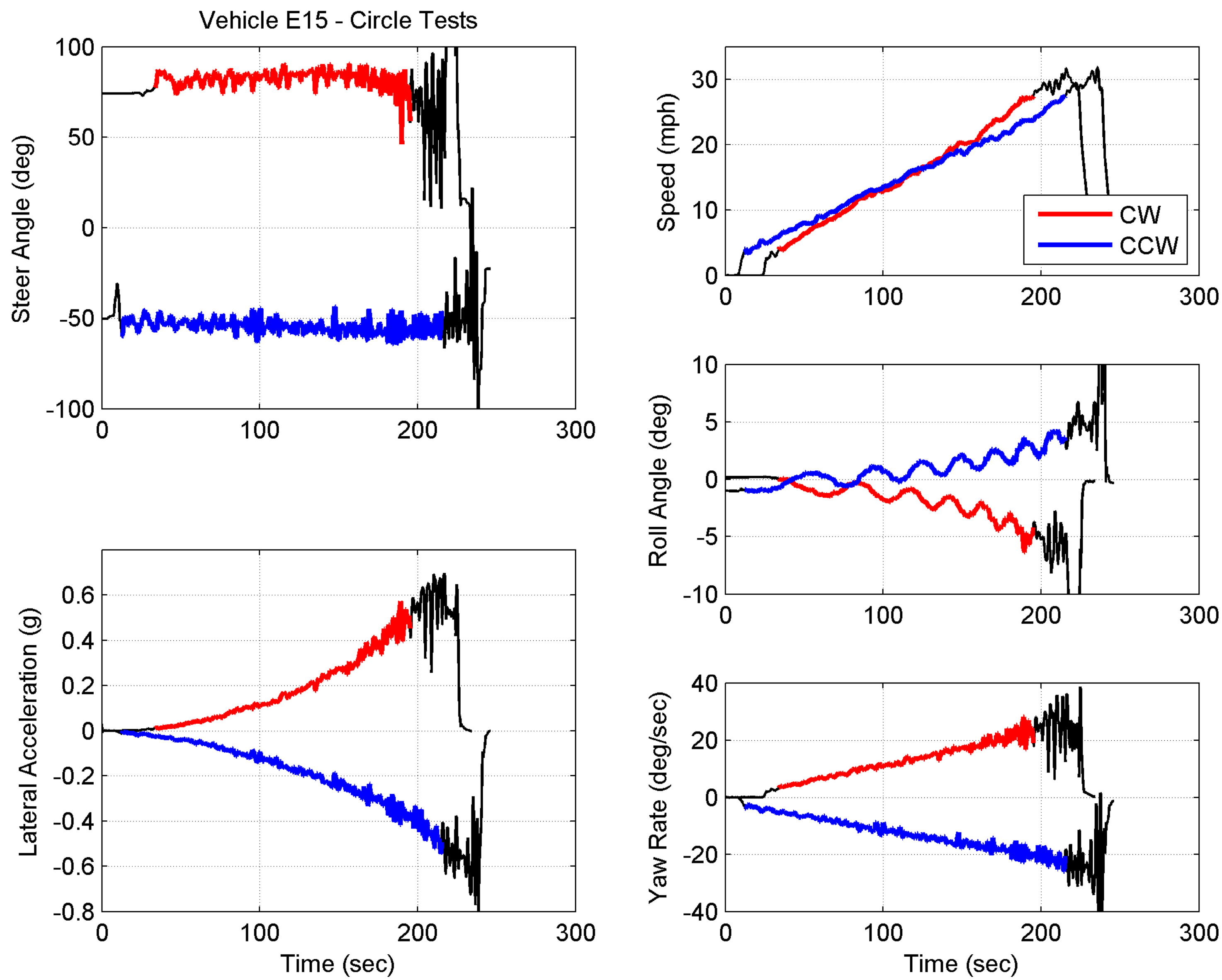

Vehicle D15 - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
150
100
50
0
-50
-100
-150
-0.6
-0.4
-0.2
0
0.2
0.4
0.6



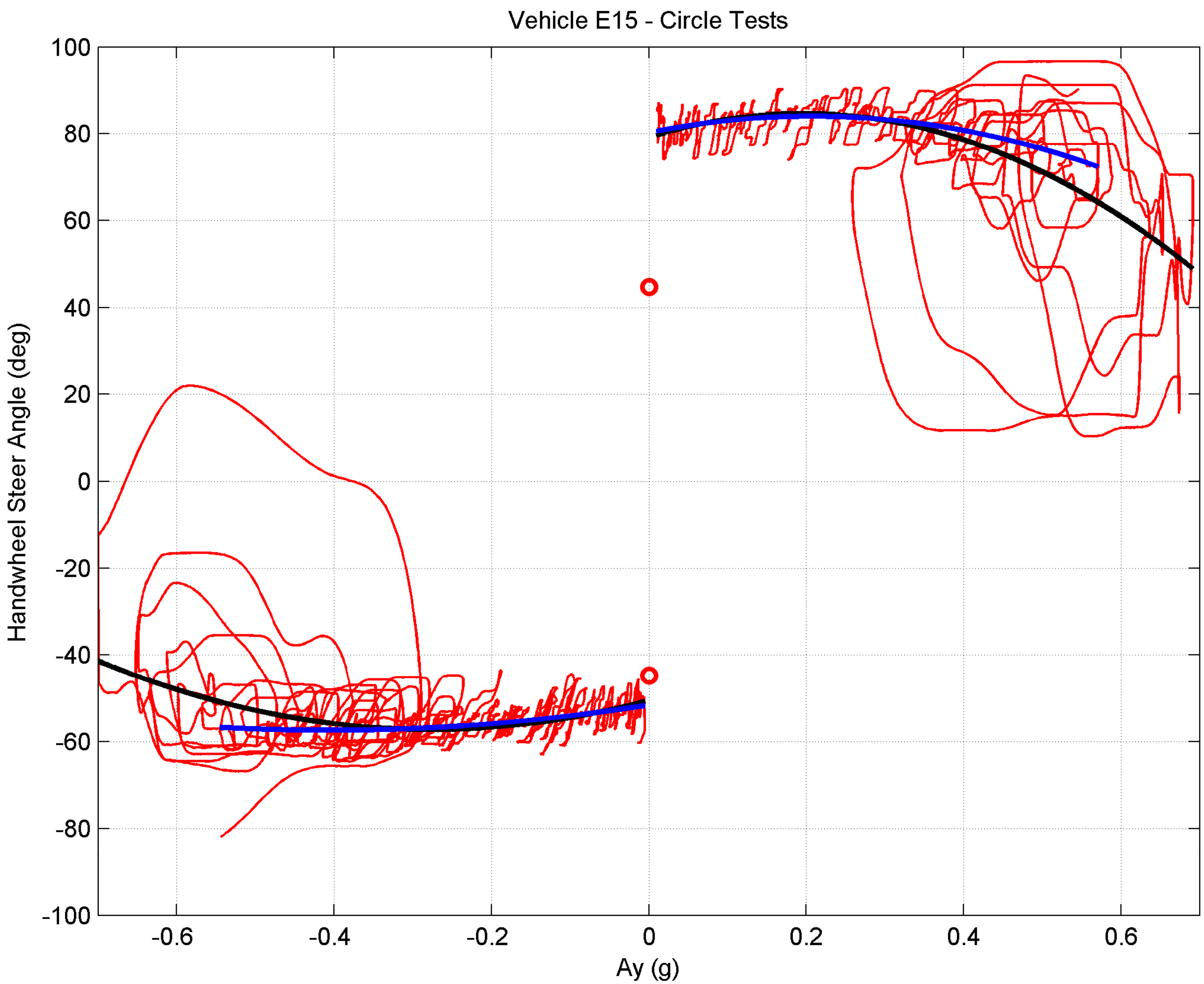
Vehicle D15 - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.22161 g
CCW Transition to Oversteer
At Ay = -0.31212 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
0.1
0.2
0.3
0.4
0.5
0.6



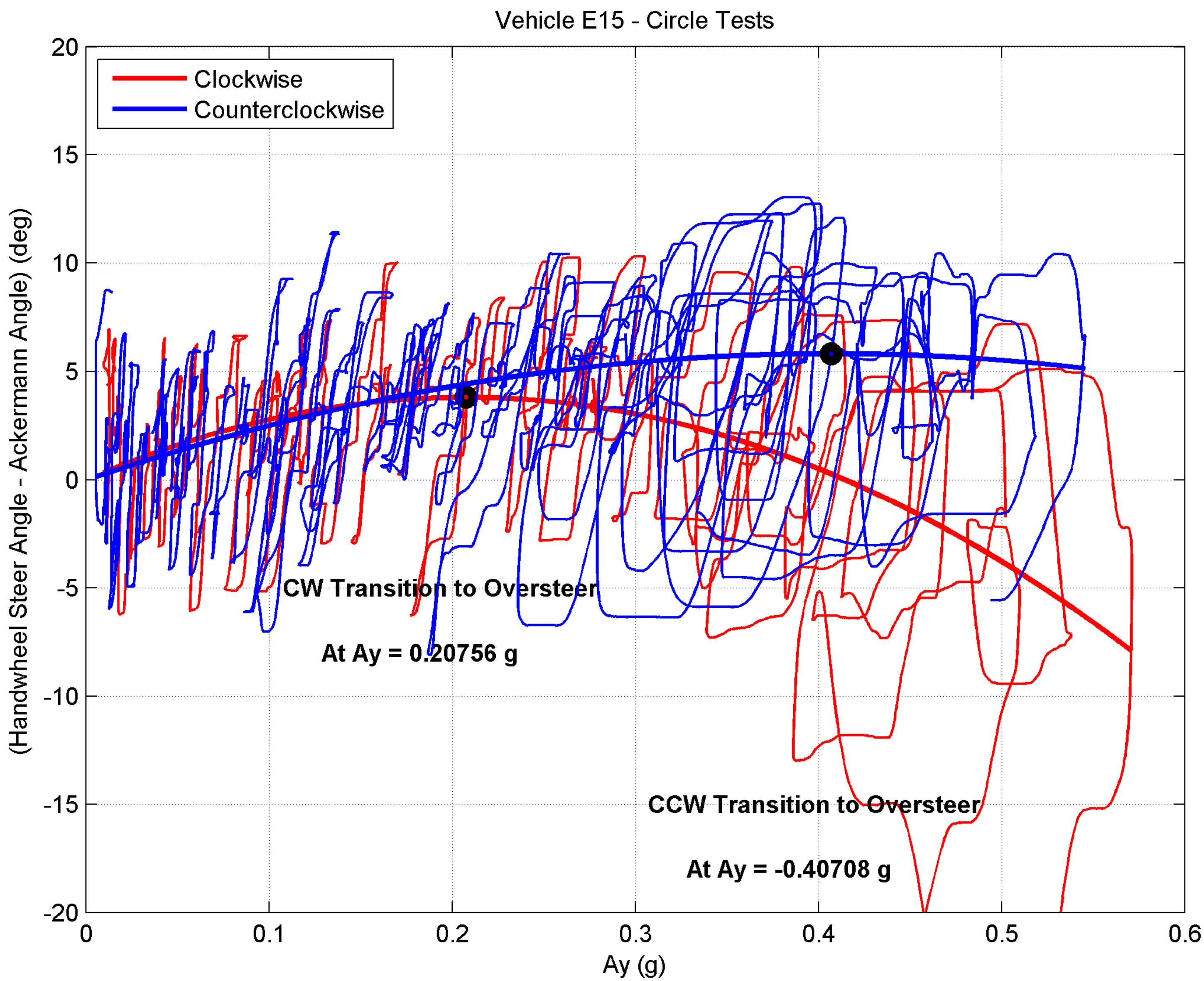
Vehicle D15 - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -6.6422 deg/g
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

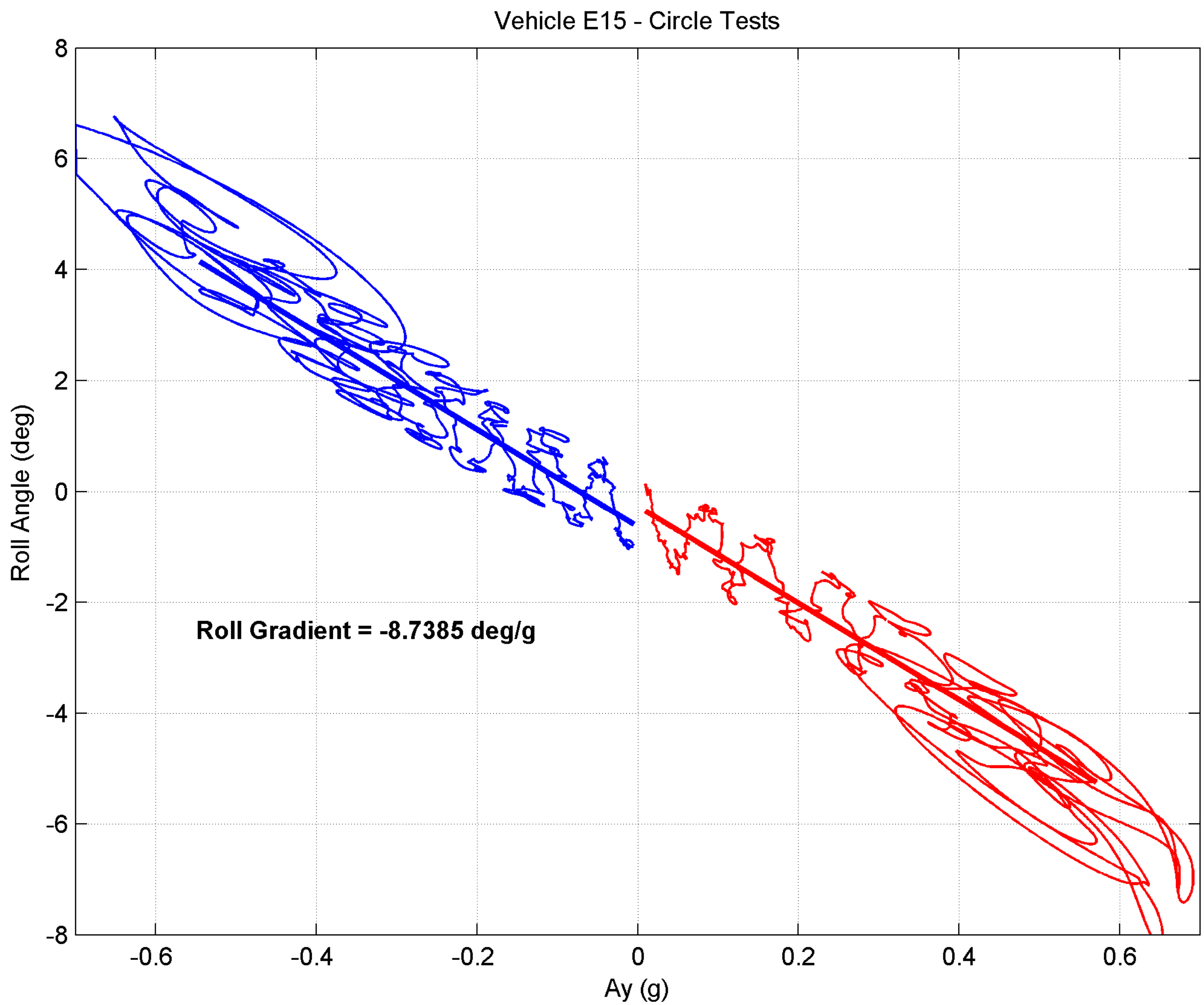


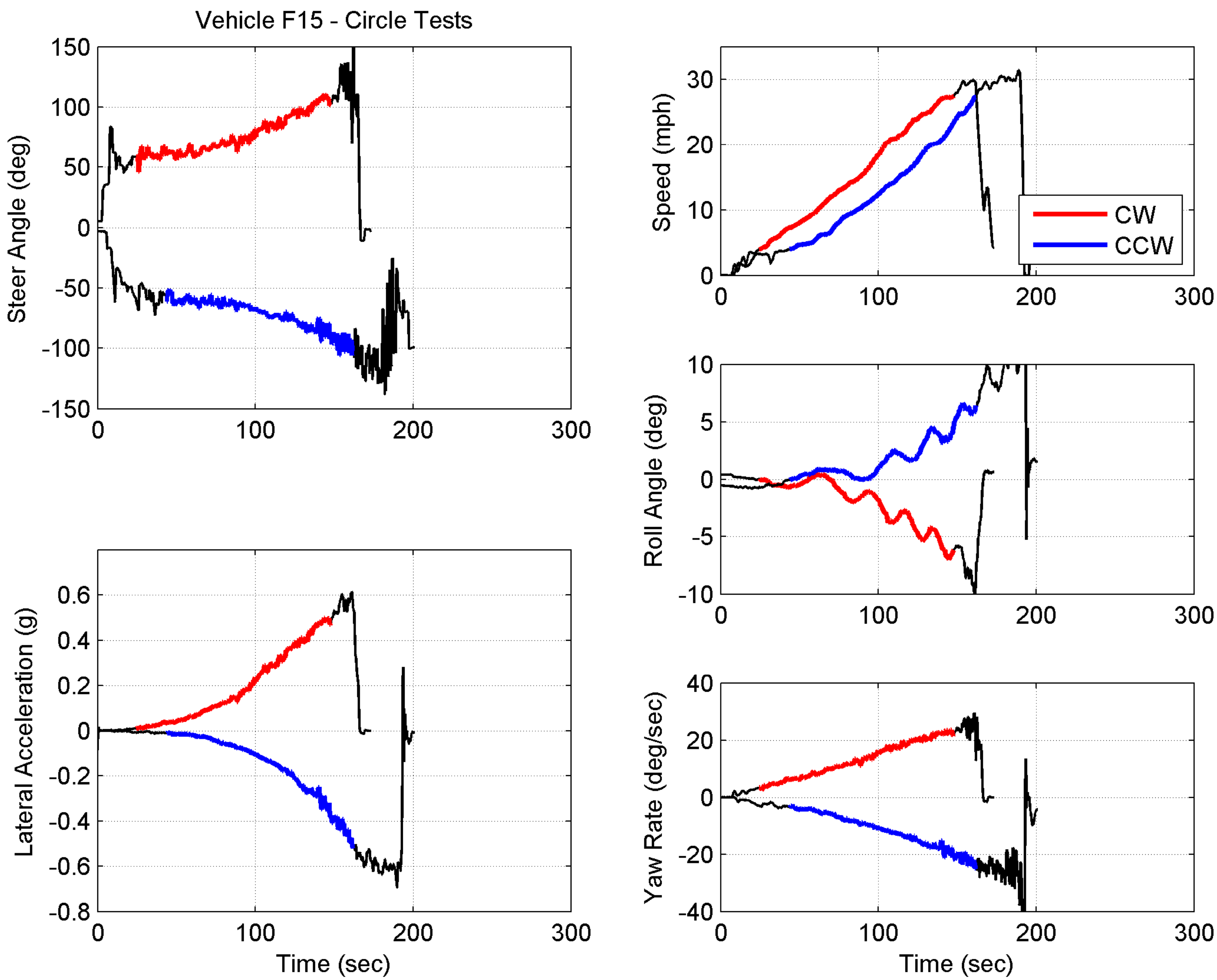
Vehicle E15 - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

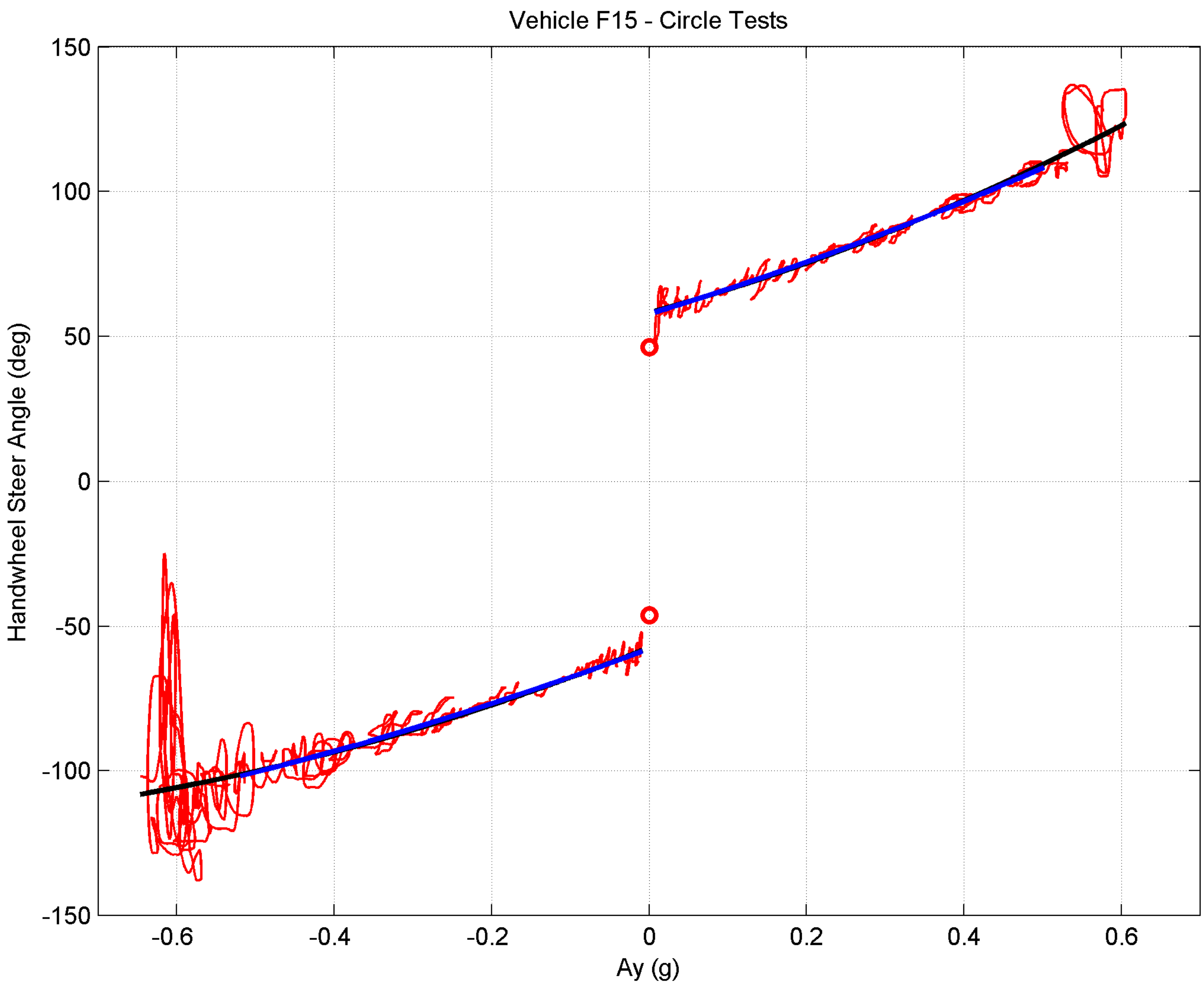


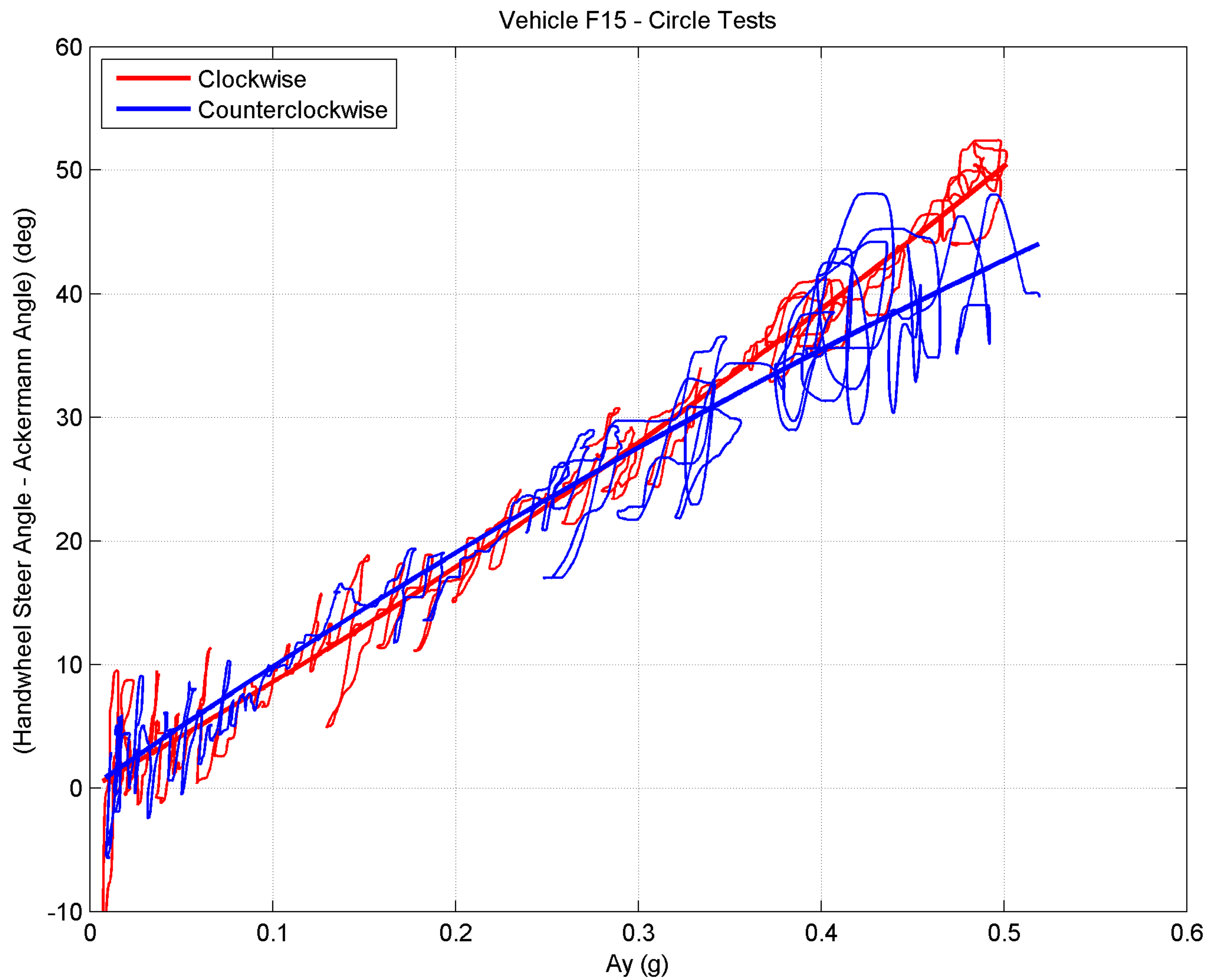
Vehicle E15 - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

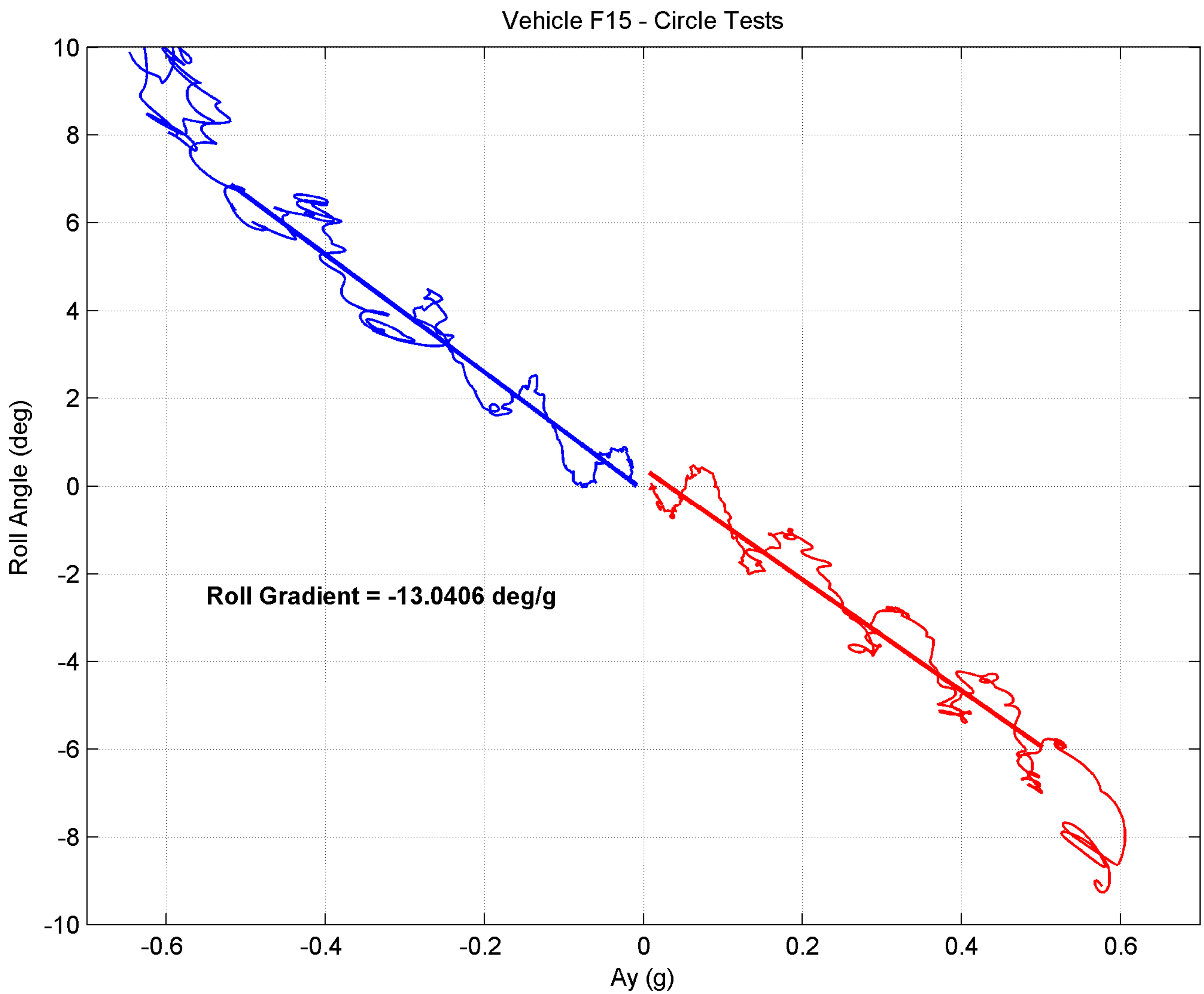

Vehicle E15 - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.20756 g
CCW Transition to Oversteer
At Ay = -0.40708 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
20
15
10
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
0.4
0.5
0.6

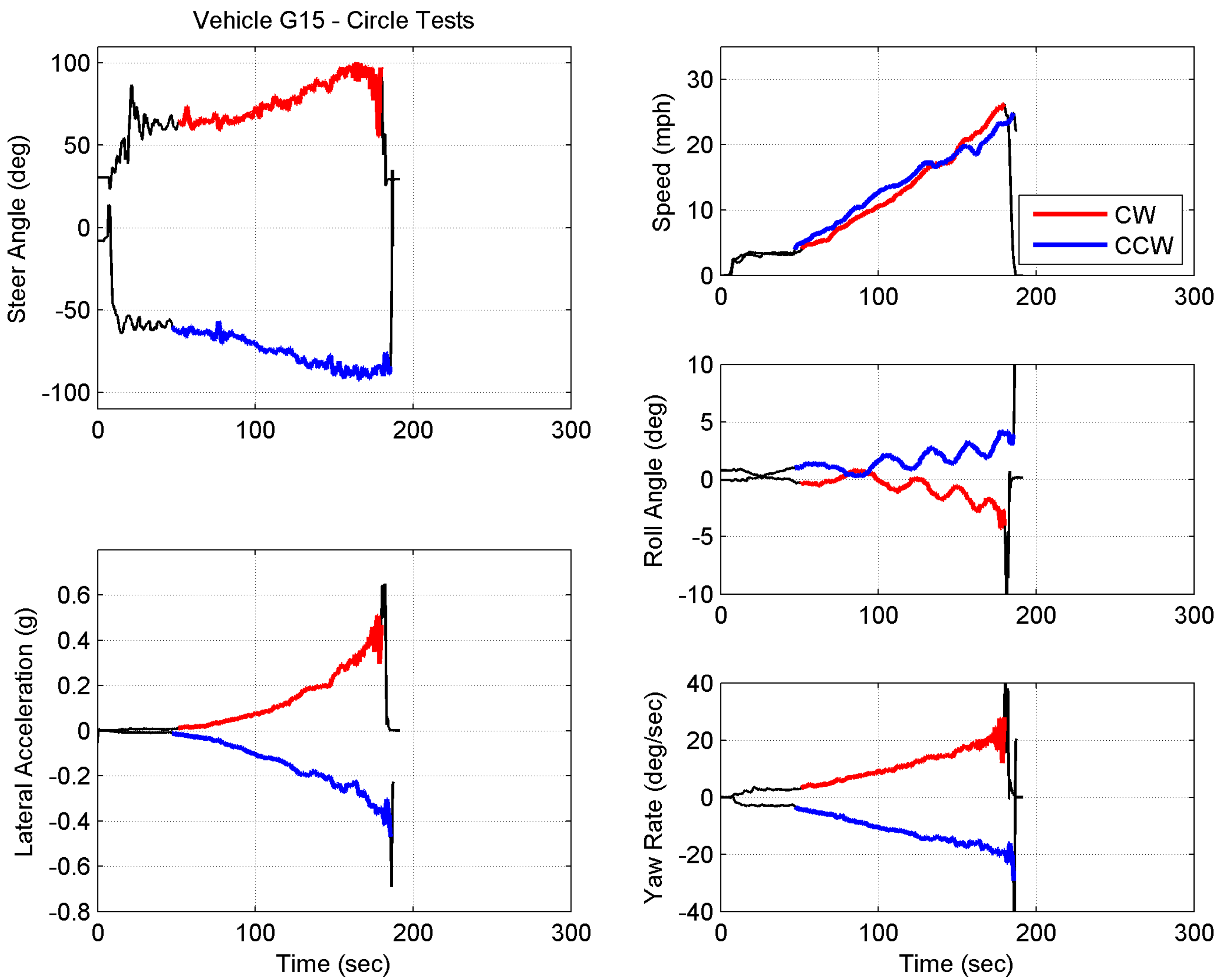

Vehicle E15 - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -8.7385 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6


Vehicle F15 - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

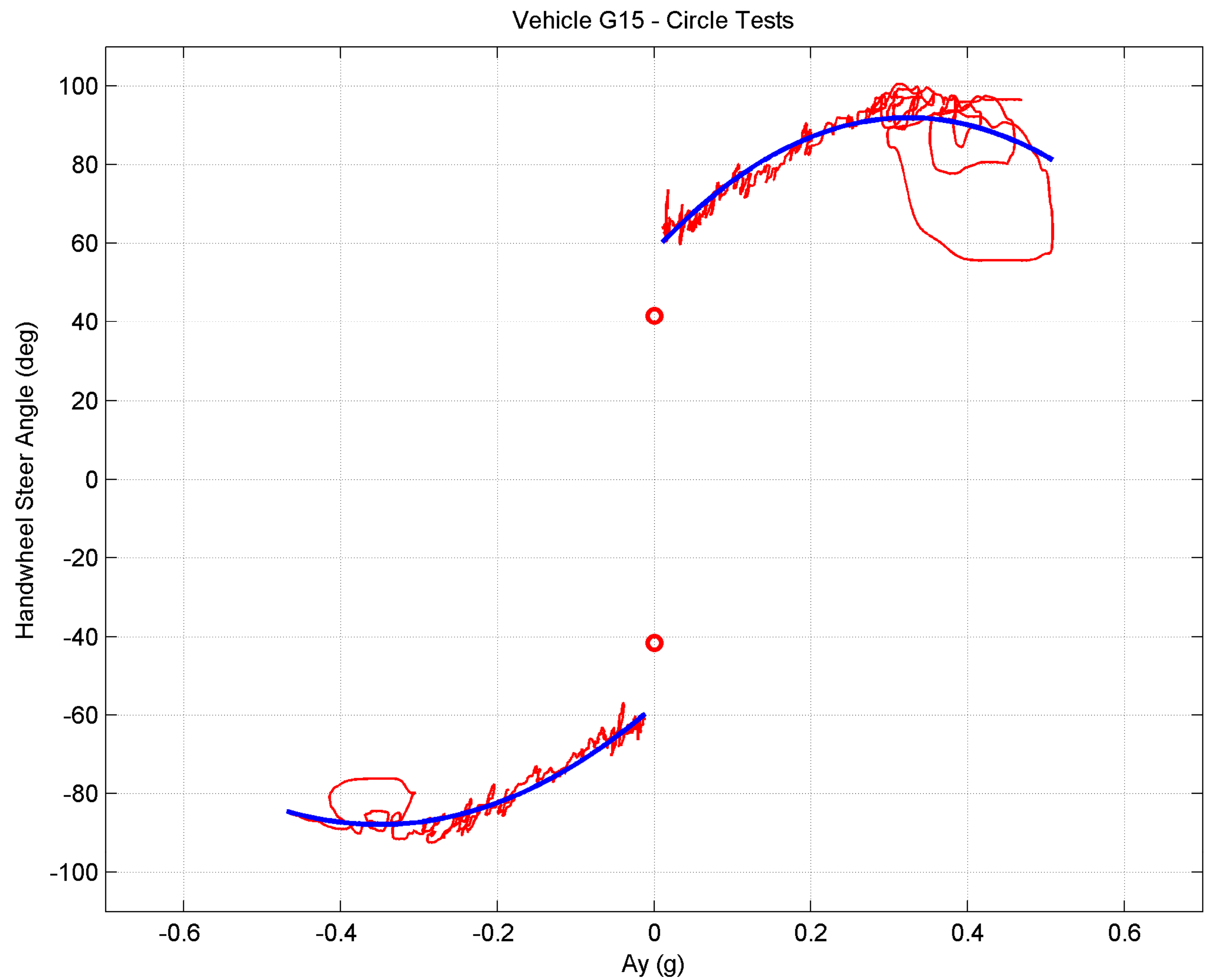

Vehicle F15 - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
150
100
50
0
-50
-100
-150
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

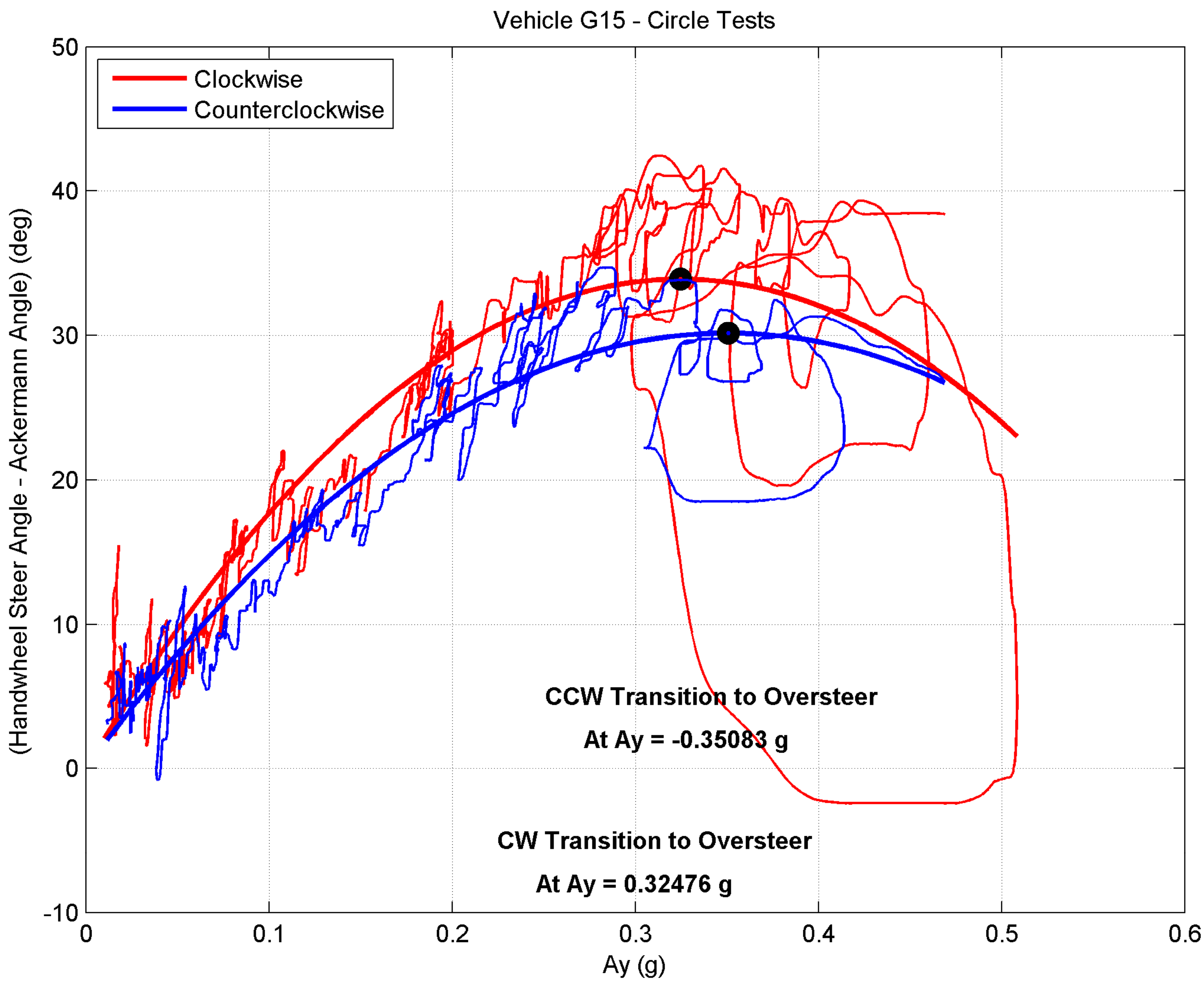

Vehicle F15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6

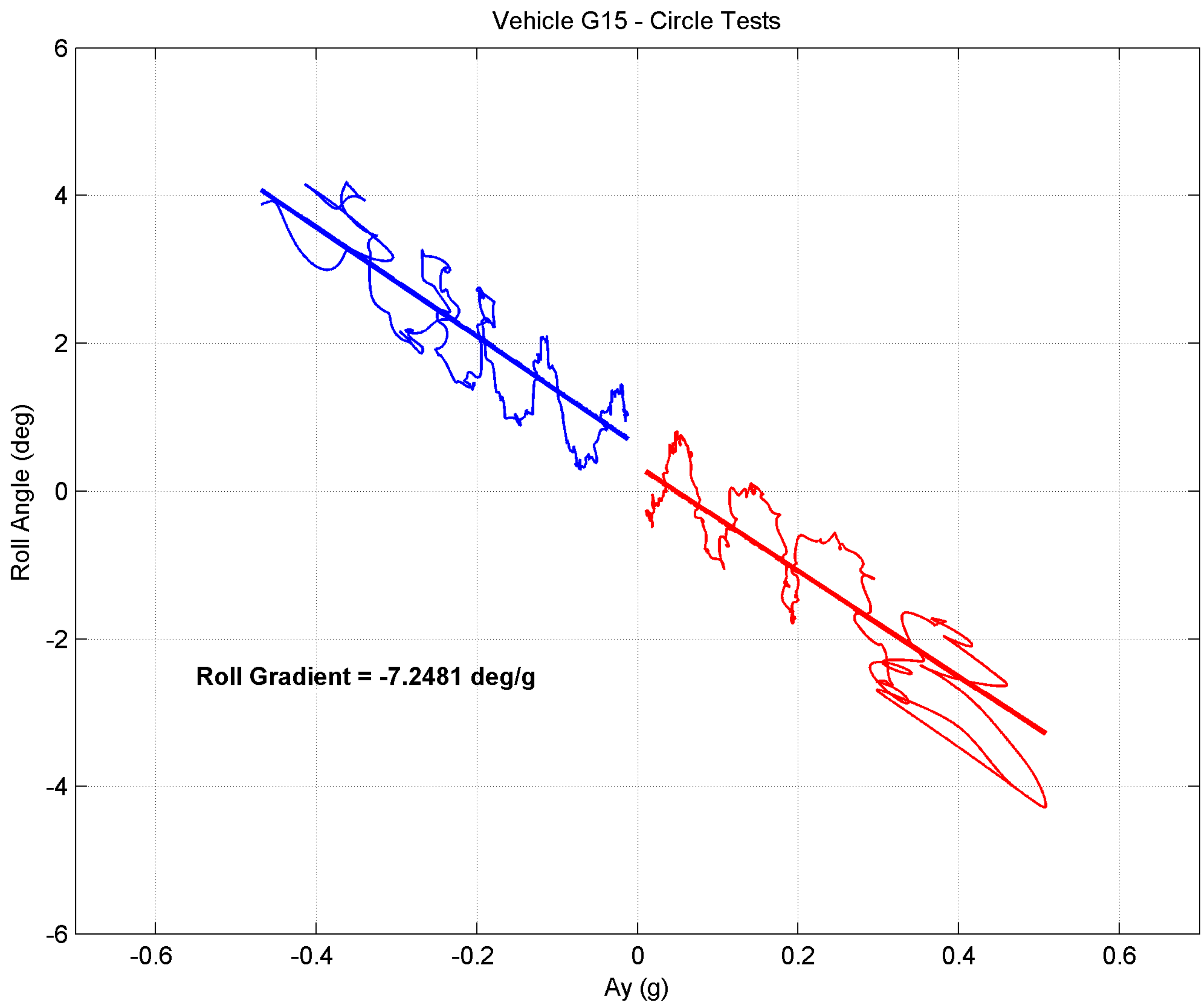

Vehicle F15 - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -13.0406 deg/g
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

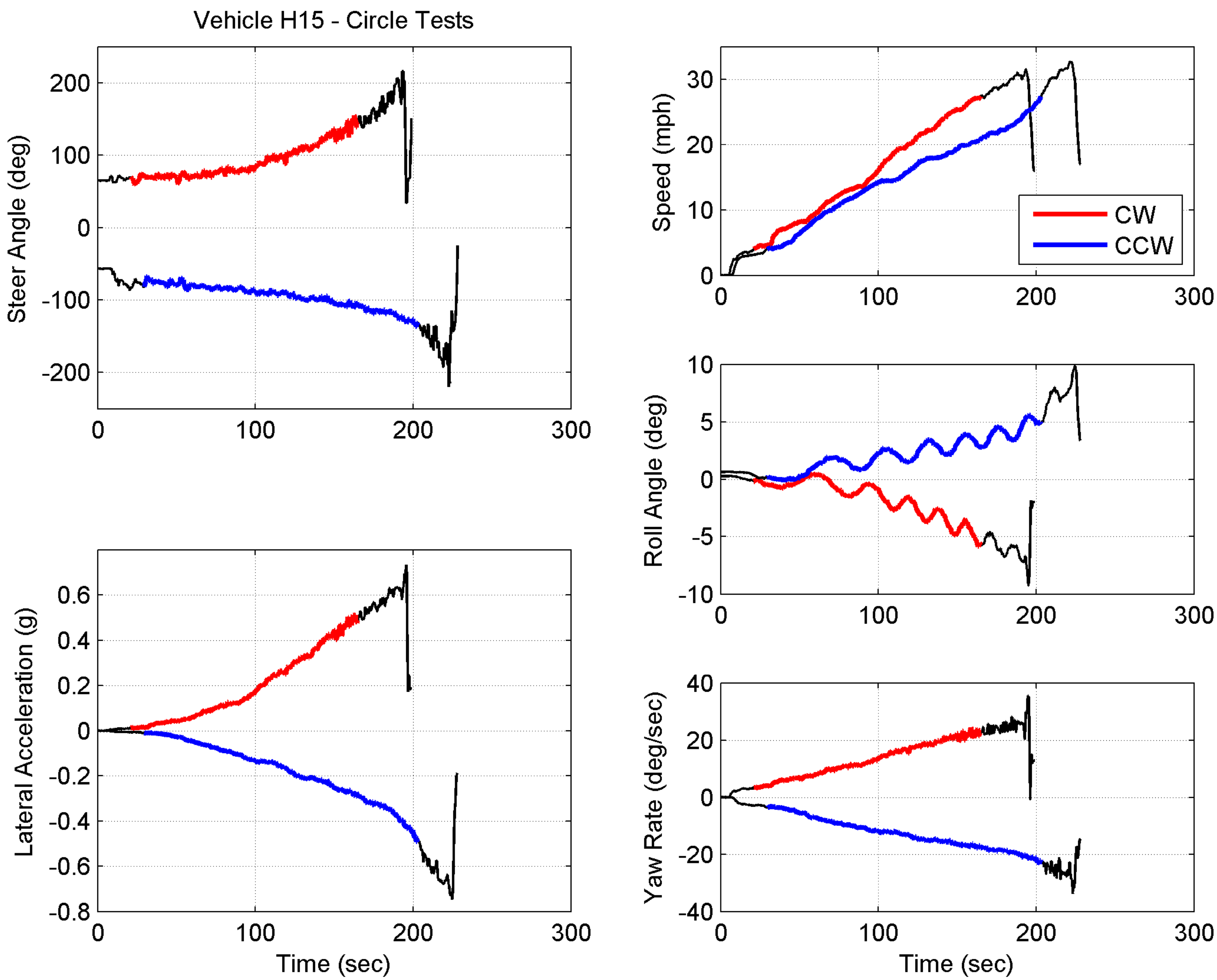


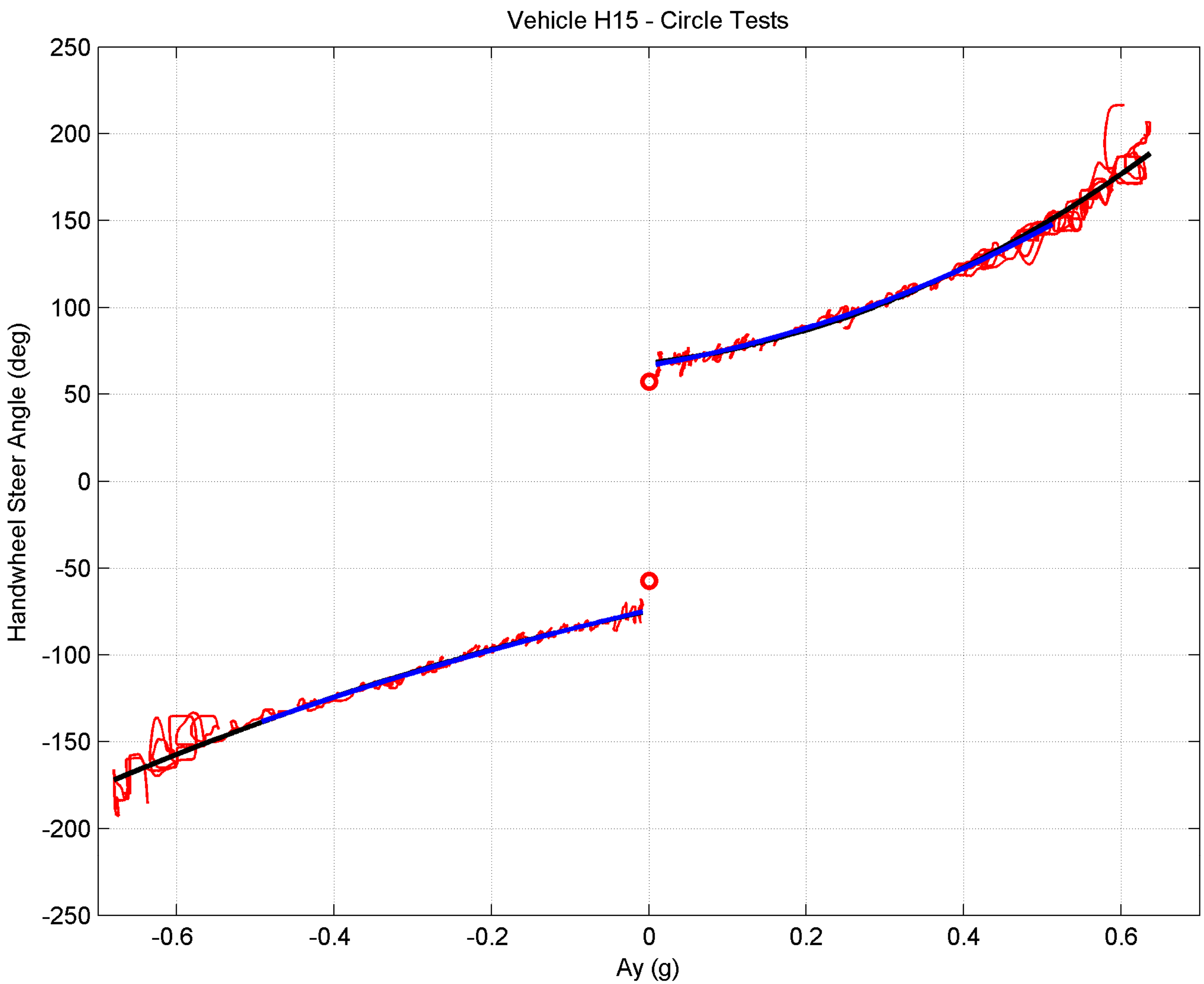
Vehicle G15 - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
30
20
10
0
CW
CCW
Roll Angle (deg)
10
5
0
-5
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

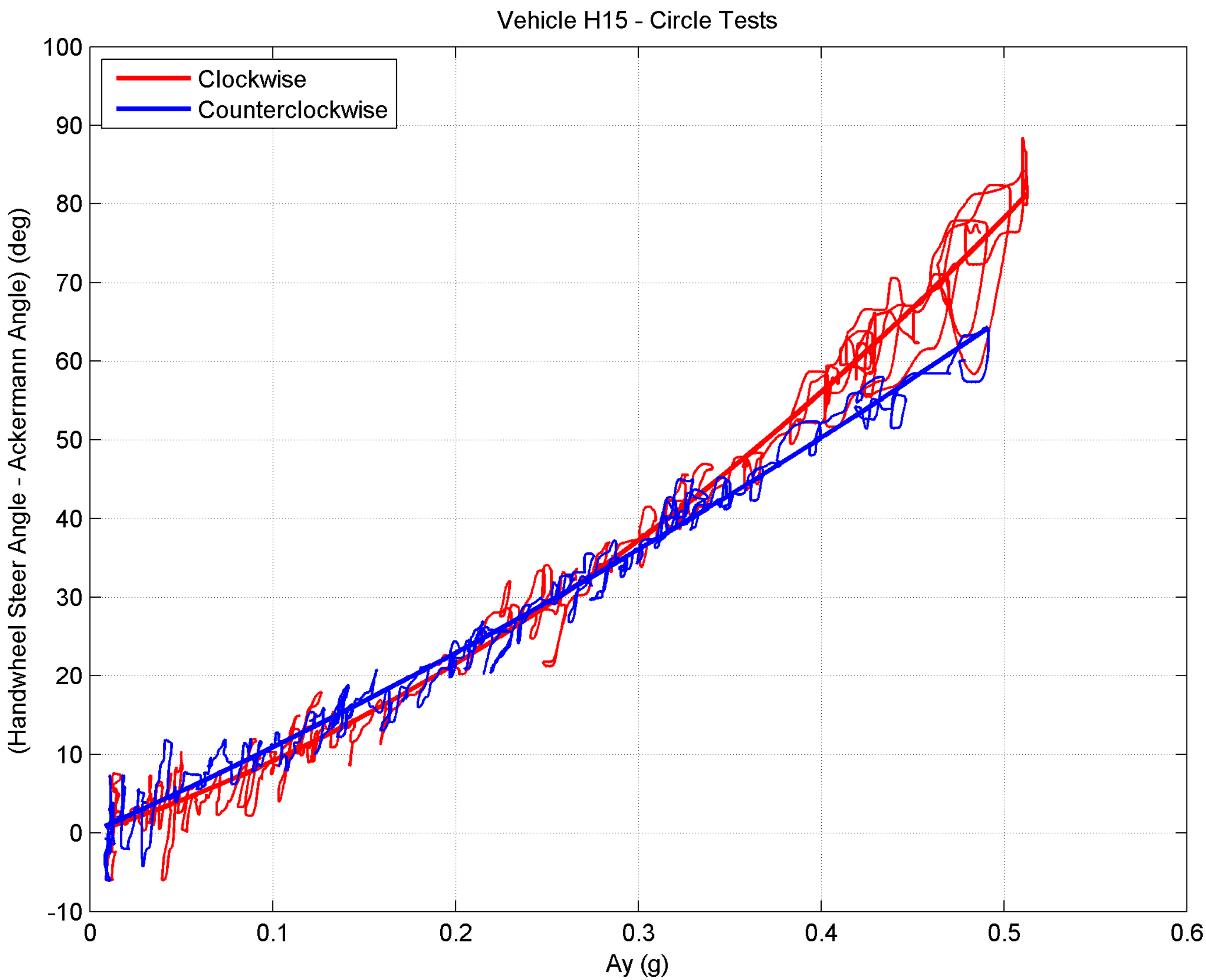

Vehicle G15 - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6


Vehicle G15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
Ay (g)
CCW Transition to Oversteer
At Ay = -0.35083 g
CW Transition to Oversteer
At Ay = 0.32476 g

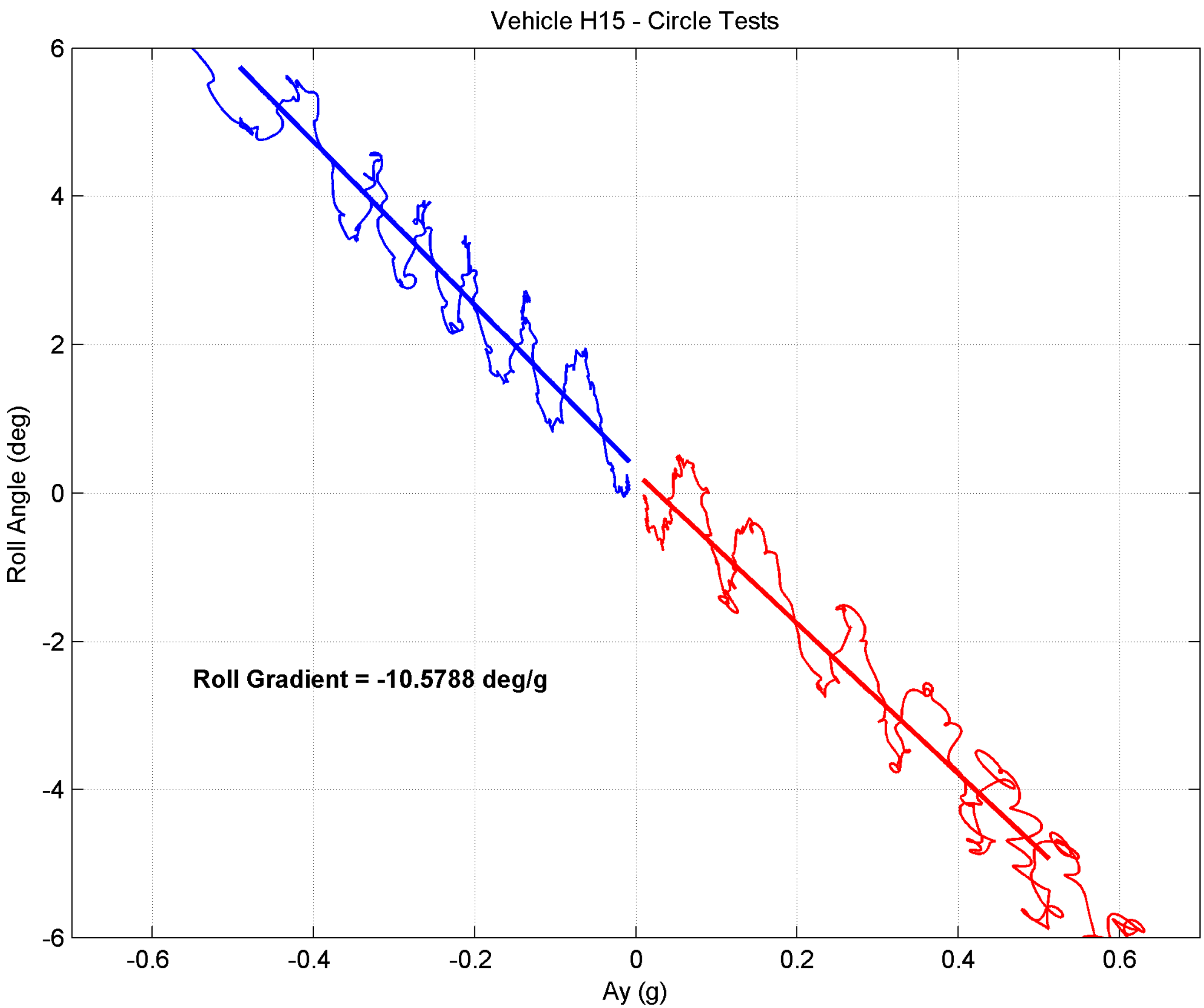

Vehicle G15 - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -7.2481 deg/g
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

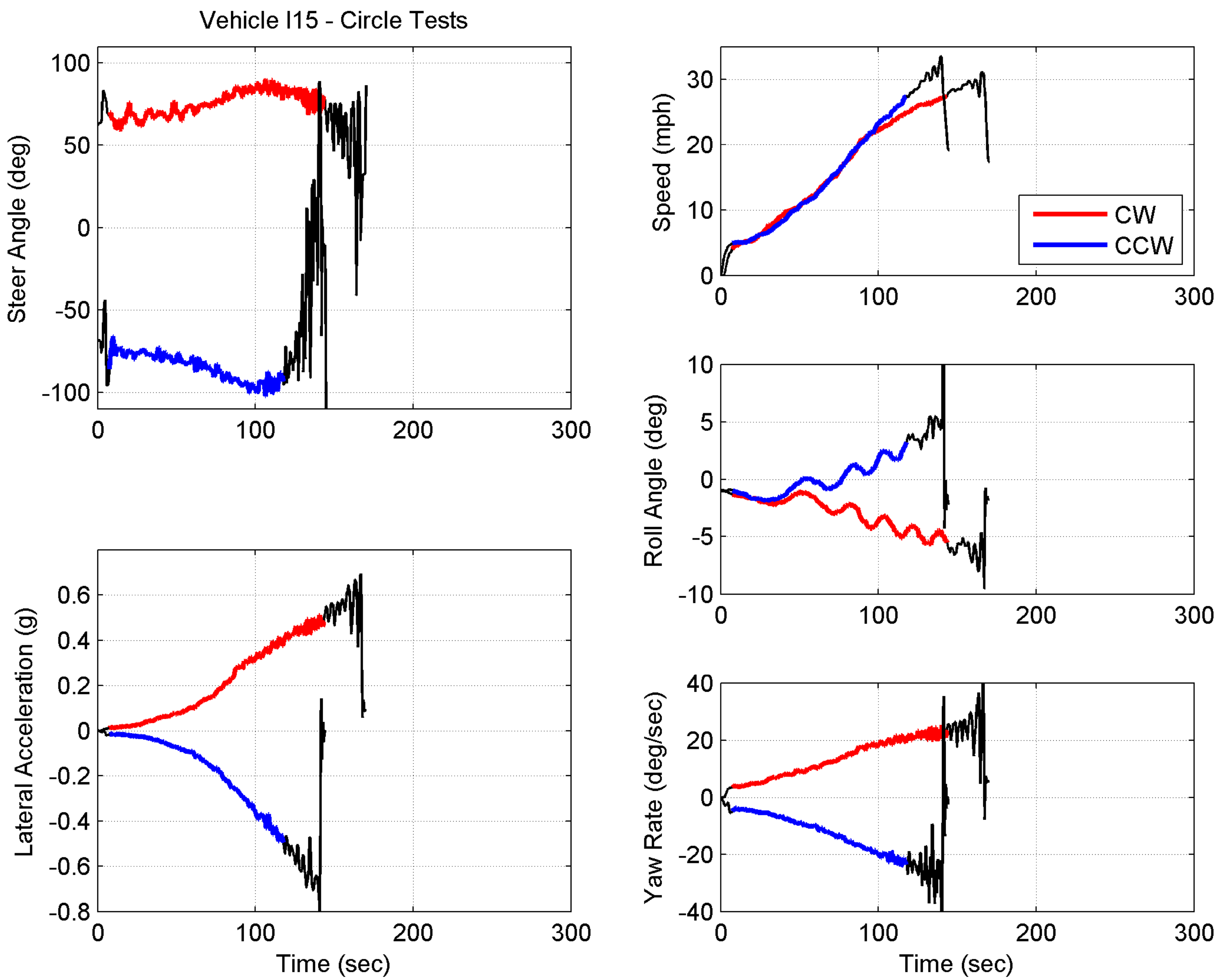

Vehicle H15 - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle H15 - Circle Tests
Handwheel Steer Angle (deg)
250
200
150
100
50
0
-50
-100
-150
-200
-250
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)

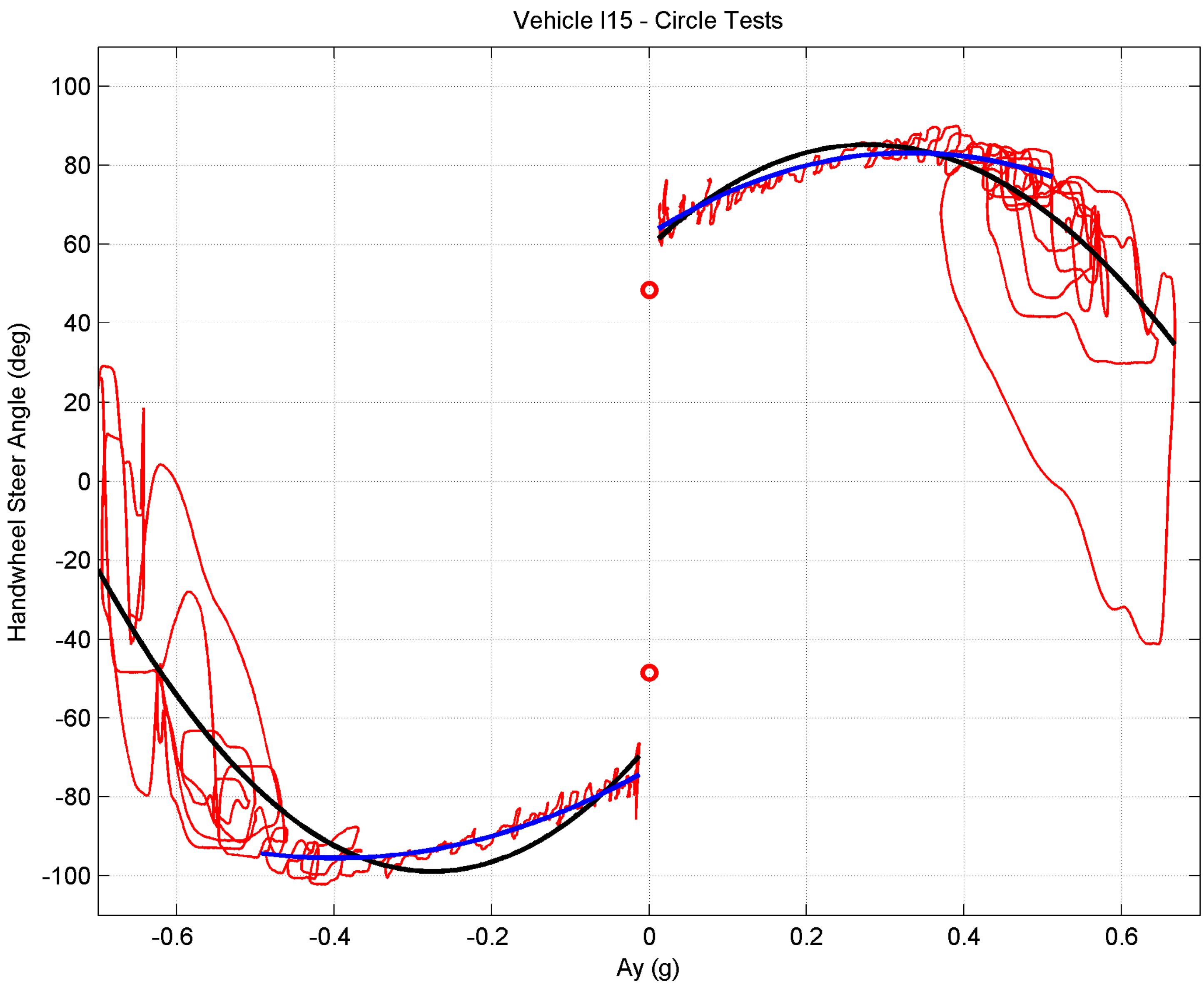


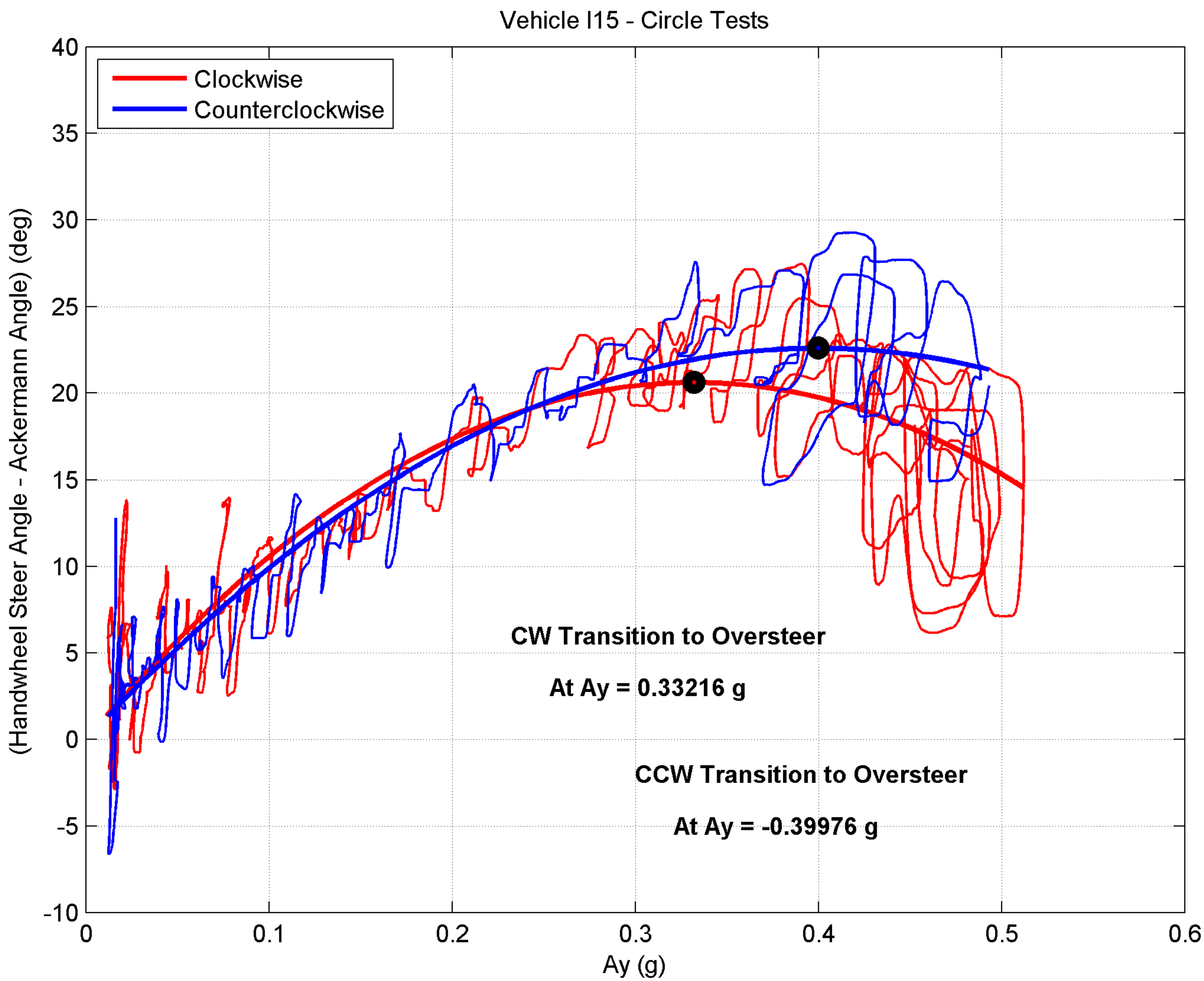
Vehicle H15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
100
90
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
Ay (g)

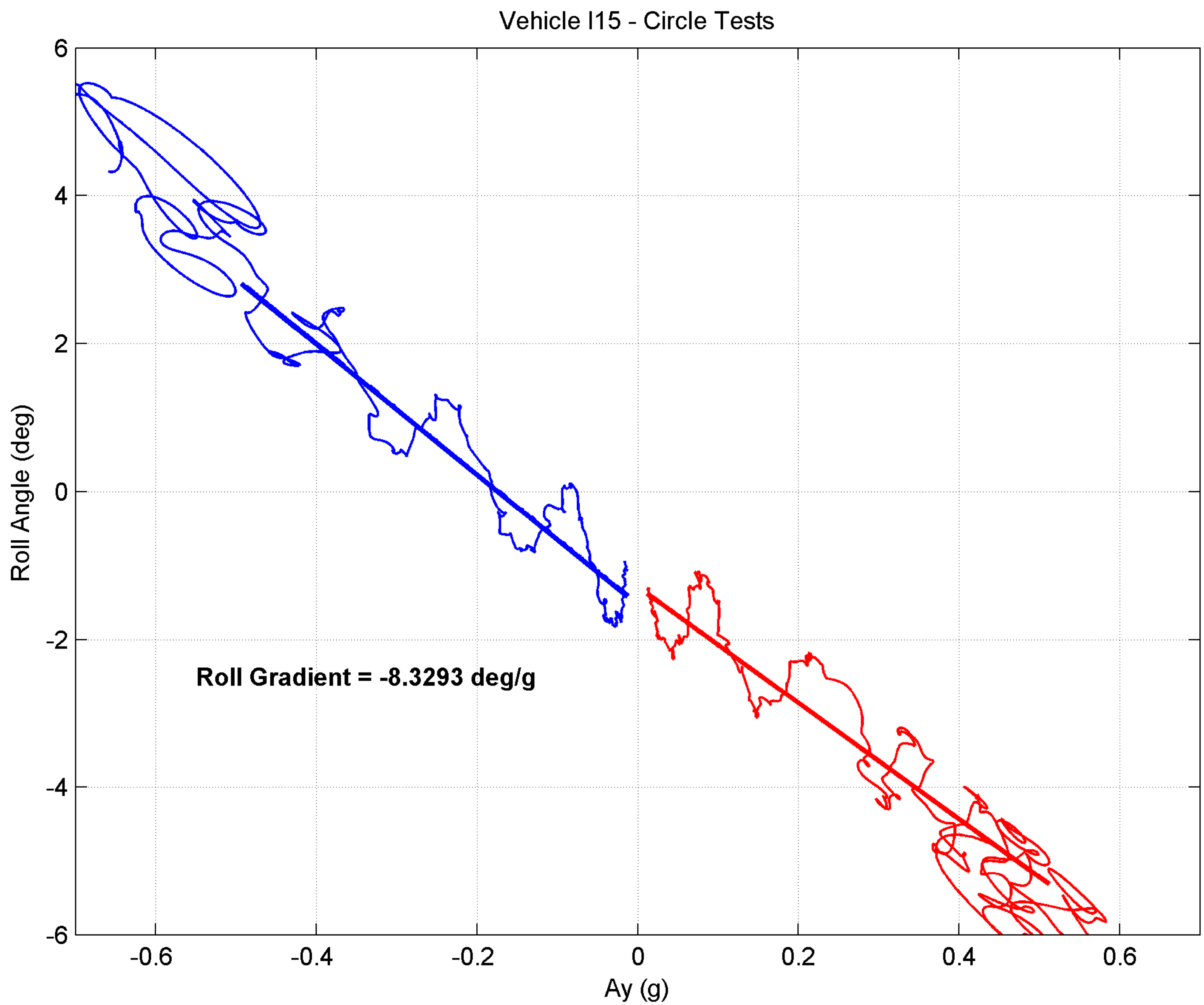

Vehicle H15 - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -10.5788 deg/g
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

