Vehicle Characteristics Measurements Of Recreational Off-Highway Vehicles

for:
Consumer Product Safety Commission

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

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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."

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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-S-10-0014. The objectives of contract CPSC-S-10-0014 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 nine vehicles. All of the vehicles were selected by CPSC, and all of them can be classified as recreational off-highway vehicles (ROV's). They all have side-by-side seating, and they all use a steering wheel, brake pedal, and throttle pedal for operator control inputs. Eight of the vehicles tested were two-passenger vehicles (Vehicles A-H in this report), and one was a four-passenger vehicle with a second row of side-by-side seating (Vehicle I in this report). The measured curb weights (weights with full fluids and no occupants or cargo) of the vehicles ranged from 1025.0 lb to 1753.4 lb. The measured average maximum speeds of the vehicles ranged from 38.1 mph to 59.2 mph in a loading condition representing Operator plus Passenger loading.

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), tilt table, and other laboratory equipment. The dynamic tests were performed on ten dates between May 3 and October 12, 2010, 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 and 11 main appendices that contain all of the test results. The four report sections are Overview, Laboratory Testing, Dynamic Testing, and Discussion of Test Results. Seven of the appendices are divided into two sections, each containing results for the two different vehicle loading conditions used during the dynamic testing.

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 three parts, one covering the vehicle characteristics and metrics determined from Vehicle Inertia Measurement Facility (VIMF) testing, one covering the vehicle characteristics and metrics determined from tilt table 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]. A photograph of a ROV on the VIMF platform is shown on Page 1 of Appendix K. 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 in the following loading conditions:

1. **Operator**
   This loading condition was specified to be the vehicle curb condition (with full fluids and with the vehicle manufacturers' specified tires and tire pressures) plus one occupant in the Operator's seating position. Each occupant (Operator and Passenger) load used was equivalent to a 95th percentile adult male weighing nominally 213 lb. For the laboratory testing, Hybrid II test dummies weighing 164 lb were used and ballast was added to their laps to bring the total occupant weights up to nominally 213 lb.

2. **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. Again, for this loading condition Hybrid II test dummies weighing 164 lb were used and ballast was added to their laps to bring the total occupant weights up to nominally 213 lb.

3. **Operator, Passenger, and Cargo Bed Load (GVWR)**
   This loading condition was specified to be the vehicle curb condition plus two occupants as above plus Cargo Bed Load. The Cargo Bed Load used was specified to be the lesser of the vehicle manufacturer's maximum cargo bed load or the load required to reach the vehicle manufacturer's Gross Vehicle Weight Rating (GVWR). This load is referred to

[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.

as the GVWR load in this report. The Cargo Bed Load used consisted of lead shot bags secured in a storage box that was laterally and longitudinally centered in the cargo bed area of each vehicle. The ballast was positioned vertically such that its CG height was nominally at the height equal to one-half of the height of the sides of the cargo bed structure.

4. **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 one of the loading conditions that were used during the dynamic testing phase of this project, and it was designed to represent the Operator and Passenger loading condition (Loading Condition #2). The total vehicle weight of Loading Condition #4 was set to match as closely as possible the total weight of Loading Condition #2. Also, for Loading Condition #4, the vehicles' lateral, longitudinal, and vertical CG positions were made to match those of Loading Condition #2 as closely as practically possible.

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, several other metrics that are used to characterize vehicle rollover resistance were computed, namely, the Static Stability Factor (SSF), the lateral stability coefficient (KST), and the Critical Sliding Velocity (CSV).

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:

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

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.

CSV is a calculation of the lateral velocity necessary to cause a rigid body representation of a vehicle to overturn upon impact with a rigid tripping mechanism. CSV is calculated using laboratory measurements of vehicle parameters. CSV is an estimate of the minimum sideways velocity required for a vehicle to just barely tip over as a result of sliding sideways into a curb (The model used to formulate CSV assumes that the vehicle rolls about a pivot axis fixed to the road plane – essentially a curb of zero height.) In addition to CG height and track width, CSV also takes into account vehicle mass and roll moment of inertia. CSV is given by:

$$CSV = \sqrt{\frac{2 \times g \times I_{oxx}}{M \times H_{CG}^2}\left(\sqrt{\frac{T_{AVE}^2}{4} + H_{CG}^2} - H_{CG}\right)}$$

where g is the Gravitational Constant,
M is the Vehicle Mass,
T_{AVE} is the Average Track Width,
H_{CG} is the Vehicle CG Height, and
I_{oxx} is the Effective Roll Moment of Inertia about the Tip Pivot, given by:

$$I_{oxx} = I_{xx} + M\left(\frac{T_{AVE}^2}{4} + H_{CG}^2\right)$$

where I_{xx} is the Vehicle Roll Moment of Inertia about its CG.

2.2 Vehicle Characteristics and Rollover Resistance Metrics Determined from Tilt Table Testing

The tilt table testing involved placing the vehicles on a rigid platform and tilting the platform so that the vehicles tilted in a direction nominally parallel to their longitudinal or roll axis. SEA uses their flat aluminum VIMF platform as their tilt table platform. The outsides of the low side tires are aligned to be parallel to the roll axis prior to testing. The platform is gradually tilted to the point when both of the high side tires lift off of the platform. The vehicles were prevented from tilting completely off of the platform by straps that restrained further tilting once the high side tires lifted two to three inches off of the platform. A thin high friction surface consisting of safety walk tape (essentially course grid sandpaper) was secured to the platform in the areas beneath the two low side tires. This surface prevented the vehicles from sliding sideways during the tilt table tests. A photograph of a ROV on the tilt table is shown on Page 1 of Appendix K.

The important factors involved in accurate tilt table testing include having a rigid and flat platform; having the ability to produce slow, smooth and consistent tilt rates; and having accurate and repeatable measures of tilt angle and point of wheel lift. The SEA tilt table platform is very rigid, having deflections of less than 0.1 inch for a vehicle weight up to 10,000 lb. It is also very flat, with a flatness tolerance of +/- 0.1 inch. SEA attaches the lift side of their tilt table platform to a shaft mounted to the mast of a forklift; and mounts solid metal wheels (rollers), that can roll along steel plates secured to the laboratory floor, on the other side of the platform. This set-up provides for smooth tilting at rates as slow as 0.1 deg/sec.

A high-accuracy inclinometer is mounted to the platform to record the tilt angle throughout the tilt table tests. Prior to using the tilt table, the inclinometer is calibrated using a sine bar, and a large 45/45/90 drafting triangle and machinists level are used to accurately confirm the 45 degree angle position. The point of two-wheel lift is determined visually, and the observer generates a signal that is recorded by the data acquisition system by pushing a button on a hand held trigger. Typically five or six tilts to two-wheel lift were conducted for each vehicle configuration tested. The tests with the closest three angles of two-wheel lift were selected and averaged together to determine the final angle of two-wheel lift. Based on repeatability evaluations conducted using a range of different vehicles, SEA believes that the repeatability of the measurements of two-wheel lift is within +/- 0.1 degrees.

Driver's side and passenger's side tilts were performed. The angle at which two-wheel lift occurs is referred to as the Tilt Table Angle (TTA). In addition to measuring TTA, the tilt table test results provided a measure of the rollover resistance metric Tilt Table Ratio (TTR). TTR is the tangent of the TTA. TTR values are lower than SSF values because suspension and tire deflections during the tilt table tests reduce the effective track widths below the values based on the rigid body concept that is the basis for SSF. During tilt table tests the load perpendicular to the road plane decreases causing the CG to rise, which also contributes to TTR being less than SSF. TTR is given mathematically by:

$$\mathrm{TTR} = \mathit{tan}\left(\mathrm{TTA}\right)$$

The tilt table tests were conducted in the same loading conditions as the VIMF tests, namely: Operator, Operator and Passenger, Operator, Passenger, and Cargo Bed Load (GVWR), and Operator, Instrumentation, and Outriggers.

2.3 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 that have roadwheel steer angle gradations, placing the rear tires on blocks of the same thickness as the alignment pads, and mounting a steering angle gradation ring on the steering wheel. 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 J.

3. DYNAMIC TESTING

This section describes the dynamic testing conducted at TRC between May 3 and October 12, 2010. The dynamic test evaluations included steering maneuvers on the flat dry asphalt surface of TRC's Vehicle Dynamics Area (VDA). TRC's measurements of peak and sliding skid numbers for the VDA surface where the tests were conducted, and which span the test dates of the dynamic tests, are listed in Table 1.

Table 1: TRC Skid Number Measurements

Location	VDA	
Pad #	V-5, dry	
Pavement	Asphalt	
Surface	Untreated	
Condition	Dry	
Date	Peak PBC	Slide SN
5/5/2010	92.5	82.2
6/1/2010	98.1	84.7
6/21/2010	92.3	85.0
7/5/2010	95.7	83.2
7/19/2010	97.0	82.8
8/2/2010	98.2	84.9
8/23/2010	93.3	83.5
9/7/2010	96.6	86.5
9/27/2010	94.6	86.3

One of SEA's tasks under this CPSC contract was to provide safety outriggers suitable for use on ROV's that provide a high level of safety during the conduct of the rollover testing and have a minimal affect on the vehicle characteristics being studied. SEA had previously conducted dynamic tests on ROVs using the NHTSA specification Light-Duty Titanium Outriggers. These outriggers consist of two titanium beams, one mounted at the front bumper location and one at the rear bumper location of the vehicle. These outriggers, which were designed to test automotive passenger vehicles, weigh in the range of 200-240 lb including all of their standard and vehicle-custom mounting structures. These outriggers have a significant affect on ROV CG heights and moments of inertia.

In an effort to minimize the affects of the safety outriggers, SEA designed and built triangulated aluminum outriggers that extend on both sides on the tests vehicles. These CPSC outriggers mount to the ROPS/OPS structures on the ROV's. Two photographs of the CPSC safety outriggers mounted on a ROV are shown on Page 2 of Appendix K. The standard weight of these outriggers is 106 lb. The CG height of the CPSC outriggers is higher than the CG height of bumper mounted outriggers, and it is generally fairly close to the test vehicle CG height. These outriggers have a much less significant affect on the ROV vehicles' CG heights and moments of inertia than heavier twin outrigger beams at the front and rear of the vehicles.

The CPSC triangulated aluminum outriggers were used on all of the test vehicles except Vehicle F. The metal tubing comprising the frame structure above the occupant compartment of this vehicle was deemed inadequate to support the loads that could be generated through the CPSC outriggers during tip-up events. For Vehicle F, a single titanium beam with nylon pucks at its ends was mounted securely to the top of the floorboard to serve as the safety outrigger. The weight of this single titanium beam outrigger and its associated mounting hardware was similar to the weight of the CPSC outriggers.

All of the dynamic tests were performed in two loading configurations, namely:

1. **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 driver and test equipment, including the outriggers. 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. This dynamic loading configuration is referred to as the representative Operator and Passenger loading configuration.

2. **Operator, Instrumentation, Outriggers and Cargo Bed Load (GVWR)**
   This dynamic testing loading condition is referred to as the representative GVWR loading configuration, and it was designed to match as closely as possible the laboratory loading condition of the Operator, Passenger, and Cargo Bed Load (GVWR). This loading includes the same loading as Condition #1 above, plus the same cargo bed loads (same weights and same positions) that were used for the GVWR loading during the laboratory testing. The dynamic loading condition in the representative Operator and Passenger loading condition (Condition #1 above) was designed to match as closely as possible the total weight and CG positions of the Operator and Passenger loading condition used during the laboratory testing. Therefore, since the same cargo bed loads were used for the laboratory and dynamic tests, the overall vehicle weight and vertical, lateral, and longitudinal CG positions for the GVWR dynamic tests are close to those in the GVWR laboratory tests.

Table 3 lists the differences between the representative Operator and Passenger loading configurations and the representative GVWR loading configurations for each test vehicle. The differences between the two loading configurations vary from 274 lb to 983 lb, depending on the vehicle manufacturers' recommended loading capacities. This is important to consider when comparing the differences in vehicle dynamic responses for the two loading conditions for a particular vehicle. In some instances, generally the cases with the lighter cargo loading, the differences in dynamic responses for the two loading conditions are not as significant as the differences in other cases with the heavier cargo loading. Page 3 of Appendix K contains two photographs showing sample ROV cargo bed loading.

Table 2: Weights of Driver and Test Equipment	
Object	**Weight (lb)**
Test Driver with Helmet	182
ASC Handwheel Unit	34
ASC Battery Box	27
ASC Electronics Box and Cables	25
SEA Data Acquisition Computer	10
Auxiliary 12V Battery	25
RT3002 GPS/IMU, Antenna, and Cables	10
SEA Power Distribution Box and Misc. Straps	7
CPSC Triangulated Aluminum Safety Outriggers	106
Total Nominal Weight	**426**

Table 3: Weight Difference Between Representative Operator and Passenger and GVWR Loading	
Vehicle	**Weight Difference (lb)**
A	355
B	274
C	487
D	983
E	496
F	601
G	911
H	357
I	458

Table 4 lists the instrumentation used during the dynamic testing. Photographs of both the RT3002 Inertial and GPS Navigation System and the Automated Steering Controller (ASC) mounted on a ROV are contained on Page 4 of Appendix K.

The RT3002 was mounted near 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 was measured and entered into the RT3002 system software. This information was used to translate the measured quantities to those at CG of the vehicle. The longitudinal and lateral accelerations measured and reported herein are accelerations parallel to the road plane, as opposed to vehicle body fixed accelerations. The vertical acceleration is the acceleration orthogonal to the longitudinal and lateral accelerations.

Table 4: Instrumentation Used During Dynamic Testing

Transducer	Measurement	Range	Accuracy or Linearity
Oxford Technical Solutions RT3002 Inertial and GPS Navigation System	Longitudinal, Lateral, and Vertical Accelerations	± 10 g	0.1% 1σ
	Roll, Pitch, and Yaw Rates	± 100 deg/s	0.1% 1σ
	Speed	No Limit Specified	0.2% 1σ
	Roll and Pitch Angles	No Limit Specified	0.03° 1σ
	Vehicle Heading and Sideslip Angle	No Limit Specified	0.1° 1σ
Encoder on SEA, Ltd. ASC	Steering Wheel Angle	± 800 deg	± 0.25 deg

In total, over 850 dynamic tests were performed on the nine vehicles. The following suite of seven different types of dynamic tests was performed using each test vehicle in both dynamic loading configurations:

- **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)**
- **Constant Throttle J-Turn (Step Steer) Tests (Initial Speed of 30 mph)**
- **Sinusoidal Sweep Steering (Frequency Response) Tests (20 mph)**
- **Constant Speed (30 mph) Steering Flick Tests**
- **Maximum Speed Tests**

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. Many 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 for all vehicles in both loading conditions.

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

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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

transitioned from understeer to oversteer during the tests.

Detailed results from the slowly increasing steer tests are contained in Appendix D for all vehicles in both loading conditions.

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 speed of 30 mph was used because it was believed that at this speed all of the vehicles tested, in both loading configurations, would result in a tip-up condition given high enough steering magnitudes. This was the case for the vehicles tested.

The steering rate used for all of the J-turn tests was 500 deg/sec. The magnitudes of the steering inputs were varied to identify the minimum steering magnitude required to result in tip-up in the 30 mph dropped throttle tests. For this testing, tip-up events are considered those that produced significant two-wheel lift and in almost all cases outrigger contact. These tests provided a measure of the minimum lateral accelerations and minimum steering wheel angles required to cause two-wheel lifts during the tests.

After identifying the minimum steering wheel magnitudes required for tip-ups in the dropped throttle J-turn tests, a series of four additional dropped throttle tests were conducted, using steering magnitudes of 25%, 50%, 75%, and 87.5% of the tip-up producing steering magnitudes. These additional tests using steps in the steering magnitudes were conducted to evaluate the vehicles' responses in J-turns at various maneuver severities, and to evaluate if lateral acceleration to steering input gains could be related to vehicle understeer/oversteer behavior.

Detailed results from dropped throttle J-turn tests are contained in Appendix E for all vehicles in both loading conditions.

3.4 Constant Throttle J-Turn (Step Steer) Tests (Initial Speed of 30 mph)

For the constant throttle J-turn tests, the test driver drove each vehicle along a straight-line path at a nominal speed of 30 mph. While holding the throttle (gas pedal) constant, he triggered the ASC to initiate the steering input. The steering rates used for the constant throttle J-turn tests were 500 deg/sec. The magnitudes of the steering inputs were varied to identify the minimum steering magnitude required to result in tip-up.

Detailed results from the constant throttle J-turn tests for all vehicles in both loading conditions are contained in Appendix F.

3.5 Sinusoidal Sweep Steering (Frequency Response) Tests (20 mph)

Sinusoidal sweep steering input tests were conducted at 20 mph (the TRC VDA has adequate length to conduct the sinusoidal sweep tests at this speed). The sinusoidal sweep steering maneuvers involved driving the vehicles at a nominal constant speed of 20 mph along an essentially straight-line path while steering in a sinusoidal manner with steering amplitude necessary to generate nominally 0.1-0.3 g of lateral acceleration. Depending on the vehicle, steering amplitudes between 35 degrees and 50 degrees were used for these tests. The ASC was used for these tests, and it was commanded to sweep the steering input frequencies from 0.5 to 3.5 Hz over the course of 40 cycles. The duration of the ASC steering input during these tests is close to 26 seconds.

The sinusoidal sweep steering tests were done to investigate any issues that might result from exciting a resonant frequency in the vehicles' responses. The sinusoidal sweep steering maneuvers were also used to generate the lateral acceleration, roll angle, roll rate, and yaw rate frequency responses to steering inputs.

Detailed results from the sinusoidal sweep steering tests are contained in Appendix G for all vehicles in both loading conditions.

3.6 Constant Speed (30 mph) Steering Flick Tests

Steering flick tests involve driving the vehicles along a straight-line path and quickly 'flicking' the steering wheel to nominally 90 degrees and letting go of the steering wheel. For the steering flick tests, the test driver drove each vehicle along a straight-line path at a nominal constant speed of 30 mph, except for Vehicle F for which the tests were inadvertently conducted at a speed of 20 mph. These tests were conducted with the OEM steering wheels on the vehicles, in place of the ASC. Since the ASC was not used for the flick tests, there were no measurements of steering input made during these tests.

The steering flick maneuvers were used to evaluate the stability of the vehicles' responses to open-loop, free control steering inputs. An unstable vehicle may respond with oscillatory or divergent behavior during a flick test. These tests indicate if a vehicle exhibits excessive oscillatory response to the flick input or if the vehicle responses do not return to a close-to-zero position after the steering is released (indicating too little self aligning steering moment or possibly too much friction in the steering system).

Detailed results from the steering flick tests are contained in Appendix H for all vehicles in both loading conditions.

3.7 Maximum Speed Tests

For the maximum speed tests, the test driver drove each vehicle along a straight-line path at maximum throttle until maximum speed was reached. For each vehicle and loading configuration, the tests were run in two opposite directions, along the direction up the TRC VDA one percent grade (roughly northward) and along the direction down the TRC VDA one percent grade (roughly southward).

Detailed results from the maximum speed tests for all vehicles in both loading conditions are contained in Appendix I.

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 J. Detailed results from all of the dynamic testing are contained in Appendix C through Appendix I. Appendix B contains a collection of bar charts, graphs, and tables summarizing selected results from both laboratory and dynamic testing. Appendix K contains photographs of the test facilities and test equipment.

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.1	Constant Radius (100 ft) Circle Test Results Representative Operator and Passenger Loading Condition
Appendix C.2	Constant Radius (100 ft) Circle Test Results Representative GVWR Loading Condition
Appendix D.1	Constant Speed (30 mph) Slowly Increasing Steer Test Results Representative Operator and Passenger Loading Condition
Appendix D.2	Constant Speed (30 mph) Slowly Increasing Steer Test Results Representative GVWR Loading Condition
Appendix E.1	Dropped Throttle J-Turn (Step Steer) Test Results (30 mph) Representative Operator and Passenger Loading Condition
Appendix E.2	Dropped Throttle J-Turn (Step Steer) Test Results (30 mph) Representative GVWR Loading Condition
Appendix F.1	Constant Throttle J-Turn (Step Steer) Test Results (30 mph) Representative Operator and Passenger Loading Condition
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Appendix G.1	Sinusoidal Sweep Steering (Frequency Response) Test Results (20 mph) Representative Operator and Passenger Loading Condition
Appendix G.2	Sinusoidal Sweep Steering (Frequency Response) Test Results (20 mph) Representative GVWR Loading Condition
Appendix H.1	Constant Speed (30 mph) Steering Flick Test Results Representative Operator and Passenger Loading Condition
Appendix H.2	Constant Speed (30 mph) Steering Flick Test Results Representative GVWR Loading Condition
Appendix I.1	Maximum Speed Test Results Representative Operator and Passenger Loading Condition
Appendix I.2	Maximum Speed Test Results Representative GVWR Loading Condition
Appendix J	Steering Ratio Test Results
Appendix K	Photographs of Test Facilities and Equipment

4.1 Discussion of Appendix A: Laboratory Test Results

Appendix A contains tabular results of laboratory measurements made by SEA. There are nine pages of results, one page for each vehicle. The first 20 rows of each table contain quantities related to the mass, center-of-gravity location, and inertia measurements, as well as static rollover propensity calculations, based on measurements made using the VIMF. The next 10 rows of each table contain results related to the tilt table measurements. The final three rows contain measured values for the front and rear ground clearances and steering ratios.

The first eight pages in Appendix A contain results for six vehicle loading configurations. For the Curb and Operator, Instrumentation, Cargo, and Outriggers (GVWR) configurations only the vehicle weight was measured (i.e. no VIMF or tilt table tests were conducted for these loading configurations). VIMF and tilt table tests were conducted for the Operator; Operator and Passenger; Operator, Passenger and Cargo (GVWR); and Operator, Instrumentation and Outriggers configurations. The ground clearance and steering ratios were measured only for the Operator and Passenger loading configuration. The last page of Appendix A contains results for Vehicle I, the four-passenger vehicle. For this vehicle, VIMF and tilt table tests were also conducted for an additional loading configuration: Operator and 3 Passengers (all occupants in this configuration weighed nominally 213 lb).

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

Page 1 of Appendix B contains a bar chart of the vehicle weight measurements. As mentioned previously, for both the Operator and Passenger and the GVWR configurations, the total weights used during the dynamic tests with outriggers were set to be as close as possible to baseline laboratory configurations without outriggers.

Page 2 contains the average track width measurements. Notice that the track widths can change significantly under different loading conditions due to suspension geometry. In general, the track widths increase under increased suspension deflection caused by increased loading.

A bar chart of the wheelbase measurements is shown on Page 3. Vehicle I is the four-passenger vehicle, and it has a significantly longer wheelbase than the other vehicles tested.

The roll, pitch, and yaw moments of inertia are contained on Pages 4-6. The measurements for the Operator and Passenger conditions show that all inertias are greater for the dynamic testing configurations with outriggers (Oper., Instr. & Outriggers) than for the laboratory testing configurations without outriggers (Operator and Passenger).

Page 7 contains the CG height measurements. The measurements for the Operator and Passenger conditions show that all CG heights for the dynamic testing configurations with outriggers (Oper., Instr. & Outriggers) were within 0.5 inches of the CG heights for laboratory testing configurations without outriggers (Operator and Passenger).

Results from the ground clearance measurements are presented on Page 8 and steering ratio measurements are presented on Page 9.

The rollover resistance metrics SSF and KST are presented for each test configuration on Pages 10 and 11, respectively. Charts comparing SSF and KST for the Operator and Passenger configurations are contained on Page 12 and for the Operator, Instrumentation, and Outriggers configurations on Page 13. SSF and KST magnitudes are close to each other in all cases, within a value of 0.01.

Values for the rollover resistance metric CSV are shown on Page 14. For the Operator and Passenger configurations, the CSV values are higher for the outrigger configurations, primarily because the vehicle roll inertias are higher with outriggers.

TTR results for the driver's side leading tilts, the passenger's side leading tilts, and the average of these two are contained on Pages 15, 16, and 17. For a given vehicle, among the loading configurations the average TTR is generally inversely related to the CG height. Charts comparing driver's side, passenger's side, and average TTR values for the Operator and Passenger configurations are contained on Page 18 and for the Operator, Instrumentation, and Outriggers configurations on Page 19. In general, the variations between the driver's side and passenger's side TTR values are related to the lateral offset of the CG positions for each vehicle and loading configuration. The measured TTR's are generally higher in the direction of tilt opposite of the direction of the lateral offset in CG position. Charts comparing TTA values for the same two loading configurations as Pages 18 and 19 are given on Pages 20 and 21.

Pages 22 through 28 contain results from the dynamic circle tests conducted in the representative Operator and Passenger loading configurations, and Pages 29 through 35 contain parallel results for the representative GVWR loading configurations. The underlying data for which the results on Pages 22 through 35 were generated are contained in Appendix C, and a discussion of the data processing used is contained in the discussion section for Appendix C.

Pages 22 and 29 contain circle test characteristic curves of steering wheel angle versus lateral acceleration in the range of 0.01 to 0.50 g for all nine 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 30 show the same results but they are shifted along the vertical axis by subtracting out the Ackermann angles. Pages 24 and 31 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. Four of the vehicles, Vehicles A, D, F and I, exhibit transitions from understeer to oversteer in both loading configurations as indicated by the slope values becoming negative as lateral acceleration increases. In the GVWR configuration, Vehicle D exhibited oversteer at all lateral acceleration levels, including 0.0 g (Page 31).

Pages 25-27 (Operator and Passenger) and Pages 32-34 (GVWR) 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 24 and 31.)

Pages 28 (Operator and Passenger) and 35 (GVWR) contain tables 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.

Pages 36 and 37 contain results from the dynamic slowly increasing steer (SIS) tests conducted in the representative Operator and Passenger loading configurations, and Pages 38 and 39 contain parallel results for the representative GVWR loading configurations. The underlying data for which the results on Pages 36 through 39 were generated are contained in Appendix D, and a discussion of the data processing used is contained in the discussion section for Appendix D.

Pages 36 and 38 contain individual SIS test characteristic curves of steering wheel angle versus lateral acceleration for each of nine vehicles. Full-page versions of these plots are contained in Appendix D. For the vehicles that transitioned from understeer to oversteer during these SIS tests, the points of transition during the tests are indicted on the graphs. Pages 37 (Operator and Passenger) and 39 (GVWR) contain tables 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. For both loading configurations, the same four vehicles that exhibited transition from understeer to oversteer during the circle tests also did so during the SIS tests.

Pages 40 through 52 contain bar charts, graphs, and tables of results that include information from the dynamic dropped throttle J-turn tests conducted in the representative Operator and Passenger loading configurations, and Pages 53 through 65 contain parallel results for the representative GVWR loading configurations. The underlying J-turn data from which the results on Pages 40 through 65 were generated are contained in Appendix E, and a discussion of the data processing used is contained in the discussion section for Appendix E.

As mentioned, the dropped throttle J-turn tests were conducted to provide measures of the minimum lateral accelerations and minimum steering wheel angles required to cause two-wheel lifts during the tests. Page 40 (Operator and Passenger) and Page 53 (GVWR) contain bar charts of the minimum lateral accelerations (A_y) required for tip-up and Pages 41 and 54 contain bar charts of the minimum steering wheel angles. The Right Turn, Left Turn, and Average values are shown on these pages.

Pages 42 (Operator and Passenger) and 55 (GVWR) contain tables summarizing the average minimum lateral accelerations and steering wheel angles used during the dropped throttle J-turn tests along with the static rollover metrics determined from the laboratory testing. The pages following these pages, Pages 43 and 56, provide a vehicle ranking of these same vehicle characteristics in ascending order of their values; that is, from the lowest value to the highest value within each column. In general, in both loading configurations, four of the vehicles, Vehicles A, B, D, and F, are among the lowest values for all of the dynamic and laboratory characteristics summarized. Of these four, Vehicles A, D, and F transitioned to oversteer during the circle and SIS tests, and these three vehicles required the least steering input to result in tip-up during the J-turn tests in both loading configurations. The other vehicle that transitioned from understeer to oversteer in the circle and SIS tests is Vehicle I, the four-passenger vehicle. This vehicle has a significantly longer wheelbase than the other vehicles. In both loading configurations, Vehicle I has the lowest relative rankings for minimum lateral acceleration at tip-up compared to its rankings for SSF and CSV.

When comparing the Operator and Passenger versus GVWR values and rankings on these pages it is important to recall that the additional amount of ballast used for the GVWR tests is different for the nine vehicles, as listed on Table 3.

Pages 44 and 45 (Operator and Passenger) and Pages 57 and 58 (GVWR) contain exhibits comparing the laboratory rollover resistance metrics to the lateral accelerations required for tip-ups in the dropped throttle J-turns. Pages 44 and 57 are bar charts of the values, while Pages 45 and 58 are graphs with plots of the rollover resistance metrics versus lateral acceleration at tip-up. Linear fits of the plots are also provided on the graphs. The graphs on Pages 45 and 58 indicate that TTR has a better correlation to lateral acceleration at tip-up than do SSF or CSV. However, none of the static metrics examined correlated very well with the minimum lateral acceleration thresholds. The data for Vehicle I, the four-passenger vehicle, has the biggest outliers from the linear fits for SSF and CSV in both loading configurations.

Summary results from the dropped throttle J-turn tests conducted using steps of 25%, 50%, 75%, 87.5%, and 100% of the steering magnitudes required to produce tip-ups are contained on Pages 46 through 52 (Operator and Passenger) and Pages 59 through 65 (GVWR). Tables containing the summary data used to generate the exhibits on these pages are contained in the last nine pages of Appendix E.1 and Appendix E.2. Pages 46 and 59 contain bar charts showing the average maximum lateral accelerations achieved in each of the J-turn step tests.

Pages 47 and 60 contain bar charts showing the magnitudes of the lateral acceleration per degree of steering input for each of the J-turn step tests. These magnitudes are simply the maximum lateral accelerations for each step test divided by the steering magnitude used during each test. These charts are normalized to the 25% gain values and re-plotted on Pages 48 and 61. Notice that the normalization causes all of 25% steering bars to have a value of 1.0. On these charts, a value greater than 1.0 indicates that at the given level of steering, greater lateral acceleration is generated per degree of steering than at the 25% level of steering. The three two-passenger vehicles that exhibited transition from understeer to oversteer in the circle and SIS tests, Vehicles A, D, and F, all have normalized gains that markedly exceed unity at the higher steering levels. Simply stated, as the J-turn maneuvers increased in severity these oversteering vehicles exhibited increased lateral acceleration gains per degree of steering input. Vehicle I, the four-passenger vehicle that exhibited a transition to oversteer, did not exhibit this trend.

A different calculation for the magnitude of lateral acceleration per degree of steering input was used to generate the bar charts shown on Pages 49 and 62. For these charts the magnitudes were calculated as the change in lateral acceleration in the range of steering indicated divided by the change in steering input in the range of steering indicated. These pages highlight the increase in gains exhibited in the steering ranges above 0-25% steering for the three two-passenger vehicles that transitioned to oversteer. As noticed using the previous gain calculation, the four-passenger vehicle, which transitioned to oversteer, did not markedly exhibit this trend at steering ranges above 0-25%.

Another gain sometimes used to characterize a vehicle is the steering wheel magnitude per g of lateral acceleration. These gains are often computed during constant speed, steady state conditions; which is not the case during these dropped throttle J-turn test. In this case, the gains shown on Pages 50 and 63 are the steering magnitudes divided by the maximum lateral accelerations in each of the J-turn step tests. In both loading conditions, the three two-passenger vehicles that exhibited transition from understeer to oversteer in the circle and SIS tests, Vehicles

A, D, and F, have the lowest gains for the J-turn tests that resulted in tip-ups, the 100% steering tests. The steering wheel angle to lateral acceleration gain for the four-passenger vehicle, Vehicle I, is among the highest for all of the vehicles. This is the vehicle with a significantly longer wheelbase than the other eight vehicles tested.

Graphical representations of the results from the J-turn step tests are presented on Pages 51 and 52 (Operator and Passenger) and Pages 64 and 65 (GVWR). Pages 51 and 64 contain graphs with plots of maximum lateral acceleration versus percentage steering during the J-turn step tests for each vehicle. In both loading configurations the slopes of these plots for the four vehicles that exhibited transition from understeer to oversteer (Vehicles A, D, F, and I) are among the lowest for the nine vehicles at the lower percentage of steering magnitudes.

Pages 52 and 65 contain graphs with plots of maximum lateral acceleration versus steering wheel angle during the J-turn step tests for each vehicle. Again, it can be observed that the three two-passenger vehicles (Vehicles A, D, and F) that transitioned to oversteer in the circle and SIS tests have the lowest steering angles required for tip-up. In both loading configurations, the slopes of the curves for the oversteering two-passenger vehicles tend upward to a greater extent during portions of the higher steering ranges than they do at low levels of steering. For the Operator and Passenger loading (Page 52) this is particularly evident for Vehicles A and E, which exhibited the most extreme oversteering conditions in the circle tests. For the GVWR loading (Page 65) Vehicle D shows the most extreme increase in slope, and it starts at a very low steering level. This is the vehicle and loading condition that exhibited oversteer at all levels of lateral acceleration in the circle tests.

A bar chart showing the roll gradients determined from the circle tests in both loading configurations is provided on Page 66. For each vehicle, the roll gradients are greater for the GVWR loading conditions than for the Operator and Passenger loading conditions. Page 67 contains a bar chart showing the maximum speeds for all nine vehicles in both loading conditions.

There are no results from the Constant Throttle J-turn, Sinusoidal Sweep Steering, Steering Flick, or Maximum Speed tests contained in this summary appendix (Appendix B). However, full results from and discussion of these tests are contained in their individual appendices and accompanying discussion sections.

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

Constant radius (100 ft) circle test results for the representative Operator and Passenger loading configuration and for the representative GVWR loading configuration are contained in Appendix C.1 and Appendix C.2, respectively.

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 100 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 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 full 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:

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

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 less than the geometric Ackermann steer angles due primarily to compliance and lash in the steering system.

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

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

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.

Asymmetries in test vehicles and lateral offsets in their CG locations can cause differences in the CW versus CCW circle test results. However, the circle test results for the vehicles tested generally show similar trends when comparing the CW and CCW data, and for the vehicles that did exhibit a transition to oversteer, the lateral acceleration values where the transitions occurred are fairly close in the CW and CCW directions. One exception to this is Vehicle E in the representative Operator and Passenger loading configuration (Page 19 of Appendix C.1), which exhibited a transition to oversteer at 0.44 g in the CW direction test and exhibited understeer throughout the CCW test.

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 37-39 of Appendices C.1 and C.2 contain graphs summarizing the 0.01 g to 0.50 g curve fit data for each vehicle. In both appendices, Page 37 contains a graph of Steering Wheel Angle versus Ay, Page 38 a graph of Handwheel Steer Angle minus (measured) Ackermann Angle versus Ay, and Page 39 a graph of Ay versus Handwheel Steer Angle minus (measured) Ackermann Angle. The graphs on Page 38 and 39 contain the same information, but different organizations prefer one presentation to the other.

Page 40 in Appendix C.1 and C.2 contains 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 Page 40 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. Automotive passenger vehicles generally exhibit linear response up to a range of 0.3 to 0.5 g., which is not the case for some of the ROV's tested.

[5] The slopes or gradients presented on Page 40 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.

Positive valued slopes indicate that the vehicle is exhibiting understeer, negative valued slopes indicate that the vehicle is exhibiting oversteer, and zero slopes indicate neutral steer. In the representative Operator and Passenger loading configuration, four of the nine vehicles tested (Vehicles F, A, I and D) transitioned from understeer to oversteer based on their CW and CWW average slopes (Page 40 in C.1). In the representative GVWR loading configuration; three of the nine vehicles tested (Vehicles F, A, and I) transitioned from understeer to oversteer based on their CW and CWW average slopes, one of the vehicles (Vehicle D) was oversteer at all lateral acceleration levels, and one of the vehicles (Vehicle C) exhibited very slight oversteer at 0.1 g but exhibited understeer at all other levels of lateral acceleration (Page 40 in C.2).

Pages 41-43 in Appendices C.1 and C.2 contain bar charts of the CW, CCW, and average slopes for the individual vehicles at all lateral accelerations evaluated. In the representative Operator and Passenger loading configuration, although Vehicle E has a negative slope for the CW test at 0.5 g, its average slope at this lateral acceleration level is positive (Page 42 in Appendix C.1).

Page 44 in both appendices 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 tables indicate 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.1 and Appendix D.2 for the representative Operator and Passenger loading configuration and for the representative GVWR loading configuration, respectively.

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 or 30 seconds, whichever came first. 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 input at the rate of 5 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.

For two of the vehicles (Vehicles C and G), the SIS test end condition was when they could no longer maintain a speed above 28 mph, due to the fact that they were either speed governed or power limited at the extremes of the SIS test conditions. Six of the test vehicles (Vehicles A, B, E, F, H, and I) had SIS test end conditions for both loading configurations that resulted in outrigger contact. In the Operator and Passenger loading configuration, Vehicle D exhibited an SIS end condition where the rear tires were slipping and spinning, and in the GVWR loading configuration Vehicle D experience outrigger contact. End conditions of outrigger contact and rear tires slipping/spinning are noted on the time domain graphs.

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 0.50 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 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. Four of the vehicles tested (Vehicles A, D, F, and I) exhibited a transition from understeer to oversteer during the SIS tests. These are the same four vehicles that exhibited transitions to oversteer in the CW and CCW circle tests. For these vehicles, 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 indicted 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 28 in both Appendix D.1 and D.2 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. The vehicles that exhibited transition to oversteer did so in both the right turn and left turn tests. When transitions occurred, the right turn and left turn lateral accelerations at which they occurred for each vehicle are relatively close to one another (within 0.1 g). As mentioned, the vehicles that exhibited transitions to oversteer in the circle test also exhibited transitions to oversteer in the SIS tests. However, because the two tests are different, the lateral accelerations at which transitions occurred are different for the two different test types. In all cases, the lateral accelerations at which transitions occurred are lower for the circle tests than for the SIS tests.

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.1 for the representative Operator and Passenger loading configuration and Appendix E.2 and for the representative GVWR loading configuration.

For each vehicle there are four pages showing time domain plots for the tests. Each of these pages shows plots of Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate. For the J-turn 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 6.0 seconds after it was applied.

The first page for each vehicle shows results from tests conducted with steering to the right and the second page shows results with steering to the left. On the first and second pages, the blue lines are the tests with the minimum steering that resulted in tip-up and the red lines are the tests with the maximum steering that did not result in tip-up.

The plots of steer angle indicate the steer magnitudes used for all of the tests. The lateral acceleration plots indicate that the maximum lateral accelerations during the tip-up tests are generally not much greater than those in the non tip-up tests, while the maximum roll angles in the tip-up tests are generally significantly higher than the non tip-up tests. This verifies the identification of the minimum steering magnitudes required for tip-ups in the tests.

The third page (right turns) and fourth page (left turns) for each vehicle show plots of five J-turns conducted using varying steering magnitudes. The steps in the steering magnitudes are 25%, 50%, 75%, 87.5%, and 100% of the minimum steering required to cause tip-up in the 30 mph dropped throttle tests.

Pages 37-45 in both E appendices contain tables listing the steering angle magnitudes and maximum lateral accelerations from each of the J-turn step tests. The right turn, left turn, and the average of right and left turn steering magnitudes and maximum lateral accelerations are presented in the tables.

4.6 Discussion of Appendix F: Constant Throttle J-Turn (Step Steer) Test Results (30 mph)

Results comparing the constant throttle J-turn test results to the dropped throttle J-turn tests are contained in Appendix F.1 and Appendix F.2 for the representative Operator and Passenger loading configuration and for the representative GVWR loading configuration, respectively.

For each vehicle there are two pages showing time domain plots for the tests. Each of these pages shows plots of Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate. 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 ASC returned the steering angle back to zero degrees or the test driver ended the data acquisition.

The first page for each vehicle shows results from tests conducted with steering to the right and the second page shows results with steering to the left. On the first and second pages, the blue lines are the tests with the minimum steering that resulted in tip-up during the constant throttle J-turn tests and the red lines are the tests with the minimum steering that resulted in tip-up during the dropped throttle J-turn tests.

With the exception of Vehicle G, all of the vehicles required less steering to produce tip-up in the constant throttle tests compared to the dropped throttle tests. During the constant throttle tests, the vehicle speeds after the steering input are greater than the vehicles speed after the steering input during the dropped throttle tests. The difference in speed between the constant throttle and dropped throttle tests after the steering input was applied was the least for Vehicle G.

The timing of the occurrence of maximum lateral acceleration and tip-up during the constant throttle tests are generally delayed when compared to the dropped throttle tests. The steering inputs were held longer for the constant throttle tests because in some instances the tip-ups did not occur until one or two seconds later during these tests than they did during the dropped throttle tests. The maximum measured lateral accelerations during the constant throttle tests are equal to or greater than those observed in the dropped throttle tests. The dropped throttle tests, given that the lateral accelerations needed to produce tip-ups are the smallest and the timing of the tip-up events are more uniform among vehicles, appear to be more reliable tests than the constant throttle tests for predicting the thresholds of a vehicles tip-up response. Also, the speeds at the initiation of the steering input are not as close to the constant target speed of 30 mph during the constant speed J-turn tests as they are during the dropped throttle J-turn tests, which rely on the ASC to trigger the steering input at precisely 30 mph.

4.7 Discussion of Appendix G: Sinusoidal Sweep Steering (Frequency Response) Test Results (20 mph)

Results from the sinusoidal sweep steering tests are contained in Appendix G.1 and Appendix G.2 for the representative Operator and Passenger loading configuration and for the representative GVWR loading configuration, respectively.

For each vehicle there are three pages of results. The first page of results for each vehicle contains representative time domain plots for one of the sinusoidal sweep tests conducted. Each of these pages shows time domain plots of Steer Angle, Lateral Acceleration (Ay), Roll Angle, Roll Rate, and Yaw Rate. The data shown was digitally low-pass filtered to 10.0 Hz using a phaseless, eighth-order, Butterworth filter.

The steering inputs used during the sinusoidal sweeps provided for meaningful frequency response computations in the range of 0.5 to 3.0 Hz. The frequency responses were computed using the transfer function estimator routine in Matlab. The second page of graphs for each vehicle contains frequency response plots of amplitude ratio and phase angle for lateral acceleration and roll angle frequency responses to steering input. The third page of graphs for each vehicle contains frequency response plots for roll rate and yaw rate. On each of the frequency response plots, results from three tests are shown.

Based on linear vehicle response theory, the low frequency values of the amplitude ratios (magnitudes) for lateral acceleration, roll angle, and yaw rate represent the steady state gains that a vehicle would have achieved if it was driven at a low (linear range) lateral acceleration steady state condition (The steady state gain for roll rate is zero.). Some of the lateral acceleration, roll angle and yaw rate frequency responses exhibited underdamped behavior; that is, the amplitude ratios (magnitudes) are greater at higher frequencies than they are at low frequency (i.e. their steady state gain values). This behavior is not unusual for automotive passenger vehicles, and it is generally not indicative of any problem unless the amplitude ratios are considerably higher at some frequencies than they are at steady state. In instances where the amplitude ratios become excessively high at higher frequencies, a driver might not be aware of increasing vehicle response under rapid steering conditions. Based on the frequency responses generated from this testing, this does not appear to be an issue for any of the vehicles tested. However, note that the frequency responses are computed from testing done at low lateral acceleration levels, and they can not be used to infer anything about the vehicles' responses at lateral accelerations above about 0.3 g, or anything about the vehicles' tip-up resistances or understeer/oversteer characteristics.

For the underdamped cases, peak yaw rate and roll angle amplitude ratios occurred in the range of 1-2 Hz. For some of the vehicles, the peaks in the yaw rate and roll angle amplitude ratios exhibited during the Operator and Passenger testing are diminished or gone completely when the vehicles are loaded to GVWR. In general, the peaks in all of the frequency response magnitudes occurred at lower frequencies during the GWVR loading configurations than they did for the Operator and Passenger loading configurations. The frequencies were the peaks occur, which indicate the linear range fundamental (natural) frequencies, are lower for the GVWR conditions because of the mass added to the vehicles during these tests.

Some vehicle manufacturers use frequency responses as a tool to assess how a vehicle might respond subjectively to a driver. The sinusoidal sweep steering tests used to generate the frequency responses were done using the ASC, and no subjective evaluations of the vehicles were considered as part of the overall characteristics determined during this work.

Overall, the time domain and frequency response curves generated did not indicate any anomalous vehicle behavior. For all of the tests conducted, the vehicles were responsive to the steering inputs and remained stable for the sweep of steering inputs applied.

4.8 Discussion of Appendix H: Constant Speed Steering Flick Test Results (30 mph)

Results from the constant speed steering flick tests are contained in Appendix H.1 for the representative Operator and Passenger loading configuration and Appendix H.2 and for the representative GVWR loading configuration.

For each vehicle there are two pages showing time domain plots for the flick tests, with the first page showing results from a right steering test and the second page showing results from a left steering test. Each of these pages shows plots of Speed, Lateral Acceleration, Roll Angle, and Yaw Rate. For the steering flick test results, the data shown was digitally low-pass filtered to 10.0 Hz using a phaseless, eighth-order, Butterworth filter. With one exception, the time domain data shown for each vehicle and configuration contains data for 4.0 seconds, commencing just prior to the start of the steering input. The exception is for Vehicle D in the GVWR loading configuration (Pages 7 and 8 of Appendix H.2), where the data is plotted for 6.0 seconds to span the time range needed for the vehicle responses to settle towards zero.

In the representative Operator and Passenger loading configurations, all of vehicles' responses returned to their near zero values within three cycles of oscillation. In the representative GVWR loading configurations, all of vehicles' responses also returned to their near zero values. Vehicle A responses returned to zero within about four cycles of oscillation and all of the other vehicles returned within three cycles of oscillation. In both loading conditions, the vehicles' responses are stable. The vehicle responses did not diverge or settle to any meaningful non-zero levels, and they all exhibited damped oscillatory responses to their near zero values.

4.9 Discussion of Appendix I: Maximum Speed Test Results

Results from the maximum speed tests are contained in Appendix I.1 for the Operator and Passenger loading configuration and Appendix I.2 and for the GVWR loading configuration.

For each vehicle and loading configuration there is one page showing time domain plots for the maximum speed tests, with results from the northbound and southbound tests. The graphs show the vehicle speeds over a range of time where the maximum speeds were achieved. The maximum northbound speeds, southbound speeds, and average speeds are listed on the graphs.

4.10 Discussion of Appendix J: Steering Ratio Test Results

Results from the steering ratio tests are contained in Appendix J. The steering ratio tests were conducted with the vehicles in their Operator and Passenger loading configurations. The steering ratio tests consisted of placing the front tires on commercial low friction wheel alignment pads that have roadwheel steer angle gradations, placing the rear tires on blocks of the same thickness as the alignment pads, and mounting a steering angle gradation ring on the steering wheel. 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.

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 A

	Curb	Operator	Operator & Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4180	4181	4182	4183	4184
Total Vehicle Weight (lb)	1218.7	1431.7	1644.5	1998.4	1644.2	1998.8
Left Front Weight (lb)	259.8	317.5	343.9	334.5	357.3	341.6
Right Front Weight (lb)	278.7	309.4	371.6	357.2	352.2	350.9
Left Rear Weight (lb)	319.5	441.2	444.0	629.4	462.4	621.5
Right Rear Weight (lb)	360.7	363.6	485.0	677.3	472.3	684.8
Front Track Width (in)	45.20	45.20	45.40	45.25	45.40	45.25
Rear Track Width (in)	43.60	43.60	44.25	45.50	44.25	45.50
Average Track Width (in)	44.40	44.40	44.83	45.38	44.83	45.38
Wheelbase (in)	75.15	75.15	75.15	75.15	75.15	75.15
CG Longitudinal (in)	41.94	42.24	42.45	49.14	42.72	49.11
CG Lateral (in)	1.09	-1.33	0.94	0.80	0.07	0.82
CG Height (in)		24.56	25.52	25.35	25.26	
Roll Inertia - I_{XX} (ft-lb-s^2)		129	155	159	190	
Pitch Inertia - I_{YY} (ft-lb-s^2)		274	286	365	298	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		288	299	376	338	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	15	24	12	
SSF		0.904	0.878	0.895	0.887	
KST		0.906	0.880	0.894	0.889	
CSV (mph)		7.32	7.17	7.17	7.47	
Tilt Table: Direction		Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Rear	Rear	Rear	Rear	
Tilt Table Angle (deg)		33.0	32.8	32.7	32.7	
Tilt Table Ratio (TTR)		0.649	0.645	0.643	0.643	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Rear	Rear	Rear	Rear	
Tilt Table Angle (deg)		37.7	32.1	32.0	33.3	
Tilt Table Ratio (TTR)		0.773	0.626	0.626	0.658	
Average Tilt Table Angle (deg)		35.3	32.4	32.4	33.0	
Average Tilt Table Ratio (TTR)		0.711	0.635	0.635	0.650	
Front Ground Clearance (in)			8.60			
Rear Ground Clearance (in)			10.20			
Steering Ratio (deg/deg)			13.2			

Vehicle B

	Curb	Operator	Operator & Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4162	4164	4166	4187	4186
Total Vehicle Weight (lb)	1025.0	1237.6	1450.1	1727.4	1475.7	1749.9
Left Front Weight (lb)	201.2	282.1	298.4	296.0	306.3	303.1
Right Front Weight (lb)	228.9	243.4	317.5	331.8	325.6	322.7
Left Rear Weight (lb)	288.3	381.7	409.0	546.3	428.5	551.5
Right Rear Weight (lb)	306.6	330.4	425.2	553.3	415.3	572.6
Front Track Width (in)	43.00	43.00	43.50	43.50	43.50	43.50
Rear Track Width (in)	40.30	40.30	41.00	41.60	41.00	41.60
Average Track Width (in)	41.65	41.65	42.25	42.55	42.25	42.55
Wheelbase (in)	76.85	76.85	76.85	76.85	76.85	76.85
CG Longitudinal (in)	44.60	44.22	44.21	48.92	43.94	49.37
CG Lateral (in)	0.93	-1.51	0.51	0.53	0.09	0.49
CG Height (in)		21.73	22.17	23.38	22.67	
Roll Inertia - I_{XX} (ft-lb-s^2)		100	122	128	145	
Pitch Inertia - I_{YY} (ft-lb-s^2)		241	250	301	272	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		243	257	303	289	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		-2	2	19	-2	
SSF		0.958	0.953	0.910	0.932	
KST		0.963	0.957	0.916	0.936	
CSV (mph)		7.52	7.55	7.10	7.56	
Tilt Table: Direction		Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Front	Front	Front	Front	
Tilt Table Angle (deg)		34.0	35.4	31.7	33.1	
Tilt Table Ratio (TTR)		0.675	0.710	0.617	0.652	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Front	Front	Front	Front	
Tilt Table Angle (deg)		38.3	34.1	31.6	34.1	
Tilt Table Ratio (TTR)		0.790	0.678	0.615	0.676	
Average Tilt Table Angle (deg)		36.2	34.8	31.6	33.6	
Average Tilt Table Ratio (TTR)		0.733	0.694	0.616	0.664	
Front Ground Clearance (in)			5.95			
Rear Ground Clearance (in)			6.90			
Steering Ratio (deg/deg)			14.9			

Vehicle C

	Curb	Operator	Operator & Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4169	4170	4171	4172	4189
Total Vehicle Weight (lb)	1441.4	1654.1	1866.6	2368.1	1882.5	2369.0
Left Front Weight (lb)	359.4	439.8	446.9	445.0	467.5	445.5
Right Front Weight (lb)	352.2	375.8	467.7	459.9	459.9	462.4
Left Rear Weight (lb)	334.8	418.6	457.4	707.6	472.1	706.5
Right Rear Weight (lb)	395.0	419.9	494.6	755.6	483.0	754.6
Front Track Width (in)	50.90	50.90	51.60	51.60	51.60	51.60
Rear Track Width (in)	50.10	50.10	51.48	51.85	51.48	51.85
Average Track Width (in)	50.50	50.50	51.54	51.73	51.54	51.73
Wheelbase (in)	75.15	75.15	75.15	75.15	75.15	75.15
CG Longitudinal (in)	38.05	38.10	38.33	46.43	38.13	46.35
CG Lateral (in)	0.93	-0.96	0.80	0.69	0.05	0.71
CG Height (in)		24.76	26.10	27.27	26.01	
Roll Inertia - I_{XX} (ft-lb-s^2)		180	211	228	236	
Pitch Inertia - I_{YY} (ft-lb-s^2)		347	363	488	381	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		372	384	505	421	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		2	8	38	8	
SSF		1.020	0.987	0.948	0.991	
KST		1.020	0.987	0.948	0.991	
CSV (mph)		8.70	8.51	8.02	8.67	
Tilt Table: Direction		Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		40.1	39.5	36.1	38.8	
Tilt Table Ratio (TTR)		0.843	0.824	0.729	0.805	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		41.6	37.5	34.6	38.7	
Tilt Table Ratio (TTR)		0.887	0.768	0.690	0.801	
Average Tilt Table Angle (deg)		40.9	38.5	35.3	38.8	
Average Tilt Table Ratio (TTR)		0.865	0.796	0.709	0.803	
Front Ground Clearance (in)			9.10			
Rear Ground Clearance (in)			9.90			
Steering Ratio (deg/deg)			15.7			

Vehicle D

	Curb	Operator	Operator & Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4190	4191	4192	4193	4194
Total Vehicle Weight (lb)	1294.9	1508.2	1720.9	2720.5	1728.6	2711.2
Left Front Weight (lb)	280.3	351.3	384.1	365.0	398.9	364.0
Right Front Weight (lb)	304.5	331.1	395.8	369.6	390.4	362.1
Left Rear Weight (lb)	341.6	451.7	448.3	976.6	460.5	975.0
Right Rear Weight (lb)	368.5	374.1	492.7	1009.3	478.8	1010.1
Front Track Width (in)	51.65	51.65	52.18	51.90	52.18	51.90
Rear Track Width (in)	48.28	48.28	49.23	49.90	49.23	49.90
Average Track Width (in)	49.96	49.96	50.70	50.90	50.70	50.90
Wheelbase (in)	75.80	75.80	75.80	75.80	75.80	75.80
CG Longitudinal (in)	41.57	41.50	41.45	55.33	41.19	55.50
CG Lateral (in)	0.99	-1.62	0.83	0.35	0.14	0.31
CG Height (in)		26.11	27.07	28.15	26.91	
Roll Inertia - I_{XX} (ft-lb-s^2)		162	185	198	219	
Pitch Inertia - I_{YY} (ft-lb-s^2)		319	333	523	353	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		340	353	546	399	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	11	49	10	
SSF		0.957	0.937	0.904	0.942	
KST		0.960	0.939	0.912	0.944	
CSV (mph)		8.14	7.99	7.41	8.23	
Tilt Table: Direction		Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		34.3	34.5	31.4	33.5	
Tilt Table Ratio (TTR)		0.681	0.688	0.611	0.662	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		37.9	32.8	30.4	33.9	
Tilt Table Ratio (TTR)		0.779	0.644	0.587	0.673	
Average Tilt Table Angle (deg)		36.1	33.6	30.9	33.7	
Average Tilt Table Ratio (TTR)		0.730	0.666	0.599	0.667	
Front Ground Clearance (in)			9.30			
Rear Ground Clearance (in)			10.75			
Steering Ratio (deg/deg)			18.0			

Vehicle E

	Curb	Operator	Operator & Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4200	4201	4202	4203	4204
Total Vehicle Weight (lb)	1402.2	1615.3	1827.9	2328.1	1831.4	2327.3
Left Front Weight (lb)	300.4	375.6	394.5	369.6	406.5	385.5
Right Front Weight (lb)	317.9	329.2	395.8	380.9	382.7	366.5
Left Rear Weight (lb)	397.4	502.3	512.7	794.3	526.3	778.5
Right Rear Weight (lb)	386.5	408.2	524.9	783.3	515.9	796.8
Front Track Width (in)	49.38	49.38	50.10	49.35	50.10	49.35
Rear Track Width (in)	48.50	48.50	48.93	49.55	48.93	49.55
Average Track Width (in)	48.94	48.94	49.51	49.45	49.51	49.45
Wheelbase (in)	75.90	75.90	75.90	75.90	75.90	75.90
CG Longitudinal (in)	42.43	42.78	43.08	51.43	43.19	51.38
CG Lateral (in)	0.12	-2.13	0.18	0.00	-0.46	-0.01
CG Height (in)		24.73	25.55	26.39	25.66	
Roll Inertia - I_{XX} (ft-lb-s^2)		147	173	187	201	
Pitch Inertia - I_{YY} (ft-lb-s^2)		326	341	461	352	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		351	363	482	403	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	16	40	13	
SSF		0.989	0.969	0.937	0.965	
KST		0.991	0.970	0.936	0.966	
CSV (mph)		8.18	8.08	7.67	8.21	
Tilt Table: Direction		Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		37.4	37.7	34.6	37.2	
Tilt Table Ratio (TTR)		0.765	0.773	0.689	0.759	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		41.6	37.7	34.2	38.9	
Tilt Table Ratio (TTR)		0.888	0.774	0.681	0.808	
Average Tilt Table Angle (deg)		39.5	37.7	34.4	38.1	
Average Tilt Table Ratio (TTR)		0.826	0.774	0.685	0.784	
Front Ground Clearance (in)			10.40			
Rear Ground Clearance (in)			10.80			
Steering Ratio (deg/deg)			14.9			

Vehicle F

	Curb	Operator	Operator & Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4195	4196	4197	4198	4199
Total Vehicle Weight (lb)	1262.4	1475.2	1688.0	2288.6	1688.1	2289.1
Left Front Weight (lb)	279.1	346.1	362.2	339.4	371.3	325.1
Right Front Weight (lb)	287.9	301.6	367.8	339.3	357.0	349.1
Left Rear Weight (lb)	349.7	462.8	477.3	805.4	485.5	822.4
Right Rear Weight (lb)	345.7	364.7	480.7	804.5	474.3	792.5
Front Track Width (in)	50.20	50.20	50.35	50.35	50.35	50.35
Rear Track Width (in)	48.35	48.35	48.70	49.35	48.70	49.35
Average Track Width (in)	49.28	49.28	49.53	49.85	49.53	49.85
Wheelbase (in)	75.05	75.05	75.05	75.05	75.05	75.05
CG Longitudinal (in)	41.34	42.10	42.59	52.79	42.67	52.95
CG Lateral (in)	0.09	-2.38	0.13	-0.01	-0.37	-0.06
CG Height (in)		27.08	28.47	29.27	28.10	
Roll Inertia - I_{XX} (ft-lb-s^2)		167	203	210	217	
Pitch Inertia - I_{YY} (ft-lb-s^2)		313	329	468	353	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		326	338	470	374	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		16	26	46	27	
SSF		0.910	0.870	0.852	0.881	
KST		0.912	0.872	0.855	0.883	
CSV (mph)		7.78	7.52	7.13	7.69	
Tilt Table: Direction		Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		34.9	35.2	30.8	35.9	
Tilt Table Ratio (TTR)		0.697	0.707	0.595	0.725	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		40.0	35.2	30.9	37.0	
Tilt Table Ratio (TTR)		0.838	0.706	0.599	0.753	
Average Tilt Table Angle (deg)		37.4	35.2	30.8	36.4	
Average Tilt Table Ratio (TTR)		0.768	0.706	0.597	0.739	
Front Ground Clearance (in)			10.50			
Rear Ground Clearance (in)			9.70			
Steering Ratio (deg/deg)			14.8			

Vehicle G

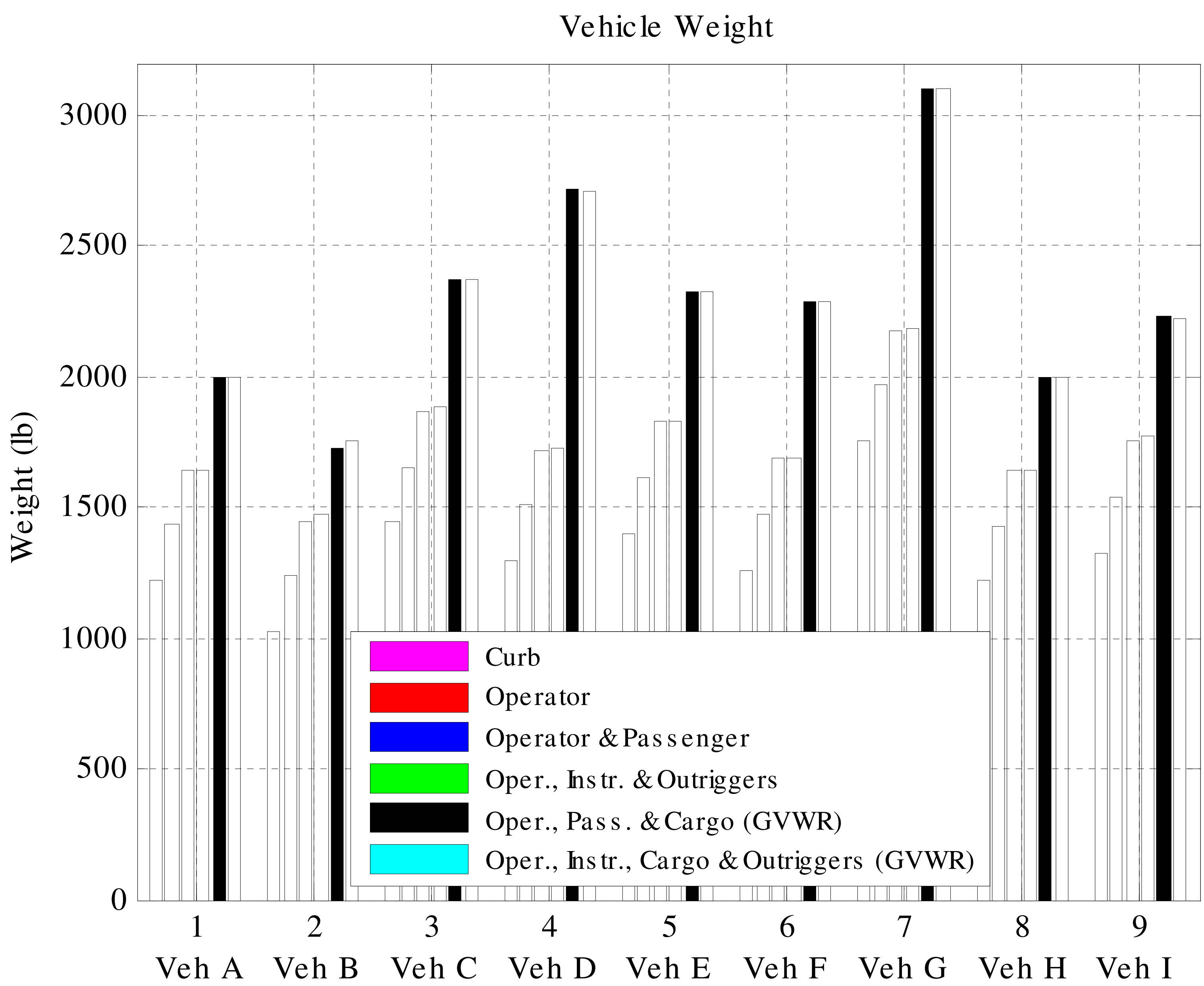
	Curb	Operator	Operator & Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4224	4225	4226	4227	4228
Total Vehicle Weight (lb)	1753.4	1966.8	2179.2	3100.6	2188.5	3099.9
Left Front Weight (lb)	375.1	458.3	497.8	507.0	500.7	502.6
Right Front Weight (lb)	373.4	413.1	494.5	497.9	491.3	492.4
Left Rear Weight (lb)	499.3	567.2	580.8	1032.6	598.8	1052.0
Right Rear Weight (lb)	505.6	528.2	606.1	1063.1	597.7	1052.9
Front Track Width (in)	50.20	51.45	51.73	51.45	51.73	51.45
Rear Track Width (in)	51.40	51.53	51.75	51.53	51.75	51.53
Average Track Width (in)	50.80	51.49	51.74	51.49	51.74	51.49
Wheelbase (in)	79.15	79.15	79.15	79.15	79.15	79.15
CG Longitudinal (in)	45.36	44.08	43.11	53.50	43.27	53.74
CG Lateral (in)	0.07	-1.10	0.26	0.18	-0.12	-0.08
CG Height (in)		24.45	25.33	26.52	25.10	
Roll Inertia - I_{XX} (ft-lb-s^2)		168	187	213	210	
Pitch Inertia - I_{YY} (ft-lb-s^2)		465	482	649	496	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		486	503	666	540	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		3	-2	40	0	
SSF		1.053	1.021	0.971	1.031	
KST		1.053	1.021	0.971	1.031	
CSV (mph)		8.74	8.50	7.90	8.69	
Tilt Table: Direction		Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Front	Front	Front	Front	
Tilt Table Angle (deg)		39.0	38.9	34.0	38.7	
Tilt Table Ratio (TTR)		0.811	0.808	0.675	0.803	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Front	Front	Front	Front	
Tilt Table Angle (deg)		41.7	38.9	33.8	39.2	
Tilt Table Ratio (TTR)		0.891	0.807	0.668	0.817	
Average Tilt Table Angle (deg)		40.4	38.9	33.9	39.0	
Average Tilt Table Ratio (TTR)		0.851	0.808	0.672	0.810	
Front Ground Clearance (in)			9.60			
Rear Ground Clearance (in)			9.80			
Steering Ratio (deg/deg)			14.7			

Vehicle H

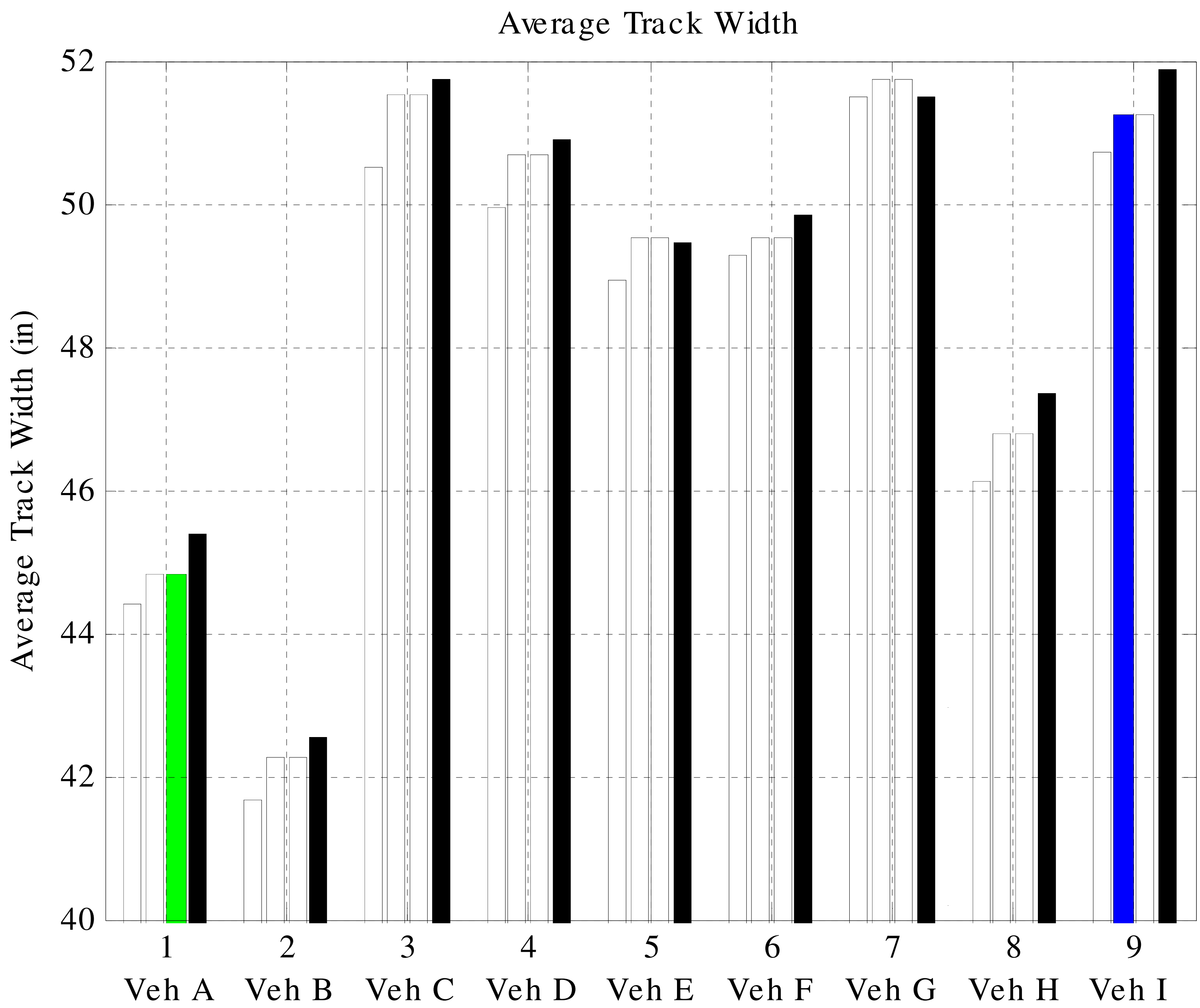
	Curb	Operator	Operator & Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4251	4252	4253	4254	4255
Total Vehicle Weight (lb)	1218.5	1430.3	1643.2	2000.5	1645.1	2001.9
Left Front Weight (lb)	252.4	326.6	340.4	343.2	348.5	342.2
Right Front Weight (lb)	284.3	300.8	374.1	345.0	364.9	349.7
Left Rear Weight (lb)	326.6	433.5	453.8	631.3	466.7	656.1
Right Rear Weight (lb)	355.2	369.4	474.9	681.0	465.0	653.9
Front Track Width (in)	44.00	44.70	45.03	45.00	45.03	45.00
Rear Track Width (in)	46.60	47.58	48.58	49.70	48.58	49.70
Average Track Width (in)	45.30	46.14	46.80	47.35	46.80	47.35
Wheelbase (in)	75.10	75.10	75.10	75.10	75.10	75.10
CG Longitudinal (in)	42.02	42.16	42.44	49.26	42.53	49.14
CG Lateral (in)	1.12	-1.45	0.78	0.61	0.21	0.06
CG Height (in)		24.96	25.72	25.39	25.50	
Roll Inertia - I_{XX} (ft-lb-s^2)		136	162	165	196	
Pitch Inertia - I_{YY} (ft-lb-s^2)		277	288	368	301	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		289	301	378	346	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	16	22	12	
SSF		0.924	0.910	0.932	0.918	
KST		0.921	0.905	0.918	0.913	
CSV (mph)		7.60	7.54	7.57	7.82	
Tilt Table: Direction		Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		35.4	36.0	35.3	35.8	
Tilt Table Ratio (TTR)		0.711	0.726	0.707	0.722	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Rear	Rear	Front	Rear	
Tilt Table Angle (deg)		38.8	35.2	35.5	36.0	
Tilt Table Ratio (TTR)		0.805	0.705	0.714	0.725	
Average Tilt Table Angle (deg)		37.1	35.6	35.4	35.9	
Average Tilt Table Ratio (TTR)		0.758	0.716	0.710	0.724	
Front Ground Clearance (in)			9.15			
Rear Ground Clearance (in)			10.95			
Steering Ratio (deg/deg)			13.3			

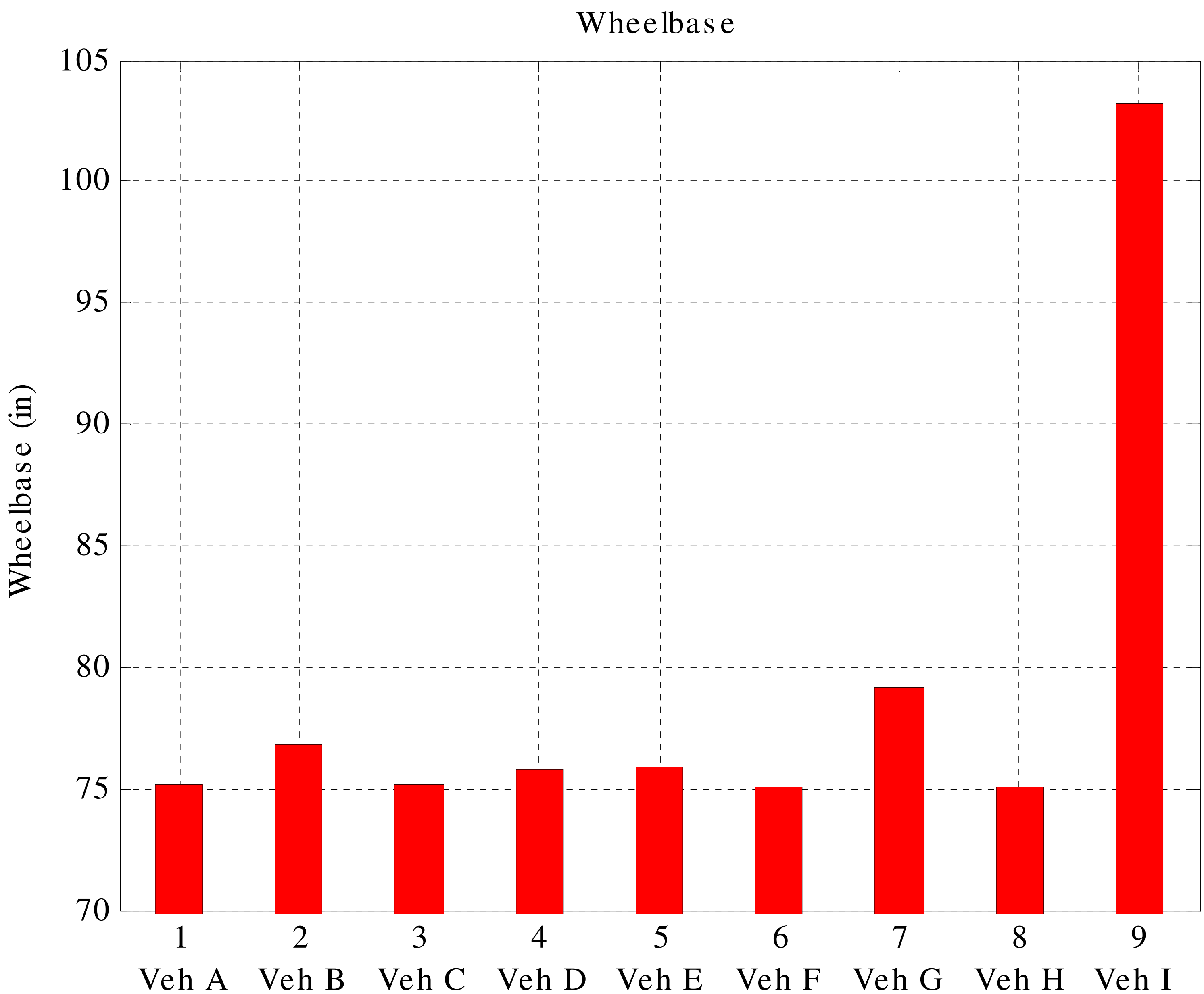
Vehicle I

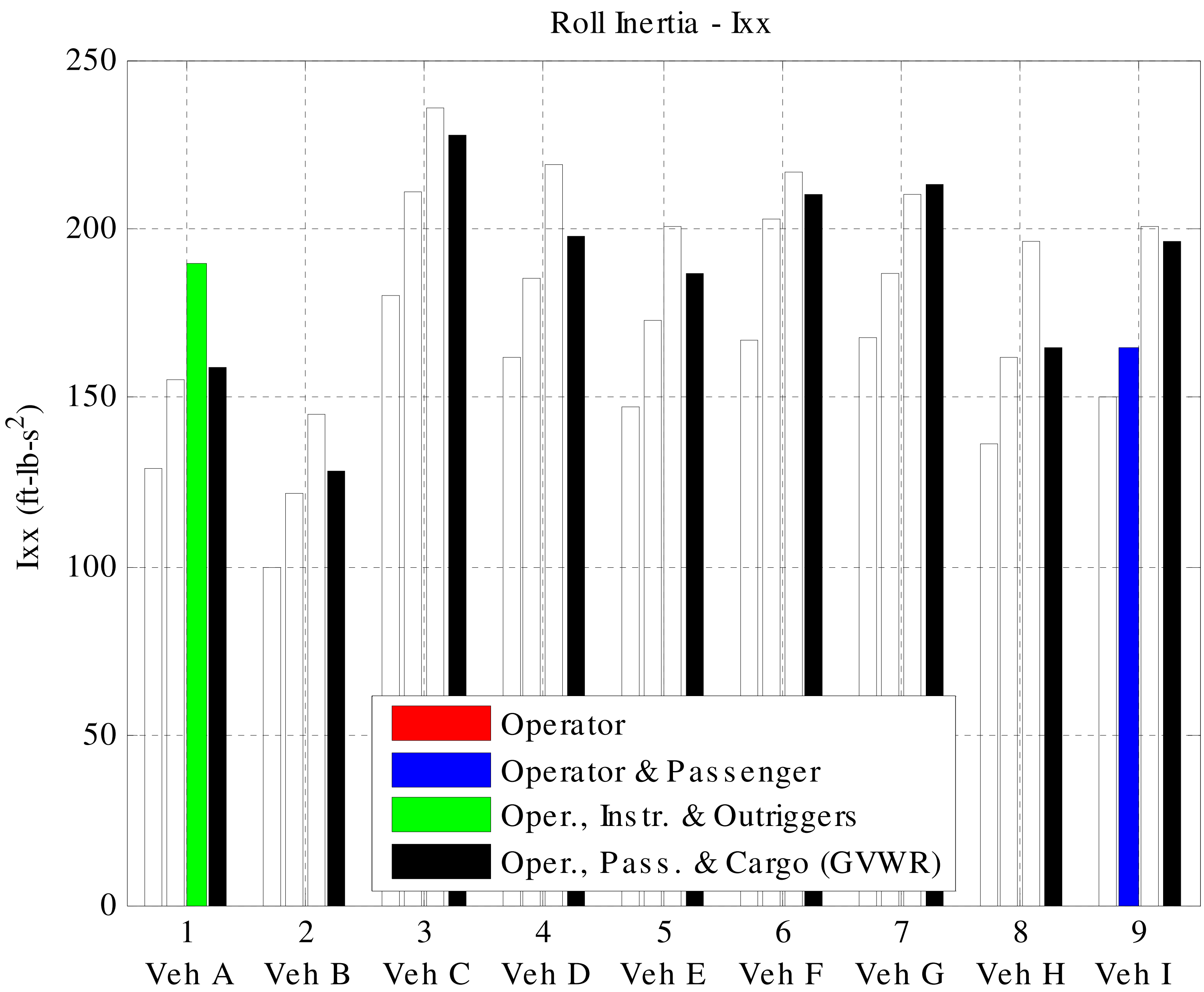
	Curb	Operator	Operator & Passenger	Operator & 3 Passenger	Operator, Passenger & Cargo (GVWR)	Operator, Inst & Outriggers	Operator, Inst, Cargo & Outriggers (GVWR)
VIMF Test Number		4259	4260	4261	4262	4263	4264
Total Vehicle Weight (lb)	1326.0	1539.0	1753.3	2177.7	2227.0	1769.3	2226.8
Left Front Weight (lb)	276.8	347.0	399.3	461.7	459.5	399.2	456.9
Right Front Weight (lb)	277.8	330.4	400.7	449.9	452.5	410.3	464.5
Left Rear Weight (lb)	367.9	459.6	461.9	618.0	646.4	487.6	657.8
Right Rear Weight (lb)	403.5	402.0	491.4	648.1	668.6	472.2	647.6
Front Track Width (in)	51.30	51.30	52.00	52.28	52.35	52.00	52.28
Rear Track Width (in)	50.15	50.15	50.50	51.30	51.40	50.50	51.30
Average Track Width (in)	50.73	50.73	51.25	51.79	51.88	51.25	51.79
Wheelbase (in)	103.25	103.25	103.25	103.25	103.25	103.25	103.25
CG Longitudinal (in)	60.07	57.80	56.14	60.03	60.97	56.01	60.53
CG Lateral (in)	0.70	-1.22	0.45	0.22	0.18	-0.06	-0.03
CG Height (in)		23.91	24.35	25.45	25.45	24.53	
Roll Inertia - I_{XX} (ft-lb-s^2)		150	165	193	196	201	
Pitch Inertia - I_{YY} (ft-lb-s^2)		517	534	579	597	560	
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		528	544	585	601	584	
Roll/Yaw - I_{XZ} (ft-lb-s^2)		-9	-11	8	15	-7	
SSF		1.061	1.052	1.017	1.019	1.045	
KST		1.062	1.054	1.019	1.021	1.046	
CSV (mph)		8.92	8.83	8.50	8.51	9.00	
Tilt Table: Direction		Driver	Driver	Driver	Driver	Driver	
Tilt Table: First Wheel Lift		Rear	Rear	Rear	Rear	Rear	
Tilt Table Angle (deg)		36.5	36.0	32.8	32.8	35.0	
Tilt Table Ratio (TTR)		0.739	0.726	0.644	0.645	0.699	
Tilt Table: Direction		Passenger	Passenger	Passenger	Passenger	Passenger	
Tilt Table: First Wheel Lift		Rear	Rear	Rear	Rear	Rear	
Tilt Table Angle (deg)		39.1	35.1	32.4	32.6	35.9	
Tilt Table Ratio (TTR)		0.811	0.702	0.635	0.639	0.725	
Average Tilt Table Angle (deg)		37.8	35.5	32.6	32.7	35.4	
Average Tilt Table Ratio (TTR)		0.775	0.714	0.640	0.642	0.71	
Front Ground Clearance (in)			10.25				
Rear Ground Clearance (in)			10.15				
Steering Ratio (deg/deg)			14.6				

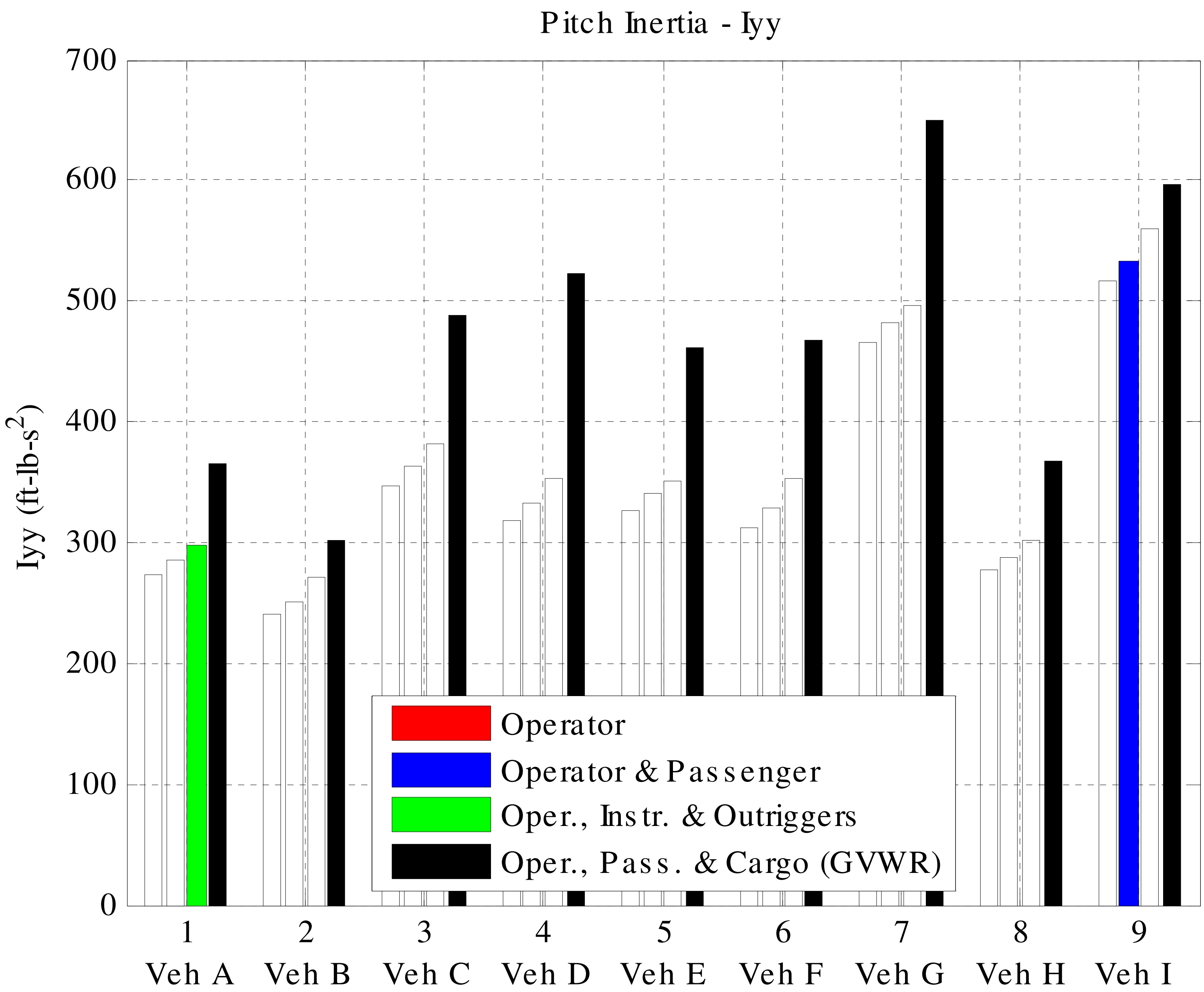


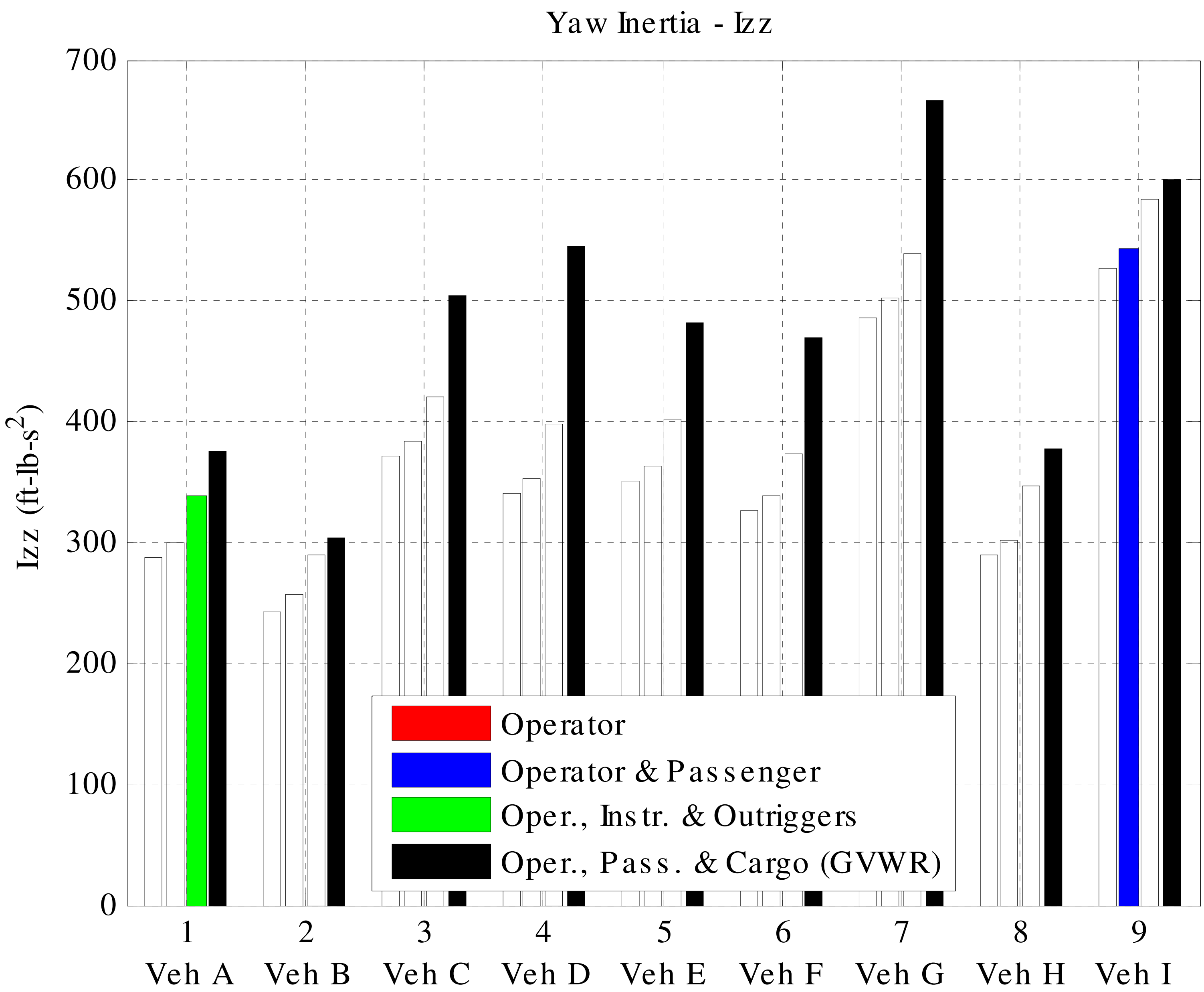
Vehicle Weight
Weight (lb)
3000
2500
2000
1500
1000
500
0
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I
Curb
Operator
Operator & Passenger
Oper., Instr. & Outriggers
Oper., Pass. & Cargo (GVWR)
Oper., Instr., Cargo & Outriggers (GVWR)

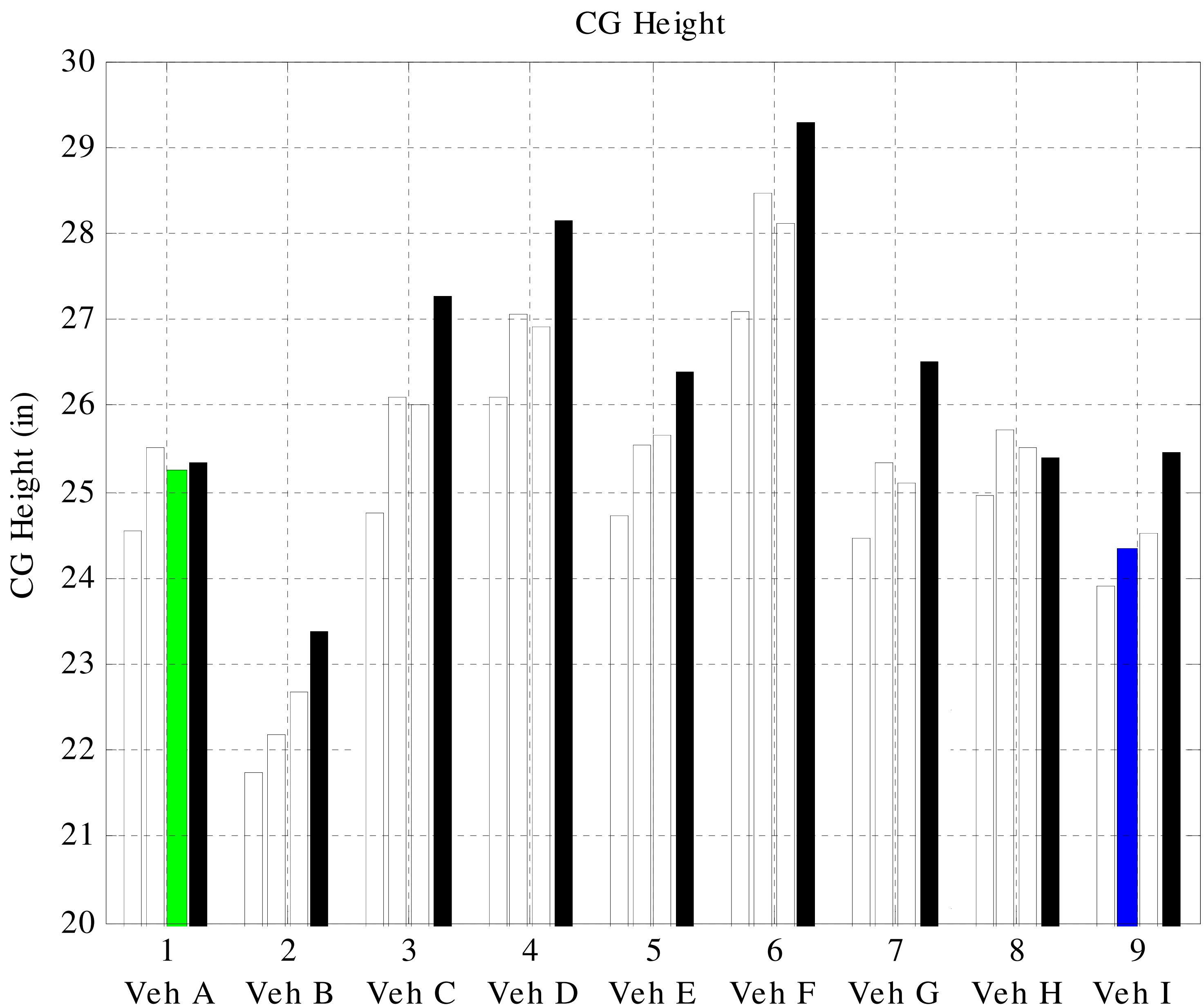

Average Track Width
Average Track Width (in)
52
50
48
46
44
42
40
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

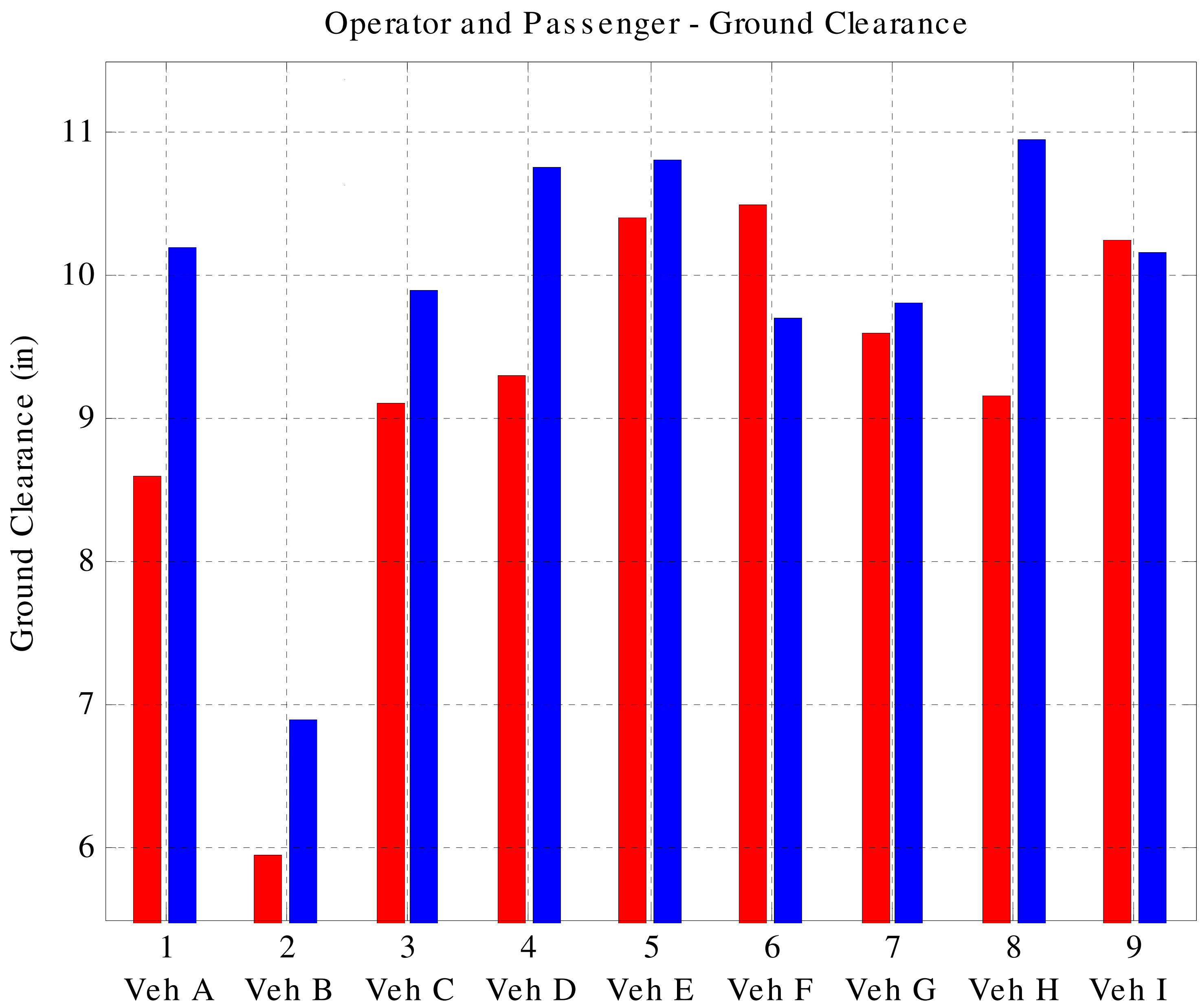

Wheelbase
Wheelbase (in)
105
100
95
90
85
80
75
70
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I


Roll Inertia - Ixx
Ixx (ft-lb-s^2)
250
200
150
100
50
0
Operator
Operator & Passenger
Oper., Instr. & Outriggers
Oper., Pass. & Cargo (GVWR)
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

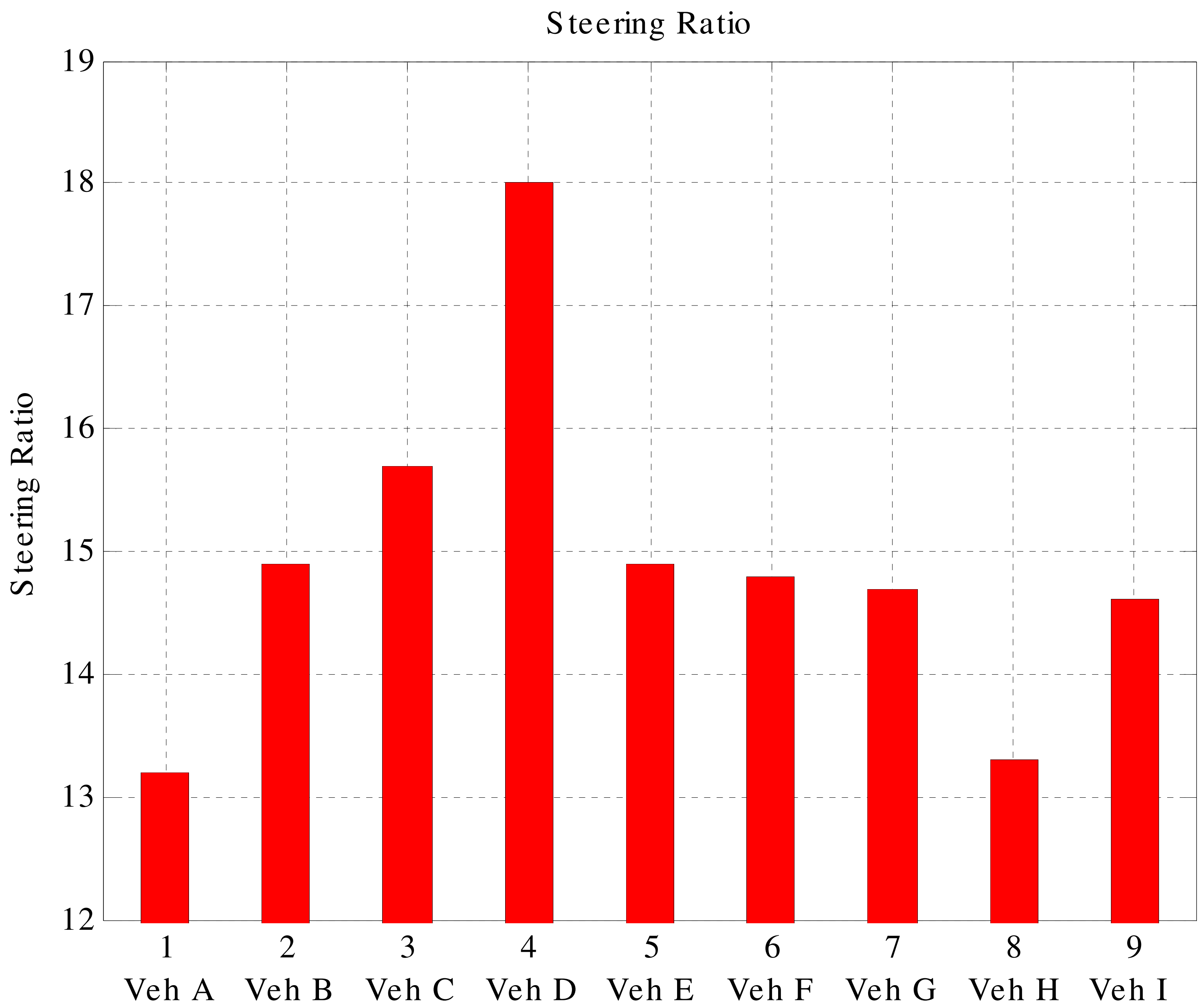

Pitch Inertia - Iyy
Iyy (ft-lb-s^2)
0
100
200
300
400
500
600
700
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I
Operator
Operator & Passenger
Oper., Instr. & Outriggers
Oper., Pass. & Cargo (GVWR)


Yaw Inertia - Izz
Izz (ft-lb-s^2)
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I
Operator
Operator & Passenger
Oper., Instr. & Outriggers
Oper., Pass. & Cargo (GVWR)

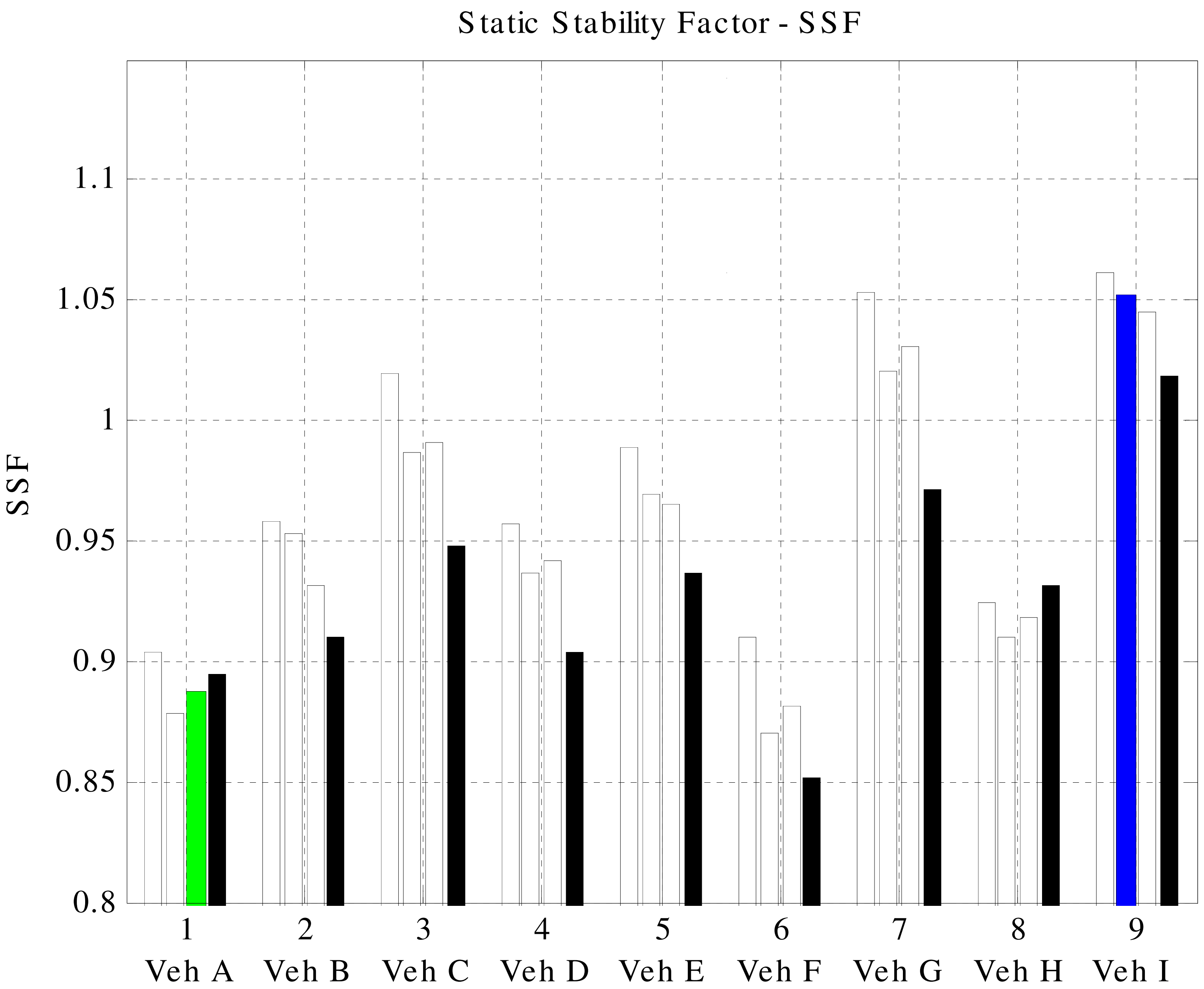

CG Height
CG Height (in)
30
29
28
27
26
25
24
23
22
21
20
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

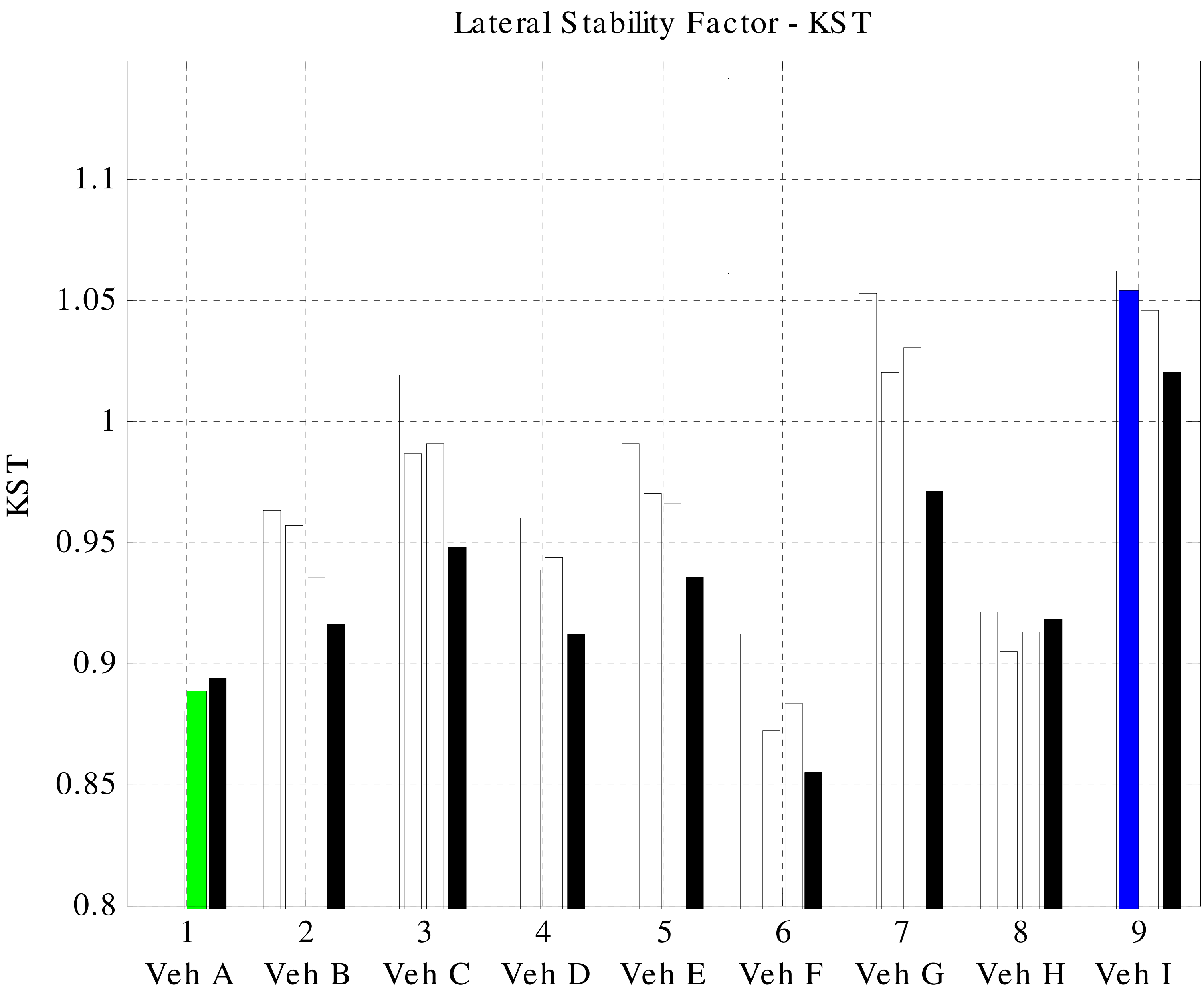


Operator and Passenger - Ground Clearance
Ground Clearance (in)
11
10
9
8
7
6
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

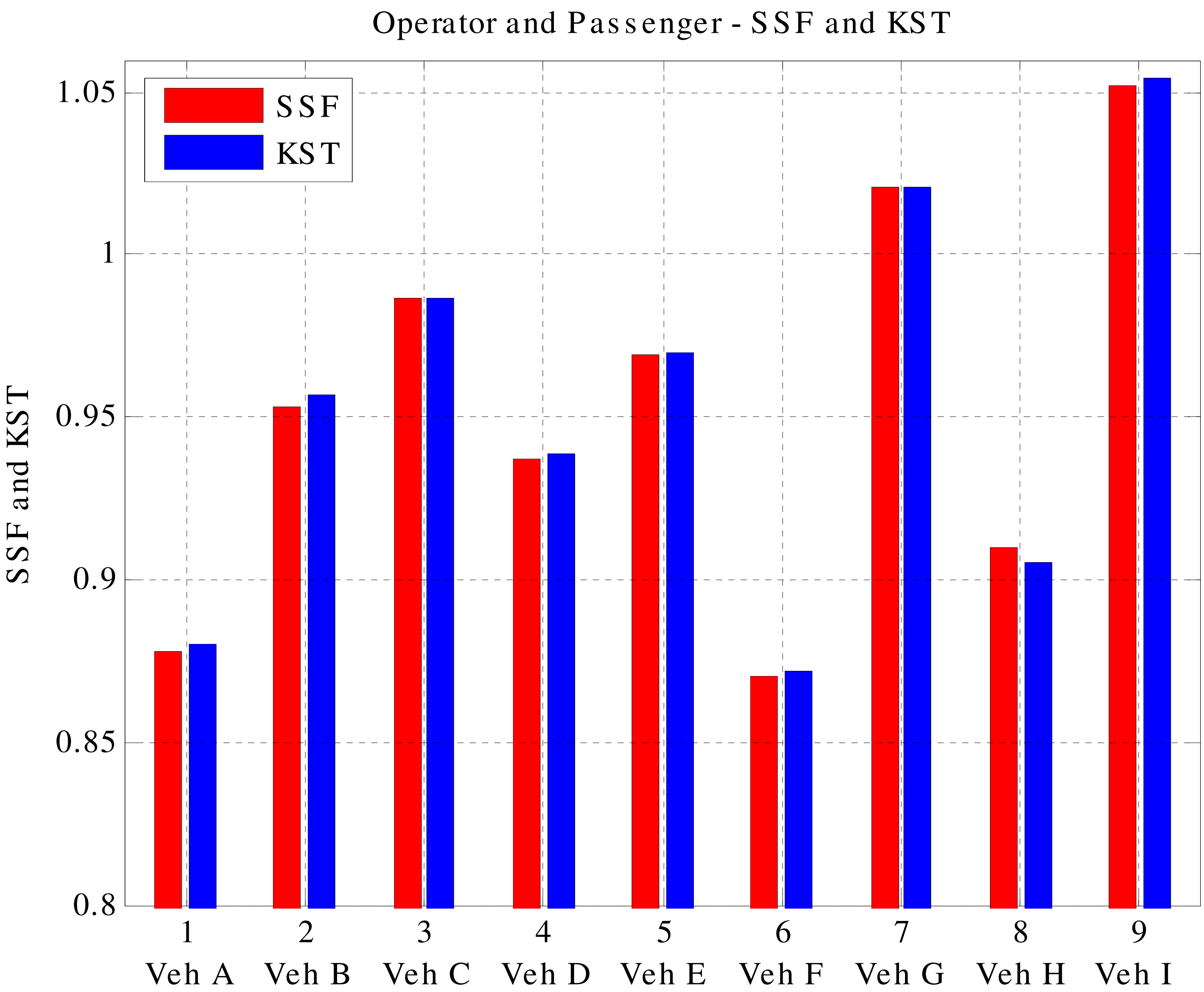


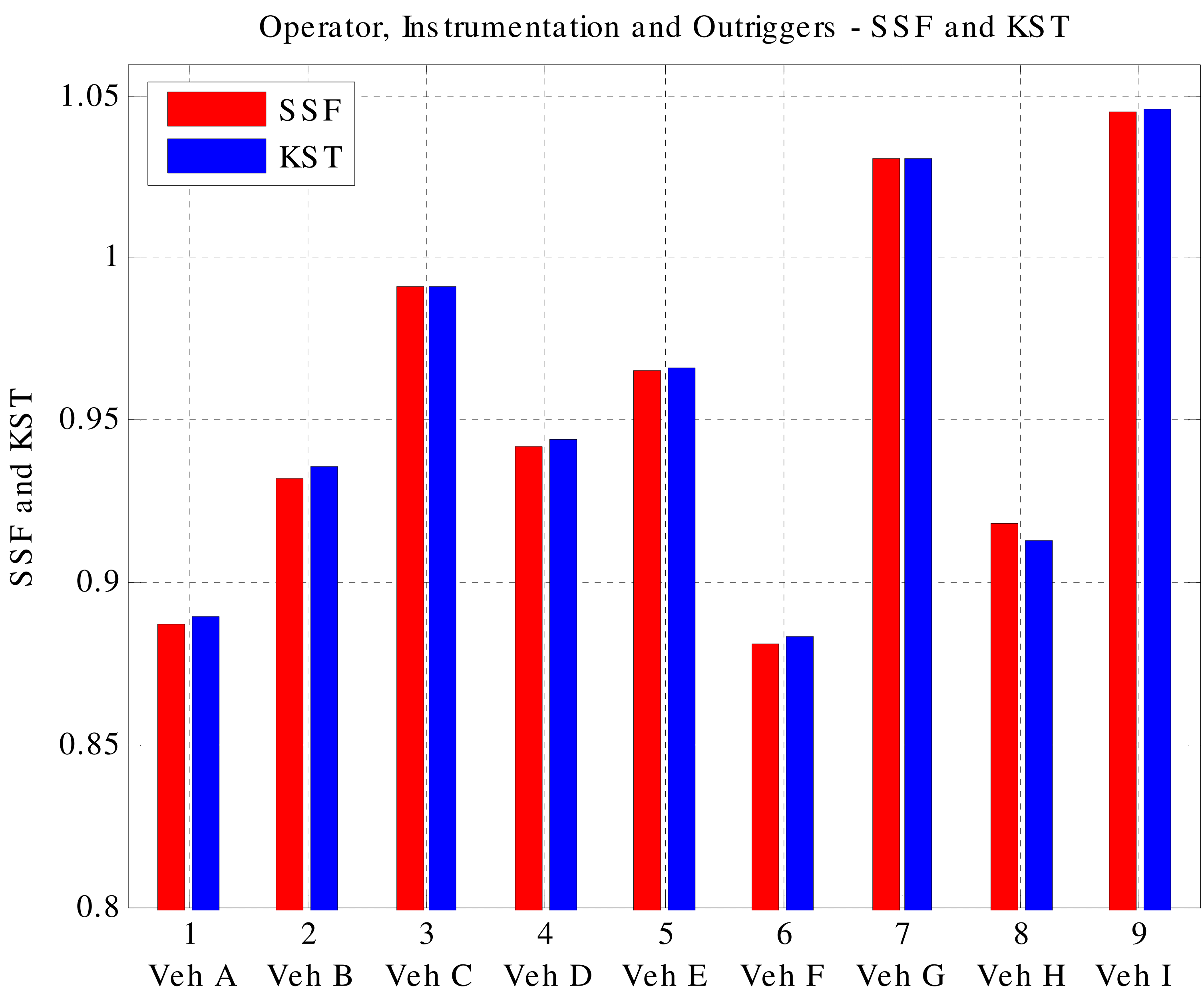
Steering Ratio
Steering Ratio
19
18
17
16
15
14
13
12
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I


Static Stability Factor - SSF
SSF
1.1
1.05
1
0.95
0.9
0.85
0.8
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

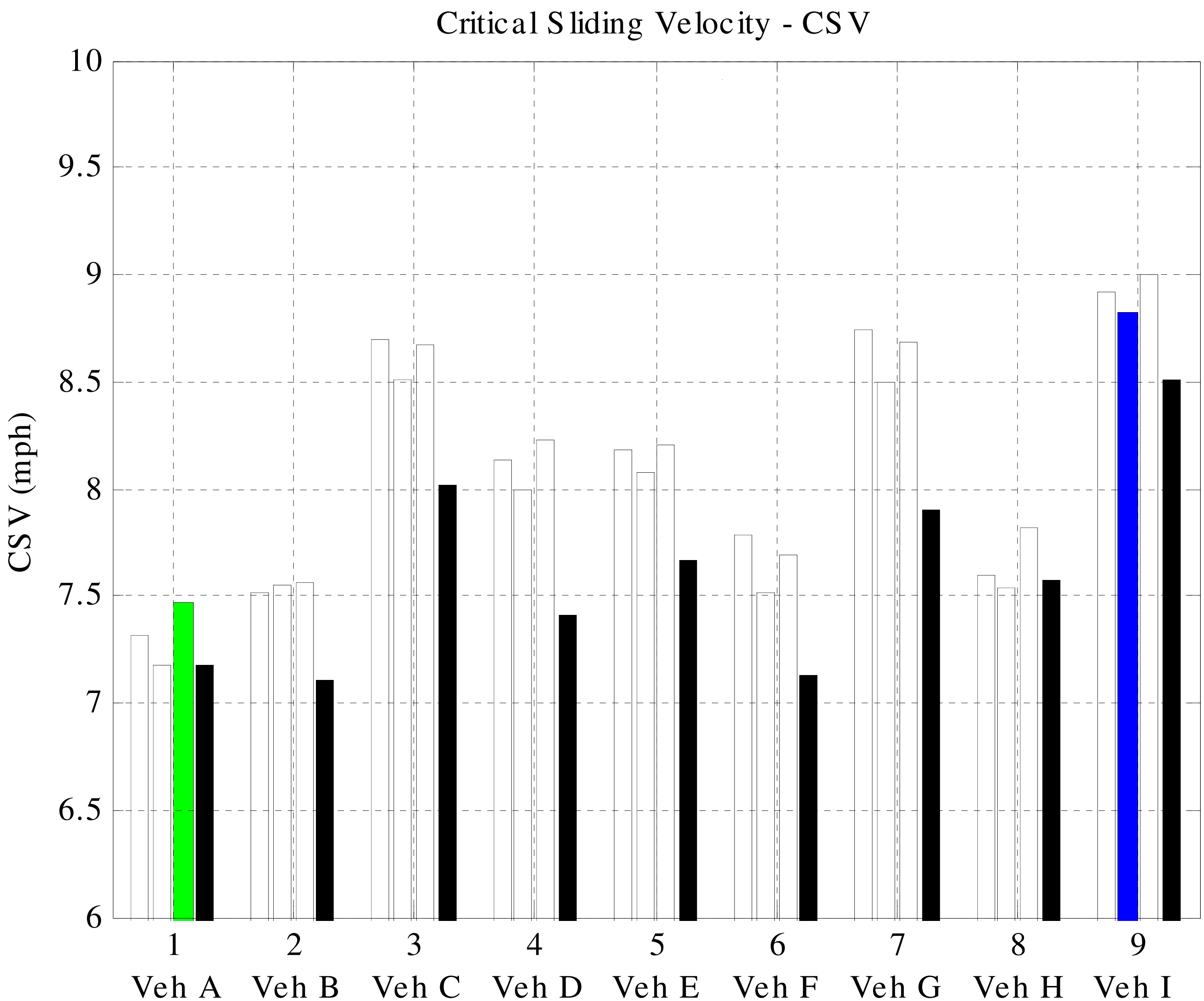


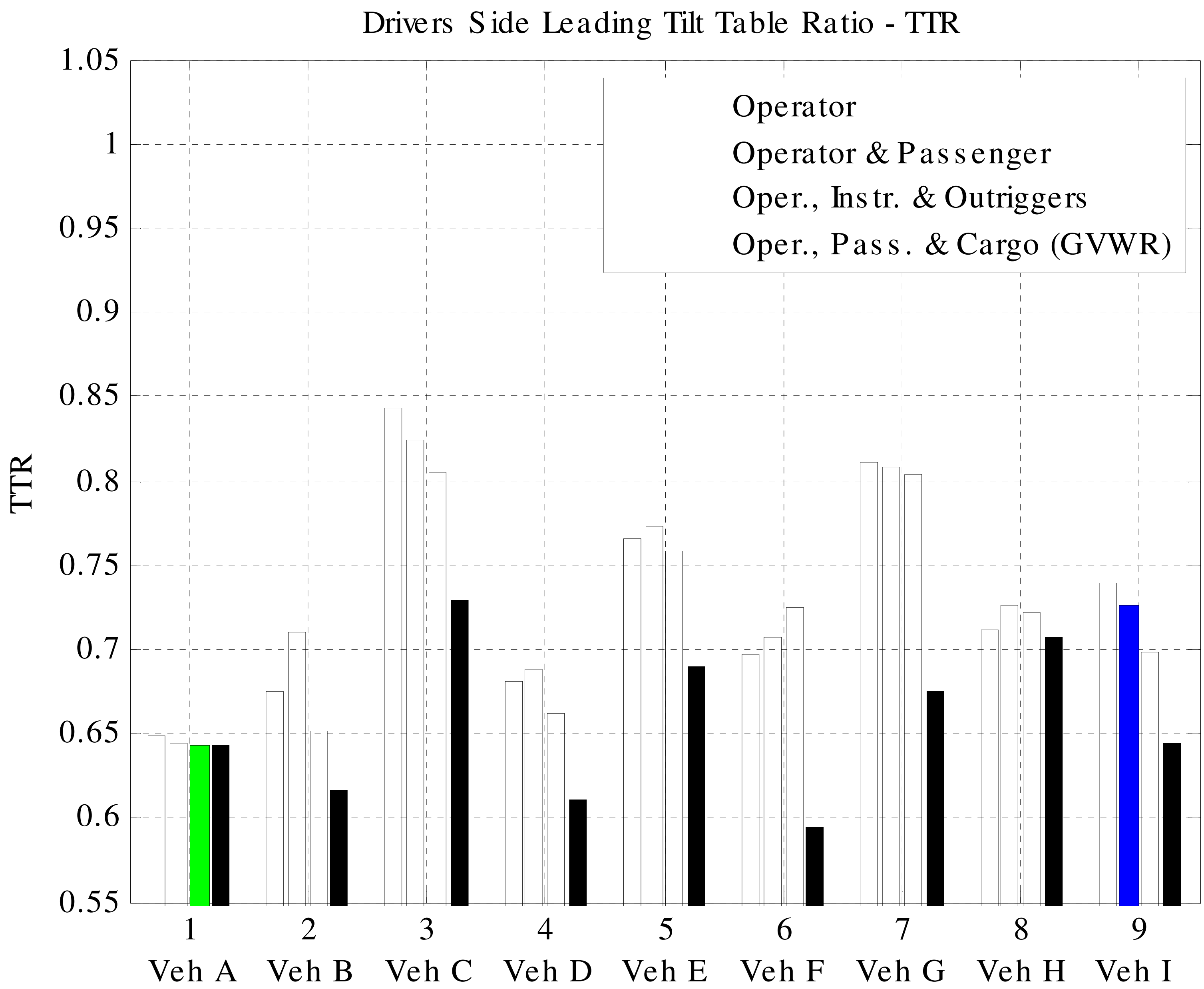
Lateral Stability Factor - KST
KST
1.1
1.05
1
0.95
0.9
0.85
0.8
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

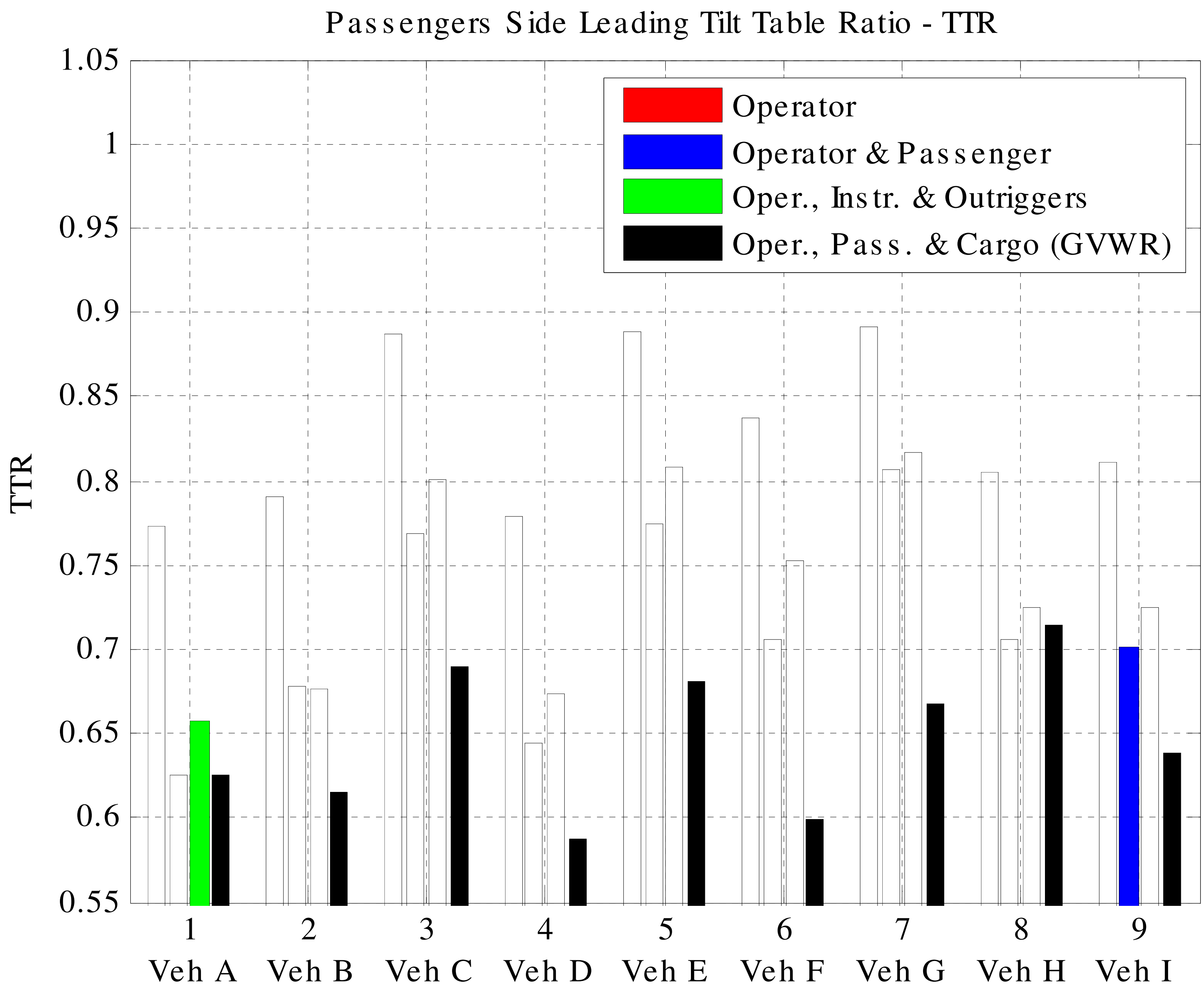

Operator and Passenger - SSF and KST
SSF
KST
SSF and KST
1.05
1
0.95
0.9
0.85
0.8
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I



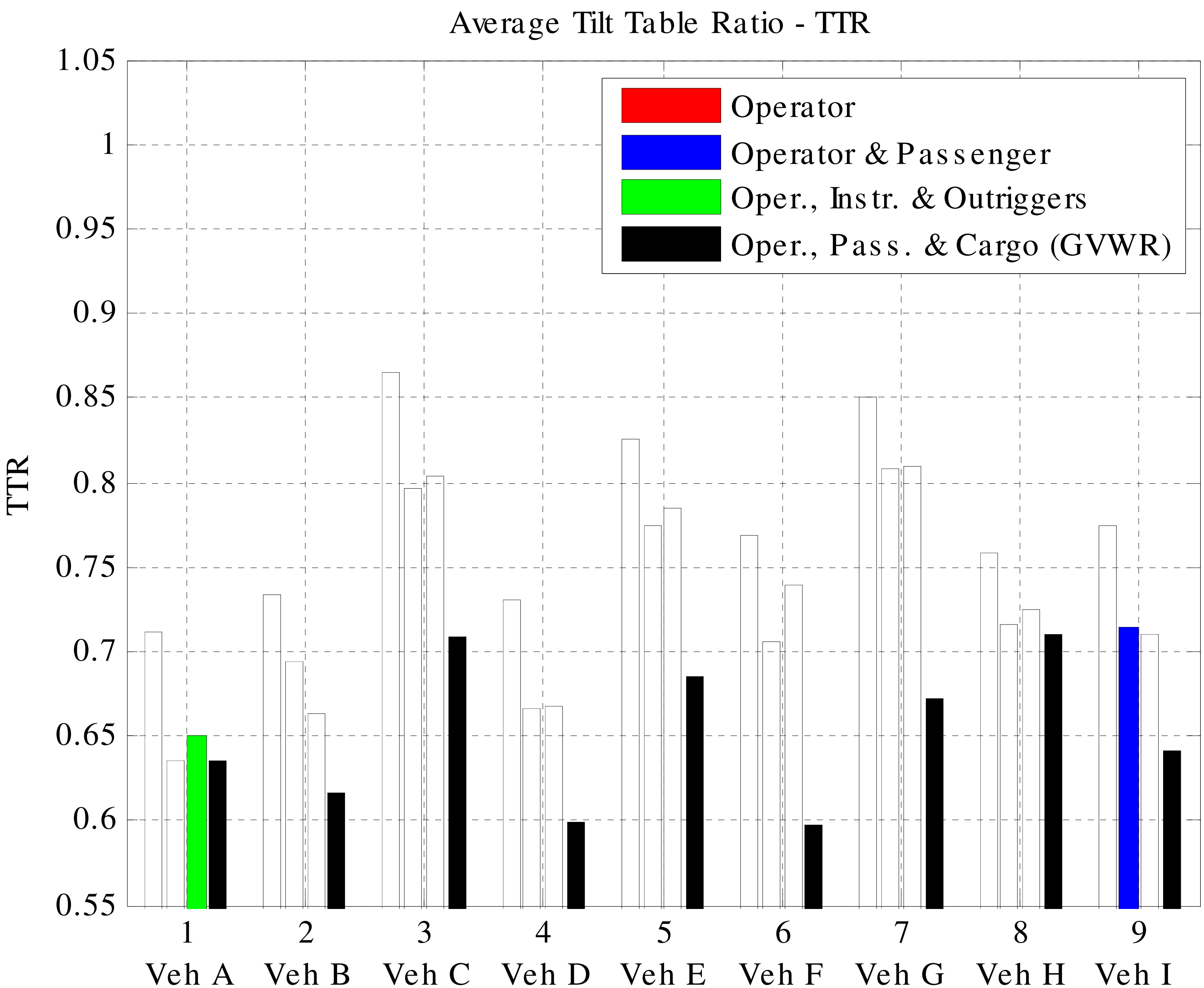
Operator, Instrumentation and Outriggers - SSF and KST
SSF
KST
SSF and KST
1.05
1
0.95
0.9
0.85
0.8
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I


Critical Sliding Velocity - CSV
CSV (mph)
10
9.5
9
8.5
8
7.5
7
6.5
6
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

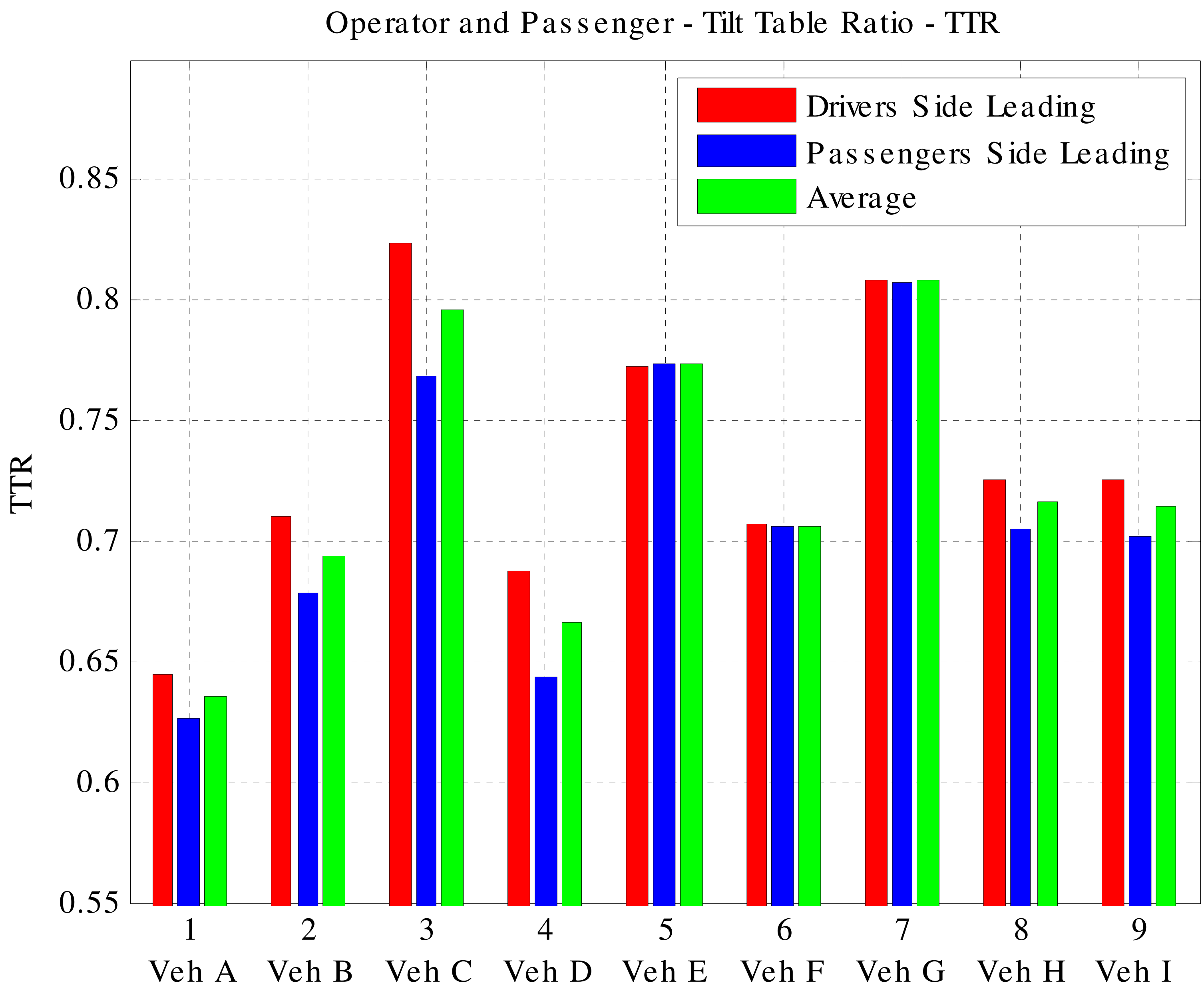

Drivers Side Leading Tilt Table Ratio - TTR
TTR
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
Operator
Operator & Passenger
Oper., Instr. & Outriggers
Oper., Pass. & Cargo (GVWR)
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I

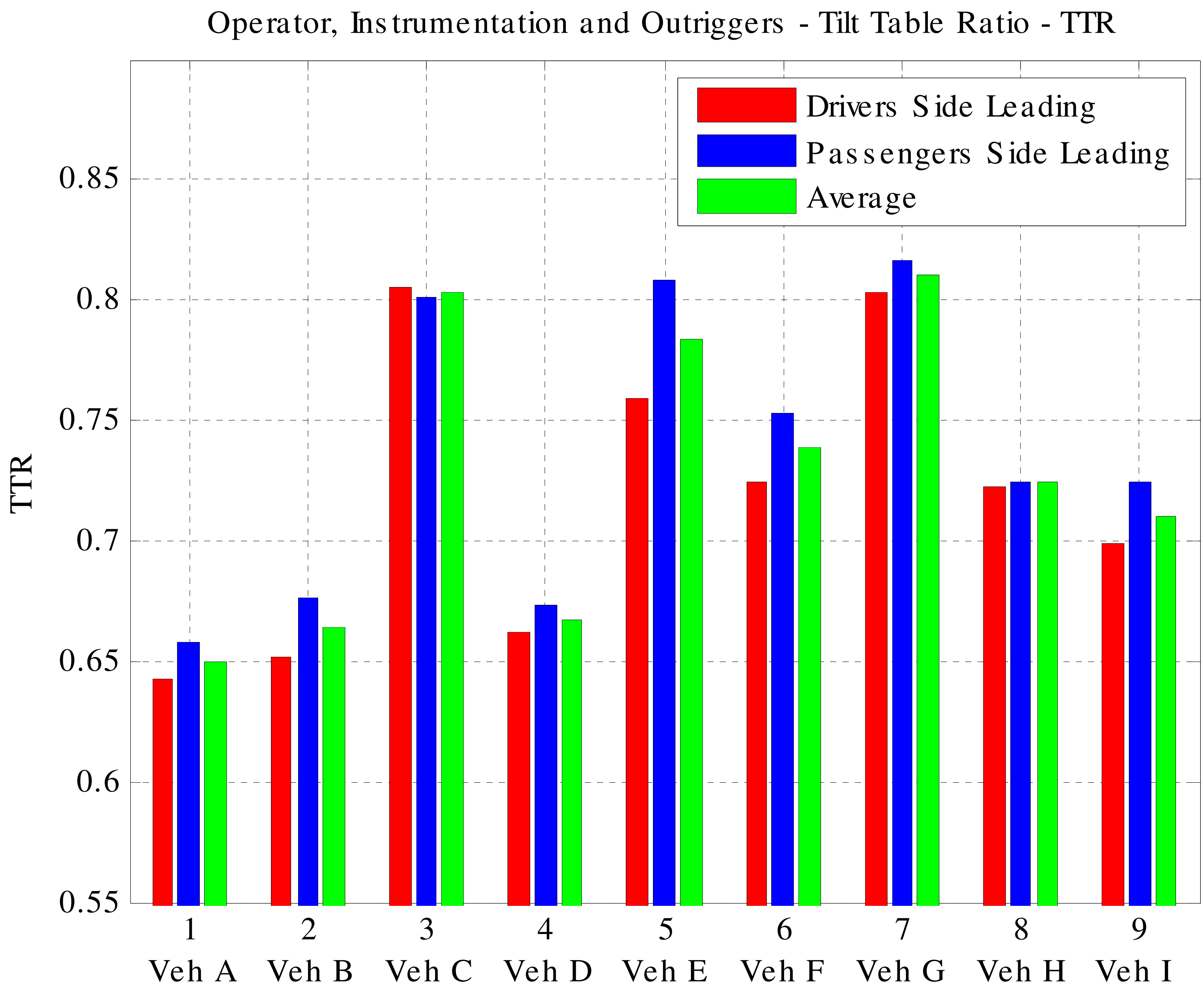


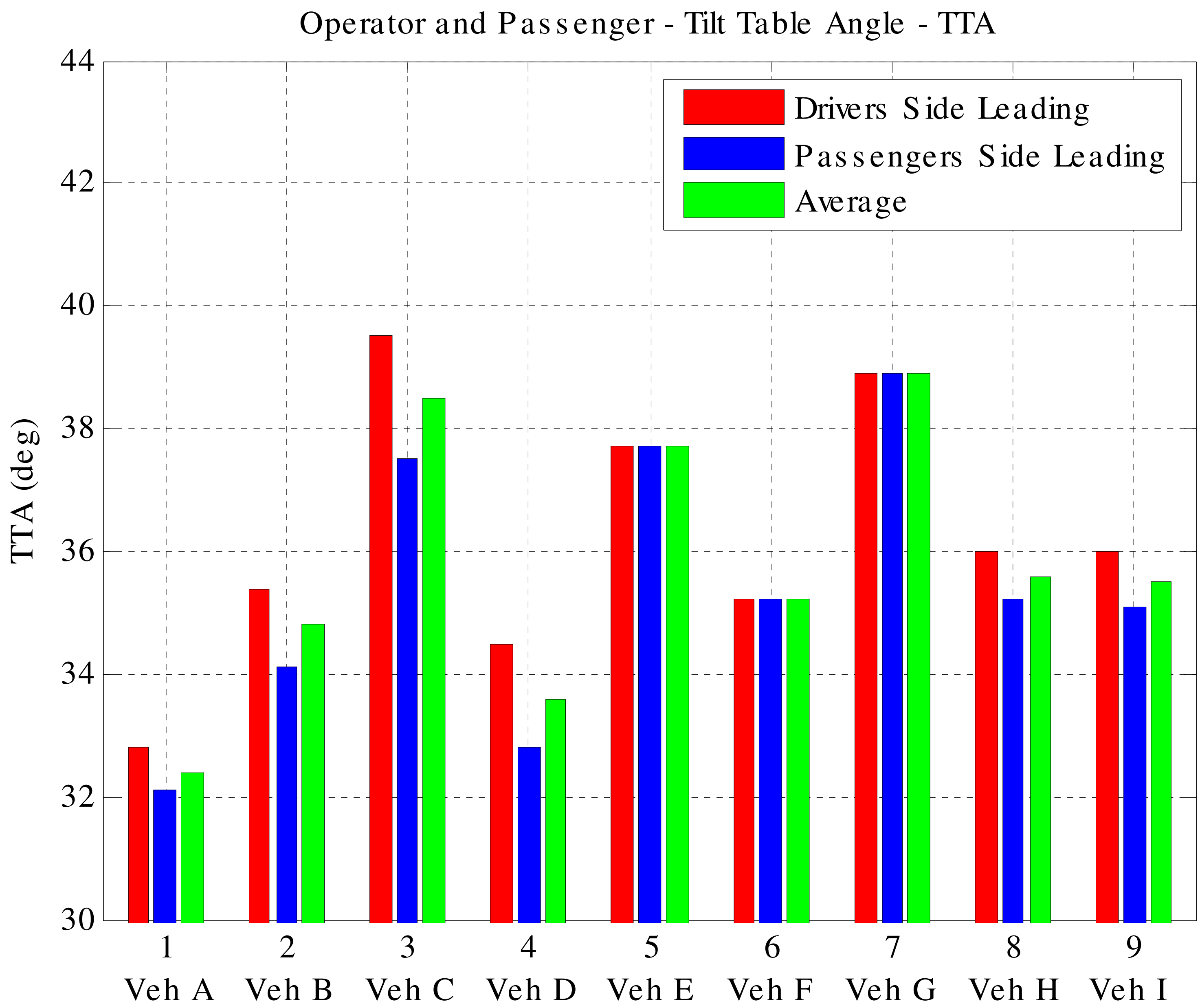
Passengers Side Leading Tilt Table Ratio - TTR
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
TTR
Operator
Operator & Passenger
Oper., Instr. & Outriggers
Oper., Pass. & Cargo (GVWR)
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

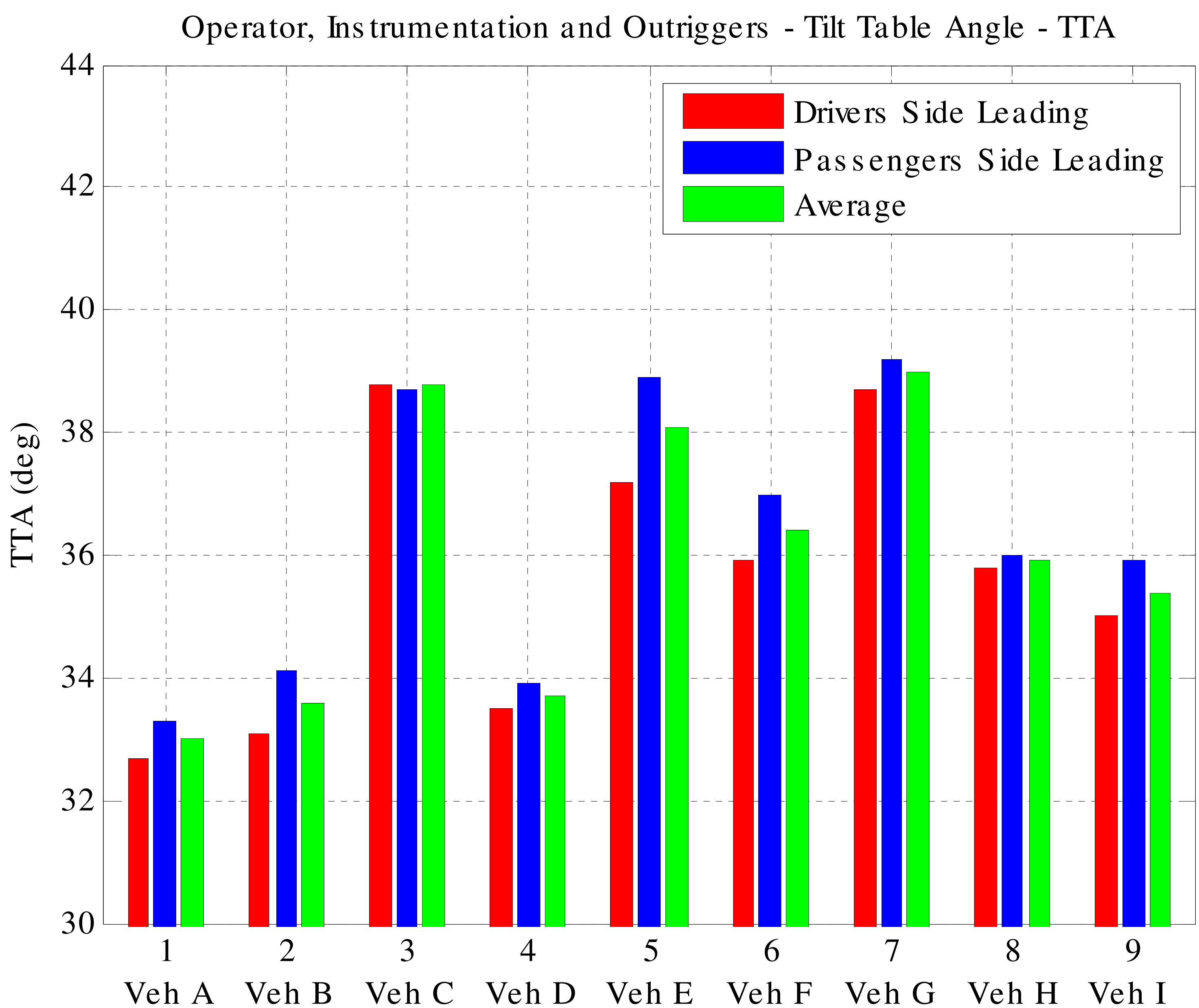


Average Tilt Table Ratio - TTR
TTR
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
Operator
Operator & Passenger
Oper., Instr. & Outriggers
Oper., Pass. & Cargo (GVWR)
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

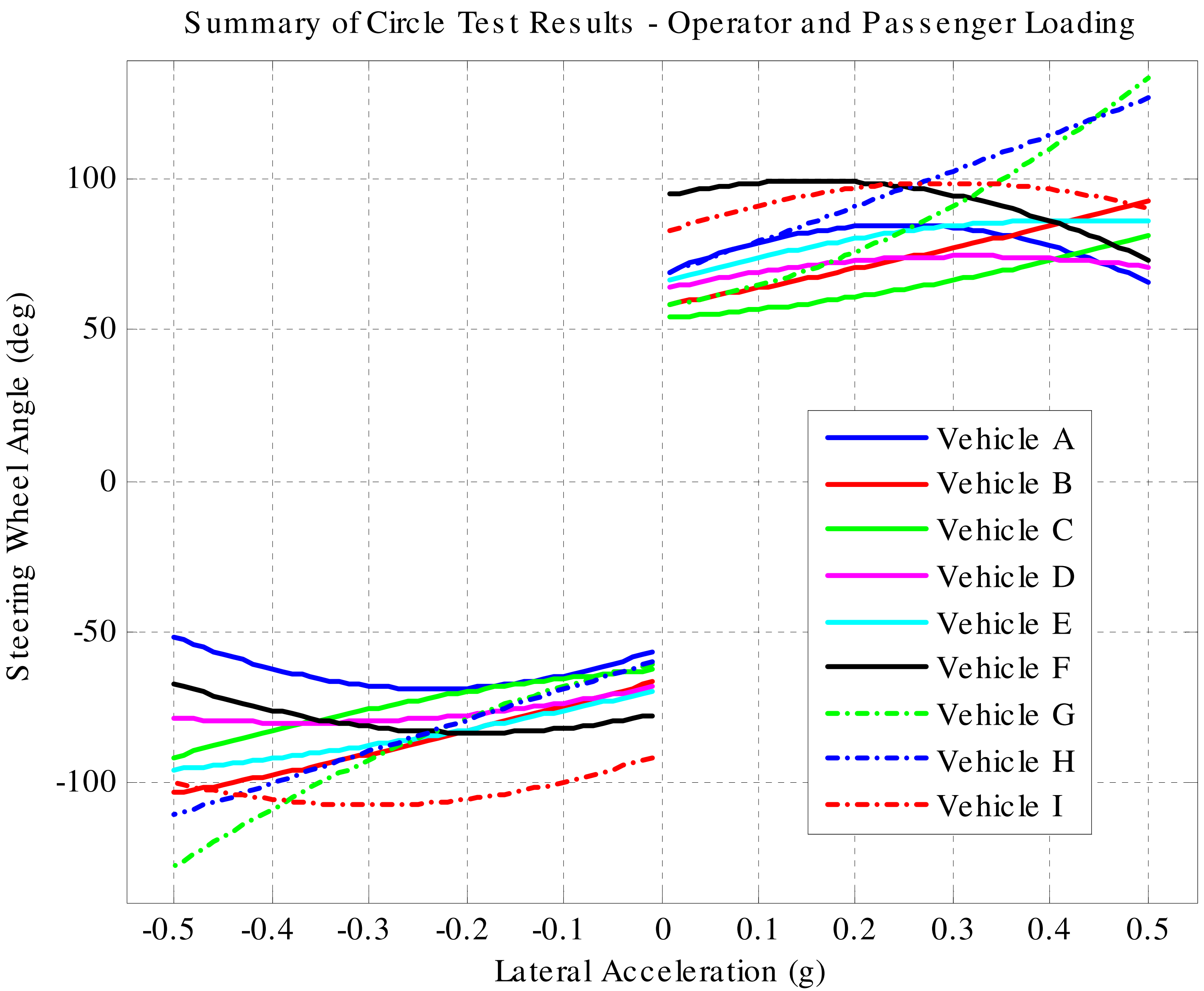

Operator and Passenger - Tilt Table Ratio - TTR
Drivers Side Leading
Passengers Side Leading
Average
TTR
0.85
0.8
0.75
0.7
0.65
0.6
0.55
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I


Operator, Instrumentation and Outriggers - Tilt Table Ratio - TTR
Drivers Side Leading
Passengers Side Leading
Average
TTR
0.85
0.8
0.75
0.7
0.65
0.6
0.55
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

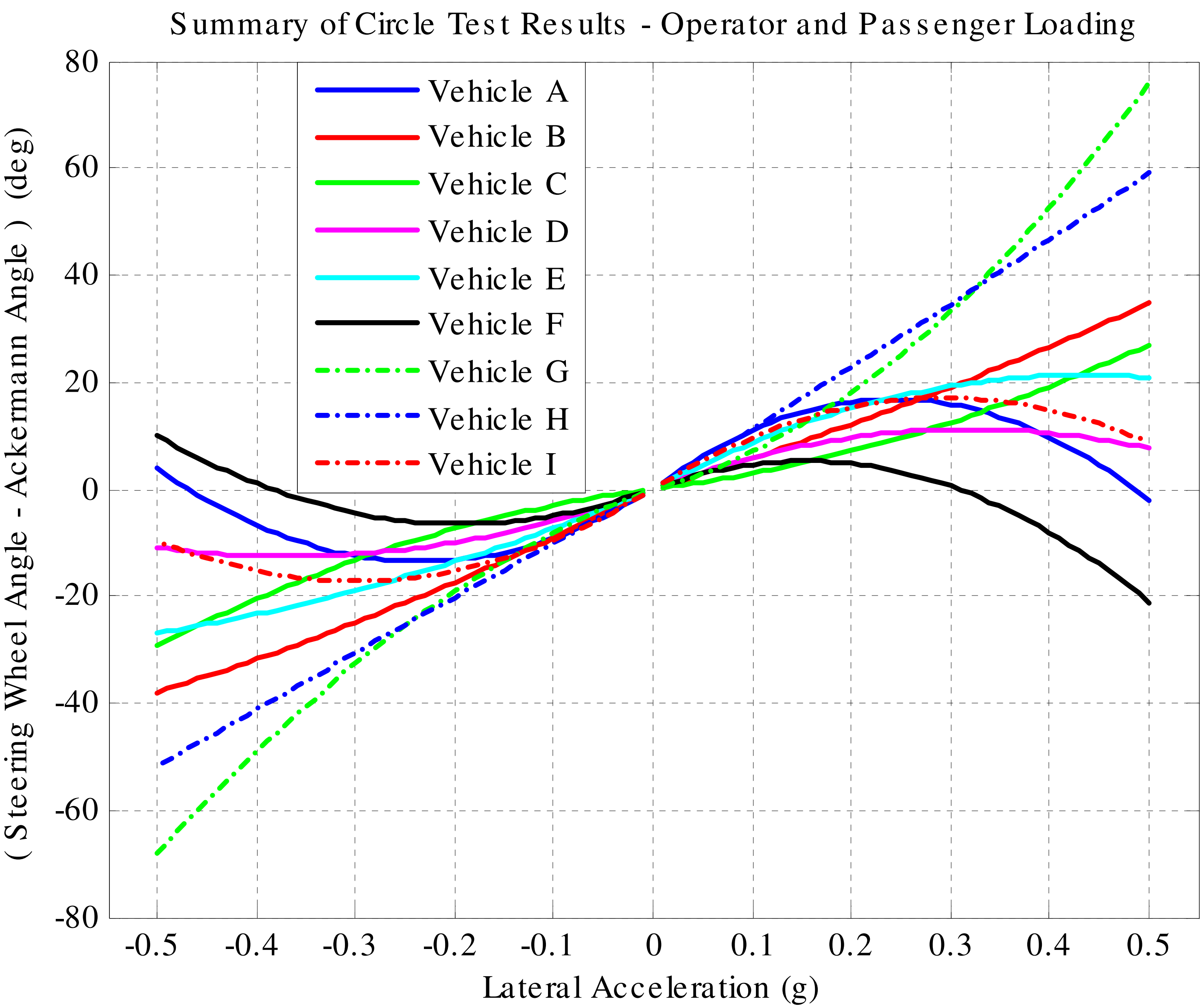

Operator and Passenger - Tilt Table Angle - TTA
Drivers Side Leading
Passengers Side Leading
Average
TTA (deg)
44
42
40
38
36
34
32
30
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

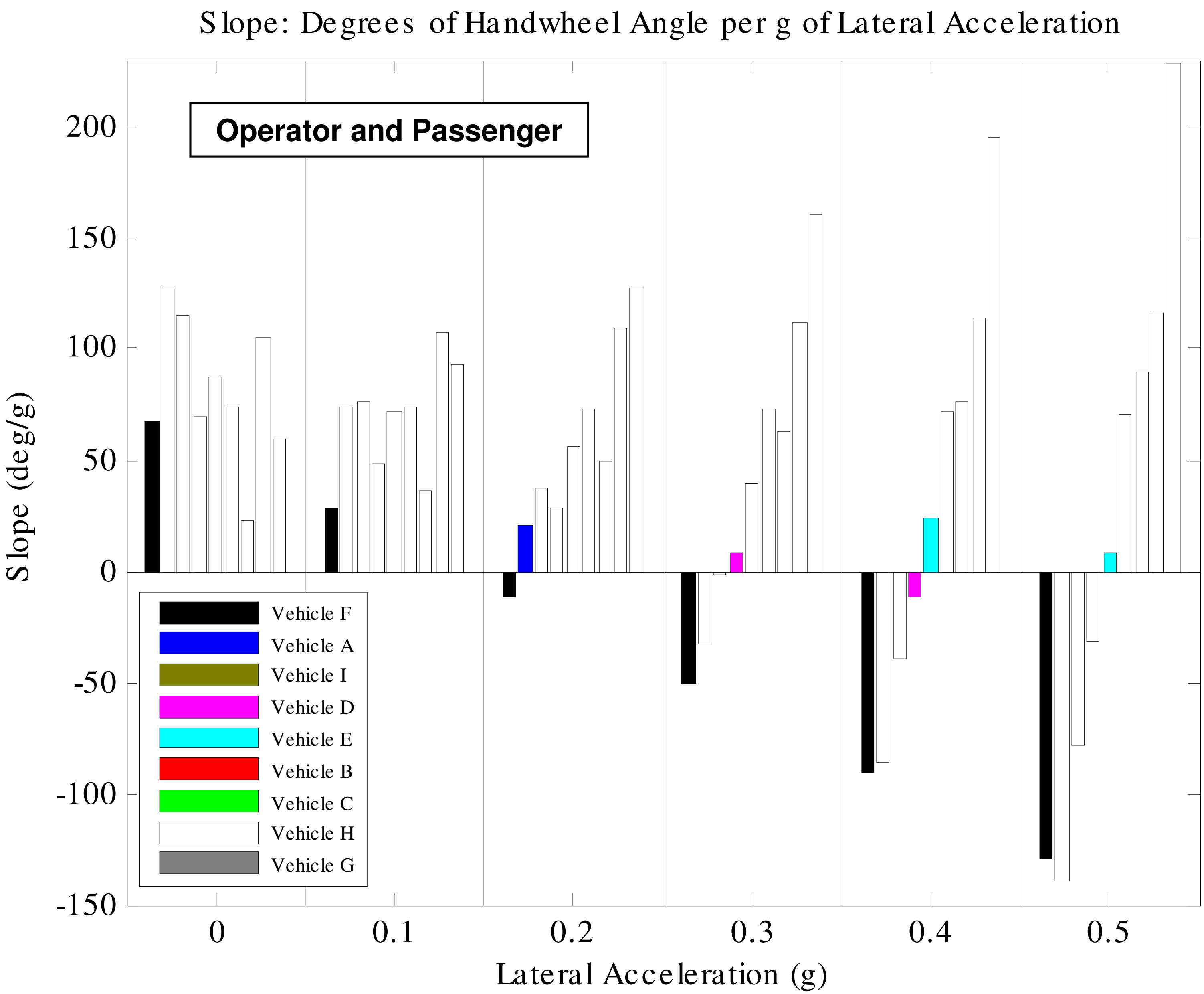


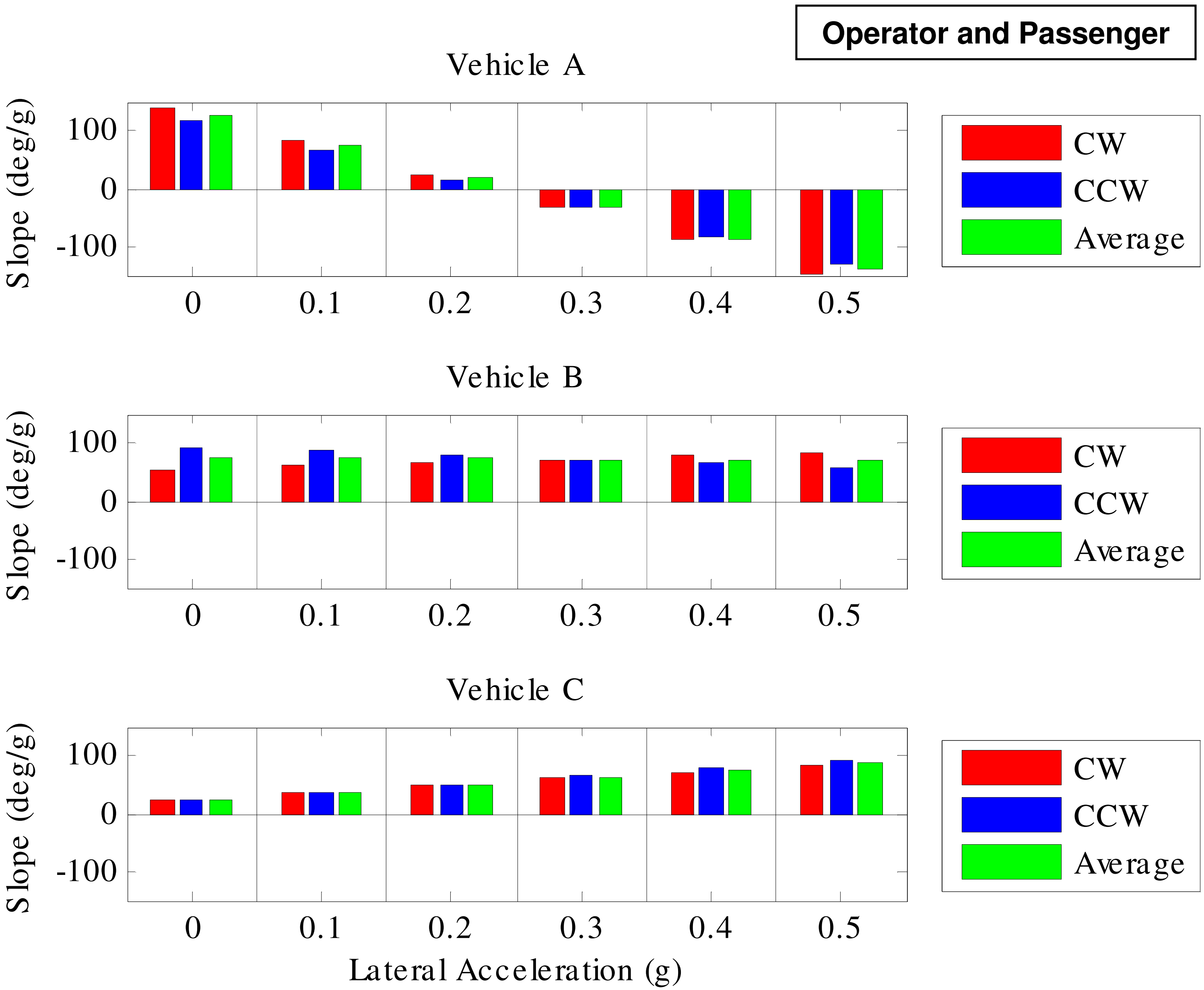
Operator, Instrumentation and Outriggers - Tilt Table Angle - TTA
Drivers Side Leading
Passengers Side Leading
Average
TTA (deg)
30
32
34
36
38
40
42
44
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

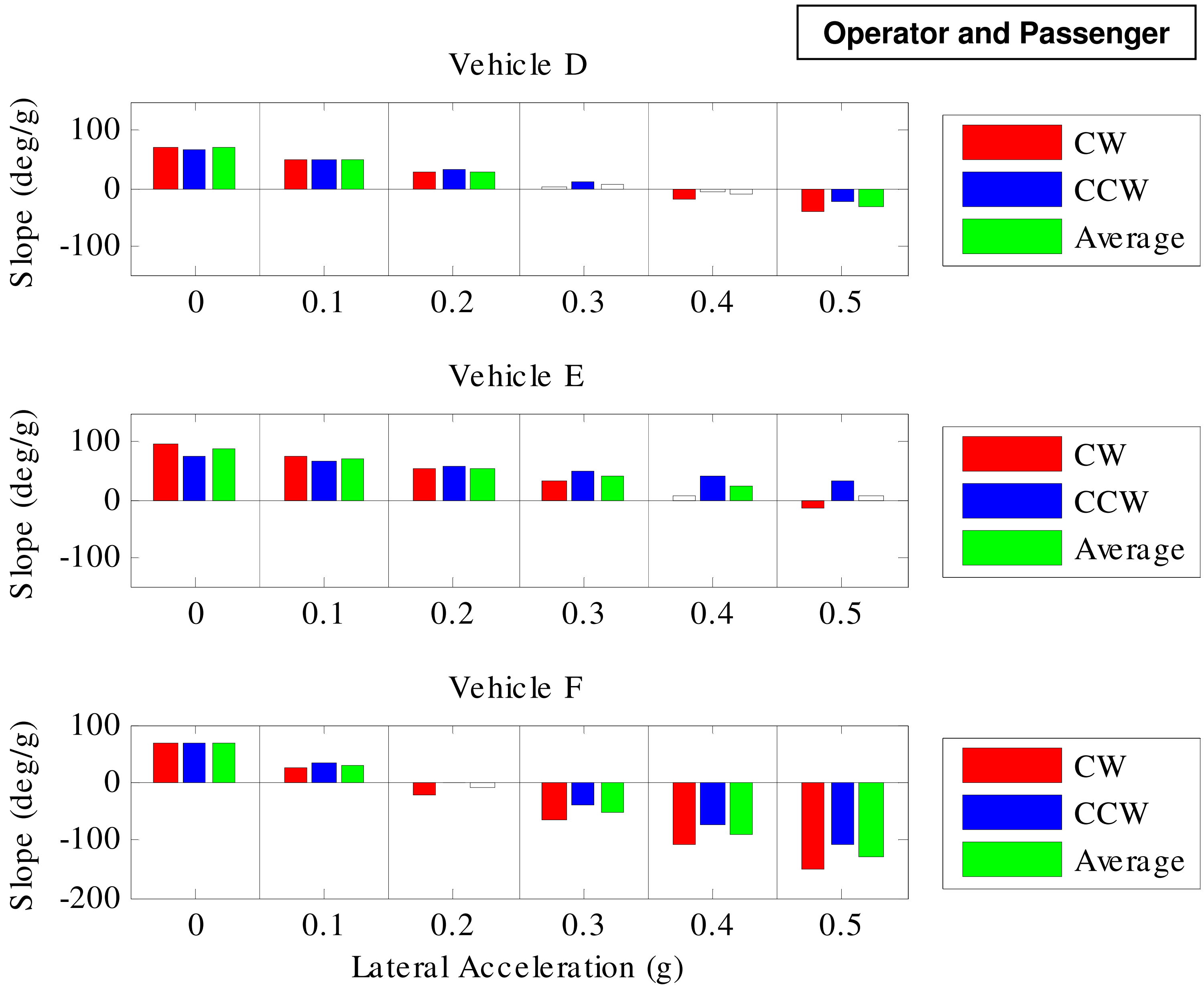


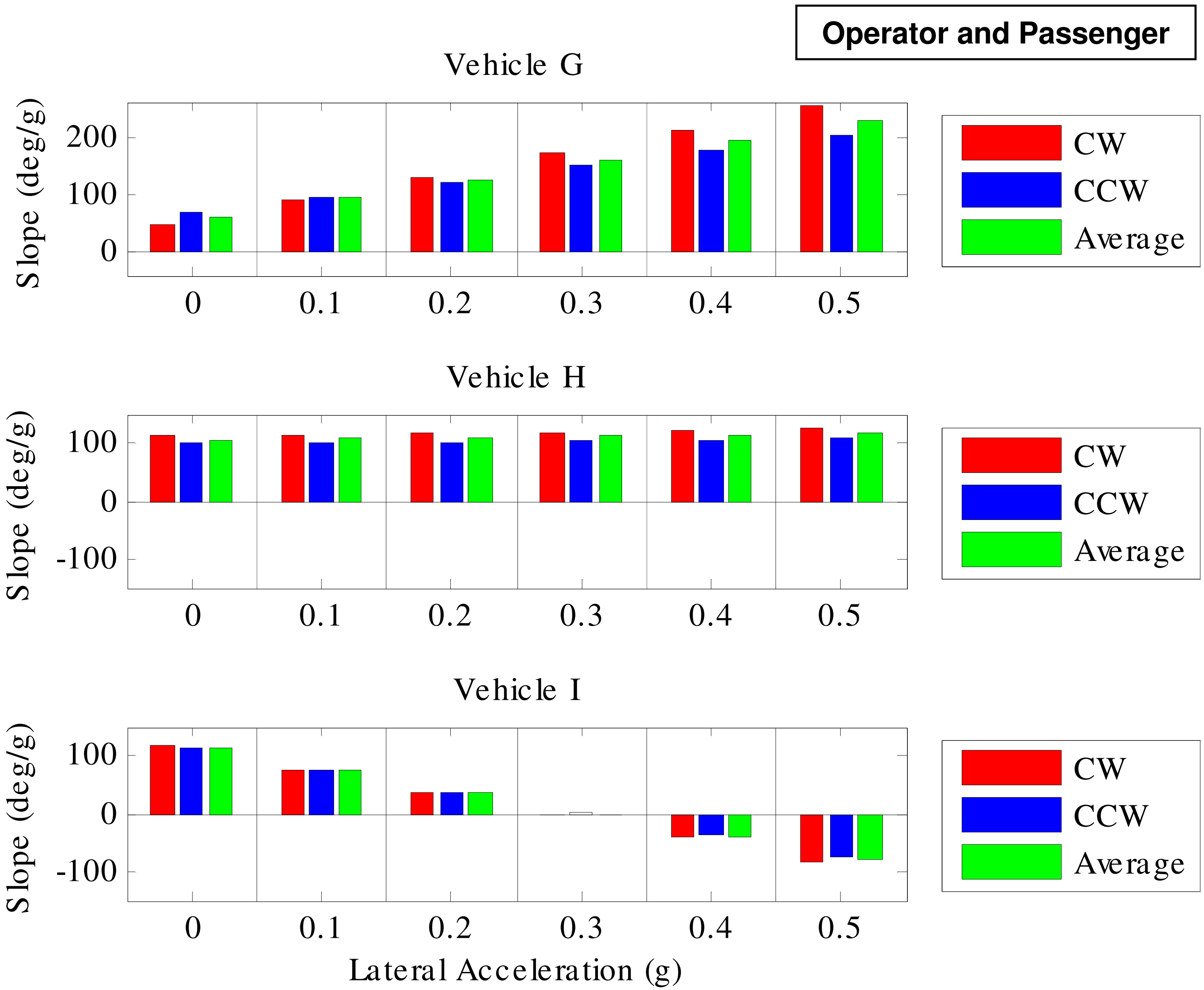
Summary of Circle Test Results - Operator and Passenger Loading
Steering Wheel Angle (deg)
100
50
0
-50
-100
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I


Summary of Circle Test Results - Operator and Passenger Loading
Vehicle A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I
(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)


Slope: Degrees of Handwheel Angle per g of Lateral Acceleration
Operator and Passenger
Slope (deg/g)
200
150
100
50
0
-50
-100
-150
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle F
Vehicle A
Vehicle I
Vehicle D
Vehicle E
Vehicle B
Vehicle C
Vehicle H
Vehicle G

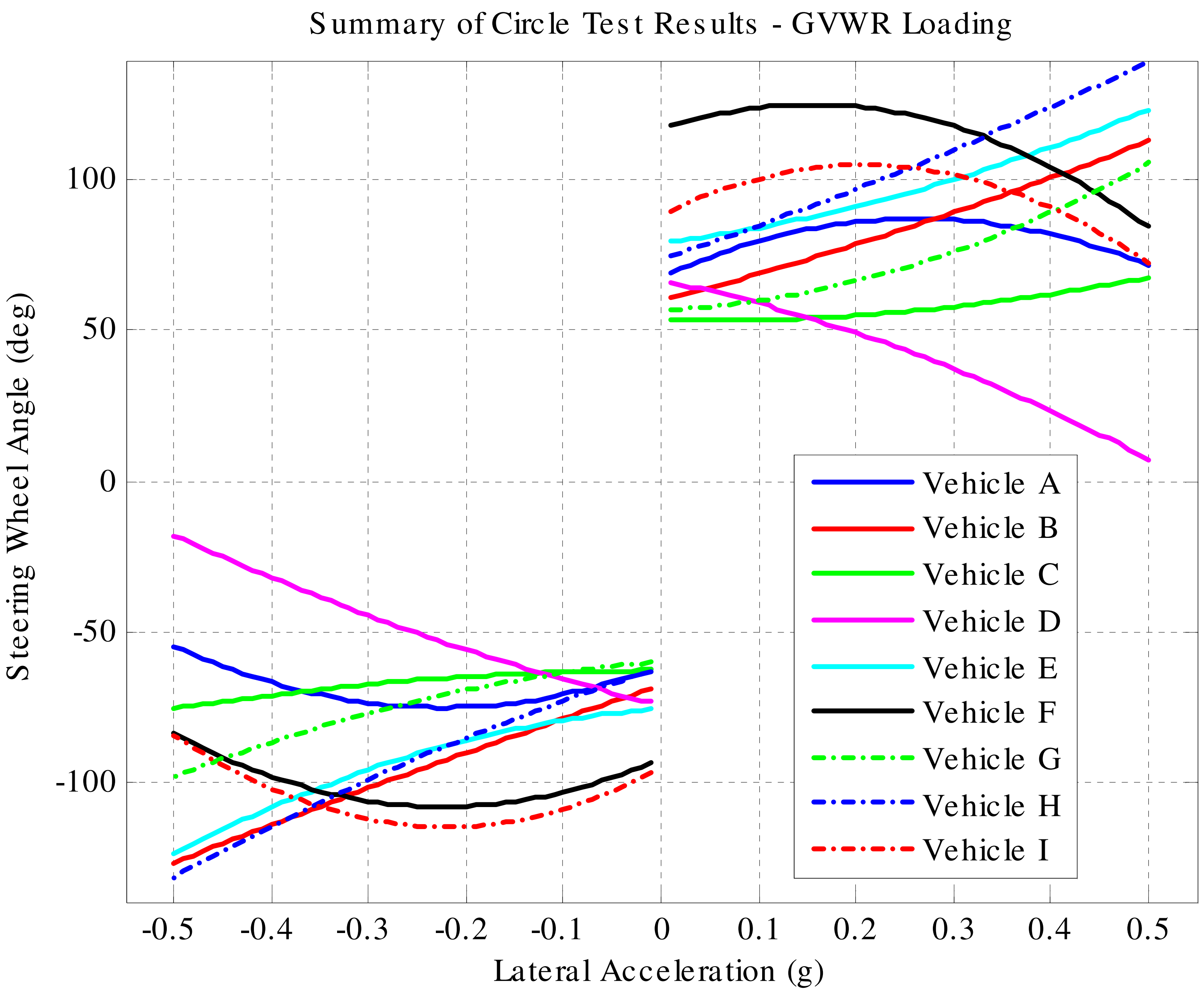

Operator and Passenger
Vehicle A
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle B
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle C
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)

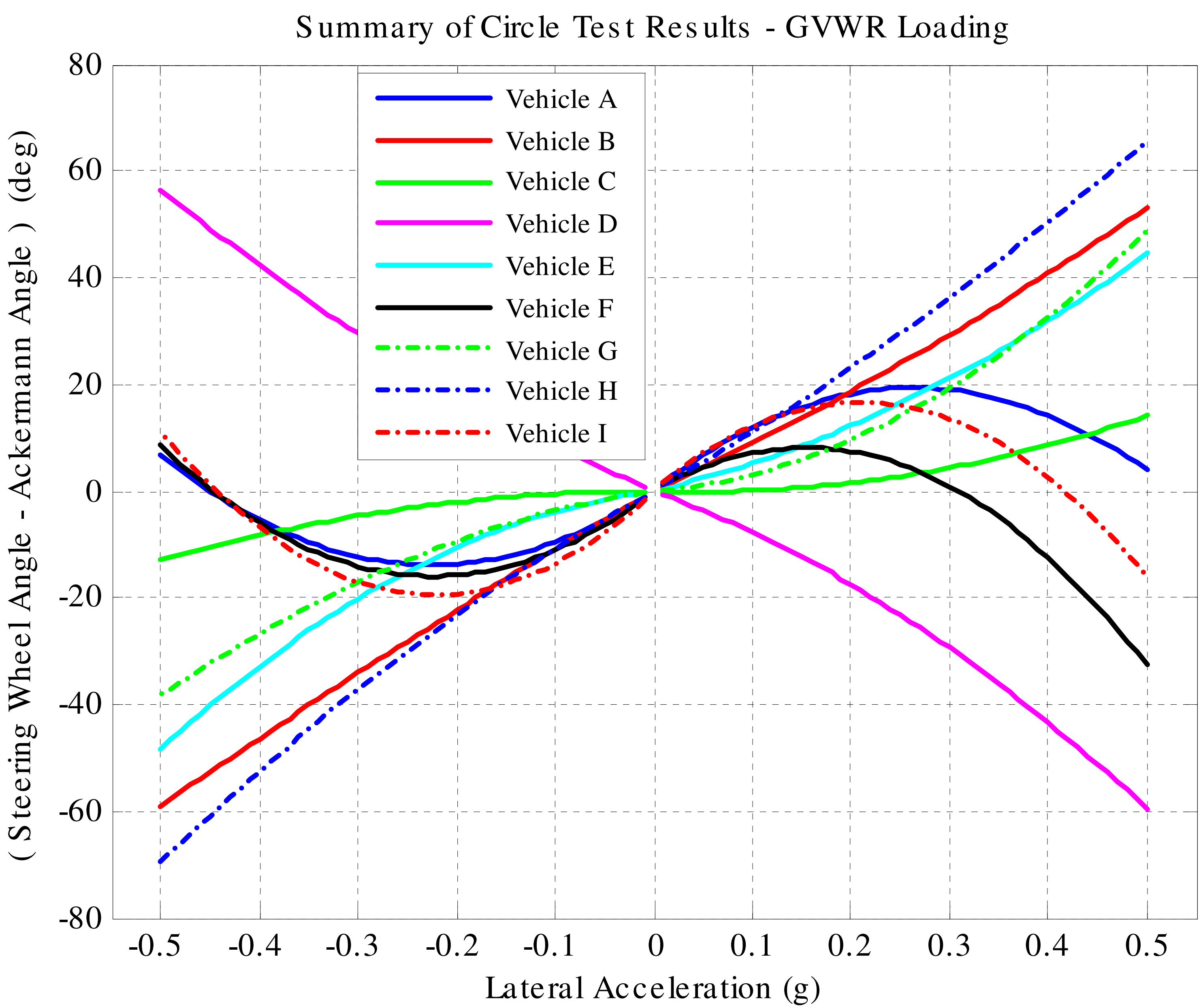

Operator and Passenger
Vehicle D
Vehicle E
Vehicle F
Slope (deg/g)
100
0
-100
-200
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

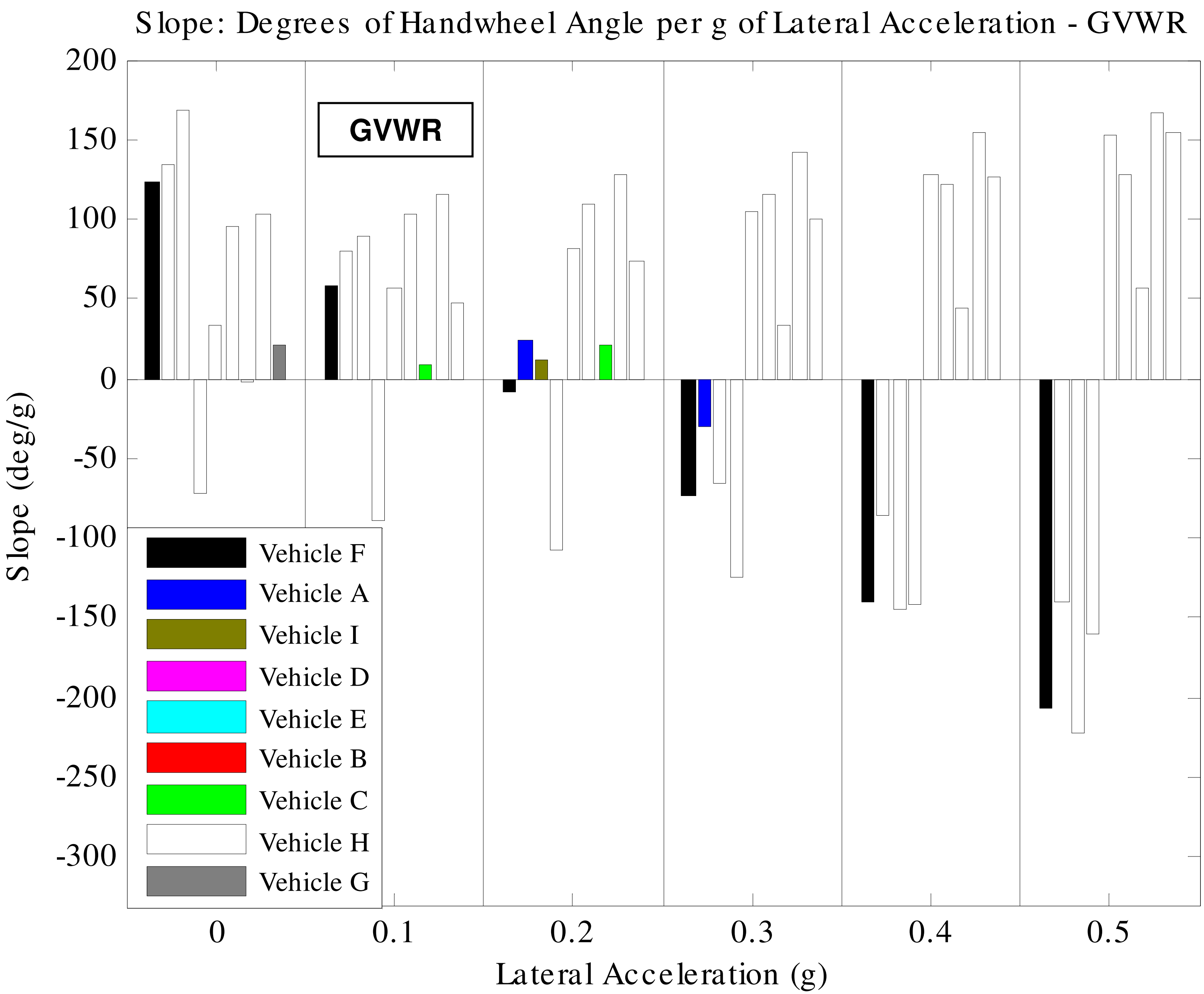


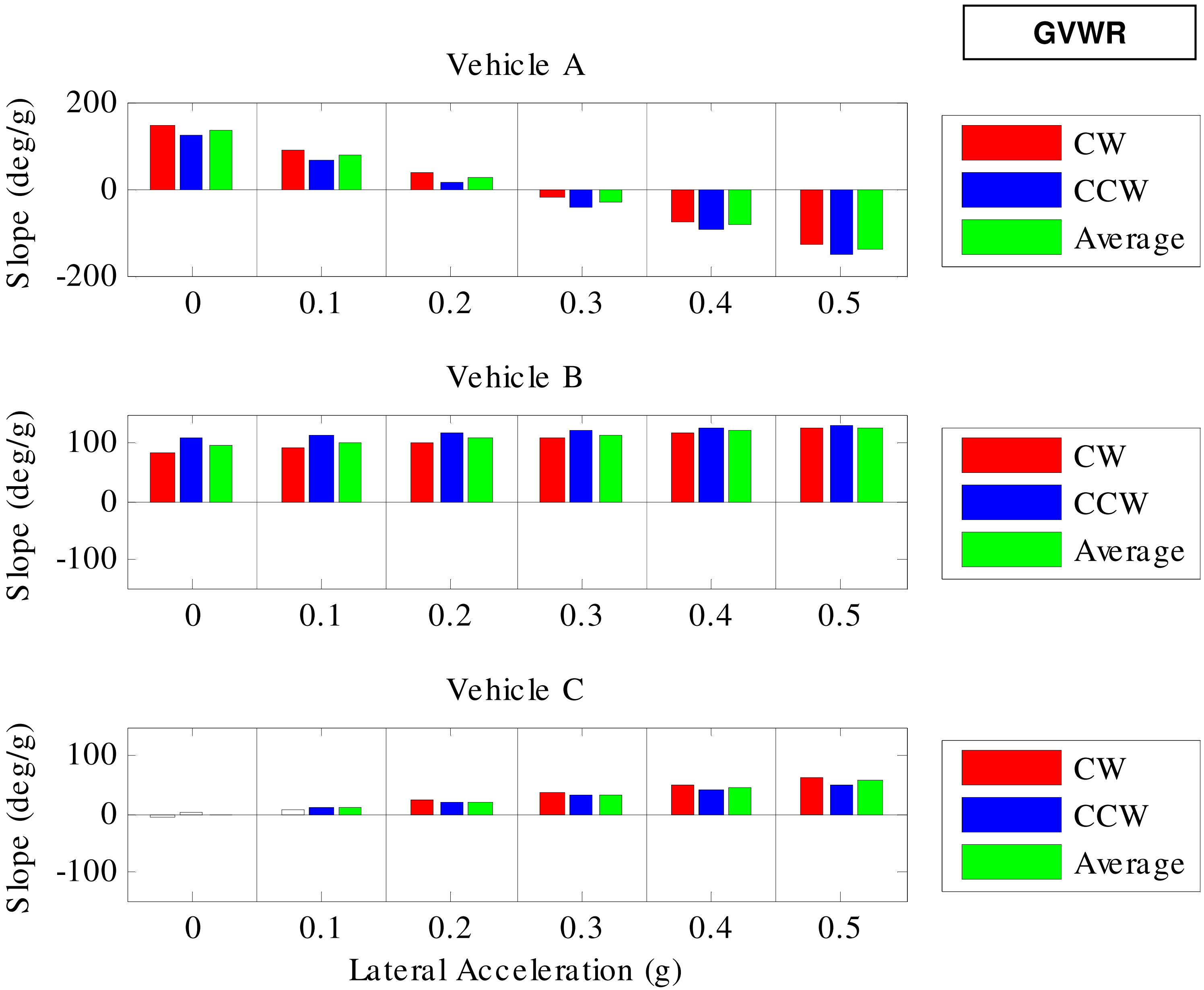
Operator and Passenger
Vehicle G
Slope (deg/g)
200
100
0
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle H
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle I
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

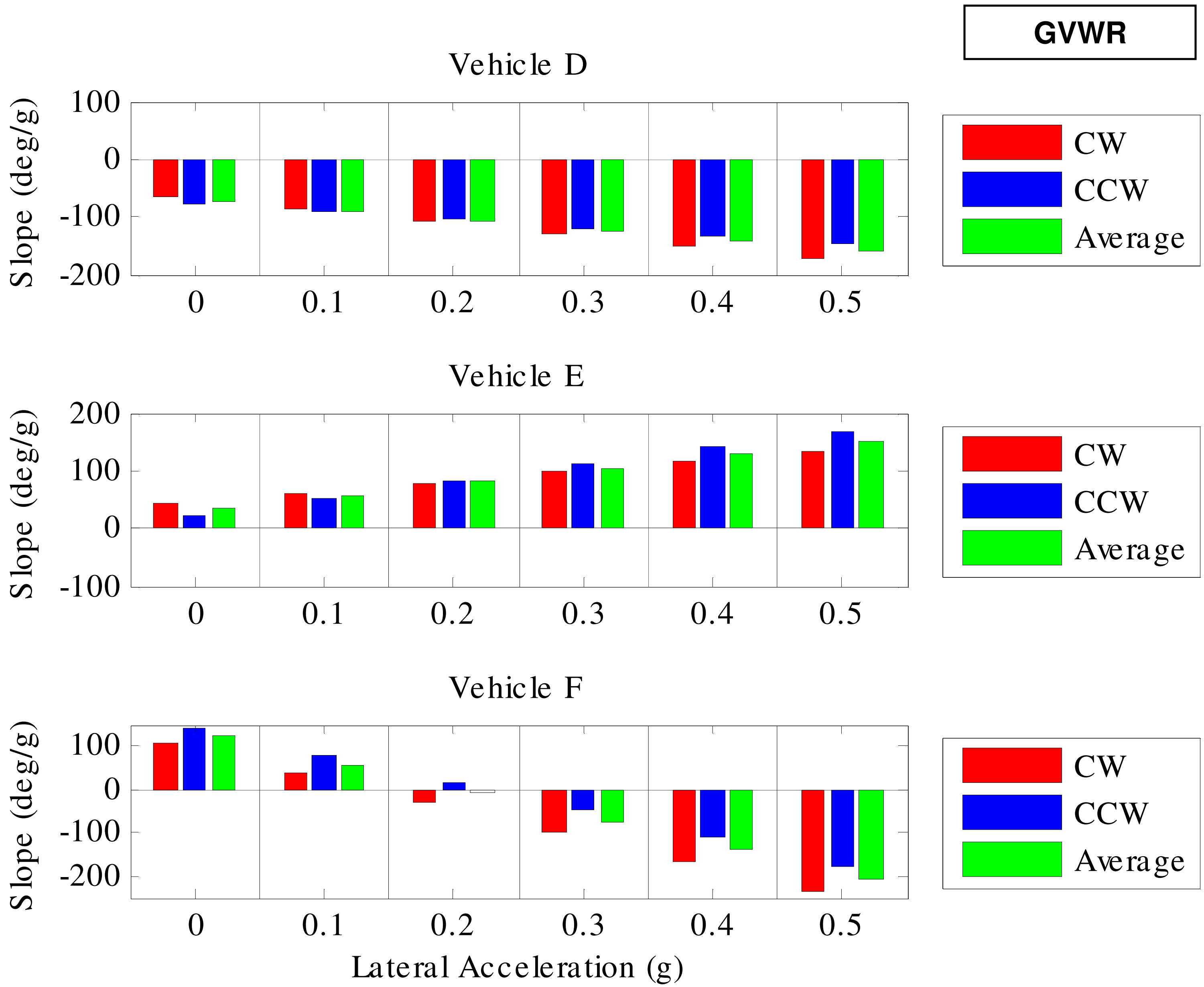
Constant Radius (100 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Operator and Passenger Loading)			
	Clockwise (g)	Counterclockwise (g)	Average (g)
Vehicle A	0.24	0.23	0.24
Vehicle B	NA	NA	NA
Vehicle C	NA	NA	NA
Vehicle D	0.32	0.37	0.35
Vehicle E	0.44	NA	NA
Vehicle F	0.15	0.19	0.17
Vehicle G	NA	NA	NA
Vehicle H	NA	NA	NA
Vehicle I	0.29	0.30	0.30

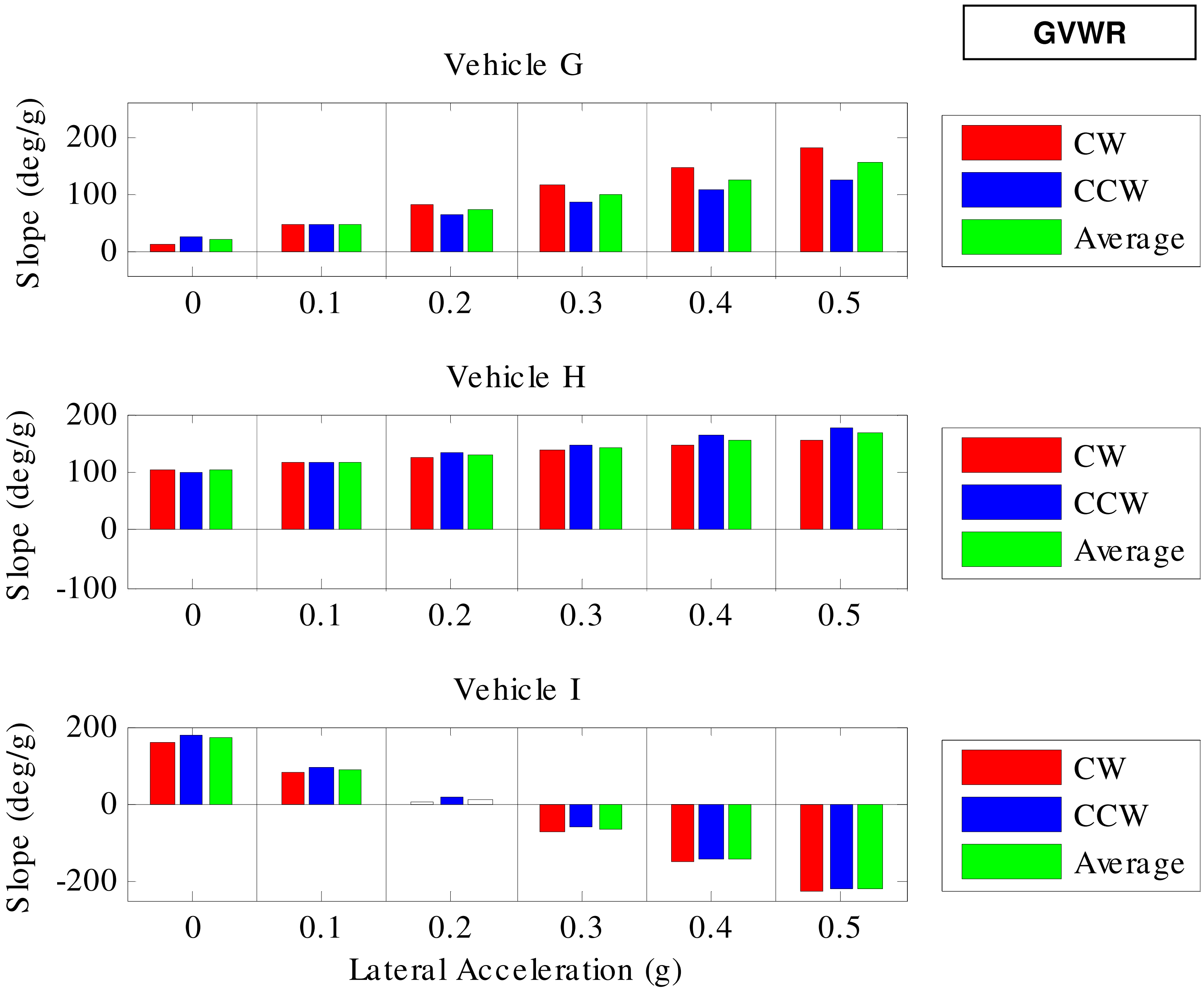

Summary of Circle Test Results - GVWR Loading
Steering Wheel Angle (deg)
100
50
0
-50
-100
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I


Summary of Circle Test Results - GVWR Loading
Vehicle A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I
(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)

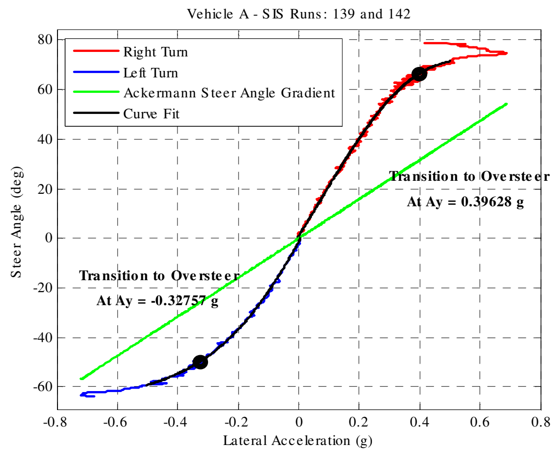

Slope: Degrees of Handwheel Angle per g of Lateral Acceleration - GVWR
GVWR
Slope (deg/g)
Lateral Acceleration (g)
200
150
100
50
0
-50
-100
-150
-200
-250
-300
0
0.1
0.2
0.3
0.4
0.5
Vehicle F
Vehicle A
Vehicle I
Vehicle D
Vehicle E
Vehicle B
Vehicle C
Vehicle H
Vehicle G

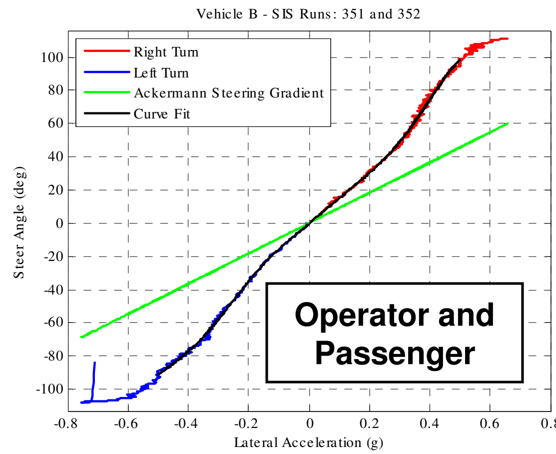

GVWR
Vehicle A
Slope (deg/g)
200
0
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle B
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle C
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

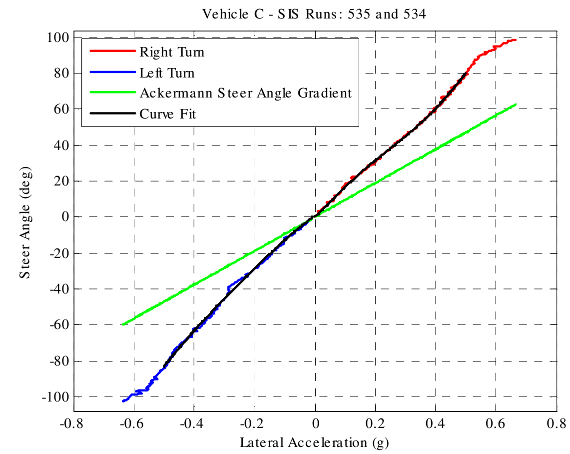

GVWR
Vehicle D
Slope (deg/g)
100
0
-100
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle E
Slope (deg/g)
200
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle F
Slope (deg/g)
100
0
-100
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)

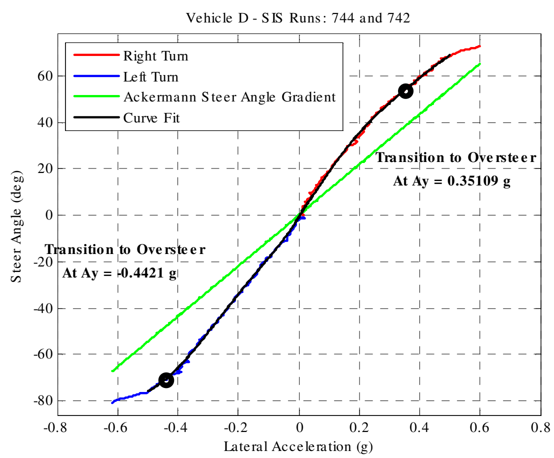

GVWR
Vehicle G
Slope (deg/g)
200
100
0
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle H
Slope (deg/g)
200
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle I
Slope (deg/g)
200
0
-200
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

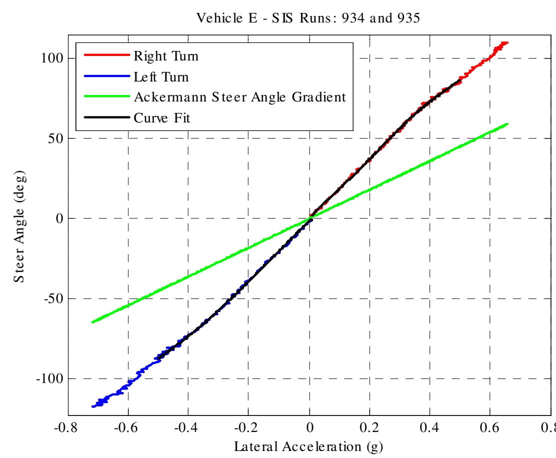
Constant Radius (100 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (GVWR)			
	Clockwise (g)	Counterclockwise (g)	Average (g)
Vehicle A	0.26	0.23	0.24
Vehicle B	NA	NA	NA
Vehicle C	NA	NA	NA
Vehicle D	0.00	0.00	0.00
Vehicle E	NA	NA	NA
Vehicle F	0.15	0.22	0.19
Vehicle G	NA	NA	NA
Vehicle H	NA	NA	NA
Vehicle I	0.21	0.22	0.21

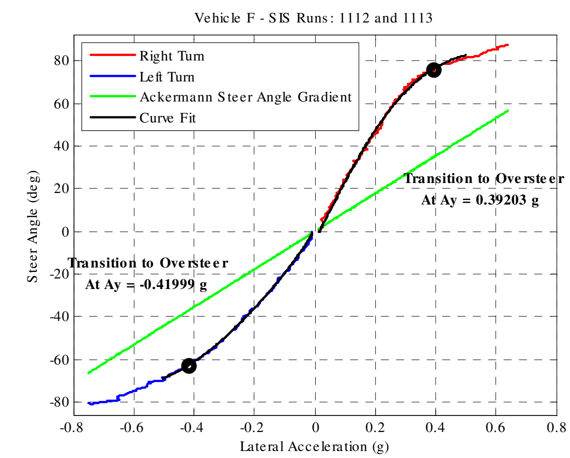

Vehicle A - SIS Runs: 139 and 142
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.39628 g
Transition to Oversteer
At Ay = -0.32757 g
Steer Angle (deg)
Lateral Acceleration (g)

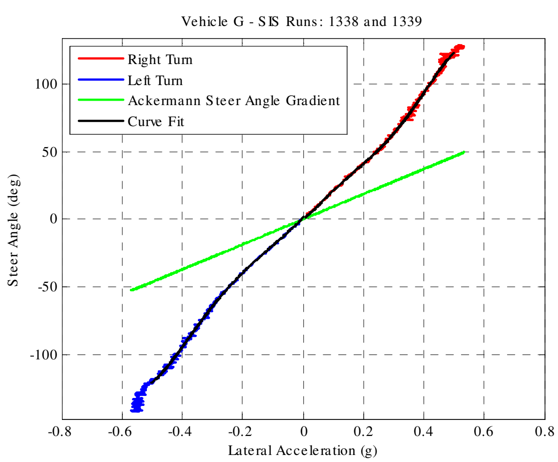

Vehicle B - SIS Runs: 351 and 352
Right Turn
Left Turn
Ackermann Steering Gradient
Curve Fit
Operator and Passenger
Steer Angle (deg)
Lateral Acceleration (g)

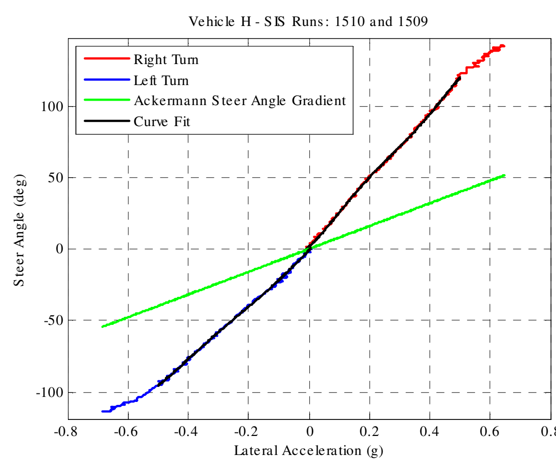

Vehicle C - SIS Runs: 535 and 534
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)

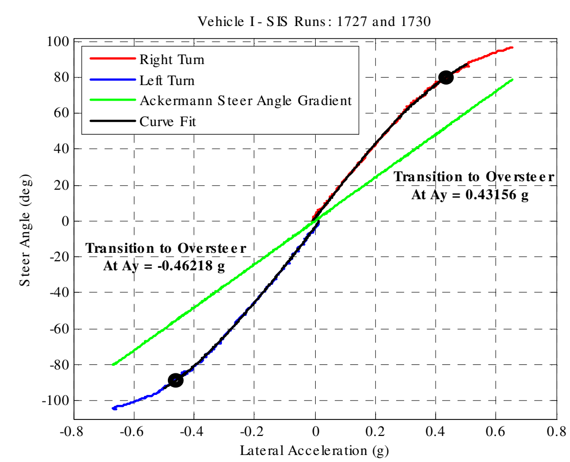

Vehicle D - SIS Runs: 744 and 742
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.35109 g
Transition to Oversteer
At Ay = -0.4421 g
Steer Angle (deg)
Lateral Acceleration (g)


Vehicle E - SIS Runs: 934 and 935
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)

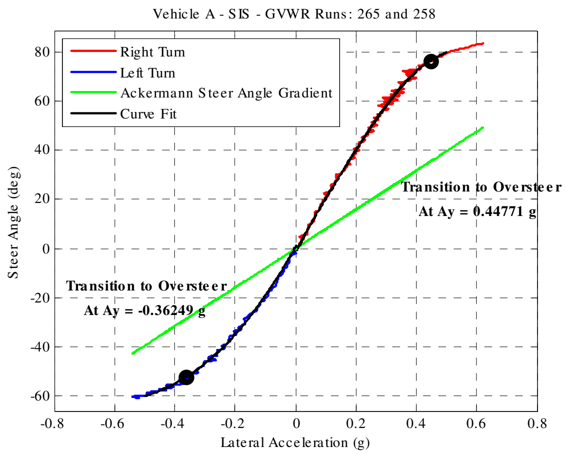

Vehicle F - SIS Runs: 1112 and 1113
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.39203 g
Transition to Oversteer
At Ay = -0.41999 g
Steer Angle (deg)
Lateral Acceleration (g)

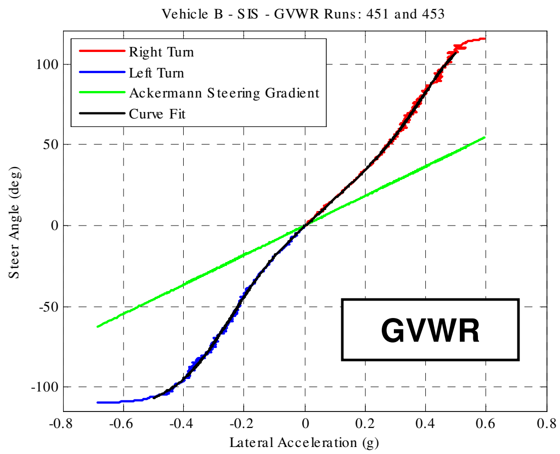

Vehicle G - SIS Runs: 1338 and 1339
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)

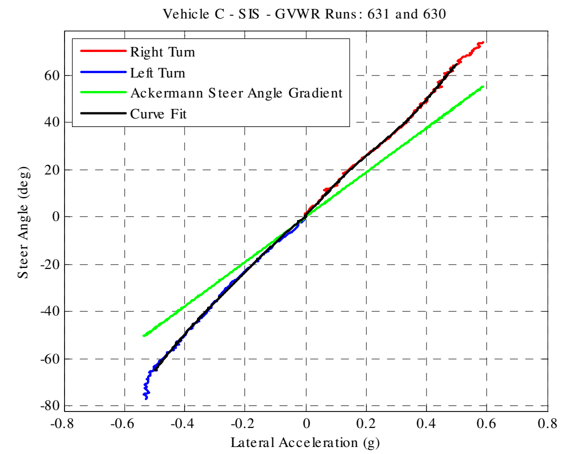

Vehicle H - SIS Runs: 1510 and 1509
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)

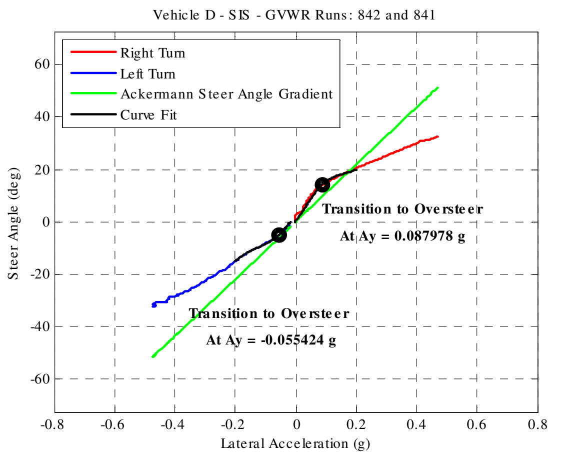

Vehicle I - SIS Runs: 1727 and 1730
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.43156 g
Transition to Oversteer
At Ay = -0.46218 g
Steer Angle (deg)
Lateral Acceleration (g)

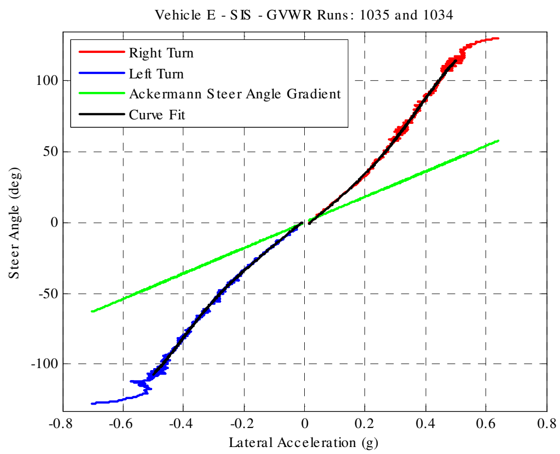
Constant Speed (30 mph) Slowly Increasing Steer Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Operator and Passenger Loading)			
	Right Turn (g)	Left Turn (g)	Average (g)
Vehicle A	0.40	0.33	0.37
Vehicle B	NA	NA	NA
Vehicle C	NA	NA	NA
Vehicle D	0.35	0.44	0.40
Vehicle E	NA	NA	NA
Vehicle F	0.39	0.42	0.41
Vehicle G	NA	NA	NA
Vehicle H	NA	NA	NA
Vehicle I	0.43	0.46	0.45

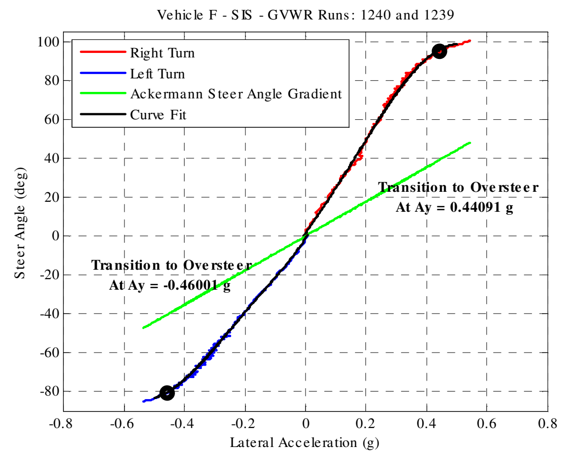

Vehicle A - SIS - GVWR Runs: 265 and 258
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.44771 g
Transition to Oversteer
At Ay = -0.36249 g
Steer Angle (deg)
Lateral Acceleration (g)

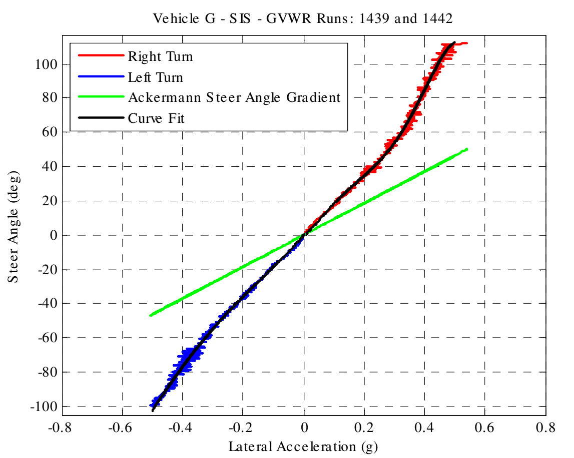

Vehicle B - SIS - GVWR Runs: 451 and 453
Right Turn
Left Turn
Ackermann Steering Gradient
Curve Fit
GVWR
Steer Angle (deg)
Lateral Acceleration (g)

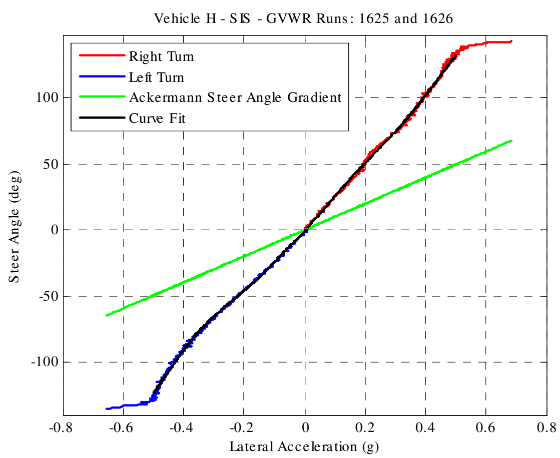

Vehicle C - SIS - GVWR Runs: 631 and 630
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)

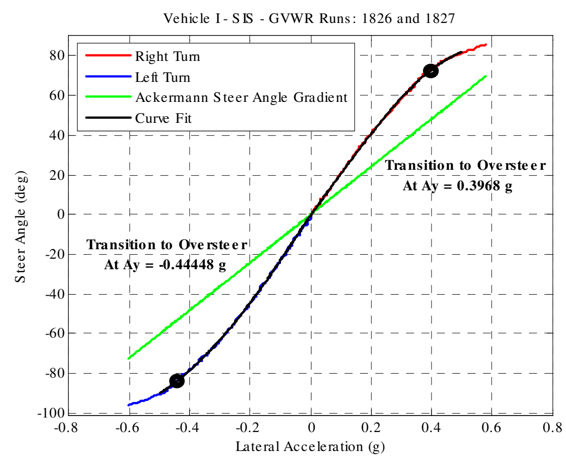

Vehicle D - SIS - GVWR Runs: 842 and 841
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.087978 g
Transition to Oversteer
At Ay = -0.055424 g
Steer Angle (deg)
Lateral Acceleration (g)


Vehicle E - SIS - GVWR Runs: 1035 and 1034
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)

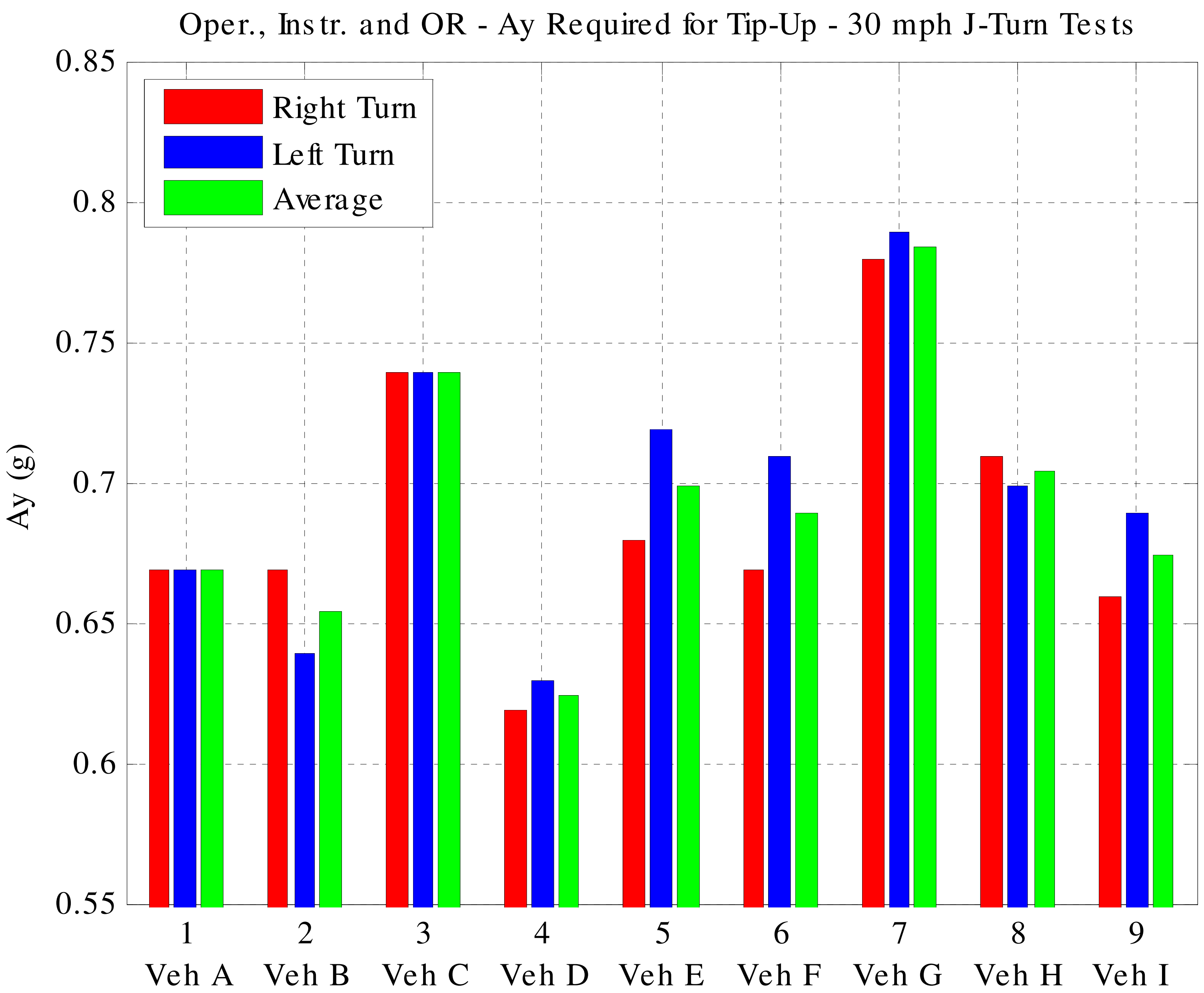

Vehicle F - SIS - GVWR Runs: 1240 and 1239
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.44091 g
Transition to Oversteer
At Ay = -0.46001 g
Steer Angle (deg)
Lateral Acceleration (g)

