

**NEW CAR ASSESSMENT PROGRAM (NCAP)
DYNAMIC ROLLOVER RESISTANCE TEST**

KIA MOTORS CORPORATION

2019 Kia Niro FWD

TEST NUMBER: 19-14

Final Report
23 April 2019



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16. Abstract An NCAP Dynamic Rollover Maneuver (Fishhook) Test was conducted on a 2019 Kia Niro FWD at Dynamic Research, Inc. on April 11, 2019. The vehicle did not experience two-wheel lift. The vehicle's steering angle at 0.3 g lateral acceleration at 50 mph was 26.7 degrees.			
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Section I INTRODUCTION

Beginning with the 2006 fiscal year, the National Highway Traffic Safety Administration (NHTSA) has engaged Dynamic Research, Inc. (DRI) of Torrance, CA to conduct dynamic rollover testing and gather data from that testing as part of NHTSA's New Car Assessment Program (NCAP).

The purpose of the testing reported herein was to determine if a typical 2019 Kia Niro FWD would experience tip-up, defined as simultaneous two-wheel lift of two inches or more at an entry speed of 50 mph or less in the Fishhook Procedure developed by NHTSA. This procedure may be found at www.regulations.gov, docket item NHTSA-2006-26555-0136.

The testing reported herein was accomplished under contract DTNH22-14-D-00332. The task order is entitled, "New Car Assessment Program (NCAP) Non-Destructive Vehicle Testing and Data Gathering."

Section II VEHICLE PREPARATION

A. TEST VEHICLE

The test vehicle was new or in as-new condition, meaning the vehicle had been driven no more than 500 miles prior to the start of dynamic rollover testing. It was acquired through a commercial rental/leasing company. Details of the test vehicle are given in Table 1.

B. TIRES

All tires used were new, and of the same make, model, size, and DOT specification of those installed on the vehicle when purchased new. Tire inflation pressures were in accordance with the recommendations indicated on each vehicle's identification placard. To further reduce the possibility of tire debanding, the tires were mounted to the rims without the use of tire mounting lubricant. Tire specifications are listed in Table 2.

C. VEHICLE LOADING

The multi-passenger load, described in the Fishhook Procedure, was used for all tests. The load and positioning of the load in the vehicle are listed in Table 3.

In addition to water dummies, the loading included instrumentation, a steering machine, and outriggers. Test vehicle bumper assemblies were removed for outrigger installation. The reduction in vehicle weight due to the removal of the bumpers was offset by the additional weight of the outriggers and their mounting system. The outrigger system typically outweighs the bumper assemblies.

Table 1. Test Vehicle Data

General Data					
Model year, make, model	2019 Kia Niro FWD				
VIN	KNDCB3LC6K524xxxx				
Body style	MPV				
Number of doors	4				
Trim level	LX				
Seating positions	Front:	2 nd row	3 rd row	4 th row	5 th row
	2	3	0	0	0
Electronic stability control	Yes				
4-Wheel ABS (Yes/No)	Yes				
Power steering (Yes/No)	Yes				
Major optional equipment	Carpeted Floor Mats				
Odometer at start of testing	22 miles				
Drivetrain					
Engine cylinder arrangement	V-4				
Engine displacement	1.6 L				
Transmission type	Automatic				
Drive arrangement	FWD				
Chassis					
Track width	F: 61.63 in (1565.4 mm) , R: 62.25 in (1581.1 mm)				
Wheelbase	106.25 in (2698.8 mm)				
Curb weight	3154 lb (1430.6 kg)				
Certification Data from Vehicle's Label					
Vehicle manufactured by	KIA MOTORS CORPORATION				
Date of manufacture	11/18				
GVWR	4189 lb (1900 kg)				
GAWR Front	2319 lb (1052 kg)				
GAWR Rear	2002 lb (908 kg)				

Table 2. Tire Information

Tire Manufacturer	Michelin
Tire Model	Energy Saver A/S GreenX
Tire Size	Front: 205/60R16 Rear: 205/60R16
Load rating	Front: 92 Rear: 92
Speed rating	Front: H Rear: H
Treadwear grade	Front: 480 Rear: 480
Traction grade	Front: A Rear: A
Temperature grade	Front: A Rear: A
Location of "Recommended Tire Pressure" label	Driver's door jamb
Recommended cold tire pressure	Front: 35 psi, (240 kPa) Rear: 35 psi, (240 kPa)
First 8 digits of DOT code	Front: B37R 04MX Rear: B37R 04MX

Table 3. Vehicle Loading

Water dummy and other loading	3 water dummies in second row
Water dummy weight	175 lb (79.4 kg)
Fuel level	Full
Weight as Tested	
Left front	1141 lb (517.5 kg)
Right front	1101 lb (499.4 kg)
Left rear	980 lb (444.5 kg)
Right rear	951 lb (431.4 kg)

D. STEERING CONTROLLER

Precise controlled steering is accomplished using a steering machine designed and constructed by DRI. DRI has used its Automated Vehicle Controller (AVC) steering machine for many vehicle tests including FMVSS 126 tests. It can provide up to 65 ft-lb torque and rates over 1300 deg/sec. The integrated angle encoder has an unlimited range with a resolution of 0.045 degrees and an accuracy of ± 0.045 degrees. The steering motor is controlled by a MicroAutoBox II from dSPACE, which also acts as the data acquisition system.

E. REAL-TIME CONTROLLER AND DATA ACQUISITION

Data acquisition is achieved using a MicroAutoBox II from dSPACE, which also serves as the real-time system for the steering controller. Data from the Oxford IMU, including Longitudinal, Lateral, and Vertical Acceleration, Roll, Yaw, and Pitch Rate, Forward and Lateral Velocity, Roll and Pitch Angle, are sent over Ethernet to the Micro AutoBox. The Oxford IMUs are calibrated per the manufacturer's recommended schedule (Table 5). The MicroAutoBox II specifications are:

Model: D-Space Micro-Autobox II 1401/1513
Base Board SN 549068
I/O Board SN 588523

Two video cameras were used to record the Fishhook runs. They were positioned nominally as shown in Figure 1. The recorded videotapes were reviewed after the Fishhook runs to check for any two-wheel lift. If any two-wheel lift was observed, eight infrared distance-measuring sensors for measurement of wheel lift (two sensors at each wheel) were then mounted for use in subsequent confirmation Fishhook tests.

F. EQUIPMENT WEIGHT

Table 4 lists the equipment and associated weights outlined in the NHTSA Laboratory Test Procedure for Dynamic Rollover and the equipment at DRI used for this specific test program. The equipment used at DRI for this test program differs slightly from the equipment that was previously used by NHTSA for rollover testing. Because DRI's equipment is lighter than NHTSA's equipment, DRI uses ballast to maintain a consistent weight and weight distribution in the vehicle.

Table 4. Weight of In-Cab Test Equipment

Equipment	Location	Equipment Weight (lb)	
		NHTSA*	DRI
Data Acquisition System	Front passenger seat	58	
Steering Machine	Handwheel	31	31
Steering Machine Electronics Box	Passenger row foot well behind the front passenger seat. If vehicle does not have a rear passenger row foot well, the Electronics Box should be placed in the front passenger seat foot well.	39	
MABX, and laptop	Front passenger seat		21
Motor control and power supply	Front passenger footwell		26
Ballast	Front passenger footwell		50
Total		128	128

* Table A.1 from US DOT NHTSA - Laboratory Test Procedure for Dynamic Rollover - The Fishhook Maneuver Test Procedure - New Car Assessment Program (NCAP) - March 2013

G. SENSORS

A list of the sensors is given in Table 5.

H. OTHER VEHICLE PREPARATION

In addition to installation and preparation discussed above, the test vehicle was prepared as follows:

- Front and rear bumpers were removed
- Outrigger mounts were installed in the bumper locations and titanium outriggers were fastened to these mounts
- Airbags were removed or otherwise disabled

Photographs of the vehicle tested are given in Appendix A.

Table 5. Sensors

Measured Variable	Sensor	Range	Resolution	Accuracy	Specifics	Serial Number	Calibration
Vehicle Tire Pressure	Tire Pressure Gauge	0-100 psi 0-690 kPa	0.01 psi 6.89 kPa	< 1% error between 20 and 100 psi	Omega DPG8001	17042707002	By: DRI Date: 6/21/2018 Due: 6/21/2019
Vehicle Total, Wheel, and Axle Load	Platform Scales (Minter)	1200 lb/platform 5338 N/platform	1 lb 4.4 N	0.5% of applied load	Intercomp SWI	1110M206352	By: DRI Date: 1/3/2019 Due: 1/3/2020
	Platform Scales (Torrance)	1500 lb/platform 6672 N/platform	1 lb 4.4 N	0.5% of applied load	Intercomp SWI	24032361	By: DRI Date: 12/11/2018 Due: 12/11/2019
Handwheel Angle	Steering Angle Encoder (Automated Steering Controller)	±800 deg	0.045 deg	±0.045 deg	DRI Automatic Vehicle Controller using D-Space Micro- Autobox II	NA	Verified by DRI at installation ¹
Longitudinal, Lateral, and Vertical Acceleration Roll, Yaw, and Pitch Rate, Forward and Lateral Velocity, Roll and Pitch Angle	Multi-Axis Inertial Sensing System	Accels ± 10g, Angular Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .001g, Angular Rate 0.01 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +	2176	By: Oxford Technical Solutions Date: 4/11/2018 Due: 4/11/2020

1 . The steering encoder is checked prior to beginning tests to verify that there are no faults. The steering controller is installed in the vehicle and the steering wheel is turned through two complete revolutions while recording data. The data are then reviewed for any dropouts or other nonlinearities that would indicate dust intrusion or faulty sectors.

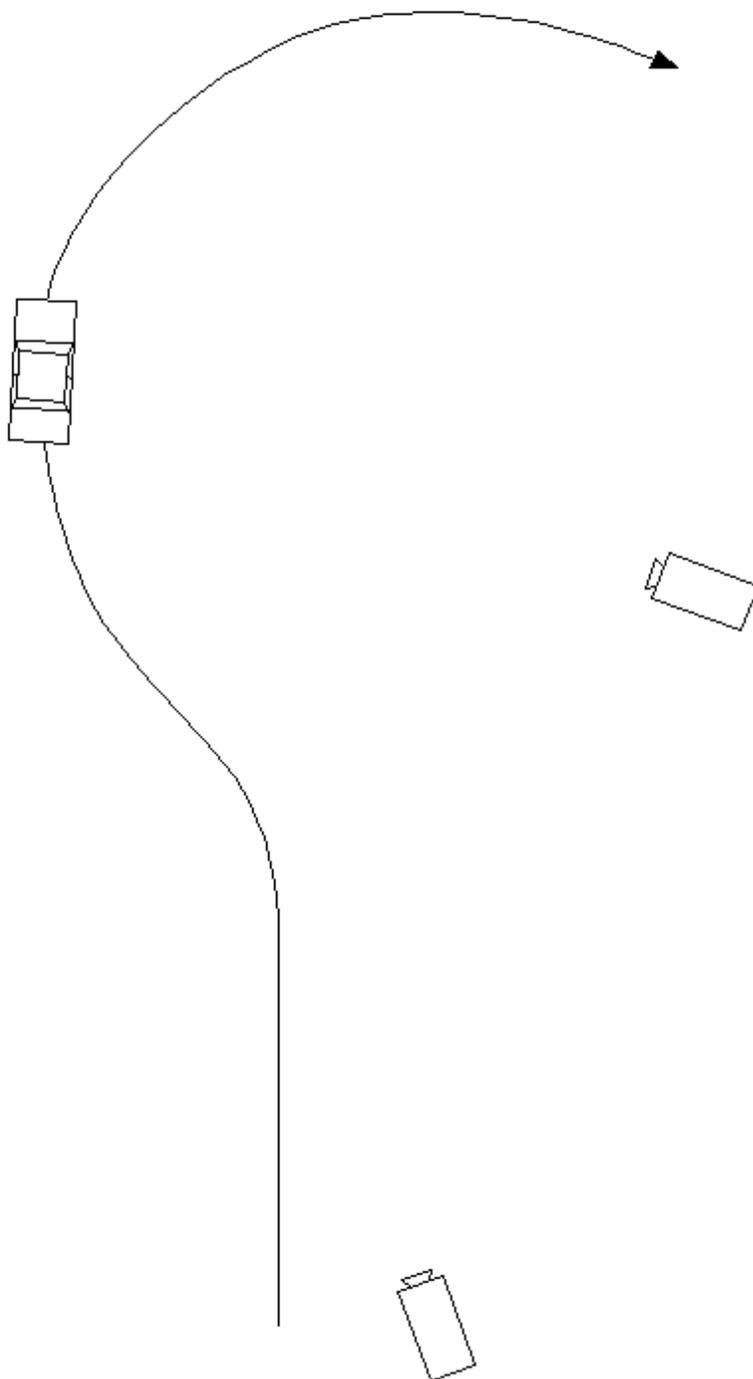


Figure 1. Nominal Position of Video Cameras for Fishhook Tests

Section III TEST PROCEDURES

This section includes a general overview of the test procedures and details of the particular test.