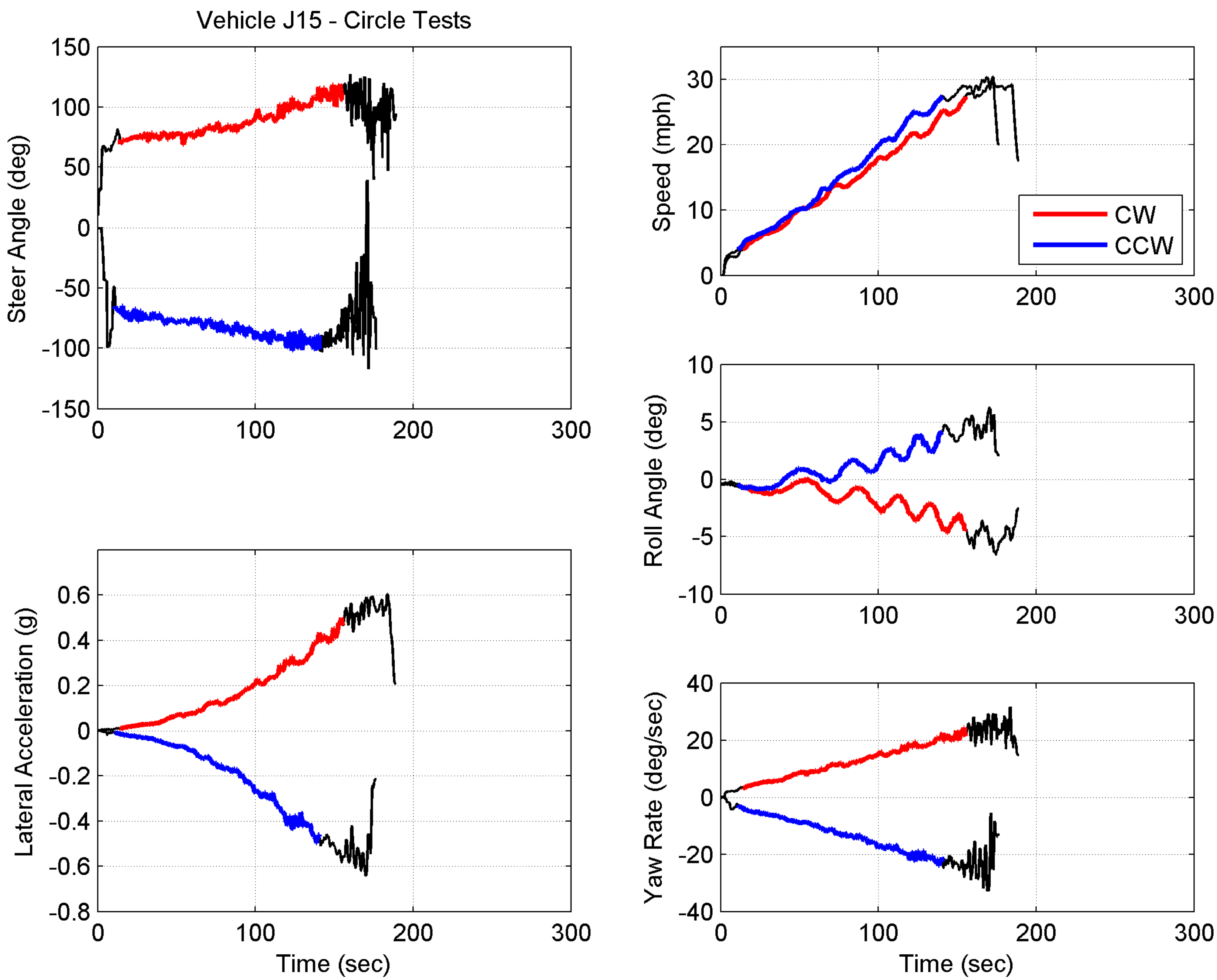


Vehicle I15 - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

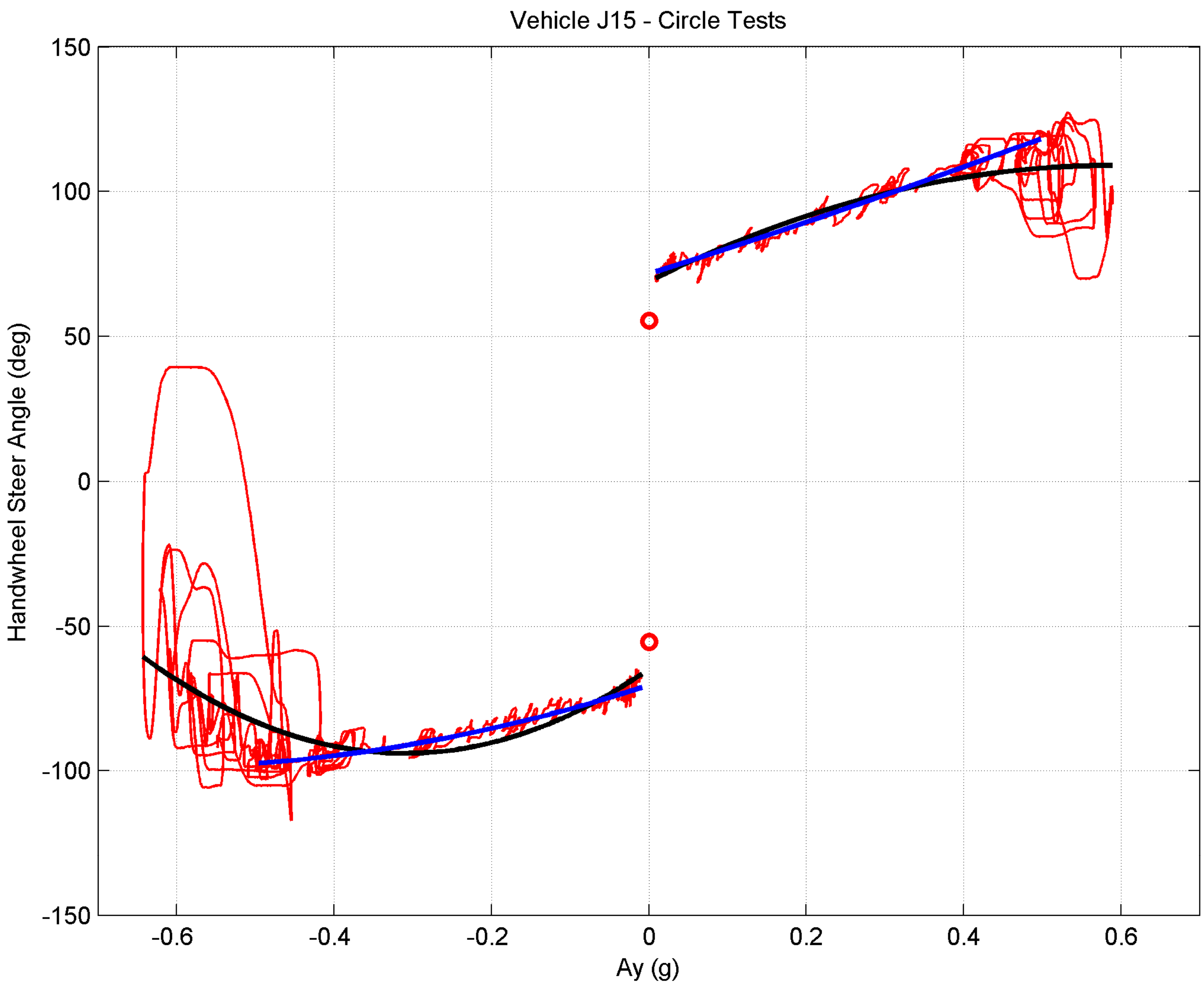

Vehicle I15 - Circle Tests
Handwheel Steer Angle (deg)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)


Vehicle I15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
40
35
30
25
20
15
10
5
0
-5
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
CW Transition to Oversteer
At Ay = 0.33216 g
CCW Transition to Oversteer
At Ay = -0.39976 g

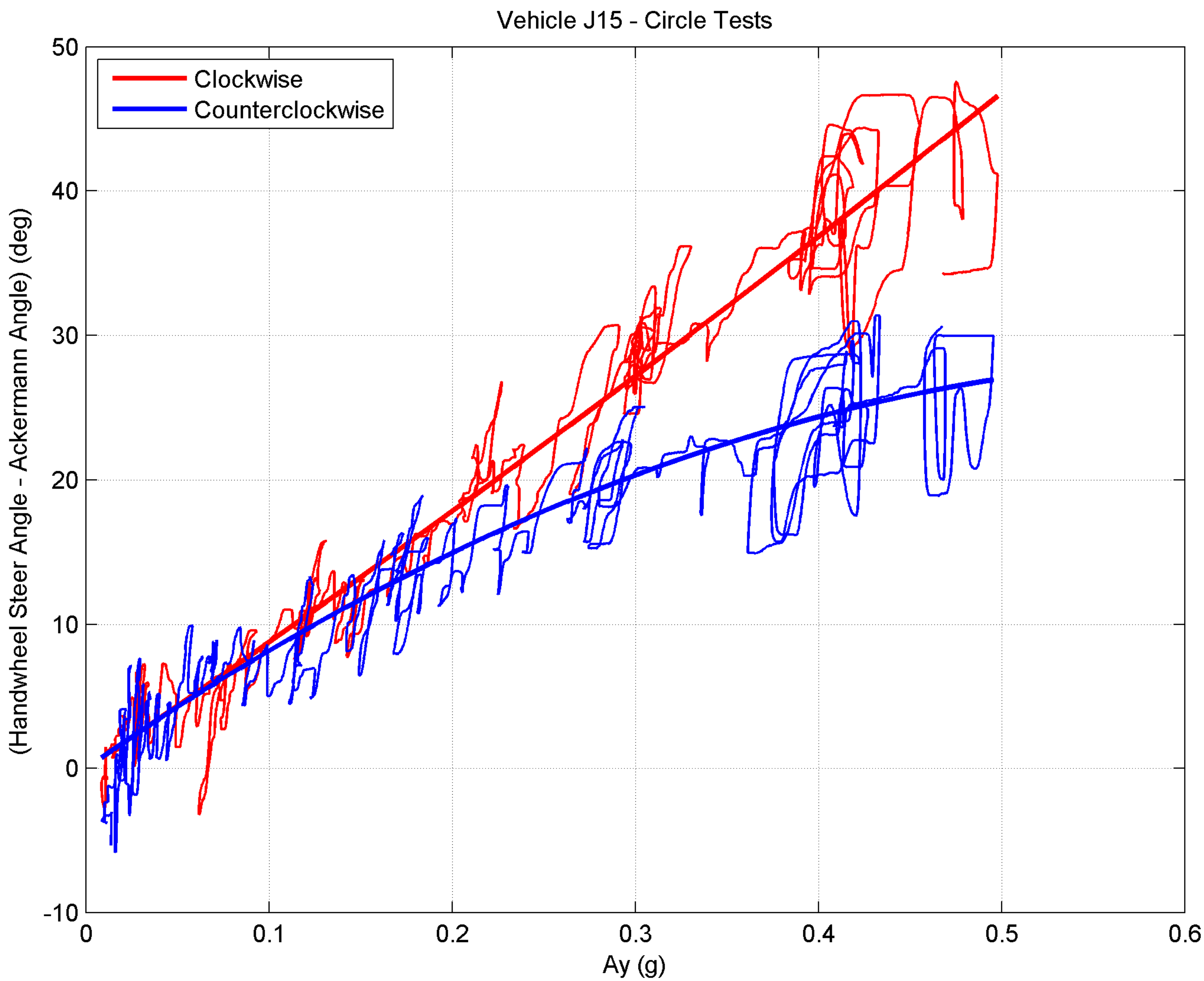

Vehicle I15 - Circle Tests
6
4
2
0
-2
-4
-6
Roll Angle (deg)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)
Roll Gradient = -8.3293 deg/g

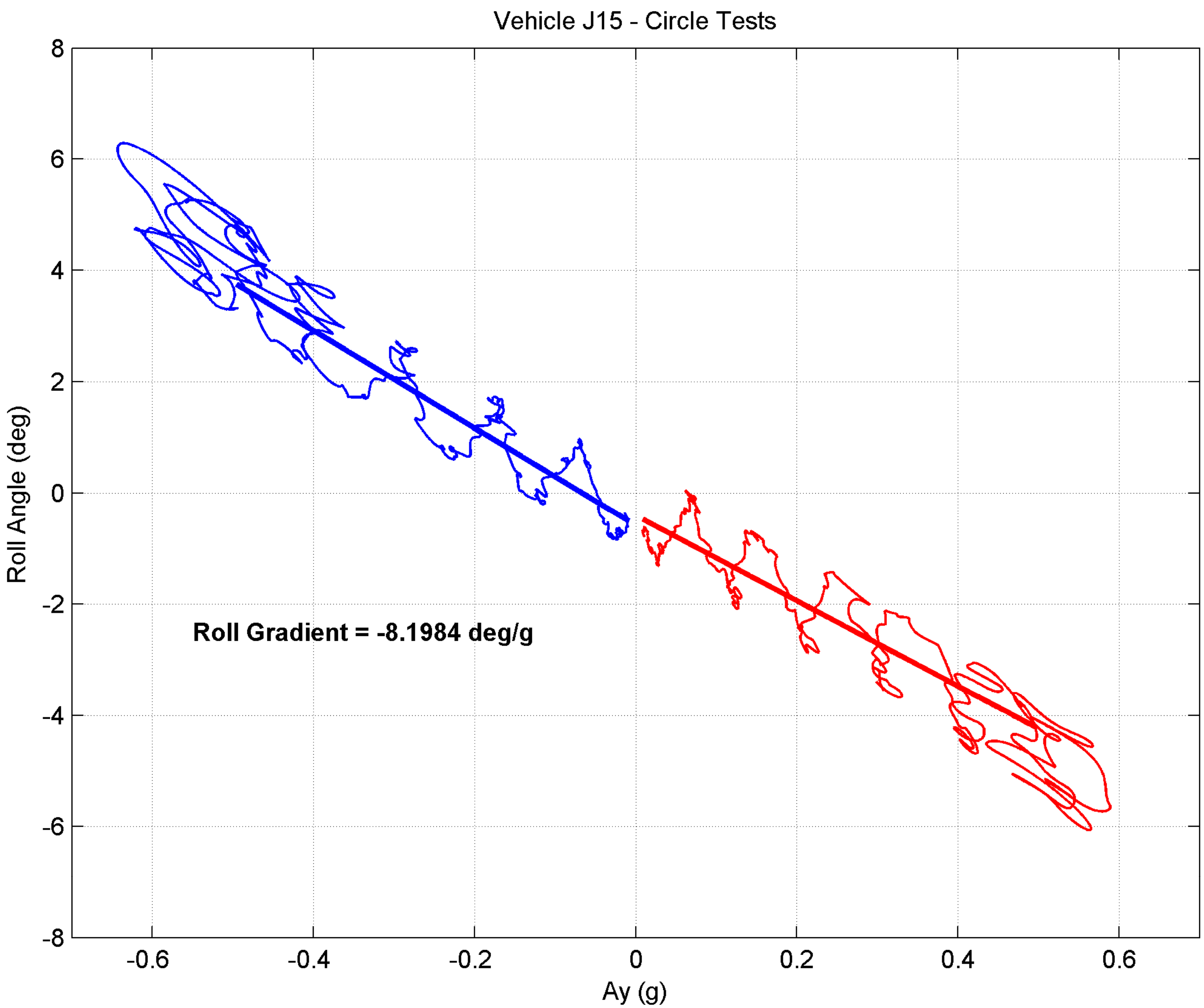


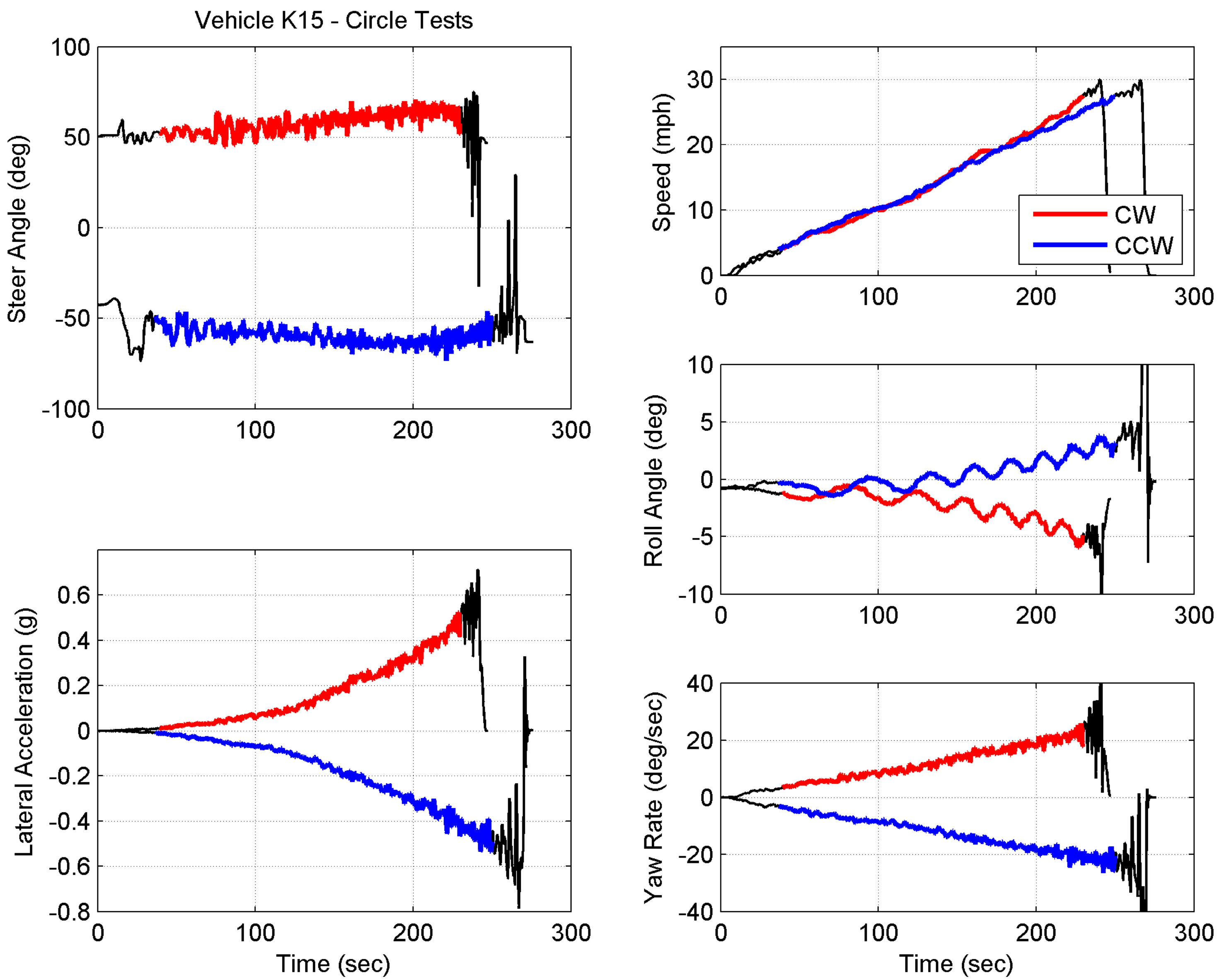
Vehicle J15 - Circle Tests
Steer Angle (deg)
150
100
50
0
-50
-100
-150
0
100
200
300
Speed (mph)
30
20
10
0
CW
CCW
Roll Angle (deg)
10
5
0
-5
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

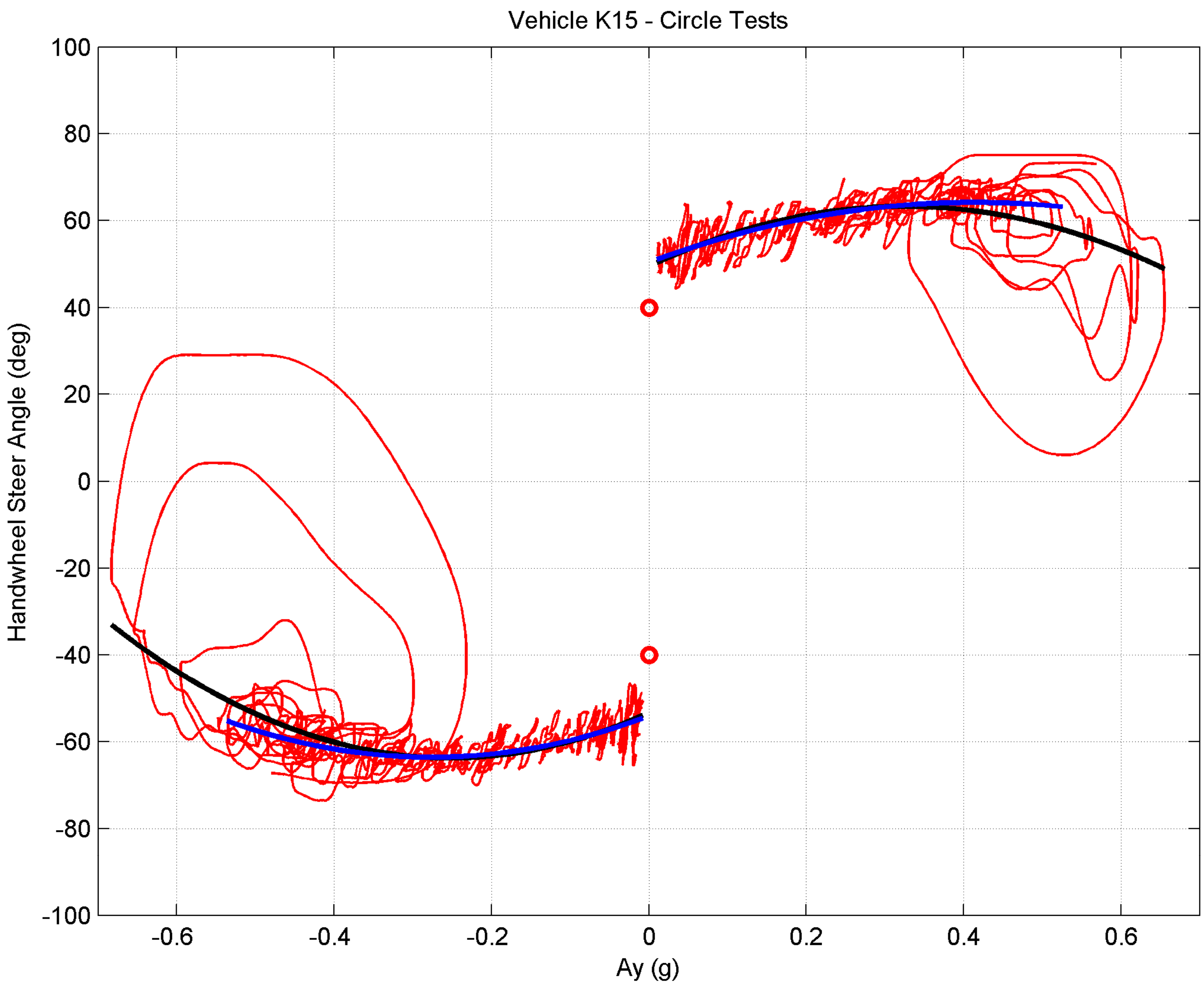


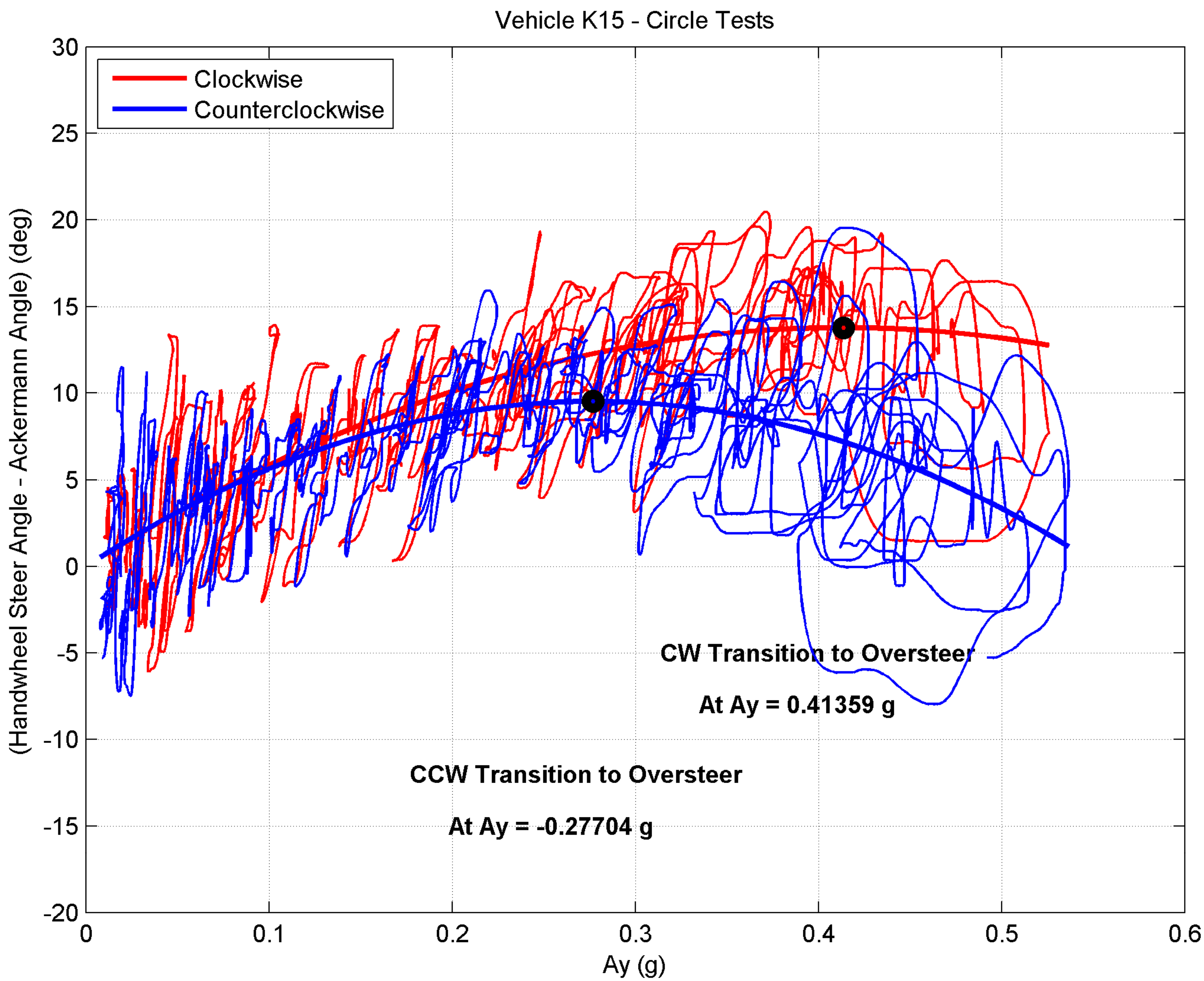
Vehicle J15 - Circle Tests
150
100
50
0
-50
-100
-150
Handwheel Steer Angle (deg)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)


Vehicle J15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6

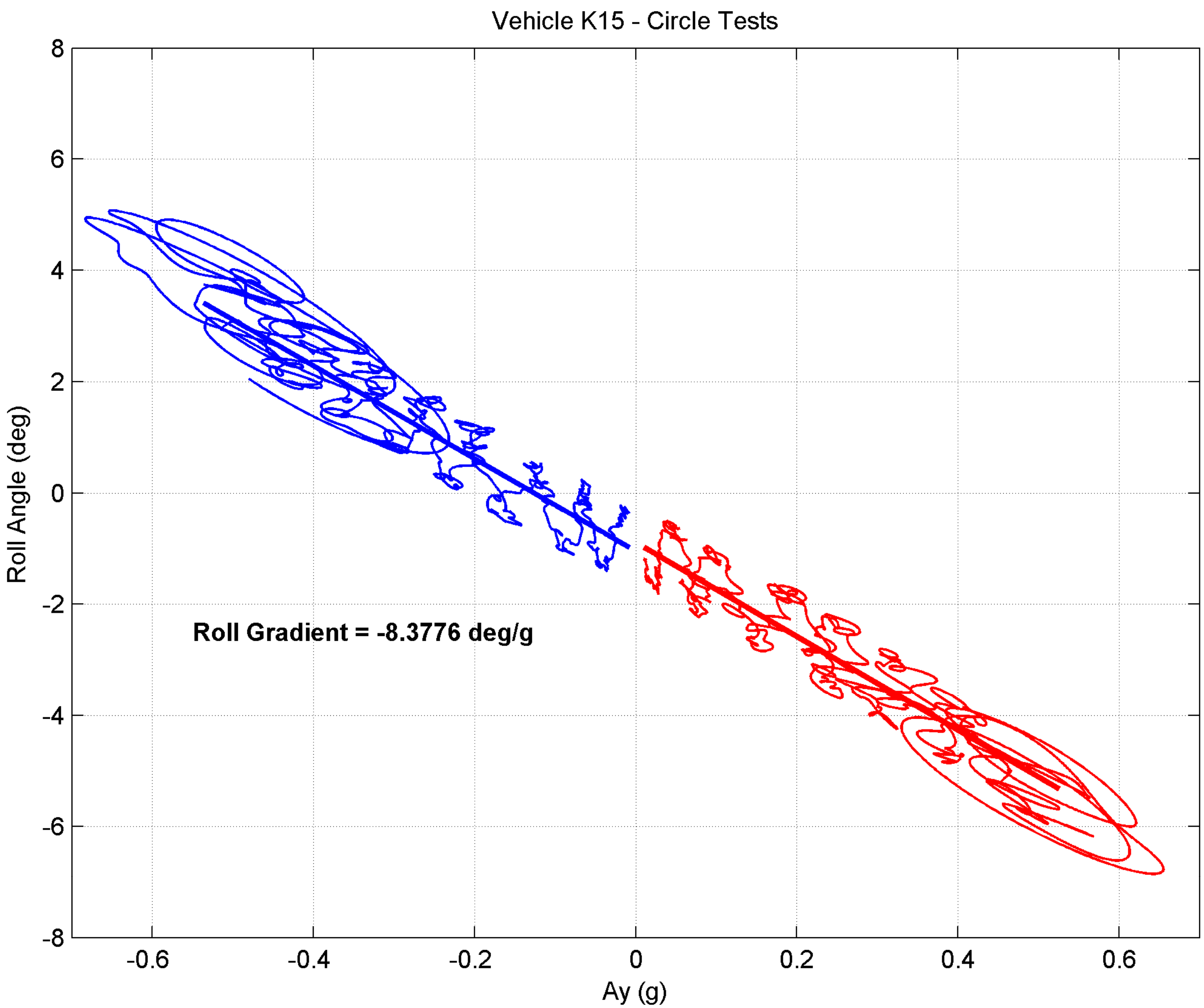

Vehicle J15 - Circle Tests
Roll Angle (deg)
Ay (g)
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Roll Gradient = -8.1984 deg/g

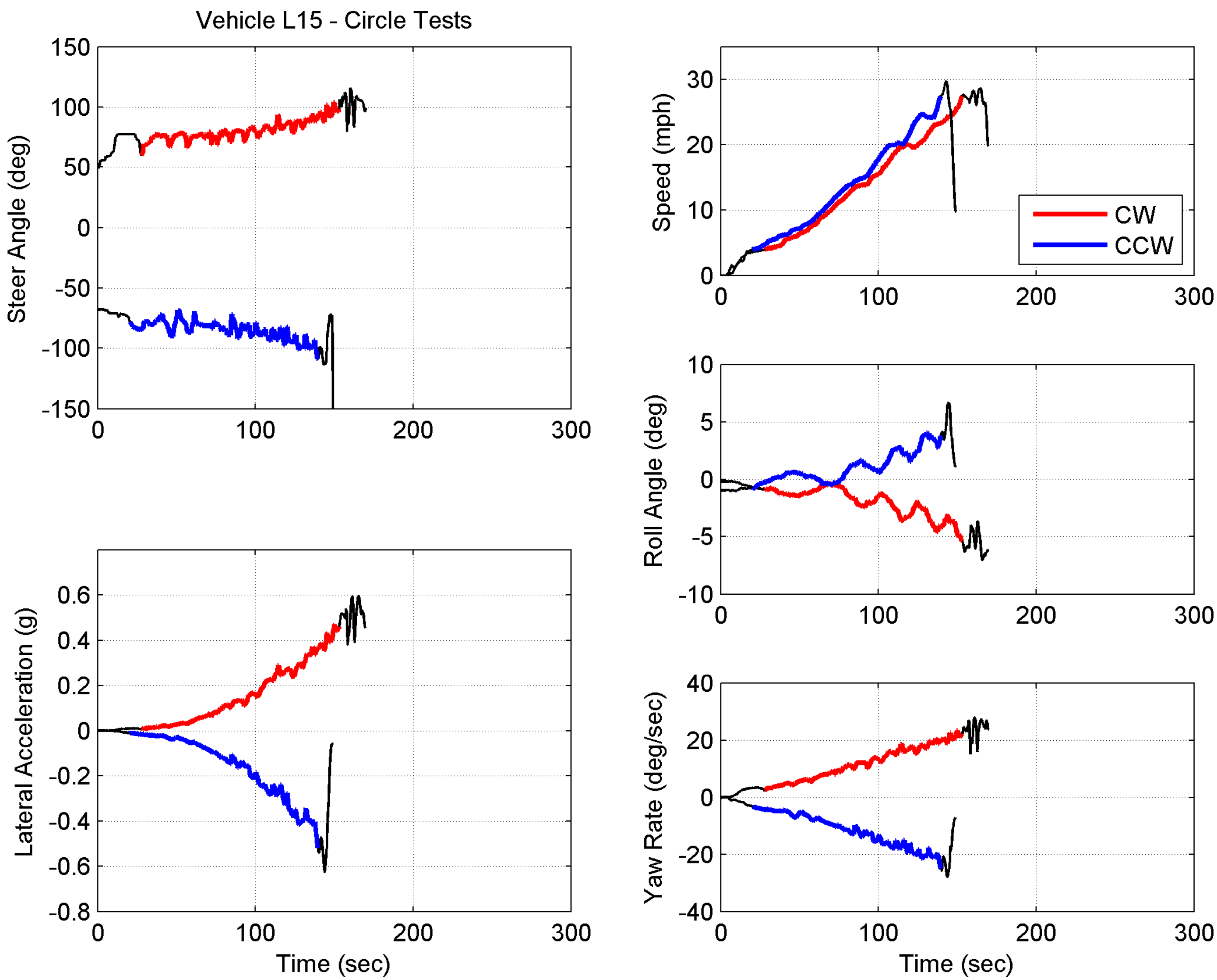

Vehicle K15 - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
100
50
0
-50
-100
30
20
10
0
10
5
0
-5
-10
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
40
20
0
-20
-40
0
100
200
300

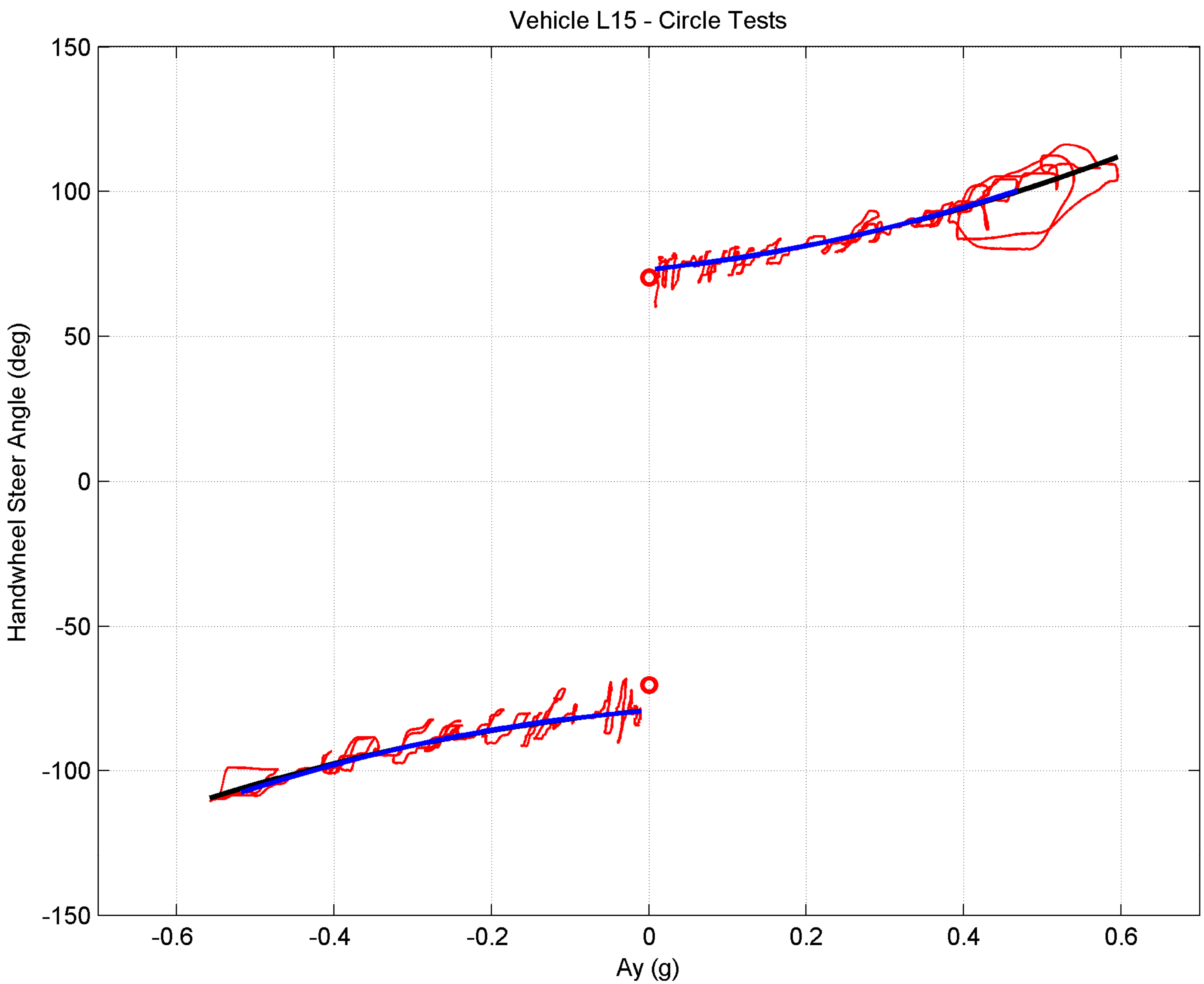

Vehicle K15 - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6



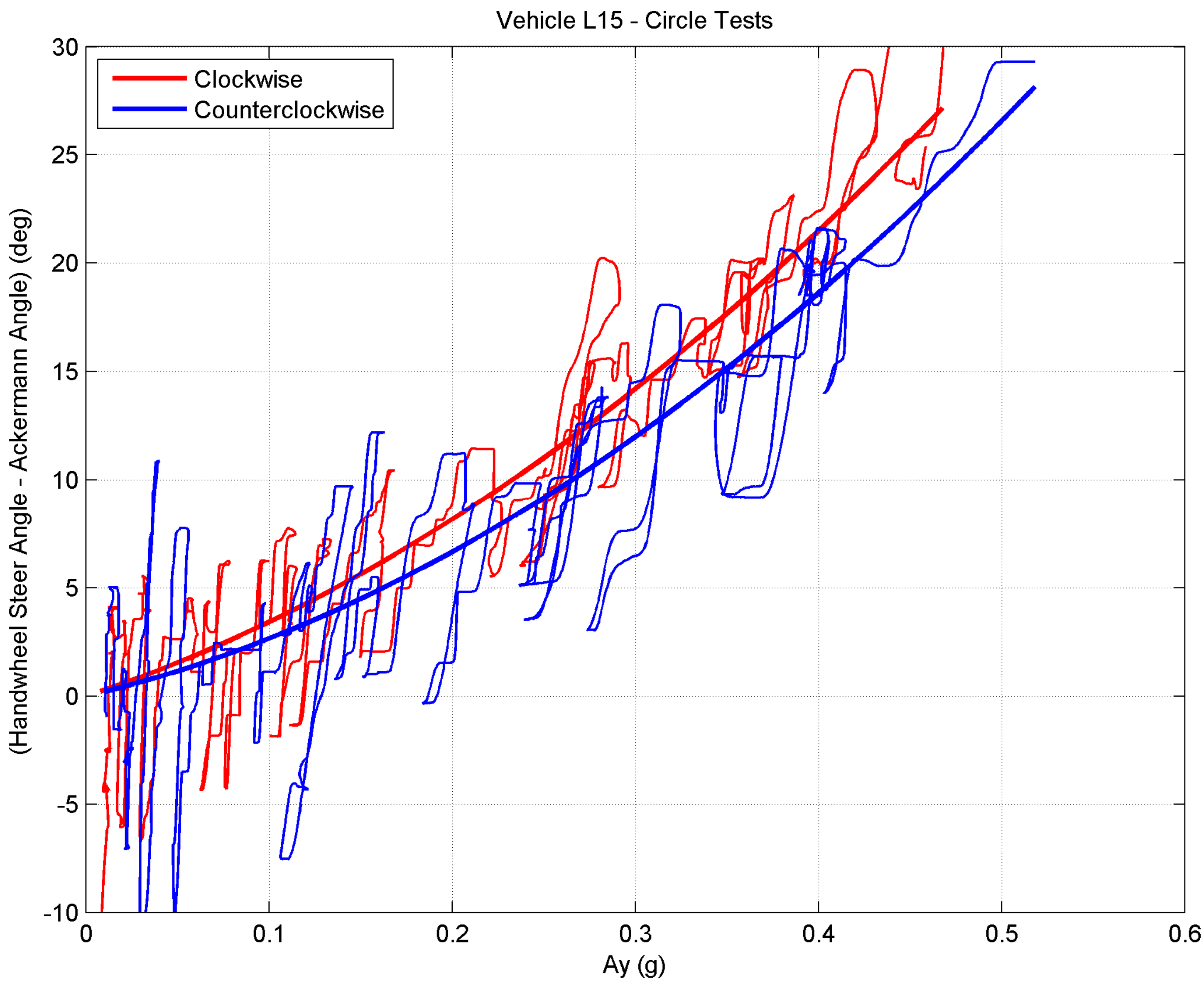
Vehicle K15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
CW Transition to Oversteer
At Ay = 0.41359 g
CCW Transition to Oversteer
At Ay = -0.27704 g
30
25
20
15
10
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
0.4
0.5
0.6


Vehicle K15 - Circle Tests
8
6
4
2
0
-2
-4
-6
-8
Roll Angle (deg)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)
Roll Gradient = -8.3776 deg/g

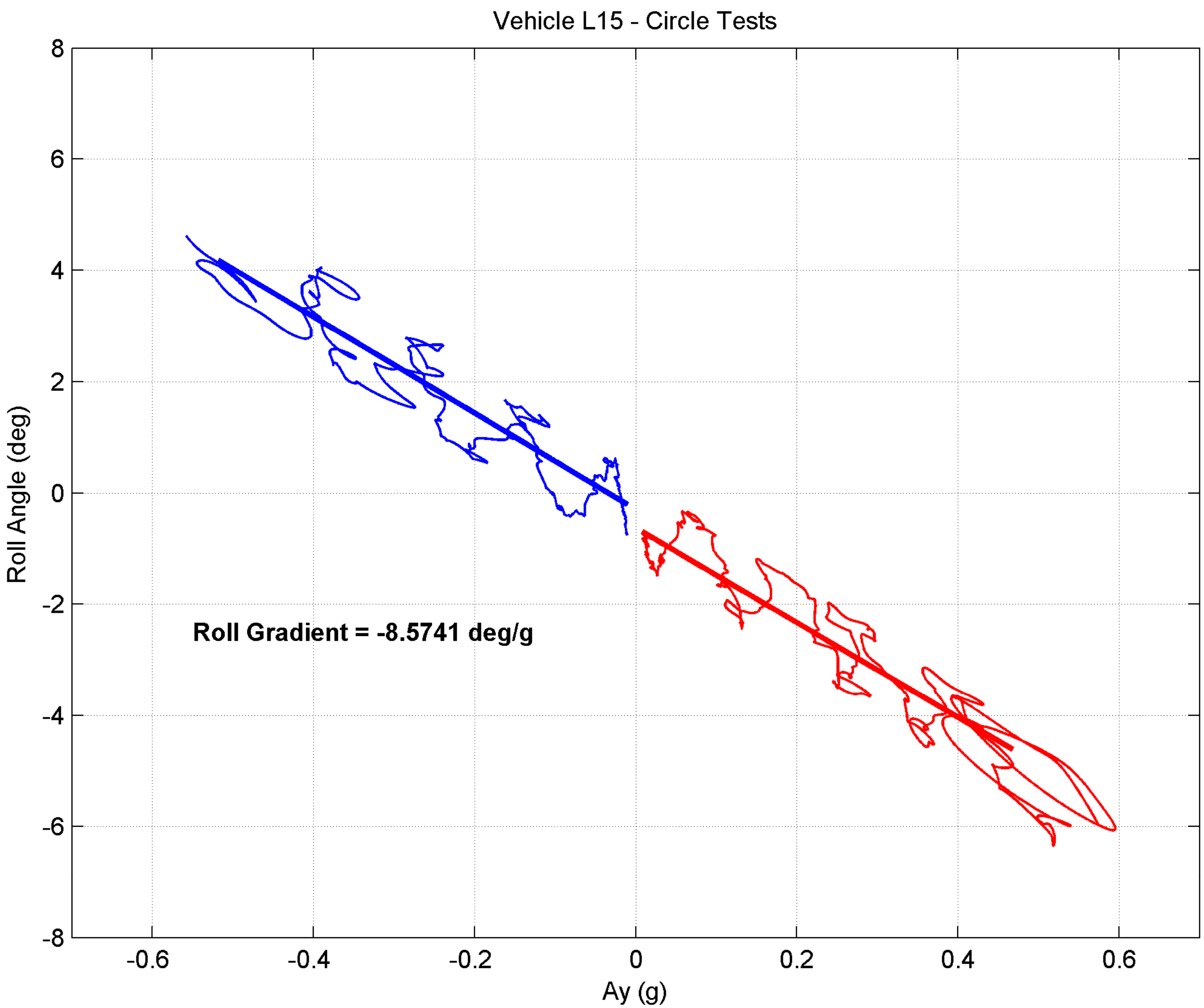

Vehicle L15 - Circle Tests
Steer Angle (deg)
150
100
50
0
-50
-100
-150
0
100
200
300
Speed (mph)
30
20
10
CW
CCW
Roll Angle (deg)
10
5
-5
-10
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
40
-20
-40
Time (sec)

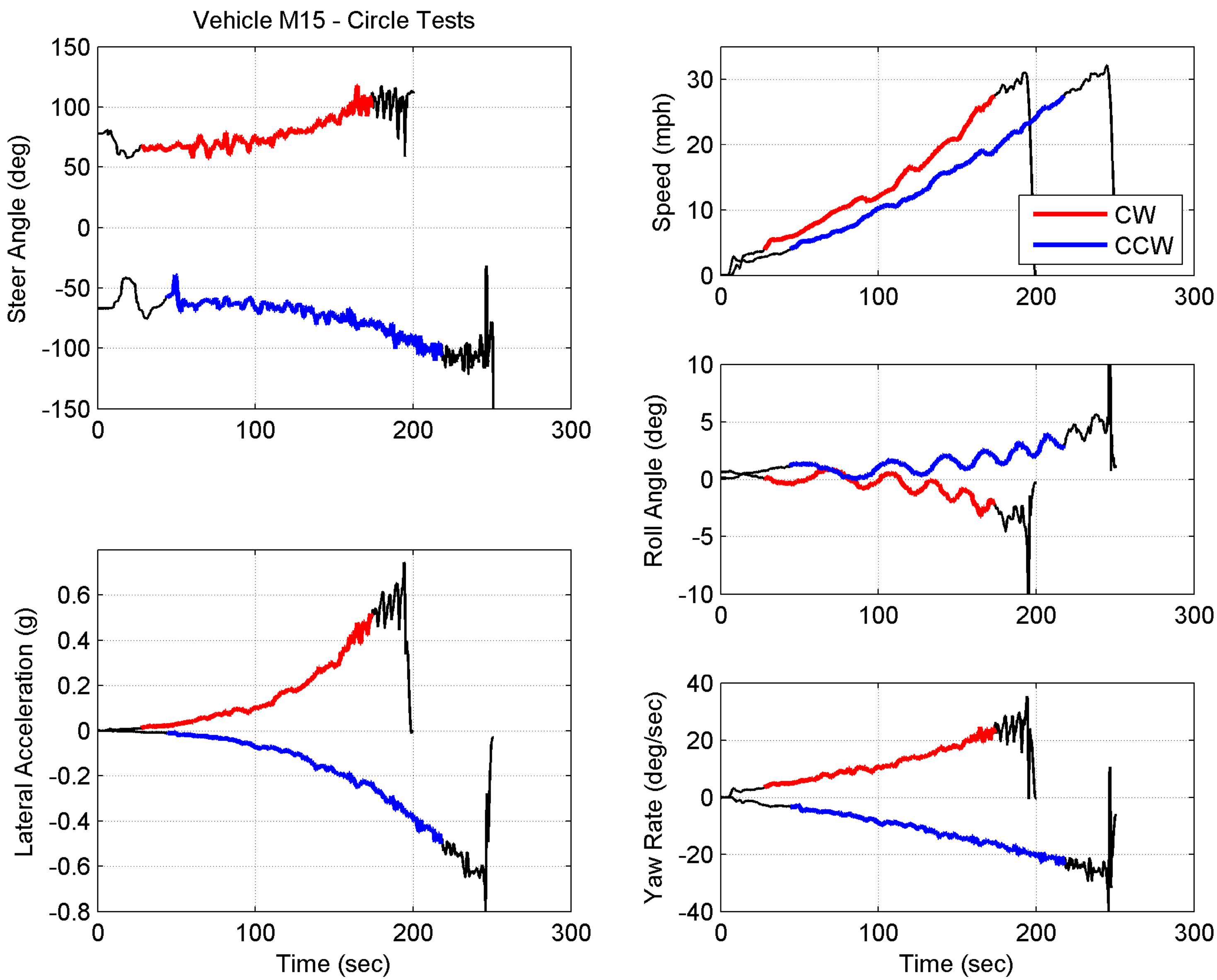


Vehicle L15 - Circle Tests
150
100
50
0
-50
-100
-150
Handwheel Steer Angle (deg)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)

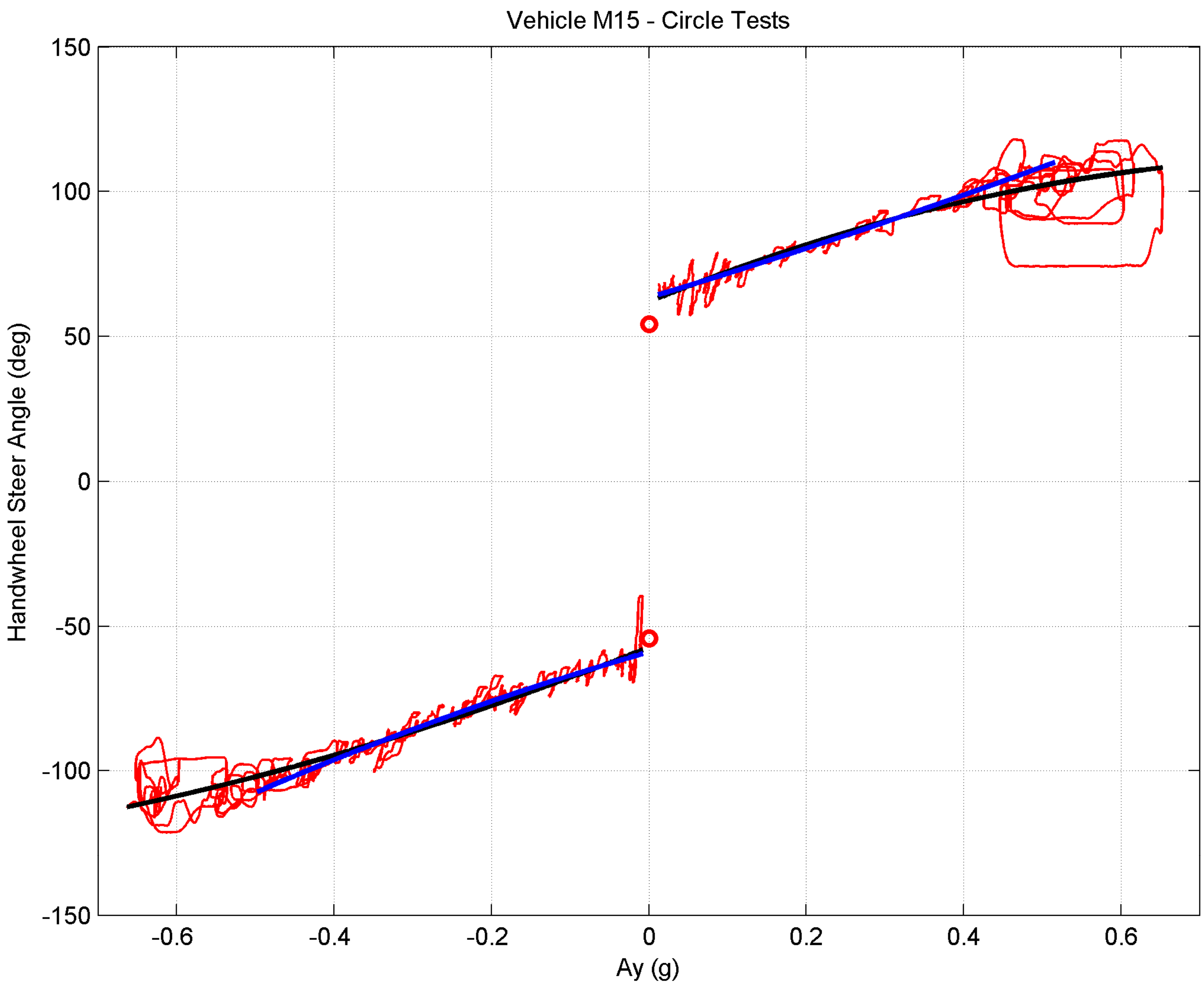


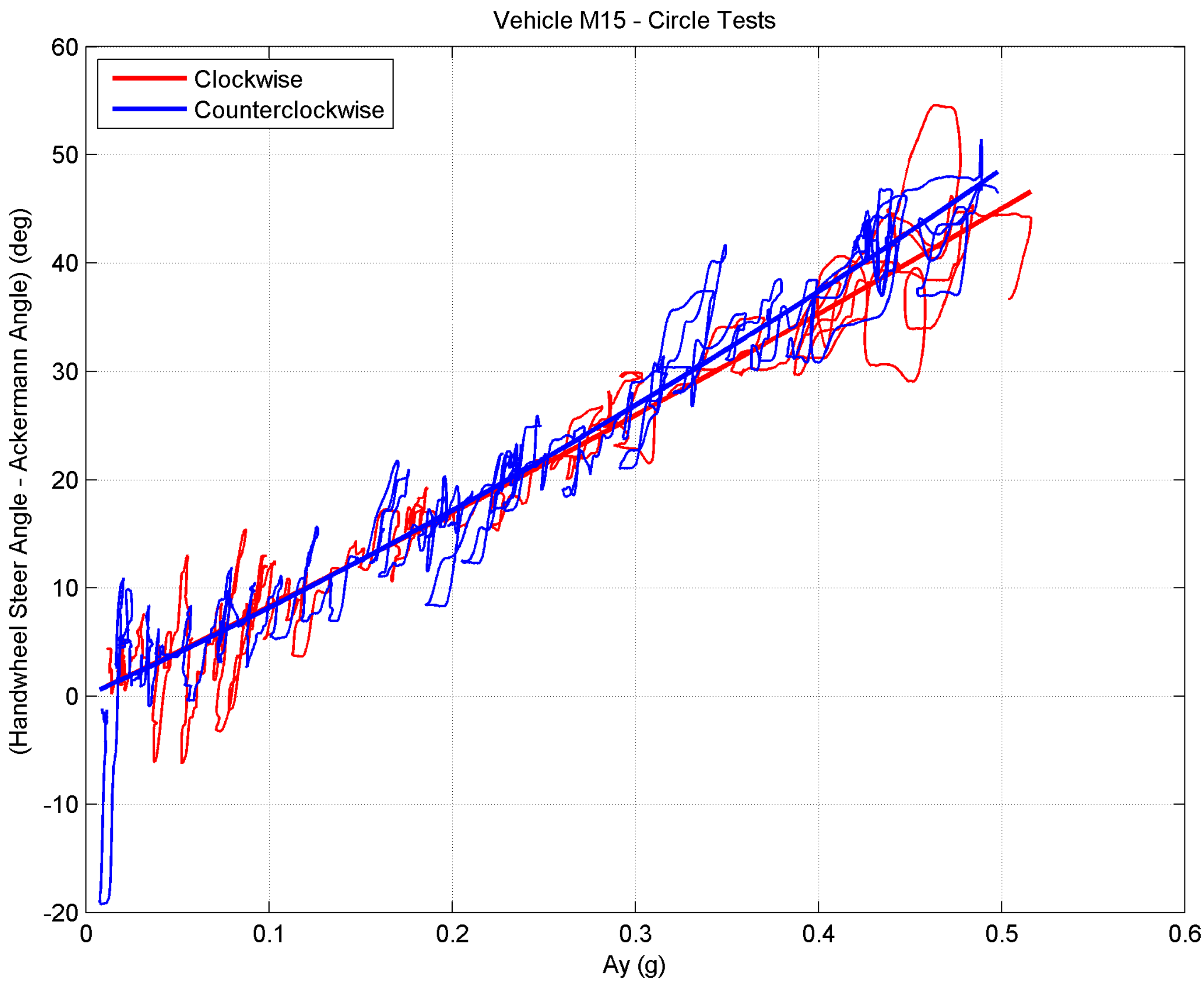
Vehicle L15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
30
25
20
15
10
5
0
-5
-10
0
0.1
0.2
0.3
0.4
0.5
0.6

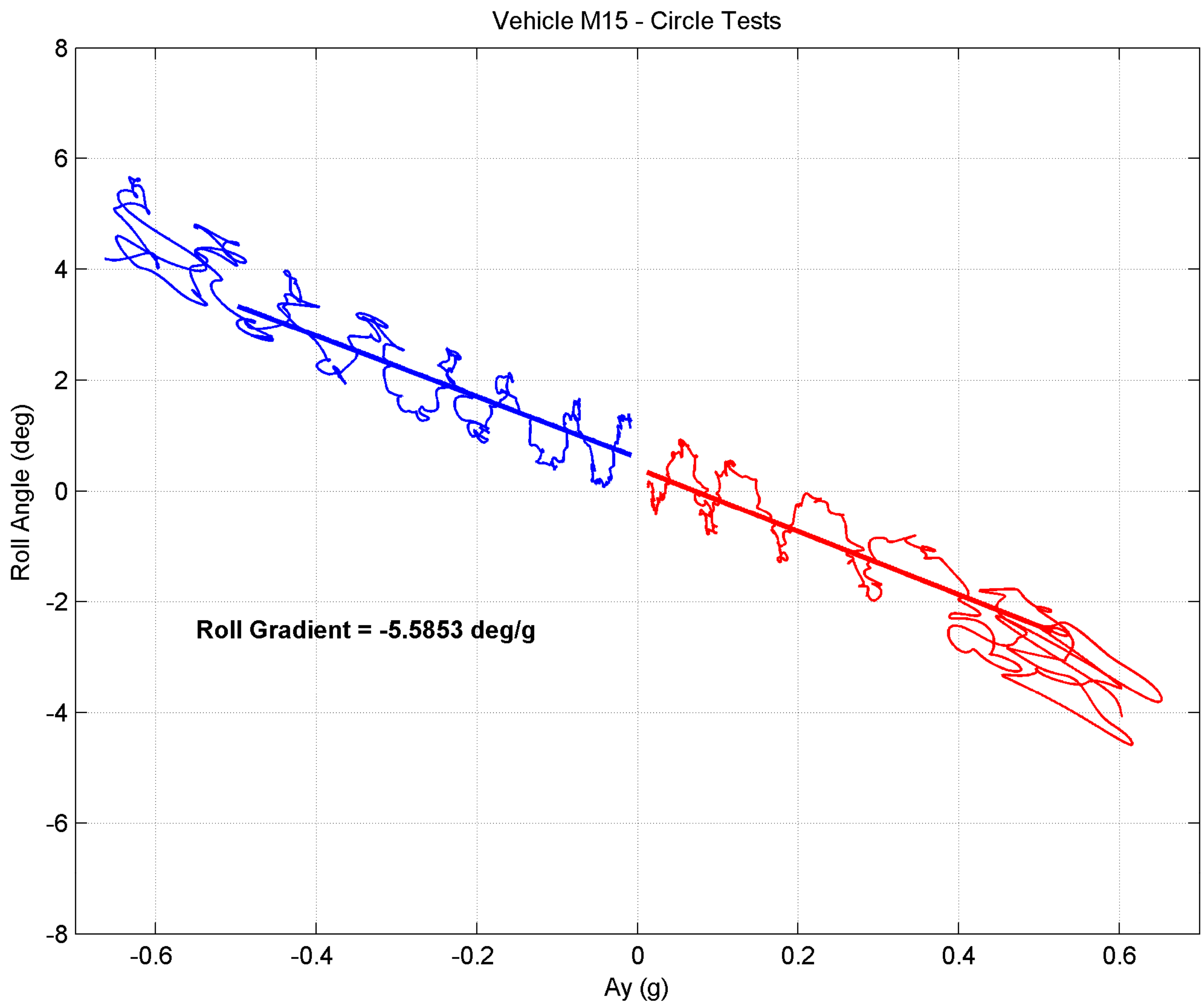

Vehicle L15 - Circle Tests
8
6
4
2
0
-2
-4
-6
-8
Roll Angle (deg)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)
Roll Gradient = -8.5741 deg/g

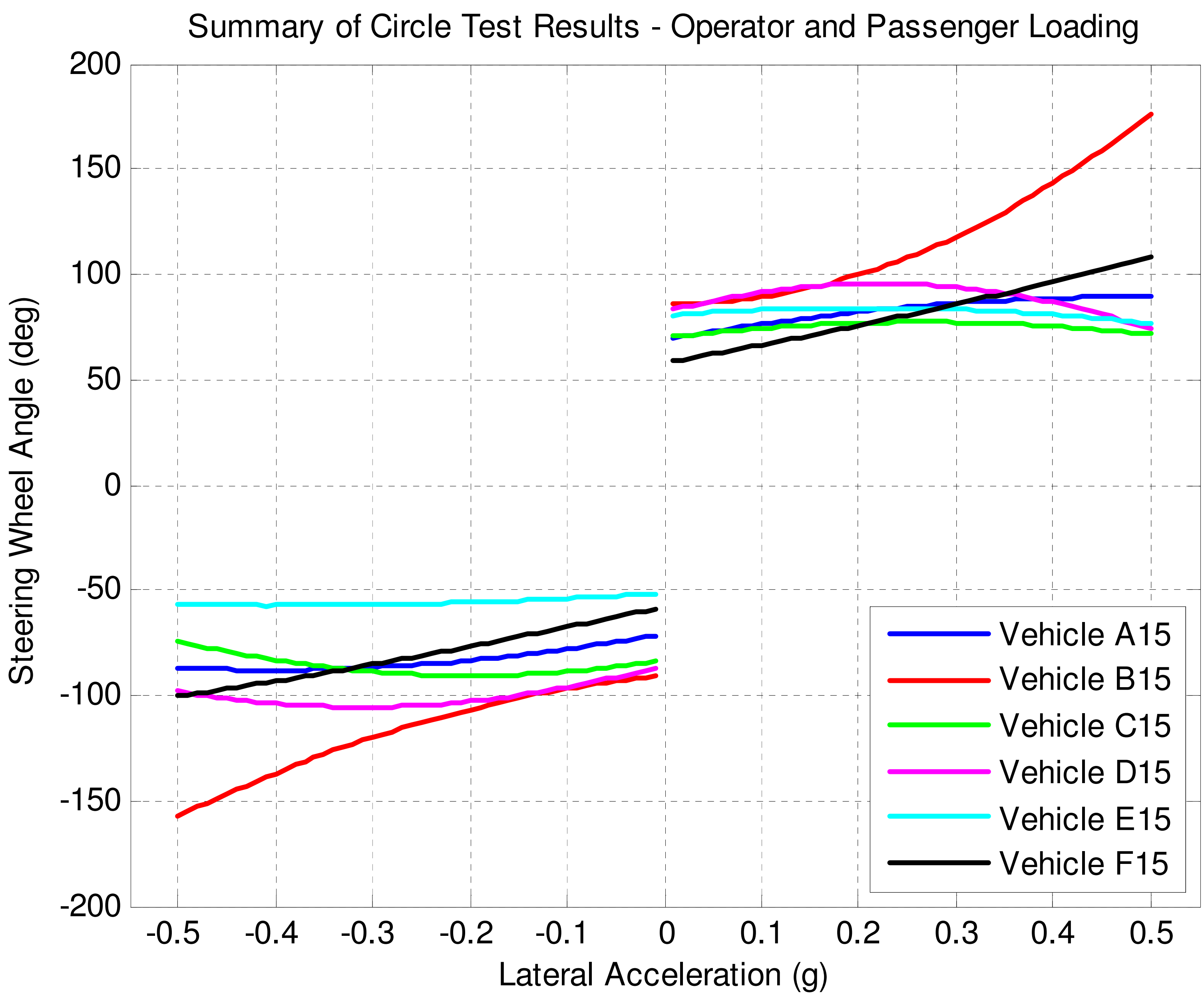


Vehicle M15 - Circle Tests
Steer Angle (deg)
150
100
50
0
-50
-100
-150
0
100
200
300
Speed (mph)
30
20
10
0
CW
CCW
Roll Angle (deg)
10
5
0
-5
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

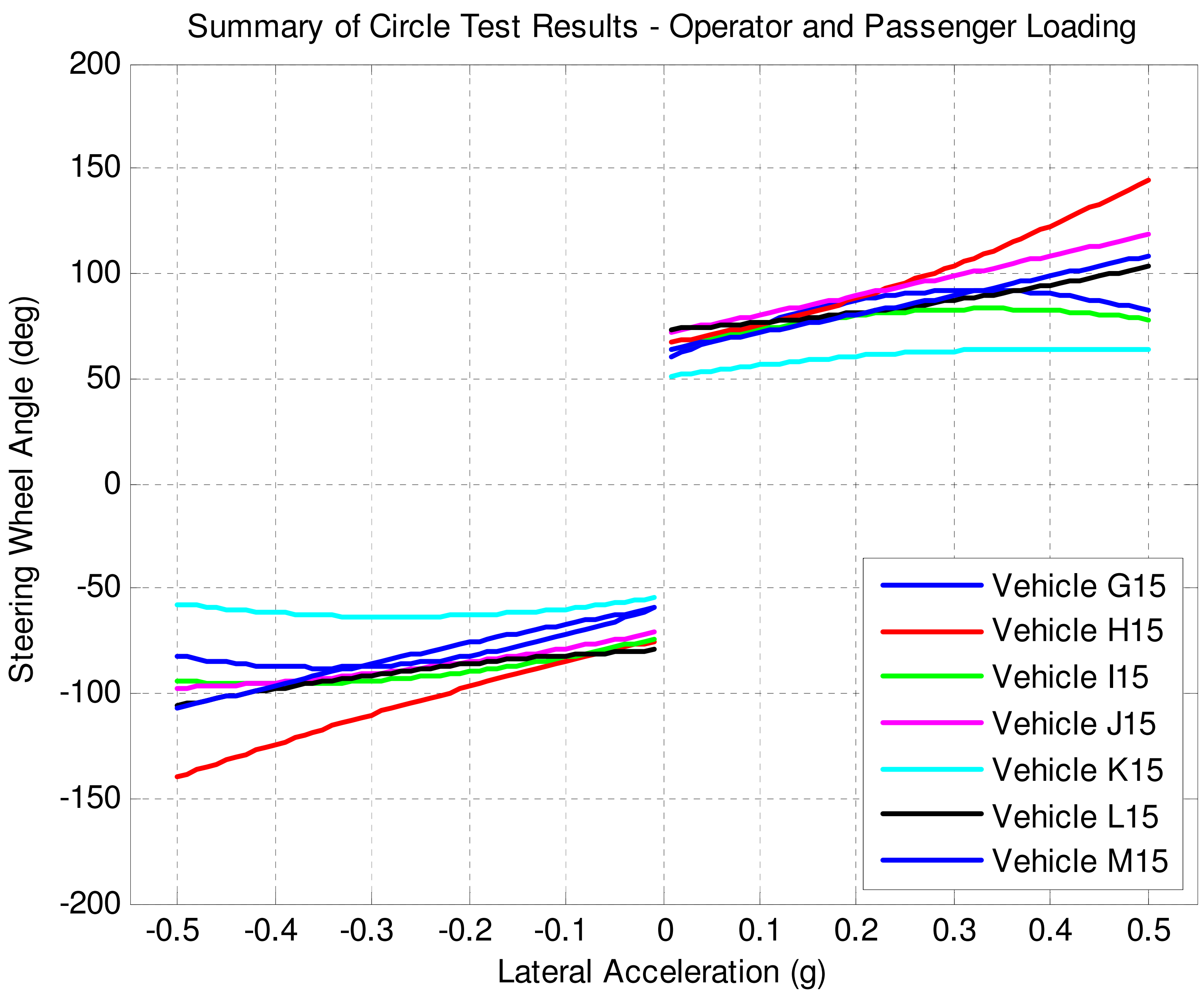

Vehicle M15 - Circle Tests
150
100
50
0
-50
-100
-150
Handwheel Steer Angle (deg)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)


Vehicle M15 - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
60
50
40
30
20
10
0
-10
-20
0
0.1
0.2
0.3
0.4
0.5
0.6

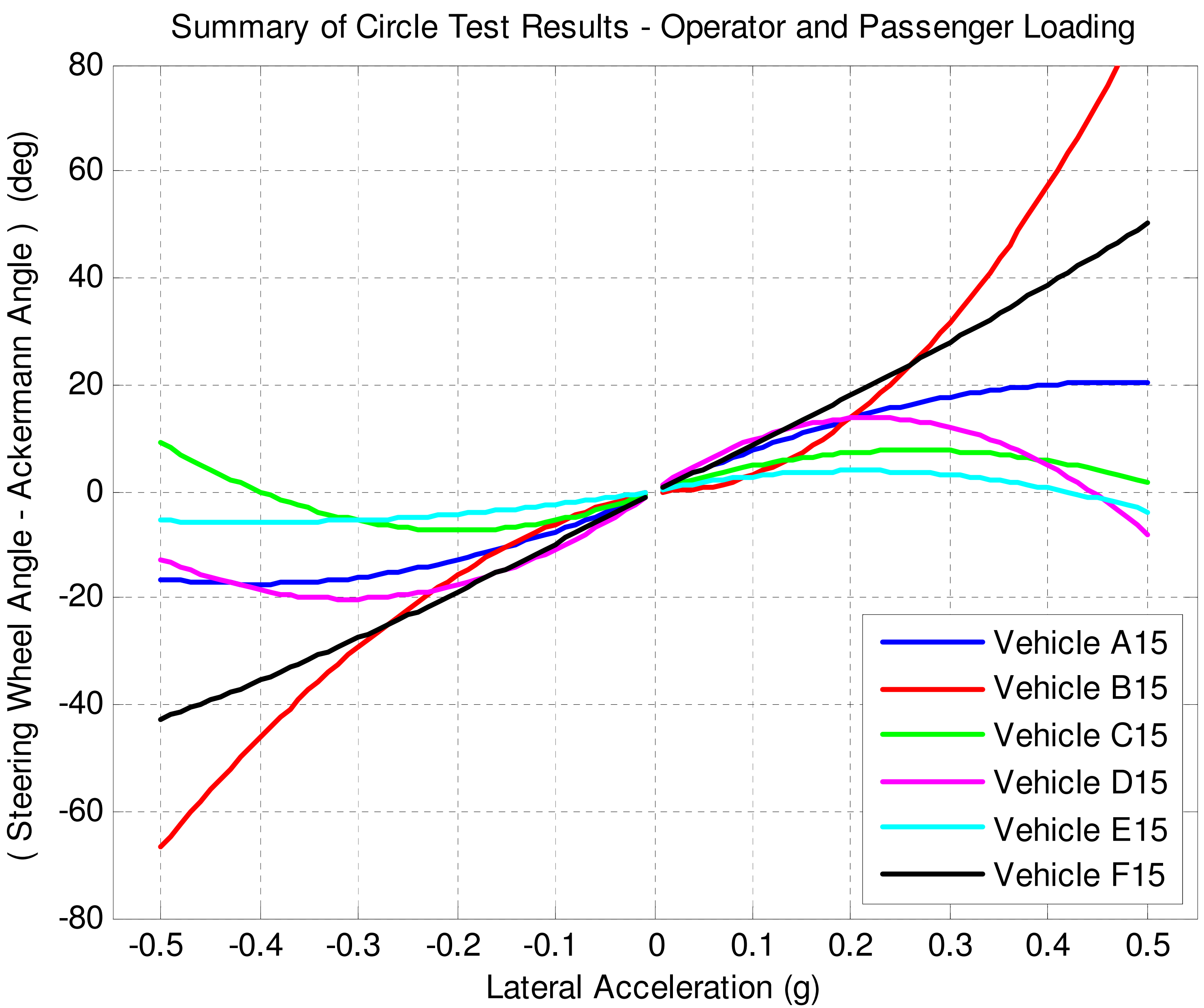

Vehicle M15 - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -5.5853 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6



