OCAS-DRI-LDW-19-08
NEW CAR ASSESSMENT PROGRAM
LANE DEPARTURE WARNING CONFIRMATION TEST

2019 Toyota Highlander

DYNAMIC RESEARCH, INC.
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8 November 2019

Final Report

Prepared Under Contract No.:DTNH22-14-D-00333

U. S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Office of Crash Avoidance Standards
1200 New Jersey Avenue, SE
West Building, 4th Floor (NRM-200)
Washington, DC 20590

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16. Abstract These tests were conducted on the subject 2019 Toyota Highlander in accordance with the specifications of the Office of Crash Avoidance Standards most current Test Procedure in docket NHTSA-2006-26555-0135 to confirm the performance of a lane departure warning system. The vehicle passed the requirements of the test for all three lane marking types and for both directions.			
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Section I
INTRODUCTION

The purpose of the testing reported herein was to confirm the performance of a Lane Departure Warning (LDW) system installed on a 2019 Toyota Highlander. The LDW system for this vehilce provides both visual and auditory alerts. The vehicle passed the requirements of the test for all three lane marking types and for both directions.

The test procedure is described in detail in the National Highway Traffic Safety Administration (NHTSA) document "LANE DEPARTURE WARNING SYSTEM CONFIRMATION TEST" from February of 2013 (Docket No. NHTSA-2006-26555-0135). Its purpose is to confirm the performance of LDW systems installed on light vehicles with gross vehicle weight ratings (GVWR) of up to 10,000 lbs. Current LDW technology relies on sensors to recognize a lane delimiting edge line. As such, the test procedures described in the document rely on painted lines, taped lines or Botts Dots being present on the test course to emulate those found on public roadways. Although it is impossible to predict what technologies could be used by future LDW systems (e.g., magnetic markers, RADAR reflective striping, ultra violet paint, infra red, etc.), it is believed that minor modifications to these procedures, when deemed appropriate, could be used to accommodate the evaluation of alternative or more advanced LDW systems.

Section II
DATA SHEETS

LANE DEPARTURE WARNING

DATA SHEET 1: TEST SUMMARY

2019 Toyota Highlander

VIN: *5TDZARFH7KS0xxxx*

Test Date: *1/21/2019*

Lane Departure Warning setting: *High Sensitivity*

Test 1 – Continuous White Line	Left: *Pass*	Right: *Pass*
Test 2 – Dashed Yellow Line	Left: *Pass*	Right: *Pass*
Test 3 – Botts Dots	Left: *Pass*	Right: *Pass*

Overall: *Pass*

LANE DEPARTURE WARNING

DATA SHEET 2: GENERAL TEST AND VEHICLE PARAMETER DATA

(Page 1 of 2)

2019 Toyota Highlander

TEST VEHICLE INFORMATION

VIN: *5TDZARFH7KS0xxxx*

Body Style: *SUV* Color: *Blizzard Pearl*

Date Received: *1/2/2019* Odometer Reading: *4 mi*

Engine: *2.7 L Inline 4*

Transmission: *Automatic*

Final Drive: *FWD*

Is the vehicle equipped with:

ABS	X	Yes	____	No
Adaptive Cruise Control	X	Yes	____	No
Collision Mitigating Brake System	X	Yes	____	No

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Toyota Motor Manufacturing, Indiana, Inc.*

Date of manufacture: *10/18*

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: *245/60R18*

Rear: *245/60R18*

Recommended cold tire pressure: Front: *250 kPa (36 psi)*

Rear: *250 kPa (36 psi)*

LANE DEPARTURE WARNING

DATA SHEET 2: GENERAL TEST AND VEHICLE PARAMETER DATA

(Page 2 of 2)

2019 Toyota Highlander

TIRES

Tire manufacturer and model: *Michelin Latitude Tour*

Front tire size: *245/60R18*

Rear tire size: *245/60R18*

VEHICLE ACCEPTANCE

Verify the following before accepting the vehicle

_X_ All options listed on the "window sticker" are present on the test vehicle

_X_ Tires and wheel rims are the same as listed.

_X_ There are no dents or other interior or exterior flaws.

_X_ The vehicle has been properly prepared and is in running condition.

_X_ Verify that spare tire, jack, lug wrench, and tool kit (if applicable) is located in the vehicle cargo area.

LANE DEPARTURE WARNING

DATA SHEET 3: TEST CONDITIONS (Page 1 of 2)

2019 Toyota Highlander

GENERAL INFORMATION

Test date: *1/21/2019*

AMBIENT CONDITIONS

Air temperature: *12.2 C (54 F)*

Wind speed: *4.1 m/s (9.2 mph)*

X Wind speed ≤ 10 m/s (22 mph)

X Tests were not performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.

X Tests were conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5000 meters). The tests were not conducted with the vehicle oriented into the sun during very low sun angle conditions, where the sun is oriented 15 degrees or less from horizontal, and camera "washout" or system inoperability results.

VEHICLE PREPARATION

Verify the following:

All non consumable fluids at 100 % capacity : X

Fuel tank is full: X

Tire pressures are set to manufacturer's recommended cold tire pressure: X

Front: *250 kPa (36 psi)*

Rear: *250 kPa (36 psi)*

LANE DEPARTURE WARNING

DATA SHEET 3: TEST CONDITIONS (Page 2 of 2)

2019 Toyota Highlander

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*568.4 kg (1253 lb)*	Right Front	*532.1 kg (1173 lb)*
Left Rear	*481.3 kg (1061 lb)*	Right Rear	*450.9 kg (994 lb)*
		Total:	*2032.7 kg (4481 lb)*

LANE DEPARTURE WARNING

DATA SHEET 4: LANE DEPARTURE WARNING SYSTEM OPERATION

2019 Toyota Highlander

How is the Lane Departure Warning presented to the driver? (Check all that apply)

- **X** Warning light
- **X** Buzzer or audible alarm
- _____ Vibration
- _____ Other

Describe the method by which the driver is alerted. For example, if the warning is a light, where is it located, its color, size, words or symbol, does it flash on and off, etc. If it is a sound, describe if it is a constant beep or a repeated beep. If it is a vibration, describe where it is felt (e.g., pedals, steering wheel), the dominant frequency, (and possibly magnitude), the type of warning (light, audible, vibration, or combination), etc.

The driver is alerted by a visual warning symbol that flashes on and off, along with a repeated high pitched audible warning at approximately 2400 Hz.

Is the vehicle equipped with a switch whose purpose is to render LDW inoperable?

- **X** Yes
- _____ No

If yes, please provide a full description including the switch location and method of operation, any associated instrument panel indicator, etc.

The vehicle is equipped with a button on the steering wheel to turn the LDW alert on or off.

Is the vehicle equipped with a control whose purpose is to adjust the range setting or otherwise influence the operation of LDW?

- _____ Yes
- **X** No

If yes, please provide a full description.

Are there other driving modes or conditions that render LDW inoperable or reduce its effectiveness? **X** Yes ____ No

If yes, please provide a full description.

- *There are shadows on the road that run parallel with or cover the white (yellow) lines.*
- *The vehicle is driven in an area without white (yellow) lines such as in front of a tollgate or checkpoint, or at an intersection, etc.*
- *The white (yellow) lines are cracked. "Botts' dots", "Raised pavement marker" or stones are present.*
- *The white (yellow) lines cannot be seen or are difficult to see due to sand, etc.*
- *The vehicle is driven on a road surface that is wet due to rain puddles, etc.*
- *The traffic lines are yellow (which may be more difficult to recognize than lines that are white).*
- *The white (yellow) lines cross over a curb, etc.*
- *The vehicle is driven on a bright surface such as concrete.*
- *The vehicle is driven on a surface that is bright due to reflected light, etc.*
- *The vehicle is driven in an area where the brightness changes suddenly such as at the entrances and exits of tunnels, etc.*
- *Light from the headlights of an oncoming vehicle, the sun, etc. enters the camera.*
- *The vehicle is driven where the road diverges, merges, etc.*
- *The vehicle is driven on a slope.*
- *The vehicle is driven on a road which tilts left or right or a winding road.*
- *The vehicle is driven on an unpaved or rough road.*
- *The vehicle is driven around a sharp curve.*
- *The traffic lane is excessively narrow or wide.*

(Continued next page)

- *The vehicle is extremely tilted due to carrying heavy luggage or having improper tire pressure.*
- *The distance to the preceding vehicle is extremely short.*
- *The vehicle is moving up and down a large amount due to road conditions during driving (poor roads or road seams).*
- *The headlight lenses are dirty and emit a faint amount of light at night or the beam axis has deviated.*
- *The vehicle is struck by a crosswind.*
- *The vehicle has just changed lanes or crossed an intersection.*
- *Snow tires, etc are equipped.*

Notes:

Section III
TEST PROCEDURES

A. Test Procedure Overview

Each LDW test involved one of three lane marking types: solid white lines, dashed yellow lines, or Botts Dots. Lane departures were done both to the left and to the right, and each test condition was repeated five times, as shown in Table 1.

Table 1. LDW Test Matrix

Lane Geometry	Line Type	Departure Direction	Number of Trials
Straight	Solid	L	5
		R	5
	Dashed	L	5
		R	5
	Botts Dots	L	5
		R	5

Prior to the start of a test series involving a given lane marking type and departure direction combination, the accuracy of the distance to lane marking measurement was verified. This was accomplished by driving the vehicle to the approximate location at which the lane departure would occur and placing the tire at the lane marking edge of interest (i.e., distance to lane marking = 0). The real-time display of distance to the lane marking was then observed to verify that the measured distance was within the tolerance (5 cm). If the measured distance was found to be greater than the tolerance, the instrumentation setup was checked and corrected, if necessary. If the measured distance was found to be within the tolerance, the instrumentation setup was considered appropriate and the test series was begun.

To begin the maneuver, the vehicle was accelerated from rest to a test speed of 72.4 km/h (45 mph), while being driven in a straight line parallel to the lane marking of interest, with the centerline of the vehicle approximately 1.83 m (6.0 ft) from the lane edge (i.e., such that the vehicle would pass through the center of the start gate). The test speed was achieved at least 60 m (200 ft) before the start gate was reached. Striking any start gate cones was not permitted, and any run in which a cone was struck was considered to be invalid.

Also, during the initialization and test phases, the test driver avoided using turn signals and avoided applying any sudden acceleration, sudden steering or sudden braking, and any use of the turn signals, sudden acceleration, sudden steering or sudden braking invalidated the test trial.

Data collection began with the vehicle at least 60 m (200 ft) from the start gate, which was configured using a pair of non-reflective, low-contrast color traffic cones. A second set of cones, placed 6 m (20 ft) longitudinally before the start gate, was used to guide the driver into the start gate. The lateral width between the cone pairs was 20 cm (8 in) greater than the width of the vehicle, and the centerline of each pair was laterally offset from the lane marking by 1.8 m (6 ft).

Once the driver passed the gate, the driver manually input sufficient steering to achieve a lane departure with a target lateral velocity of 0.5 m/s with respect to the lane line. As shown in Figure 1, two additional non-reflective cones were used to guide the driver in making this steering maneuver. Throughout the maneuver, the driver modulated the throttle or used cruise control, as appropriate, such that vehicle speed remained at constant speed. The test was considered complete when the vehicle crossed at least 1 m (3.3 ft) over the lane edge boundary.

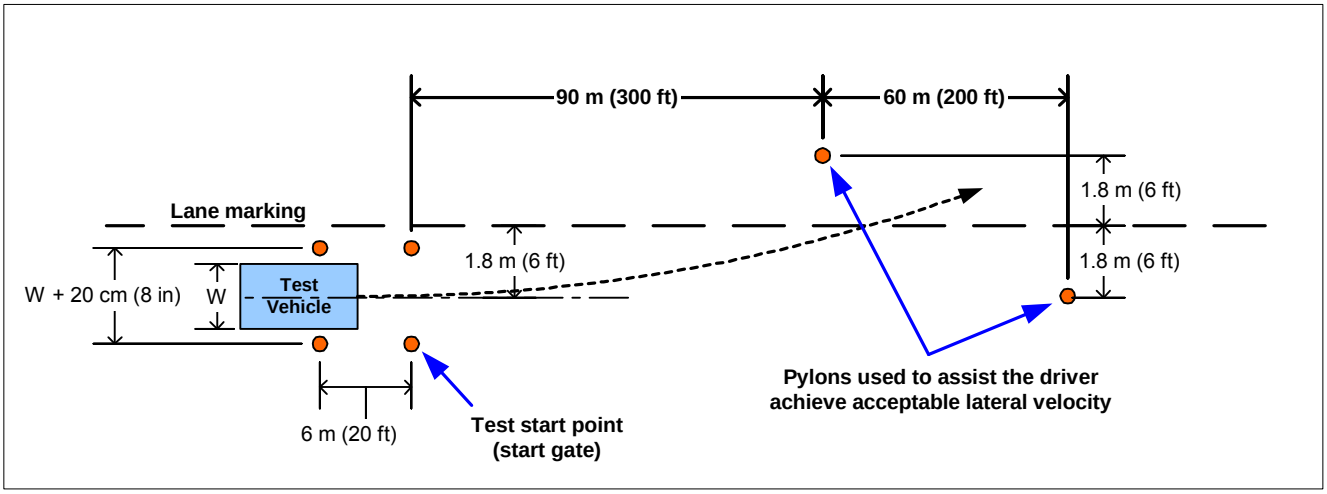


Figure 1. Position of Cones Used to Assist Driver

Data collected included vehicle speed, position, and yaw rate. In addition to cone strikes, vehicle speed and yaw rate data were used to identify invalid runs as described in Section C below. Data from trials where speed or yaw rate were outside of the performance specification were not considered valid.

B. Lane Delineation Markings

The Office of Crash Avoidance Standards' Test Procedure for the confirmation of a lane departure warning system contains a requirement that all lane markings meet United States Department of Transportation (USDOT) specifications as described in the Manual on Uniform Traffic Control Devices (MUTCD) and be considered in "very good condition".

1. Lane Marker Width

The width of the edge line marker was 10 to 15 cm (4 to 6 in). This is considered to be a normal width for longitudinal pavement markings under Section 3A.05 of the MUTCD.

2. Line Marking Color and Reflectivity

Lane marker color and reflectivity met all applicable standards. These standards include those from the International Commission of Illumination (CIE) for color and the American Society for Testing and Materials (ASTM) on lane marker reflectance.

3. Line Styles

The tests described in this document required the use of three lane line configurations: continuous solid white, discontinuous dashed yellow, and discontinuous with raised pavement markers.

- Continuous White Line
  A continuous white line is defined as a white line that runs for the entire length of the test course.

- Dashed Yellow Line
  As stated in the MUTCD, and as shown in Figure 2, a discontinuous dashed yellow line is defined as by a series of 3 m (10 ft) broken (dashed) yellow line segments, spaced 9.1 m (30 ft) apart.

- Raised Pavement Marker Line (Botts Dots)
  California Standard Plans indicates raised pavement markers are commonly used in lieu of painted strips for marking roads in California. Other states, mainly in the southern part of the United States, rely on them as well. These markers may be white or yellow, depending on the specific application, following the same basic colors of their analogous white and yellow painted lines. Following the California 2006 Standard Plans, three types of raised pavement markings are

used to form roadway lines. It is believed that these types of roadway markings are the hardest for an LDW sensor system to process. Type A and Type AY are non-reflective circular domes that are approximately 10 cm (4 in) in diameter and approximately 1.8 cm (0.7 in) high. Type C and D are square markings that are retro reflective in two directions measuring approximately 10 x 10 x 5 cm (4 x 4 x 0.5 in), and Type G and H that are the same as C and D only retro reflective in a single direction.

For the tests described in this document, raised pavement markers were set up following California Standard Plan A20A, Detail 4, as shown in Figure 3. Note that in this figure, the squares are Type D yellow reflectors and the circles are yellow Type AY discs.