A. TEST PROCEDURE OVERVIEW

This test was conducted in accordance with NHTSA's NCAP Rollover Resistance Test Procedure (Fishhook) as described in the Federal Register (68 FR 59250). Detailed descriptions of the test procedure, pass/fail criteria, and data acquisition specifications may be found at docket NHTSA-2001-9663.

There are two major components of the test procedure, the Slowly Increasing Steer (SIS) pre-test and the Fishhook test.

The Slowly Increasing Steer (SIS) maneuver was used to characterize the steady state lateral dynamics of each vehicle, and is based on the "Constant Speed, Variable Steer" test defined in SAE J266. The maneuver is used to determine the handwheel angle that produces a lateral acceleration of 0.3 g at 50 mph. This handwheel angle is then used to determine the magnitude of steering to be used for the NHTSA Fishhook maneuver.

SIS tests were performed at a constant speed of 50 mph. Handwheel angle was input at a rate of 13.5 deg/sec, from 0 to an angle that provided at least 0.55 g. Three tests were conducted in each direction, and the data for the six runs were averaged to obtain the handwheel angle that produced 0.3 g at 50 mph.

The Fishhook test is a programmed steering maneuver that is implemented via the steering controller. The vehicle was initially steered in one direction and then the steering was reversed. The timing, magnitude, and rate of the steering were prescribed by the Fishhook Procedure.

To begin the maneuver, the vehicle was driven in a straight line at a speed slightly greater than the desired entrance speed. The driver then released the throttle. When the vehicle was at the target speed, the steering controller automatically initiated the steering maneuver. Following completion of the steering reversal the handwheel position was maintained for three seconds, and then returned to zero angle in 1 second.

The tests were conducted in both left-right and right-left directions. The “Default” test series used a handwheel angle equal to 6.5 times the handwheel angle that produced 0.3 g at 50 mph in the SIS tests, and initial vehicle speeds beginning at 35 mph and concluding up to 50 mph (if no two-wheel lift occurs). Supplemental tests were also done, as specified in the Fishhook Procedure.

B. TEST CONDITIONS

1. Test Surface

The tests were conducted on the Vehicle Dynamics Area at DRI’s Minter Field facility, located near Bakersfield, California, on 4/11/2019. The VDA has a smooth, flat (slope less than 0.5% throughout) asphaltic concrete surface. Its dimensions are as shown in Figure 2. It was built in the spring of 2005.

VDA surface friction measurements were accomplished using the DRI Mobile Tire Tester. Three runs were done, one at each of three previously determined locations. Each run provided for a minimum of 3 seconds of tire friction at constant normal load, slip angle, and speed in a free rolling condition. The test was accomplished using an ASTM E1136 tire with an inflation pressure of 35 (± 0.5) psi at a test speed of 40 (± 0.5) mph. The net slip angle of the test tire for each test run was 7.5 deg. The test tire was no older than 6 months from the date of manufacture. The surface friction measurement results are shown in Table 6.

Table 6. Surface Friction

Date of surface friction measurements	4/10/2019
Average normalized lateral force	0.817

2. Fishhook Handwheel Angles

The 0.3 g handwheel angle obtained from the SIS tests and the handwheel angles used in the Fishhook tests are shown in Table 7.

Table 7. Handwheel Angles

0.3 g handwheel angle (from SIS tests at 50 mph)	26.7°
5.5 scalar handwheel angle for Fishhook Test	147°
6.5 scalar handwheel angle for Fishhook Test	174°

3. Weather Conditions

The weather conditions, recorded at the end of testing, are shown in Table 8.

Table 8. Weather Conditions

Ambient temperature	69.8° F (21° C)
Wind Speed	8 mph (3.6 m/s)
Wind Direction	320

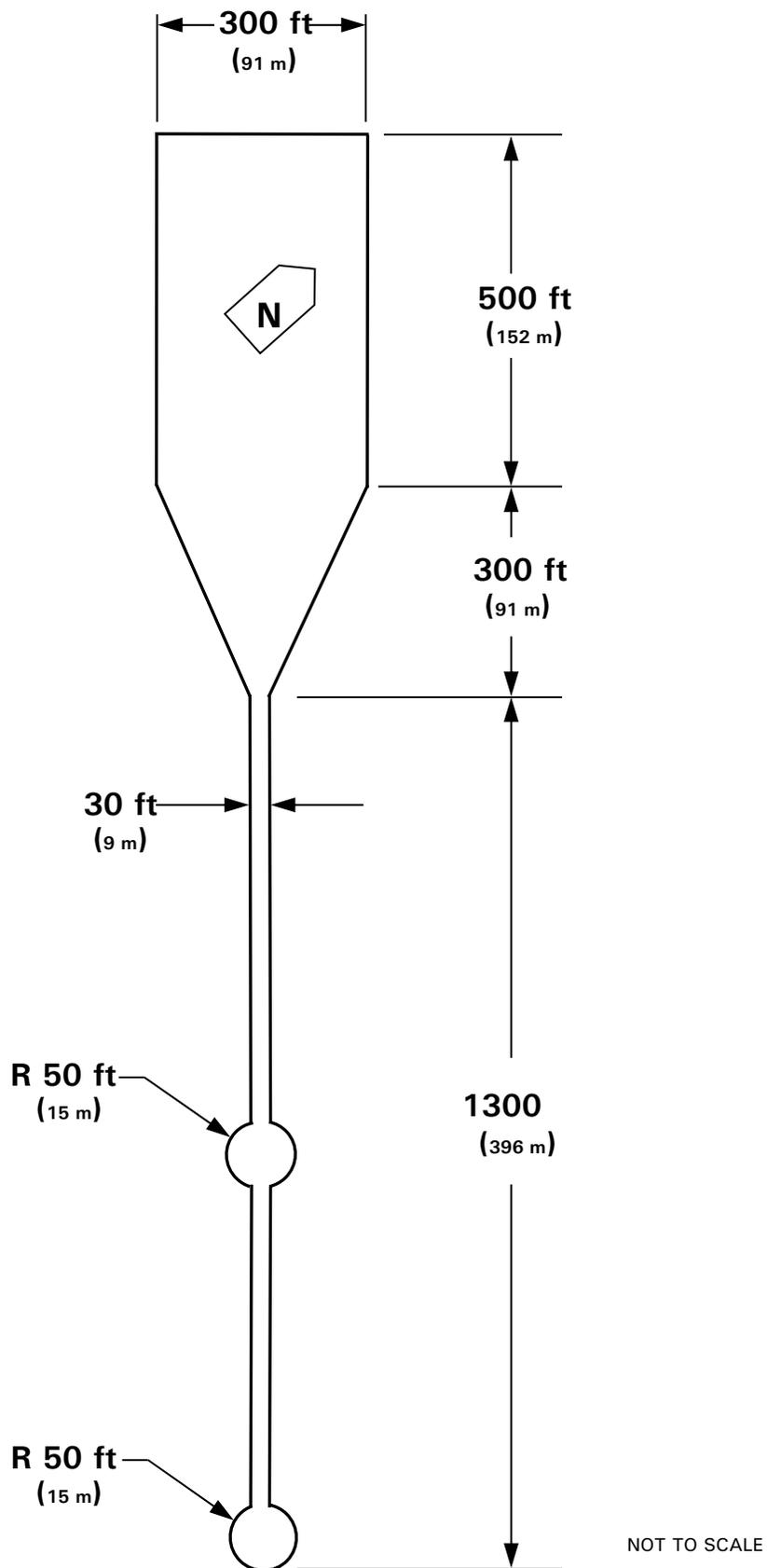


Figure 2. DRI-Minter Vehicle Dynamics Area

Section IV RESULTS

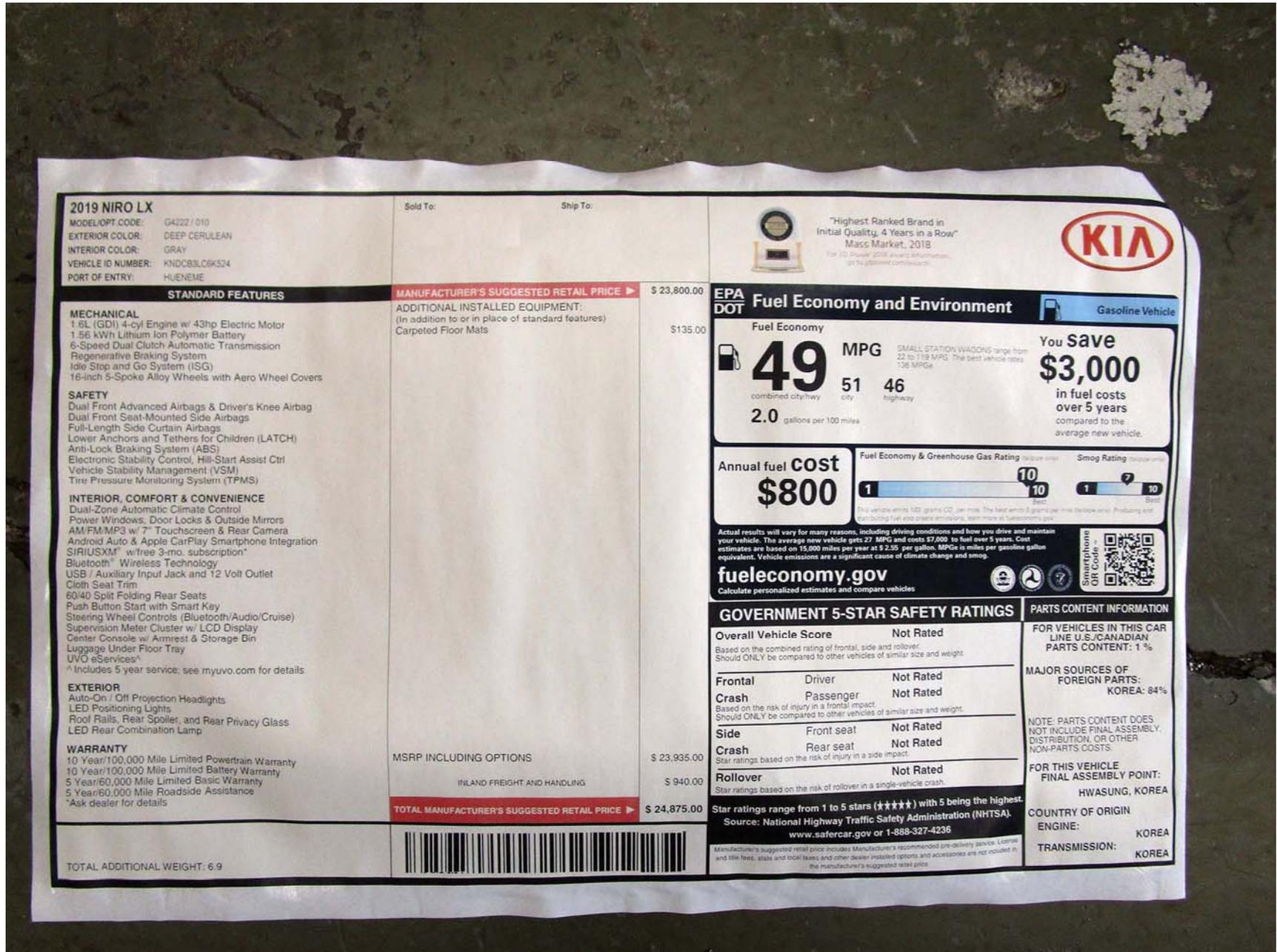
The test run log is given in Appendix B. The Slowly Increasing Steer Test Worksheet is given in Appendix C. Appendix D contains time history plots for the 50 mph runs and any runs which resulted in two-wheel lift. For the 2019 Kia Niro FWD, there was no two-wheel lift at any test condition.

