CPSC Staff Statement on SEA, Ltd. Report "Vehicle Characteristics Measurements of ATVs Tested on Groomed Dirt"[1]

February 2018

The report titled, "Vehicle Characteristics Measurements of ATVs Tested on Groomed Dirt," presents the results of autonomous dynamic vehicle testing conducted by SEA, Ltd (SEA) on 12 model year 2014-2015 adult single-rider all-terrain vehicles (ATVs) to study lateral stability and handling characteristics of ATVs on a groomed dirt surface. The same 12 vehicles were previously tested under a separate task order to establish baseline performance of the vehicles with a single rider. The results of those tests were published in a report titled, "Vehicle Characteristics Measurements of All-Terrain Vehicles."[2] All task orders were conducted under contract HHSP233201400030I. This contract is funded by CPSC and is administered under an interagency agreement with the U.S. Department of Health and Human Services. The work represented by this report is part of a larger effort by CPSC staff to develop test methods, collect static and dynamic data, and identify opportunities for improvement regarding ATV performance characteristics related to vehicle stability and safety. The following reports have been published under this effort and are available at: **https://www.cpsc.gov/Research-Statistics/sports-recreation/atv-and-rovs**:

- Vehicle Characteristics Measurements of All-Terrain Vehicles;
- Effects on Vehicle Characteristics of Two Persons Riding ATVs;
- Effects on ATV Vehicle Characteristics of Rider Active Weight Shift.

Follow-on work is under way to test three selected vehicles with characteristics that have been modified to study effects on steering and stability. Additionally, staff has previously identified a need for future testing, when resources are available, to include autonomous rollover testing and rollover simulation testing, with a goal to discover opportunities to reduce the likelihood and severity of injury.

[1] This statement was prepared by the CPSC staff, and the attached report was produced by SEA for CPSC staff. The statement and report have not been reviewed or approved by, and do not necessarily represent the views of, the Commission.

[2] Report titled, "Vehicle Characteristics Measurements of All-Terrain Vehicles," retrieved from: **https://www.cpsc.gov/s3fs-public/SEA_Report_to_CPSC_Vehicle_Characteristics_Measurements_of_All_Terrain_Vehicles.pdf**.

Vehicle Characteristics Measurements of ATVs Tested on Groomed Dirt

Results from Tests on Twelve 2014-2015 Model Year Vehicles

for:
U.S. Consumer Product Safety Commission

November 2017

Vehicle Dynamics Division
7001 Buffalo Parkway
Columbus, Ohio 43229

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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. (SEA) for the U.S. Consumer Product Safety Commission (CPSC) under U.S. Department of Health and Human Services (HHS) contract HHSP233201400030I.

This report covers work completed on Task Order 4 of the multi-task contract:

- Test twelve (12) ATVs for lateral stability and handling characteristics on a groomed dirt surface.

This report contains test results for measurements made on twelve 2014-2015 model year vehicles. The vehicles are designated Vehicle A through Vehicle L. Vehicles A-J are model year 2014 vehicles, and Vehicles K and L are model year 2015 vehicles.

Task Order 1 on this contract was to make characteristics measurements on these same 12 vehicles in the Driver Plus Instrumentation (DPI) loading condition (representing a nominal 215 lb driver) and in the Gross Vehicle Weight (GVW) loading condition. The SEA report to CPSC on these measurements is titled *Vehicle Characteristics Measurements of All-Terrain Vehicles – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, [3] and it contains results from laboratory and dynamic test track measurements made on all 12 vehicles. For the previous Task Order 1 testing, all 12 of the vehicles were tested in DPI loading condition and nine of them were also tested in the GVW loading condition. Vehicles B, H and I, were tested only in the DPI loading condition; because for these vehicles the added weight of the test driver and instrumentation brought the total test weight up to near their manufacturer-specified maximum weight ratings. Vehicles B, H and I are the only three manual transmission vehicles and they are the three lightest vehicles. All of the dynamic testing for the Task Order 1 measurements were conducted with a human test driver.

Task Order 2 on this contract was to make characteristics measurements on these same 12 vehicles in a two-person (driver and passenger) loading condition. For the two-person loading condition, the vehicles were each tested at a total test weight nominally 430 lb (representing two 215 riders) above the curb weight for each vehicle. All the testing was conducted using SEA's ATV Robotic Test Driver (ATV RTD). The ATV RTD is a system of automated steering, throttle, brake, and clutch controllers along with differential GPS that was used to conduct the tests in a fully autonomous mode, without a human test driver. Conducting the tests autonomously provided a means to use ballast fixed rigidly to the vehicle to represent the driver and passenger mass. The SEA report to CPSC on these measurements is titled *Effects on Vehicle Characteristics of Two Persons Riding ATVs – Results from Tests on Twelve 2014-2015 Model Year Vehicles*.[4]

Task Order 3 on this contract was to make characteristics measurements on these same 12 vehicles to evaluate the effects on rollover resistance and vehicle handling characteristics when rider active

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[3] *Vehicle Characteristics Measurements of All-Terrain Vehicles – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Report to CPSC, November 2016. **https://www.cpsc.gov/s3fs-public/SEA_Report_to_CPSC_Vehicle_Characteristics_Measurements_of_All_Terrain_Vehicles.pdf**

[4] *Effects on Vehicle Characteristics of Two Persons Riding ATVs – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Report to CPSC, September 2017. **https://www.cpsc.gov/s3fs-public/SEA-Final-Report-to-CPSC-2-Rider-ATV-Study.pdf?V0ixJO3o_kbtsmIBeKUInRAFx6hVocs5**

weight shift is employed. For the Task Order 3 rider active weight shift study, the vehicles were each tested at a total test weight nominally 215 lb (representing a 215 driver) above the curb weight for each vehicle. All the testing was conducted autonomously using SEA's ATV Robotic Test Driver (ATV RTD). Conducting the tests autonomously provided a means to use ballast fixed rigidly to the vehicle to represent the rider mass. The same ballast weight frame that was used to load the vehicles to the two-person loading condition in the Task Order 2 study was used in this study. Three different driver lateral lean angles were evaluated, one representing an upright driver (0° lateral lean angle), one representing a driver with a 20° lateral lean angle, and one representing a driver with a 40° lateral lean angle. The SEA report to CPSC on these measurements is titled *Effects on ATV Vehicle Characteristics of Rider Active Weight Shift – Results from Tests on Twelve 2014-2015 Model Year Vehicles*.[5]

Task Order 4 (as did Task Orders 2 and 3) involved doing only dynamic tests and doing the tests autonomously. Conducting the tests without a human driver mitigated the potential for having the test results influenced by human drivers shifting their weight to secure themselves to the vehicles during the tests and it eliminated the need to have the drivers attempt to lean to specific lateral lean angles. For the Task Order 4 groomed dirt study, the vehicles were each tested at a total test weight nominally 215 lb (representing a 215 driver) above the curb weight for each vehicle. The same ballast weight frame that was used in the Task Orders 2 and 3 studies was used in this study. The tests were conducted using the Task Order 3 loading condition that represents an upright driver, with 0° lateral lean angle. Replicating one of the same loading conditions that was used for tests on asphalt provided the opportunity for making direct comparisons of measured characteristics on groomed dirt and asphalt surfaces. Also, using the upright driver loading condition facilitated testing the vehicles in both the right and left turn directions.

All of the vehicles were selected by CPSC. All of the vehicles have straddle seating and their intended use is for a single occupant, the driver. All of the vehicles have clear warning labels stating "Never Carry a Passenger" or "Never Carry Passengers." All of the vehicles have handlebar (tiller) steering, thumb activated throttles, and hand and foot activated brakes.

The measured curb weights (weights with full fluids and no drivers or cargo) of the vehicles ranged from 395.5 lb to 832.0 lb. The measured average maximum speeds of the vehicles ranged from 45.7 mph to 74.0 mph in a loading condition representing driver-only loading.

Table 1 contains a list of assorted vehicle information and tire specifications for the 12 vehicles. The measured curb weights and maximum speeds are listed.

Also listed in Table 1 is information on the transmission types (Automatic or Manual) and whether the vehicle has a Solid Rear Axle or Independent Rear Suspension. All of the vehicles with solid rear axles are two-wheel drive (2WD) only vehicles. All of the vehicles with independent rear suspensions are equipped with selectable four-wheel drive (4WD) or all-wheel drive (AWD). Table 1 contains the manufacturers' specified driveline setting options for each of the vehicles. All vehicles were tested in two-wheel drive mode, and in their most open driveline configurations (which was locked rear differential for all 12 vehicles tested).

Table 1 also lists the front and rear tire make, tire size, and tire pressure for each vehicle.

[5] *Effects on ATV Vehicle Characteristics of Rider Active Weight Shift – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Link to report (currently in 6b review).

The dynamic tests were performed by SEA on numerous dates between June 1, 2017 and August 24, 2017. All of the vehicles were tested on SEA's groomed dirt test pad in Columbus, Ohio. The following suite of dynamic tests was performed for each vehicle:

- **Constant Radius (50 ft) (Circle) Tests**
- **Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)**
- **Constant Steer Tests (Yaw Rate Ratio Tests)**

This report contains four main sections: Overview, Dynamic Testing, Discussion of Test Results, and Comparison of Autonomous Driver Only Results on Groomed Dirt to Autonomous Driver Only Results on Asphalt. There are also three appendices containing test results, and one appendix containing photographs of test equipment.

Table 1: Test Vehicle Information and Tire Specifications		
Vehicle A **Curb Weight: 523.9 lb** **Maximum Speed: 47.0 mph**	**Automatic Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Maxxis MU13	Maxxis MU13
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	3.6	3.6
Vehicle B **Curb Weight: 432.8 lb** **Maximum Speed: 70.0 mph**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Maxxis M976Y	Maxxis M976Y
Tire Size	AT21X7-10	AT20X10-9
Tire Pressure (psi)	4	4
Vehicle C **Curb Weight: 650.8 lb** **Maximum Speed: 66.0 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Maxxis MU19A	Maxxis MU19A
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	5	4.4
Vehicle D **Curb Weight: 714.0 lb** **Maximum Speed: 45.8 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Kaden Duro 45J	Kaden Duro 52J
Tire Size	AT25X8-12 6 Ply	AT25X10-12 6 Ply
Tire Pressure (psi)	5	5
Vehicle E **Curb Weight: 734.1 lb** **Maximum Speed: 45.7 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Kaden Duro 45J	Kaden Duro 52J
Tire Size	AT25X8-12 6 Ply	AT25X10-12 6 Ply
Tire Pressure (psi)	5	5
Vehicle F **Curb Weight: 526.2 lb** **Maximum Speed: 53.5 mph**	**Automatic Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Kenda Pathfinder	Kenda Pathfinder
Tire Size	AT22X7-10 4 Ply	AT22X10-10 4 Ply
Tire Pressure (psi)	4	3.5

Table 1 (Continued): Test Vehicle Information and Tire Specifications		
Vehicle G **Curb Weight: 694.0 lb** **Maximum Speed: 69.0 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD or 4WD**	
	Front Tires	Rear Tires
Tire Make	Duro DI-K911	Duro DI-K911
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	5	5
Vehicle H **Curb Weight: 395.5 lb** **Maximum Speed: 71.5 mph**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Dunlop KT391	Dunlop KT396
Tire Size	AT21X7R10 ☆☆	AT20X10R9 ☆☆
Tire Pressure (psi)	4.4	3.9
Vehicle I **Curb Weight: 408.4 lb** **Maximum Speed: 63.0 mph**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Ohtsu Radial HTRAK M/R101	Ohtsu Radial HTRAK M/R101
Tire Size	AT22X7-10 4 Ply	AT22X10-9 4 Ply
Tire Pressure (psi)	4	4
Vehicle J **Curb Weight: 649.8 lb** **Maximum Speed: 60.5 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD or AWD**	
	Front Tires	Rear Tires
Tire Make	Dunlop KT511	Dunlop KT515
Tire Size	AT25X8 R12	AT25X10 R12
Tire Pressure (psi)	4.4	3.6
Vehicle K **Curb Weight: 832.0 lb** **Maximum Speed: 74.0 mph**	**Automatic Transmission** **Independent Rear Suspension** **2x4, 4x4, or 4x4 Lock**	
	Front Tires	Rear Tires
Tire Make	Carlisle AT489 II	Carlisle AT489 II
Tire Size	AT 26X8-14 6 Ply	AT 26X10-14 6 Ply
Tire Pressure (psi)	7	7
Vehicle L **Curb Weight: 716.4 lb** **Maximum Speed: 52.7 mph**	**Automatic Transmission** **Independent Rear Suspension** **2x4 or AWD**	
	Front Tires	Rear Tires
Tire Make	Wanda NS388	Wanda NS388
Tire Size	AT24X8-12 6 Ply	AT24X10-12 6 Ply
Tire Pressure (psi)	5	5

2. DYNAMIC TESTING

This section describes the dynamic tests conducted on numerous dates between June 1, 2017 and August 24, 2017. All of the vehicles were tested at SEA in Columbus, Ohio, on their groomed dirt vehicle dynamics test pad. The groomed dirt test pad is approximately 300 ft by 300 ft square, and it has a grade of 0.33 percent. The test surface was maintained to be free of vegetation and rocks larger than about an inch in diameter. The dirt pad was regularly groomed using a 60-inch-wide commercial groomer (DR Power Grader 60" Pro Model) and dragmat. The groomer has selectable depth tines and a skid blade, and the drag mat was dragged behind the groomer. On test days when it did not rain since the last grooming, the groomer tines were retracted and only the groomer skid blade and drag mat were used to groom the surface. On test days when it did rain since the last grooming, the groomer tines were set to approximately one inch depth (to break up the top crust on the soil caused by rain); and the tines, blade and drag mat were used for grooming. The test surface can be described as hard packed soil with a loose top layer, and it is similar to a dirt surface that might be found on some off-road trails.

All of the vehicles with automatic transmissions were tested in two-wheel drive mode, and in their most-open driveline configurations. The vehicles with manual transmissions were tested in second gear (as they were when they were tested previously).

2.1 Vehicle Loading Condition

The loading condition used for all of the testing was the representative driver only loading condition, with 0° lateral lean angle. Pages 1, 5 and 6 of Appendix D contain photographs of two of the test vehicles in the groomed dirt loading condition. For these autonomous tests, a weight frame constructed of 80/20 T-slot aluminum bars was used to rigidly hold enough steel weights to bring the total test weight up to nominally 215 lb (representing a 215 driver) above the curb weight for each vehicle. The frame was designed so the steel weights could be adjusted vertically, so that the center-of-gravity (CG) height of the added ballast would represent the CG height of a 215 lb driver (with a nominal CG height 10 inches above the lowest point of their position on the seat).

The driver only loading condition was specified to be the vehicle curb condition plus the weight (nominally 215 lb) of the test instrumentation and equipment that included: measurement transducers, SEA's ATV RTD,[6] SEA's ATV safety outriggers,[7] an auxiliary 24V battery, and the

[6] The ATV RTD consists of a computer-controlled 24V electric motor that mounts to the front rack of an ATV for steering control. A four-bar linkage arrangement is used to connect the motor drive gear to an aluminum rod that is connected to the ATV steering column beneath the ATV handlebars. The ATV RTD also includes up to three other computer-controlled 24V electric motors that mount to the aluminum rod inserted beneath the ATV handlebars. One motor is used to control the throttle, one is used to apply the right-hand brake, and in the case of the manual transmission vehicles, one is used to control the clutch on the left side of the handlebar. The ATV RTD also includes a GPS/IMU (OxTS RT3002 or OxTS RT4002), an electronics box (with a National Instruments (NI) cRIO, the on-vehicle computer with the motor controllers and data acquisition software), and antennas for wireless communication. Pages 2-4 of Appendix D contain photographs of the ATV RTD. Also, for the groomed dirt testing, an additional antenna was used for wireless communication (Pages 1, 5 and 6 of Appendix D show a white, Fluidmesh network antenna mounted near the top of the weight frame).

[7] SEA designed ATV-specific safety outriggers consisting of a single aluminum tubular beam structure that mounts to the underside of the ATVs. For the groomed dirt tests, the adjustable height white nylon pads (used for testing on asphalt) on the ends of the outriggers were replaced with the adjustable height black nylon pucks, and these interact with the dirt surface to prevent the vehicles from tipping over. Page 5 of Appendix D contains photographs of these standard ATV safety outriggers with the groomed dirt pucks. These standard ATV outriggers could not be used on the three lightest ATVs tested, the manual transmission vehicles, because their

ballast weight frame described above. Table 2 lists the nominal weights of the components that comprise the driver only loading condition.

Table 2: Driver Only Loading

Component	Automatic Transmission Vehicles Nominal Weight (lb)	Manual Transmission Vehicles Nominal Weight (lb)
Components Mounted at Front of Each Vehicle Base Plate, Steer Motor, Throttle Motor, Brake Motor, Clutch Motor (for Manual Transmission Vehicles), Steering Column Transducer, and Associated Linkages	37.2	44.5
Components Mounted at Rear of Each Vehicle Base Frame, Electronics Box, GPS/IMU (RT3002), 24V Battery, and Antennas	57.6	57.6
Standard ATV Outriggers	29.0	NA
Light-Vehicle ATV Outriggers	NA	23.5
Weight Frame and Miscellaneous Ballast	91.2	89.4
Total Nominal Driver Only Weight	**215.0**	**215.0**

The right-most columns (labeled "Autonomous Groomed Dirt Ballast to Driver Loading") in the tables contained in Appendix A contain the actual test weight, corner weights, track widths, wheelbase, and CG longitudinal and lateral positions for all 12 vehicles in the driver only, groomed dirt loading condition (test weights for other loading conditions used for CPSC tests are also included in these tables).

2.2 Test Instrumentation

The instrumentation used during the testing is listed in Table 3. The GPS/IMU (RT3002 or RT4002) was mounted on the rear base frame of each vehicle. The base frames were constructed using 80/20 T-slot aluminum bars and aluminum plates. For each vehicle, the longitudinal, lateral, and vertical offsets from the center of the RT3002/RT4002 to the actual vehicle CG location were measured and entered into the RT3002/RT4002 system software. This information was used to translate the measured quantities to those at the CG of the vehicle. The lateral accelerations measured and reported herein are accelerations parallel to the road plane, as opposed to vehicle body-fixed accelerations.

Steering column angle (handlebar steering angle) was measured using either a digital rotary

frames were too close to the ground when they were loaded to test weight. For these three vehicles, SEA designed, built and used the light-vehicle ATV outriggers shown on Page 6 of Appendix D. These outriggers attached to the foot pegs of the vehicles and were further supported by an aluminum brace to the frame.

encoder or an analog string potentiometer. Page 7 of Appendix D contains photographs of the arrangement used to measure steering column angle using both instruments. A split sheave, with an inner (bore) diameter sized to fit securely around the steering column shaft was fixed around each steering column. In all cases, the steering ratios between the steering column sensor and roadwheel angles were measured, and these were used to determine the Roadwheel Steer Angles (shown on the graphical results in Appendix C).

Table 3: Instrumentation Used During Dynamic Testing

Transducer	Measurement	Range	Accuracy
Oxford Technical Solutions (OxTS) RT3002 or RT4002 Inertial and GPS Navigation System	Longitudinal, Lateral, and Vertical Accelerations	± 100 m/s^2 (± 10 g)	0.01 m/s^2 (0.001 g)
	Roll, Pitch, and Yaw Rates	± 100 deg/s	0.01 deg/s
	Speed	No Limit Specified	0.05 km/h (0.03 mph)
	Roll and Pitch Angles	-180 to +180 deg	0.03 deg
	Vehicle Heading	0 to 360 deg	0.1 deg
Steering Column Encoder or Potentiometer	Steering Column Angle (Handlebar Angle)	No Limit Specified	± 0.25 deg

2.3 Constant Radius (50 ft) (Circle) Tests

Constant Radius or Circle tests were used to evaluate the vehicles' understeer characteristics.[8] A Constant Radius test involves driving a vehicle on a circular path of constant radius (50 ft in this case). The test vehicles were autonomously driven in both the clockwise and counterclockwise directions. The ATV RTD was used to steer the vehicles and control the vehicle throttle (speed) during these tests.

A circular path of 50 ft radius was generated in GPS coordinates and the "path-following" feature of the RTD was used to control the steering input during these tests. The path-following algorithm has a collection of parameters used to model driver look-ahead distance, vehicle steering properties, and other steering-related control gains that were adjusted to provide good path following for each vehicle tested.

For the vehicles with automatic transmissions, the throttle input was increased in piecewise linear steps to generate speed profiles from a very low speed up to a speed where the lateral acceleration reached 0.4 g.

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

For vehicles with manual transmissions, the vehicles were tested in second gear. For these vehicles, the RTD was programmed to increase the throttle and slowly engage the clutch. The throttle and clutch positions were synchronized and tuned for each vehicle to provide smooth take offs. Once the vehicles started moving, the throttles were backed off so the vehicle could achieve a low speed at the start of the circle tests. The throttle inputs were then increased in piecewise linear steps to generate speed profiles up to a speed where the lateral acceleration reached 0.4 g.

Constant Radius tests were used to determine if the vehicles transitioned from understeer to oversteer during the tests. Roll gradients, vehicle roll angle response as a function of lateral acceleration, were also computed from these tests. Detailed results from the Constant Radius tests are contained in Appendix C.

2.4 Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 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 RTD drove each vehicle along a straight-line path (defined by GPS coordinates) from low speed up to a speed of 21 mph. The RTD throttle inputs were programmed to generate the appropriate speed profiles so that the J-Turn maneuvers would take place near the center of the test pad. Once 21 mph was achieved, the RTD then dropped the throttle and triggered the steering input precisely when the vehicle speed reached 20 mph. For the manual transmission vehicles, the clutch was left engaged when the throttle was dropped. The handlebar (motor) steering input rates used were 40 deg/sec, and the steering dwell or hold time used was 10.0 seconds, at which time the steering angle was programmed to return to 0 deg. The test engineer typically stopped the RTD program once the vehicle came to a stop at the end of each test, before 10 seconds of steering hold time. This eliminated the need to return the steering angle to zero while the vehicle was stopped, which helped preserve RTD 24V battery life by eliminating the need to use relatively high steering torques to steer the vehicle while it was not moving.

The J-Turn test procedure involved initially running tests with steering magnitudes less than the steering required to produce tip-up events, events that have visual two-wheel lift outcomes. The handlebar steering input magnitude was gradually increased in 1.0 degree increments to the point where a test run resulted in a two-wheel lift event. Then another test run using 0.5 degrees less steering input was used to refine the steering required for two-wheel lift. Once the steering input magnitude required for visual two-wheel lift was determined, repeat test runs using this steering input were conducted. For testing on asphalt, typically the repeat runs using this same steering input could be used to produce three runs that resulted in visual two-wheel lift. However, on the groomed dirt surface the steering magnitudes required for two-wheel lift are not as consistent as they are on asphalt. For many of the vehicles, when testing on the groomed dirt the steering inputs required for two-wheel lift had to be varied up or down by 0.5 to 1.0 degrees to produce runs that resulted in visual two-wheel lifts. Nonetheless, all of the two-wheel lift outcome results contained in this report are for runs that had visual two-wheel lift. Some of the included runs did result in mild outrigger contact, but no runs that involved hard or sustained outrigger contact are included in the results.

These tests provided a measure of the minimum peak lateral acceleration (Threshold Ay) required to cause visual two-wheel lifts during the tests. Detailed results from the Dropped Throttle J-Turn

tests are contained in Appendix C.

2.5 Constant Steer Tests (Yaw Rate Ratio Tests)

Constant Steer tests are yet another well established method used to evaluate a vehicle's understeer characteristics.[9] The recreational off-highway vehicle (ROV) industry groups Recreational Off-Highway Vehicle Association (ROHVA) and Outdoor Power Equipment Institute (OPEI), as well as CPSC, have used Constant Steer tests to evaluate vehicle yaw rate divergence. The industry groups have developed protocols for computing the ratio of yaw rate gain at a high lateral acceleration range (0.4-0.5 g) divided by the yaw rate gain at a low lateral acceleration range (0.1-0.2 g), and this ratio is referred to here as Yaw Rate Ratio. At the time of this report, both ROHVA[10] and OPEI[11] have industry voluntary standards that describe similar test and data reduction protocols for computing Yaw Rate Ratio for ROVs. The same test and data reduction protocols were used for the current ATV testing. The only significant difference is that for the ATV testing, the high range of lateral accelerations was reduced to a range of 0.3 g to 0.4 g because the ATVs tested exhibit rollover at a lower lateral acceleration range (from 0.38 g to 0.50 g) than ROVs.

The test procedure used for the Yaw Rate Ratio tests was:

1. The test procedure used when these vehicles were tested on asphalt was: Follow a 100 ft diameter (50 ft radius) circle at a speed less than 10 mph until the mean steer angle required to maintain the circular path is established (this is referred to as "initial steer" in this report). However, for each vehicle the same initial steer angle that was used for the autonomous tests on asphalt were used for the autonomous tests conducted on groomed dirt. Accordingly, the vehicles that had initial path radii of 50 ft on asphalt had approximately 50 ft initial path radii on groomed dirt, and the vehicles that had initial path radii of 25 ft on asphalt had approximately 25 ft initial path radii on groomed dirt. The smaller path radius of 25 ft was used on the vehicles that exhibited enough understeer (radius of circle path increases) to potentially run off of the available test surface when they were tested on asphalt.
2. The ATV RTD was then used to steer the steering column (handlebars) to the initial steer angle and hold it there for the duration of the test.
3. The vehicle was then steadily accelerated at a rate not to exceed 1 mph/second. Efforts were made to program the RTD throttle to complete each test run in 30-60 seconds. *Test Note: Most of the tests were conducted in 30-60 seconds, but for a few vehicles runs up to 80 seconds in duration were conducted before the lateral acceleration reached 0.4 g.*
4. The tests were ended by the RTD program when a lateral acceleration above 0.4 g was achieved.
5. Items 2-4 were repeated until at least five runs in the first steer direction were completed.
6. Item 1 was repeated in the opposite steer direction, and then Items 2-4 were repeated until at least five runs in the opposite steer direction were completed.

[9] Ibid

[10] American National Standard for Recreational Off-Highway Vehicles, ANSI/ROHVA 1-2016, May 2016.

[11] American National Standard for Multipurpose Off-Highway Utility Vehicles, ANSI/OPEI B71.9-2016, August 2016.

These tests provided a measure of the Yaw Rate Ratios (defined in Section 3.2.3). Detailed results from the Constant Steer tests (Yaw Rate Ratio tests) are contained in Appendix C.

3. DISCUSSION OF TEST RESULTS

Appendix B contains a collection of tables and bar charts summarizing selected results from the dynamic testing. Detailed graphical results from all of the dynamic testing conducted are contained in Appendix C. This section of the report contains discussions of the results in Appendices B and C.

3.1 Discussion of Appendix B: Summary Tables and Bar Charts

Page 1 of Appendix B contains a summary table of the clockwise (CW), counterclockwise (CCW), and Average lateral acceleration levels at which the vehicles that transitioned from understeer to oversteer did so during the autonomous groomed dirt tests. "NA" in the table indicates that no transition to oversteer occurred. Page 2 of Appendix B contains a bar chart showing the Roll Gradients, which are the amount of roll angle in degrees per "g" of lateral acceleration measured during the Circle tests.

Page 3 contains a table and Page 4 a bar chart of the Threshold Lateral Acceleration (Threshold Ay) determined from the 20 mph Dropped Throttle J-Turn tests. Threshold Ay is the minimum peak lateral acceleration required to cause visual two-wheel lift during the J-Turn tests, and it is a metric that is used to categorize a vehicle's tip-up or rollover resistance. Vehicle D did not experience any two-wheel lift during any of the 20 mph Dropped Throttle J-Turn runs conducted on groomed dirt, even those conducted using the vehicle's maximum steering magnitude of 38 degrees. Additional tests, 22 mph Dropped Throttle J-Turn tests, were conducted on Vehicle D using 38° steering magnitude and none of these tests resulted in two-wheel lift outcomes. Therefore, the lateral acceleration value of 0.528 g shown for Vehicle D on Pages 3 and 4 is not the Threshold Ay value; it is the average of the peak lateral accelerations measured during the 12 tests using maximum steering magnitude and an initial speed of 22 mph. When tested on the asphalt surface, Vehicle D had a Threshold Ay (based on tests with two-wheel lift outcomes) of 0.579 g. On the groomed dirt surface, using maximum steering input did not generate enough front axle corning force (i.e. the front tires experienced more lateral slip on groomed dirt than on asphalt) to cause the vehicle to turn hard enough to generate lateral acceleration levels needed to result in two-wheel lift outcomes, even when the test speed was increased to 22 mph.

Page 5 of Appendix B contains a table listing the Right Turn, Left Turn, and Average values for the final Yaw Rate Ratios determined from the Constant Steer (Yaw Rate Ratio) tests. This table also contains a column listing the maximum lateral acceleration (Ay) used during the post-processing of the test results for each vehicle (0.4 g for all vehicles in this study), and a column listing the initial path radius used for each vehicle. Page 6 is a bar chart of the Yaw Rate Ratio results.

3.2 Discussion of Appendix C: Results from Dynamic Tests

Appendix C contains the graphical test results for all 12 vehicles tested, in the following order:

- Constant Radius (50 ft) (Circle) Tests
- Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph, except for tests conducted on Vehicle D which have an Initial Speed of 22 mph)
- Constant Steer Tests (Yaw Rate Ratio Tests)

Table 4 lists the contents of Appendix C, listing the pages containing results for each of the 12 vehicles.

Table 4: Appendix C Table of Contents

Vehicle	Page Numbers	Vehicle	Page Numbers
A	1-16	G	97-112
B	17-32	H	113-128
C	33-48	I	129-144
D	49-64	J	145-160
E	65-80	K	161-176
F	81-96	L	177-192

The discussion in this section will cover each test in the order listed above. A couple of general comments regarding the graphs presented for all test types are:

- The lateral accelerations shown on the graphs are the lateral accelerations parallel to the road plane, not the vehicle body-fixed lateral accelerations.
- The steering angles shown on the graphs are roadwheel steer angles, which are the measured steering column angles divided by the measured steering ratios (The measured steering ratios between the steering columns and roadwheels ranged from 1.21:1 to 1.62:1.).
- The ATV RTD was used for all of the Circle, J-Turn, and Yaw Rate Ratio tests. For tests using the ATV RTD, the commanded steering input is the input to the ATV RTD steering motor. The ATV RTD steering angle and the steering column angle are not exactly one-to-one, due to compliance in the ATV RTD four-bar linkage arrangement, its motor base mounting to the vehicles, and the handlebars.

3.2.1 Constant Radius (50 ft) (Circle) Tests

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 Roadwheel 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 circle tests are quasi-steady state tests, and it is common to use a low pass filter on data from these tests. The time domain data shown for each vehicle contains all of the data from the time the test engineer started the ATV RTD data acquisition (prior to when the vehicle started to move forward on the circle) to the time when the ATV RTD stopped collecting data (after at least 0.4 g lateral acceleration was achieved and the test was ended).

On the first page of Circle test graphs for each vehicle, the thin black lines for the CW and CCW tests show the full range of data collected. The thicker lines (red for CW and blue for CCW)

indicate the range of data used to fit the subsequent understeer and roll gradient characteristic curves. These ranges typically start from the time the vehicle attained a speed of 5.5 mph, which is a lateral acceleration of 0.04 g on a 50 ft radius circle. By the time most of the vehicles reached 5.5 mph, the RTD steering had settled to a steady state. However, in a few cases, a speed somewhat greater than 5.5 mph was needed before the RTD steering settled to steady state. The range of data used for the curve fits was ended when the vehicle attained a lateral acceleration of 0.40 g or the maximum vehicle speed during the test. 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[12] 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 overall rates of speed increase during the Circle tests conducted are less than the J266 recommended maximum allowable rate.

The second page for each vehicle shows graphs of Roadwheel 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 and blue lines show data in the selected ranges, as described above. For both the CW and CCW data, there is a thicker blue line indicating second-order polynomial curve fits to the range of data selected. 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:

$$\delta_{sw\ (Geometric\ Ac\ker mann)} = \frac{(180/\pi)\times K \times L}{R}$$

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

The third page for each vehicle contains a graph of Roadwheel Steer Angle (measured) minus 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 data selected for each vehicle as described above, and 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 input required to maintain the circular path increases as the vehicle speed increases, neutral steer can be defined as the condition when the steering 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 input required to maintain the circular path decreases as the vehicle speed increases. The second-order polynomial curve fits do a good job of representing the underlying data whether the particular test vehicle exhibits understeer, neutral steer, or oversteer characteristics during the Circle tests.

All of the vehicles tested exhibit understeer at low levels of lateral acceleration and then all of the vehicles except Vehicles C, D, E and L transition to oversteer at higher levels of lateral

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

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

The fourth page for each vehicle contains a graph 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 selected for each test. The thick lines are linear curve fits to the CW and CCW data over the selected ranges. The average of the CW and CCW curve fit slopes are listed on the graphs as the Roll Gradient.

3.2.2 Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)

For each vehicle, there are five pages of results for the Dropped Throttle J-Turn tests. The first four pages show time domain plots for the tests. The first and third pages for each vehicle show plots of Roadwheel Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate; for the six Southbound and the six Northbound runs, respectively. The second and forth pages for each vehicle show larger plots of Lateral Acceleration; for the six Southbound and six Northbound runs, respectively. For the J-Turn test results, the data shown was digitally low-pass filtered to 2.0 Hz using a phaseless, eighth-order, Butterworth filter. For tests conducted by SEA for CPSC on Recreational Off-Highway Vehicles (ROVs), the same 2.0 Hz. filter was used to filter all J-Turn test data used to select peak lateral acceleration values (Threshold Ay values) during J-Turn tests that resulted in two-wheel lift outcomes. Justification for using a 2.0 Hz low pass filter for selecting peak lateral accelerations is presented in the SEA report to CPSC titled *Repeatability of J-Turn Testing of Four Recreational Off-Highway Vehicles*.[13] The time domain data shown for each vehicle contains data from 0.5 seconds before the ATV RTD steering input was applied until 5.0 seconds after it was applied.

For each vehicle, the plots contain results from three Southbound right steer J-Turns, three Southbound left steer J-Turns, three Northbound right steer J-Turns, and three Northbound left steer J-Turns. In all cases (except for Vehicle D), the plots contain results for tests that resulted in visually determined two-wheel lift. As mentioned previously, for Vehicle D the results shown are from tests at 22 mph using maximum steering input of 38 degrees that did not result in two-wheel lift outcomes. An SAE standard sign convention is used, with Roadwheel Steer Angle, Lateral Acceleration, and Yaw Rate being positive for right turns and Roll Angle being negative for right turns.

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

[13] *Repeatability of J-Turn Testing of Four Recreational Off-Highway Vehicles*, CPSC Contract CPSC-D-11-0003, SEA, Ltd. Report to CPSC, September 2013.
https://www.cpsc.gov/s3fs-public/SEAReporttoCPSCRepeatabilityTestingSeptember%202013.pdf

The summary pages show the peak lateral accelerations for the three runs conducted in the Southbound right steer direction, Southbound left steer direction, Northbound right steer direction, and Northbound left steer direction. The mean values and standard deviations from each of the three sample runs are shown on the summary pages. Also, the average values of the six Southbound and six Northbound runs are shown, as is the average of all 12 runs, which is the Threshold Ay value (except for Vehicle D which did not experience two-wheel lift). Page 3 of Appendix B contains a table listing the Threshold Ay values for each vehicle (except Vehicle D for which the average maximum lateral acceleration is listed because two-wheel lift did not occur).

3.2.3 Constant Steer Tests (Yaw Rate Ratio Tests)

There are seven pages of Constant Steer test results for each vehicle. The first page shows time domain plots of Roadwheel Steer Angle, Estimated Ay (Estimated Lateral Acceleration), Speed, Roll Angle, and Yaw Rate. There are plots for the five right direction steer tests (CW tests) and for the five left direction steer tests (CCW tests). For all of the graphs from the Constant Steer tests, the Roadwheel Steer Angle, Speed, Roll Angle and Yaw Rate data shown is unfiltered. Per the OPEI and ROHVA ANSI protocols, the Estimated Ay data shown is computed by multiplying the Yaw Rate (filtered using a low-pass Butterworth filter with a cut-off frequency of 1.0 Hz) and Speed (filtered using a low-pass Butterworth filter with a cut-off frequency of 1.0 Hz). The thin lines show all of the data collected for each run, and the thick lines indicate the data that was selected for post processing, when the Estimated Ay is in the range of 0.1-0.2 g and in the range of 0.3-0.4 g.

The second page of results from the Constant Steer tests contains the plots of Estimated Ay versus Speed for all ten tests. The data is plotted up to the point of maximum Estimated Ay. The maximum Estimated Ay levels shown on these graphs are greater than 0.4 g, the selected end point lateral acceleration level for data processing. For all of the Yaw Rate Ratio tests, the tests were not stopped before the Estimated Ay reached at least 0.4 g. At the end of the tests, the lateral accelerations increase as soon as the throttle (and vehicle speed) is dropped. When the vehicle speed drops, weight is shifted to the front axle and the vehicles tend to turn in, generally increasing lateral acceleration, roll angle and yaw rate. However, data after the speed was dropped at the ends of the tests was not used in the analyses to compute Yaw Rate Ratios.

The third page of results contains the plot of Yaw Rate versus Speed for all ten tests, and this is the graph that also shows the slope values for the individual test run initial and final ranges (and their standard deviations), the individual test run CW and CCW slope ratios (and their standard deviations), the average CW and CCW slope ratios (the Yaw Rate Ratios), and the final average of the CW and CCW slope ratios (the Average Ratio). All of the linear curve fits in the initial and final ranges are shown, and the thick black lines indicate where combinations of yaw rate and speed equal 0.4 g of lateral acceleration.

The following steps were taken to compute the slopes and Yaw Rate Ratios contained on the third page graphs:

1. For each test run, to determine the data regions for analysis, the yaw rate and speed channels were filtered using a low-pass Butterworth filter with a cut-off frequency of 1 Hz. Then the estimated lateral acceleration in units of “g’s” was computed using the following equation:

$$\text{Estimated } A_y = \frac{\pi}{180} \times \frac{\text{Yaw Rate} \times \text{Speed}}{32.2}$$

where Yaw Rate is in deg/sec and Speed is in ft/sec.

The protocol used to compute Estimated Ay is the same as the protocols contained in ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016.[14]

2. The estimated lateral acceleration, Estimated Ay, was used to determine the start and stop points for the following regions:
   a. The Initial Region is from 0.1 to 0.2 g.
   b. The Final Region is from 0.3 to 0.4 g.

3. For each test run, in both the initial and final regions, linear slopes of unfiltered yaw rate versus data index and linear slopes of unfiltered speed versus data index were computed.[15] The slopes can be classified as:
   a. Y1 = linear slope of the yaw rate versus index plot for Initial Region
   b. Y2 = linear slope of the yaw rate versus index plot for Final Region
   c. V1 = linear slope of the vehicle speed versus index plot for Initial Region
   d. V2 = linear slope of the vehicle speed versus index plot for Final Region

4. The Yaw Rate Ratio (R) for each run was then computed using the following equation:

$$\text{Yaw Rate Ratio (R)} = \frac{\left(\frac{Y2}{V2}\right)}{\left(\frac{Y1}{V1}\right)}$$

Note: This value may be negative or positive.

5. Steps 1 through 4 were then repeated for all ten test runs.

6. The following final slope ratios were then computed:
   a. Right Turn Yaw Rate Ratio (CW Average) = Average of the absolute values of the 5 right turn test runs
   b. Left Turn Yaw Rate Ratio (CCW Average) = Average of the absolute values of the 5 left turn test runs
   c. Average Yaw Rate Ratio (Average Ratio) = Average of the Right Turn and Left Turn Yaw Rate Ratios

[14] The equations given in ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 to compute Estimated Ay differ from the equation listed above because metric dimensions are used in the voluntary standards. However, all of the equations compute Estimated Ay in units of "g's", by dividing by the gravitational constant defined as 9.8 m/s^2 or 32.2 ft/s^2.

[15] The ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 protocols specify computing slopes versus *time*. Given the form of the final computation for Yaw Rate Ratio, computing the slopes versus *time* or versus *data index* result in the same answer for Yaw Rate Ratio.

The fourth and fifth pages for each test condition contain magnified sections of the individual final slope regions for the right turn (CW) and left turn (CCW) runs, respectively. These graphs also contain black lines indicating where combinations of yaw rate and speed equal 0.4 g of lateral acceleration. A vehicle with severe oversteer in the final slope region will have a steep slope (high Final Slope value), and this will produce a high Yaw Rate Ratio. Steep final slopes are indicative of divergent vehicle behavior, a condition when the yaw rate and lateral acceleration gains are high and the vehicle is prone to yaw and/or tip-up instability.

The sixth and seventh pages show individual path plots for the right turn (CW) and left turn (CCW) runs, respectively. As speed is increased during a Constant Steer test, an understeering vehicle will travel on a path of increasing radius, and an oversteering vehicle will travel on a path of decreasing radius. The path plot graphs have green, red, and black line portions, indicating ranges of lateral acceleration during the runs. The initial regions are shown with the green lines and the final regions are shown with the red lines.

Vehicles D and E are the most understeering vehicles tested. These two vehicles have Yaw Rate Ratios less than one and they did not transition to oversteer during any of the Circle tests conducted. Vehicles C and L also have low Yaw Rate Ratios, and they did not transition to oversteer during any of the Circle tests conducted on groomed dirt. Vehicle K also has low Yaw Rate Ratios close to 1.0, but it did transition to oversteer during the Circle tests.

Page 5 in Appendix B contains a summary table of the Right Turn (CW), Left Turn (CCW), and Average Yaw Rate Ratios computed from the Constant Steer tests. Page 6 in Appendix B is a bar chart of the Yaw Rate Ratio results.

The ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 criteria for passing their constant steer handling test using an ROV is that neither the right turn Yaw Rate Ratio nor the left turn Yaw Rate Ratio exceeds 4.5.

4. COMPARISON OF AUTONOMOUS DRIVER ONLY RESULTS ON GROOMED DIRT TO AUTONOMOUS DRIVER ONLY RESULTS ON ASPHALT

Previous Task Order 3 testing[16], provides limited data on autonomous testing of all 12 test vehicles on an asphalt test surface. To meet the objective of Task Order 3, which was to evaluate the effect of rider lean on rollover resistance and vehicle handling characteristics, autonomous tests were conducted with each vehicle in the counterclockwise and left turn directions at 0º rider lean, and then at angles representing 20º and 40º rider lean. This provided data on the effect of a rider leaning to the left. Tests were not conducted in the right turn or clockwise direction because the effects of lean were not expected to be different and the required time and funding resources were outside the scope of Task Order 3. Nevertheless, the data on autonomous vehicle tests conducted at 0º lean in the counterclockwise and left turn directions can be compared to autonomous tests conducted at 0º lean on a groomed dirt surface. This section contains a comparison of the results from the autonomous tests conducted on groomed dirt with those conducted on asphalt in only the left turn and counterclockwise directions. A more complete comparison would require a new task order with the specific objective to obtain autonomous test data at 0º rider lean on an asphalt surface for comparison to autonomous test data at 0º rider lean on a groomed dirt surface.

Efforts were made to keep the vehicle loading conditions used for the groomed dirt tests as similar as practically possible to the loading conditions used for the asphalt tests. Also, for the tests on both surfaces, efforts were made to tune the RTD steering and throttle controls to achieve quality path following and speed profiles, so the autonomous driver inputs used for each vehicle were similar for both test programs.

4.1 Comparison of Circle Test Results

Table 5 is a summary table of the lateral acceleration levels at which the vehicles that transitioned from understeer to oversteer did so during the autonomous groomed dirt and autonomous asphalt Circle tests. For the groomed dirt tests, the values listed are the average of CW and CCW Circle tests, and for the asphalt tests values listed are from one CCW Circle test. "NA" in the table indicates that no transition to oversteer occurred.

On both surfaces four of the vehicles, Vehicles C, D, E and L, remained understeering through the entire range of lateral accelerations tested (i.e. they did not transition to oversteer). For five of the vehicles (Vehicles B, F, H, I and J) the transition acceleration values are higher for the groomed dirt tests than for the asphalt tests. Conversely, three of the vehicles (Vehicles A, G and K) have higher transition acceleration values for the tests conducted on asphalt.

Figure 1 is a bar chart showing the Roll Gradients, the amount of roll angle in degrees per "g" of lateral acceleration measured during the Circle tests conducted on groomed dirt and asphalt. The values shown for the groomed dirt tests are the average of the CW and CCW tests, and for the asphalt tests they are from a single CCW test. The Roll Gradients measured on the two surfaces are relatively close. Six of the vehicles have higher Roll Gradients on the groomed dirt surface while the other six have higher Roll Gradients on the asphalt surface.

4.2 Comparison of J-Turn Test Results

[16] *Effects on ATV Vehicle Characteristics of Driver Active Weight Shift – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Report to CPSC, In Review.

A summary of the Threshold Lateral Acceleration (Threshold Ay) values determined from the 20 mph Dropped Throttle J-Turn tests measured on both surfaces is given in Table 6. A bar chart with the same information is provided in Figure 2. The bar chart also shows each of the vehicle curb weights. For the groomed dirt tests, the values shown are the average of 12 runs (six right turn tests and six left turn tests), and for the tests conducted on asphalt the values shown are the average of six left turn tests.

As mentioned, on groomed dirt Vehicle D did not experience any two-wheel lift tests outcomes, even for tests conducted with an initial speed of 22 mph and using the vehicle's maximum steering angle of 38 degrees. The lateral acceleration values shown for Vehicle D on groomed dirt are the average maximum lateral accelerations achieved during the 22 mph, maximum steering tests.

Vehicle J has the same Threshold Ay value on groomed dirt and on asphalt test surfaces. Two of the vehicles (Vehicles K and L) have slightly higher Threshold Ay values (within 0.014 g) on groomed dirt than on asphalt; while four vehicles (Vehicles C, E, G and H) have slightly higher Threshold Ay values (within 0.015 g) on asphalt. Excluding Vehicle D, the remaining four vehicles (Vehicles A, B, F and I) all have higher Threshold Ay values on asphalt (by at least 0.024 g) than they do on groomed dirt.

Figure 3 is a bar chart showing the same information as Figure 2, but Figure 3 is ranked using the groomed dirt test Threshold Ay values, with the vehicle with the lowest value starting on the left. The five vehicles with the lowest Threshold Ay values on groomed dirt are the same five vehicles with the lowest Threshold Ay values on asphalt. The vehicle with the highest Threshold Ay on groomed dirt (Vehicle H) also has the highest Threshold Ay on asphalt.

The average steering magnitudes used for the J-Turn tests are shown on Figure 4. The order of the vehicles in Figure 4 matches the order of the vehicles shown in Figure 3. For nine of the eleven vehicles that experienced two-wheel lifts on both test surfaces, the steering magnitudes required to produce two-wheel lift outcomes are higher on the groomed dirt surface than on the asphalt surface. Six of the vehicles (Vehicles A, C, E, H, K and L) required more than two degrees of additional steering magnitude on groomed dirt than on asphalt.

Generally, for the J-Turn tests conducted on the groomed dirt surface, the front tires experience more lateral slip than on asphalt. This means that more steering magnitude is required to generate enough tire lateral force to cause the vehicle to turn enough to generate lateral accelerations that result in two-wheel lift outcomes. However, this is not the case for all vehicles, as several vehicles required similar or even slightly less steering magnitude to generate two-wheel lift on groomed dirt than on asphalt.

On groomed dirt, the rise of lateral acceleration up to its peak (Threshold Ay) is generally delayed compared to its rise on asphalt. This is consistent with the fact that generally more steering input is required on groomed dirt than on asphalt. Likely this delay in response allows more time for the vehicles to generate roll motion, and thereby tends to reduce the lateral acceleration needed to generate visual two-wheel lift outcomes.

4.3 Comparison of Yaw Rate Ratio Test Results

Table 7 contains results comparing the Yaw Rate Ratios determined from Constant Steer tests

conducted on groomed dirt and asphalt. The tests conducted on asphalt were conducted only in the CCW (left turn) direction, so the values in Table 7 are all for CCW tests. Figure 5 contains a bar chart of the information listed on Table 7, ranked by the Yaw Rate Ratios measured on groomed dirt.

As mentioned, Vehicles C, D, E and L did not transition to oversteer during the Circle tests on groomed dirt or asphalt; and these four vehicles have Yaw Rate Ratios below or close to 1.0 on both surfaces. Vehicle K also has low Yaw Rate Ratios on both surfaces. For the other seven vehicles, three of them (Vehicles G, I, and J) have higher Yaw Rate Ratios on asphalt and four of them (Vehicles A, B, F, and H) have higher Yaw Rate Ratios on groomed dirt.

For several vehicles, there is a large disparity between the values measured on groomed dirt and asphalt. For example, Vehicle B has a significantly higher Yaw Rate Ratio on groomed dirt while Vehicle J has a significantly higher value on asphalt. Figures 6 and 7 contain results from tests conducted on groomed dirt (left columns) and asphalt (right columns) for Vehicle B and Vehicle J, respectively. The top row of both figures shows plots of Estimated Ay versus Speed, and the bottom row plots of Yaw Rate versus Speed (which include the Yaw Rate Ratio curve fits and values). Additional graphs associated with the groomed dirt runs are contain in Appendix C of this report, while additional graphs associated with the asphalt runs are contained in the report from the Task Order 3 rider-active study.[17] The differences in Yaw Rate Ratio calculations can be attributed to the fact that during the tests with high Yaw Rate Ratio values, the Estimated Ay (which is computed by multiplying Yaw Rate times Speed) responses fluctuate in the range of 0.3-0.4 g. The red circles on Figures 6 and 7 indicate the areas of fluctuation between 0.3-0.4 g; and they are associated with the high Yaw Rate Ratio for Vehicle B on groomed dirt and for Vehicle J on asphalt. Conversely, the Estimated Ay traces for Vehicle B on asphalt and Vehicle J on groomed dirt are relatively smooth in the range of 0.3-0.4 g, and the Yaw Rate Ratio values computed for these CCW tests are 3.36 and 3.22, respectively. Based on these results, the occurrence of yaw fluctuations during the Yaw Rate Ratio tests is not dependent on the test surface. The balance of axle side forces that generate yaw motions caused Vehicle B to fluctuate between 0.3-0.4 g on groomed dirt, but for Vehicle J the fluctuations were on asphalt.

4.4 Summary

As stated before, this is a preliminary comparison of autonomous testing of the 12 test vehicles on an asphalt surface (with 0º rider lean and tests constrained in the counterclockwise, left turn direction) with autonomous testing on a groomed dirt surface. There is mixed bag of correlation between the results from tests conducted on groomed dirt and on asphalt. During Circle tests on both surfaces, the same four vehicles (Vehicles C, D, E and L) remained understeering up to the tests' limits of 0.4 g. For the remaining vehicles, five of them transitioned to oversteer at higher lateral accelerations on groomed dirt tests and three of them transitioned to oversteer at higher lateral accelerations on asphalt.

Vehicle D did not experience a two-wheel lift during any of the J-Turn tests conducted on groomed dirt, even those at a higher test speed of 22 mph and using maximum steering input. In general, the Threshold Ay values are higher on asphalt than on groomed dirt, as seven of the other eleven vehicles have higher values on asphalt. One vehicle has the same Threshold Ay value on both surfaces, and two vehicles have slightly higher values on groomed dirt. The same five vehicles

[17] *Effects on ATV Vehicle Characteristics of Rider Active Weight Shift – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Report to CPSC, In Review.

that have the lowest Threshold Ay values on groomed dirt have the lowest values on asphalt, and one vehicle has the highest Threshold Ay value on both surfaces.

The steering magnitudes required to produce two-wheel outcomes are generally greater on the groomed dirt surface than on the asphalt surface, as nine of the eleven vehicles that experienced two-wheel lift on both test surfaces required greater steering input on groomed dirt.

The same four vehicles that did not transition to oversteer during the Circle tests on groomed dirt or asphalt had Yaw Rate Ratios below or close to 1.0 on both surfaces. Vehicle K also has low Yaw Rate Ratios on both surfaces.

For the other seven vehicles, three of them have higher Yaw Rate Ratios on asphalt and four of them have higher Yaw Rate Ratios on groomed dirt. Furthermore, of these seven vehicles, several of them have significantly different Yaw Rate Ratios on groomed dirt than on asphalt. The underlying data shows that oscillations in the yaw rates and lateral accelerations in the range of 0.3-0.4 g are greater on groomed dirt for some vehicles, but greater on asphalt for other vehicles.

Table 5: Comparison of US to OS Transition Points

Constant Radius (50 ft) Circle Tests **Lateral Acceleration Level at Point of Transition from Understeer to Oversteer** **Autonomous Groomed Dirt Values: Average of CW and CCW Tests** **Autonomous Asphalt Values: CCW Tests**		
	Autonomous Groomed Dirt (g)	**Autonomous Asphalt (g)**
Vehicle A	**0.16**	**0.17**
Vehicle B	**0.24**	**0.18**
Vehicle C	**NA**	**NA**
Vehicle D	**NA**	**NA**
Vehicle E	**NA**	**NA**
Vehicle F	**0.20**	**0.13**
Vehicle G	**0.11**	**0.17**
Vehicle H	**0.25**	**0.15**
Vehicle I	**0.23**	**0.18**
Vehicle J	**0.21**	**0.17**
Vehicle K	**0.23**	**0.25**
Vehicle L	**NA**	**NA**

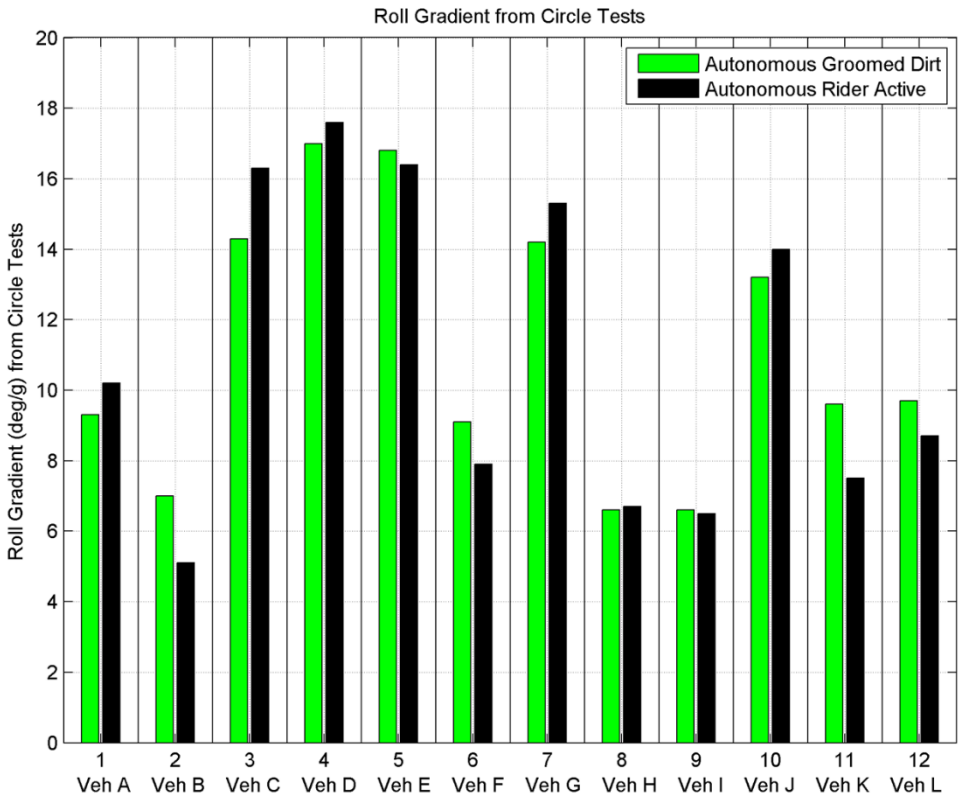


Figure 1: Comparison of Roll Gradients

Table 6: Comparison of Threshold Ay Values

20 mph Dropped Throttle J-Turn Tests Threshold Lateral Acceleration Autonomous Groomed Dirt Values: Average of Right and Left Turns Autonomous Asphalt Values: Left Turns		
	Autonomous Groomed Dirt (g)	Autonomous Asphalt (g)
Vehicle A	0.406	0.448
Vehicle B	0.547	0.585
Vehicle C	0.505	0.520
Vehicle D	0.528 (Max Steering Used – 22 mph No Two-Wheel Lift Outcomes)	0.579
Vehicle E	0.562	0.570
Vehicle F	0.426	0.465
Vehicle G	0.445	0.459
Vehicle H	0.598	0.602
Vehicle I	0.527	0.551
Vehicle J	0.505	0.505
Vehicle K	0.554	0.540
Vehicle L	0.563	0.558

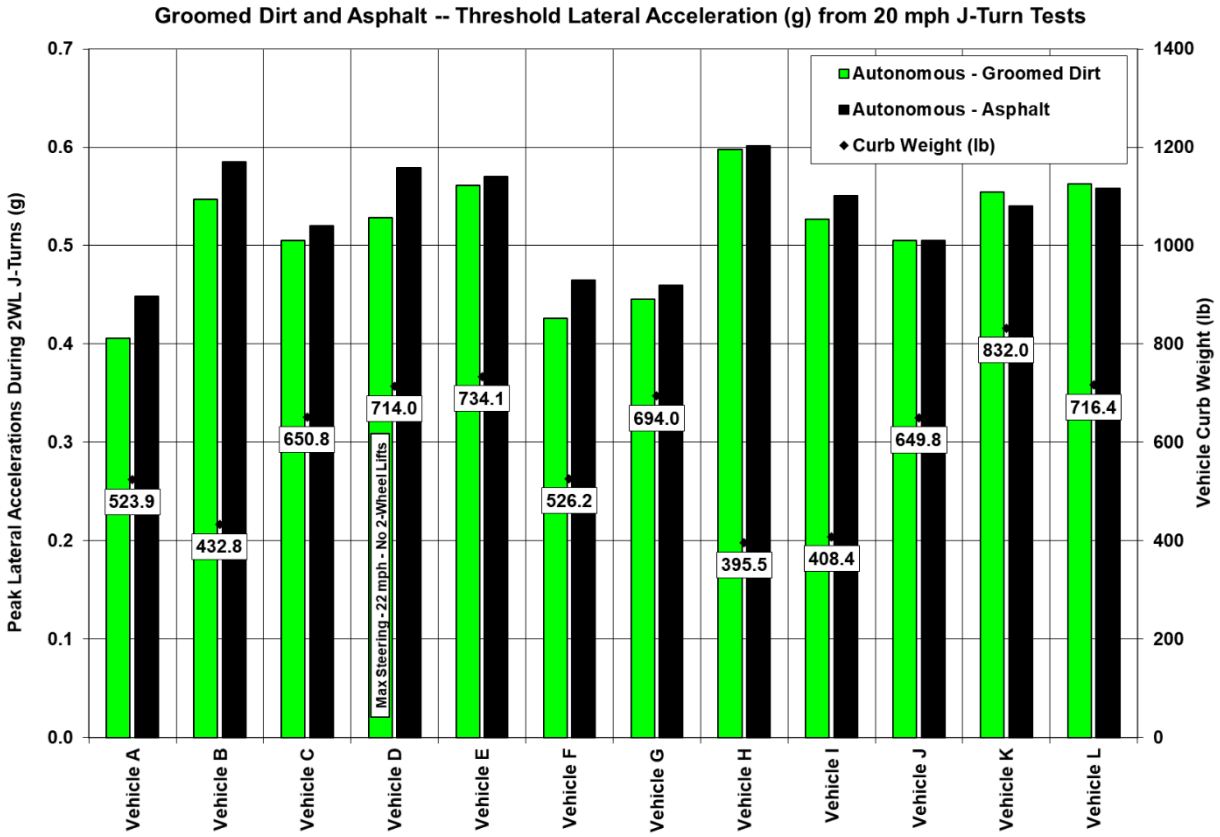


Figure 2: Comparison of Threshold Ay Values

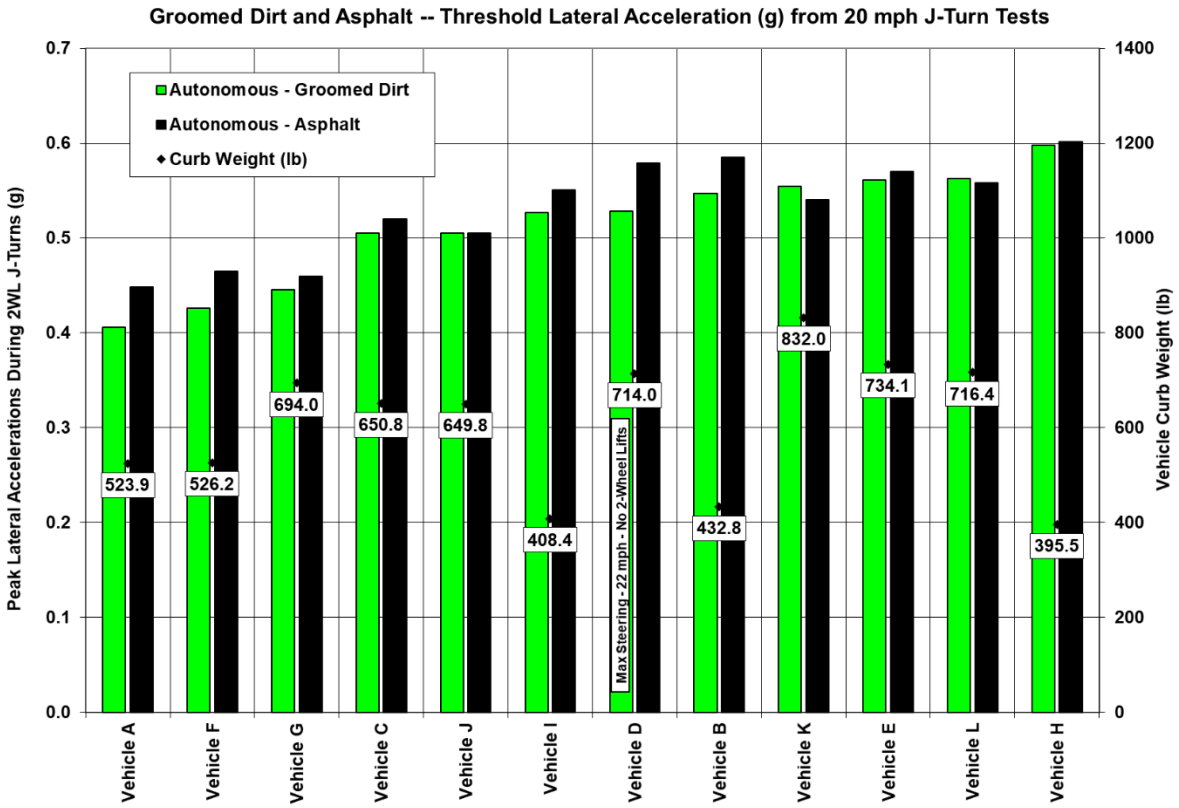


Figure 3: Ranked (by Groomed Dirt Tests) Threshold Ay Values

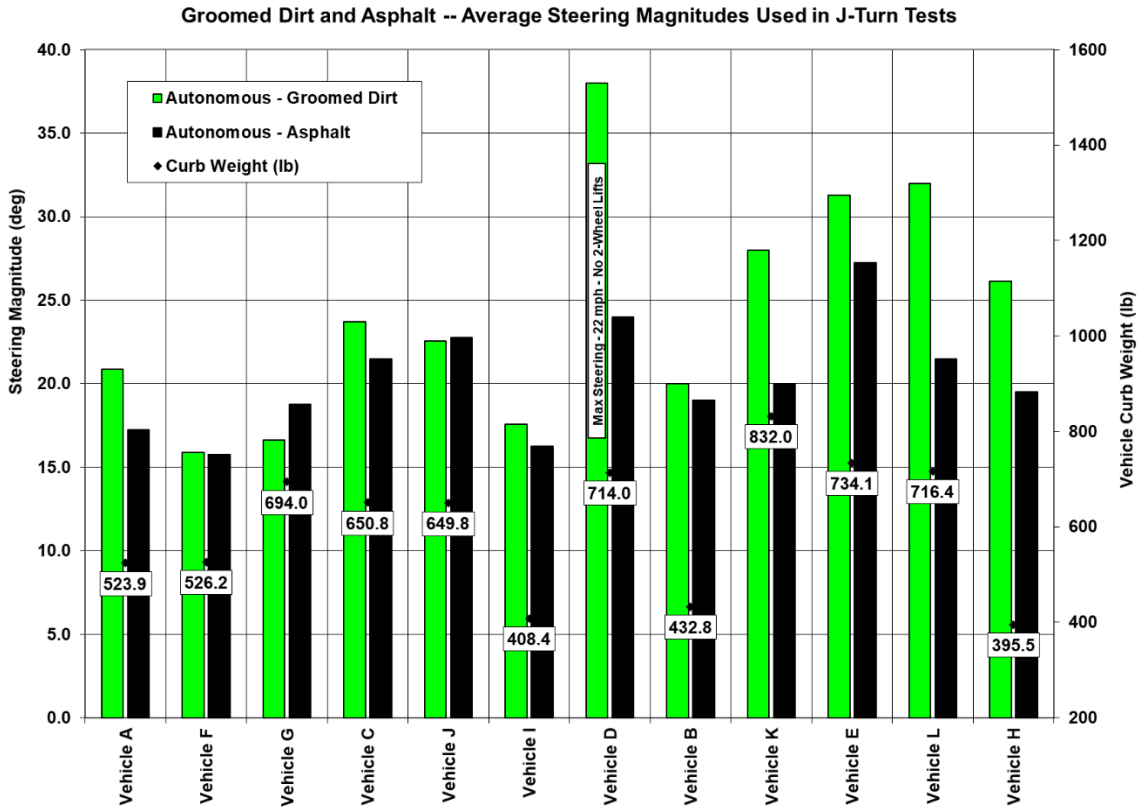


Figure 4: Roadwheel Steering Magnitudes used in J-Turn Tests

Table 7: Comparison of Yaw Rate Ratio Values

Constant Steer Tests Yaw Rate Ratios Autonomous Groomed Dirt Values: CCW Tests Autonomous Asphalt Values: CCW Tests		
	Autonomous Groomed Dirt Ratio	Autonomous Asphalt Ratio
Vehicle A	29.6	9.70
Vehicle B	147	3.36
Vehicle C	0.26	0.53
Vehicle D	0.57	0.25
Vehicle E	0.40	0.14
Vehicle F	7.94	4.65
Vehicle G	7.37	8.40
Vehicle H	16.3	9.89
Vehicle I	1.90	7.22
Vehicle J	3.22	18.1
Vehicle K	1.06	2.24
Vehicle L	1.34	1.27

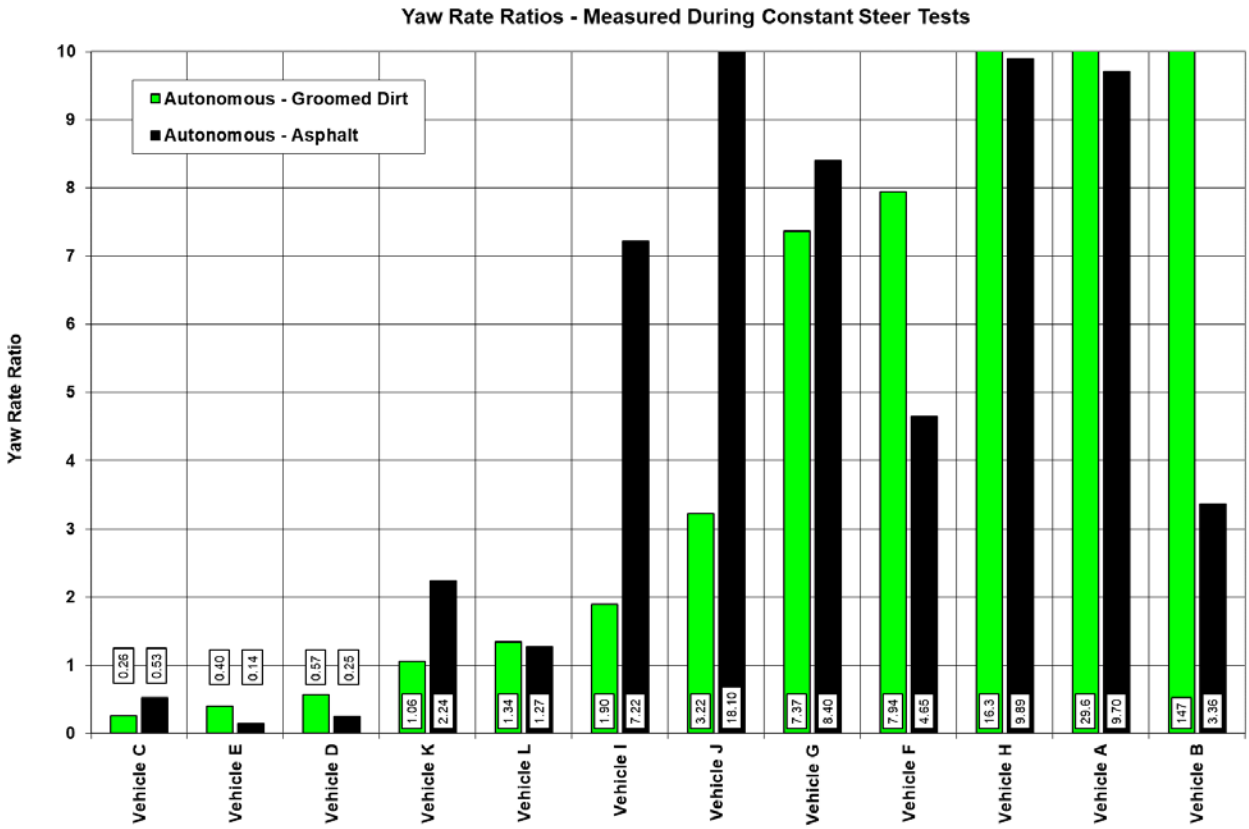
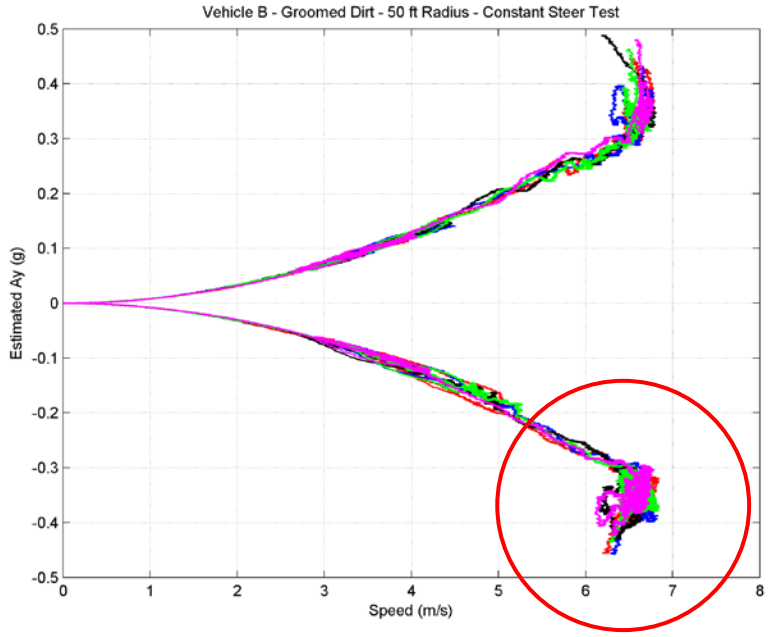
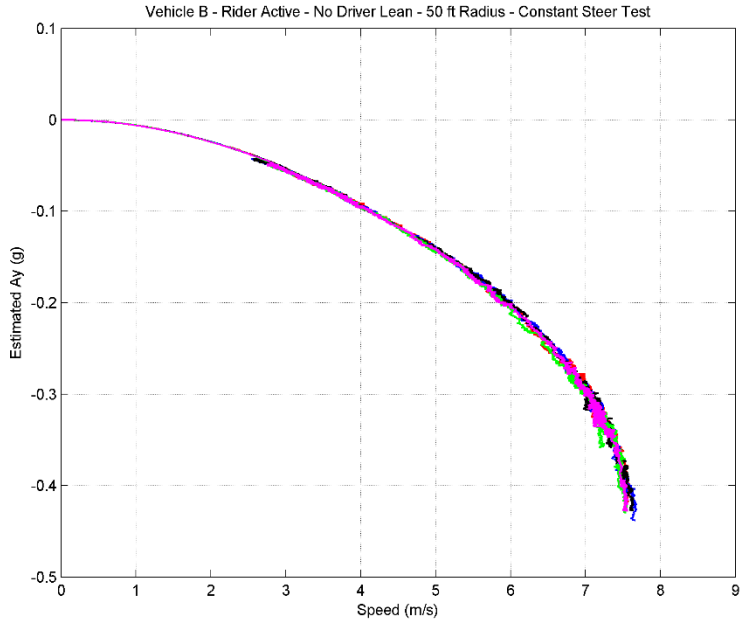
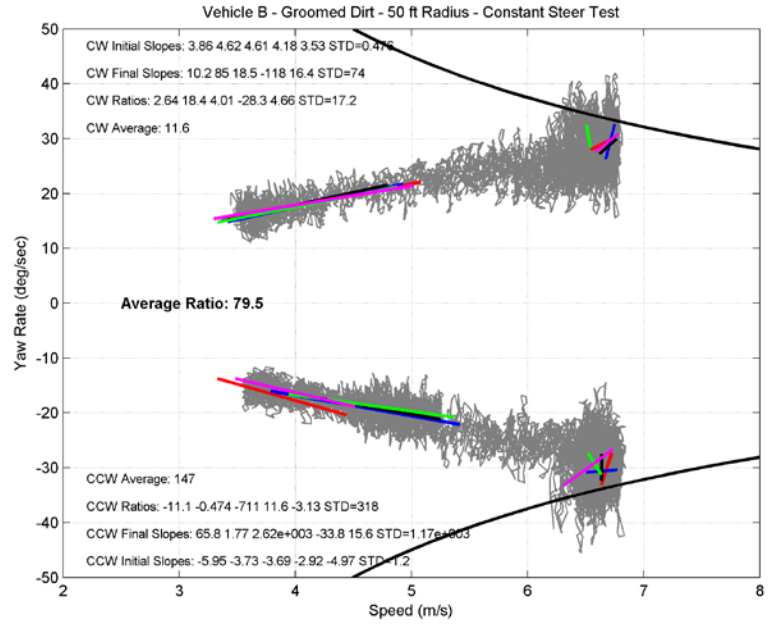
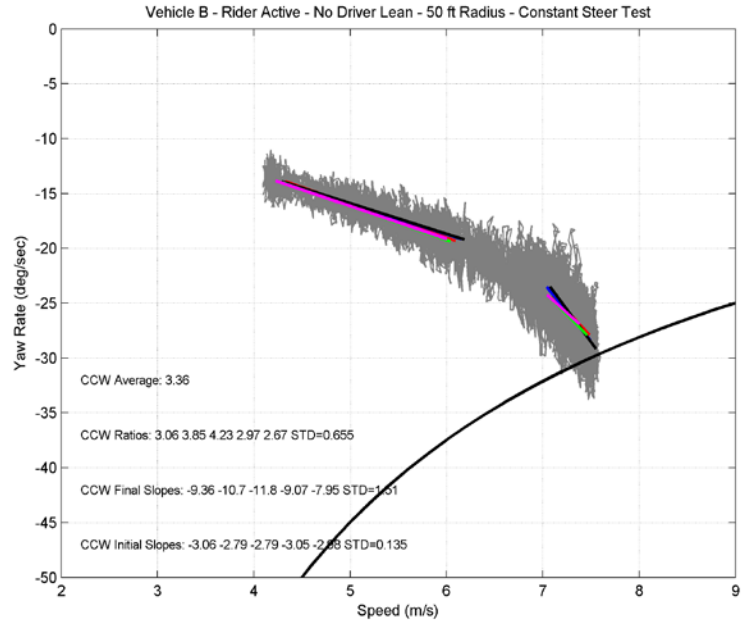


Figure 5: Ranked (by Groomed Dirt Tests) Yaw Rate Ratio Values



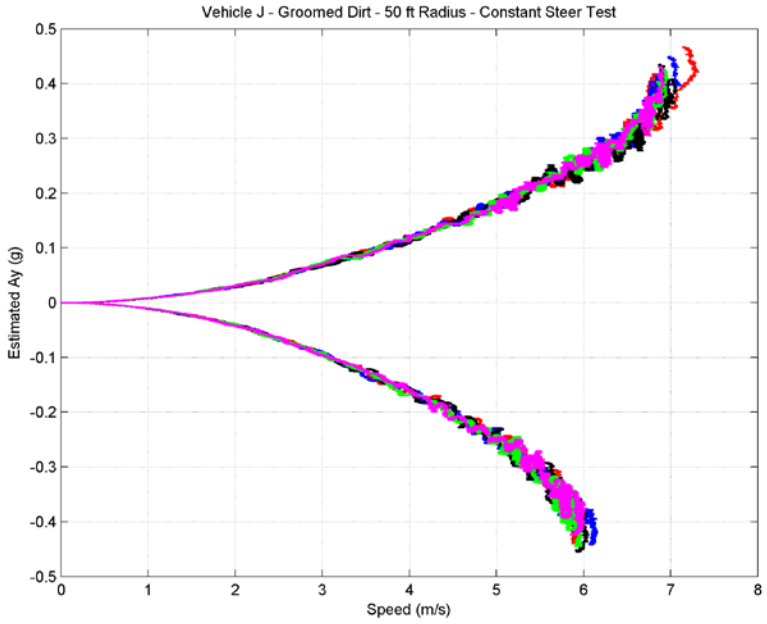


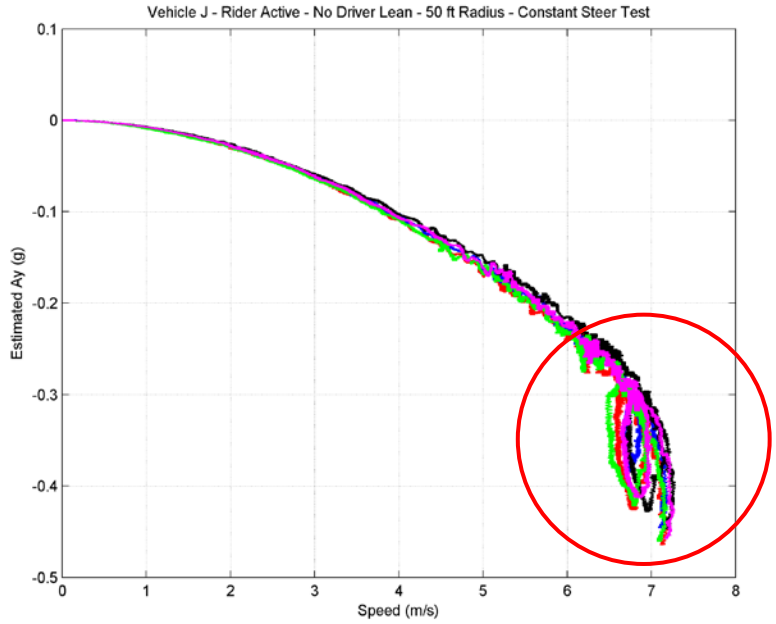


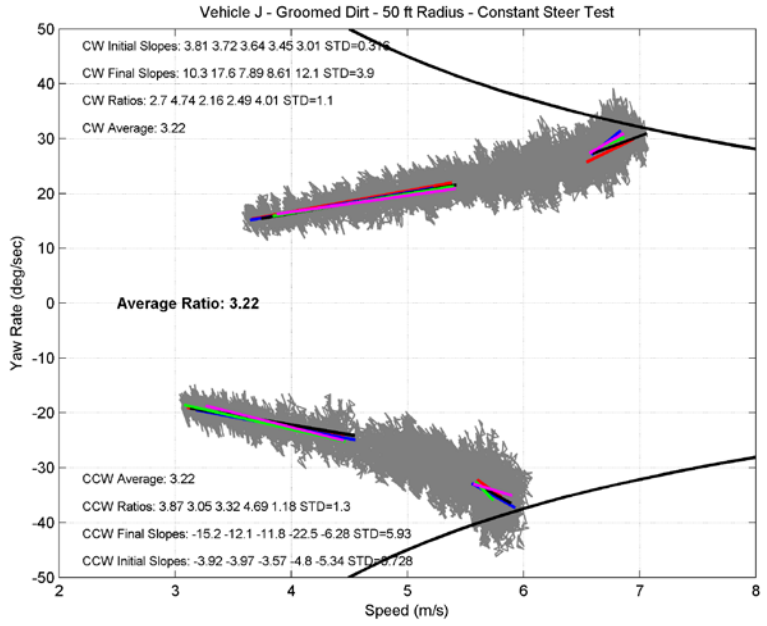


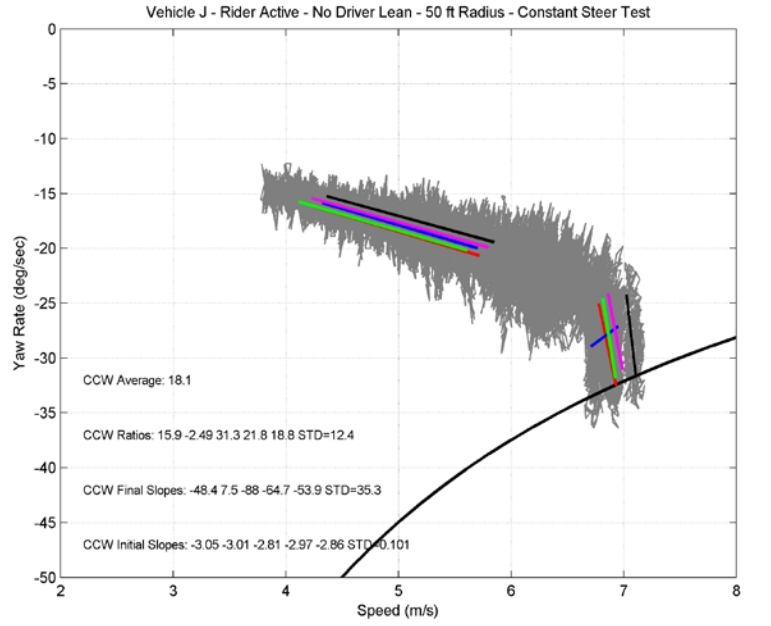
Vehicle B – Groomed Dirt **Vehicle B – Asphalt**

Figure 6: Results from Vehicle B Yaw Rate Ratio Tests on Groomed Dirt (Left) and Asphalt (Right)









Vehicle J – Groomed Dirt **Vehicle J – Asphalt**

Figure 7: Results from Vehicle J Yaw Rate Ratio Tests on Groomed Dirt (Left) and Asphalt (Right)

Vehicle A

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5765	5766	5842			
Total Vehicle Weight (lb)	523.9	737.1	759.6	989.7	741.1	1004.1	753.1
Left Front Weight (lb)	151.5	177.3	198.3	232.2	168.4	187.6	170.6
Right Front Weight (lb)	118.4	161.0	176.8	212.1	160.4	226	160.1
Left Rear Weight (lb)	132.0	206.1	204.4	293.5	211.6	300.2	210.5
Right Rear Weight (lb)	122.0	192.7	180.1	251.9	200.7	290.3	211.9
Front Track Width (in)	33.20	33.50	33.66	33.93	33.50	33.93	33.50
Rear Track Width (in)	32.25	32.30	32.28	32.35	32.30	32.35	32.30
Average Track Width (in)	32.73	32.90	32.97	33.14	32.90	33.14	32.90
Wheelbase (in)	48.40	48.35	48.30	48.25	48.35	48.25	48.35
CG Longitudinal (in)	23.47	26.16	24.45	26.59	26.90	28.38	27.12
CG Lateral (in)	-1.36	-0.66	-0.99	-1.02	-0.42	0.49	-0.20
CG Height (in)		23.61	22.65	25.00			
Roll Inertia - I_{XX} (ft-lb-s^2)		55	66	86			
Pitch Inertia - I_{YY} (ft-lb-s^2)		73	80	141			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		54	63	115			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	3	8			
SSF		0.697	0.728	0.663			
KST		0.698	0.728	0.664			
Steering Ratio (deg/deg)			1.42				

Vehicle B

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5768	5769				
Total Vehicle Weight (lb)	432.8	644.9	689.6		660.8	859.6	666.4
Left Front Weight (lb)	117.8	144.0	174.5		143.8	164.2	139.2
Right Front Weight (lb)	101.4	130.9	156.6		140.9	158.4	142.7
Left Rear Weight (lb)	107.7	181.7	172.0		185.1	258.1	190.1
Right Rear Weight (lb)	105.9	188.3	186.5		191.0	278.9	194.4
Front Track Width (in)	37.78	38.13	38.45		38.13	38.58	38.13
Rear Track Width (in)	35.58	35.50	35.40		35.50	35.50	35.50
Average Track Width (in)	36.68	36.81	36.93		36.81	37.04	36.81
Wheelbase (in)	50.30	50.85	50.85		50.85	51.50	50.85
CG Longitudinal (in)	24.82	29.17	26.44		28.94	32.17	29.34
CG Lateral (in)	-0.79	-0.21	-0.13		0.07	0.30	0.21
CG Height (in)		22.77	22.34				
Roll Inertia - I_{XX} (ft-lb-s^2)		48	48				
Pitch Inertia - I_{YY} (ft-lb-s^2)		61	71				
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		42	56				
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	4				
SSF		0.808	0.826				
KST		0.813	0.828				
Steering Ratio (deg/deg)			1.34				

Vehicle C

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5771	5772	5844			
Total Vehicle Weight (lb)	650.8	863.6	885.0	1135.1	864.0	1080.2	880.0
Left Front Weight (lb)	175.1	208.3	224.7	251.5	195.0	212.7	200.2
Right Front Weight (lb)	163.9	199.5	221.9	245.1	194.0	210.3	192.0
Left Rear Weight (lb)	155.9	231.6	225.7	317.5	236.7	324.6	240.1
Right Rear Weight (lb)	155.9	224.2	212.7	321.0	238.3	332.6	247.7
Front Track Width (in)	39.71	39.95	39.95	40.10	39.95	40.10	39.95
Rear Track Width (in)	37.66	38.40	38.45	38.85	38.40	38.85	38.40
Average Track Width (in)	38.69	39.18	39.20	39.48	39.18	39.48	39.18
Wheelbase (in)	49.33	49.30	49.30	49.30	49.30	49.30	49.30
CG Longitudinal (in)	23.63	26.02	24.42	27.73	27.10	29.99	27.33
CG Lateral (in)	-0.34	-0.37	-0.35	-0.05	0.01	0.10	-0.02
CG Height (in)		23.74	22.97	25.50			
Roll Inertia - I_{XX} (ft-lb-s^2)		75	78	109			
Pitch Inertia - I_{YY} (ft-lb-s^2)		92	101	174			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		72	83	147			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		7	5	18			
SSF		0.825	0.853	0.774			
KST		0.826	0.853	0.776			
Steering Ratio (deg/deg)			1.62				

Vehicle D

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5774	5775	5845			
Total Vehicle Weight (lb)	714.0	927.4	948.8	1227.9	929.7	1143.8	941.7
Left Front Weight (lb)	179.9	216.3	234.7	268.9	206.6	229.5	211.5
Right Front Weight (lb)	169.7	205.7	223.9	269.9	203.7	225.5	198.5
Left Rear Weight (lb)	181.7	254.2	246.6	352.7	254.2	338.6	259.6
Right Rear Weight (lb)	182.7	251.2	243.6	336.4	265.2	350.2	272.1
Front Track Width (in)	39.46	39.90	39.99	40.40	39.90	40.40	39.90
Rear Track Width (in)	38.08	38.88	38.85	39.64	38.88	39.64	38.88
Average Track Width (in)	38.77	39.39	39.42	40.02	39.39	40.02	39.39
Wheelbase (in)	50.05	49.88	49.90	50.00	49.88	50.00	49.88
CG Longitudinal (in)	25.54	27.18	25.78	28.06	27.87	30.11	28.16
CG Lateral (in)	-0.26	-0.29	-0.29	-0.25	0.17	0.13	-0.02
CG Height (in)		24.14	23.54	26.27			
Roll Inertia - I_{XX} (ft-lb-s^2)		75	74	119			
Pitch Inertia - I_{YY} (ft-lb-s^2)		108	114	200			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		88	99	170			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	6	16			
SSF		0.816	0.837	0.762			
KST		0.817	0.838	0.763			
Steering Ratio (deg/deg)			1.22				

Vehicle E

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5777	5778	5846			
Total Vehicle Weight (lb)	734.1	947.6	968.9	1248.5	948.5	1160.7	959.8
Left Front Weight (lb)	190.3	221.1	245.4	277.0	208.9	231.9	218.1
Right Front Weight (lb)	168.5	210.1	220.9	260.1	209.1	230.7	203.5
Left Rear Weight (lb)	186.9	260.3	251.7	357.8	257.0	346.4	262.2
Right Rear Weight (lb)	188.4	256.1	250.9	353.6	273.5	351.7	276.0
Front Track Width (in)	39.48	39.80	40.05	40.50	39.80	40.50	39.80
Rear Track Width (in)	38.13	39.05	39.20	39.80	39.05	39.80	39.05
Average Track Width (in)	38.80	39.43	39.63	40.15	39.43	40.15	39.43
Wheelbase (in)	49.95	49.95	49.95	49.95	49.95	49.95	49.95
CG Longitudinal (in)	25.54	27.22	25.91	28.46	27.94	30.04	28.01
CG Lateral (in)	-0.55	-0.32	-0.52	-0.34	0.34	0.07	-0.02
CG Height (in)		23.70	23.12	26.24			
Roll Inertia - I_{XX} (ft-lb-s^2)		72	76	125			
Pitch Inertia - I_{YY} (ft-lb-s^2)		108	116	201			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		95	100	169			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	6	20			
SSF		0.832	0.857	0.765			
KST		0.832	0.857	0.766			
Steering Ratio (deg/deg)			1.21				

Vehicle F

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5780	5781	5847			
Total Vehicle Weight (lb)	526.2	739.8	761.4	924.0	741.5	954.5	737.5
Left Front Weight (lb)	149.1	166.1	190.7	211.9	162.4	188.7	160.5
Right Front Weight (lb)	122.7	172.1	179.2	198.3	159.4	184.3	166.9
Left Rear Weight (lb)	151.6	213.1	208.6	270.9	220.8	300.9	223.8
Right Rear Weight (lb)	102.8	188.5	182.9	242.9	198.9	280.6	186.3
Front Track Width (in)	32.14	32.55	32.45	32.76	32.55	32.76	32.55
Rear Track Width (in)	30.71	30.95	30.89	30.98	30.95	30.98	30.95
Average Track Width (in)	31.43	31.75	31.67	31.87	31.75	31.87	31.75
Wheelbase (in)	46.20	46.20	46.20	46.20	46.20	46.20	46.20
CG Longitudinal (in)	22.34	25.08	23.76	25.69	26.15	28.15	25.69
CG Lateral (in)	-2.23	-0.38	-0.77	-0.71	-0.52	-0.40	-0.65
CG Height (in)		23.45	22.38	24.04			
Roll Inertia - I_{XX} (ft-lb-s^2)		53	60	74			
Pitch Inertia - I_{YY} (ft-lb-s^2)		74	78	114			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		52	60	93			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		6	4	11			
SSF		0.677	0.708	0.663			
KST		0.678	0.708	0.665			
Steering Ratio (deg/deg)			1.29				

Vehicle G

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5783	5784	5848			
Total Vehicle Weight (lb)	694.0	909.4	928.6	1168.7	913.5	1127.7	918.6
Left Front Weight (lb)	174.2	215.4	223.9	253.3	198.2	220.2	201.7
Right Front Weight (lb)	168.1	199.1	219.4	251.0	198.7	222.5	200.6
Left Rear Weight (lb)	175.9	246.6	242.5	332.9	253.8	337.6	251.3
Right Rear Weight (lb)	175.8	248.3	242.8	331.5	262.8	347.4	265.0
Front Track Width (in)	36.35	36.45	36.50	36.45	36.45	36.45	36.45
Rear Track Width (in)	35.60	36.10	36.06	36.60	36.10	36.60	36.10
Average Track Width (in)	35.98	36.28	36.28	36.53	36.28	36.53	36.28
Wheelbase (in)	50.55	50.65	50.60	50.60	50.65	50.60	50.65
CG Longitudinal (in)	25.62	27.56	26.44	28.77	28.64	30.74	28.47
CG Lateral (in)	-0.16	-0.29	-0.08	-0.06	0.19	0.20	0.25
CG Height (in)		24.07	23.34	26.13			
Roll Inertia - I_{XX} (ft-lb-s^2)		79	75	109			
Pitch Inertia - I_{YY} (ft-lb-s^2)		110	117	198			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		88	96	163			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	5	17			
SSF		0.753	0.777	0.699			
KST		0.754	0.777	0.699			
Steering Ratio (deg/deg)			1.41				

Vehicle H

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5789	5790				
Total Vehicle Weight (lb)	395.5	608.7	654.6		621.6	821.2	624.5
Left Front Weight (lb)	103.2	130.8	160.0		123.8	138.0	121.6
Right Front Weight (lb)	93.4	121.8	161.2		126.9	148.0	127.9
Left Rear Weight (lb)	99.6	178.8	163.7		186.9	269.7	188.9
Right Rear Weight (lb)	99.3	177.3	169.7		184.0	265.5	186.1
Front Track Width (in)	38.75	39.00	39.35		39.00	38.85	39.00
Rear Track Width (in)	35.30	35.35	35.33		35.35	35.60	35.35
Average Track Width (in)	37.03	37.18	37.34		37.18	37.23	37.18
Wheelbase (in)	49.25	49.60	49.30		49.60	50.13	49.60
CG Longitudinal (in)	24.77	29.02	25.11		29.60	32.67	29.78
CG Lateral (in)	-0.49	-0.33	0.20		0.01	0.15	0.12
CG Height (in)		22.08	21.45				
Roll Inertia - I_{XX} (ft-lb-s^2)		48	46				
Pitch Inertia - I_{YY} (ft-lb-s^2)		59	69				
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		43	52				
Roll/Yaw - I_{XZ} (ft-lb-s^2)		3	4				
SSF		0.842	0.870				
KST		0.849	0.871				
Steering Ratio (deg/deg)			1.41				

Vehicle I

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5786	5787				
Total Vehicle Weight (lb)	408.4	621.6	656.8		633.2	837.5	629.9
Left Front Weight (lb)	100.9	131.8	157.7		123.2	142.4	122.3
Right Front Weight (lb)	95.9	132.1	147.1		125.3	140.4	124.0
Left Rear Weight (lb)	113.6	187.3	186.3		198.1	284.9	192.7
Right Rear Weight (lb)	98.0	170.4	165.7		186.6	269.8	190.9
Front Track Width (in)	35.85	36.40	36.50		36.40	36.30	36.40
Rear Track Width (in)	35.55	35.63	35.63		35.63	35.63	35.63
Average Track Width (in)	35.70	36.01	36.06		36.01	35.97	36.01
Wheelbase (in)	47.95	48.35	48.40		48.35	49.35	48.35
CG Longitudinal (in)	24.84	27.82	25.94		29.37	32.69	29.44
CG Lateral (in)	-0.90	-0.48	-0.85		-0.26	-0.36	0.00
CG Height (in)		23.29	22.71				
Roll Inertia - I_{XX} (ft-lb-s^2)		51	49				
Pitch Inertia - I_{YY} (ft-lb-s^2)		56	68				
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		51	53				
Roll/Yaw - I_{XZ} (ft-lb-s^2)		2	3				
SSF		0.773	0.794				
KST		0.774	0.795				
Steering Ratio (deg/deg)			1.33				

Vehicle J

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5792	5793	5851			
Total Vehicle Weight (lb)	649.8	862.4	885.2	1135.3	869.1	1086.3	884.1
Left Front Weight (lb)	172.3	202.7	216.1	255.7	195.7	218.1	195.1
Right Front Weight (lb)	160.9	195.8	208.8	248.6	195.9	220.9	203.0
Left Rear Weight (lb)	151.2	230.4	228.1	313.0	232.7	321.3	245.5
Right Rear Weight (lb)	165.4	233.5	232.2	318.0	244.8	326.0	240.5
Front Track Width (in)	36.05	36.73	36.79	36.96	36.73	36.96	36.73
Rear Track Width (in)	37.13	38.01	38.00	38.38	38.01	38.38	38.01
Average Track Width (in)	36.59	37.37	37.39	37.67	37.37	37.67	37.37
Wheelbase (in)	50.50	50.45	50.35	50.25	50.45	50.25	50.45
CG Longitudinal (in)	24.60	27.14	26.18	27.93	27.72	29.94	27.73
CG Lateral (in)	0.09	-0.08	-0.06	-0.03	0.27	0.13	0.06
CG Height (in)		23.76	23.08	25.40			
Roll Inertia - I_{XX} (ft-lb-s^2)		69	68	87			
Pitch Inertia - I_{YY} (ft-lb-s^2)		98	103	176			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		69	89	154			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		8	8	14			
SSF		0.786	0.810	0.742			
KST		0.785	0.810	0.740			
Steering Ratio (deg/deg)			1.42				

Vehicle K

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5795	5796	5852			
Total Vehicle Weight (lb)	832.0	1044.8	1070.7	1412.1	1045.6	1258.7	1086.2
Left Front Weight (lb)	206.7	239.9	241.8	283.8	227.0	253.4	223.2
Right Front Weight (lb)	192.0	220.6	224.7	268.3	217.7	246.7	230.3
Left Rear Weight (lb)	227.2	295.8	303.9	435.4	294.9	372.6	320.4
Right Rear Weight (lb)	206.1	288.5	300.3	424.6	306.0	386.0	312.3
Front Track Width (in)	39.96	40.83	40.83	41.30	40.83	41.30	40.83
Rear Track Width (in)	38.20	39.24	39.16	40.13	39.24	40.13	39.24
Average Track Width (in)	39.08	40.03	39.99	40.71	40.03	40.71	40.03
Wheelbase (in)	53.15	53.15	53.20	53.20	53.15	53.20	53.15
CG Longitudinal (in)	27.68	29.72	30.02	32.40	30.54	32.06	30.96
CG Lateral (in)	-0.84	-0.51	-0.39	-0.38	0.03	0.10	-0.01
CG Height (in)		23.44	22.92	25.51			
Roll Inertia - I_{XX} (ft-lb-s^2)		73	79	110			
Pitch Inertia - I_{YY} (ft-lb-s^2)		130	138	234			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		116	126	208			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	5	17			
SSF		0.854	0.873	0.798			
KST		0.856	0.875	0.800			
Steering Ratio (deg/deg)			1.43				

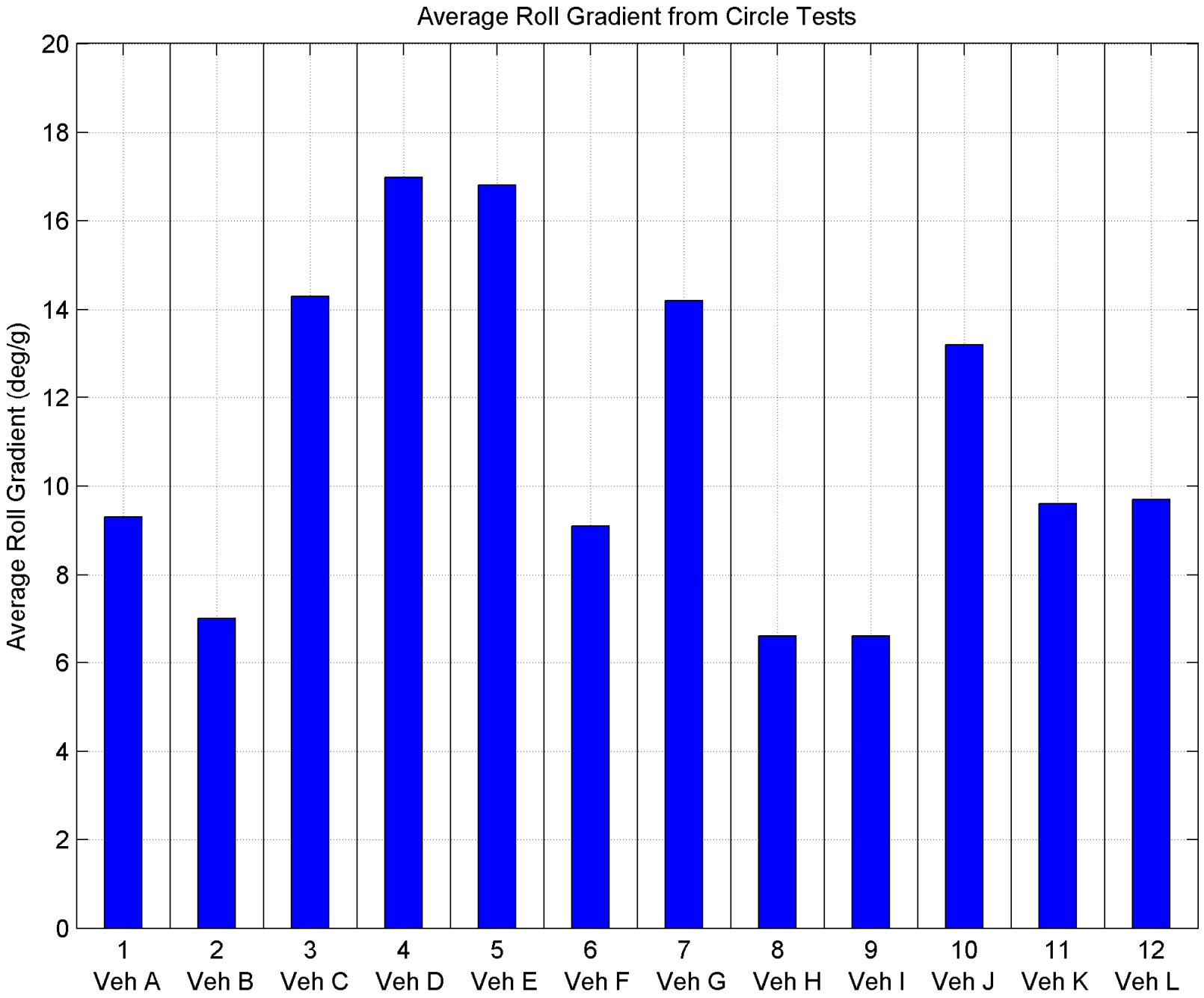
Vehicle L

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders	Autonomous Groomed Dirt Ballast to Driver Loading
VIMF Test Number		5798	5799	5853			
Total Vehicle Weight (lb)	716.4	929.1	951.1	1201.3	932.4	1142.1	947.3
Left Front Weight (lb)	185.8	216.9	235.3	261.4	205.6	231.1	198.8
Right Front Weight (lb)	159.6	202.4	217.1	250.3	197.4	221.0	206.7
Left Rear Weight (lb)	189.5	253.1	246.8	342.1	253.1	334.7	269.1
Right Rear Weight (lb)	181.5	256.7	251.9	347.5	276.3	355.3	272.7
Front Track Width (in)	39.59	39.76	39.80	39.40	39.76	39.40	39.76
Rear Track Width (in)	37.00	37.50	37.50	36.90	37.50	36.90	37.50
Average Track Width (in)	38.29	38.63	38.65	38.15	38.63	38.15	38.63
Wheelbase (in)	50.50	50.60	50.60	50.45	50.60	50.45	50.60
CG Longitudinal (in)	26.15	27.76	26.53	28.96	28.73	30.48	28.94
CG Lateral (in)	-0.93	-0.24	-0.28	-0.10	0.29	0.16	0.24
CG Height (in)		22.96	22.53	25.02			
Roll Inertia - I_{XX} (ft-lb-s^2)		78	84	132			
Pitch Inertia - I_{YY} (ft-lb-s^2)		115	120	185			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		98	101	157			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	7	18			
SSF		0.841	0.858	0.762			
KST		0.844	0.859	0.766			
Steering Ratio (deg/deg)			1.60				

Constant Radius (50 ft) Circle Tests

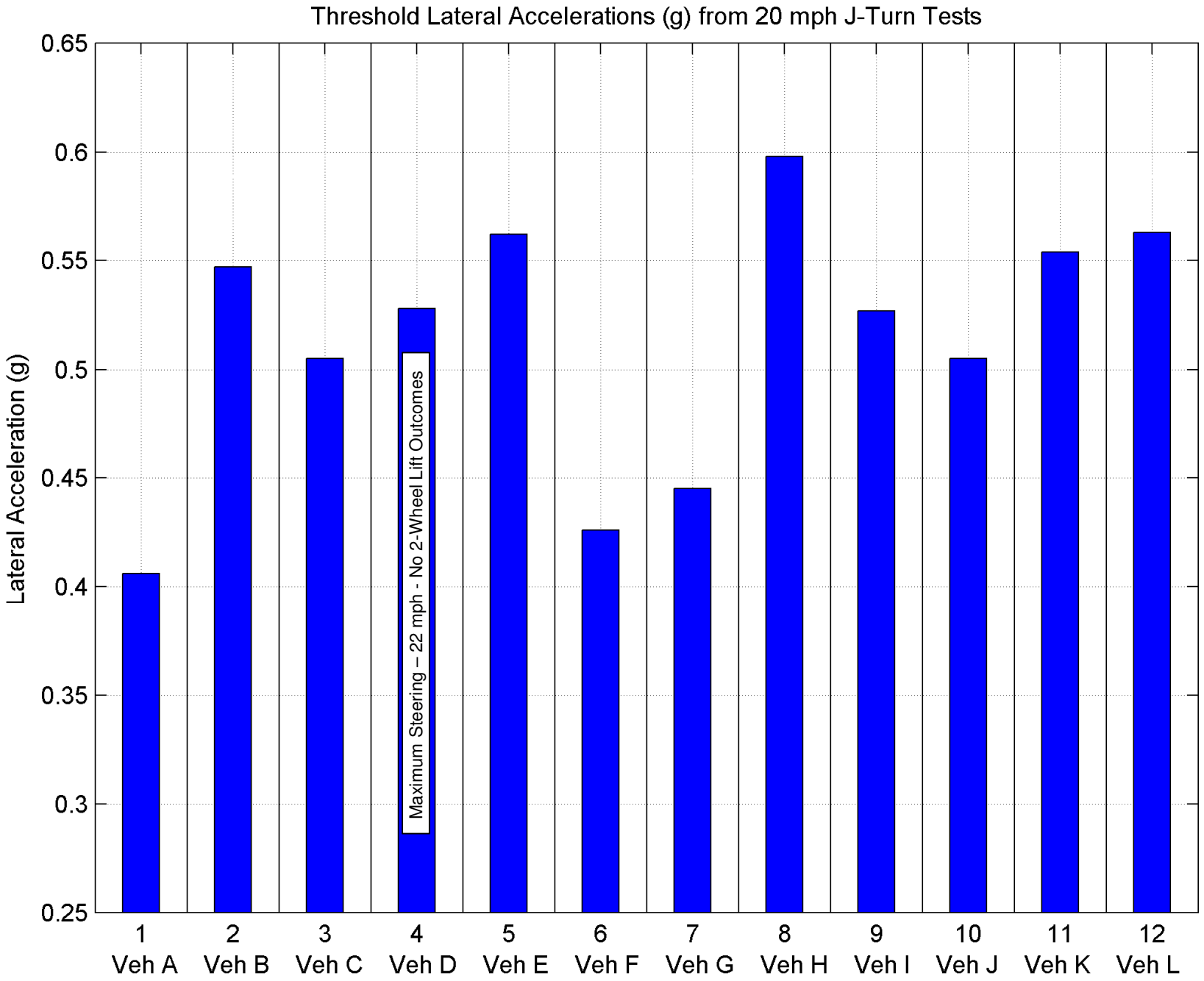
Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Autonomous Groomed Dirt Study)

	CW (g)	CCW (g)	Average (g)
Vehicle A	0.16	0.17	0.16
Vehicle B	0.27	0.21	0.24
Vehicle C	NA	NA	NA
Vehicle D	NA	NA	NA
Vehicle E	NA	NA	NA
Vehicle F	0.18	0.22	0.20
Vehicle G	0.10	0.13	0.11
Vehicle H	0.26	0.24	0.25
Vehicle I	0.23	0.24	0.23
Vehicle J	0.18	0.24	0.21
Vehicle K	0.21	0.25	0.23
Vehicle L	NA	NA	NA