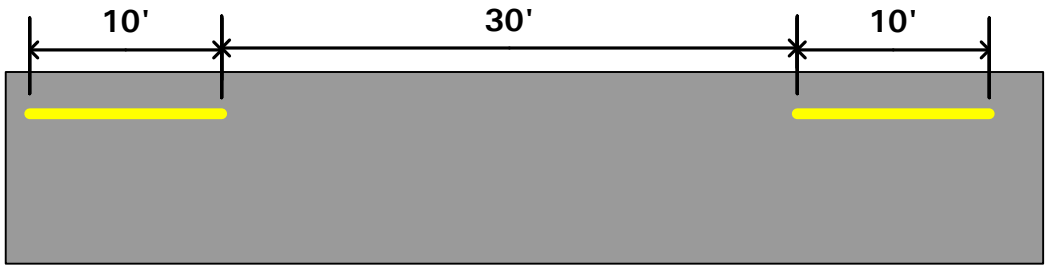


Figure 2. MUTCD Discontinuous Dashed Line Specifications

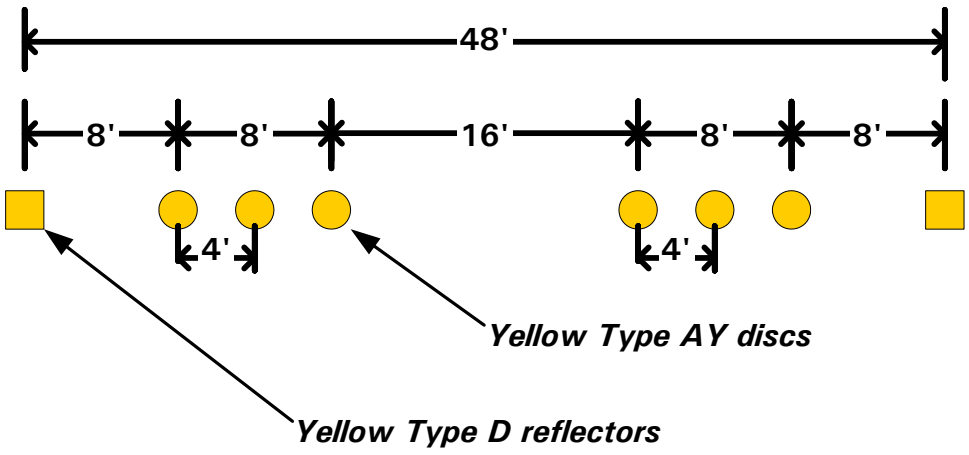


Figure 3. California Standard Plan A20A, Detail 4

C. Test Validity

1. Speed

All LDW tests were conducted at 72.4 km/h (45 mph). Test speed was monitored and a test was considered valid if the test speed remained within ± 2 km/h (± 1.2 mph) of the 72.4 km/h (45 mph) target speed. It was required that the speed must remain within this window from the start of the test until any part of the vehicle crossed a lane line by 1 m (3.3 ft) or more.

2. Lateral Velocity

All tests were conducted with a lateral velocity of 0.1 to 0.6 m/s (0.3 to 2.0 ft/s), measured with respect to the lane line at the time of the alert. To assist the test driver in being able to efficiently establish the target lateral velocity, cones were positioned in the manner shown in Figure 1.

3. Yaw Rate

It was required that the magnitude of the vehicle's yaw rate could not exceed 1.0 deg/sec at any time during lane departure maneuver, from the time the vehicle passes through the start gate to the instant the vehicle has crossed a lane line by 1 m (3.3 ft).

D. Pass/Fail Criteria

The measured test data were used to determine the pass/fail outcome for each trial. The outcome was based on whether the LDW produced an appropriate alert during the maneuver. In the context of this test procedure, a lane departure is said to occur when any part of the two-dimensional polygon used to represent the test vehicle breaches the inboard lane line edge (i.e., the edge of the line closed to the vehicle before the departure occurs). In the case of tests performed in this procedure, the front corner of the polygon, defined as the intersection of center of the front wheels (longitudinally) with the outboard edge of the front tire (laterally) , crossed the line edge first. So, for example, if the vehicle departed its lane to the left, the left front corner of the polygon would first breach the lane line edge.

For an individual trial to be considered a "pass":

- Test speed, lateral velocity, and yaw rate validity conditions must be satisfied.
- The LDW alert must <u>not</u> occur when the lateral position of the vehicle

is greater than 0.75 m (2.5 ft) from the lane line edge (i.e., prior to the lane departure).

- The LDW alert must occur before the lane departure exceeds 0.3 m (1.0 ft).

For an overall "Pass" the LDW system must satisfy the pass criteria for 3 of 5 individual trials for each combination of departure direction and lane line type (60 percent), and pass 20 of the 30 trials overall (66 percent).

E. Instrumentation

Table 2 lists the sensors, signal conditioning, and data acquisition equipment used for these tests.

Table 2. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	0.5 psi 3.45 kPa	Ashcroft, D1005PS	17042707002	By: DRI Date: 6/21/2018 Due: 6/21/2019
Platform Scales	Vehicle Total, Wheel, and Axle Load	8000 lb 35.6 kN	±1.0% of applied load	Intercomp, SWII	1110M206352	By: DRI Date: 1/3/2019 Due: 1/3/2020
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	NA
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots Accel: ±100 m/s^2 Angular Rate: ±100 deg/s Angular Disp: ±180 deg	Position: ±2 cm Velocity: 0.05 km/h Accel: ≤ 0.01% of full range Angular Rate: ≤ 0.01% of full range Roll/Pitch Angle: ±0.03 deg Heading Angle: ±0.1 deg	Oxford Technical Solutions (OXTS), Inertial+	2182	By: Oxford Technical Solutions1 Date: 10/16/2017 Due: 10/16/2019
Real-Time Calculation of Position and Velocity Relative to Lane Markings	Distance and velocity to lane markings	Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	NA

[1] Oxford Technical Solutions recommends calibration every two years.

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	NA	NA
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	NA	NA
Coordinate Measurement Machine	Inertial Sensing System Coordinates	0-8 ft 0-2.4 m	±.0020 in. ±.051 mm (Single point articulation accuracy)	Faro Arm, Fusion	UO8-05-08-06636	By: DRI Date: 1/2/2019 Due: 1/2/2020

Type	Description	Mfr, Model	Serial Number
Data Acquisition System	Data acquisition is achieved using a dSPACE MicroAutoBox II 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 MicroAutoBox. The Oxford IMUs are calibrated per the manufacturer's recommended schedule (listed above).	D-Space Micro-Autobox II 1401/1513	
		Base Board	549068
		I/O Board	588523

For systems that implement audible or haptic alerts, part of the pre-test instrumentation verification process is to determine the tonal frequency of the audible warning or the vibration frequency of the tactile warning through use of the PSD (Power Spectral Density) function in Matlab. This is accomplished in order to identify the center frequency around which a band-pass filter is applied to subsequent audible or tactile warning data so that the beginning of such warnings can be programmatically determined. The bandpass filter used for these warning signal types is a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 3.

Table 3. Audible and Tactile Warning Filter Parameters

Warning Type	Filter Order	Peak-to-Peak Ripple	Minimum Stop Band Attenuation	Pass-Band Frequency Range
Audible	5^{th}	3 dB	60 dB	Identified Center Frequency ± 5%
Tactile	5^{th}	3 dB	60 dB	Identified Center Frequency ± 20%

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

Figure A3. Window Sticker (Monroney Label)

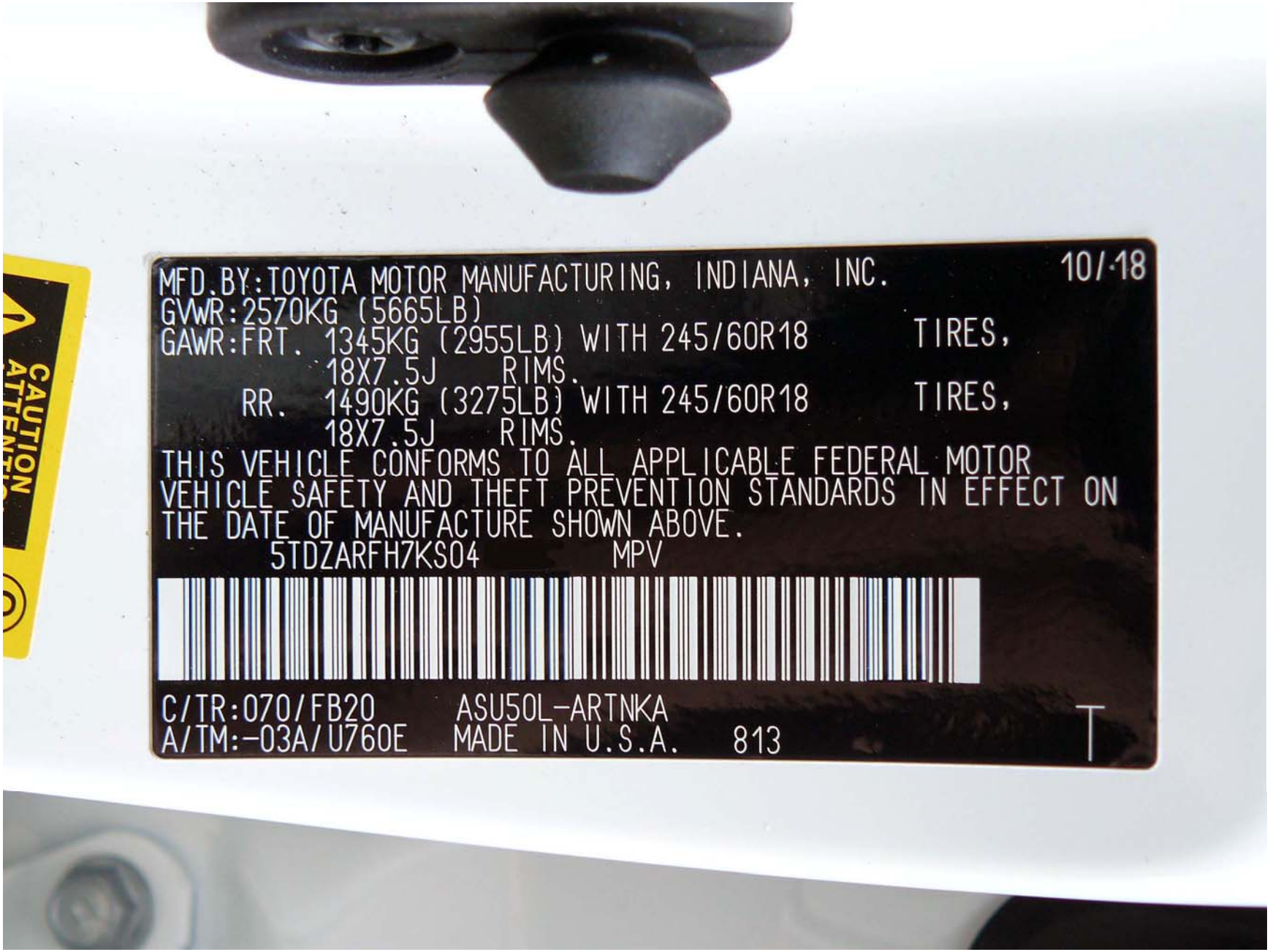


Figure A4. Vehicle Certification Label

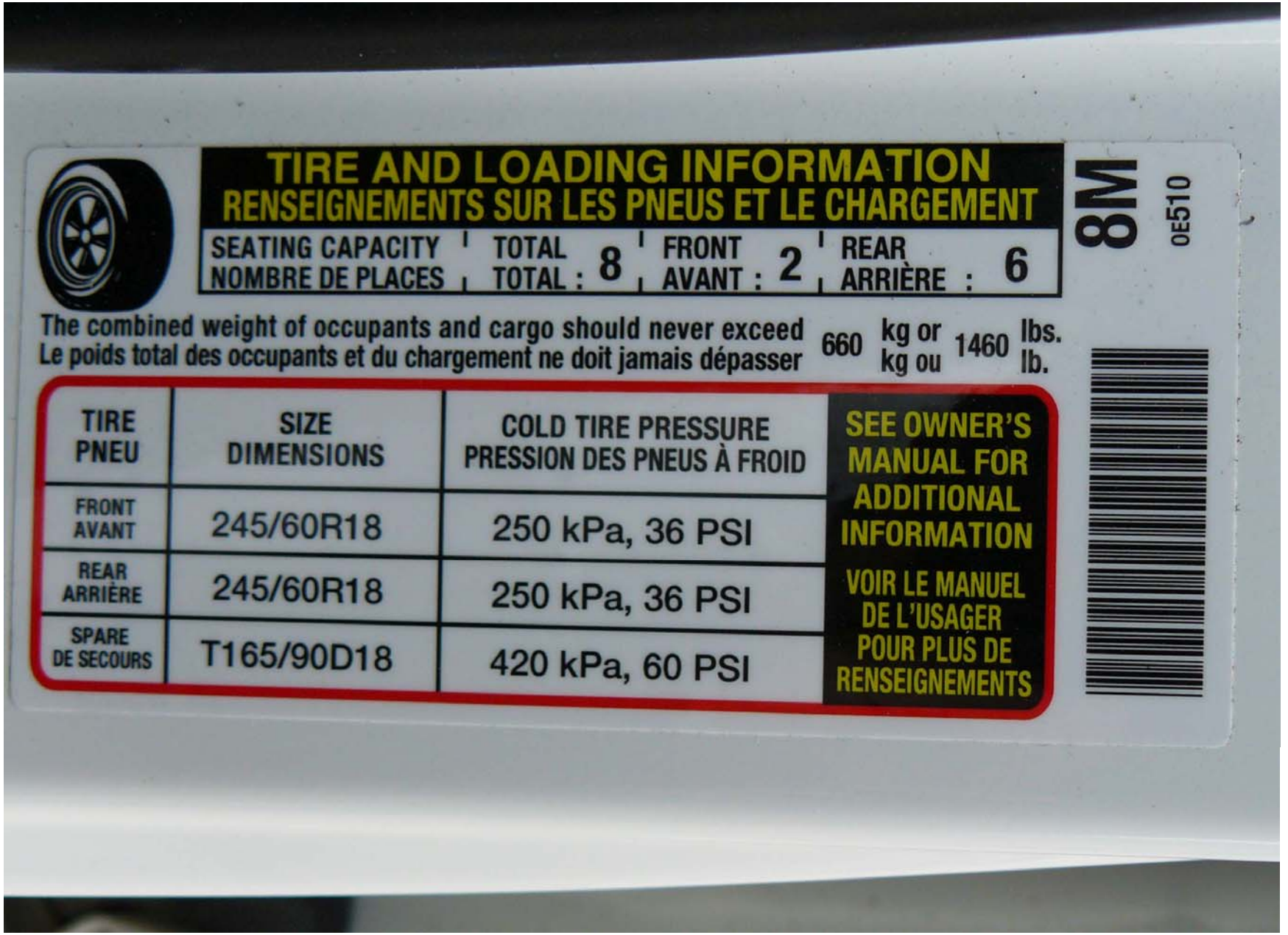


Figure A5. Tire Placard

Figure A6. DGPS, Inertial Measurement Unit and MicroAutoBox Installed in Subject Vehicle

Figure A7. Computer Installed in Test Vehicle

Figure A8. Sensor for Detecting Auditory Alerts

Figure A9. Sensor for Detecting Visual Alerts

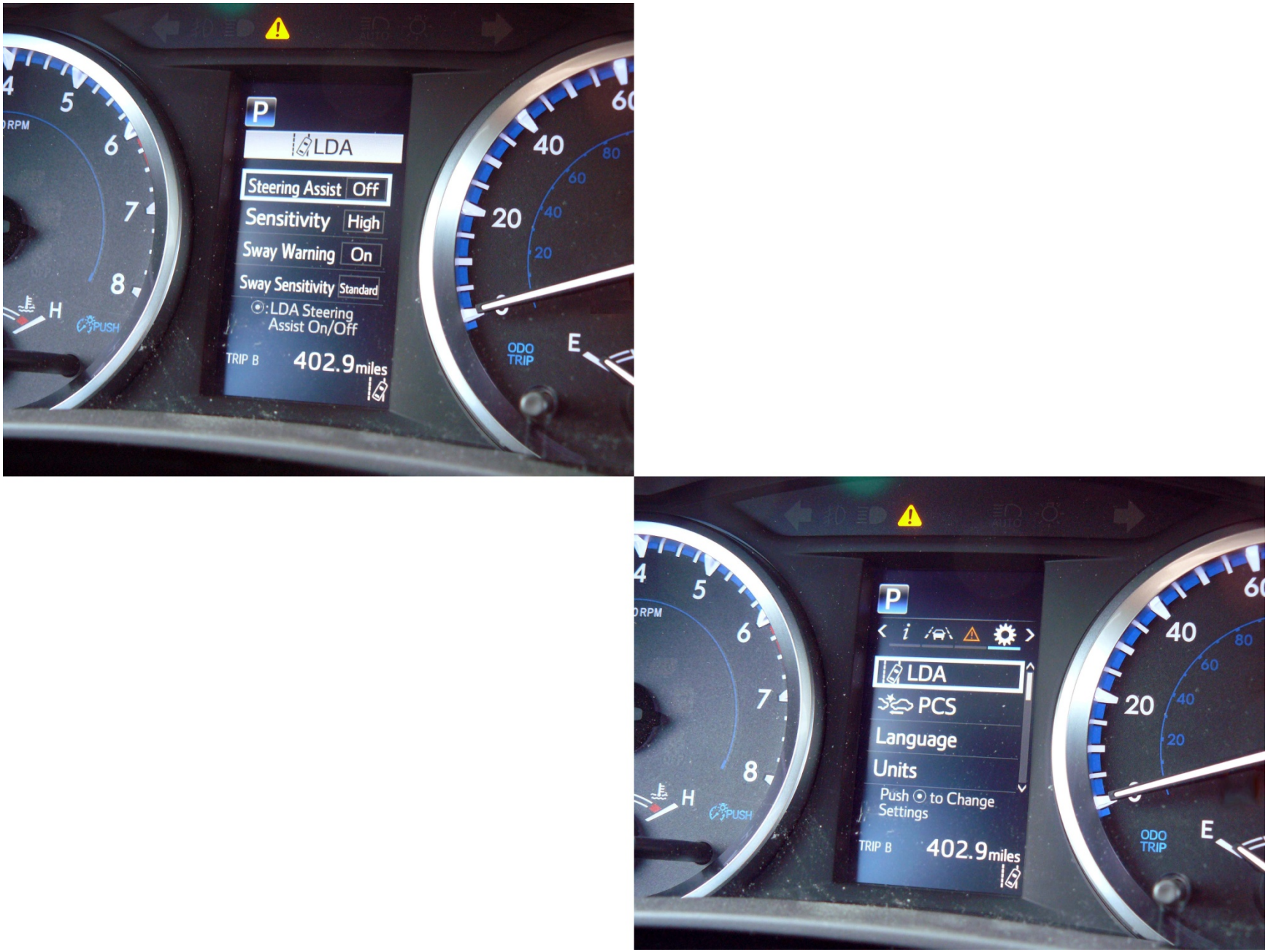


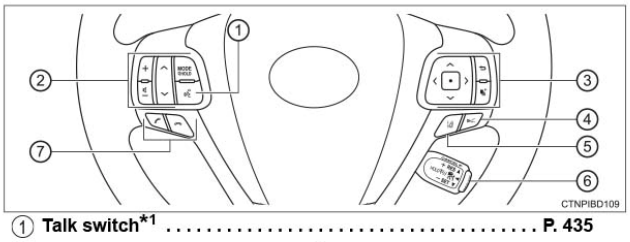
Figure A10. LDA Settings Menu Options

Figure A11. LDW On/Off Switch

Figure A12. LDW Instrument Panel Visual Display

APPENDIX B

Excerpts from Owner's Manual



Warning lights

Warning lights inform the driver of malfunctions in the indicated vehicle's systems.

