

**NCAP-KAR-DR-22-01  
NEW CAR ASSESSMENT PROGRAM (NCAP)  
DYNAMIC ROLLOVER RESISTANCE TEST**

**FORD MOTOR CO.**

**2021 FORD TRANSIT 350 HR 15-PASS AWD 4-DOOR VAN**

**PREPARED BY:  
APPLUS IDIADA KARCO ENGINEERING, LLC.  
9270 HOLLY ROAD  
ADELANTO, CA 92301**



**JANUARY 12, 2022**

**FINAL REPORT**

**PREPARED FOR:  
U.S. DEPARTMENT OF TRANSPORTATION  
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION  
NEW CAR ASSESSMENT PROGRAM  
MAIL CODE: NRM-110  
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WASHINGTON, D.C. 20590**

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Prepared By: Mr. Maximilian Kester, Project Engineer  
Applus IDIADA KARCO Engineering, LLC.

Approved By: Mr. Bernat Ferrer, Program Manager  
Applus IDIADA KARCO Engineering, LLC.

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## TECHNICAL REPORT DOCUMENTATION PAGE

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<b>16. Abstract</b> An NCAP Dynamic Rollover Maneuver (Fishhook) Test was conducted on a 2021 Ford Transit 350 HR 15-Pass AWD 4-Door Van by Applus+ IDIADA KARCO Engineering, LLC. on January 6, 2022. The vehicle did not experience two-wheel lift. The vehicle's steering angle at 0.3 g lateral acceleration at 50 mph was 34.4 degrees.			
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## **SECTION I INTRODUCTION**

The National Highway Traffic Safety Administration (NHTSA) has engaged Applus+ IDIADA KARCO Engineering, LLC 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 2021 Ford Transit 350 HR 15-Pass AWD 4-Door Van 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 Dynamic Rollover Test Procedure developed by NHTSA. This procedure may be found at [www.regulations.gov](http://www.regulations.gov), docket item NHTSA-2006-26555-0136.

The testing reported herein was accomplished under contract 693JJ920D000011.

## **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

<b>General Data</b>					
Model year, make, model	2021 Ford Transit				
VIN	1FBAX9XGXMKA99075				
Body style	Van				
Number of doors	4				
Trim level	350 HR 15-Pass XLT				
Seating positions	Front:	2 <sup>nd</sup> row	3 <sup>rd</sup> row	4 <sup>th</sup> row	5 <sup>th</sup> row
	2	3	3	3	4
Electronic stability control	Yes				
4-Wheel ABS (Yes/No)	Yes				
Power steering (Yes/No)	Yes				
Major optional equipment	-				
Odometer at start of testing	490 miles				
<b>Drivetrain</b>					
Engine cylinder arrangement	V6				
Engine displacement	3.5L				
Transmission type	Automatic				
Drive arrangement	AWD				
<b>Chassis</b>					
Track width	F: 68.5 in (1740 mm), R: 69.8 in (1772 mm)				
Wheelbase	147.8 in (3754 mm)				
Curb weight	6870 lb (3116.2 kg)				
<b>Certification Data from Vehicle's Label</b>					
Vehicle manufactured by	Ford Motor Co.				
Date of manufacture	11/21				
GVWR	9550 lb (4332 kg)				
GAWR Front	4465 lb (2025 kg)				
GAWR Rear	5830 lb (2644 kg)				

Table 2. Tire Information

Tire Manufacturer	Continental
Tire Model	Van Contact A/S
Tire Size	Front: 235/65R16C Rear: 235/65R16C
Load rating	Front: 121 Rear: 121
Speed rating	Front: R Rear: R
Treadwear grade	Front: N/A Rear: N/A
Traction grade	Front: N/A
Temperature grade	Front: N/A Rear: A
Location of "Recommended Tire Pressure" label	Driver's door jamb
Recommended cold tire pressure	Front: 57 psi, (393 kPa) Rear: 75 psi, (517 kPa)
DOT code (8 first digits)	Front: 16Y0 4DR8 Rear: 16Y0 4DR8

Table 3. Vehicle Loading

Water dummy and other loading	Multi-Passenger Configuration 2 water dummies in second row, 1 in third row
Water dummy weight	525.1 lb (238.2 kg)
Fuel level	Full
<b>Weight as Tested</b>	
Left front	1305 lb (957.5 kg)
Right front	1155 lb (932.0 kg)
Left rear	1239 lb (913.0 kg)
Right rear	1261 lb (906.0 kg)
Total weight	4960.4 lb (3708.5 kg)

## D. STEERING CONTROLLER

Precise steering control is accomplished using a steering machine designed and constructed by ABD. It can provide up to 45 ft-lb torque and at rates over 1000 deg/sec. The integrated angle encoder has an unlimited range with a resolution of 0.25 degrees and an accuracy of  $\pm 0.25$  degrees. The steering motor is controlled by RC8 software from ABD, which also acts as the data acquisition system.

## E. REAL-TIME CONTROLLER AND DATA ACQUISITION

Data acquisition is achieved using a MOSES Meas X, which also serves as the real-time system for the steering controller. Data from the OXTS, 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 MOSES MeasX. The Oxford IMUs are calibrated per the manufacturer's recommended schedule (Table 5).

Two video cameras were used to record the Fishhook runs. They were positioned nominally as shown in Figure 1. The recorded video was reviewed after the Fishhook runs to check for any two-wheel lift. If any two-wheel lift was observed, four 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 Applus+ IDIADA KARCO Engineering, LLC used for this specific test program.

Table 4. Weight of In-Cab Test Equipment

Equipment	Location	Equipment Weight (lb)	
		NHTSA*	IDIADA
Data Acquisition System	Front passenger seat	58	35
GPS Inertial unit	At the chassis in a flat and rigid surface		7
Steering Machine	Handwheel	31	51
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 footwell.	39	39
	<b>Total</b>	<b>128</b>	<b>132</b>

\* 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. Sensor Specifications

Type	Measured Variable	Sensor	Range	Resolution	Accuracy	Specifics	Serial Number	Calibration	Unit
<i>Multi-Axis Inertial Sensing System</i>	Longitudinal speed	GPS inertial unit	-	0.01 %/s 0.01 m/s <sup>2</sup>	±0.1	OXTS (RT)	1611	By: IDIADA Date: 6/16/2020 Due: 6/16/2022	km/h
<i>Distance Measuring System</i>	Lateral speed		-		±0.1				km/h
	Longitudinal acc.		±100		±0.1				m/s <sup>2</sup>
<i>Radar Speed Sensor</i>	Lateral acc.		±100		±0.05				°
	Roll angle		±100		±0.05				°
<i>Data Flag (Roll Rate Flag)</i>	Pitch angle		±100		±0.1				%/s
	Yaw angle		±100		±0.1				%/s
	Roll rate		±100		±0.1				%/s
	Pitch rate		±100		±0.1				%/s
Yaw rate	±100		±0.1		%/s				
<i>Angle Encoder<sup>1</sup></i>	Steering angle	Steering wheel robot	>1000	0.25 deg	±0.20 ±0.25	ABD	1491/20	By: IDIADA Date: 11/28/2021 Due: 11/28/2022	°
<i>Data Flag (Handwheel Command Flag)</i>	Steering torque		60						Nm
<i>Infrared Distance Measuring System</i>	Tire wheel lift	Height sensors	300-700	0.01 mm	±0.8	OPTImess	OMS 4140-9155 OMS 4140-9156 OMS 4140-9157 OMS 4140-9158	By: IDIADA Date: 11/11/2021 Due: 11/11/2022	mm
<i>Load Cell</i>	Brake Pedal Force	Load Cell	±600	-	±0.5	Novatech	29730	By: IDIADA Date: 01/18/2021 Due: 01/18/2022	N
<i>Acquisition system</i>	-	Acquisition system	200	-	-	IDIADA Moses MEAS X	180749	By: IDIADA Date: 05/21/2020 Due: 05/21/2022	-

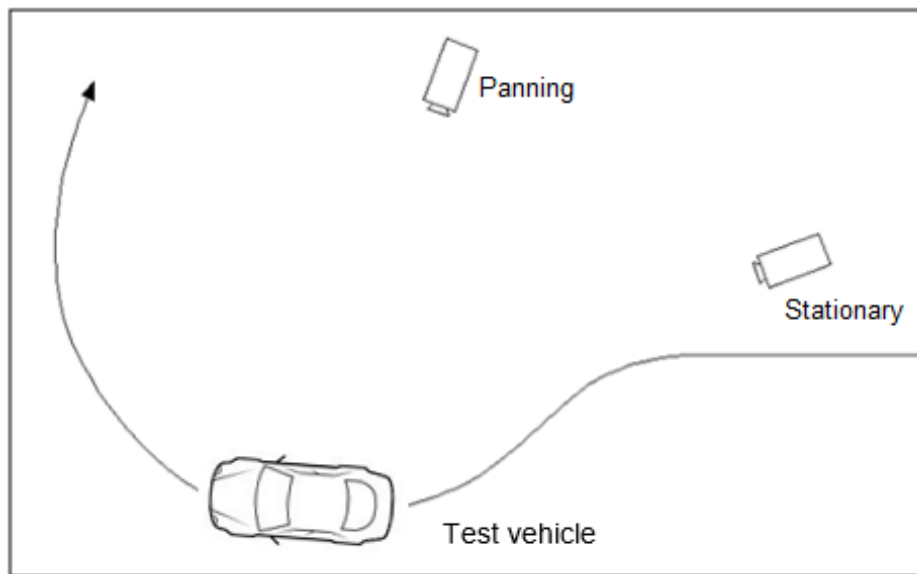


Figure 1. Nominal Position of Video Cameras for Fishhook Tests

### **SECTION III**

#### **TEST PROCEDURES**

##### **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 3 seconds, and then returned to zero angle in 2 seconds.

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 (VDA) at HONDA Proving Center facility, located in Cantil, California, on 1/6/2022. The VDA has a smooth, flat (slope less than 0.5% throughout) asphaltic concrete surface. Its dimensions are as shown in Figure 2. The test was accomplished using an ASTM F2493 16 inch SRTT 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 surface friction measurement results are shown in Table 6.