Average Roll Gradient from Circle Tests
Average Roll Gradient (deg/g)
0
2
4
6
8
10
12
14
16
18
20
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
10
Veh J
11
Veh K
12
Veh L

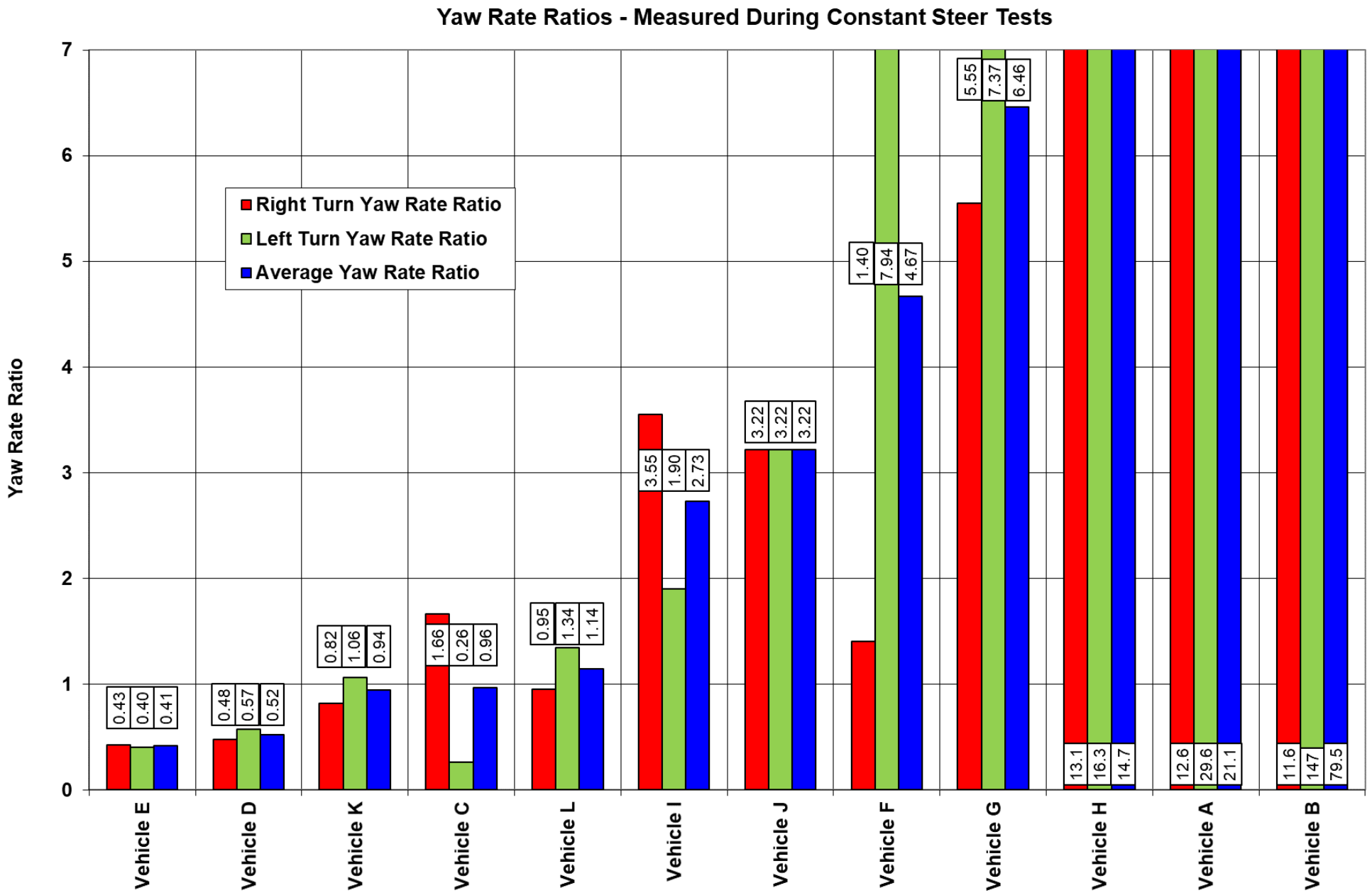
20 mph Dropped Throttle J-Turn Tests
Threshold Lateral Acceleration
(Autonomous Groomed Dirt Study)

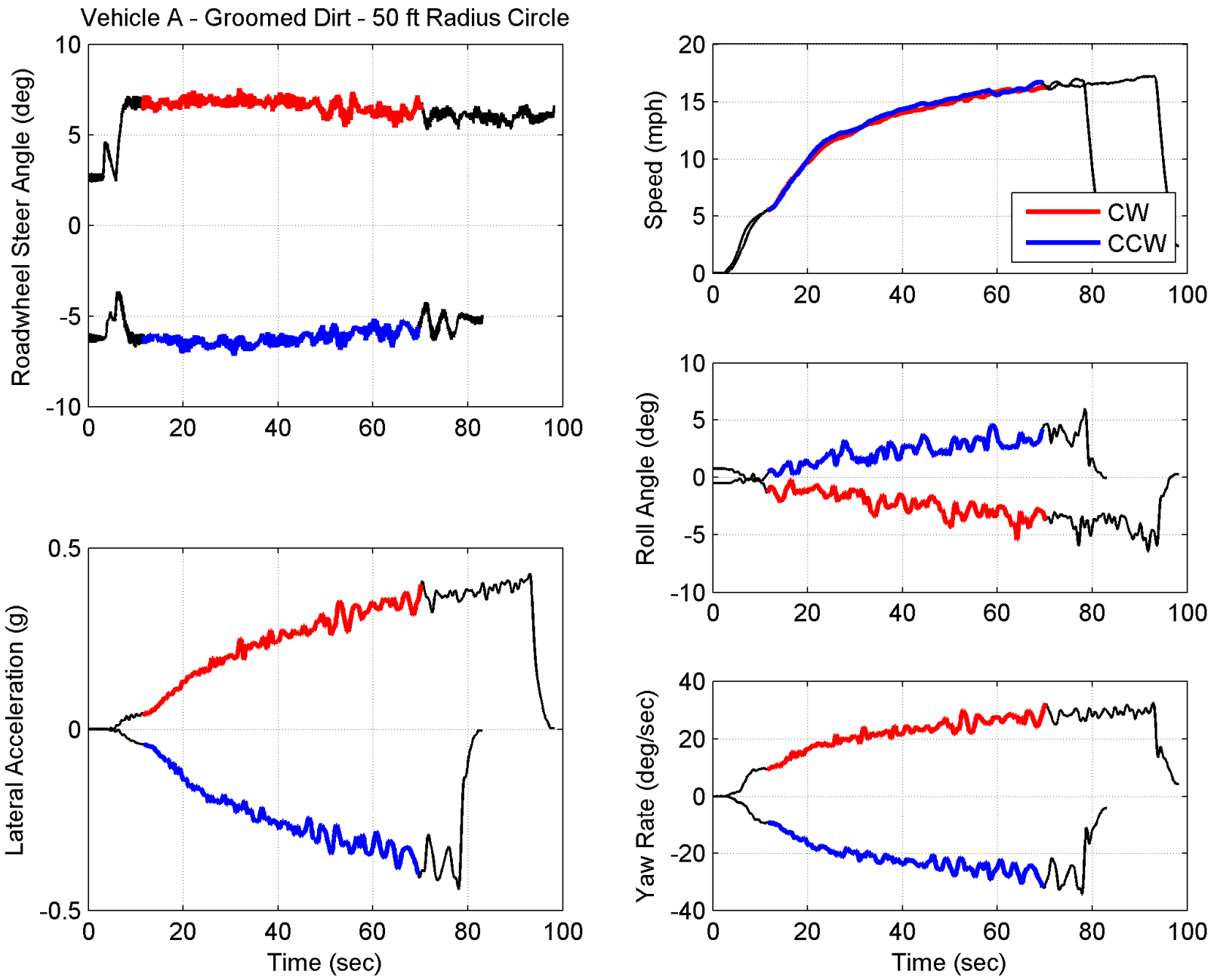
	Threshold Lateral Acceleration (g)	
Vehicle A	0.406	
Vehicle B	0.547	
Vehicle C	0.505	
Vehicle D	0.528	Maximum Steering Used – 22 mph No Two-Wheel Lift Outcomes
Vehicle E	0.562	
Vehicle F	0.426	
Vehicle G	0.445	
Vehicle H	0.598	
Vehicle I	0.527	
Vehicle J	0.505	
Vehicle K	0.554	
Vehicle L	0.563	

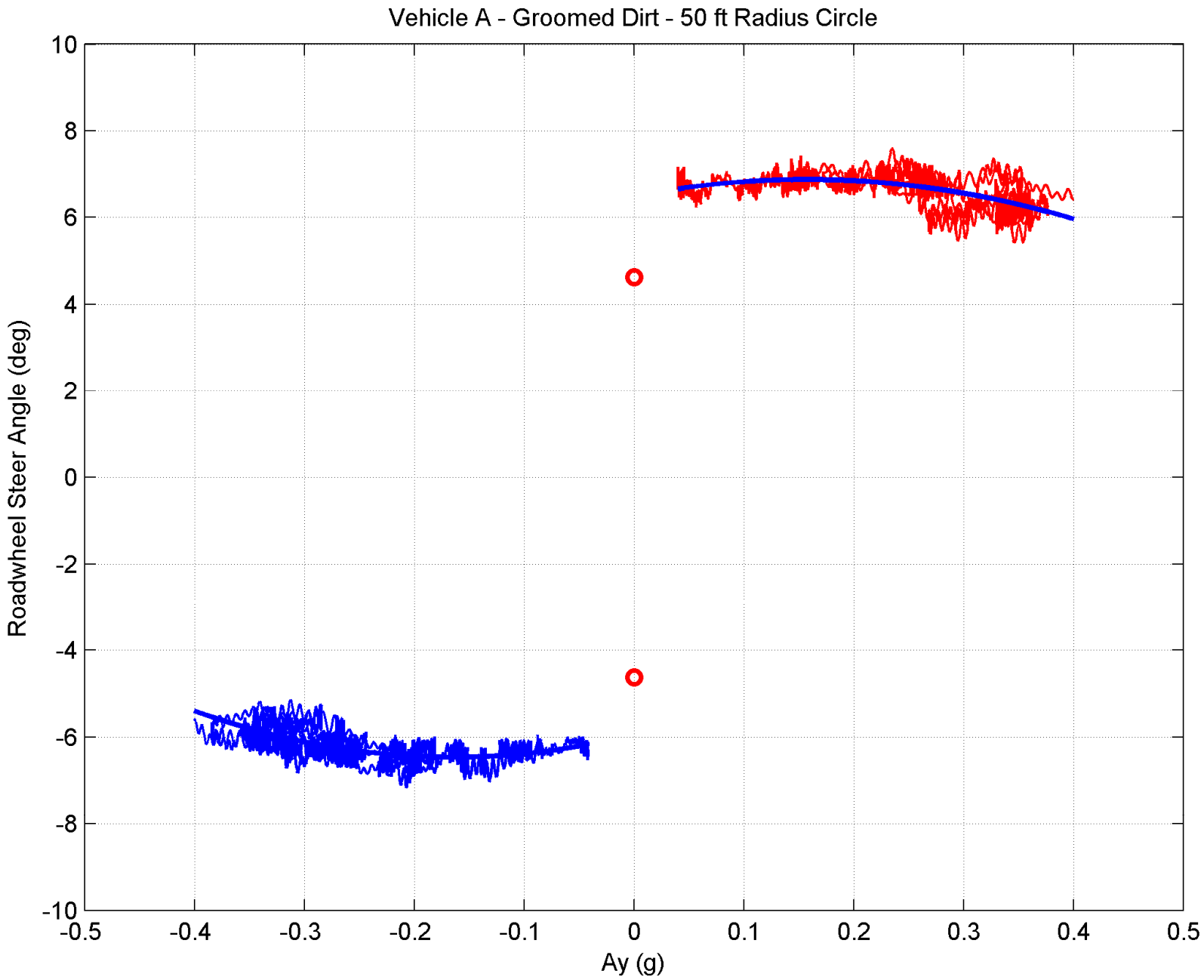

Threshold Lateral Accelerations (g) from 20 mph J-Turn Tests
Lateral Acceleration (g)
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
Maximum Steering – 22 mph - No 2-Wheel Lift Outcomes
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I
10 Veh J
11 Veh K
12 Veh L

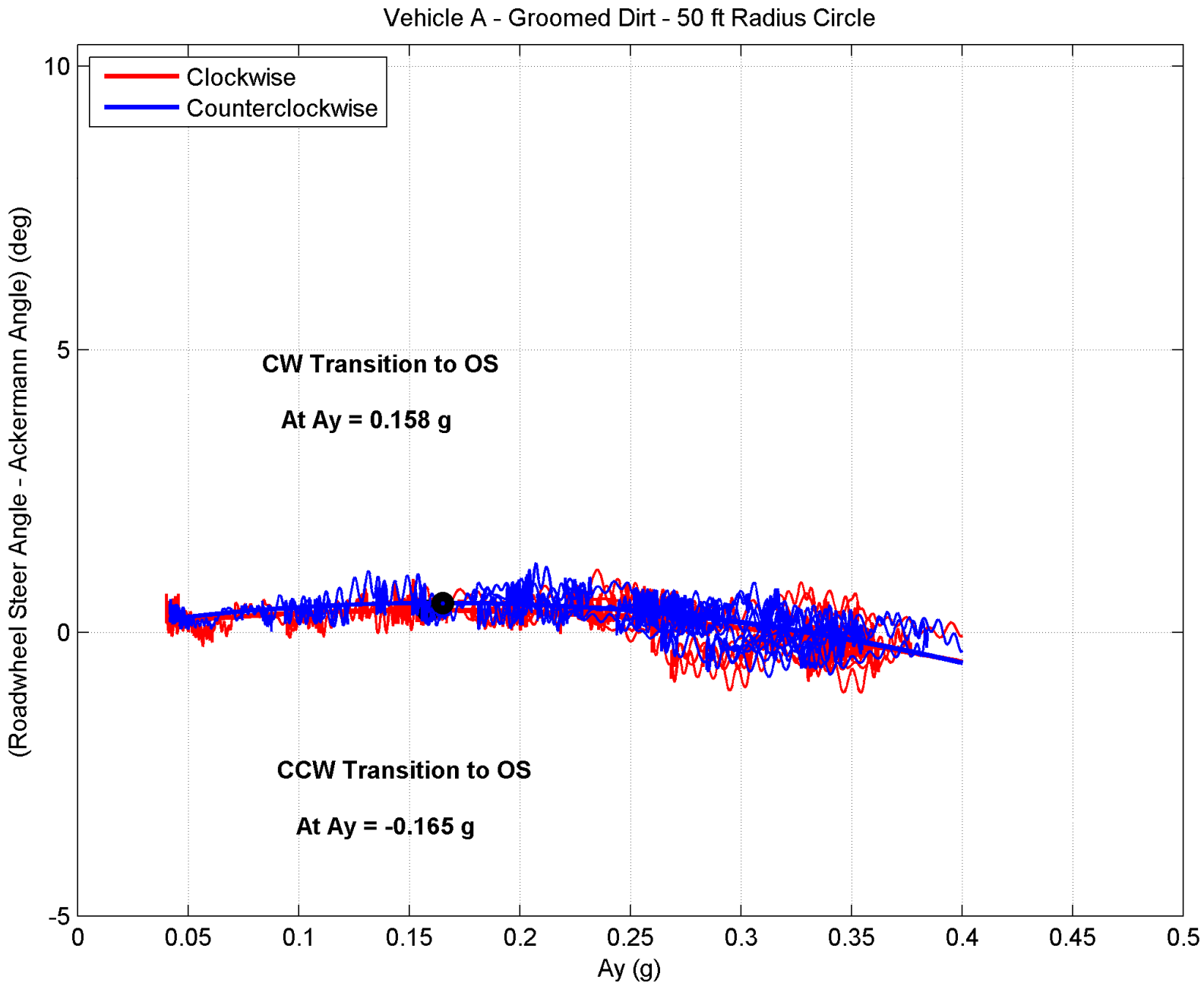
Constant Steer Tests
Yaw Rate Ratios
(Autonomous Groomed Dirt Study)

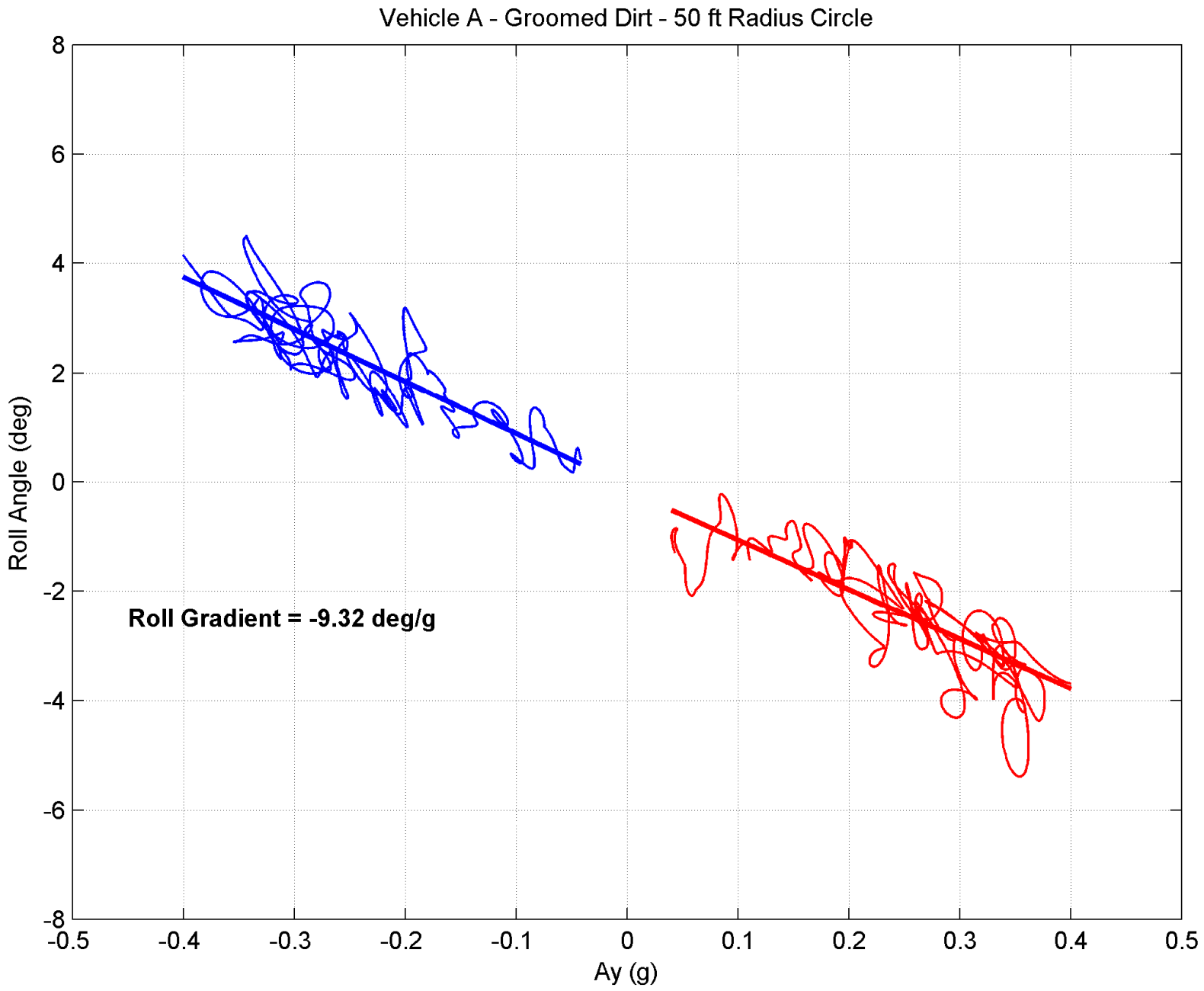
	Maximum Ay Used (g)	Initial Path Radius (ft)	Right Turn Ratio	Left Turn Ratio	Average Ratio
Vehicle A	0.40	50	12.6	29.6	21.1
Vehicle B	0.40	25	11.6	147	79.5
Vehicle C	0.40	50	1.66	0.26	0.96
Vehicle D	0.40	25	0.48	0.57	0.52
Vehicle E	0.40	25	0.43	0.40	0.41
Vehicle F	0.40	50	1.40	7.94	4.67
Vehicle G	0.40	50	5.55	7.37	6.46
Vehicle H	0.40	50	13.1	16.3	14.7
Vehicle I	0.40	50	3.55	1.90	2.73
Vehicle J	0.40	50	3.22	3.22	3.22
Vehicle K	0.40	25	0.82	1.06	0.94
Vehicle L	0.40	25	0.95	1.34	1.14

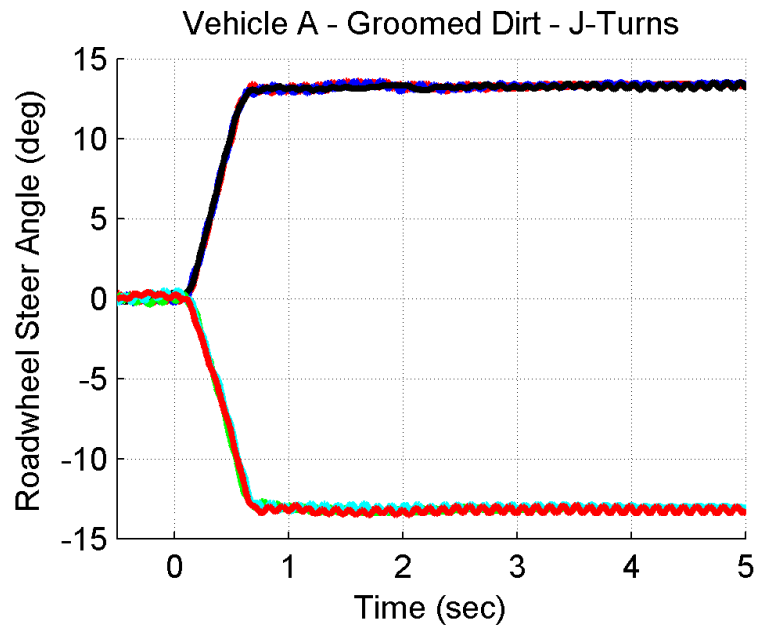

Yaw Rate Ratios - Measured During Constant Steer Tests
Yaw Rate Ratio
Right Turn Yaw Rate Ratio
Left Turn Yaw Rate Ratio
Average Yaw Rate Ratio
0
1
2
3
4
5
6
7
0.43
0.40
0.41
0.48
0.57
0.52
0.82
1.06
0.94
1.66
0.26
0.96
0.95
1.34
1.14
3.55
1.90
2.73
3.22
3.22
3.22
1.40
7.94
4.67
5.55
7.37
6.46
13.1
16.3
14.7
12.6
29.6
21.1
11.6
147
79.5
Vehicle E
Vehicle D
Vehicle K
Vehicle C
Vehicle L
Vehicle I
Vehicle J
Vehicle F
Vehicle G
Vehicle H
Vehicle A
Vehicle B

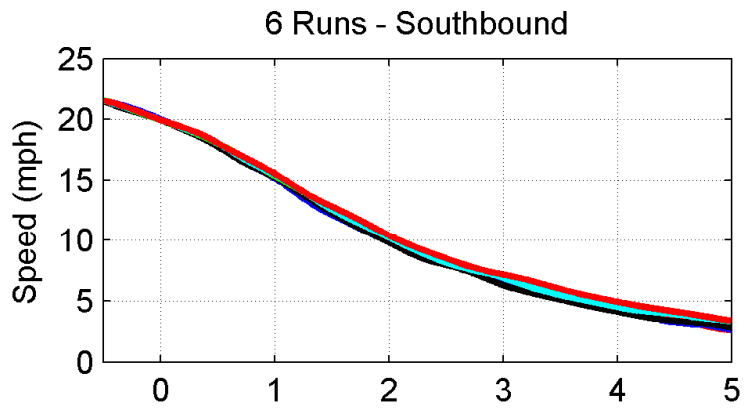

Vehicle A - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

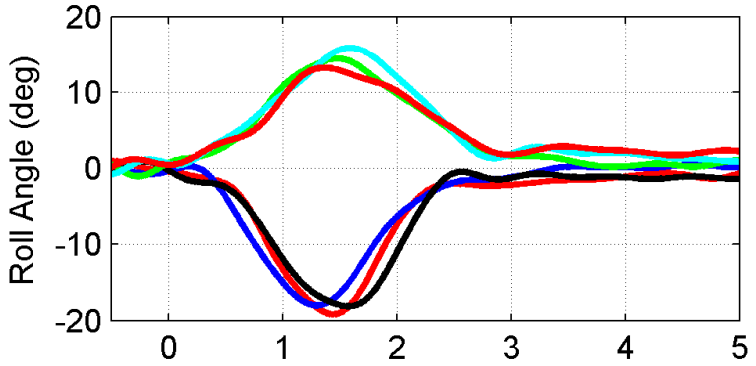

Vehicle A - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

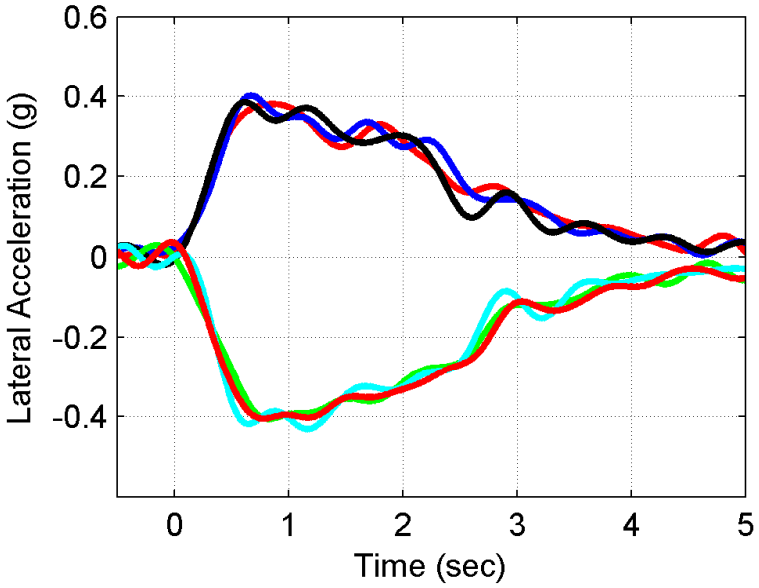

Vehicle A - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.158 g
CCW Transition to OS
At Ay = -0.165 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

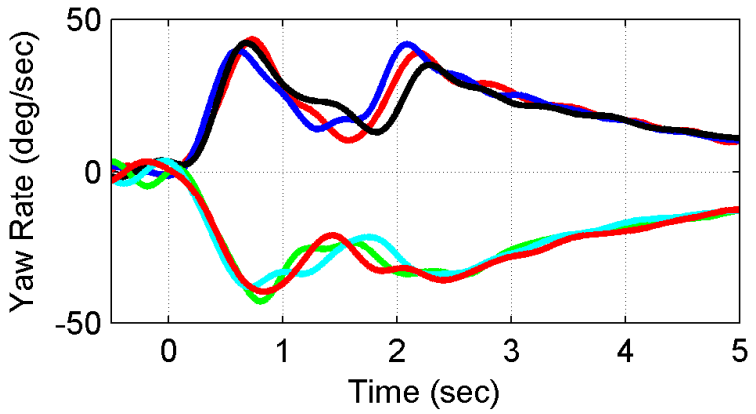

Vehicle A - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -9.32 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

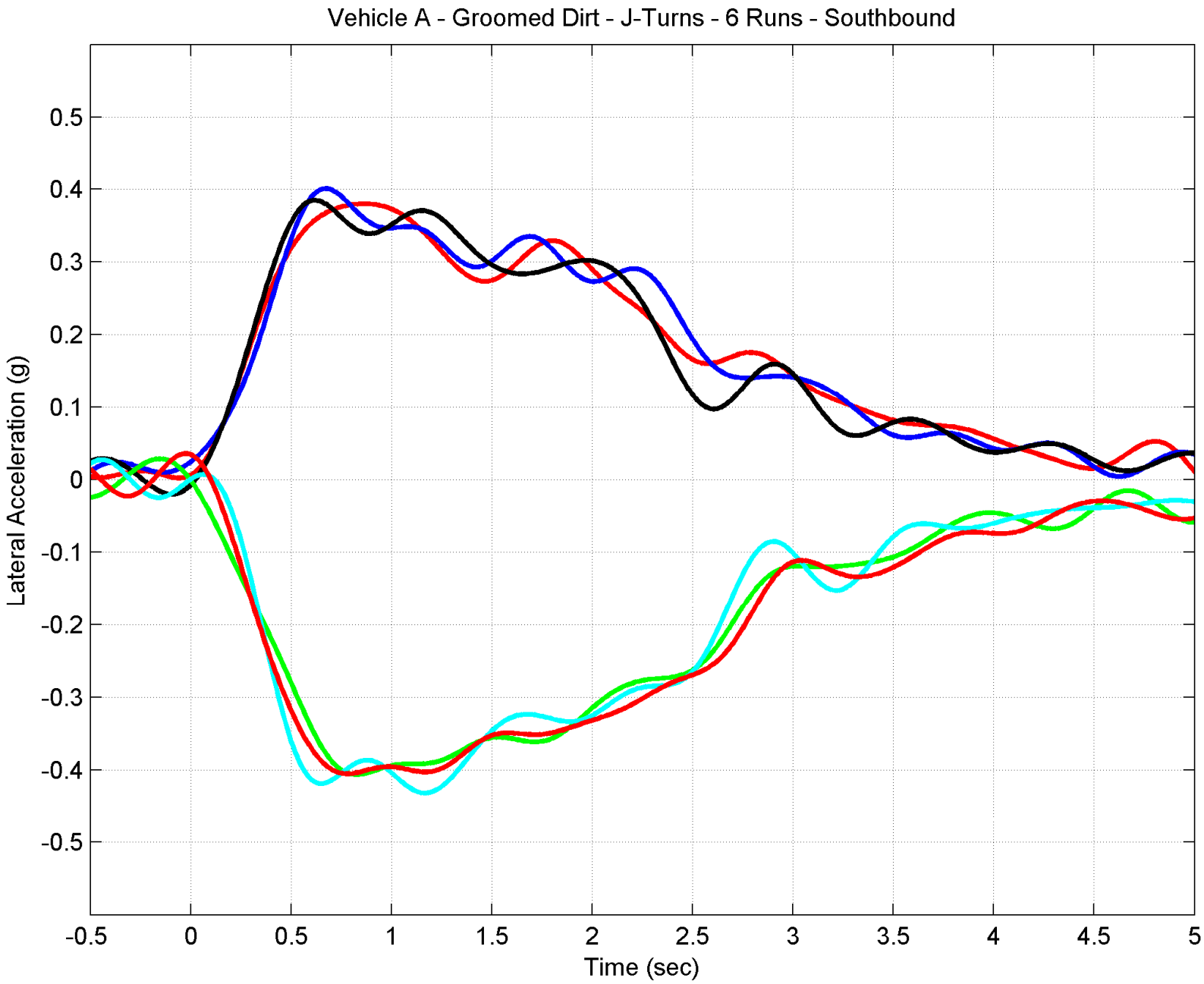

Vehicle A - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)

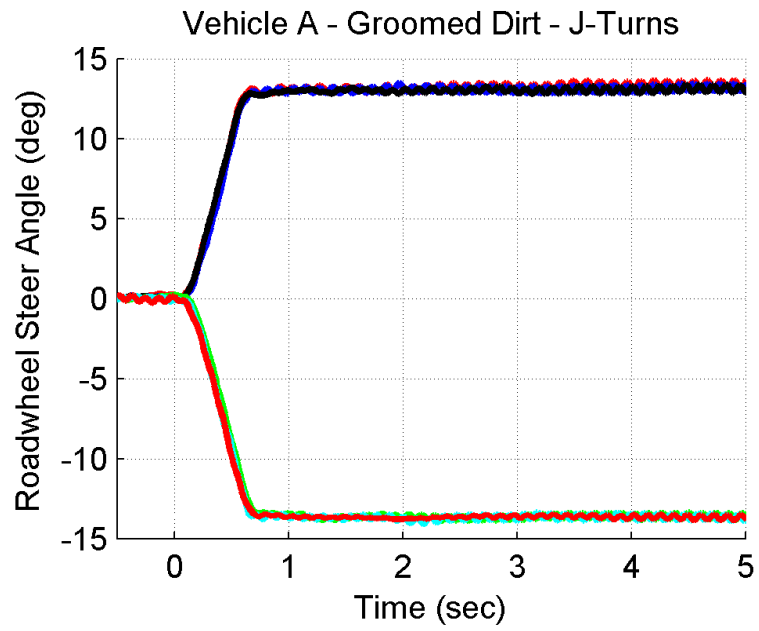

6 Runs - Southbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5

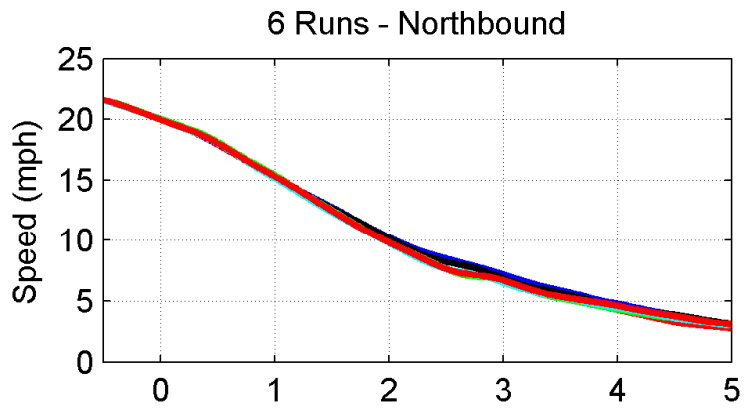

Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5

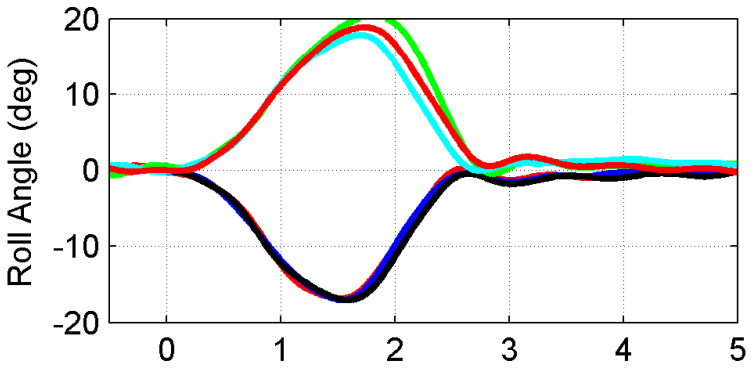

Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)

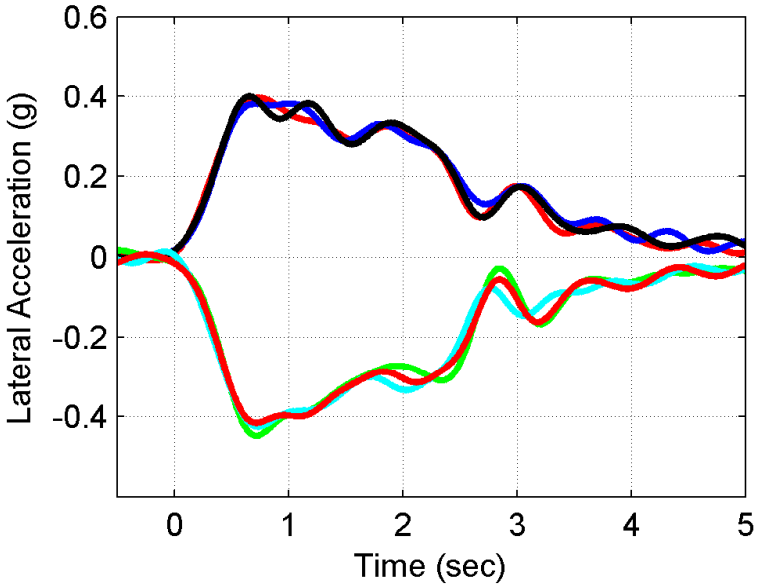

Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)

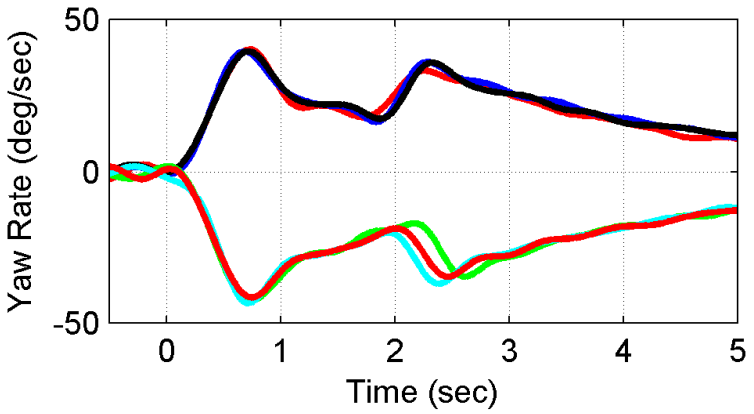

Vehicle A - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

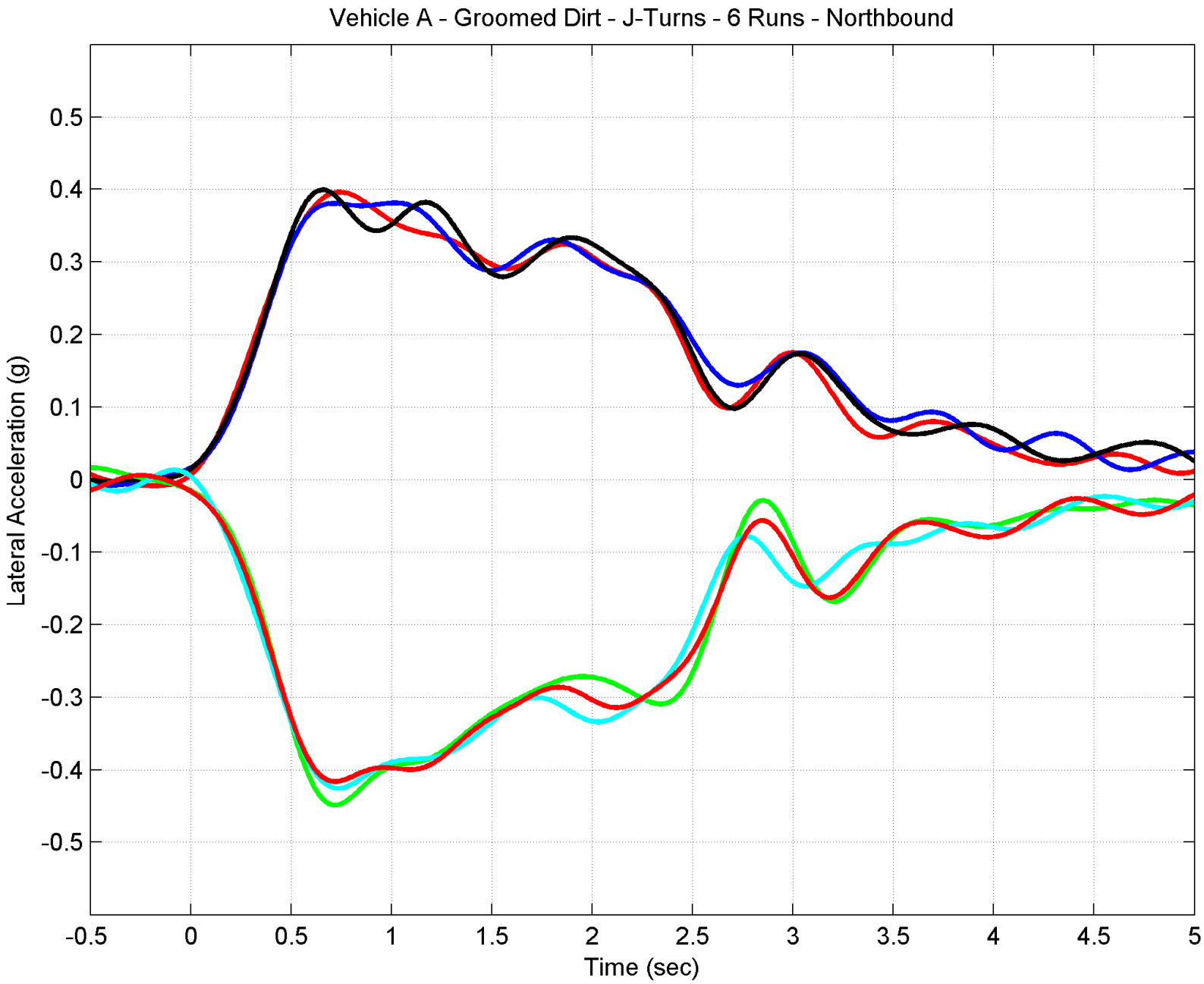

Vehicle A - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5


Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle A - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle A - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.380	-0.406
2	0.401	-0.432
3	0.385	-0.405
Mean Value of 3 Runs	0.388	-0.414
Standard Deviation of 3 Runs	0.011	0.015

Average of 6 North Runs

0.401

Run Number	North Right Turns	North Left Turns
1	0.396	-0.448
2	0.381	-0.425
3	0.399	-0.416
Mean Value of 3 Runs	0.392	-0.430
Standard Deviation of 3 Runs	0.009	0.017

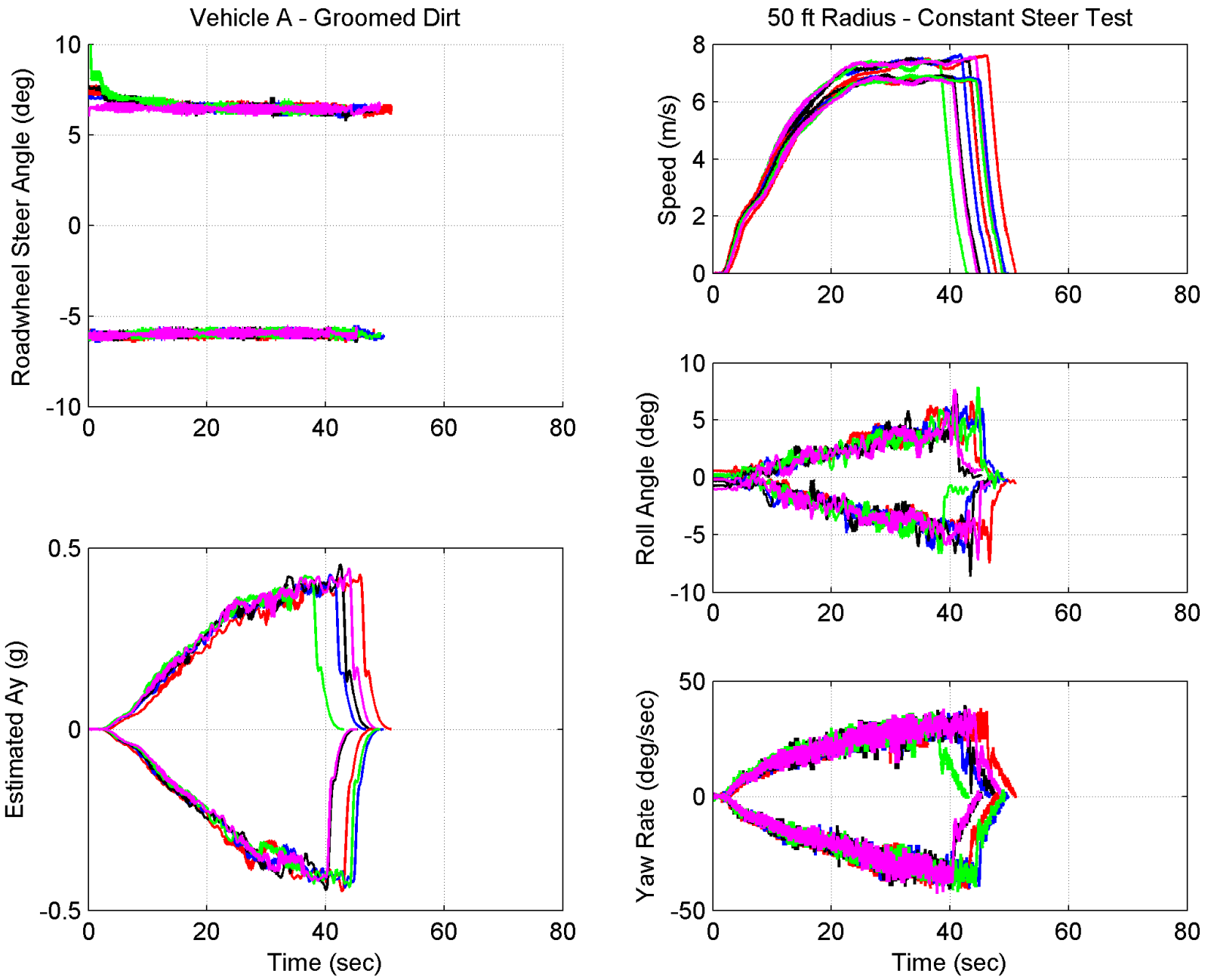
Average of 6 South Runs

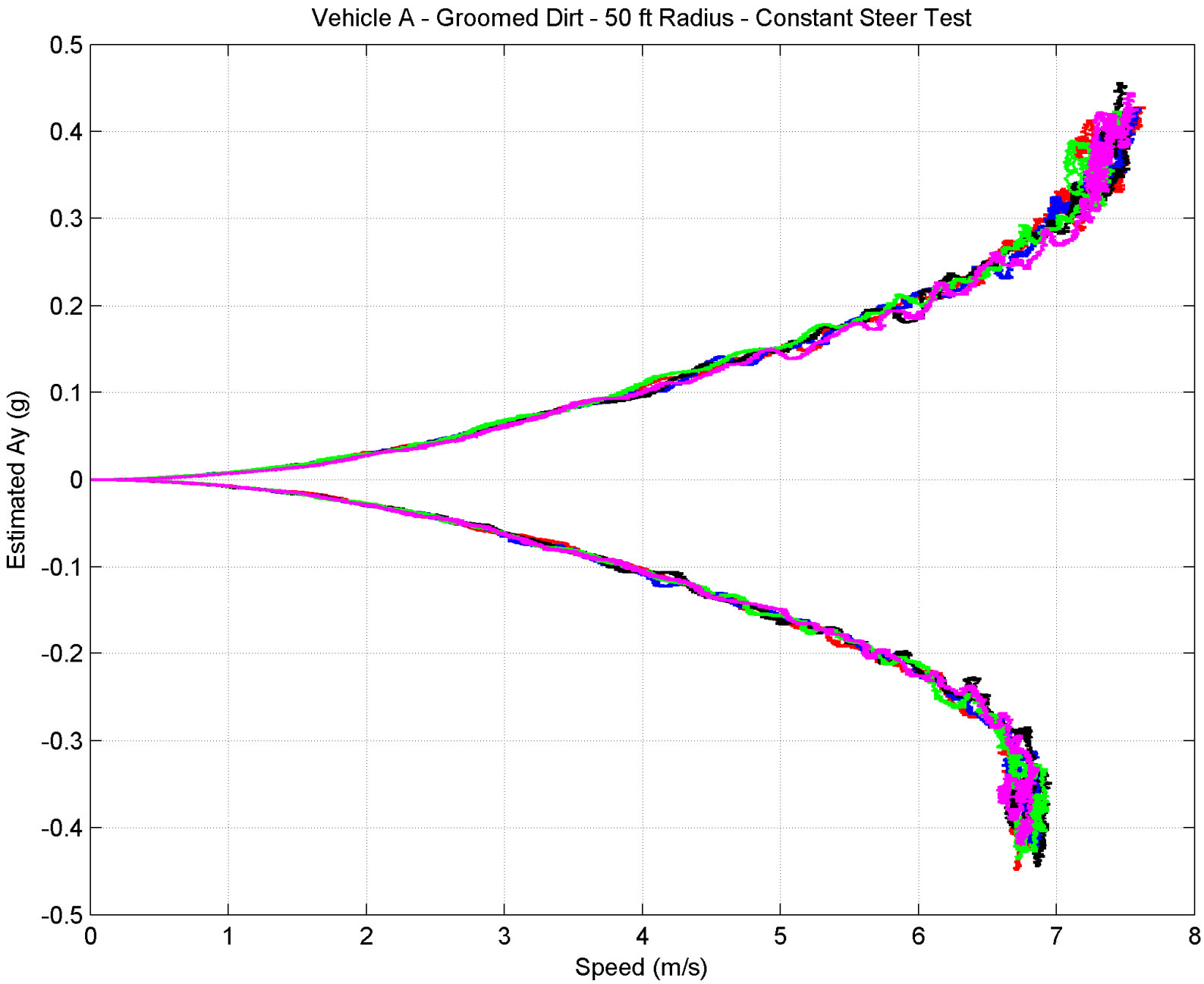
0.411

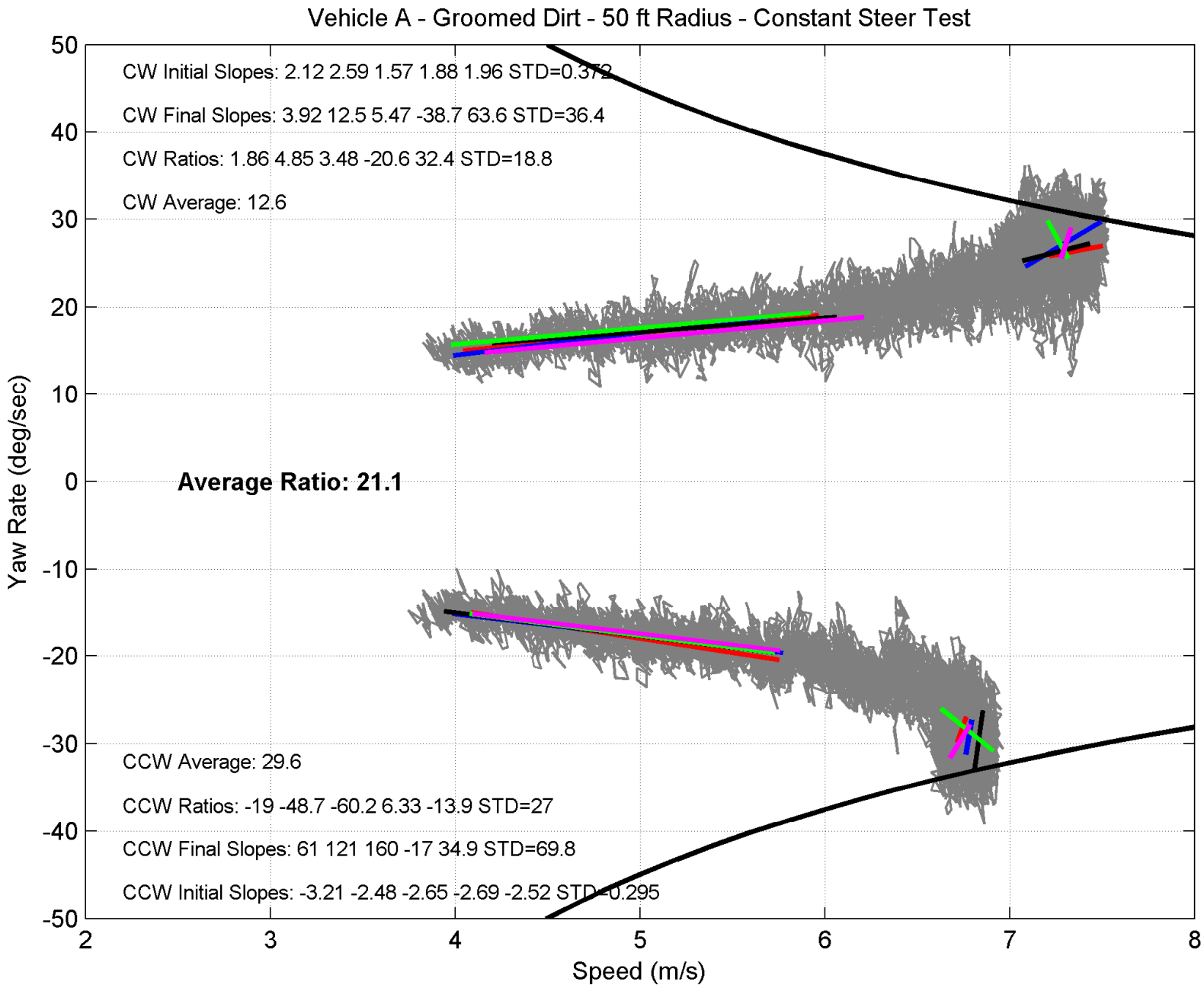
Average of All 12 Runs

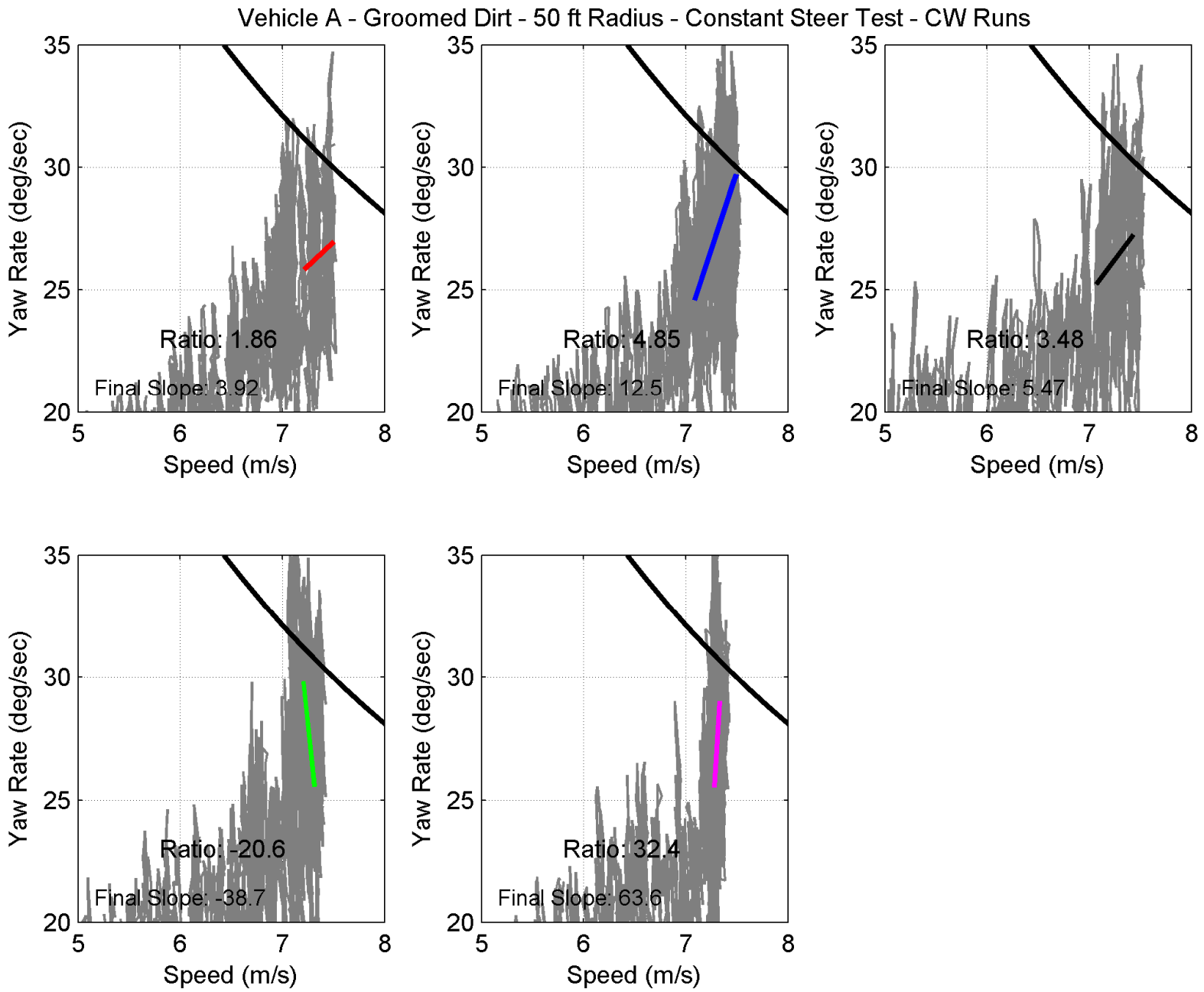
0.406

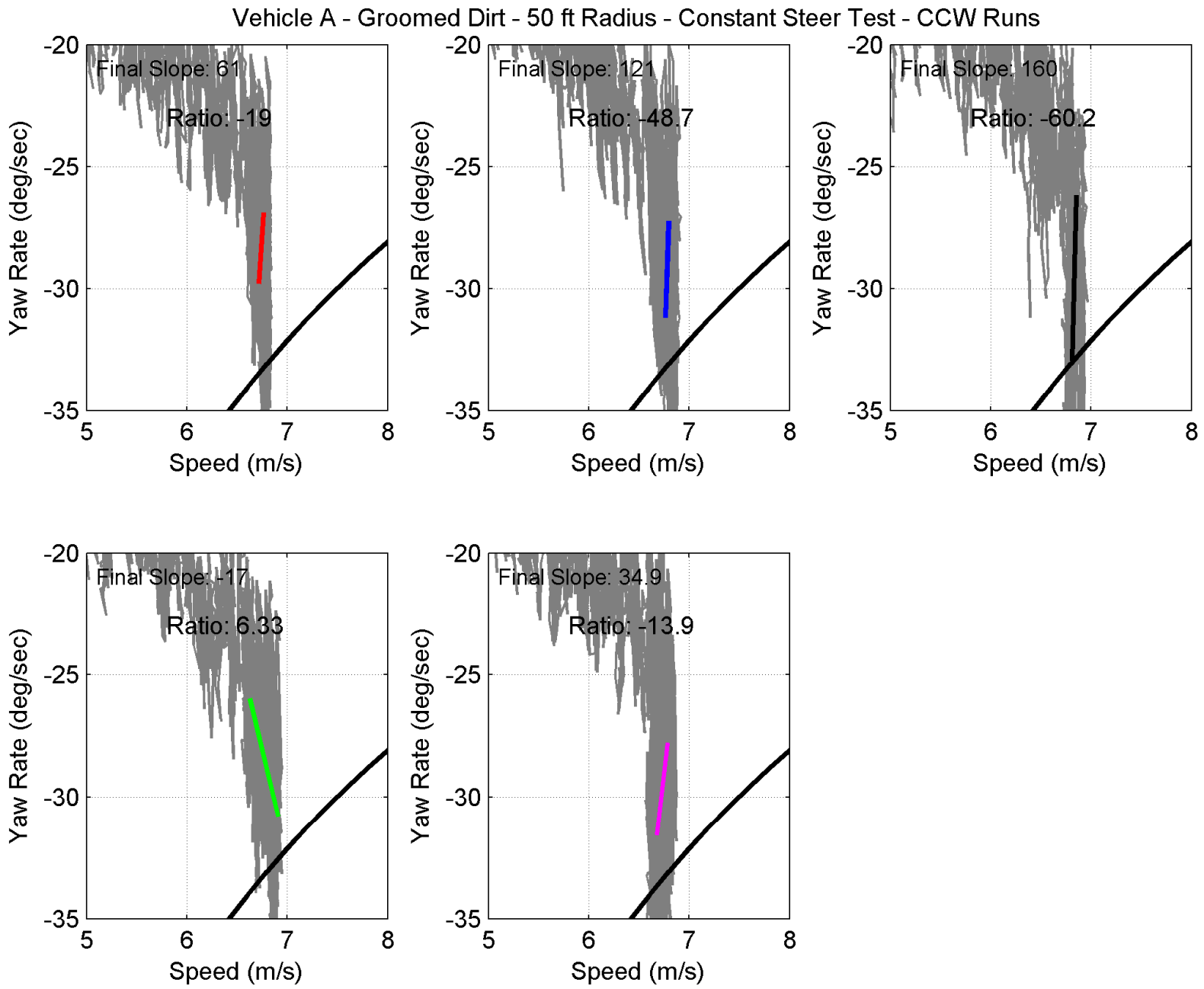
Threshold Ay

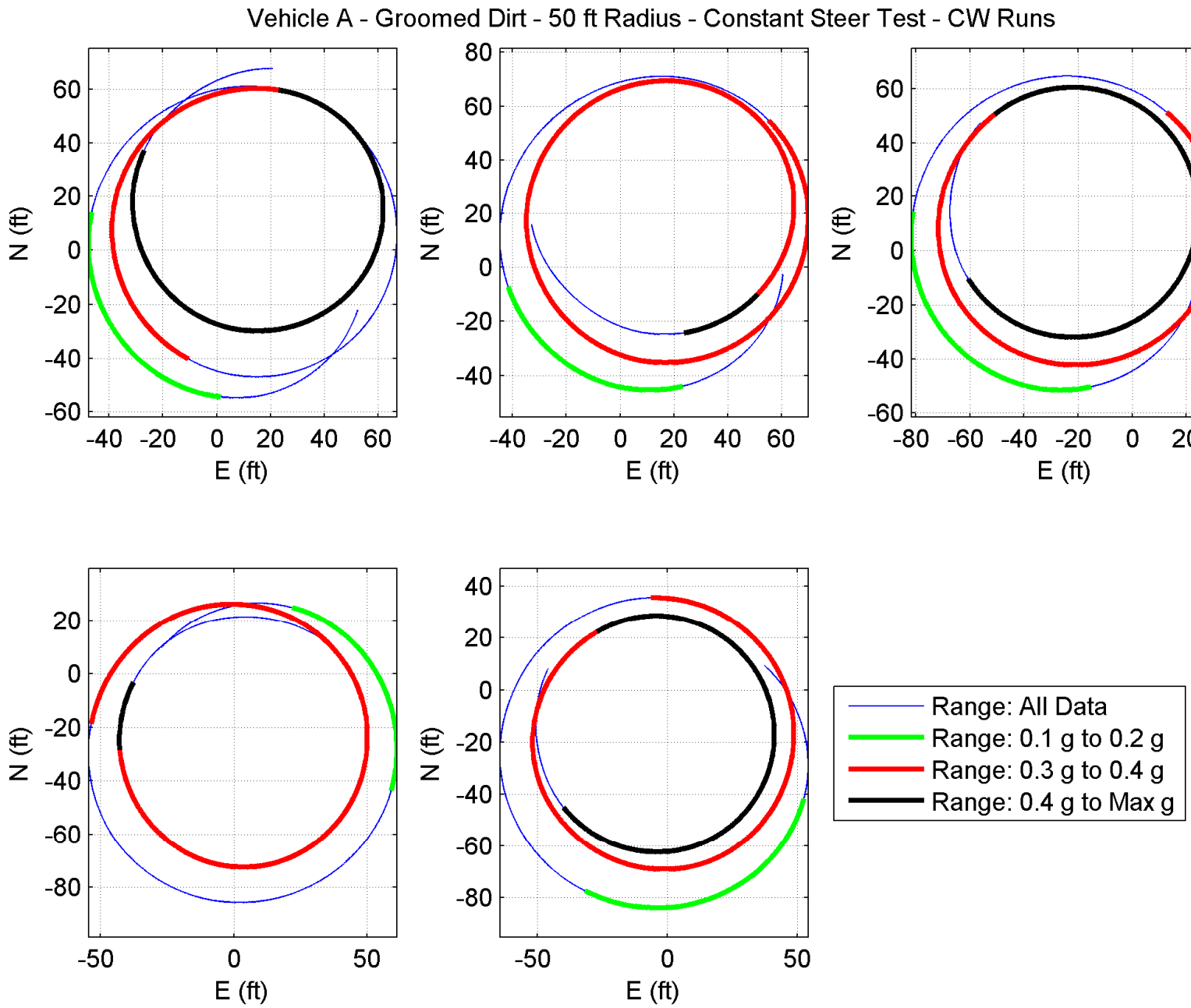

Vehicle A - Groomed Dirt
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

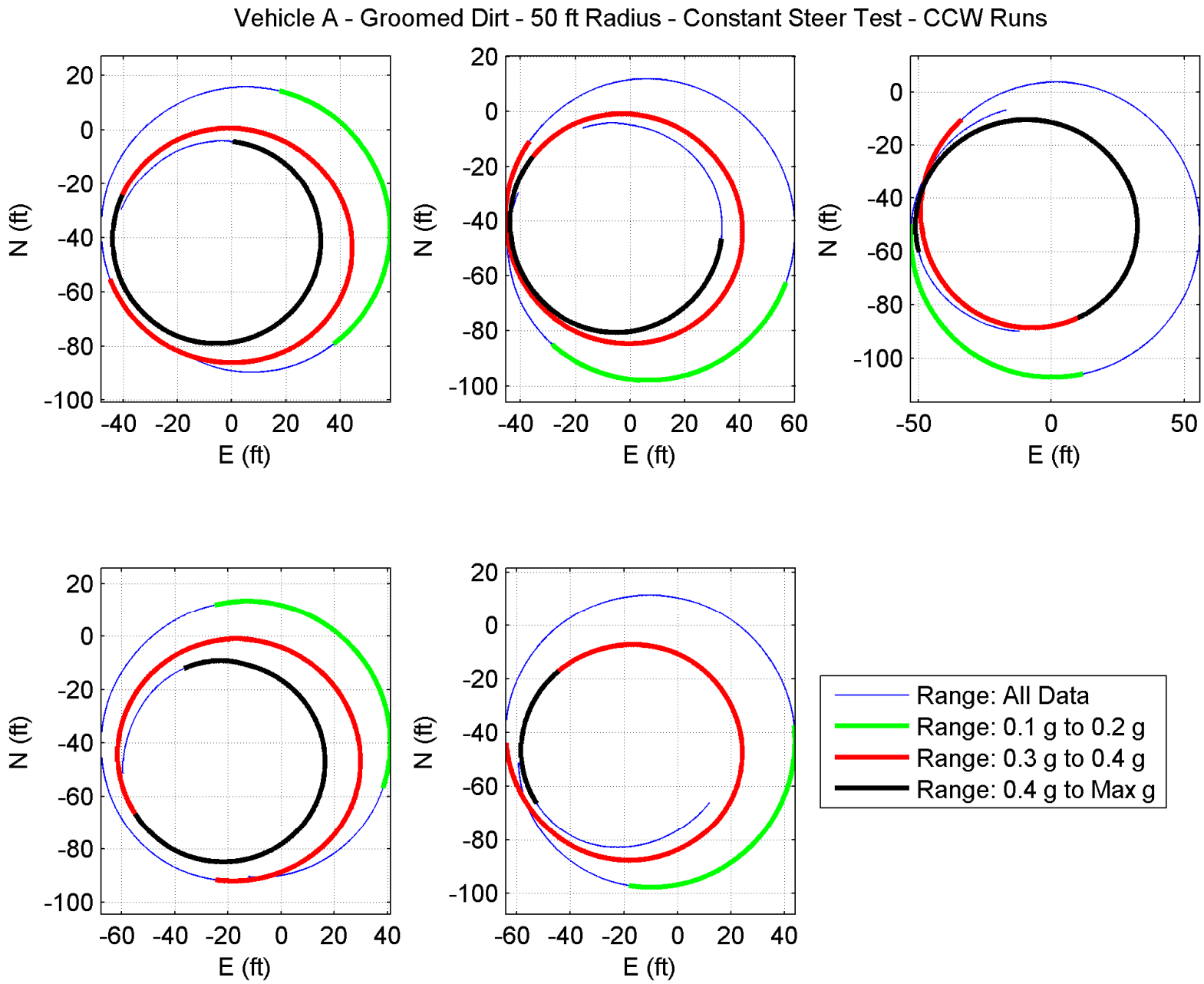

Vehicle A - Groomed Dirt - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8

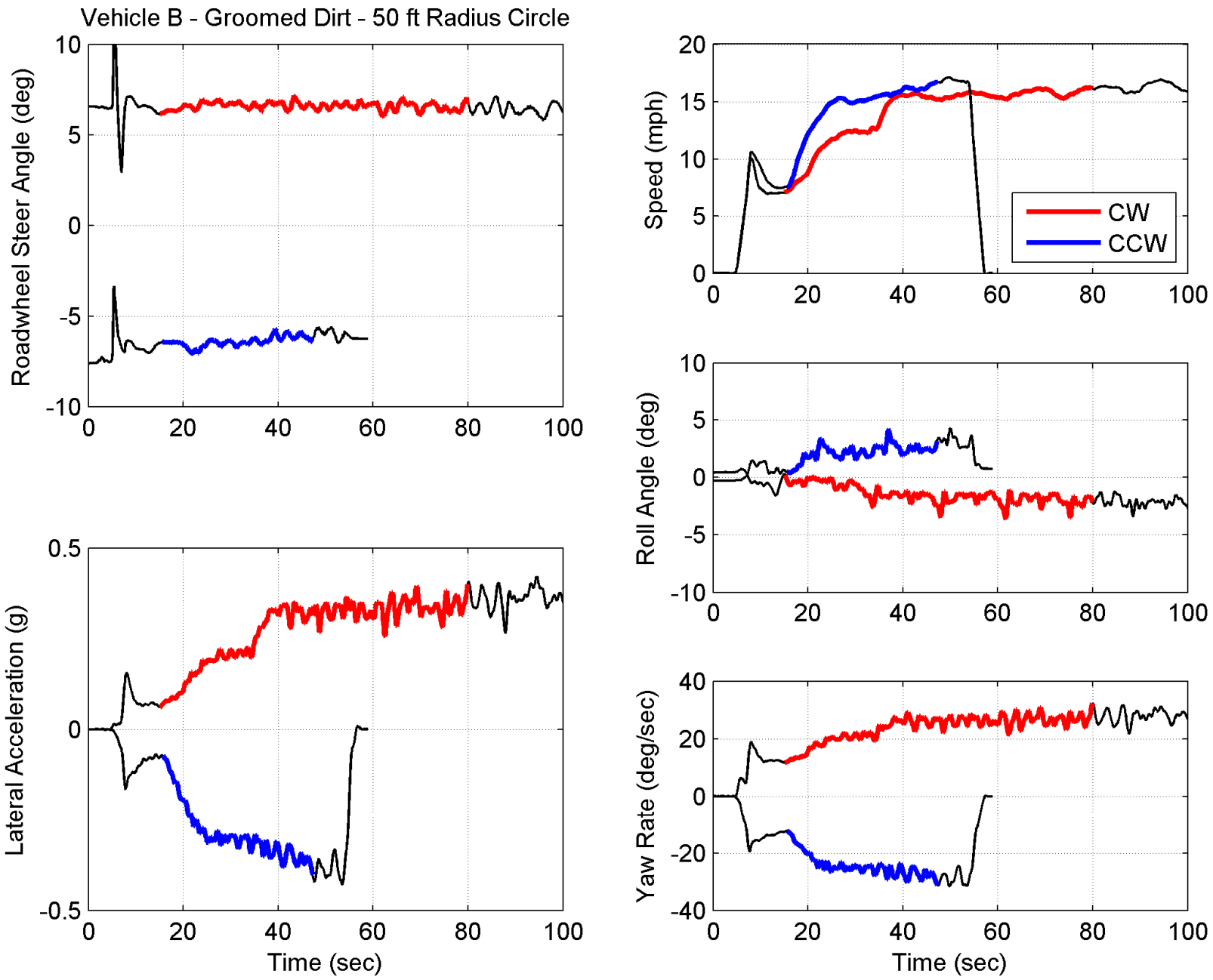

Vehicle A - Groomed Dirt - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.12 2.59 1.57 1.88 1.96 STD=0.372
CW Final Slopes: 3.92 12.5 5.47 -38.7 63.6 STD=36.4
CW Ratios: 1.86 4.85 3.48 -20.6 32.4 STD=18.8
CW Average: 12.6
Average Ratio: 21.1
CCW Average: 29.6
CCW Ratios: -19 -48.7 -60.2 6.33 -13.9 STD=27
CCW Final Slopes: 61 121 160 -17 34.9 STD=69.8
CCW Initial Slopes: -3.21 -2.48 -2.65 -2.69 -2.52 STD=0.295
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8

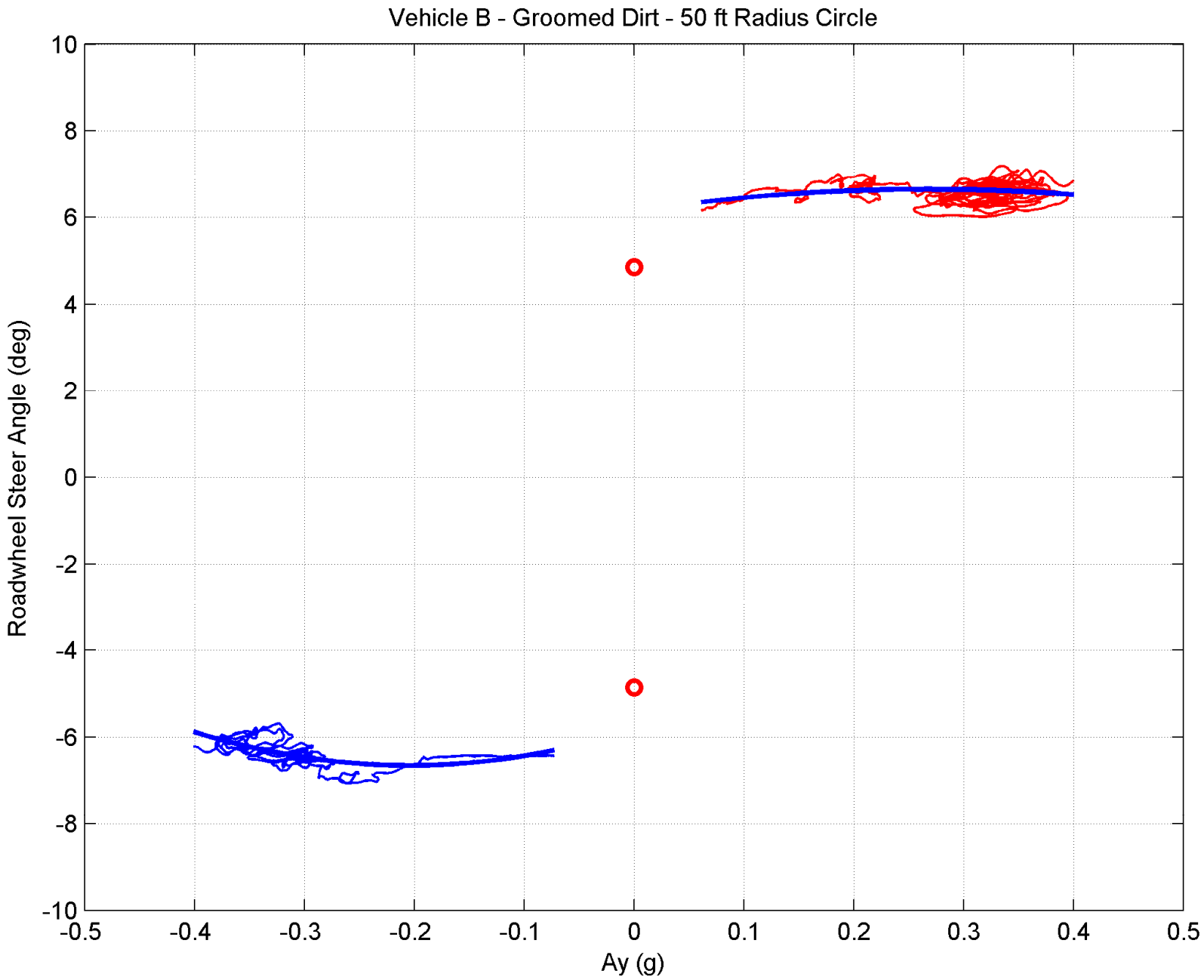

Vehicle A - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 1.86
Final Slope: 3.92
Ratio: 4.85
Final Slope: 12.5
Ratio: 3.48
Final Slope: 5.47
Ratio: -20.6
Final Slope: -38.7
Ratio: 32.4
Final Slope: 63.6

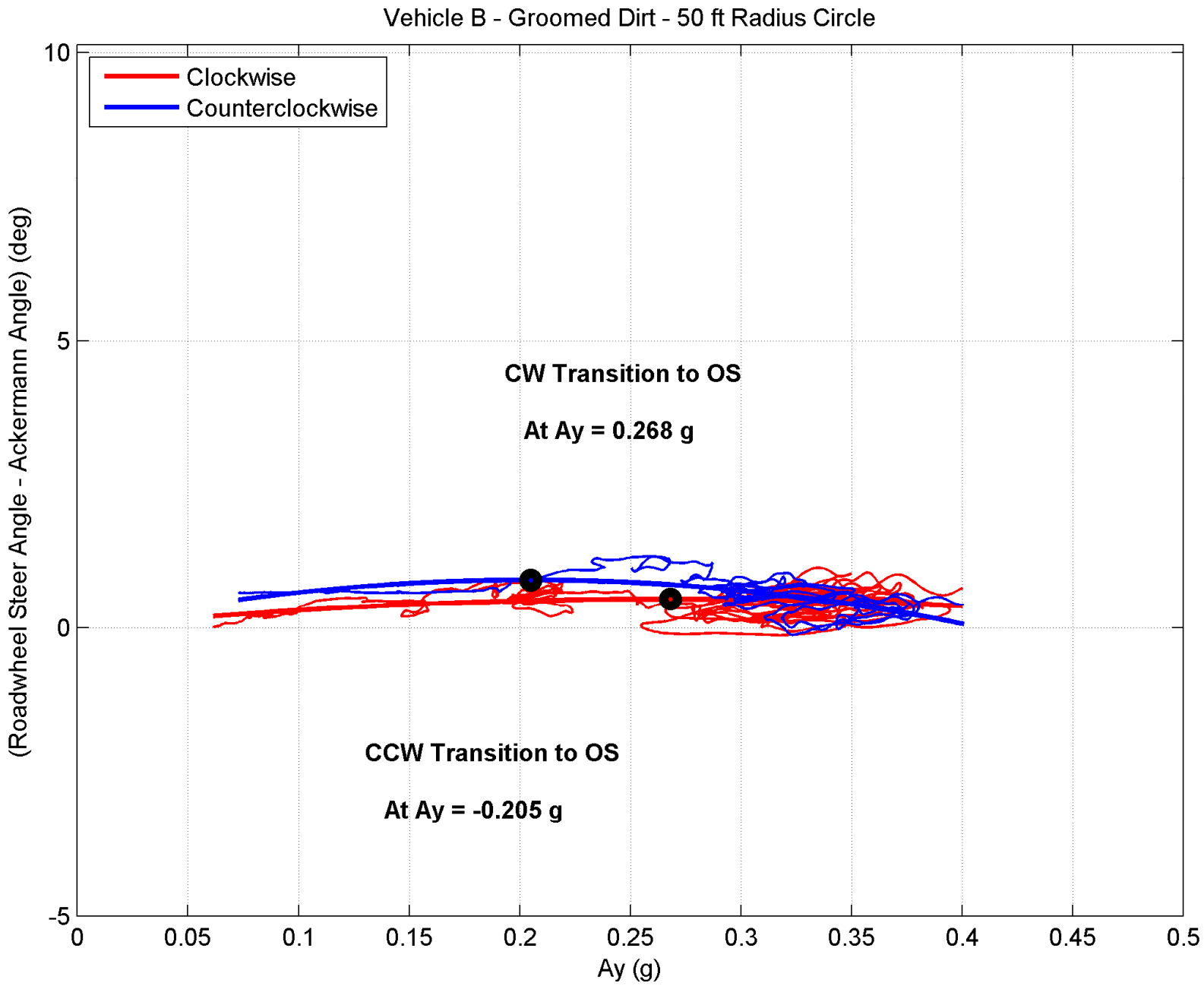

Vehicle A - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 61
Ratio: -19
Final Slope: 121
Ratio: -48.7
Final Slope: 160
Ratio: -60.2
Final Slope: -17
Ratio: 6.33
Final Slope: 34.9
Ratio: -13.9
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
5
6
7
8

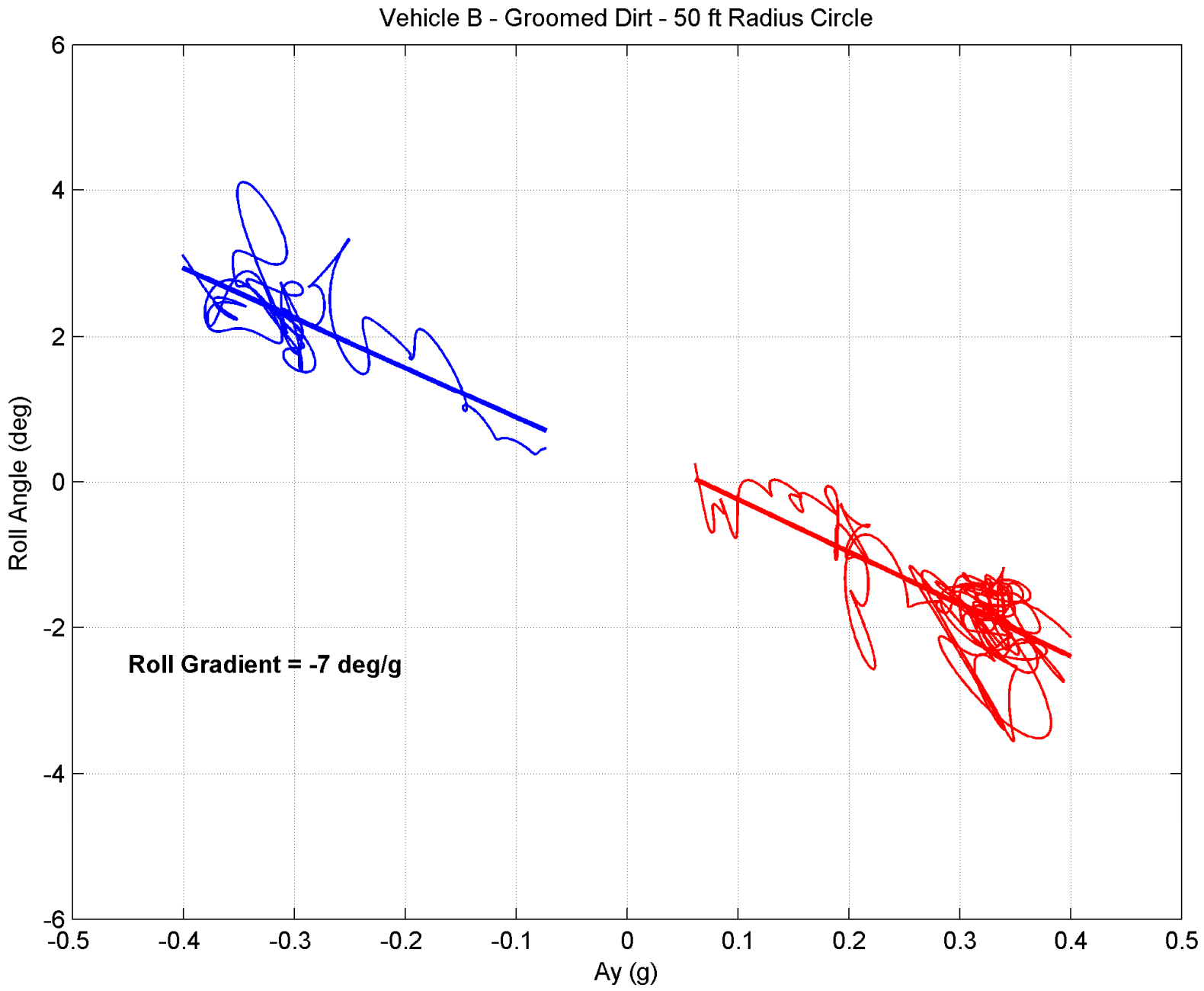

Vehicle A - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

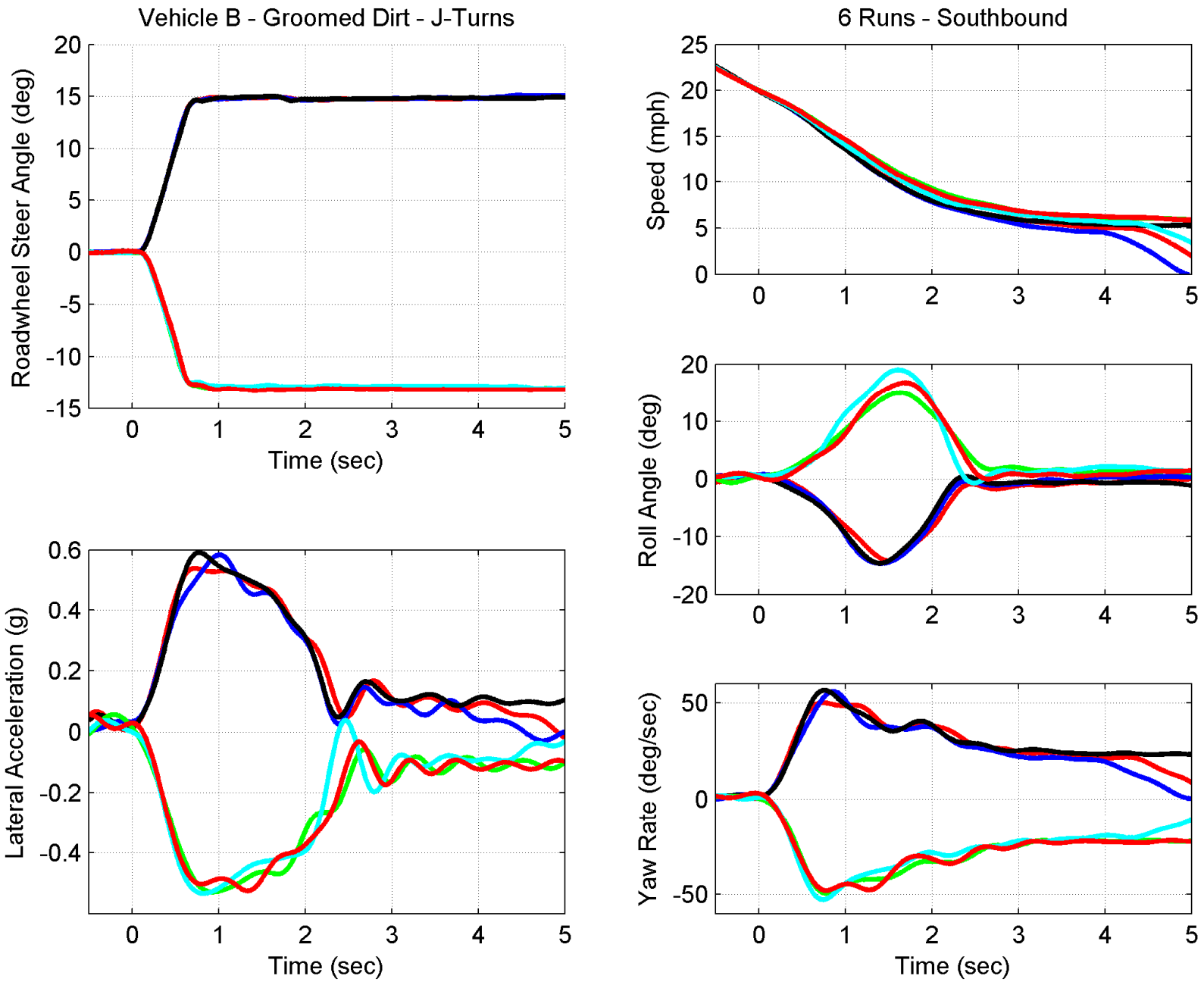

Vehicle A - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

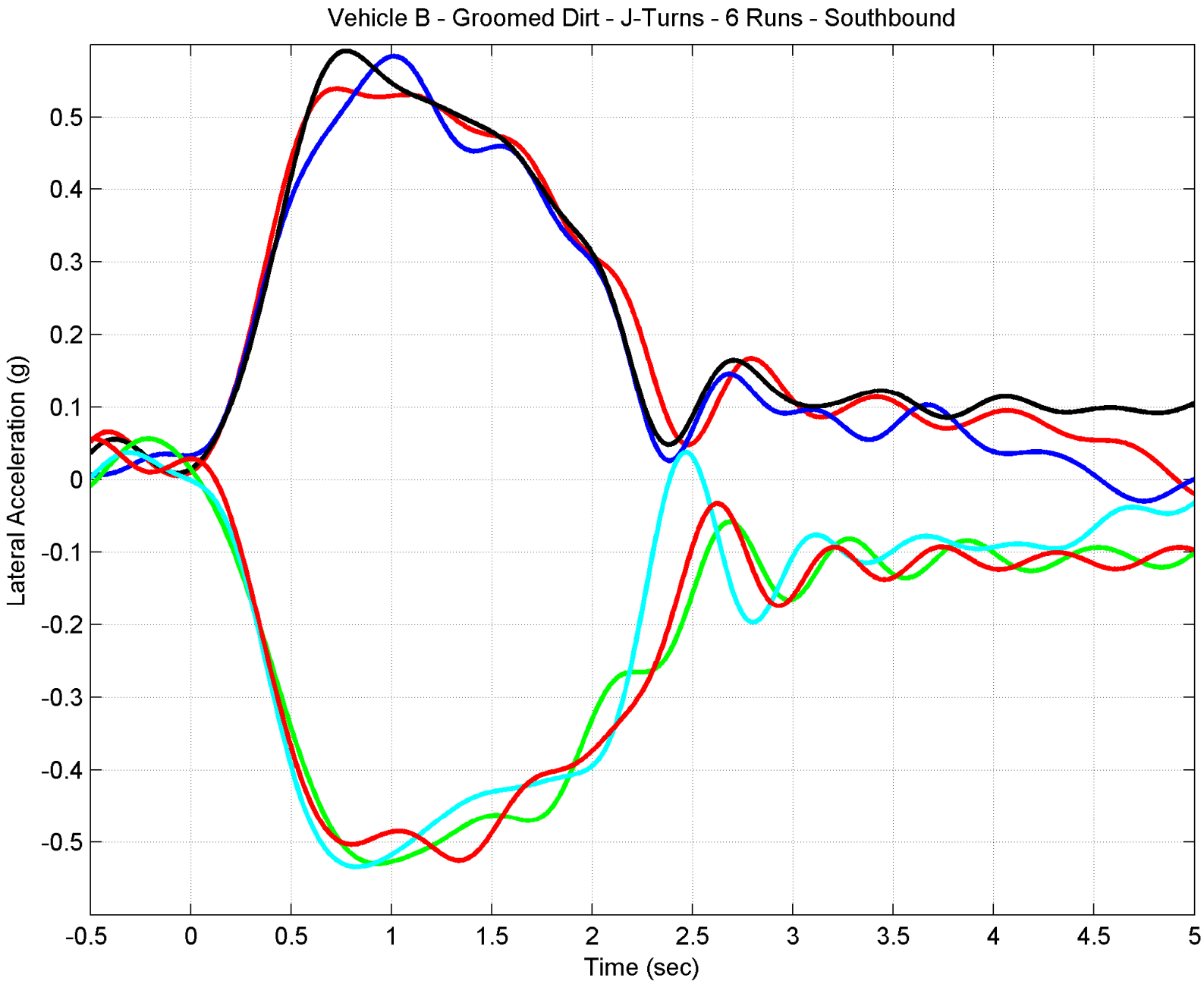

Vehicle B - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

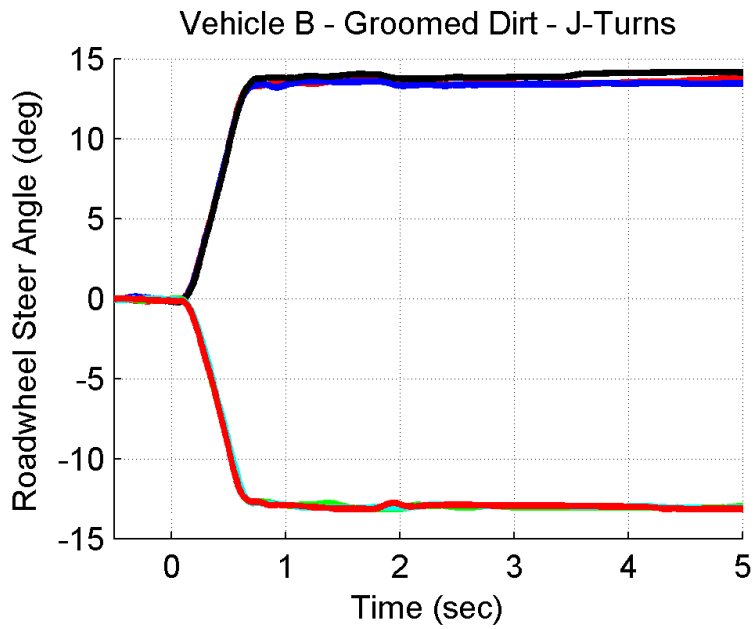

Vehicle B - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

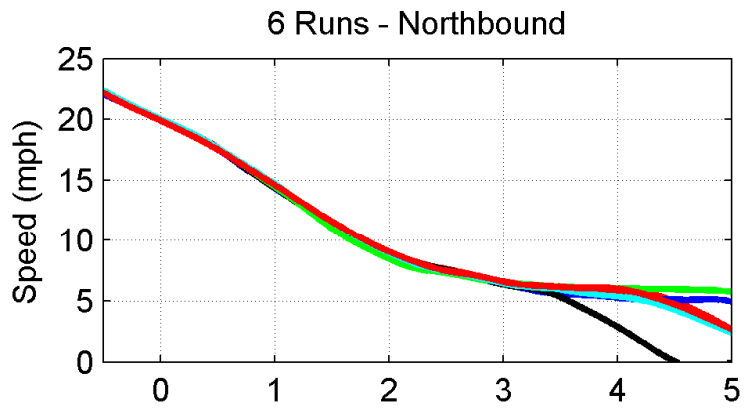

Vehicle B - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.268 g
CCW Transition to OS
At Ay = -0.205 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

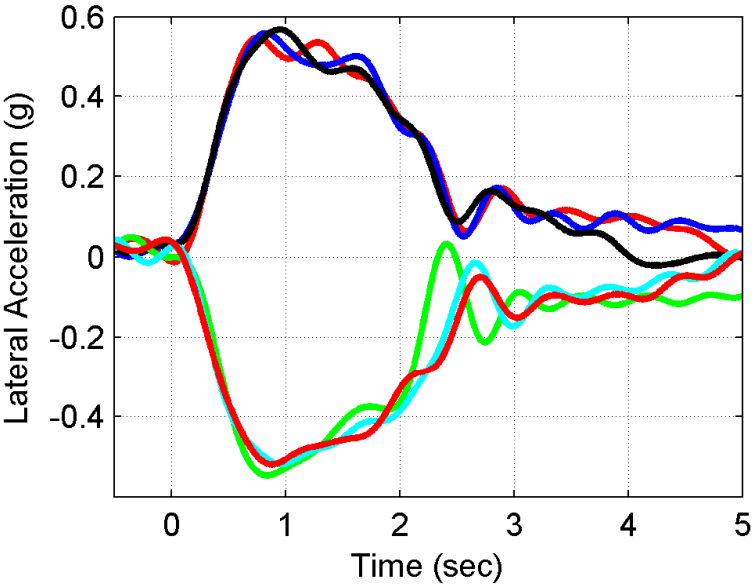

Vehicle B - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -7 deg/g
6
4
2
0
-2
-4
-6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

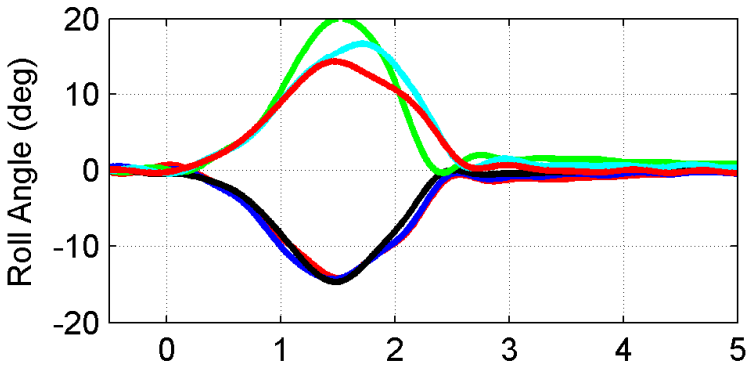

Vehicle B - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
6 Runs - Southbound
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

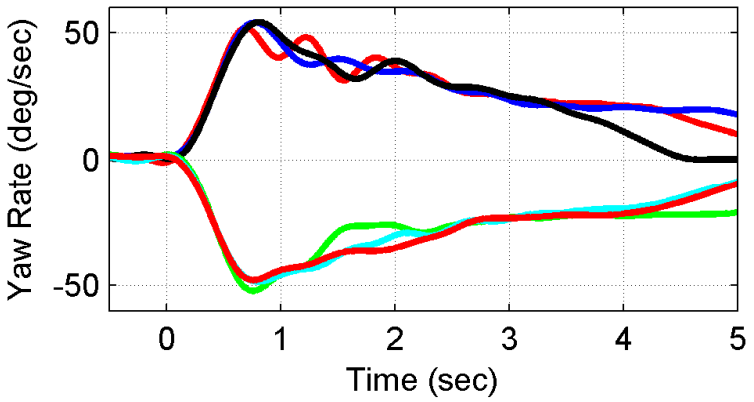

Vehicle B - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

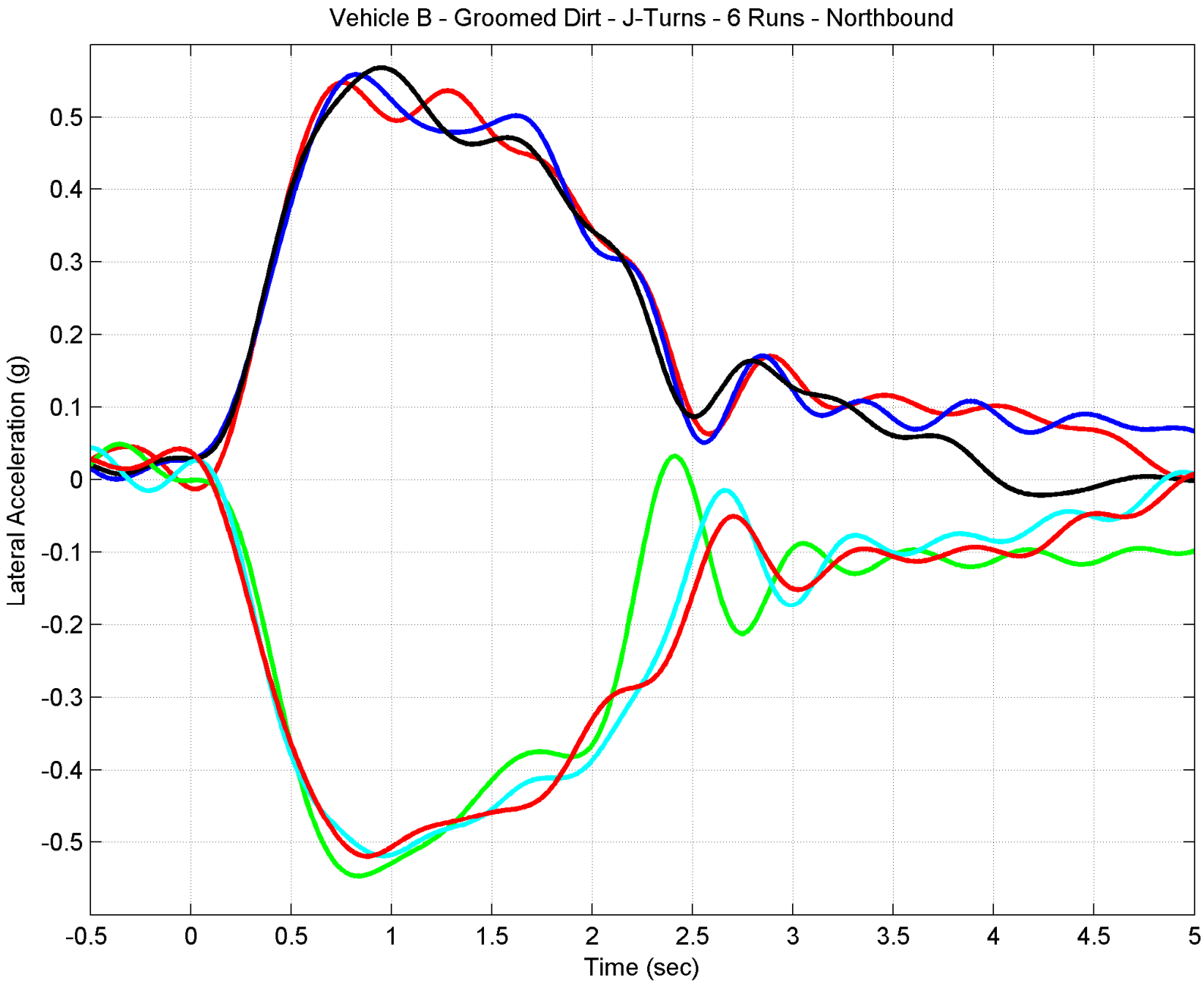

Vehicle B - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5


Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle B - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle B - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.539	-0.530
2	0.584	-0.534
3	0.591	-0.525
Mean Value of 3 Runs	0.571	-0.530
Standard Deviation of 3 Runs	0.028	0.004

Average of 6 North Runs

0.550

Run Number	North Right Turns	North Left Turns
1	0.547	-0.547
2	0.559	-0.519
3	0.568	-0.520
Mean Value of 3 Runs	0.558	-0.528
Standard Deviation of 3 Runs	0.010	0.016