*1 BRAKE (U.S.A.)	Brake system warning light (→P. 583)	(Amber)	LDA (Lane Departure Alert with steering control) indicator (→P. 585)
*1 (Canada)	Brake system warning light (→P. 583)	*1	Slip indicator (→P. 584)
*1 CHECK (U.S.A.)	Malfunction indicator lamp (→P. 583)		Low fuel level warning light (→P. 584)
*1 (Canada)	Malfunction indicator lamp (→P. 583)		Driver's and front passenger's seat belt reminder light (→P. 584)
*1	SRS warning light (→P. 583)	*4 REAR	Rear seat seat belt reminder lights (→P. 584)
*1 ABS (U.S.A.)	ABS warning light (→P. 583)	*2, 5 OFF	Stop & Start cancel indicator (→P. 585)
*1 (Canada)	ABS warning light (→P. 583)	*1	Master warning light (→P. 586)
*1	Electric power steering system warning light (→P. 584)	*1	Tire pressure warning light (→P. 586)
*1, 3 OFF	PCS (Pre-Collision System) warning light (→P. 585)	*1 PARK (U.S.A)	Parking brake warning light (→P. 584)

Indicators

The indicators inform the driver of the operating state of the vehicle's various systems.


Turn signal indicator (→P. 239)


(U.S.A.)
Headlight indicator (→P. 241)


(Canada)
Tail light indicator (→P. 241)


Headlight high beam indicator (→P. 242)

Automatic High Beam indicator (→P. 245)

*2

Front fog light indicator (→P. 249)


Dynamic radar cruise control (constant speed control mode) indicator (→P. 300)


Dynamic radar cruise control (vehicle-to-vehicle distance control mode) indicator (→P. 296)

Dynamic radar cruise control "SET" indicator (→P. 296, 300)

*1, 5


PCS (Pre-Collision System) warning light (→P. 267)


LDA (Lane Departure Alert with steering control) indicator (→P. 281)

*2, 3

Intuitive parking assist indicator

*2


BSM (Blind Spot Monitor) indicator(→P. 323)

*2, 6, 7

BSM (Blind Spot Monitor) outside rear view mirror indicators (→P. 323)

*1, 4

Slip indicator (→P. 340)

*1


VSC OFF indicator (→P. 340)

*1, 2

All-wheel drive lock indicator (→P. 337)

*2

Downhill assist control system indicator (→P. 344)

*8

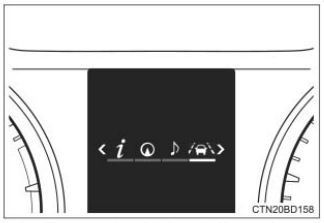
Security indicator (→P. 86, 88)

*1, 9


Eco Driving Indicator Light (→P. 108)

Multi-information display

Display contents



Drive information

Select to display various drive data. (→P. 103)

Navigation system-linked display (if equipped)

Select to display the following navigation system-linked information.

- Route guidance
- Compass display (north-up display/heading-up display)

Audio system-linked display (if equipped)

Select to enable selection of an audio source or track on the meter using the meter control switches.

Driving assist system information

Select to display the operational status of the following systems:

- Dynamic radar cruise control (→P. 291)
- LDA (Lane Departure Alert with steering control) (→P. 281)

Stop & Start system information (if equipped)

Select to display the operational status of the Stop & Start system. (→P. 304)

Warning message display

Select to display warning messages and measures to be taken if a malfunction is detected. (→P. 593)

Settings display

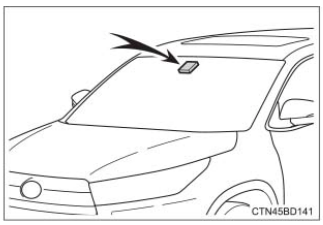
Select to change the meter display settings. (→P. 105)

LDA (Lane Departure Alert with steering control)

Summary of functions

When driving on highways and freeways with white (yellow) lines, this function alerts the driver when the vehicle might depart from its lane and provides assistance by operating the steering wheel to keep the vehicle in its lane.

The LDA system recognizes visible white (yellow) lines with the camera sensor on the upper portion of the windshield.

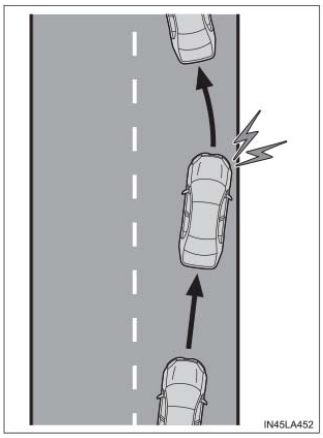


Functions included in LDA system

◆ Lane departure alert function

When the system determines that the vehicle might depart from its lane, a warning is displayed on the multi-information display and the warning buzzer sounds to alert the driver.

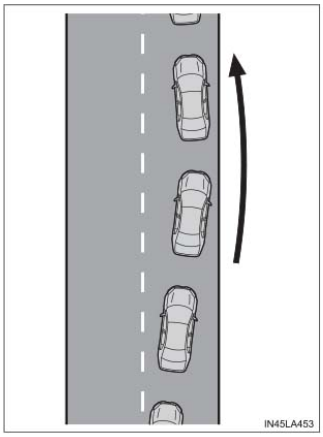
When the warning buzzer sounds, check the surrounding road situation and carefully operate the steering wheel to move the vehicle back to the center of the lane.



◆ Steering control function

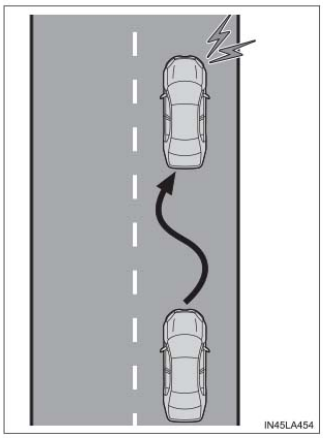
When the system determines that the vehicle might depart from its lane, the system provides assistance as necessary by operating the steering wheel in small amounts for a short period of time to keep the vehicle in its lane.

If the system detects that the steering wheel has not been operated for a fixed amount of time or the steering wheel is not being firmly gripped, a warning is displayed on the multi-information display and the warning buzzer sounds.



◆ Vehicle sway warning function

When the vehicle is swaying or appears as if it may depart from its lane multiple times, the warning buzzer sounds and a message is displayed on the multi-information display to alert the driver.



⚠ WARNING

■ **Before using LDA system**

Do not rely solely upon the LDA system. The LDA system does not automatically drive the vehicle or reduce the amount of attention that must be paid to the area in front of the vehicle. The driver must always assume full responsibility for driving safely by paying careful attention to the surrounding conditions and operating the steering wheel to correct the path of the vehicle. Also, the driver must take adequate breaks when fatigued, such as from driving for a long period of time.
Failure to perform appropriate driving operations and pay careful attention may lead to an accident, resulting in death or serious injury.

■ **To avoid operating LDA system by mistake**

When not using the LDA system, use the LDA switch to turn the system off.

■ **Situations unsuitable for LDA system**

Do not use the LDA system in the following situations.
The system may not operate properly and lead to an accident, resulting in death or serious injury.

- A spare tire, tire chains, etc., are equipped.
- When the tires have been excessively worn, or when the tire inflation pressure is low.
- Tires which differ by structure, manufacturer, brand or tread pattern are used.
- Objects or patterns that could be mistaken for white (yellow) lines are present on the side of the road (guardrails, curbs, reflective poles, etc.).
- Vehicle is driven on a snow-covered road.
- White (yellow) lines are difficult to see due to rain, snow, fog, dust, etc.
- Asphalt repair marks, white (yellow) line marks, etc. are present due to road repair.
- Vehicle is driven in a temporary lane or restricted lane due to construction work.
- Vehicle is driven on a road surface which is slippery due to rainy weather, fallen snow, freezing, etc.
- Vehicle is driven in traffic lanes other than on highways and freeways.
- Vehicle is driven in a construction zone.
- Vehicle is towing a trailer or another vehicle.

⚠ WARNING

■ **Preventing LDA system malfunctions and operations performed by mistake**

- Do not modify the headlights or place stickers, etc. on the surface of the lights.
- Do not modify the suspension etc. If the suspension etc. needs to be replaced, contact your Toyota dealer.
- Do not install or place anything on the hood or grille. Also, do not install a grille guard (bull bars, kangaroo bar, etc.).
- If your windshield needs repairs, contact your Toyota dealer.

Turning LDA system on

Press the LDA switch to turn the LDA system on.

The LDA indicator illuminates and a message is displayed on the multi-information display.

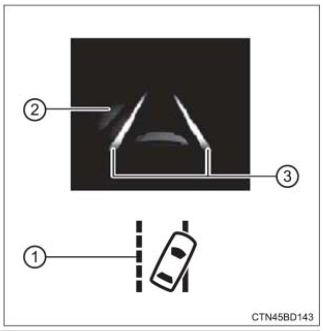
Press the LDA switch again to turn the LDA system off.

When the LDA system is turned on or off, operation of the LDA system continues in the same condition the next time the engine is started.

Indications on the multi-information display

① LDA indicator

The illumination condition of the indicator informs the driver of the system operation status.



LDA indicator	System operation status
Illuminated in white	LDA system is operating.
Illuminated in green	Steering wheel assistance of the steering control function is operating.
Flashing in amber	Lane departure alert function is operating.

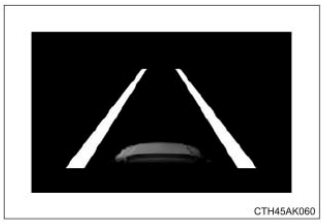
② Operation display of steering wheel operation support

Indicates that steering wheel assistance of the steering control function is operating.

③ Lane departure alert function display

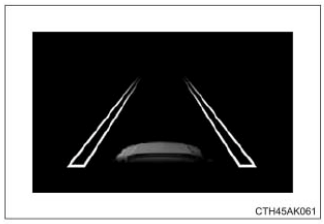
Displayed when the multi-information display is switched to the driving assist system information screen.

▶ Inside of displayed white lines is white



Indicates that the system is recognizing white (yellow) lines. When the vehicle departs from its lane, the white line displayed on the side the vehicle departs from flashes amber.

▶ Inside of displayed white lines is black



Indicates that the system is not able to recognize white (yellow) lines or is temporarily canceled.

■ **Operation conditions of each function**

● Lane departure alert function

This function operates when all of the following conditions are met.

- LDA is turned on.
- Vehicle speed is approximately 32 mph (50 km/h) or more.
- System recognizes white (yellow) lines.
- Width of traffic lane is approximately 9.8 ft. (3 m) or more.
- Turn signal lever is not operated.
- Vehicle is driven on a straight road or around a gentle curve with a radius of more than approximately 492 ft. (150 m).
- No system malfunctions are detected. (→P. 583)

● Steering control function

This function operates when all of the following conditions are met in addition to the operation conditions for the lane departure alert function.

- Setting for "Steering Assist" on ⚙ of the multi-information display is set to "On". (→P. 105)
- Vehicle is not accelerated or decelerated by a certain amount or more.
- Steering wheel is not operated with a steering force level suitable for changing lanes.
- ABS, VSC, TRAC and PCS (Pre-Collision System) are not operating.
- TRAC or VSC is not turned off.

● Vehicle sway warning function

This function operates when all of the following conditions are met.

- Setting for "Sway Warning" on ⚙ of the multi-information display is set to "On".(→P. 105)
- Vehicle speed is approximately 32 mph (50 km/h) or more.
- Width of traffic lane is approximately 9.8 ft. (3 m) or more.
- No system malfunctions are detected. (→P. 583)

■ **Temporary cancellation of functions**

When the operation conditions are no longer met, a function may be temporarily canceled. However, when the operation conditions are met again, operation of the function is automatically restored. (→P. 287)

■ **Steering control function**

Depending on the vehicle speed, lane departure situation, road conditions, etc., the driver may not feel the function is operating or the function may not operate at all.

■ **Lane departure alert function**

The warning buzzer may be difficult to hear due to external noise, audio playback, etc.

■ **Hands off steering wheel warning**

When the system determines that the driver has removed their hands from the steering wheel while the steering control function is operating, a warning message urging the driver to hold the steering wheel and the symbol shown in the illustration are displayed on the multi-information display.


CTH45BT187

If the driver continues to keep their hands off of the steering wheel, a buzzer sounds and a warning message and the symbol shown in the illustration are displayed on the multi-information display. This warning also operates in the same way when the driver continuously operates the steering wheel only a small amount. Always keep your hands on the steering wheel when using this system, regardless of warnings.
Depending on the vehicle and road conditions, the warning may not operate.

■ **Vehicle sway warning function**

When the system determines that the vehicle is swaying while the vehicle sway warning function is operating, a buzzer sounds and a warning message urging the driver to rest and the symbol shown in the illustration are simultaneously displayed on the multi-information display.
Depending on the vehicle and road conditions, the warning may not operate.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■ **White (yellow) lines are only on one side of road**

The LDA system will not operate for the side on which white (yellow) lines could not be recognized.

■ **Conditions in which functions may not operate properly**

In the following situations, the camera sensor may not detect white (yellow) lines and various functions may not operate normally.

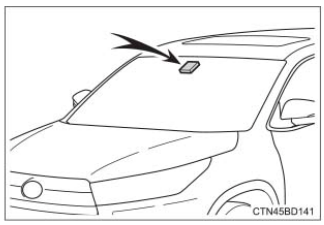
- There are shadows on the road that run parallel with, or cover, the white (yellow) lines.
- The vehicle is driven in an area without white (yellow) lines, such as in front of a tollgate or checkpoint, or at an intersection, etc.
- The white (yellow) lines are cracked, “Botts’ dots”, “Raised pavement marker” or stones are present.
- The white (yellow) lines cannot be seen or are difficult to see due to sand, etc.
- The vehicle is driven on a road surface that is wet due to rain, puddles, etc.
- The traffic lines are yellow (which may be more difficult to recognize than lines that are white).
- The white (yellow) lines cross over a curb, etc.
- The vehicle is driven on a bright surface, such as concrete.
- The vehicle is driven on a surface that is bright due to reflected light, etc.
- The vehicle is driven in an area where the brightness changes suddenly, such as at the entrances and exits of tunnels, etc.
- Light from the headlights of an oncoming vehicle, the sun, etc. enters the camera.
- The vehicle is driven where the road diverges, merges, etc.
- The vehicle is driven on a slope.
- The vehicle is driven on a road which tilts left or right, or a winding road.
- The vehicle is driven on an unpaved or rough road.
- The vehicle is driven around a sharp curve.
- The traffic lane is excessively narrow or wide.
- The vehicle is extremely tilted due to carrying heavy luggage or having improper tire pressure.
- The distance to the preceding vehicle is extremely short.
- The vehicle is moving up and down a large amount due to road conditions during driving (poor roads or road seams).
- The headlight lenses are dirty and emit a faint amount of light at night, or the beam axis has deviated.
- The vehicle is struck by a crosswind.
- The vehicle has just changed lanes or crossed an intersection.
- Snow tires, etc. are equipped.

LDA (Lane Departure Alert with steering control)

Summary of functions

When driving on highways and freeways with white (yellow) lines, this function alerts the driver when the vehicle might depart from its lane and provides assistance by operating the steering wheel to keep the vehicle in its lane.

The LDA system recognizes visible white (yellow) lines with the camera sensor on the upper portion of the windshield.