Table 6. Lateral Surface Friction

Date of lateral surface friction measurements	1/6/2022
Average lateral friction coefficient	1.04
Date of peak braking coefficient measurements	11/29/2021
Peak braking coefficient	1.06

**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)	34.4°
5.5 scalar handwheel angle for Fishhook Test	189.2°



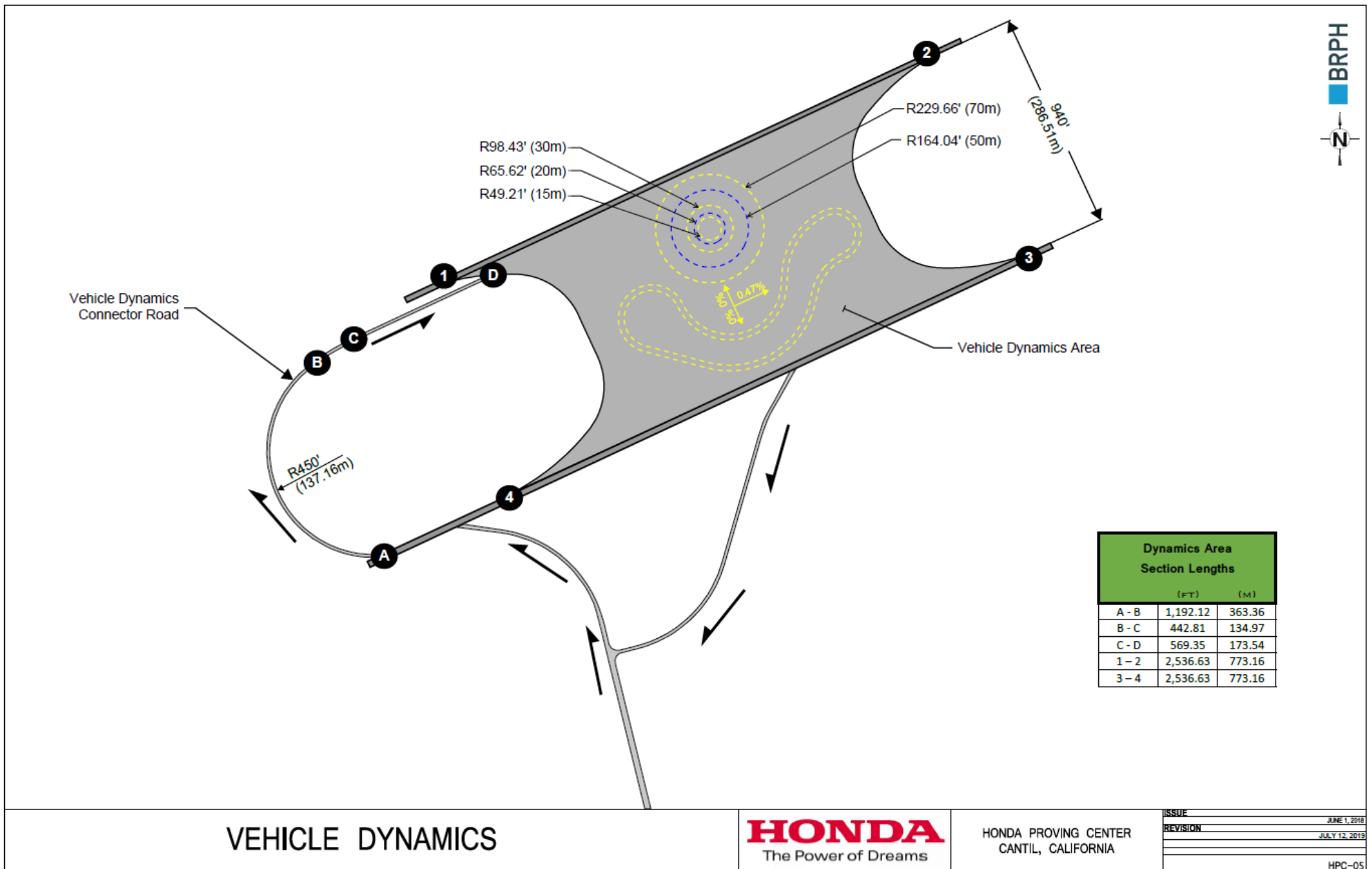
6.5 scalar handwheel angle for Fishhook Test	223.6°
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### 3. Weather Conditions

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

Table 8. Weather Conditions

Ambient temperature	52 °F (11 °C)
Wind Speed	1.1 mph (0.5 m/s)
Wind Direction	East



VEHICLE DYNAMICS



HONDA PROVING CENTER  
CANTIL, CALIFORNIA

ISSUE	JUNE 1, 2018
REVISION	JULY 12, 2019
	HPC-05

Figure 2. Vehicle Dynamics Area at Honda Proving Center

## **SECTION IV**

### **RESULTS**

There is Appendix A with the photographic documentation. The test run log is given in Appendix B. A summary of the Slowly Increasing Steer Test 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 2021 Ford Transit 350 HR 15-Pass AWD 4-Door Van there was no two-wheel lift at any test condition.

**APPENDIX A  
PHOTOGRAPHS**

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KAN-000640 CA

9-NORMAL, NB, 200640, MK212

8330

120211103 4981

ULC CERT CERT CERT TRD RAMP BUMP CAMP BOOK EXPL

002356 312/1892

1FBAX9XGX MKA9 NB

GEPL



VEHICLE DESCRIPTION

**TRANSIT**

2021 350 HR PASS XLT AWD  
XLT TRIM  
3.5L ECOBOOST V6 (GAS)  
10-SPEED TRANSMISSION

**MK A99075**

EXTERIOR  
OXFORD WHITE  
INTERIOR  
DARK PALAZZO GRAY CLOTH

STANDARD EQUIPMENT INCLUDED AT NO EXTRA CHARGE

**EXTERIOR**

- AUXILIARY FUEL PORT
- BUMPERS - BODY COLOR
- DOOR - SINGLE SLIDING SIDE
- DOORS - CARGO REAR W/ 180-DEGREE SWING-OUT
- FOG LAMPS
- FULL SIZE SPARE TIRE/WHEEL
- HEADLAMP COURTESY DELAY
- HEADLAMPS - AUTOMATIC
- WIPERS - RAIN-SENSING

**INTERIOR**

- AIR CONDITIONING
- ASSIST HANDLE - B-PILLAR
- ASSIST HANDLES - A-PILLAR
- CENTER CONSOLE W/STORAGE
- CRUISE CONTROL
- ILLUMINATED SUN VISORS
- LOCKING GLOVE BOX
- POWERPOINT - 12V (FRONT)
- STEERING - TILT/TELESCOPIC WHEEL WITH AUDIO

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- LANE-KEEPING SYSTEM
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- TIRE PRESSURE MONIT SYS

**WARRANTY**

- 3YR/36,000 BUMPER / BUMPER
- 5YR/60,000 POWERTRAIN
- 5YR/60,000 ROADSIDE ASSIST

INCLUDED ON THIS VEHICLE

- OPTIONAL EQUIPMENT/OTHER**  
PREFERRED EQUIPMENT PKG.302A  
3.5L ECOBOOST V6 (GAS)  
3.73 LIMITED SLIP AXLE  
FRONT LICENSE PLATE BRACKET  
9550H GVWR PACKAGE  
ENGINE BLOCK HEATER (400W)  
50 STATE EMISSIONS  
HD TRAILER TOW PACKAGE  
LONG-ARM PWR HEAT MIRRORS  
RADIO - SYNC3, 8" SCN W/NAV  
ADAPTIVE CRUISE CONTROL  
FRONT/REAR SPLITVIEW CAMERA  
DUAL BATTERIES (70 AMP-HR)  
SRW - SILVER STEEL W/ LUGS  
FRONT OVERHEAD SHELF  
TRAILER BRAKE CONTROLLER  
EXTND LENGTH RUNNING BOARDS  
2 ADDITIONAL KEYS  
PRIVACY GLASS  
15-PASSENGER SEATS

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- 405.00
- 655.00
- 75.00
- 500.00
- 1,495.00

PRICE INFORMATION

BASE PRICE	\$51,380.00
TOTAL OPTIONS/OTHER	7,175.00
TOTAL VEHICLE & OPTIONS/OTHER DESTINATION & DELIVERY	58,555.00
	1,695.00

(MSRP)

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California Air Resources Board

Gasoline Vehicle

**Environmental Performance**

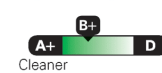
These ratings are not directly comparable to the U.S. EPA/DOT light-duty vehicle label ratings. For information on how to compare, please see [www.arb.ca.gov/ep\\_label](http://www.arb.ca.gov/ep_label).

Protect the environment. Choose vehicles with **higher ratings**:

**Greenhouse Gas Rating** (tailpipe only)



**Smog Rating** (tailpipe only)



Vehicle emissions are a primary contributor to climate change and smog. Ratings are determined by the California Air Resources Board based on this vehicle's measured emissions.



**GOVERNMENT 5-STAR SAFETY RATINGS**

**Overall Vehicle Score Not Rated**

Based on the combined ratings of frontal, side and rollover. Should ONLY be compared to other vehicles of similar size and weight.

Frontal Crash	Driver Passenger	★ ★ ★ ★
---------------	------------------	---------

Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.

Side Crash	Front seat Rear seat	★ ★ ★ ★ ★
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Based on the risk of injury in a side impact.

**Rollover Not Rated**

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](http://www.safercar.gov) or 1-888-327-4236

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The FordPass Connect™ modem is active and sending vehicle data (e.g., diagnostics) to Ford. See in-vehicle Settings for connectivity options.



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12/16/2021

1202111034981

Figure A1. Monroney Label



Figure A2. Right Front View, Test Vehicle As-Delivered





Figure A3. Left Rear View, Test Vehicle As-Delivered



Figure A4. Left Front View, Test Vehicle in Test Condition



Figure A5. Right Rear View, Test Vehicle in Test Condition

MFD. BY FORD MOTOR CO. DATE: 11/21 GVWR: 4332 KG ( 9550 LB)  
 FRONT GAWR: 2025 KG ( 4465 LB) REAR GAWR: 2644 KG ( 5830 LB)  
 WITH 235/65R16C 121/119R TIRES WITH 235/65R16C 121/119R TIRES  
 16x6.5J RIMS 16x6.5J RIMS  
 AT 390 kPa/ 57 PSI COLD AT 520 kPa/ 75 PSI COLD  
 THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE  
 SAFETY STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.  
 VIN: 1FBAX9XGXMKA99075 TYPE: Bus (Not school bus)



EXT PNT: YZ RC: 71 DSO:  

WB	INT TR	TP/PS	R	AXLE	TR	SPR	
148	CK		4	7L	U	AAAA	F0277
						ULC	T0285

  
 1202111034981 U5A-3520472-AA

Figure A6. Vehicle's Certification Label



## TIRE AND LOADING INFORMATION

SEATING CAPACITY TOTAL : 15 FRONT: 2 REAR: 13

The combined weight of occupants and cargo should never exceed : 1129 kg or 2489 lbs.

▽ 5USA-1532-AA (TLU) FoMoCo

TIRE	SIZE	COLD TIRE PRESSURE
FRONT	235/65R16C 121/119R	390 KPA, 57 PSI
REAR	235/65R16C 121/119R	520 KPA, 75 PSI
SPARE	235/65R16C 121/119R	520 KPA, 75 PSI