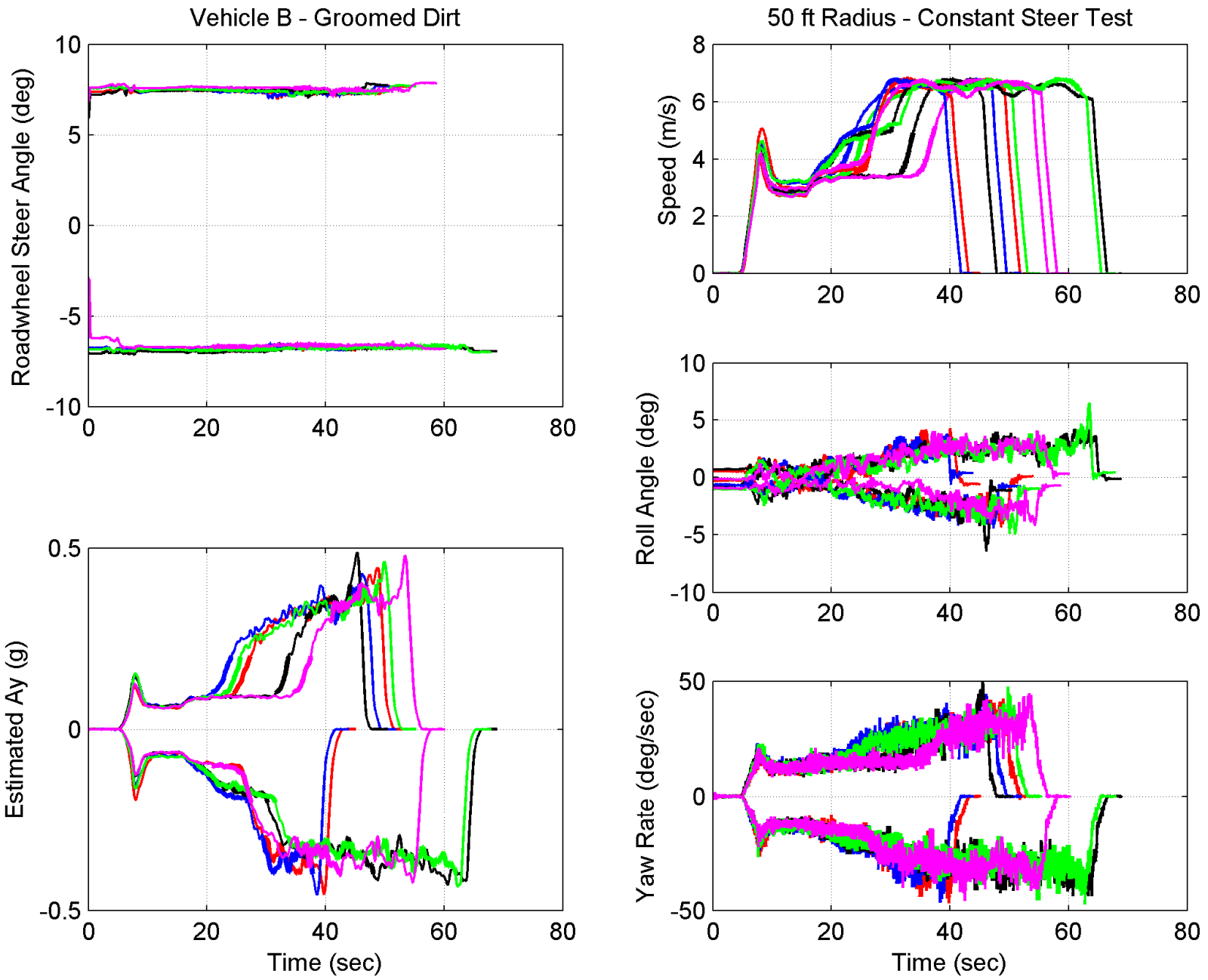
Average of 6 South Runs

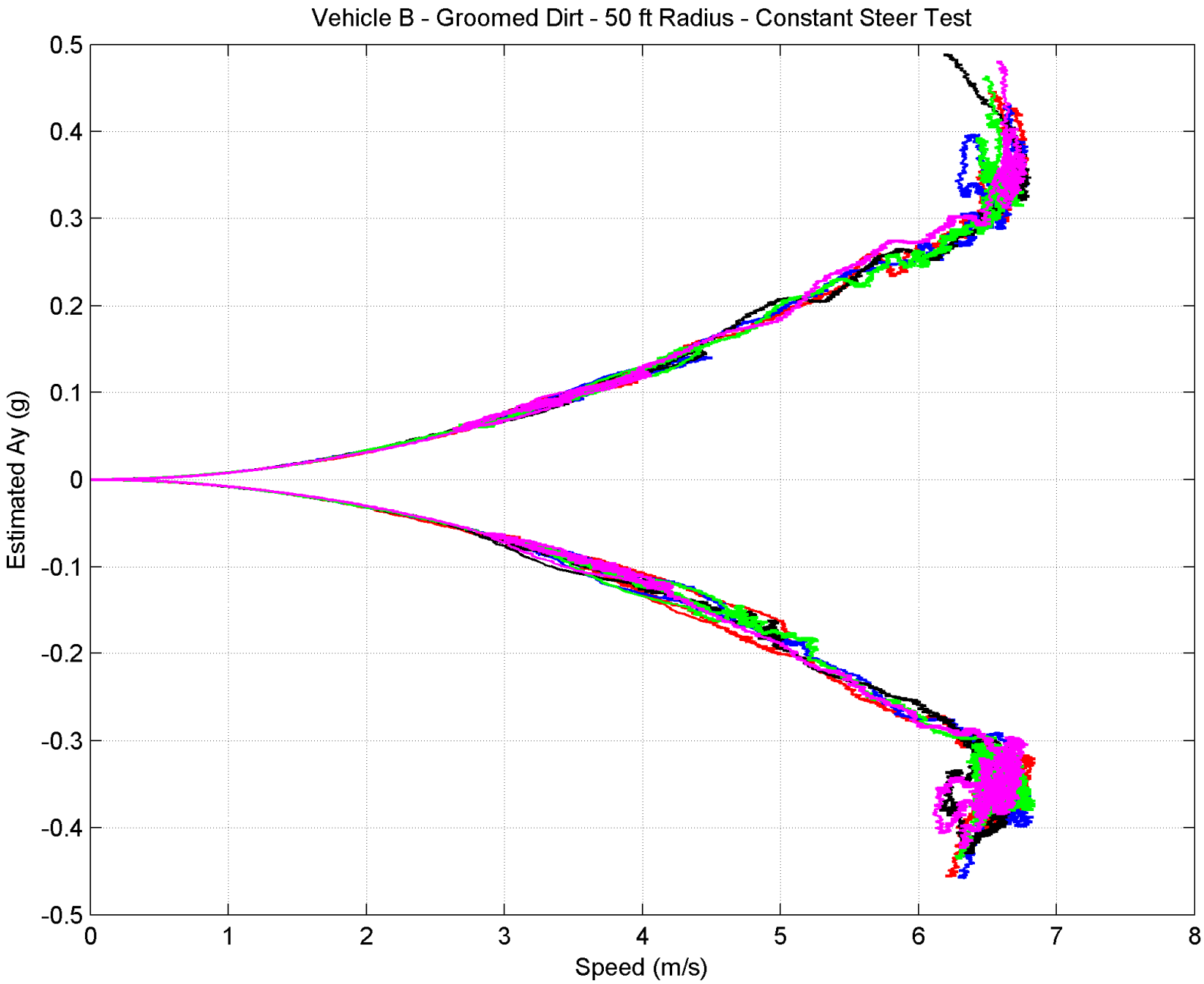
0.543

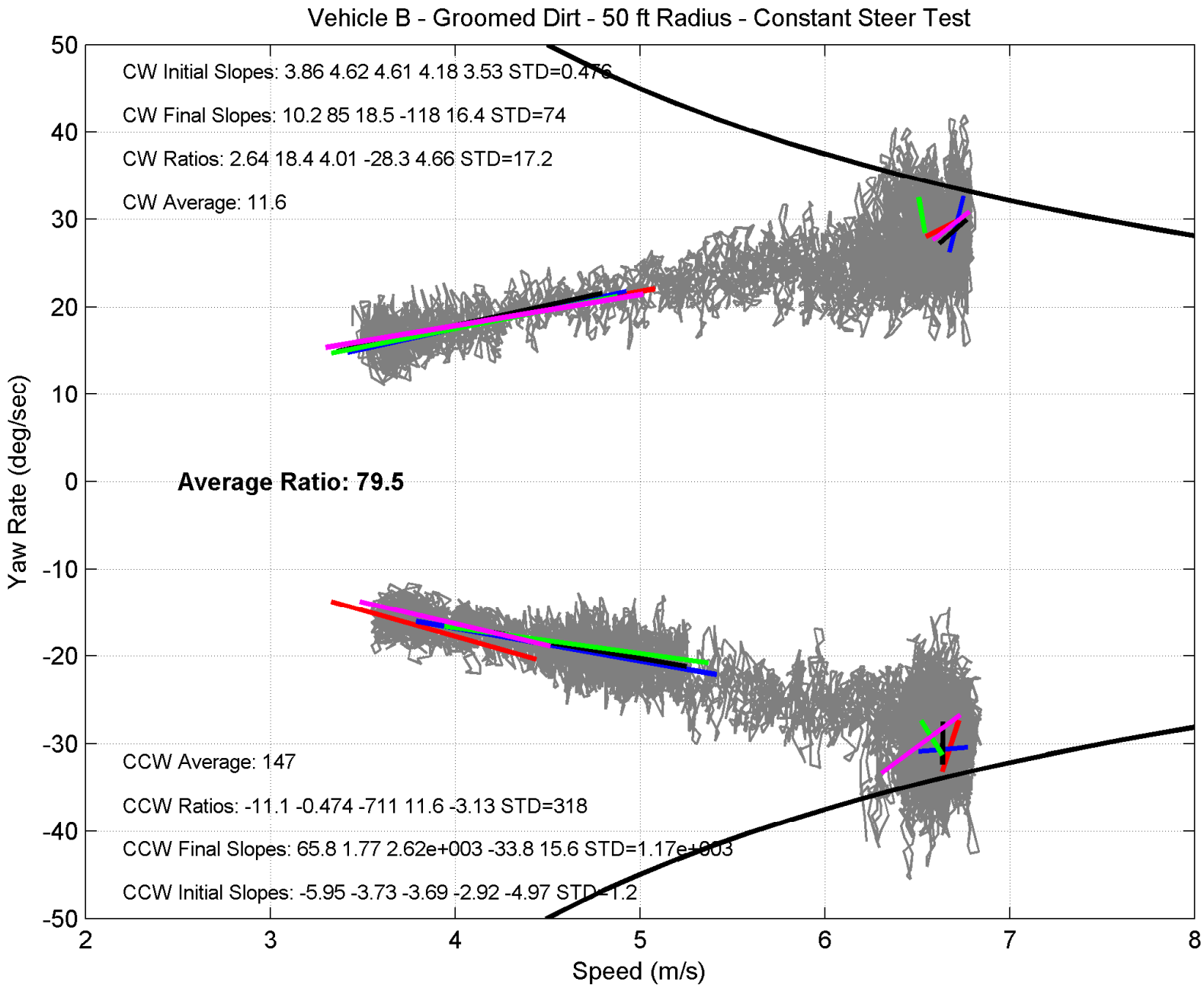
Average of All 12 Runs

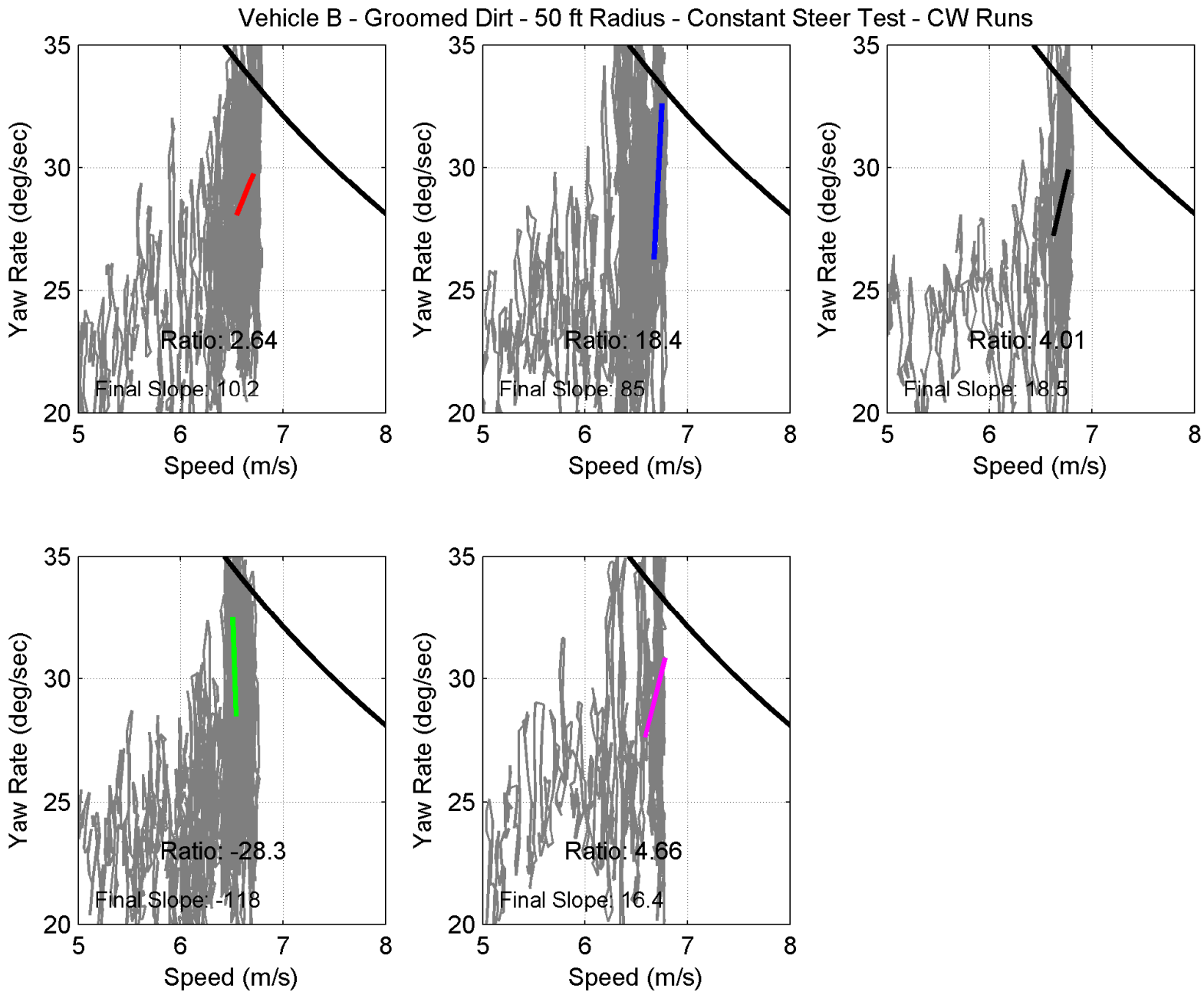
0.547

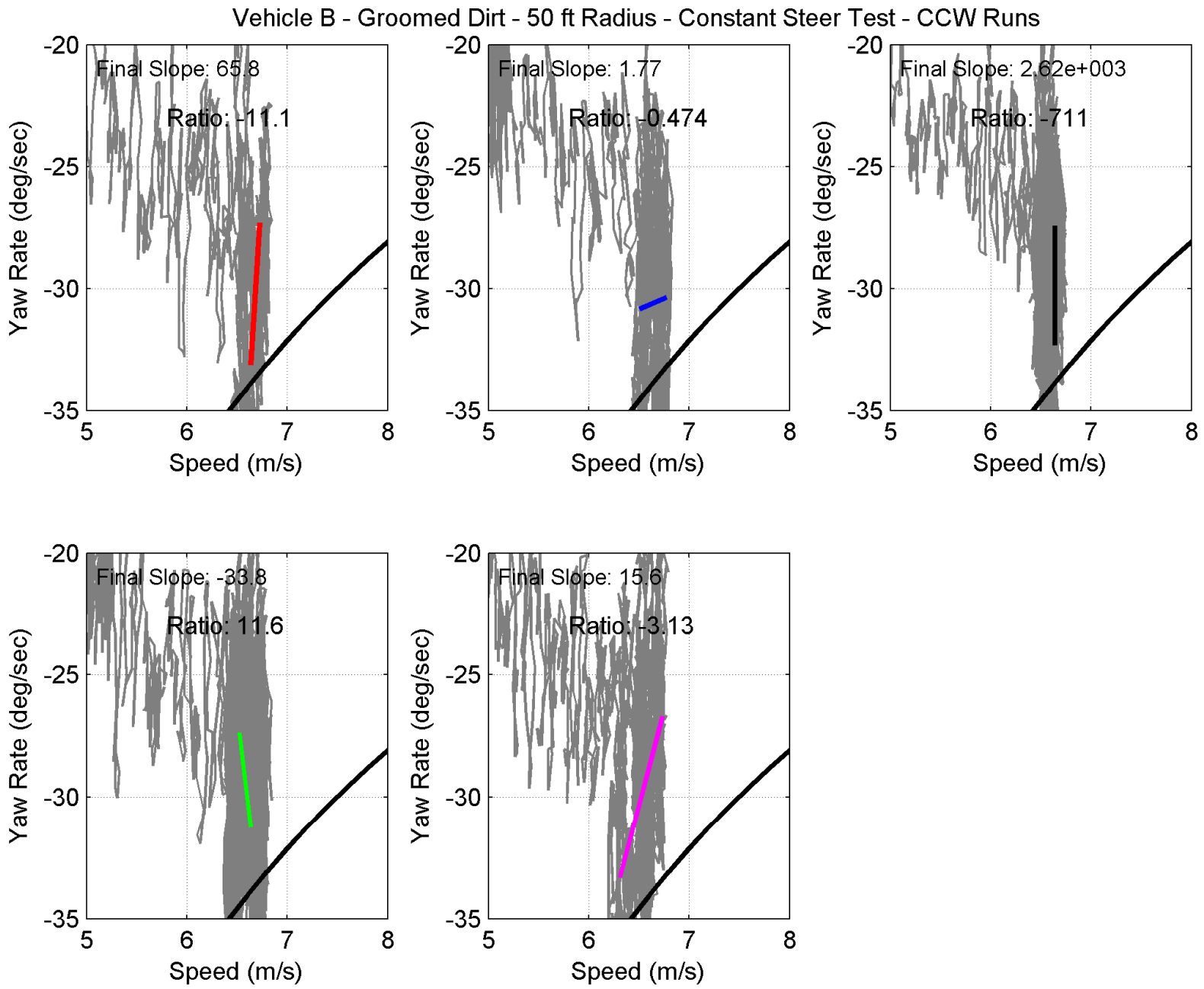
Threshold Ay

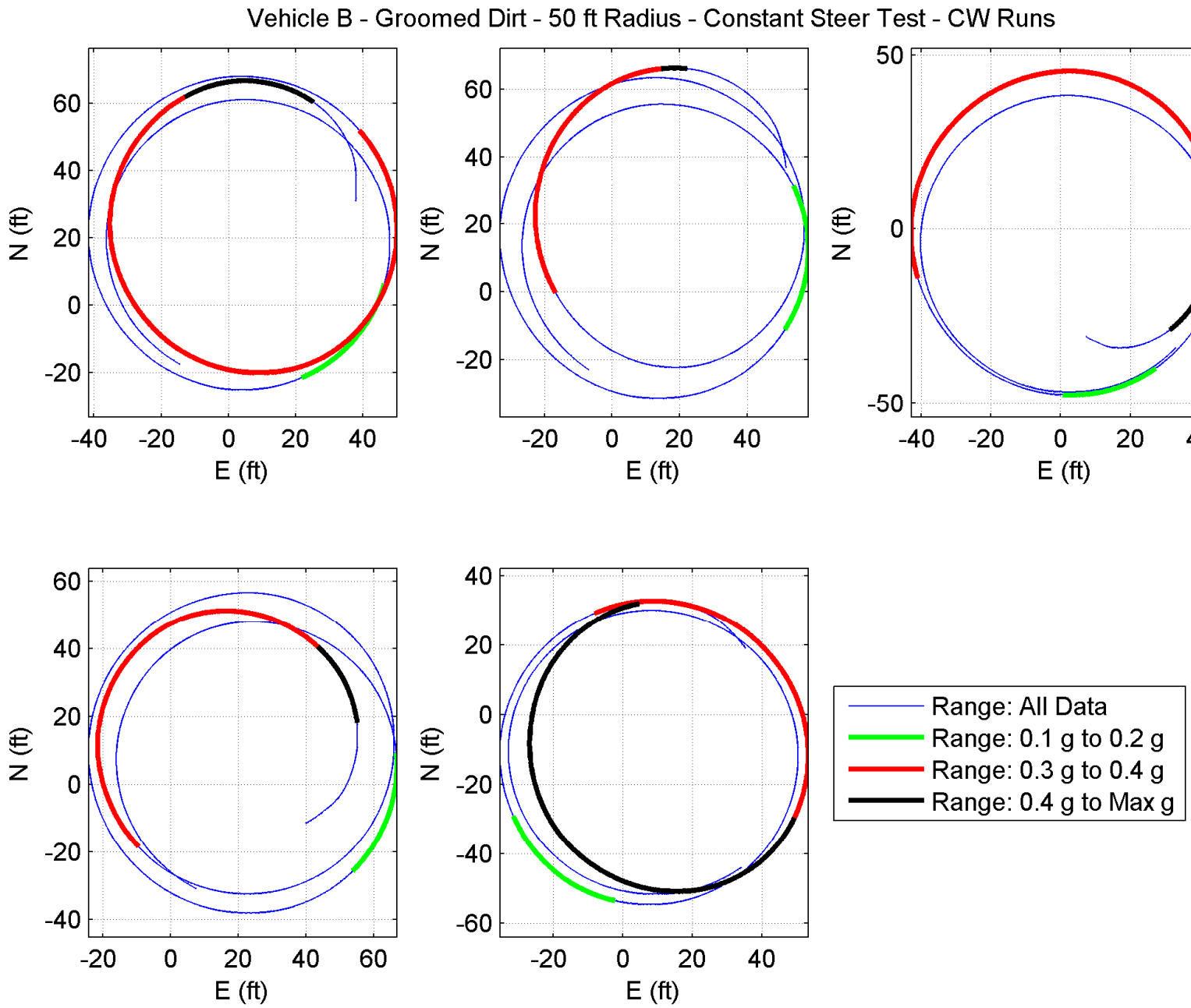

Vehicle B - Groomed Dirt
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
0
20
40
60
80
Estimated Ay (g)
0.5
0
-0.5
Time (sec)
50 ft Radius - Constant Steer Test
Speed (m/s)
8
6
4
2
0
Roll Angle (deg)
Yaw Rate (deg/sec)
50
-50

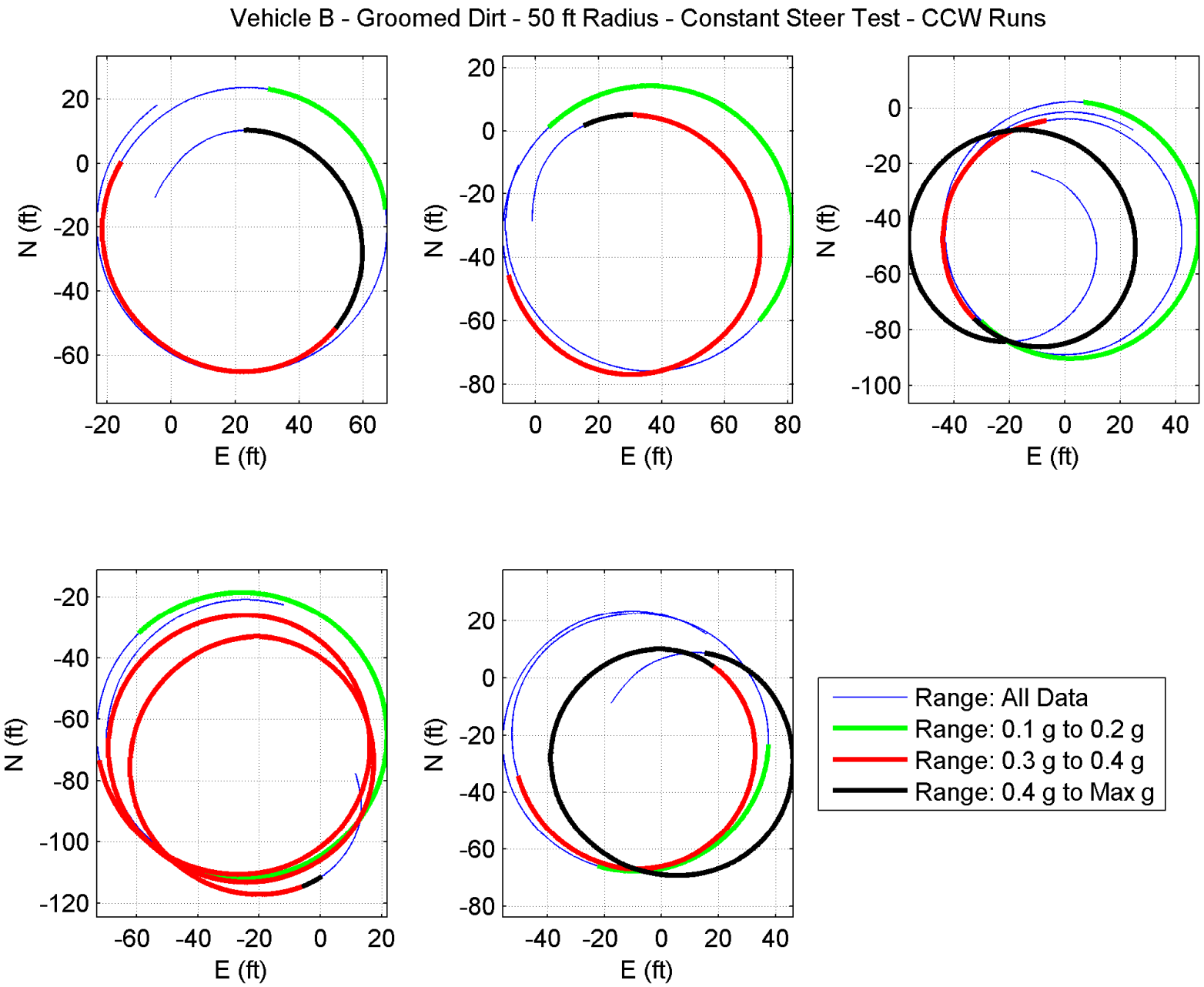

Vehicle B - Groomed Dirt - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8

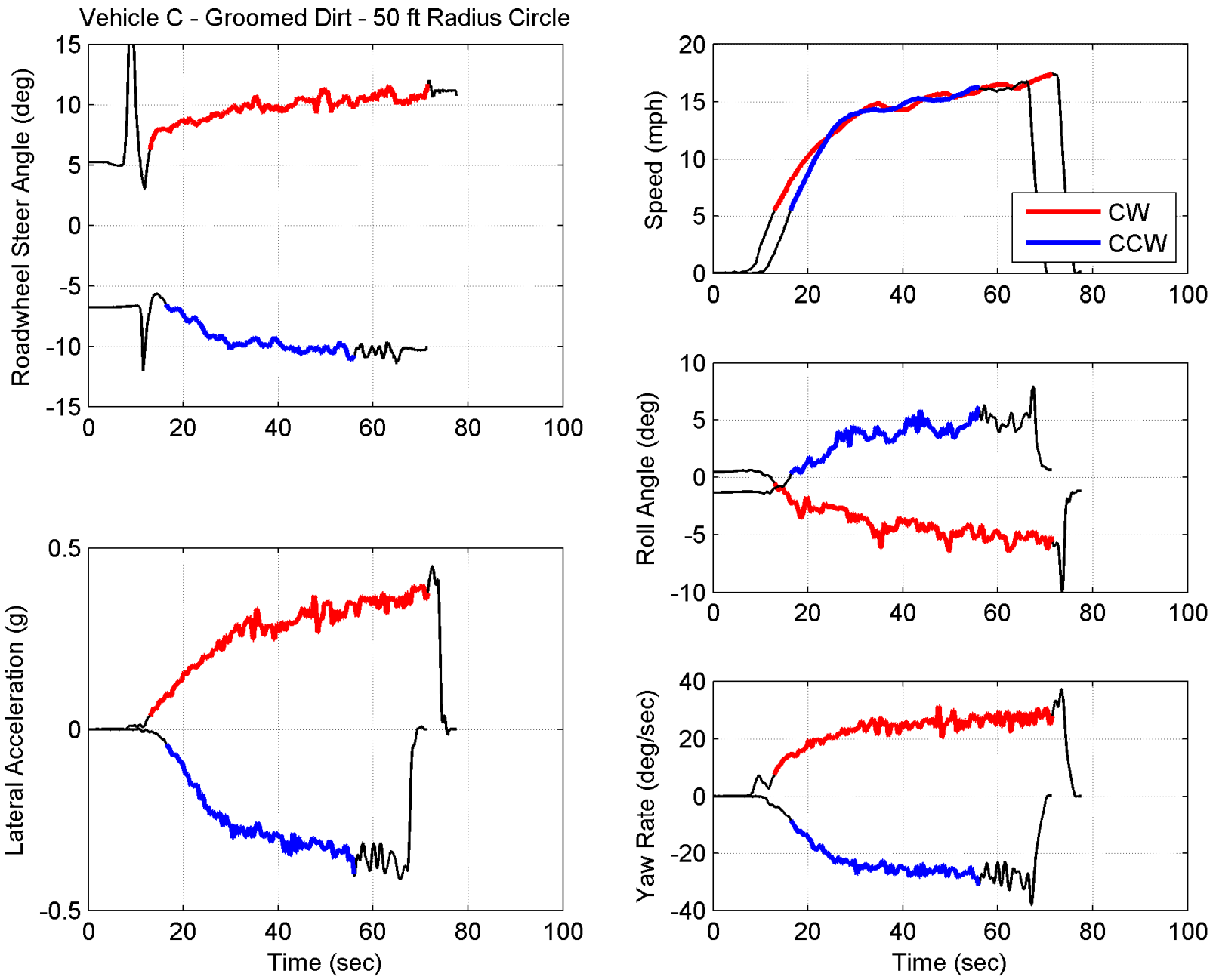

Vehicle B - Groomed Dirt - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 3.86 4.62 4.61 4.18 3.53 STD=0.476
CW Final Slopes: 10.2 85 18.5 -118 16.4 STD=74
CW Ratios: 2.64 18.4 4.01 -28.3 4.66 STD=17.2
CW Average: 11.6
Average Ratio: 79.5
CCW Average: 147
CCW Ratios: -11.1 -0.474 -711 11.6 -3.13 STD=318
CCW Final Slopes: 65.8 1.77 2.62e+003 -33.8 15.6 STD=1.17e+003
CCW Initial Slopes: -5.95 -3.73 -3.69 -2.92 -4.97 STD=1.2
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8

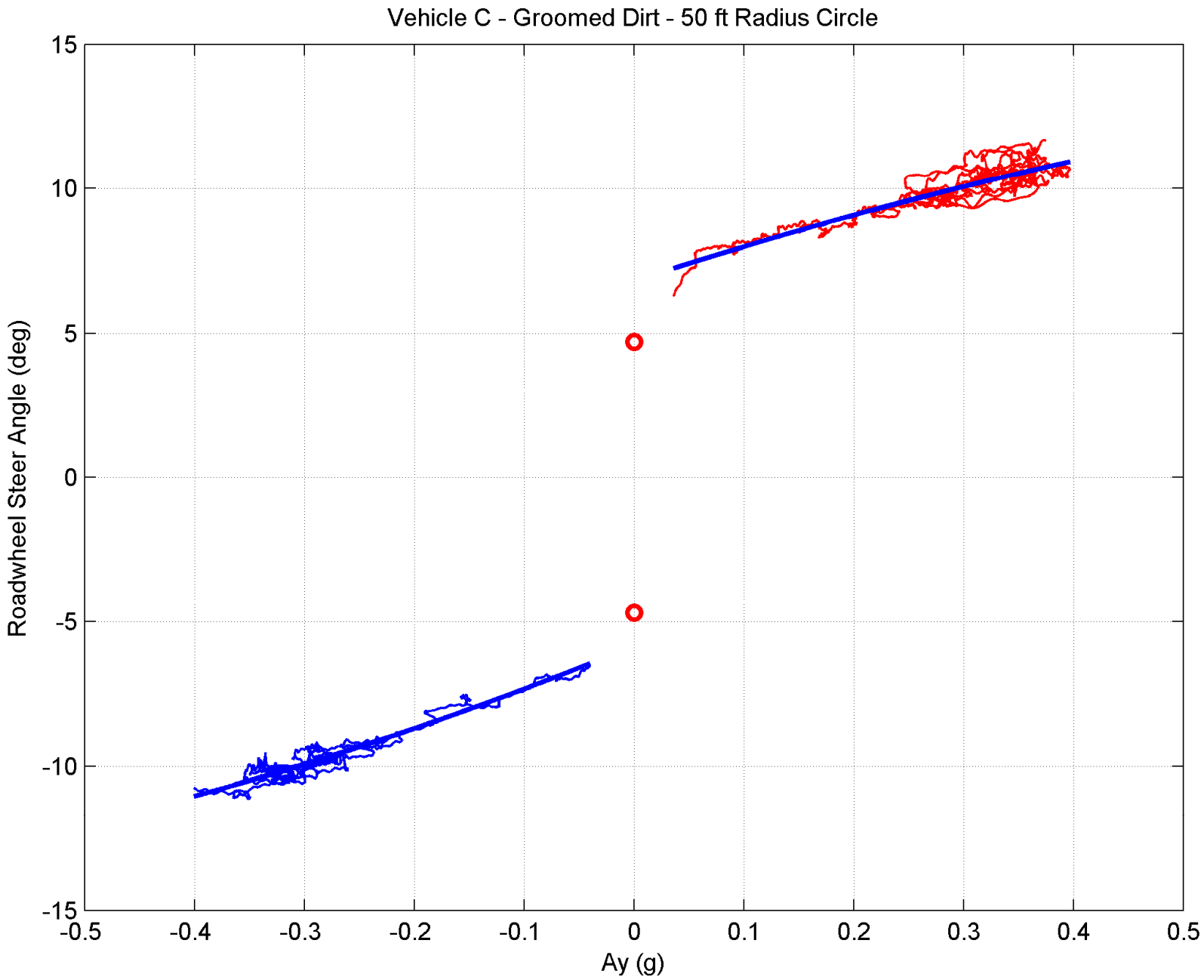

Vehicle B - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 2.64
Final Slope: 10.2
Ratio: 18.4
Final Slope: 85
Ratio: 4.01
Final Slope: 18.5
Ratio: -28.3
Final Slope: -118
Ratio: 4.66
Final Slope: 16.4

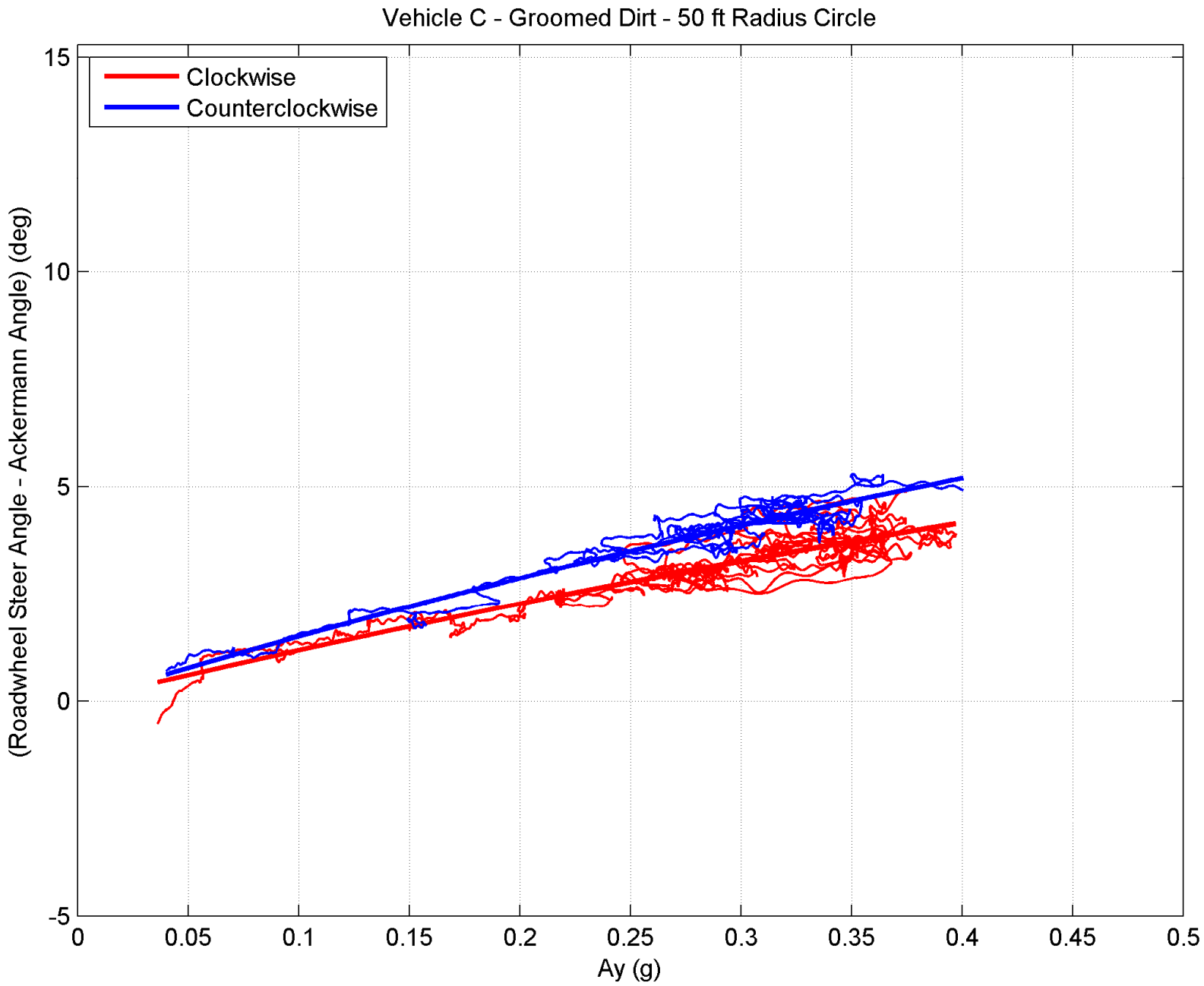

Vehicle B - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 65.8
Ratio: -11.1
Final Slope: 1.77
Ratio: -0.474
Final Slope: 2.62e+003
Ratio: -711
Final Slope: -33.8
Ratio: 11.6
Final Slope: 15.6
Ratio: -3.13
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
5
6
7
8

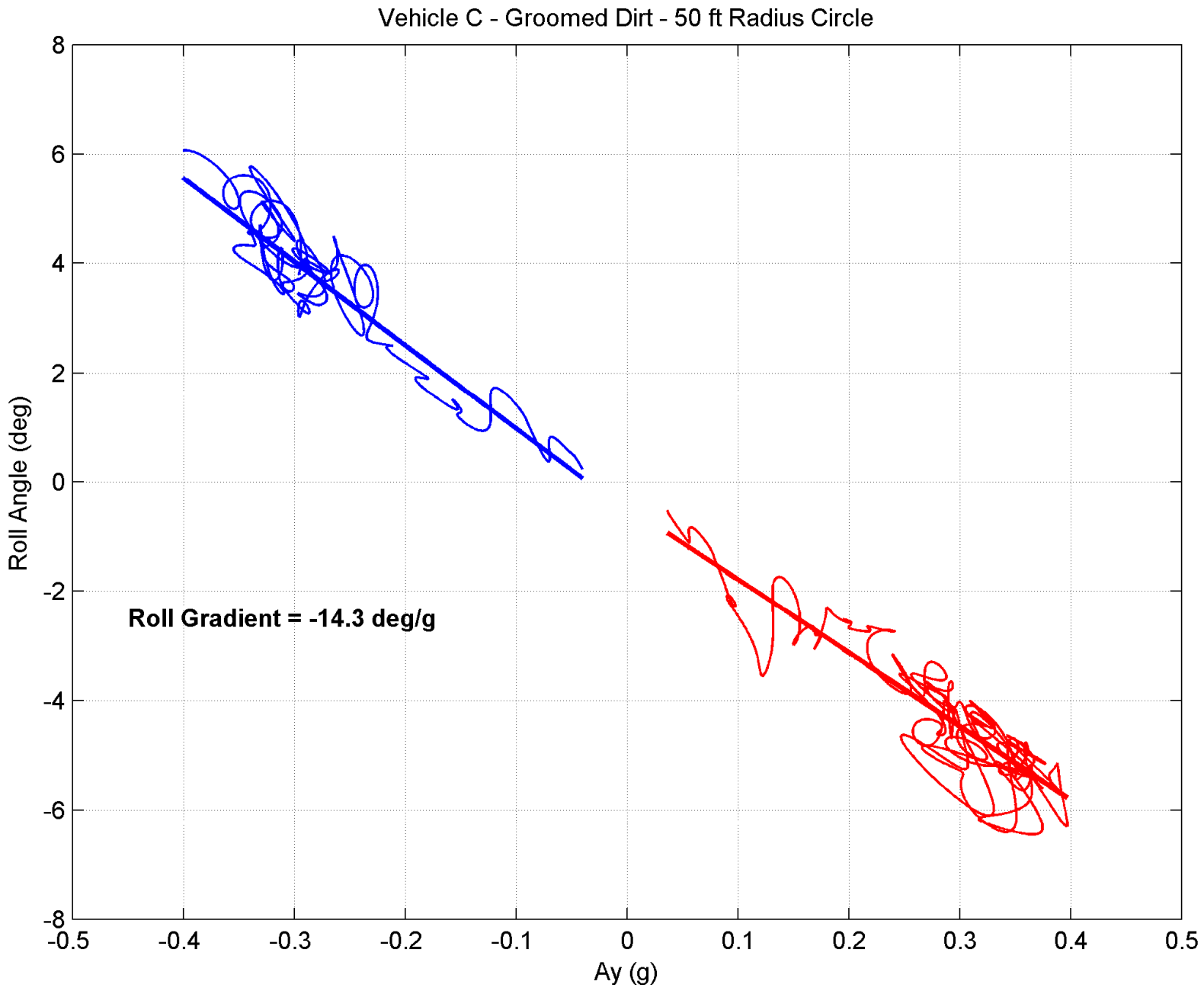

Vehicle B - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

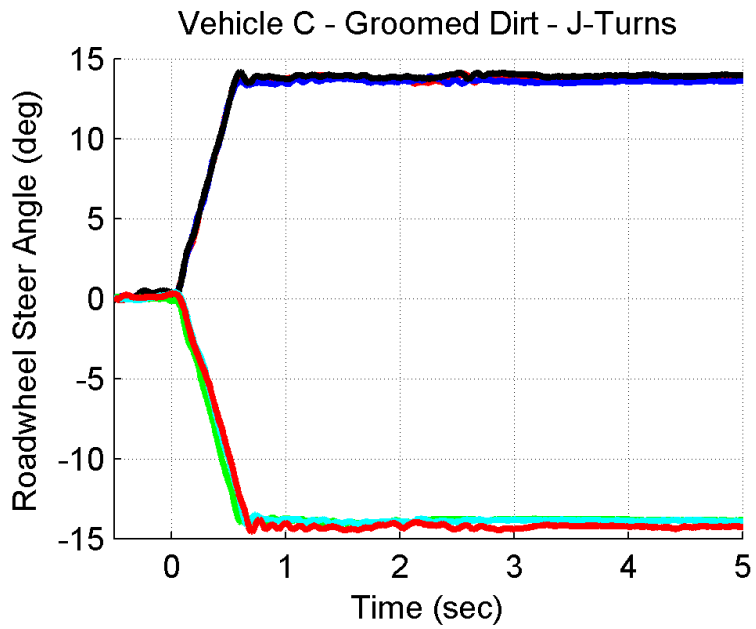

Vehicle B - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

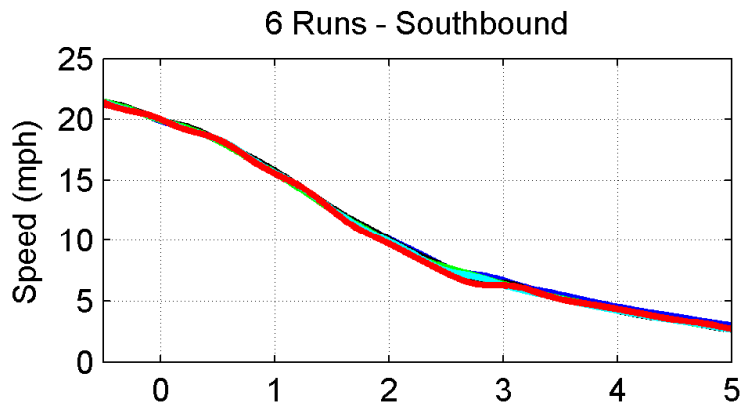

Vehicle C - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

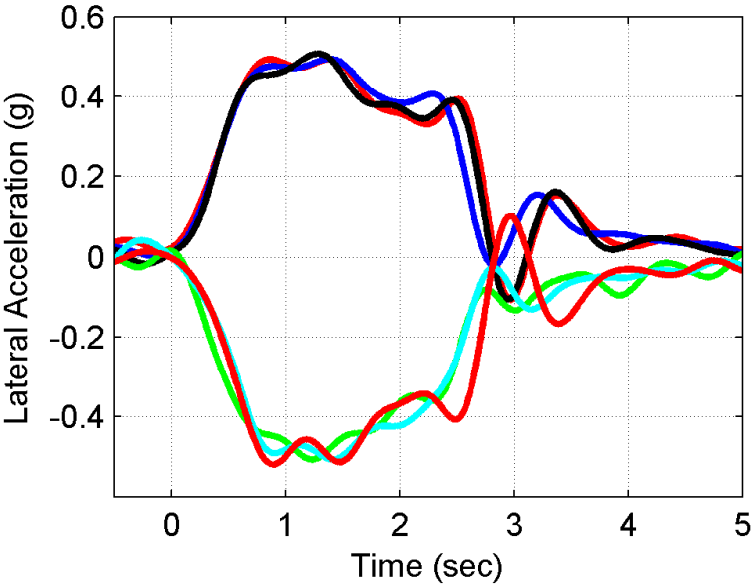

Vehicle C - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

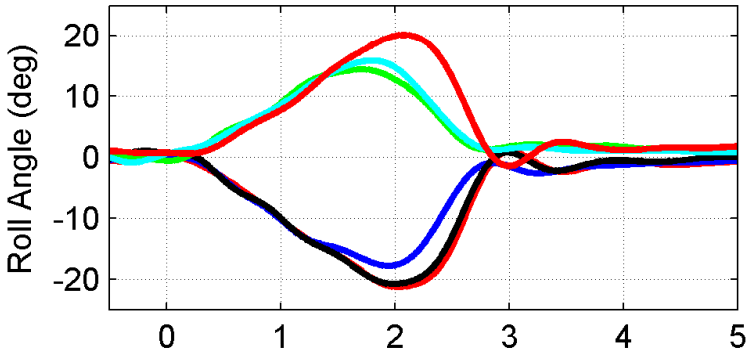

Vehicle C - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
(Roadwheel Steer Angle - Ackermann Angle) (deg)
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Ay (g)

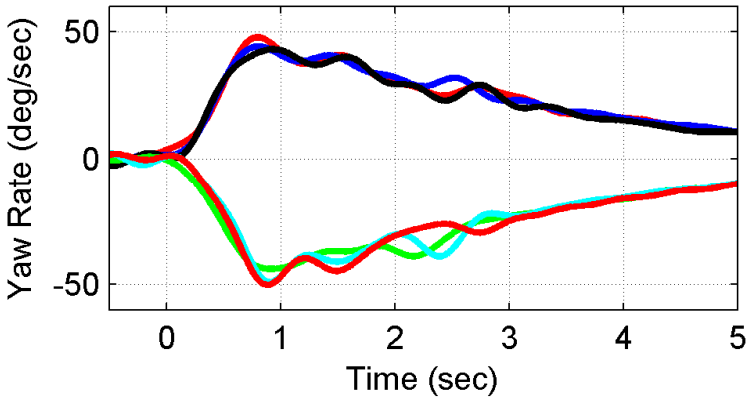

Vehicle C - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -14.3 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

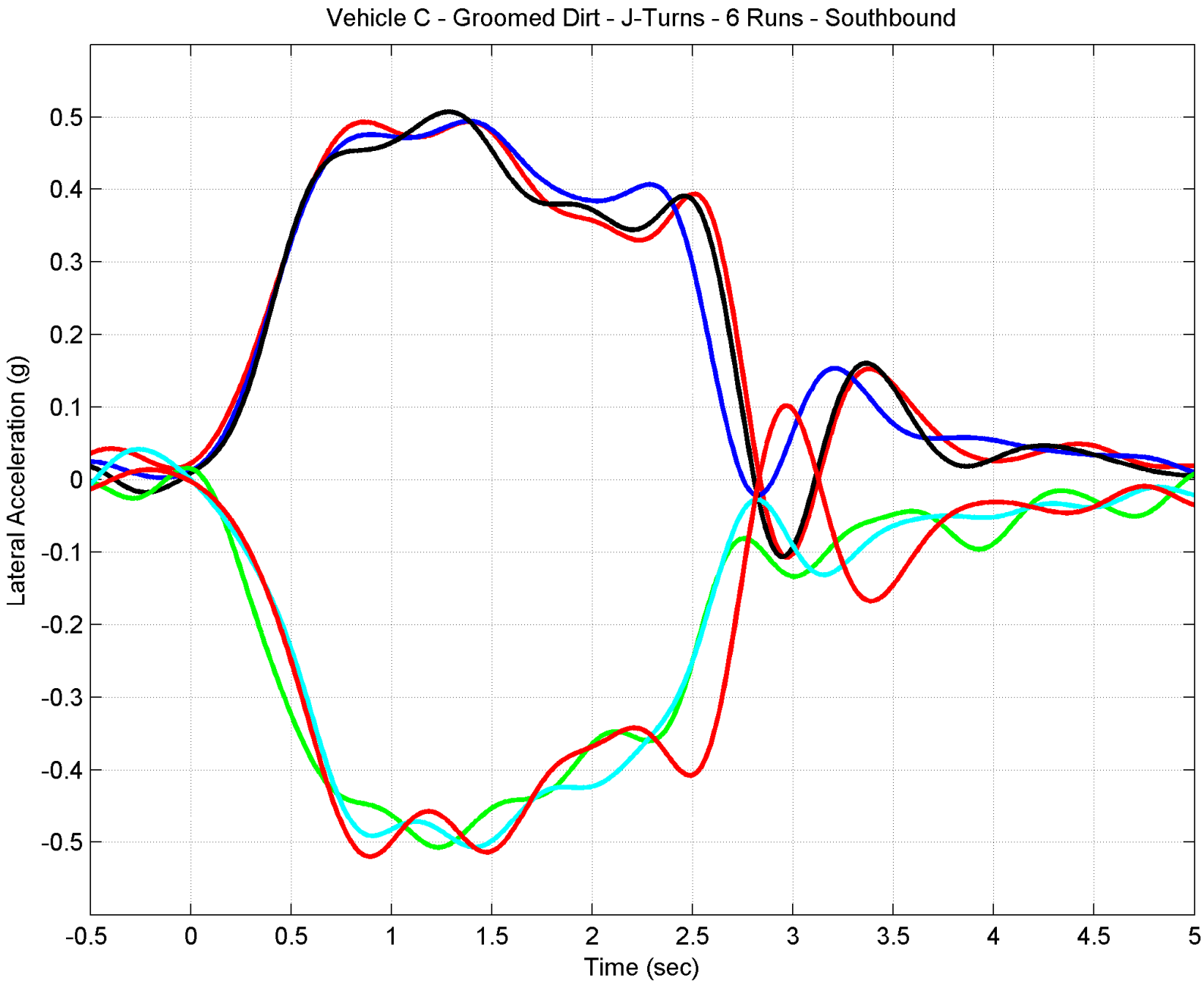

Vehicle C - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)

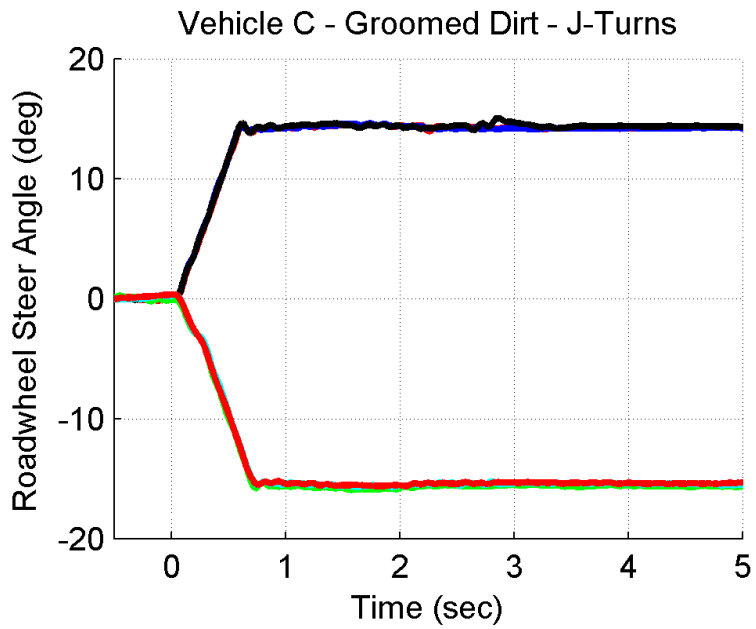

6 Runs - Southbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5

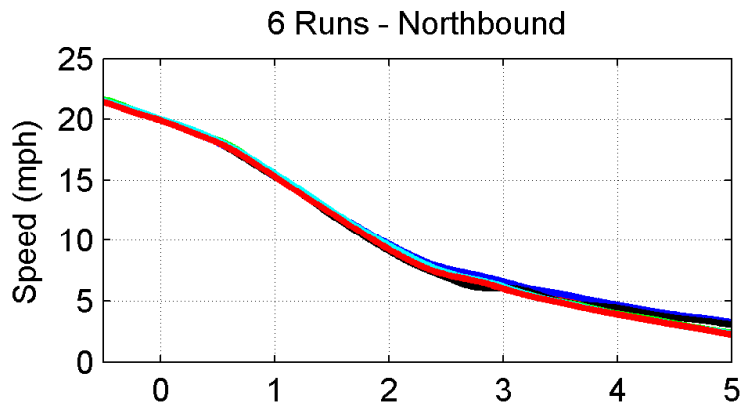

Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)

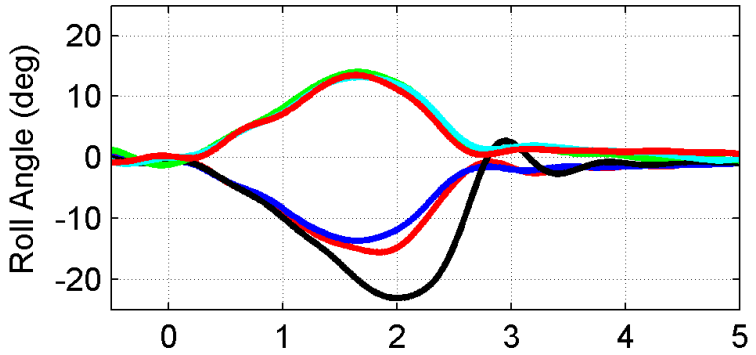

Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5

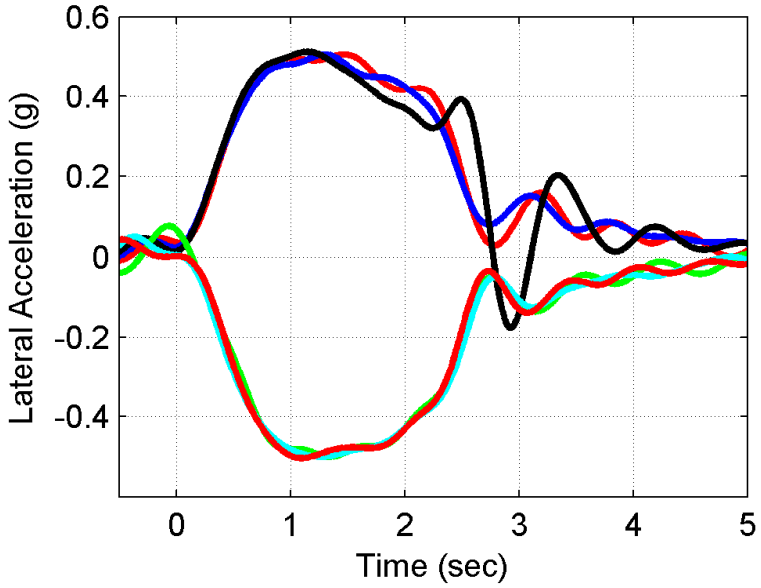

Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)

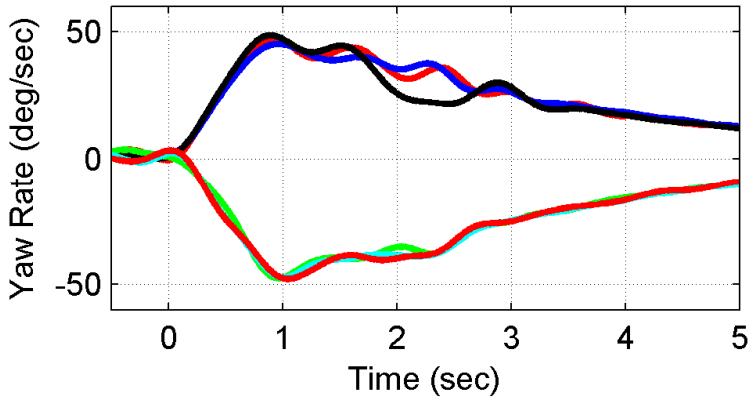

Vehicle C - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

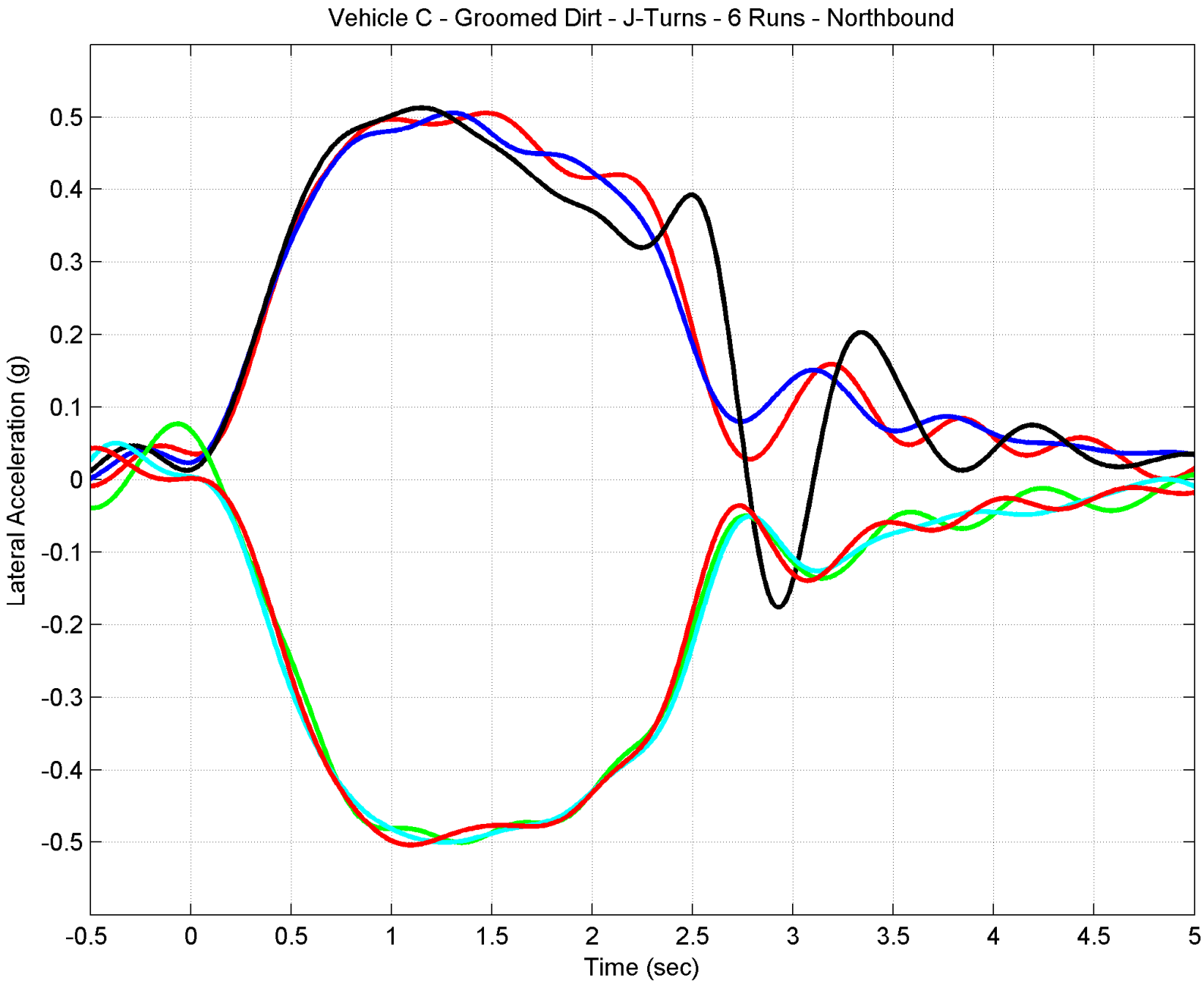

Vehicle C - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5


Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle C - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle C - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.494	-0.507
2	0.494	-0.507
3	0.507	-0.520
Mean Value of 3 Runs	0.498	-0.511
Standard Deviation of 3 Runs	0.008	0.007

Average of 6 North Runs

0.505

Run Number	North Right Turns	North Left Turns
1	0.506	-0.501
2	0.506	-0.501
3	0.513	-0.504
Mean Value of 3 Runs	0.508	-0.502
Standard Deviation of 3 Runs	0.004	0.002

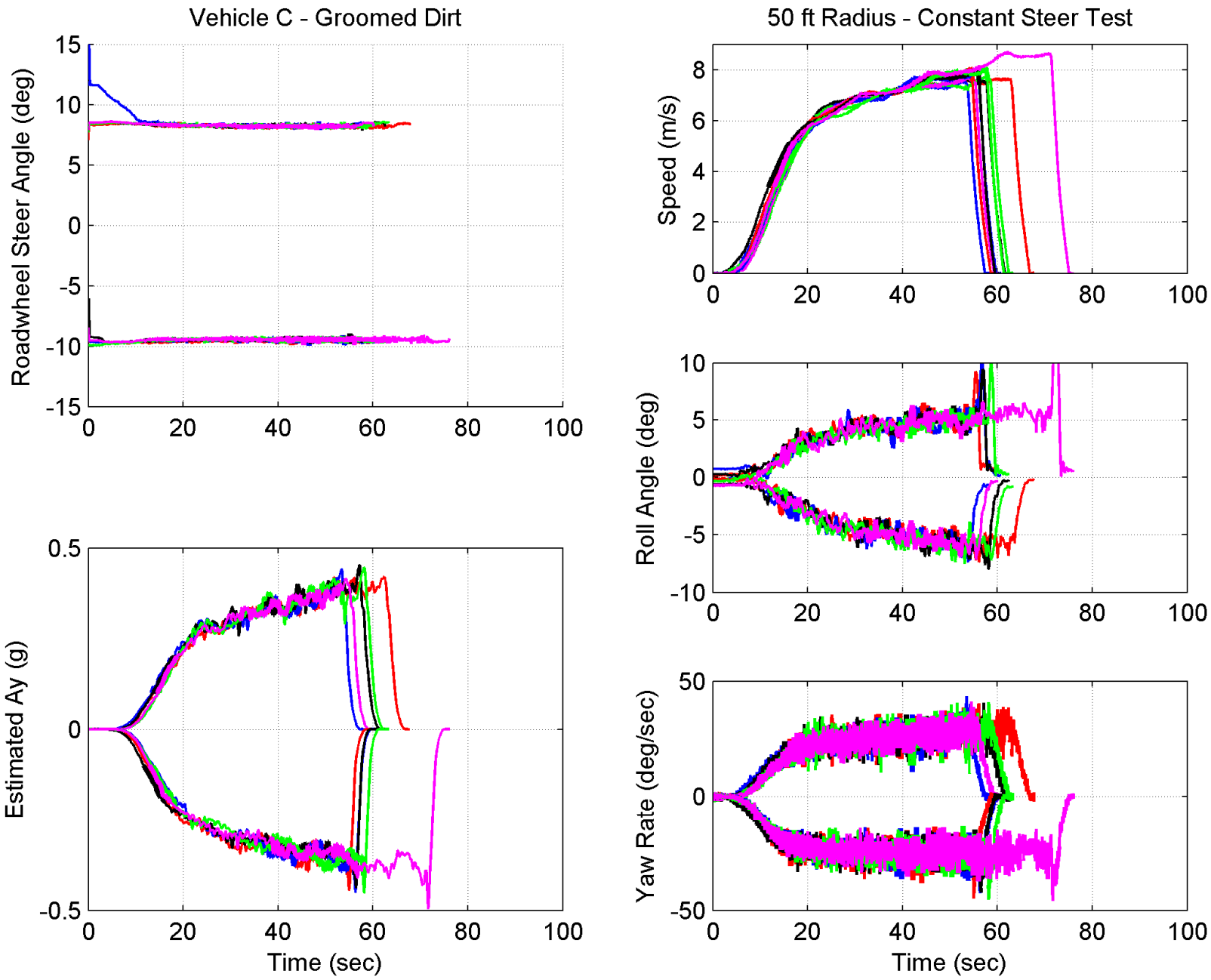
Average of 6 South Runs

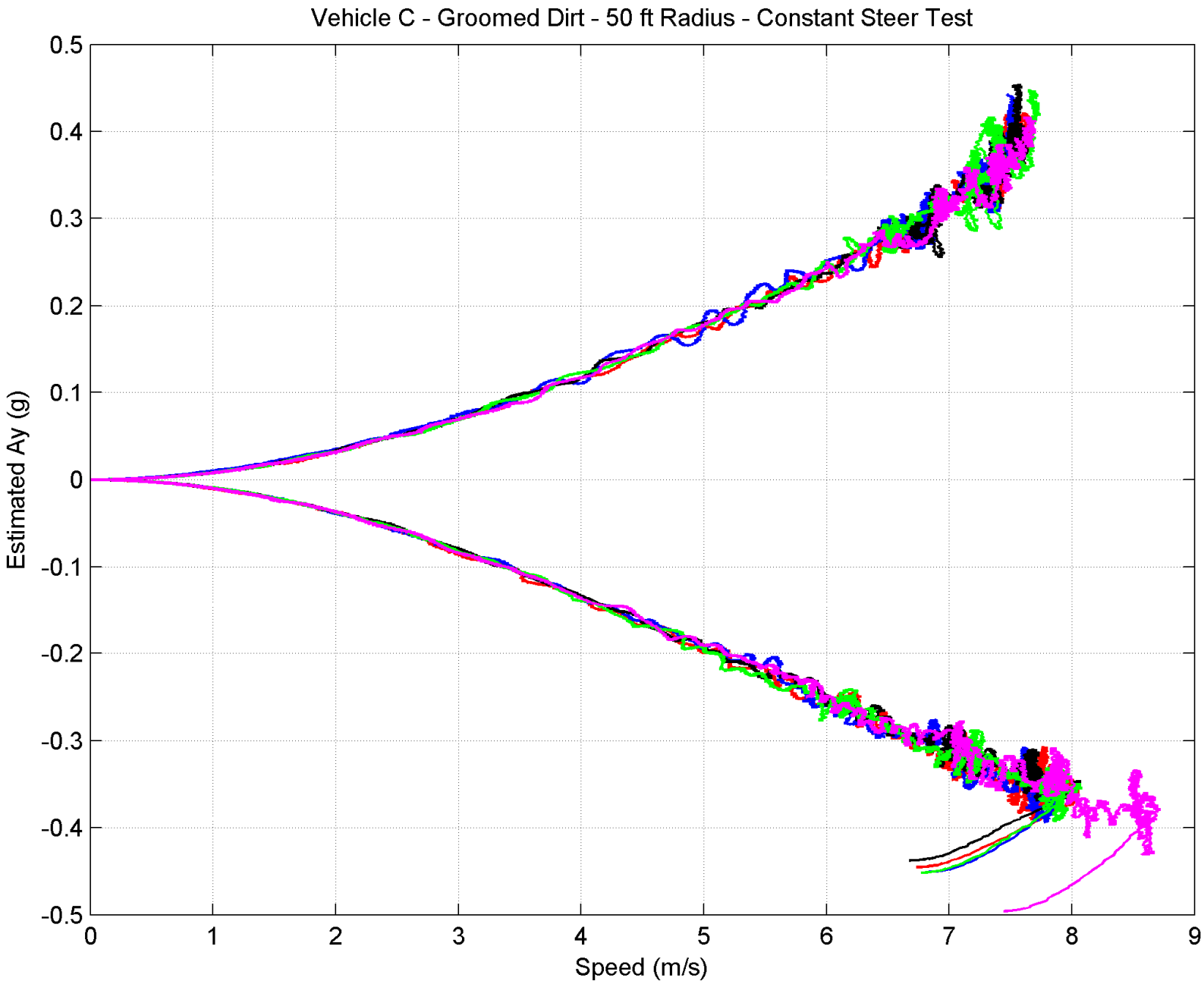
0.505

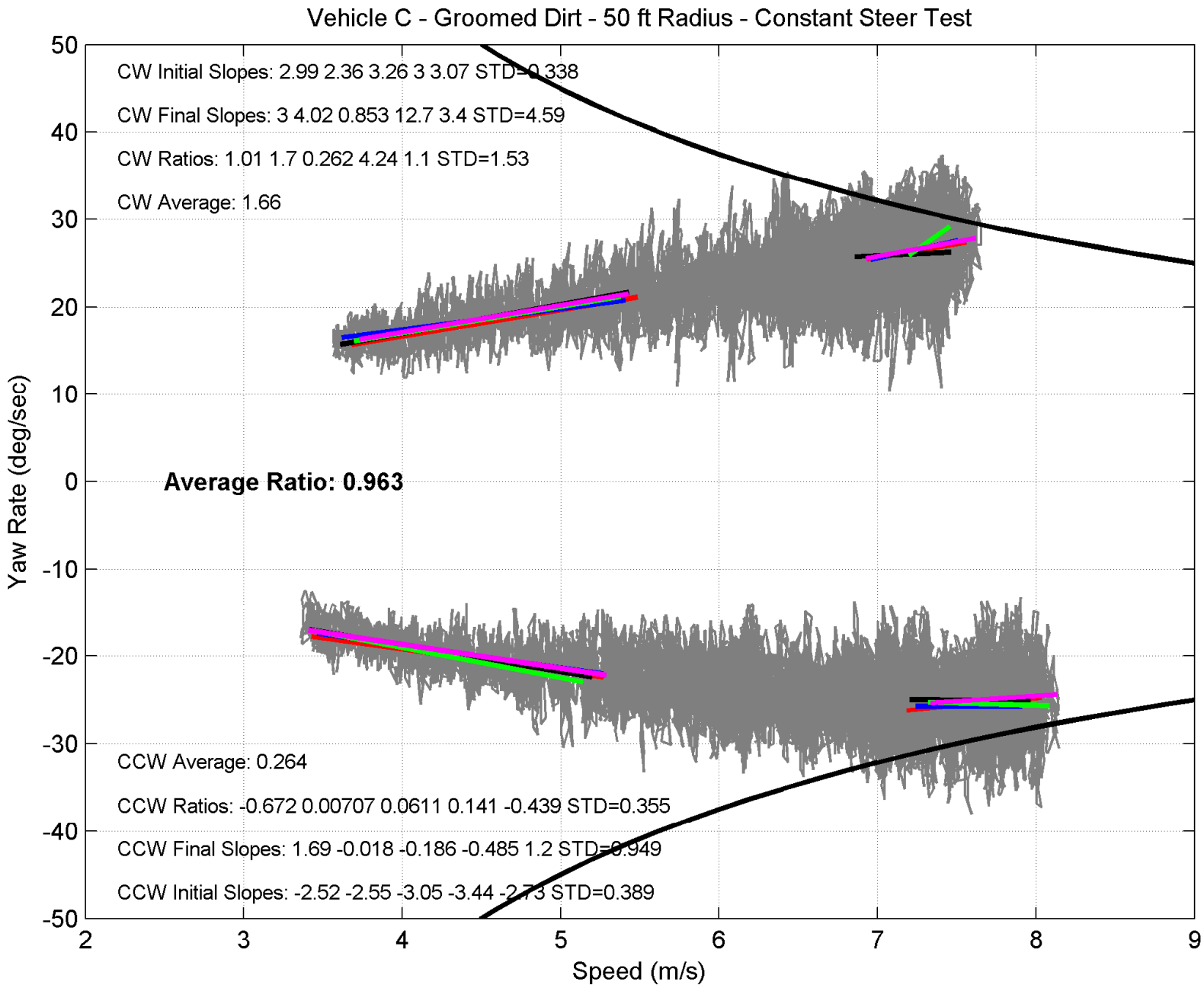
Average of All 12 Runs

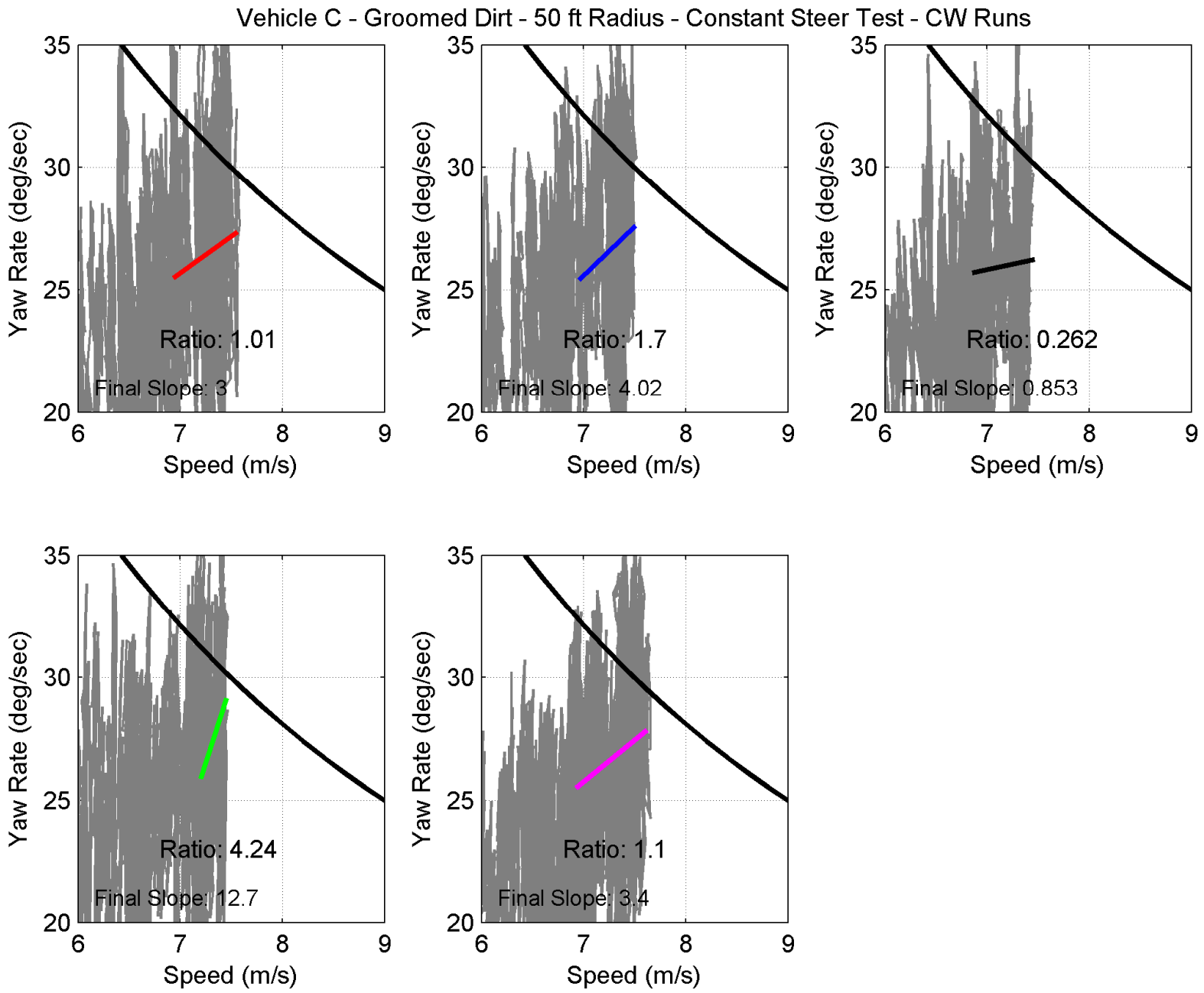
0.505

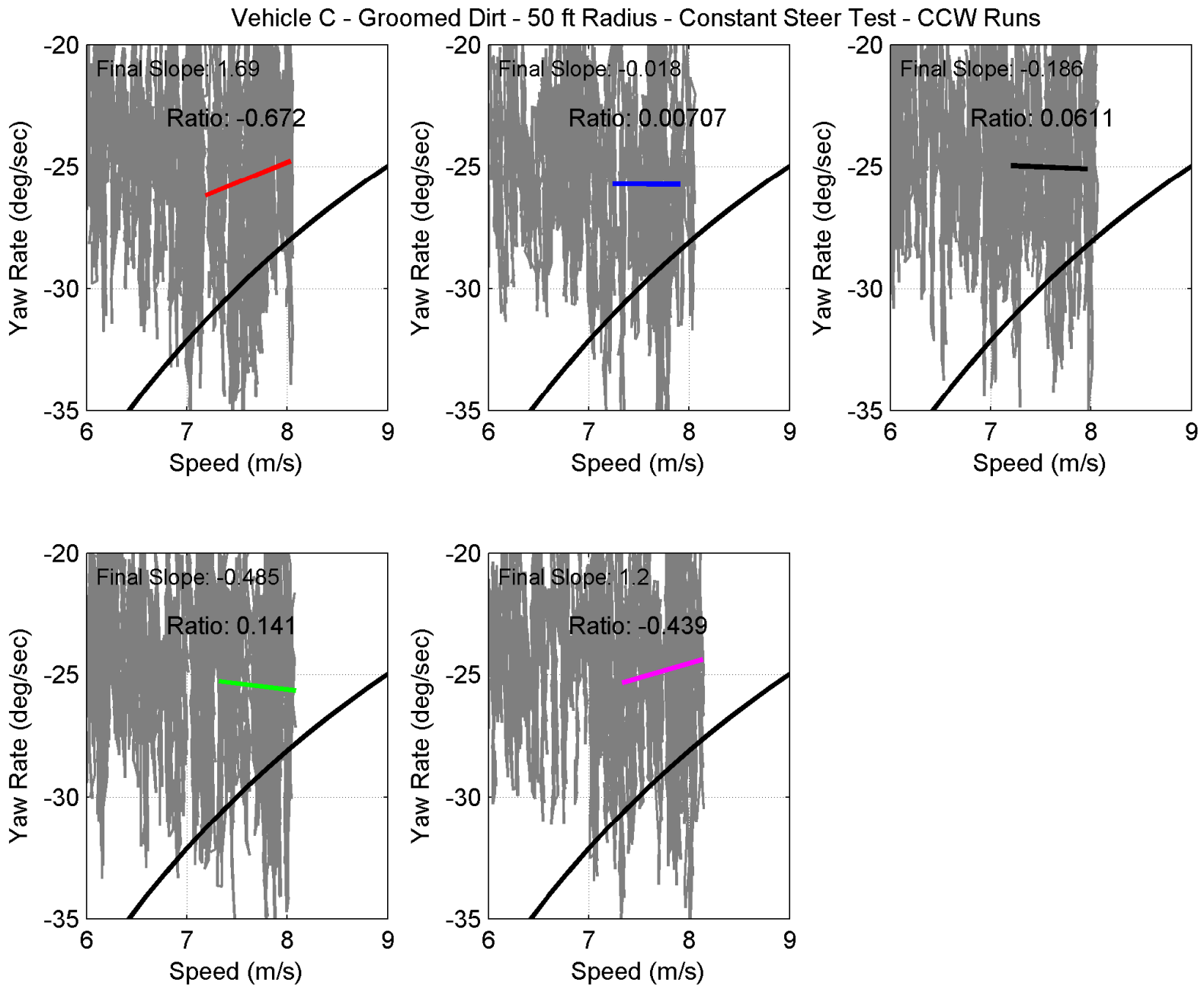
Threshold Ay

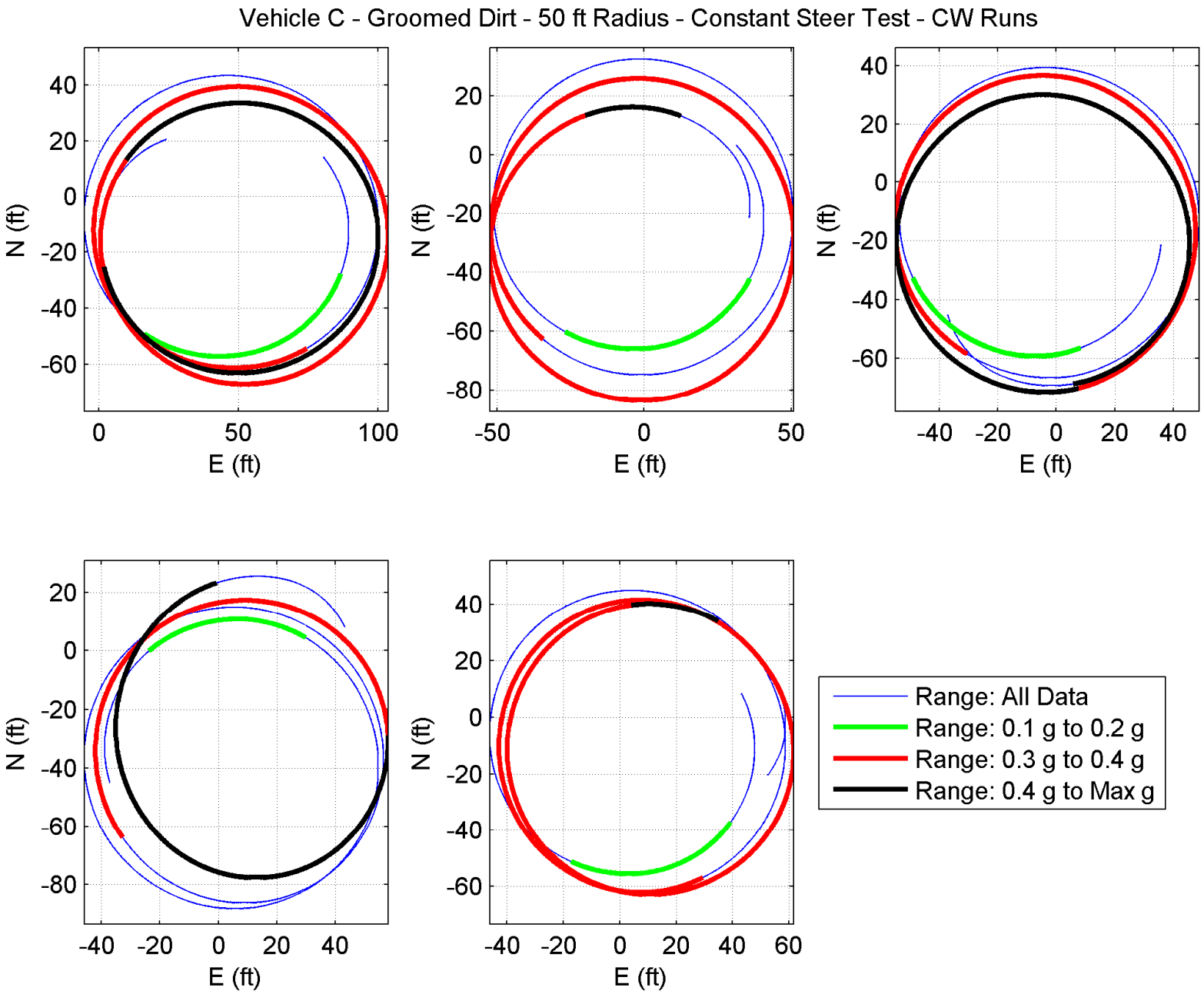

Vehicle C - Groomed Dirt
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
20
40
60
80
100
Estimated Ay (g)
0.5
0
-0.5
Time (sec)
50 ft Radius - Constant Steer Test
Speed (m/s)
8
6
4
2
0
Roll Angle (deg)
10
5
0
-5
-10
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

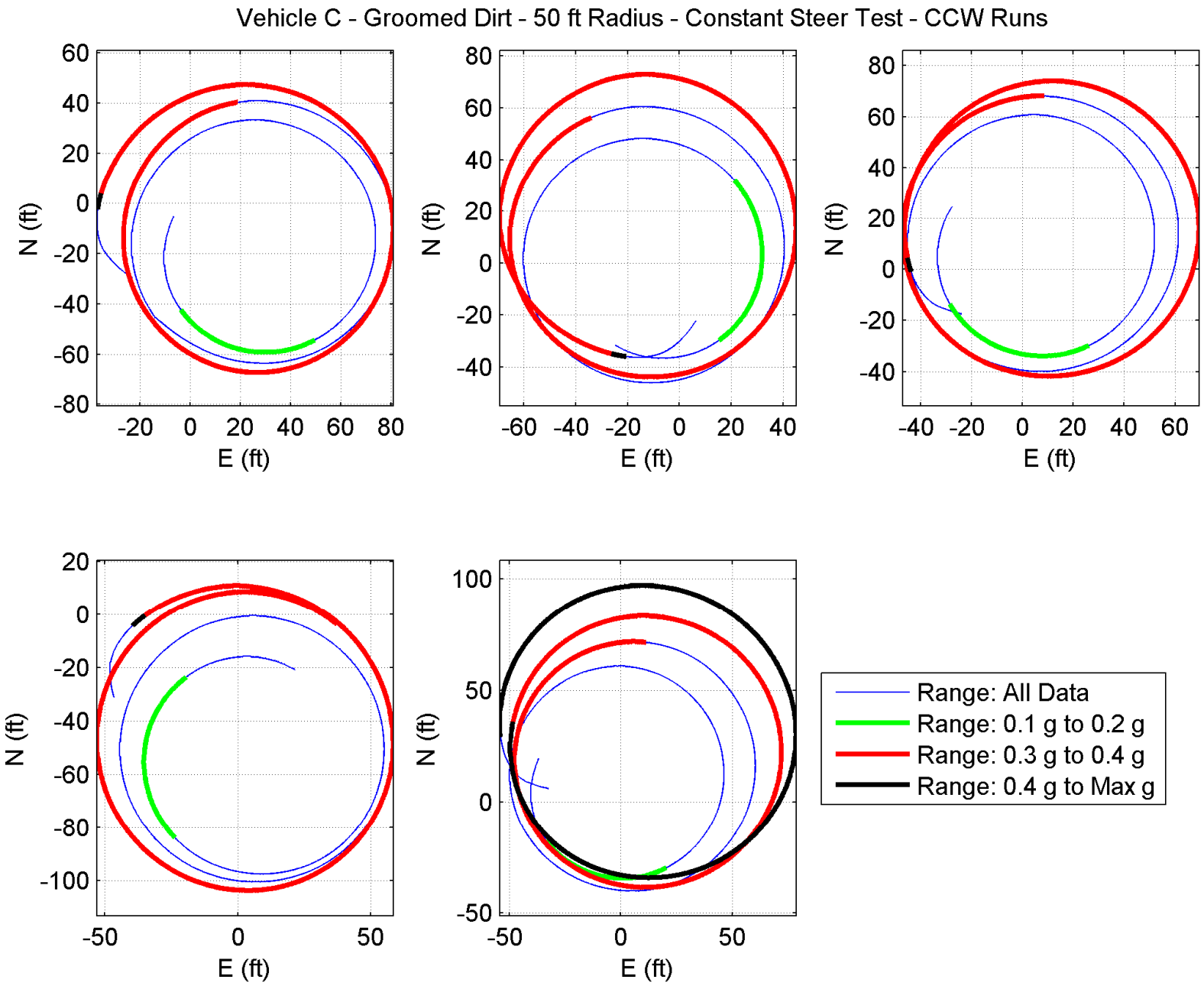

Vehicle C - Groomed Dirt - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

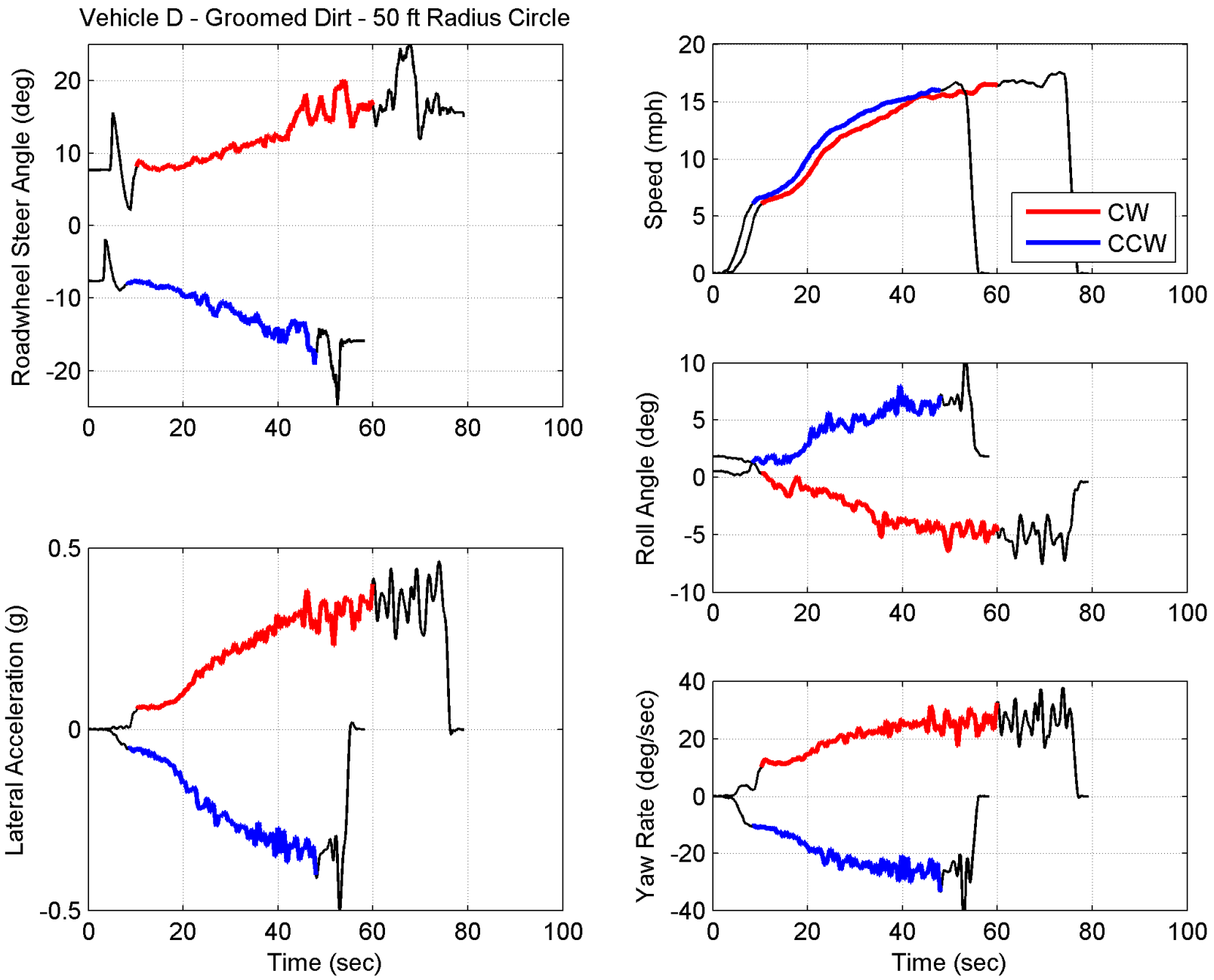

Vehicle C - Groomed Dirt - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 2.99 2.36 3.26 3 3.07 STD=0.338
CW Final Slopes: 3 4.02 0.853 12.7 3.4 STD=4.59
CW Ratios: 1.01 1.7 0.262 4.24 1.1 STD=1.53
CW Average: 1.66
Average Ratio: 0.963
CCW Average: 0.264
CCW Ratios: -0.672 0.00707 0.0611 0.141 -0.439 STD=0.355
CCW Final Slopes: 1.69 -0.018 -0.186 -0.485 1.2 STD=0.949
CCW Initial Slopes: -2.52 -2.55 -3.05 -3.44 -2.73 STD=0.389
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8
9

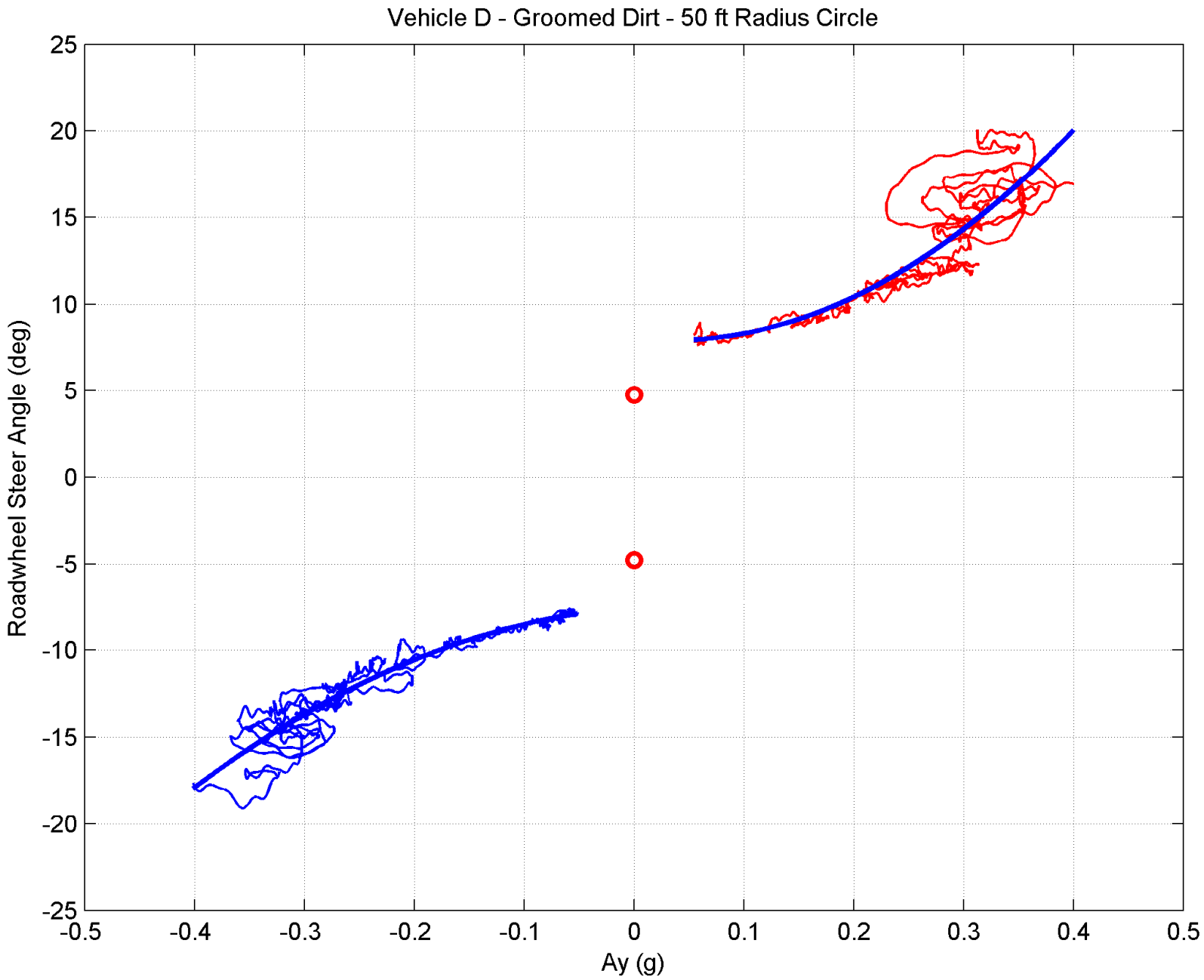

Vehicle C - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 1.01
Final Slope: 3
Ratio: 1.7
Final Slope: 4.02
Ratio: 0.262
Final Slope: 0.853
Ratio: 4.24
Final Slope: 12.7
Ratio: 1.1
Final Slope: 3.4

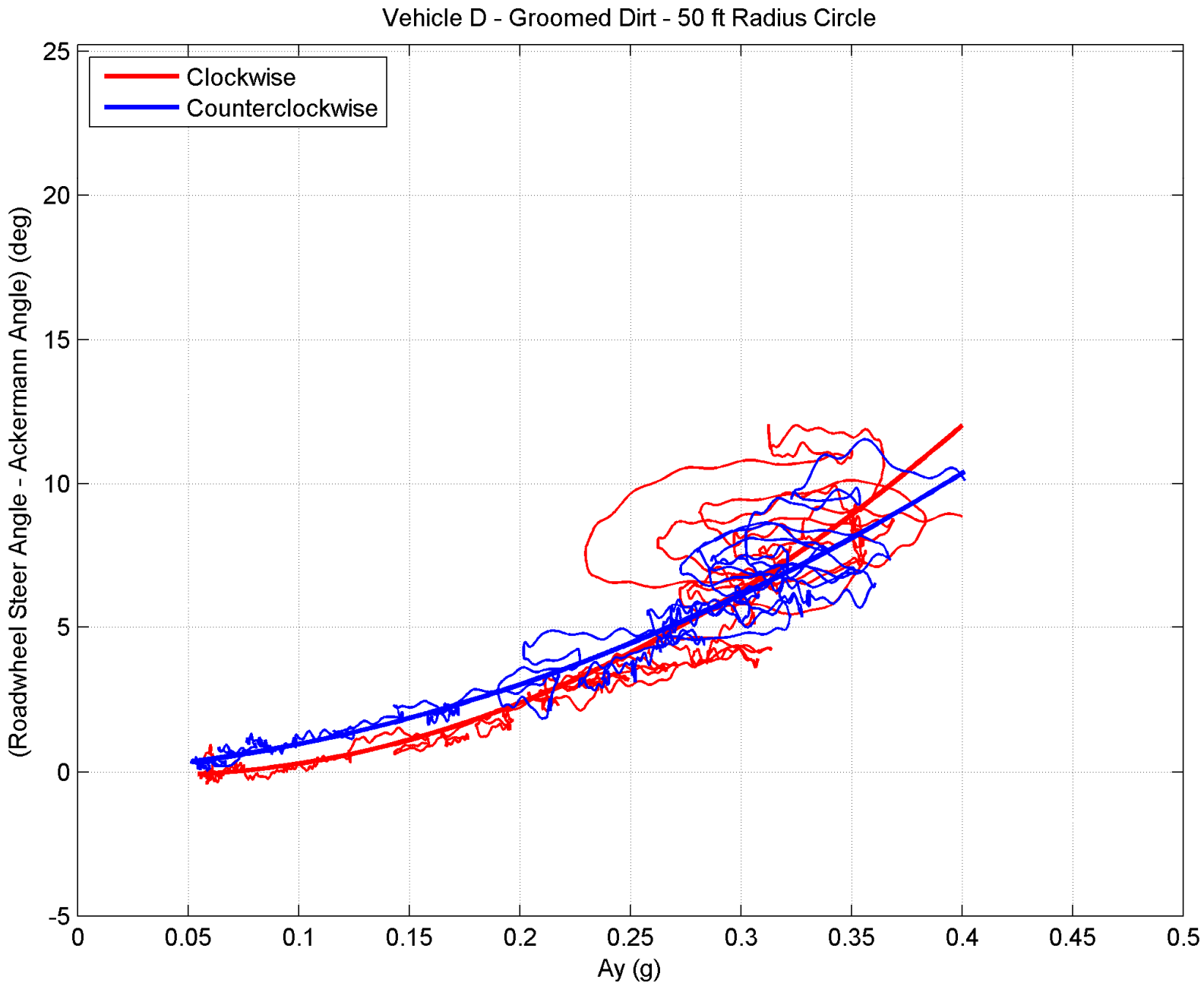

Vehicle C - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 1.69
Ratio: -0.672
Final Slope: -0.018
Ratio: 0.00707
Final Slope: -0.186
Ratio: 0.0611
Final Slope: -0.485
Ratio: 0.141
Final Slope: 1.2
Ratio: -0.439
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

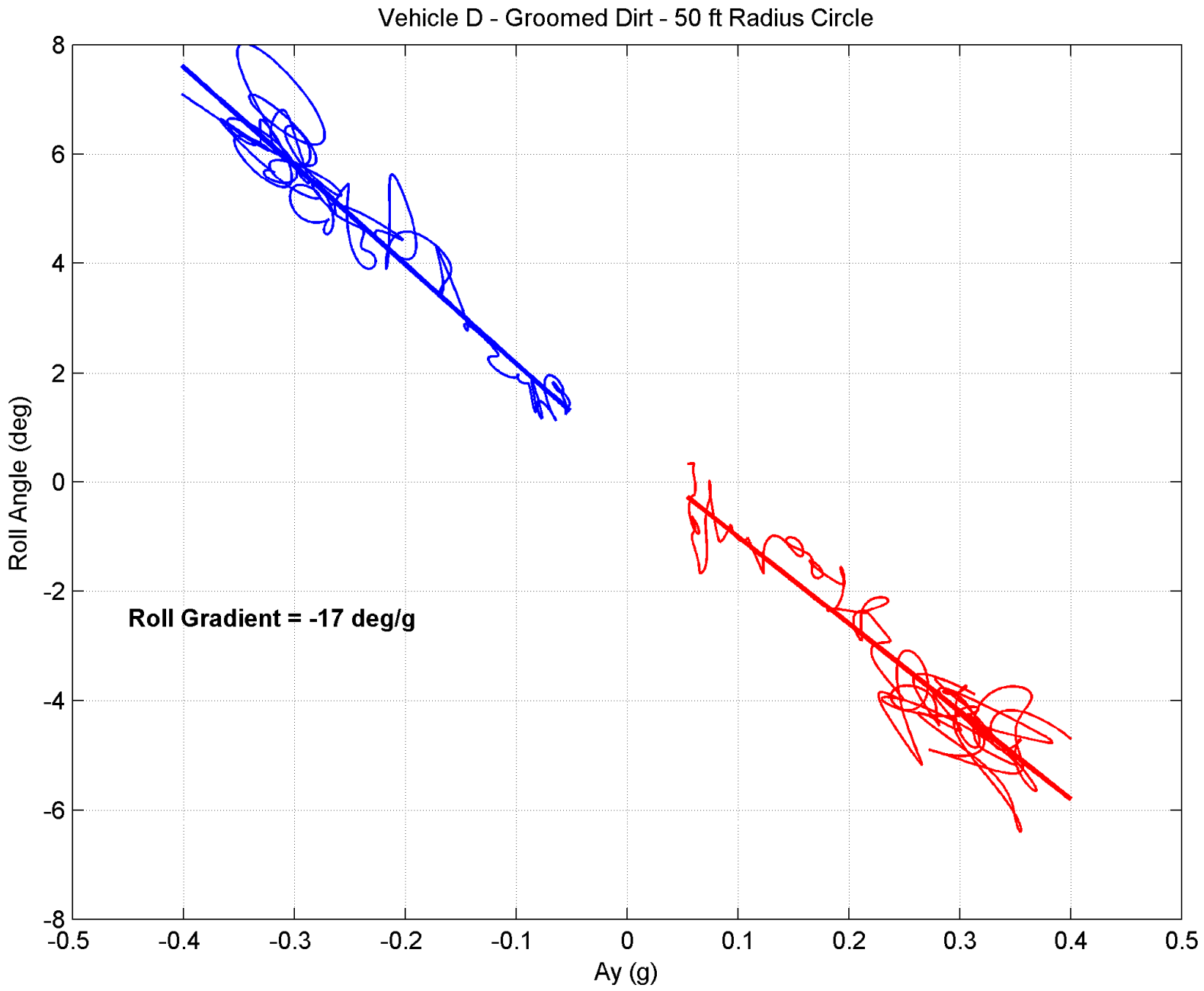

Vehicle C - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

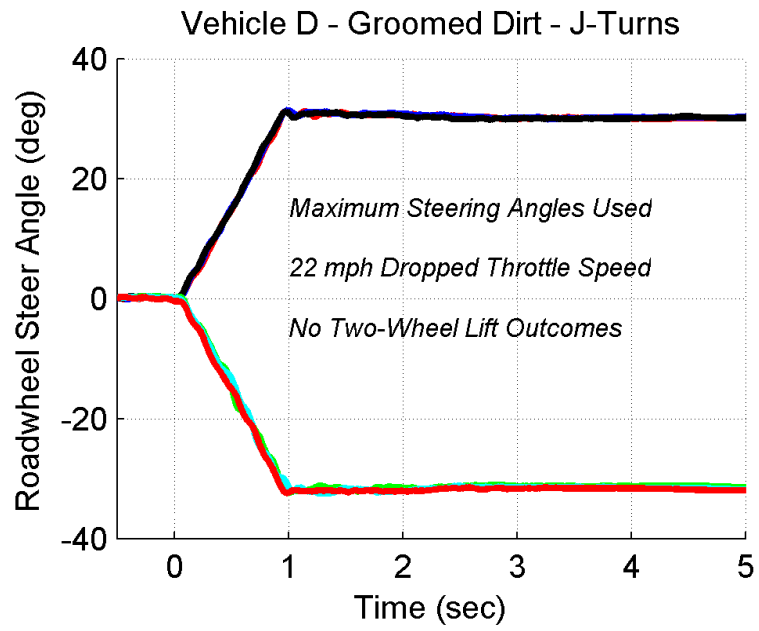

Vehicle C - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

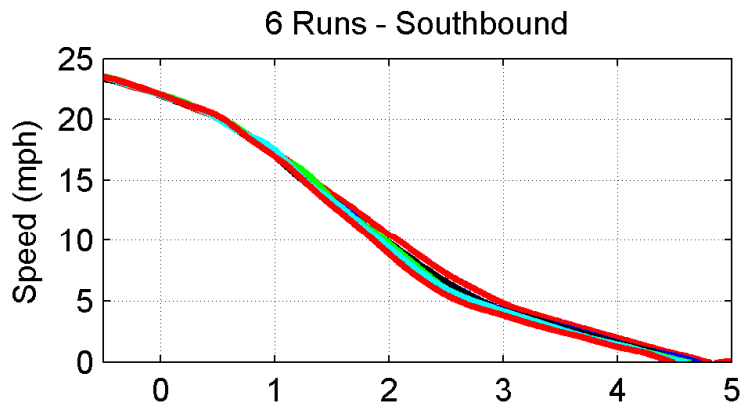

Vehicle D - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

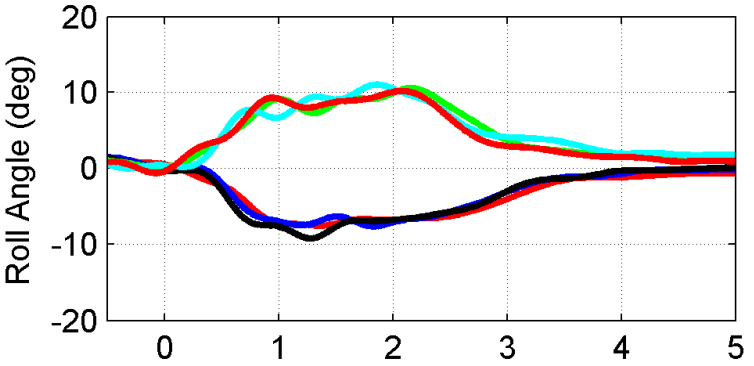

Vehicle D - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

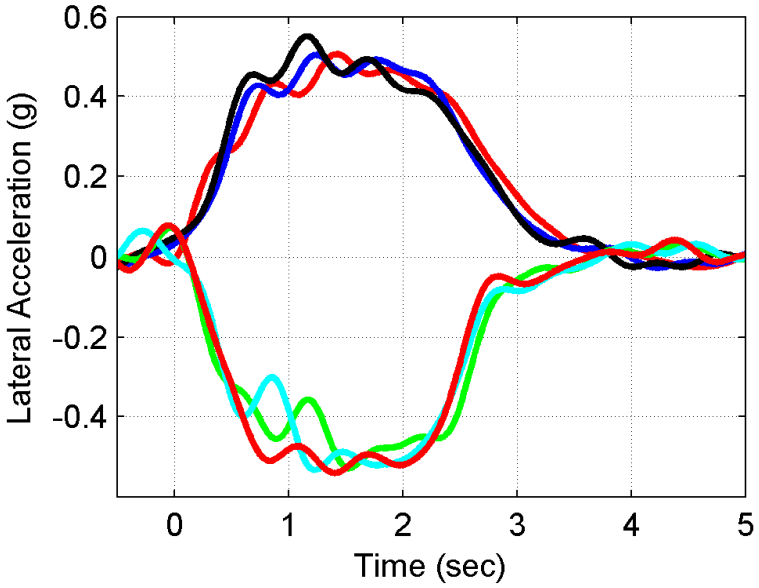

Vehicle D - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
25
20
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

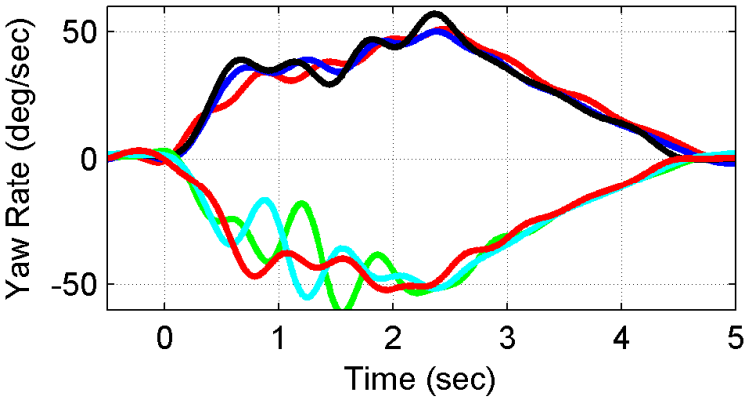

Vehicle D - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -17 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

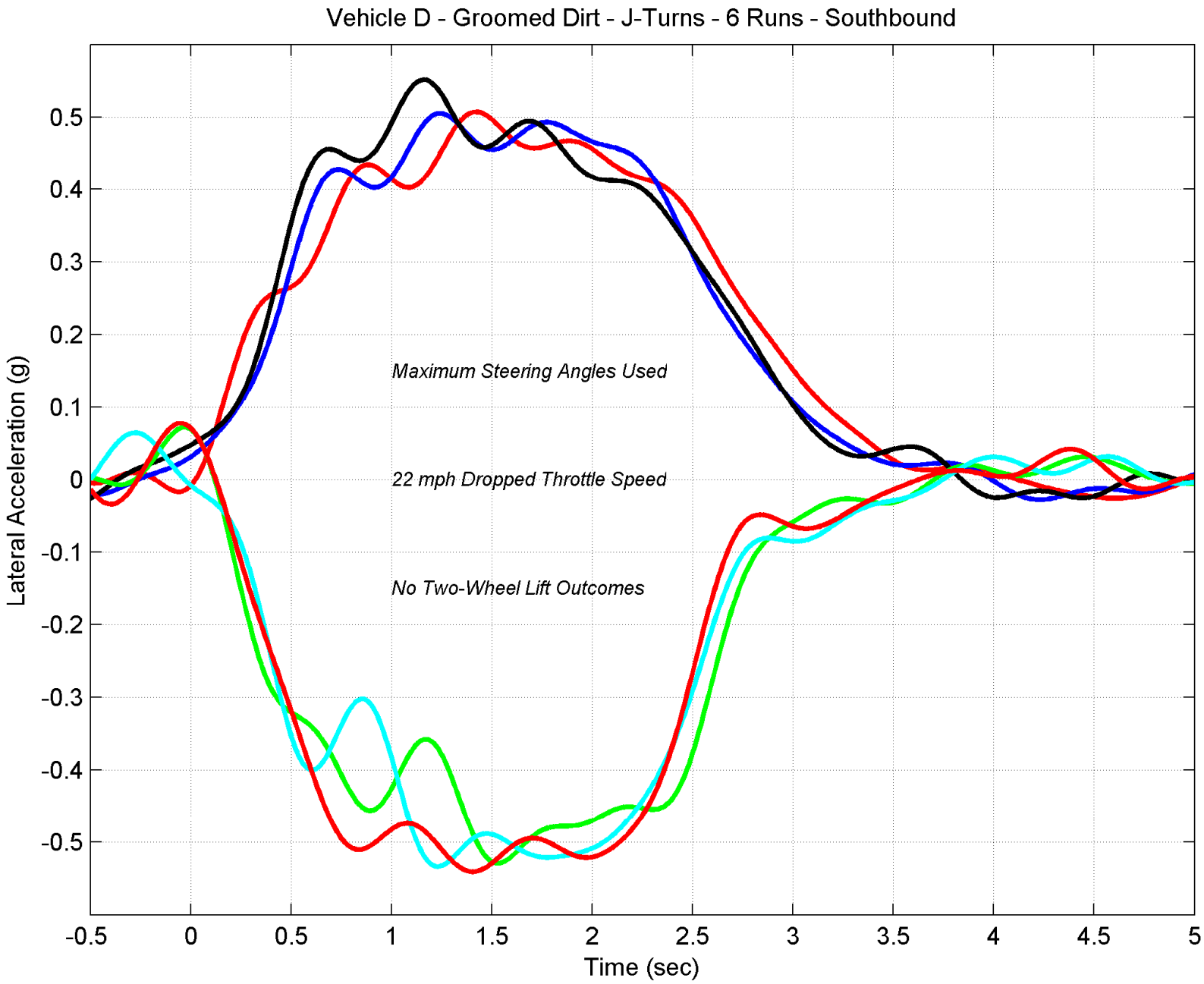

Vehicle D - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
Maximum Steering Angles Used
22 mph Dropped Throttle Speed
No Two-Wheel Lift Outcomes
Time (sec)