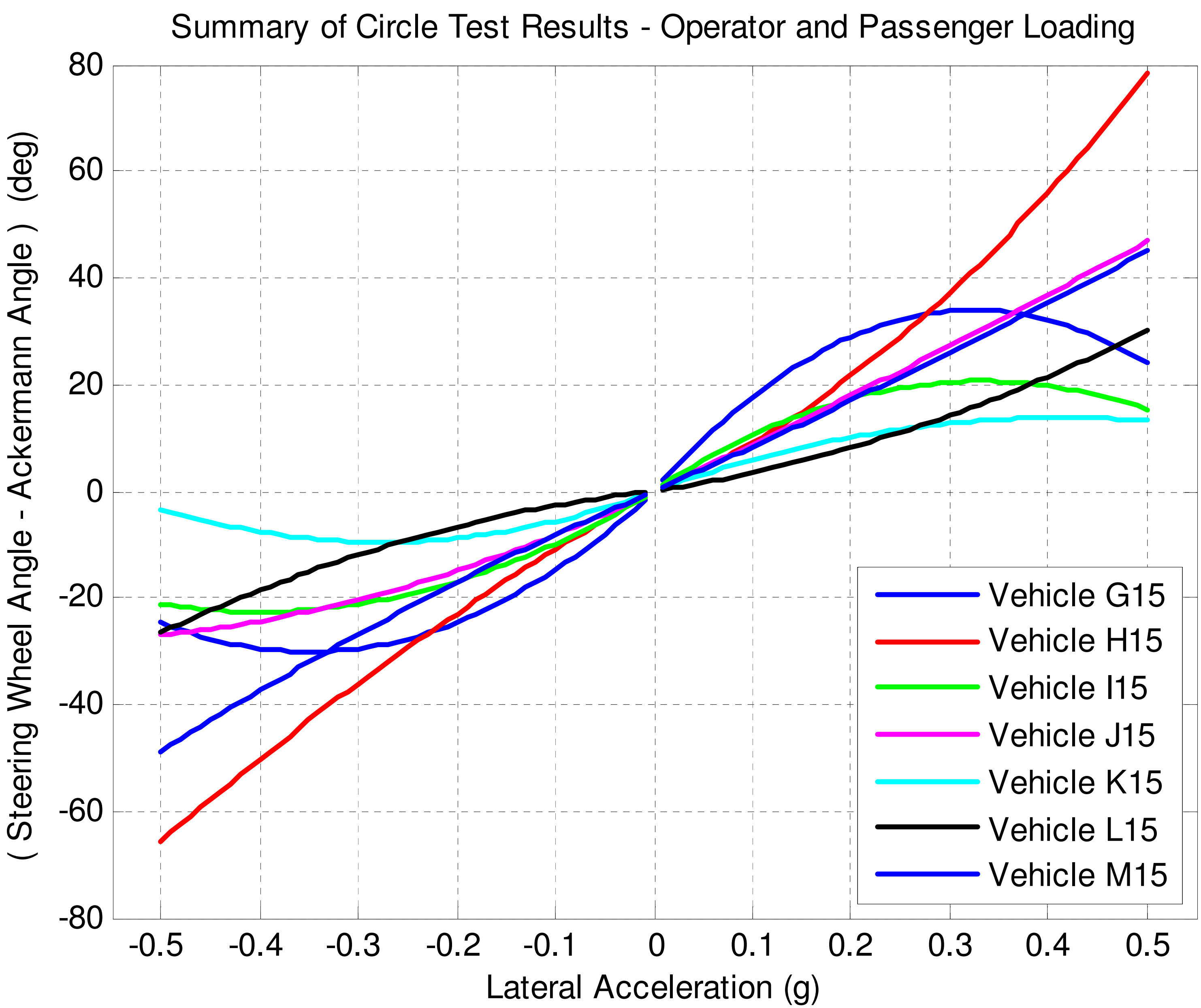
Summary of Circle Test Results - Operator and Passenger Loading
Steering Wheel Angle (deg)
Lateral Acceleration (g)
200
150
100
50
0
-50
-100
-150
-200
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Vehicle A15
Vehicle B15
Vehicle C15
Vehicle D15
Vehicle E15
Vehicle F15

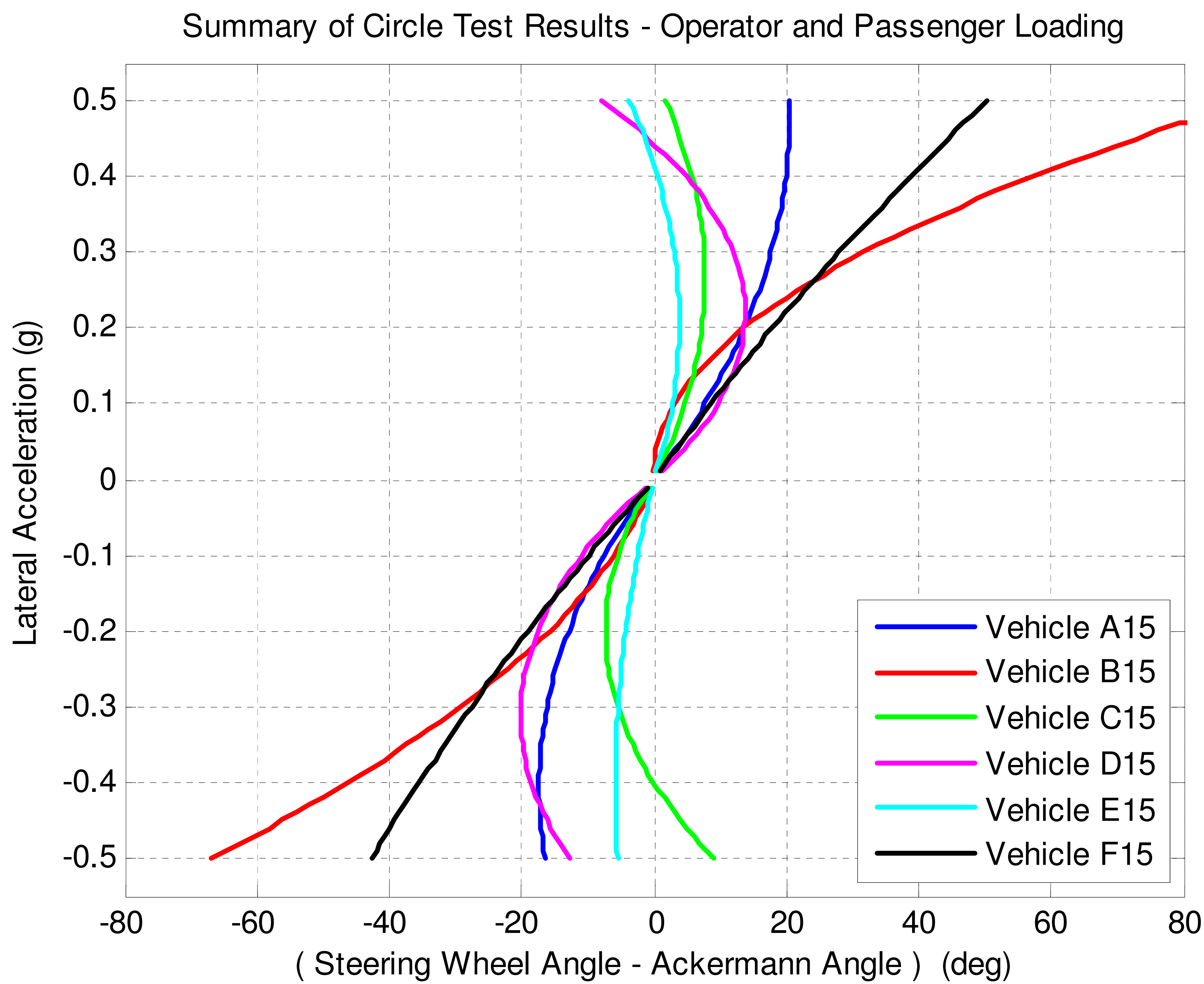


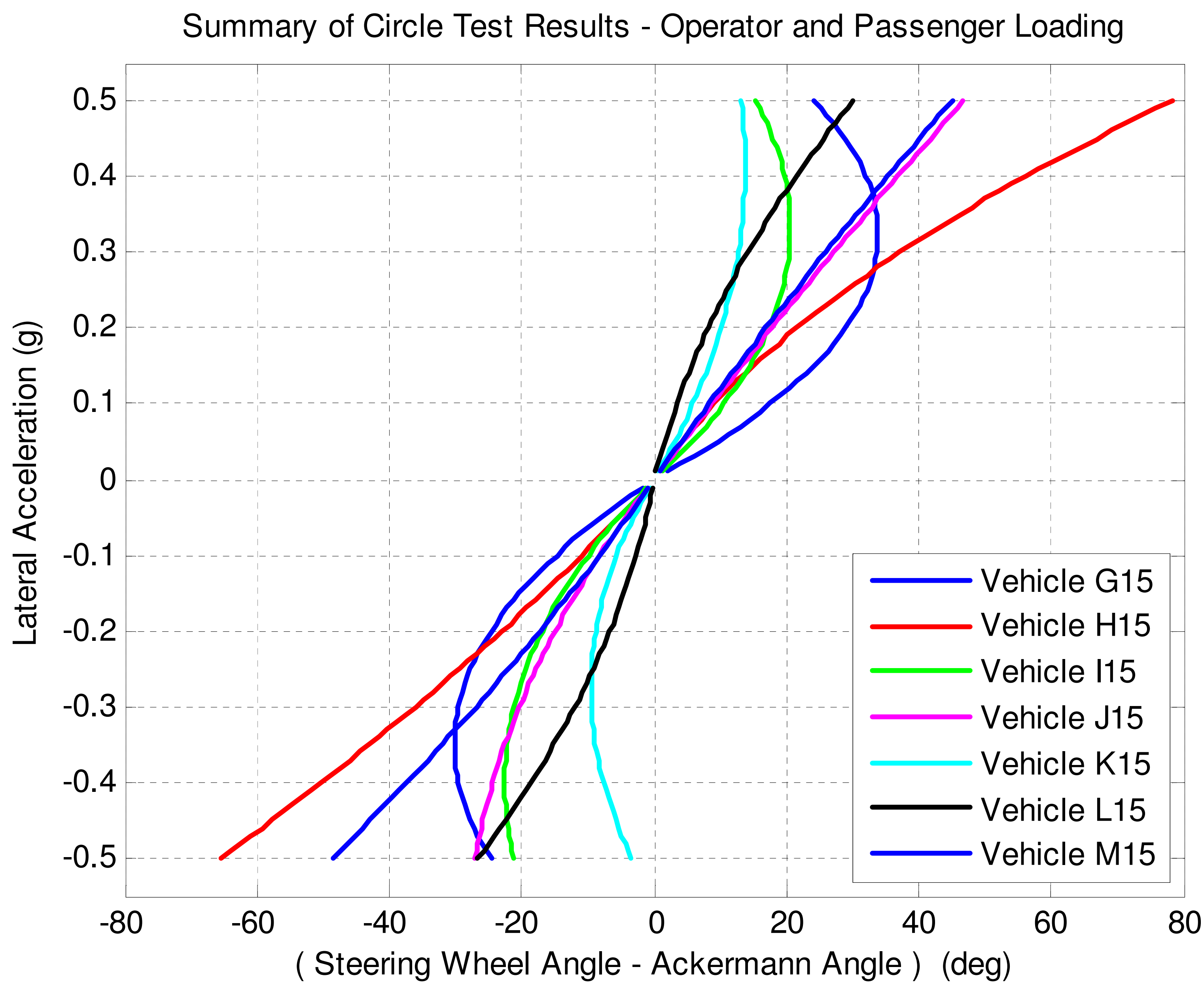
Summary of Circle Test Results - Operator and Passenger Loading
Steering Wheel Angle (deg)
200
150
100
50
0
-50
-100
-150
-200
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle G15
Vehicle H15
Vehicle I15
Vehicle J15
Vehicle K15
Vehicle L15
Vehicle M15

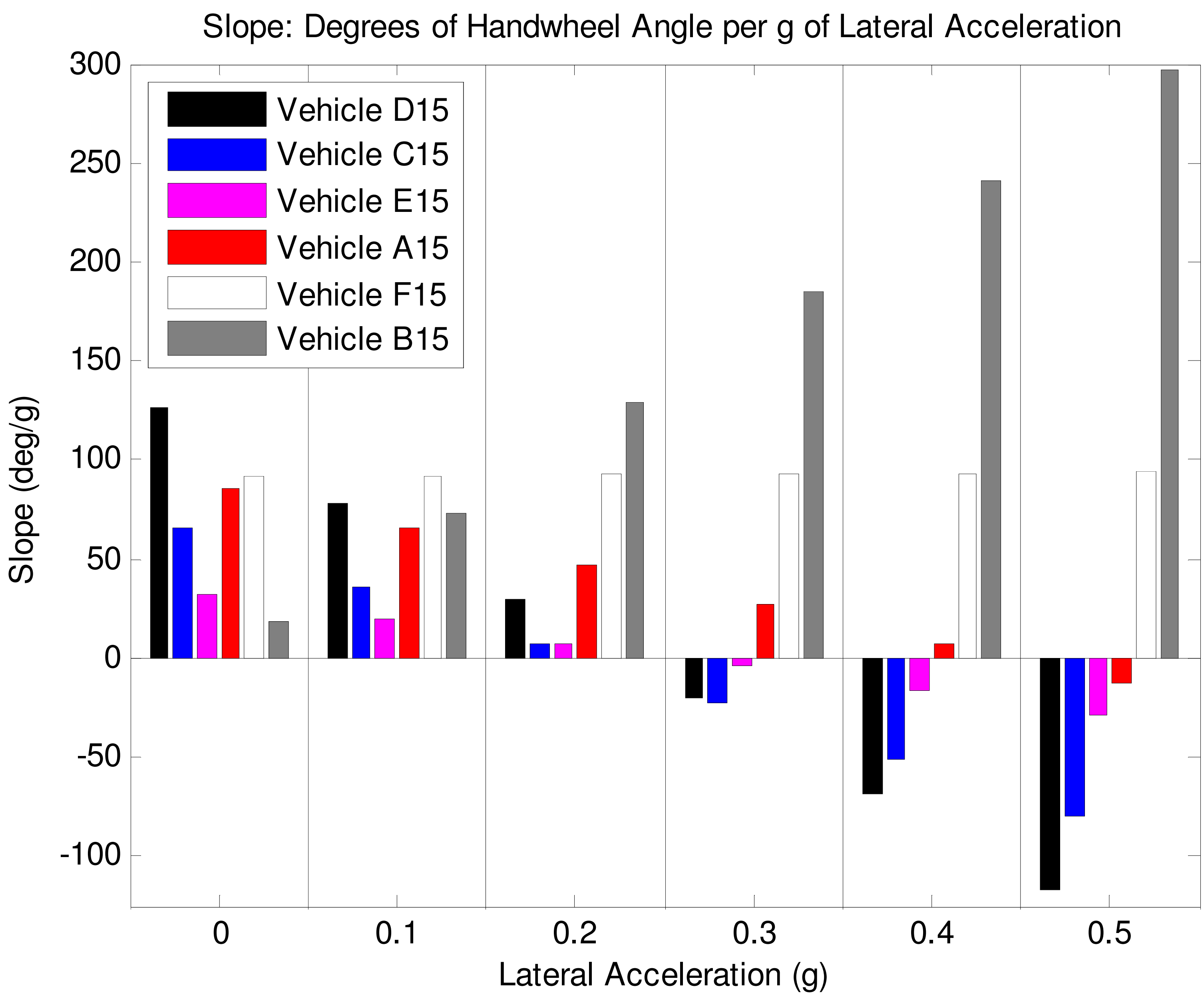


Summary of Circle Test Results - Operator and Passenger Loading
80
60
40
20
0
-20
-40
-60
-80
(Steering Wheel Angle - Ackermann Angle) (deg)
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle A15
Vehicle B15
Vehicle C15
Vehicle D15
Vehicle E15
Vehicle F15

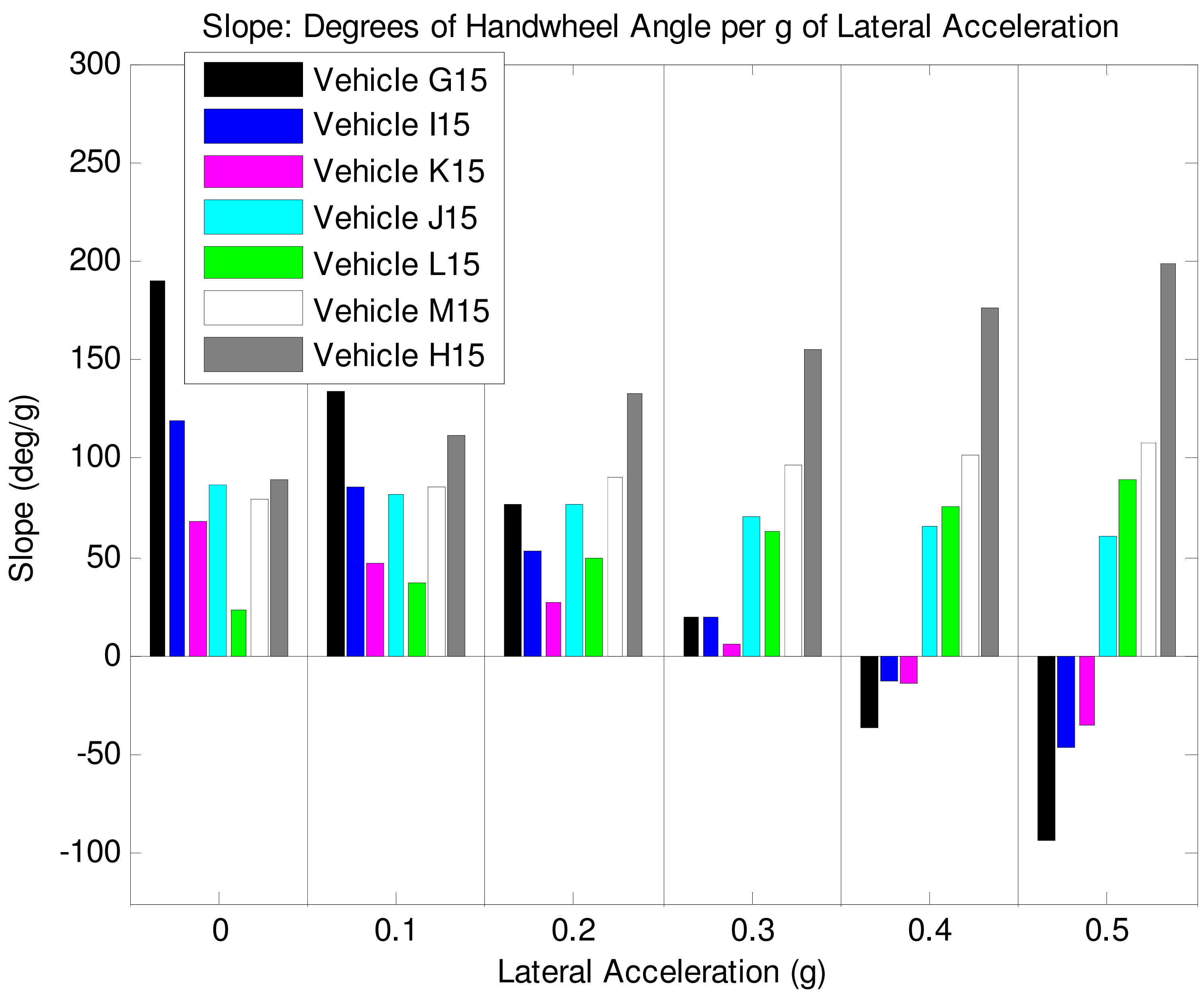

Summary of Circle Test Results - Operator and Passenger Loading
(Steering Wheel Angle - Ackermann Angle) (deg)
80
60
40
20
0
-20
-40
-60
-80
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle G15
Vehicle H15
Vehicle I15
Vehicle J15
Vehicle K15
Vehicle L15
Vehicle M15

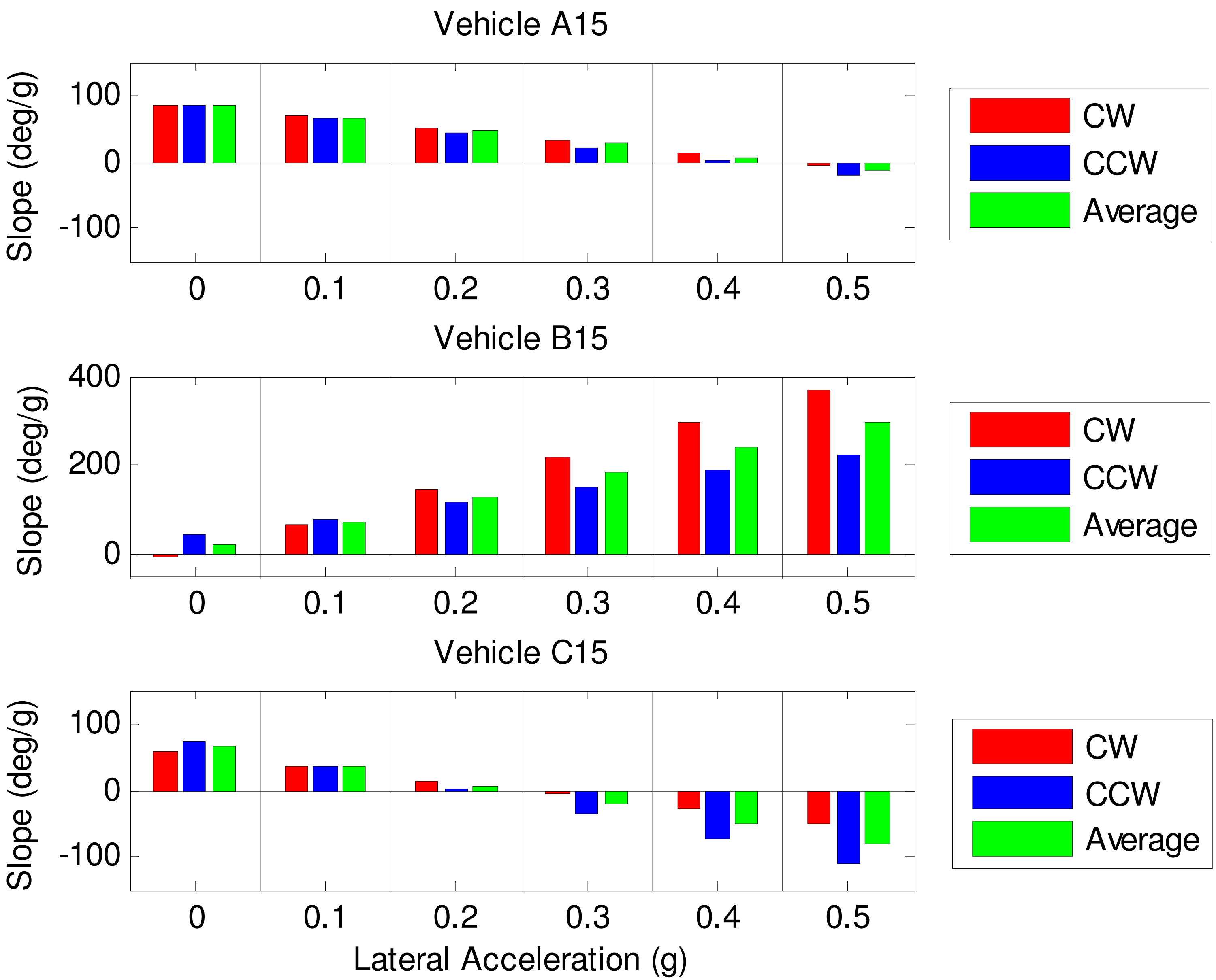

Summary of Circle Test Results - Operator and Passenger Loading
Lateral Acceleration (g)
(Steering Wheel Angle - Ackermann Angle) (deg)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-80
-60
-40
-20
0
20
40
60
80
Vehicle A15
Vehicle B15
Vehicle C15
Vehicle D15
Vehicle E15
Vehicle F15

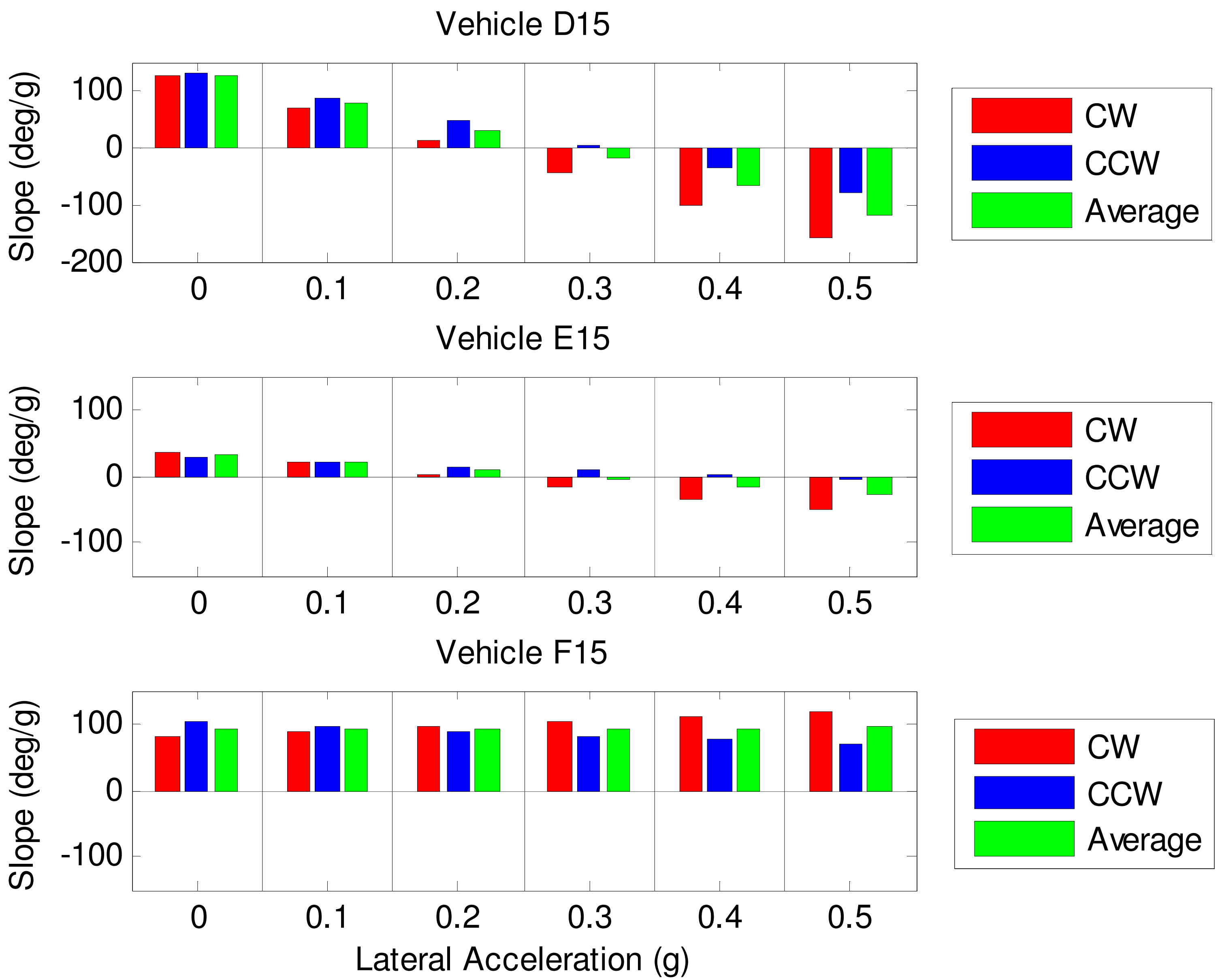

Summary of Circle Test Results - Operator and Passenger Loading
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-80
-60
-40
-20
0
20
40
60
80
(Steering Wheel Angle - Ackermann Angle) (deg)
Vehicle G15
Vehicle H15
Vehicle I15
Vehicle J15
Vehicle K15
Vehicle L15
Vehicle M15

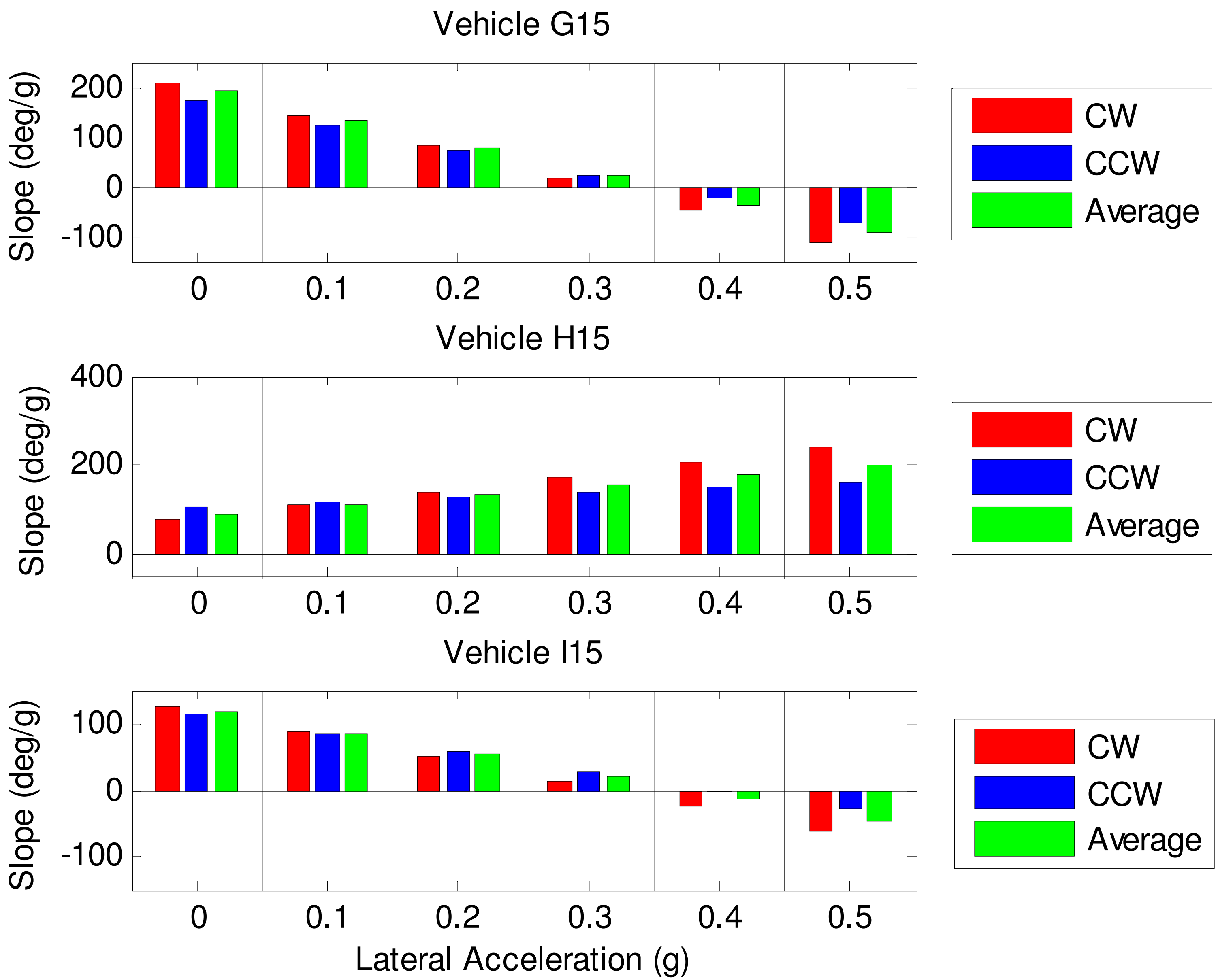


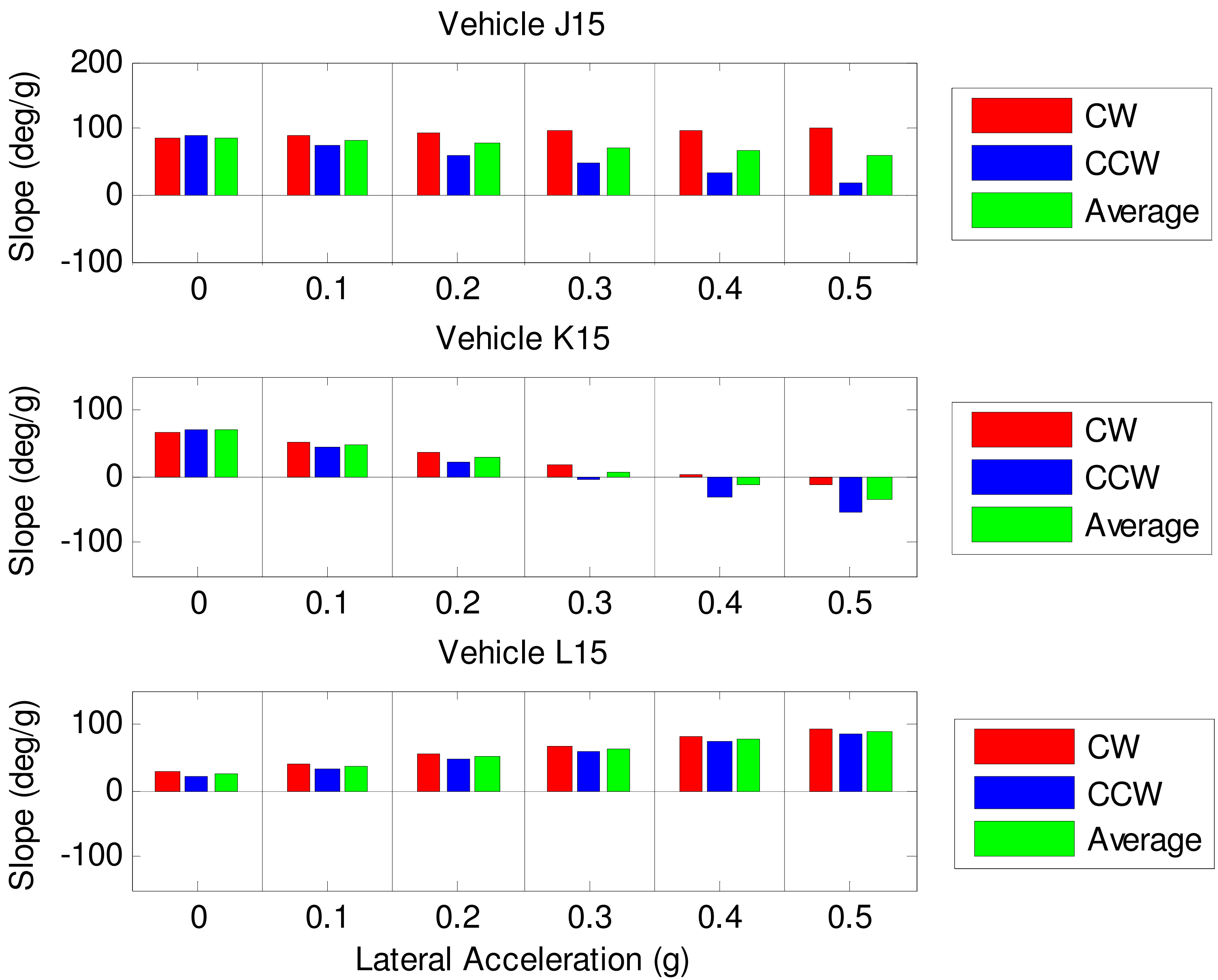
Slope: Degrees of Handwheel Angle per g of Lateral Acceleration
Vehicle D15
Vehicle C15
Vehicle E15
Vehicle A15
Vehicle F15
Vehicle B15
Slope (deg/g)
300
250
200
150
100
50
0
-50
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)

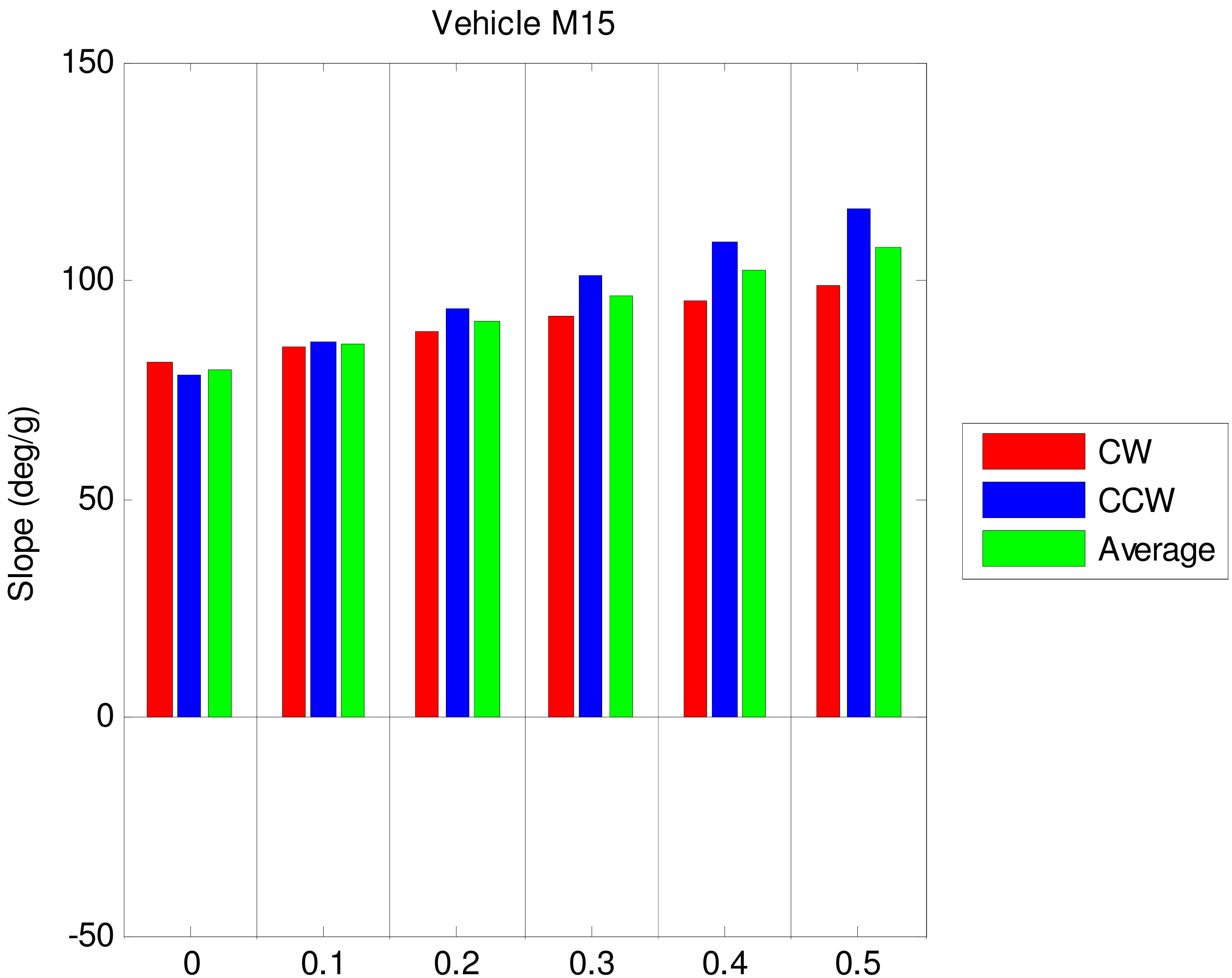

Slope: Degrees of Handwheel Angle per g of Lateral Acceleration
Vehicle G15
Vehicle I15
Vehicle K15
Vehicle J15
Vehicle L15
Vehicle M15
Vehicle H15
Slope (deg/g)
300
250
200
150
100
50
0
-50
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)


Vehicle A15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle B15
Slope (deg/g)
400
200
0
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle C15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

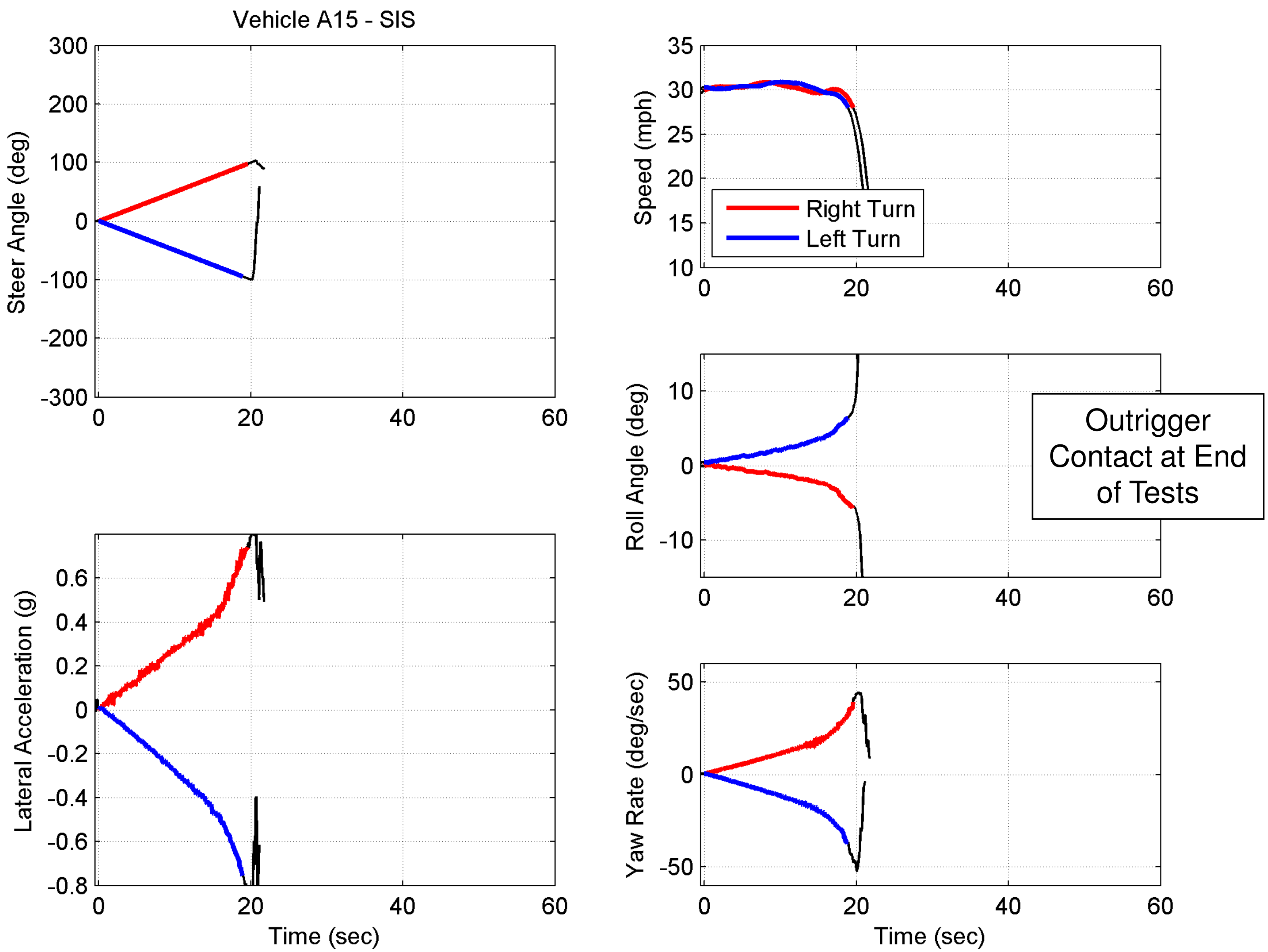

Vehicle D15
Slope (deg/g)
100
0
-100
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle E15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle F15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

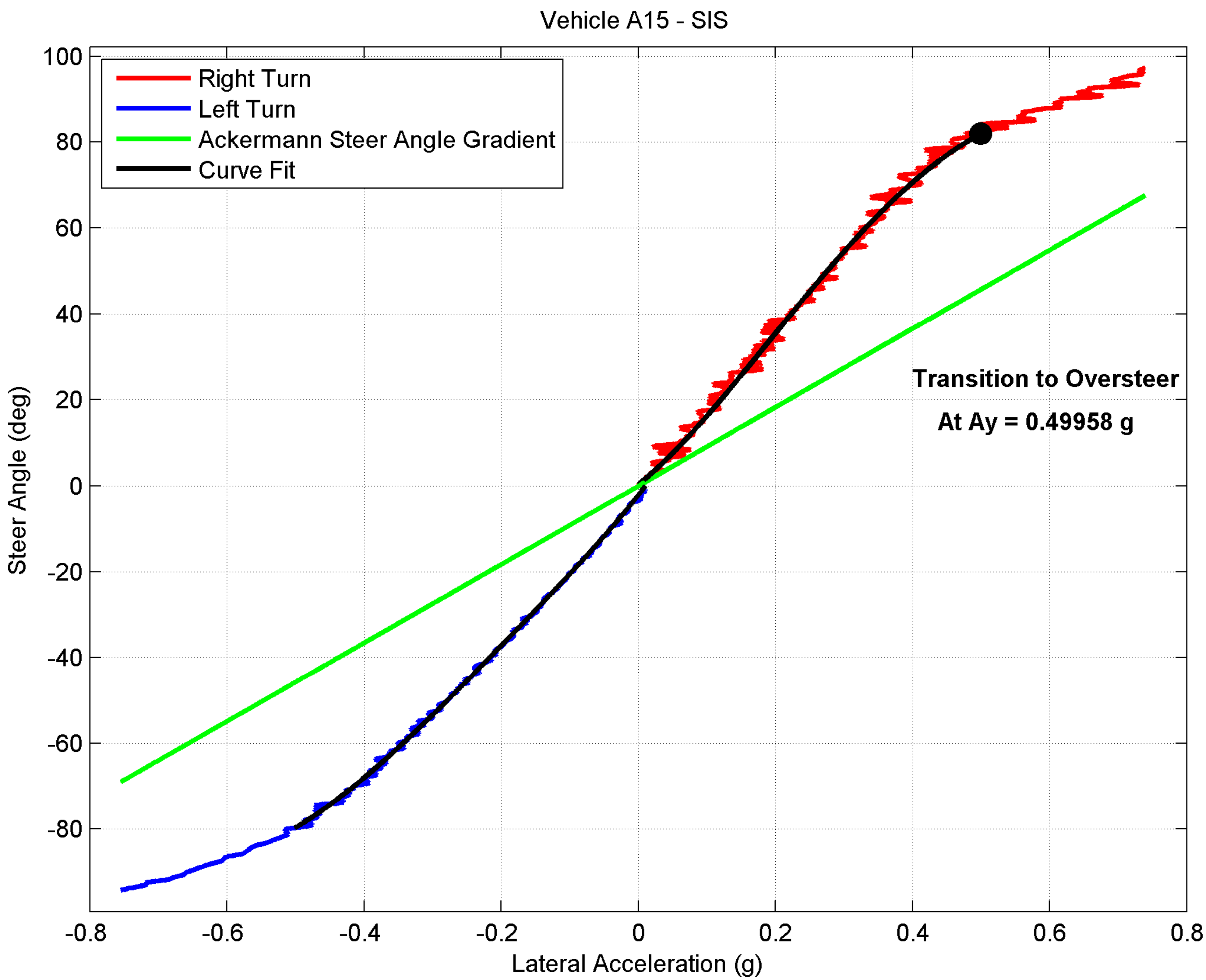

Vehicle G15
Slope (deg/g)
200
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle H15
Slope (deg/g)
400
200
0
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle I15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)

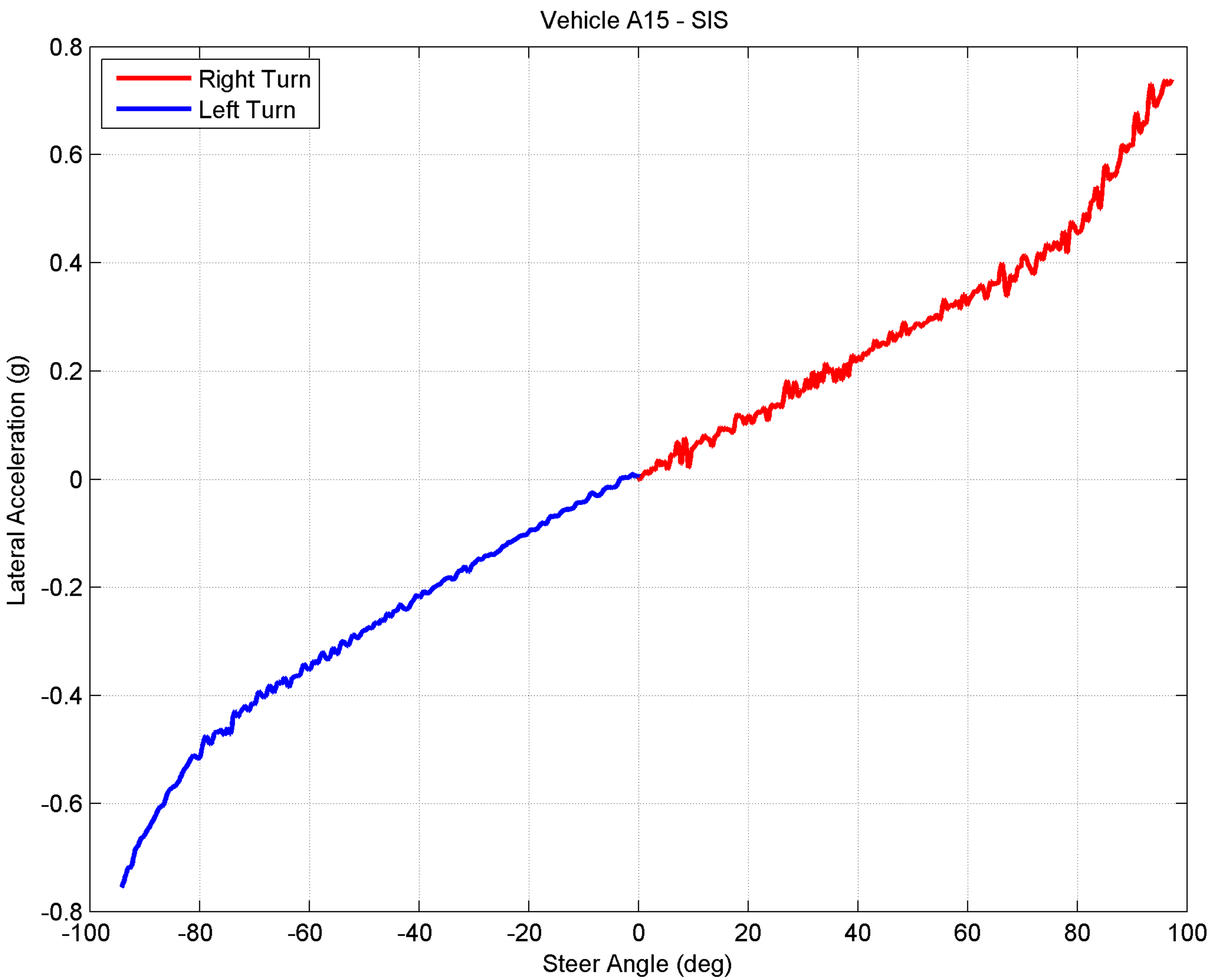

Vehicle J15
Slope (deg/g)
200
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle K15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle L15
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average


Vehicle M15
150
100
50
0
-50
Slope (deg/g)
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average

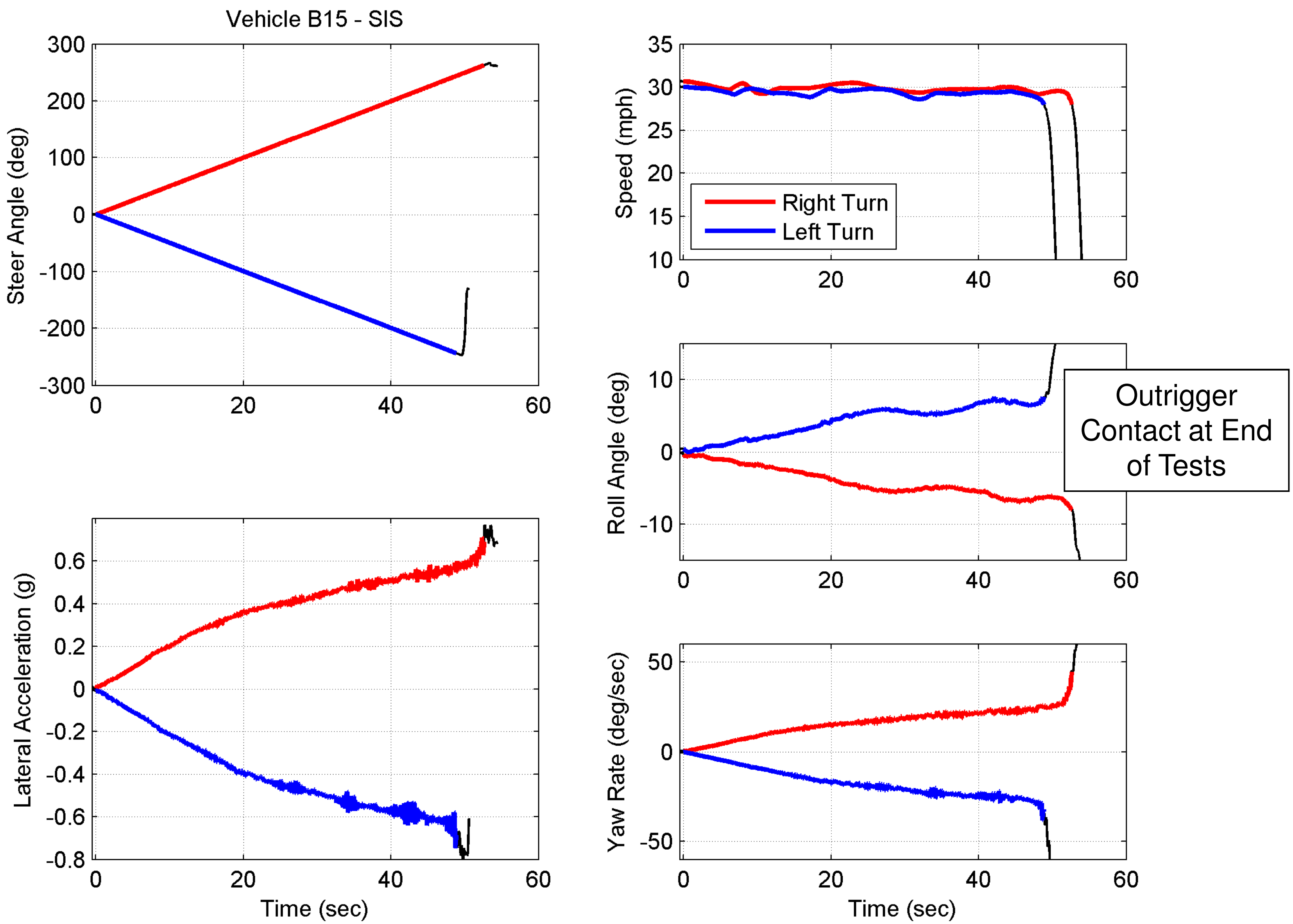
Constant Radius (100 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Operator and Passenger Loading)			
	CW (g)	CCW (g)	Average (g)
Vehicle A15	0.48	0.41	0.44
Vehicle B15	NA	NA	NA
Vehicle C15	0.27	0.20	0.23
Vehicle D15	0.22	0.31	0.27
Vehicle E15	0.21	0.41	0.31
Vehicle F15	NA	NA	NA
Vehicle G15	0.32	0.35	0.34
Vehicle H15	NA	NA	NA
Vehicle I15	0.33	0.40	0.37
Vehicle J15	NA	NA	NA
Vehicle K15	0.41	0.28	0.35
Vehicle L15	NA	NA	NA
Vehicle M15	NA	NA	NA

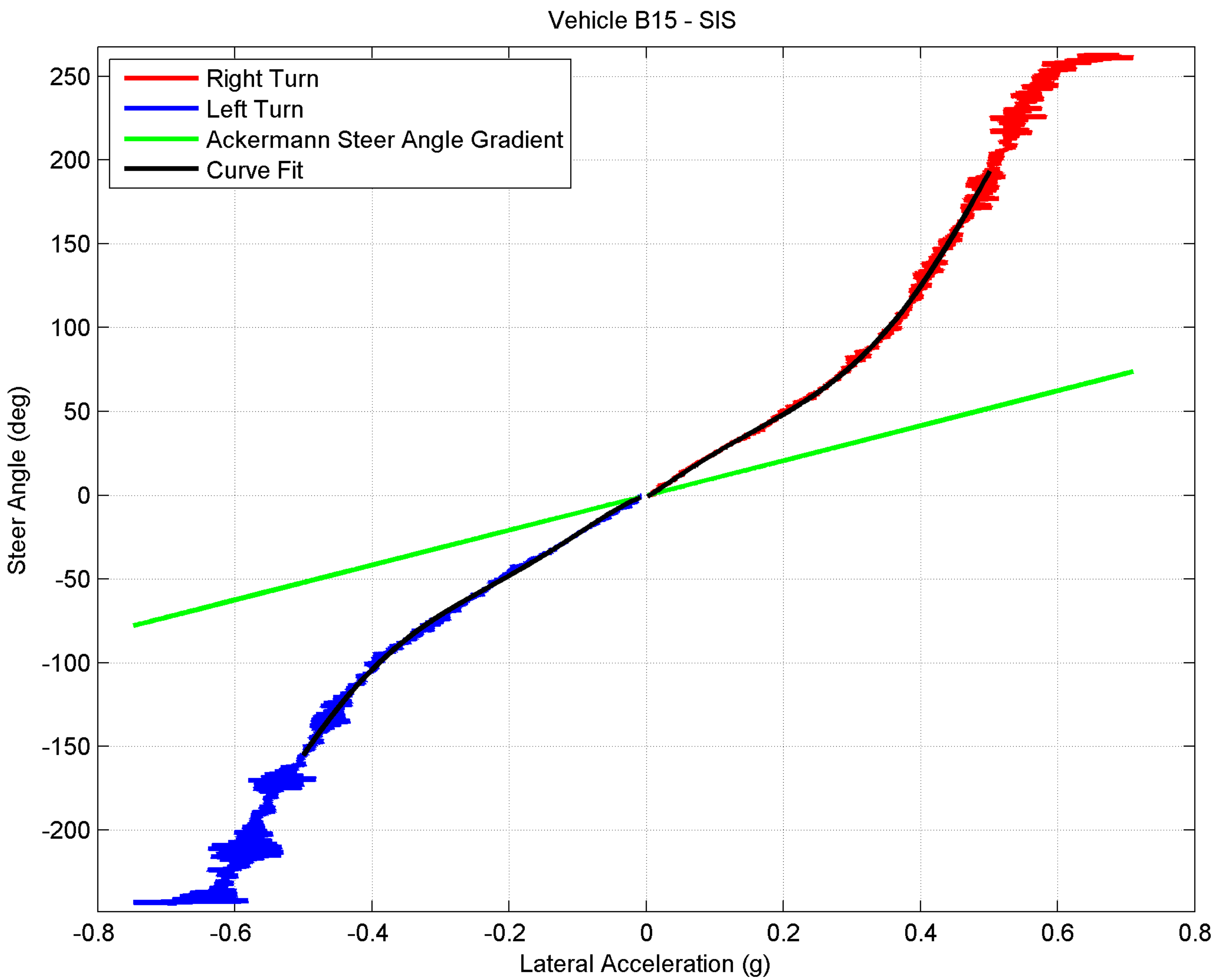

Vehicle A15 - SIS
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Outrigger Contact at End of Tests
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle A15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.49958 g
Steer Angle (deg)
Lateral Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

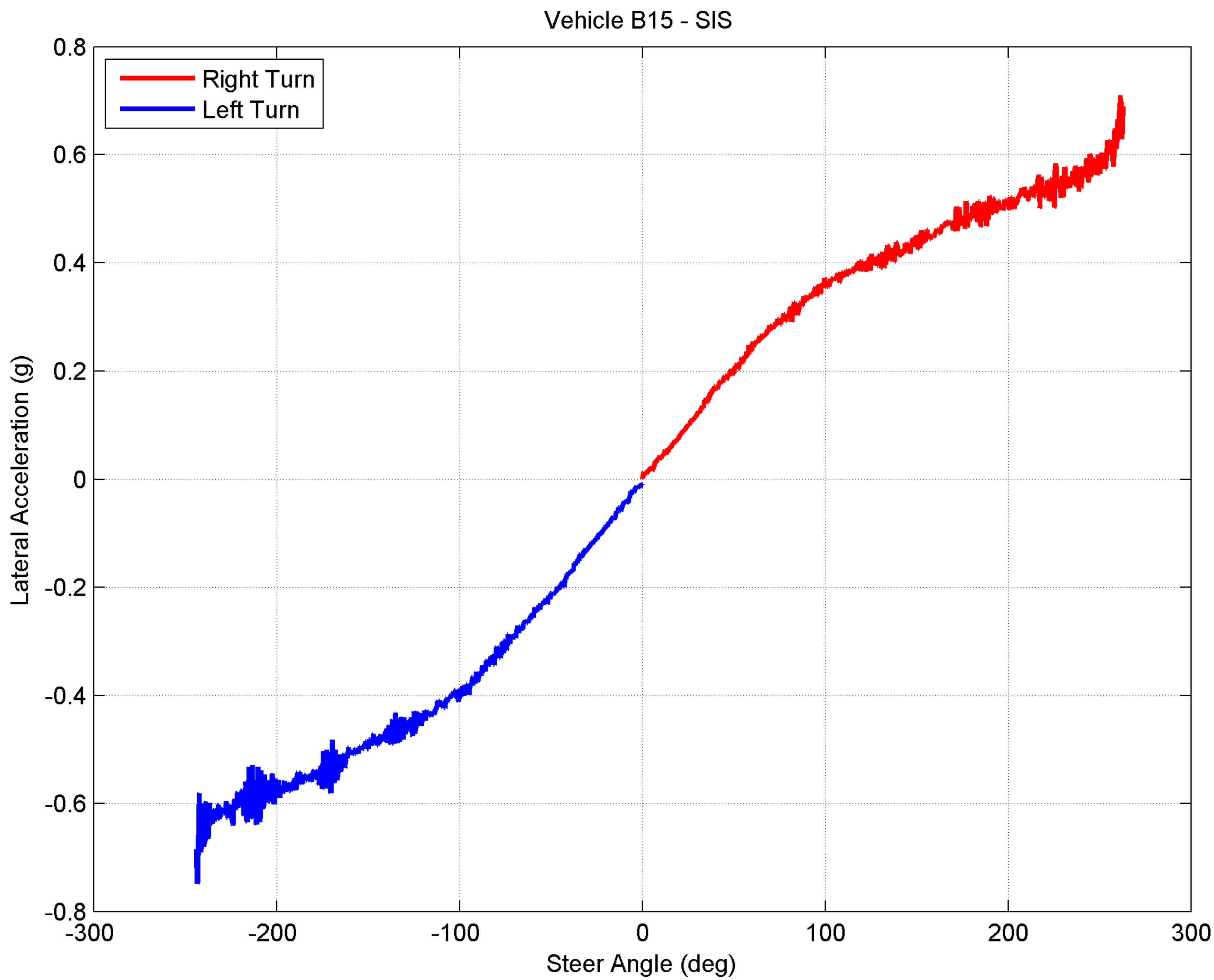


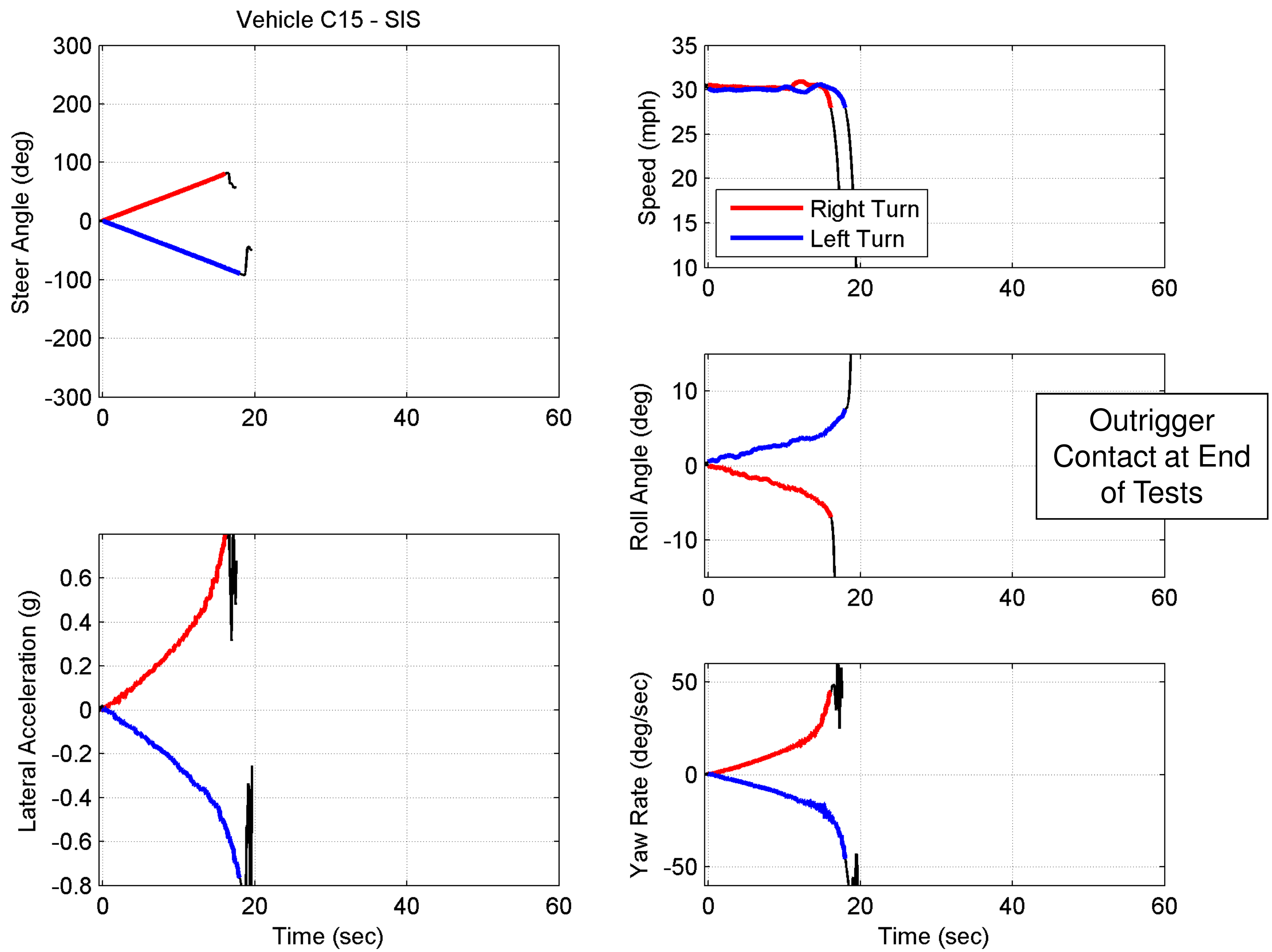
Vehicle A15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-100
-80
-60
-40
-20
0
20
40
60
80
100
Steer Angle (deg)

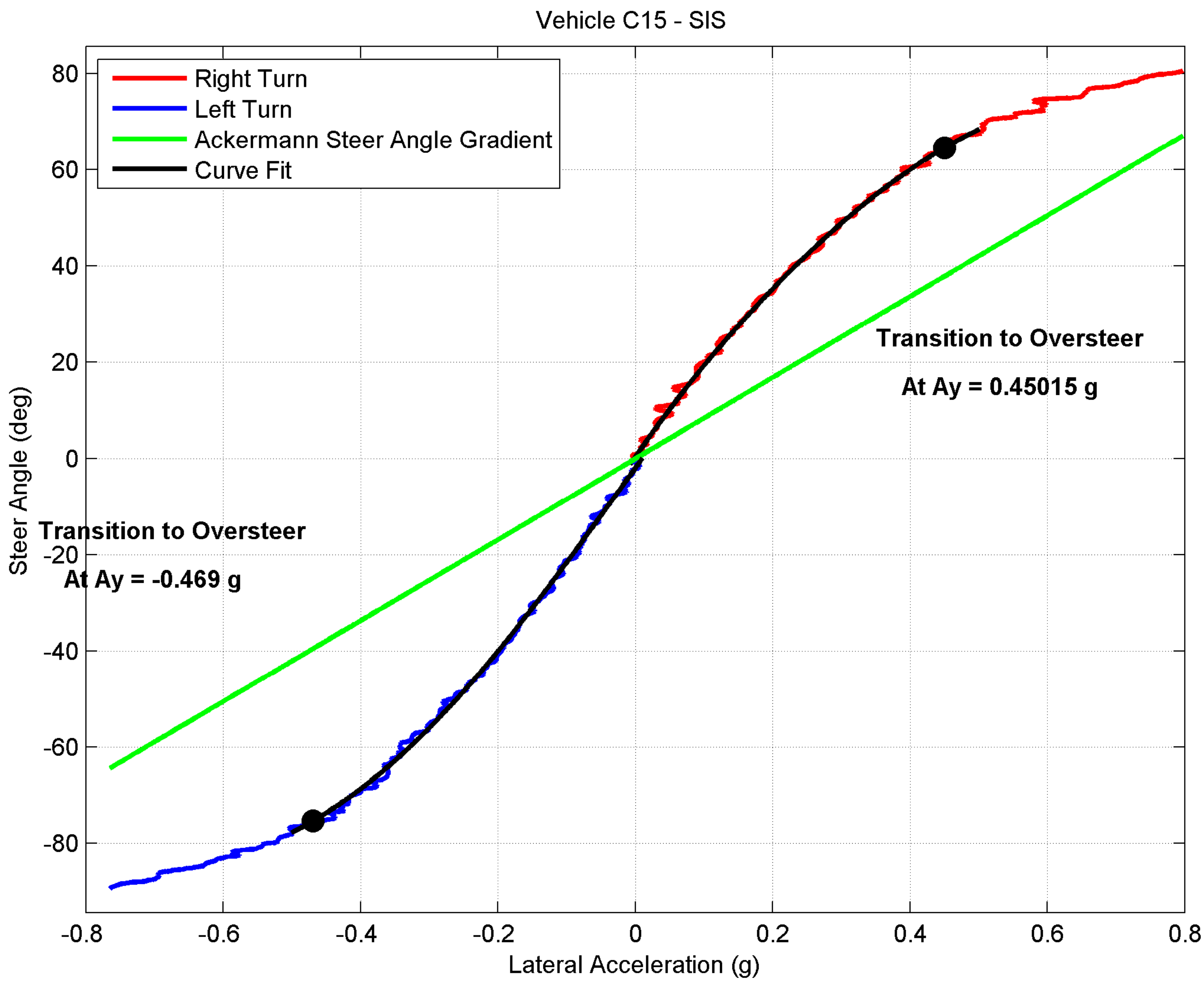

Vehicle B15 - SIS
Steer Angle (deg)
300
200
100
0
-100
-200
-300
0
20
40
60
Speed (mph)
35
30
25
20
15
10
Right Turn
Left Turn
Roll Angle (deg)
10
-10
Outrigger Contact at End of Tests
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
50
-50
Time (sec)



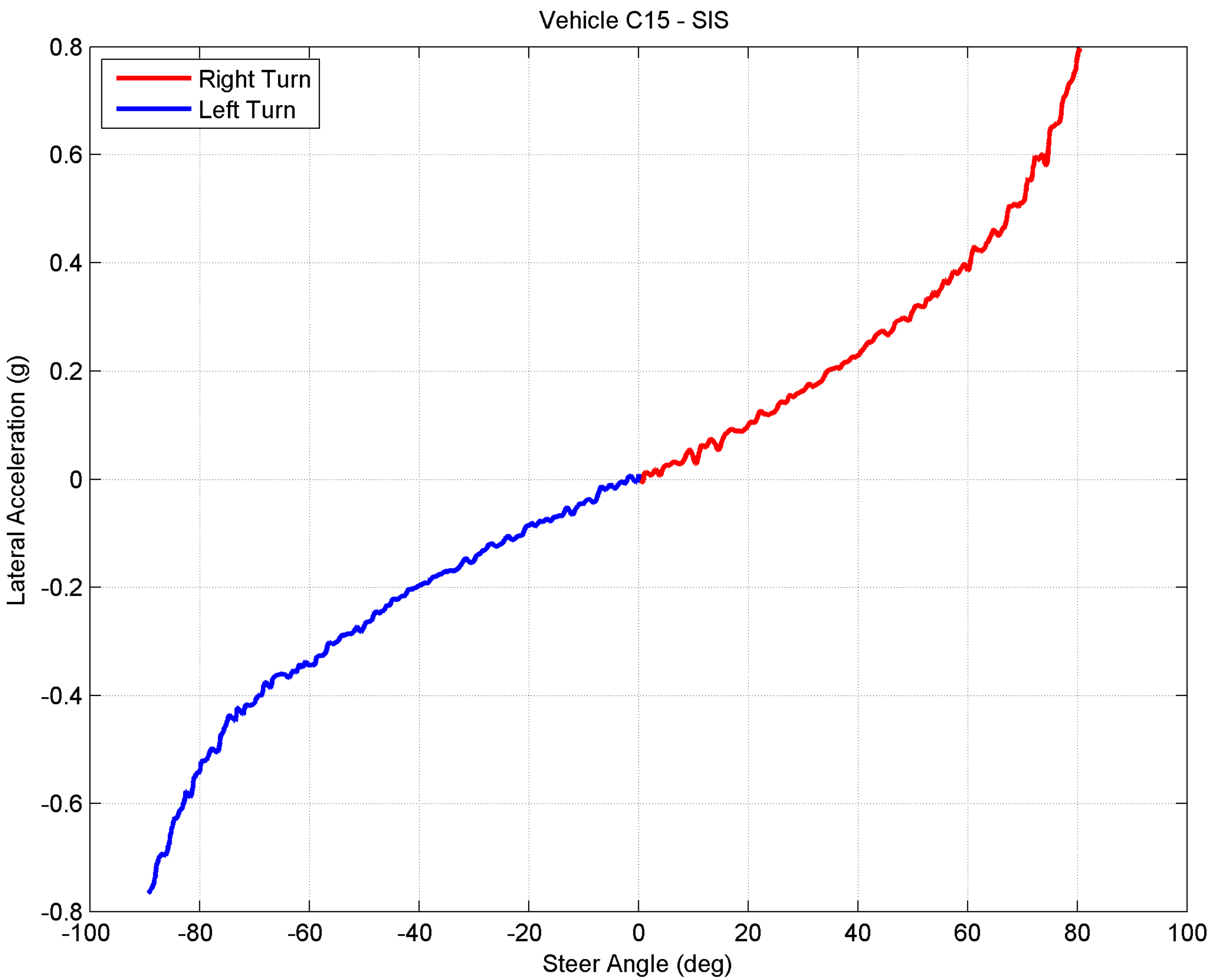
Vehicle B15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)
250
200
150
100
50
0
-50
-100
-150
-200
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