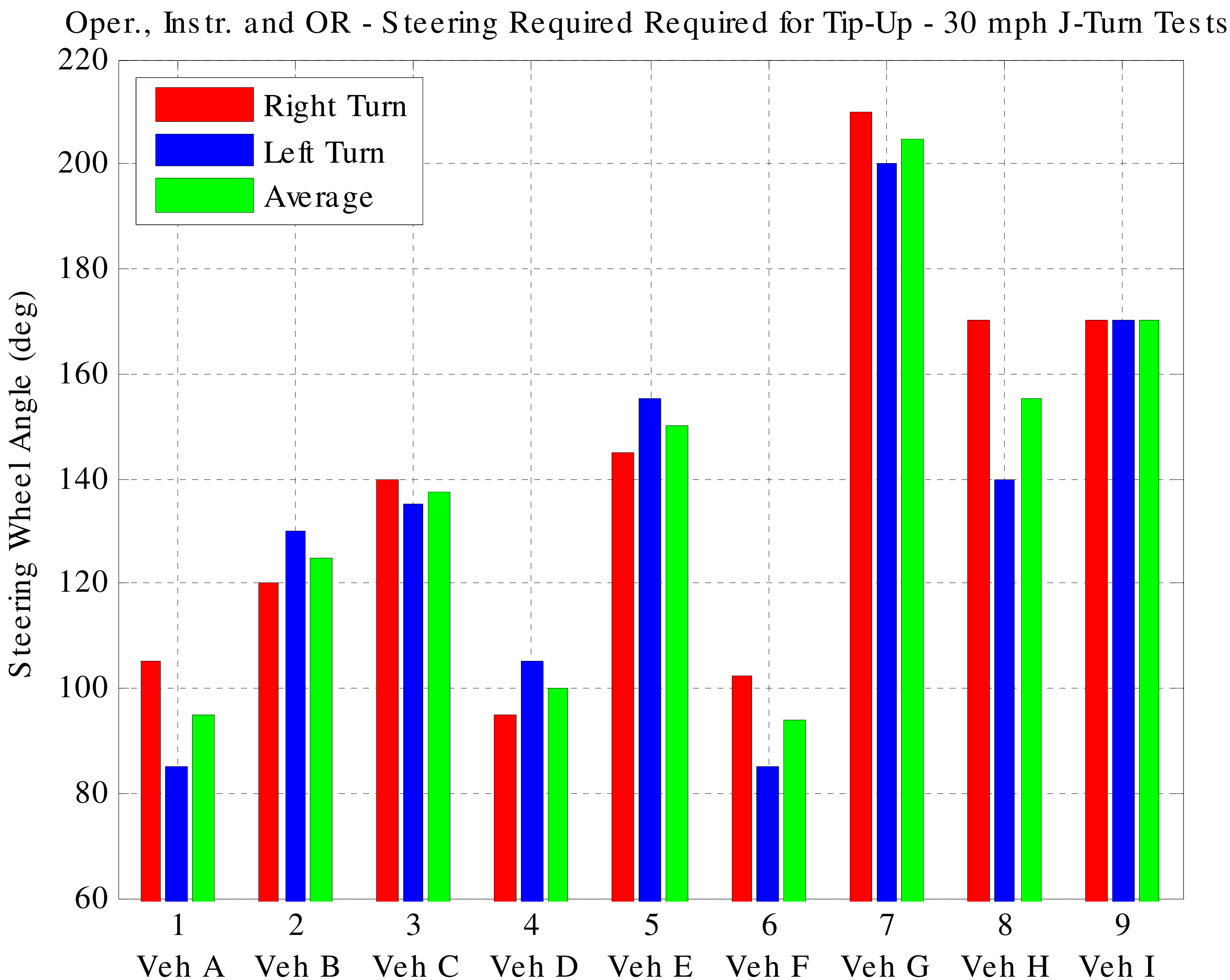

Vehicle G - SIS - GVWR Runs: 1439 and 1442
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)


Vehicle H - SIS - GVWR Runs: 1625 and 1626
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)


Vehicle I - SIS - GVWR Runs: 1826 and 1827
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.3968 g
Transition to Oversteer
At Ay = -0.44448 g
Steer Angle (deg)
Lateral Acceleration (g)

Constant Speed (30 mph) Slowly Increasing Steer Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (GVWR)			
	Right Turn (g)	Left Turn (g)	Average (g)
Vehicle A	0.45	0.36	0.41
Vehicle B	NA	NA	NA
Vehicle C	NA	NA	NA
Vehicle D	0.09	0.06	0.07
Vehicle E	NA	NA	NA
Vehicle F	0.44	0.46	0.45
Vehicle G	NA	NA	NA
Vehicle H	NA	NA	NA
Vehicle I	0.40	0.44	0.42


Oper., Instr. and OR - Ay Required for Tip-Up - 30 mph J-Turn Tests
Right Turn
Left Turn
Average
Ay (g)
0.85
0.8
0.75
0.7
0.65
0.6
0.55
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I

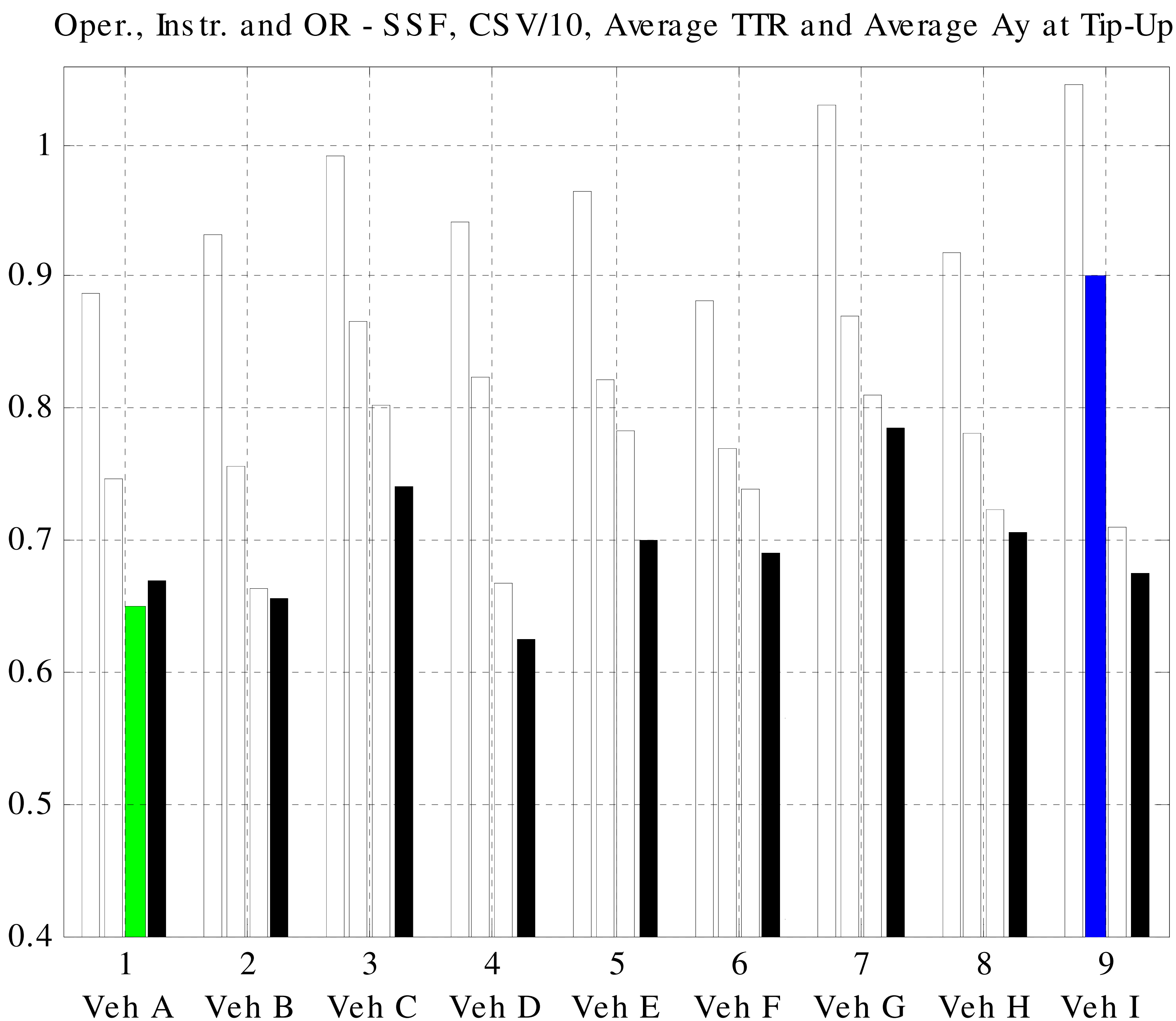


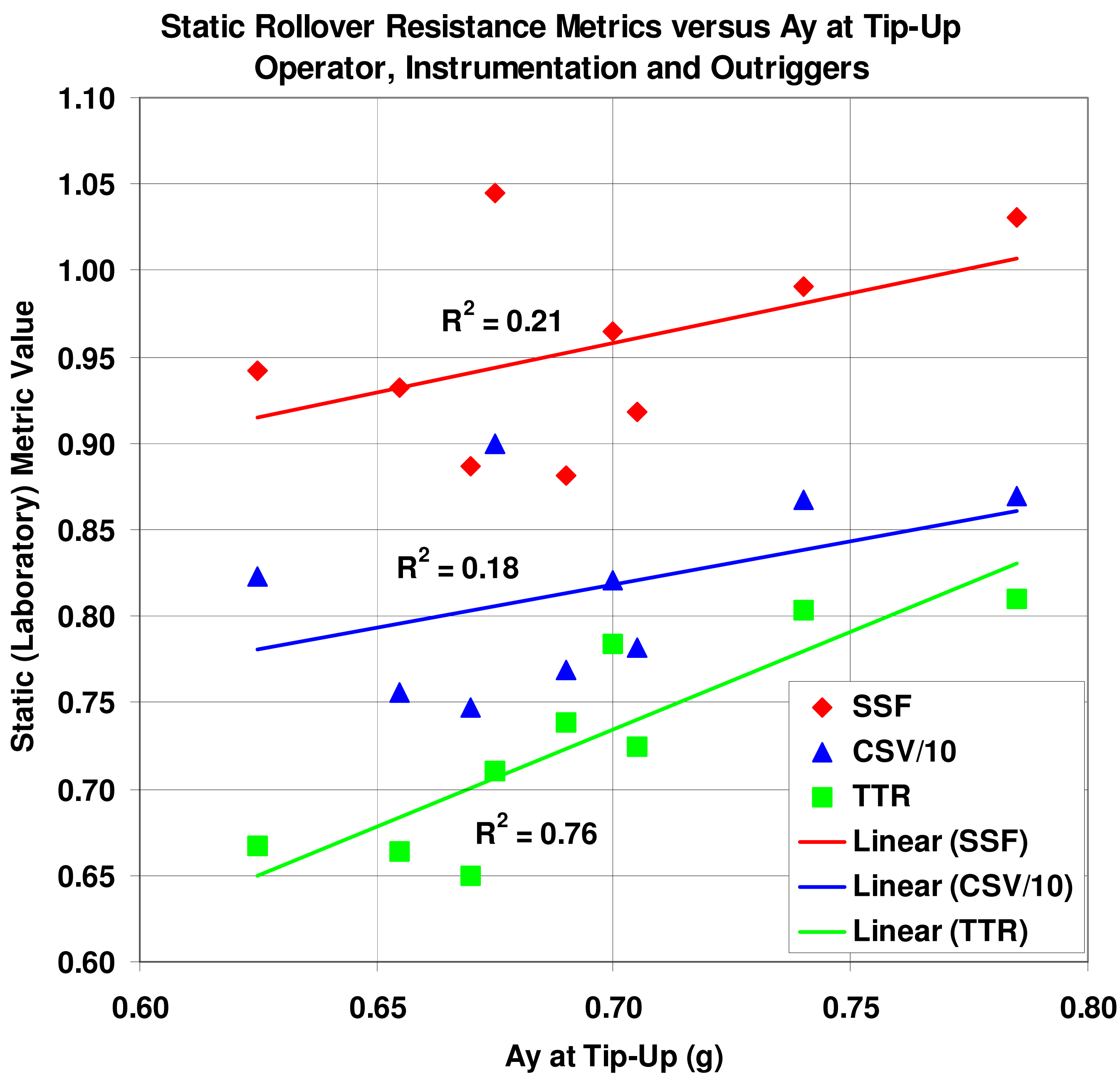
Oper., Instr. and OR - Steering Required Required for Tip-Up - 30 mph J-Turn Tests
Right Turn
Left Turn
Average
Steering Wheel Angle (deg)
220
200
180
160
140
120
100
80
60
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

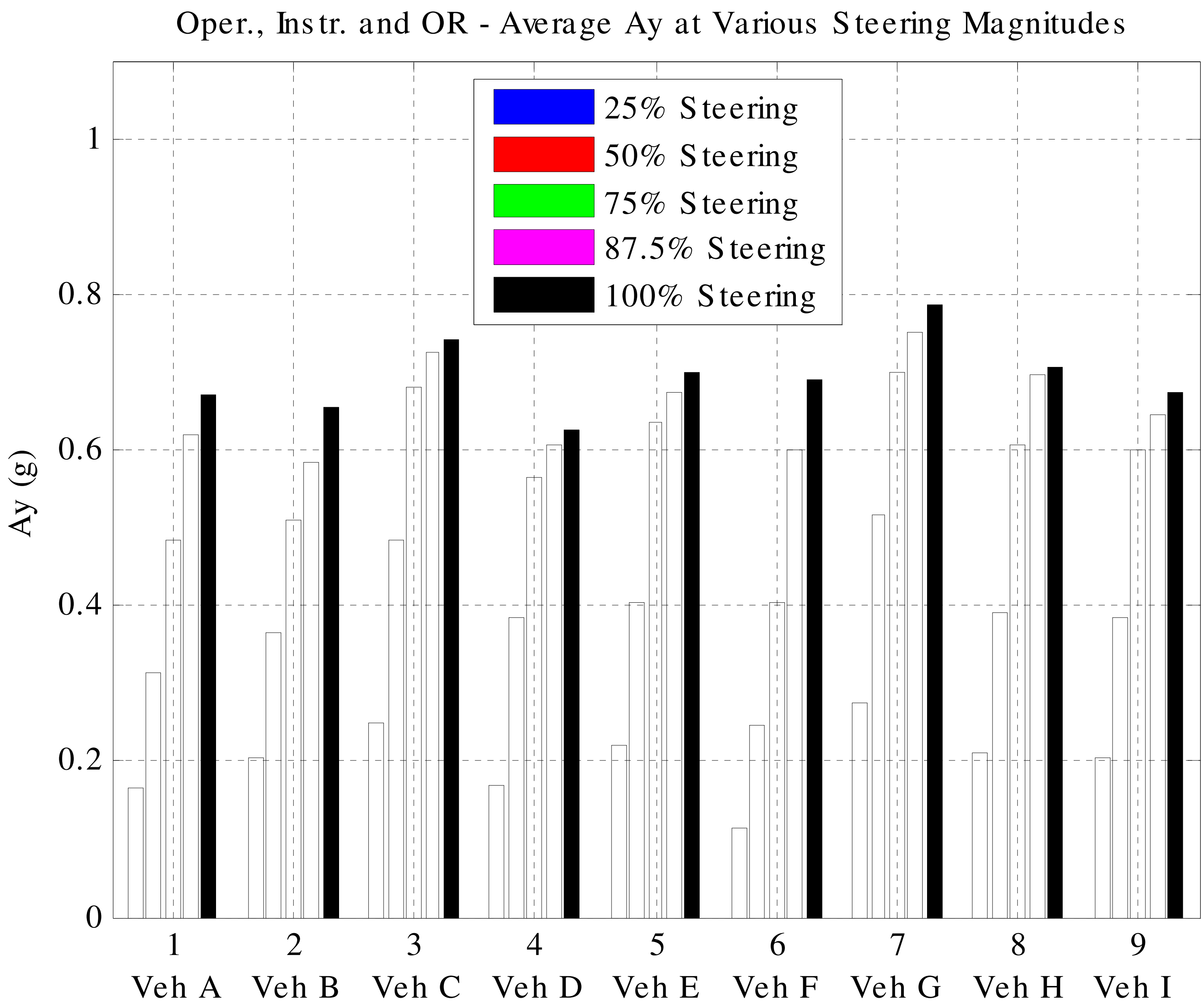
Summary of Ay and Steering Required for Tip-Up in 30 mph J-Turns and Static Rollover Resistance Metrics (Operator, Instrumentation and Outriggers)					
Vehicle	Ay at Tip-Up (g)	Steering at Tip-Up (deg)	SSF (--)	CSV/10 (mph/10)	TTR (--)
A	0.670	95.0	0.887	0.747	0.650
B	0.655	125.0	0.932	0.756	0.664
C	0.740	137.5	0.991	0.867	0.803
D	0.625	100.0	0.942	0.823	0.667
E	0.700	150.0	0.965	0.821	0.784
F	0.690	93.8	0.881	0.769	0.739
G	0.785	205.0	1.031	0.869	0.810
H	0.705	155.0	0.918	0.782	0.724
I	0.675	170.0	1.045	0.900	0.710

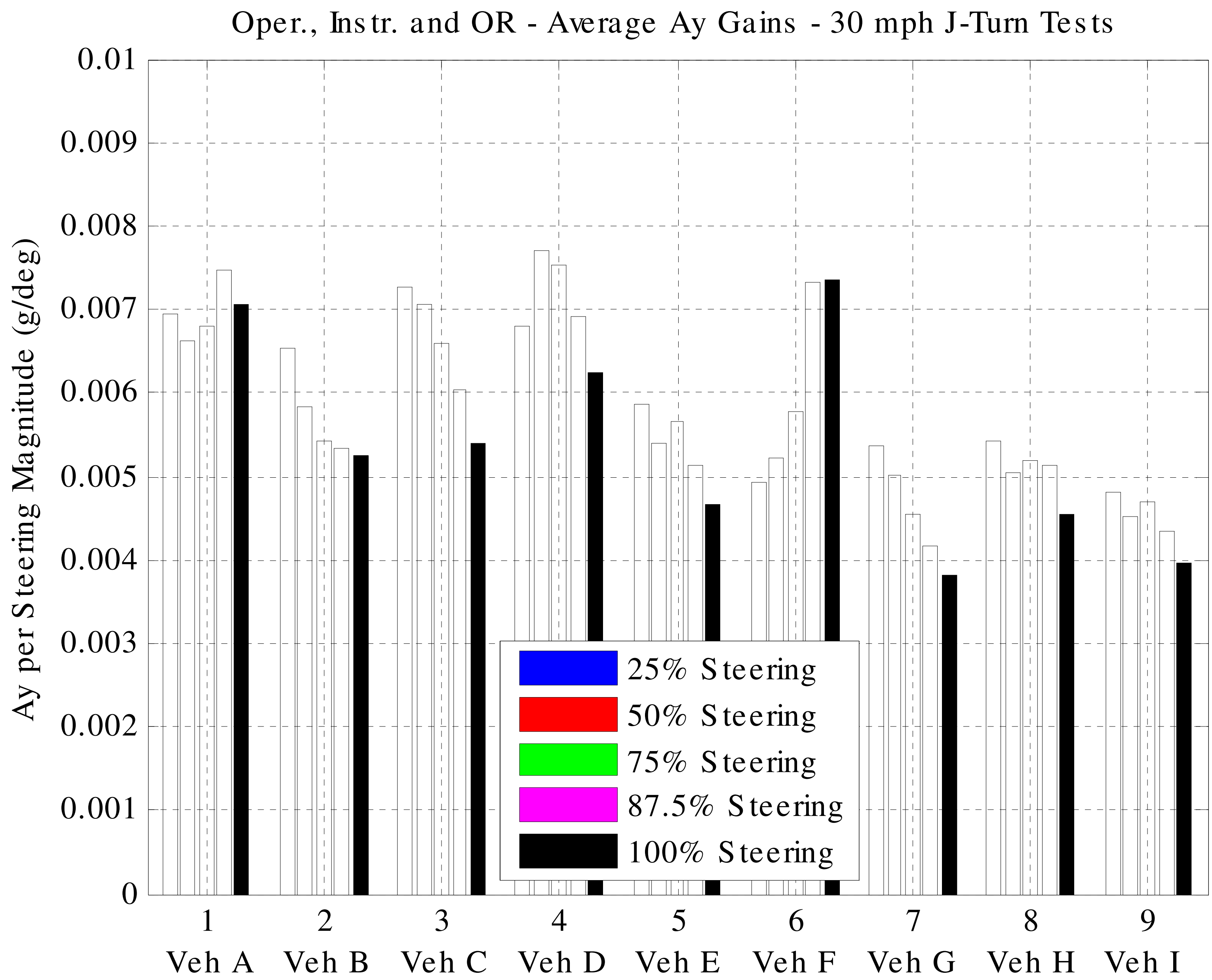
Vehicle Ascending Rank Order of Ay and Steering Required for Tip-Up in J-Turns and Static Rollover Resistance Metrics (Operator, Instrumentation and Outriggers)				
Ay at Tip-Up (g)	Steering at Tip-Up (deg)	SSF (--)	CSV/10 (mph/10)	TTR (--)
D	F	F	A	A
B	A	A	B	B
A	D	H	F	D
I	B	B	H	I
F	C	D	E	H
E	E	E	D	F
H	H	C	C	E
C	I	G	G	C
G	G	I	I	G

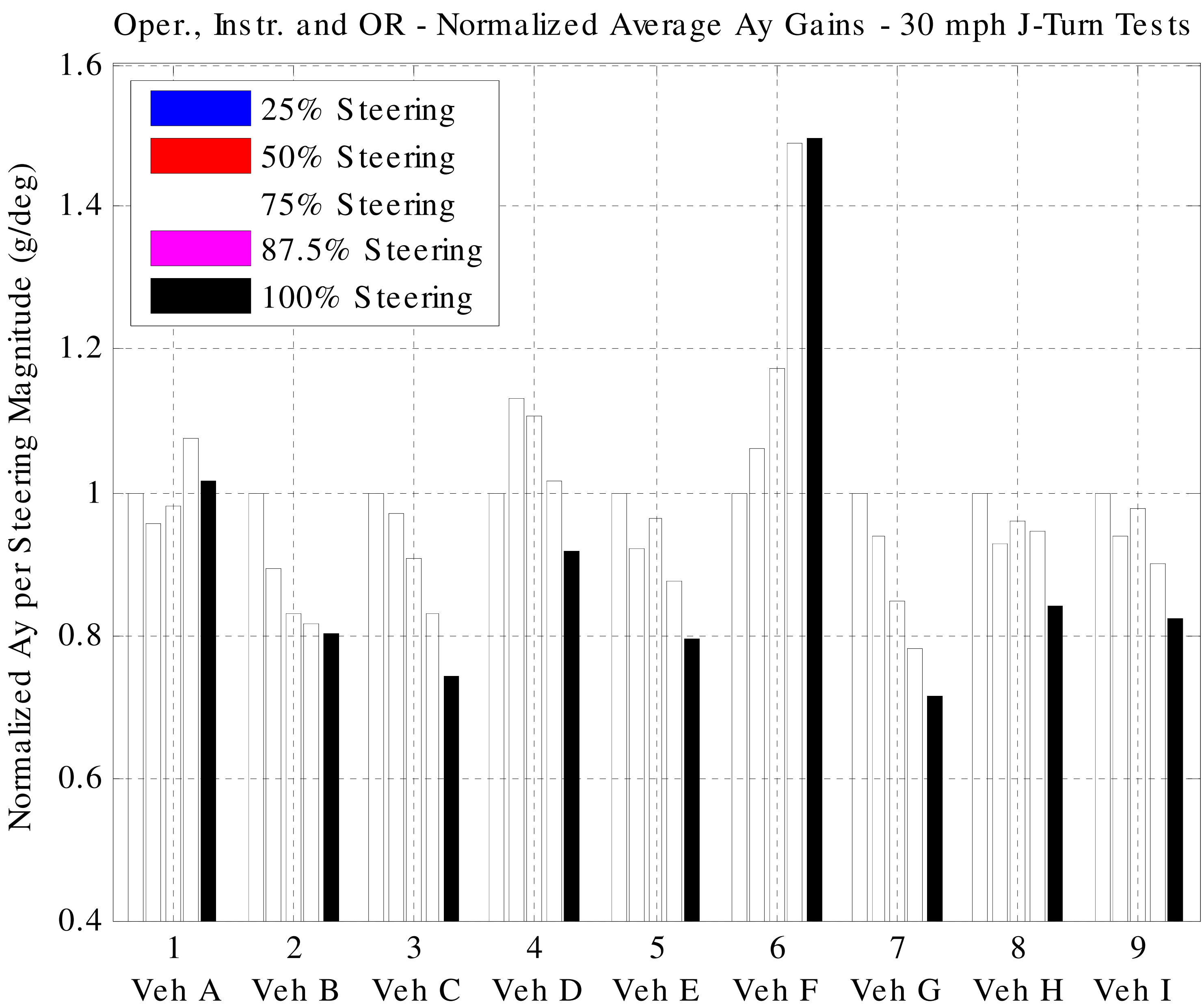
Vehicles A, D, F, and I exhibited transient from Understeer to Oversteer in Circle and SIS Tests
Vehicle I is the 4-Passenger Vehicle

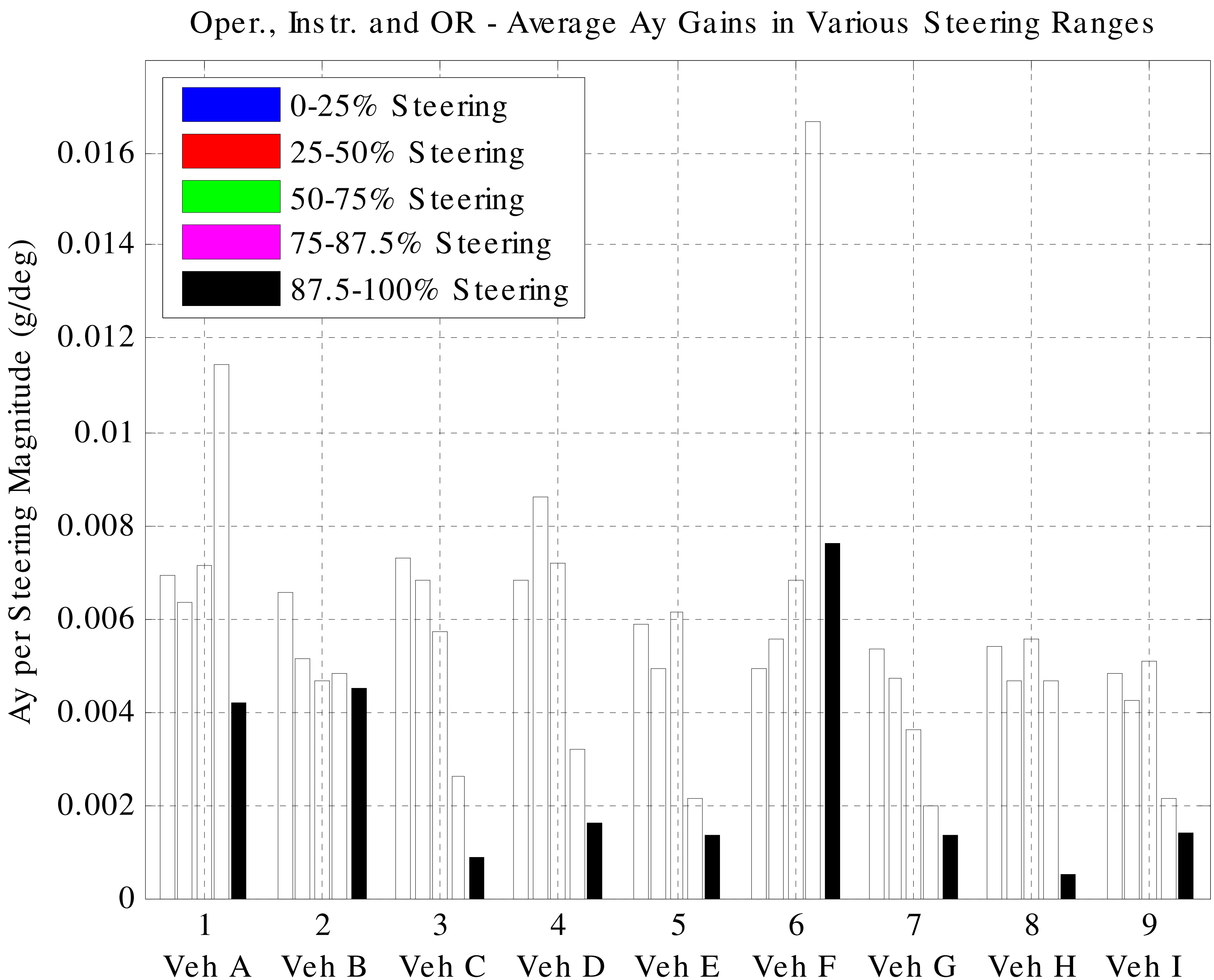

Oper., Instr. and OR - SSF, CSV/10, Average TTR and Average Ay at Tip-Up
1
0.9
0.8
0.7
0.6
0.5
0.4
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I

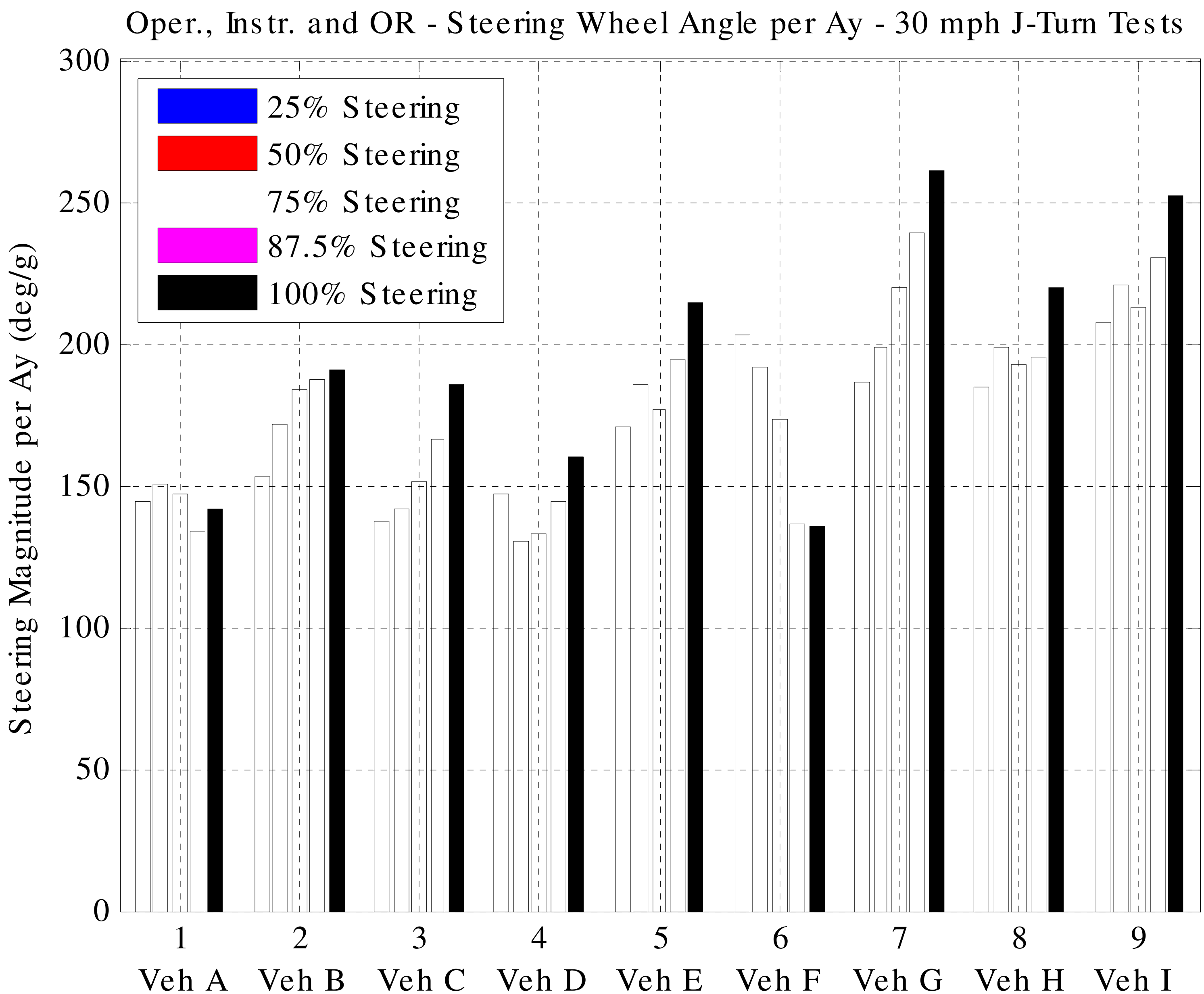

Static Rollover Resistance Metrics versus Ay at Tip-Up
Operator, Instrumentation and Outriggers
Static (Laboratory) Metric Value
Ay at Tip-Up (g)
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.60
0.65
0.70
0.75
0.80
R2 = 0.21
R2 = 0.18
R2 = 0.76
SSF
CSV/10
TTR
Linear (SSF)
Linear (CSV/10)
Linear (TTR)

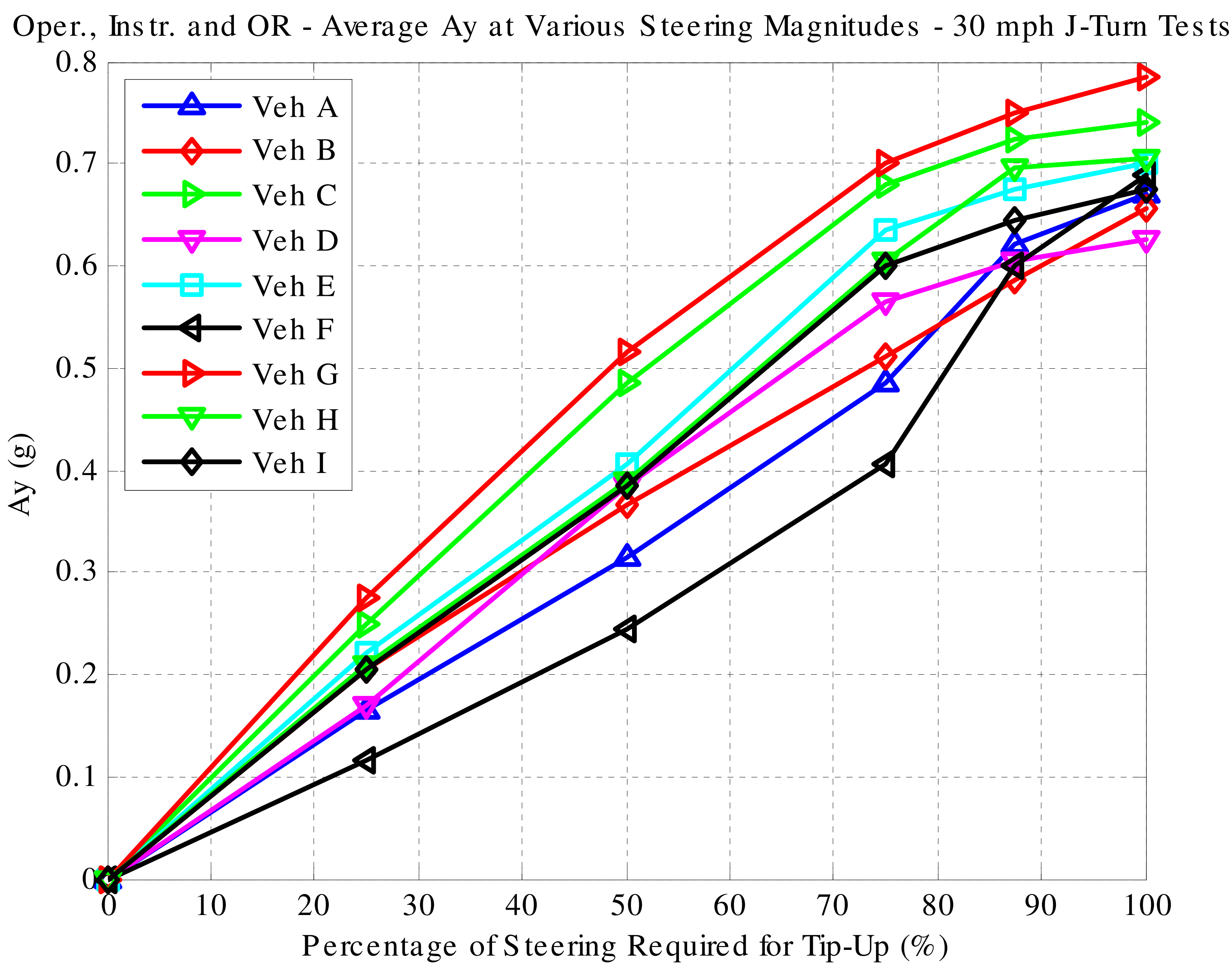

Oper., Instr. and OR - Average Ay at Various Steering Magnitudes
25% Steering
50% Steering
75% Steering
87.5% Steering
100% Steering
Ay (g)
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

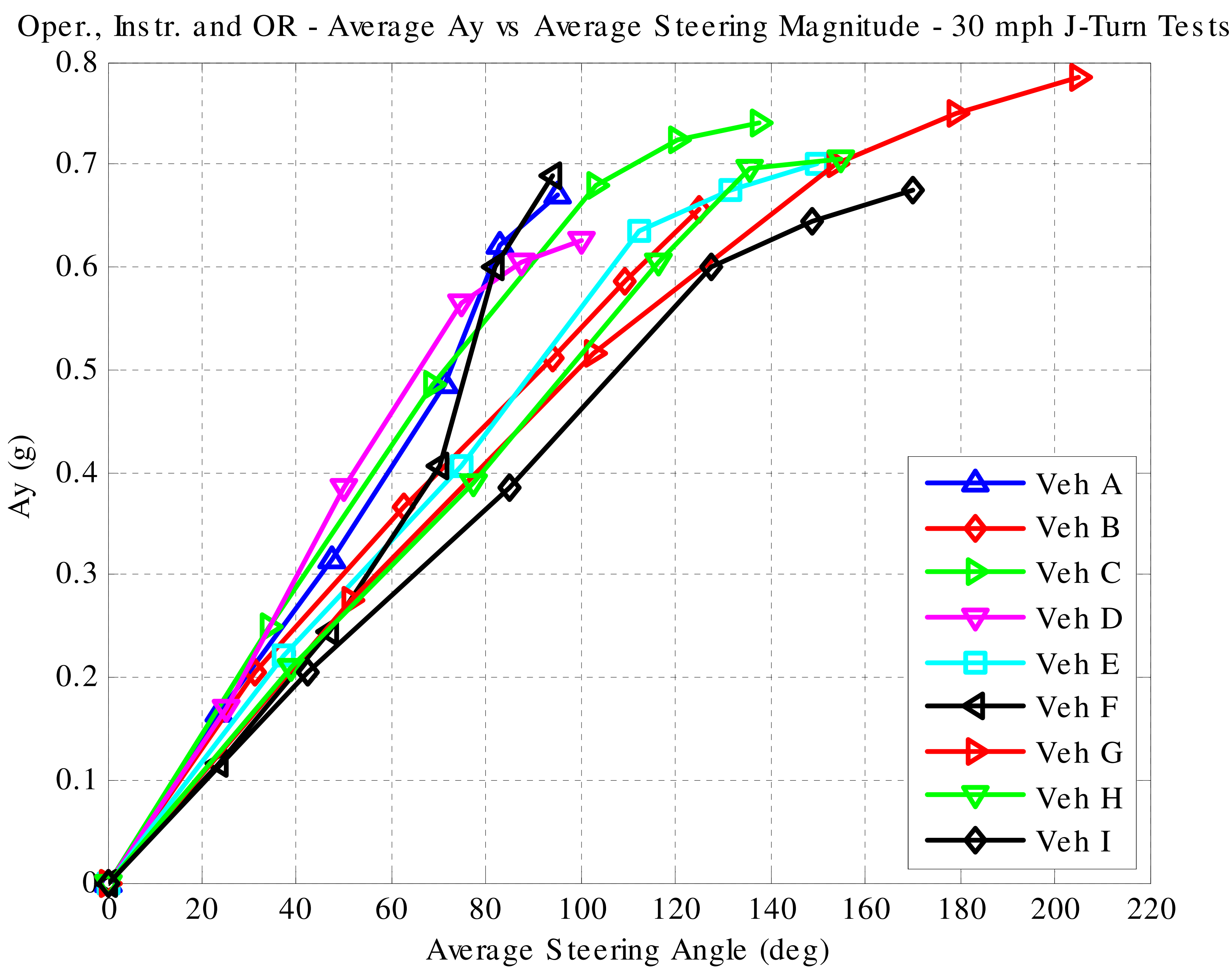

Oper., Instr. and OR - Average Ay Gains - 30 mph J-Turn Tests
Ay per Steering Magnitude (g/deg)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I
25% Steering
50% Steering
75% Steering
87.5% Steering
100% Steering

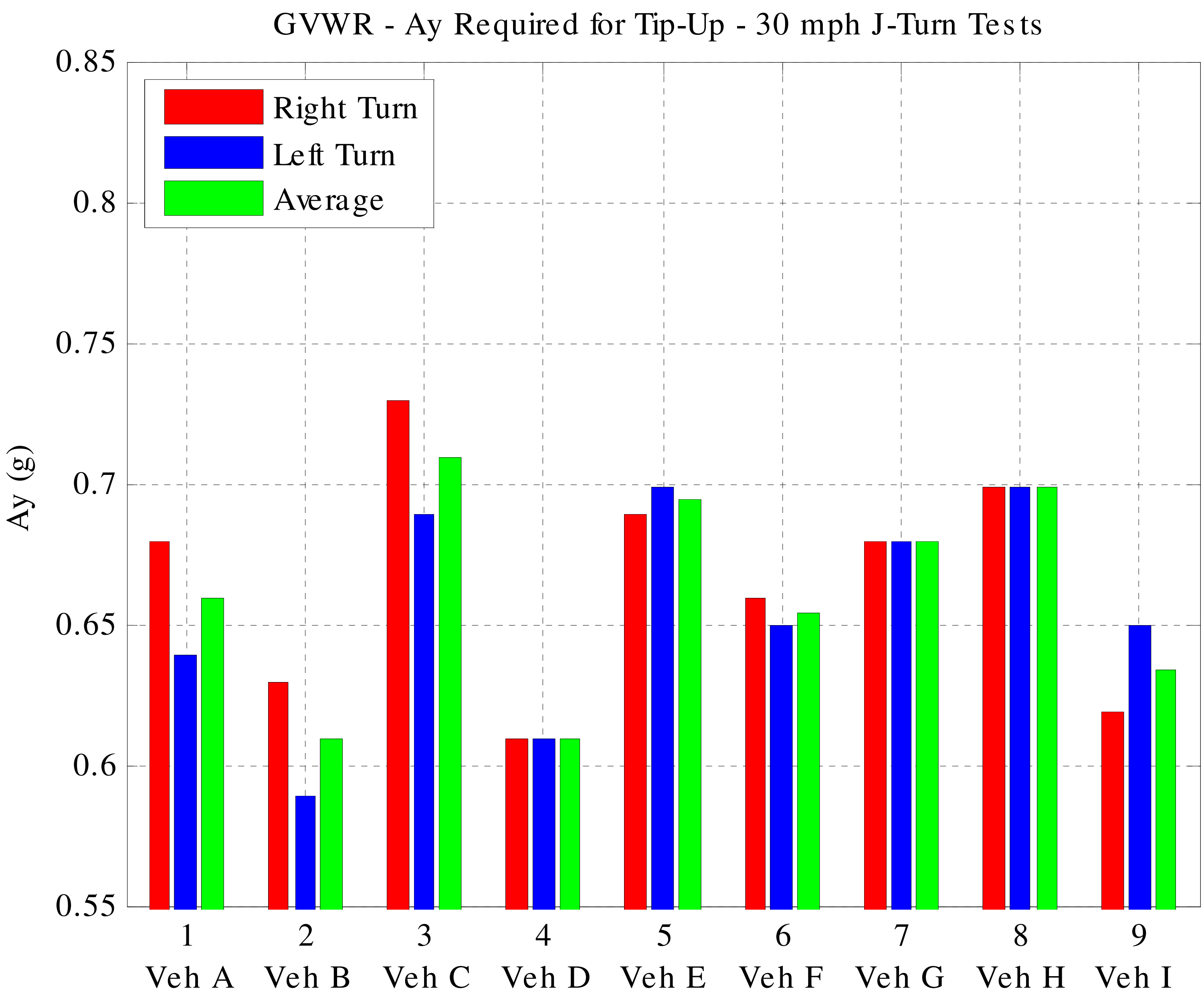

Oper., Instr. and OR - Normalized Average Ay Gains - 30 mph J-Turn Tests
1.6
1.4
1.2
1
0.8
0.6
0.4
Normalized Ay per Steering Magnitude (g/deg)
25% Steering
50% Steering
75% Steering
87.5% Steering
100% Steering
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

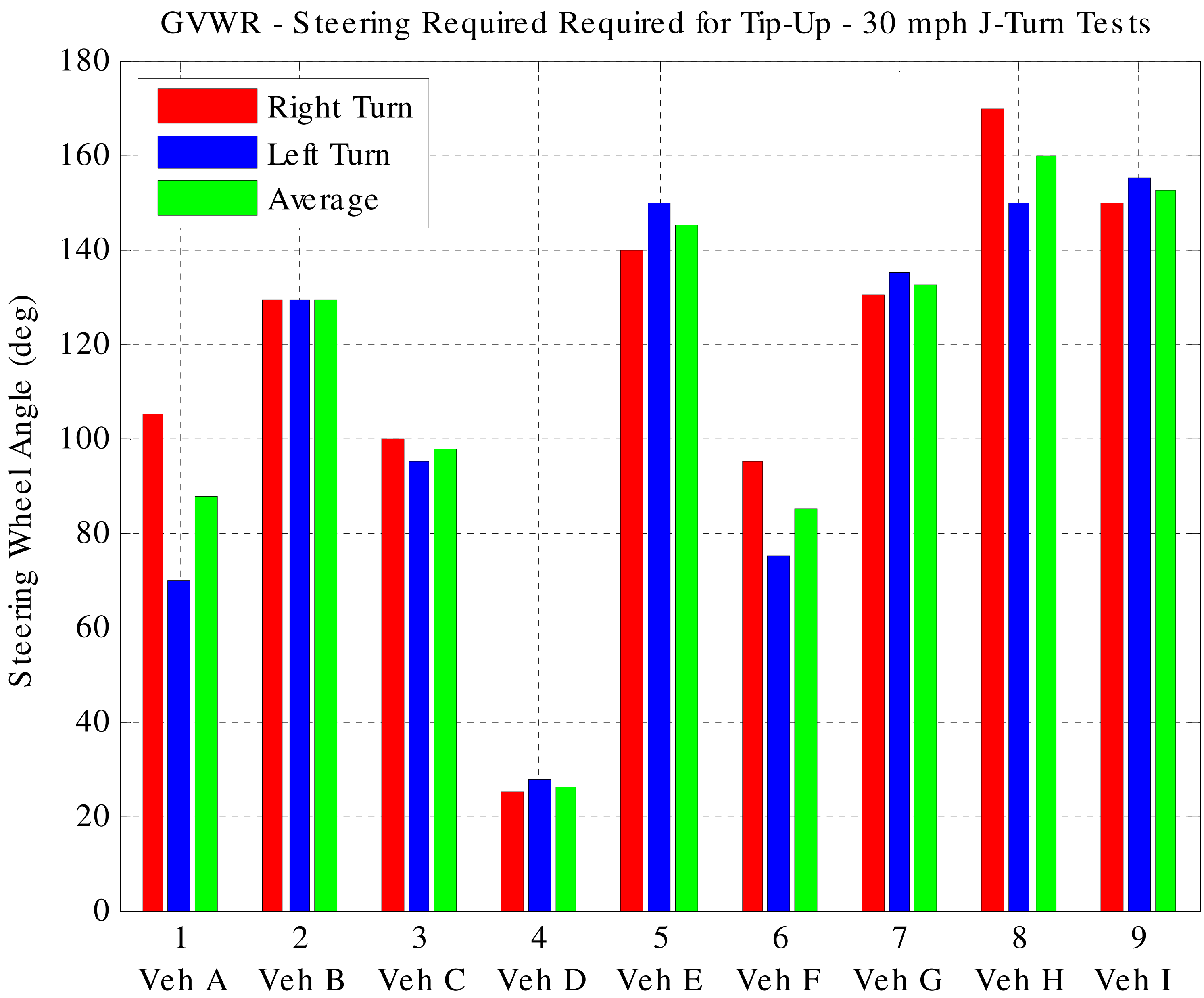

Oper., Instr. and OR - Average Ay Gains in Various Steering Ranges
0-25% Steering
25-50% Steering
50-75% Steering
75-87.5% Steering
87.5-100% Steering
Ay per Steering Magnitude (g/deg)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I


Oper., Instr. and OR - Steering Wheel Angle per Ay - 30 mph J-Turn Tests
Steering Magnitude per Ay (deg/g)
25% Steering
50% Steering
75% Steering
87.5% Steering
100% Steering
0
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I


Oper., Instr. and OR - Average Ay at Various Steering Magnitudes - 30 mph J-Turn Tests
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Ay (g)
0
10
20
30
40
50
60
70
80
90
100
Percentage of Steering Required for Tip-Up (%)
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I


Oper., Instr. and OR - Average Ay vs Average Steering Magnitude - 30 mph J-Turn Tests
Ay (g)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Average Steering Angle (deg)
0
20
40
60
80
100
120
140
160
180
200
220
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

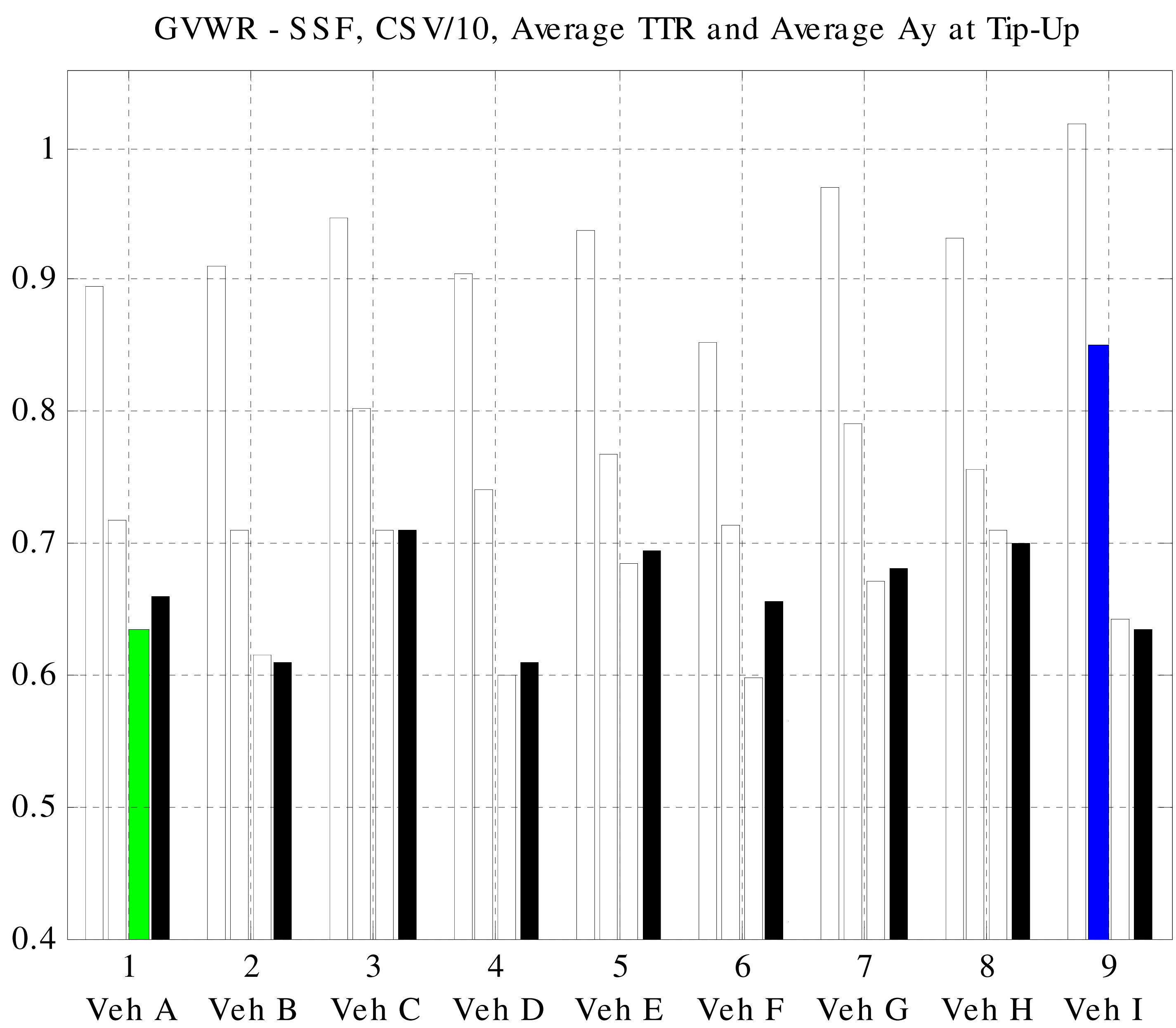

GVWR - Ay Required for Tip-Up - 30 mph J-Turn Tests
0.85
0.8
0.75
0.7
0.65
0.6
0.55
Ay (g)
Right Turn
Left Turn
Average
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

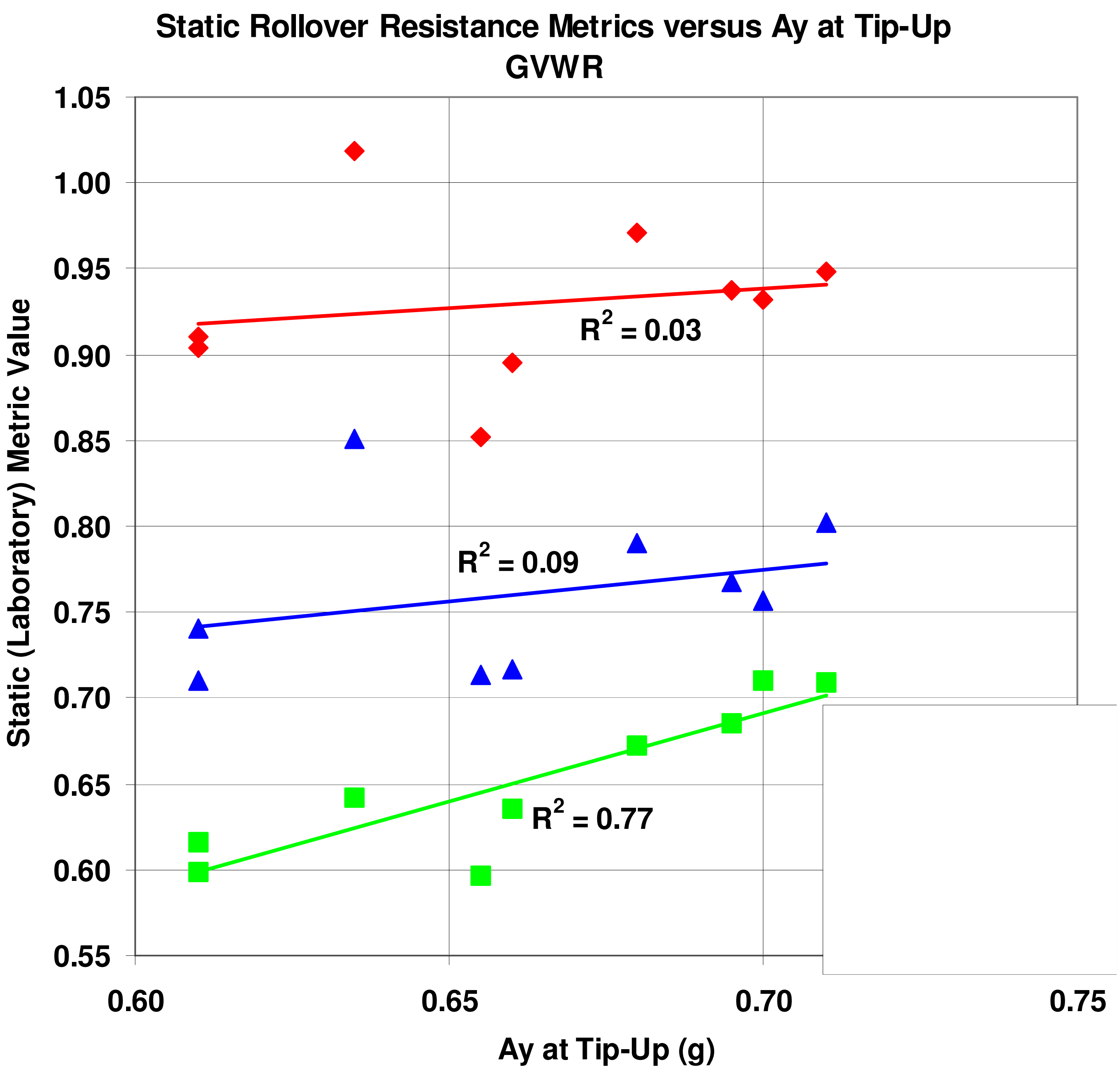

GVWR - Steering Required Required for Tip-Up - 30 mph J-Turn Tests
Right Turn
Left Turn
Average
Steering Wheel Angle (deg)
0
20
40
60
80
100
120
140
160
180
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

Summary of Ay and Steering Required for Tip-Up in 30 mph J-Turns and Static Rollover Resistance Metrics (GVWR)					
Vehicle	Ay at Tip-Up (g)	Steering at Tip-Up (deg)	SSF (--)	CSV/10 (mph/10)	TTR (--)
A	0.660	87.5	0.895	0.717	0.635
B	0.610	129.0	0.910	0.710	0.616
C	0.710	97.5	0.948	0.802	0.709
D	0.610	26.3	0.904	0.741	0.599
E	0.695	145.0	0.937	0.767	0.685
F	0.655	85.0	0.852	0.713	0.597
G	0.680	132.5	0.971	0.790	0.672
H	0.700	160.0	0.932	0.757	0.710
I	0.635	152.5	1.019	0.851	0.642

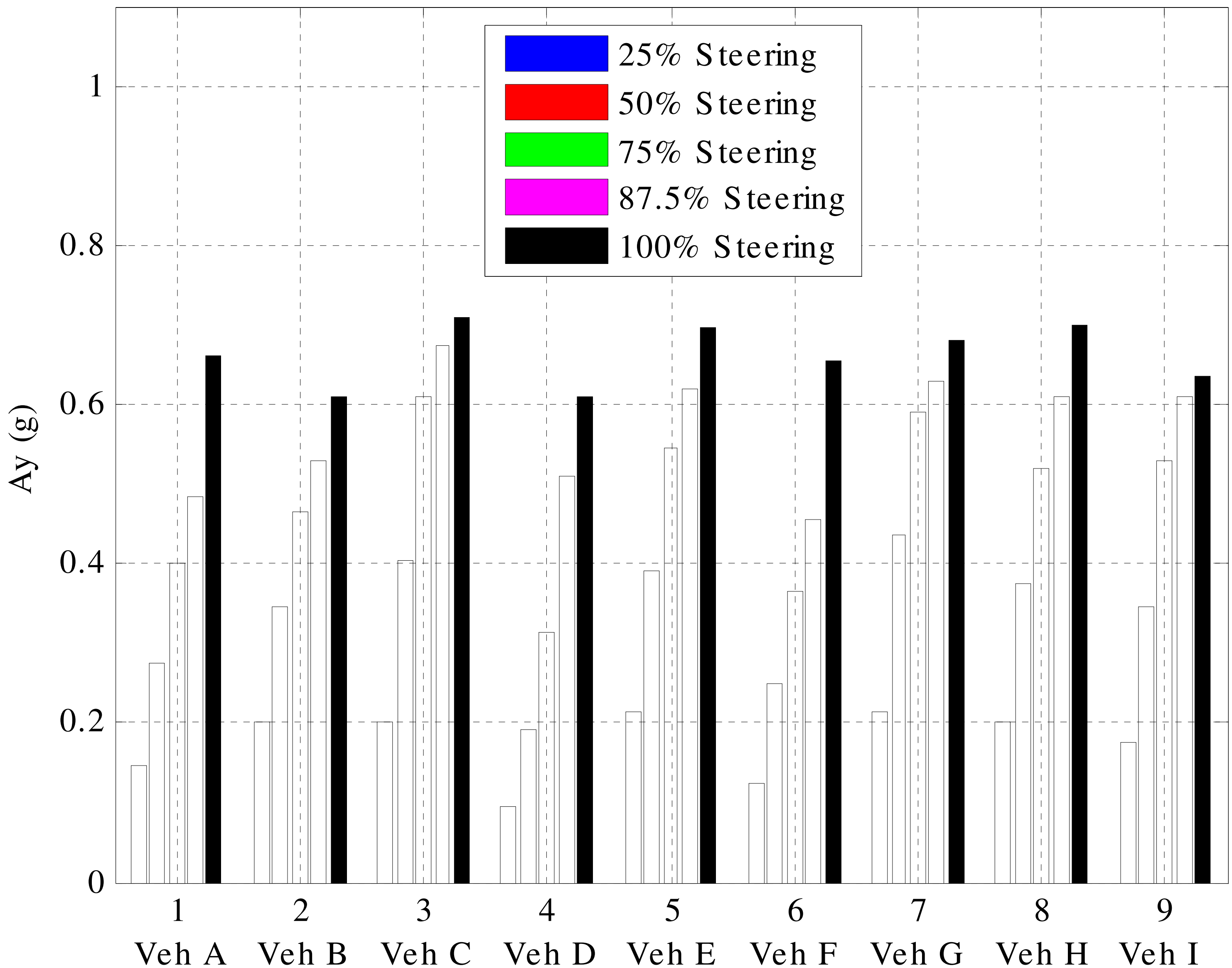
Vehicle Ascending Rank Order of Ay and Steering Required for Tip-Up in J-Turns and Static Rollover Resistance Metrics (GVWR)				
Ay at Tip-Up (g)	Steering at Tip-Up (deg)	SSF (--)	CSV/10 (mph/10)	TTR (--)
B	D	F	B	F
D	F	A	F	D
I	A	D	A	B
F	C	B	D	A
A	B	H	H	I
G	G	E	E	G
E	E	C	G	E
H	I	G	C	C
C	H	I	I	H

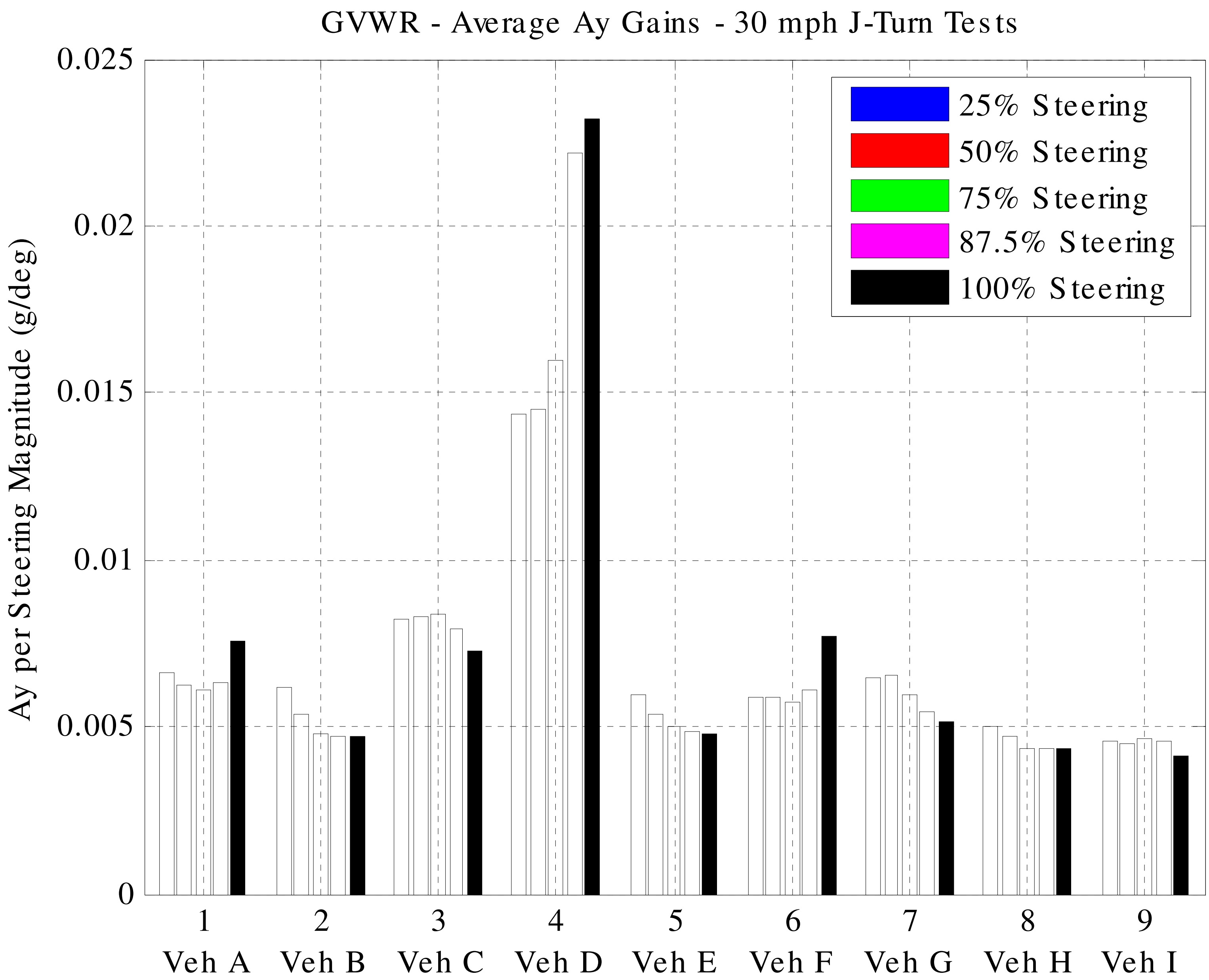
Vehicles A, D, F, and I exhibited transient from Understeer to Oversteer in Circle and SIS Tests
Vehicle I is the 4-Passenger Vehicle


GVWR - SSF, CSV/10, Average TTR and Average Ay at Tip-Up
1
0.9
0.8
0.7
0.6
0.5
0.4
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

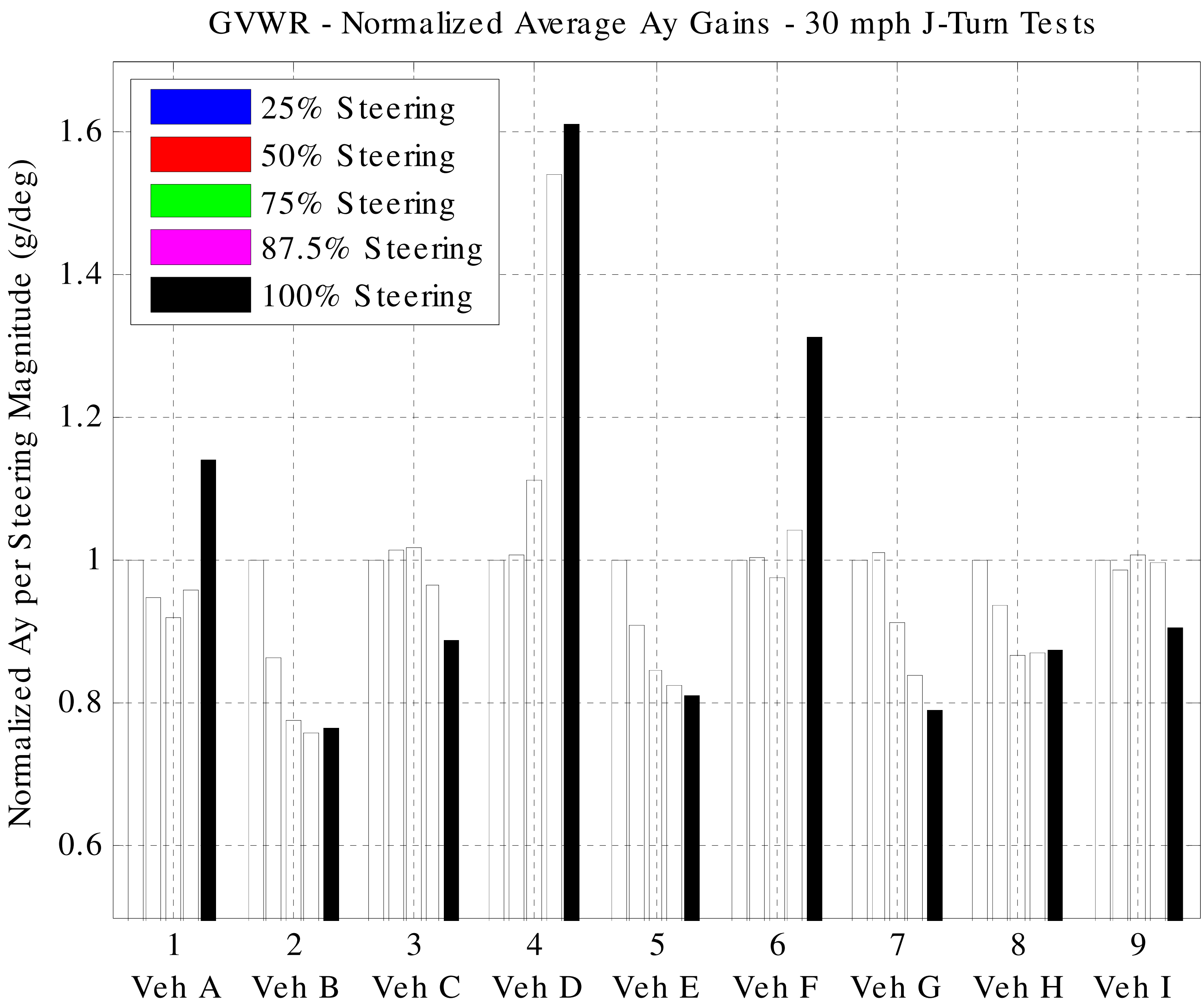

Static Rollover Resistance Metrics versus Ay at Tip-Up
GVWR
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
Static (Laboratory) Metric Value
$R^2 = 0.03$
$R^2 = 0.09$
$R^2 = 0.77$
0.60
0.65
0.70
0.75
Ay at Tip-Up (g)

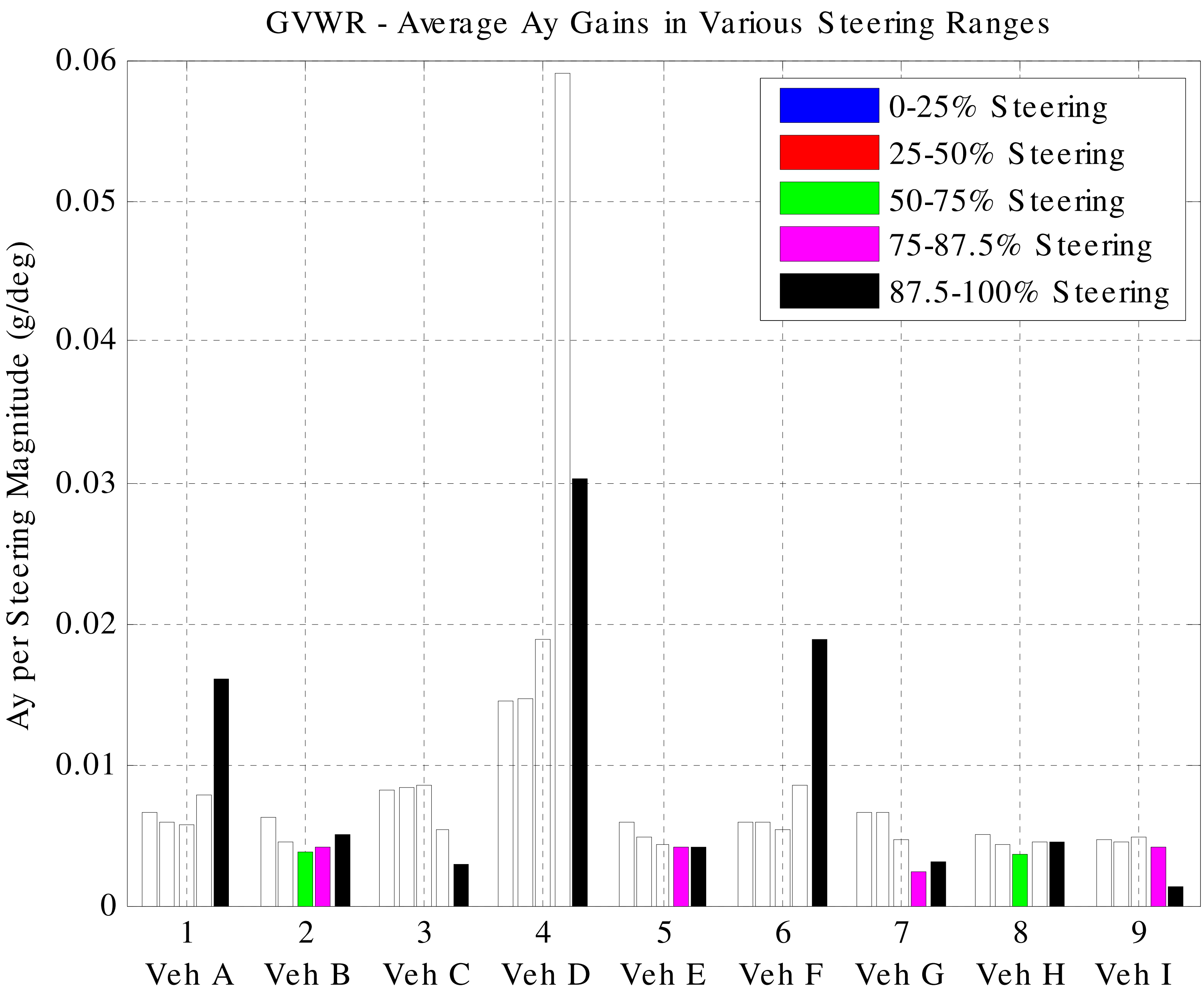
GVWR - Average Ay at Various Steering Magnitudes

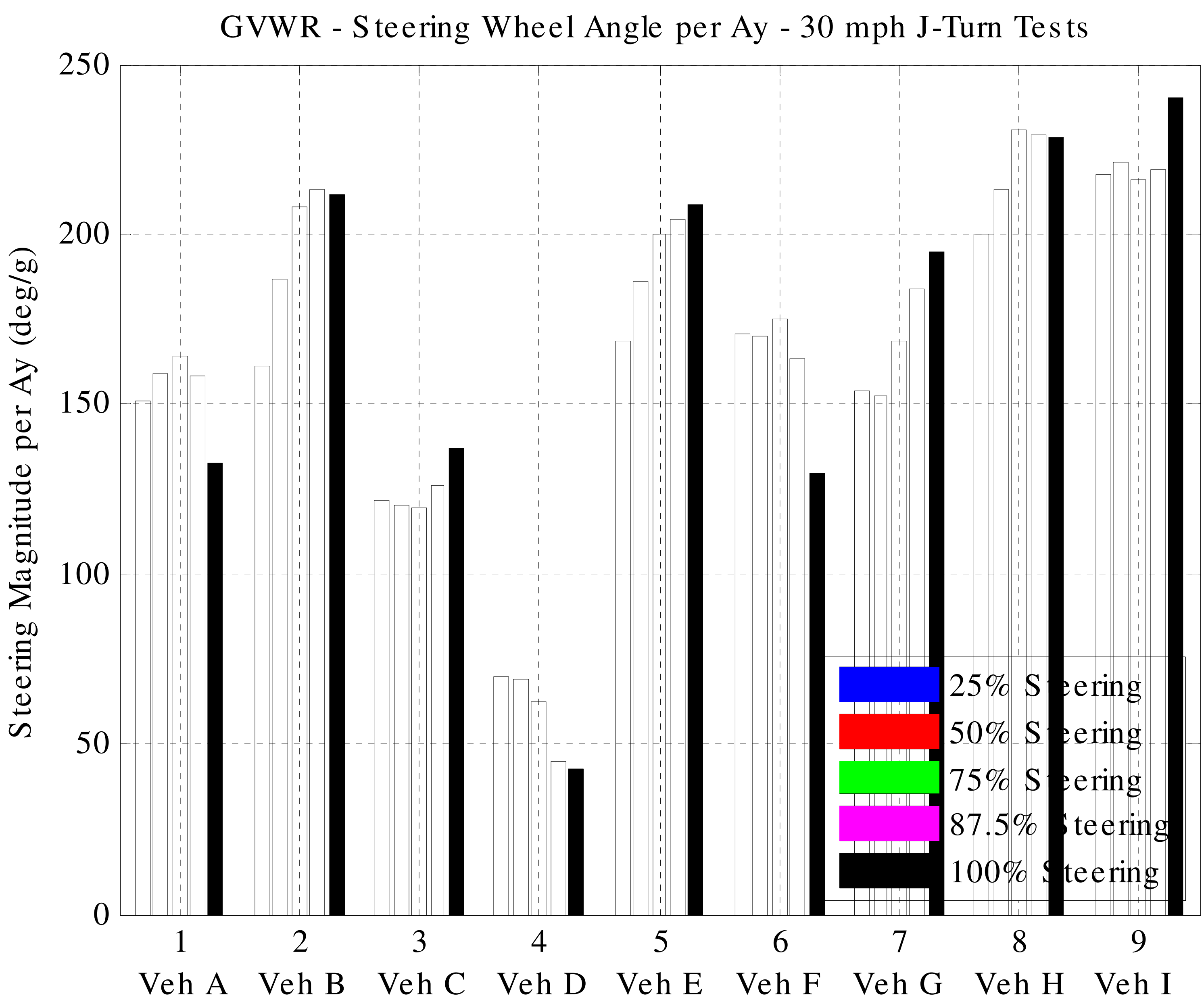




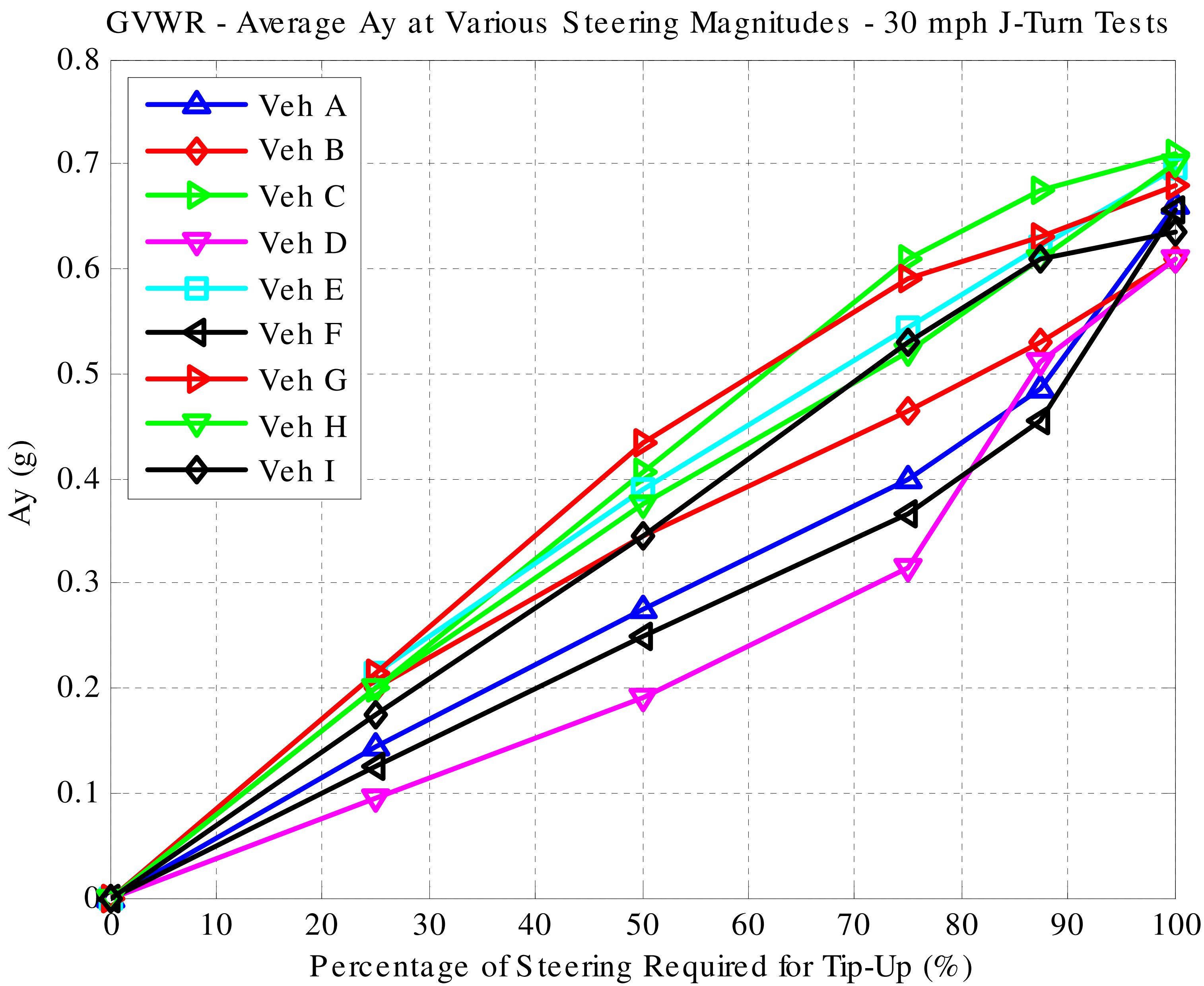
GVWR - Average Ay Gains - 30 mph J-Turn Tests
Ay per Steering Magnitude (g/deg)
0.025
0.02
0.015
0.01
0.005
0
25% Steering
50% Steering
75% Steering
87.5% Steering
100% Steering
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

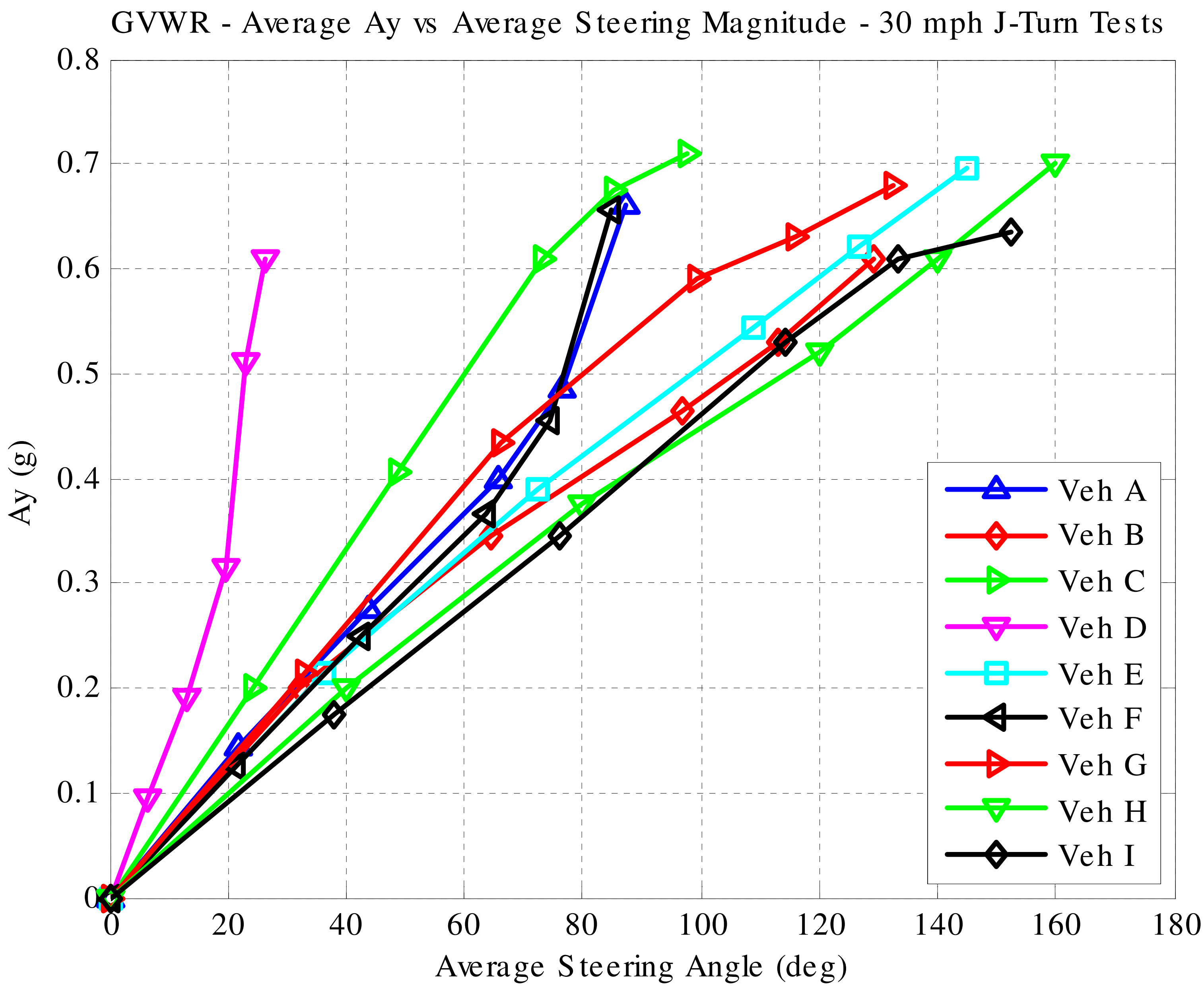

GVWR - Normalized Average Ay Gains - 30 mph J-Turn Tests
25% Steering
50% Steering
75% Steering
87.5% Steering
100% Steering
Normalized Ay per Steering Magnitude (g/deg)
1.6
1.4
1.2
1
0.8
0.6
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

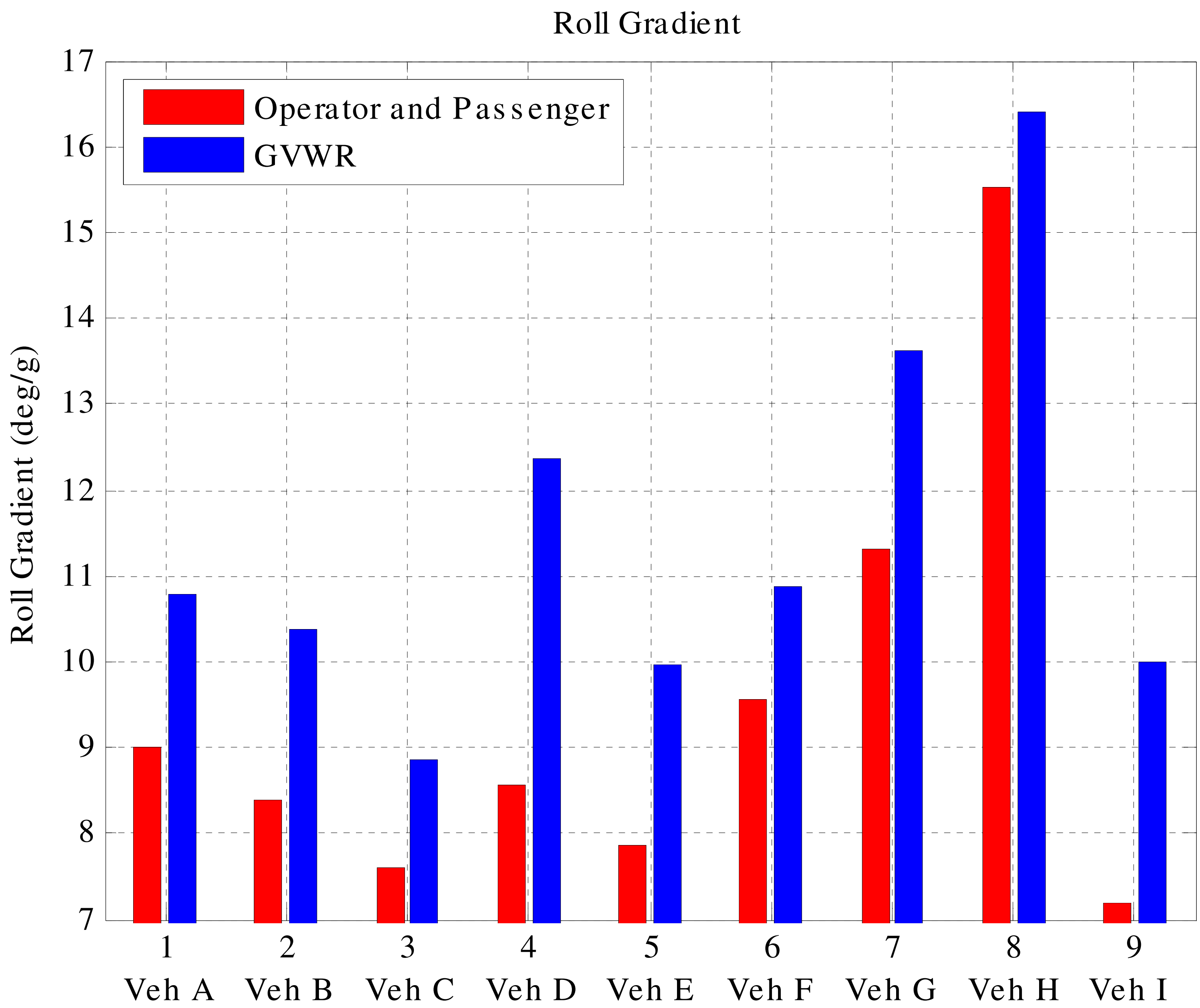

GVWR - Average Ay Gains in Various Steering Ranges
Ay per Steering Magnitude (g/deg)
0.06
0.05
0.04
0.03
0.02
0.01
0
0-25% Steering
25-50% Steering
50-75% Steering
75-87.5% Steering
87.5-100% Steering
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I

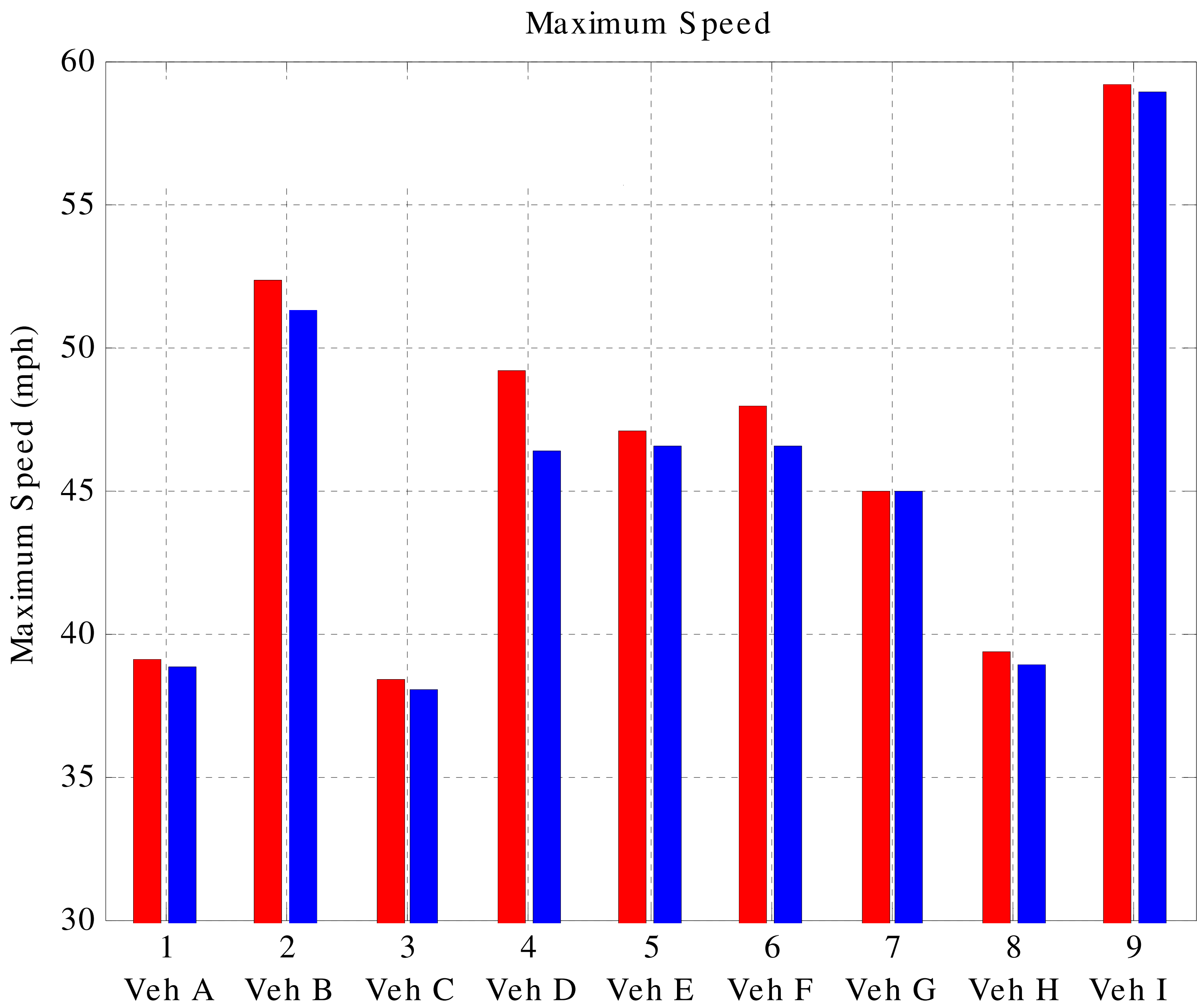


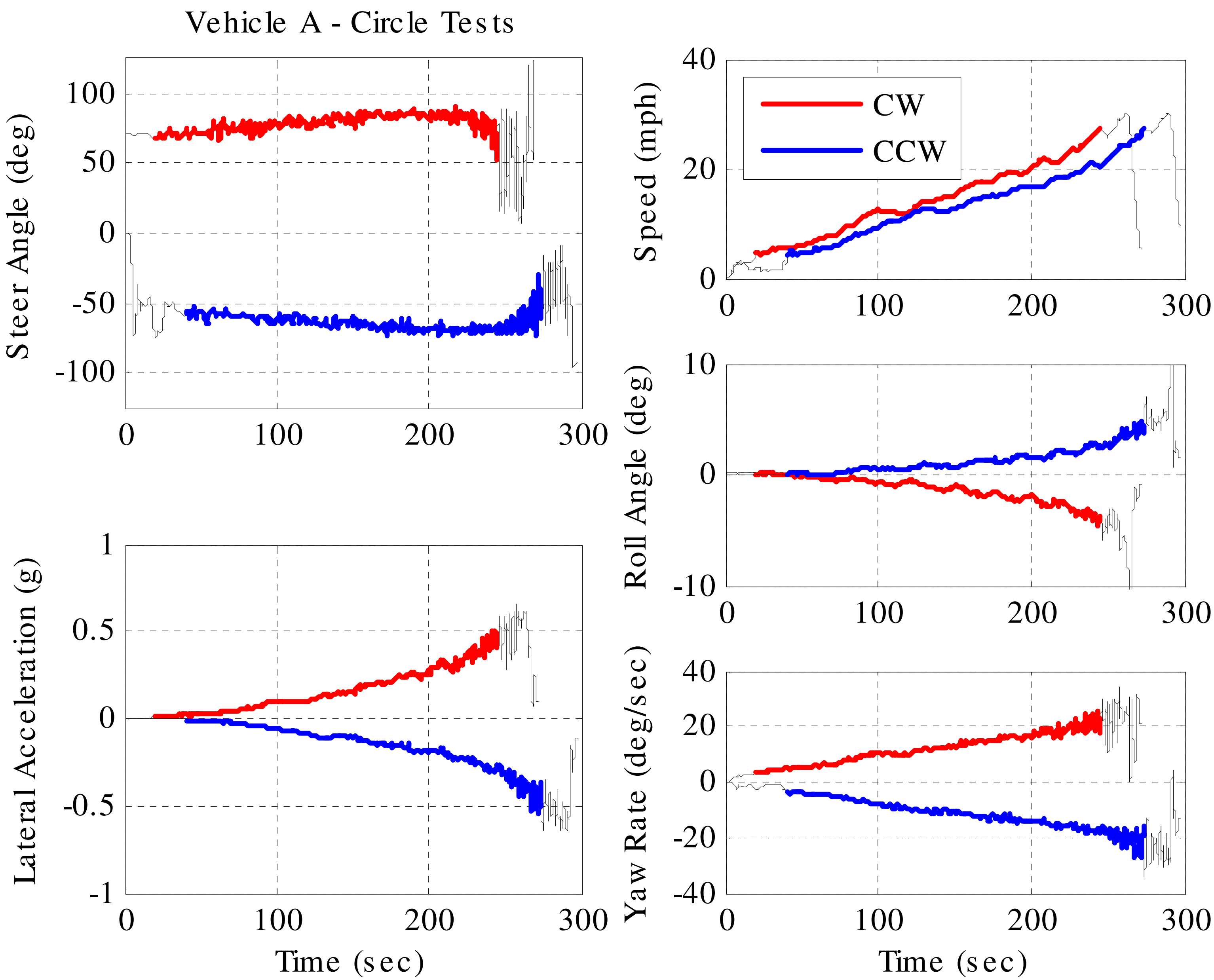
GVWR - Steering Wheel Angle per Ay - 30 mph J-Turn Tests
Steering Magnitude per Ay (deg/g)
250
200
150
100
50
0
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I
25% Steering
50% Steering
75% Steering
87.5% Steering
100% Steering

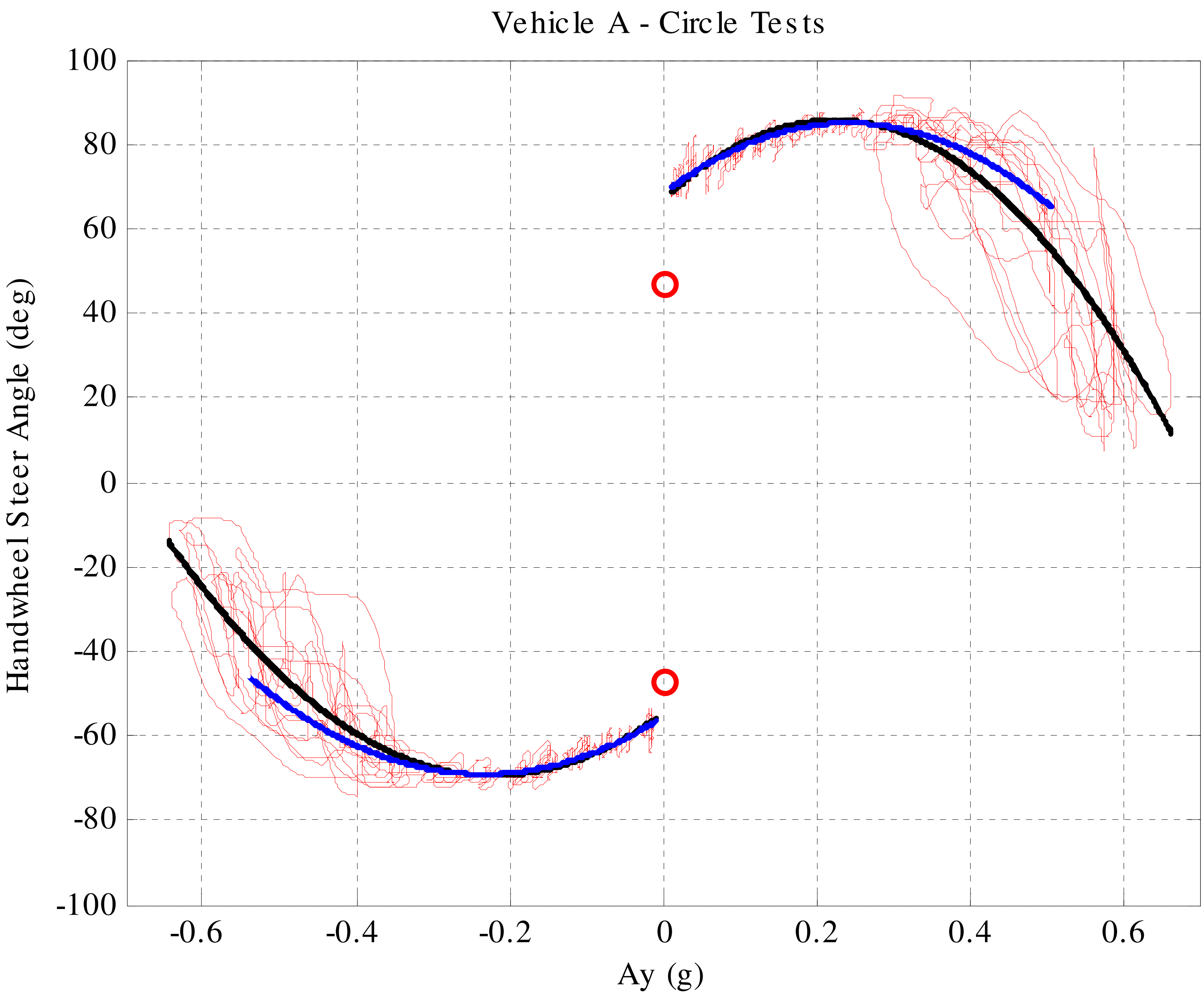

GVWR - Average Ay at Various Steering Magnitudes - 30 mph J-Turn Tests
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I
Ay (g)
Percentage of Steering Required for Tip-Up (%)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
10
20
30
40
50
60
70
80
90
100

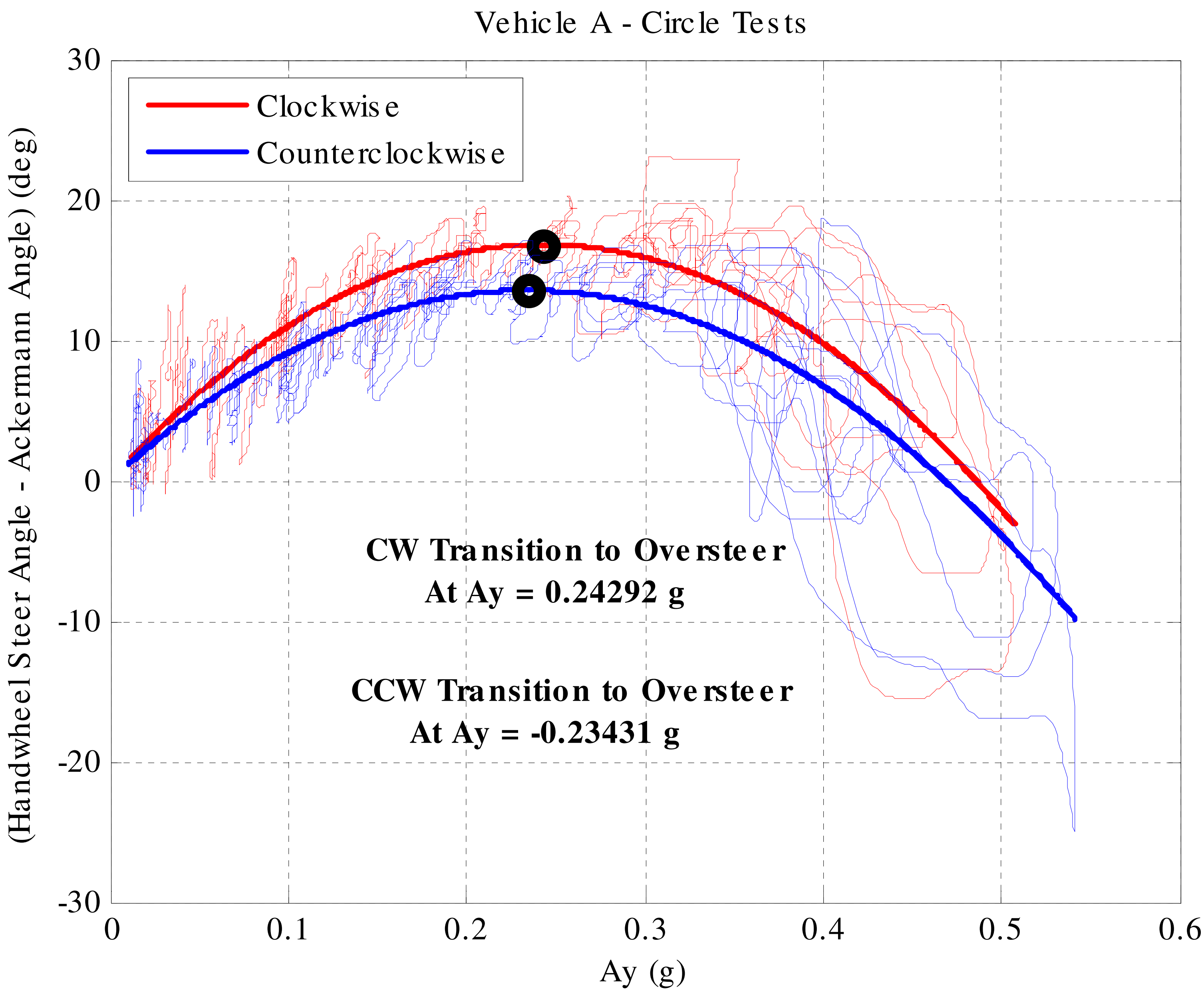

GVWR - Average Ay vs Average Steering Magnitude - 30 mph J-Turn Tests
Ay (g)
Average Steering Angle (deg)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
140
160
180
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

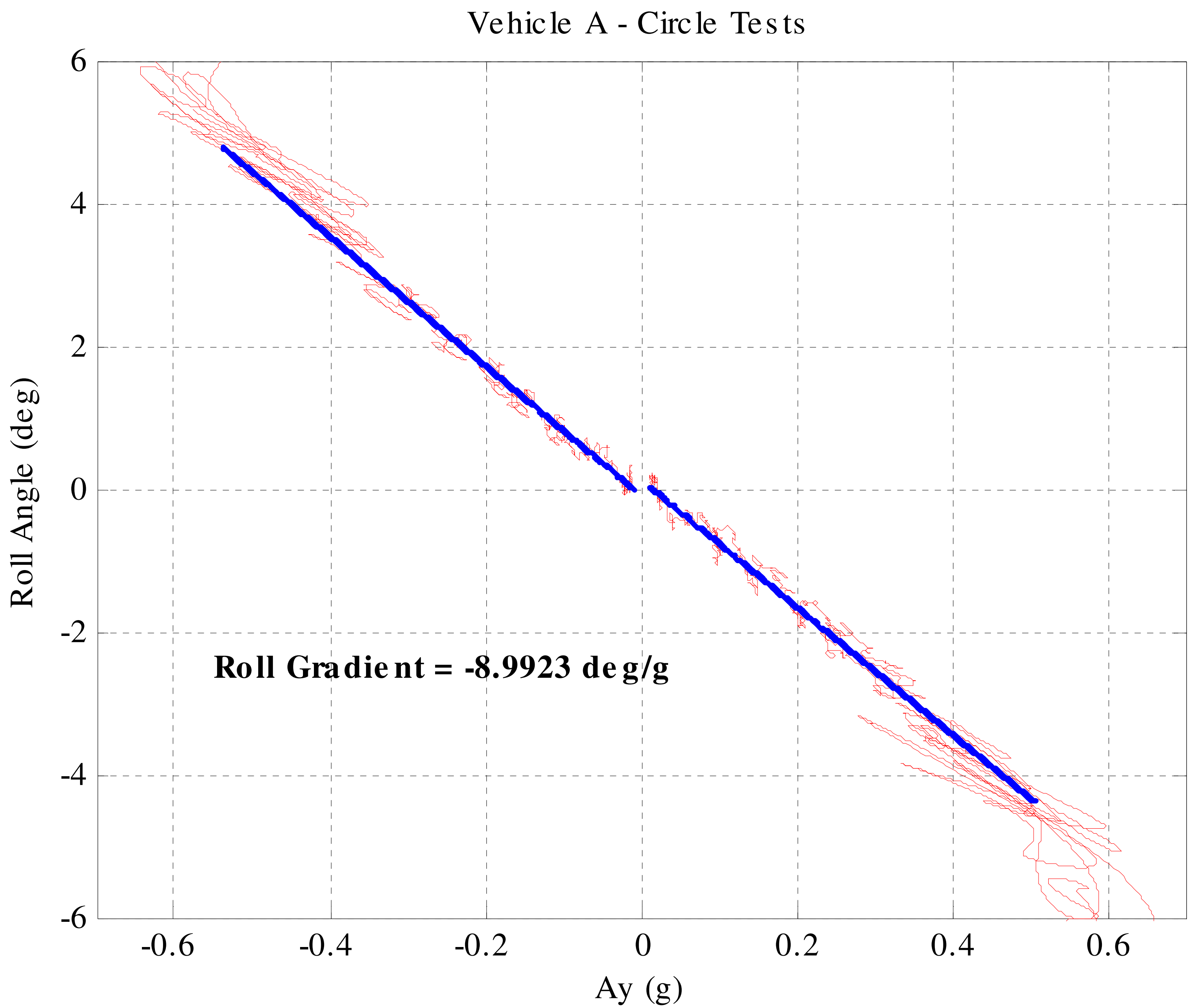

Roll Gradient
Operator and Passenger
GVWR
Roll Gradient (deg/g)
17
16
15
14
13
12
11
10
9
8
7
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I


Maximum Speed
Maximum Speed (mph)
60
55
50
45
40
35
30
1
2
3
4
5
6
7
8
9
Veh A
Veh B
Veh C
Veh D
Veh E
Veh F
Veh G
Veh H
Veh I

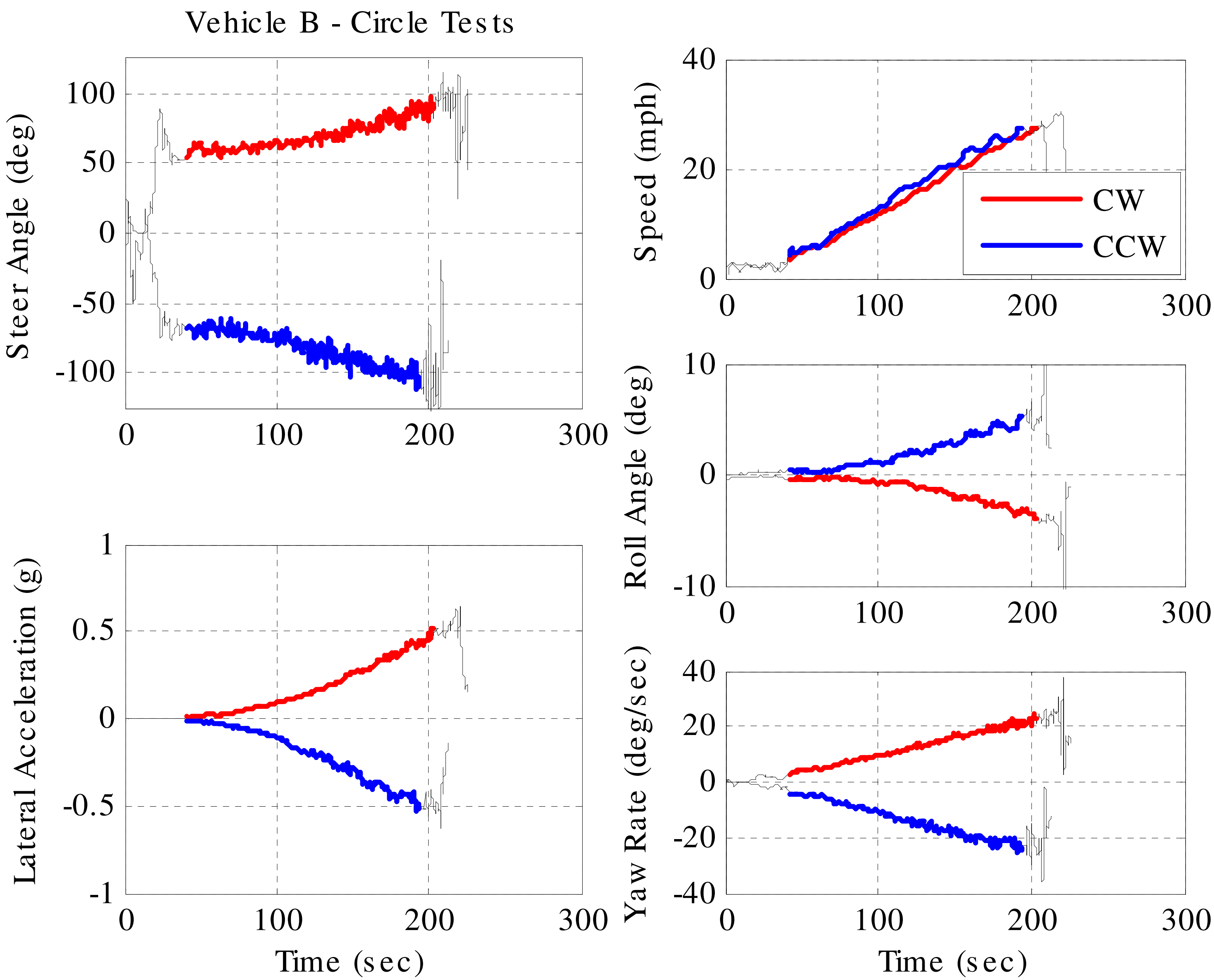

Vehicle A - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)


Vehicle A - 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)

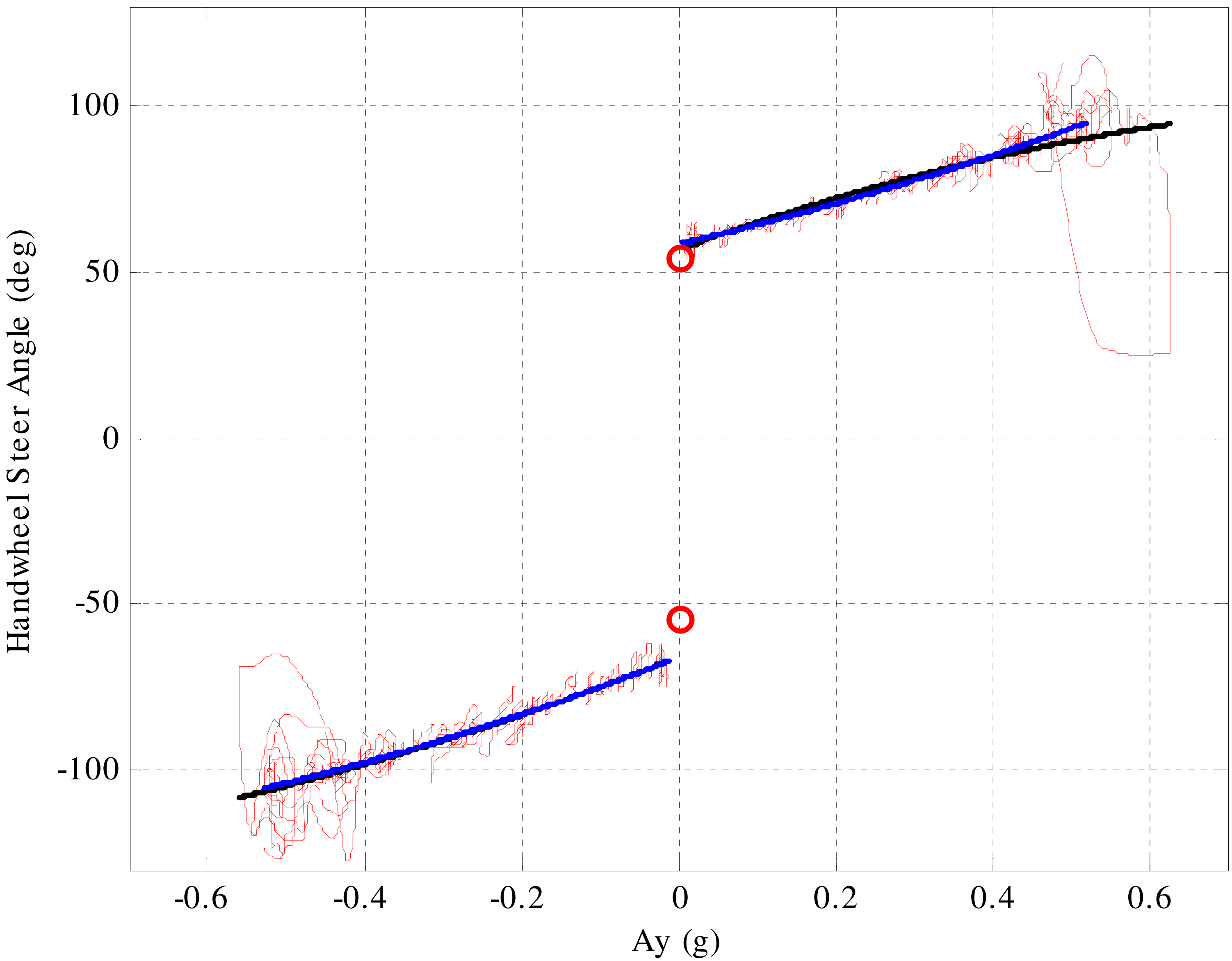

Vehicle A - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.24292 g
CCW Transition to Oversteer
At Ay = -0.23431 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
30
20
10
0
-10
-20
-30
0
0.1
0.2
0.3
0.4
0.5
0.6

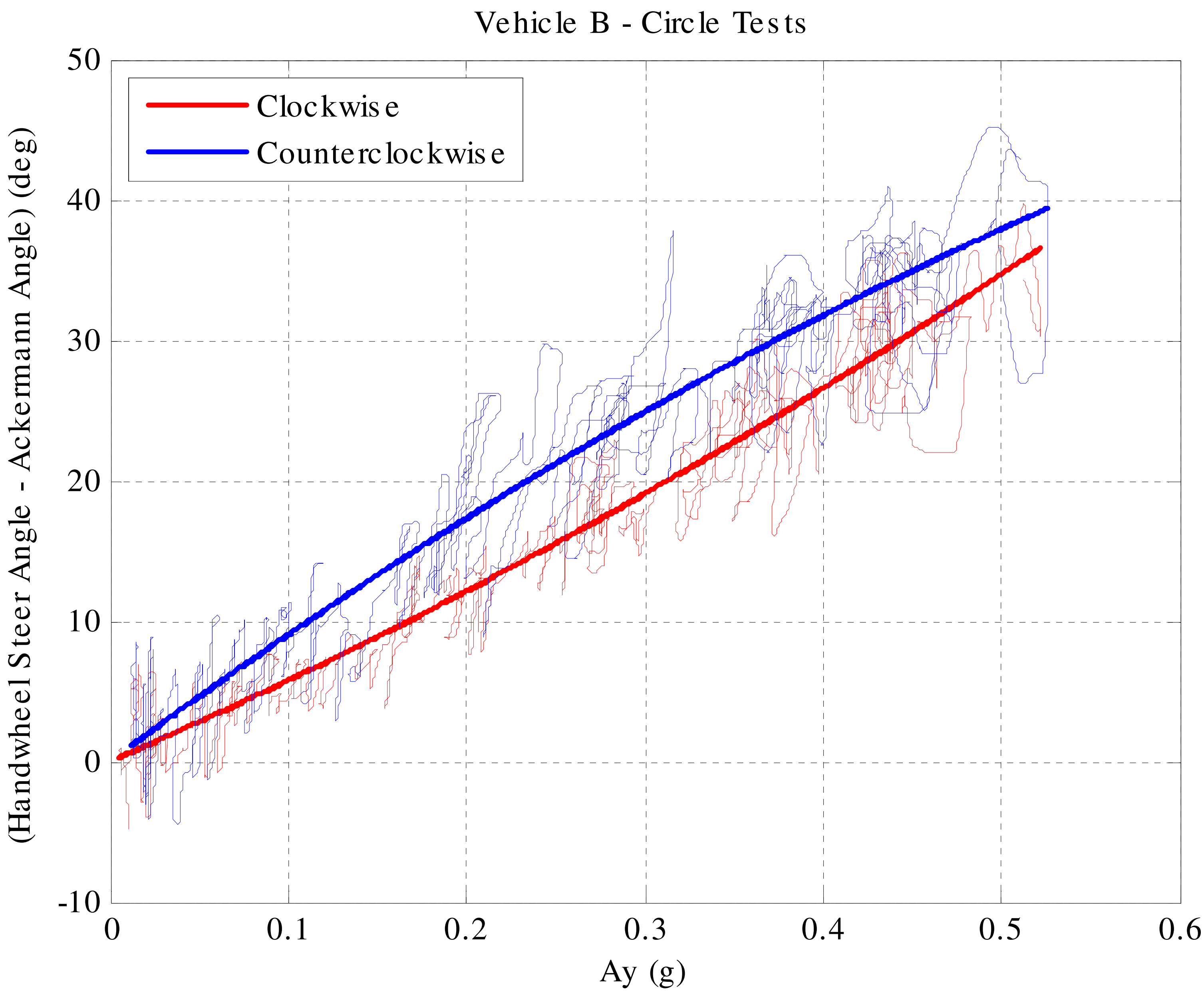


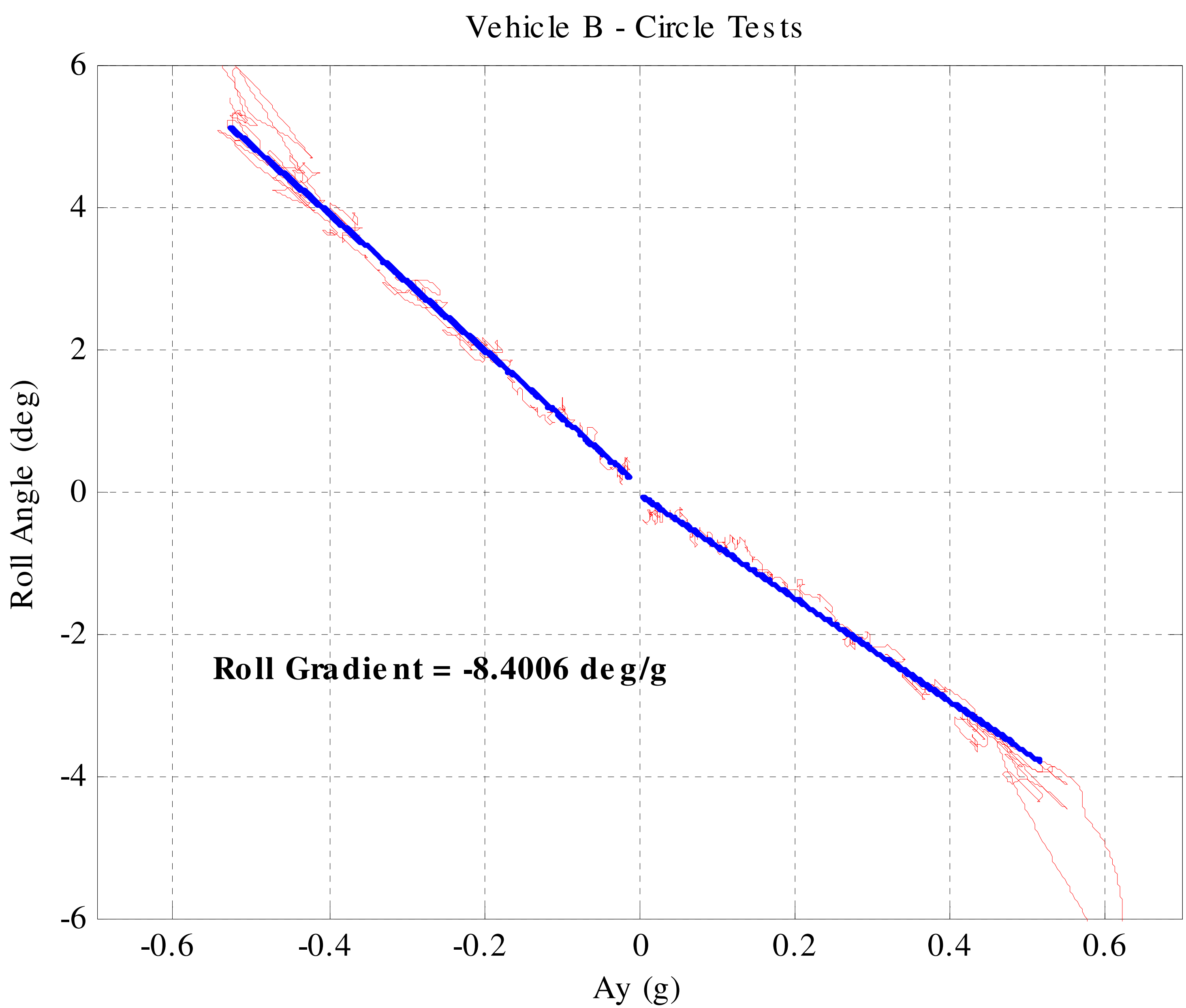
Vehicle A - Circle Tests
6
4
2
0
-2
-4
-6
Roll Angle (deg)
Roll Gradient = -8.9923 deg/g
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)


Vehicle B - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

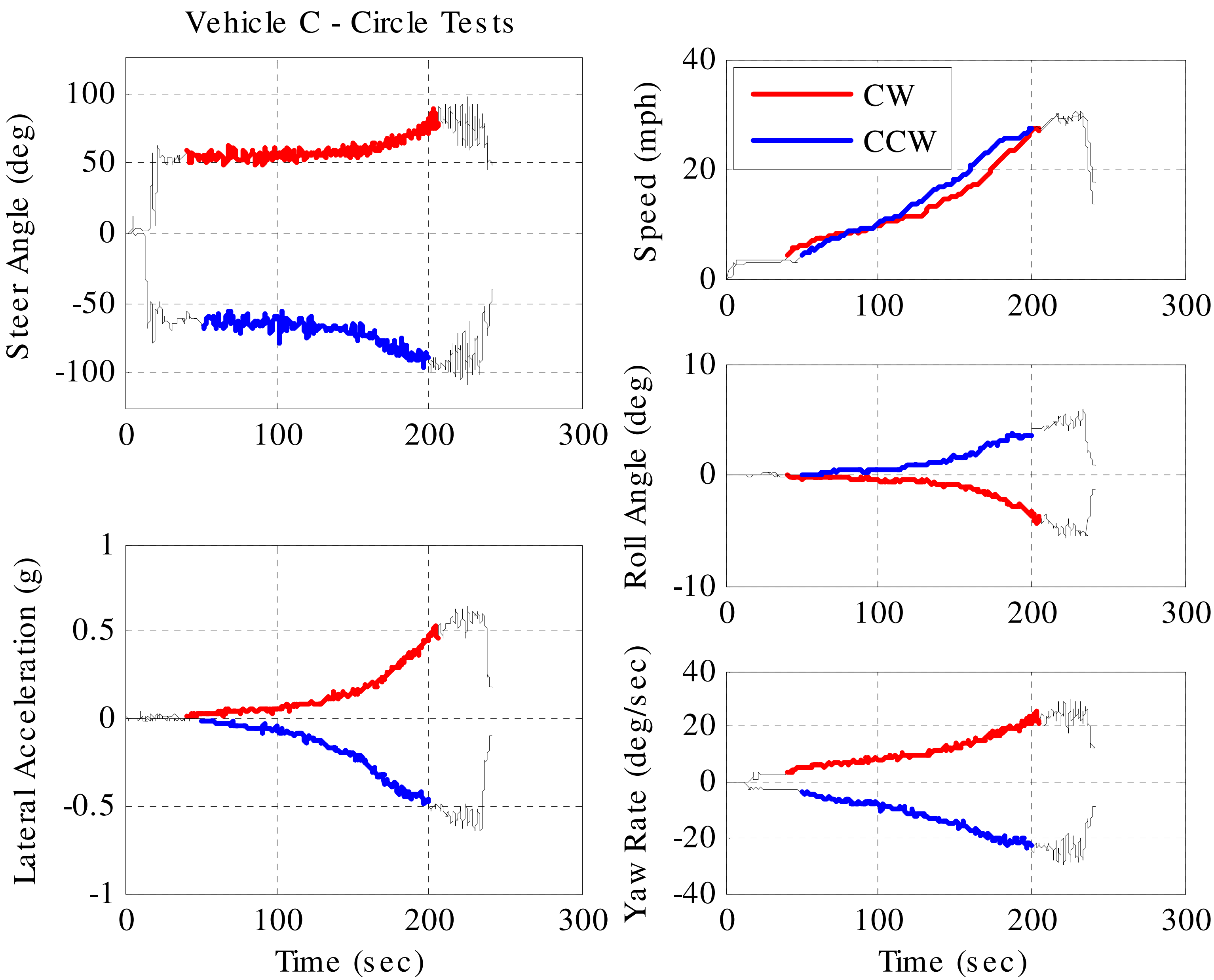
Vehicle B - Circle Tests

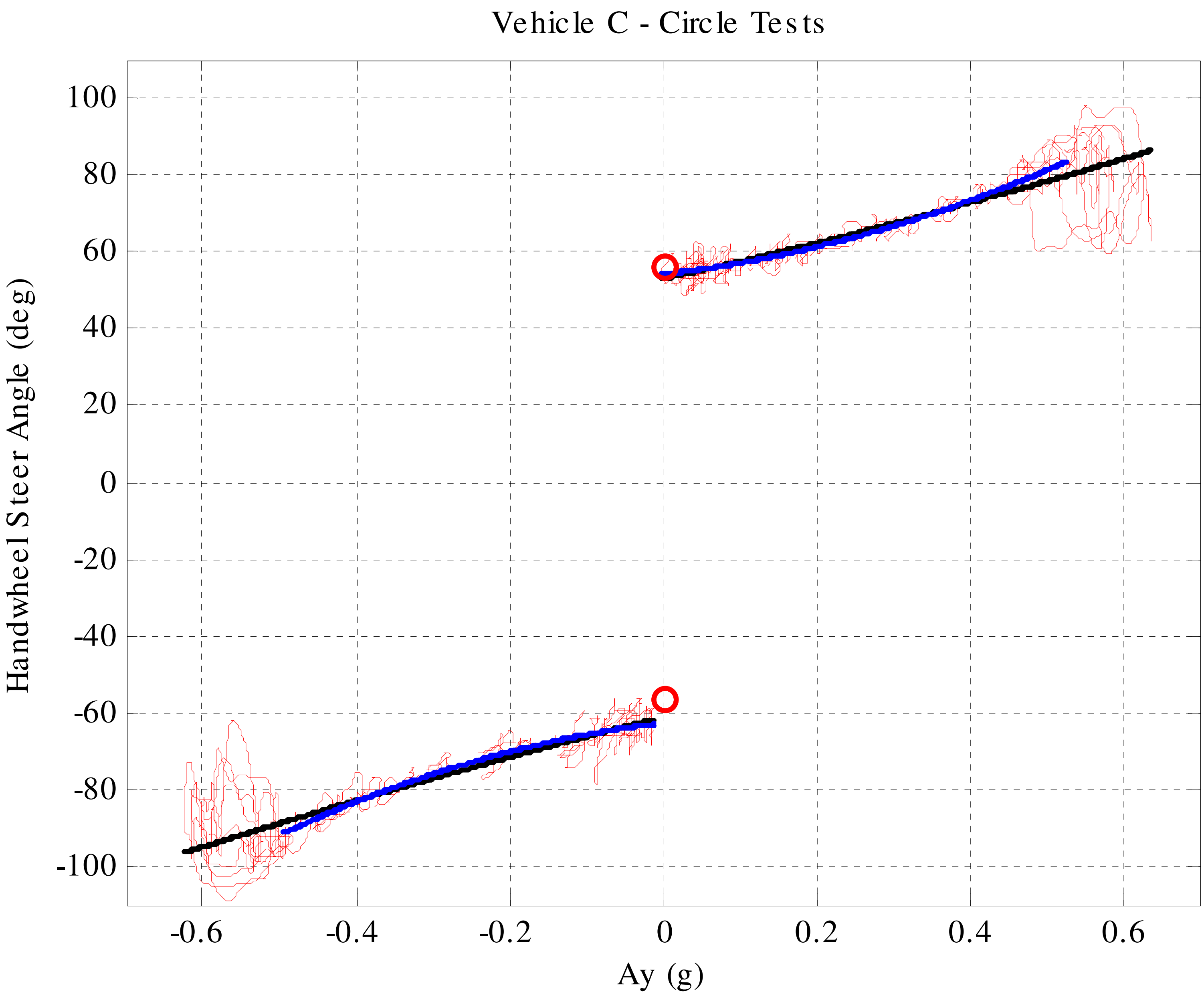


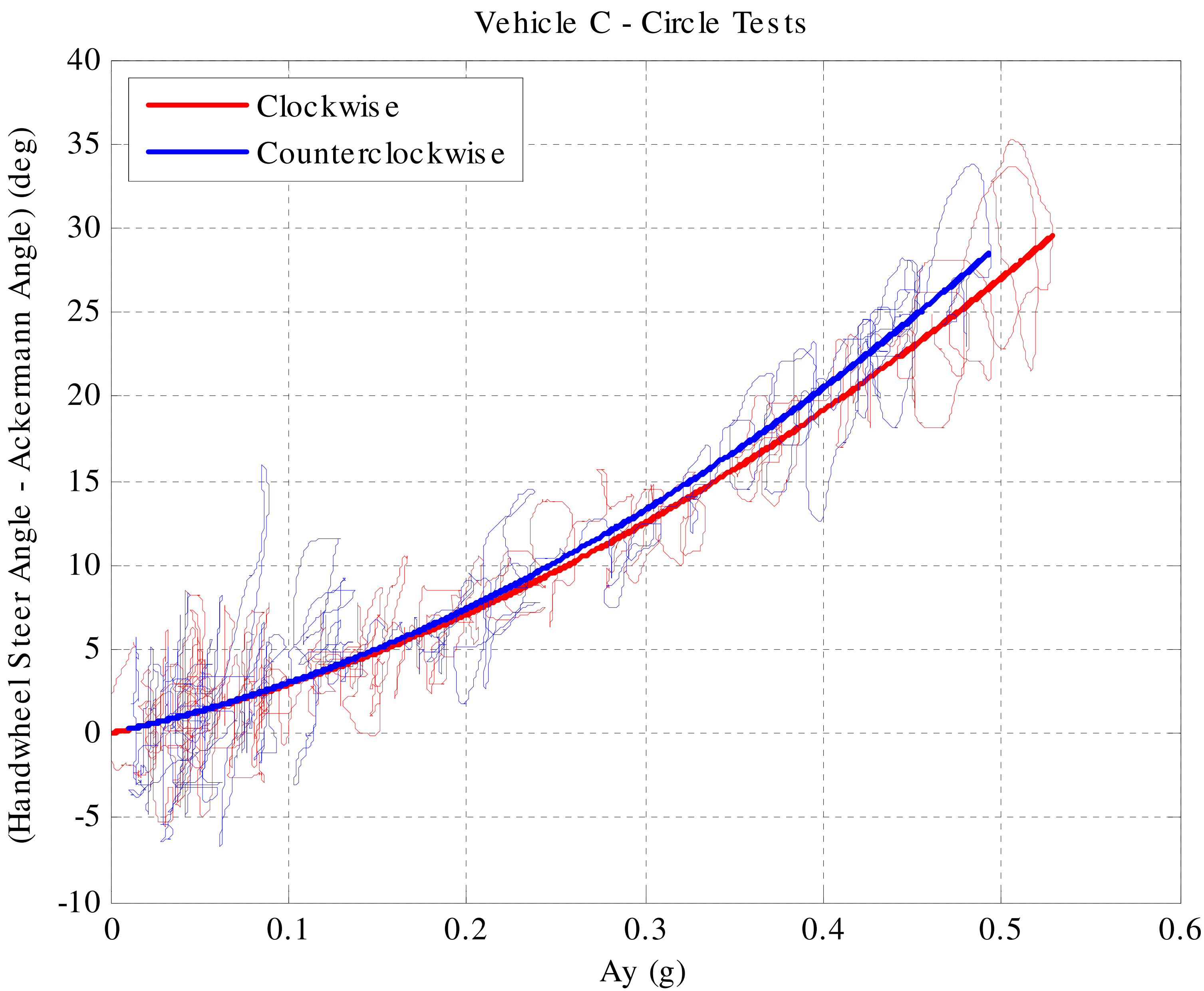

Vehicle B - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6

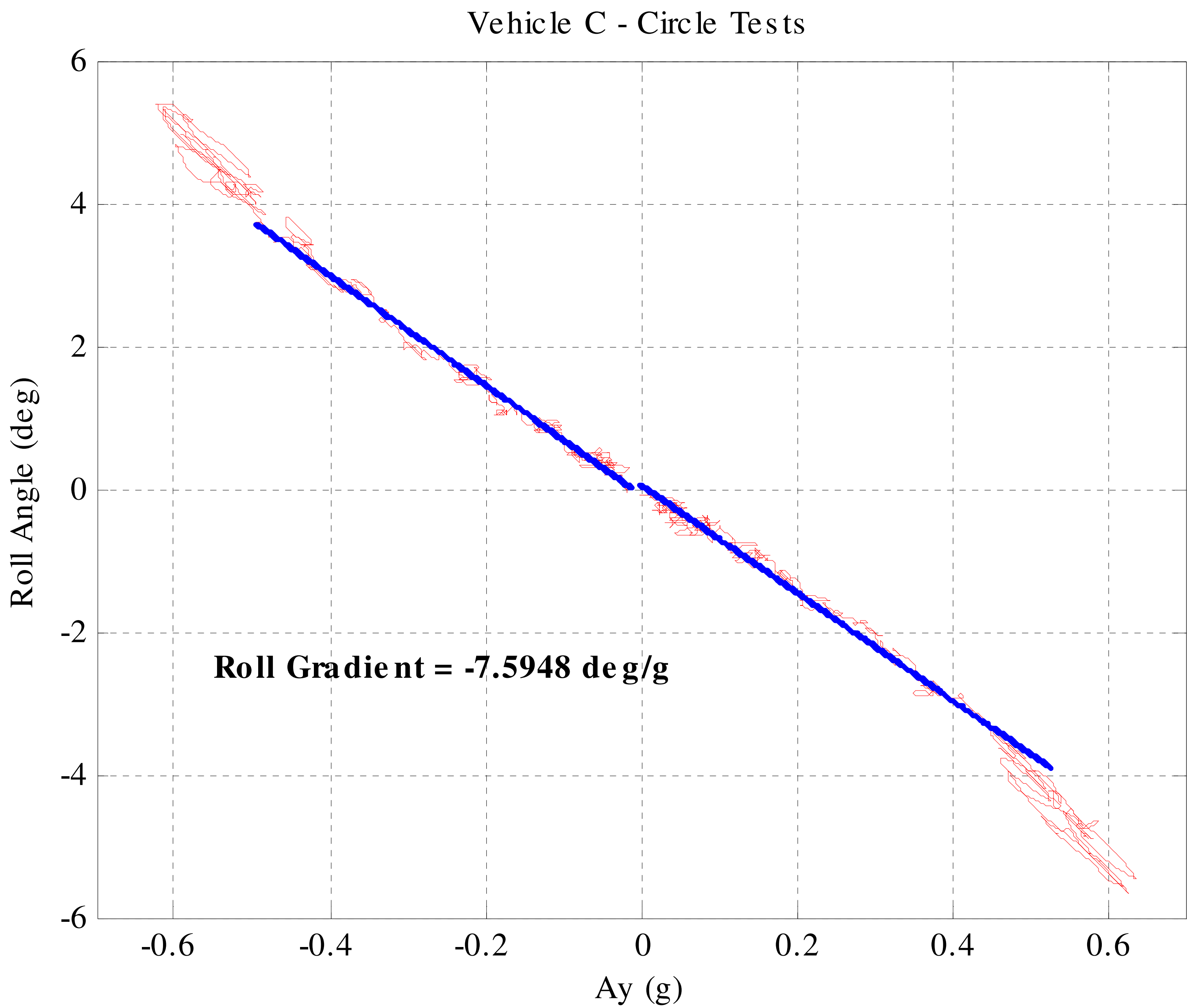


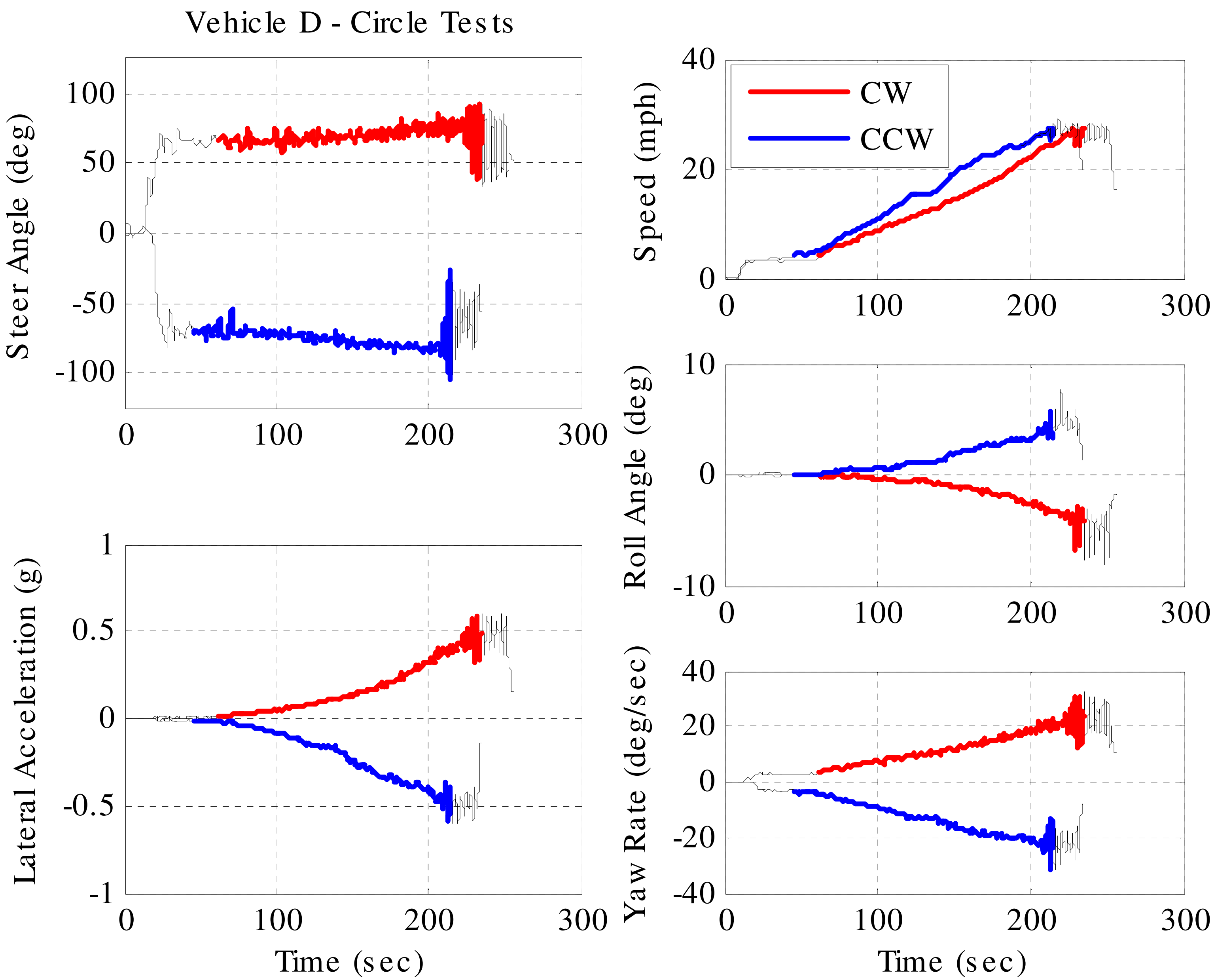
Vehicle B - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -8.4006 deg/g
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6


Vehicle C - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

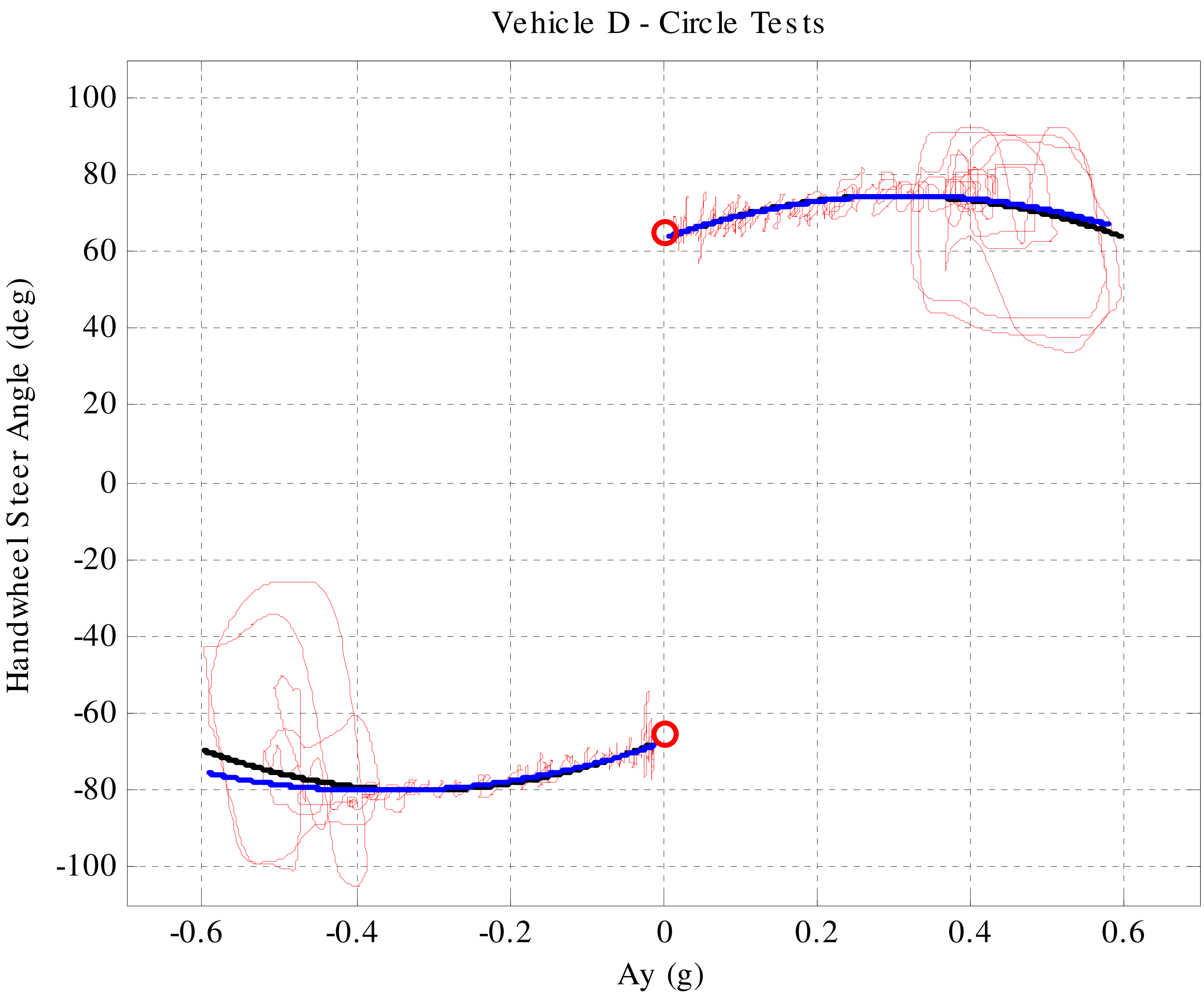

Vehicle C - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

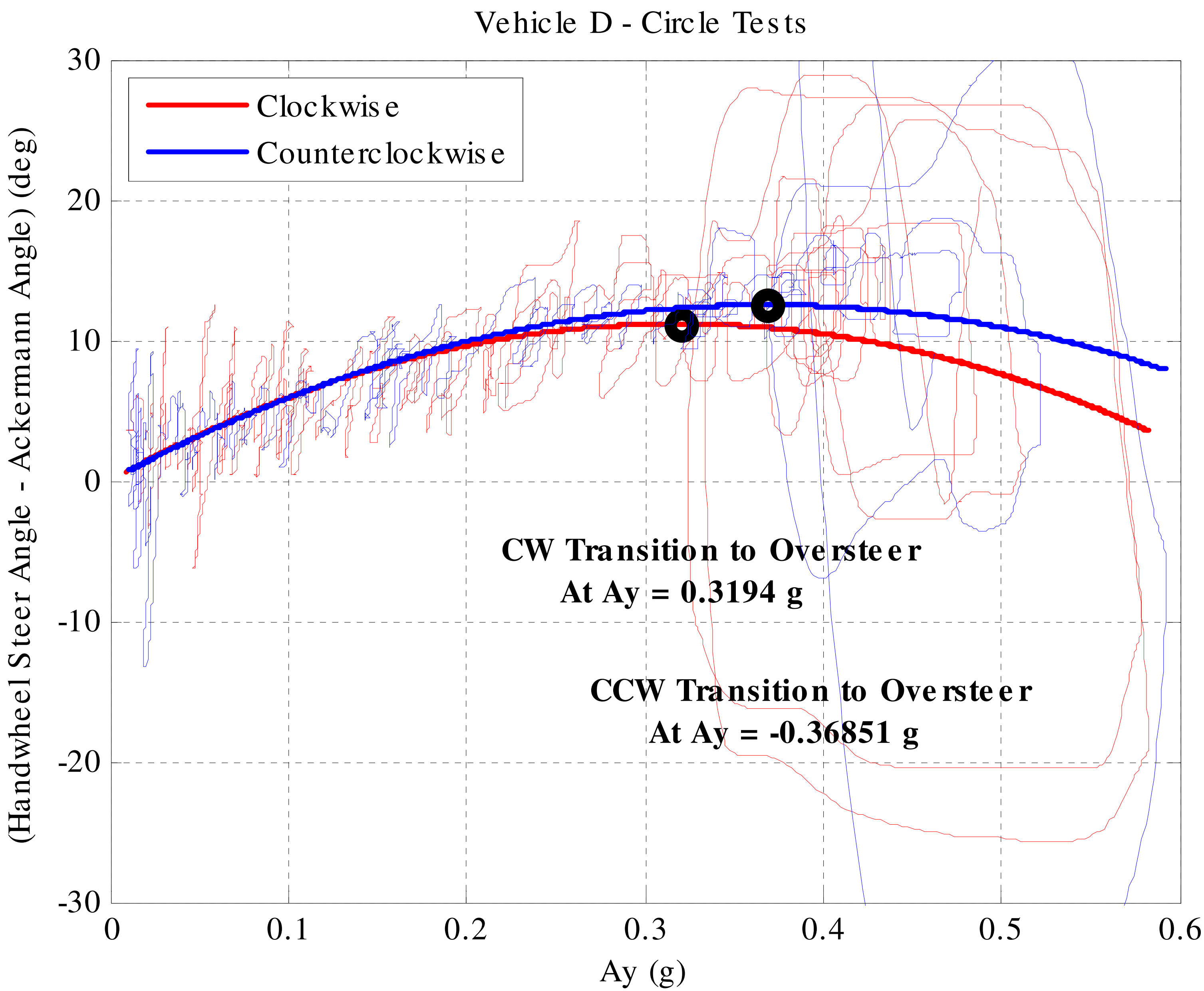

Vehicle C - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
40
35
30
25
20
15
10
5
0
-5
-10
0
0.1
0.2
0.3
0.4
0.5
0.6

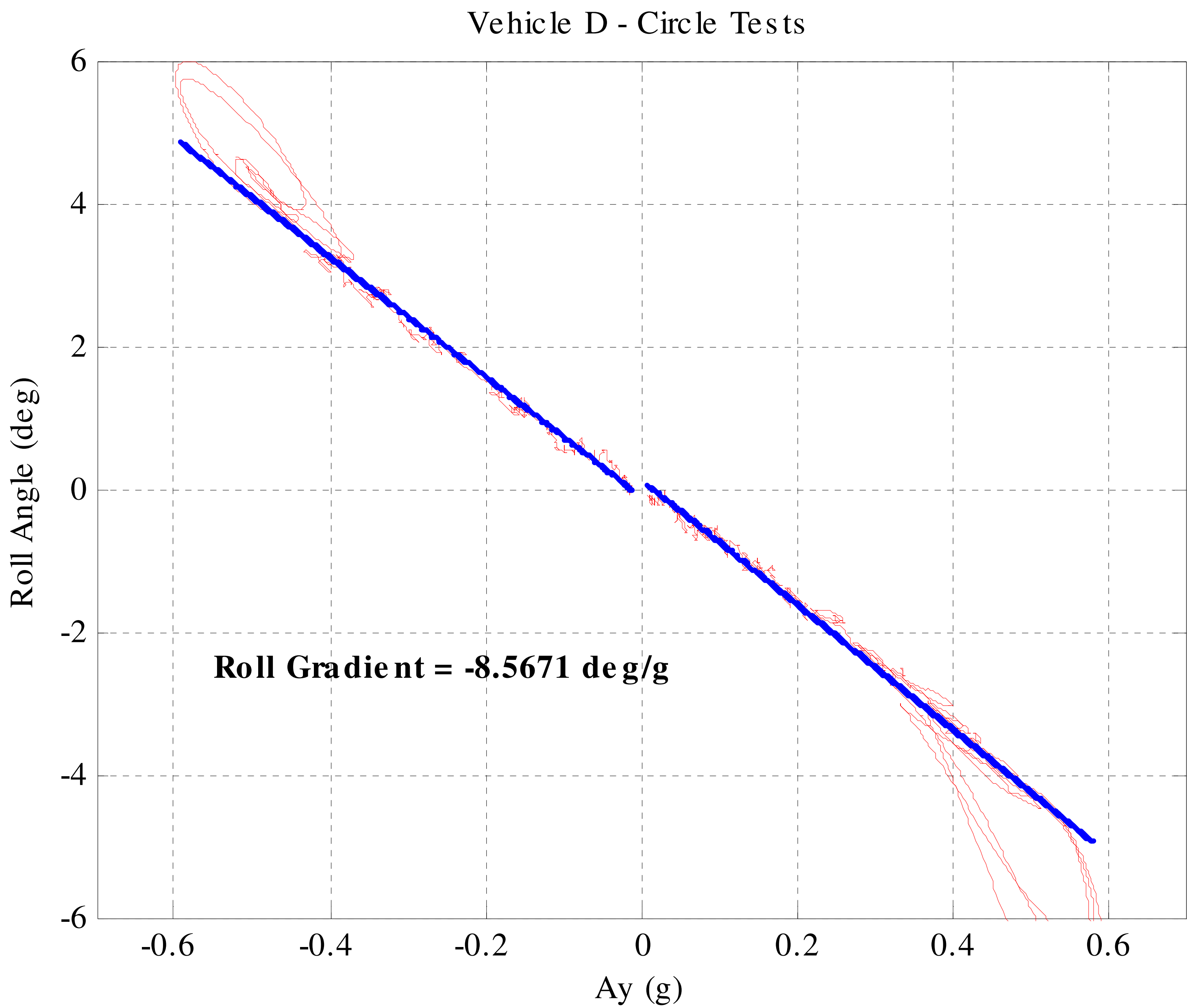

Vehicle C - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -7.5948 deg/g
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

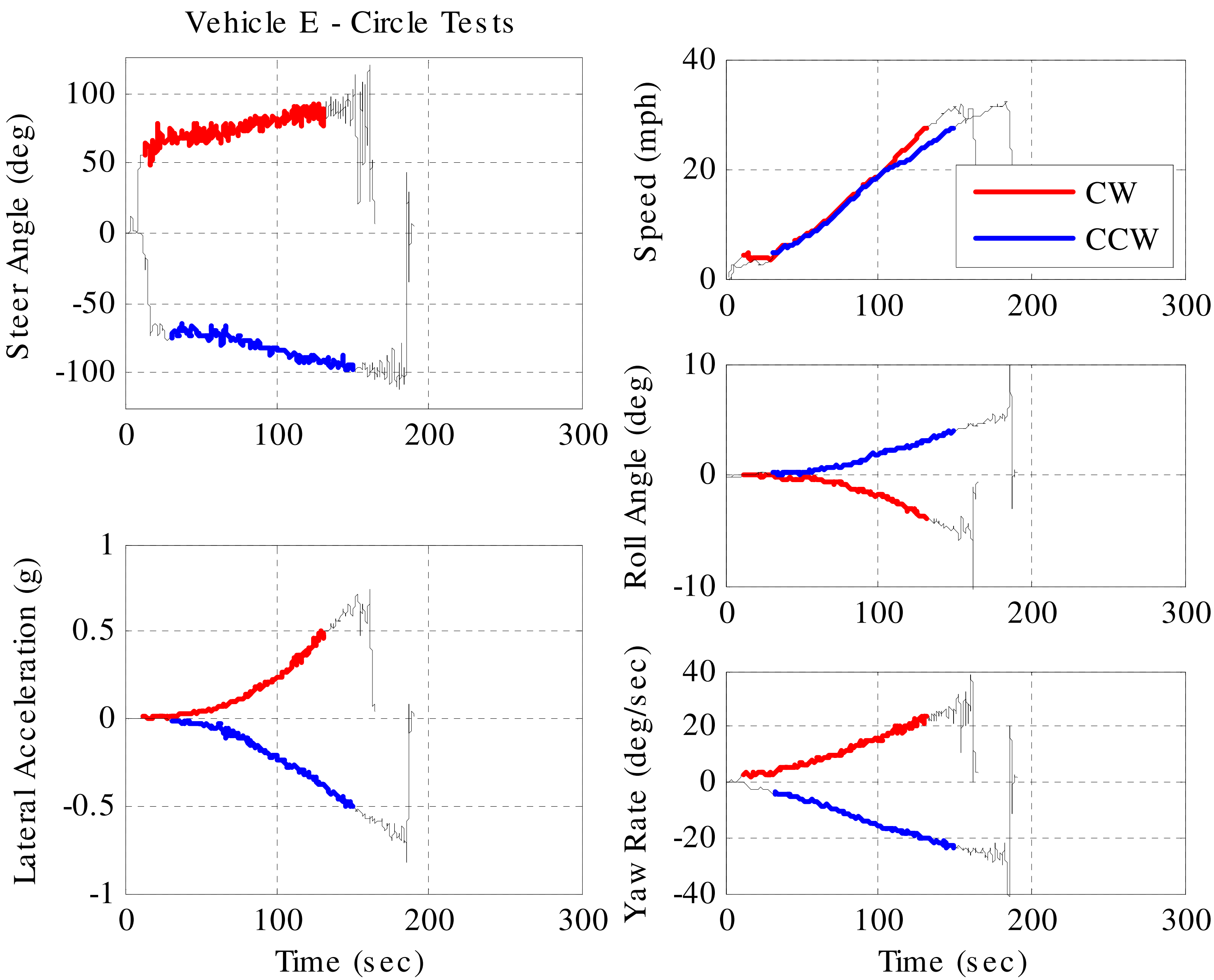


Vehicle D - Circle Tests
Steer Angle (deg)
Lateral Acceleration (g)
Speed (mph)
CW
CCW
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

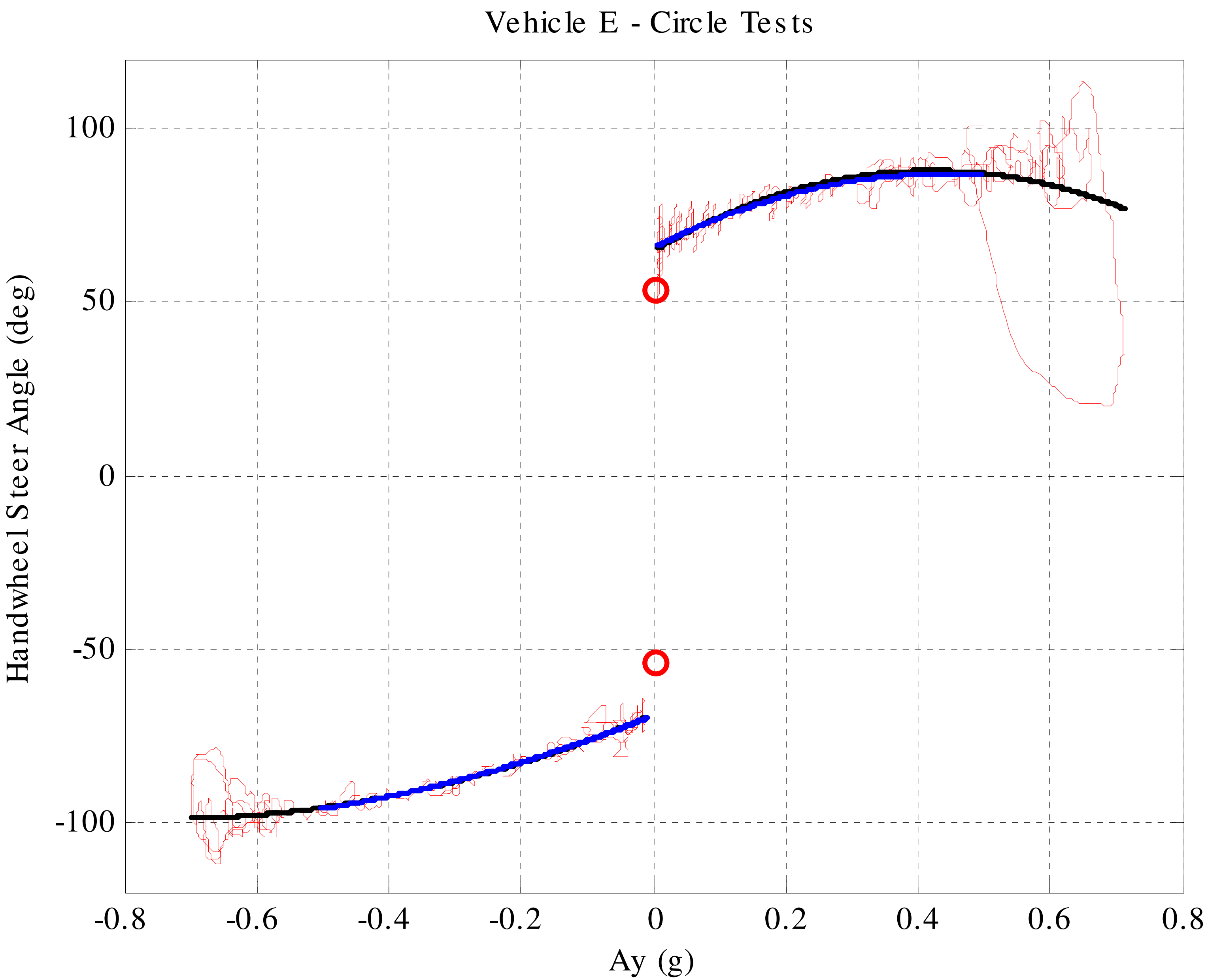

Vehicle D - Circle Tests
Handwheel Steer Angle (deg)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)

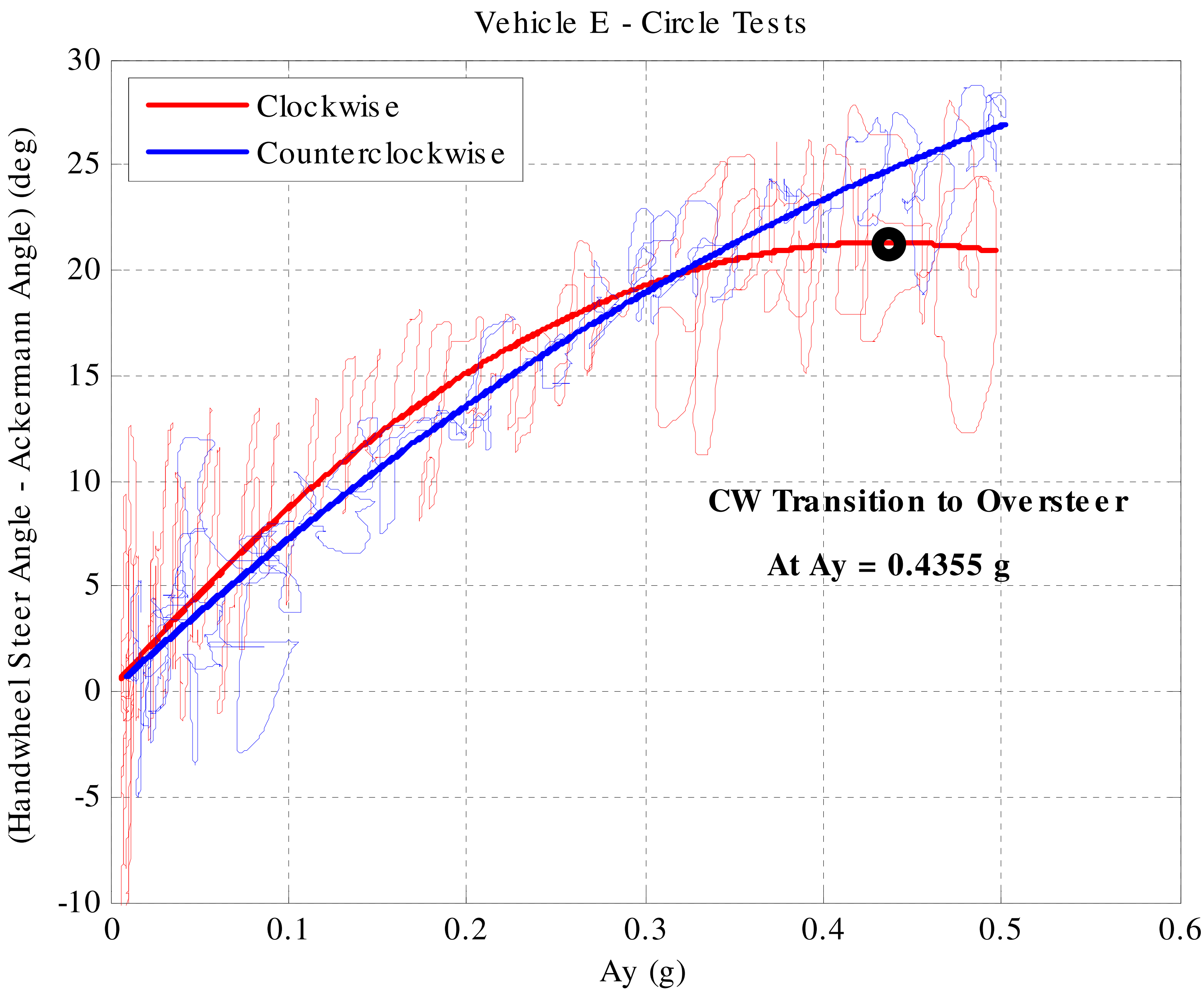

Vehicle D - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
CW Transition to Oversteer
At Ay = 0.3194 g
CCW Transition to Oversteer
At Ay = -0.36851 g
30
20
10
0
-10
-20
-30
0
0.1
0.2
0.3
0.4
0.5
0.6

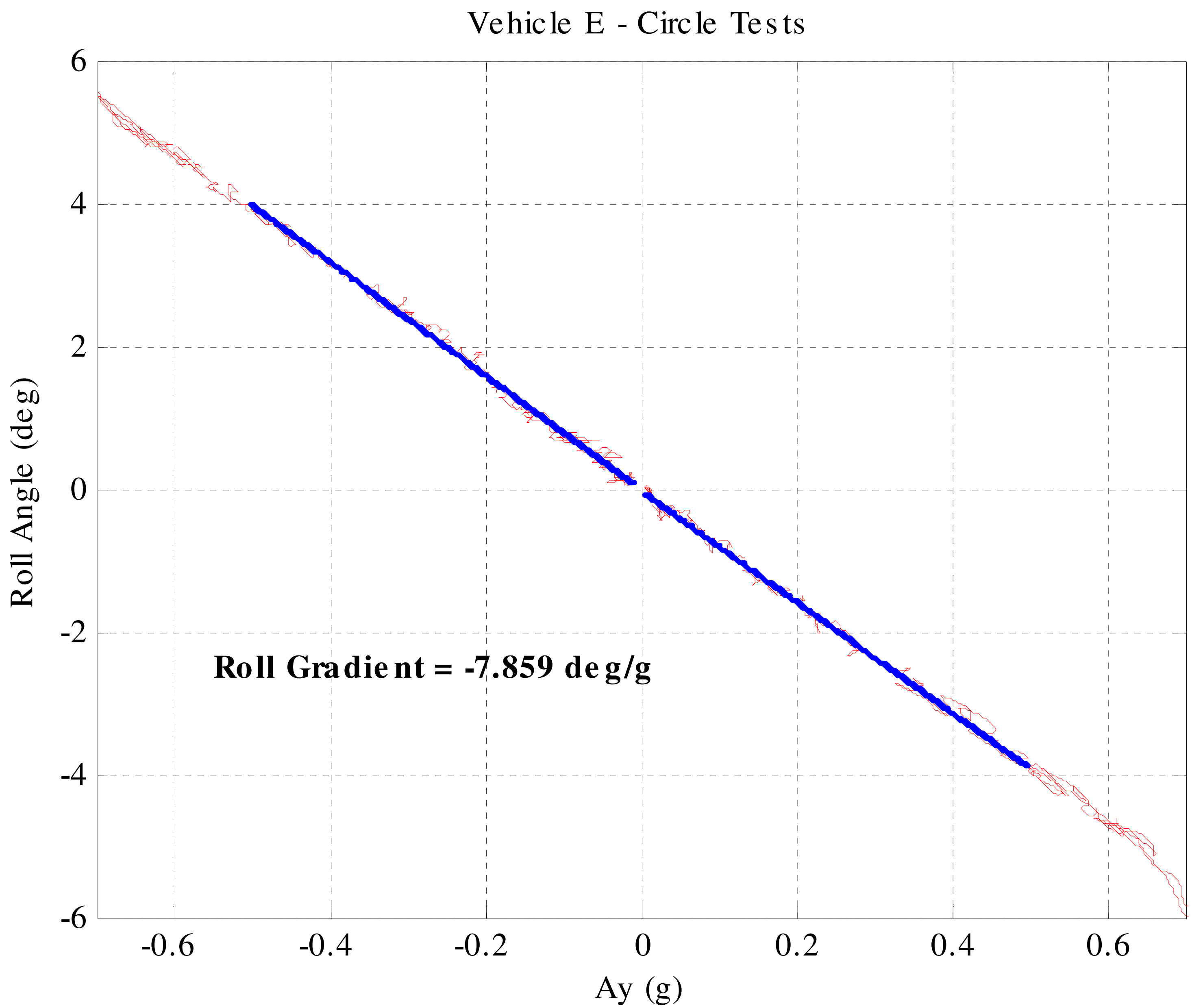

Vehicle D - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -8.5671 deg/g
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6



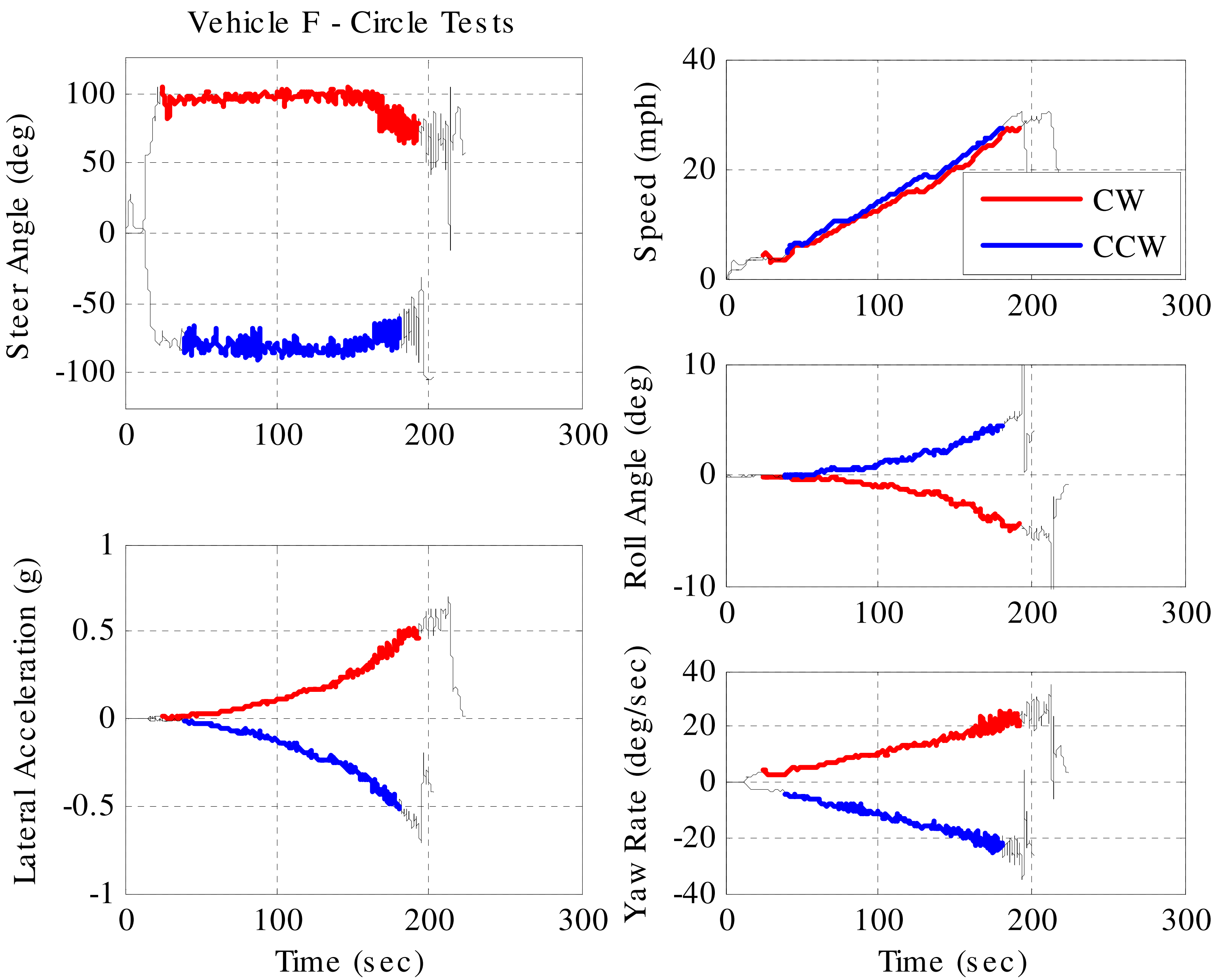
Vehicle E - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

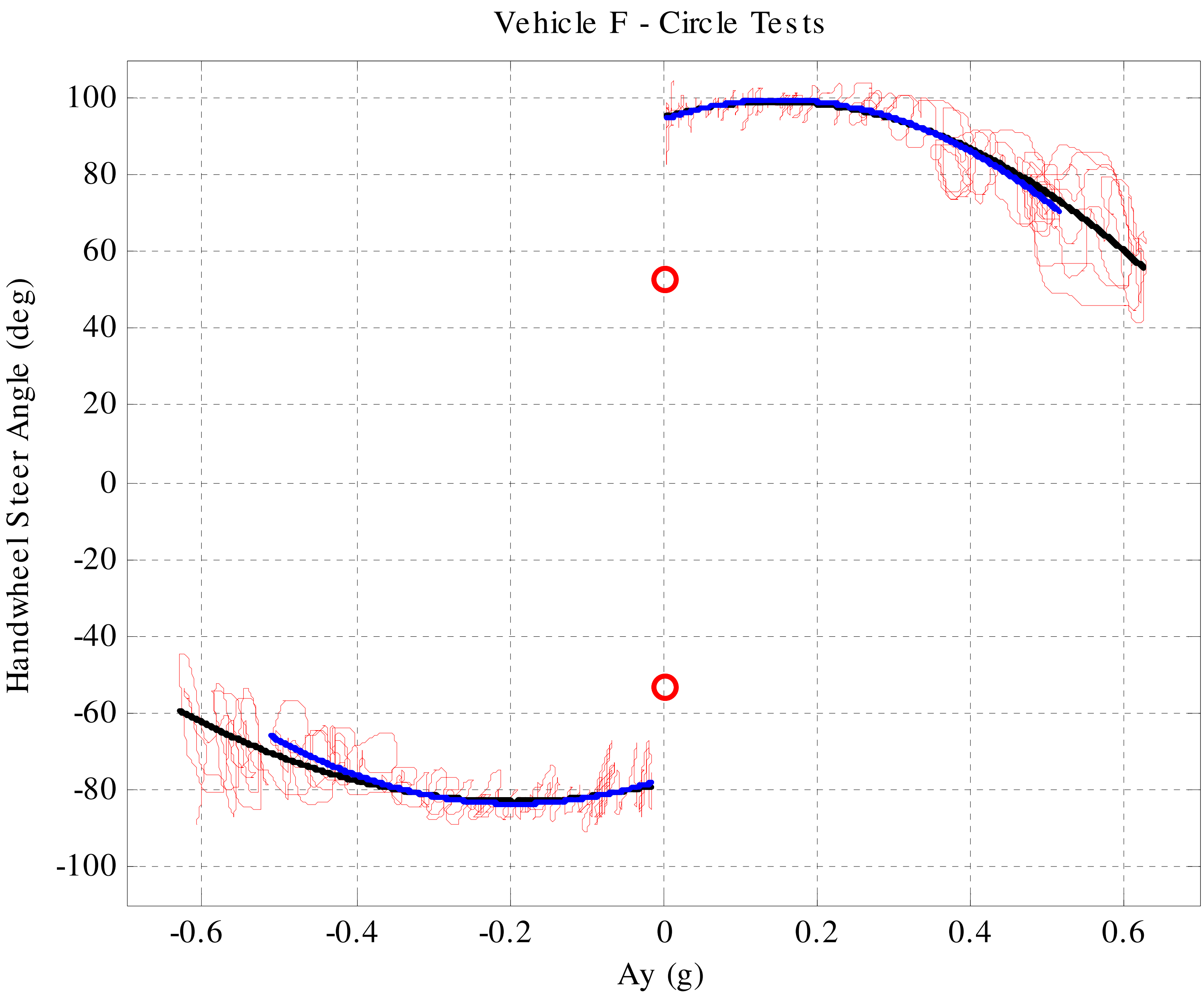

Vehicle E - Circle Tests
Handwheel Steer Angle (deg)
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Ay (g)

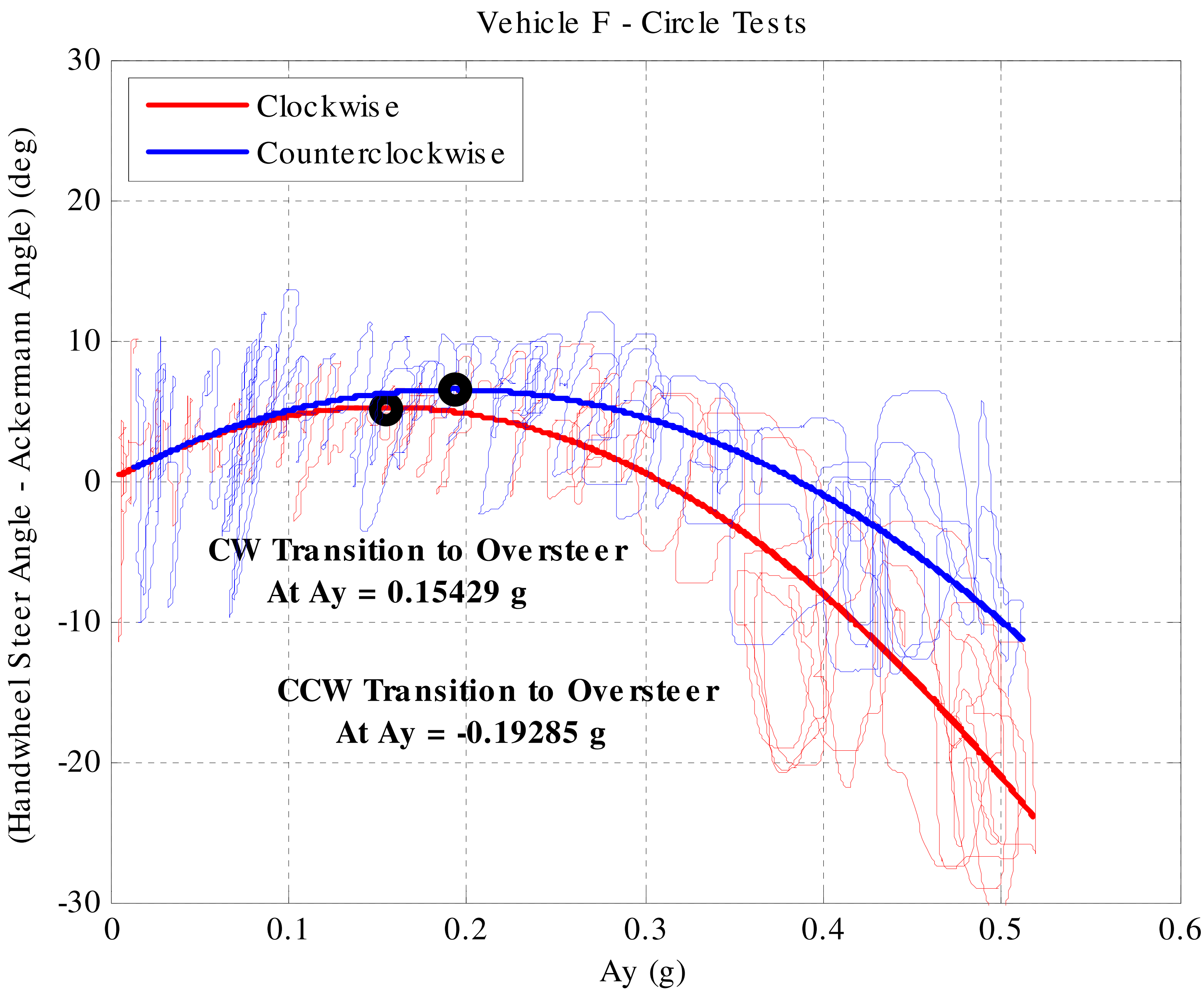

Vehicle E - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.4355 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
30
25
20
15
10
5
0
-5
-10
0
0.1
0.2
0.3
0.4
0.5
0.6



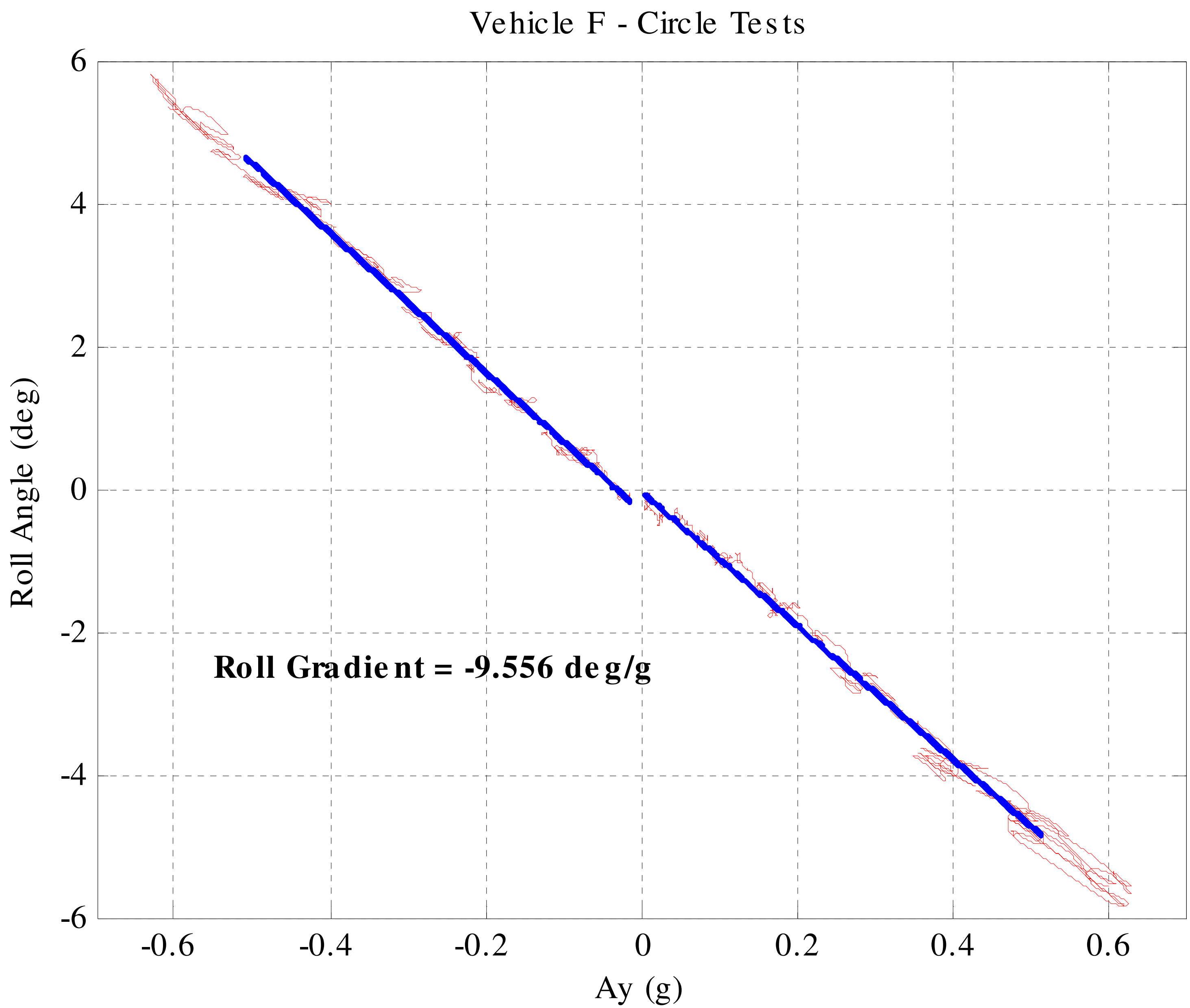
Vehicle E - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -7.859 deg/g
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6


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

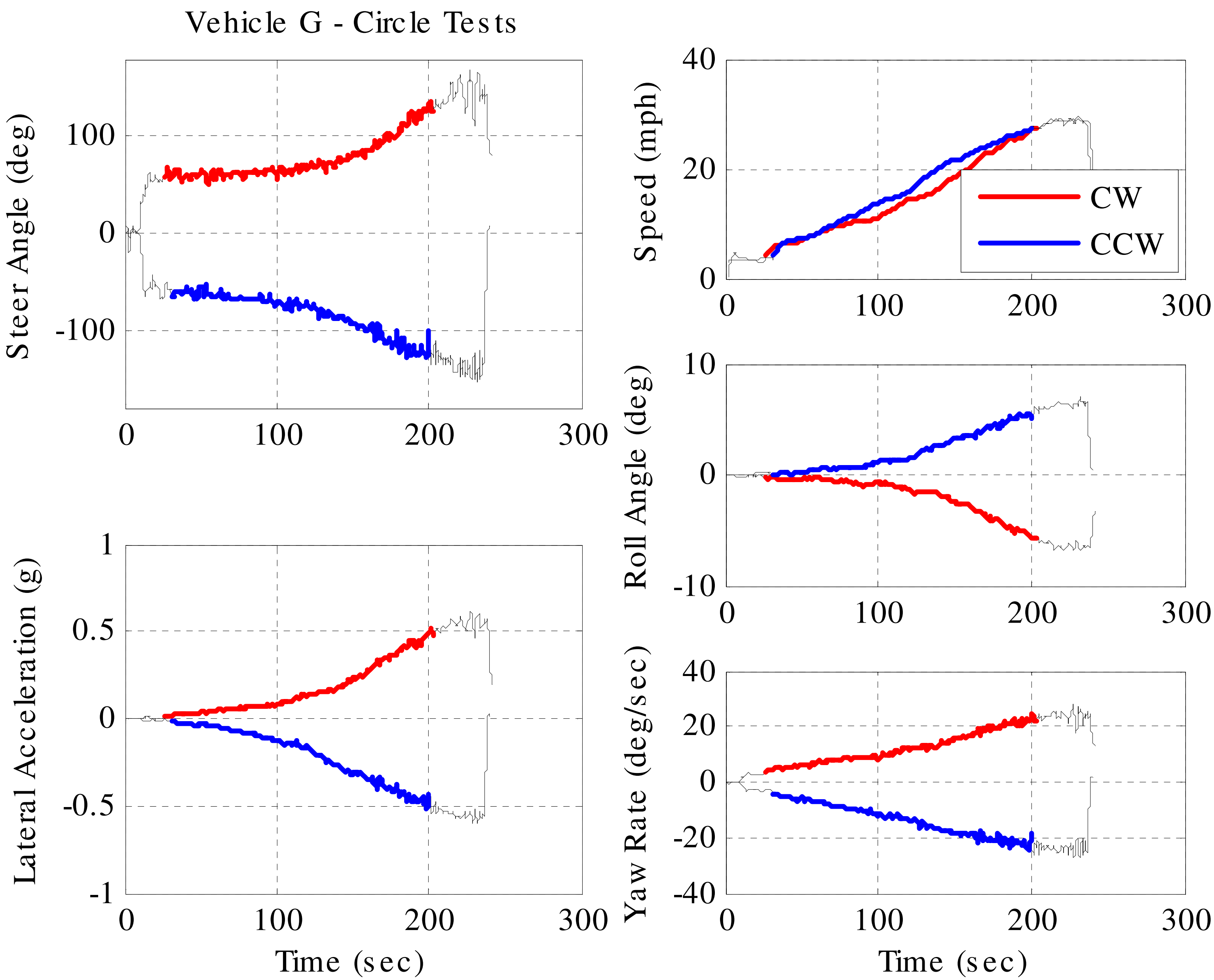

Vehicle F - Circle Tests
100
80
60
40
20
0
-20
-40
-60
-80
-100
Handwheel Steer Angle (deg)
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)



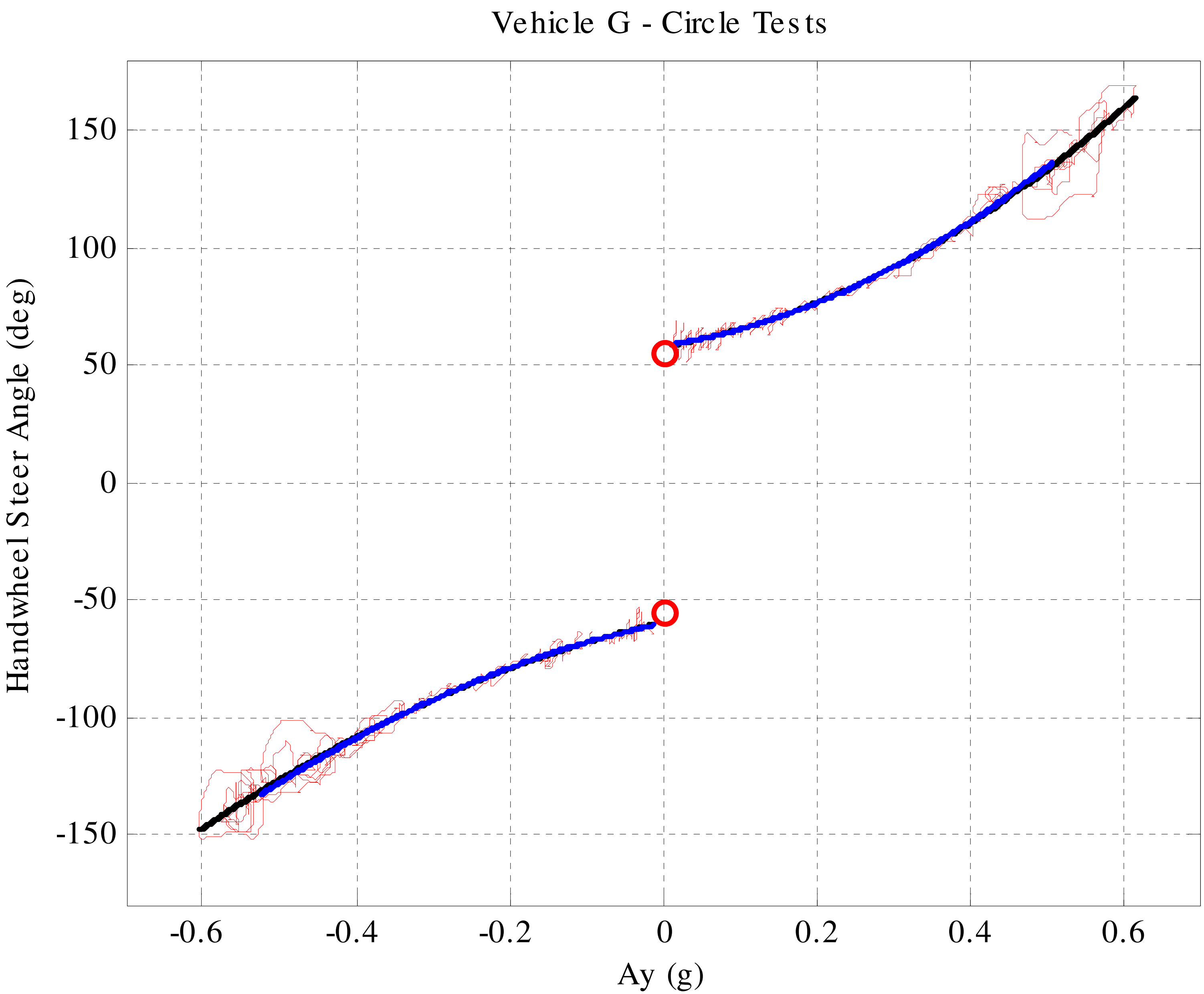
Vehicle F - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.15429 g
CCW Transition to Oversteer
At Ay = -0.19285 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
30
20
10
0
-10
-20
-30
0
0.1
0.2
0.3
0.4
0.5
0.6

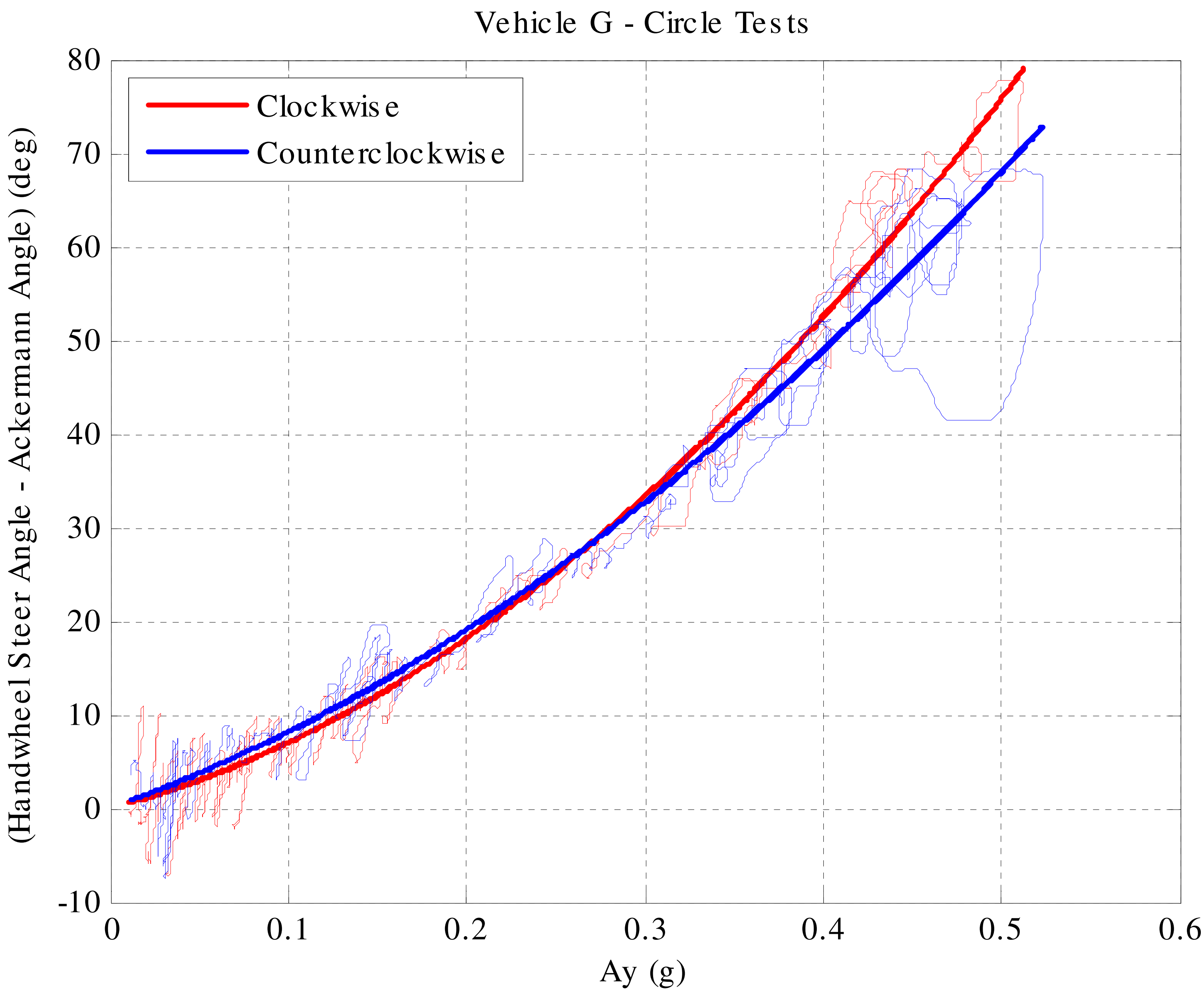


Vehicle F - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -9.556 deg/g
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

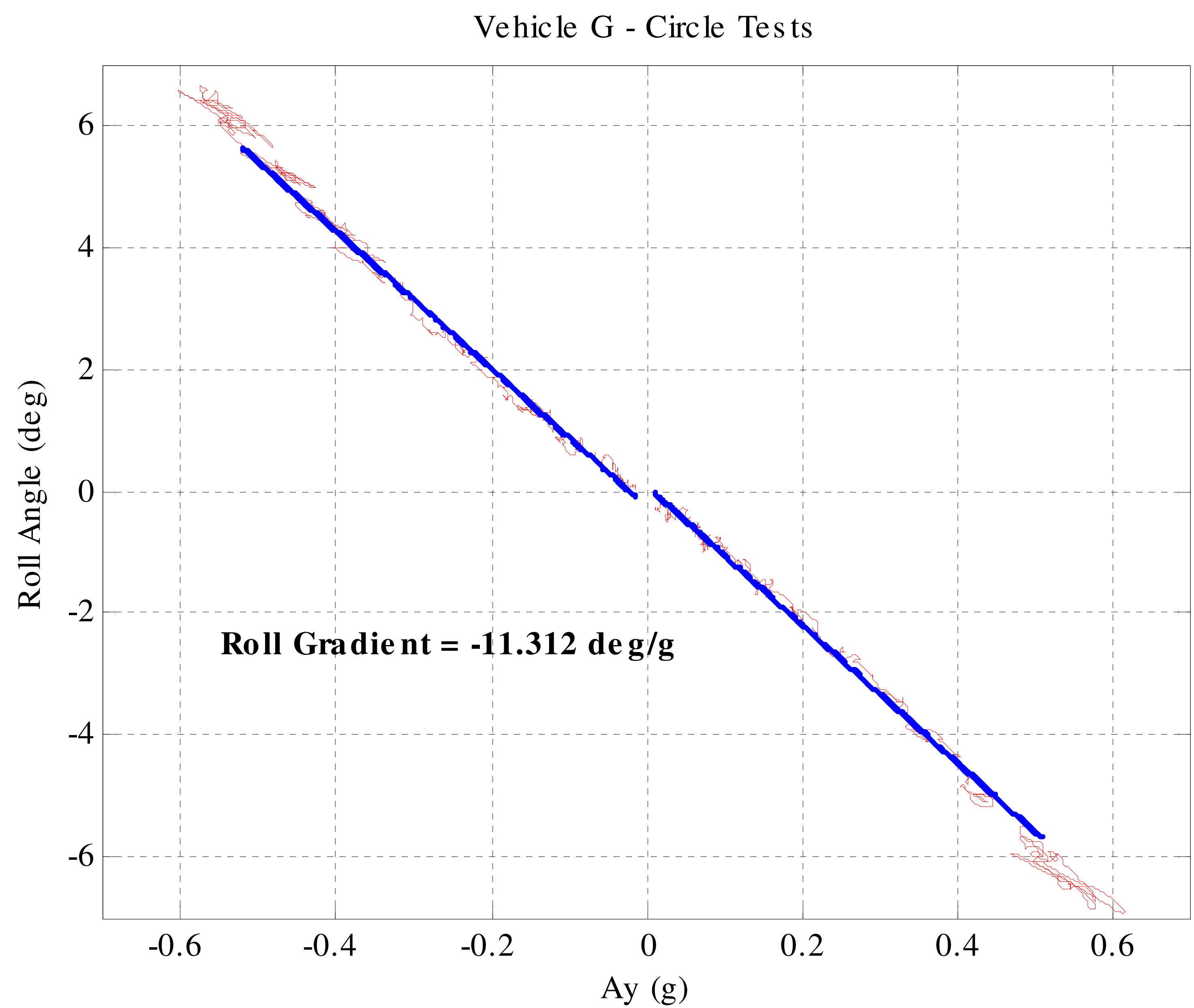


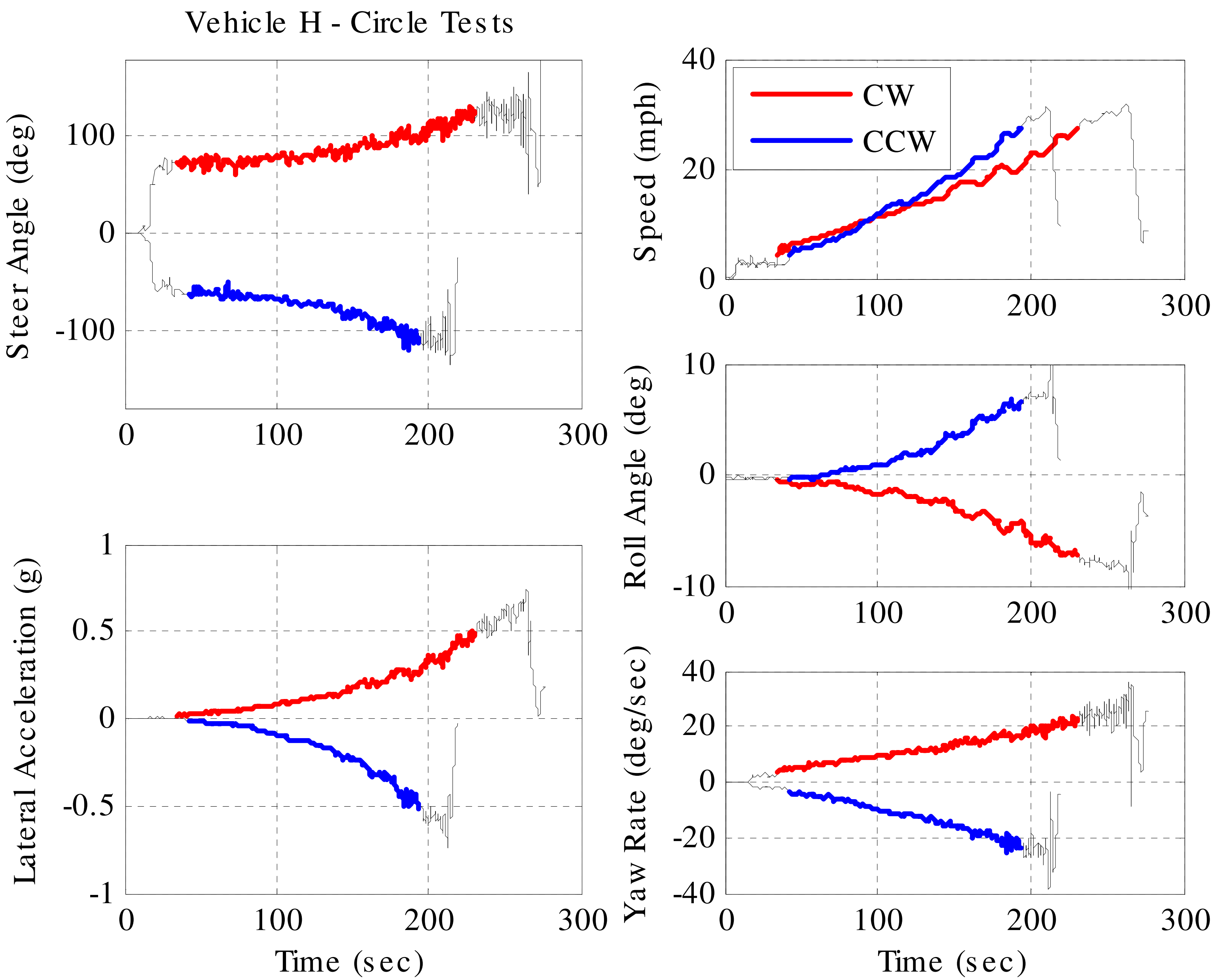
Vehicle G - Circle Tests
Steer Angle (deg)
100
0
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

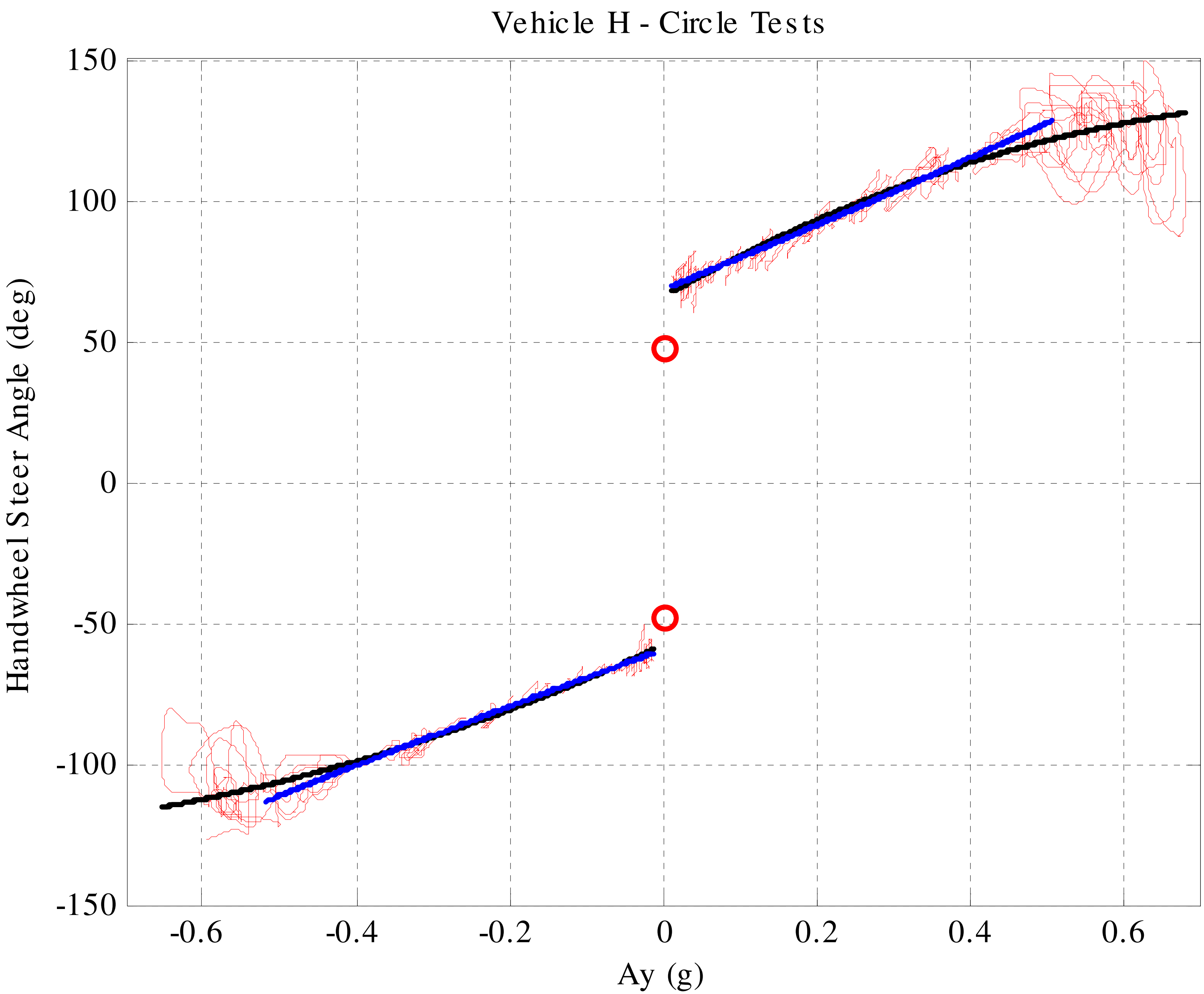

Vehicle G - Circle Tests
Handwheel Steer Angle (deg)
150
100
50
0
-50
-100
-150
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)

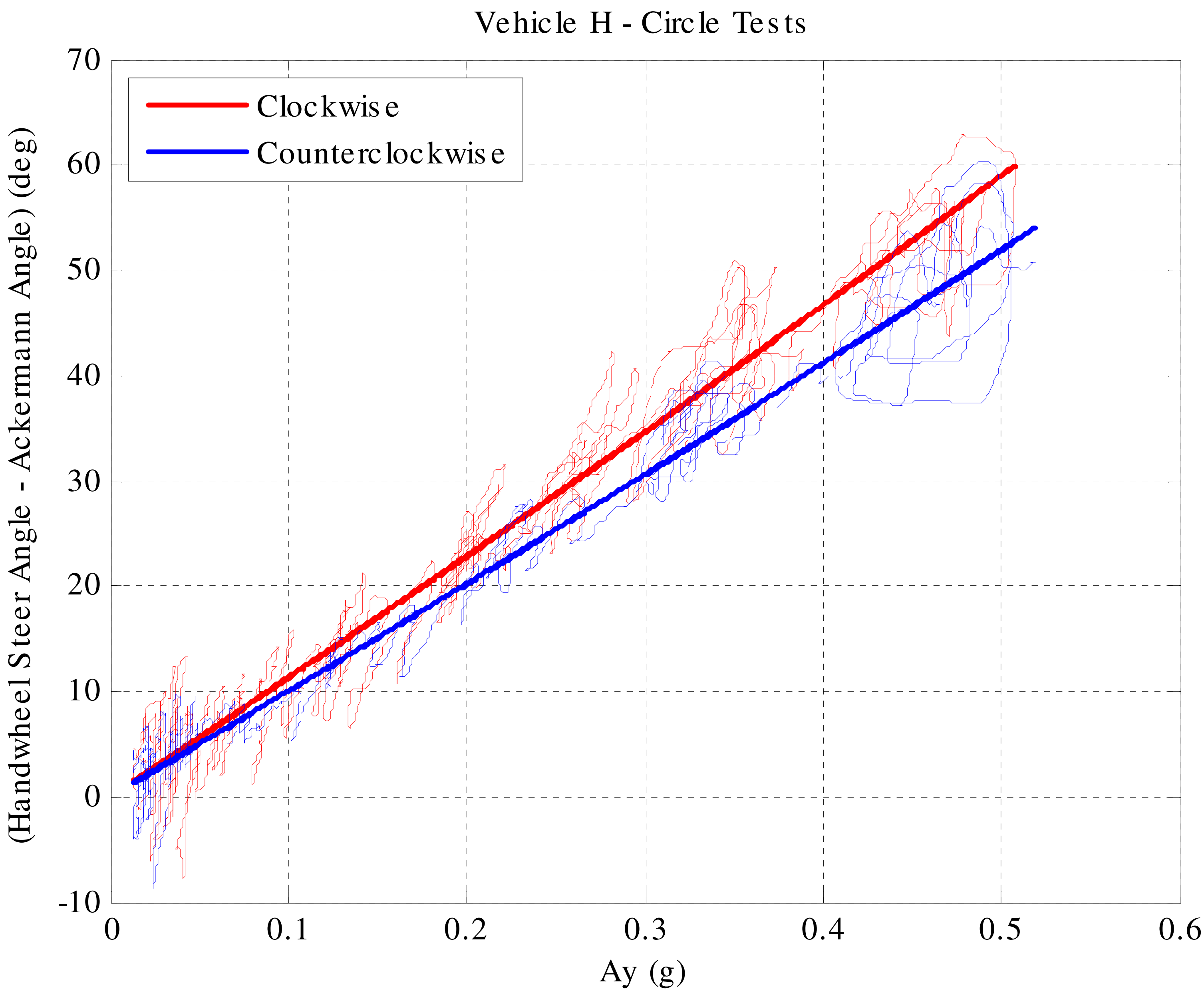


Vehicle G - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
Ay (g)

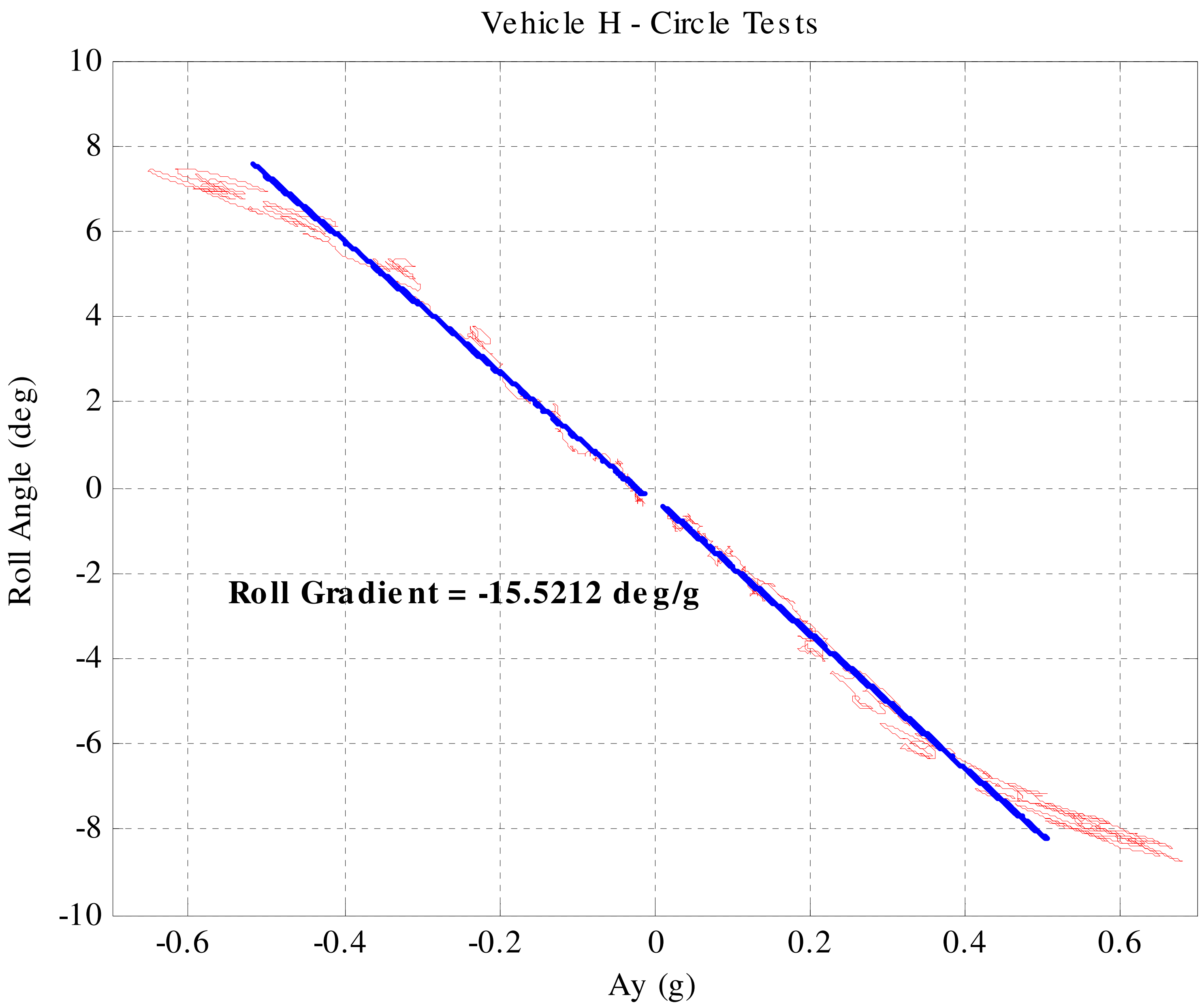

Vehicle G - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -11.312 deg/g
6
4
2
0
-2
-4
-6
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