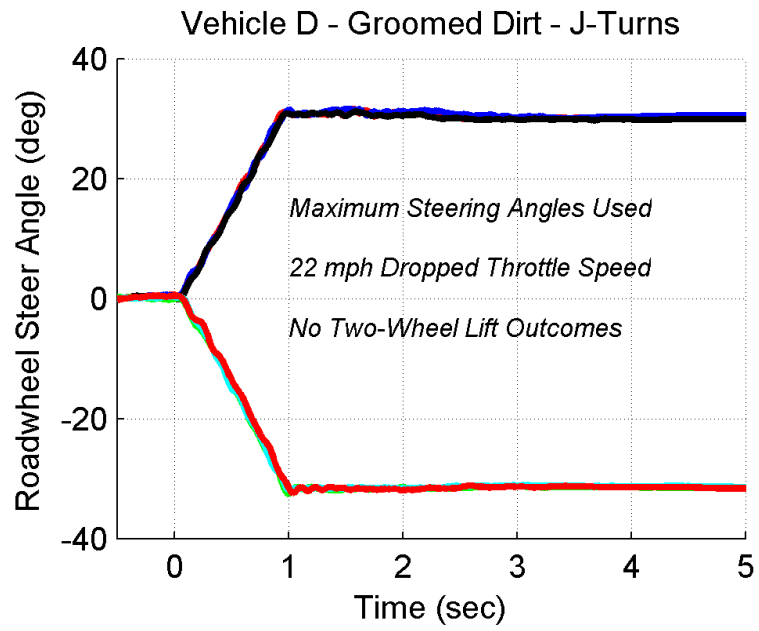

6 Runs - Southbound
Speed (mph)

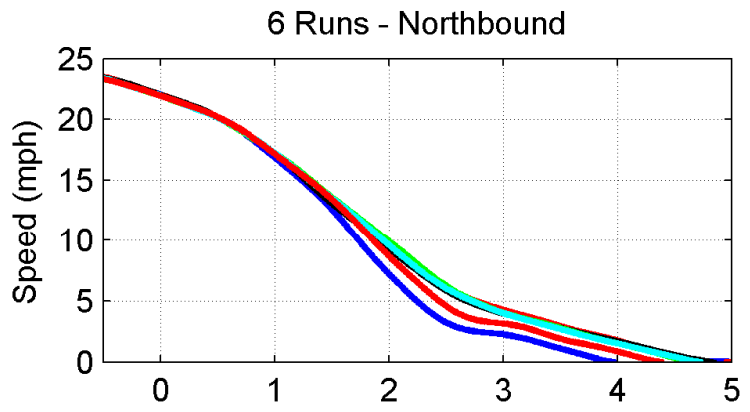

Roll Angle (deg)

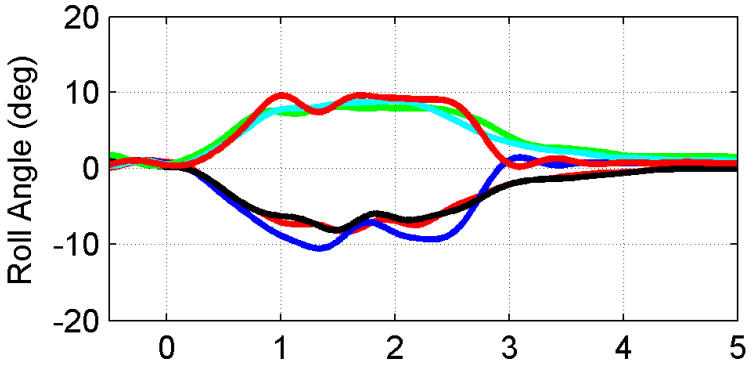

Lateral Acceleration (g)
Time (sec)

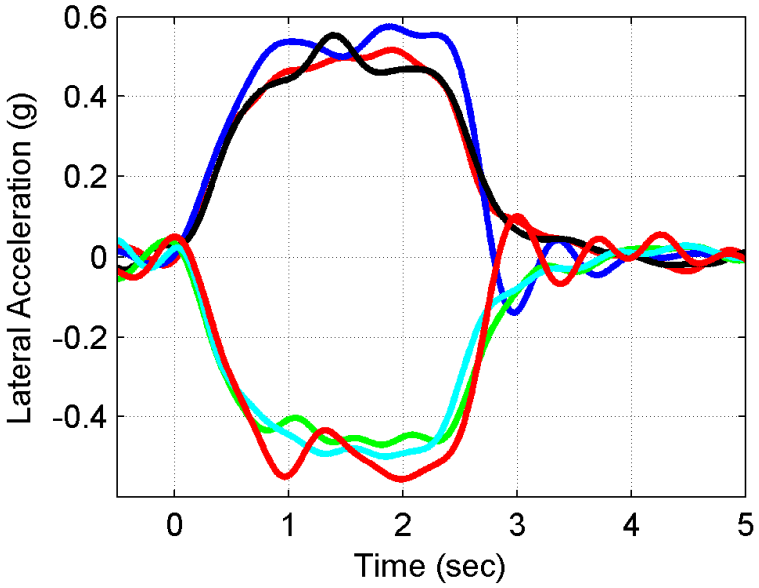

Yaw Rate (deg/sec)
Time (sec)

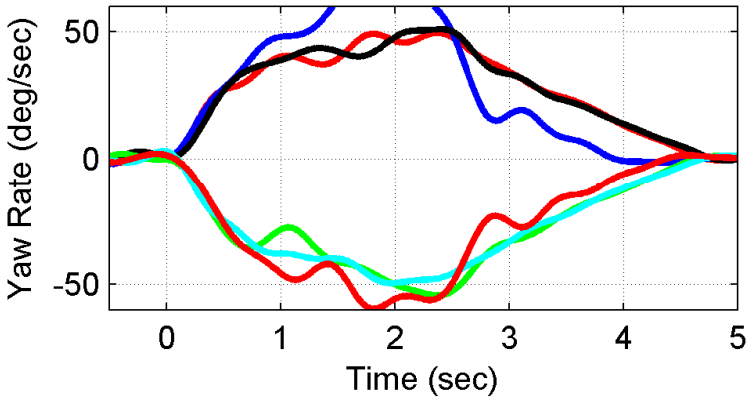

Vehicle D - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
Time (sec)
Maximum Steering Angles Used
22 mph Dropped Throttle Speed
No Two-Wheel Lift Outcomes
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

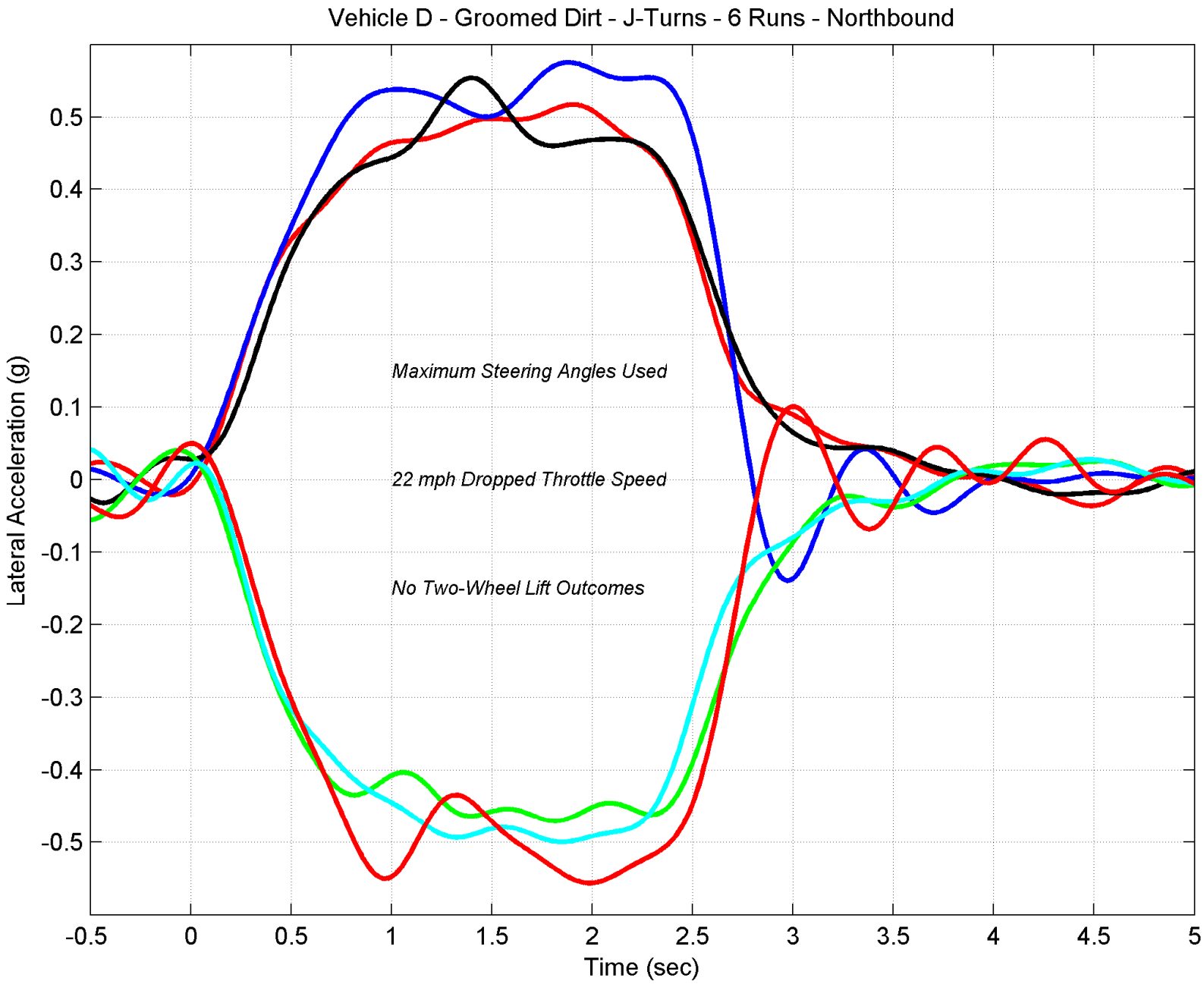

Vehicle D - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
Maximum Steering Angles Used
22 mph Dropped Throttle Speed
No Two-Wheel Lift Outcomes
Time (sec)


6 Runs - Northbound
Speed (mph)


Roll Angle (deg)


Lateral Acceleration (g)
Time (sec)


Yaw Rate (deg/sec)
Time (sec)


Vehicle D - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
Time (sec)
Maximum Steering Angles Used
22 mph Dropped Throttle Speed
No Two-Wheel Lift Outcomes
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle D - Groomed Dirt Results

Peak Lateral Accelerations During Maximum Steer J-Turn Tests at 22 mph

Run Number	South Right Turns	South Left Turns
1	0.507	-0.529
2	0.505	-0.534
3	0.551	-0.541
Mean Value of 3 Runs	0.521	-0.535
Standard Deviation of 3 Runs	0.026	0.006

Average of 6 North Runs

0.528

Run Number	North Right Turns	North Left Turns
1	0.517	-0.470
2	0.575	-0.500
3	0.554	-0.556
Mean Value of 3 Runs	0.549	-0.509
Standard Deviation of 3 Runs	0.029	0.044

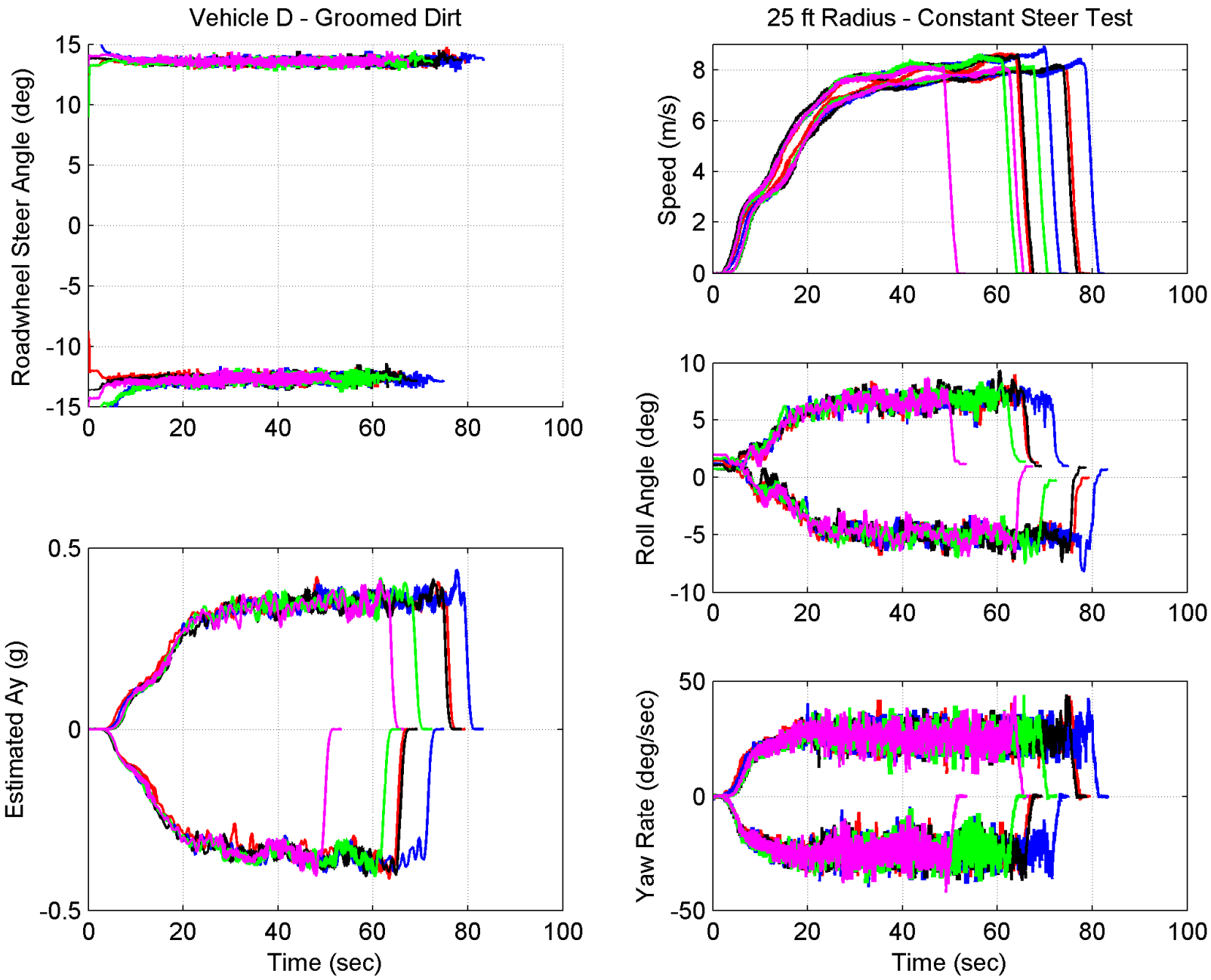
Average of 6 South Runs

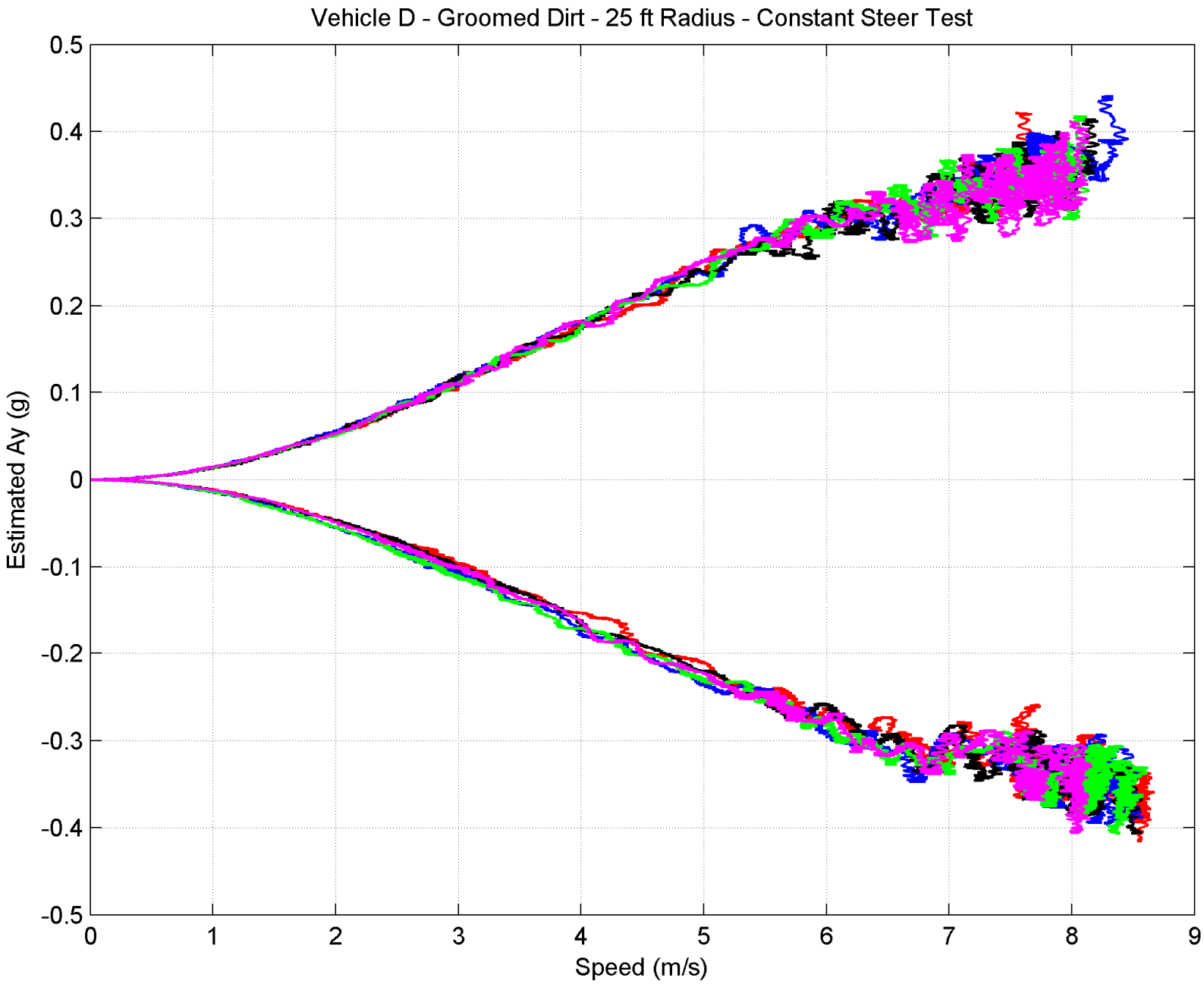
0.529

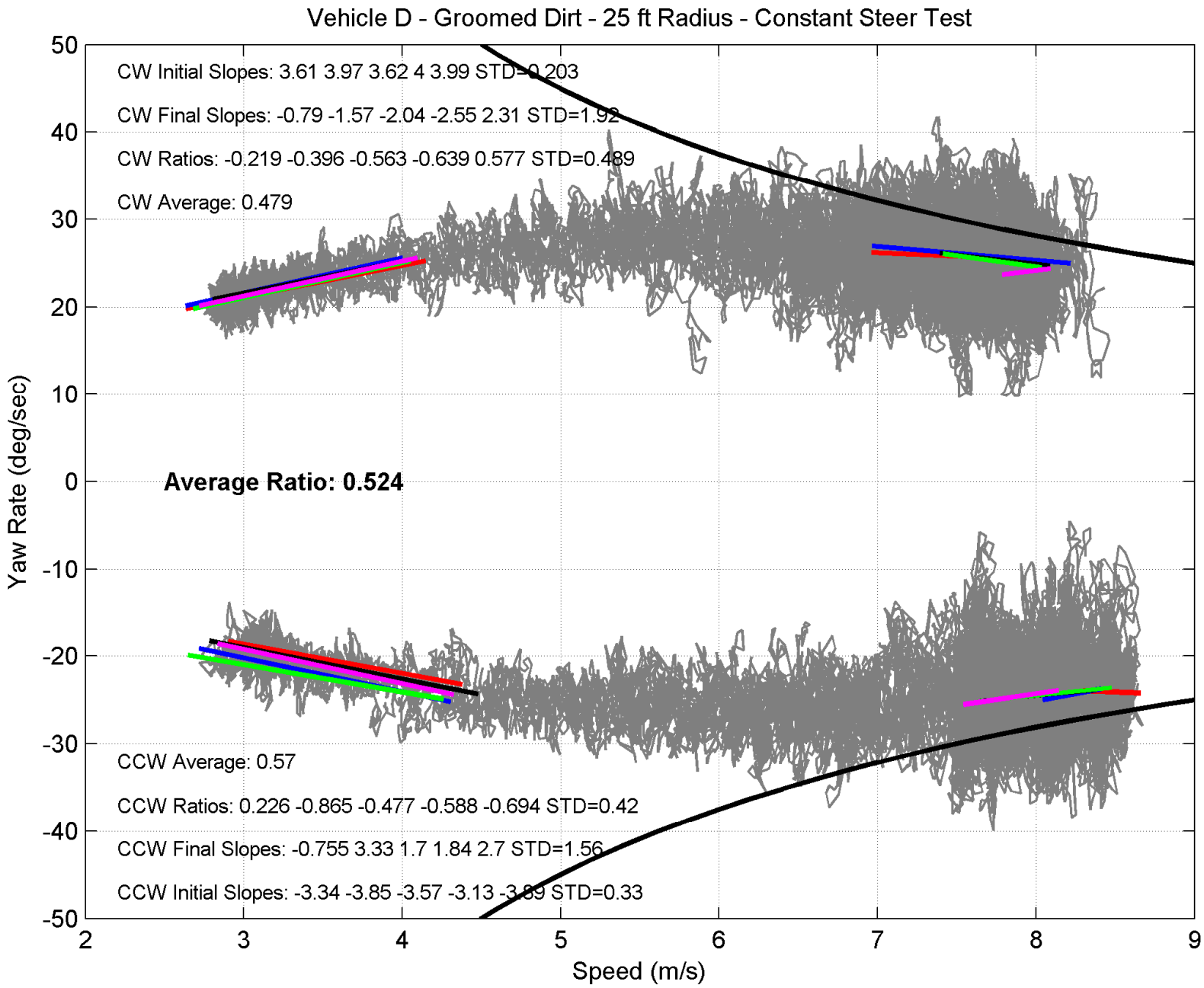
Average of All 12 Runs

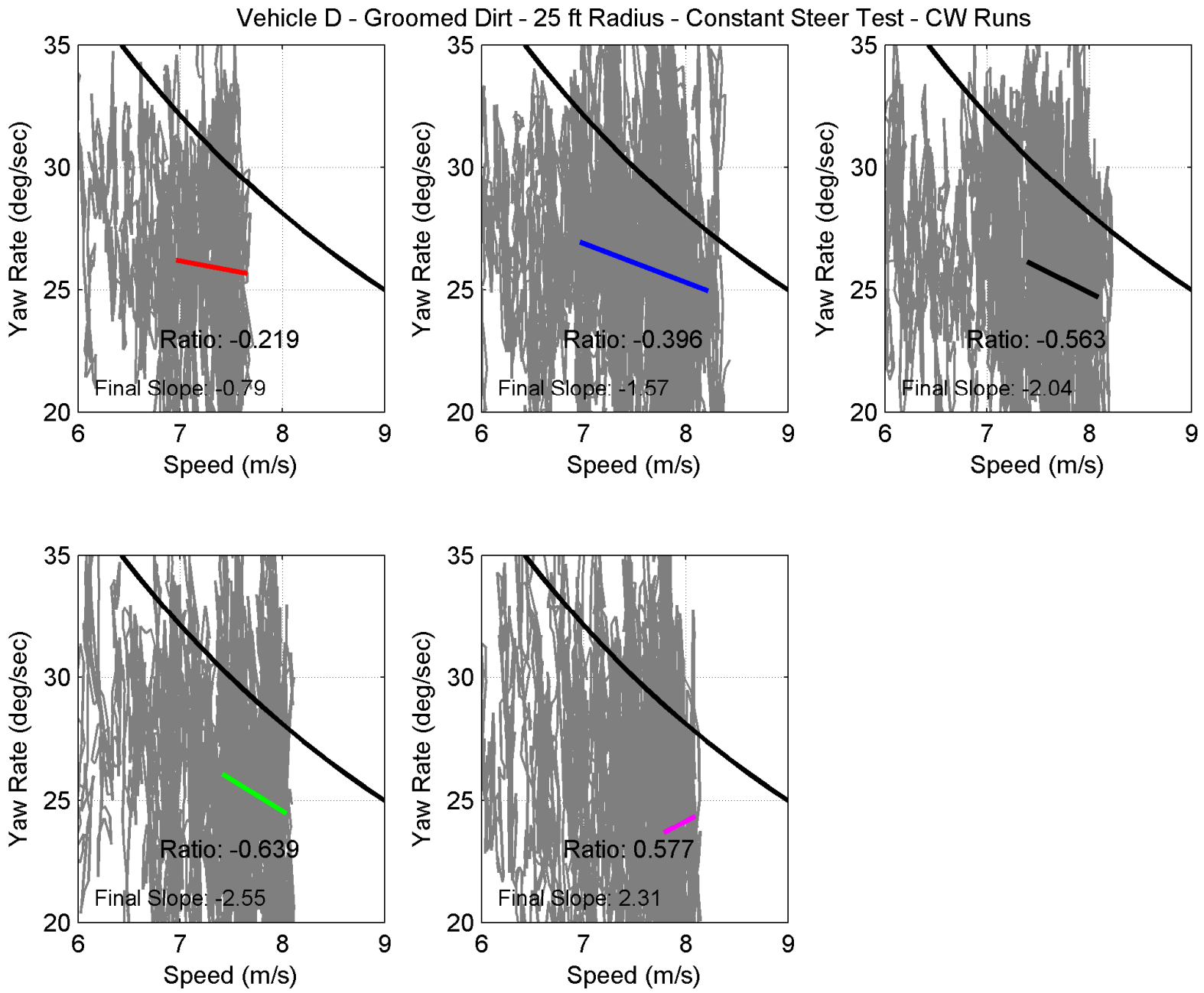
0.528

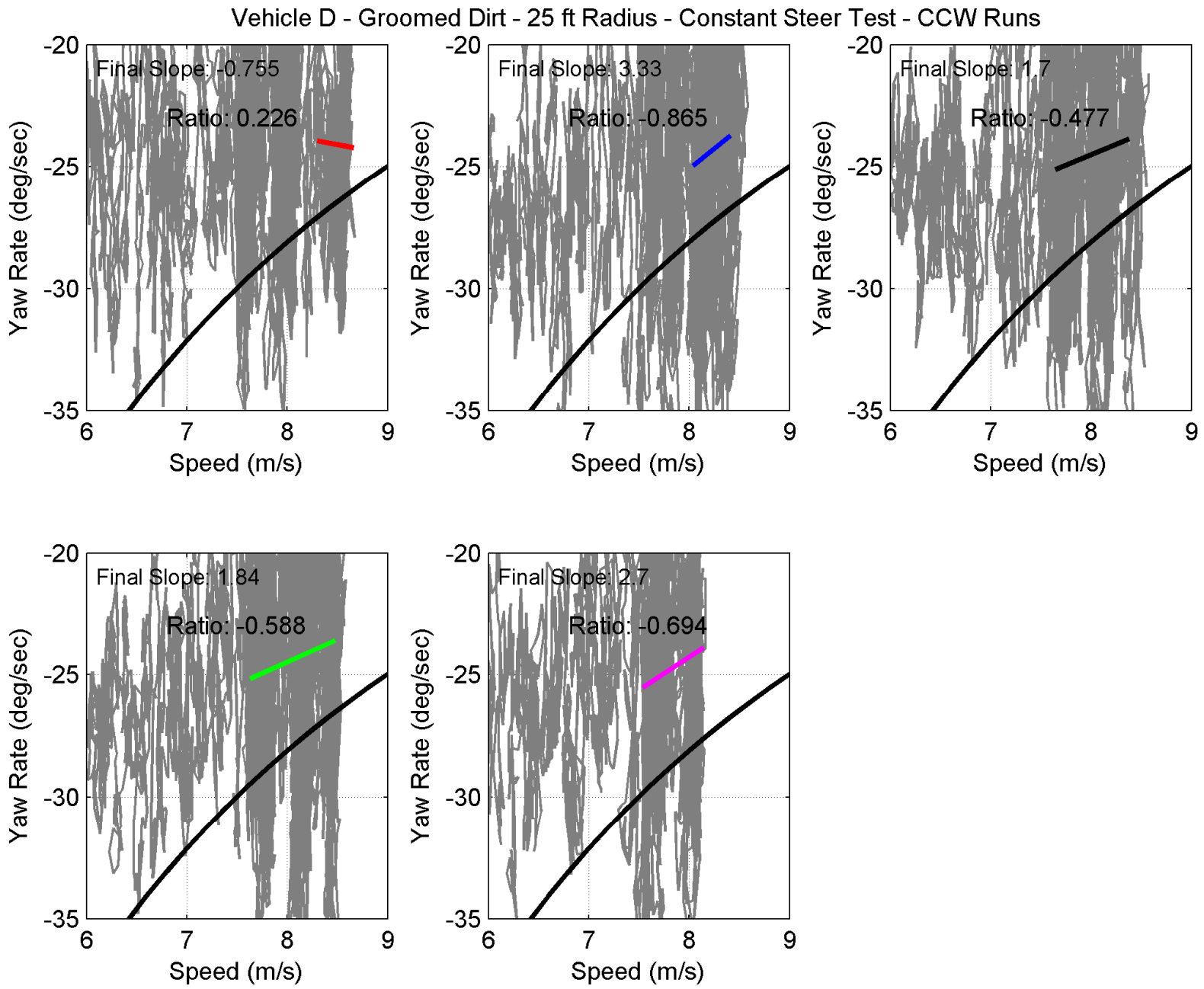
- Peak Ay
- Max Steer
- 22 mph

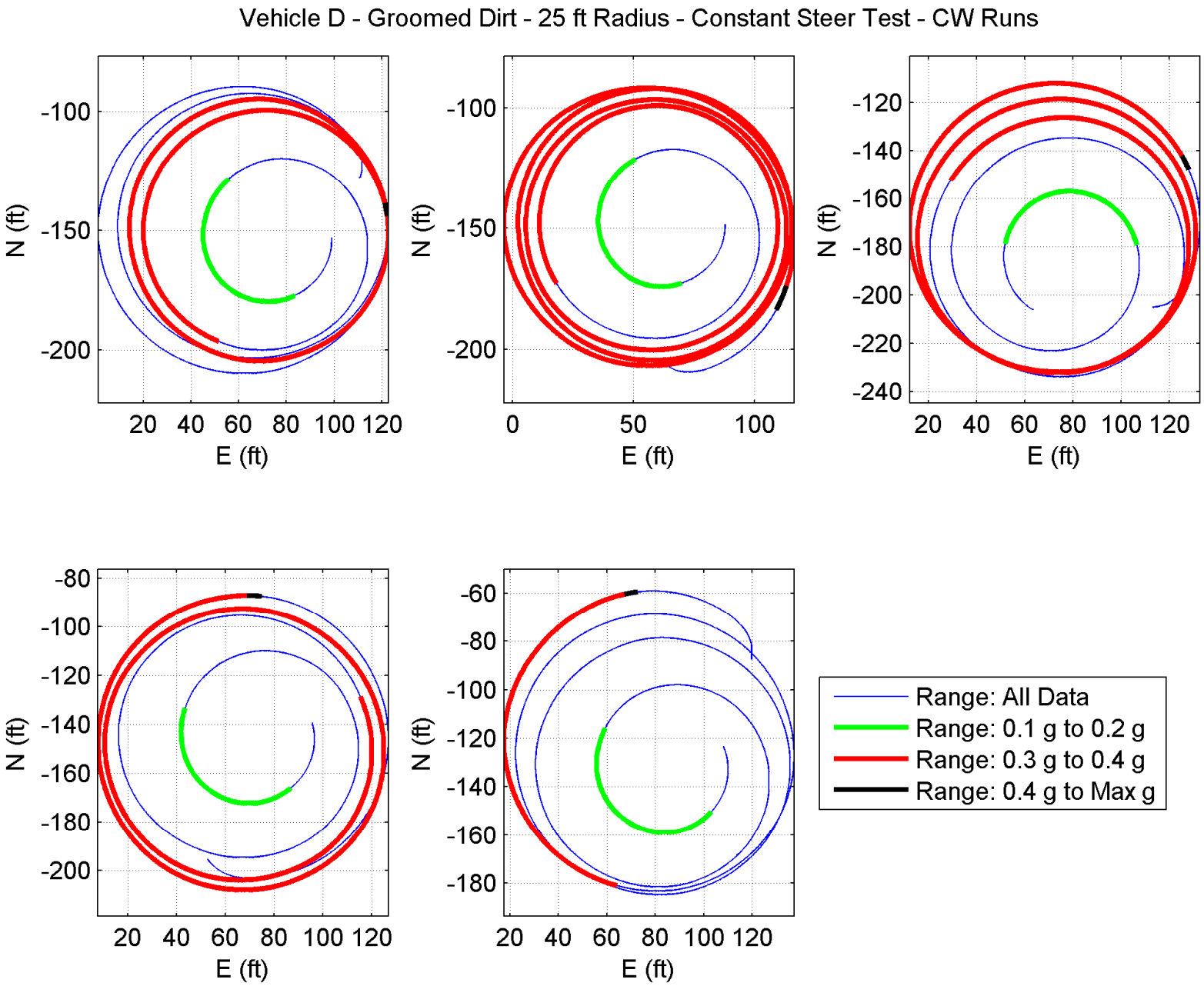

Vehicle D - Groomed Dirt
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

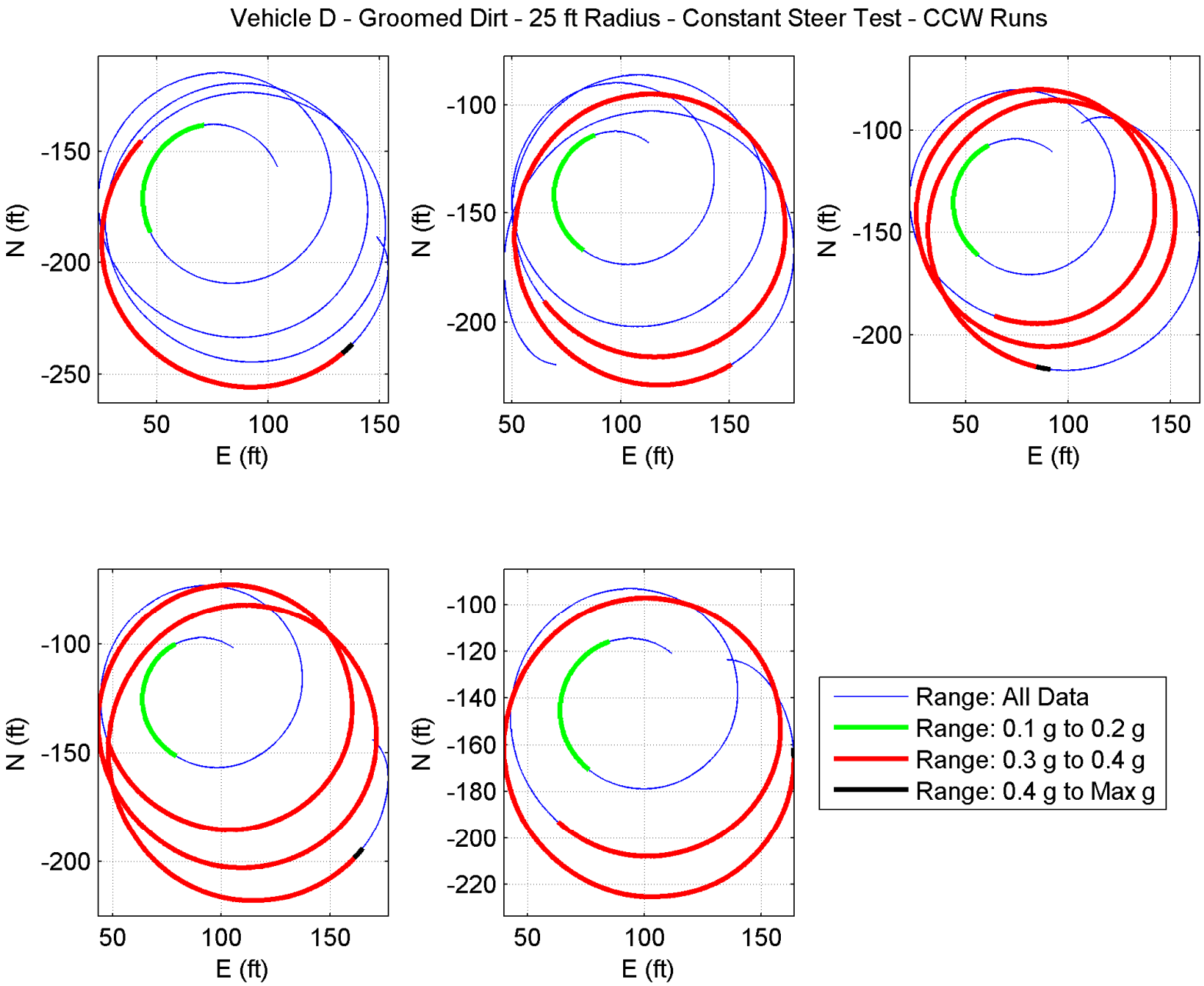

Vehicle D - Groomed Dirt - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

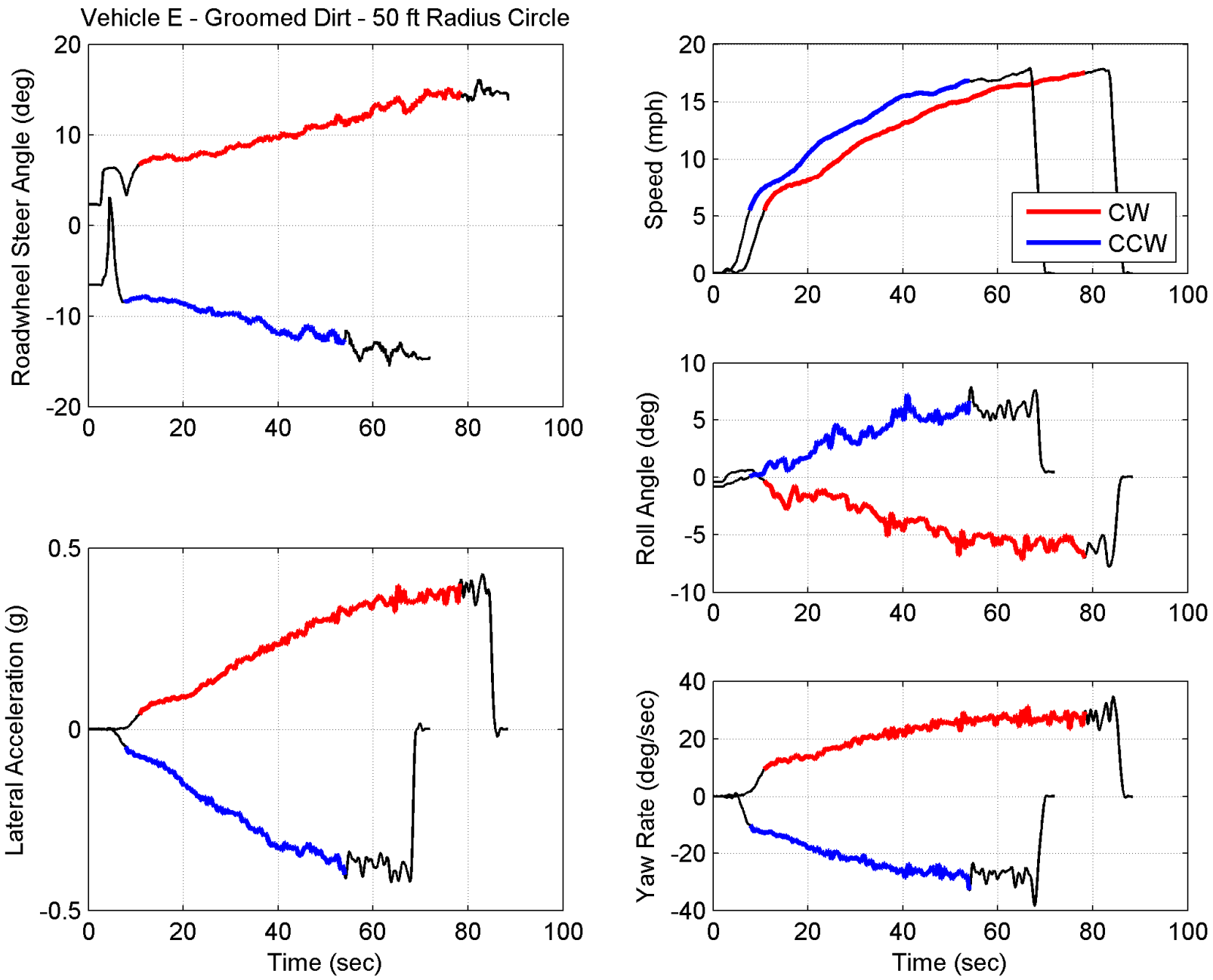

Vehicle D - Groomed Dirt - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 3.61 3.97 3.62 4 3.99 STD=0.203
CW Final Slopes: -0.79 -1.57 -2.04 -2.55 2.31 STD=1.92
CW Ratios: -0.219 -0.396 -0.563 -0.639 0.577 STD=0.489
CW Average: 0.479
Average Ratio: 0.524
CCW Average: 0.57
CCW Ratios: 0.226 -0.865 -0.477 -0.588 -0.694 STD=0.42
CCW Final Slopes: -0.755 3.33 1.7 1.84 2.7 STD=1.56
CCW Initial Slopes: -3.34 -3.85 -3.57 -3.13 -3.89 STD=0.33
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8
9

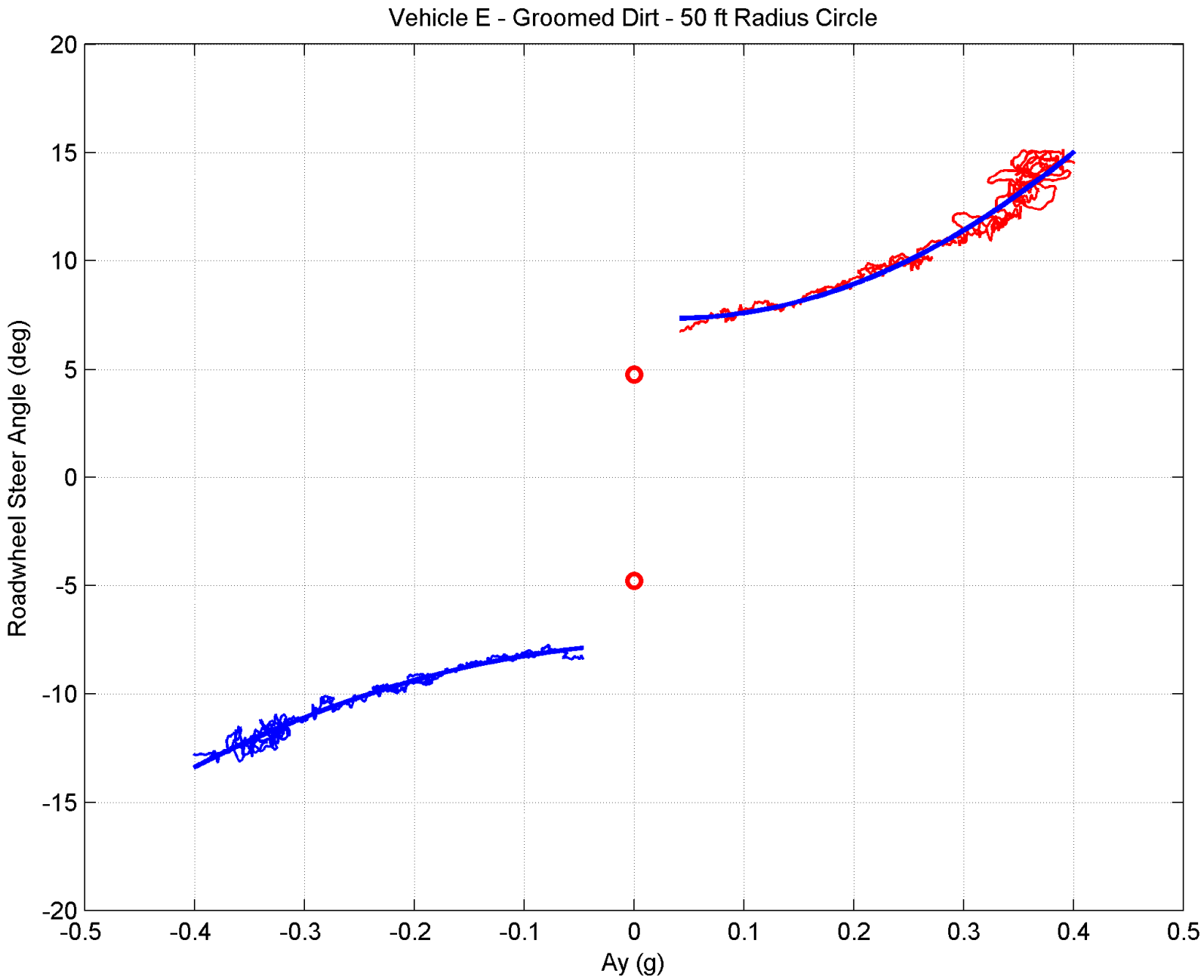

Vehicle D - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: -0.219
Final Slope: -0.79
Ratio: -0.396
Final Slope: -1.57
Ratio: -0.563
Final Slope: -2.04
Ratio: -0.639
Final Slope: -2.55
Ratio: 0.577
Final Slope: 2.31

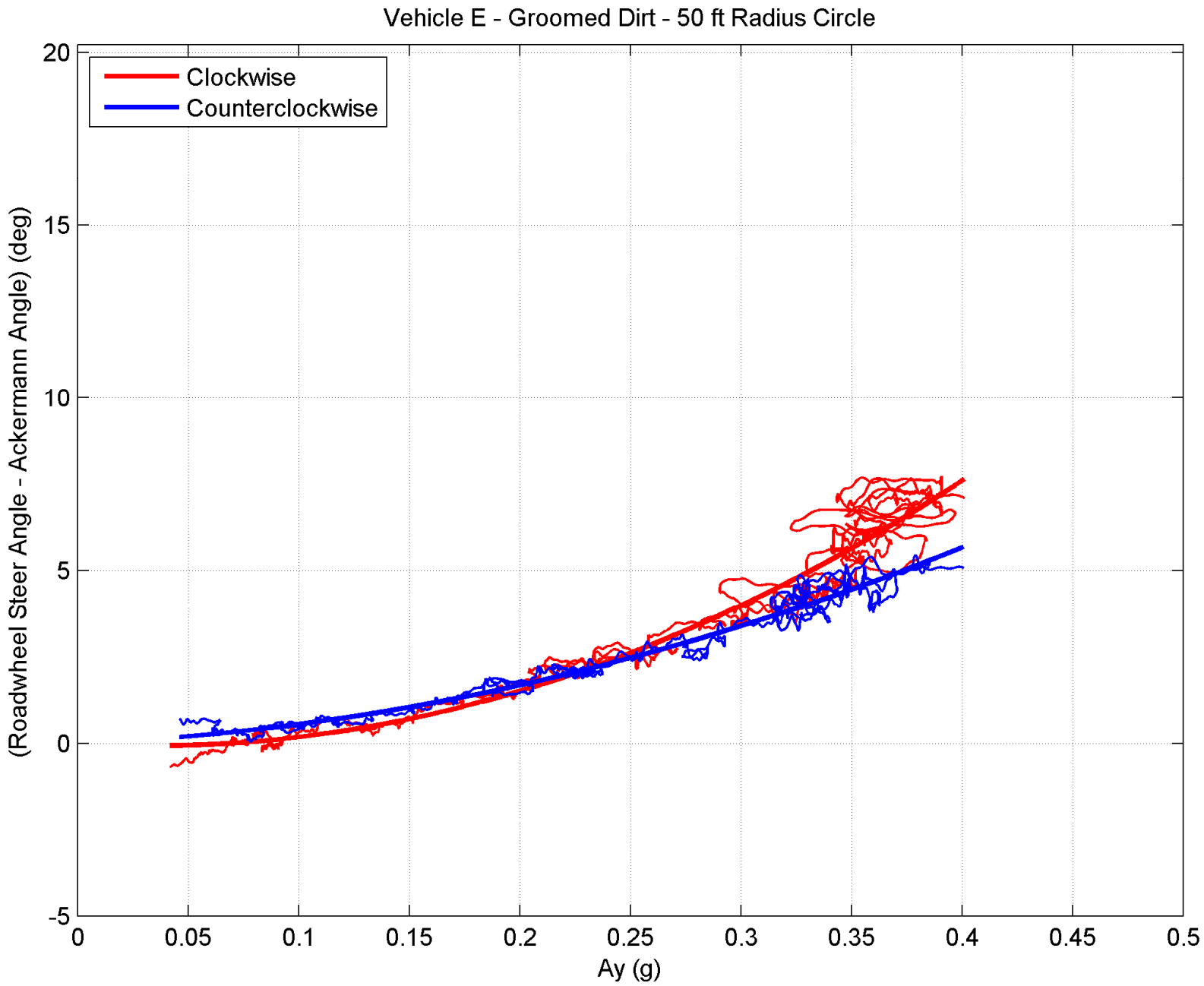

Vehicle D - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -0.755
Ratio: 0.226
Final Slope: 3.33
Ratio: -0.865
Final Slope: 1.7
Ratio: -0.477
Final Slope: 1.84
Ratio: -0.588
Final Slope: 2.7
Ratio: -0.694
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

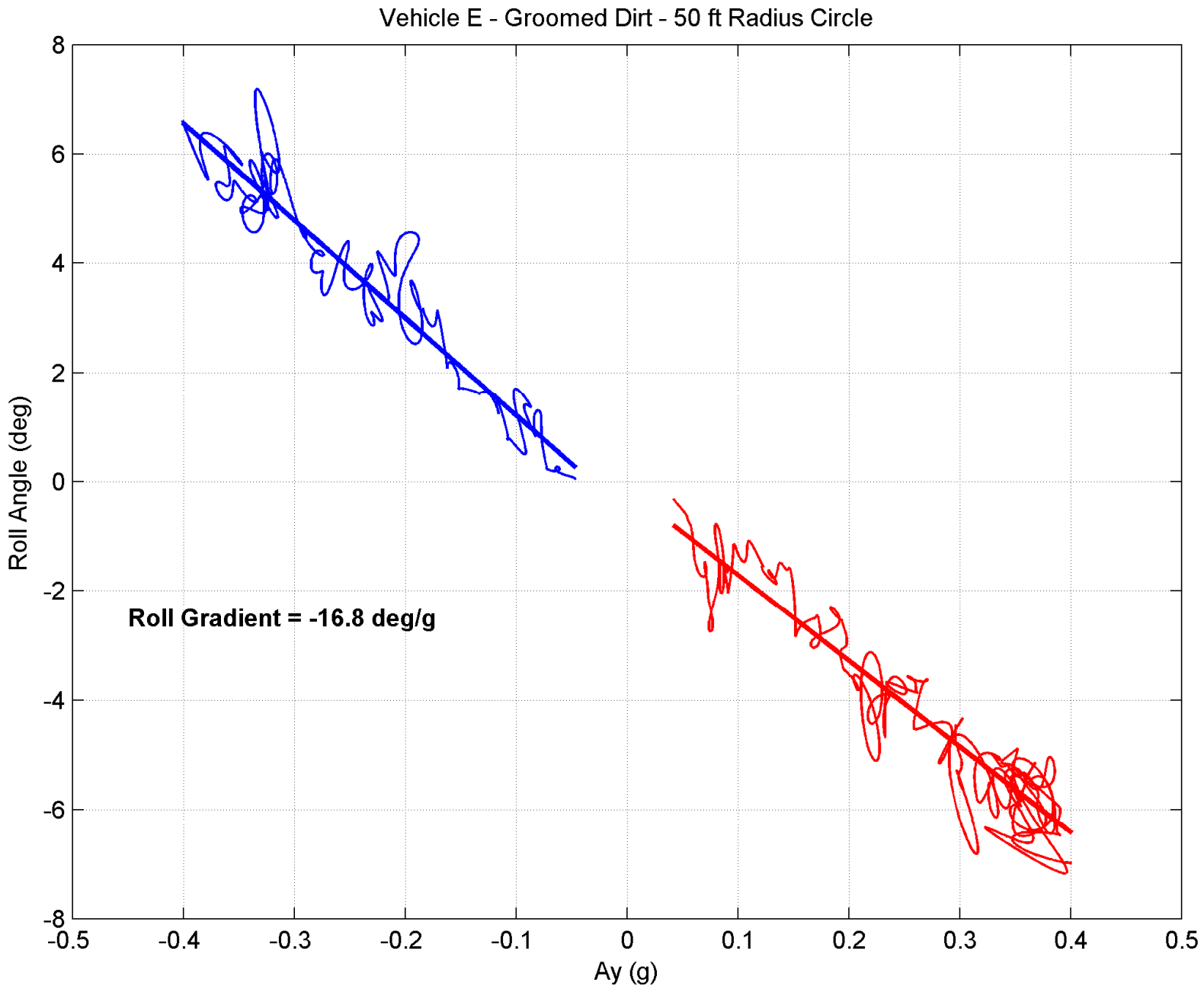

Vehicle D - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
-100
-150
-200
20 40 60 80 100 120
0 50 100
-120
-140
-160
-180
-220
-240
-80
-60
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

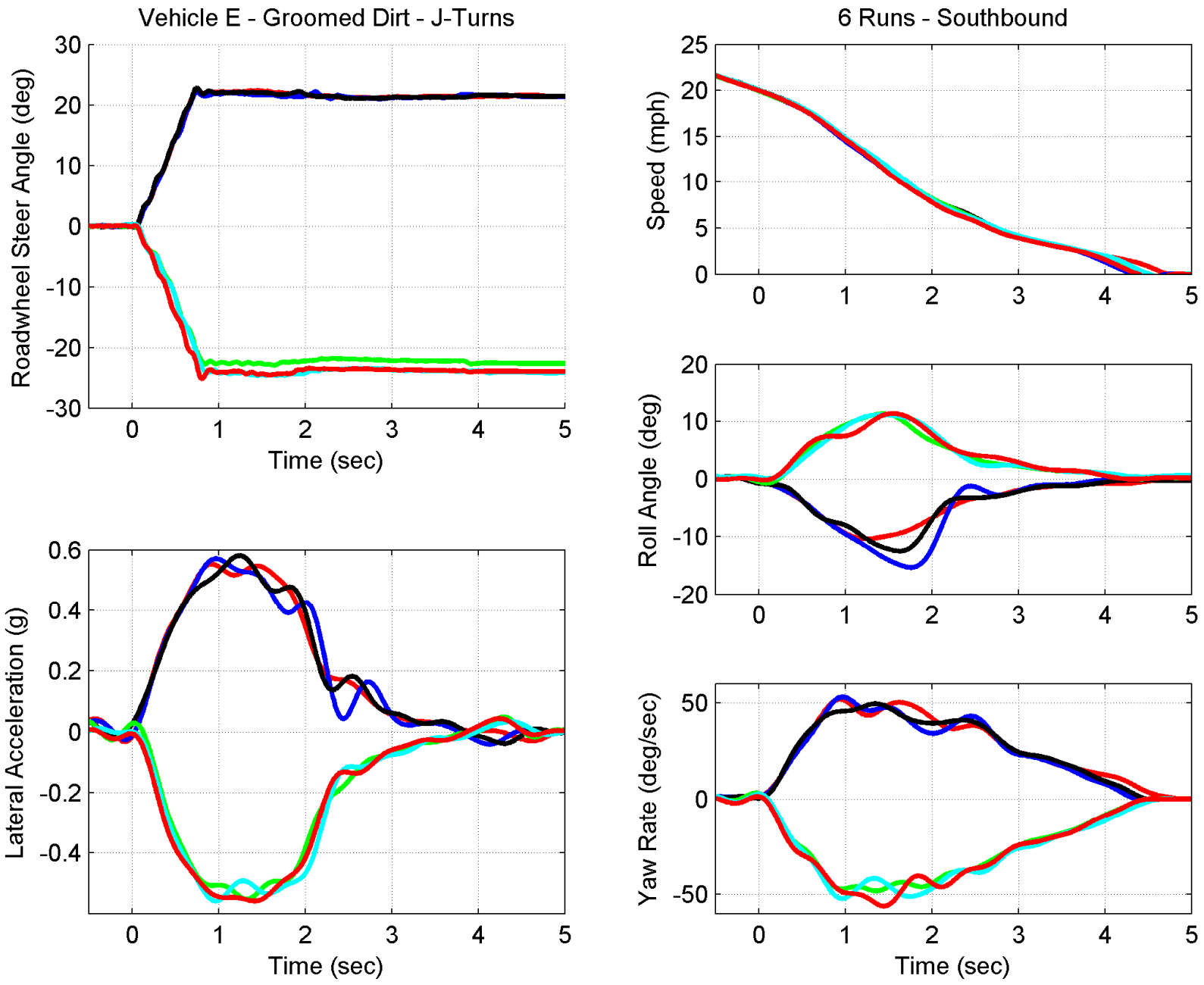

Vehicle D - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
-150
-200
-250
-100
-120
-140
-160
-180
-220
50
100
150
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

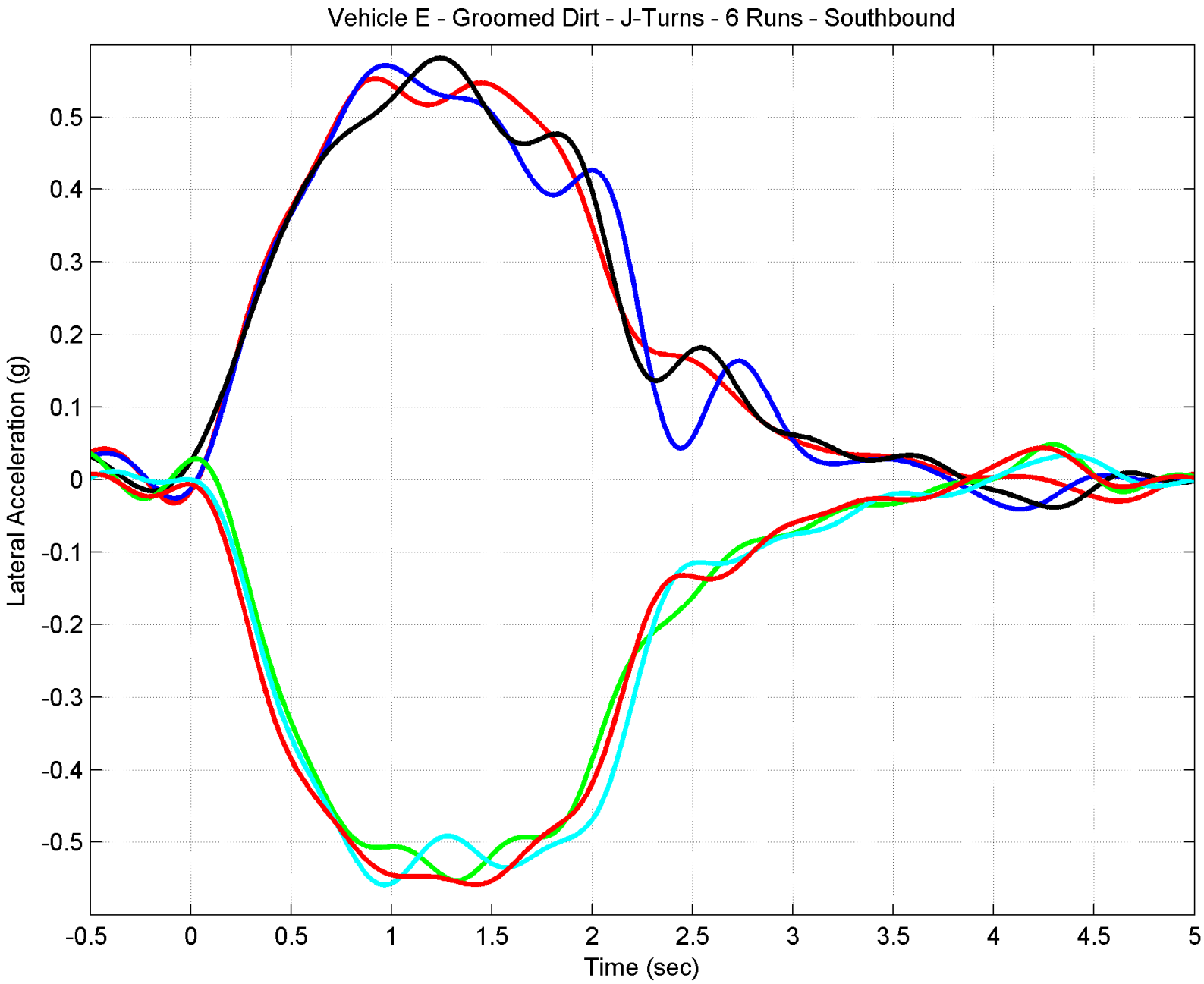

Vehicle E - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

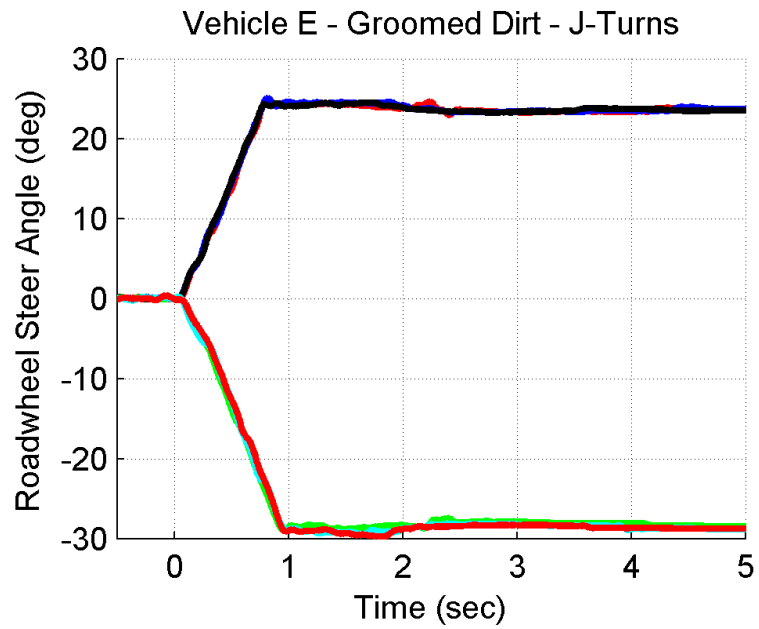

Vehicle E - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
20
15
10
5
0
-5
-10
-15
-20
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

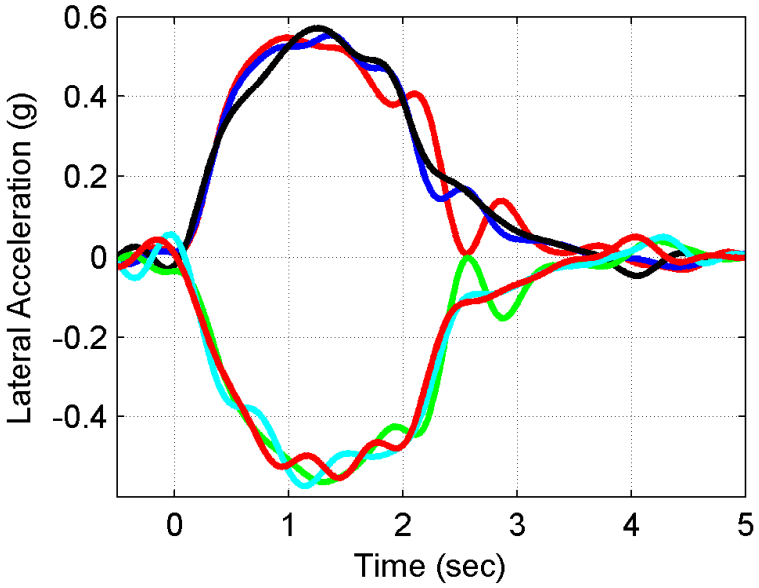

Vehicle E - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
20
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

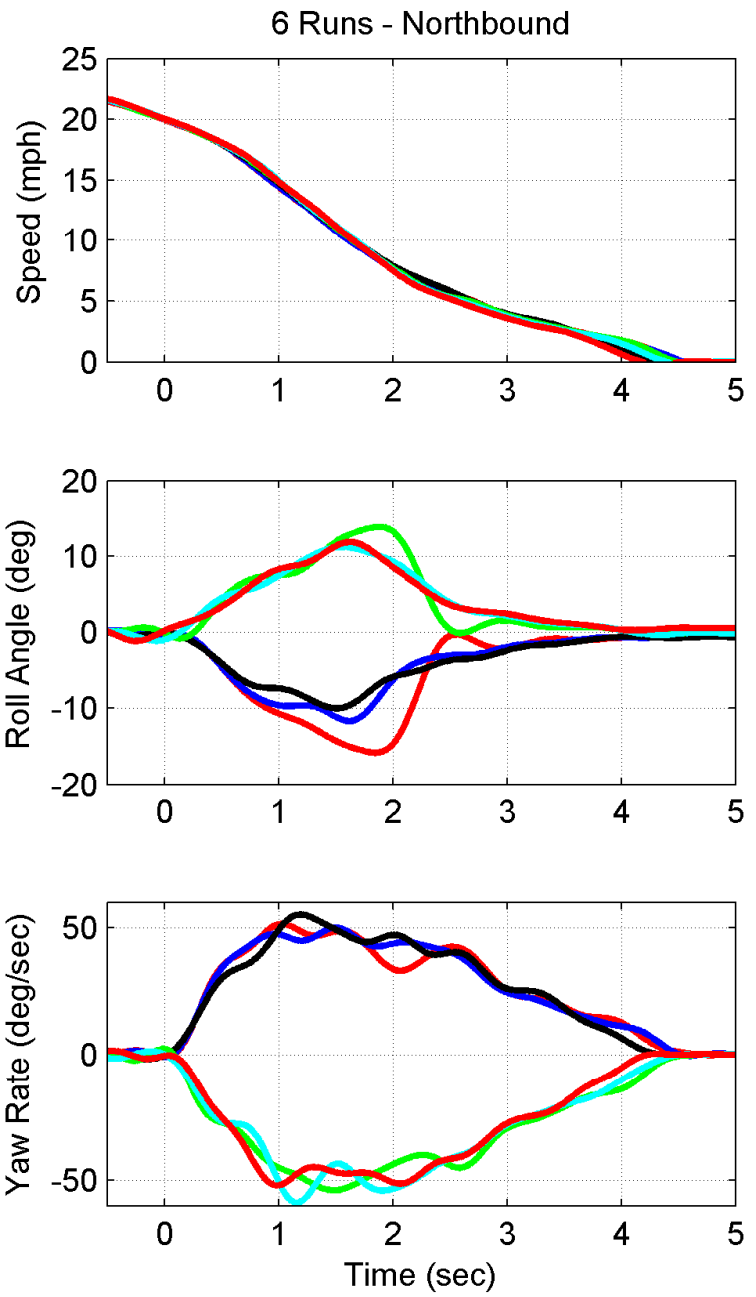

Vehicle E - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -16.8 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

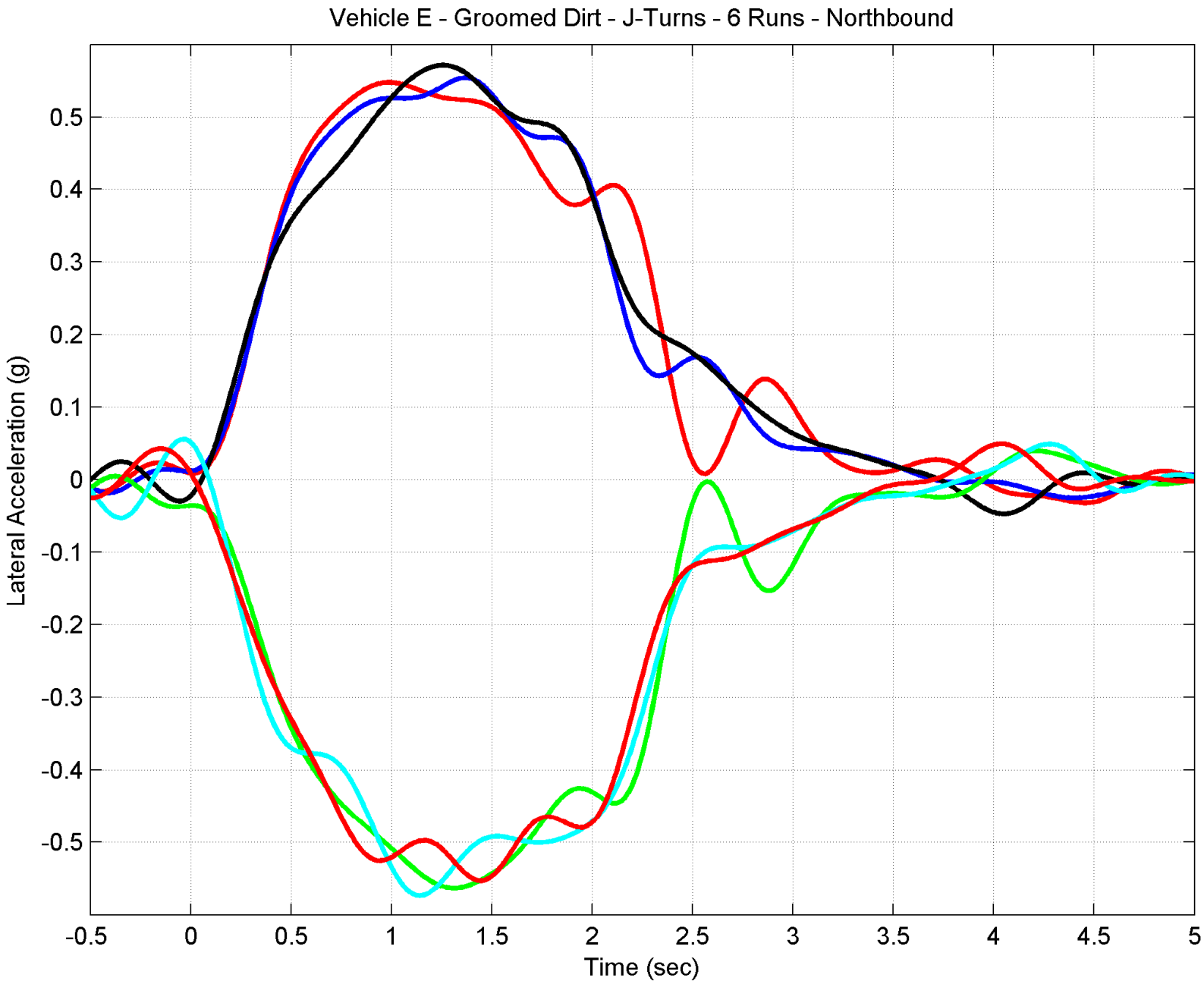

Vehicle E - Groomed Dirt - J-Turns
6 Runs - Southbound
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle E - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle E - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
30
20
10
0
-10
-20
-30
0
1
2
3
4
5
Time (sec)


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5
Roll Angle (deg)
20
10
0
-10
-20
Yaw Rate (deg/sec)
50
0
-50
Time (sec)


Vehicle E - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle E - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.553	-0.553
2	0.571	-0.559
3	0.581	-0.559
Mean Value of 3 Runs	0.568	-0.557
Standard Deviation of 3 Runs	0.014	0.004

Average of 6 North Runs

0.563

Run Number	North Right Turns	North Left Turns
1	0.548	-0.563
2	0.554	-0.574
3	0.571	-0.553
Mean Value of 3 Runs	0.558	-0.563
Standard Deviation of 3 Runs	0.012	0.010

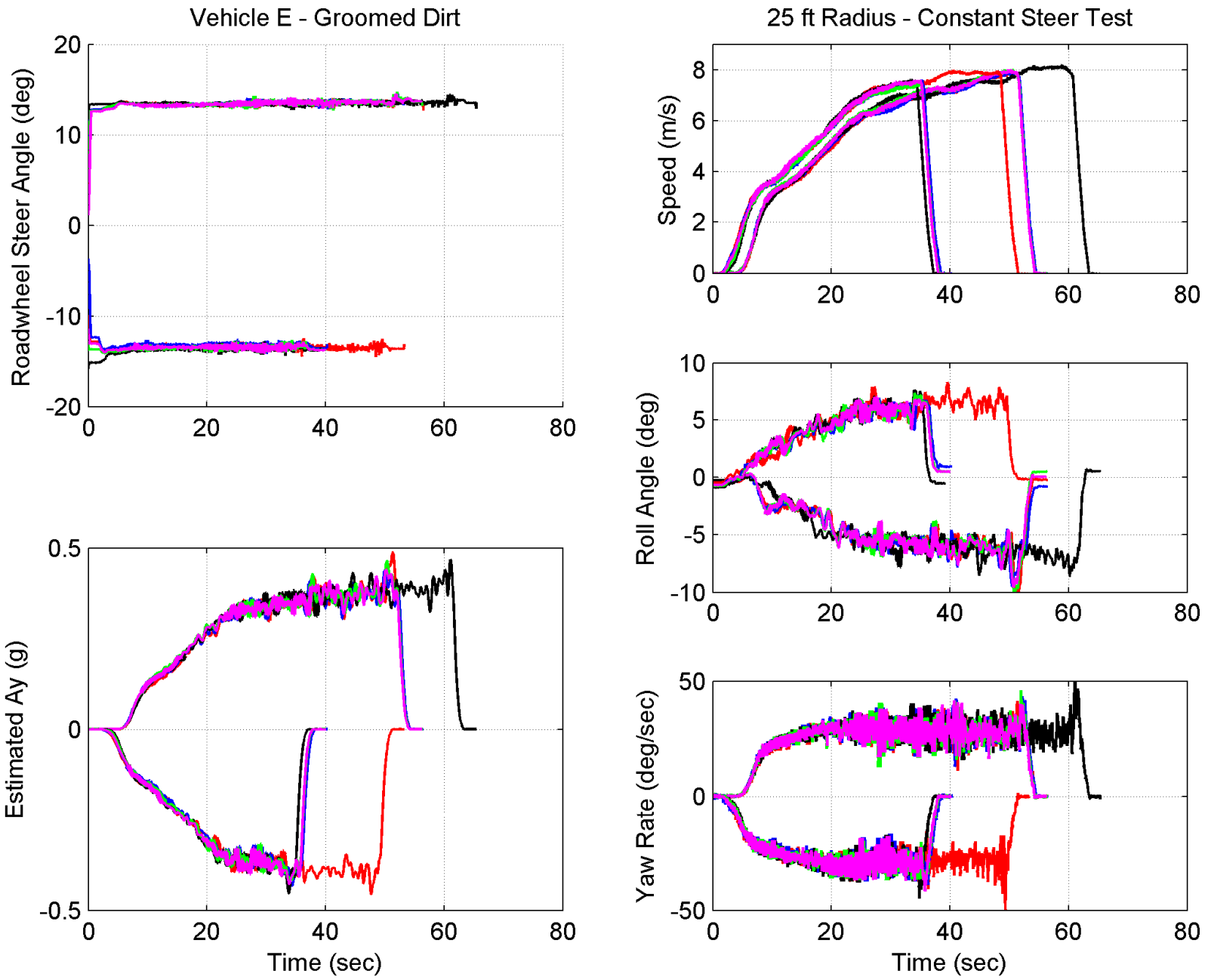
Average of 6 South Runs

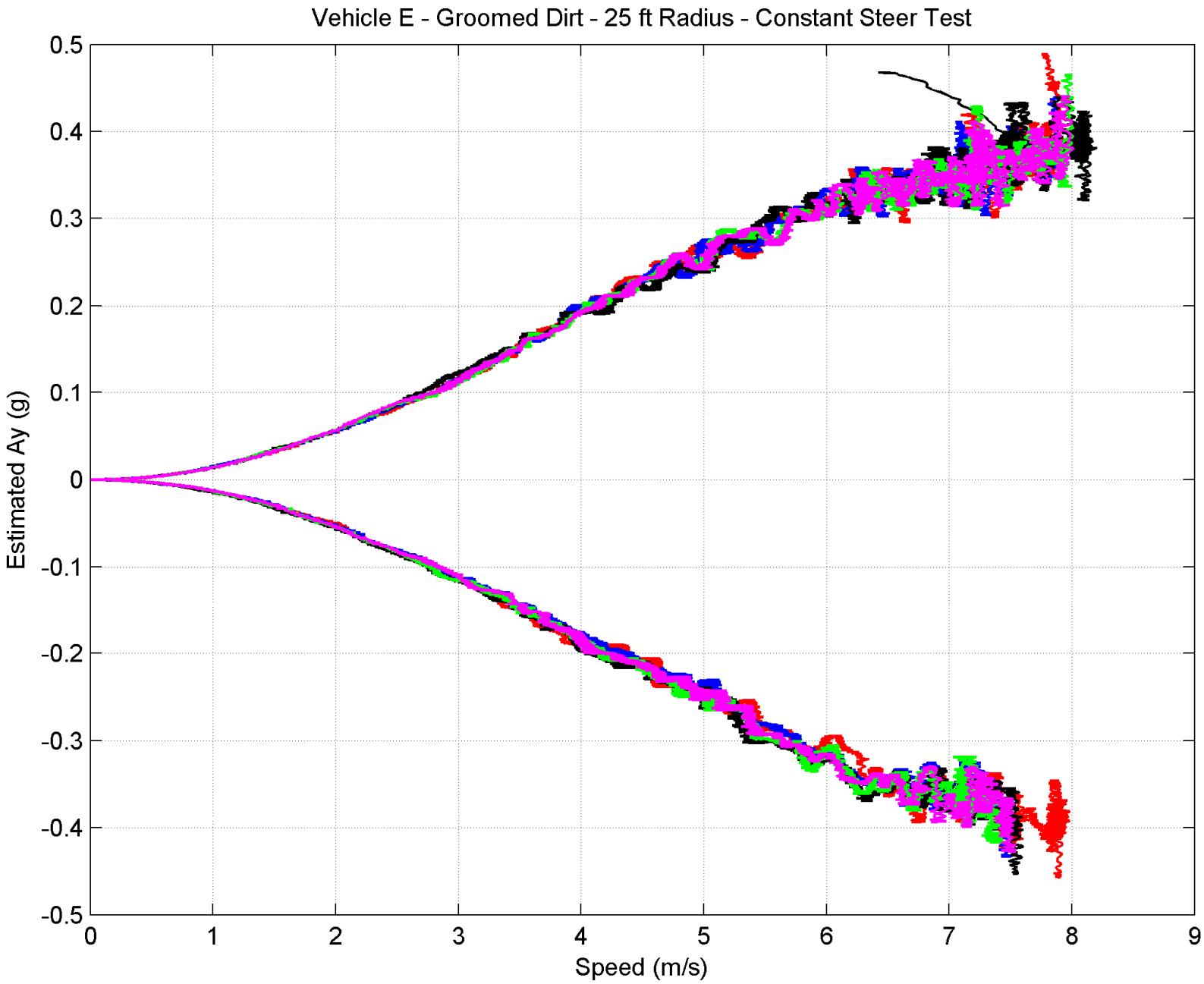
0.561

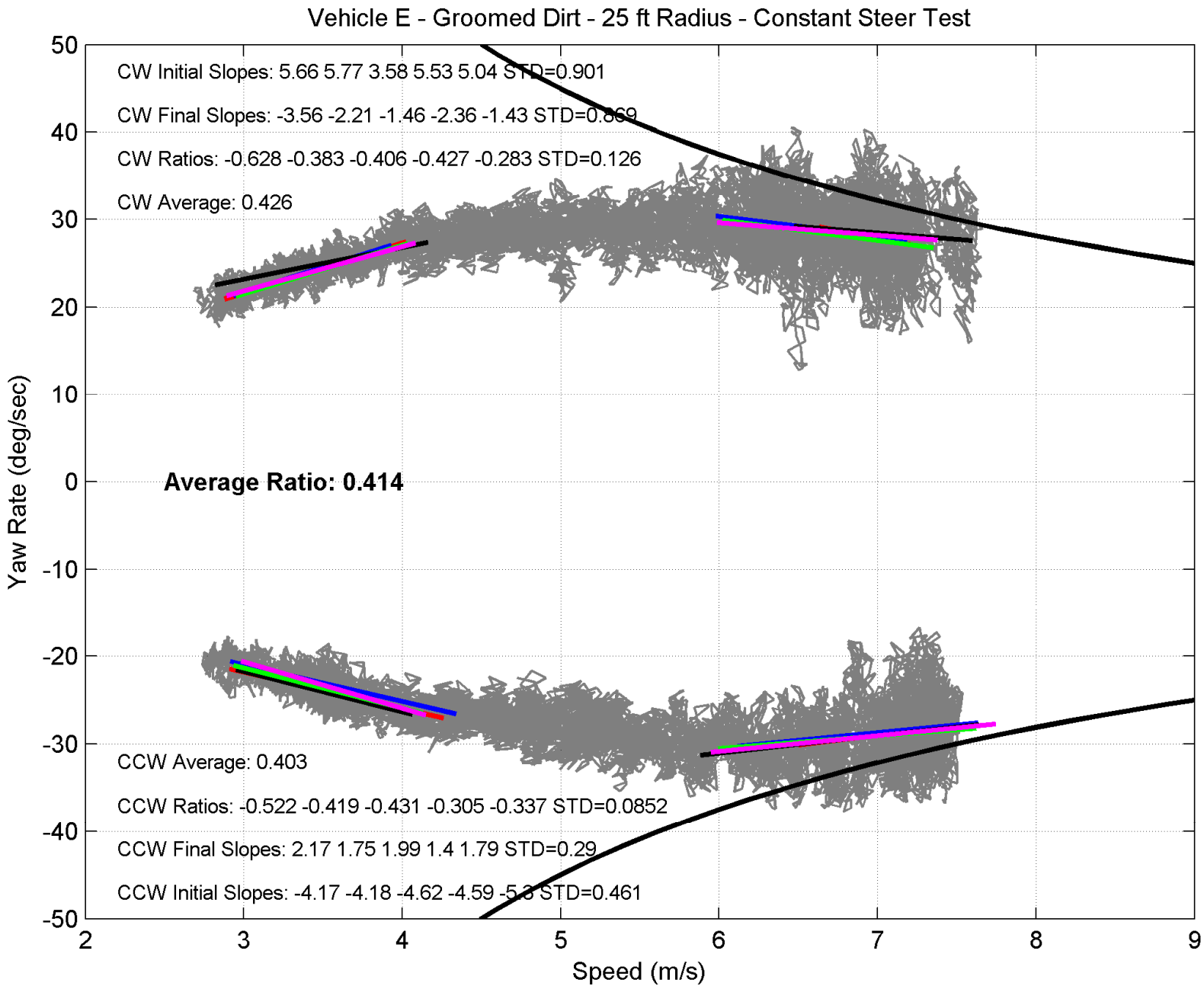
Average of All 12 Runs

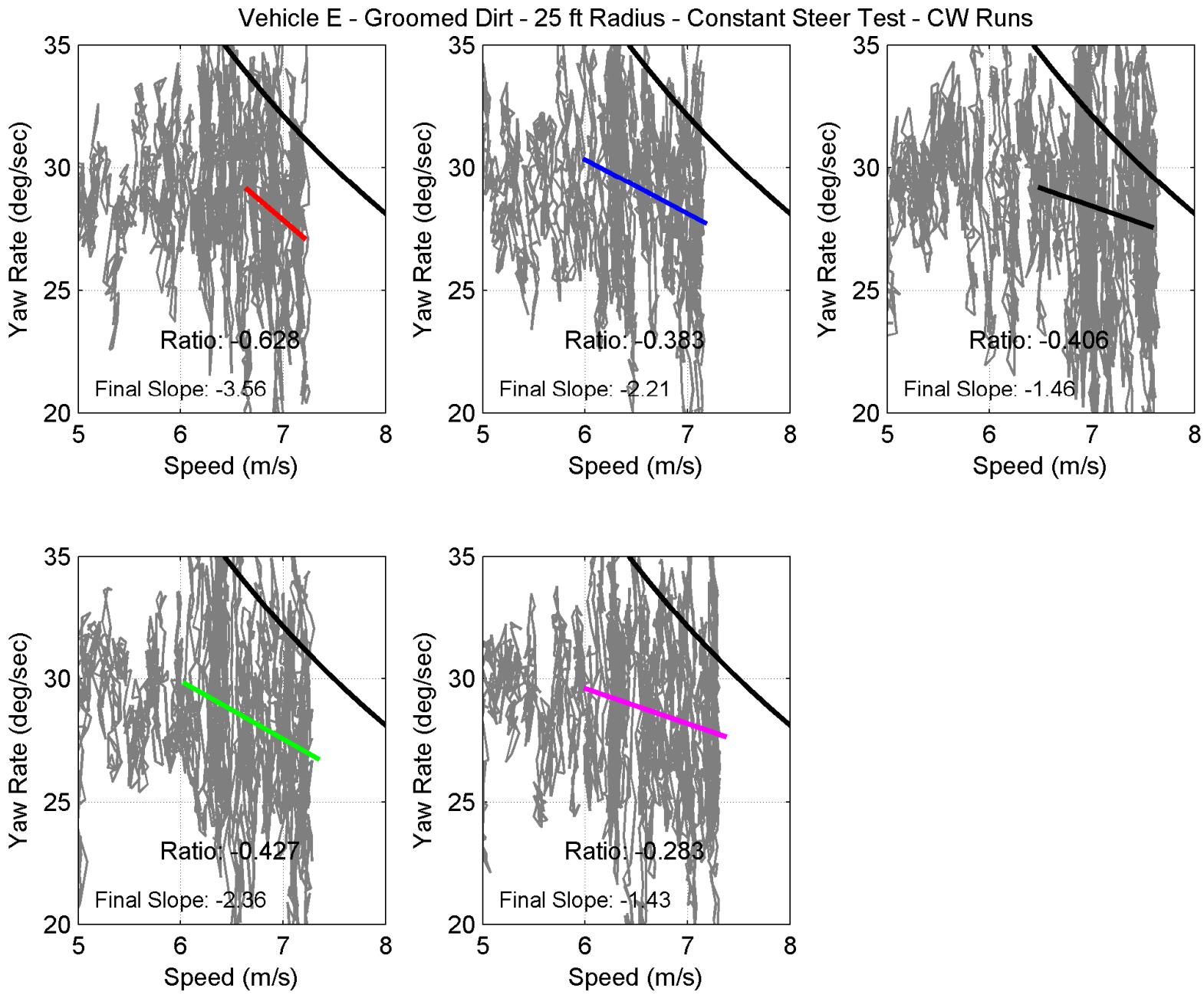
0.562

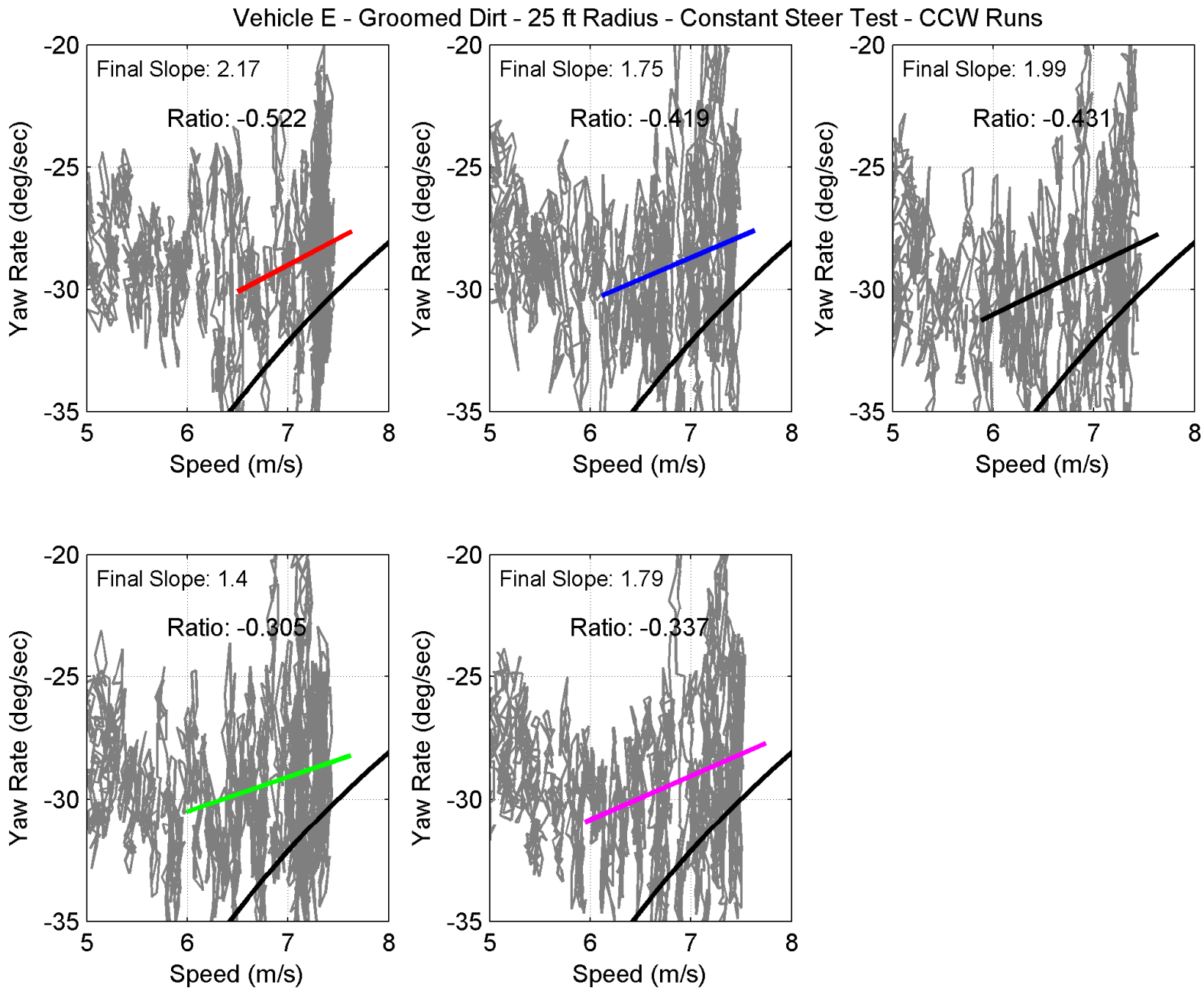
Threshold Ay

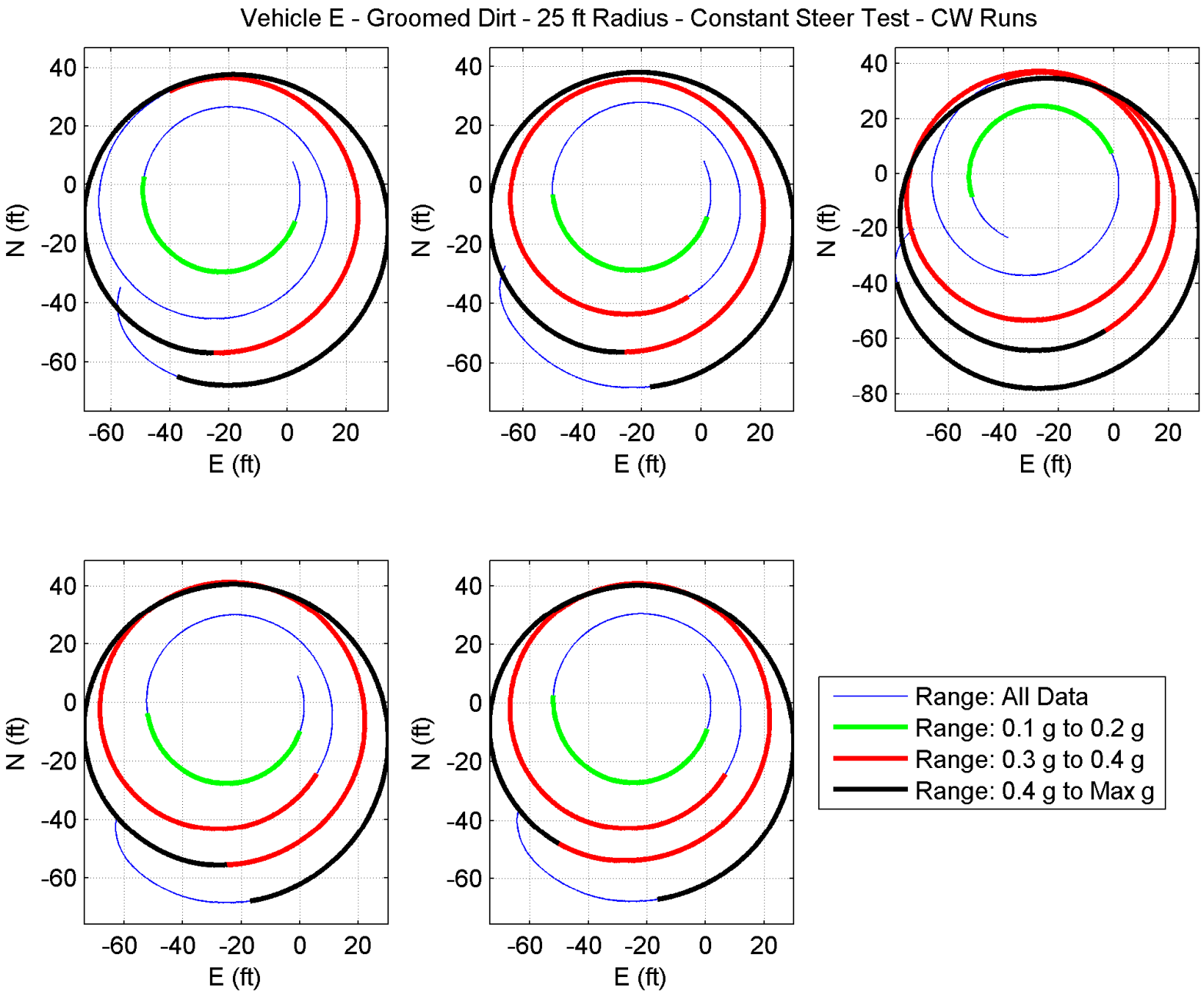

Vehicle E - Groomed Dirt
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
20
40
60
80
Estimated Ay (g)
0.5
0
-0.5
Time (sec)
25 ft Radius - Constant Steer Test
Speed (m/s)
8
6
4
2
0
Roll Angle (deg)
10
5
0
-5
-10
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

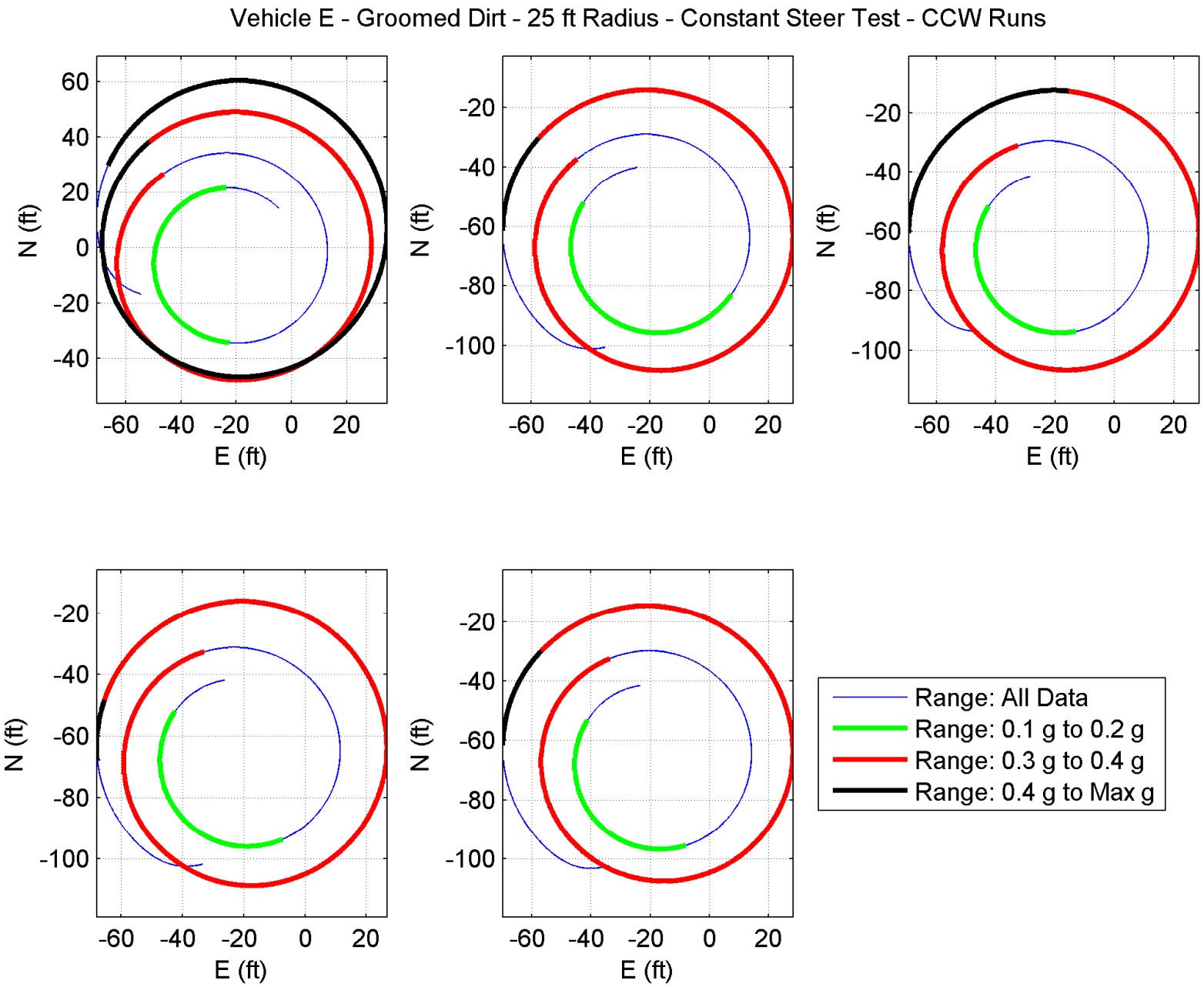

Vehicle E - Groomed Dirt - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

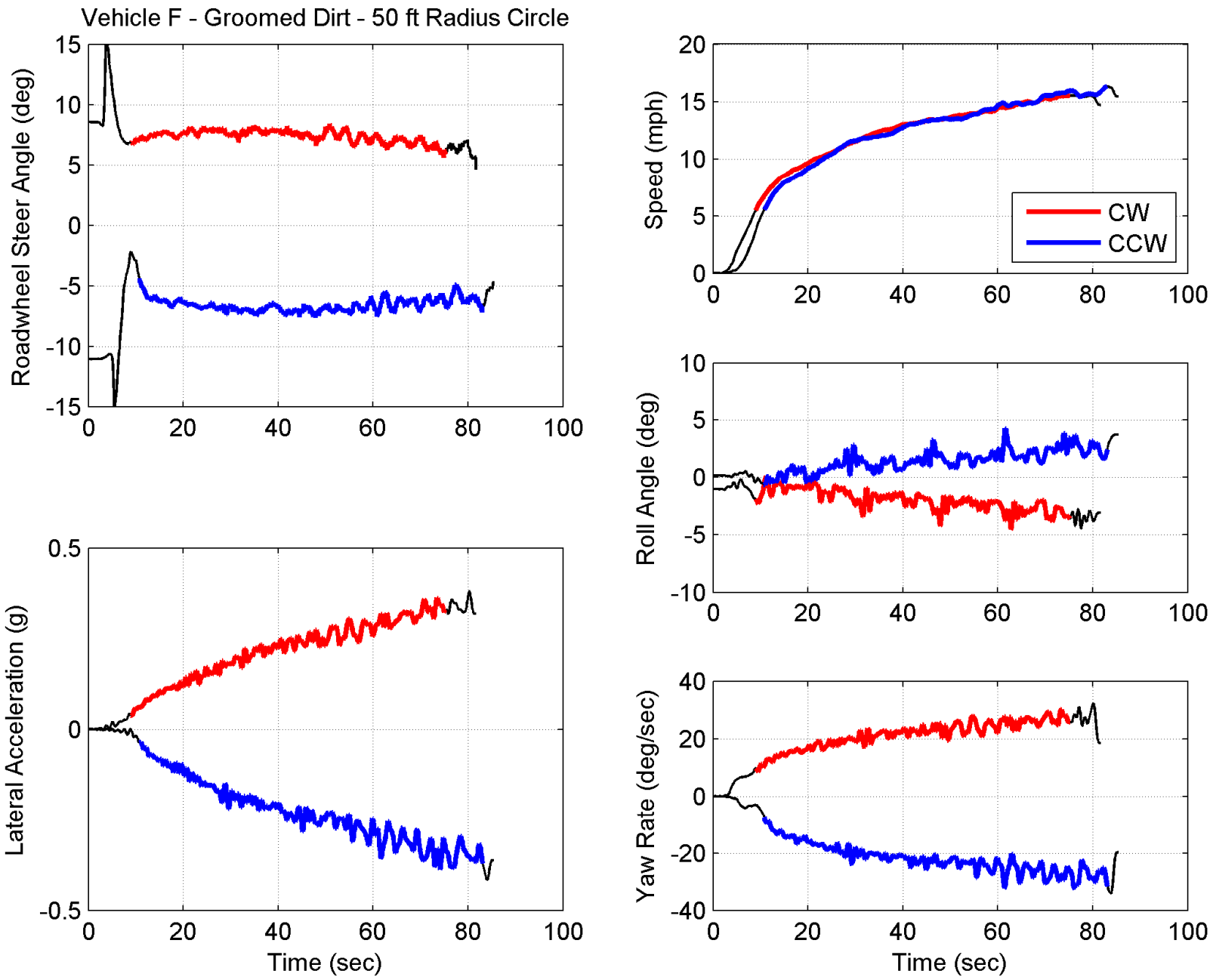

Vehicle E - Groomed Dirt - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 5.66 5.77 3.58 5.53 5.04 STD=0.901
CW Final Slopes: -3.56 -2.21 -1.46 -2.36 -1.43 STD=0.869
CW Ratios: -0.628 -0.383 -0.406 -0.427 -0.283 STD=0.126
CW Average: 0.426
Average Ratio: 0.414
CCW Average: 0.403
CCW Ratios: -0.522 -0.419 -0.431 -0.305 -0.337 STD=0.0852
CCW Final Slopes: 2.17 1.75 1.99 1.4 1.79 STD=0.29
CCW Initial Slopes: -4.17 -4.18 -4.62 -4.59 -5.3 STD=0.461
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8
9

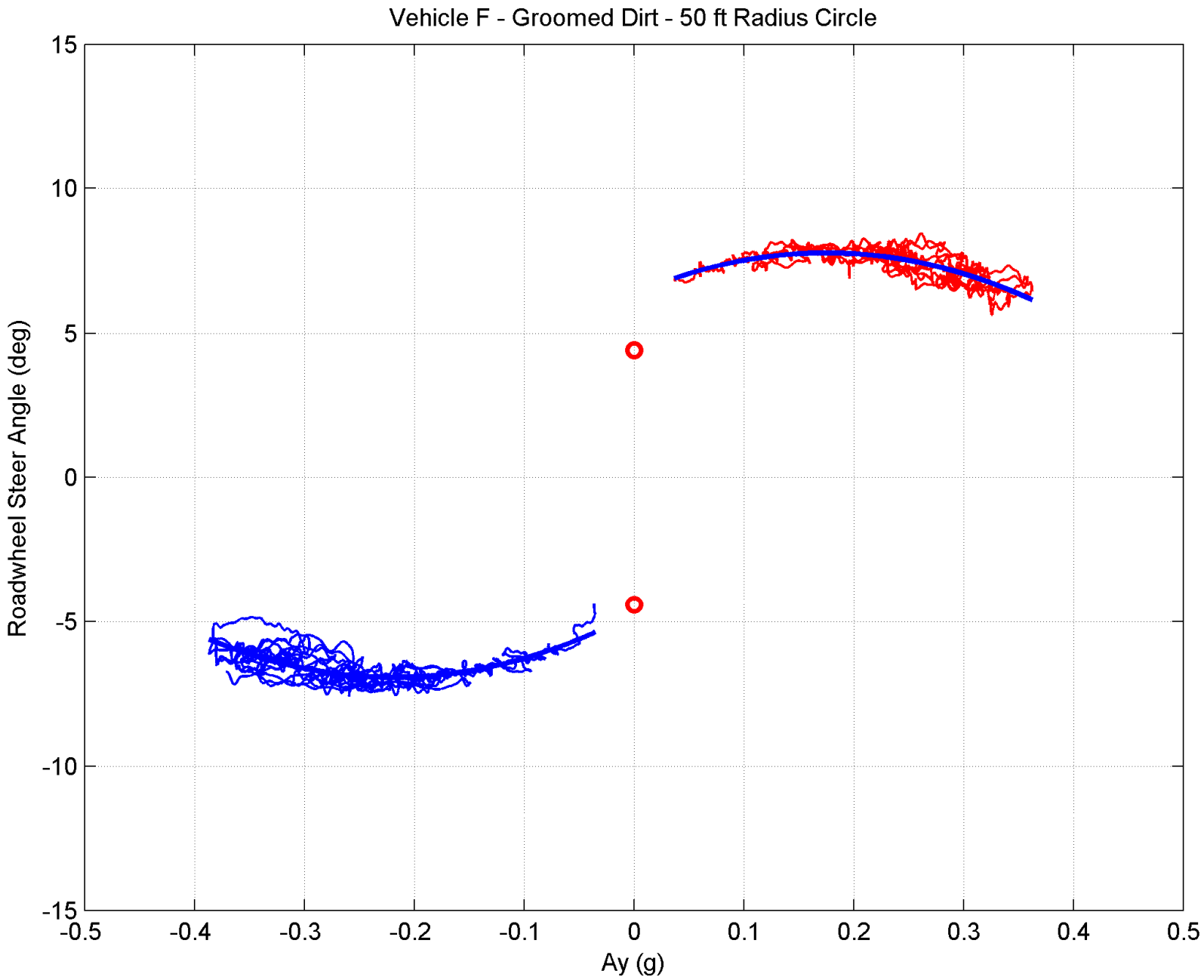

Vehicle E - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: -0.628
Final Slope: -3.56
Ratio: -0.383
Final Slope: -2.21
Ratio: -0.406
Final Slope: -1.46
Ratio: -0.427
Final Slope: -2.36
Ratio: -0.283
Final Slope: -1.43