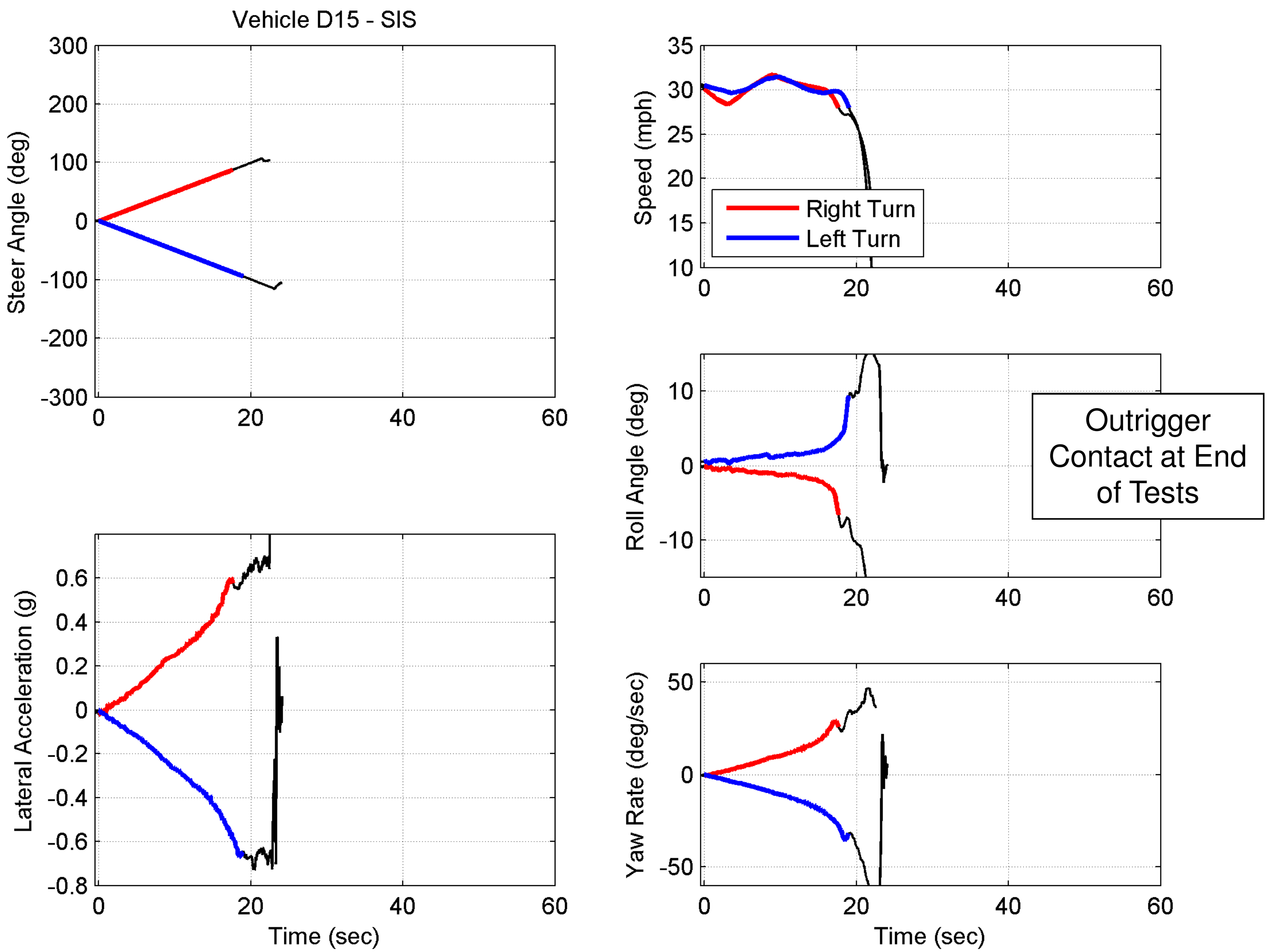

Vehicle B15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-300
-200
-100
0
100
200
300
Steer Angle (deg)


Vehicle C15 - SIS
Steer Angle (deg)
300
200
100
0
-100
-200
-300
0
20
40
60
Speed (mph)
35
30
25
20
15
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Outrigger Contact at End of Tests
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

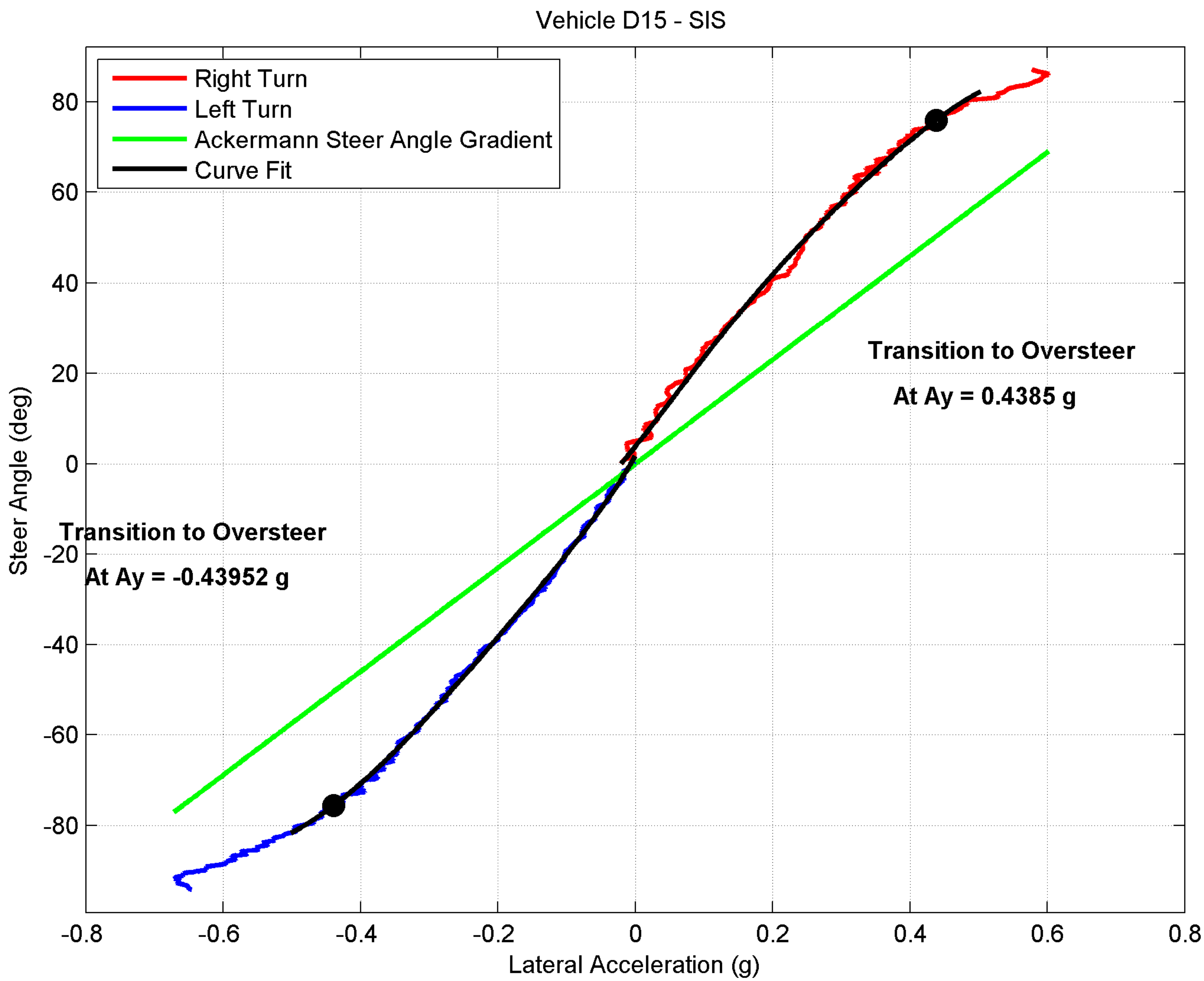


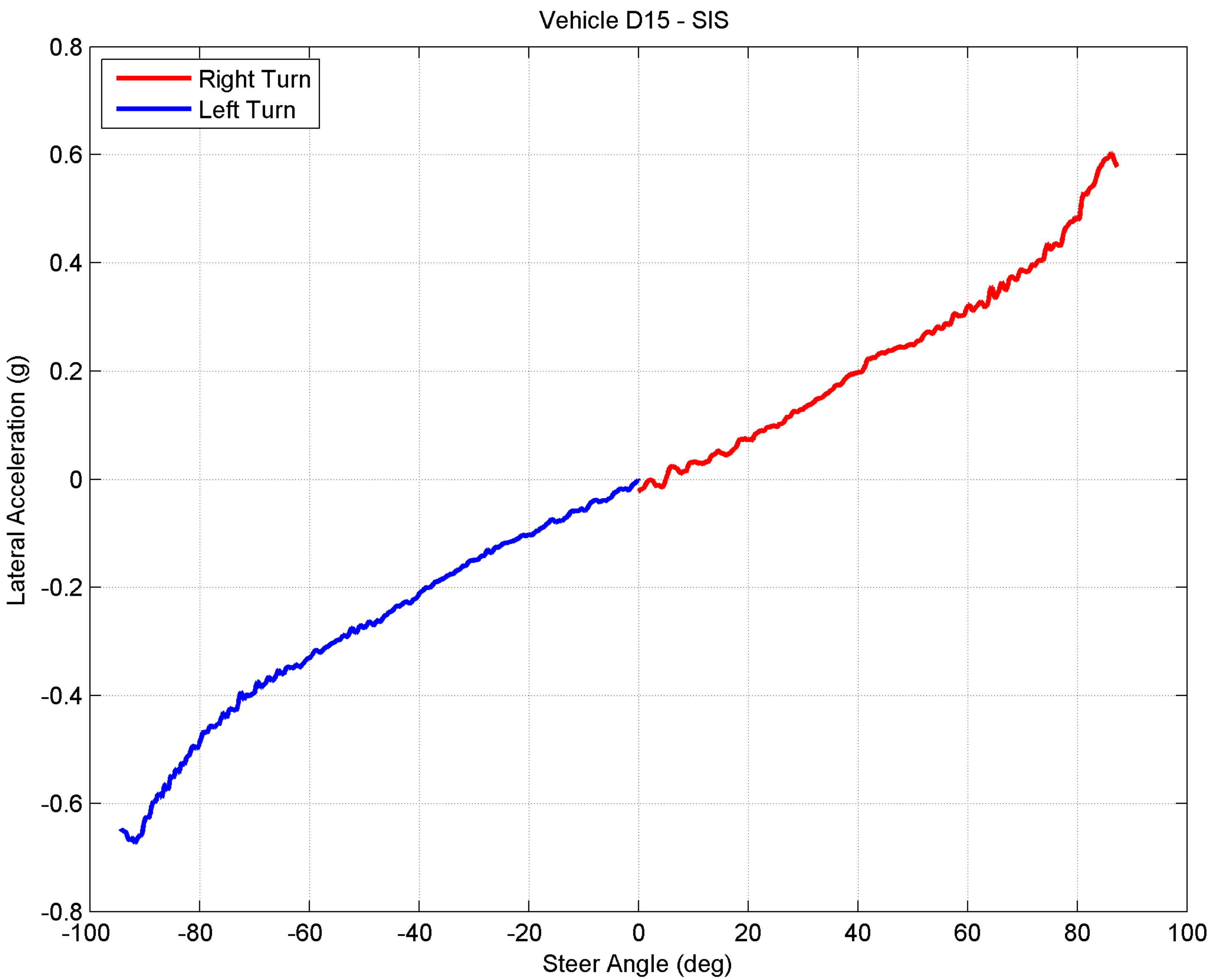
Vehicle C15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.45015 g
Transition to Oversteer
At Ay = -0.469 g
Steer Angle (deg)
Lateral Acceleration (g)
80
60
40
20
0
-20
-40
-60
-80
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

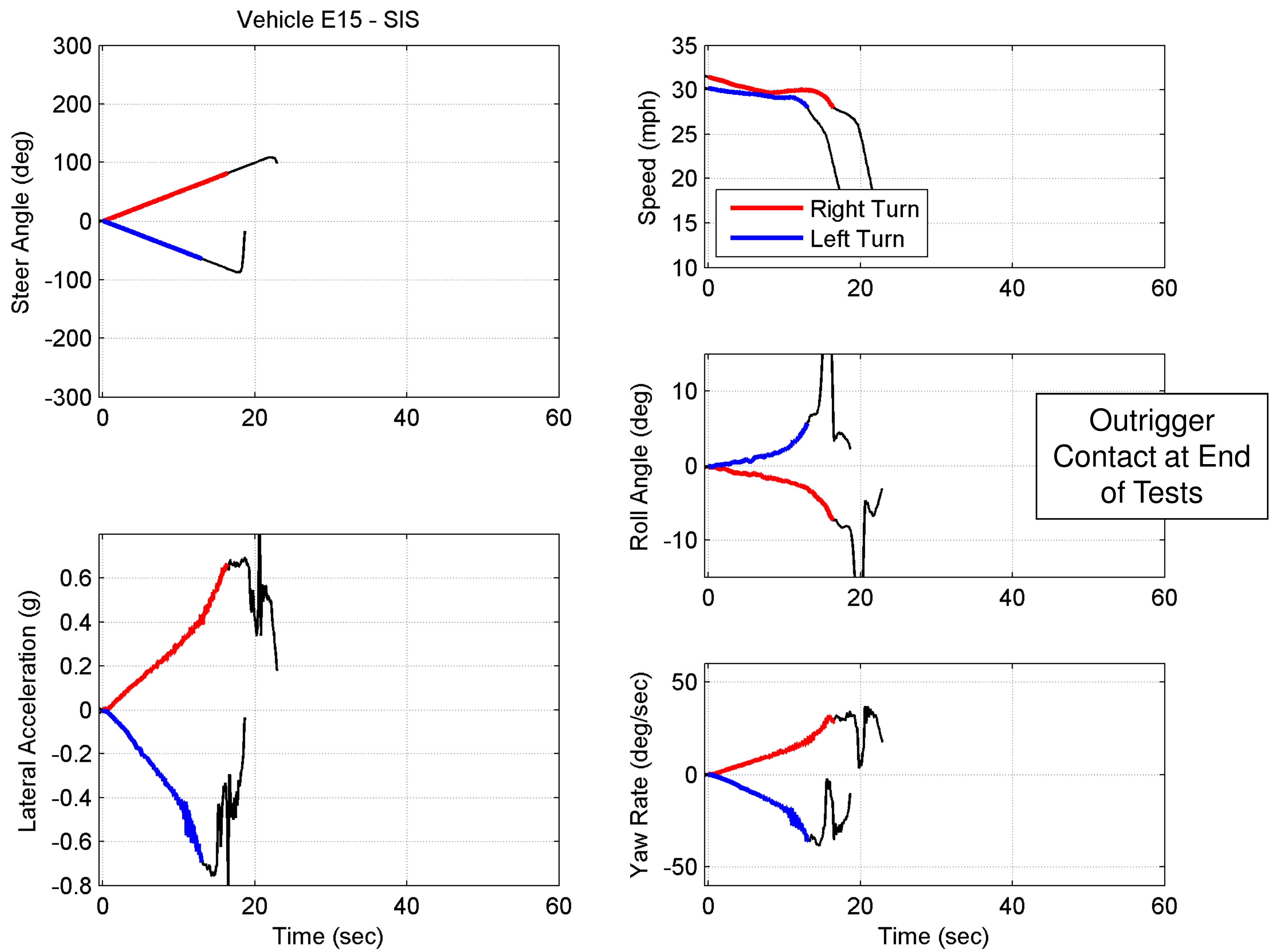

Vehicle C15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-100
-80
-60
-40
-20
0
20
40
60
80
100

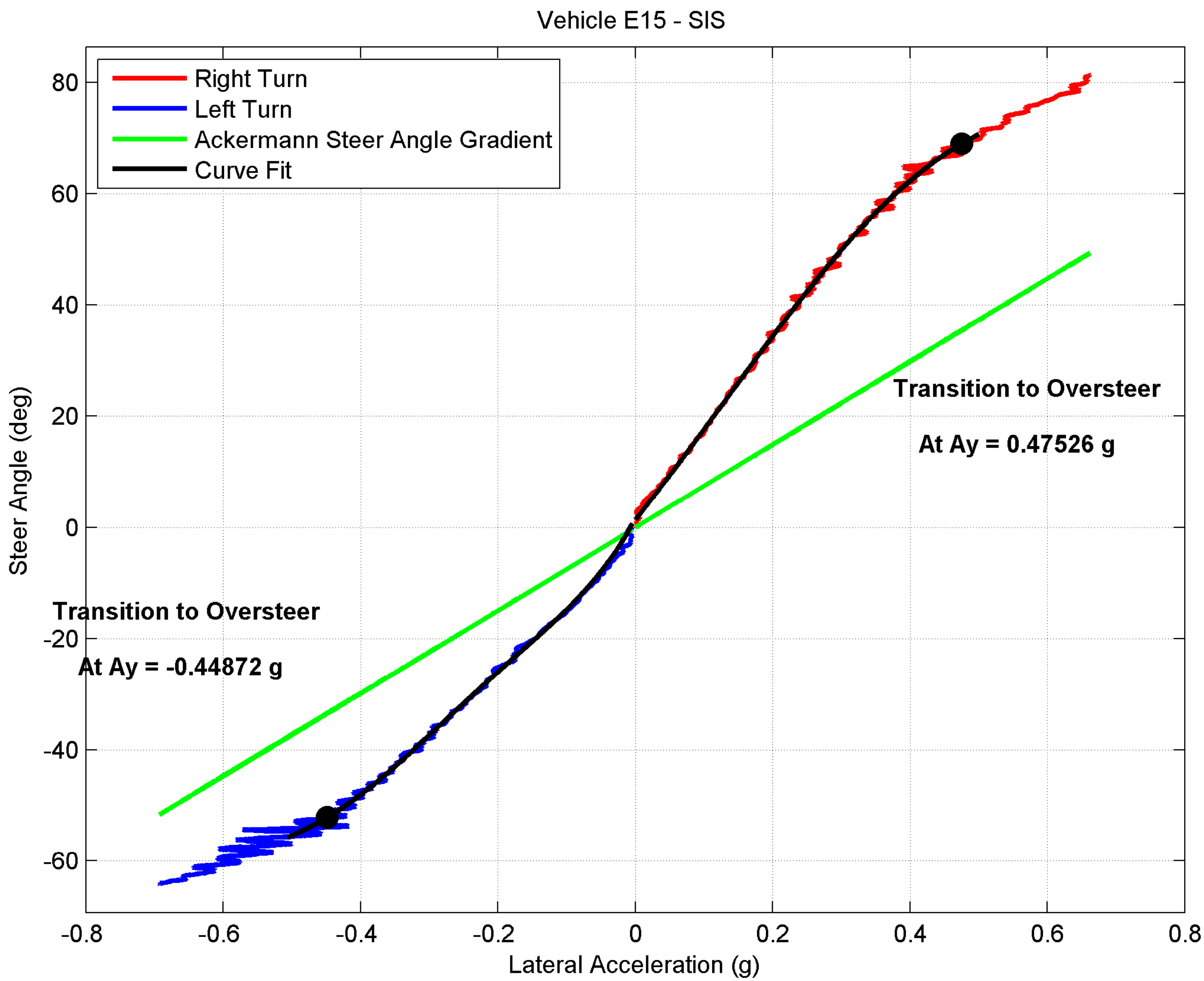


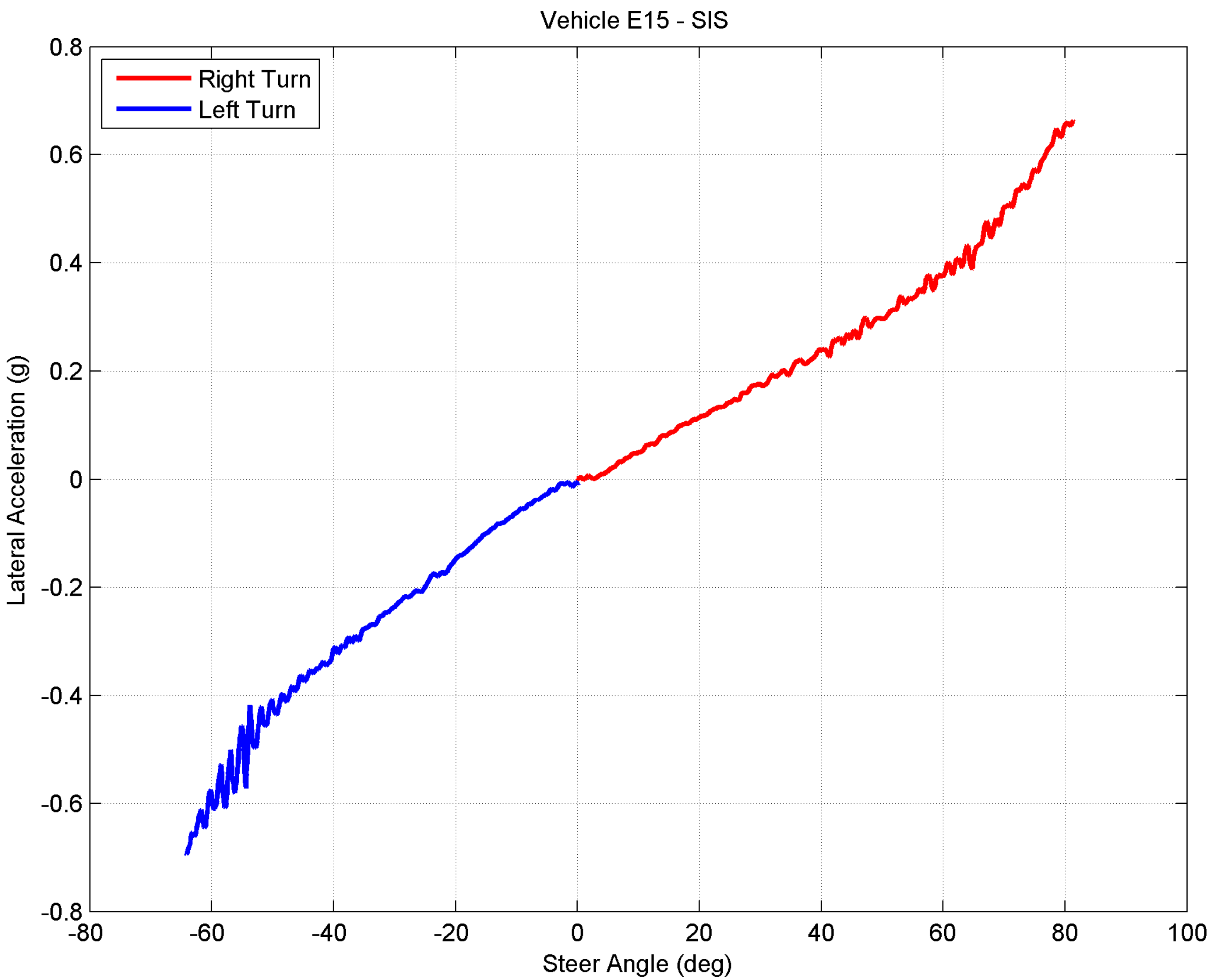
Vehicle D15 - SIS
Steer Angle (deg)
300
200
100
0
-100
-200
-300
0
20
40
60
Speed (mph)
35
30
25
20
15
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Outrigger Contact at End of Tests
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

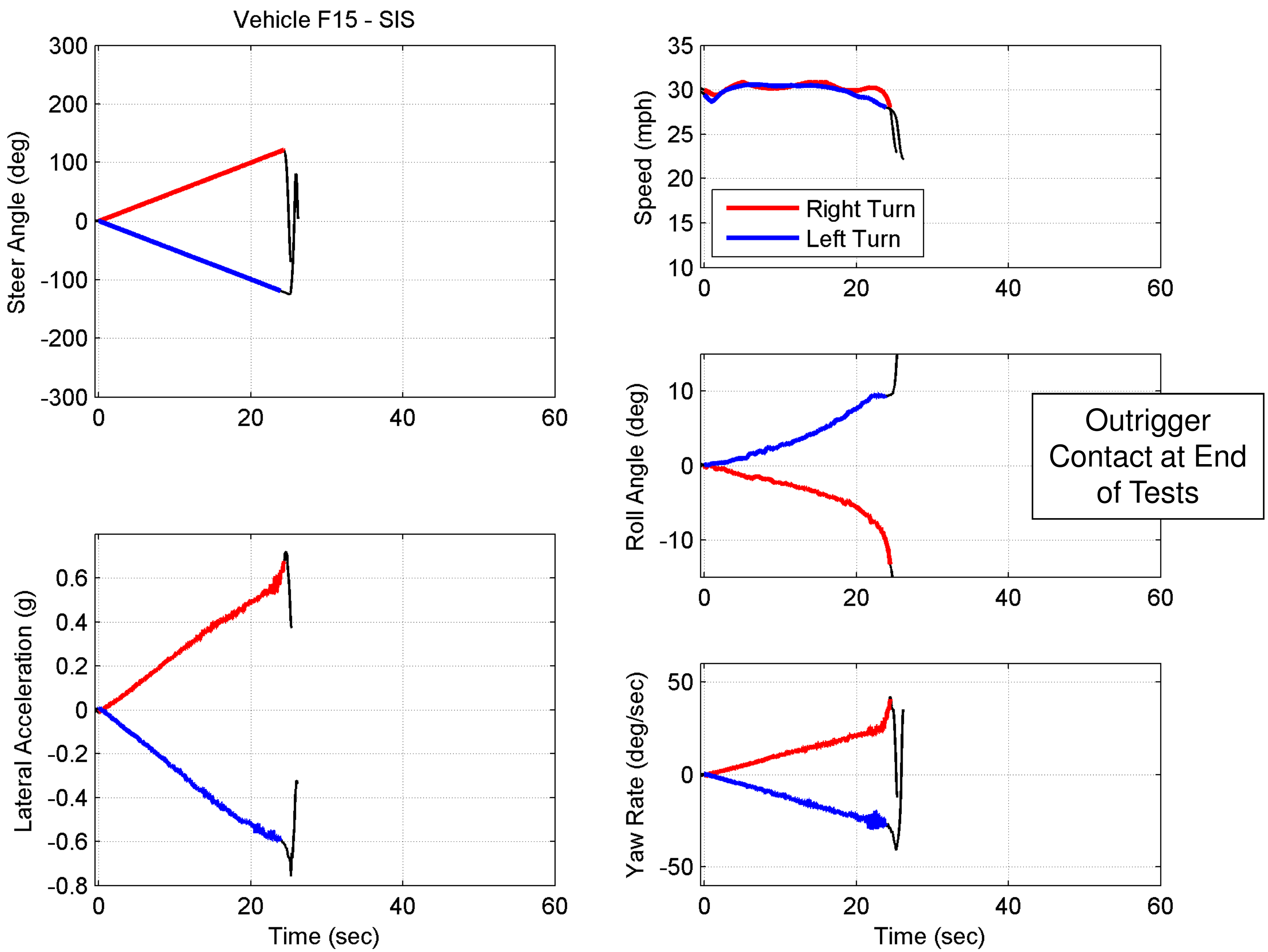

Vehicle D15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.4385 g
Transition to Oversteer
At Ay = -0.43952 g
Steer Angle (deg)
Lateral Acceleration (g)
80
60
40
20
0
-20
-40
-60
-80
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

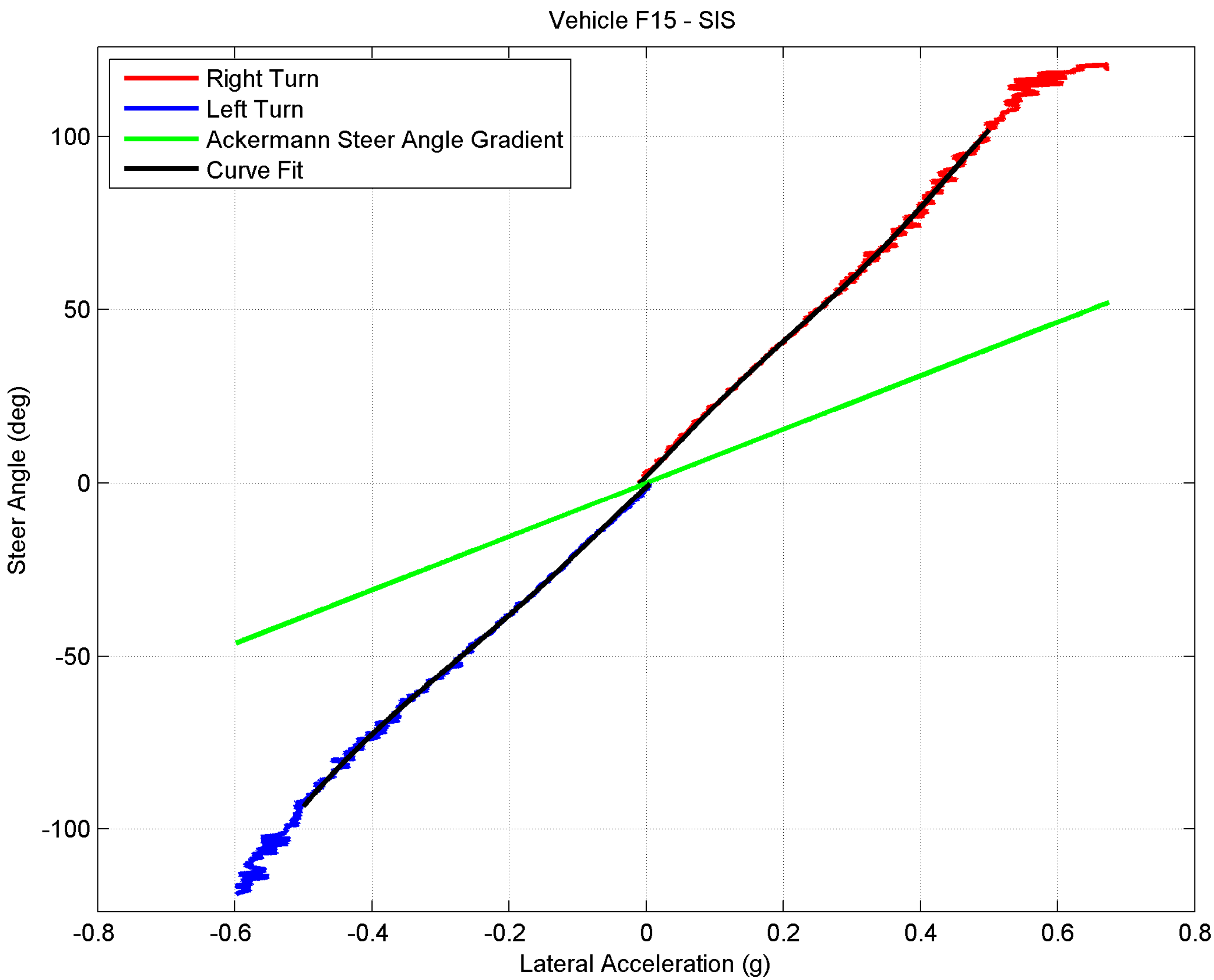

Vehicle D15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-100
-80
-60
-40
-20
0
20
40
60
80
100
Steer Angle (deg)


Vehicle E15 - SIS
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Outrigger Contact at End of Tests
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

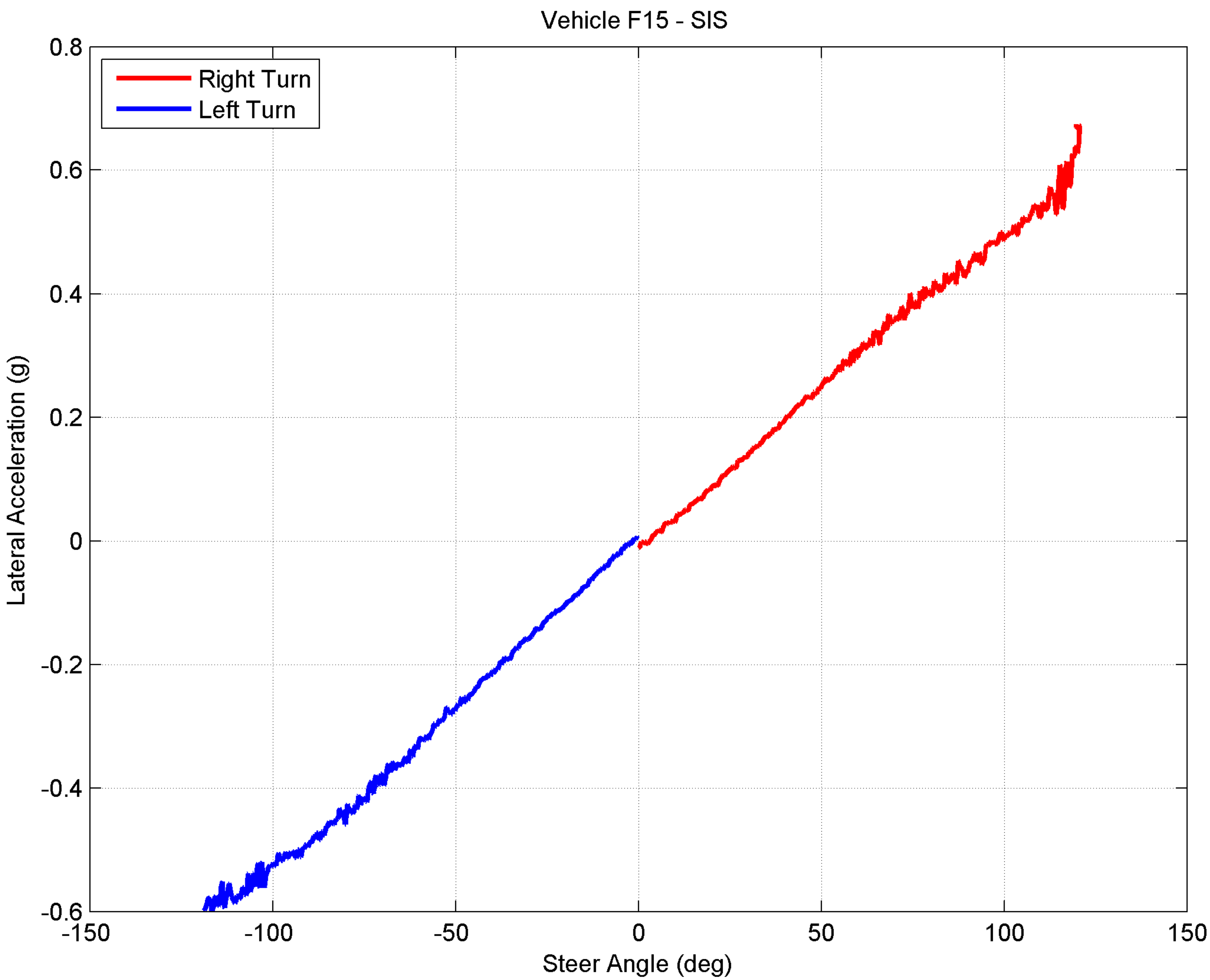

Vehicle E15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.47526 g
Transition to Oversteer
At Ay = -0.44872 g
Steer Angle (deg)
Lateral Acceleration (g)
80
60
40
20
0
-20
-40
-60
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

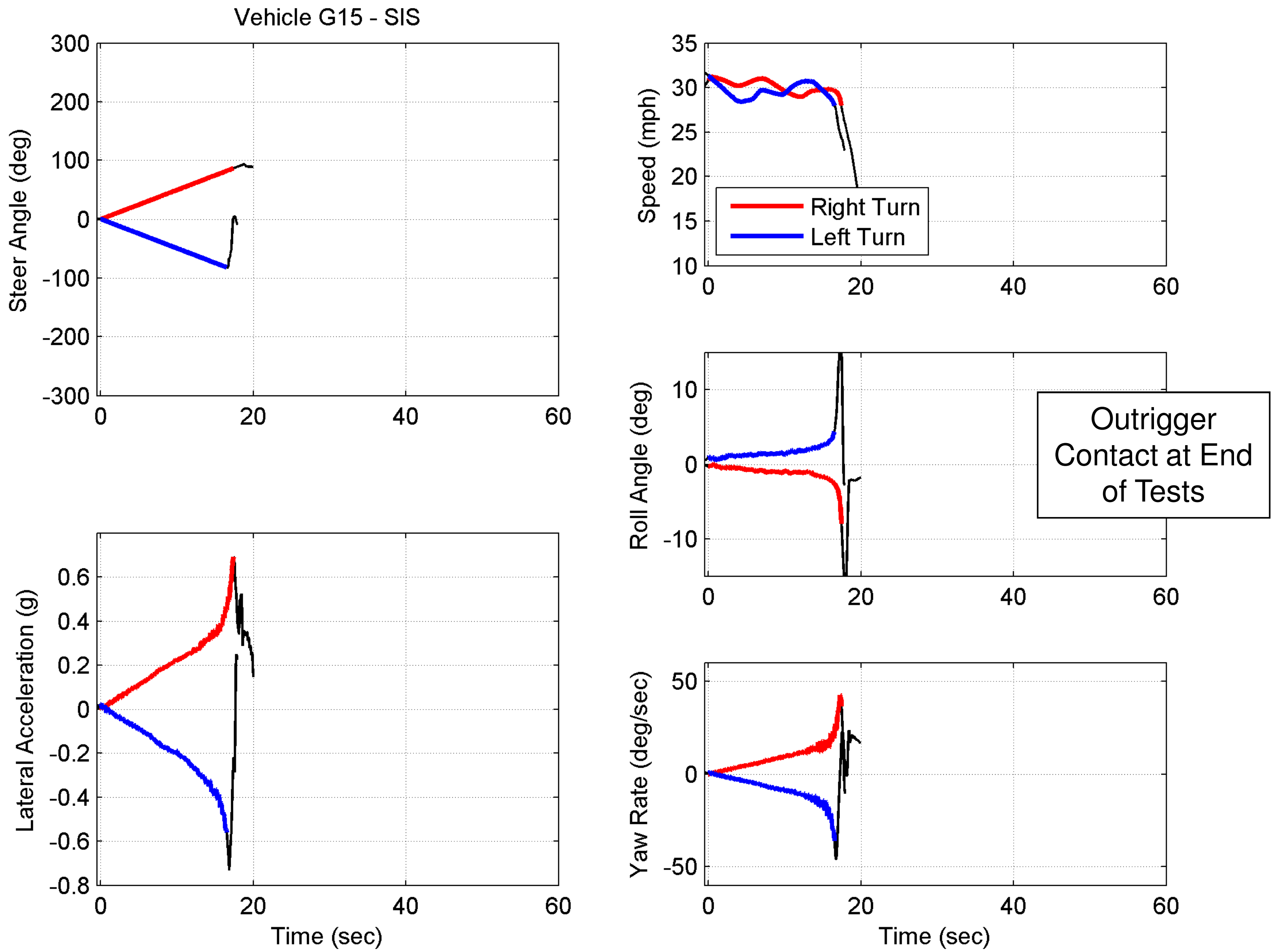

Vehicle E15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-80
-60
-40
-20
0
20
40
60
80
100

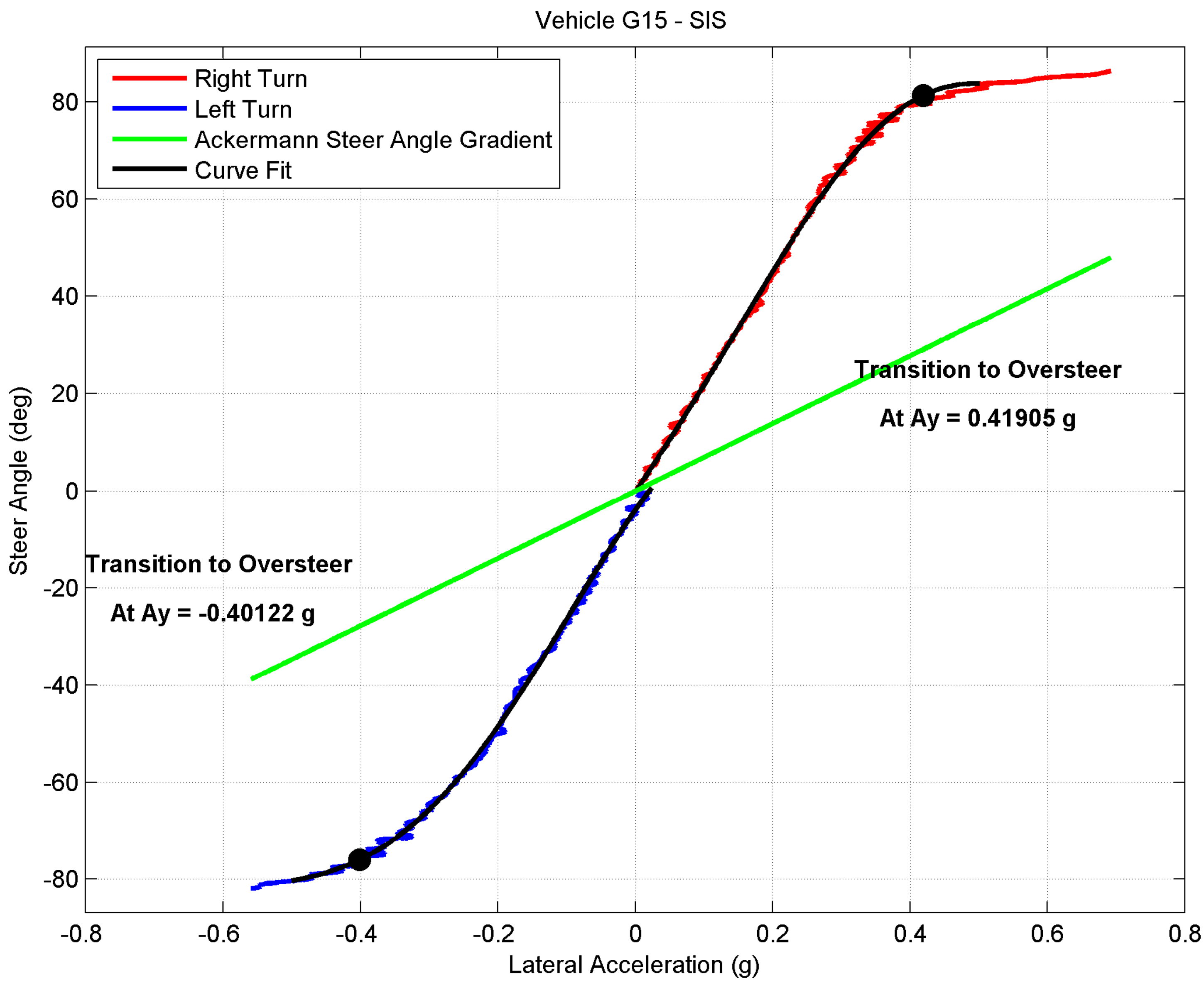

Vehicle F15 - SIS
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Outrigger Contact at End of Tests
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

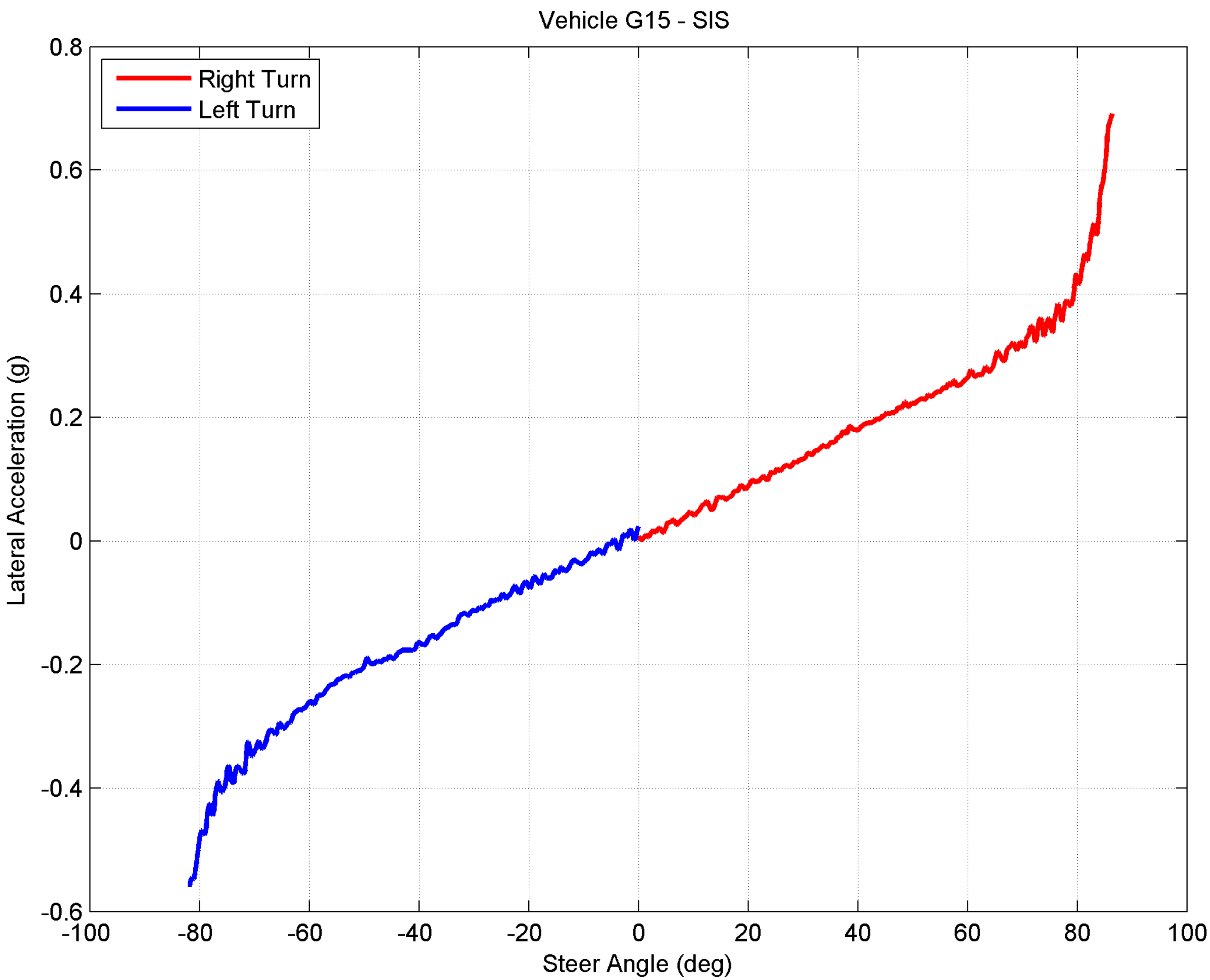


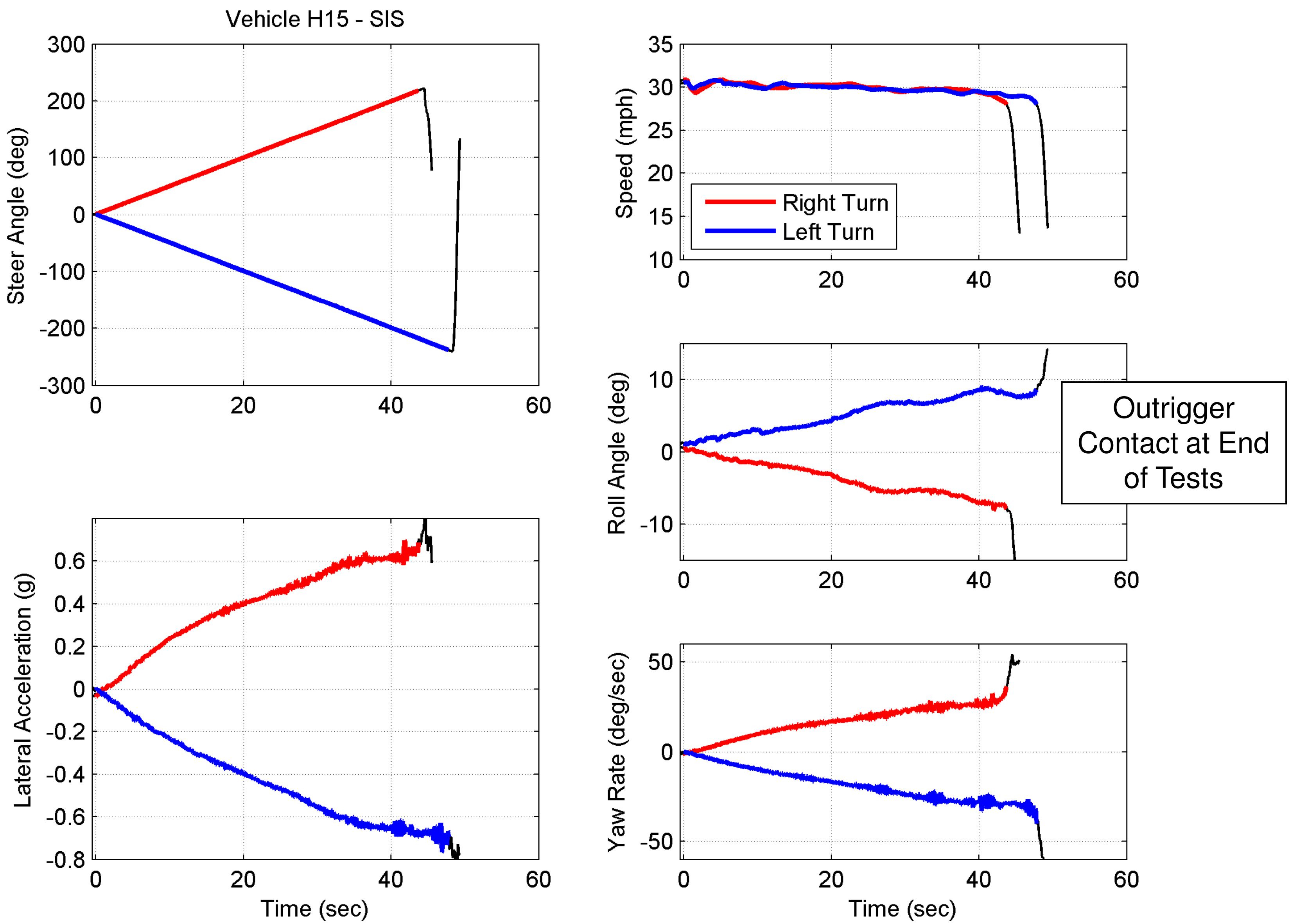
Vehicle F15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Steer Angle (deg)
Lateral Acceleration (g)

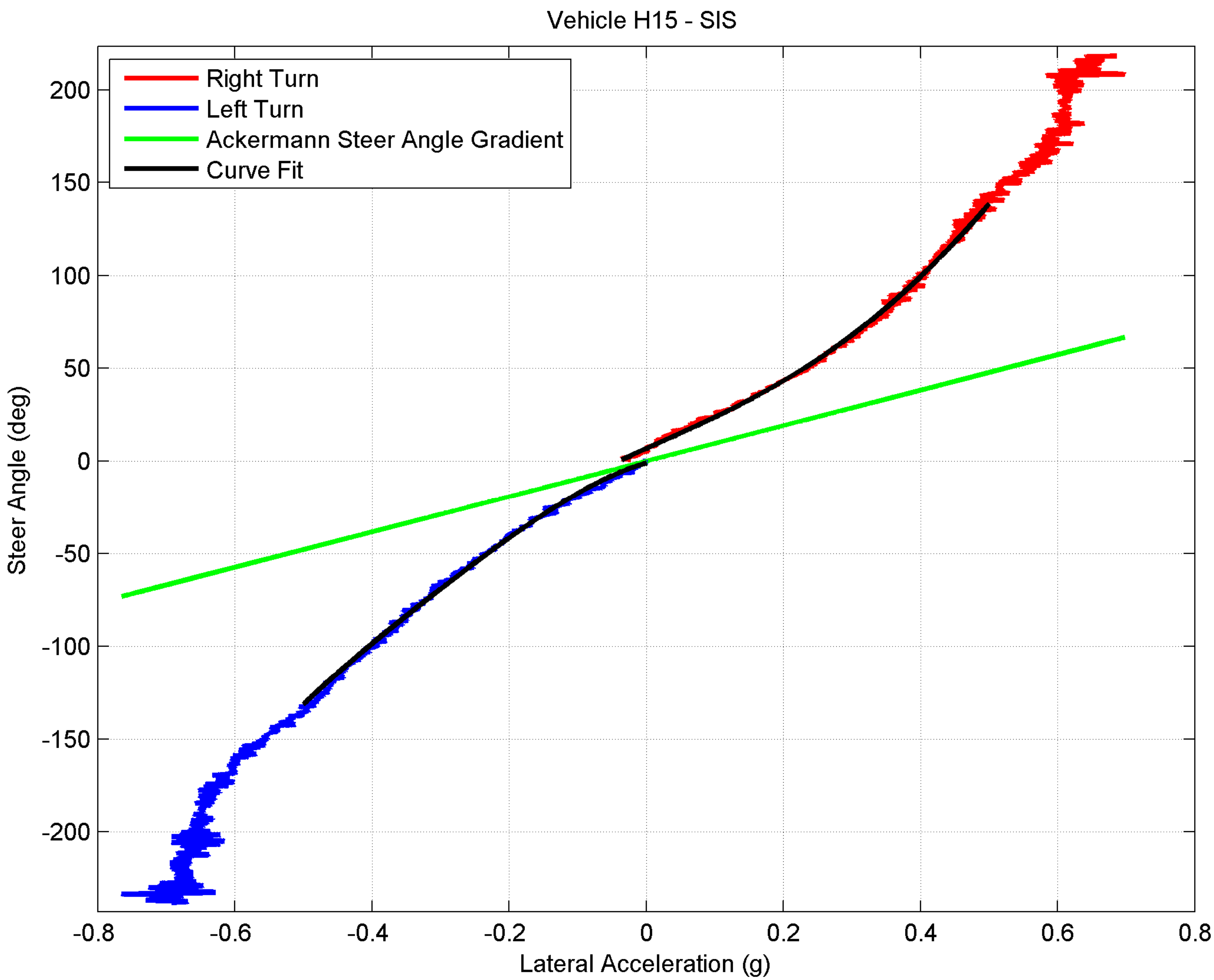

Vehicle F15 - SIS
Right Turn
Left Turn
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Lateral Acceleration (g)
-150
-100
-50
0
50
100
150
Steer Angle (deg)

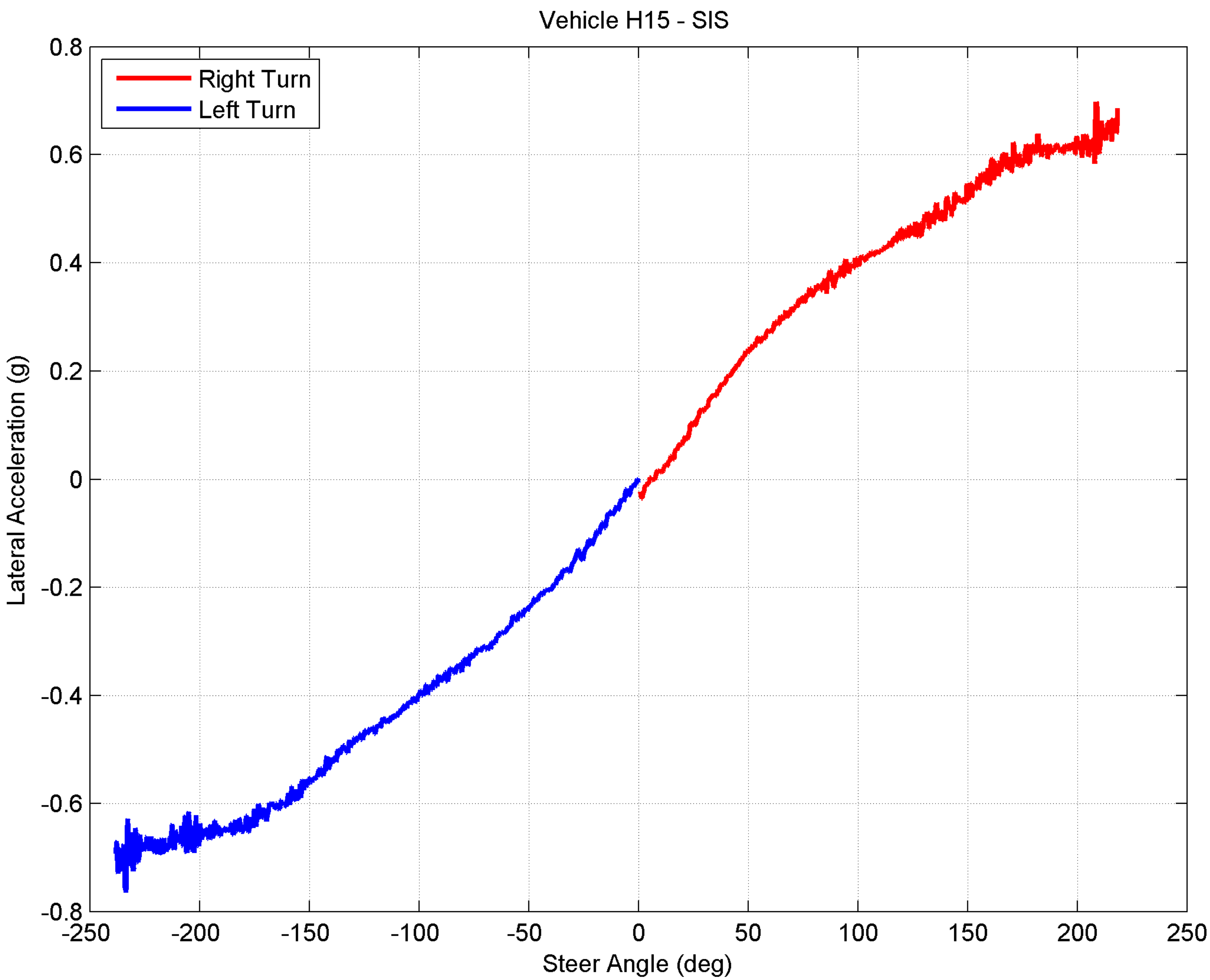

Vehicle G15 - SIS
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Outrigger Contact at End of Tests
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle G15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.41905 g
Transition to Oversteer
At Ay = -0.40122 g
Steer Angle (deg)
Lateral Acceleration (g)
80
60
40
20
0
-20
-40
-60
-80
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

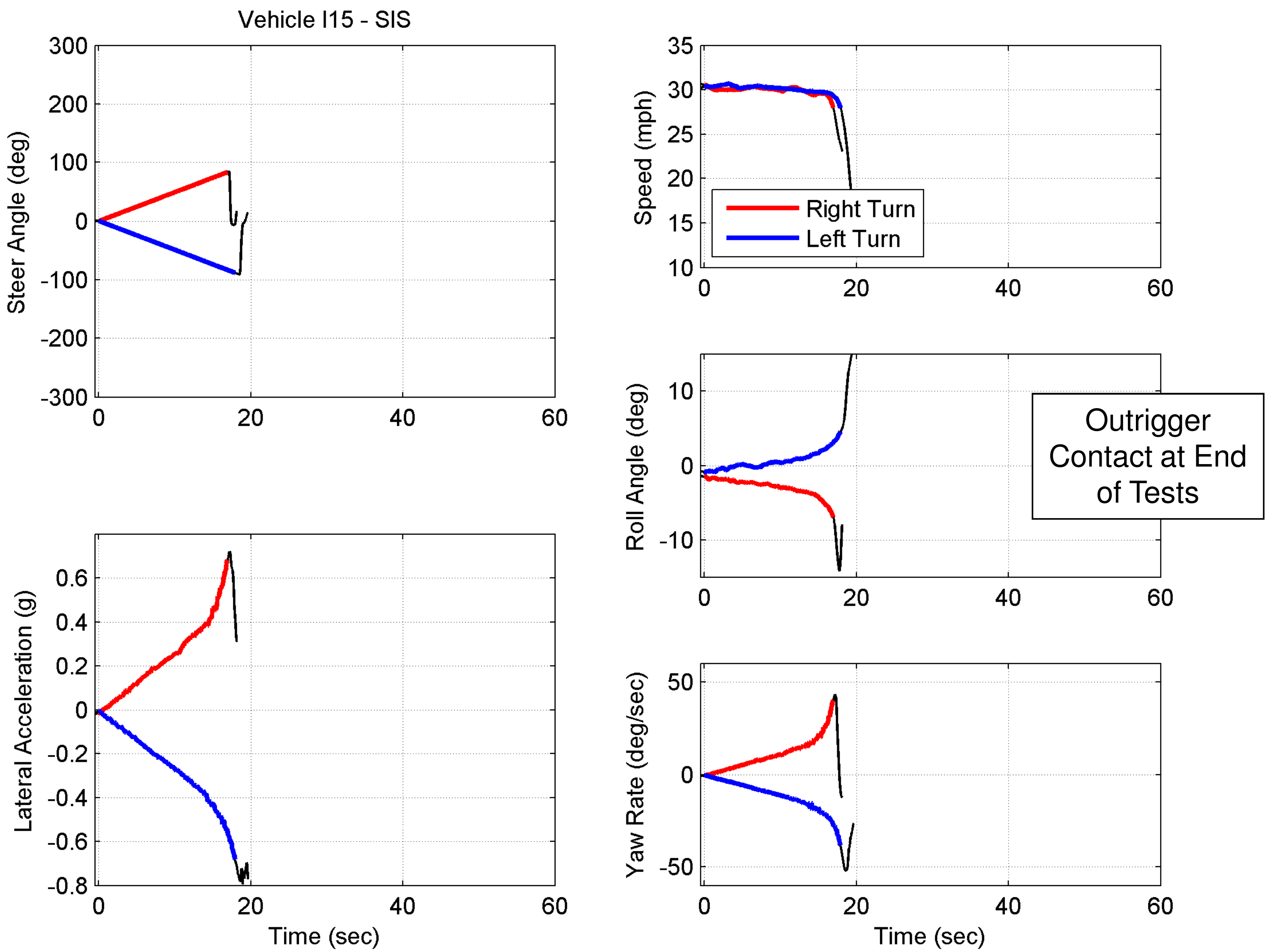

Vehicle G15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-100
-80
-60
-40
-20
0
20
40
60
80
100


Vehicle H15 - SIS
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Outrigger Contact at End of Tests
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

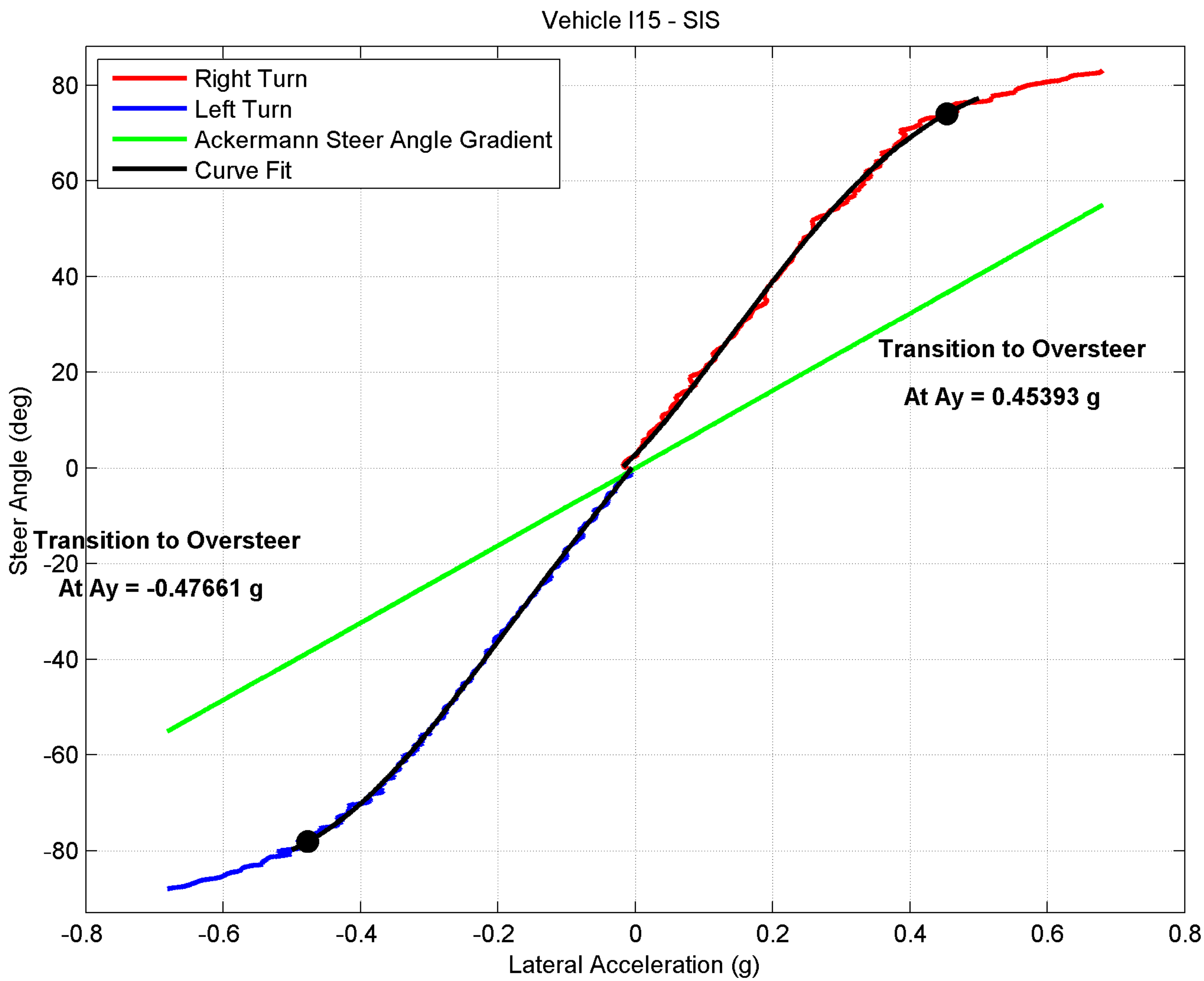

Vehicle H15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)
200
150
100
50
0
-50
-100
-150
-200
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8



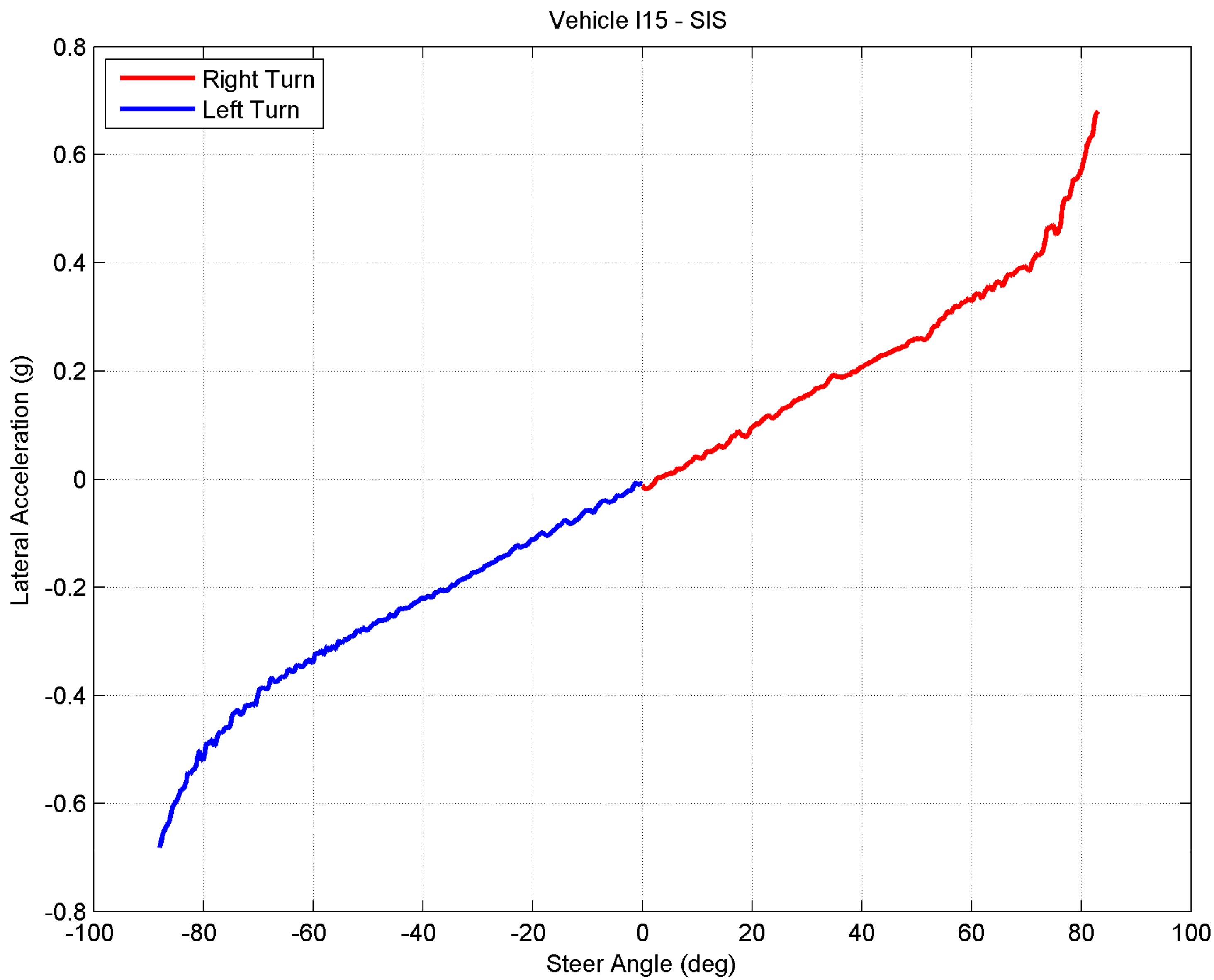
Vehicle H15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-250
-200
-150
-100
-50
0
50
100
150
200
250



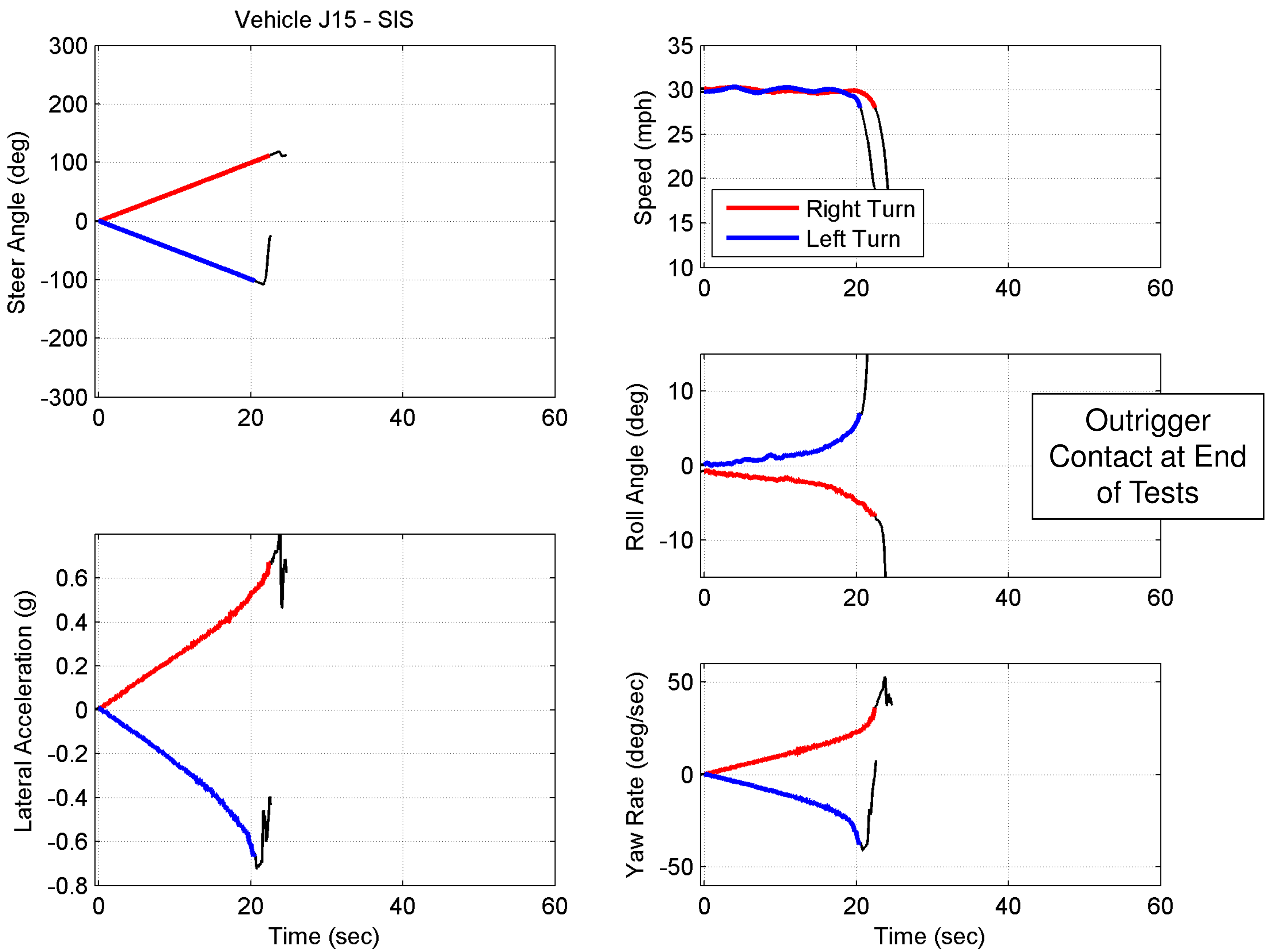
Vehicle I15 - SIS
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Outrigger Contact at End of Tests
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

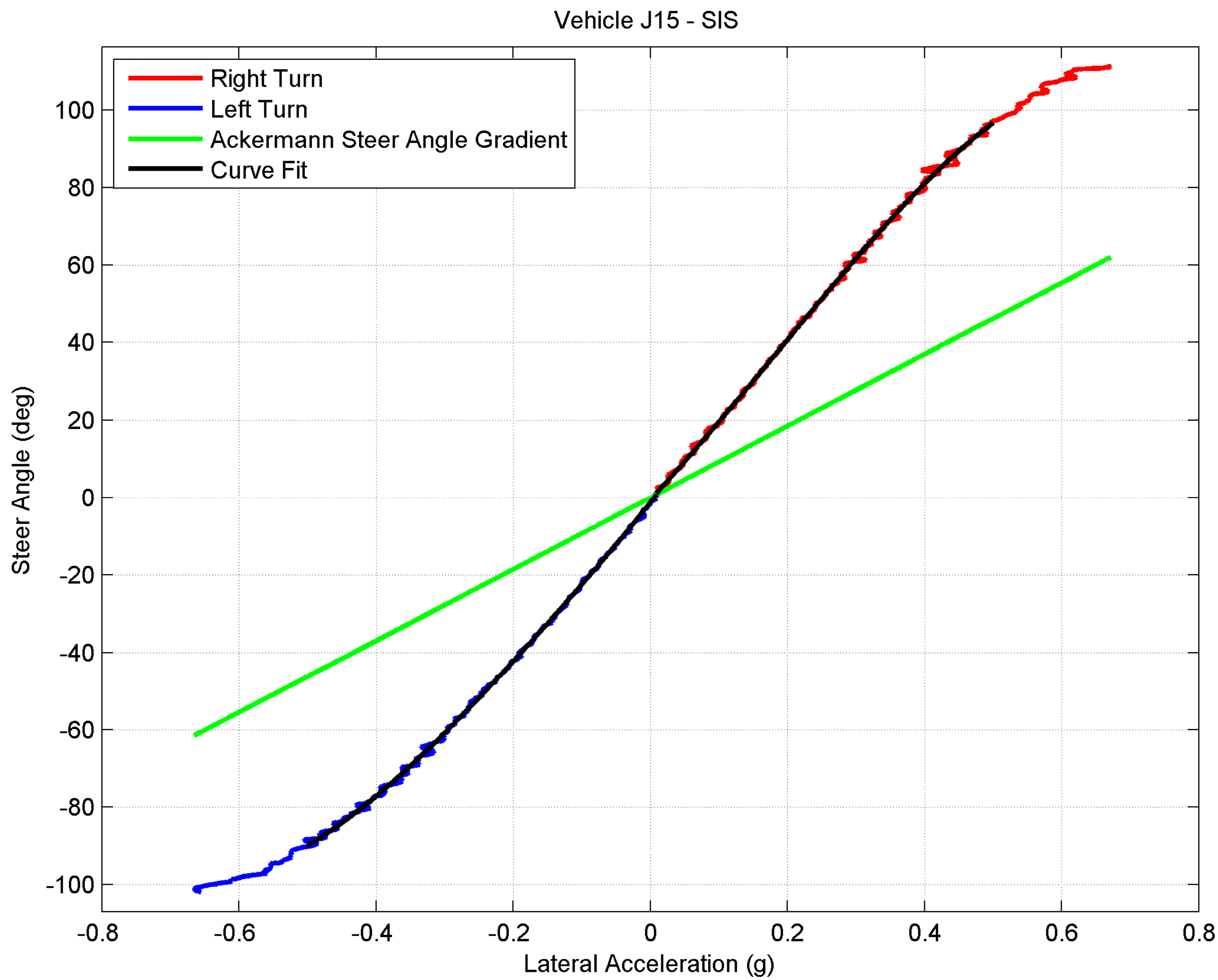


Vehicle I15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.45393 g
Transition to Oversteer
At Ay = -0.47661 g
Steer Angle (deg)
Lateral Acceleration (g)
80
60
40
20
0
-20
-40
-60
-80
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