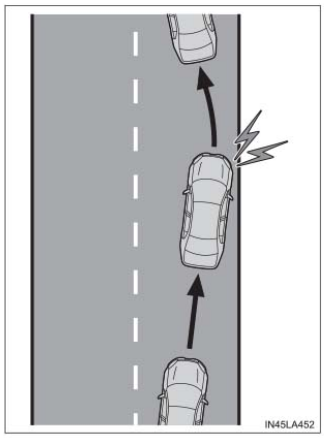


Functions included in LDA system

◆ Lane departure alert function

When the system determines that the vehicle might depart from its lane, a warning is displayed on the multi-information display and the warning buzzer sounds to alert the driver.

When the warning buzzer sounds, check the surrounding road situation and carefully operate the steering wheel to move the vehicle back to the center of the lane.



WARNING

■ **Driving with snow tires**

Observe the following precautions to reduce the risk of accidents.
Failure to do so may result in a loss of vehicle control and cause death or serious injury.

- Use tires of the size specified.
- Maintain the recommended level of air pressure.
- Do not drive in excess of 75 mph (120 km/h), regardless of the type of snow tires being used.
- Use snow tires on all, not just some wheels.

■ **Driving with tire chains**

Observe the following precautions to reduce the risk of accidents.
Failure to do so may result in the vehicle being unable to be driven safely, and may cause death or serious injury.

- Do not drive in excess of the speed limit specified for the tire chains being used, or 30 mph (50 km/h), whichever is lower.
- Avoid driving on bumpy road surfaces or over potholes.
- Avoid sudden acceleration, abrupt steering, sudden braking and shifting operations that cause sudden engine braking.
- Slow down sufficiently before entering a curve to ensure that vehicle control is maintained.
- Do not use LDA (Lane Departure Alert with steering control) system.

NOTICE

■ **Repairing or replacing snow tires**

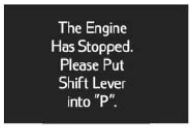
Request repairs or replacement of snow tires from Toyota dealers or legitimate tire retailers.
This is because the removal and attachment of snow tires affects the operation of the tire pressure warning valves and transmitters.

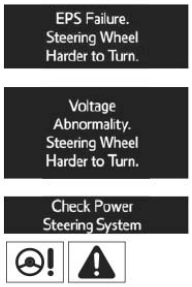
■ **Fitting tire chains**

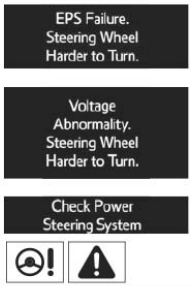
The tire pressure warning valves and transmitters may not function correctly when tire chains are fitted.

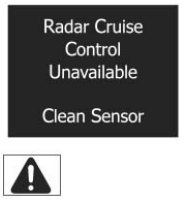
Warning light	Warning light/Details/Actions
 (Flashes or illuminates)	**PCS (Pre-Collision System) warning light** Indicates a malfunction in the PCS (Pre-Collision System) or that the system is temporarily unavailable due to the vehicle being extremely hot/cold, or dirt around a front sensor, etc. (→P. 279, 593) → **Follow the instructions displayed on the multi-information display. (→P. 279, 593)** If the PCS (Pre-Collision System) or VSC (Vehicle Stability Control) system is disabled, the PCS warning light will illuminate. → **P. 280**
 (Amber)	**LDA (Lane Departure Alert with steering control) indicator** The indicator comes on and a warning message is displayed to indicate that the LDA (Lane Departure Alert with steering control) system is not available temporarily or has detected a malfunction. → **P. 594**
 (Flashes)	**Stop & Start cancel indicator*3** Indicates a malfunction in the Stop & Start system (The Stop & Start cancel indicator will come on when the system is canceled.: →P. 305) → **Have the vehicle inspected by your Toyota dealer immediately.**

Warning message and warning buzzer list

Warning message	Details/Actions
	Indicates that: • There is a high possibility of a frontal collision; or • The pre-collision braking function is operating A buzzer also sounds. → **Slow the vehicle by applying the brakes.**
  (Flashes)	Indicates that the engine was stopped with the shift lever not in P A buzzer also sounds. → **Shift the shift lever to P.**
  (Flashes)	Indicates that the engine was stopped while driving A buzzer also sounds. → **Stop the vehicle in a safe place such as the shoulder of a road.**
	Indicates that your vehicle is nearing the vehicle ahead (in vehicle-to-vehicle distance control mode) A buzzer also sounds. → **Slow the vehicle by applying the brakes.**
  (Amber) (Flashes)	Indicates that the vehicle has deviated from the lane (while the LDA [Lane Departure Alert with steering control] system is operating) • The lane line on the side the vehicle has deviated from flashes in amber. • A buzzer also sounds. → **Check around the vehicle and back to inside of the lane lines.**

Warning message	Details/Actions
  (If equipped)	Indicates that an intuitive parking assist-sensor is dirty or covered with ice A buzzer also sounds. → **Clean the sensor.**
	Indicates a malfunction in the EPS (Electric Power Steering) system A buzzer also sounds. → **Have the vehicle inspected by your Toyota dealer.**
	Indicates that the vehicle is being driven at 3 mph (5 km/h) or more with the parking brake still engaged A buzzer also sounds. → **Release the parking brake.**
	Indicates that the LDA (Lane Departure Alert with steering control) system has determined that the driver does not have the hands on the steering wheel while the steering control function is on If the driver operates the steering wheel only a small amount, the system may be unable to detect the steering wheel operations and this warning may be displayed. A buzzer also sounds. → **Firmly hold the steering wheel.**

Warning message	Details/Actions
  (If equipped)	Indicates that an intuitive parking assist-sensor is dirty or covered with ice A buzzer also sounds. → **Clean the sensor.**
	Indicates a malfunction in the EPS (Electric Power Steering) system A buzzer also sounds. → **Have the vehicle inspected by your Toyota dealer.**
	Indicates that the vehicle is being driven at 3 mph (5 km/h) or more with the parking brake still engaged A buzzer also sounds. → **Release the parking brake.**
	Indicates that the LDA (Lane Departure Alert with steering control) system has determined that the driver does not have the hands on the steering wheel while the steering control function is on If the driver operates the steering wheel only a small amount, the system may be unable to detect the steering wheel operations and this warning may be displayed. A buzzer also sounds. → **Firmly hold the steering wheel.**

Warning message	Details/Actions
	Indicates that the engine coolant temperature is too high A buzzer also sounds. → **P. 646**
	Indicates a malfunction in the vehicle's charging system. → **Immediately stop the vehicle in a safe place and contact your Toyota dealer. Continuing to drive the vehicle may be dangerous.**
	Indicates that the radar sensor is dirty or covered with ice A buzzer also sounds. → **Clean the sensor.**
	Indicates that the dynamic radar cruise control system cannot be used temporarily due to bad weather A buzzer also sounds. → **Use the dynamic radar cruise control system when it becomes available again.**

Warning message	Details/Actions
	Indicates that the system is temporarily unavailable due to a malfunction in a sensor other than the camera sensor A buzzer also sounds. → **Turn the LDA (Lane Departure Alert with steering control) system off, wait for a little while, and then turn the LDA (Lane Departure Alert with steering control) system back on.**
	Indicates that a Blind Spot Monitor sensor or the surrounding area on the rear bumper is dirty or covered with snow, ice, etc. or that a sensor is misaligned A buzzer also sounds. → **Clean off the dirt, snow, ice, etc. and drive the vehicle with the operation conditions of the BSM function (→P. 328) satisfied for approximately 10 minutes. If the warning message does not disappear, the sensor may be misaligned. Have the vehicle inspected by your Toyota dealer.**
	Indicates a malfunction in the dynamic radar cruise control system. • Press the "ON-OFF" button once to deactivate the system, and then press the button again to reactivate the system. • A buzzer also sounds. → **Have the vehicle inspected by your Toyota dealer.**
	Indicates a malfunction in the LDA (Lane Departure Alert with steering control) system A buzzer also sounds. → **Have the vehicle inspected by your Toyota dealer.**

■ **If you have a flat front tire on a road covered with snow or ice (vehicles with a compact spare tire)**

Install the compact spare tire on one of the rear wheels of the vehicle. Perform the following steps and fit tire chains to the front tires:

1. Replace a rear tire with the compact spare tire.
2. Replace the flat front tire with the tire removed from the rear of the vehicle.
3. Fit tire chains to the front tires.

⚠ WARNING

■ **When using the compact spare tire (vehicles with a compact spare tire)**

- Remember that the compact spare tire provided is specifically designed for use with your vehicle. Do not use your compact spare tire on another vehicle.
- Do not use more than one compact spare tires simultaneously.
- Replace the compact spare tire with a standard tire as soon as possible.
- Avoid sudden acceleration, abrupt steering, sudden braking and shifting operations that cause sudden engine braking.

■ **When the compact spare tire is attached (vehicles with a compact spare tire)**

The vehicle speed may not be correctly detected, and the following systems may not operate correctly:

- ABS & Brake assist
- VSC
- TRAC
- Dynamic radar cruise control
- Pre-Collision System
- EPS
- Automatic High Beam
- LDA (Lane Departure Alert with steering control)
- Intuitive parking assist (if equipped)
- Navigation system (if equipped)

Also, not only can the following system not be utilized fully, but it may even negatively affect the drive-train components:

- AWD system (if equipped)

■ **LDA (Lane Departure Alert with steering control) (→P. 281)**

Function	Default setting	Customized setting	①	②	③
Steering Assist	On	Off	—	O	—
Alert sensitivity	Standard	High	—	O	—
Vehicle sway warning	On	Off	—	O	—
Vehicle sway warning sensitivity	Standard	Low	—	O	—
		High			

■ **PCS (Pre-Collision System) (→P. 267)**

Function	Default setting	Customized setting	①	②	③
PCS (Pre-Collision System)	On	Off	—	O	—
Alert timing	 (Middle)	 (Far)	—	O	—
		 (Near)			

APPENDIX C

Run Log

Subject Vehicle: *2019 Toyota Highlander* Test Date: *1/21/2019*

Driver: *A. Ricci*

Note: For Distance at Warning positive values indicate inside the lane

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Pass/Fail	Notes
1	**Botts**	**Right**	N			Yaw Rate, No Light Signal Due to Airbag Warning
2			Y	0.93	Pass	
3			Y	0.61	Pass	
4			Y	0.80	Pass	
5			Y	0.77	Pass	
6			Y	0.64	Pass	
7			Y	0.63	Pass	
8			Y	0.52	Pass	
9	**Botts**	**Left**	Y	0.58	Pass	
10			Y	0.11	Pass	
11			Y	0.66	Pass	
12			Y	0.34	Pass	
13			Y	0.44	Pass	
14			Y	0.48	Pass	
15			Y	0.39	Pass	

Subject Vehicle: *2019 Toyota Highlander* Test Date: *1/21/2019*

Driver: *A. Ricci*

Note: For Distance at Warning positive values indicate inside the lane

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Pass/Fail	Notes
16	**Solid**	**Left**	Y	0.70	Pass	
17			Y	0.94	Pass	
18			Y	0.86	Pass	
19			Y	0.31	Pass	
20			Y	0.27	Pass	
21			Y	0.42	Pass	
22			Y	0.62	Pass	
23	Solid	Right	Y	0.74	Pass	
24			Y	0.74	Pass	
25			Y	0.71	Pass	
26			Y	0.78	Pass	
27			Y	0.79	Pass	
28			Y	0.38	Pass	
29			Y	0.55	Pass	

Subject Vehicle: *2019 Toyota Highlander* Test Date: *1/21/2019*

Driver: *A. Ricci*

Note: For Distance at Warning positive values indicate inside the lane

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Pass/Fail	Notes
30	**Dashed**	**Right**	Y	0.73	Pass	
31			Y	0.68	Pass	
32			Y	0.28	Pass	
33			Y	0.41	Pass	
34			Y		Fail	No Warning
35			Y	0.72	Pass	
36			Y	0.16	Pass	
37	**Dashed**	**Left**	Y	0.65	Pass	
38			Y	0.20	Pass	
39			Y	0.41	Pass	
40			Y	0.15	Pass	
41			Y	0.84	Pass	
42			Y	0.33	Pass	
43			Y	0.28	Pass	

APPENDIX D

Time History Plots

LIST OF FIGURES

Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from the Subject Vehicle, as well as pass/fail envelopes and thresholds. The following is a description of data types shown in the time history plots, as well as a description of the color code for data envelopes.

Time History Plot Description

Time history figures include the following sub-plots:

- Warning – indicates timing of warning issued by LDW system. Depending on the type of LDW alert or instrumentation used to measure the alert, this can be any of the following:
    - Filtered and rectified sound signal
    - Filtered and rectified acceleration (e.g., steering wheel vibration)
    - Light sensor signal
    - Discrete on/off value
- Speed (mph) – speed of the Subject Vehicle
- Yaw Rate (deg/sec) – yaw rate of the Subject Vehicle
- Distance to Lane Edge (ft) – lateral distance (in lane coordinates) from the outer front tire bulge to the inside edge of the lane marking of interest for a given test (a positive value indicates the vehicle is completely within the lane while a negative value indicates that the outer front tire bulge has crossed over the inner lane marking edge). The distance to the lane edge at the moment the LDW alert is issued, is displayed to the right of subplot.
- Lateral Lane Velocity (ft/sec) – lateral velocity (in lane coordinates) of the outer front tire bulge
- Bird's Eye View – Indicates the position of the Subject Vehicle with respect to the lane marking of interest for a given test. Green rectangles represent the Subject Vehicle's position at approximately 2 second intervals, while the yellow rectangle indicates the position of the Subject Vehicle at the time of LDW warning issuance. **Note:** The Bird's Eye View representation is not synchronized to the time history plots above it. It is a spatial, not temporal, representation.

Note that the minimum (worst) GPS fix type is displayed in the lower right corner of each page. The only valid fix type is RTK fixed (displayed in green). If the fix type during any portion of the test was anything other than RTK fixed, then "RTK Fixed OR LESS!!" is displayed in red.

Envelopes and Thresholds

Each of the time history plot figures can contain either green or yellow envelopes and/or black threshold lines. These envelopes and thresholds are used to programmatically and visually determine the validity of a given test run. Envelope and threshold exceedances are indicated with either red shading or red asterisks, and red text is placed to the right side of the plot indicating the type of exceedance.

Green envelopes indicate that the time-varying data should not exceed the envelope boundaries at any time within the envelope. Exceedances of a green envelope are indicated by red shading in the area between the measured time-varying data and the envelope boundaries.

Yellow envelopes indicate that the time-varying data should not exceed the envelope only at the right end. Exceedances at the right extent of a yellow envelope are indicated by red asterisks. Data within the boundaries at the right extent of a yellow envelope are indicated by green circles.

For the warning plot, a dashed black threshold line indicates the threshold used to determine the onset of the LDW alert. The alert is considered on the first time the alert signal crosses this threshold line.

Color Codes

Color codes have been adopted to easily identify the types of data, envelopes and thresholds used in the plots.

Color codes can be broken into three categories:

1. Validation envelopes and thresholds
2. Instantaneous samplings
3. Text

1. Validation envelope and threshold color codes:
   - Green envelope = time varying data must be within the envelope at all times in order to be valid

- Yellow envelope = time varying data must be within limits at right end
- Black threshold (Solid) = time varying data must not exceed this threshold in order to be valid
- Black threshold (Dashed) = for reference only – this can include warning level thresholds which are used to determine the timing of the alert

2. Instantaneous sampling color codes:
   - Green circle = passing or valid value at a given moment in time
   - Red asterisk = failing or invalid value at a given moment in time

3. Text color codes:
   - Green = passing or valid value
   - Red = failing or invalid value

Examples of time history plots (including passing, failing and invalid runs) are shown in Figure D1 through Figure D3. Actual time history data plots for the vehicle under consideration are provided subsequently.