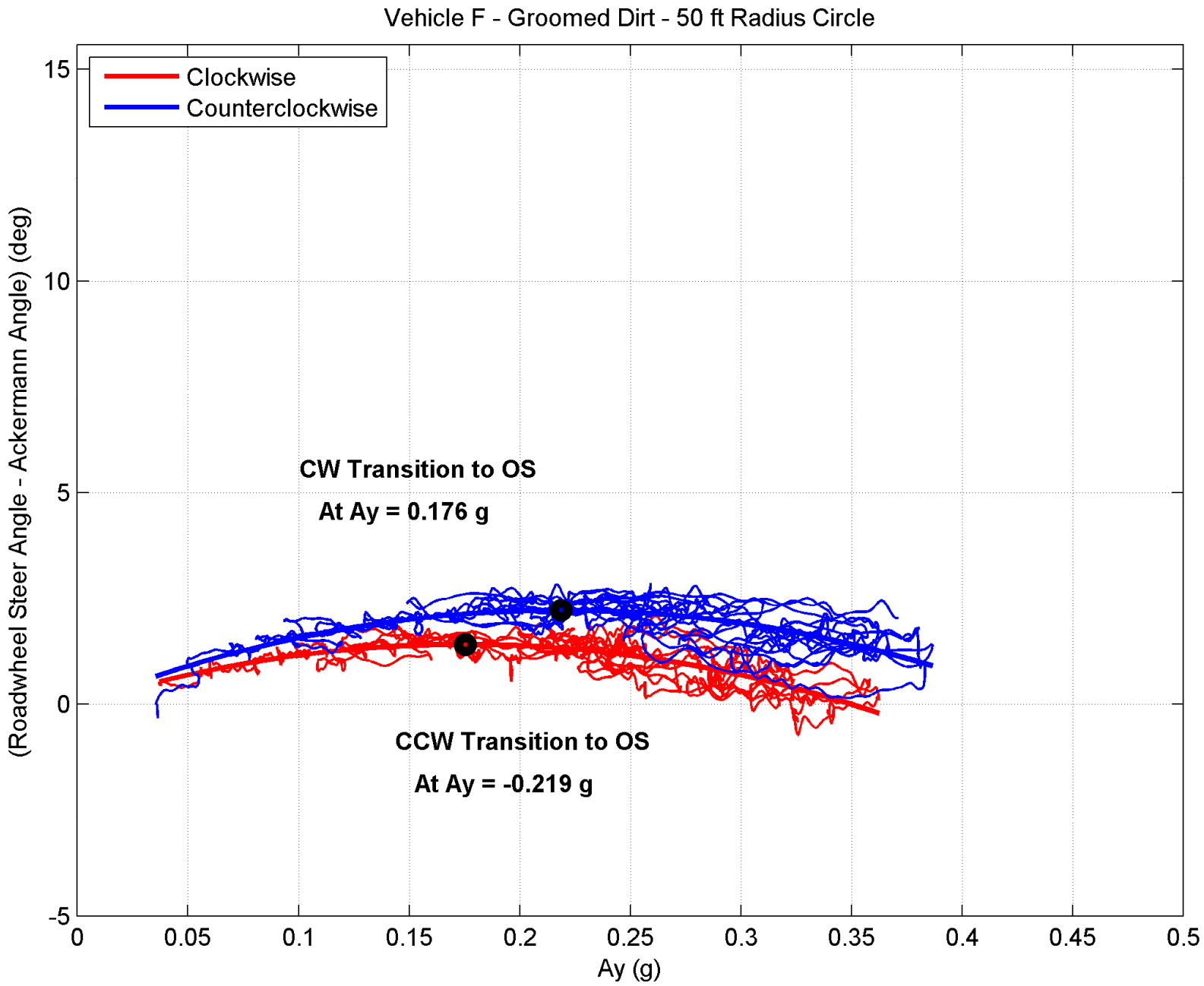

Vehicle E - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 2.17
Ratio: -0.522
Final Slope: 1.75
Ratio: -0.419
Final Slope: 1.99
Ratio: -0.431
Final Slope: 1.4
Ratio: -0.305
Final Slope: 1.79
Ratio: -0.337
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
5
6
7
8

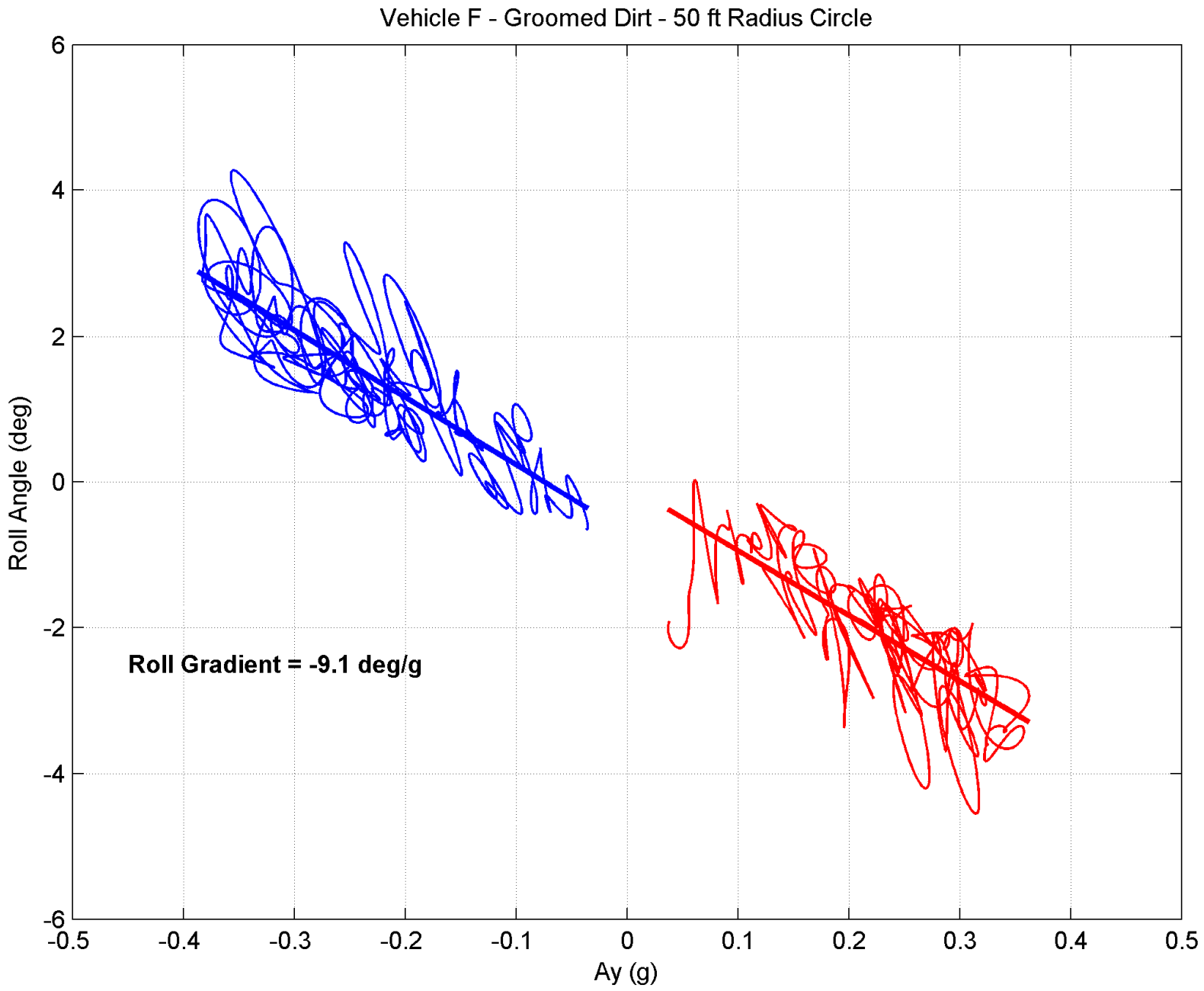

Vehicle E - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

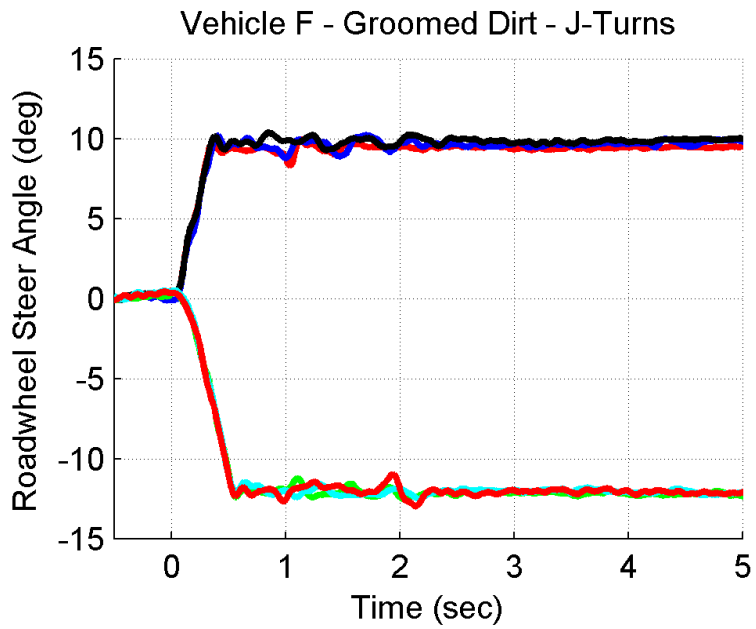

Vehicle E - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

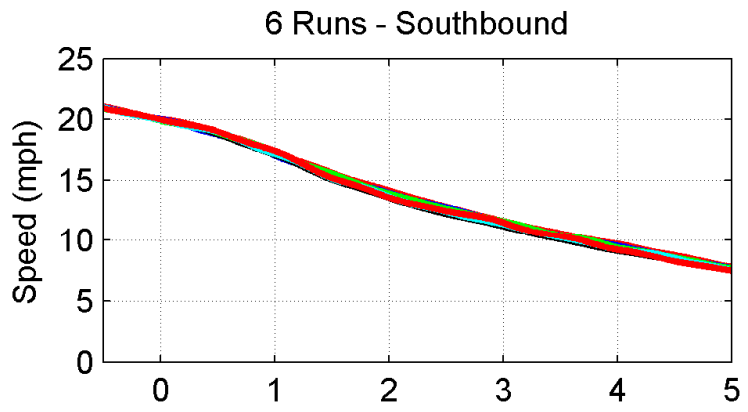

Vehicle F - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

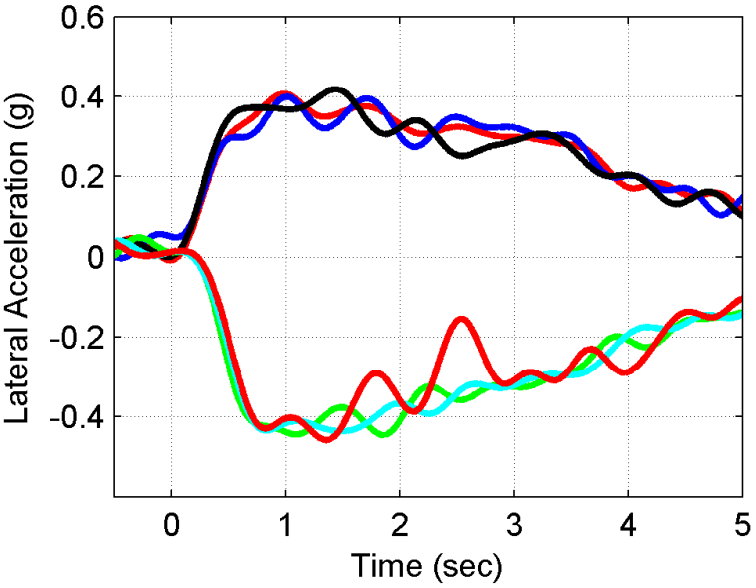

Vehicle F - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
Ay (g)

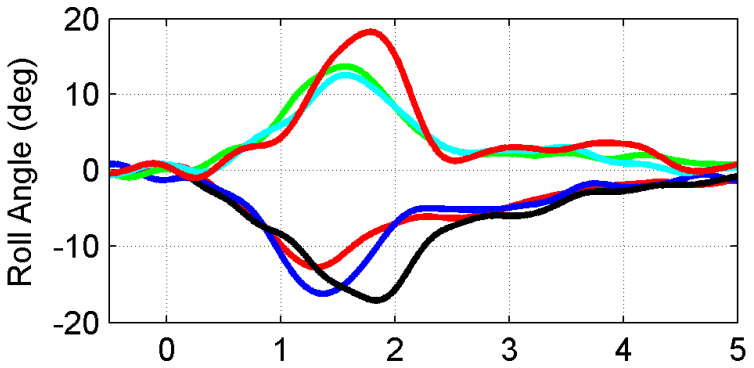

Vehicle F - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.176 g
CCW Transition to OS
At Ay = -0.219 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

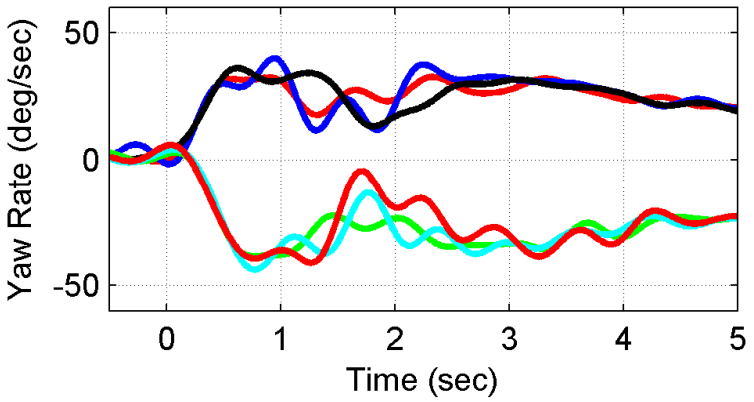

Vehicle F - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -9.1 deg/g
6
4
2
0
-2
-4
-6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

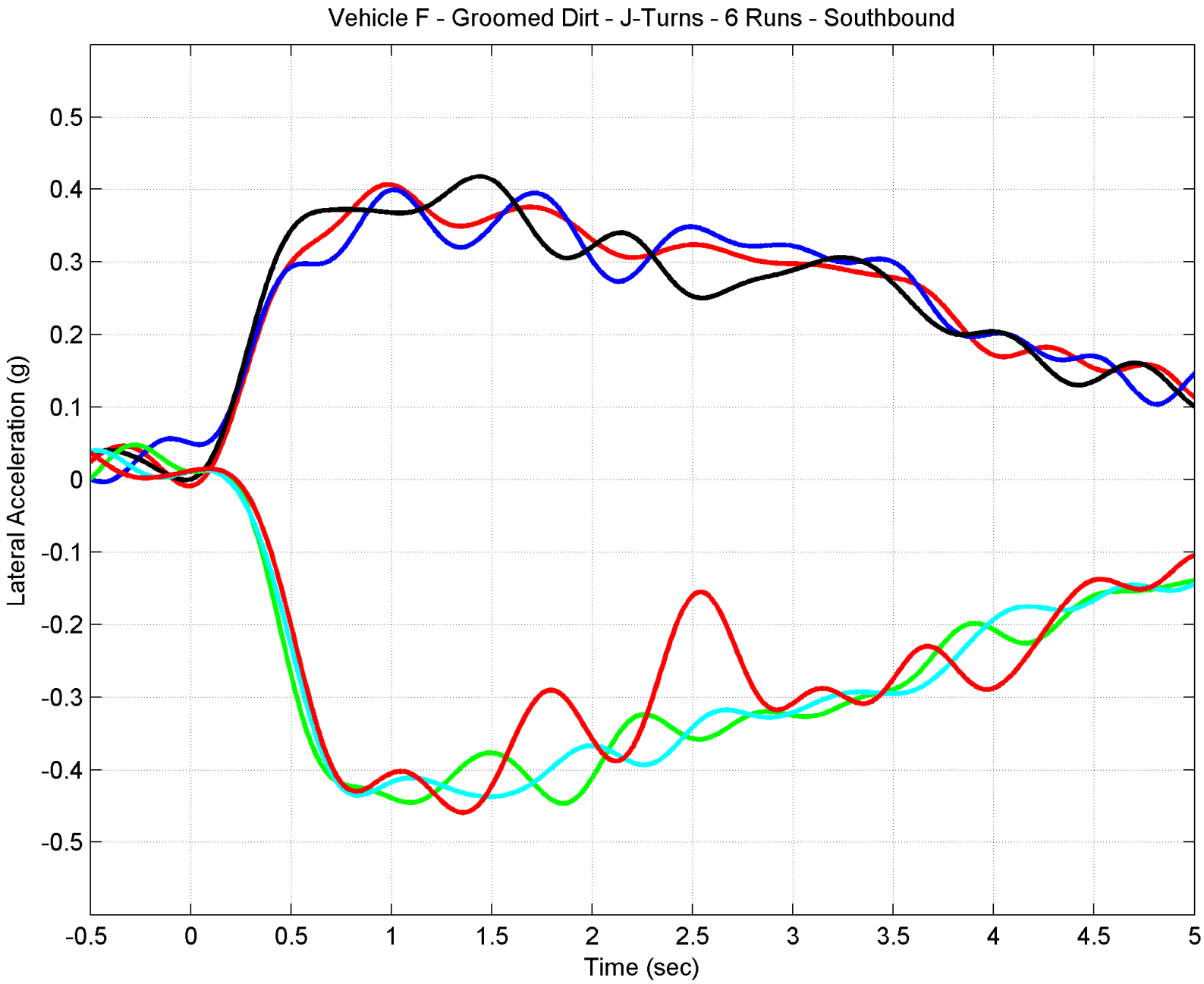

Vehicle F - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)

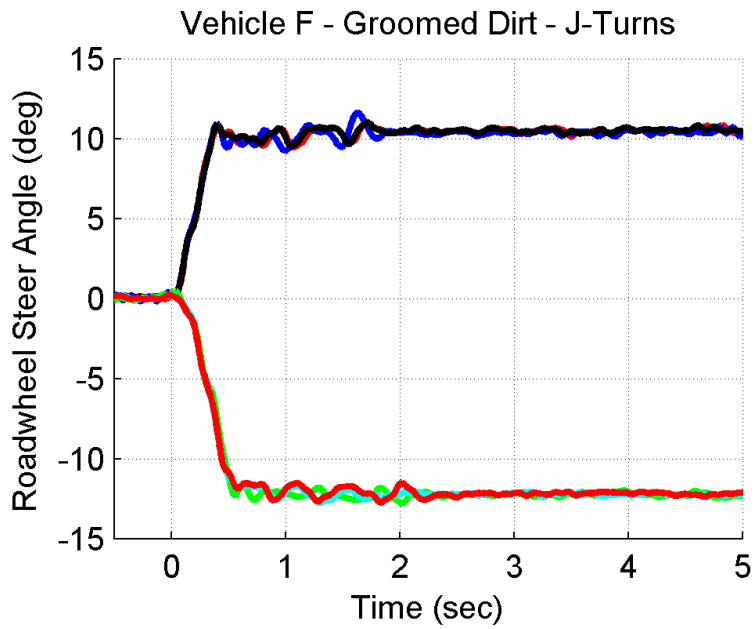

6 Runs - Southbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5

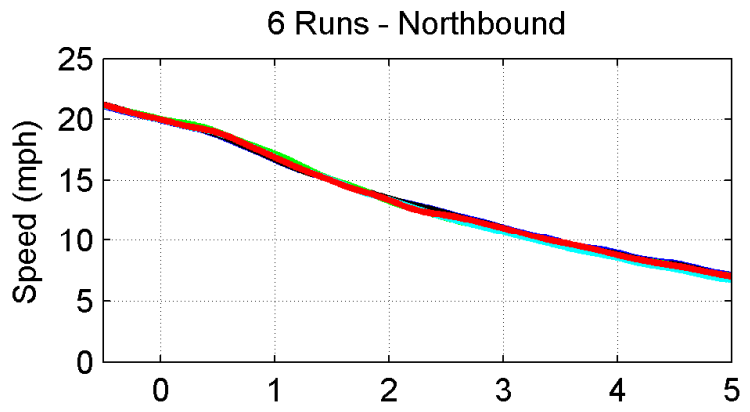

Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)

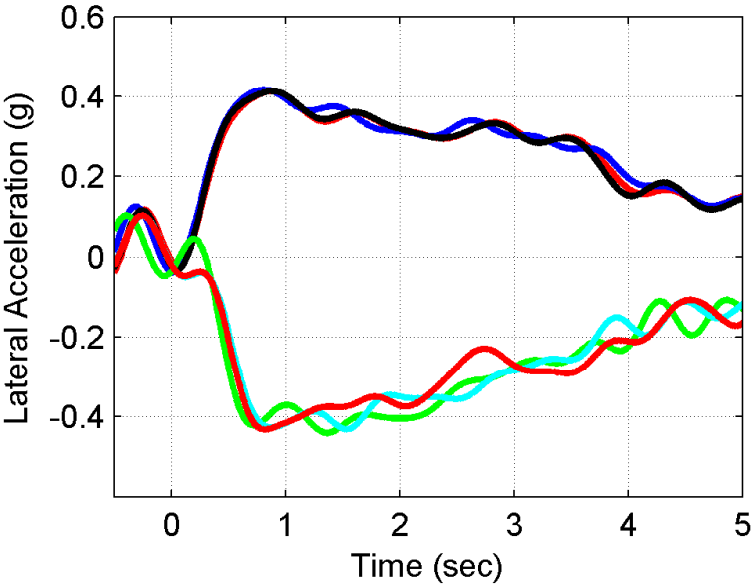

Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5

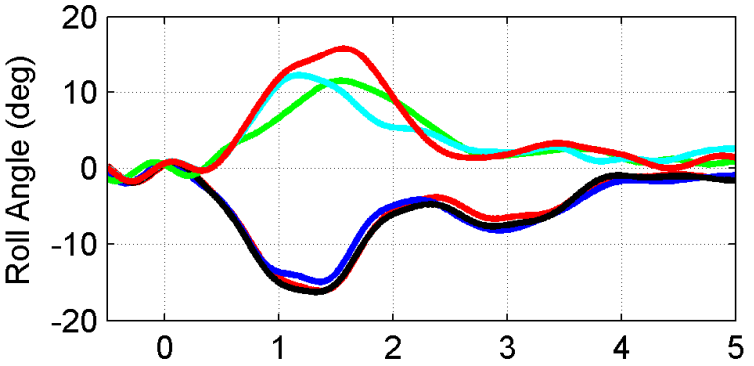

Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)

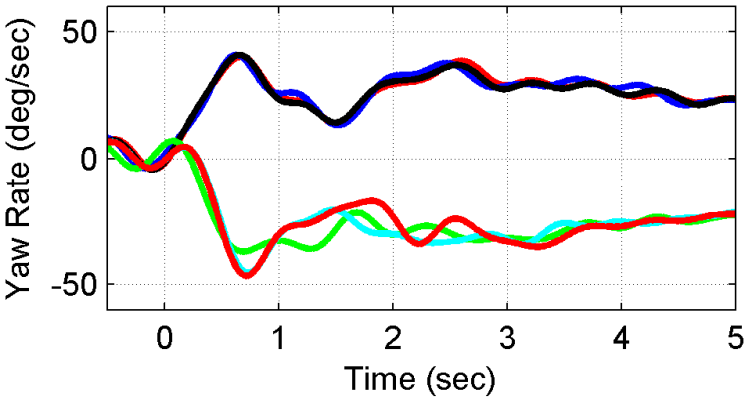

Vehicle F - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

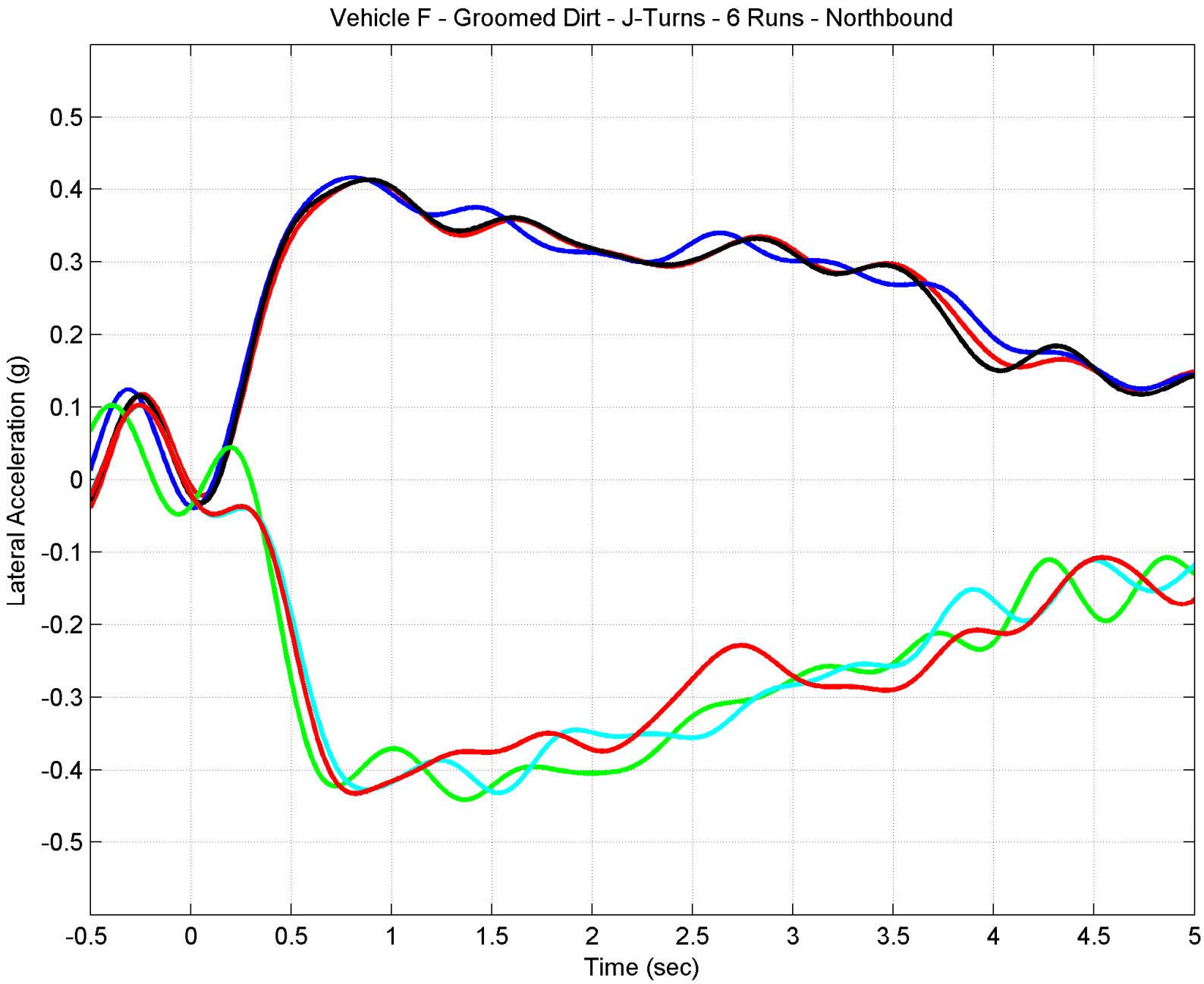

Vehicle F - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5


Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle F - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle F - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.406	-0.446
2	0.399	-0.437
3	0.418	-0.458
Mean Value of 3 Runs	0.408	-0.447
Standard Deviation of 3 Runs	0.009	0.011

Average of 6 North Runs

0.427

Run Number	North Right Turns	North Left Turns
1	0.413	-0.441
2	0.416	-0.431
3	0.413	-0.432
Mean Value of 3 Runs	0.414	-0.435
Standard Deviation of 3 Runs	0.002	0.005

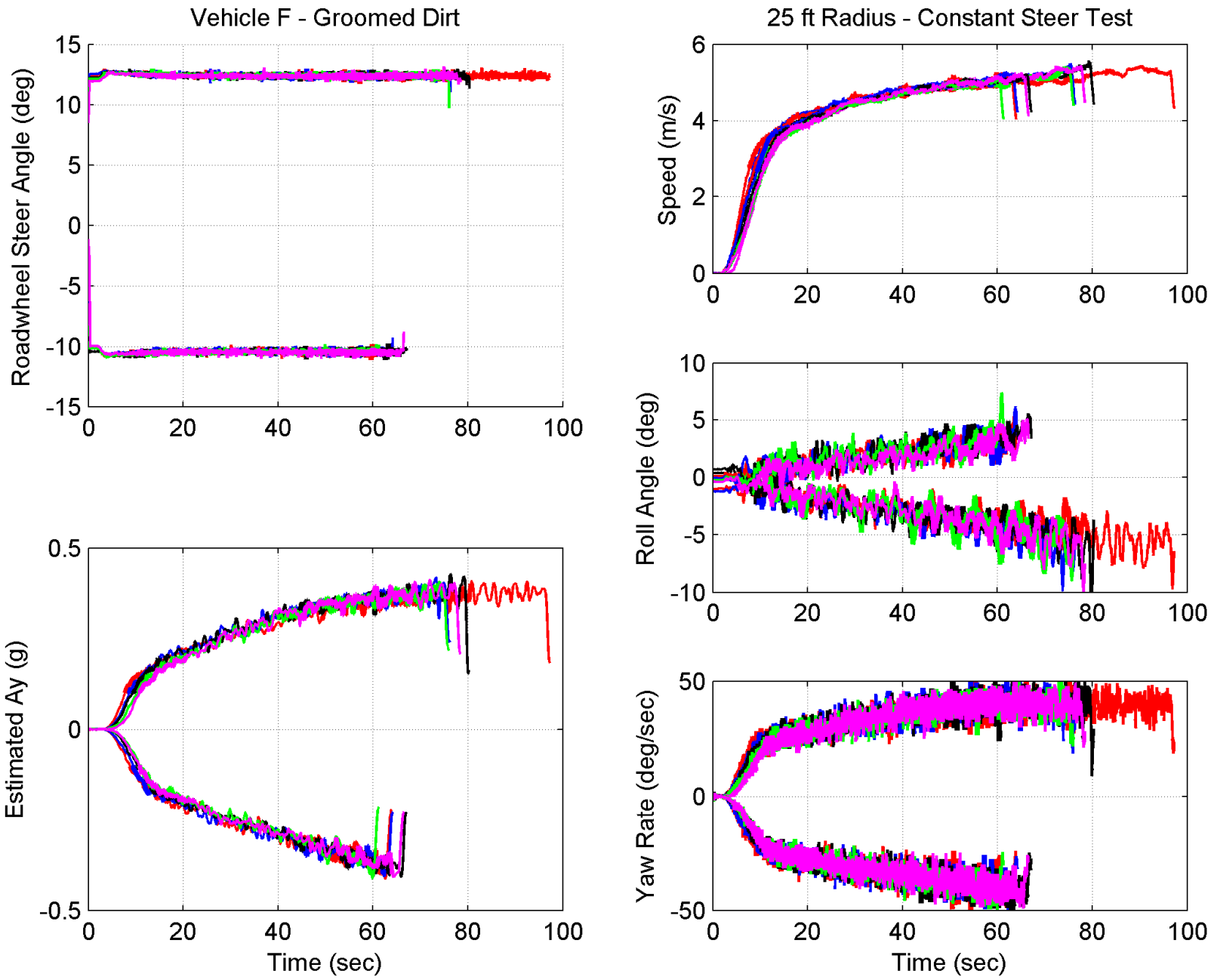
Average of 6 South Runs

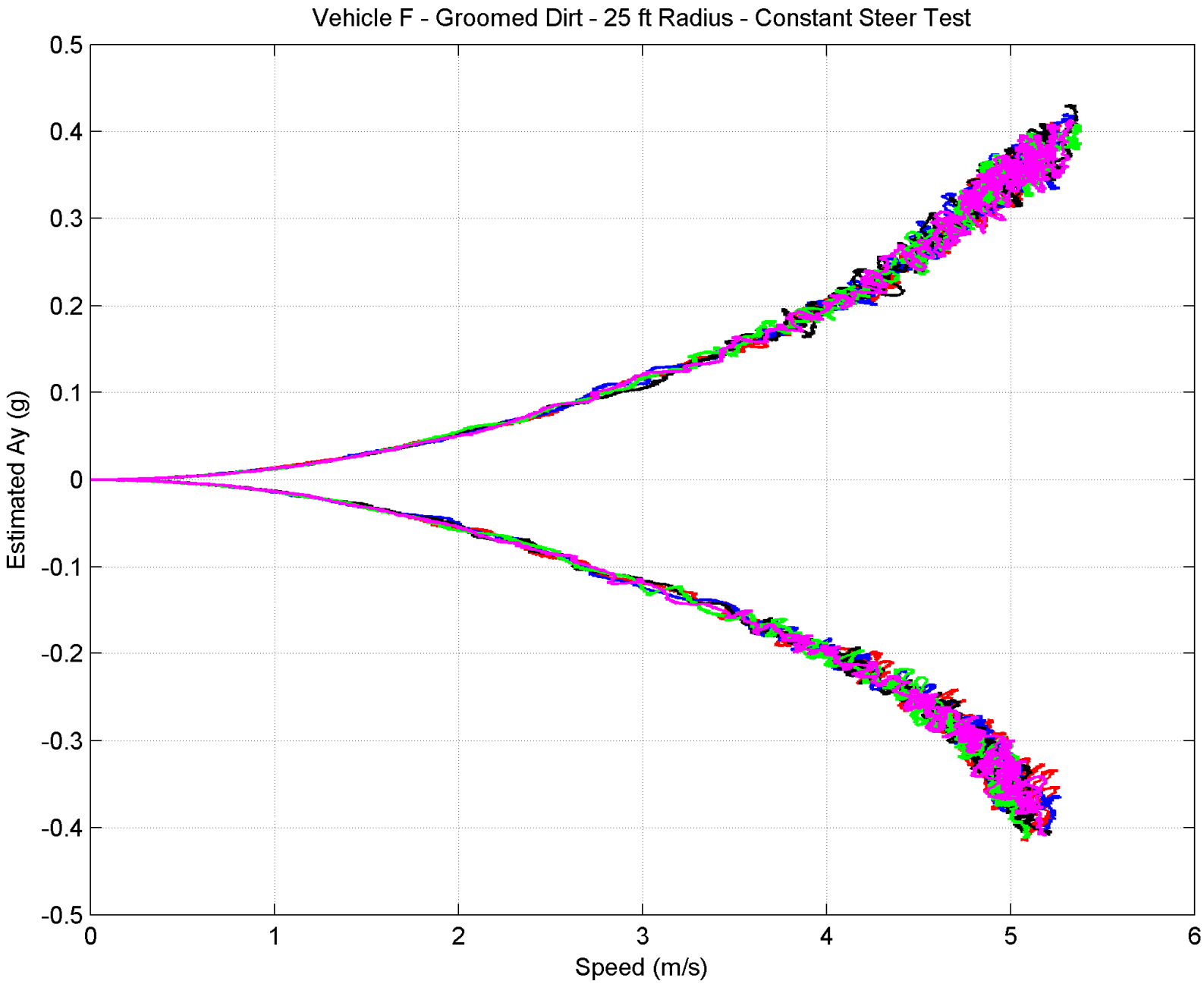
0.424

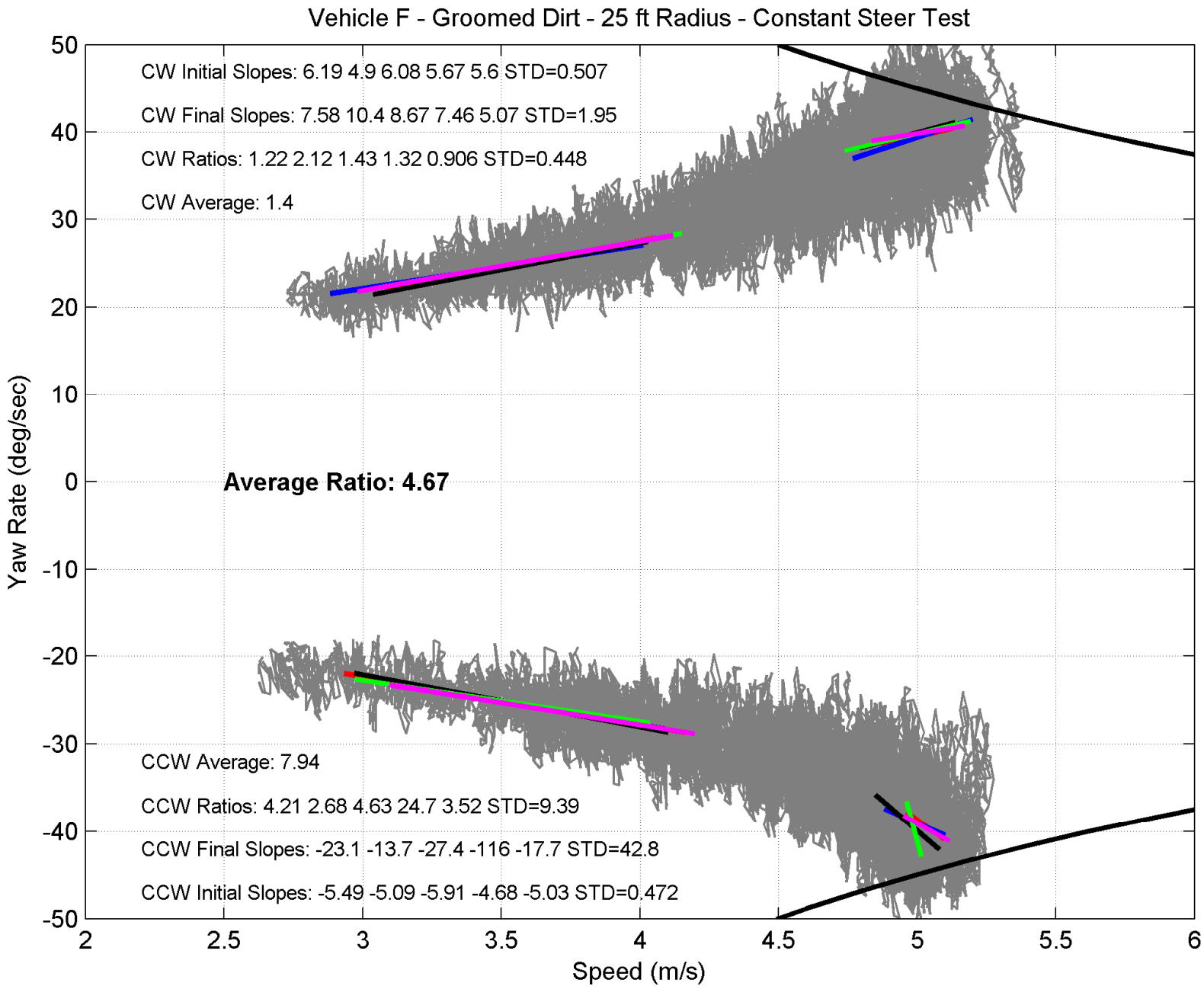
Average of All 12 Runs

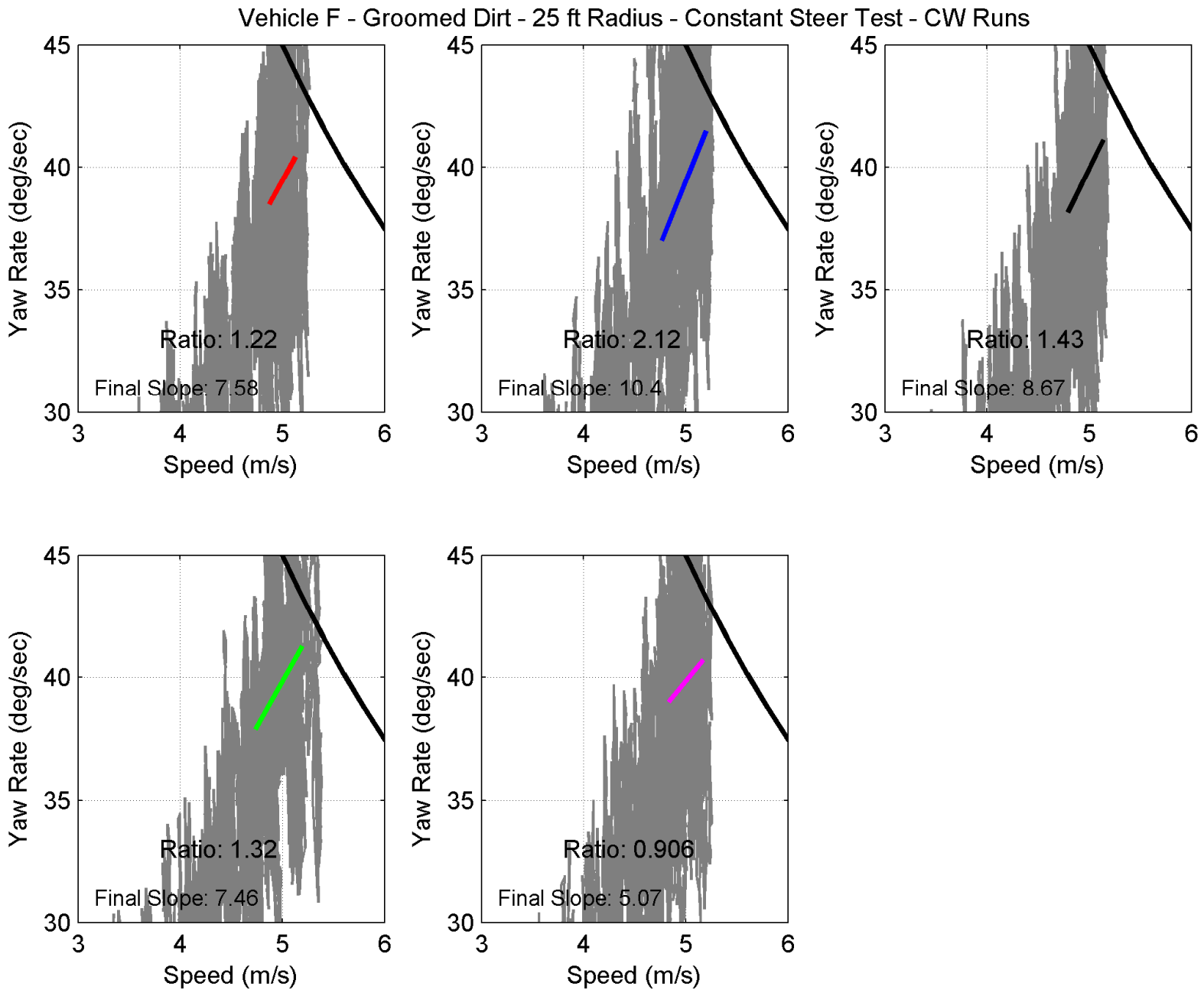
0.426

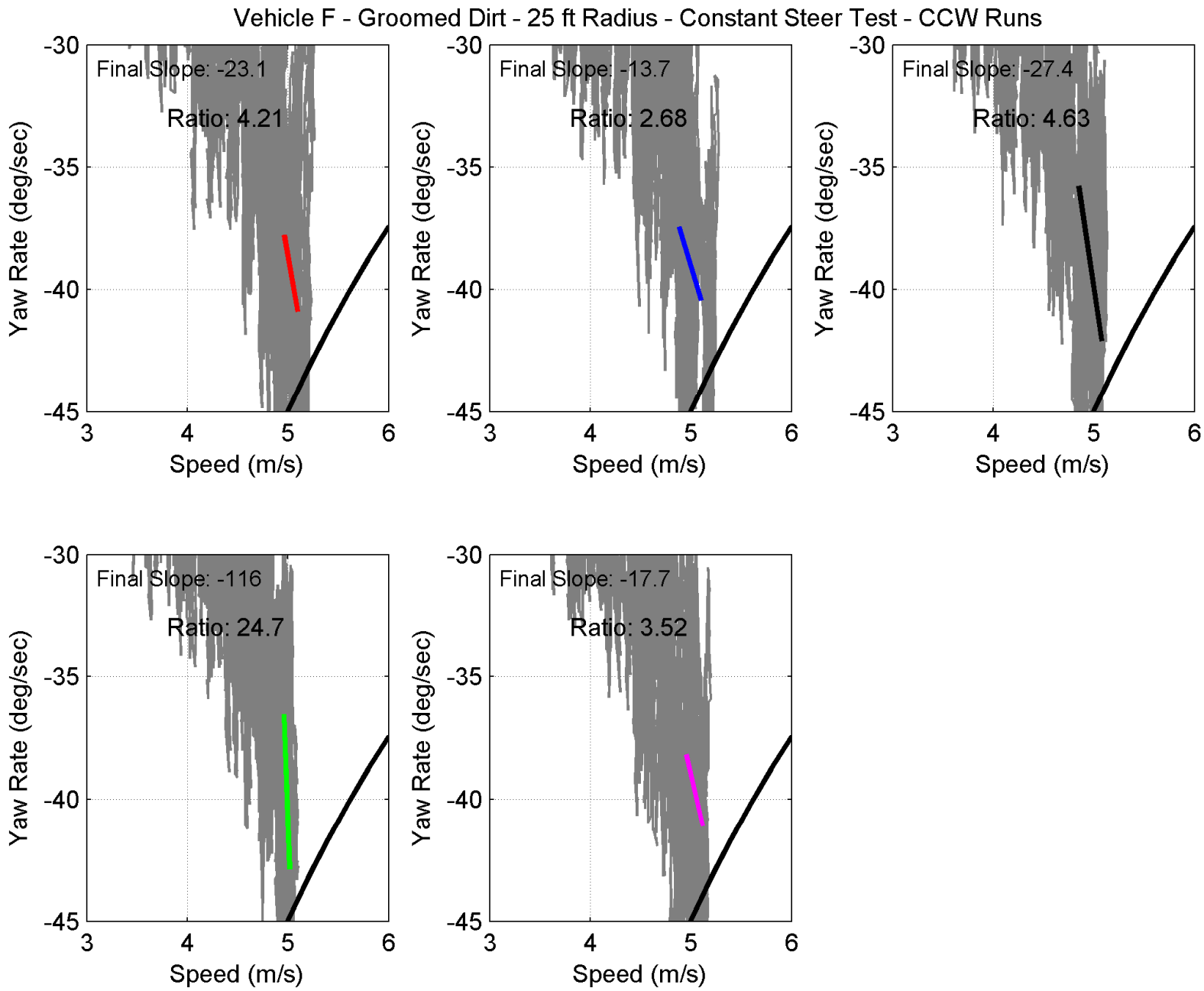
Threshold Ay

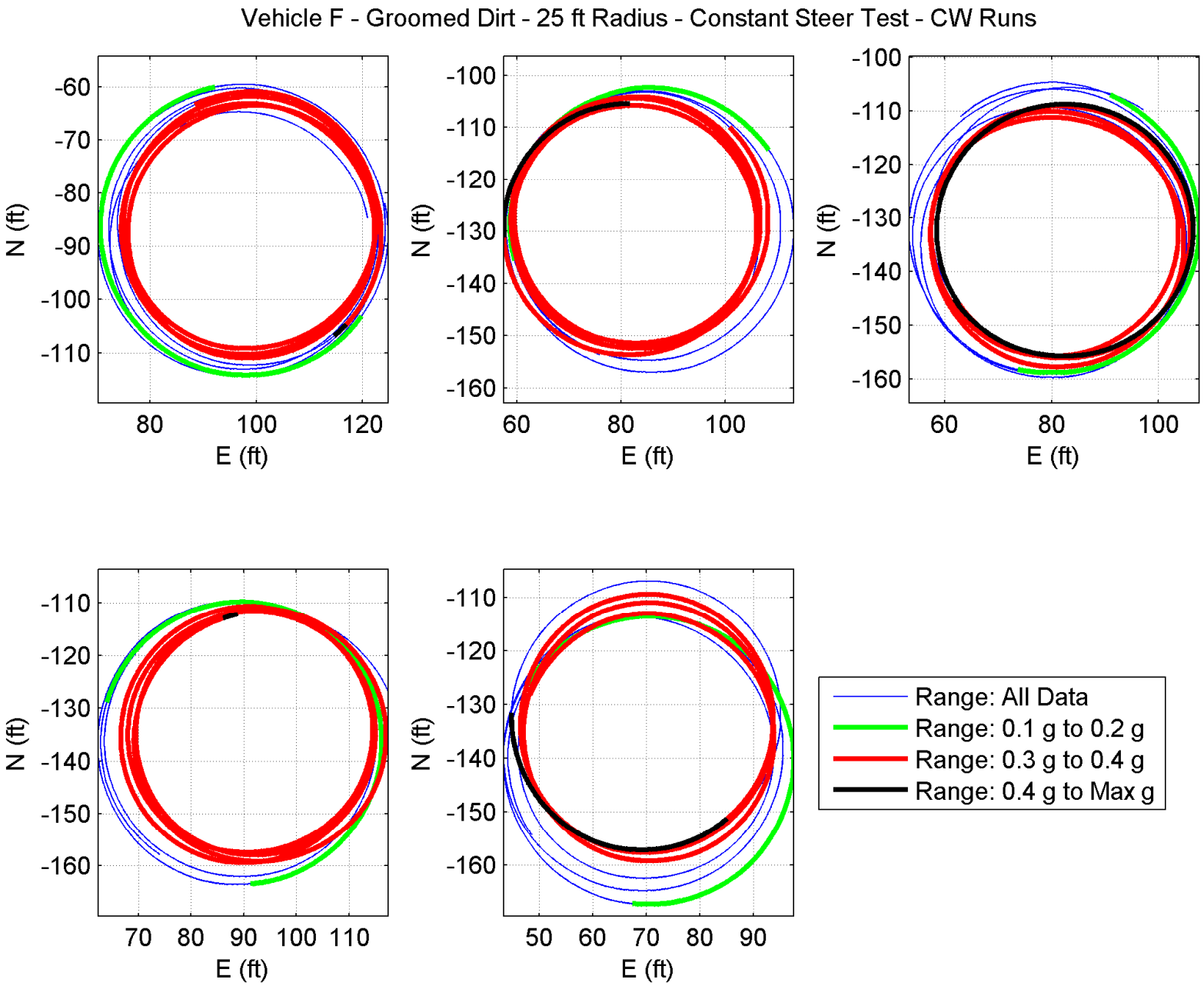

Vehicle F - Groomed Dirt
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

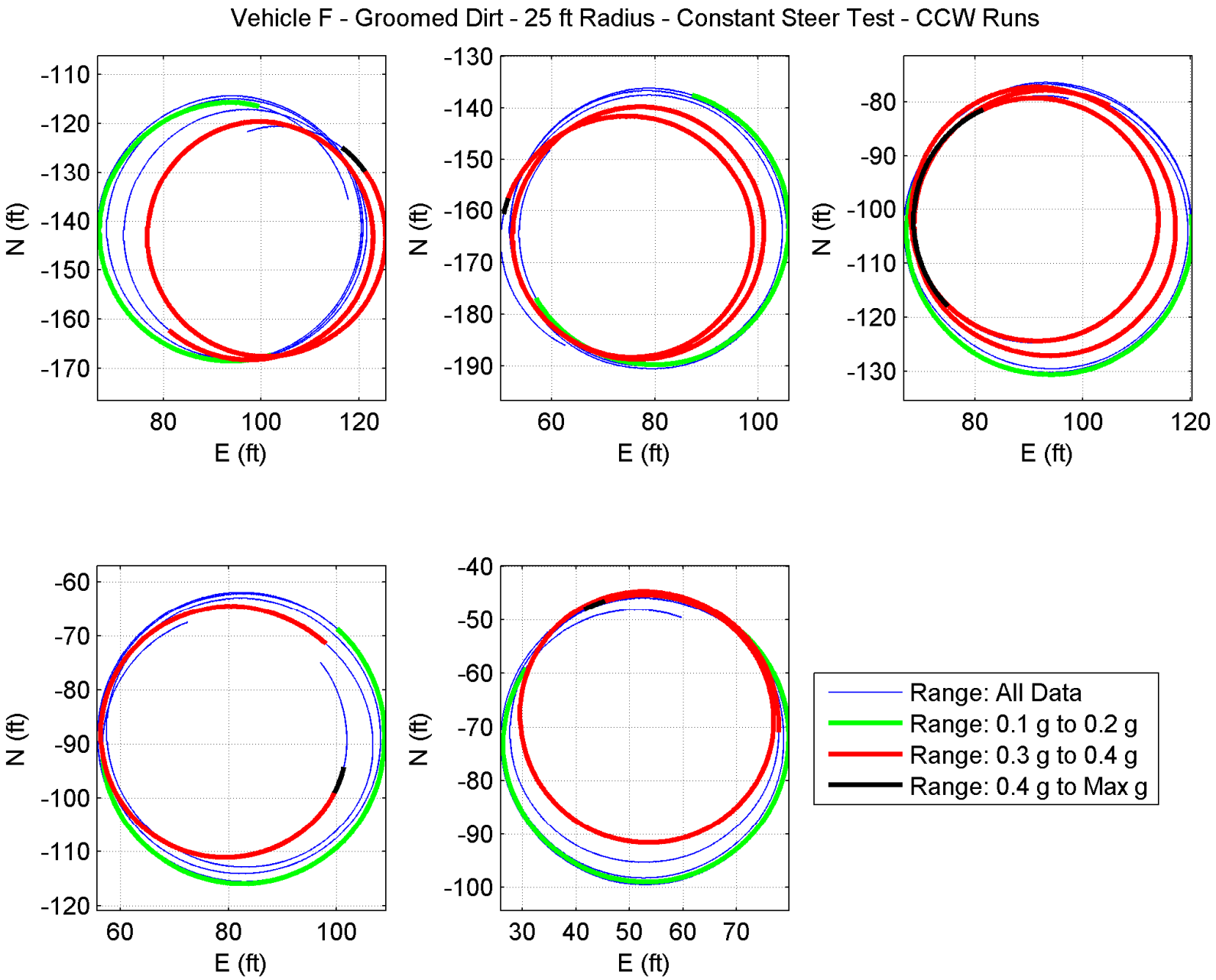

Vehicle F - Groomed Dirt - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6

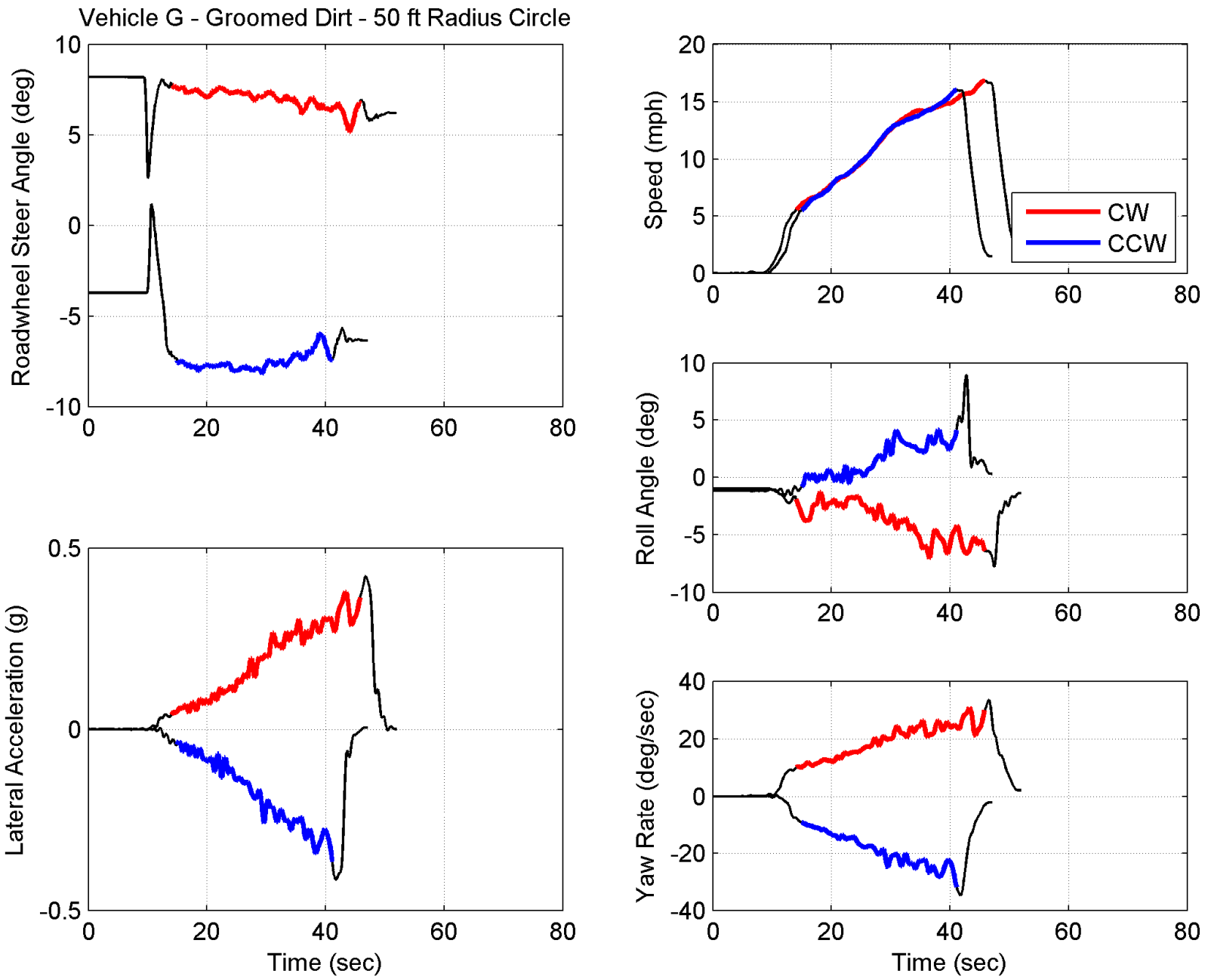

Vehicle F - Groomed Dirt - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 6.19 4.9 6.08 5.67 5.6 STD=0.507
CW Final Slopes: 7.58 10.4 8.67 7.46 5.07 STD=1.95
CW Ratios: 1.22 2.12 1.43 1.32 0.906 STD=0.448
CW Average: 1.4
Average Ratio: 4.67
CCW Average: 7.94
CCW Ratios: 4.21 2.68 4.63 24.7 3.52 STD=9.39
CCW Final Slopes: -23.1 -13.7 -27.4 -116 -17.7 STD=42.8
CCW Initial Slopes: -5.49 -5.09 -5.91 -4.68 -5.03 STD=0.472
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
2.5
3
3.5
4
4.5
5
5.5
6

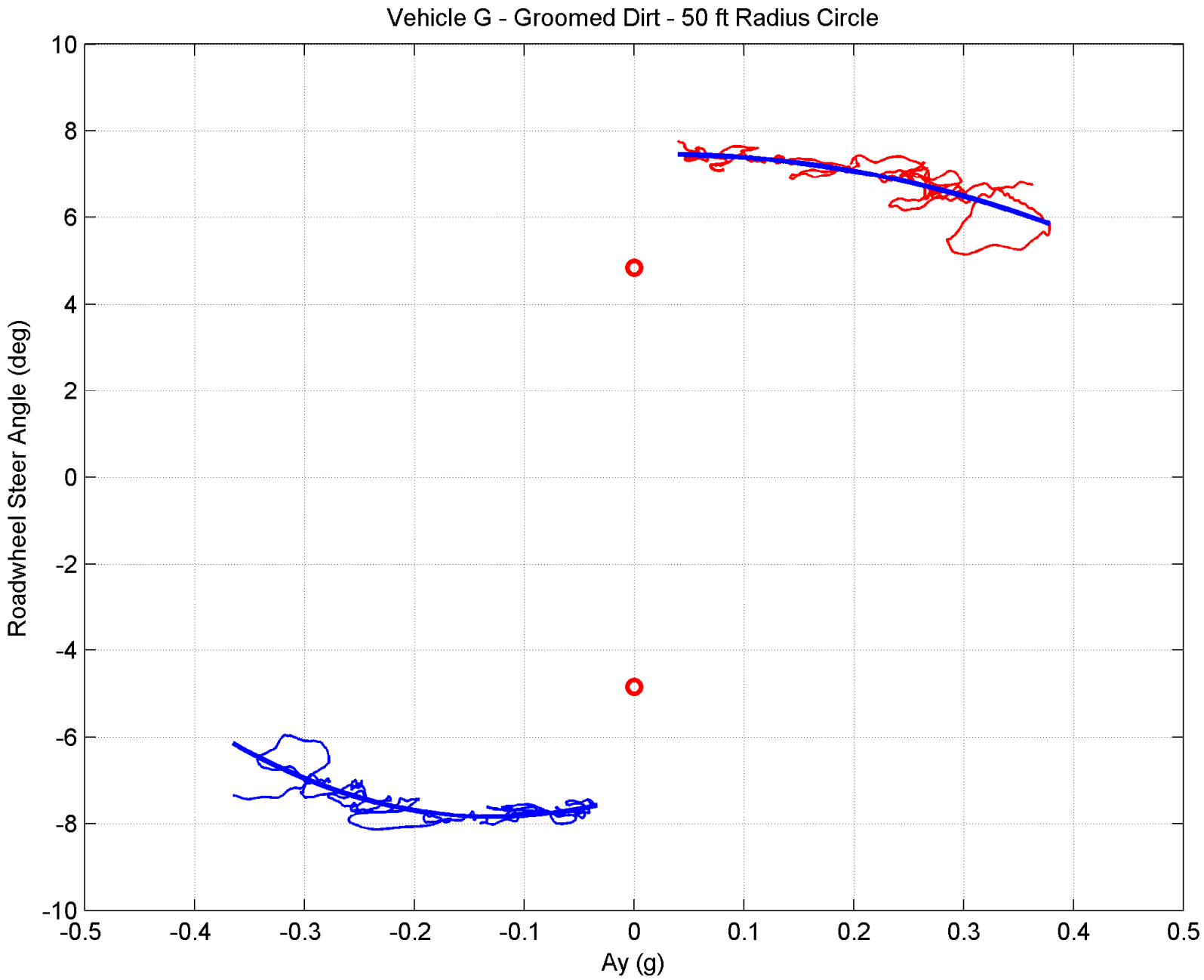

Vehicle F - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 1.22
Final Slope: 7.58
Ratio: 2.12
Final Slope: 10.4
Ratio: 1.43
Final Slope: 8.67
Ratio: 1.32
Final Slope: 7.46
Ratio: 0.906
Final Slope: 5.07

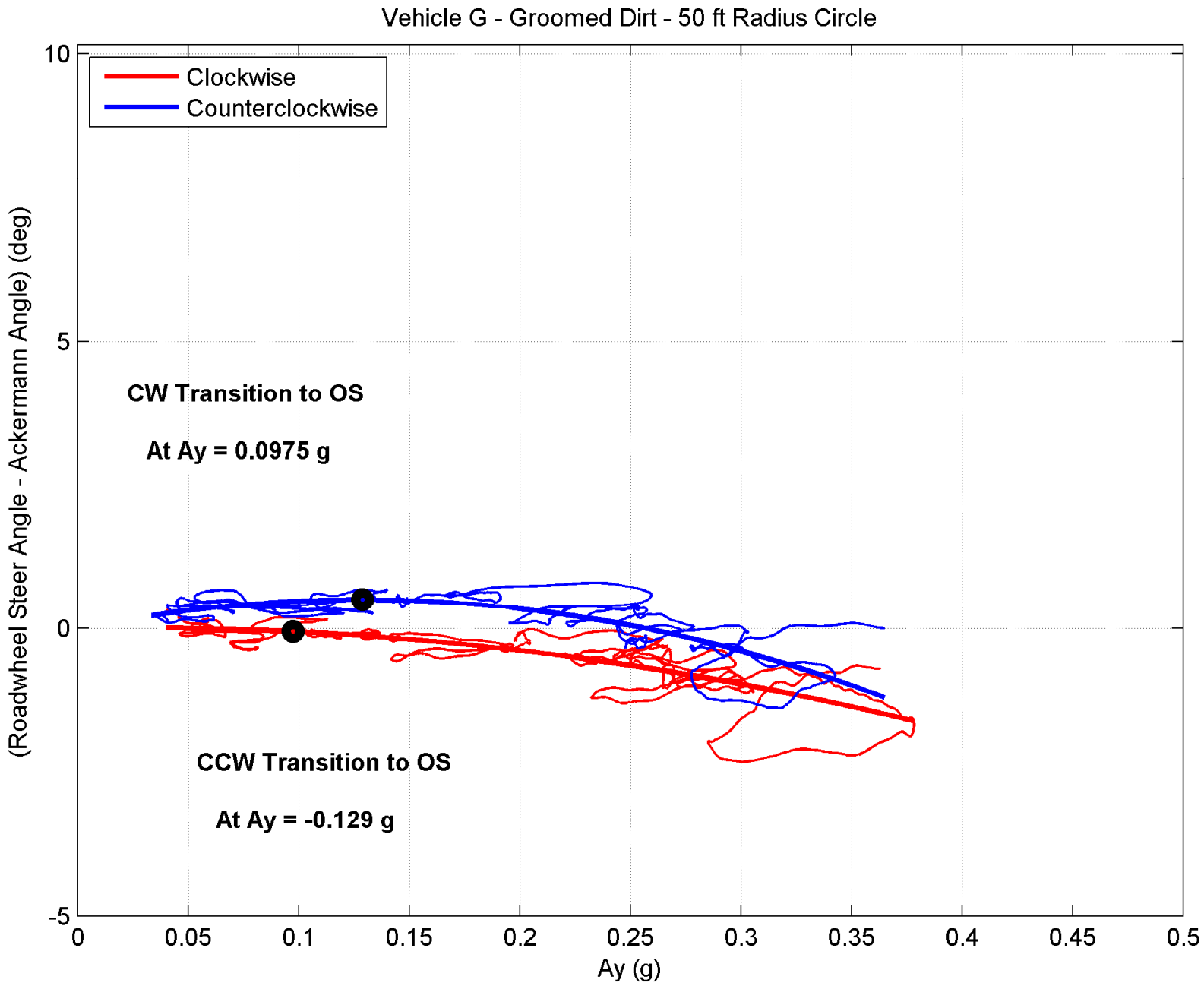

Vehicle F - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -23.1
Ratio: 4.21
Final Slope: -13.7
Ratio: 2.68
Final Slope: -27.4
Ratio: 4.63
Final Slope: -116
Ratio: 24.7
Final Slope: -17.7
Ratio: 3.52
Yaw Rate (deg/sec)
Speed (m/s)
-30
-35
-40
-45
3
4
5
6

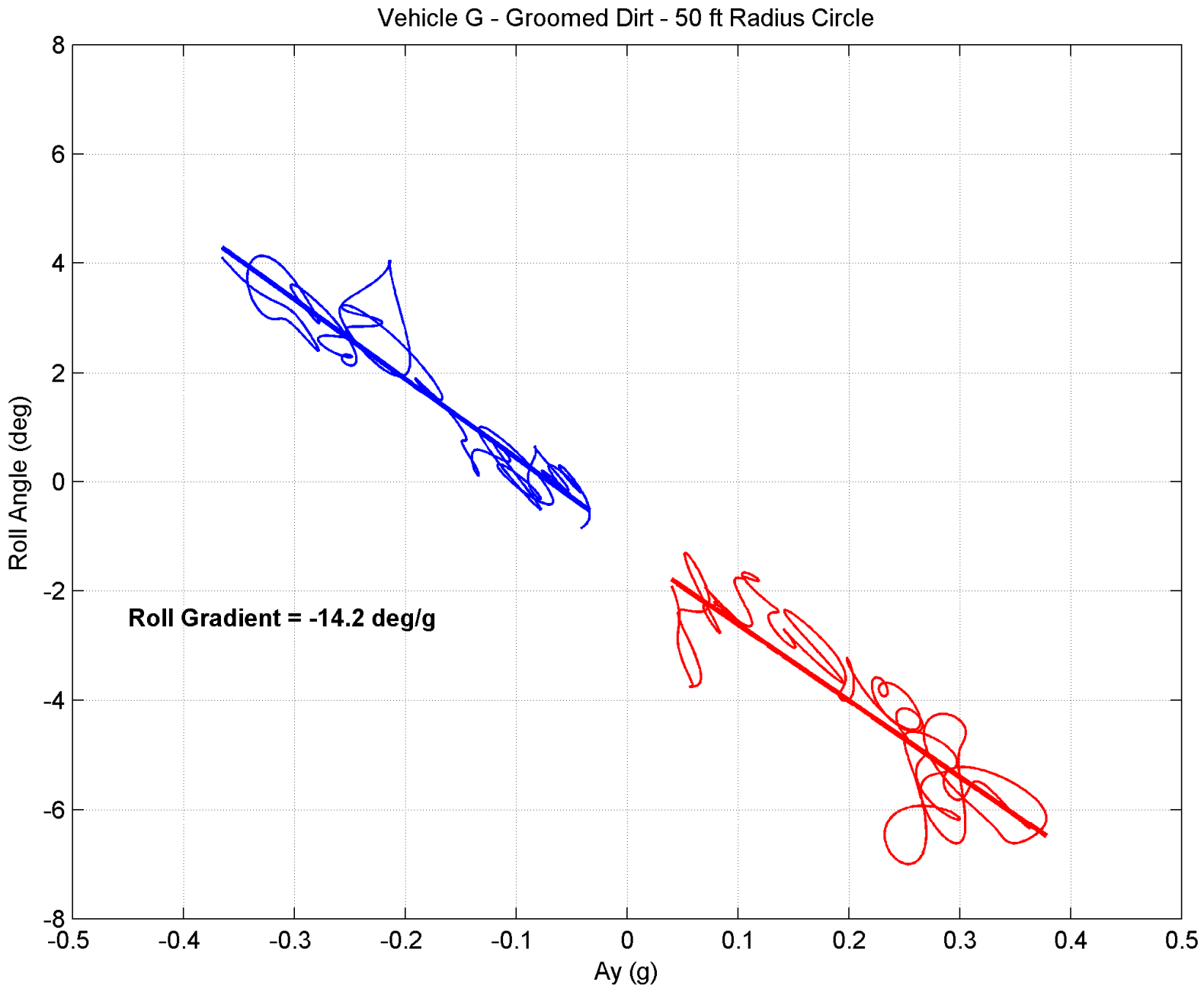

Vehicle F - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
-60
-70
-80
-90
-100
-110
80
100
120
-100
-110
-120
-130
-140
-150
-160
60
80
100
-100
-110
-120
-130
-140
-150
-160
60
80
100
-110
-120
-130
-140
-150
-160
70
80
90
100
110
-110
-120
-130
-140
-150
-160
50
60
70
80
90
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

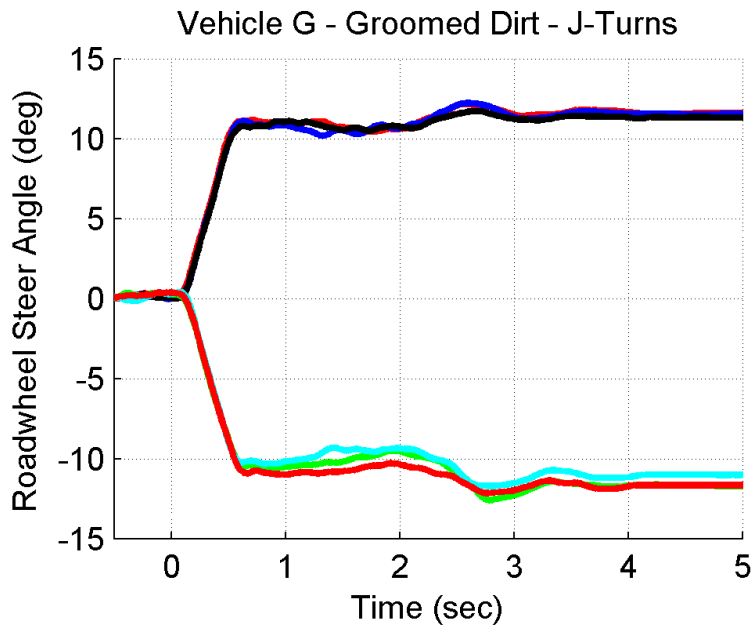

Vehicle F - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
-110
-120
-130
-140
-150
-160
-170
80
100
120
-130
-140
-150
-160
-170
-180
-190
60
80
100
-80
-90
-100
-110
-120
-130
-60
-70
-80
-90
-100
-110
-120
60
80
100
-40
-50
-60
-70
-80
-90
-100
30
40
50
60
70
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

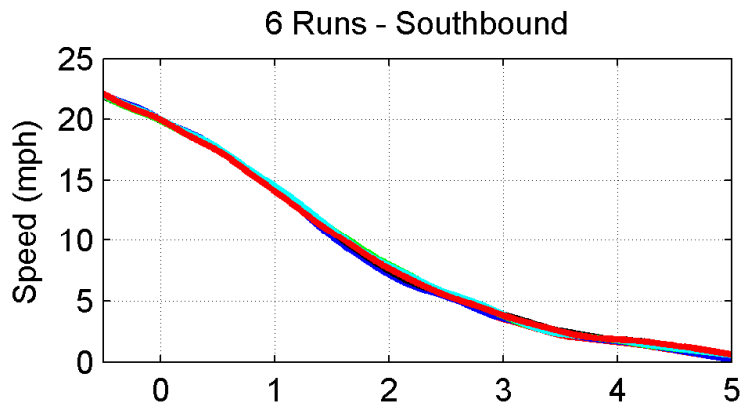

Vehicle G - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

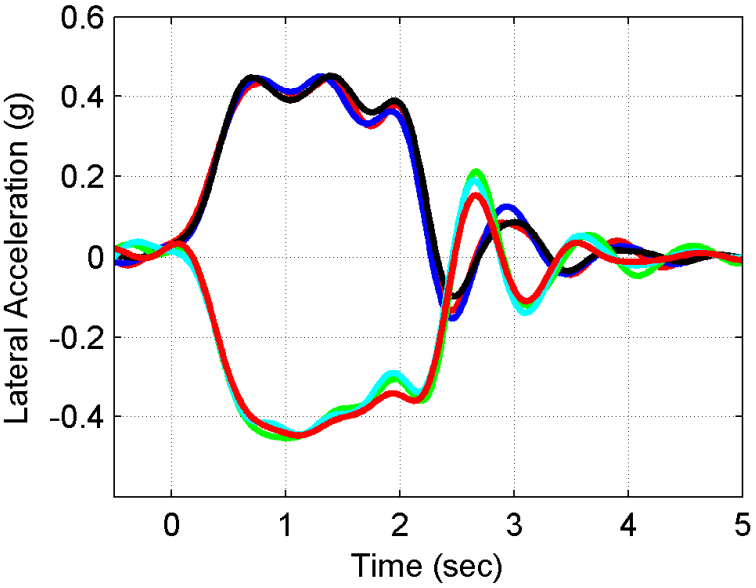

Vehicle G - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

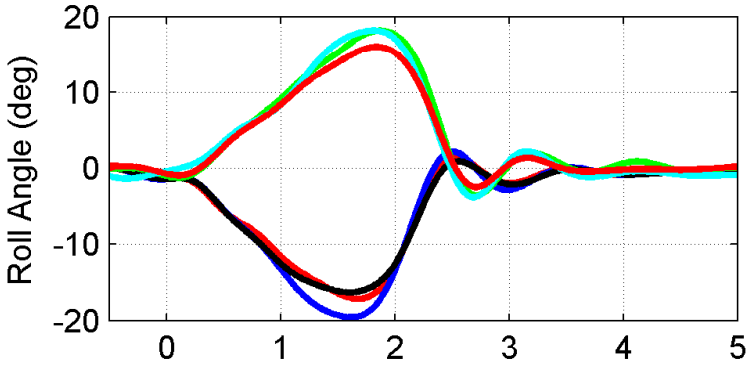

Vehicle G - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.0975 g
CCW Transition to OS
At Ay = -0.129 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

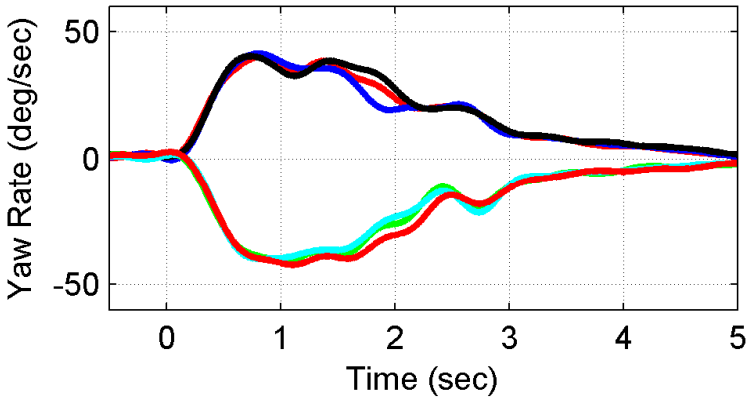

Vehicle G - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -14.2 deg/g
8
6
4
2
0
-2
-4
-6
-8
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

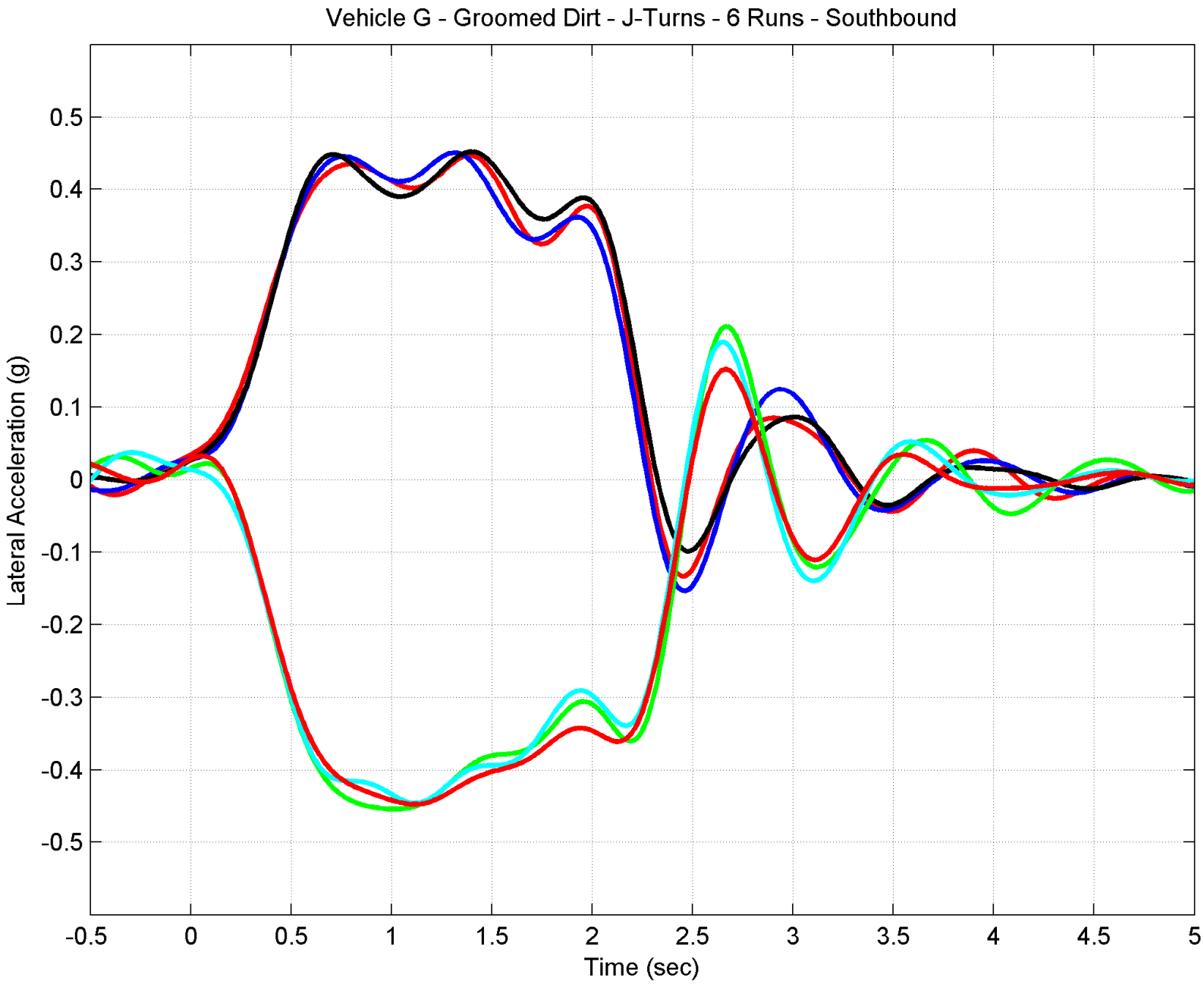

Vehicle G - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)

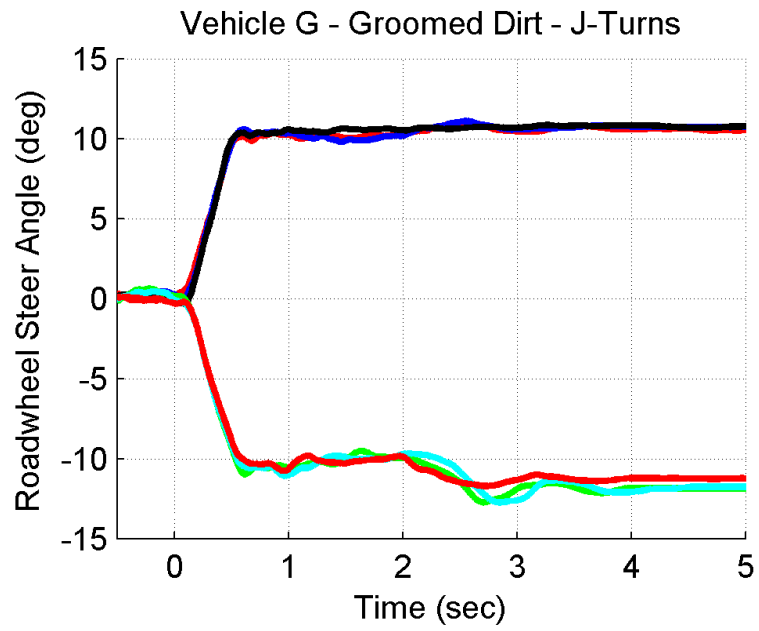

6 Runs - Southbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5

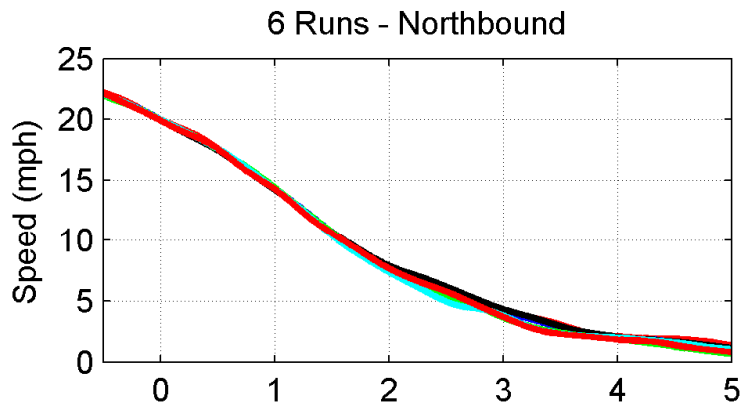

Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)

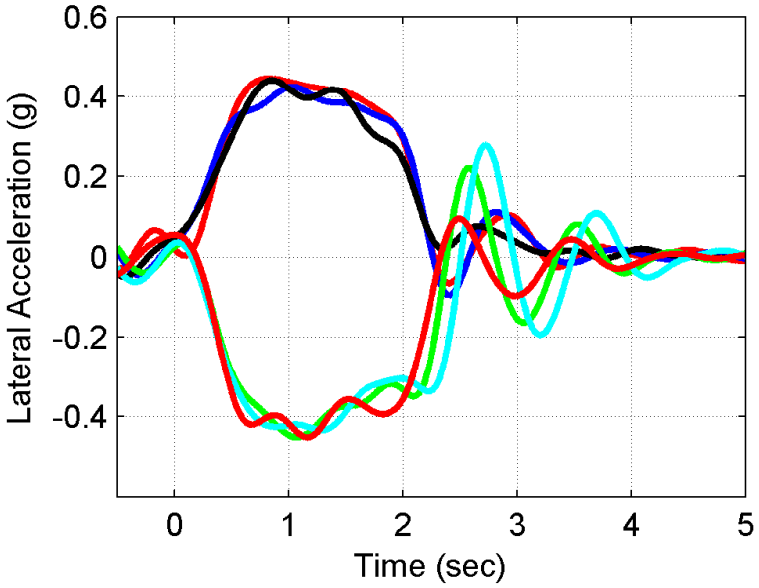

Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5

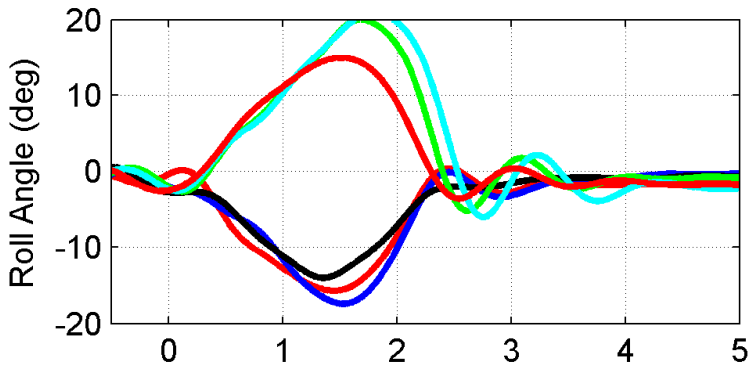

Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)

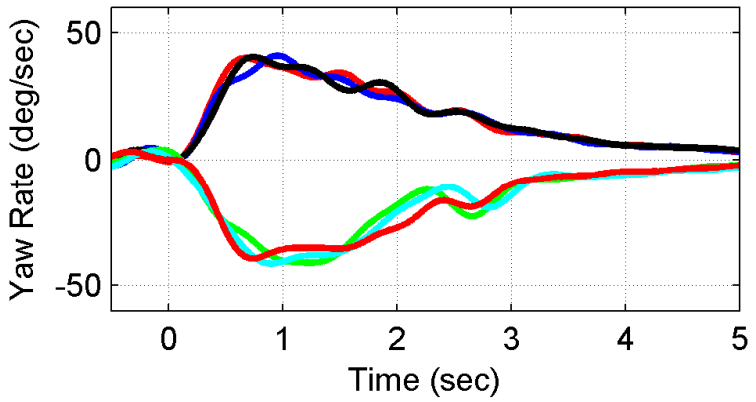

Vehicle G - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

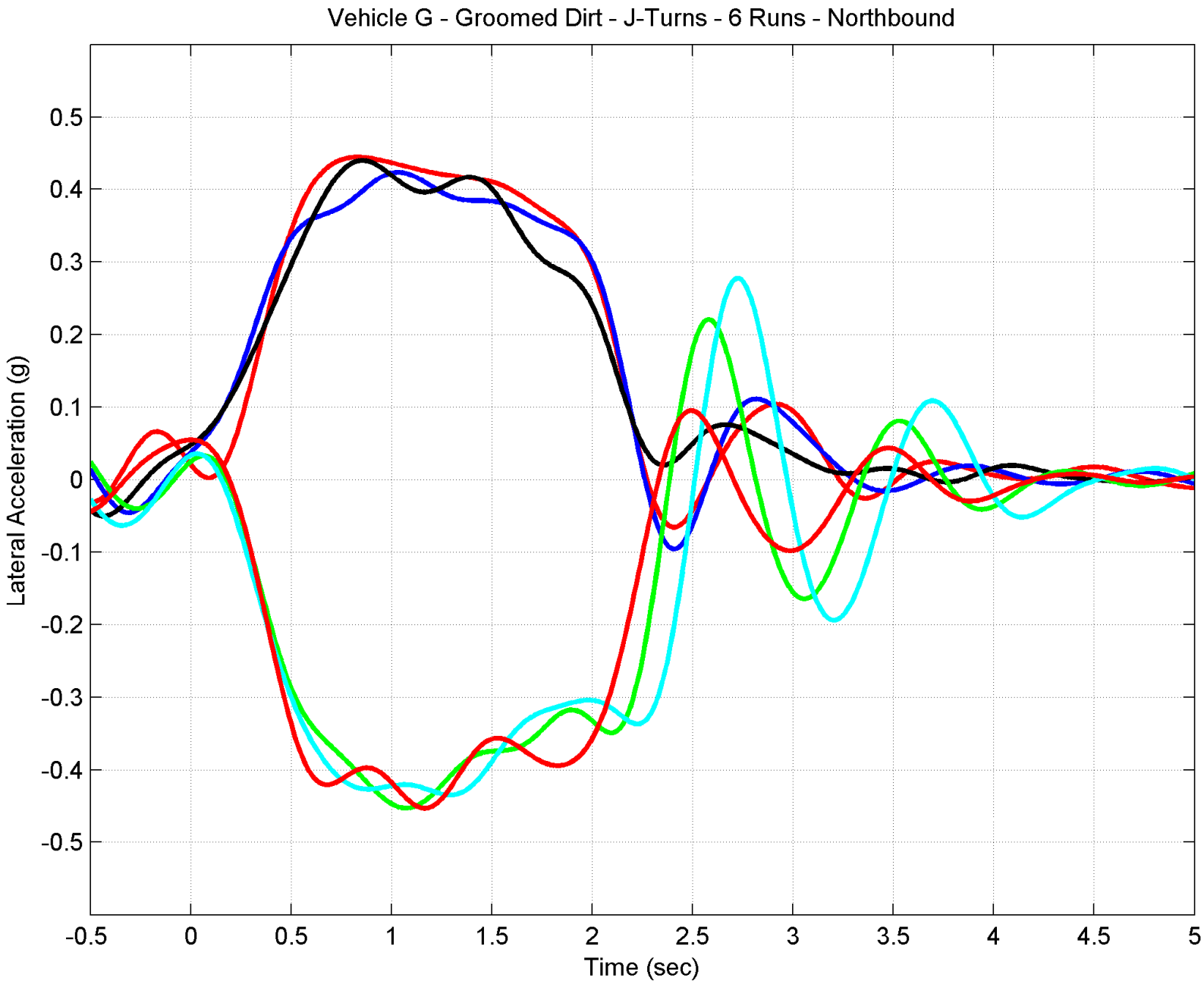

Vehicle G - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5


Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle G - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle G - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.447	-0.454
2	0.451	-0.445
3	0.452	-0.447
Mean Value of 3 Runs	0.450	-0.449
Standard Deviation of 3 Runs	0.003	0.004

Average of 6 North Runs

0.449

Run Number	North Right Turns	North Left Turns
1	0.445	-0.452
2	0.424	-0.434
3	0.440	-0.452
Mean Value of 3 Runs	0.436	-0.446
Standard Deviation of 3 Runs	0.011	0.010

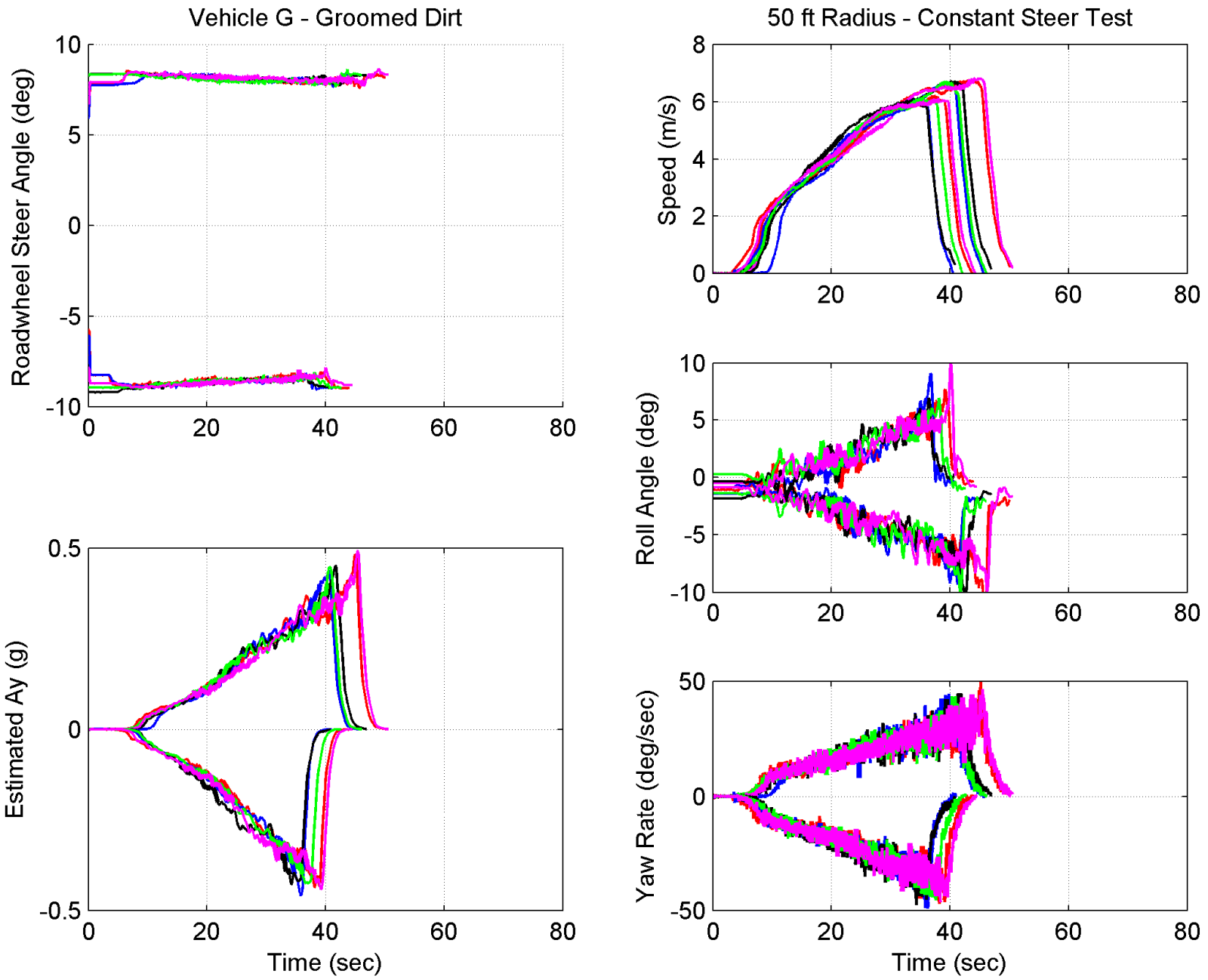
Average of 6 South Runs

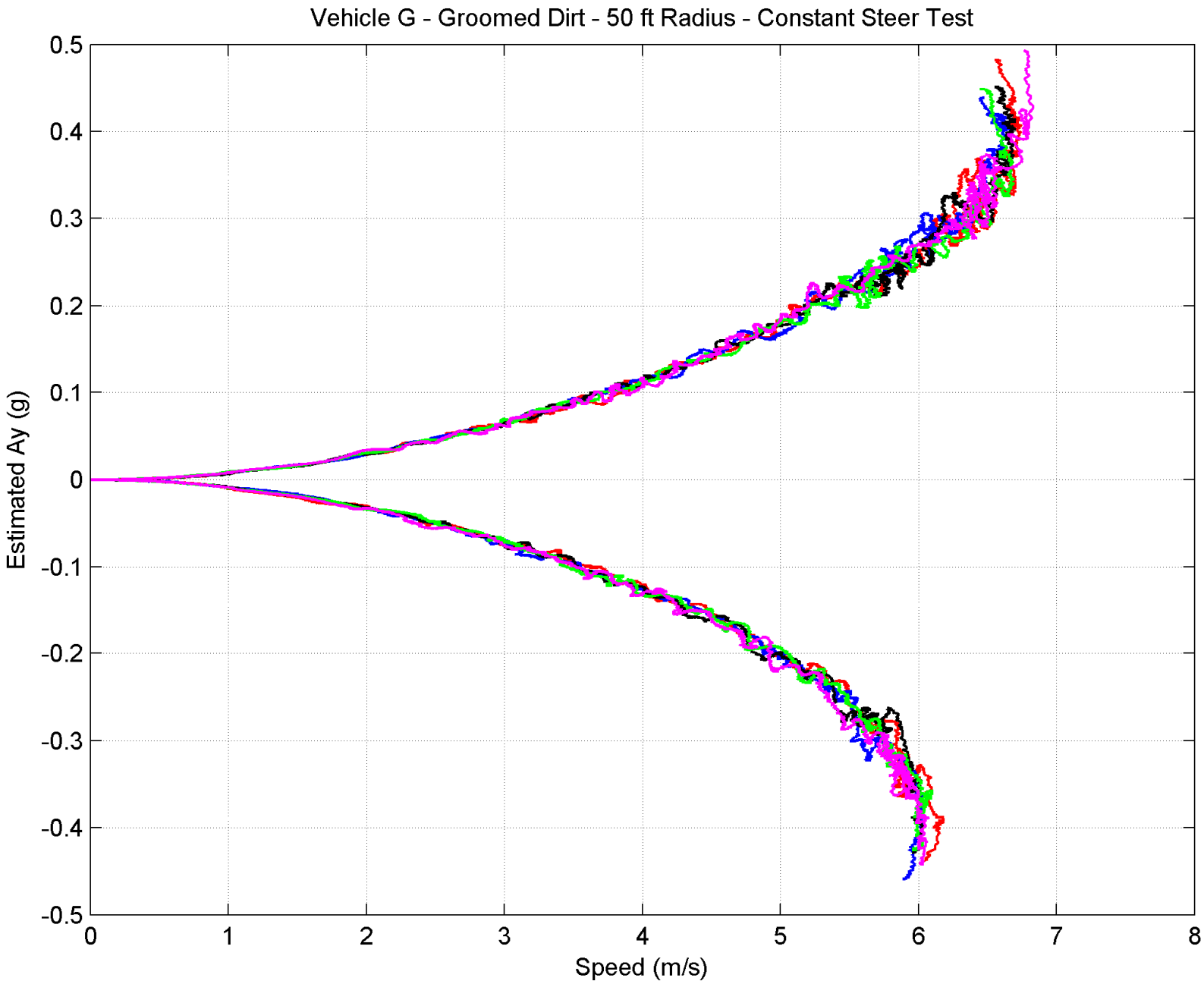
0.441

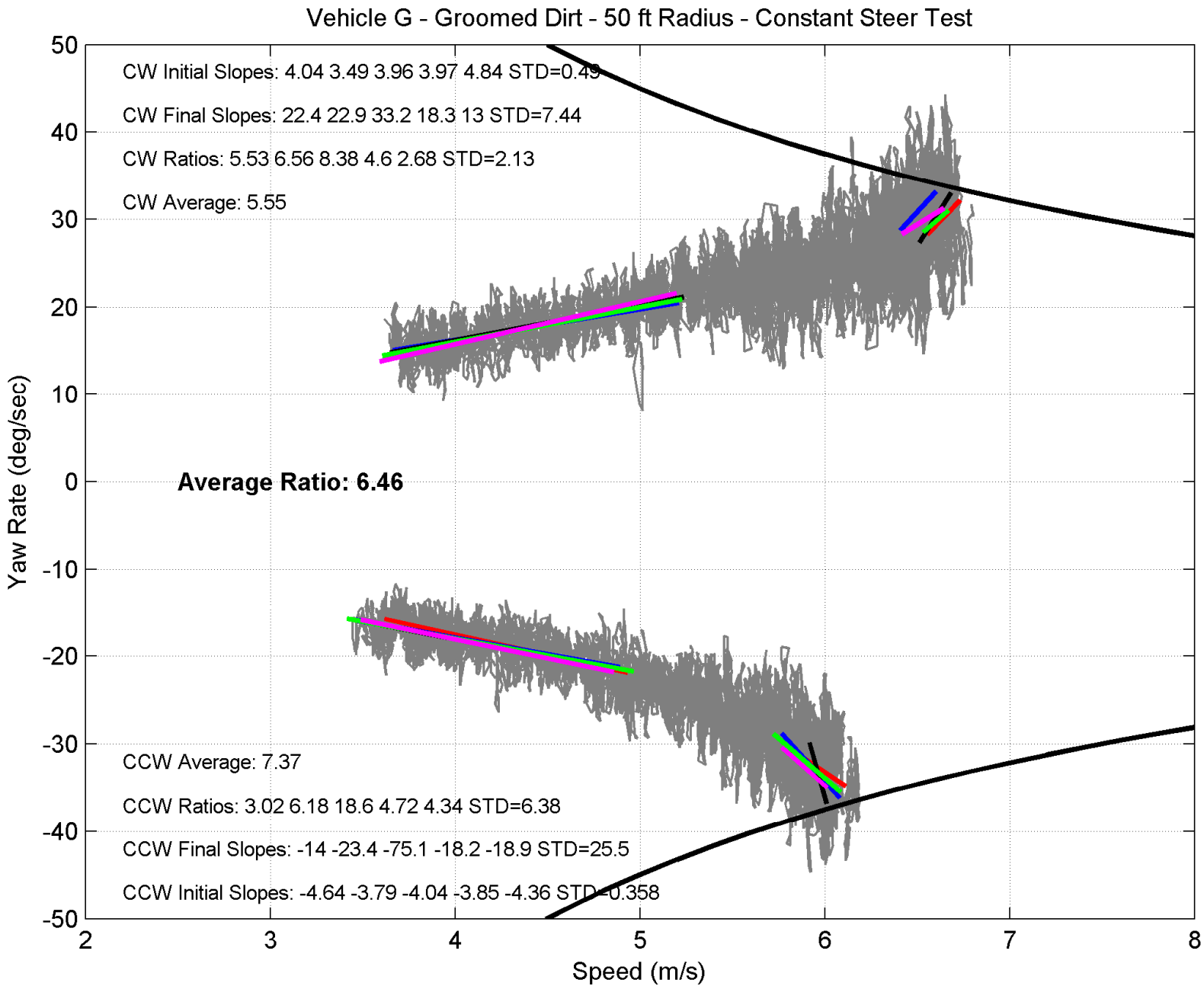
Average of All 12 Runs

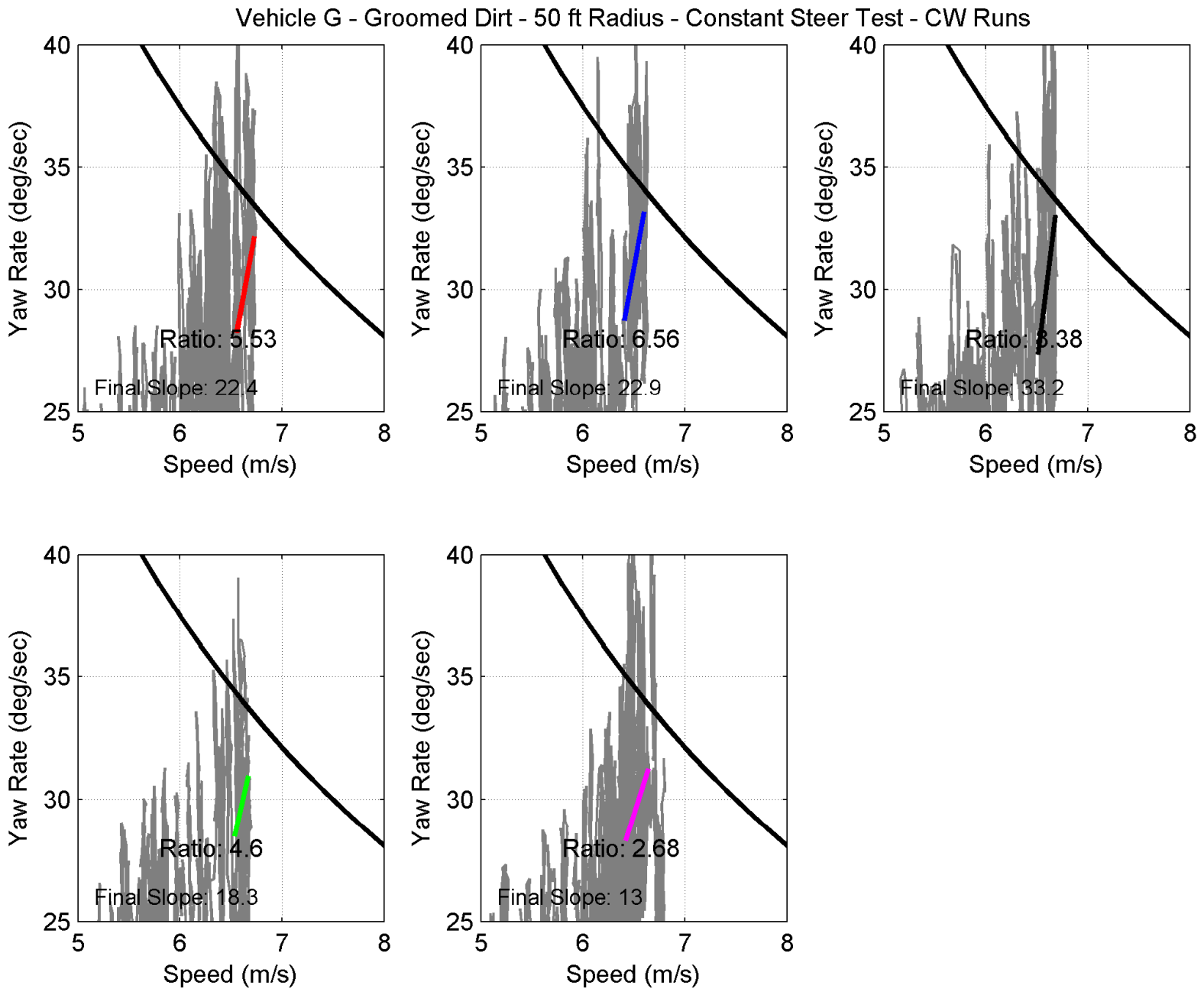
0.445

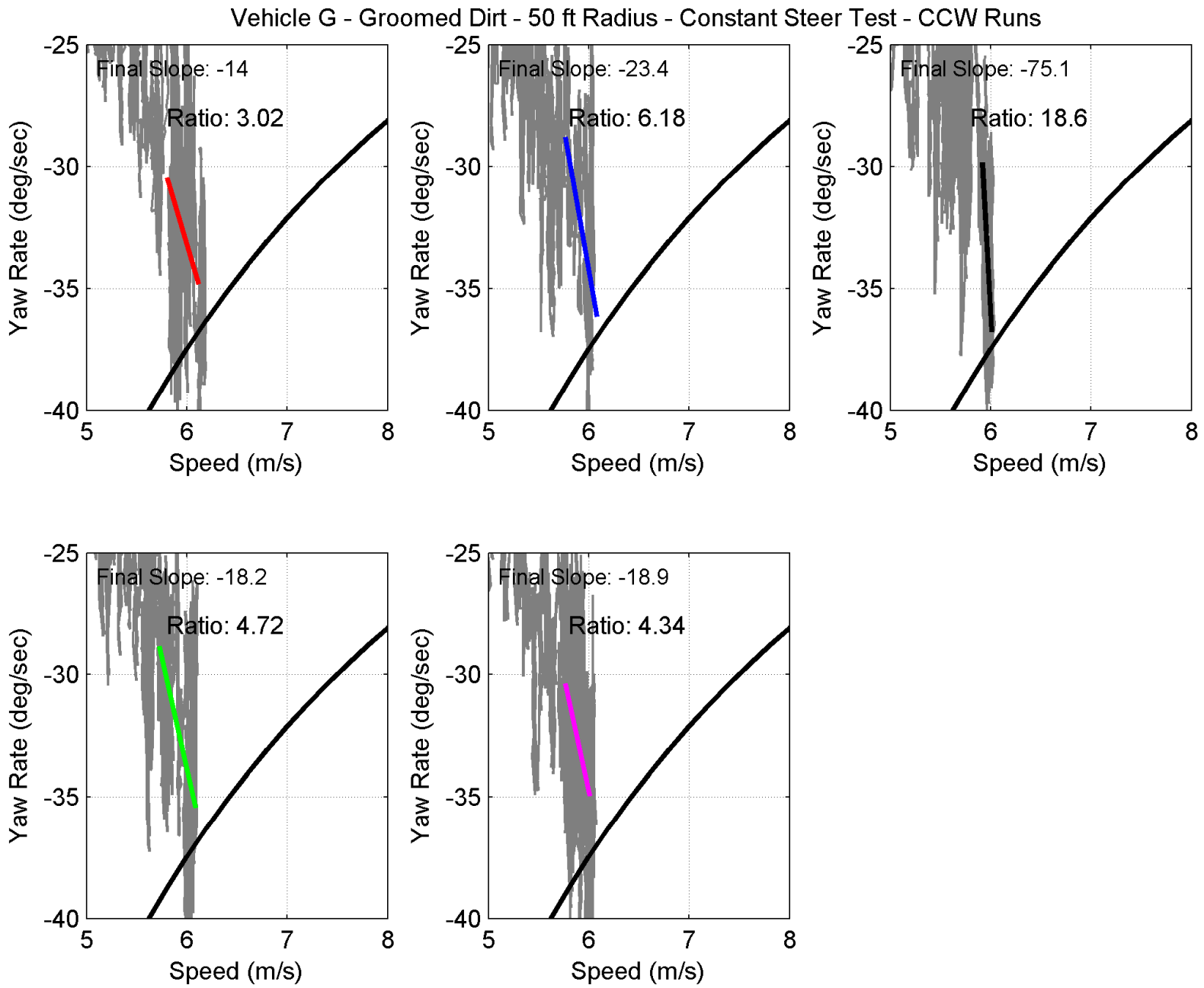
Threshold Ay

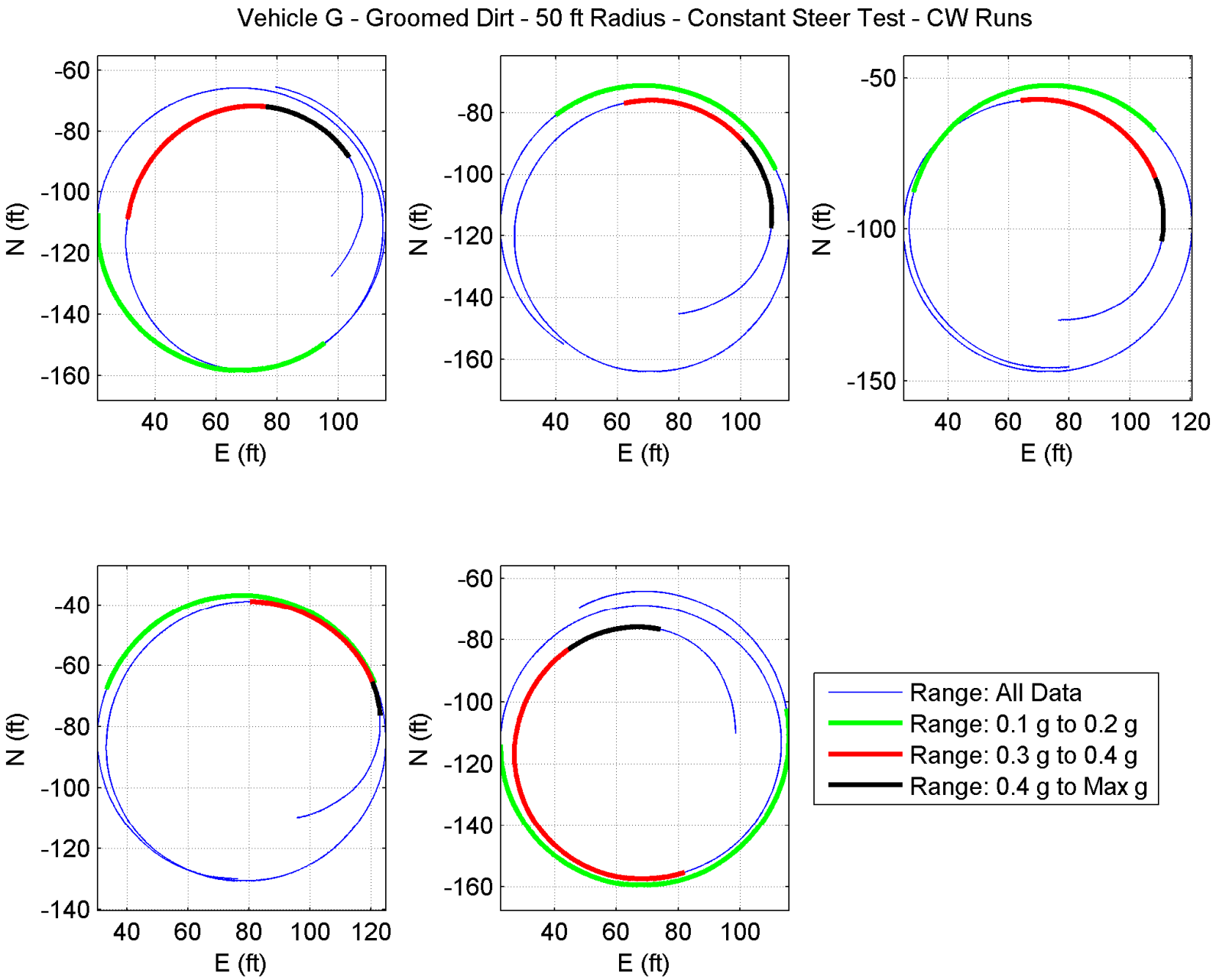

Vehicle G - Groomed Dirt
Roadwheel Steer Angle (deg)
10
5
0
-5
-10
0
20
40
60
80
Estimated Ay (g)
0.5
0
-0.5
Time (sec)
50 ft Radius - Constant Steer Test
Speed (m/s)
8
6
4
2
0
Roll Angle (deg)
10
5
0
-5
-10
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