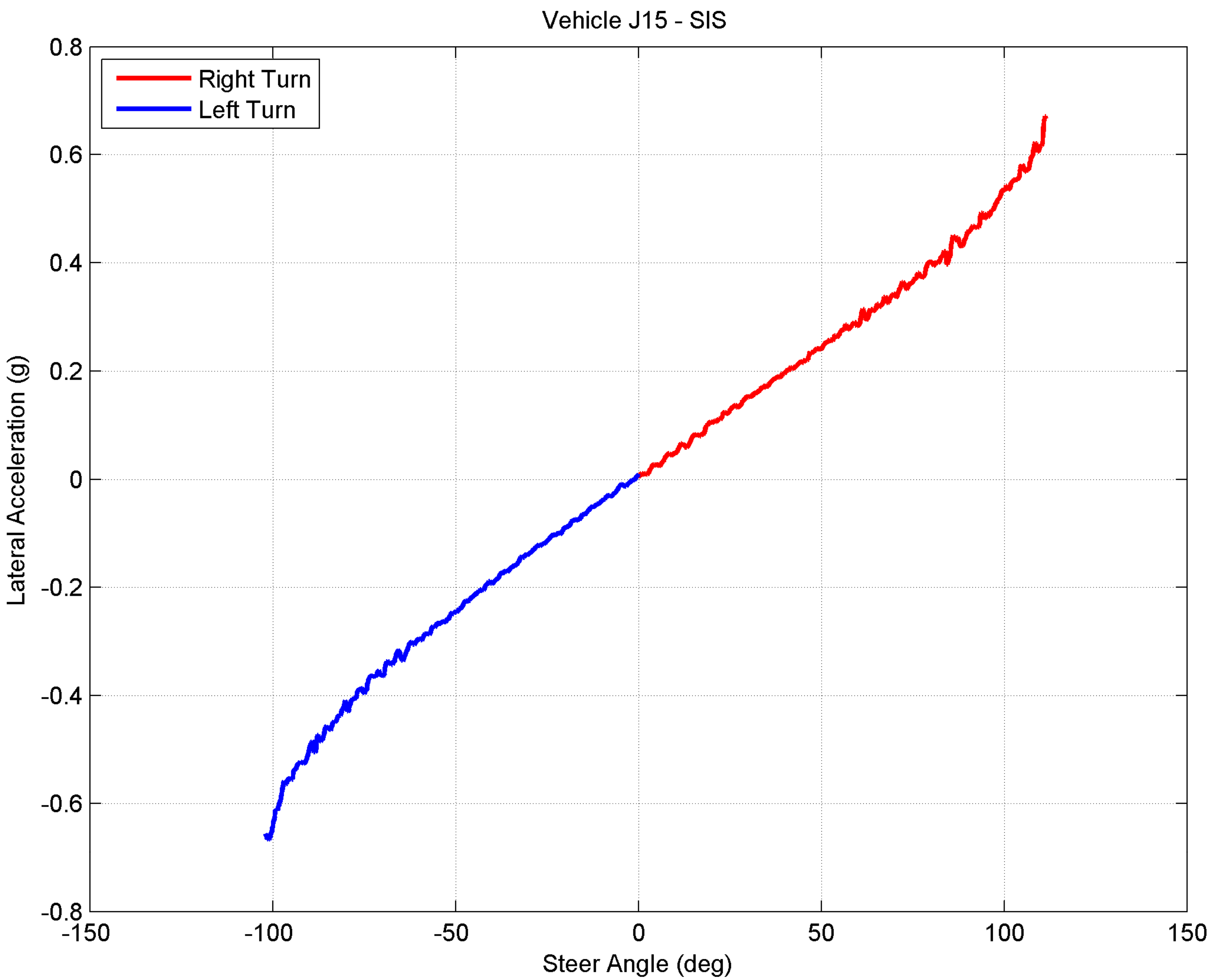


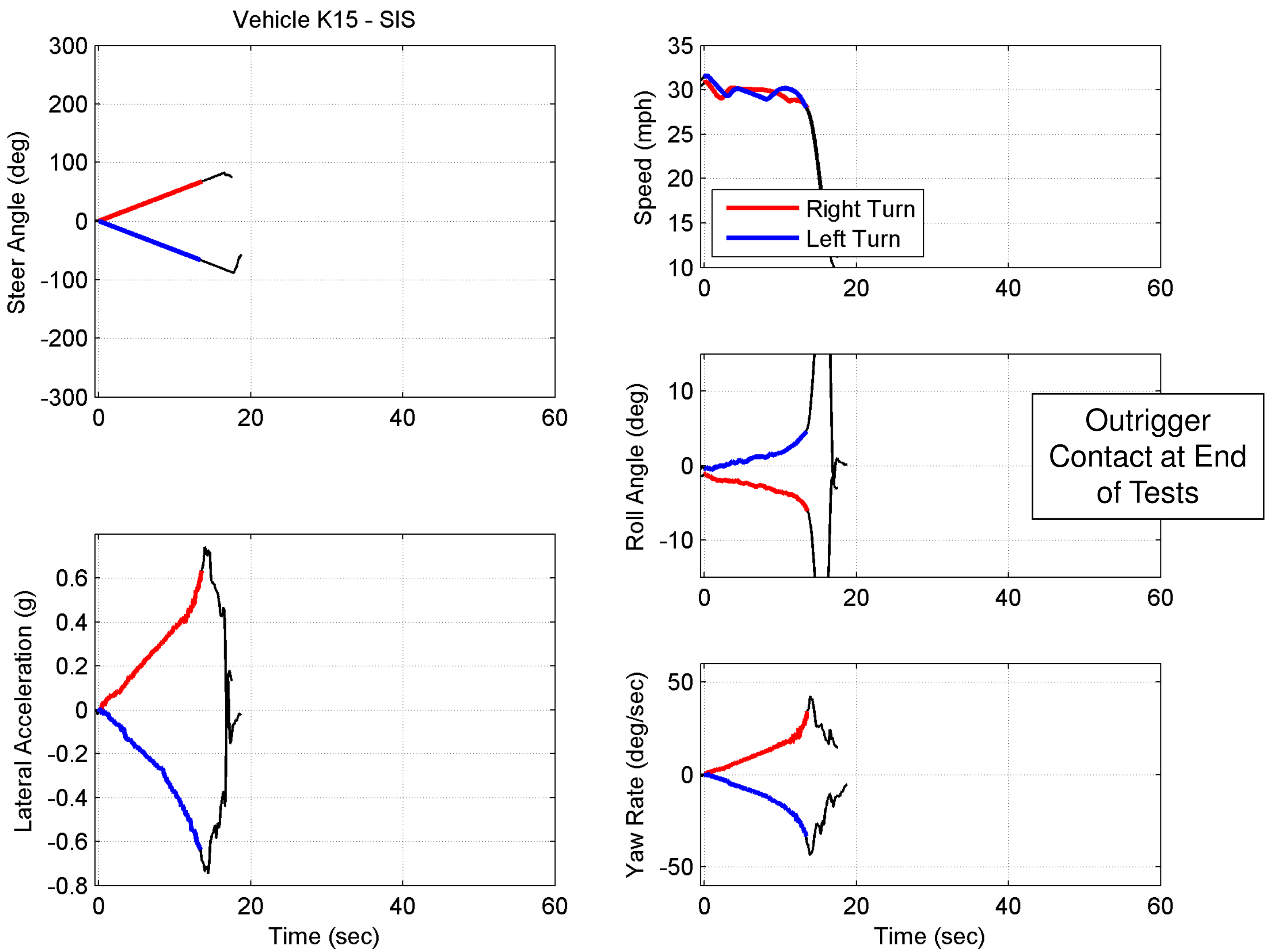
Vehicle I15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-100
-80
-60
-40
-20
0
20
40
60
80
100
Steer Angle (deg)

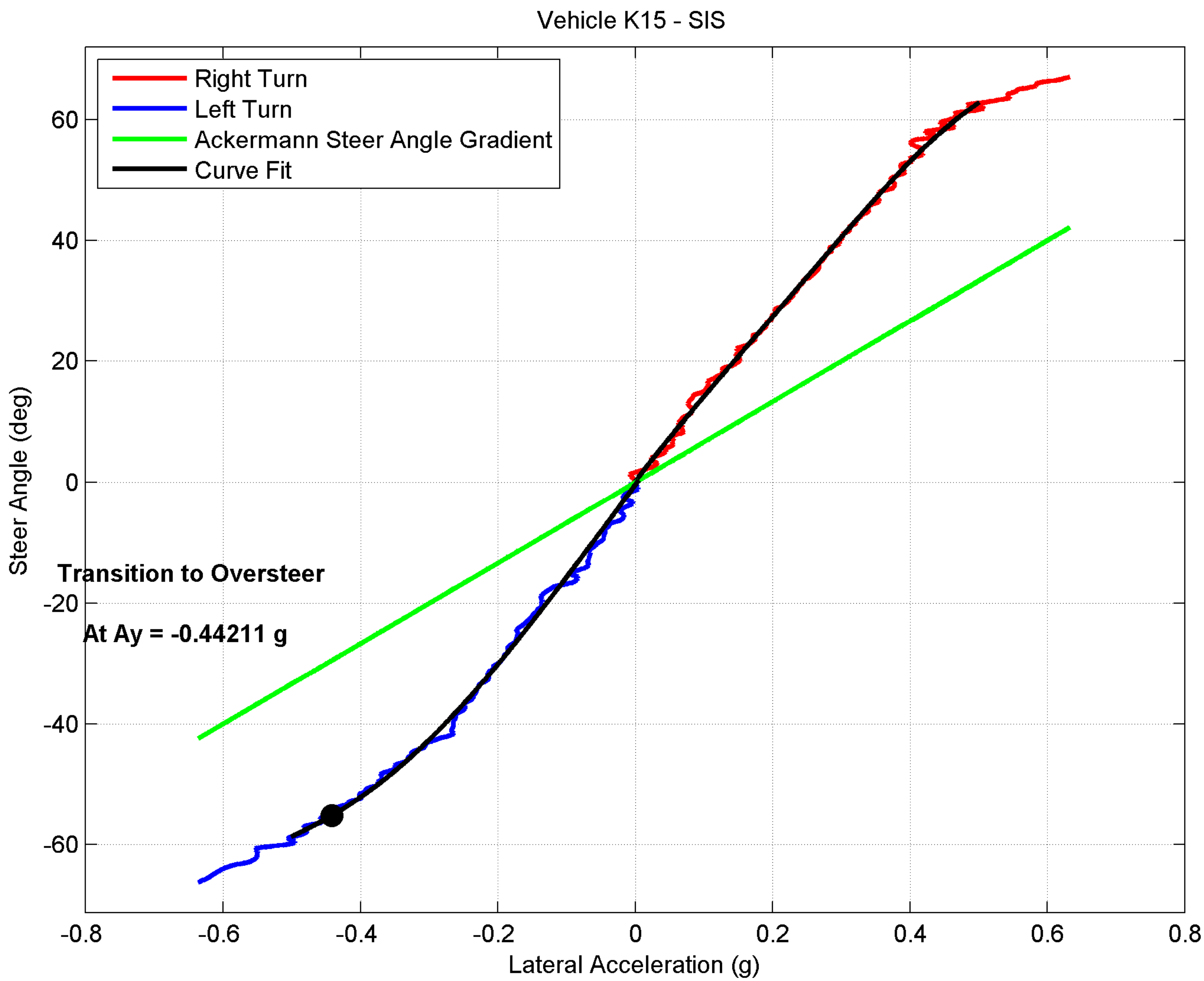

Vehicle J15 - SIS
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Outrigger Contact at End of Tests
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

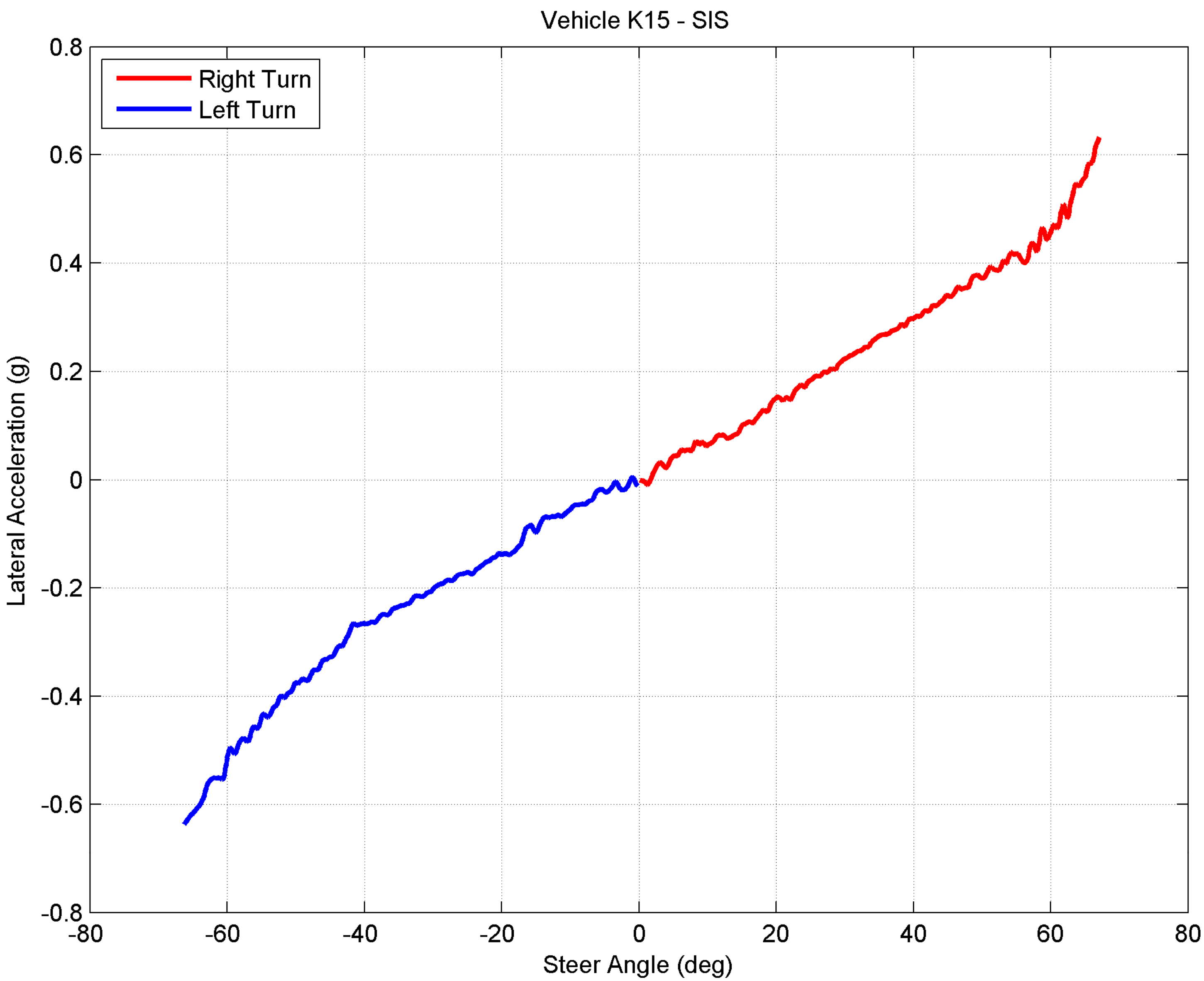


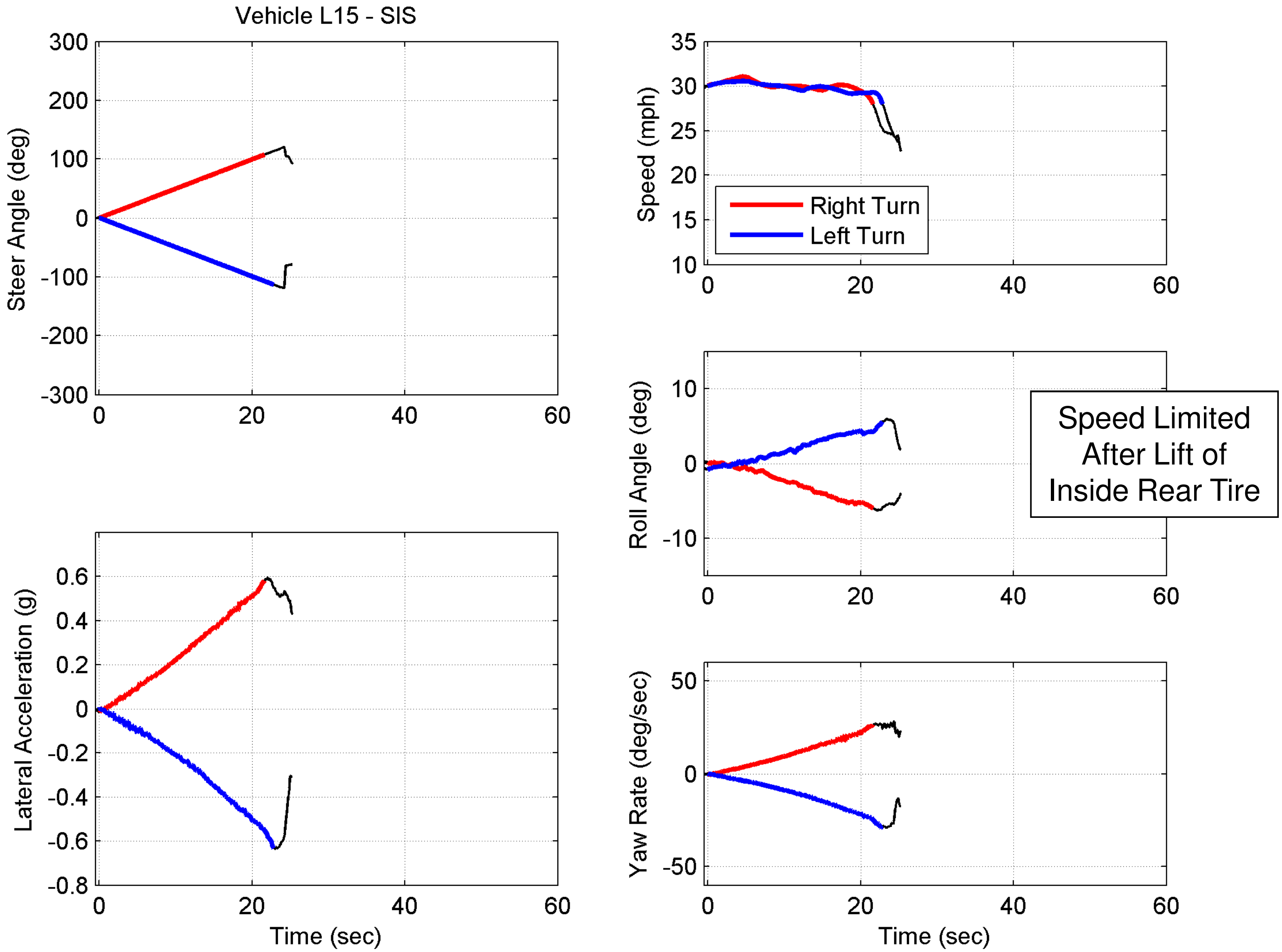
Vehicle J15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

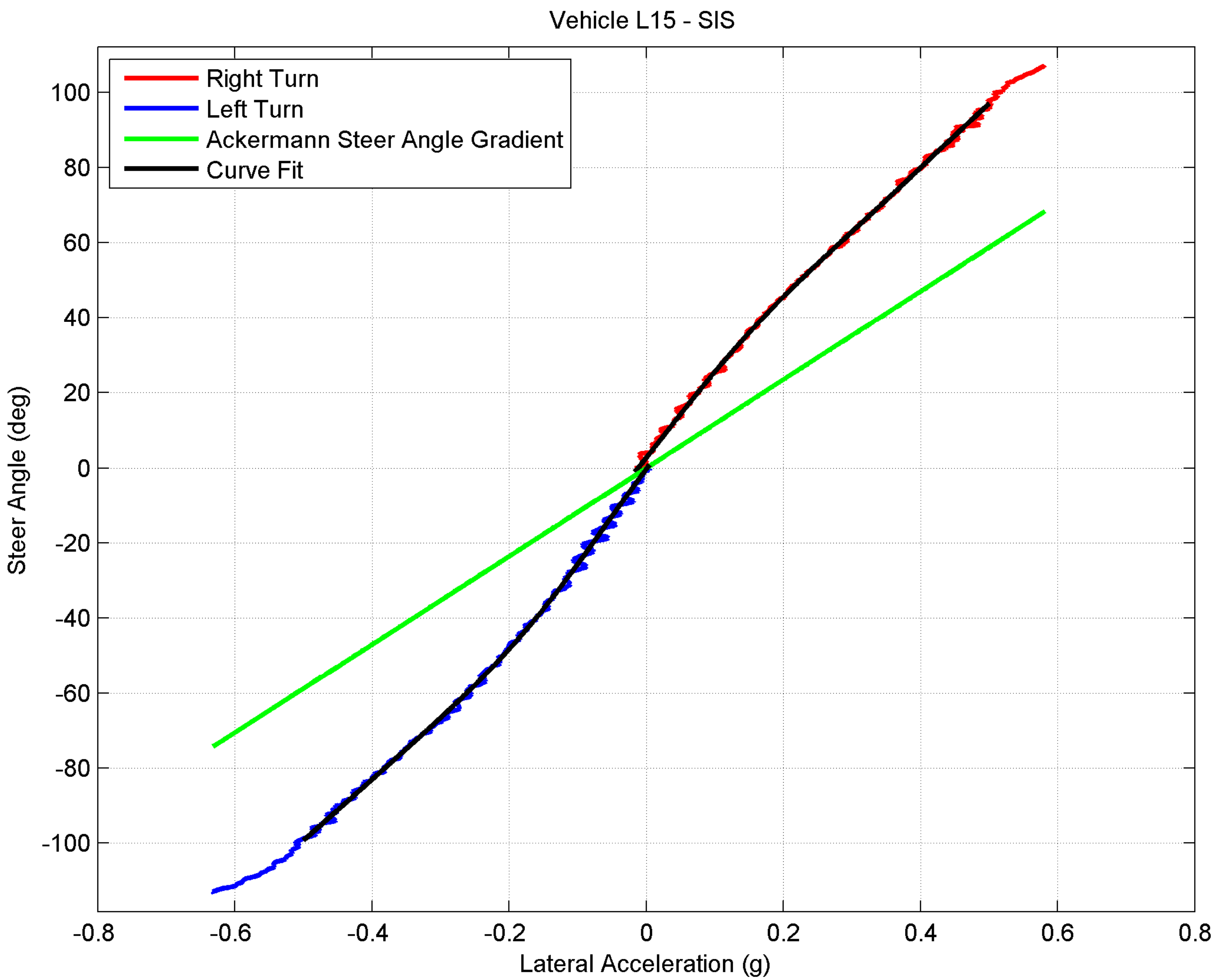

Vehicle J15 - SIS
Right Turn
Left Turn
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Lateral Acceleration (g)
-150
-100
-50
0
50
100
150
Steer Angle (deg)

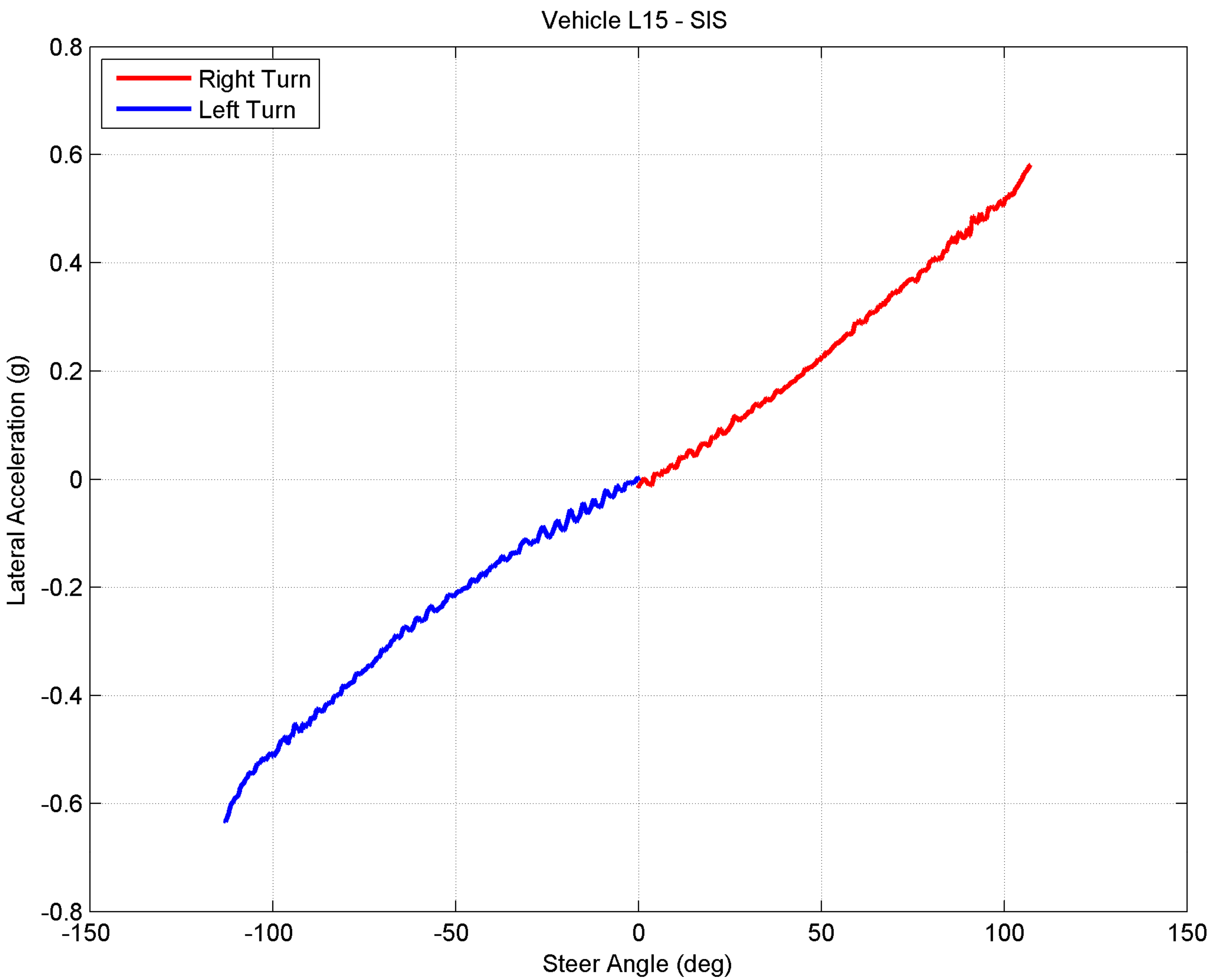

Vehicle K15 - SIS
Steer Angle (deg)
300
200
100
0
-100
-200
-300
0
20
40
60
Speed (mph)
35
30
25
20
15
10
Right Turn
Left Turn
Roll Angle (deg)
10
-10
Outrigger Contact at End of Tests
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
50
-50
Time (sec)


Vehicle K15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = -0.44211 g
Steer Angle (deg)
Lateral Acceleration (g)
60
40
20
0
-20
-40
-60
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

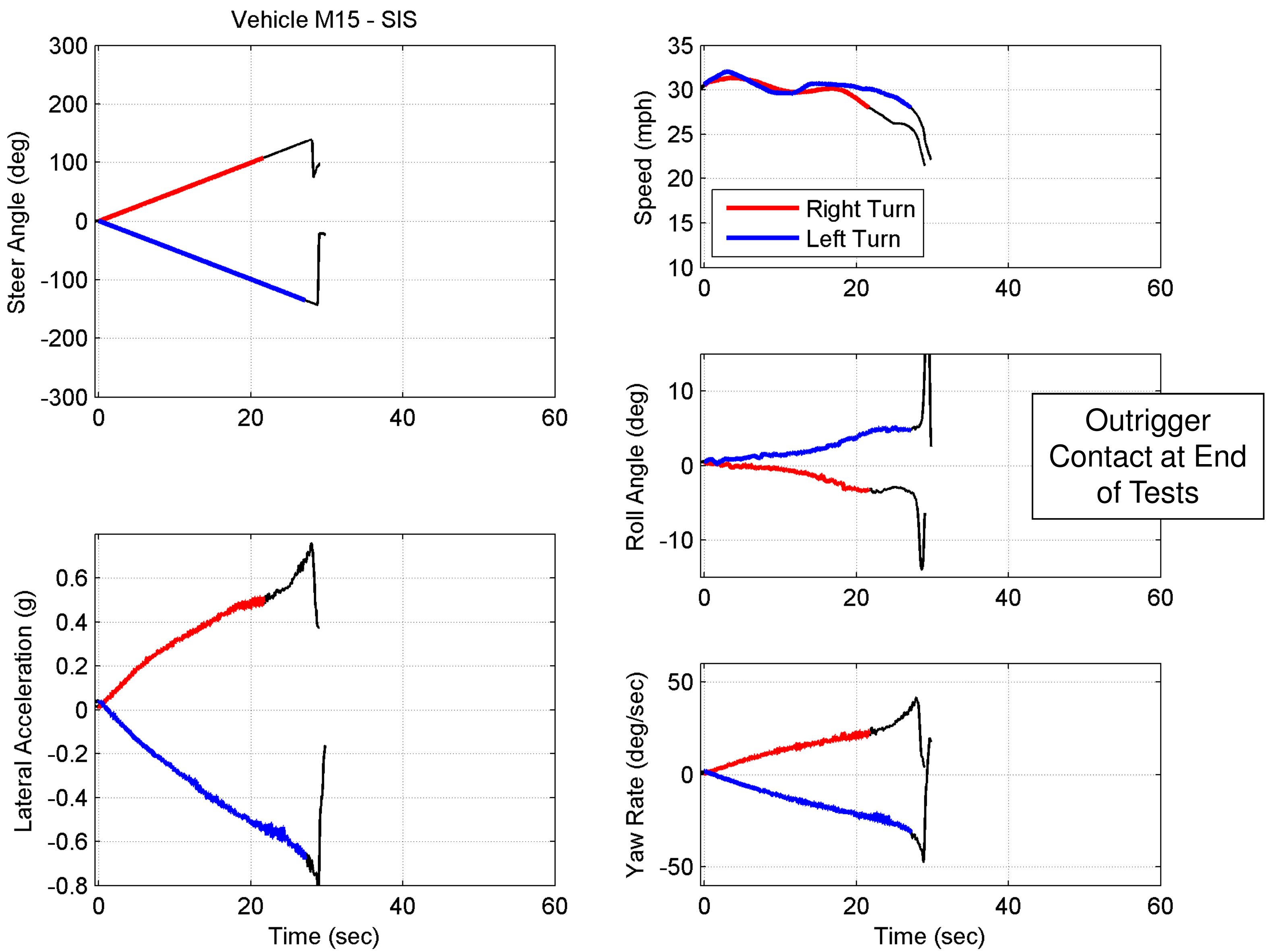

Vehicle K15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-80
-60
-40
-20
0
20
40
60
80
Steer Angle (deg)

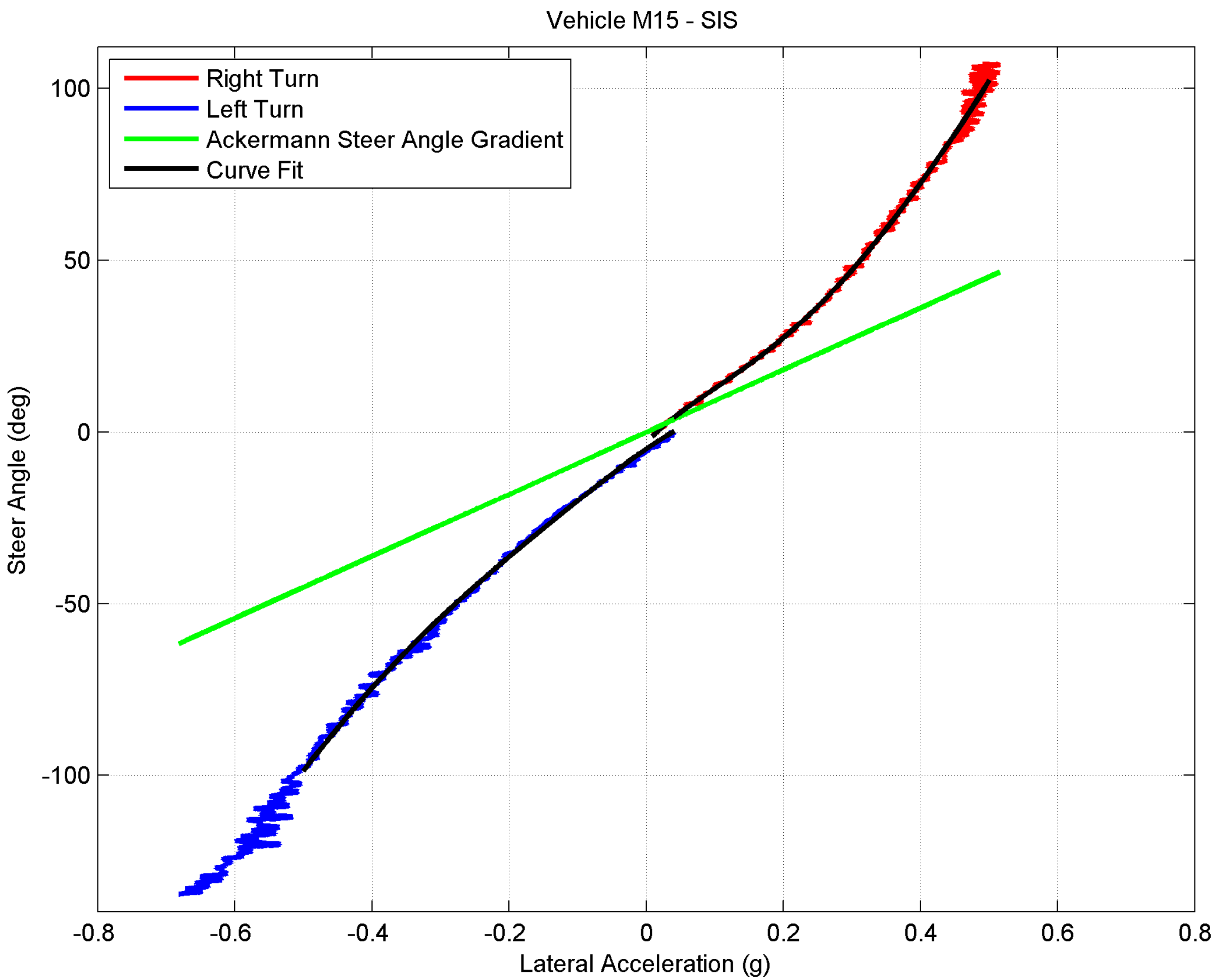

Vehicle L15 - SIS
Steer Angle (deg)
300
200
100
0
-100
-200
-300
0
20
40
60
Speed (mph)
35
30
25
20
15
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Speed Limited
After Lift of
Inside Rear Tire
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

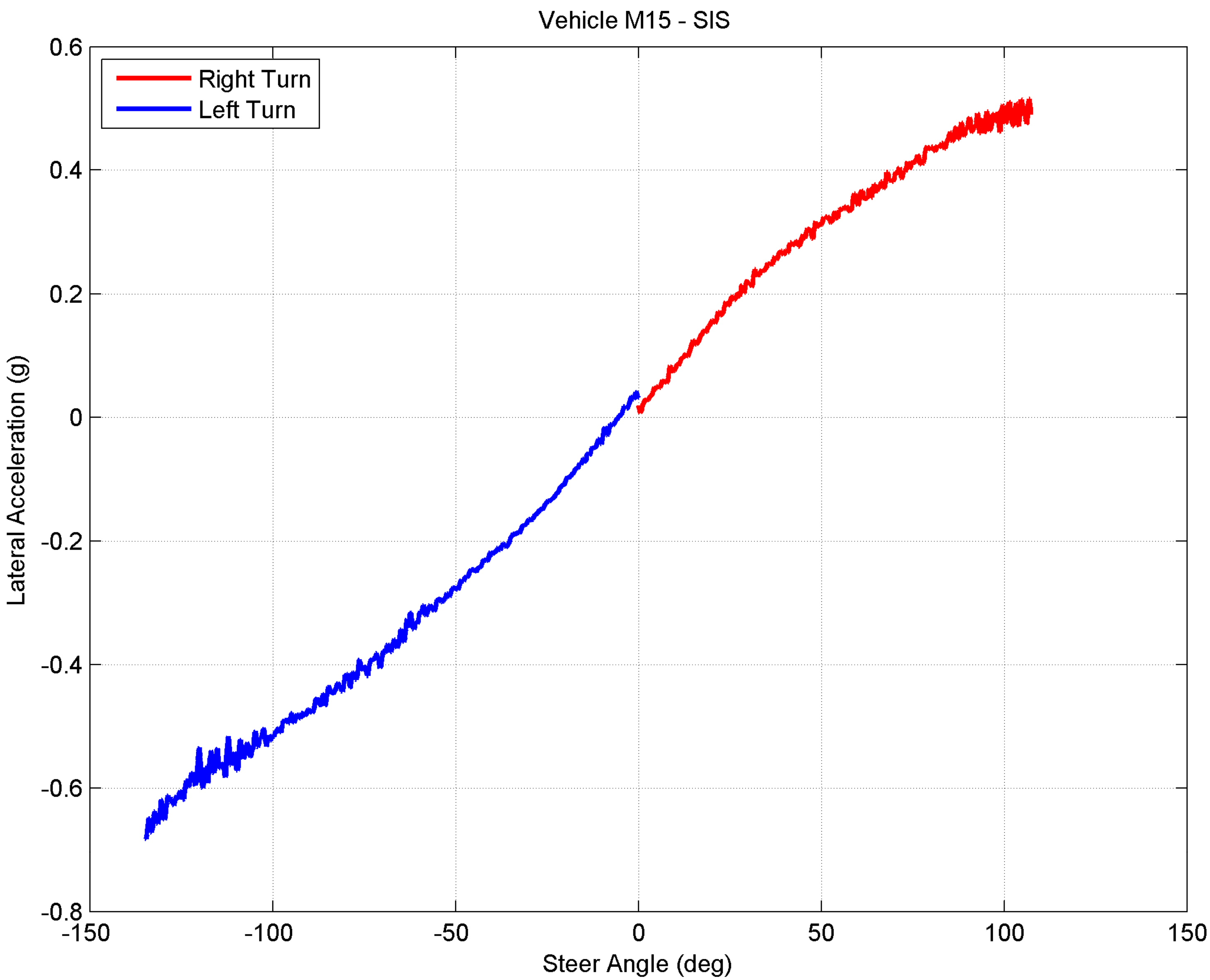

Vehicle L15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Lateral Acceleration (g)



Vehicle L15 - SIS
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150

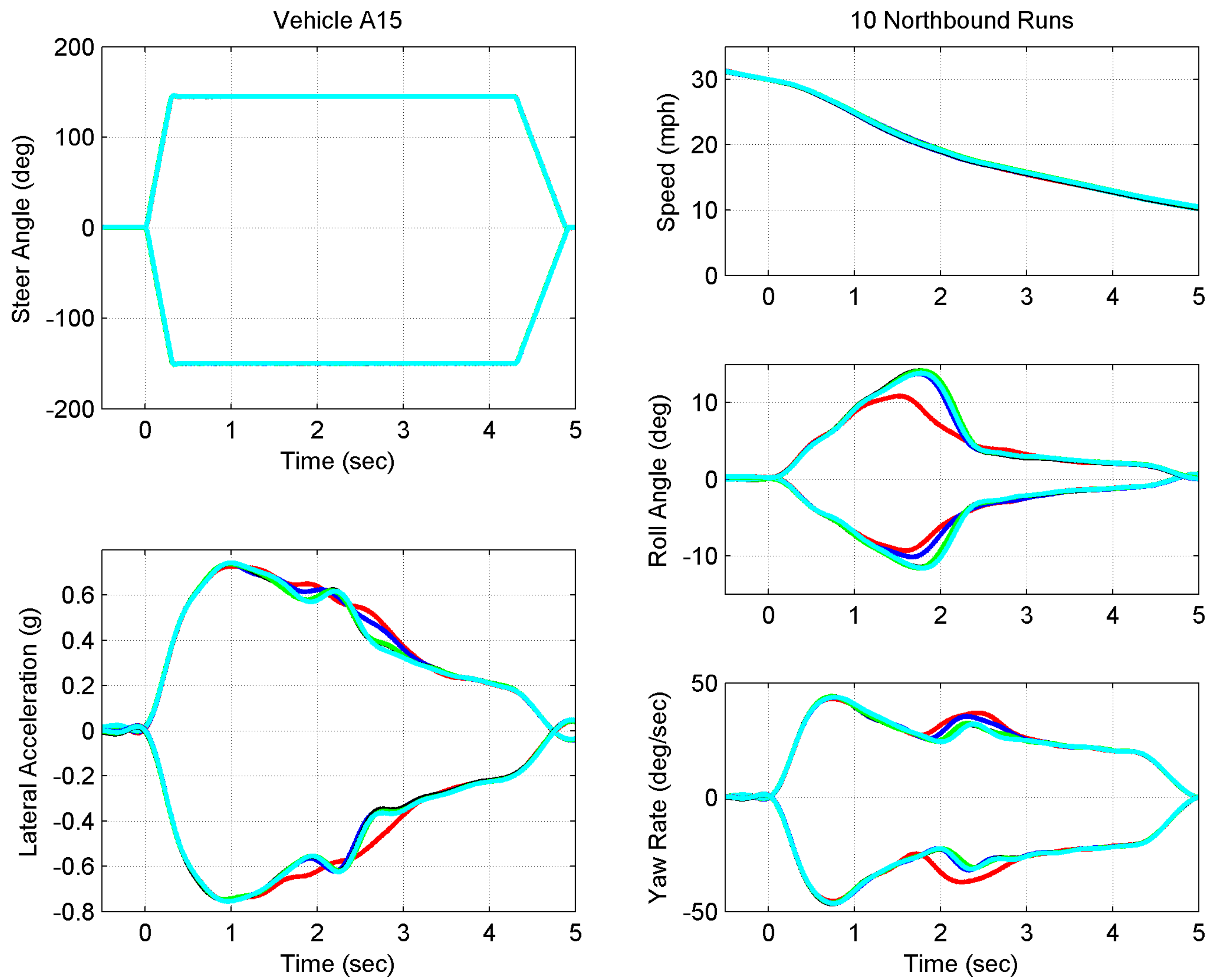

Vehicle M15 - SIS
Steer Angle (deg)
300
200
100
0
-100
-200
-300
0
20
40
60
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Speed (mph)
35
30
25
20
15
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Outrigger Contact at End of Tests
Yaw Rate (deg/sec)
50
0
-50
Time (sec)


Vehicle M15 - SIS
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

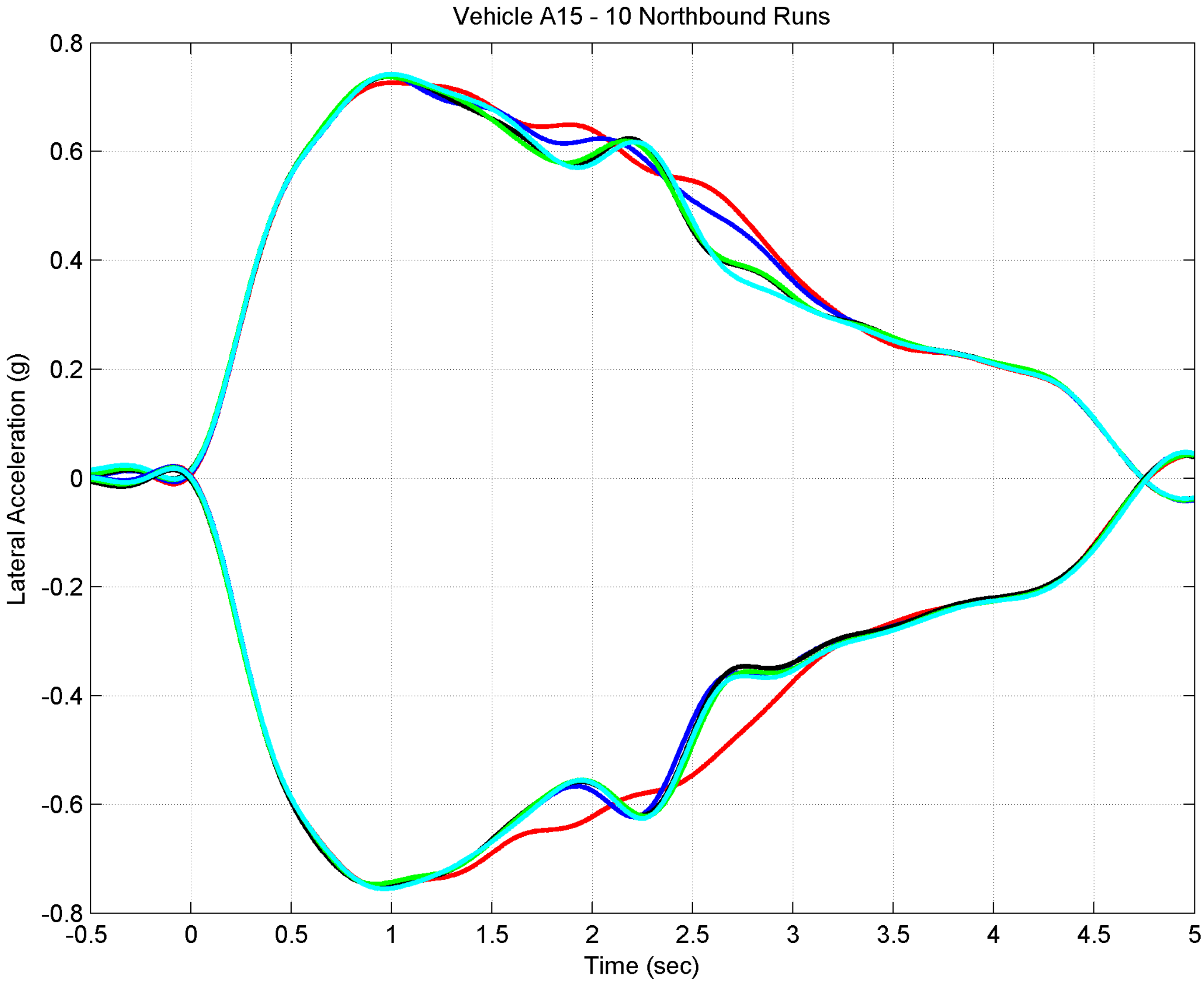


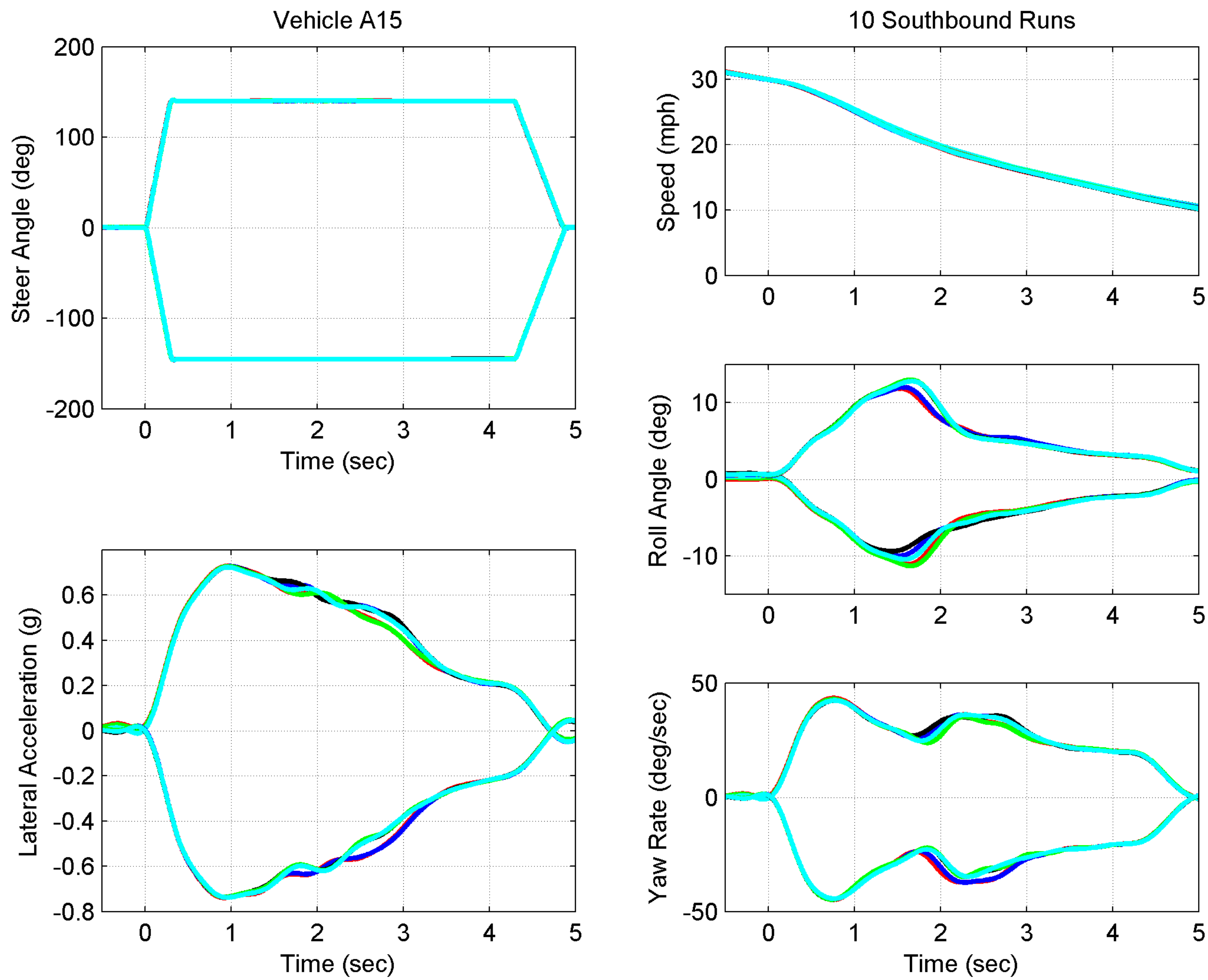
Vehicle M15 - SIS
Right Turn
Left Turn
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Lateral Acceleration (g)
-150
-100
-50
0
50
100
150
Steer Angle (deg)

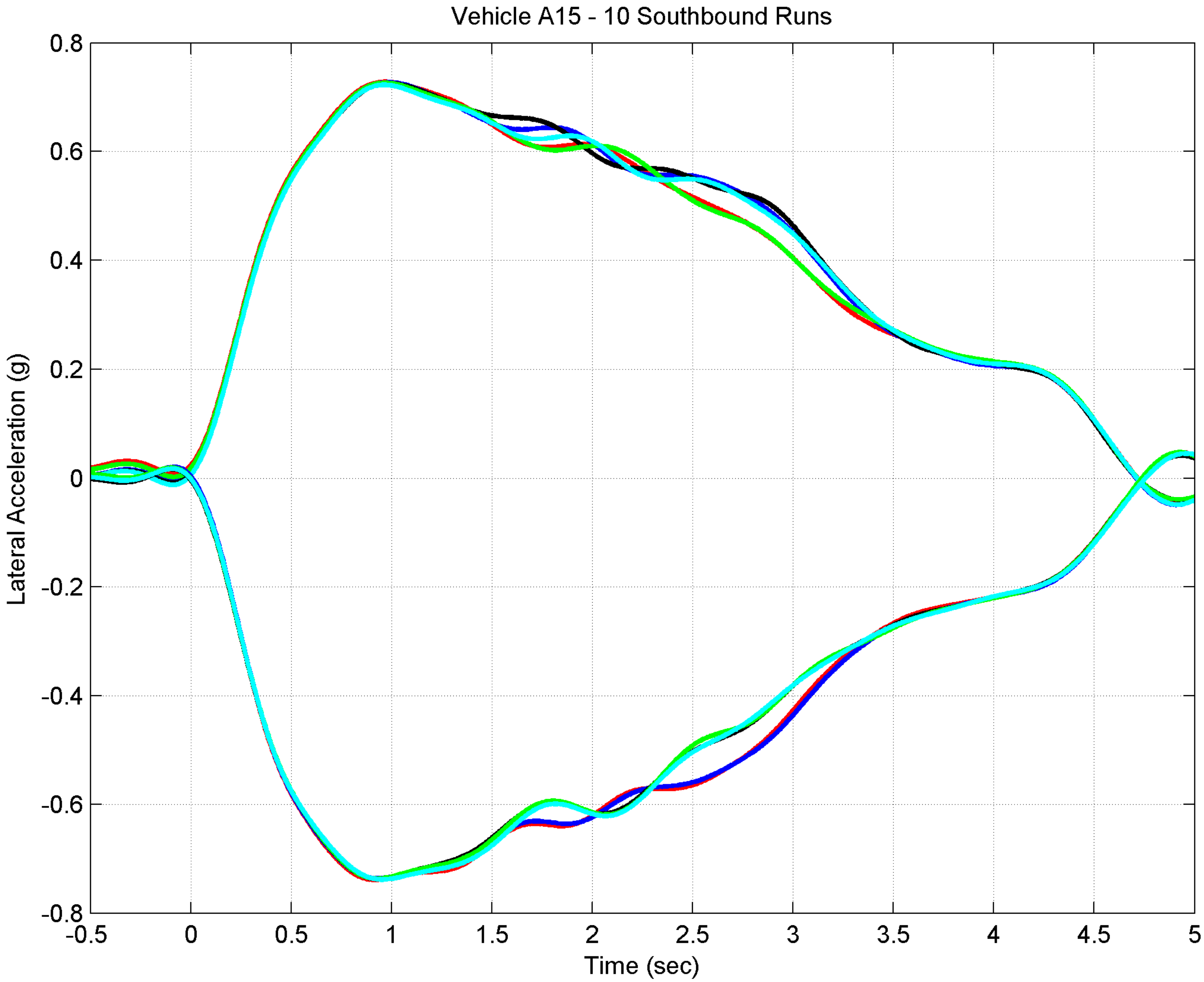
Constant Speed (30 mph) Slowly Increasing Steer Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Operator and Passenger Loading)			
	Right Turn (g)	Left Turn (g)	Average (g)
Vehicle A15	0.50	NA	NA
Vehicle B15	NA	NA	NA
Vehicle C15	0.45	0.47	0.46
Vehicle D15	0.44	0.44	0.44
Vehicle E15	0.48	0.45	0.46
Vehicle F15	NA	NA	NA
Vehicle G15	0.42	0.40	0.41
Vehicle H15	NA	NA	NA
Vehicle I15	0.45	0.48	0.47
Vehicle J15	NA	NA	NA
Vehicle K15	NA	0.44	NA
Vehicle L15	NA	NA	NA
Vehicle M15	NA	NA	NA



Vehicle A15
10 Northbound Runs
Steer Angle (deg)
200
100
0
-100
-200
Time (sec)
Speed (mph)
30
20
10
Roll Angle (deg)
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
50
-50
-10
0
1
2
3
4
5


Vehicle A15 - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle A15
10 Southbound Runs
Steer Angle (deg)
200
100
0
-100
-200
Time (sec)
Speed (mph)
30
20
10
Roll Angle (deg)
-10
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
50
-50
0
1
2
3
4
5


Vehicle A15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle A15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.7268	-0.7523
2	0.7392	-0.7510
3	0.7385	-0.7478
4	0.7375	-0.7471
5	0.7421	-0.7556
Mean Value of 5 Runs	0.7368	-0.7508
Standard Deviation of 5 Runs	0.006	0.003

Average of 10 Northbound Runs

0.7438

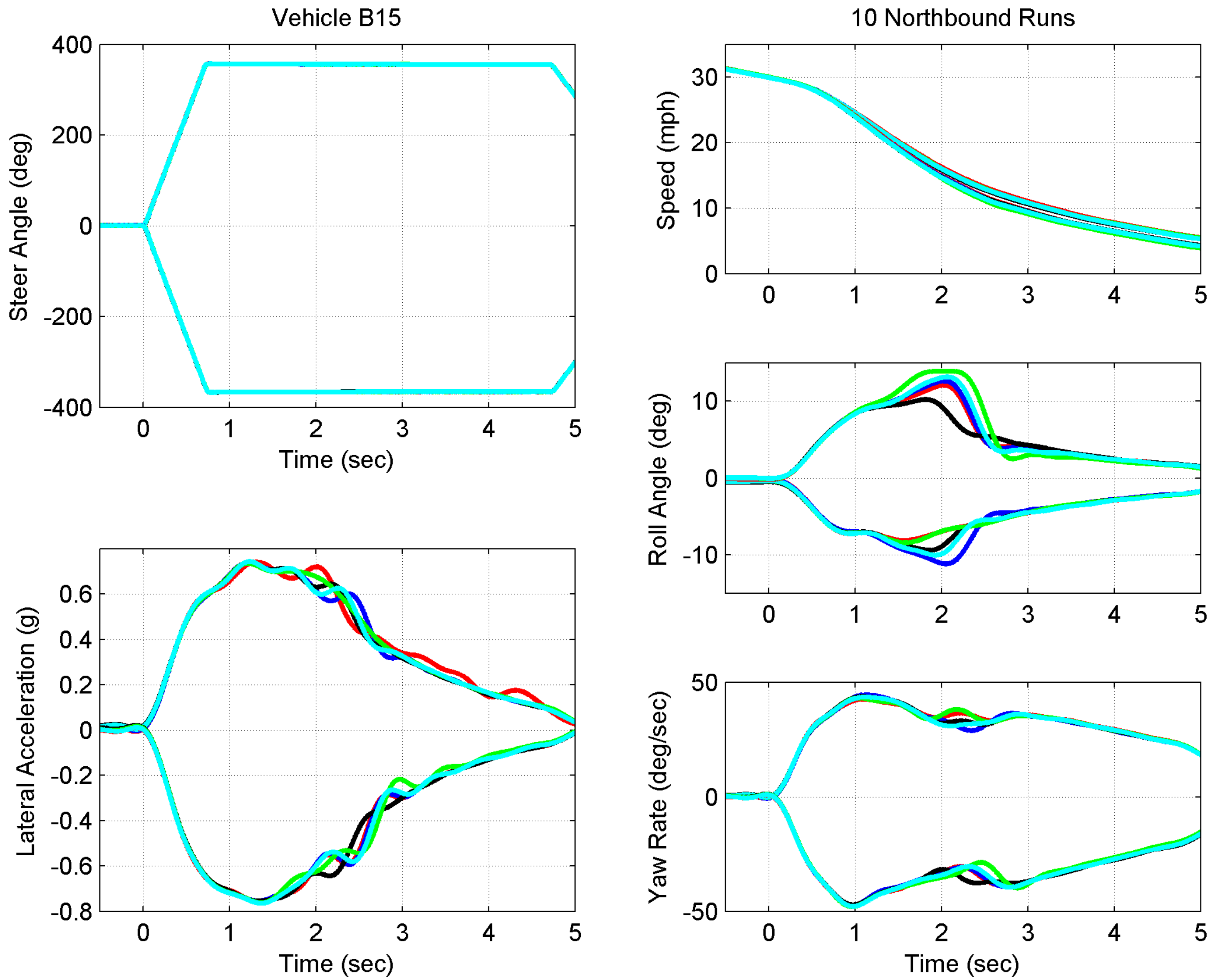
Average of All 20 Runs

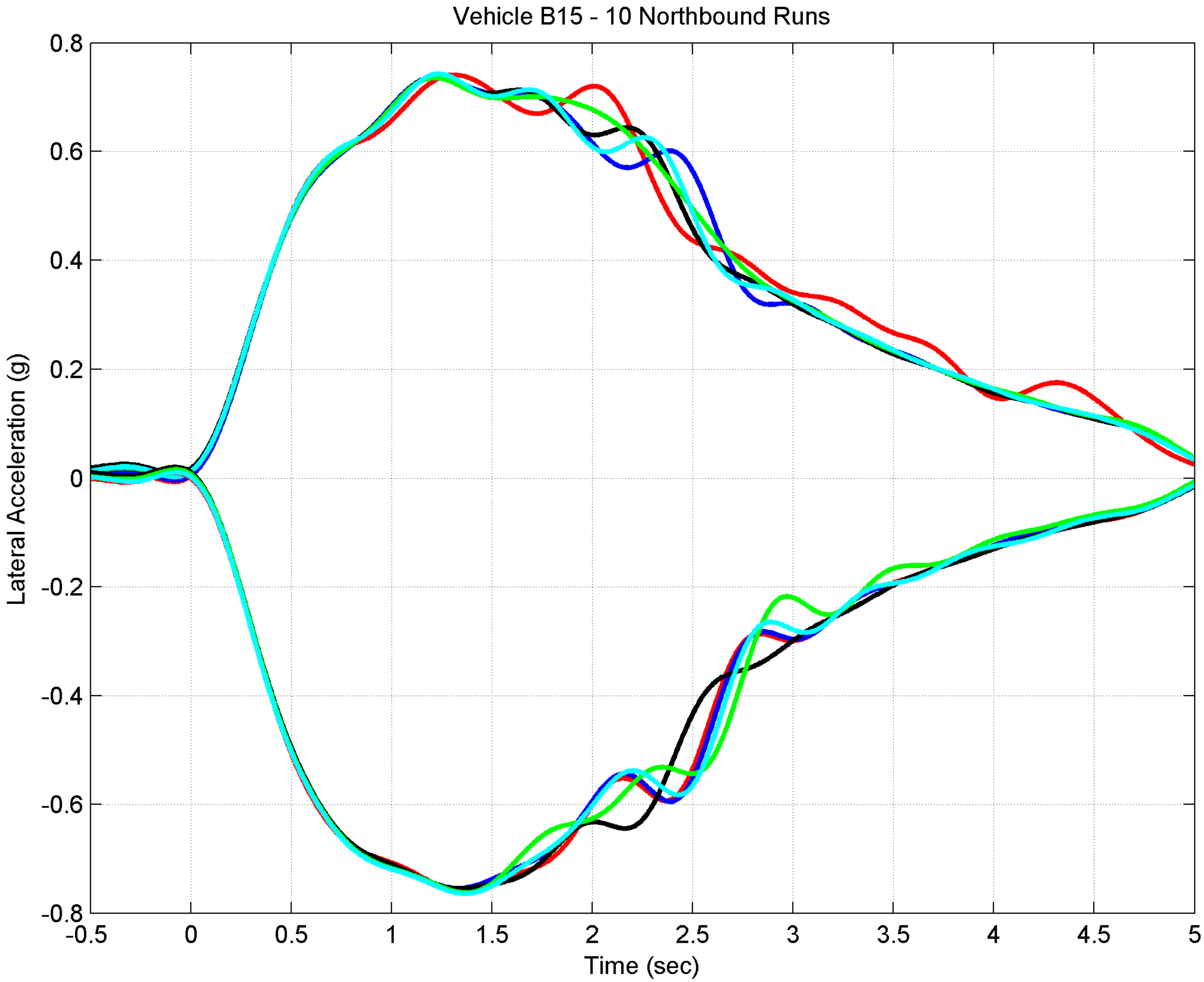
0.738

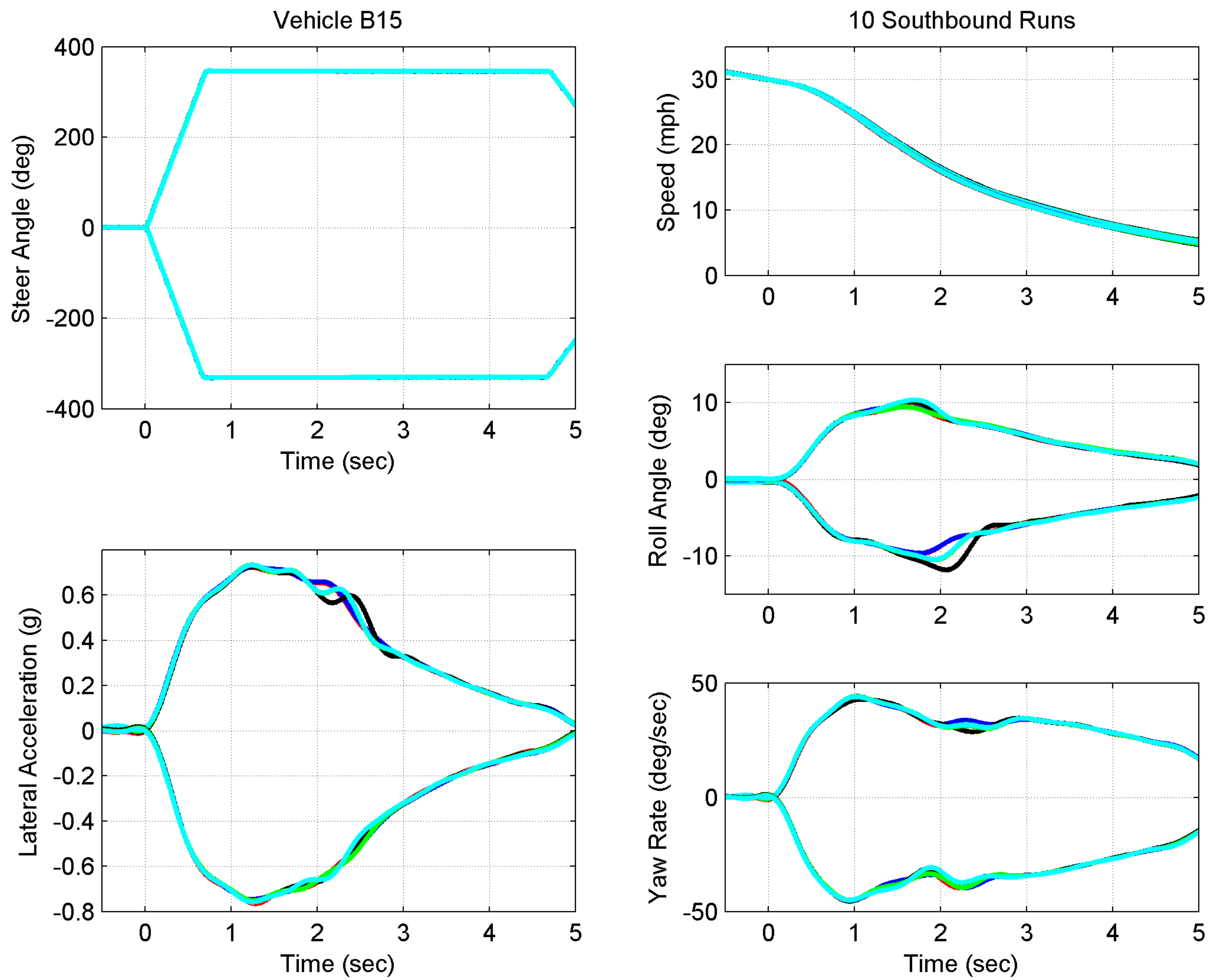
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.7281	-0.7392
2	0.7276	-0.7365
3	0.7256	-0.7374
4	0.7266	-0.7369
5	0.7228	-0.7385
Mean Value of 5 Runs	0.7261	-0.7377
Standard Deviation of 5 Runs	0.002	0.001

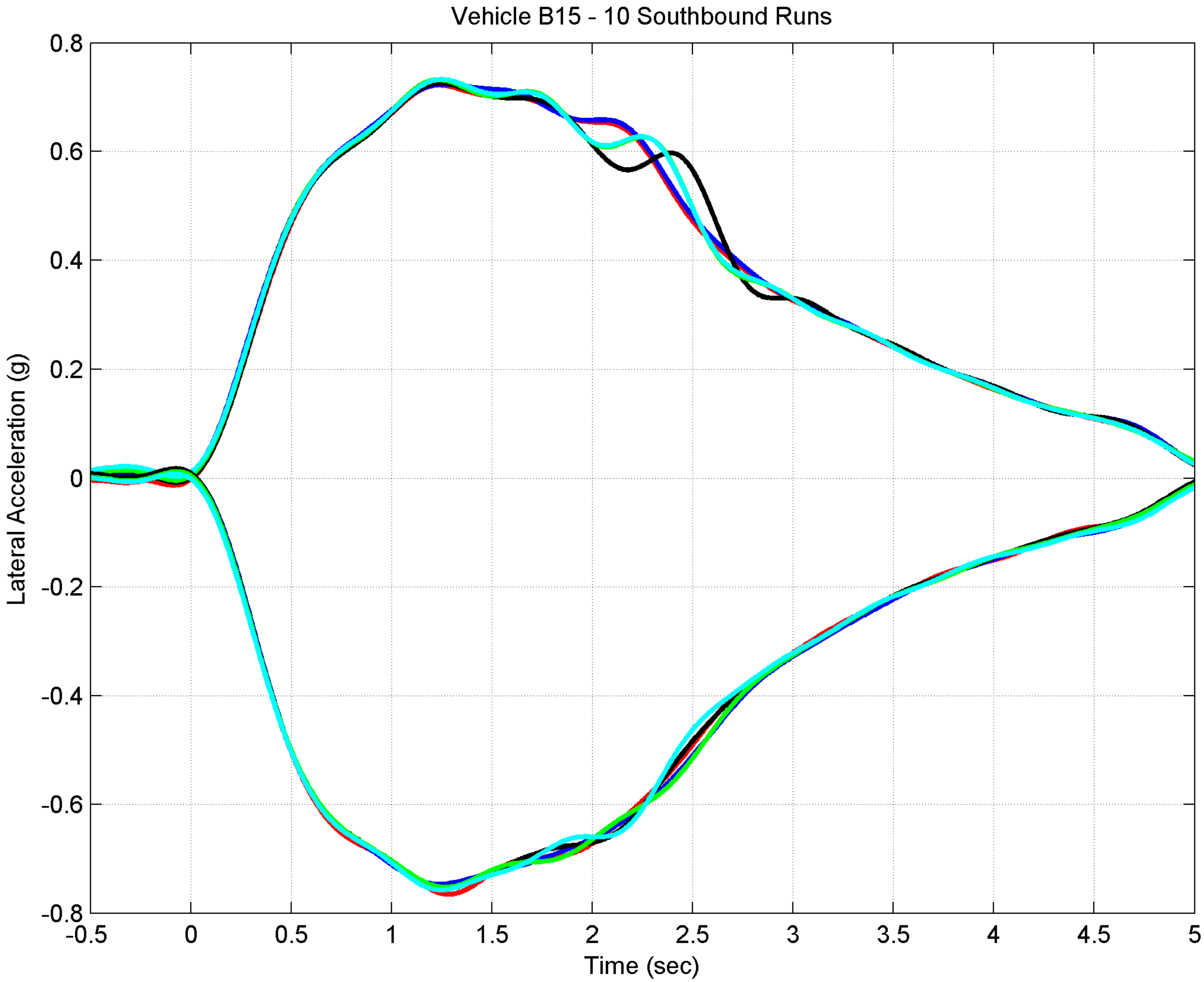
Average of 10 Southbound Runs

0.7319


Vehicle B15
10 Northbound Runs
Steer Angle (deg)
400
200
0
-200
-400
Time (sec)
0
1
2
3
4
5
Speed (mph)
30
20
10
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
50
0
-50


Vehicle B15 - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle B15
10 Southbound Runs
Steer Angle (deg)
400
200
0
-200
-400
0 1 2 3 4 5
Time (sec)
Speed (mph)
30
20
10
0
0 1 2 3 4 5
Roll Angle (deg)
10
0
-10
0 1 2 3 4 5
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0 1 2 3 4 5
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
0 1 2 3 4 5
Time (sec)


Vehicle B15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle B15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.7409	-0.7591
2	0.7374	-0.7545
3	0.7382	-0.7550
4	0.7358	-0.7626
5	0.7429	-0.7645
Mean Value of 5 Runs	0.7390	-0.7592
Standard Deviation of 5 Runs	0.003	0.004