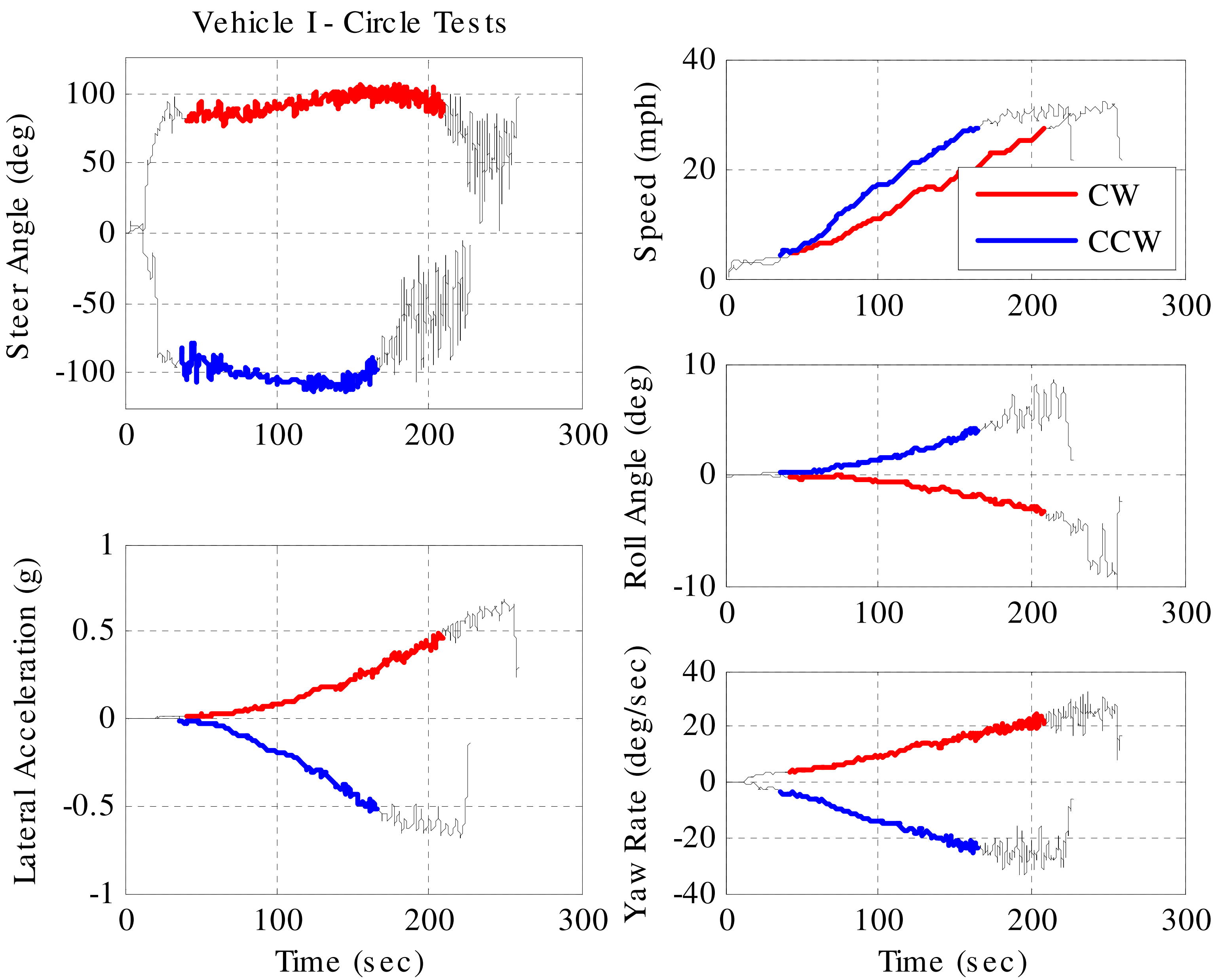

Vehicle H - Circle Tests
Steer Angle (deg)
100
0
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)


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

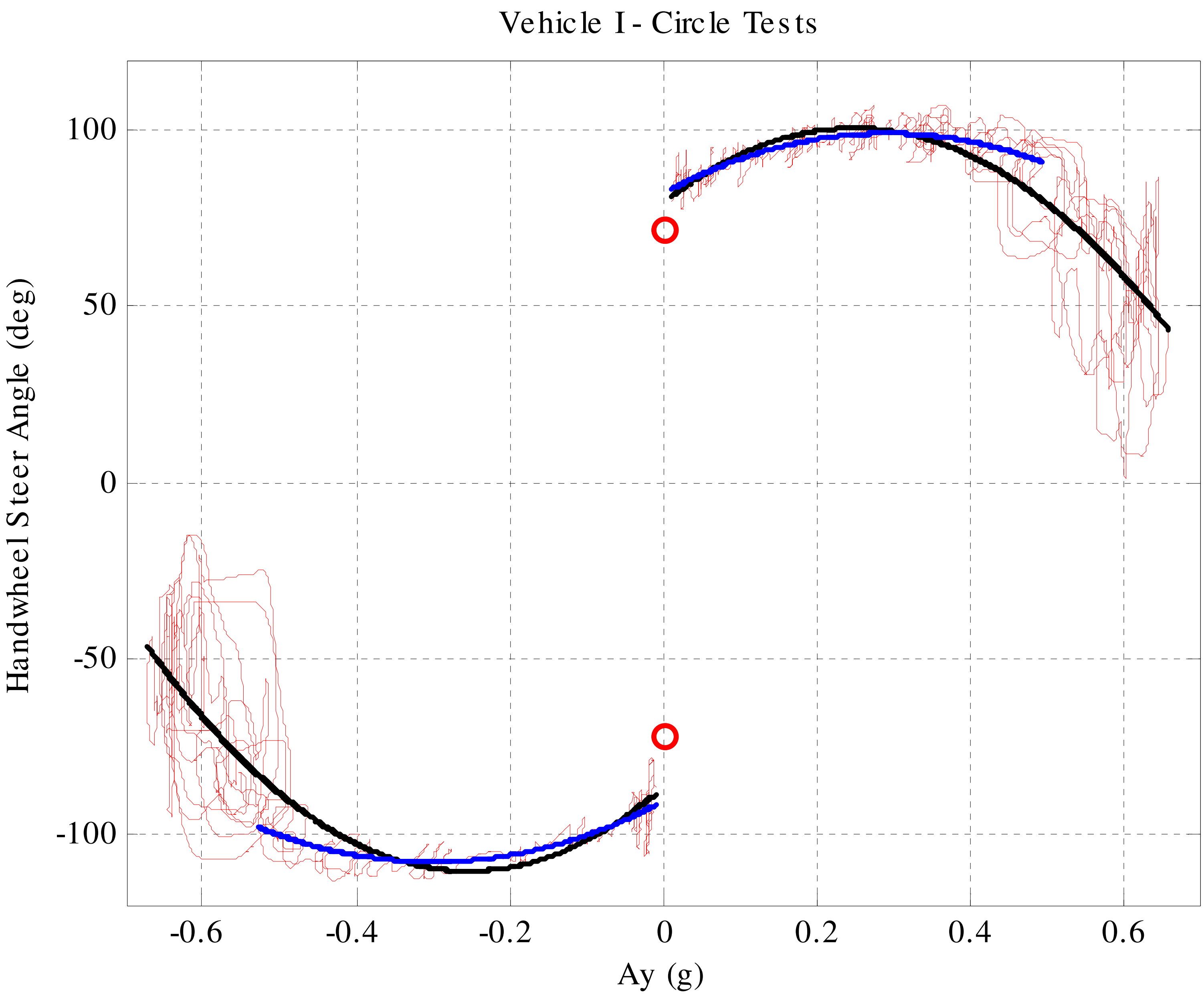


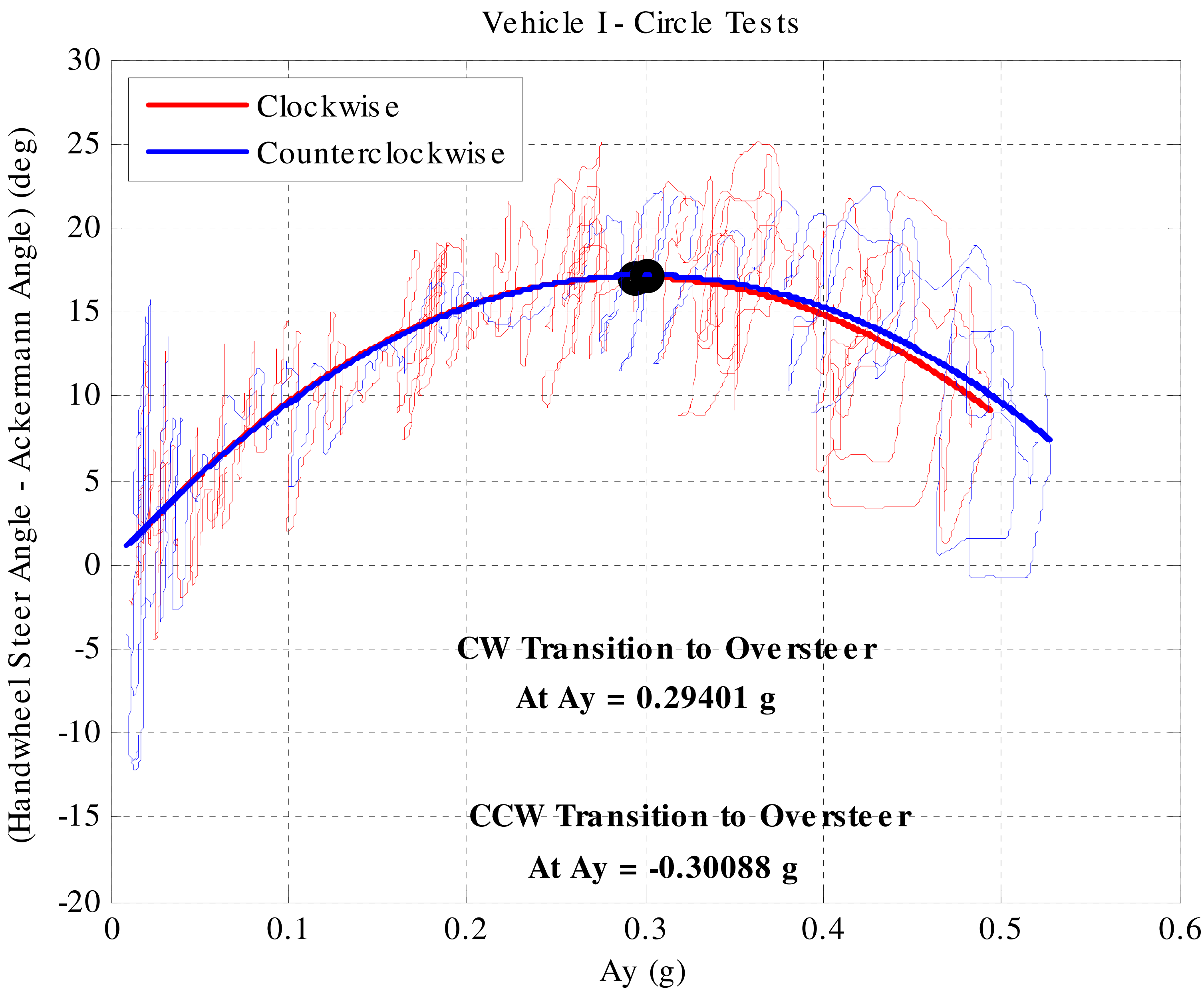
Vehicle H - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
Ay (g)


Vehicle H - Circle Tests
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Roll Angle (deg)
Ay (g)
Roll Gradient = -15.5212 deg/g

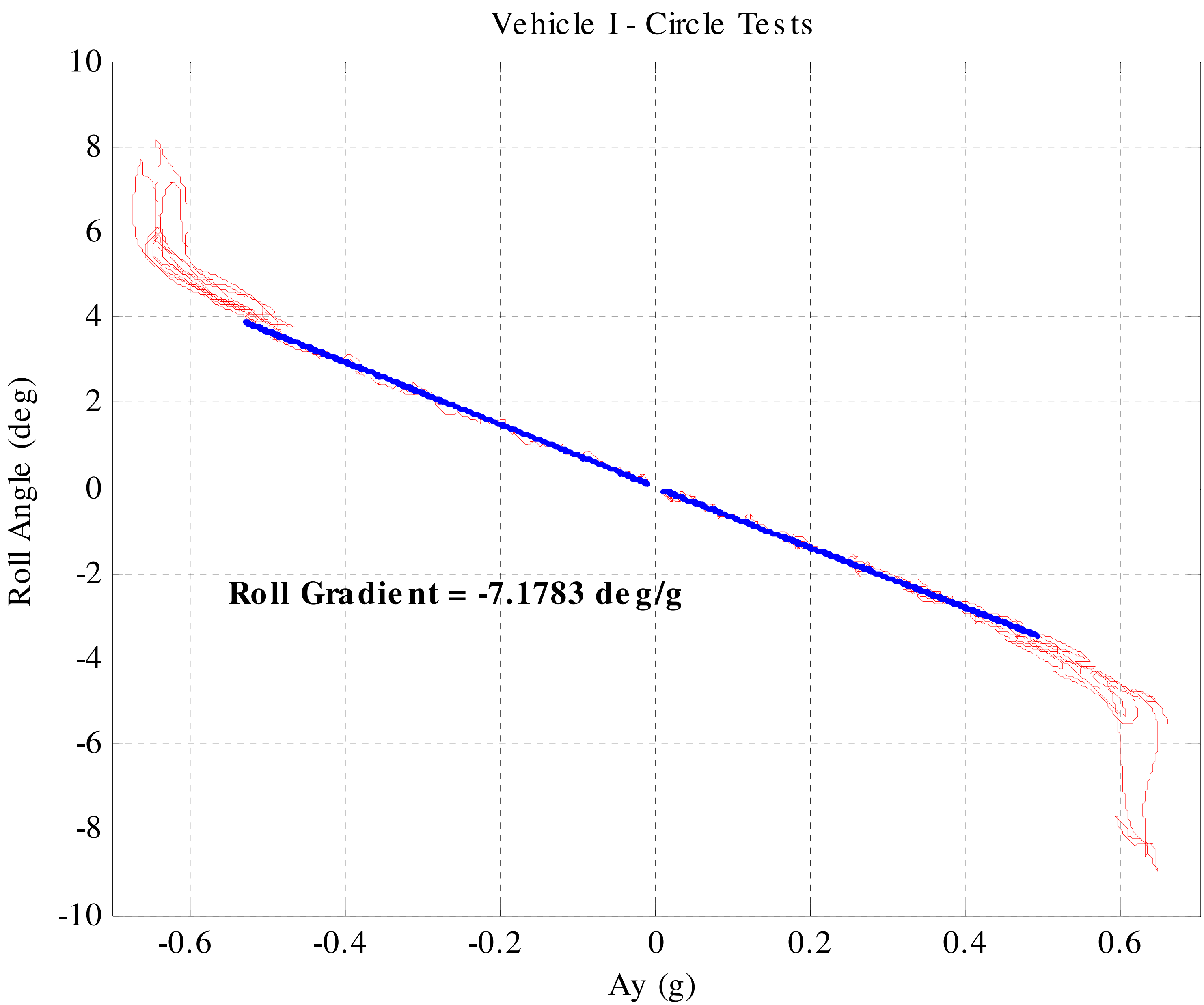


Vehicle I - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

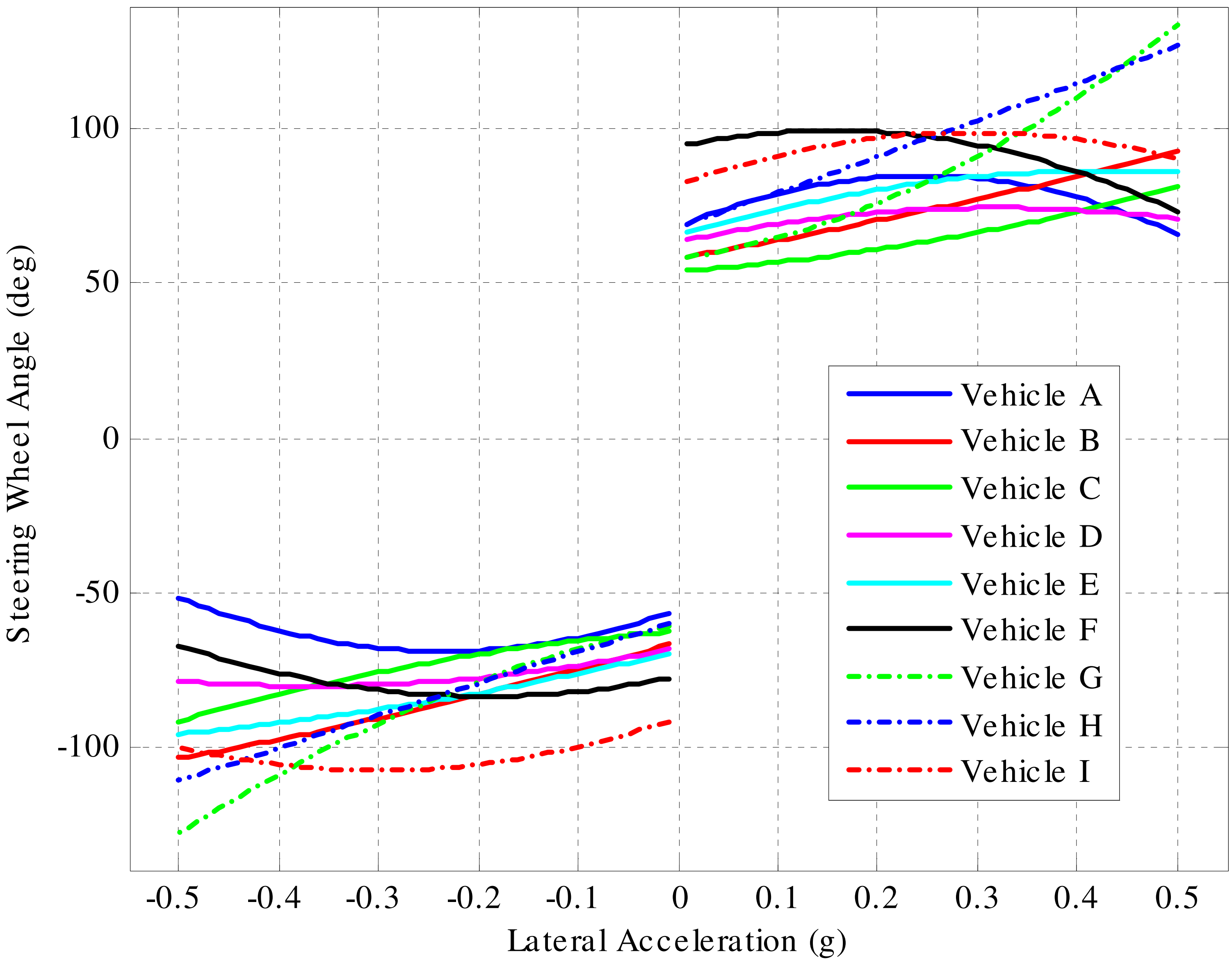

Vehicle I - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
100
50
0
-50
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

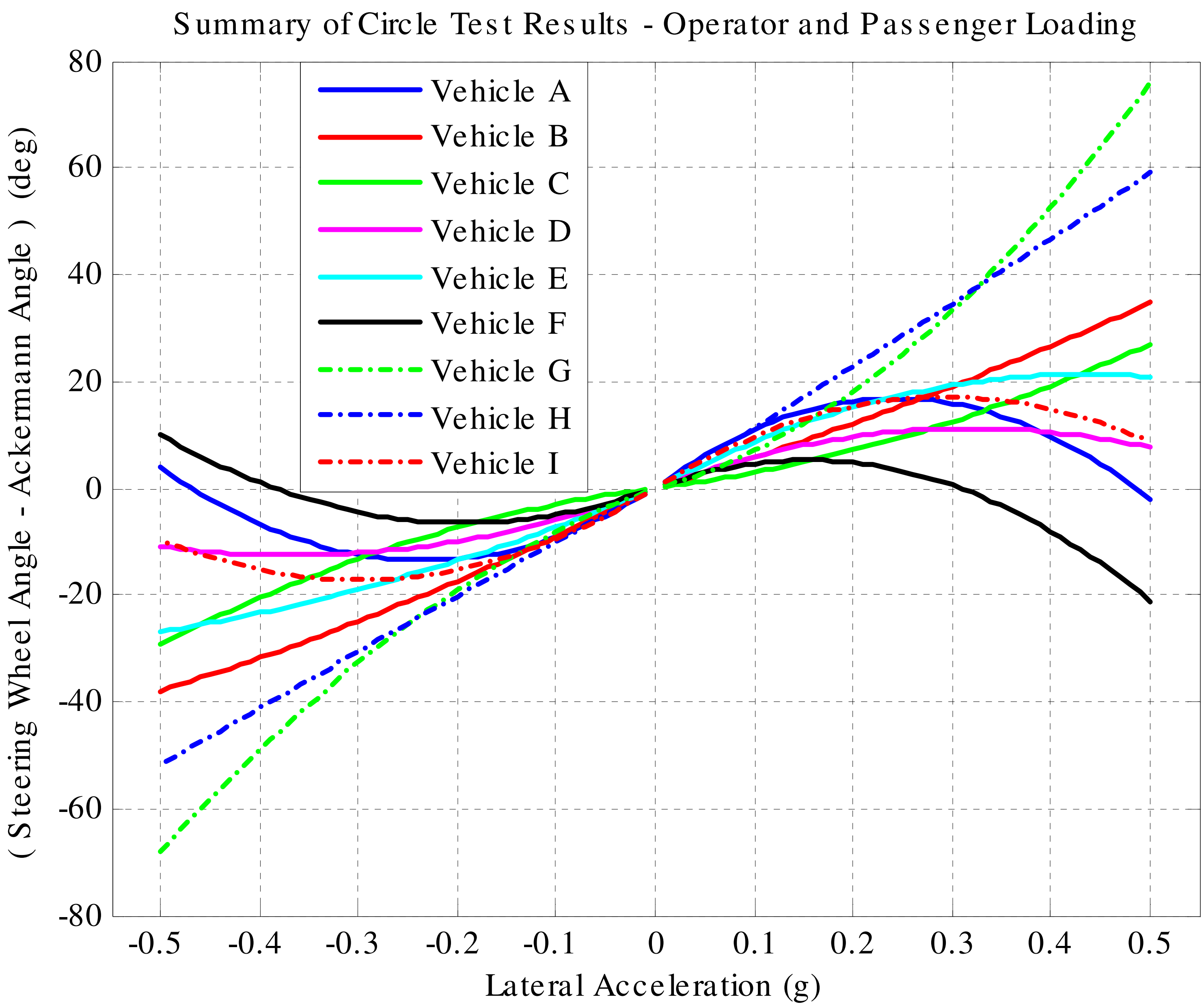


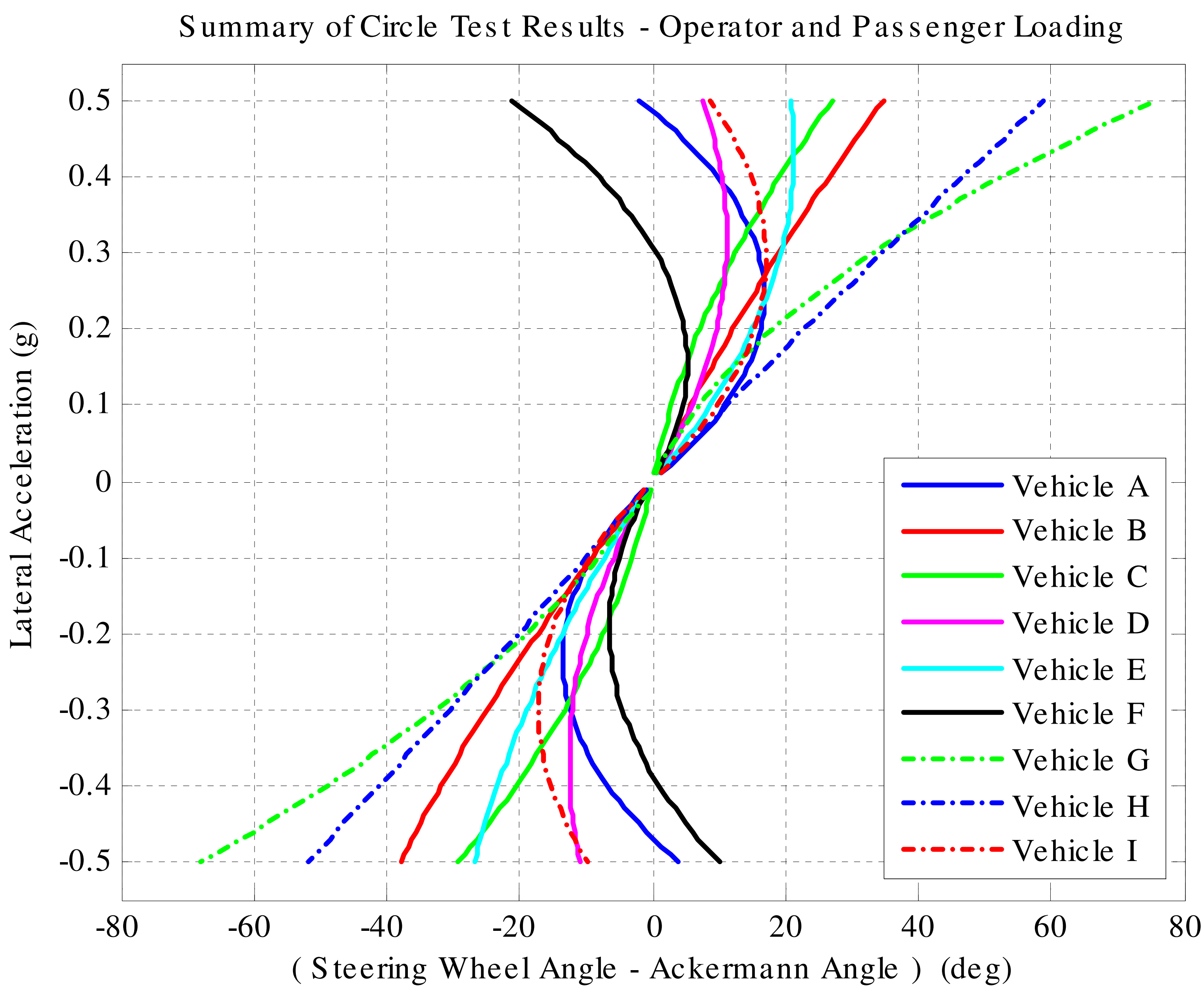
Vehicle I - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.29401 g
CCW Transition to Oversteer
At Ay = -0.30088 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
30
25
20
15
10
5
0
-5
-10
-15
-20
0
0.1
0.2
0.3
0.4
0.5
0.6


Vehicle I - Circle Tests
10
8
6
4
2
0
-2
-4
-6
-8
-10
Roll Angle (deg)
Roll Gradient = -7.1783 deg/g
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)

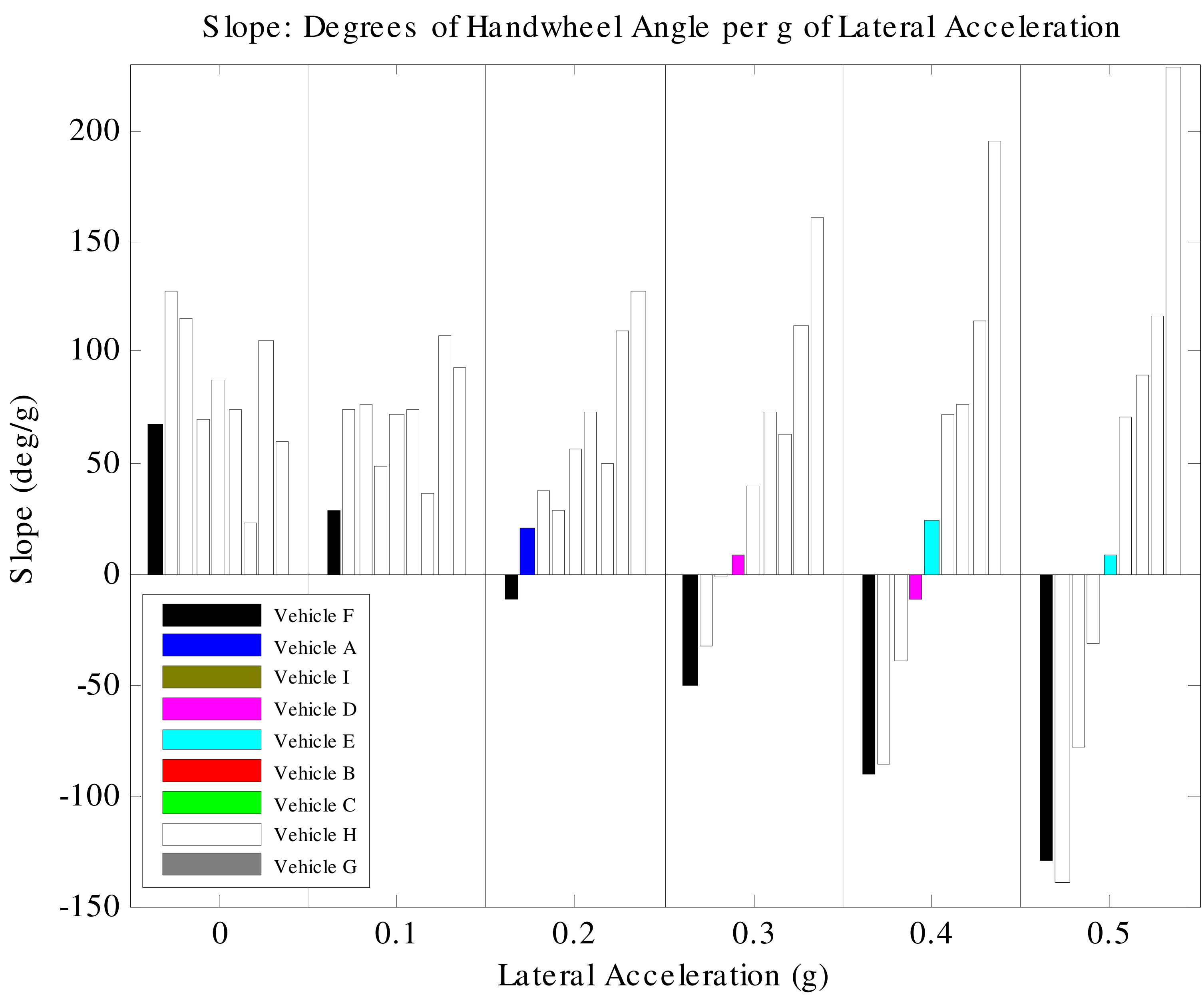
Summary of Circle Test Results - Operator and Passenger Loading

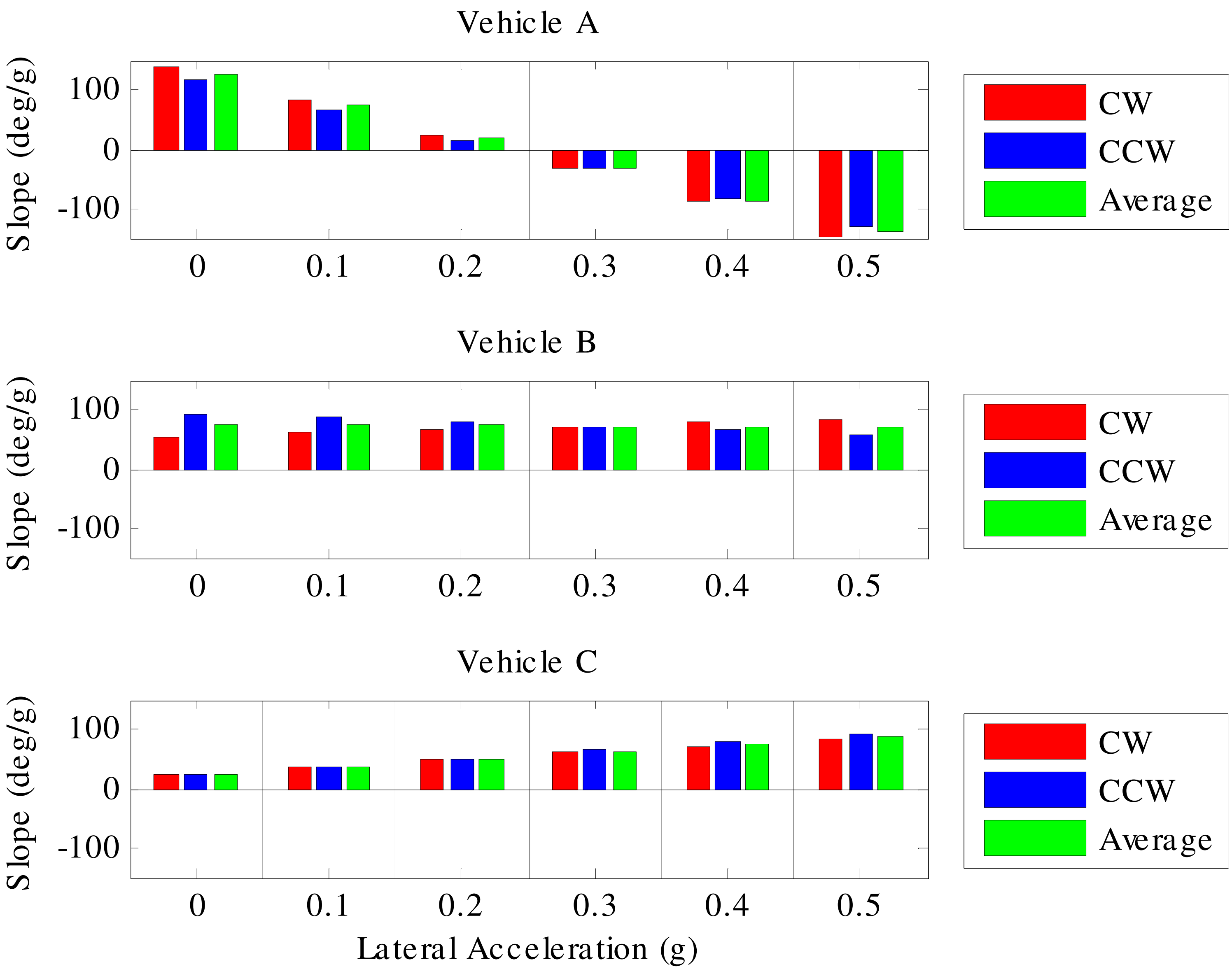


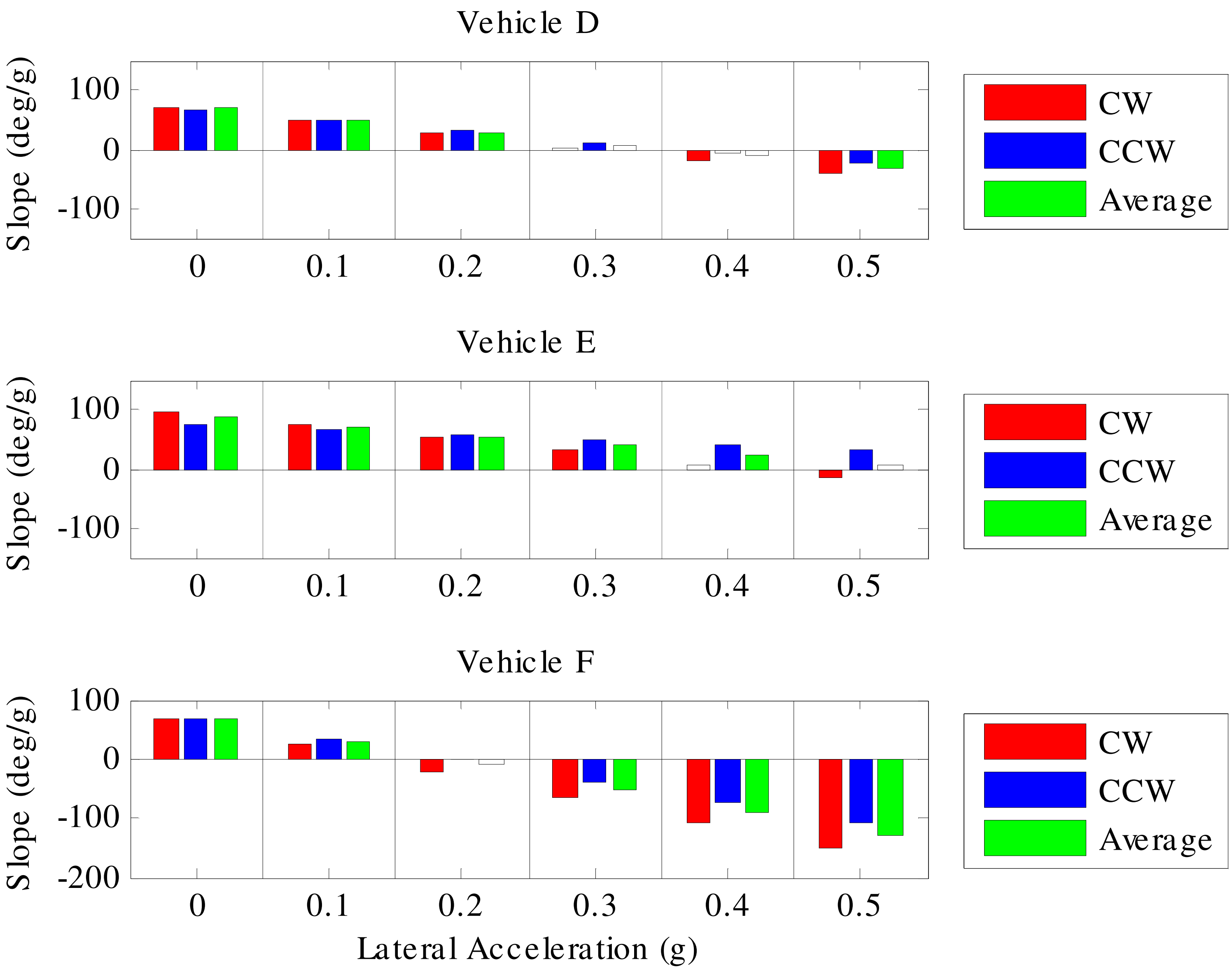

Summary of Circle Test Results - Operator and Passenger Loading
Vehicle A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I
(Steering Wheel Angle - Ackermann Angle) (deg)
80
60
40
20
0
-20
-40
-60
-80
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)

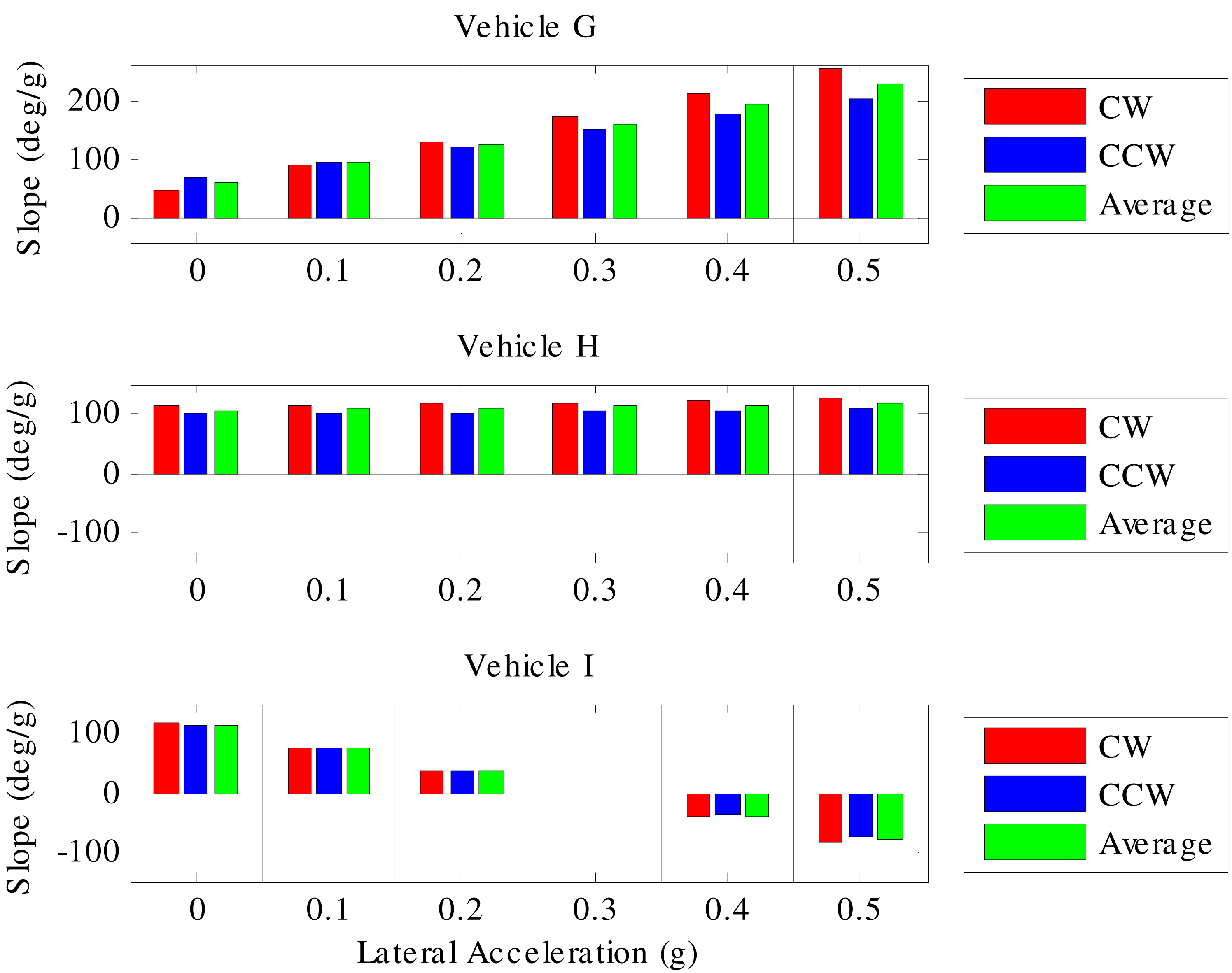


Summary of Circle Test Results - Operator and Passenger Loading
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-80
-60
-40
-20
0
20
40
60
80
(Steering Wheel Angle - Ackermann Angle) (deg)
Vehicle A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I

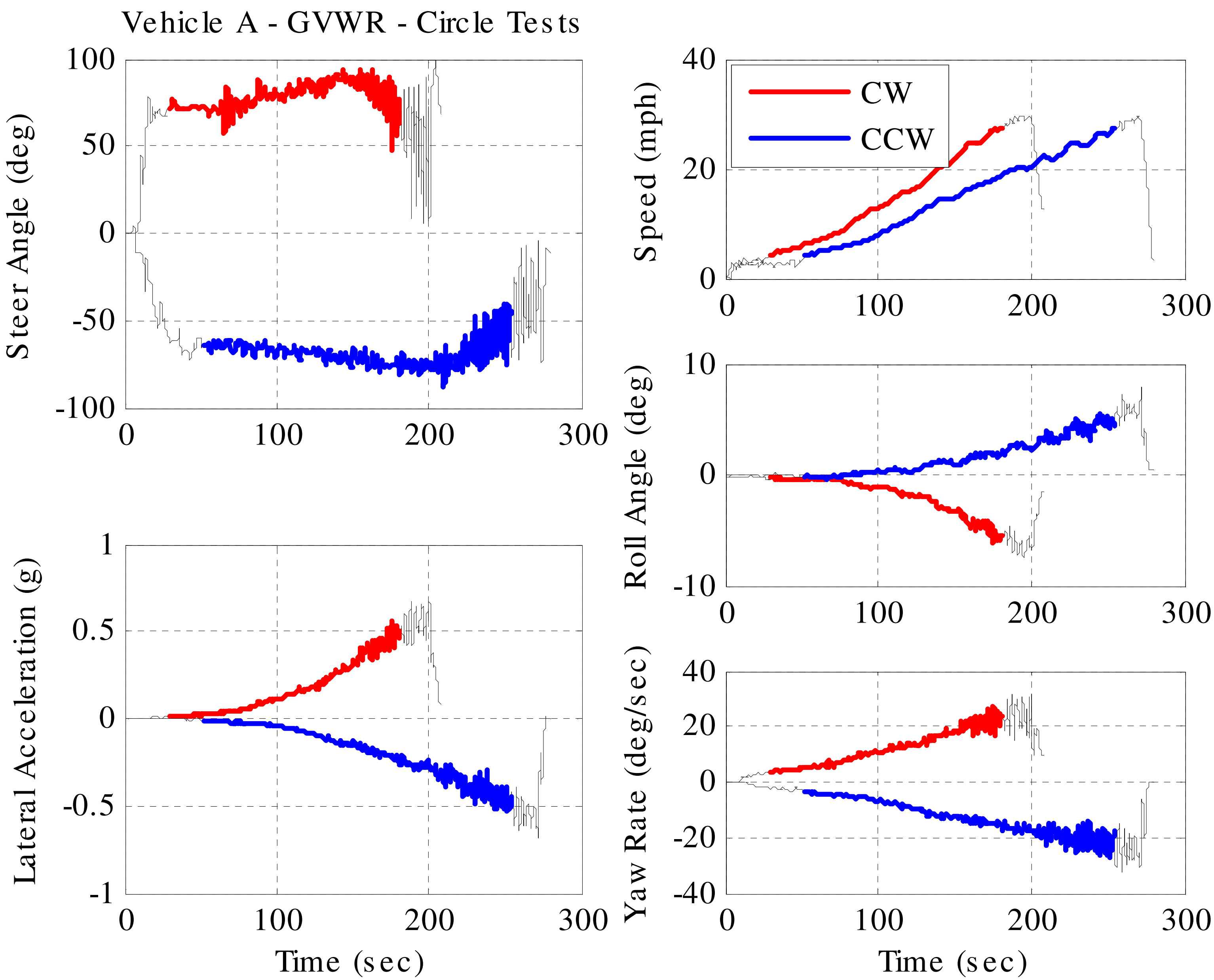

Slope: Degrees of Handwheel Angle per g of Lateral Acceleration
Slope (deg/g)
200
150
100
50
0
-50
-100
-150
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle F
Vehicle A
Vehicle I
Vehicle D
Vehicle E
Vehicle B
Vehicle C
Vehicle H
Vehicle G

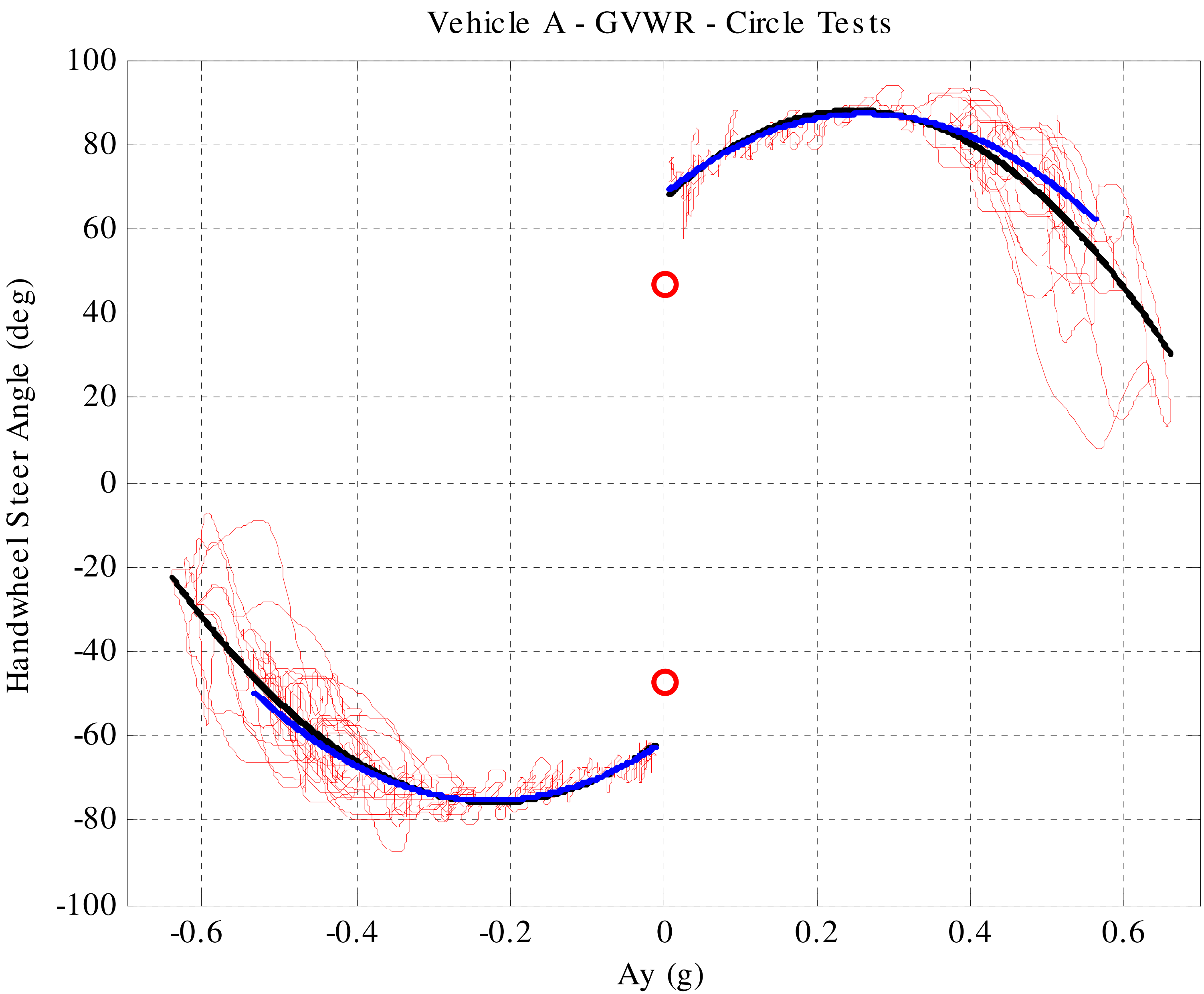

Vehicle A
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle B
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle C
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

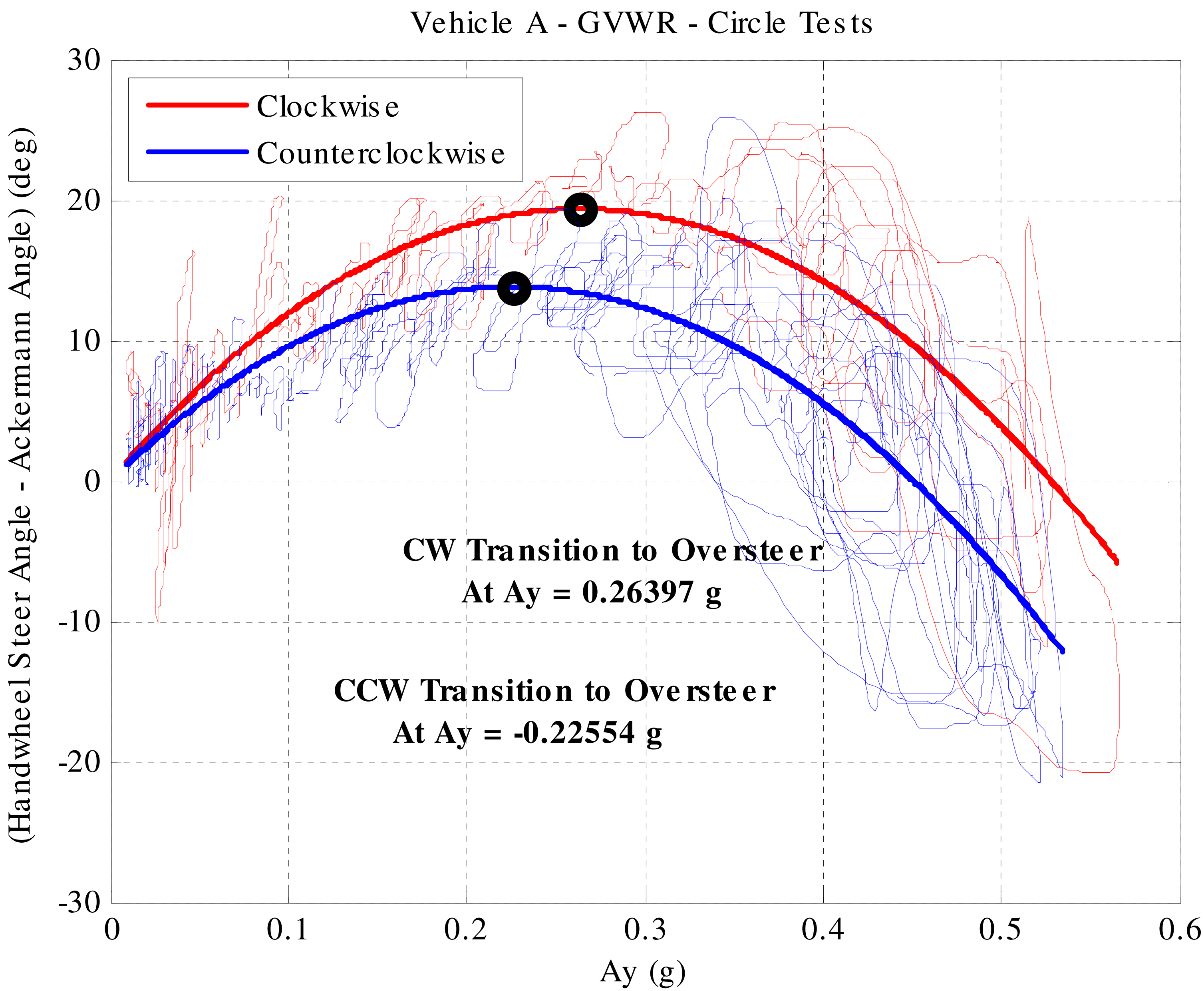

Vehicle D
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle E
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle F
Slope (deg/g)
100
0
-100
-200
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average


Vehicle G
Slope (deg/g)
200
100
0
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle H
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle I
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
CW
CCW
Average

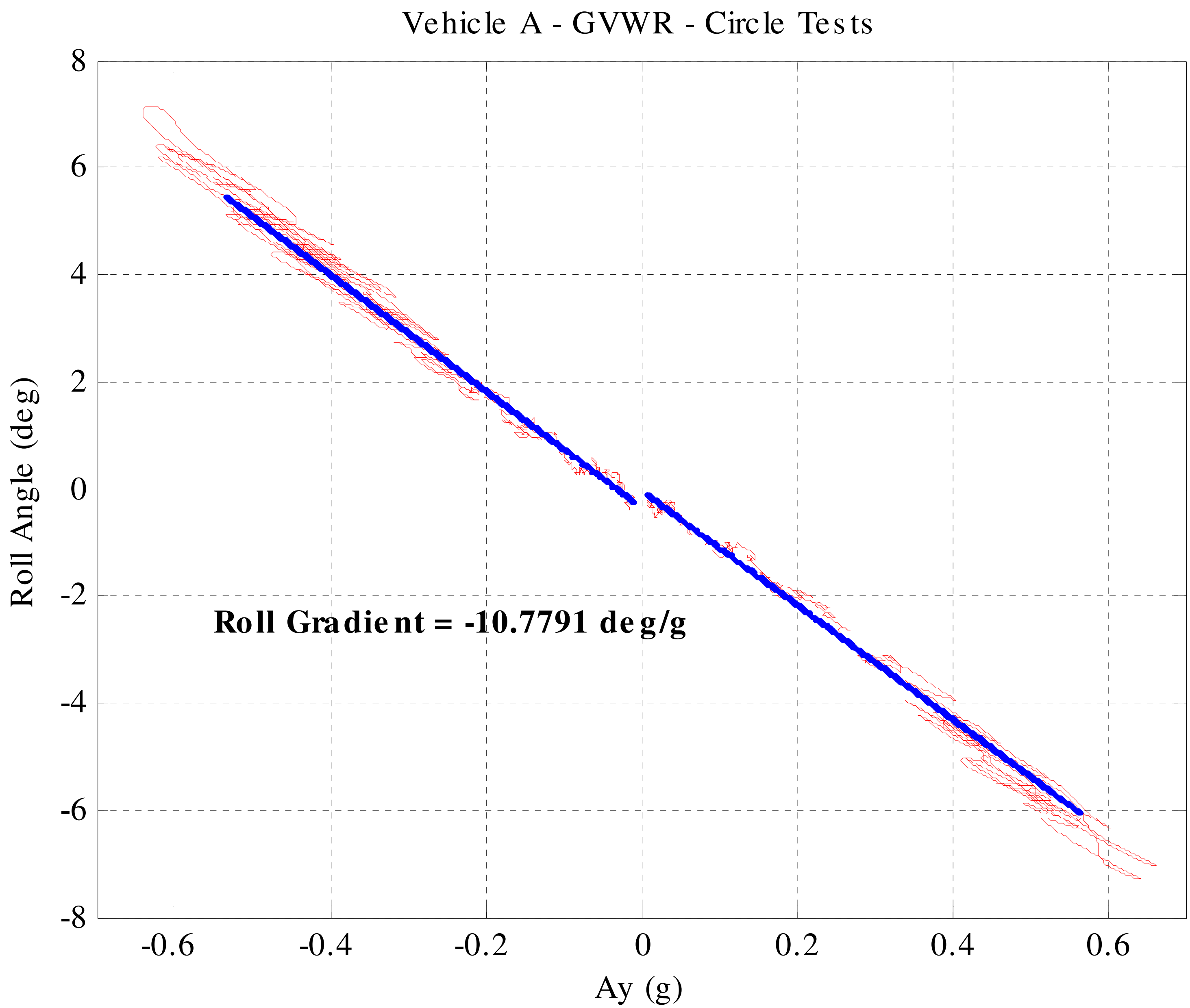
Constant Radius (100 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Operator and Passenger Loading)			
	Clockwise (g)	Counterclockwise (g)	Average (g)
Vehicle A	0.24	0.23	0.24
Vehicle B	NA	NA	NA
Vehicle C	NA	NA	NA
Vehicle D	0.32	0.37	0.35
Vehicle E	0.44	NA	NA
Vehicle F	0.15	0.19	0.17
Vehicle G	NA	NA	NA
Vehicle H	NA	NA	NA
Vehicle I	0.29	0.30	0.30

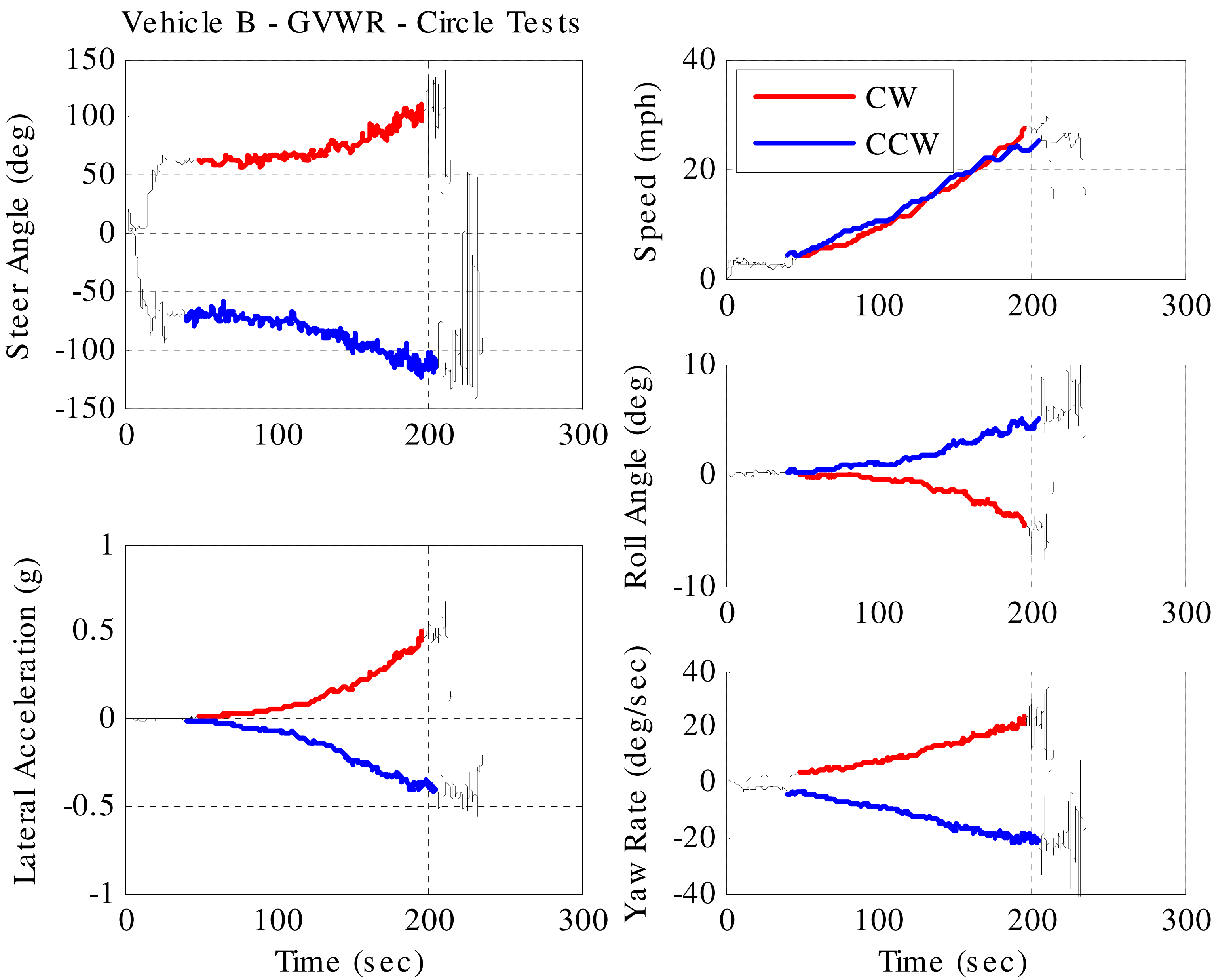

Vehicle A - GVWR - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)


Vehicle A - GVWR - 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

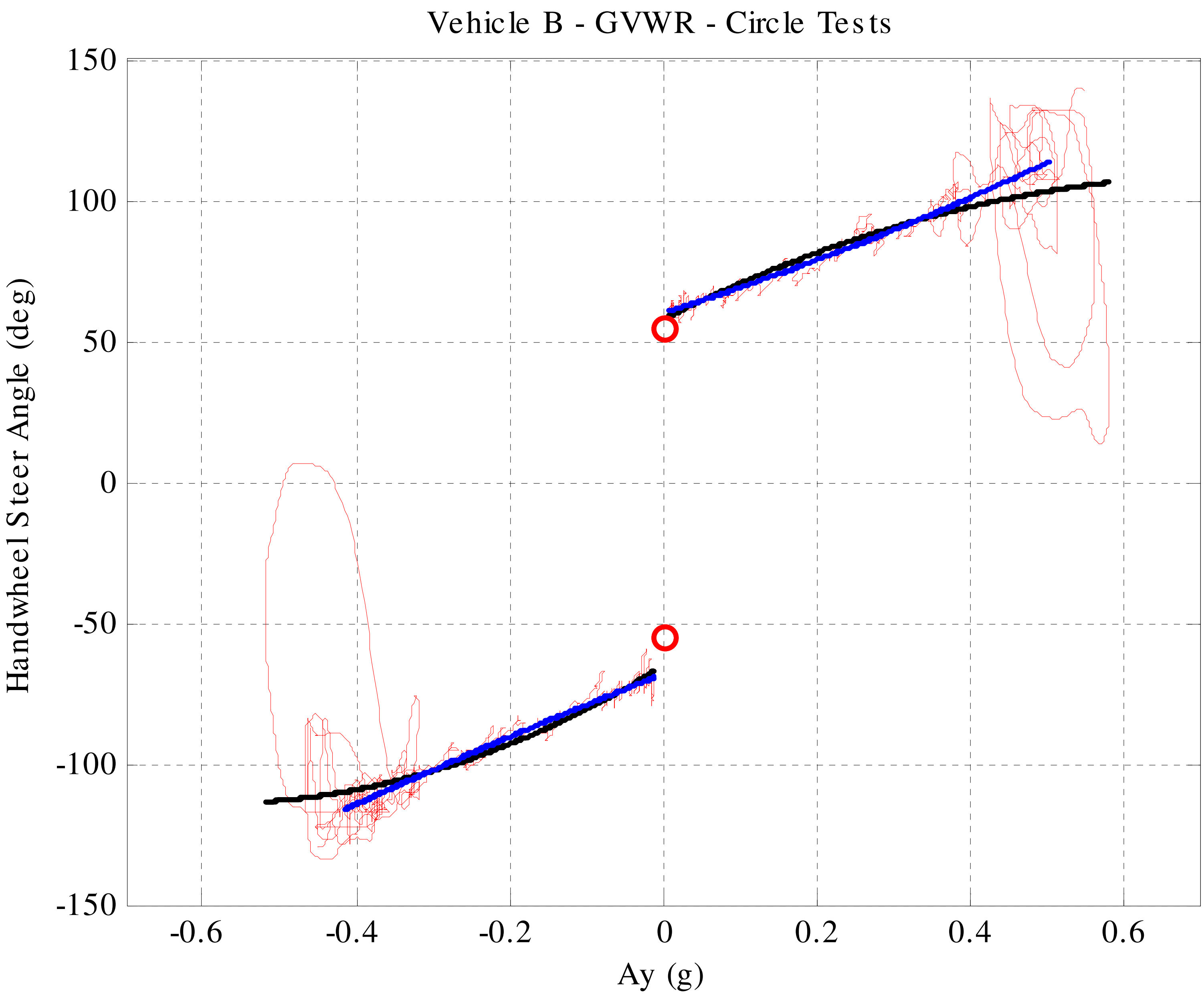


Vehicle A - GVWR - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.26397 g
CCW Transition to Oversteer
At Ay = -0.22554 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
30
20
10
0
-10
-20
-30
0
0.1
0.2
0.3
0.4
0.5
0.6

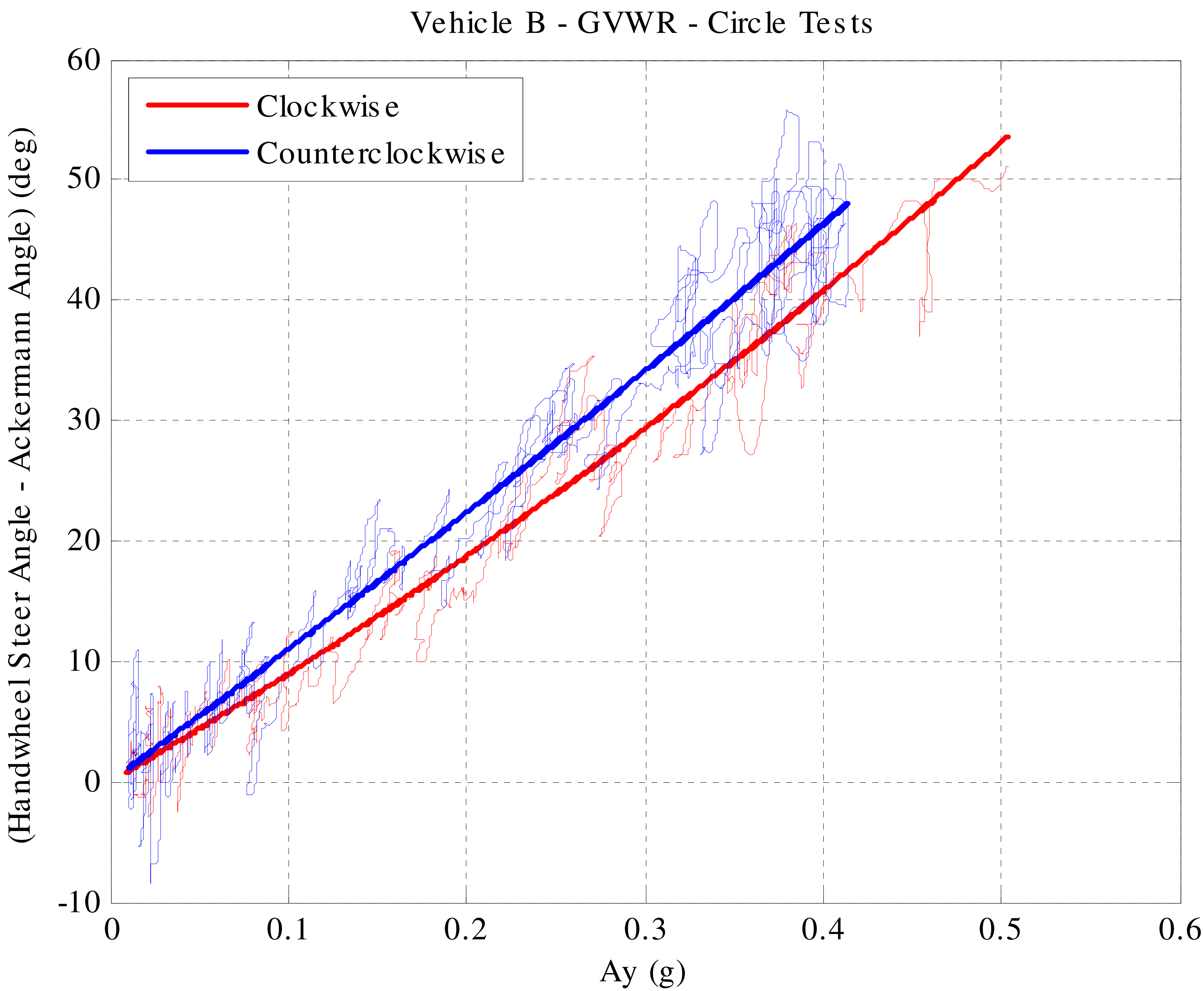

Vehicle A - GVWR - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -10.7791 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

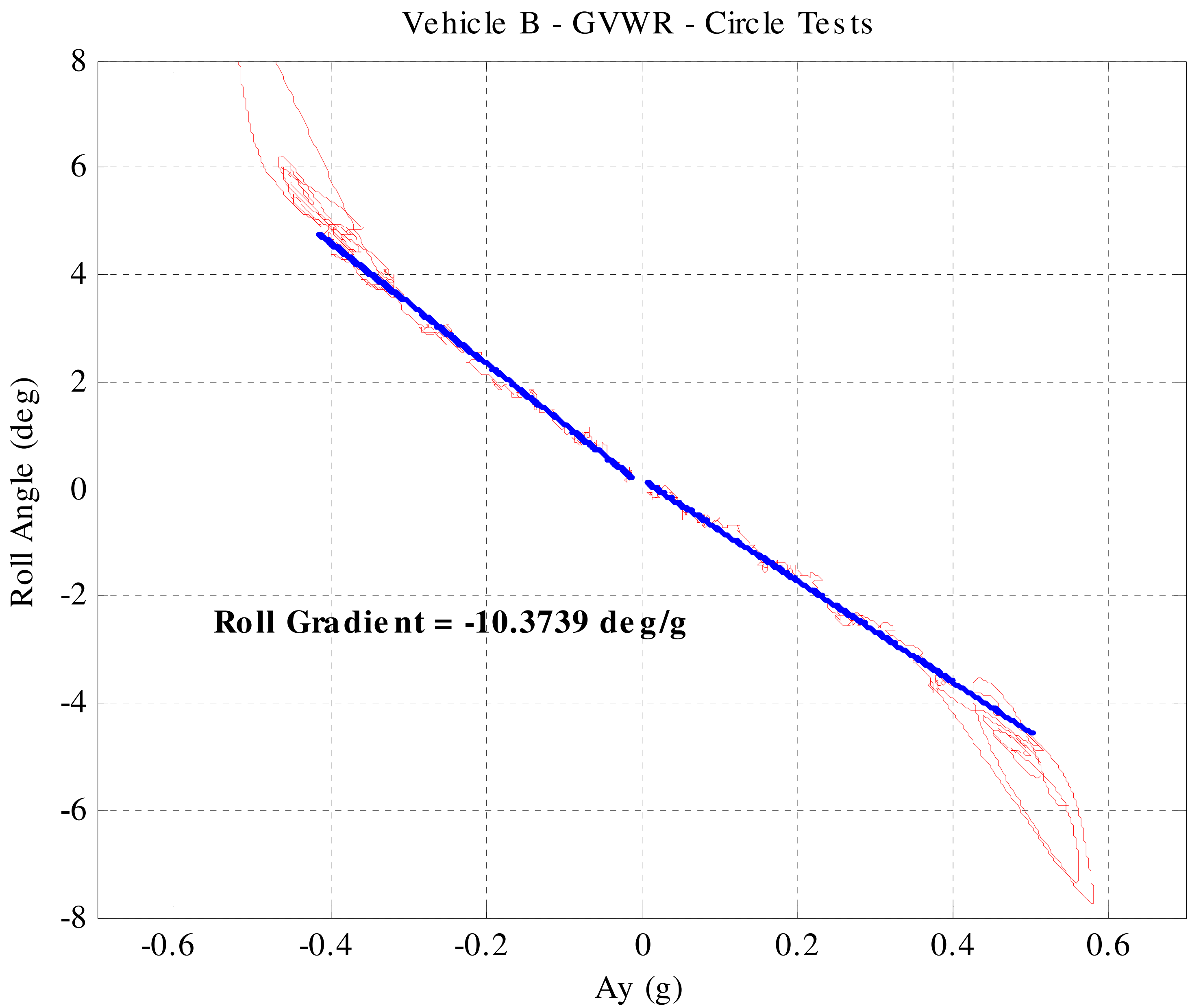


Vehicle B - GVWR - Circle Tests
Steer Angle (deg)
150
100
50
0
-50
-100
-150
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

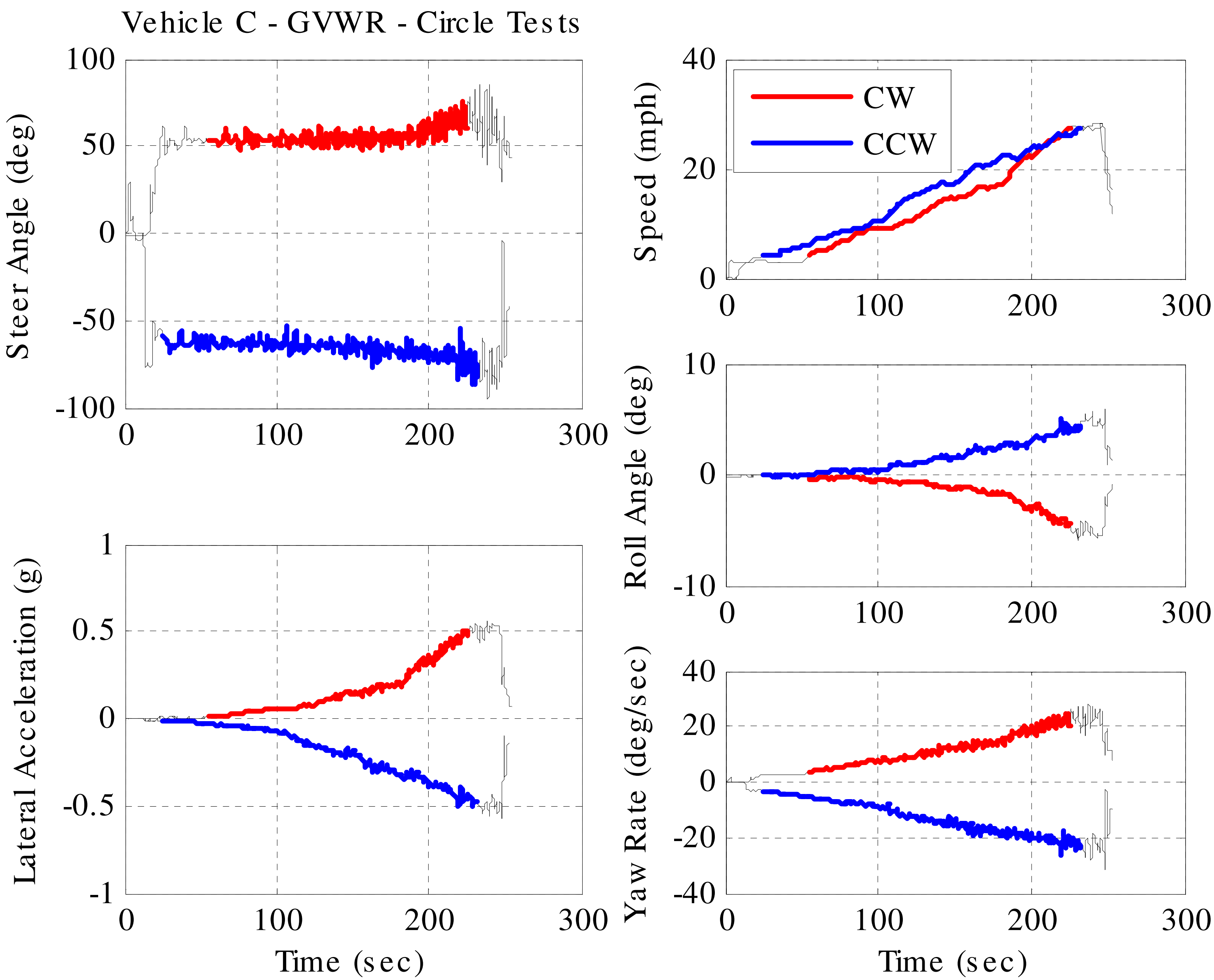


Vehicle B - GVWR - Circle Tests
Handwheel Steer Angle (deg)
150
100
50
0
-50
-100
-150
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)

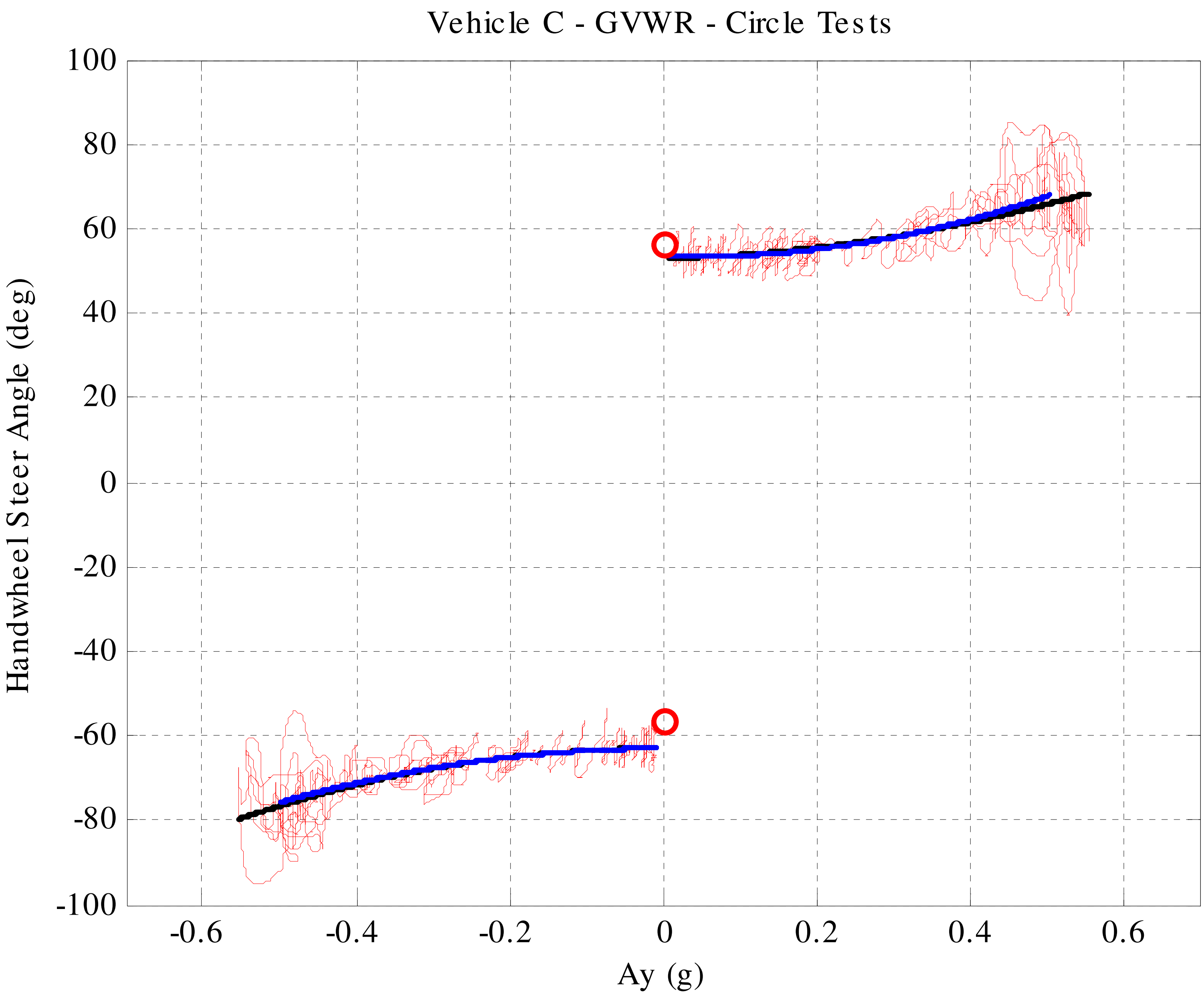

Vehicle B - GVWR - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
Ay (g)

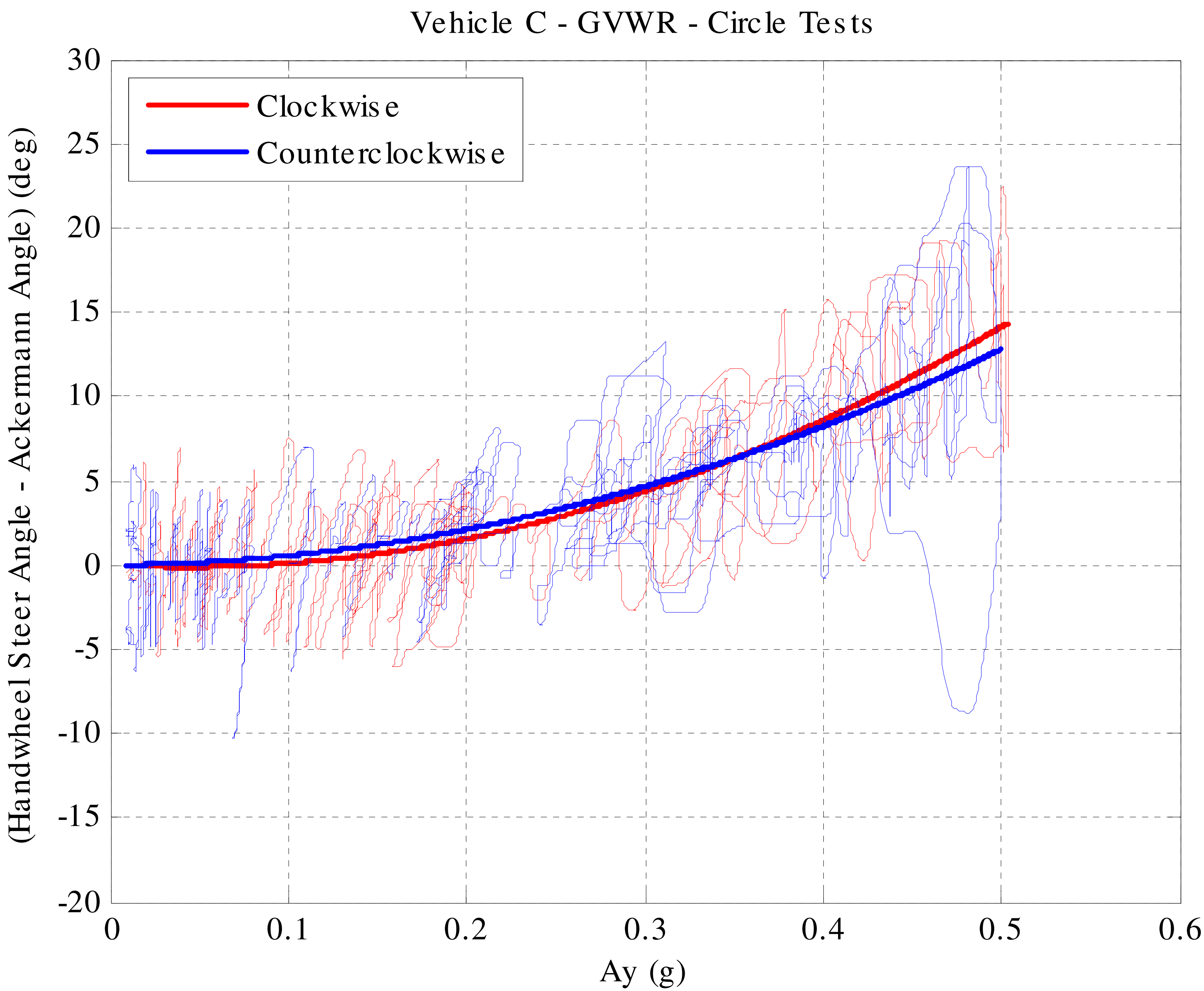


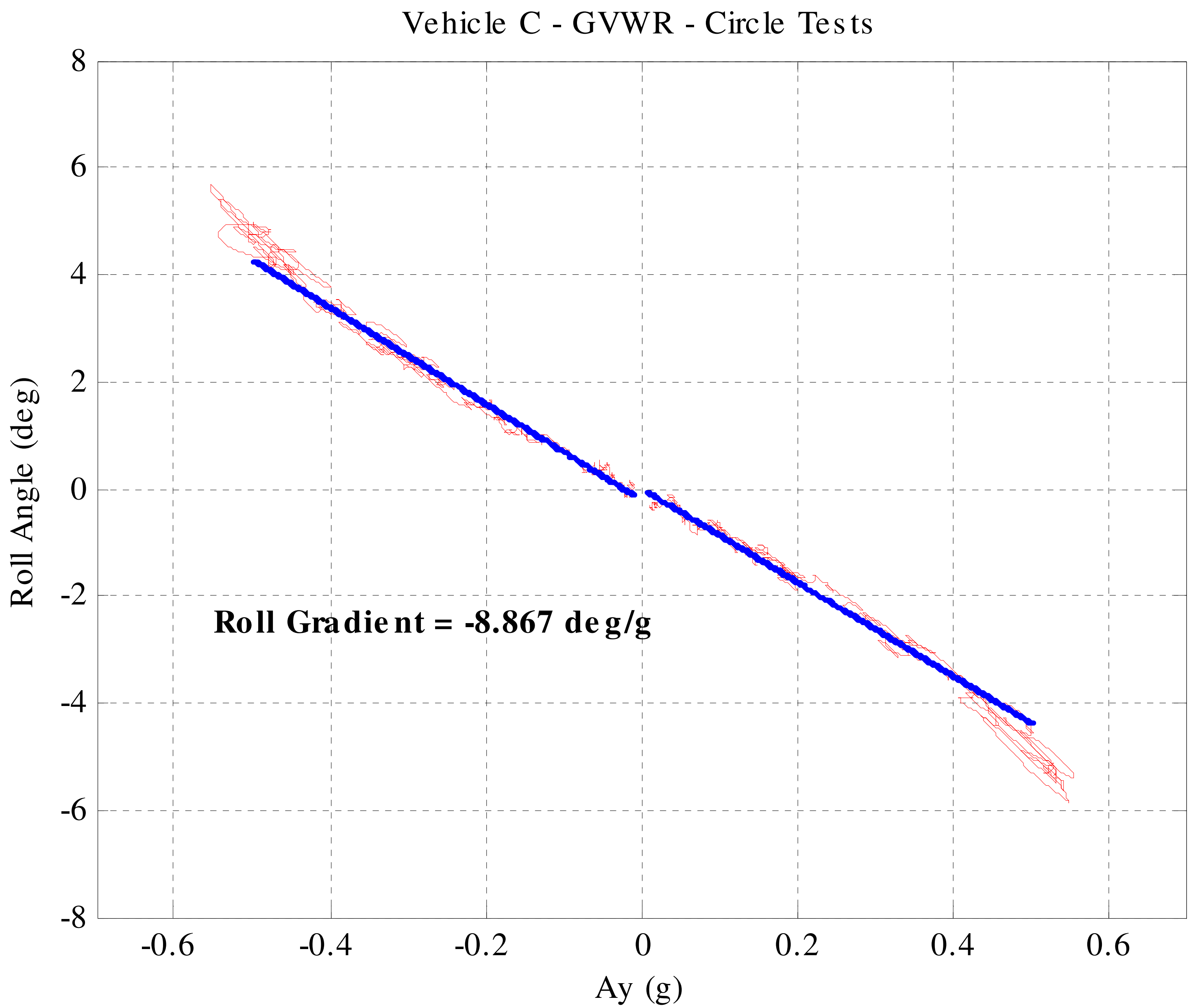
Vehicle B - GVWR - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -10.3739 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6



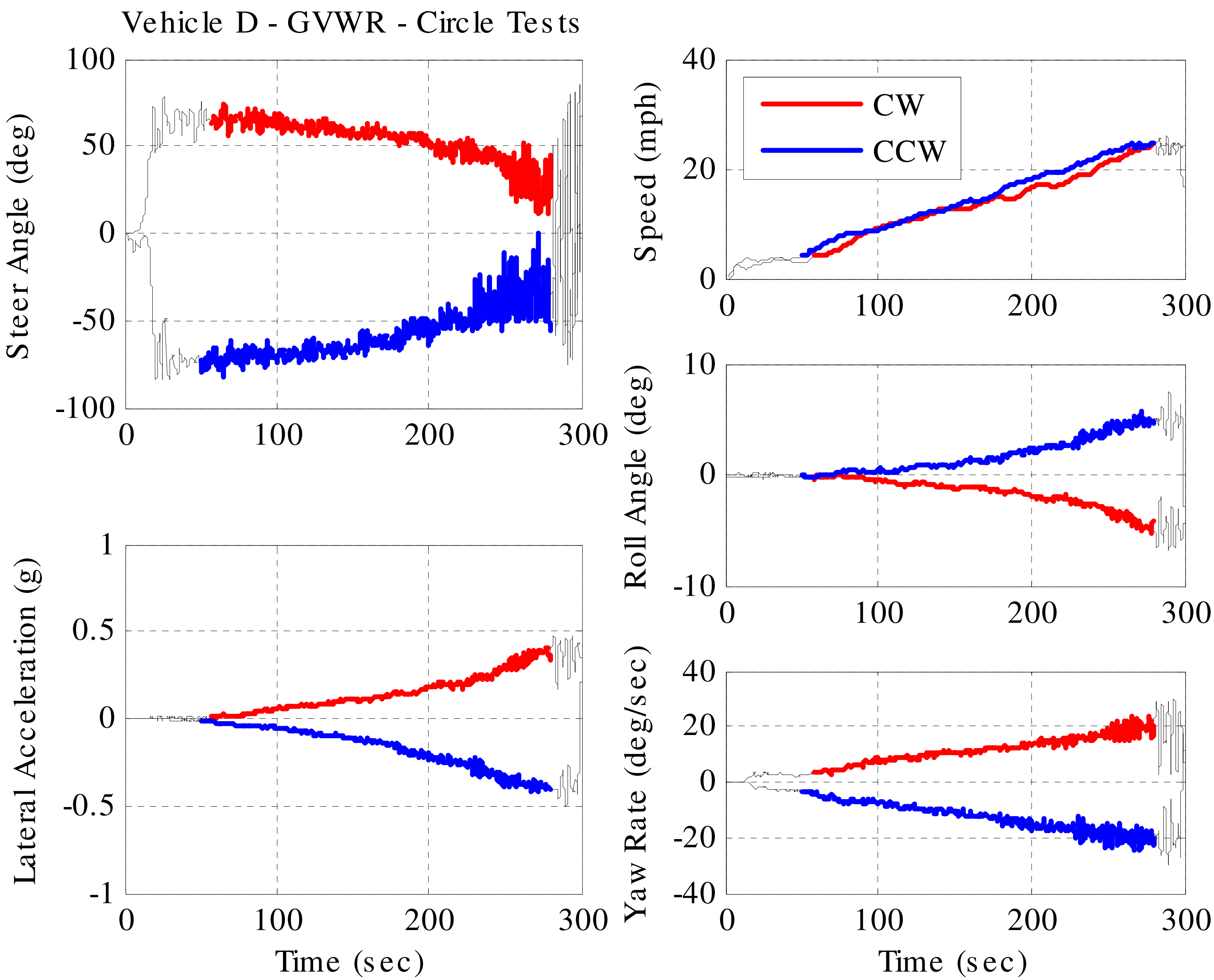
Vehicle C - GVWR - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

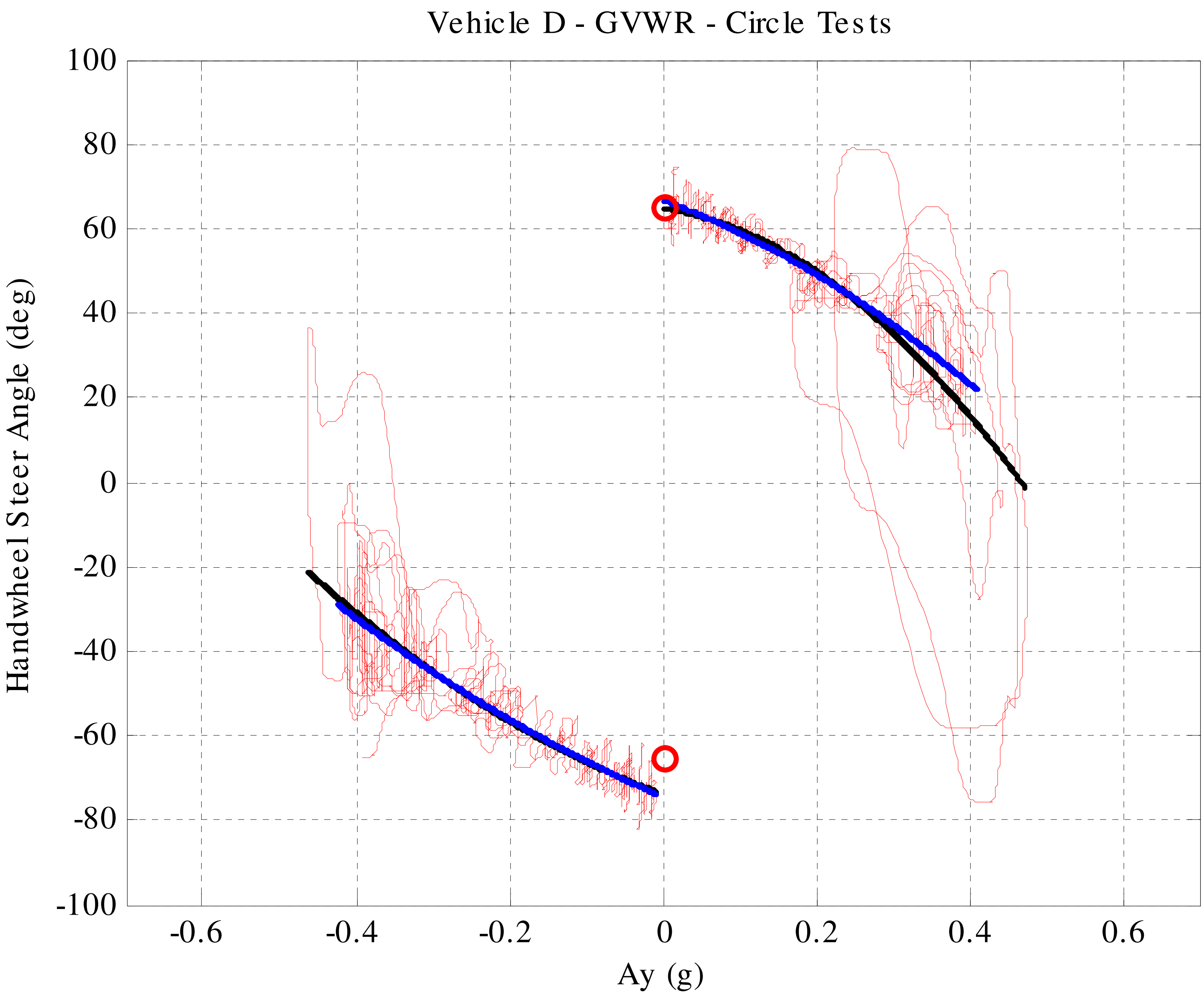

Vehicle C - GVWR - Circle Tests
Handwheel Steer Angle (deg)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)


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

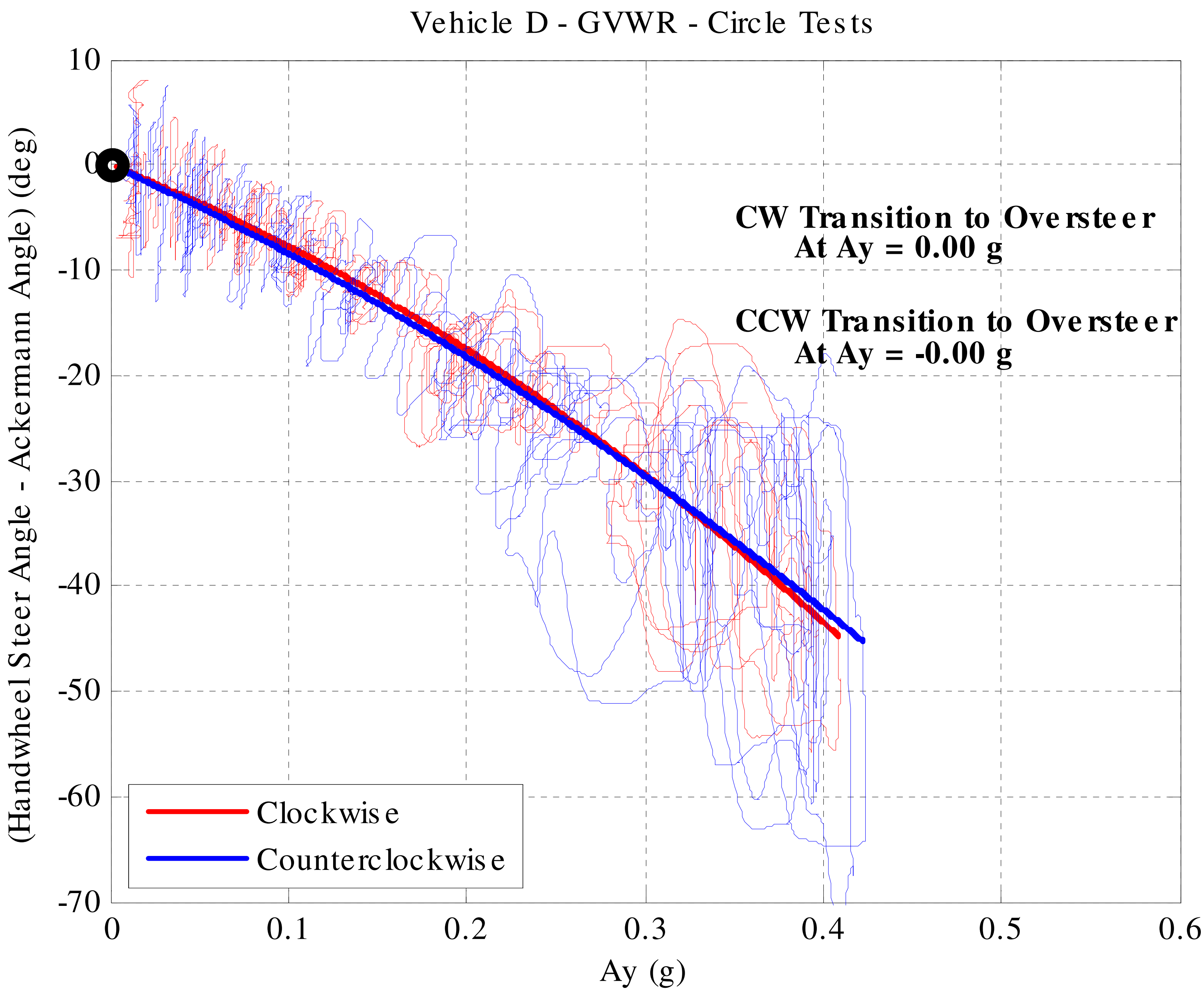


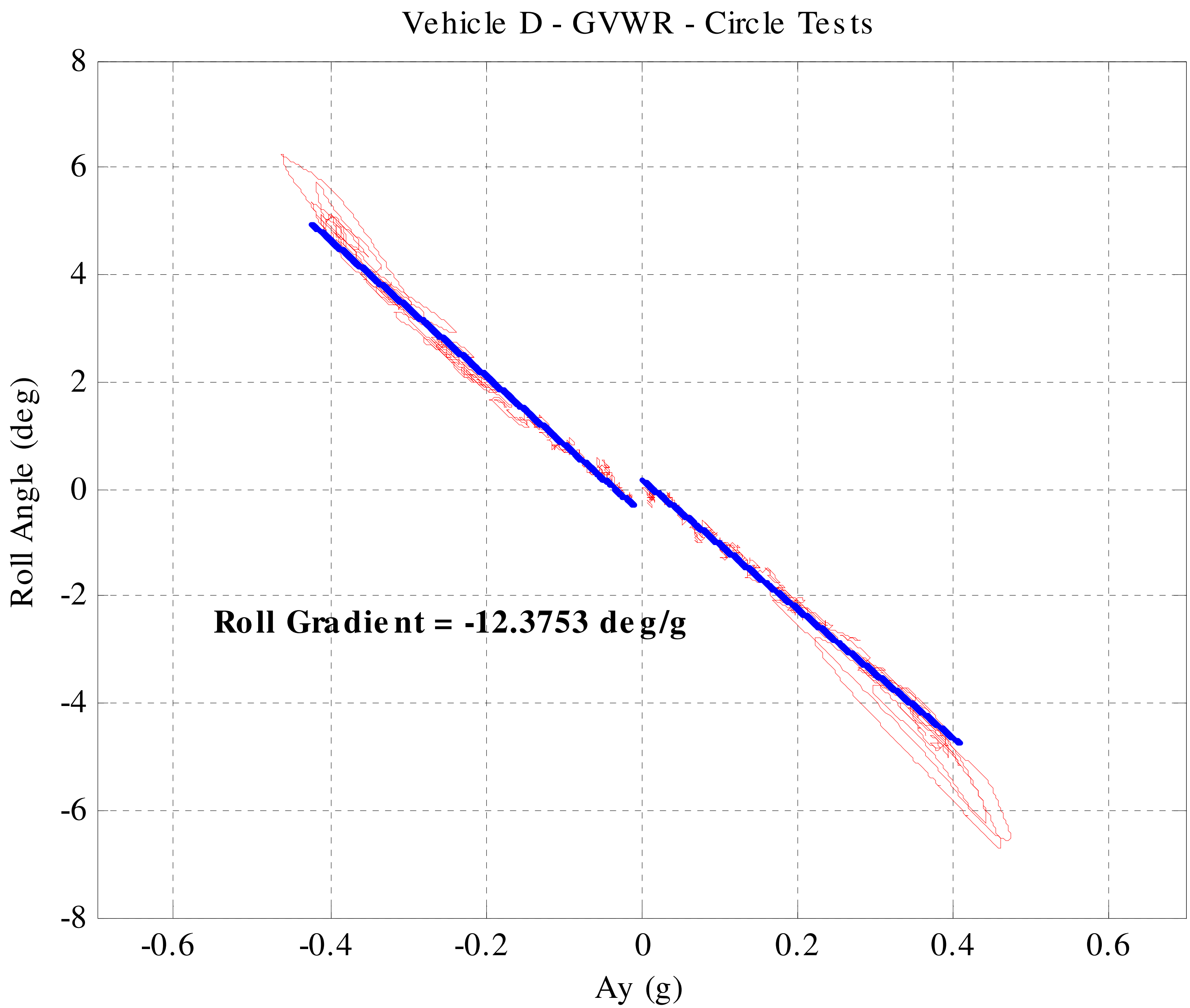
Vehicle C - GVWR - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -8.867 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6


Vehicle D - GVWR - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

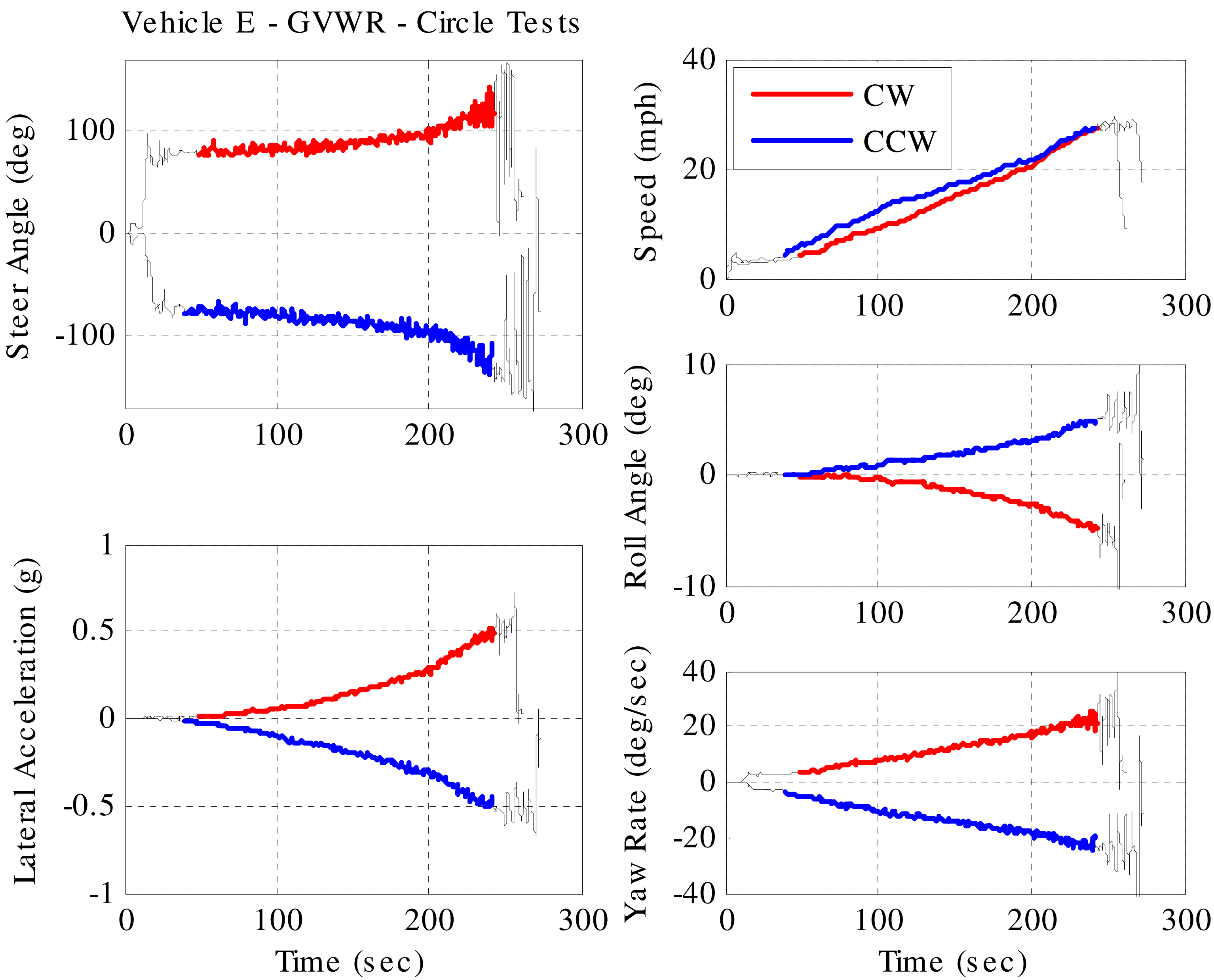


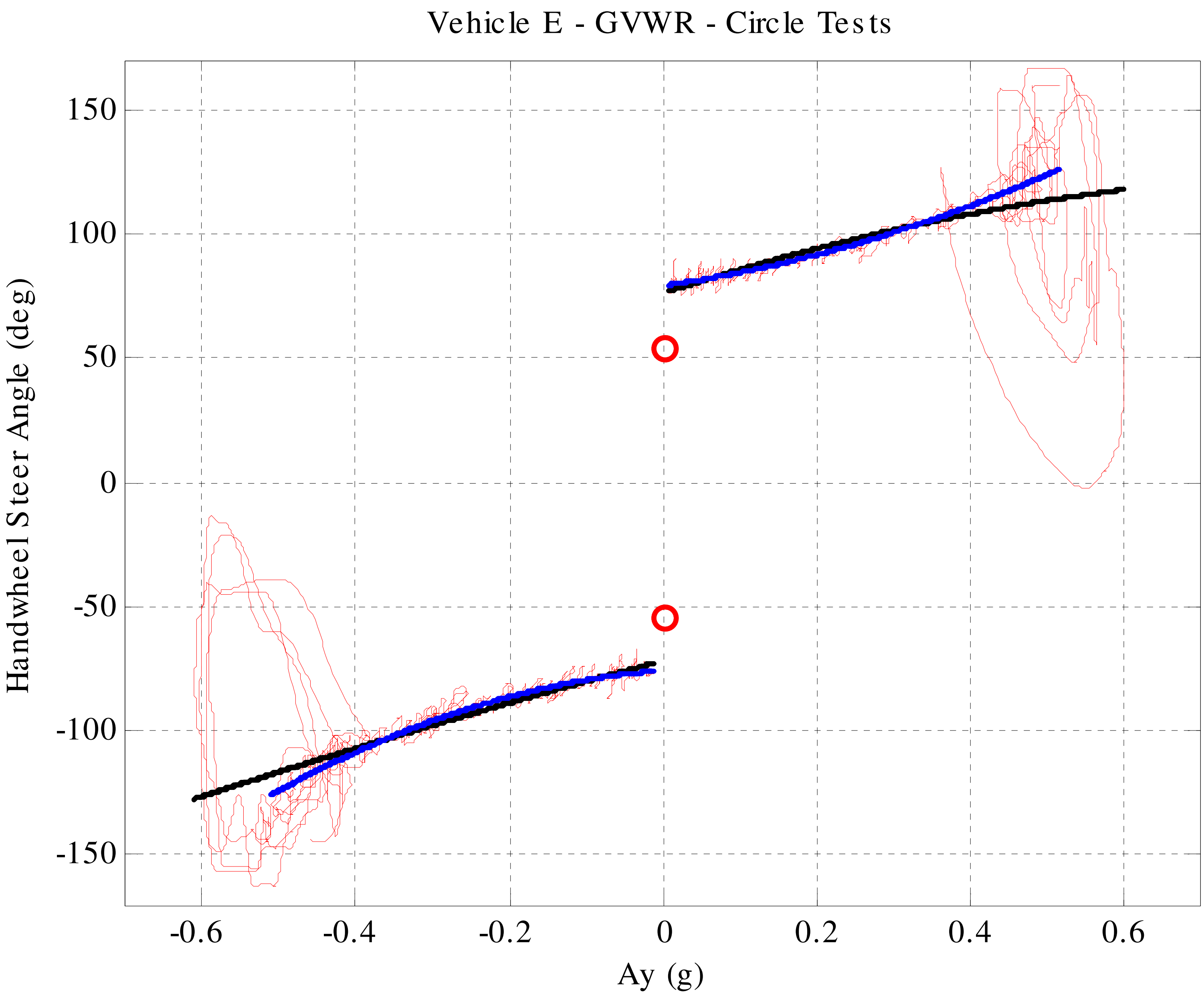
Vehicle D - GVWR - Circle Tests
Handwheel Steer Angle (deg)
Ay (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

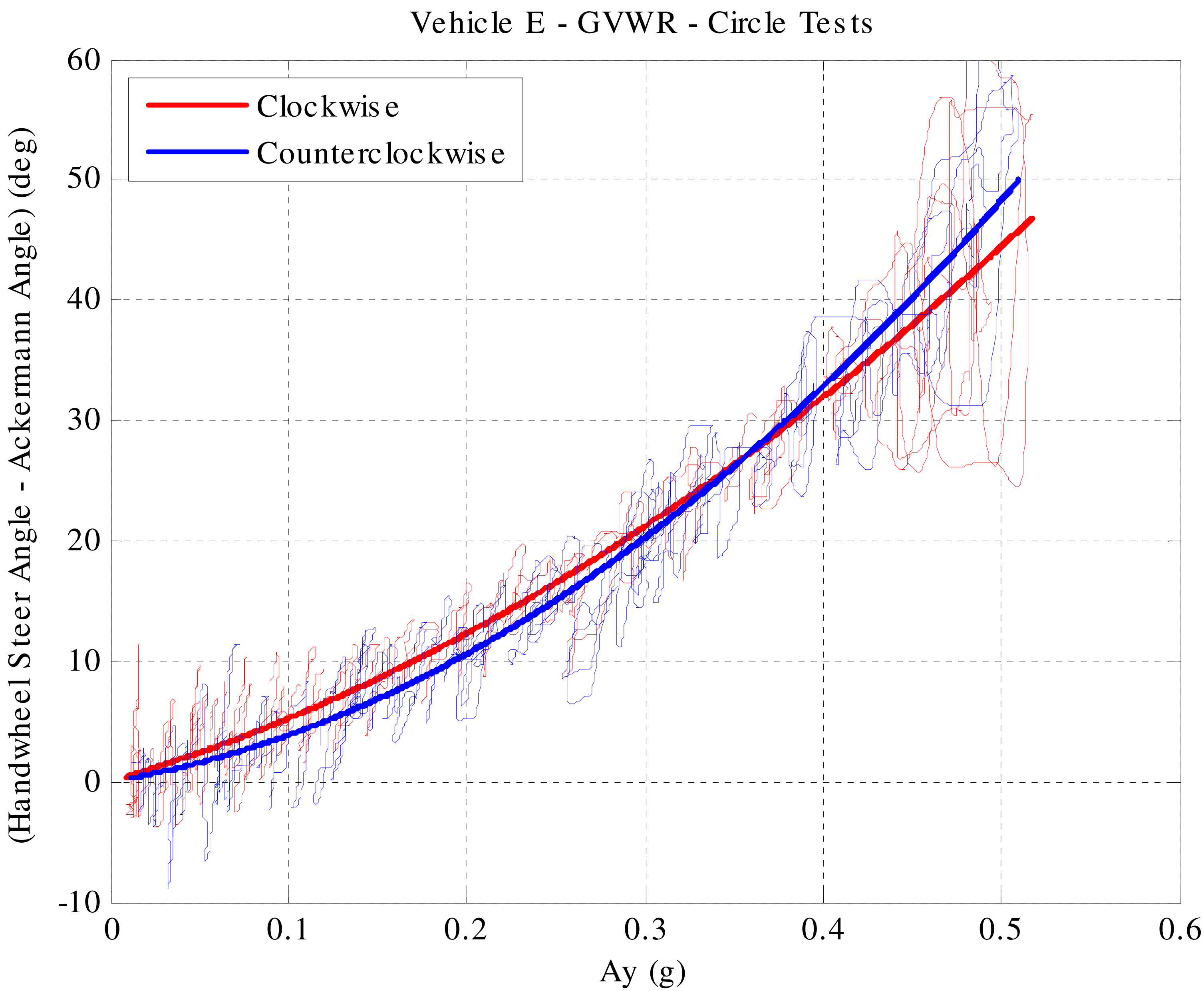

Vehicle D - GVWR - Circle Tests
CW Transition to Oversteer
At Ay = 0.00 g
CCW Transition to Oversteer
At Ay = -0.00 g
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
0
-10
-20
-30
-40
-50
-60
-70
0
0.1
0.2
0.3
0.4
0.5
0.6



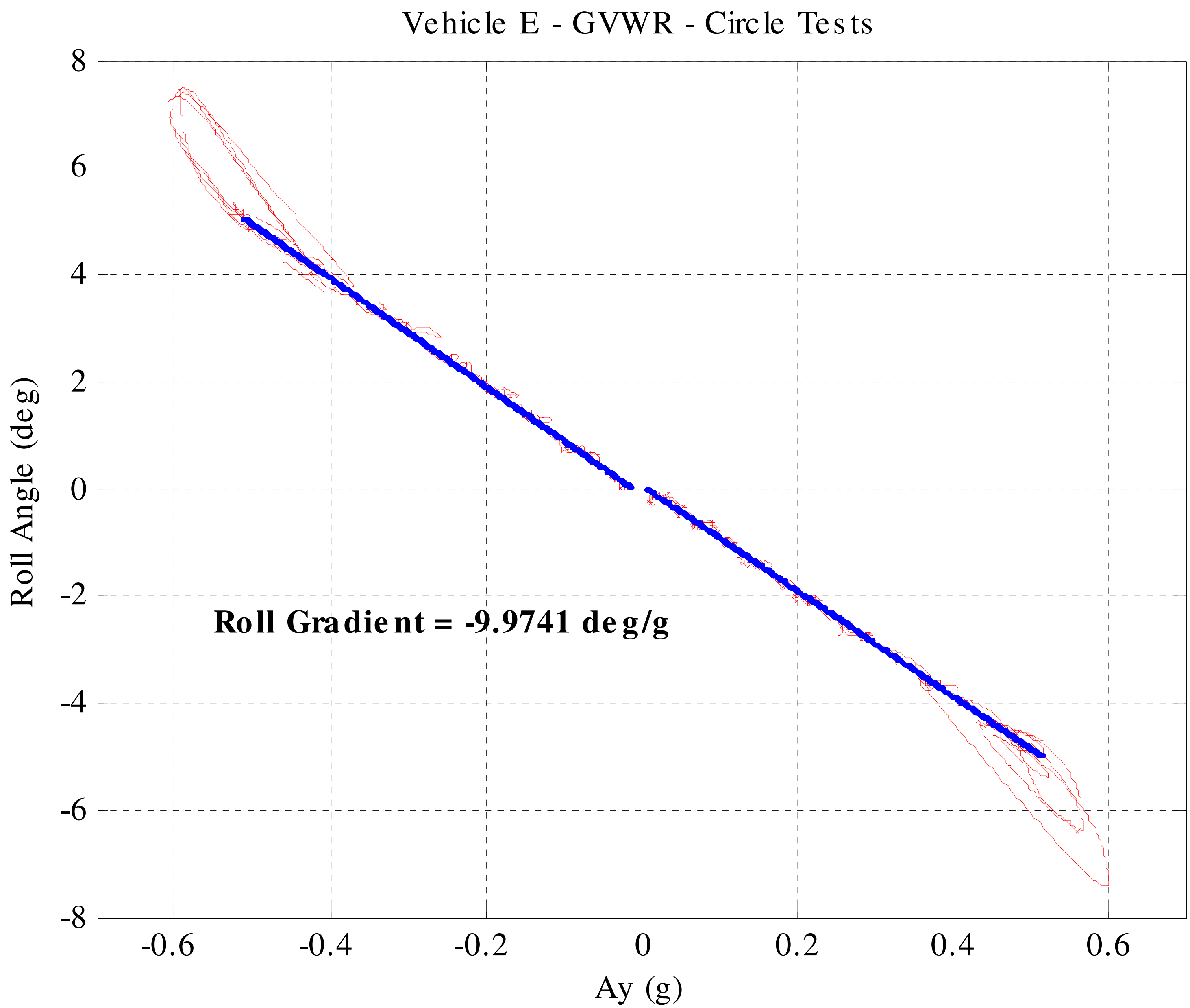
Vehicle D - GVWR - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -12.3753 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6


Vehicle E - GVWR - Circle Tests
Steer Angle (deg)
100
0
-100
0
100
200
300
CW
CCW
Speed (mph)
40
20
0
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

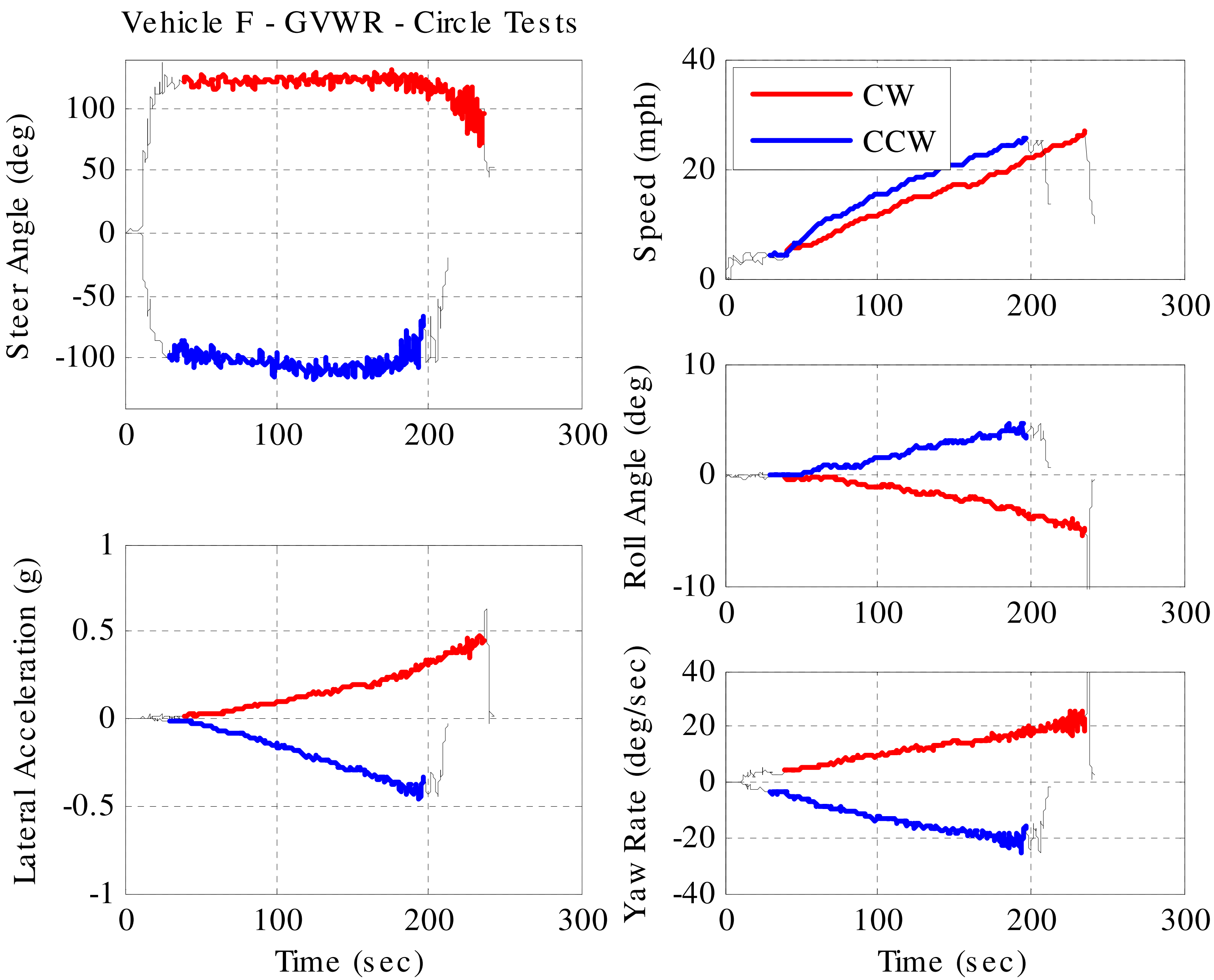

Vehicle E - GVWR - Circle Tests
Handwheel Steer Angle (deg)
150
100
50
0
-50
-100
-150
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)



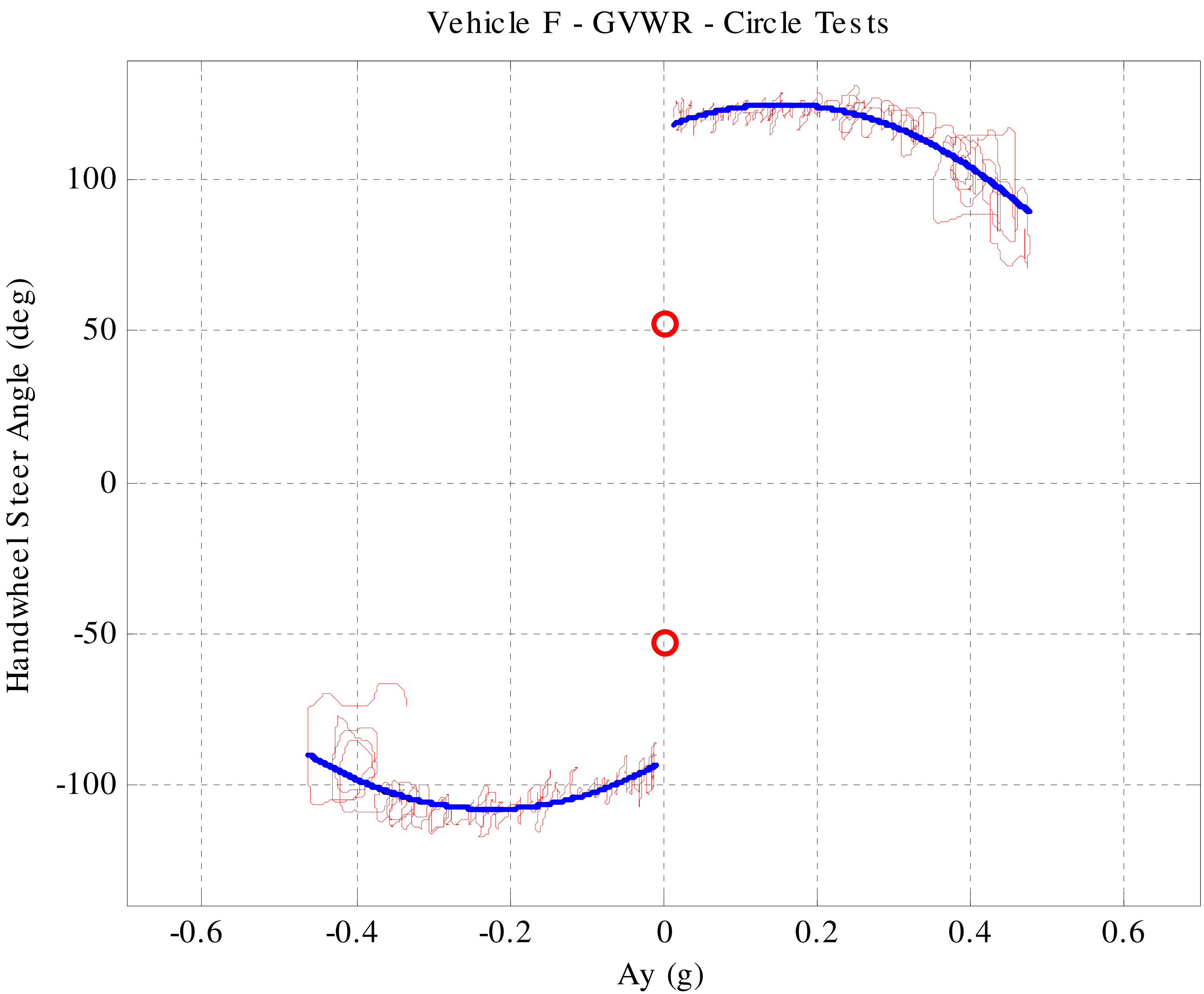
Vehicle E - GVWR - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6

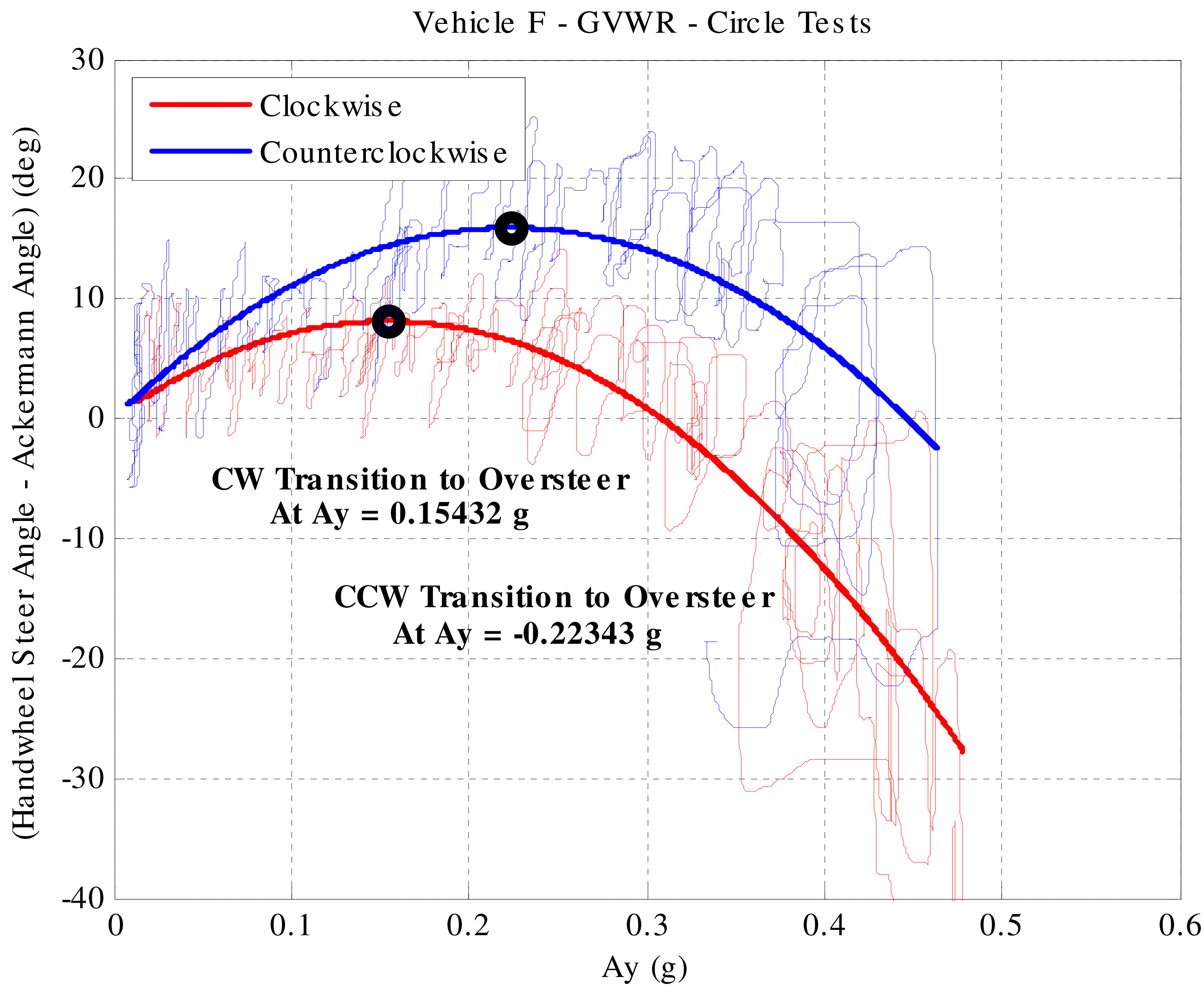


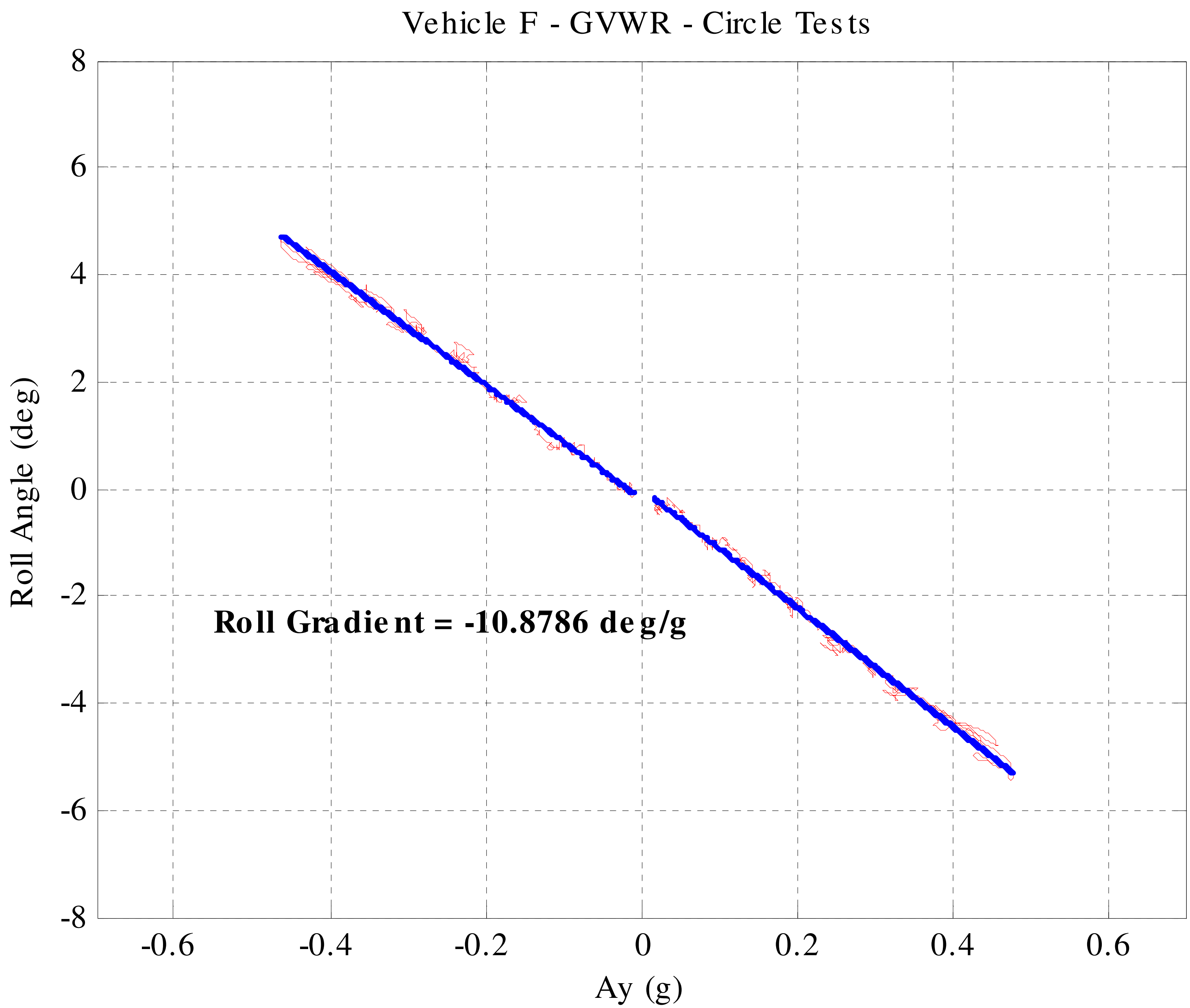
Vehicle E - GVWR - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -9.9741 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

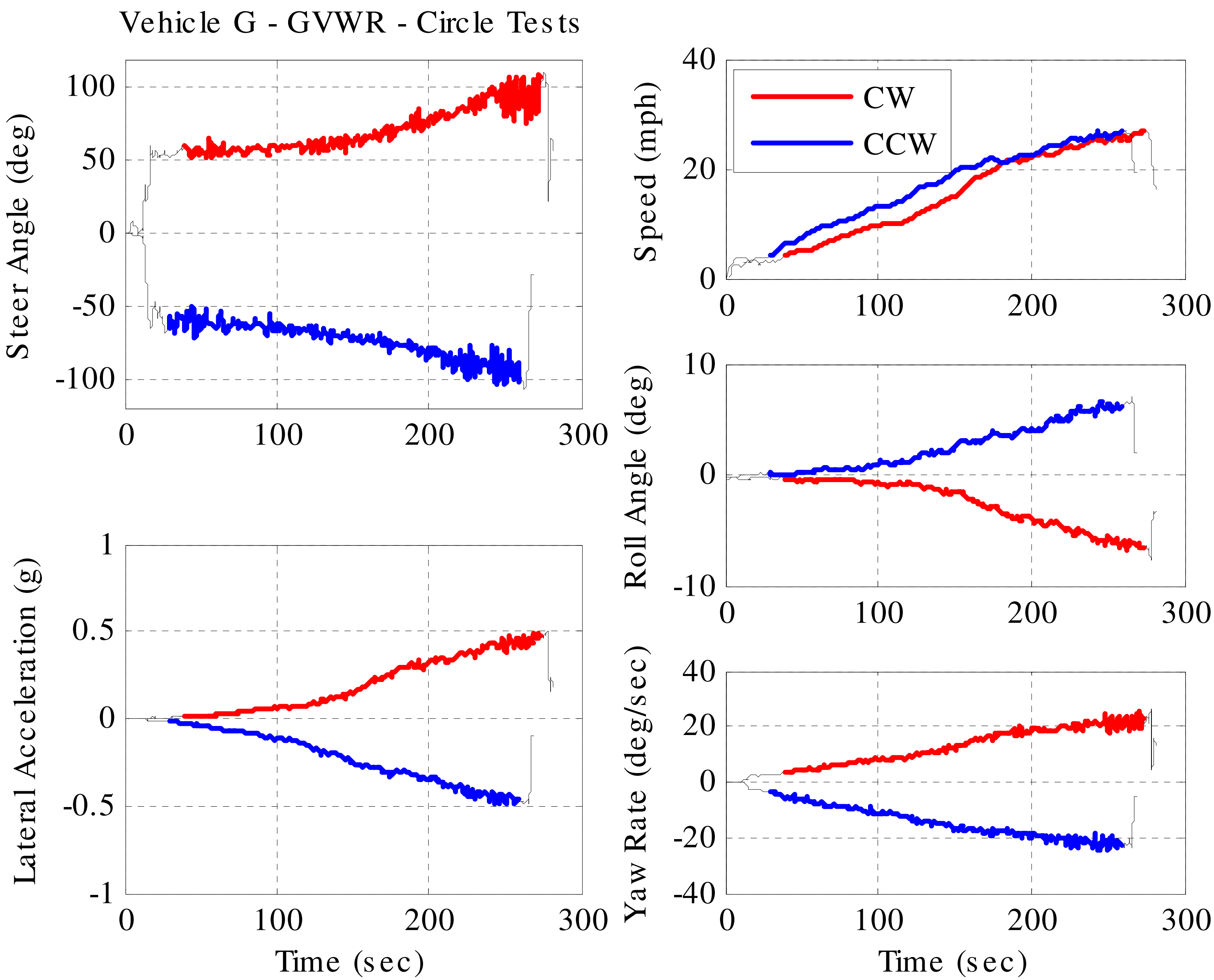


Vehicle F - GVWR - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

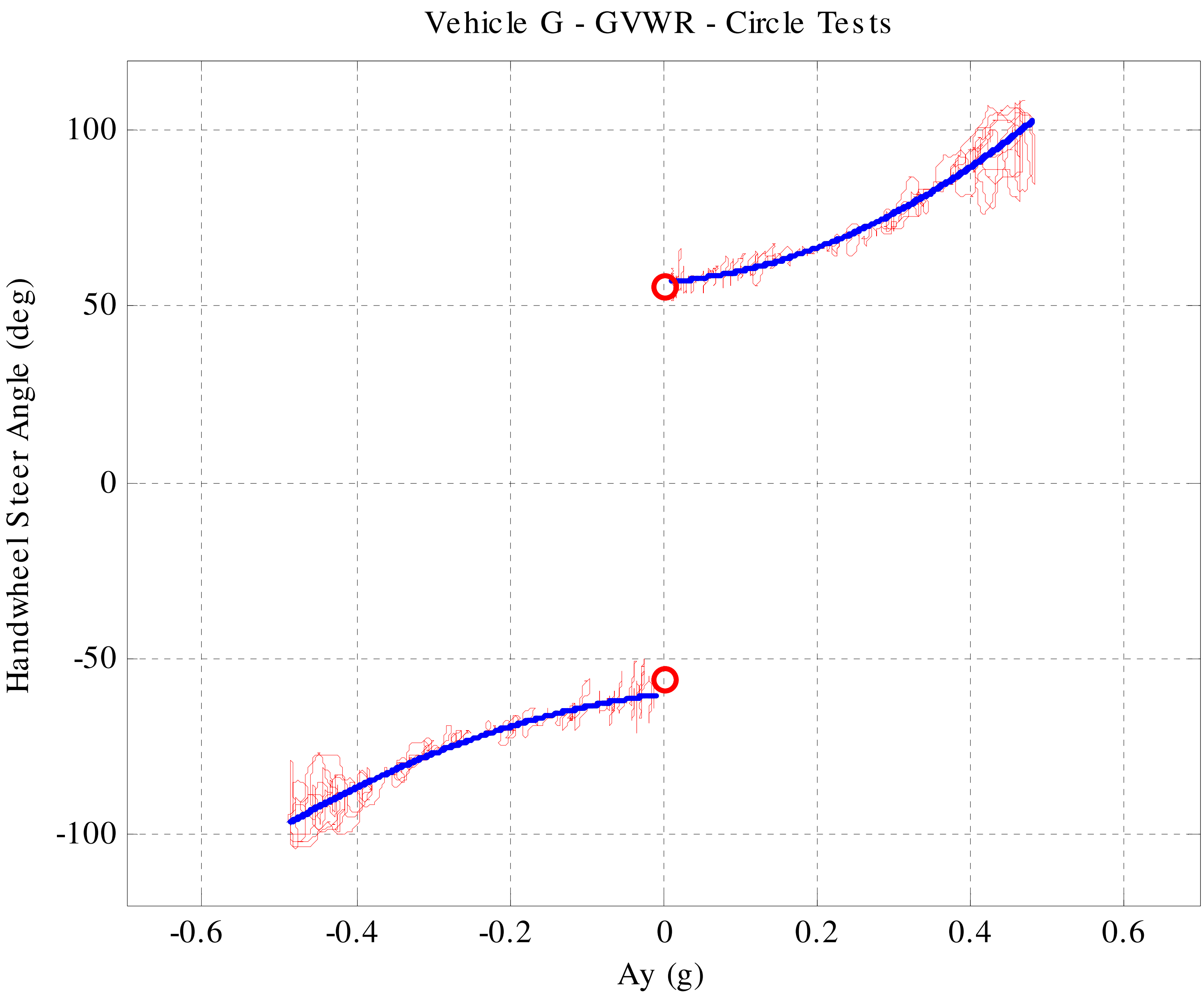

Vehicle F - GVWR - Circle Tests
Handwheel Steer Angle (deg)
100
50
0
-50
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)


Vehicle F - GVWR - Circle Tests
Clockwise
Counterclockwise
CW Transition to Oversteer
At Ay = 0.15432 g
CCW Transition to Oversteer
At Ay = -0.22343 g
(Handwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
30
20
10
0
-10
-20
-30
-40
0
0.1
0.2
0.3
0.4
0.5
0.6

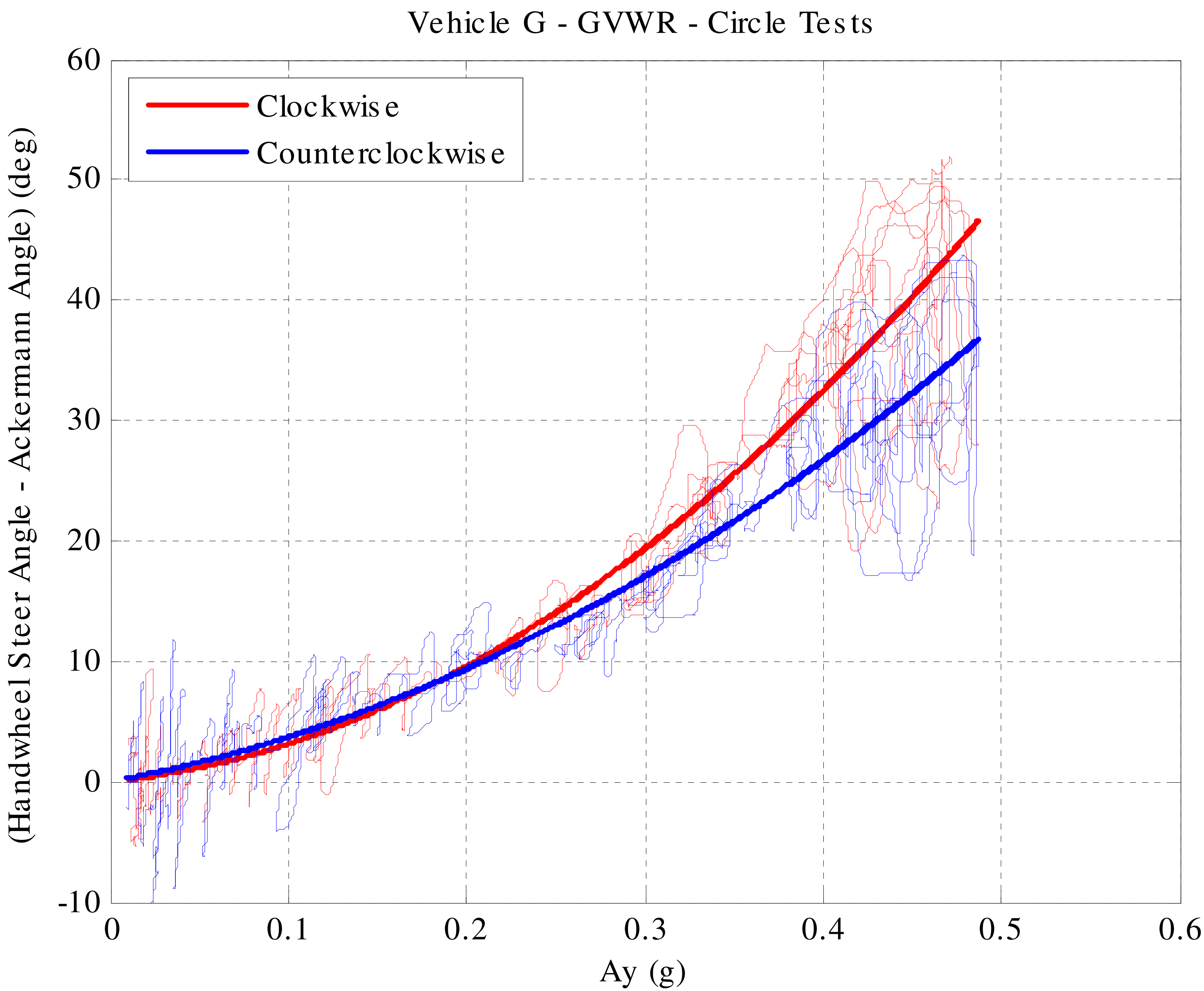

Vehicle F - GVWR - Circle Tests
8
6
4
2
0
-2
-4
-6
-8
Roll Angle (deg)
Roll Gradient = -10.8786 deg/g
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)

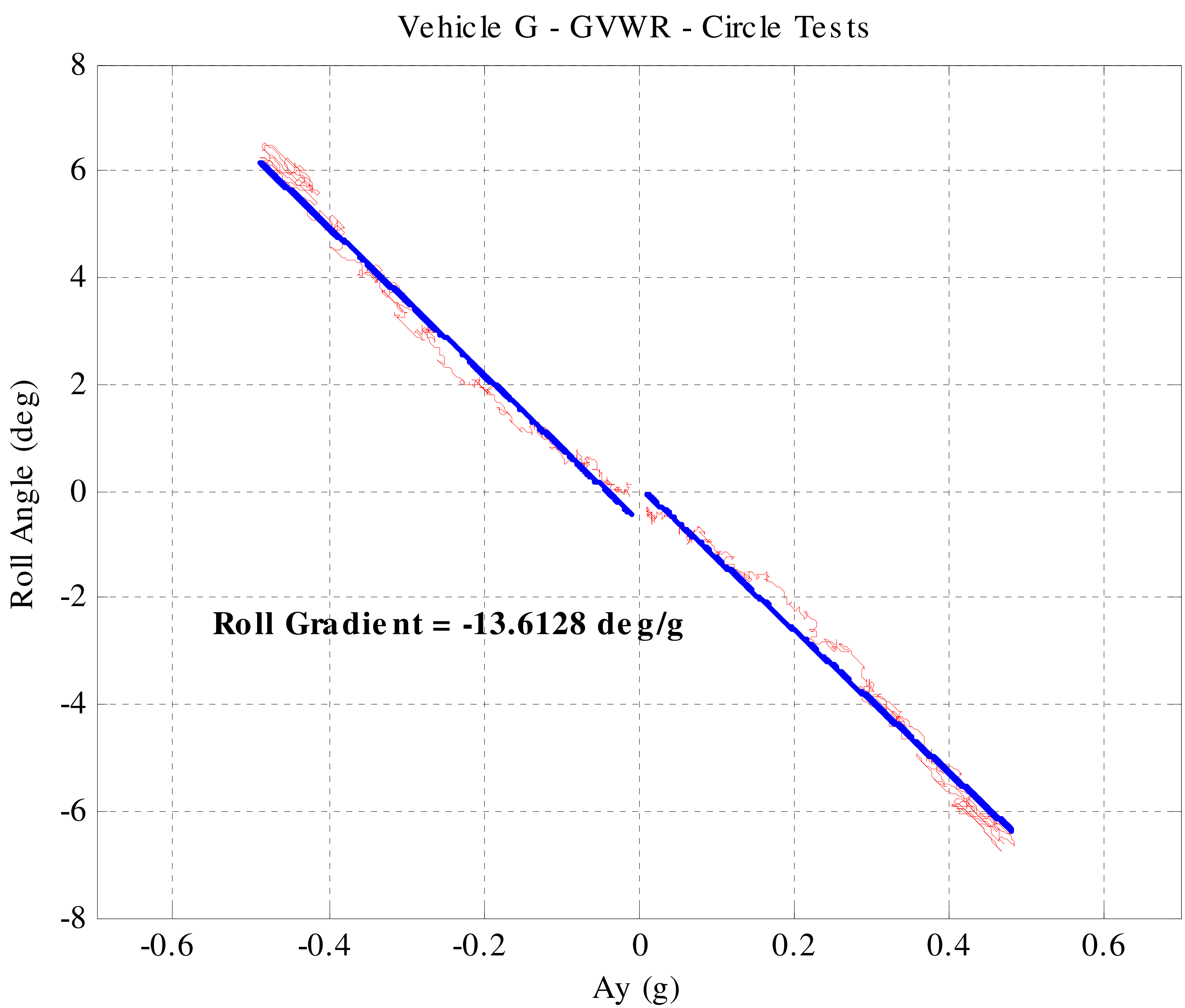


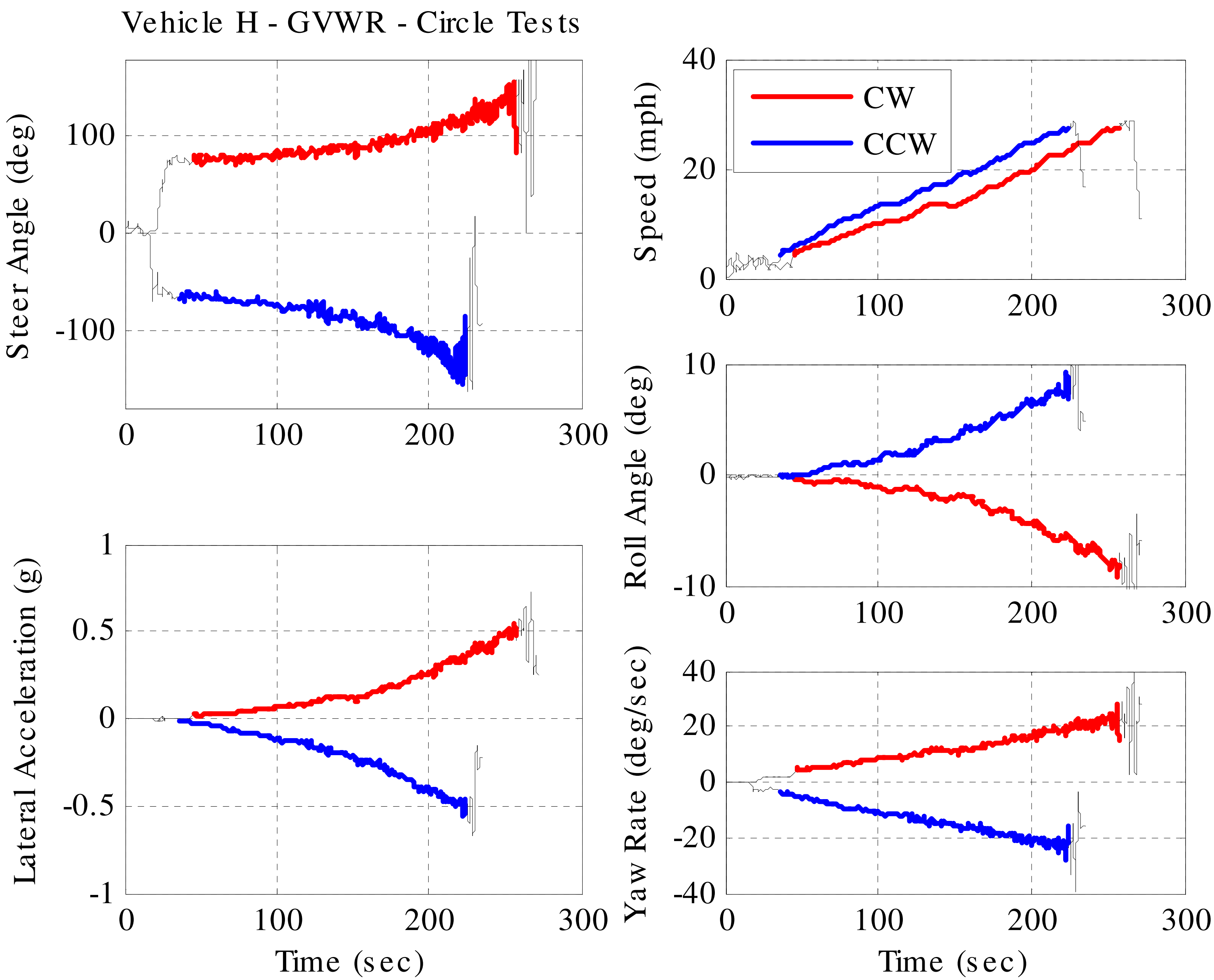
Vehicle G - GVWR - Circle Tests
Steer Angle (deg)
100
50
0
-50
-100
0
100
200
300
Speed (mph)
40
20
0
CW
CCW
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
1
0.5
0
-0.5
-1
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)



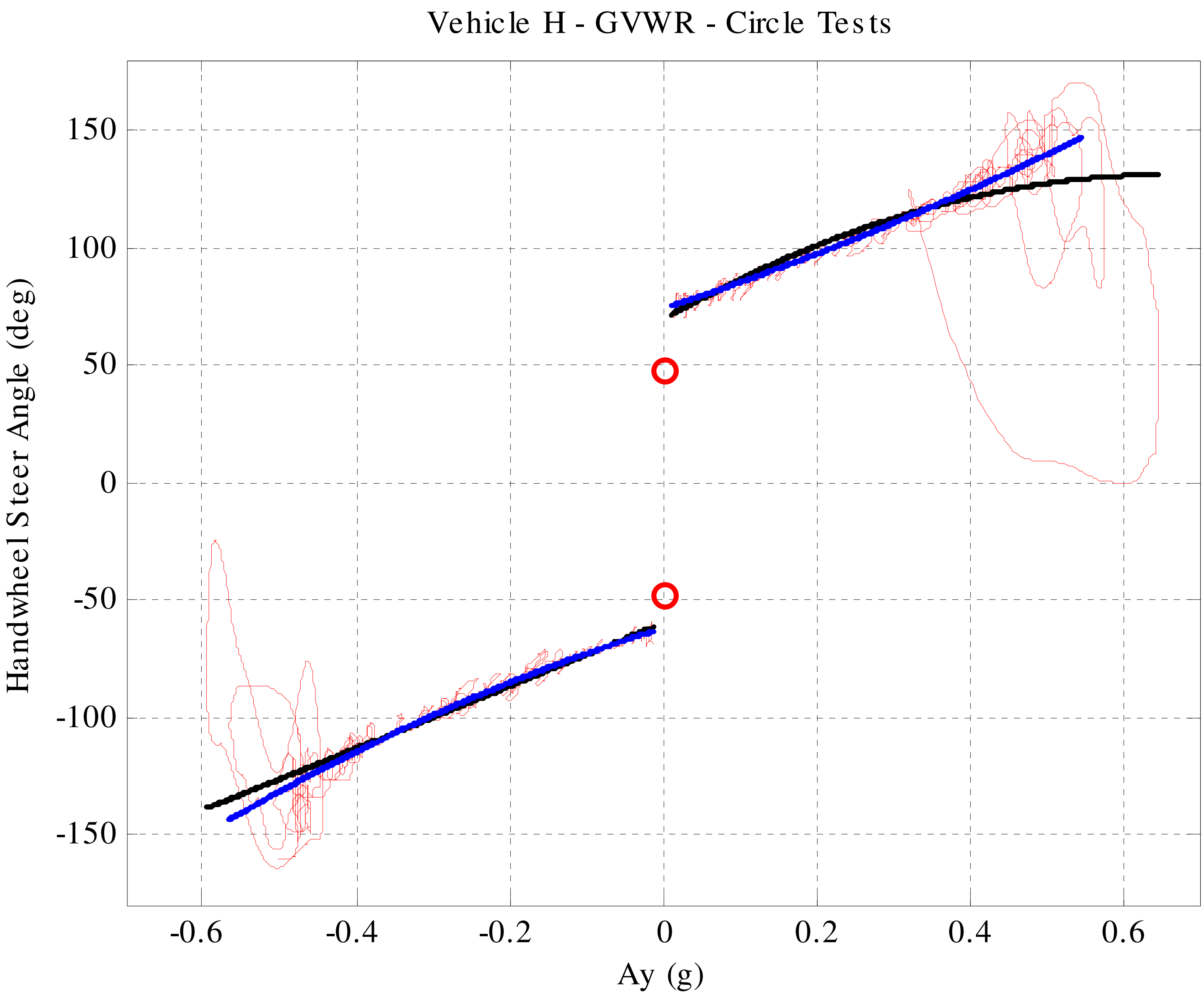
Vehicle G - GVWR - Circle Tests
Handwheel Steer Angle (deg)
100
50
0
-50
-100
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)


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

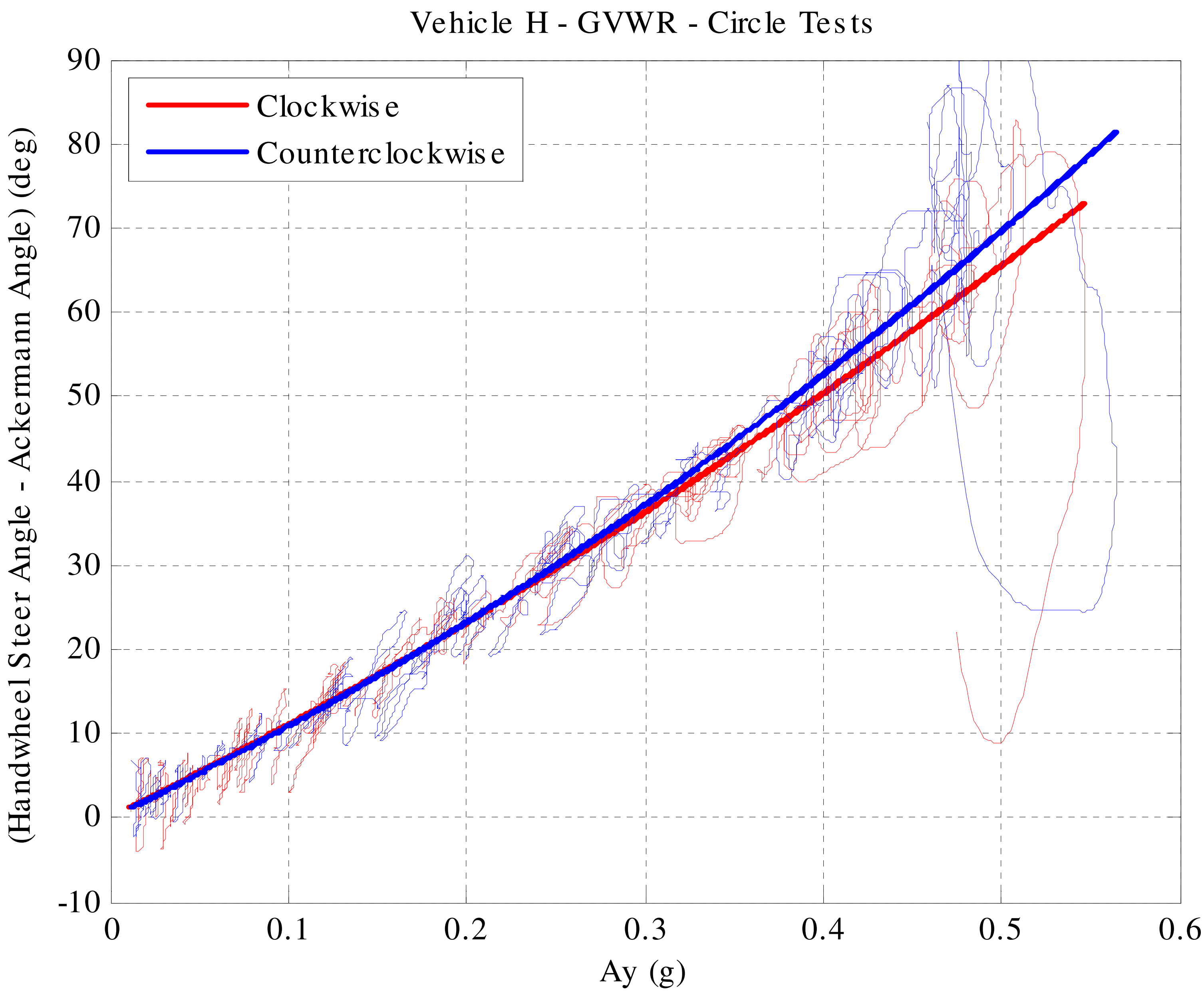

Vehicle G - GVWR - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -13.6128 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

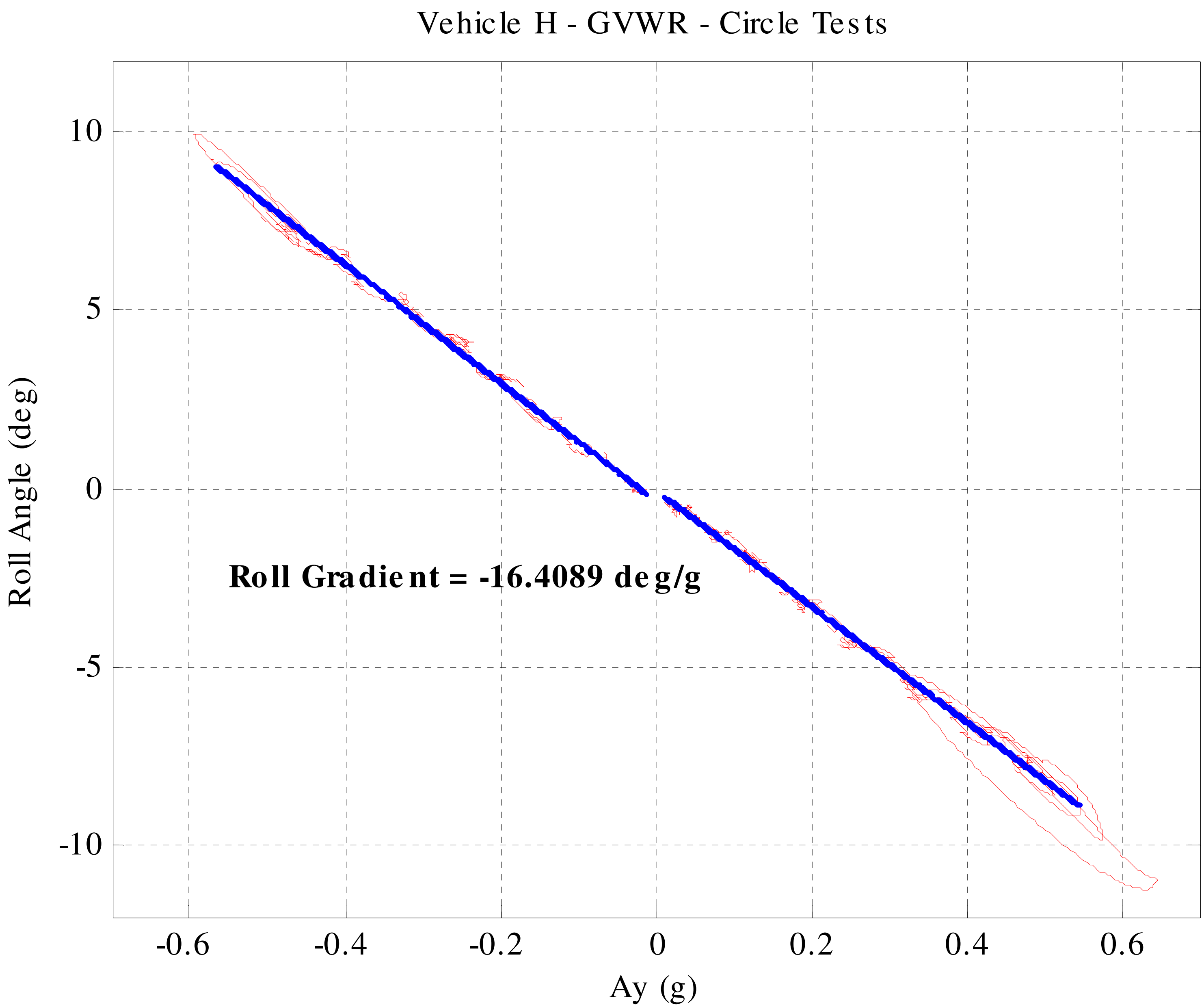


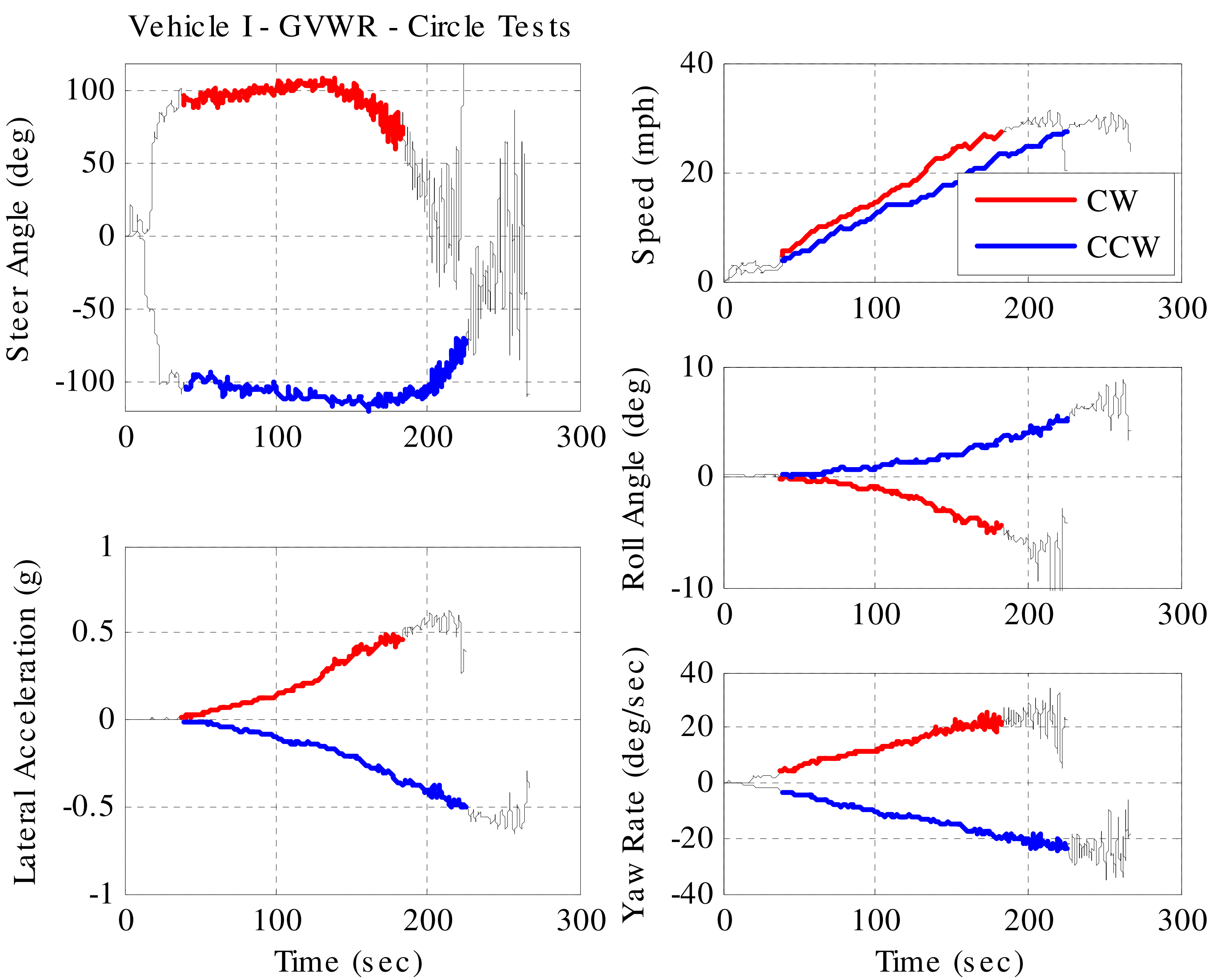
Vehicle H - GVWR - Circle Tests
Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



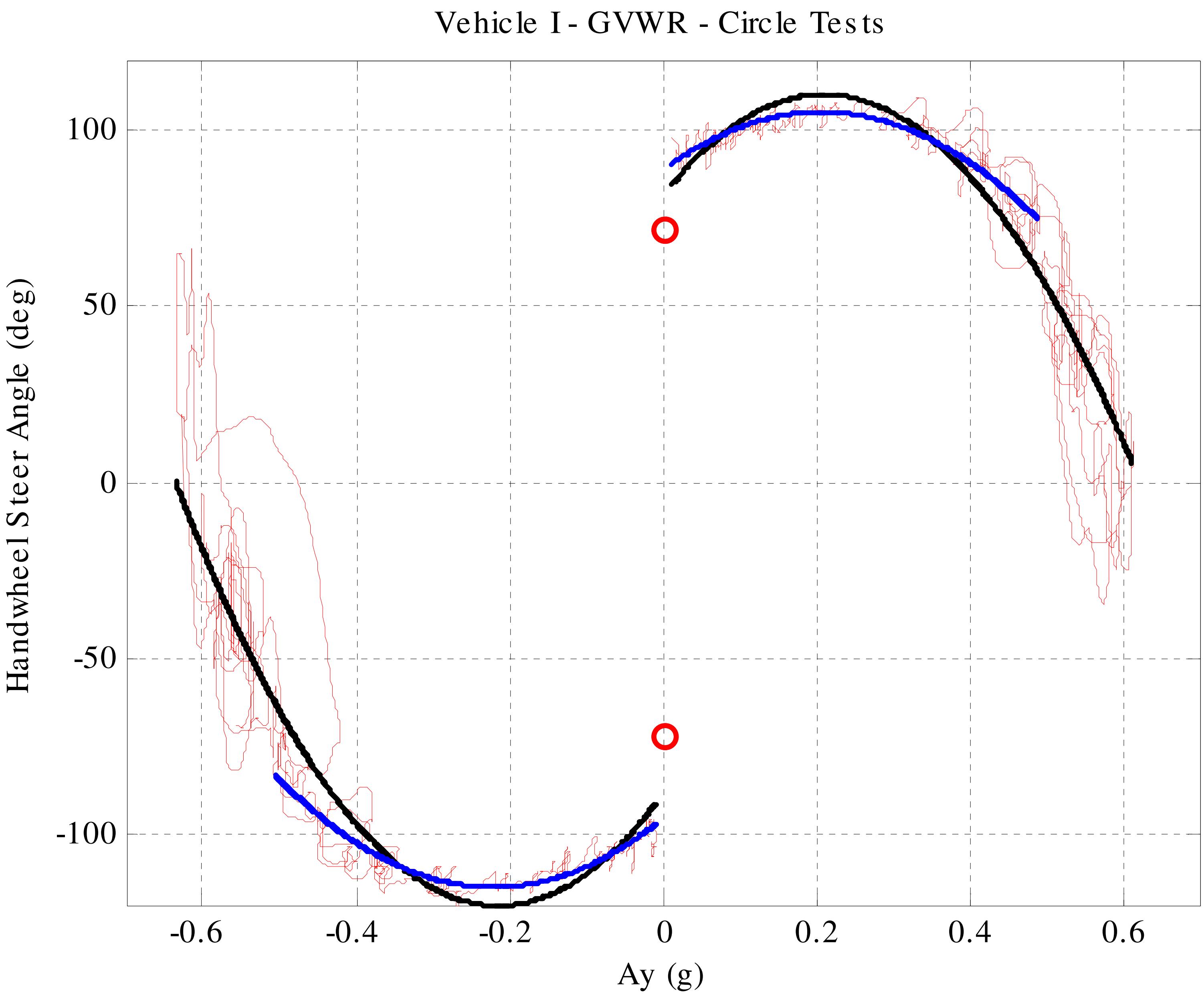
Vehicle H - GVWR - Circle Tests
Handwheel Steer Angle (deg)
150
100
50
0
-50
-100
-150
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
Ay (g)

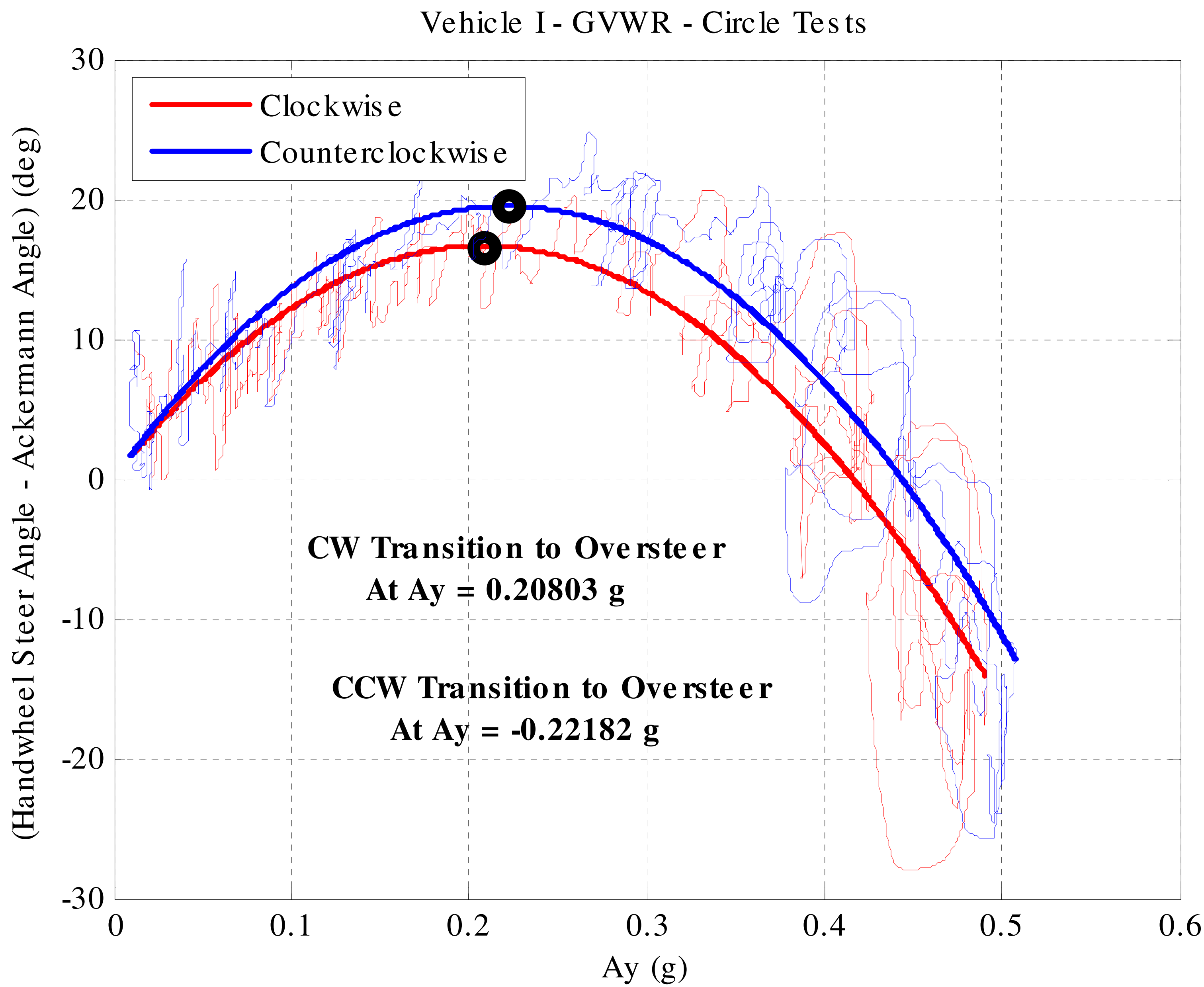

Vehicle H - GVWR - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
90
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
Ay (g)

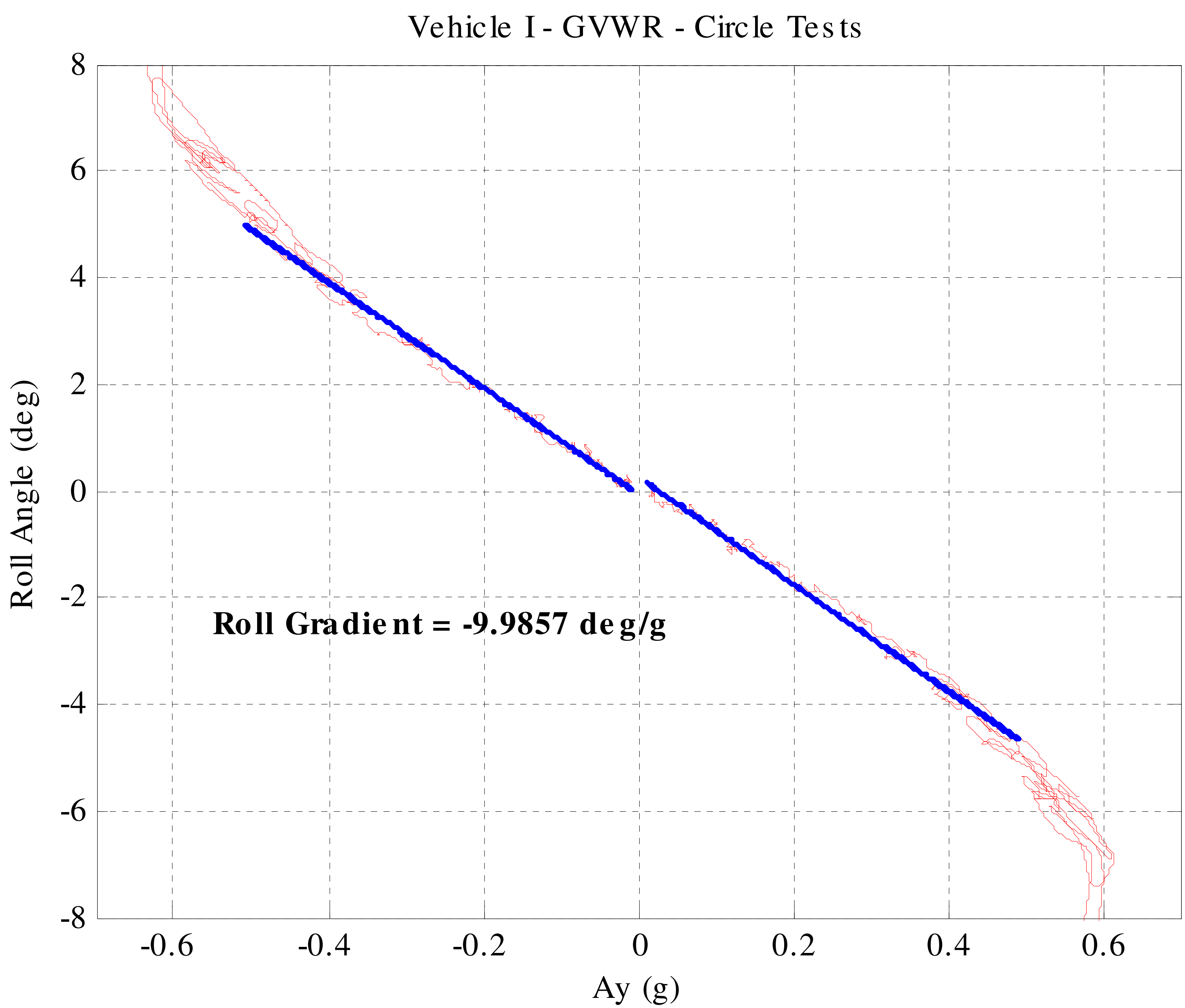

Vehicle H - GVWR - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -16.4089 deg/g
10
5
0
-5
-10
-0.6
-0.4
-0.2
0
0.2
0.4
0.6



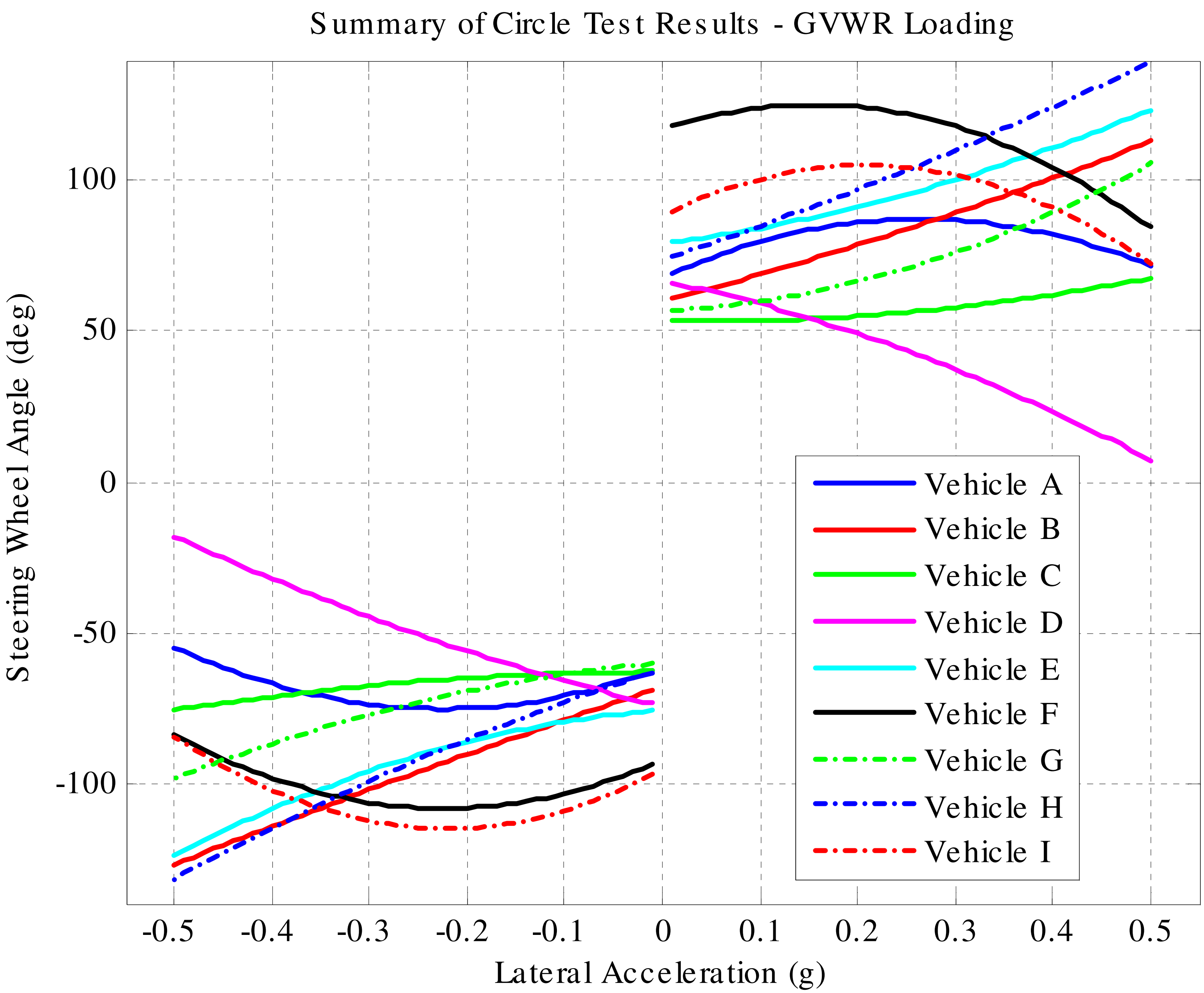
Vehicle I - GVWR - Circle Tests
Steer Angle (deg)
Lateral Acceleration (g)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
CW
CCW


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

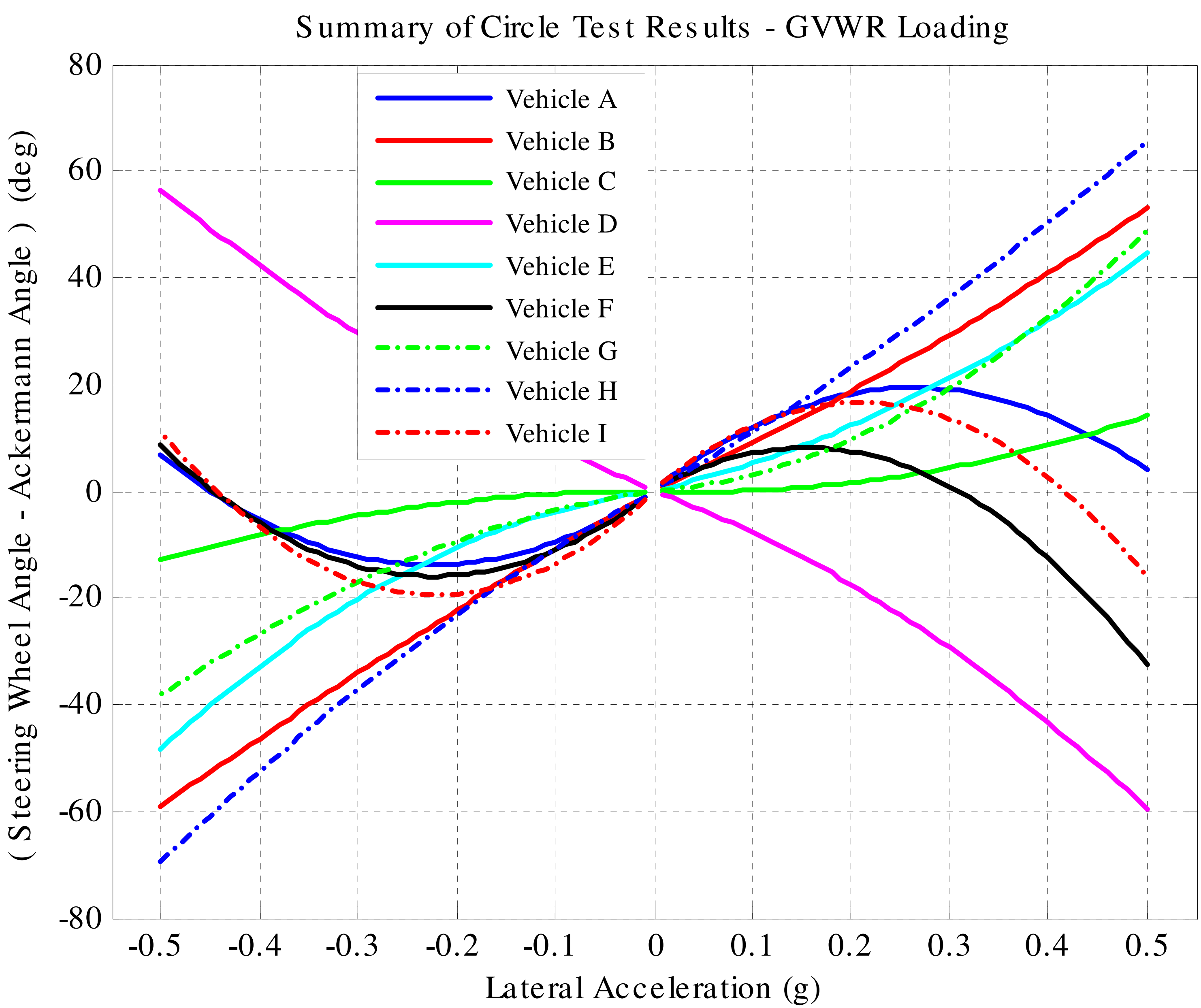

Vehicle I - GVWR - Circle Tests
Clockwise
Counterclockwise
(Handwheel Steer Angle - Ackermann Angle) (deg)
30
20
10
0
-10
-20
-30
CW Transition to Oversteer
At Ay = 0.20803 g
CCW Transition to Oversteer
At Ay = -0.22182 g
0
0.1
0.2
0.3
0.4
0.5
0.6
Ay (g)

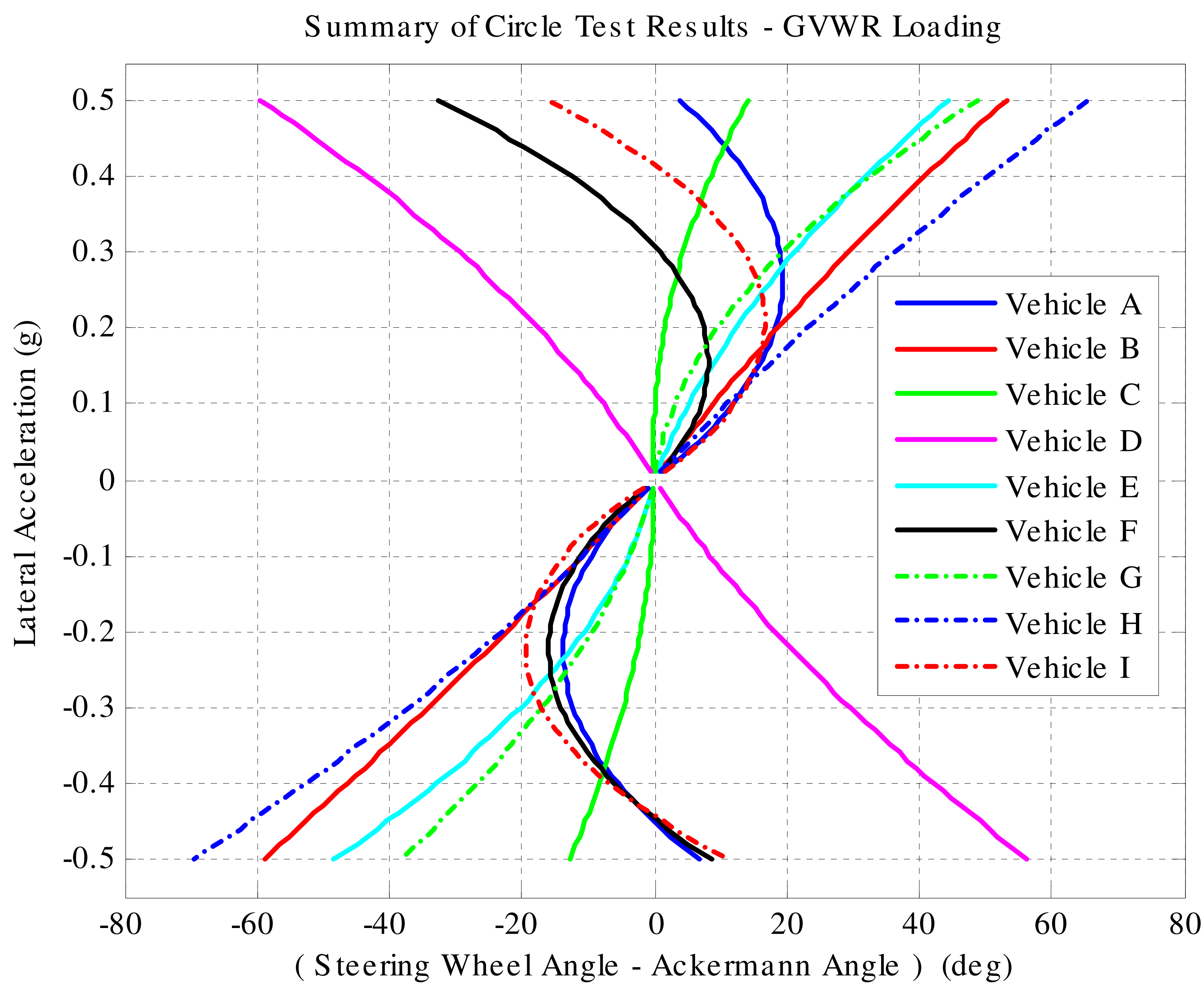


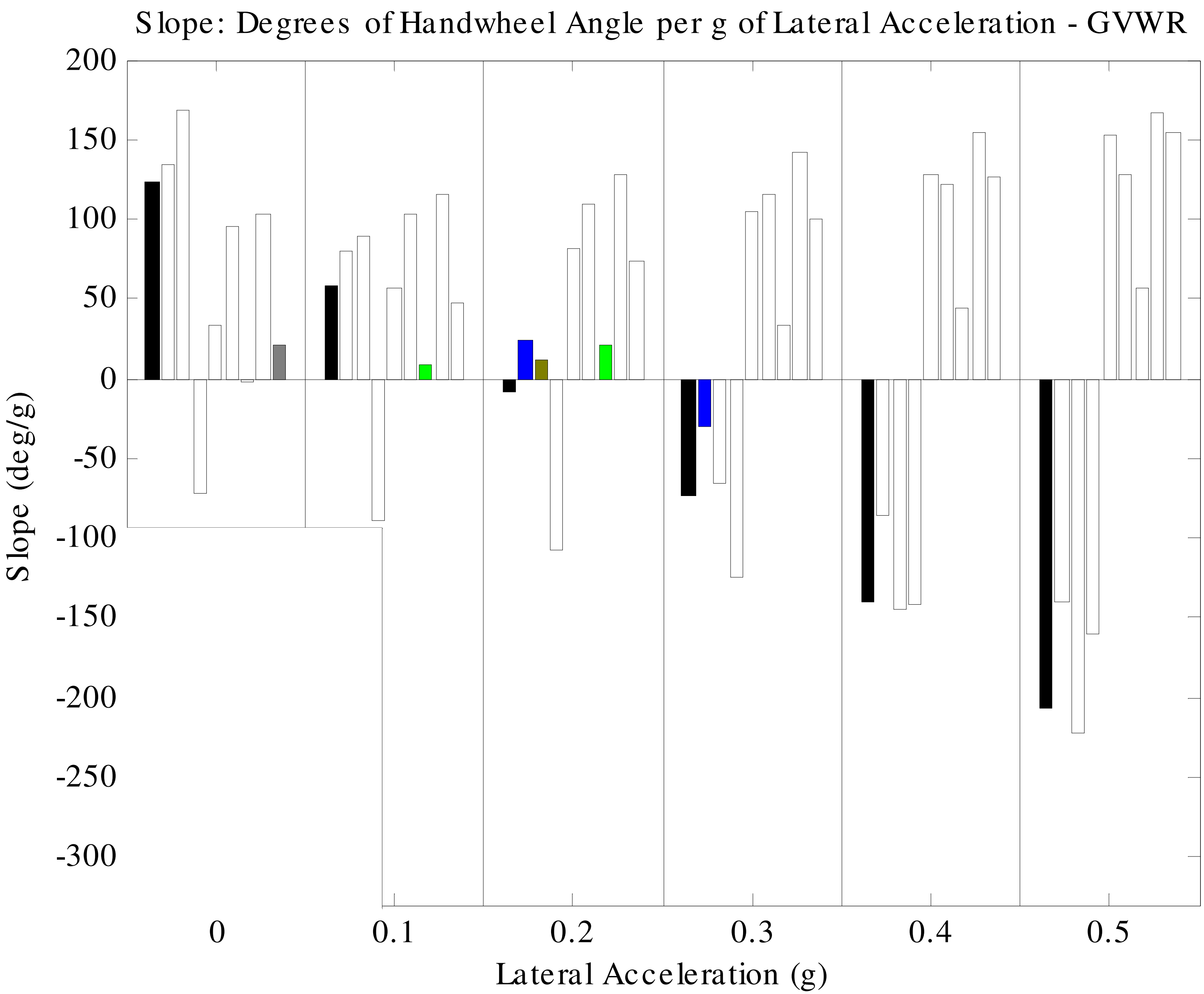
Vehicle I - GVWR - Circle Tests
Roll Angle (deg)
Ay (g)
Roll Gradient = -9.9857 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6

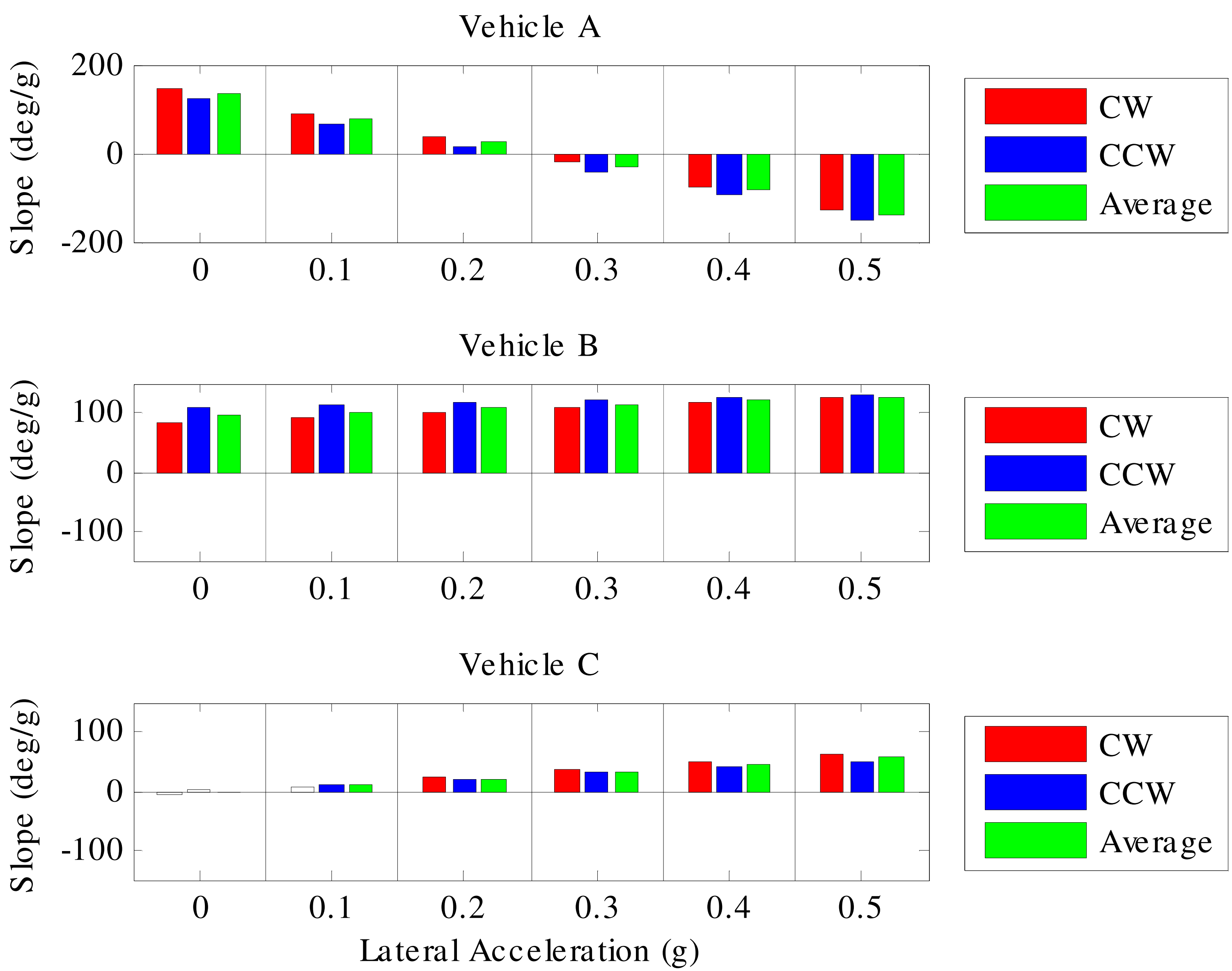


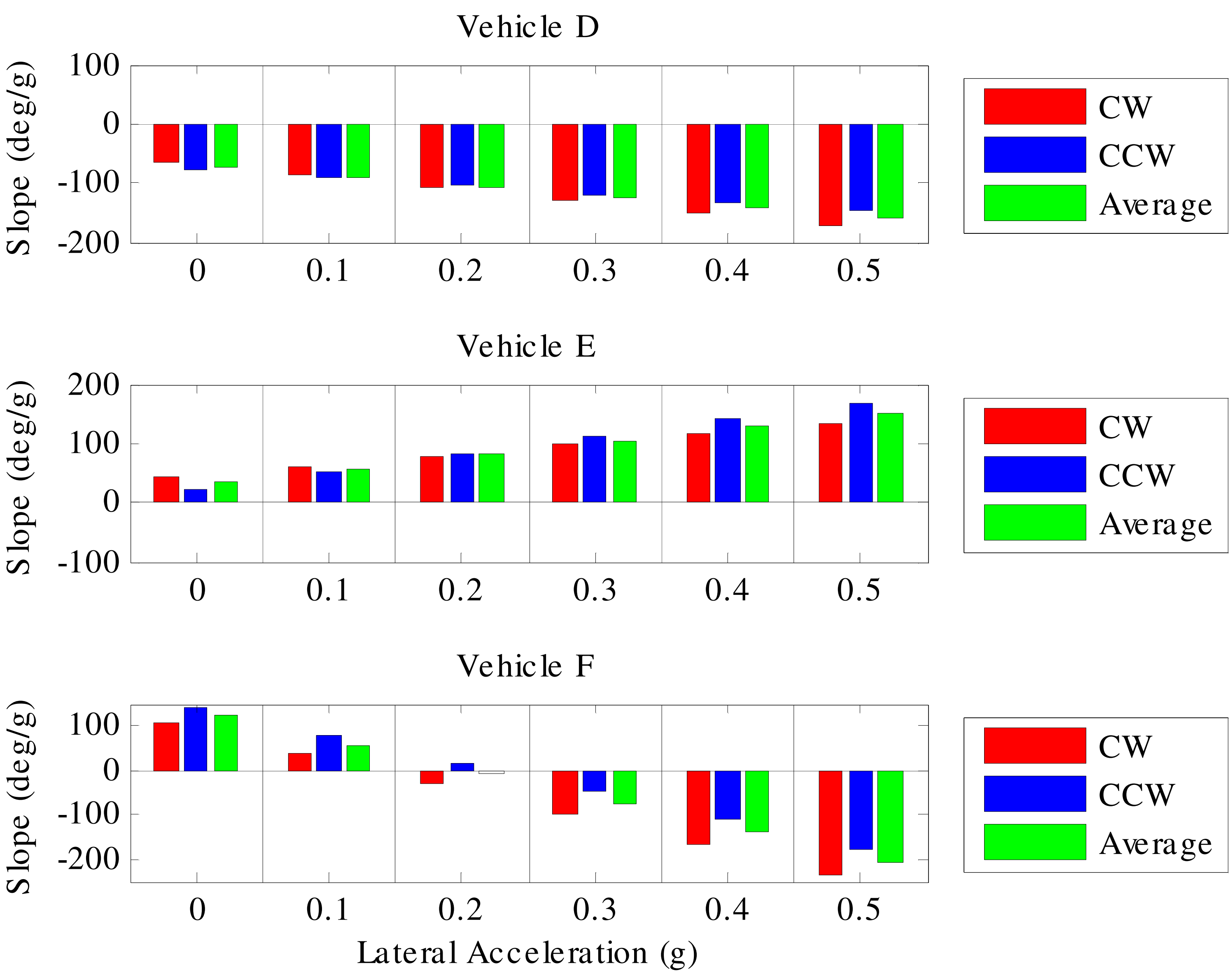
Summary of Circle Test Results - GVWR Loading
Steering Wheel Angle (deg)
100
50
0
-50
-100
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I

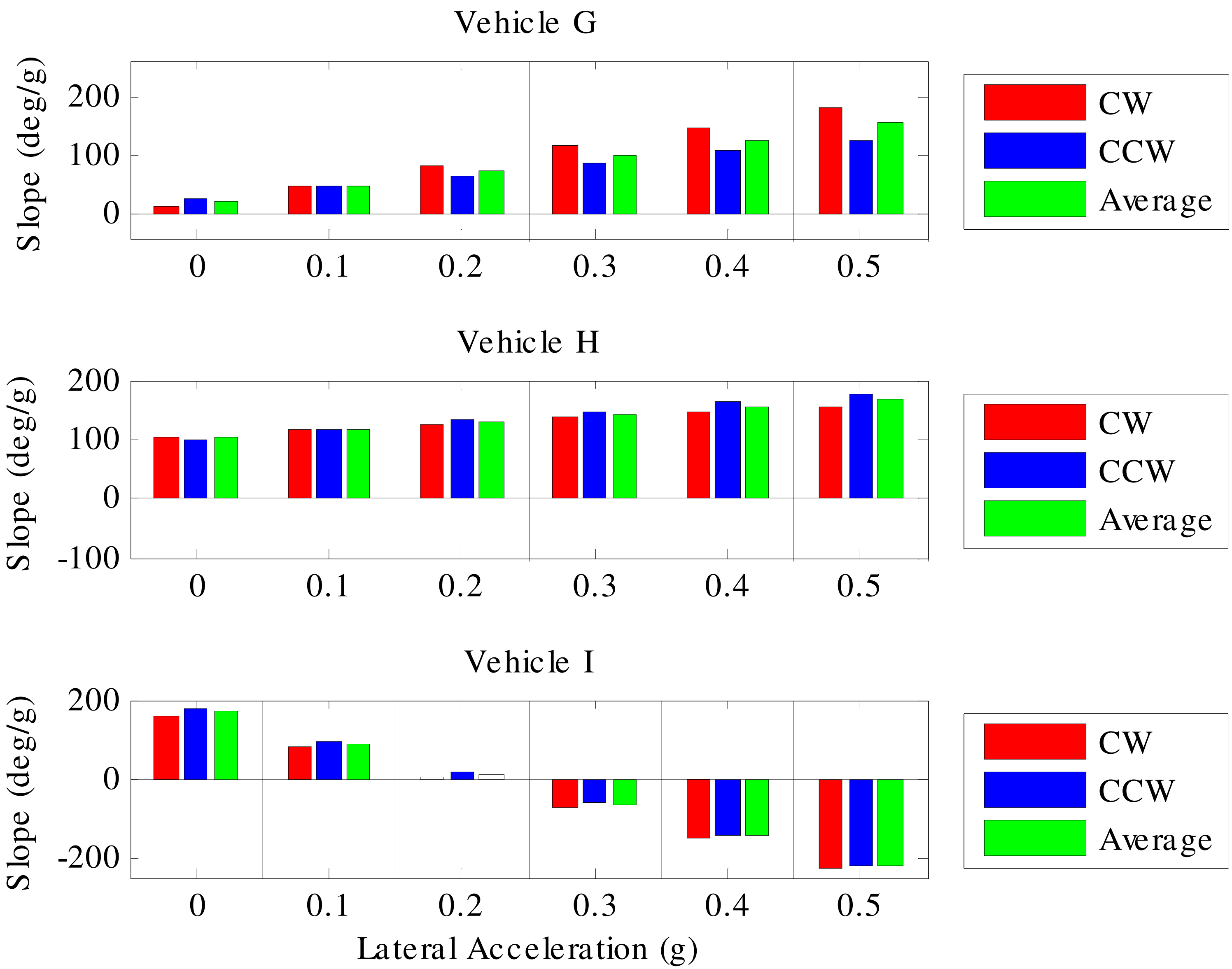

Summary of Circle Test Results - GVWR Loading
(Steering Wheel Angle - Ackermann Angle) (deg)
80
60
40
20
0
-20
-40
-60
-80
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)
Vehicle A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I


Summary of Circle Test Results - GVWR 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 A
Vehicle B
Vehicle C
Vehicle D
Vehicle E
Vehicle F
Vehicle G
Vehicle H
Vehicle I

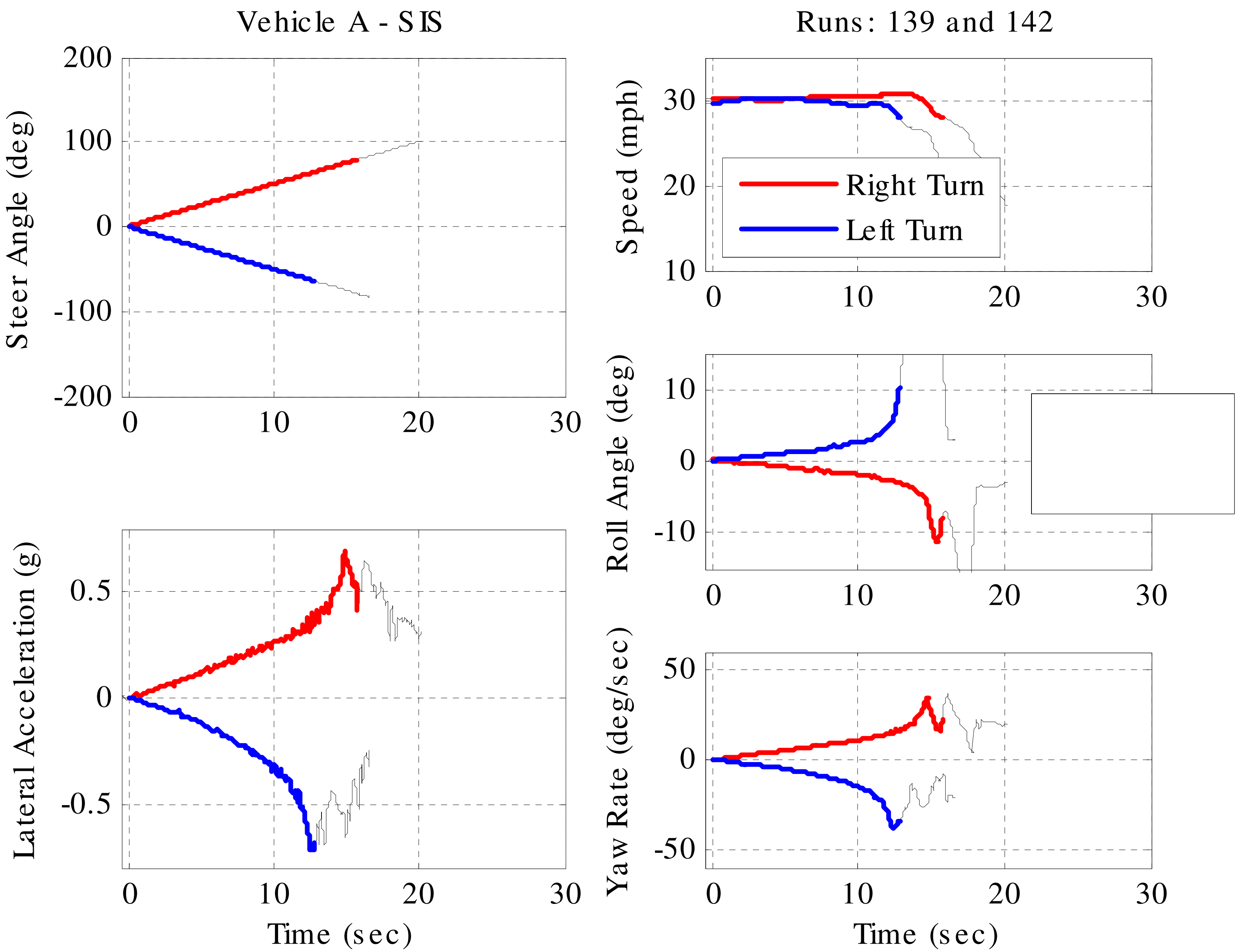

Slope: Degrees of Handwheel Angle per g of Lateral Acceleration - GVWR
Slope (deg/g)
200
150
100
50
0
-50
-100
-150
-200
-250
-300
0
0.1
0.2
0.3
0.4
0.5
Lateral Acceleration (g)


Vehicle A
Slope (deg/g)
200
0
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle B
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle C
Slope (deg/g)
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)

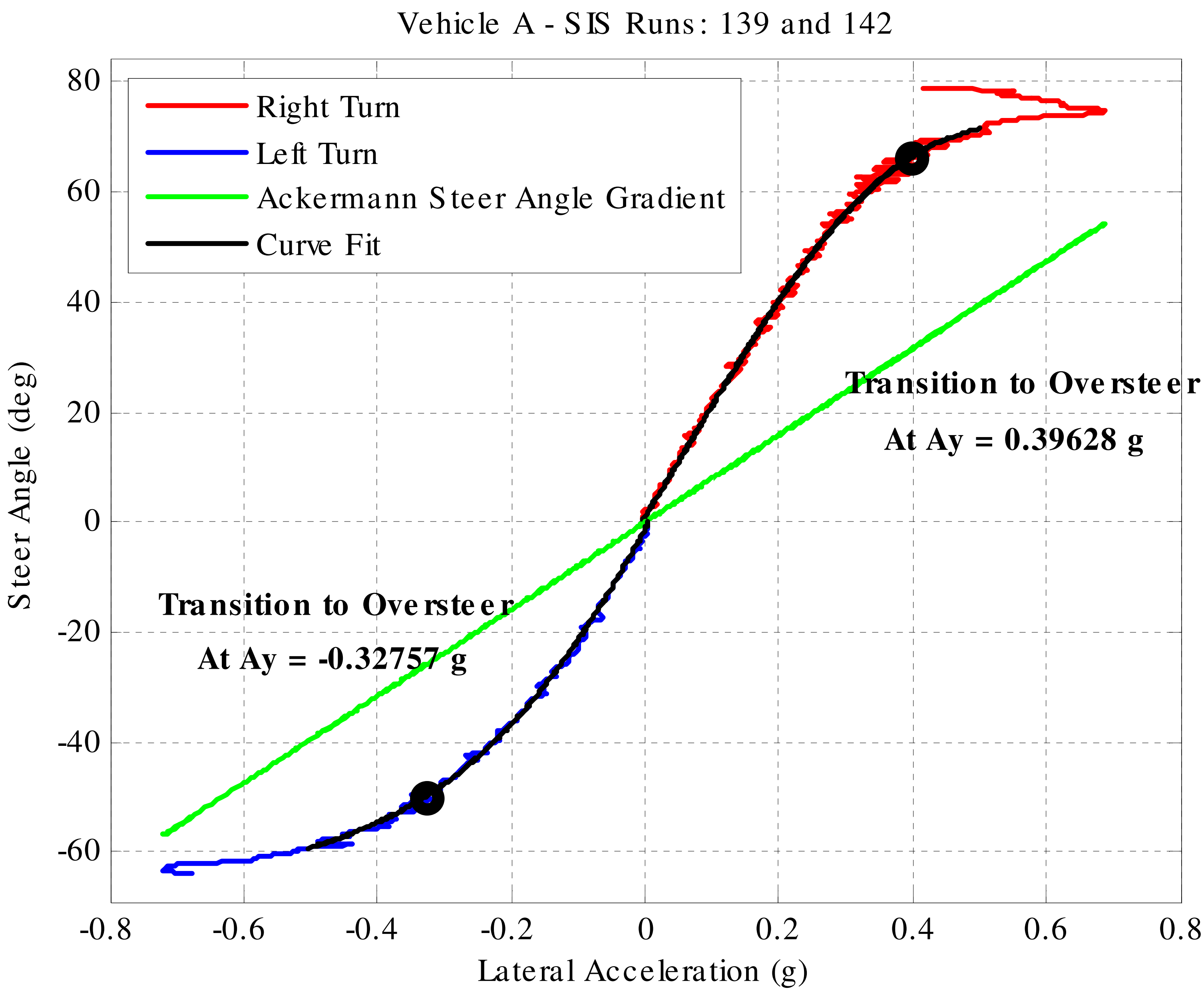

Vehicle D
Slope (deg/g)
100
0
-100
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle E
Slope (deg/g)
200
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle F
Slope (deg/g)
100
0
-100
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)


Vehicle G
Slope (deg/g)
200
100
0
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle H
Slope (deg/g)
200
100
0
-100
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Vehicle I
Slope (deg/g)
200
0
-200
0
0.1
0.2
0.3
0.4
0.5
CW
CCW
Average
Lateral Acceleration (g)