APPENDIX A

Photographs

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2019 NIRO LX MODEL/OPT CODE: G4222 / 010 EXTERIOR COLOR: DEEP CERULEAN INTERIOR COLOR: GRAY VEHICLE ID NUMBER: KNDCB3LC6K524 PORT OF ENTRY: HUENEME		Sold To: _____ Ship To: _____		<p>"Highest Ranked Brand in Initial Quality, 4 Years in a Row" Mass Market, 2018 <small>For U.S. Dealer 2018 award information, go to jdpower.com/kia.</small></p>																
STANDARD FEATURES MECHANICAL 1.6L (GDI) 4-cyl Engine w/ 43hp Electric Motor 1.56 kWh Lithium Ion Polymer Battery 6-Speed Dual Clutch Automatic Transmission Regenerative Braking System Idle Stop and Go System (ISG) 16-inch 5-Spoke Alloy Wheels with Aero Wheel Covers SAFETY Dual Front Advanced Airbags & Driver's Knee Airbag Dual Front Seat-Mounted Side Airbags Full-Length Side Curtain Airbags Lower Anchors and Tethers for Children (LATCH) Anti-Lock Braking System (ABS) Electronic Stability Control, Hill-Start Assist Ctrl Vehicle Stability Management (VSM) Tire Pressure Monitoring System (TPMS) INTERIOR, COMFORT & CONVENIENCE Dual-Zone Automatic Climate Control Power Windows, Door Locks & Outside Mirrors AM/FM/MP3 w/ 7" Touchscreen & Rear Camera Android Auto & Apple CarPlay Smartphone Integration SIRIUSXM SM w/free 3-mo. subscription* Bluetooth SM Wireless Technology USB / Auxiliary Input Jack and 12 Volt Outlet Cloth Seat Trim 60/40 Split Folding Rear Seats Push Button Start with Smart Key Steering Wheel Controls (Bluetooth/Audio/Cruise) Supervision Meter Cluster w/ LCD Display Center Console w/ Armrest & Storage Bin Luggage Under Floor Tray UVO eServices SM *Includes 5 year service; see myuvo.com for details EXTERIOR Auto-On / Off Projection Headlights LED Positioning Lights Roof Rails, Rear Spoiler, and Rear Privacy Glass LED Rear Combination Lamp WARRANTY 10 Year/100,000 Mile Limited Powertrain Warranty 10 Year/100,000 Mile Limited Battery Warranty 5 Year/60,000 Mile Limited Basic Warranty 5 Year/60,000 Mile Roadside Assistance *Ask dealer for details		MANUFACTURER'S SUGGESTED RETAIL PRICE ▶ \$ 23,800.00 ADDITIONAL INSTALLED EQUIPMENT: (In addition to or in place of standard features) Carpeted Floor Mats \$135.00		EPA DOT Fuel Economy and Environment Gasoline Vehicle Fuel Economy <p>49 MPG combined city/hwy 51 city 46 highway 2.0 gallons per 100 miles</p> <p>You Save \$3,000 in fuel costs over 5 years compared to the average new vehicle.</p>																
		Annual fuel cost \$800		Fuel Economy & Greenhouse Gas Rating (EPA estimate) Smog Rating (EPA estimate) <p>Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 27 MPG and costs \$7,000 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at \$ 2.55 per gallon. MPG is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.</p>																
		MSRP INCLUDING OPTIONS \$ 23,935.00 INLAND FREIGHT AND HANDLING \$ 940.00 TOTAL MANUFACTURER'S SUGGESTED RETAIL PRICE ▶ \$ 24,875.00		GOVERNMENT 5-STAR SAFETY RATINGS Overall Vehicle Score Not Rated Based on the combined rating of frontal, side and rollover. Should ONLY be compared to other vehicles of similar size and weight. <table border="1"> <tr> <td>Frontal</td> <td>Driver</td> <td>Not Rated</td> </tr> <tr> <td>Crash</td> <td>Passenger</td> <td>Not Rated</td> </tr> <tr> <td>Side</td> <td>Front seat</td> <td>Not Rated</td> </tr> <tr> <td>Crash</td> <td>Rear seat</td> <td>Not Rated</td> </tr> <tr> <td>Rollover</td> <td></td> <td>Not Rated</td> </tr> </table> Star ratings based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight. Star ratings based on the risk of injury in a side impact. Star ratings based on the risk of rollover in a single-vehicle crash. Star ratings range from 1 to 5 stars (★★★★★) with 5 being the highest. Source: National Highway Traffic Safety Administration (NHTSA). www.safercar.gov or 1-888-327-4236		Frontal	Driver	Not Rated	Crash	Passenger	Not Rated	Side	Front seat	Not Rated	Crash	Rear seat	Not Rated	Rollover		Not Rated
Frontal	Driver	Not Rated																		
Crash	Passenger	Not Rated																		
Side	Front seat	Not Rated																		
Crash	Rear seat	Not Rated																		
Rollover		Not Rated																		
TOTAL ADDITIONAL WEIGHT: 6.9				PARTS CONTENT INFORMATION FOR VEHICLES IN THIS CAR LINE U.S./CANADIAN PARTS CONTENT: 1 % MAJOR SOURCES OF FOREIGN PARTS: KOREA: 84% NOTE: PARTS CONTENT DOES NOT INCLUDE FINAL ASSEMBLY, DISTRIBUTION, OR OTHER NON-PARTS COSTS. FOR THIS VEHICLE FINAL ASSEMBLY POINT: HWASUNG, KOREA COUNTRY OF ORIGIN: KOREA ENGINE: KOREA TRANSMISSION: KOREA																

Figure A1. Window Sticker



Figure A2. Front View, Test Vehicle as Delivered



Figure A3. Rear View, Test Vehicle as Delivered



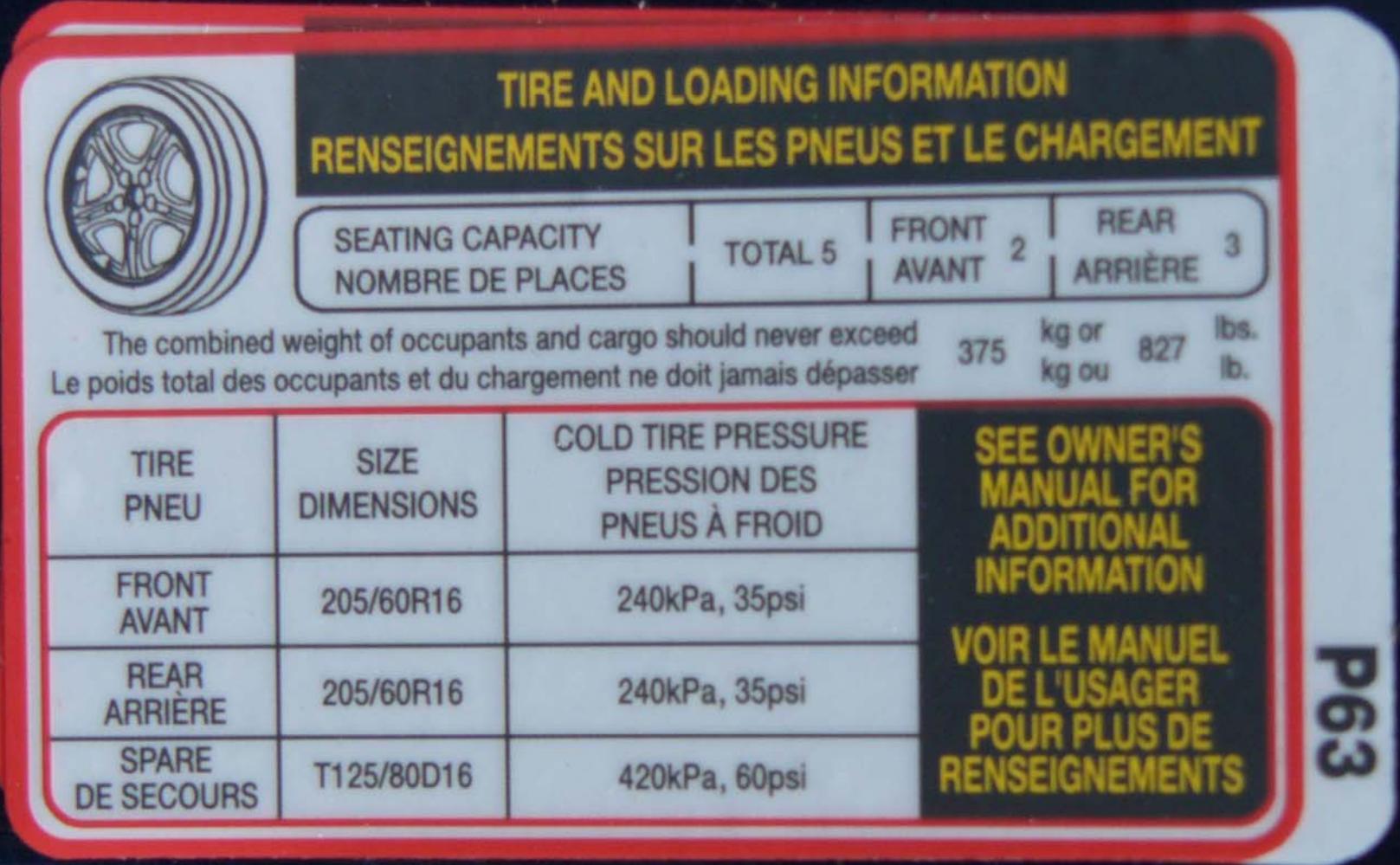
Figure A4. Front View, Test Vehicle in Test Condition



Figure A5. Rear View, Test Vehicle in Test Condition



Figure A6. Certification Label



TIRE AND LOADING INFORMATION
RENSEIGNEMENTS SUR LES PNEUS ET LE CHARGEMENT

SEATING CAPACITY / NOMBRE DE PLACES: TOTAL 5, FRONT AVANT 2, REAR ARRIÈRE 3

The combined weight of occupants and cargo should never exceed 375 kg or 827 lbs.
 Le poids total des occupants et du chargement ne doit jamais dépasser 375 kg ou 827 lb.

TIRE PNEU	SIZE DIMENSIONS	COLD TIRE PRESSURE / PRESSION DES PNEUS À FROID
FRONT AVANT	205/60R16	240kPa, 35psi
REAR ARRIÈRE	205/60R16	240kPa, 35psi
SPARE DE SECOURS	T125/80D16	420kPa, 60psi

SEE OWNER'S MANUAL FOR ADDITIONAL INFORMATION
VOIR LE MANUEL DE L'USAGER POUR PLUS DE RENSEIGNEMENTS

P63

Figure A7. Tire Placard

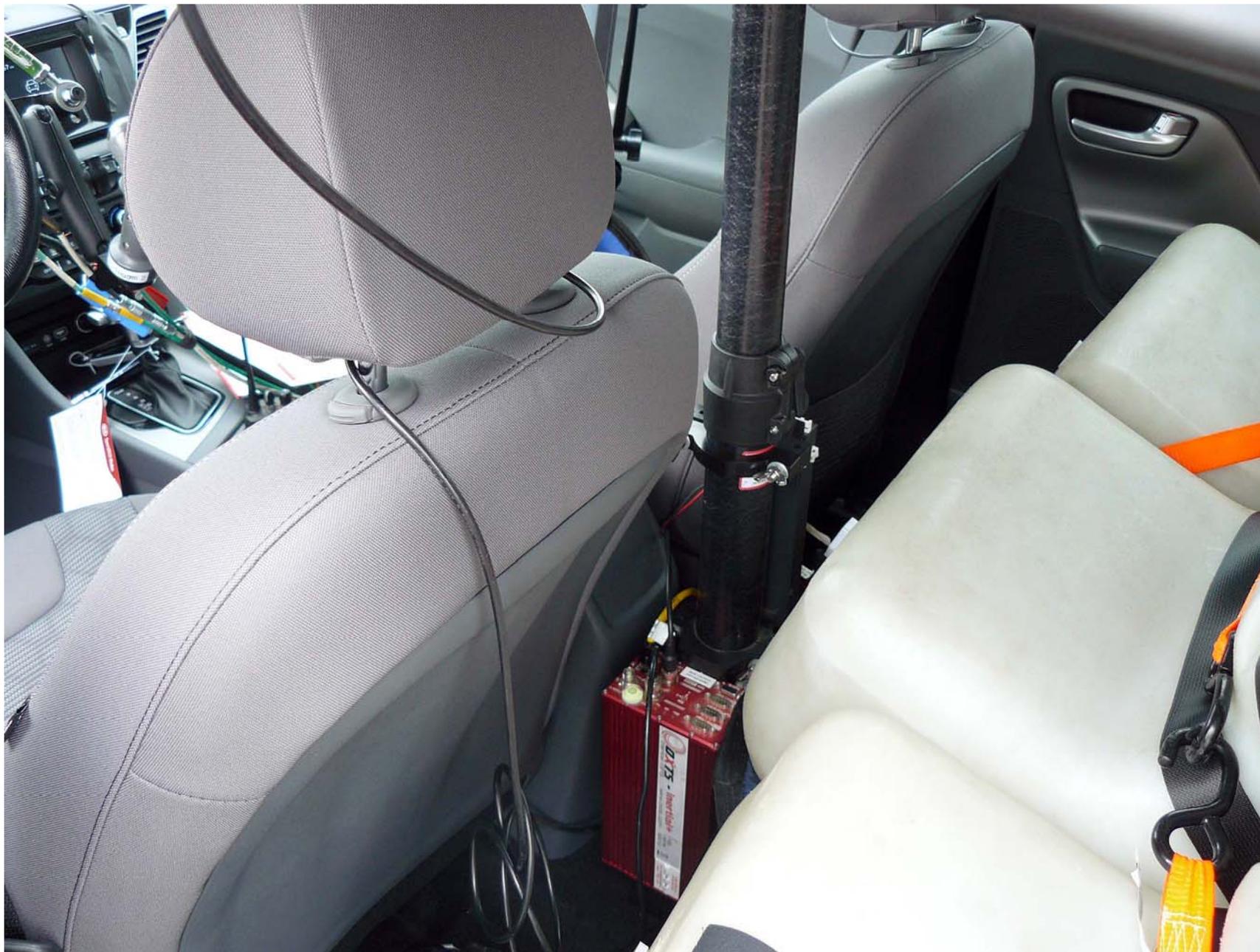


Figure A8. Instrumentation in Test Vehicle



Figure A9. Steering Computer and Computer



Figure A10. Ballast Condition

APPENDIX B

Test Run Log

Vehicle: **2019 Kia Niro FWD**Driver: **Jonathan Robel**Test Date: **4/11/2019**

Run Number	Test Type	Speed (mph)	Handwheel Angle (deg)	Dir. of First Steer	2 Wheel Lift	Notes
1	Tire Warm-Up	35	60	NA	NA	
2	"	"	80	"	"	
3	"	"	"	"	"	
4	"	"	"	"	"	
5	2x SWA last cycle	"	"	"	"	
6	Static	0	0			
7	Steady State	50	0			
8	Slowly Increasing Steer	50	50	Left	NA	
9	"	"	40	"	"	
10	"	"	"	"	"	
11	"	"	"	"	"	
12	"	"	"	Right	"	
13	"	"	"	"	"	
14	"	"	"	"	"	
15	6.5 Scalar Fishhook	35	174	Left	No	
16	"	40	"	"	"	
17	"	45	"	"	"	
18	"	47.5	"	"	"	
19	"	50	"	"	"	
20	5.5 Scalar Fishhook	45	147	Left	No	
21	"	47.5	"	"	"	
22	"	50	"	"	"	
	"					