SEE OWNERS  
MANUAL FOR  
ADDITIONAL  
INFORMATION



Figure A7. Vehicle's Tire Information Placard

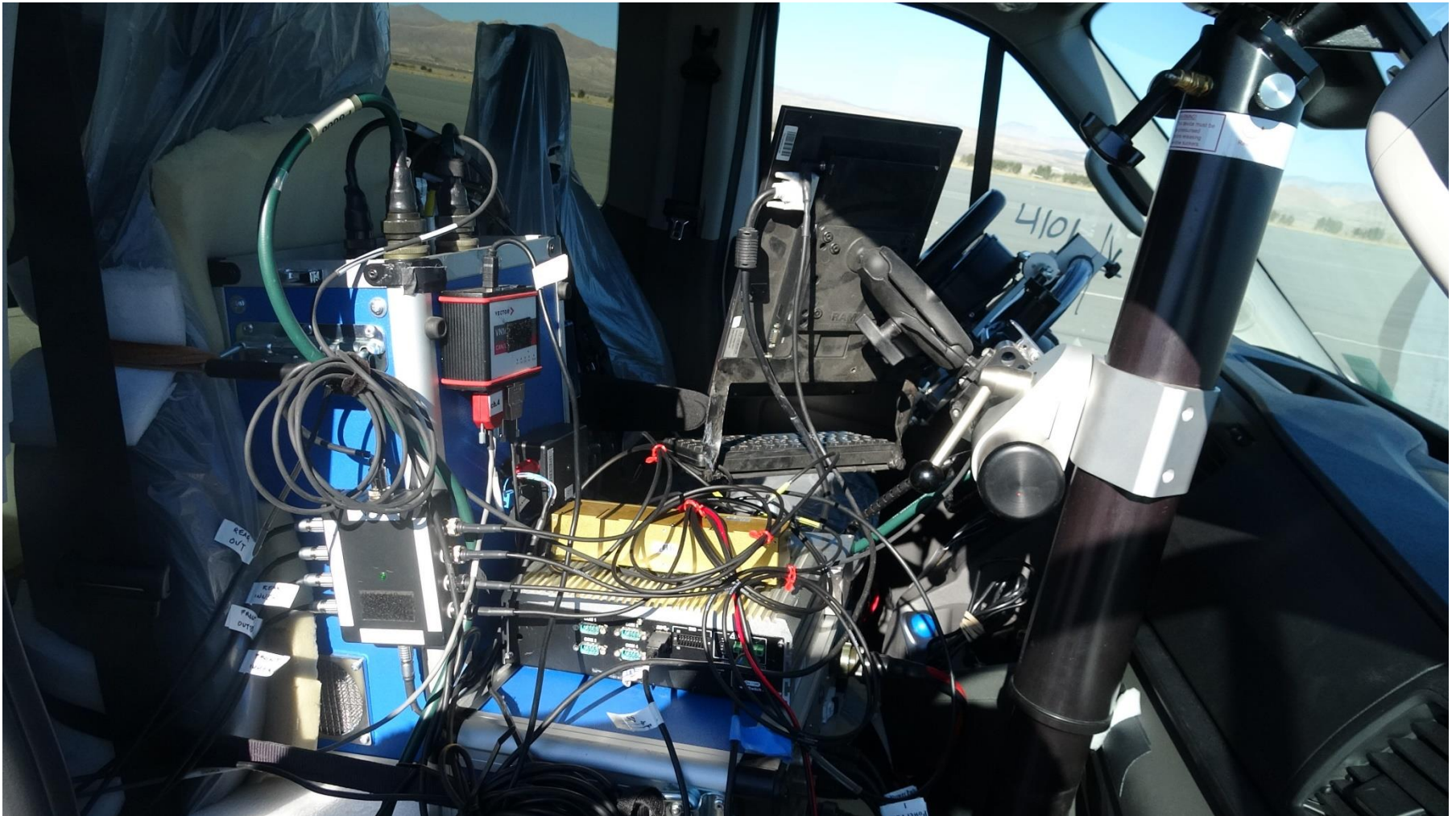


Figure A8. Instrumentation in Test Vehicle



Figure A9. Steering Controller and Computer



Figure A10. Ballast Condition



**APPENDIX B  
TEST RUN LOG**

Run Number	Test Type	Speed (mph)	Handwheel Angle (deg)	Dir. of First Steer	2 Wheel Lift	Notes
1	Tire Warm-Up	35	30.0	Left	N/A	Resulted in ay = 0.12 g
2	"	"	143.5	"	"	Resulted in ay = 0.40 g
3	"	"	"	"	"	
4	"	"	"	"	"	
5	2x SWA last cycle	"	286.6	"	"	2x SWA last cycle
6	Static	0	0	N/A	N/A	
7	Steady State	50	0	N/A	N/A	
8	<b>Slowly Increasing Steer</b>	50	30.0	Left	N/A	
9	"	"	50.8	Left	"	HW angle at 0.3 g = -32.4
10	"	"	"	Left	"	HW angle at 0.3 g = -32.8
11	"	"	"	Left	"	HW angle at 0.3 g = -31.9
12	"	"	"	Right	"	HW angle at 0.3 g = 37.5
13	"	"	"	Right	"	HW angle at 0.3 g = 36.4
14	"	"	"	Right	"	HW angle at 0.3 g = 35.8
						Average = <b>34.4</b>
15	<b>Fishhook 6.5 Scalar</b>	35	-223.6	Left	No	
16	"	40	"	"	"	
17	"	45	"	"	"	
18	"	47.5	"	"	"	
19	"	50	"	"	"	
20	<b>Fishhook 6.5 Scalar</b>	35	223.6	Right	No	
21	"	40	"	"	"	
22	"	45	"	"	"	

Run Number	Test Type	Speed (mph)	Handwheel Angle (deg)	Dir. of First Steer	2 Wheel Lift	Notes
23	"	47.5	"	"	"	
24	"	50	"	"	"	
25	<b>Fishhook 5.5 Scalar</b>	45	-189.2	Left	No	
26	"	47.5	"	"	"	
27	"	50	"	"	"	
28	<b>Fishhook 5.5 Scalar</b>	45	189.2	Right	No	
29	"	47.5	"	"	"	
30	"	50	"	"	"	

**APPENDIX C**  
**SLOWLY INCREASING STEER TEST WORKSHEET**

2021 Ford Transit 350 HR 15-Pass AWD 4-Door Van, Multi-Passenger Configuration,  
 Test Date: 1/6/2022



**Slowly Increasing Steer**



Vehicle: 2021 Ford Transit 15P  
 Test Date: 1/6/2022  
 Analysis Date: 1/6/2022  
 Analysed by: MK  
 Executed by: JL  
 Configuration: ESC on

Weight Condition: Test condition  
 Test Track: Dynamic Platform  
 Test Speed: 80 km/h

Run	Dir of Steer	Start speed [mph]	End speed [mph]	Speed red [%]	Index of ay	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
sis2_001	L	50.3	0.5	98.9	685	-32.4	-0.300	-210.6	-0.2925	-178.2	-0.2475	0.9913	4	204
sis2_002	L	50.3	0.6	98.8	684	-32.8	-0.300	-213.4	-0.2963	-180.5	-0.2507	0.9967	15	215
sis2_003	L	50.0	1.1	97.8	684	-31.9	-0.300	-207.3	-0.2880	-175.4	-0.2437	0.9829	9	209
sis2_004	R	49.9	0.3	99.3	772	37.5	0.300	243.8	0.3386	206.3	0.2865	0.9978	37	237
sis2_005	R	49.7	0.4	99.2	754	36.4	0.300	236.4	0.3284	200.1	0.2779	0.9974	19	219
sis2_006	R	50.3	-0.1	100.1	727	35.6	0.300	231.2	0.3211	195.6	0.2717	0.9981	12	212

Mean: 34.4

**Steering Controller Input values**

Scalar 6.5 values:

Initial HW angle: 223.6 deg

Reversal HW angle: -223.6 deg

Scalar 5.5 values:

Initial HW angle: 189.2 deg

Reversal HW angle: -189.2 deg

**APPENDIX D**  
**TIME HISTORY PLOTS**

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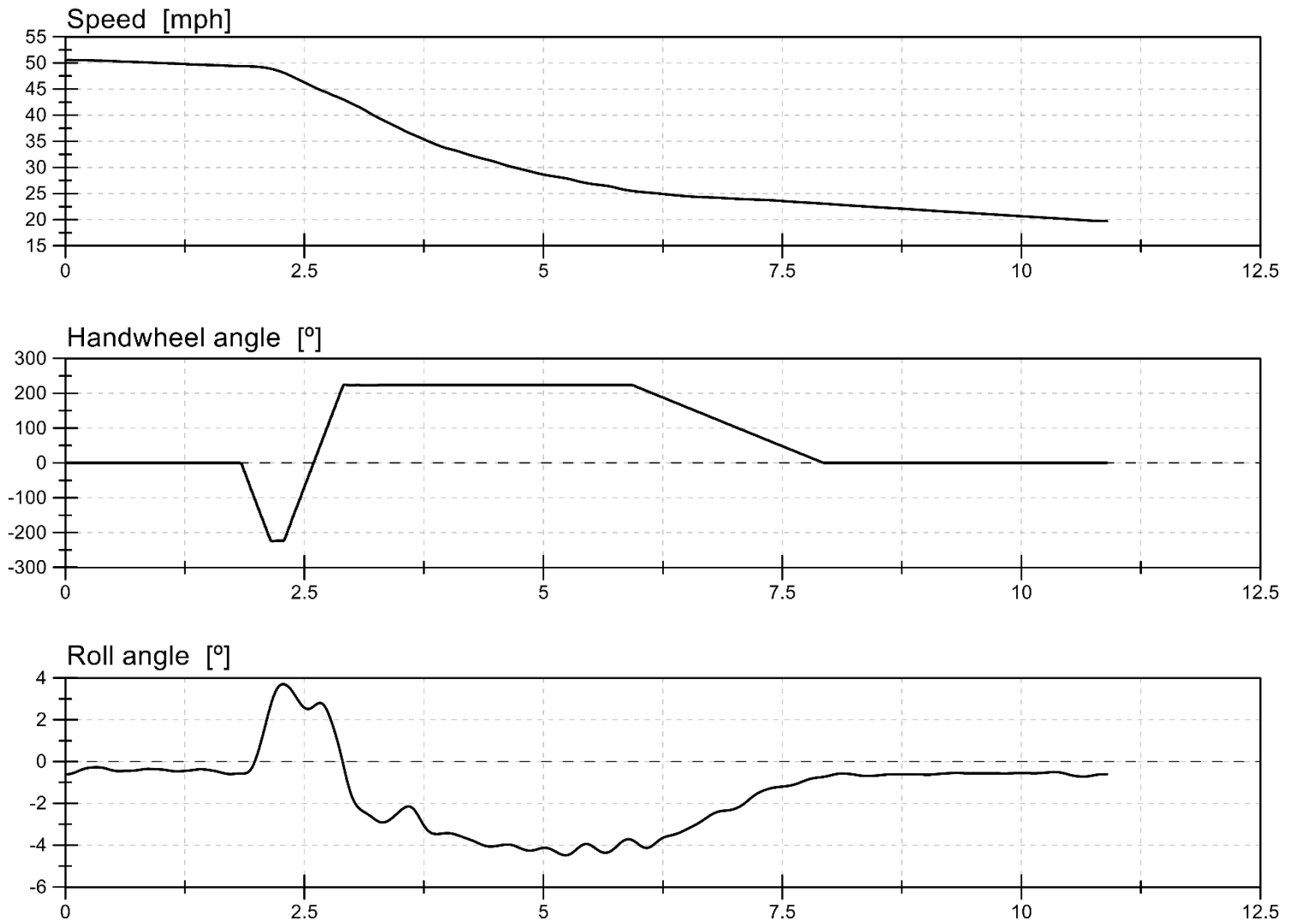


Figure D1. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Default Test Series, L-R, 50 mph