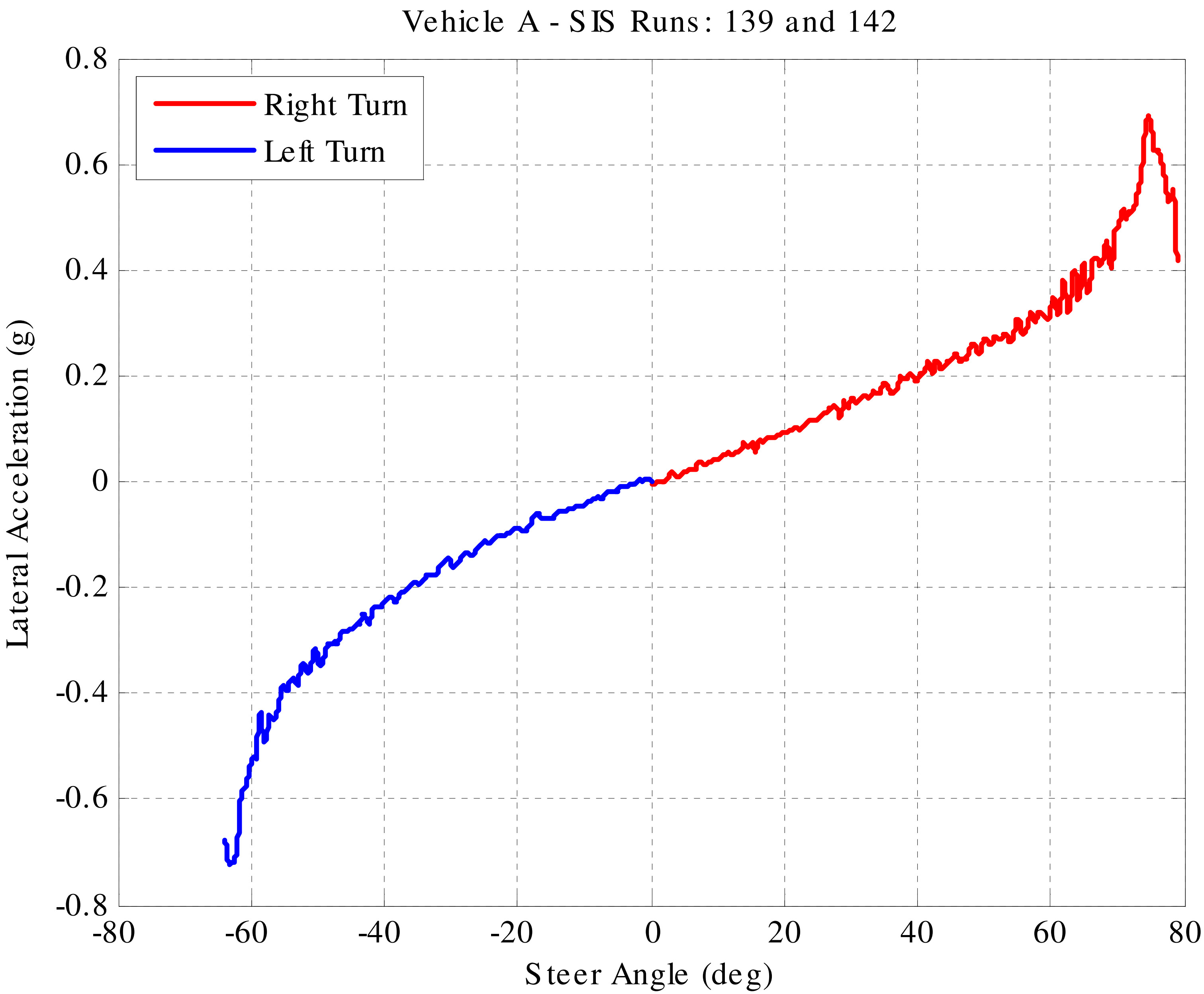
Constant Radius (100 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (GVWR)			
	Clockwise (g)	Counterclockwise (g)	Average (g)
Vehicle A	0.26	0.23	0.24
Vehicle B	NA	NA	NA
Vehicle C	NA	NA	NA
Vehicle D	0.00	0.00	0.00
Vehicle E	NA	NA	NA
Vehicle F	0.15	0.22	0.19
Vehicle G	NA	NA	NA
Vehicle H	NA	NA	NA
Vehicle I	0.21	0.22	0.21



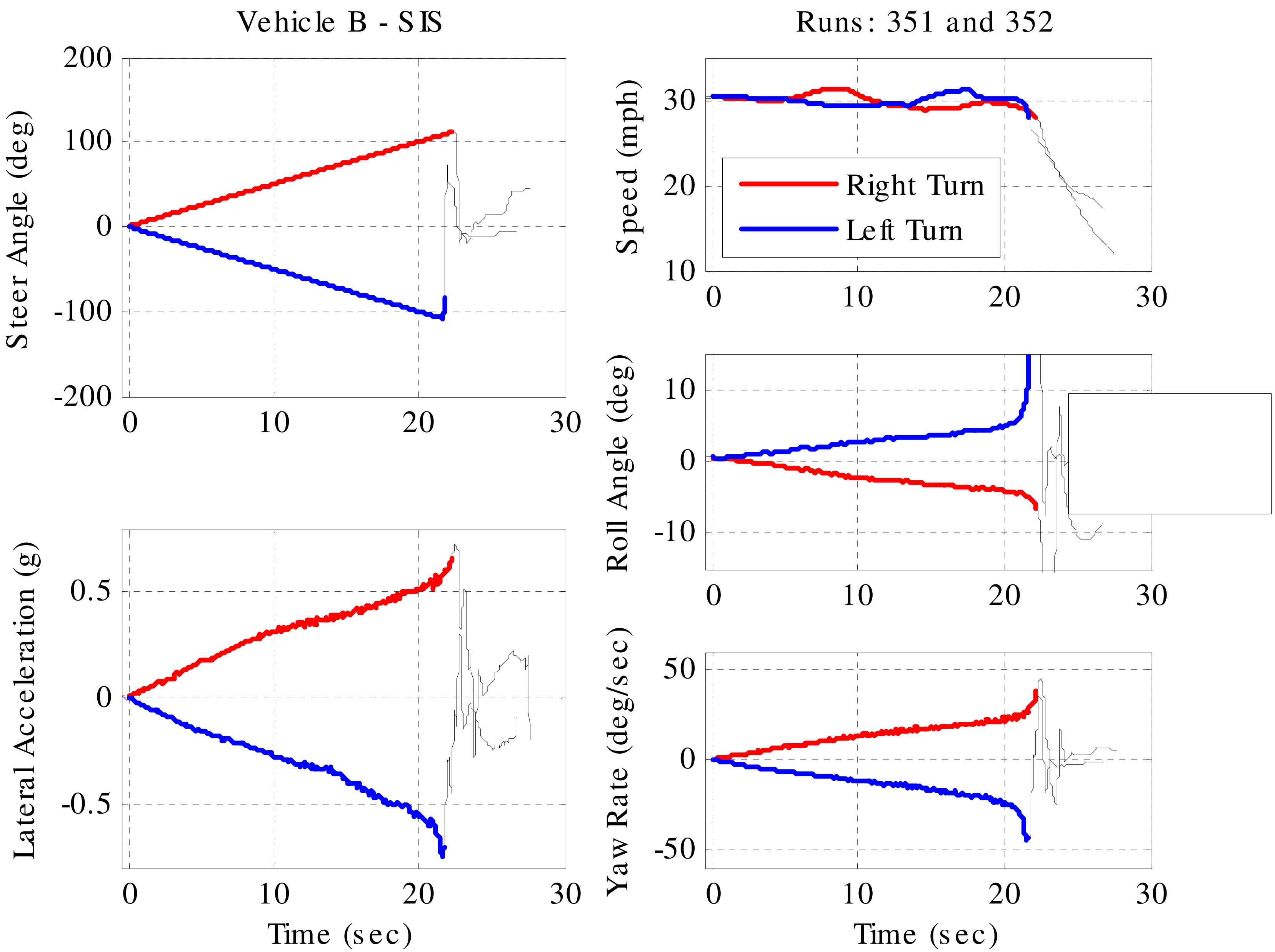
Vehicle A - SIS
Runs: 139 and 142
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
-10
Lateral Acceleration (g)
0.5
-0.5
Time (sec)
Yaw Rate (deg/sec)
50
-50

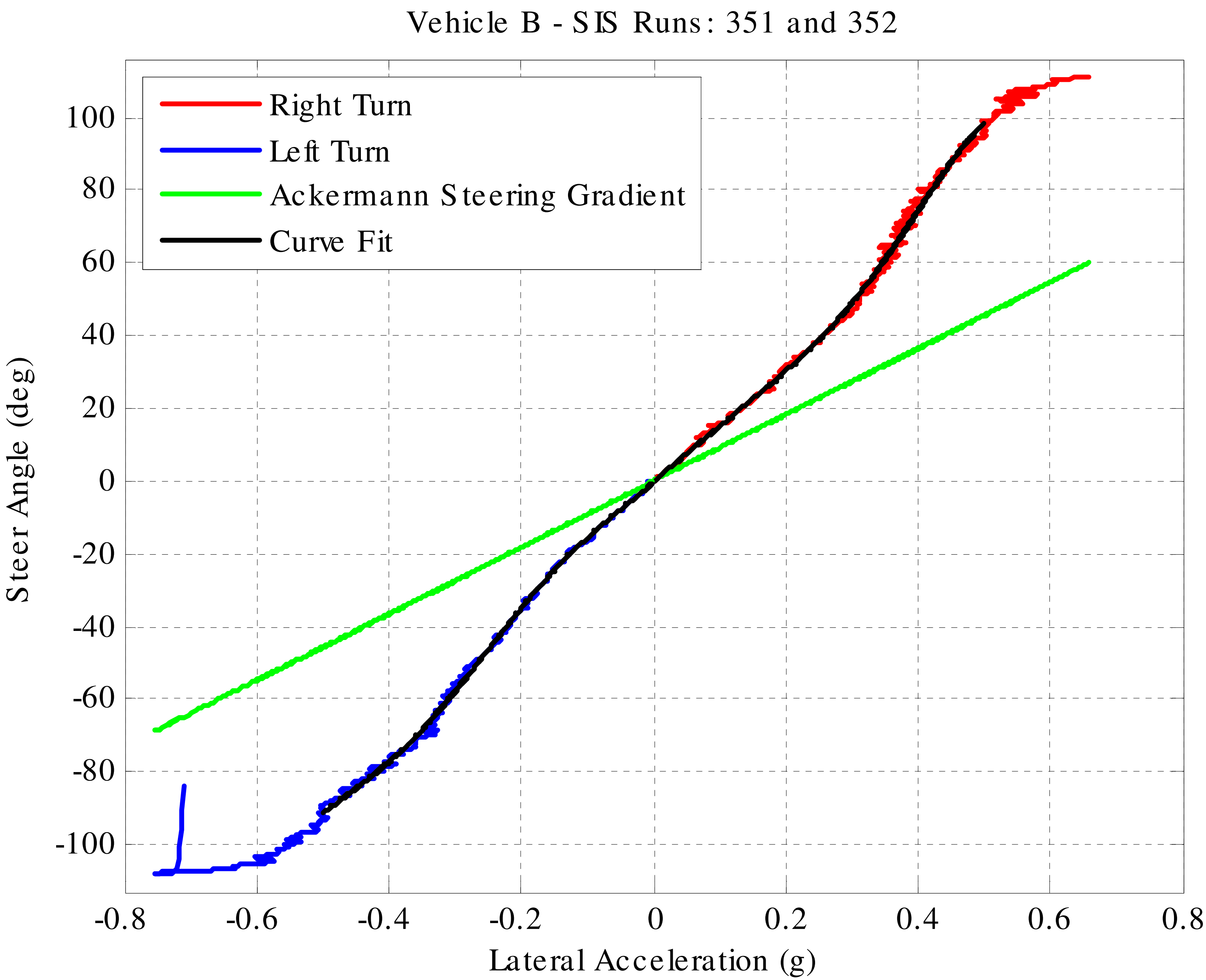


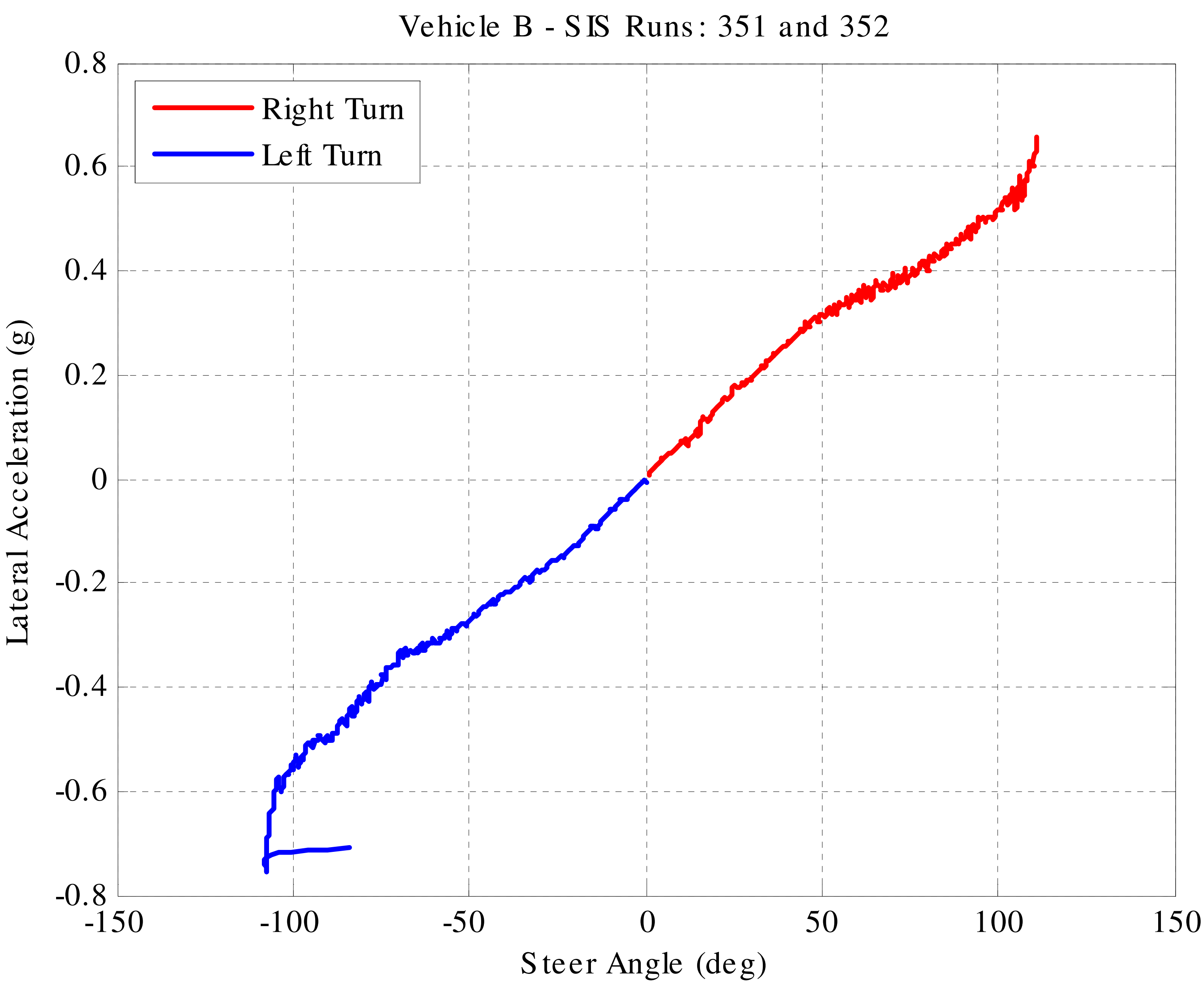
Vehicle A - SIS Runs: 139 and 142
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.39628 g
Transition to Oversteer
At Ay = -0.32757 g
Steer Angle (deg)
80
60
40
20
0
-20
-40
-60
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Lateral Acceleration (g)

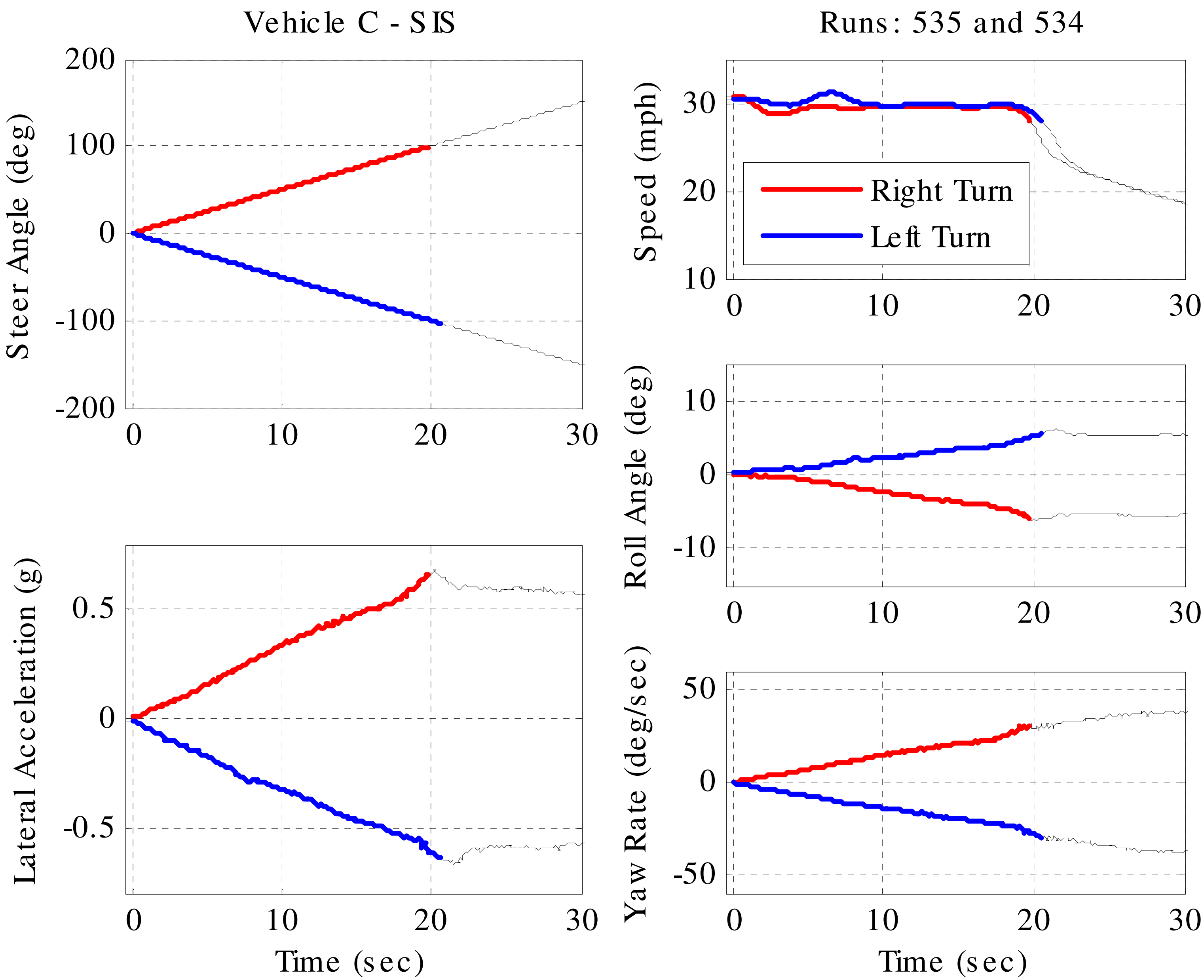


Vehicle A - SIS Runs: 139 and 142
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-80
-60
-40
-20
0
20
40
60
80

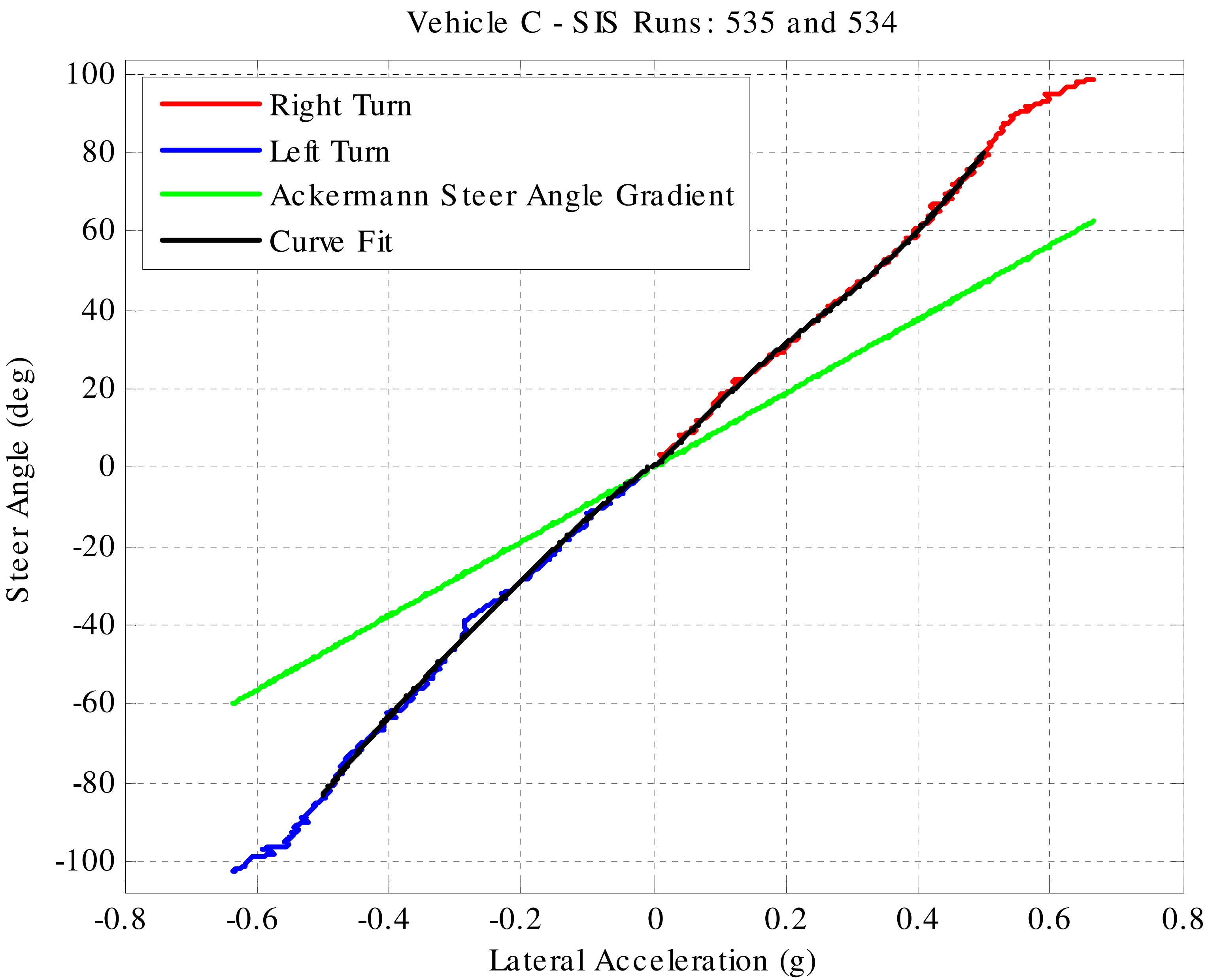

Vehicle B - SIS
Runs: 351 and 352
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

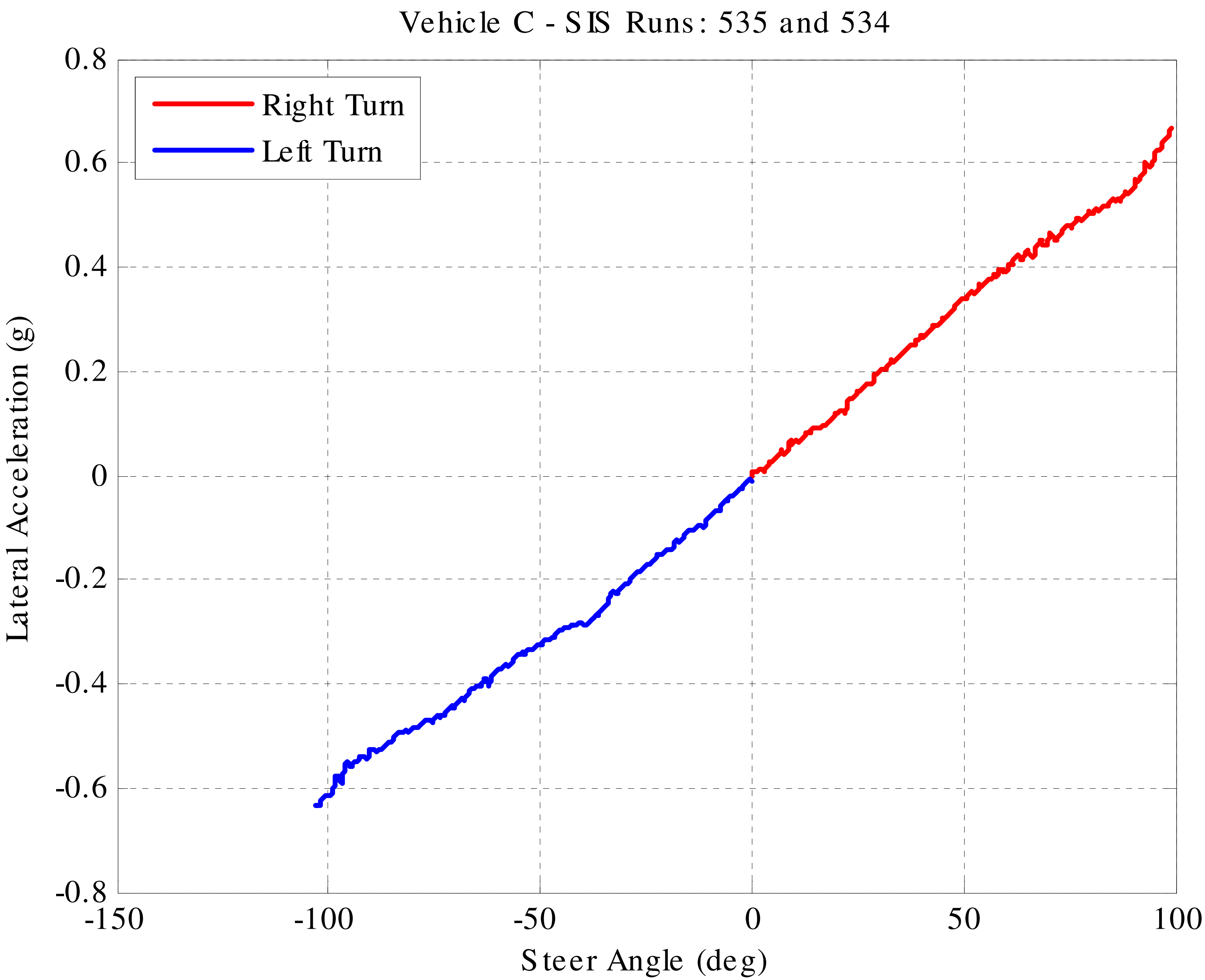

Vehicle B - SIS Runs: 351 and 352
Right Turn
Left Turn
Ackermann Steering Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

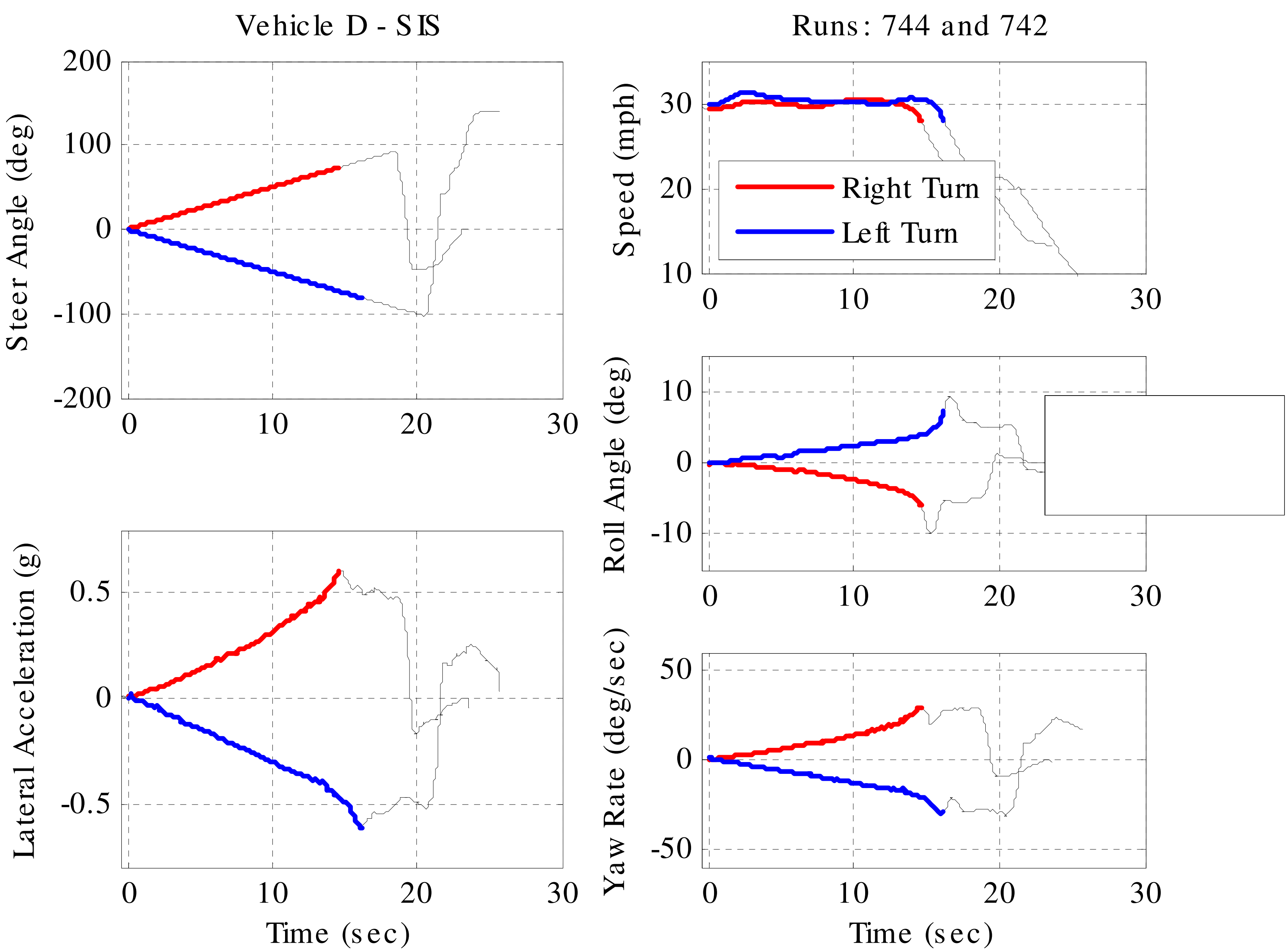

Vehicle B - SIS Runs: 351 and 352
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150
Steer Angle (deg)



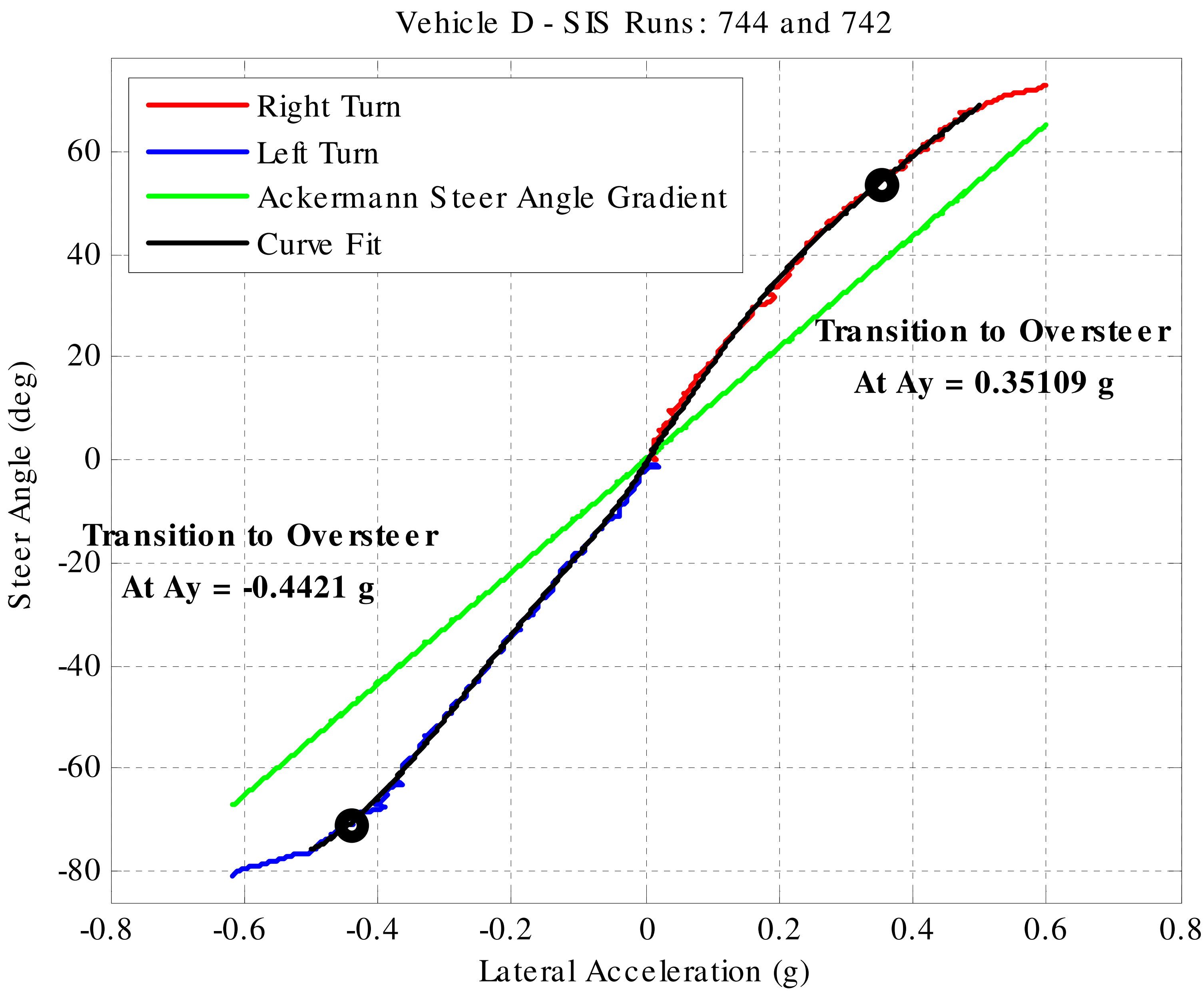
Vehicle C - SIS
Runs: 535 and 534
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
-10
Lateral Acceleration (g)
0.5
-0.5
Yaw Rate (deg/sec)
50
-50
Time (sec)


Vehicle C - SIS Runs: 535 and 534
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

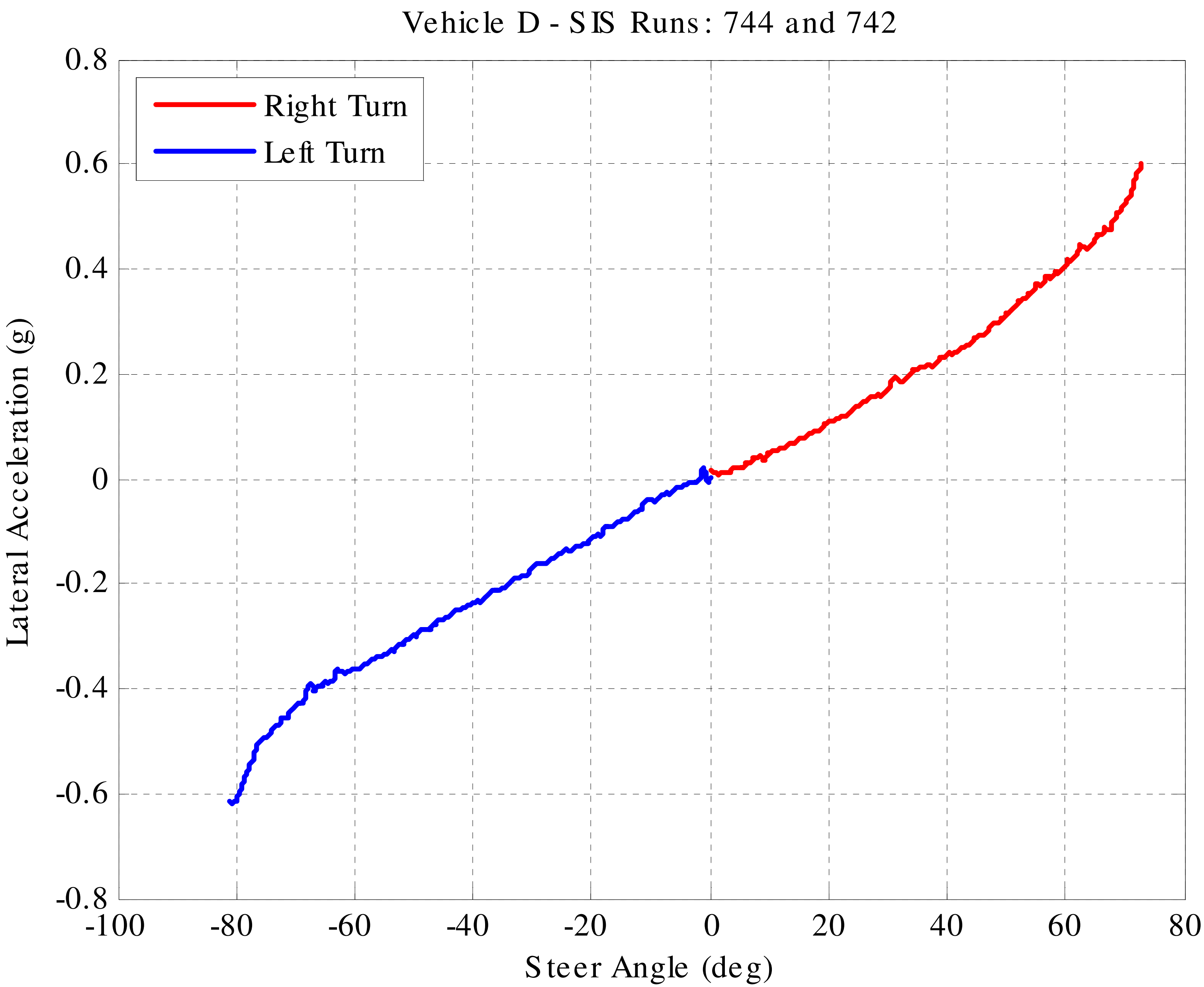

Vehicle C - SIS Runs: 535 and 534
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
Steer Angle (deg)



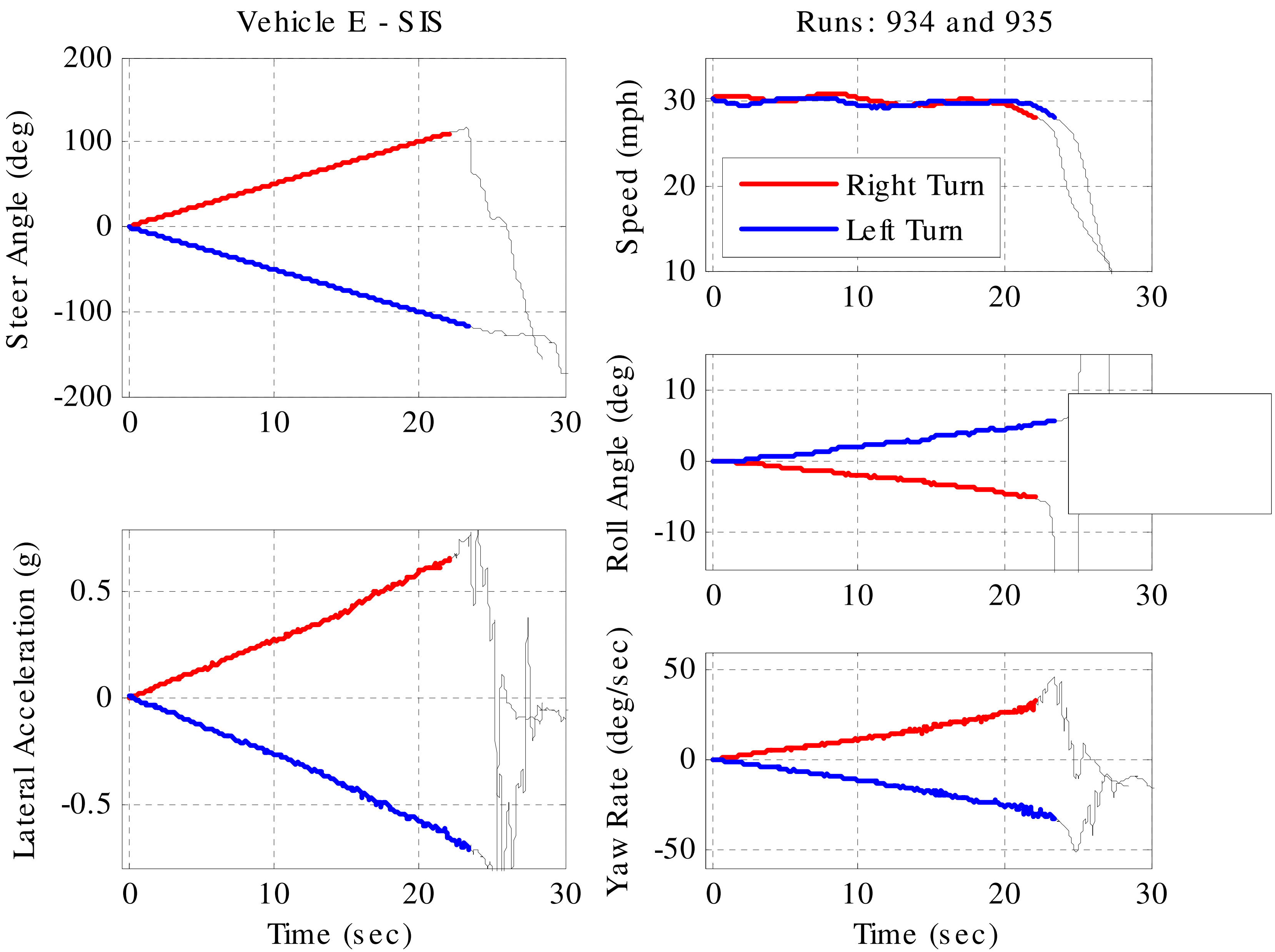
Vehicle D - SIS
Runs: 744 and 742
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

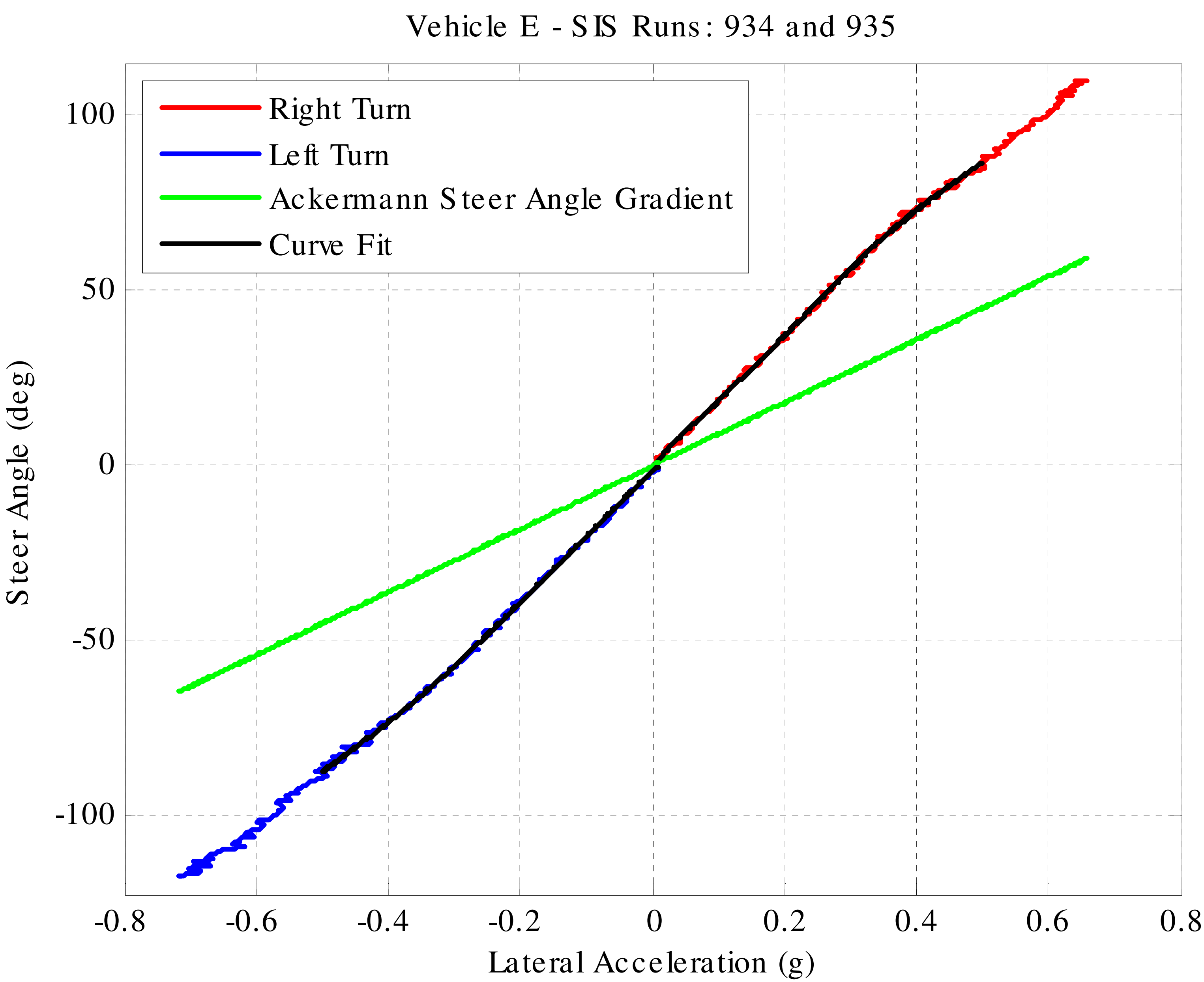


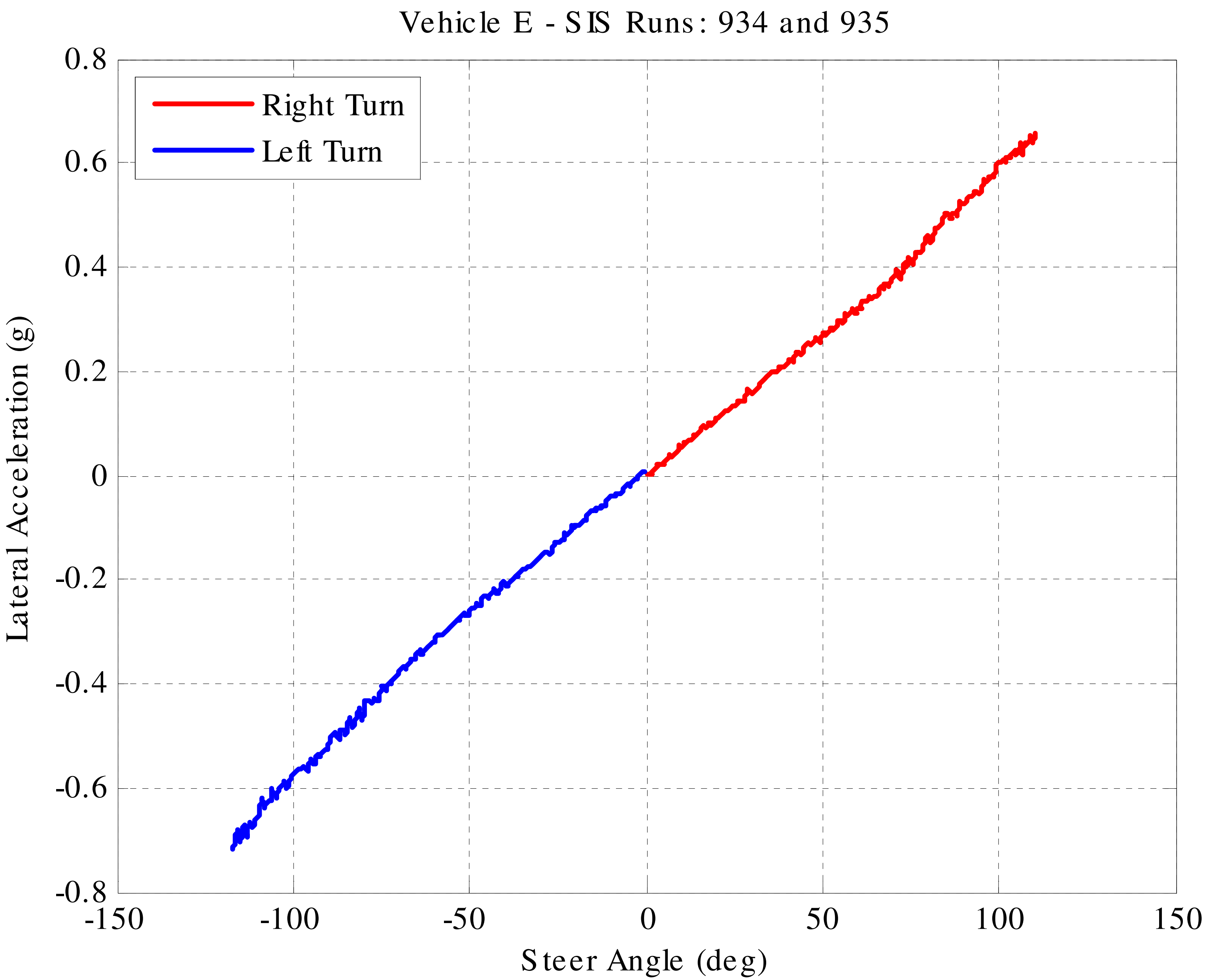
Vehicle D - SIS Runs: 744 and 742
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.35109 g
Transition to Oversteer
At Ay = -0.4421 g
Steer Angle (deg)
Lateral Acceleration (g)
60
40
20
0
-20
-40
-60
-80
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8



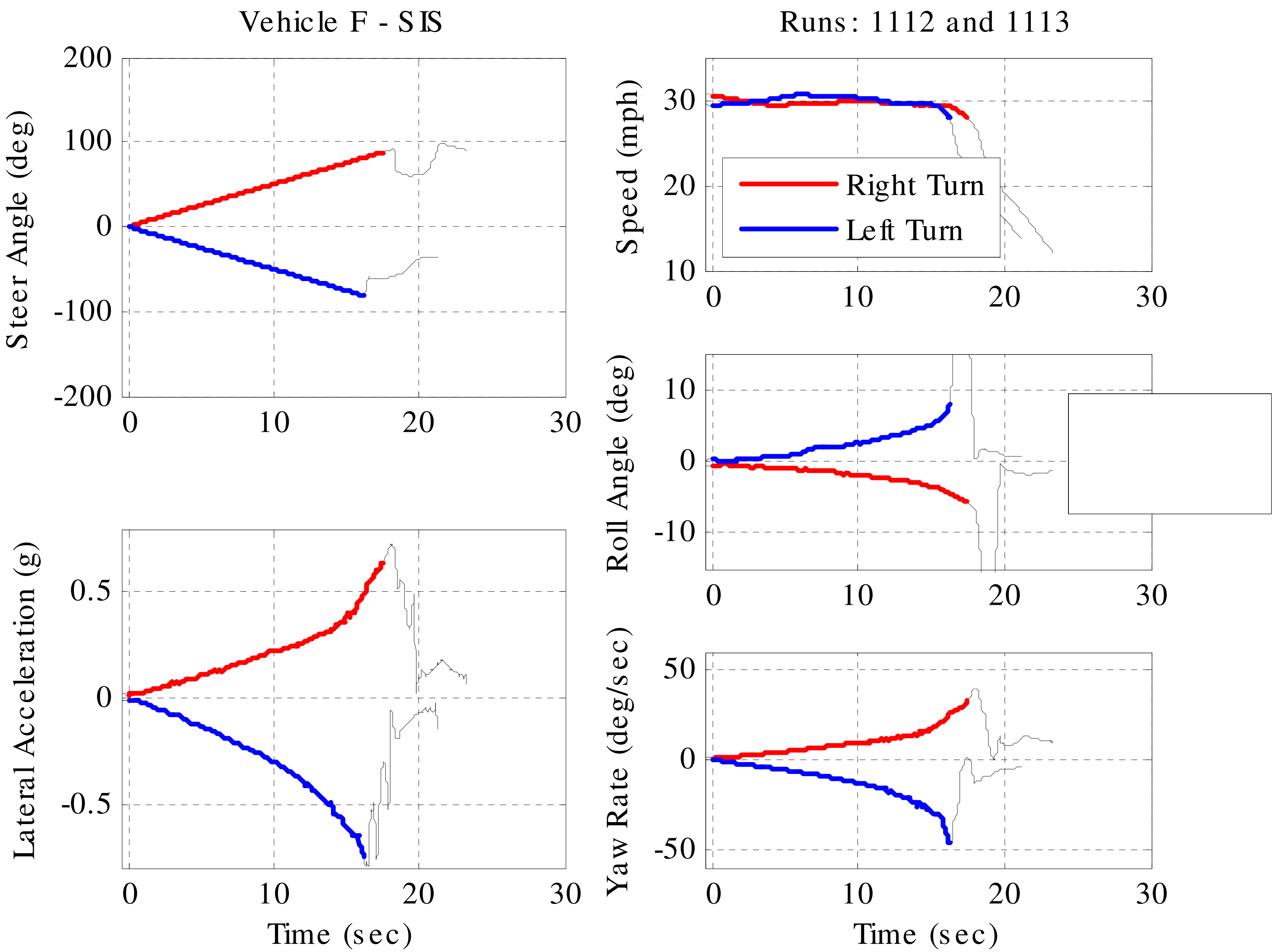
Vehicle D - SIS Runs: 744 and 742
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-100
-80
-60
-40
-20
0
20
40
60
80
Steer Angle (deg)


Vehicle E - SIS
Runs: 934 and 935
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
50
-50
Time (sec)
Time (sec)

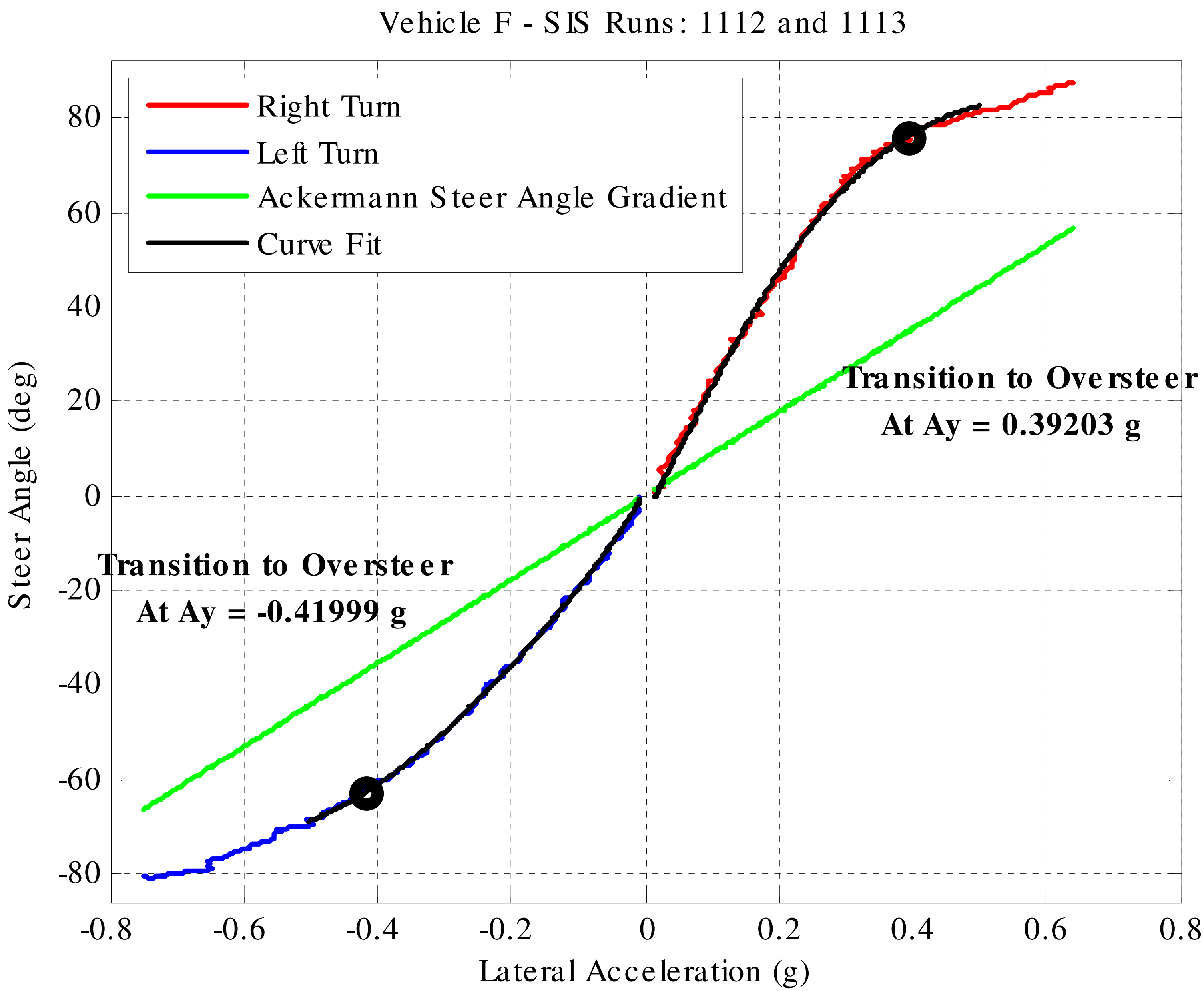

Vehicle E - SIS Runs: 934 and 935
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8



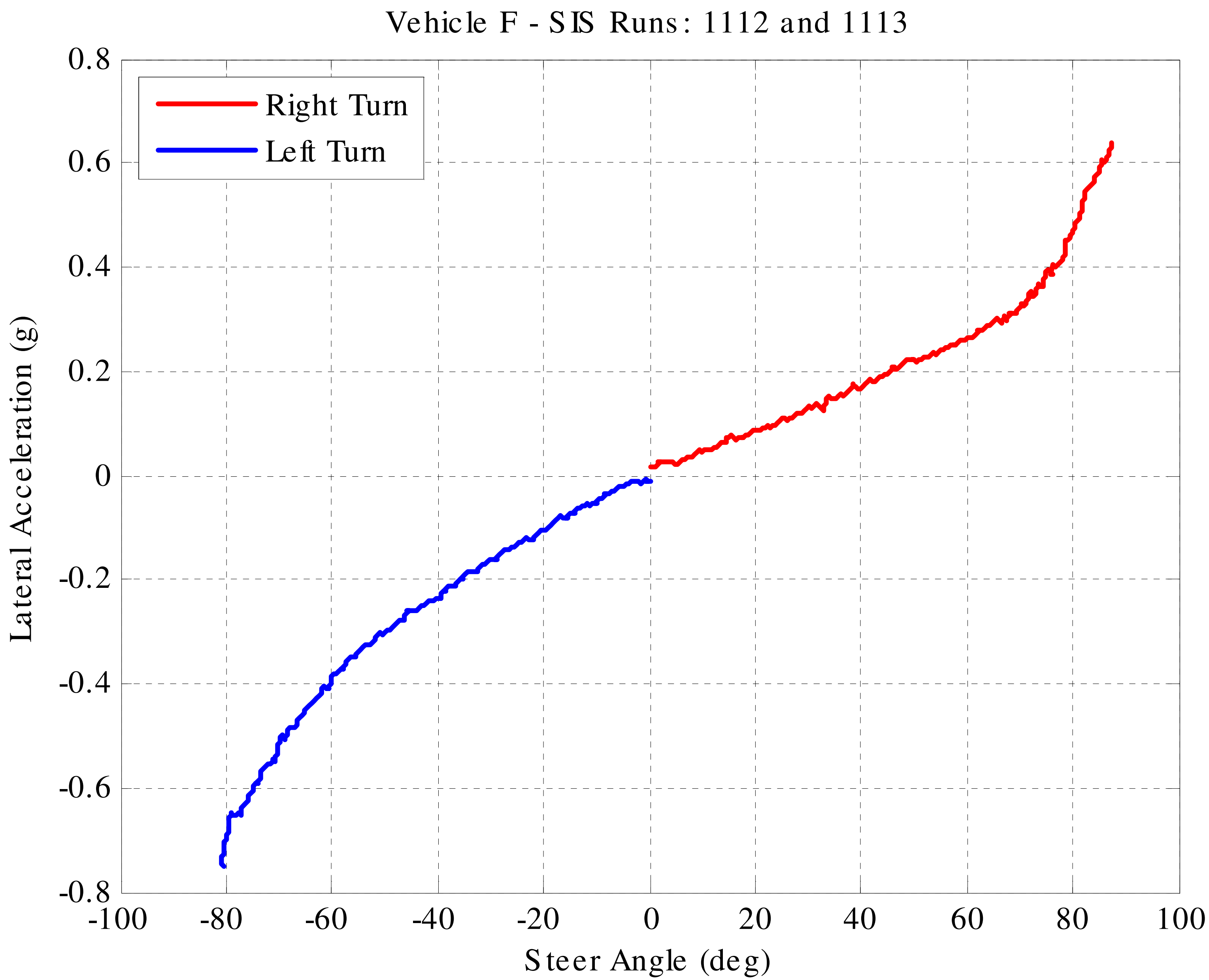
Vehicle E - SIS Runs: 934 and 935
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150

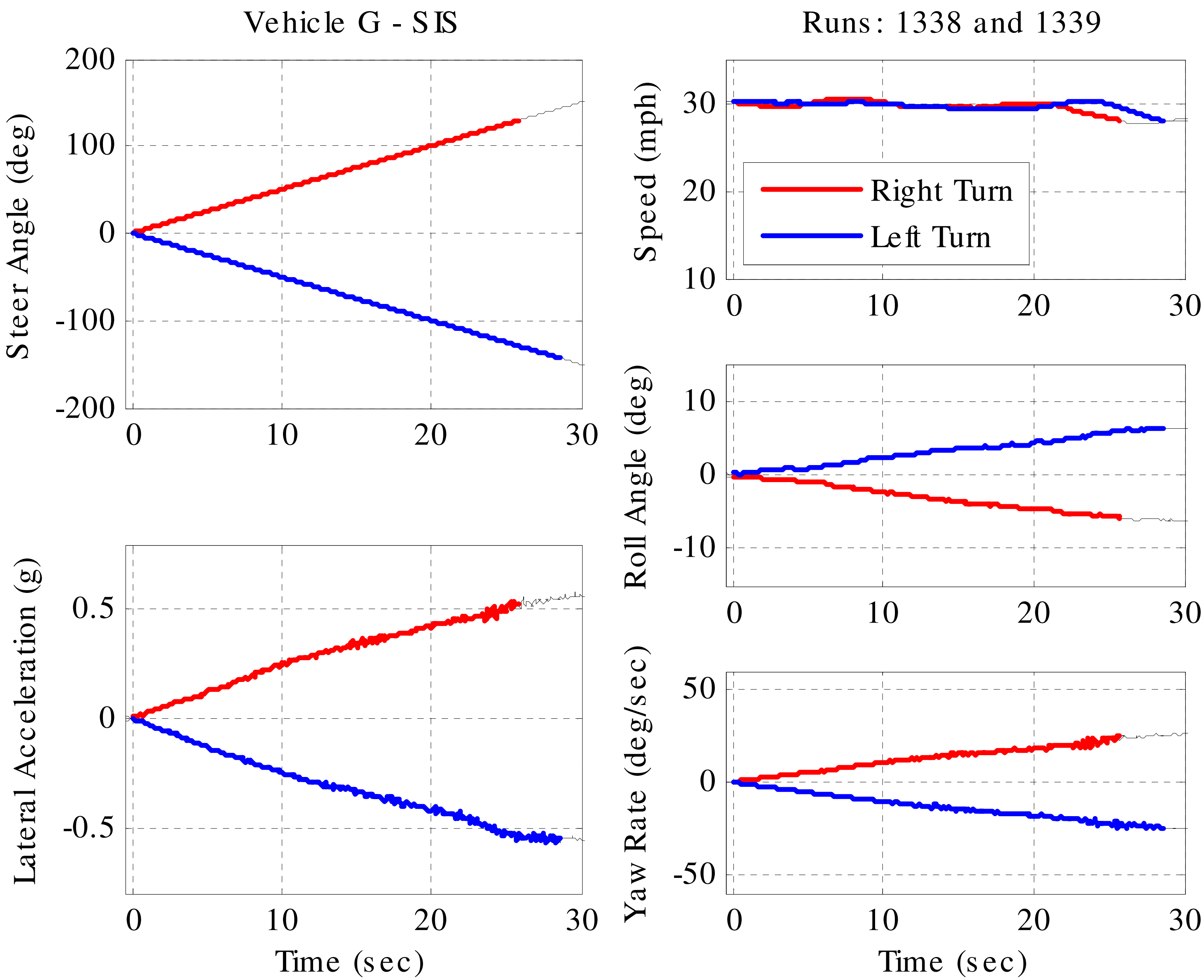


Vehicle F - SIS
Runs: 1112 and 1113
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

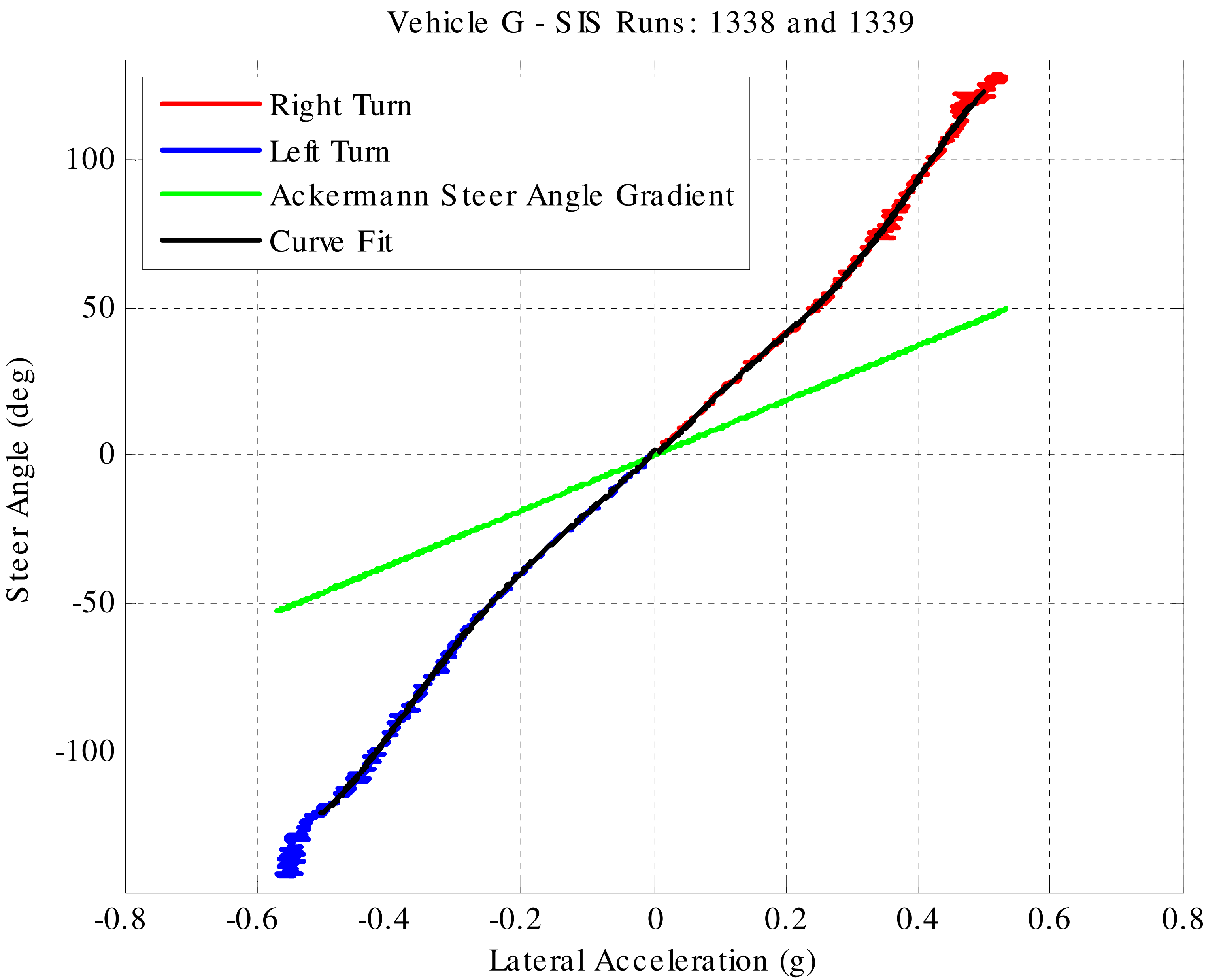


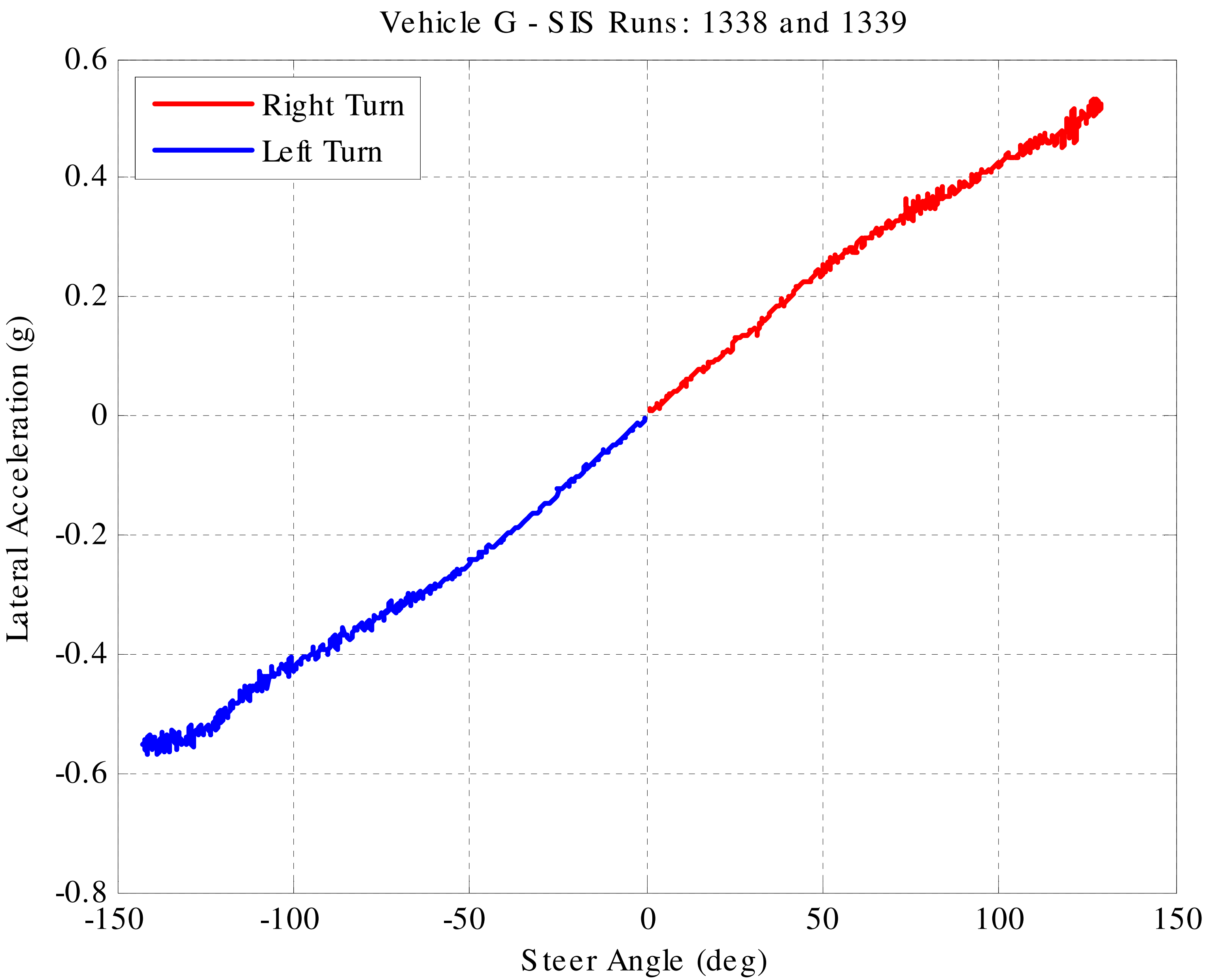
Vehicle F - SIS Runs: 1112 and 1113
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.39203 g
Transition to Oversteer
At Ay = -0.41999 g
Steer Angle (deg)
Lateral Acceleration (g)
80
60
40
20
0
-20
-40
-60
-80
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8


Vehicle F - SIS Runs: 1112 and 1113
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)

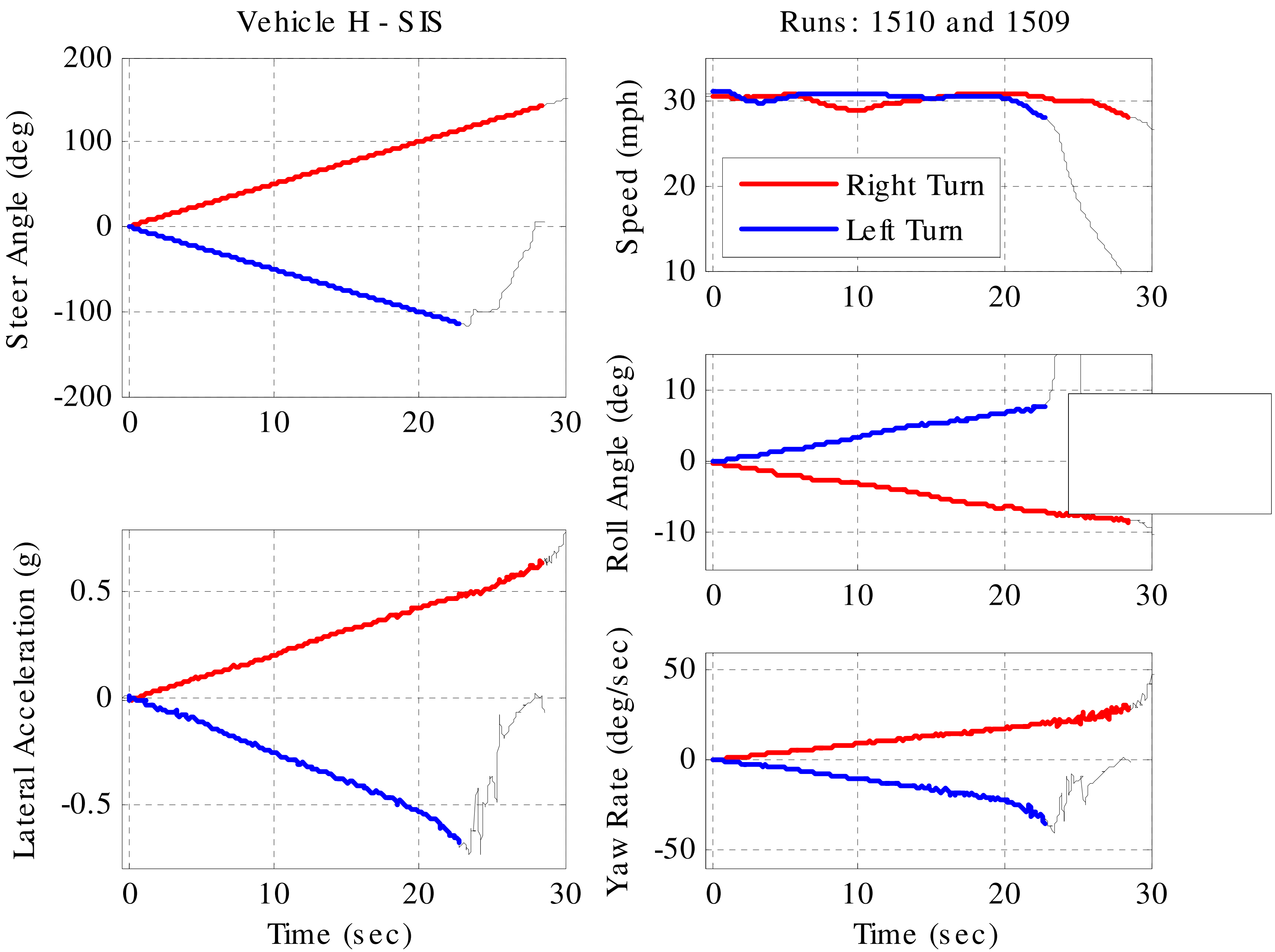


Vehicle G - SIS
Runs: 1338 and 1339
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

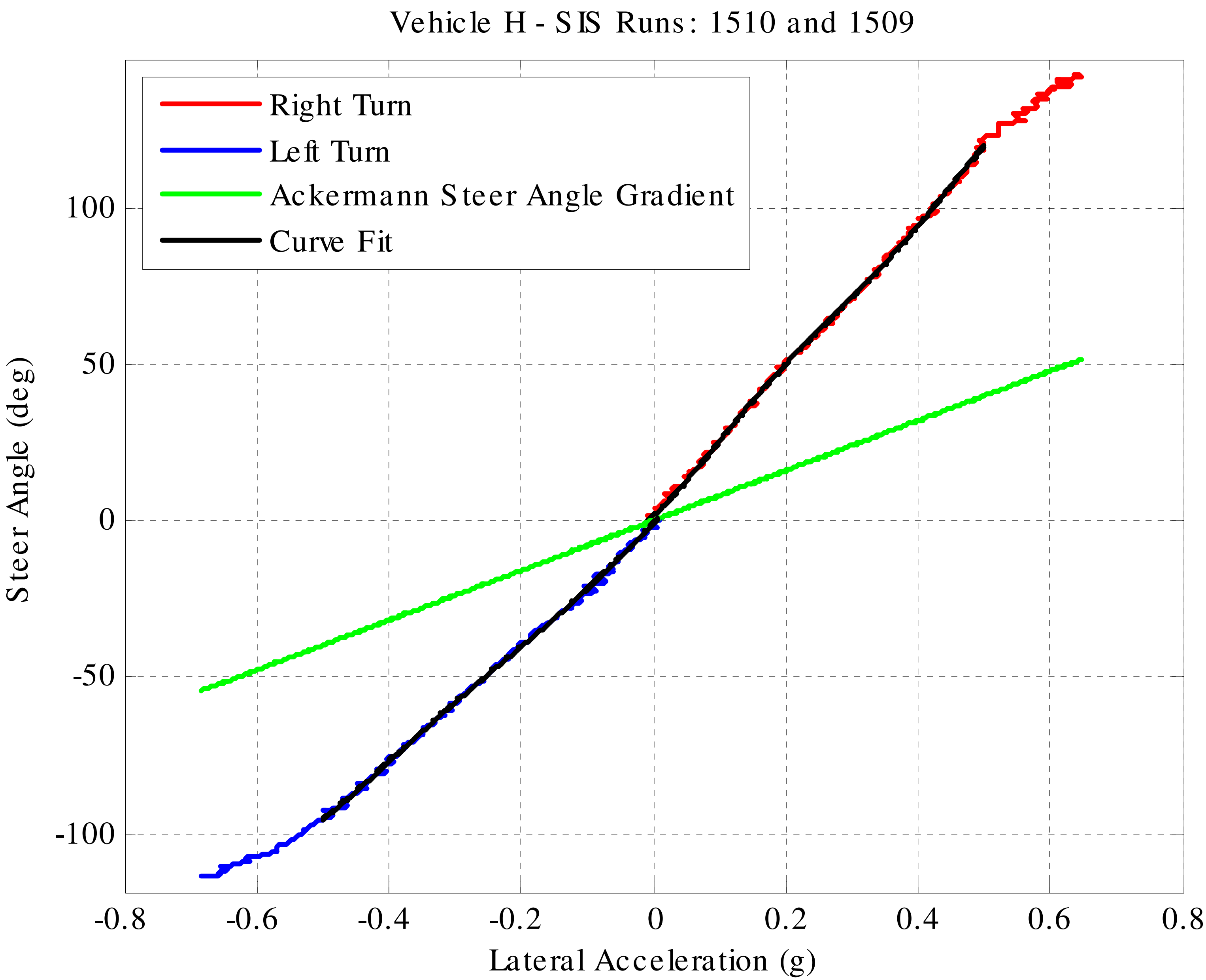

Vehicle G - SIS Runs: 1338 and 1339
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Lateral Acceleration (g)



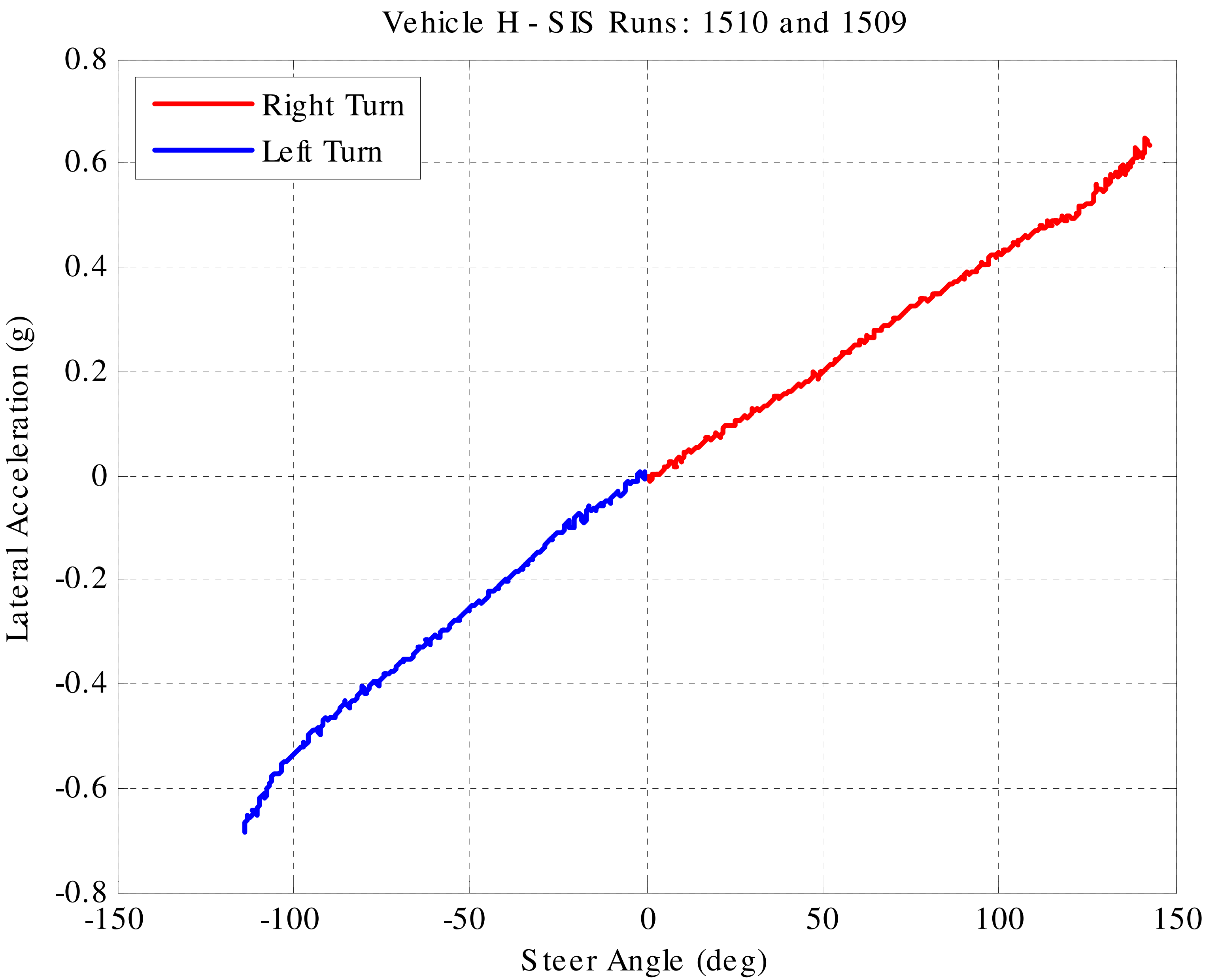
Vehicle G - SIS Runs: 1338 and 1339
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150

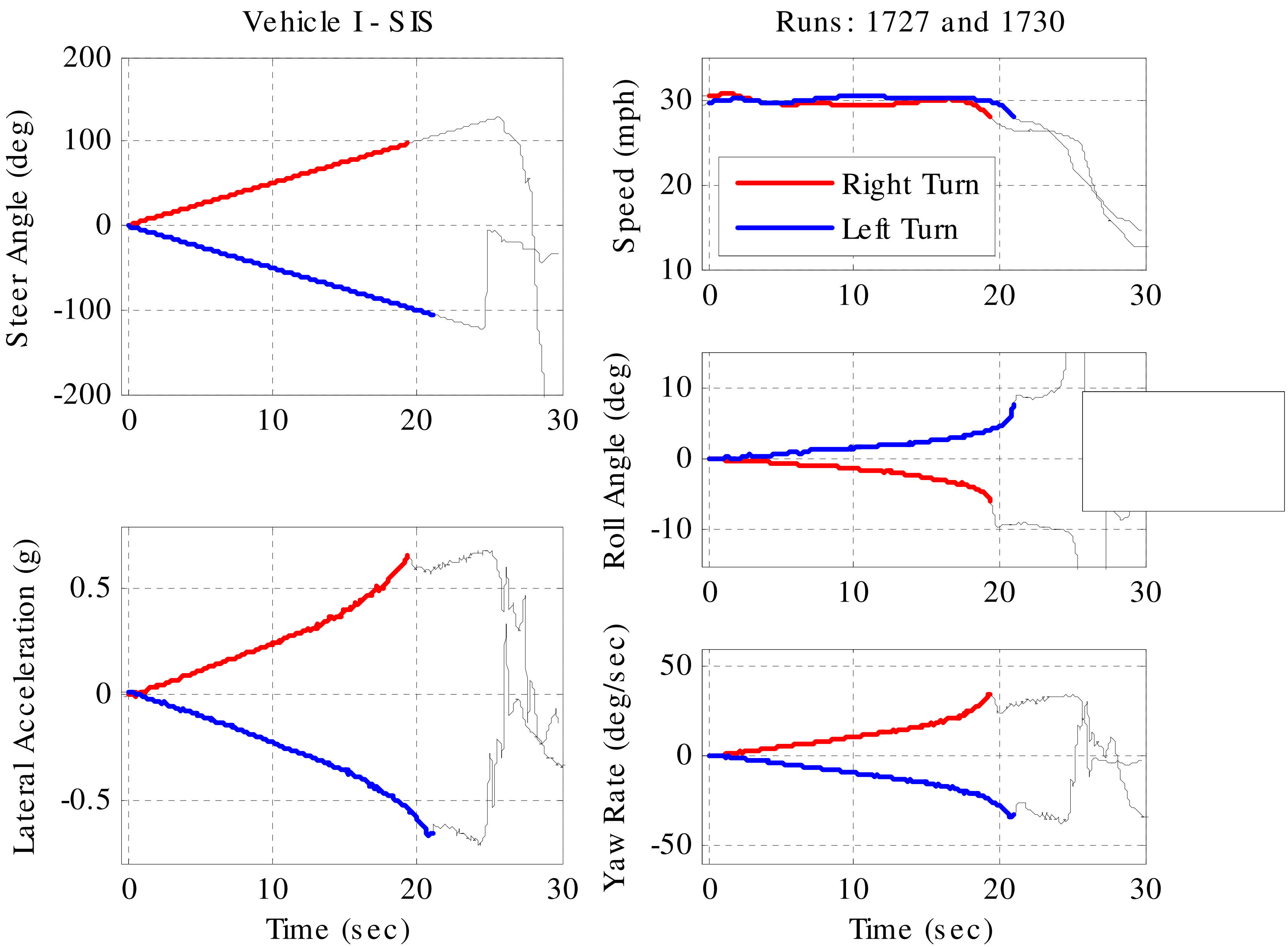


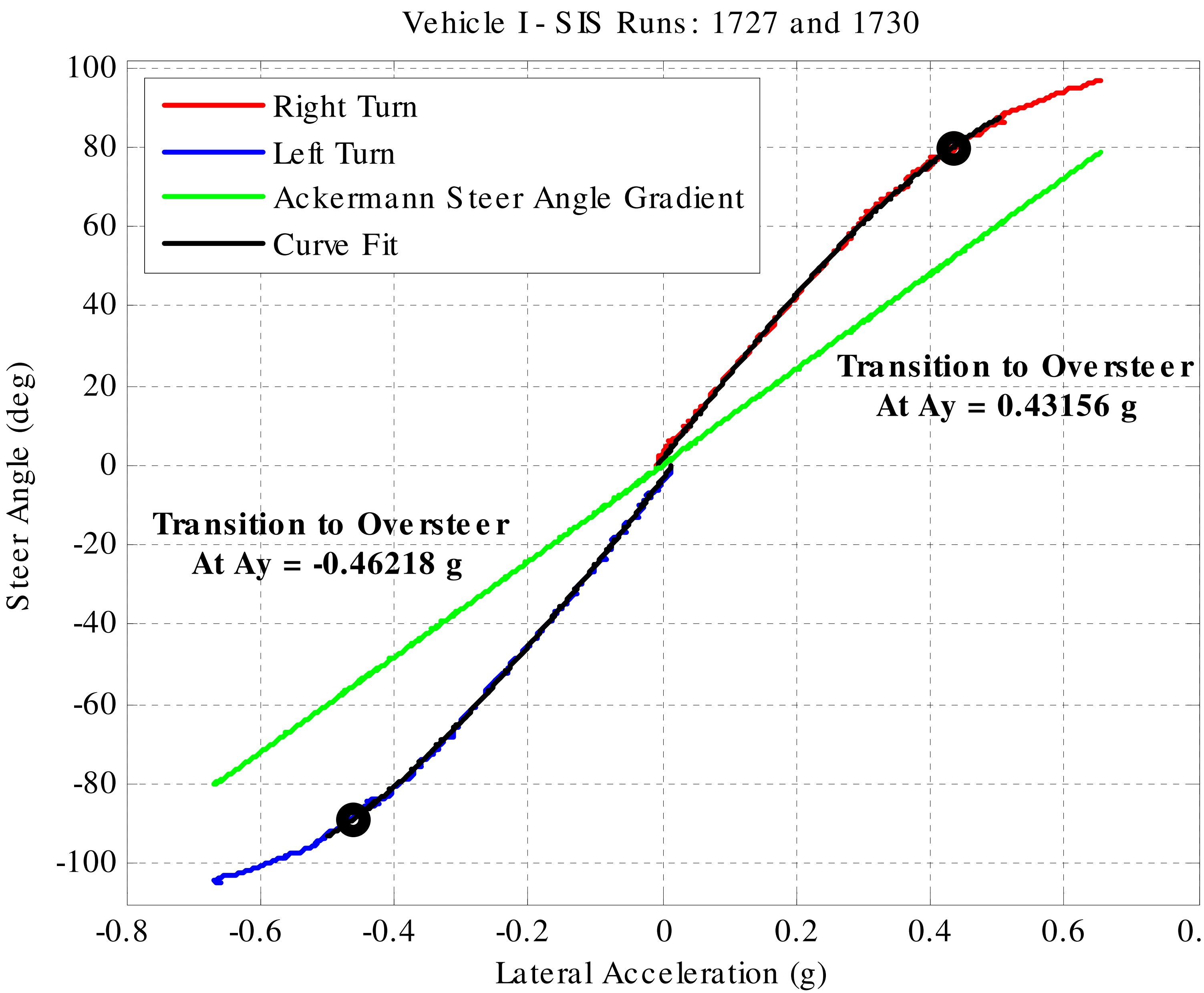
Vehicle H - SIS
Runs: 1510 and 1509
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

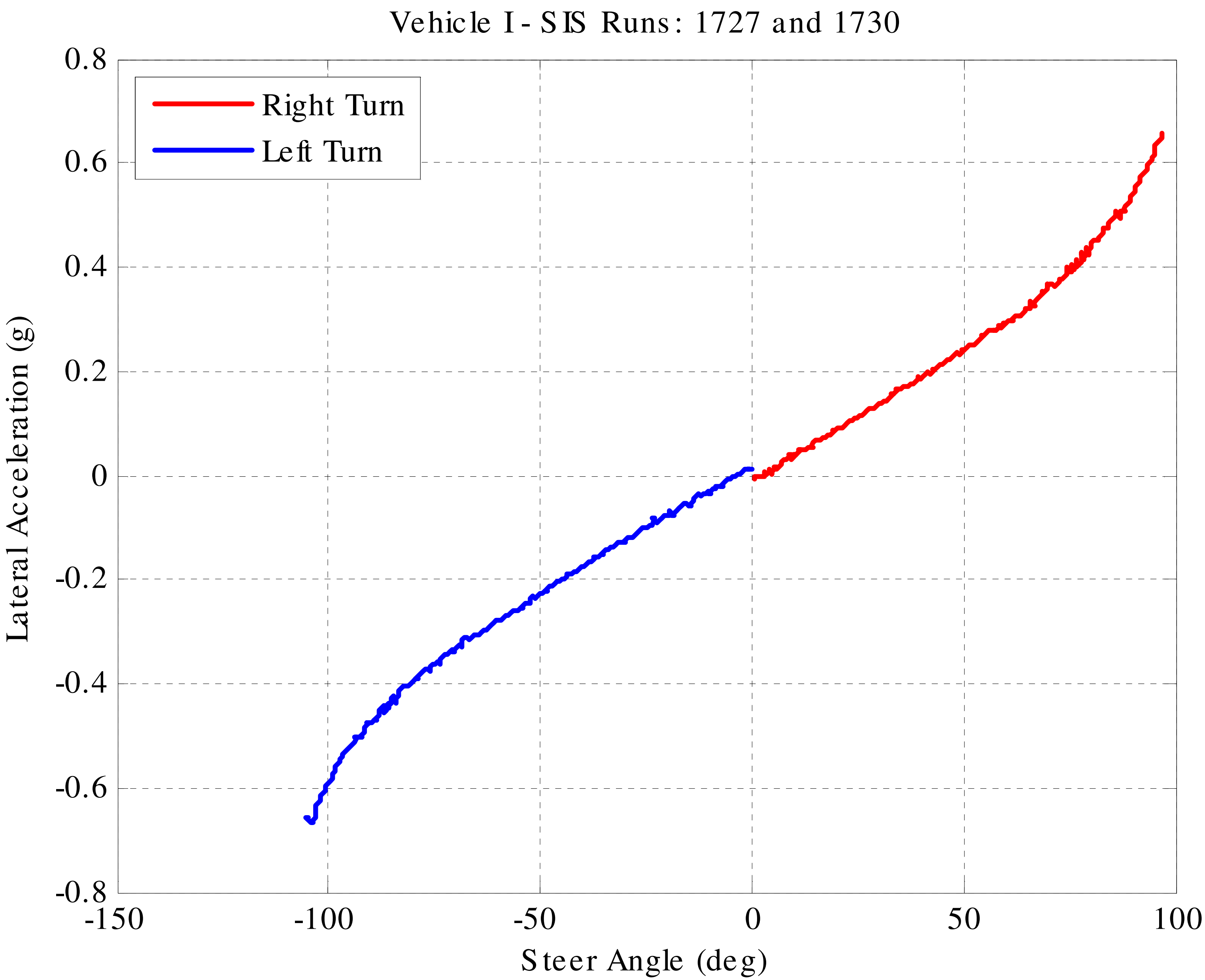


Vehicle H - SIS Runs: 1510 and 1509
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Lateral Acceleration (g)


Vehicle H - SIS Runs: 1510 and 1509
Right Turn
Left Turn
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150
Steer Angle (deg)

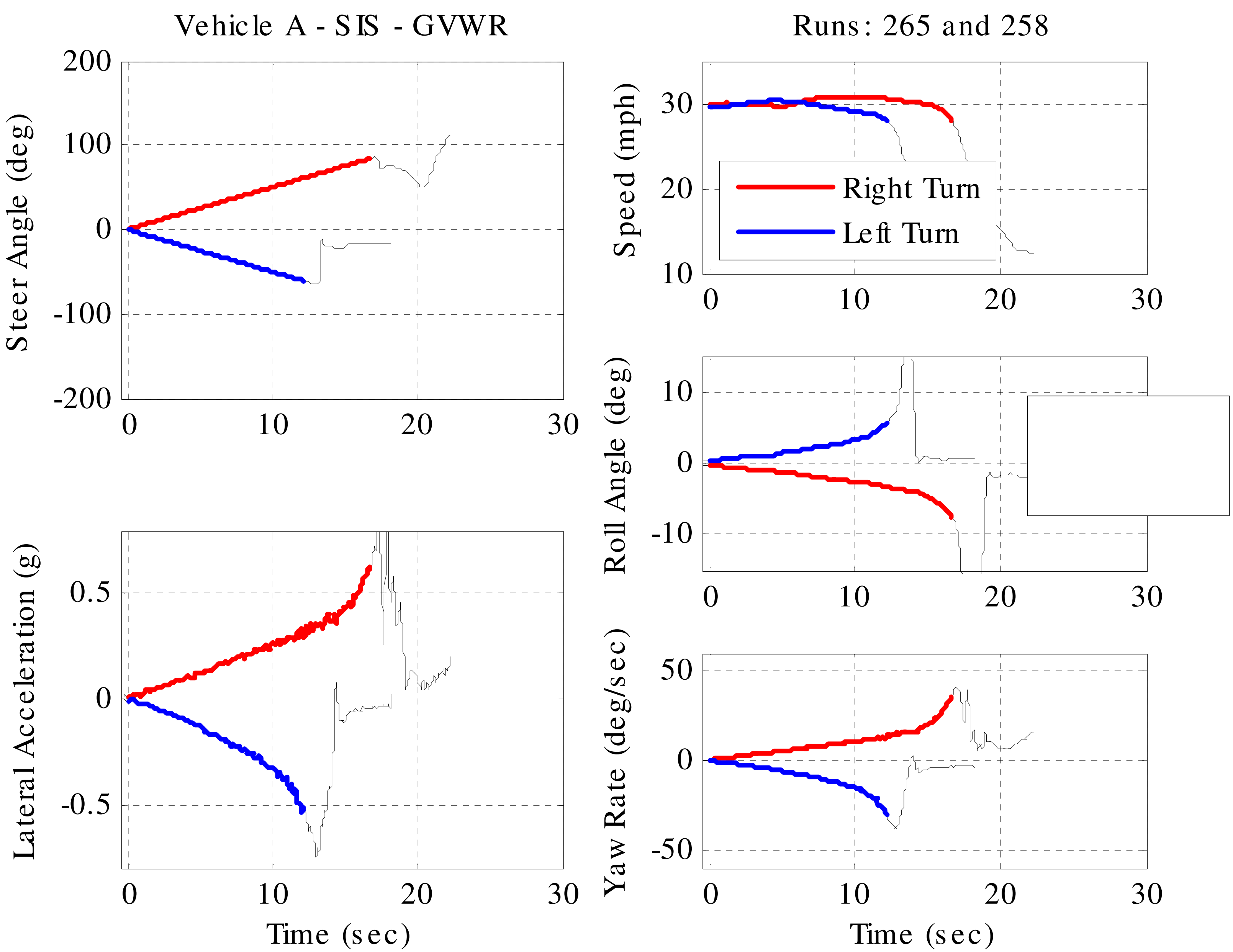

Vehicle I - SIS
Runs: 1727 and 1730
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Time (sec)
Yaw Rate (deg/sec)
50
0
-50
Time (sec)


Vehicle I - SIS Runs: 1727 and 1730
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.43156 g
Transition to Oversteer
At Ay = -0.46218 g
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)

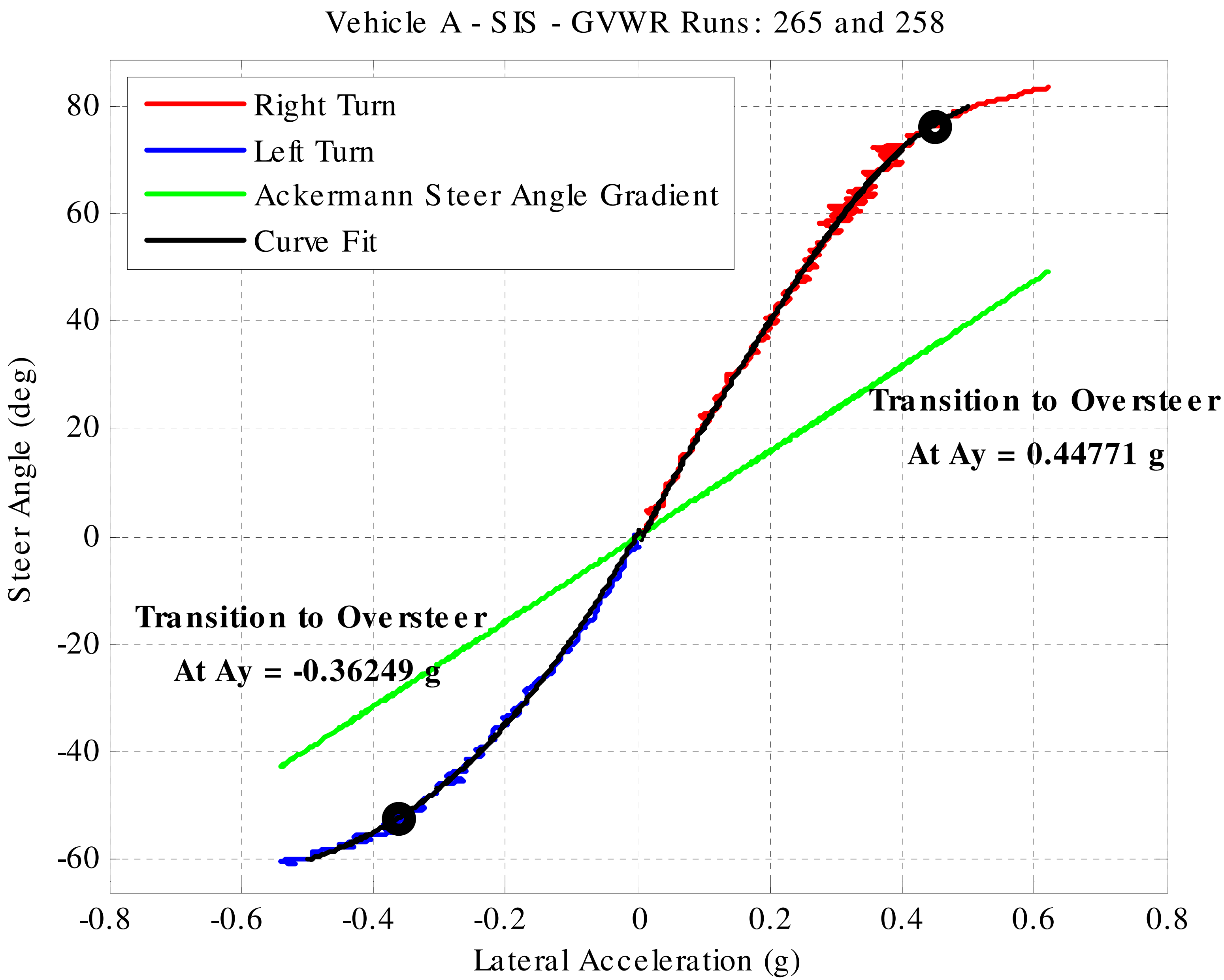


Vehicle I - SIS Runs: 1727 and 1730
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100

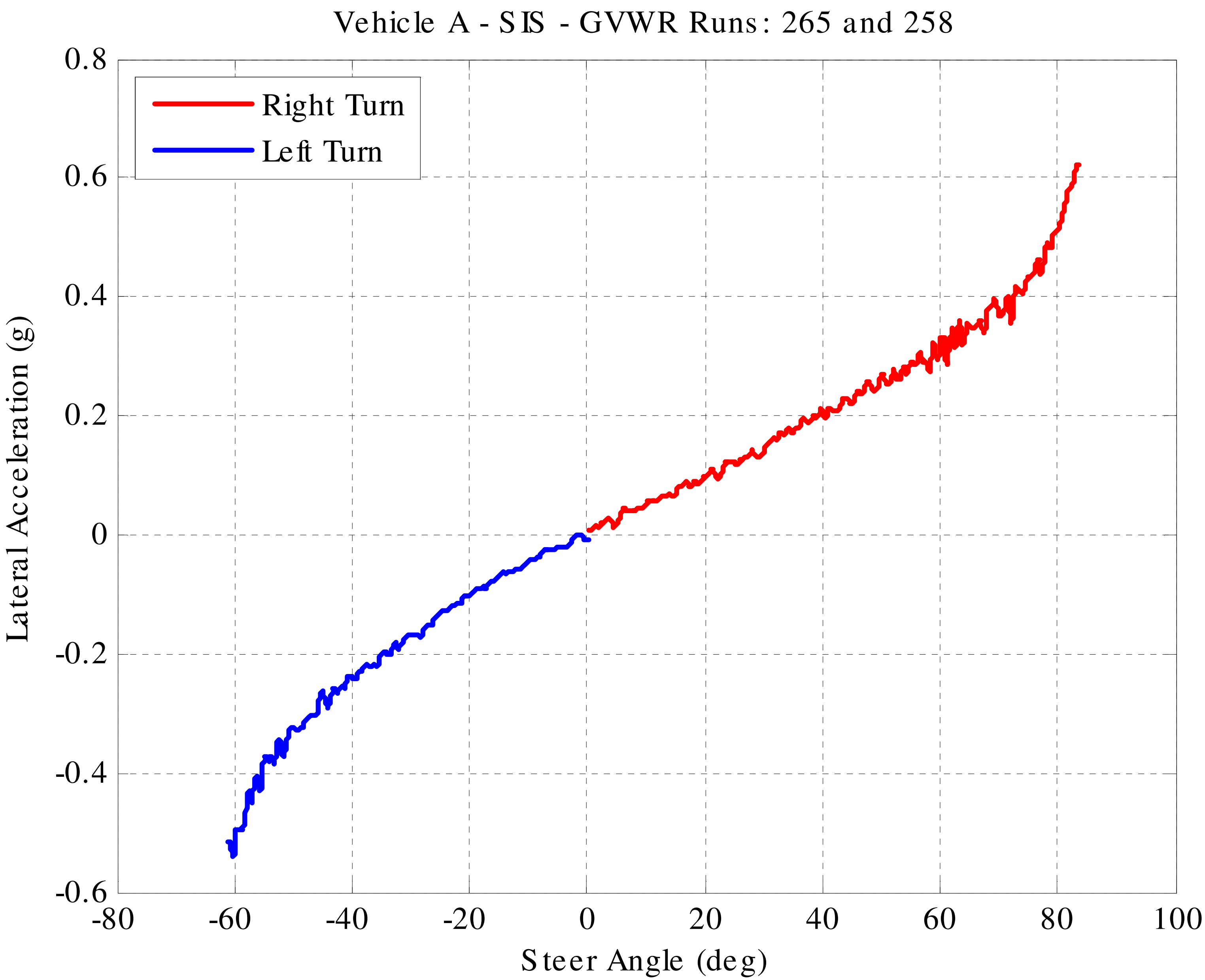
Constant Speed (30 mph) Slowly Increasing Steer Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Operator and Passenger Loading)			
	Right Turn (g)	Left Turn (g)	Average (g)
Vehicle A	0.40	0.33	0.37
Vehicle B	NA	NA	NA
Vehicle C	NA	NA	NA
Vehicle D	0.35	0.44	0.40
Vehicle E	NA	NA	NA
Vehicle F	0.39	0.42	0.41
Vehicle G	NA	NA	NA
Vehicle H	NA	NA	NA
Vehicle I	0.43	0.46	0.45

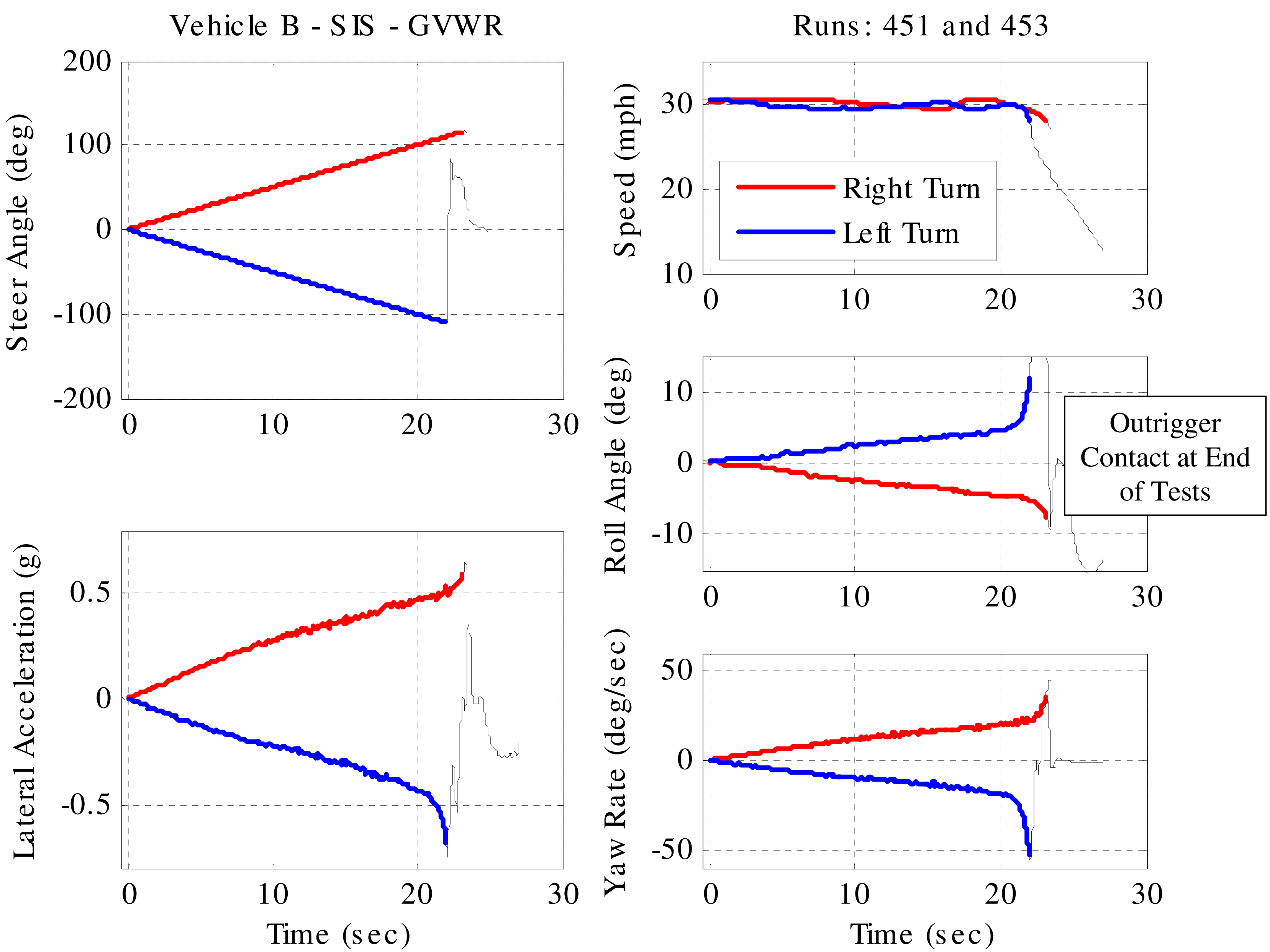


Vehicle A - SIS - GVWR
Runs: 265 and 258
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

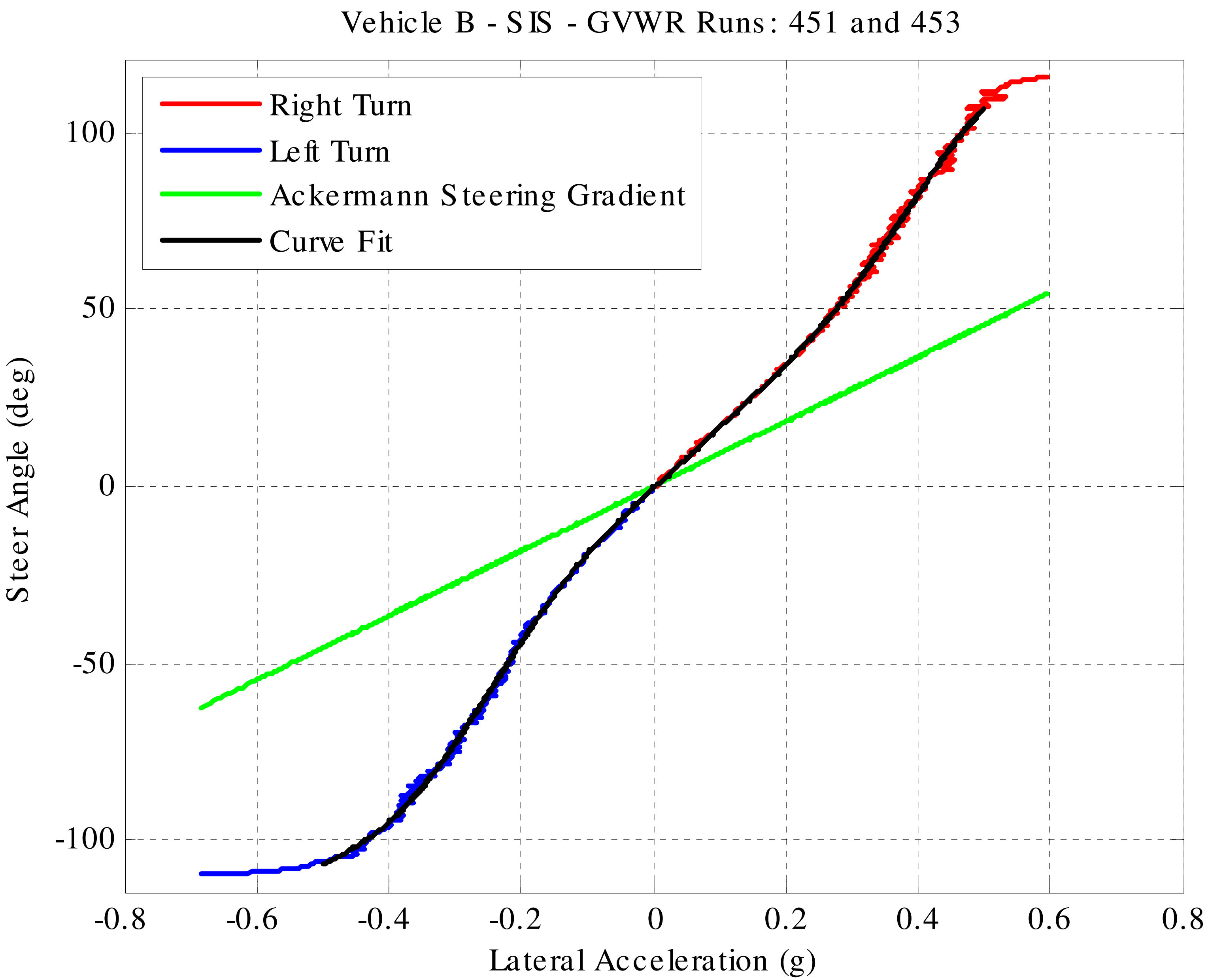


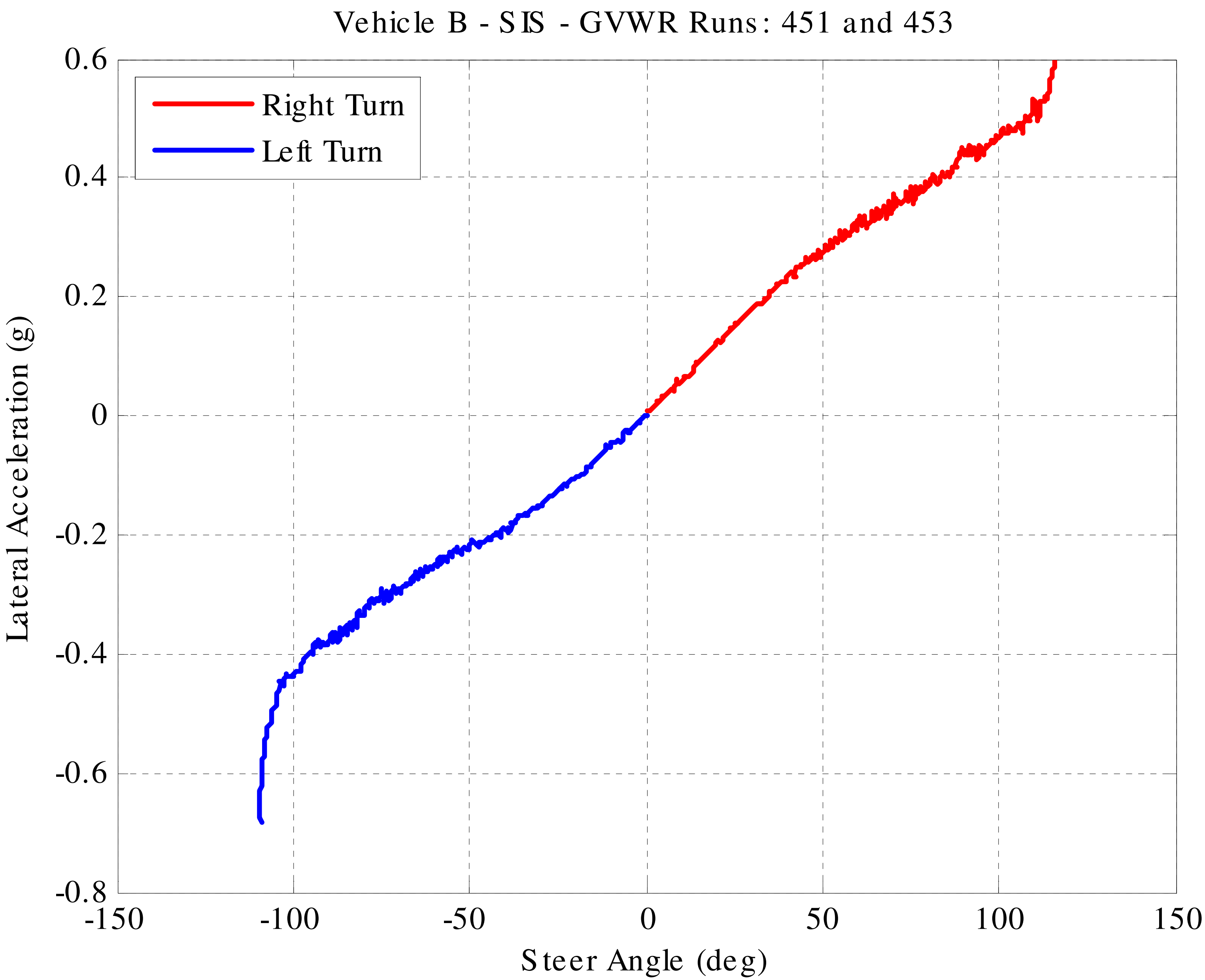
Vehicle A - SIS - GVWR Runs: 265 and 258
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.44771 g
Transition to Oversteer
At Ay = -0.36249 g
Steer Angle (deg)
Lateral Acceleration (g)
80
60
40
20
0
-20
-40
-60
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

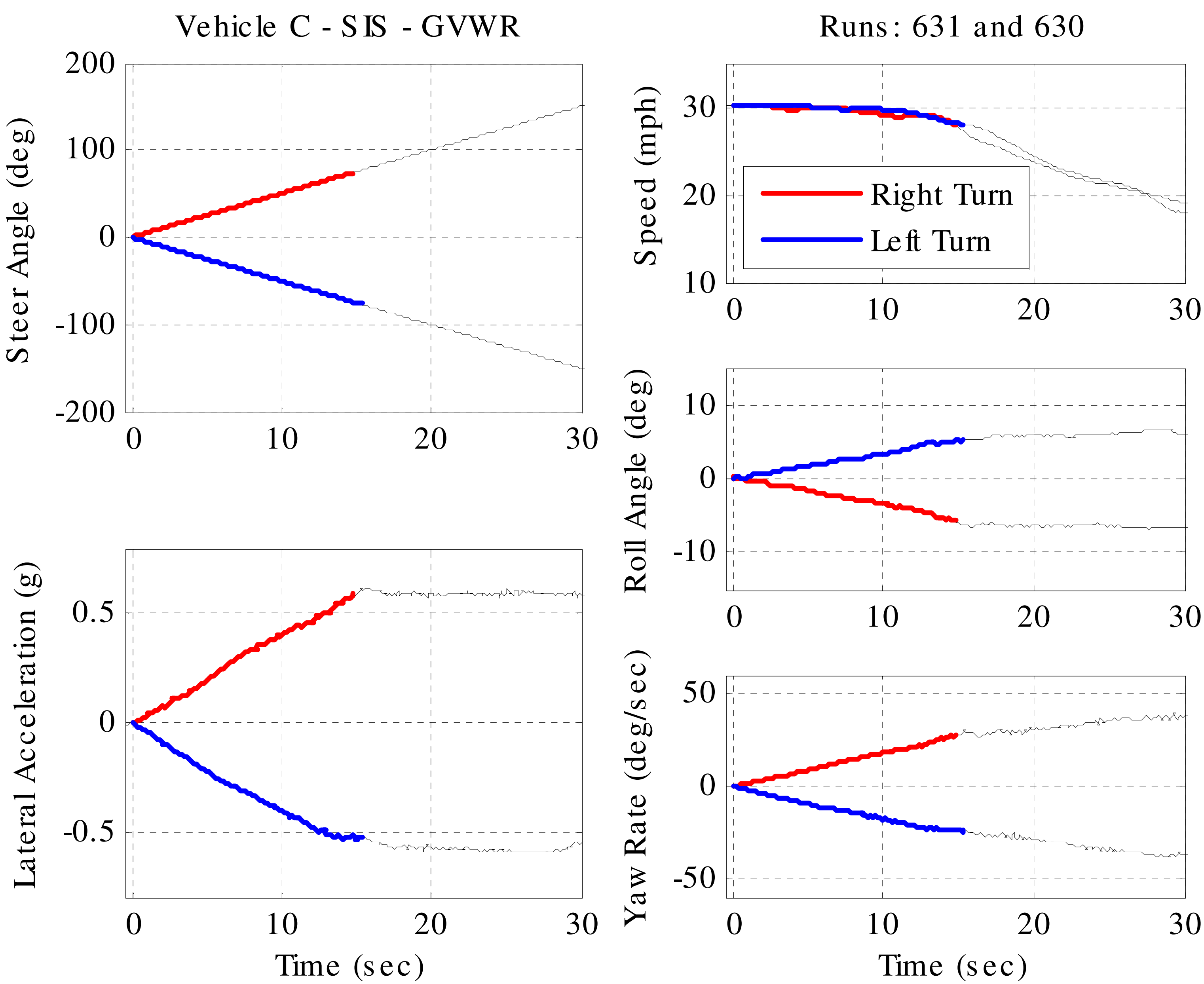

Vehicle A - SIS - GVWR Runs: 265 and 258
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-80
-60
-40
-20
0
20
40
60
80
100



Vehicle B - SIS - GVWR
Runs: 451 and 453
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
Outrigger Contact at End of Tests
Lateral Acceleration (g)
0.5
-0.5
Yaw Rate (deg/sec)
50
-50
Time (sec)

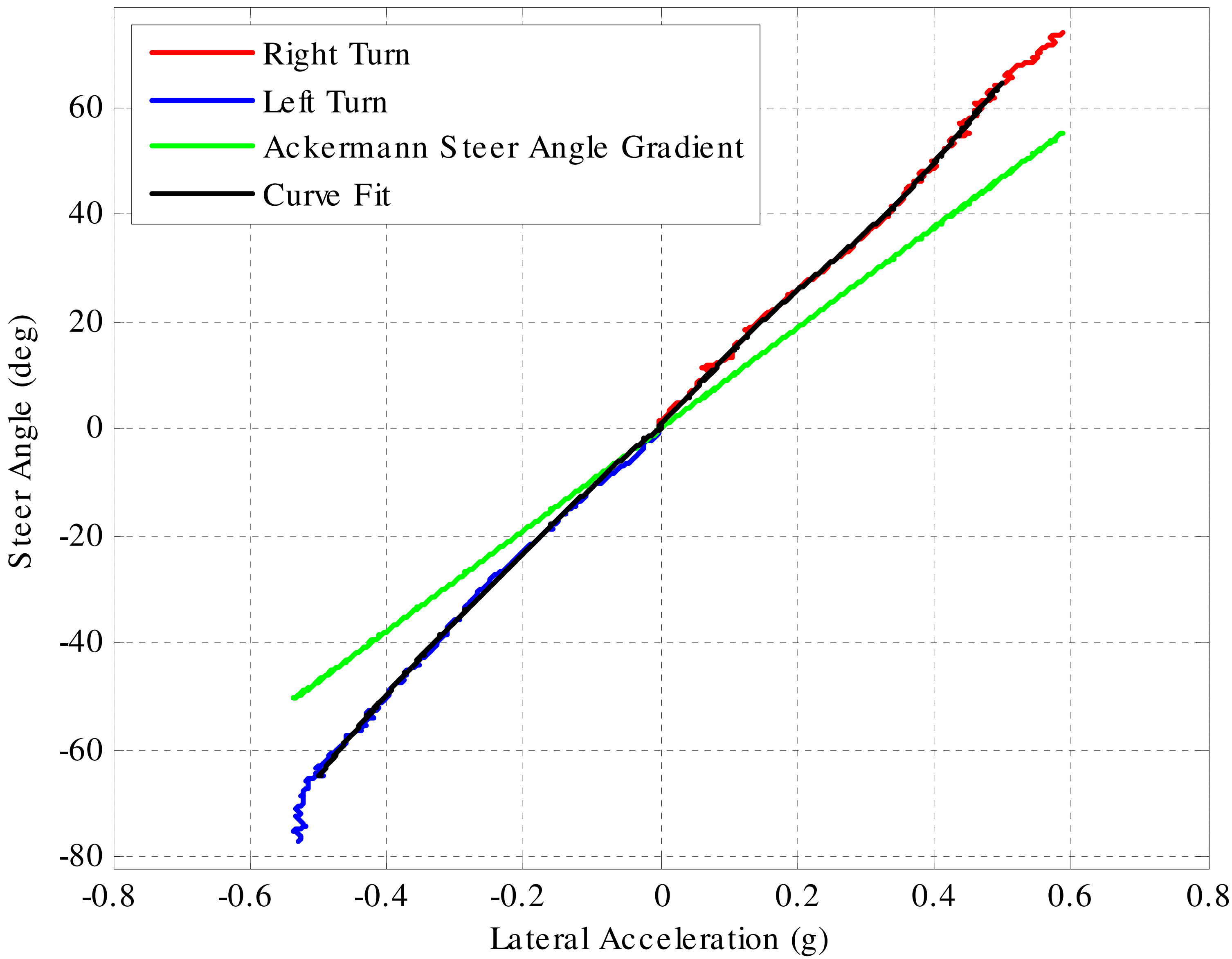

Vehicle B - SIS - GVWR Runs: 451 and 453
Right Turn
Left Turn
Ackermann Steering Gradient
Curve Fit
Steer Angle (deg)
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Lateral Acceleration (g)

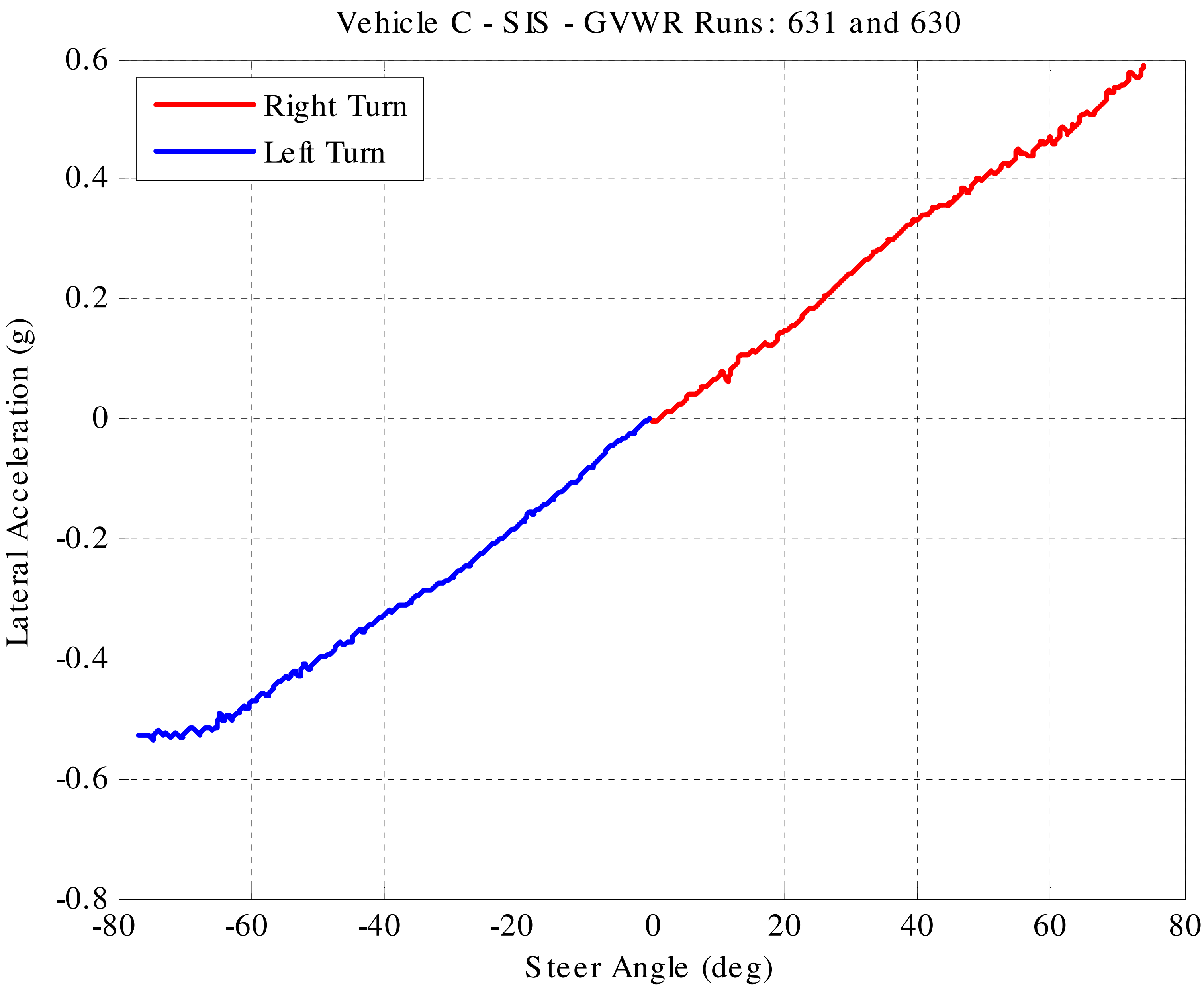

Vehicle B - SIS - GVWR Runs: 451 and 453
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150

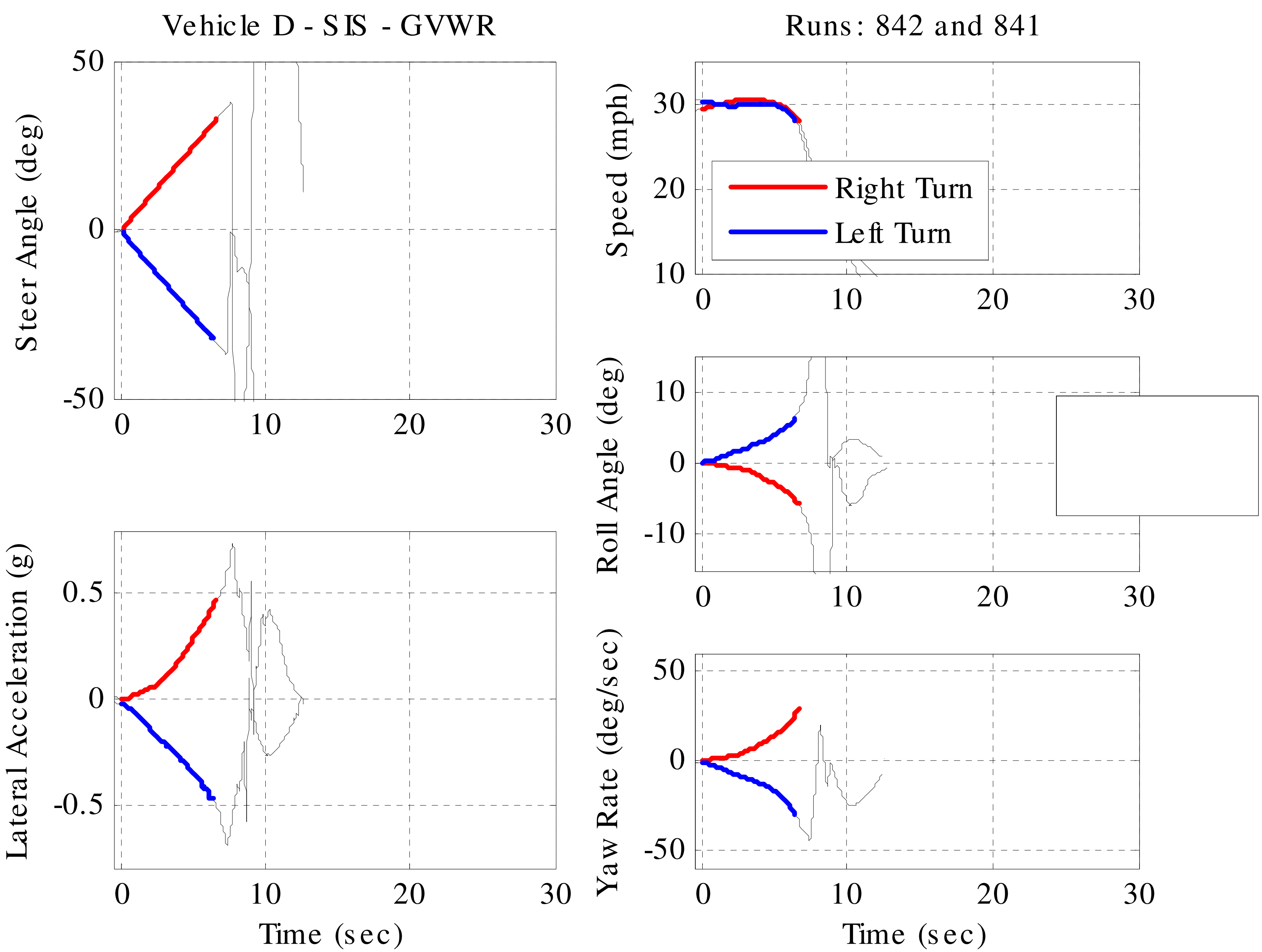


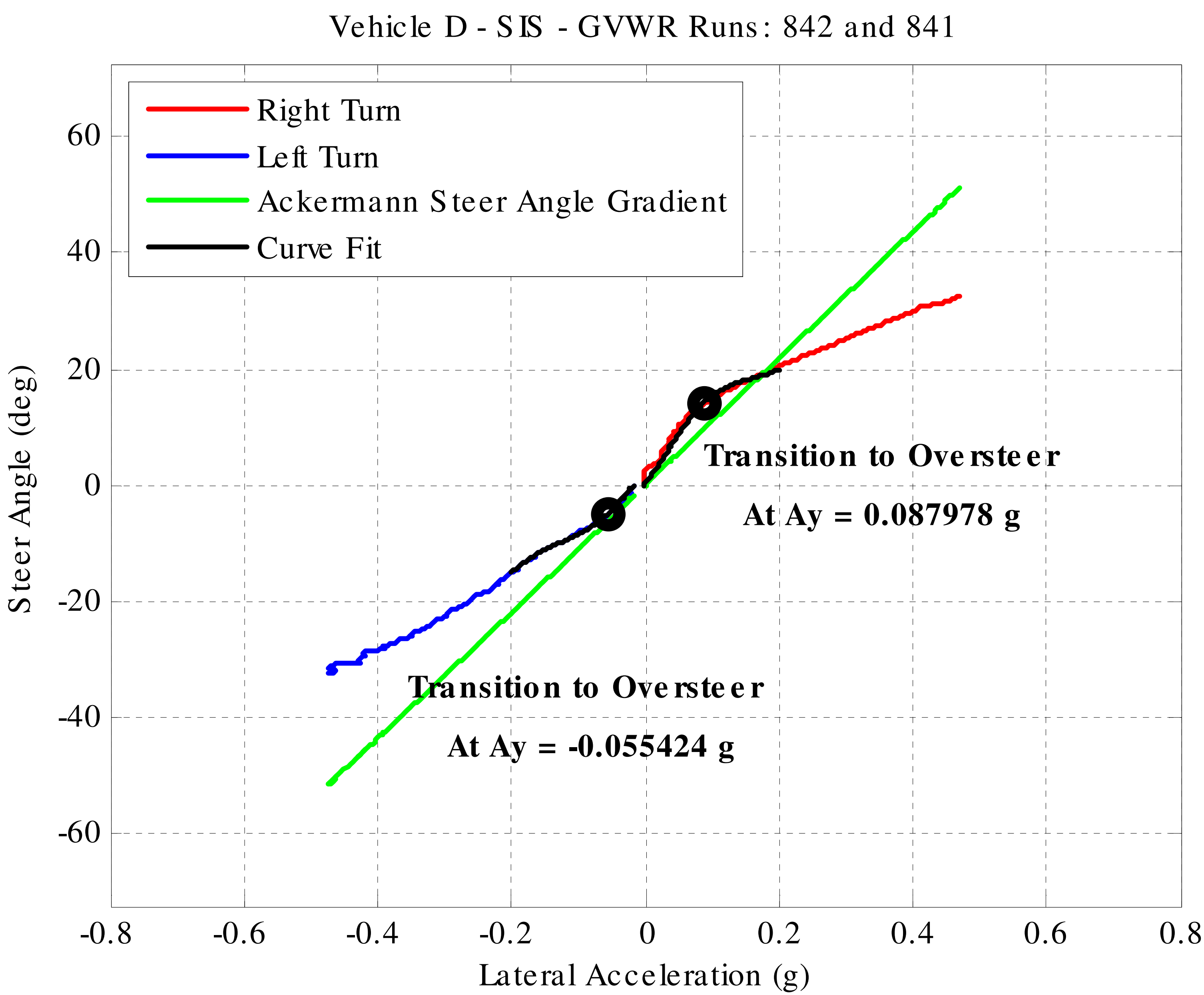
Vehicle C - SIS - GVWR
Runs: 631 and 630
Steer Angle (deg)
Lateral Acceleration (g)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)
Right Turn
Left Turn

Vehicle C - SIS - GVWR Runs: 631 and 630

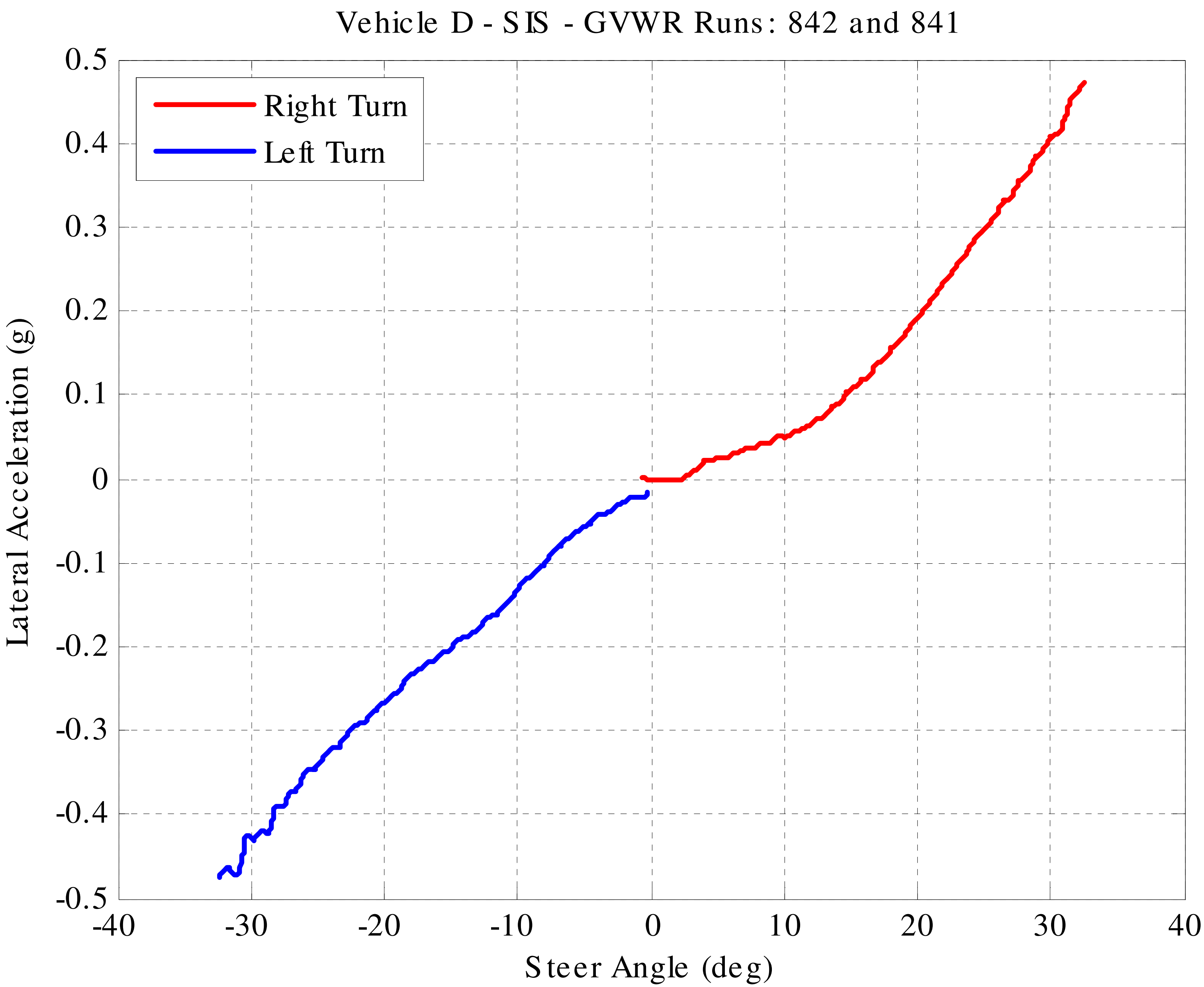



Vehicle C - SIS - GVWR Runs: 631 and 630
Right Turn
Left Turn
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-80
-60
-40
-20
0
20
40
60
80
Steer Angle (deg)

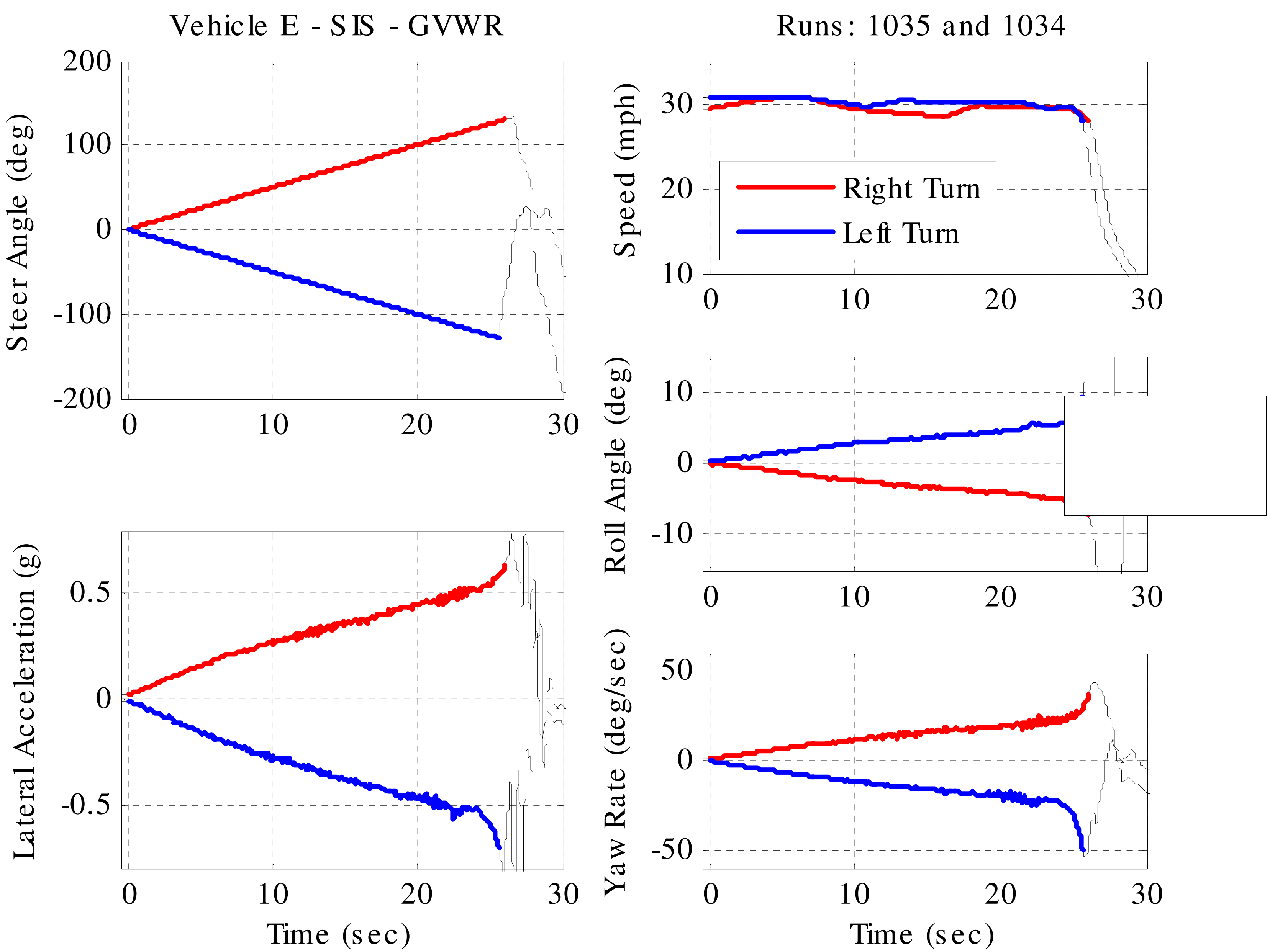

Vehicle D - SIS - GVWR
Runs: 842 and 841
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
50
0
-50
30
20
10
0
-10
0.5
-0.5
-50
0
10
20
30



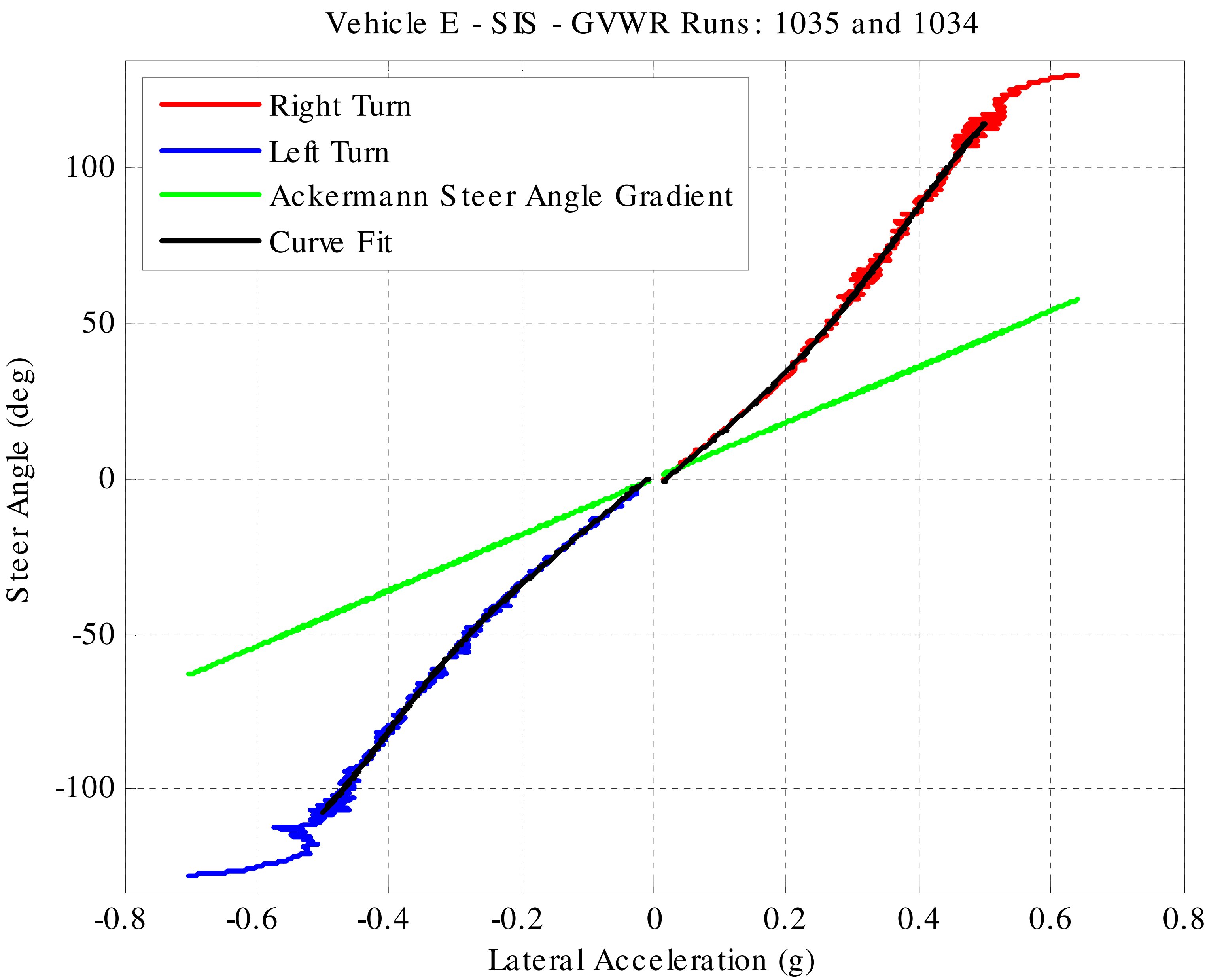
Vehicle D - SIS - GVWR Runs: 842 and 841
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.087978 g
Transition to Oversteer
At Ay = -0.055424 g
Steer Angle (deg)
Lateral Acceleration (g)
60
40
20
0
-20
-40
-60
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

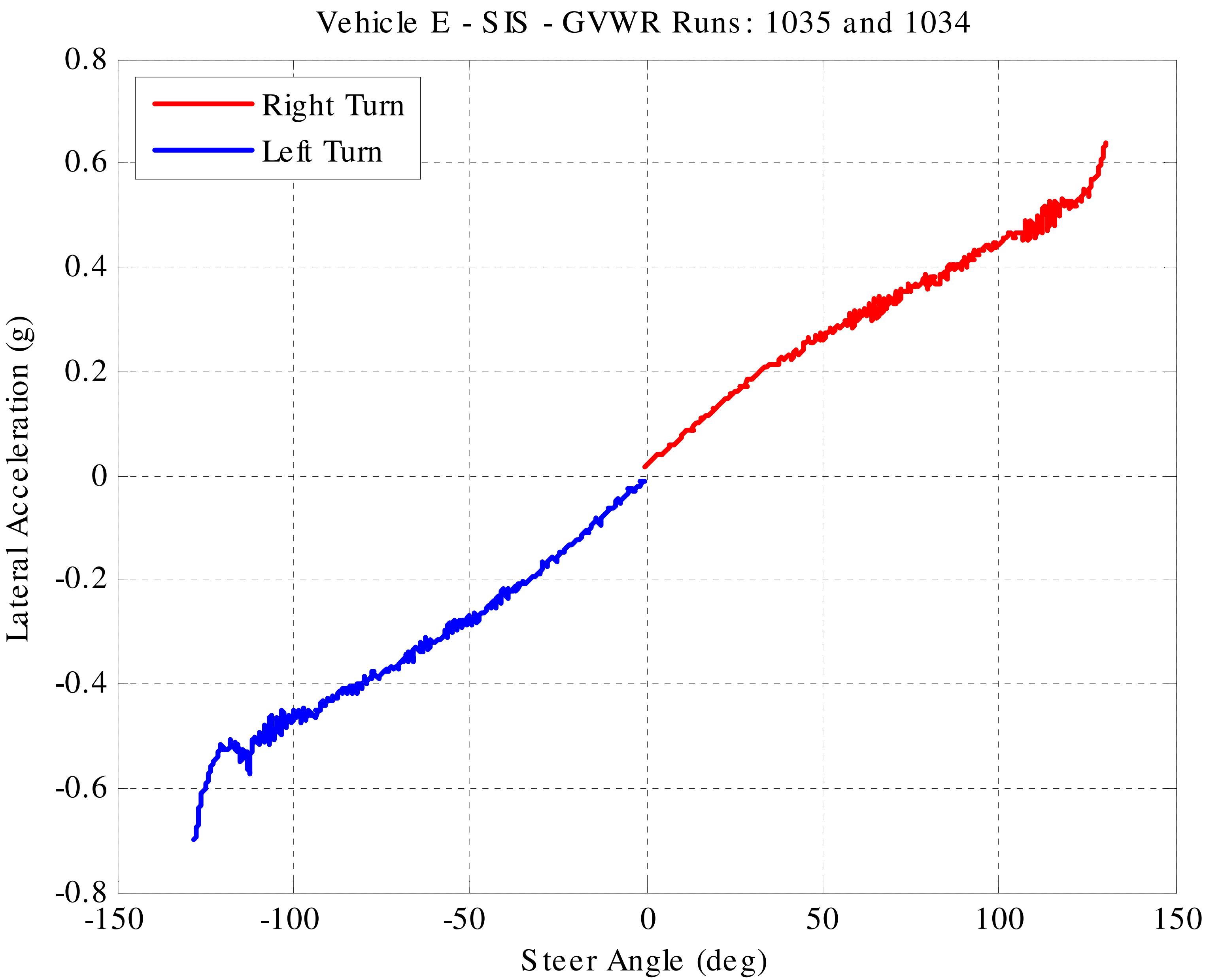


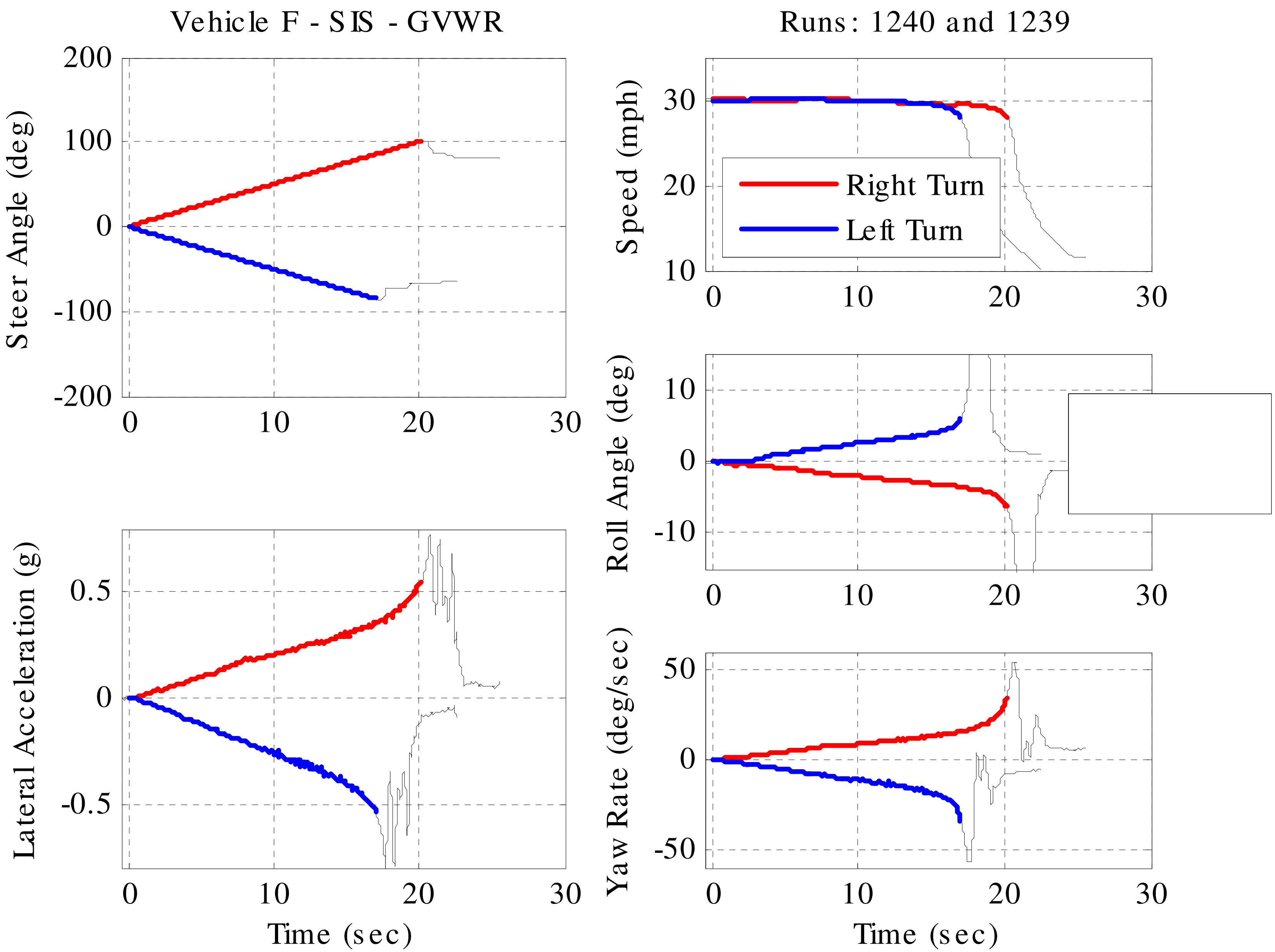
Vehicle D - SIS - GVWR Runs: 842 and 841
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-40
-30
-20
-10
0
10
20
30
40

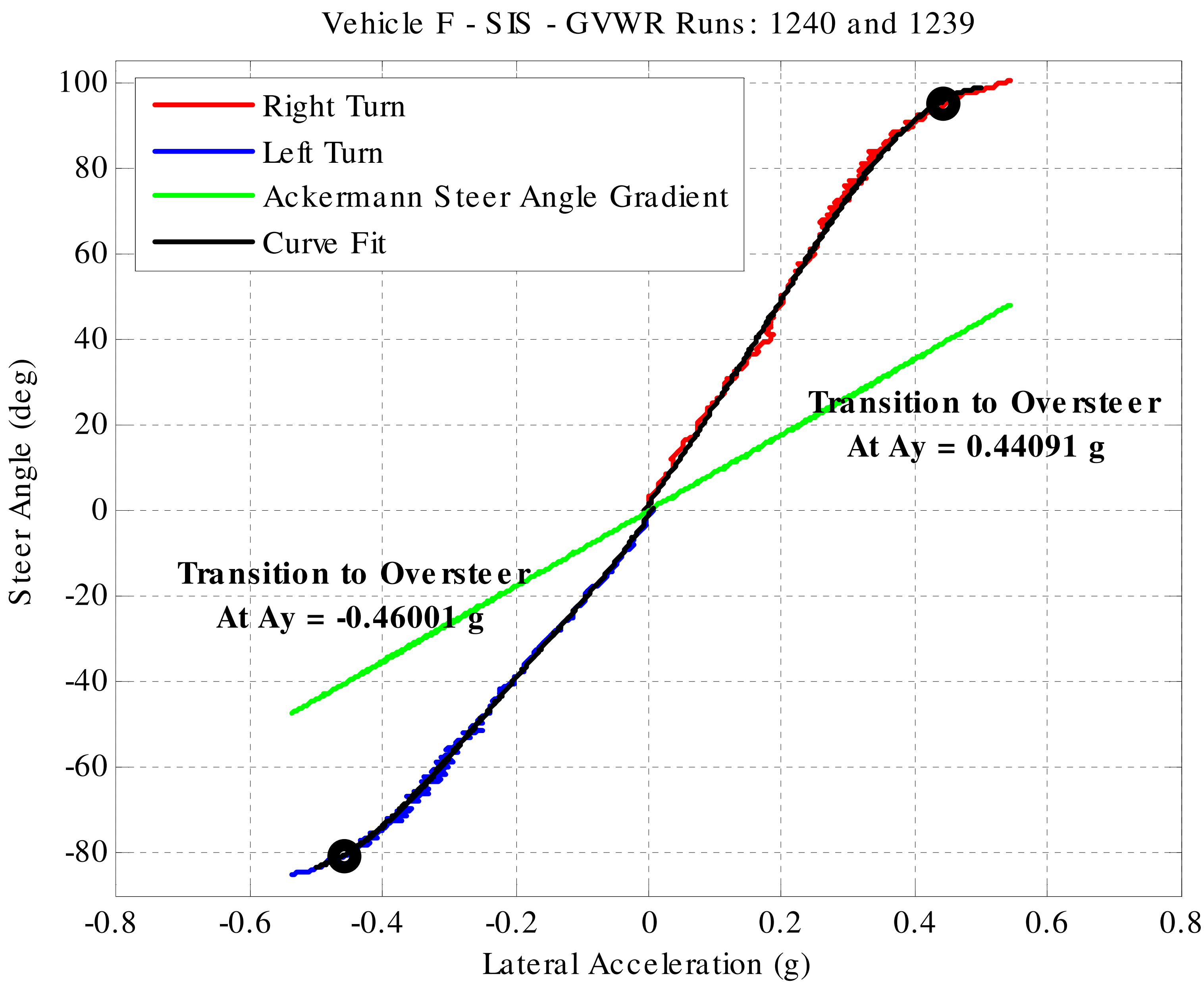


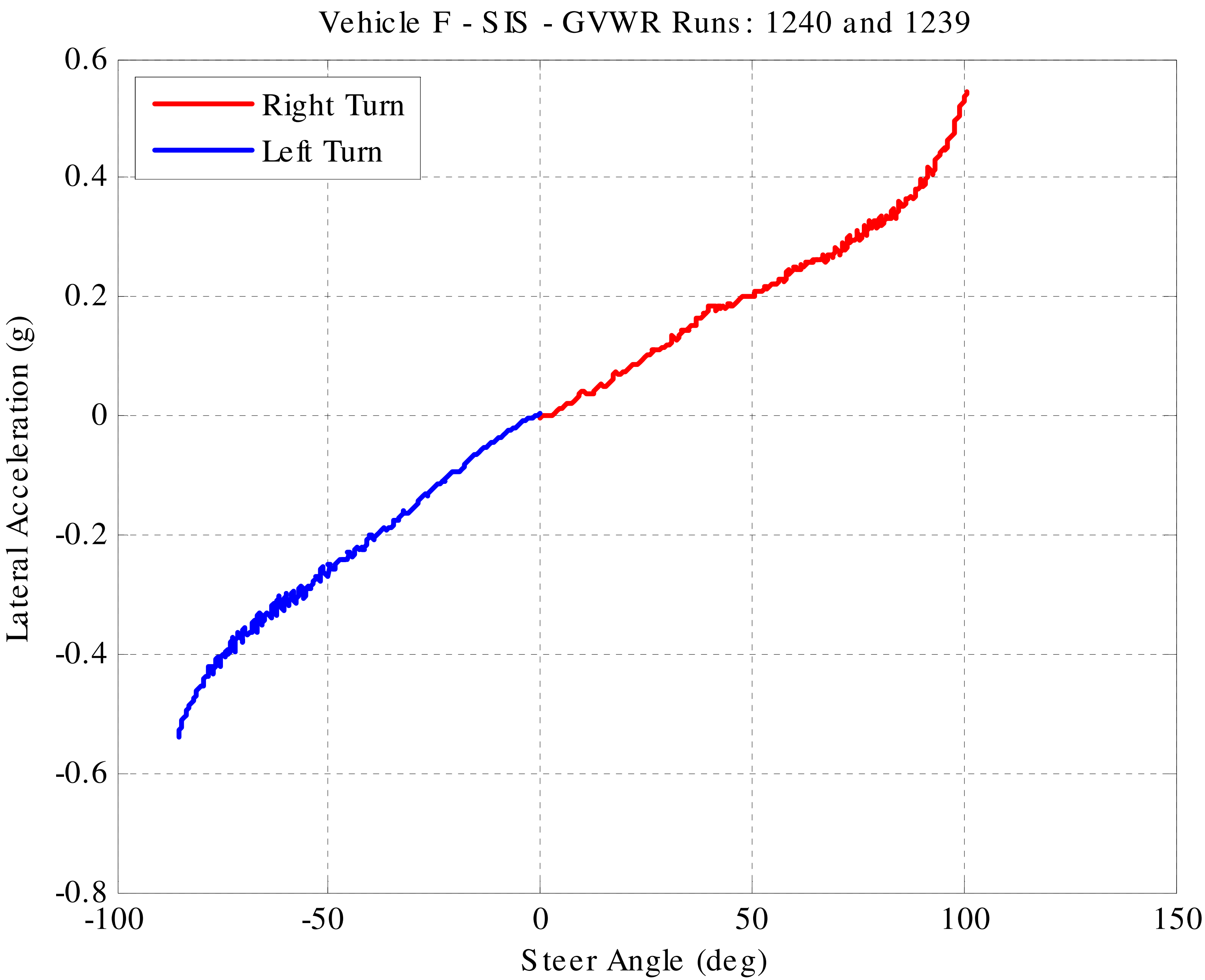
Vehicle E - SIS - GVWR
Runs: 1035 and 1034
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
50
0
-50
Time (sec)
Time (sec)


Vehicle E - SIS - GVWR Runs: 1035 and 1034
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Lateral Acceleration (g)

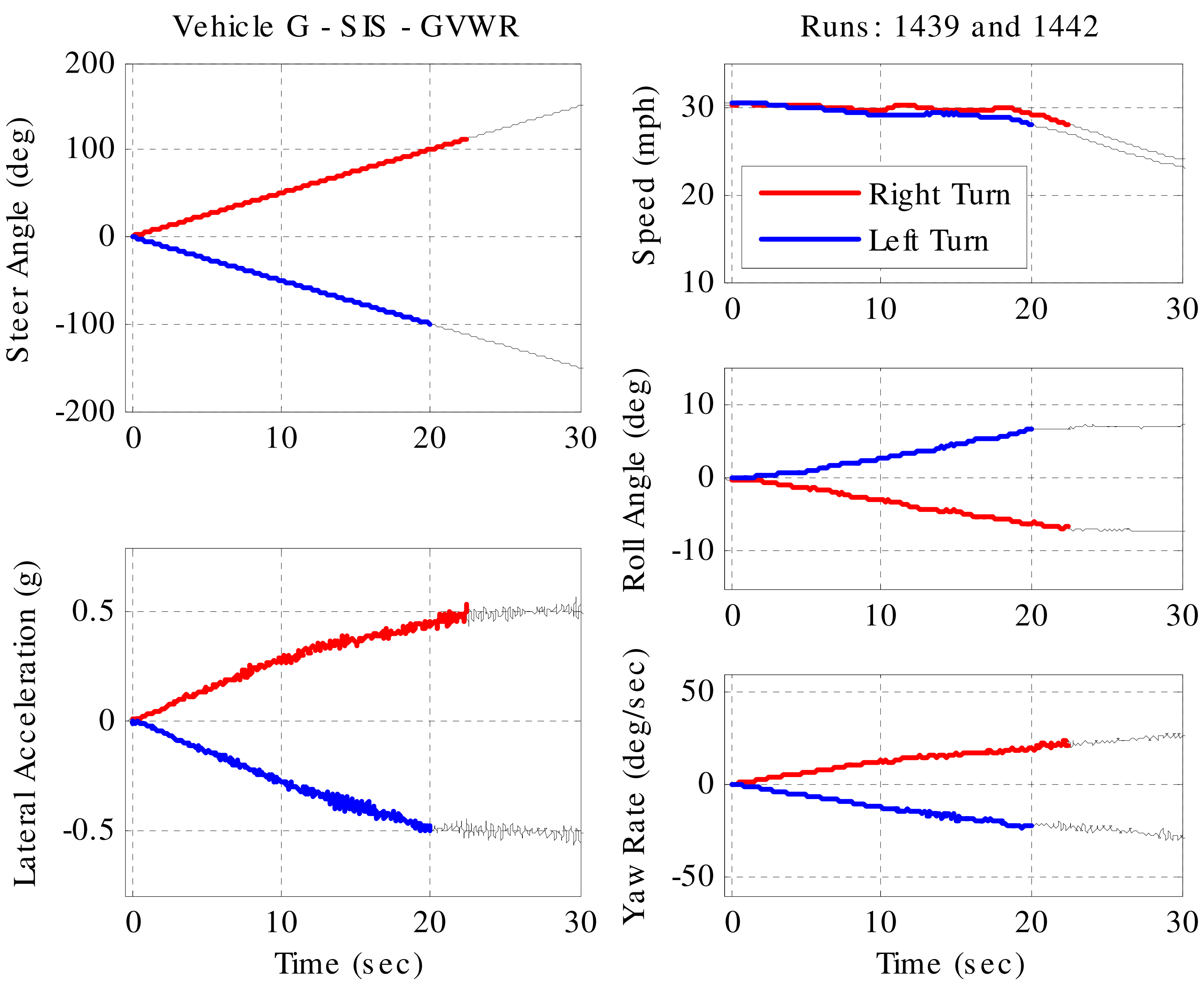

Vehicle E - SIS - GVWR Runs: 1035 and 1034
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150


Vehicle F - SIS - GVWR
Runs: 1240 and 1239
Steer Angle (deg)
Speed (mph)
Right Turn
Left Turn
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

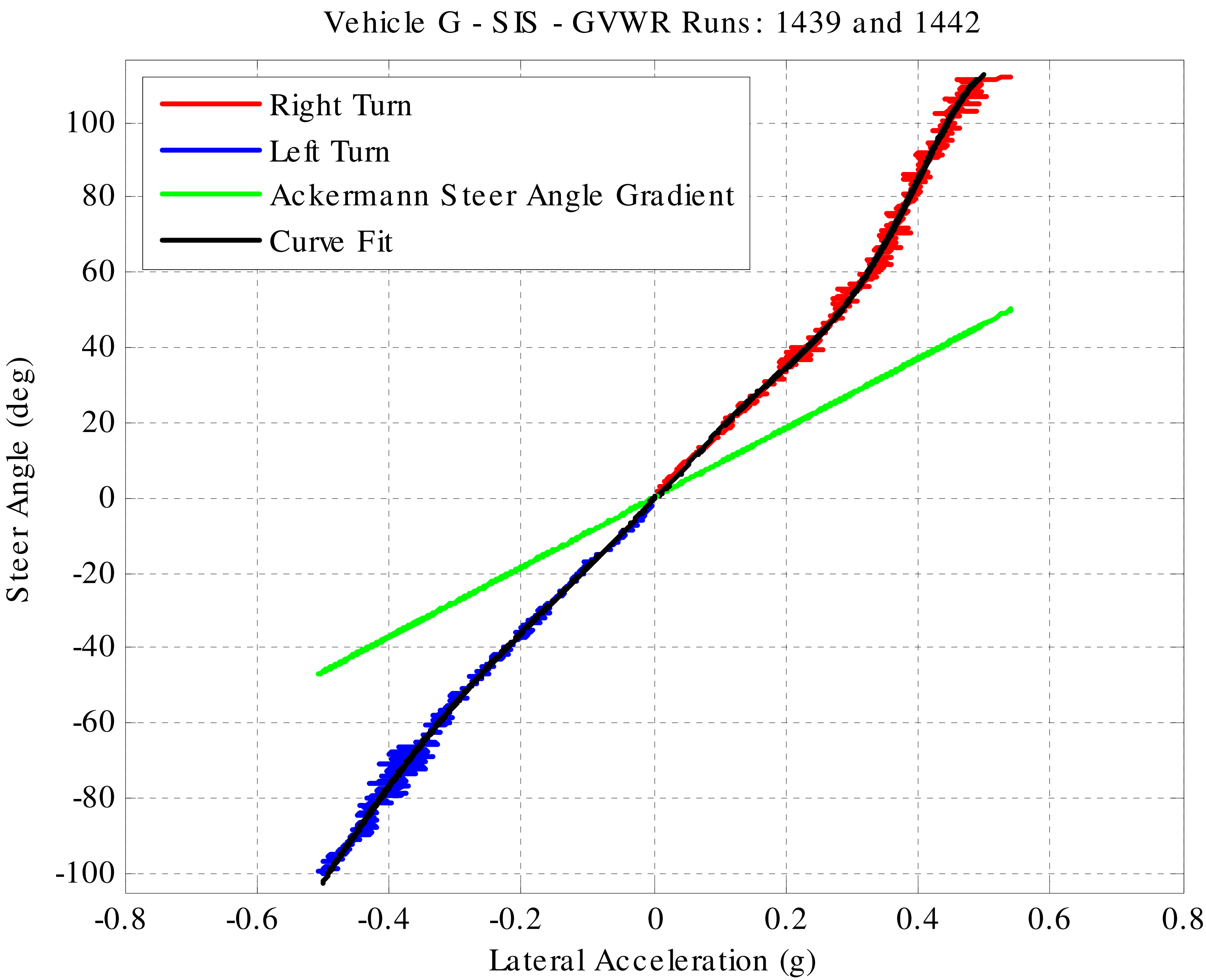

Vehicle F - SIS - GVWR Runs: 1240 and 1239
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.44091 g
Transition to Oversteer
At Ay = -0.46001 g
Steer Angle (deg)
Lateral Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8



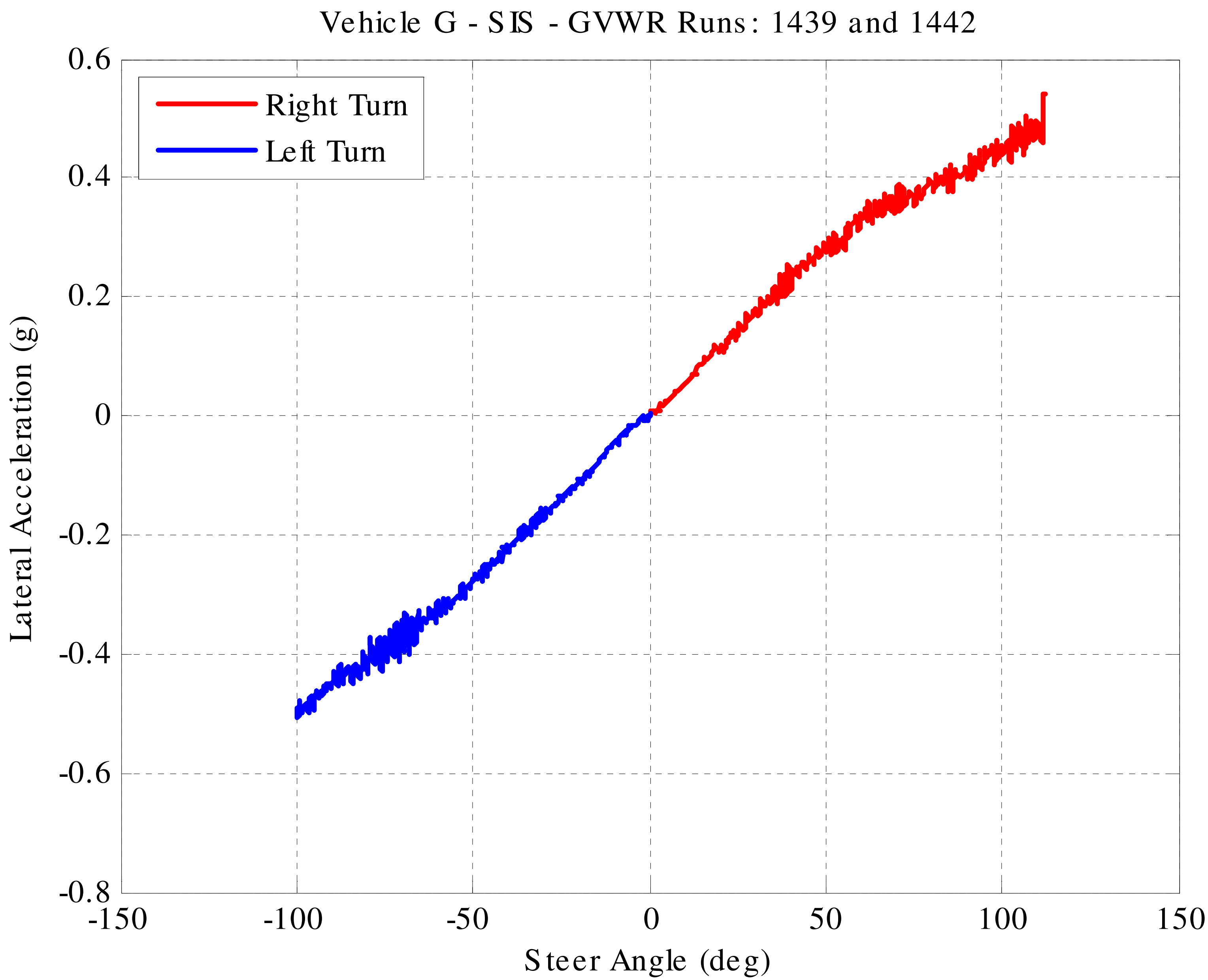
Vehicle F - SIS - GVWR Runs: 1240 and 1239
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-100
-50
0
50
100
150



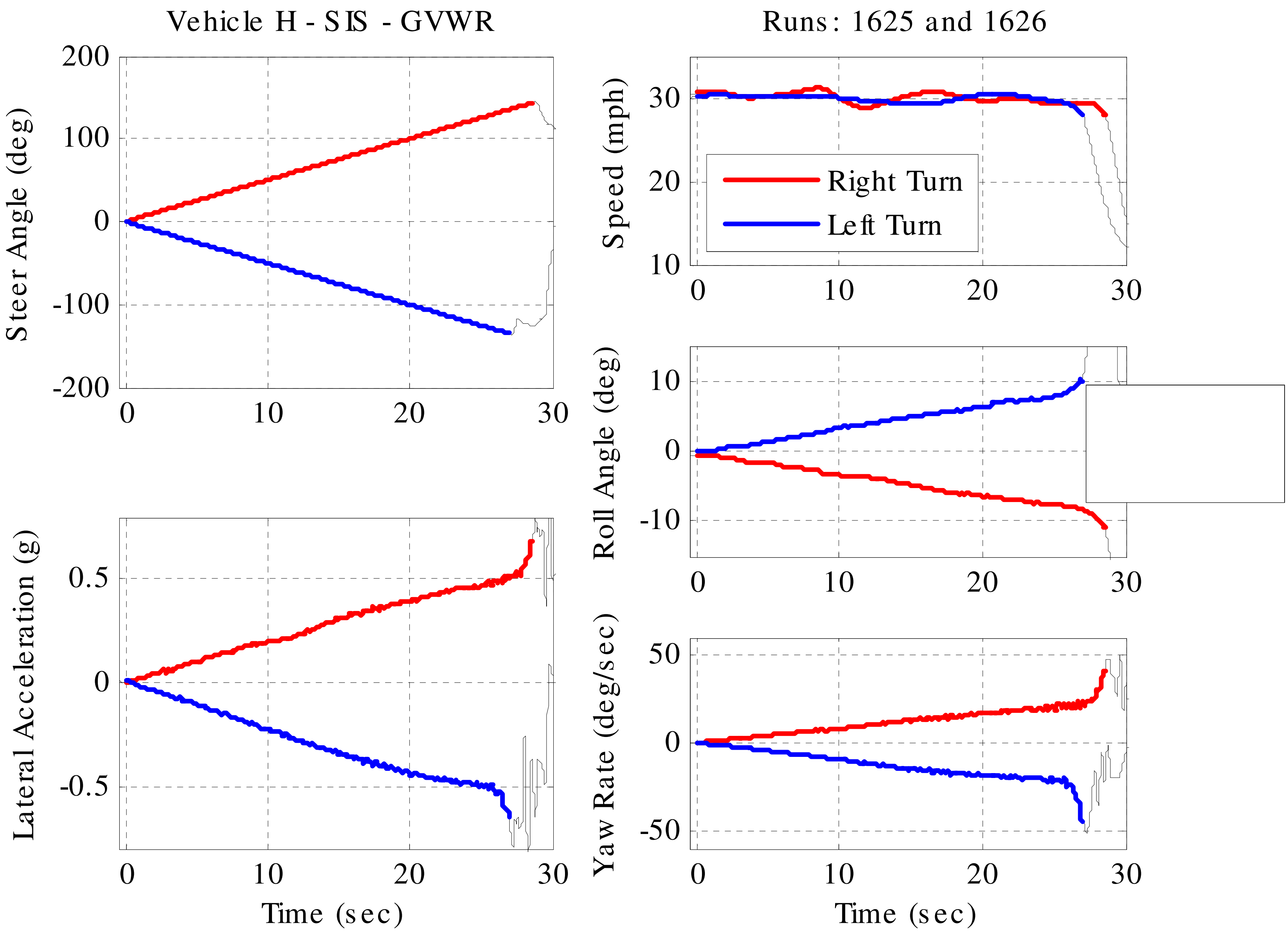
Vehicle G - SIS - GVWR
Runs: 1439 and 1442
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
50
0
-50
Time (sec)
Time (sec)

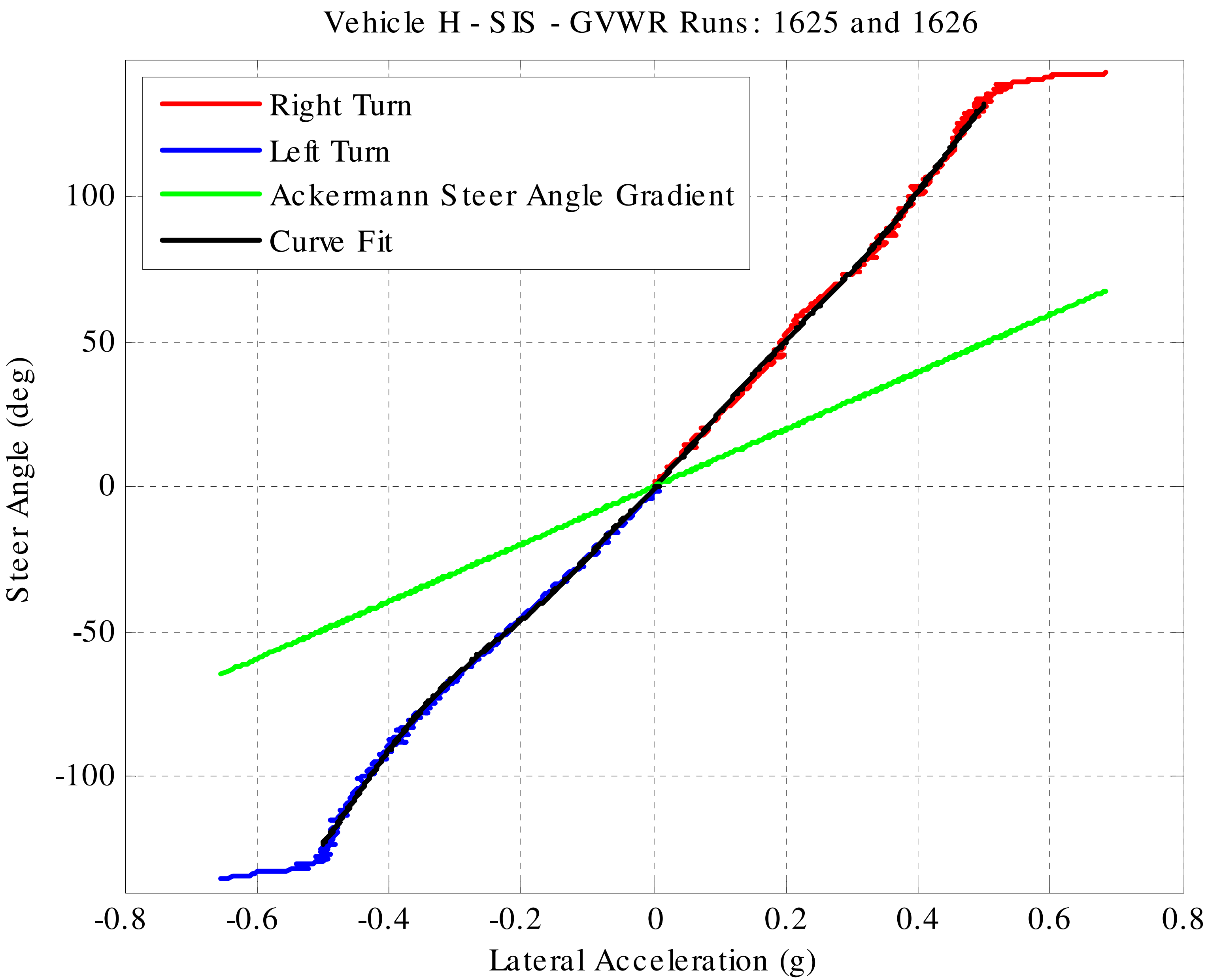


Vehicle G - SIS - GVWR Runs: 1439 and 1442
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
Lateral Acceleration (g)
100
80
60
40
20
0
-20
-40
-60
-80
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

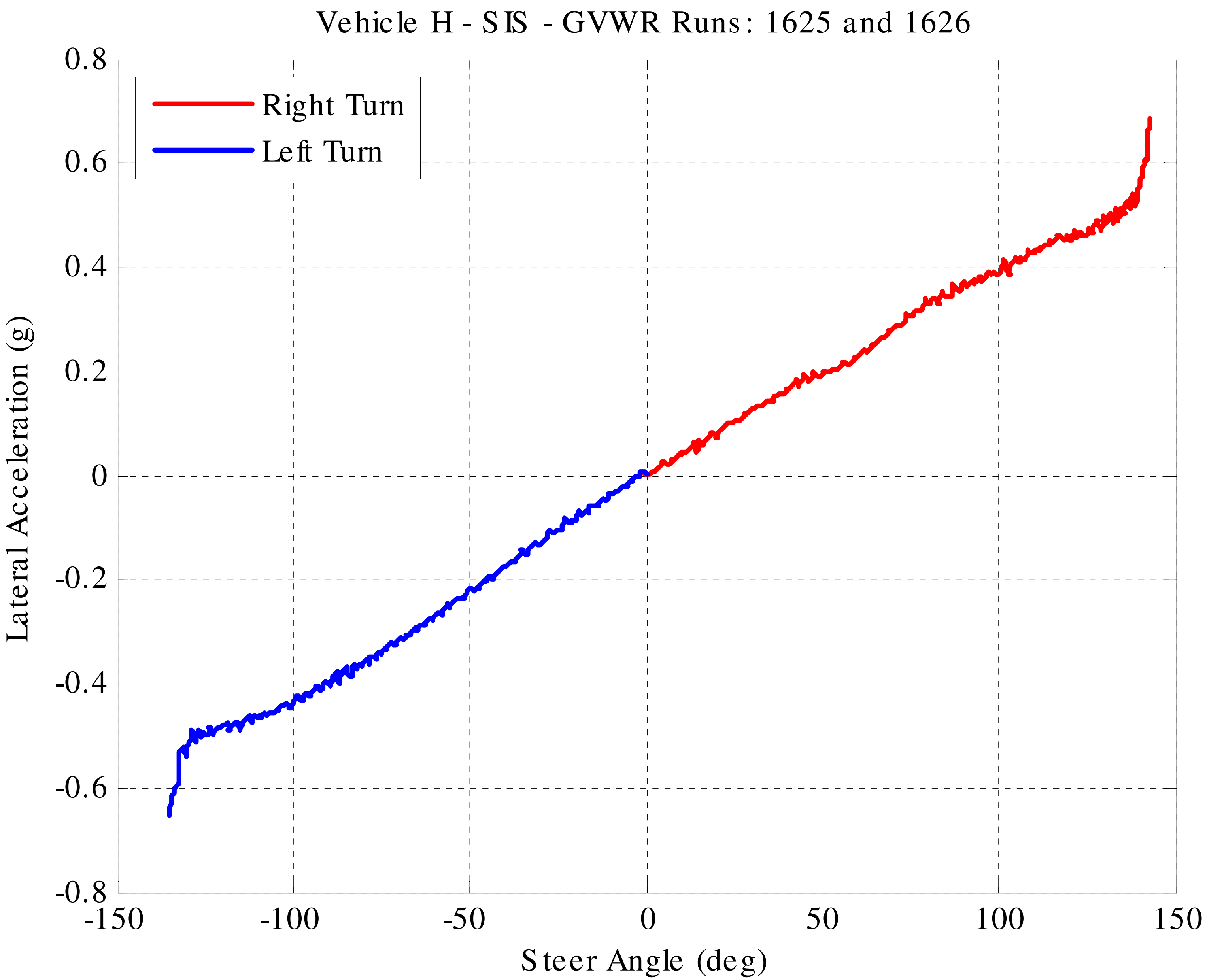


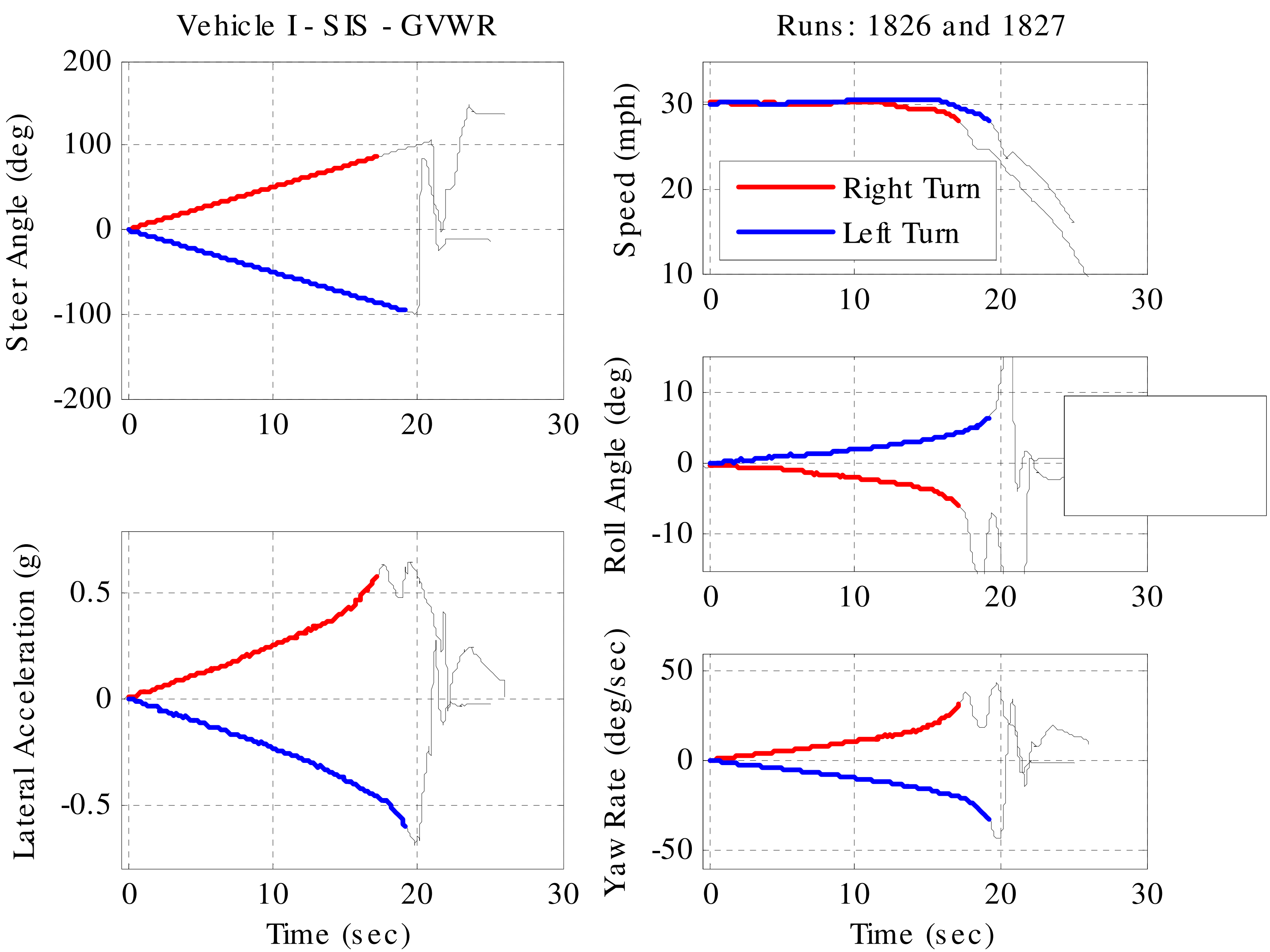
Vehicle G - SIS - GVWR Runs: 1439 and 1442
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150


Vehicle H - SIS - GVWR
Runs: 1625 and 1626
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
50
0
-50
Time (sec)
Time (sec)

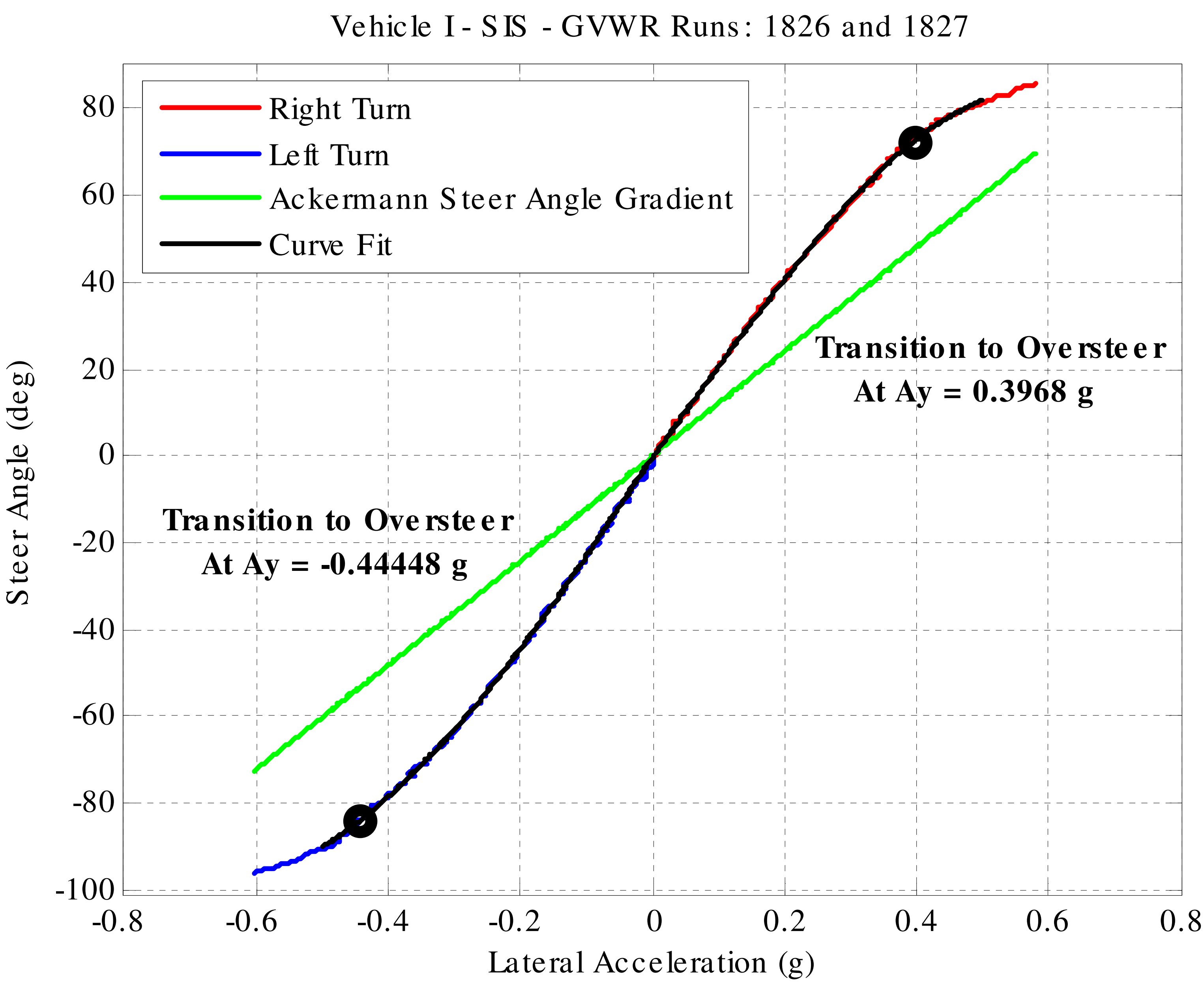


Vehicle H - SIS - GVWR Runs: 1625 and 1626
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Steer Angle (deg)
100
50
0
-50
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Lateral Acceleration (g)

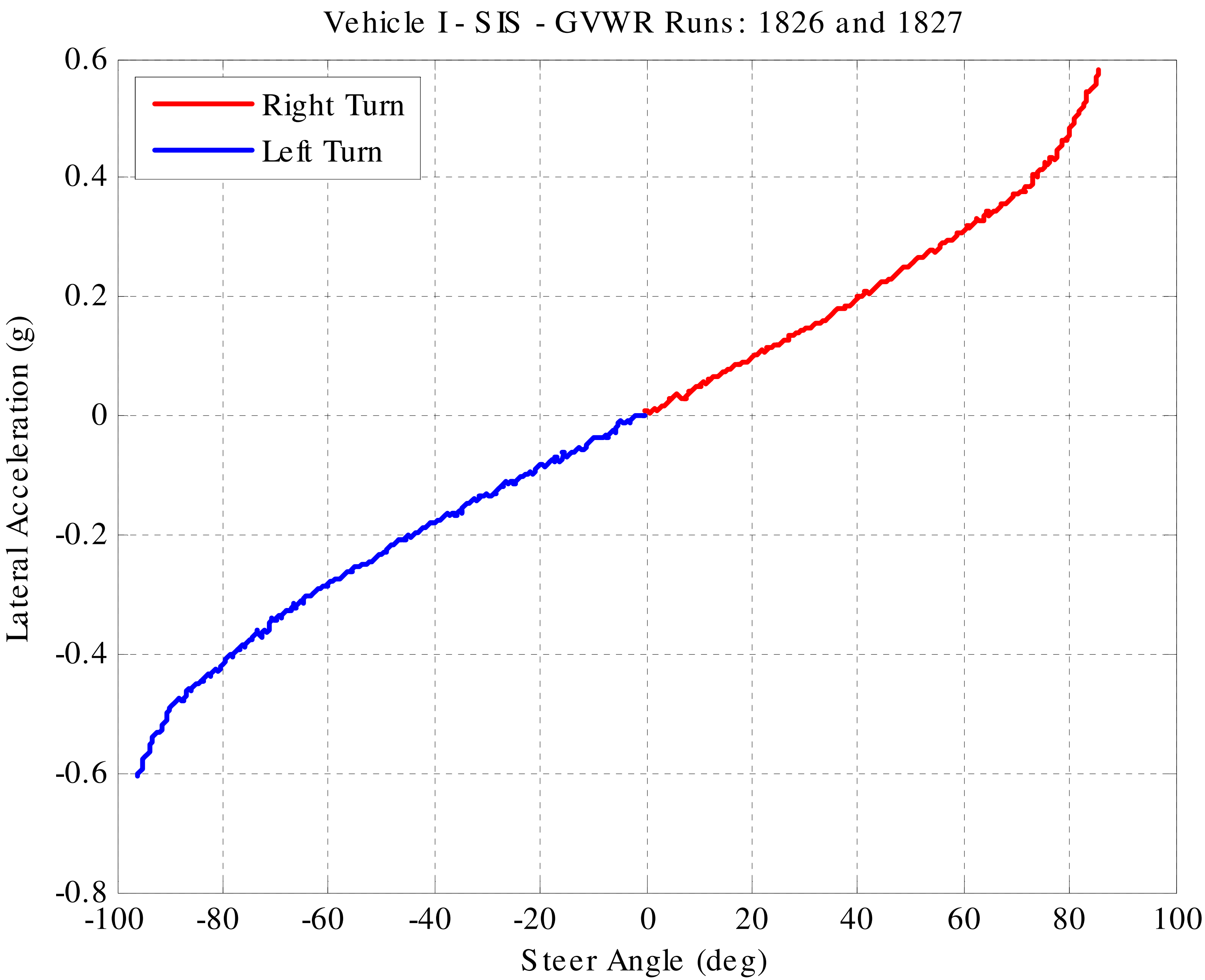

Vehicle H - SIS - GVWR Runs: 1625 and 1626
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-150
-100
-50
0
50
100
150



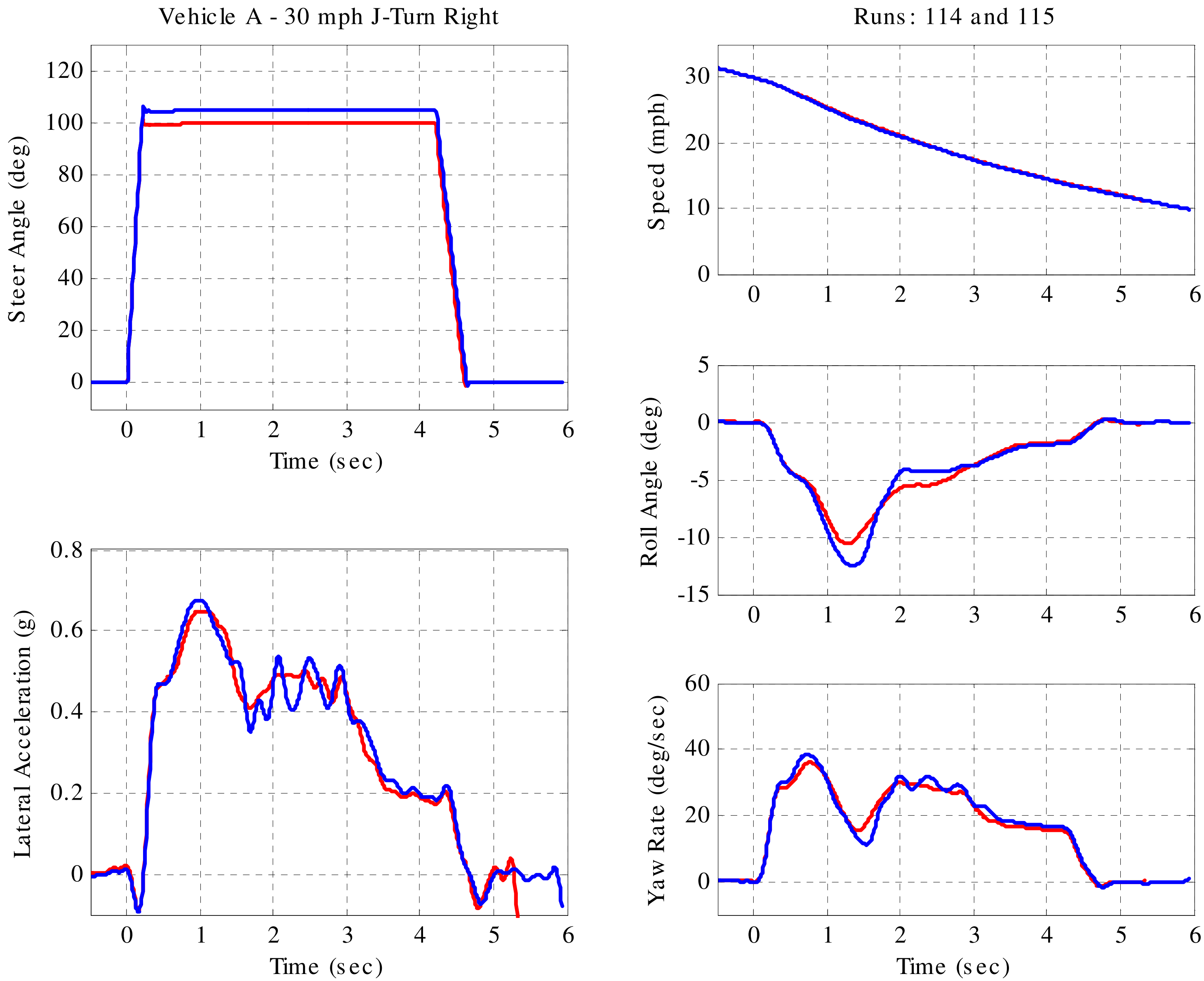
Vehicle I - SIS - GVWR
Runs: 1826 and 1827
Steer Angle (deg)
200
100
0
-100
-200
0
10
20
30
Speed (mph)
30
20
10
Right Turn
Left Turn
Roll Angle (deg)
10
0
-10
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

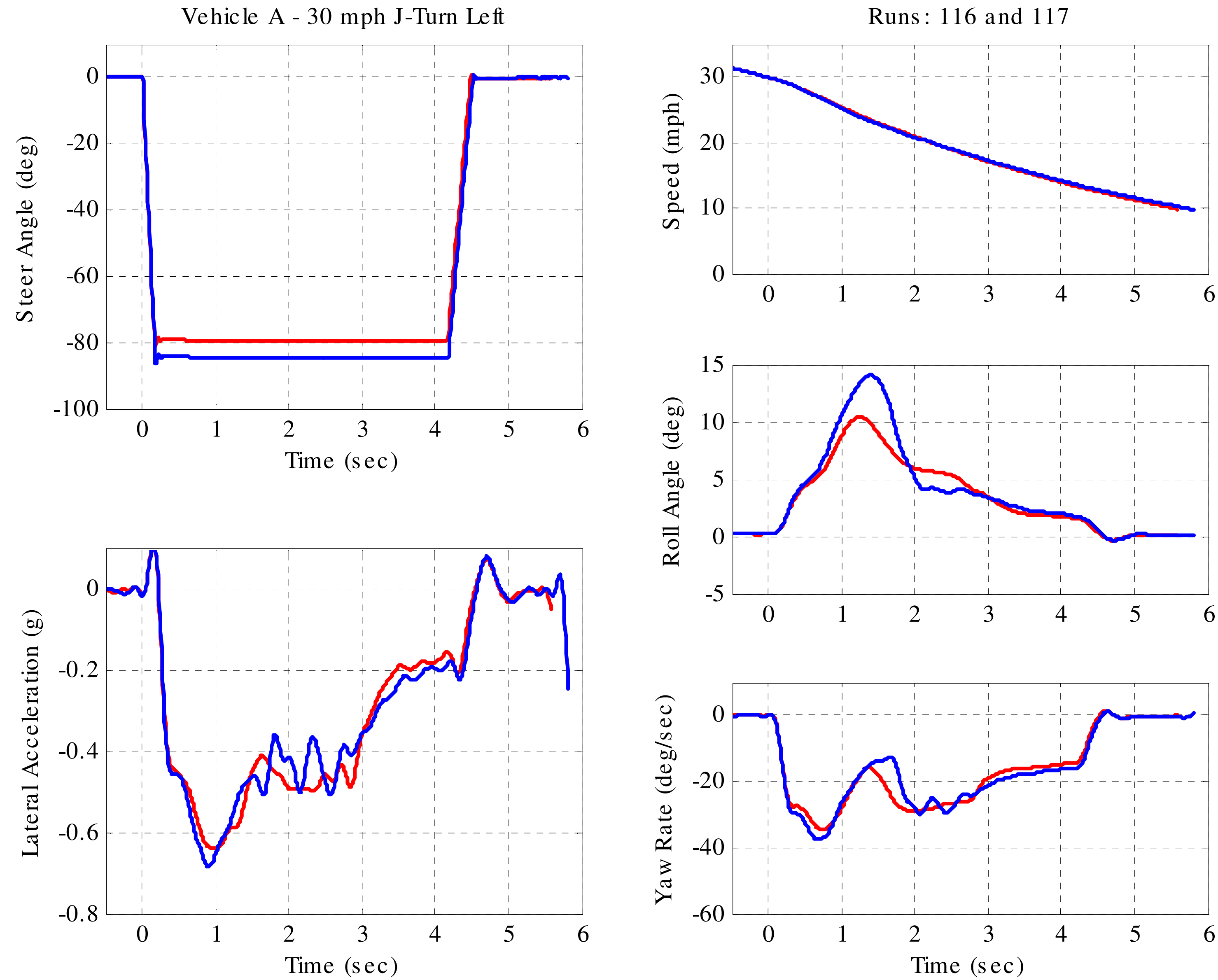


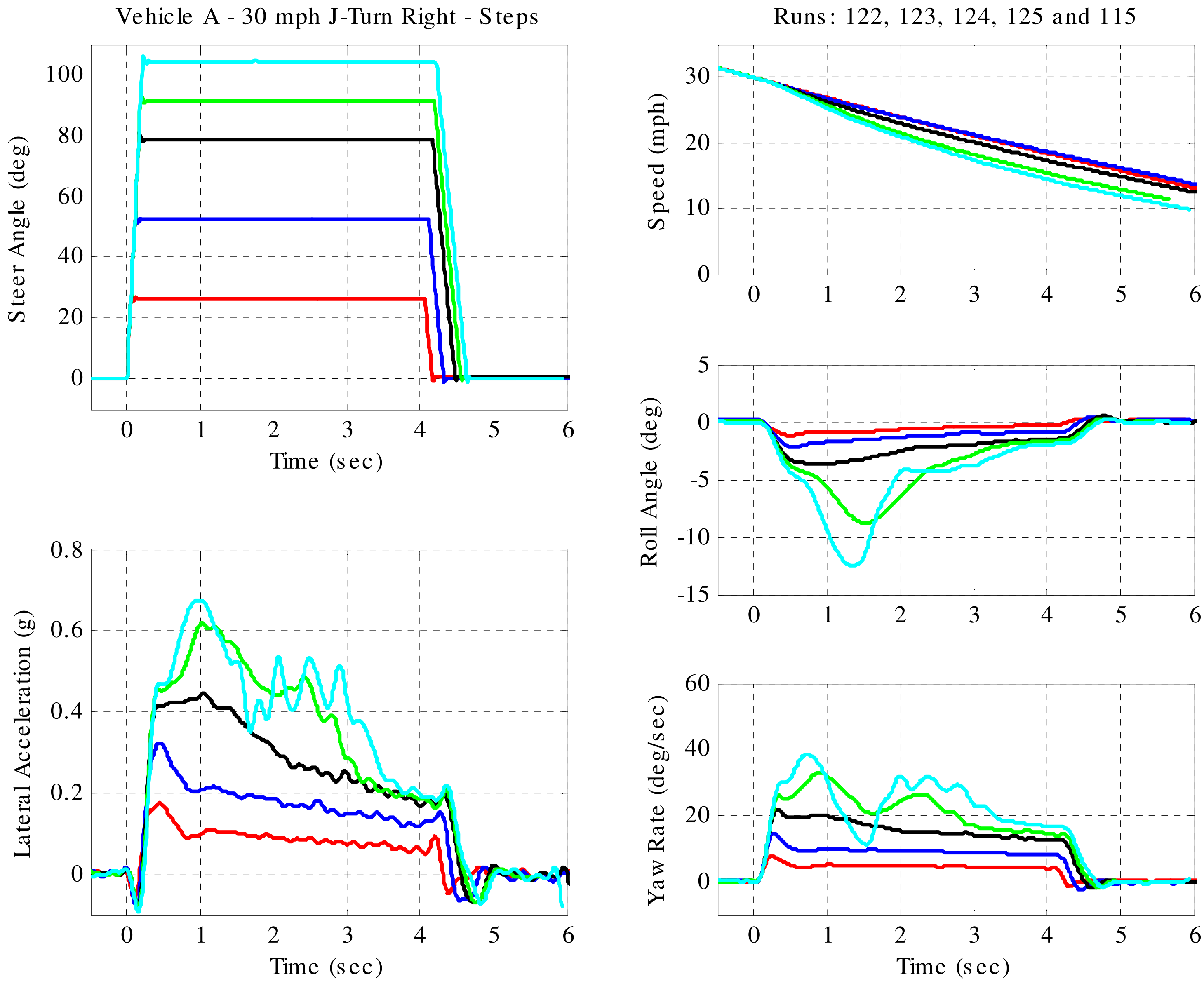
Vehicle I - SIS - GVWR Runs: 1826 and 1827
Right Turn
Left Turn
Ackermann Steer Angle Gradient
Curve Fit
Transition to Oversteer
At Ay = 0.3968 g
Transition to Oversteer
At Ay = -0.44448 g
Steer Angle (deg)
80
60
40
20
0
-20
-40
-60
-80
-100
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Lateral Acceleration (g)


Vehicle I - SIS - GVWR Runs: 1826 and 1827
Right Turn
Left Turn
Lateral Acceleration (g)
Steer Angle (deg)
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

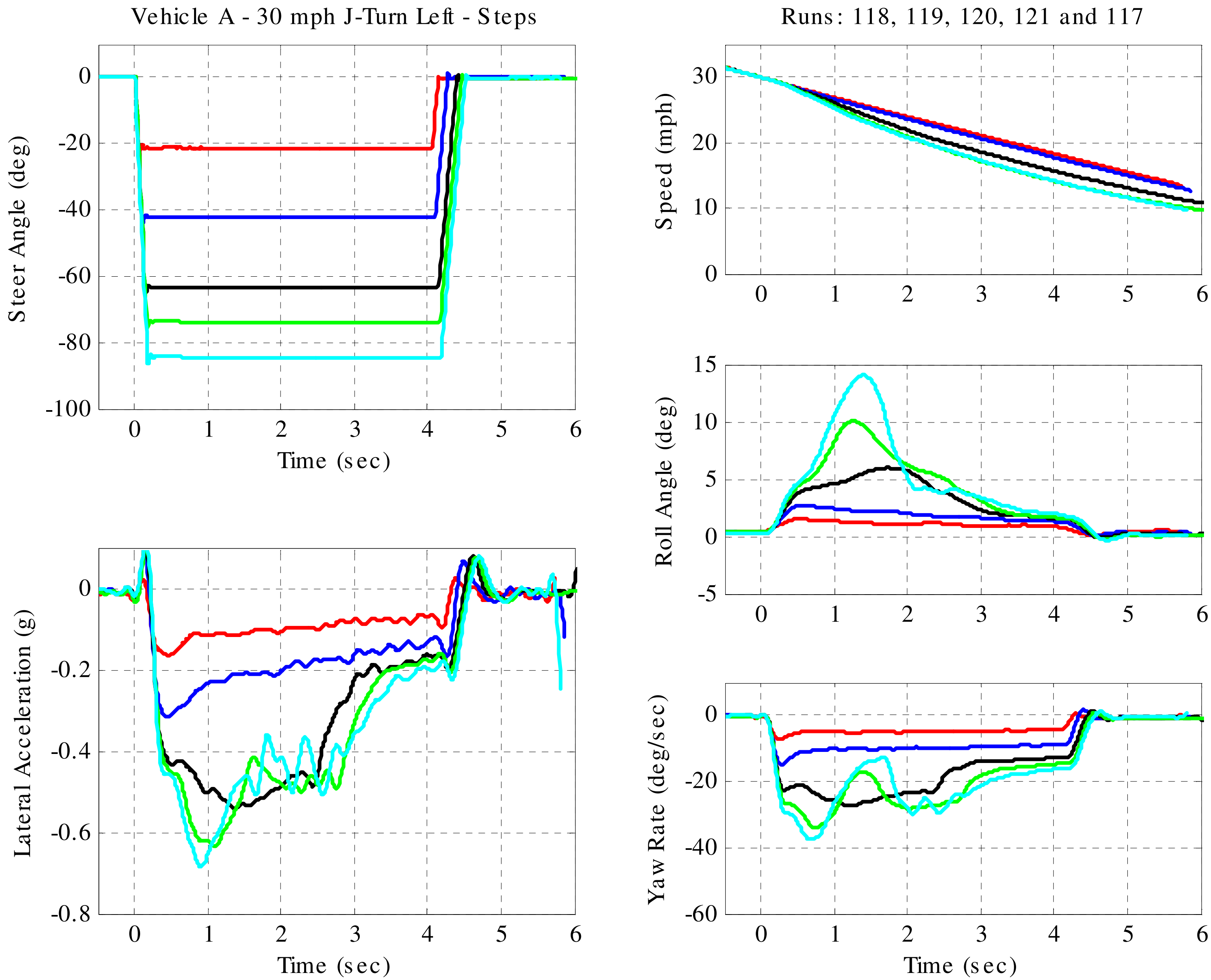
Constant Speed (30 mph) Slowly Increasing Steer Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (GVWR)			
	Right Turn (g)	Left Turn (g)	Average (g)
Vehicle A	0.45	0.36	0.41
Vehicle B	NA	NA	NA
Vehicle C	NA	NA	NA
Vehicle D	0.09	0.06	0.07
Vehicle E	NA	NA	NA
Vehicle F	0.44	0.46	0.45
Vehicle G	NA	NA	NA
Vehicle H	NA	NA	NA
Vehicle I	0.40	0.44	0.42