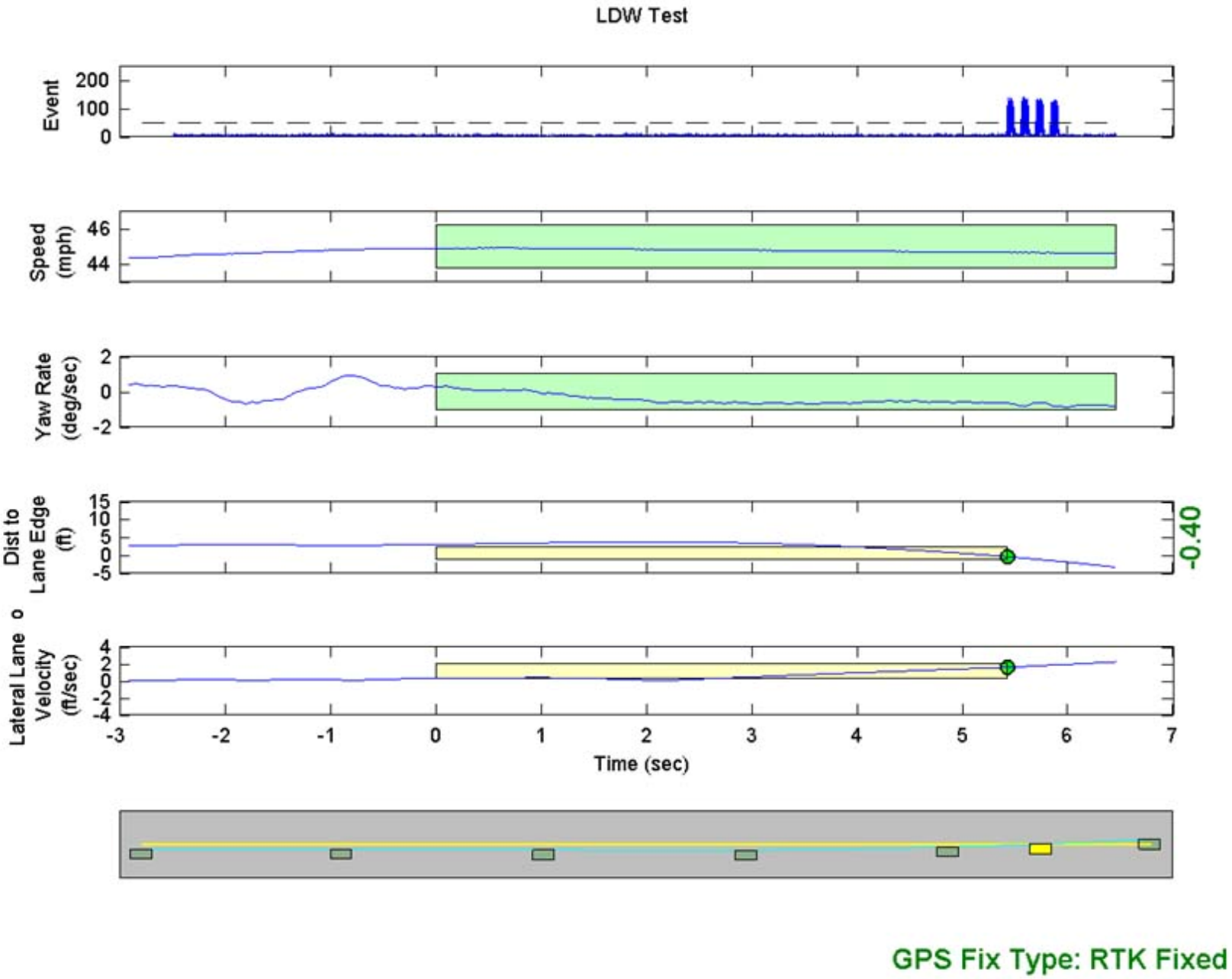


Figure D1. Example Time History for Lane Departure Warning Test, Passing

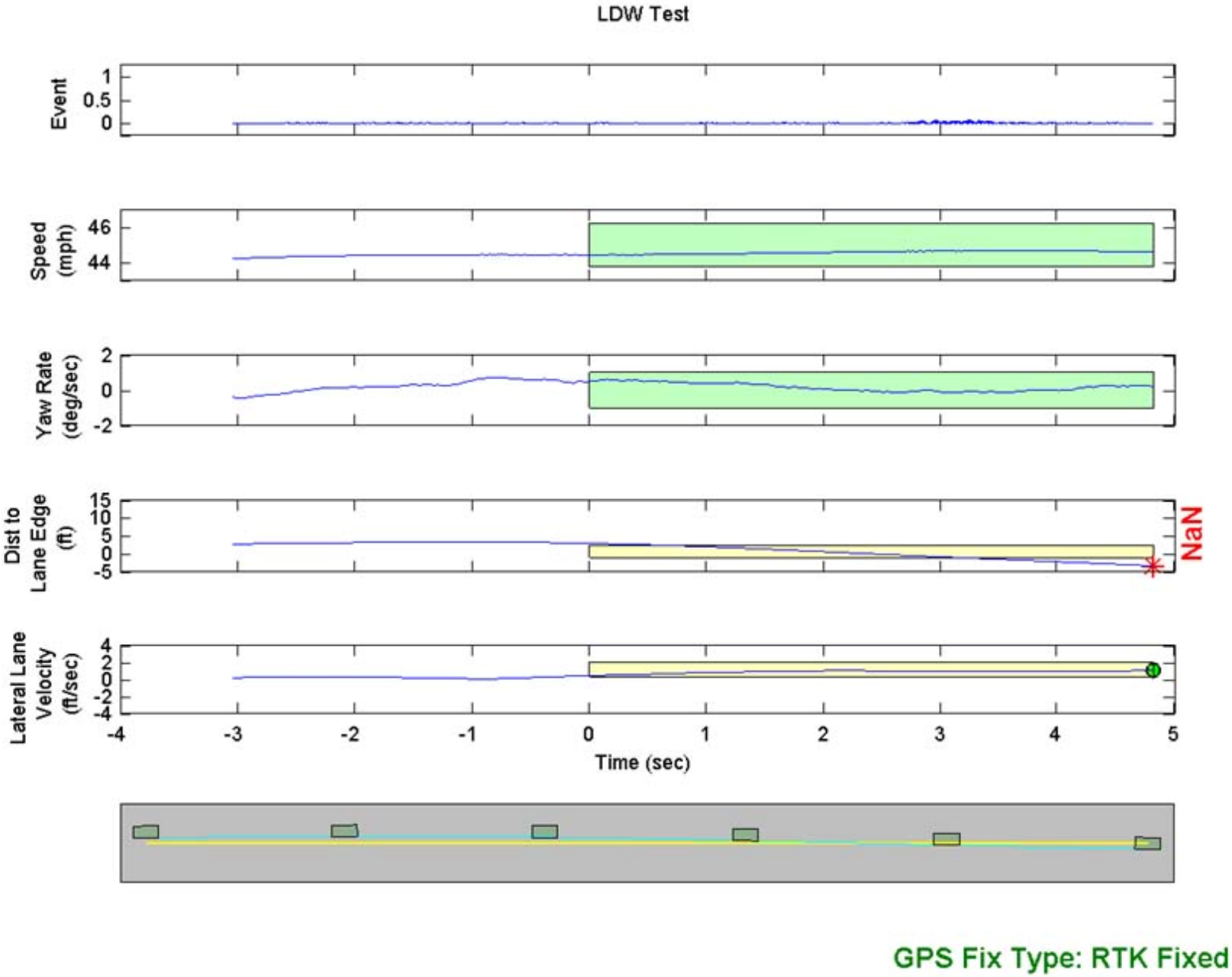


Figure D2. Example Time History for Lane Departure Warning Test, Failing, No Warning Issued

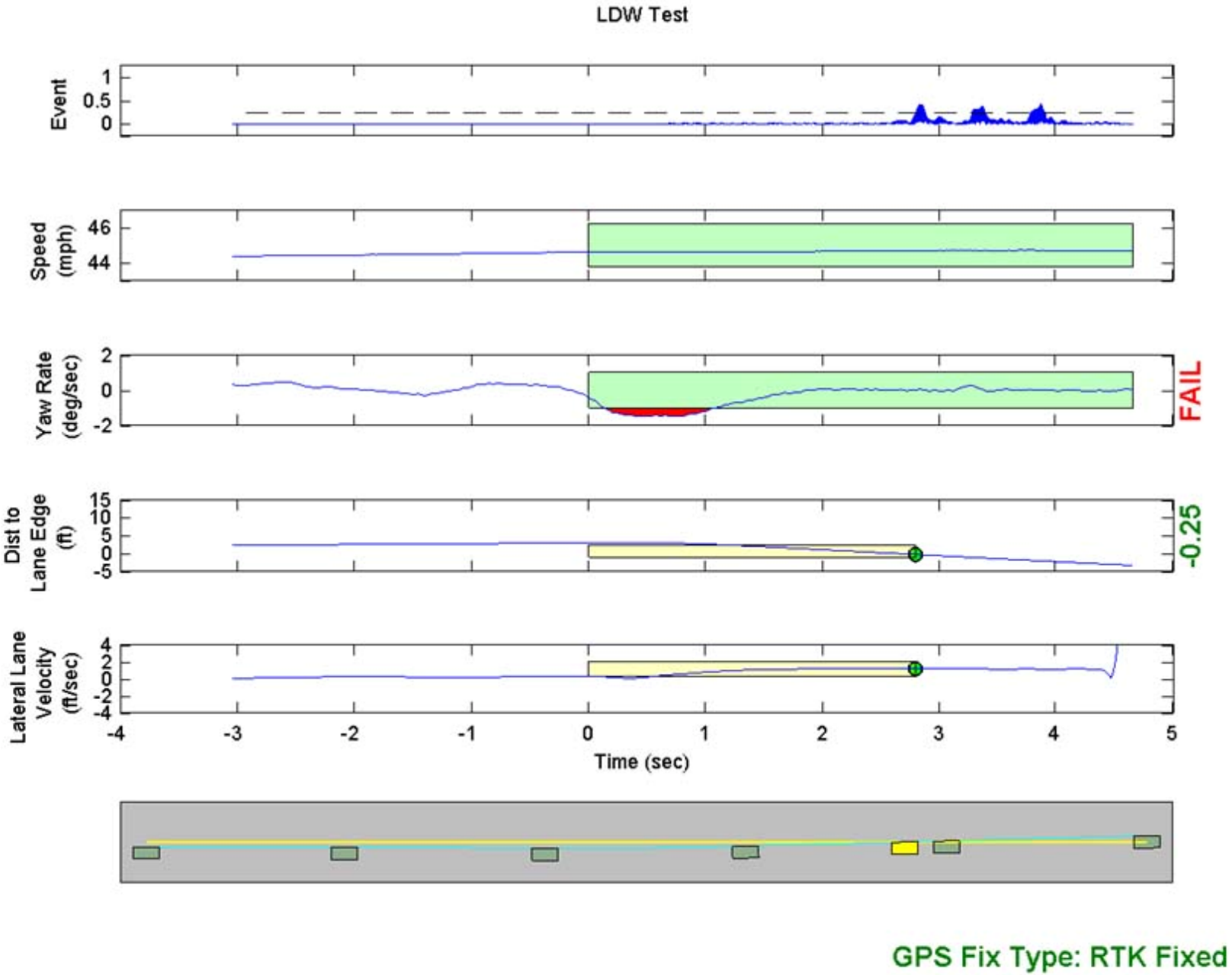


Figure D3. Example Time History for Lane Departure Warning Test, Invalid Run Due to Subject Vehicle Yaw Rate