Vehicle: **2019 Kia Niro FWD**Driver: **Jonathan Robel**Test Date: **4/11/2019**

Run Number	Test Type	Speed (mph)	Handwheel Angle (deg)	Dir. of First Steer	2 Wheel Lift	Notes
23	6.5 Scalar Fishhook	35	174	Right	No	
24	"	40	"	"	"	
25	"	45	"	"	"	
26	"	47.5	"	"	"	
27	"	50	"	"	"	
28	5.5 Scalar Fishhook	45	147	Right	No	
29	"	47.5	"	"	"	
30	"	50	"	"	"	

APPENDIX C

Slowly Increasing Steer Test Worksheet

NCAP, 2019 Kia Niro FWD , Multi-Passenger Load, Test Date: 4/11/2019

SIS_out_v2

Run	Dir of Steer	Start Speed (mph)	End Speed (mph)	Speed Red. (%)	Index of ay @ 0.3g	HW Angle (deg) at 0.3g	ay (g) @ 0.3g index	6.5x HW Angle (deg)	Ramp Time (sec) at 6.5x	5.5x HW Angle (deg)	Ramp Time (sec) at 5.5x	R2	Zero Begin Index	Zero End Index
9	1	50.1	0.2	99.5	1207	-26.9	-0.303	-174.9	-0.2429	-148	-0.2055	0.9985	600	800
10	1	49.9	1.8	96.3	1213	-27.3	-0.301	-177.5	-0.2466	-150.2	-0.2086	0.9987	600	800
11	1	49.9	2.7	94.7	1210	-27.1	-0.302	-176.1	-0.2446	-149.0	-0.207	0.9992	600	800
12	0	50.2	0.4	99.1	1198	26.5	0.300	172.1	0.239	145.6	0.2023	0.9961	600	800
13	0	49.8	1.9	96.2	1193	26.1	0.295	169.7	0.2357	143.6	0.1995	0.9965	600	800
14	0	50.0	0.1	99.8	1194	26.2	0.301	170.2	0.2364	144	0.2000	0.9977	600	800

Mean: 26.7 0.3 173 0.241 147 0.204

Steering Controller Input Values

Scalar 6.5 values:

Initial HW angle: 173 deg
Initial time: 0.241 s
Reversal HW angle: -173 deg
Reversal time: 0.482 s

Scalar 5.5 values:

Initial HW angle: 147 deg
Initial time: 0.204 s
Reversal HW angle: -147 deg
Reversal time: 173 s

APPENDIX D

Time History Plots

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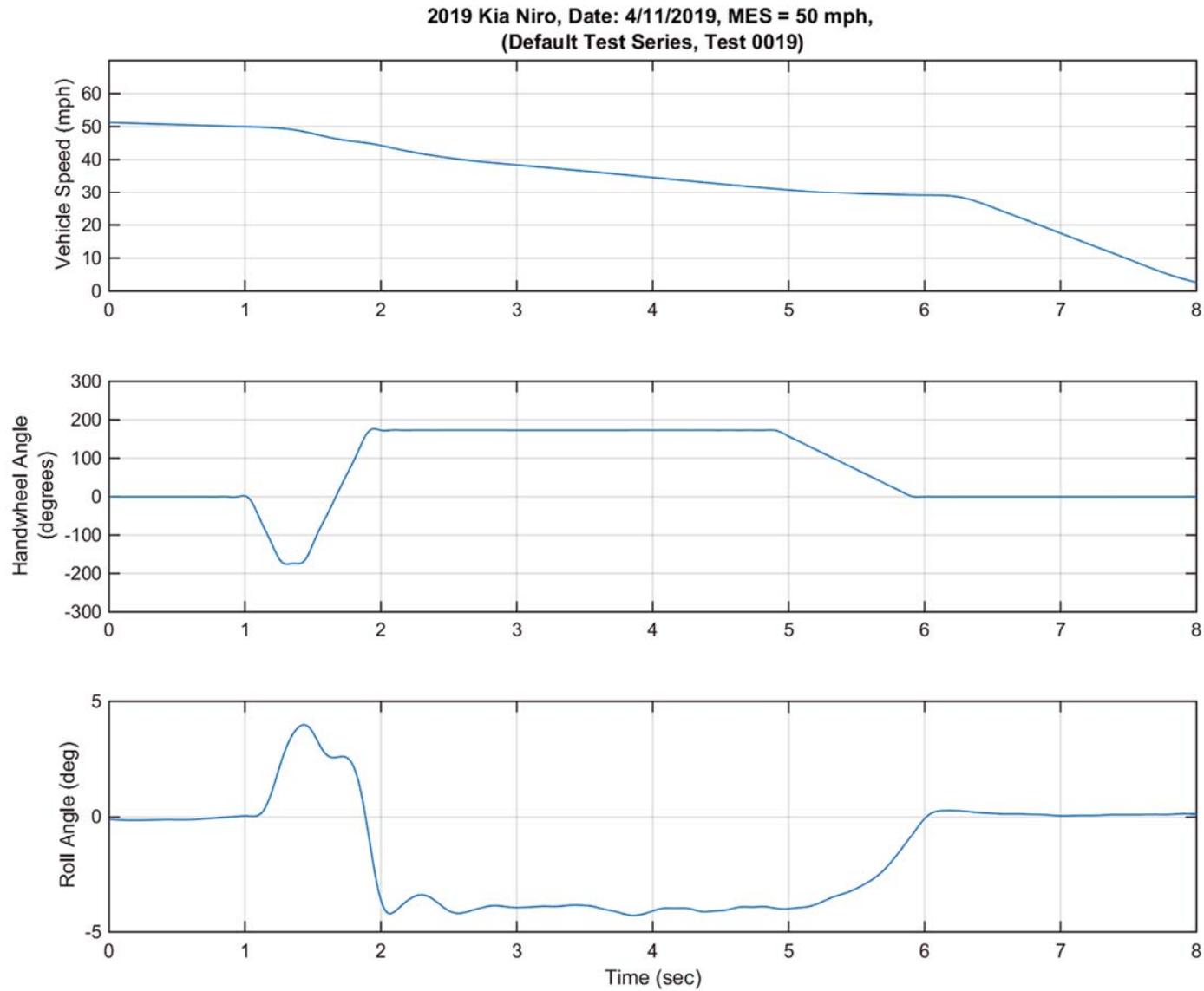


Figure D1. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Default Test Series, L-R, 50 mph

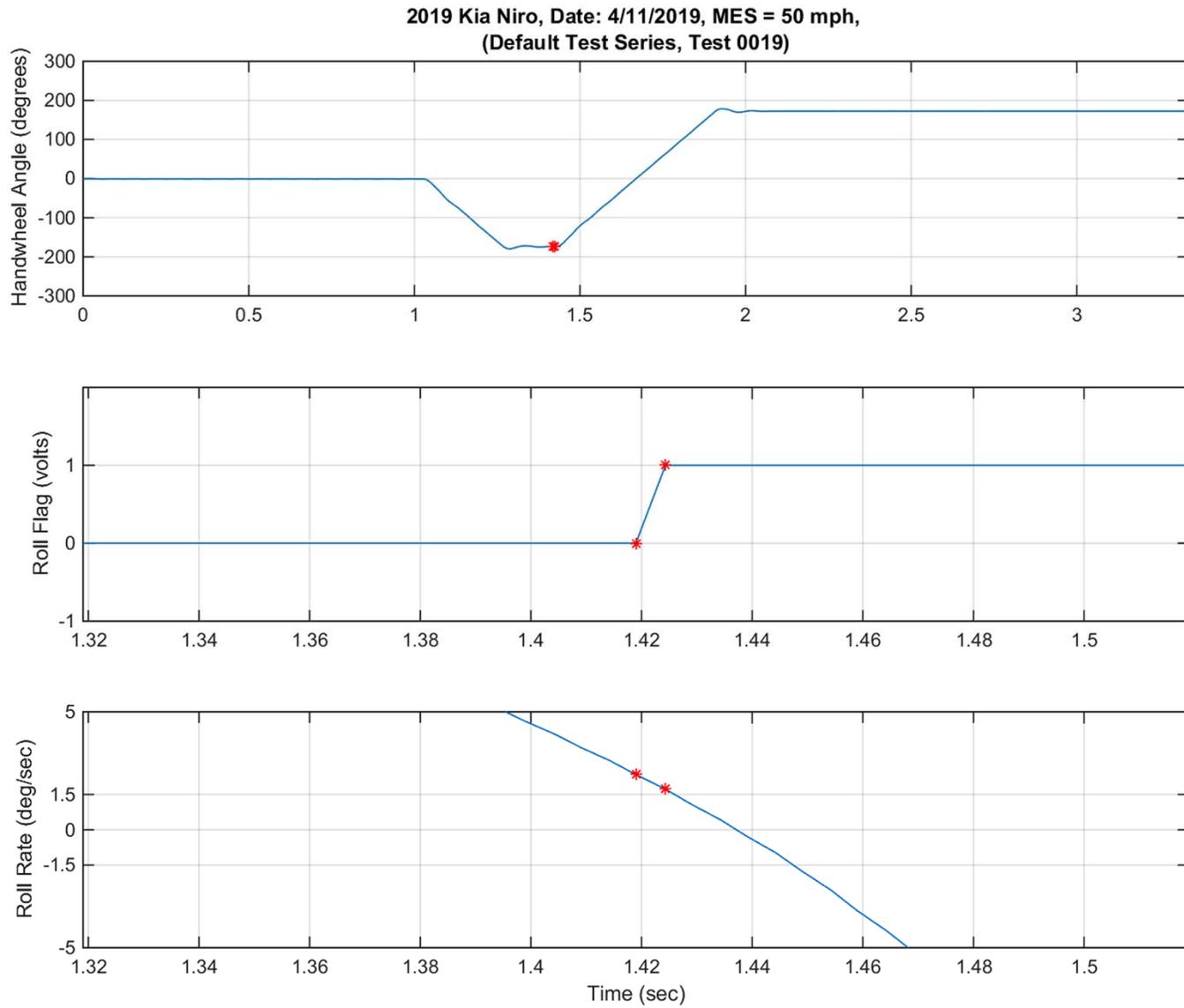


Figure D2. Steering Machine Operation Time History Plots for Default Test Series, L-R, 50 mph