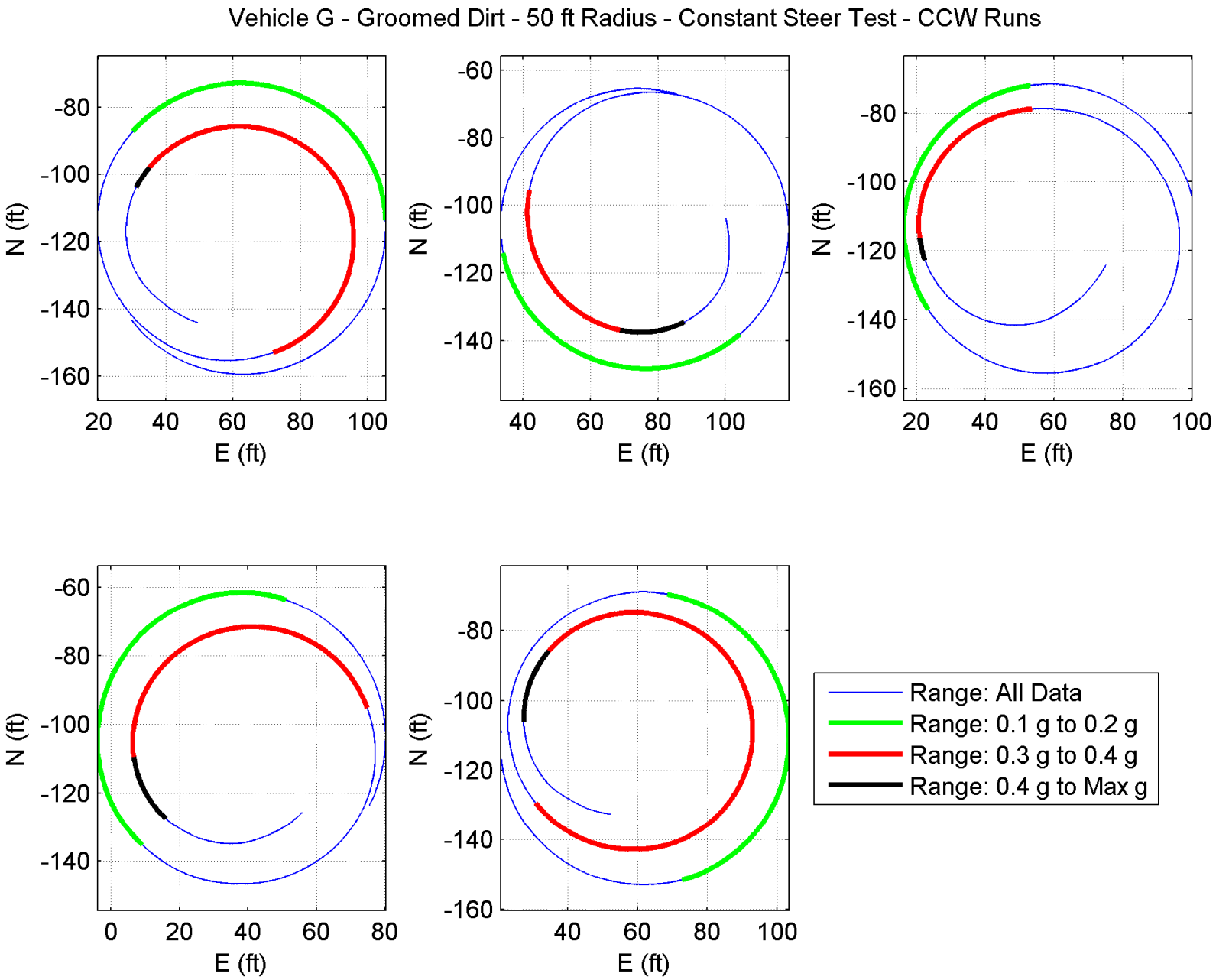

Vehicle G - Groomed Dirt - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8

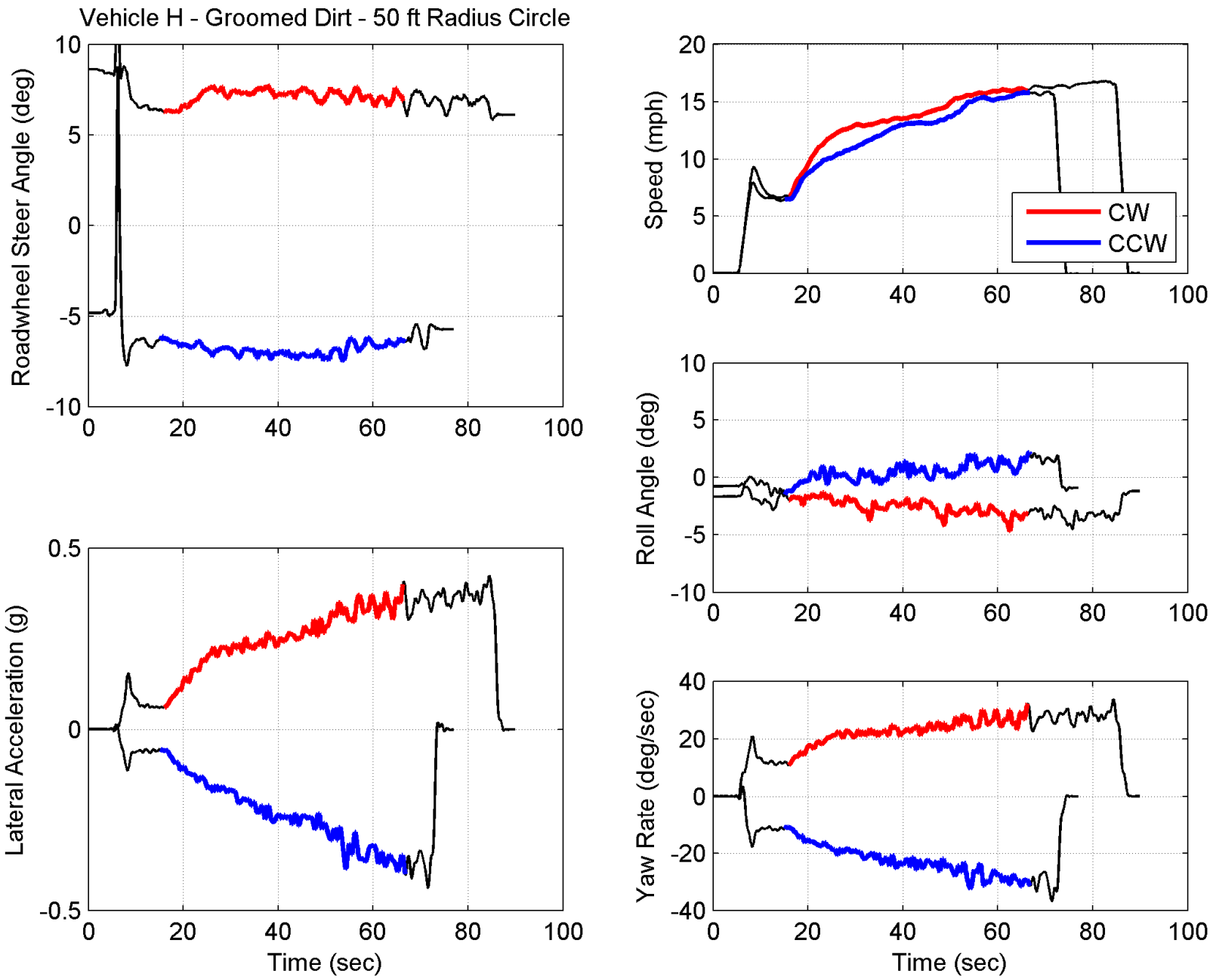

Vehicle G - Groomed Dirt - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 4.04 3.49 3.96 3.97 4.84 STD=0.49
CW Final Slopes: 22.4 22.9 33.2 18.3 13 STD=7.44
CW Ratios: 5.53 6.56 8.38 4.6 2.68 STD=2.13
CW Average: 5.55
Average Ratio: 6.46
CCW Average: 7.37
CCW Ratios: 3.02 6.18 18.6 4.72 4.34 STD=6.38
CCW Final Slopes: -14 -23.4 -75.1 -18.2 -18.9 STD=25.5
CCW Initial Slopes: -4.64 -3.79 -4.04 -3.85 -4.36 STD=0.358
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8

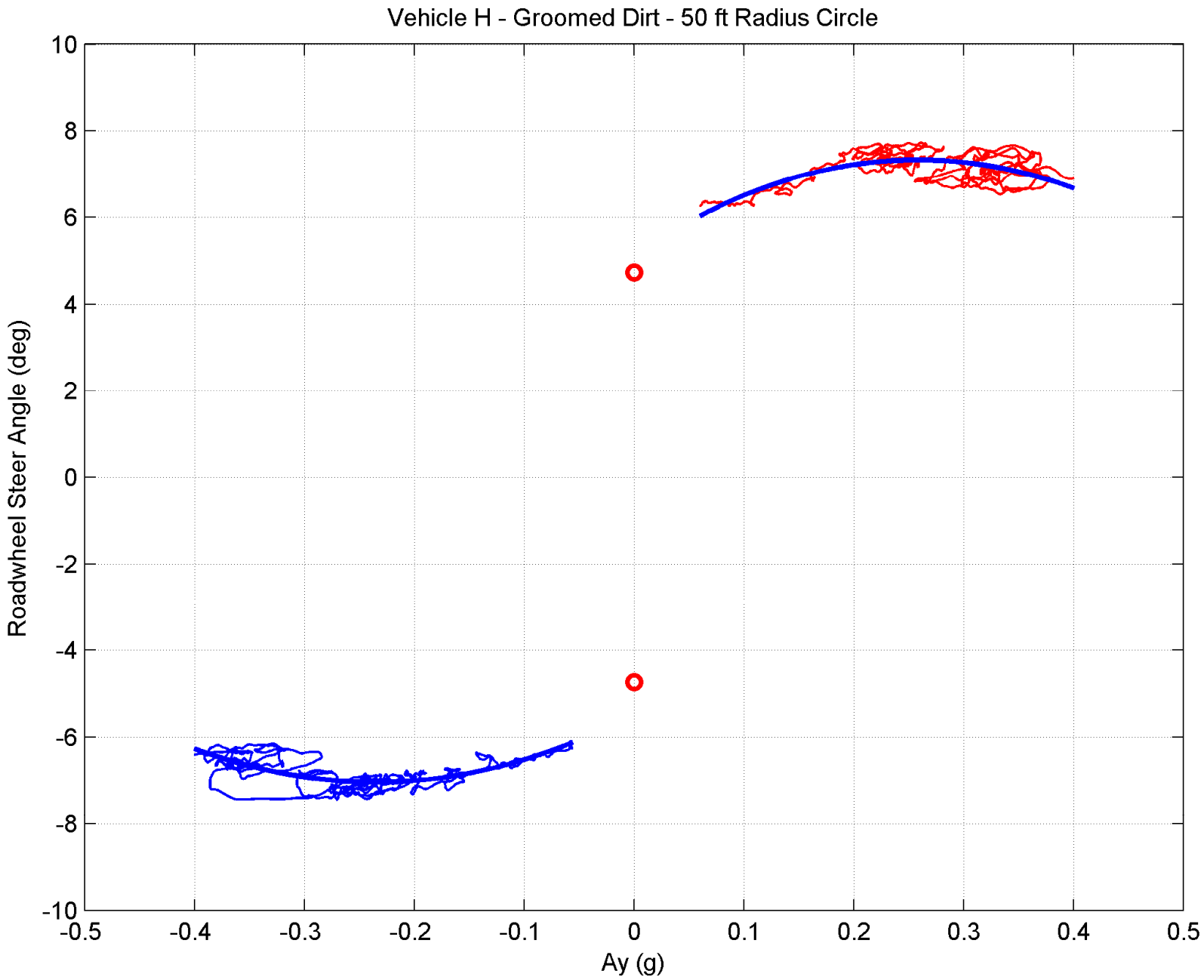

Vehicle G - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 5.53
Final Slope: 22.4
Ratio: 6.56
Final Slope: 22.9
Ratio: 8.38
Final Slope: 33.2
Ratio: 4.6
Final Slope: 18.3
Ratio: 2.68
Final Slope: 13

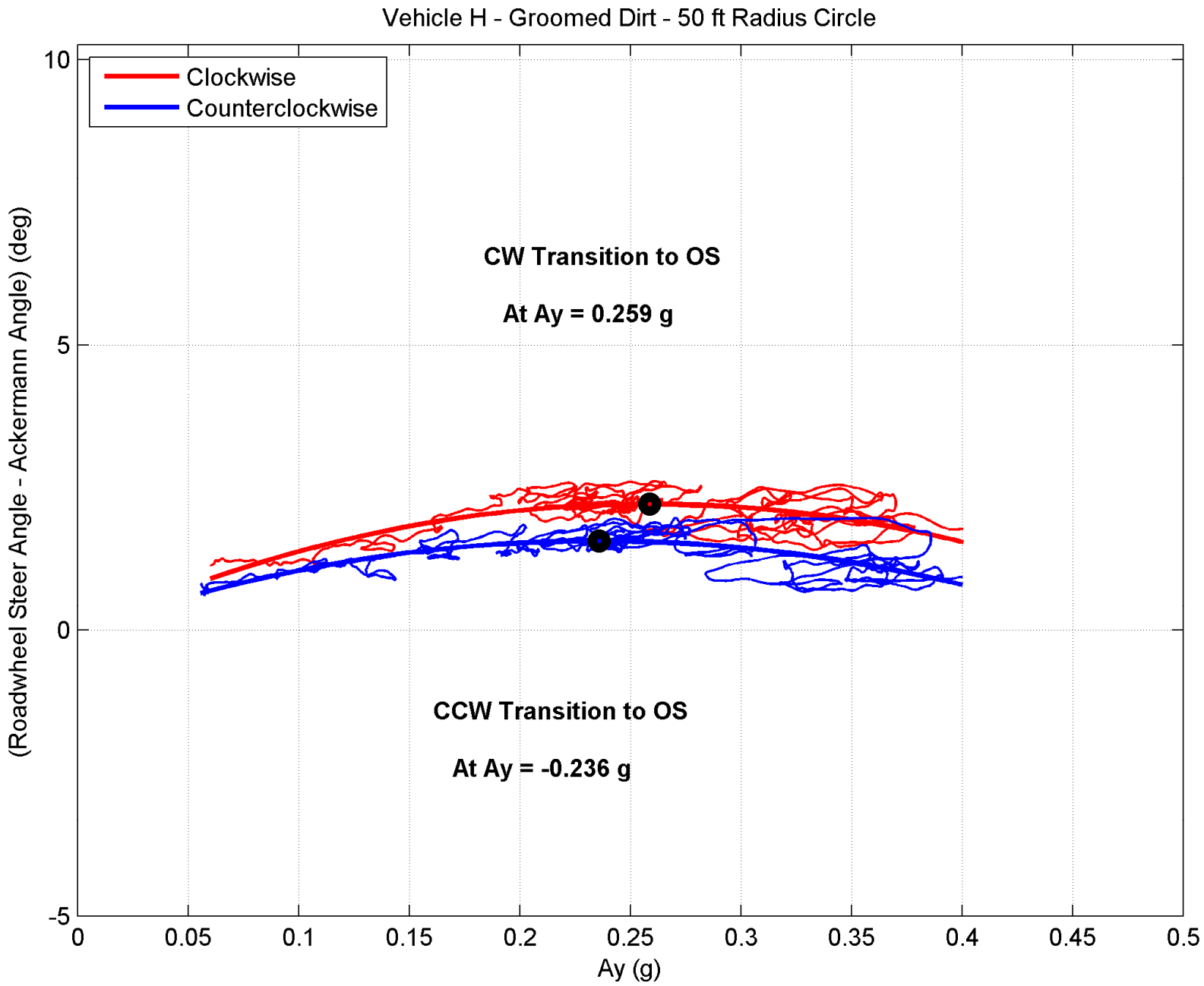

Vehicle G - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -14
Ratio: 3.02
Final Slope: -23.4
Ratio: 6.18
Final Slope: -75.1
Ratio: 18.6
Final Slope: -18.2
Ratio: 4.72
Final Slope: -18.9
Ratio: 4.34
Yaw Rate (deg/sec)
Speed (m/s)
-25
-30
-35
-40
5
6
7
8

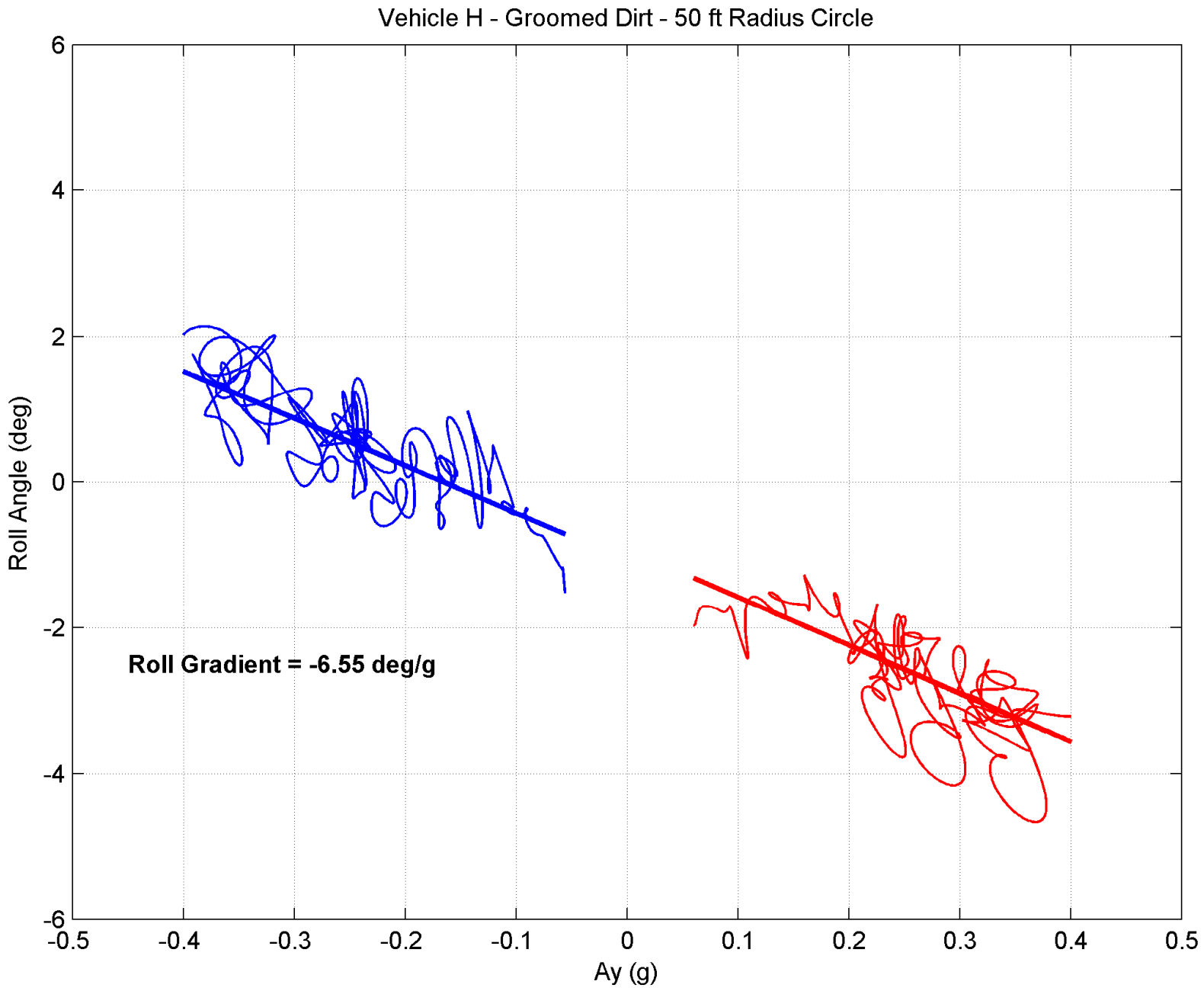

Vehicle G - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

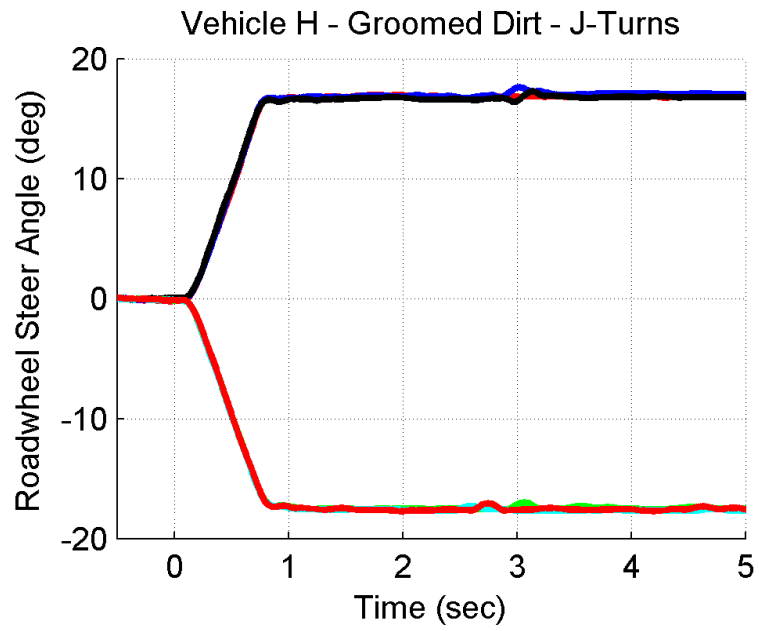

Vehicle G - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

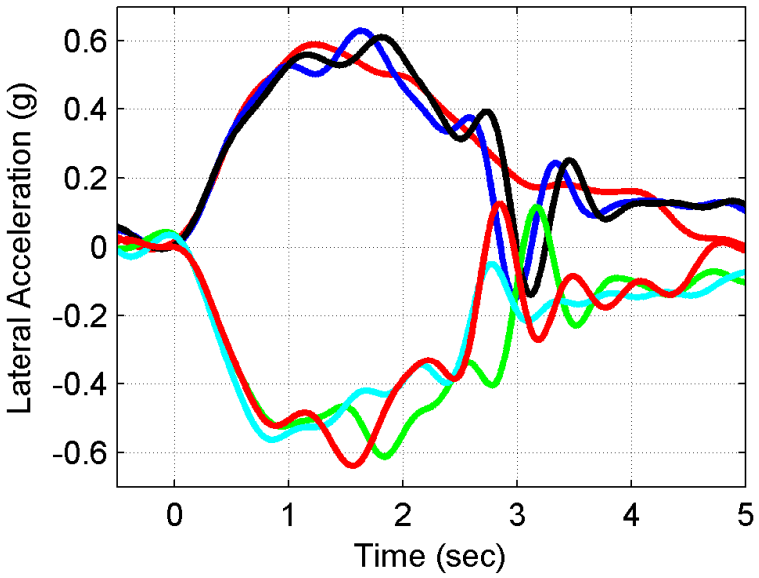

Vehicle H - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

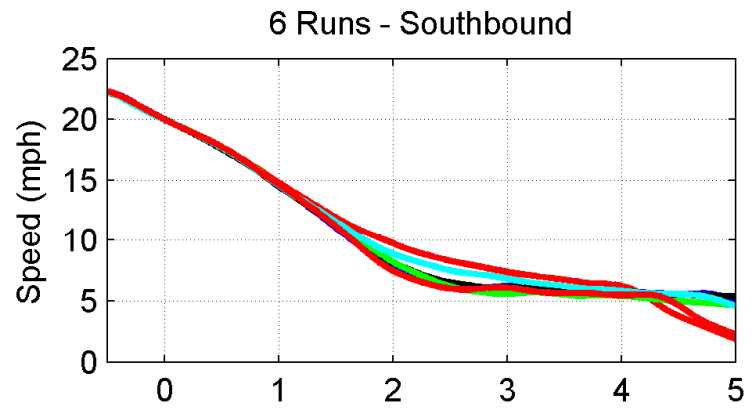

Vehicle H - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

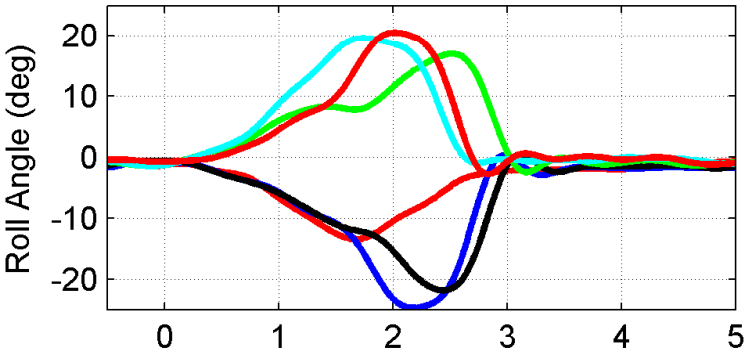

Vehicle H - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.259 g
CCW Transition to OS
At Ay = -0.236 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

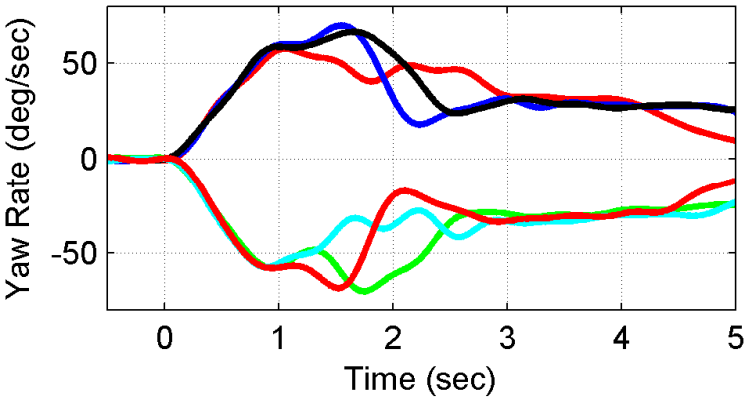

Vehicle H - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -6.55 deg/g
6
4
2
0
-2
-4
-6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

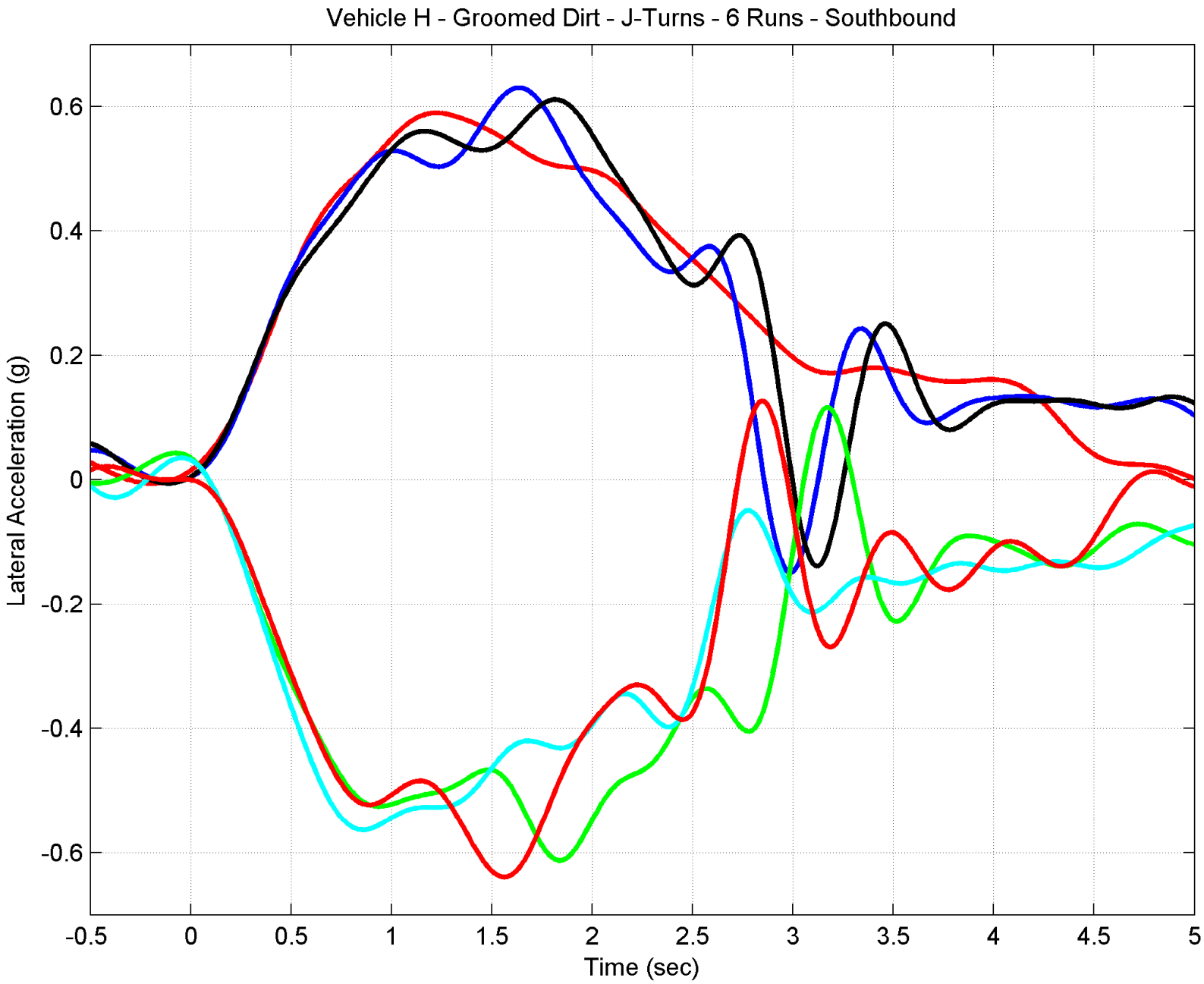

Vehicle H - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5
Time (sec)

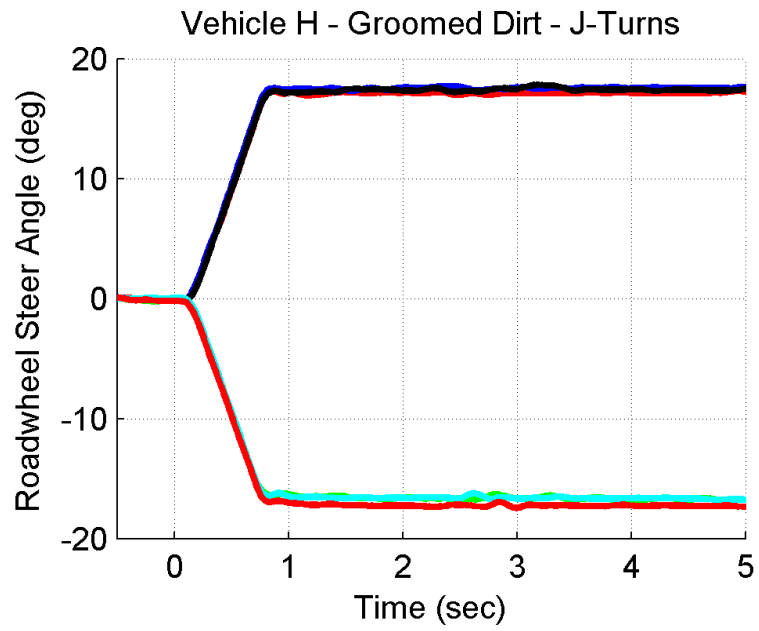

Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
1
2
3
4
5
Time (sec)

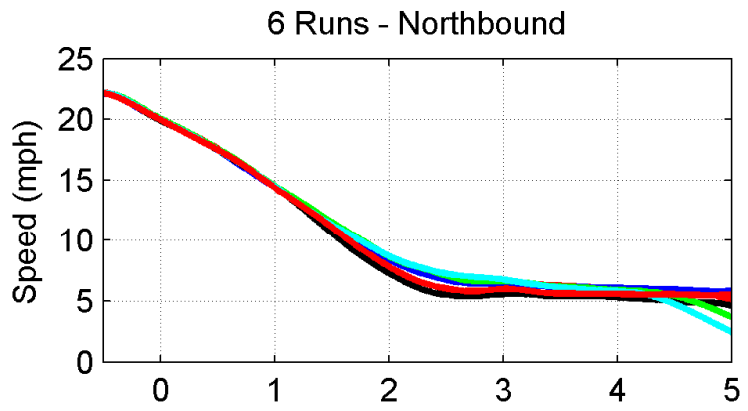

6 Runs - Southbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5

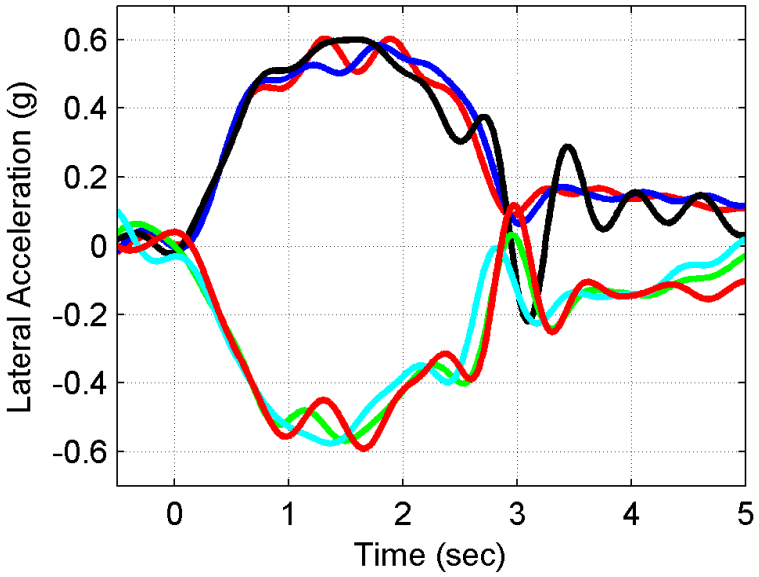

Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5

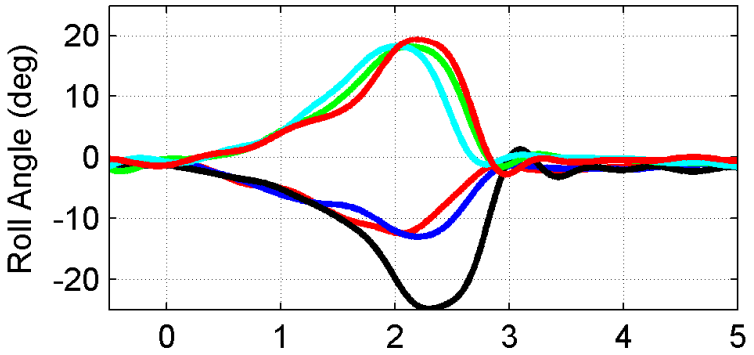

Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)

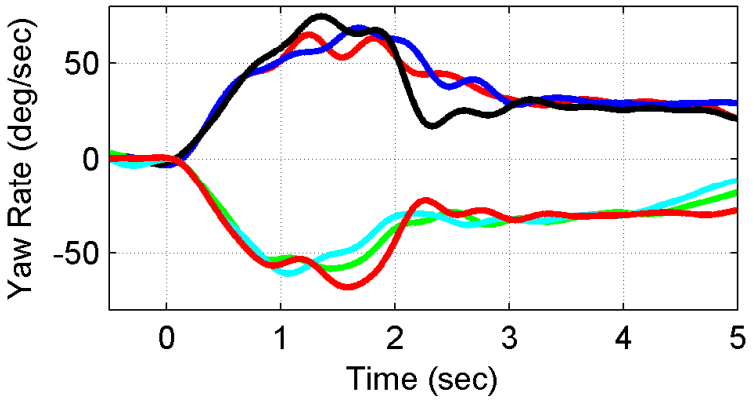

Vehicle H - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

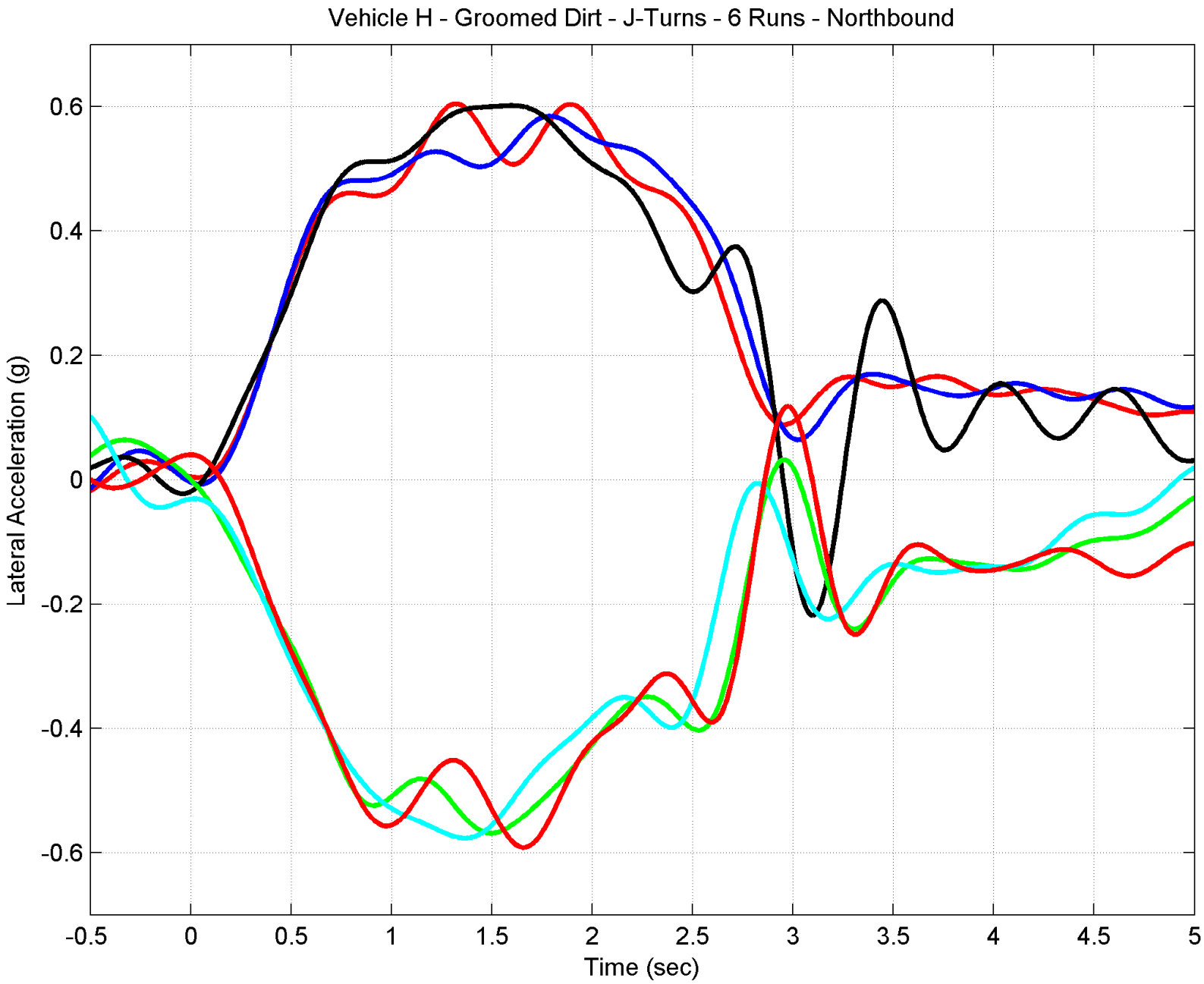

Vehicle H - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
1
2
3
4
5
Time (sec)


Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5


Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle H - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle H - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.590	-0.613
2	0.630	-0.563
3	0.612	-0.640
Mean Value of 3 Runs	0.611	-0.605
Standard Deviation of 3 Runs	0.020	0.039

Average of 6 North Runs

0.608

Run Number	North Right Turns	North Left Turns
1	0.605	-0.569
2	0.585	-0.577
3	0.602	-0.592
Mean Value of 3 Runs	0.597	-0.579
Standard Deviation of 3 Runs	0.011	0.012

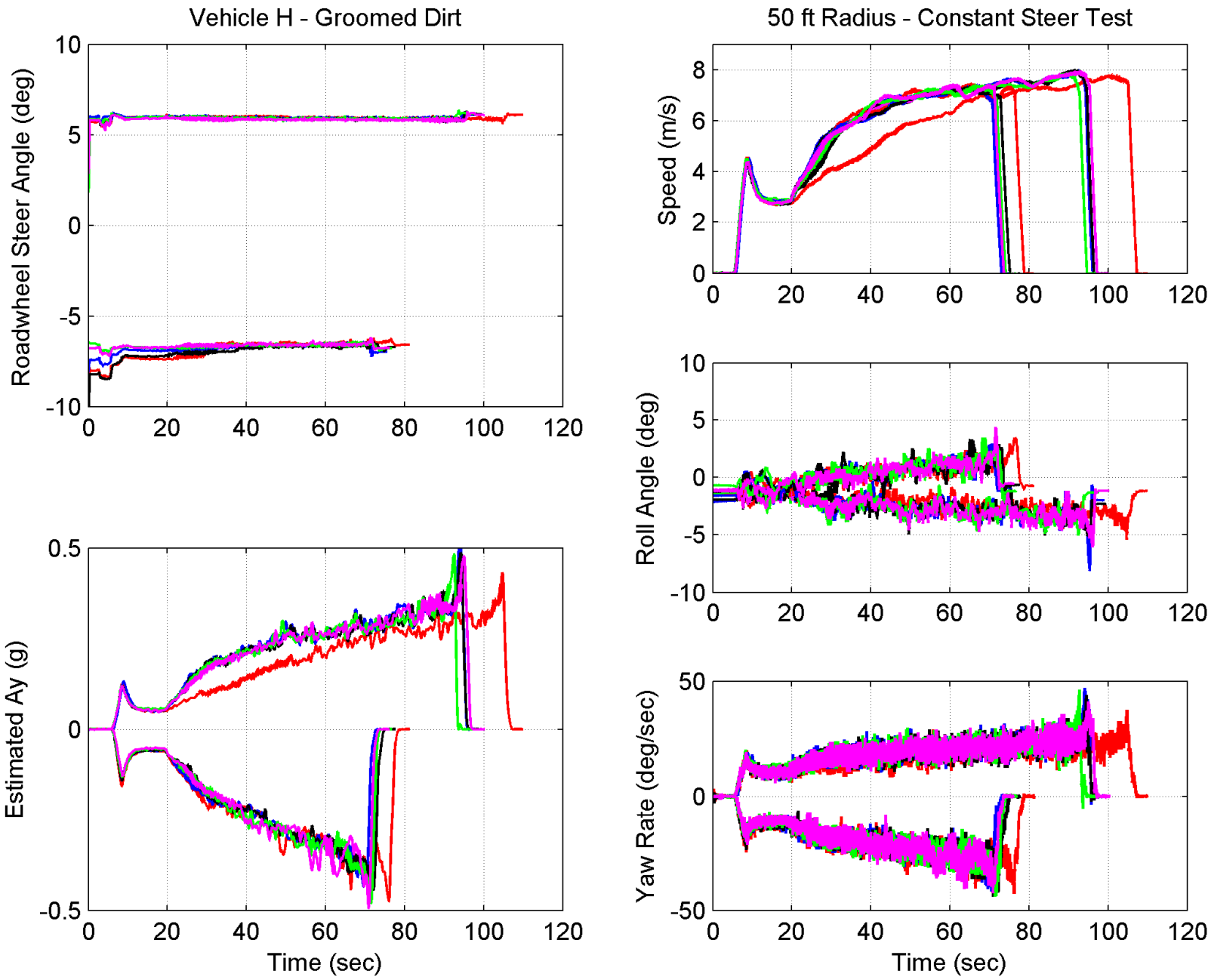
Average of 6 South Runs

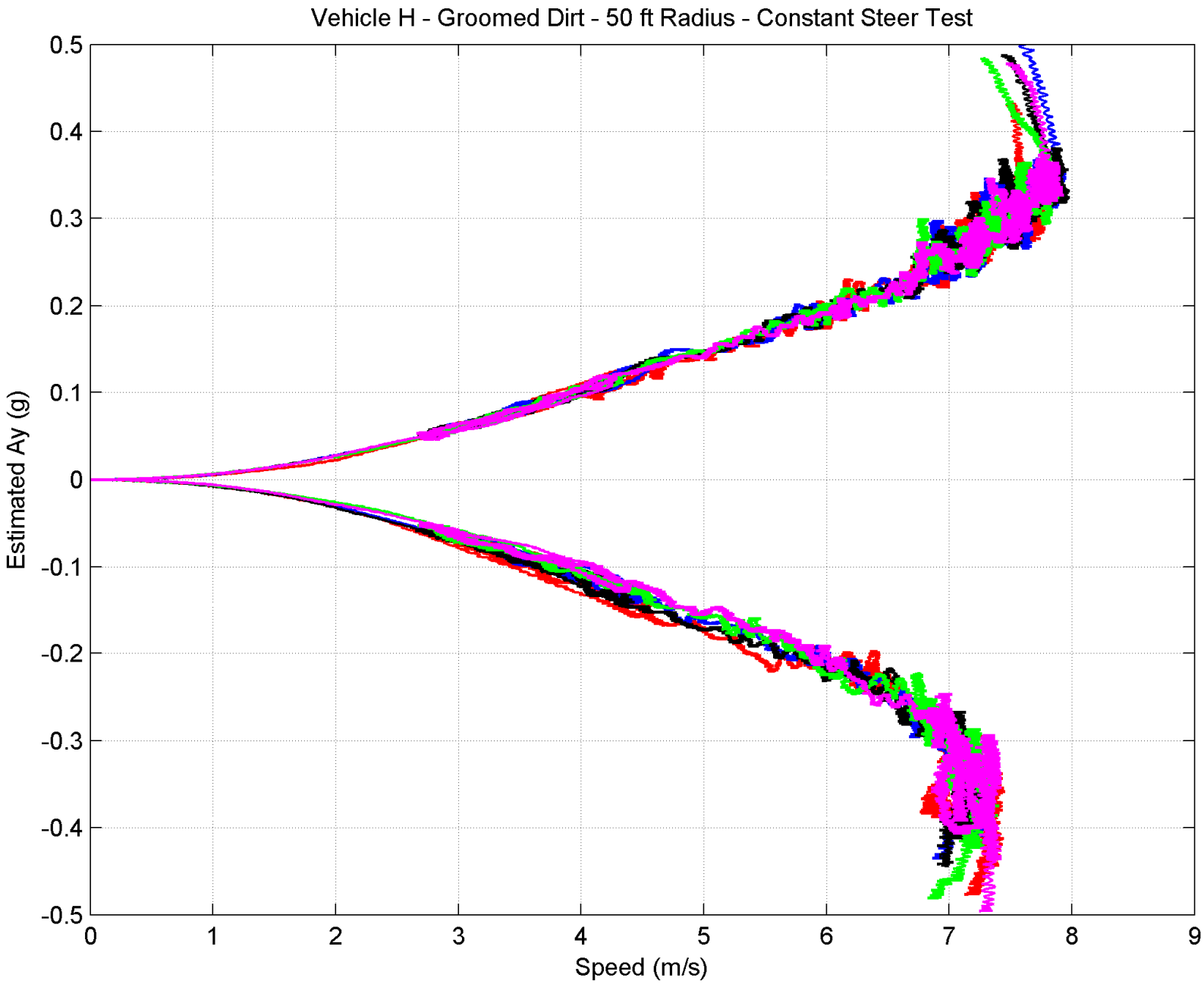
0.588

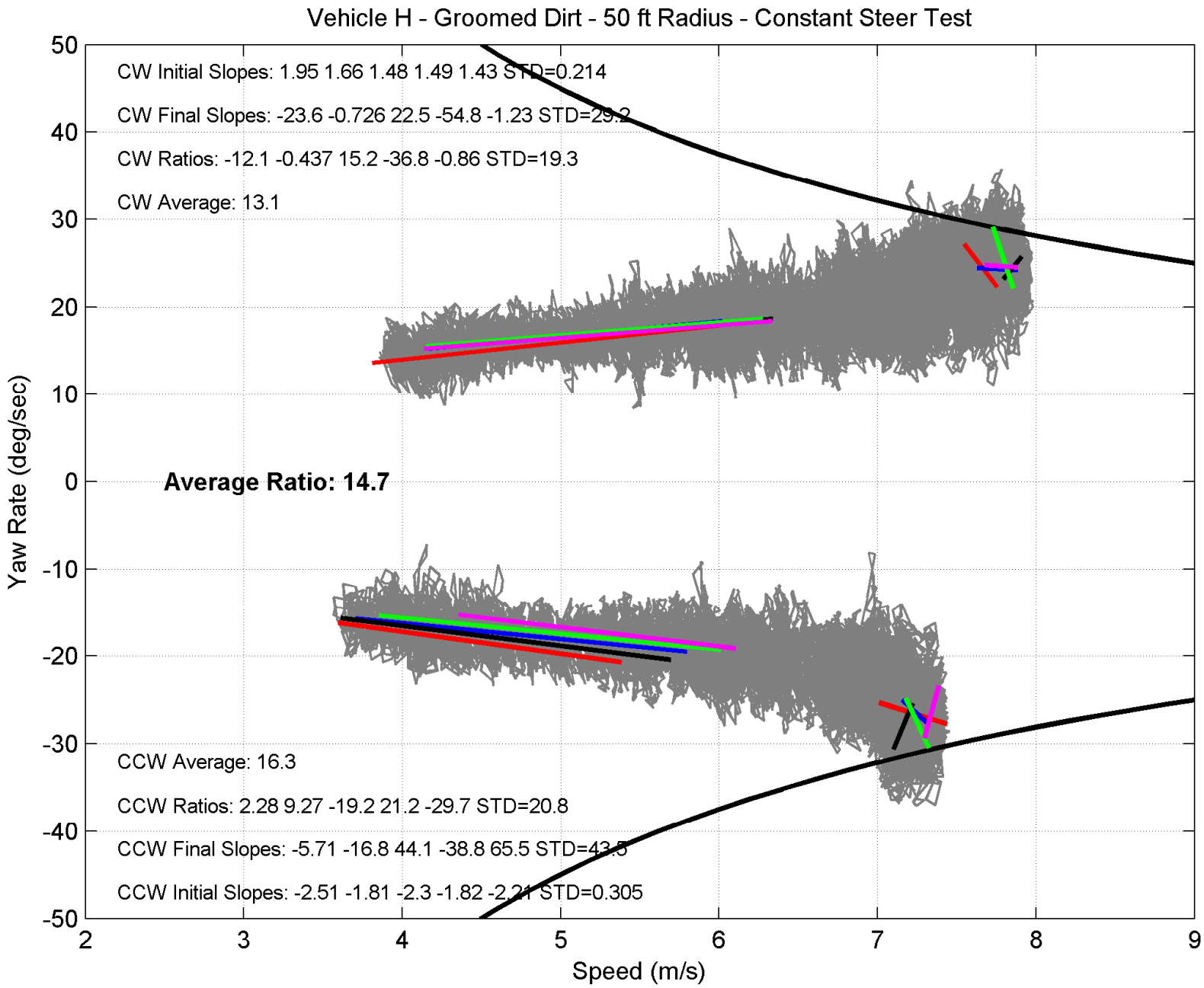
Average of All 12 Runs

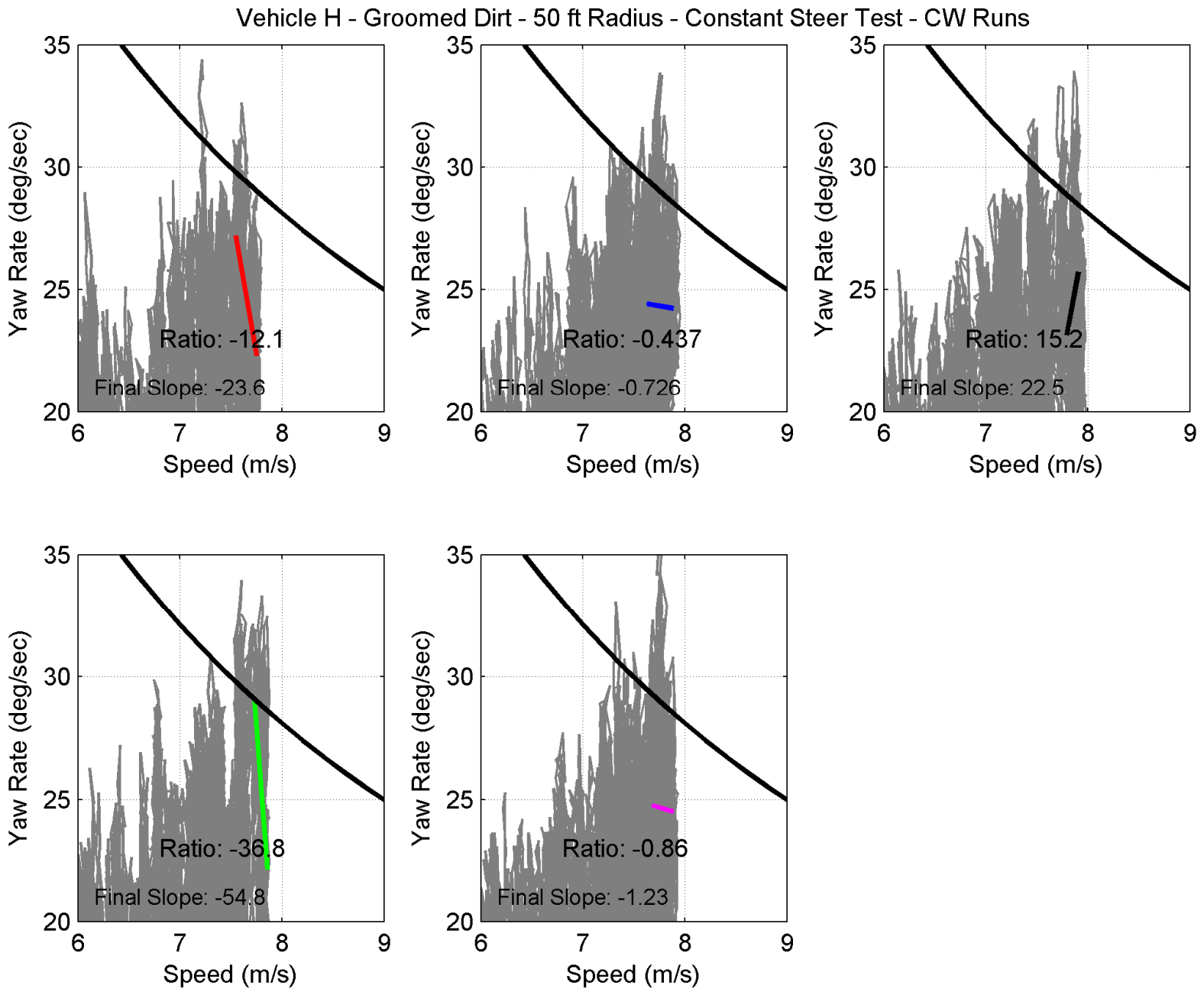
0.598

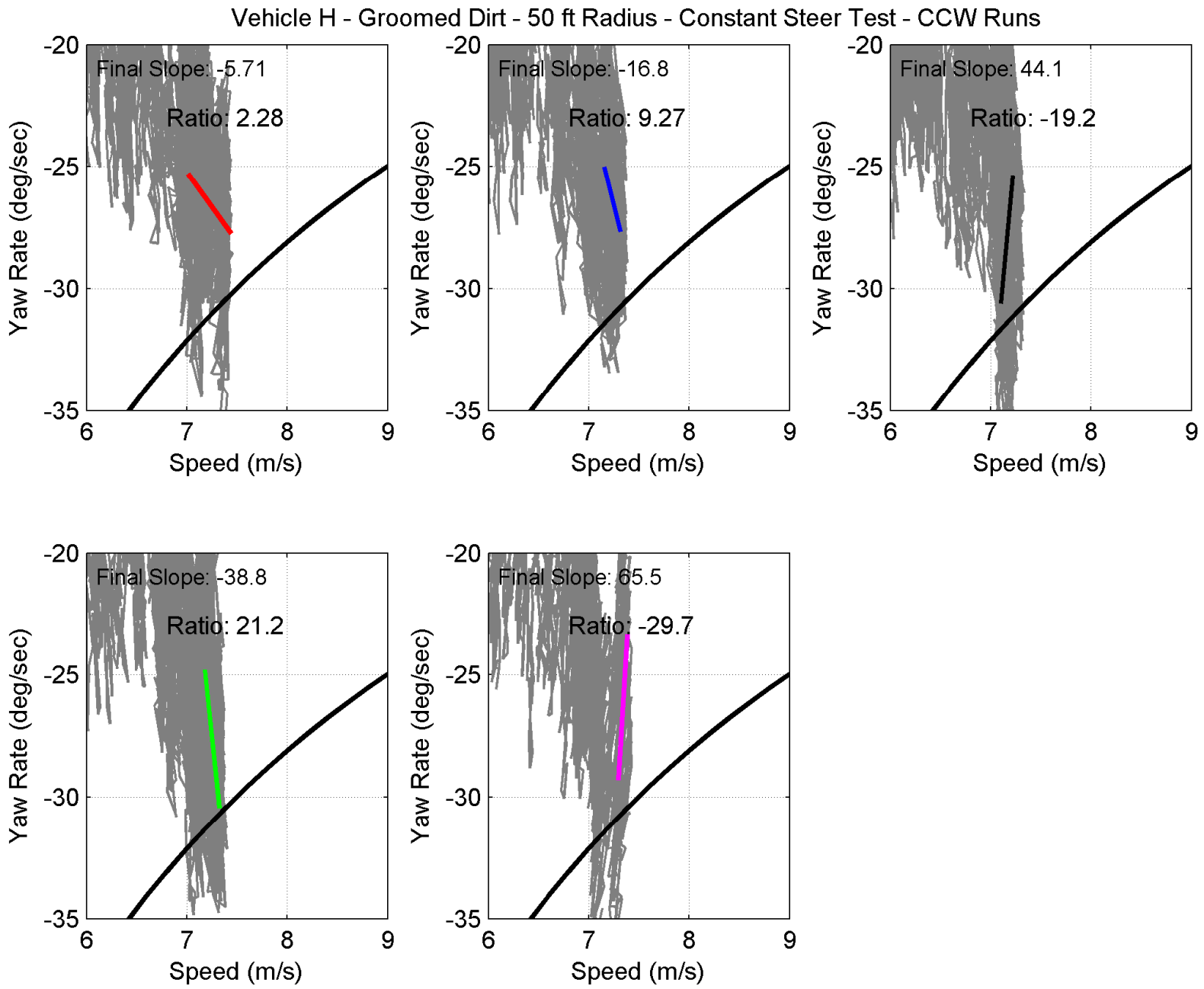
Threshold Ay

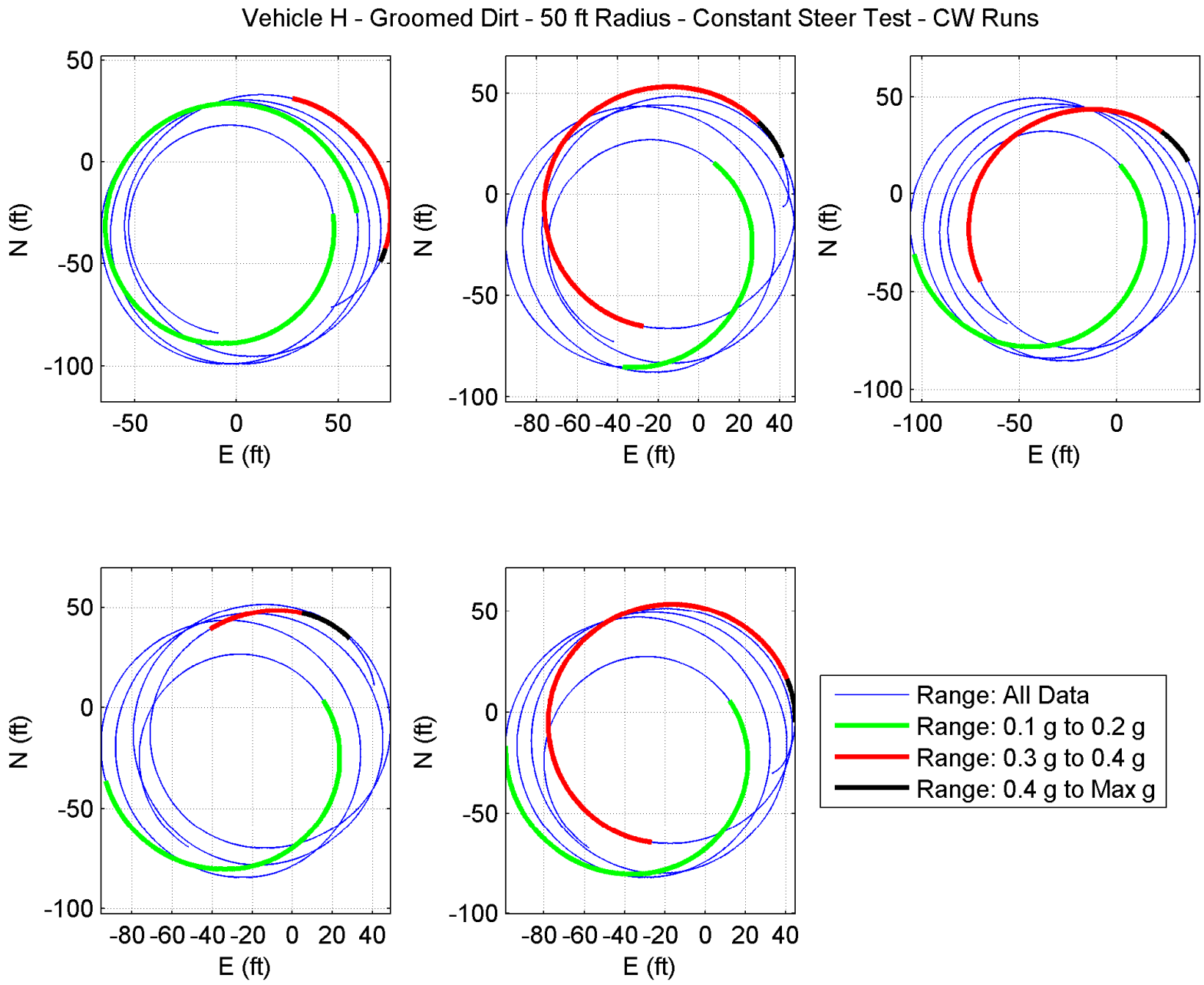

Vehicle H - Groomed Dirt
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

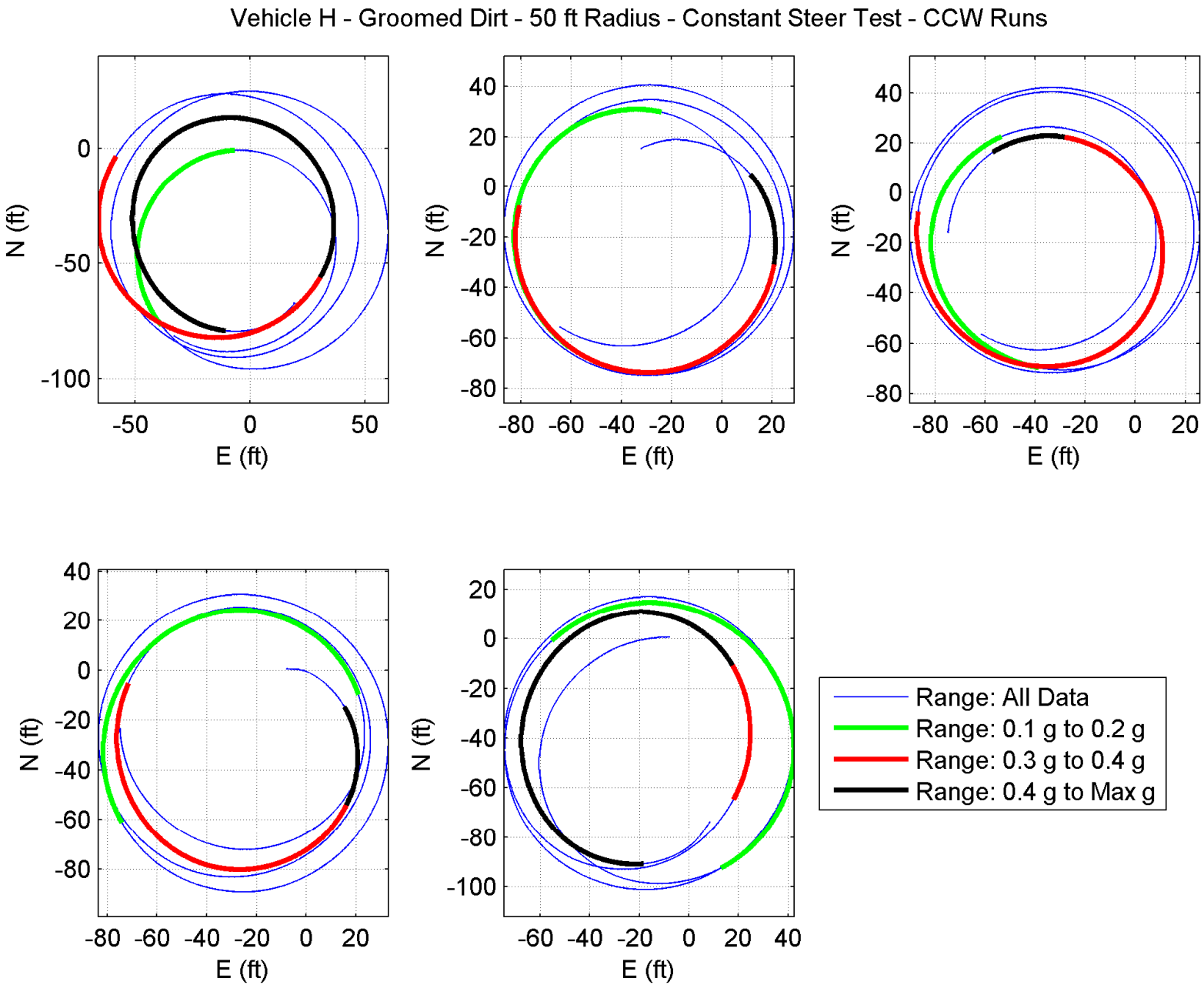

Vehicle H - Groomed Dirt - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

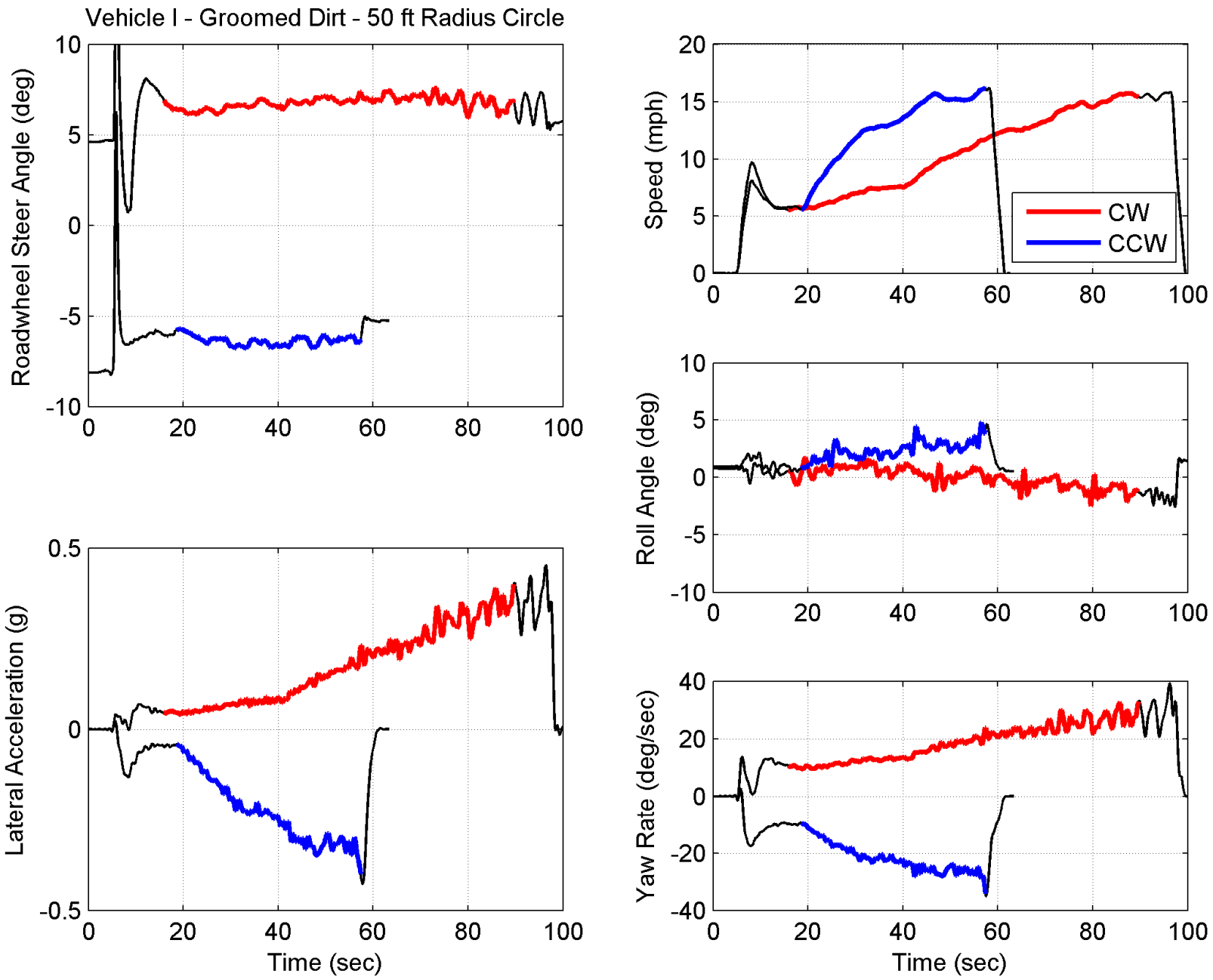

Vehicle H - Groomed Dirt - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 1.95 1.66 1.48 1.49 1.43 STD=0.214
CW Final Slopes: -23.6 -0.726 22.5 -54.8 -1.23 STD=29.2
CW Ratios: -12.1 -0.437 15.2 -36.8 -0.86 STD=19.3
CW Average: 13.1
Average Ratio: 14.7
CCW Average: 16.3
CCW Ratios: 2.28 9.27 -19.2 21.2 -29.7 STD=20.8
CCW Final Slopes: -5.71 -16.8 44.1 -38.8 65.5 STD=43.5
CCW Initial Slopes: -2.51 -1.81 -2.3 -1.82 -2.21 STD=0.305
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8
9

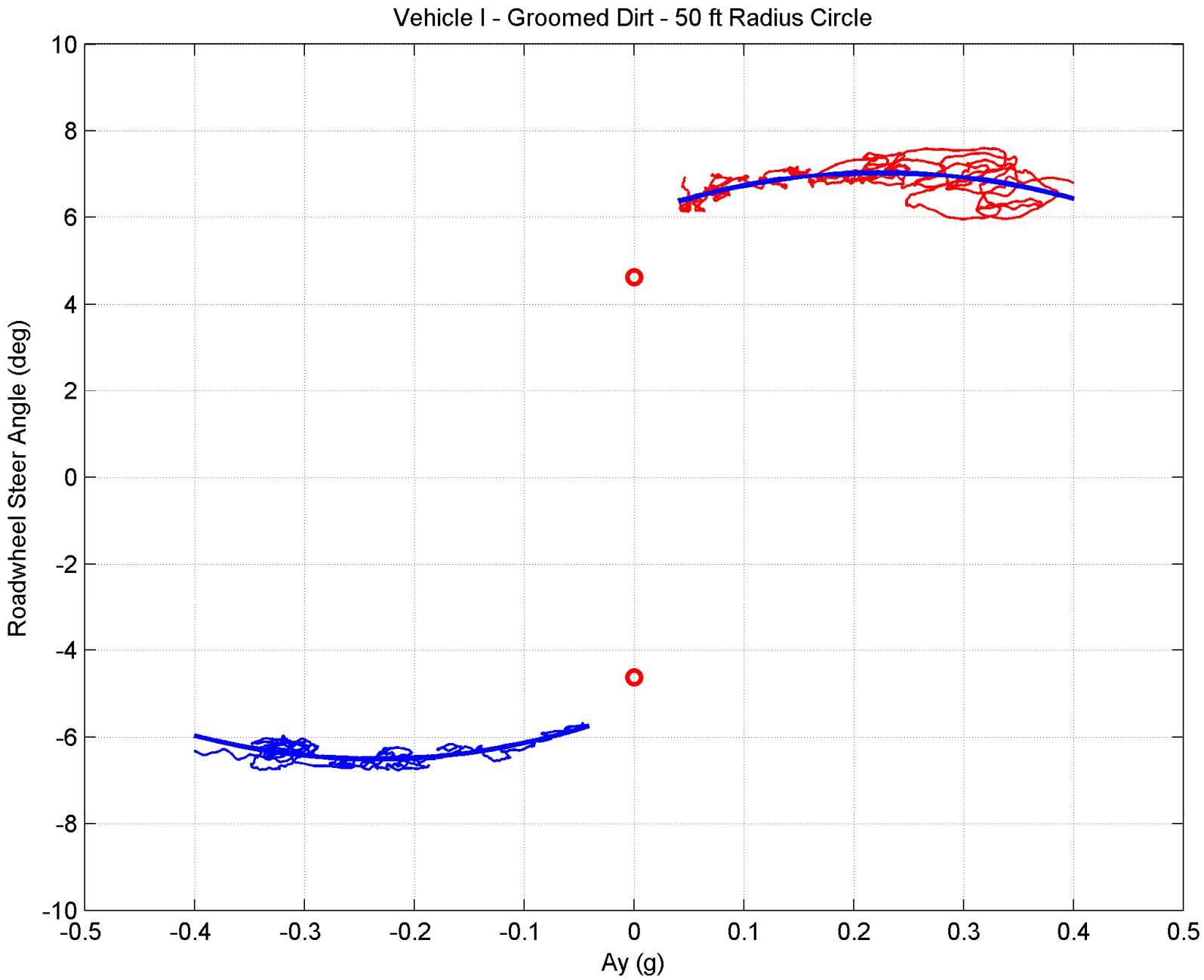

Vehicle H - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: -12.1
Final Slope: -23.6
Ratio: -0.437
Final Slope: -0.726
Ratio: 15.2
Final Slope: 22.5
Ratio: -36.8
Final Slope: -54.8
Ratio: -0.86
Final Slope: -1.23

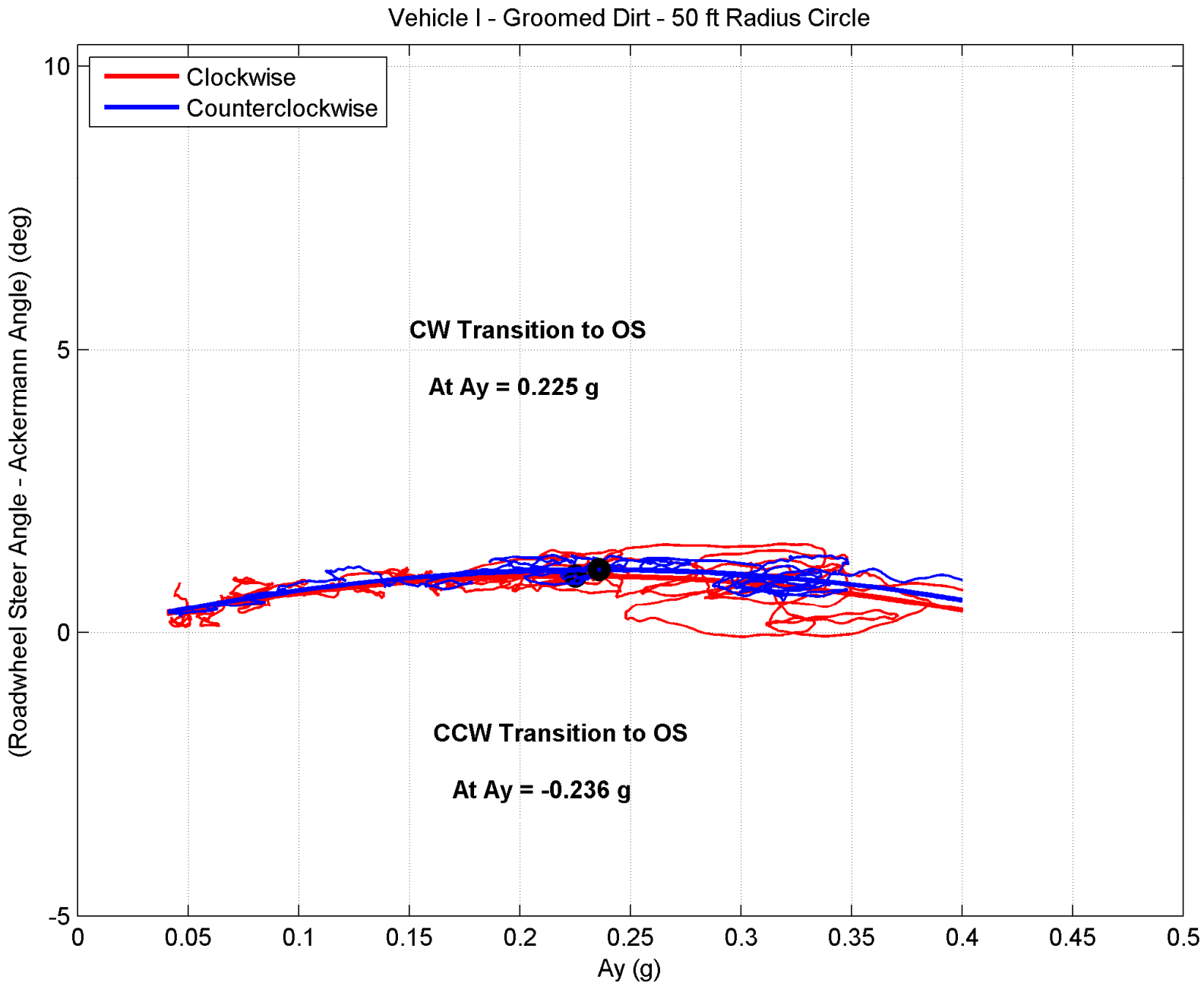

Vehicle H - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -5.71
Ratio: 2.28
Final Slope: -16.8
Ratio: 9.27
Final Slope: 44.1
Ratio: -19.2
Final Slope: -38.8
Ratio: 21.2
Final Slope: 65.5
Ratio: -29.7
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

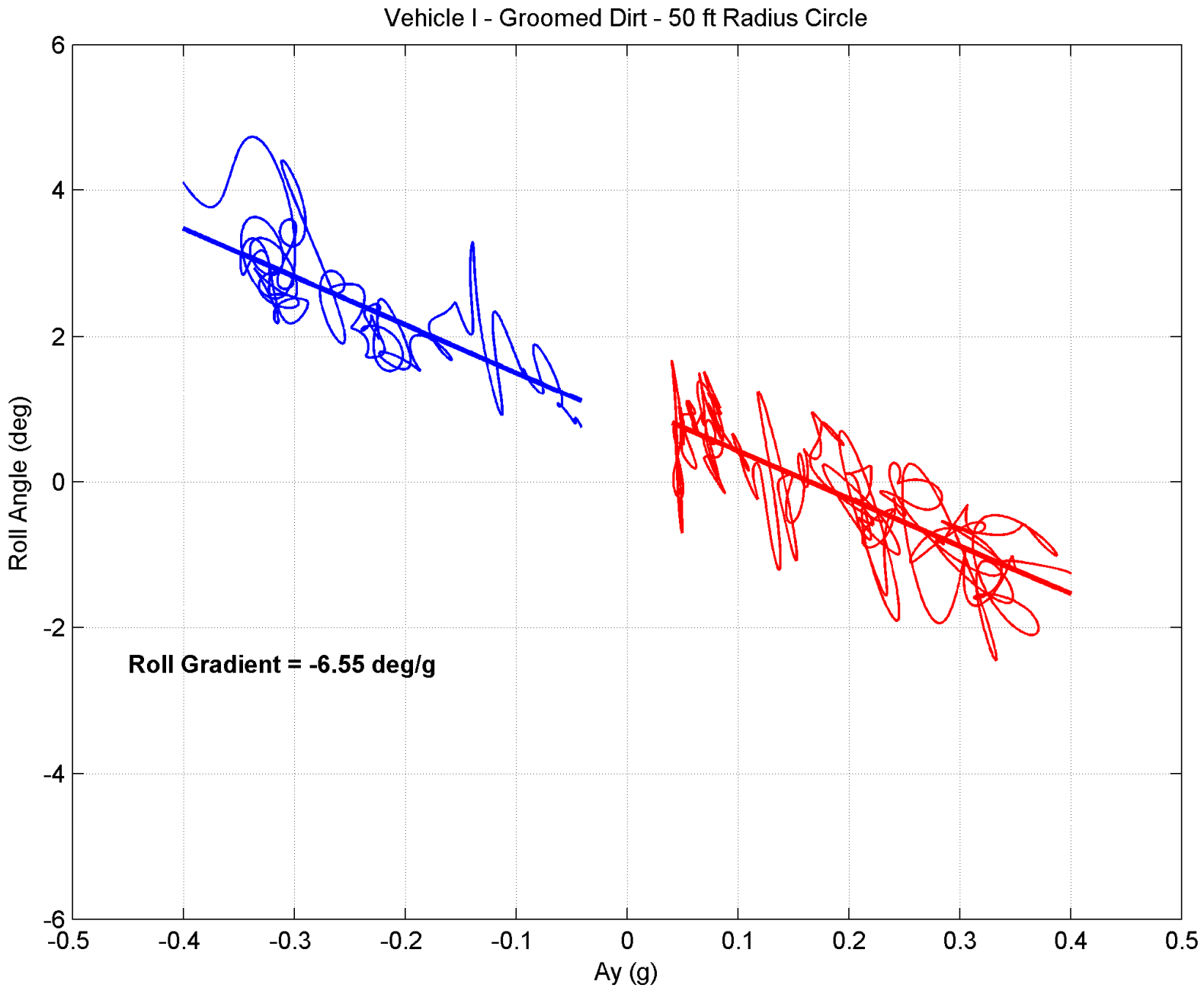

Vehicle H - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
50
0
-50
-100
-80 -60 -40 -20 0 20 40
-100 -50 0
-50 0 50
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

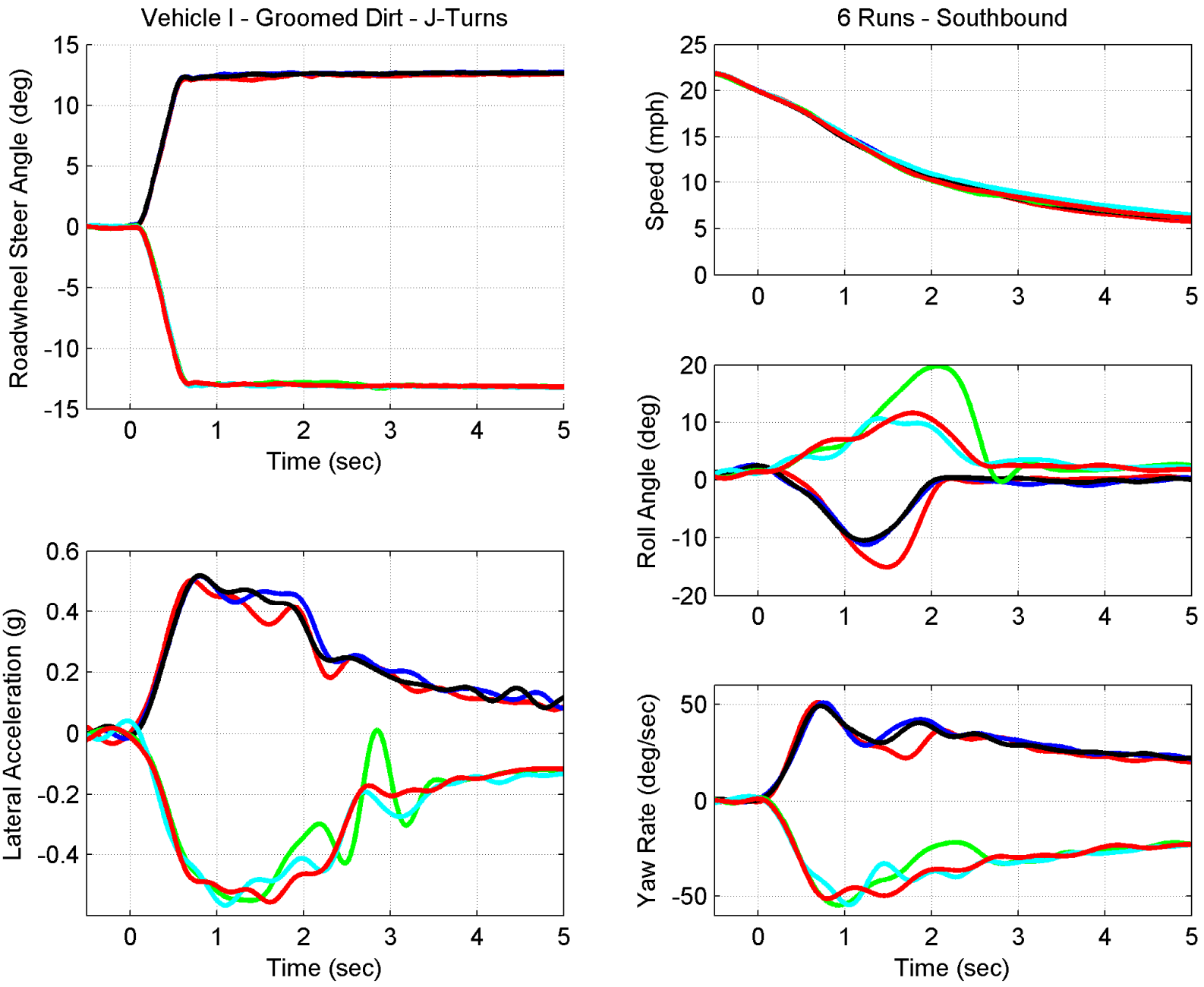

Vehicle H - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

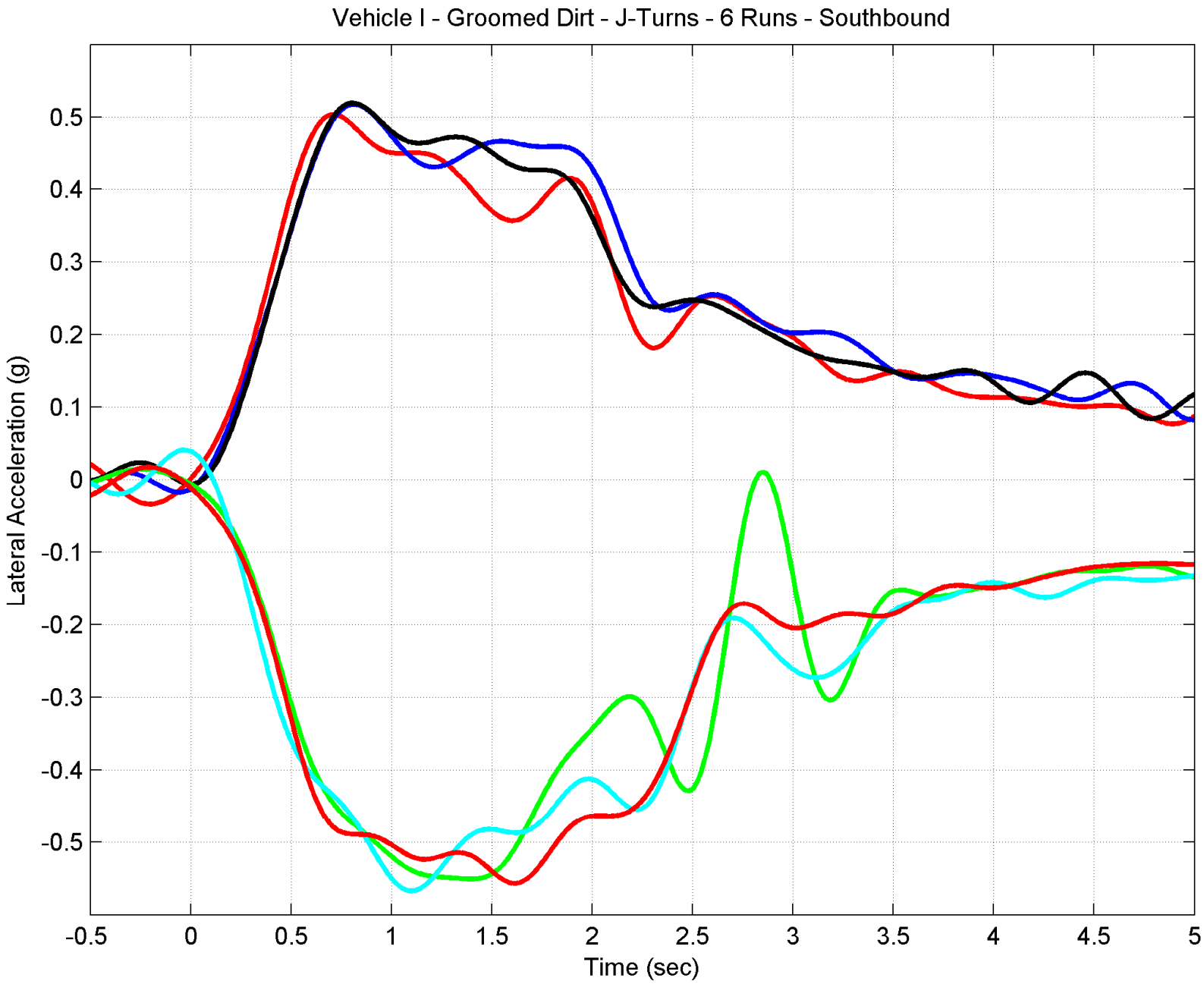

Vehicle I - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

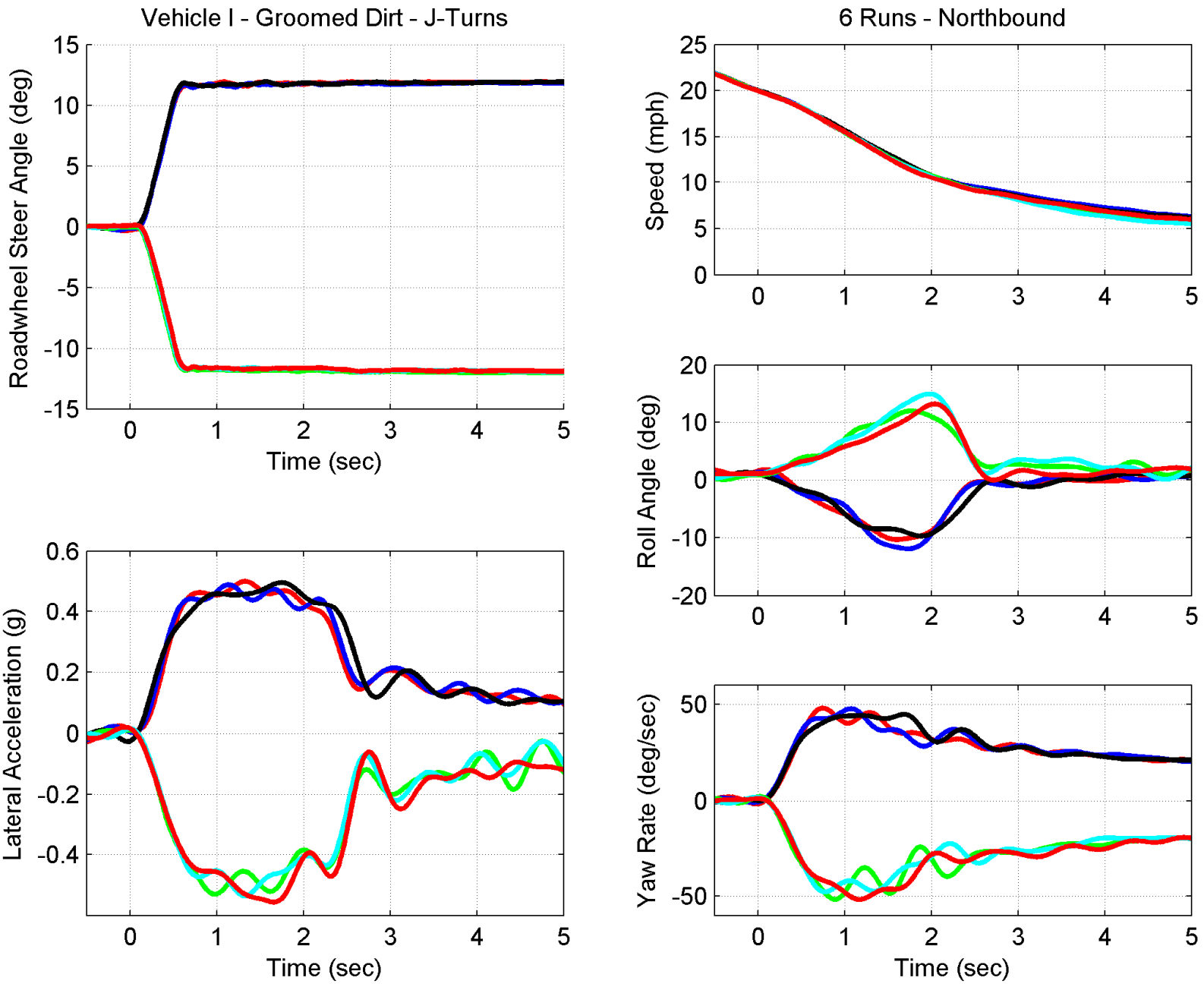

Vehicle I - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

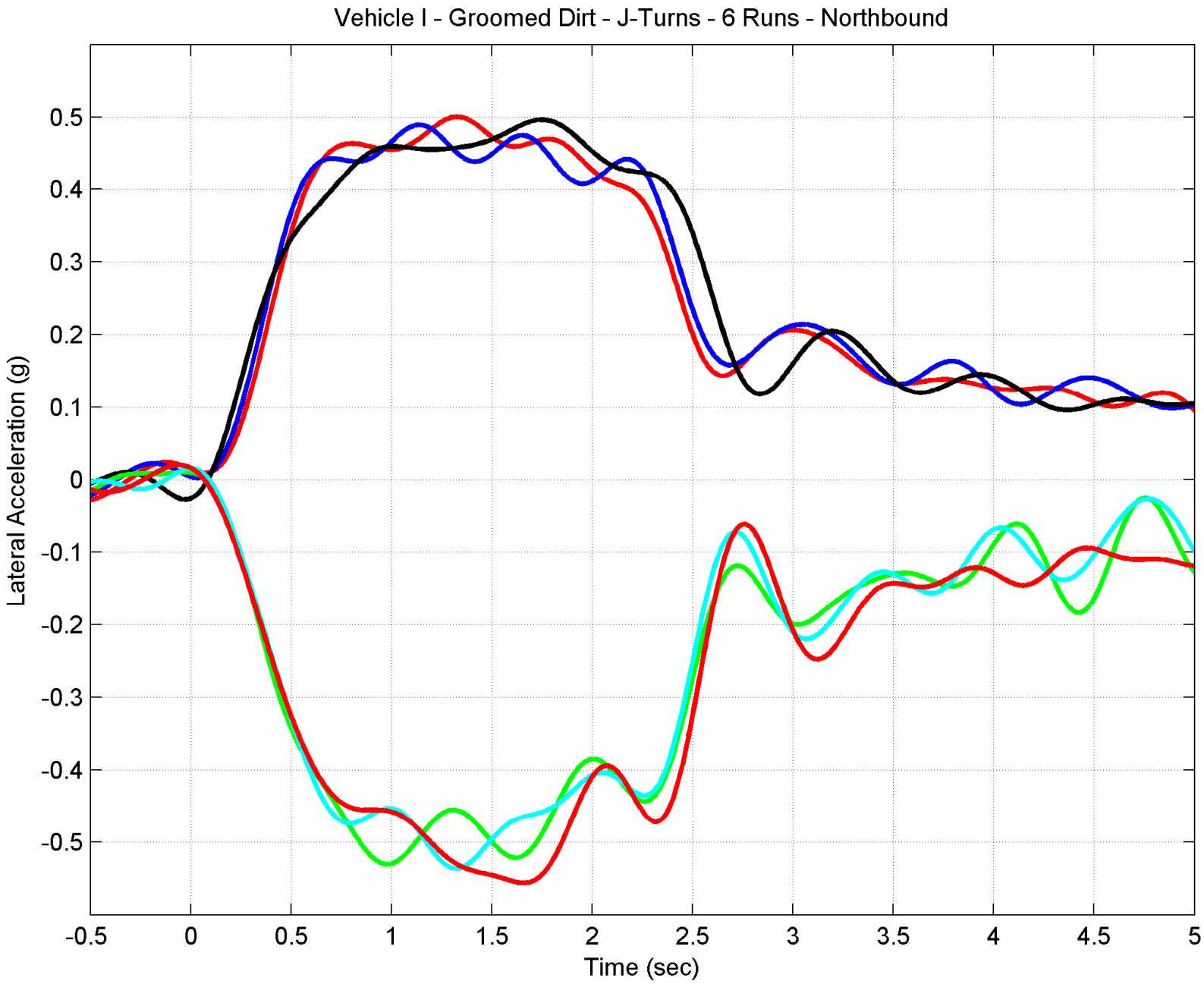

Vehicle I - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.225 g
CCW Transition to OS
At Ay = -0.236 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


Vehicle I - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -6.55 deg/g
6
4
2
0
-2
-4
-6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5


Vehicle I - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
Time (sec)
6 Runs - Southbound
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)


Vehicle I - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle I - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
6 Runs - Northbound
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)


Vehicle I - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle I - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.503	-0.551
2	0.517	-0.567
3	0.519	-0.557
Mean Value of 3 Runs	0.513	-0.558
Standard Deviation of 3 Runs	0.009	0.008

Average of 6 North Runs

0.536

Run Number	North Right Turns	North Left Turns
1	0.500	-0.531
2	0.489	-0.536
3	0.496	-0.556
Mean Value of 3 Runs	0.495	-0.541
Standard Deviation of 3 Runs	0.006	0.013