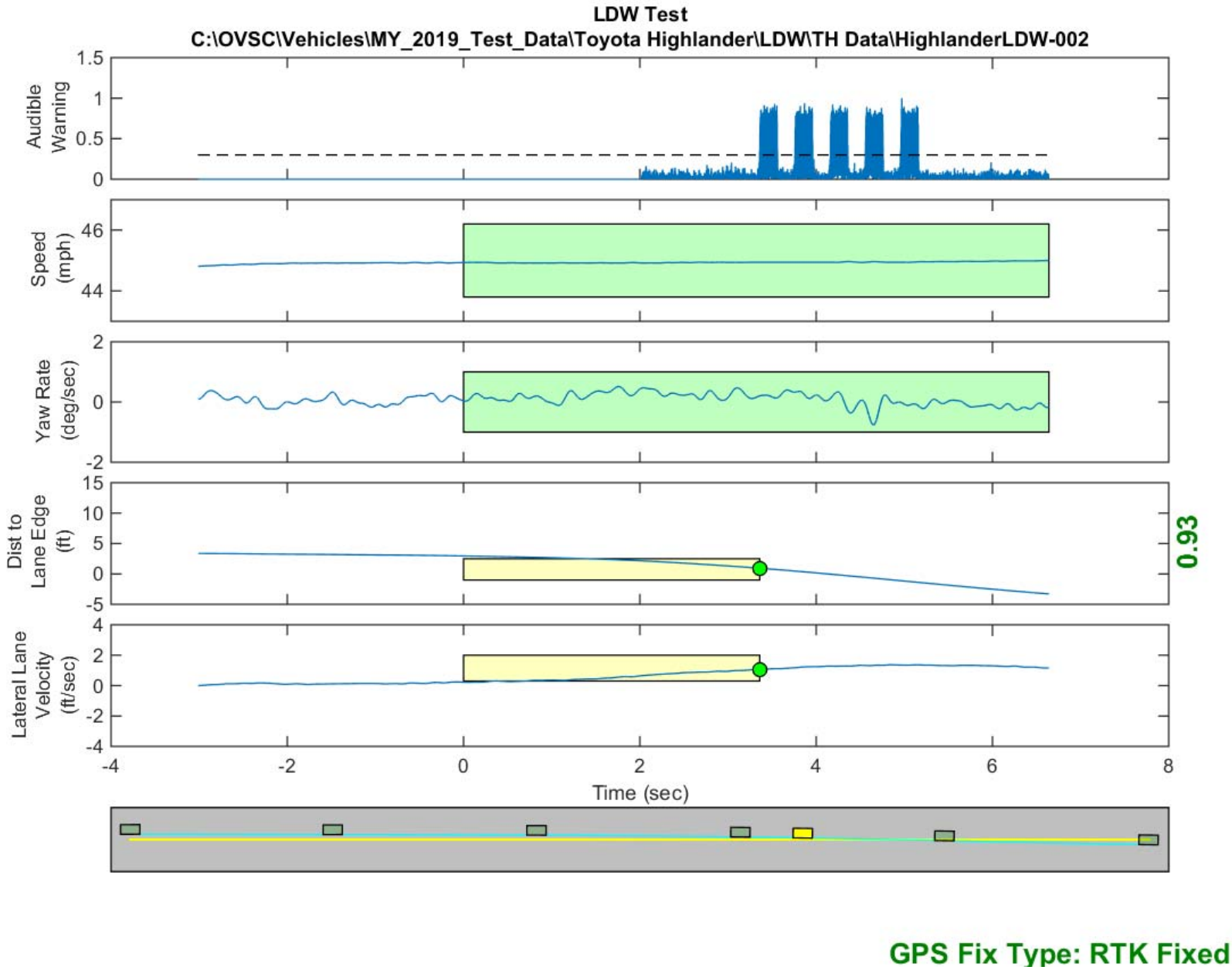


Figure D4. Time History for Run 02, Botts Dots, Right Departure, Audible Warning

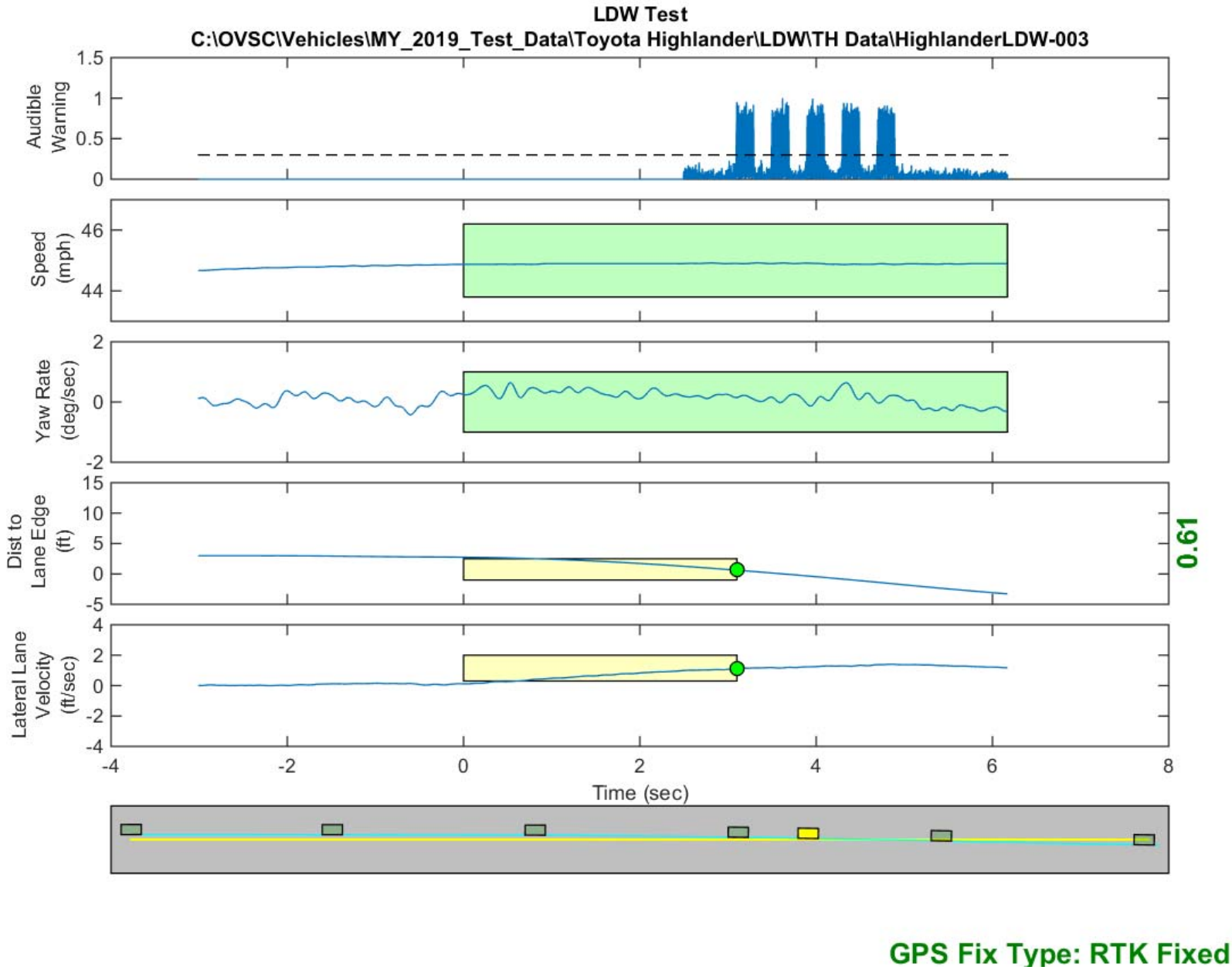


Figure D5. Time History for Run 03, Botts Dots, Right Departure, Audible Warning

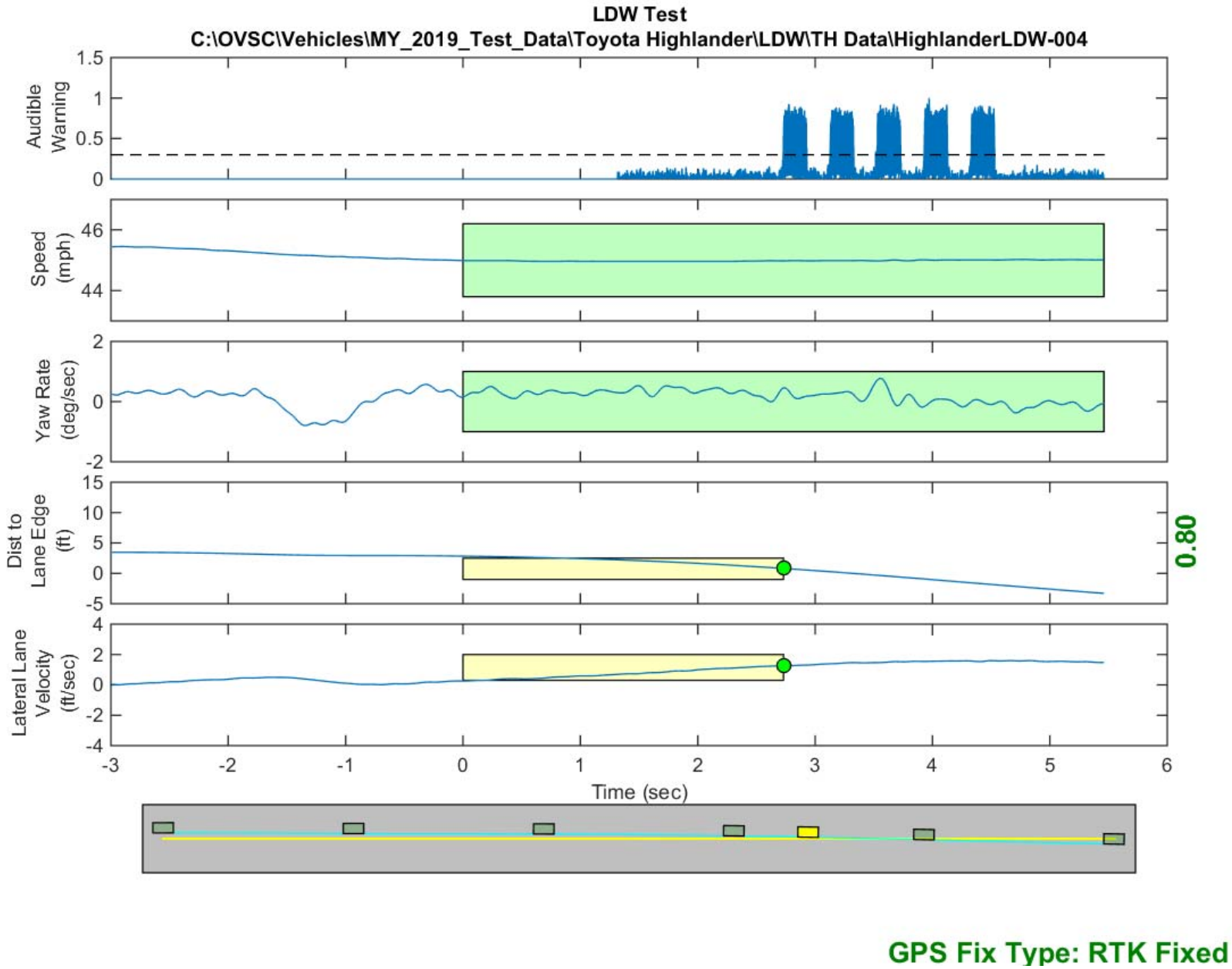


Figure D6. Time History for Run 04, Botts Dots, Right Departure, Audible Warning

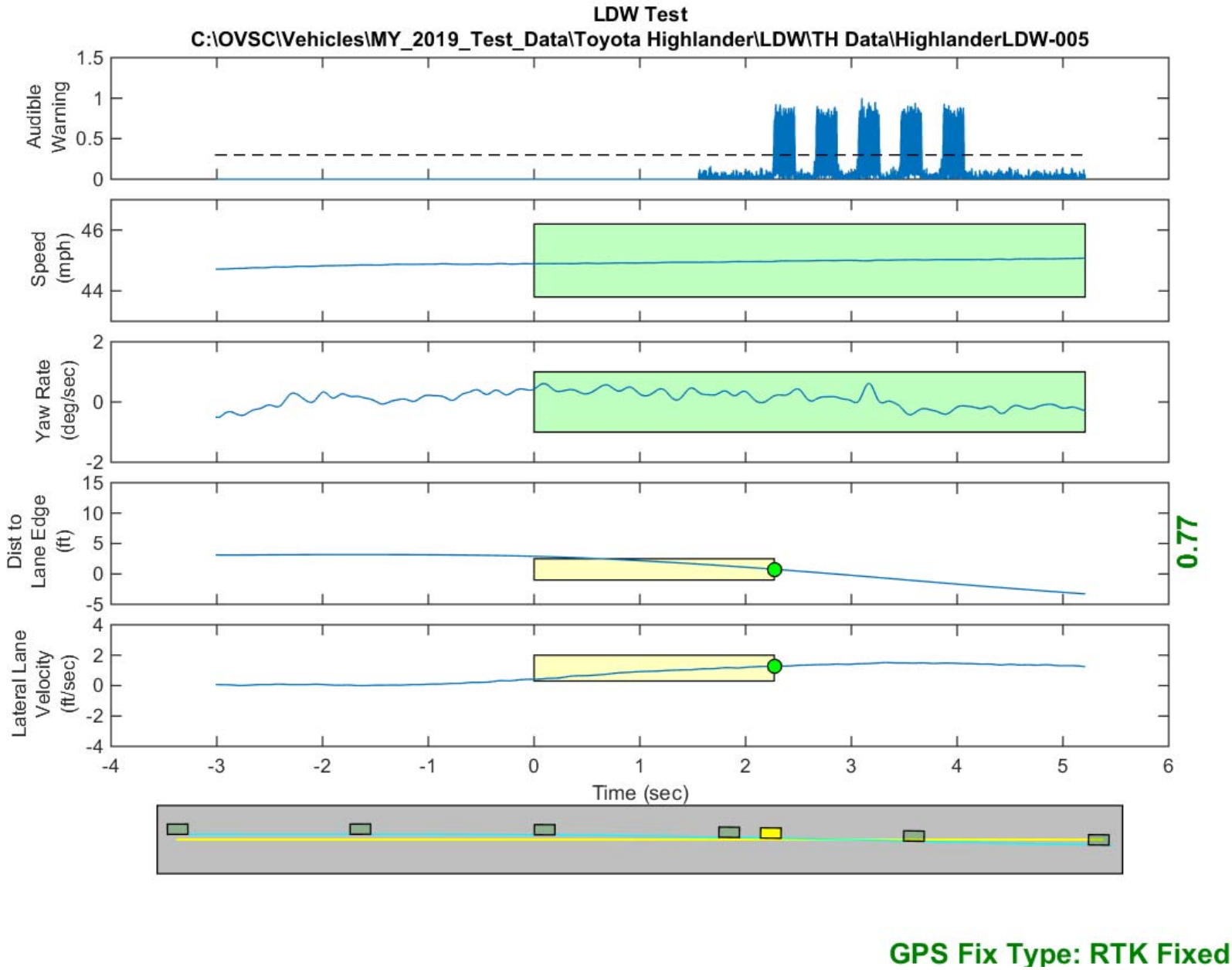


Figure D7. Time History for Run 05, Botts Dots, Right Departure, Audible Warning

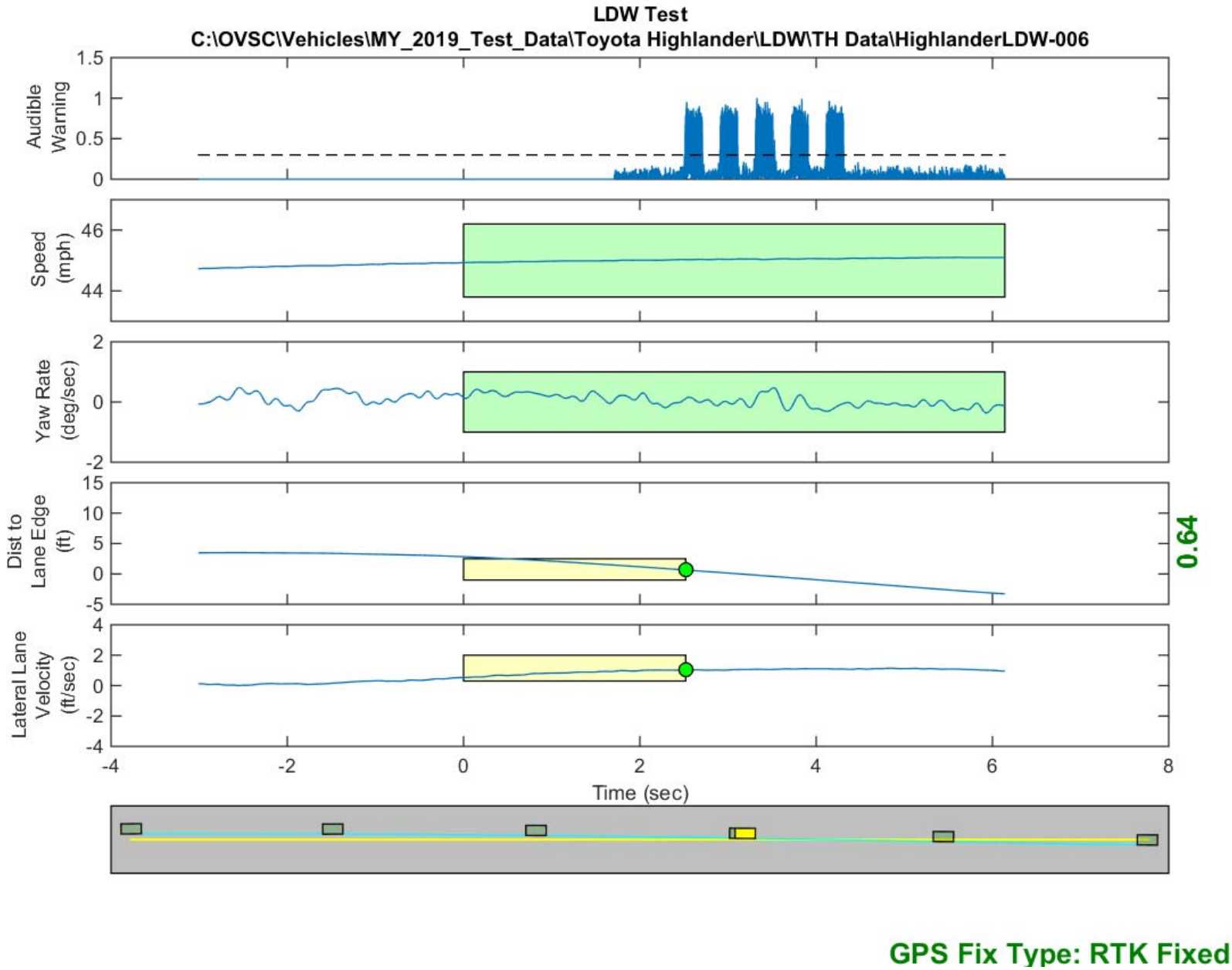


Figure D8. Time History for Run 06, Botts Dots, Right Departure, Audible Warning

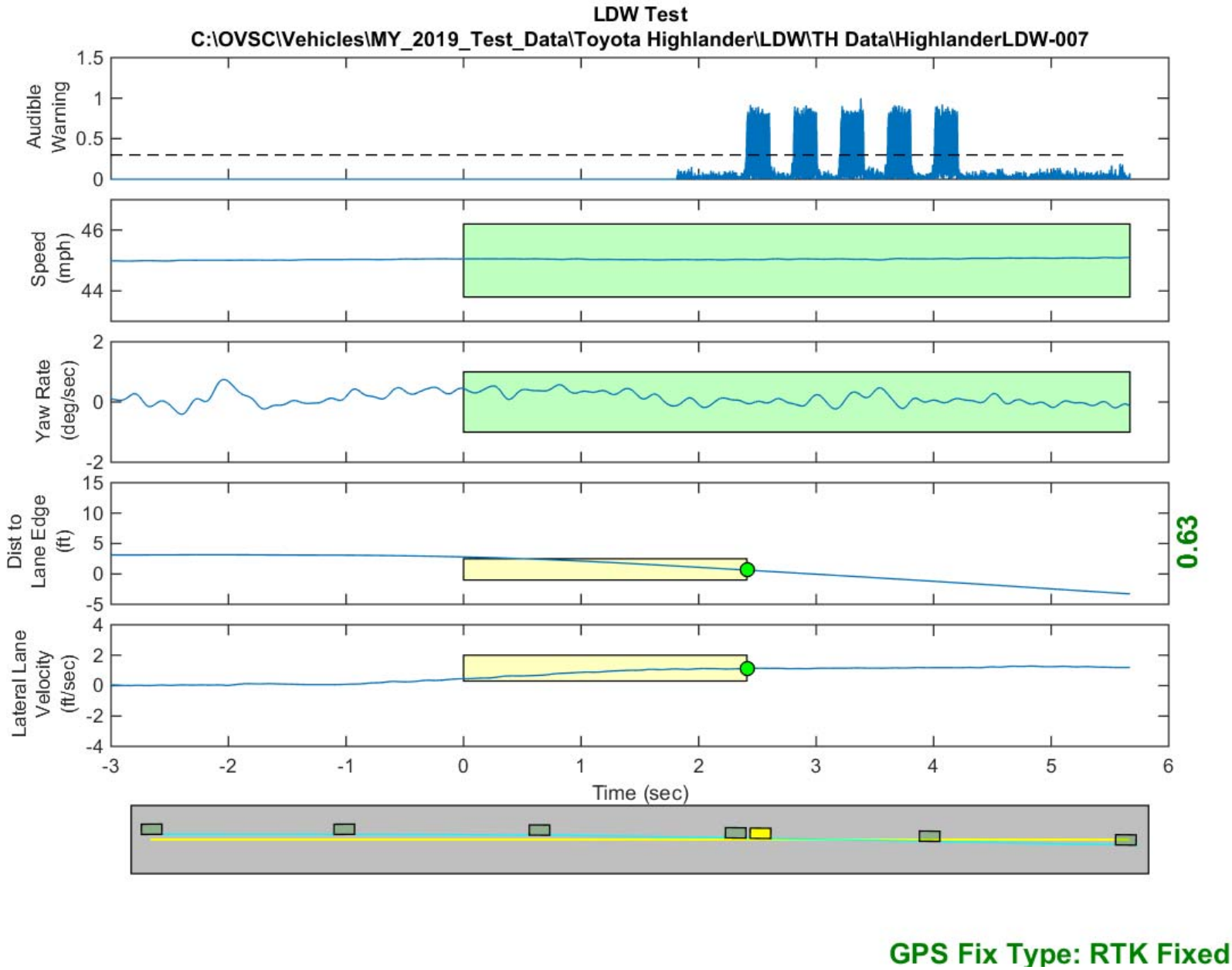


Figure D9. Time History for Run 07, Botts Dots, Right Departure, Audible Warning

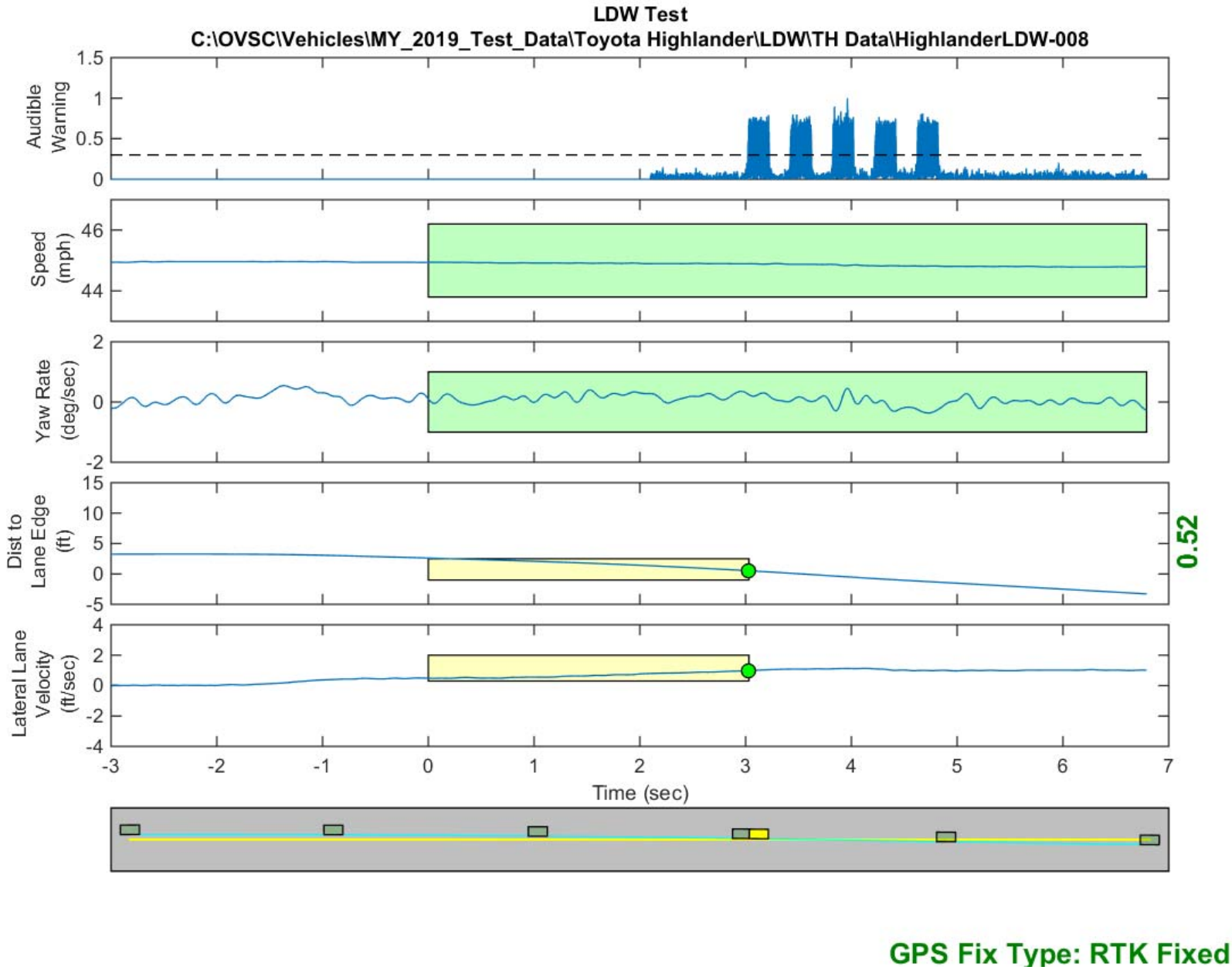


Figure D10. Time History for Run 08, Botts Dots, Right Departure, Audible Warning