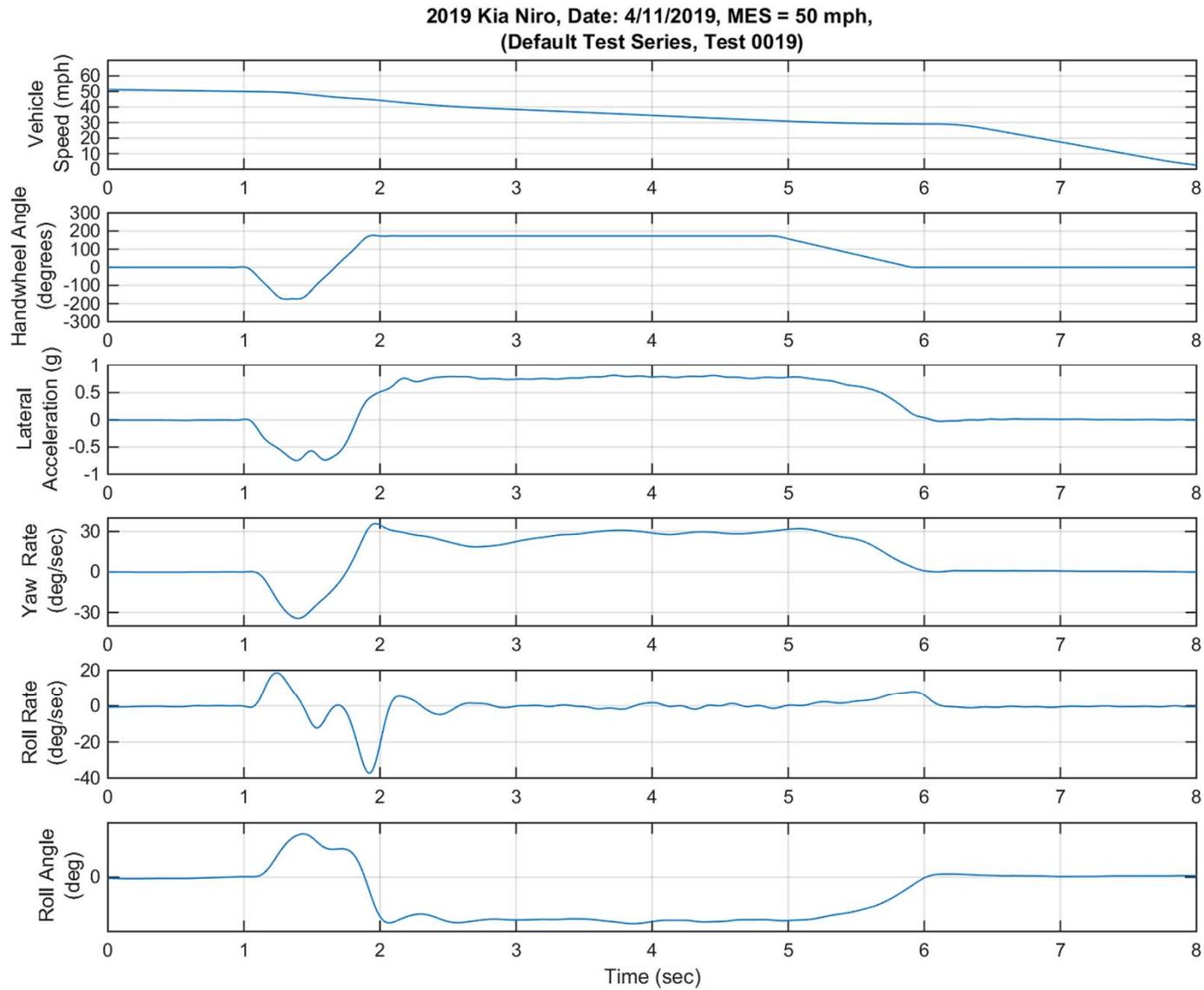


Figure D3. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots For Default Test Series, L-R, 50 mph

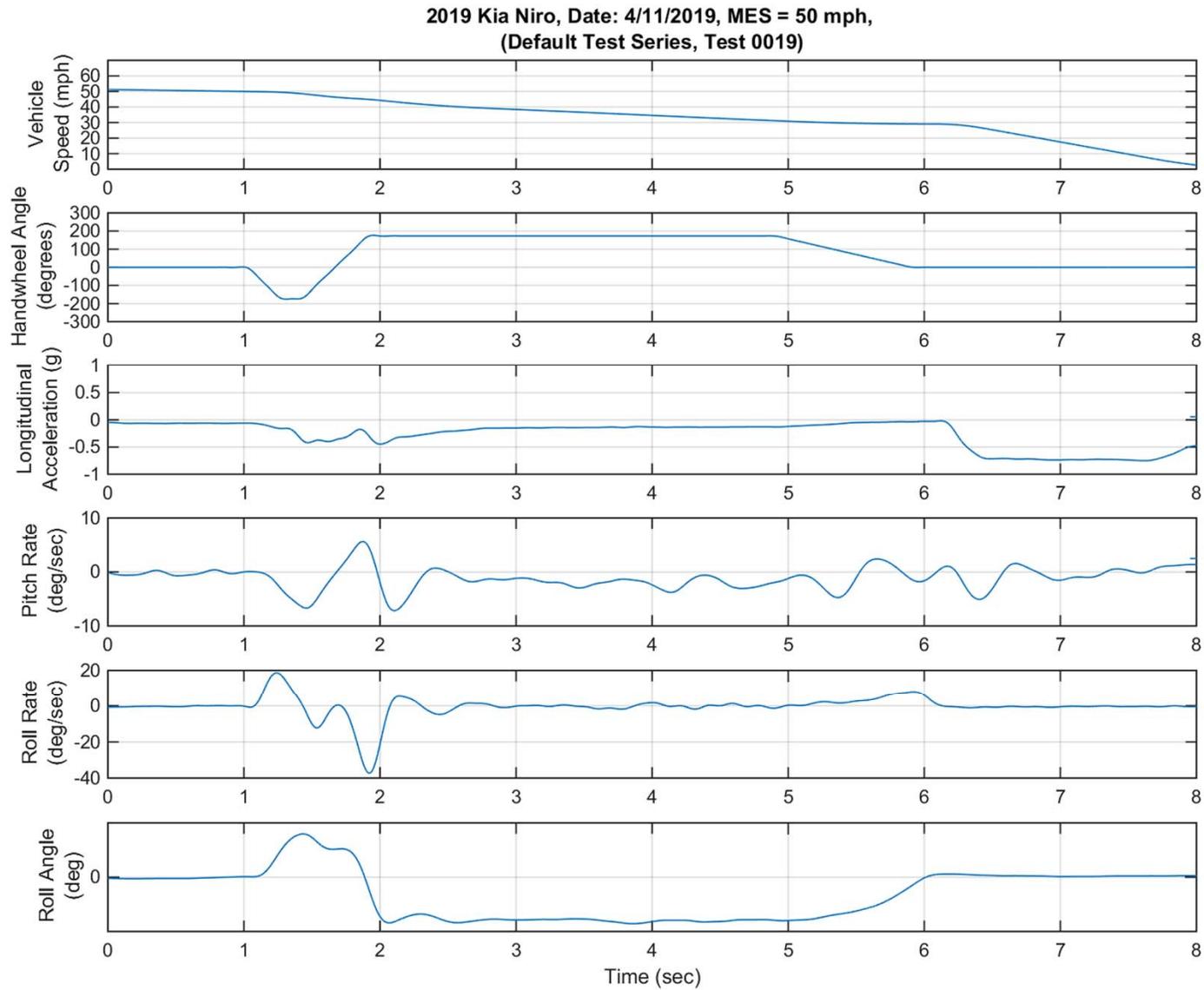


Figure D4. Pitch Rate and Longitudinal Acceleration Time History Plots for Default Test Series, L-R, 50 mph

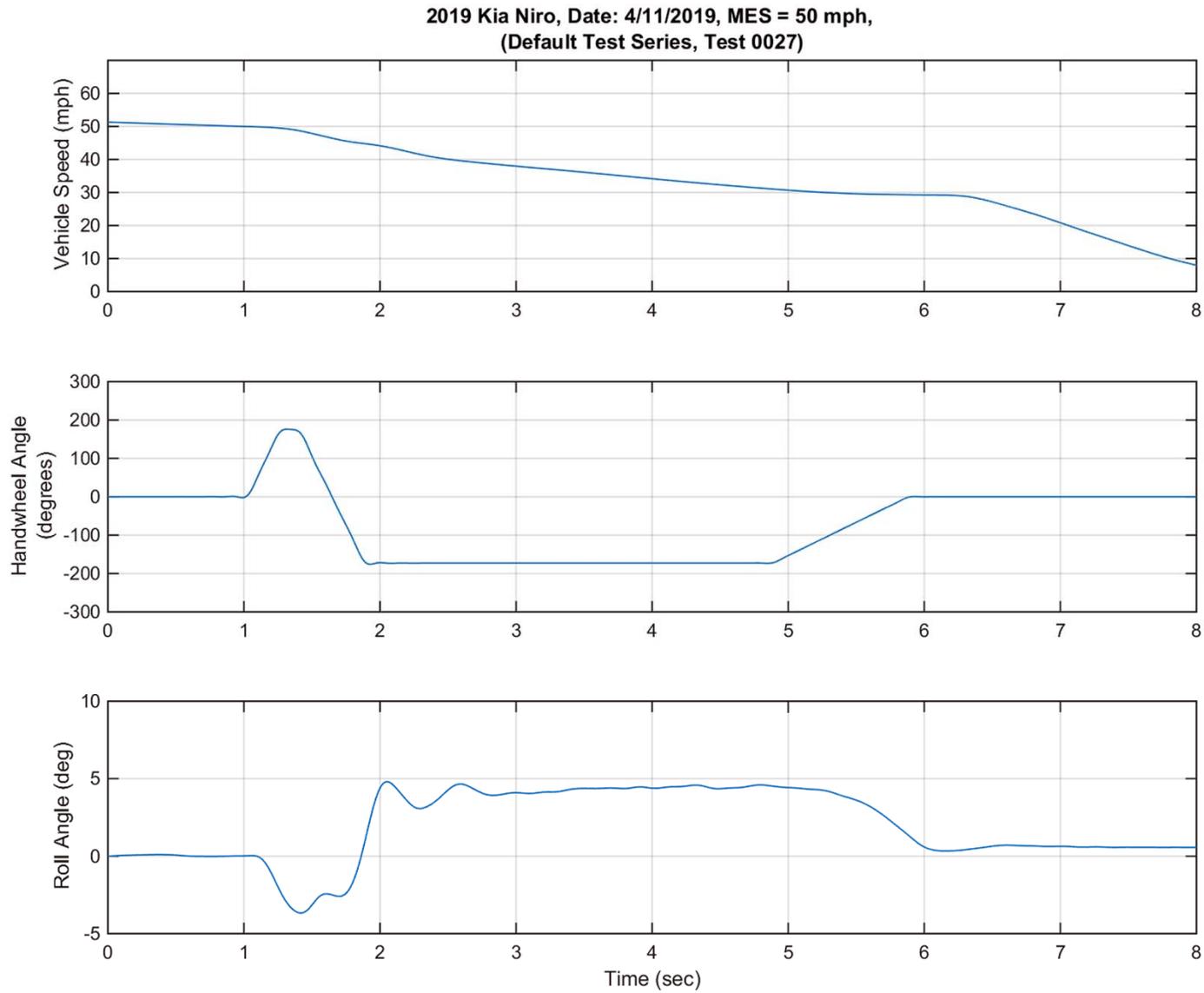


Figure D5. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Default Test Series, R-L, 50 mph

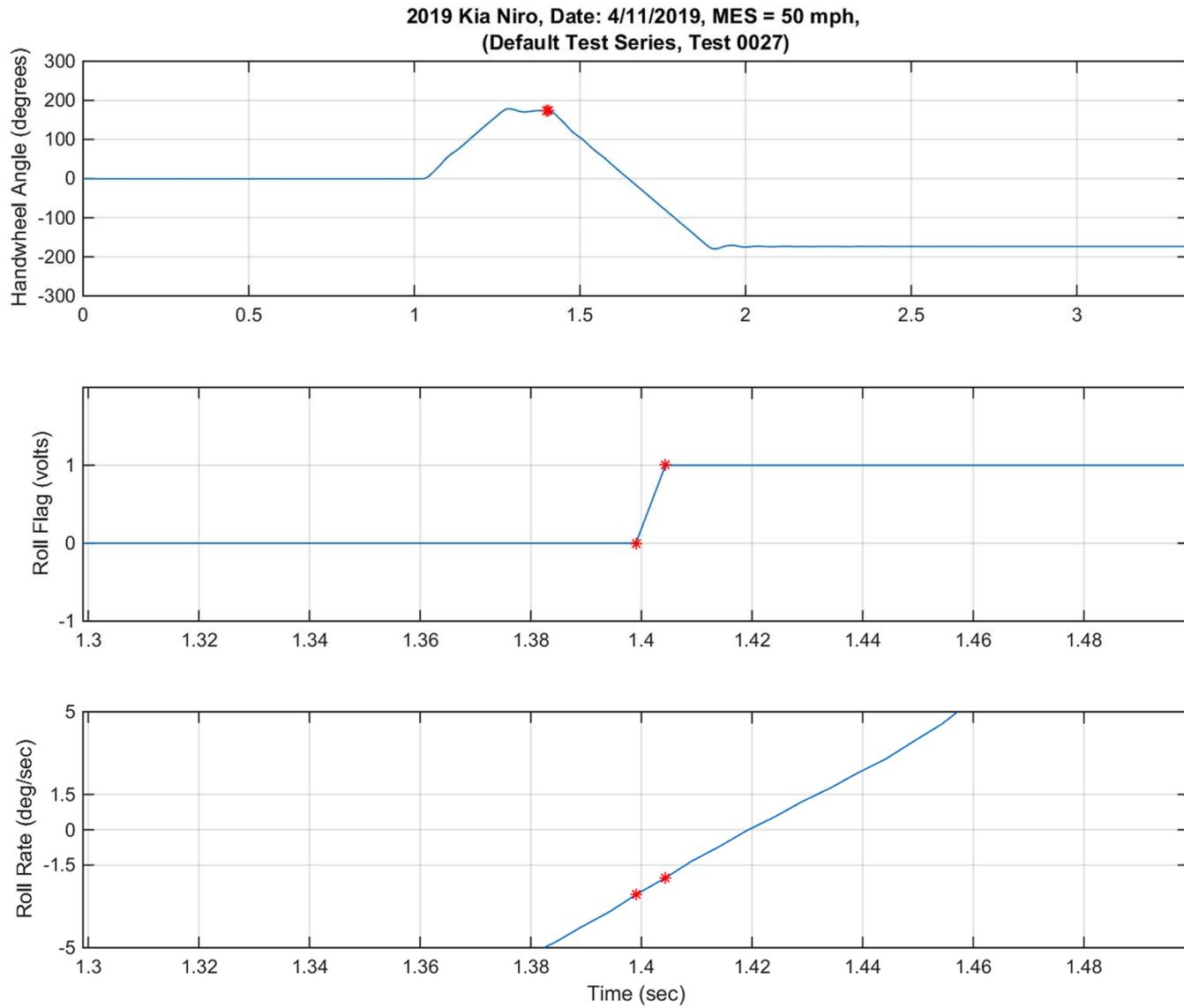


Figure D6. Steering Machine Operation Time History Plots for Default Test Series, R-L, 50 mph