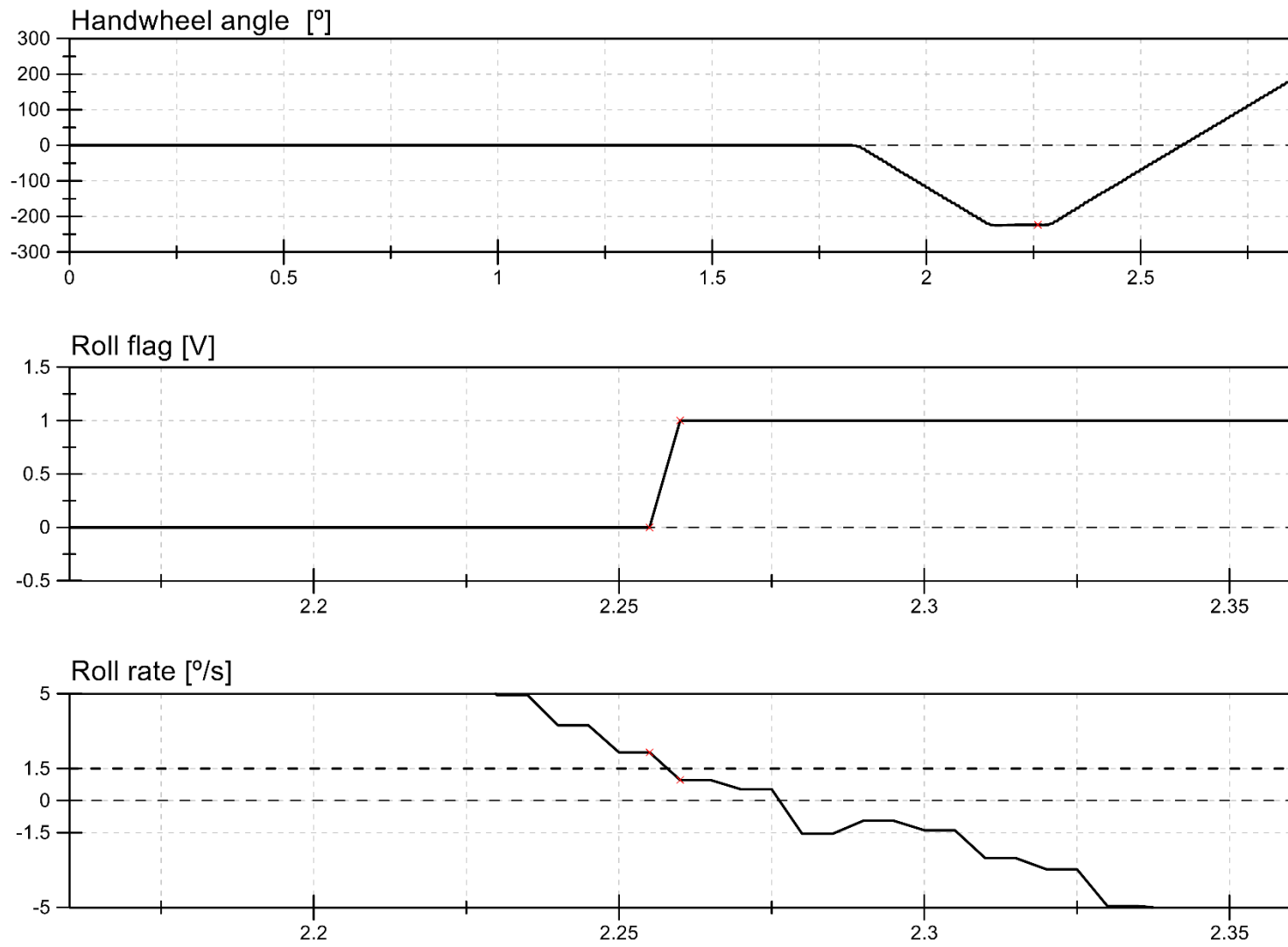


Figure D2. Steering Machine Operation Time History Plots for Default Test Series, L-R, 50 mph

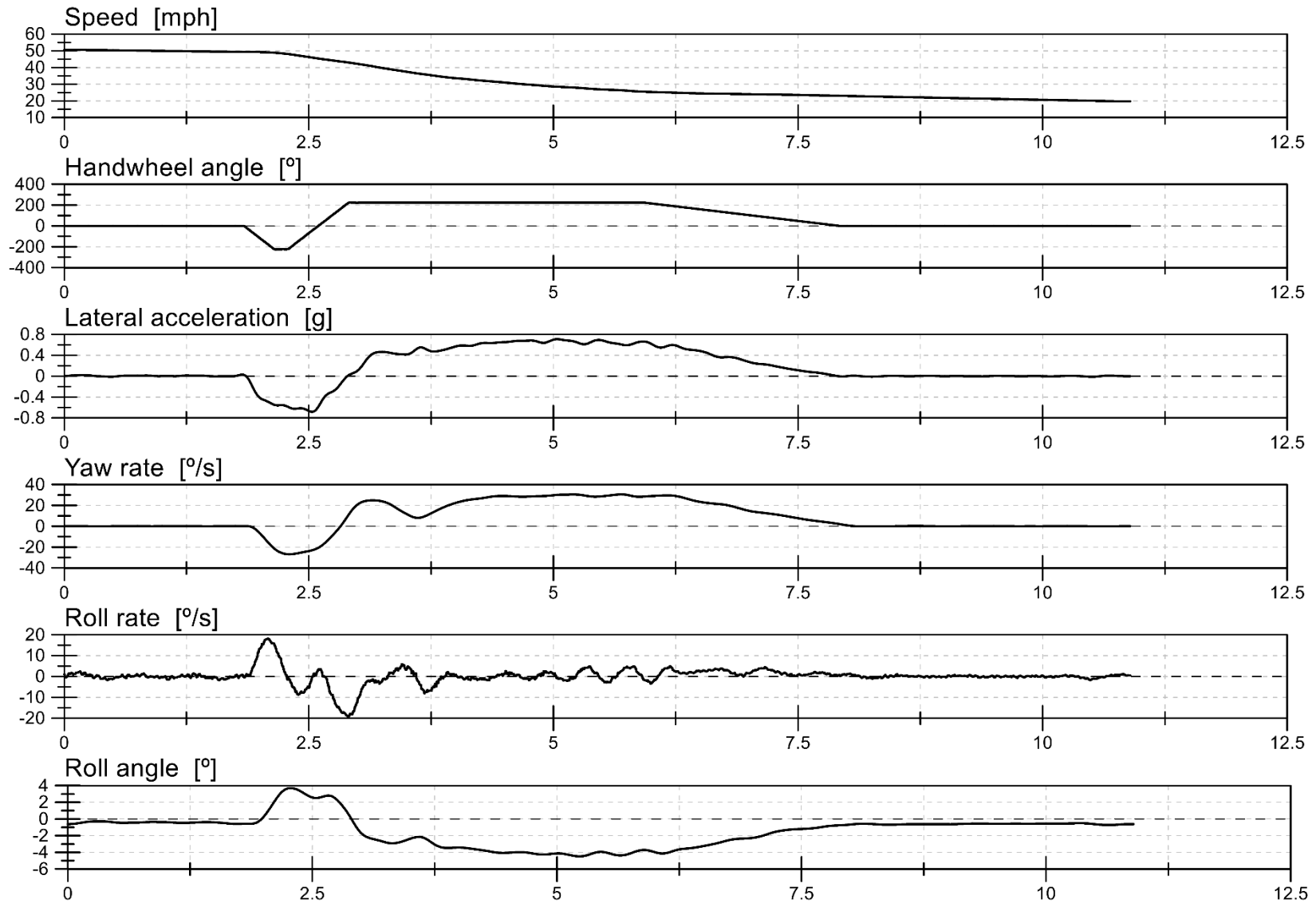


Figure D3. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Default Test Series, L-R, 50 mph

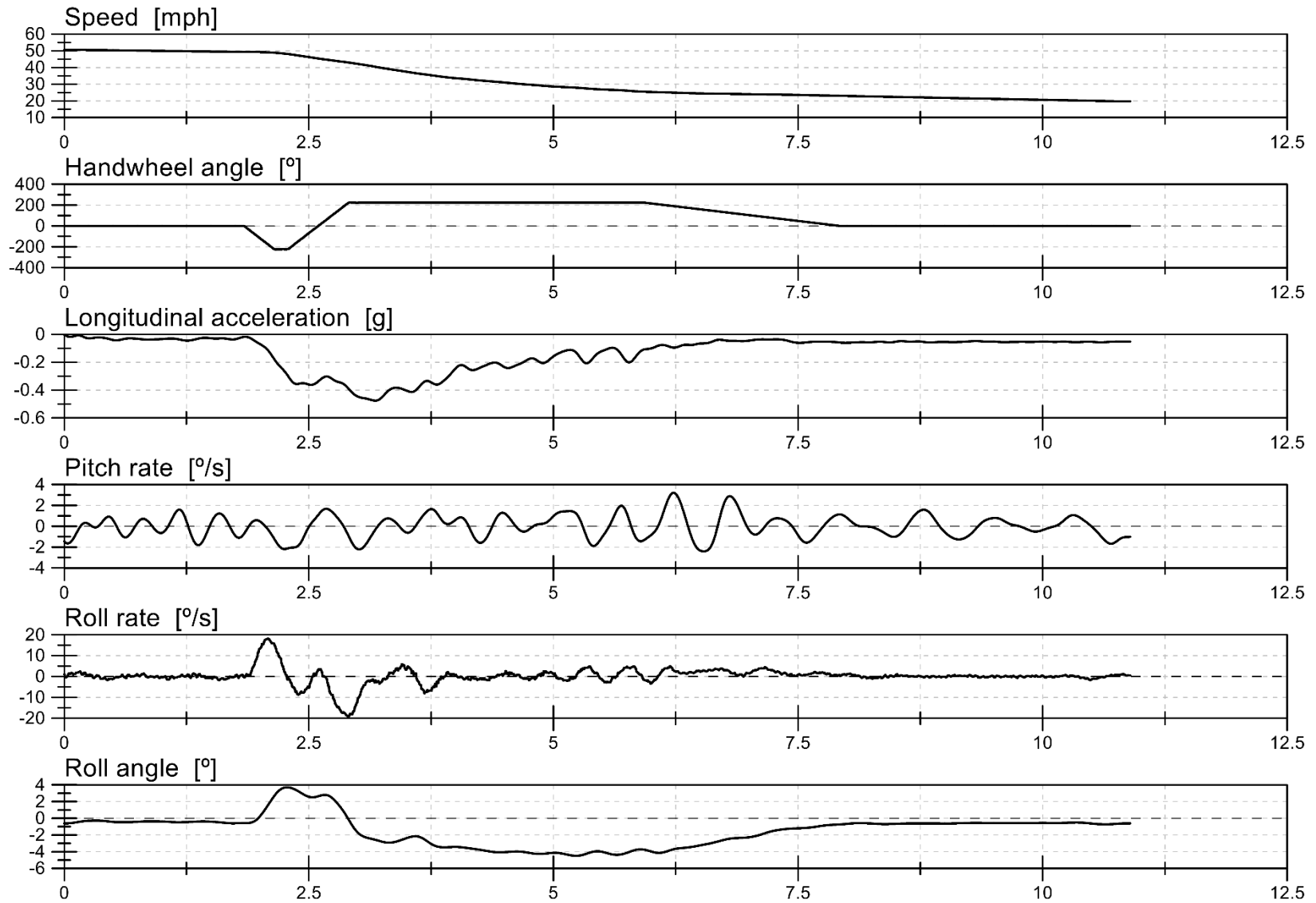


Figure D4. Pitch Rate and Longitudinal Acceleration Time History Plots for Default Test Series, L-R, 50 mph