Average of 10 Northbound Runs

0.7491

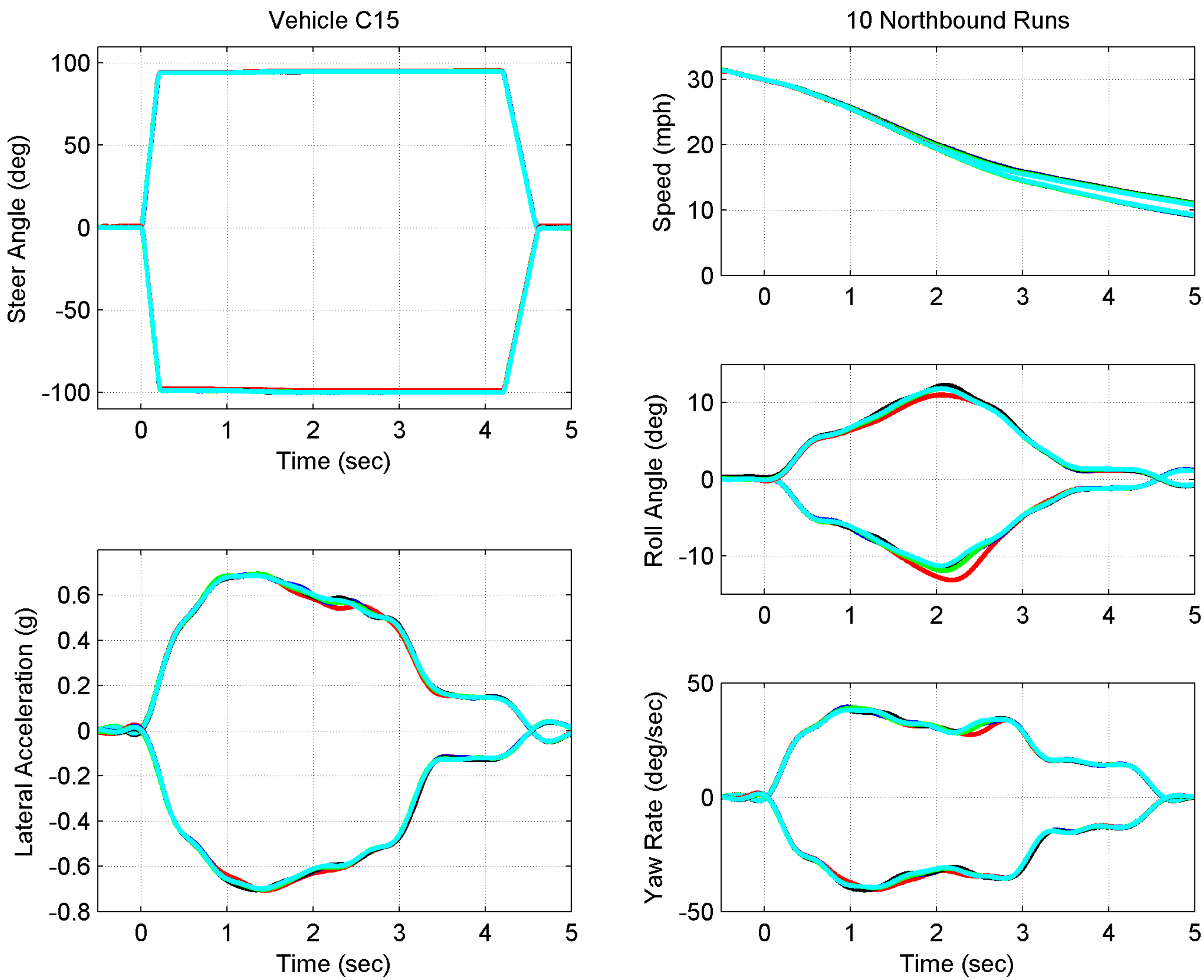
Average of All 20 Runs

0.745

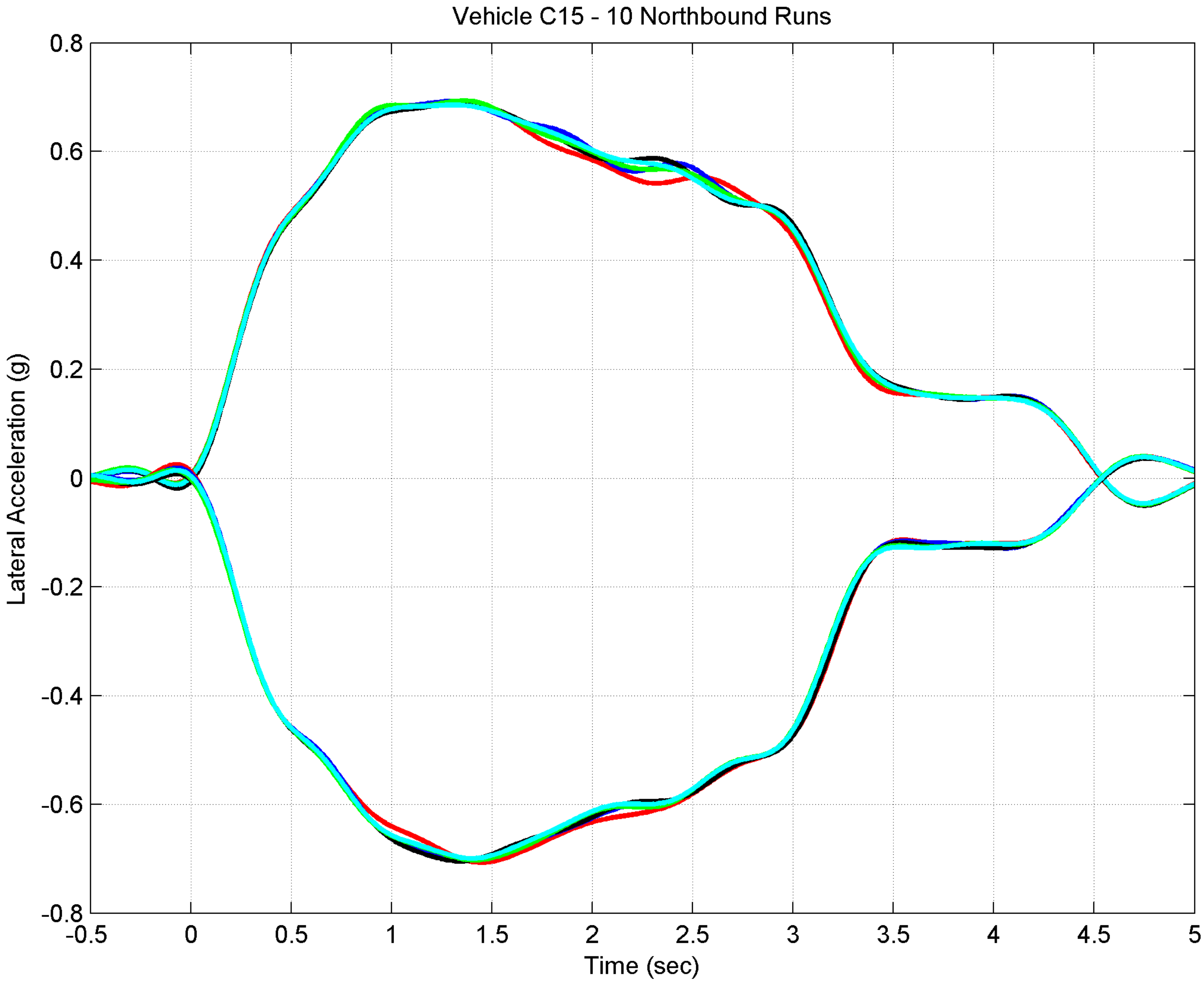
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.7221	-0.7656
2	0.7238	-0.7470
3	0.7257	-0.7565
4	0.7323	-0.7528
5	0.7328	-0.7578
Mean Value of 5 Runs	0.7273	-0.7560
Standard Deviation of 5 Runs	0.005	0.007

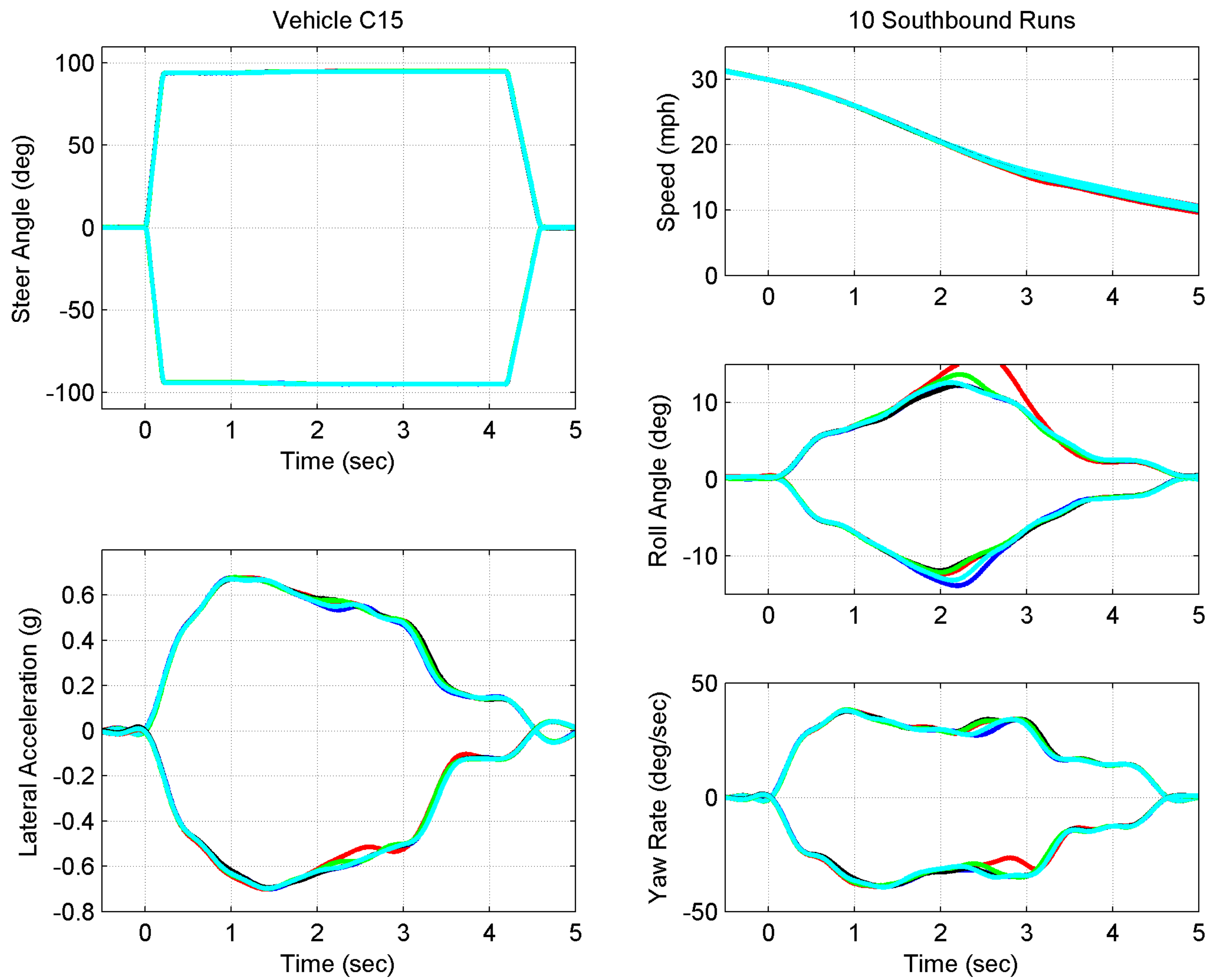
Average of 10 Southbound Runs

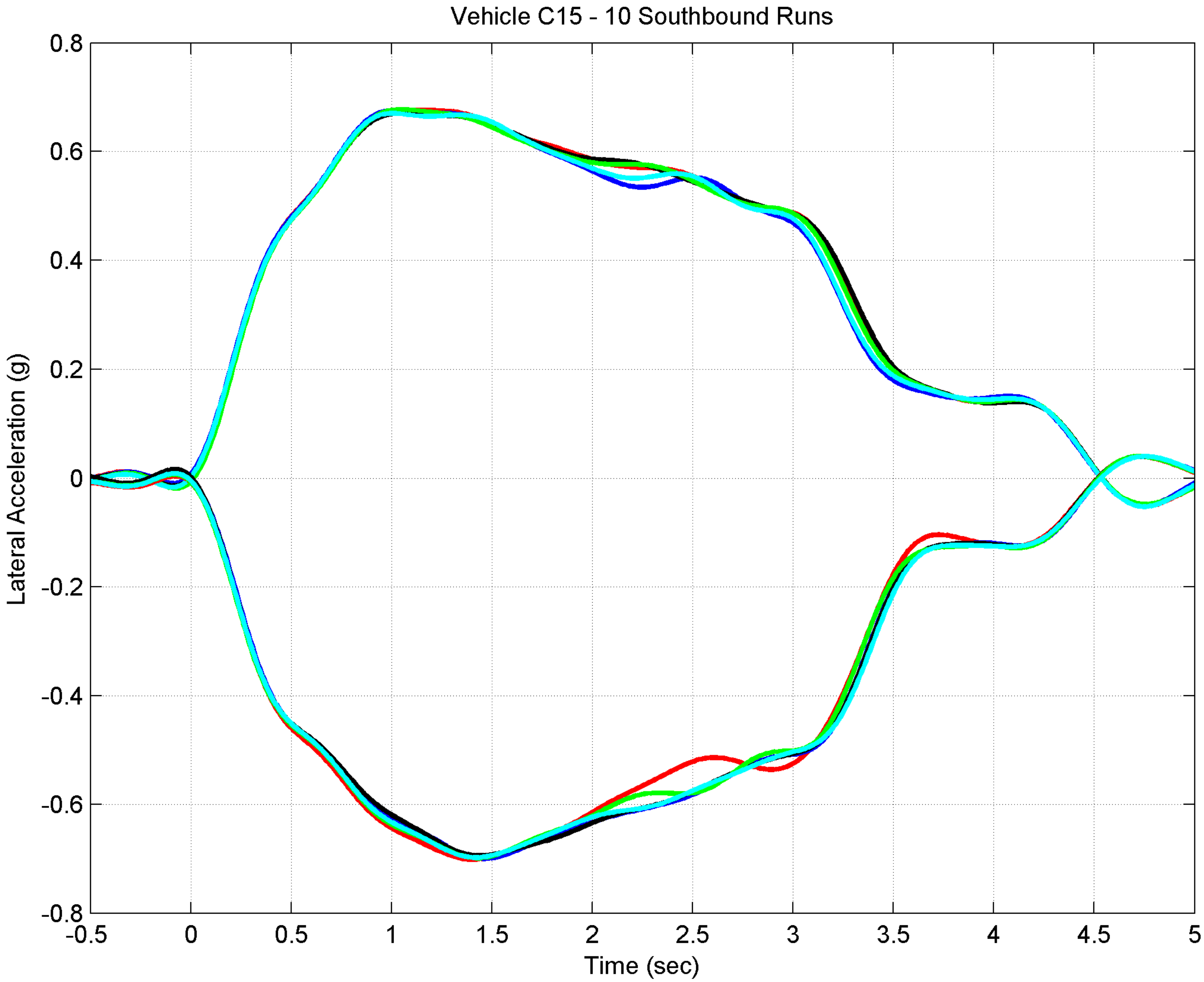
0.7416



Vehicle C15
10 Northbound Runs
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle C15 - 10 Northbound Runs
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle C15
10 Southbound Runs
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)


Vehicle C15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle C15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.6921	-0.7073
2	0.6923	-0.7021
3	0.6913	-0.7050
4	0.6939	-0.7030
5	0.6858	-0.6999
Mean Value of 5 Runs	0.6911	-0.7035
Standard Deviation of 5 Runs	0.003	0.003

Average of 10 Northbound Runs

0.6973

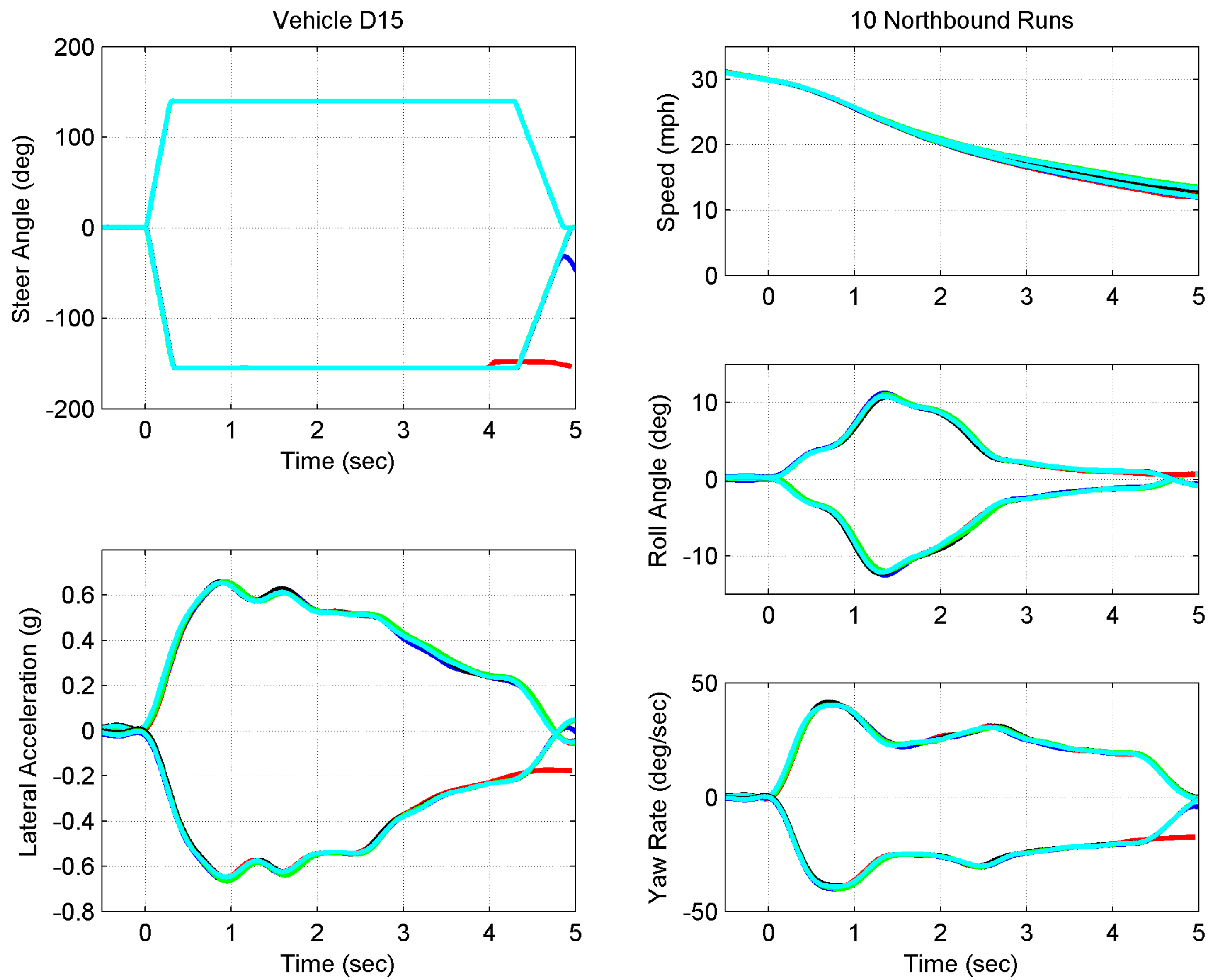
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.6764	-0.7019
2	0.6763	-0.7003
3	0.6702	-0.6941
4	0.6777	-0.6992
5	0.6704	-0.6982
Mean Value of 5 Runs	0.6742	-0.6987
Standard Deviation of 5 Runs	0.004	0.003

Average of 10 Southbound Runs

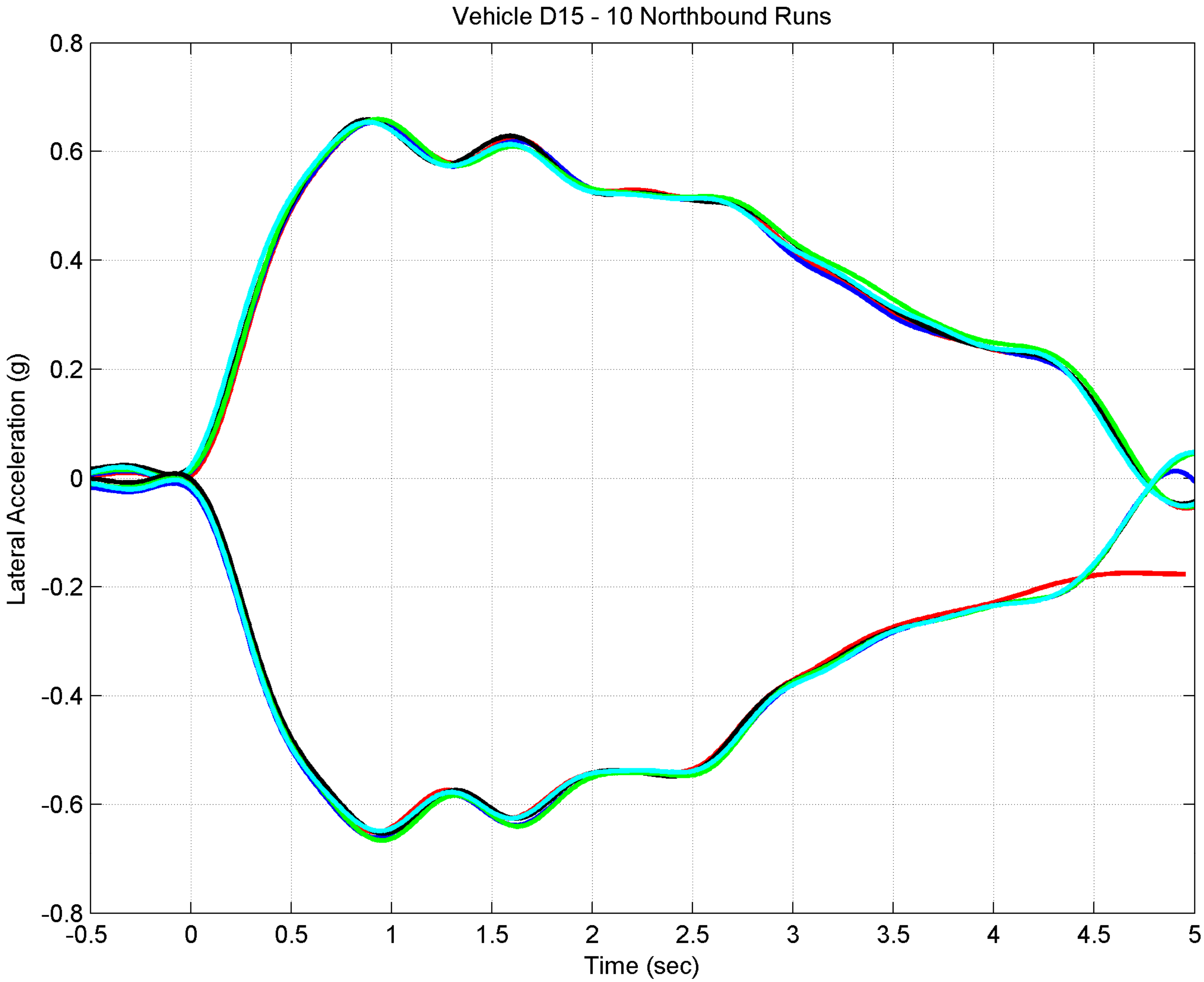
0.6865

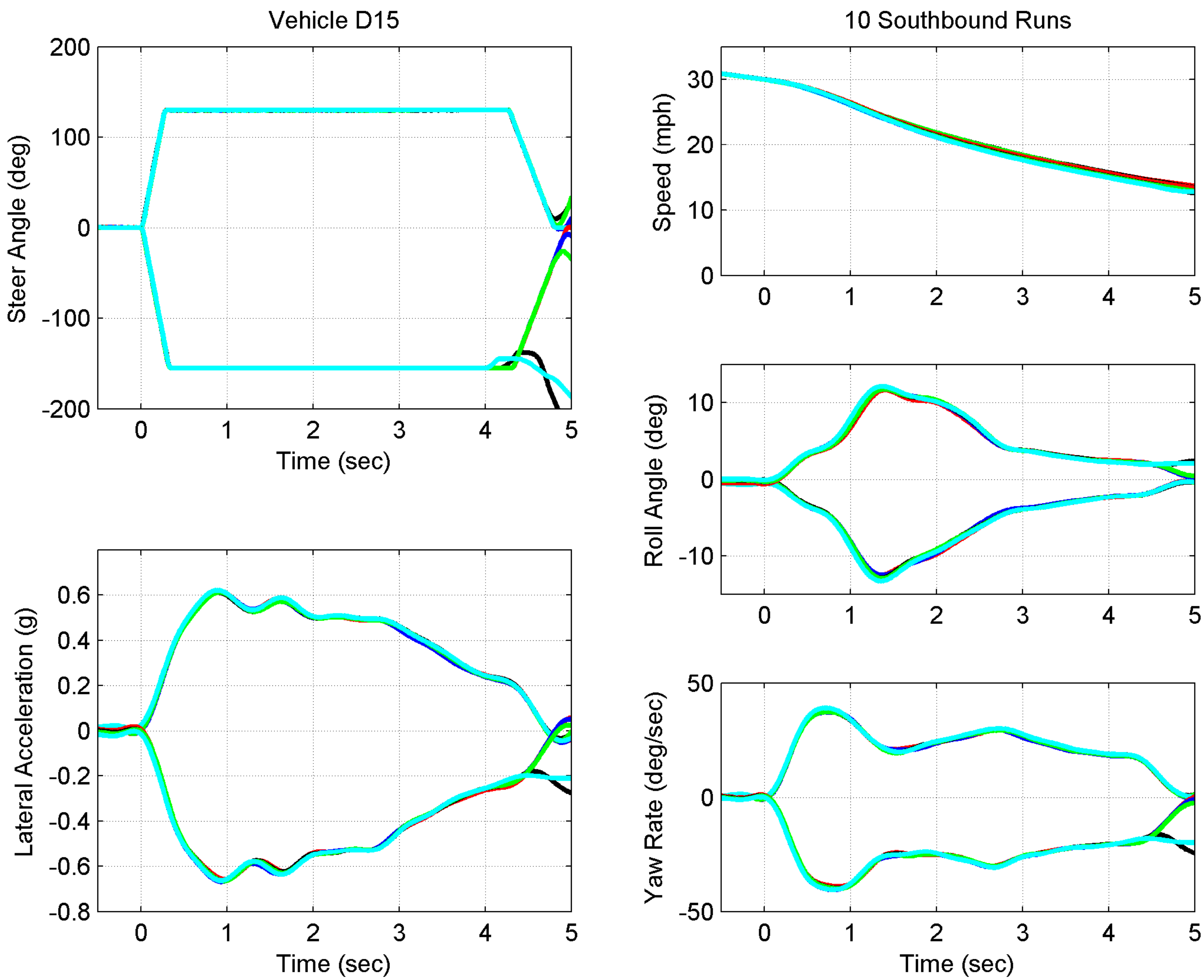
Average of All 20 Runs

0.692

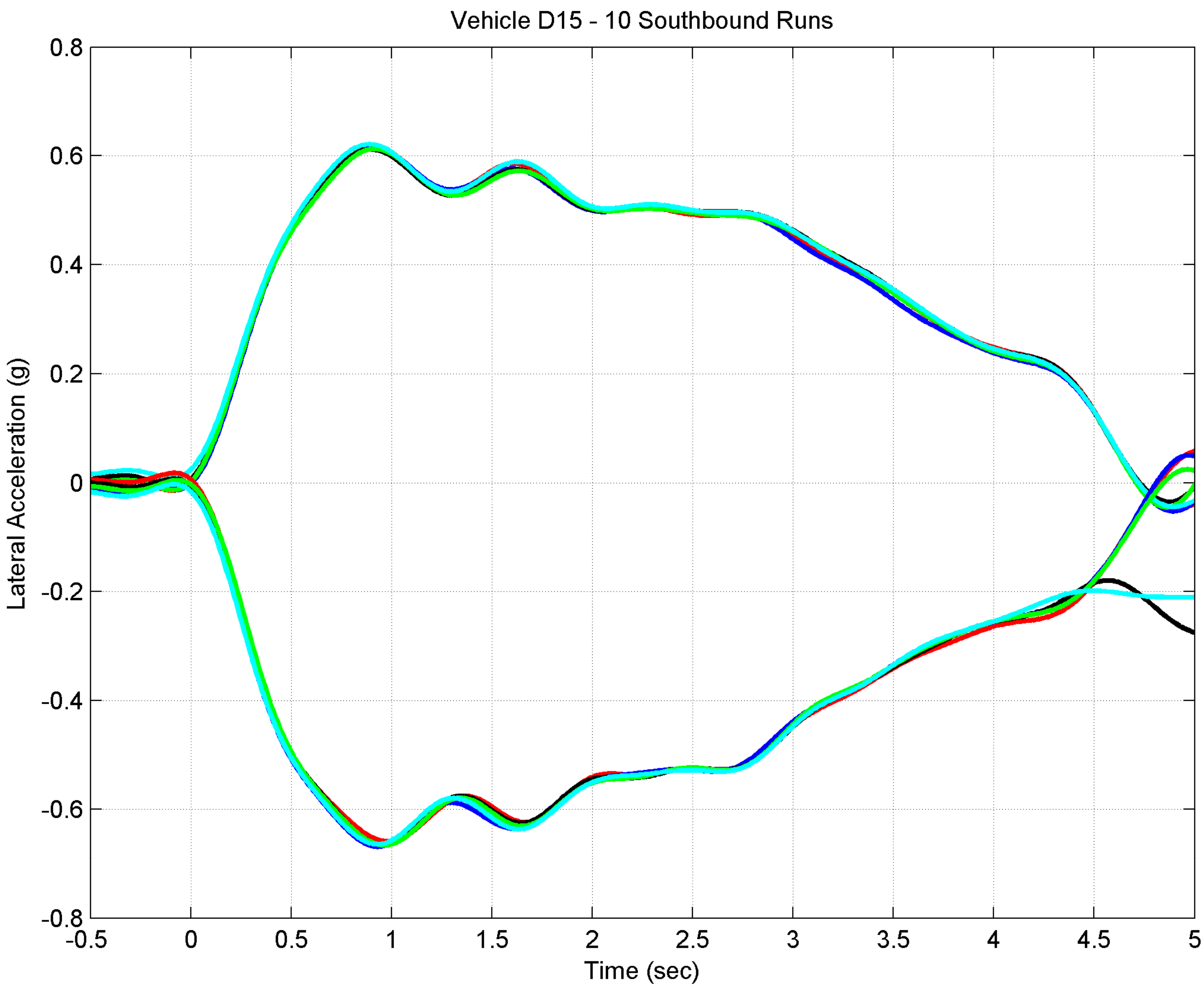


Vehicle D15
10 Northbound Runs
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)


Vehicle D15 - 10 Northbound Runs
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)



Vehicle D15
10 Southbound Runs
Steer Angle (deg)
200
100
0
-100
-200
0 1 2 3 4 5
Time (sec)
Speed (mph)
30
20
10
0
0 1 2 3 4 5
Roll Angle (deg)
10
0
-10
0 1 2 3 4 5
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0 1 2 3 4 5
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
0 1 2 3 4 5
Time (sec)


Vehicle D15 - 10 Southbound Runs
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle D15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.6576	-0.6511
2	0.6537	-0.6614
3	0.6589	-0.6532
4	0.6595	-0.6664
5	0.6543	-0.6488
Mean Value of 5 Runs	0.6568	-0.6562
Standard Deviation of 5 Runs	0.003	0.007

Average of 10 Northbound Runs

0.6565

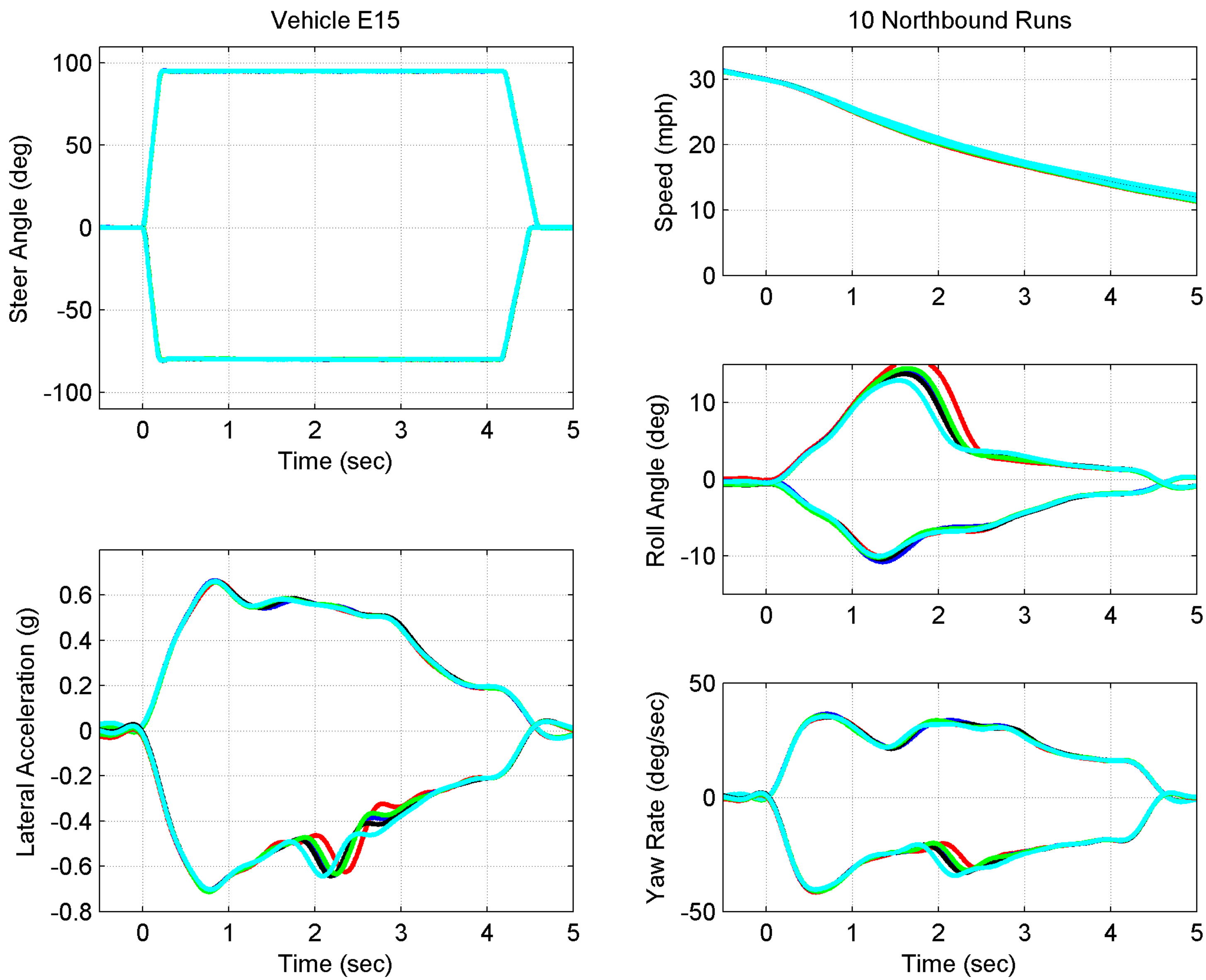
Average of All 20 Runs

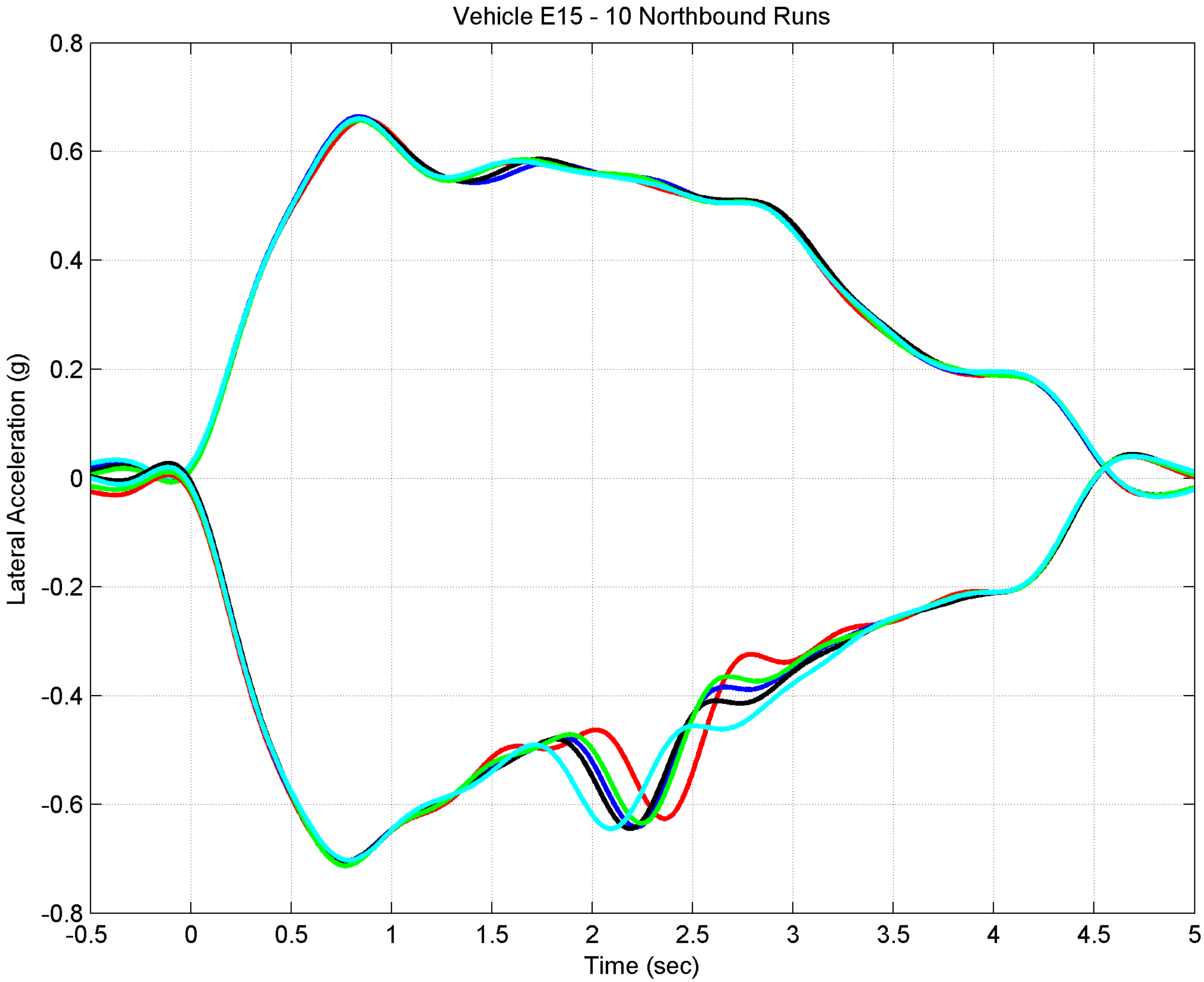
0.648

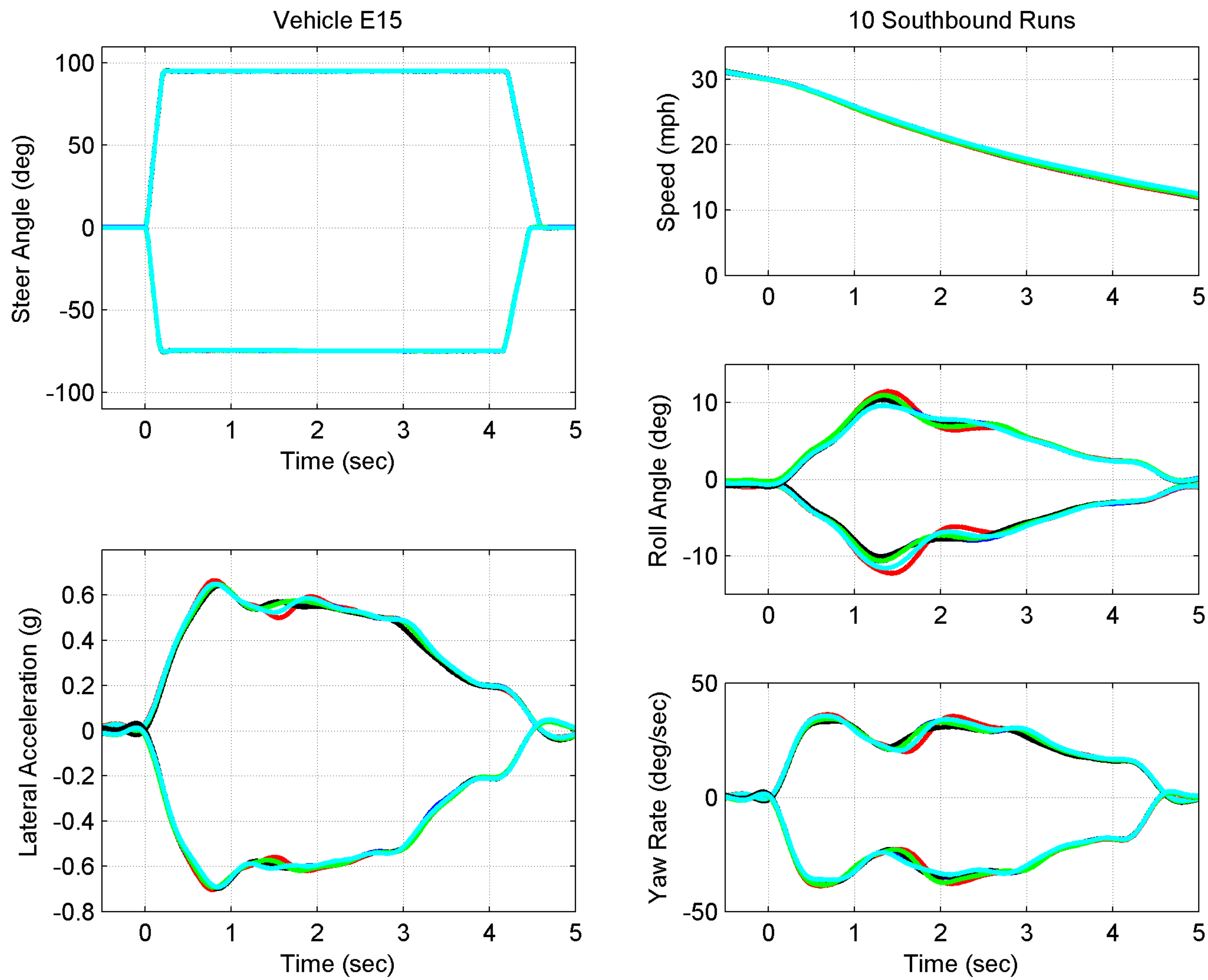
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.6153	-0.6589
2	0.6152	-0.6687
3	0.6114	-0.6648
4	0.6121	-0.6660
5	0.6212	-0.6642
Mean Value of 5 Runs	0.6150	-0.6645
Standard Deviation of 5 Runs	0.004	0.004

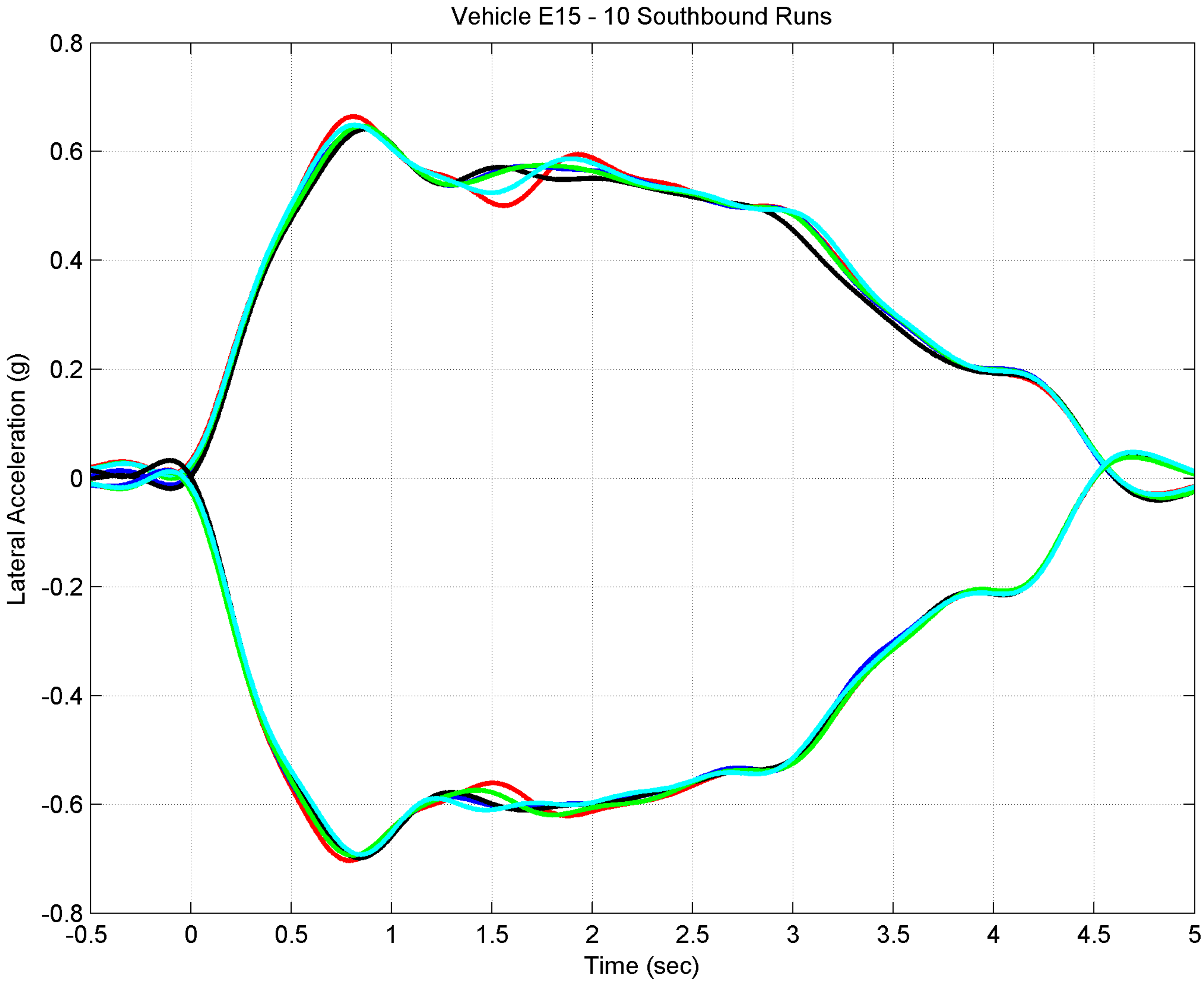
Average of 10 Southbound Runs

0.6398


Vehicle E15
10 Northbound Runs
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle E15 - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle E15
10 Southbound Runs
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle E15 - 10 Southbound Runs
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle E15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.6589	-0.7099
2	0.6643	-0.7055
3	0.6607	-0.7045
4	0.6574	-0.7134
5	0.6606	-0.7035
Mean Value of 5 Runs	0.6604	-0.7074
Standard Deviation of 5 Runs	0.003	0.004

Average of 10 Northbound Runs

0.6839

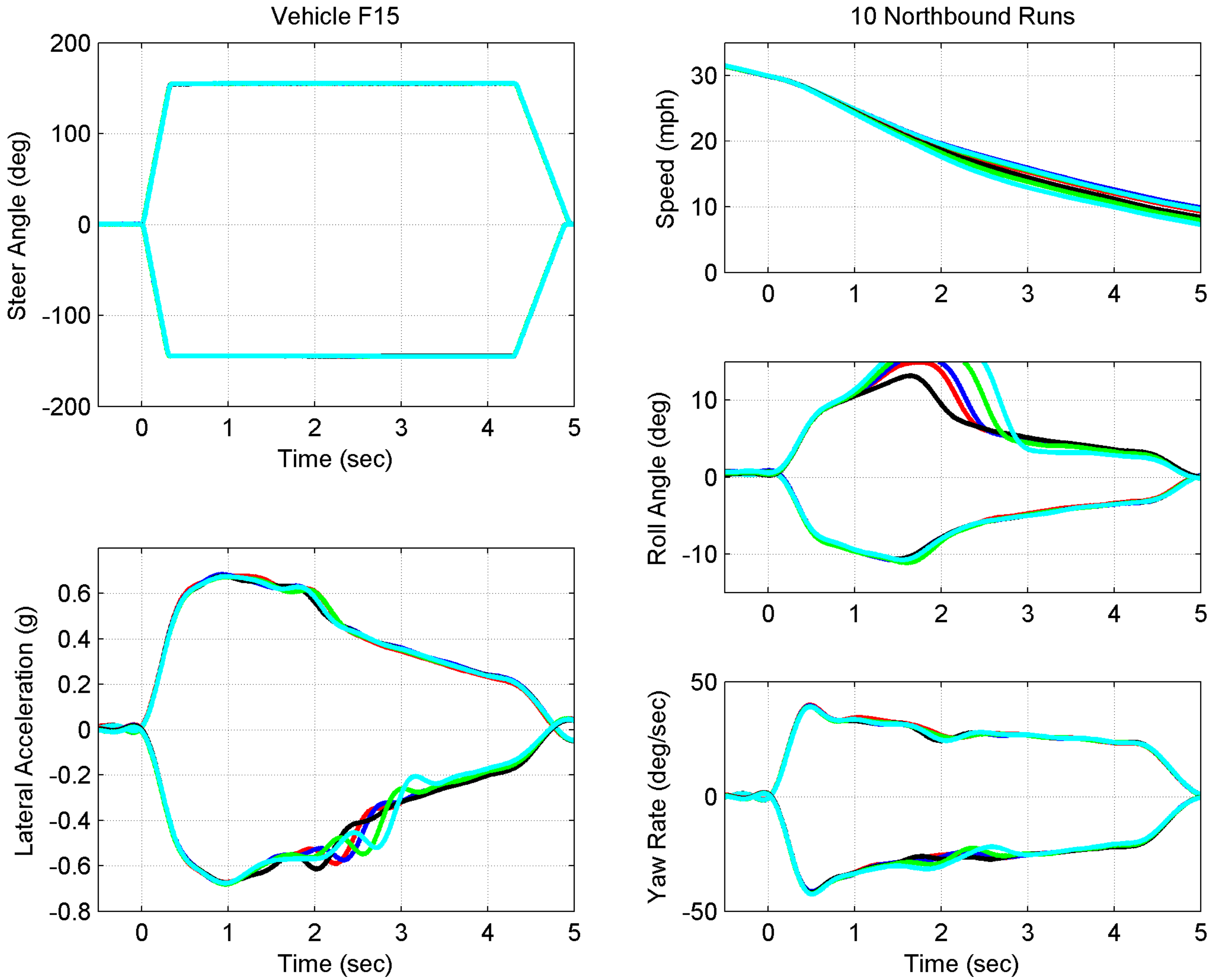
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.6644	-0.7041
2	0.6427	-0.6928
3	0.6413	-0.6993
4	0.6470	-0.6944
5	0.6488	-0.6926
Mean Value of 5 Runs	0.6488	-0.6966
Standard Deviation of 5 Runs	0.009	0.005

Average of 10 Southbound Runs

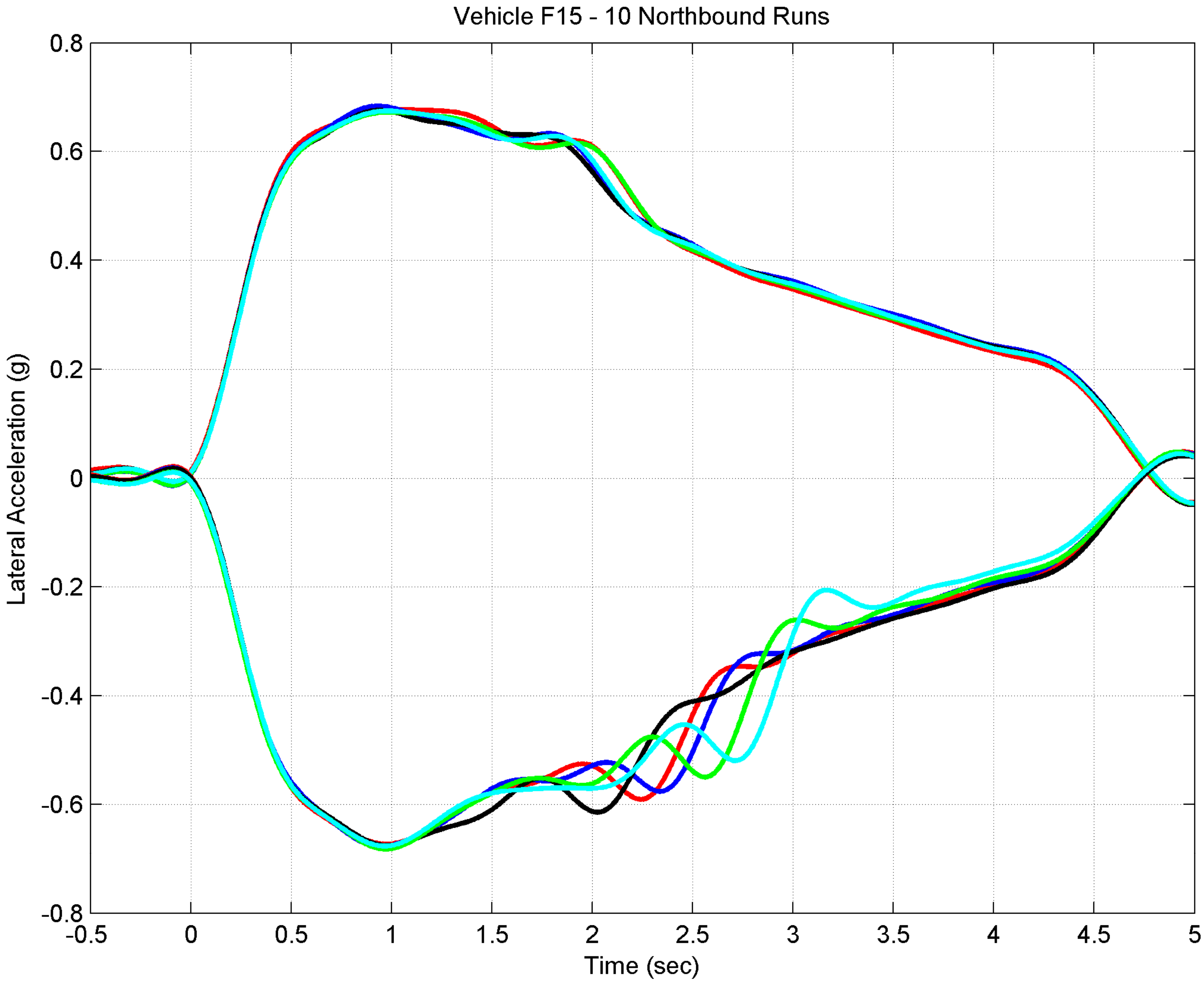
0.6727

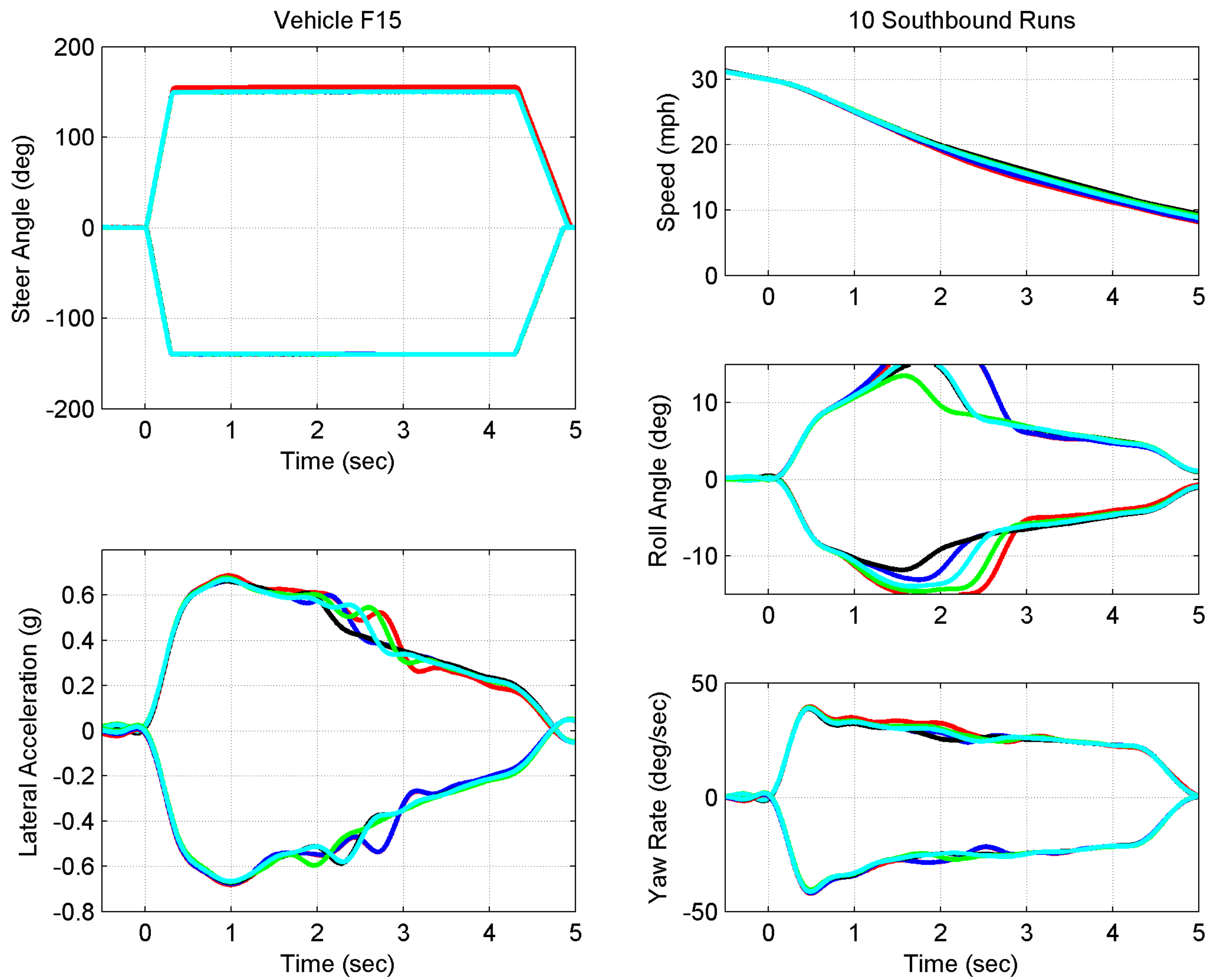
Average of All 20 Runs

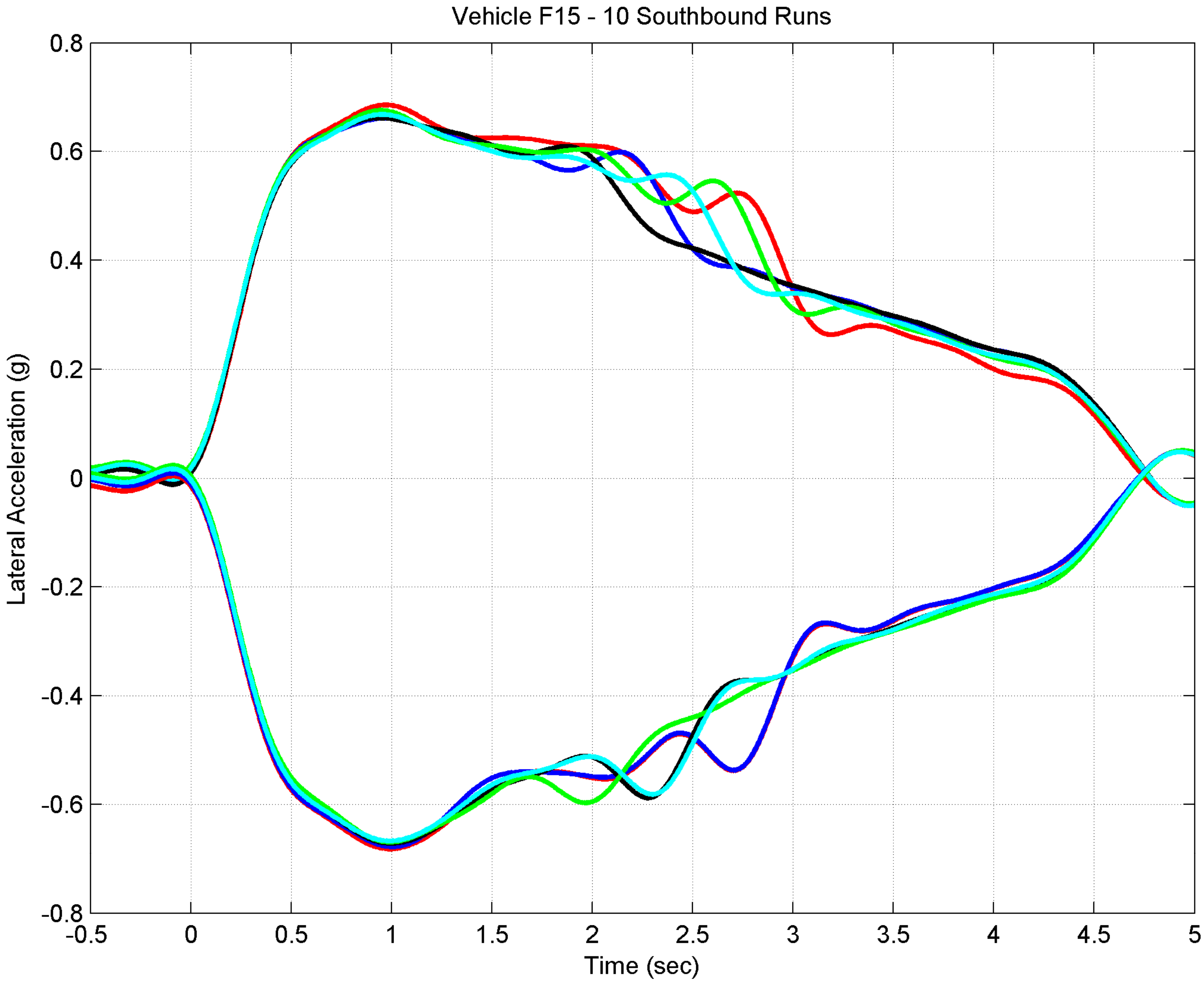
0.678



Vehicle F15
10 Northbound Runs
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle F15 - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle F15
10 Southbound Runs
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle F15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle F15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.6774	-0.6726
2	0.6839	-0.6771
3	0.6763	-0.6756
4	0.6726	-0.6820
5	0.6748	-0.6765
Mean Value of 5 Runs	0.6770	-0.6768
Standard Deviation of 5 Runs	0.004	0.003

Average of 10 Northbound Runs

0.6769

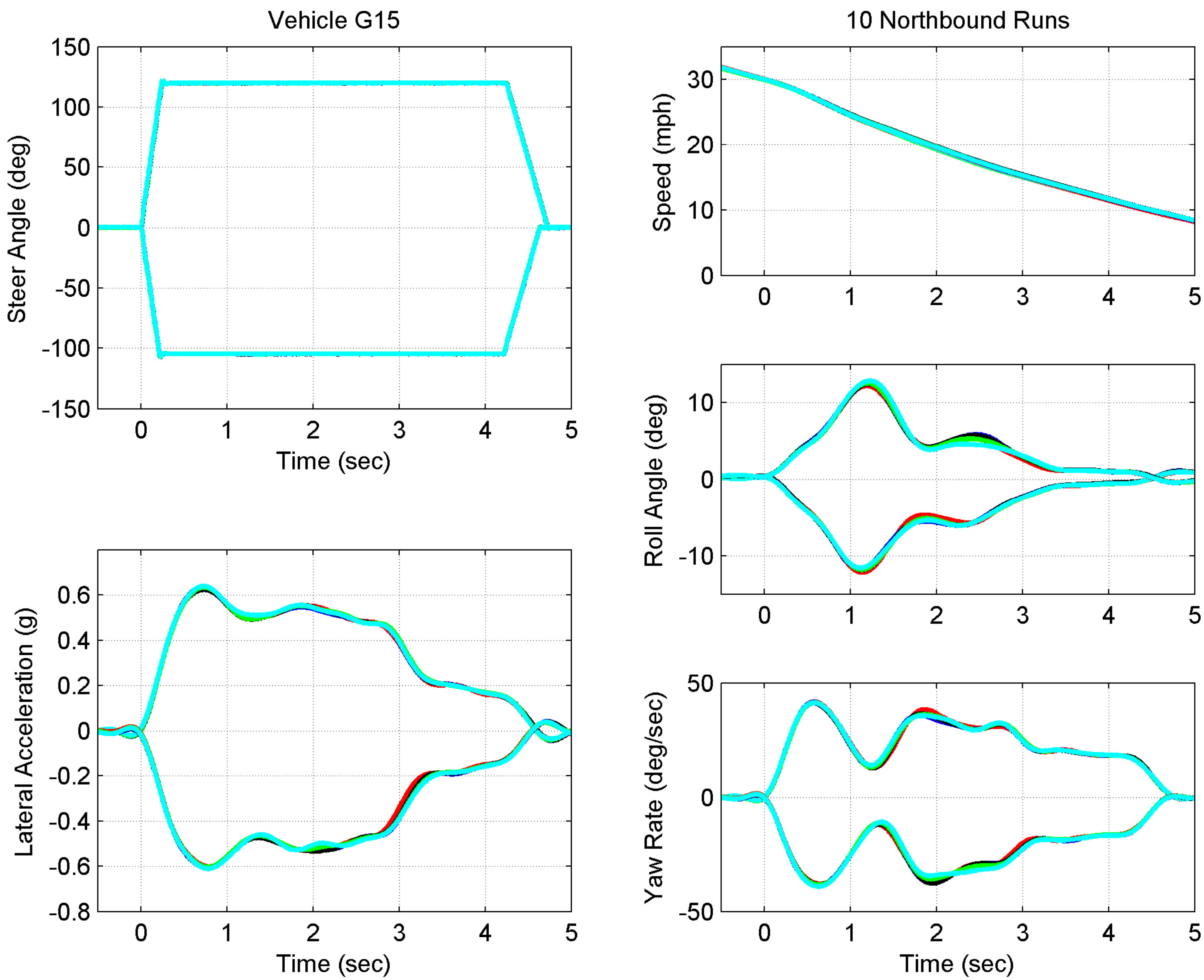
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.6859	-0.6818
2	0.6615	-0.6778
3	0.6620	-0.6715
4	0.6758	-0.6693
5	0.6684	-0.6670
Mean Value of 5 Runs	0.6707	-0.6735
Standard Deviation of 5 Runs	0.010	0.006

Average of 10 Southbound Runs

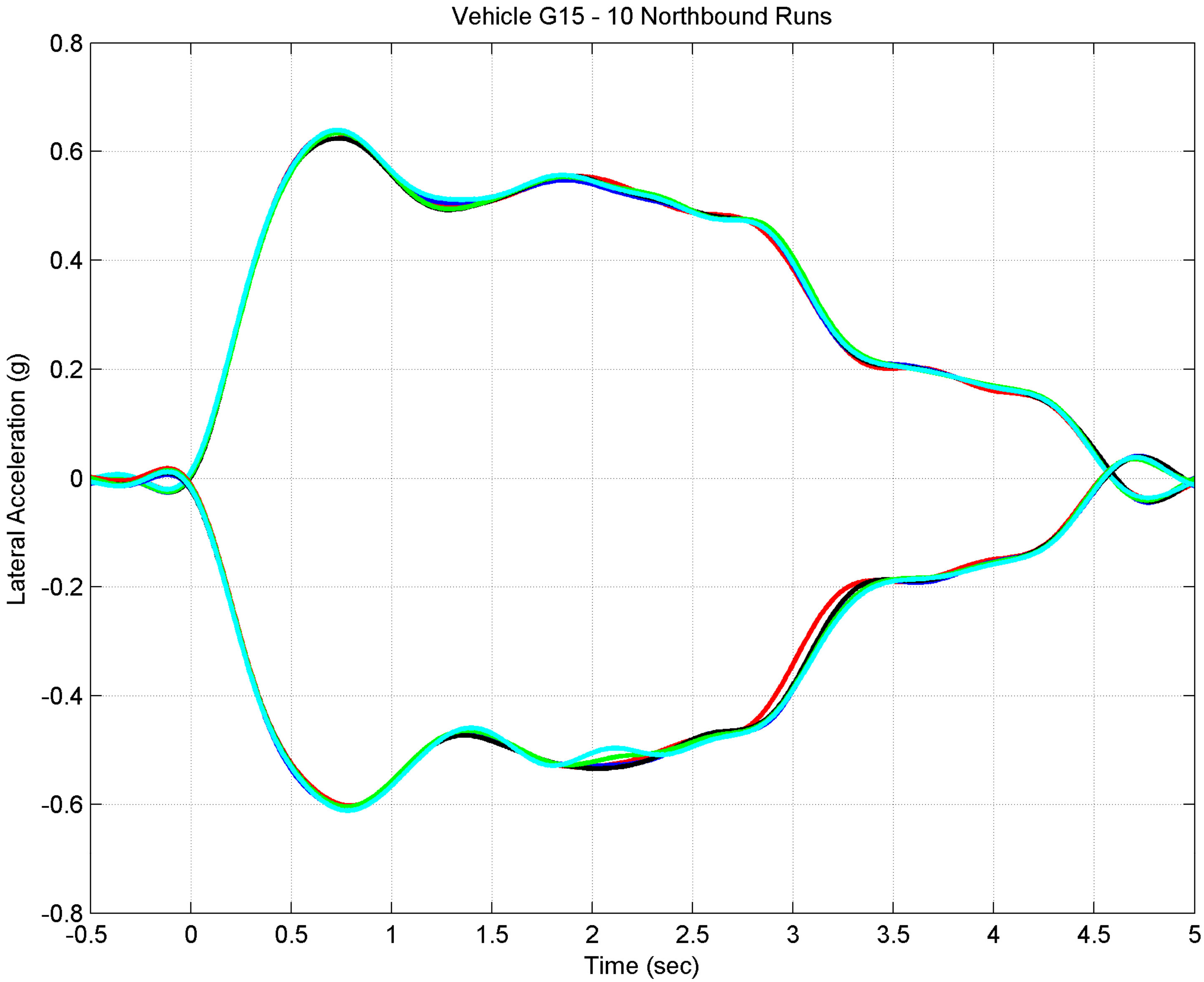
0.6721

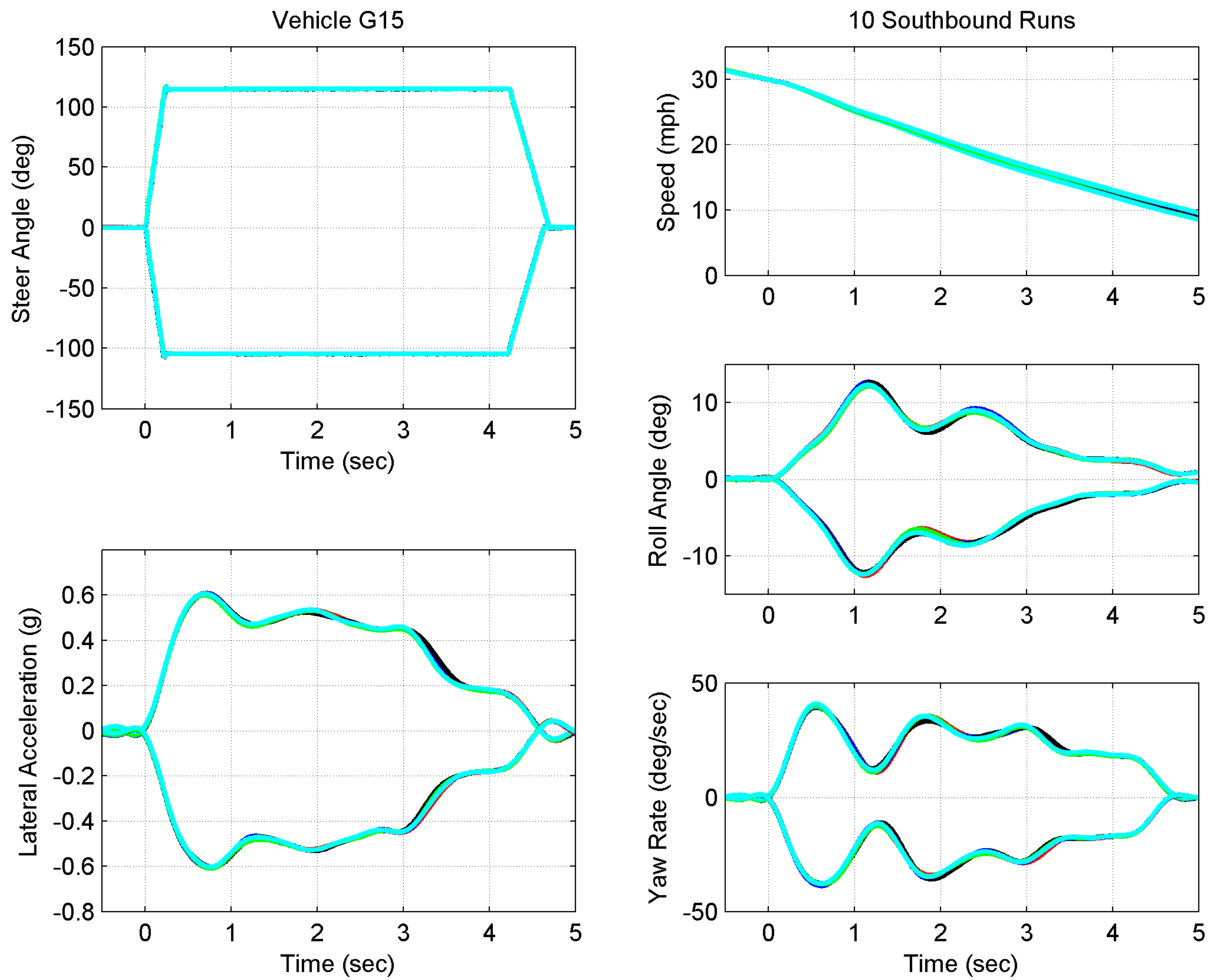
Average of All 20 Runs

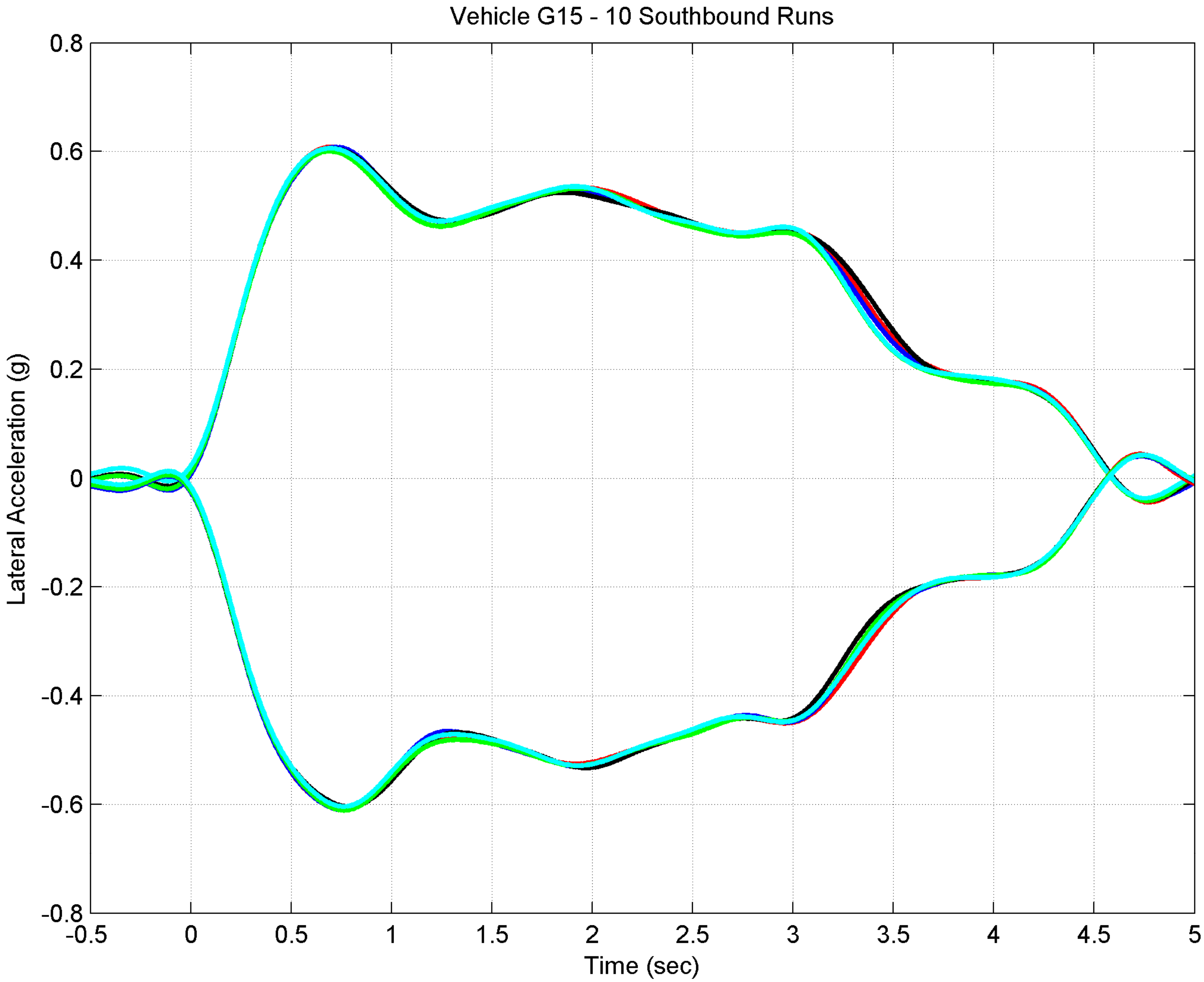
0.674



Vehicle G15
10 Northbound Runs
Steer Angle (deg)
150
100
50
0
-50
-100
-150
Time (sec)
Speed (mph)
30
20
10
Roll Angle (deg)
10
-10
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
-50
0
1
2
3
4
5
Time (sec)