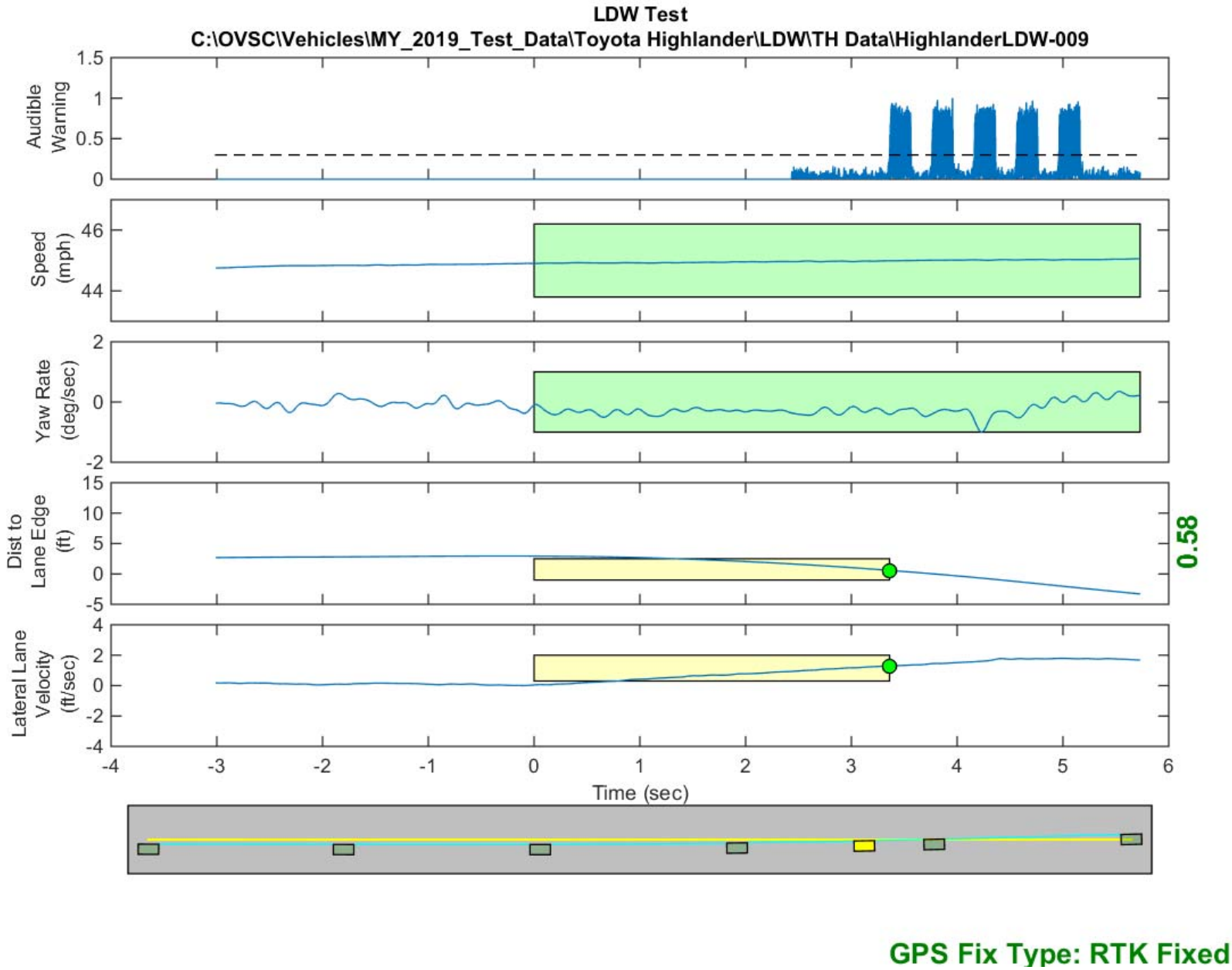


Figure D11. Time History for Run 09, Botts Dots, Left Departure, Audible Warning

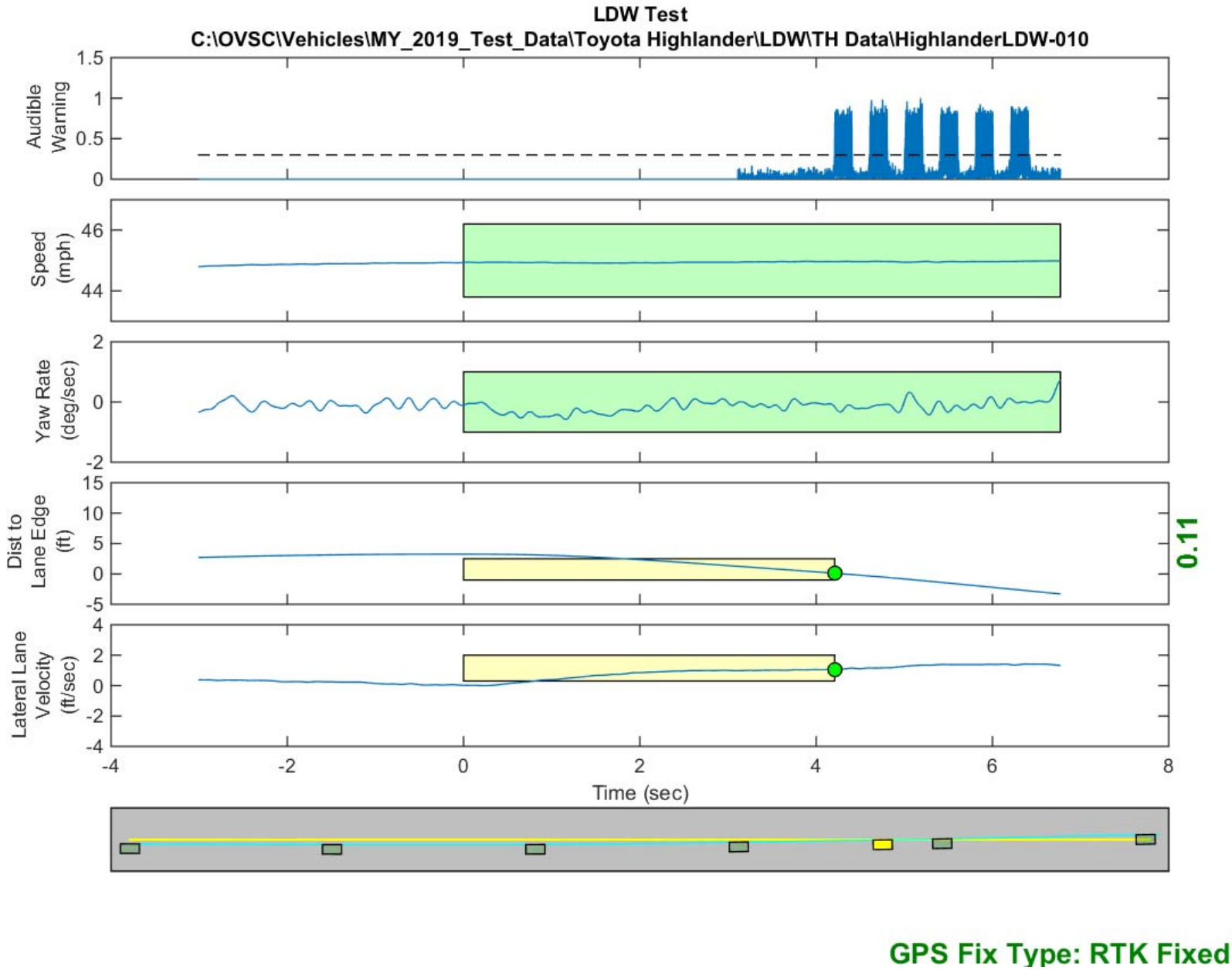


Figure D12. Time History for Run 10, Botts Dots, Left Departure, Audible Warning

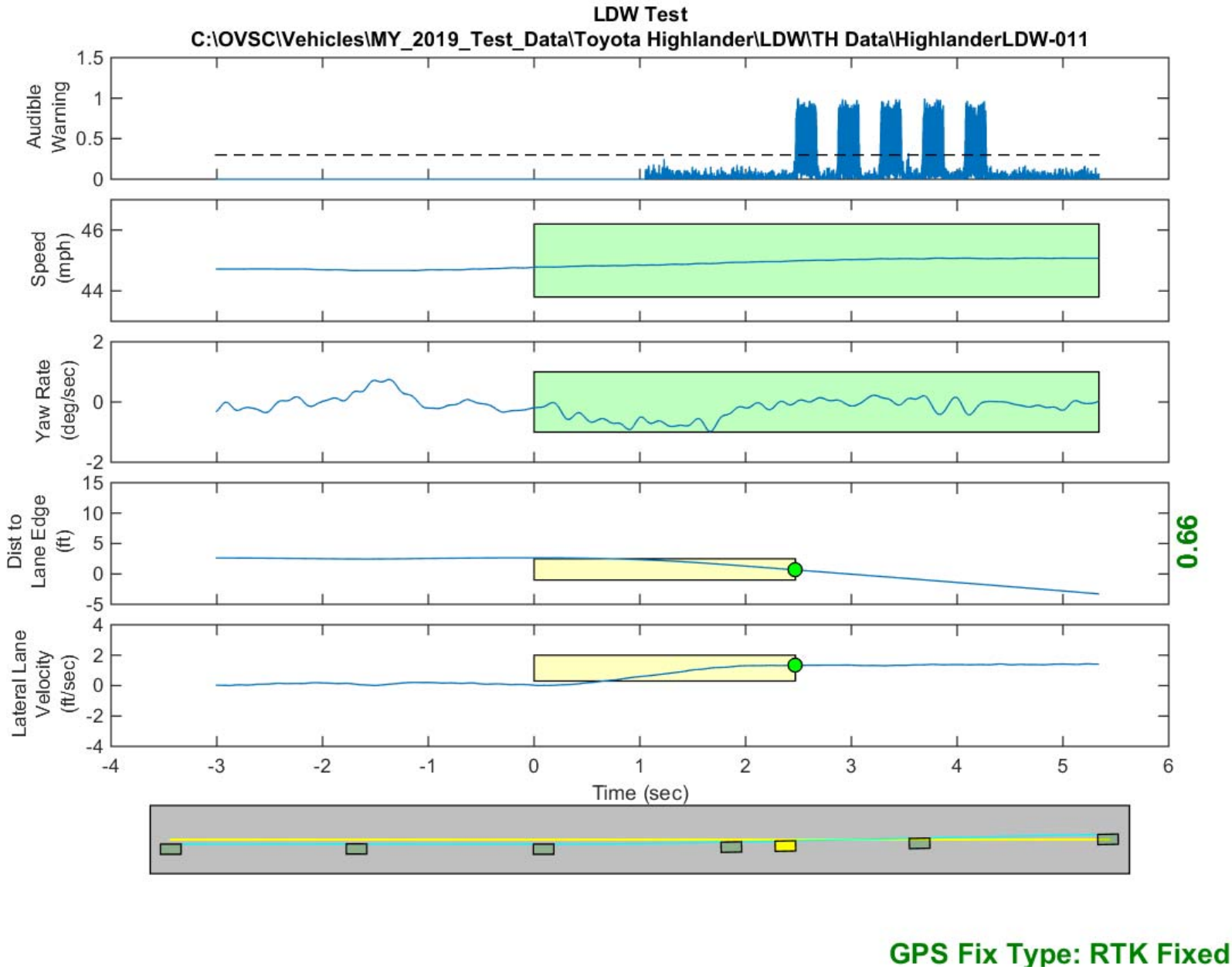


Figure D13. Time History for Run 11, Botts Dots, Left Departure, Audible Warning

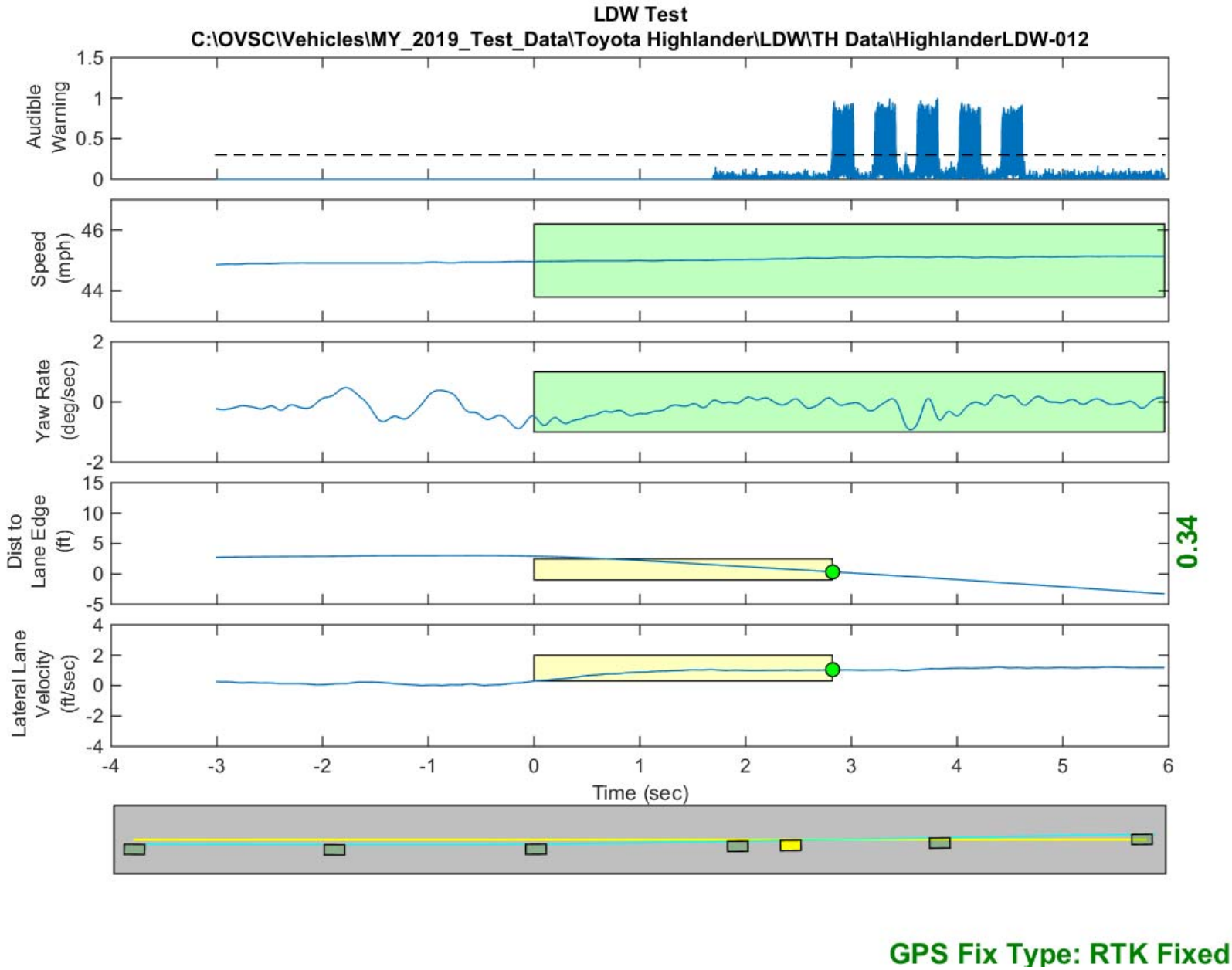


Figure D14. Time History for Run 12, Botts Dots, Left Departure, Audible Warning