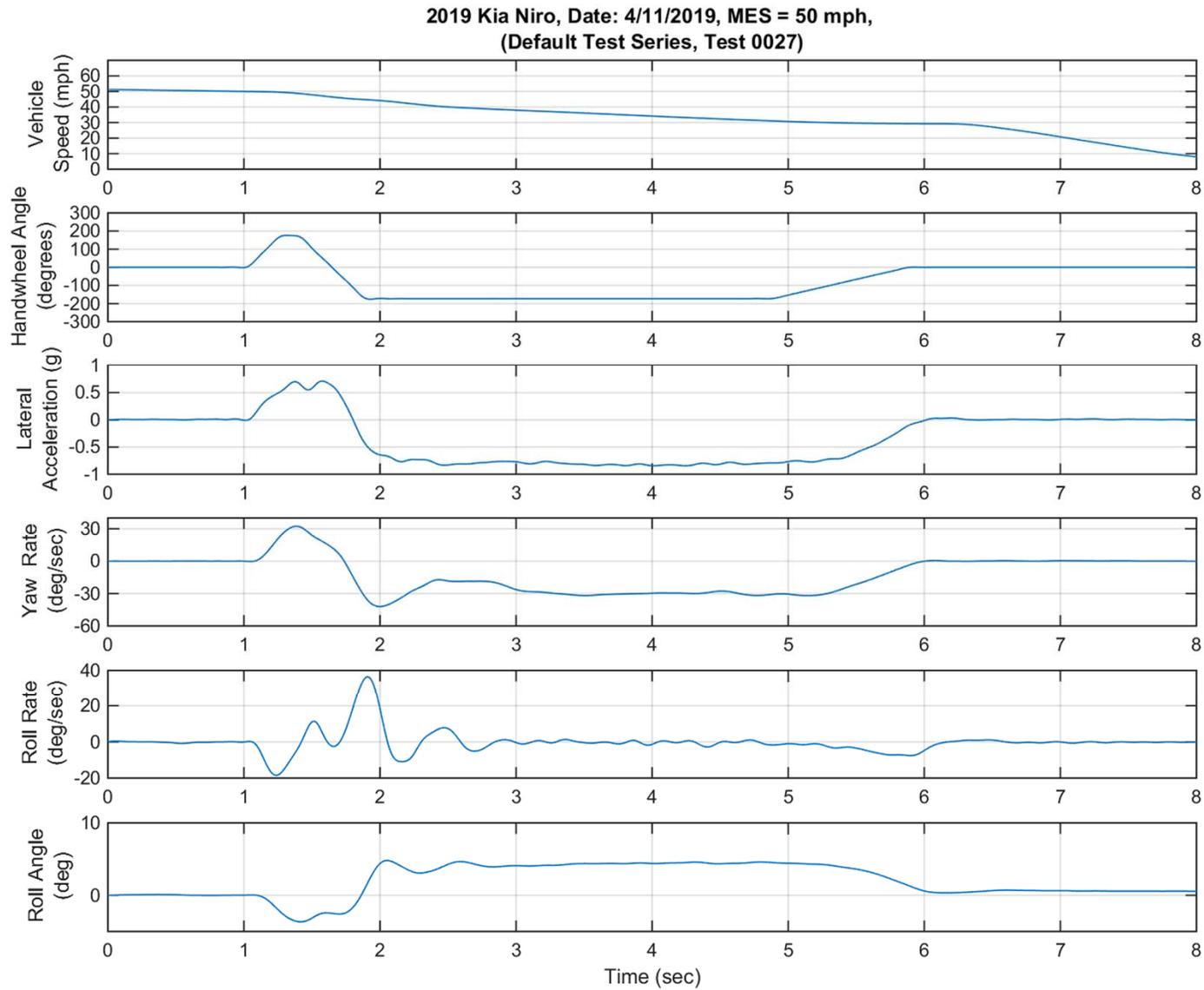


Figure D7. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Default Test Series, R-L, 50 mph

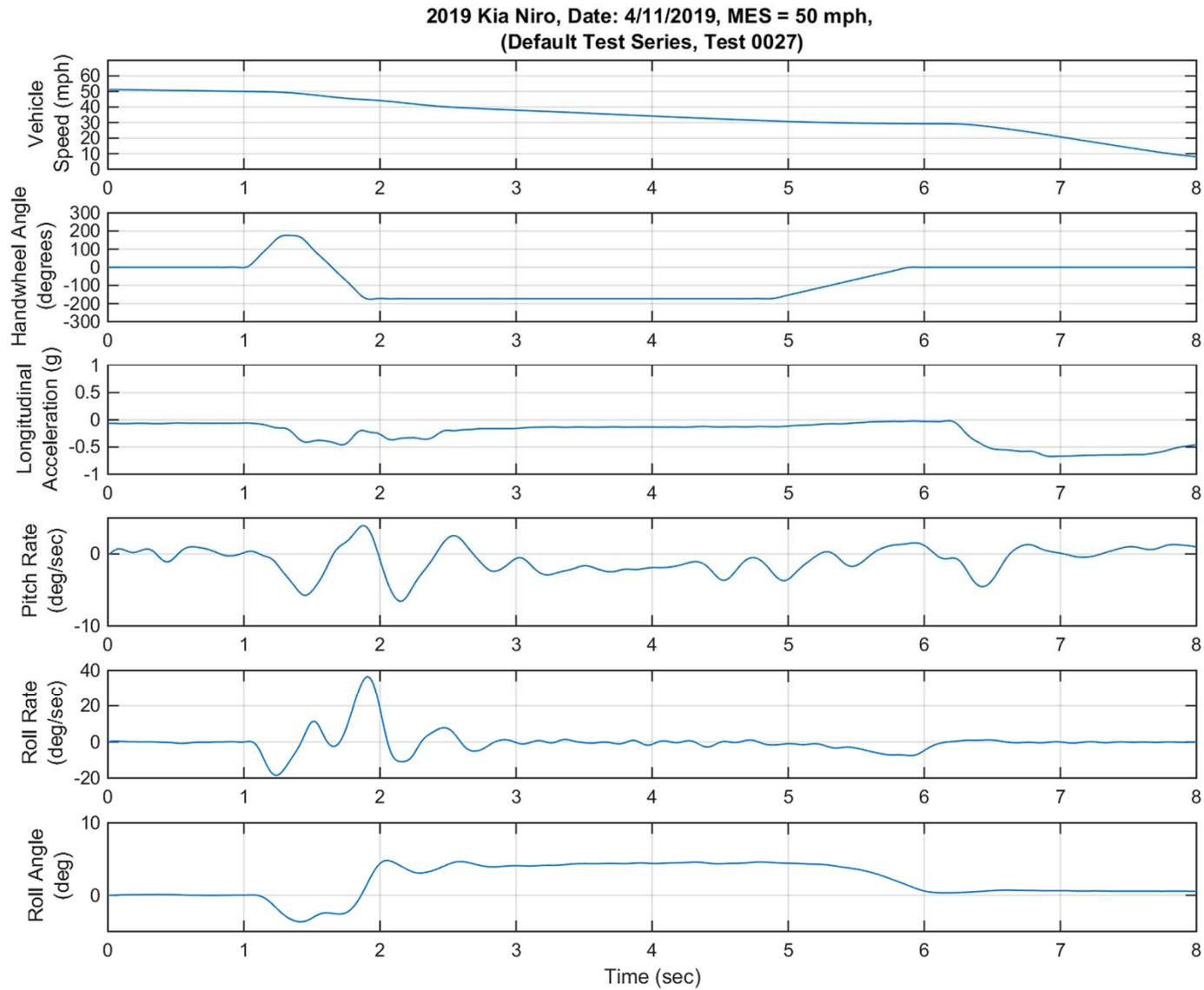


Figure D8. Pitch Rate and Longitudinal Acceleration Time History Plots or Default Test Series, R-L, 50 mph