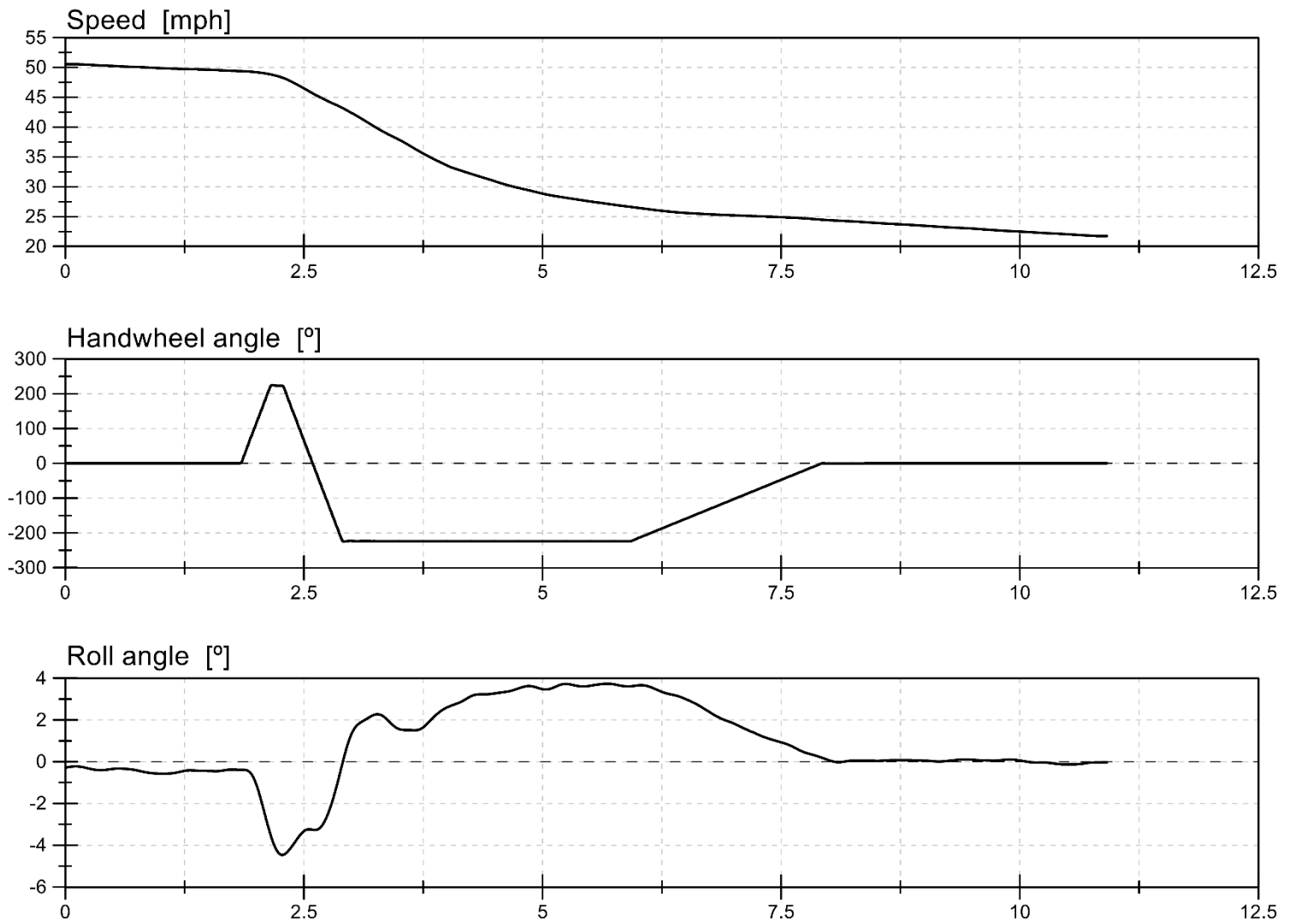


Figure D5. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Default Test Series, R-L, 50 mph

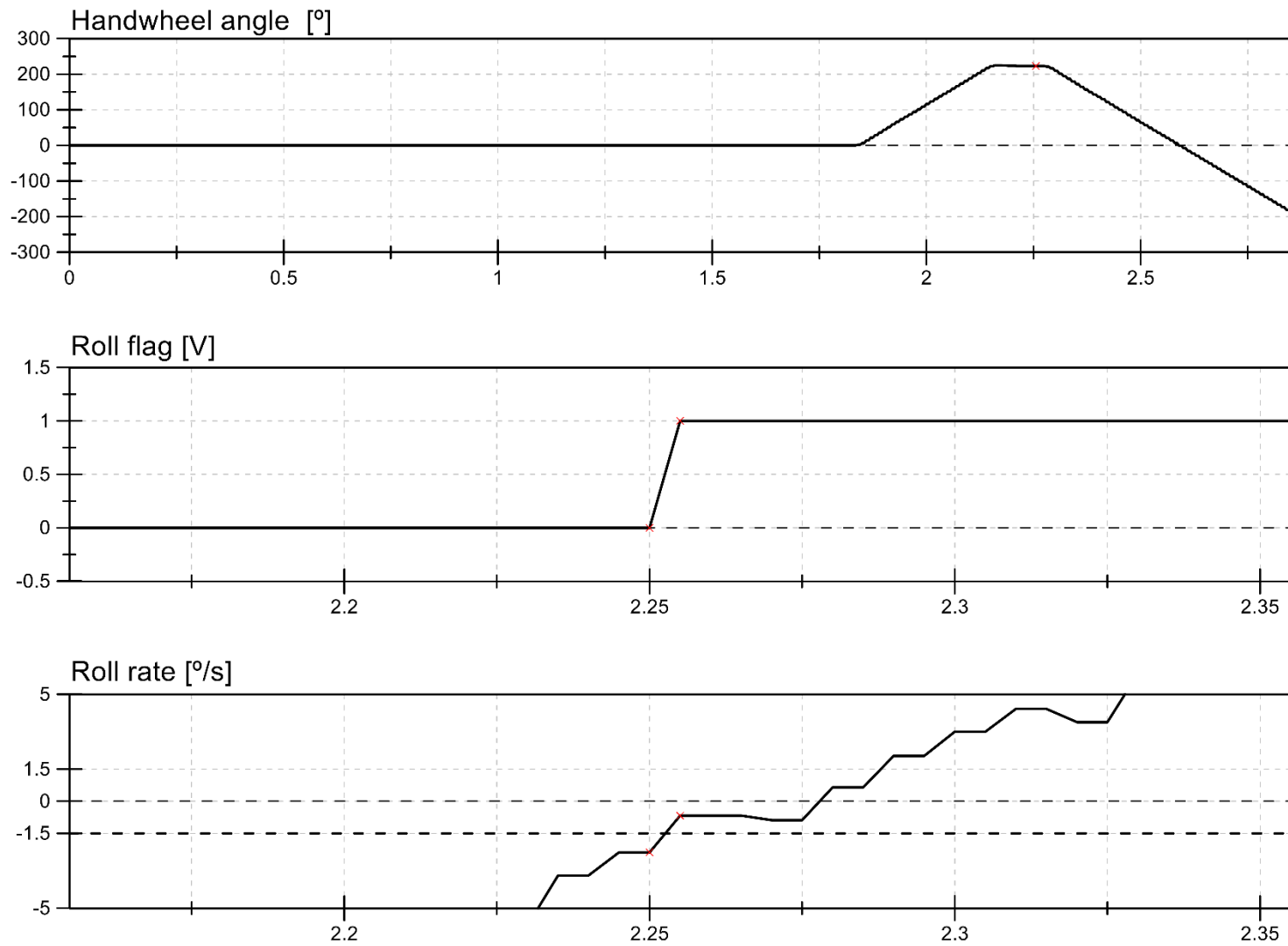


Figure D6. Steering Machine Operation Time History Plots for Default Test Series, R-L, 50 mph

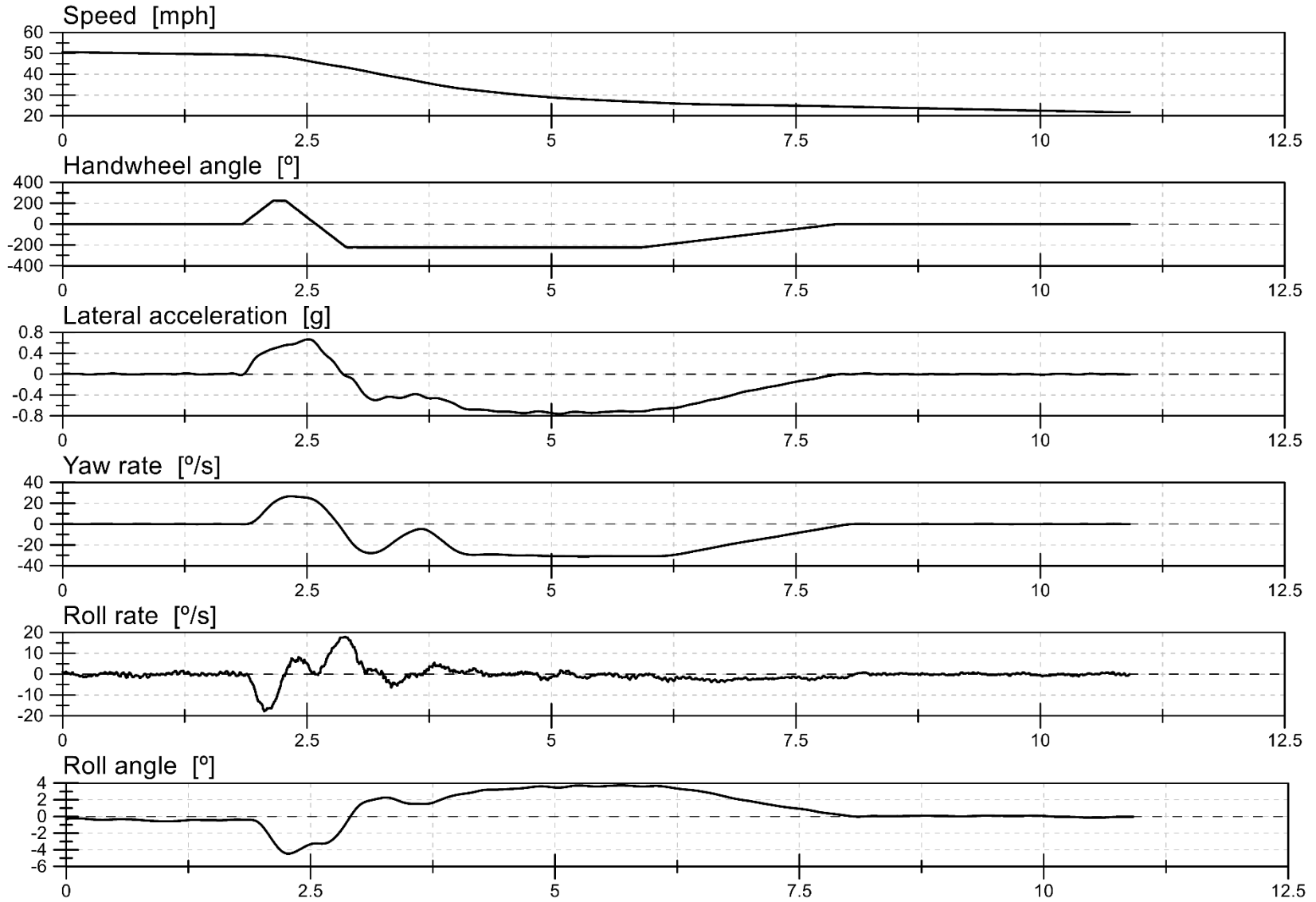


Figure D7. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Default Test Series, R-L, 50 mph