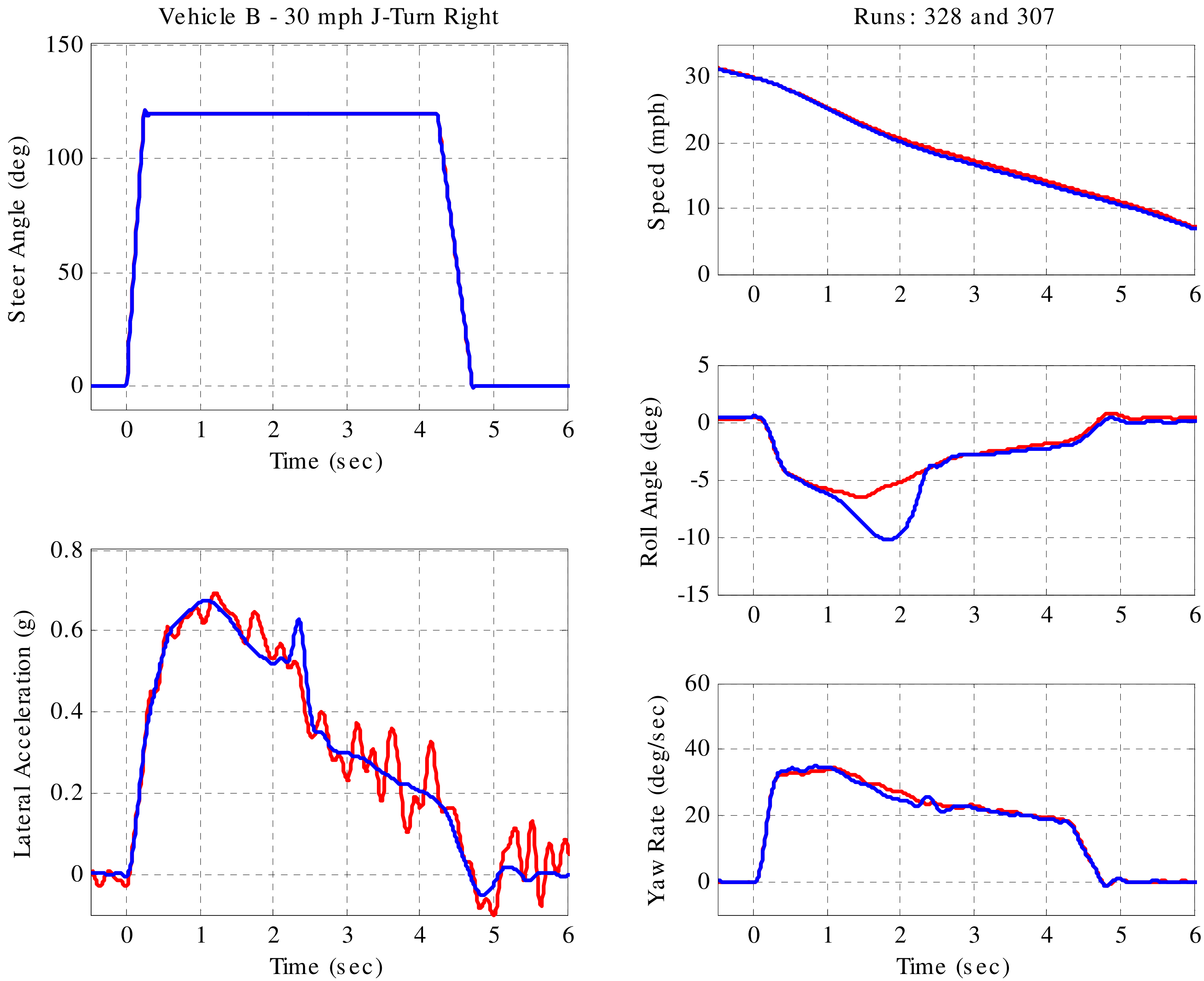

Vehicle A - 30 mph J-Turn Right
Runs: 114 and 115
Steer Angle (deg)
120
100
80
60
40
20
0
Time (sec)
0
1
2
3
4
5
6
Speed (mph)
30
20
10
0
Roll Angle (deg)
5
0
-5
-10
-15
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Yaw Rate (deg/sec)
60
40
20
0
Time (sec)


Vehicle A - 30 mph J-Turn Left
Runs: 116 and 117
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

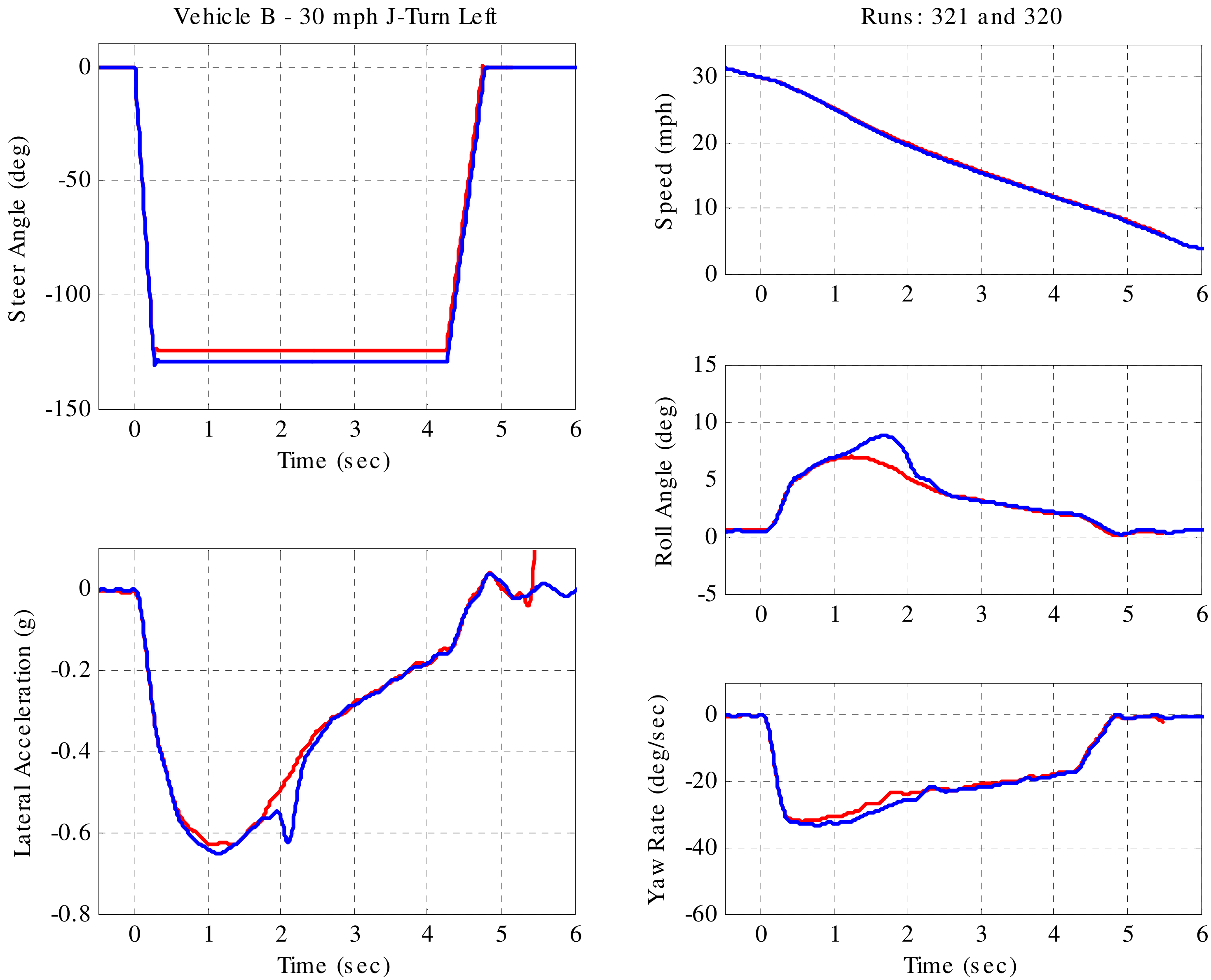


Vehicle A - 30 mph J-Turn Right - Steps
Runs: 122, 123, 124, 125 and 115
Steer Angle (deg)
100
80
60
40
20
0
0 1 2 3 4 5 6
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
5
0
-5
-10
-15
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Yaw Rate (deg/sec)
60
40
20
0

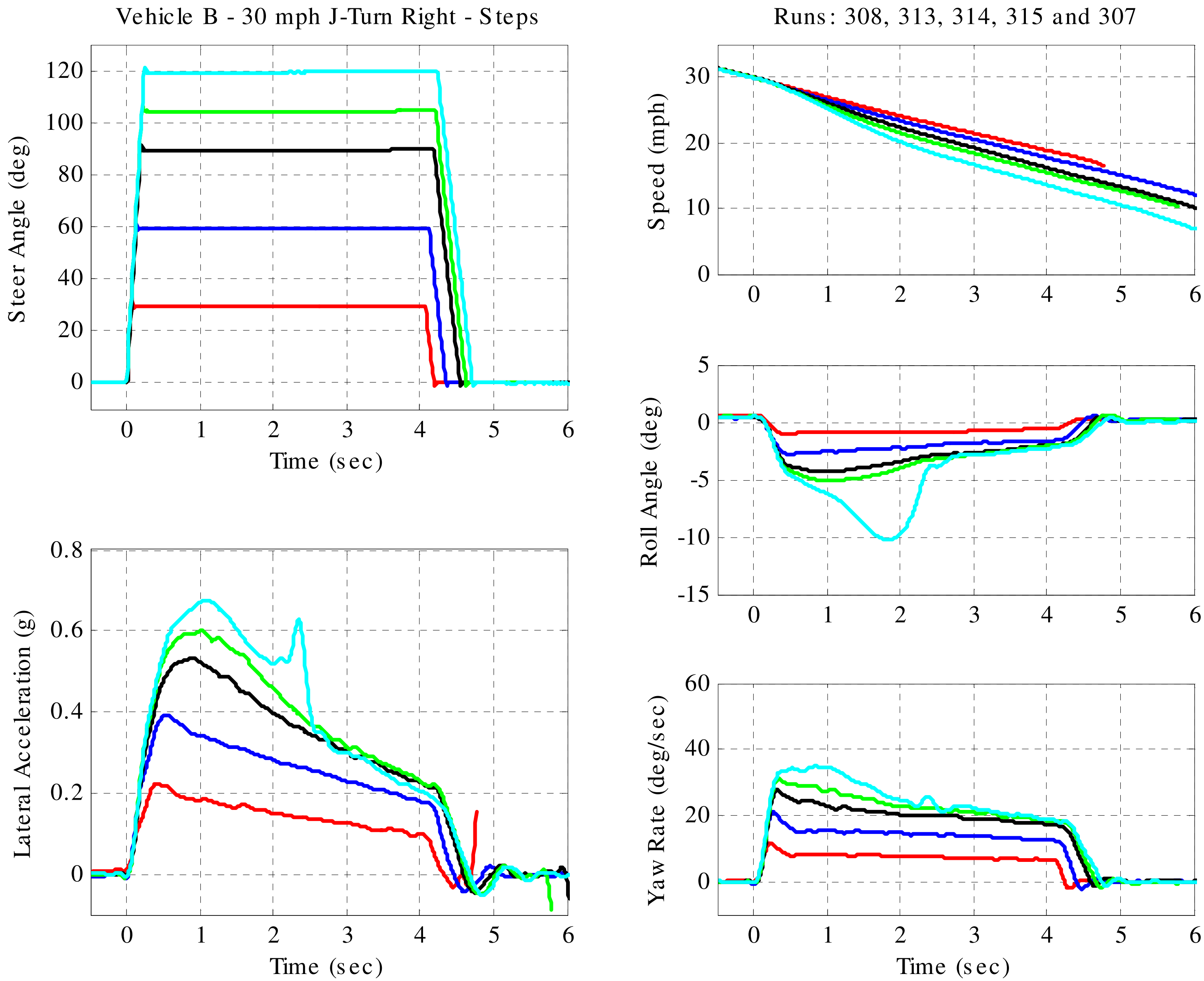

Vehicle A - 30 mph J-Turn Left - Steps
Runs: 118, 119, 120, 121 and 117
Steer Angle (deg)
0
-20
-40
-60
-80
-100
Time (sec)
0 1 2 3 4 5 6
Speed (mph)
30
20
10
0
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60

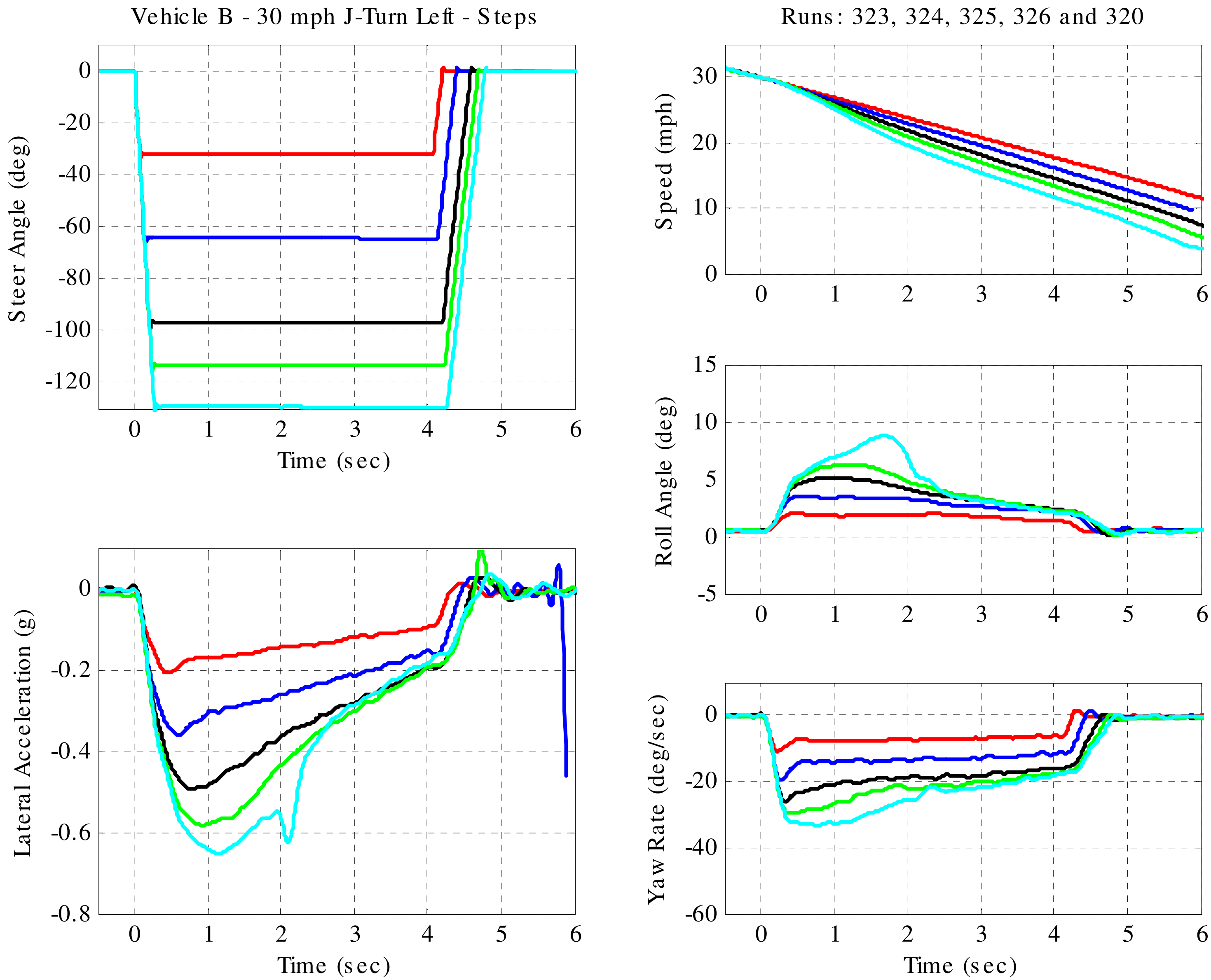


Vehicle B - 30 mph J-Turn Right
Runs: 328 and 307
Steer Angle (deg)
150
100
50
0
Time (sec)
0 1 2 3 4 5 6
Speed (mph)
30
20
10
0
Roll Angle (deg)
5
0
-5
-10
-15
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Yaw Rate (deg/sec)
60
40
20
0
Time (sec)
Time (sec)

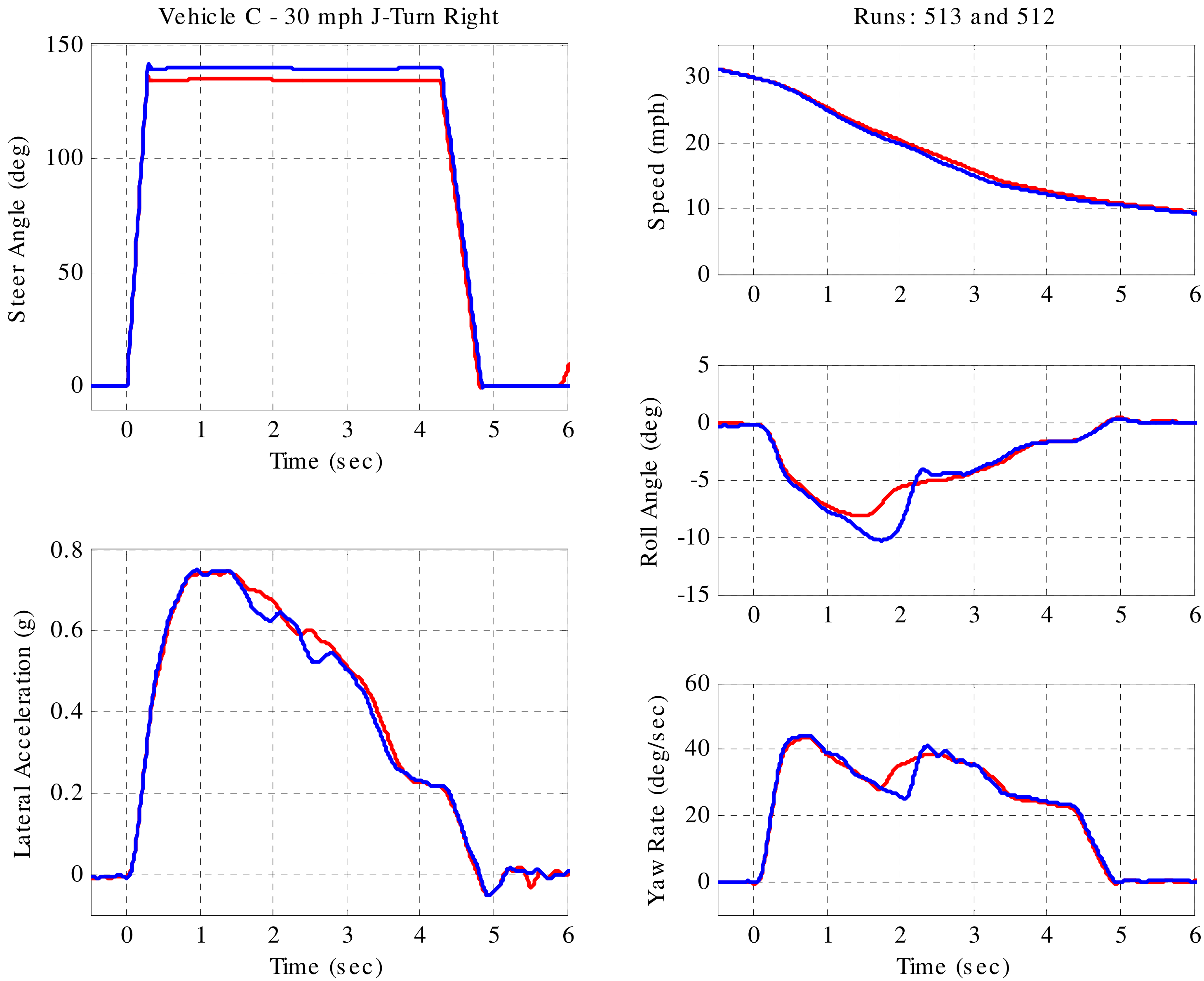


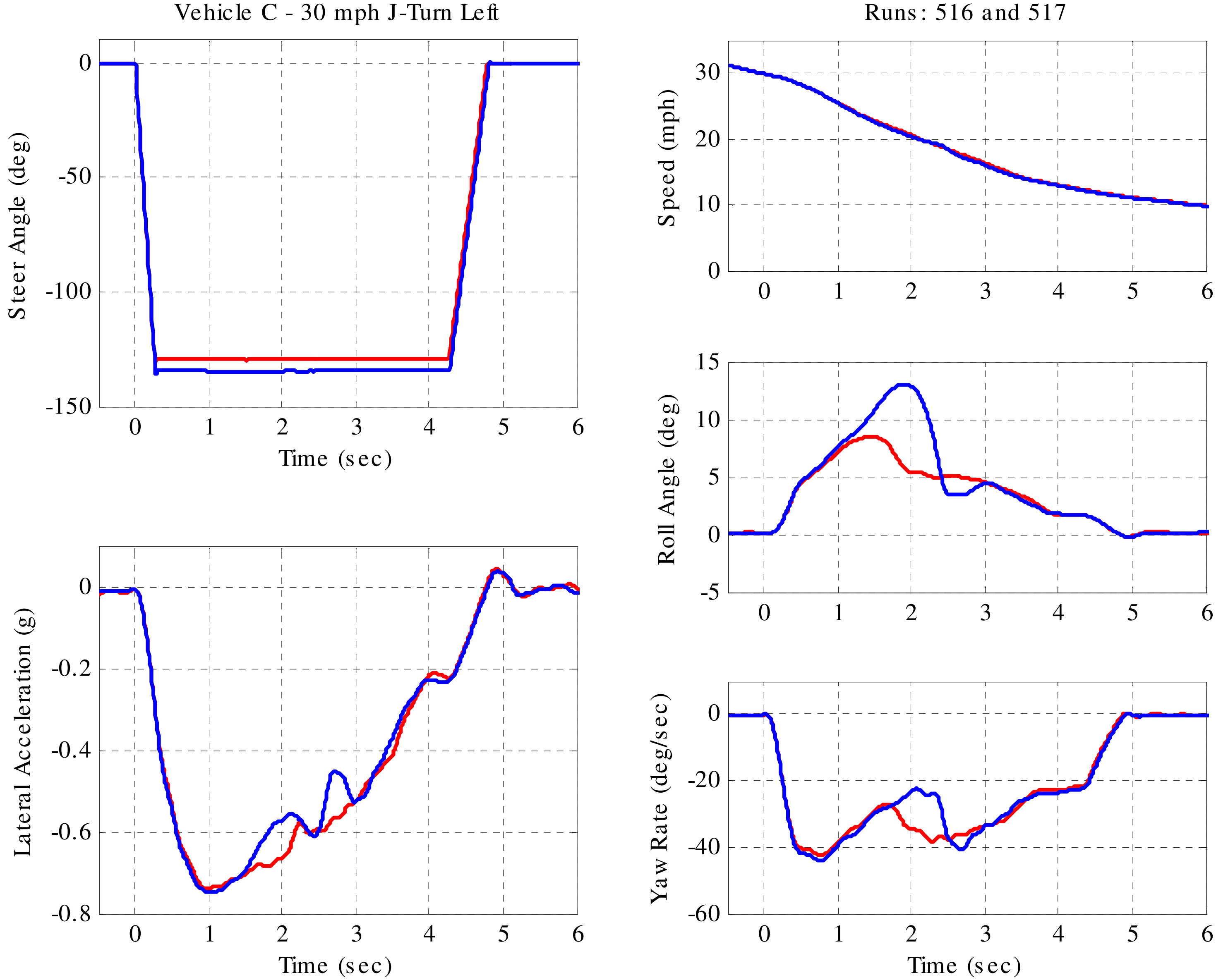
Vehicle B - 30 mph J-Turn Left
Runs: 321 and 320
Steer Angle (deg)
0
-50
-100
-150
Time (sec)
0
1
2
3
4
5
6
Speed (mph)
30
20
10
0
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60

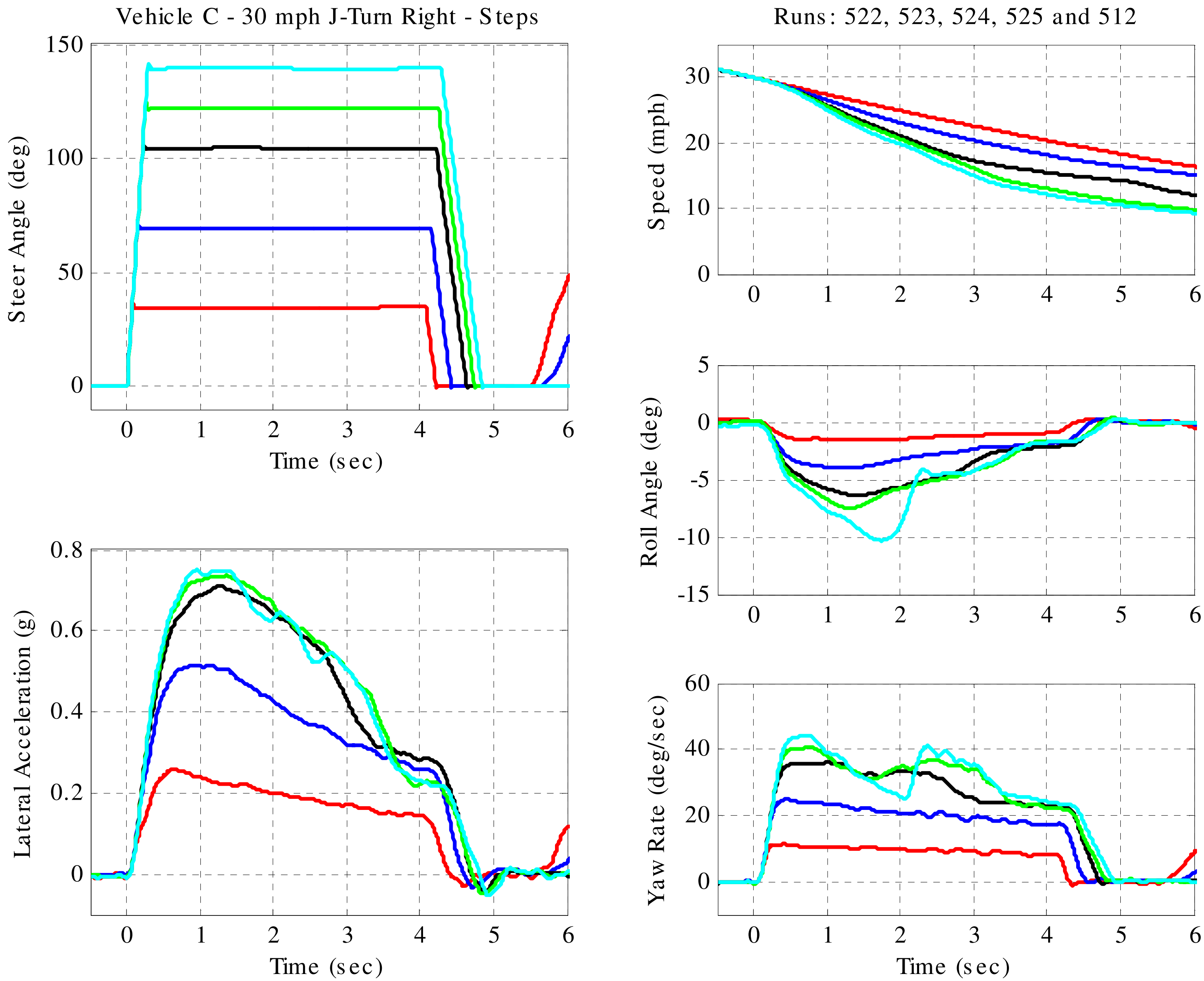

Vehicle B - 30 mph J-Turn Right - Steps
Runs: 308, 313, 314, 315 and 307
Steer Angle (deg)
120
100
80
60
40
20
0
0 1 2 3 4 5 6
Time (sec)
Speed (mph)
30
20
10
0
0 1 2 3 4 5 6
Roll Angle (deg)
5
0
-5
-10
-15
0 1 2 3 4 5 6
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6
Time (sec)
Yaw Rate (deg/sec)
60
40
20
0
0 1 2 3 4 5 6
Time (sec)



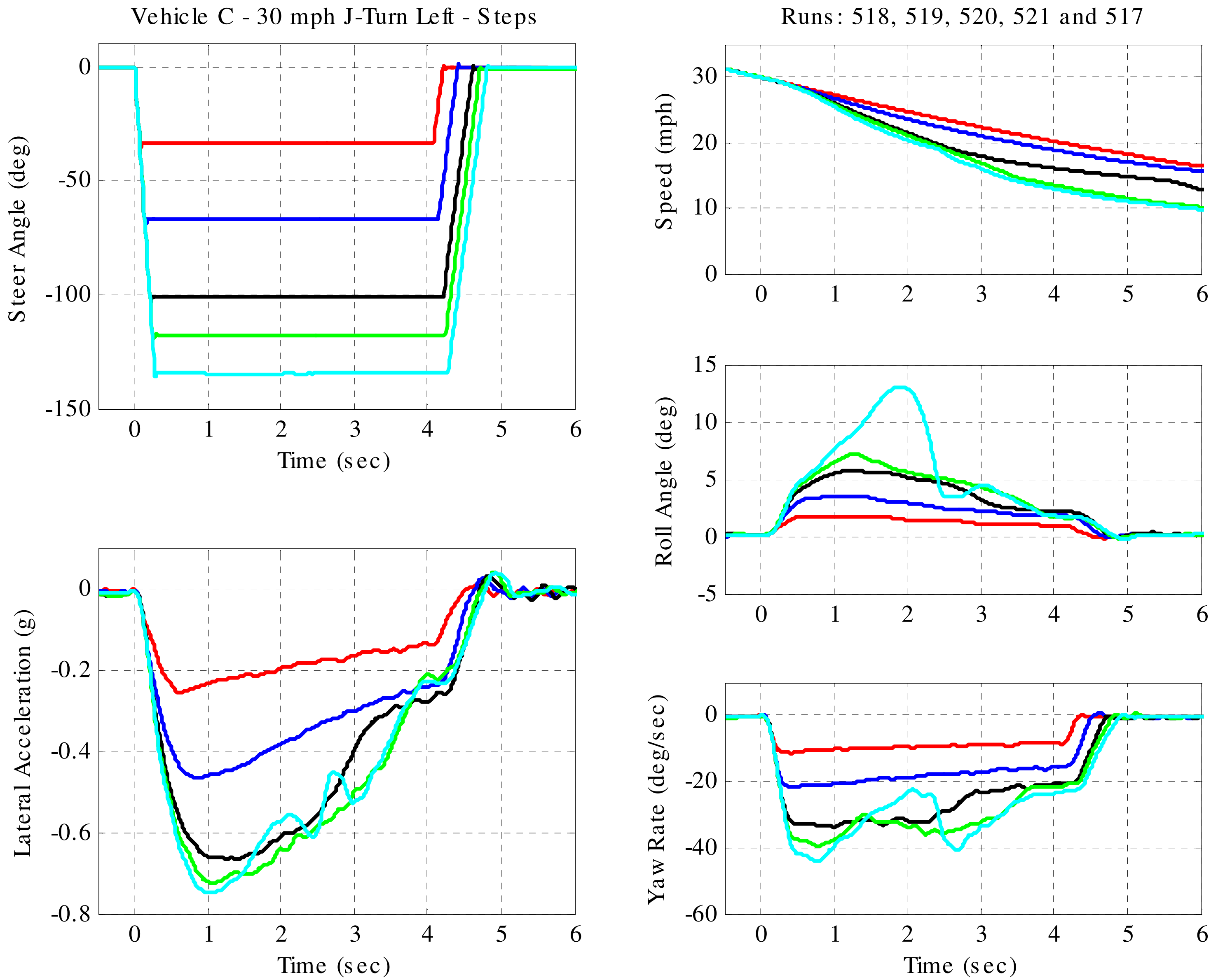
Vehicle B - 30 mph J-Turn Left - Steps
Runs: 323, 324, 325, 326 and 320
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

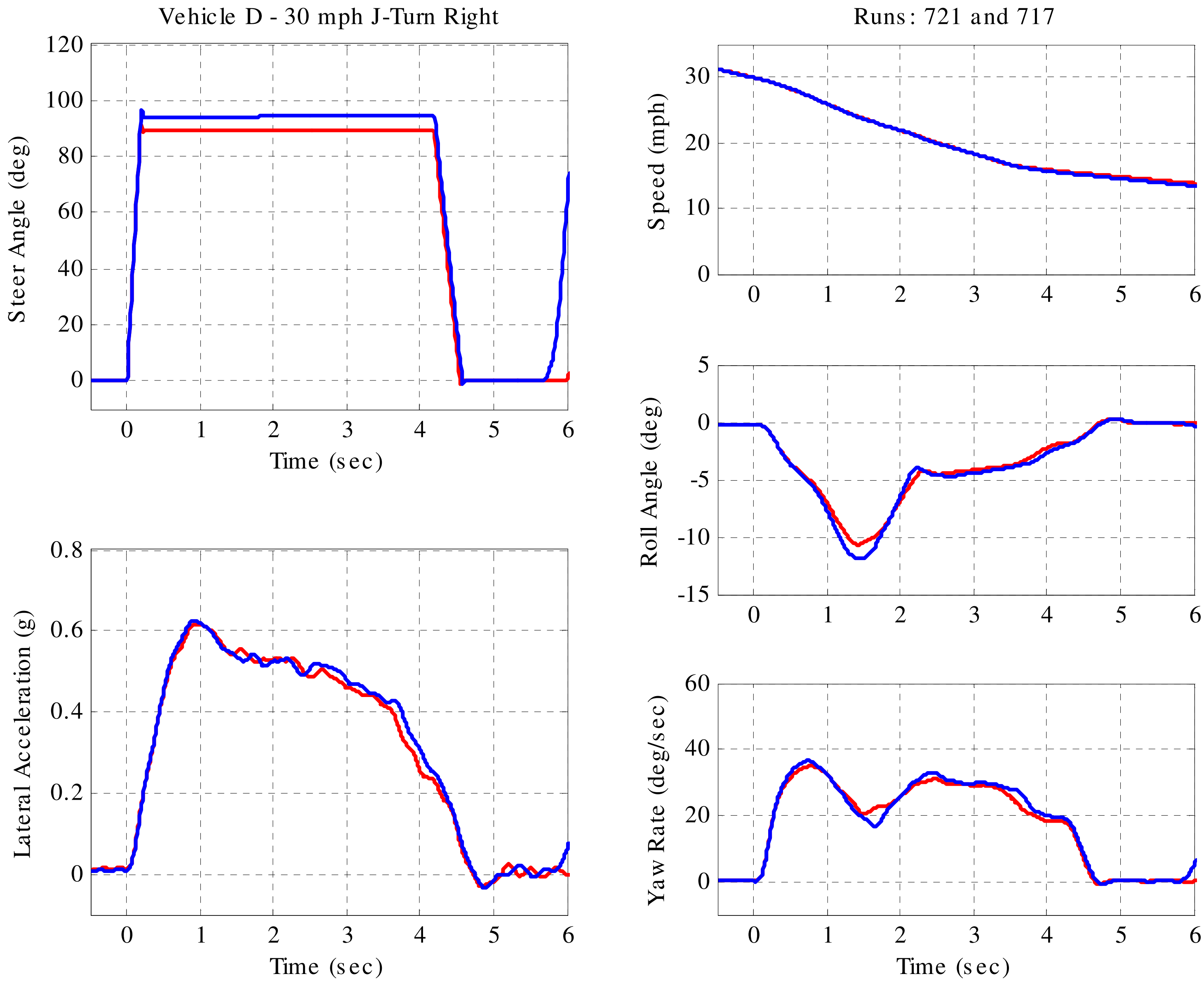

Vehicle C - 30 mph J-Turn Right
Runs: 513 and 512
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

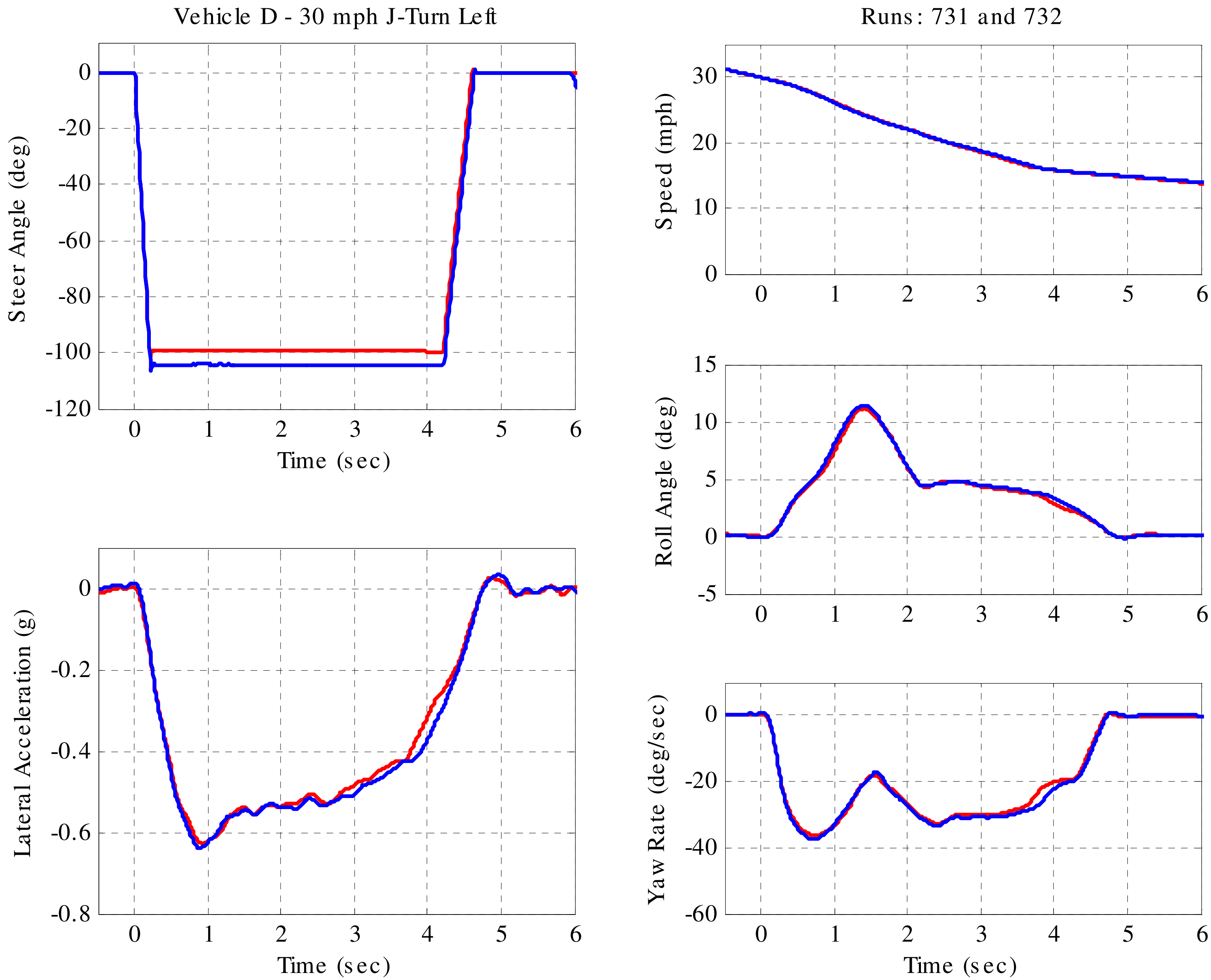

Vehicle C - 30 mph J-Turn Left
Runs: 516 and 517
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)



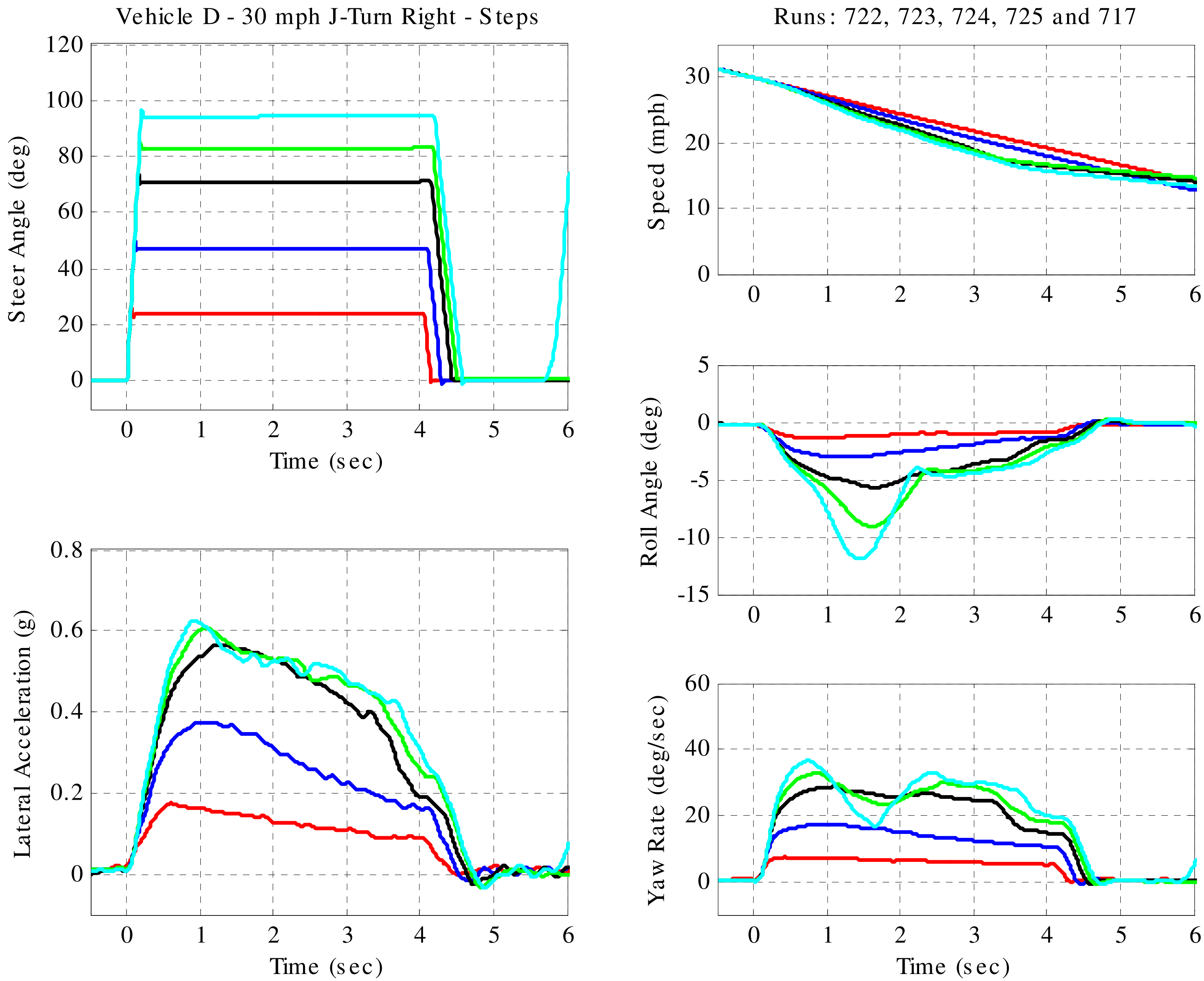
Vehicle C - 30 mph J-Turn Right - Steps
Runs: 522, 523, 524, 525 and 512
Steer Angle (deg)
150
100
50
0
Time (sec)
Speed (mph)
30
20
10
Roll Angle (deg)
5
-5
-10
-15
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
Yaw Rate (deg/sec)
60
40
0
1
2
3
4
5
6

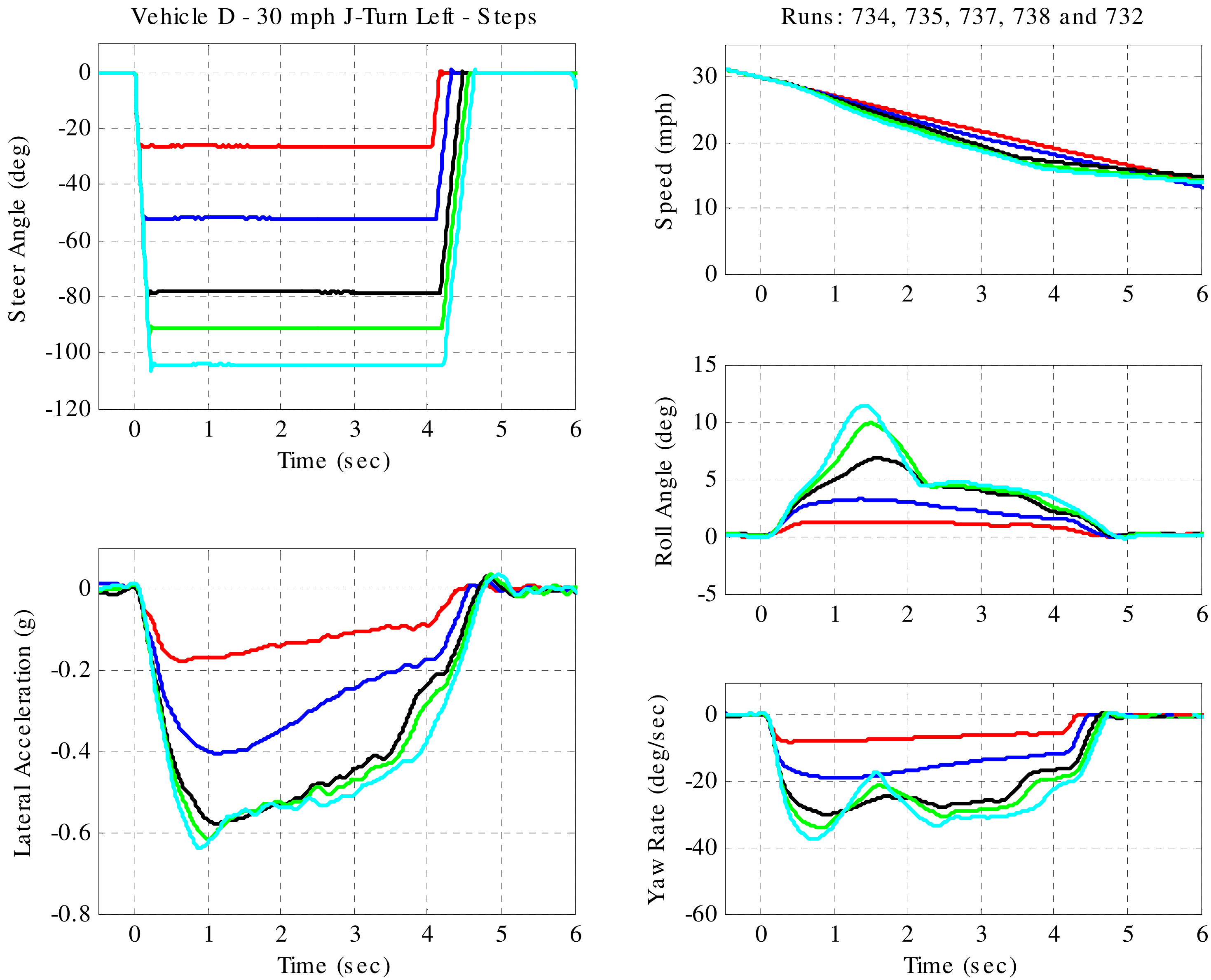

Vehicle C - 30 mph J-Turn Left - Steps
Runs: 518, 519, 520, 521 and 517
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)


Vehicle D - 30 mph J-Turn Right
Runs: 721 and 717
Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

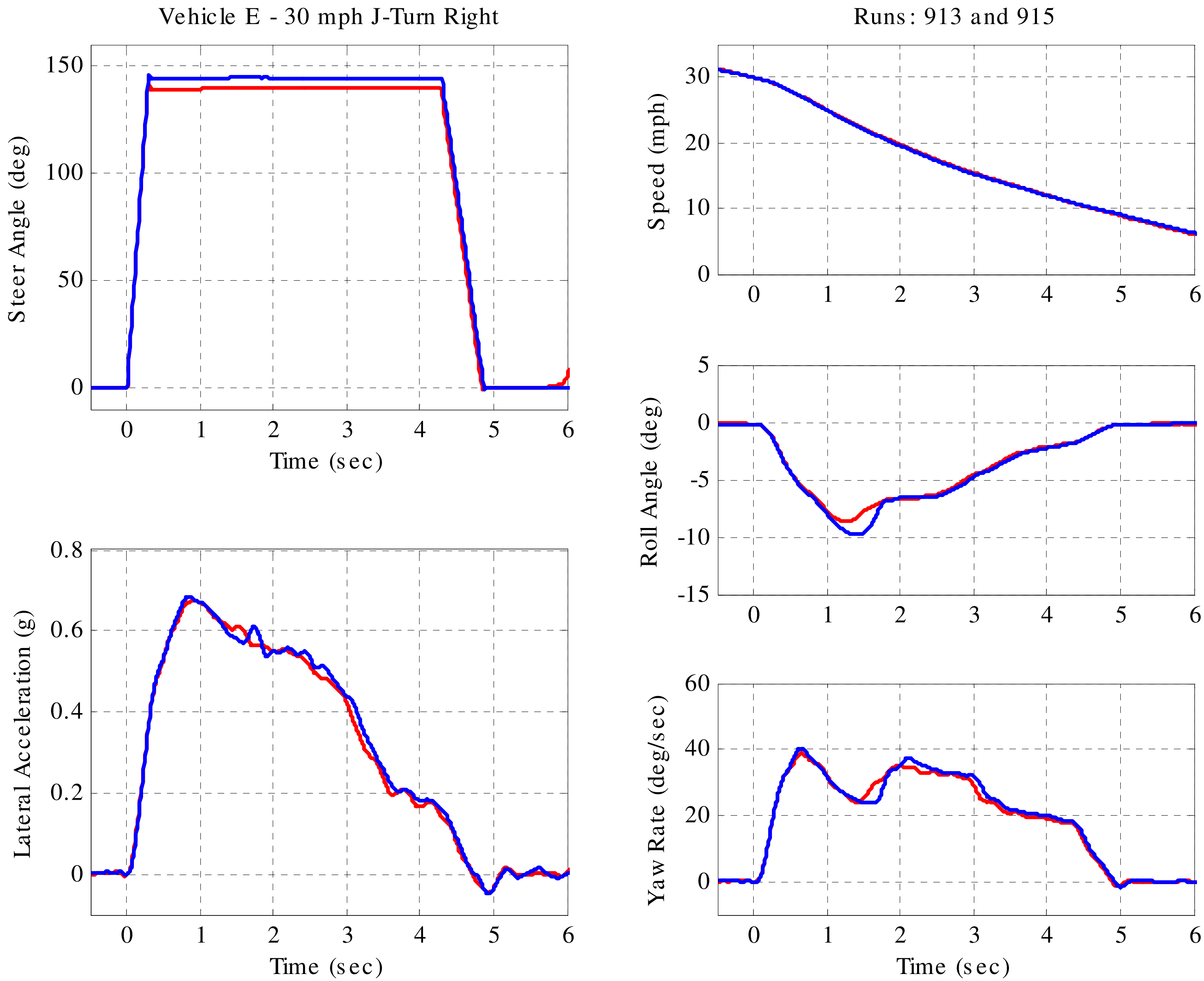


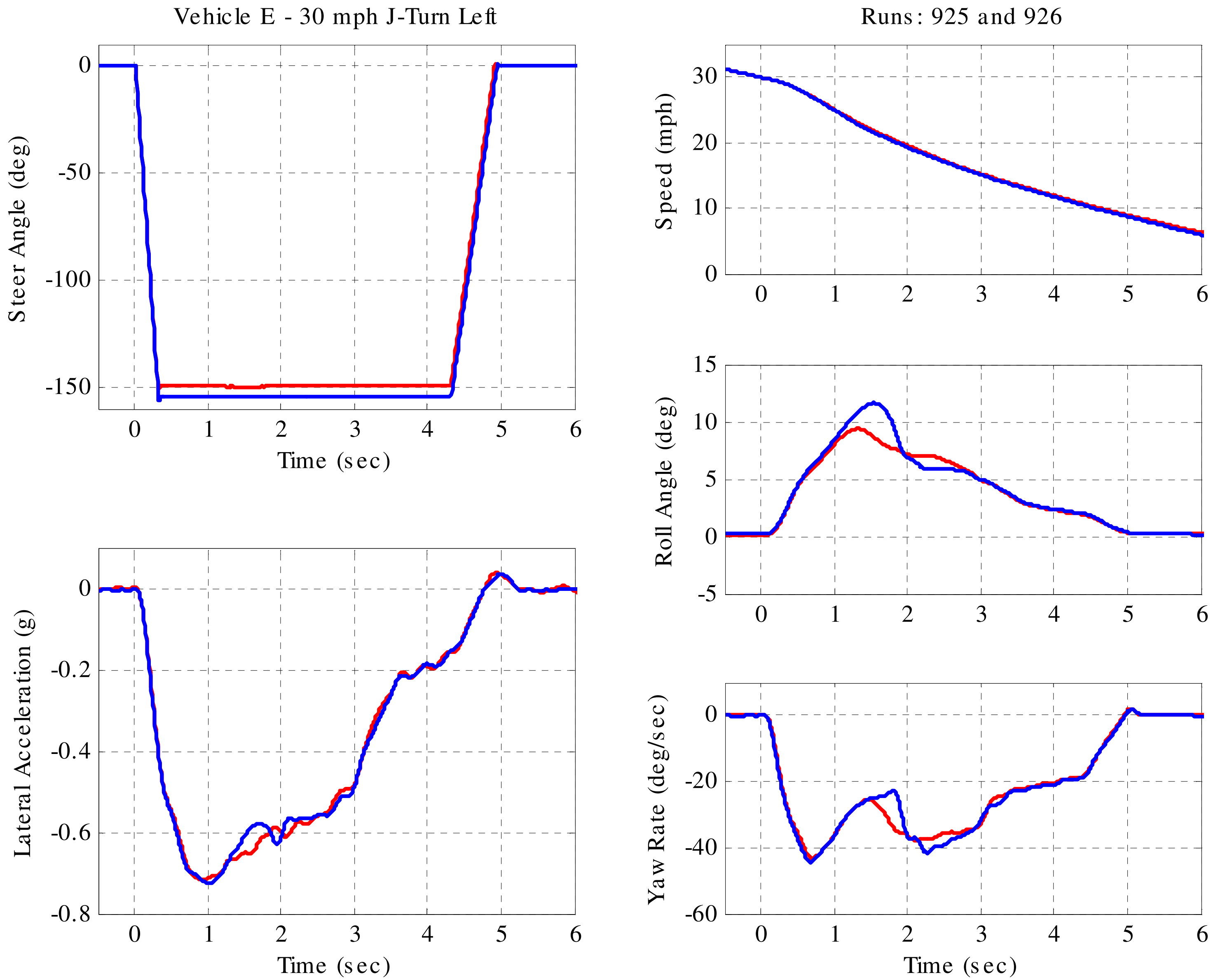
Vehicle D - 30 mph J-Turn Left
Runs: 731 and 732
Steer Angle (deg)
0
-20
-40
-60
-80
-100
-120
Time (sec)
Speed (mph)
30
20
10
Roll Angle (deg)
15
5
-5
Lateral Acceleration (g)
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
-60
0
1
2
3
4
5
6


Vehicle D - 30 mph J-Turn Right - Steps
Runs: 722, 723, 724, 725 and 717
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

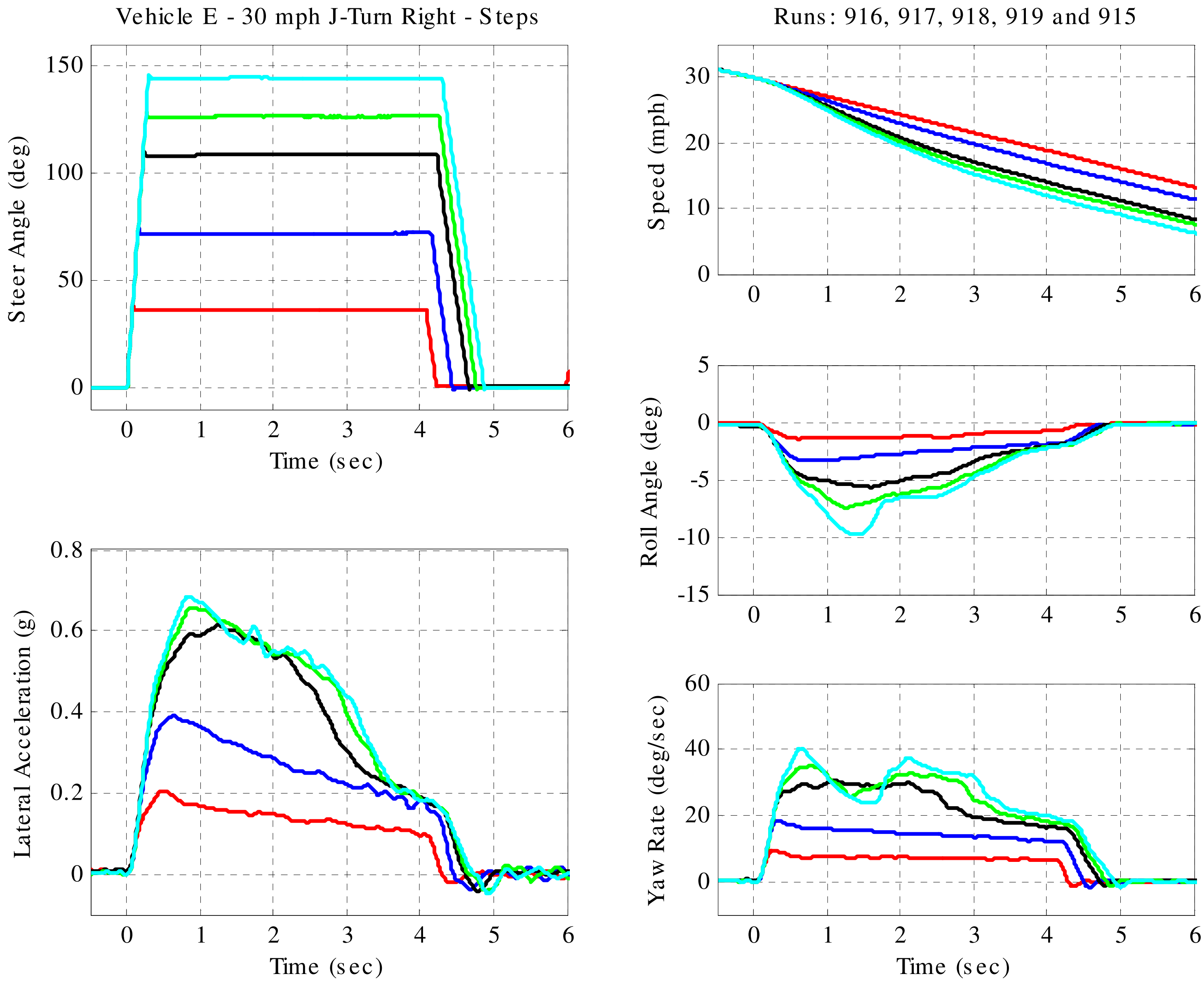


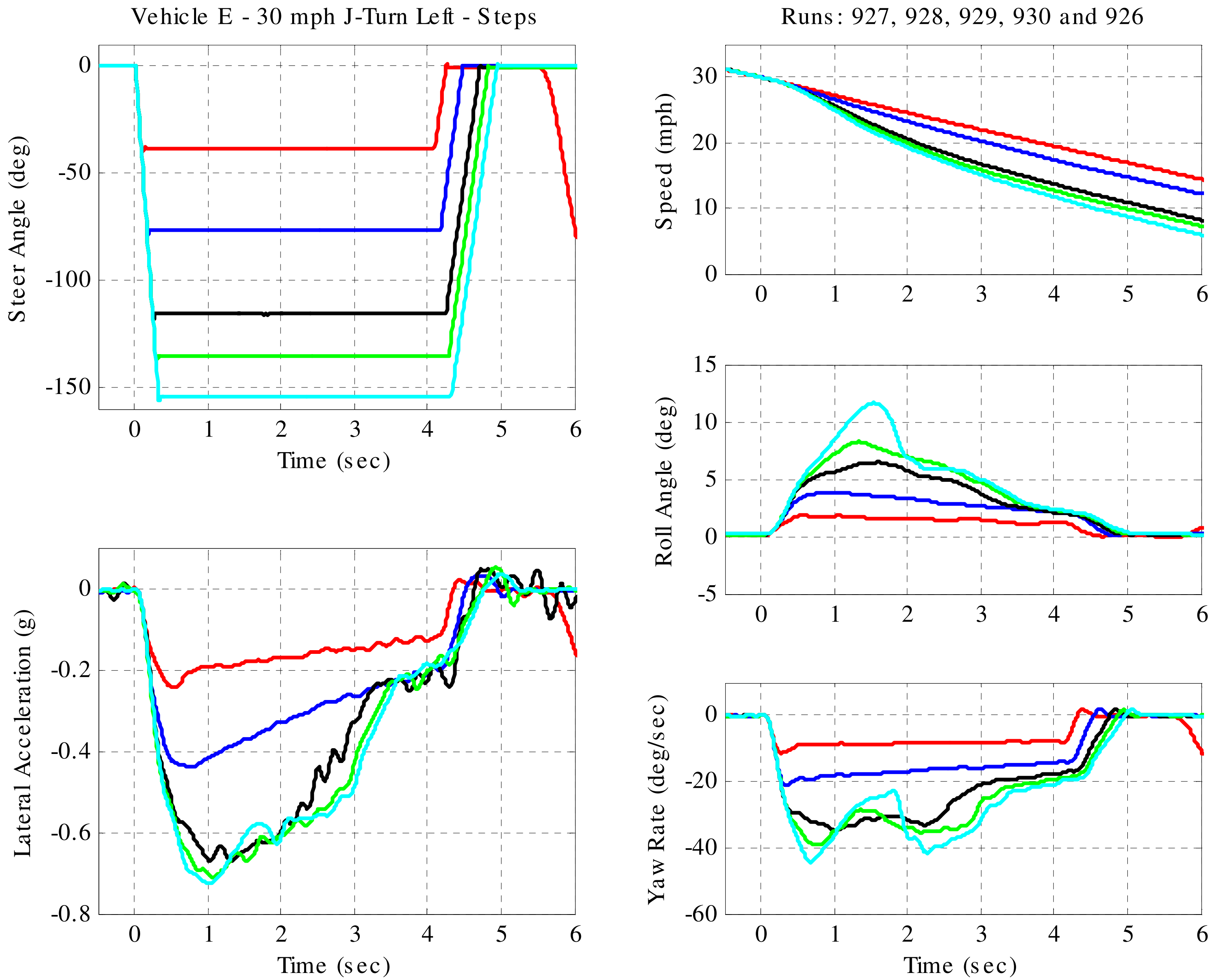
Vehicle D - 30 mph J-Turn Left - Steps
Runs: 734, 735, 737, 738 and 732
Steer Angle (deg)
0
-20
-40
-60
-80
-100
-120
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60
0 1 2 3 4 5 6

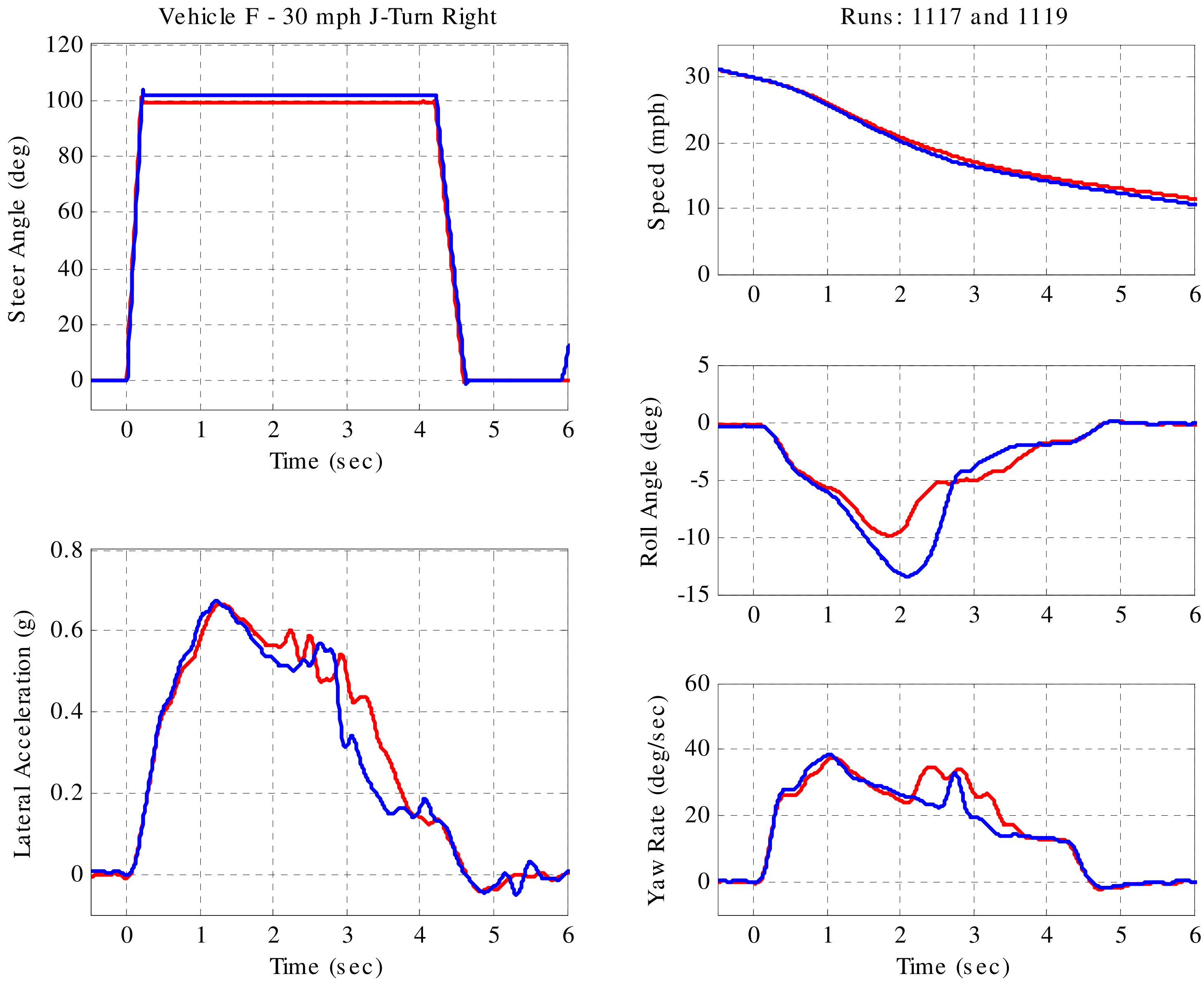

Vehicle E - 30 mph J-Turn Right
Runs: 913 and 915
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

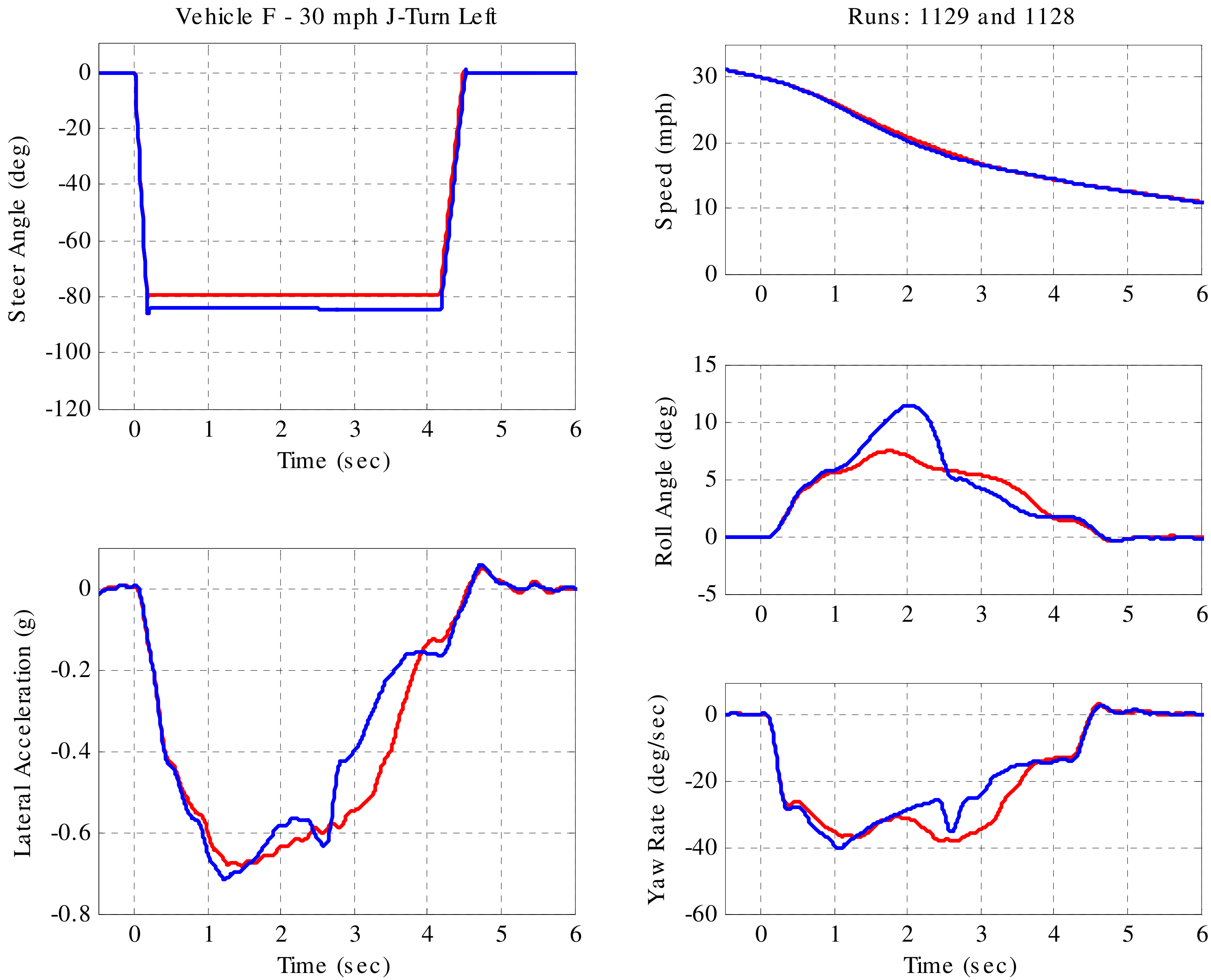


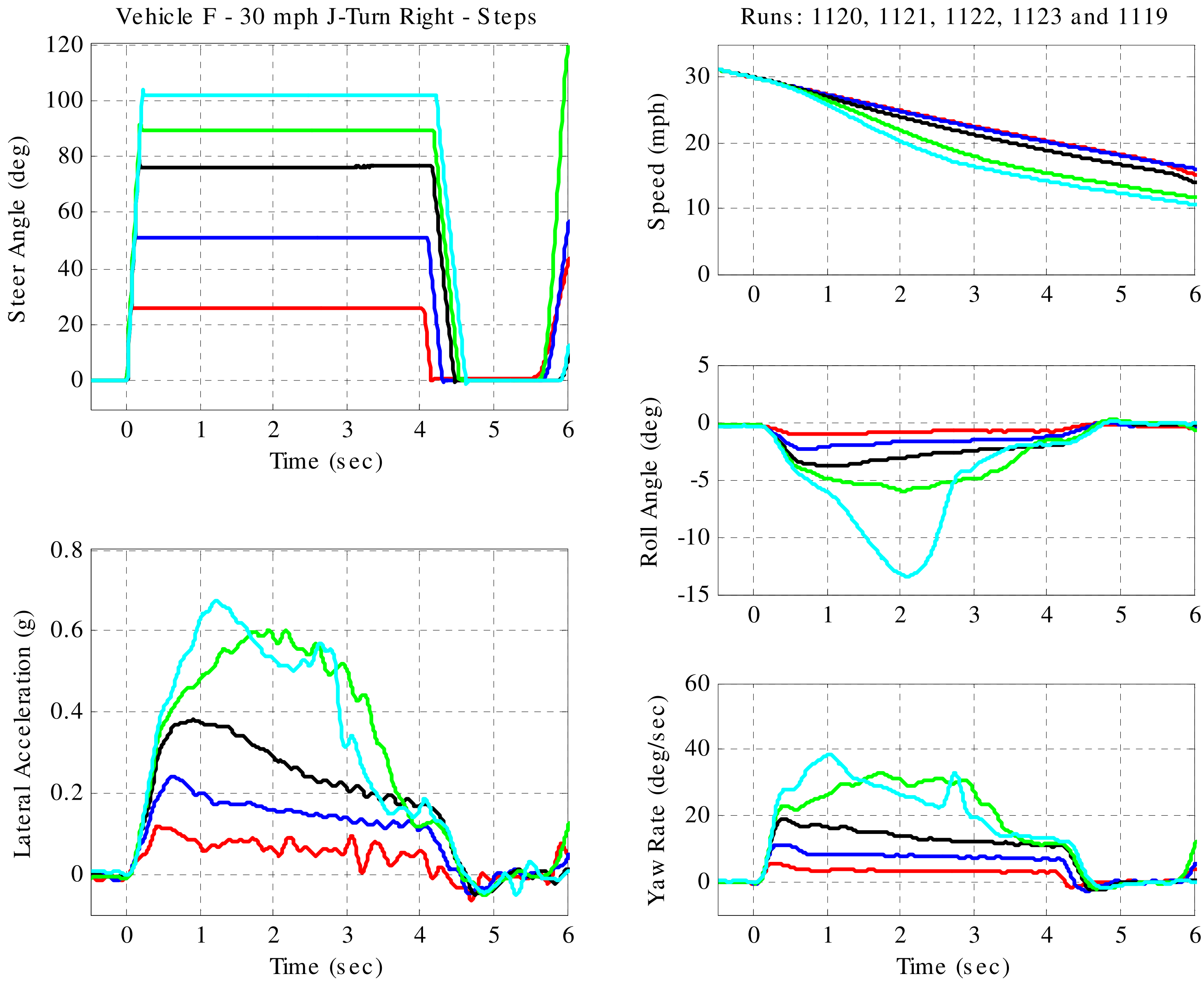
Vehicle E - 30 mph J-Turn Left
Runs: 925 and 926
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

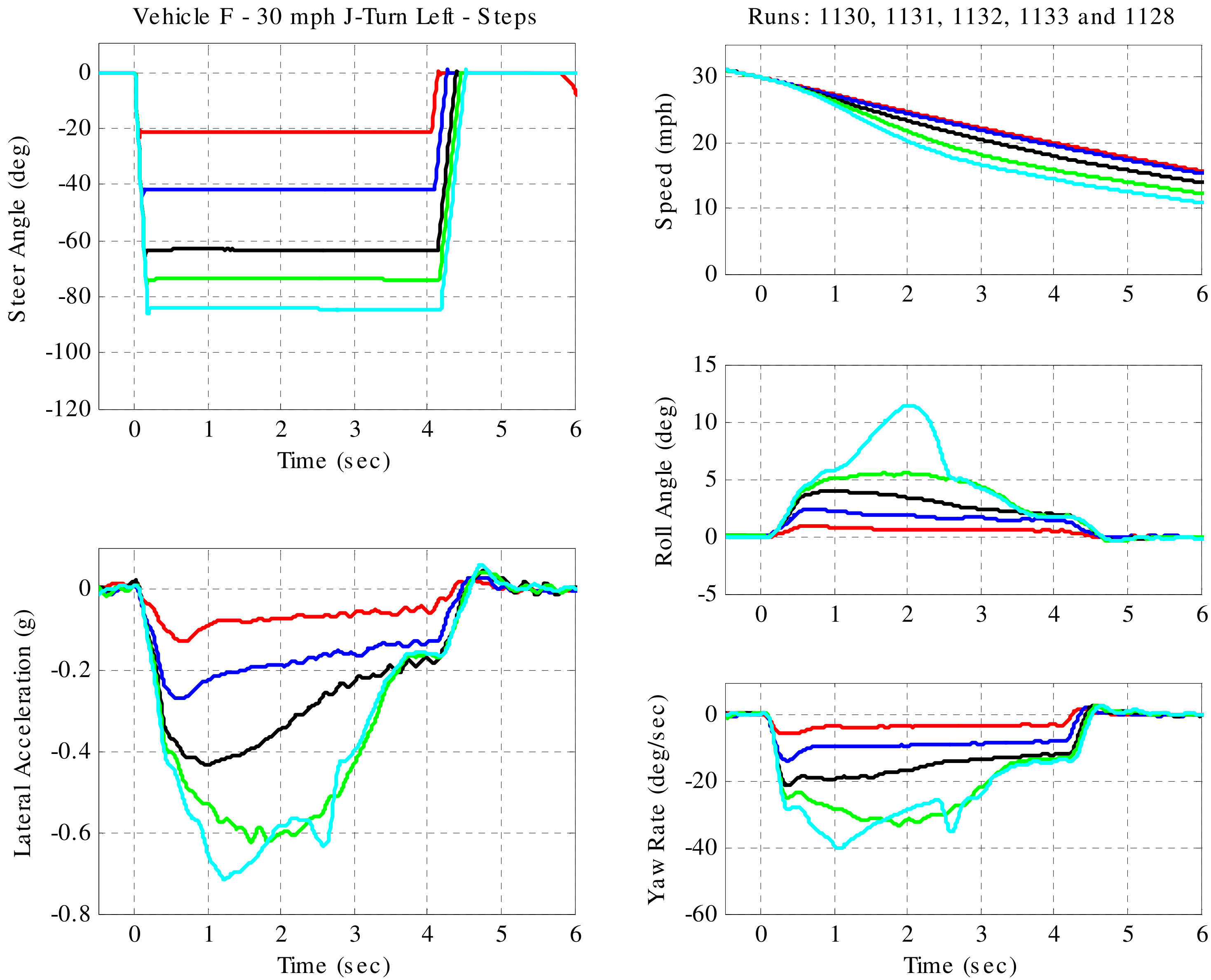

Vehicle E - 30 mph J-Turn Right - Steps
Runs: 916, 917, 918, 919 and 915
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle E - 30 mph J-Turn Left - Steps
Runs: 927, 928, 929, 930 and 926
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

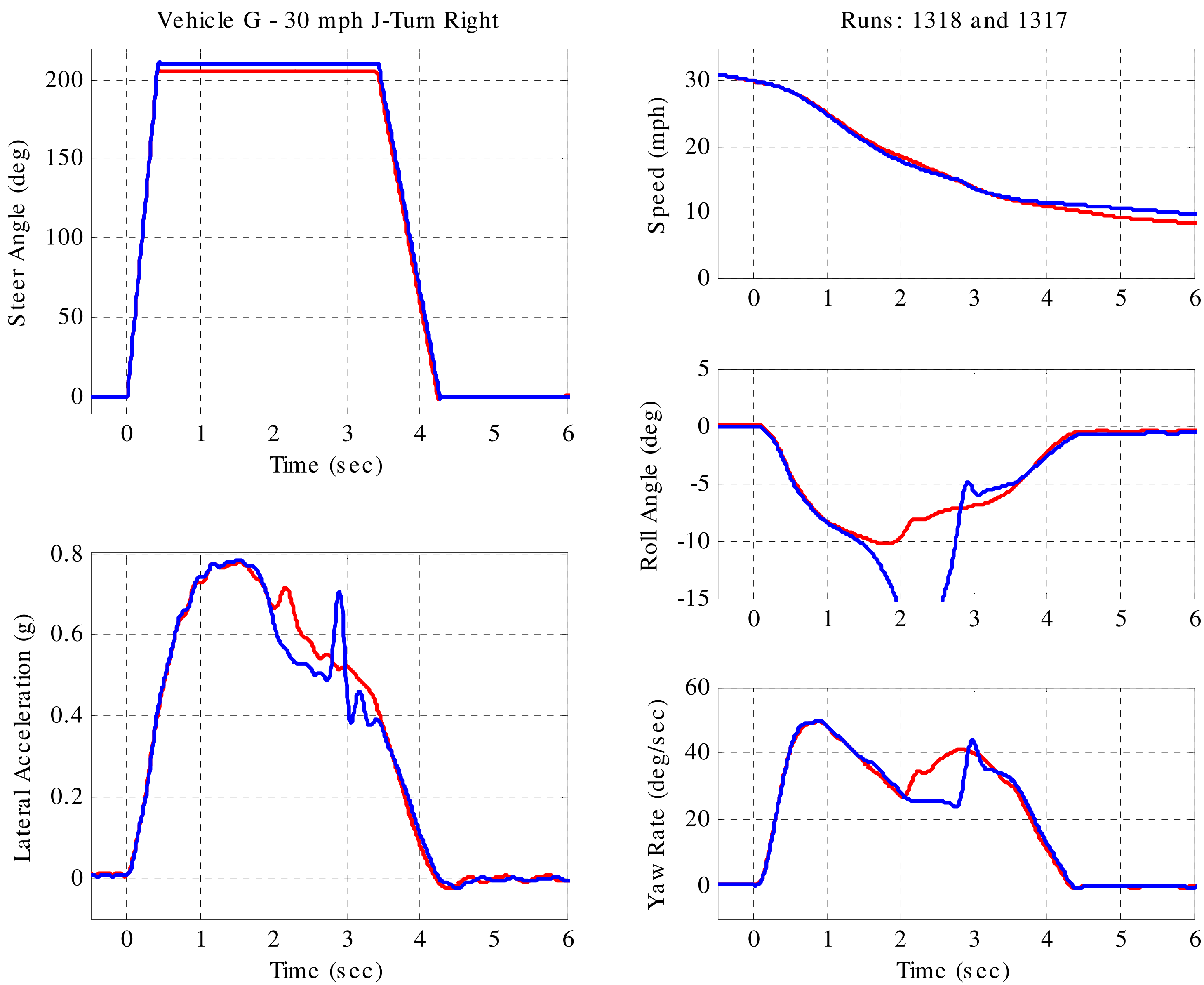

Vehicle F - 30 mph J-Turn Right
Runs: 1117 and 1119
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)

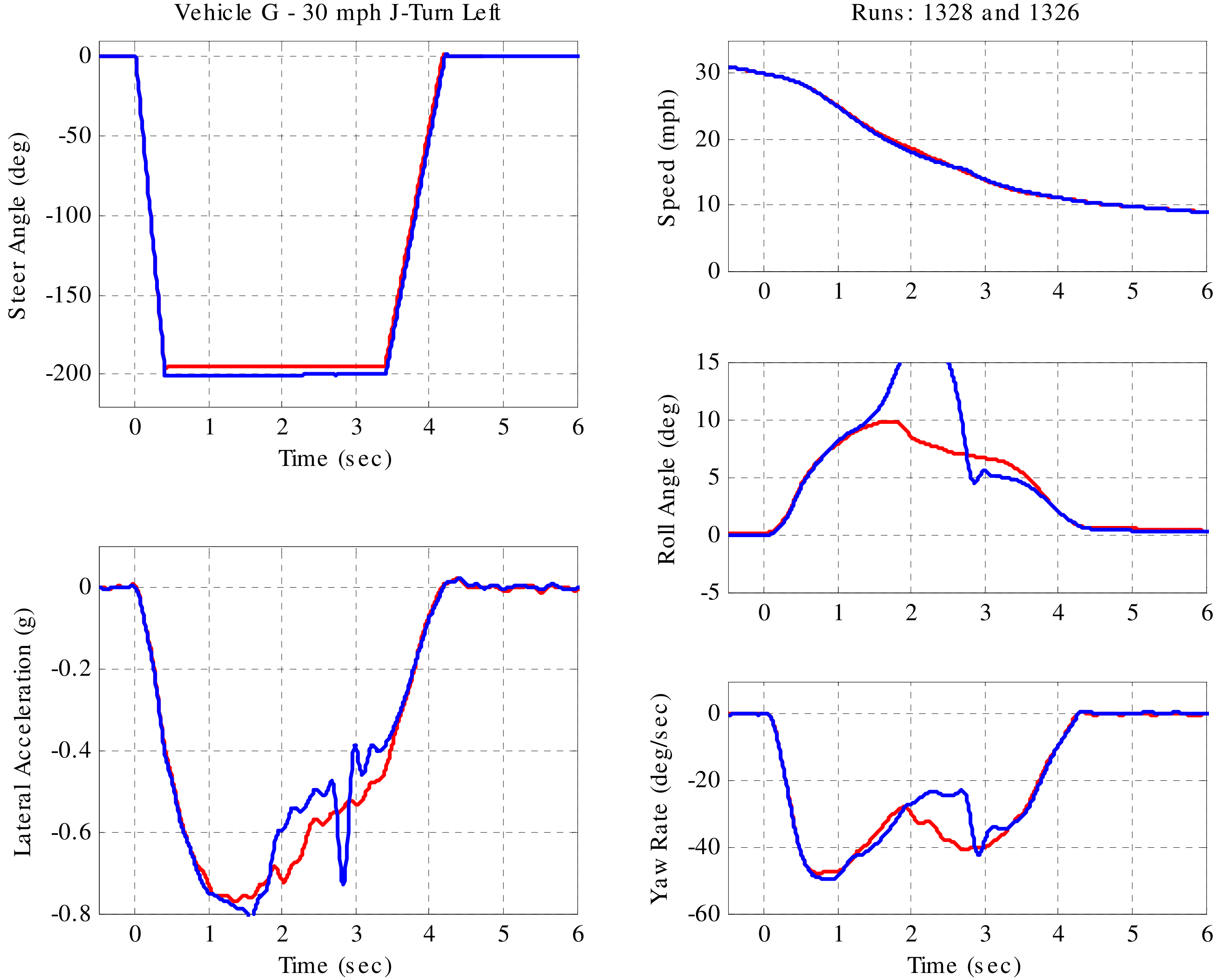

Vehicle F - 30 mph J-Turn Left
Runs: 1129 and 1128
Steer Angle (deg)
0
-20
-40
-60
-80
-100
-120
Time (sec)
Speed (mph)
30
20
10
Roll Angle (deg)
15
5
-5
Lateral Acceleration (g)
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
1
2
3
4
6


Vehicle F - 30 mph J-Turn Right - Steps
Runs: 1120, 1121, 1122, 1123 and 1119
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

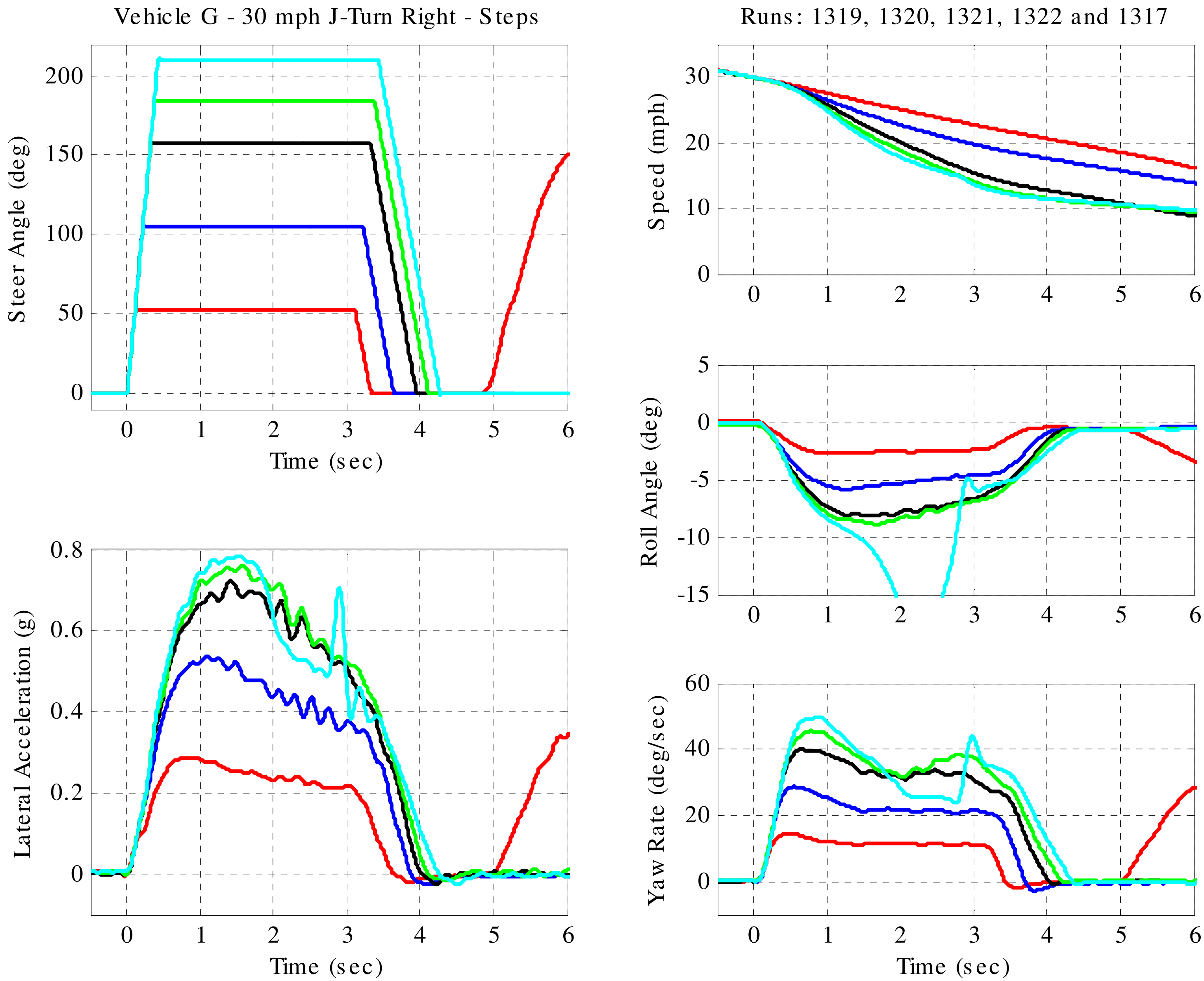


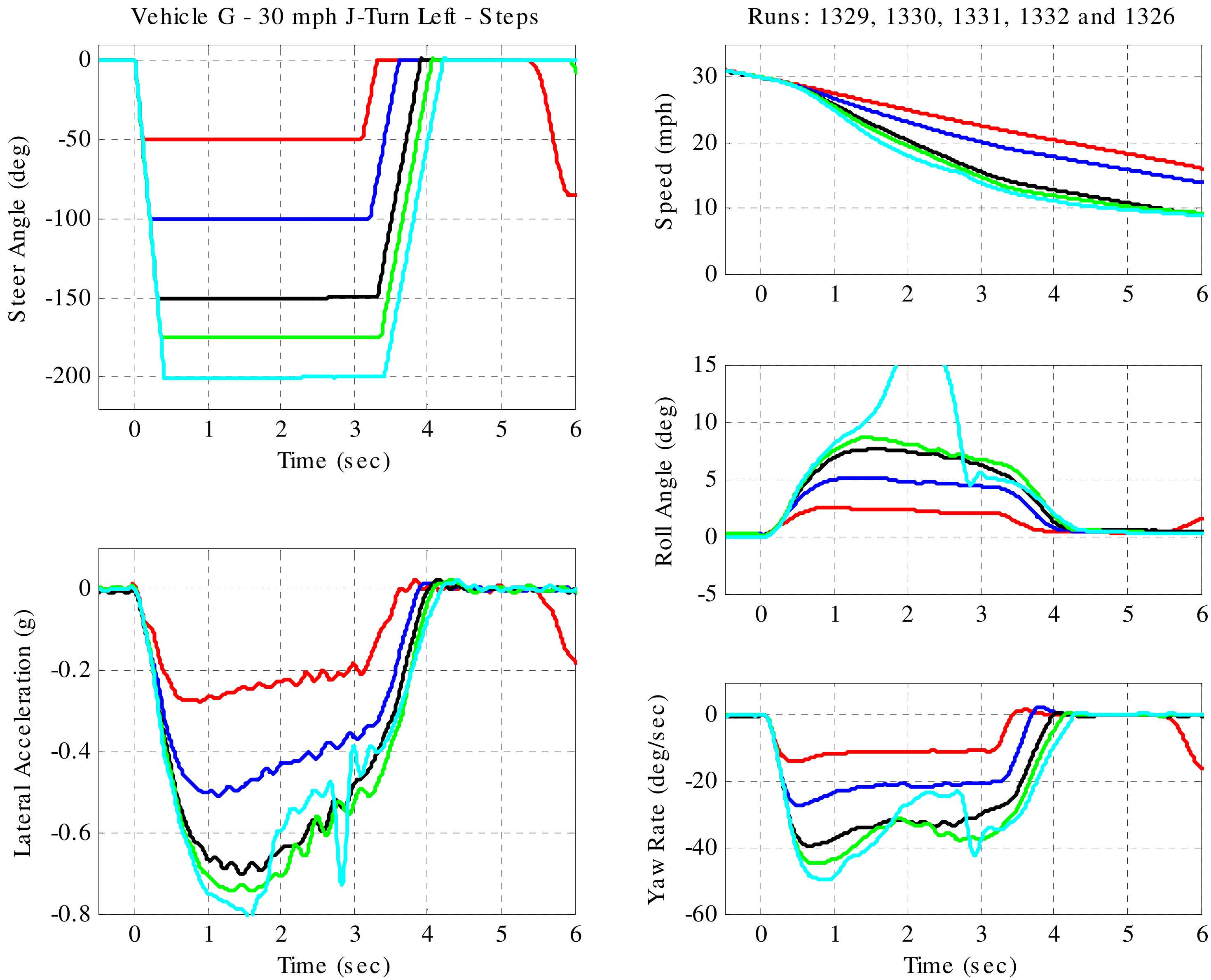
Vehicle F - 30 mph J-Turn Left - Steps
Runs: 1130, 1131, 1132, 1133 and 1128
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle G - 30 mph J-Turn Right
Runs: 1318 and 1317
Steer Angle (deg)
200
150
100
50
0
0
1
2
3
4
5
6
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
5
0
-5
-10
-15
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Yaw Rate (deg/sec)
60
40
20
0

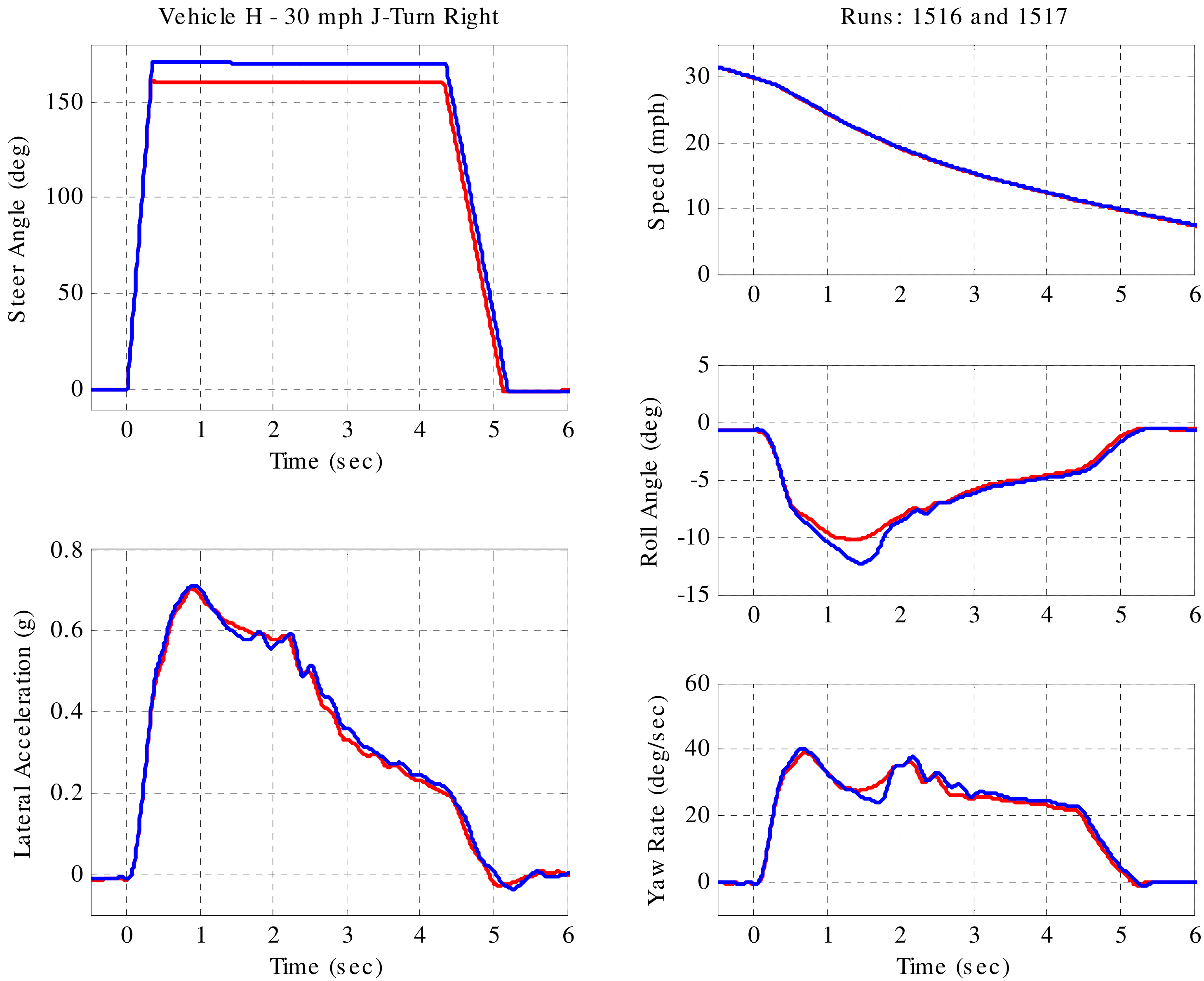


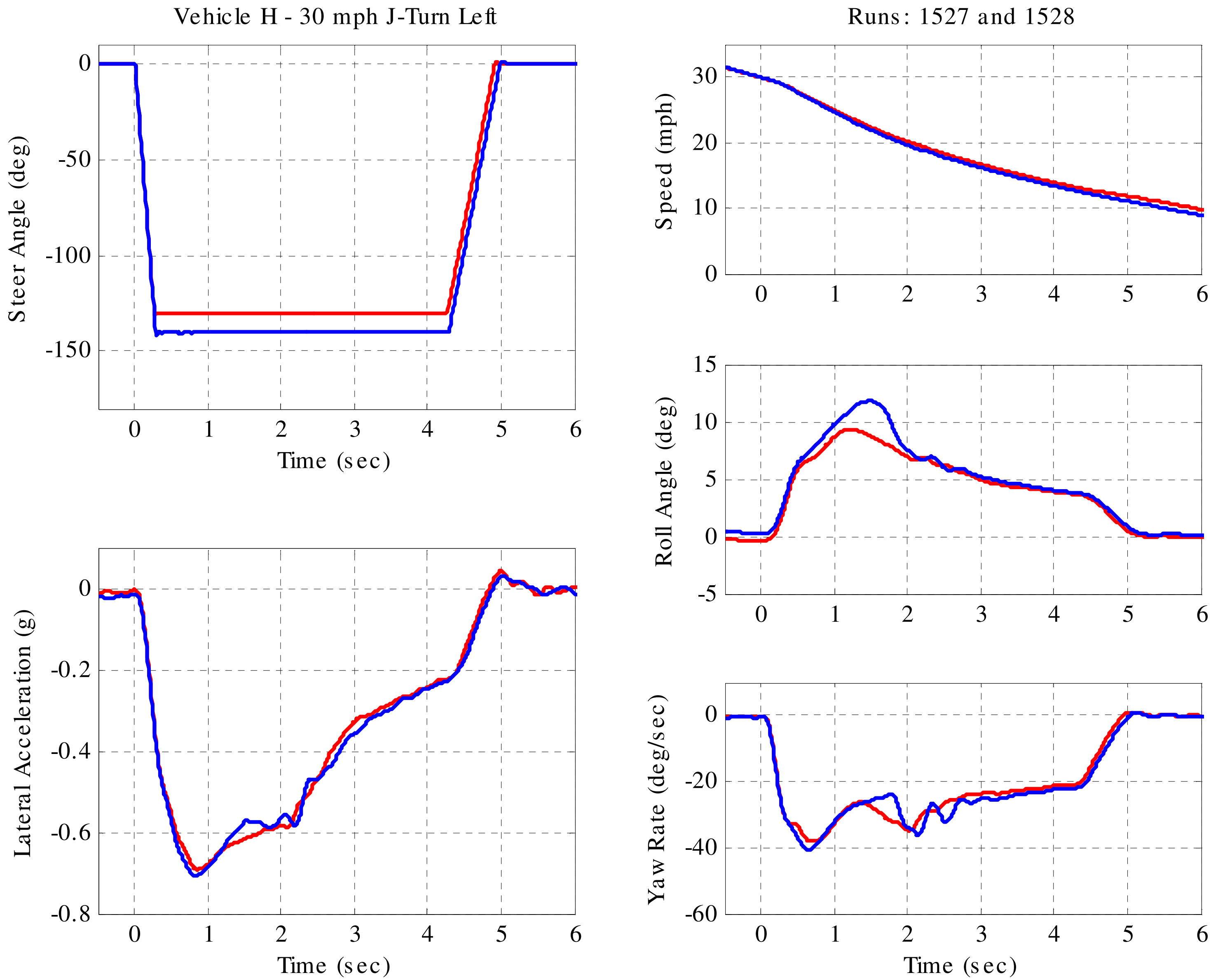
Vehicle G - 30 mph J-Turn Left
Runs: 1328 and 1326
Steer Angle (deg)
0
-50
-100
-150
-200
Time (sec)
0 1 2 3 4 5 6
Speed (mph)
30
20
10
0
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60

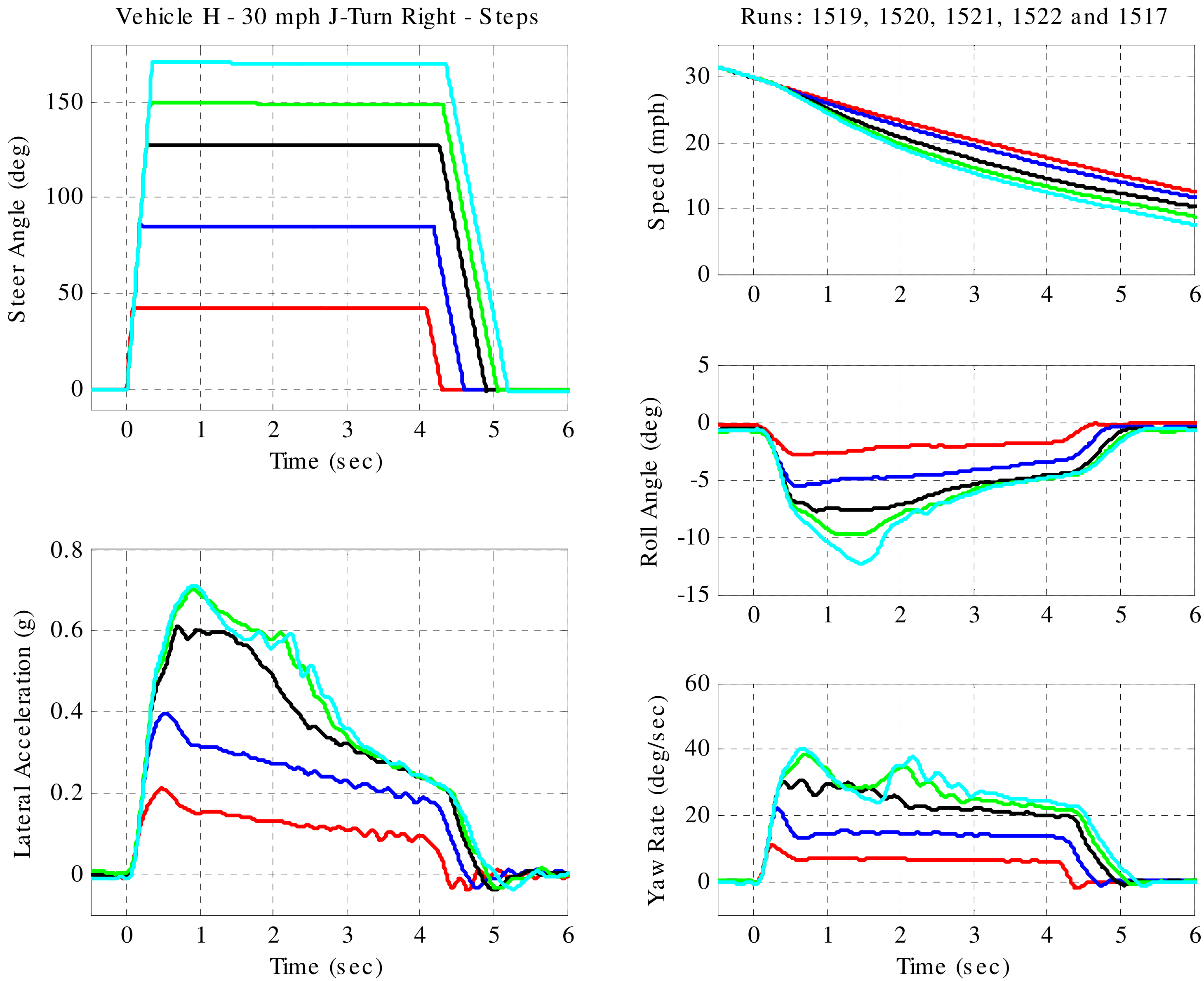

Vehicle G - 30 mph J-Turn Right - Steps
Runs: 1319, 1320, 1321, 1322 and 1317
Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

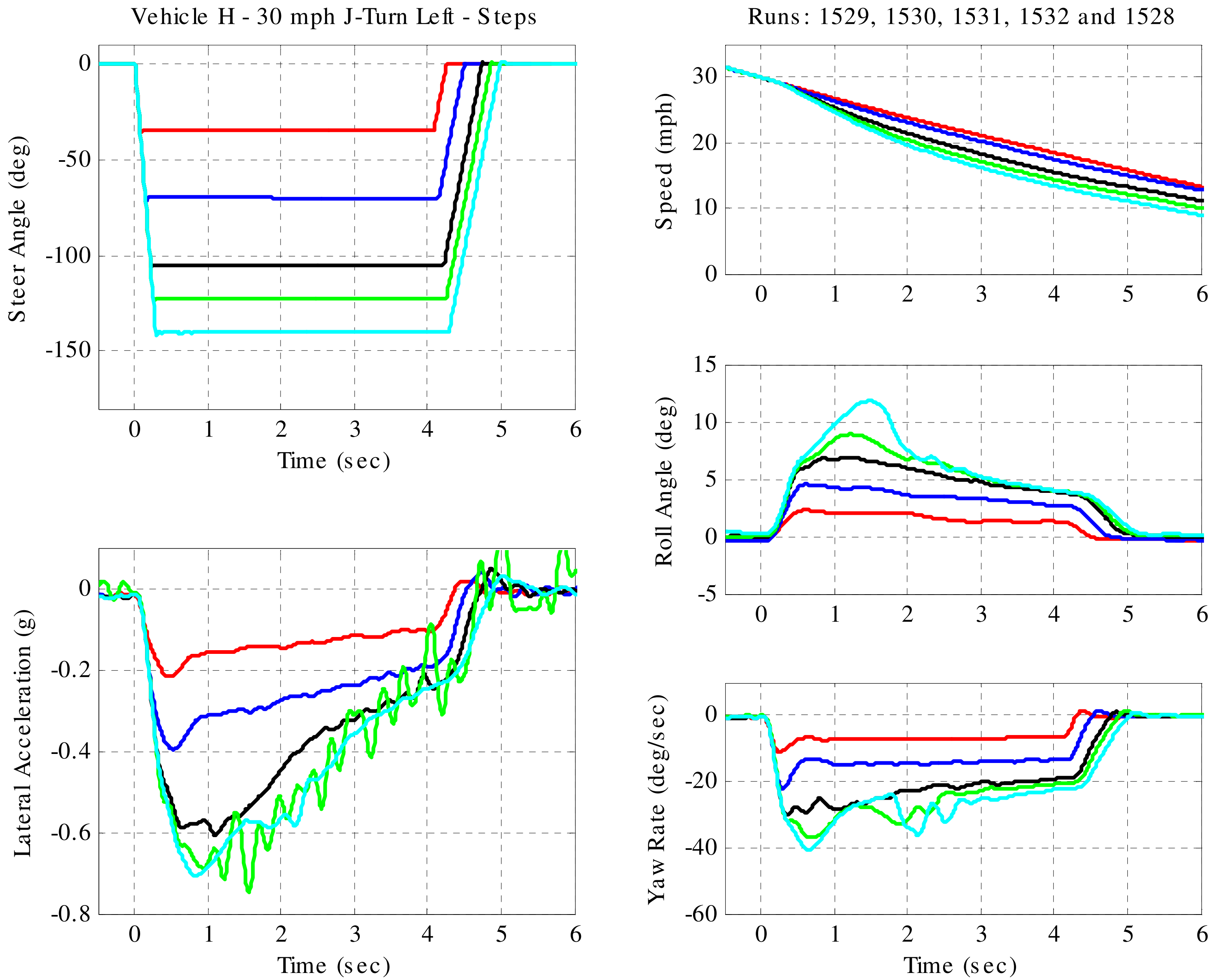


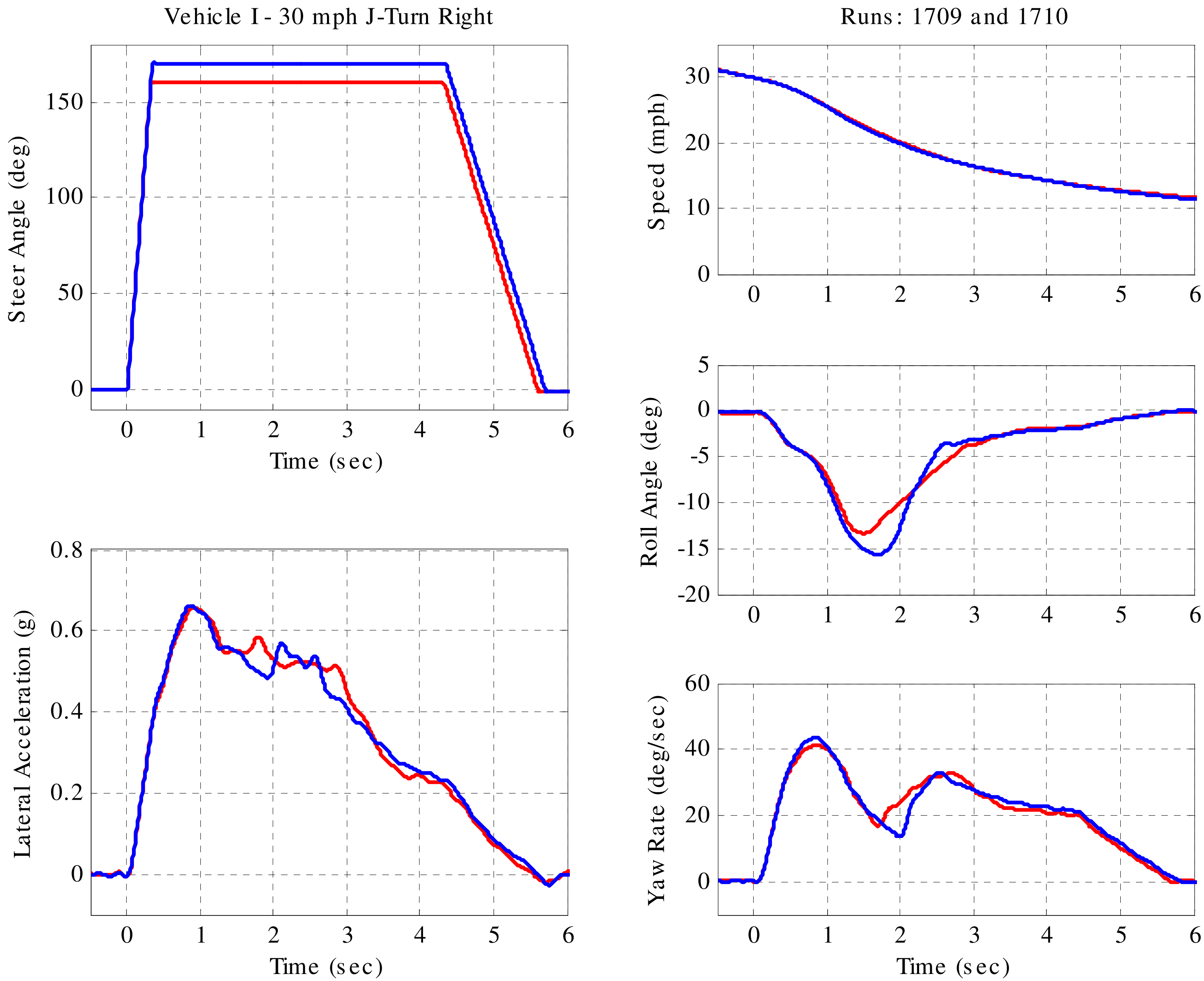
Vehicle G - 30 mph J-Turn Left - Steps
Runs: 1329, 1330, 1331, 1332 and 1326
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

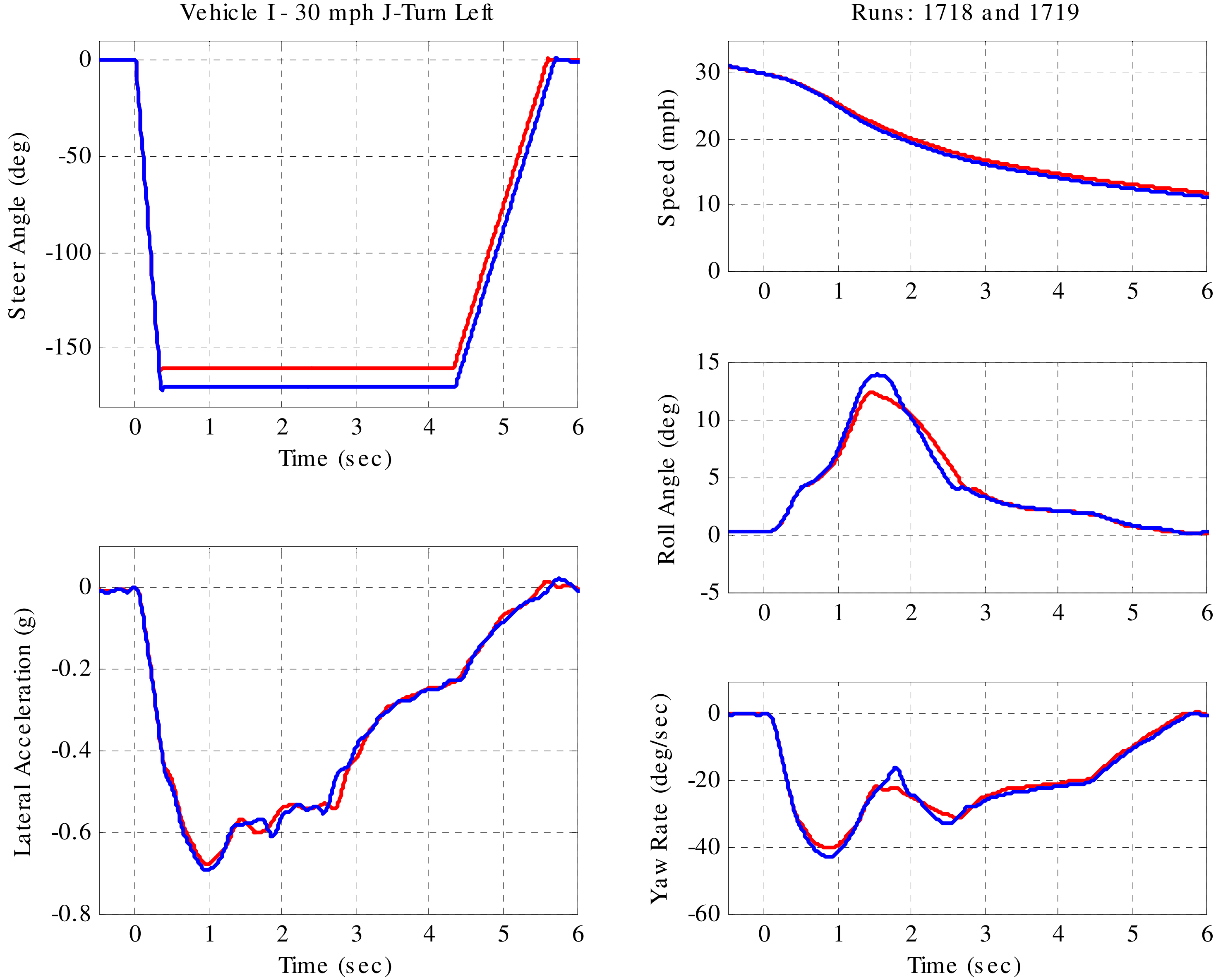

Vehicle H - 30 mph J-Turn Right
Runs: 1516 and 1517
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle H - 30 mph J-Turn Left
Runs: 1527 and 1528
Steer Angle (deg)
0
-50
-100
-150
Time (sec)
0
1
2
3
4
5
6
Speed (mph)
30
20
10
0
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60

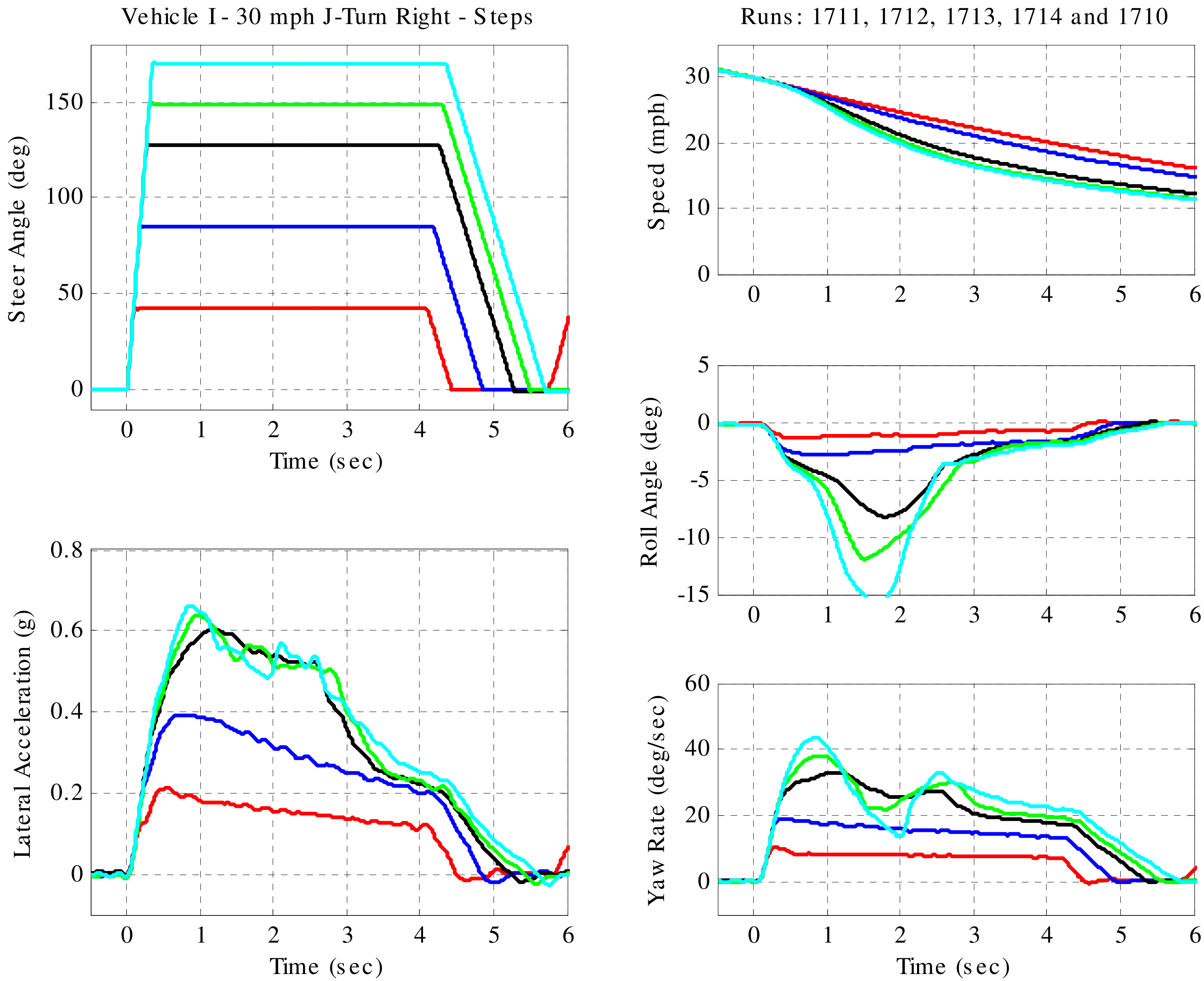

Vehicle H - 30 mph J-Turn Right - Steps
Runs: 1519, 1520, 1521, 1522 and 1517
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

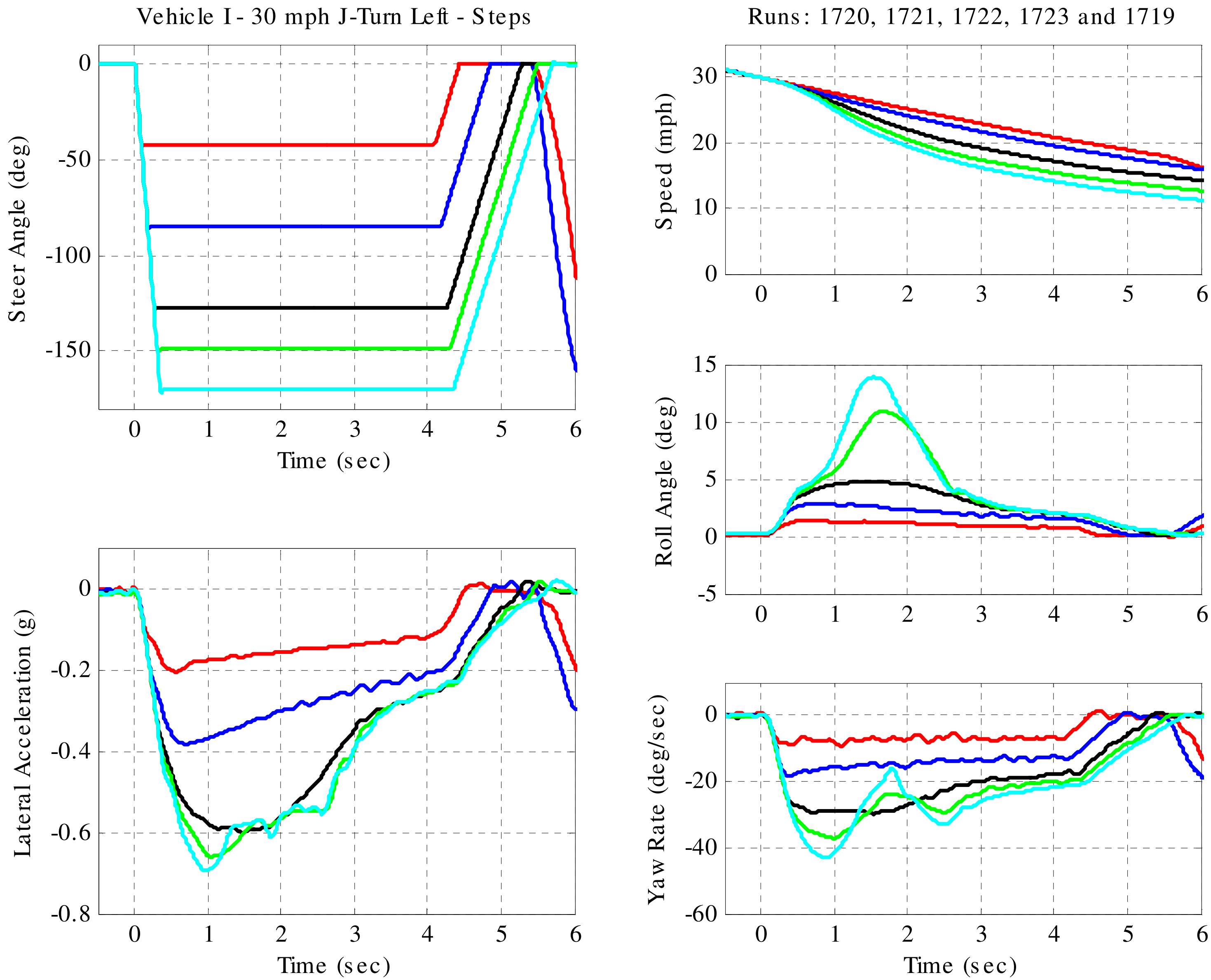

Vehicle H - 30 mph J-Turn Left - Steps
Runs: 1529, 1530, 1531, 1532 and 1528
Steer Angle (deg)
0
-50
-100
-150
Time (sec)
Speed (mph)
30
20
10
Roll Angle (deg)
15
5
-5
Lateral Acceleration (g)
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
-20
-40
-60
0 1 2 3 4 5 6


Vehicle I - 30 mph J-Turn Right
Runs: 1709 and 1710
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)



Vehicle I - 30 mph J-Turn Left
Runs: 1718 and 1719
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)


Vehicle I - 30 mph J-Turn Right - Steps
Runs: 1711, 1712, 1713, 1714 and 1710
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)



Vehicle I - 30 mph J-Turn Left - Steps
Runs: 1720, 1721, 1722, 1723 and 1719
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle A – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	26.3	0.17	-21.3	-0.16	23.8	0.165
50.0	52.5	0.32	-42.5	-0.31	47.5	0.315
75.0	78.8	0.44	-63.8	-0.53	71.3	0.485
87.5	91.9	0.61	-74.4	-0.63	83.1	0.620
100.0	105.0	0.67	-85.0	-0.67	95.0	0.670

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle B – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	30.0	0.21	-32.5	-0.20	31.3	0.205
50.0	60.0	0.38	-65.0	-0.35	62.5	0.365
75.0	90.0	0.53	-97.5	-0.49	93.8	0.510
87.5	105.0	0.59	-113.8	-0.58	109.4	0.585
100.0	120.0	0.67	-130.0	-0.64	125.0	0.655

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle C – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	35.0	0.25	-33.8	-0.25	34.4	0.250
50.0	70.0	0.51	-67.5	-0.46	68.8	0.485
75.0	105.0	0.70	-101.3	-0.66	103.1	0.680
87.5	122.5	0.73	-118.1	-0.72	120.3	0.725
100.0	140.0	0.74	-135.0	-0.74	137.5	0.740

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle D – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	23.8	0.17	-26.3	-0.17	25.0	0.170
50.0	47.5	0.37	-52.5	-0.40	50.0	0.385
75.0	71.3	0.56	-78.8	-0.57	75.0	0.565
87.5	83.1	0.60	-91.9	-0.61	87.5	0.605
100.0	95.0	0.62	-105.0	-0.63	100.0	0.625

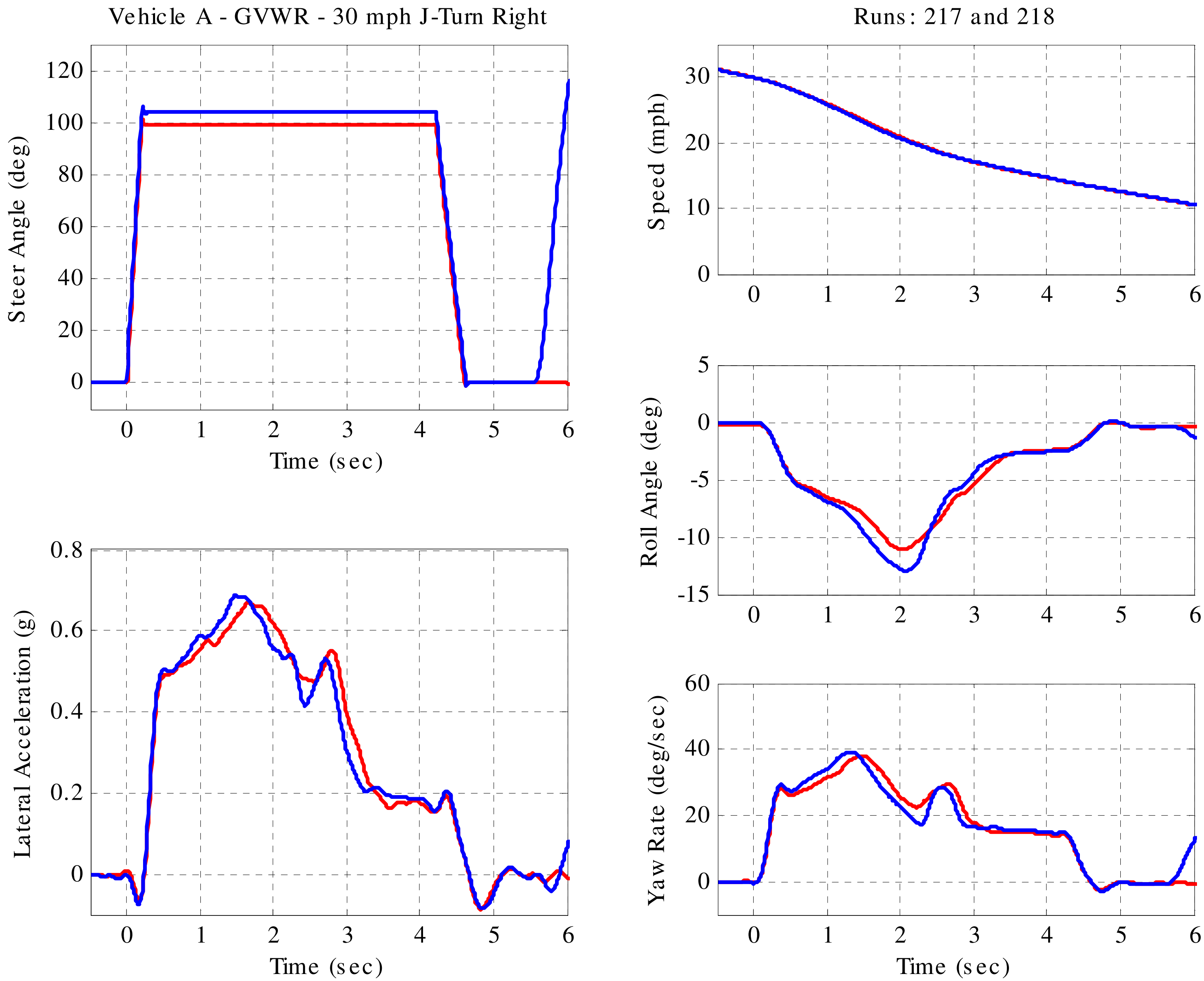
Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle E – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	36.3	0.20	-38.8	-0.24	37.5	0.220
50.0	72.5	0.38	-77.5	-0.43	75.0	0.405
75.0	108.8	0.61	-116.3	-0.66	112.5	0.635
87.5	126.9	0.65	-135.6	-0.70	131.3	0.675
100.0	145.0	0.68	-155.0	-0.72	150.0	0.700

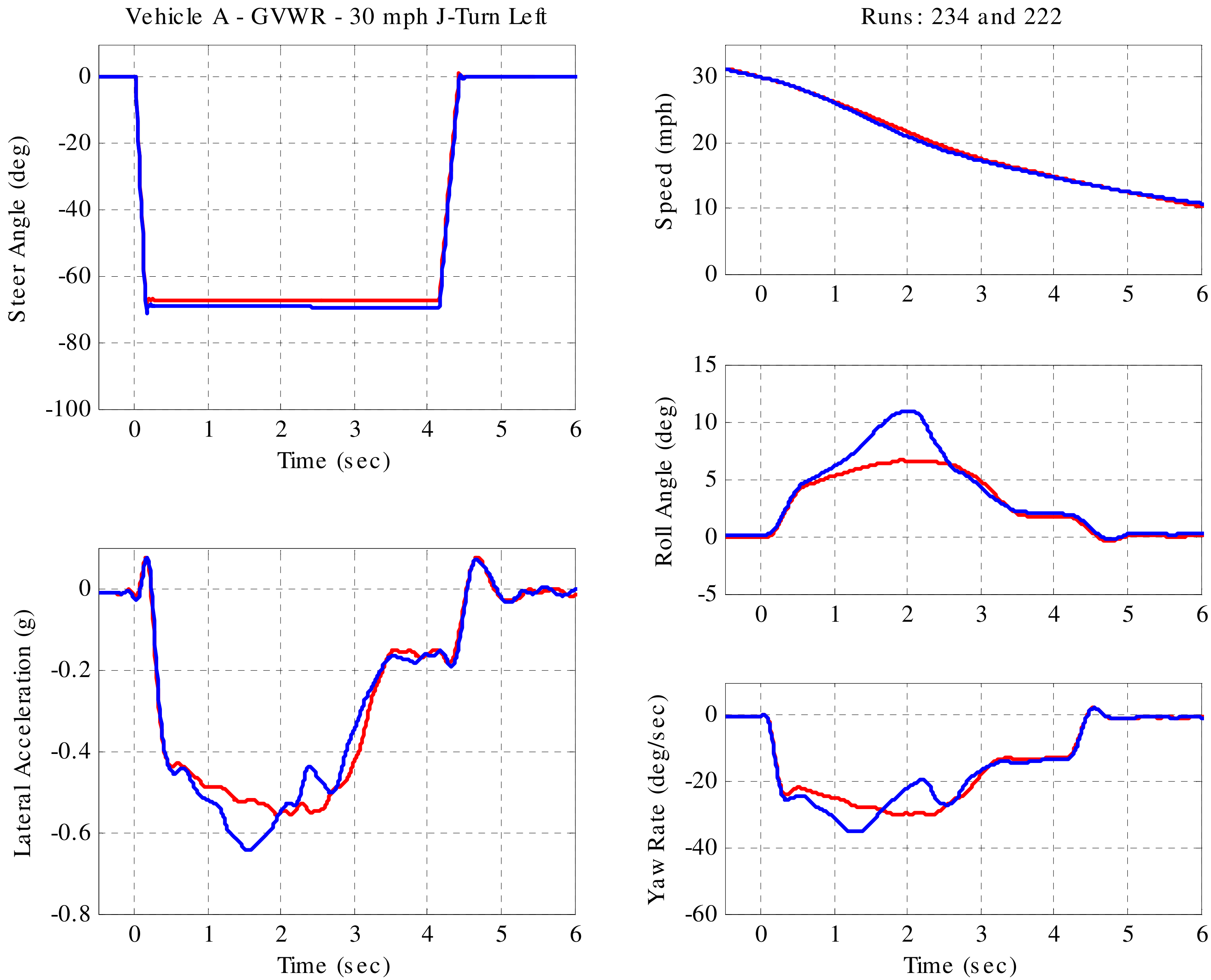
Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle F – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	25.6	0.11	-21.3	-0.12	23.4	0.115
50.0	51.3	0.23	-42.5	-0.26	46.9	0.245
75.0	76.9	0.38	-63.8	-0.43	70.3	0.405
87.5	89.7	0.59	-74.4	-0.61	82.0	0.600
100.0	102.5	0.67	-85.0	-0.71	93.8	0.690

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle G – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	52.5	0.28	-50.0	-0.27	51.3	0.275
50.0	105.0	0.53	-100.0	-0.50	102.5	0.515
75.0	157.5	0.71	-150.0	-0.69	153.8	0.700
87.5	183.8	0.76	-175.0	-0.74	179.4	0.750
100.0	210.0	0.78	-200.0	-0.79	205.0	0.785

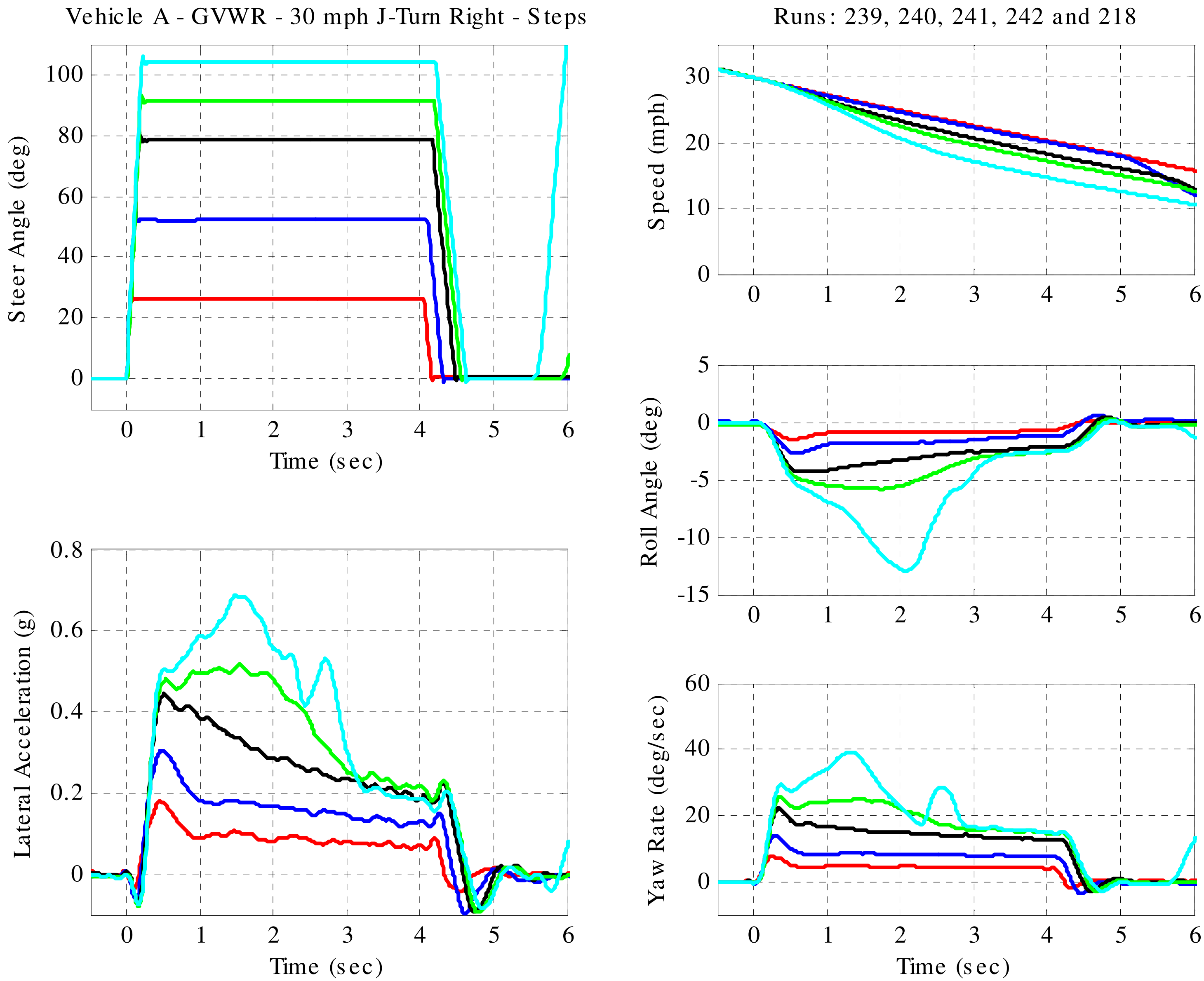
Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle H – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	42.5	0.21	-35.0	-0.21	38.8	0.210
50.0	85.0	0.39	-70.0	-0.39	77.5	0.390
75.0	127.5	0.61	-105.0	-0.60	116.3	0.605
87.5	148.8	0.70	-122.5	-0.69	135.6	0.695
100.0	170.0	0.71	-140.0	-0.70	155.0	0.705

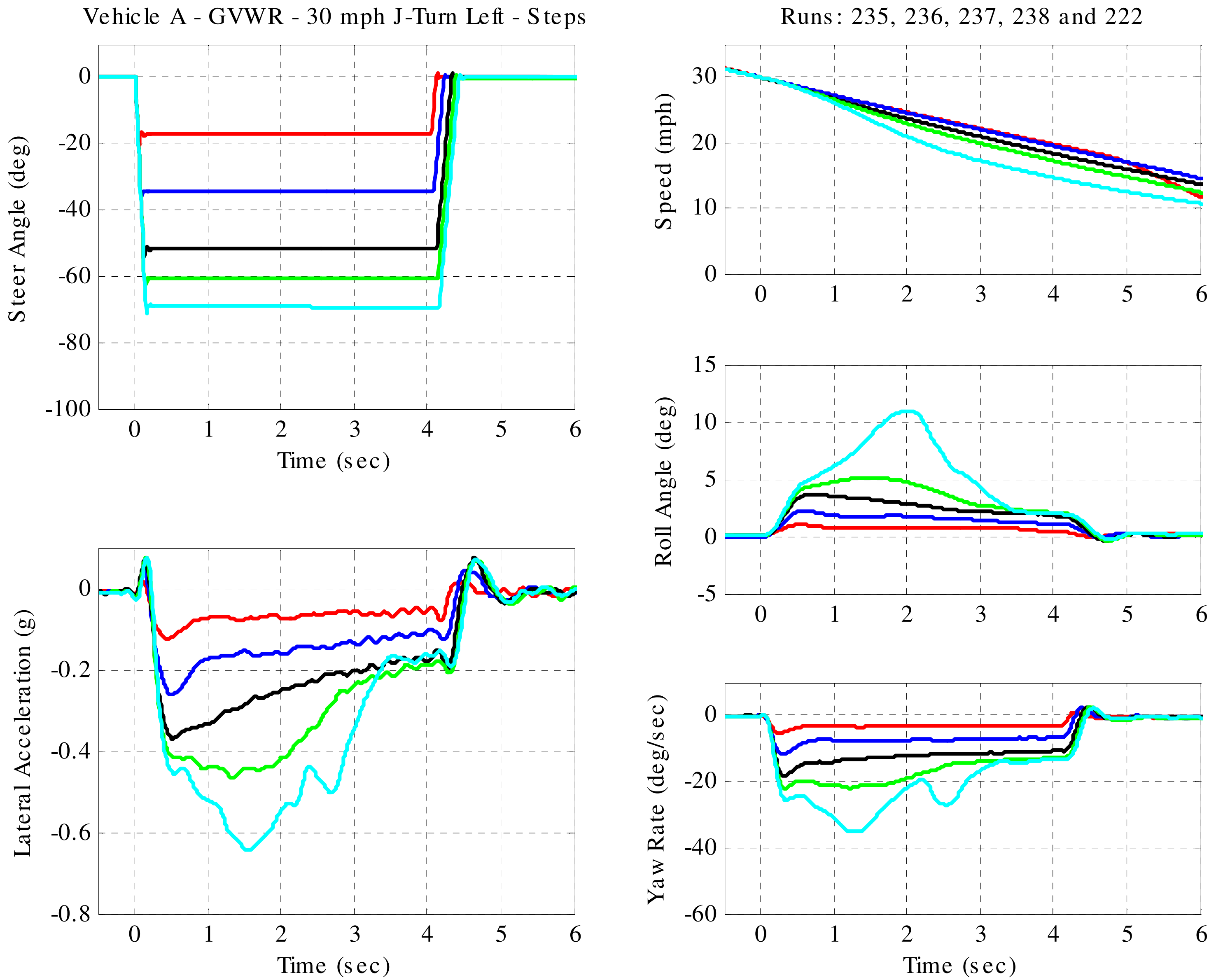
Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle I – Operator and Passenger Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	42.5	0.21	-42.5	-0.20	42.5	0.205
50.0	85.0	0.39	-85.0	-0.38	85.0	0.385
75.0	127.5	0.60	-127.5	-0.60	127.5	0.600
87.5	148.8	0.64	-148.8	-0.65	148.8	0.645
100.0	170.0	0.66	-170.0	-0.69	170.0	0.675


Vehicle A - GVWR - 30 mph J-Turn Right
Runs: 217 and 218
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)

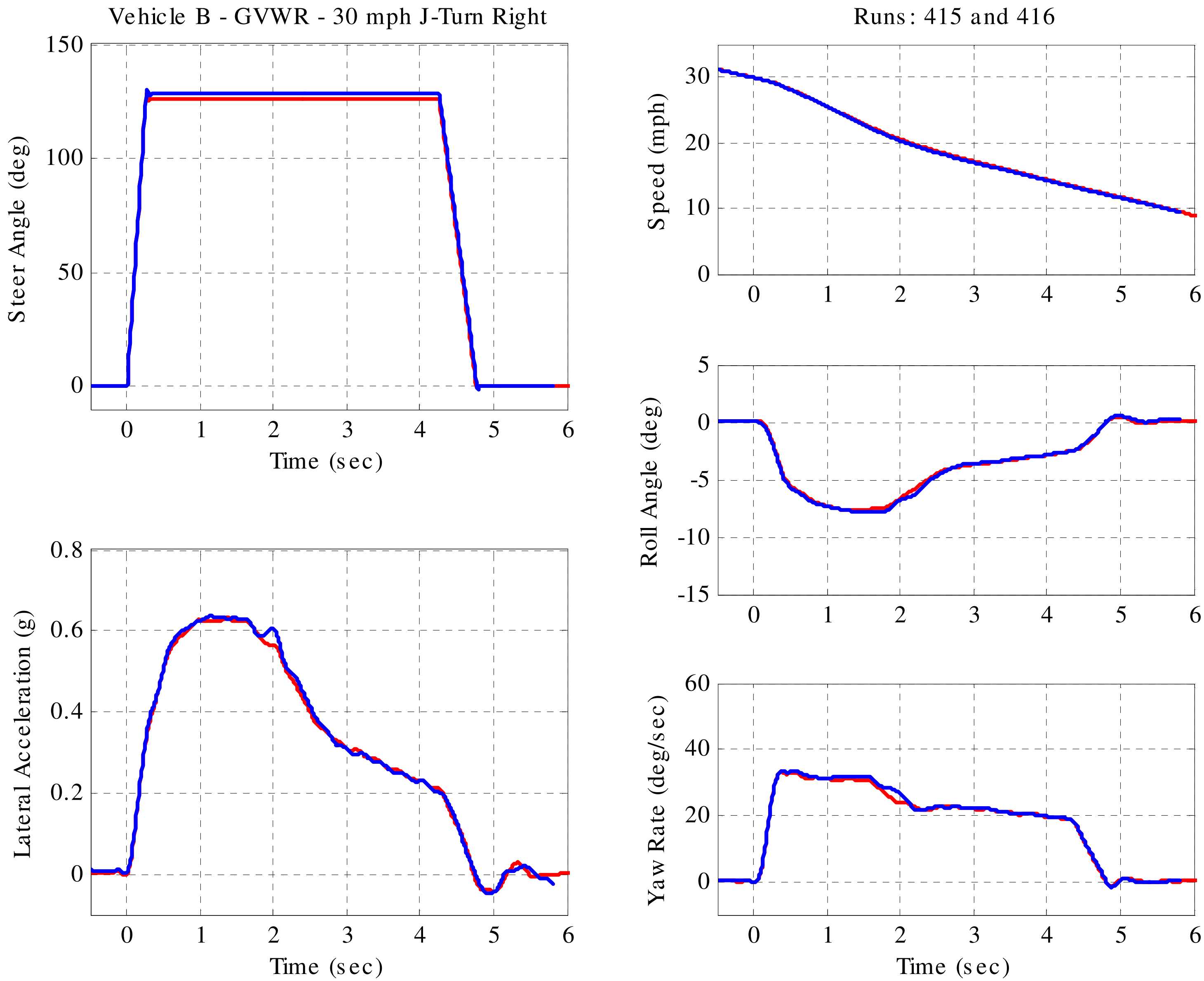


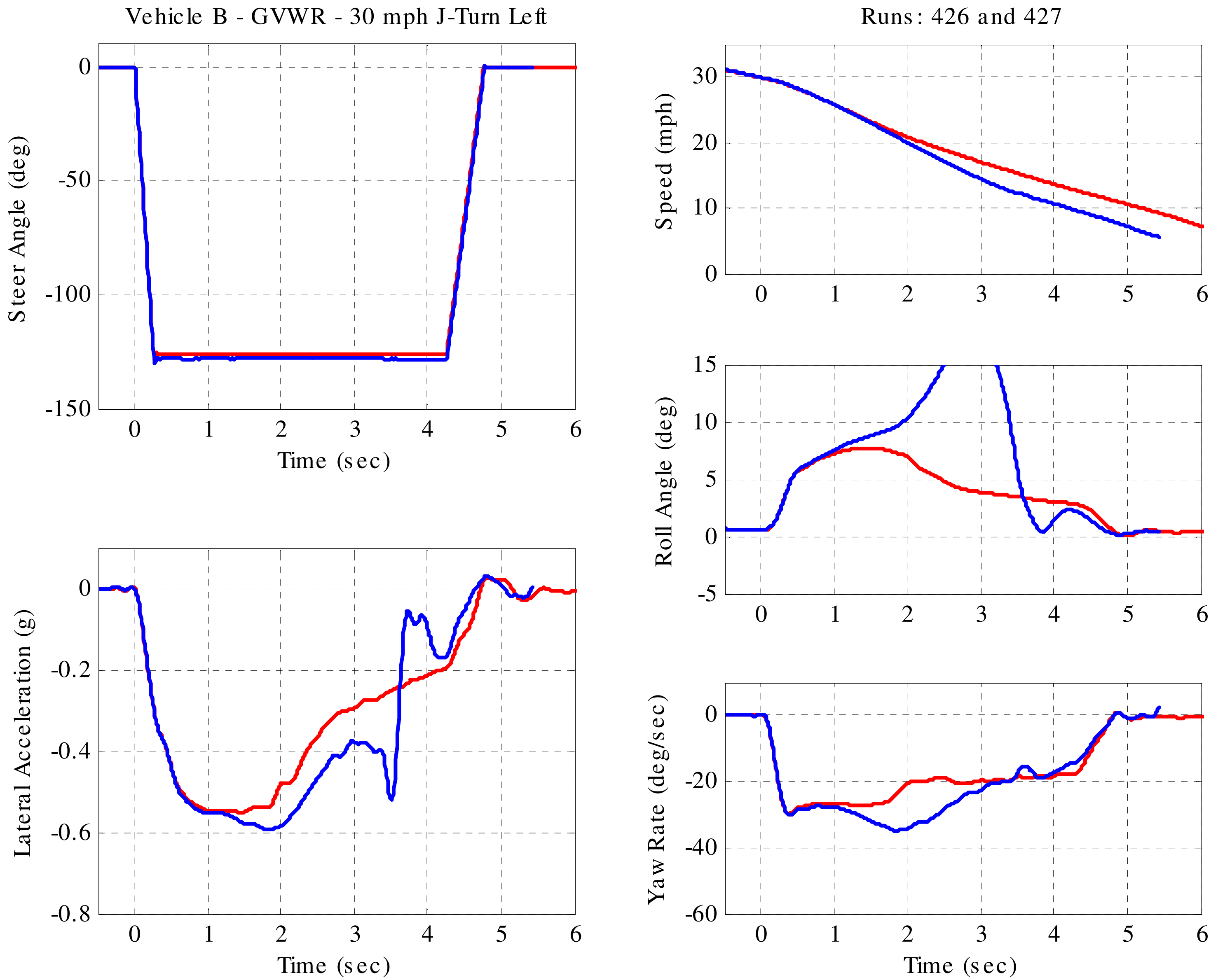
Vehicle A - GVWR - 30 mph J-Turn Left
Runs: 234 and 222
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle A - GVWR - 30 mph J-Turn Right - Steps
Runs: 239, 240, 241, 242 and 218
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

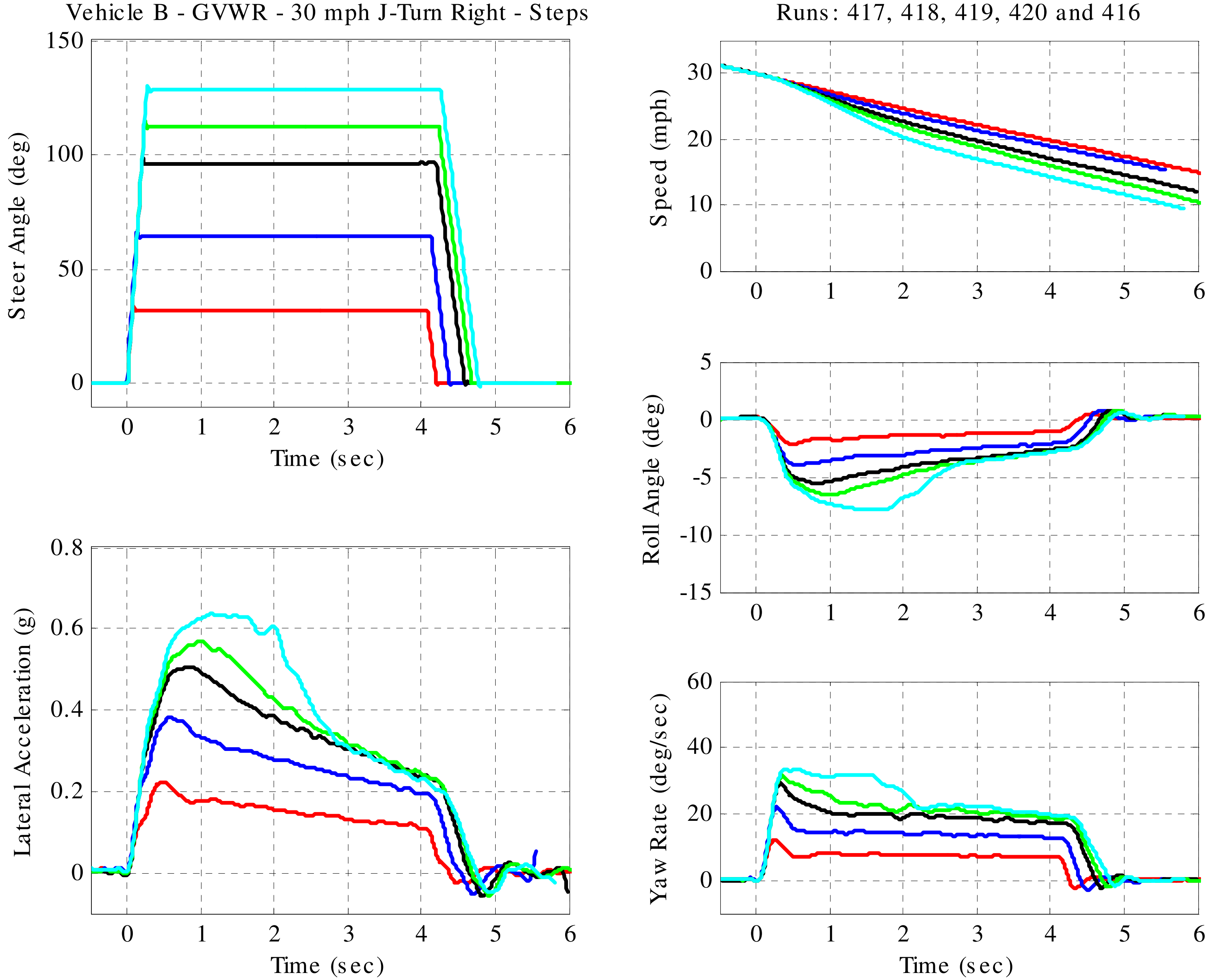


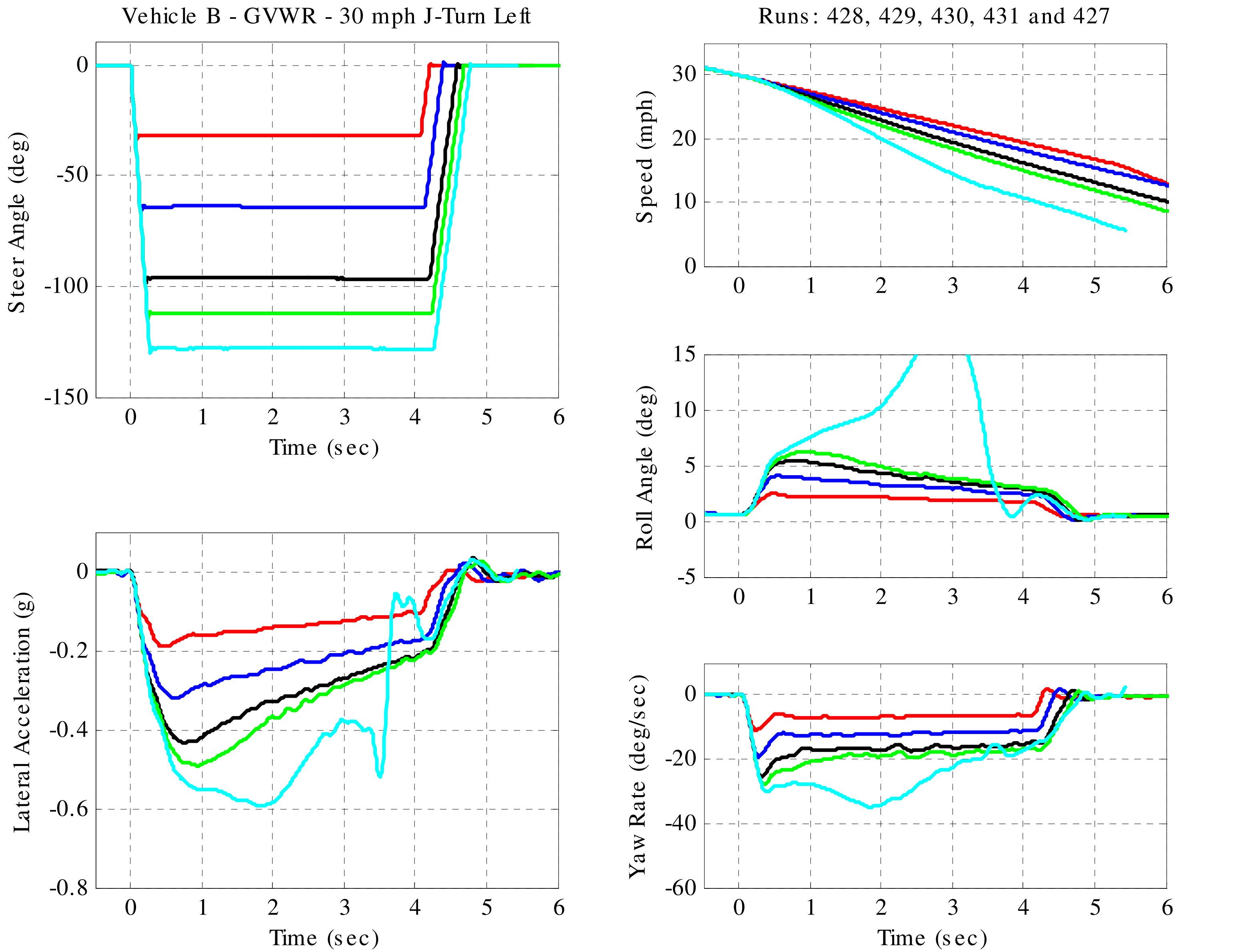
Vehicle A - GVWR - 30 mph J-Turn Left - Steps
Runs: 235, 236, 237, 238 and 222
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle B - GVWR - 30 mph J-Turn Right
Runs: 415 and 416
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

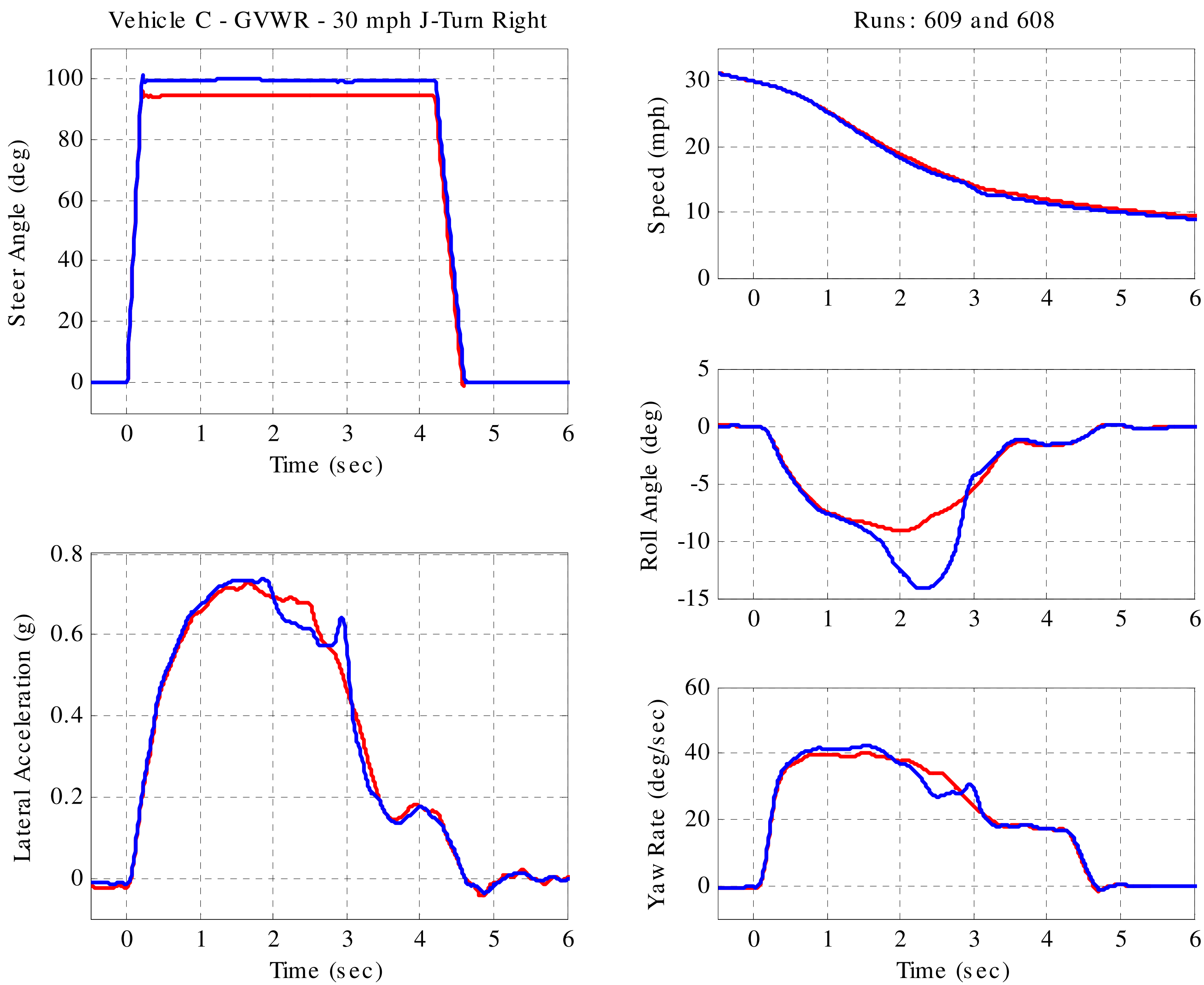


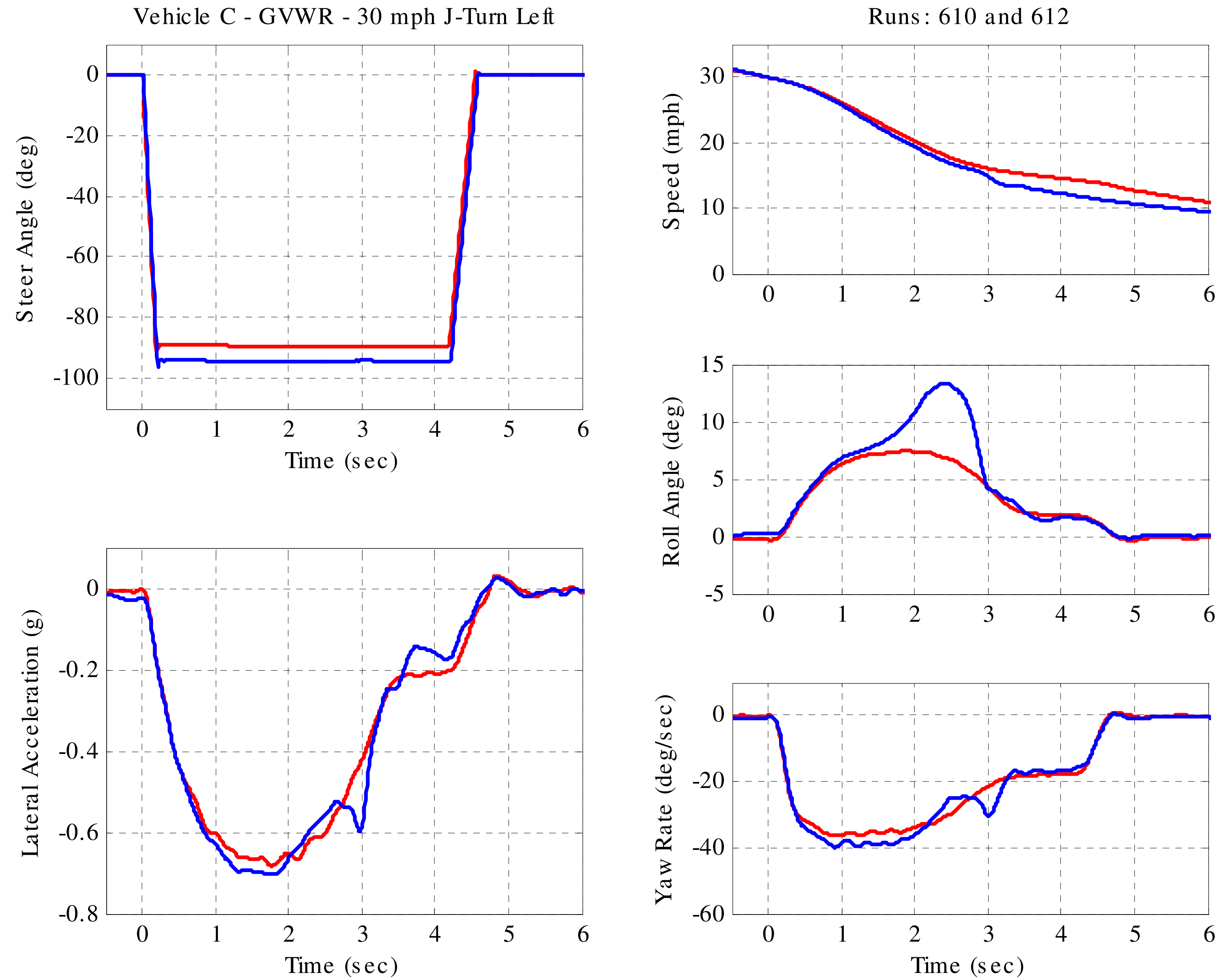
Vehicle B - GVWR - 30 mph J-Turn Left
Runs: 426 and 427
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

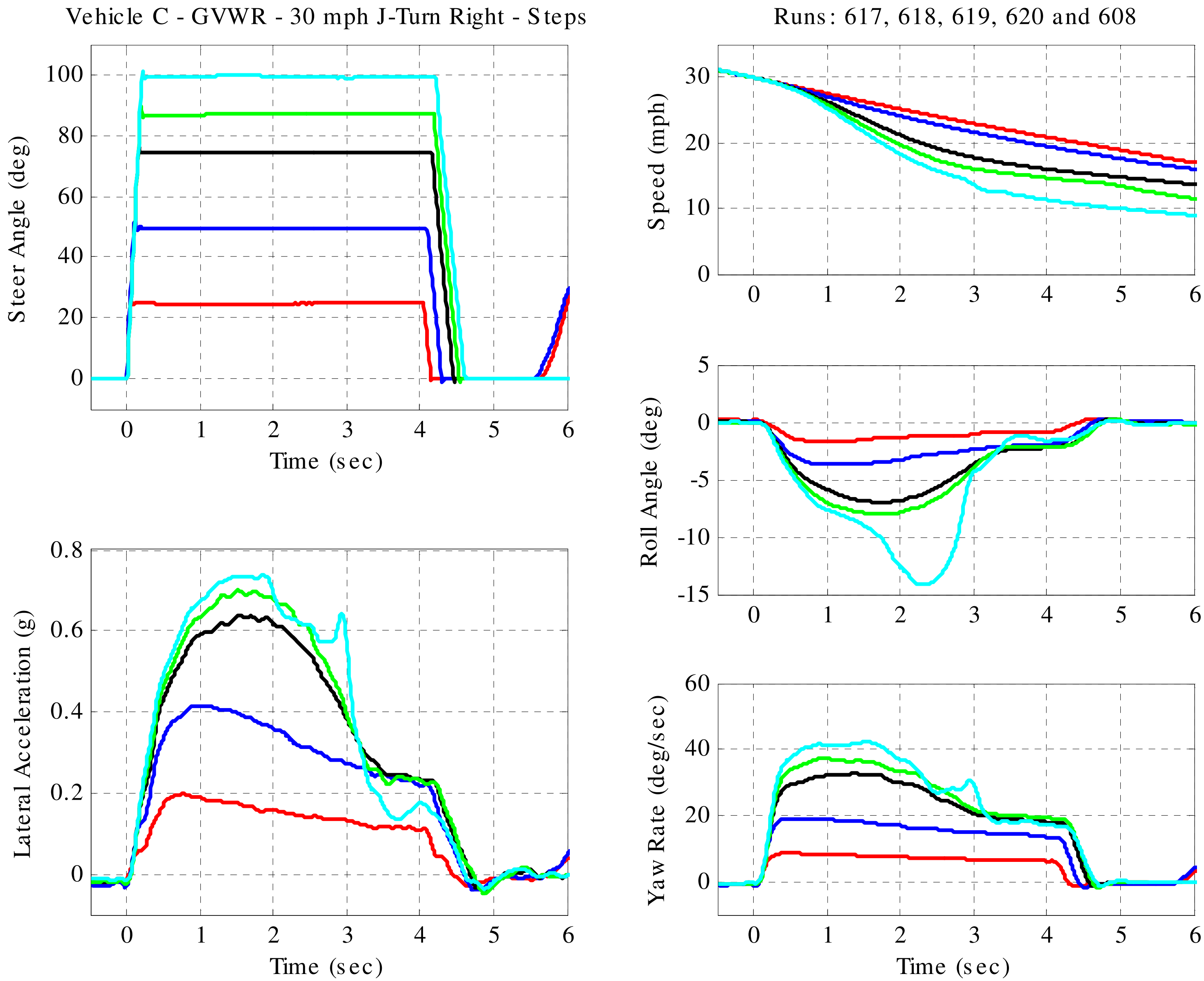

Vehicle B - GVWR - 30 mph J-Turn Right - Steps
Runs: 417, 418, 419, 420 and 416
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



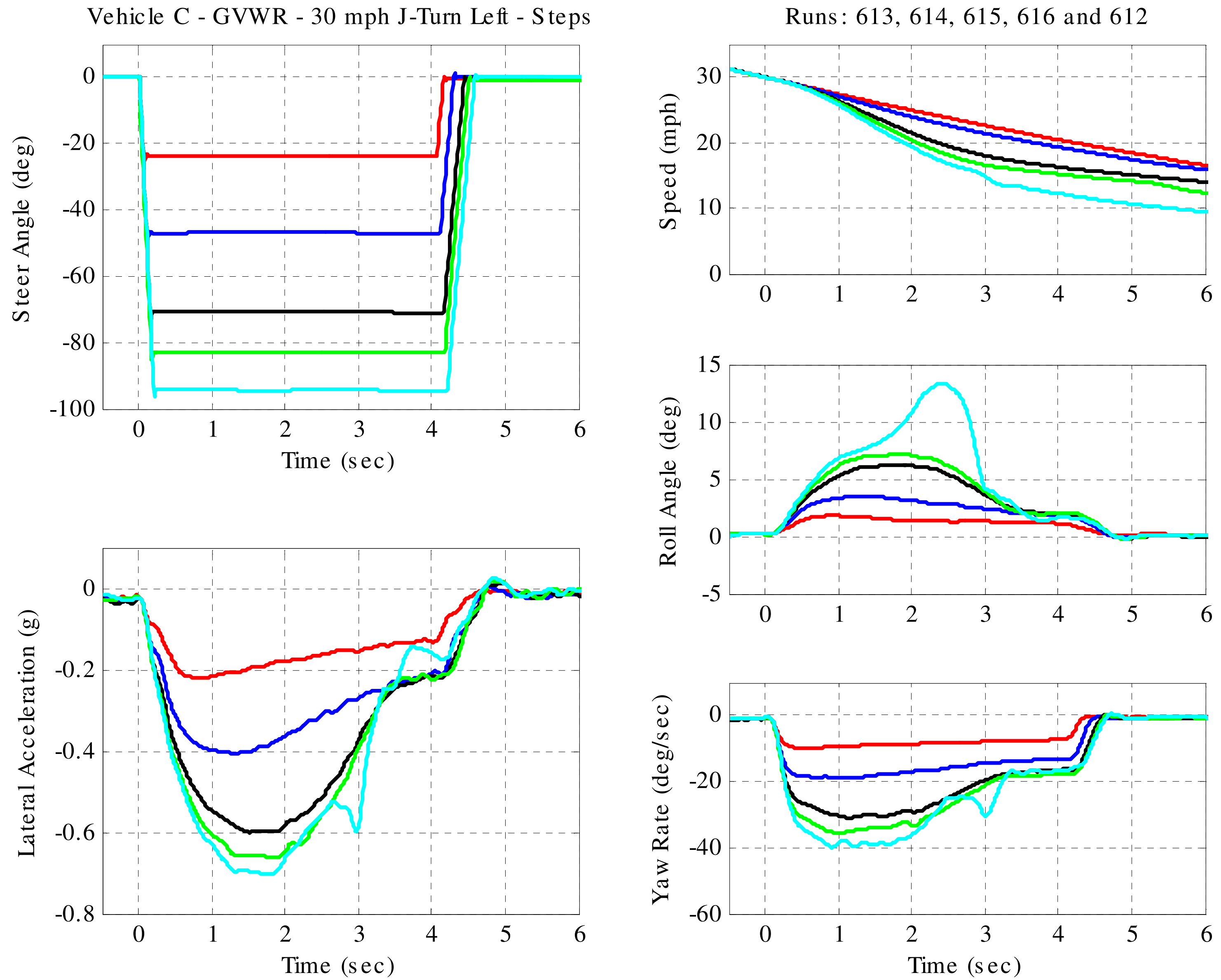
Vehicle B - GVWR - 30 mph J-Turn Left
Runs: 428, 429, 430, 431 and 427
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle C - GVWR - 30 mph J-Turn Right
Runs: 609 and 608
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

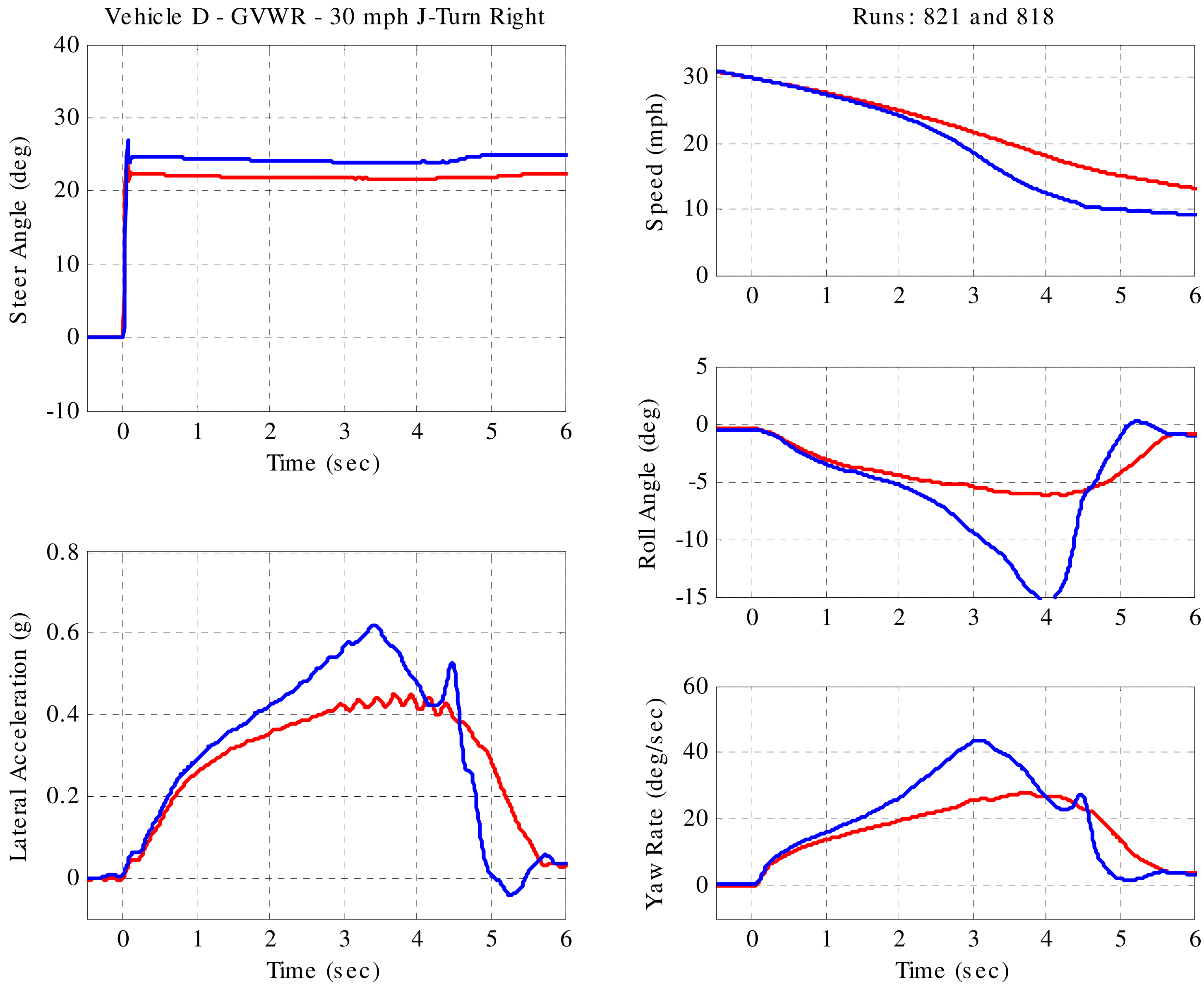

Vehicle C - GVWR - 30 mph J-Turn Left
Runs: 610 and 612
Steer Angle (deg)
0
-20
-40
-60
-80
-100
Time (sec)
0 1 2 3 4 5 6
Speed (mph)
30
20
10
0
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60

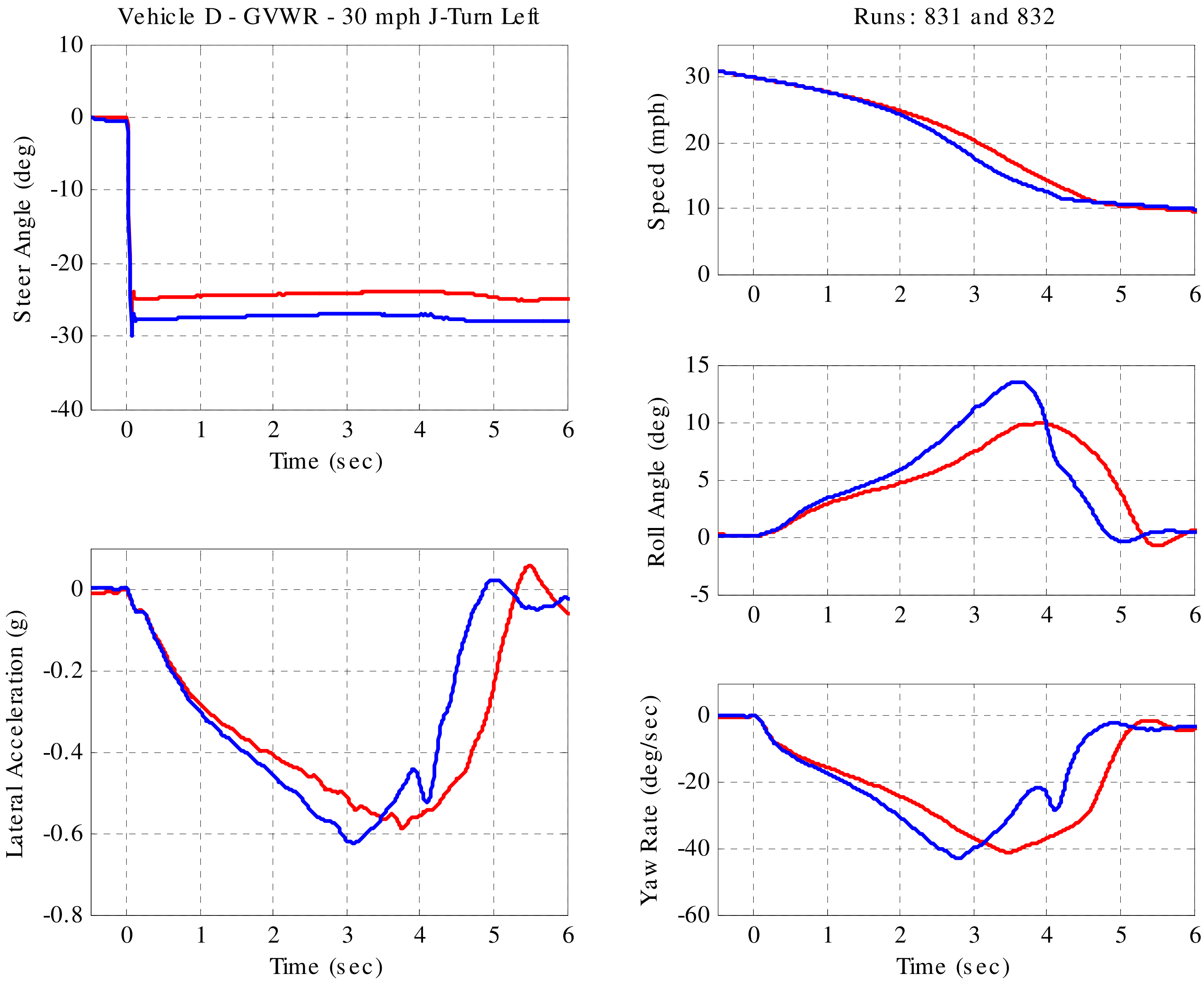


Vehicle C - GVWR - 30 mph J-Turn Right - Steps
Runs: 617, 618, 619, 620 and 608
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

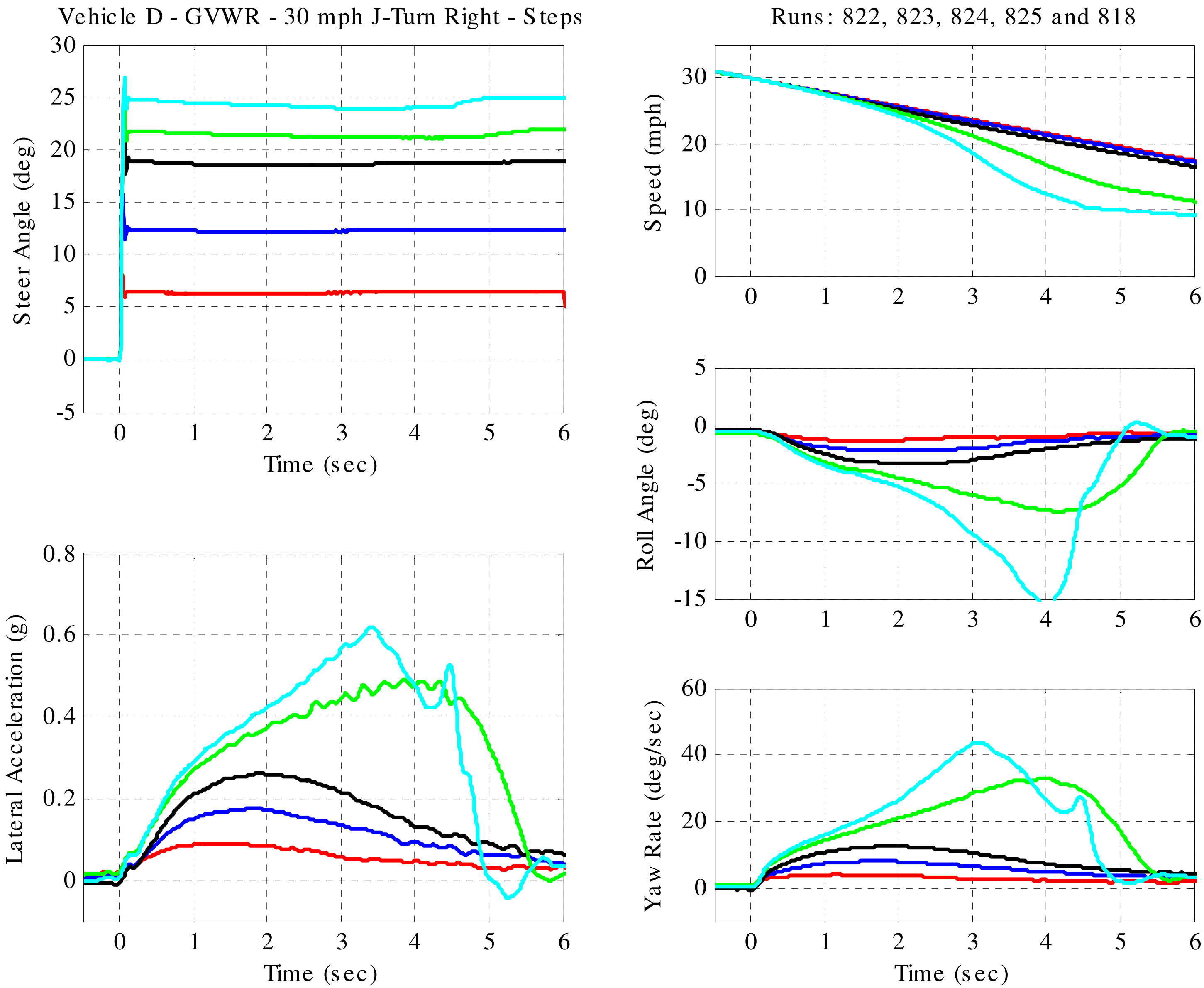


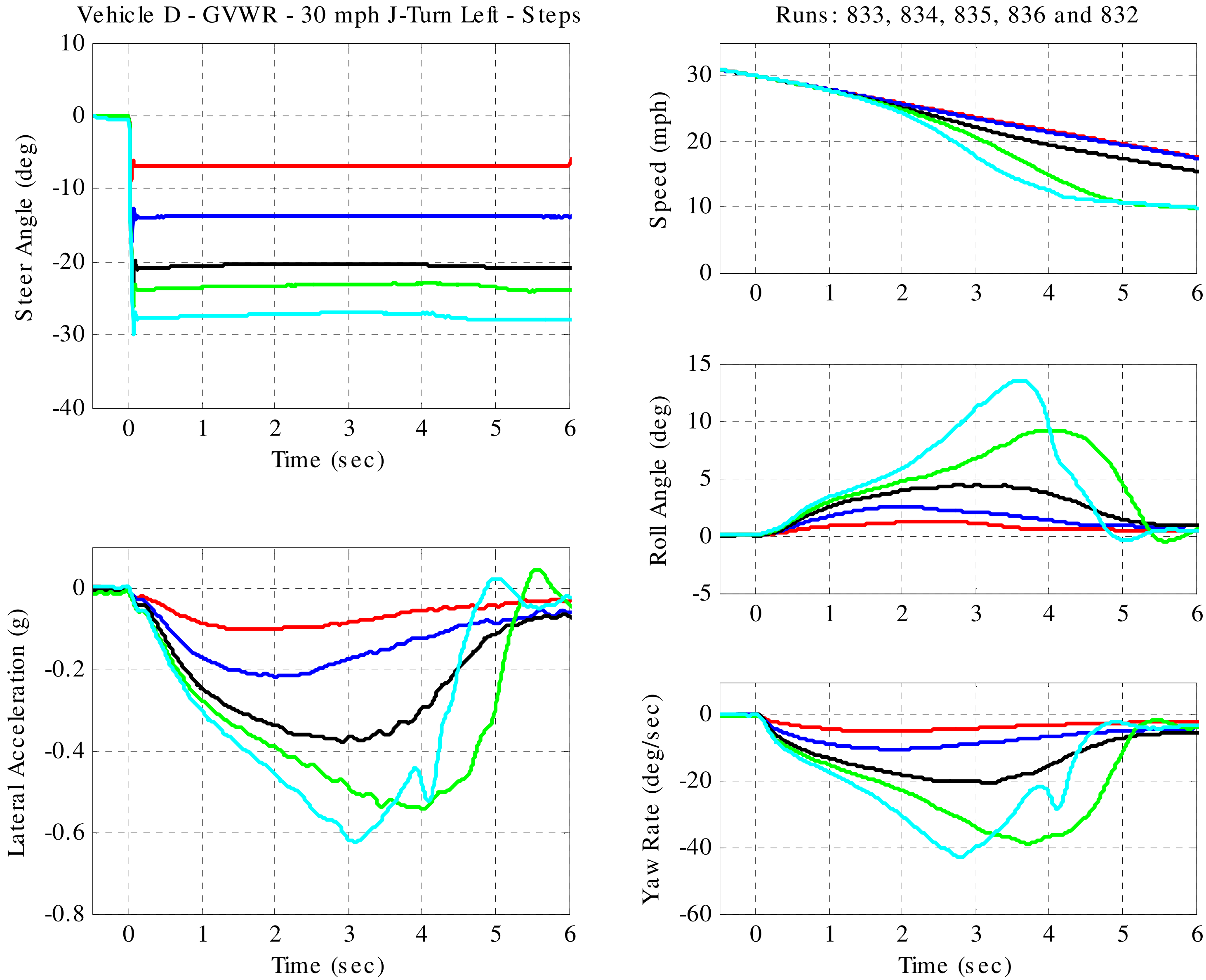
Vehicle C - GVWR - 30 mph J-Turn Left - Steps
Runs: 613, 614, 615, 616 and 612
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)

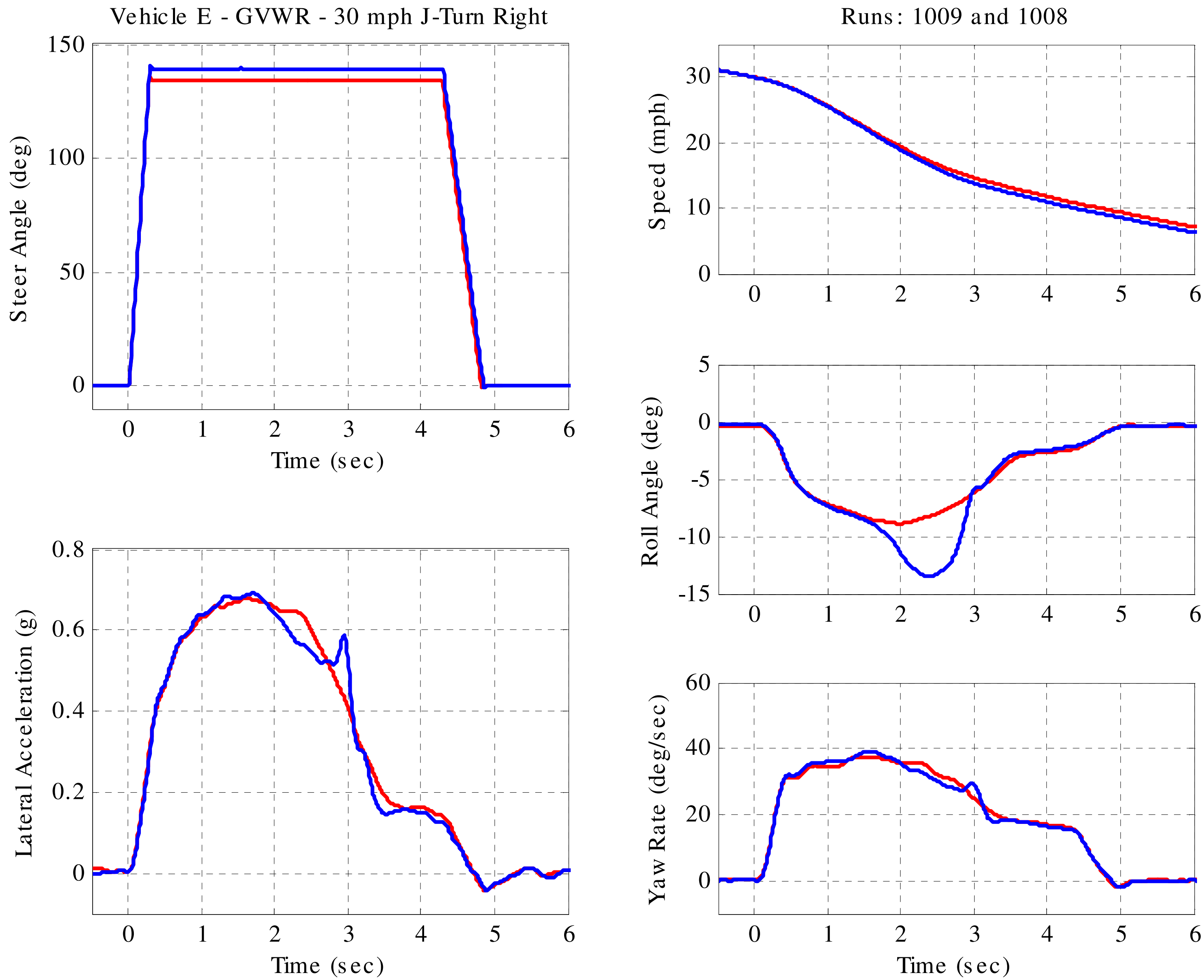

Vehicle D - GVWR - 30 mph J-Turn Right
Runs: 821 and 818
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

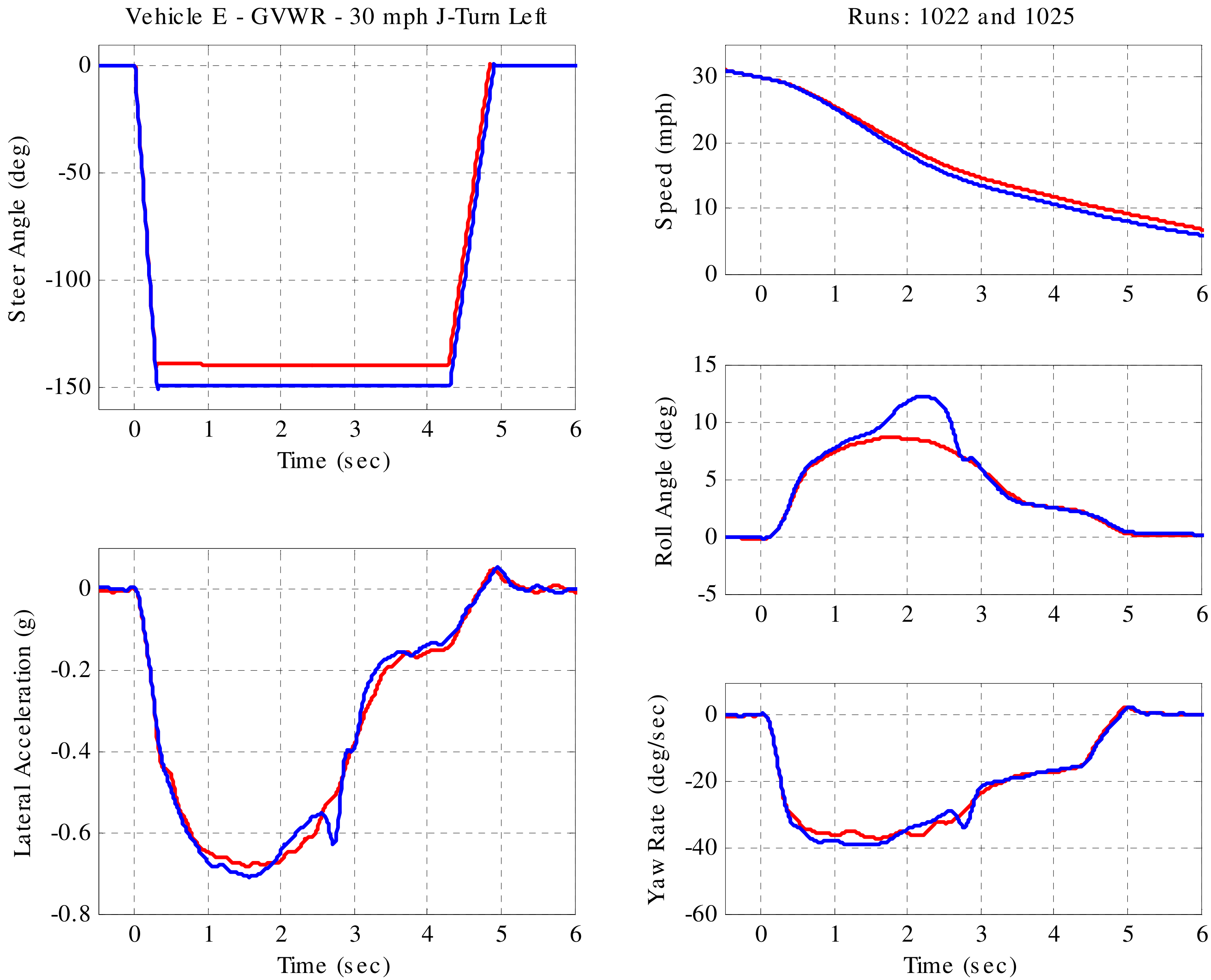


Vehicle D - GVWR - 30 mph J-Turn Left
Runs: 831 and 832
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

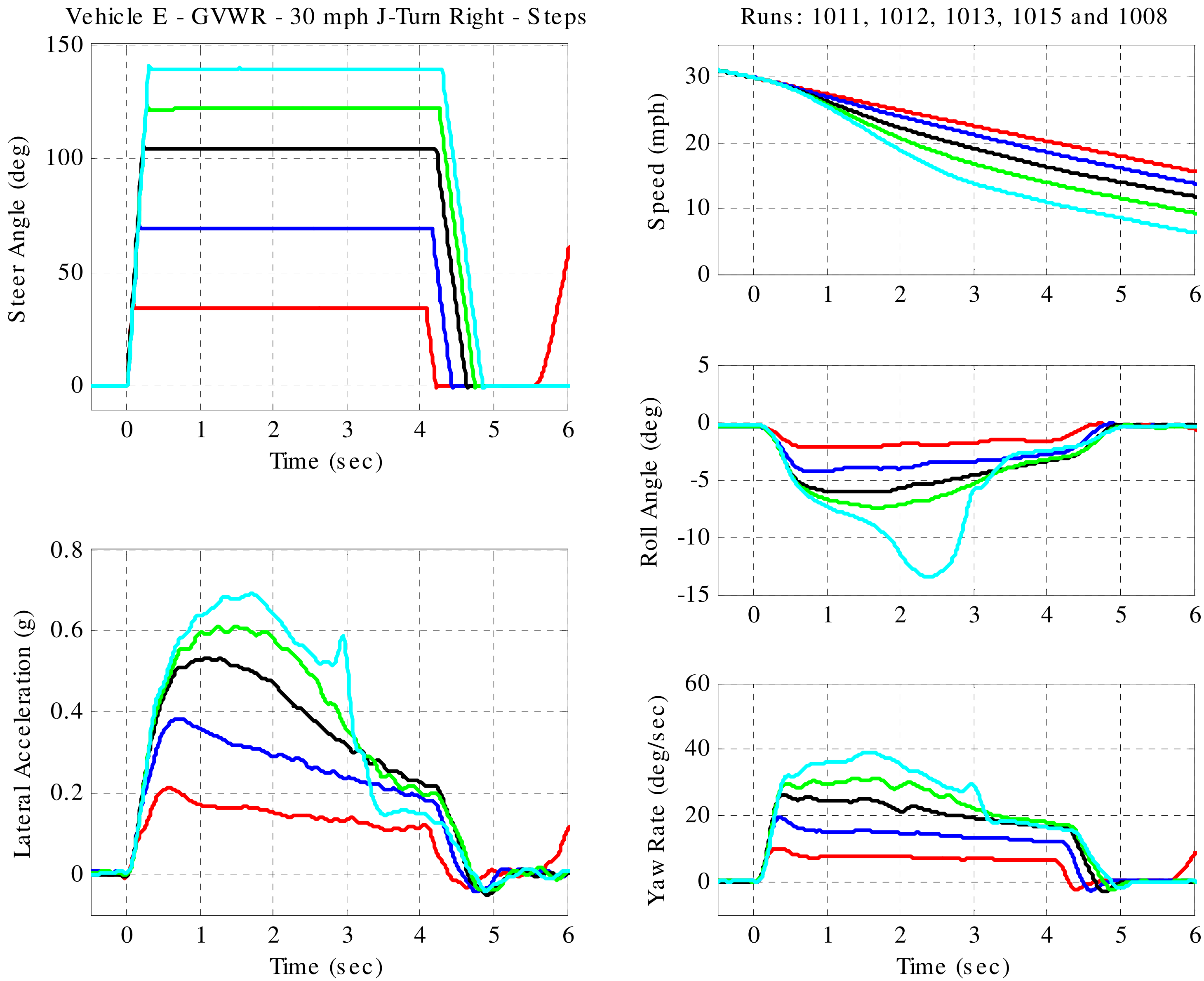

Vehicle D - GVWR - 30 mph J-Turn Right - Steps
Runs: 822, 823, 824, 825 and 818
Steer Angle (deg)
30
25
20
15
10
5
0
-5
0
1
2
3
4
5
6
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
5
0
-5
-10
-15
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Time (sec)
Yaw Rate (deg/sec)
60
40
20
0
Time (sec)

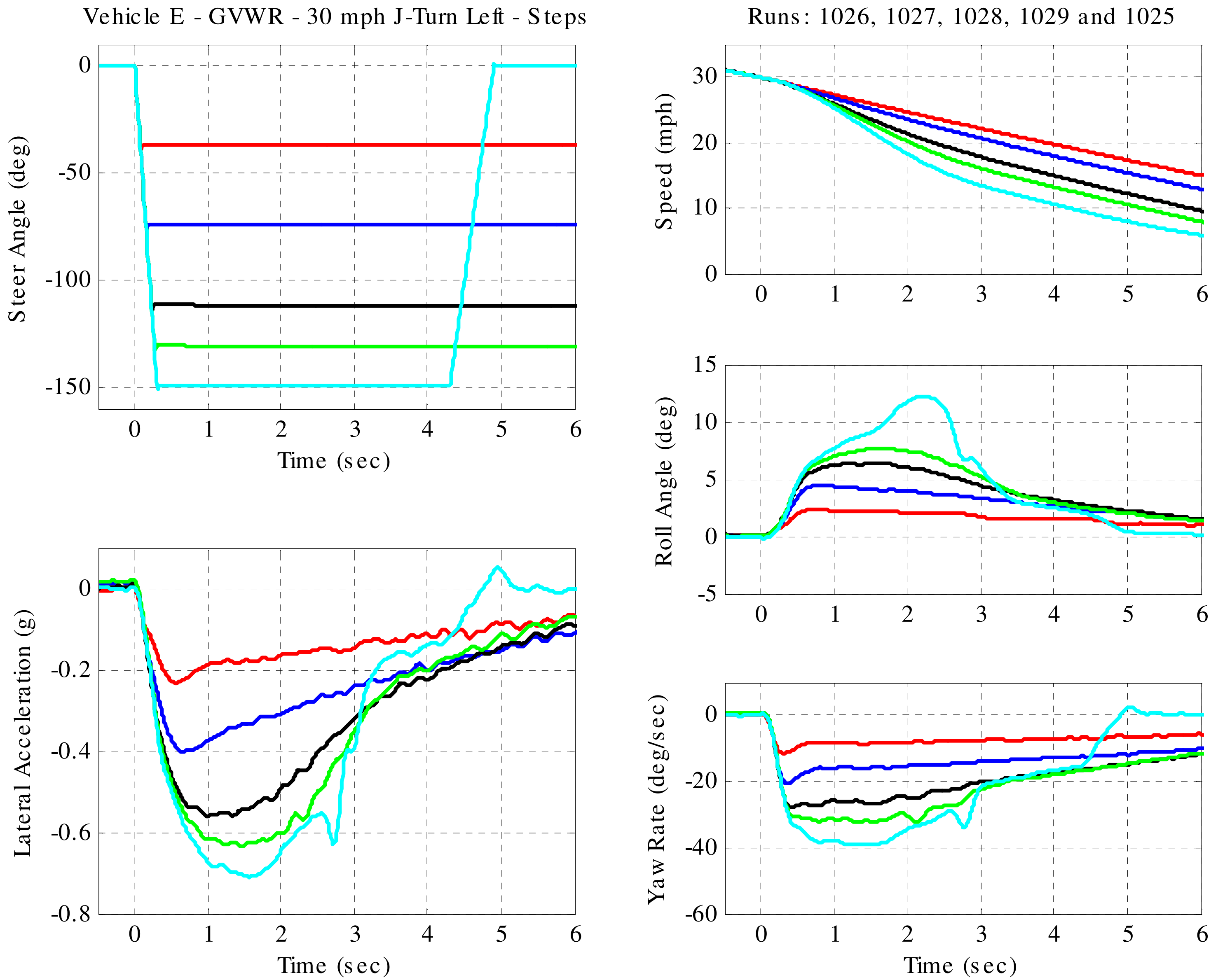

Vehicle D - GVWR - 30 mph J-Turn Left - Steps
Runs: 833, 834, 835, 836 and 832
Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)


Vehicle E - GVWR - 30 mph J-Turn Right
Runs: 1009 and 1008
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

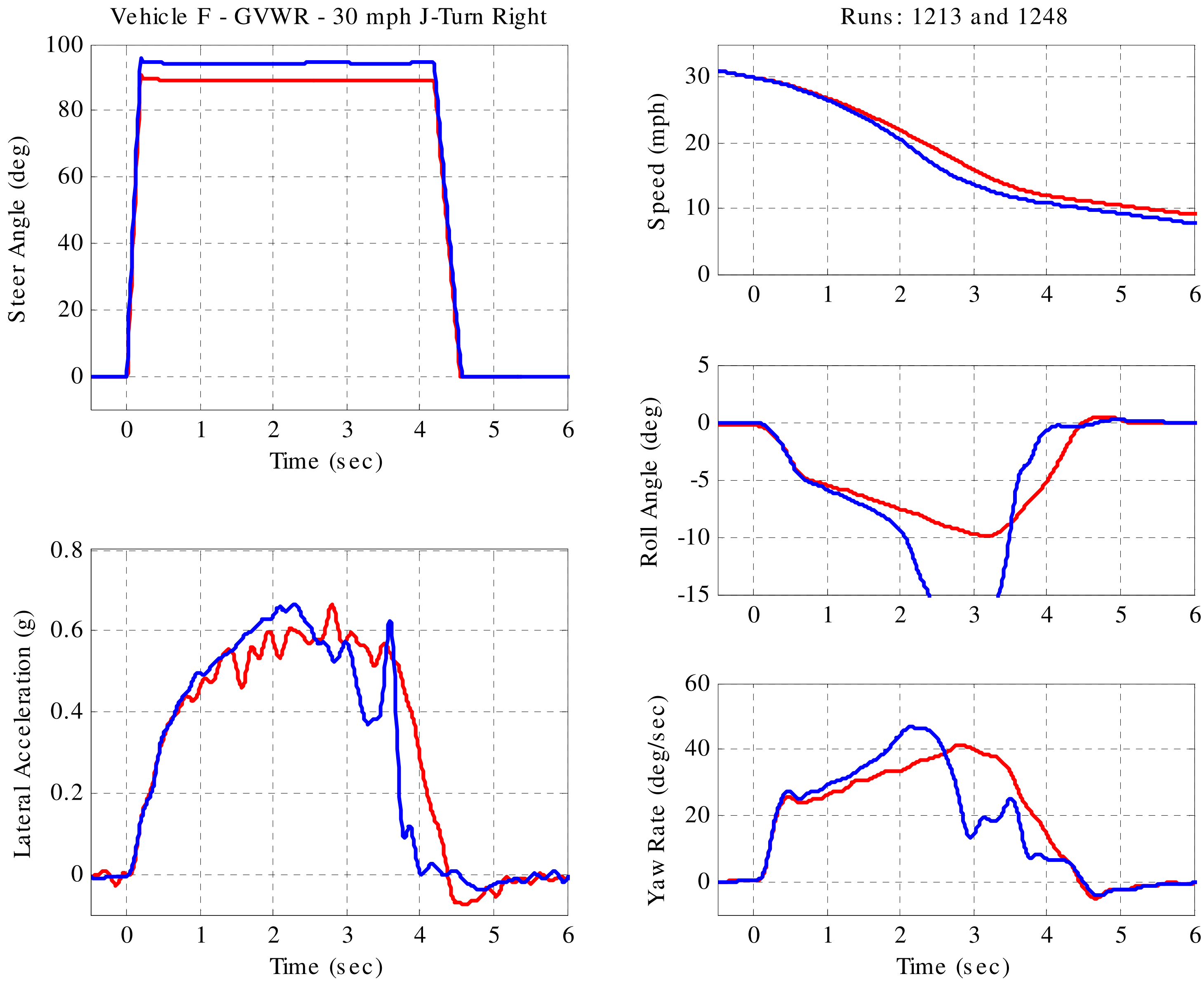


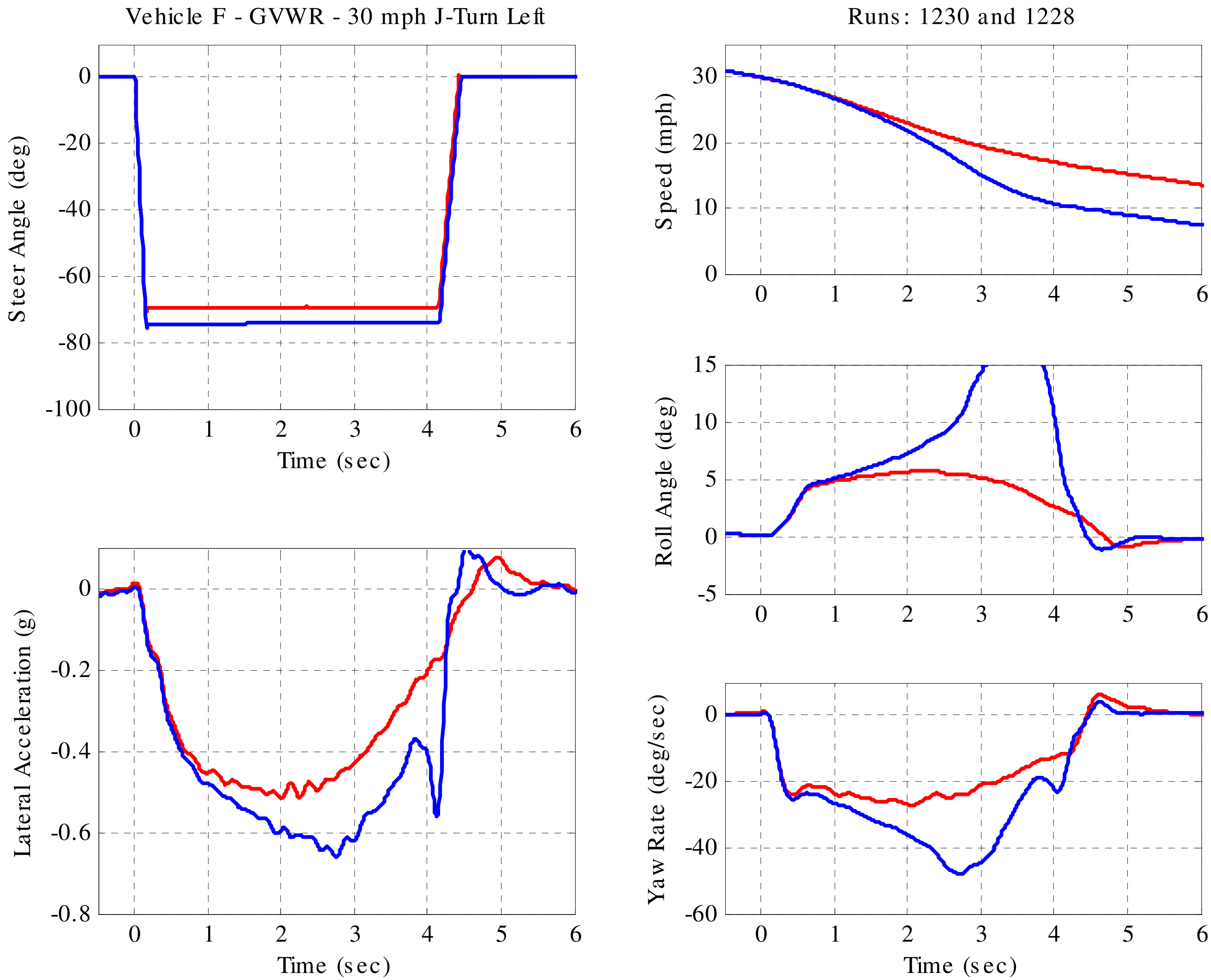
Vehicle E - GVWR - 30 mph J-Turn Left
Runs: 1022 and 1025
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)


Vehicle E - GVWR - 30 mph J-Turn Right - Steps
Runs: 1011, 1012, 1013, 1015 and 1008
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