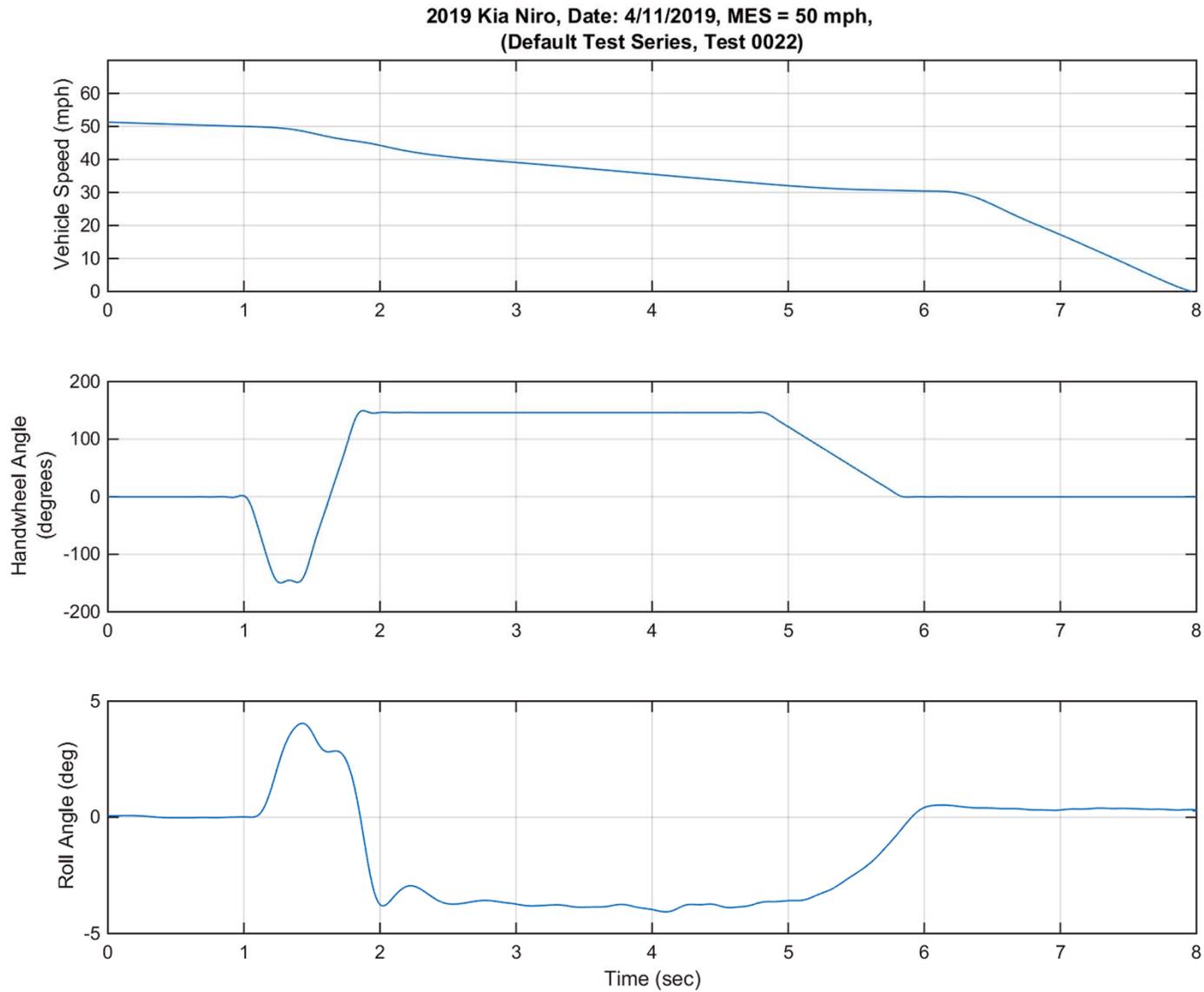


Figure D9. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

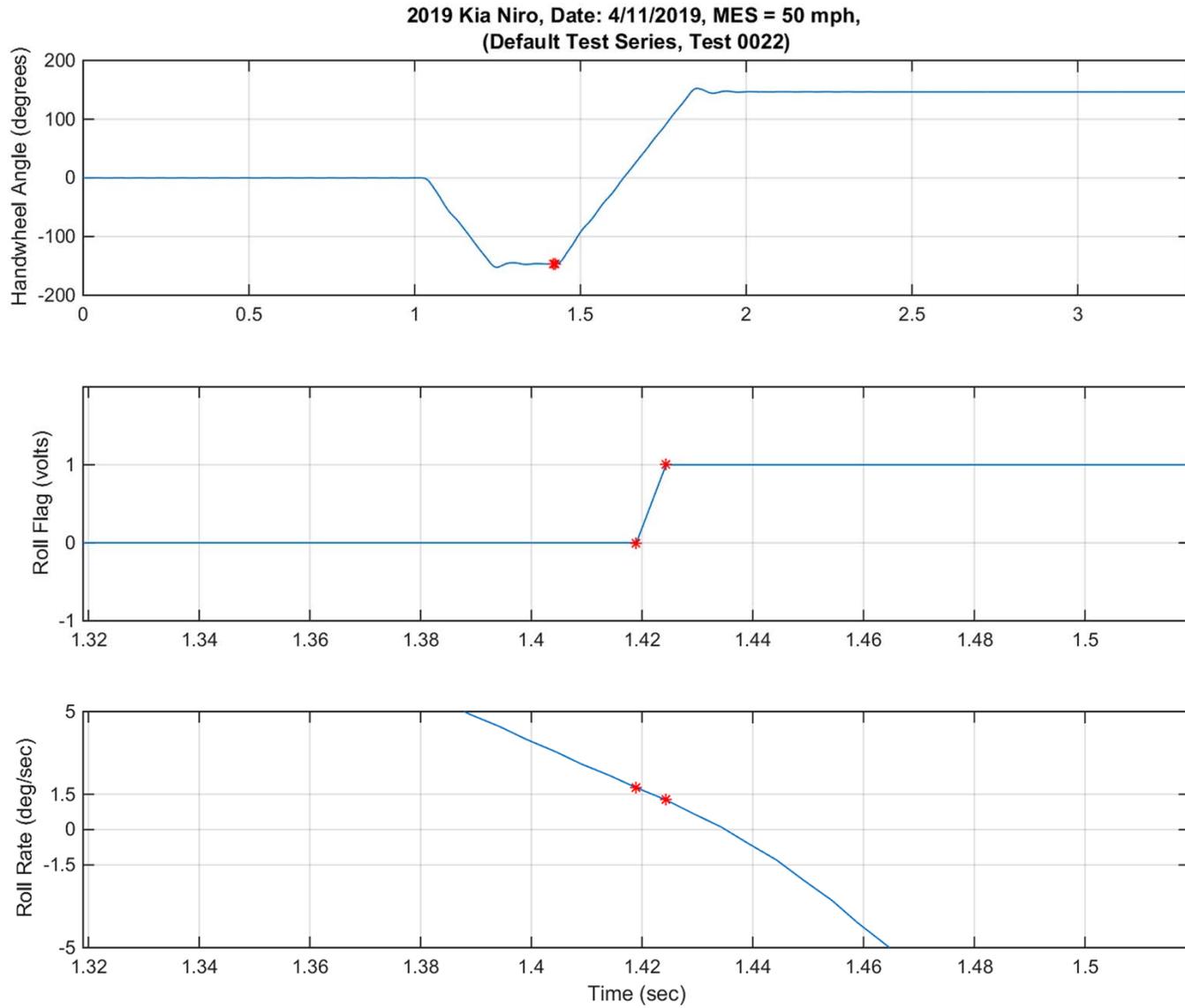


Figure D10. Steering Machine Operation Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

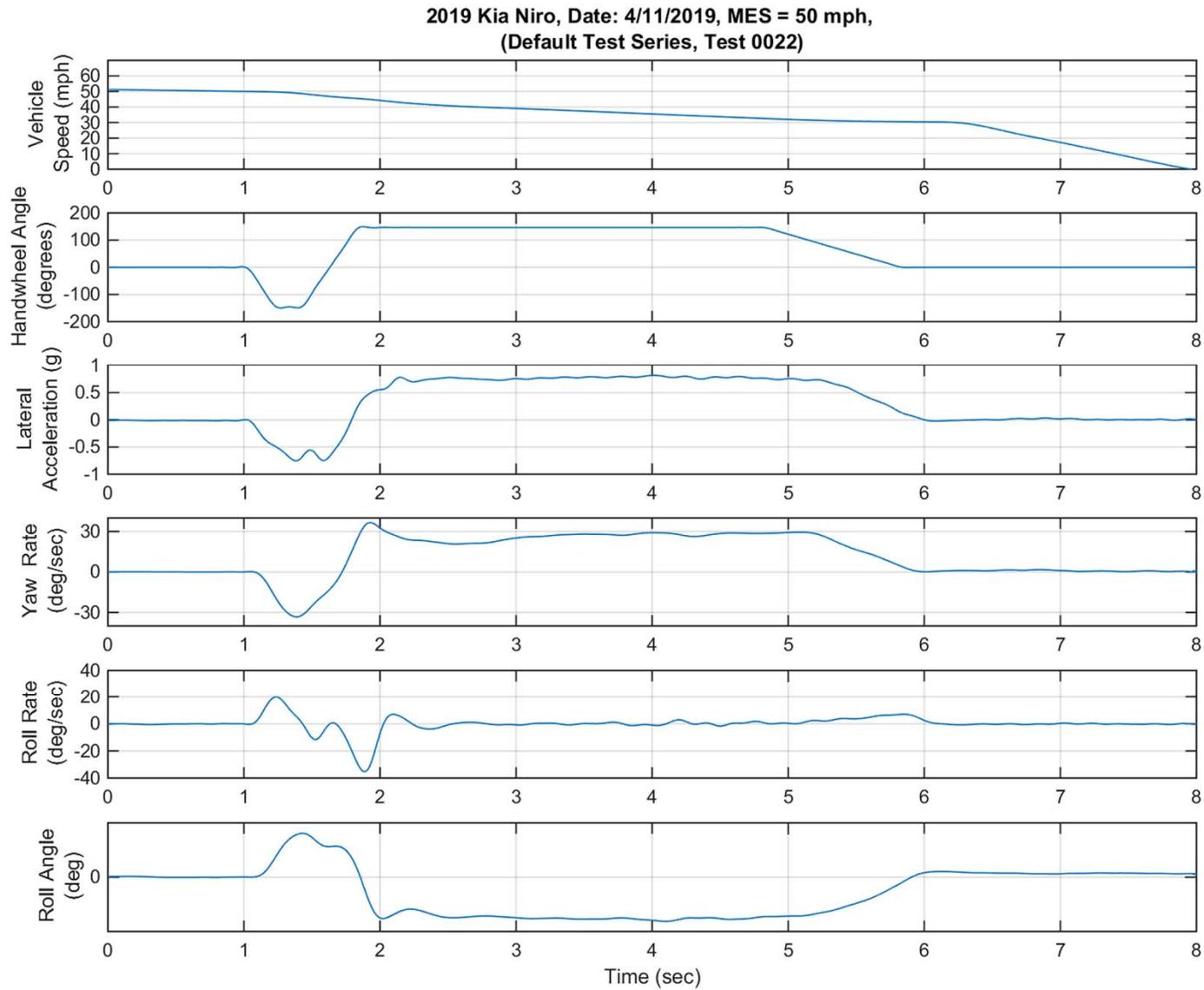


Figure D11. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

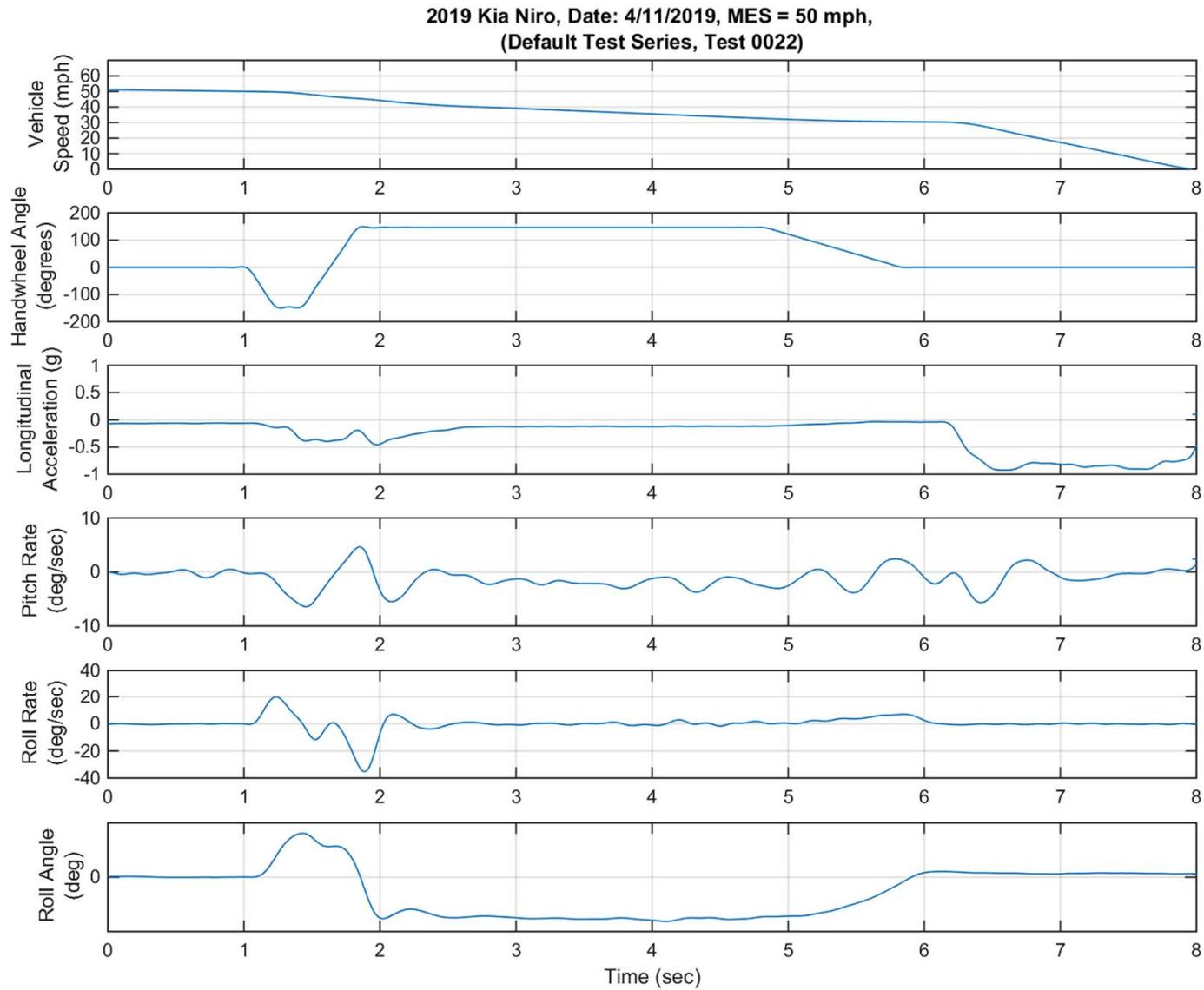


Figure D12. Pitch Rate and Longitudinal Acceleration Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