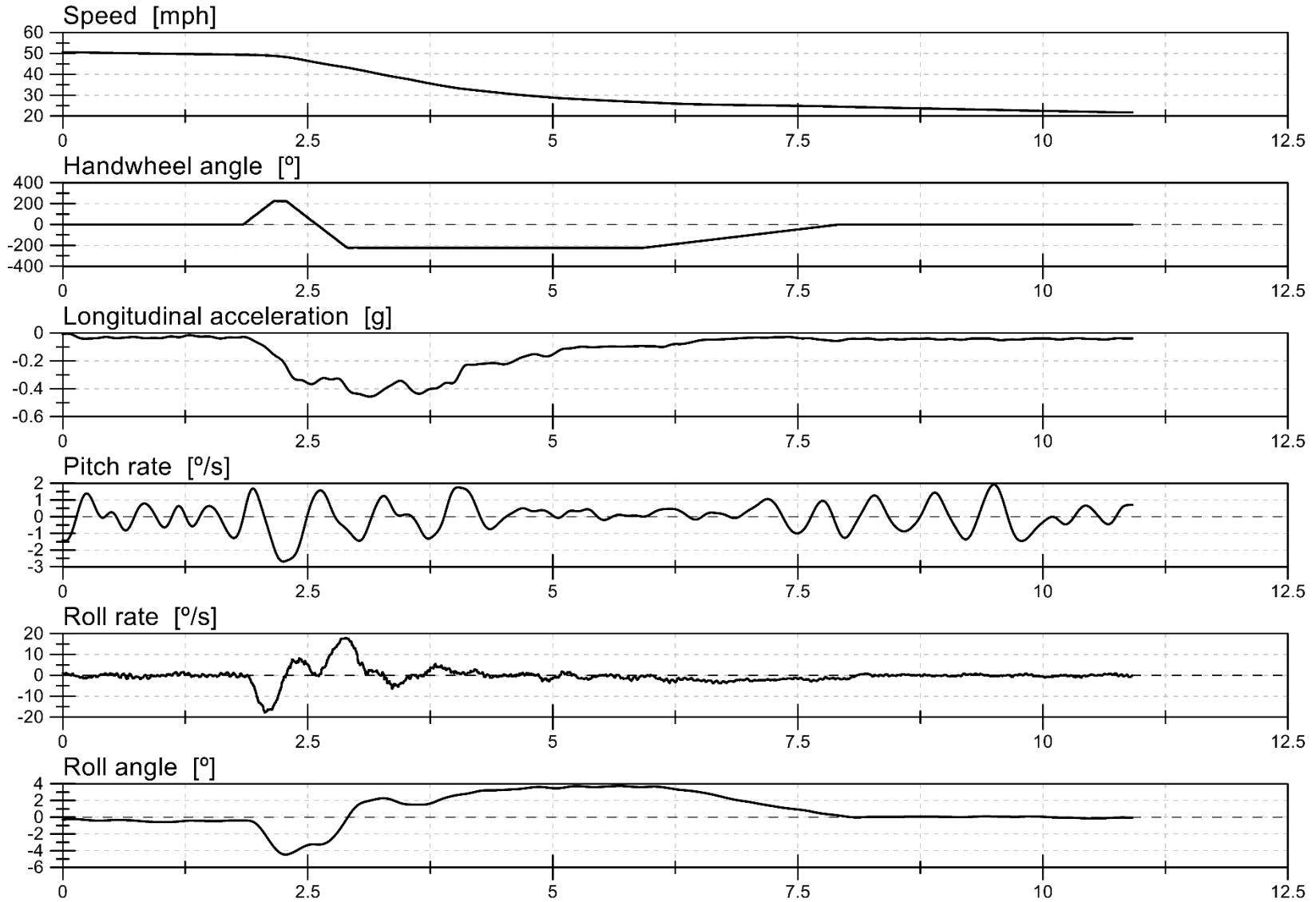


Figure D8. Pitch Rate and Longitudinal Acceleration Time History Plots for Default Test Series, R-L, 50 mph

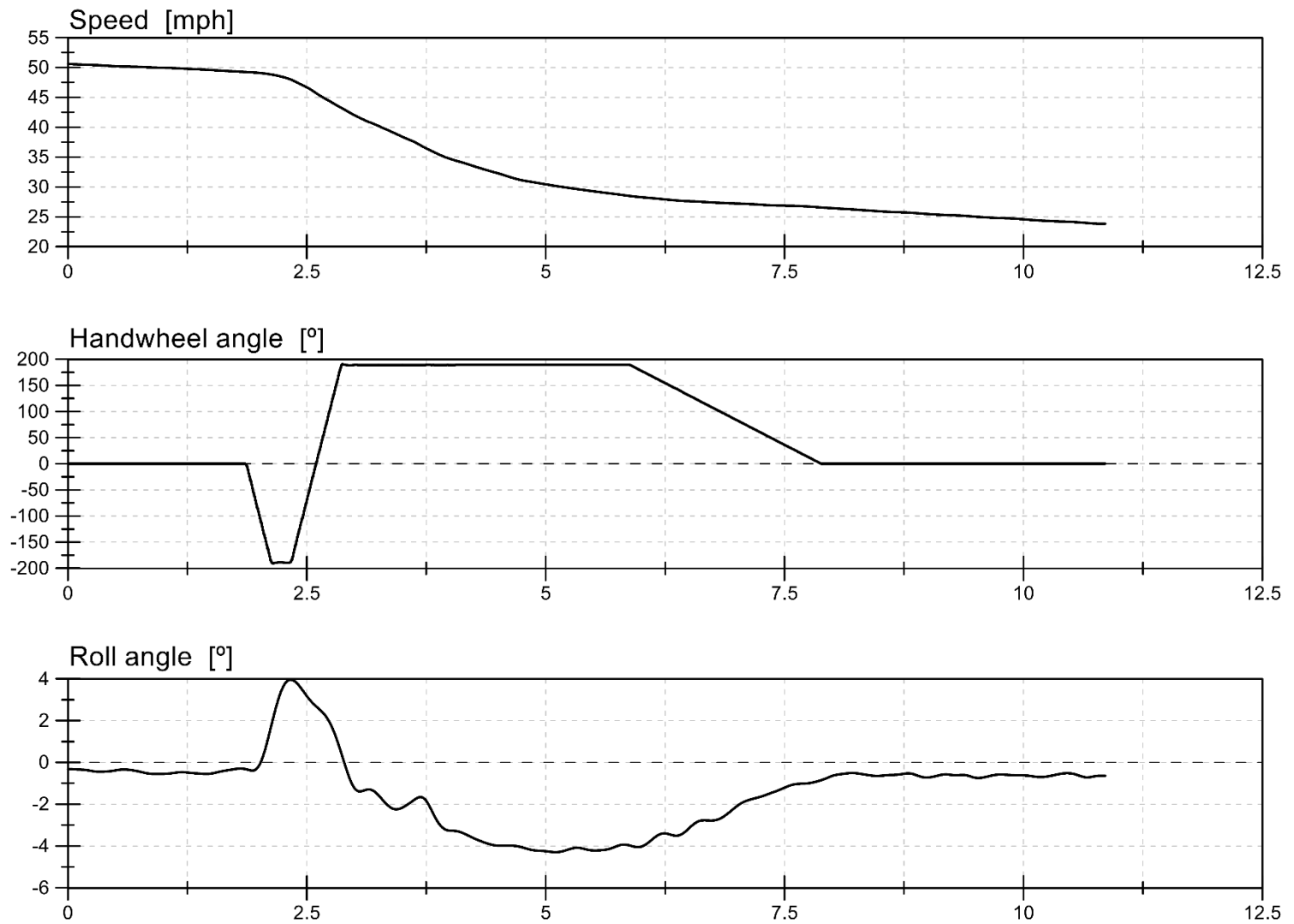


Figure D9. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Supplemental 2 Test Series, L-R, 50 mph



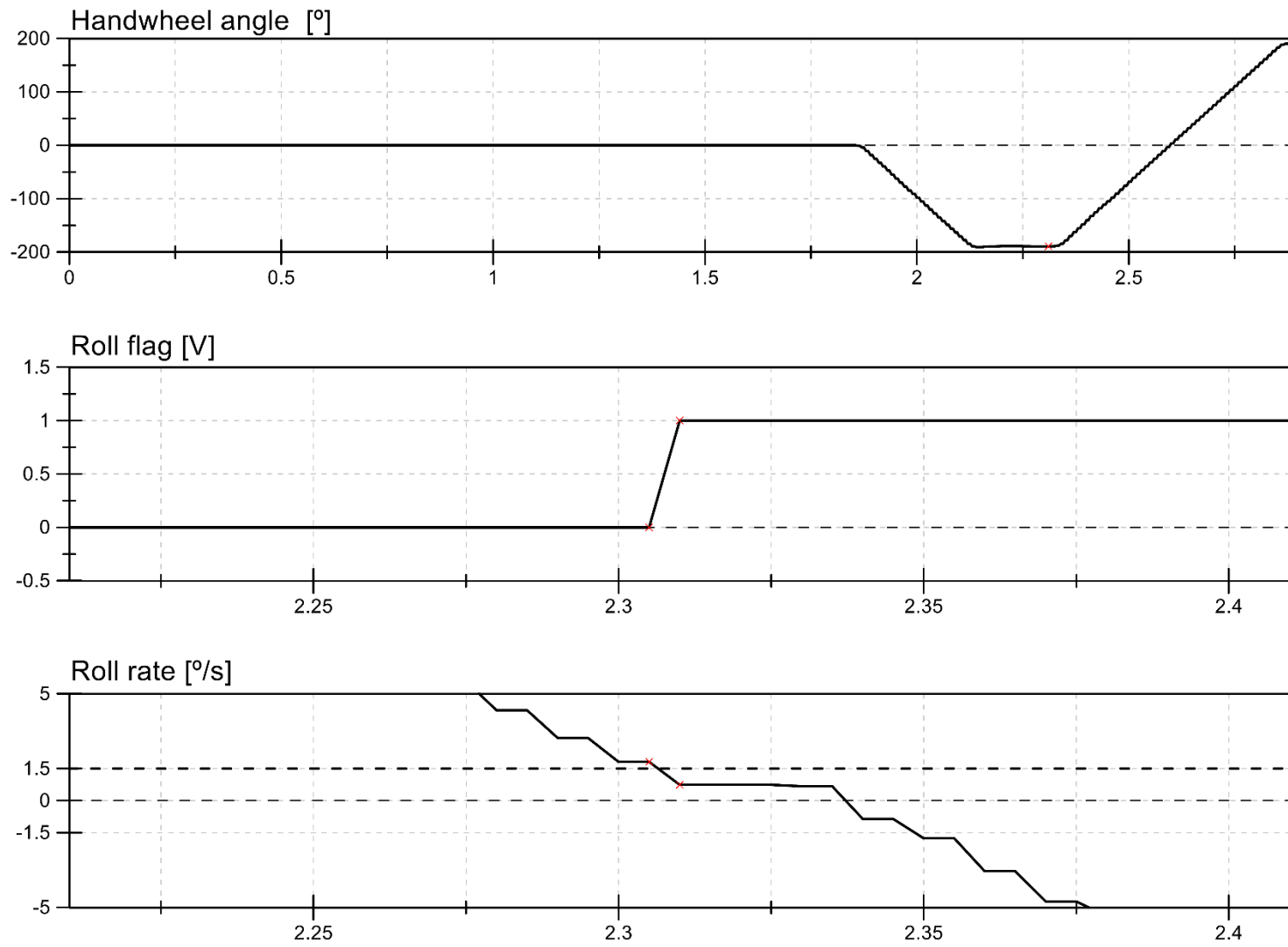


Figure D10. Steering Machine Operation Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