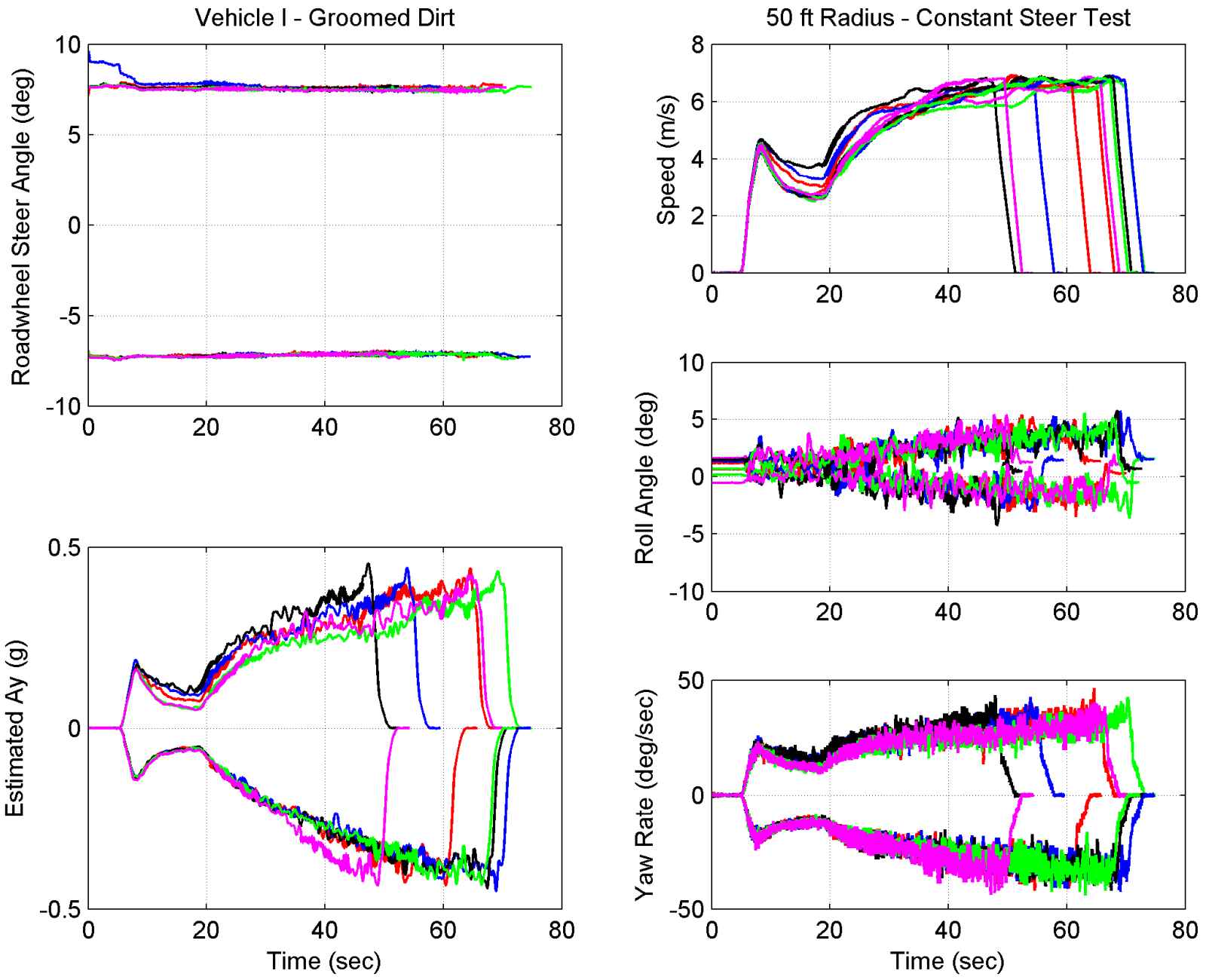
Average of 6 South Runs

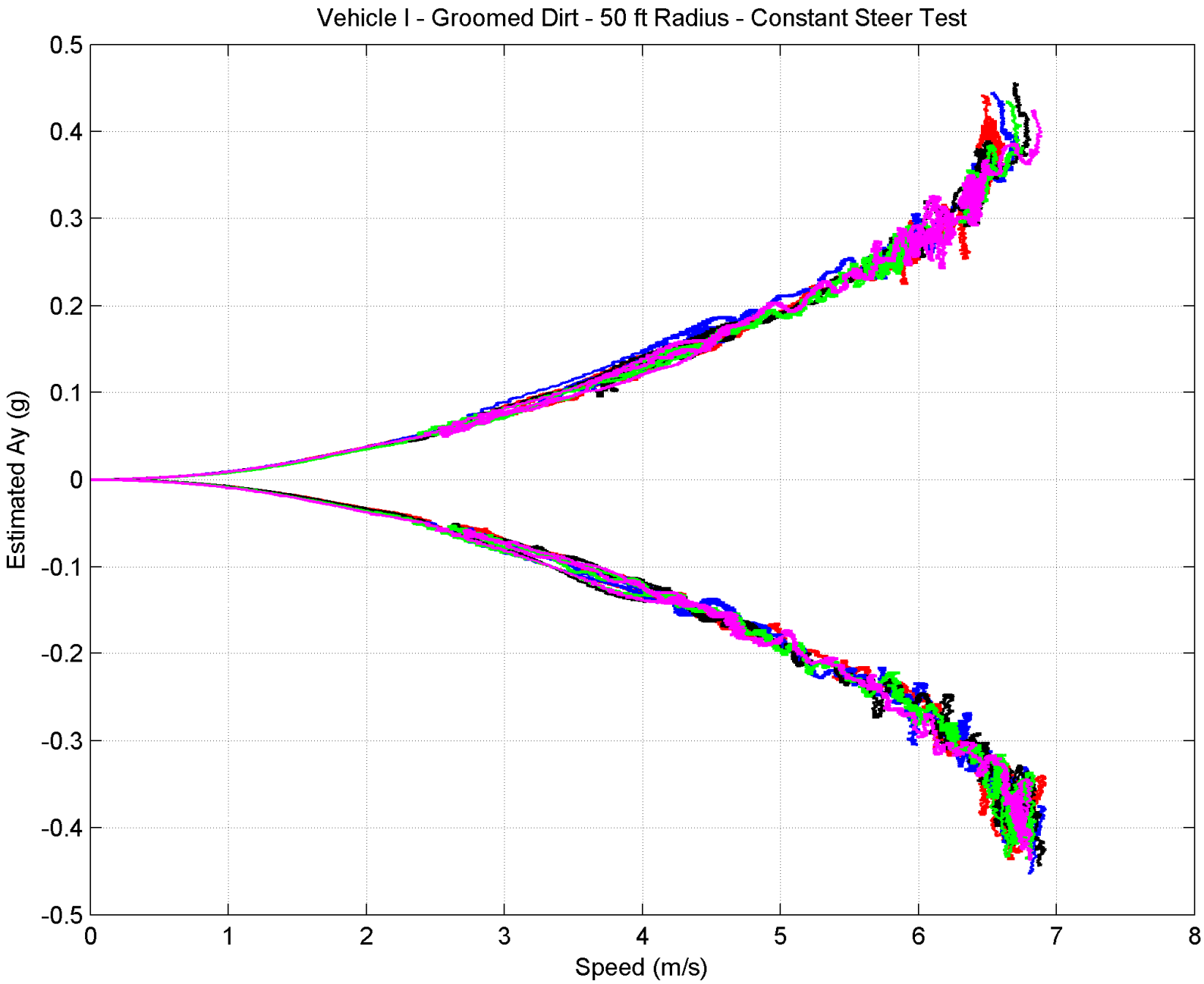
0.518

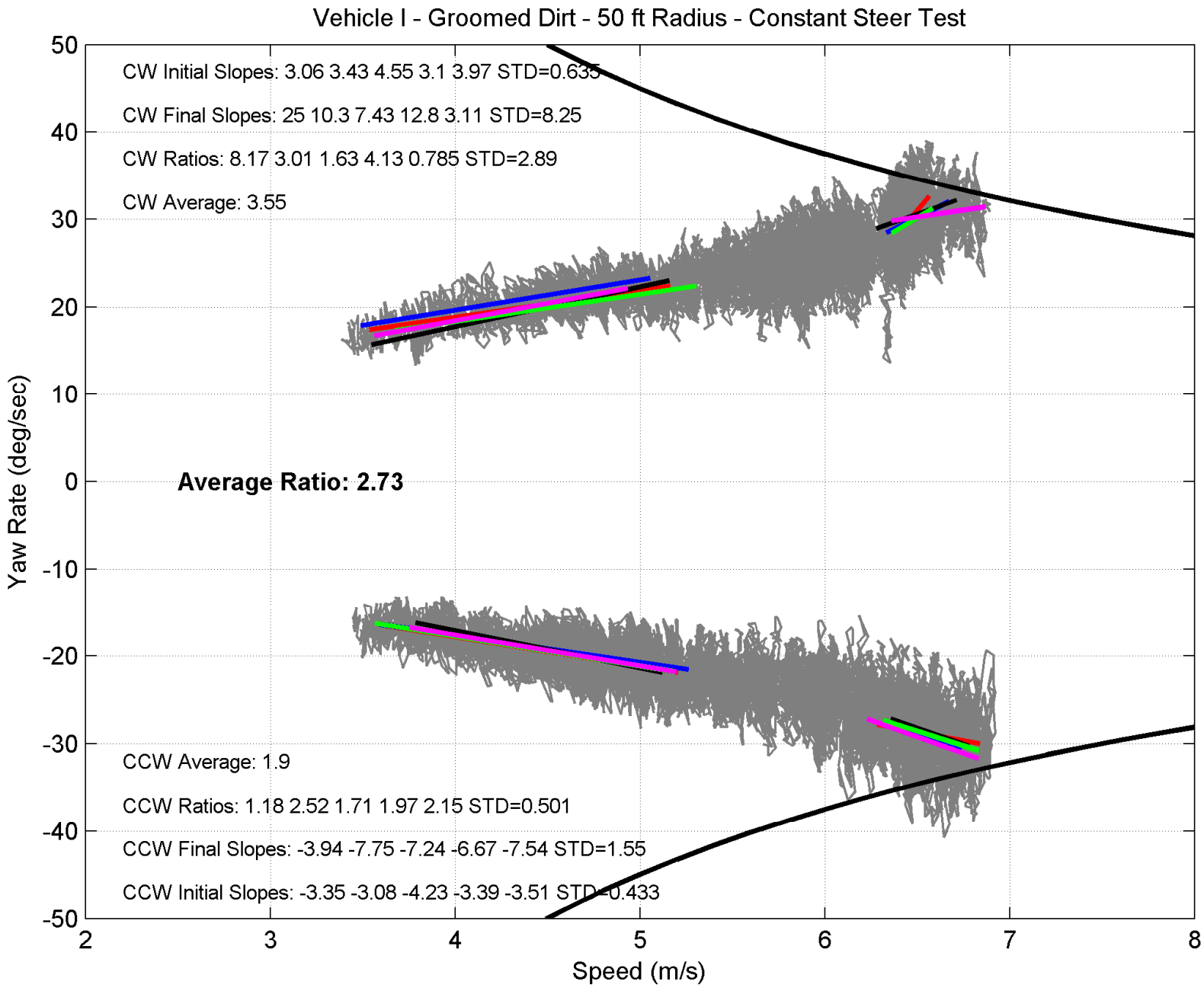
Average of All 12 Runs

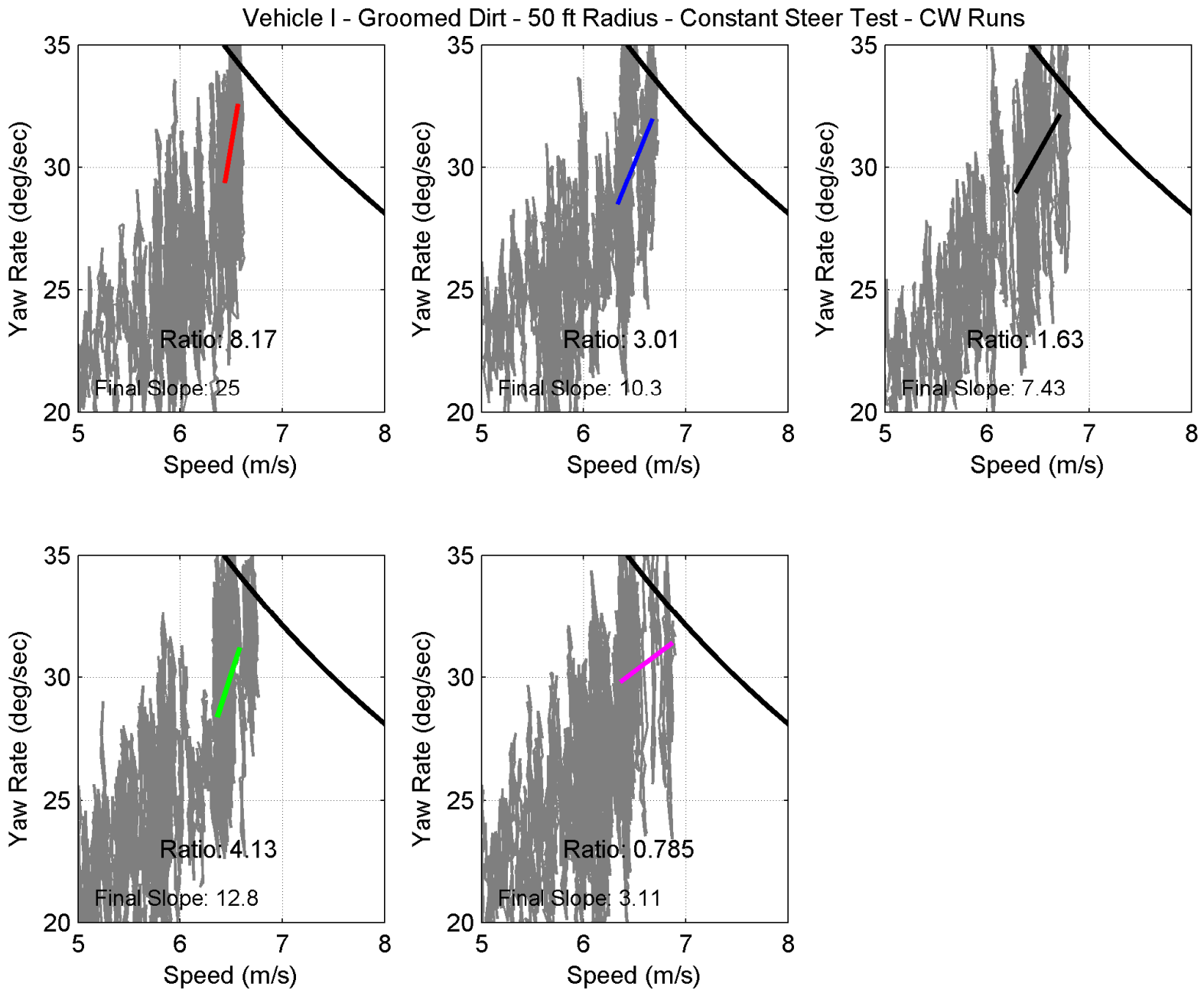
0.527

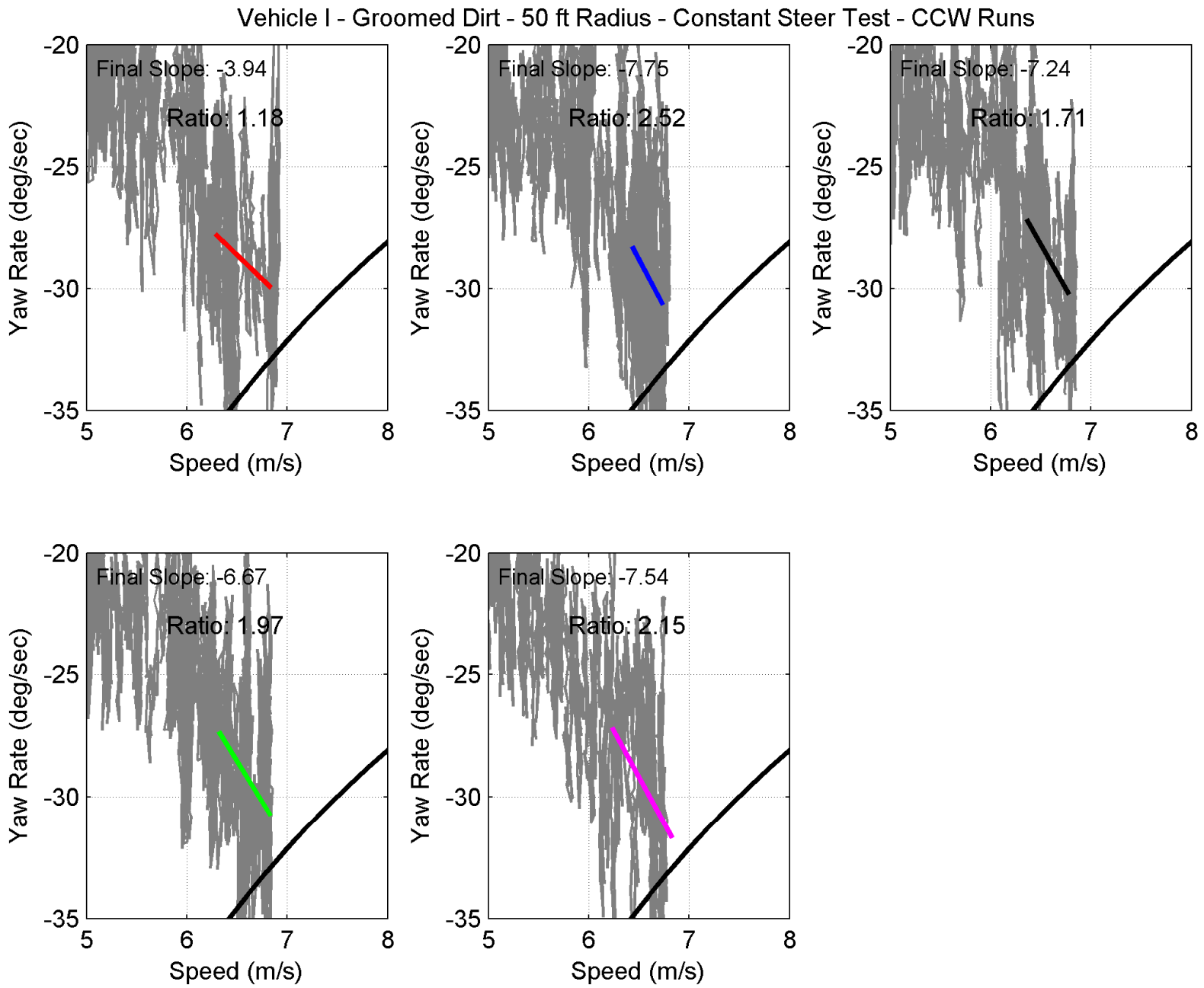
Threshold Ay

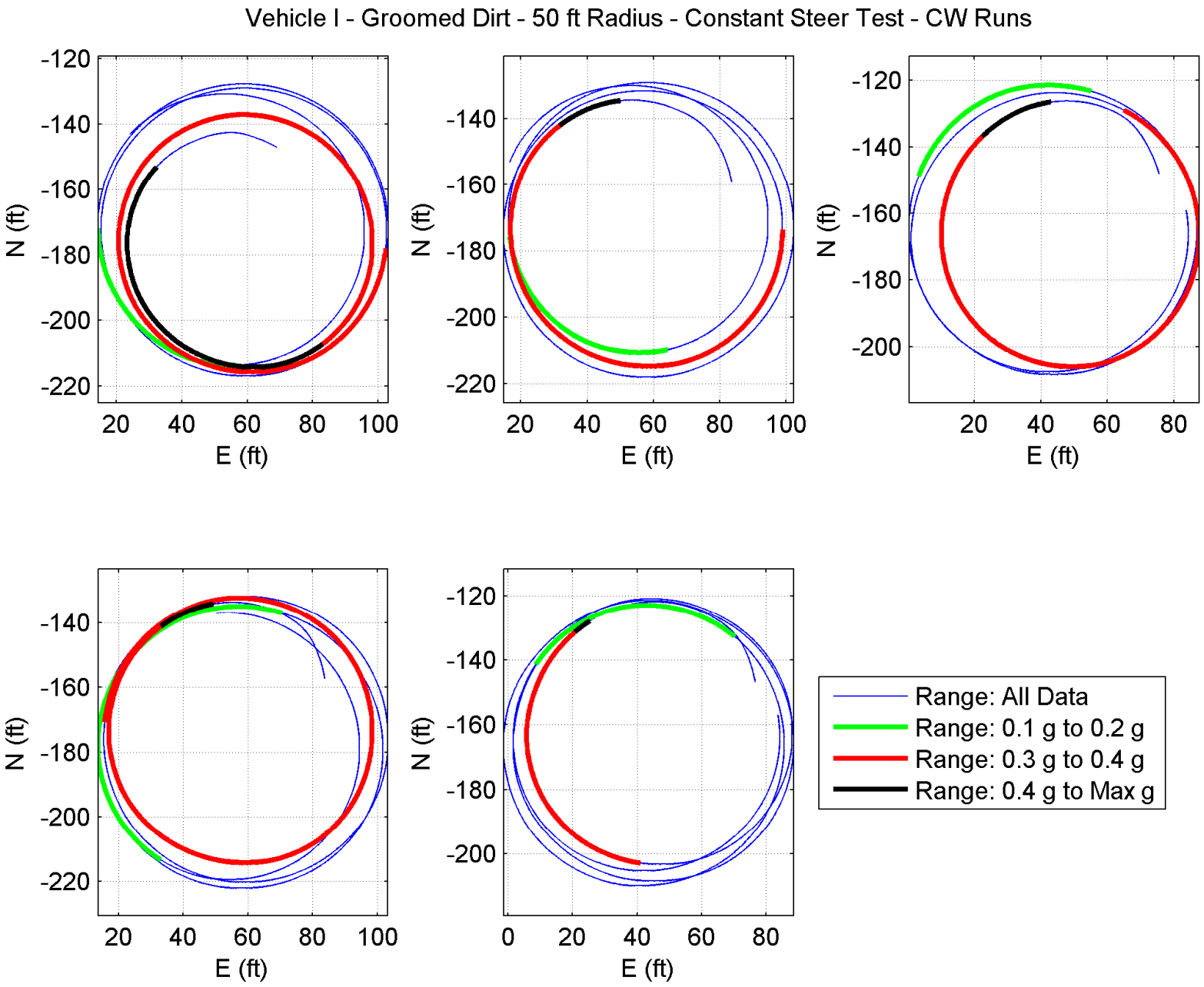

Vehicle I - Groomed Dirt
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

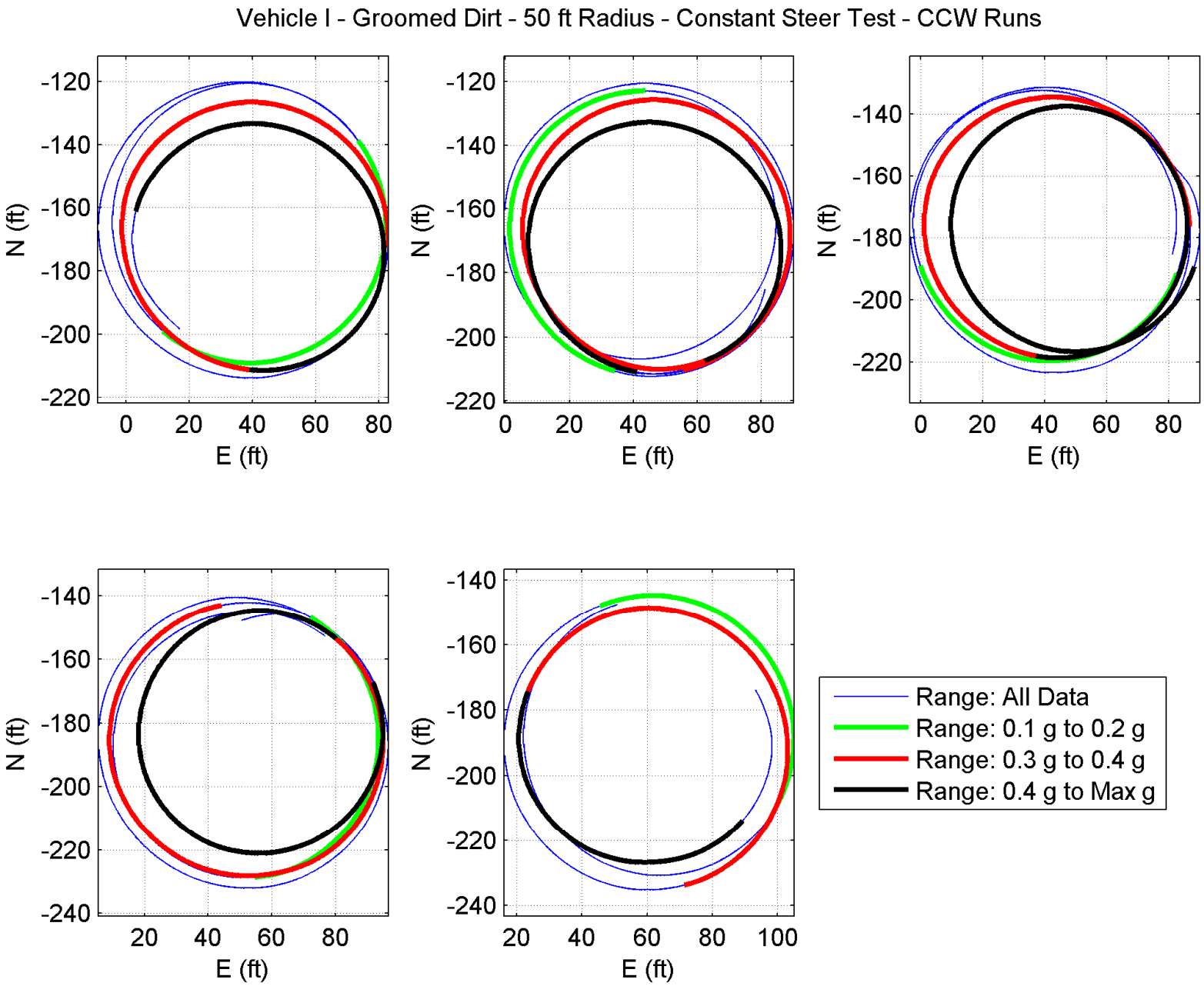

Vehicle I - Groomed Dirt - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8

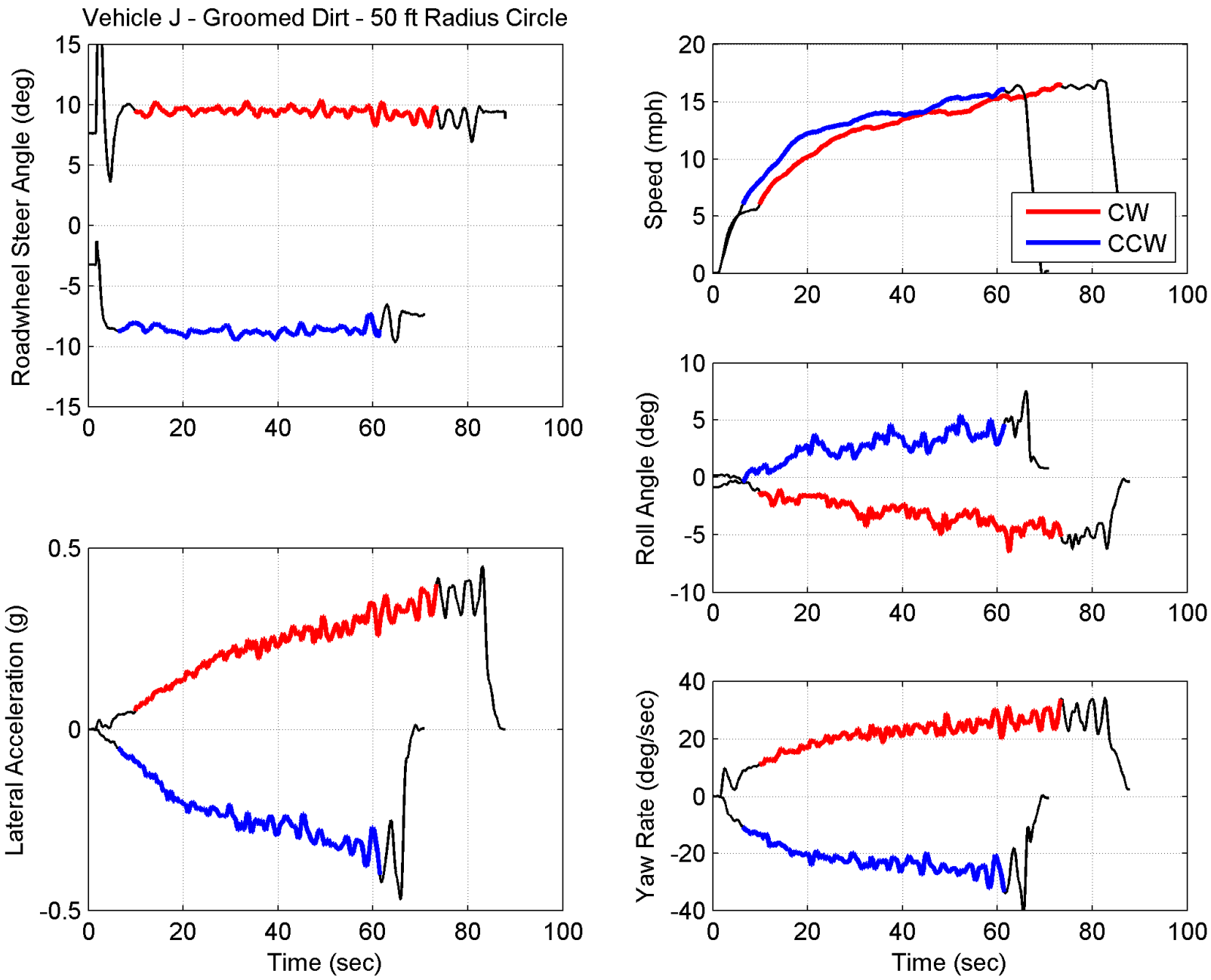

Vehicle I - Groomed Dirt - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 3.06 3.43 4.55 3.1 3.97 STD=0.635
CW Final Slopes: 25 10.3 7.43 12.8 3.11 STD=8.25
CW Ratios: 8.17 3.01 1.63 4.13 0.785 STD=2.89
CW Average: 3.55
Average Ratio: 2.73
CCW Average: 1.9
CCW Ratios: 1.18 2.52 1.71 1.97 2.15 STD=0.501
CCW Final Slopes: -3.94 -7.75 -7.24 -6.67 -7.54 STD=1.55
CCW Initial Slopes: -3.35 -3.08 -4.23 -3.39 -3.51 STD=0.433
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8

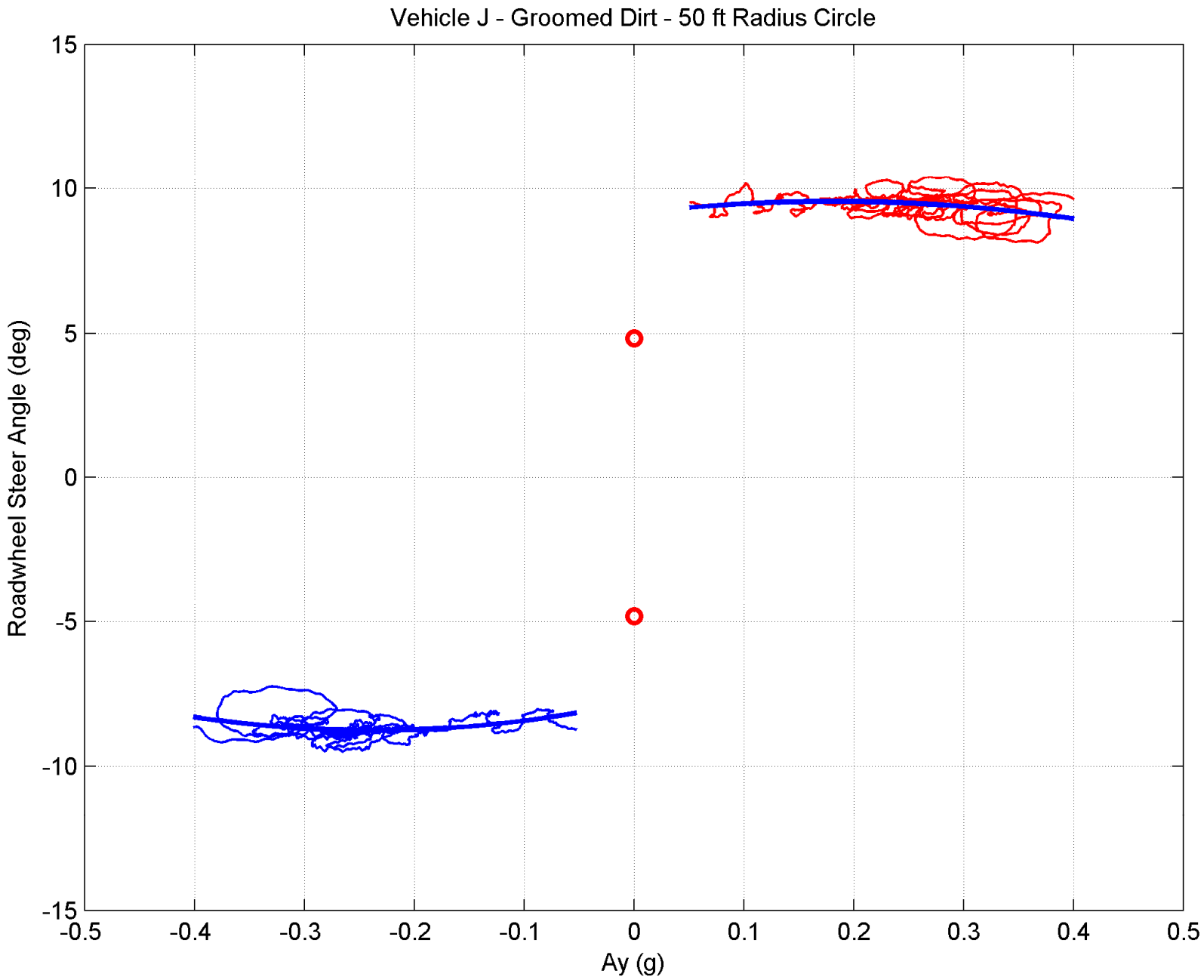

Vehicle I - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 8.17
Final Slope: 25
Ratio: 3.01
Final Slope: 10.3
Ratio: 1.63
Final Slope: 7.43
Ratio: 4.13
Final Slope: 12.8
Ratio: 0.785
Final Slope: 3.11

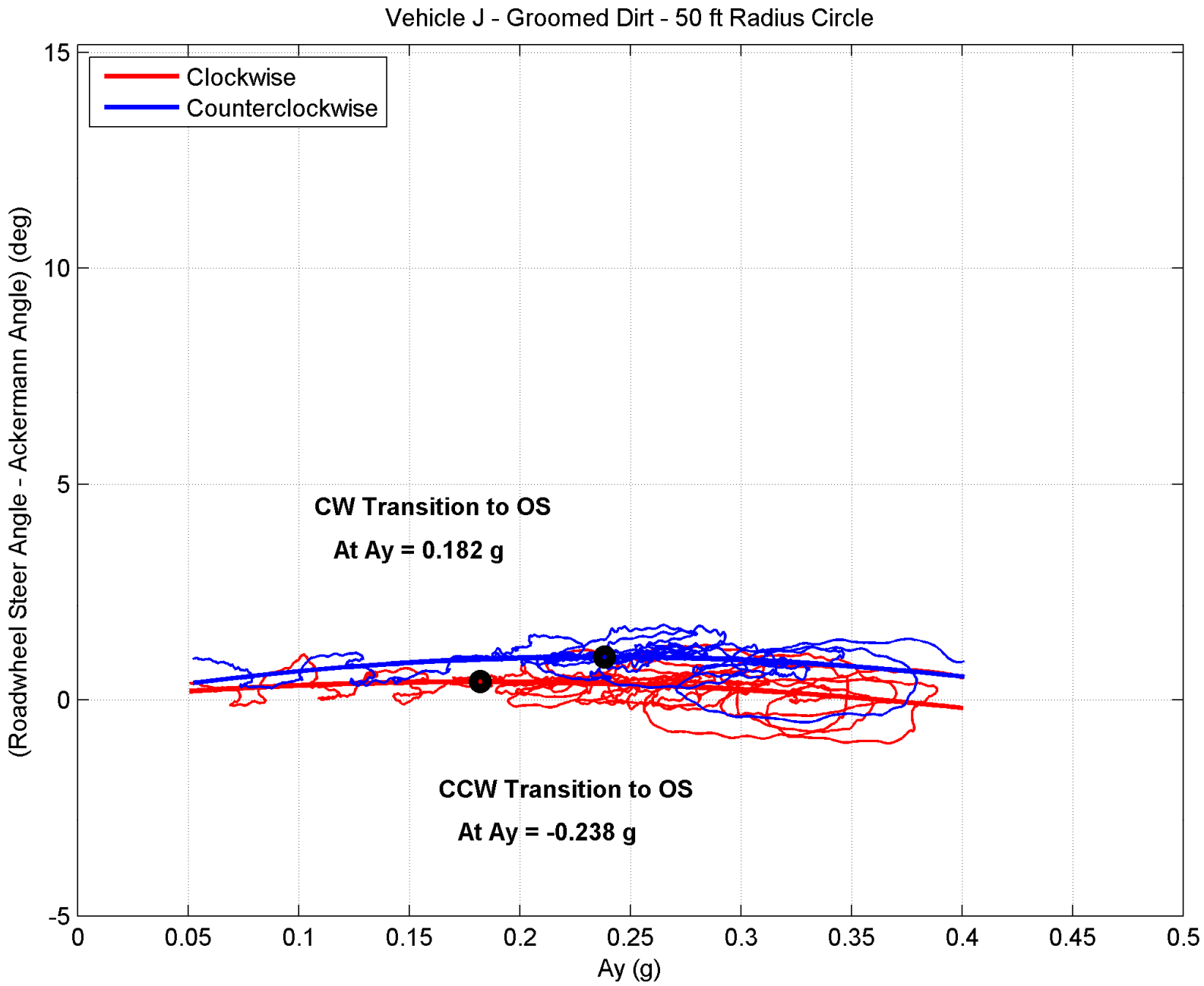

Vehicle I - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -3.94
Ratio: 1.18
Final Slope: -7.75
Ratio: 2.52
Final Slope: -7.24
Ratio: 1.71
Final Slope: -6.67
Ratio: 1.97
Final Slope: -7.54
Ratio: 2.15
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
5
6
7
8

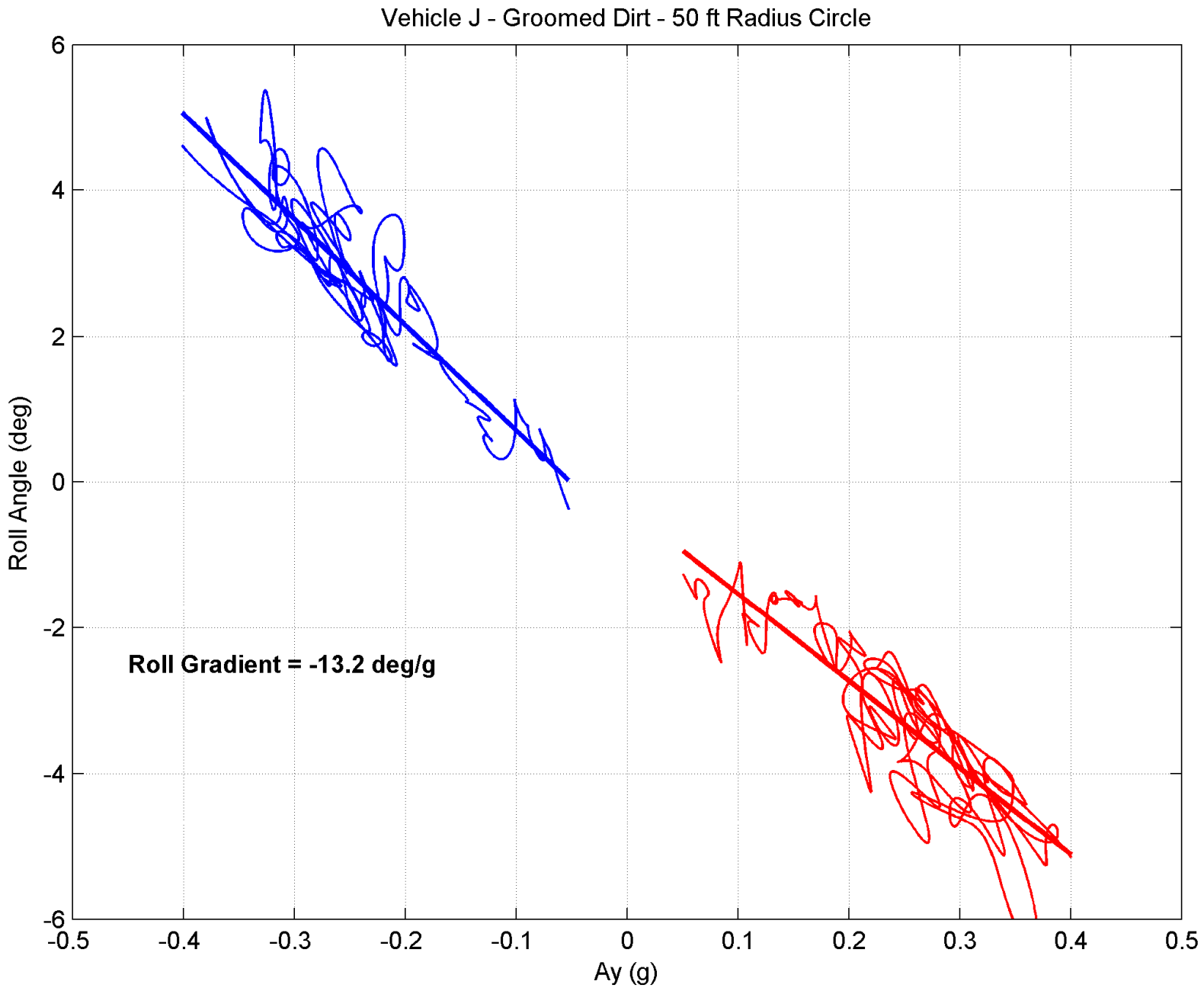

Vehicle I - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
-120
-140
-160
-180
-200
-220
20
40
60
80
100
0
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

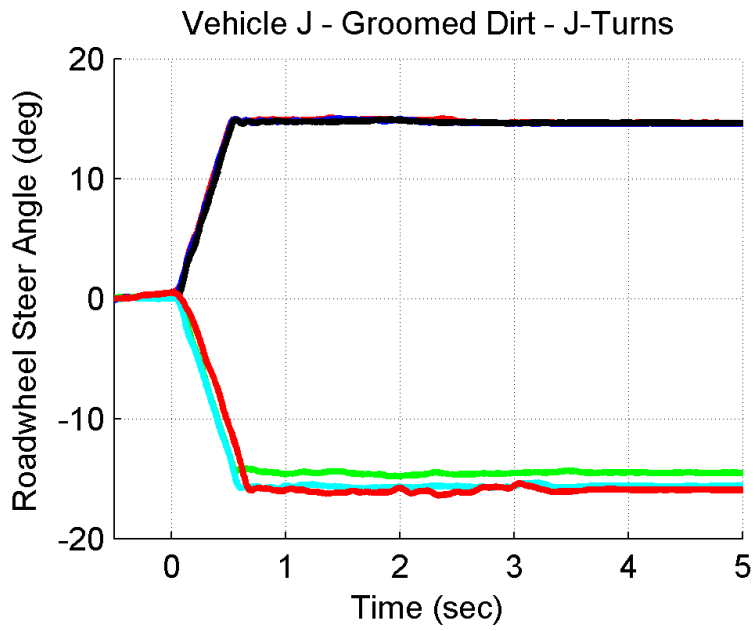

Vehicle I - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

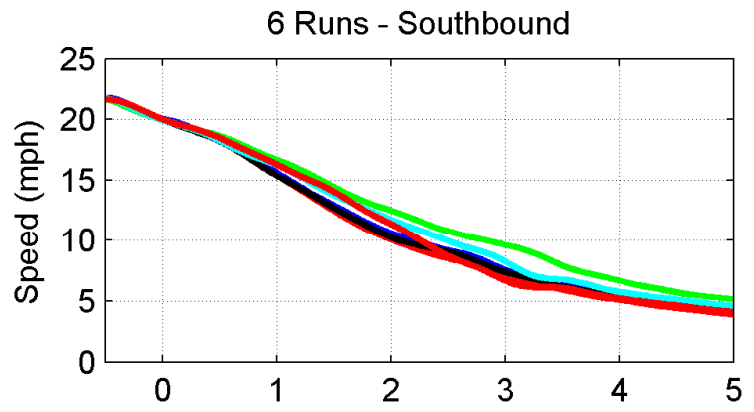

Vehicle J - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

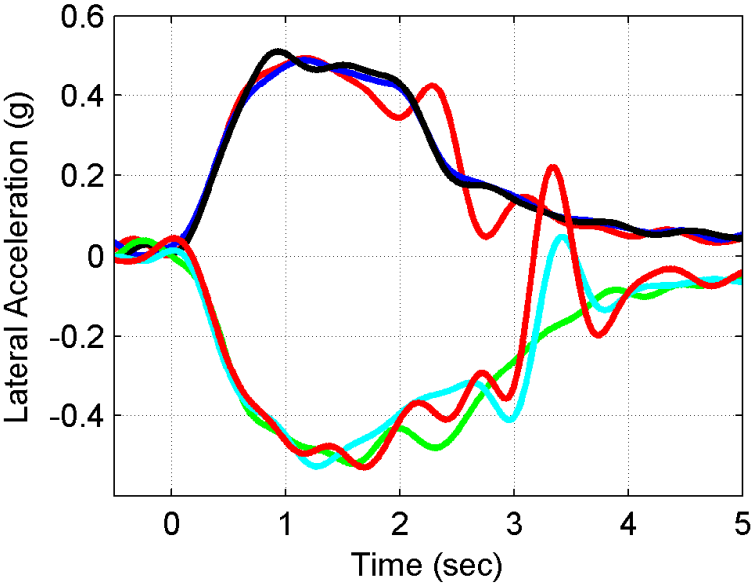

Vehicle J - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
15
10
5
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

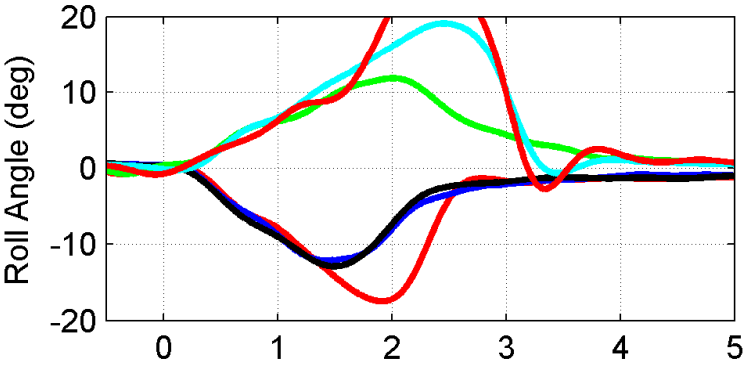

Vehicle J - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.182 g
CCW Transition to OS
At Ay = -0.238 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
15
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

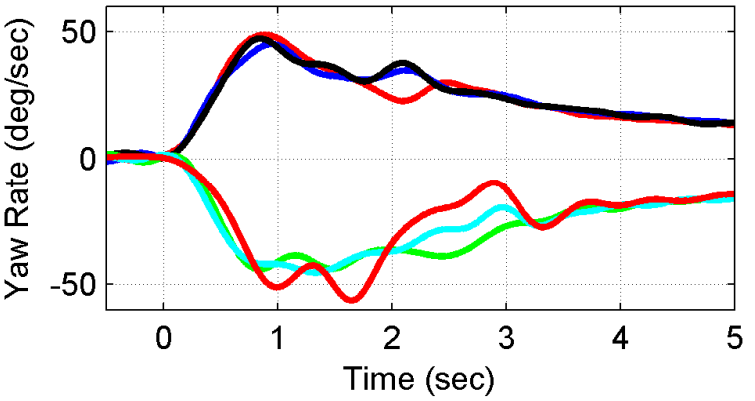

Vehicle J - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -13.2 deg/g
6
4
2
0
-2
-4
-6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

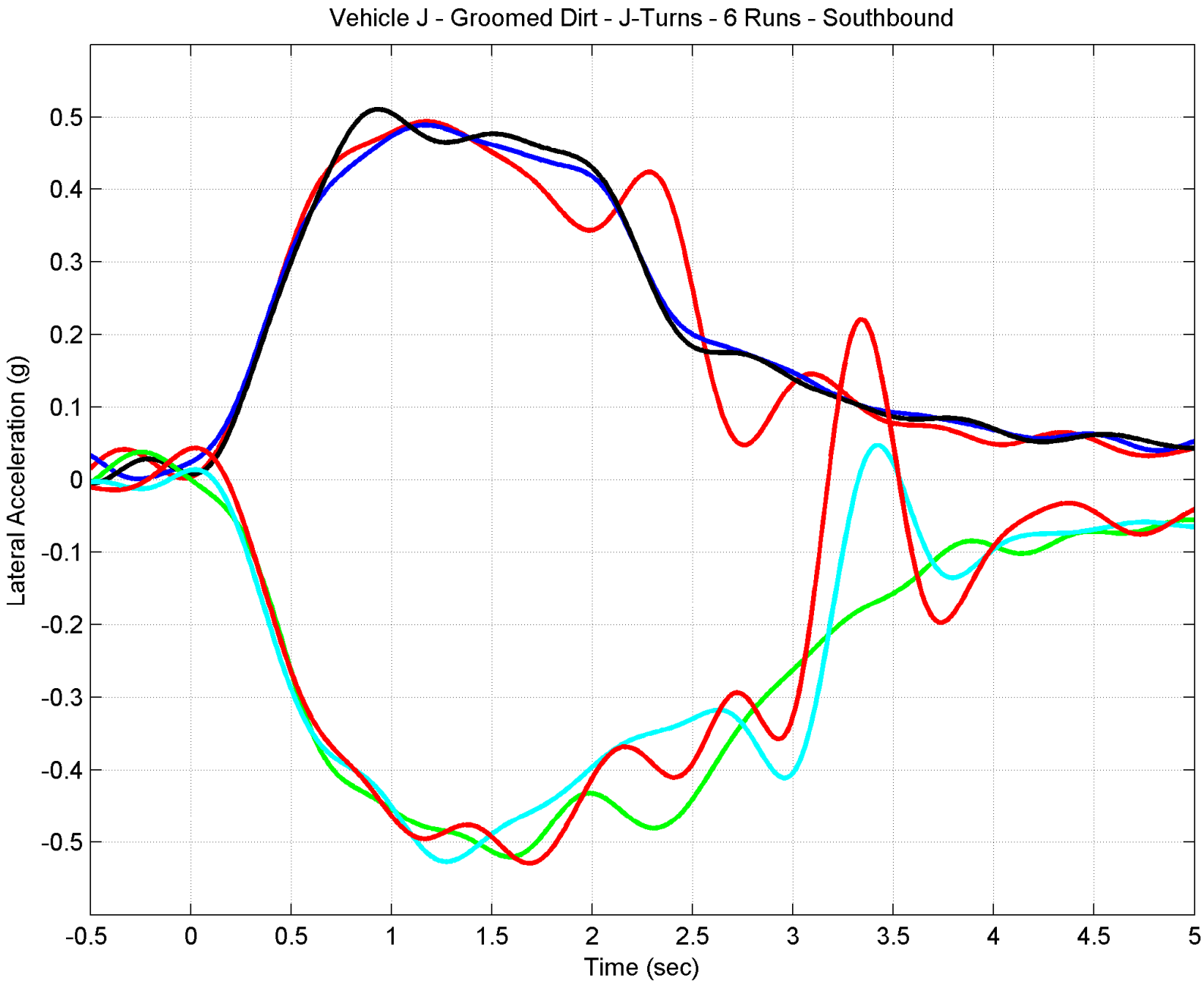

Vehicle J - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5
Time (sec)

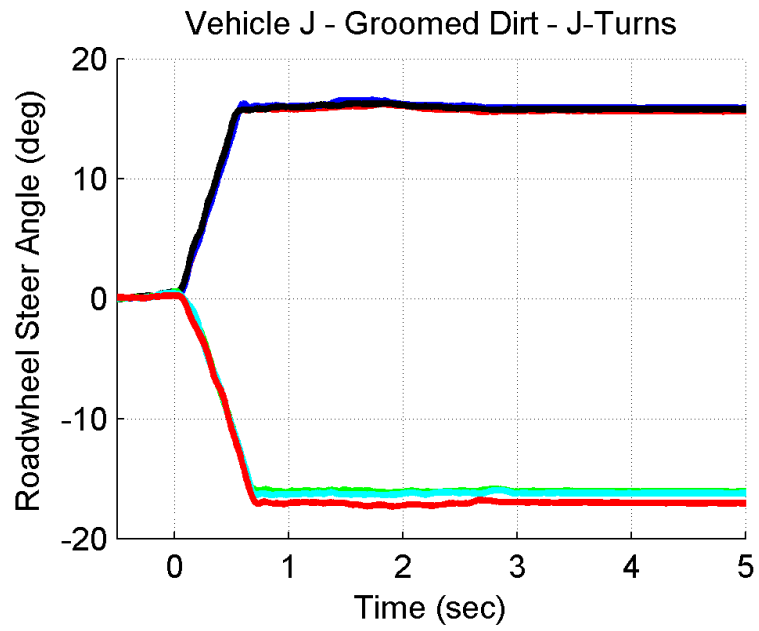

6 Runs - Southbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5

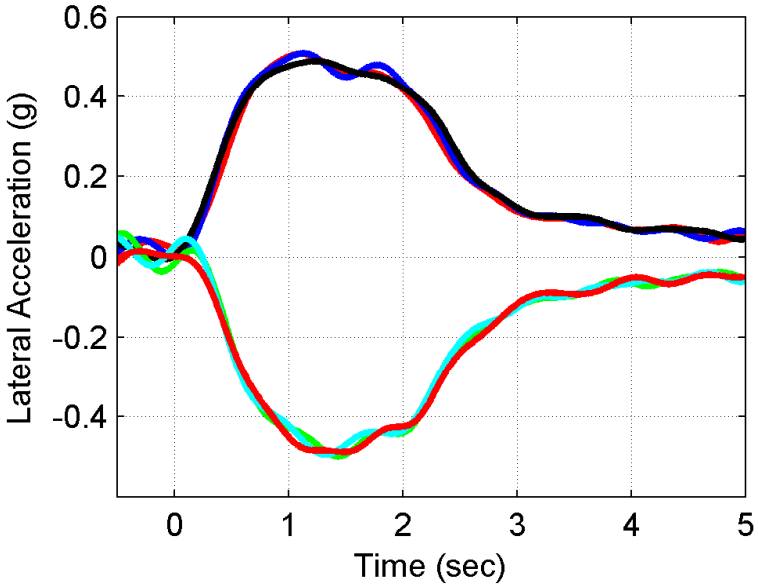

Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)

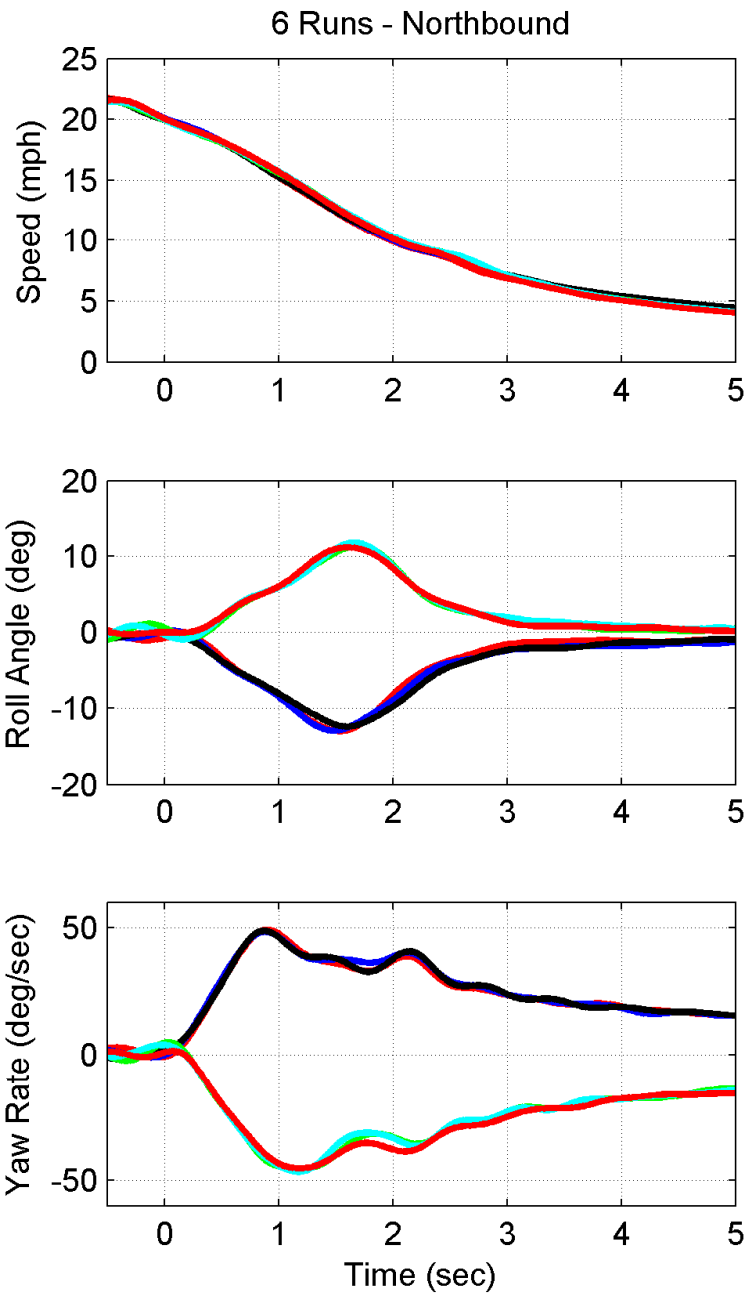

Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5

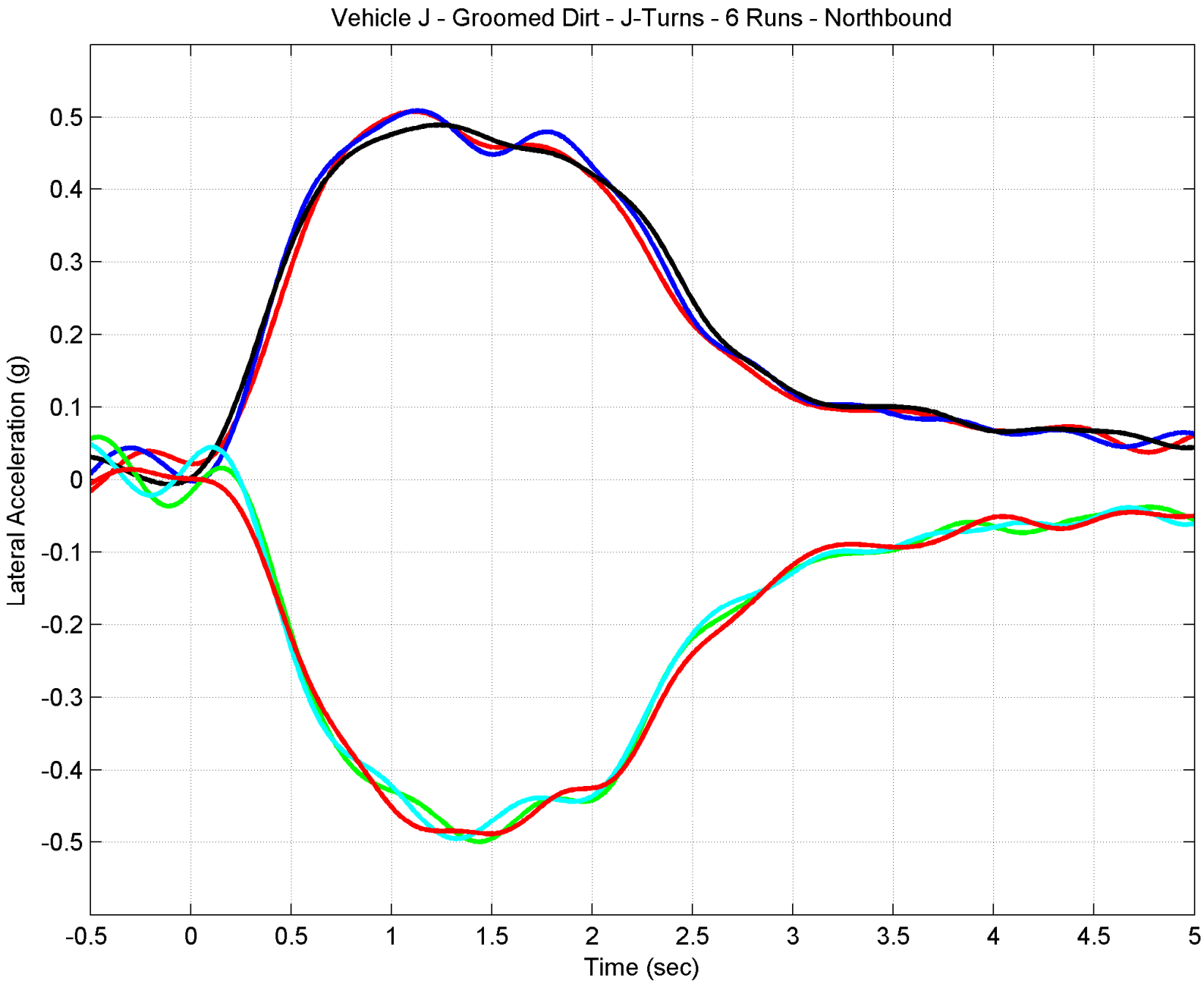

Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle J - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle J - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5
Time (sec)


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5
Roll Angle (deg)
20
10
0
-10
-20
Yaw Rate (deg/sec)
50
0
-50
Time (sec)


Vehicle J - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle J - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.494	-0.521
2	0.489	-0.527
3	0.511	-0.529
Mean Value of 3 Runs	0.498	-0.526
Standard Deviation of 3 Runs	0.011	0.004

Average of 6 North Runs

0.512

Run Number	North Right Turns	North Left Turns
1	0.508	-0.500
2	0.509	-0.495
3	0.489	-0.489
Mean Value of 3 Runs	0.502	-0.494
Standard Deviation of 3 Runs	0.011	0.006

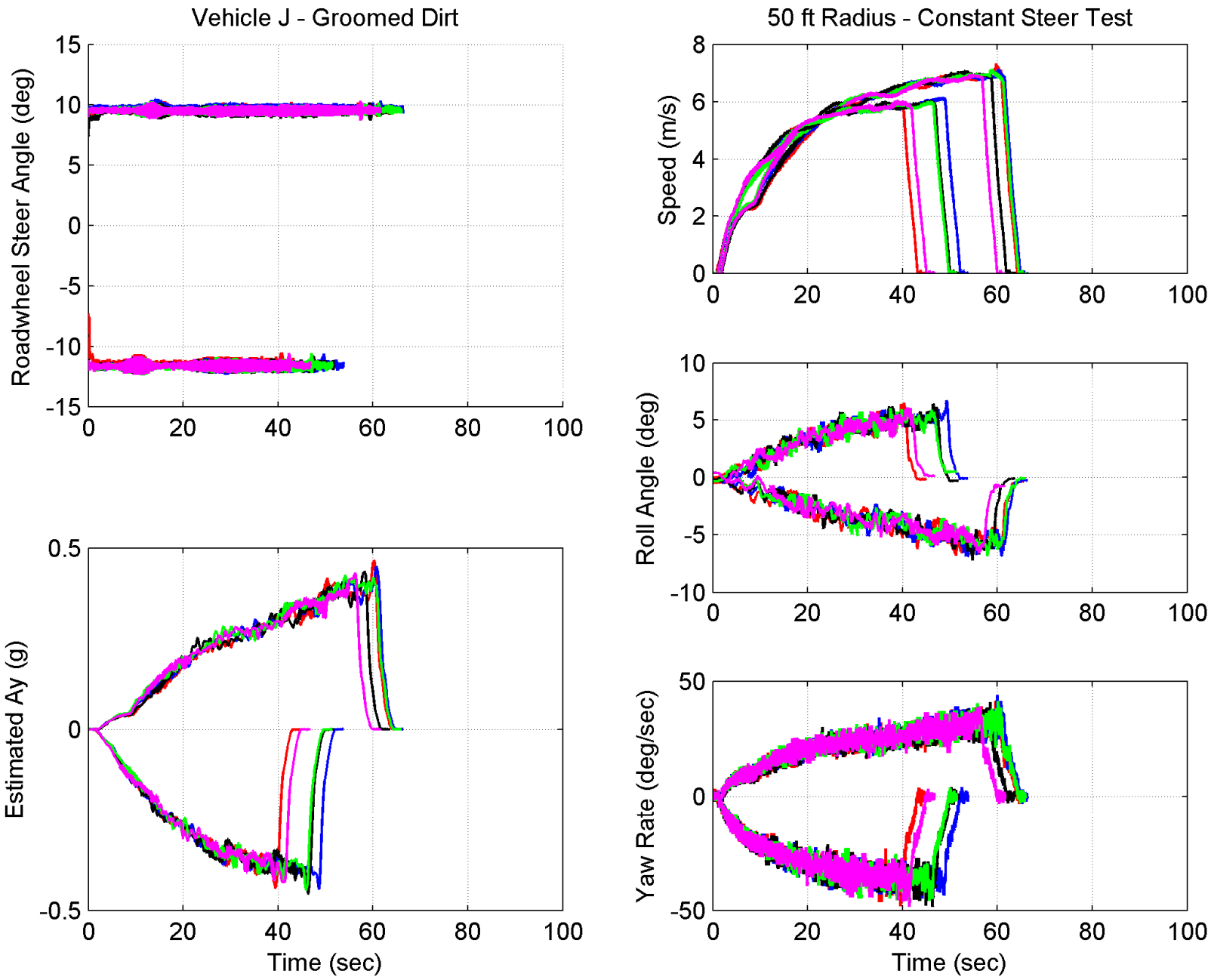
Average of 6 South Runs

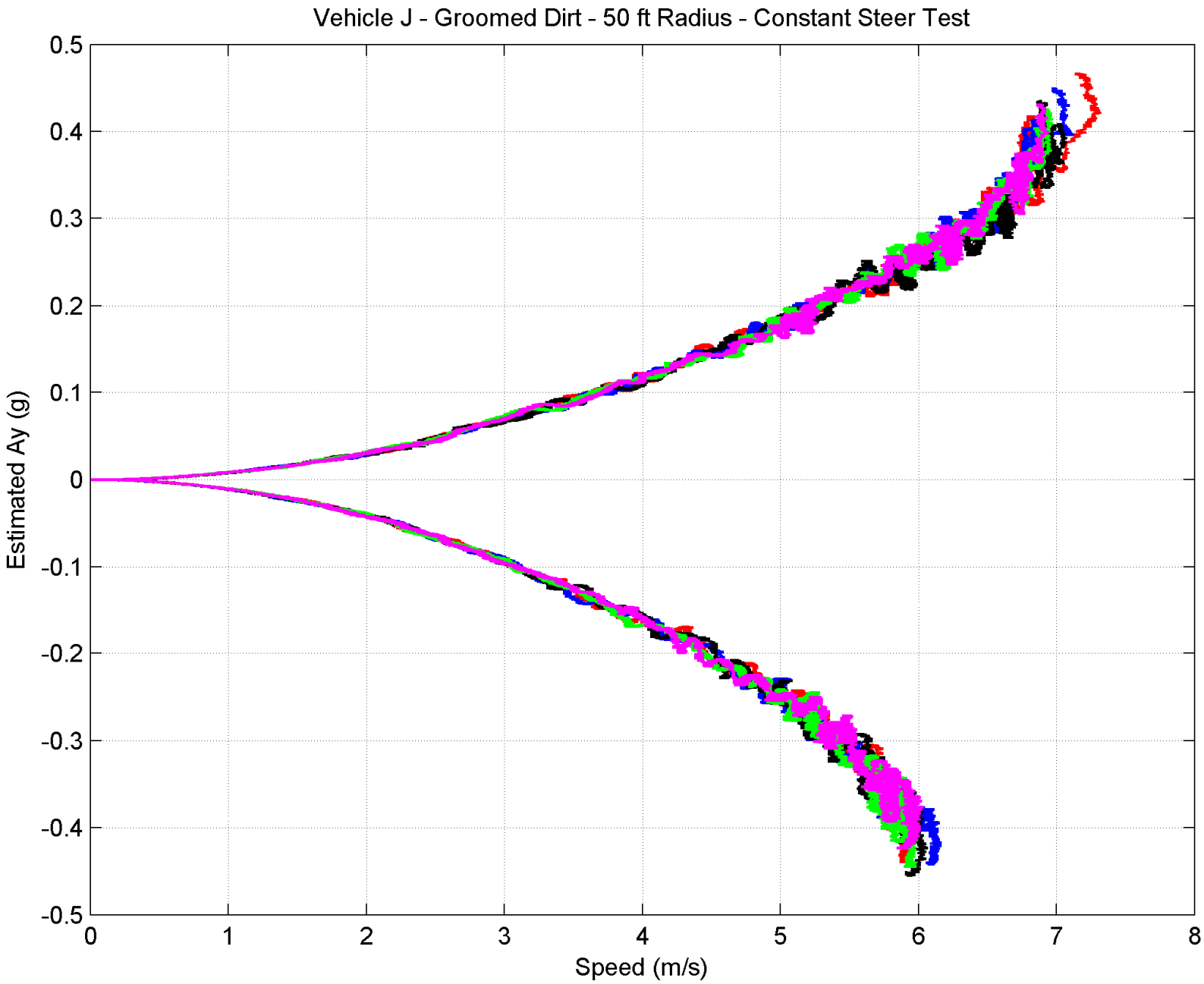
0.498

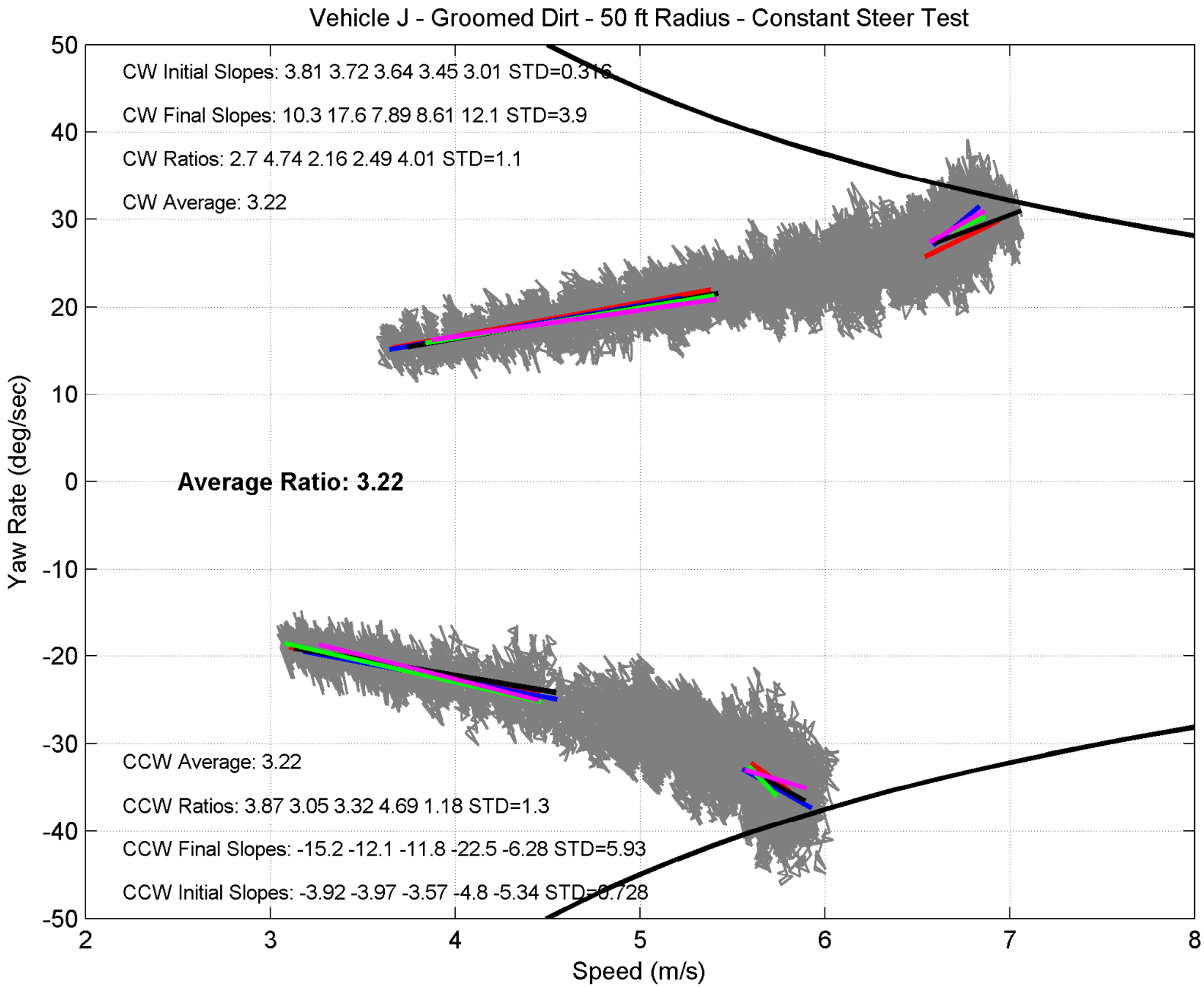
Average of All 12 Runs

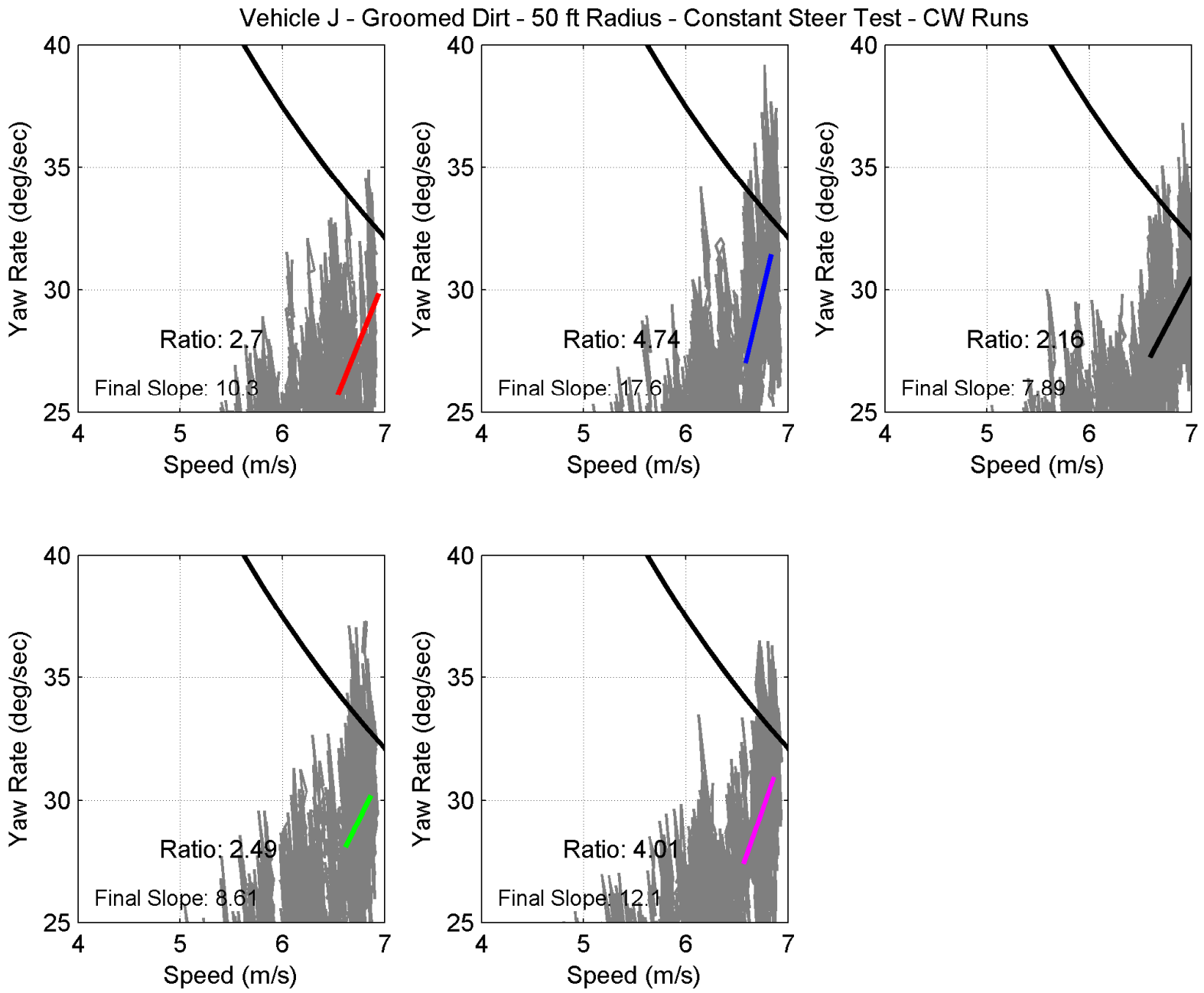
0.505

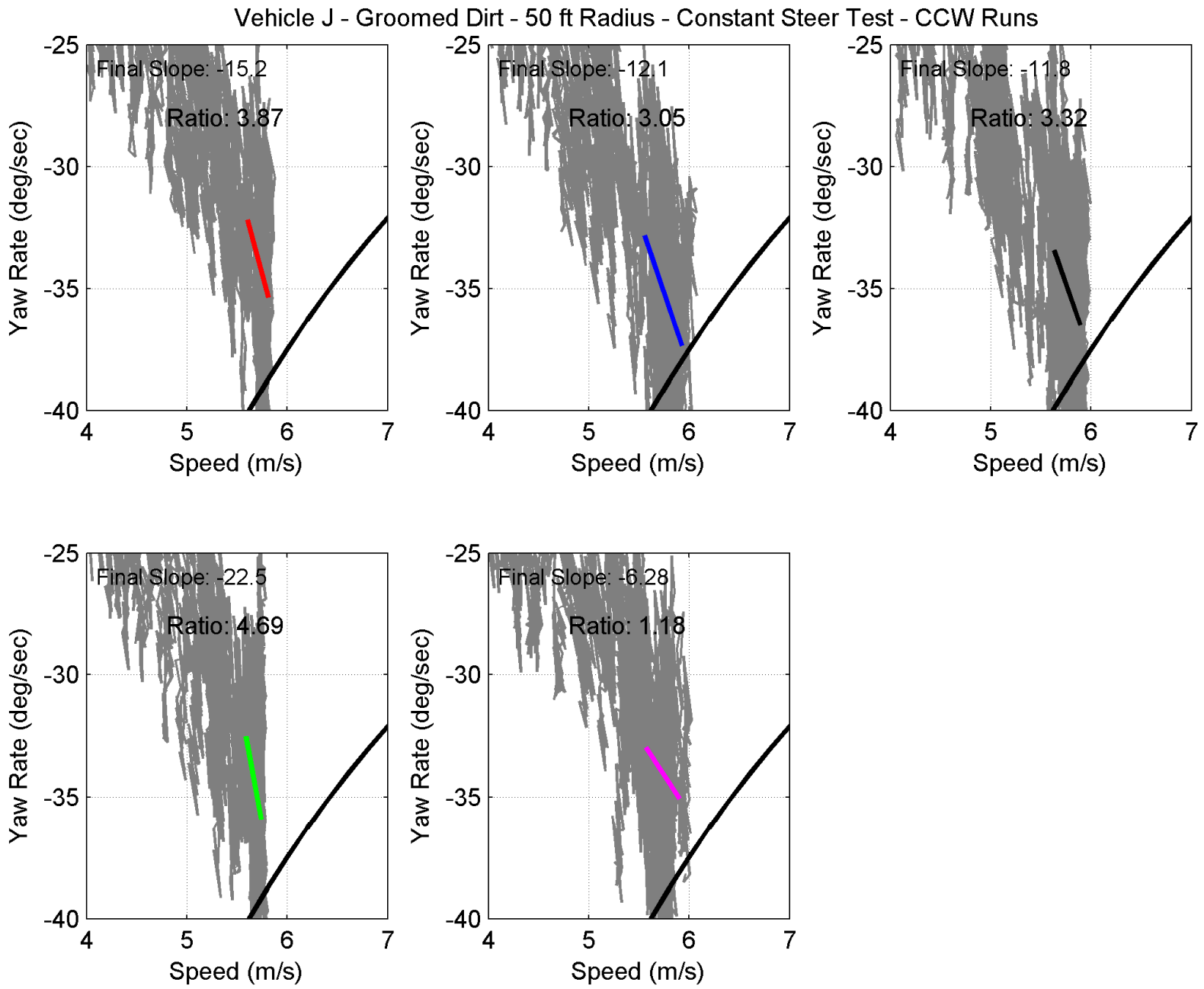
Threshold Ay

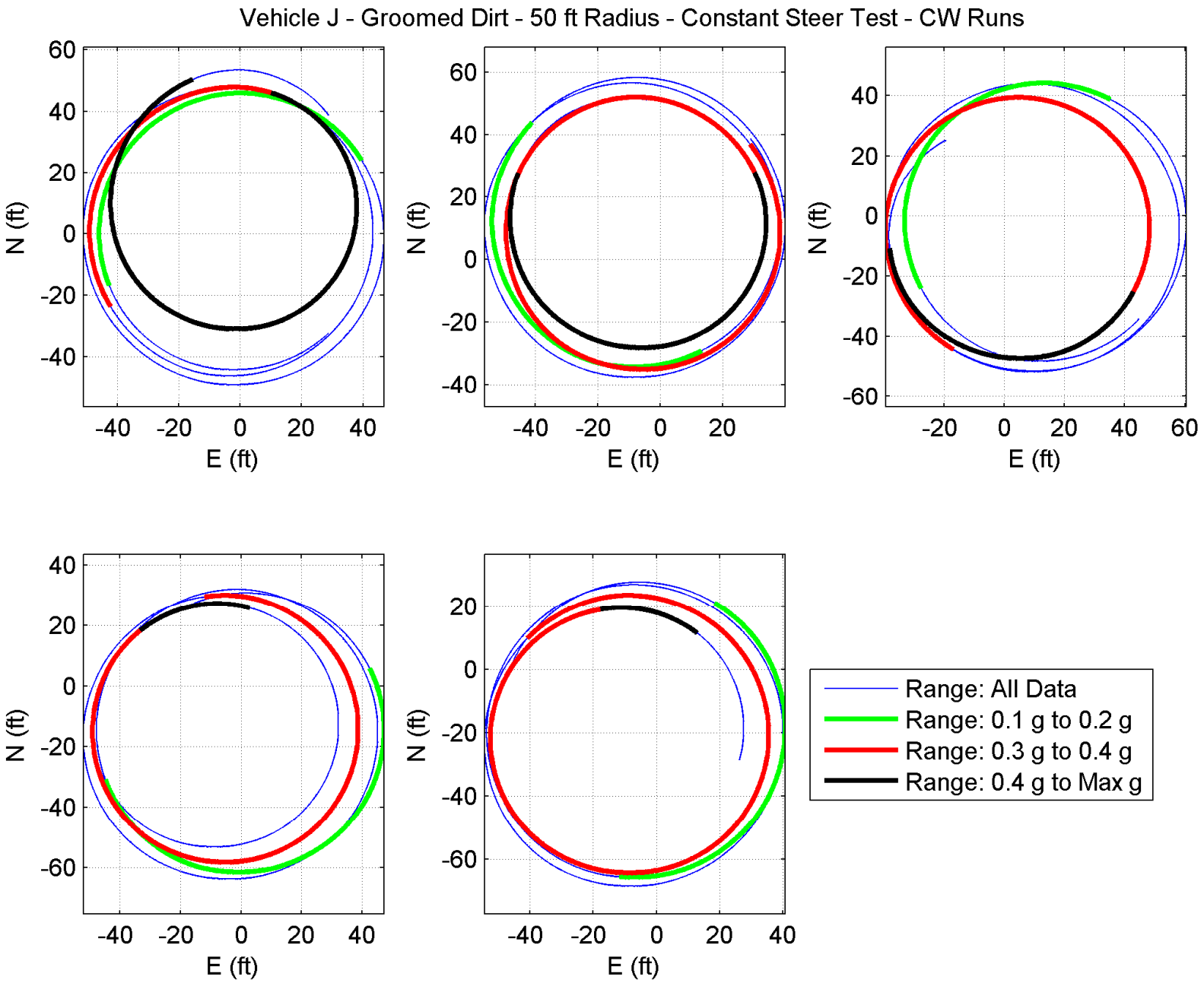

Vehicle J - Groomed Dirt
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
20
40
60
80
100
Estimated Ay (g)
0.5
0
-0.5
Time (sec)
50 ft Radius - Constant Steer Test
Speed (m/s)
8
6
4
2
0
Roll Angle (deg)
10
5
0
-5
-10
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

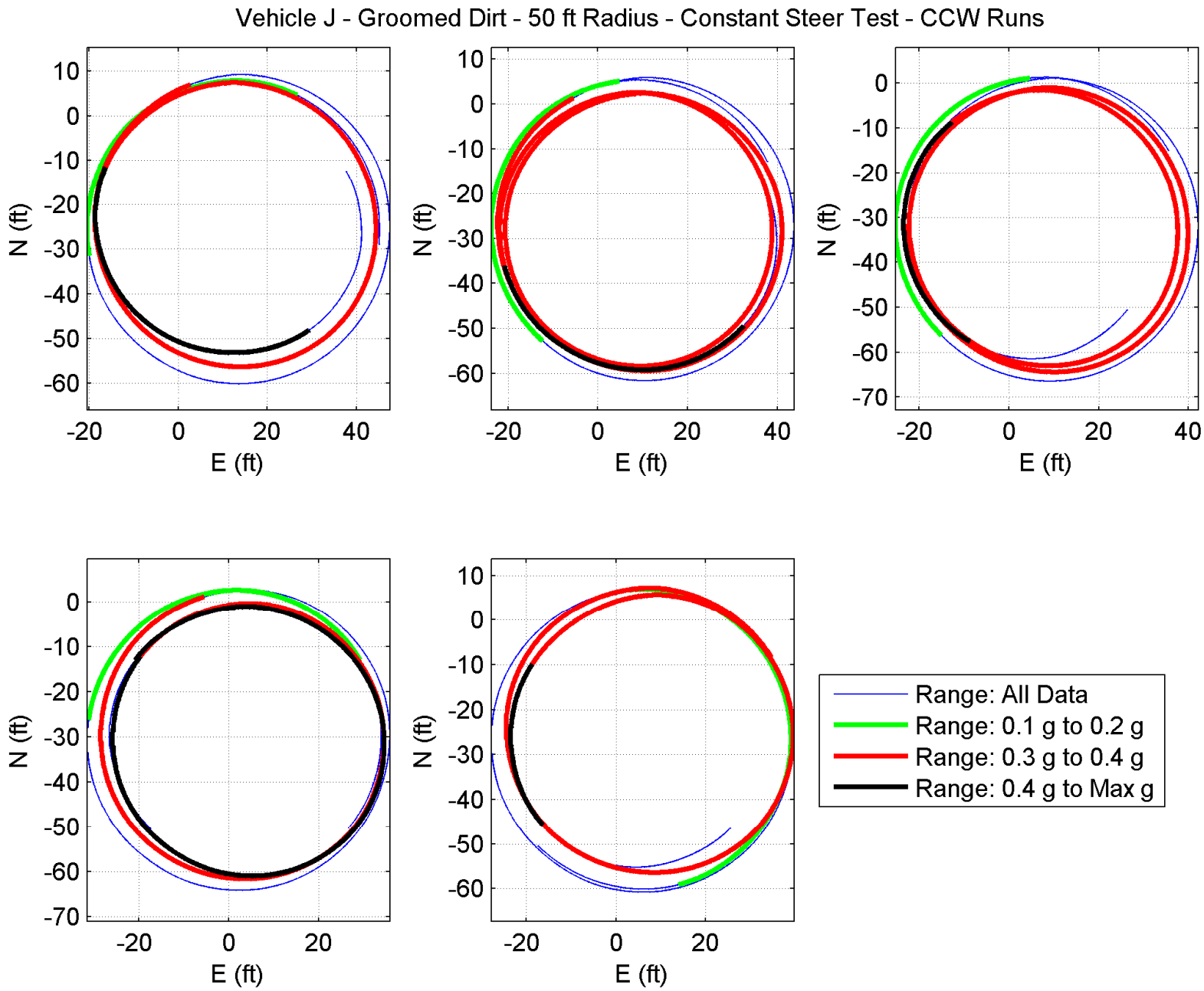

Vehicle J - Groomed Dirt - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8

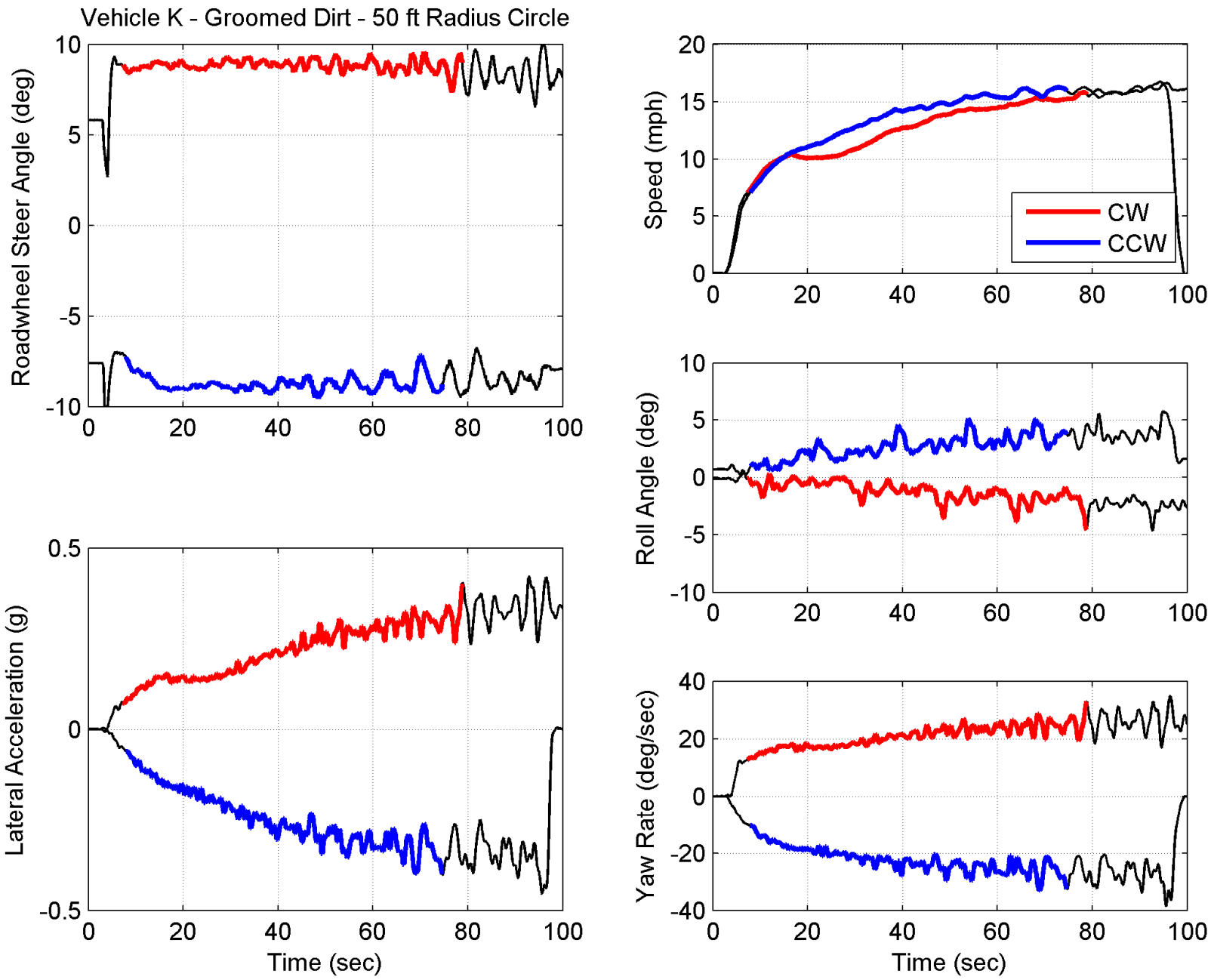

Vehicle J - Groomed Dirt - 50 ft Radius - Constant Steer Test
CW Initial Slopes: 3.81 3.72 3.64 3.45 3.01 STD=0.316
CW Final Slopes: 10.3 17.6 7.89 8.61 12.1 STD=3.9
CW Ratios: 2.7 4.74 2.16 2.49 4.01 STD=1.1
CW Average: 3.22
Average Ratio: 3.22
CCW Average: 3.22
CCW Ratios: 3.87 3.05 3.32 4.69 1.18 STD=1.3
CCW Final Slopes: -15.2 -12.1 -11.8 -22.5 -6.28 STD=5.93
CCW Initial Slopes: -3.92 -3.97 -3.57 -4.8 -5.34 STD=0.728
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
3
4
5
6
7
8

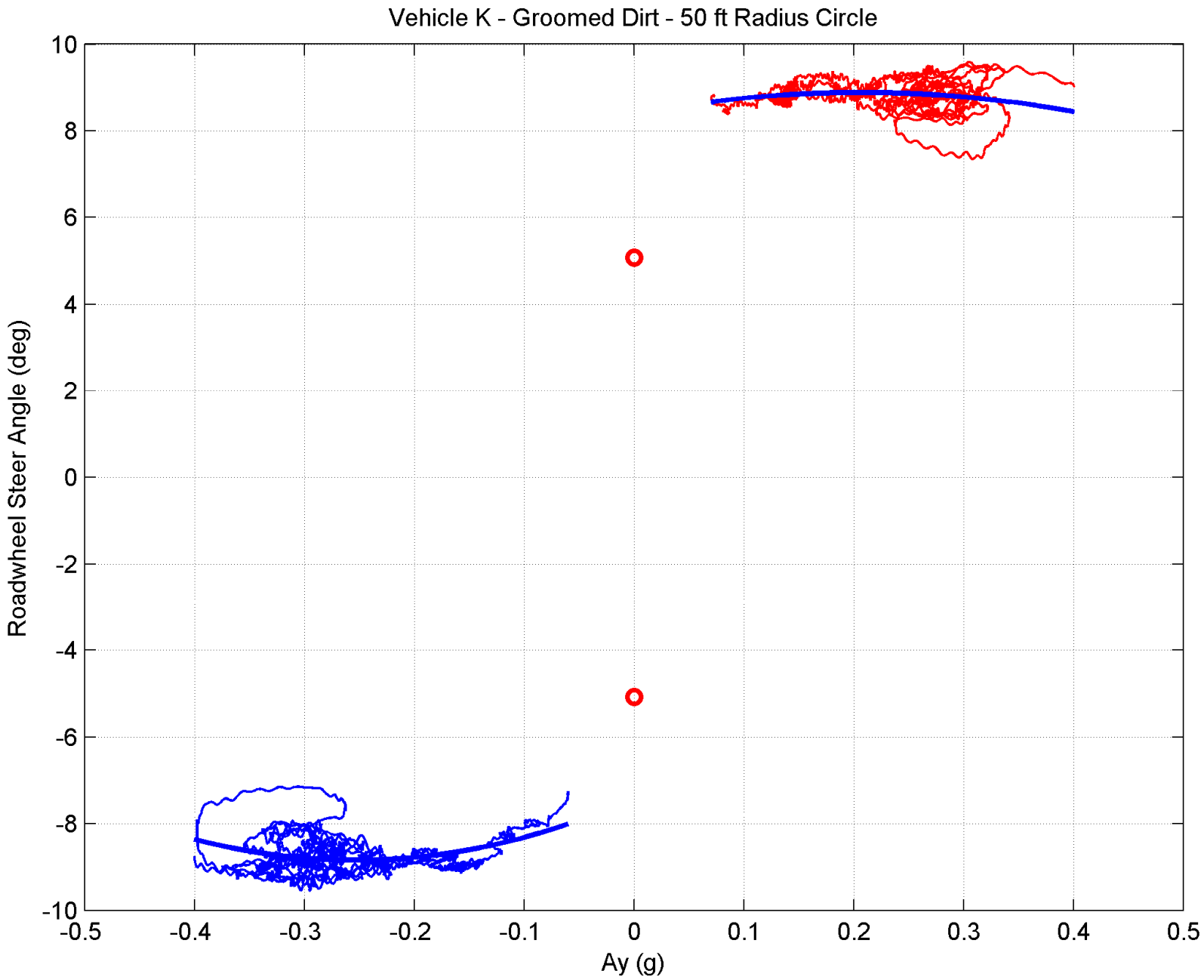

Vehicle J - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 2.7
Final Slope: 10.3
Ratio: 4.74
Final Slope: 17.6
Ratio: 2.16
Final Slope: 7.89
Ratio: 2.49
Final Slope: 8.61
Ratio: 4.01
Final Slope: 12.1

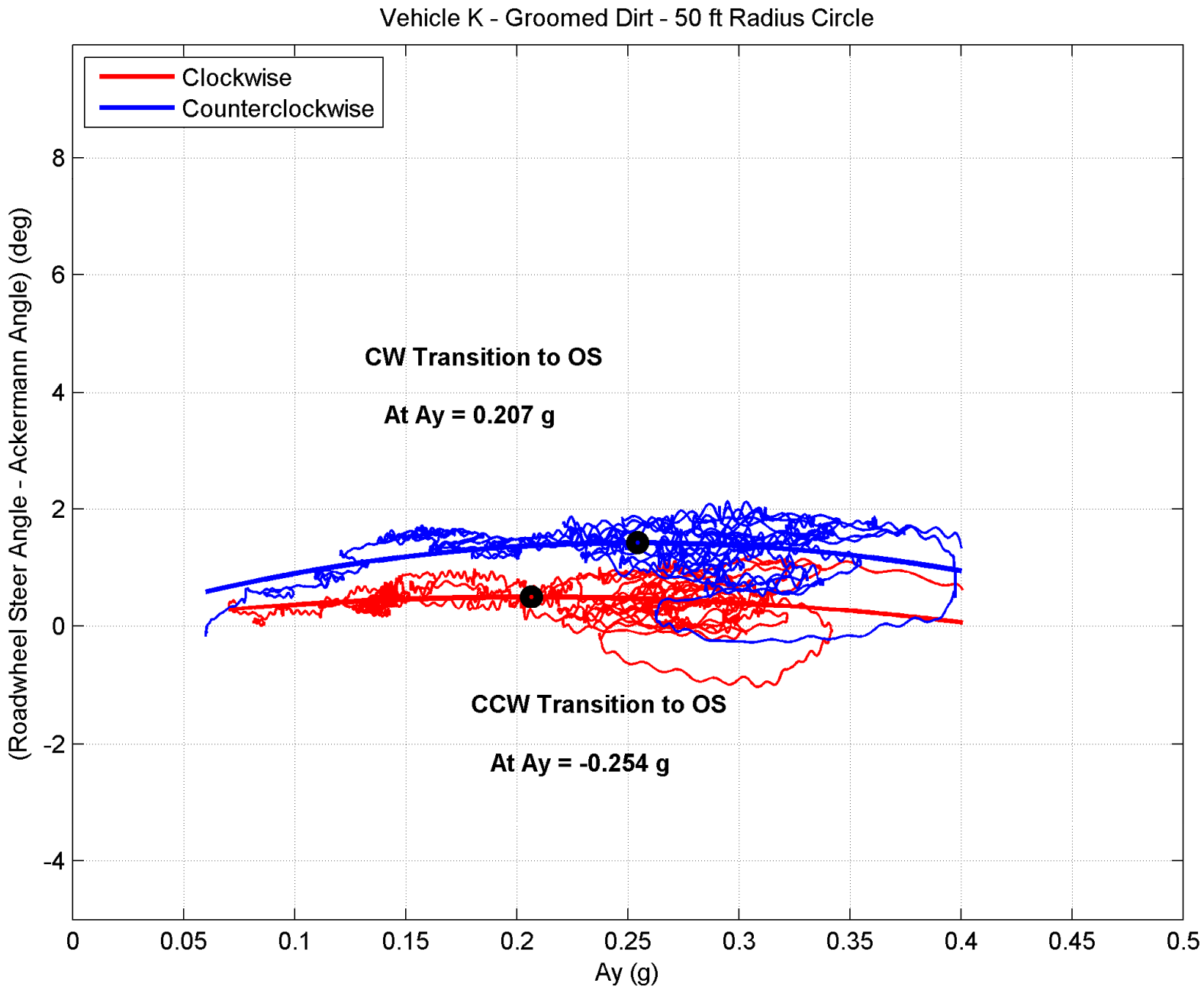

Vehicle J - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -15.2
Ratio: 3.87
Final Slope: -12.1
Ratio: 3.05
Final Slope: -11.8
Ratio: 3.32
Final Slope: -22.5
Ratio: 4.69
Final Slope: -6.28
Ratio: 1.18
Yaw Rate (deg/sec)
Speed (m/s)
-25
-30
-35
-40
4
5
6
7

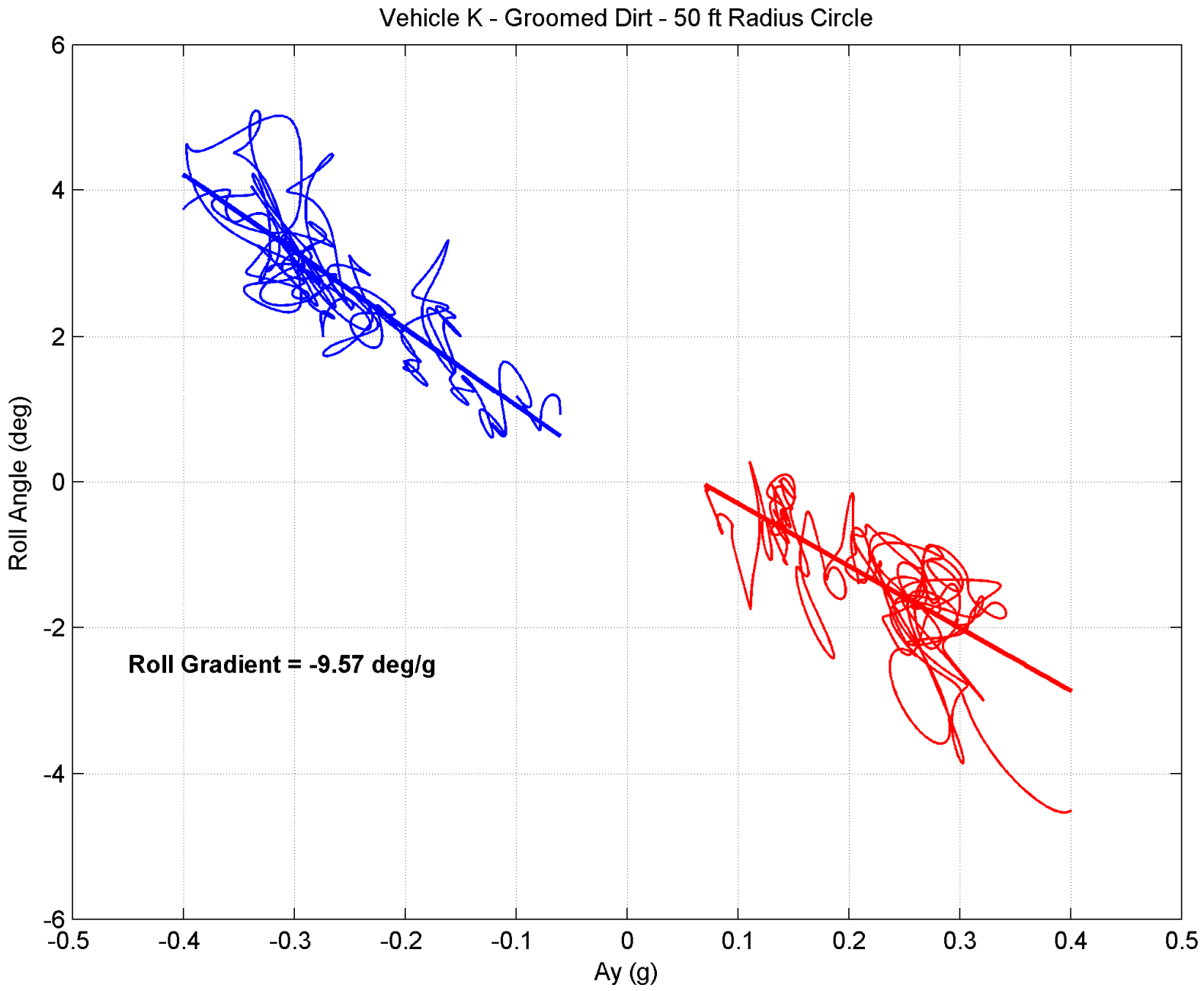

Vehicle J - Groomed Dirt - 50 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

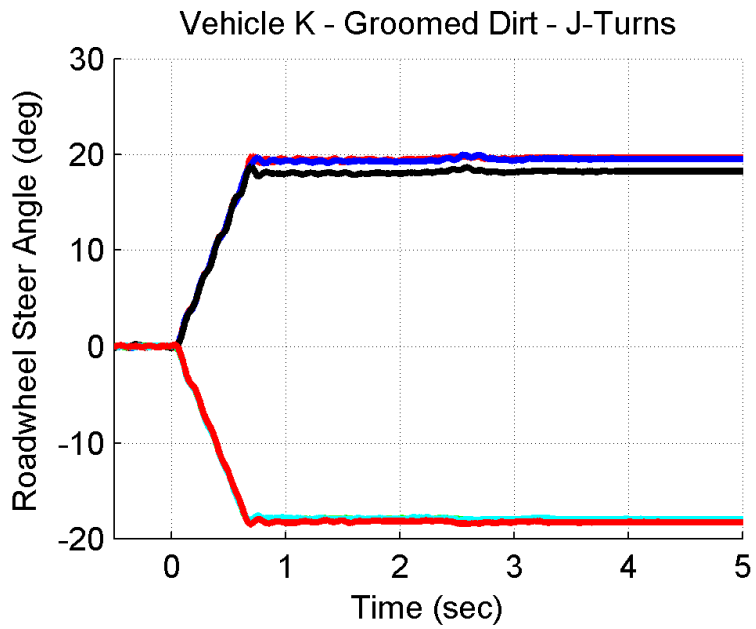

Vehicle J - Groomed Dirt - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

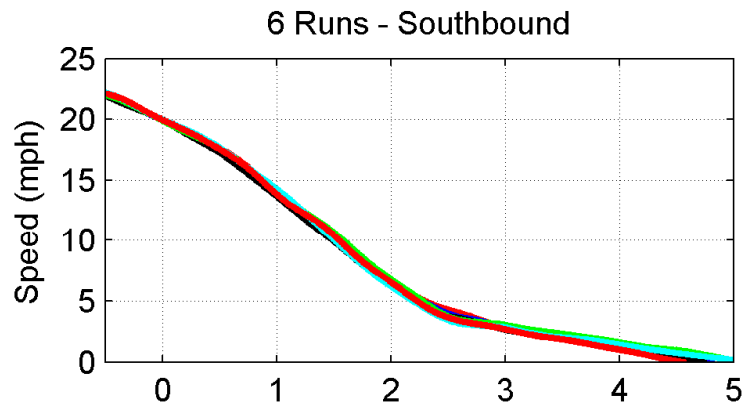

Vehicle K - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

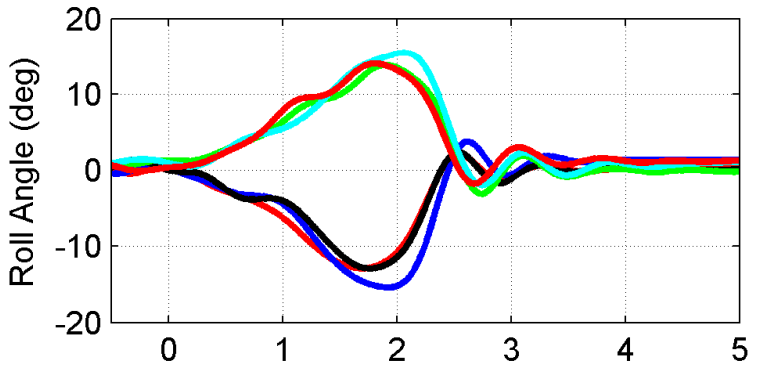

Vehicle K - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

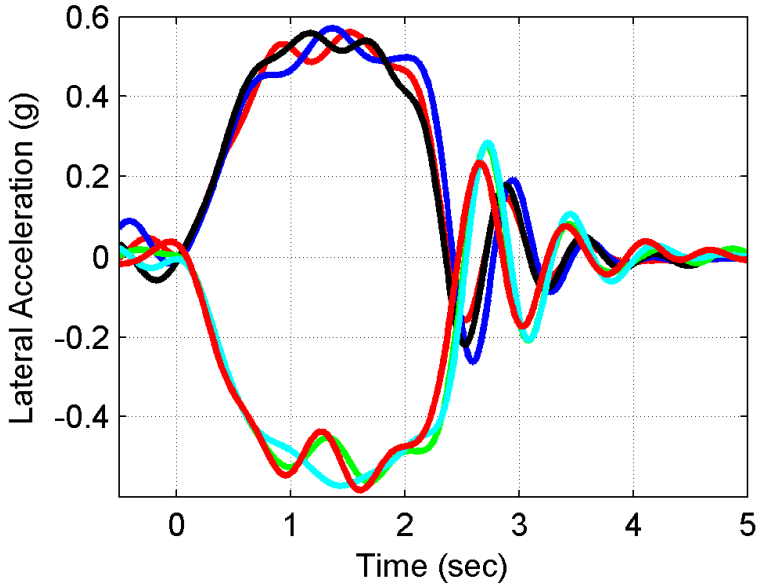

Vehicle K - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
CW Transition to OS
At Ay = 0.207 g
CCW Transition to OS
At Ay = -0.254 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
8
6
4
2
0
-2
-4
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

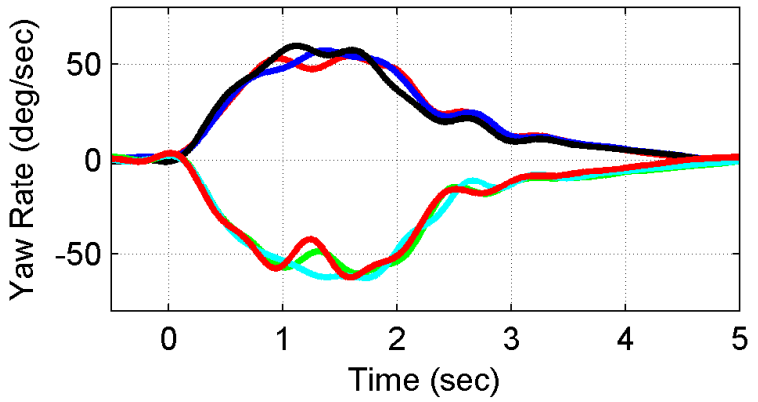

Vehicle K - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -9.57 deg/g
6
4
2
0
-2
-4
-6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

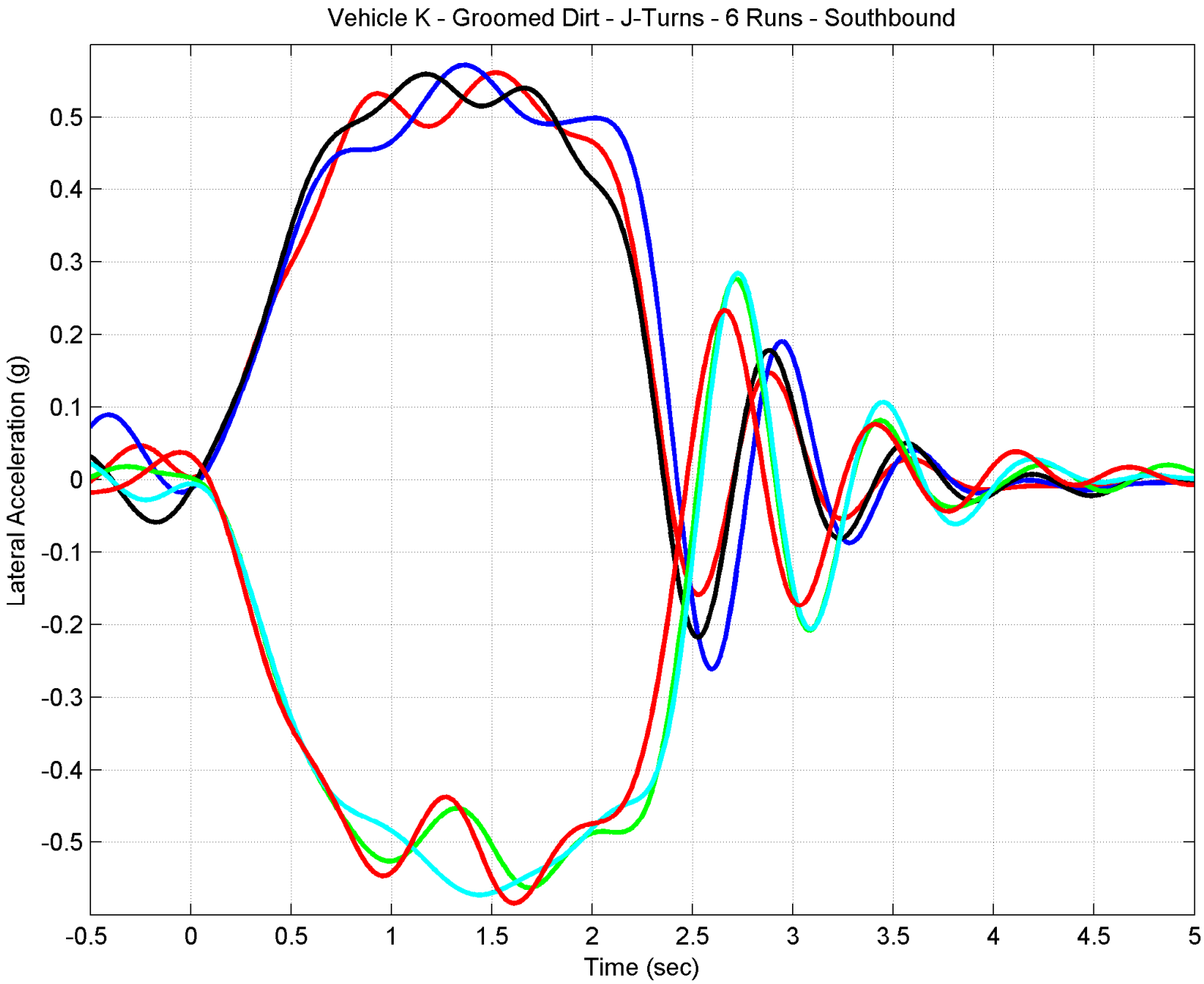

Vehicle K - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
30
20
10
0
-10
-20
0
1
2
3
4
5
Time (sec)