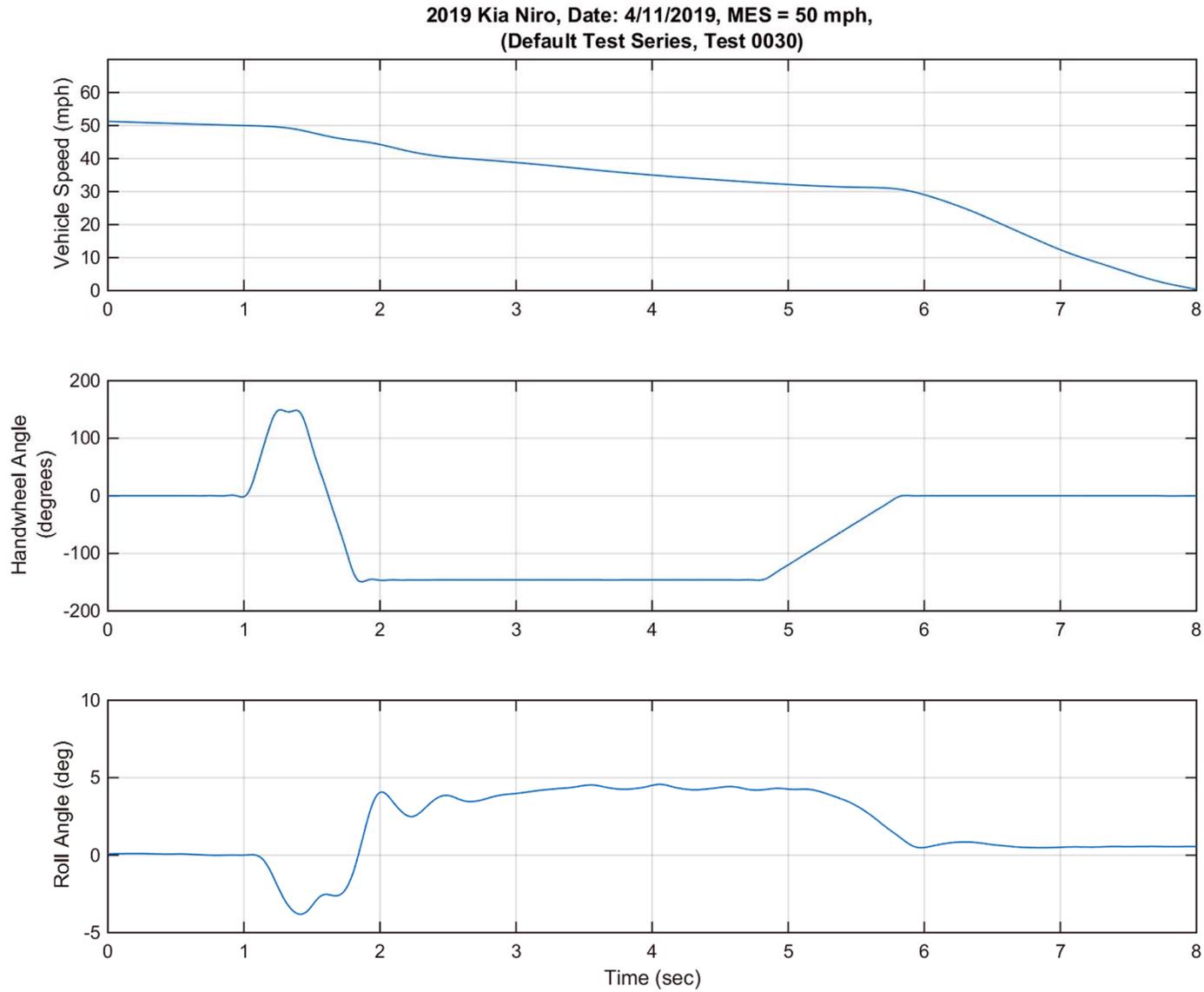


Figure D13. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

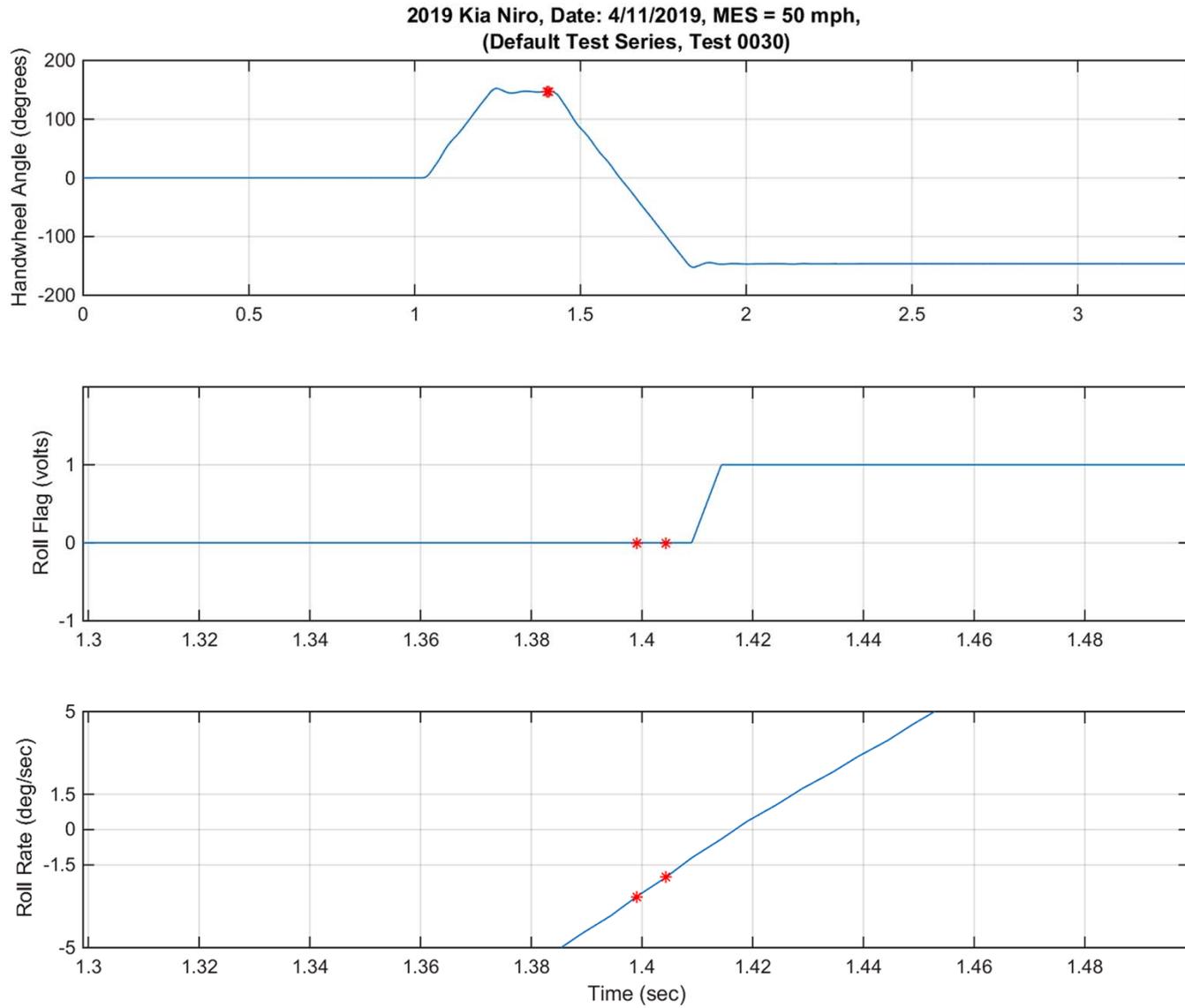


Figure D14. Steering Machine Operation Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

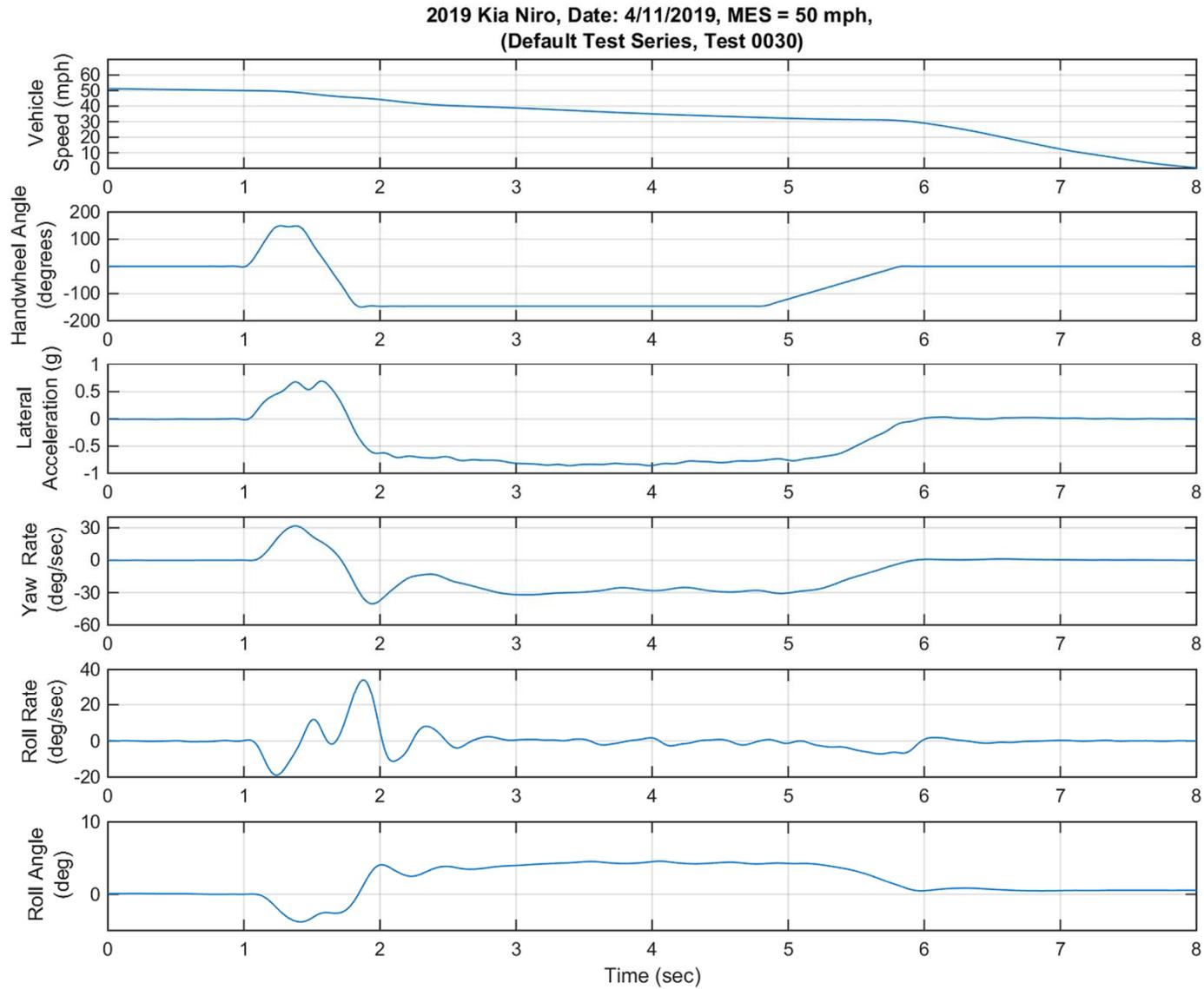


Figure D15. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

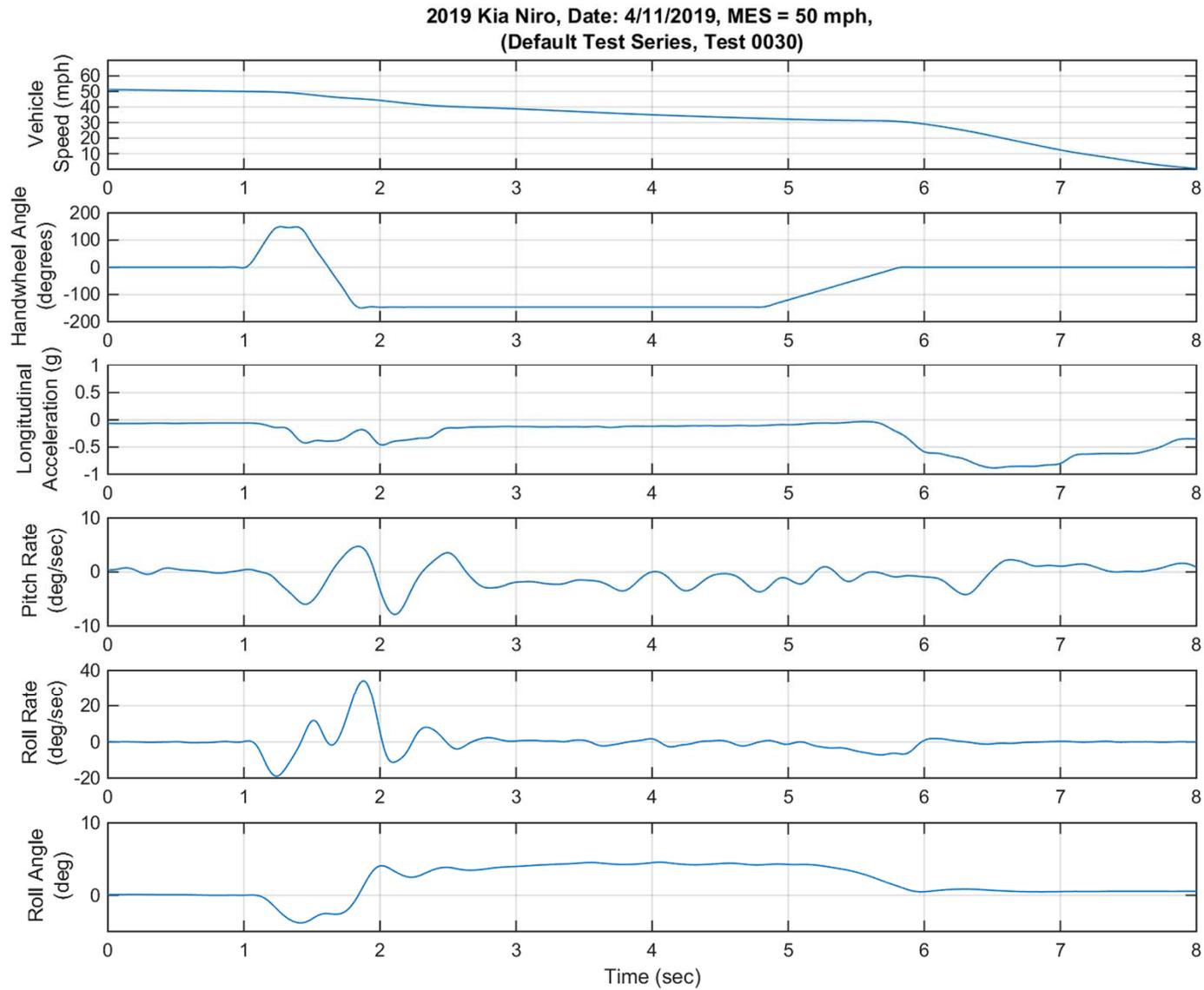


Figure D16. Pitch Rate and Longitudinal Acceleration Time History Plots for Supplemental 2 Test Series, R-L, 50 mph