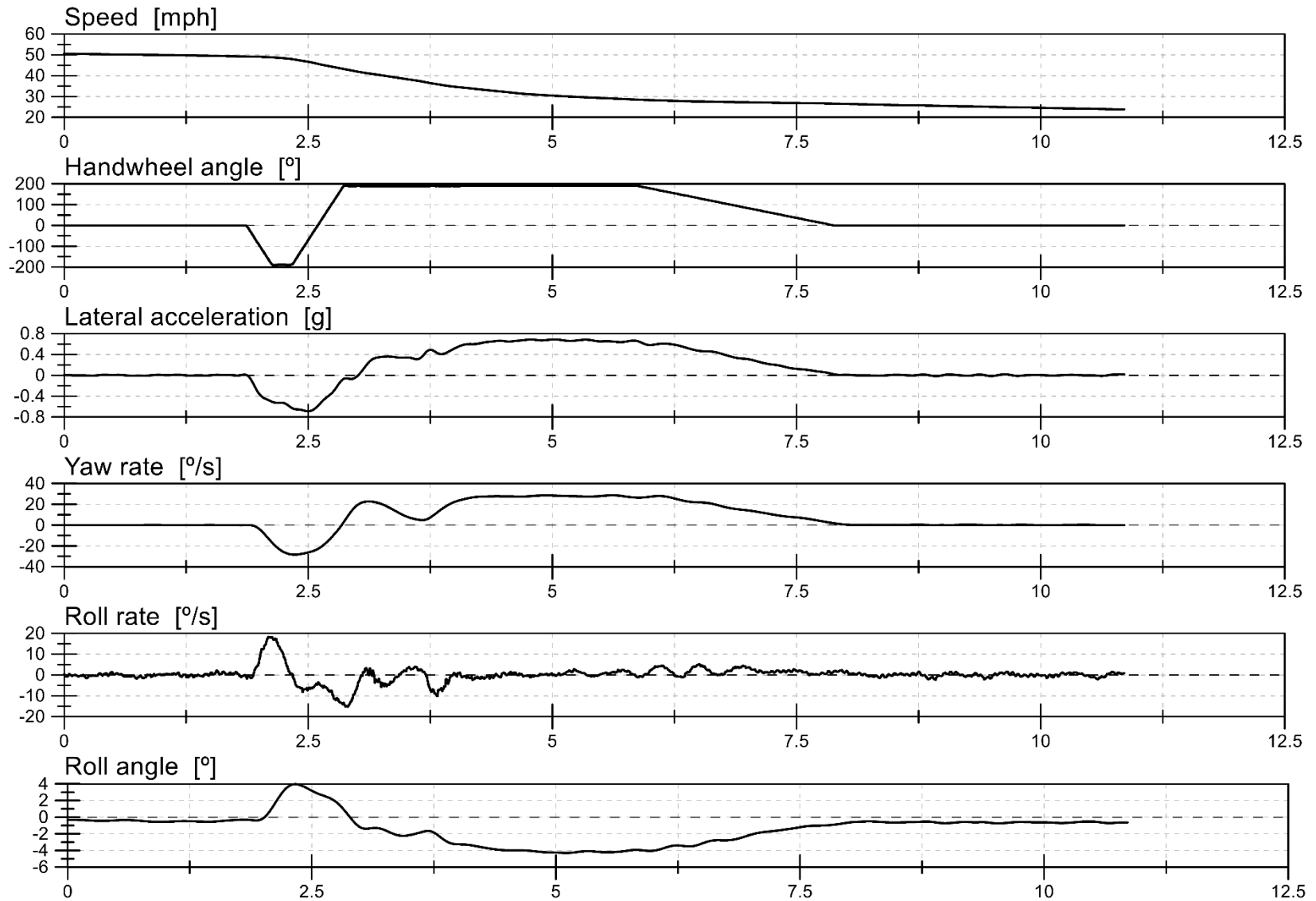


Figure D11. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

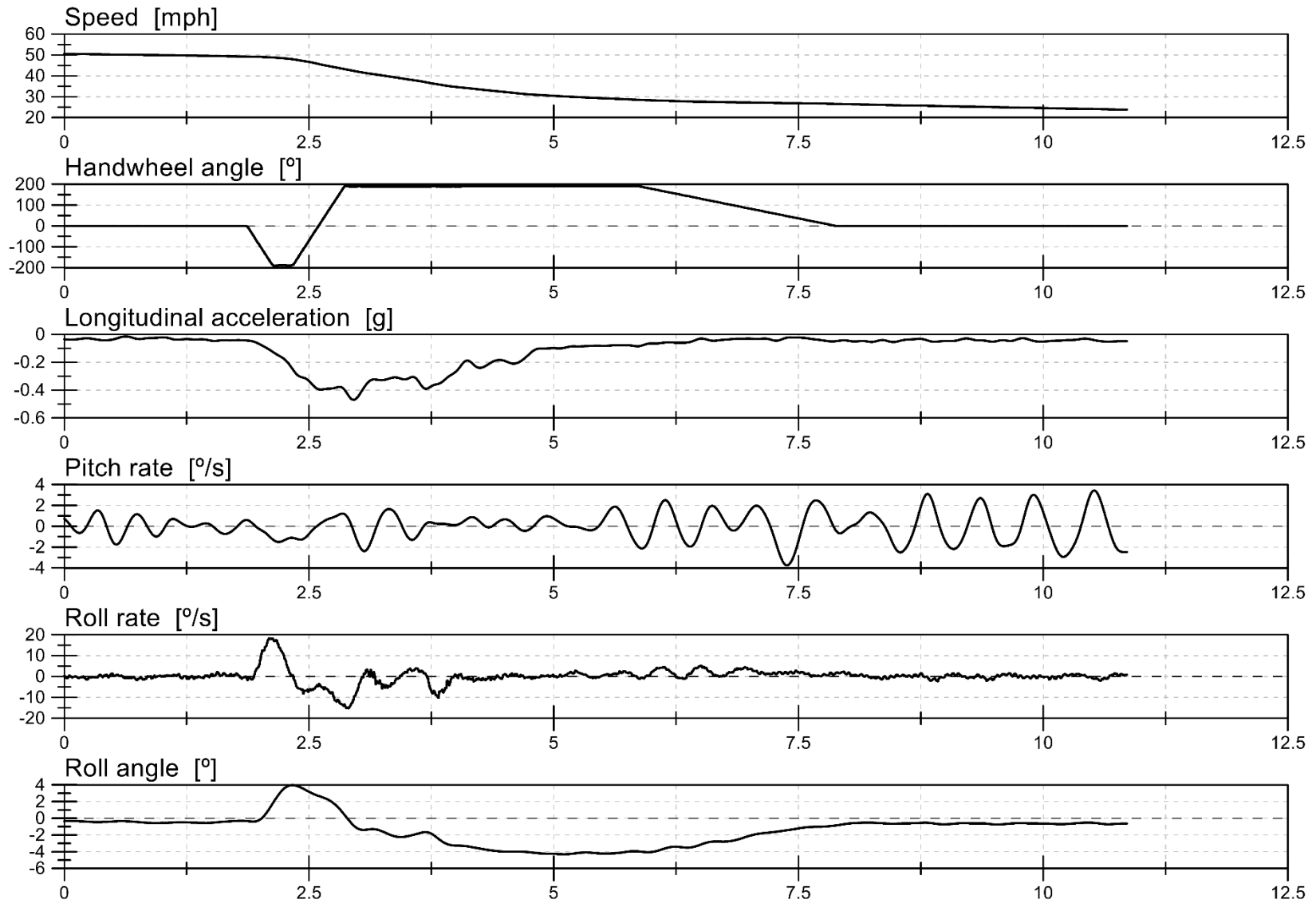


Figure D12. Pitch Rate and Longitudinal Acceleration Time History Plots for Supplemental 2 Test Series, L-R, 50 mph

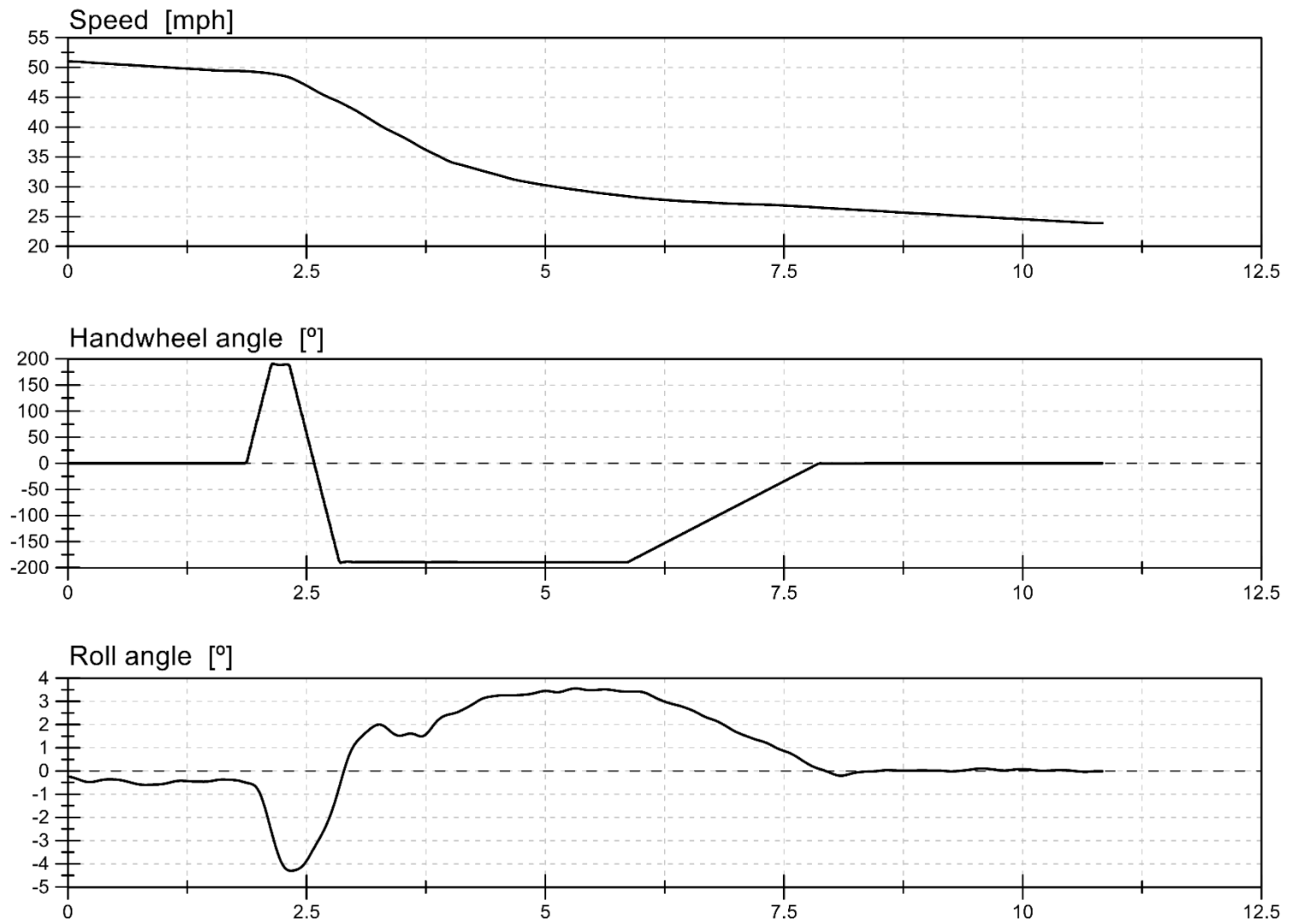


Figure D13. Vehicle Speed, Handwheel Angle, and Roll Angle Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