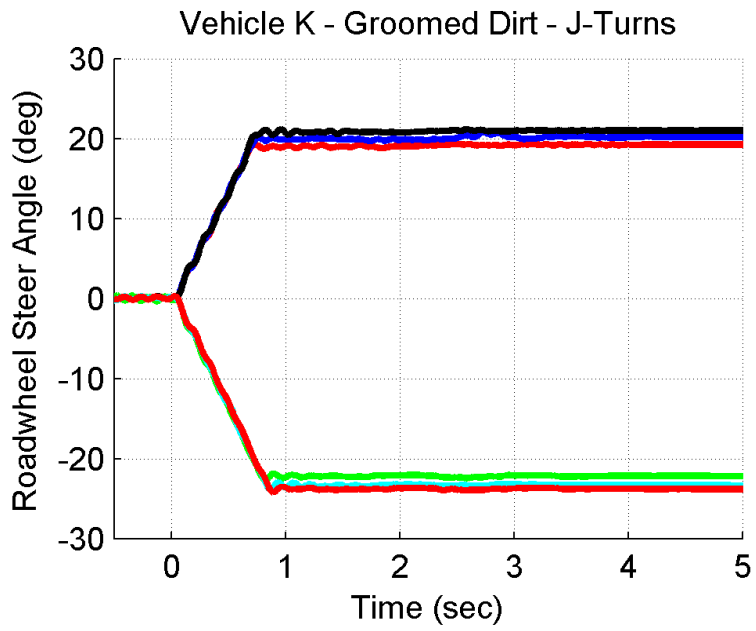

6 Runs - Southbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5

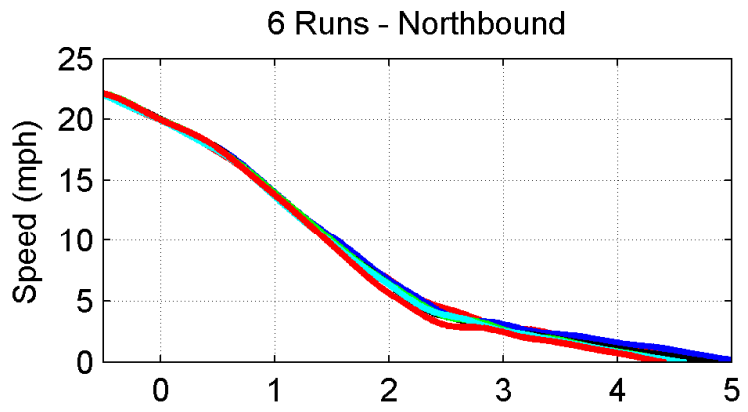

Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5

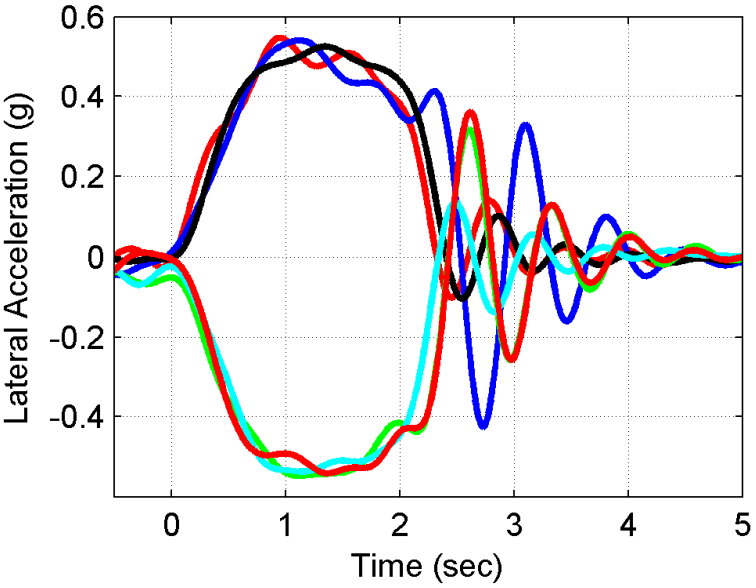

Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)

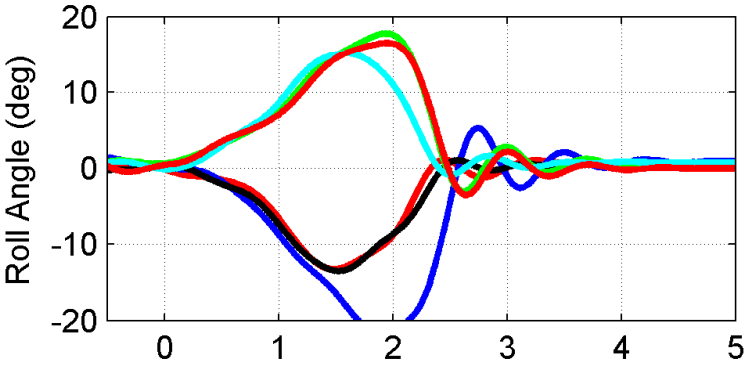

Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)

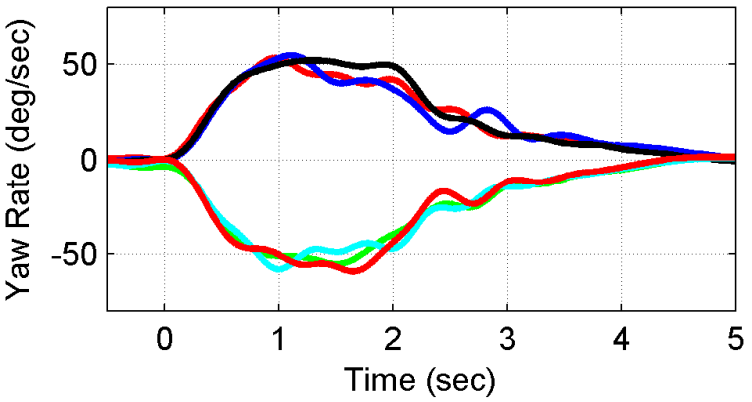

Vehicle K - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

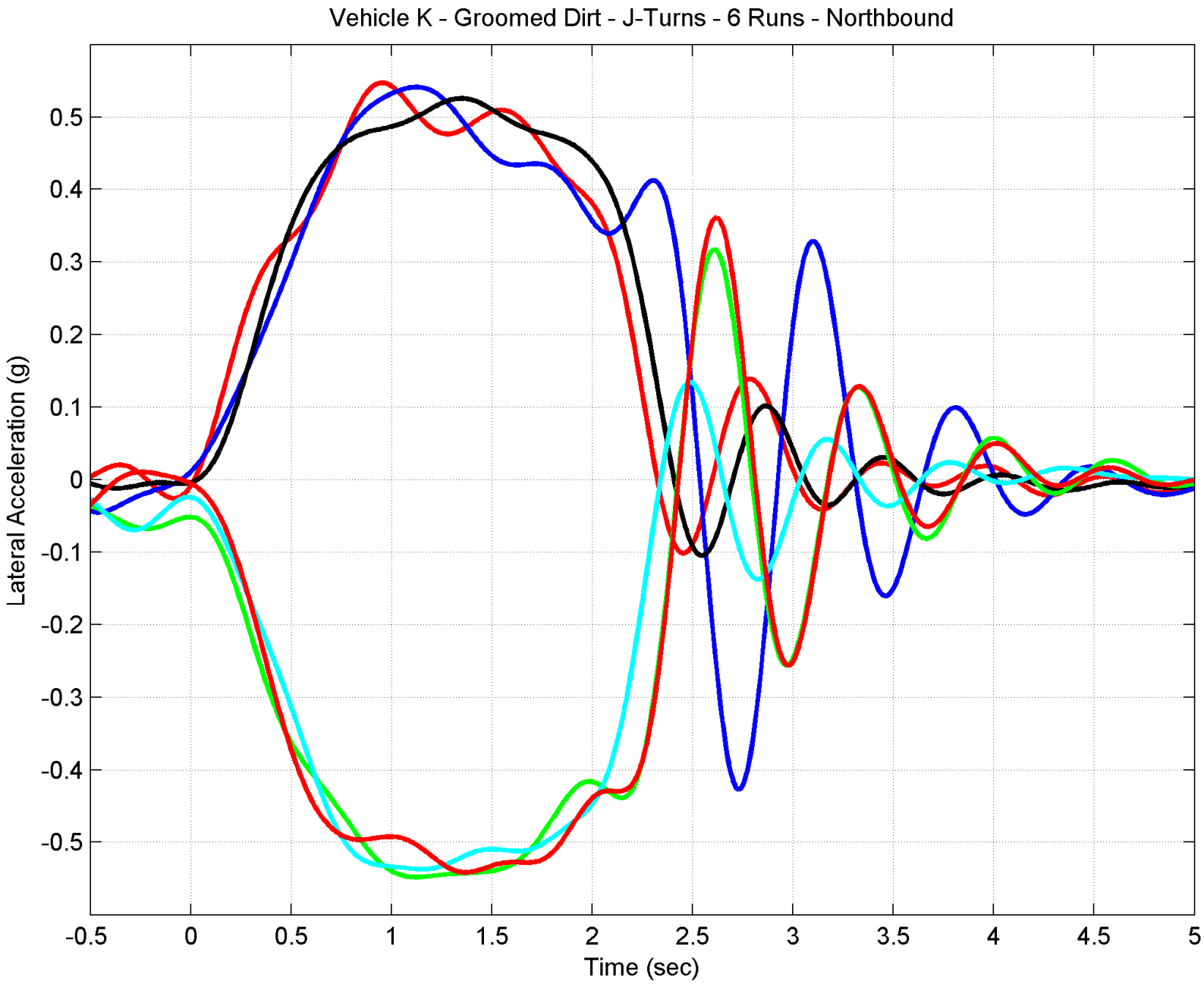

Vehicle K - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
30
20
10
0
-10
-20
-30
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5


Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle K - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle K - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.561	-0.563
2	0.572	-0.573
3	0.559	-0.584
Mean Value of 3 Runs	0.564	-0.573
Standard Deviation of 3 Runs	0.007	0.011

Average of 6 North Runs

0.569

Run Number	North Right Turns	North Left Turns
1	0.547	-0.548
2	0.541	-0.537
3	0.526	-0.542
Mean Value of 3 Runs	0.538	-0.542
Standard Deviation of 3 Runs	0.011	0.005

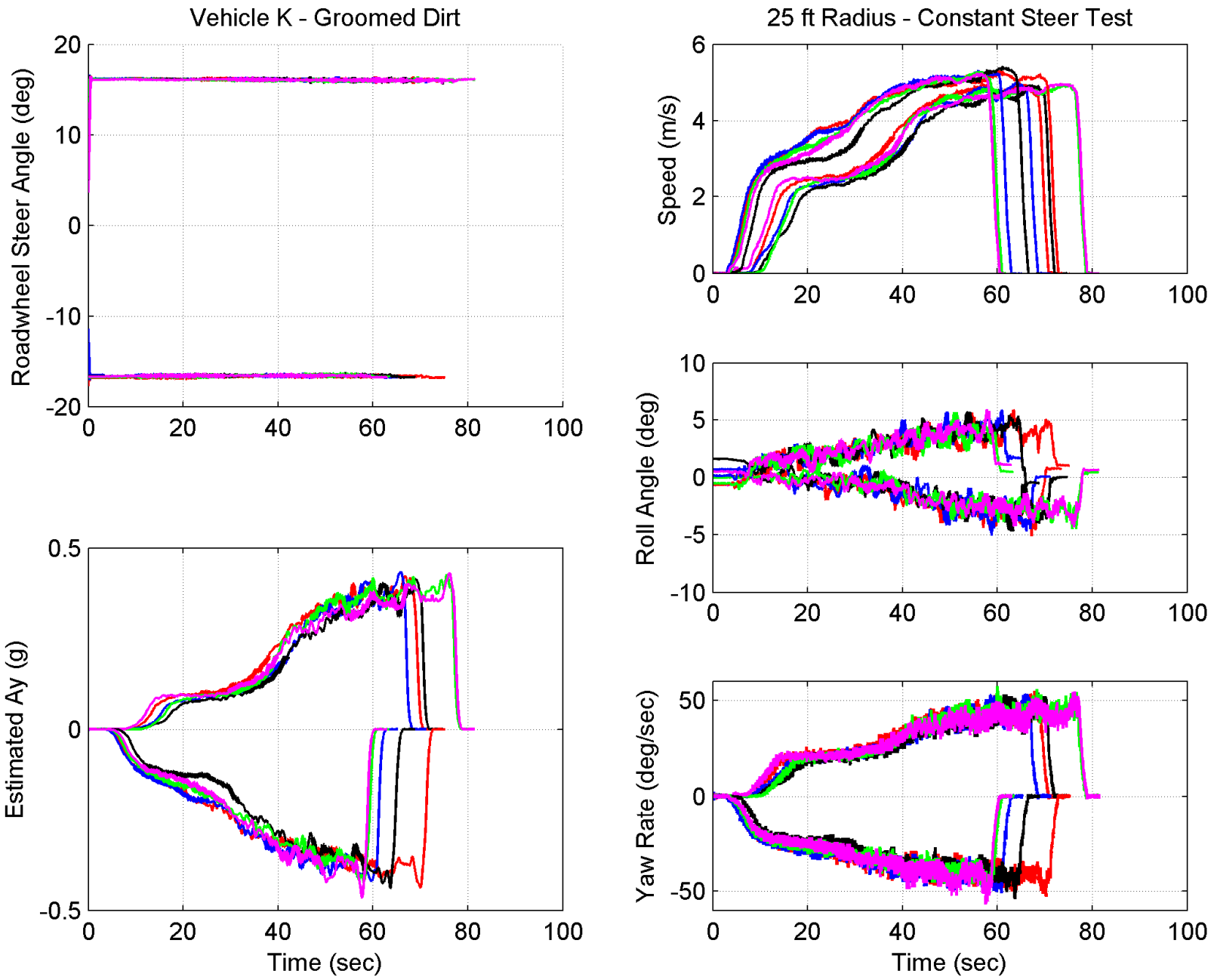
Average of 6 South Runs

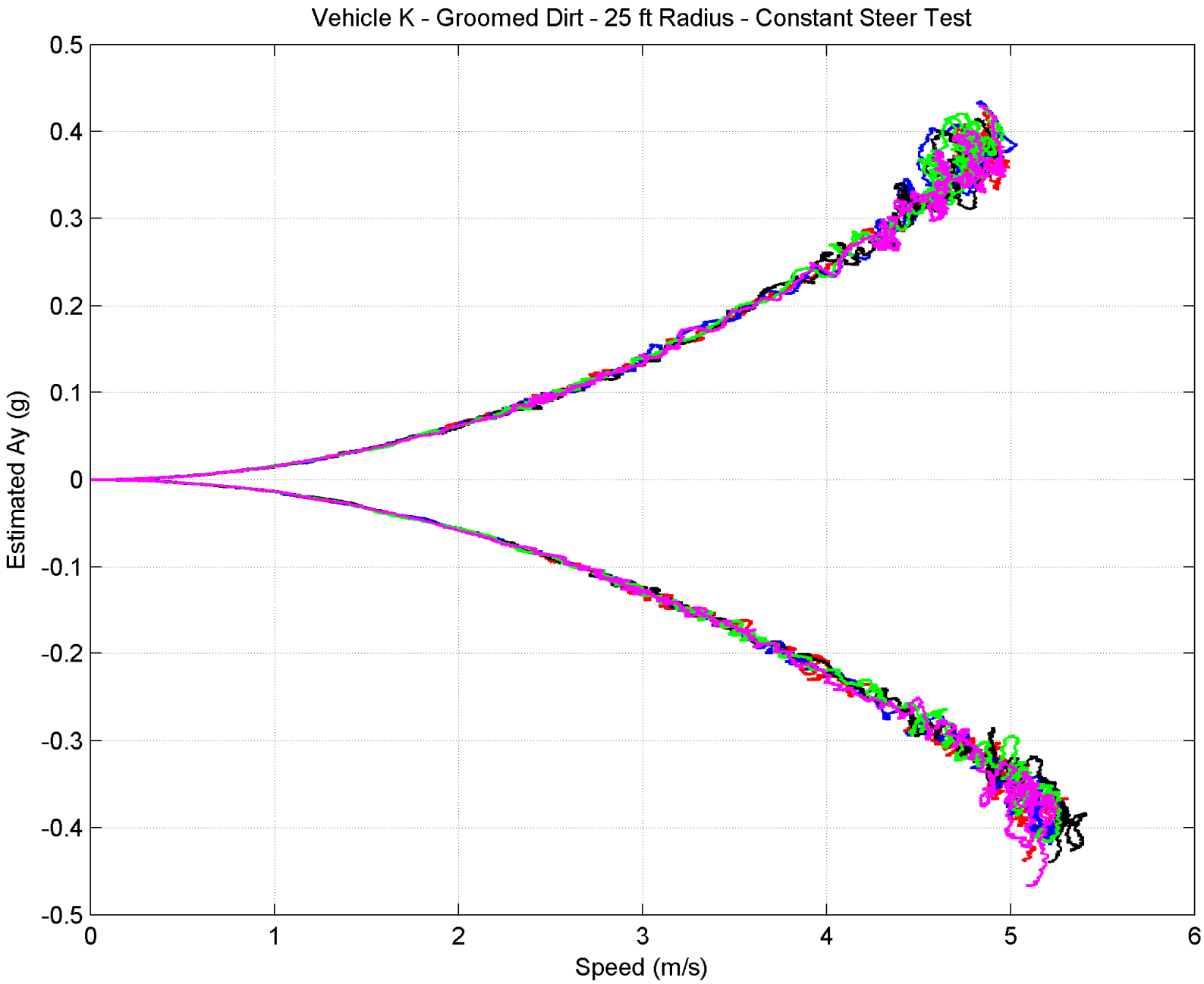
0.540

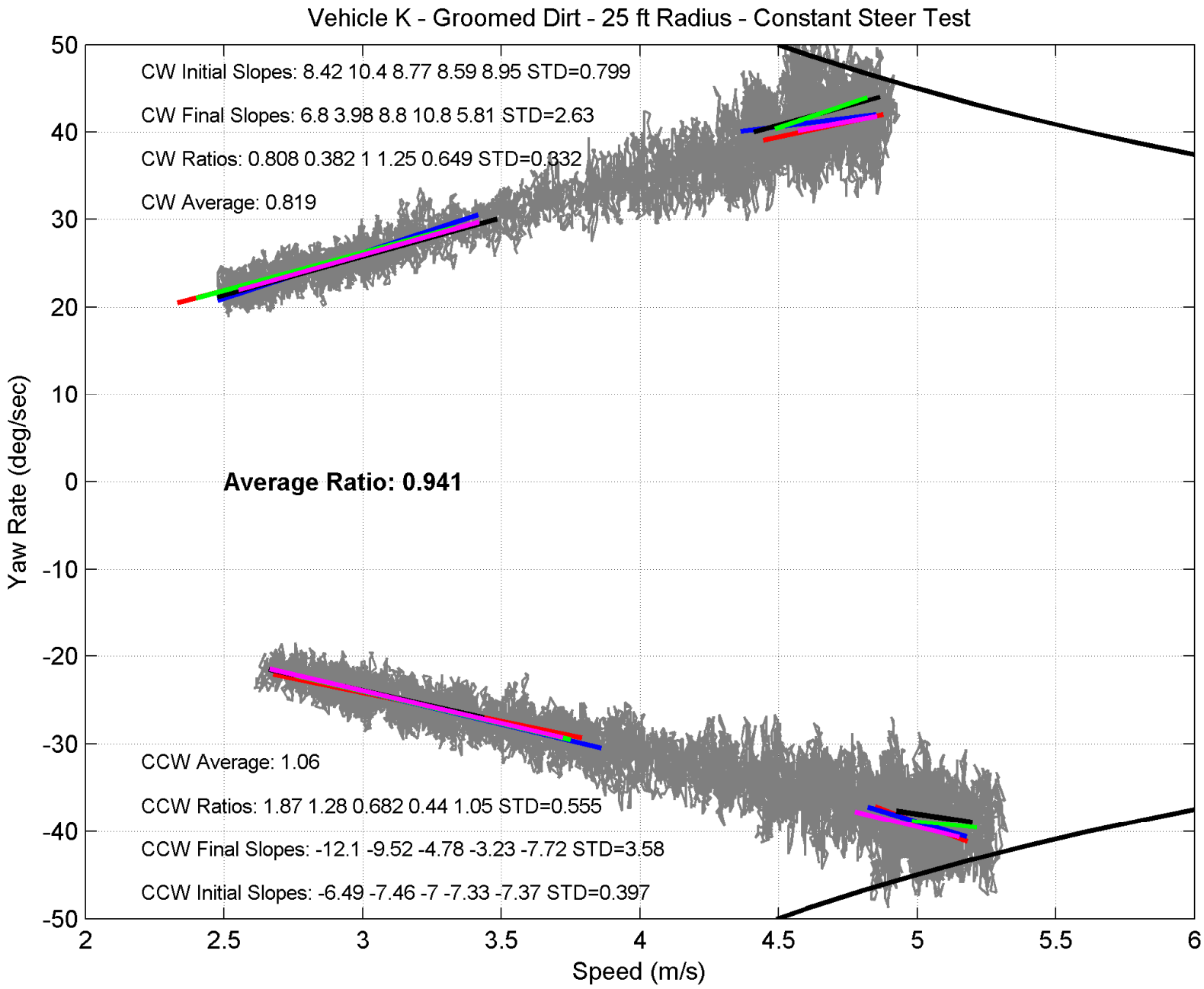
Average of All 12 Runs

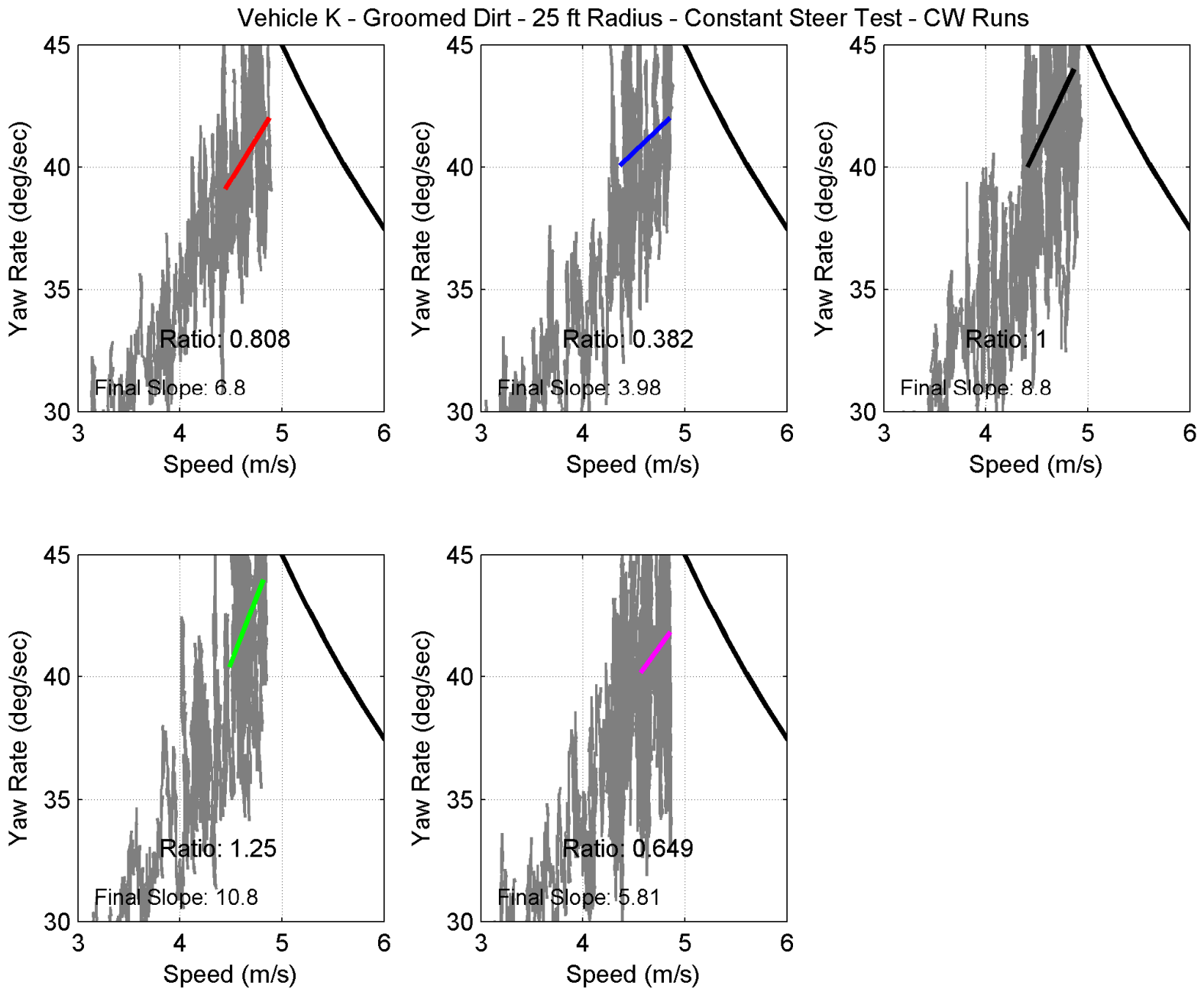
0.554

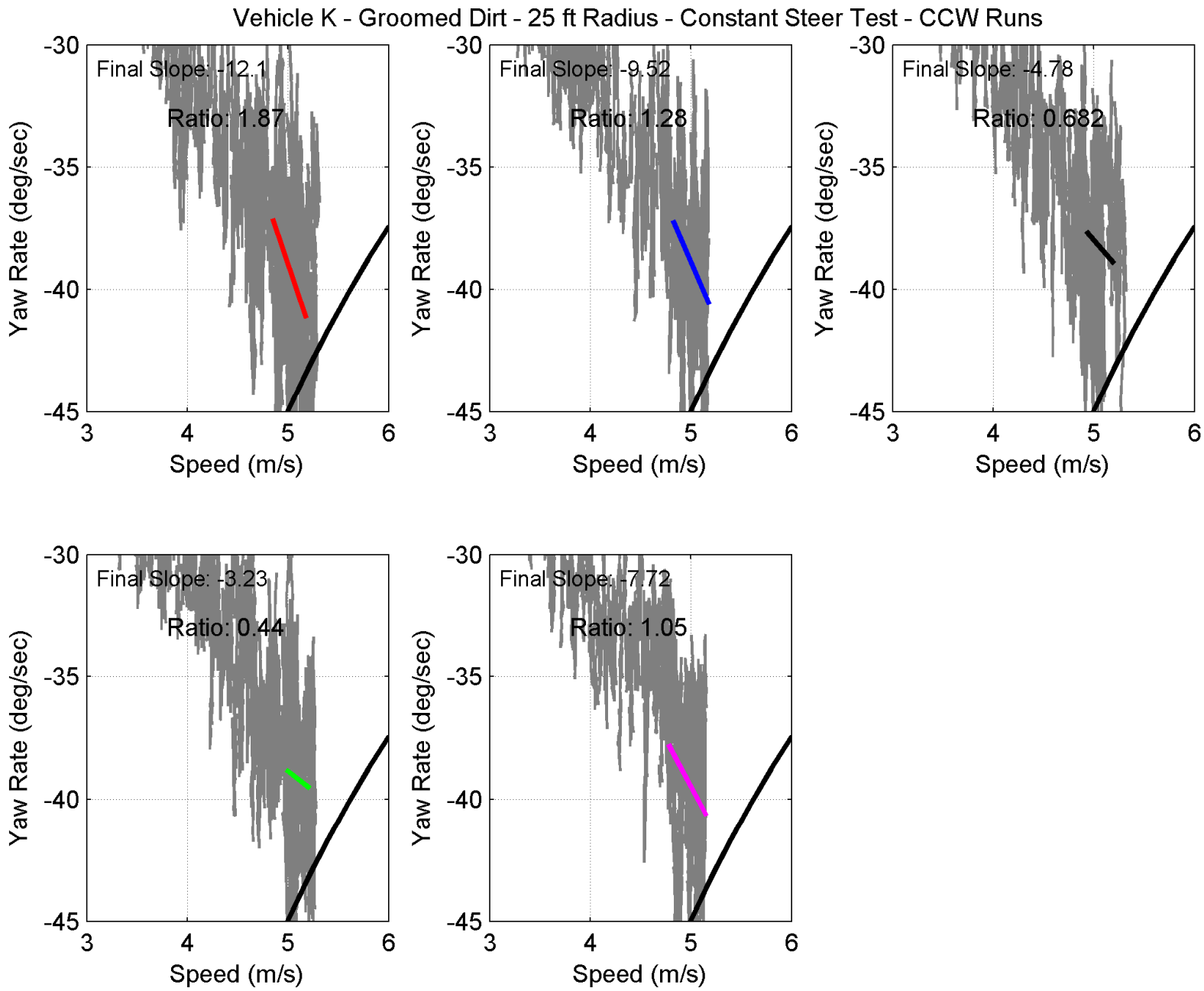
Threshold Ay

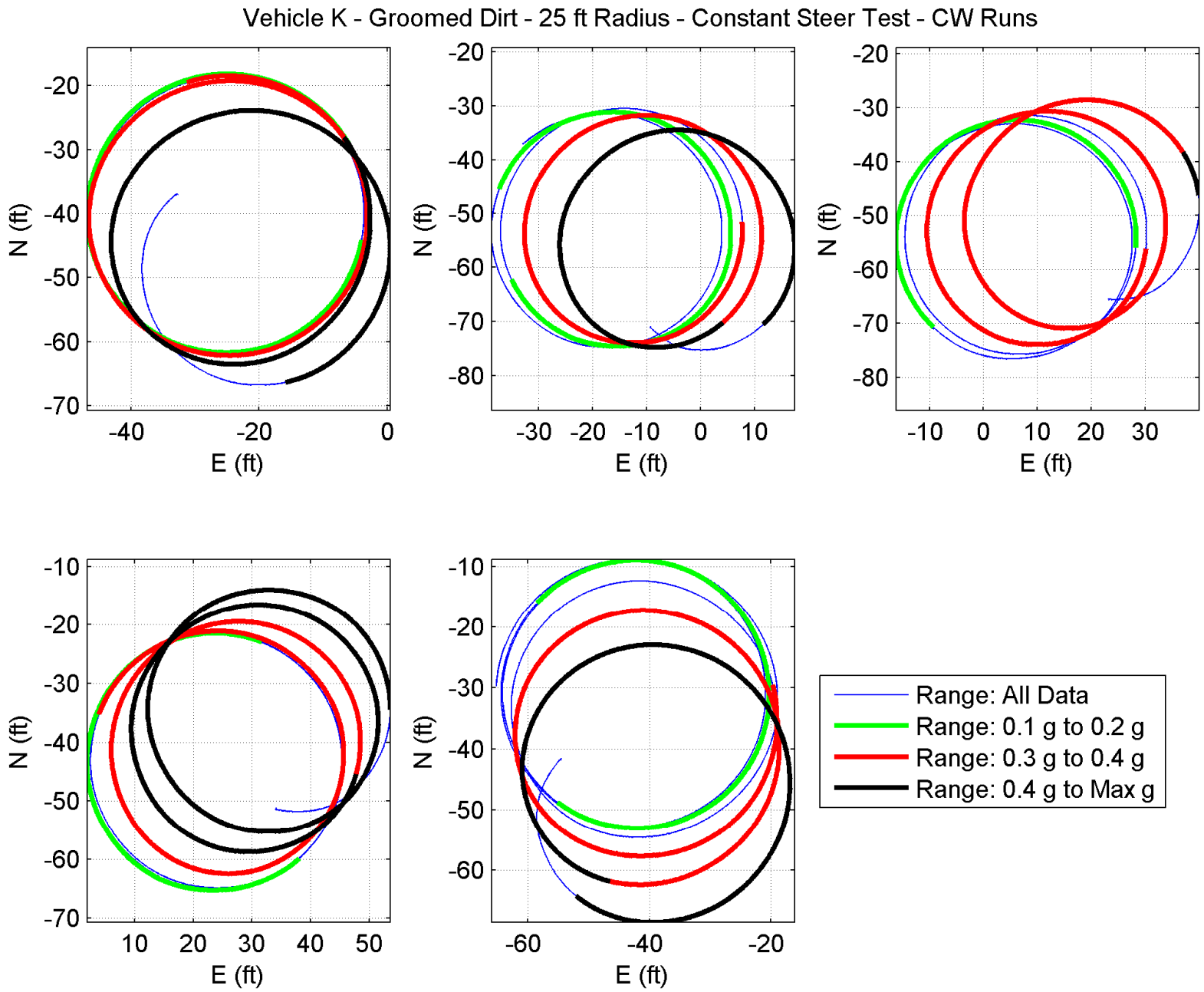

Vehicle K - Groomed Dirt
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

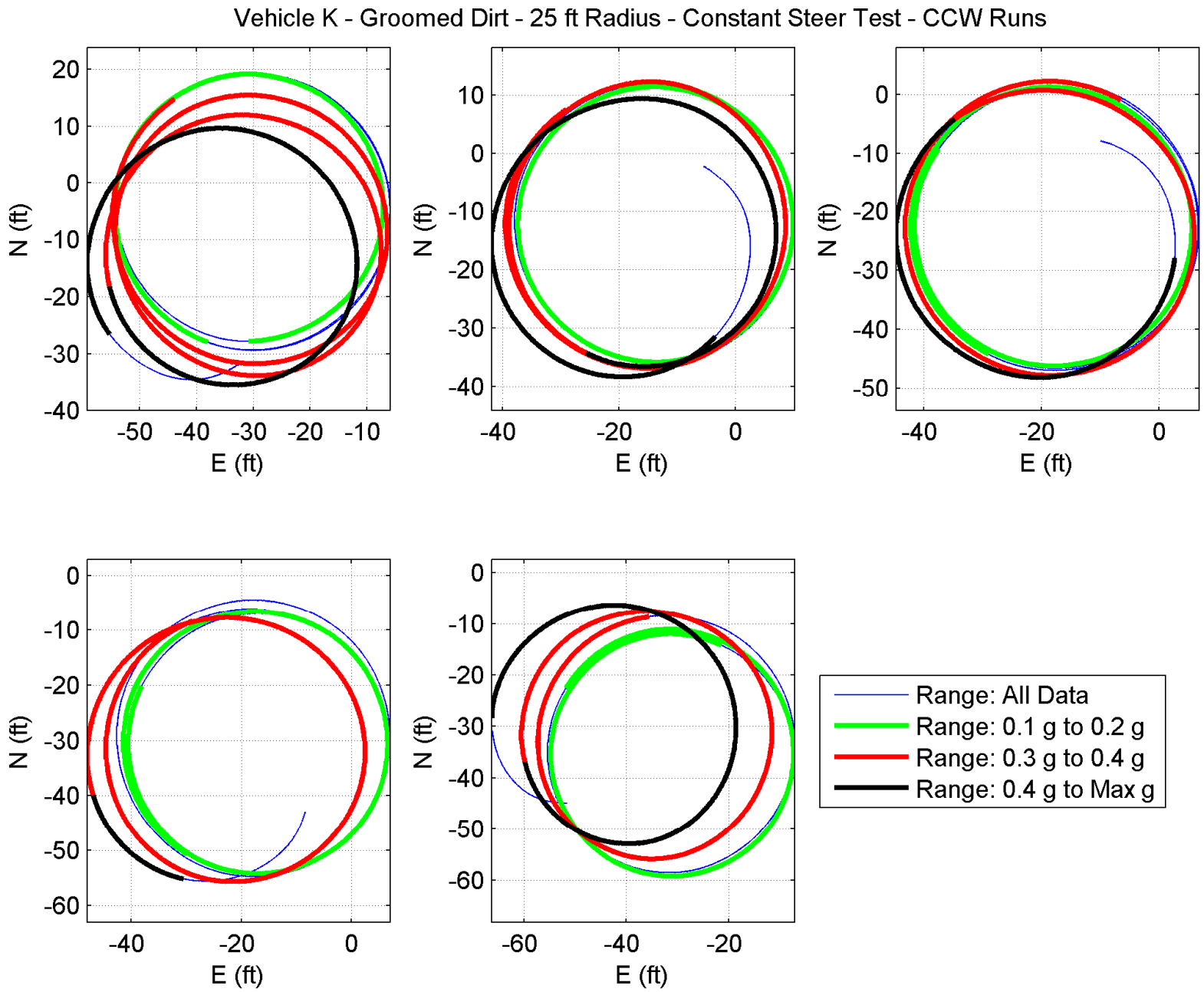

Vehicle K - Groomed Dirt - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6

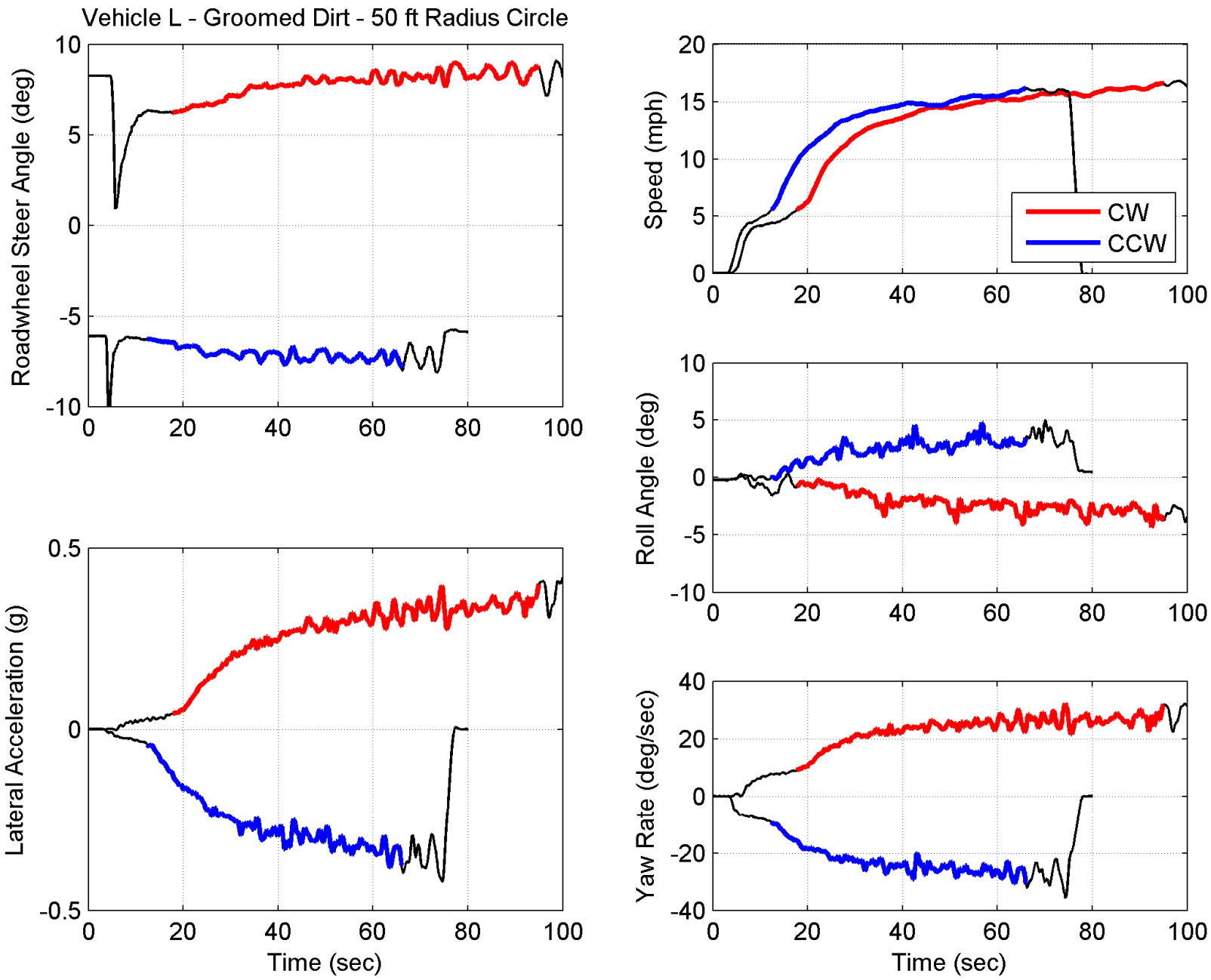

Vehicle K - Groomed Dirt - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 8.42 10.4 8.77 8.59 8.95 STD=0.799
CW Final Slopes: 6.8 3.98 8.8 10.8 5.81 STD=2.63
CW Ratios: 0.808 0.382 1 1.25 0.649 STD=0.332
CW Average: 0.819
Average Ratio: 0.941
CCW Average: 1.06
CCW Ratios: 1.87 1.28 0.682 0.44 1.05 STD=0.555
CCW Final Slopes: -12.1 -9.52 -4.78 -3.23 -7.72 STD=3.58
CCW Initial Slopes: -6.49 -7.46 -7 -7.33 -7.37 STD=0.397
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
2.5
3
3.5
4
4.5
5
5.5
6

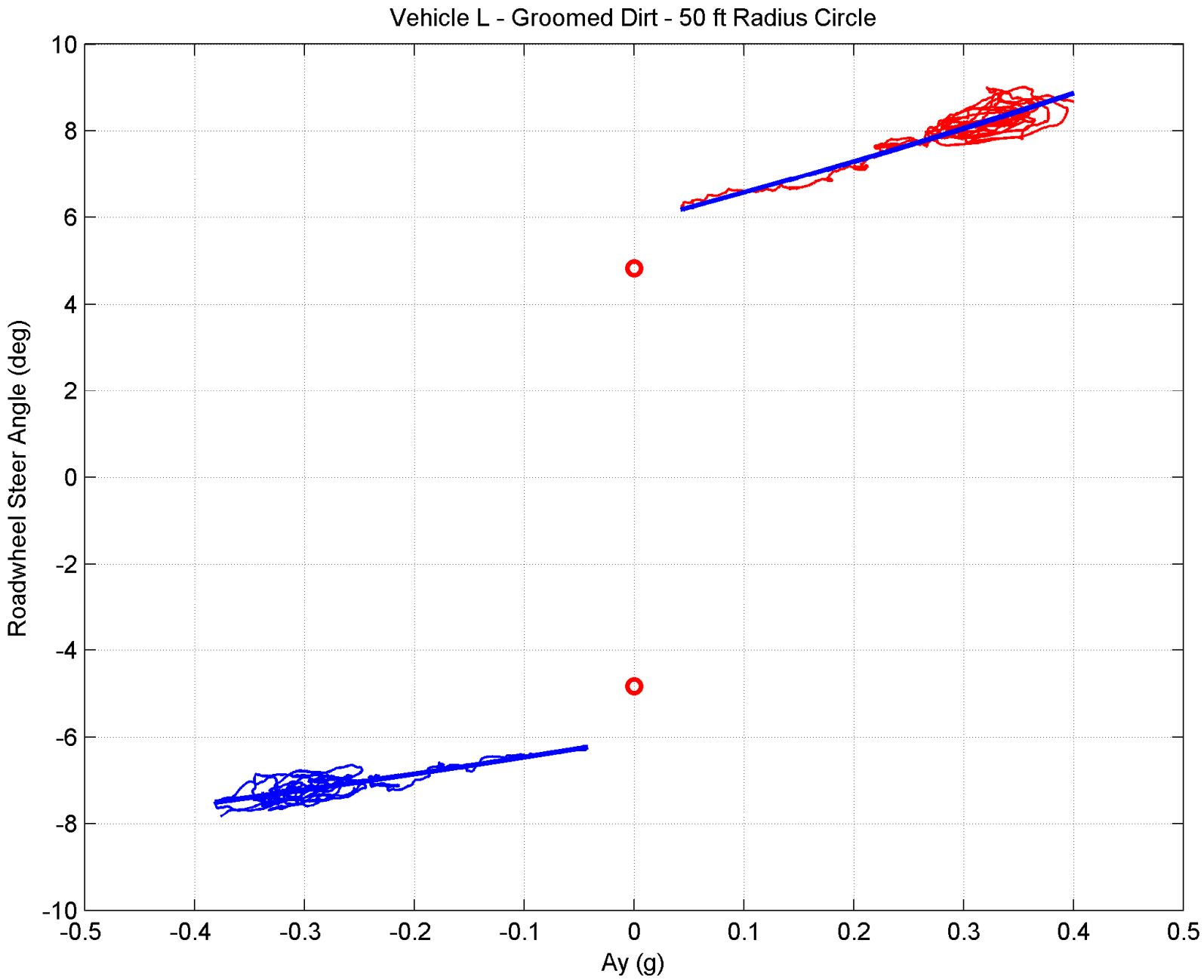

Vehicle K - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 0.808
Final Slope: 6.8
Ratio: 0.382
Final Slope: 3.98
Ratio: 1
Final Slope: 8.8
Ratio: 1.25
Final Slope: 10.8
Ratio: 0.649
Final Slope: 5.81

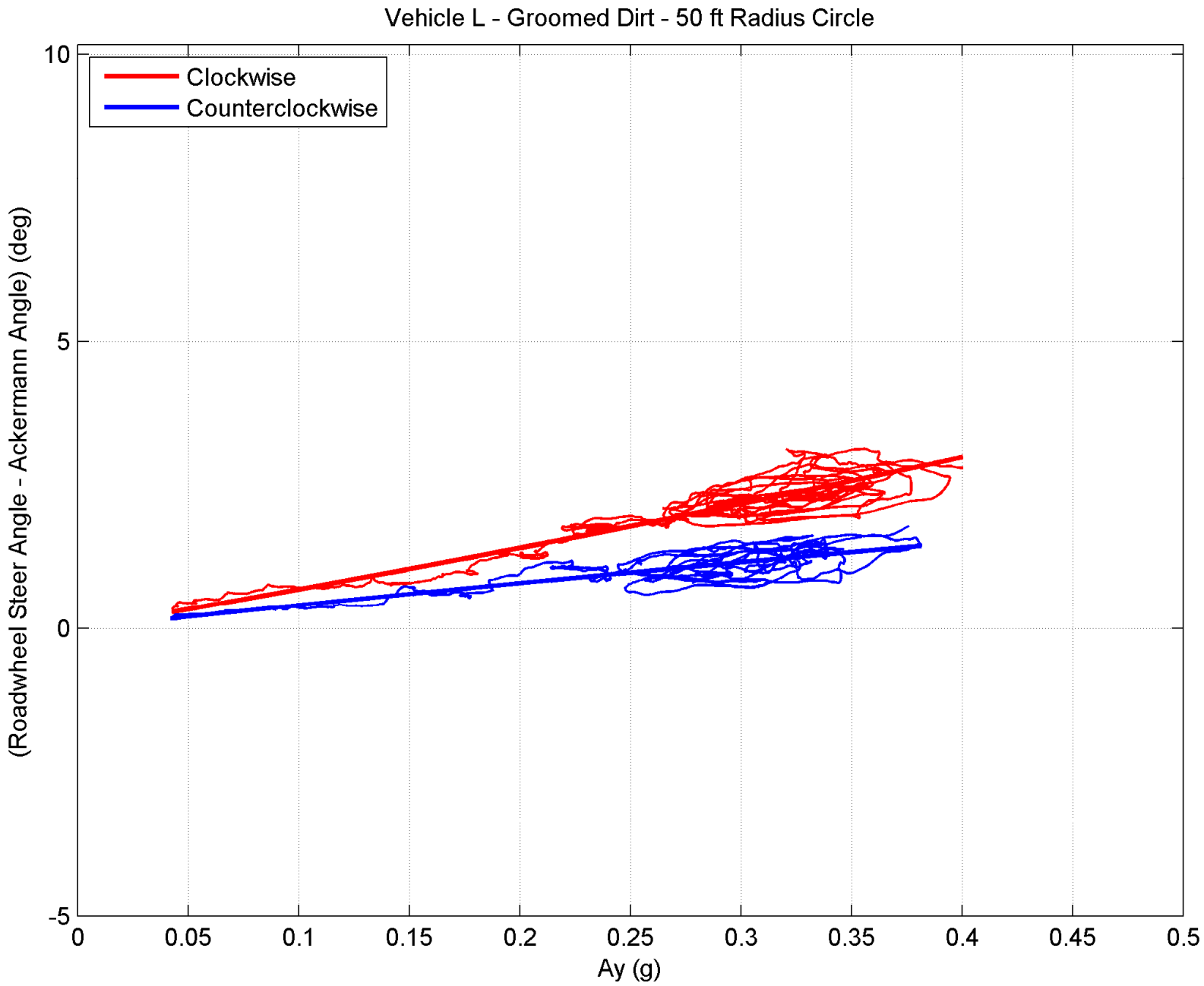

Vehicle K - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -12.1
Ratio: 1.87
Final Slope: -9.52
Ratio: 1.28
Final Slope: -4.78
Ratio: 0.682
Final Slope: -3.23
Ratio: 0.44
Final Slope: -7.72
Ratio: 1.05
Yaw Rate (deg/sec)
Speed (m/s)
-30
-35
-40
-45
3
4
5
6

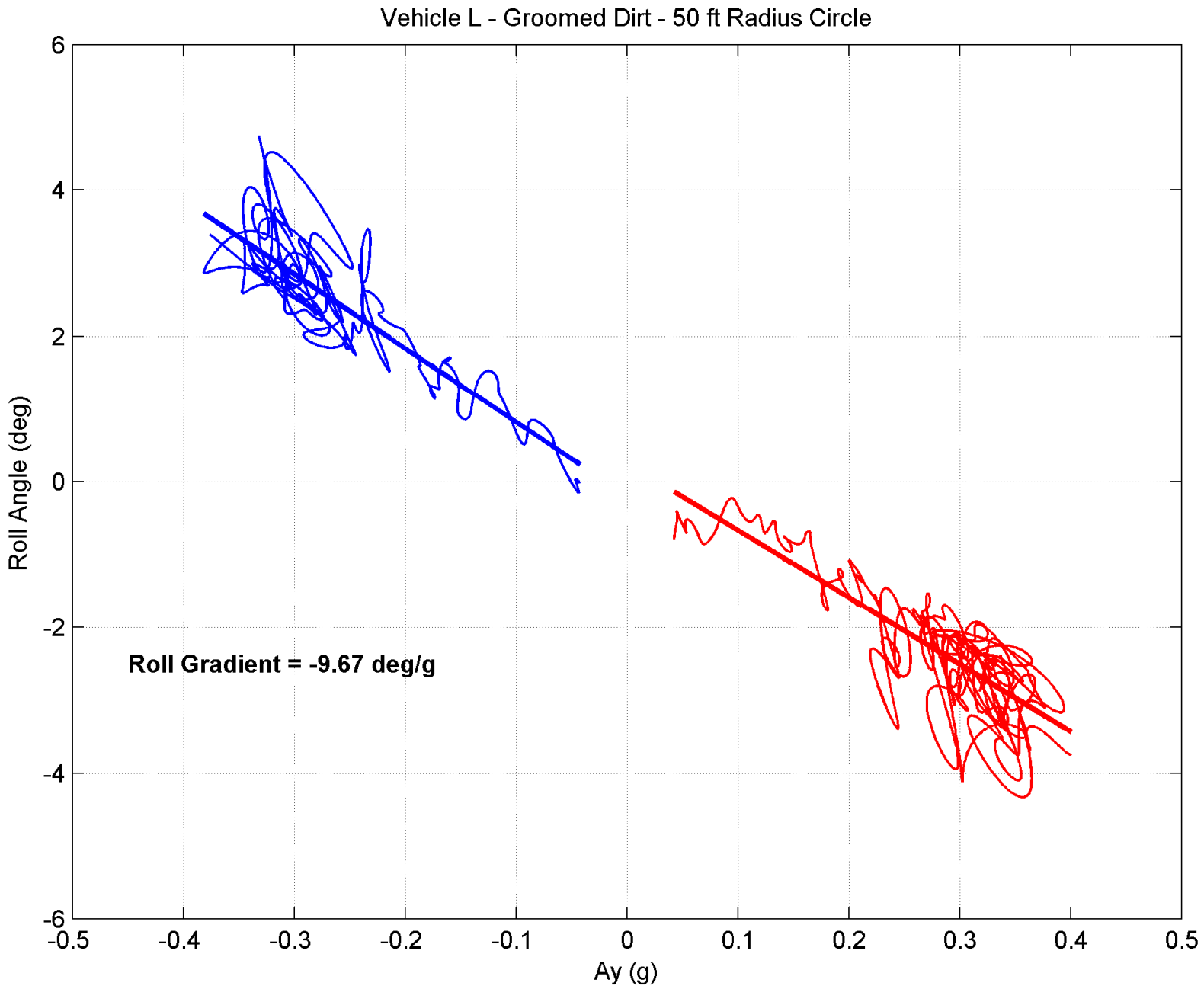

Vehicle K - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

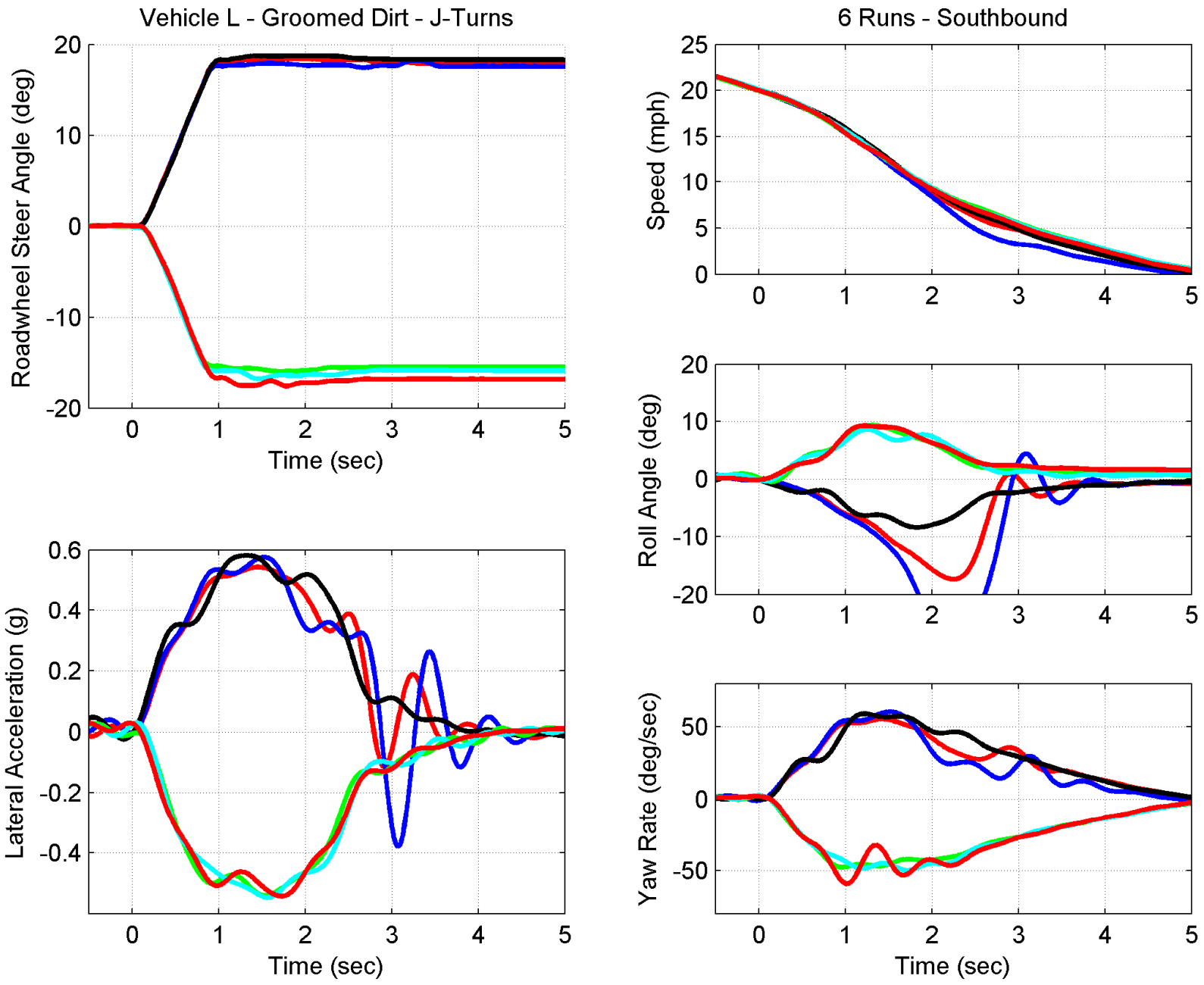

Vehicle K - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

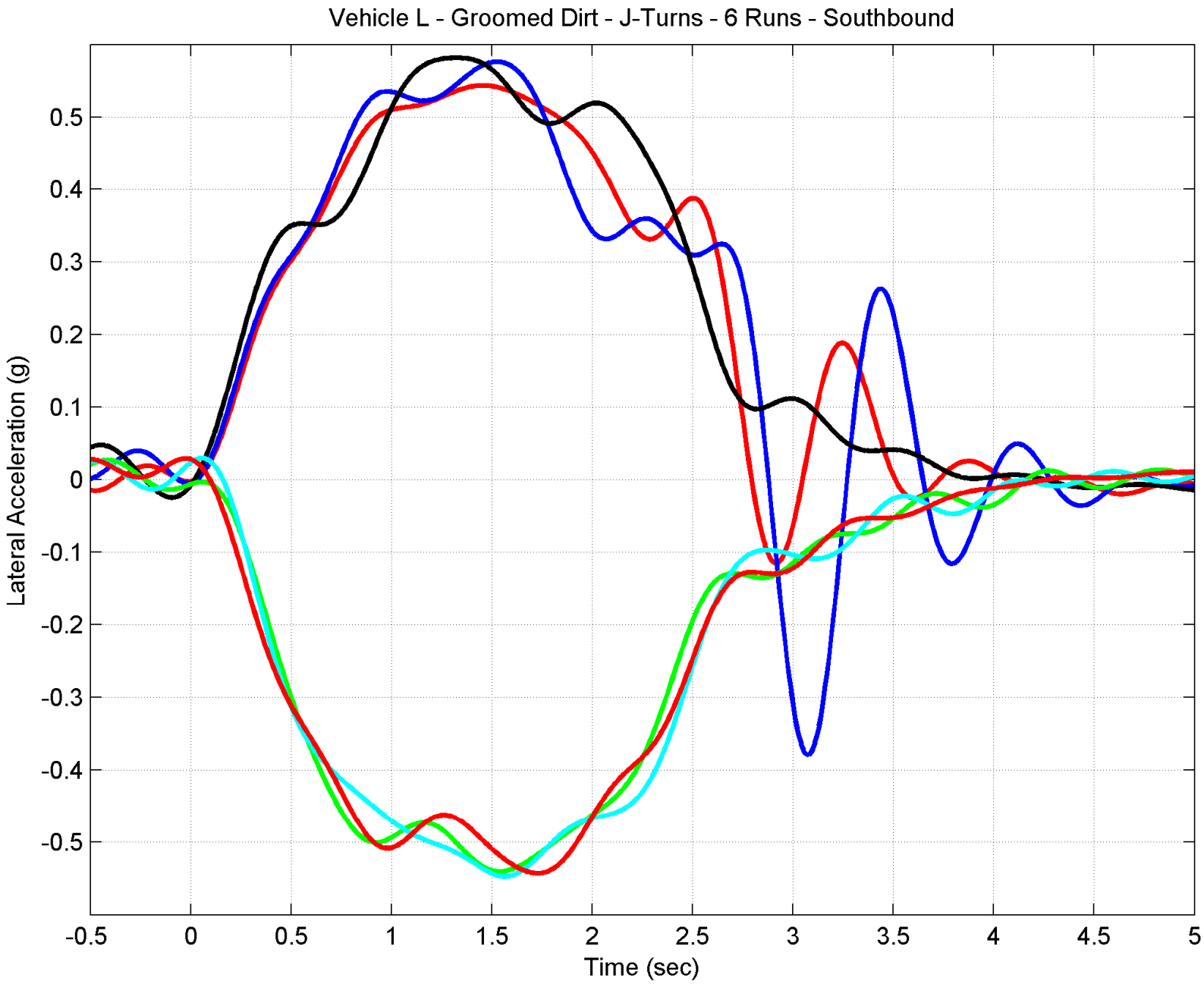

Vehicle L - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Speed (mph)
CW
CCW
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

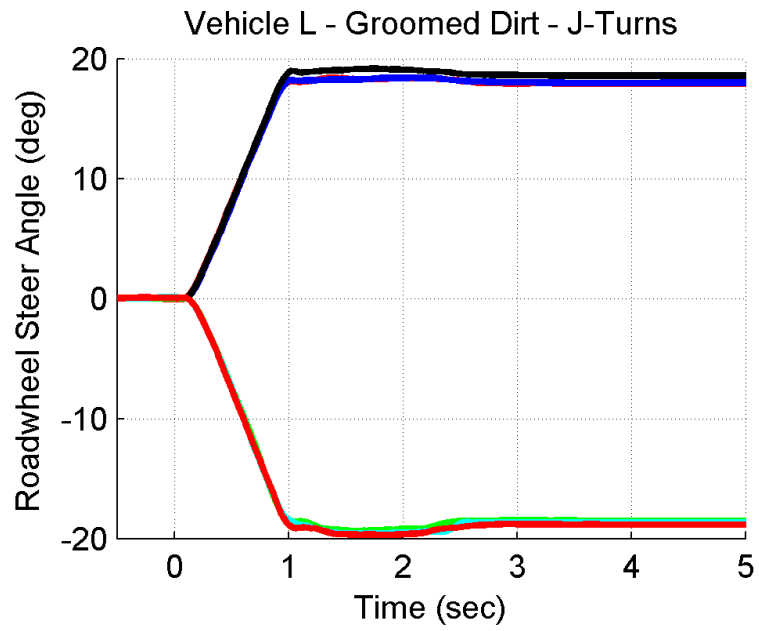

Vehicle L - Groomed Dirt - 50 ft Radius Circle
Roadwheel Steer Angle (deg)
Ay (g)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

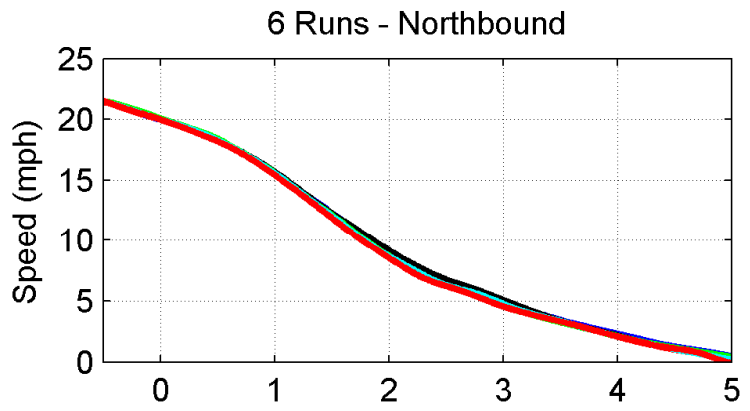

Vehicle L - Groomed Dirt - 50 ft Radius Circle
Clockwise
Counterclockwise
(Roadwheel Steer Angle - Ackermann Angle) (deg)
10
5
0
-5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Ay (g)

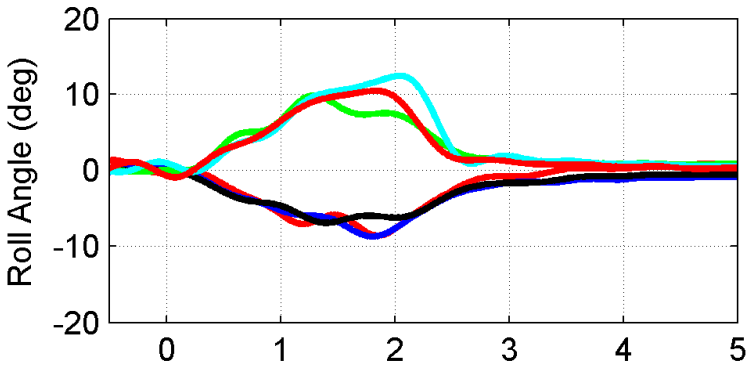

Vehicle L - Groomed Dirt - 50 ft Radius Circle
Roll Angle (deg)
Ay (g)
Roll Gradient = -9.67 deg/g
6
4
2
0
-2
-4
-6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

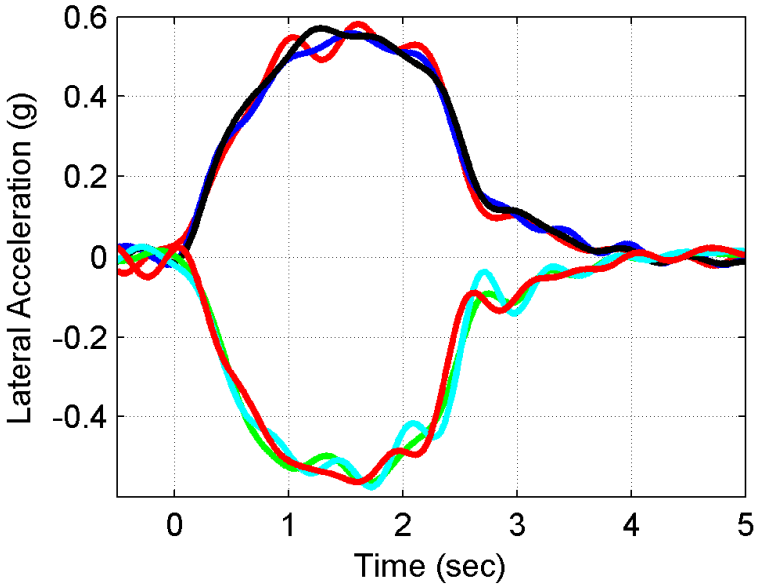

Vehicle L - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
6 Runs - Southbound
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)

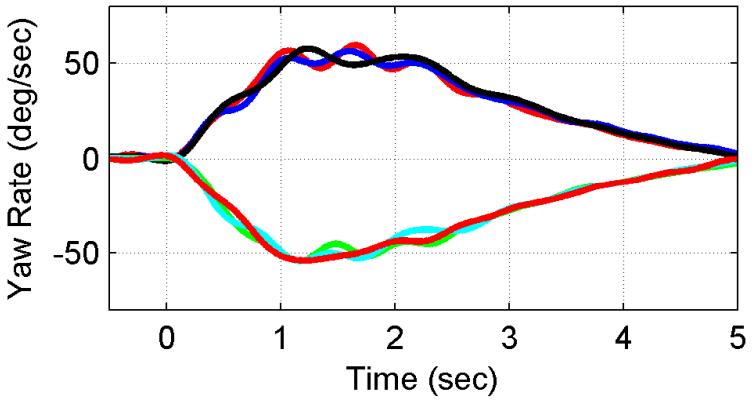

Vehicle L - Groomed Dirt - J-Turns - 6 Runs - Southbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

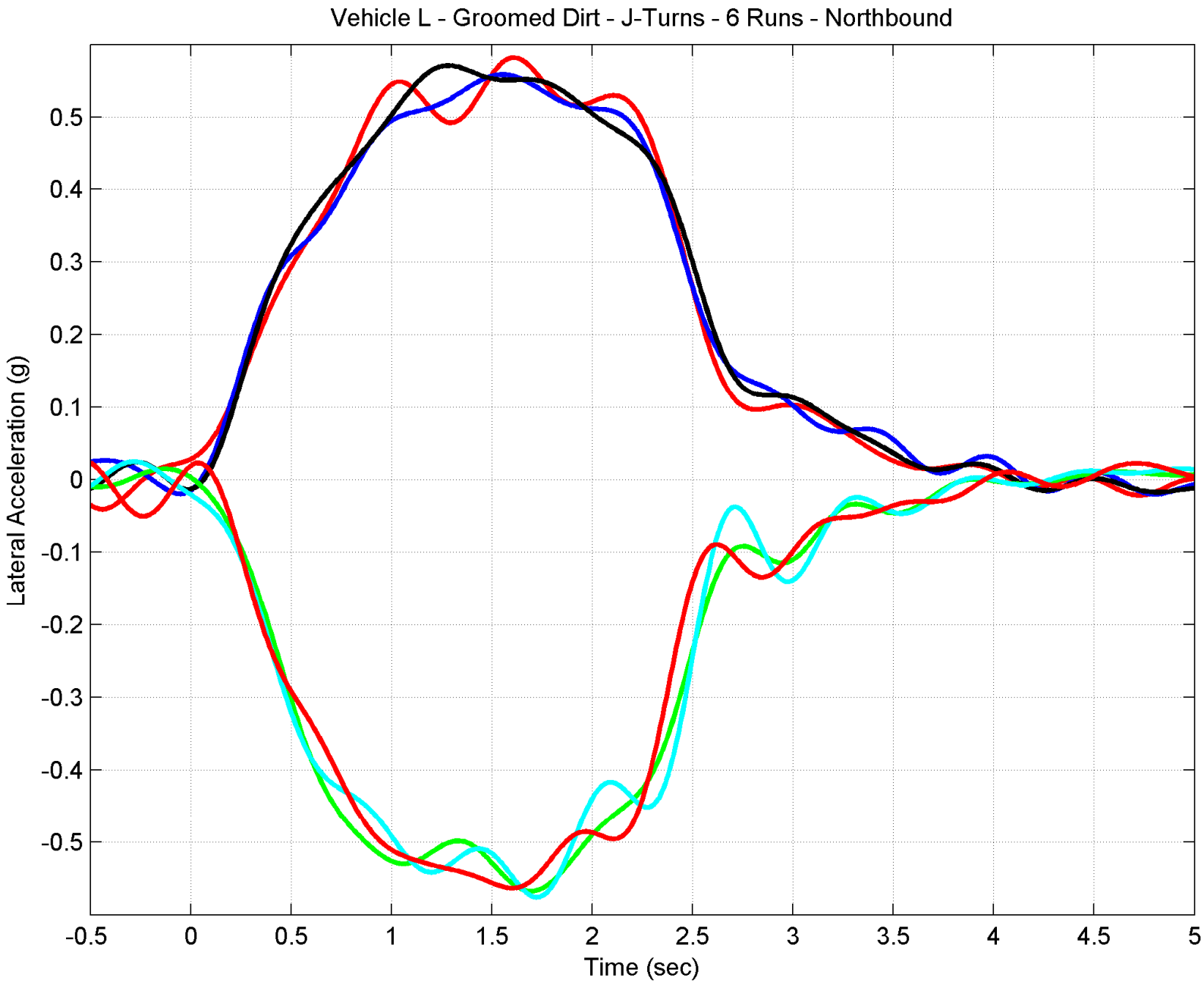

Vehicle L - Groomed Dirt - J-Turns
Roadwheel Steer Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5
Time (sec)


6 Runs - Northbound
Speed (mph)
25
20
15
10
5
0
0
1
2
3
4
5


Roll Angle (deg)
20
10
0
-10
-20
0
1
2
3
4
5


Lateral Acceleration (g)
0.6
0.4
0.2
0
-0.2
-0.4
0
1
2
3
4
5
Time (sec)


Yaw Rate (deg/sec)
50
0
-50
0
1
2
3
4
5
Time (sec)


Vehicle L - Groomed Dirt - J-Turns - 6 Runs - Northbound
Lateral Acceleration (g)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle L - Groomed Dirt Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

Run Number	South Right Turns	South Left Turns
1	0.543	-0.541
2	0.576	-0.547
3	0.582	-0.543
Mean Value of 3 Runs	0.567	-0.544
Standard Deviation of 3 Runs	0.021	0.003

Average of 6 North Runs

0.555

Run Number	North Right Turns	North Left Turns
1	0.582	-0.568
2	0.559	-0.576
3	0.571	-0.563
Mean Value of 3 Runs	0.570	-0.569
Standard Deviation of 3 Runs	0.012	0.006

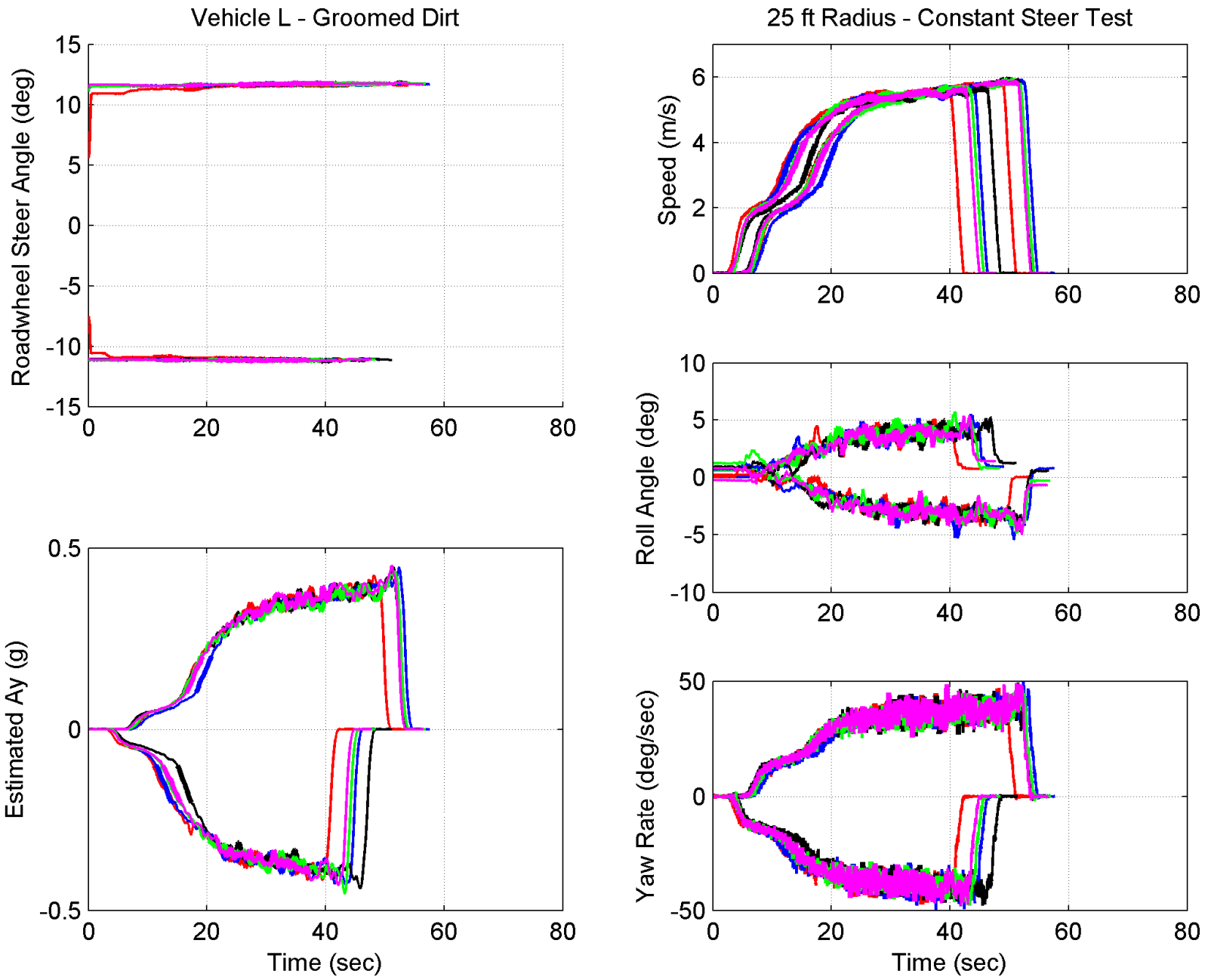
Average of 6 South Runs

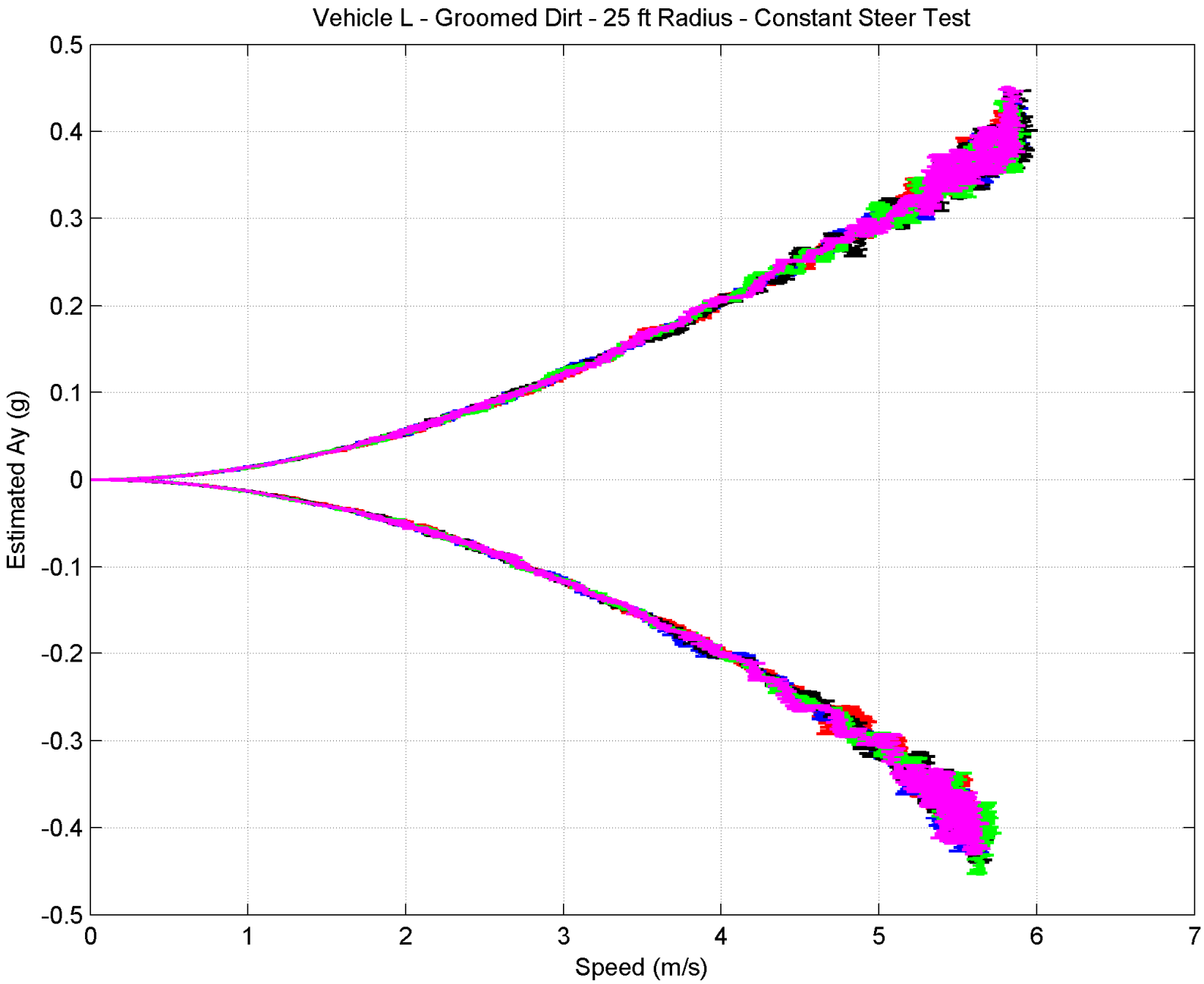
0.570

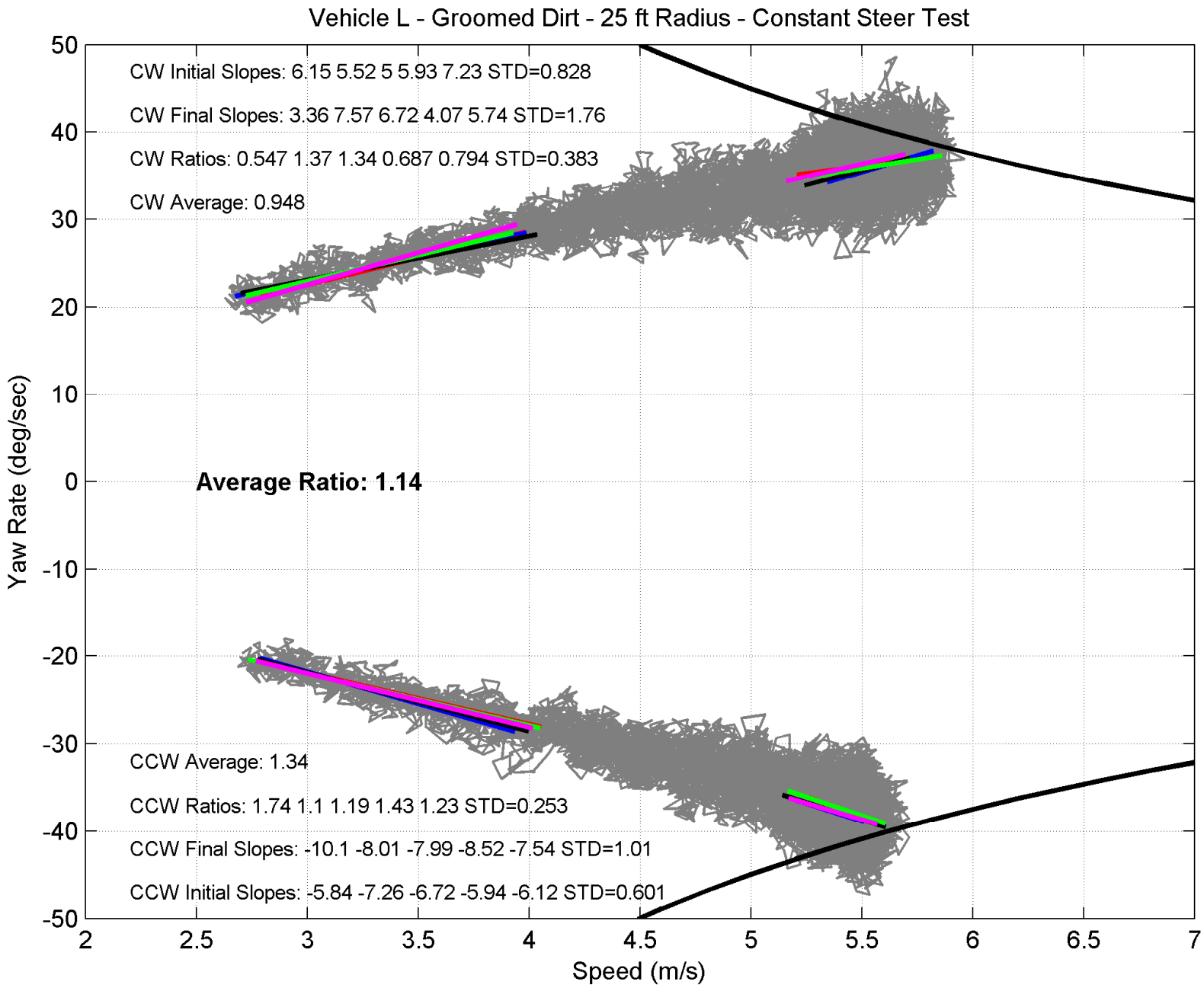
Average of All 12 Runs

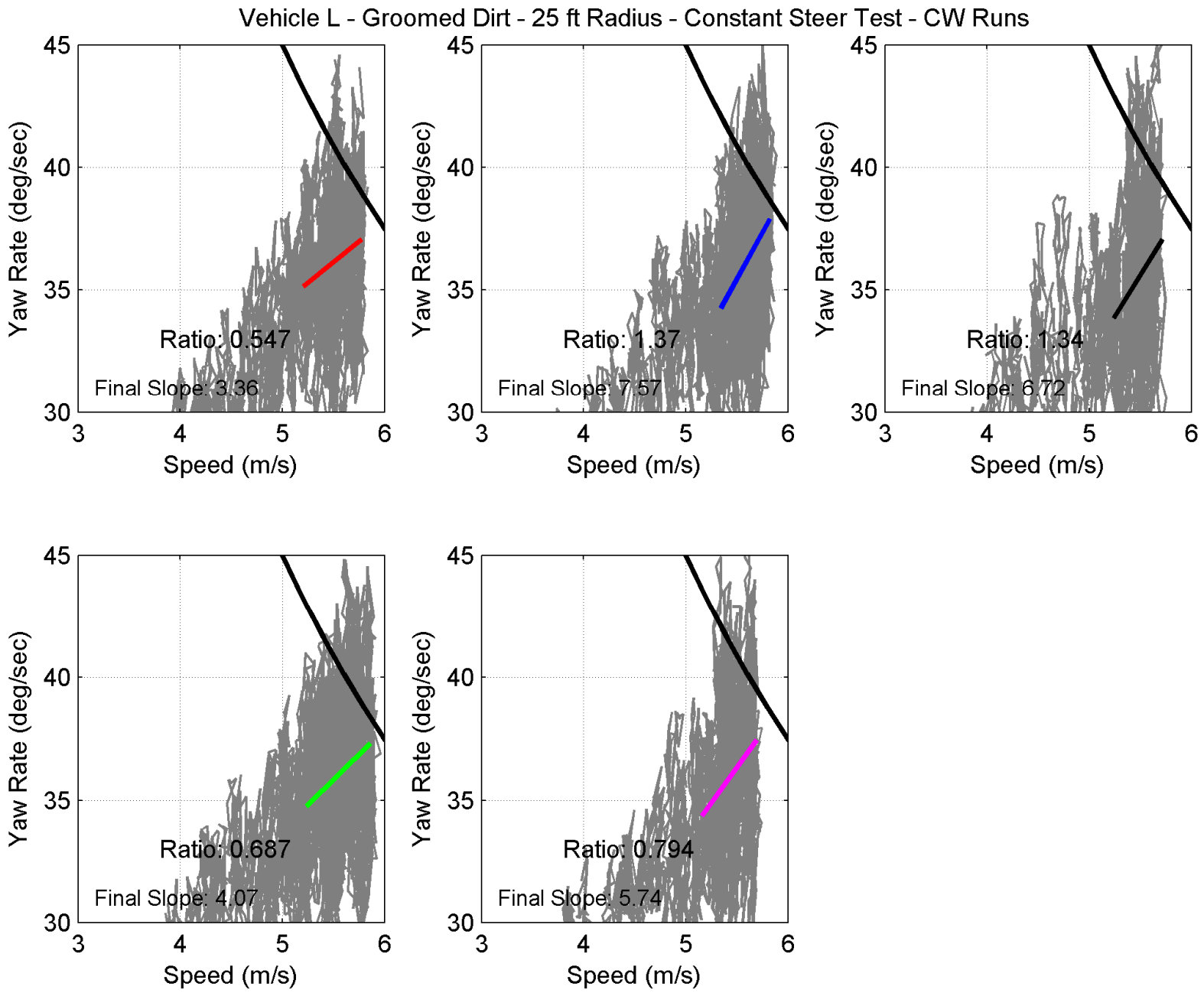
0.563

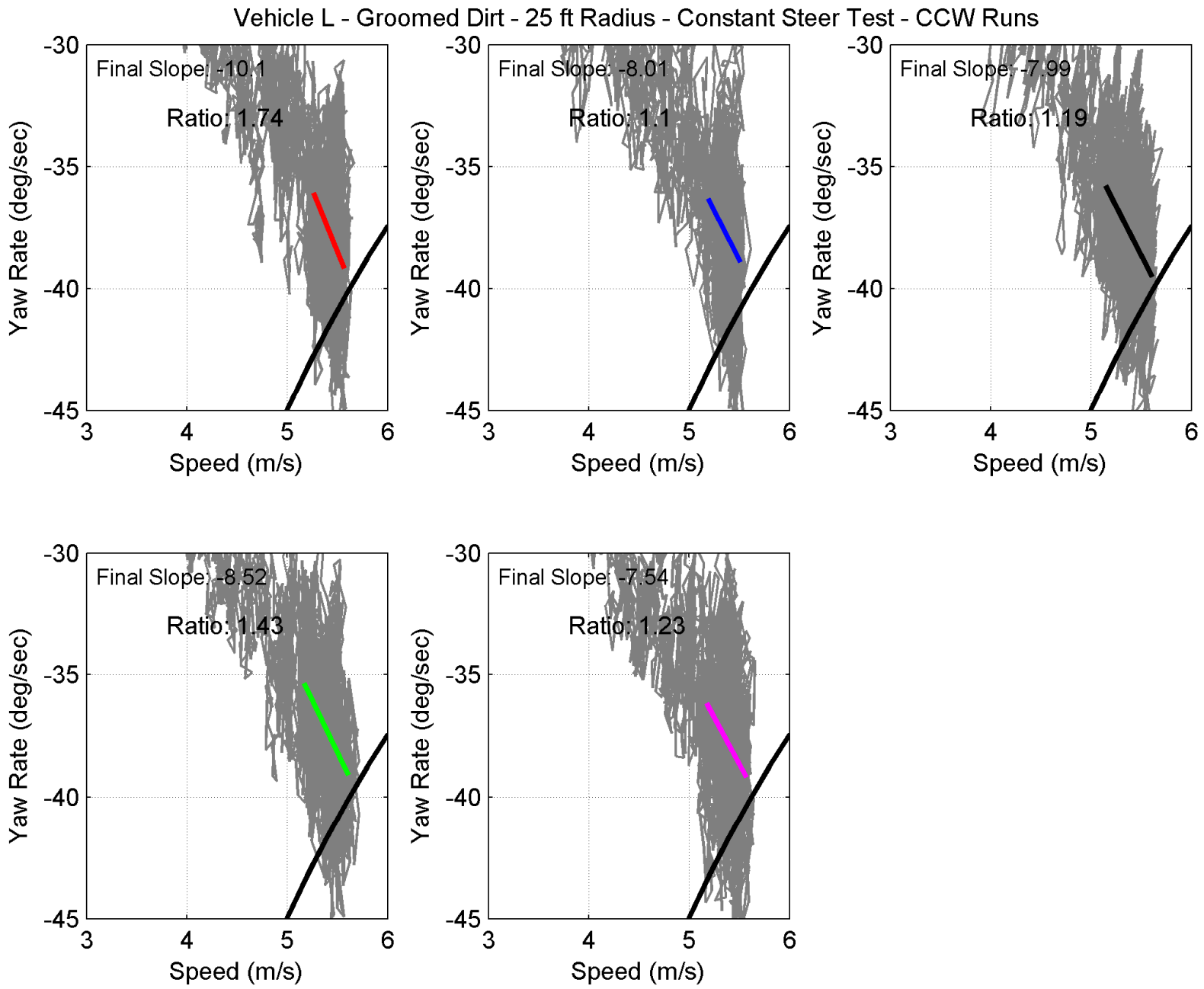
Threshold Ay

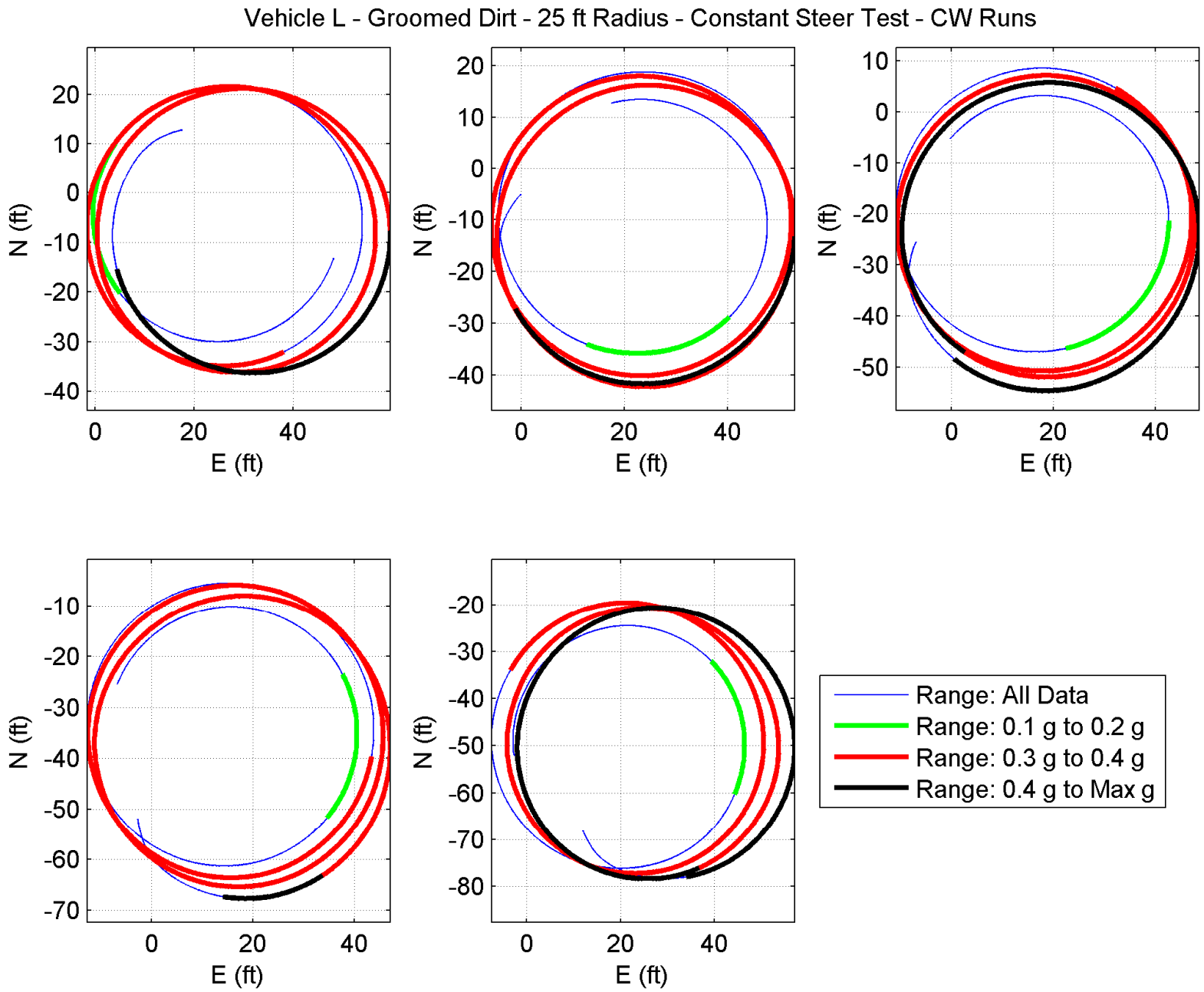

Vehicle L - Groomed Dirt
Roadwheel Steer Angle (deg)
15
10
5
0
-5
-10
-15
0
20
40
60
80
Estimated Ay (g)
0.5
0
-0.5
Time (sec)
25 ft Radius - Constant Steer Test
Speed (m/s)
6
4
2
0
Roll Angle (deg)
10
5
0
-5
-10
Yaw Rate (deg/sec)
50
0
-50
Time (sec)

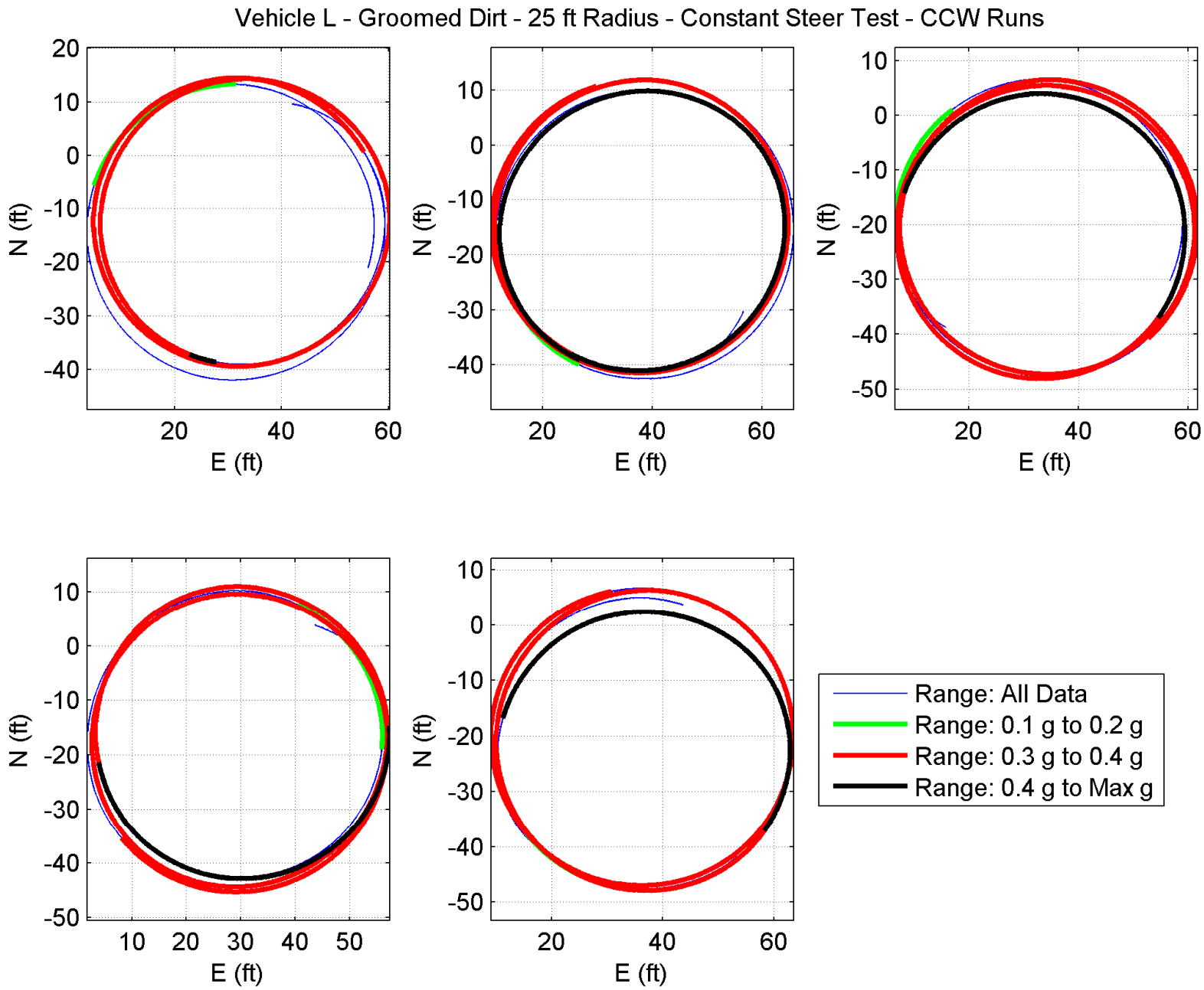

Vehicle L - Groomed Dirt - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7


Vehicle L - Groomed Dirt - 25 ft Radius - Constant Steer Test
CW Initial Slopes: 6.15 5.52 5 5.93 7.23 STD=0.828
CW Final Slopes: 3.36 7.57 6.72 4.07 5.74 STD=1.76
CW Ratios: 0.547 1.37 1.34 0.687 0.794 STD=0.383
CW Average: 0.948
Average Ratio: 1.14
CCW Average: 1.34
CCW Ratios: 1.74 1.1 1.19 1.43 1.23 STD=0.253
CCW Final Slopes: -10.1 -8.01 -7.99 -8.52 -7.54 STD=1.01
CCW Initial Slopes: -5.84 -7.26 -6.72 -5.94 -6.12 STD=0.601
Yaw Rate (deg/sec)
Speed (m/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7


Vehicle L - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
Yaw Rate (deg/sec)
Speed (m/s)
Ratio: 0.547
Final Slope: 3.36
Ratio: 1.37
Final Slope: 7.57
Ratio: 1.34
Final Slope: 6.72
Ratio: 0.687
Final Slope: 4.07
Ratio: 0.794
Final Slope: 5.74

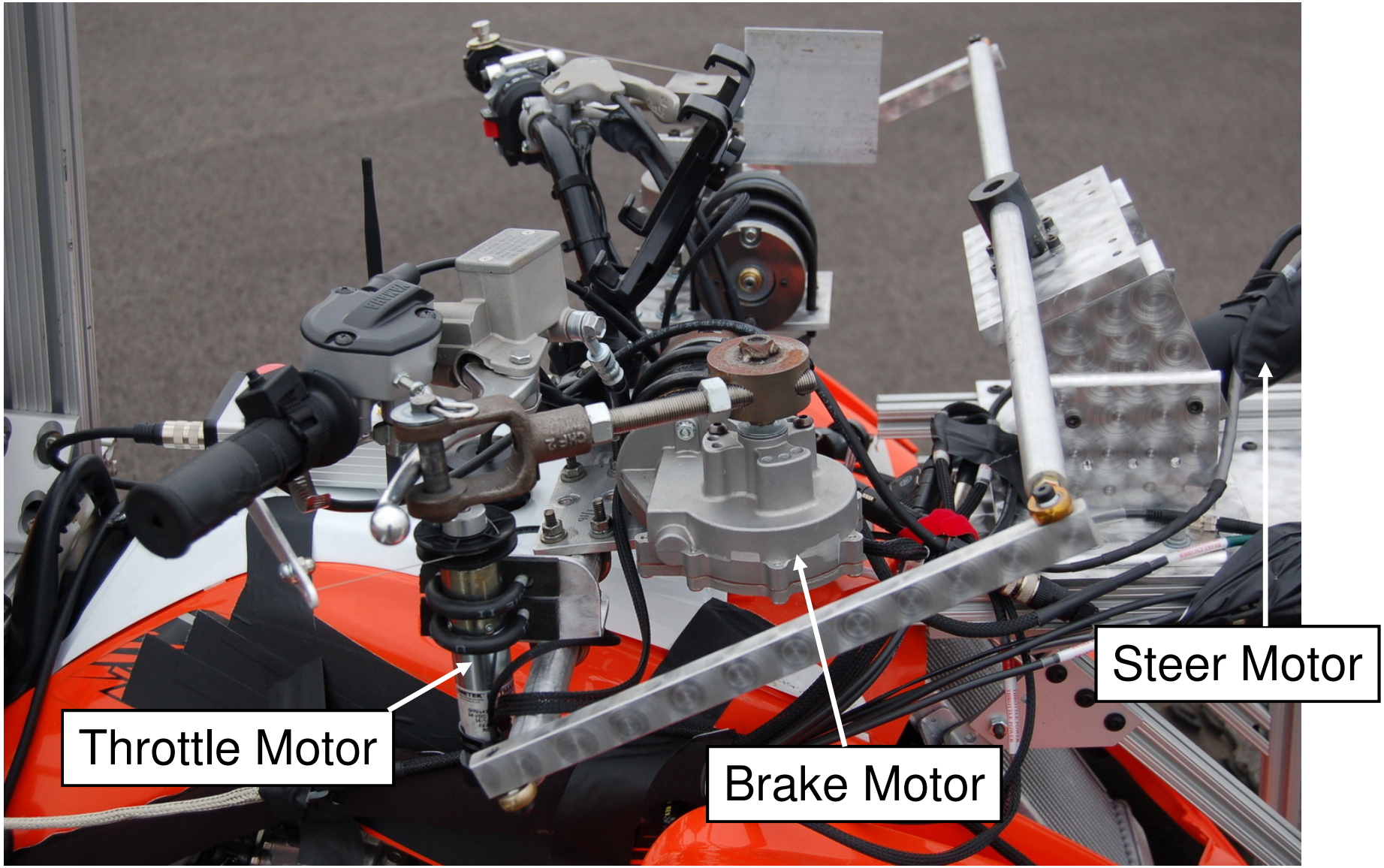

Vehicle L - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -10.1
Ratio: 1.74
Final Slope: -8.01
Ratio: 1.1
Final Slope: -7.99
Ratio: 1.19
Final Slope: -8.52
Ratio: 1.43
Final Slope: -7.54
Ratio: 1.23
Yaw Rate (deg/sec)
Speed (m/s)
-30
-35
-40
-45
3
4
5
6


Vehicle L - Groomed Dirt - 25 ft Radius - Constant Steer Test - CW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g


Vehicle L - Groomed Dirt - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

Side View of Test Vehicle in Groomed Dirt Loading Condition

Photographs of SEA ATV Robotic Test Driver (RTD) Components (Throttle, Brake and Steer Motors)

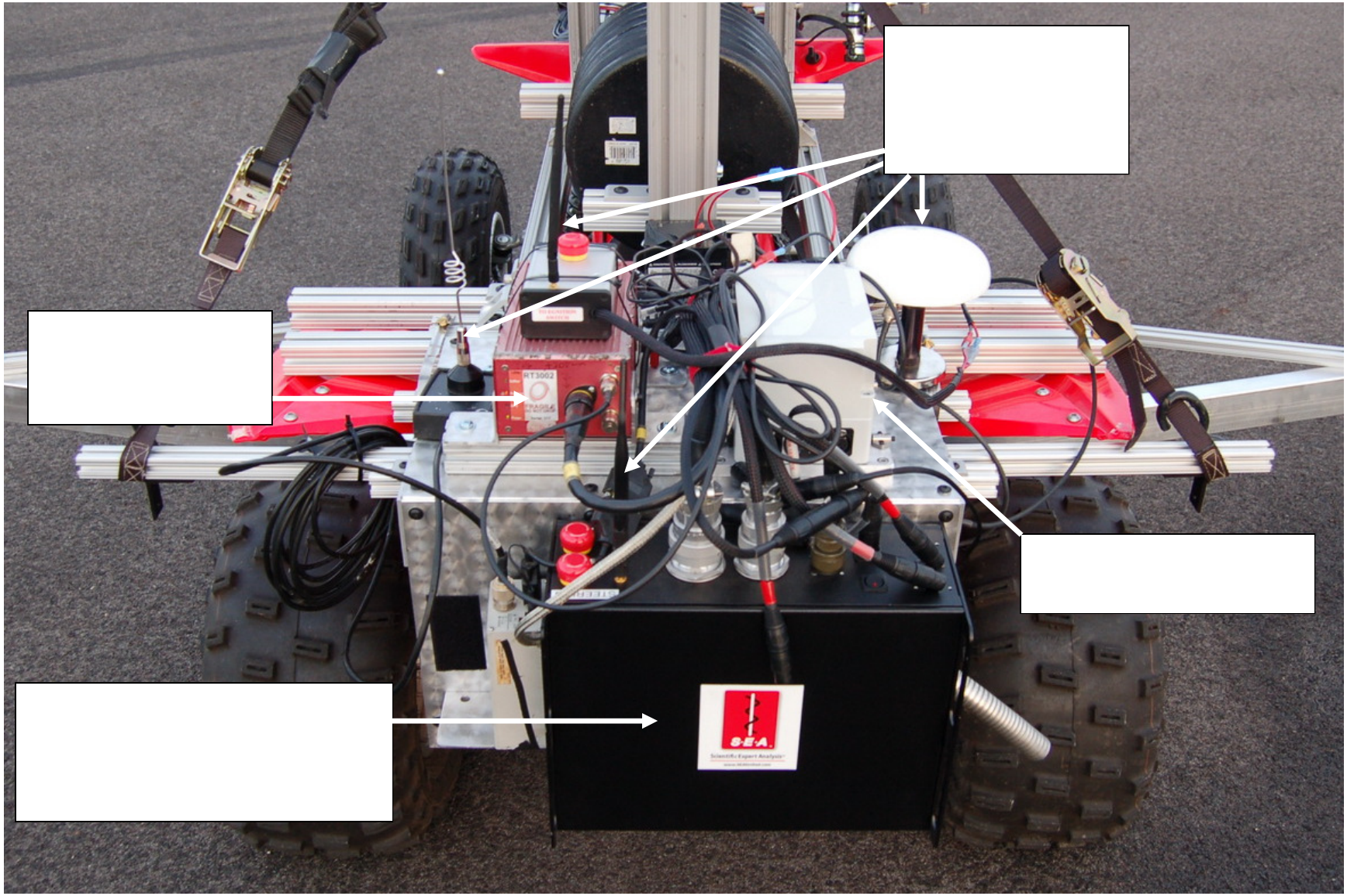


Photographs of SEA ATV Robotic Test Driver (RTD) Component (Clutch Motor)

Clutch Motor
Shown in Clutch
Engaged Position

Clutch Motor
Shown in Clutch
Disengaged Position

Photographs of SEA ATV Robotic Test Driver (RTD) Components (GPS/IMU, Control Box, and Antennas)



Photographs of SEA Standard ATV Safety Outriggers with Groomed Dirt Pucks

Photographs of SEA Light-Vehicle ATV Safety Outriggers

Photographs of Steering Column Angle Encoder (Left) and Potentiometer (Right)