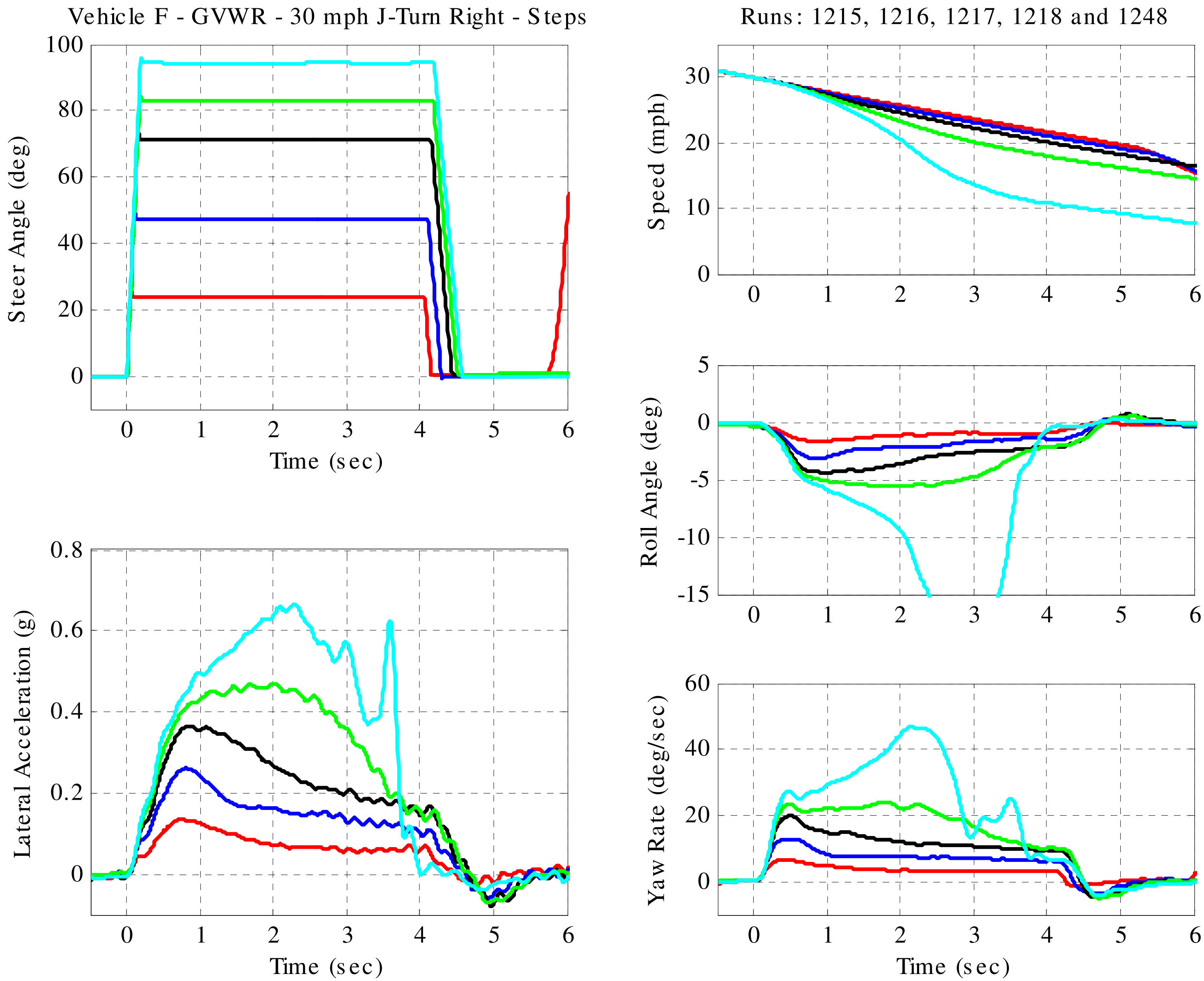


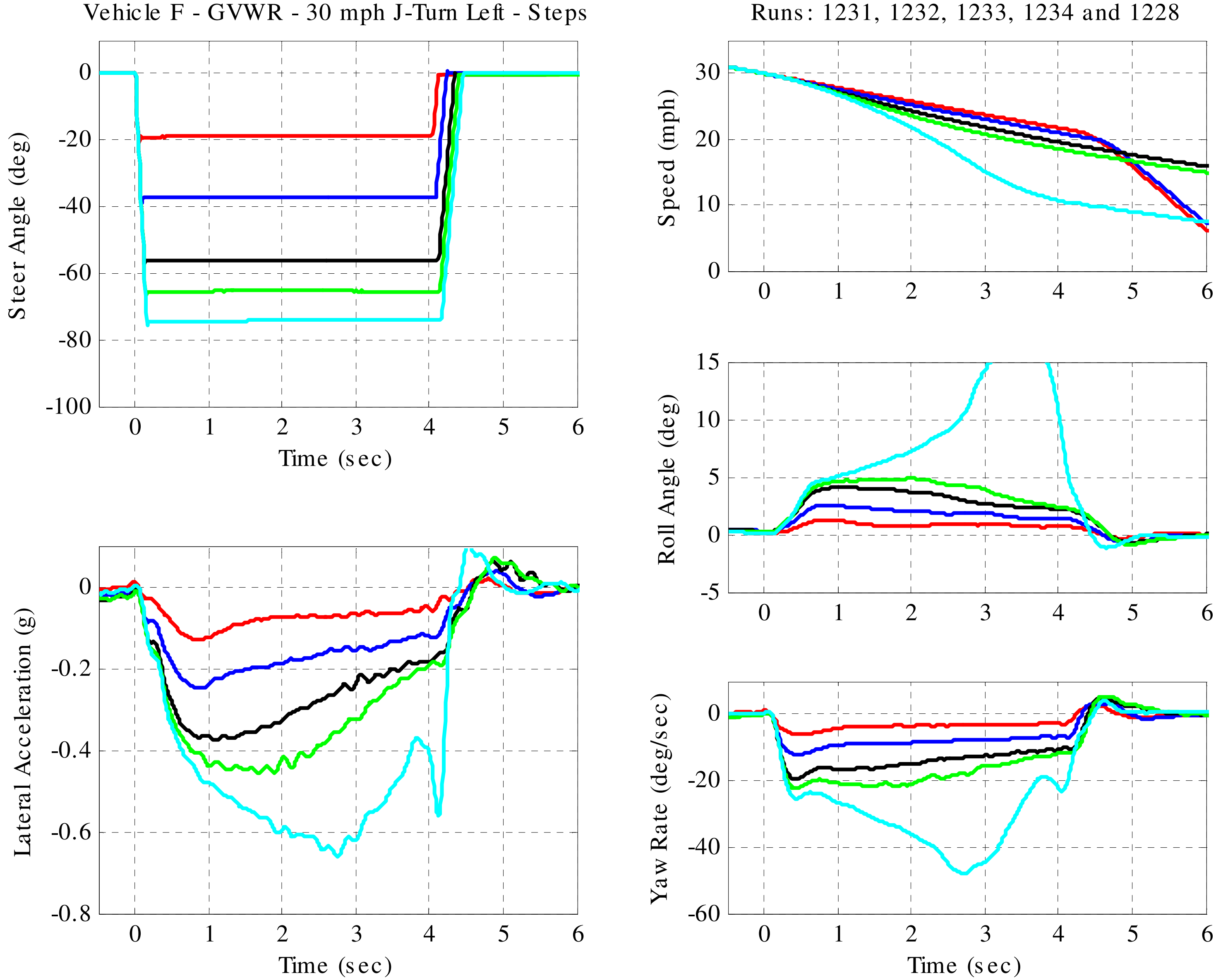
Vehicle E - GVWR - 30 mph J-Turn Left - Steps
Runs: 1026, 1027, 1028, 1029 and 1025
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

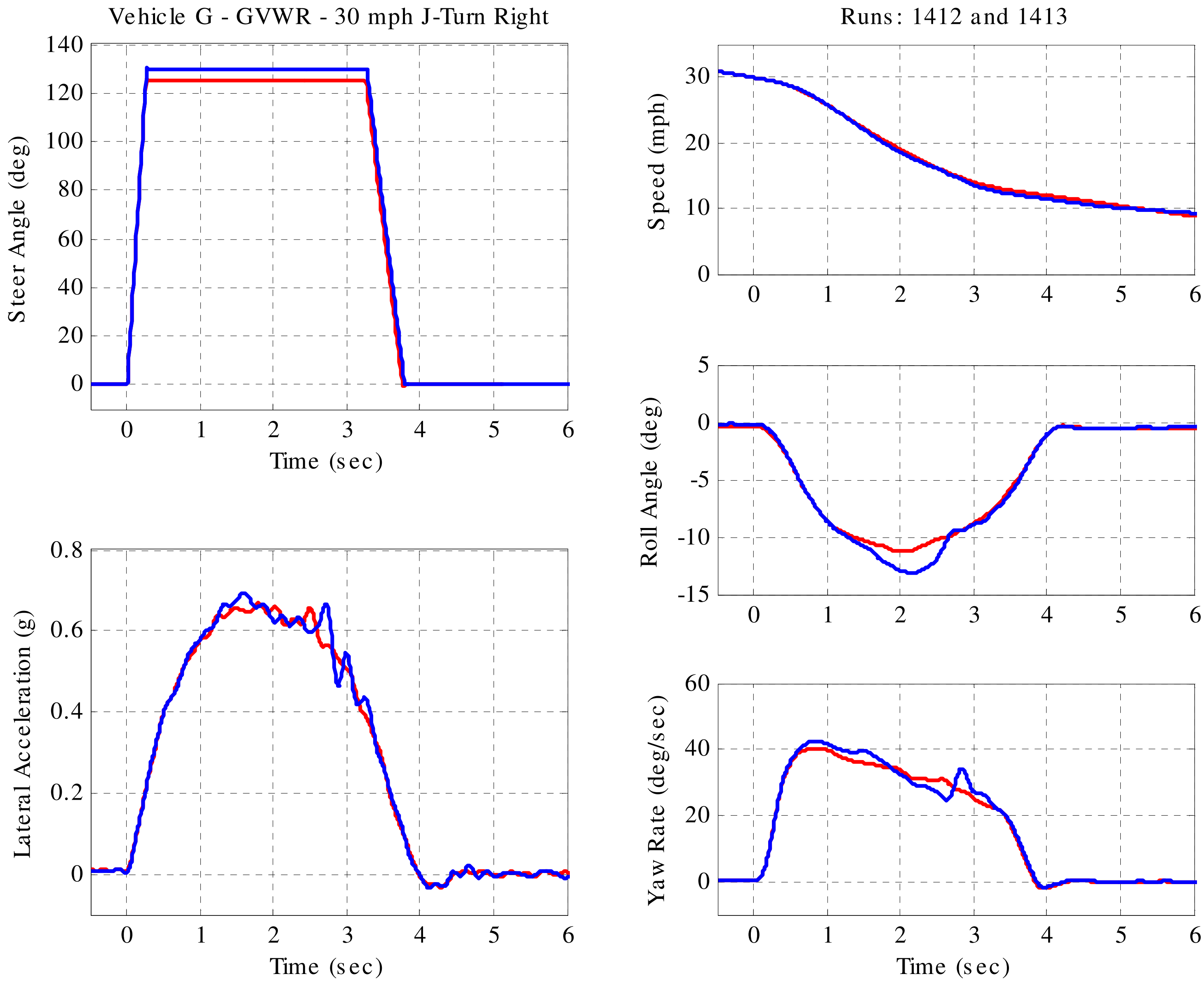

Vehicle F - GVWR - 30 mph J-Turn Right
Runs: 1213 and 1248
Steer Angle (deg)
100
80
60
40
20
0
Time (sec)
0
1
2
3
4
5
6
Speed (mph)
30
20
10
0
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Roll Angle (deg)
5
0
-5
-10
-15
Yaw Rate (deg/sec)
60
40
20
0

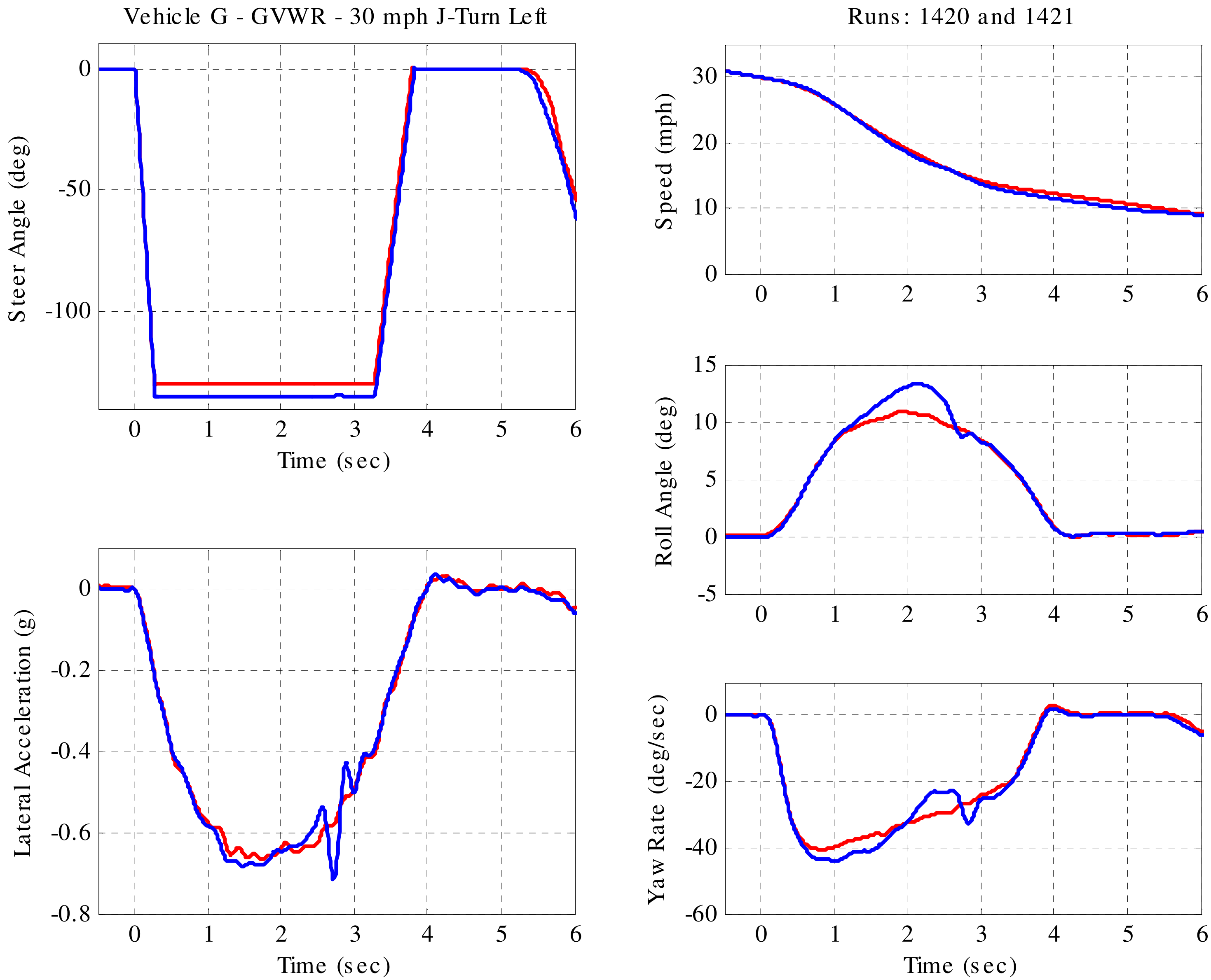


Vehicle F - GVWR - 30 mph J-Turn Left
Runs: 1230 and 1228
Steer Angle (deg)
0
-20
-40
-60
-80
-100
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Time (sec)
Yaw Rate (deg/sec)
0
-20
-40
-60
Time (sec)
0
1
2
3
4
5
6

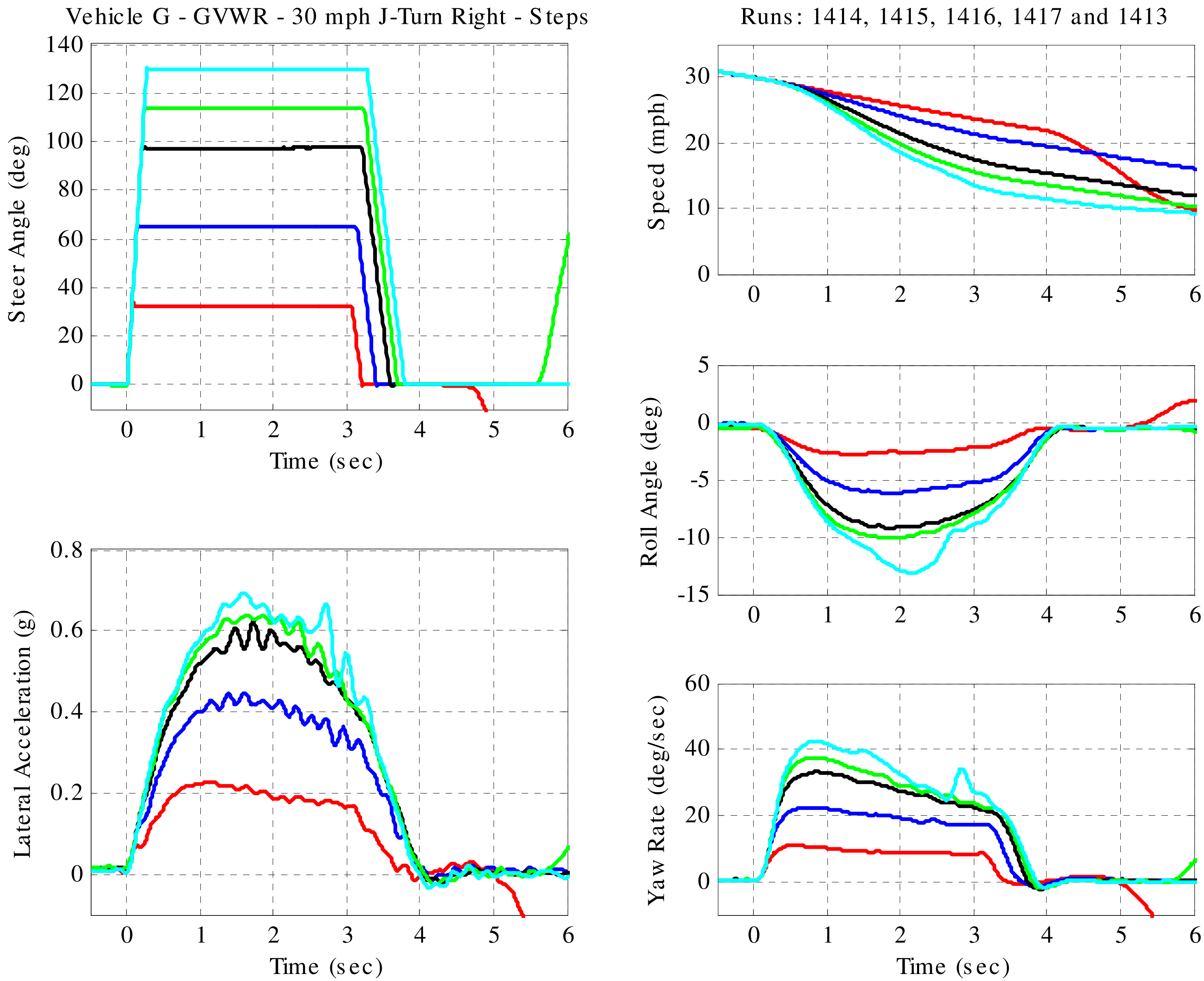

Vehicle F - GVWR - 30 mph J-Turn Right - Steps
Runs: 1215, 1216, 1217, 1218 and 1248
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle F - GVWR - 30 mph J-Turn Left - Steps
Runs: 1231, 1232, 1233, 1234 and 1228
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle G - GVWR - 30 mph J-Turn Right
Runs: 1412 and 1413
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



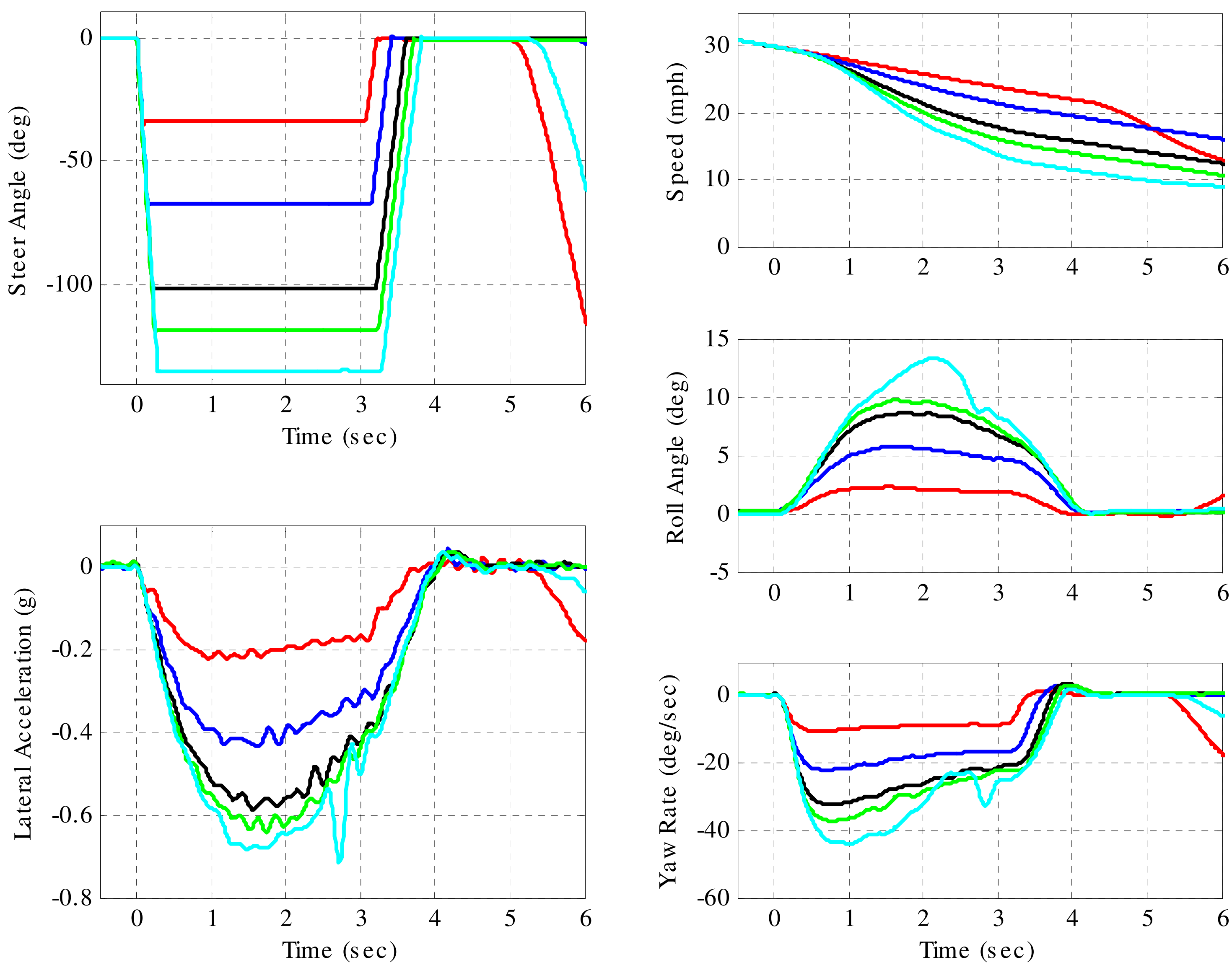
Vehicle G - GVWR - 30 mph J-Turn Left
Runs: 1420 and 1421
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

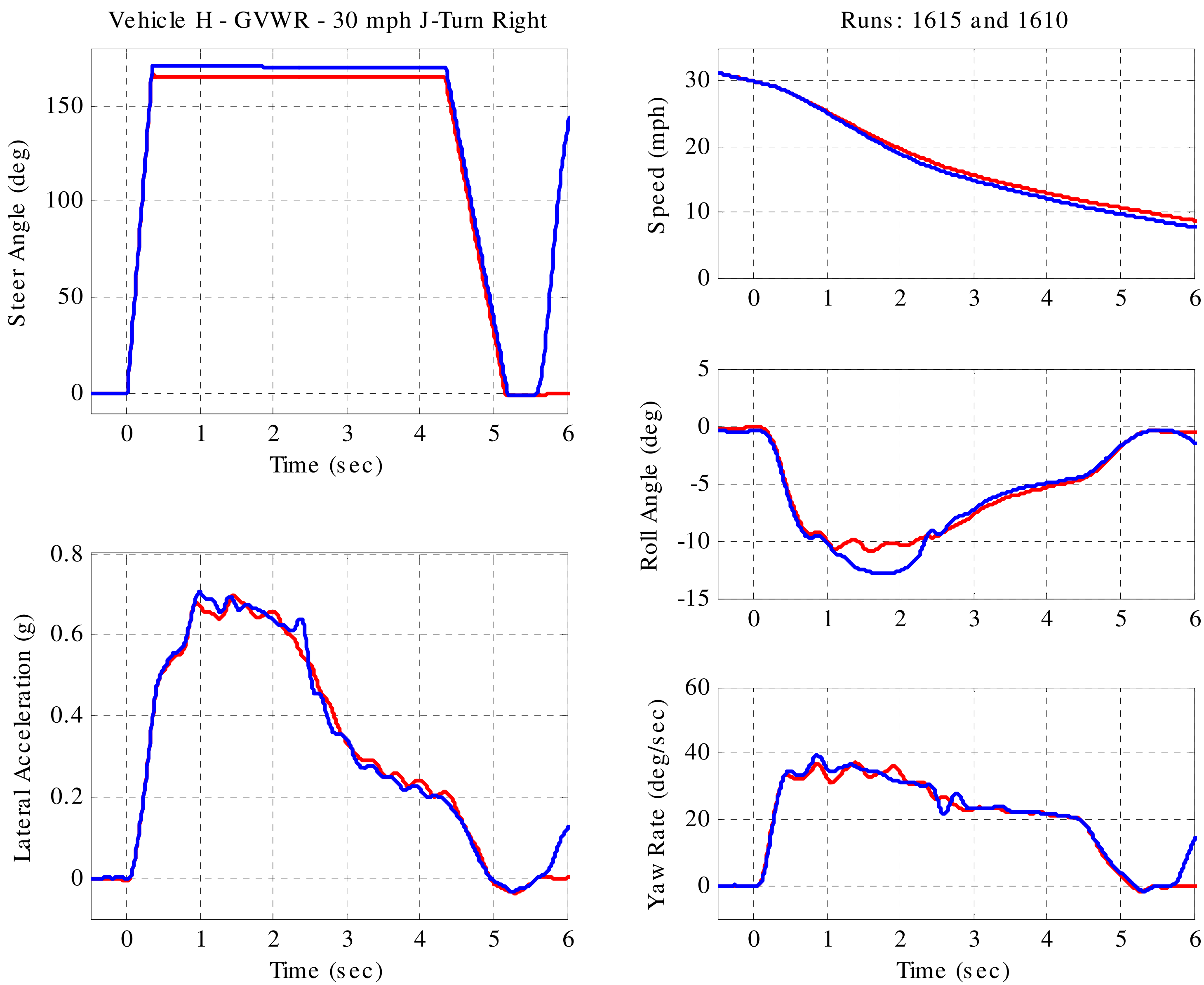


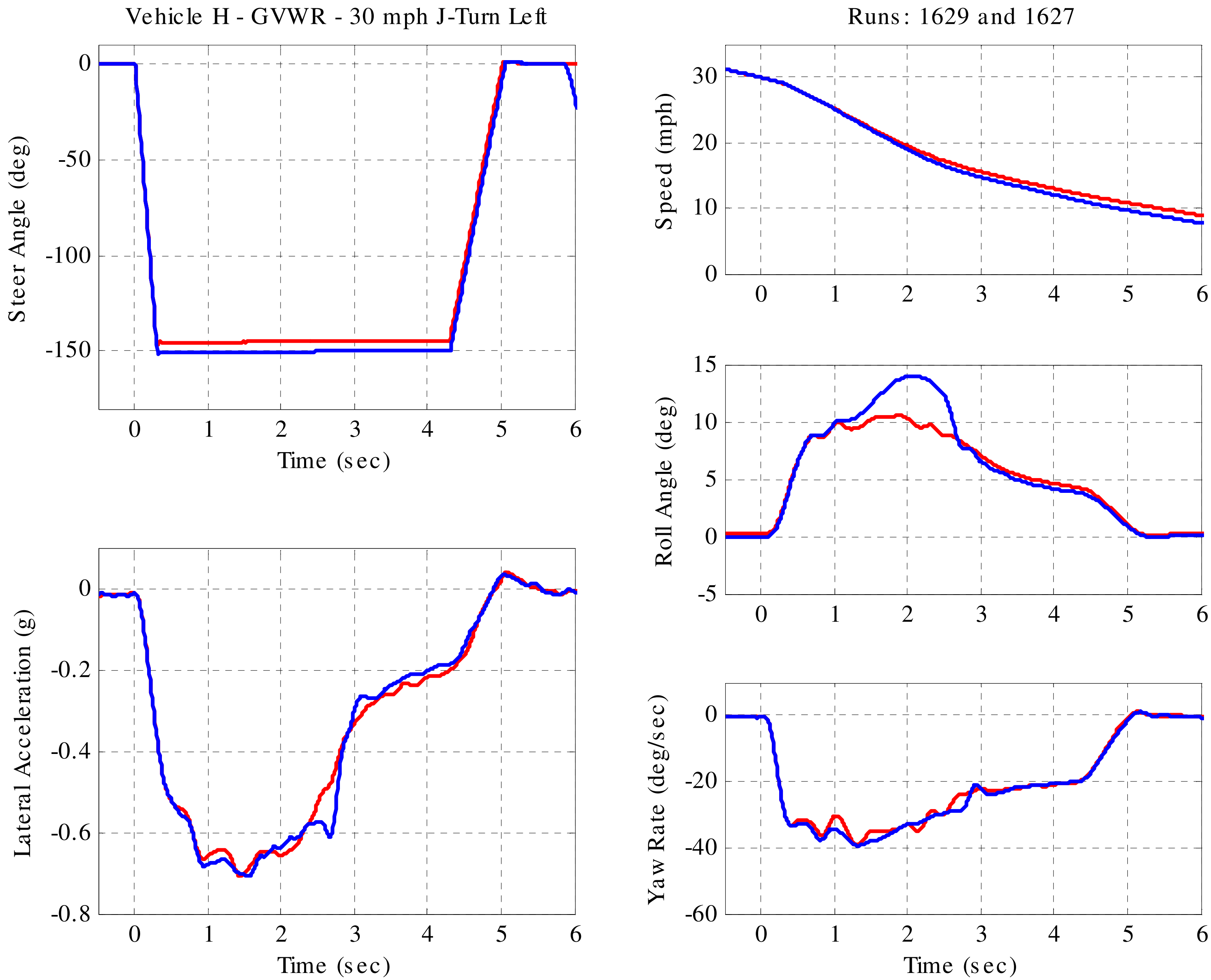
Vehicle G - GVWR - 30 mph J-Turn Right - Steps
Runs: 1414, 1415, 1416, 1417 and 1413
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

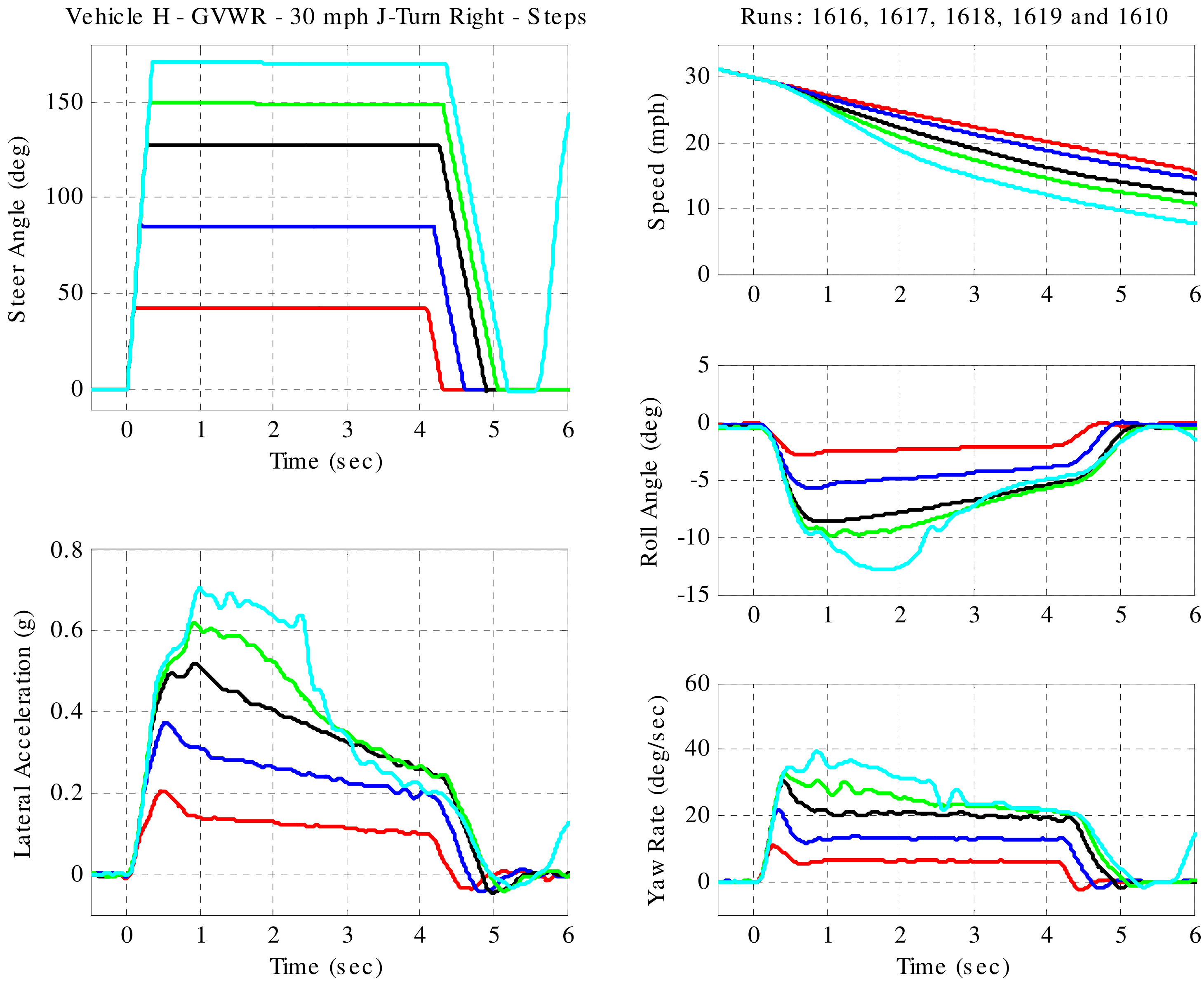
Vehicle G - GVWR - 30 mph J-Turn Left - Steps

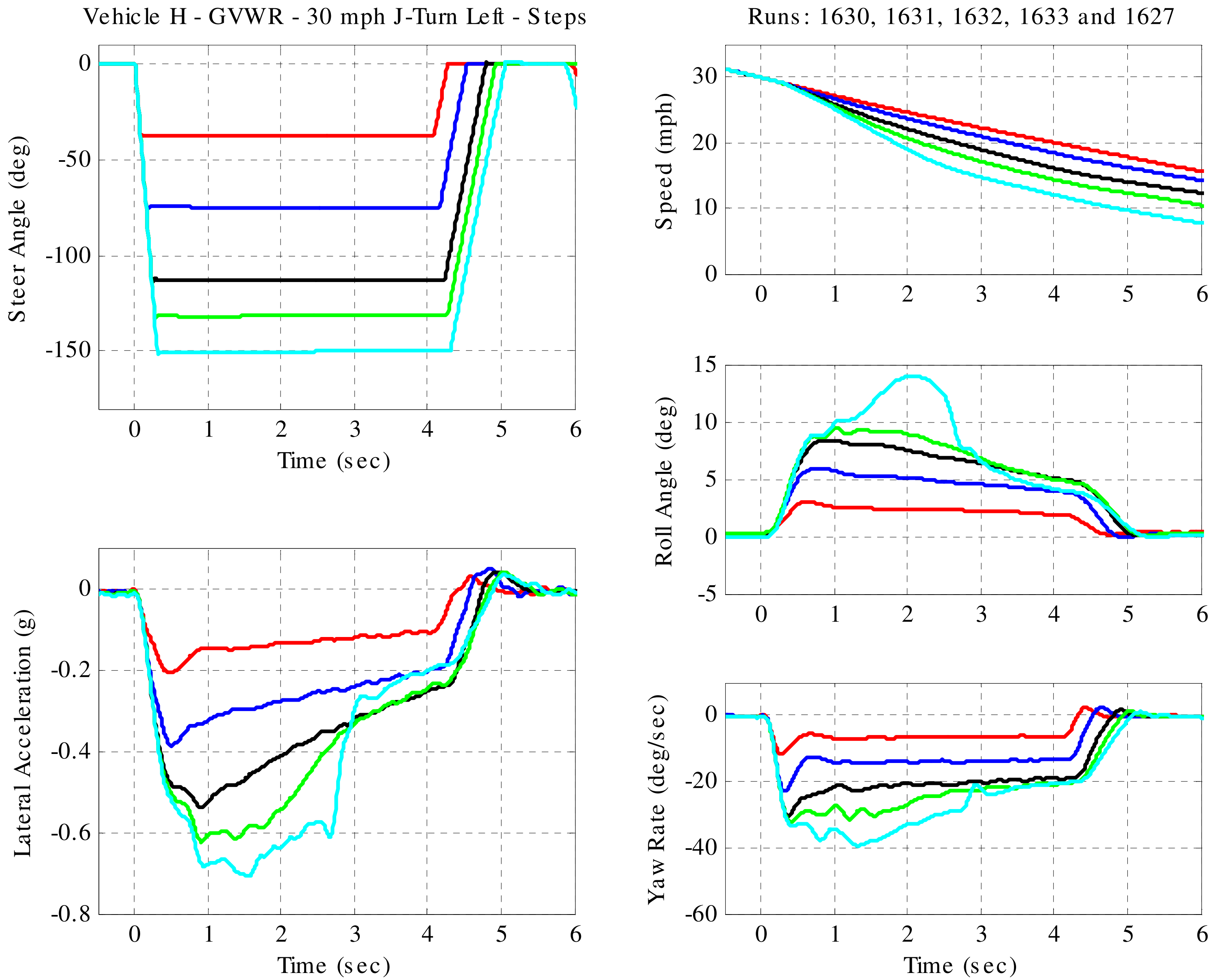
Runs: 1422, 1423, 1425, 1426 and 1421



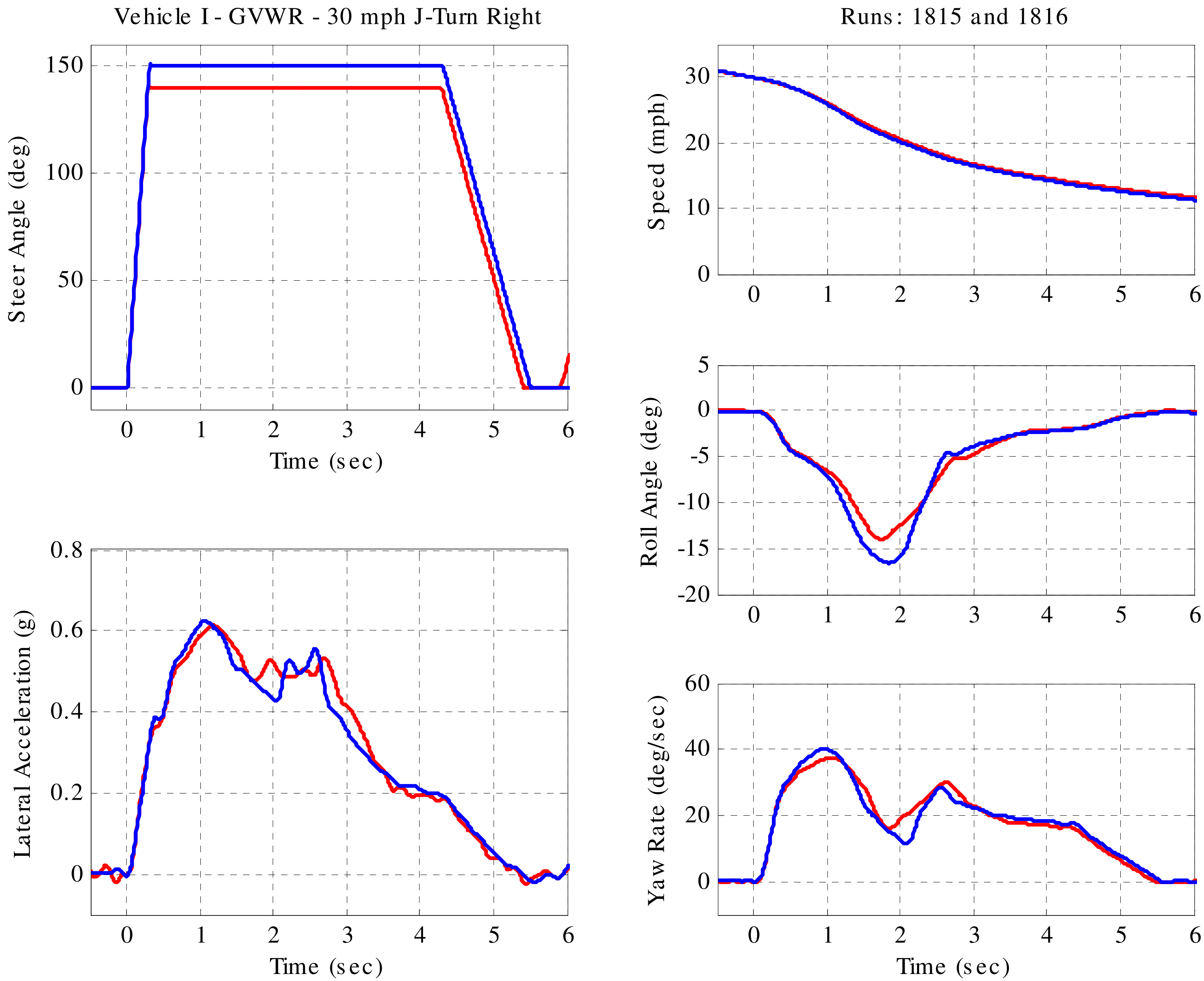

Vehicle H - GVWR - 30 mph J-Turn Right
Runs: 1615 and 1610
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

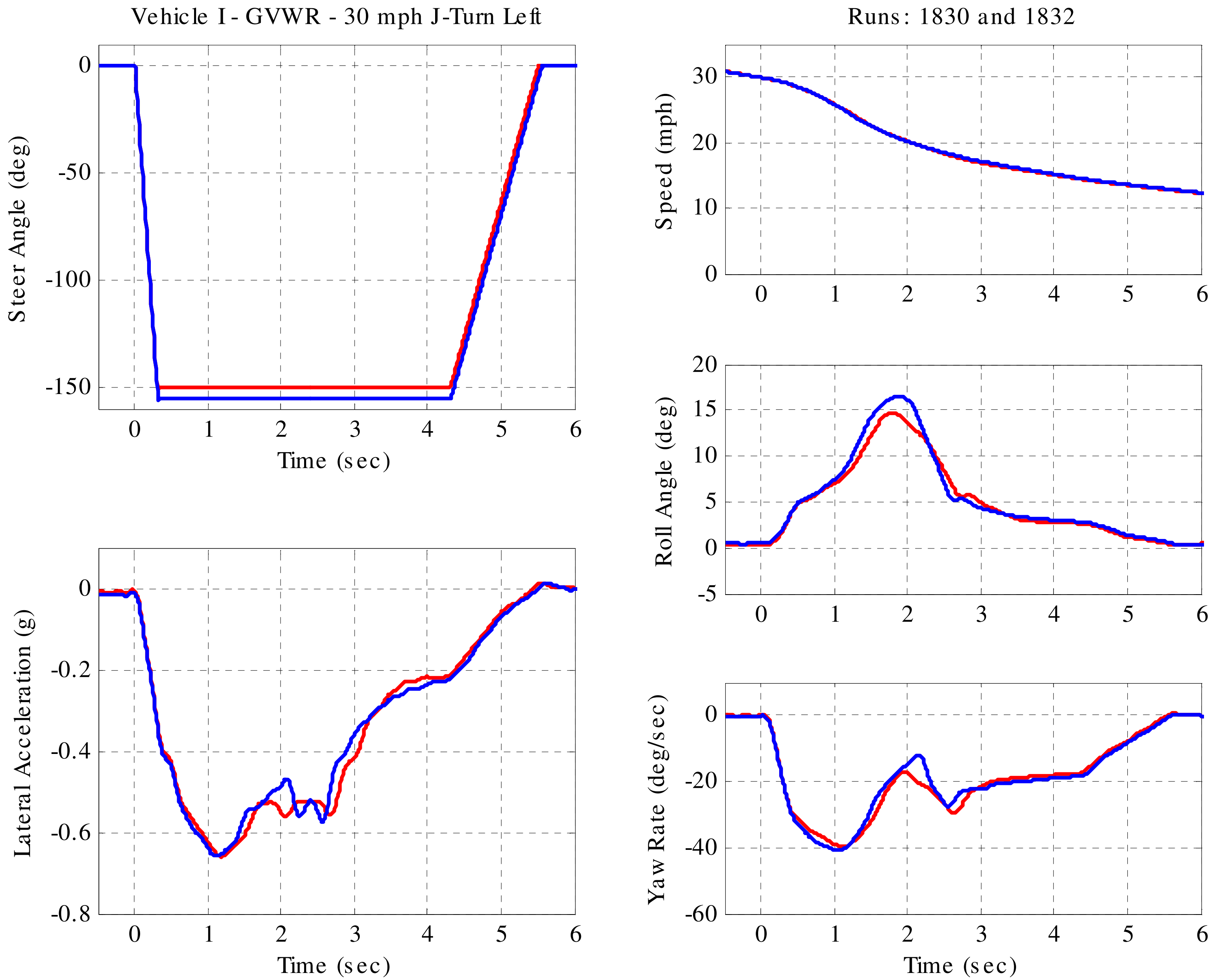

Vehicle H - GVWR - 30 mph J-Turn Left
Runs: 1629 and 1627
Steer Angle (deg)
0
-50
-100
-150
Time (sec)
0 1 2 3 4 5 6
Speed (mph)
30
20
10
0
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60


Vehicle H - GVWR - 30 mph J-Turn Right - Steps
Runs: 1616, 1617, 1618, 1619 and 1610
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

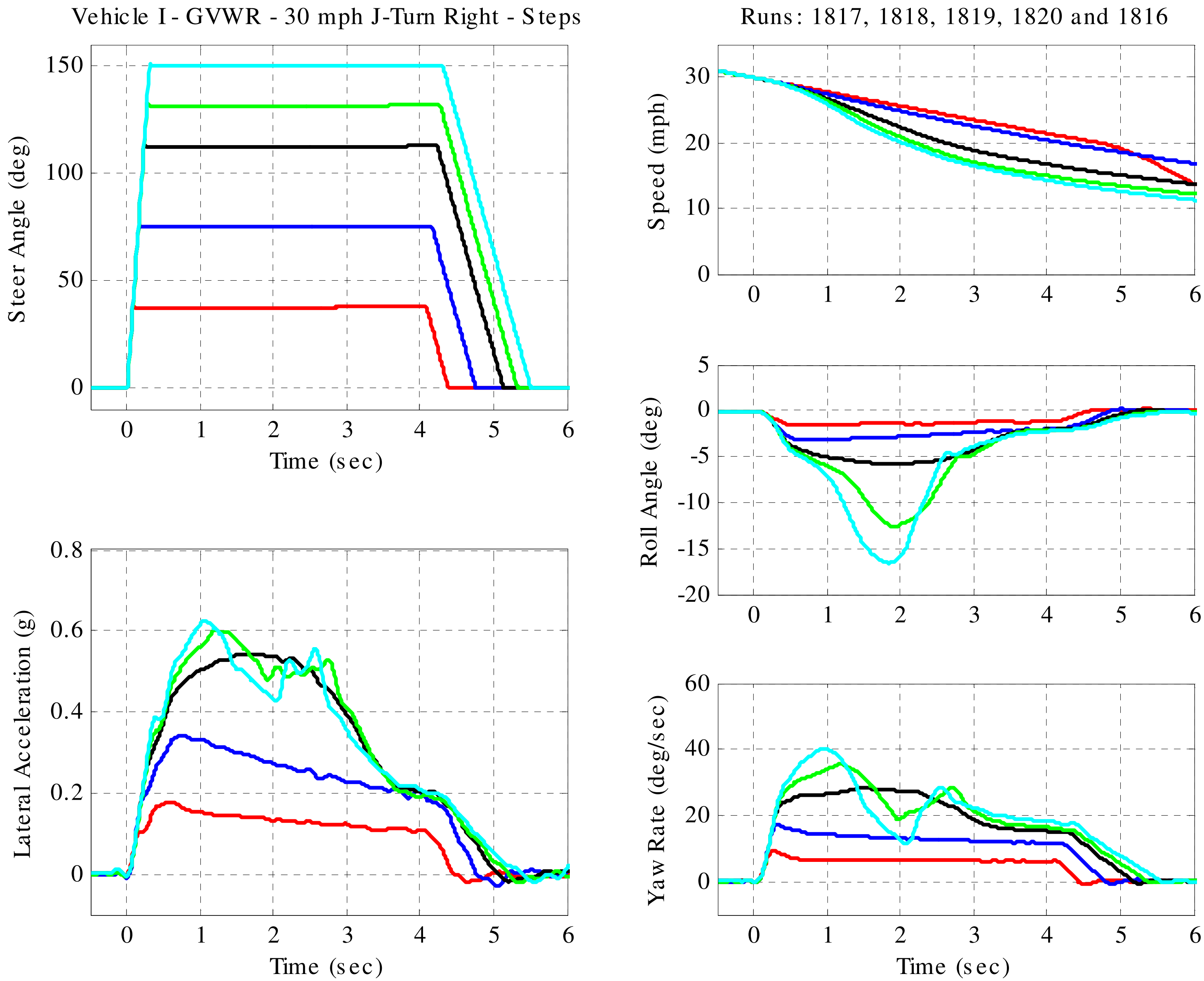


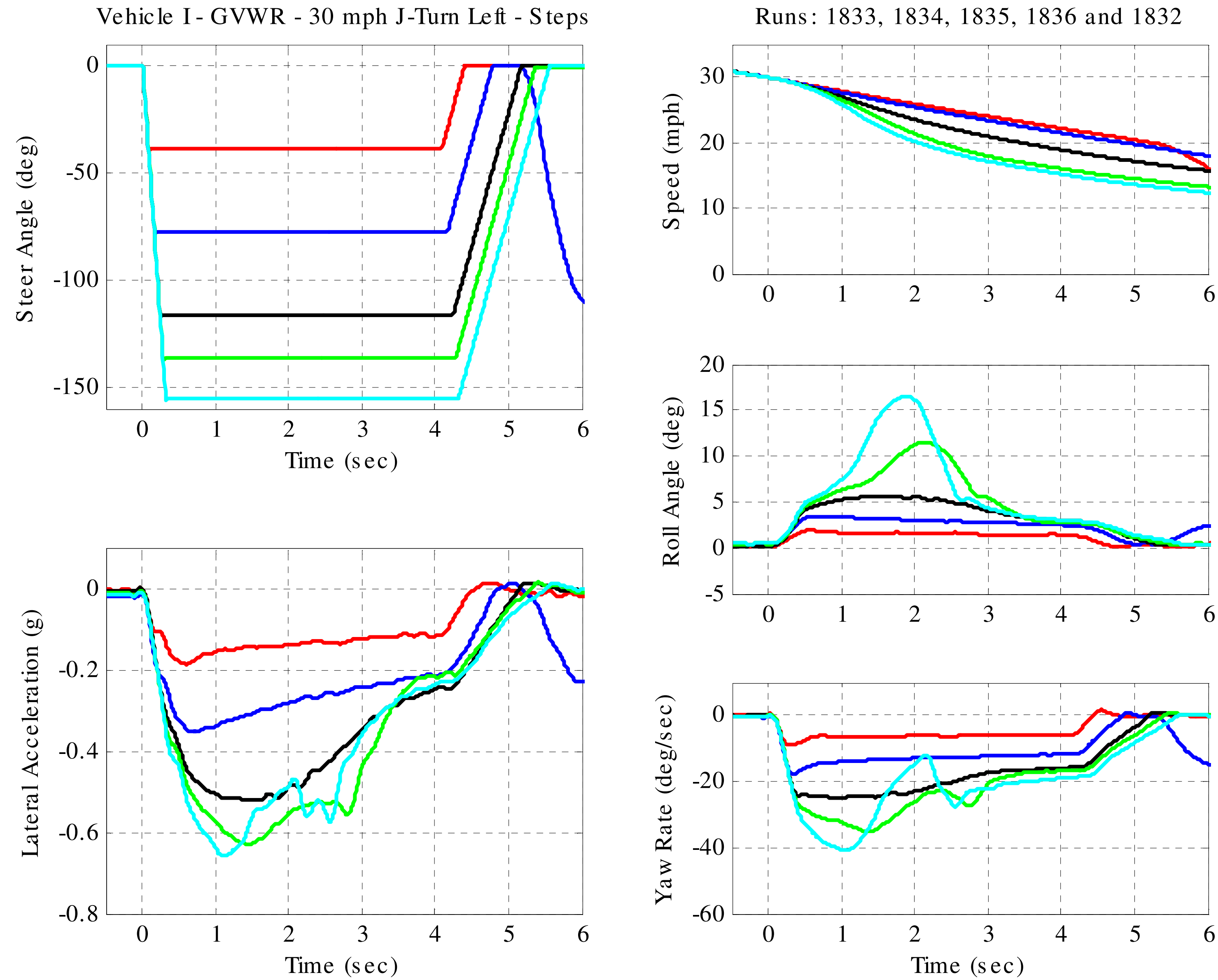
Vehicle H - GVWR - 30 mph J-Turn Left - Steps
Runs: 1630, 1631, 1632, 1633 and 1627
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle I - GVWR - 30 mph J-Turn Right
Runs: 1815 and 1816
Steer Angle (deg)
150
100
50
0
Time (sec)
Speed (mph)
30
20
10
0
Roll Angle (deg)
5
0
-5
-10
-15
-20
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Yaw Rate (deg/sec)
60
40
20
0
0
1
2
3
4
5
6
Time (sec)



Vehicle I - GVWR - 30 mph J-Turn Left
Runs: 1830 and 1832
Steer Angle (deg)
0
-50
-100
-150
Time (sec)
0 1 2 3 4 5 6
Speed (mph)
30
20
10
0
Roll Angle (deg)
20
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60


Vehicle I - GVWR - 30 mph J-Turn Right - Steps
Runs: 1817, 1818, 1819, 1820 and 1816
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle I - GVWR - 30 mph J-Turn Left - Steps
Runs: 1833, 1834, 1835, 1836 and 1832
Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle A – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	26.3	0.17	-17.5	-0.12	21.9	0.145
50.0	52.5	0.30	-35.0	-0.25	43.8	0.275
75.0	78.8	0.44	-52.5	-0.36	65.6	0.400
87.5	91.9	0.51	-61.3	-0.46	76.6	0.485
100.0	105.0	0.68	-70.0	-0.64	87.5	0.660

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle B – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	32.3	0.22	-32.3	-0.18	32.3	0.200
50.0	64.5	0.38	-64.5	-0.31	64.5	0.345
75.0	96.8	0.50	-96.8	-0.43	96.8	0.465
87.5	112.9	0.57	-112.9	-0.49	112.9	0.530
100.0	129.0	0.63	-129.0	-0.59	129.0	0.610

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle C – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	Steering Angle (deg)	Lateral Accel. (g)	Steering Angle (deg)	Lateral Accel. (g)	Steering Angle (deg)	Lateral Accel. (g)
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	25.0	0.19	-23.8	-0.21	24.4	0.200
50.0	50.0	0.41	-47.5	-0.40	48.8	0.405
75.0	75.0	0.63	-71.3	-0.59	73.1	0.610
87.5	87.5	0.69	-83.1	-0.66	85.3	0.675
100.0	100.0	0.73	-95.0	-0.69	97.5	0.710

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle D – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	6.3	0.09	-6.9	-0.10	6.6	0.095
50.0	12.5	0.17	-13.8	-0.21	13.1	0.190
75.0	18.8	0.26	-20.6	-0.37	19.7	0.315
87.5	21.9	0.48	-24.1	-0.54	23.0	0.510
100.0	25.0	0.61	-27.5	-0.61	26.3	0.610

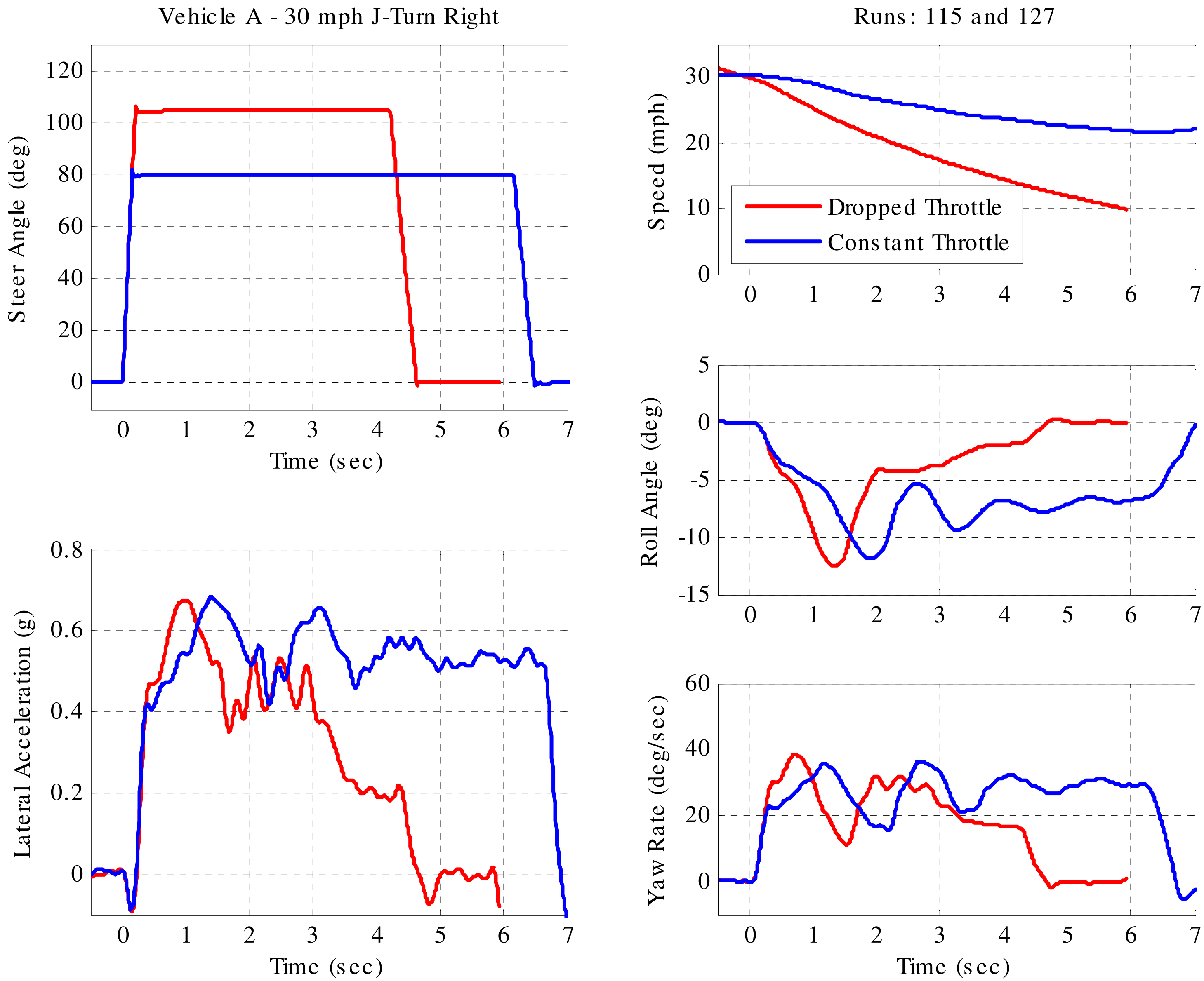
Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle E – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	35.0	0.21	-37.5	-0.22	36.3	0.215
50.0	70.0	0.38	-75.0	-0.40	72.5	0.390
75.0	105.0	0.53	-112.5	-0.56	108.8	0.545
87.5	122.5	0.61	-131.3	-0.63	126.9	0.620
100.0	140.0	0.69	-150.0	-0.70	145.0	0.695

Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle F – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	23.8	0.13	-18.8	-0.12	21.3	0.125
50.0	47.5	0.26	-37.5	-0.24	42.5	0.250
75.0	71.3	0.36	-56.3	-0.37	63.8	0.365
87.5	83.1	0.46	-65.6	-0.45	74.4	0.455
100.0	95.0	0.66	-75.0	-0.65	85.0	0.655

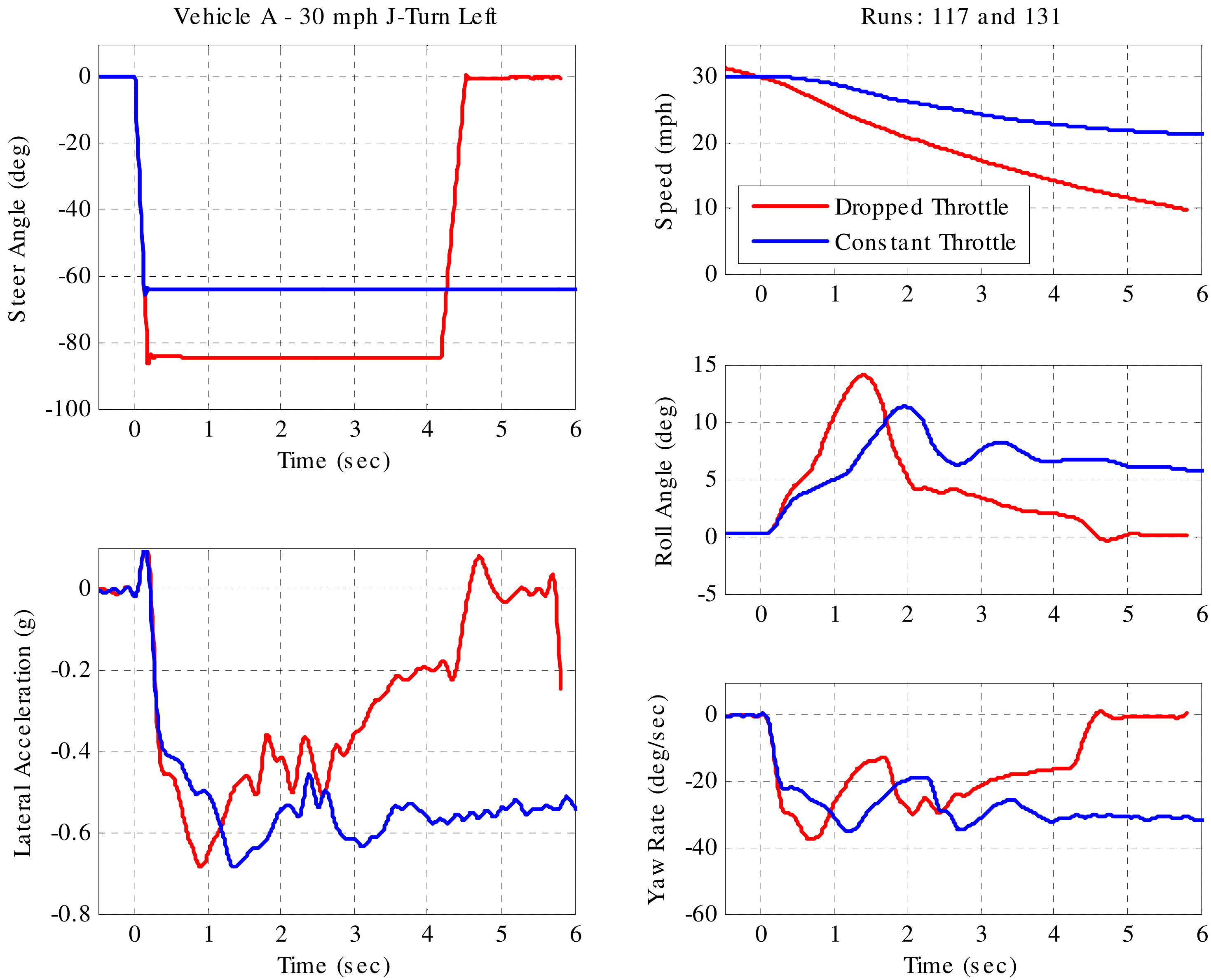
Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle G – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	32.5	0.22	-33.8	-0.21	33.1	0.215
50.0	65.0	0.44	-67.5	-0.43	66.3	0.435
75.0	97.5	0.60	-101.3	-0.58	99.4	0.590
87.5	113.8	0.63	-118.1	-0.63	115.9	0.630
100.0	130.0	0.68	-135.0	-0.68	132.5	0.680

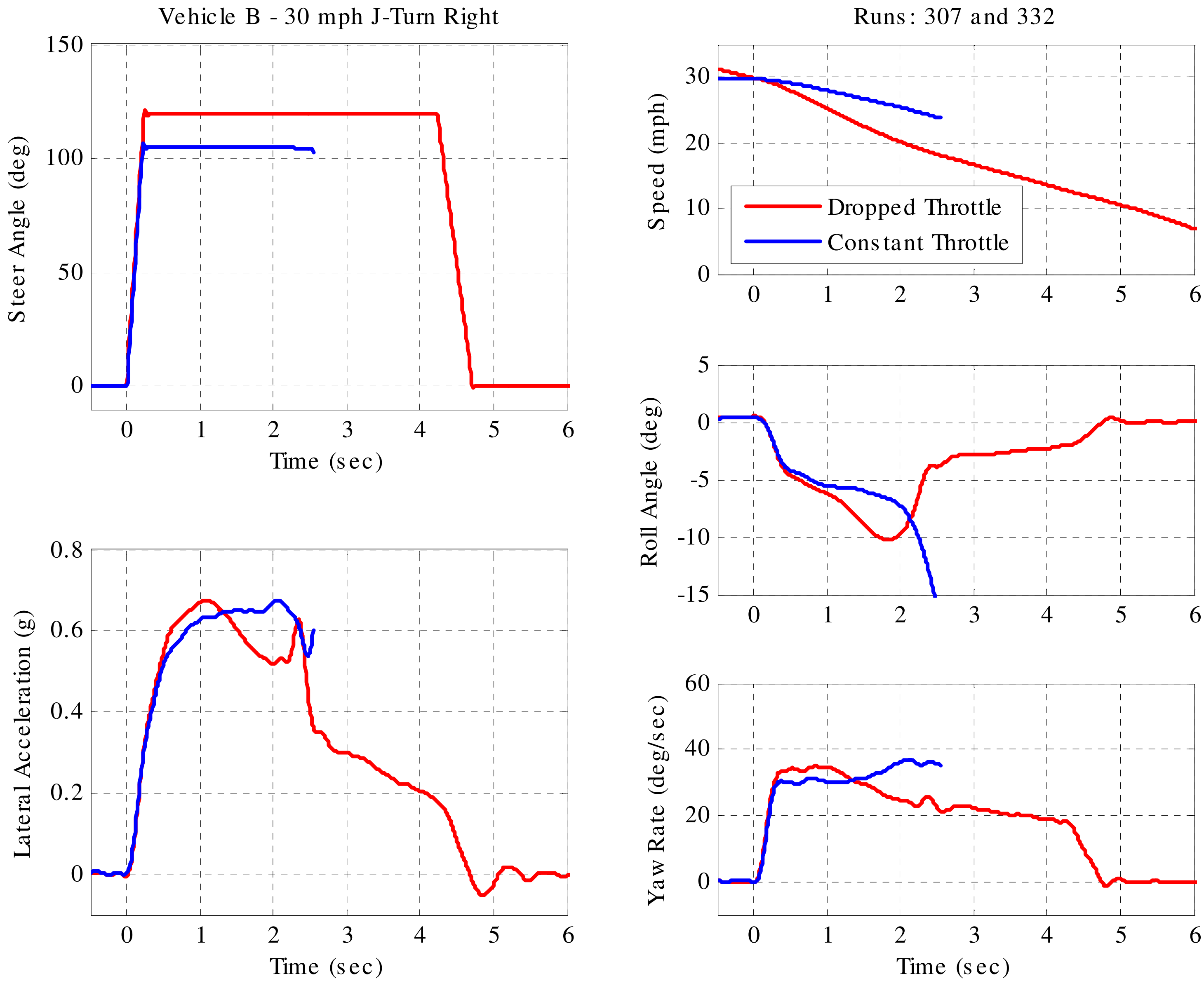
Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle H – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	Steering Angle (deg)	Lateral Accel. (g)	Steering Angle (deg)	Lateral Accel. (g)	Steering Angle (deg)	Lateral Accel. (g)
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	42.5	0.20	-37.5	-0.20	40.0	0.200
50.0	85.0	0.37	-75.0	-0.38	80.0	0.375
75.0	127.5	0.51	-112.5	-0.53	120.0	0.520
87.5	148.8	0.61	-131.3	-0.61	140.0	0.610
100.0	170.0	0.70	-150.0	-0.70	160.0	0.700

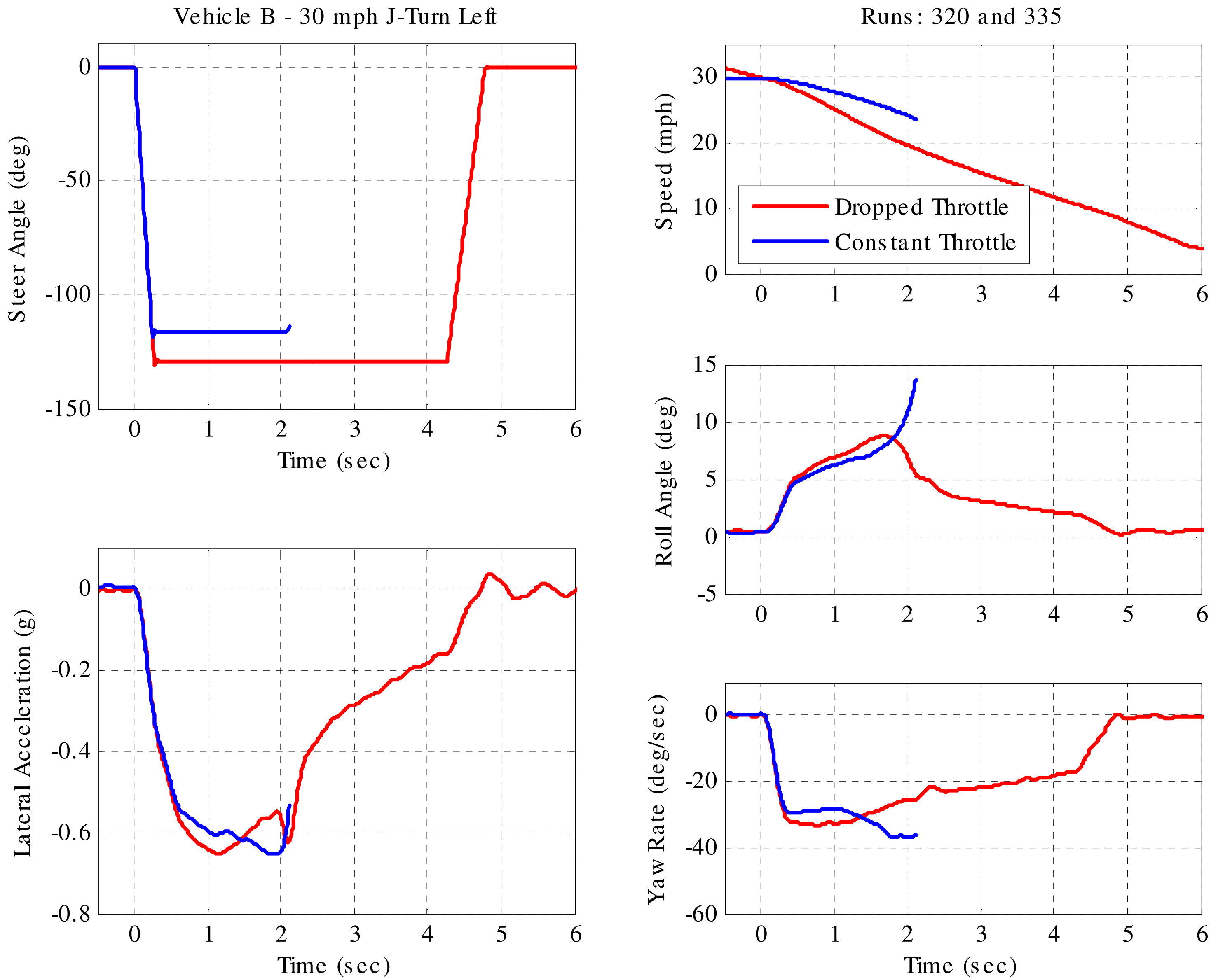
Maximum Lateral Accelerations During Dropped Throttle J-Turns Vehicle I – GVWR Loading						
	Right Steer Maneuvers		Left Steer Maneuvers		Average of Right and Left Maneuvers	
Percentage of Steering Required for Two Wheel Lift (%)	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**	**Steering Angle (deg)**	**Lateral Accel. (g)**
0.0	0.0	0.00	0.0	0.00	0.0	0.000
25.0	37.5	0.17	-38.8	-0.18	38.1	0.175
50.0	75.0	0.34	-77.5	-0.35	76.3	0.345
75.0	112.5	0.54	-116.3	-0.52	114.4	0.530
87.5	131.3	0.60	-135.6	-0.62	133.4	0.610
100.0	150.0	0.62	-155.0	-0.65	152.5	0.635

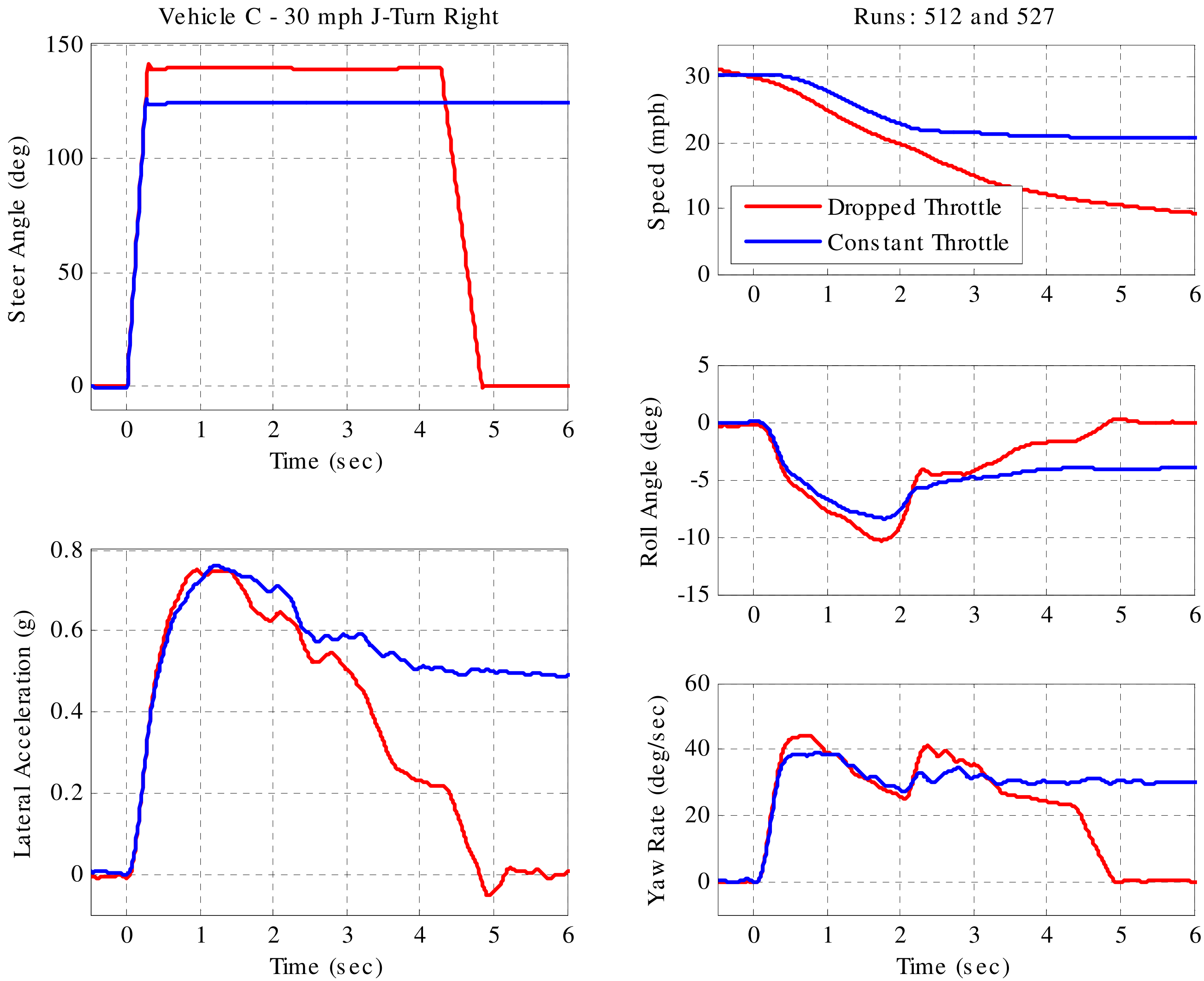


Vehicle A - 30 mph J-Turn Right
Runs: 115 and 127
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

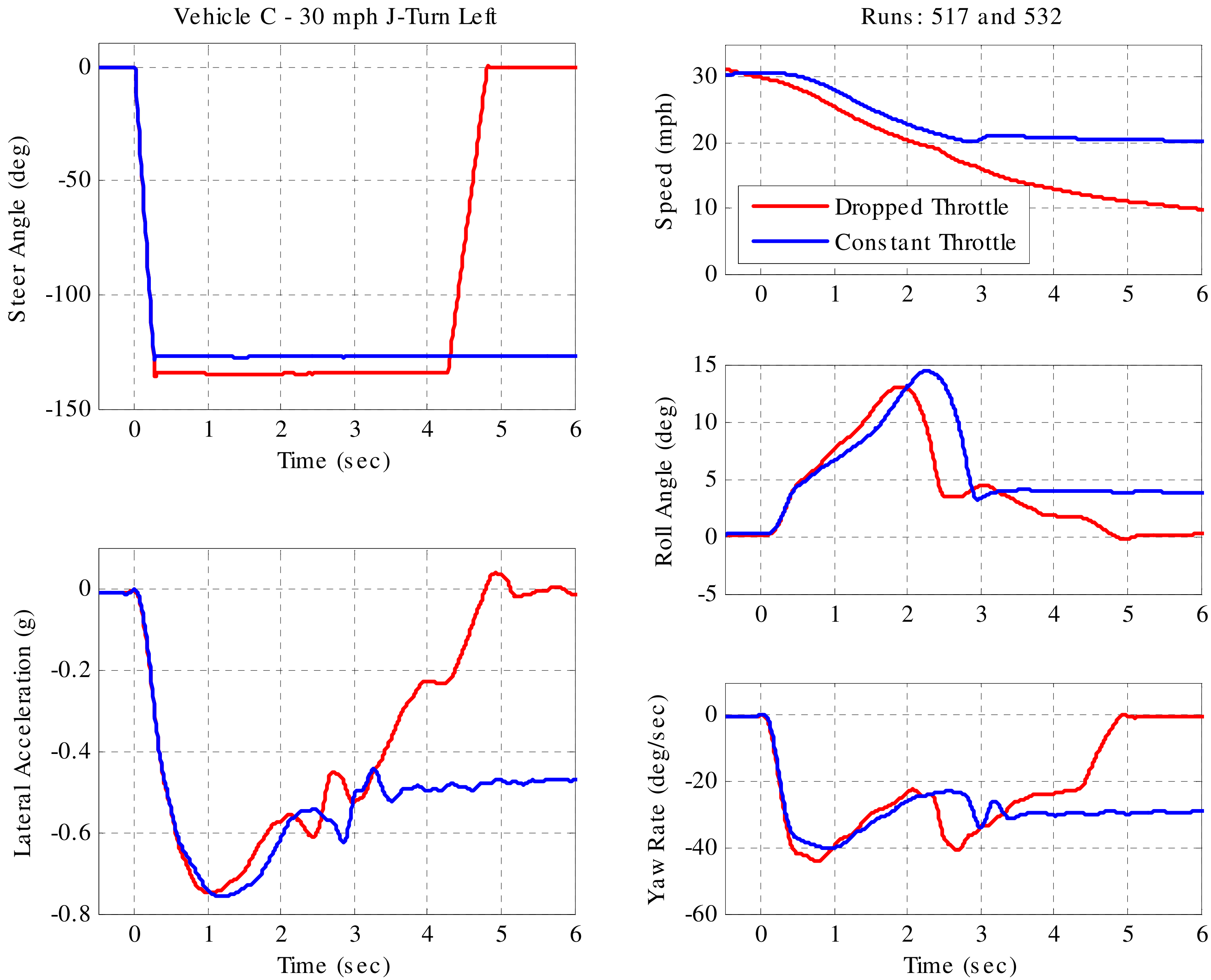

Vehicle A - 30 mph J-Turn Left
Runs: 117 and 131
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle B - 30 mph J-Turn Right
Runs: 307 and 332
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

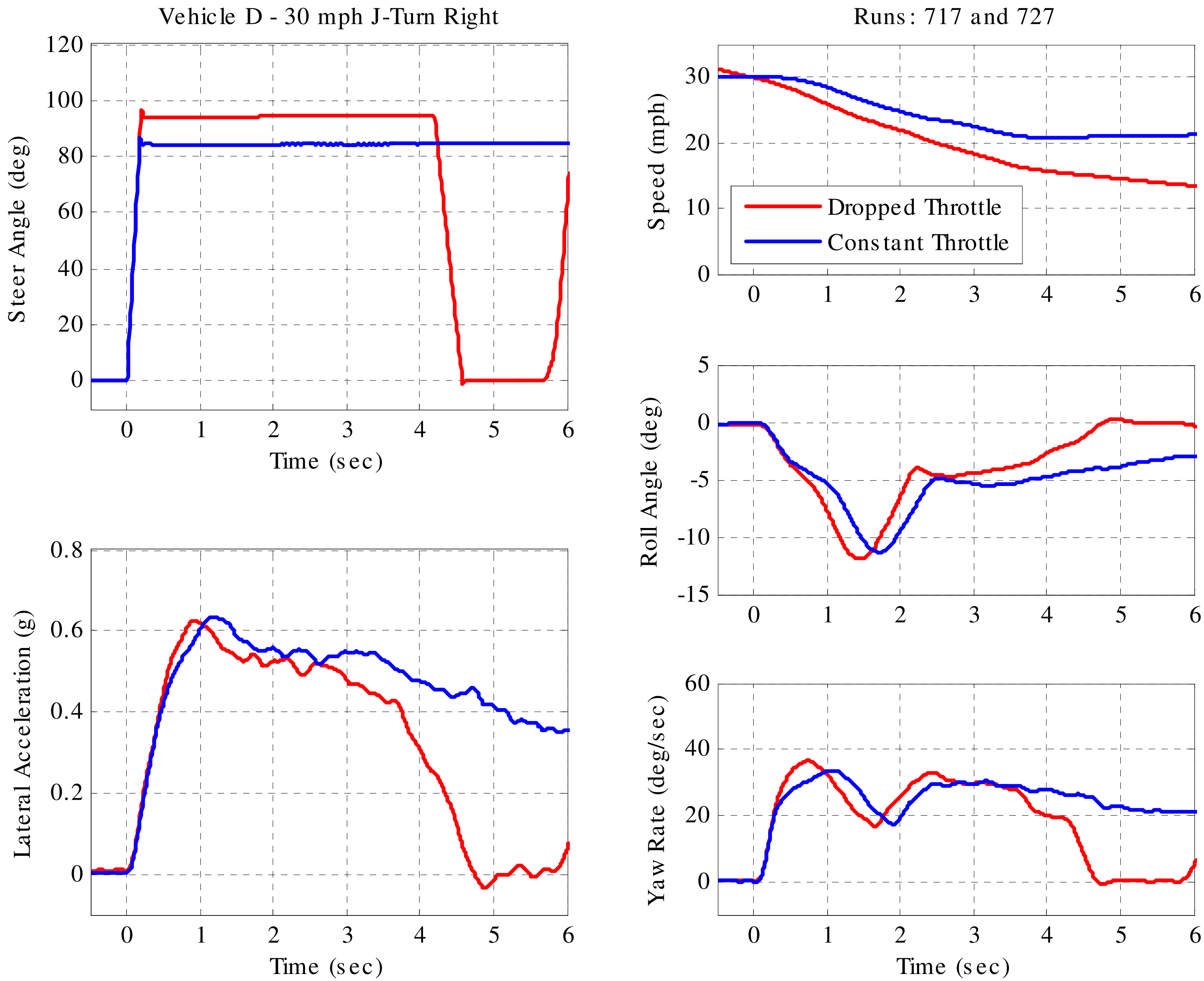

Vehicle B - 30 mph J-Turn Left
Runs: 320 and 335
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



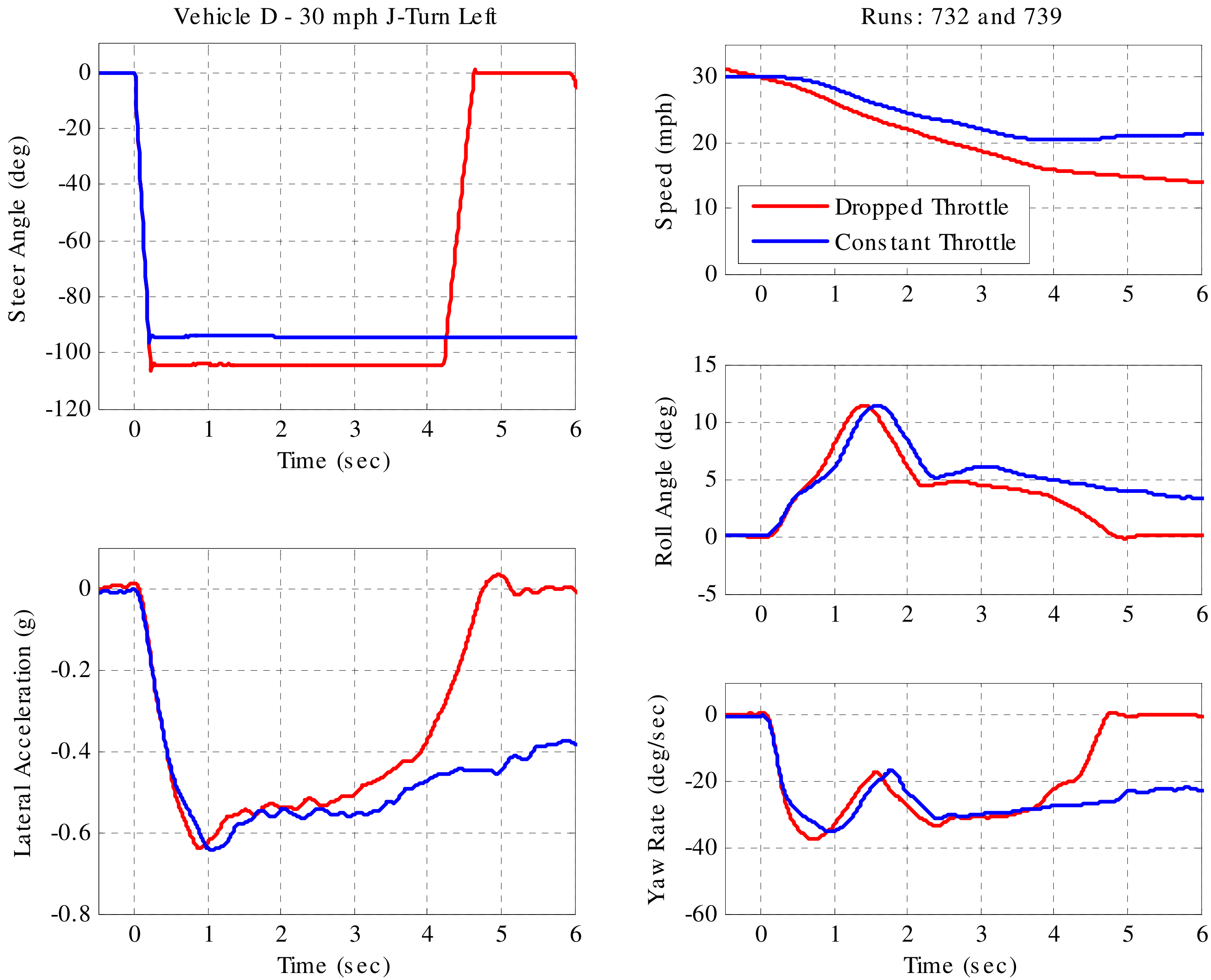
Vehicle C - 30 mph J-Turn Right
Runs: 512 and 527
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

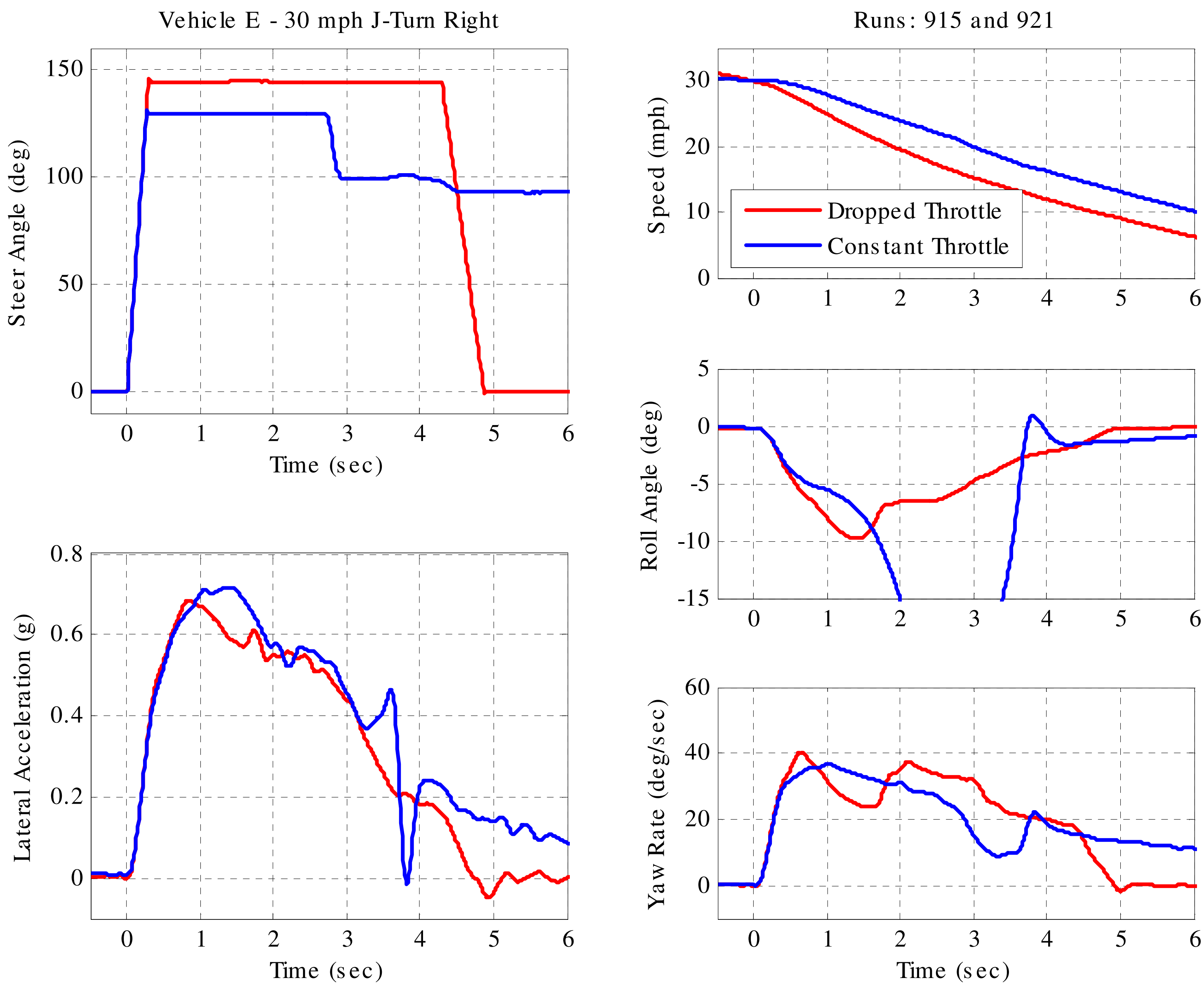


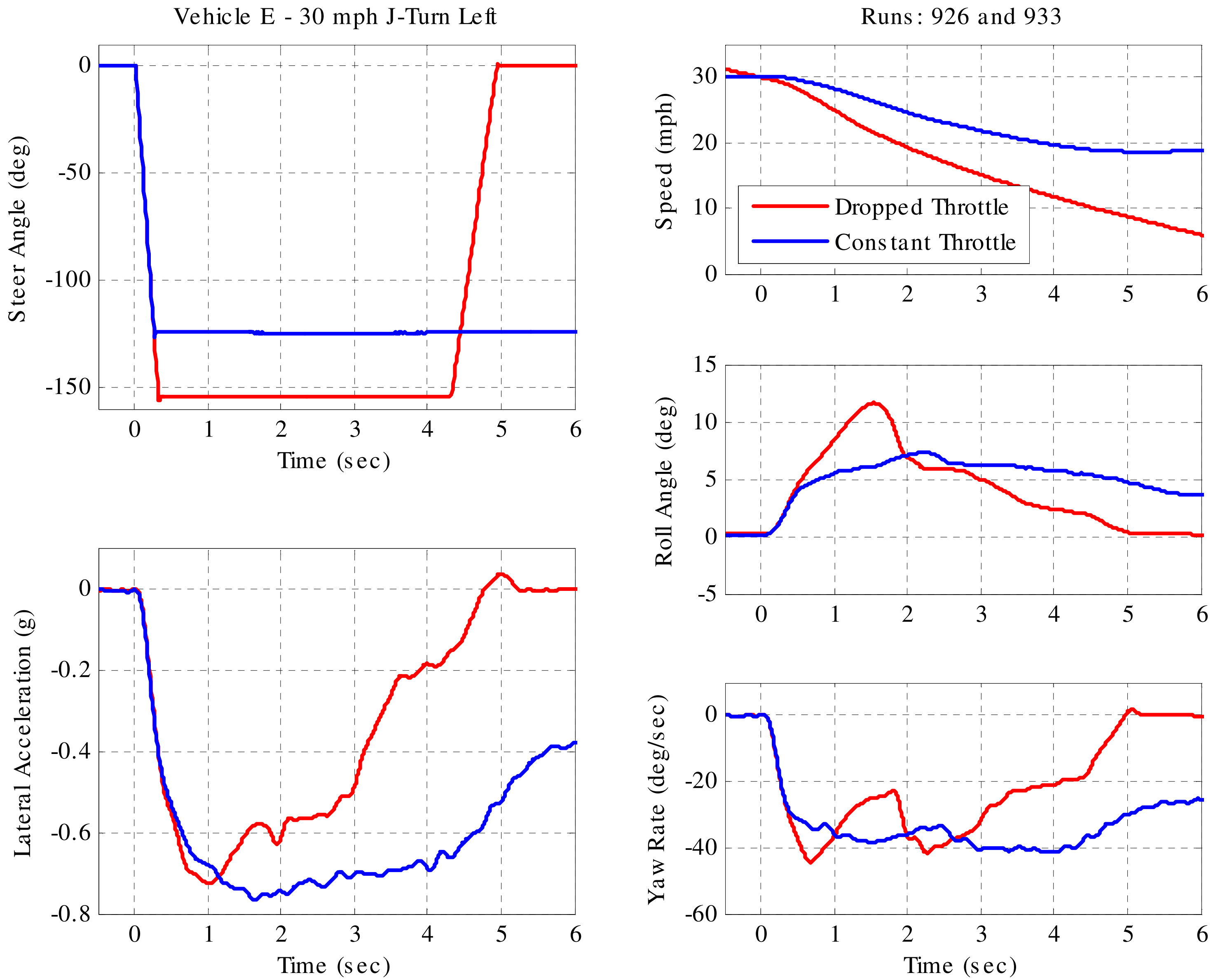
Vehicle C - 30 mph J-Turn Left
Runs: 517 and 532
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

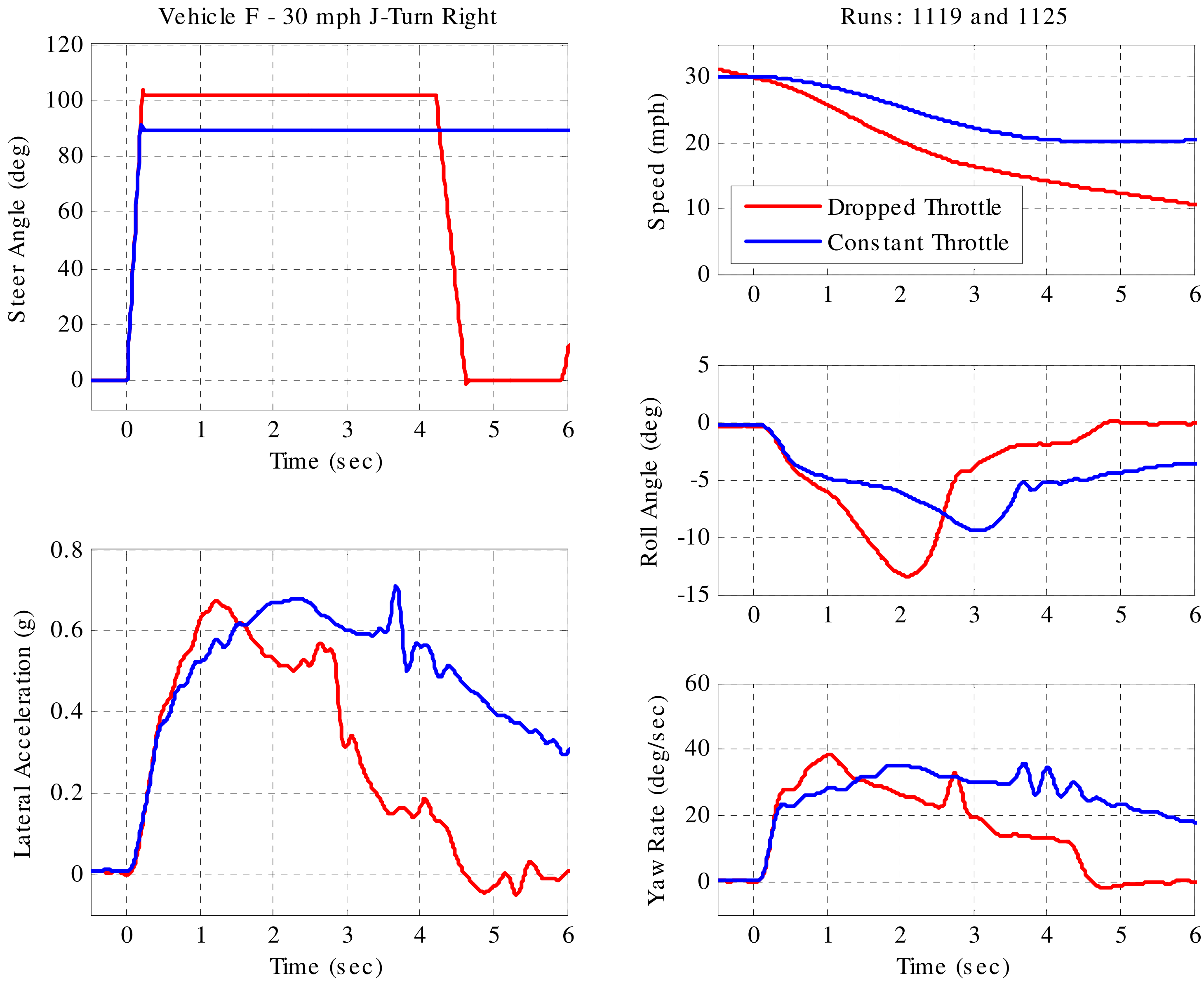


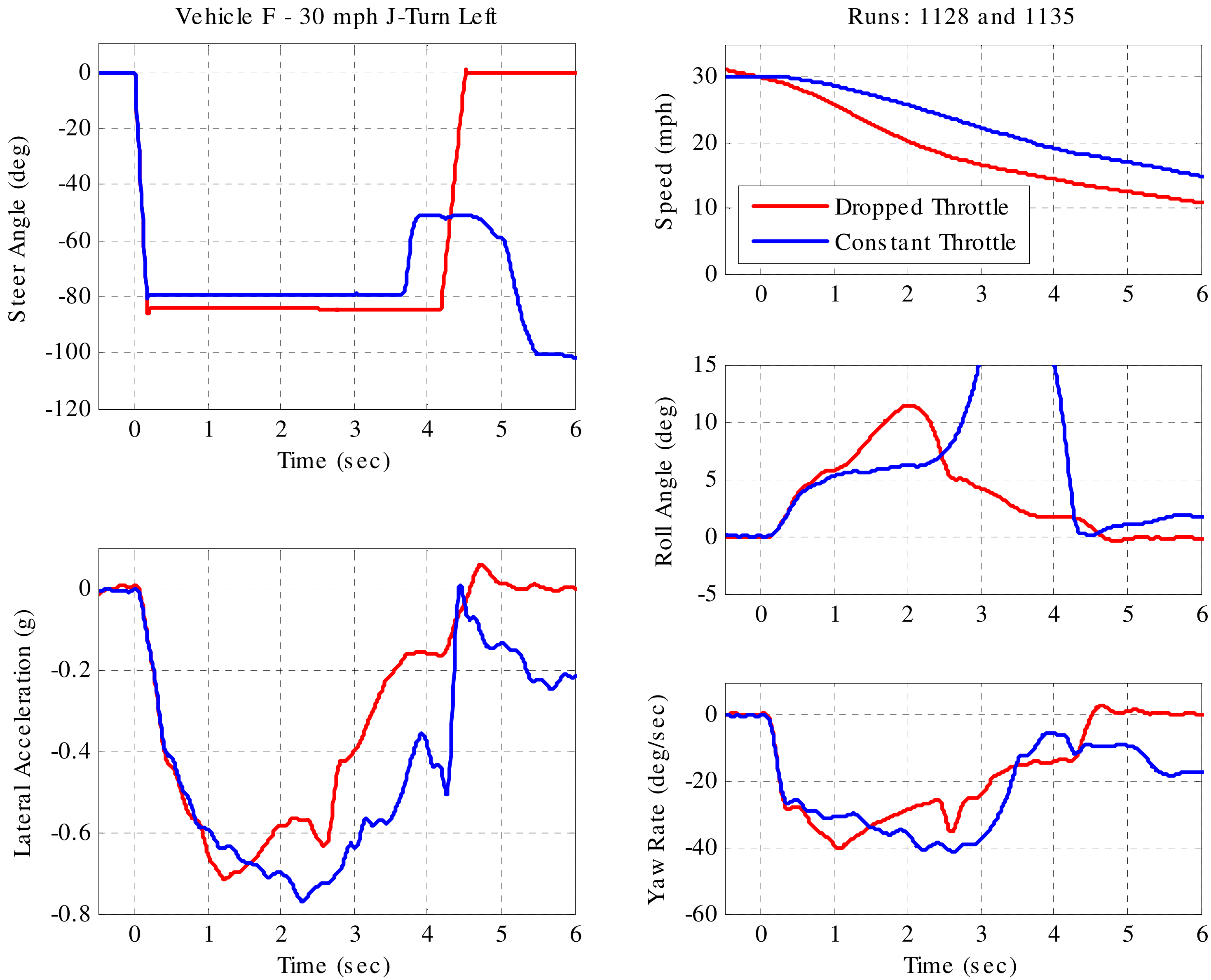
Vehicle D - 30 mph J-Turn Right
Runs: 717 and 727
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)


Vehicle D - 30 mph J-Turn Left
Runs: 732 and 739
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

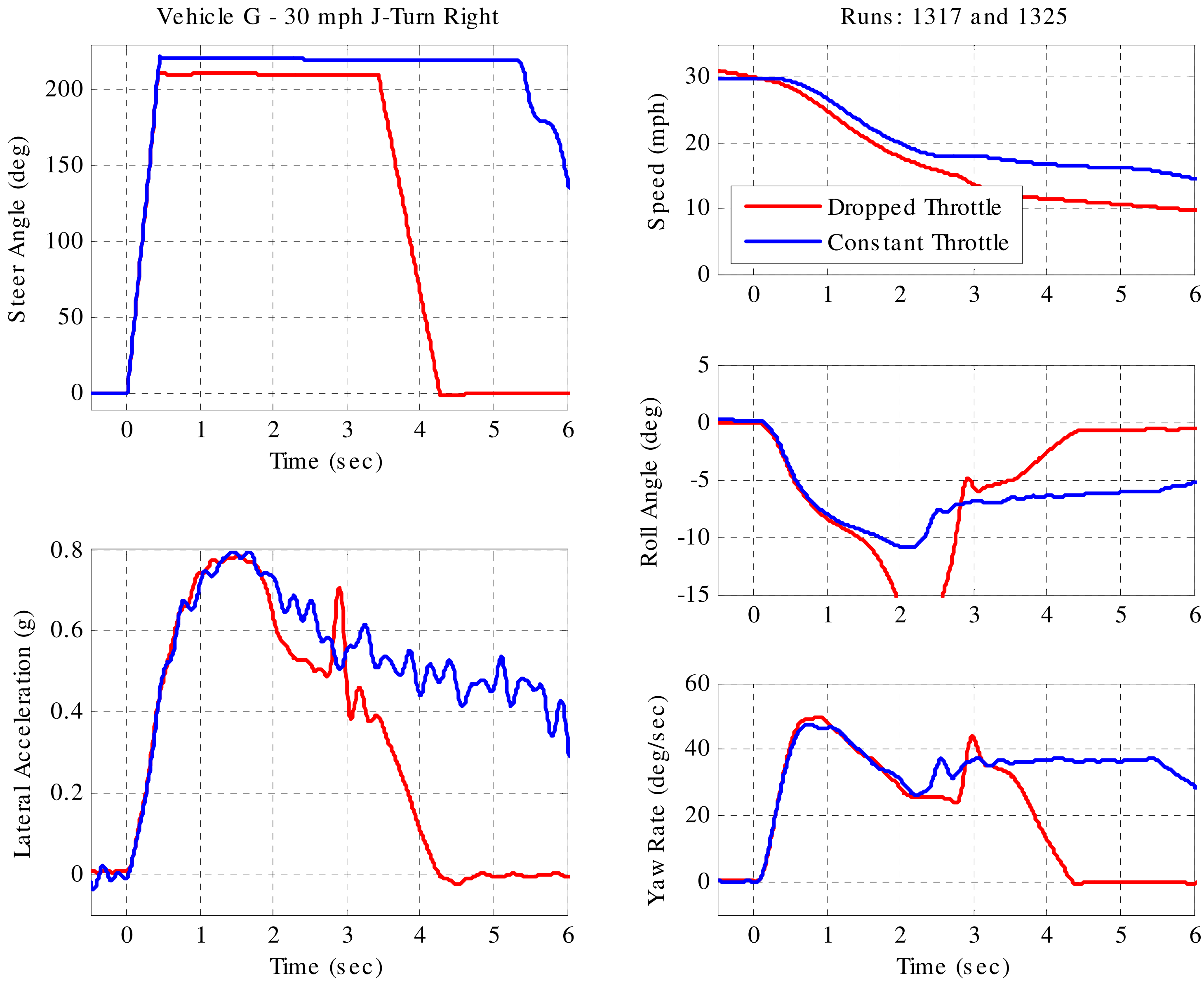

Vehicle E - 30 mph J-Turn Right
Runs: 915 and 921
Steer Angle (deg)
150
100
50
0
0 1 2 3 4 5 6
Time (sec)
Speed (mph)
30
20
10
0
Dropped Throttle
Constant Throttle
Roll Angle (deg)
5
0
-5
-10
-15
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Yaw Rate (deg/sec)
60
40
20
0
Time (sec)

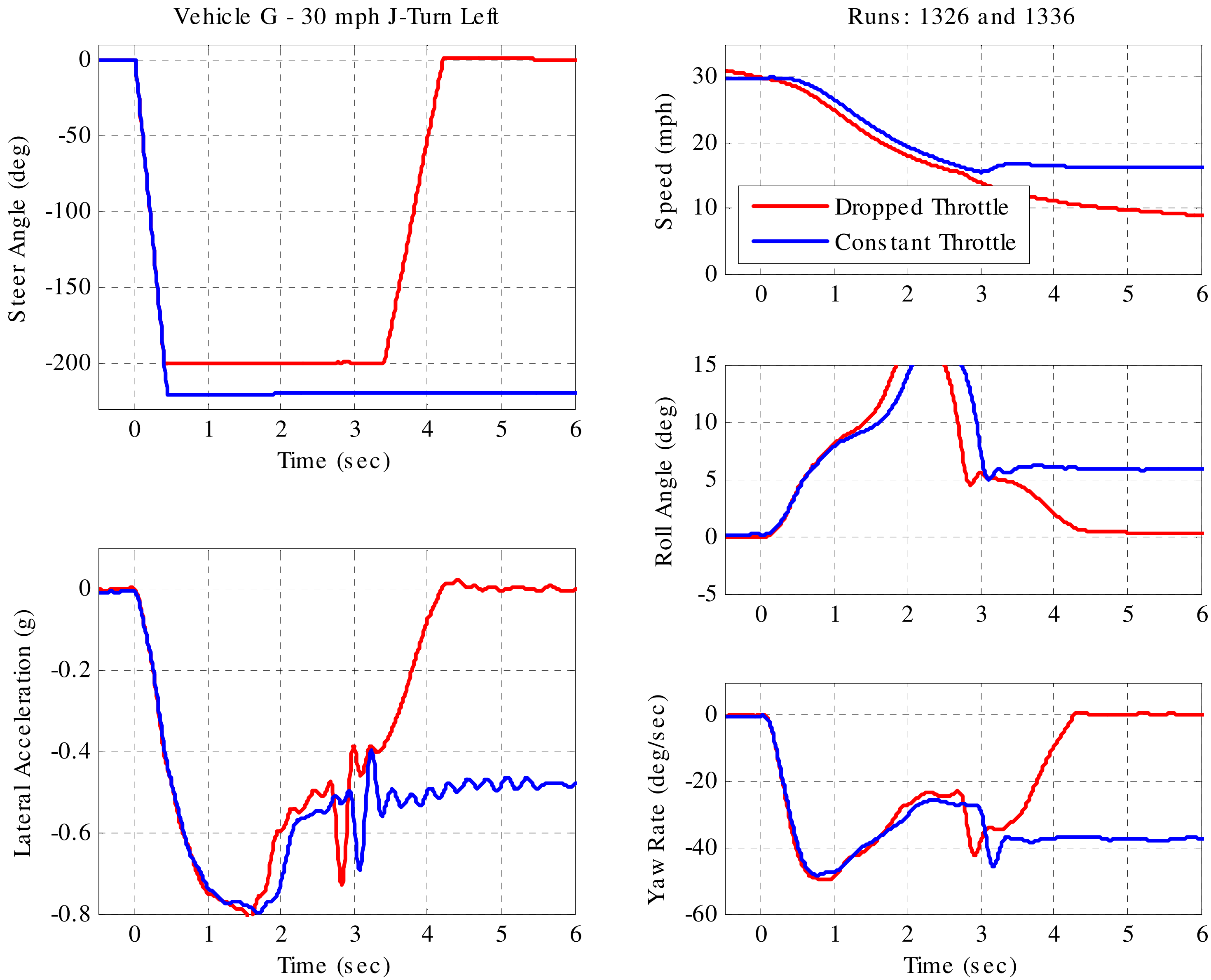

Vehicle E - 30 mph J-Turn Left
Runs: 926 and 933
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

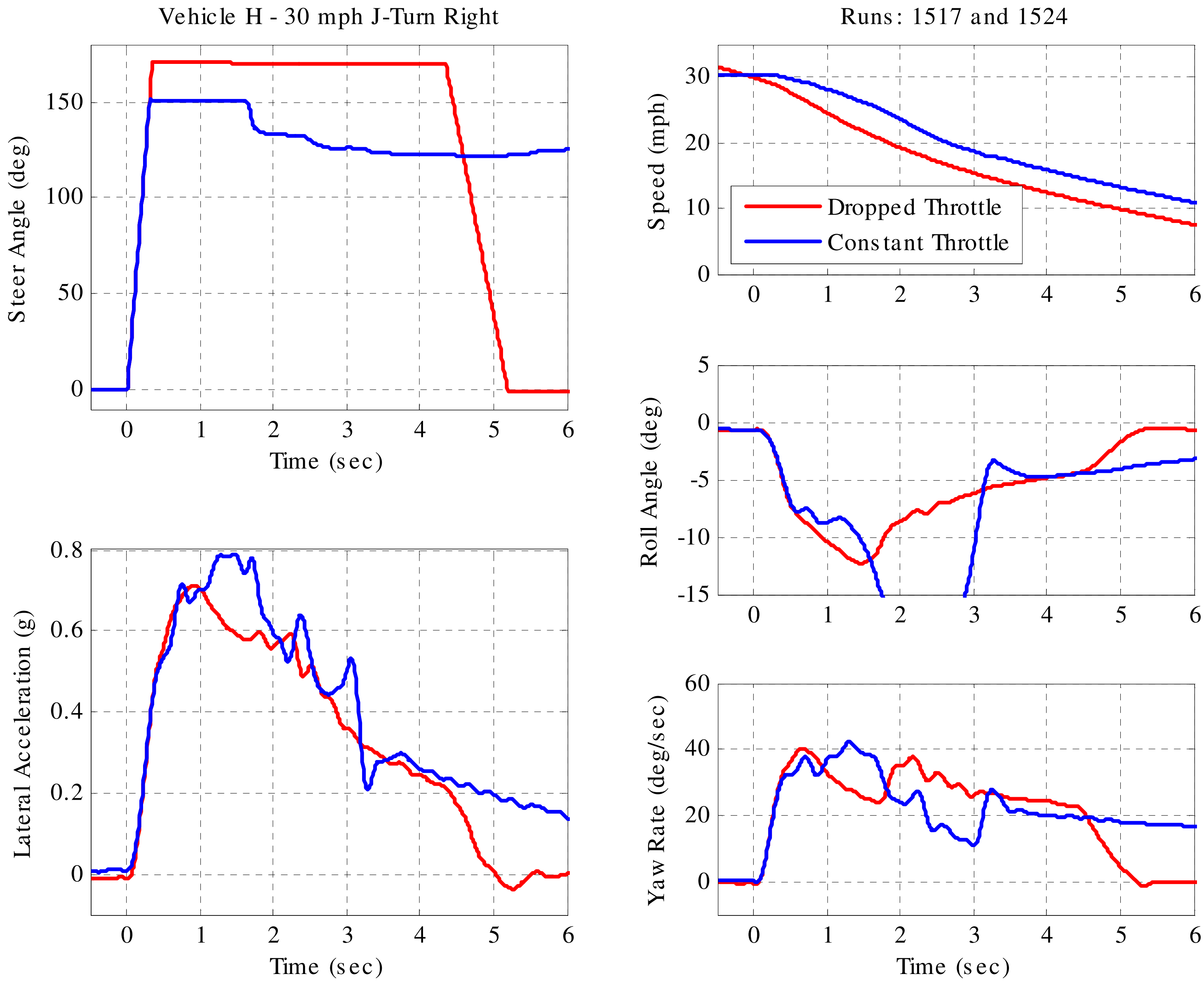

Vehicle F - 30 mph J-Turn Right
Runs: 1119 and 1125
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

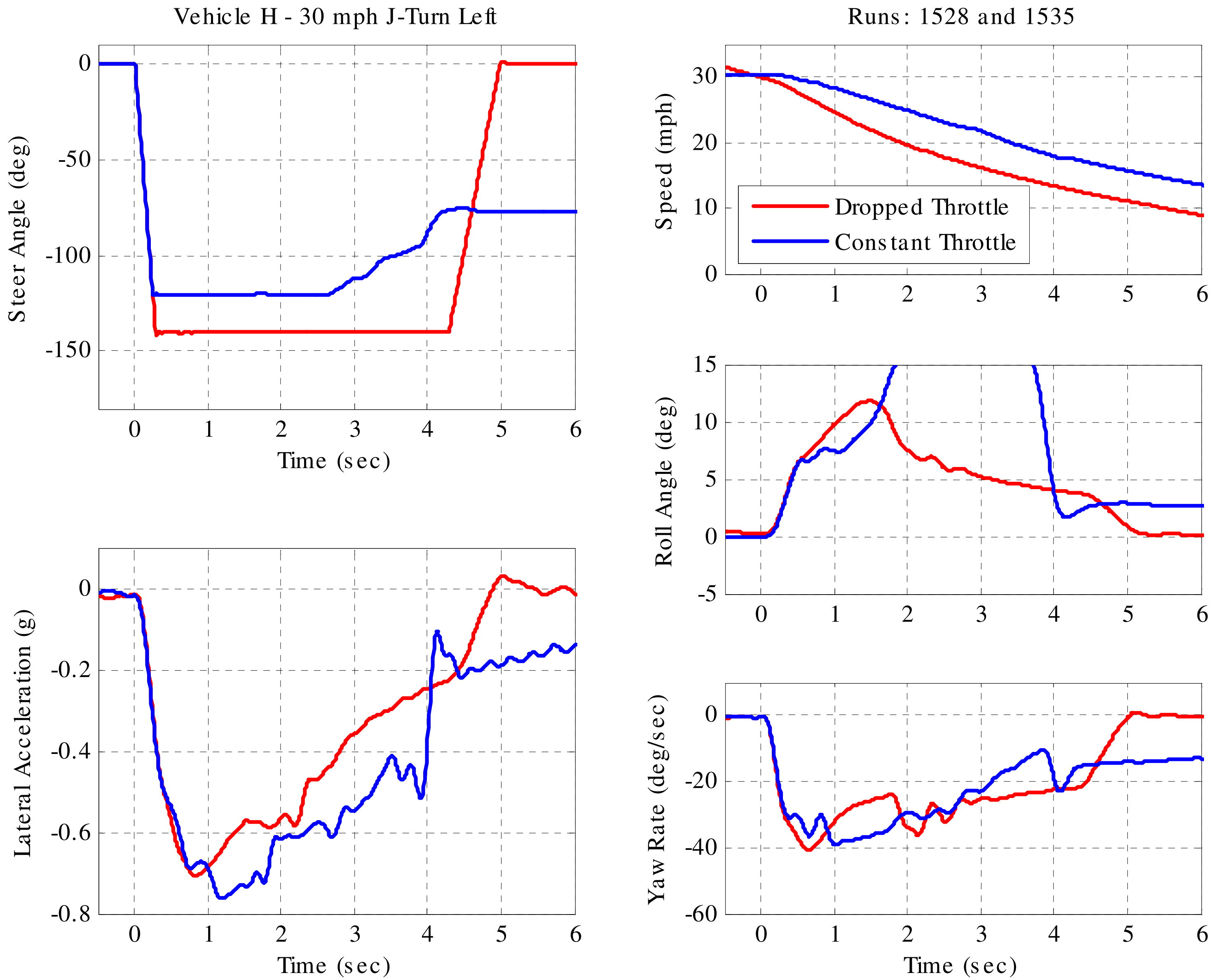


Vehicle F - 30 mph J-Turn Left
Runs: 1128 and 1135
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

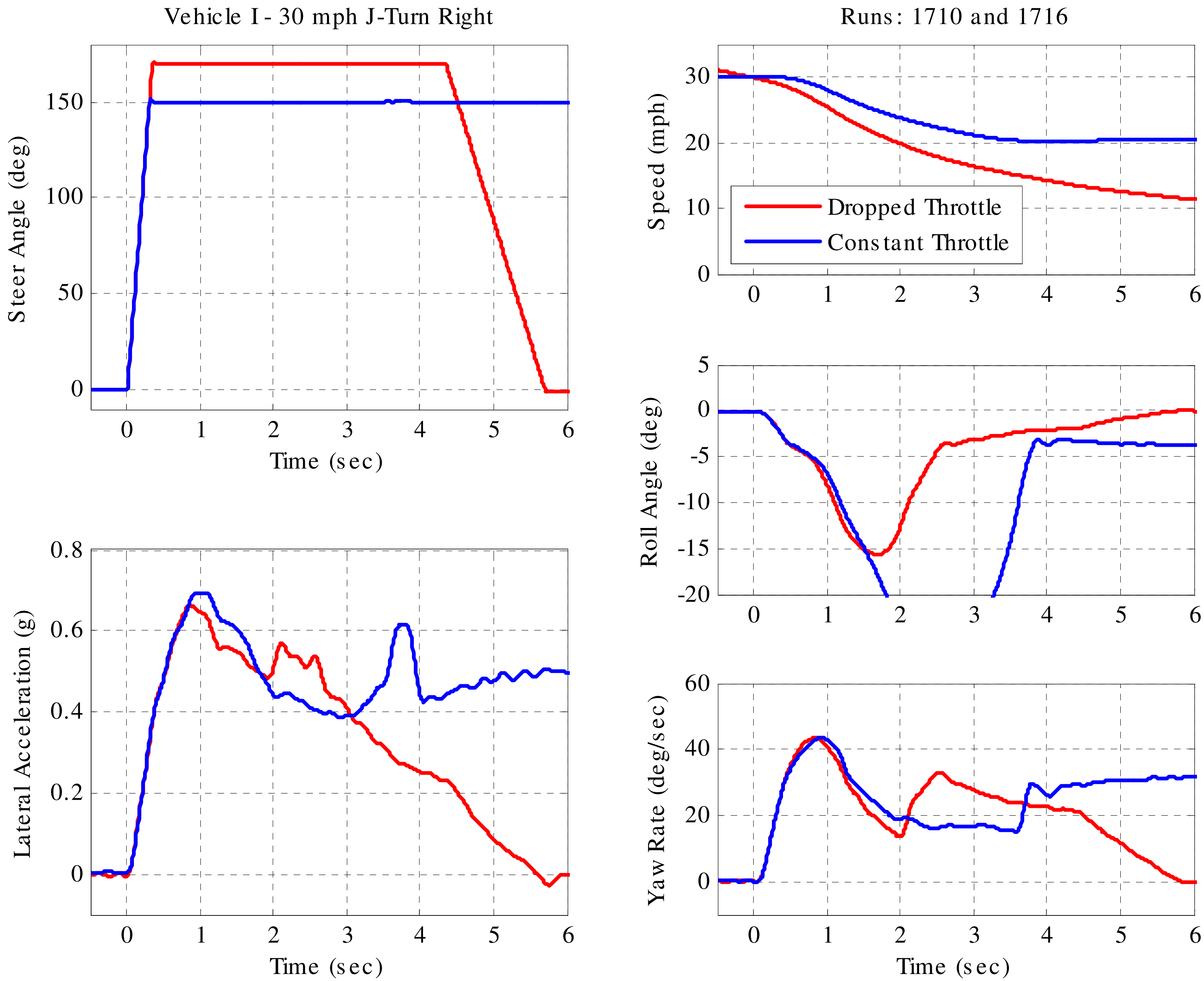

Vehicle G - 30 mph J-Turn Right
Runs: 1317 and 1325
Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

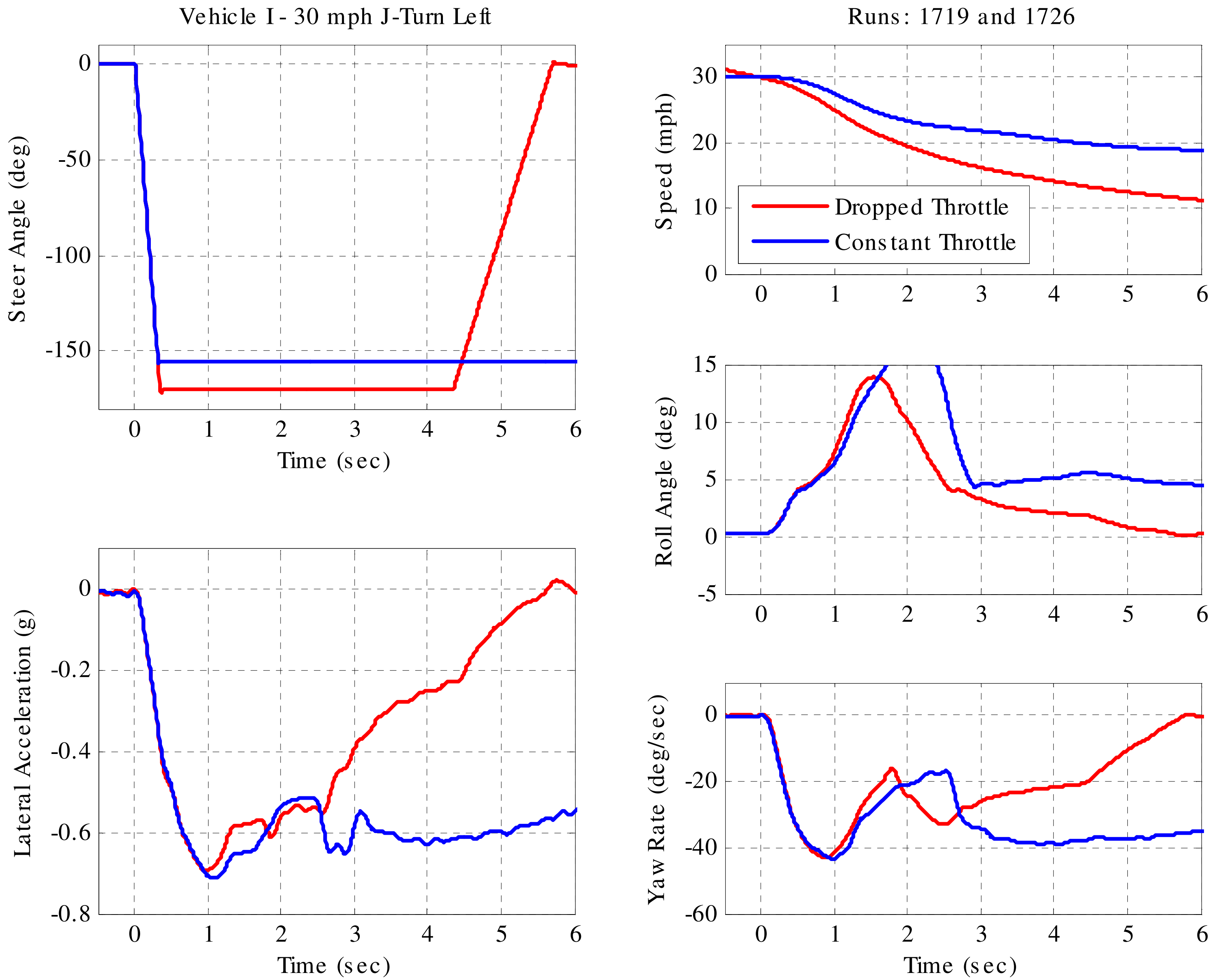

Vehicle G - 30 mph J-Turn Left
Runs: 1326 and 1336
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

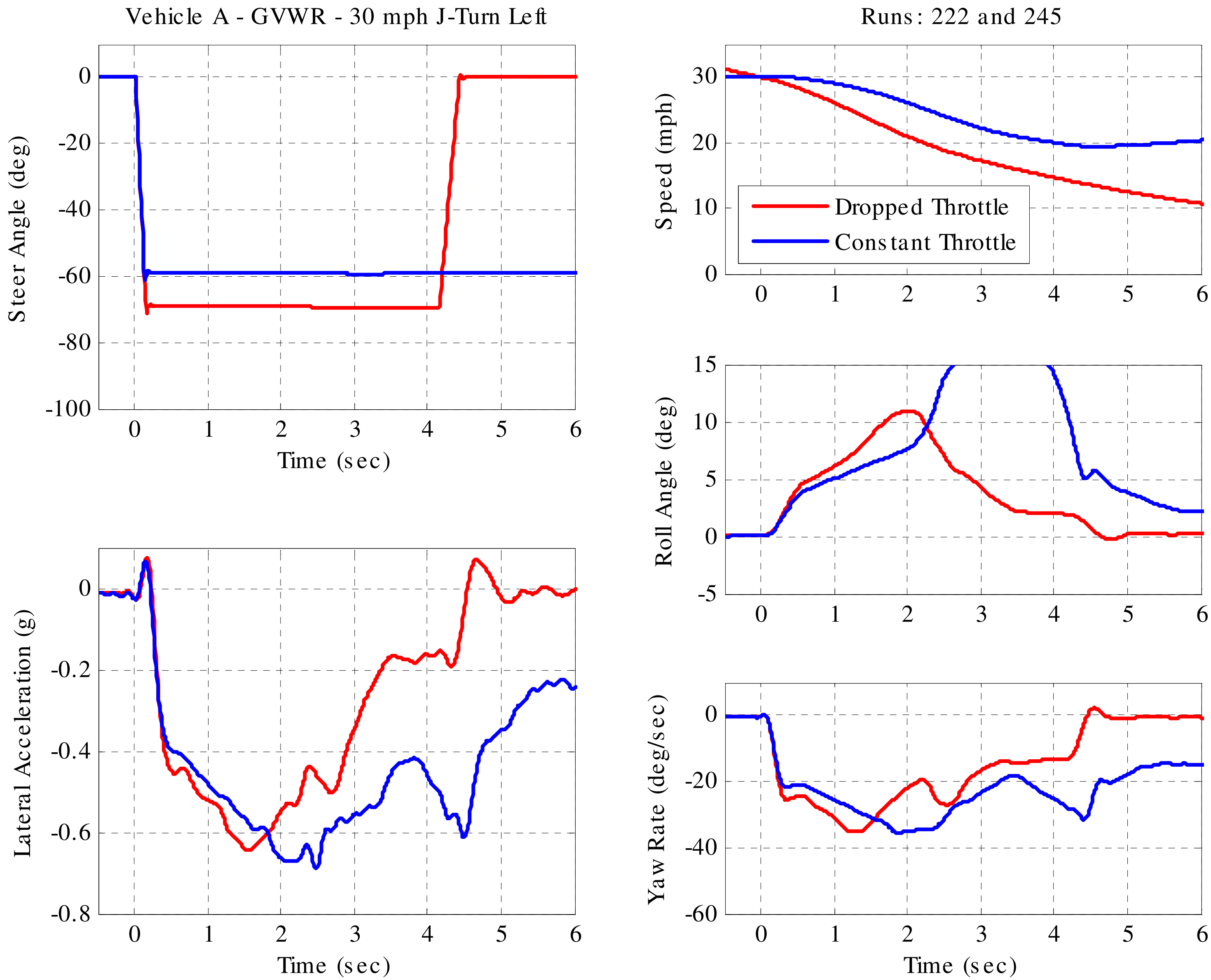

Vehicle H - 30 mph J-Turn Right
Runs: 1517 and 1524
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

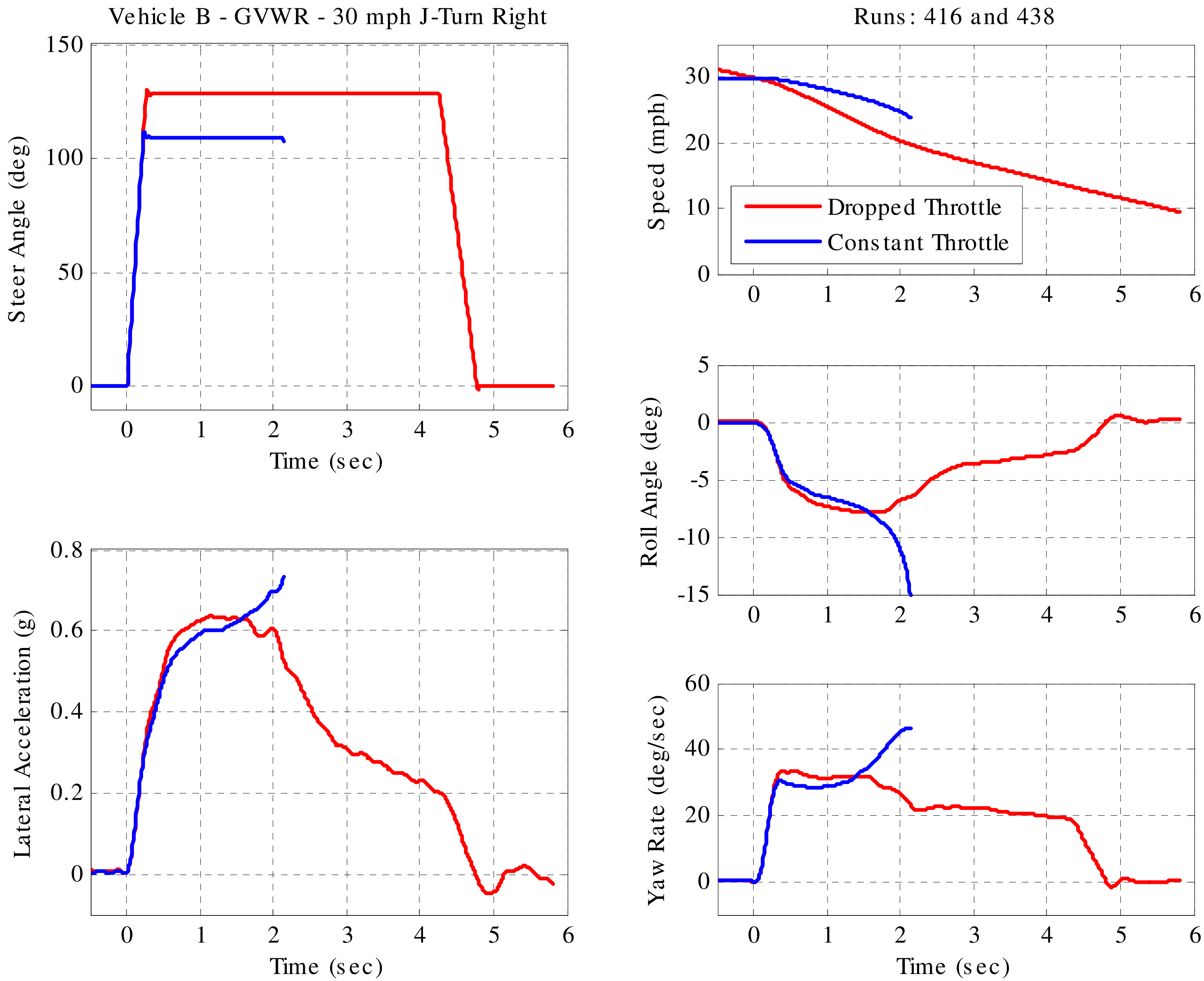


Vehicle H - 30 mph J-Turn Left
Runs: 1528 and 1535
Steer Angle (deg)
0
-50
-100
-150
Time (sec)
Speed (mph)
30
20
10
Dropped Throttle
Constant Throttle
Roll Angle (deg)
15
5
-5
Lateral Acceleration (g)
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
-20
-40
-60
0
1
2
3
4
5
6

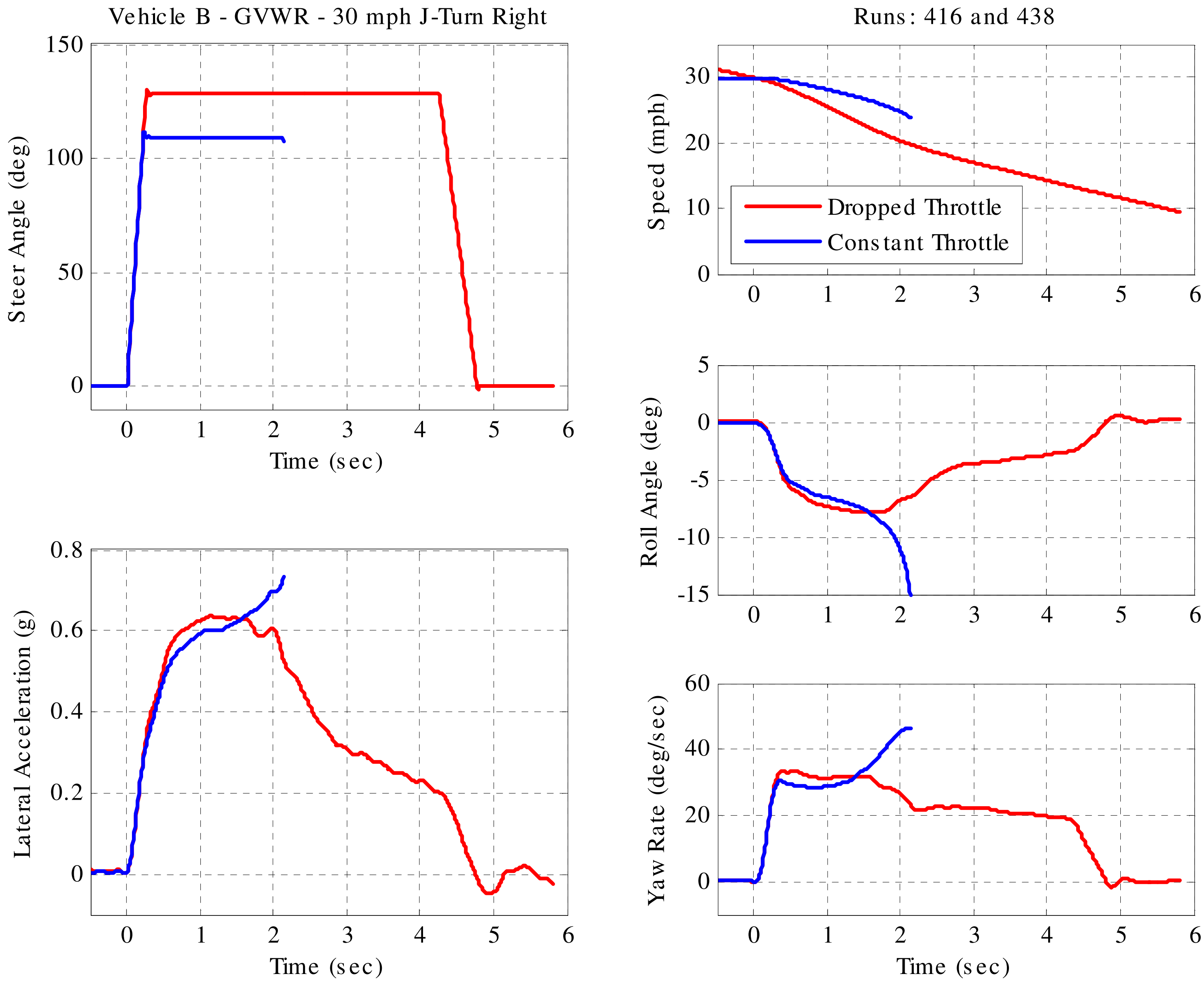

Vehicle I - 30 mph J-Turn Right
Runs: 1710 and 1716
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

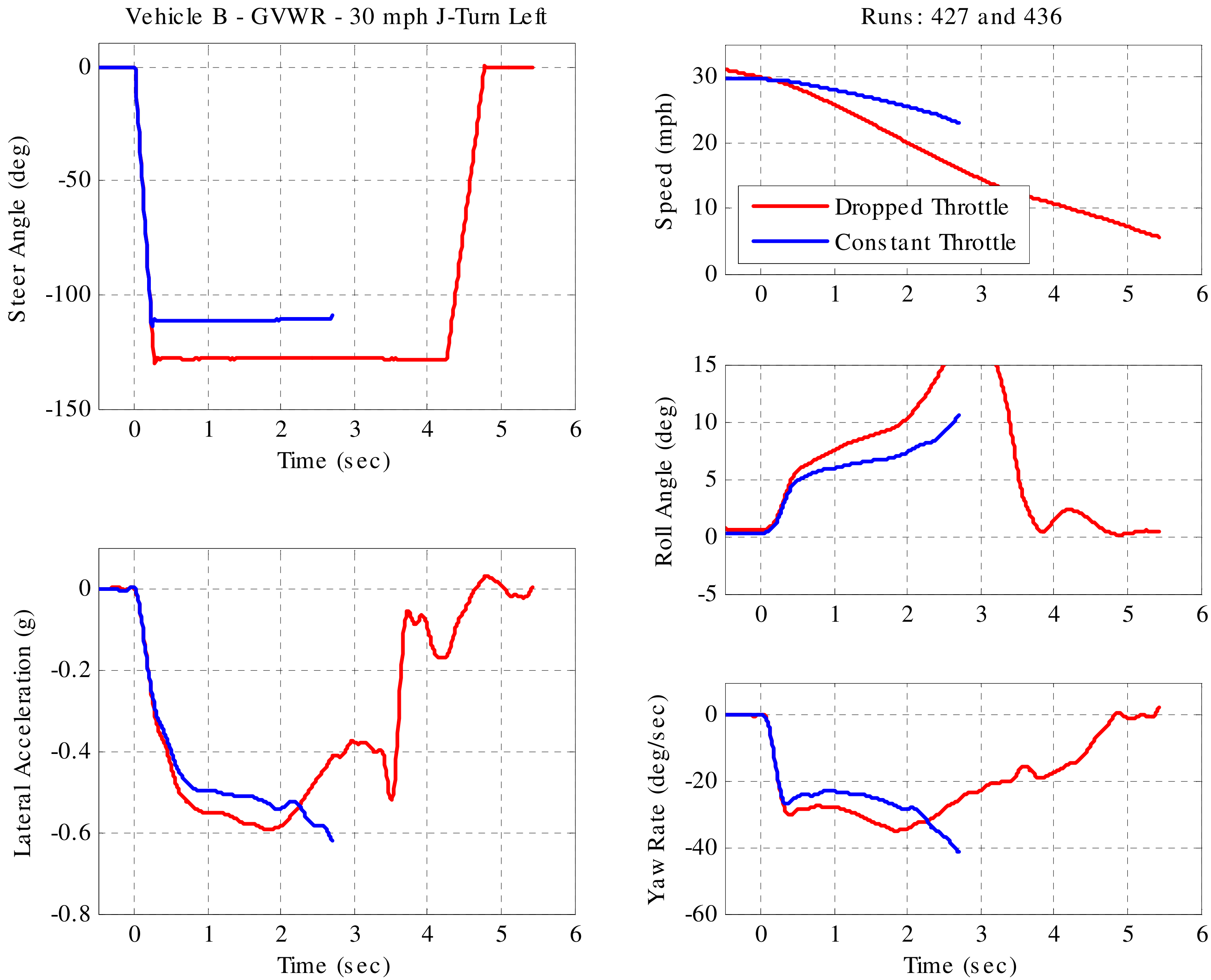

Vehicle I - 30 mph J-Turn Left
Runs: 1719 and 1726
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

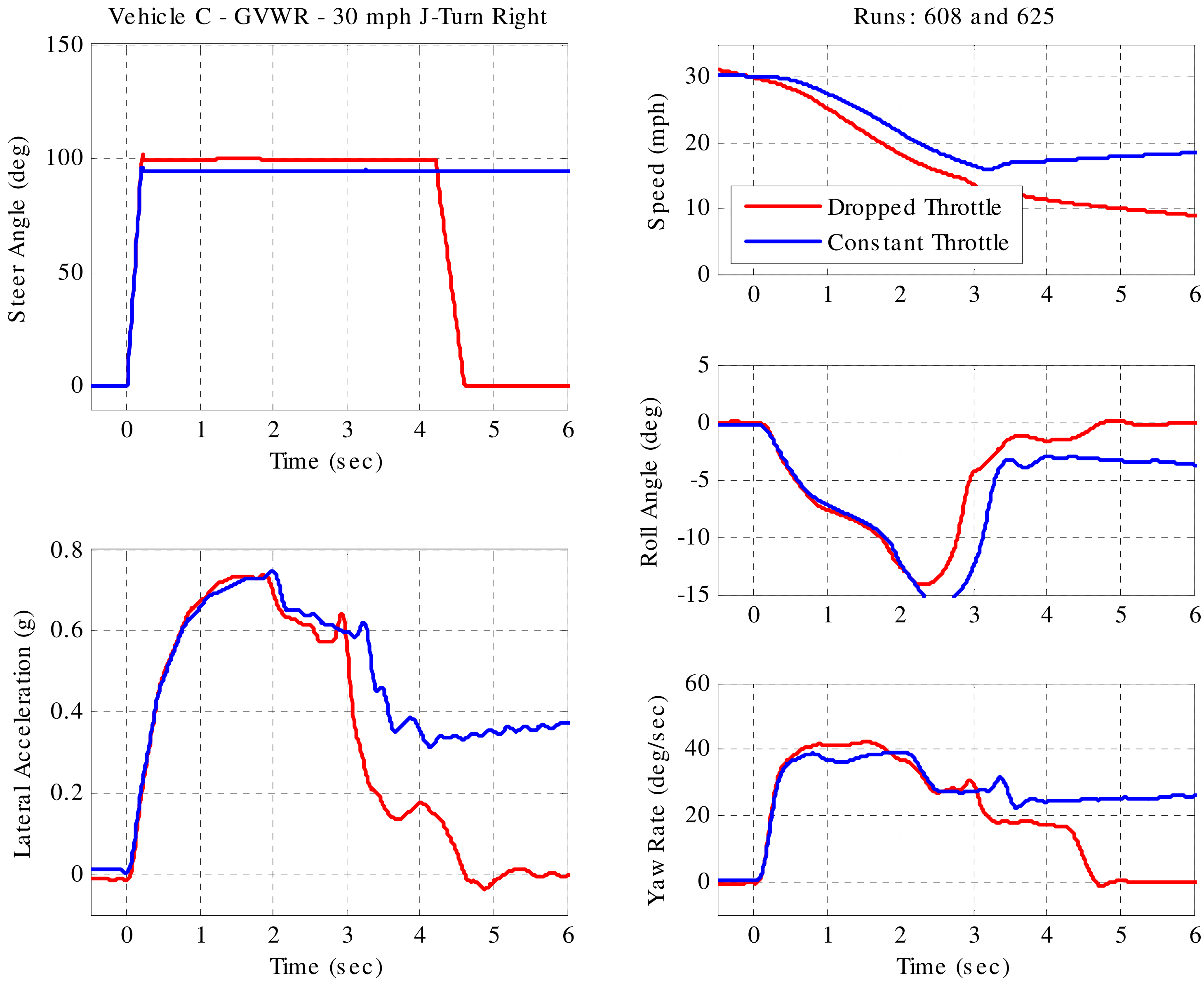

Vehicle A - GVWR - 30 mph J-Turn Left
Runs: 222 and 245
Steer Angle (deg)
0
-20
-40
-60
-80
-100
Time (sec)
Speed (mph)
30
20
10
0
Dropped Throttle
Constant Throttle
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60
0
1
2
3
4
5
6



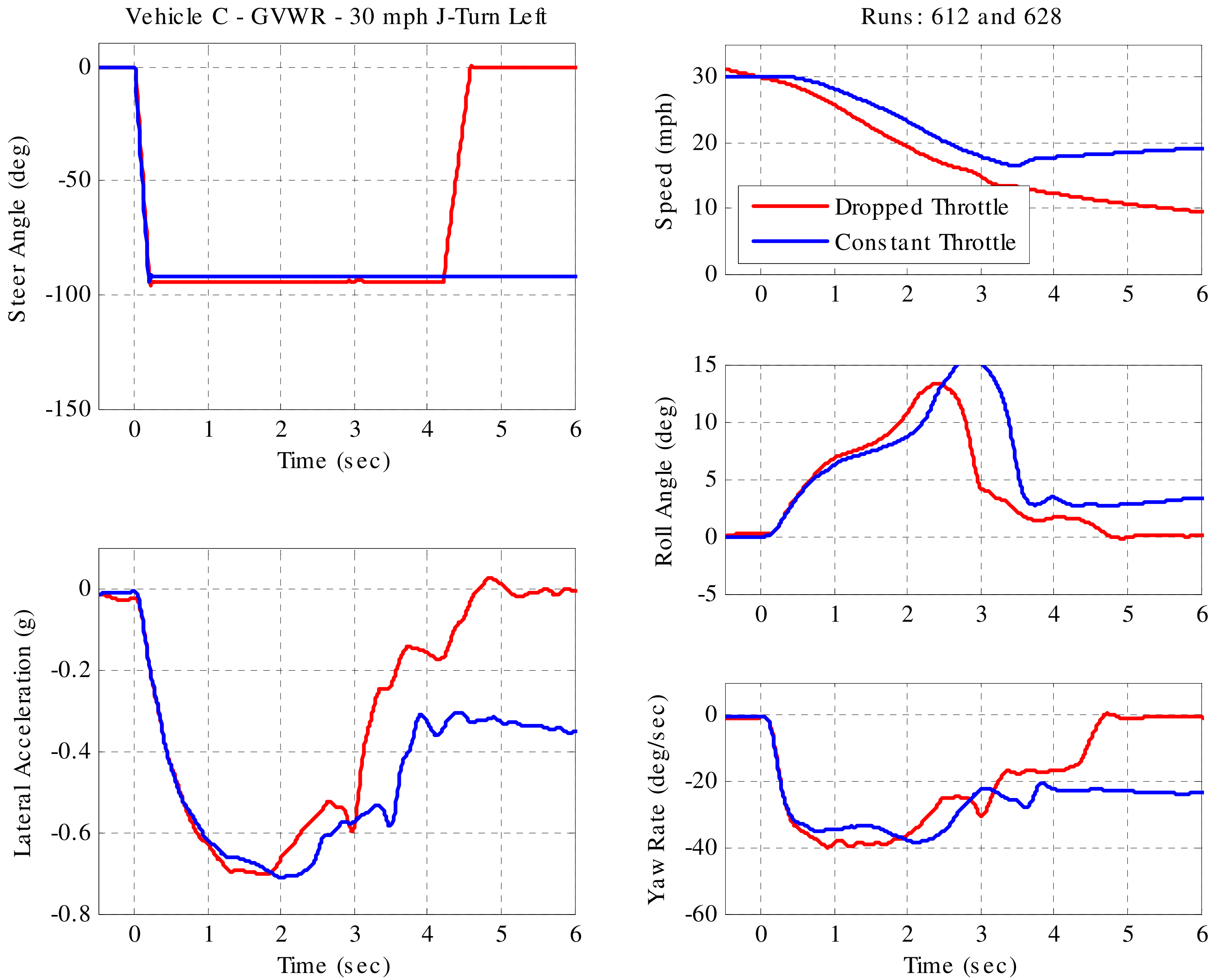
Vehicle B - GVWR - 30 mph J-Turn Right
Runs: 416 and 438
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

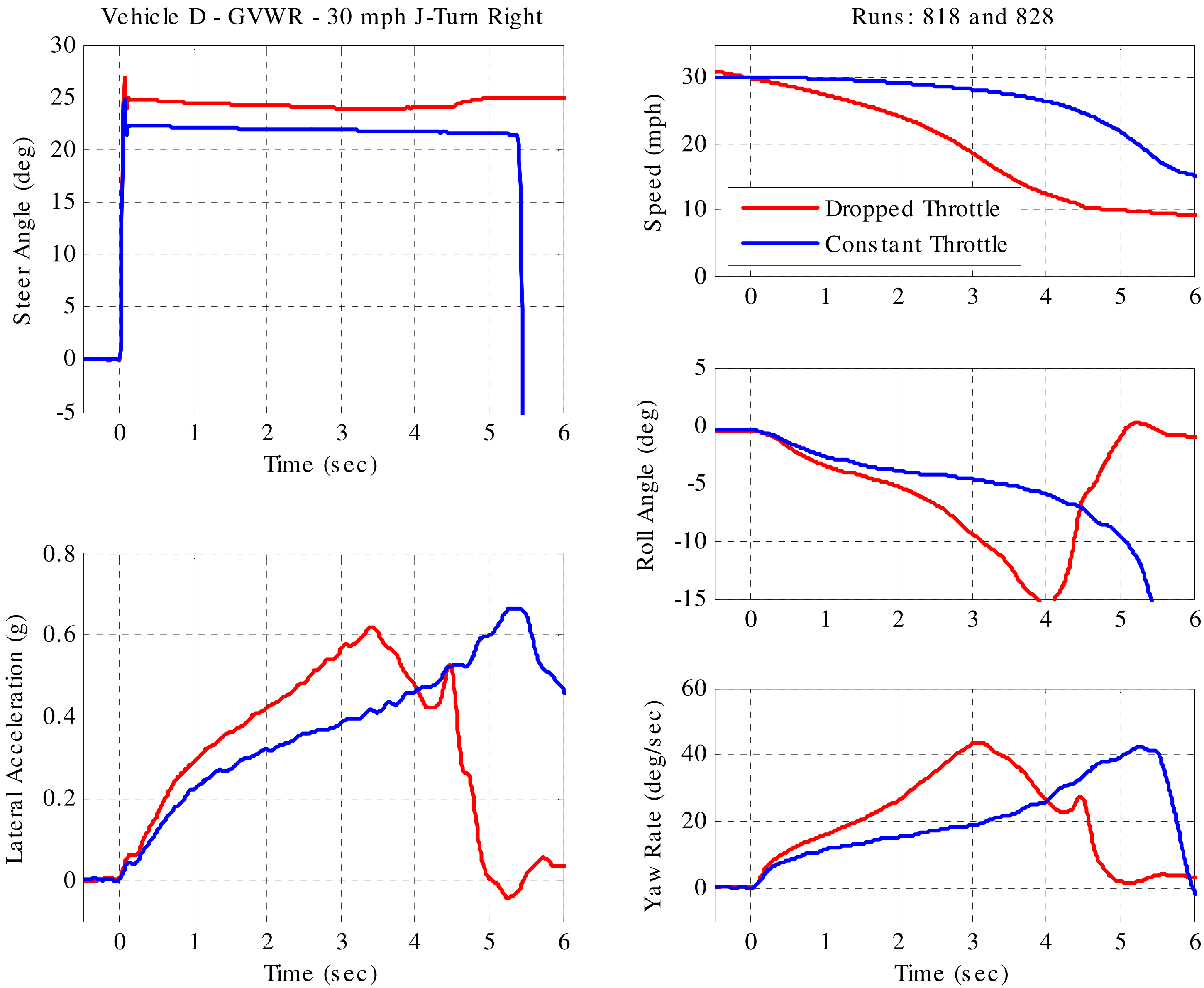

Vehicle B - GVWR - 30 mph J-Turn Right
Runs: 416 and 438
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

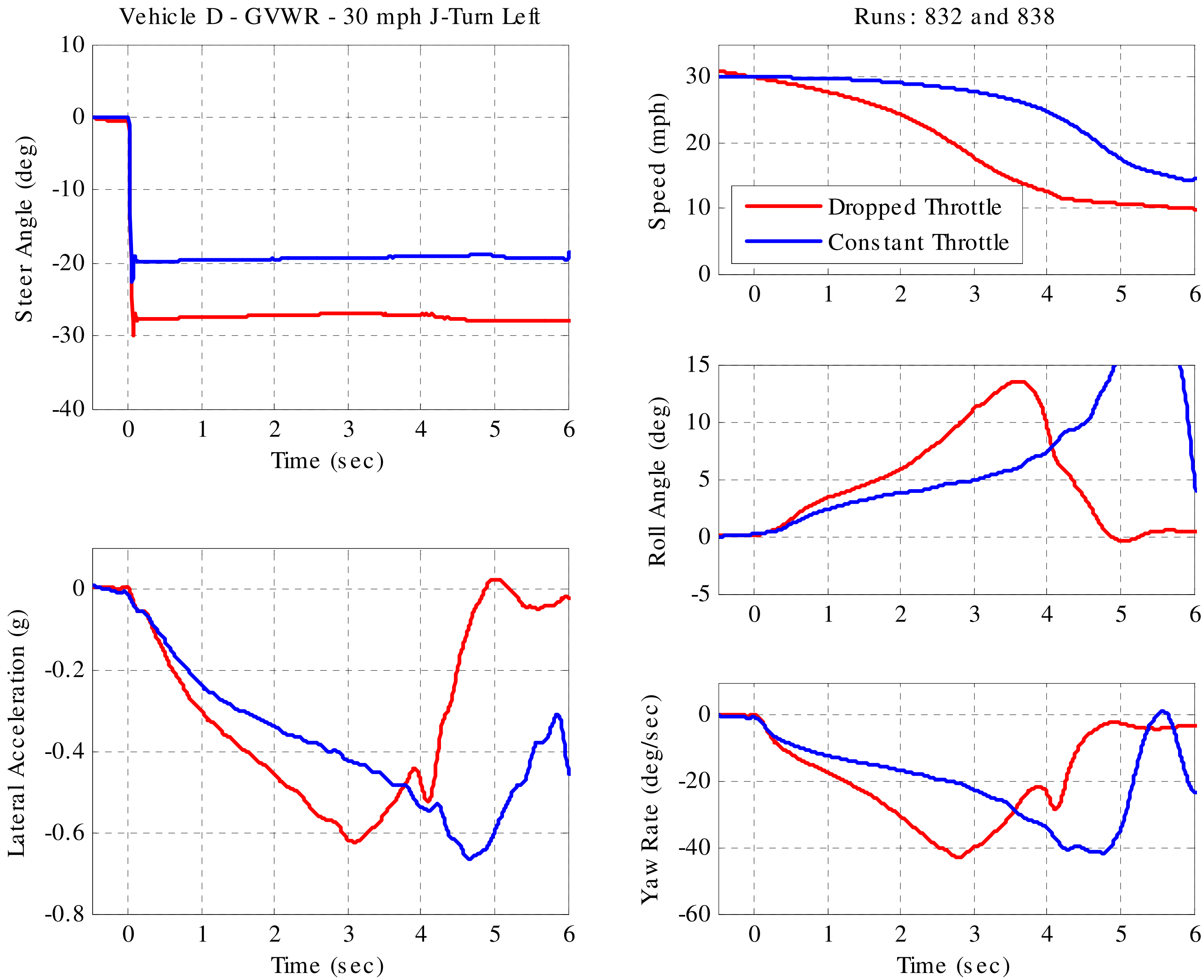

Vehicle B - GVWR - 30 mph J-Turn Left
Runs: 427 and 436
Steer Angle (deg)
0
-50
-100
-150
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
0
1
2
3
4
5
6

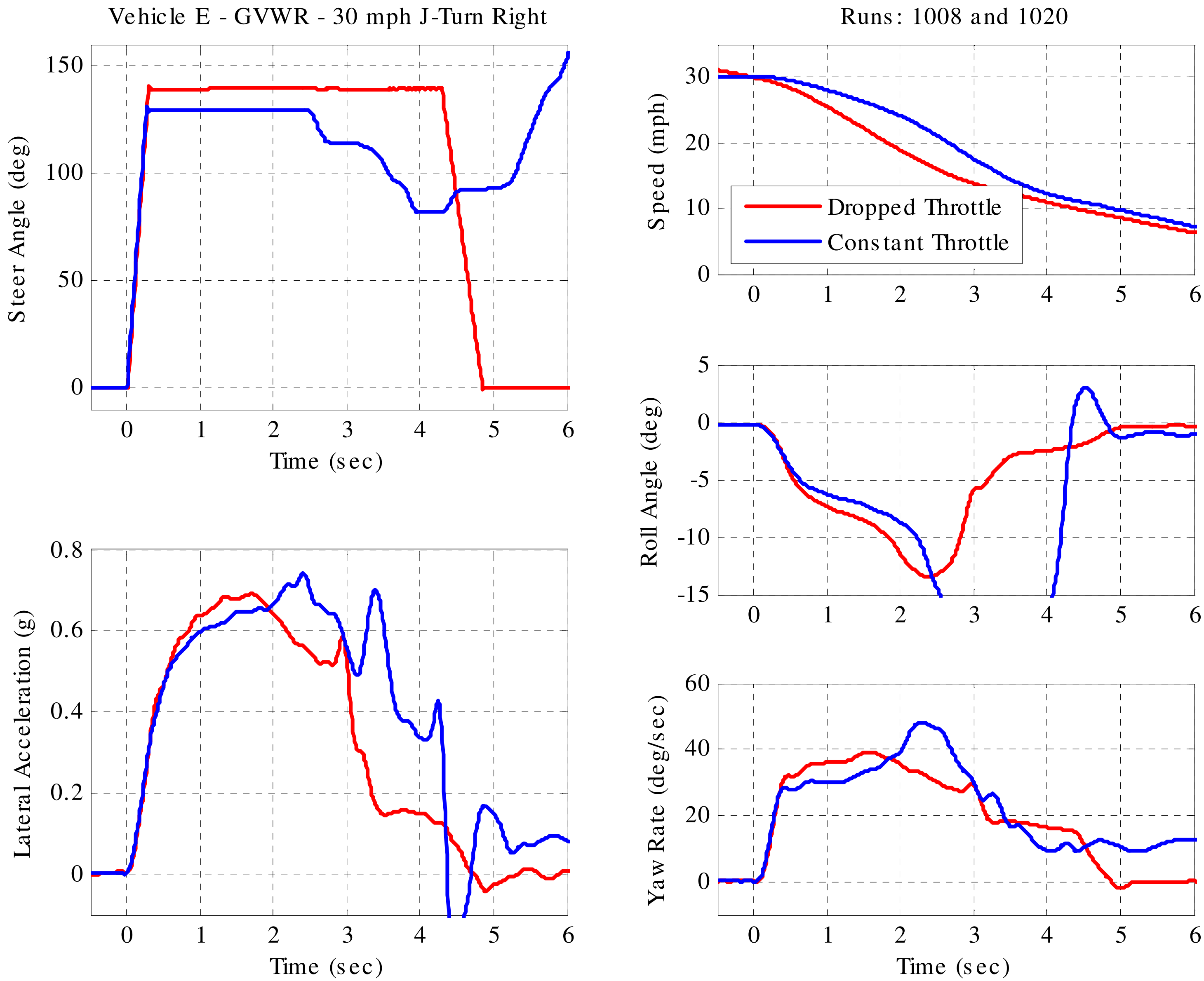


Vehicle C - GVWR - 30 mph J-Turn Right
Runs: 608 and 625
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

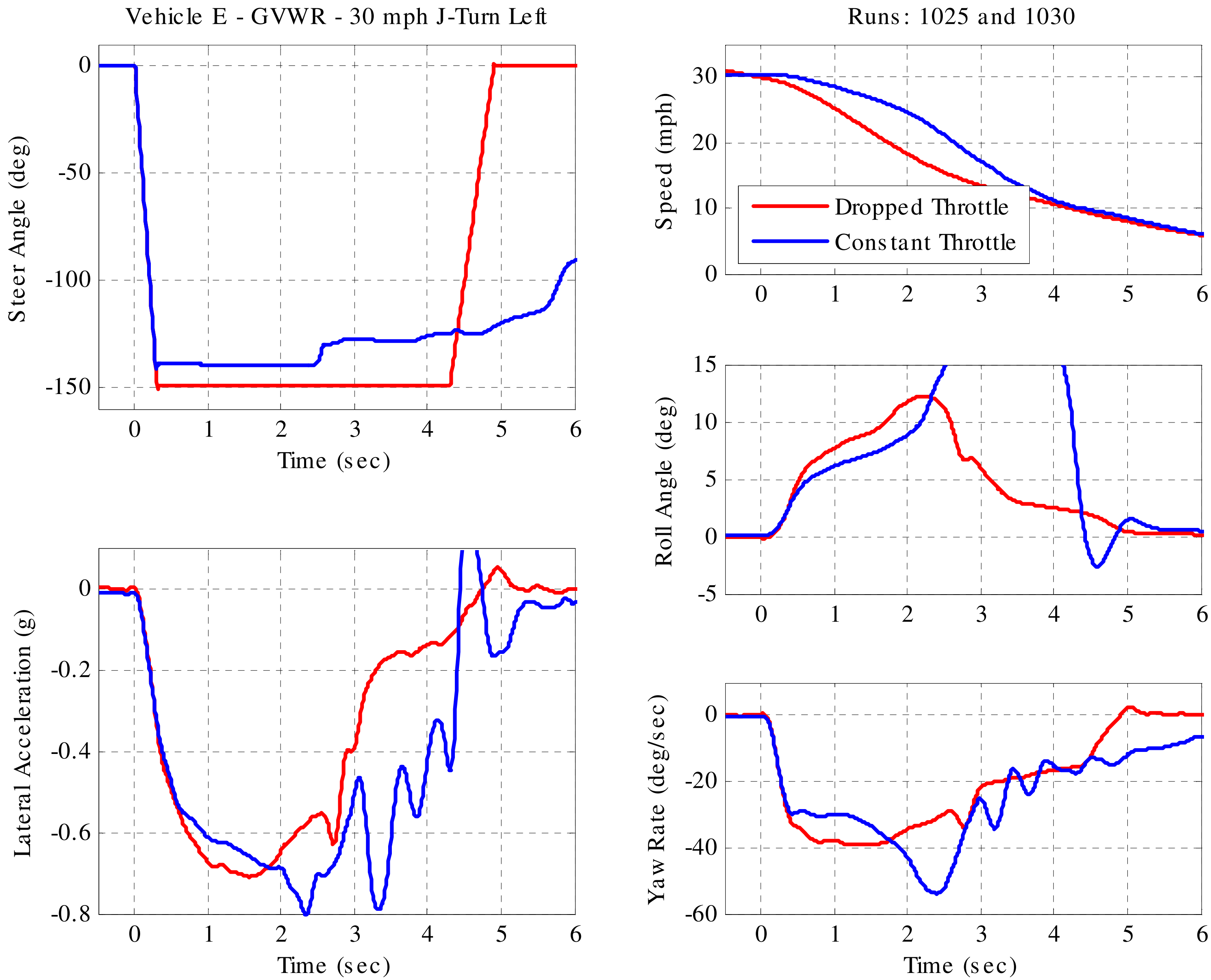

Vehicle C - GVWR - 30 mph J-Turn Left
Runs: 612 and 628
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

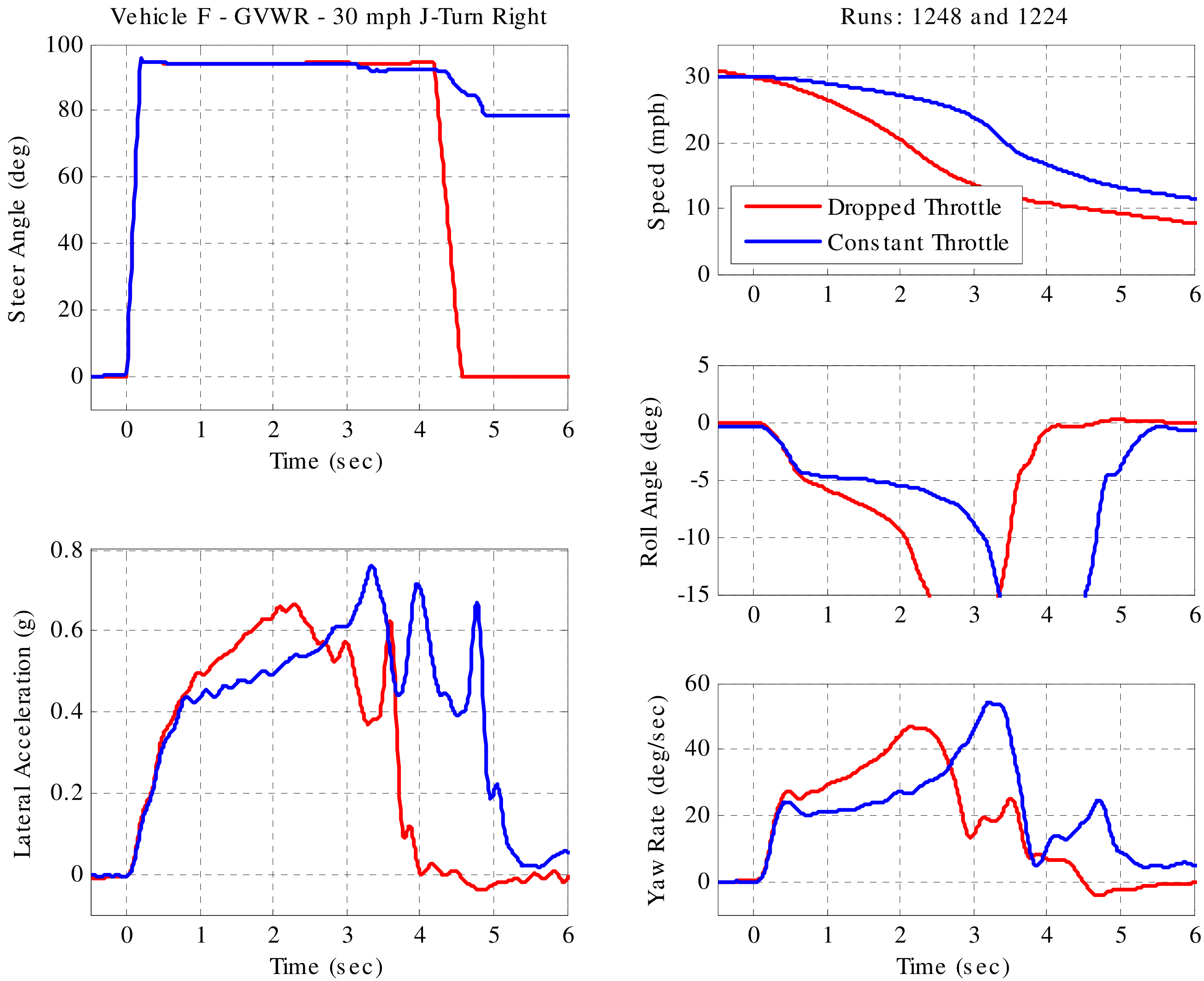

Vehicle D - GVWR - 30 mph J-Turn Right
Runs: 818 and 828
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

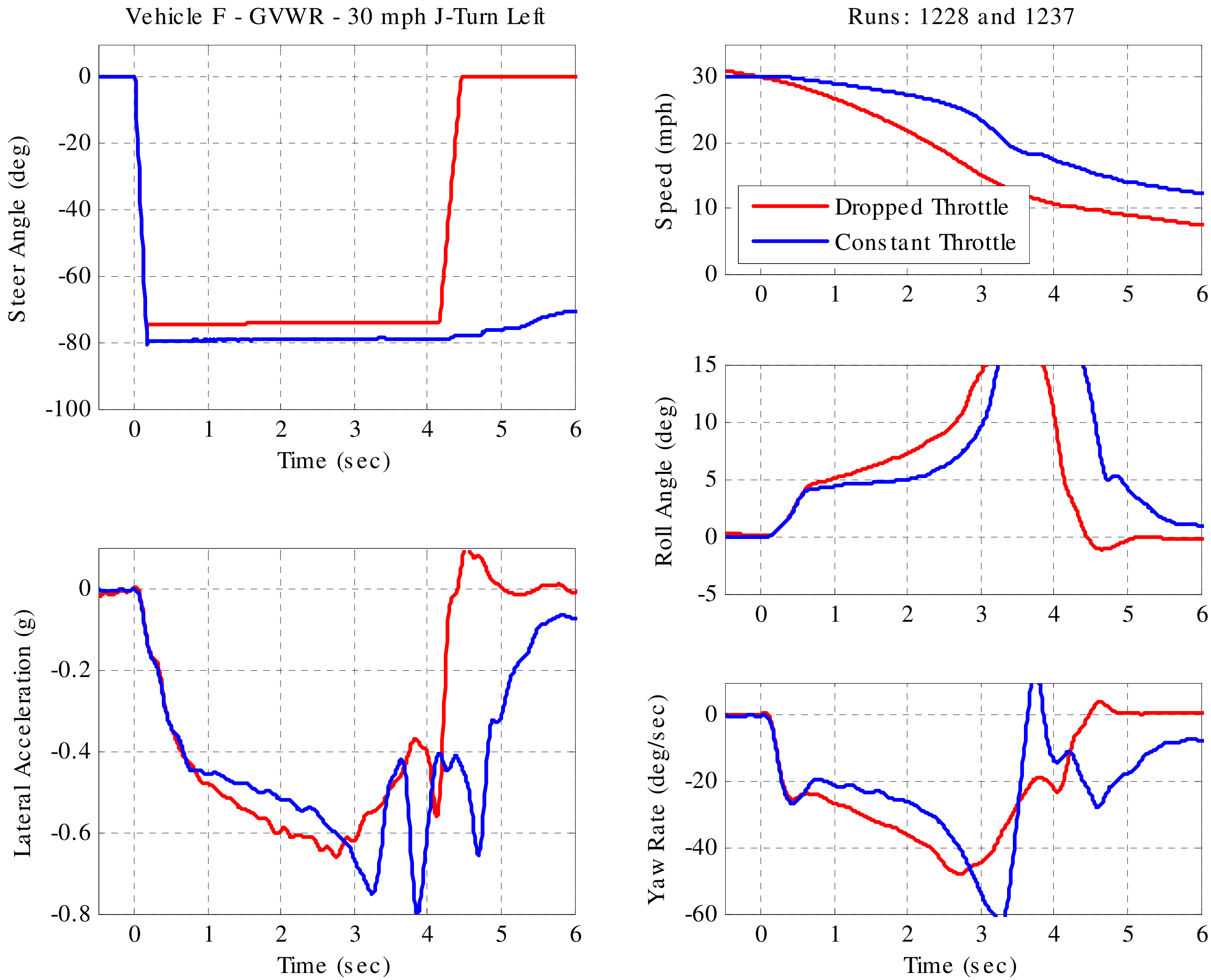

Vehicle D - GVWR - 30 mph J-Turn Left
Runs: 832 and 838
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



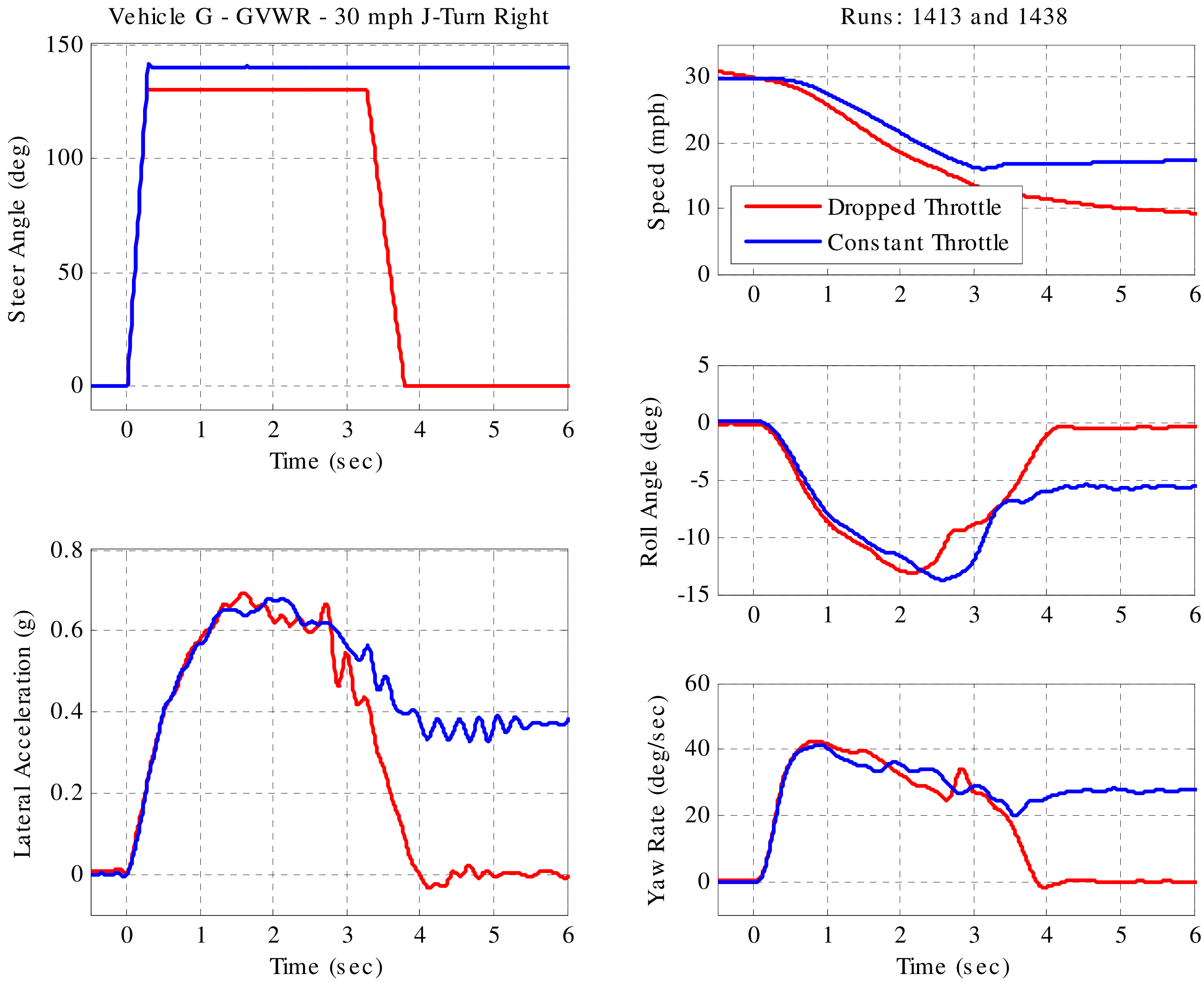
Vehicle E - GVWR - 30 mph J-Turn Right
Runs: 1008 and 1020
Steer Angle (deg)
150
100
50
0
Time (sec)
0 1 2 3 4 5 6
Lateral Acceleration (g)
0.8
0.6
0.4
0.2
0
Time (sec)
Speed (mph)
30
20
10
0
Dropped Throttle
Constant Throttle
Roll Angle (deg)
5
0
-5
-10
-15
Yaw Rate (deg/sec)
60
40
20
0
Time (sec)


Vehicle E - GVWR - 30 mph J-Turn Left
Runs: 1025 and 1030
Steer Angle (deg)
0
-50
-100
-150
Time (sec)
0
1
2
3
4
5
6
Speed (mph)
30
20
10
0
Dropped Throttle
Constant Throttle
Roll Angle (deg)
15
10
5
0
-5
Lateral Acceleration (g)
0
-0.2
-0.4
-0.6
-0.8
Yaw Rate (deg/sec)
0
-20
-40
-60

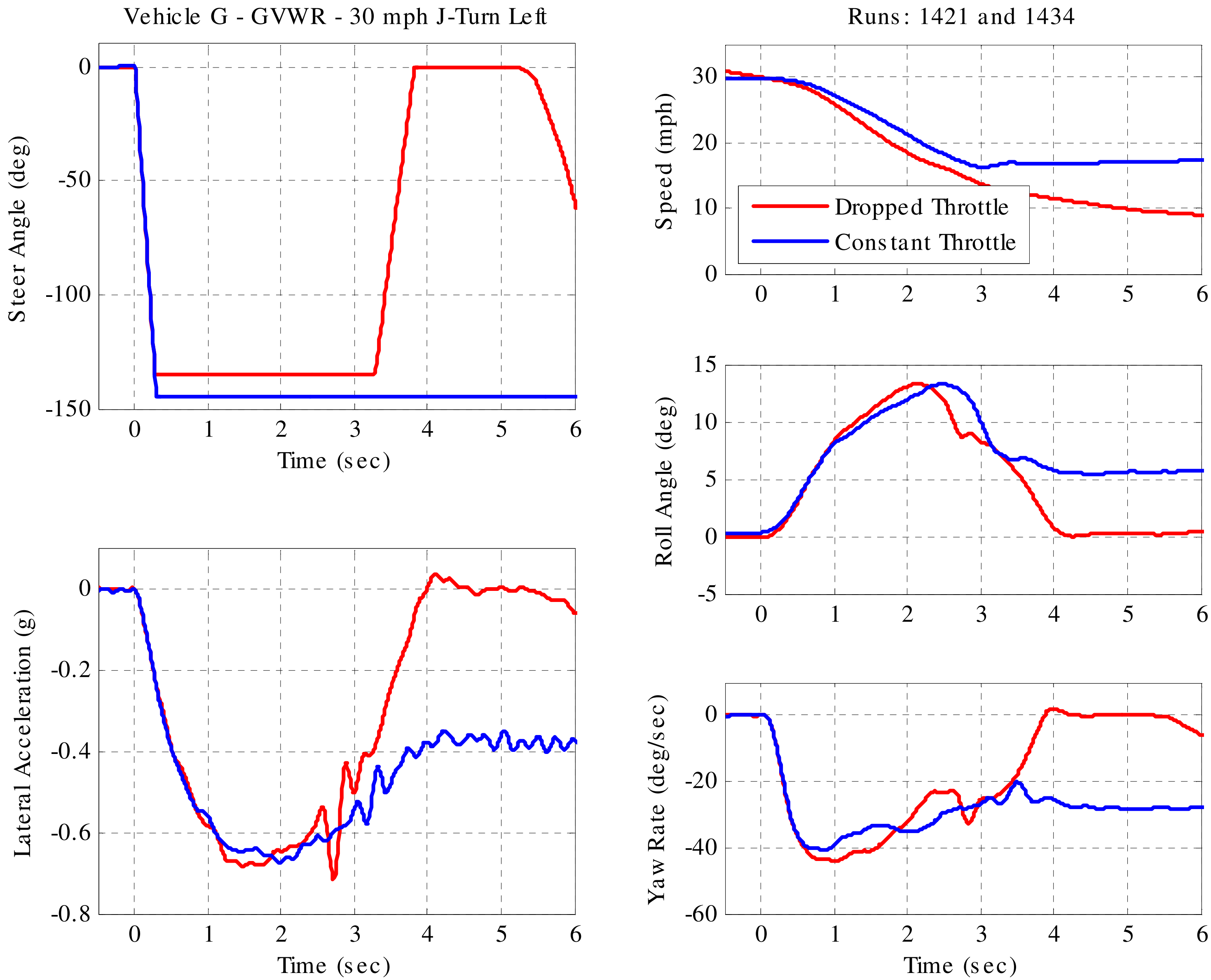

Vehicle F - GVWR - 30 mph J-Turn Right
Runs: 1248 and 1224
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



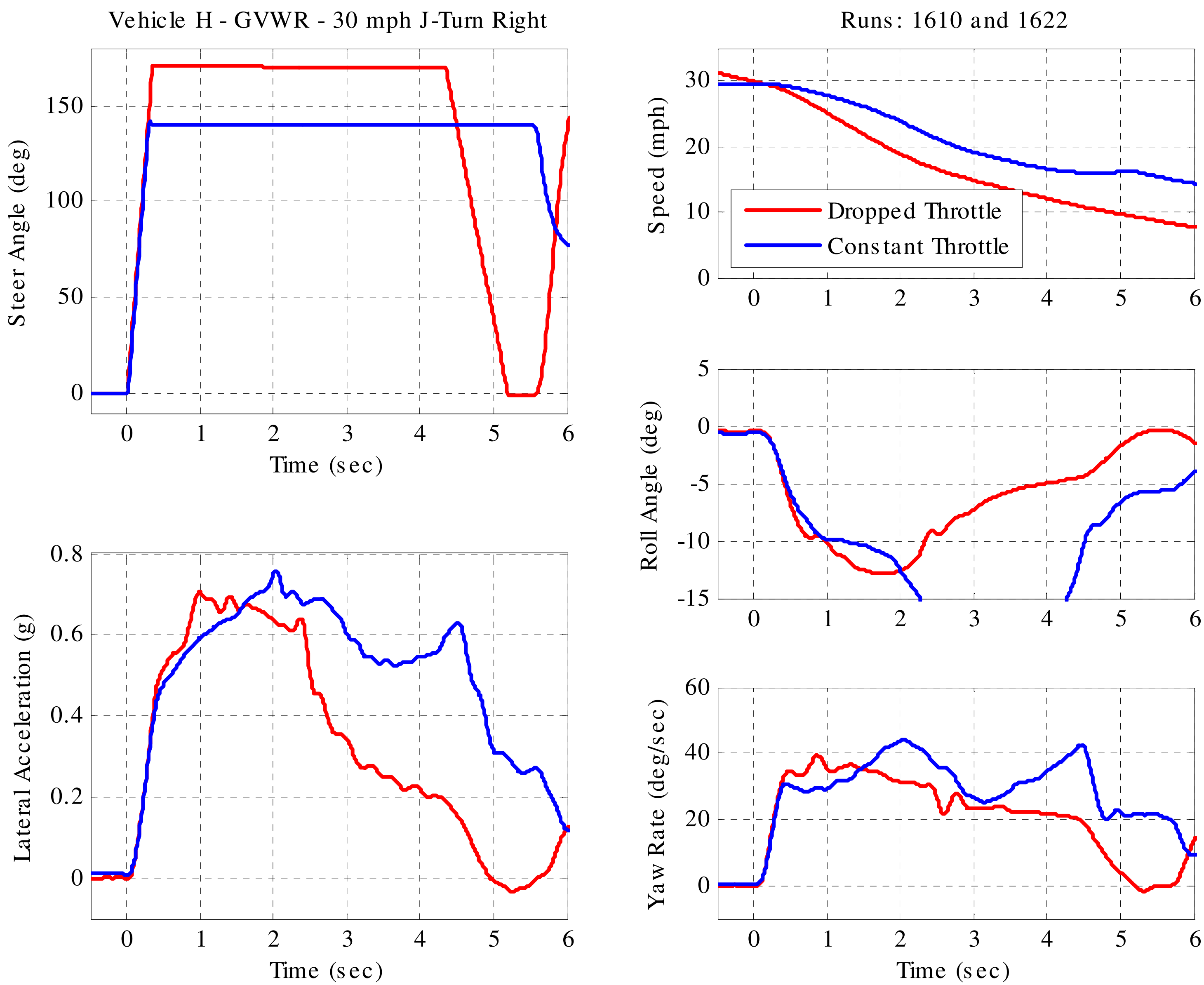
Vehicle F - GVWR - 30 mph J-Turn Left
Runs: 1228 and 1237
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)



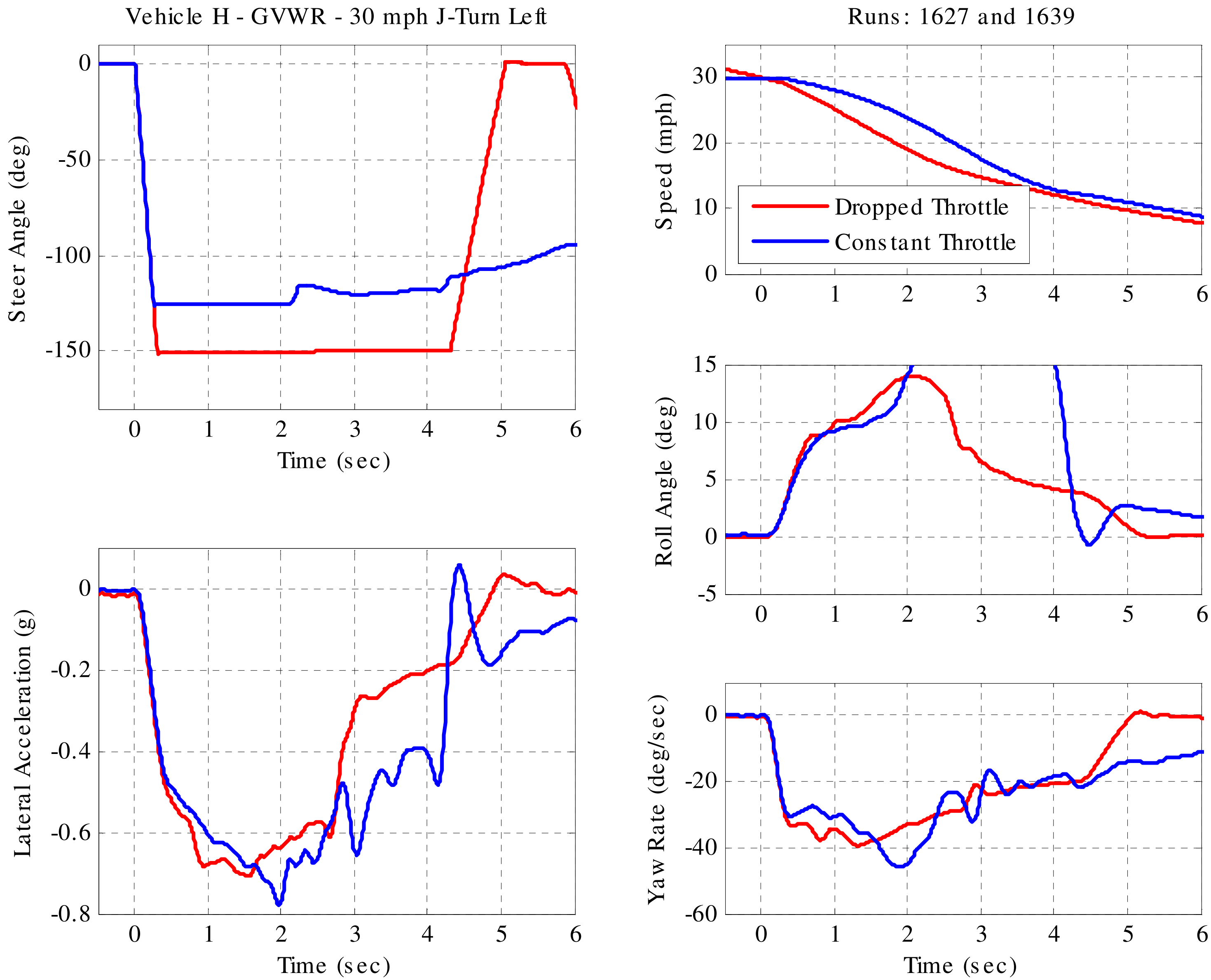
Vehicle G - GVWR - 30 mph J-Turn Right
Runs: 1413 and 1438
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

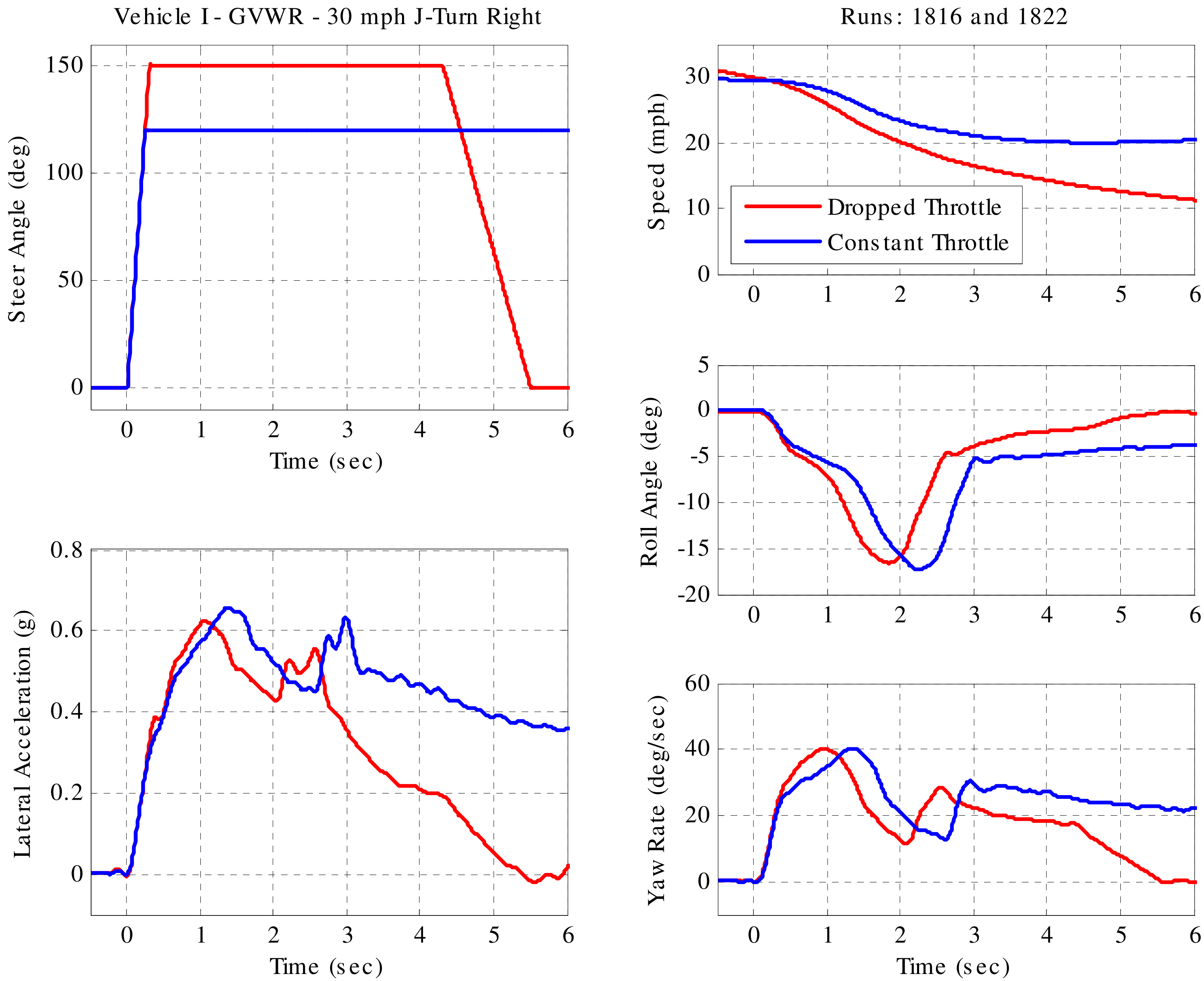


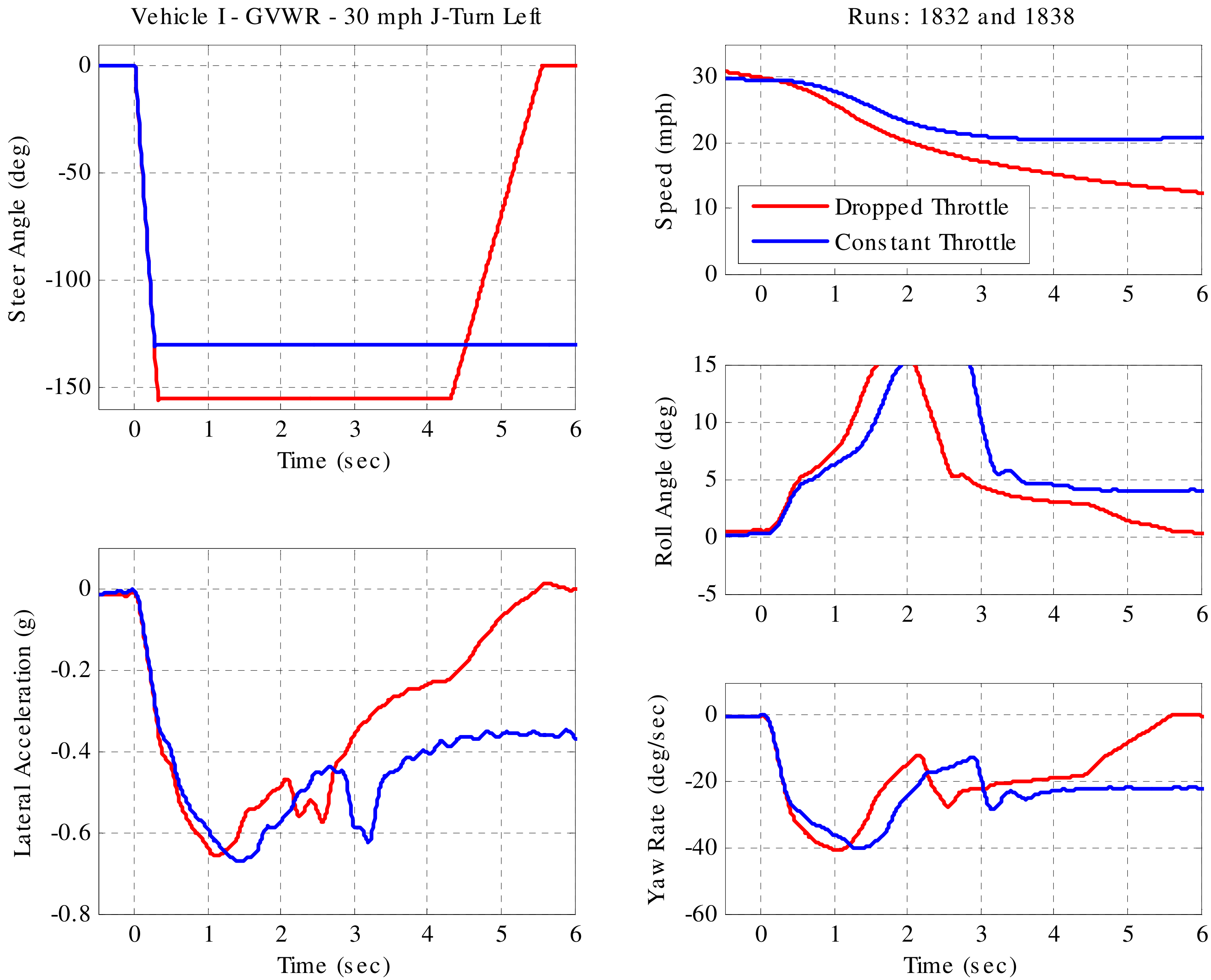
Vehicle G - GVWR - 30 mph J-Turn Left
Runs: 1421 and 1434
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



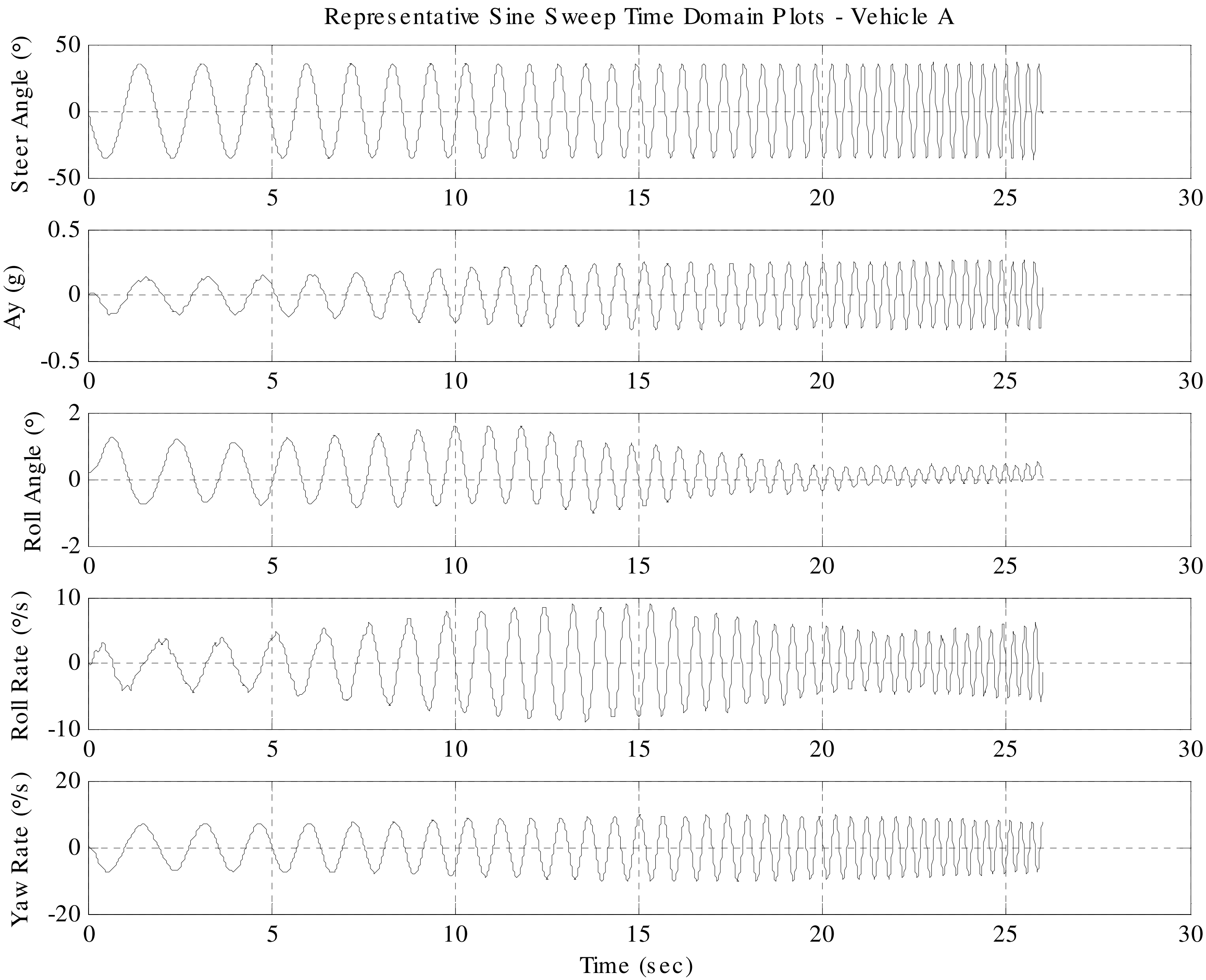
Vehicle H - GVWR - 30 mph J-Turn Right
Runs: 1610 and 1622
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

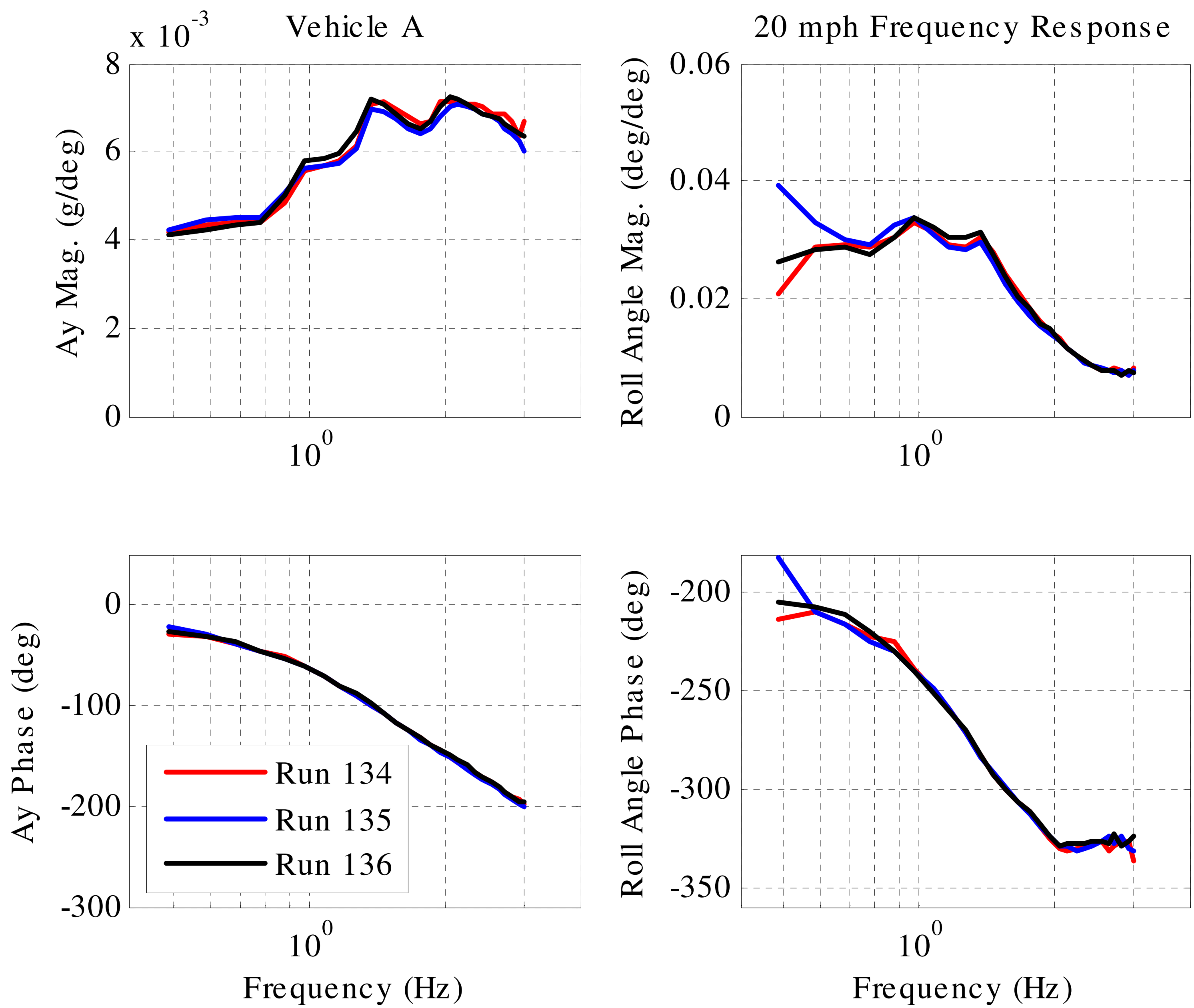

Vehicle H - GVWR - 30 mph J-Turn Left
Runs: 1627 and 1639
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

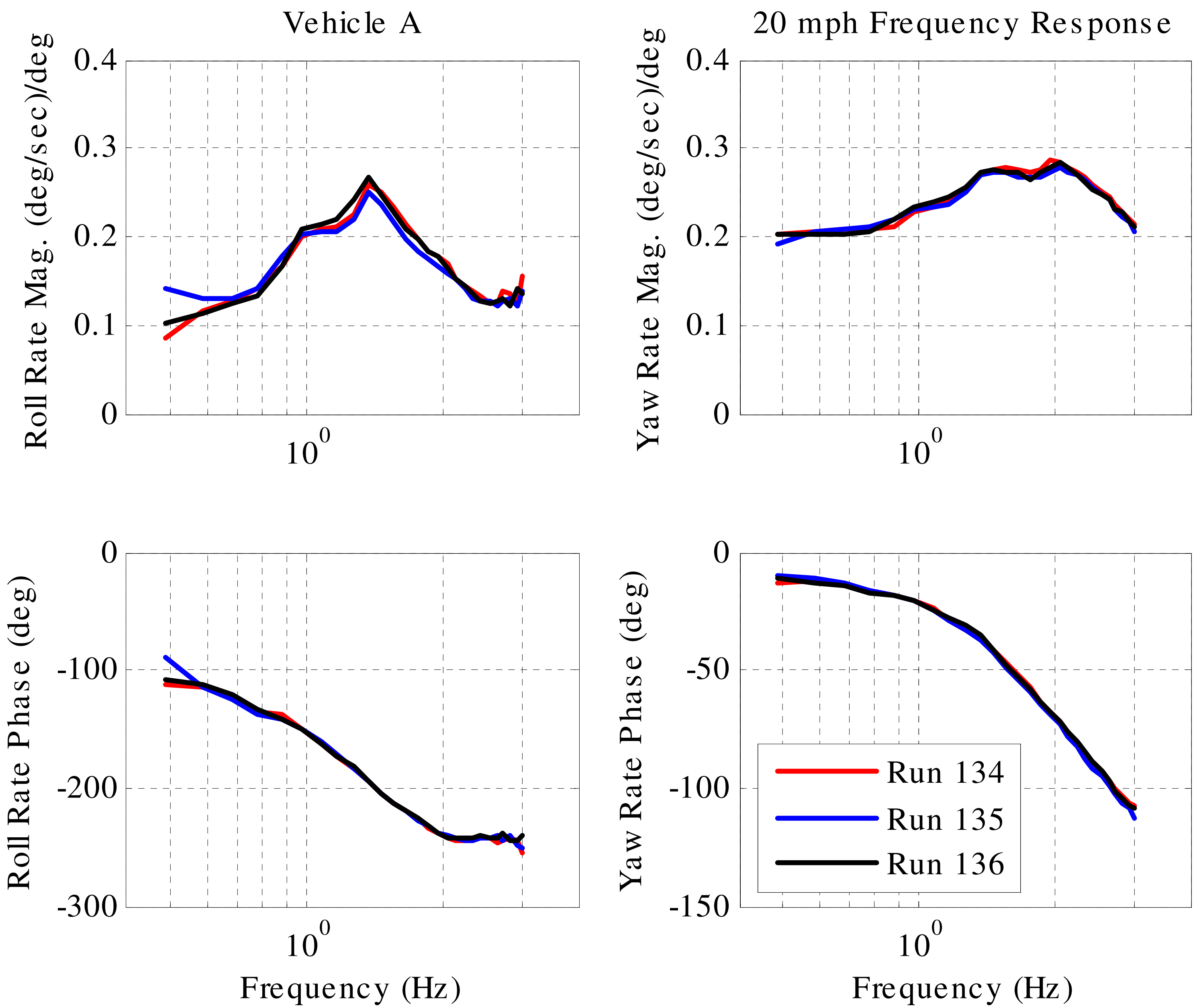

Vehicle I - GVWR - 30 mph J-Turn Right
Runs: 1816 and 1822
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

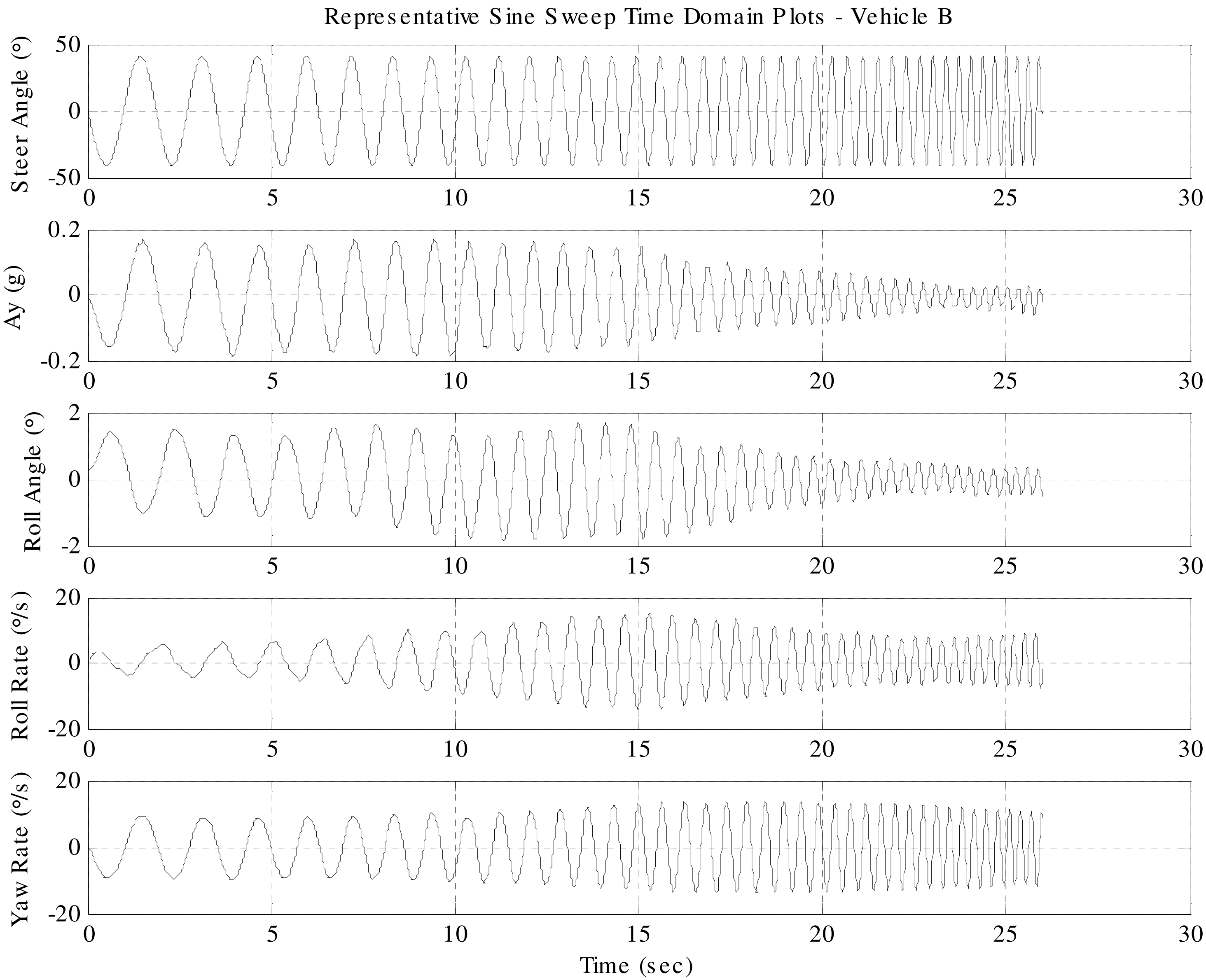


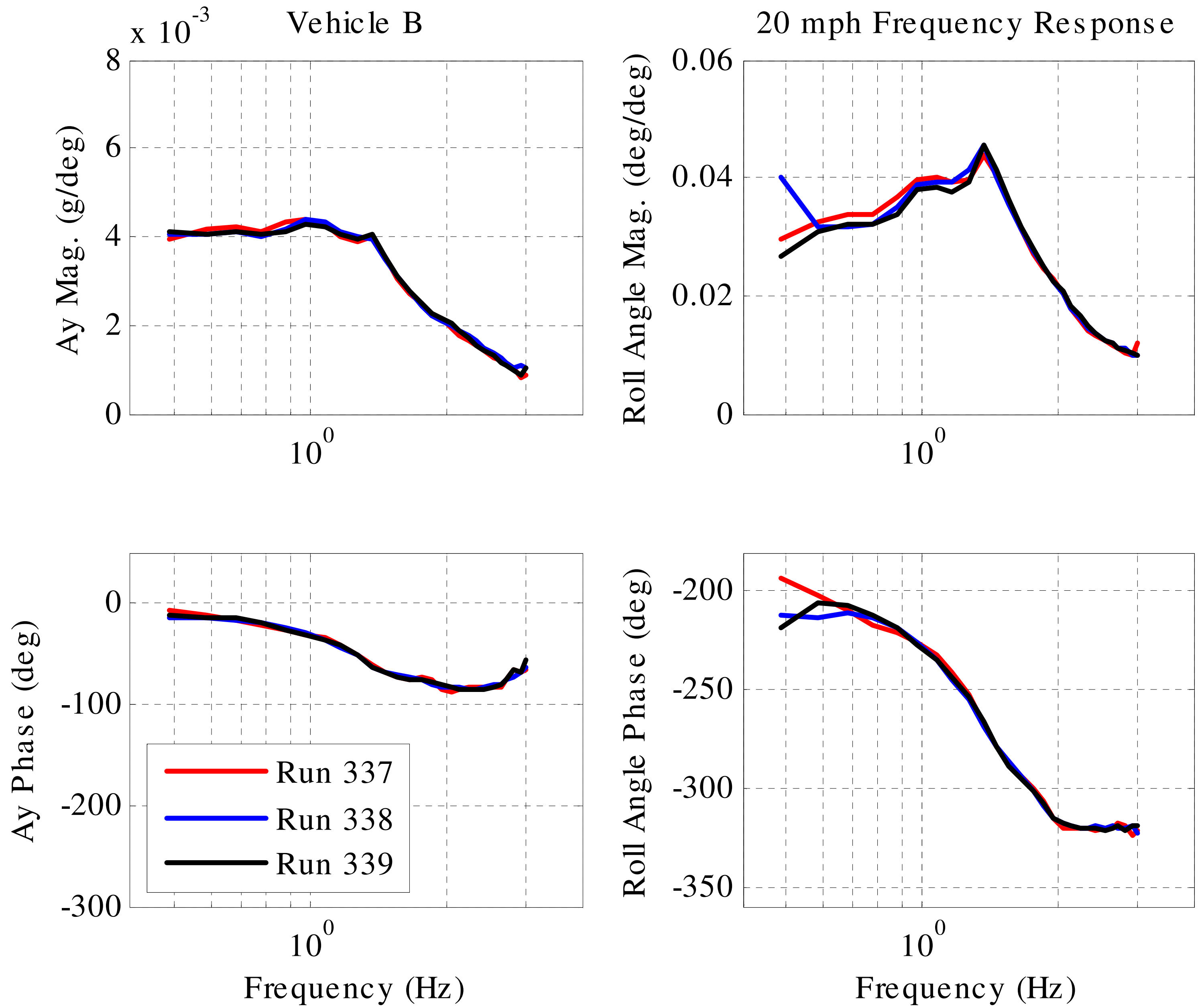
Vehicle I - GVWR - 30 mph J-Turn Left
Runs: 1832 and 1838
Steer Angle (deg)
Time (sec)
Speed (mph)
Dropped Throttle
Constant Throttle
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

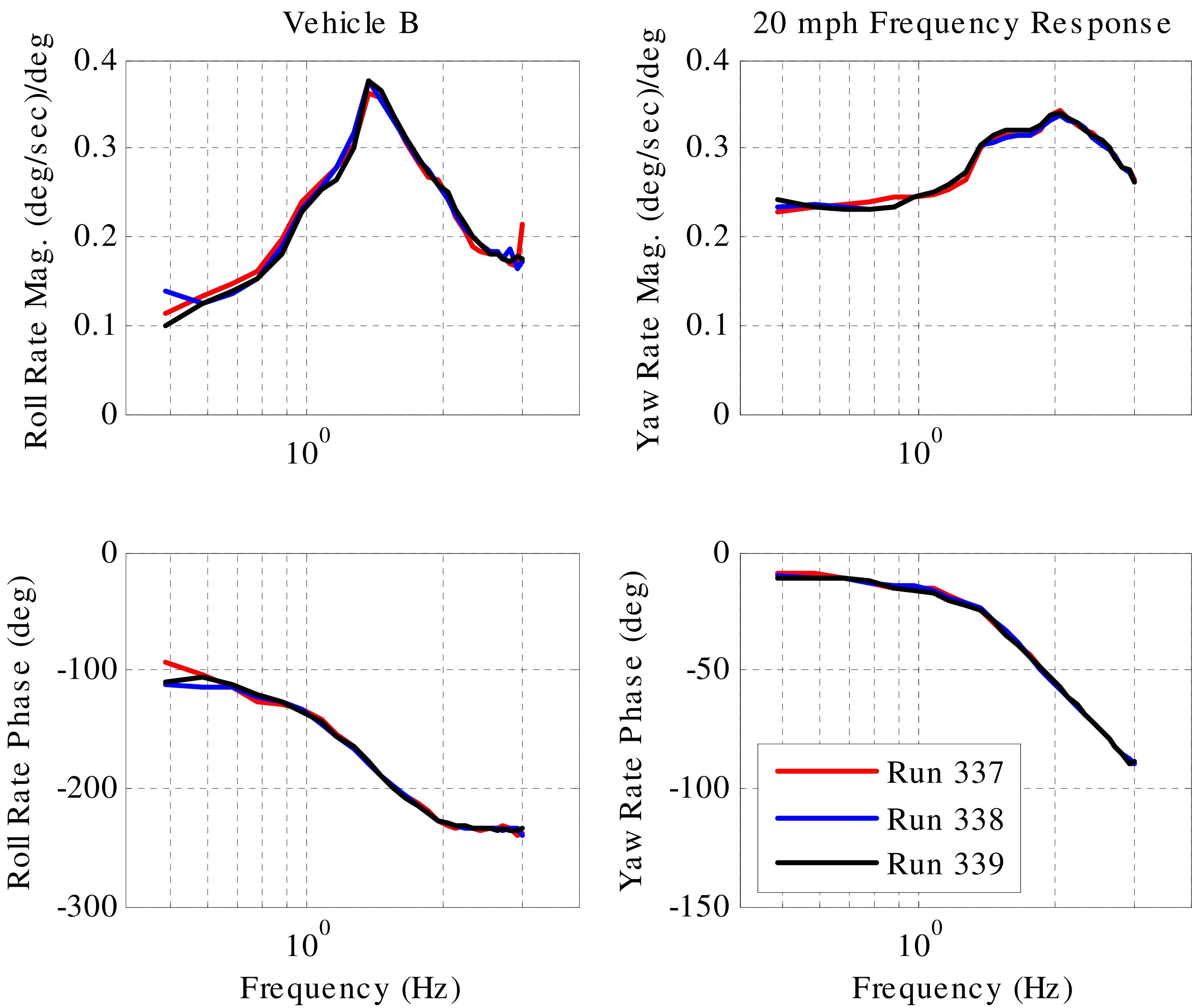

Representative Sine Sweep Time Domain Plots - Vehicle A
Steer Angle (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)
50
0
-50
0.5
-0.5
2
-2
10
-10
20
-20
0
5
10
15
20
25
30