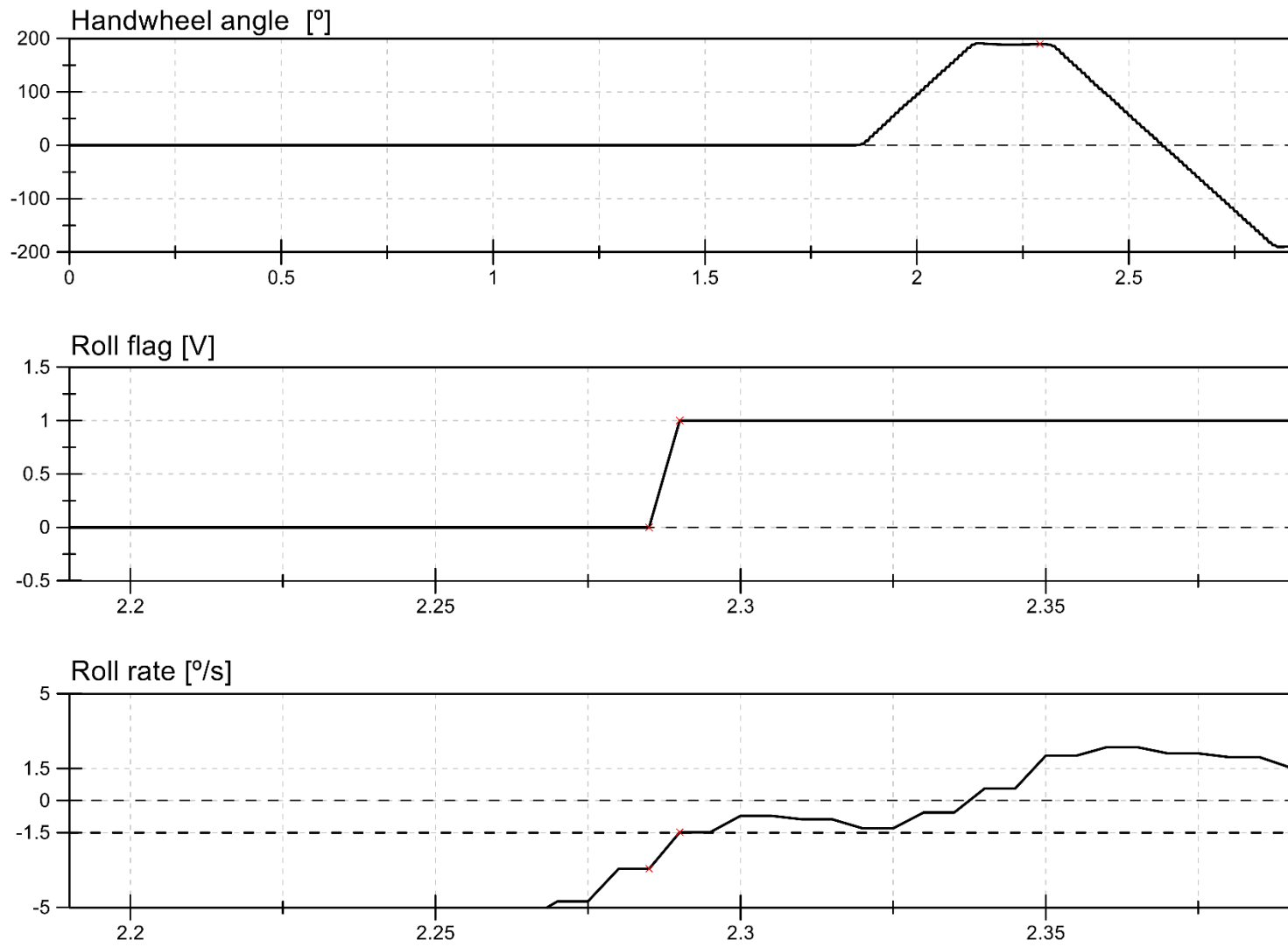


Figure D14. Steering Machine Operation Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

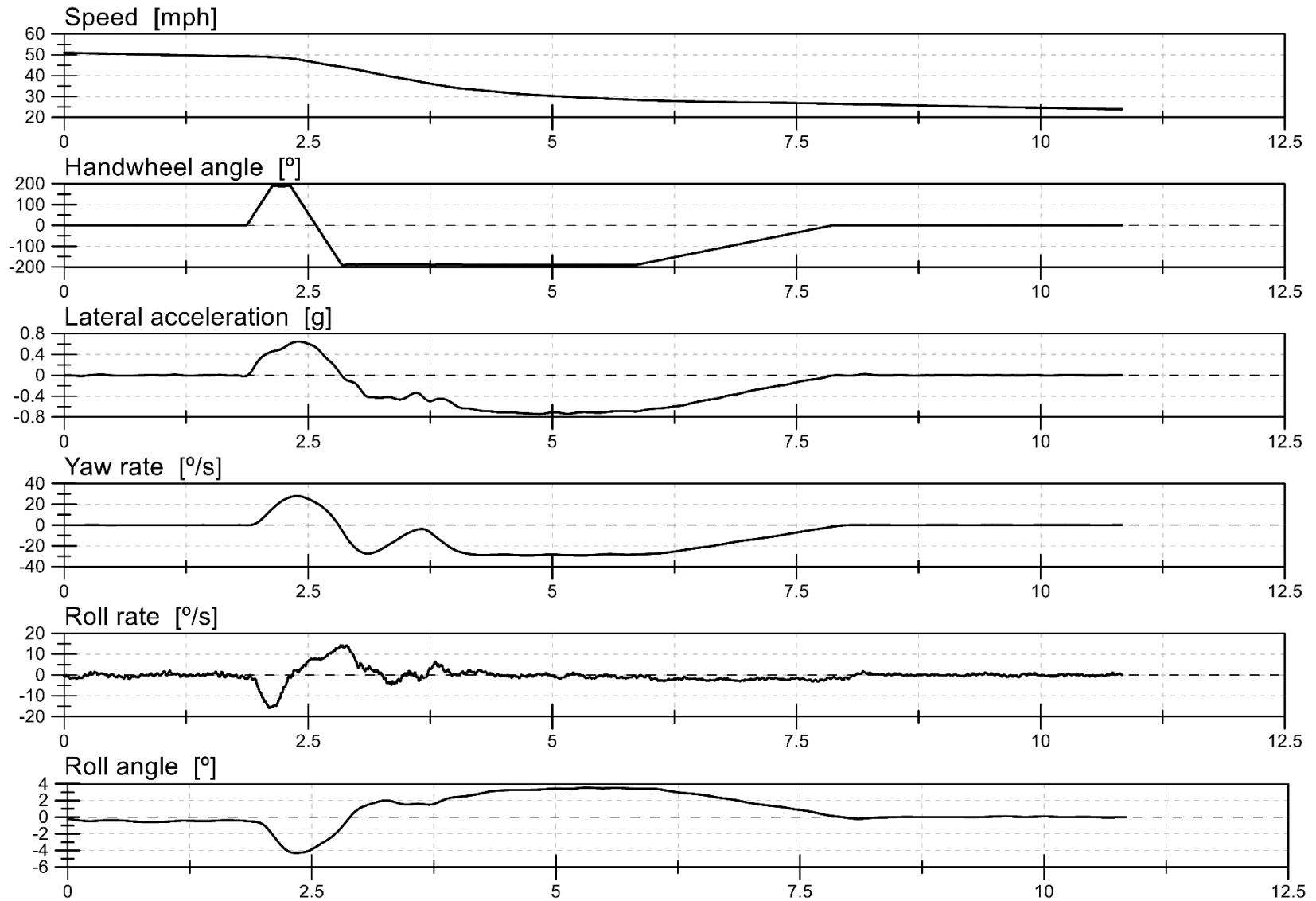


Figure D15. Yaw Rate, Roll Rate, and Lateral Acceleration Time History Plots for Supplemental 2 Test Series, R-L, 50 mph

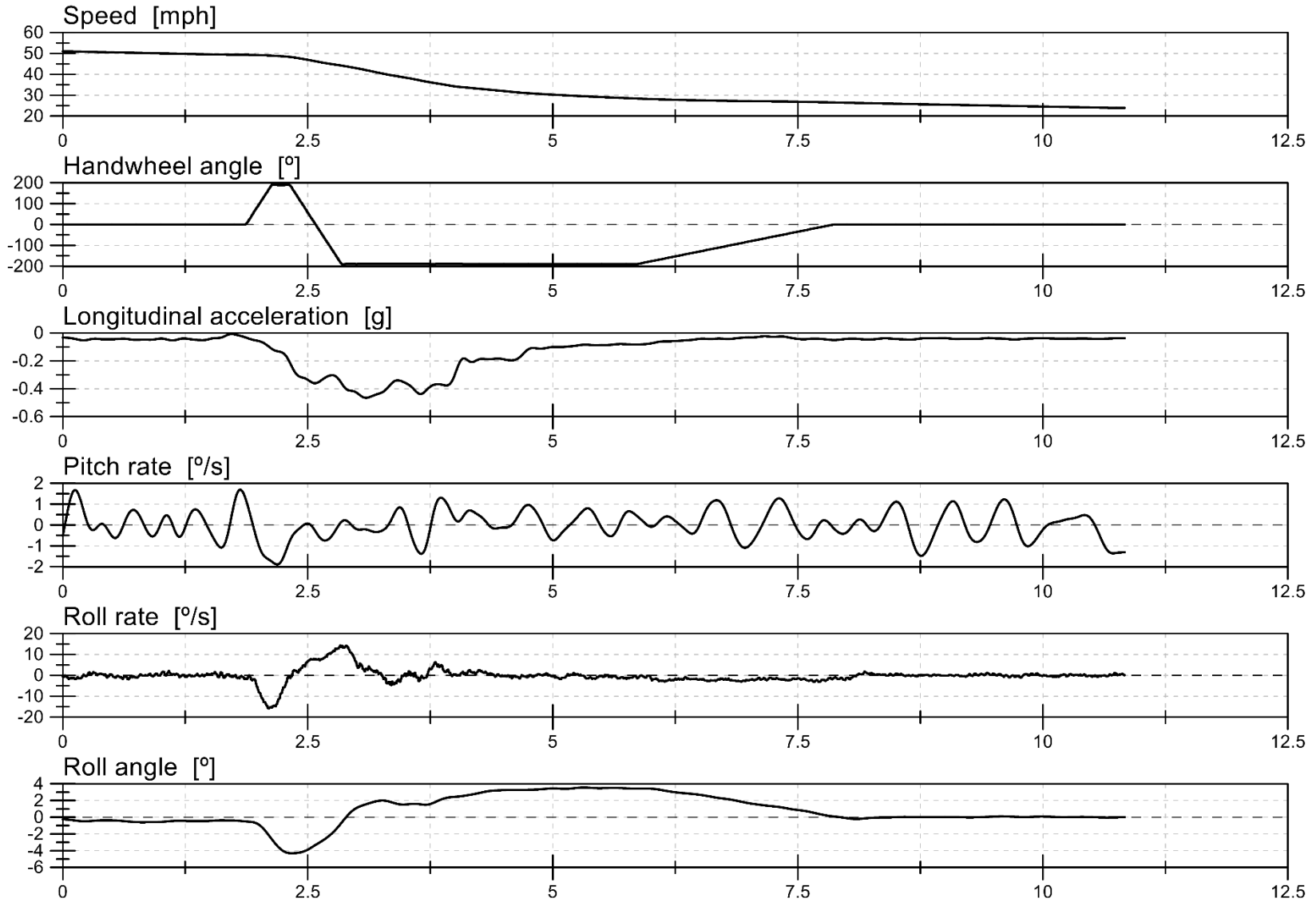


Figure D16. Pitch Rate and Longitudinal Acceleration Time History Plots for Supplemental 2 Test Series, R-L, 50 mph