Vehicle G15 - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle G15
10 Southbound Runs
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)


Vehicle G15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle G15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.6338	-0.6023
2	0.6360	-0.6076
3	0.6242	-0.6073
4	0.6345	-0.6042
5	0.6396	-0.6113
Mean Value of 5 Runs	0.6336	-0.6065
Standard Deviation of 5 Runs	0.006	0.003

Average of 10 Northbound Runs

0.6201

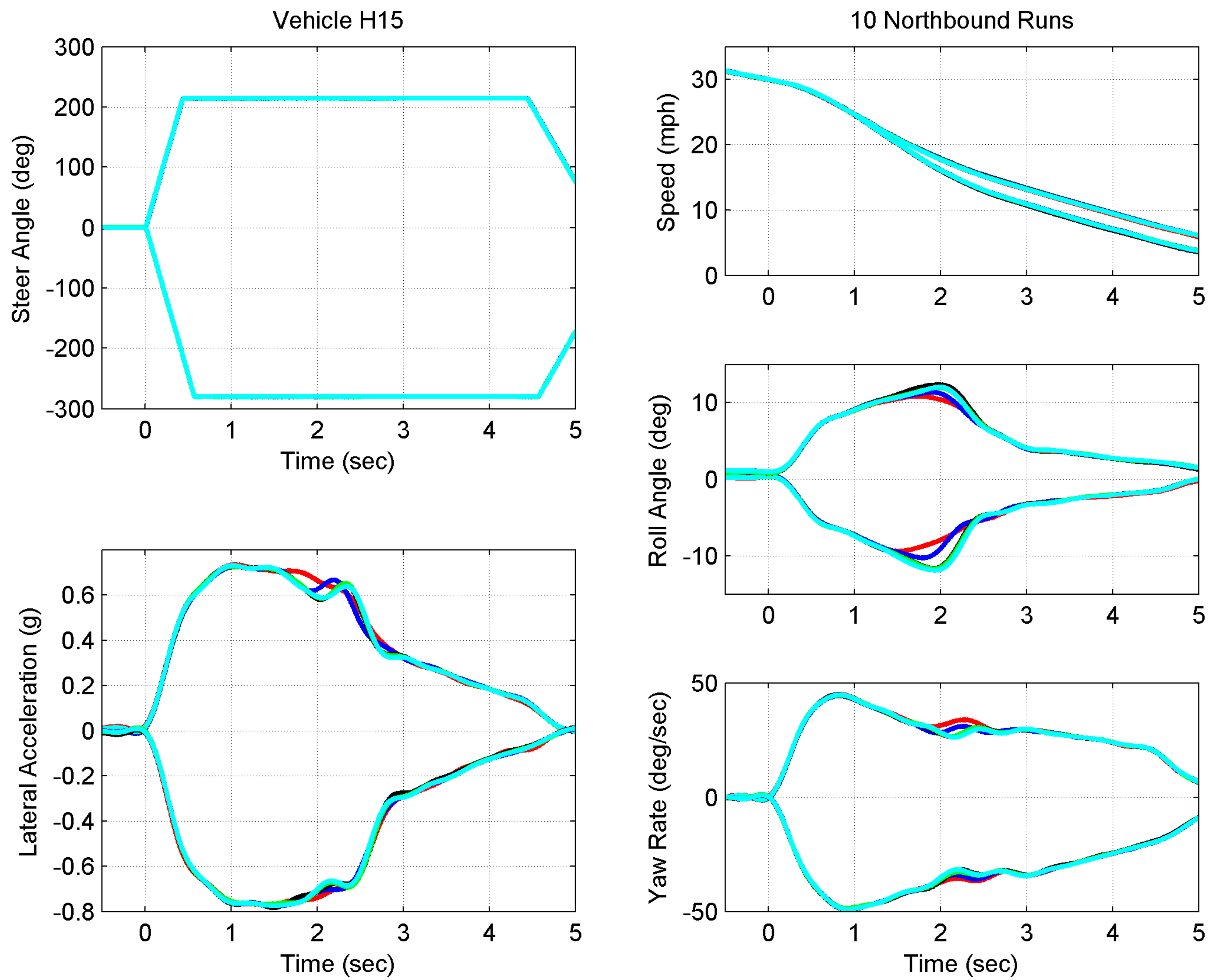
Average of All 20 Runs

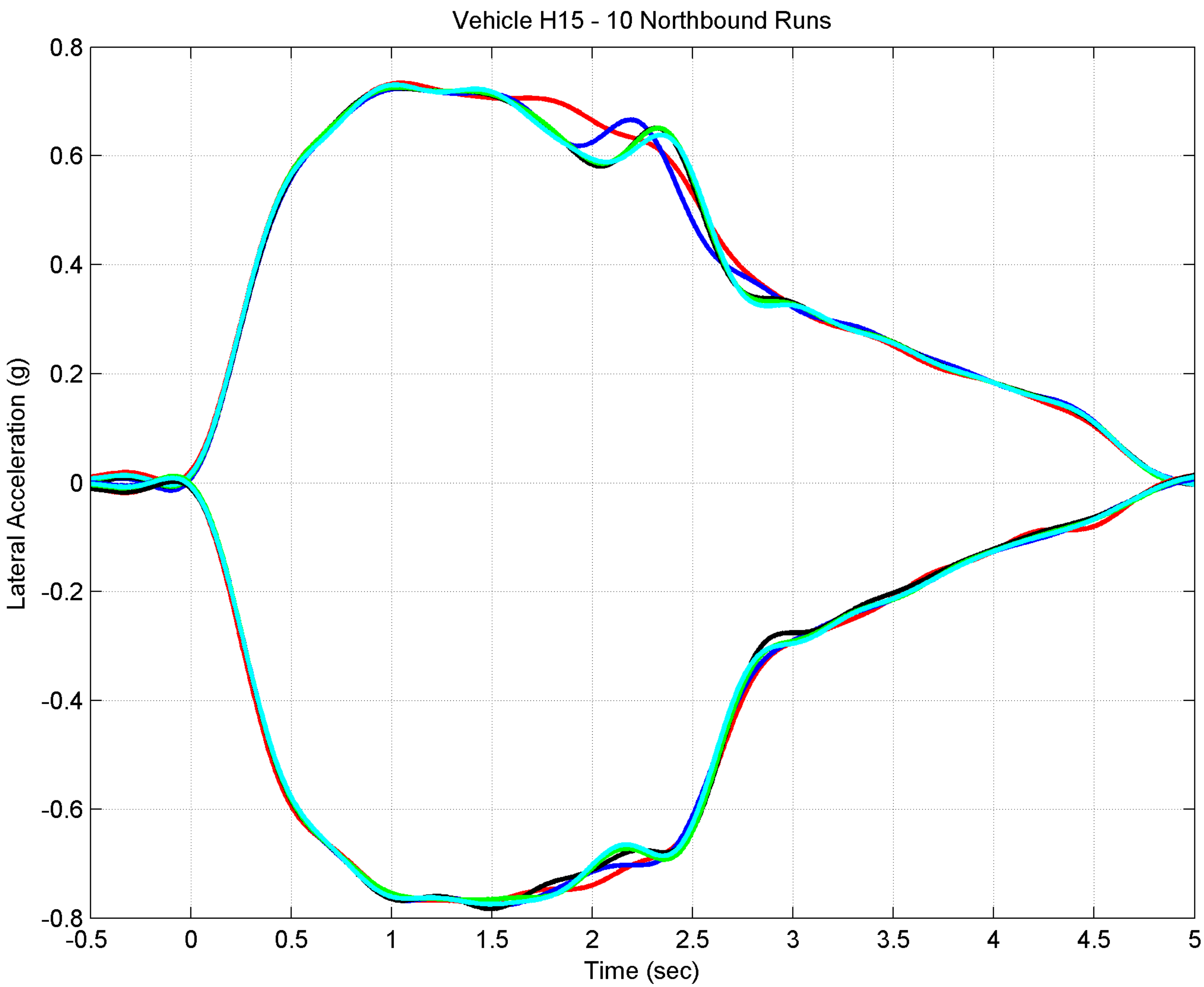
0.613

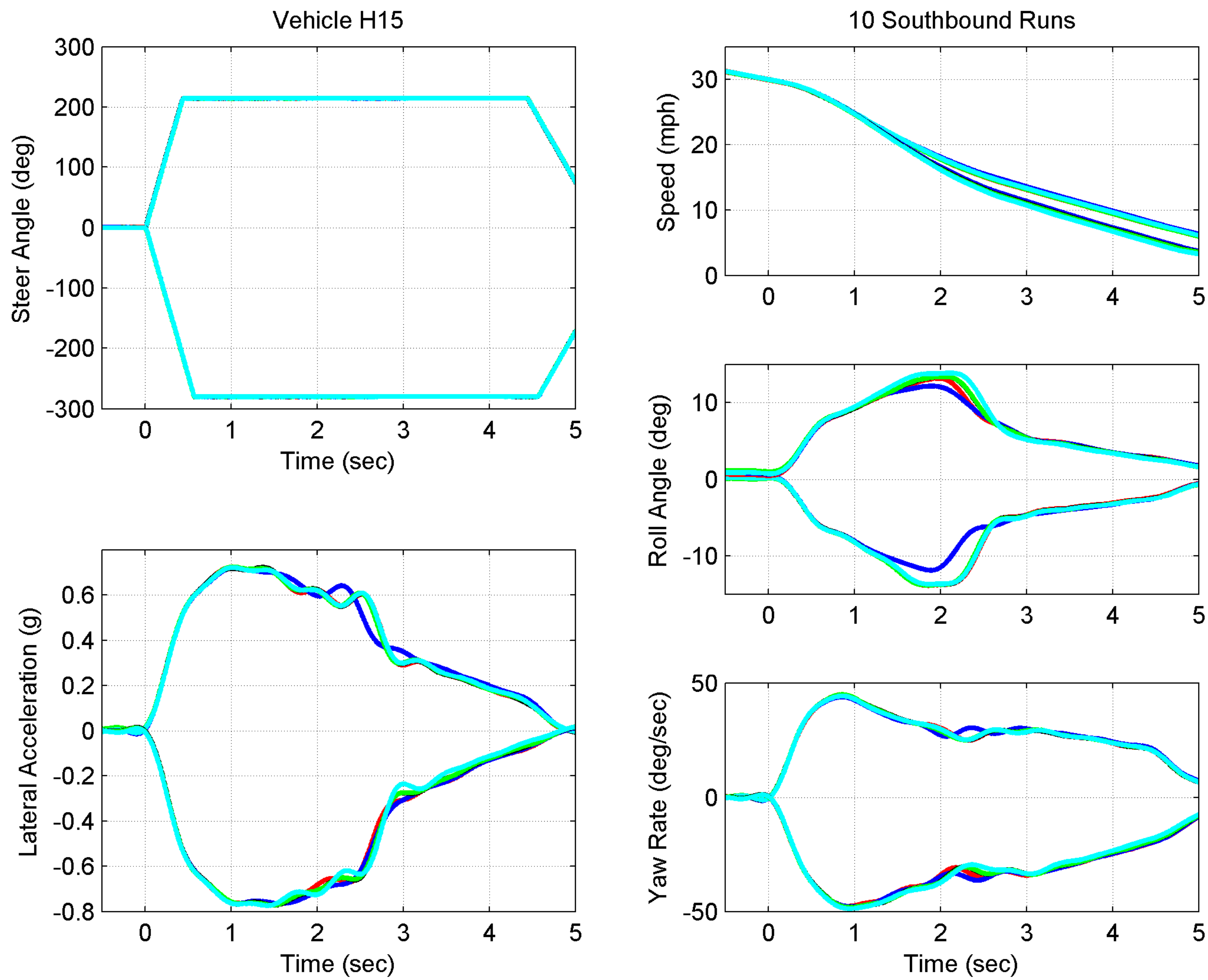
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.6079	-0.6065
2	0.6075	-0.6104
3	0.6045	-0.6041
4	0.6001	-0.6108
5	0.6055	-0.6039
Mean Value of 5 Runs	0.6051	-0.6071
Standard Deviation of 5 Runs	0.003	0.003

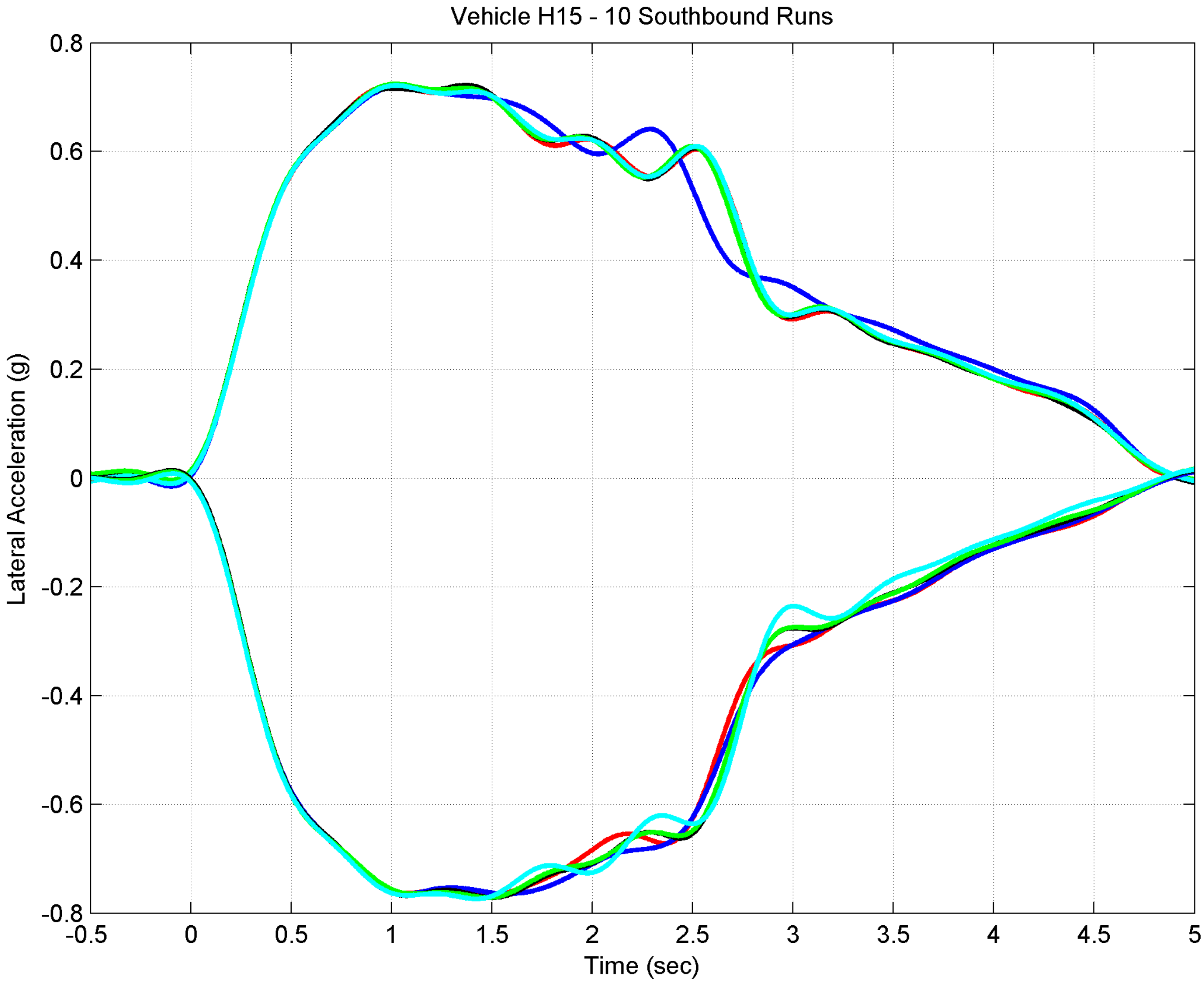
Average of 10 Southbound Runs

0.6061


Vehicle H15
10 Northbound Runs
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle H15 - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle H15
10 Southbound Runs
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle H15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle H15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.7339	-0.7721
2	0.7238	-0.7765
3	0.7246	-0.7831
4	0.7258	-0.7671
5	0.7307	-0.7744
Mean Value of 5 Runs	0.7277	-0.7746
Standard Deviation of 5 Runs	0.004	0.006

Average of 10 Northbound Runs

0.7512

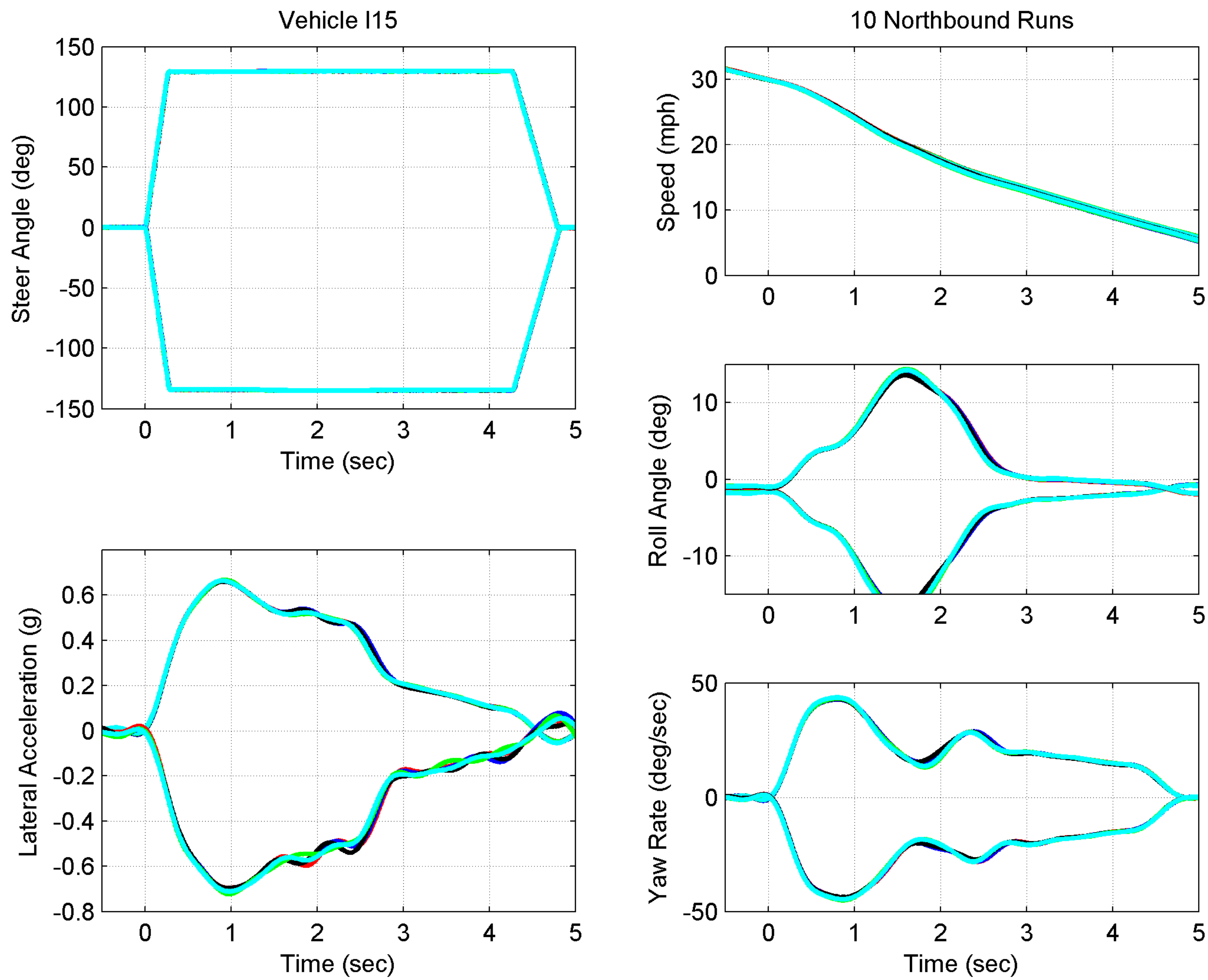
Average of All 20 Runs

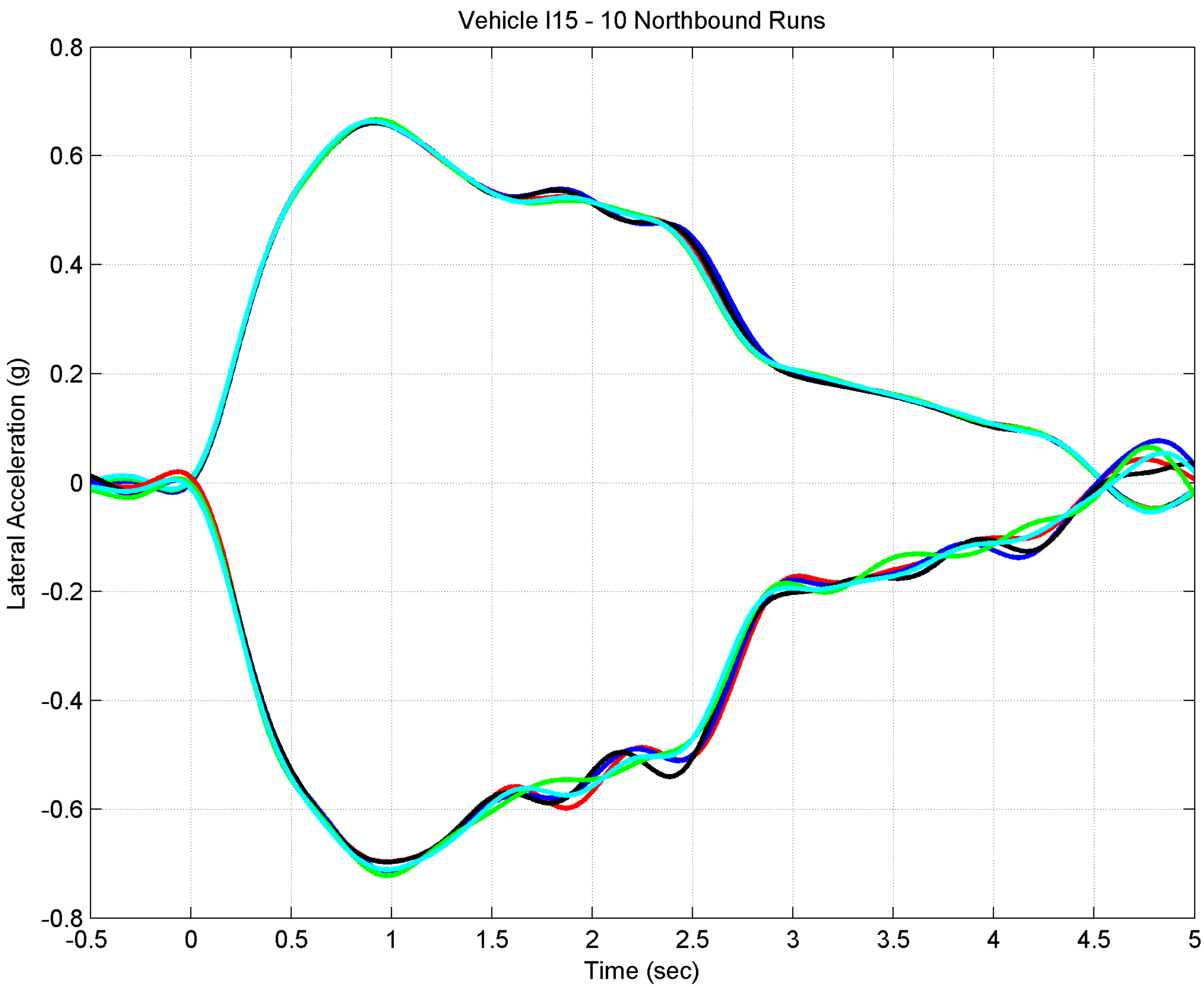
0.749

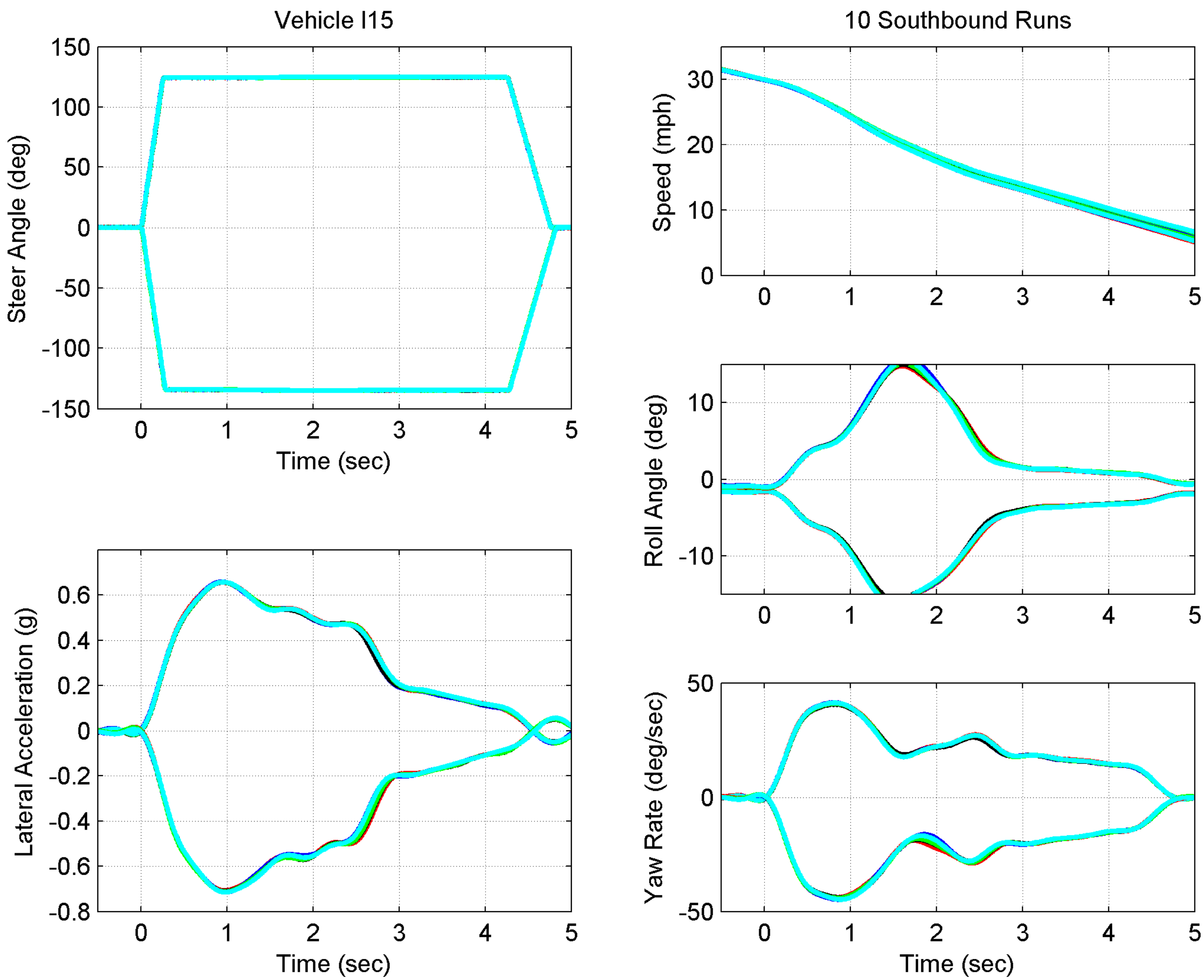
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.7211	-0.7658
2	0.7207	-0.7656
3	0.7223	-0.7717
4	0.7245	-0.7717
5	0.7217	-0.7740
Mean Value of 5 Runs	0.7220	-0.7698
Standard Deviation of 5 Runs	0.001	0.004

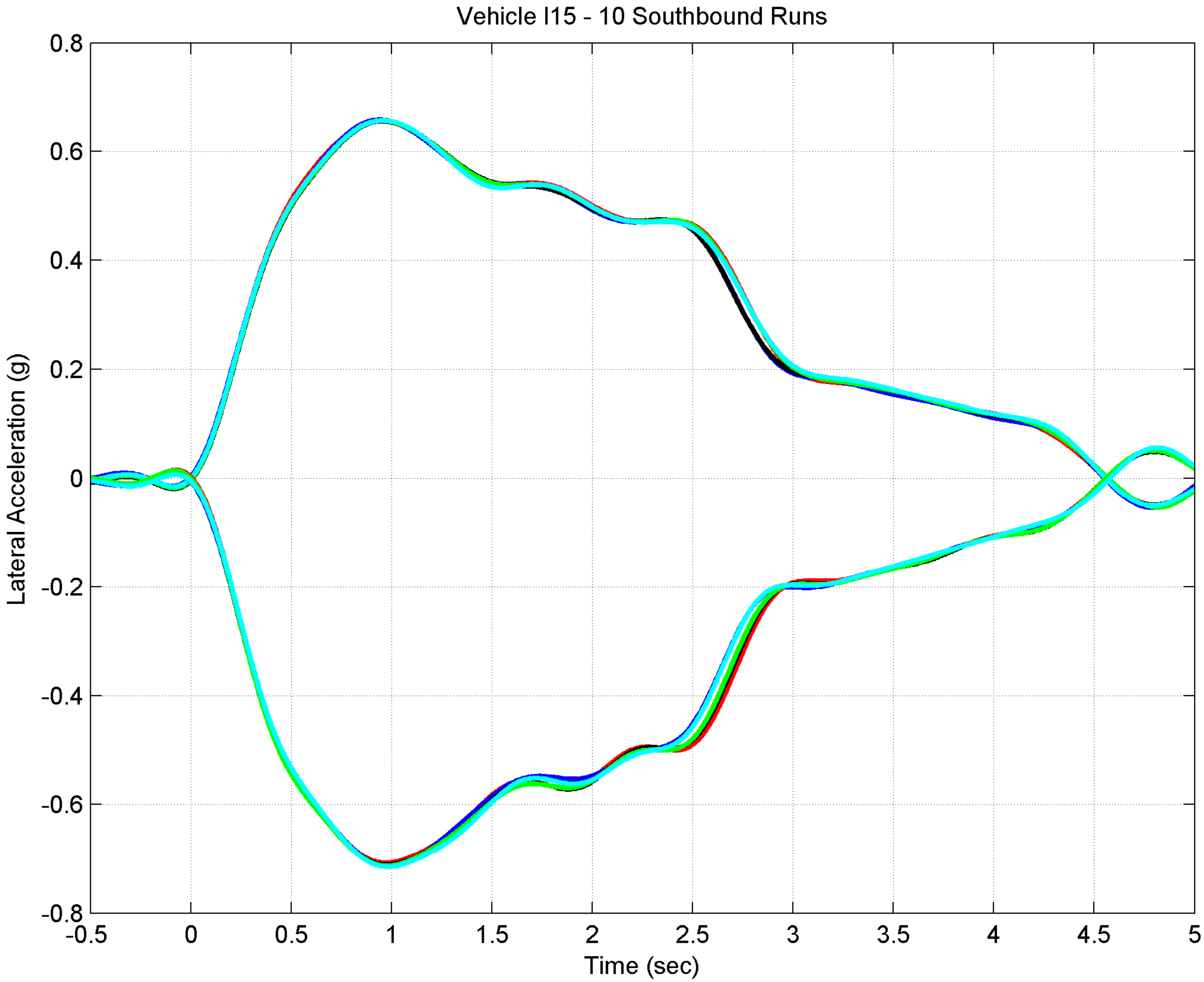
Average of 10 Southbound Runs

0.7459


Vehicle I15
10 Northbound Runs
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle I15 - 10 Northbound Runs
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle I15
10 Southbound Runs
Steer Angle (deg)
150
100
50
0
-50
-100
-150
Time (sec)
Speed (mph)
30
20
10
Roll Angle (deg)
-10
Lateral Acceleration (g)
0.6
0.4
0.2
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
-50
0 1 2 3 4 5


Vehicle I15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

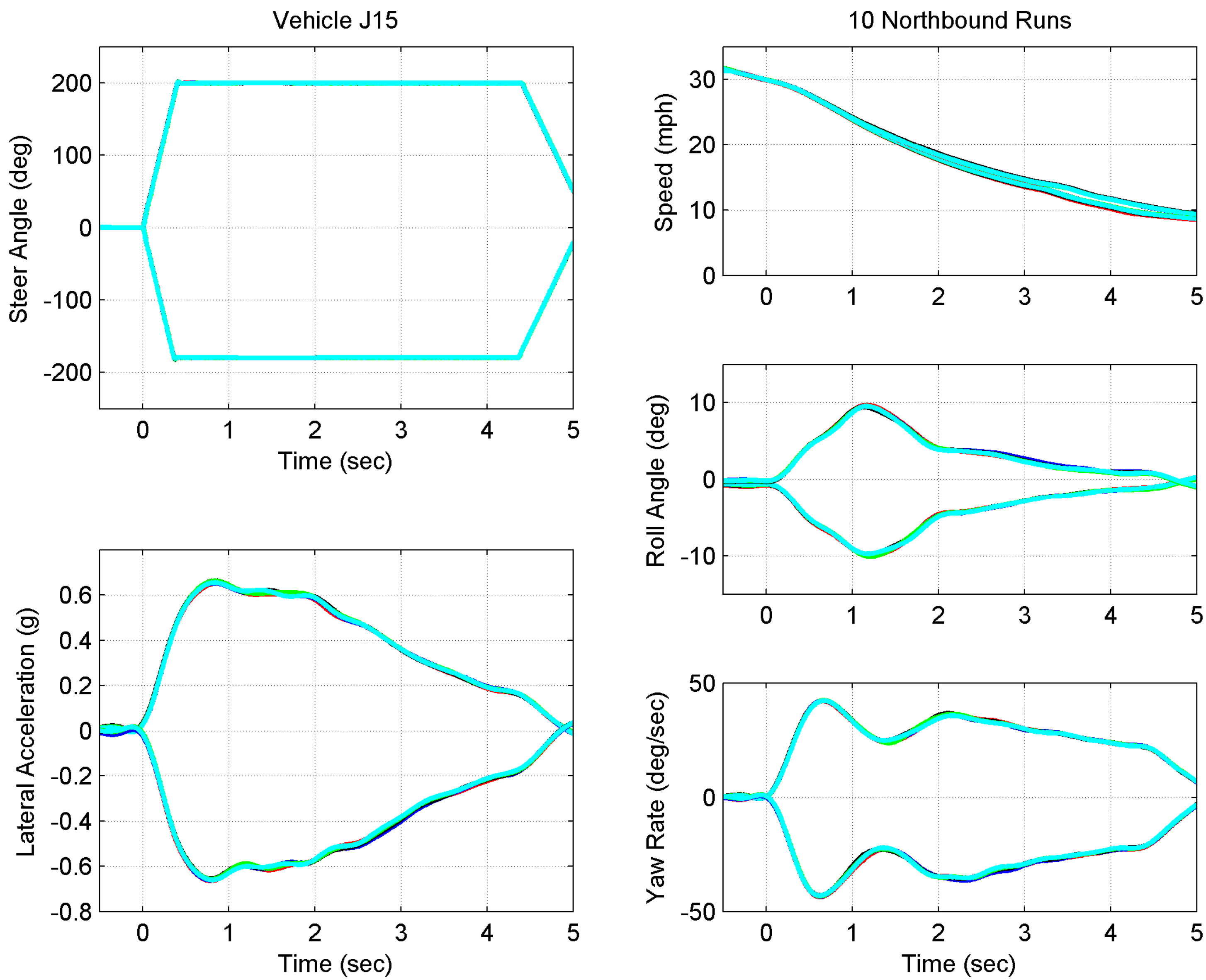
Vehicle I15

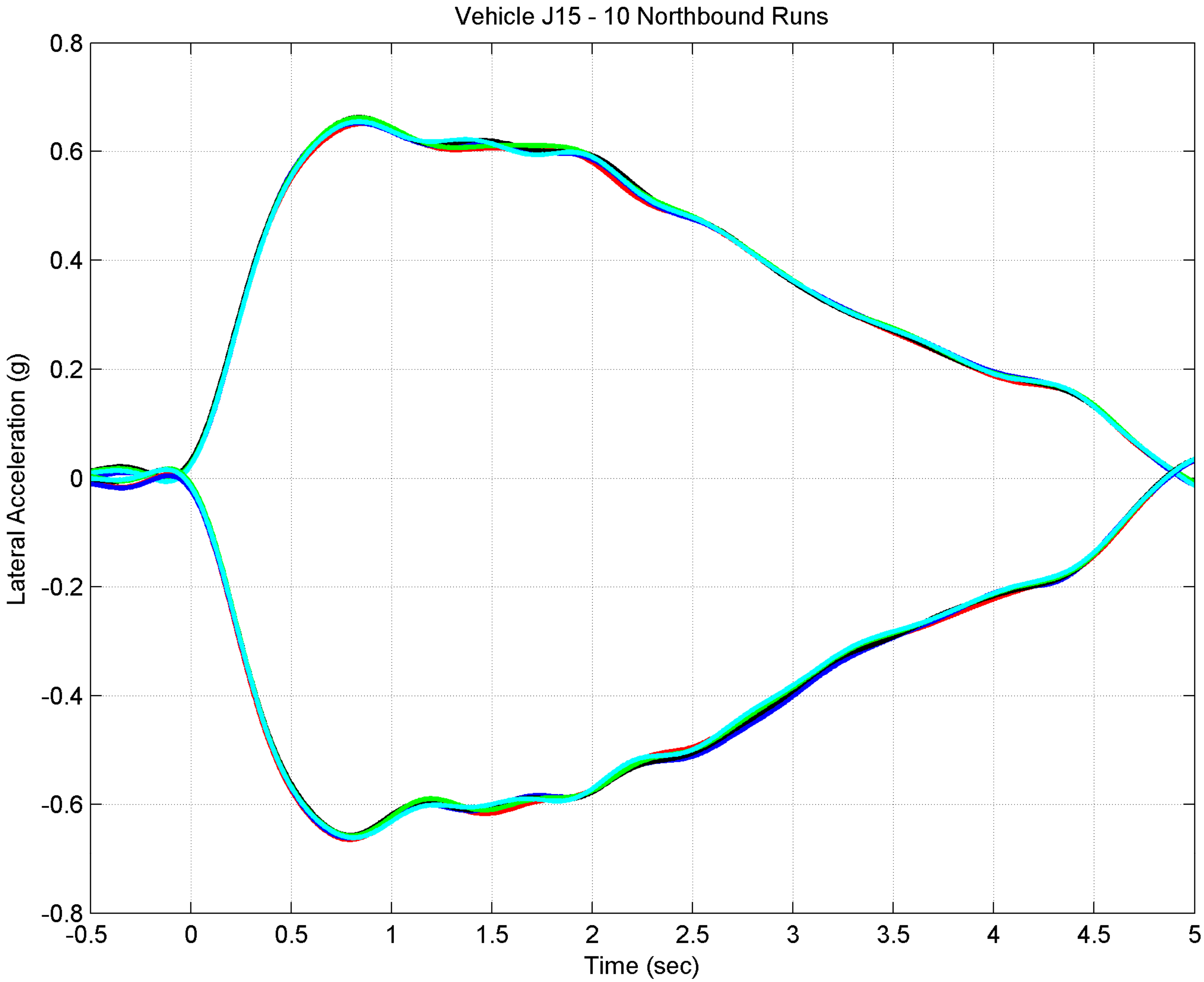
Run Number	Northbound Right Turns	Northbound Left Turns	
1	0.6633	-0.6973	
2	0.6609	-0.7133	
3	0.6602	-0.6977	
4	0.6670	-0.7226	
5	0.6634	-0.7114	**Average of 10 Northbound Runs**
Mean Value of 5 Runs	0.6630	-0.7084	**0.6857**
Standard Deviation of 5 Runs	0.003	0.011	

Average of All 20 Runs

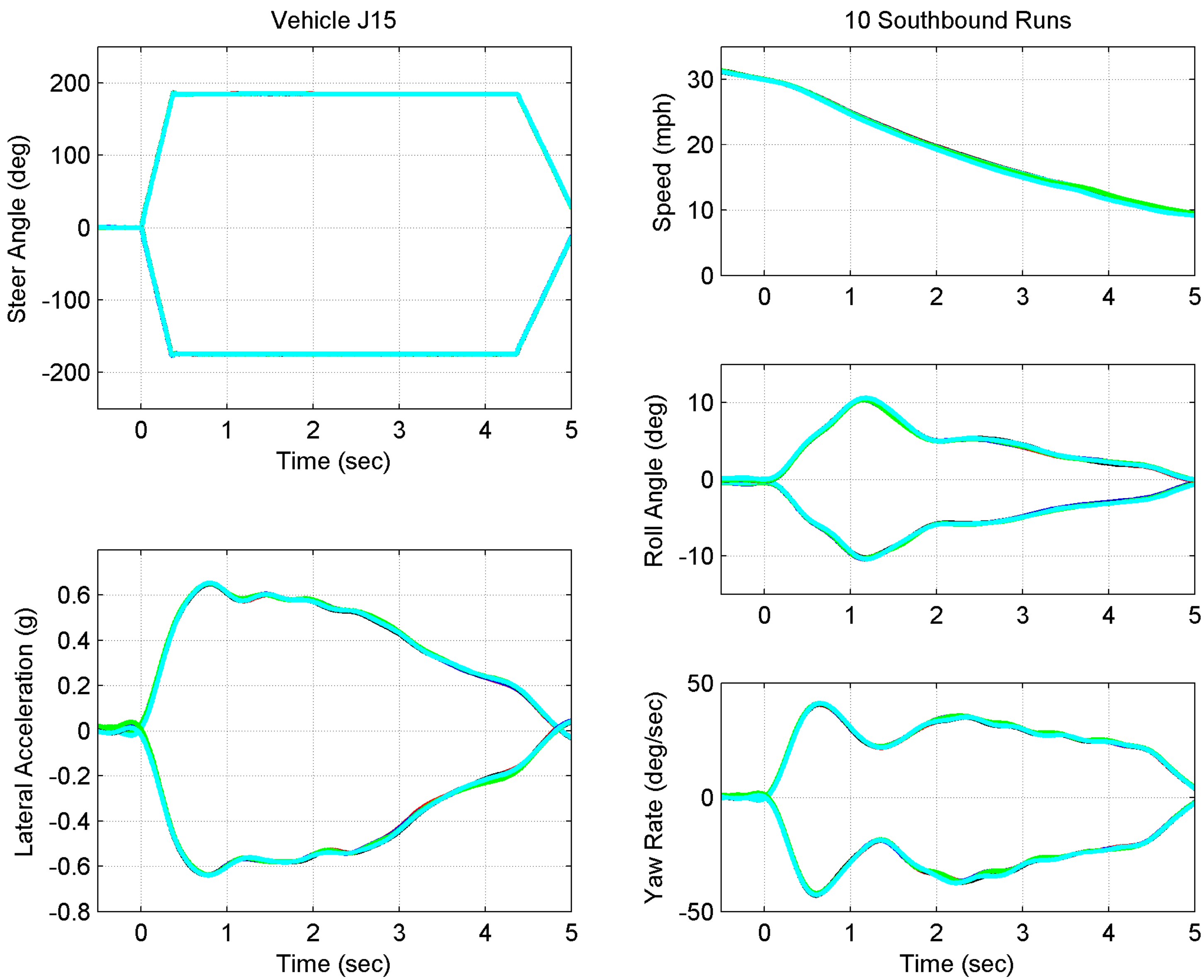
0.685

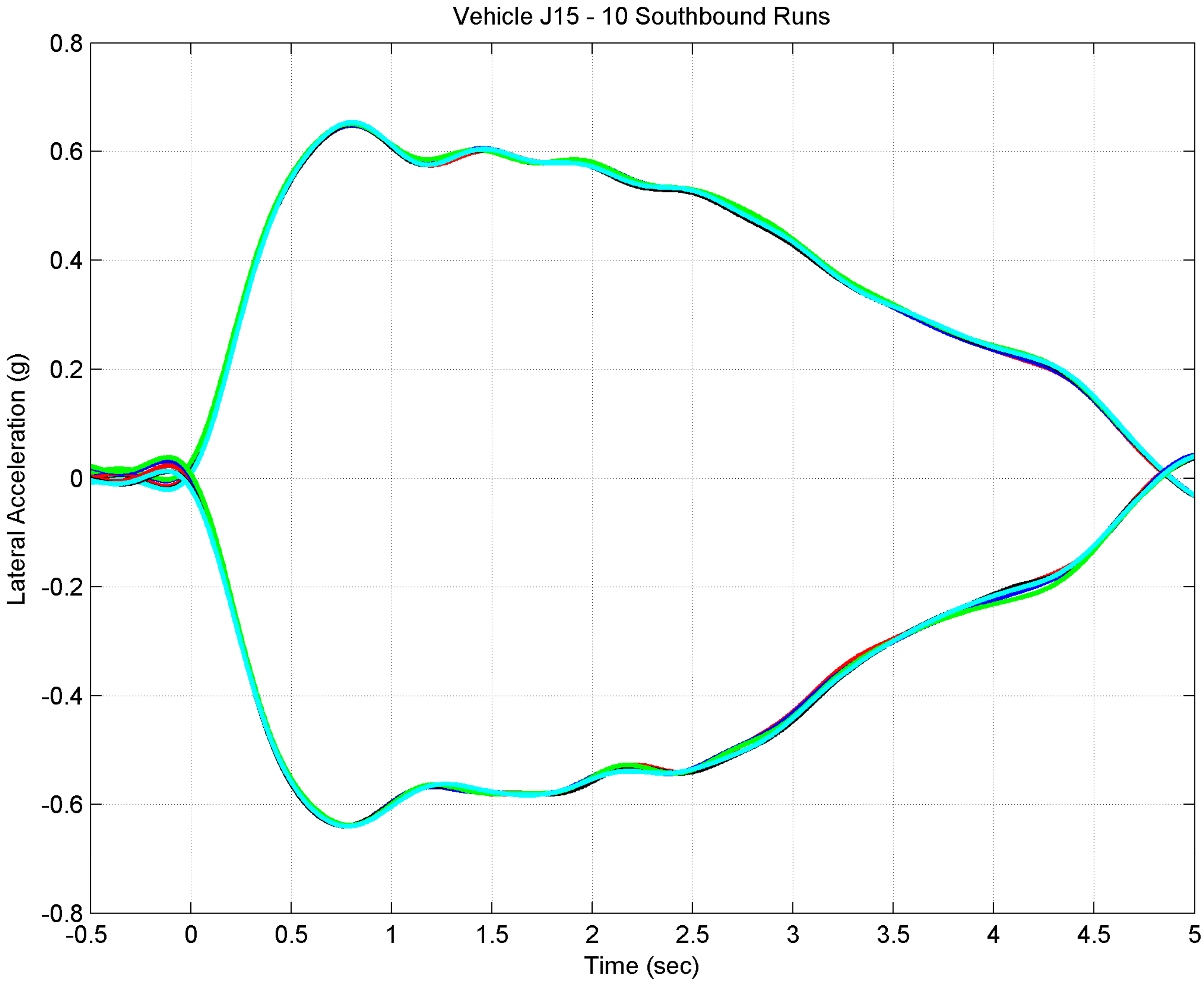
Run Number	Southbound Right Turns	Southbound Left Turns	
1	0.6559	-0.7079	
2	0.6585	-0.7146	
3	0.6564	-0.7111	
4	0.6569	-0.7134	
5	0.6574	-0.7151	**Average of 10 Southbound Runs**
Mean Value of 5 Runs	0.6570	-0.7124	**0.6847**
Standard Deviation of 5 Runs	0.001	0.003	


Vehicle J15
10 Northbound Runs
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



Vehicle J15 - 10 Northbound Runs
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle J15
10 Southbound Runs
Steer Angle (deg)
200
100
0
-100
-200
0
1
2
3
4
5
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
50
0
-50



Vehicle J15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle J15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.6517	-0.6647
2	0.6525	-0.6615
3	0.6633	-0.6566
4	0.6625	-0.6576
5	0.6553	-0.6611
Mean Value of 5 Runs	0.6571	-0.6603
Standard Deviation of 5 Runs	0.006	0.003

Average of 10 Northbound Runs

0.6587

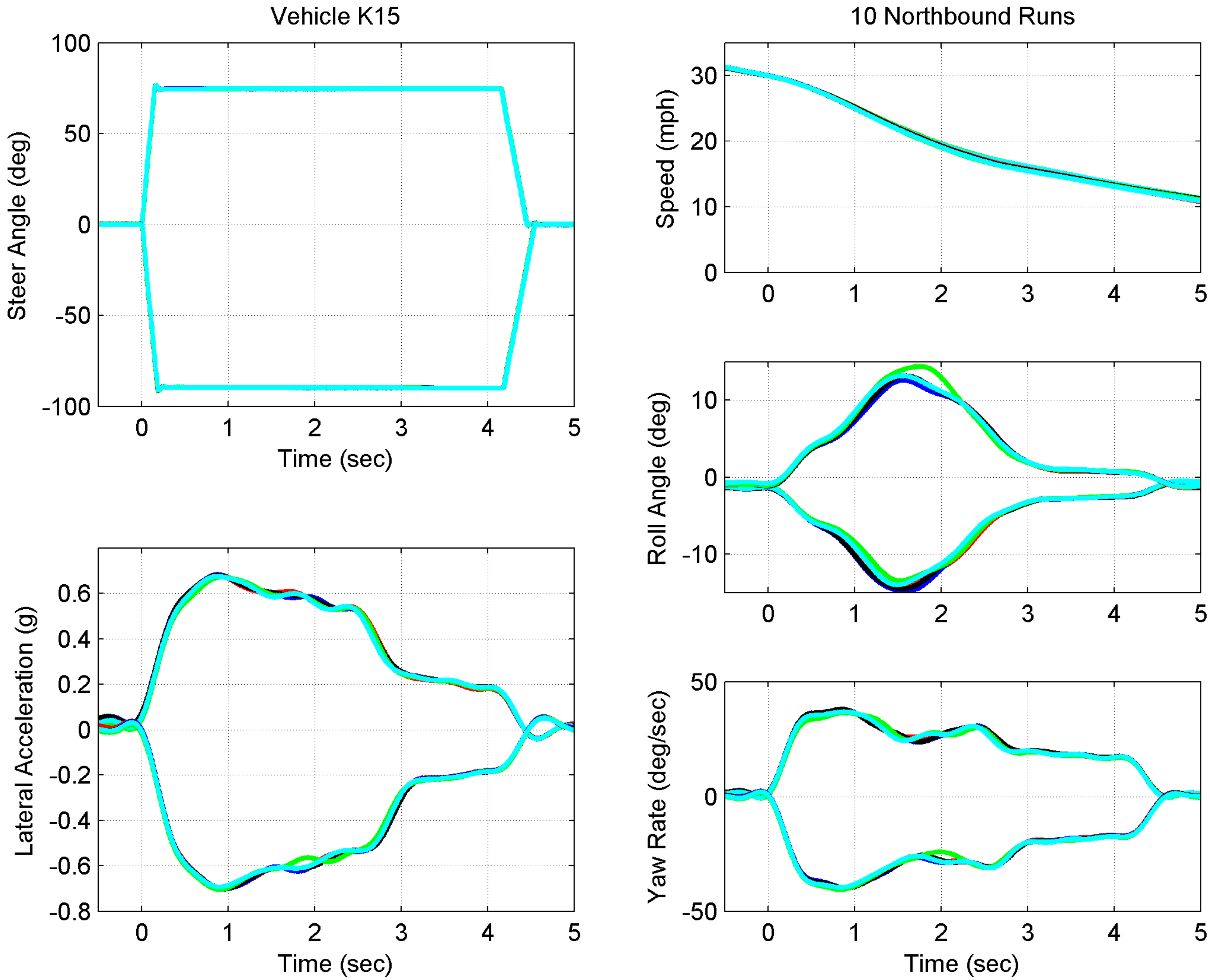
Average of All 20 Runs

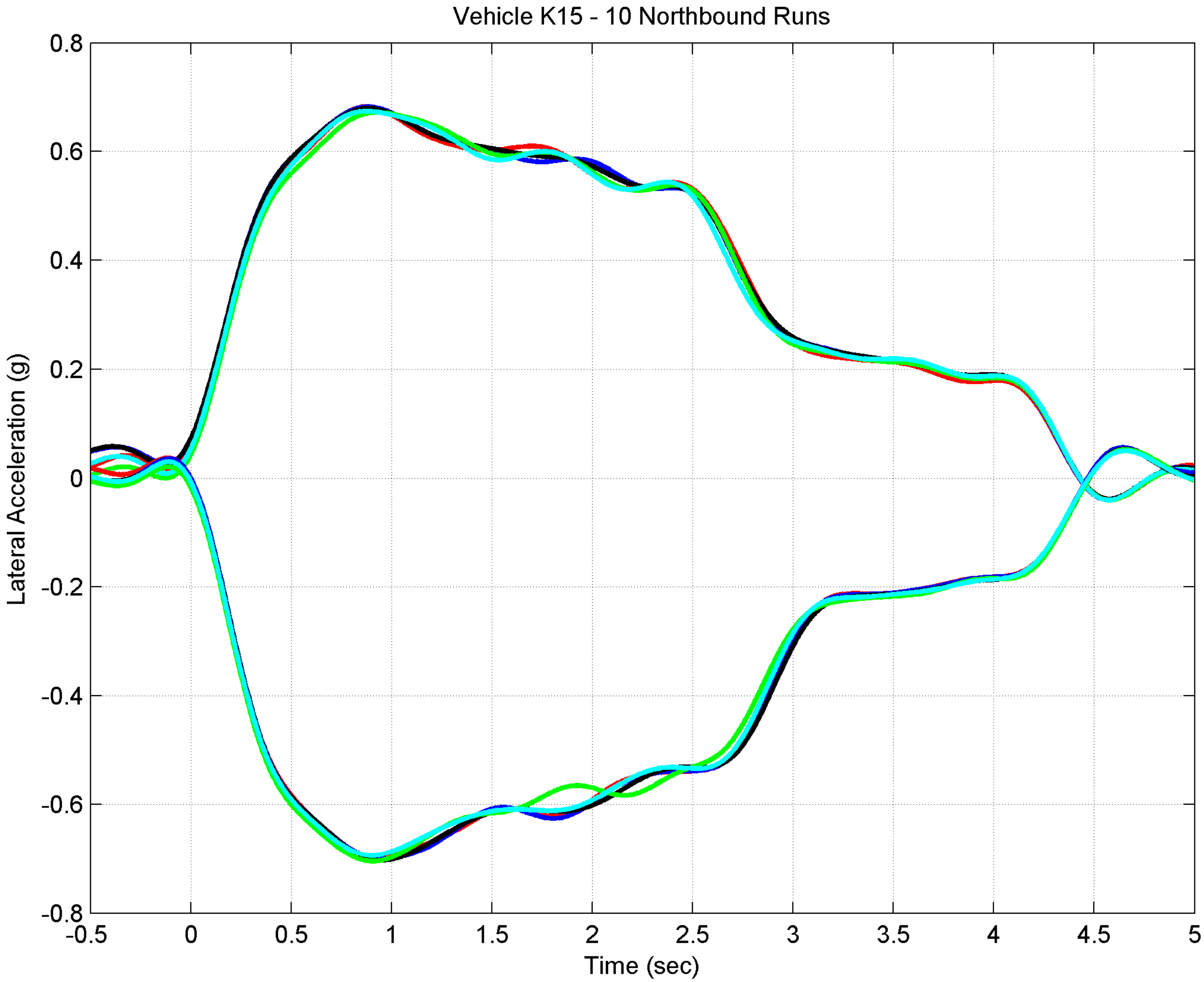
0.652

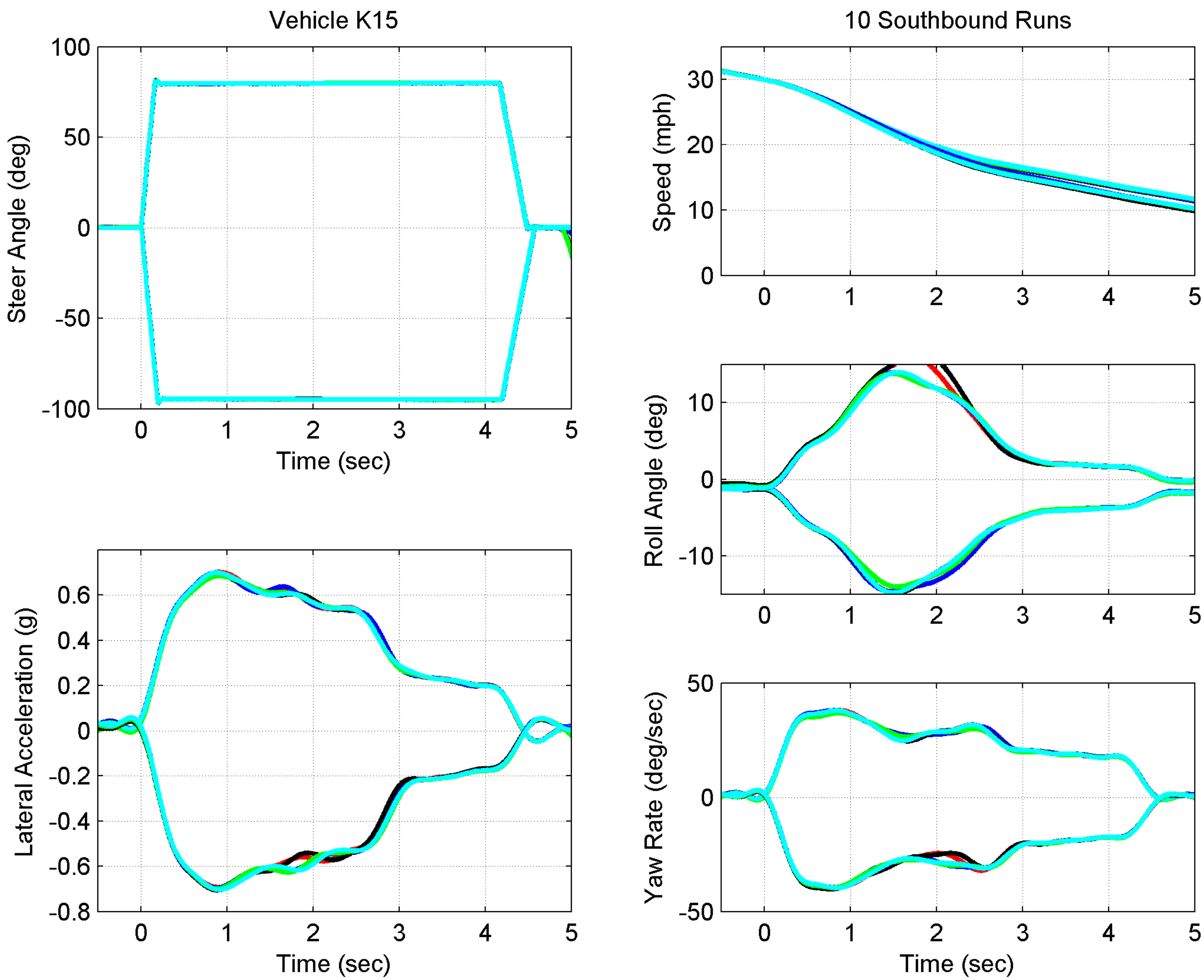
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.6488	-0.6401
2	0.6484	-0.6397
3	0.6505	-0.6394
4	0.6512	-0.6383
5	0.6537	-0.6400
Mean Value of 5 Runs	0.6505	-0.6395
Standard Deviation of 5 Runs	0.002	0.001

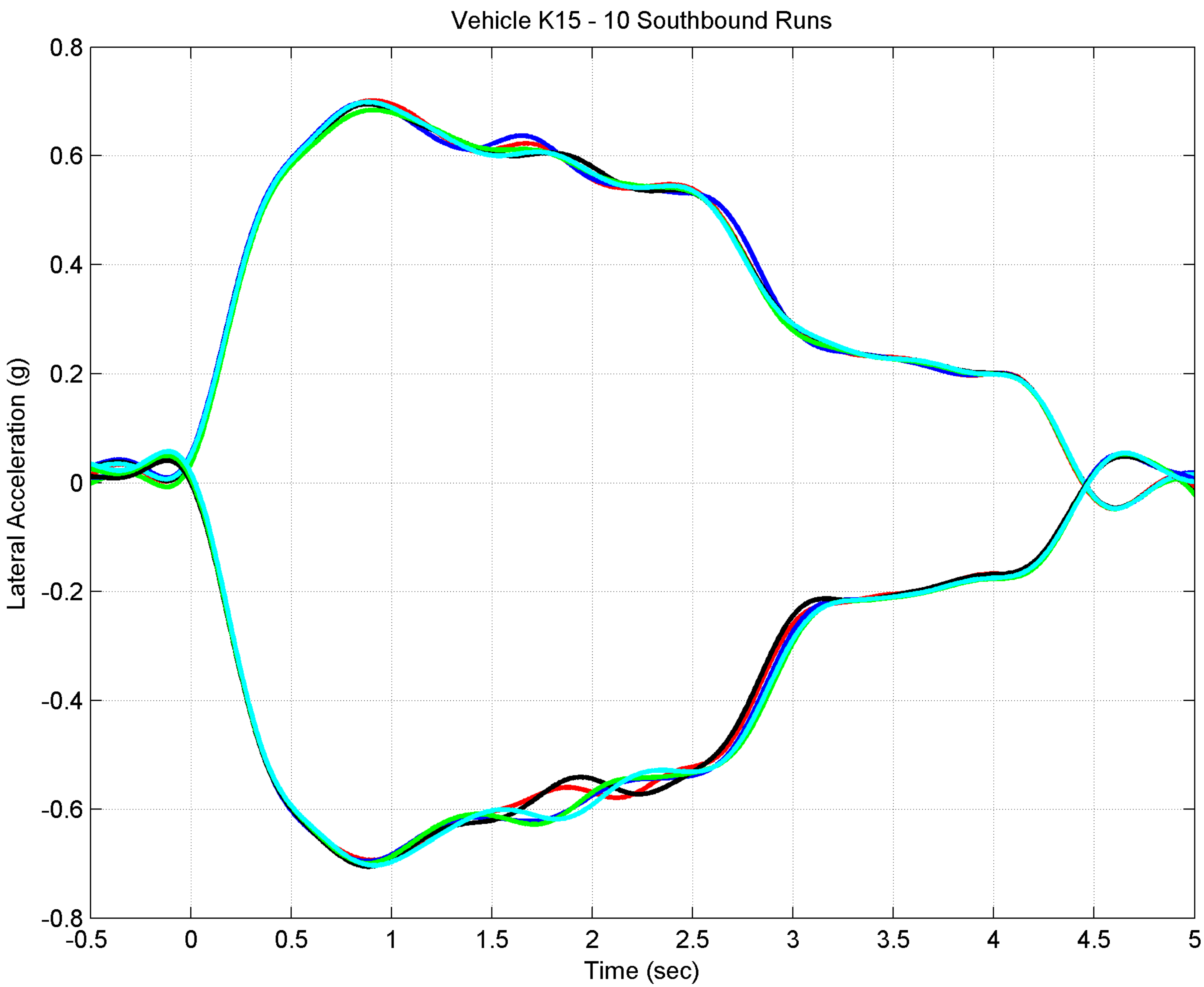
Average of 10 Southbound Runs

0.6450


Vehicle K15
10 Northbound Runs
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle K15 - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle K15
10 Southbound Runs
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle K15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle K15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.6830	-0.6979
2	0.6824	-0.7004
3	0.6799	-0.7033
4	0.6720	-0.7048
5	0.6745	-0.6940
Mean Value of 5 Runs	0.6784	-0.7001
Standard Deviation of 5 Runs	0.005	0.004

Average of 10 Northbound Runs

0.6892

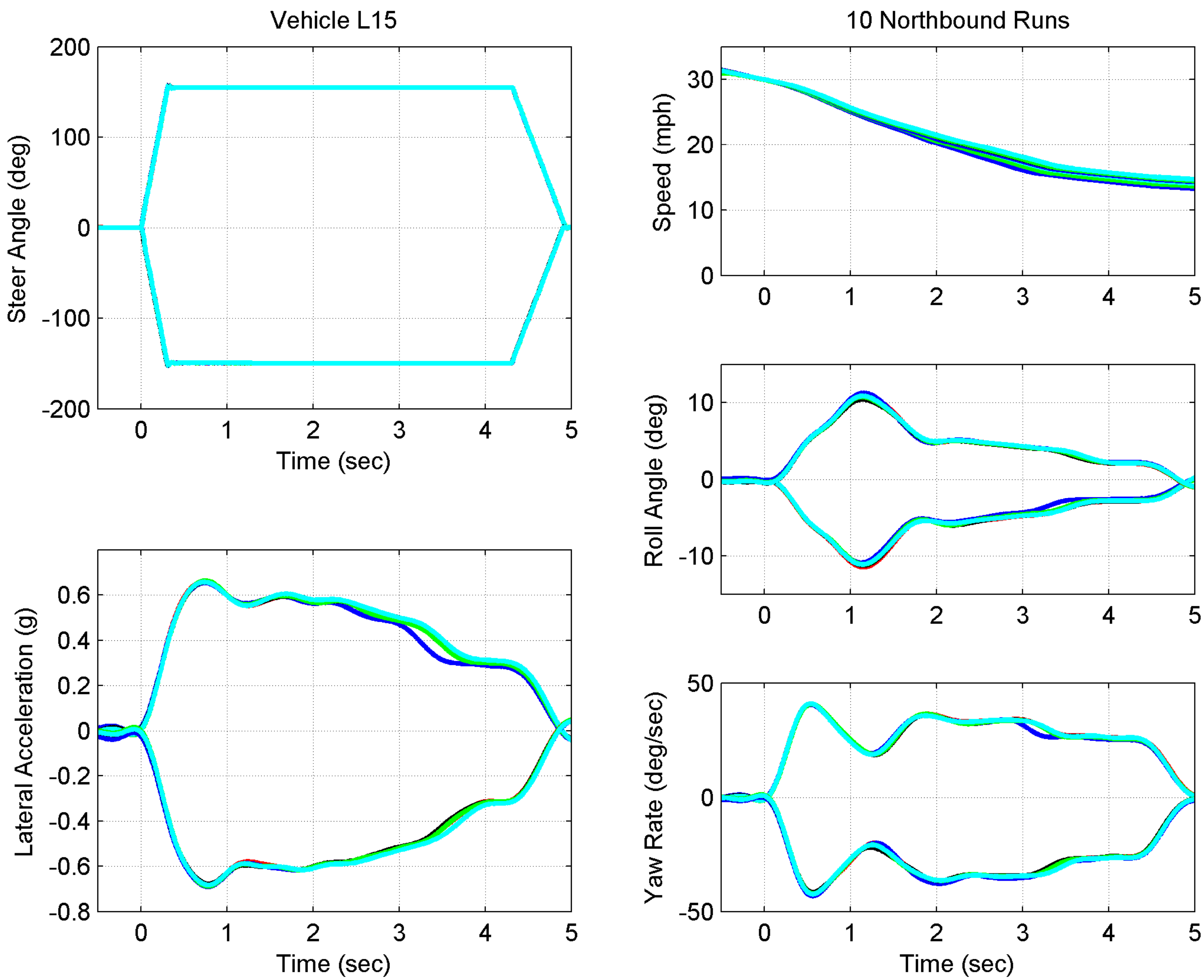
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.7017	-0.6932
2	0.6983	-0.6963
3	0.6955	-0.7057
4	0.6842	-0.7003
5	0.6991	-0.7038
Mean Value of 5 Runs	0.6958	-0.6999
Standard Deviation of 5 Runs	0.007	0.005

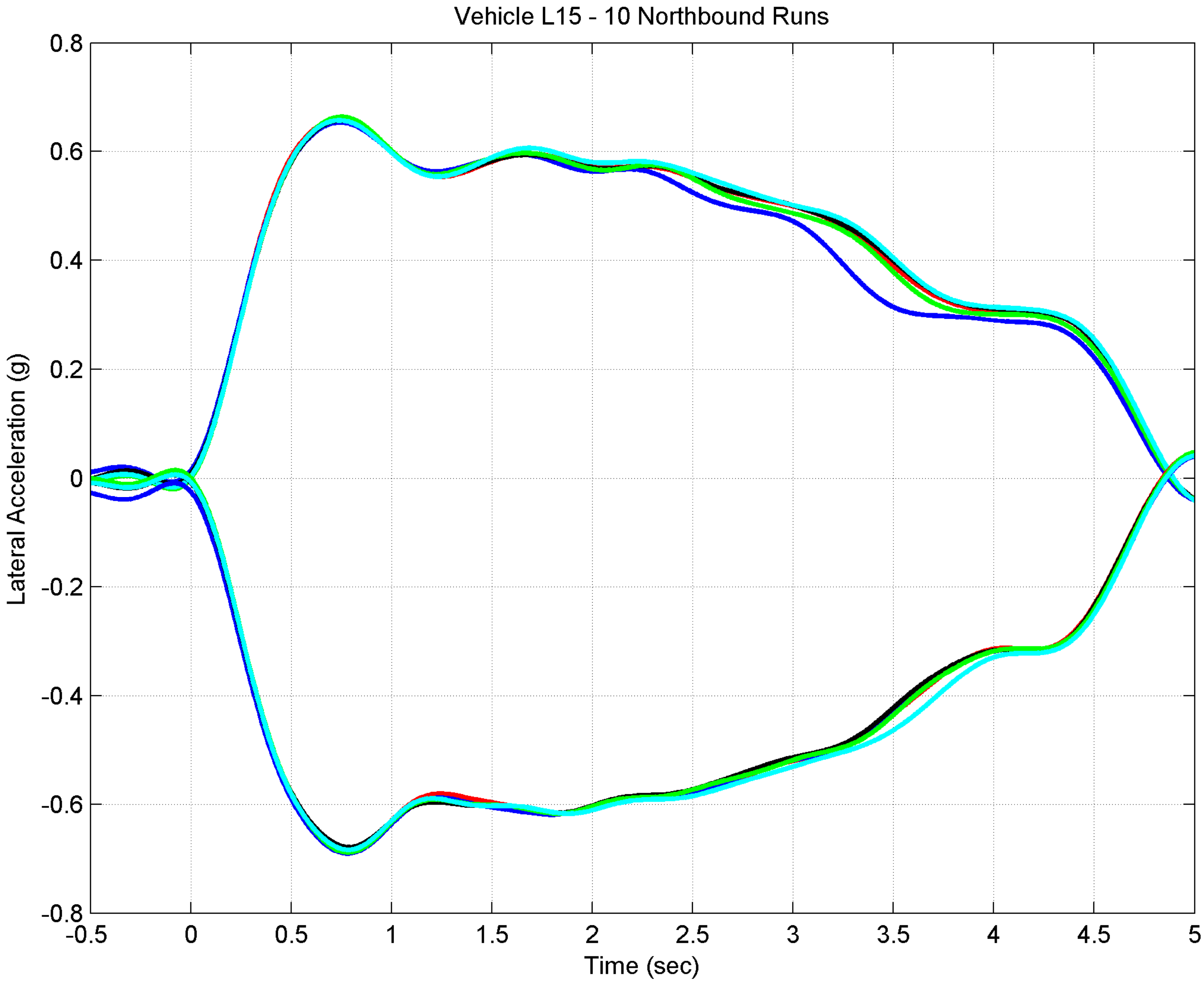
Average of 10 Southbound Runs

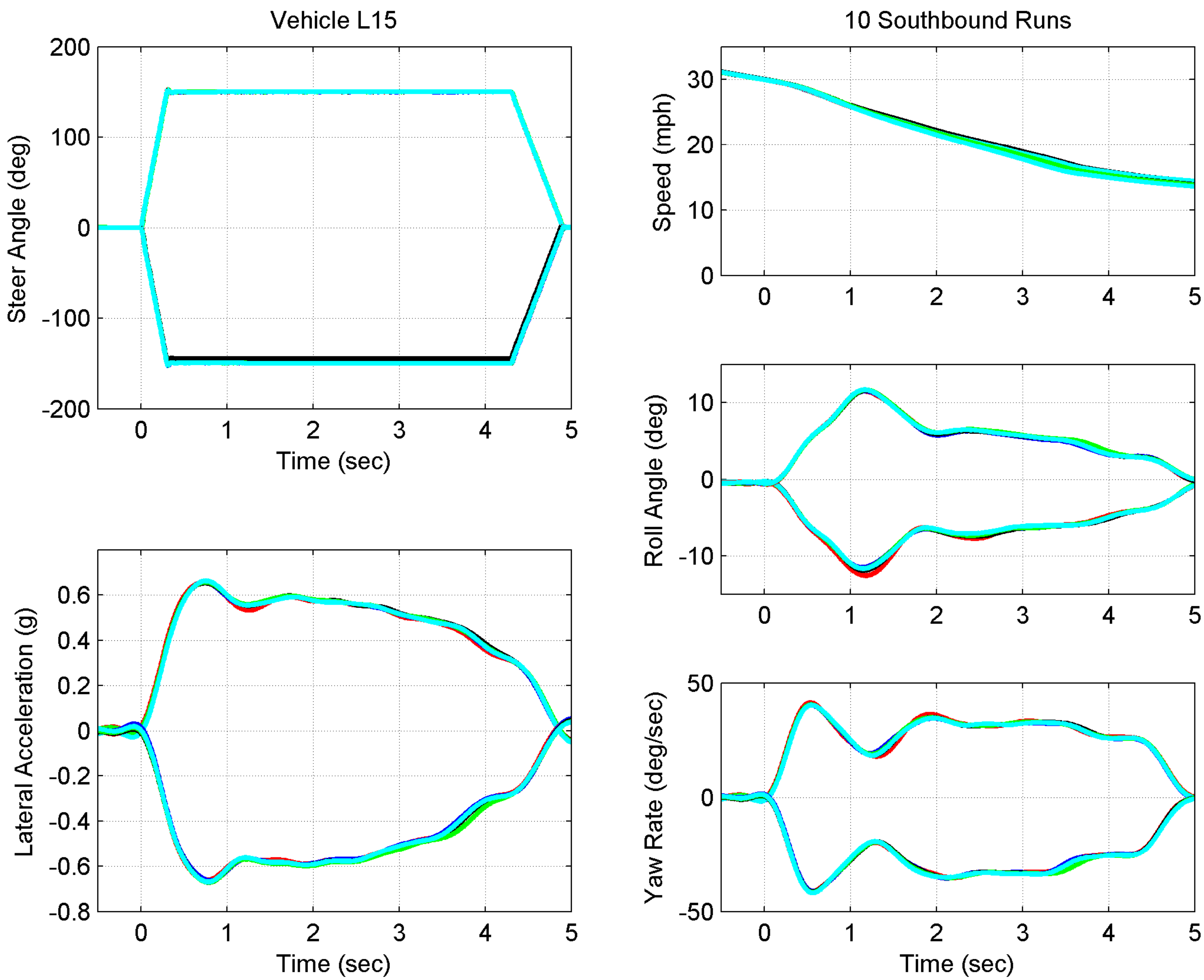
0.6978

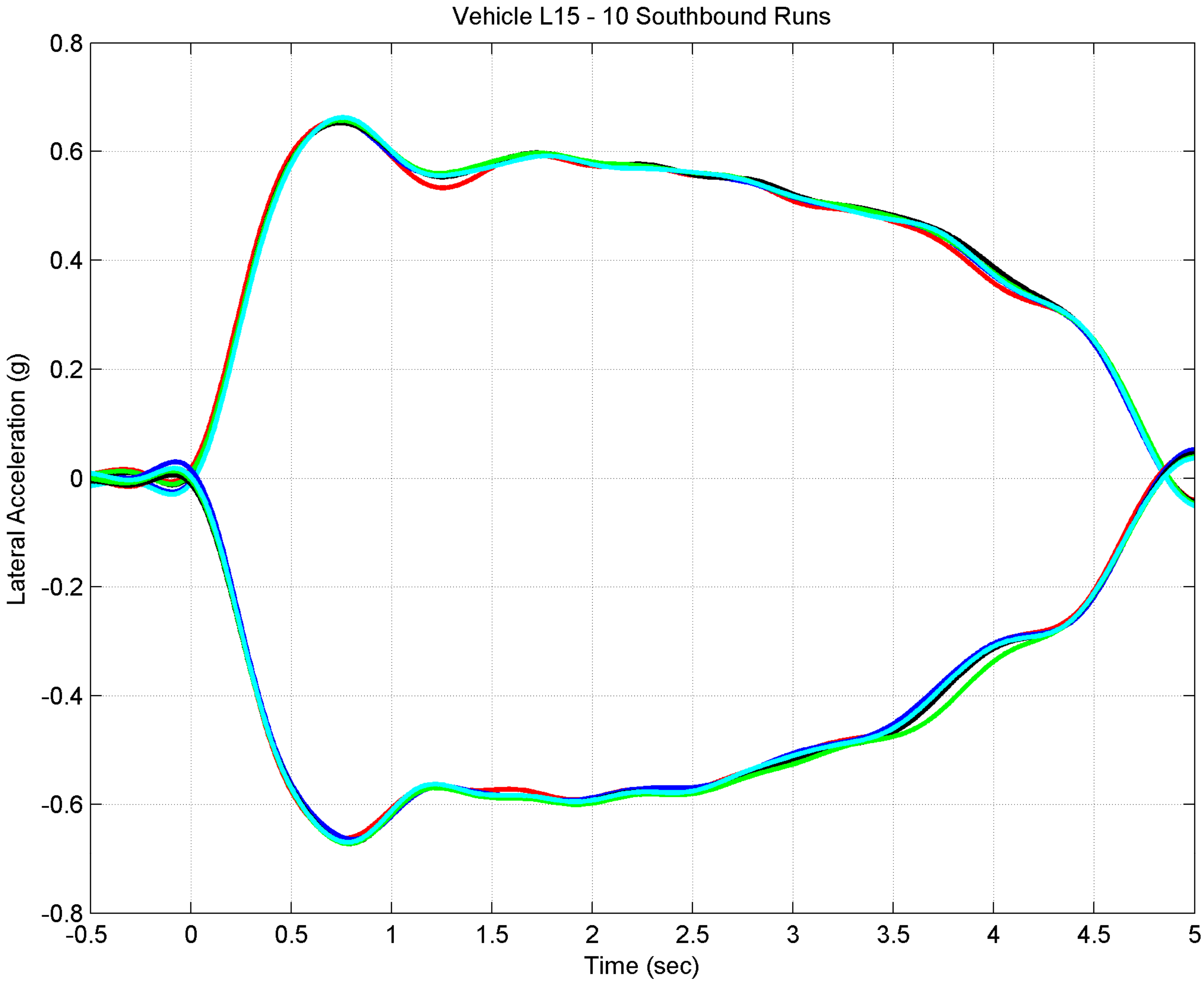
Average of All 20 Runs

0.694


Vehicle L15
10 Northbound Runs
Steer Angle (deg)
200
100
0
-100
-200
Time (sec)
0
1
2
3
4
5
Speed (mph)
30
20
10
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
50
0
-50