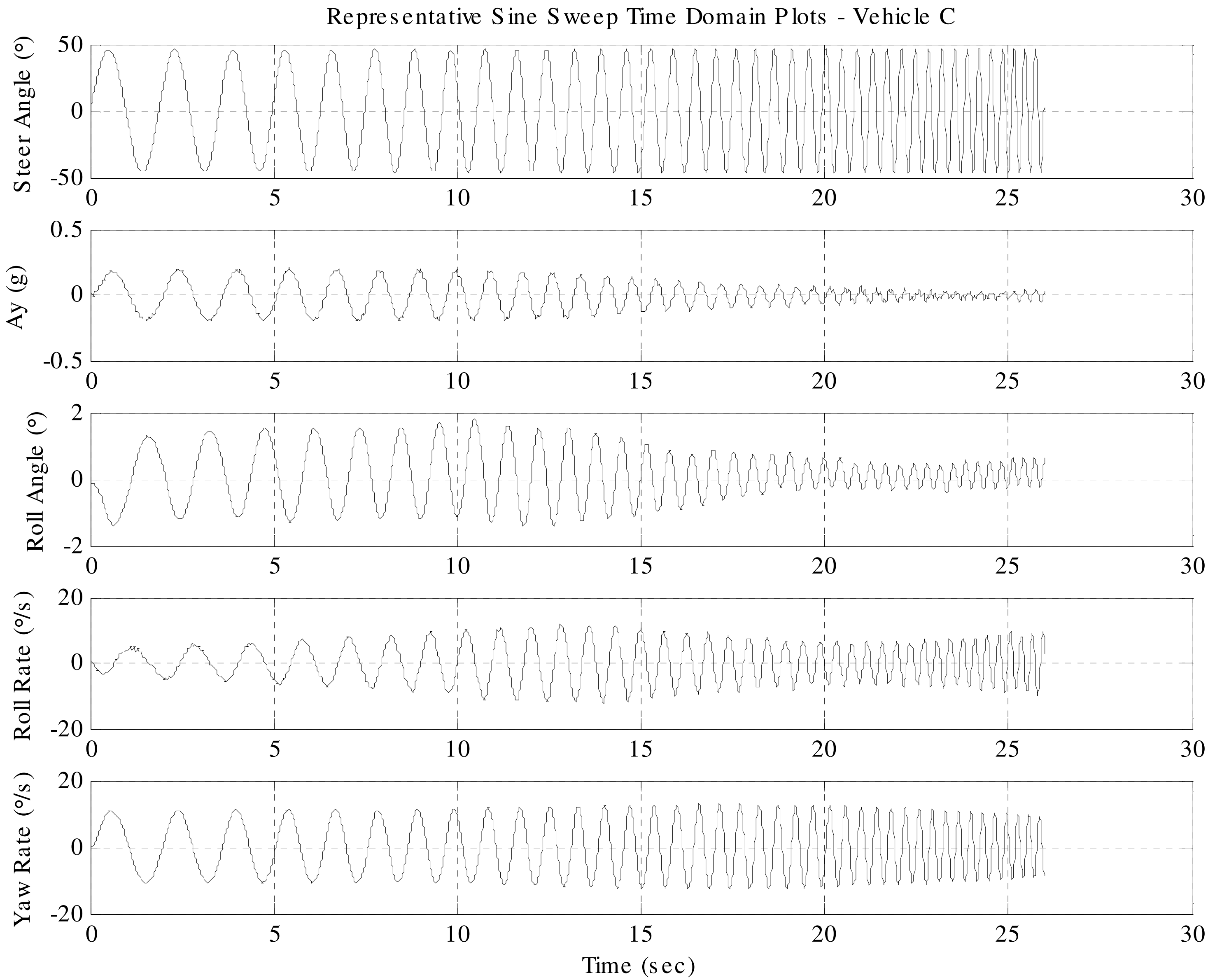

Vehicle A
20 mph Frequency Response
x 10^-3
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 134
Run 135
Run 136
Frequency (Hz)
10^0
8
6
4
2
0
0.06
0.04
0.02
-100
-200
-300
-250
-350


Vehicle A
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
Run 134
Run 135
Run 136

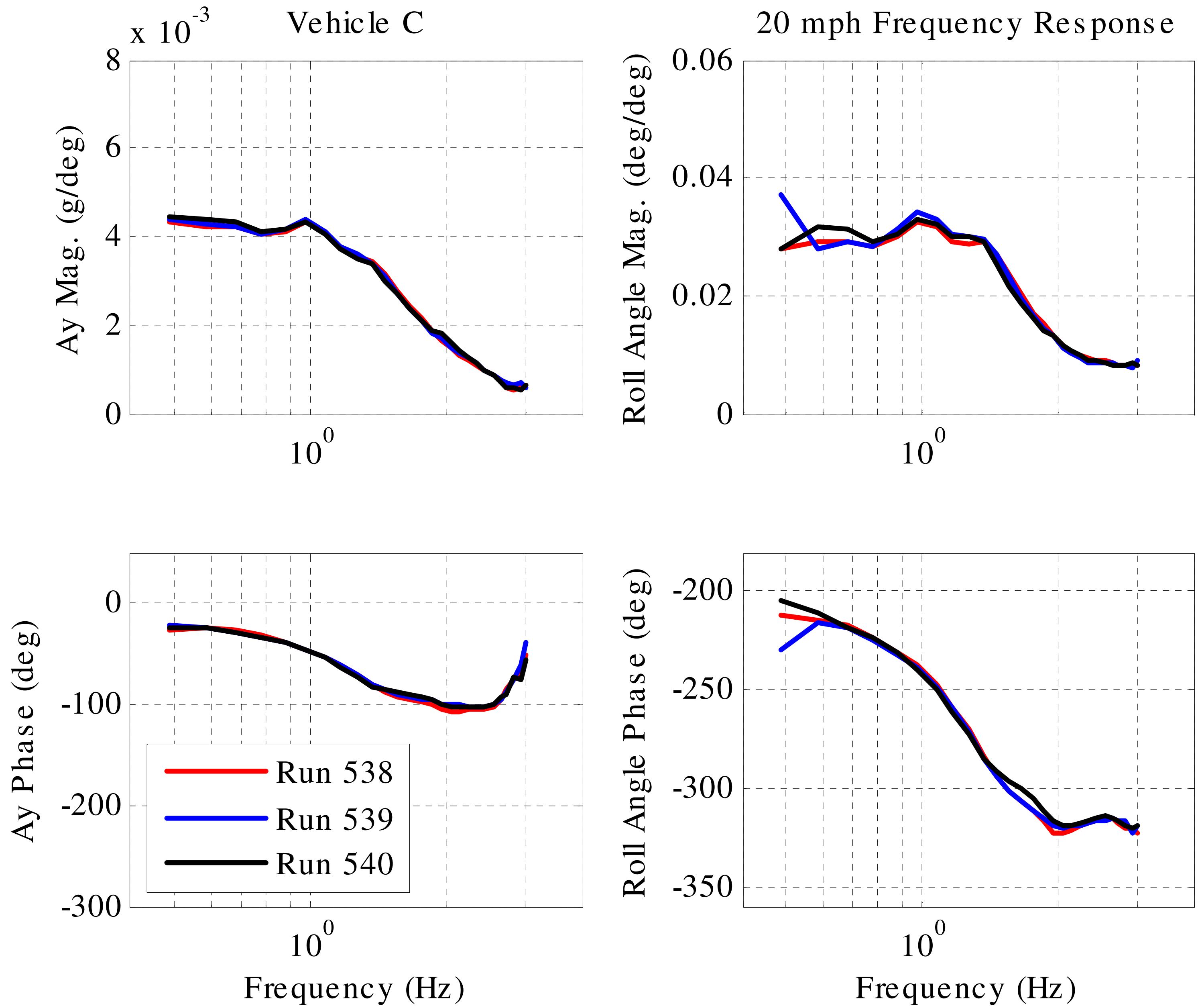

Representative Sine Sweep Time Domain Plots - Vehicle B
Steer Angle (°)
50
0
-50
Ay (g)
0.2
0
-0.2
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
20
0
-20
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)


Vehicle B
20 mph Frequency Response
x 10^-3
Ay Mag. (g/deg)
8
6
4
2
0
Roll Angle Mag. (deg/deg)
0.06
0.04
0.02
0
10^0
Ay Phase (deg)
0
-100
-200
-300
Run 337
Run 338
Run 339
Roll Angle Phase (deg)
-200
-250
-300
-350
Frequency (Hz)
Frequency (Hz)

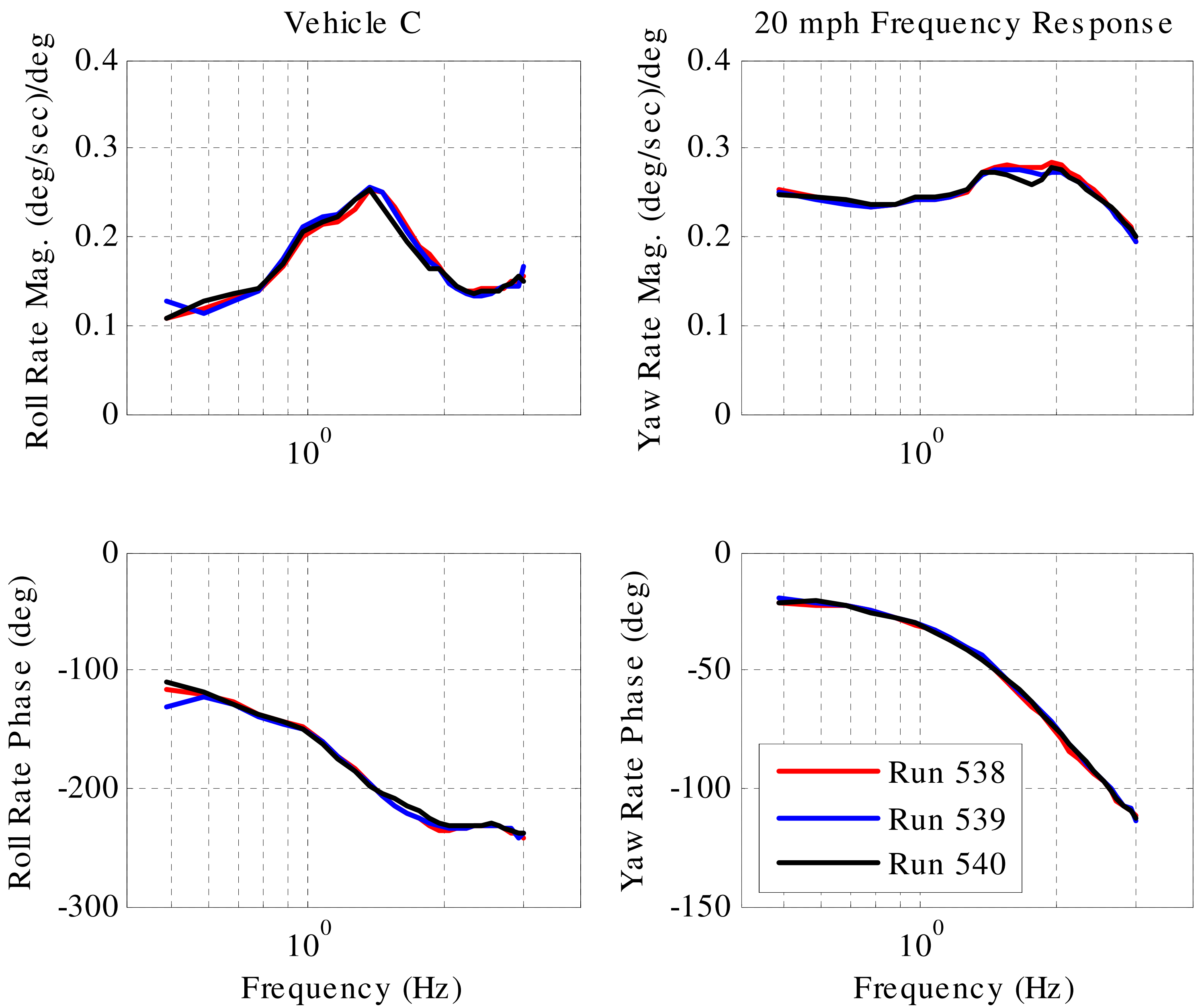

Vehicle B
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
0.4
0.3
0.2
0.1
0
-100
-200
-300
-50
-150
10^0
Frequency (Hz)
Run 337
Run 338
Run 339

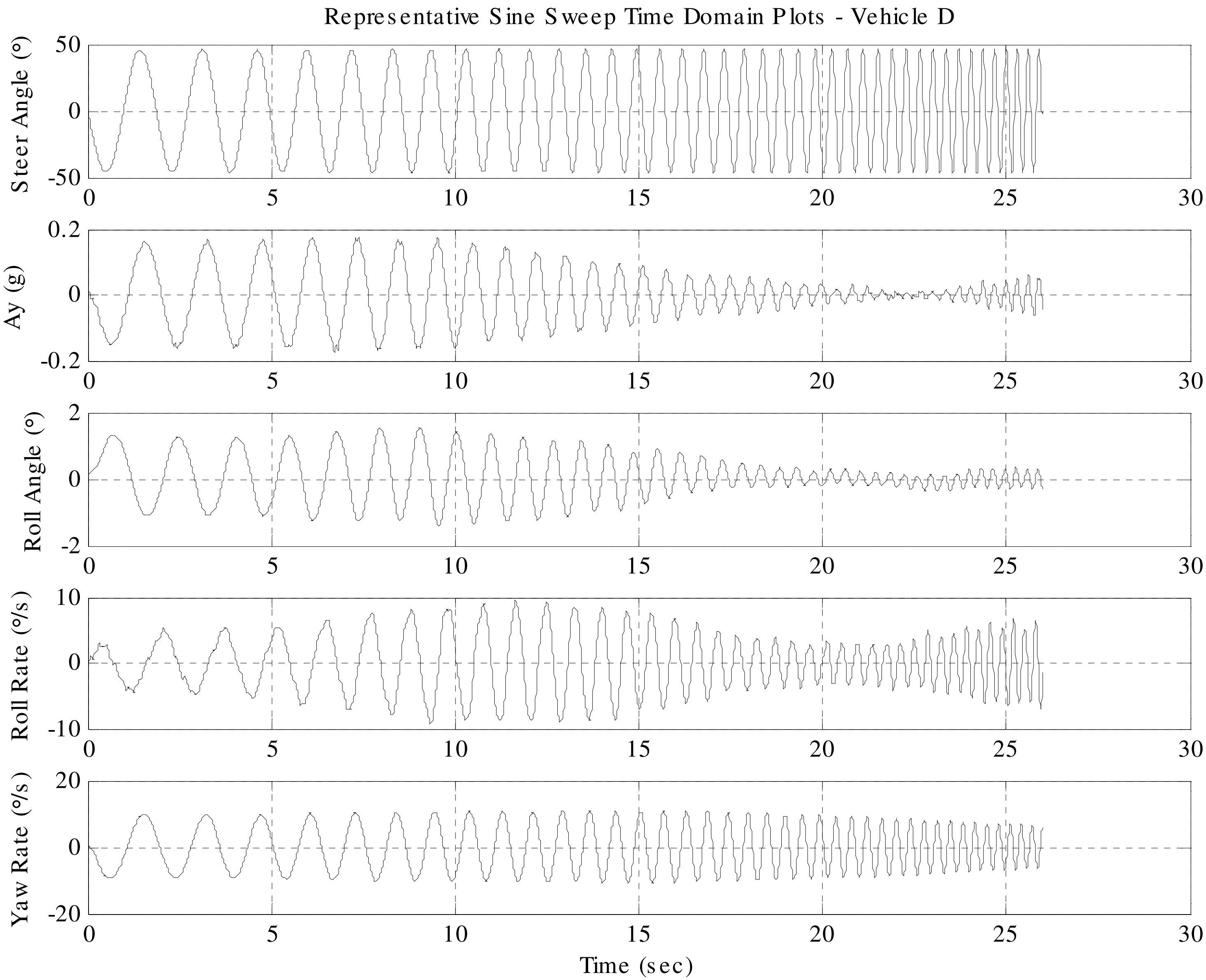


Representative Sine Sweep Time Domain Plots - Vehicle C
Steer Angle (°)
50
0
-50
Ay (g)
0.5
0
-0.5
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
20
0
-20
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

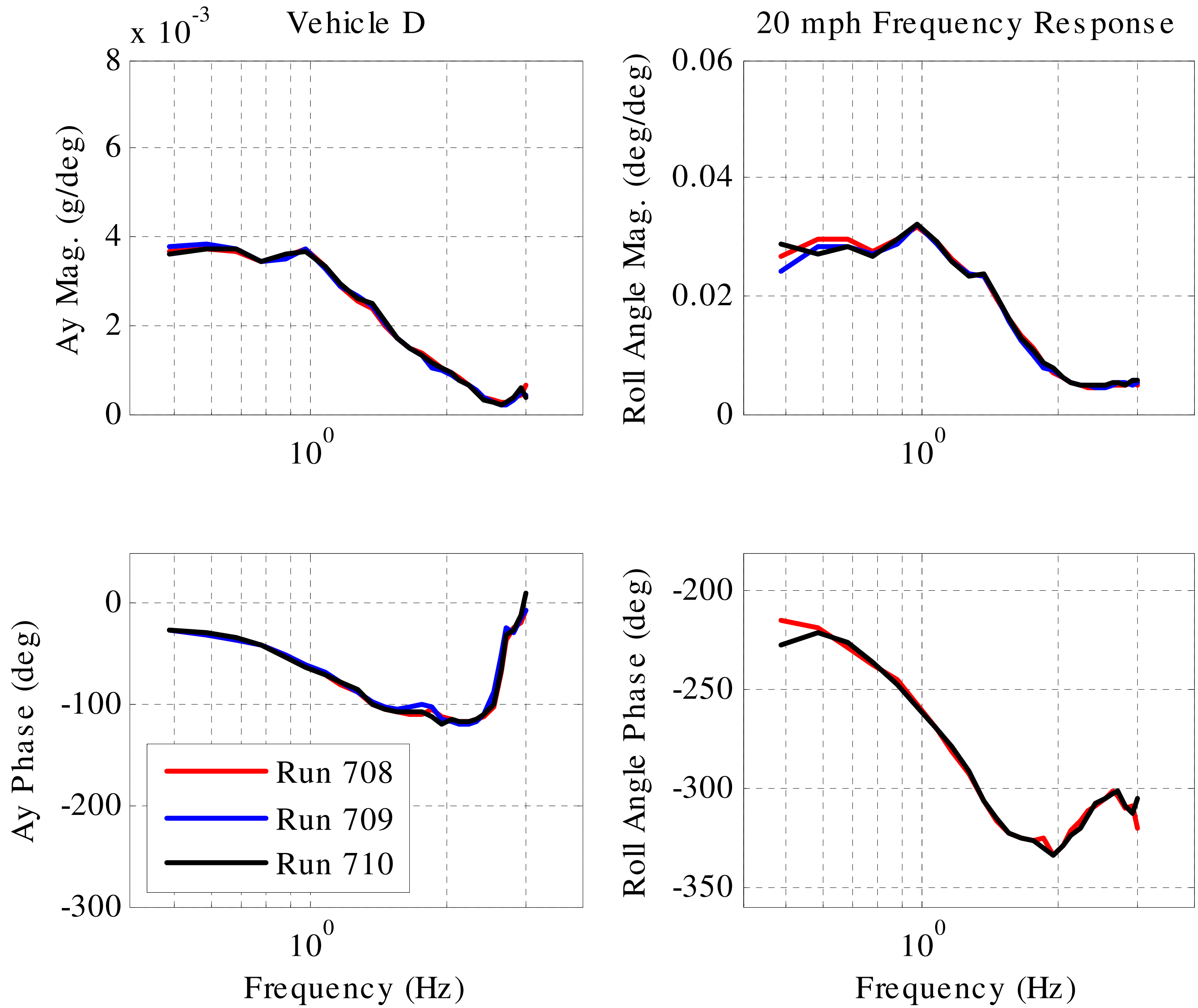


Vehicle C
20 mph Frequency Response
x 10^-3
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Frequency (Hz)
Frequency (Hz)
Run 538
Run 539
Run 540

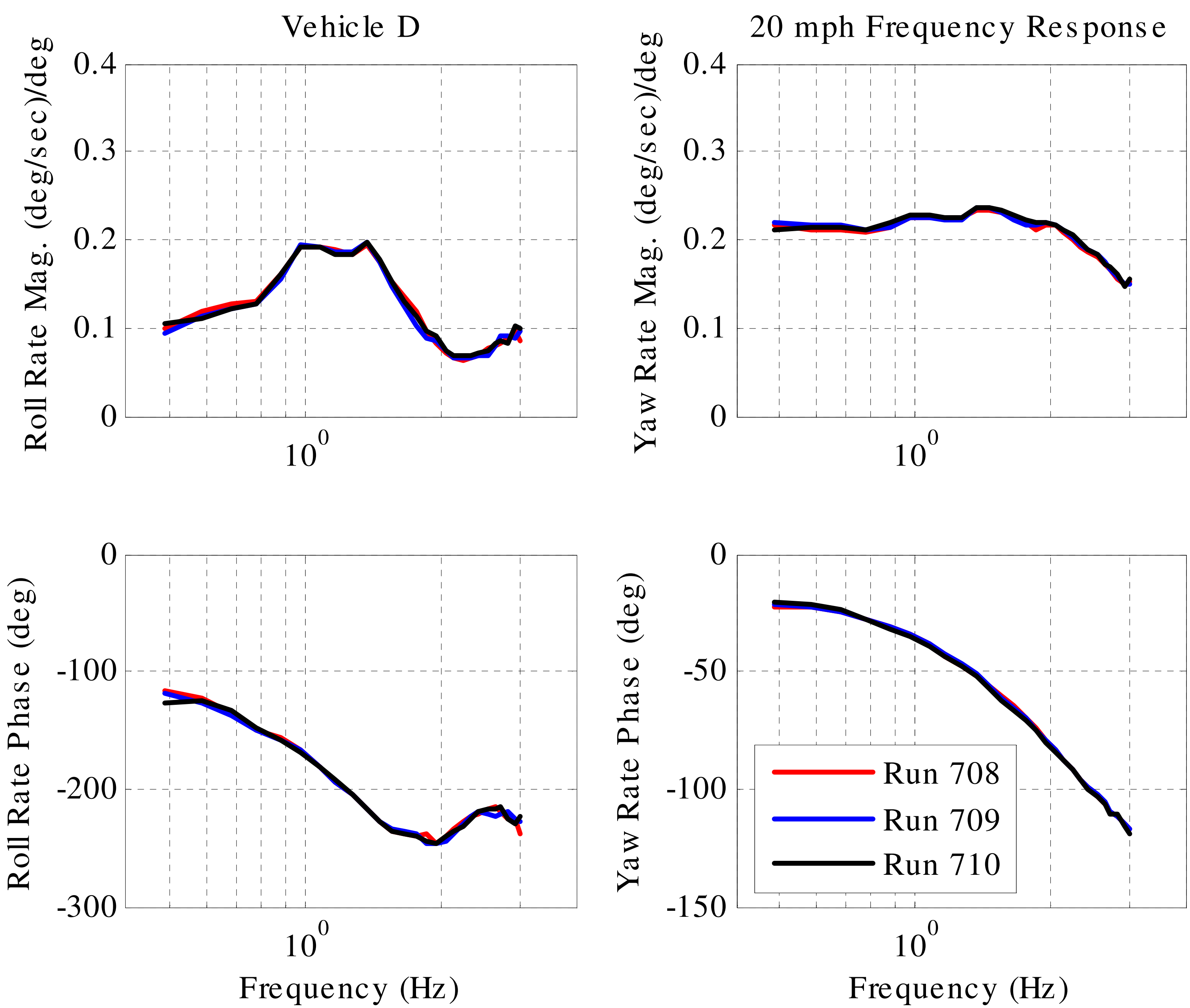

Vehicle C
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
10^0
0.4
0.3
0.2
0.1
0
-100
-200
-300
-50
-150
Run 538
Run 539
Run 540

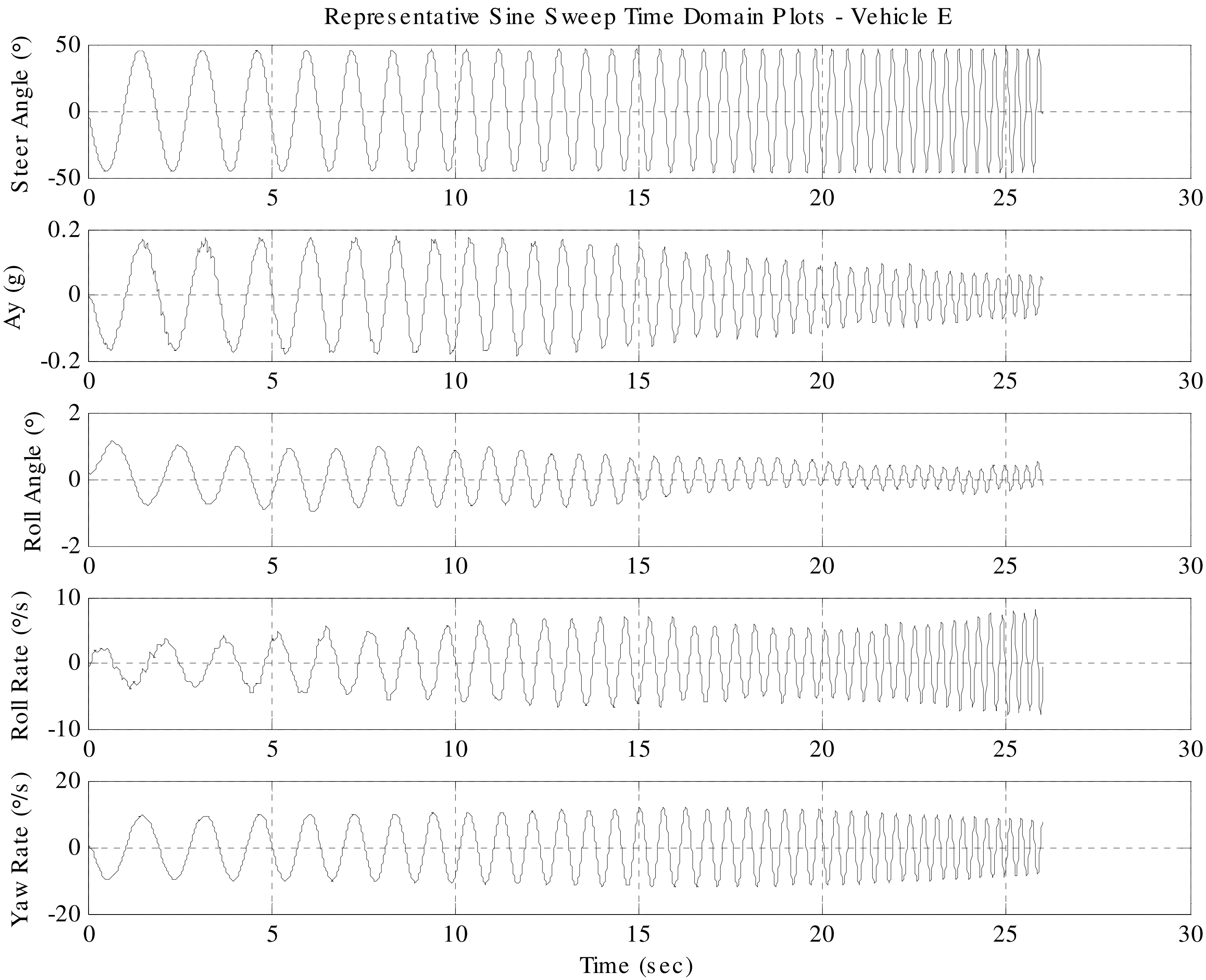


Representative Sine Sweep Time Domain Plots - Vehicle D
Steer Angle (°)
50
0
-50
Ay (g)
0.2
0
-0.2
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
10
0
-10
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

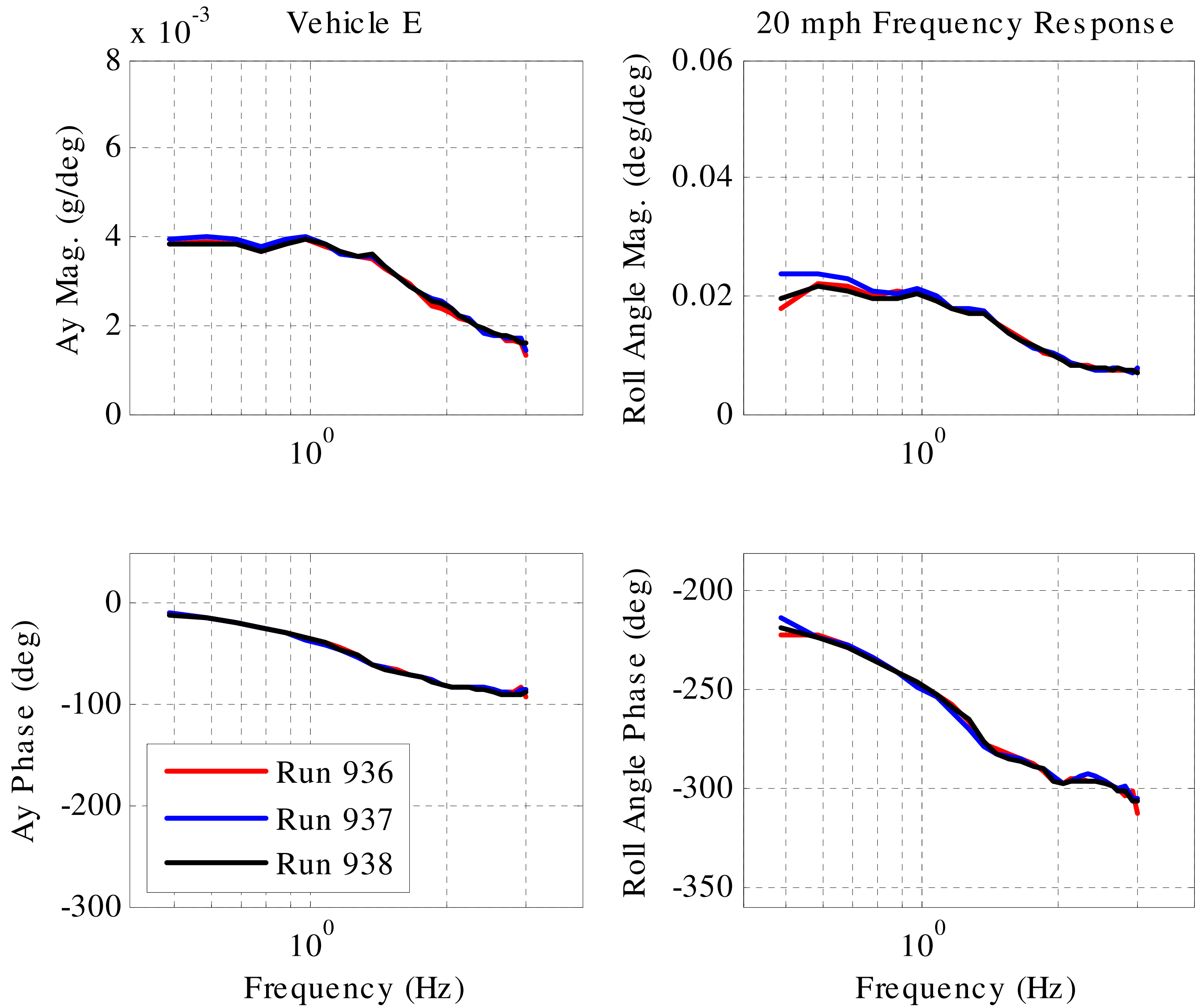


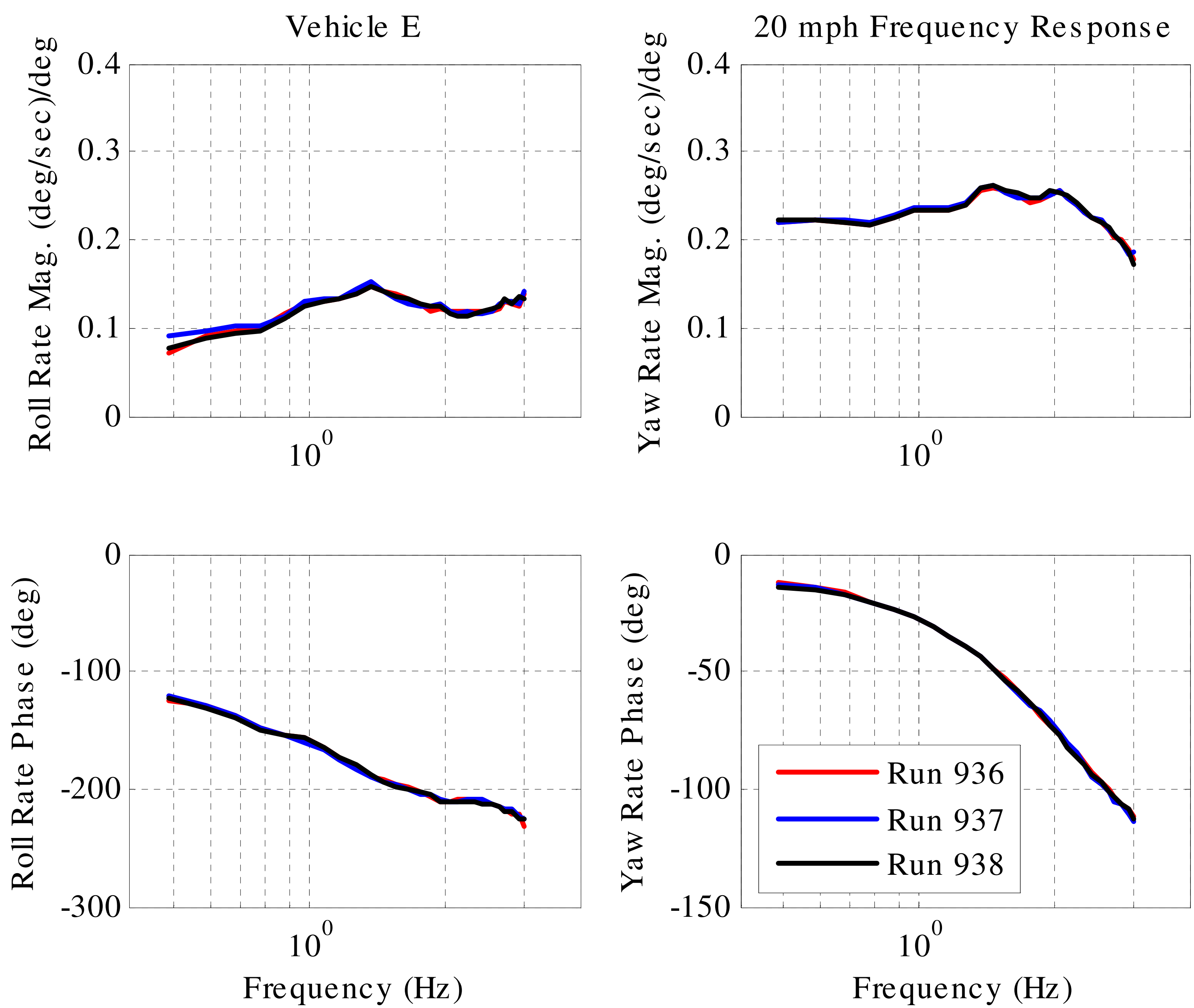
Vehicle D
20 mph Frequency Response
x 10^-3
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Frequency (Hz)
Frequency (Hz)
Run 708
Run 709
Run 710

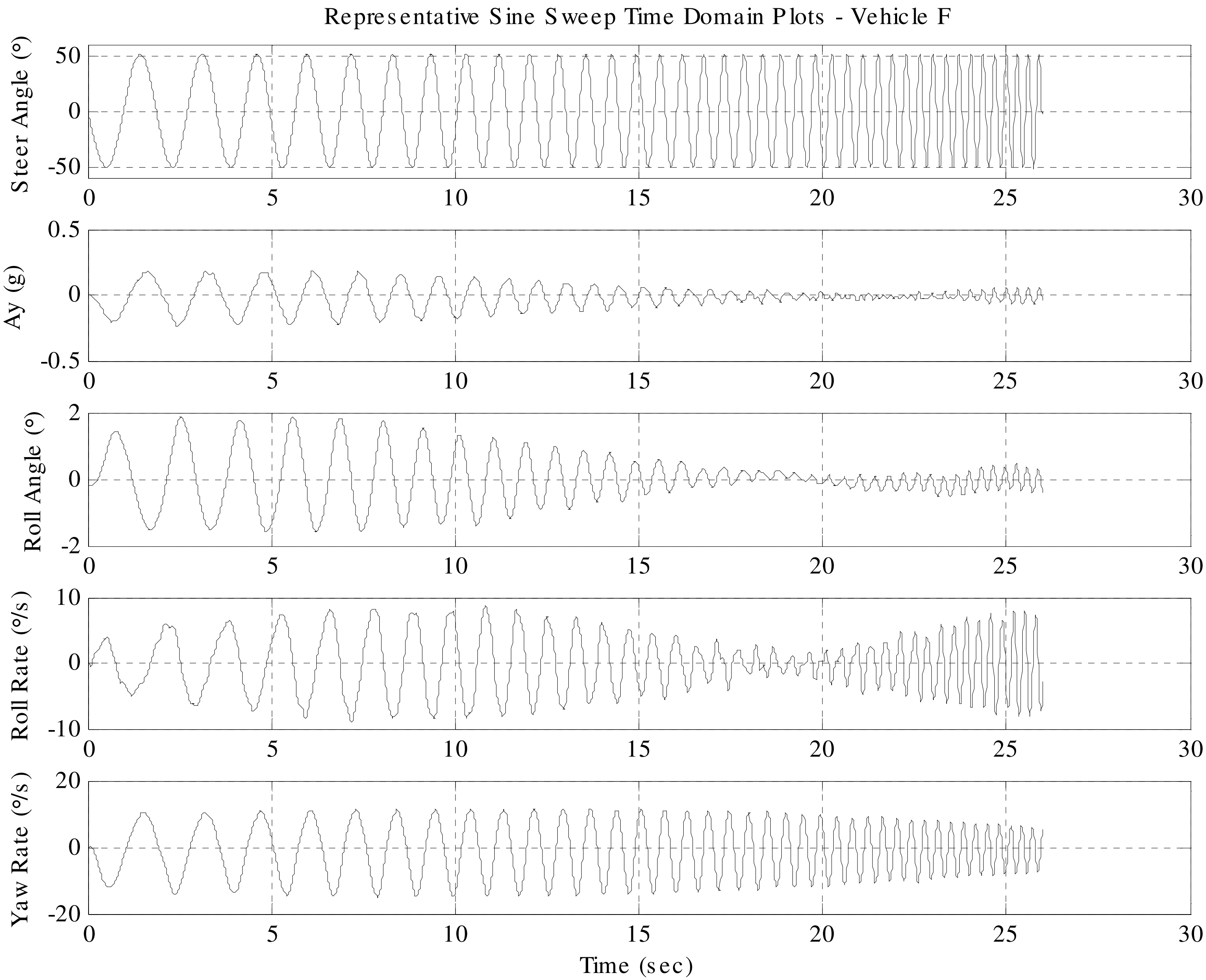

Vehicle D
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
0.4
0.3
0.2
0.1
0
-100
-200
-300
-50
-150
10^0
Frequency (Hz)
Run 708
Run 709
Run 710



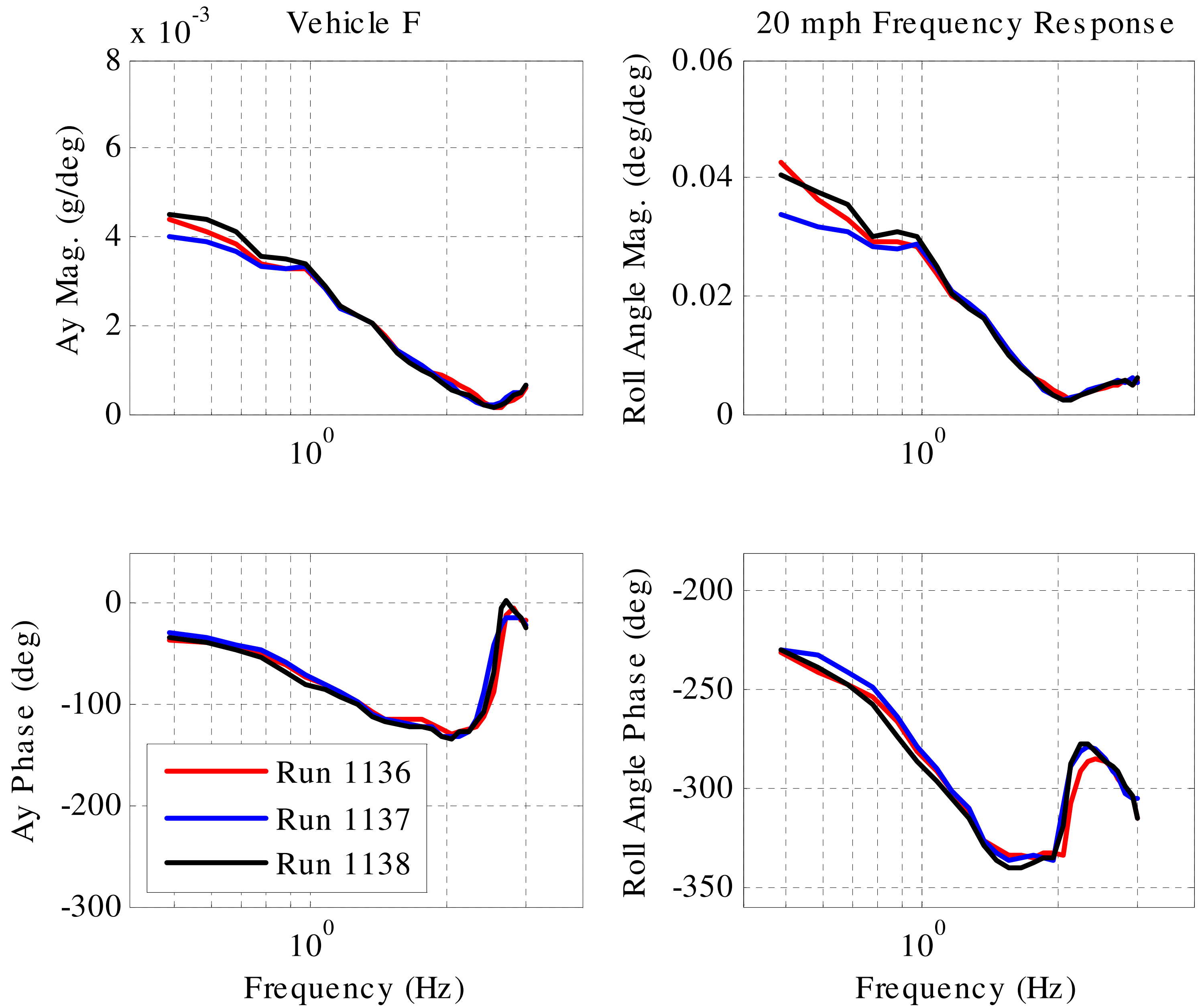
Representative Sine Sweep Time Domain Plots - Vehicle E
Steer Angle (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)


Vehicle E
20 mph Frequency Response
x 10-3
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Frequency (Hz)
Frequency (Hz)
Run 936
Run 937
Run 938

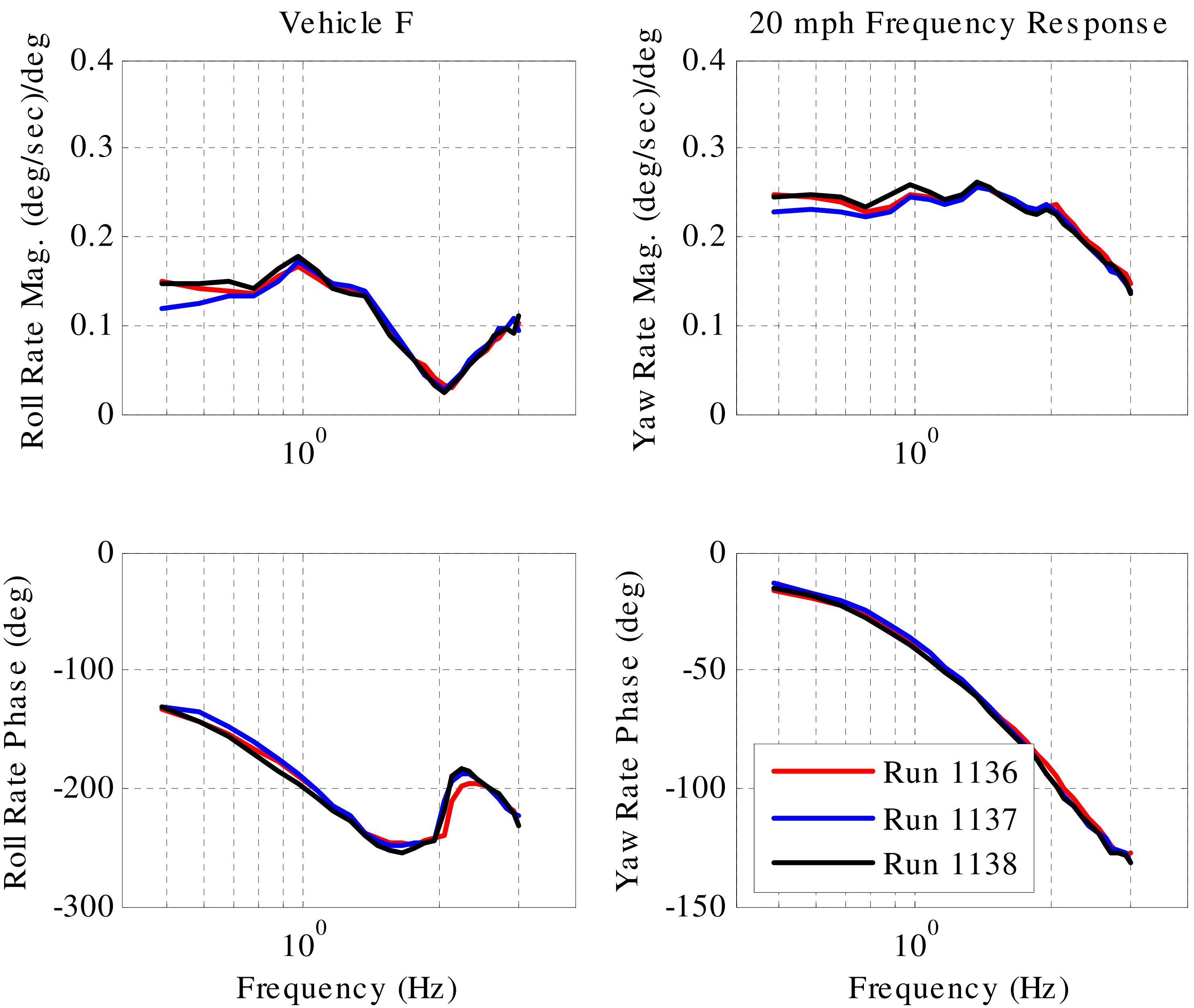

Vehicle E
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
0
-100
-200
-300
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
0
-50
-100
-150
10^0
Frequency (Hz)
Run 936
Run 937
Run 938

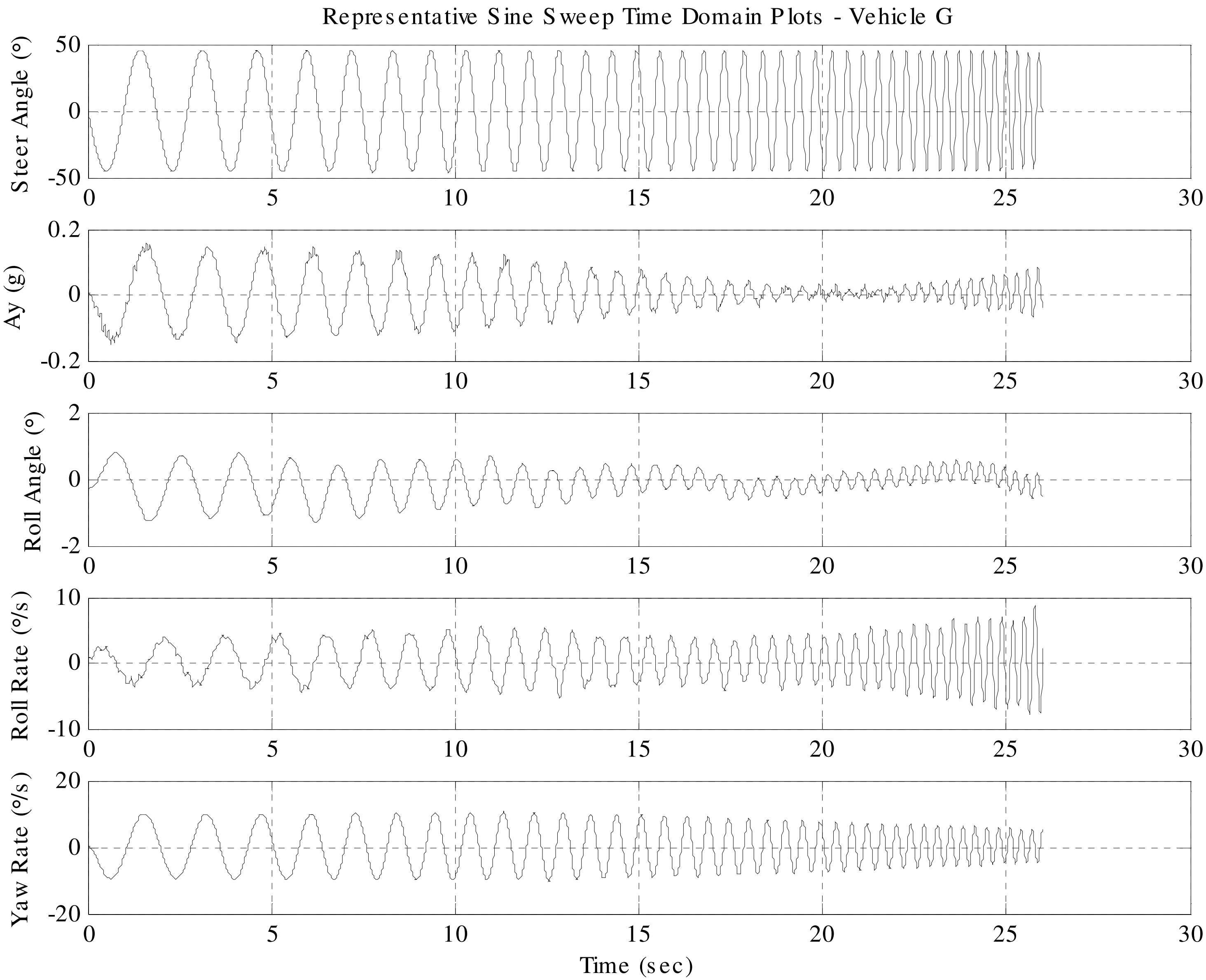


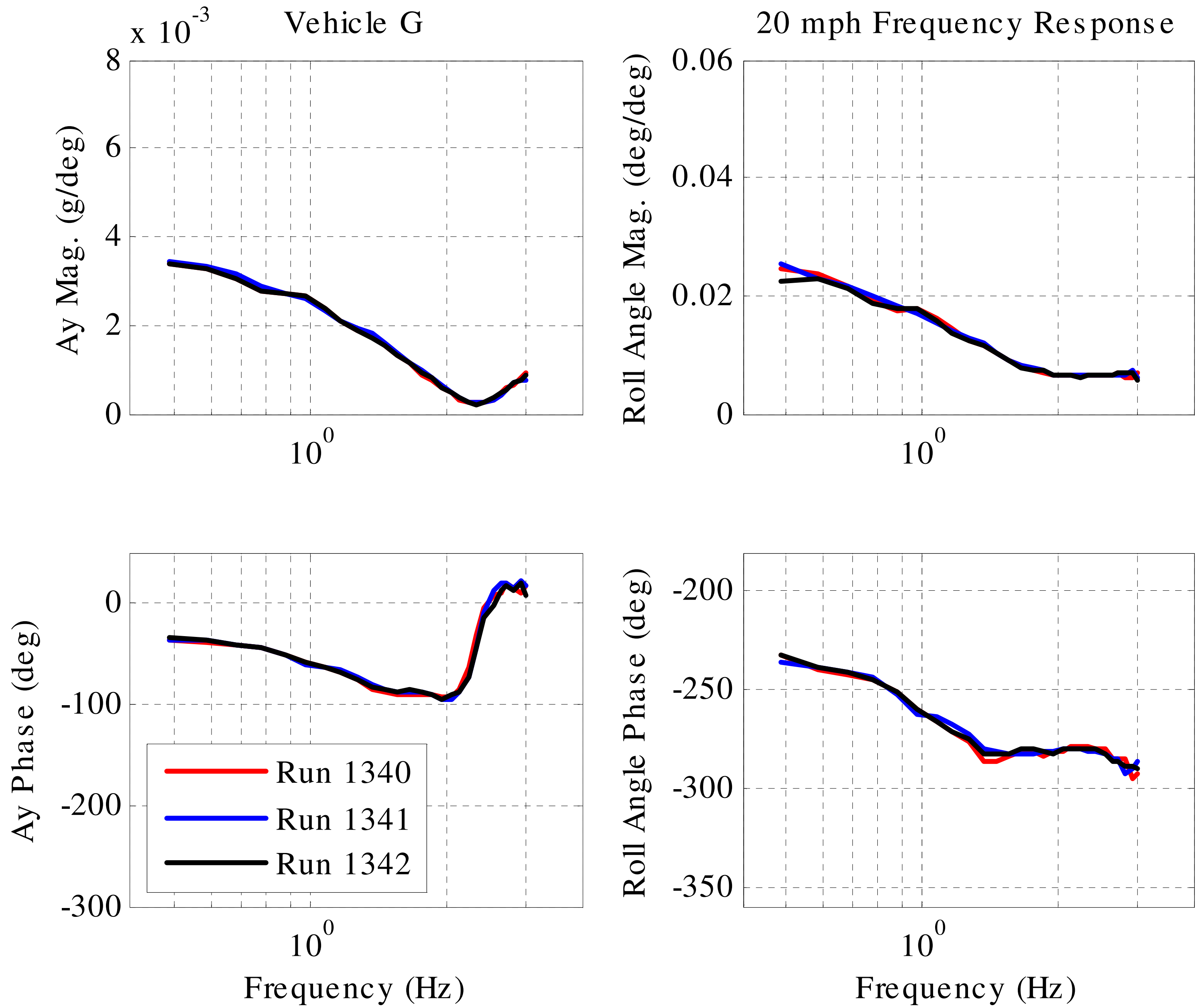
Representative Sine Sweep Time Domain Plots - Vehicle F
Steer Angle (°)
50
0
-50
Ay (g)
0.5
0
-0.5
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
10
0
-10
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)



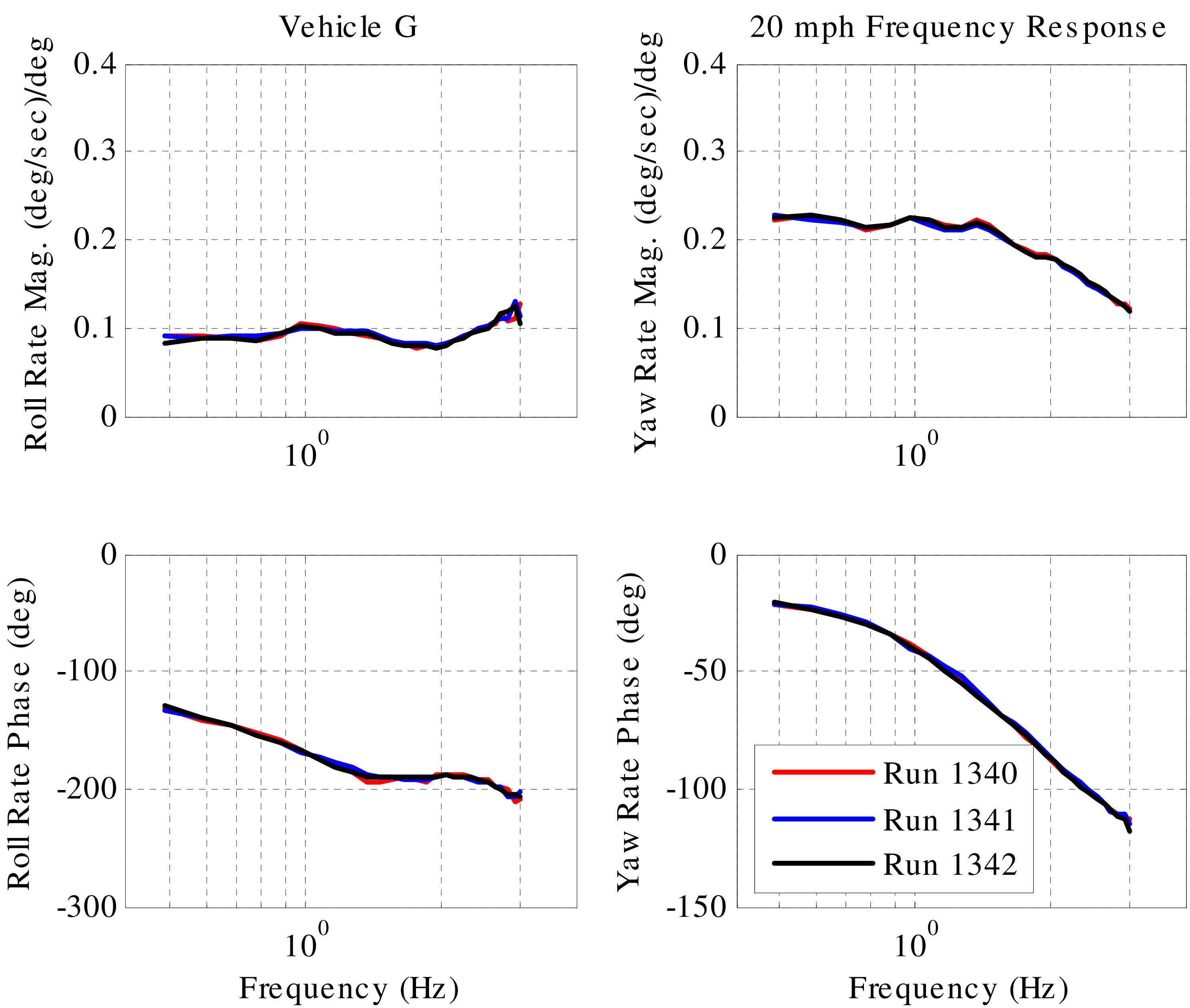
Vehicle F
20 mph Frequency Response
x 10^-3
8
6
4
2
0
Ay Mag. (g/deg)
0.06
0.04
0.02
0
Roll Angle Mag. (deg/deg)
10^0
10^0
0
-100
-200
-300
Ay Phase (deg)
Run 1136
Run 1137
Run 1138
-200
-250
-300
-350
Roll Angle Phase (deg)
10^0
Frequency (Hz)
10^0
Frequency (Hz)


Vehicle F
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
0
-100
-200
-300
-50
-150
Frequency (Hz)
Run 1136
Run 1137
Run 1138

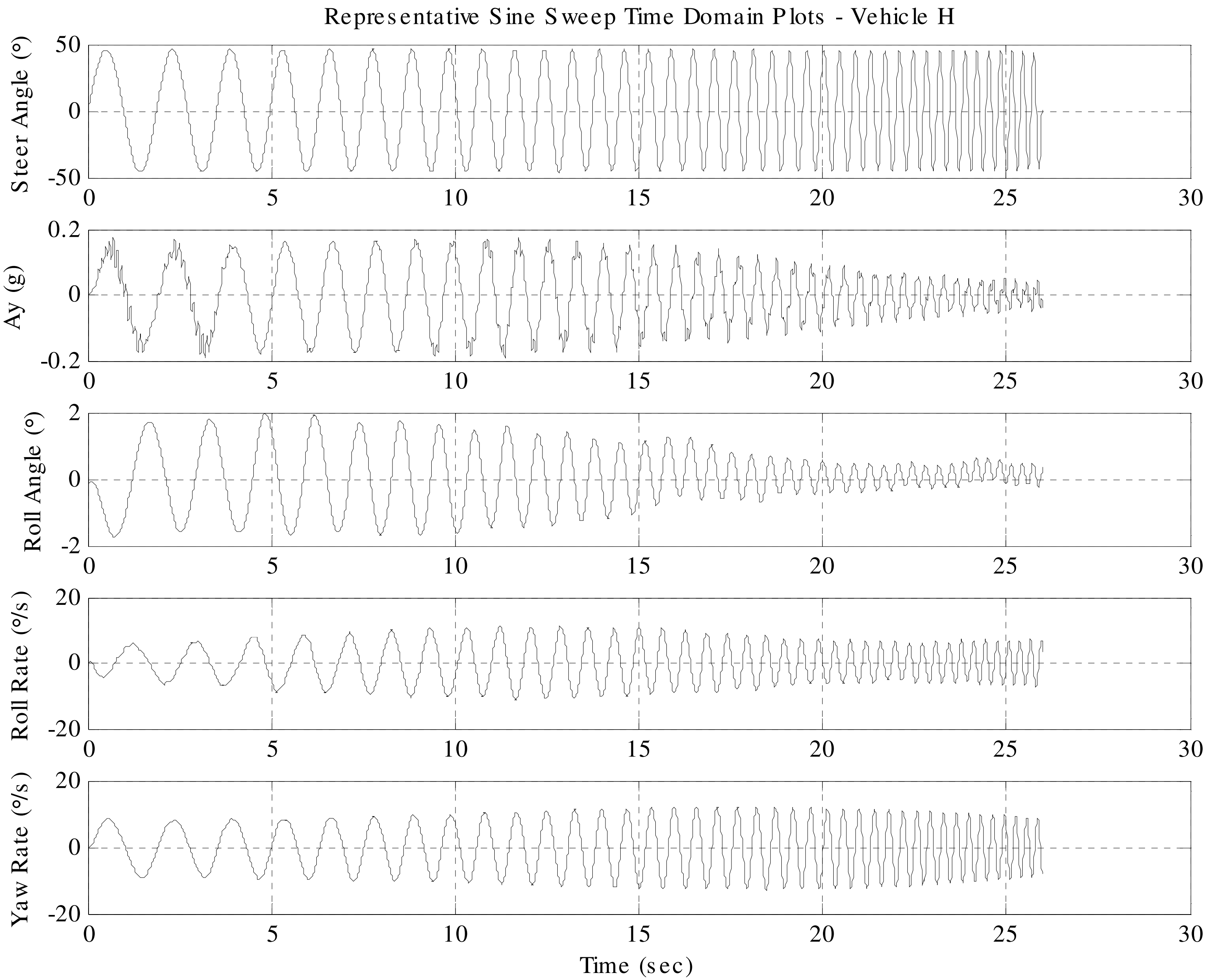

Representative Sine Sweep Time Domain Plots - Vehicle G
Steer Angle (°)
50
0
-50
Ay (g)
0.2
0
-0.2
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
10
0
-10
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

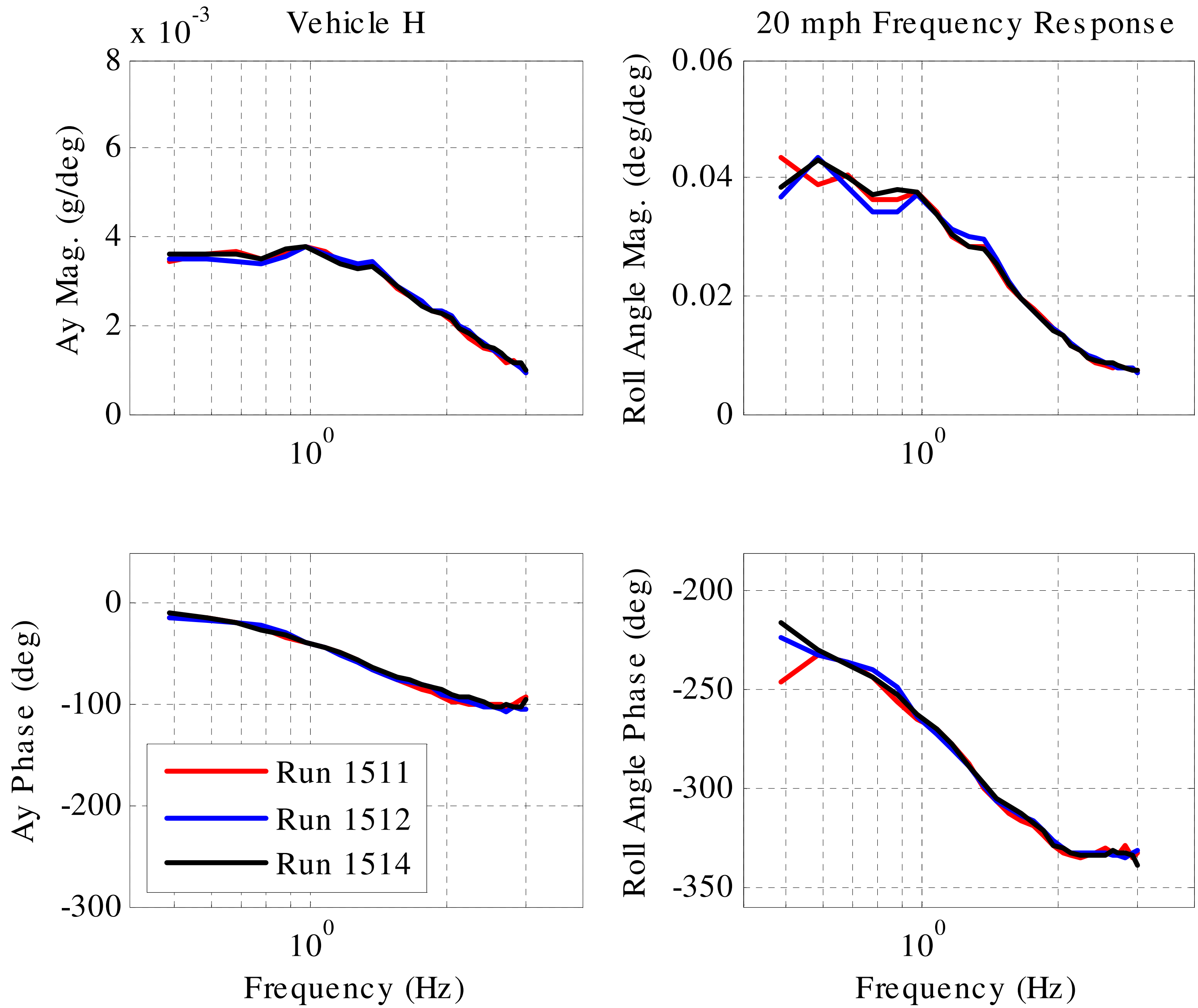


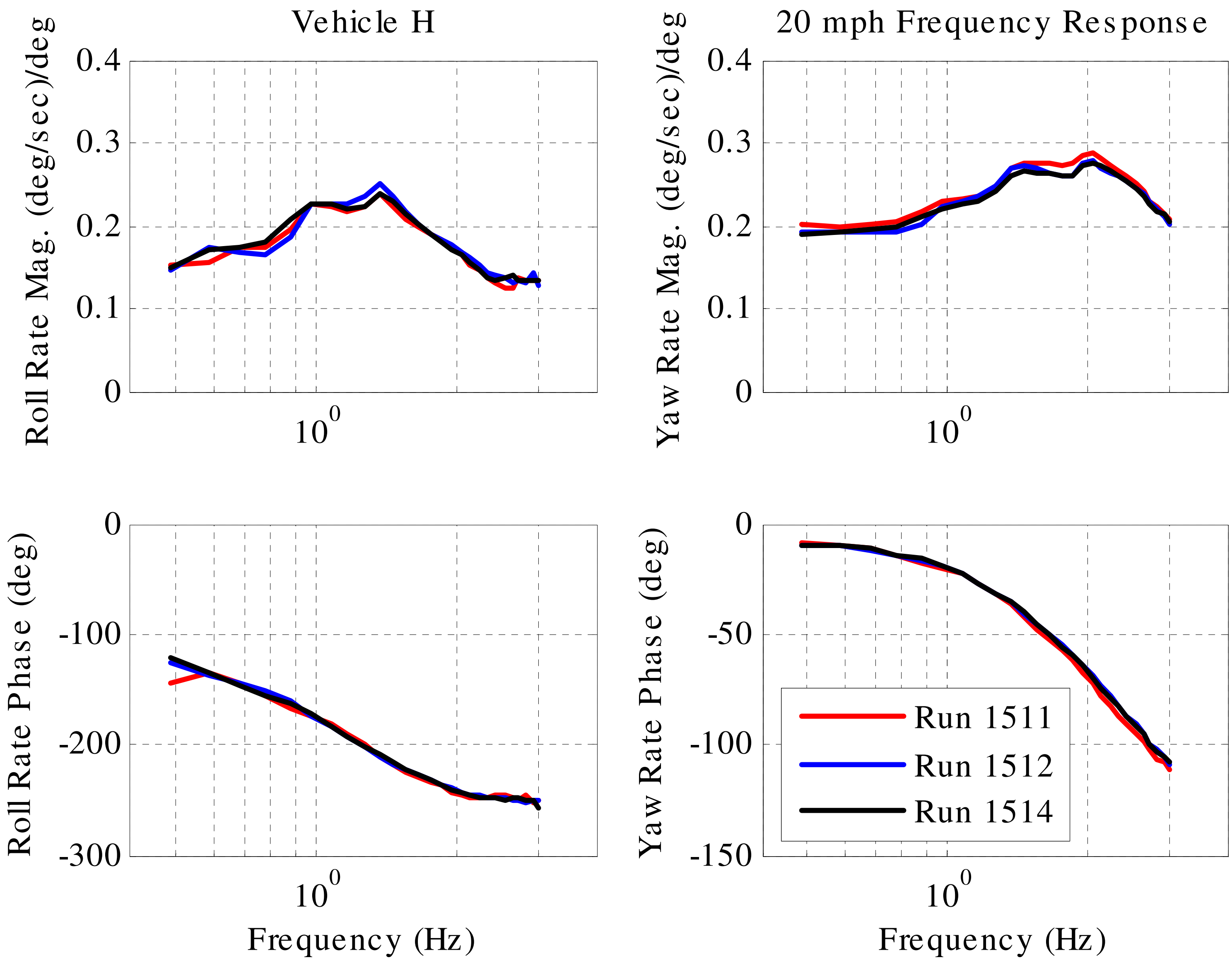
Vehicle G
20 mph Frequency Response
x 10^-3
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 1340
Run 1341
Run 1342
Frequency (Hz)
Frequency (Hz)



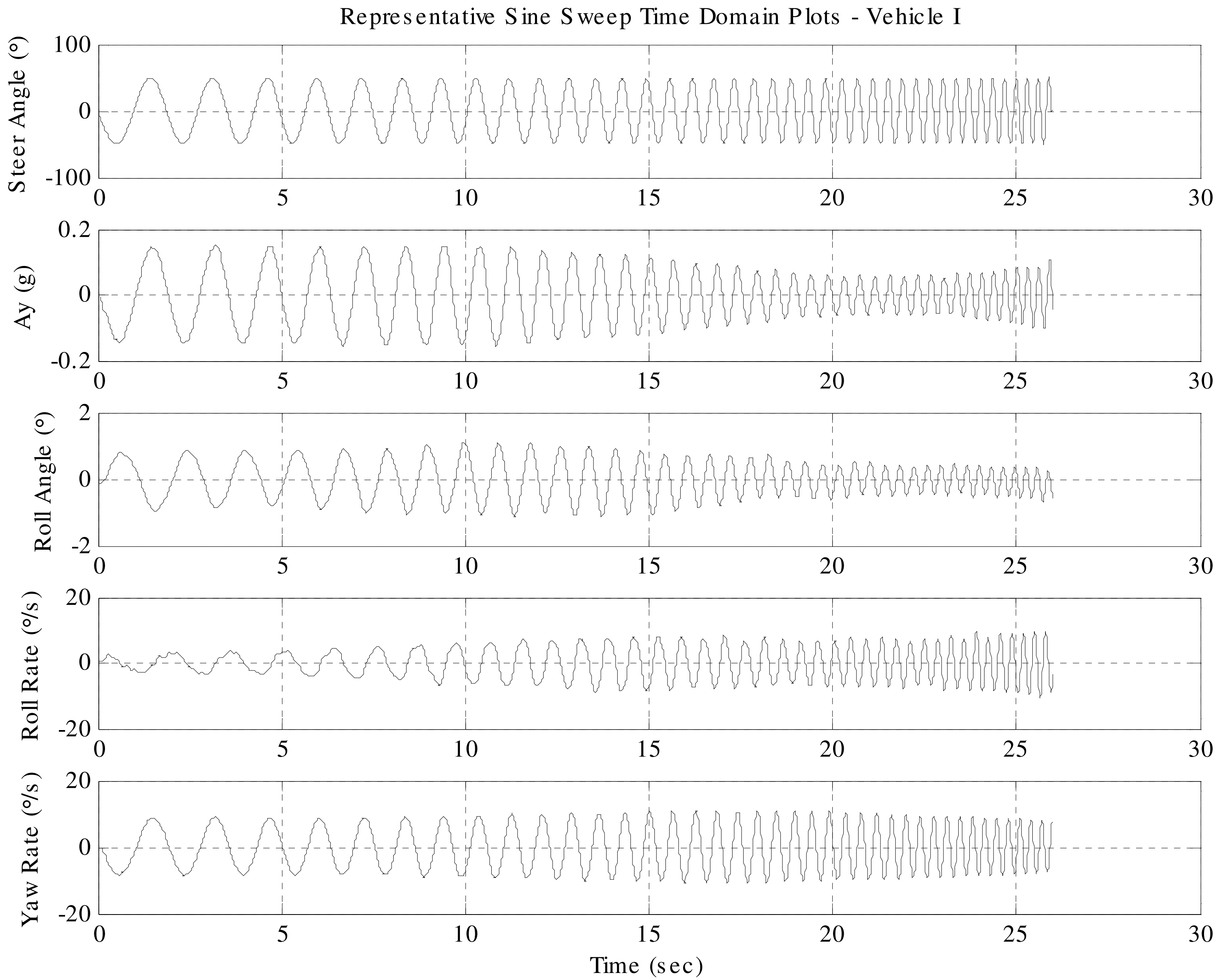
Vehicle G
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
0.4
0.3
0.2
0.1
0
-100
-200
-300
-50
-150
10^0
Frequency (Hz)
Run 1340
Run 1341
Run 1342

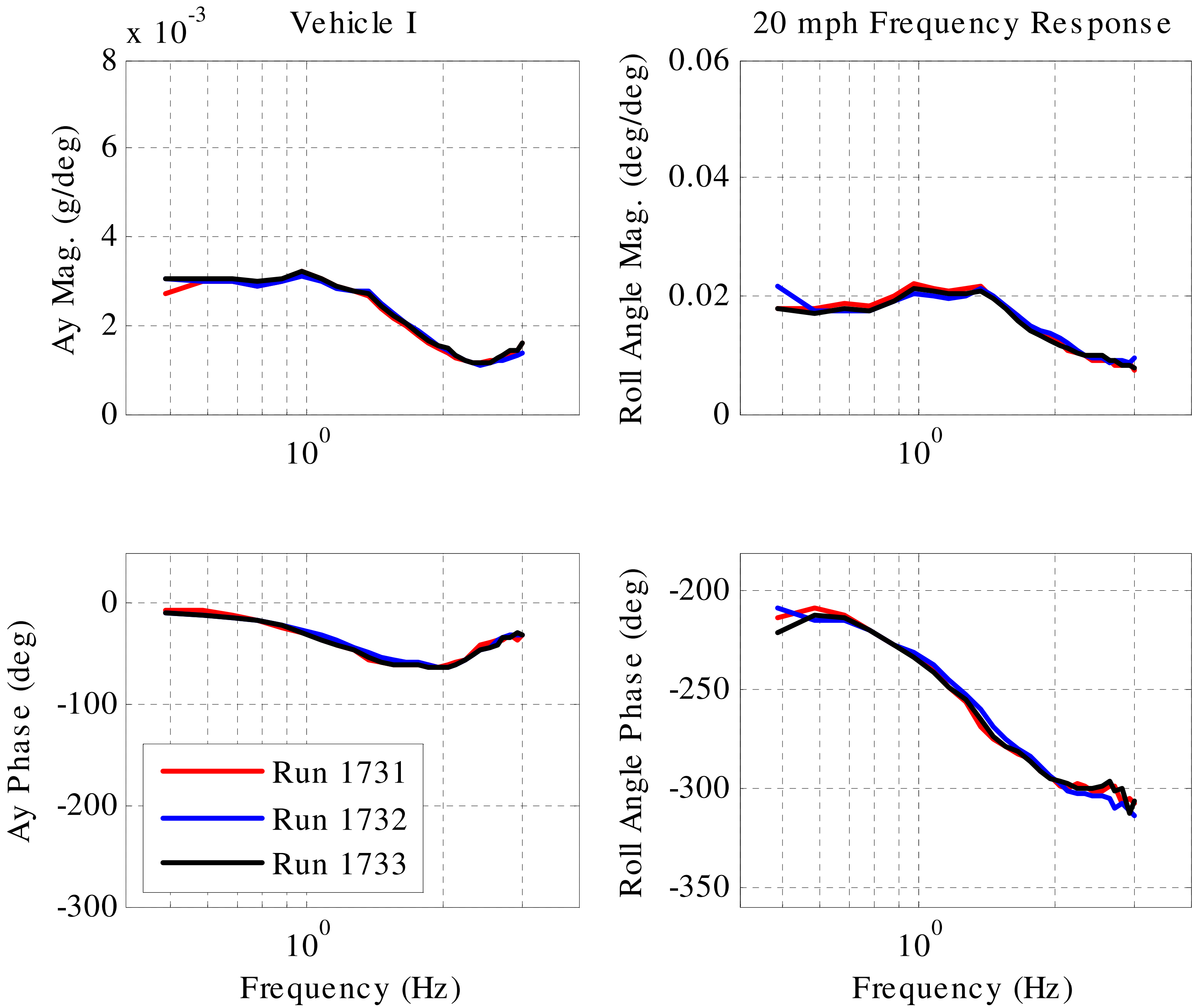

Representative Sine Sweep Time Domain Plots - Vehicle H
Steer Angle (°)
50
0
-50
Ay (g)
0.2
0
-0.2
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
20
0
-20
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)


Vehicle H
20 mph Frequency Response
x 10^-3
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 1511
Run 1512
Run 1514
Frequency (Hz)
Frequency (Hz)

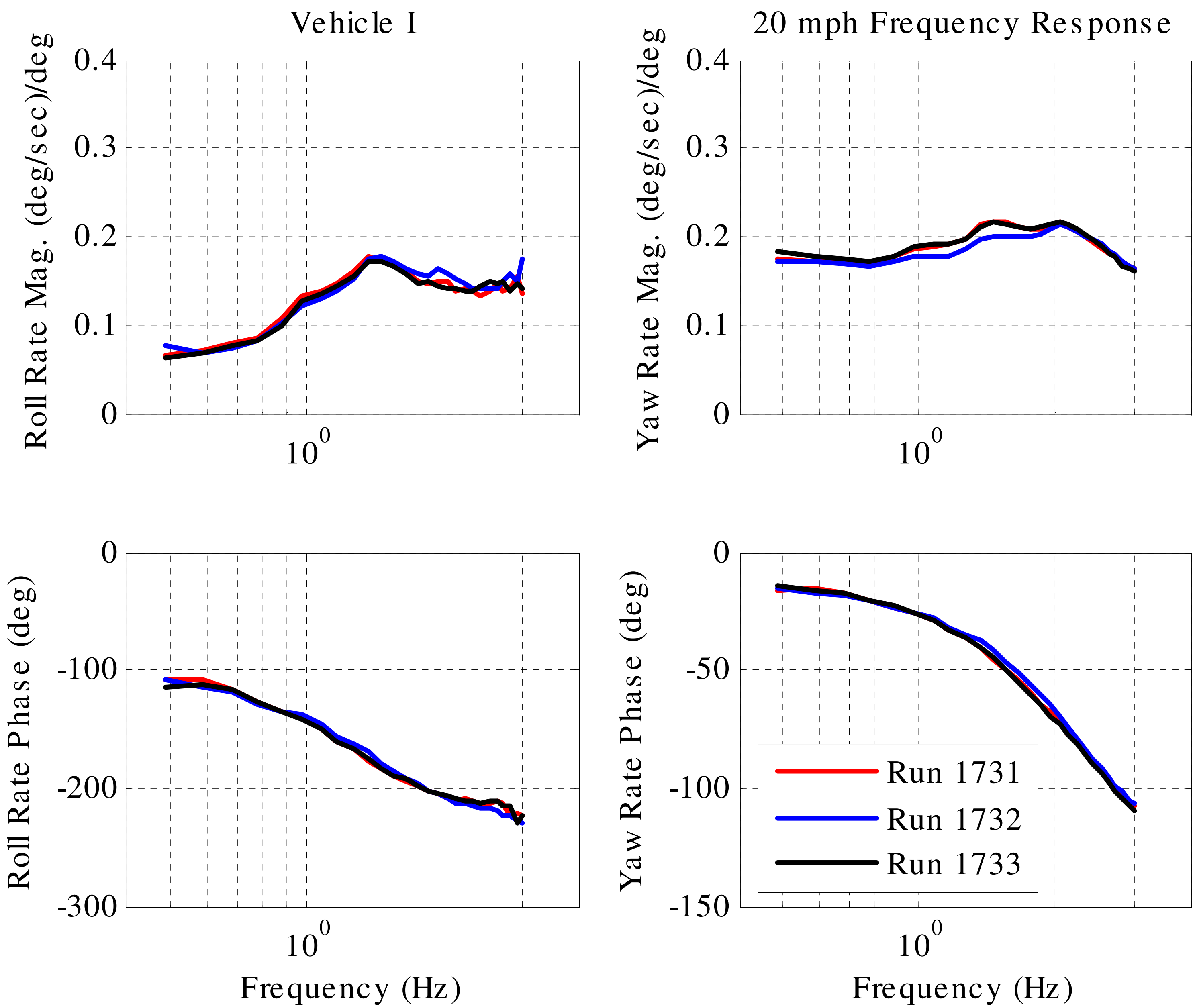


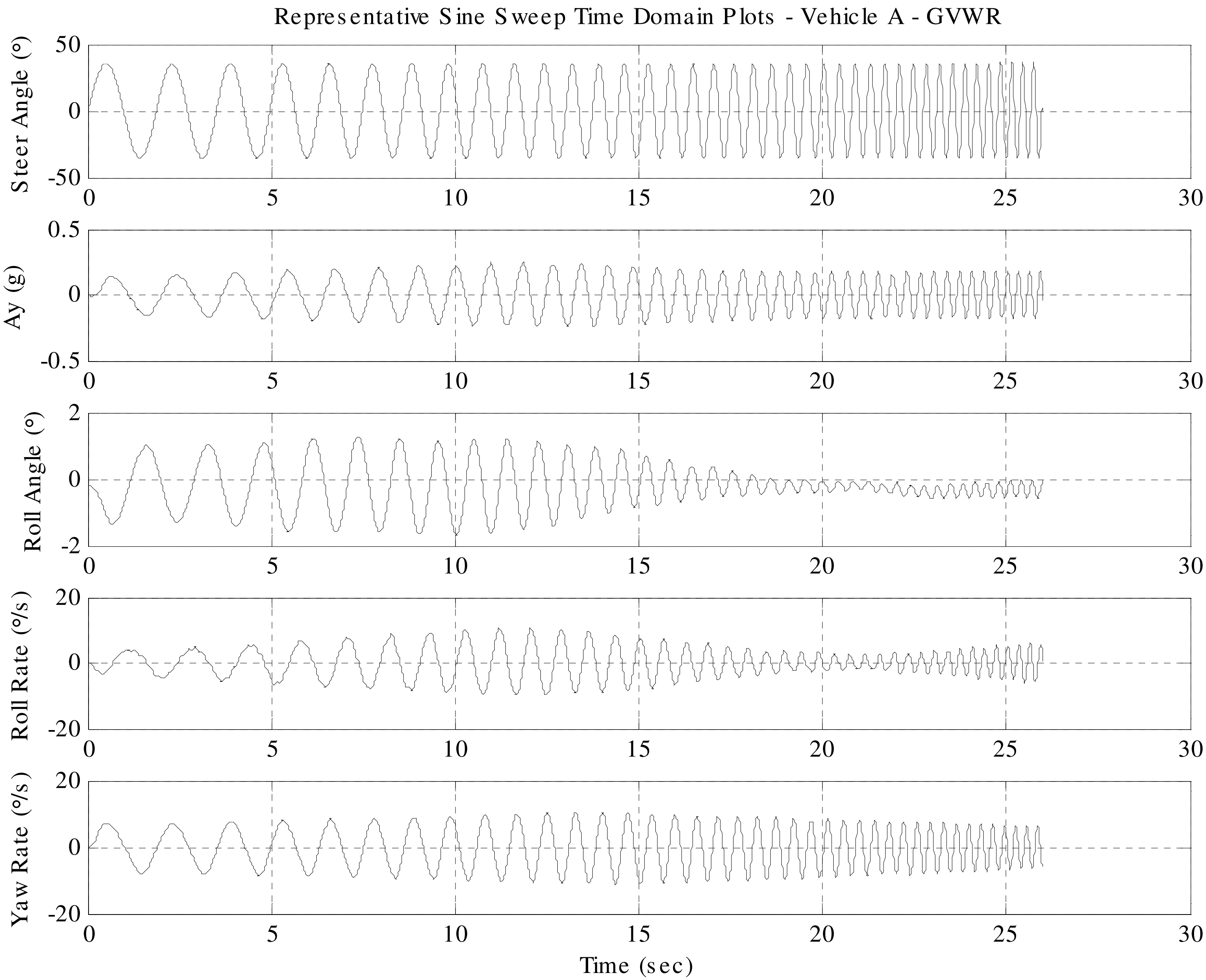
Vehicle H
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
0
-100
-200
-300
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
0
-50
-100
-150
Run 1511
Run 1512
Run 1514
10^0
Frequency (Hz)

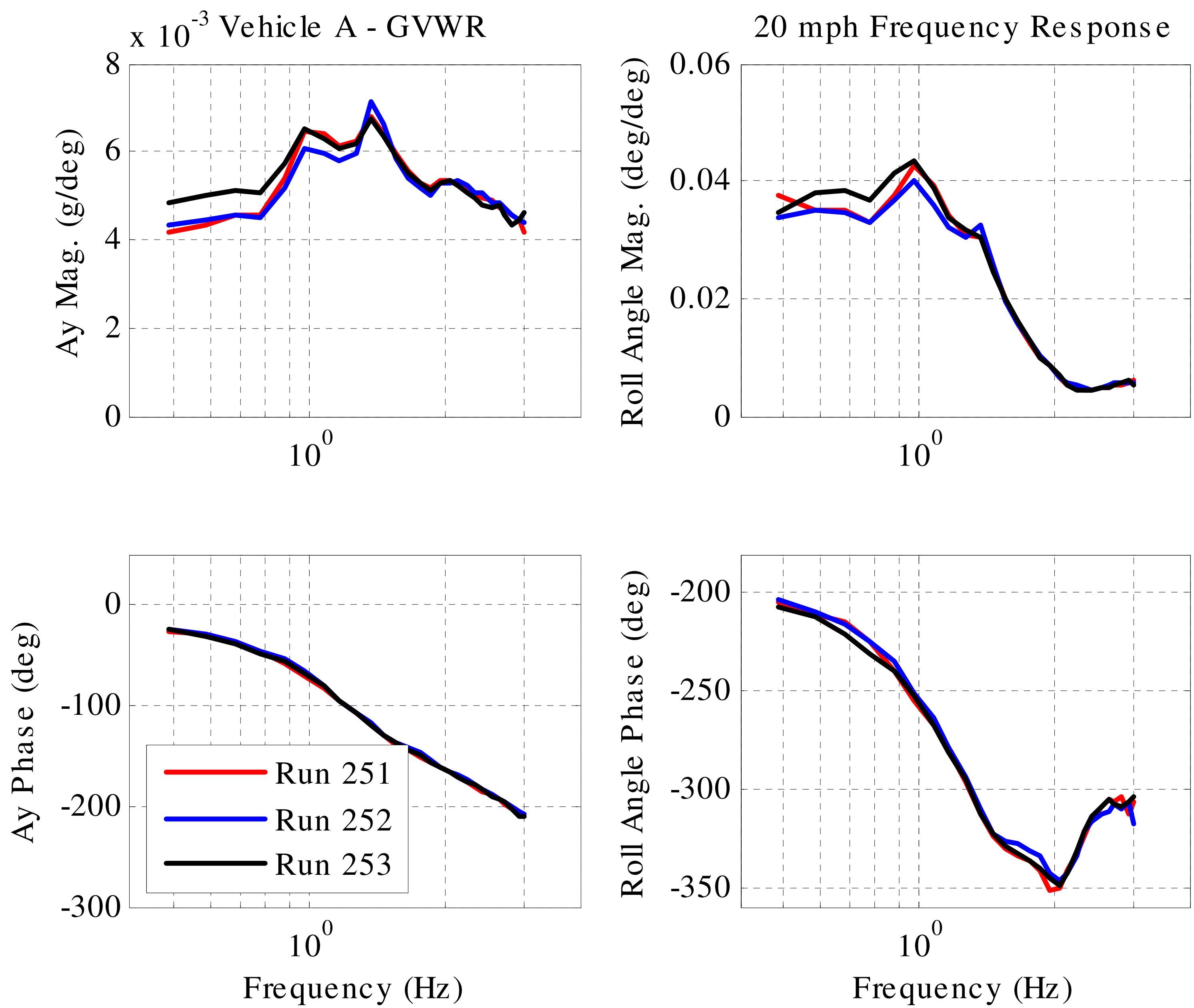

Representative Sine Sweep Time Domain Plots - Vehicle I
Steer Angle (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

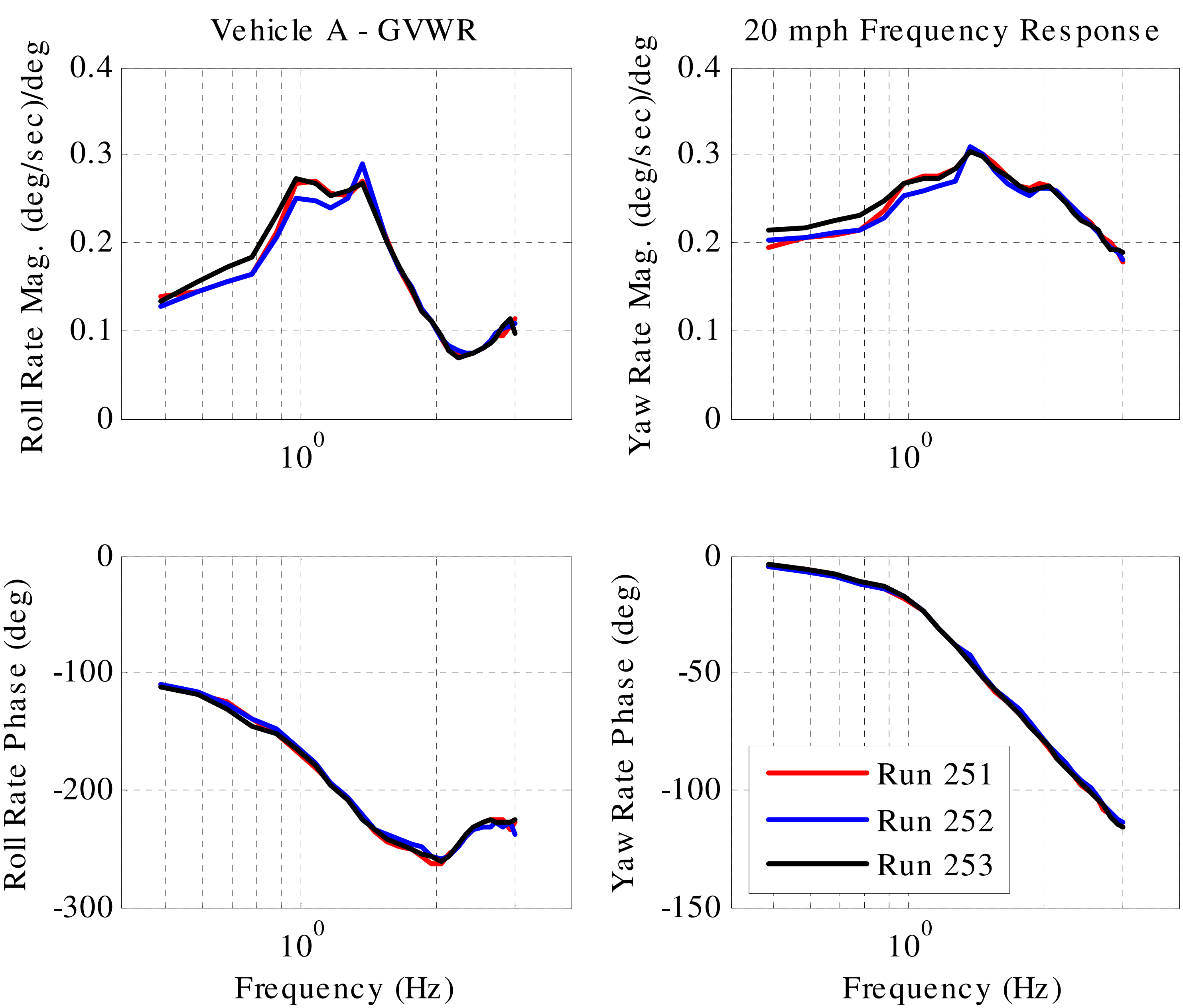


Vehicle I
20 mph Frequency Response
x 10^-3
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 1731
Run 1732
Run 1733
Frequency (Hz)

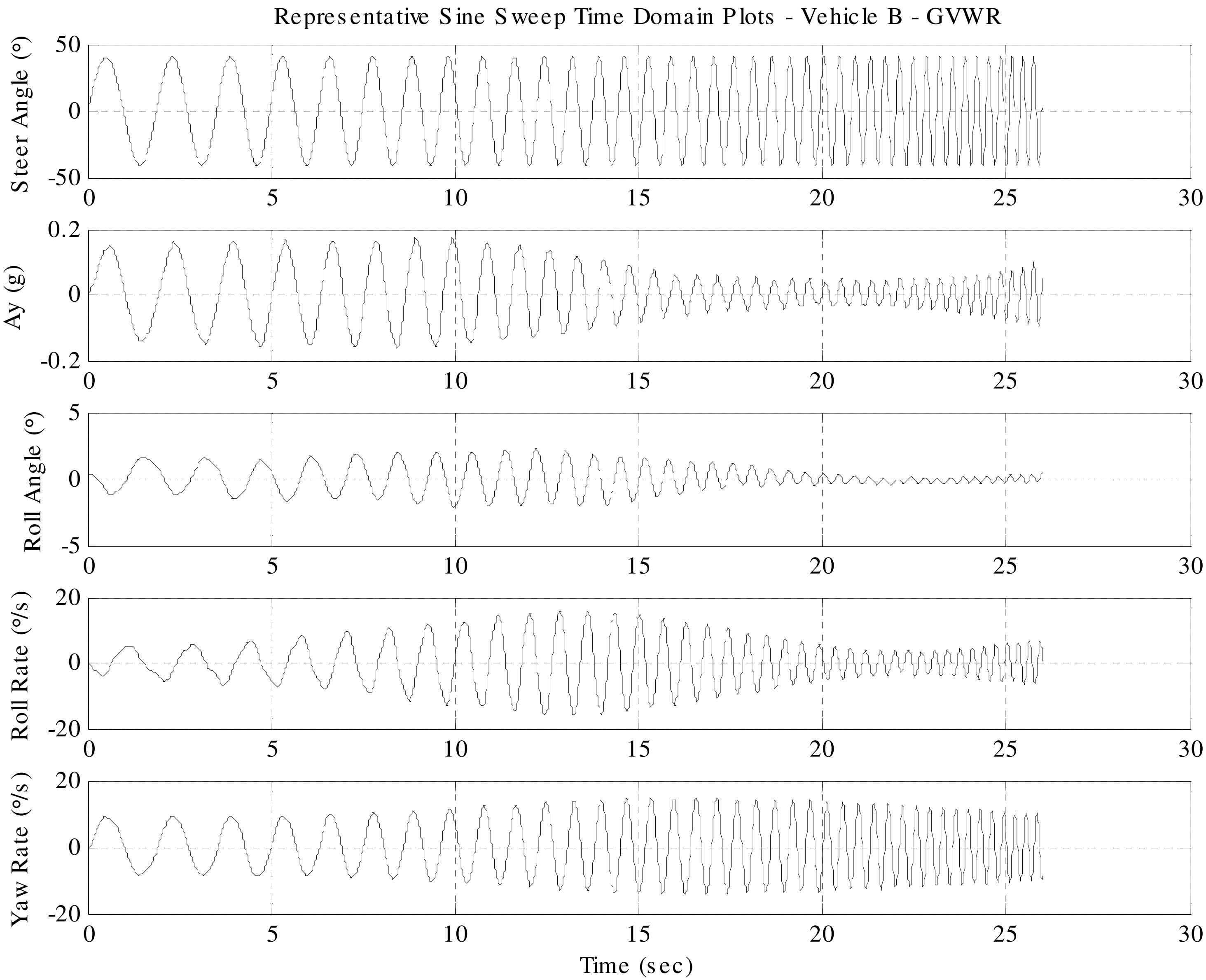

Vehicle I
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
0
-100
-200
-300
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
0
-50
-100
-150
10^0
Frequency (Hz)
Run 1731
Run 1732
Run 1733

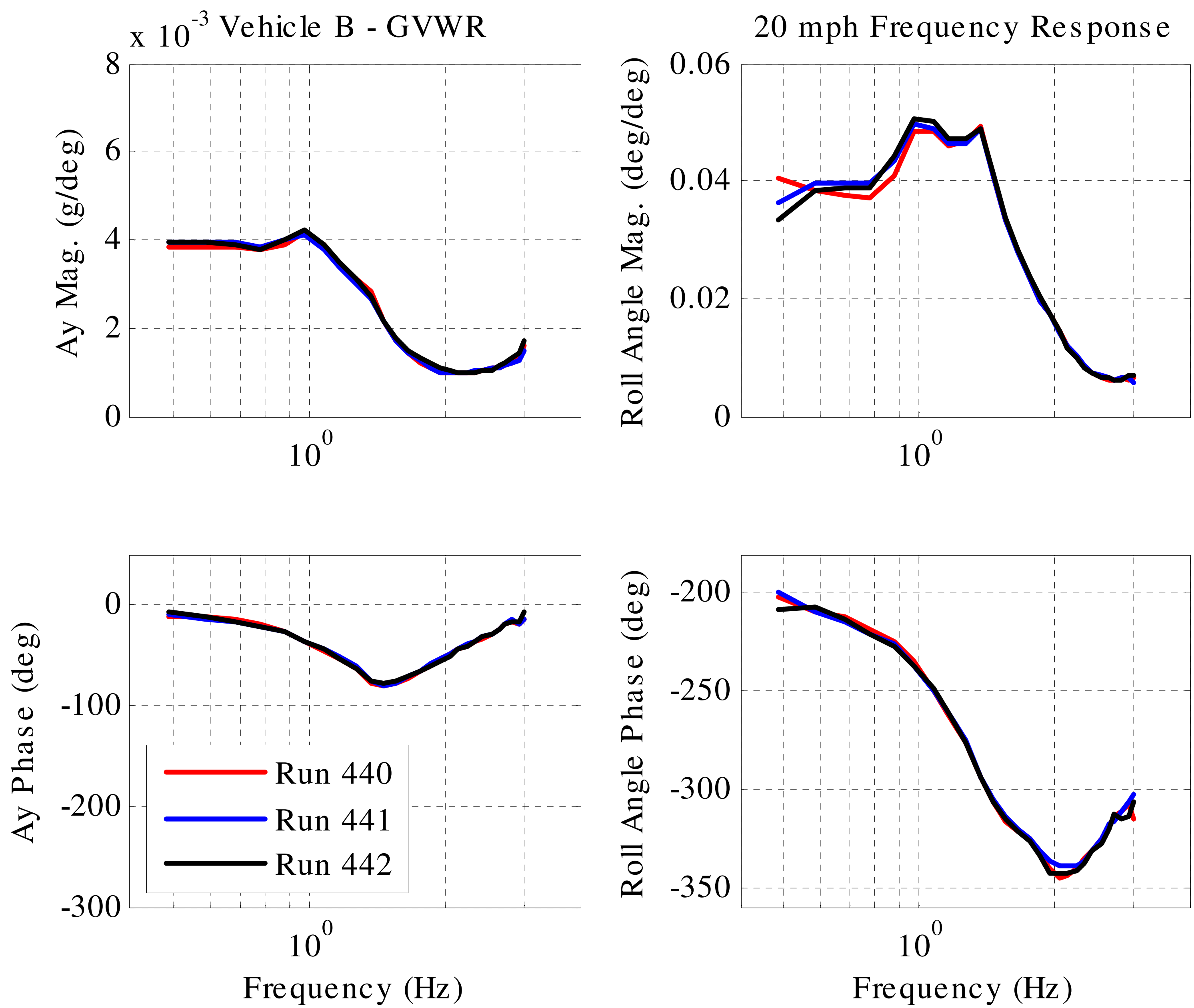

Representative Sine Sweep Time Domain Plots - Vehicle A - GVWR
Steer Angle (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)


x 10^-3 Vehicle A - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Frequency (Hz)
Run 251
Run 252
Run 253

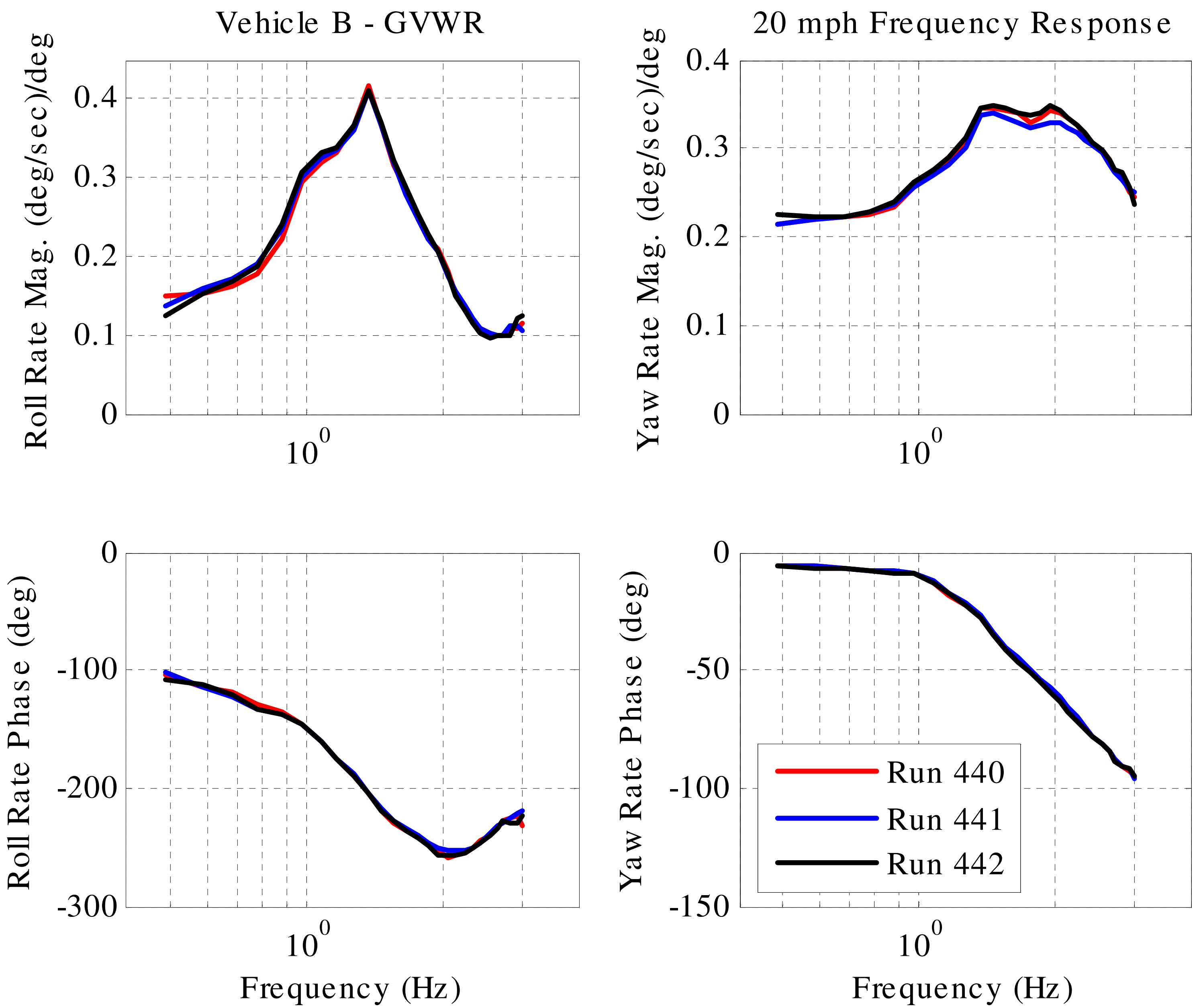


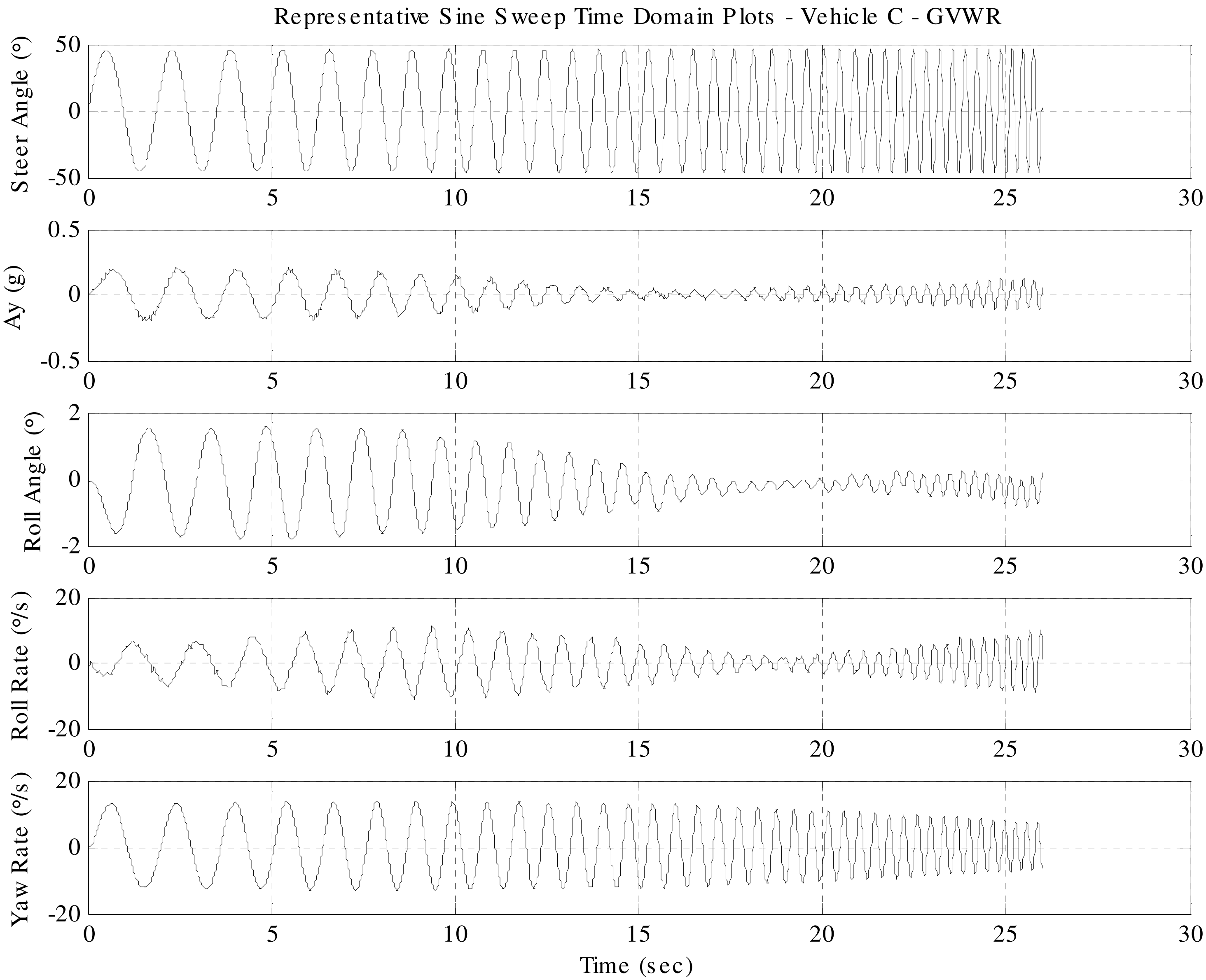
Vehicle A - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
0
-100
-200
-300
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
0
-50
-100
-150
Run 251
Run 252
Run 253
10^0
Frequency (Hz)

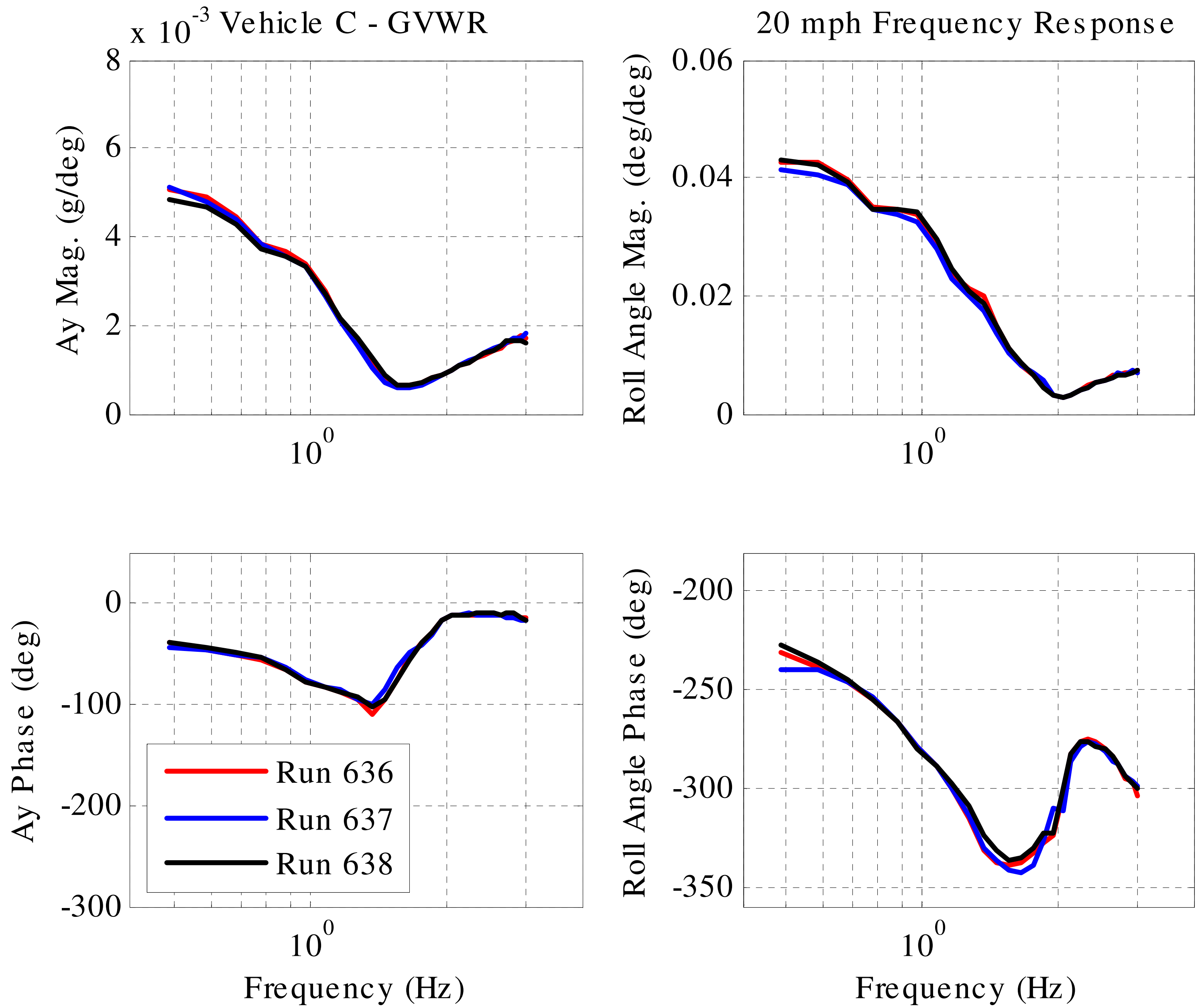

Representative Sine Sweep Time Domain Plots - Vehicle B - GVWR
Steer Angle (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)
50
0
-50
0.2
-0.2
5
-5
20
-20
0
5
10
15
20
25
30



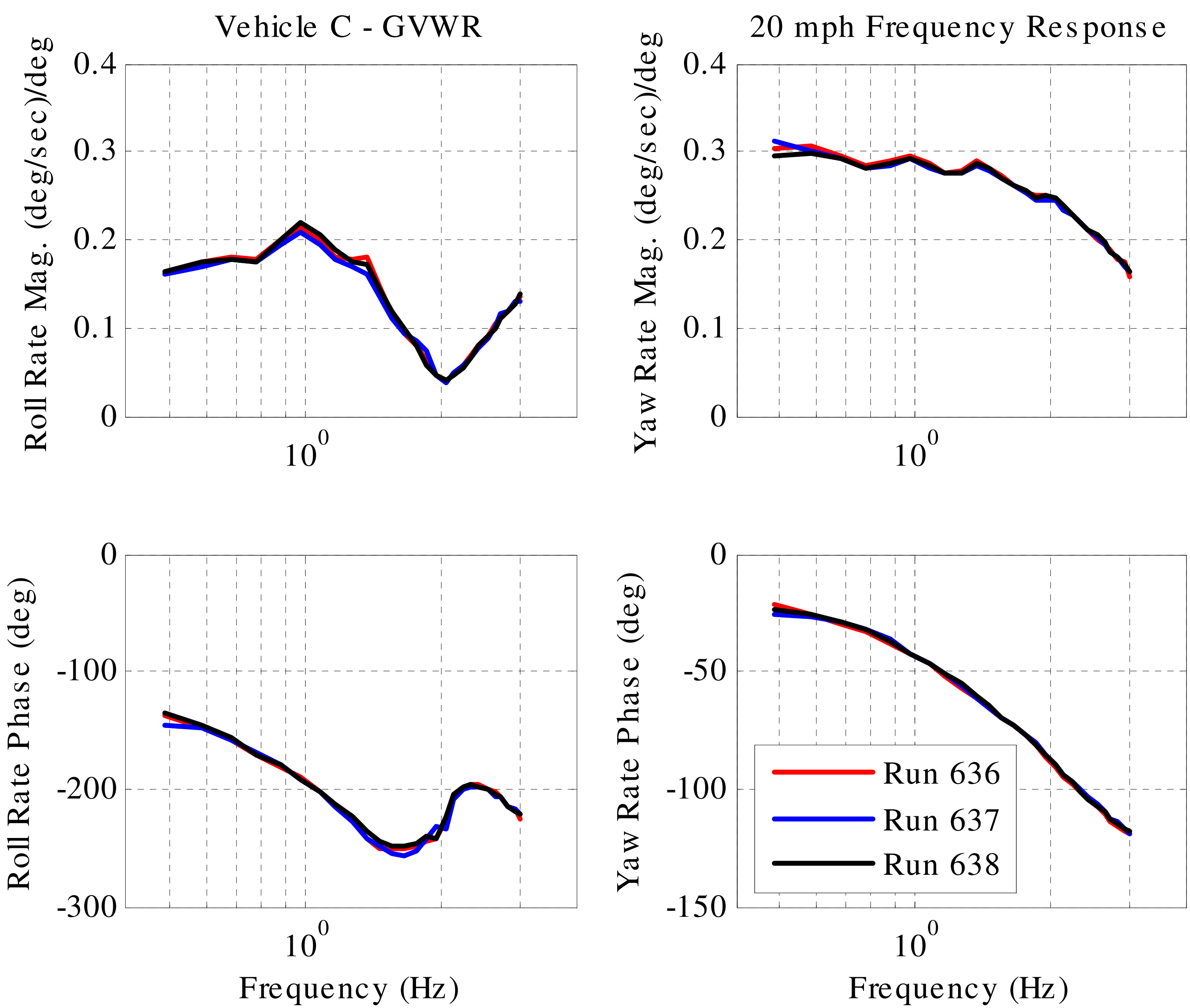
x 10^-3 Vehicle B - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Frequency (Hz)
Frequency (Hz)
Run 440
Run 441
Run 442


Vehicle B - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
0
-100
-200
-300
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
0
-50
-100
-150
Run 440
Run 441
Run 442
10^0
Frequency (Hz)

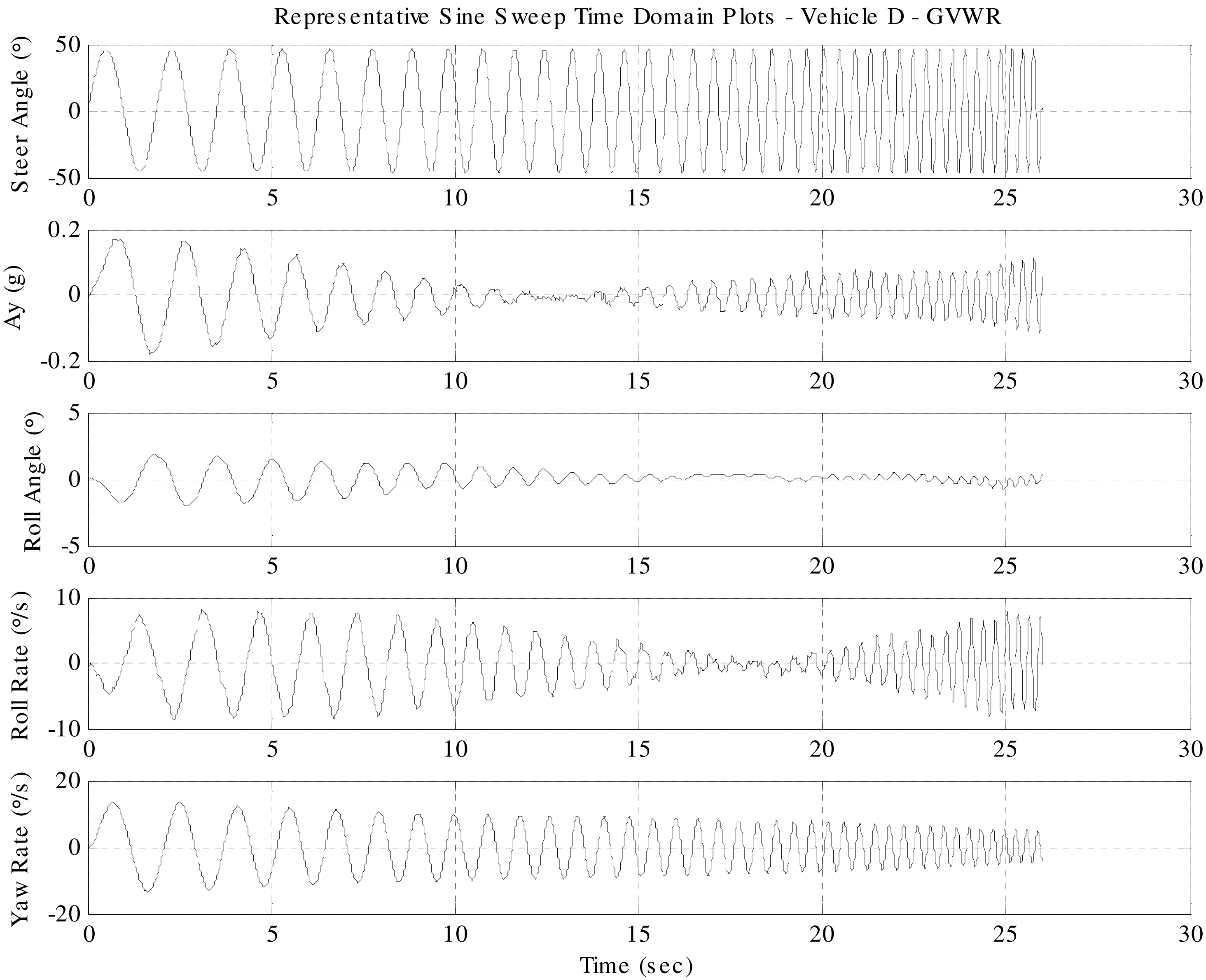

Representative Sine Sweep Time Domain Plots - Vehicle C - GVWR
Steer Angle (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

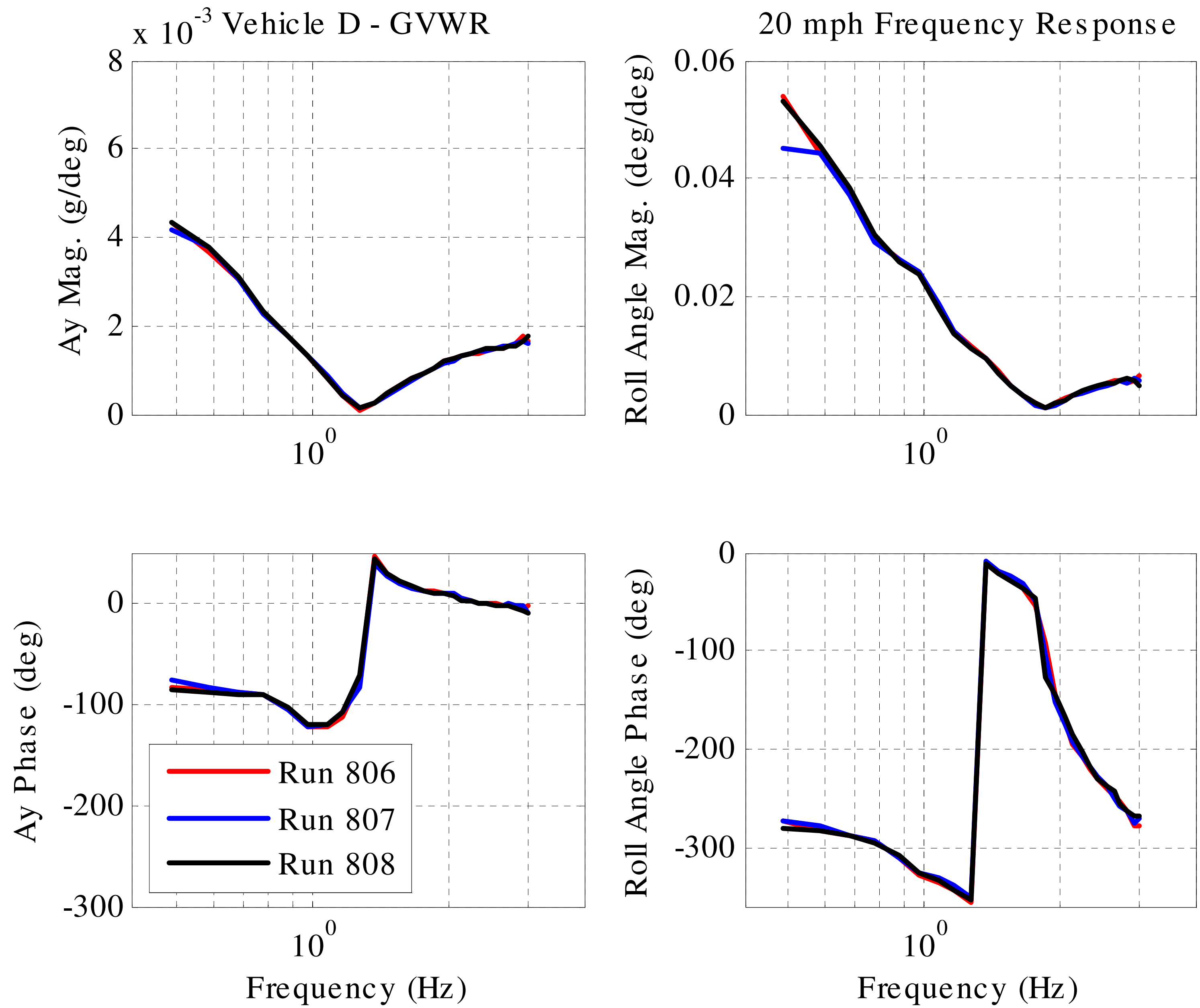


x 10^-3 Vehicle C - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 636
Run 637
Run 638
Frequency (Hz)
Frequency (Hz)

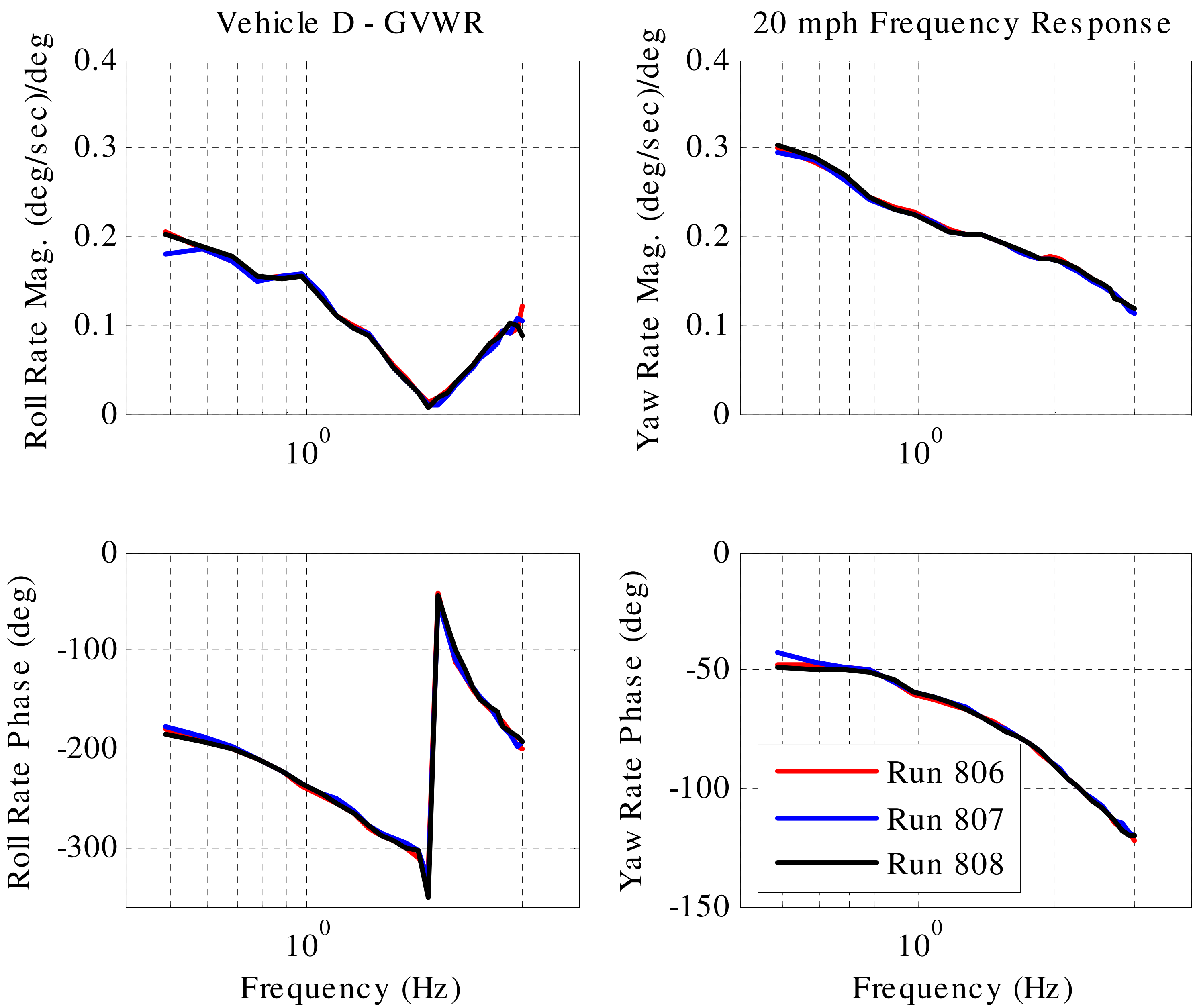


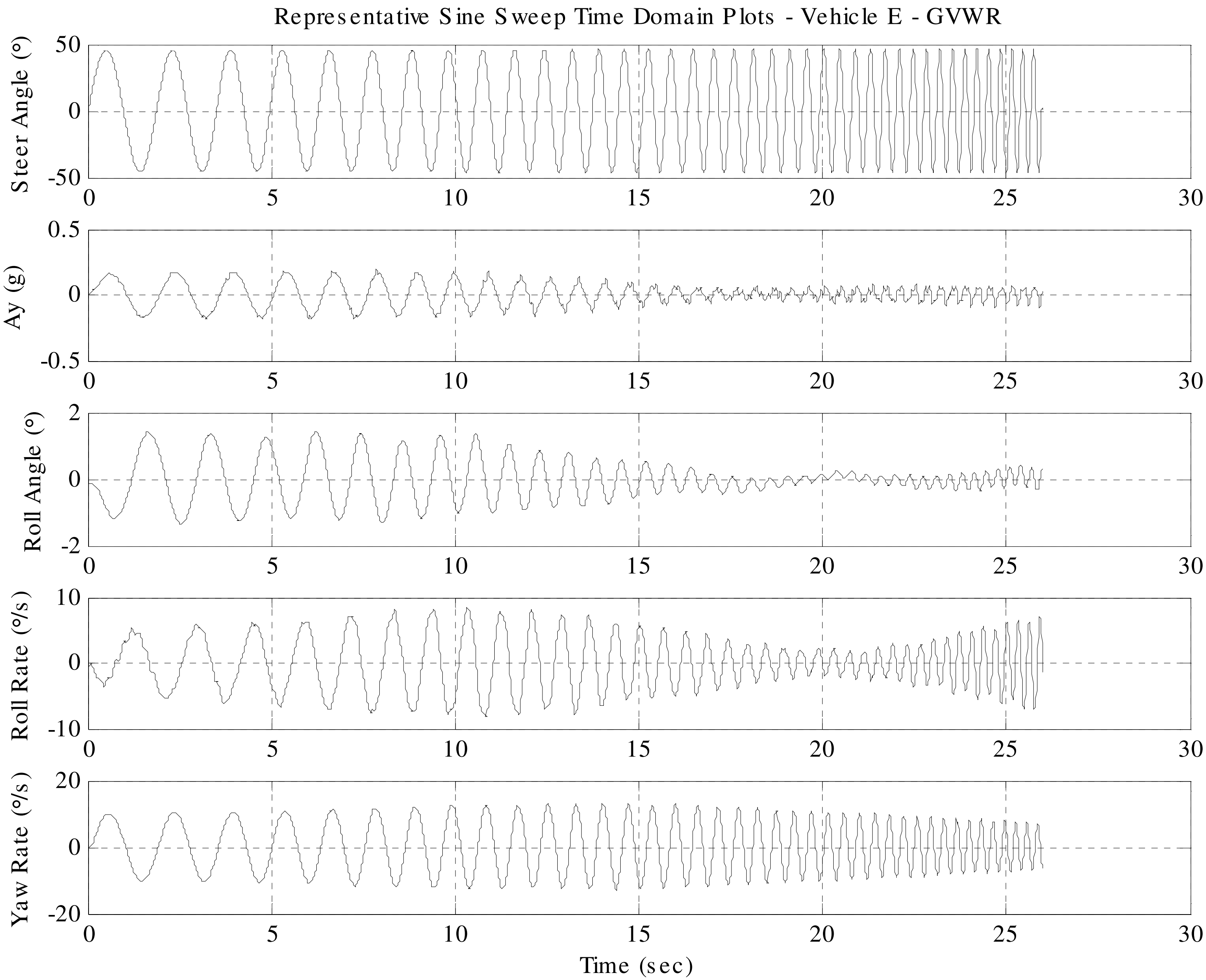
Vehicle C - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
0.4
0.3
0.2
0.1
0
0
-100
-200
-300
-50
-150
10^0
Frequency (Hz)
Run 636
Run 637
Run 638

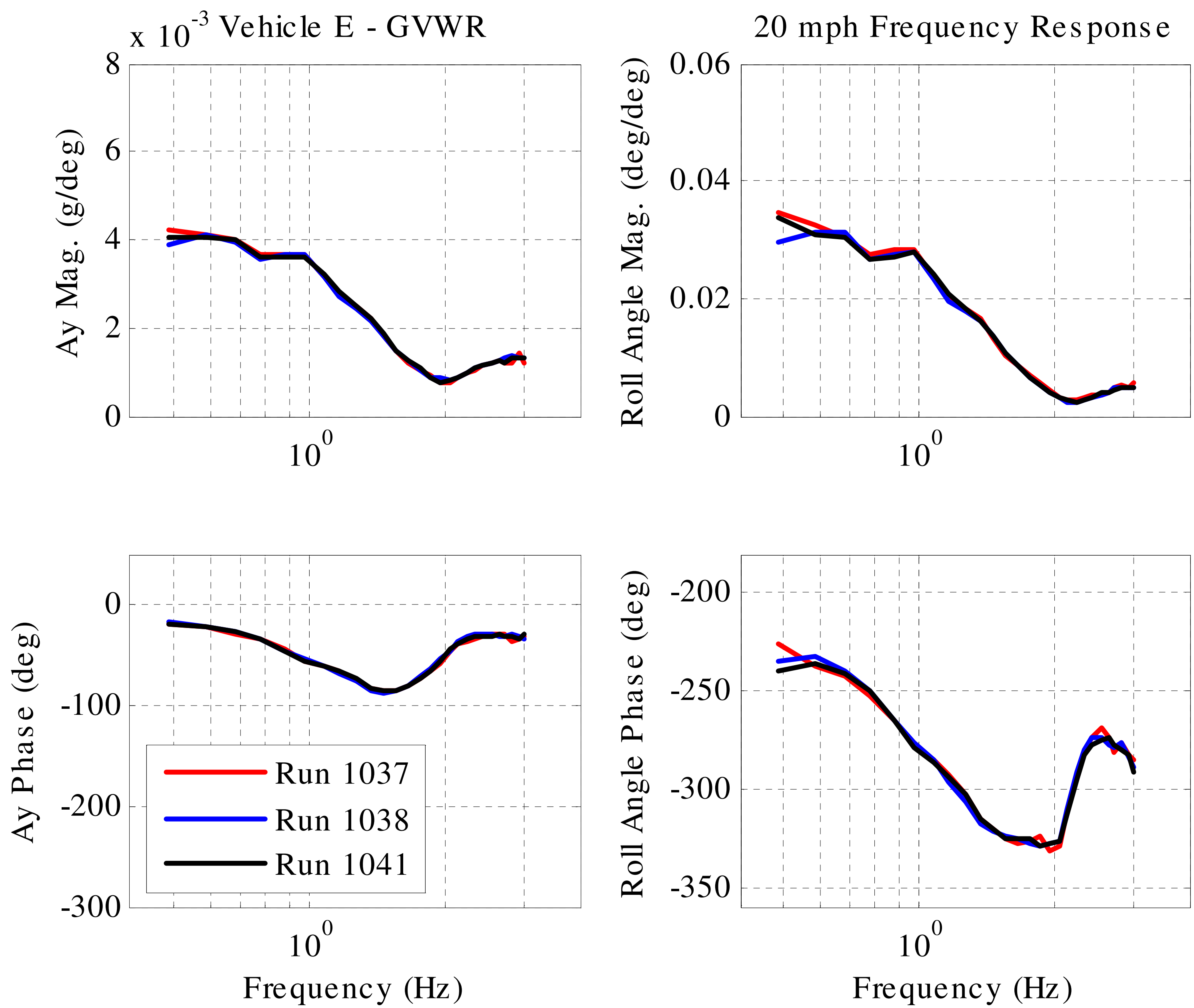

Representative Sine Sweep Time Domain Plots - Vehicle D - GVWR
Steer Angle (°)
50
0
-50
Ay (g)
0.2
0
-0.2
Roll Angle (°)
5
0
-5
Roll Rate (°/s)
10
0
-10
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

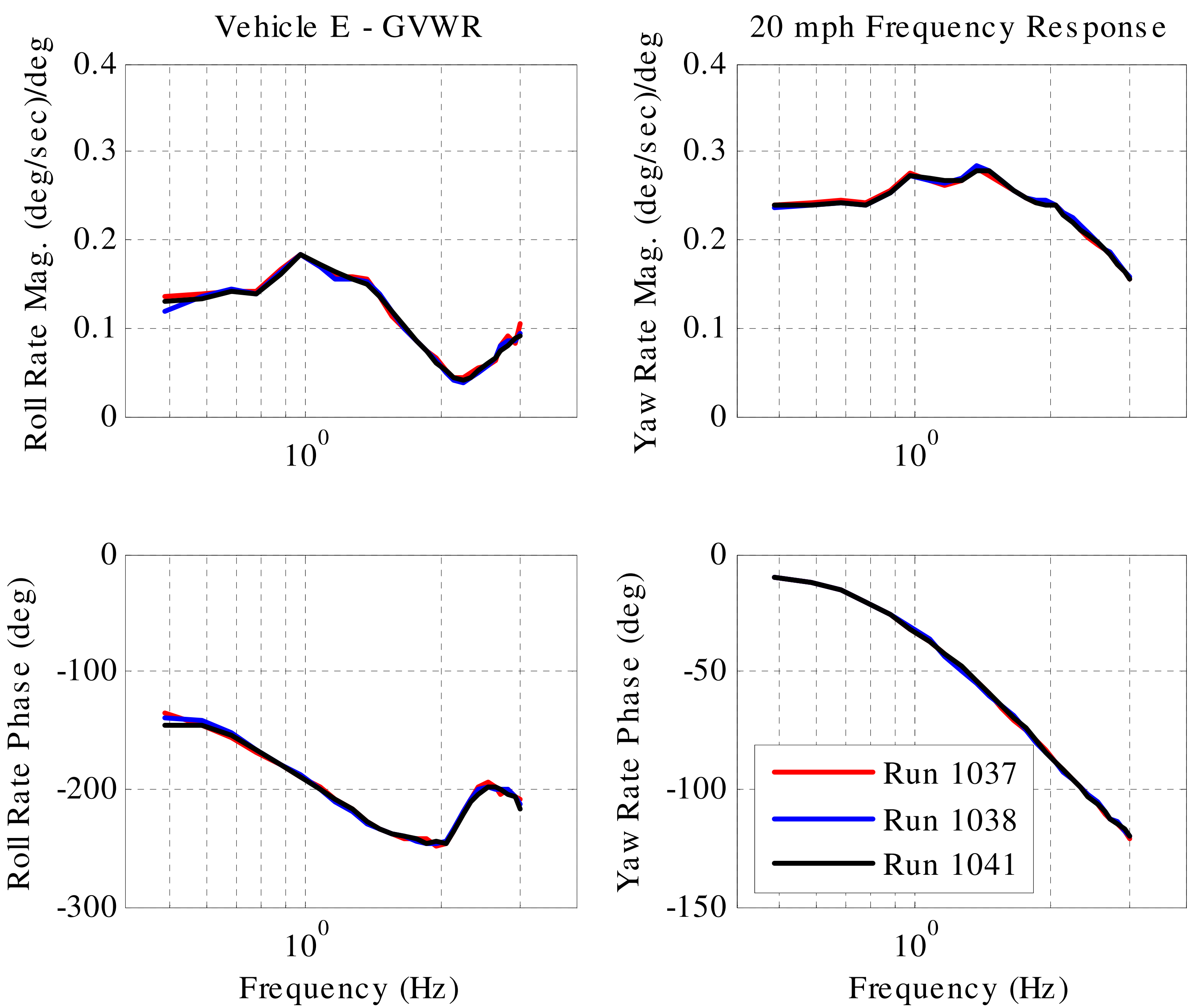


x 10^-3 Vehicle D - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 806
Run 807
Run 808
Frequency (Hz)
Frequency (Hz)

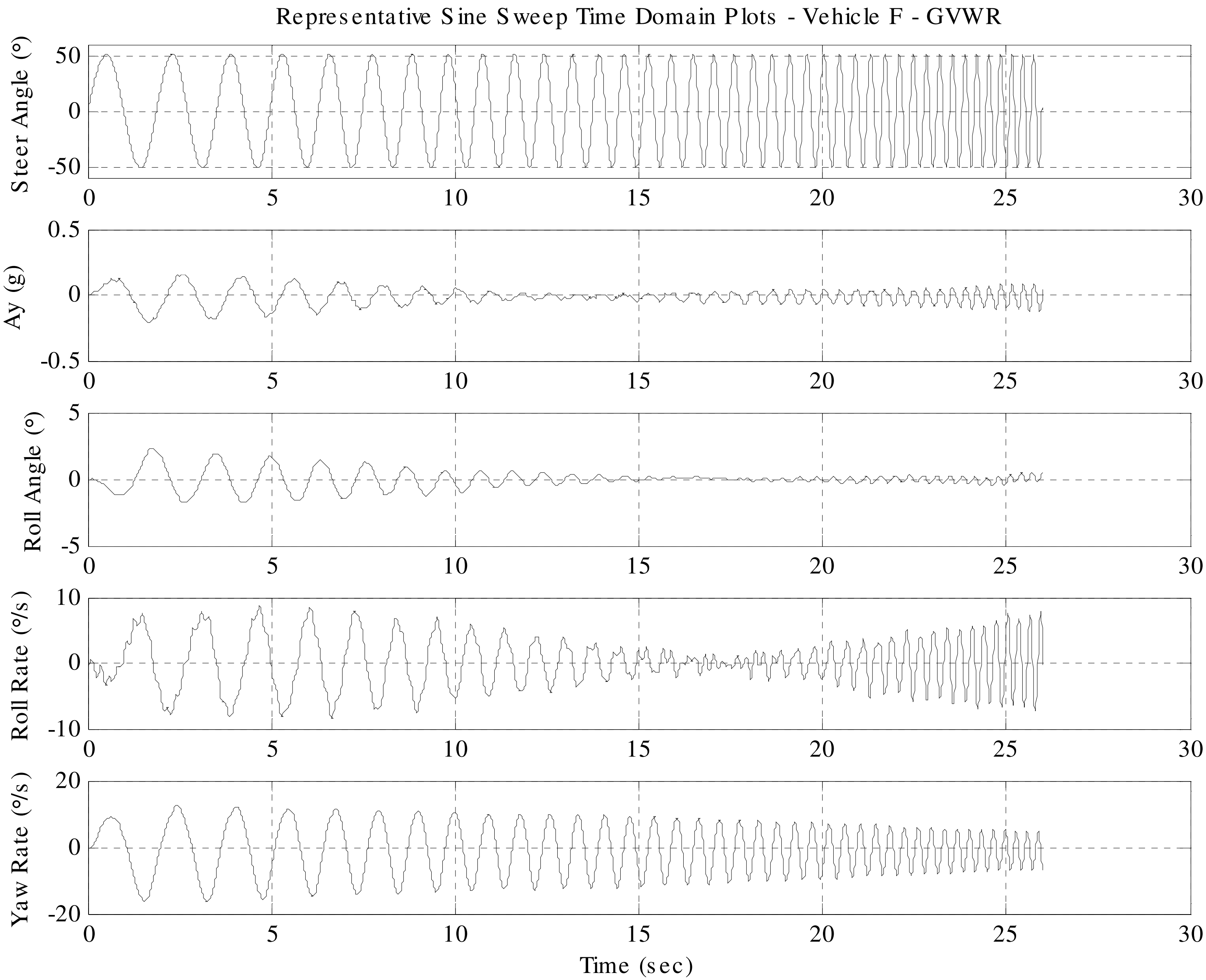

Vehicle D - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
-100
-200
-300
-50
-150
Run 806
Run 807
Run 808
Frequency (Hz)


Representative Sine Sweep Time Domain Plots - Vehicle E - GVWR
Steer Angle (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

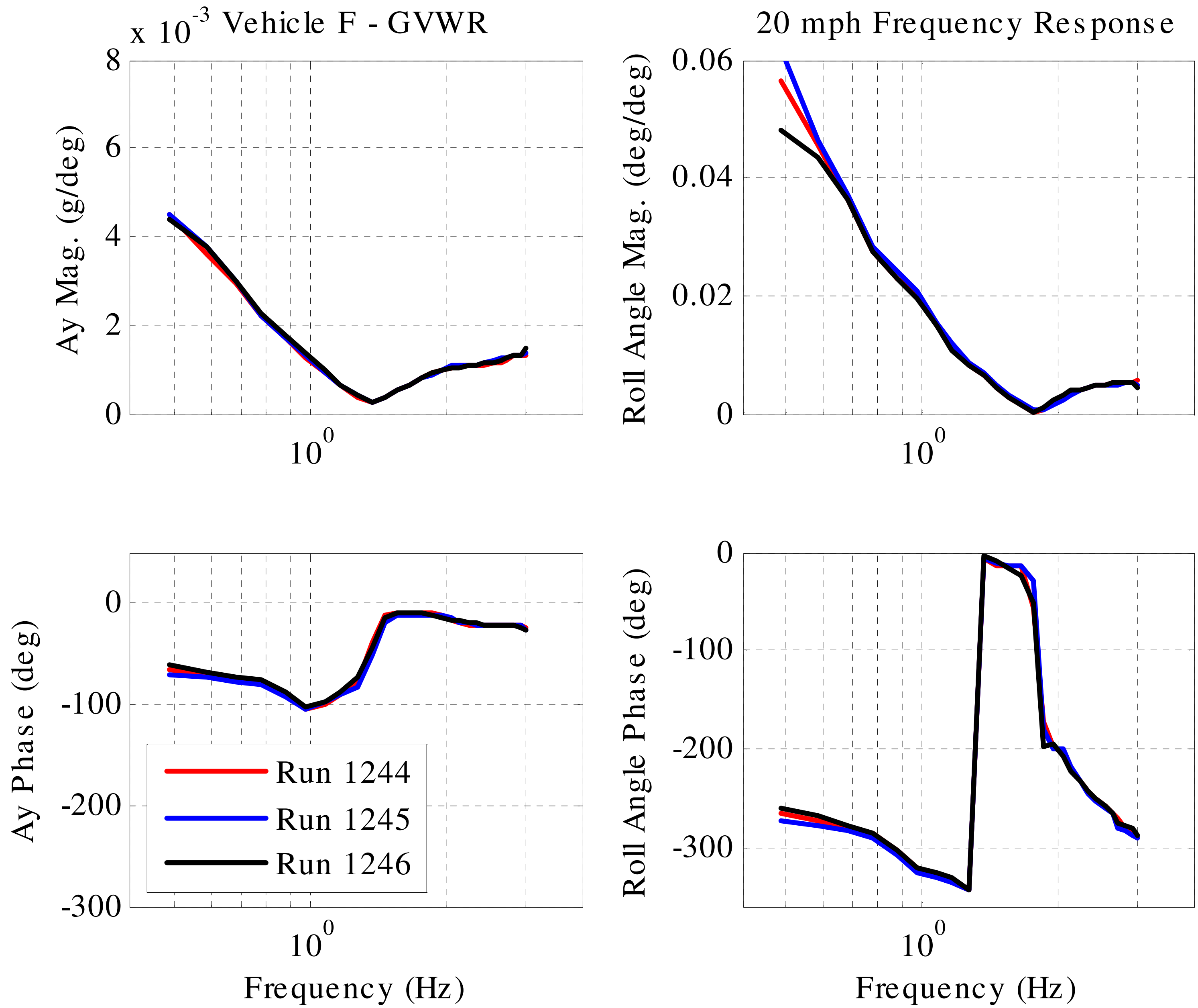

x 10^-3 Vehicle E - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 1037
Run 1038
Run 1041
Frequency (Hz)
Frequency (Hz)

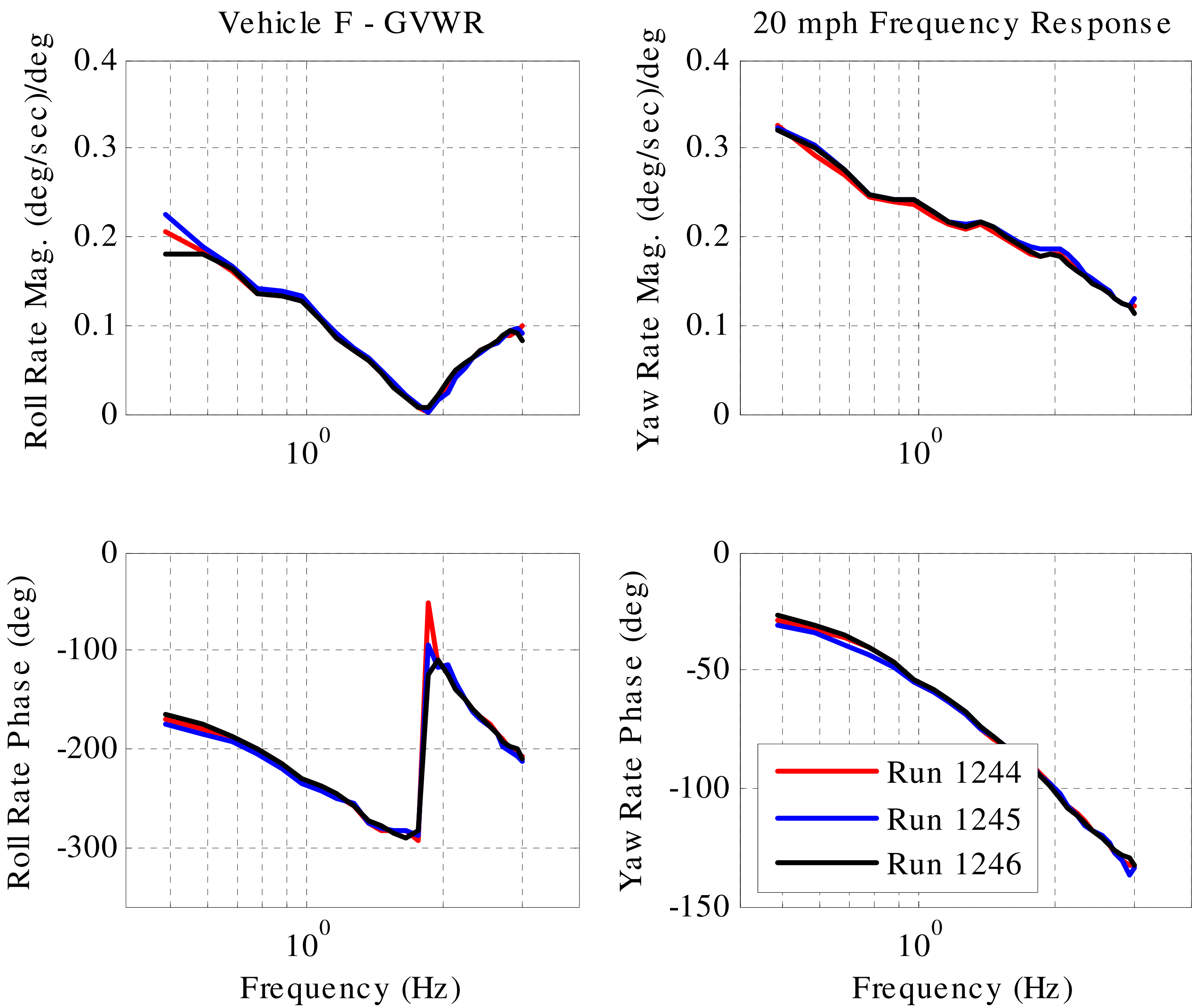


Vehicle E - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
0.4
0.3
0.2
0.1
0
0
-100
-200
-300
-50
-150
10^0
Frequency (Hz)
Run 1037
Run 1038
Run 1041

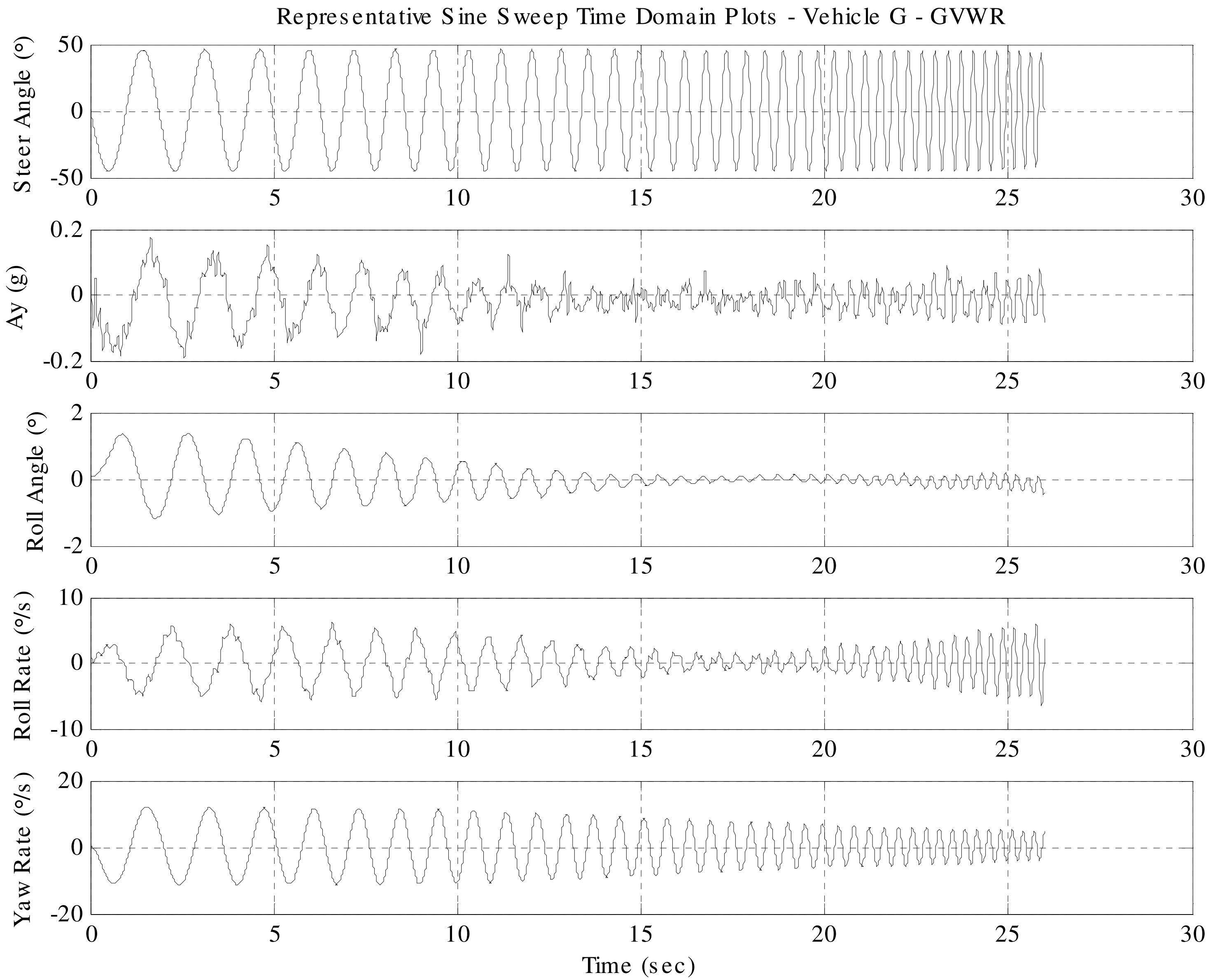


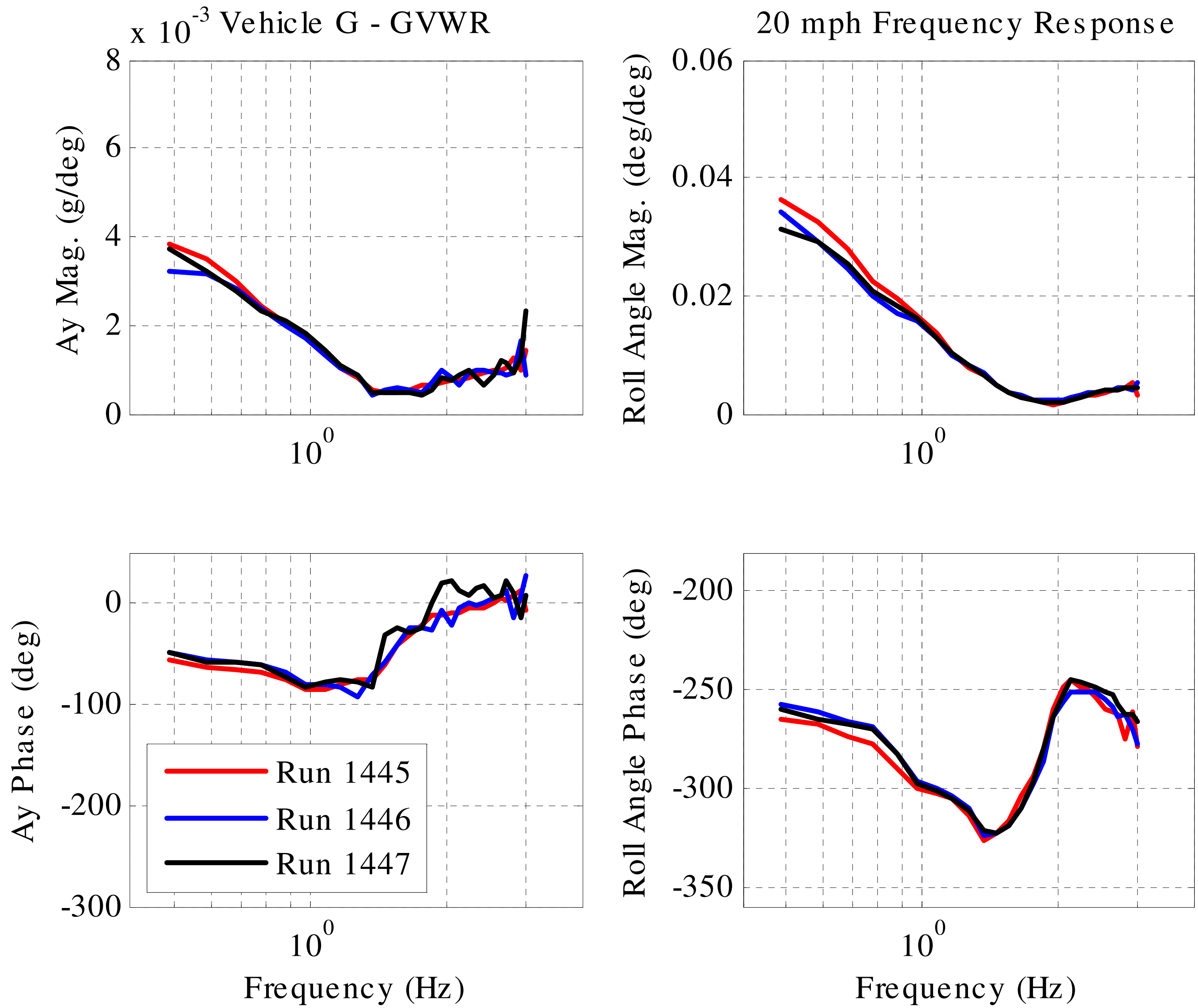
Representative Sine Sweep Time Domain Plots - Vehicle F - GVWR
Steer Angle (°)
50
0
-50
Ay (g)
0.5
0
-0.5
Roll Angle (°)
5
0
-5
Roll Rate (°/s)
10
0
-10
Yaw Rate (°/s)
20
0
-20
0 5 10 15 20 25 30
Time (sec)


x 10^-3 Vehicle F - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Frequency (Hz)
Frequency (Hz)
Run 1244
Run 1245
Run 1246

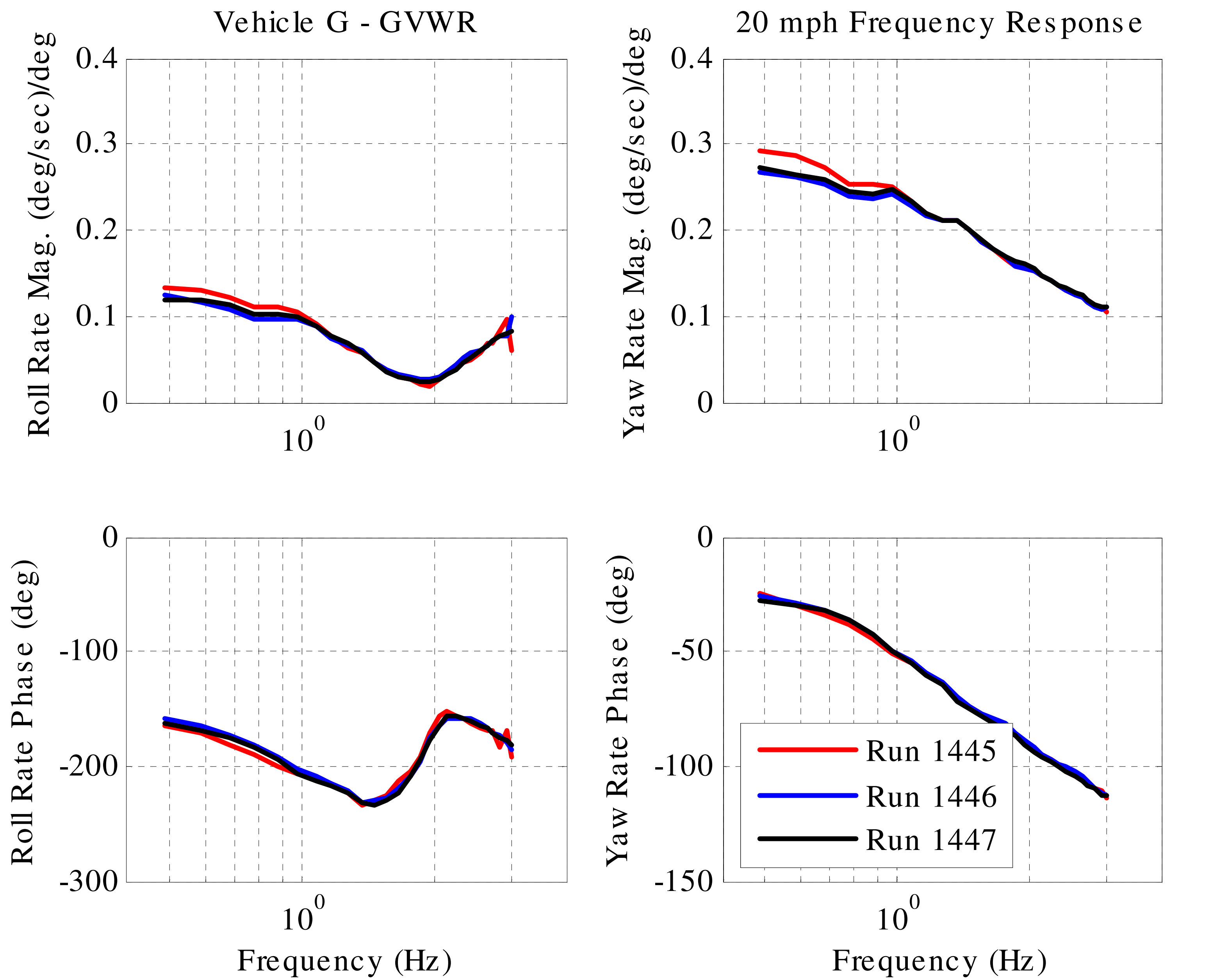


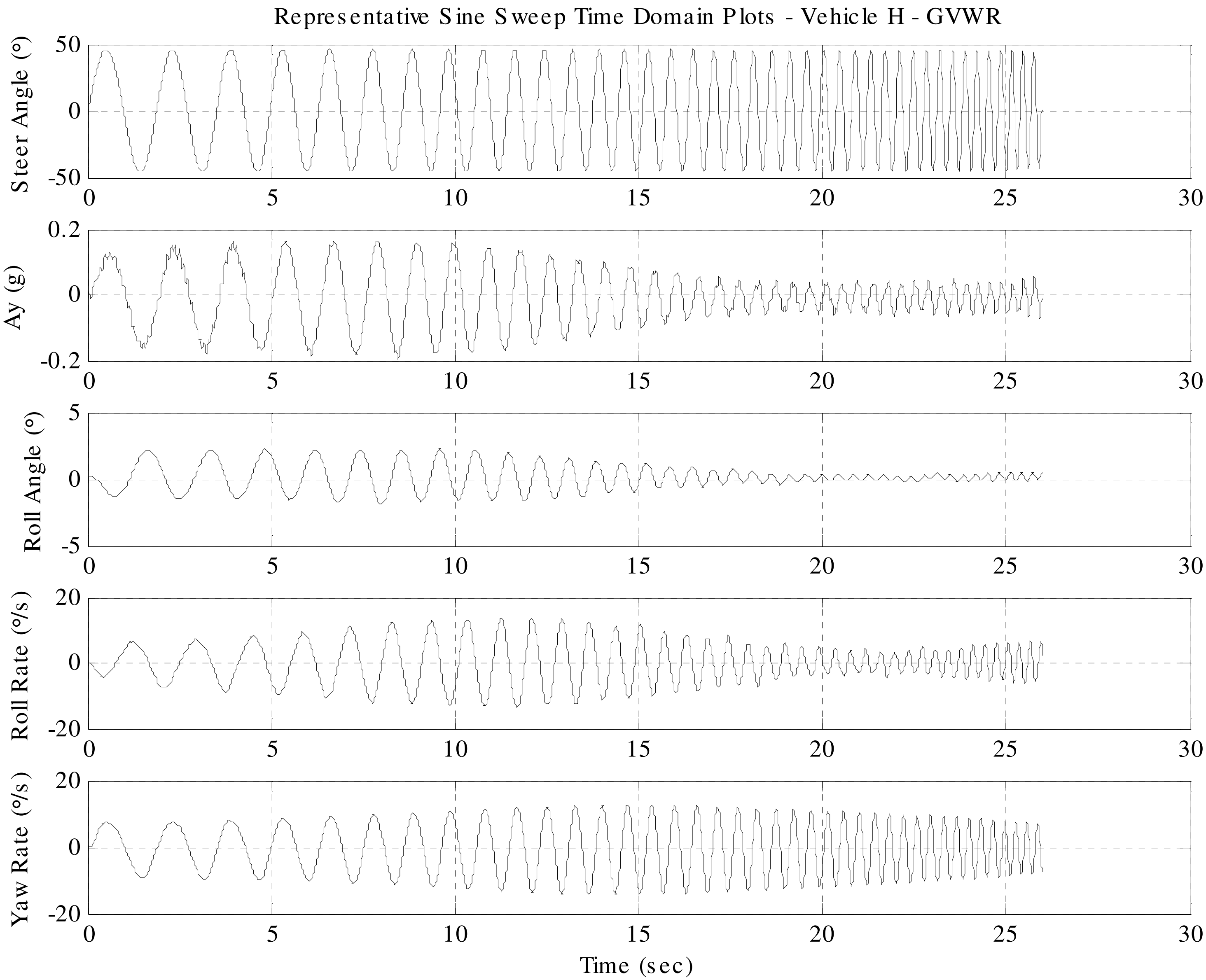
Vehicle F - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
Frequency (Hz)
Frequency (Hz)
Run 1244
Run 1245
Run 1246

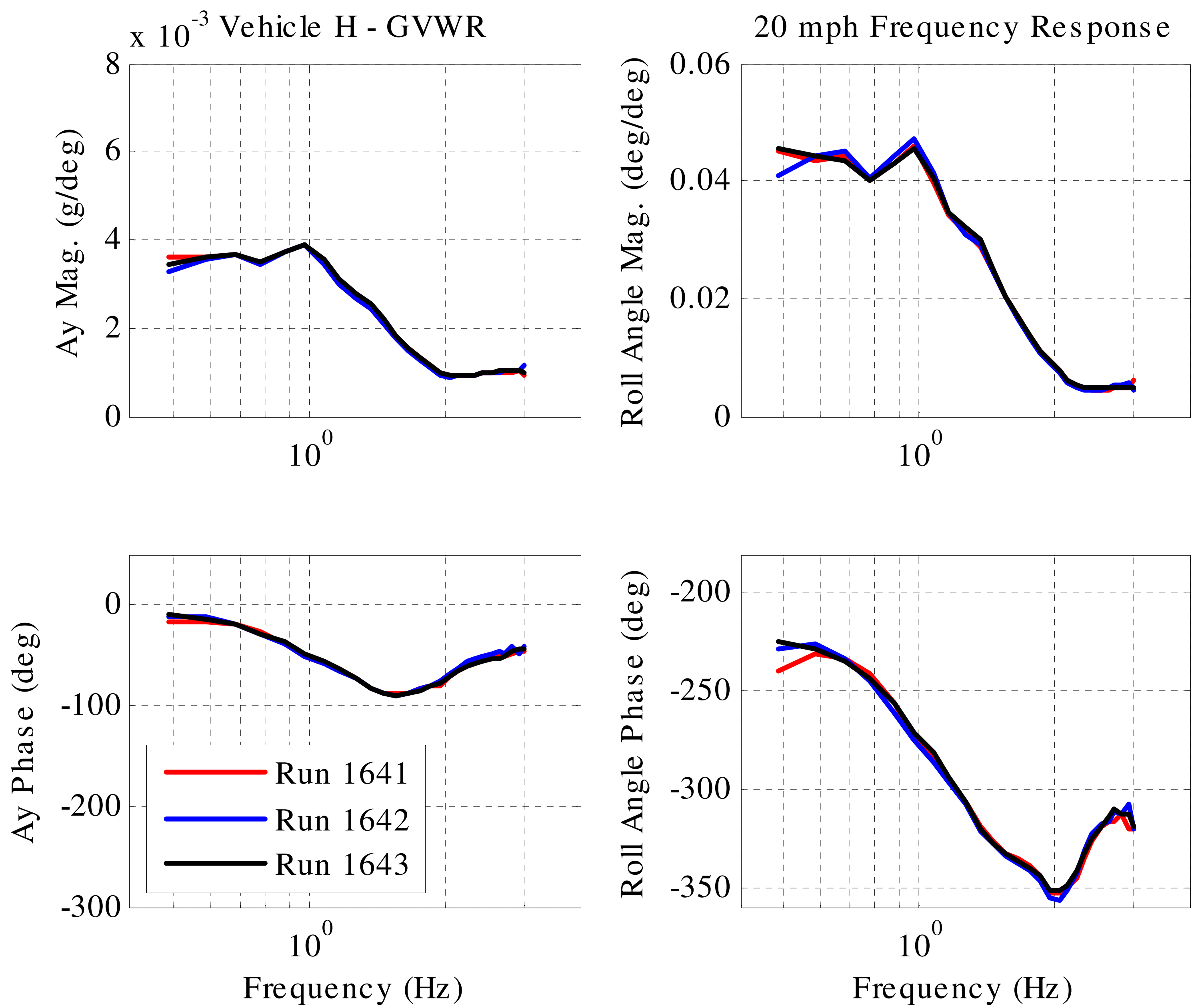

Representative Sine Sweep Time Domain Plots - Vehicle G - GVWR
Steer Angle (°)
50
0
-50
Ay (g)
0.2
0
-0.2
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
10
0
-10
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

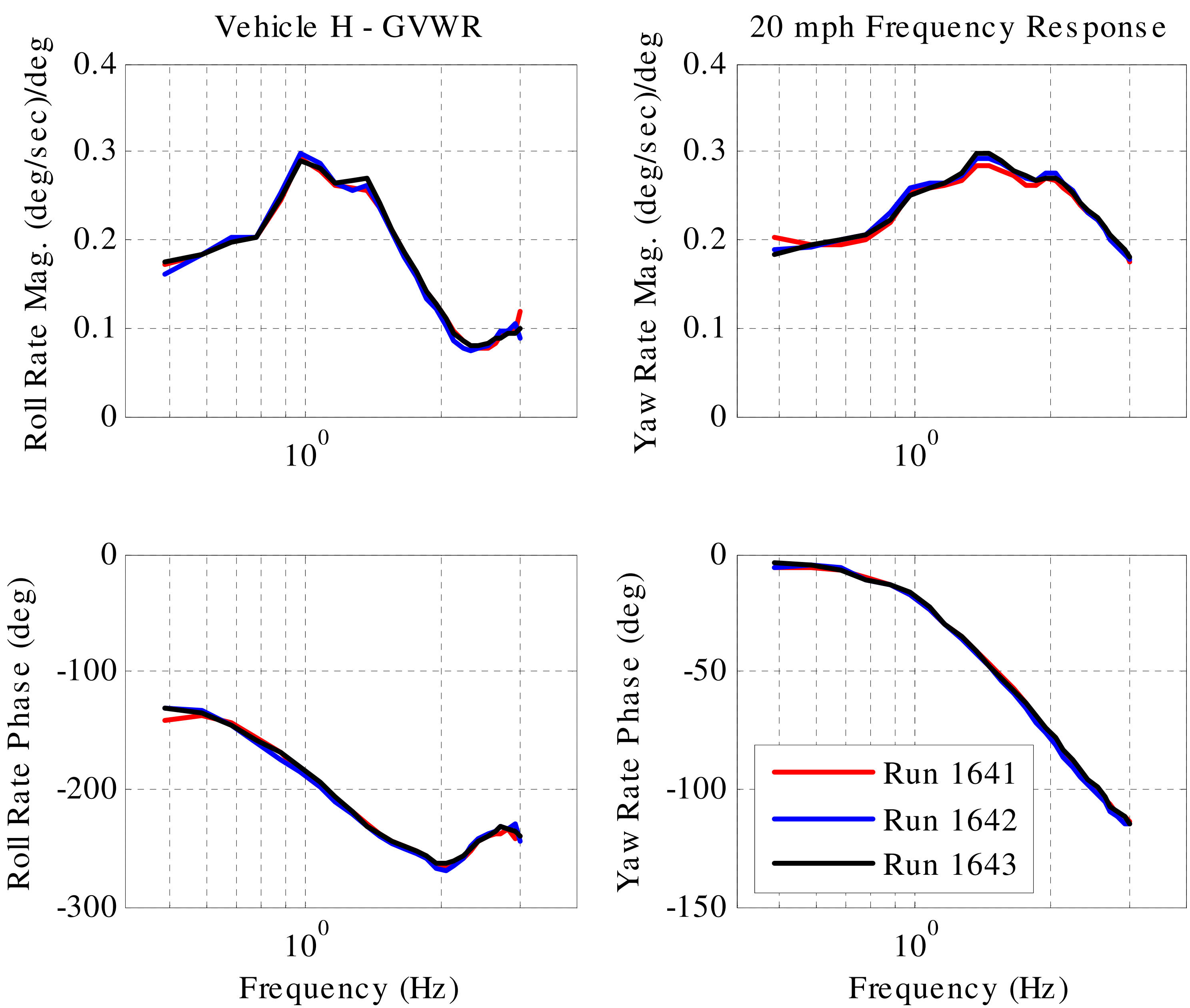


x 10^-3 Vehicle G - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 1445
Run 1446
Run 1447
Frequency (Hz)
Frequency (Hz)

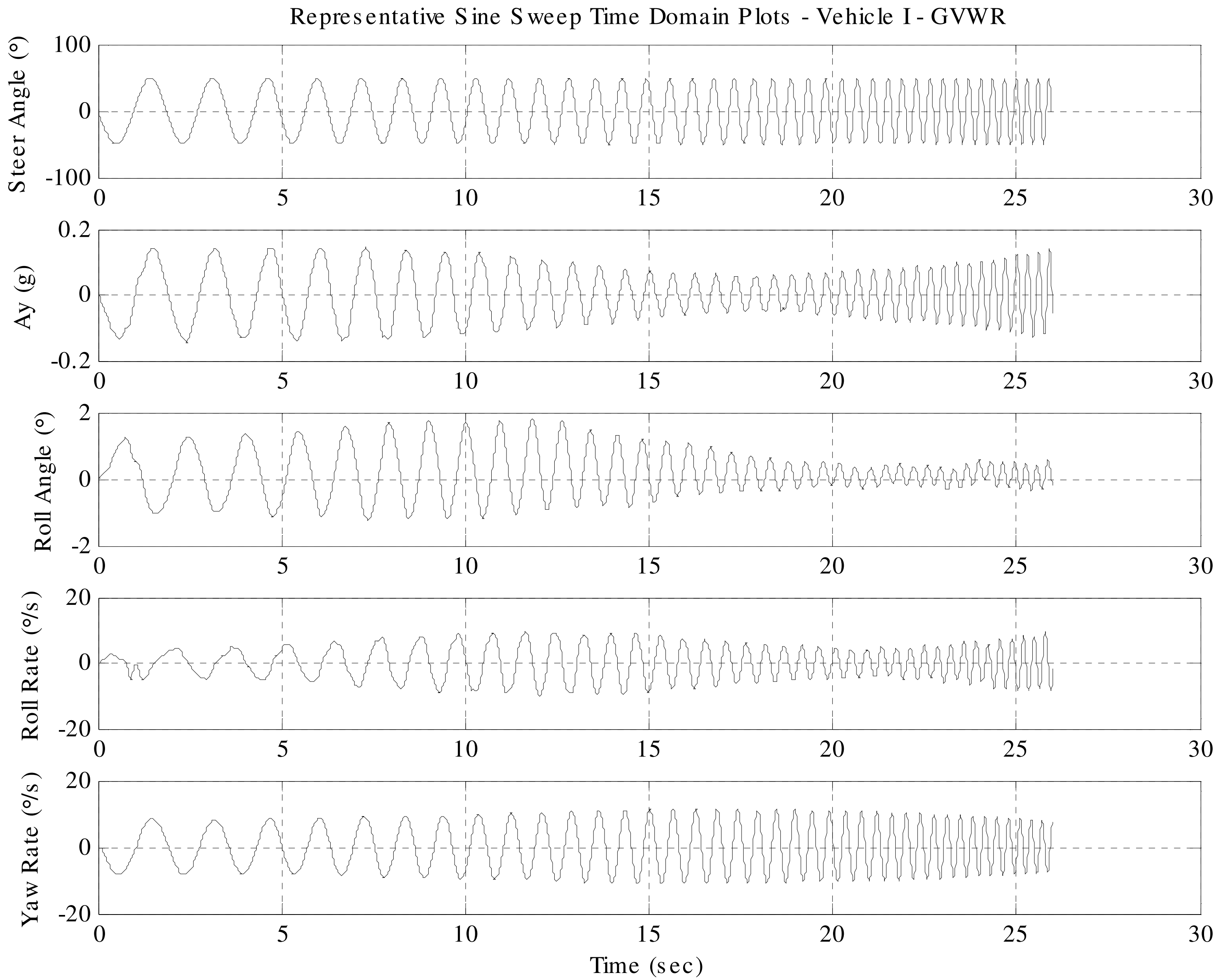

Vehicle G - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
0
-100
-200
-300
10^0
Frequency (Hz)
Yaw Rate Phase (deg)
0
-50
-100
-150
Run 1445
Run 1446
Run 1447
10^0
Frequency (Hz)

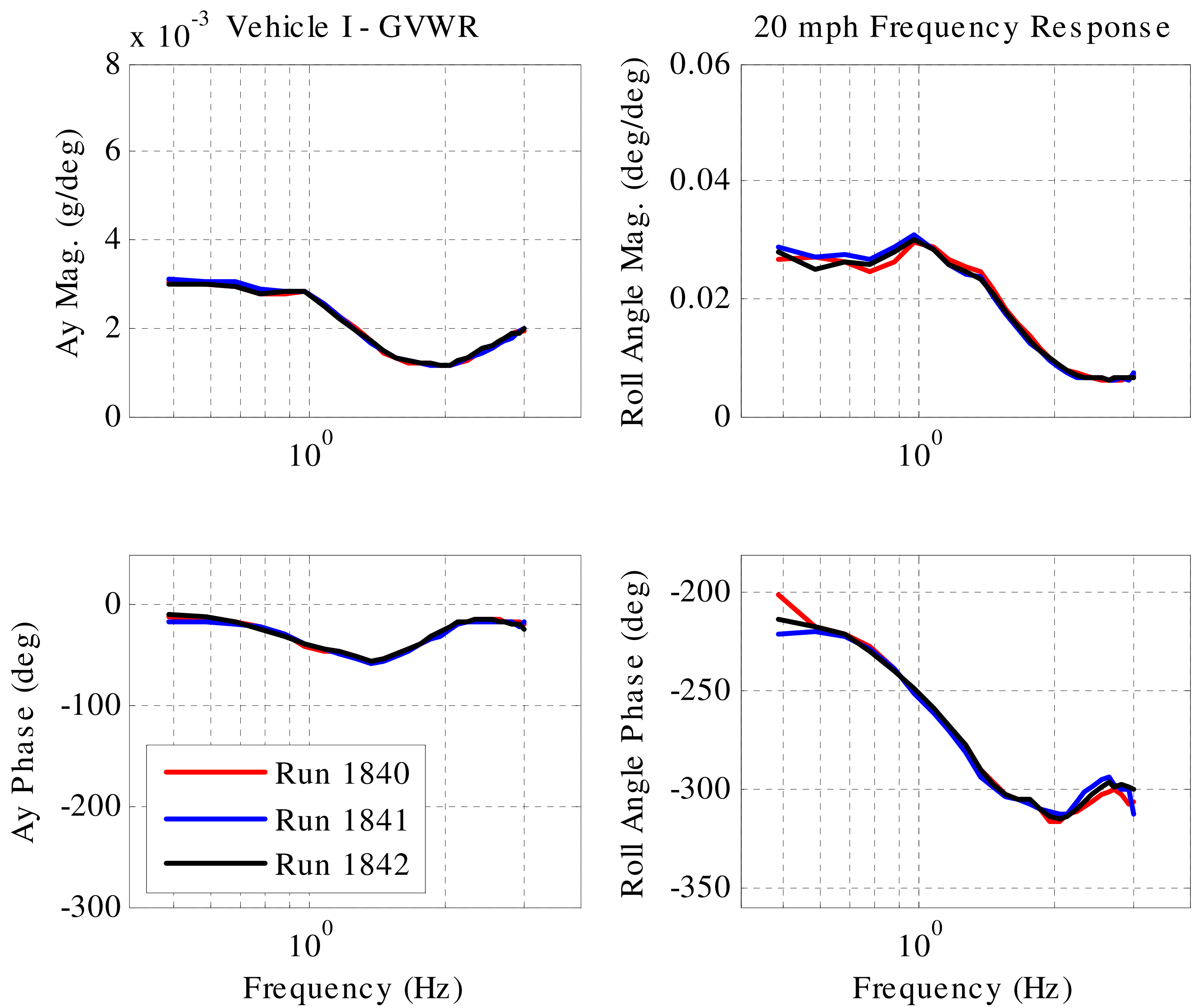

Representative Sine Sweep Time Domain Plots - Vehicle H - GVWR
Steer Angle (°)
Ay (g)
Roll Angle (°)
Roll Rate (°/s)
Yaw Rate (°/s)
Time (sec)

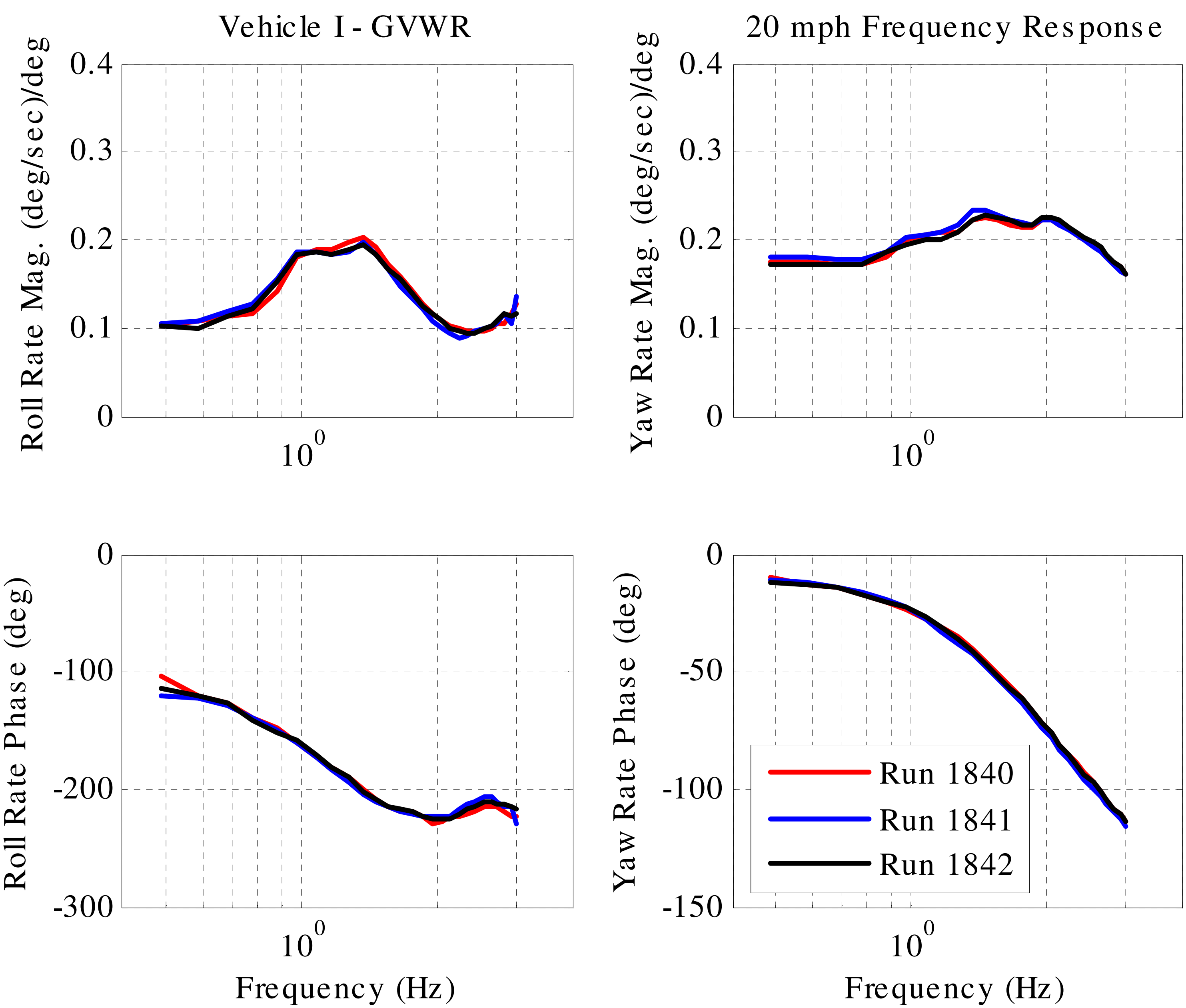

x 10^-3 Vehicle H - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 1641
Run 1642
Run 1643
Frequency (Hz)
Frequency (Hz)

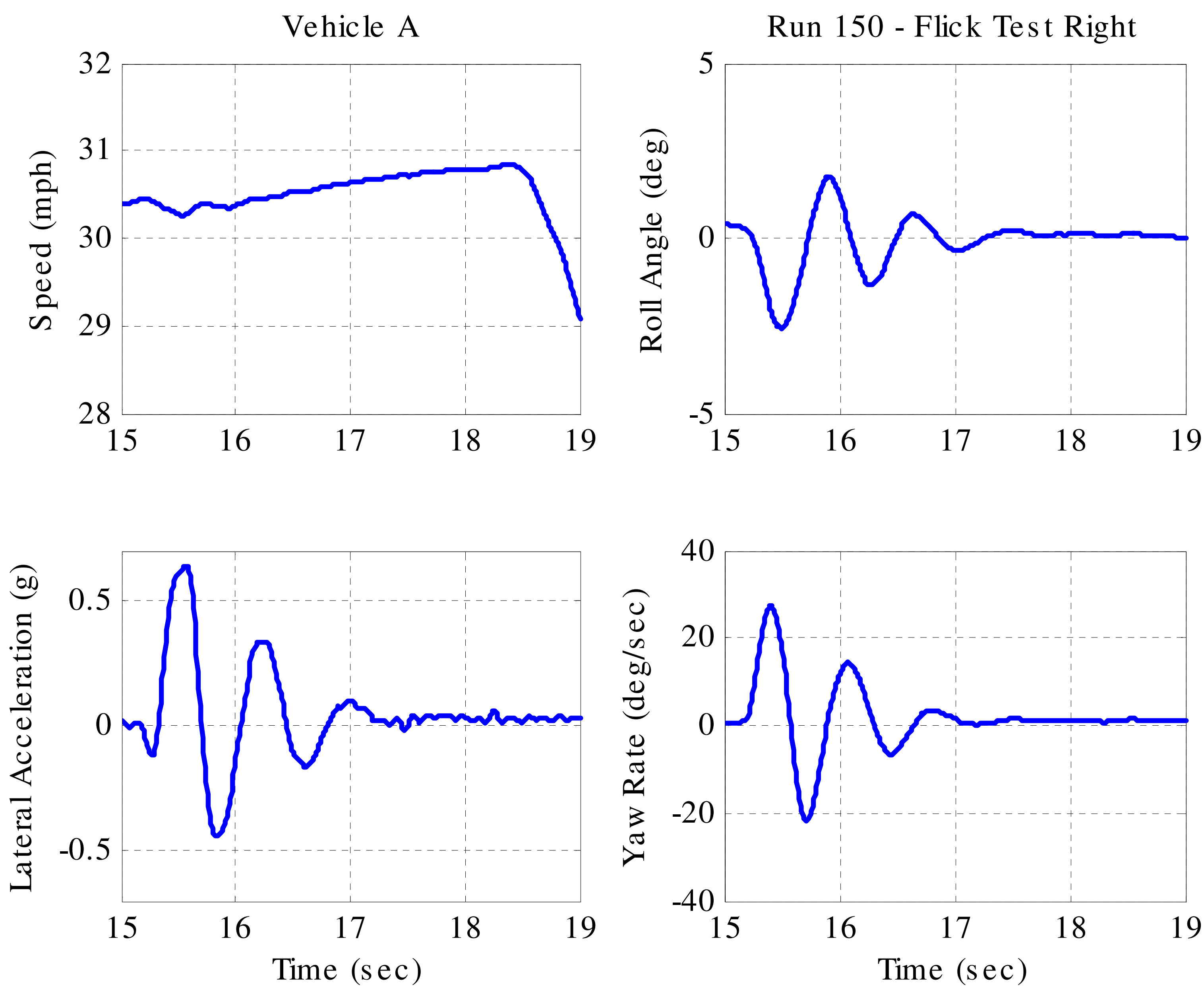


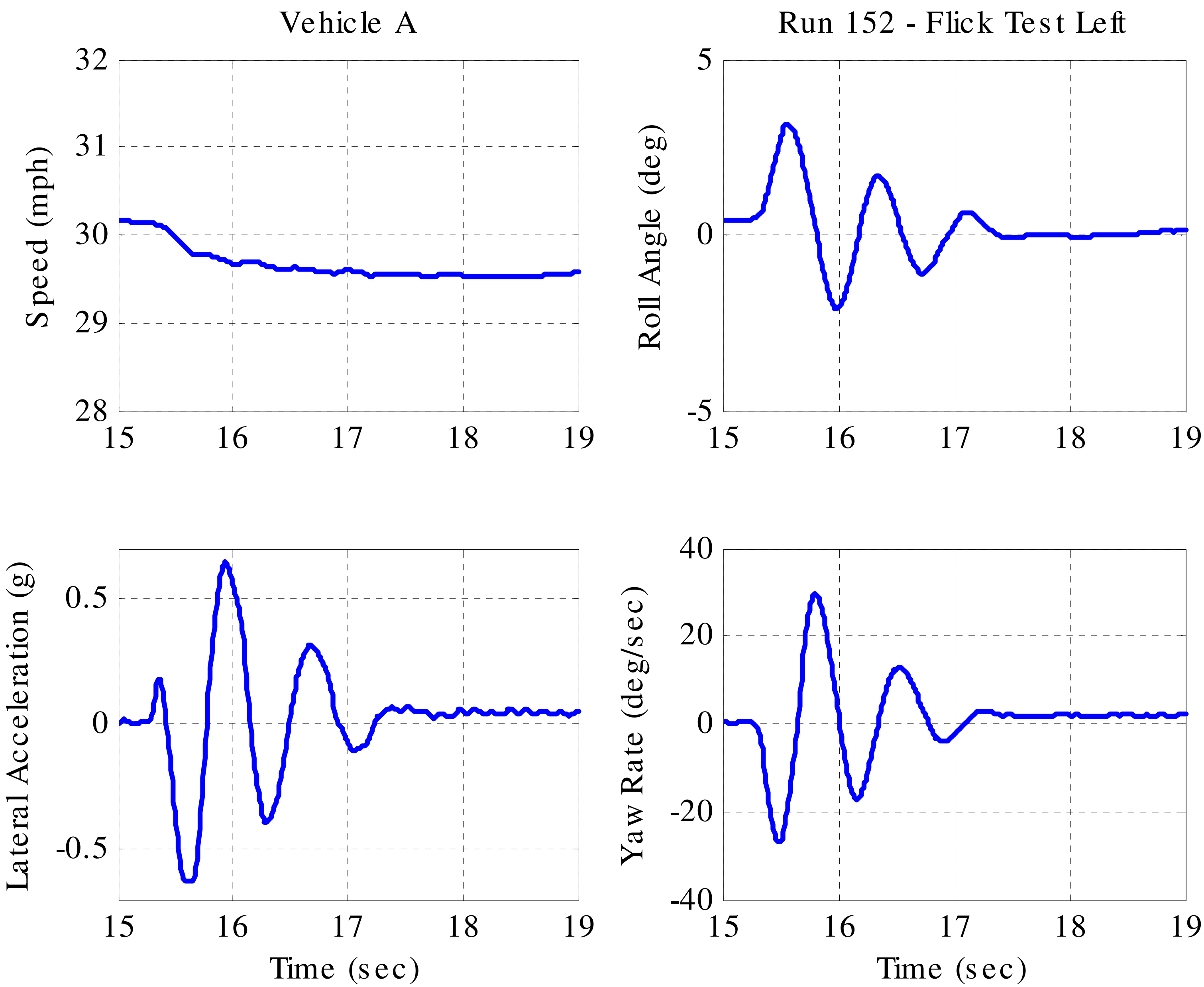
Vehicle H - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
0.4
0.3
0.2
0.1
0
10^0
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
0
-100
-200
-300
0
-50
-100
-150
Run 1641
Run 1642
Run 1643
Frequency (Hz)
Frequency (Hz)


Representative Sine Sweep Time Domain Plots - Vehicle I - GVWR
Steer Angle (°)
100
0
-100
Ay (g)
0.2
0
-0.2
Roll Angle (°)
2
0
-2
Roll Rate (°/s)
20
0
-20
Yaw Rate (°/s)
20
0
-20
0
5
10
15
20
25
30
Time (sec)

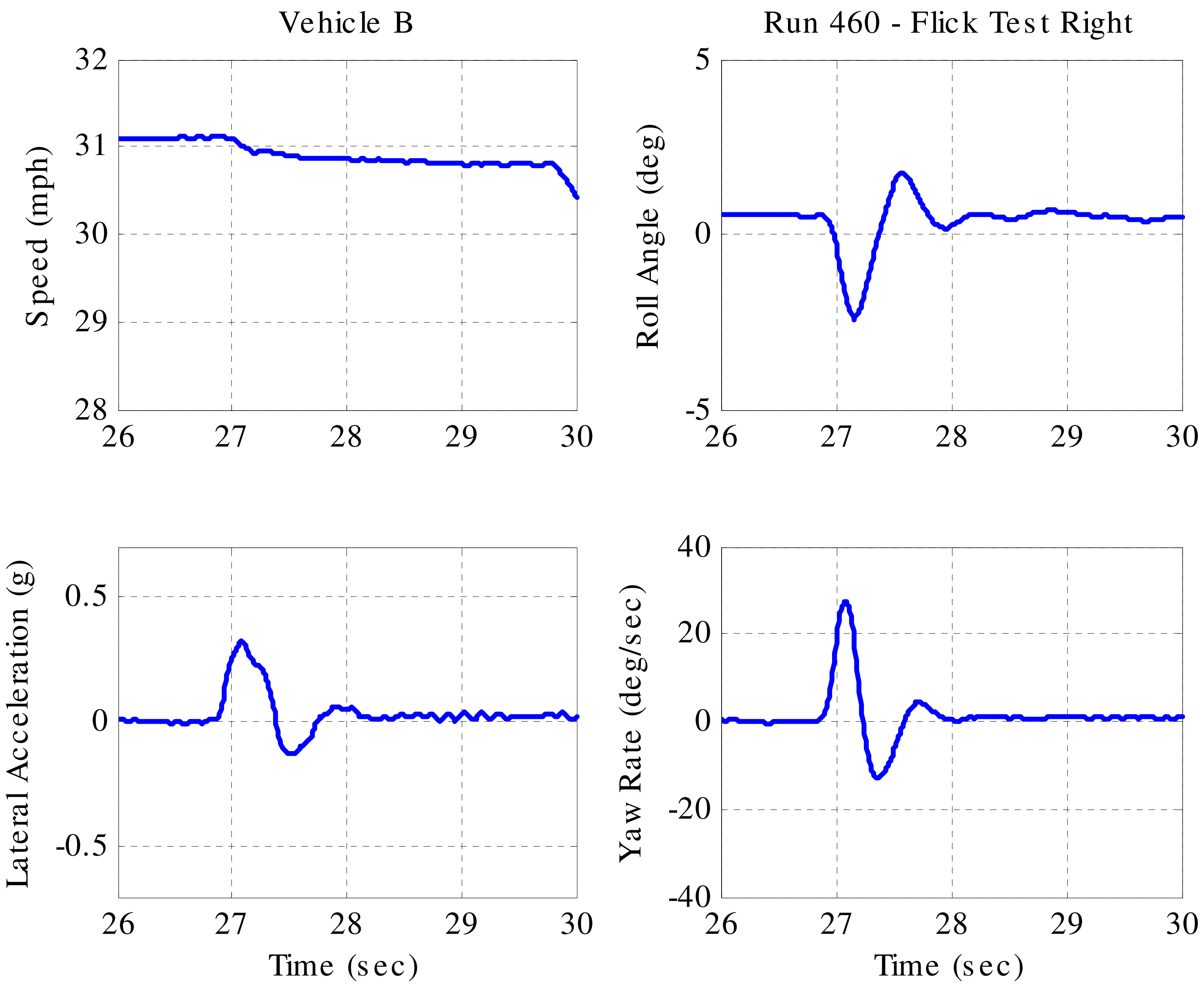

x 10^-3 Vehicle I - GVWR
20 mph Frequency Response
Ay Mag. (g/deg)
Roll Angle Mag. (deg/deg)
Ay Phase (deg)
Roll Angle Phase (deg)
Run 1840
Run 1841
Run 1842
Frequency (Hz)
Frequency (Hz)

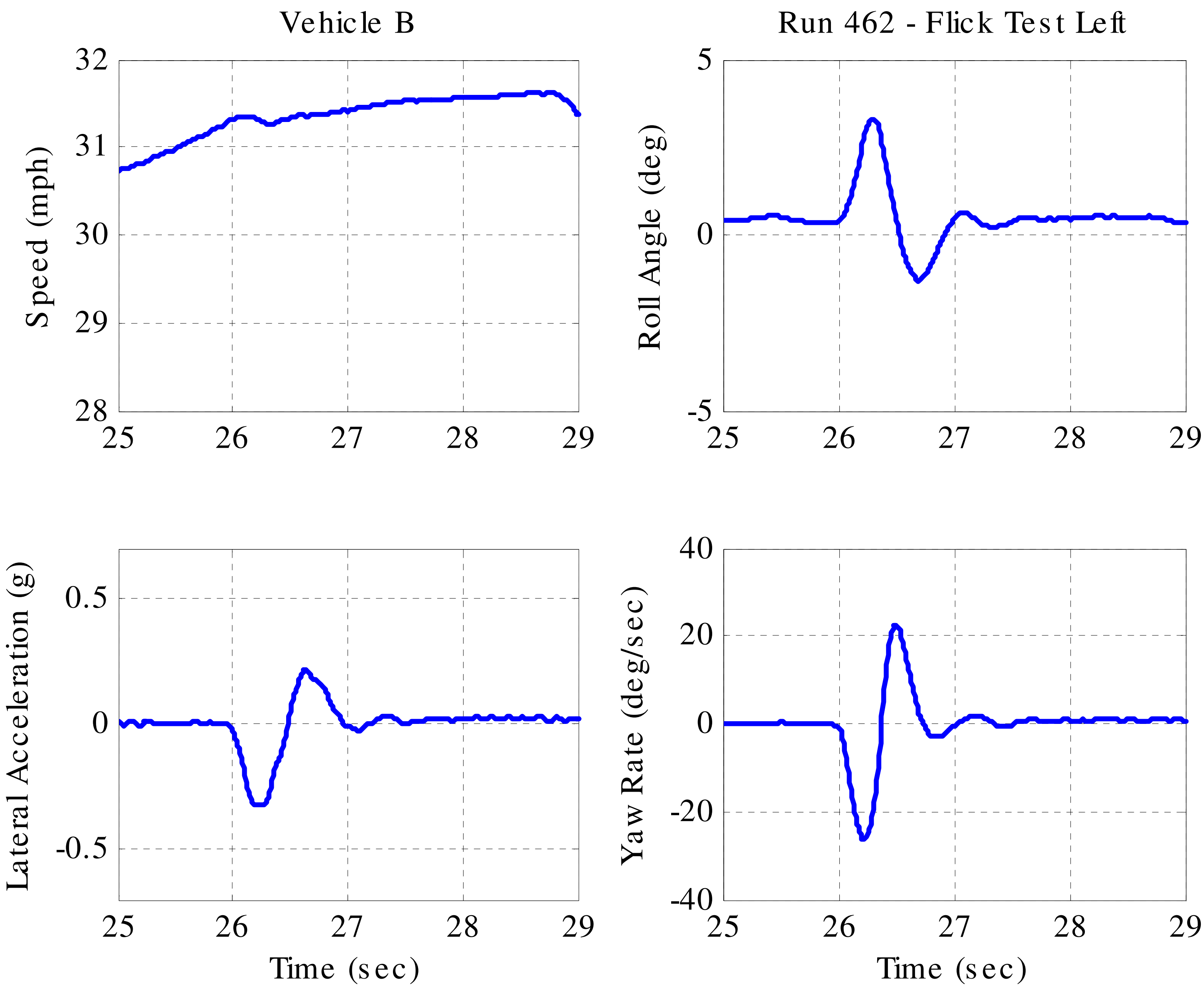

Vehicle I - GVWR
20 mph Frequency Response
Roll Rate Mag. (deg/sec)/deg
Yaw Rate Mag. (deg/sec)/deg
Roll Rate Phase (deg)
Yaw Rate Phase (deg)
0.4
0.3
0.2
0.1
0
0
-100
-200
-300
-50
-150
10^0
Frequency (Hz)
Run 1840
Run 1841
Run 1842

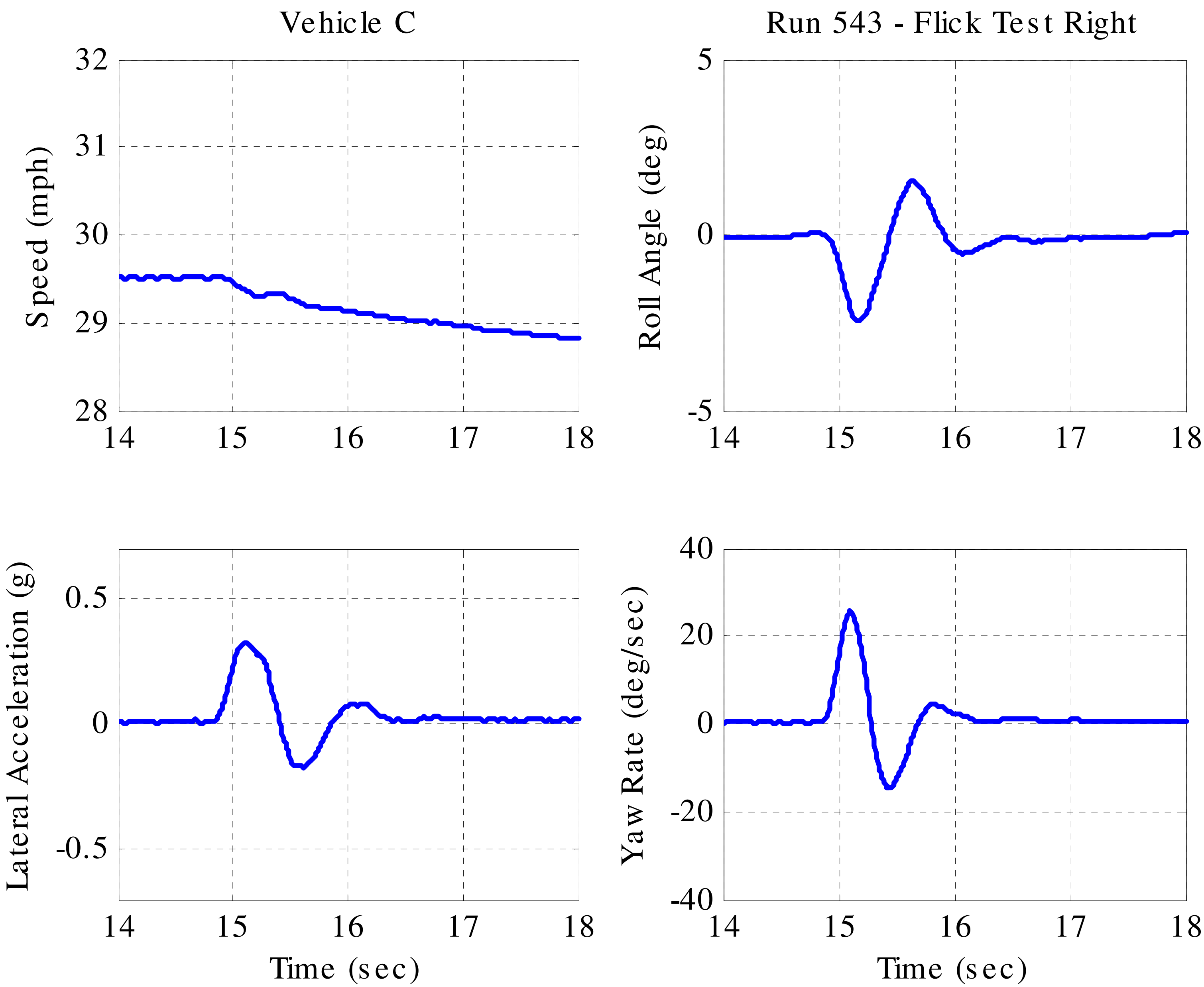

Vehicle A
Run 150 - Flick Test Right
Speed (mph)
32
31
30
29
28
15
16
17
18
19
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40

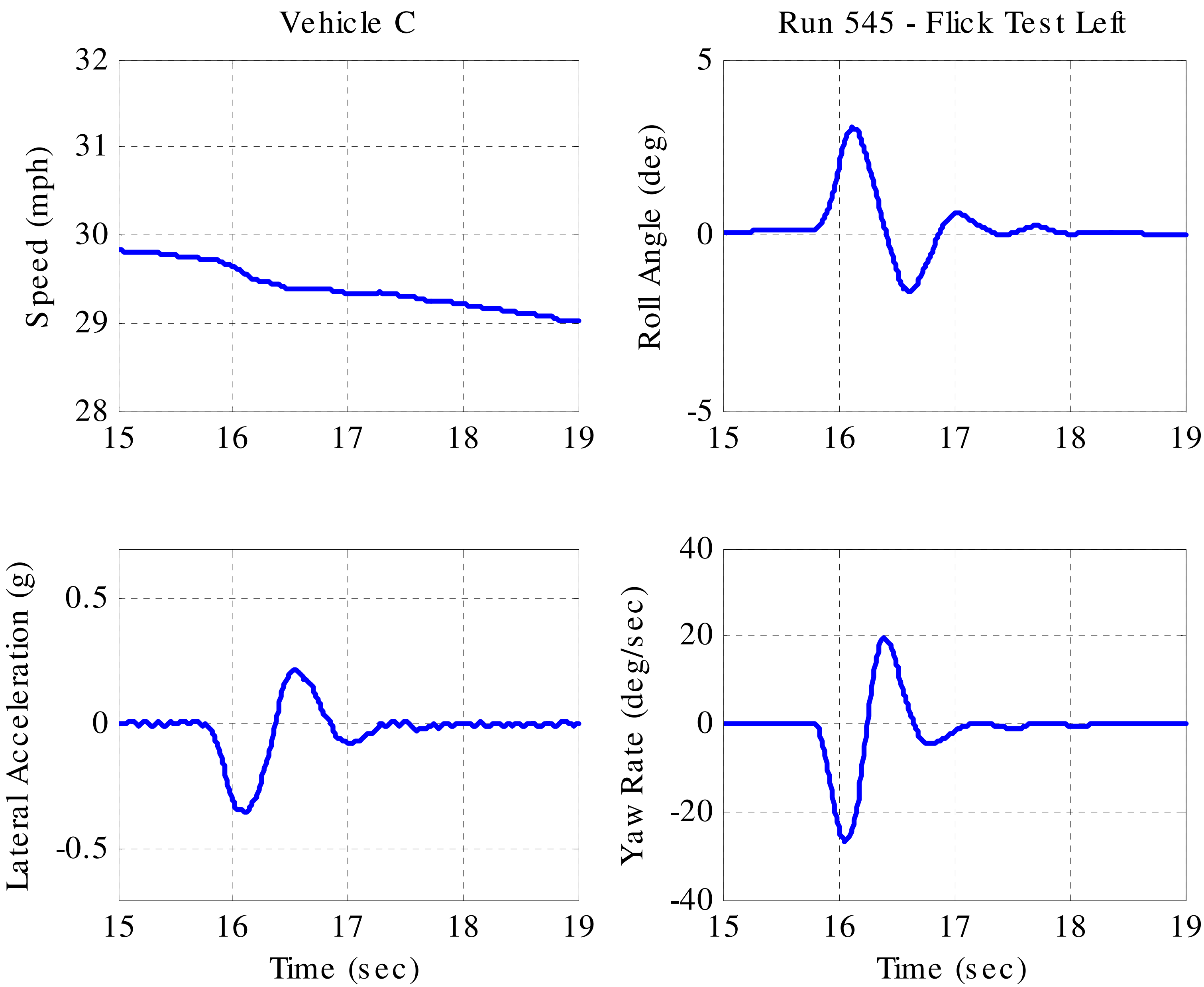


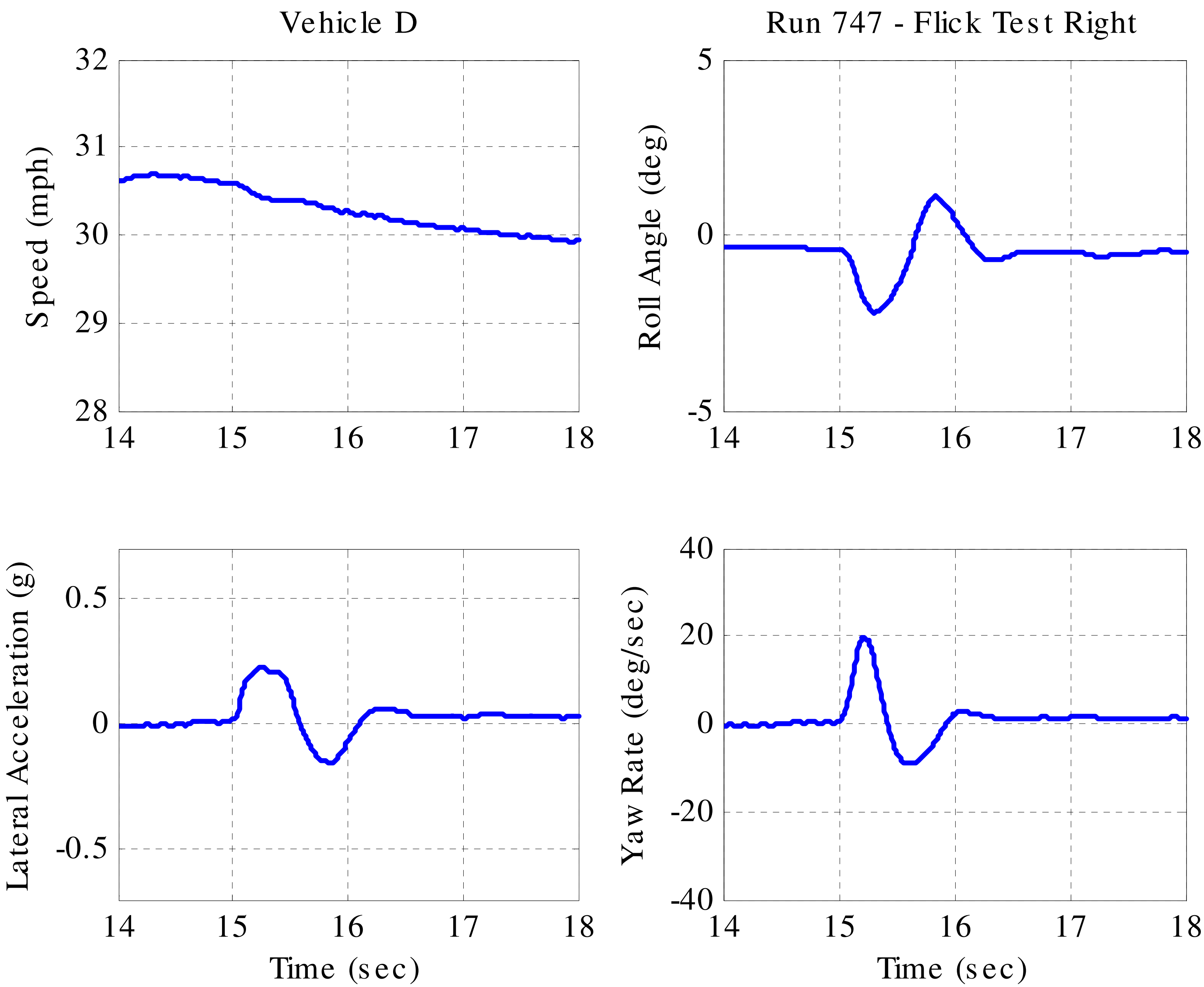
Vehicle A
Run 152 - Flick Test Left
Speed (mph)
32
31
30
29
28
15
16
17
18
19
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

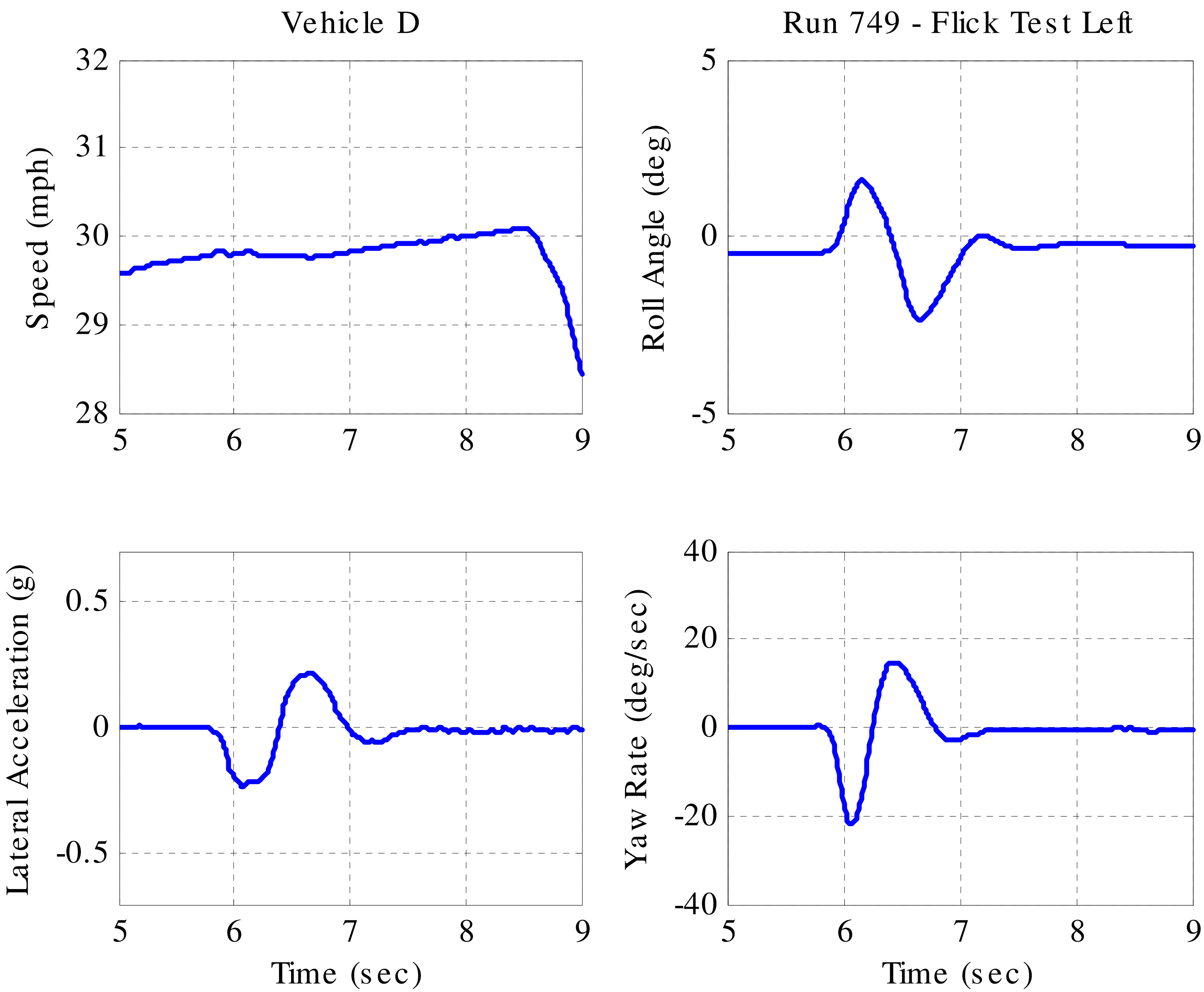

Vehicle B
Run 460 - Flick Test Right
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
26
27
28
29
30
Time (sec)
Time (sec)

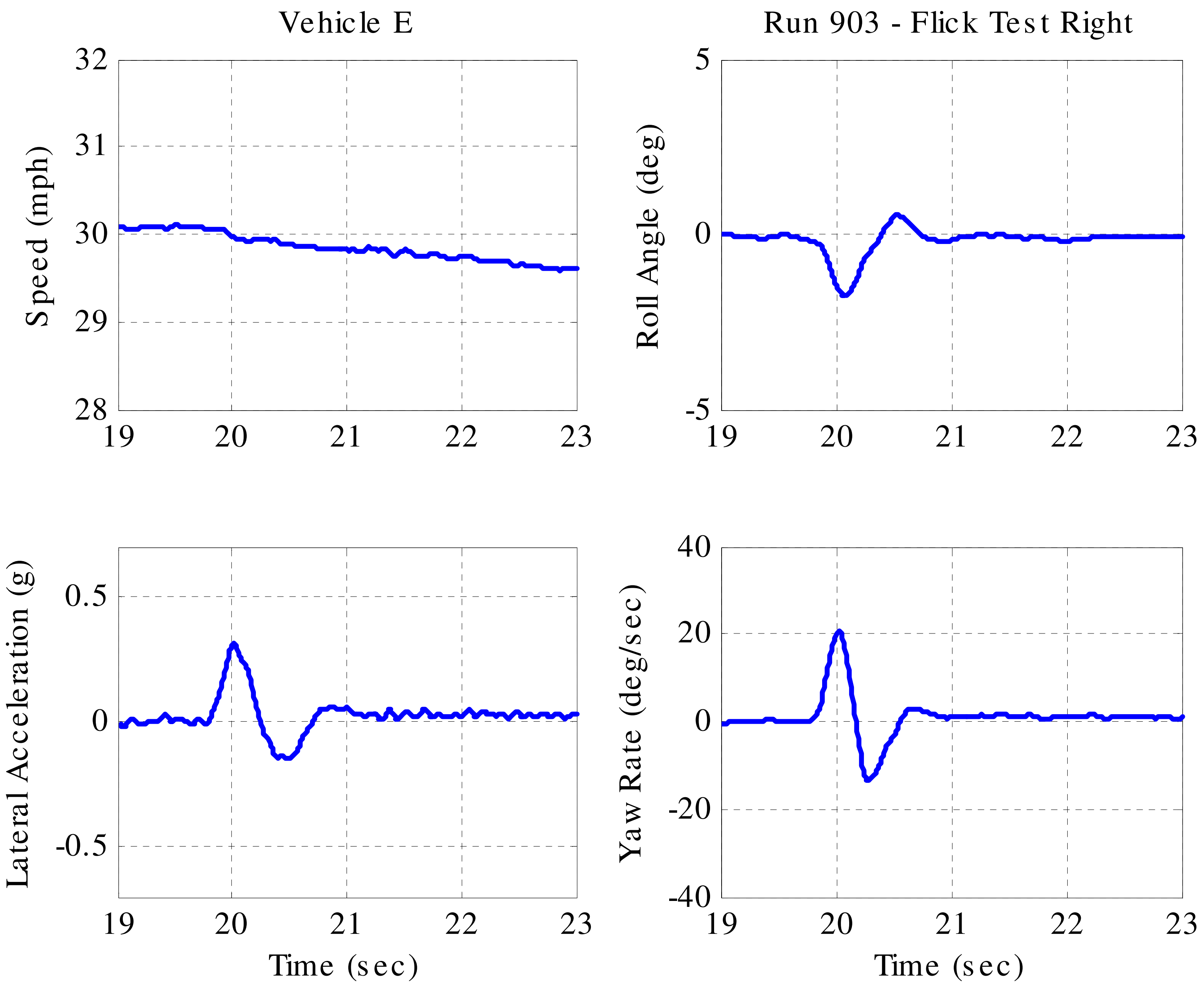

Vehicle B
Run 462 - Flick Test Left
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
25
26
27
28
29
Time (sec)
Time (sec)

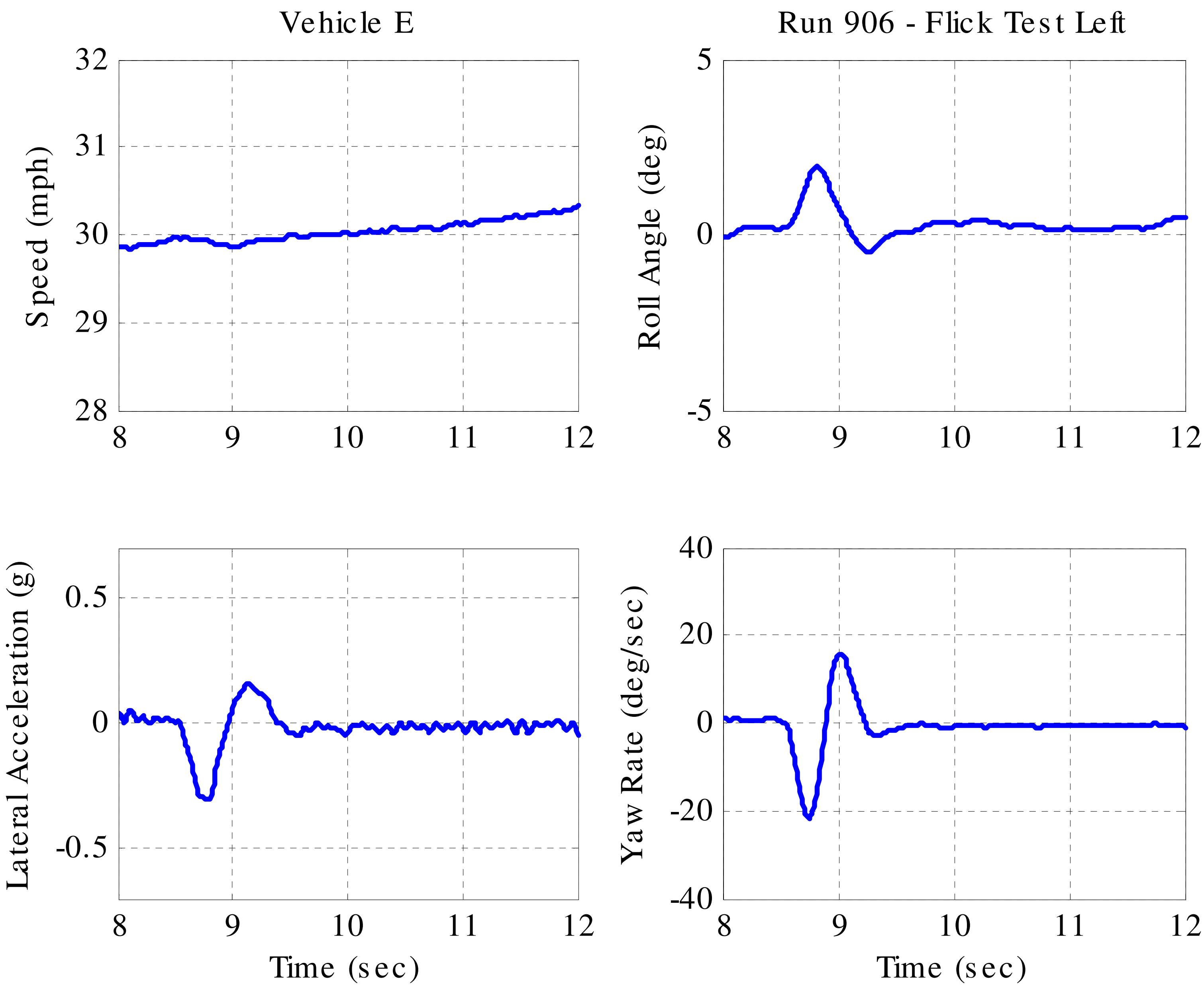

Vehicle C
Run 543 - Flick Test Right
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
14
15
16
17
18
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)


Vehicle C
Run 545 - Flick Test Left
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

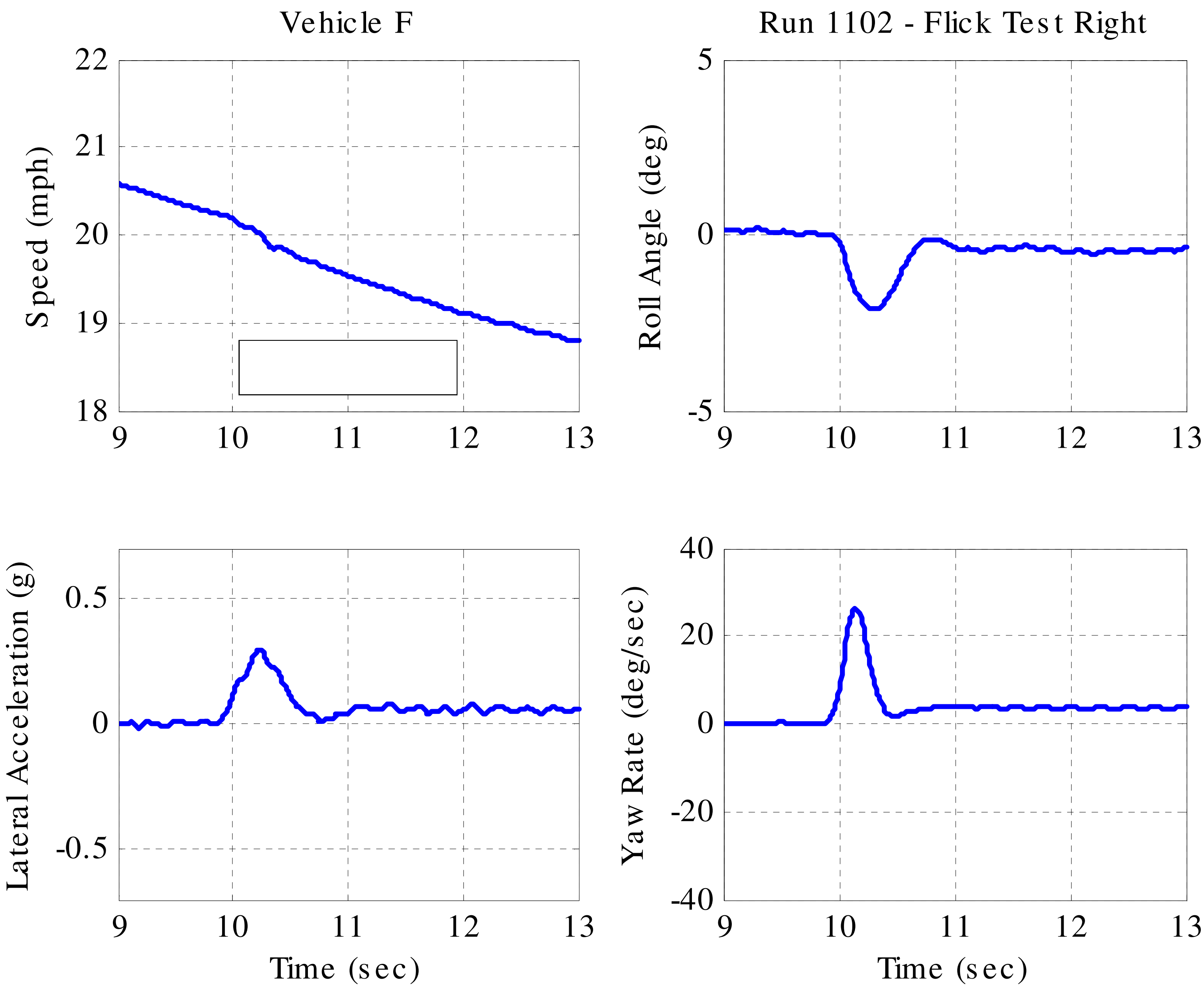

Vehicle D
Run 747 - Flick Test Right
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

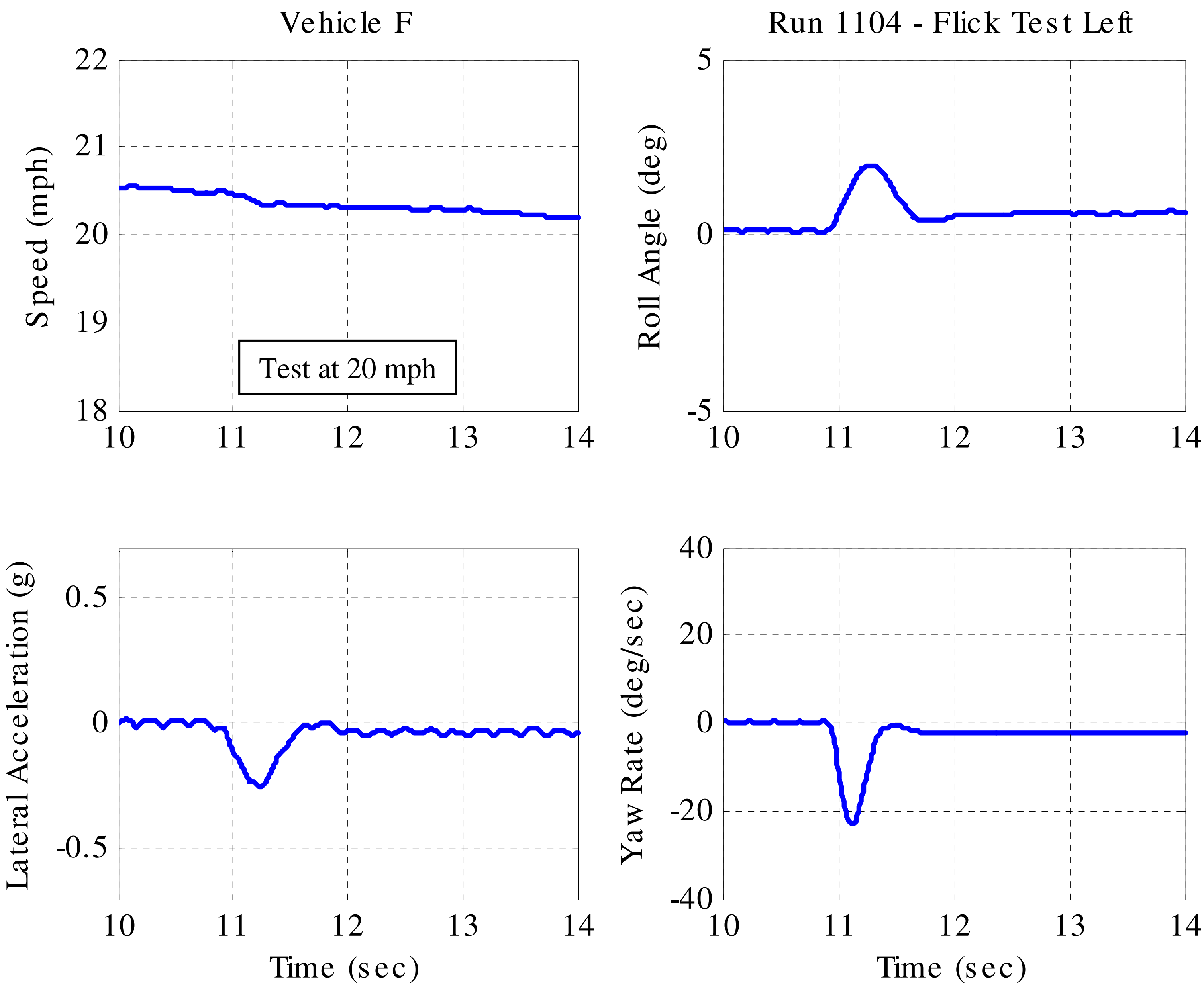

Vehicle D
Run 749 - Flick Test Left
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
32
31
30
29
28
5
0
-5
0.5
0
-0.5
40
20
0
-20
-40
5
6
7
8
9

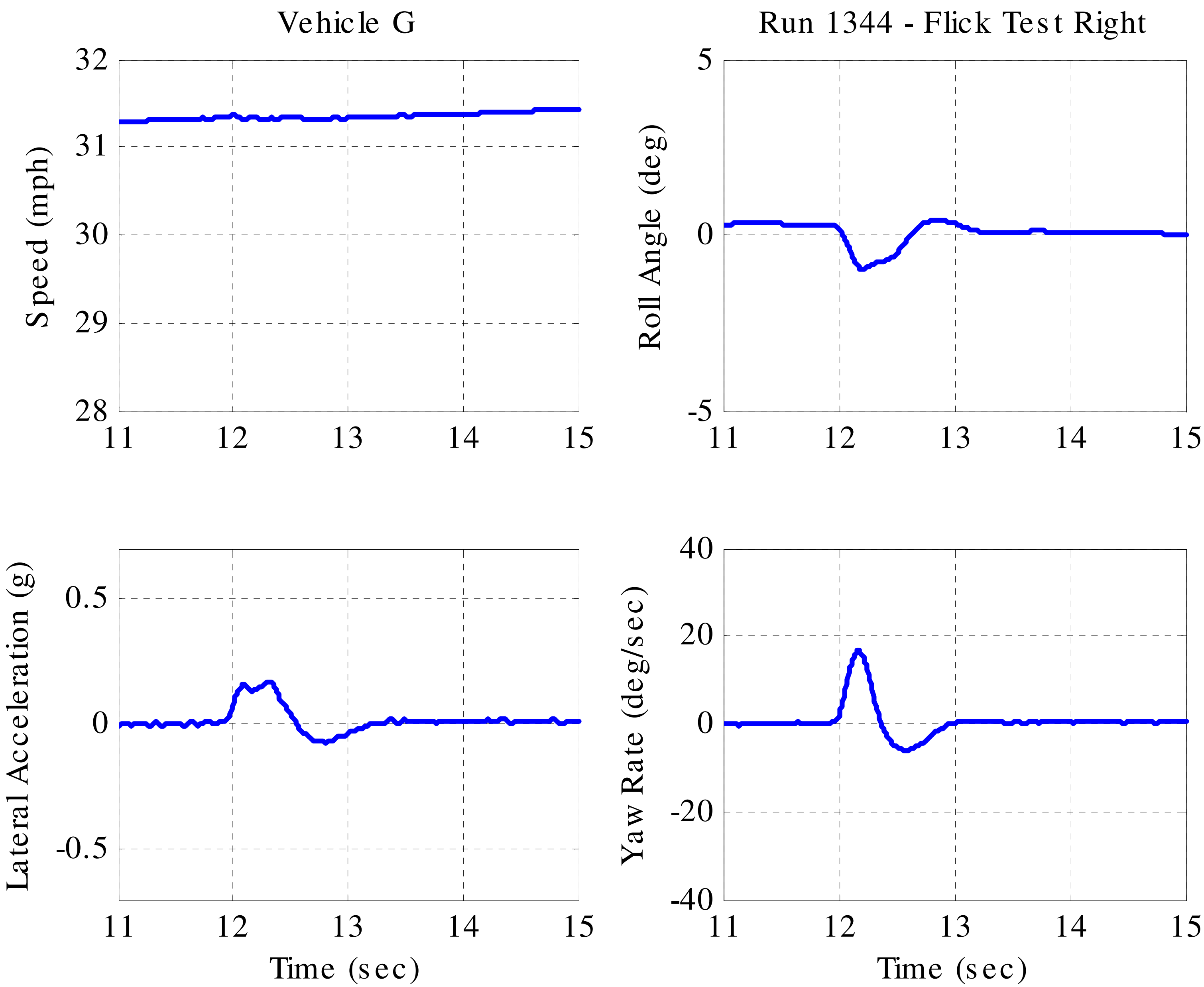

Vehicle E
Run 903 - Flick Test Right
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

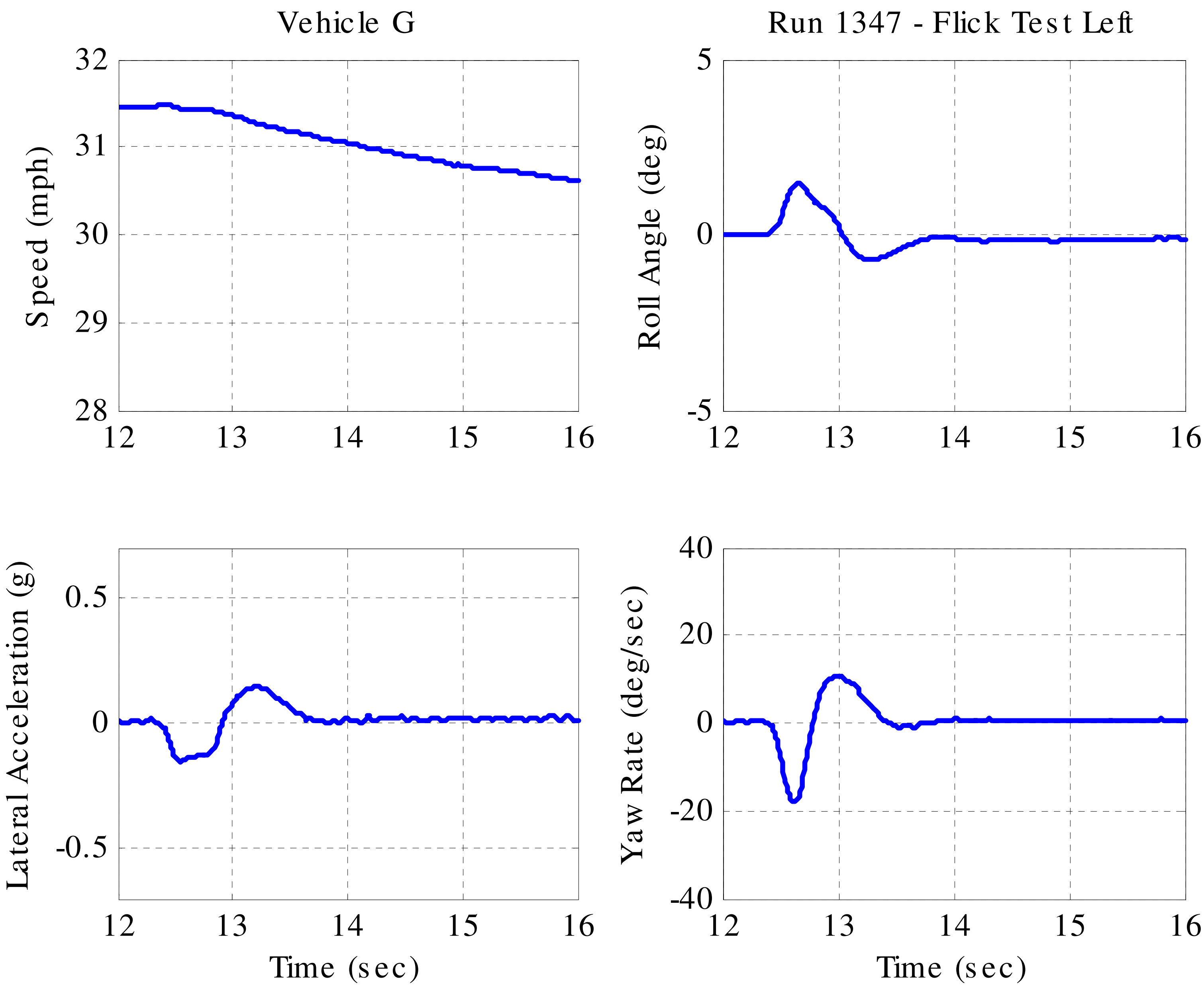


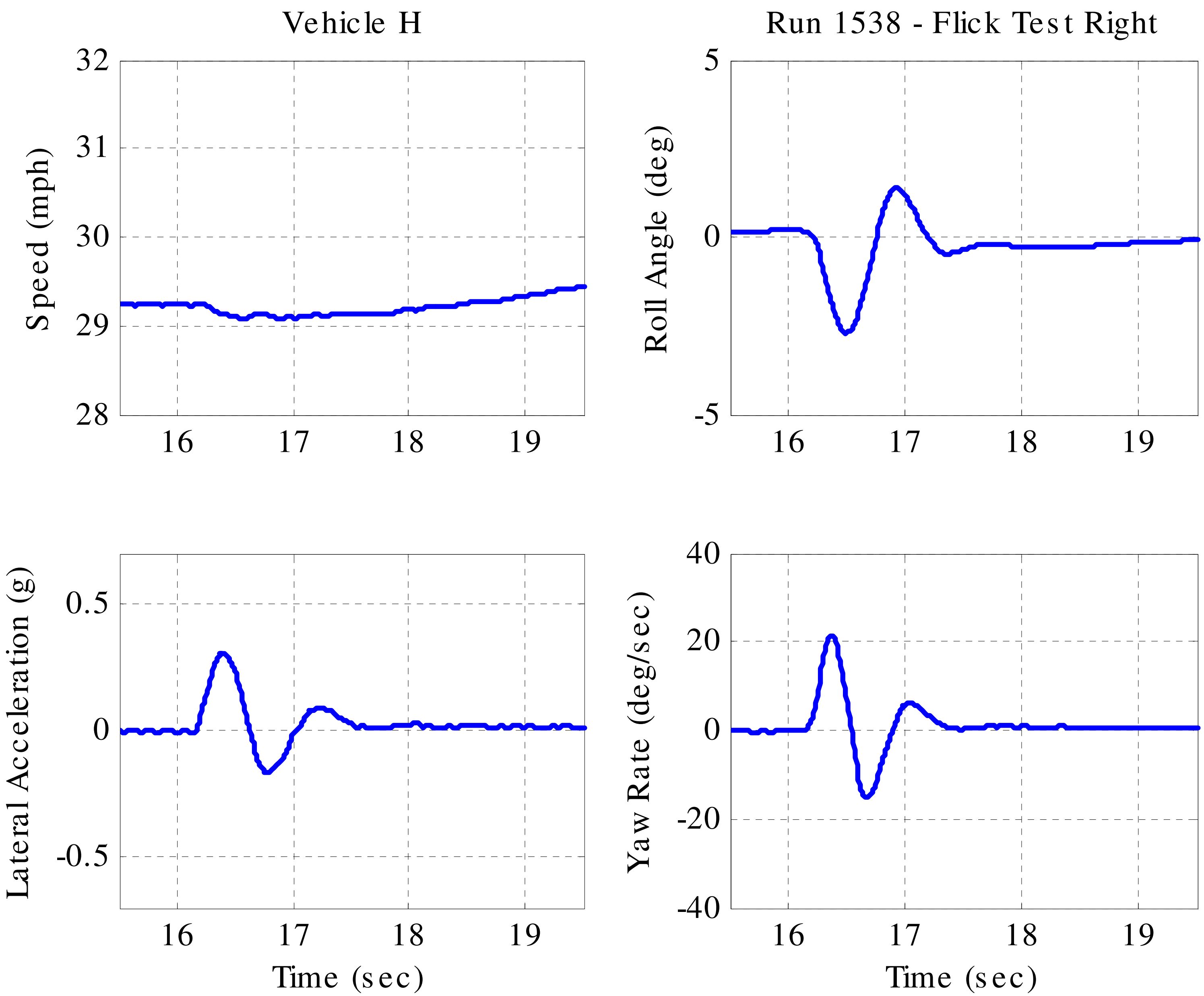
Vehicle E
Run 906 - Flick Test Left
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
32
31
30
29
28
5
0
-5
0.5
0
-0.5
40
20
0
-20
-40
8
9
10
11
12


Vehicle F
Run 1102 - Flick Test Right
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

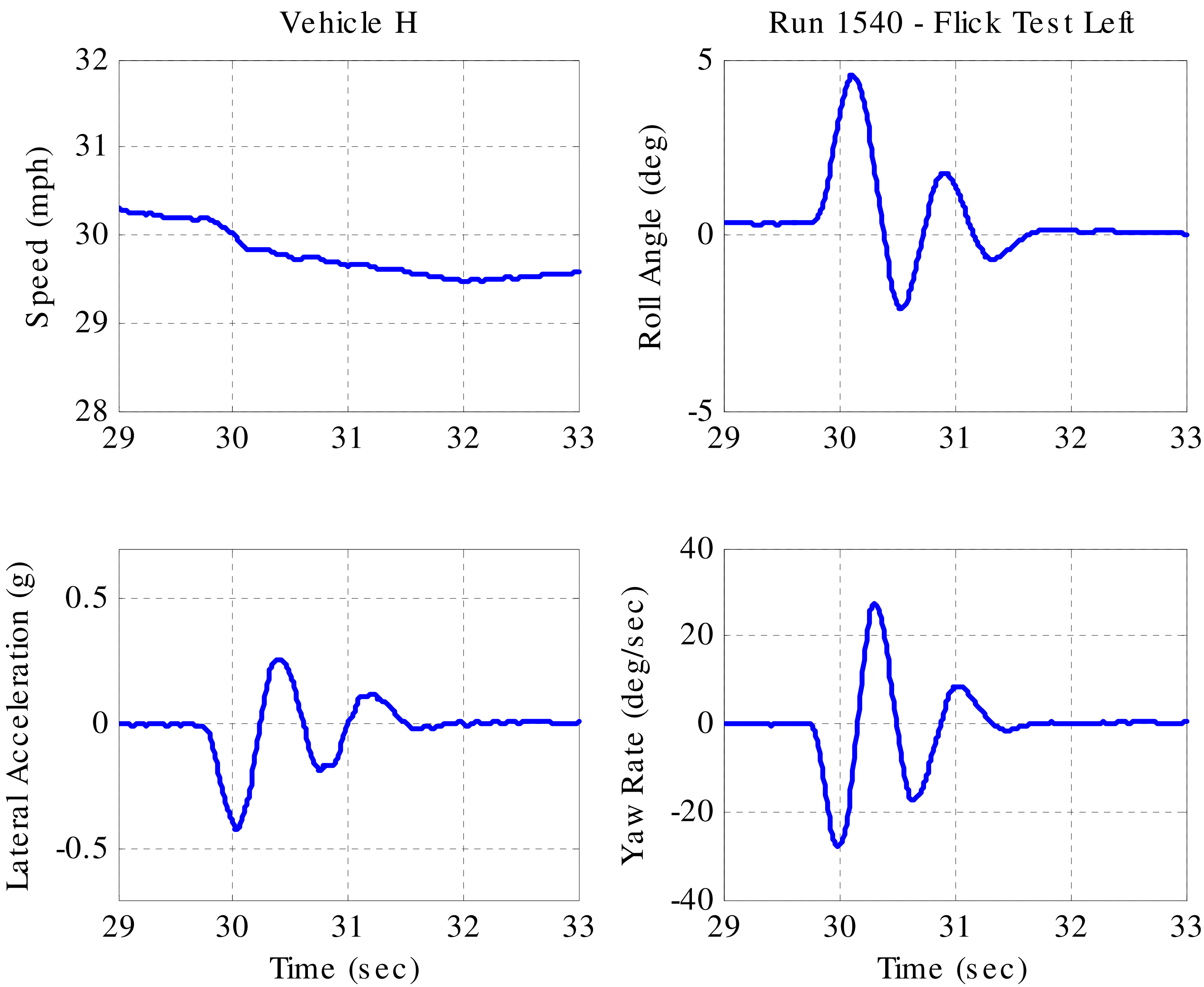

Vehicle F
Run 1104 - Flick Test Left
Speed (mph)
22
21
20
19
18
Test at 20 mph
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
10
11
12
13
14
Time (sec)

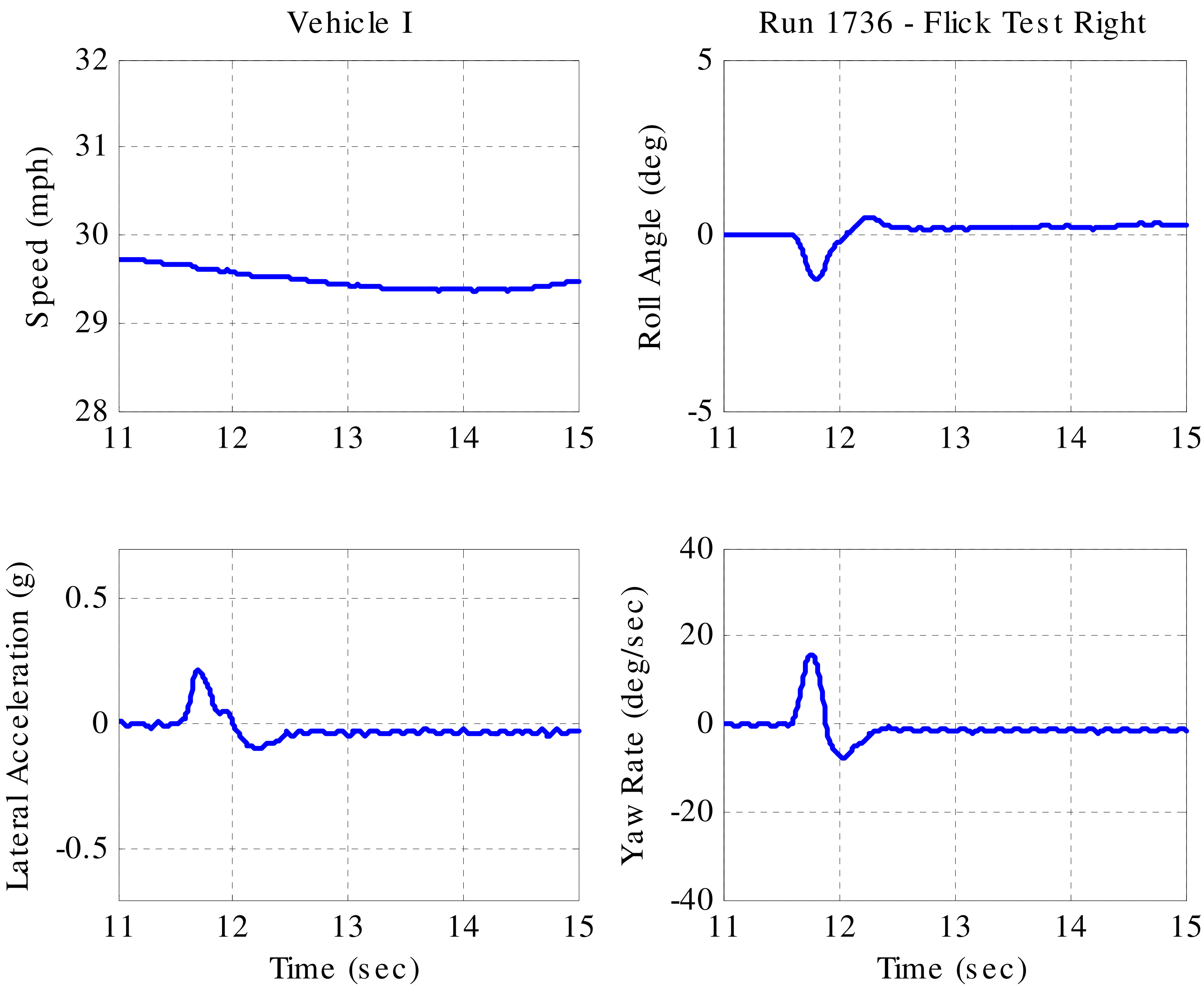

Vehicle G
Run 1344 - Flick Test Right
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

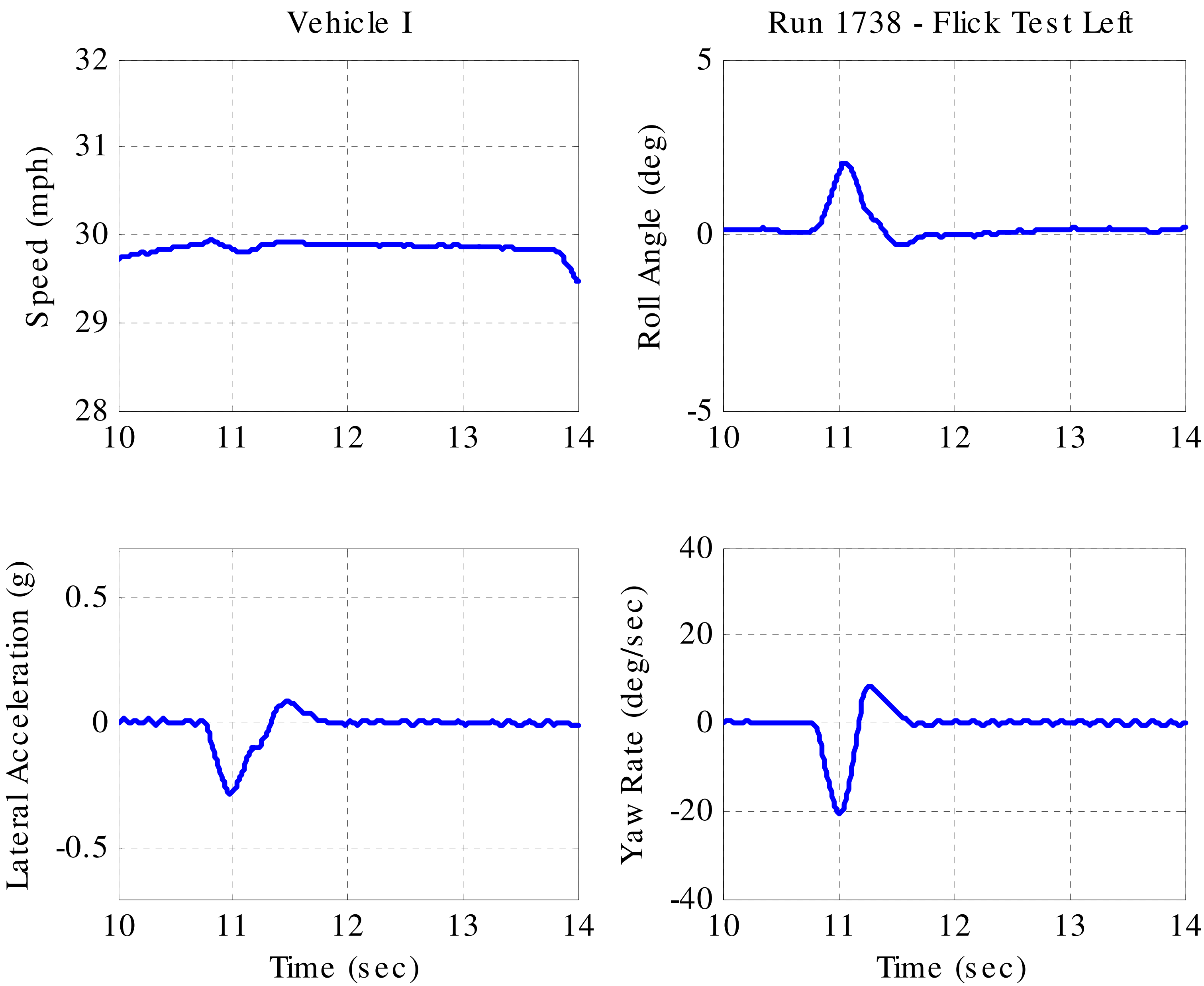

Vehicle G
Run 1347 - Flick Test Left
Speed (mph)
32
31
30
29
28
12
13
14
15
16
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

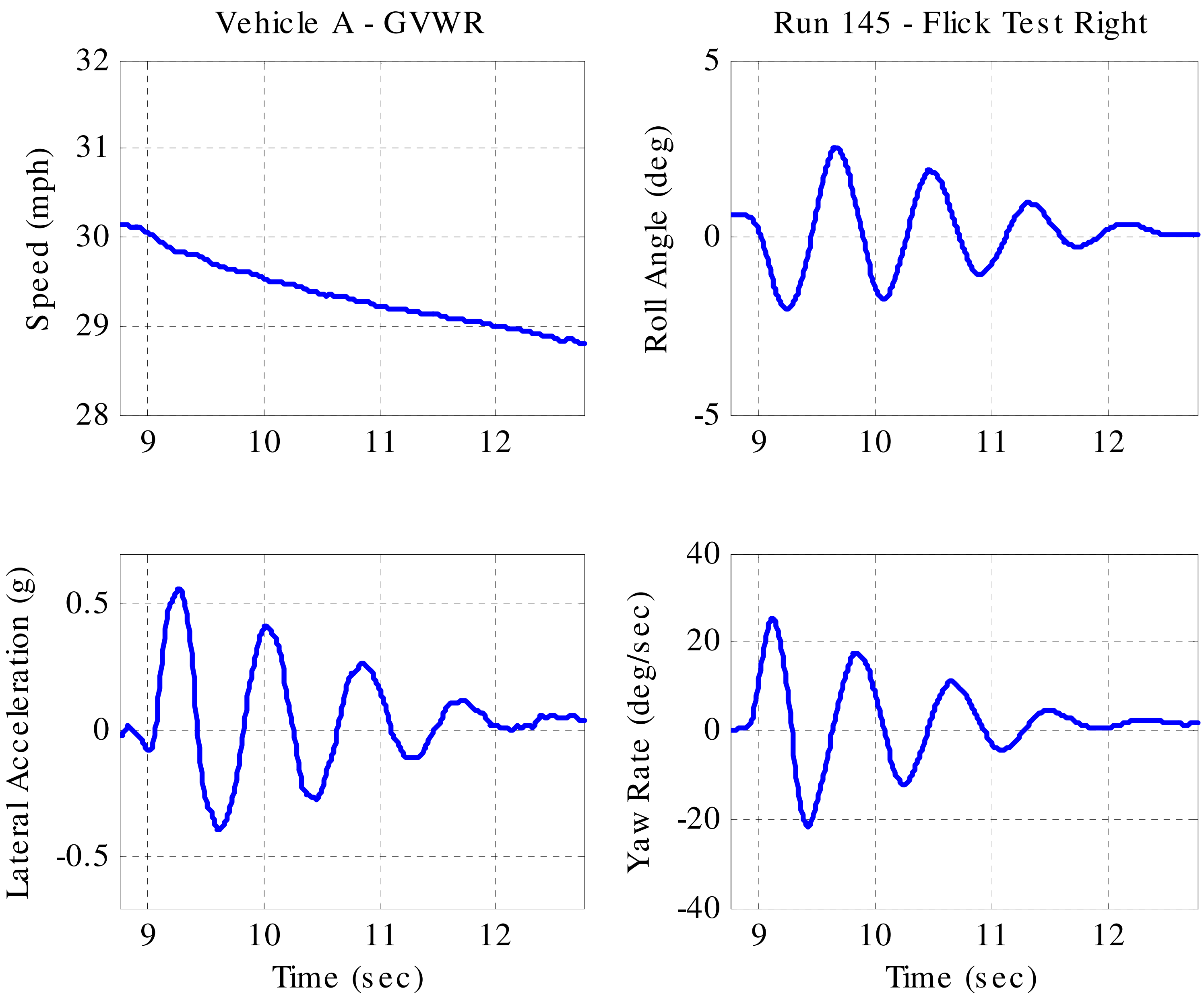


Vehicle H
Run 1538 - Flick Test Right
Speed (mph)
32
31
30
29
28
16
17
18
19
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
-20
-40
Time (sec)
Time (sec)

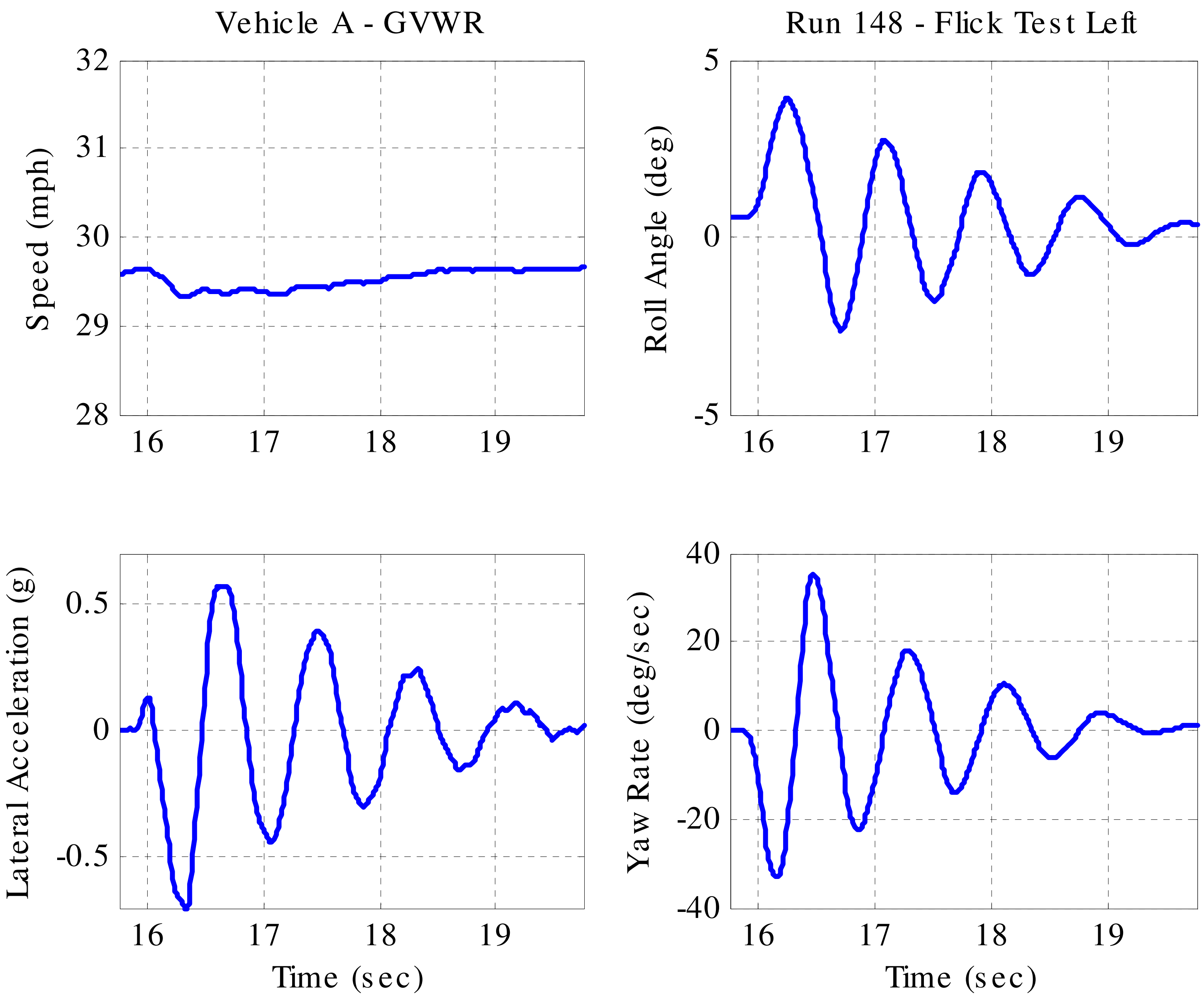

Vehicle H
Run 1540 - Flick Test Left
Speed (mph)
32
31
30
29
28
29
30
31
32
33
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

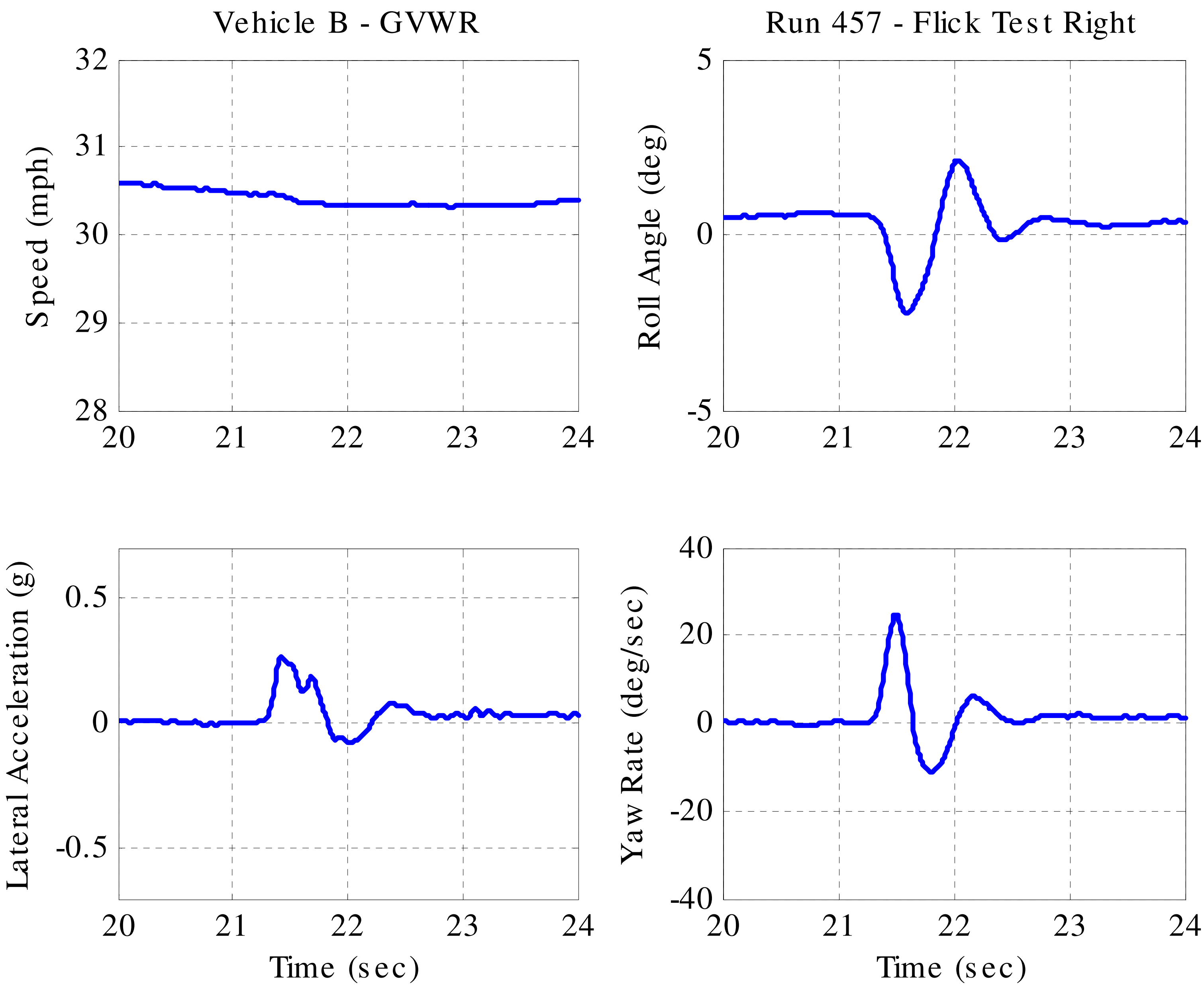

Vehicle I
Run 1736 - Flick Test Right
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

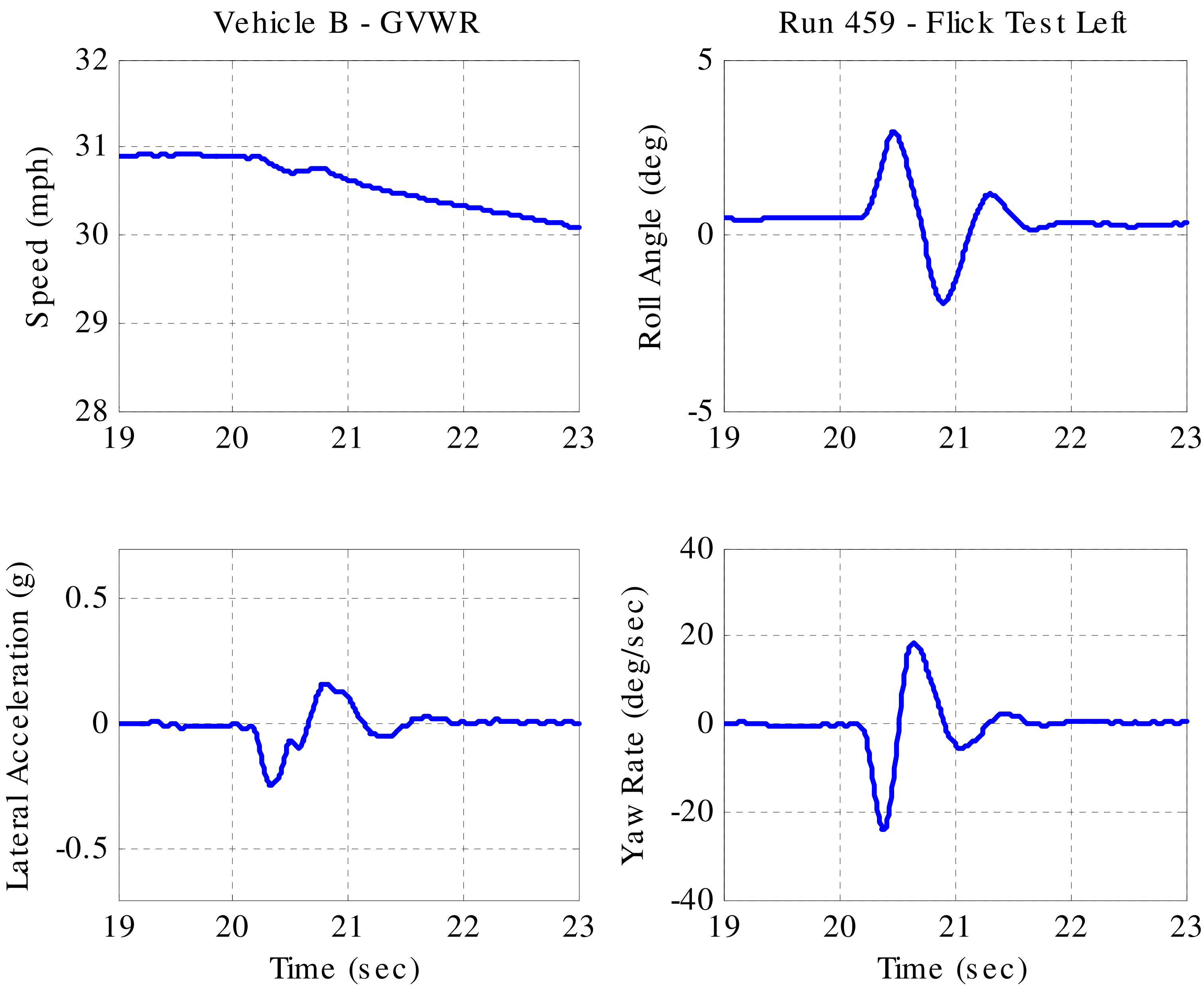

Vehicle I
Run 1738 - Flick Test Left
Speed (mph)
32
31
30
29
28
10
11
12
13
14
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

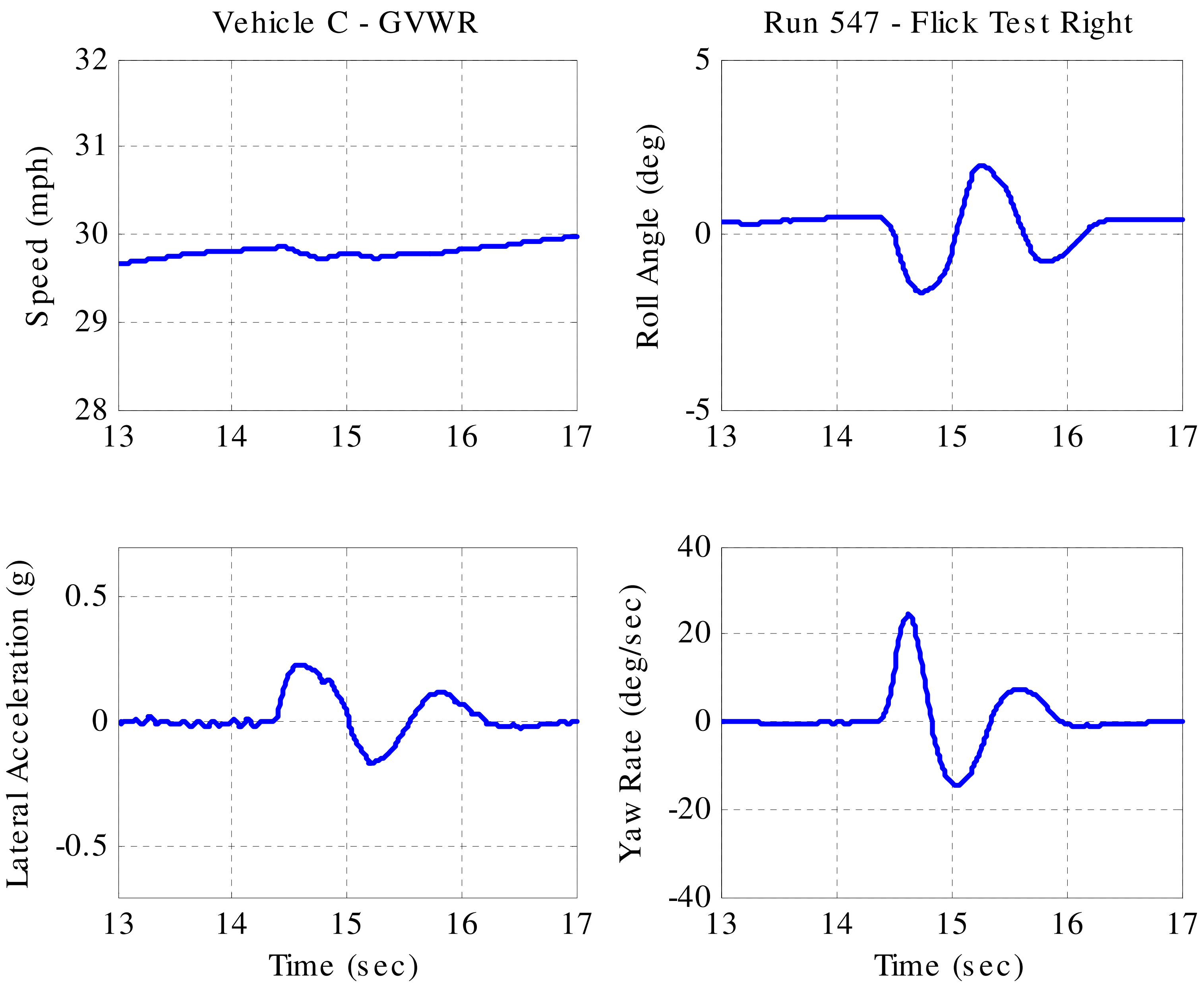


Vehicle A - GVWR
Run 145 - Flick Test Right
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
9
10
11
12
Time (sec)
Time (sec)

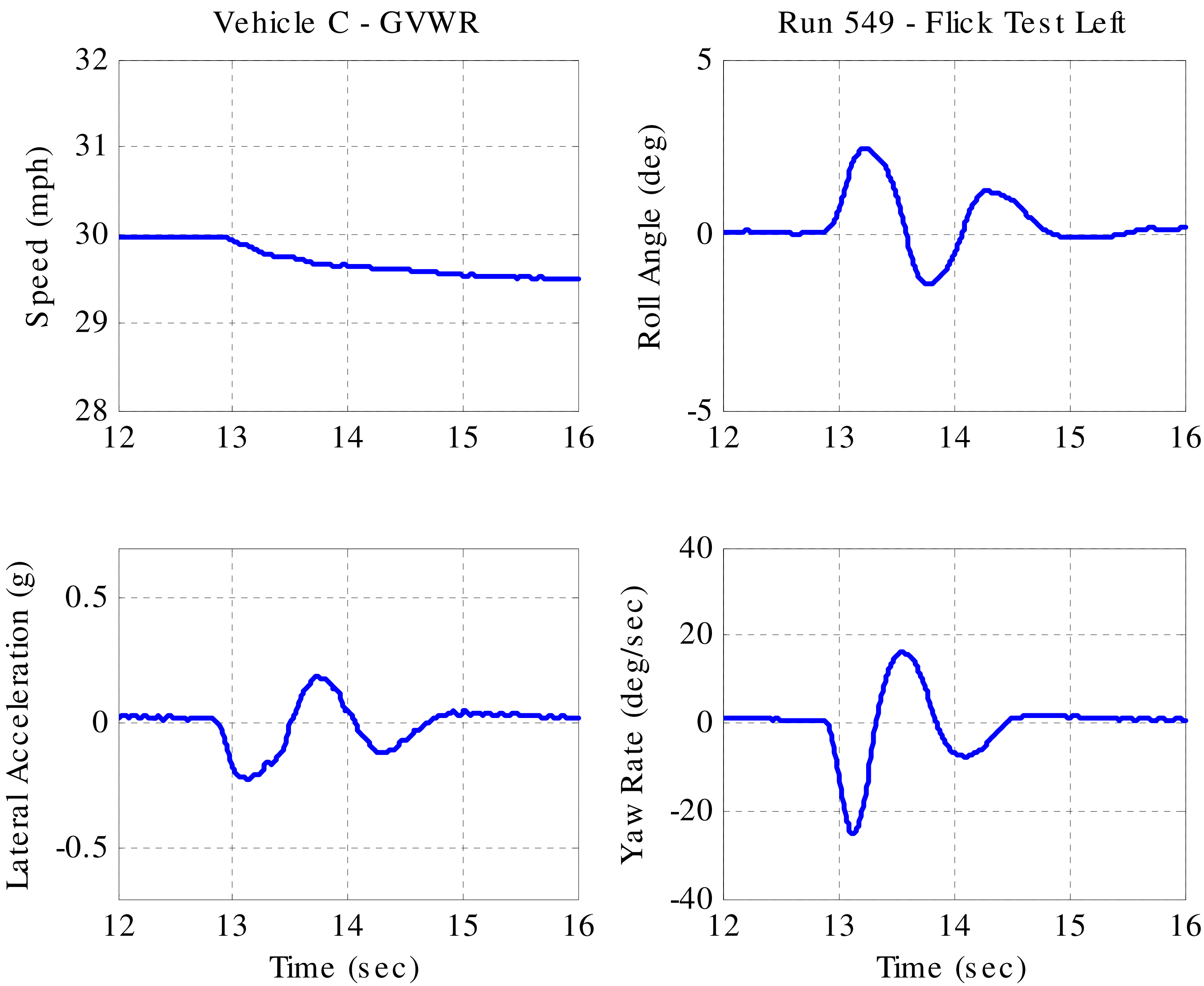

Vehicle A - GVWR
Run 148 - Flick Test Left
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
16
17
18
19
Time (sec)
Time (sec)

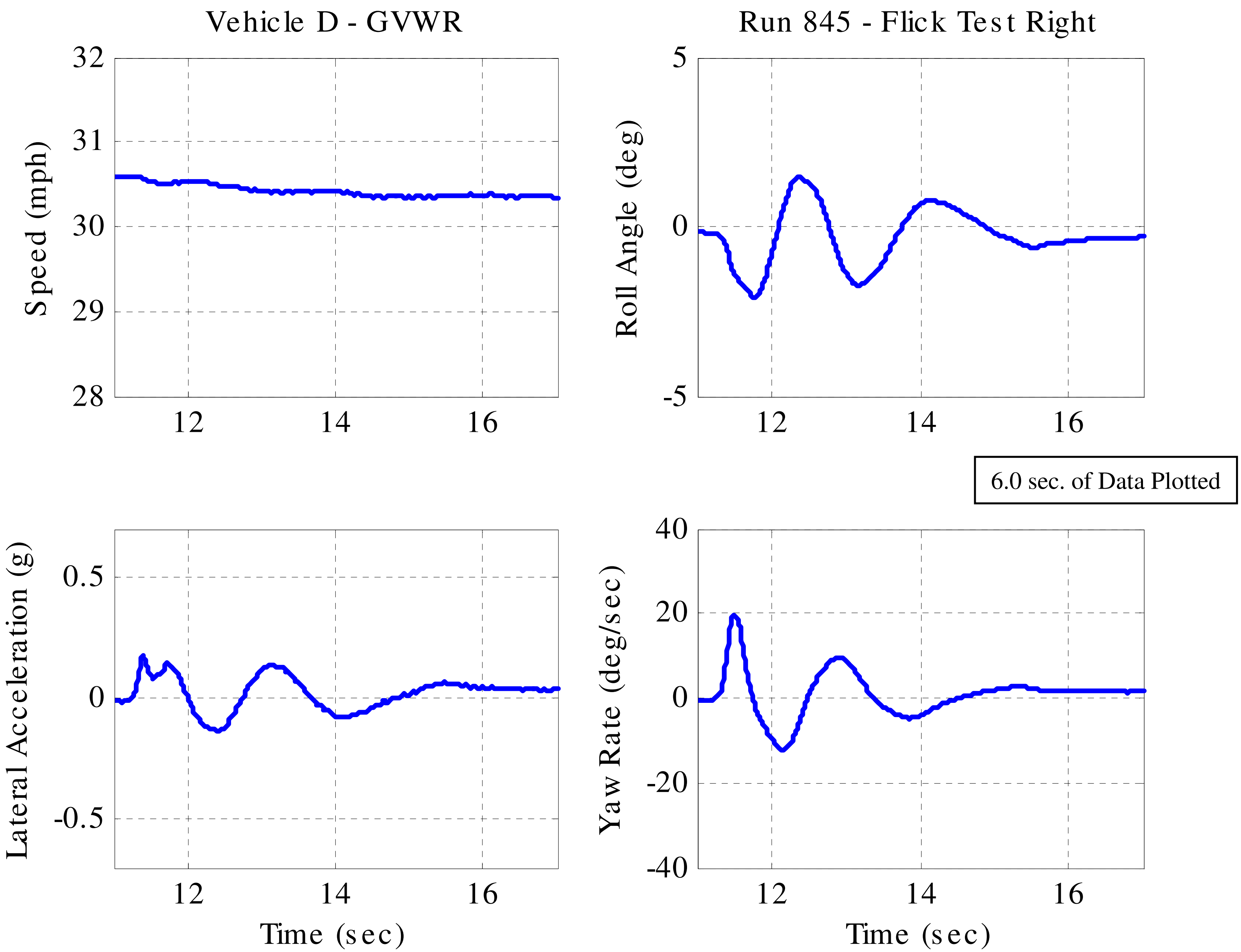

Vehicle B - GVWR
Run 457 - Flick Test Right
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
20
21
22
23
24
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)

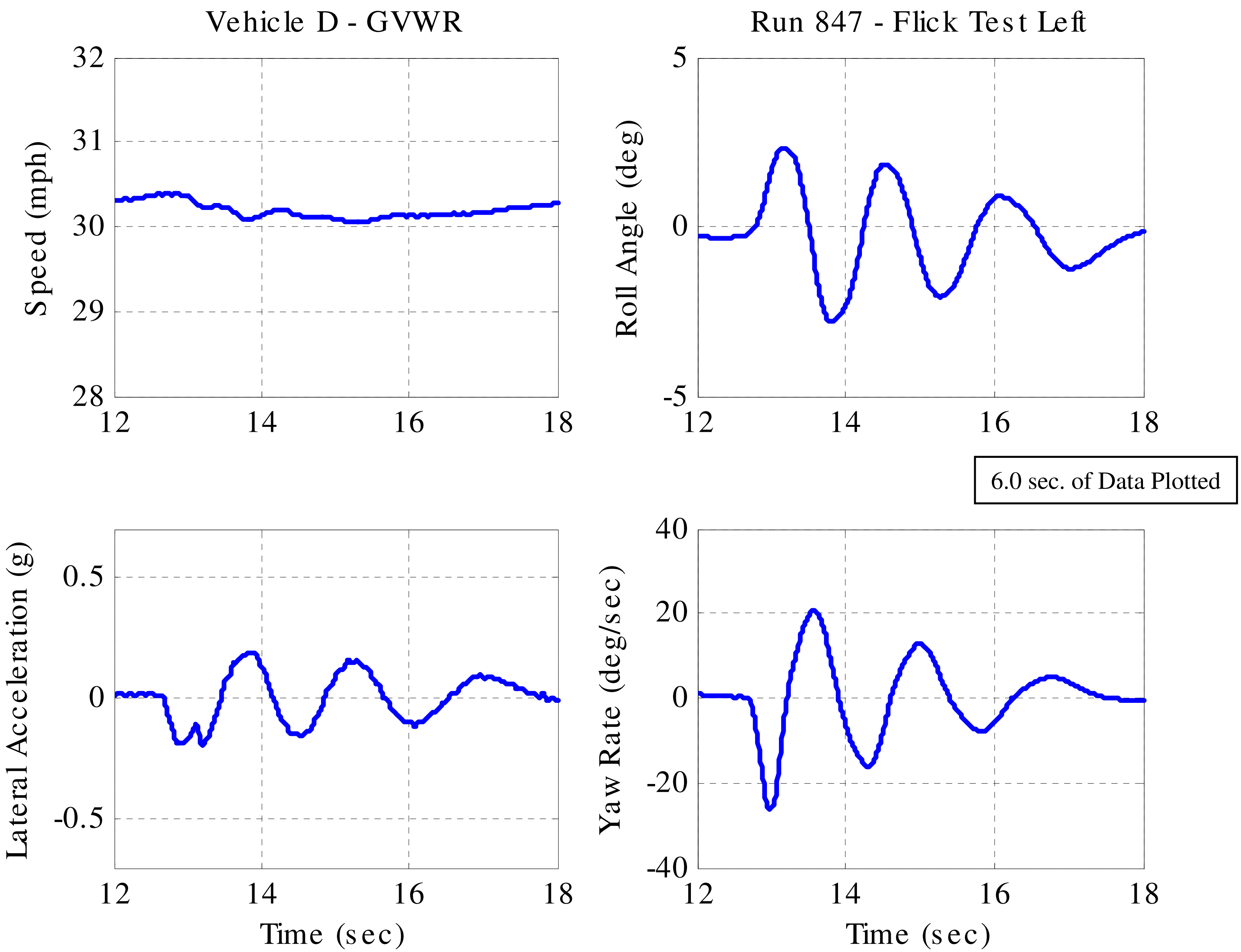

Vehicle B - GVWR
Run 459 - Flick Test Left
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
19
20
21
22
23
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)



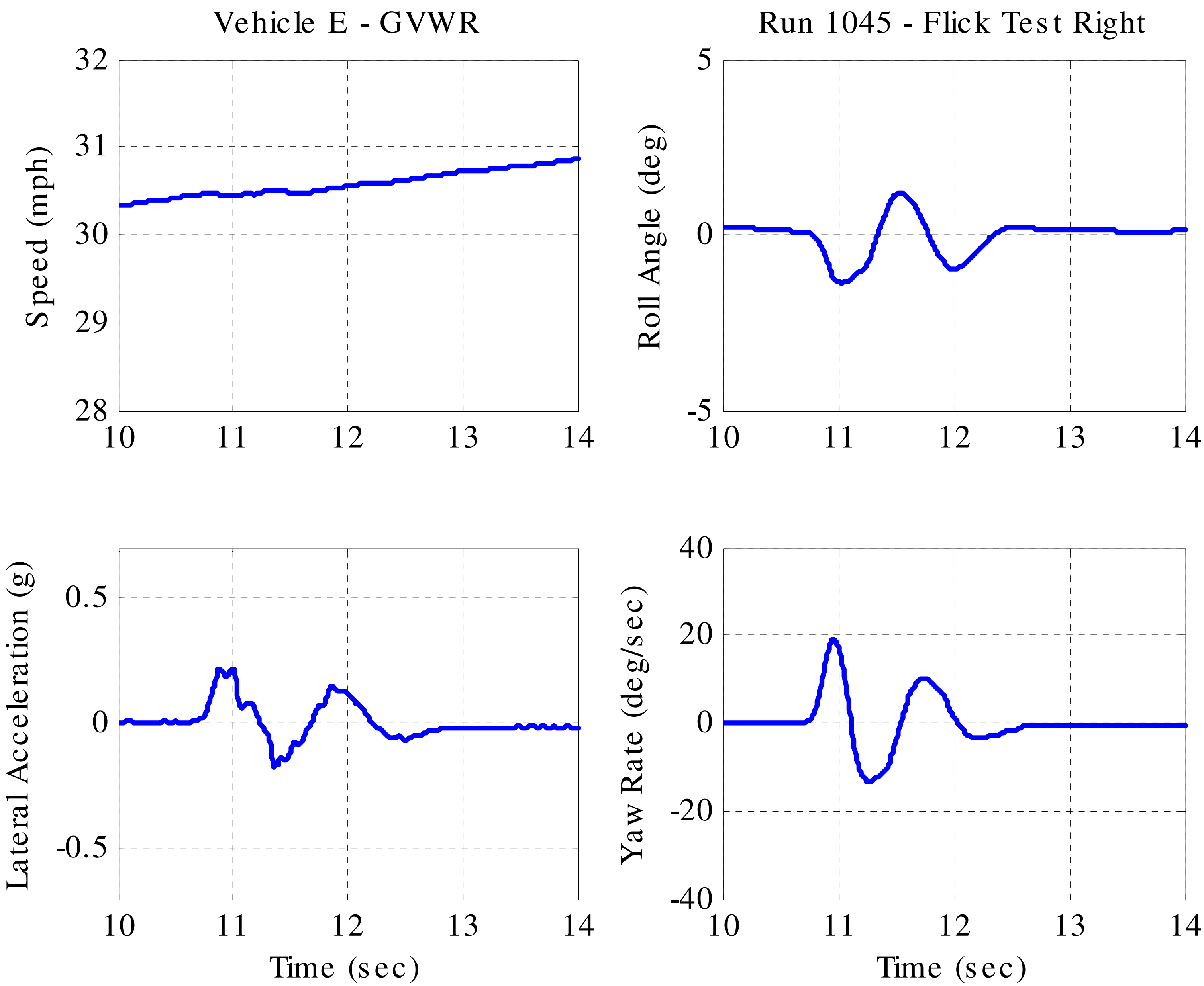
Vehicle C - GVWR
Run 547 - Flick Test Right
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
13
14
15
16
17
Time (sec)
Time (sec)

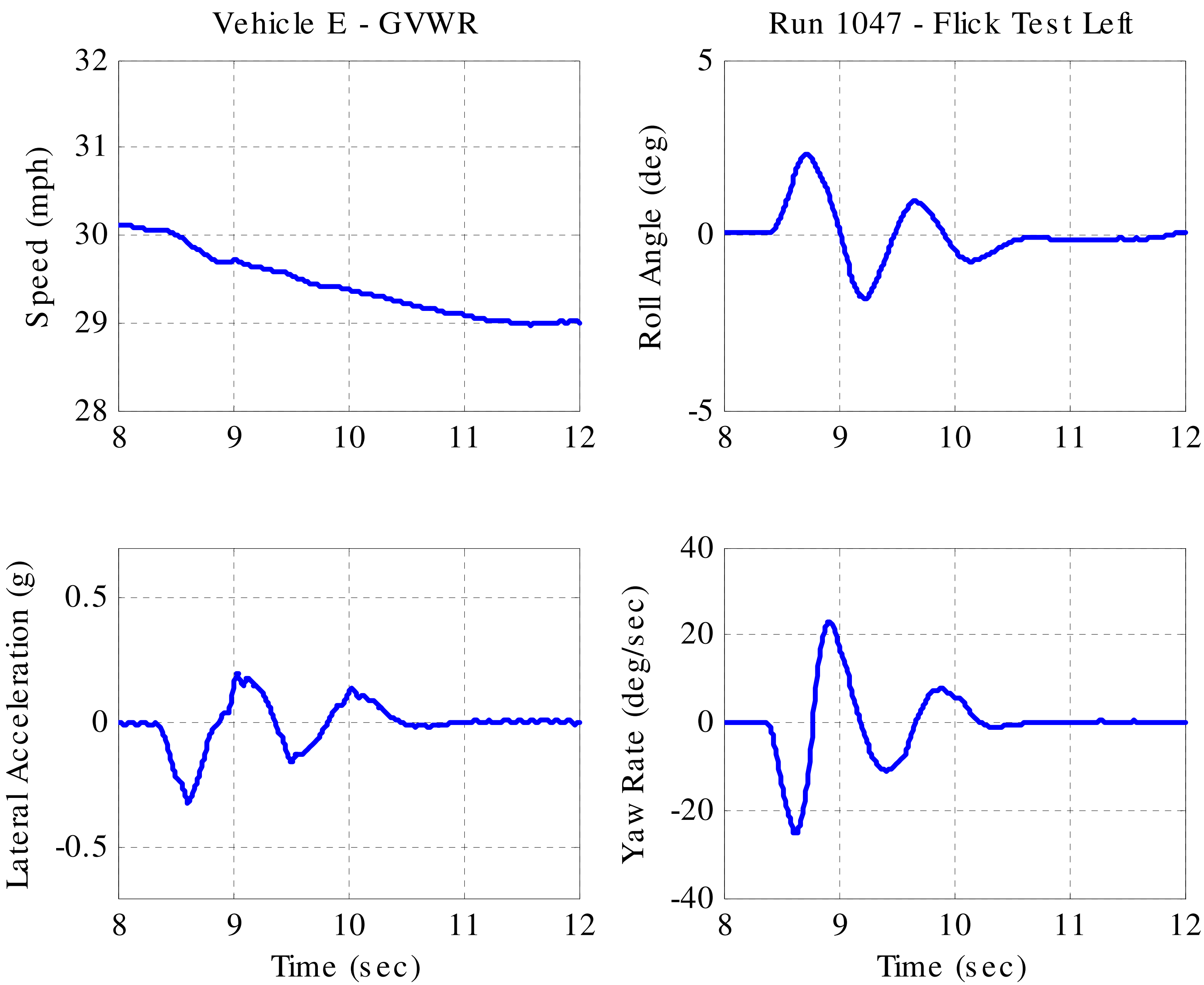

Vehicle C - GVWR
Run 549 - Flick Test Left
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

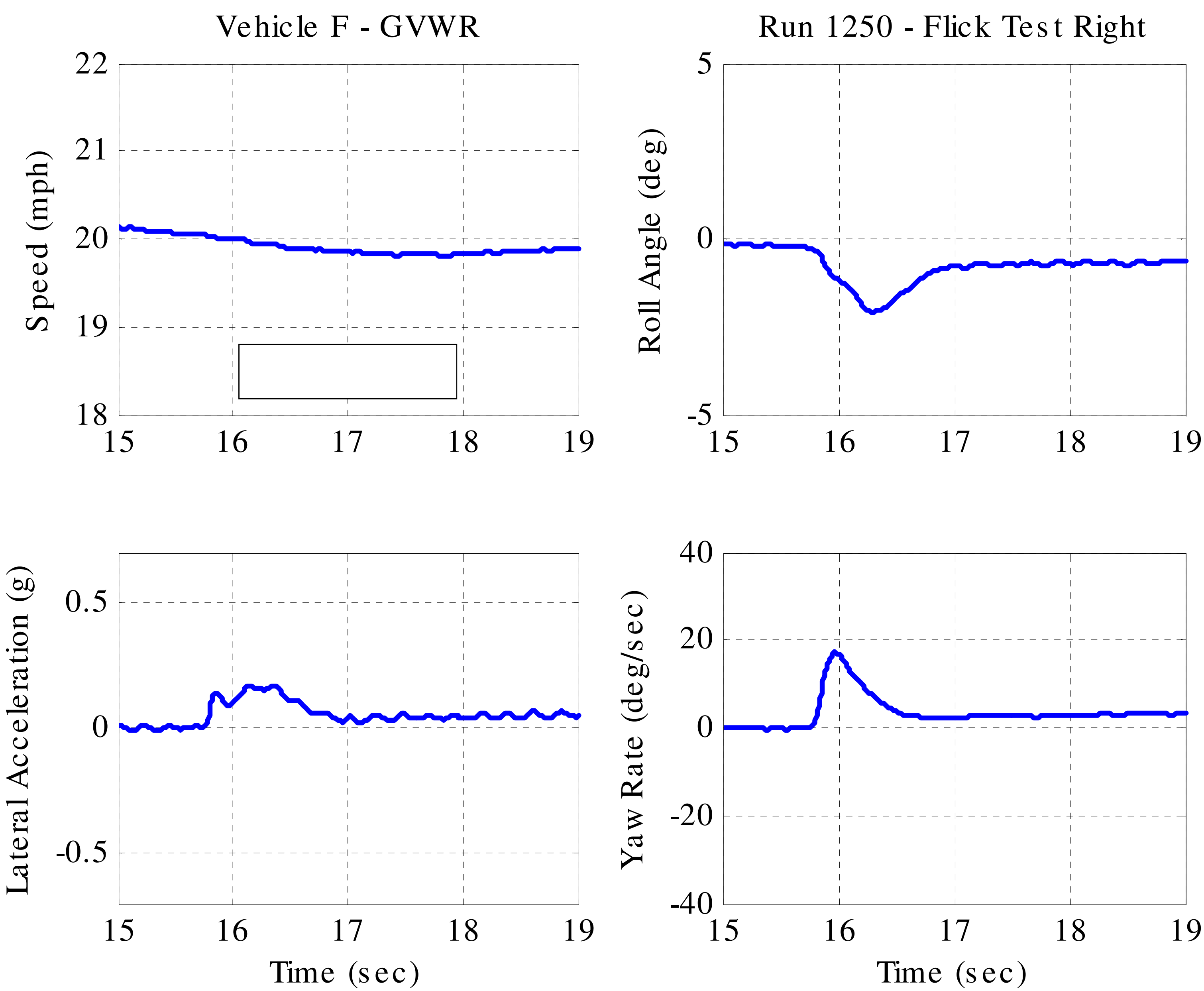

Vehicle D - GVWR
Run 845 - Flick Test Right
Speed (mph)
Roll Angle (deg)
6.0 sec. of Data Plotted
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle D - GVWR
Run 847 - Flick Test Left
Speed (mph)
32
31
30
29
28
12
14
16
18
Roll Angle (deg)
5
0
-5
6.0 sec. of Data Plotted
Lateral Acceleration (g)
0.5
0
-0.5
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40

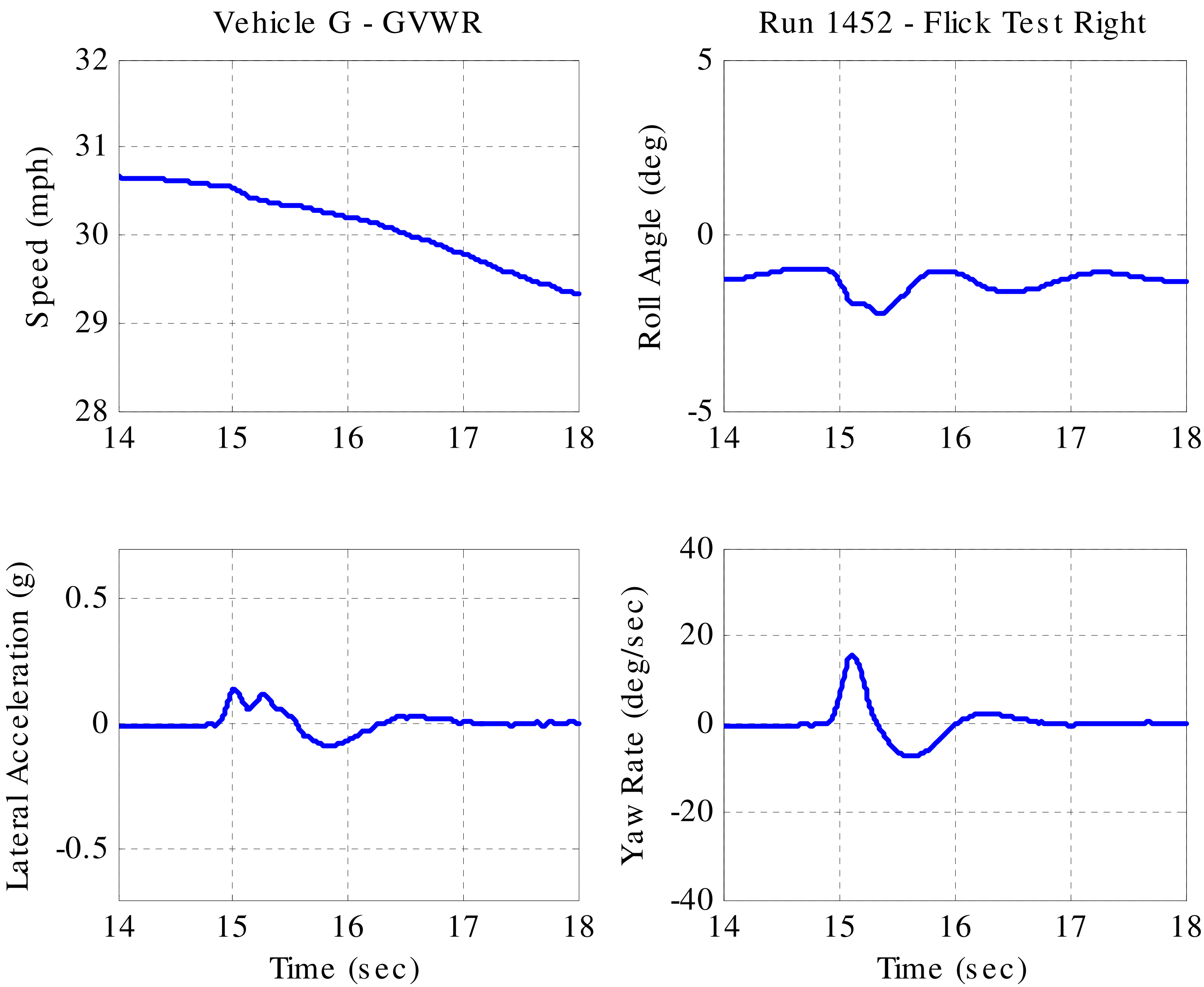

Vehicle E - GVWR
Run 1045 - Flick Test Right
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle E - GVWR
Run 1047 - Flick Test Left
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

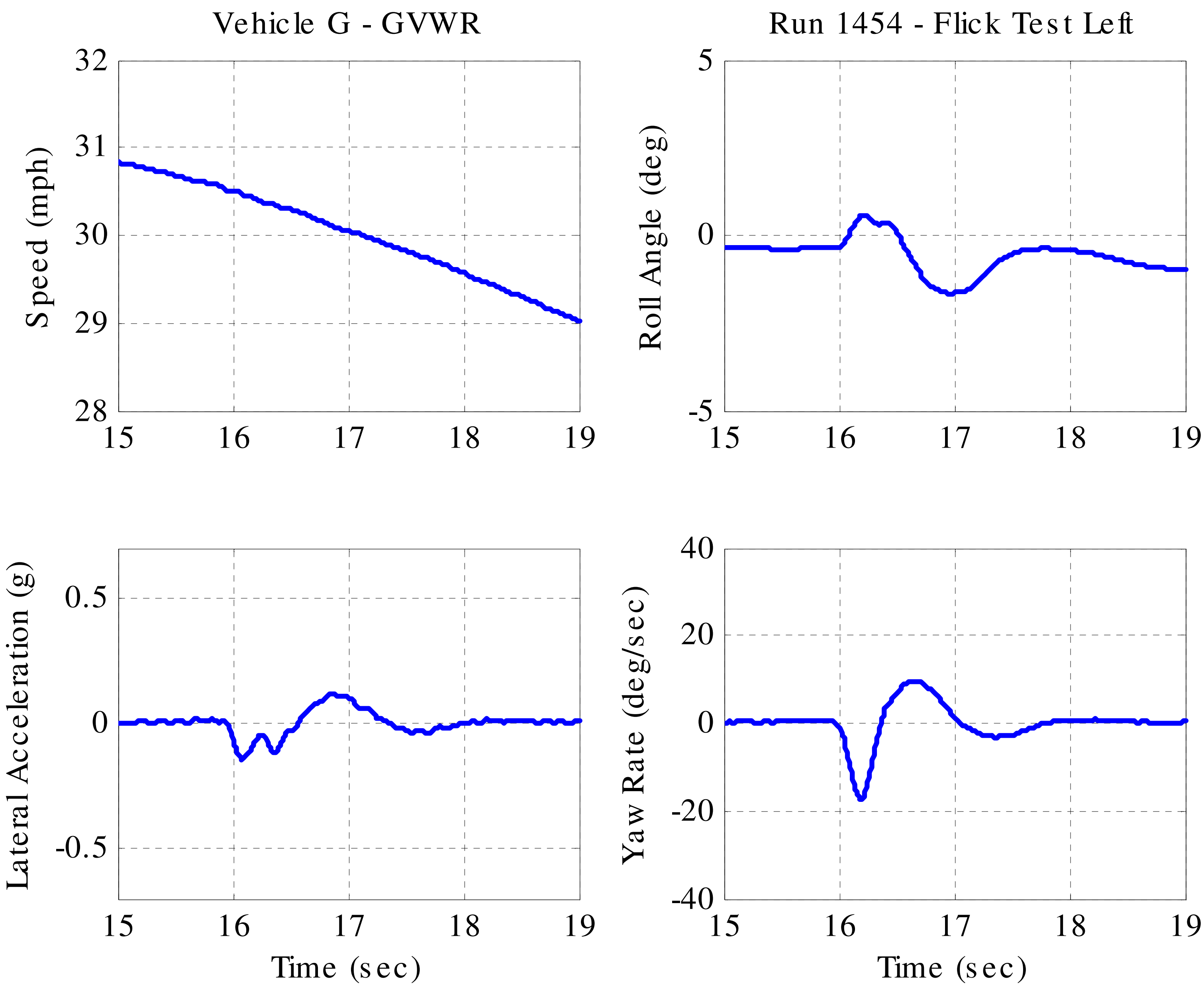


Vehicle F - GVWR
Run 1250 - Flick Test Right
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

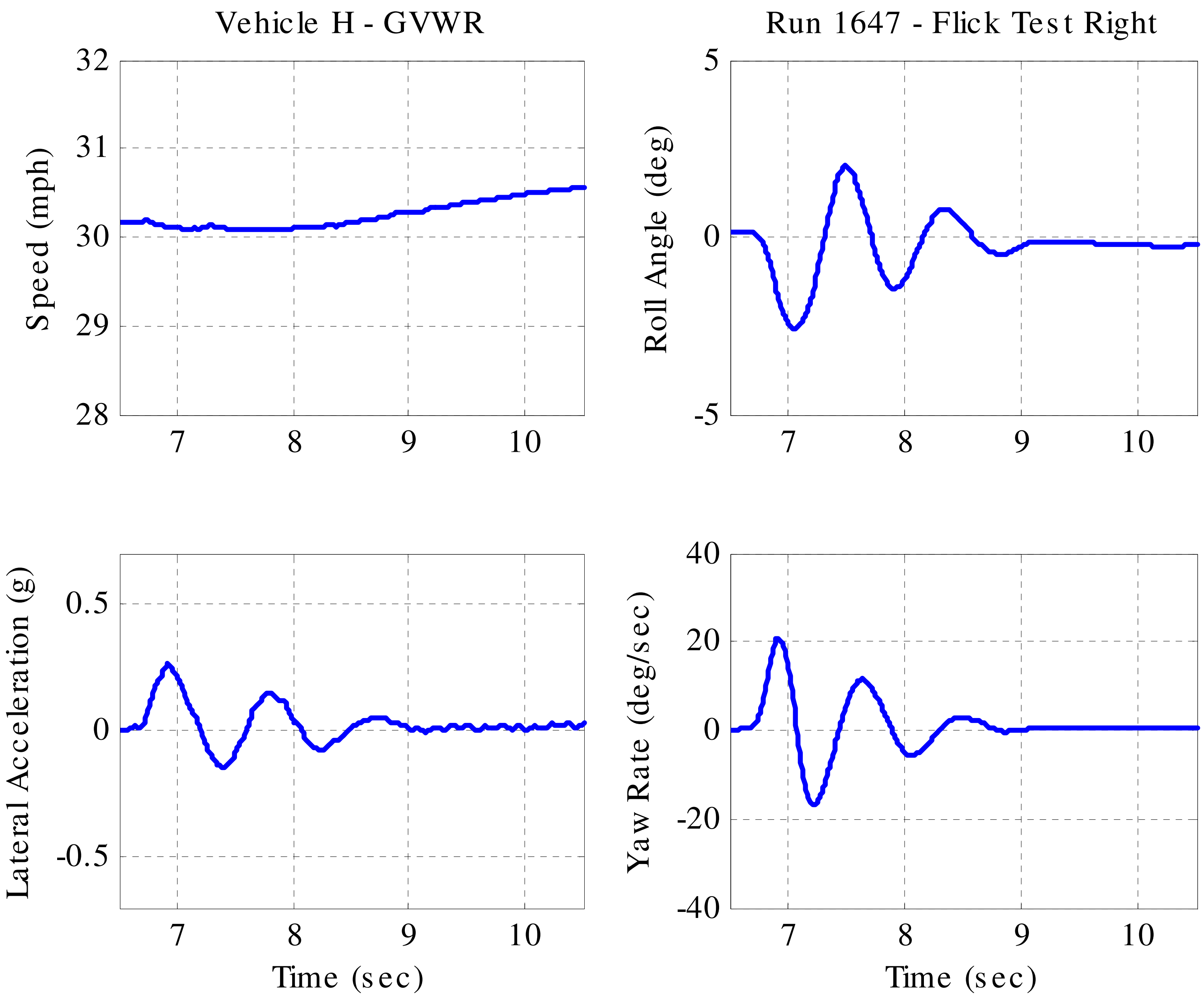

Vehicle F - GVWR
Run 1252 - Flick Test Left
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



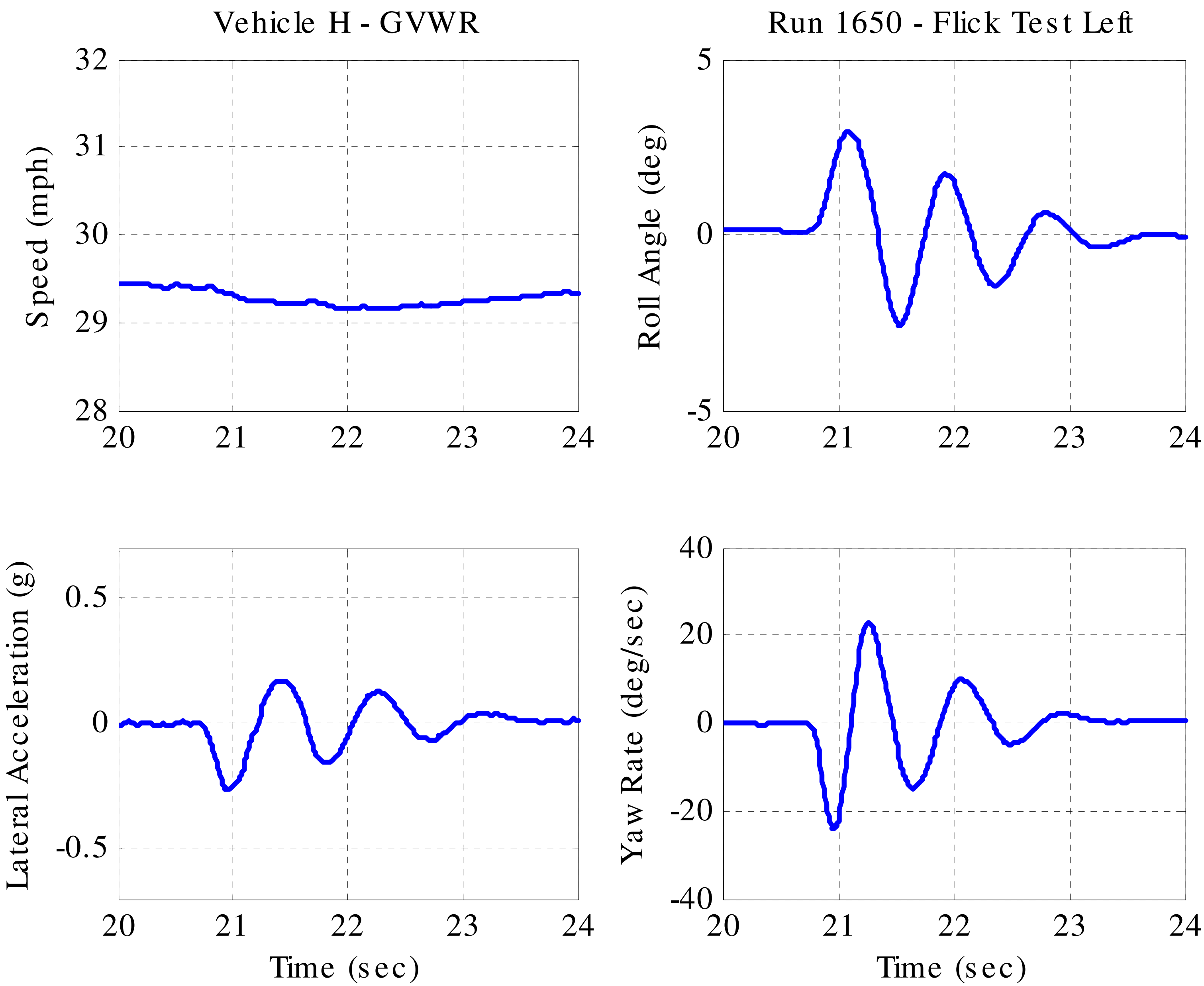
Vehicle G - GVWR
Run 1452 - Flick Test Right
Speed (mph)
32
31
30
29
28
14
15
16
17
18
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)
Time (sec)



Vehicle G - GVWR
Run 1454 - Flick Test Left
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



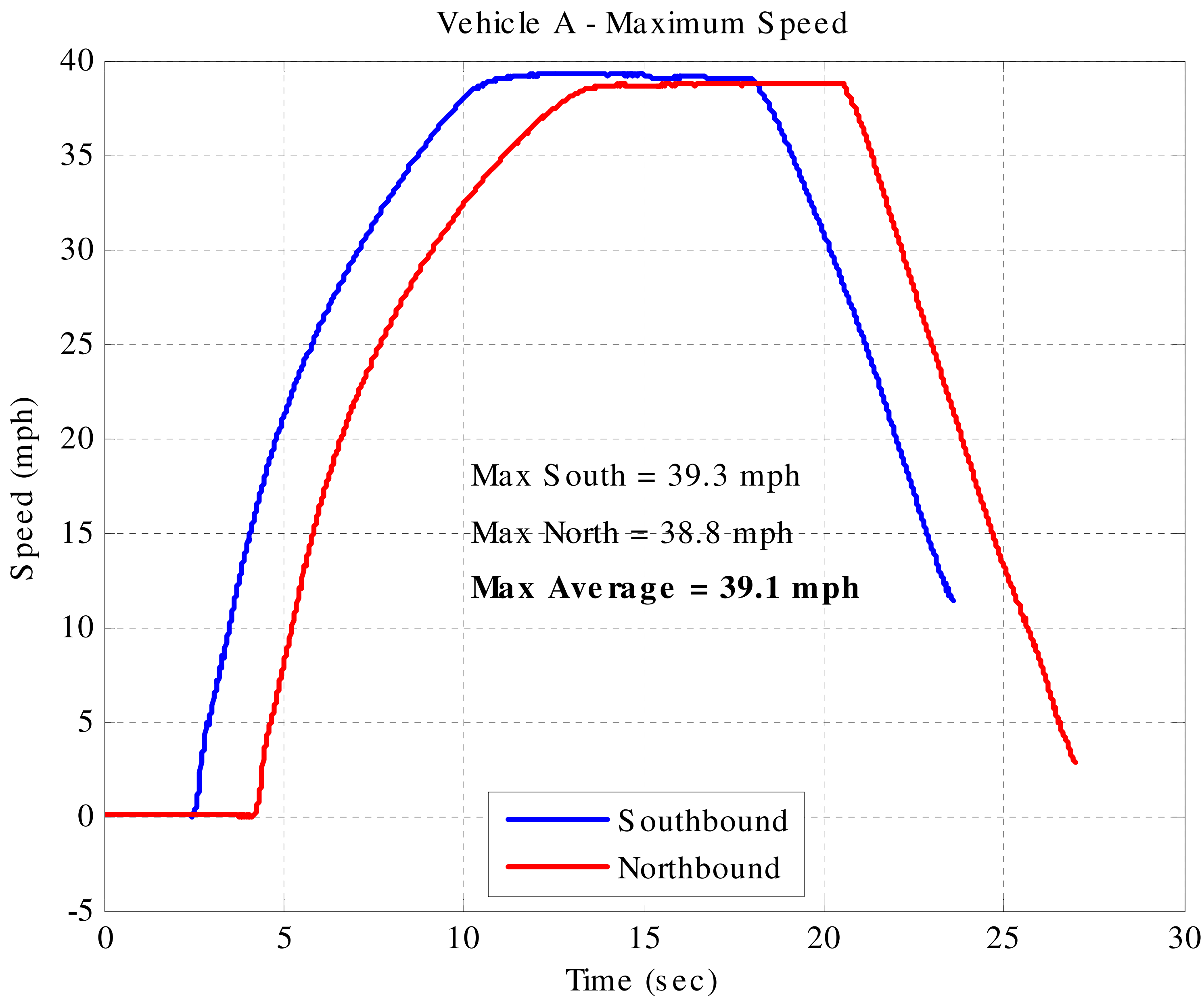
Vehicle H - GVWR
Run 1647 - Flick Test Right
Speed (mph)
32
31
30
29
28
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Yaw Rate (deg/sec)
40
20
0
-20
-40
7
8
9
10
Time (sec)
Time (sec)

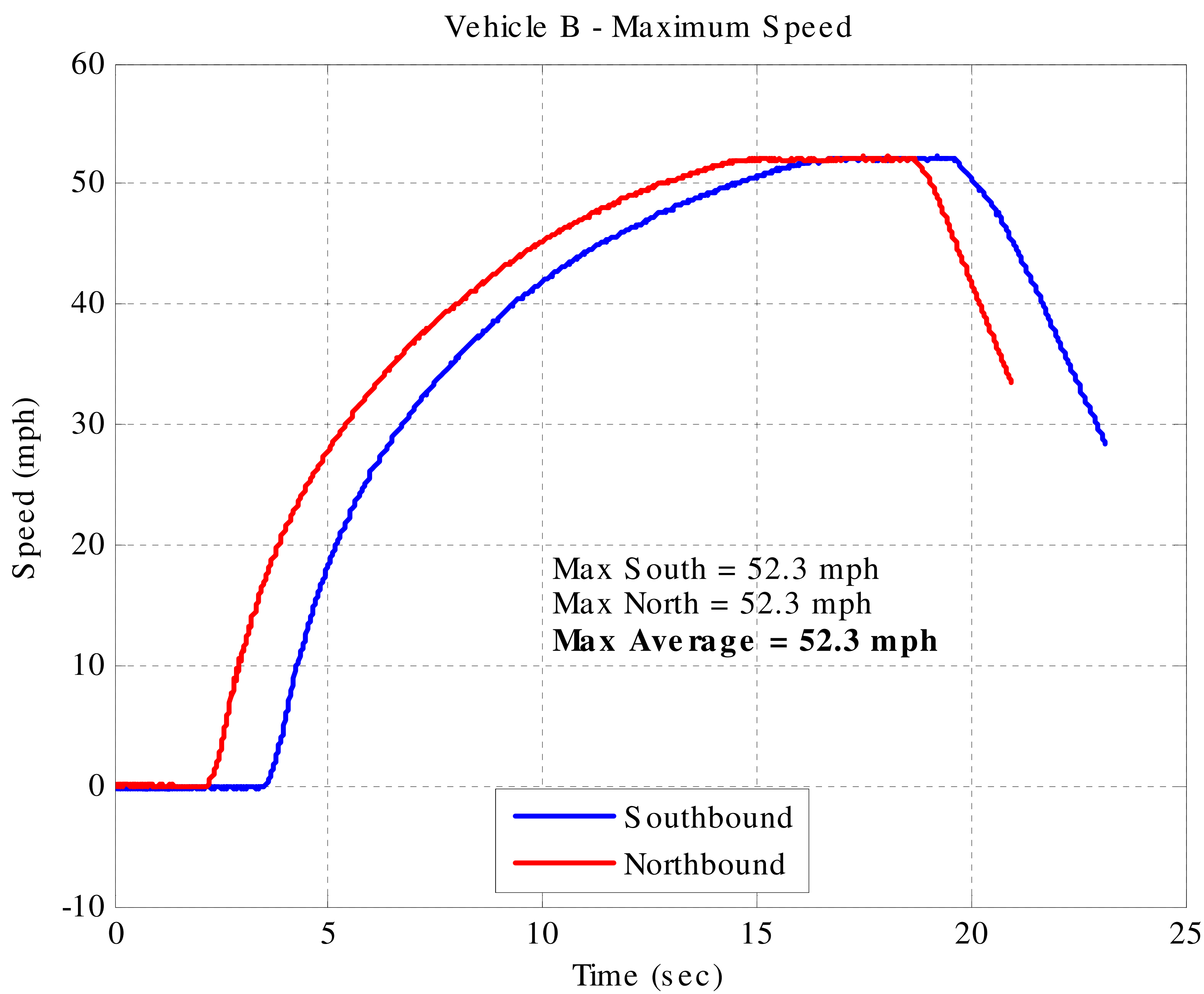


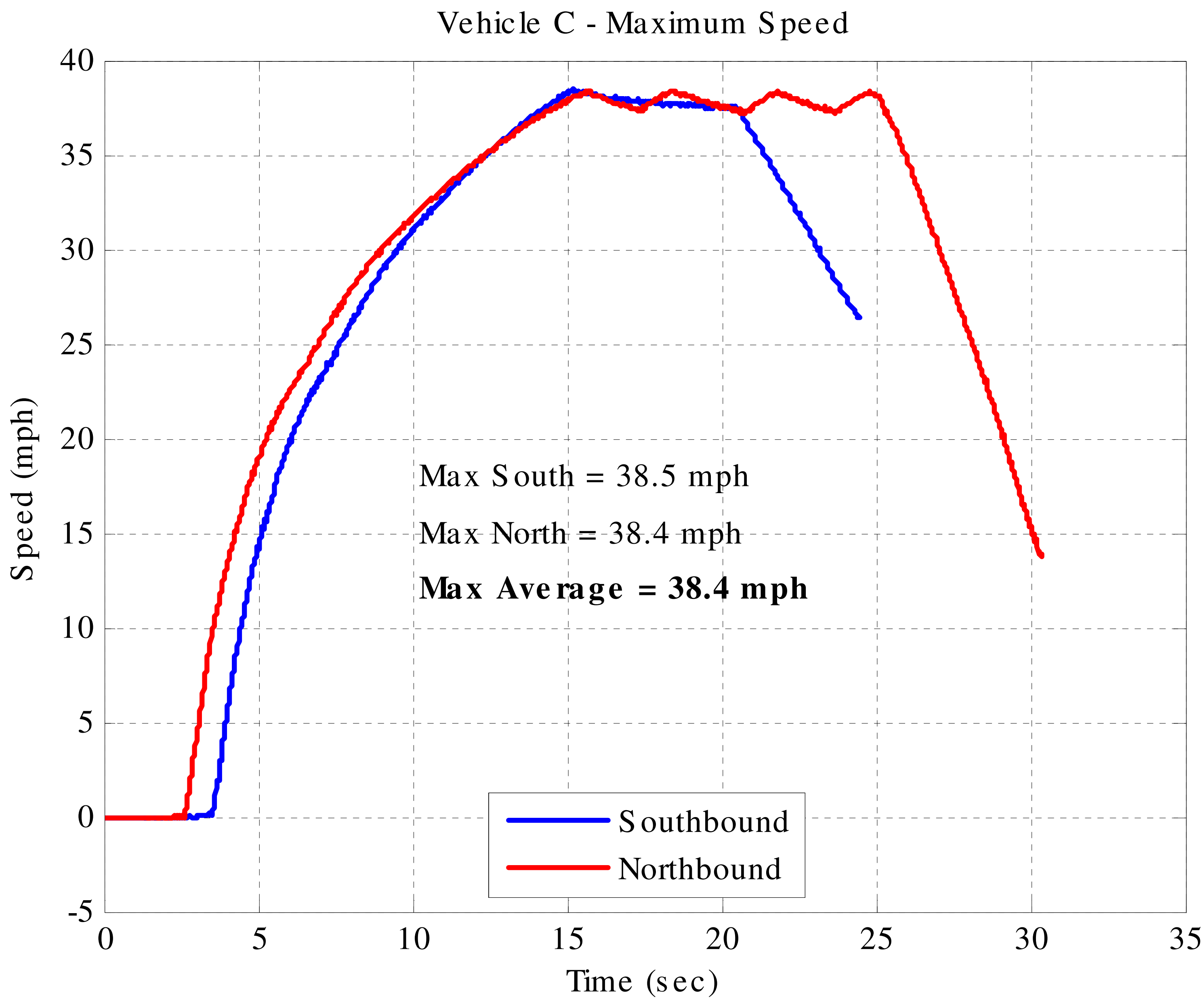
Vehicle H - GVWR
Run 1650 - Flick Test Left
Speed (mph)
32
31
30
29
28
20
21
22
23
24
Roll Angle (deg)
5
0
-5
Lateral Acceleration (g)
0.5
0
-0.5
Time (sec)
Yaw Rate (deg/sec)
40
20
0
-20
-40
Time (sec)

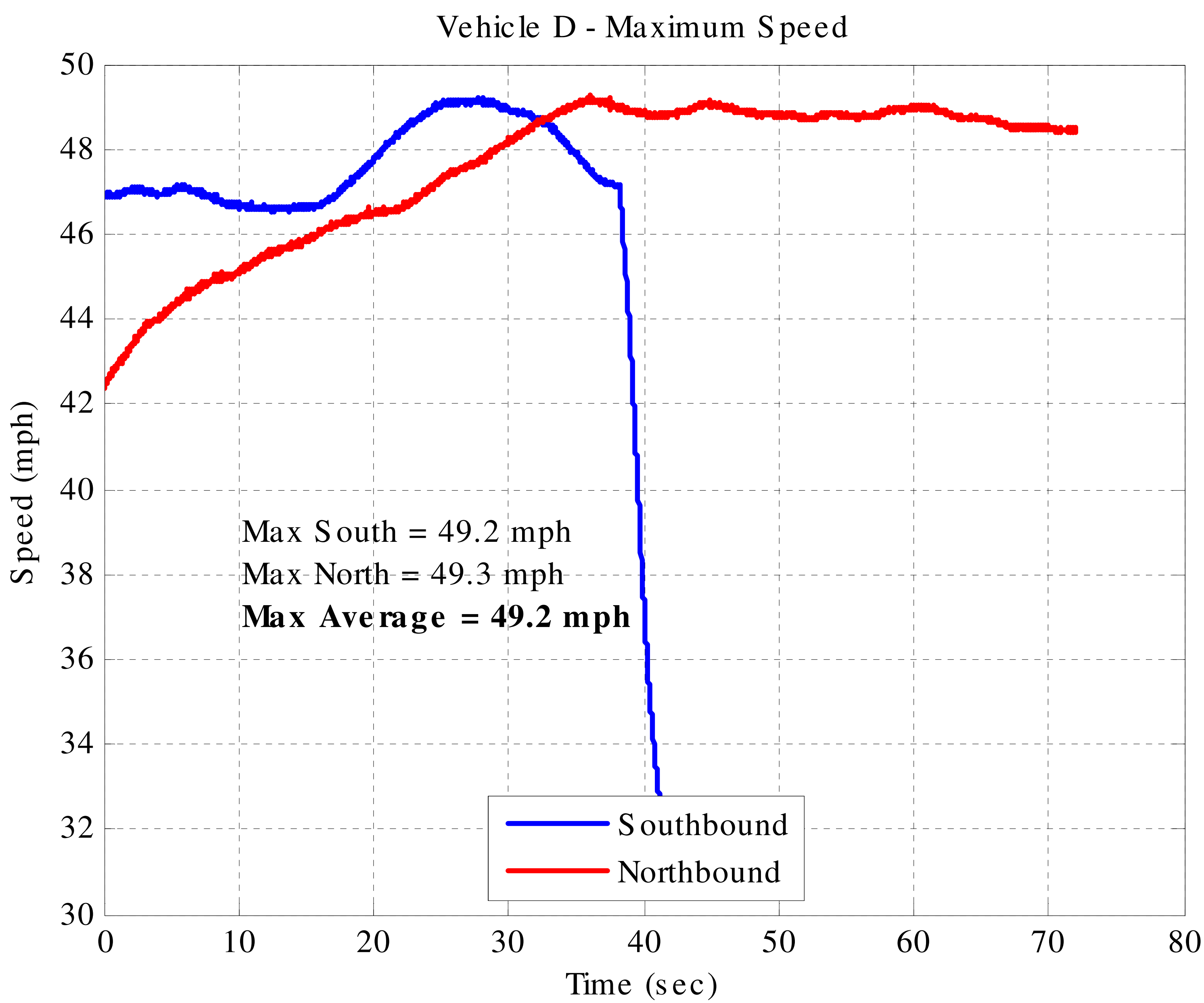

Vehicle I - GVWR
Run 1845 - Flick Test Right
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

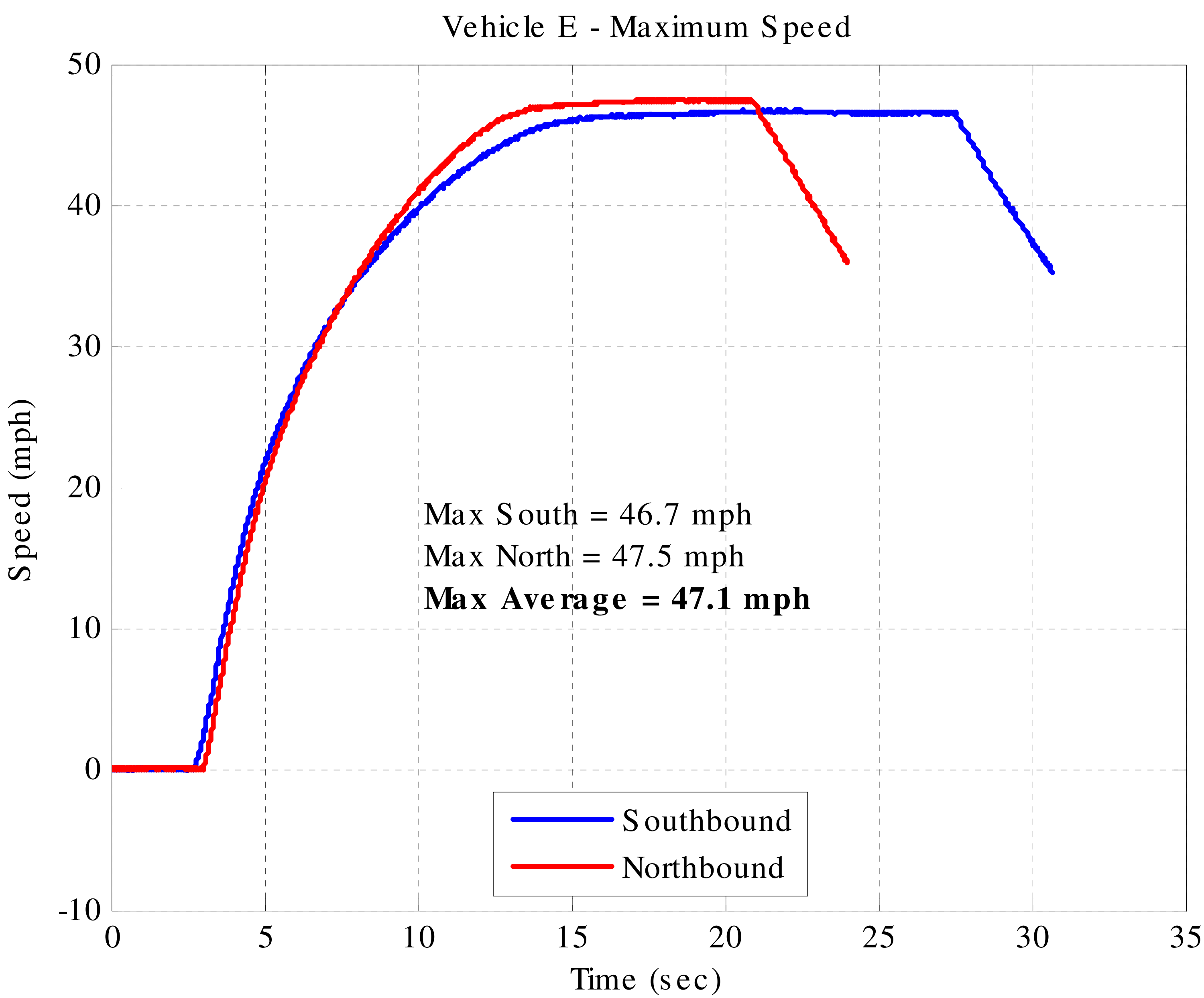

Vehicle I - GVWR
Run 1847 - Flick Test Left
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

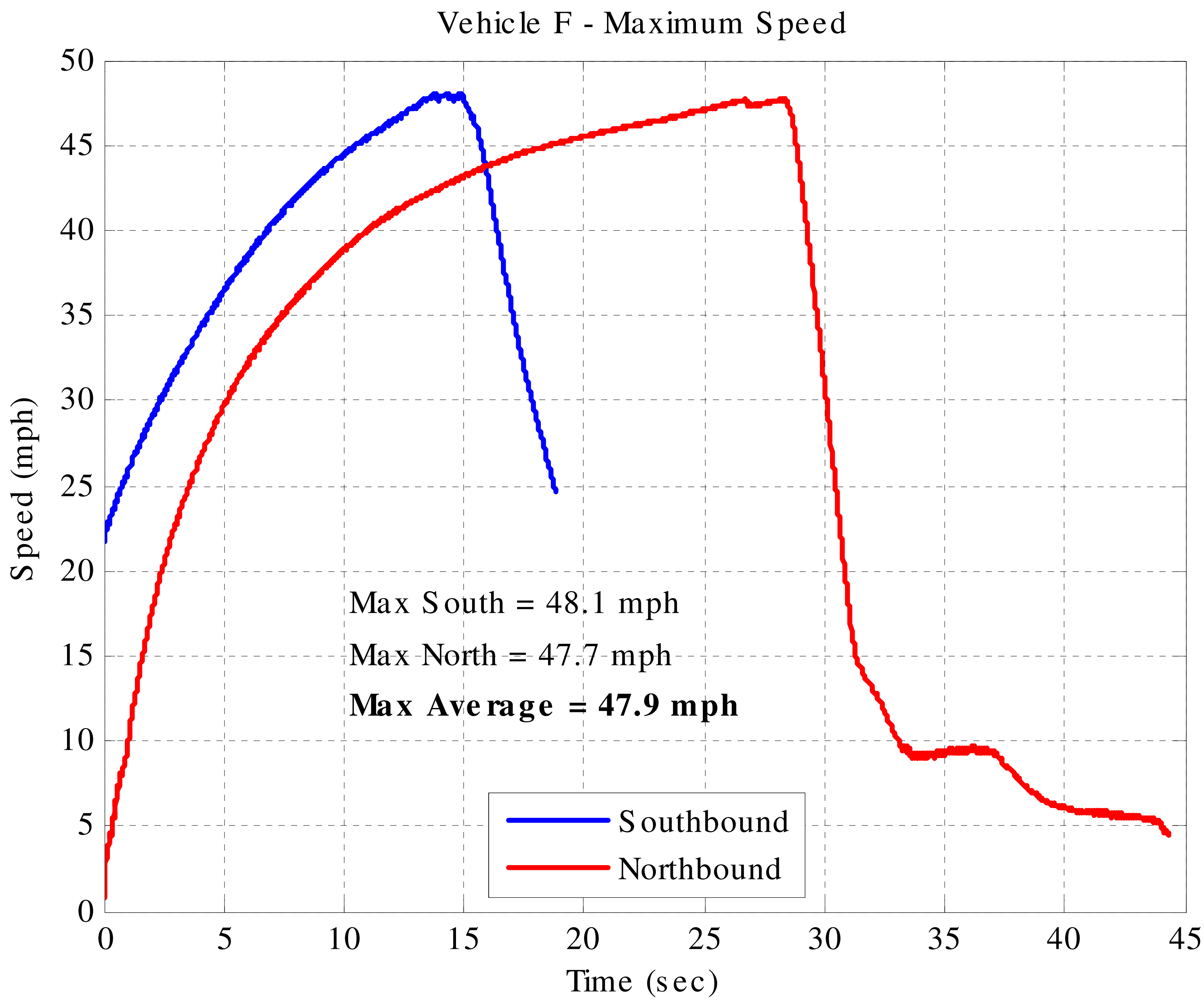

Vehicle A - Maximum Speed
Speed (mph)
Time (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
Max South = 39.3 mph
Max North = 38.8 mph
Max Average = 39.1 mph
Southbound
Northbound

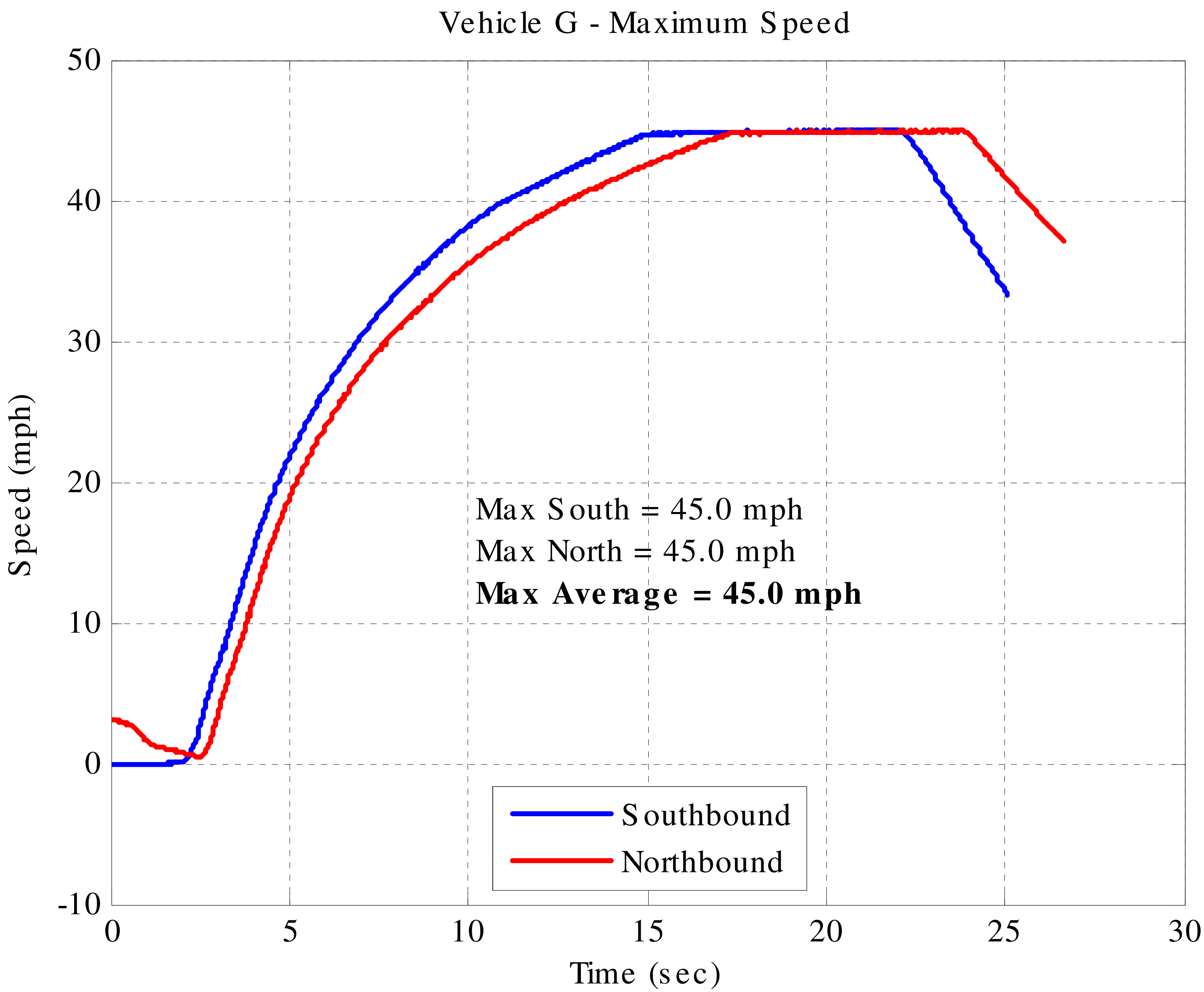

Vehicle B - Maximum Speed
Speed (mph)
60
50
40
30
20
10
0
-10
0
5
10
15
20
25
Time (sec)
Max South = 52.3 mph
Max North = 52.3 mph
Max Average = 52.3 mph
Southbound
Northbound


Vehicle C - Maximum Speed
Speed (mph)
Time (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
Max South = 38.5 mph
Max North = 38.4 mph
Max Average = 38.4 mph
Southbound
Northbound

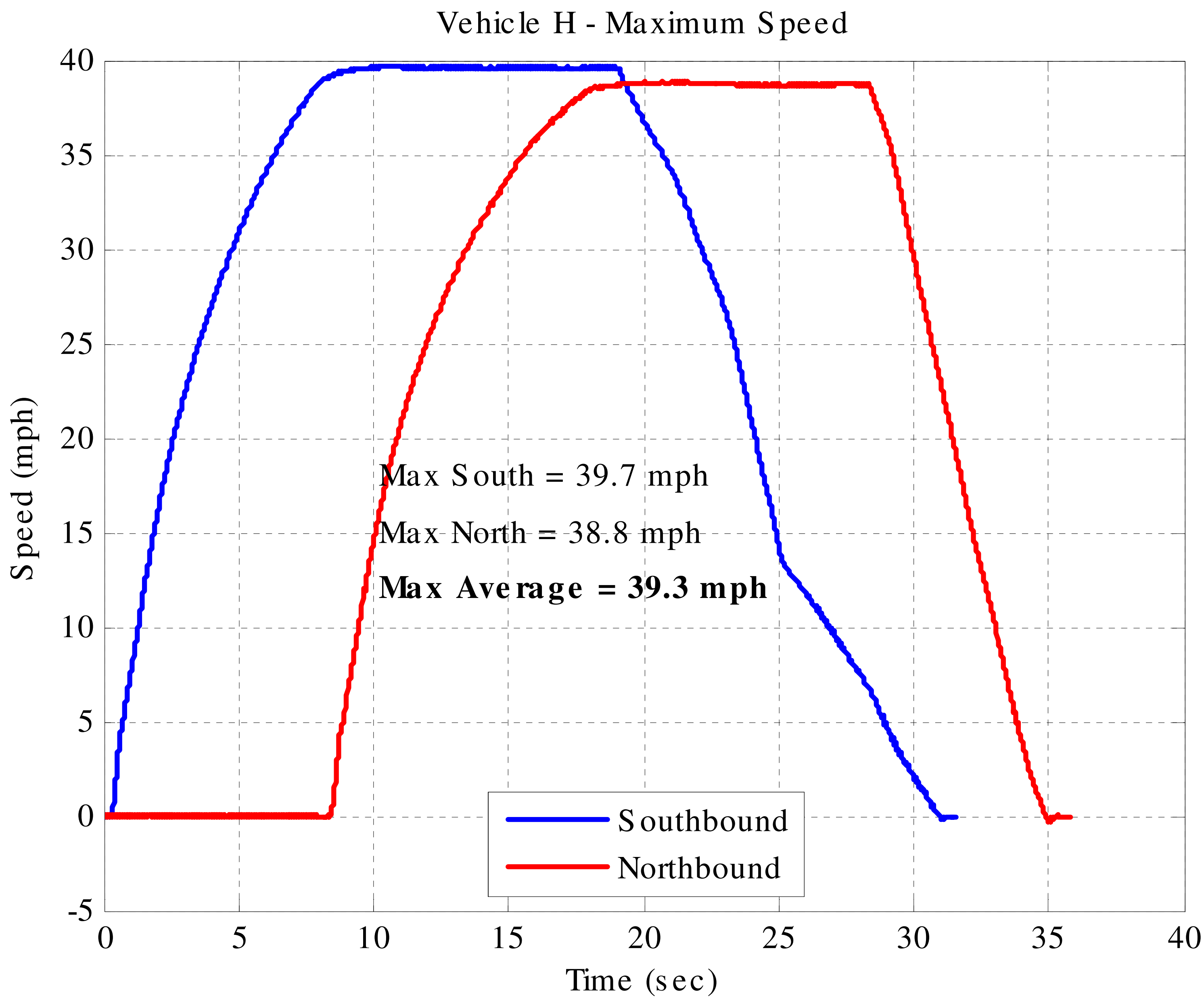

Vehicle D - Maximum Speed
Speed (mph)
Time (sec)
50
48
46
44
42
40
38
36
34
32
30
0
10
20
30
40
50
60
70
80
Max South = 49.2 mph
Max North = 49.3 mph
Max Average = 49.2 mph
Southbound
Northbound

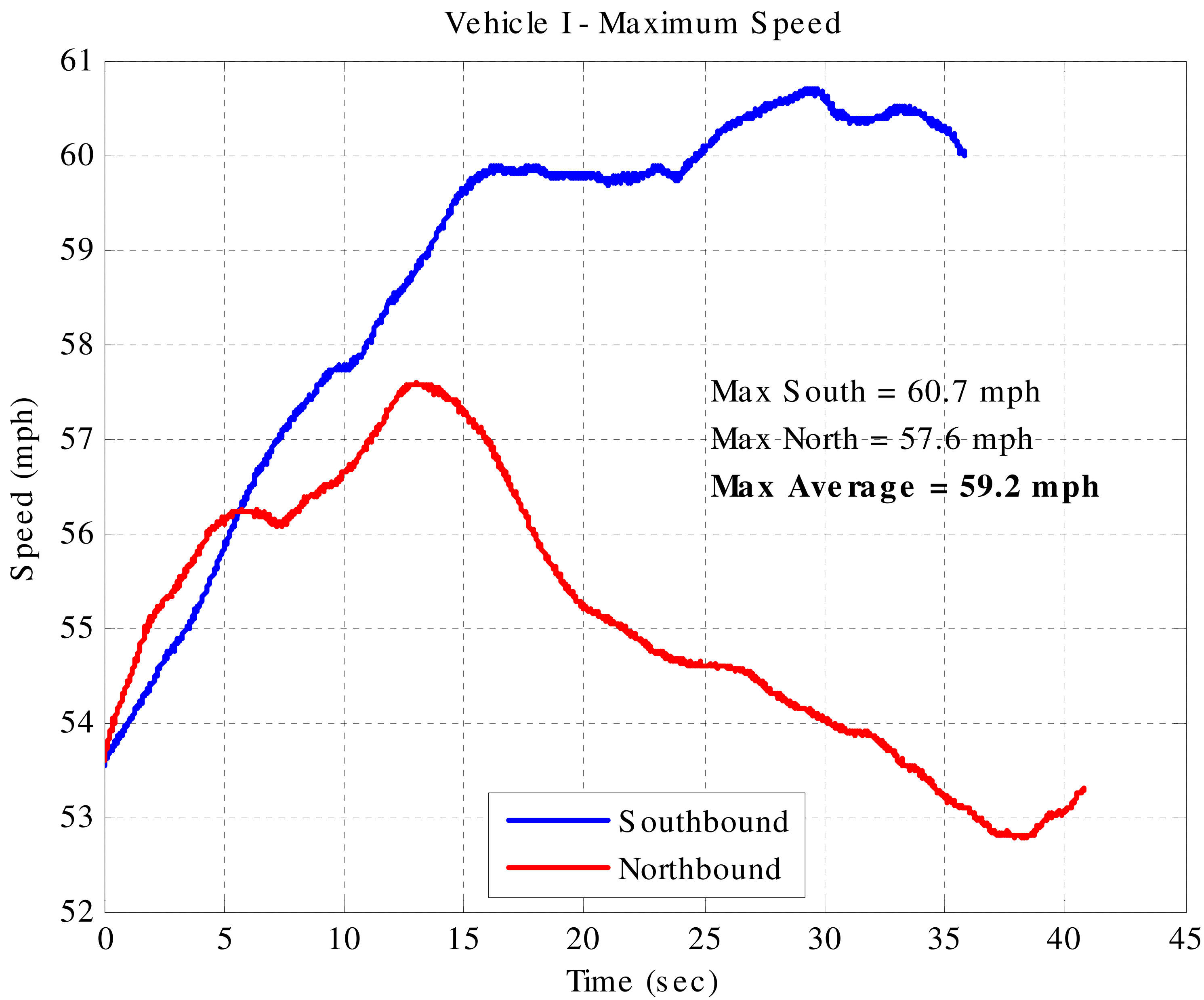

Vehicle E - Maximum Speed
Speed (mph)
Time (sec)
50
40
30
20
10
0
-10
0
5
10
15
20
25
30
35
Max South = 46.7 mph
Max North = 47.5 mph
Max Average = 47.1 mph
Southbound
Northbound

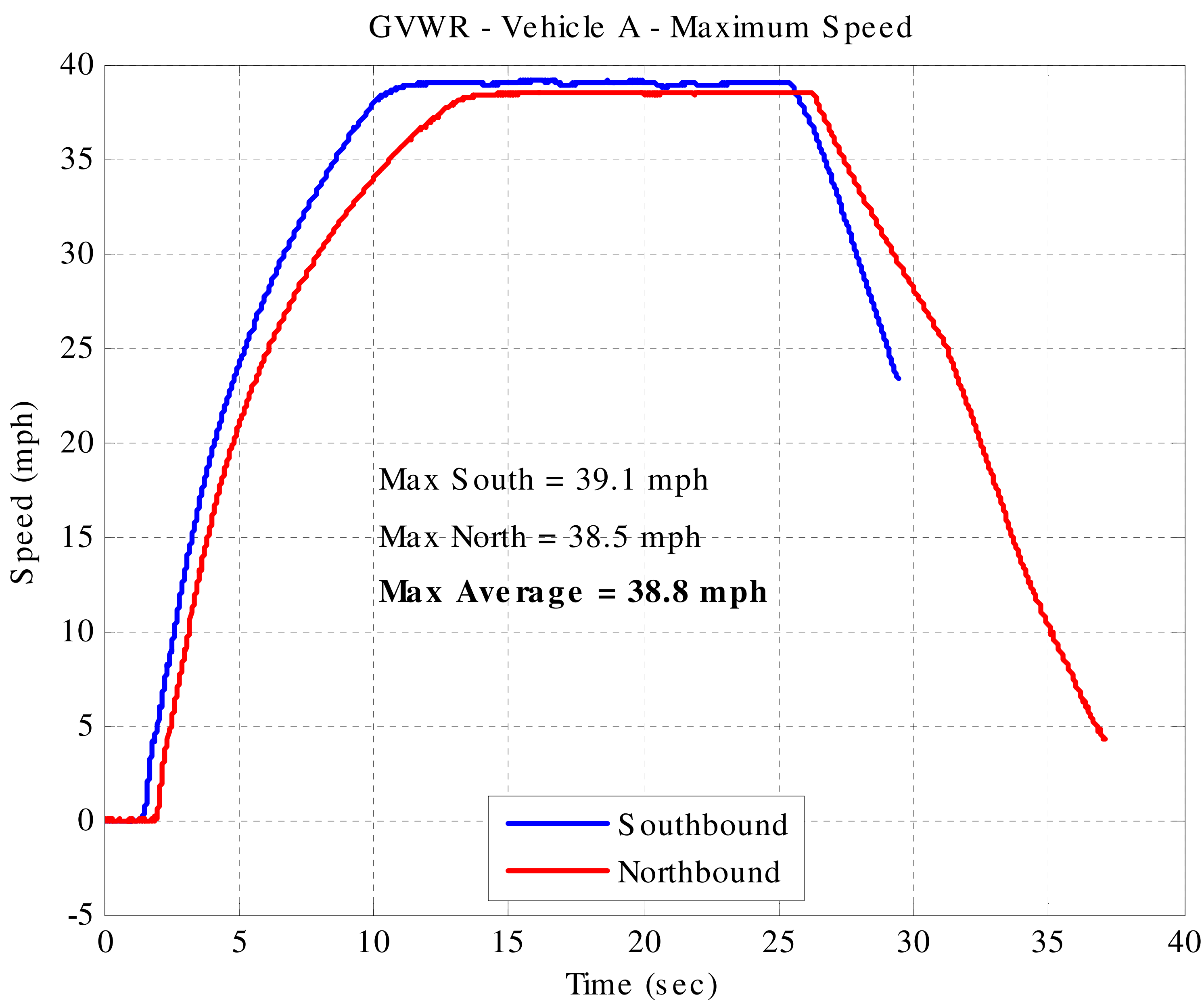

Vehicle F - Maximum Speed
Speed (mph)
0
5
10
15
20
25
30
35
40
45
50
Time (sec)
0
5
10
15
20
25
30
35
40
45
Max South = 48.1 mph
Max North = 47.7 mph
Max Average = 47.9 mph
Southbound
Northbound

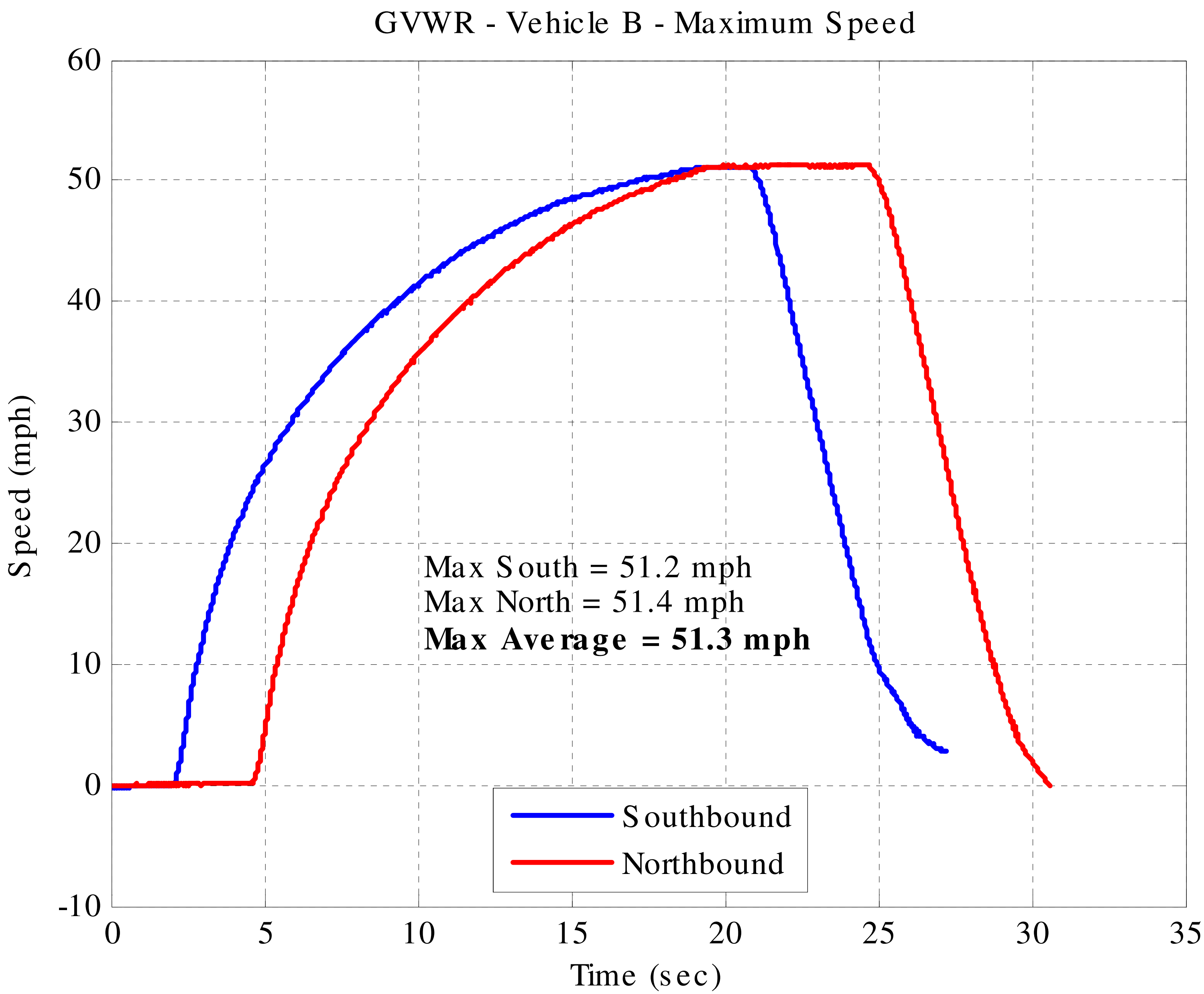


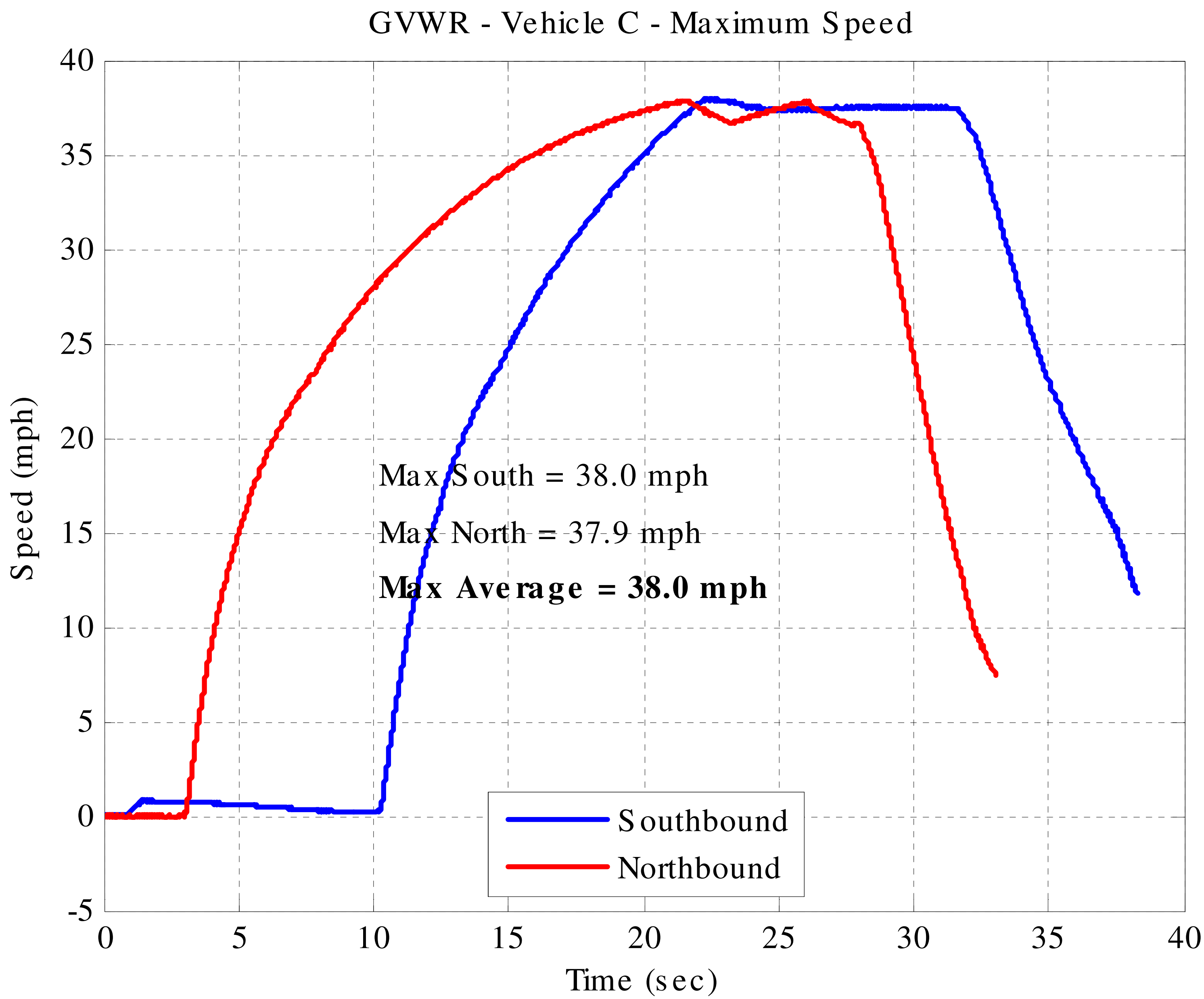
Vehicle G - Maximum Speed
Speed (mph)
Time (sec)
50
40
30
20
10
0
-10
0
5
10
15
20
25
30
Max South = 45.0 mph
Max North = 45.0 mph
Max Average = 45.0 mph
Southbound
Northbound

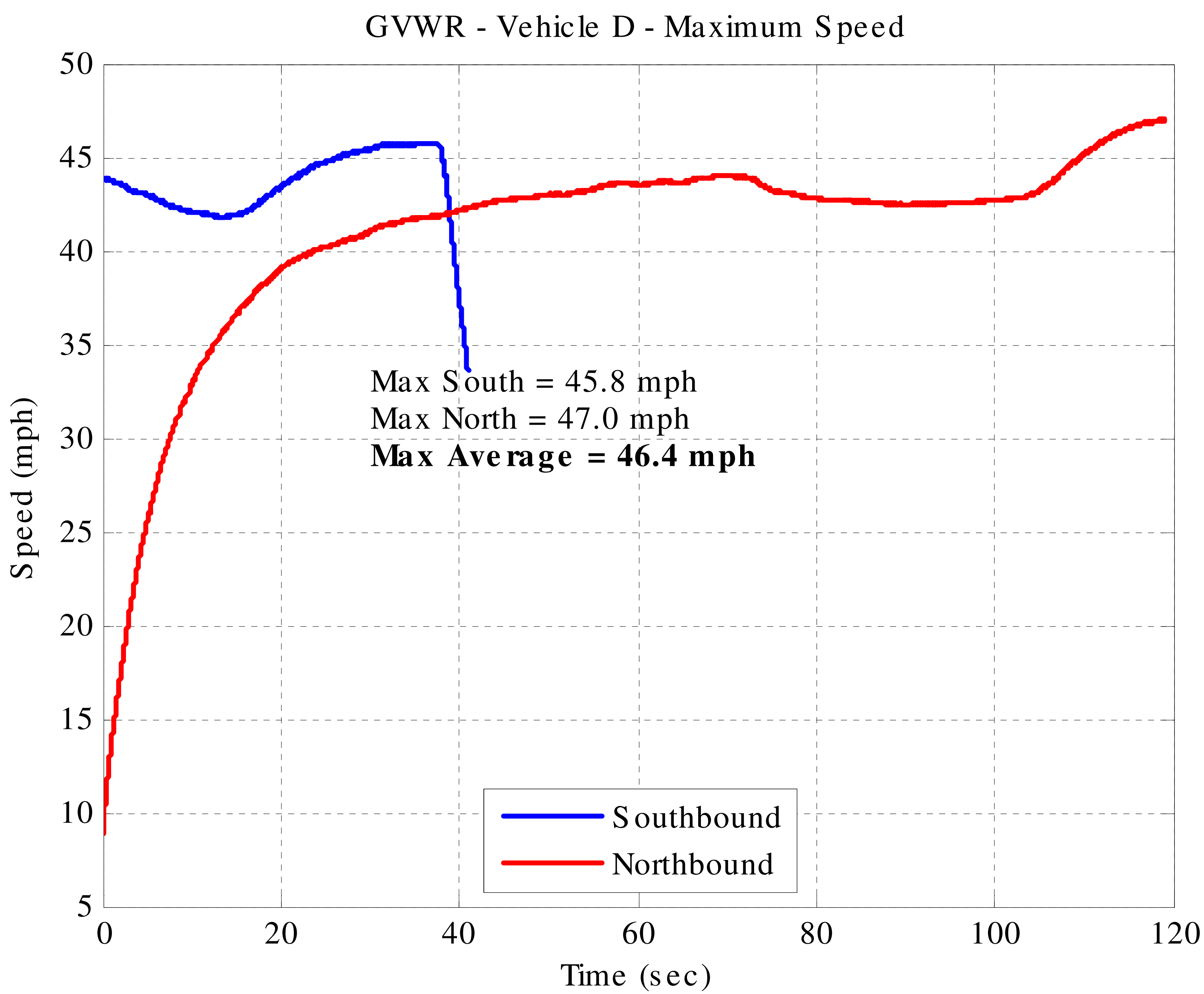

Vehicle H - Maximum Speed
40
35
30
25
20
15
10
5
0
-5
Speed (mph)
0
5
10
15
20
25
30
35
40
Time (sec)
Max South = 39.7 mph
Max North = 38.8 mph
Max Average = 39.3 mph
Southbound
Northbound

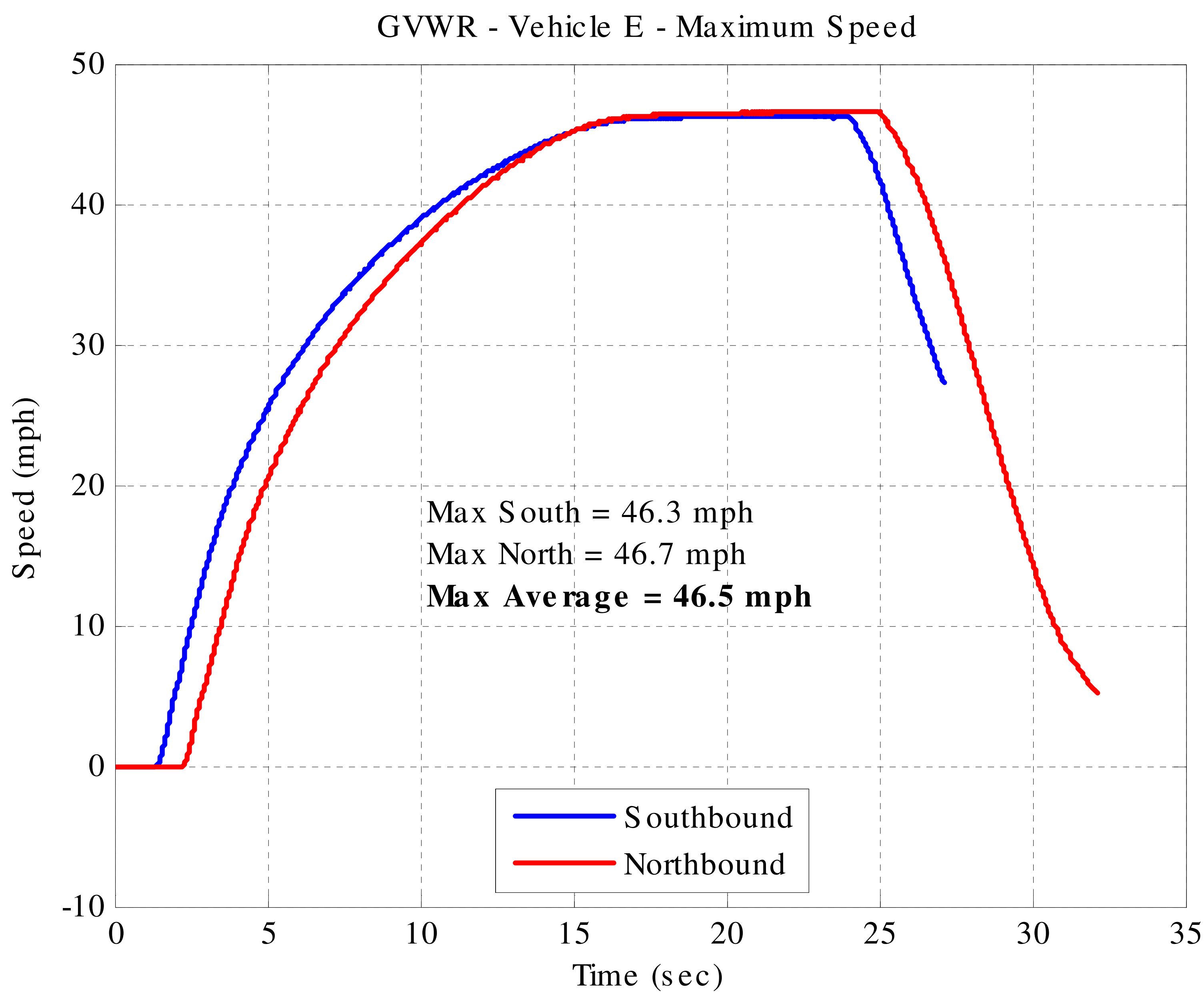

Vehicle I - Maximum Speed
Speed (mph)
Time (sec)
61
60
59
58
57
56
55
54
53
52
0
5
10
15
20
25
30
35
40
45
Max South = 60.7 mph
Max North = 57.6 mph
Max Average = 59.2 mph
Southbound
Northbound

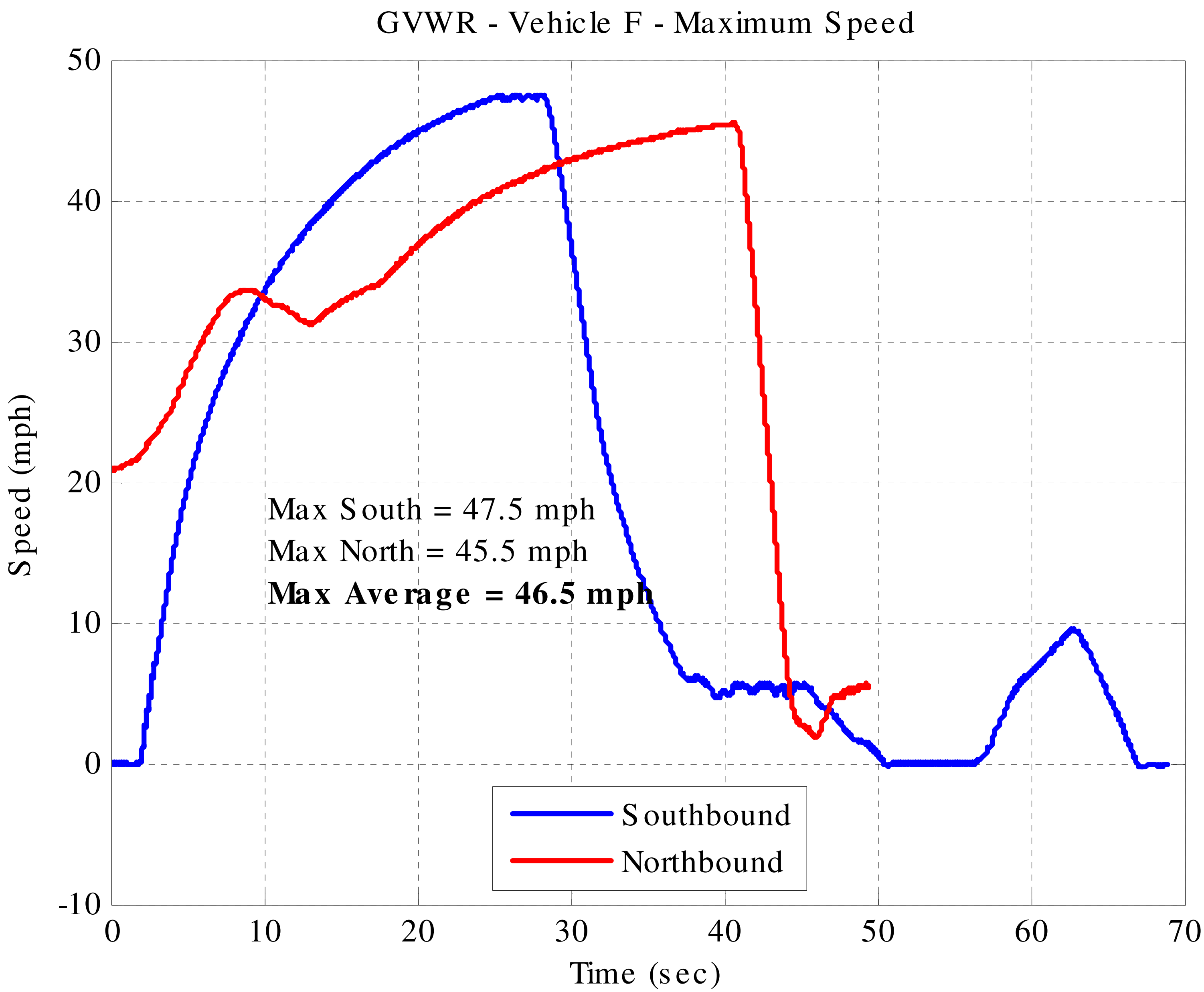

GVWR - Vehicle A - Maximum Speed
Max South = 39.1 mph
Max North = 38.5 mph
Max Average = 38.8 mph
Southbound
Northbound
Speed (mph)
Time (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40


GVWR - Vehicle B - Maximum Speed
Speed (mph)
Time (sec)
Max South = 51.2 mph
Max North = 51.4 mph
Max Average = 51.3 mph
Southbound
Northbound
60
50
40
30
20
10
0
-10
0
5
10
15
20
25
30
35

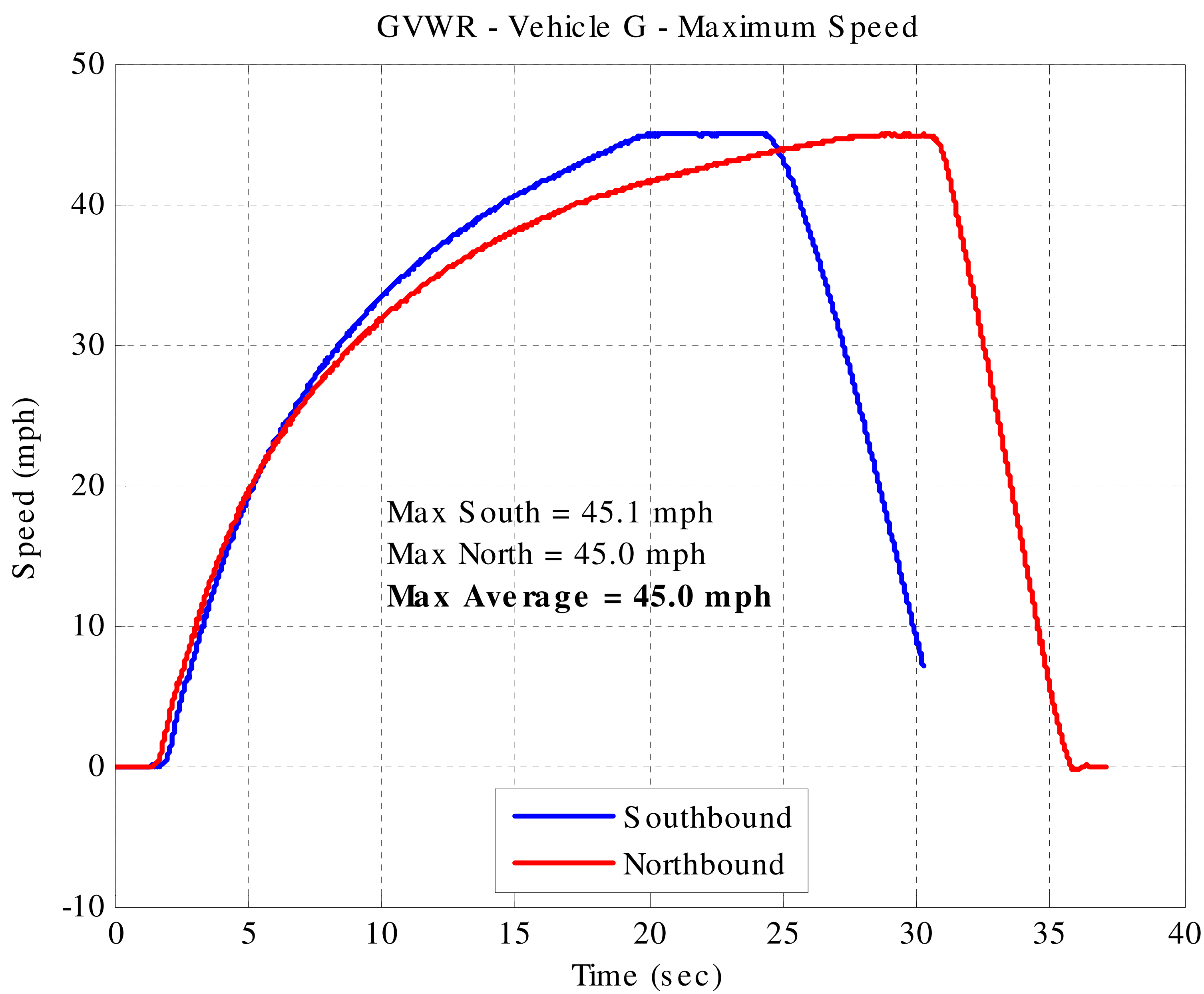

GVWR - Vehicle C - Maximum Speed
Speed (mph)
Time (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40
Max South = 38.0 mph
Max North = 37.9 mph
Max Average = 38.0 mph
Southbound
Northbound

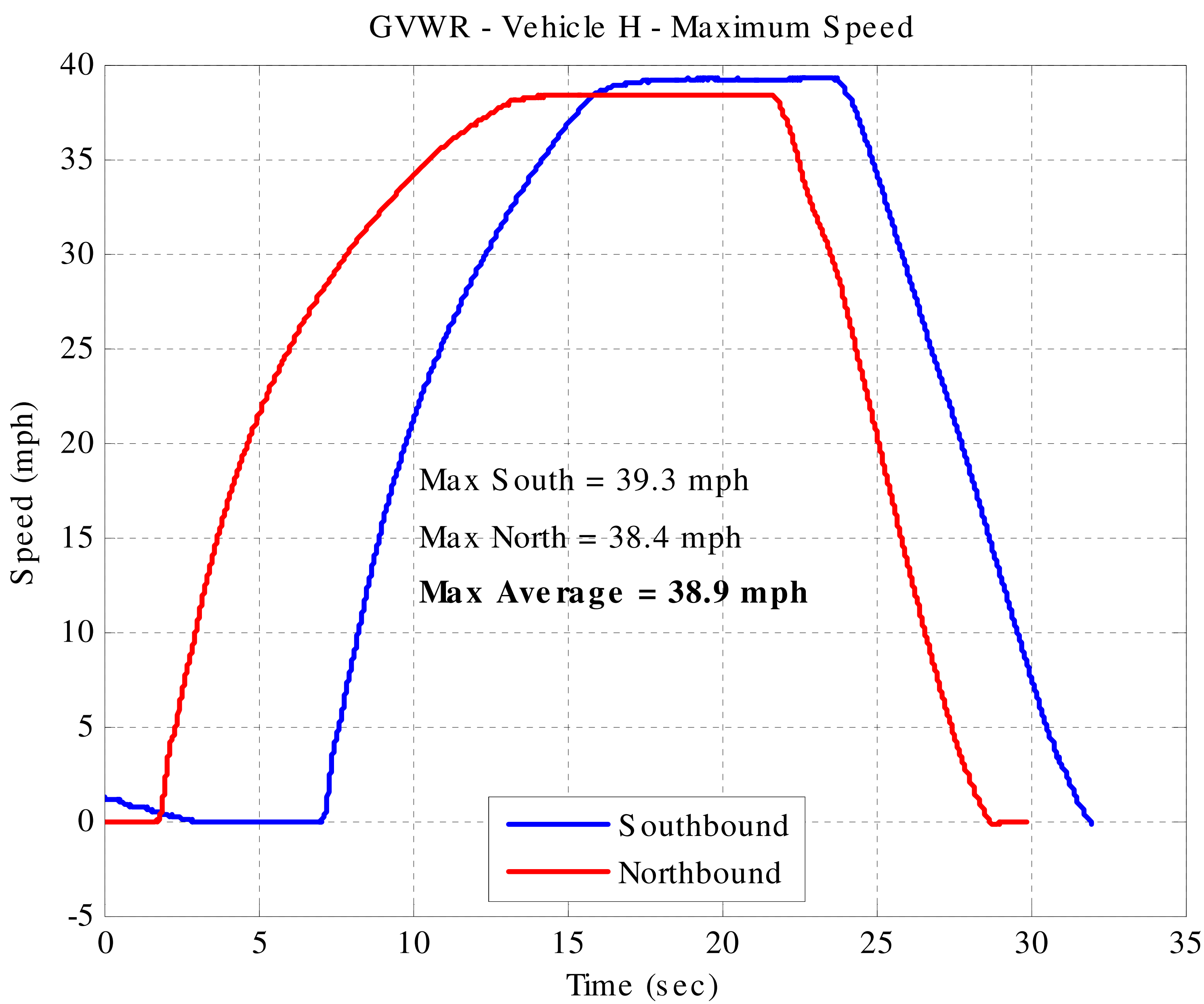

GVWR - Vehicle D - Maximum Speed
Speed (mph)
Time (sec)
50
45
40
35
30
25
20
15
10
5
0
20
40
60
80
100
120
Max South = 45.8 mph
Max North = 47.0 mph
Max Average = 46.4 mph
Southbound
Northbound

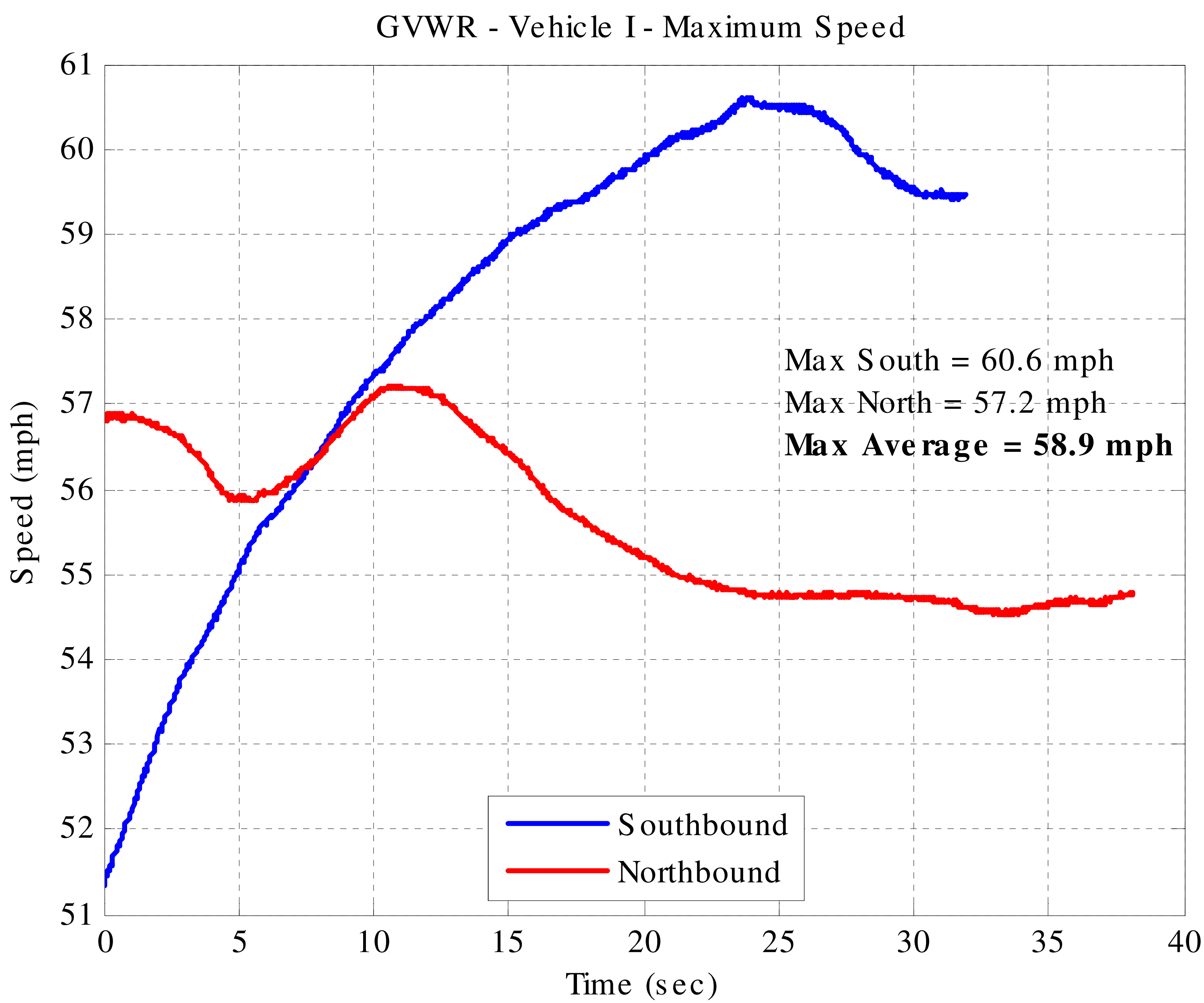

GVWR - Vehicle E - Maximum Speed
Speed (mph)
50
40
30
20
10
0
-10
0
5
10
15
20
25
30
35
Time (sec)
Max South = 46.3 mph
Max North = 46.7 mph
Max Average = 46.5 mph
Southbound
Northbound

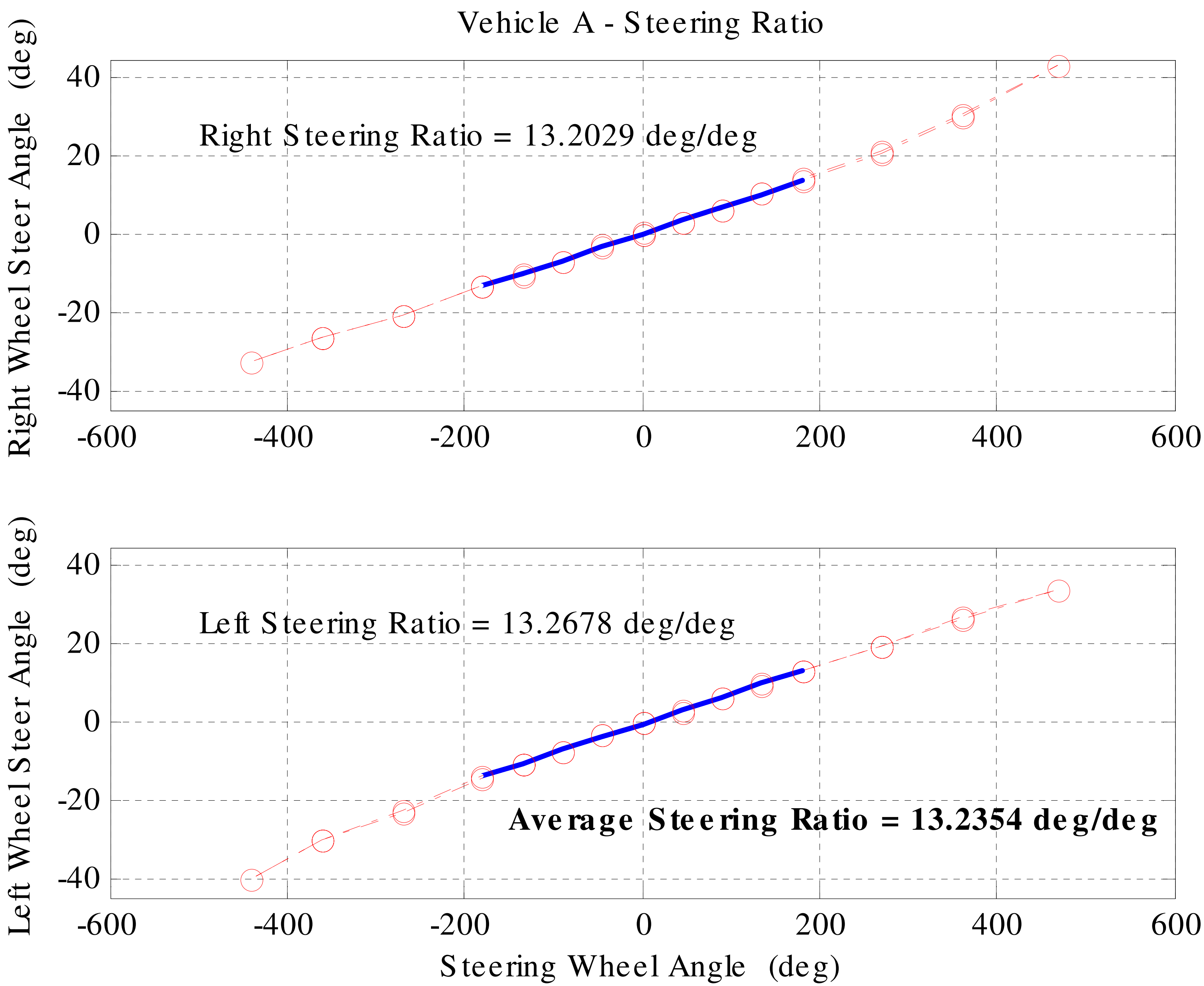


GVWR - Vehicle F - Maximum Speed
Speed (mph)
Time (sec)
50
40
30
20
10
0
-10
0
10
20
30
40
50
60
70
Max South = 47.5 mph
Max North = 45.5 mph
Max Average = 46.5 mph
Southbound
Northbound

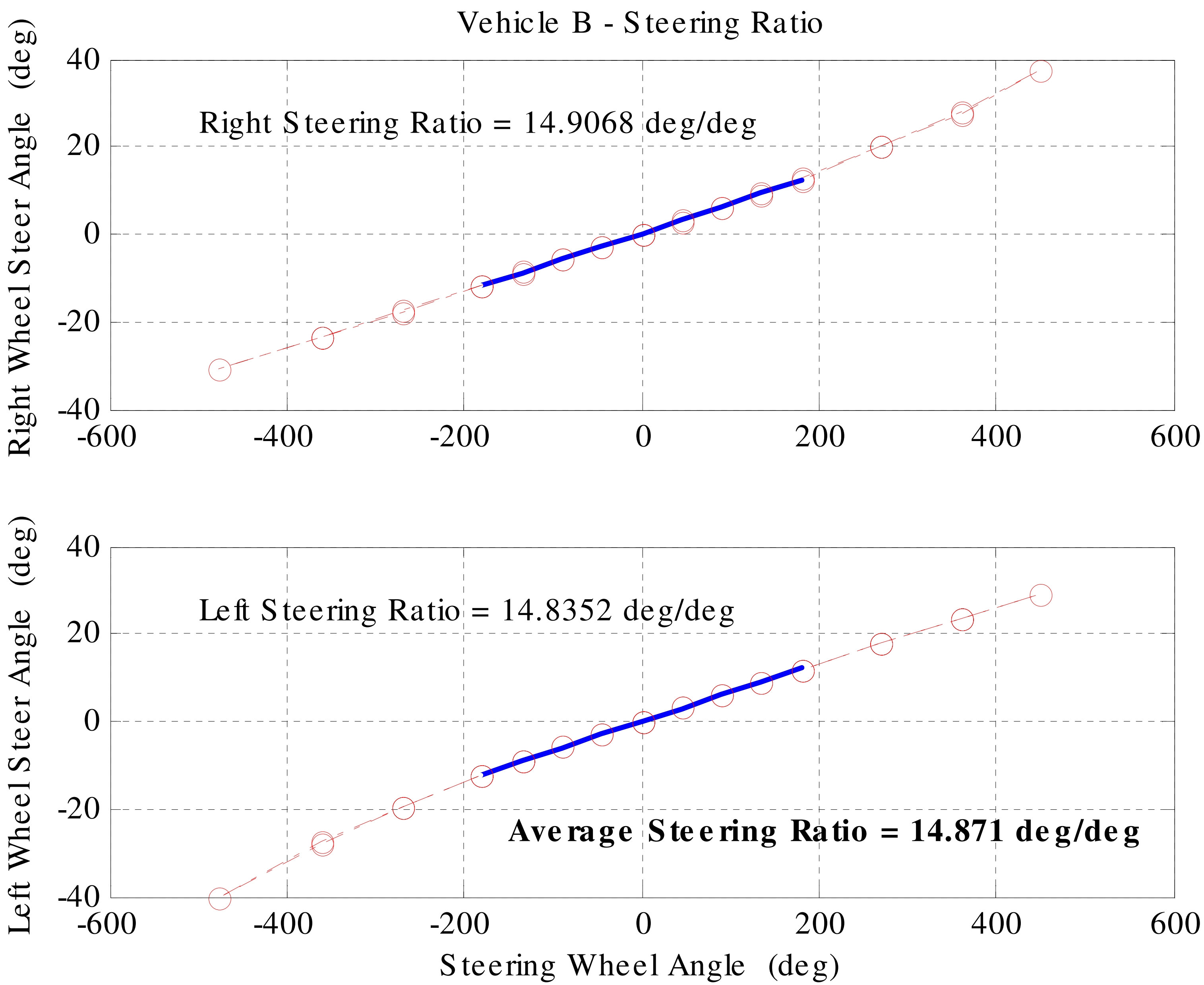

GVWR - Vehicle G - Maximum Speed
Speed (mph)
Time (sec)
50
40
30
20
10
0
-10
0
5
10
15
20
25
30
35
40
Max South = 45.1 mph
Max North = 45.0 mph
Max Average = 45.0 mph
Southbound
Northbound

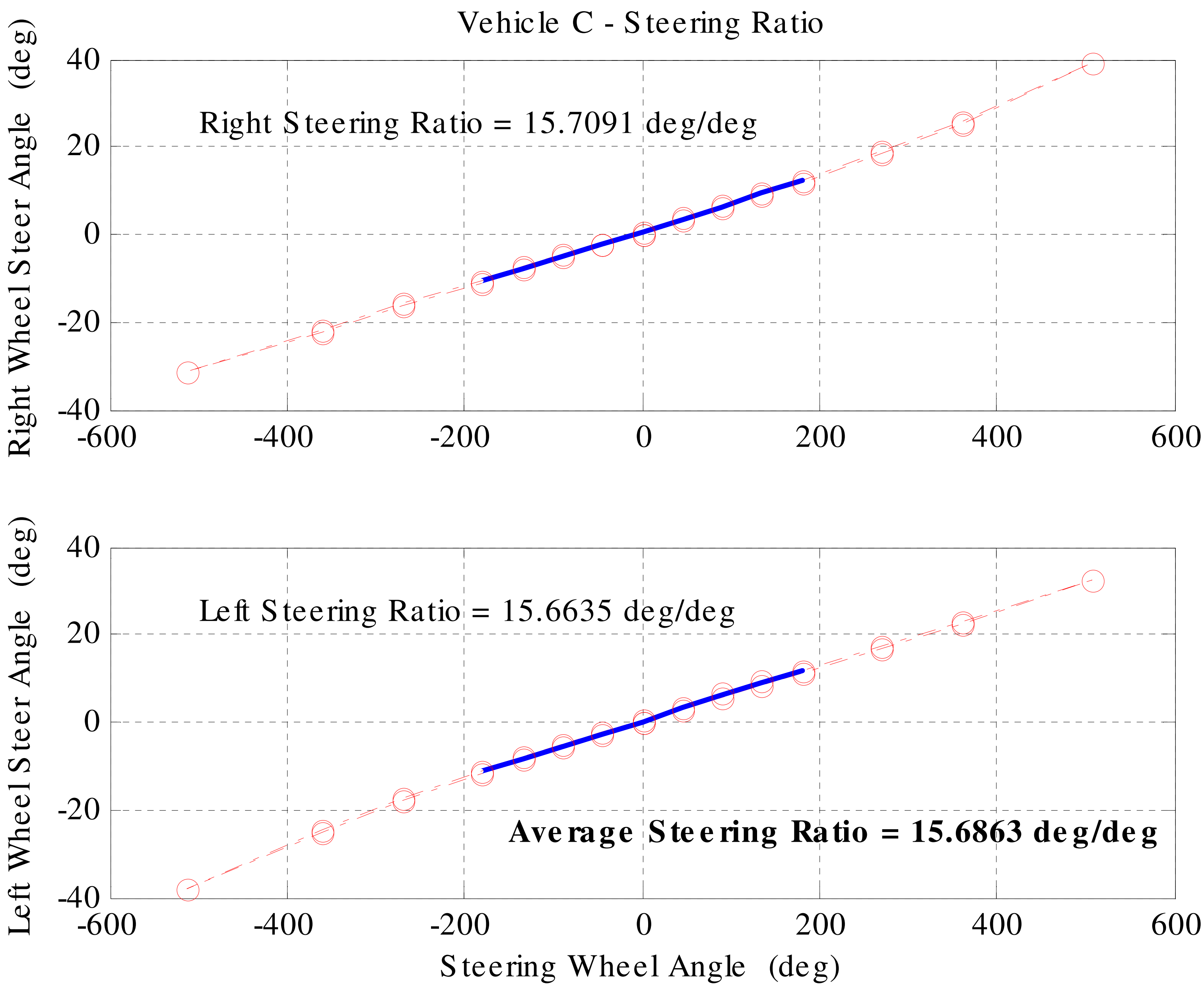

GVWR - Vehicle H - Maximum Speed
Speed (mph)
Time (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
Max South = 39.3 mph
Max North = 38.4 mph
Max Average = 38.9 mph
Southbound
Northbound


GVWR - Vehicle I - Maximum Speed
Max South = 60.6 mph
Max North = 57.2 mph
Max Average = 58.9 mph
Southbound
Northbound
Speed (mph)
Time (sec)
61
60
59
58
57
56
55
54
53
52
51
0
5
10
15
20
25
30
35
40

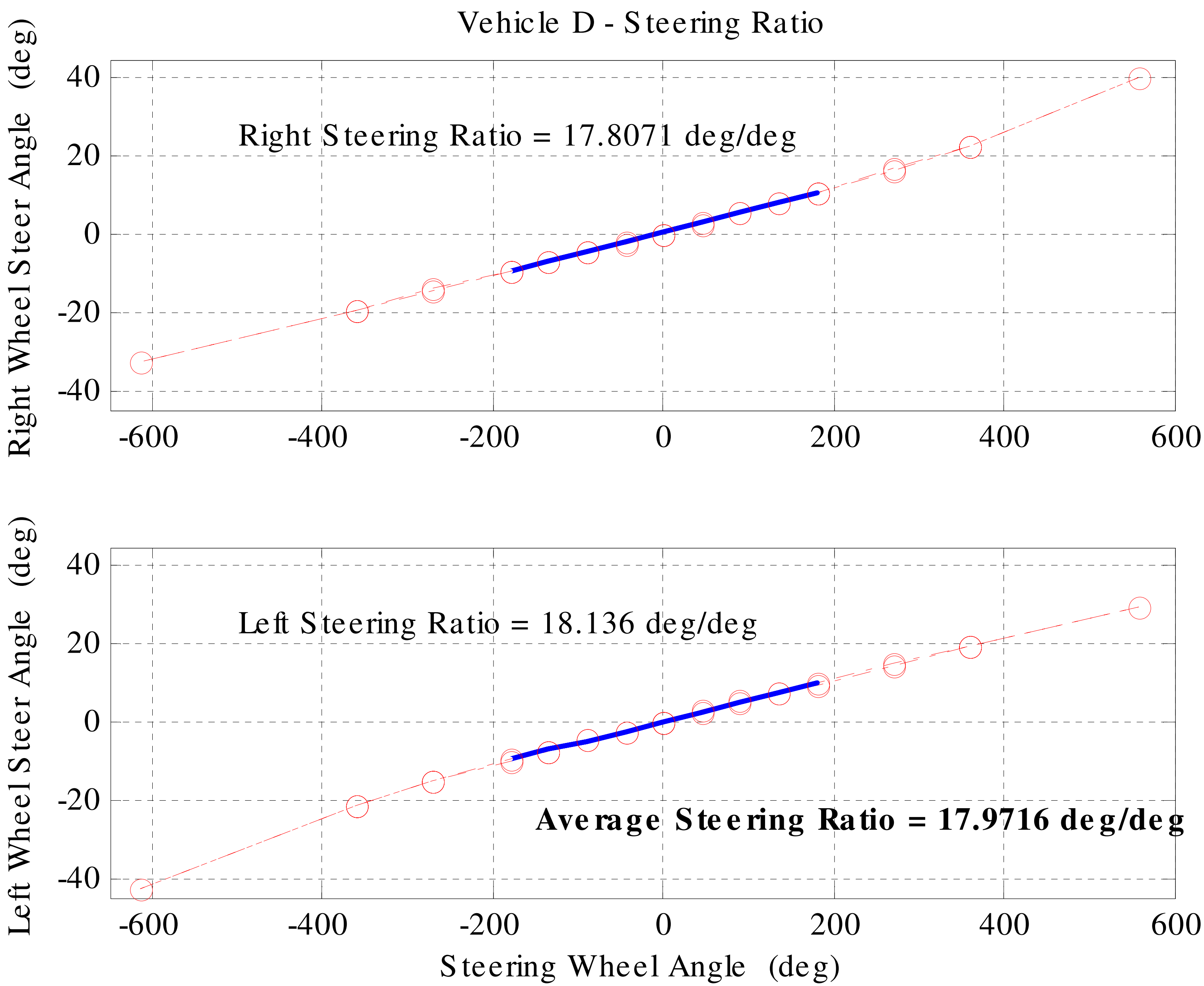


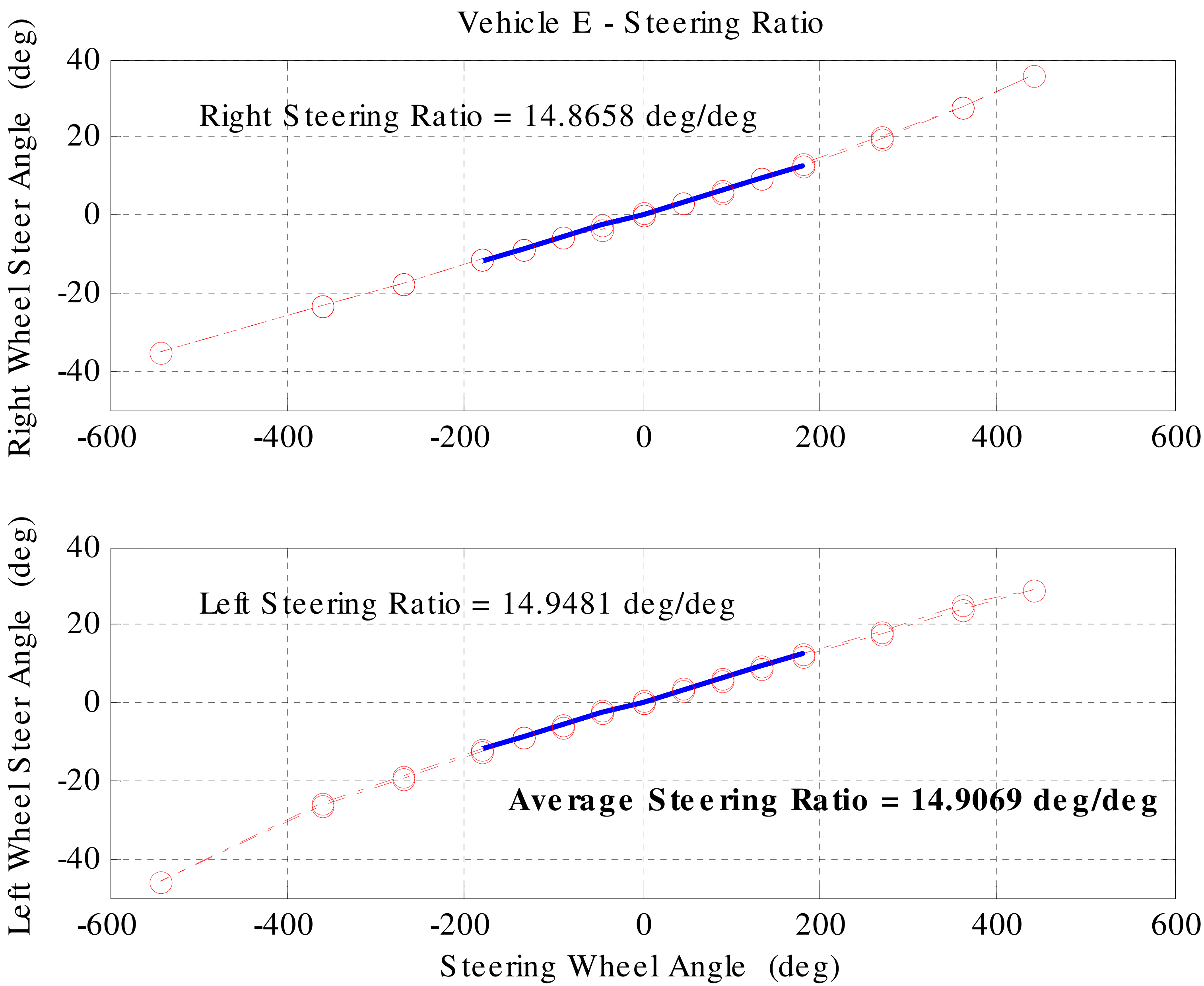
Vehicle A - Steering Ratio
Right Steering Ratio = 13.2029 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 13.2678 deg/deg
Average Steering Ratio = 13.2354 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

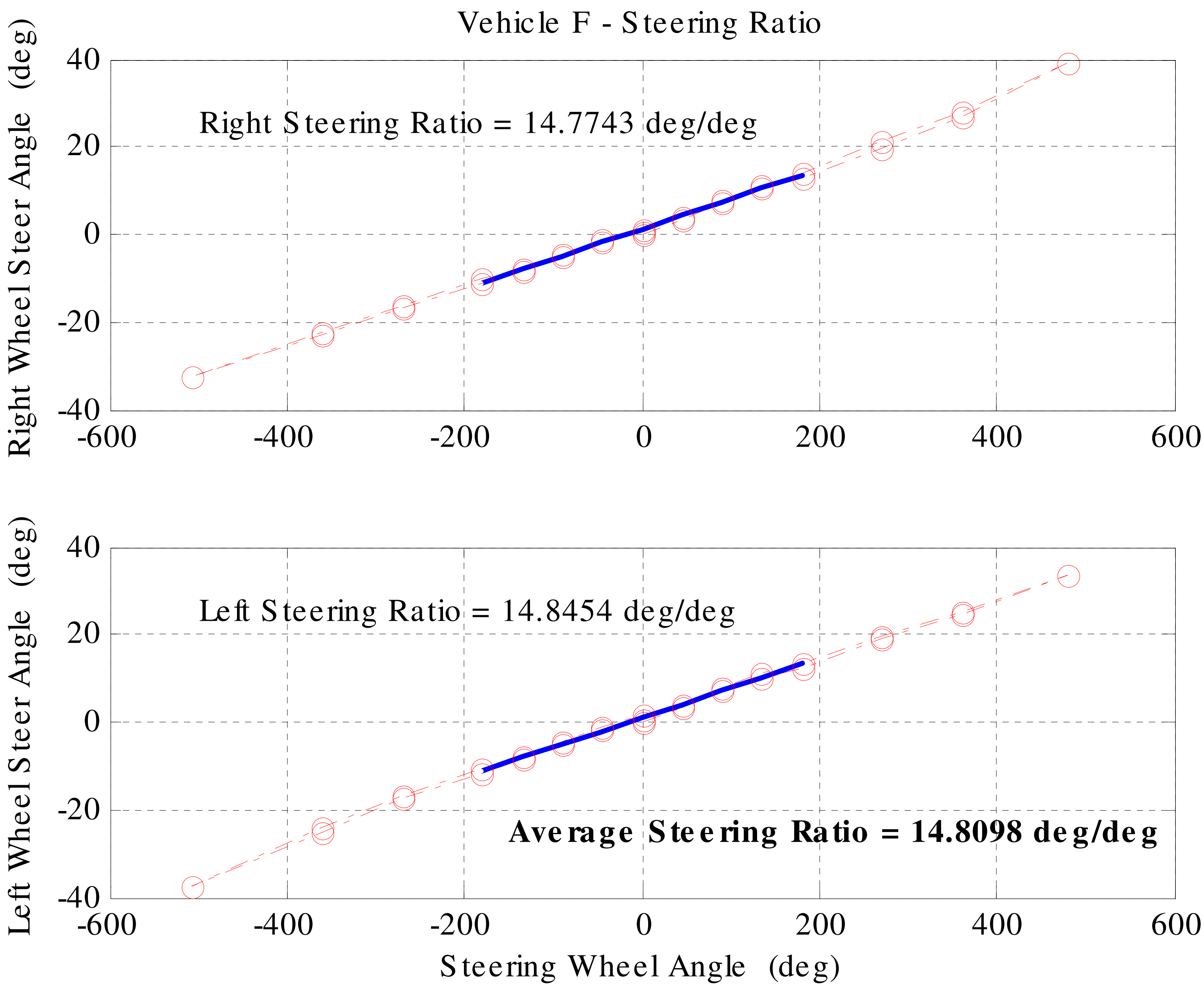

Vehicle B - Steering Ratio
Right Steering Ratio = 14.9068 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 14.8352 deg/deg
Average Steering Ratio = 14.871 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

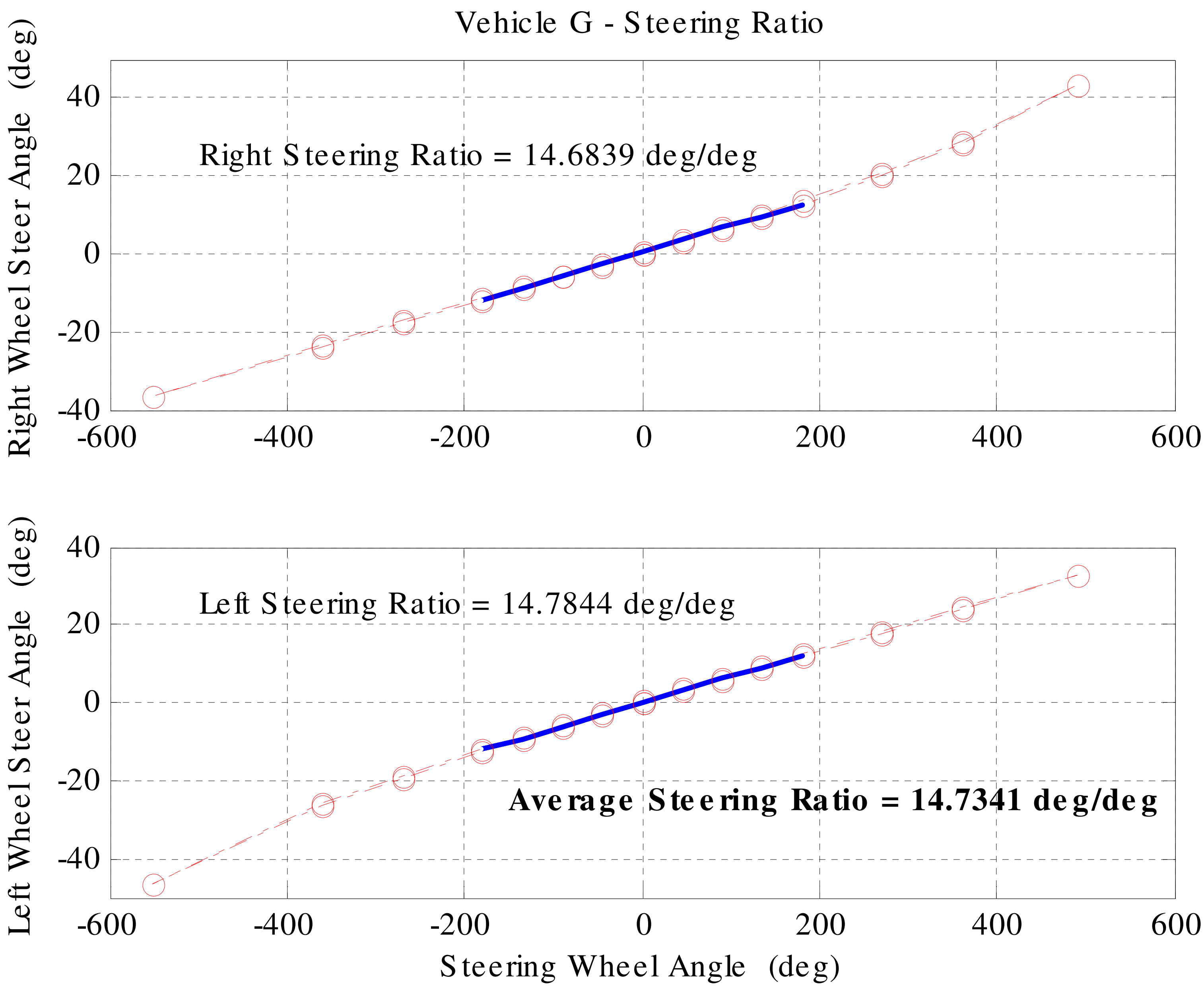


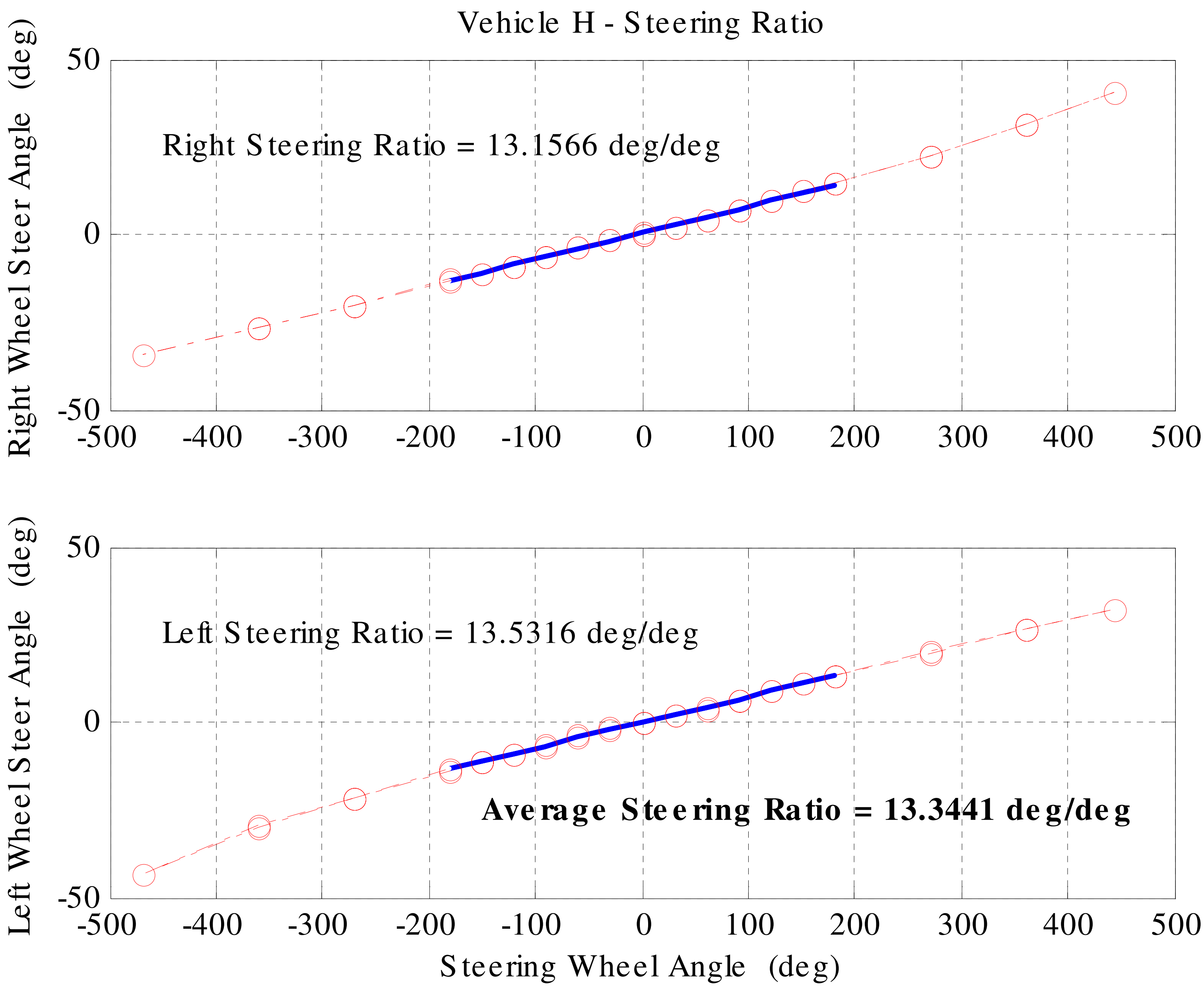
Vehicle C - Steering Ratio
Right Steering Ratio = 15.7091 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 15.6635 deg/deg
Average Steering Ratio = 15.6863 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

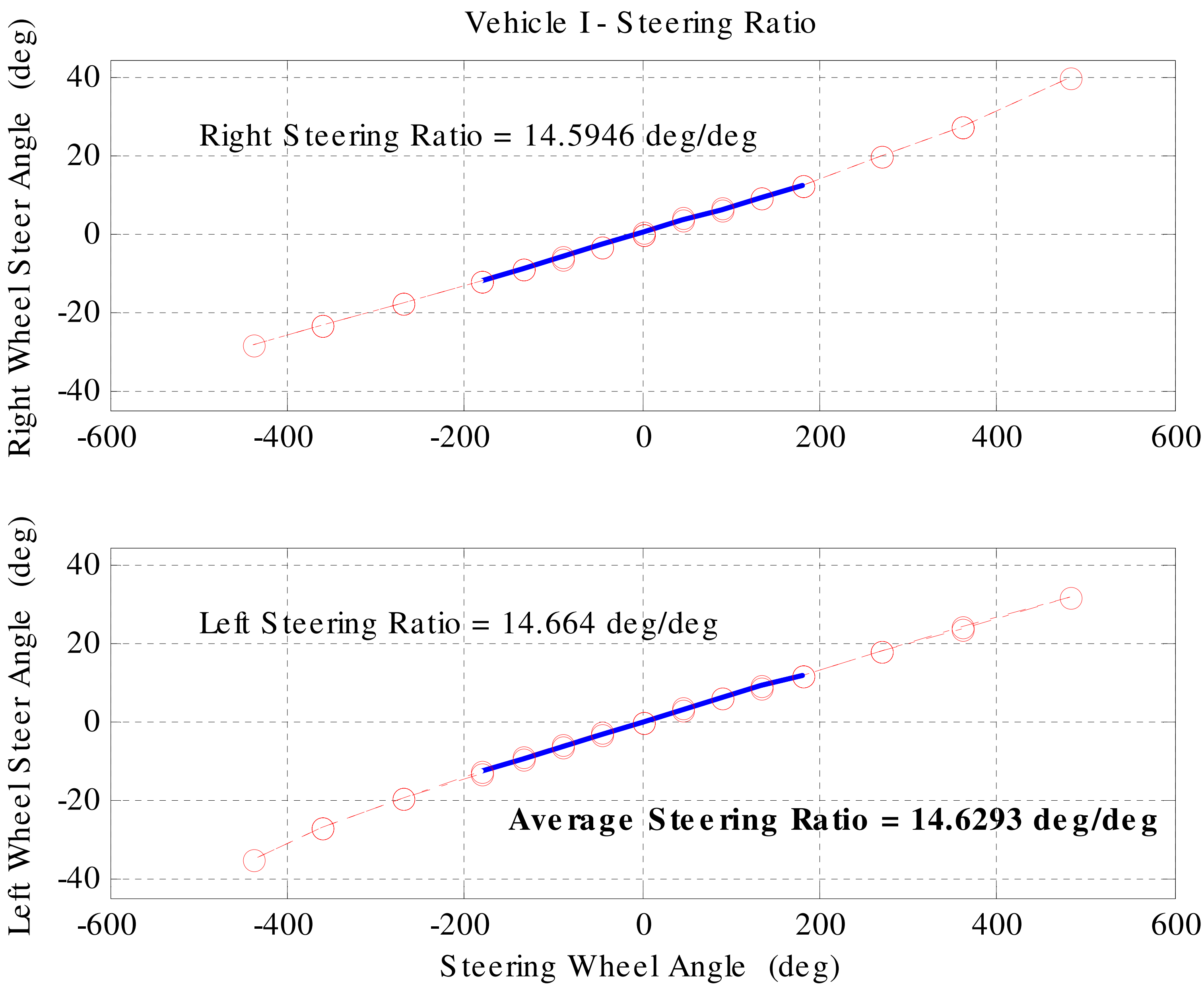

Vehicle D - Steering Ratio
Right Steering Ratio = 17.8071 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 18.136 deg/deg
Average Steering Ratio = 17.9716 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)


Vehicle E - Steering Ratio
Right Steering Ratio = 14.8658 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 14.9481 deg/deg
Average Steering Ratio = 14.9069 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

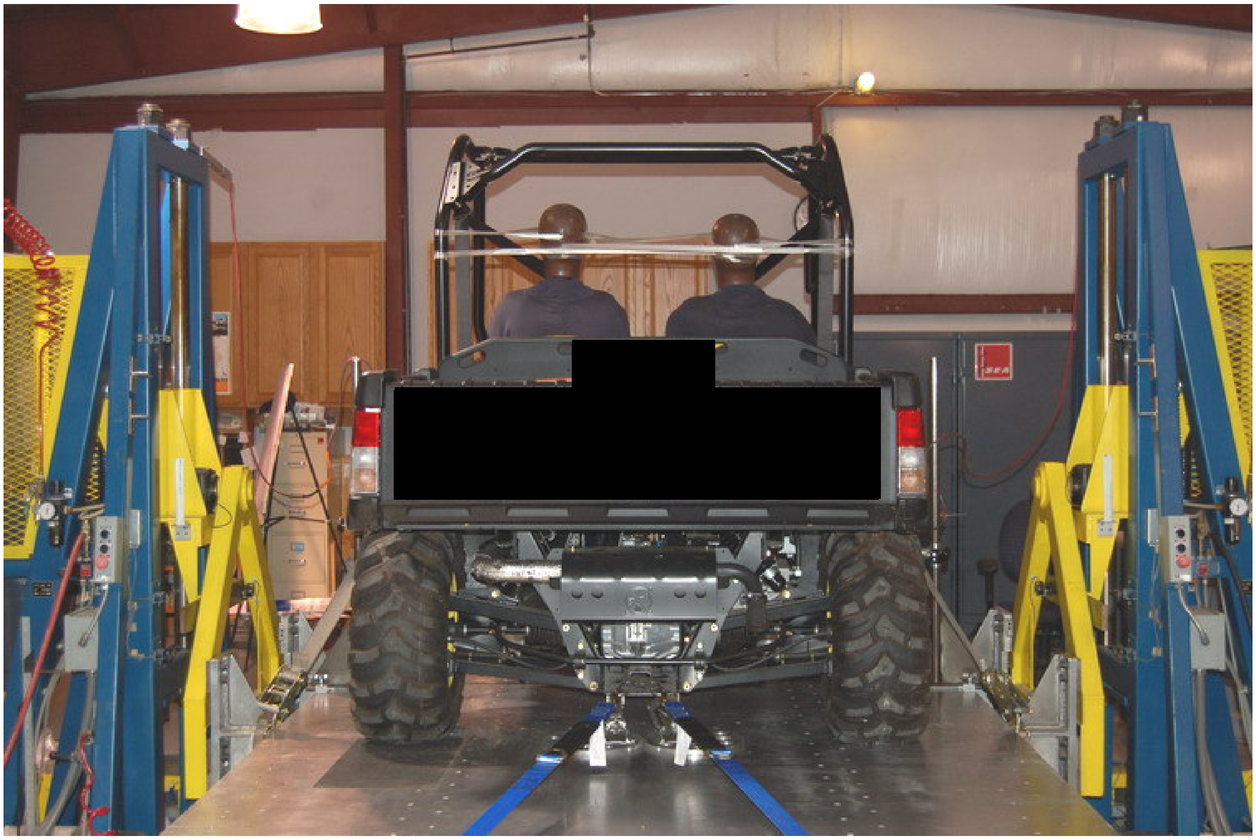

Vehicle F - Steering Ratio
Right Steering Ratio = 14.7743 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 14.8454 deg/deg
Average Steering Ratio = 14.8098 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)


Vehicle G - Steering Ratio
Right Wheel Steer Angle (deg)
Right Steering Ratio = 14.6839 deg/deg
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Wheel Steer Angle (deg)
Left Steering Ratio = 14.7844 deg/deg
Average Steering Ratio = 14.7341 deg/deg
Steering Wheel Angle (deg)


Vehicle H - Steering Ratio
Right Steering Ratio = 13.1566 deg/deg
Right Wheel Steer Angle (deg)
50
0
-50
-500 -400 -300 -200 -100 0 100 200 300 400 500
Left Steering Ratio = 13.5316 deg/deg
Average Steering Ratio = 13.3441 deg/deg
Left Wheel Steer Angle (deg)
50
0
-50
-500 -400 -300 -200 -100 0 100 200 300 400 500
Steering Wheel Angle (deg)



Vehicle I - Steering Ratio
Right Steering Ratio = 14.5946 deg/deg
Right Wheel Steer Angle (deg)
40
20
0
-20
-40
-600
-400
-200
0
200
400
600
Left Steering Ratio = 14.664 deg/deg
Average Steering Ratio = 14.6293 deg/deg
Left Wheel Steer Angle (deg)
Steering Wheel Angle (deg)

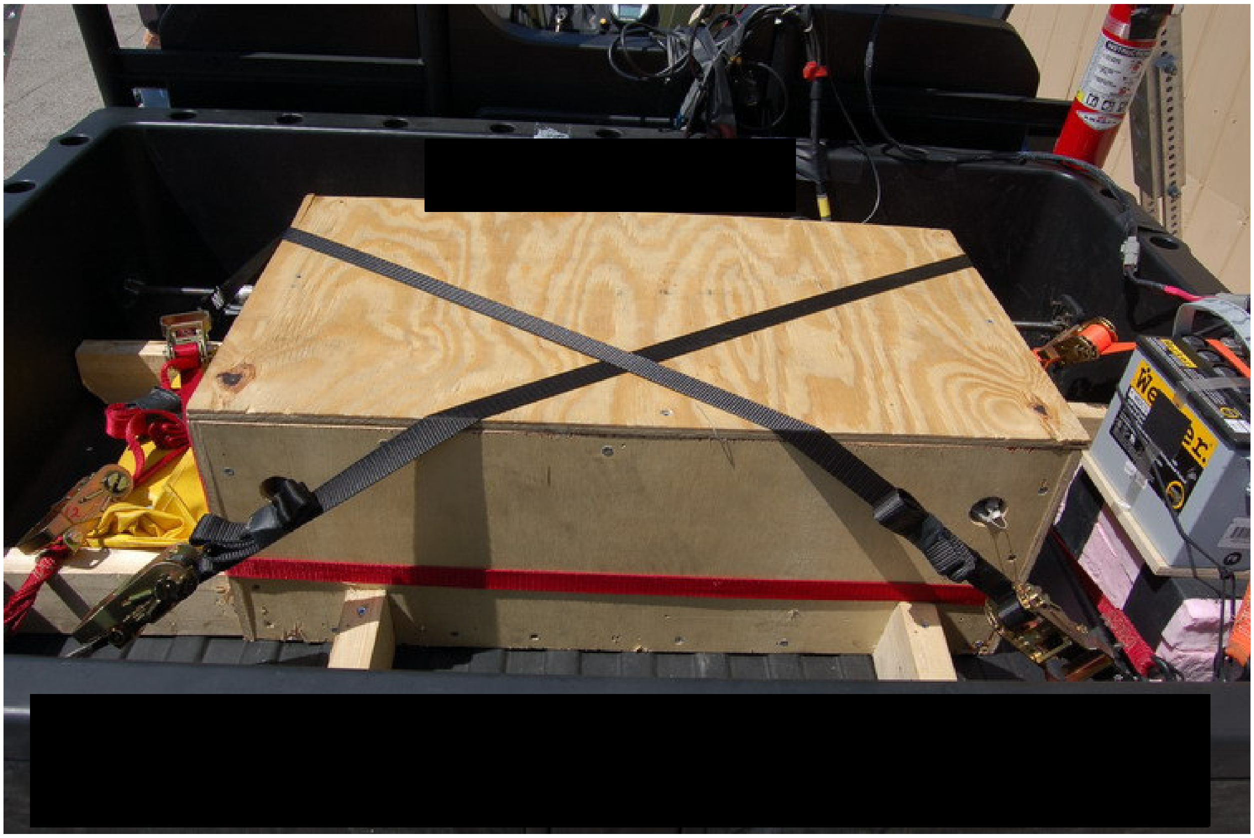


ROV on Vehicle Inertia Measurement Facility (VIMF)

ROV on Tilt Table

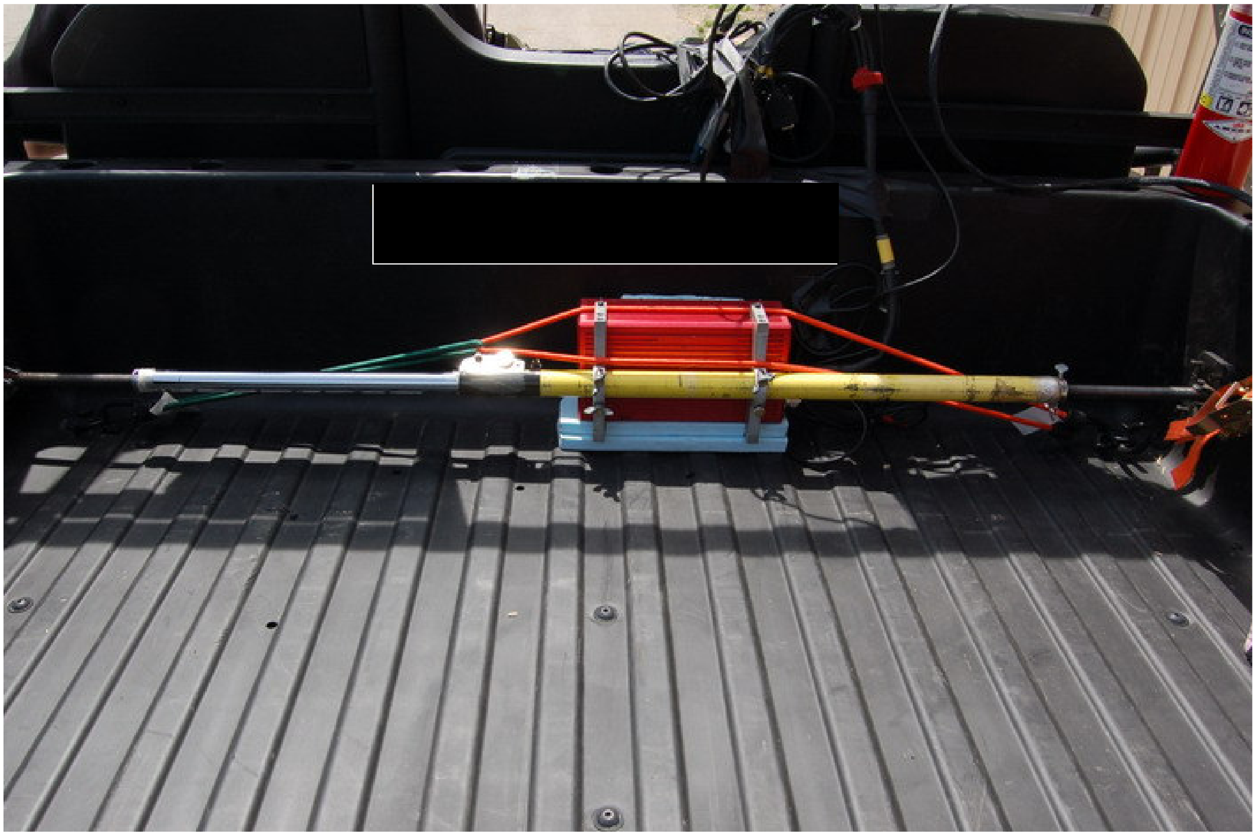
Side View of ROV with CPSC Safety Outriggers

Front View of ROV with CPSC Safety Outriggers



Sample ROV Cargo Bed Loading

Sample ROV Cargo Bed Loading



RT3002 Inertial and GPS Navigation System (Red Box) Mounted on a ROV

Automated Steering Controller (ASC) Mounted on a ROV