Vehicle L15 - 10 Northbound Runs
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle L15
10 Southbound Runs
Steer Angle (deg)
200
100
0
-100
-200
0
1
2
3
4
5
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
Time (sec)



Vehicle L15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle L15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.65825	-0.68166
2	0.65388	-0.69063
3	0.65742	-0.67867
4	0.66381	-0.68891
5	0.65758	-0.68354
Mean Value of 5 Runs	0.6582	-0.6847
Standard Deviation of 5 Runs	0.004	0.005

Average of 10 Northbound Runs

0.6714

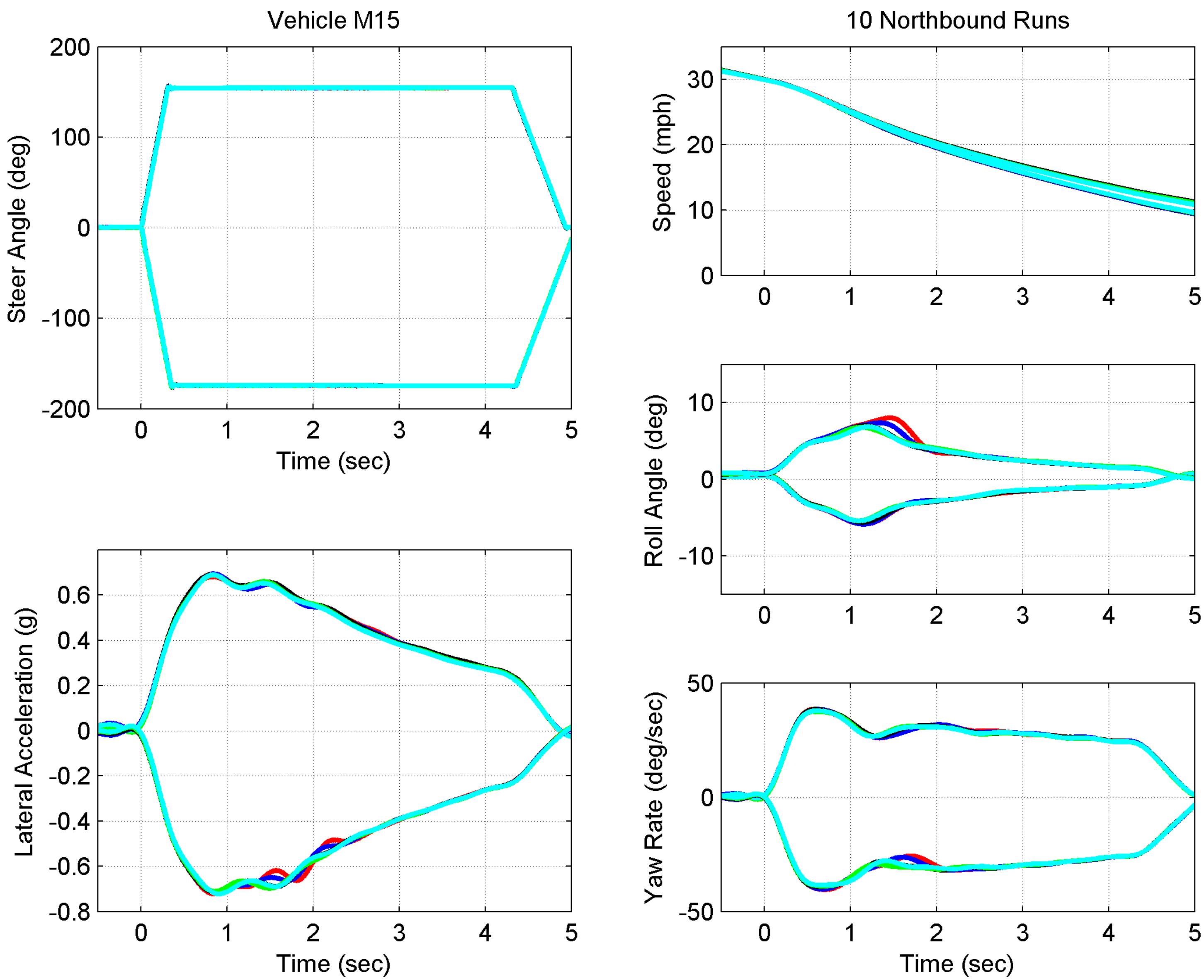
Average of All 20 Runs

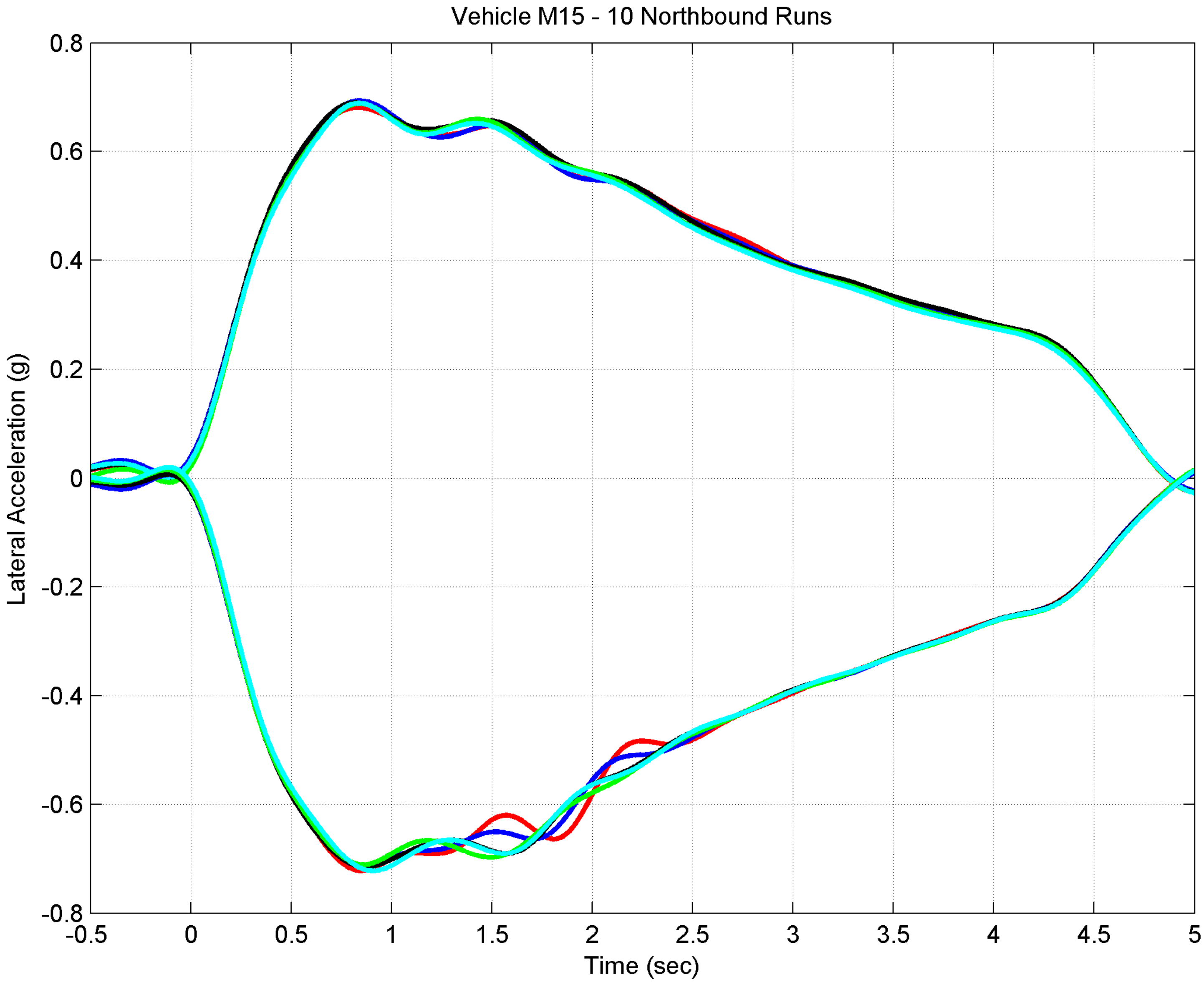
0.667

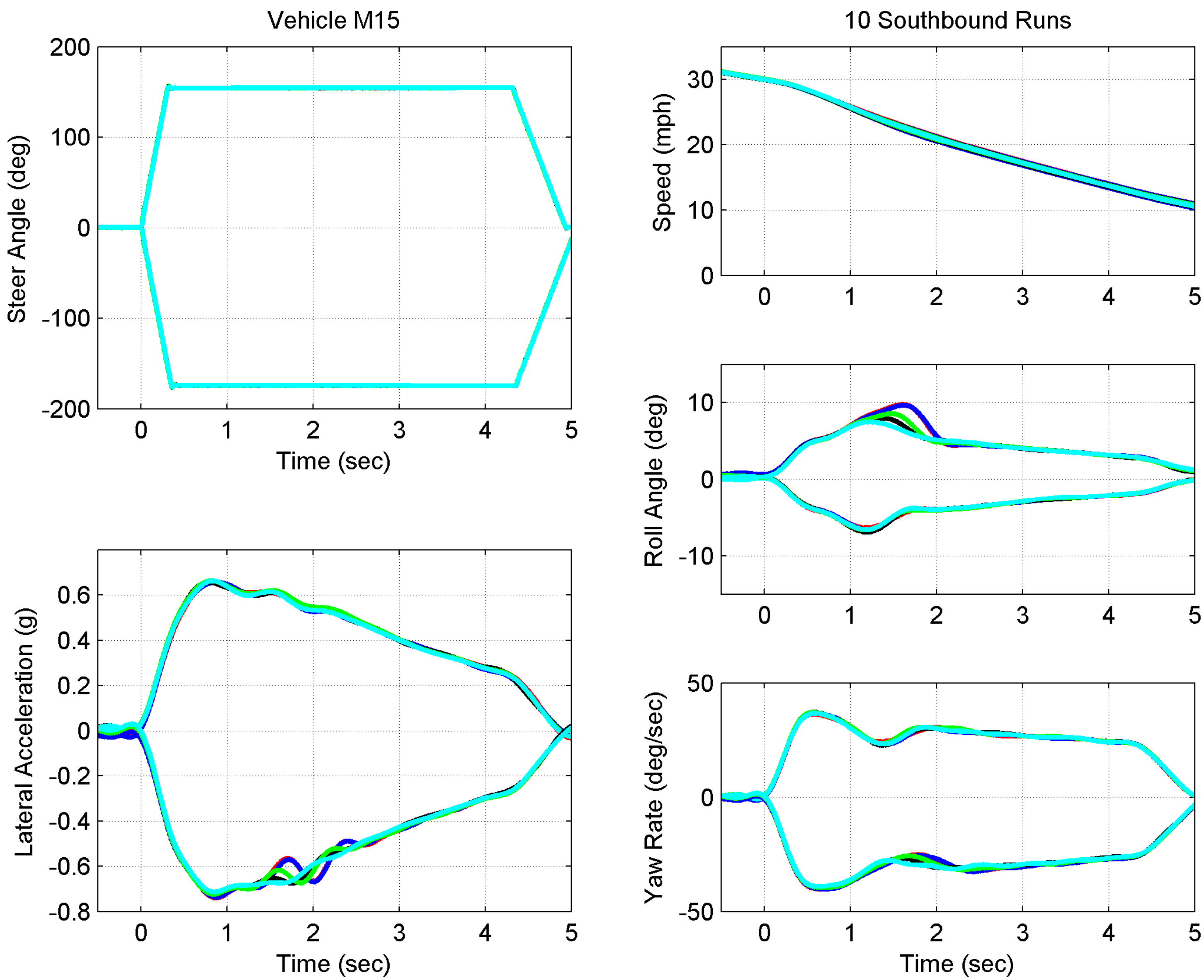
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.65682	-0.66187
2	0.65638	-0.66414
3	0.6529	-0.67216
4	0.65757	-0.67235
5	0.66279	-0.66966
Mean Value of 5 Runs	0.6573	-0.6680
Standard Deviation of 5 Runs	0.004	0.005

Average of 10 Southbound Runs

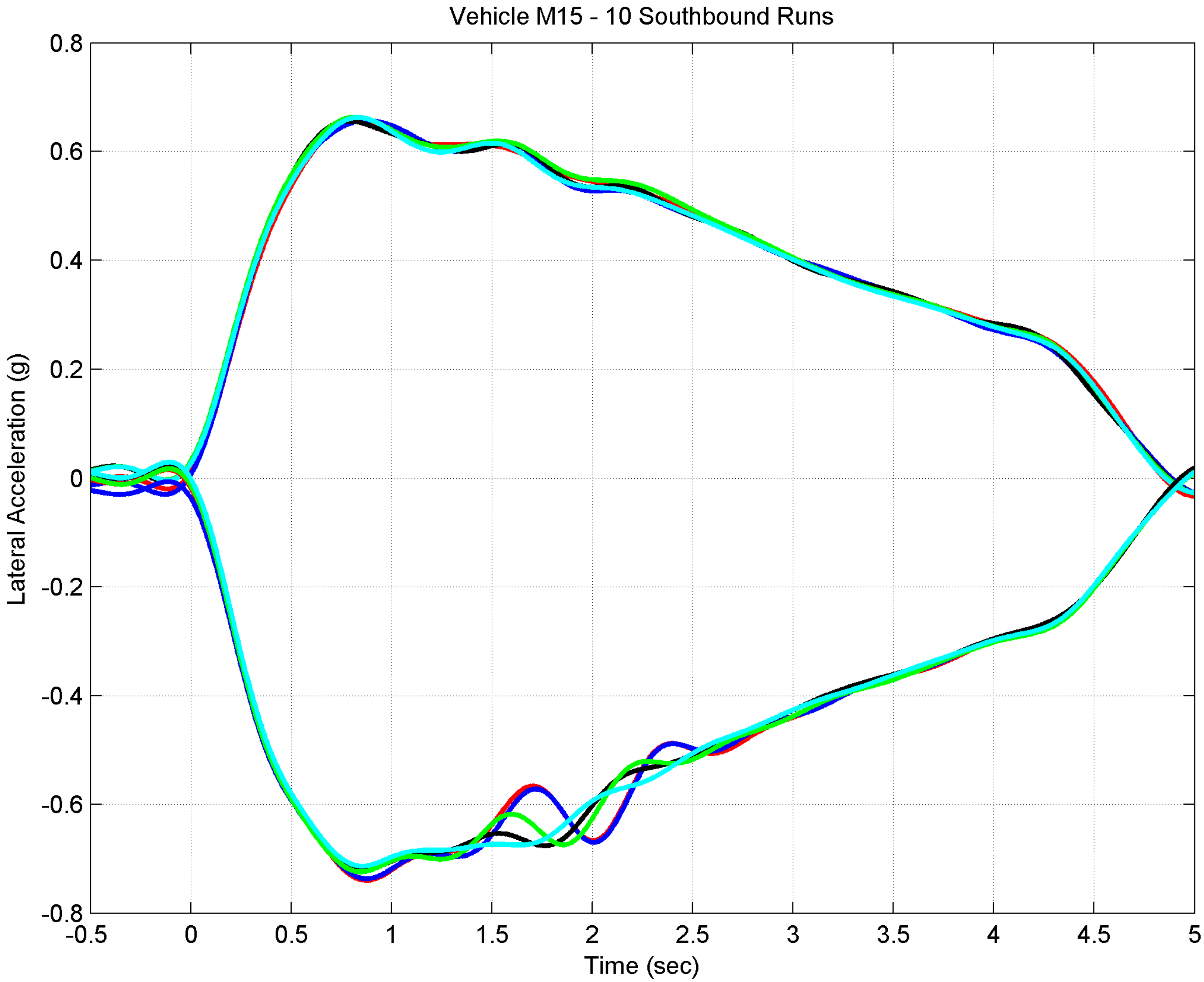
0.6627


Vehicle M15
10 Northbound Runs
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle M15 - 10 Northbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle M15
10 Southbound Runs
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle M15 - 10 Southbound Runs
Lateral Acceleration (g)
Time (sec)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle M15

Run Number	Northbound Right Turns	Northbound Left Turns
1	0.6809	-0.7223
2	0.6936	-0.7139
3	0.6901	-0.7156
4	0.6883	-0.7115
5	0.6893	-0.7226
Mean Value of 5 Runs	0.6884	-0.7172
Standard Deviation of 5 Runs	0.005	0.005

Average of 10 Northbound Runs

0.7028

Average of All 20 Runs

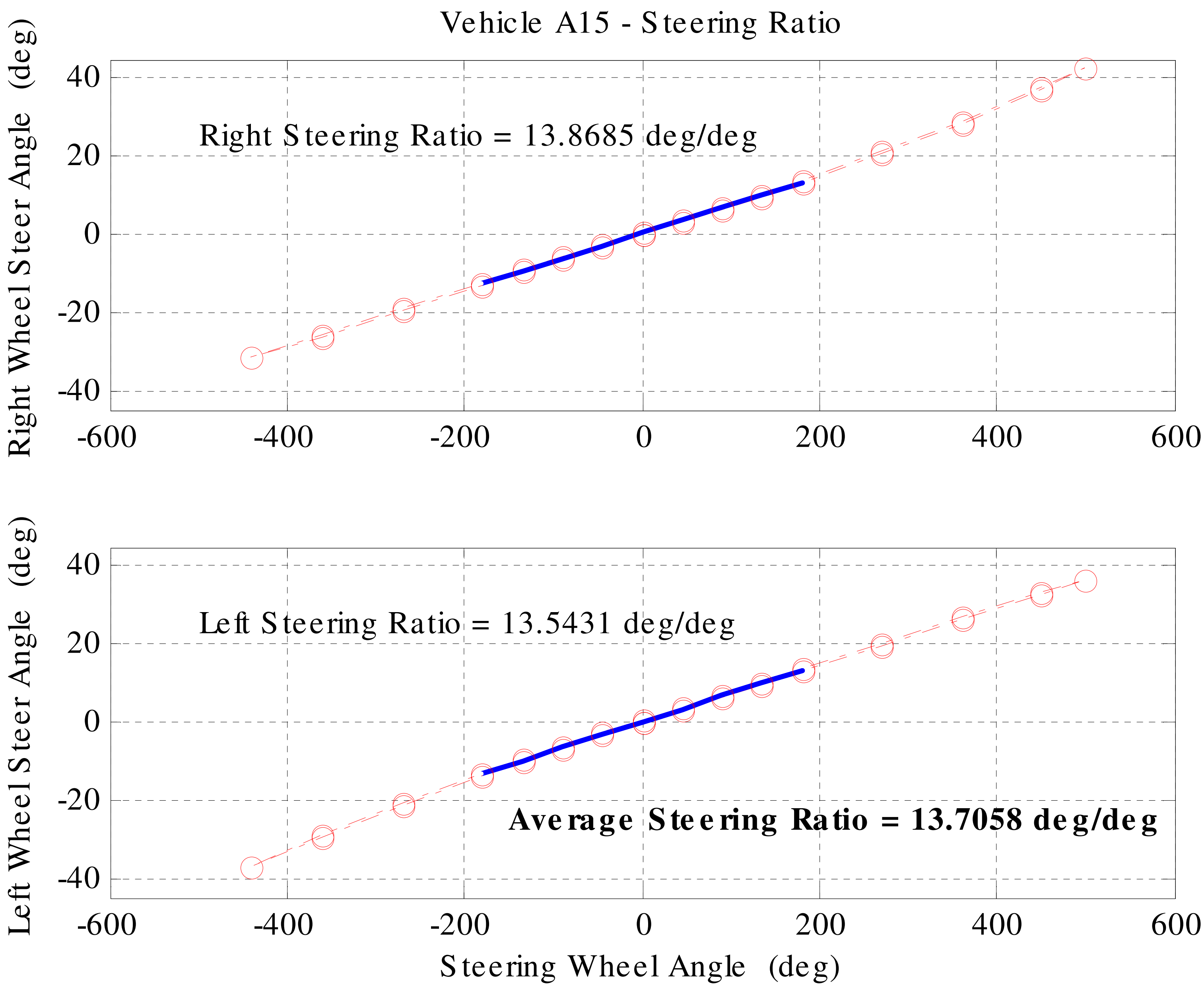
0.698

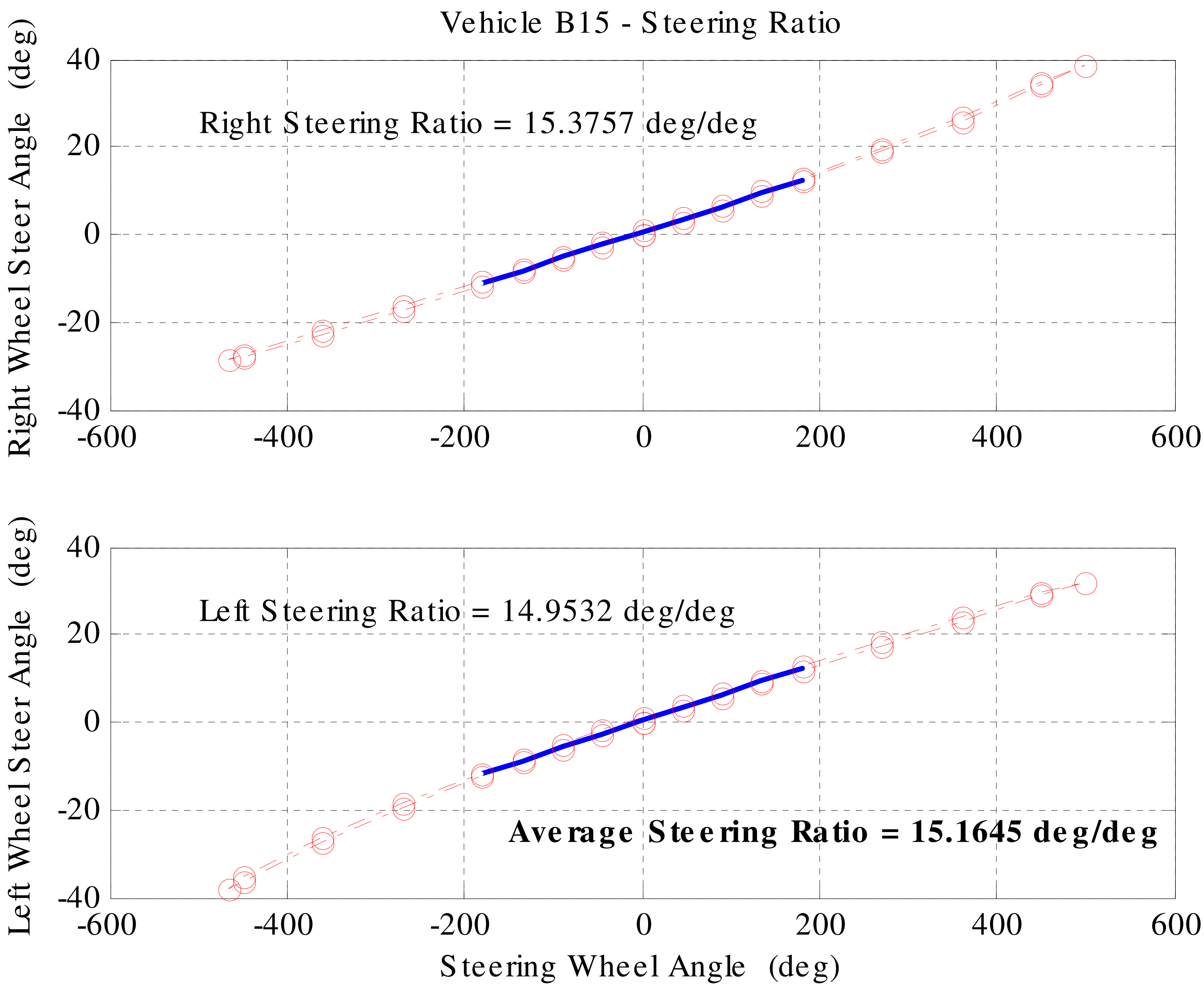
Run Number	Southbound Right Turns	Southbound Left Turns
1	0.6591	-0.7403
2	0.6569	-0.7373
3	0.6562	-0.7210
4	0.6634	-0.7245
5	0.6628	-0.7142
Mean Value of 5 Runs	0.6597	-0.7274
Standard Deviation of 5 Runs	0.003	0.011

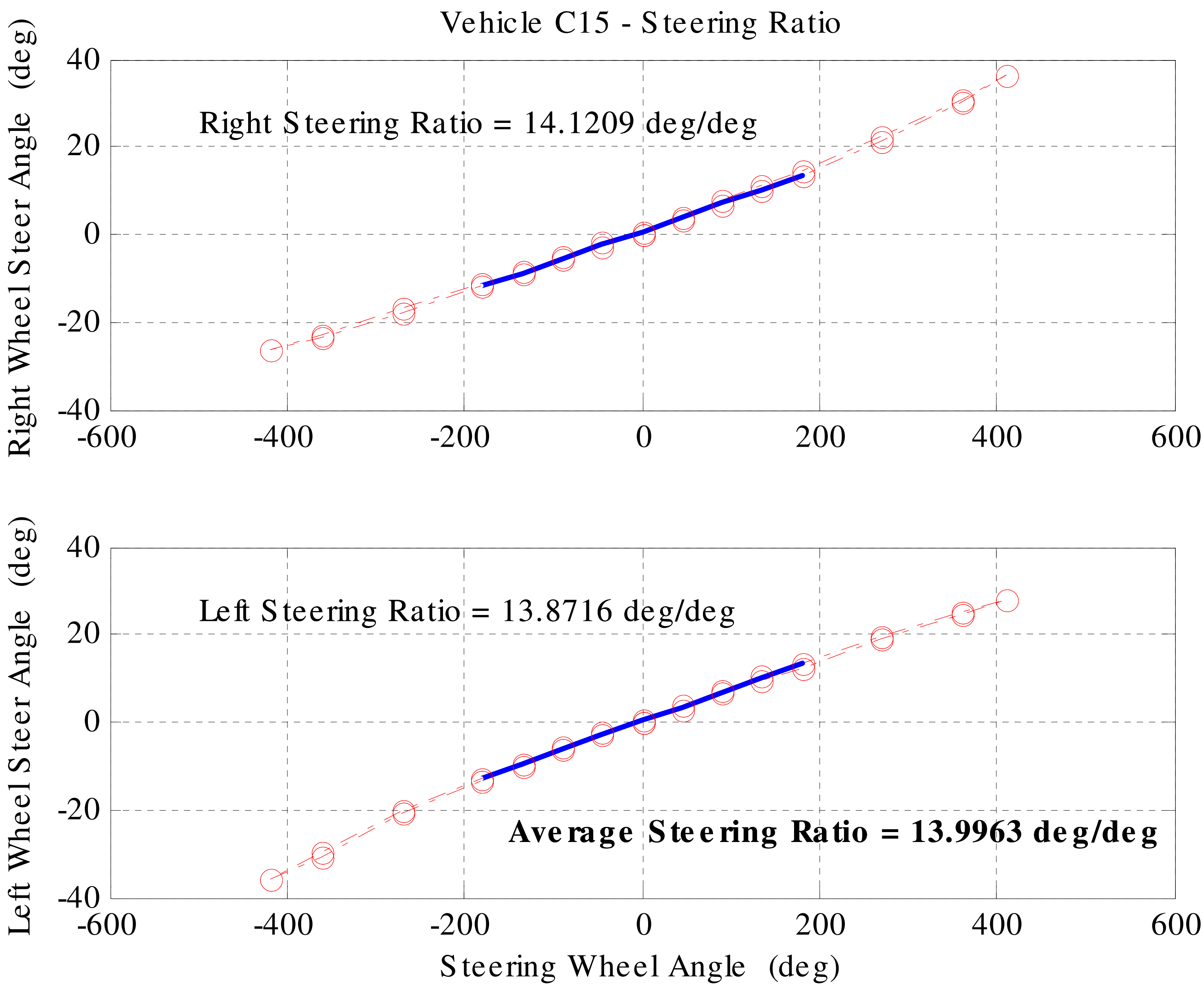
Average of 10 Southbound Runs

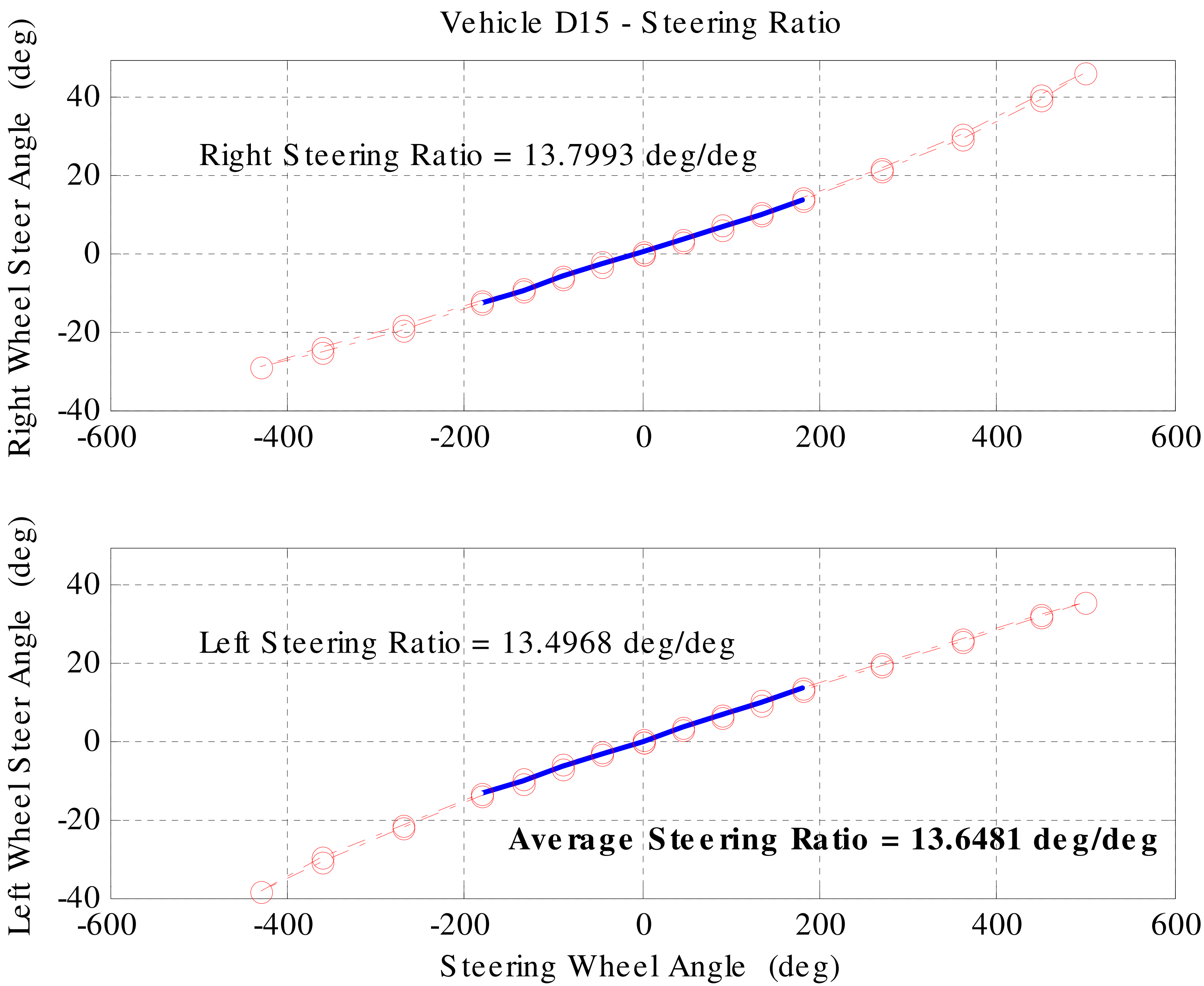
0.6936

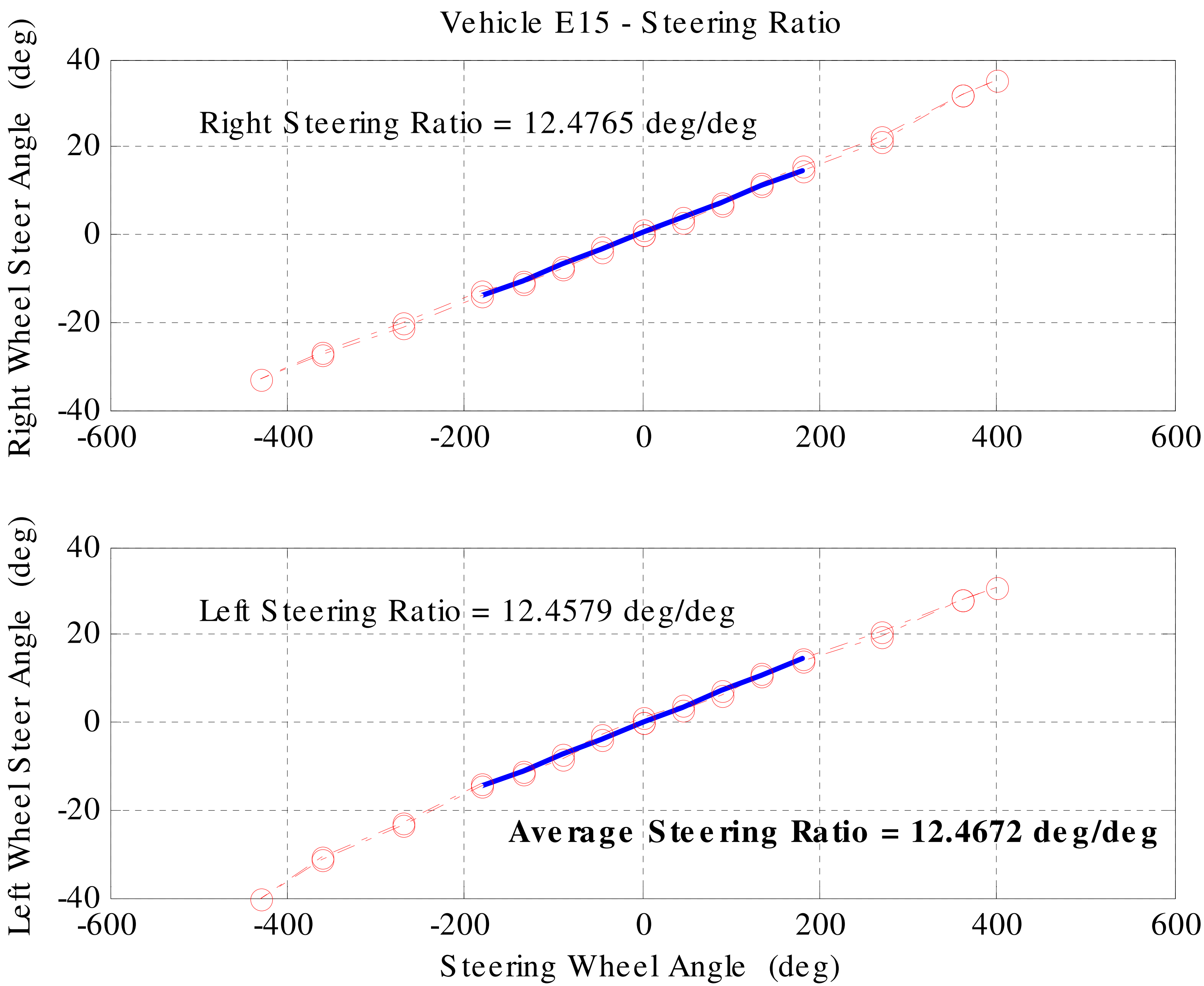
Steering Magnitudes and Threshold Lateral Accelerations During 30 mph Dropped Throttle J-Turns										
Vehicle	Northbound Runs				Southbound Runs				**Average Steering Angle (deg)**	**Average Lateral Accel. (g)**
	Right Steering Angle (deg)	Right Lateral Accel. (g)	Left Steering Angle (deg)	Left Lateral Accel. (g)	Right Steering Angle (deg)	Right Lateral Accel. (g)	Left Steering Angle (deg)	Left Lateral Accel. (g)		
Vehicle A15	145	0.7368	150	0.7508	140	0.7261	145	0.7377	**145.0**	**0.738**
Vehicle B15	355	0.7390	365	0.7592	345	0.7273	330	0.7560	**348.8**	**0.745**
Vehicle C15	95	0.6911	100	0.7035	95	0.6742	95	0.6987	**96.3**	**0.692**
Vehicle D15	140	0.6568	155	0.6562	130	0.6150	155	0.6645	**145.0**	**0.648**
Vehicle E15	95	0.6604	80	0.7074	95	0.6488	75	0.6966	**86.3**	**0.678**
Vehicle F15	155	0.6770	145	0.6768	150	0.6707	140	0.6735	**147.5**	**0.674**
Vehicle G15	120	0.6336	105	0.6065	115	0.6051	105	0.6071	**111.3**	**0.613**
Vehicle H15	215	0.7277	280	0.7746	215	0.7220	280	0.7698	**247.5**	**0.749**
Vehicle I15	130	0.6630	135	0.7084	125	0.6570	135	0.7124	**131.3**	**0.685**
Vehicle J15	200	0.6571	180	0.6603	185	0.6505	175	0.6395	**185.0**	**0.652**
Vehicle K15	75	0.6784	90	0.7001	80	0.6958	95	0.6999	**85.0**	**0.694**
Vehicle L15	155	0.6582	150	0.6847	150	0.6573	148	0.6680	**150.8**	**0.667**
Vehicle M15	155	0.6884	175	0.7172	155	0.6597	175	0.7274	**165.0**	**0.698**

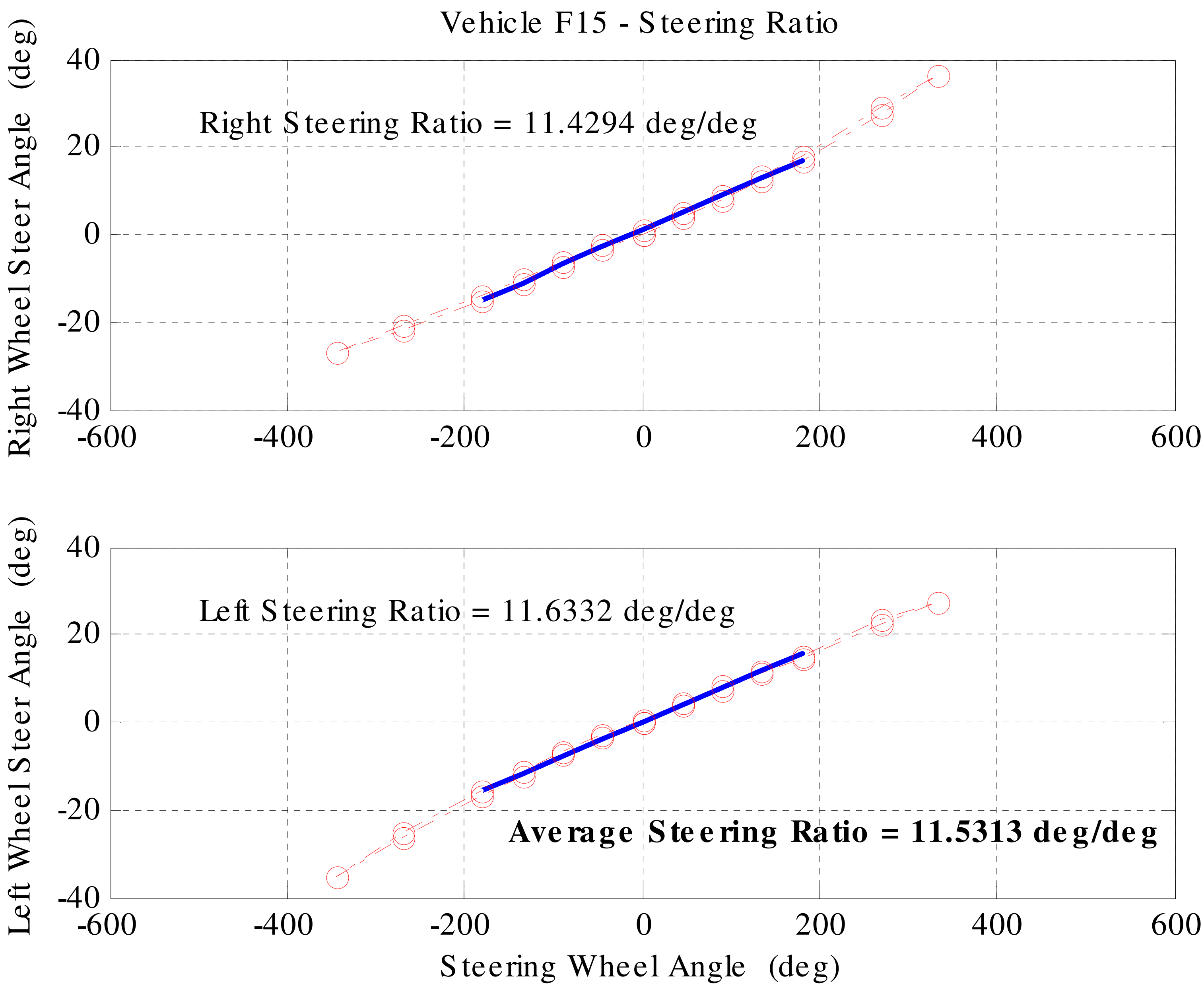

Vehicle A15 - Steering Ratio
Right Steering Ratio = 13.8685 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 13.5431 deg/deg
Average Steering Ratio = 13.7058 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

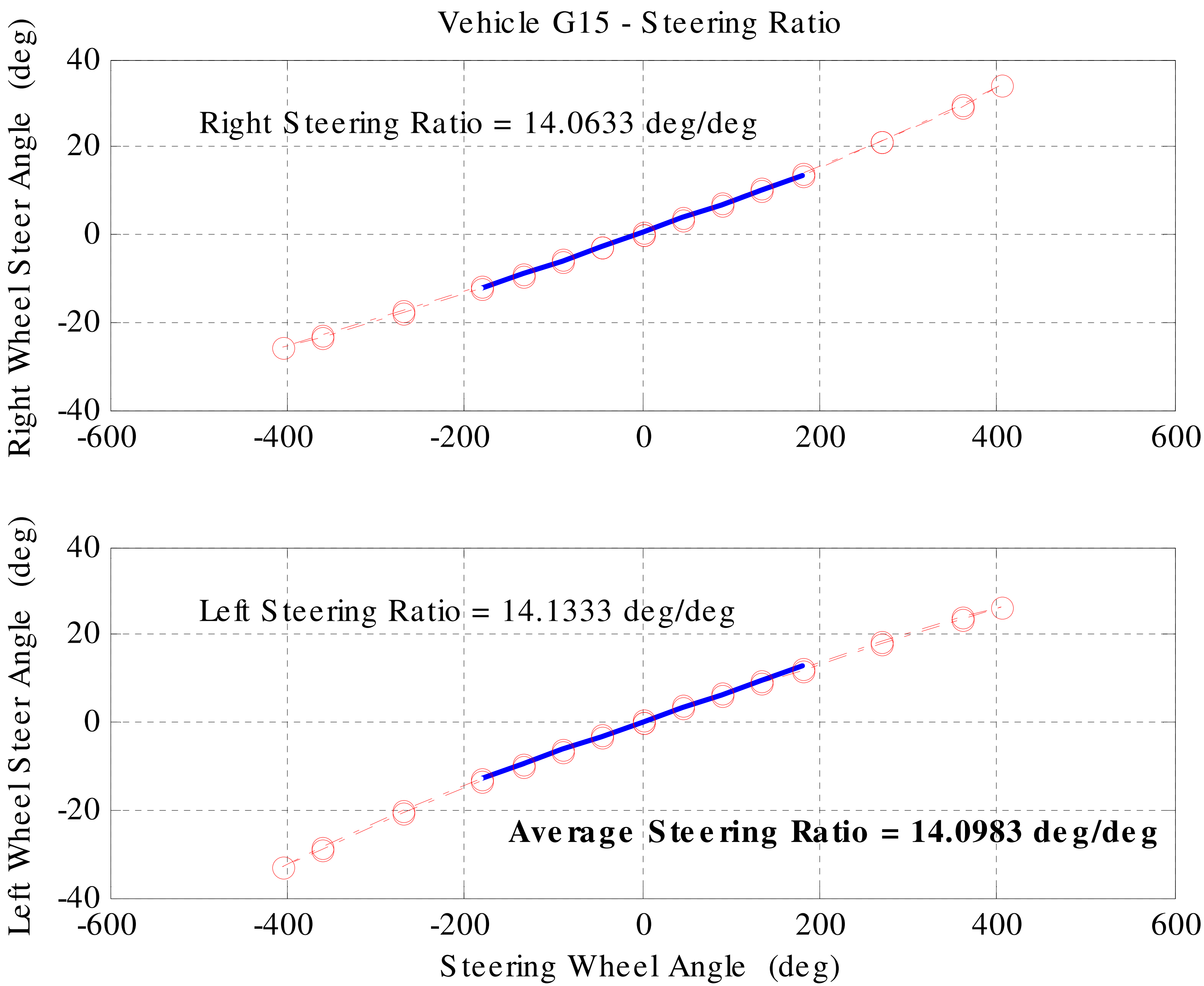

Vehicle B15 - Steering Ratio
Right Steering Ratio = 15.3757 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 14.9532 deg/deg
Average Steering Ratio = 15.1645 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

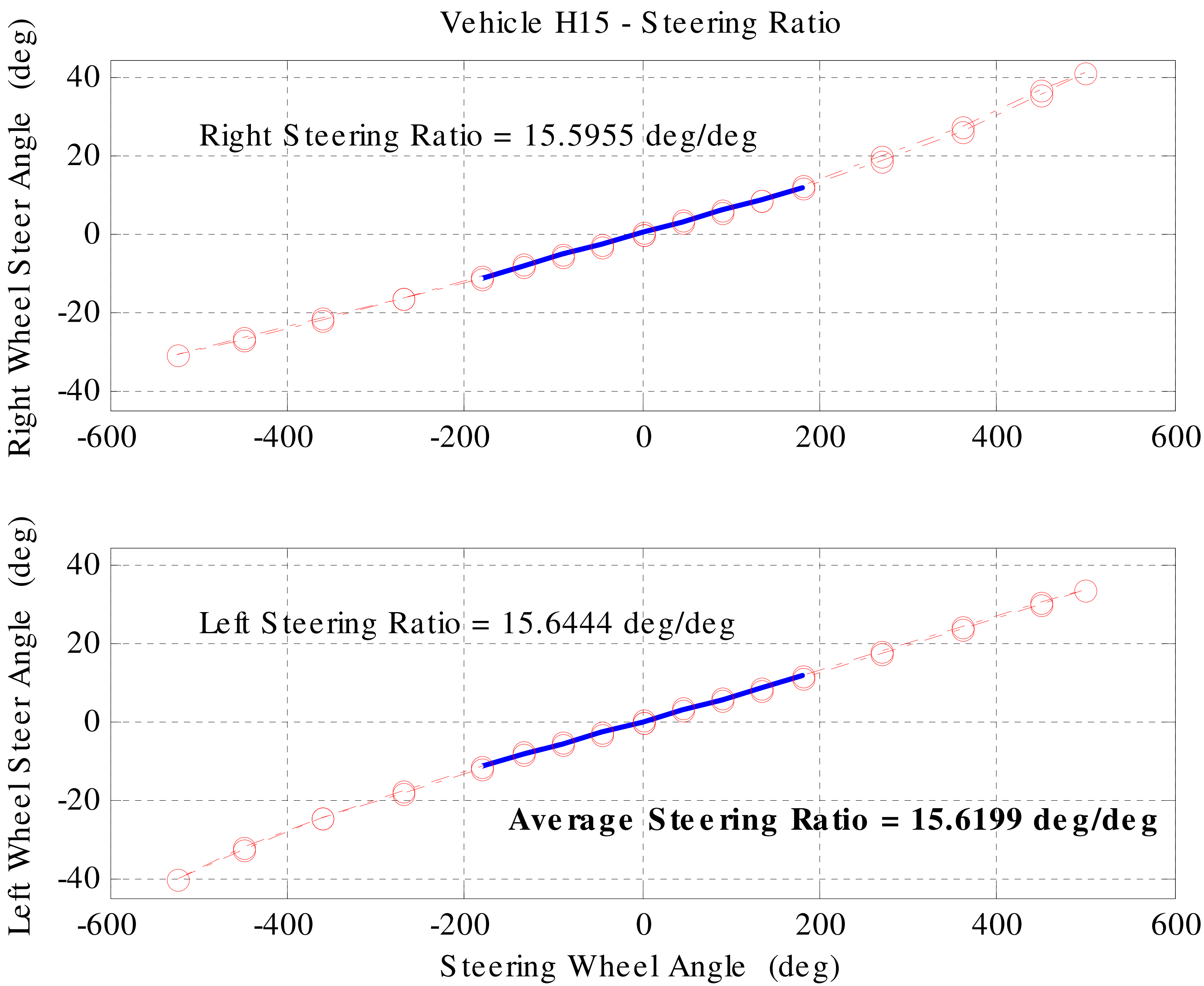

Vehicle C15 - Steering Ratio
Right Steering Ratio = 14.1209 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 13.8716 deg/deg
Average Steering Ratio = 13.9963 deg/deg
Left Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Steering Wheel Angle (deg)

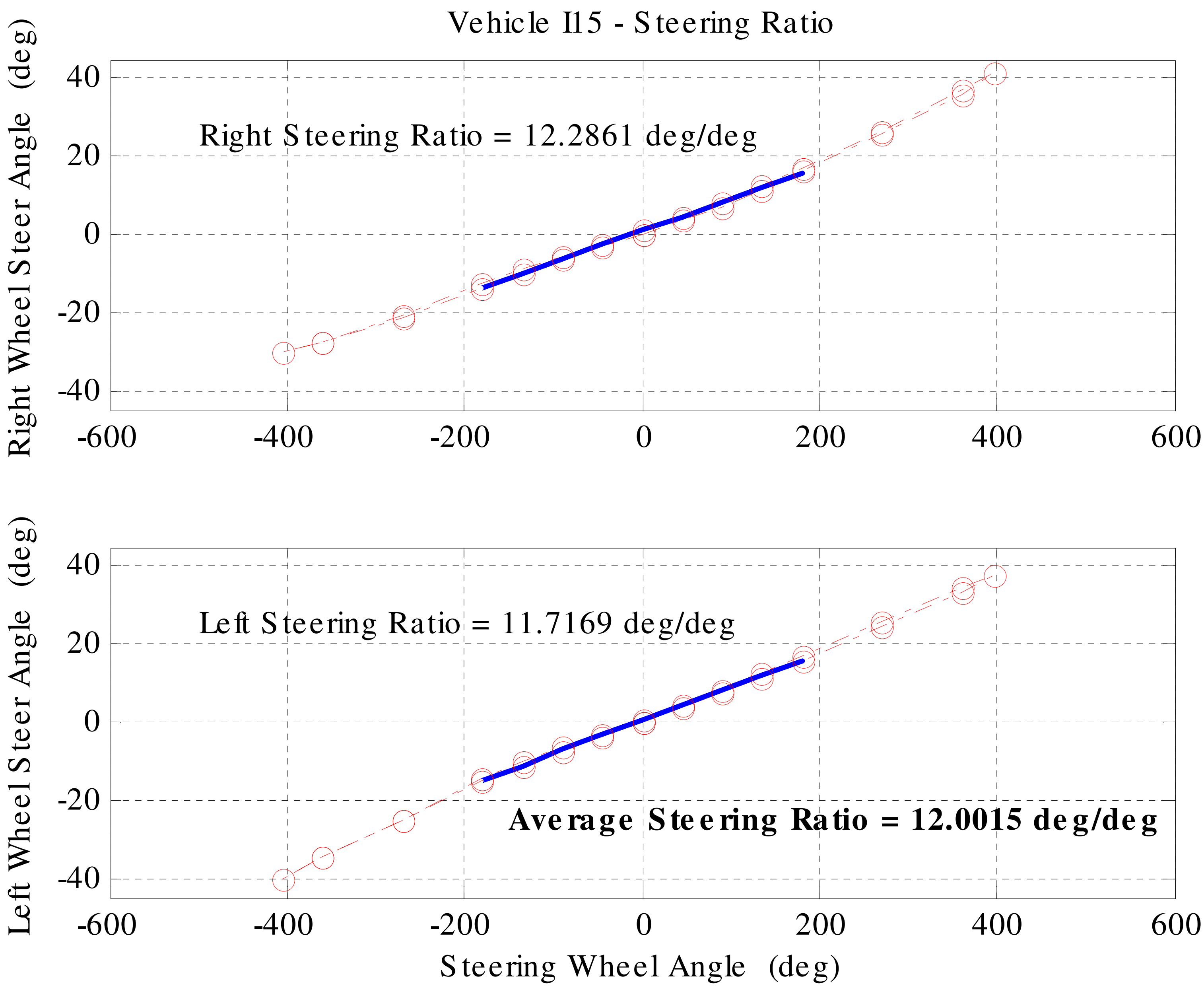

Vehicle D15 - Steering Ratio
Right Steering Ratio = 13.7993 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 13.4968 deg/deg
Average Steering Ratio = 13.6481 deg/deg
Left Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Steering Wheel Angle (deg)

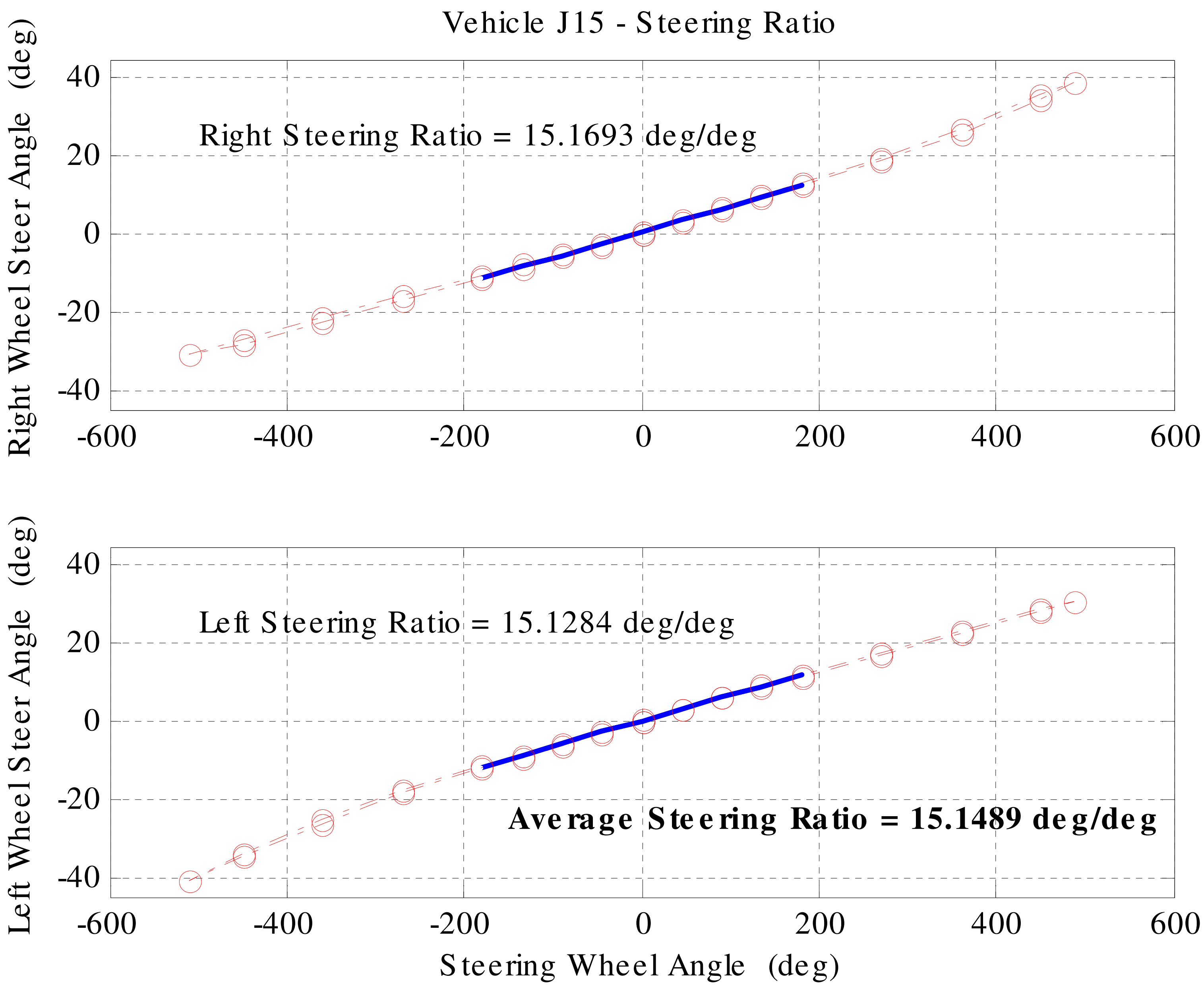

Vehicle E15 - Steering Ratio
Right Steering Ratio = 12.4765 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 12.4579 deg/deg
Average Steering Ratio = 12.4672 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)


Vehicle F15 - Steering Ratio
Right Steering Ratio = 11.4294 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 11.6332 deg/deg
Average Steering Ratio = 11.5313 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

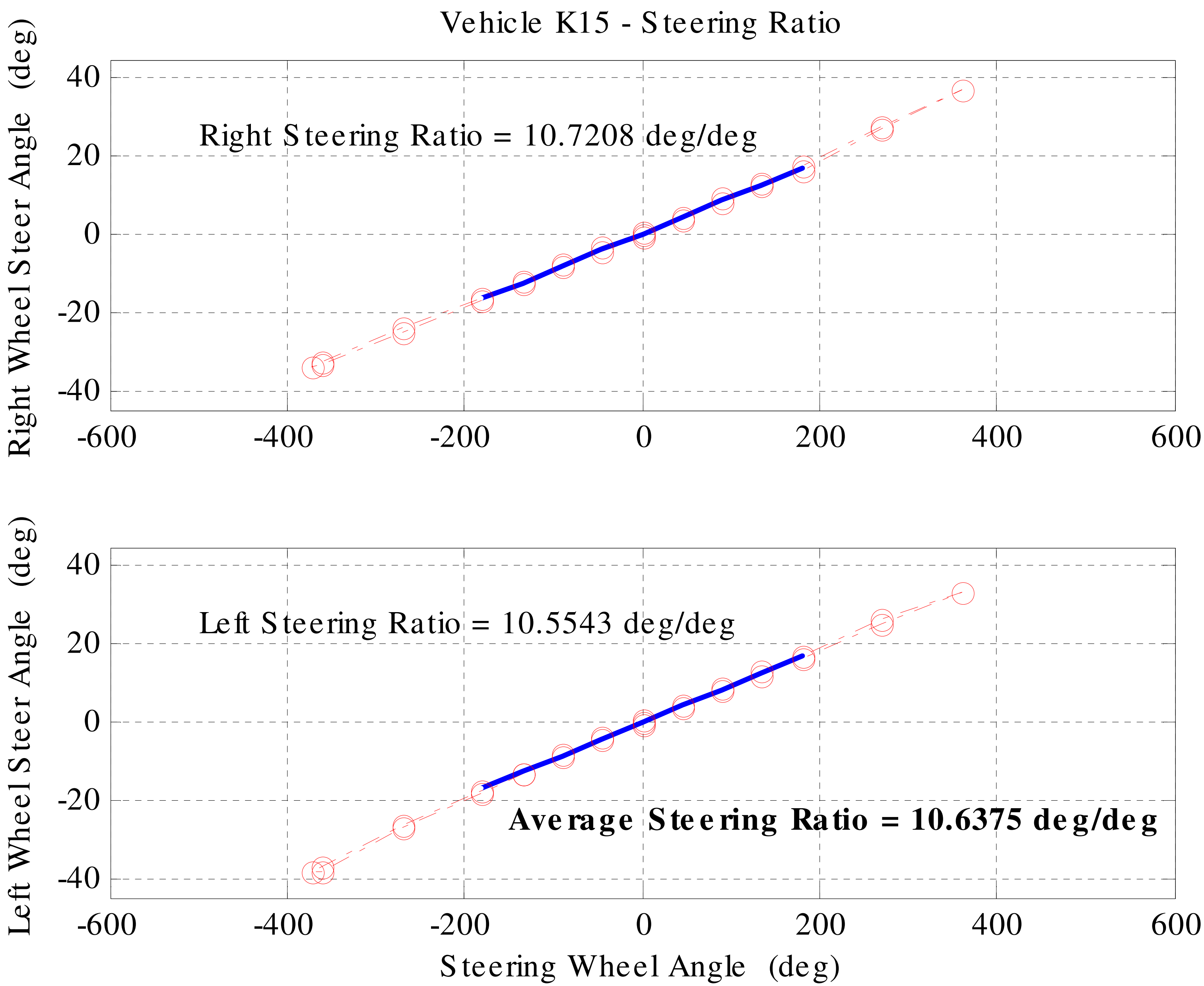

Vehicle G15 - Steering Ratio
Right Steering Ratio = 14.0633 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 14.1333 deg/deg
Average Steering Ratio = 14.0983 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

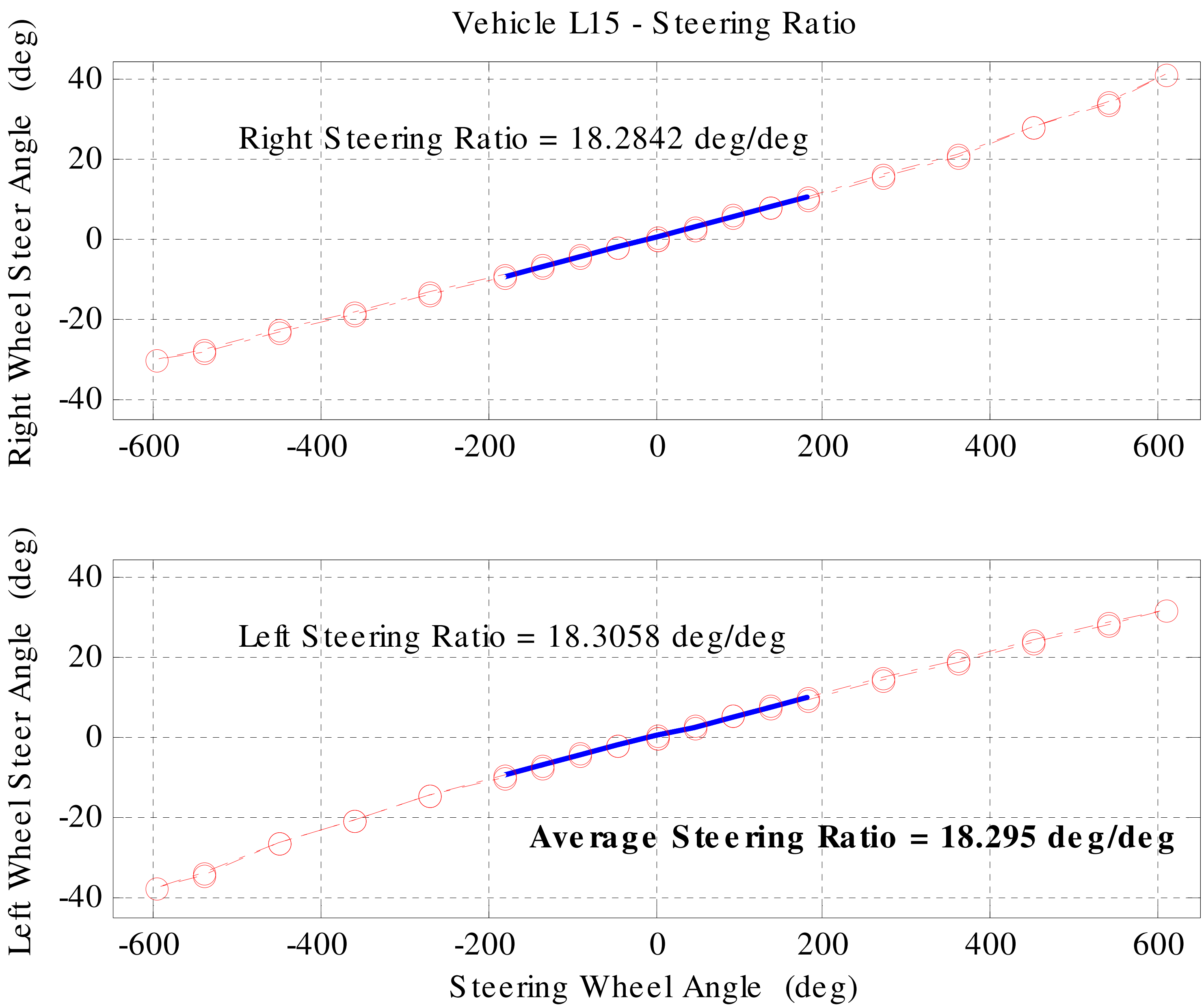

Vehicle H15 - Steering Ratio
Right Steering Ratio = 15.5955 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 15.6444 deg/deg
Average Steering Ratio = 15.6199 deg/deg
Left Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Steering Wheel Angle (deg)

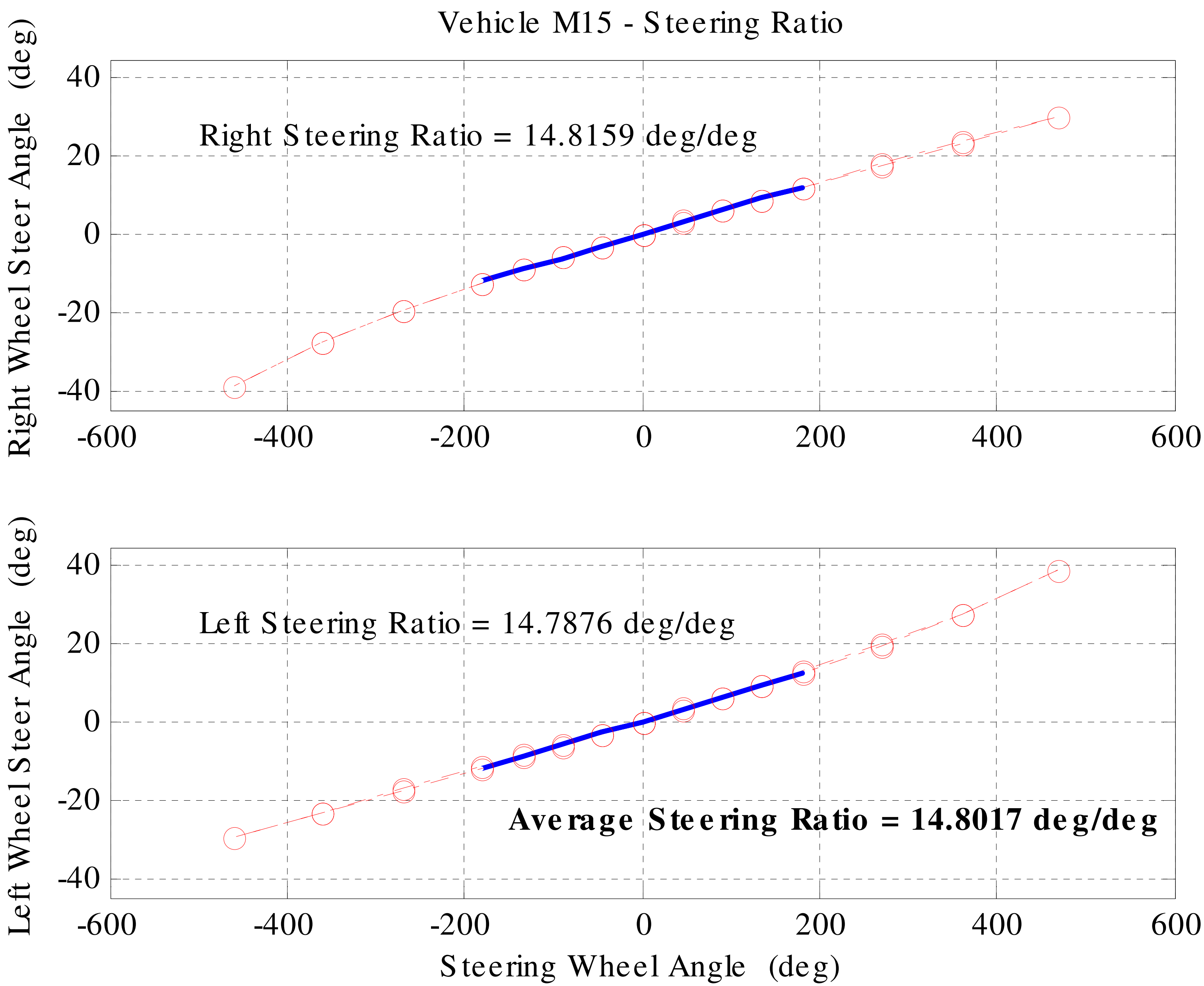

Vehicle I15 - Steering Ratio
Right Steering Ratio = 12.2861 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 11.7169 deg/deg
Average Steering Ratio = 12.0015 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)



Vehicle J15 - Steering Ratio
Right Steering Ratio = 15.1693 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 15.1284 deg/deg
Average Steering Ratio = 15.1489 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)


Vehicle K15 - Steering Ratio
Right Steering Ratio = 10.7208 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 10.5543 deg/deg
Average Steering Ratio = 10.6375 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)


Vehicle L15 - Steering Ratio
Right Steering Ratio = 18.2842 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 18.3058 deg/deg
Average Steering Ratio = 18.295 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)


Vehicle M15 - Steering Ratio
Right Steering Ratio = 14.8159 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 14.7876 deg/deg
Average Steering Ratio = 14.8017 deg/deg
Left Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Steering Wheel Angle (deg)