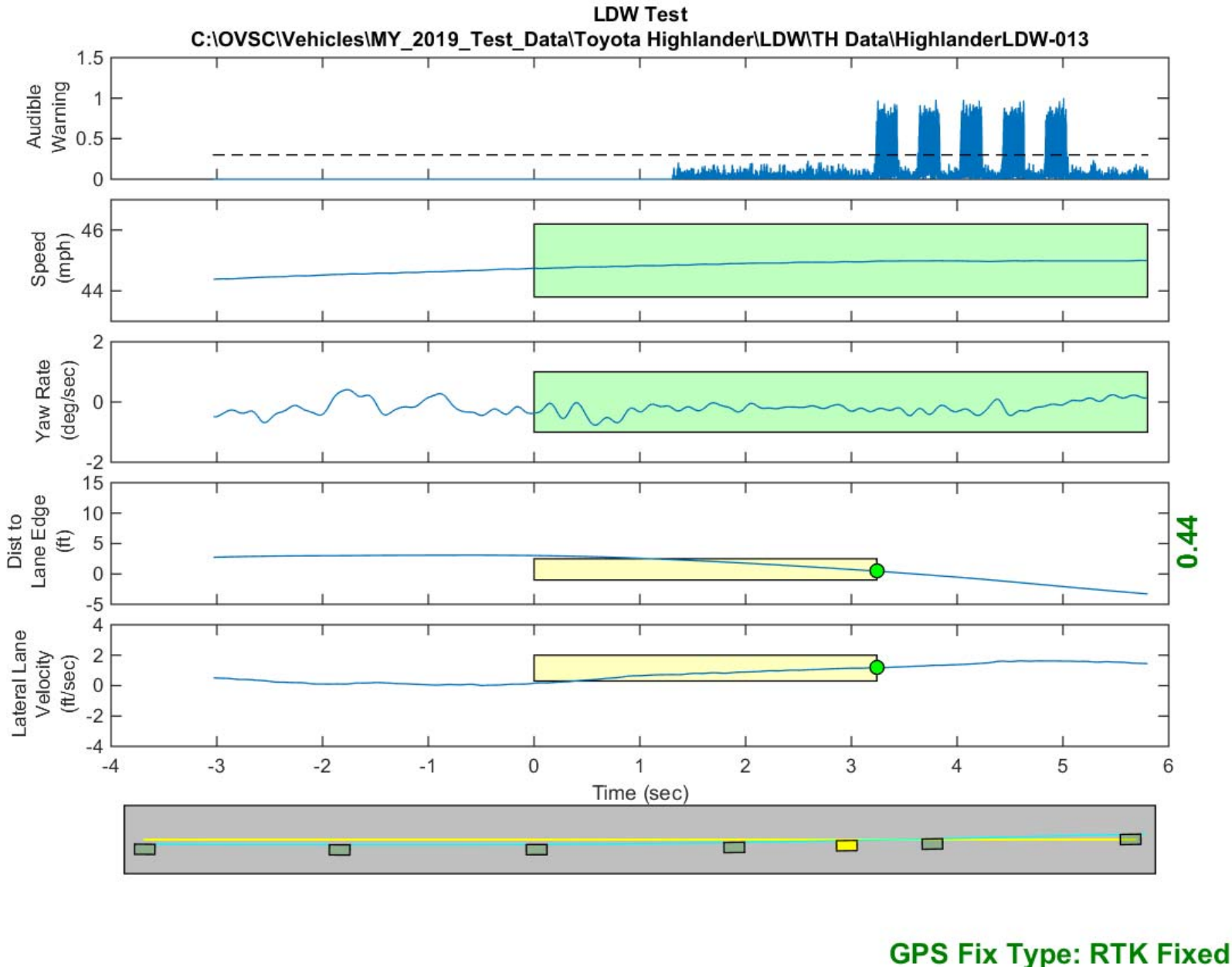


Figure D15. Time History for Run 13, Botts Dots, Left Departure, Audible Warning

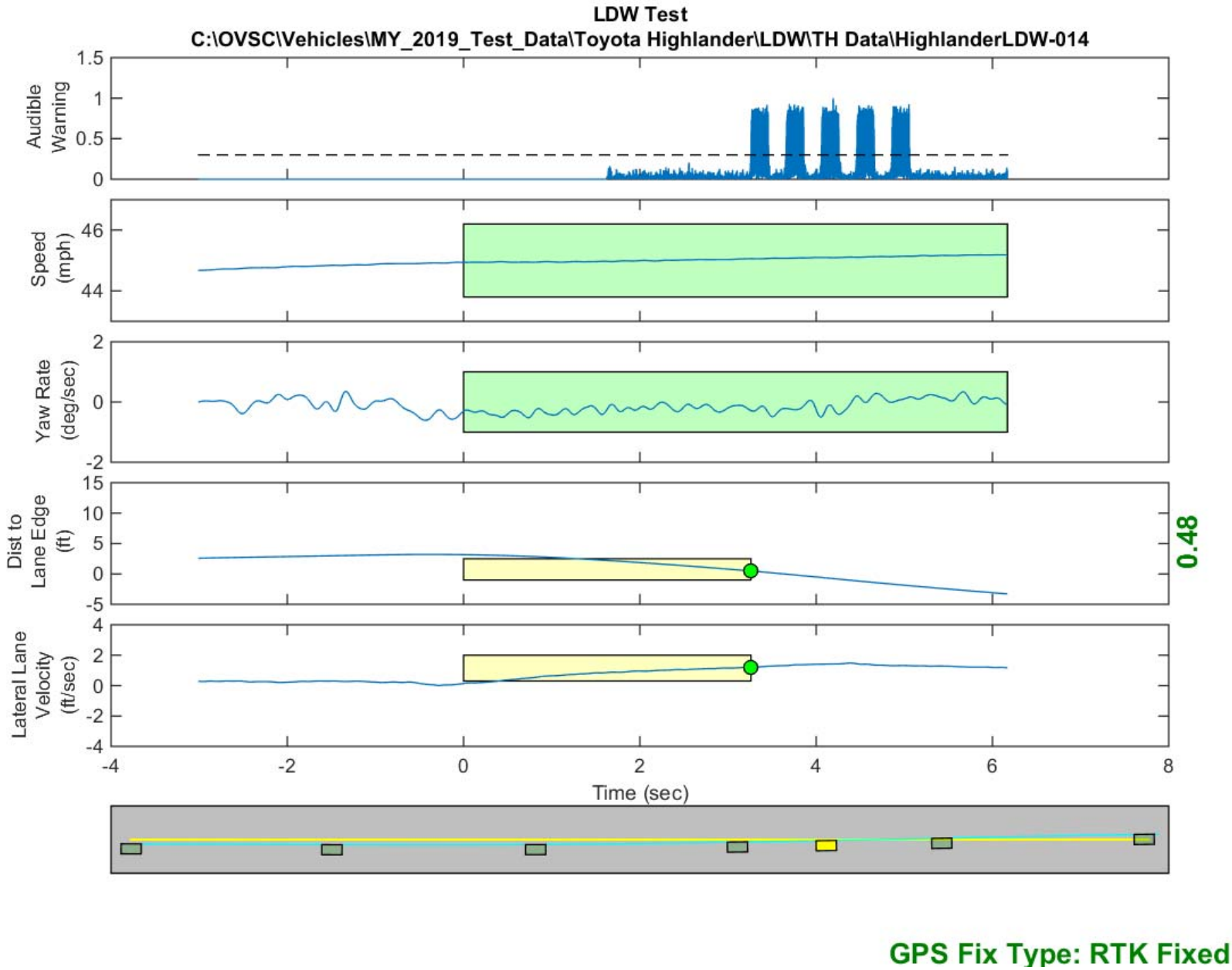


Figure D16. Time History for Run 14, Botts Dots, Left Departure, Audible Warning

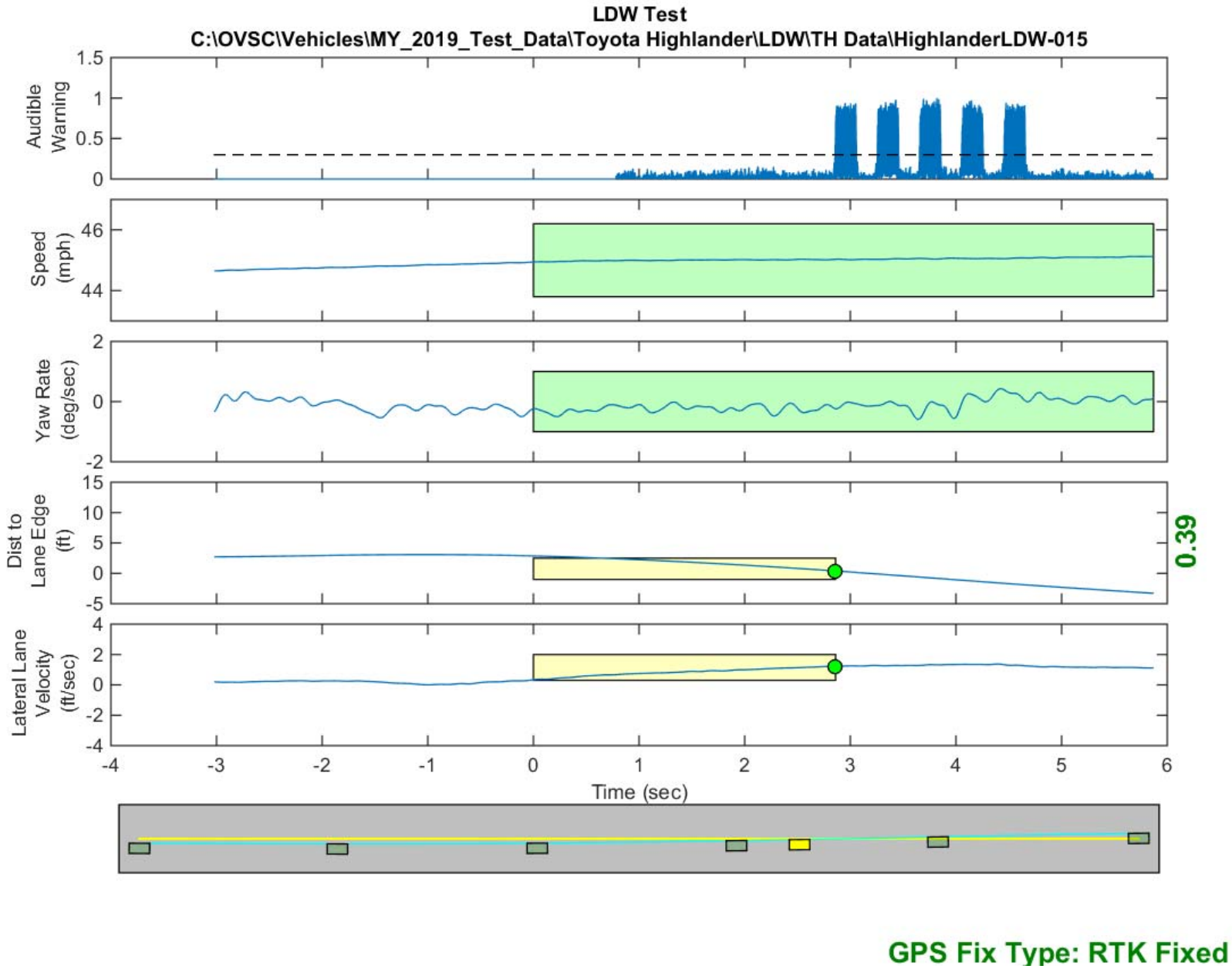


Figure D17. Time History for Run 15, Botts Dots, Left Departure, Audible Warning

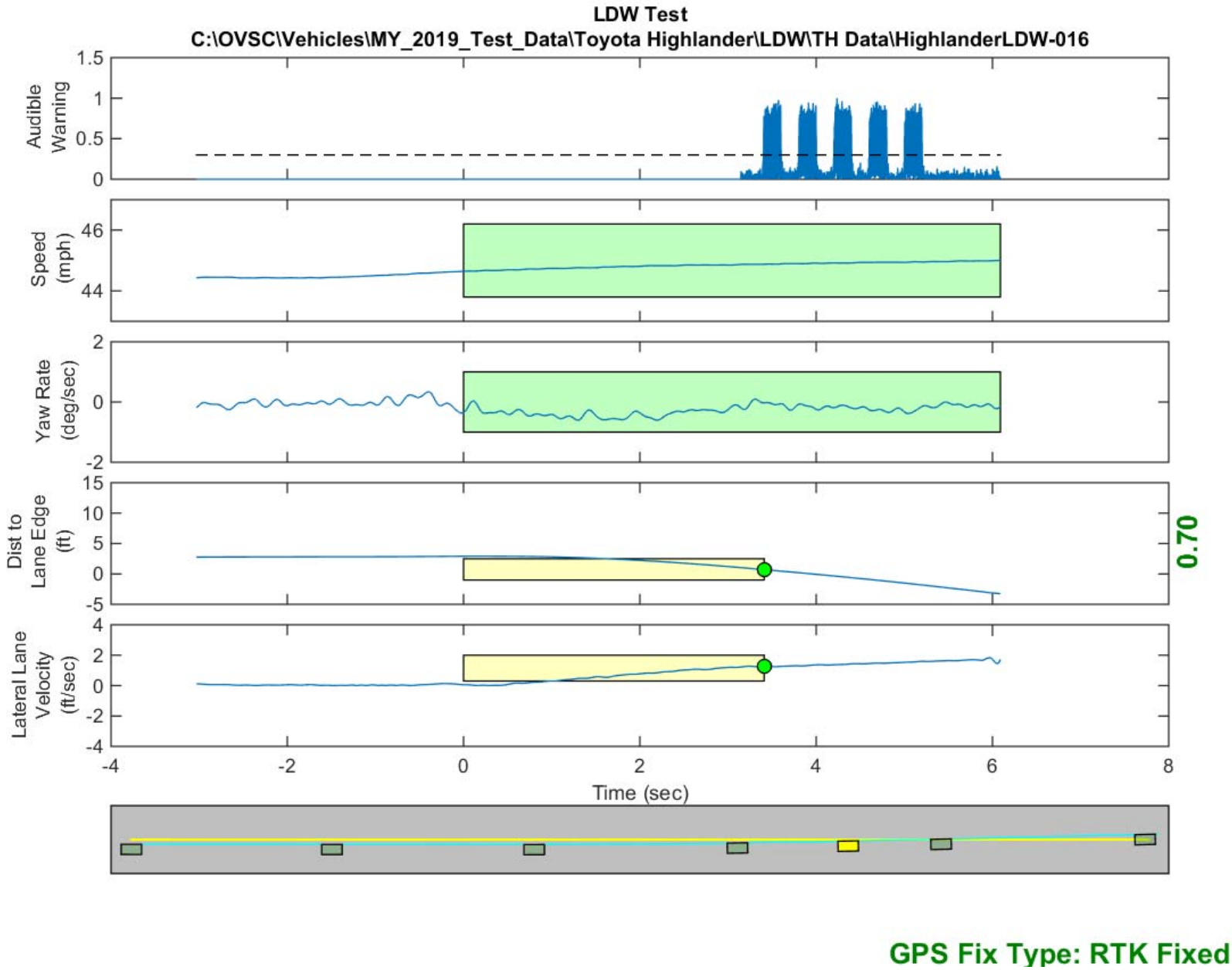


Figure D18. Time History for Run 16, Solid Line, Left Departure, Audible Warning

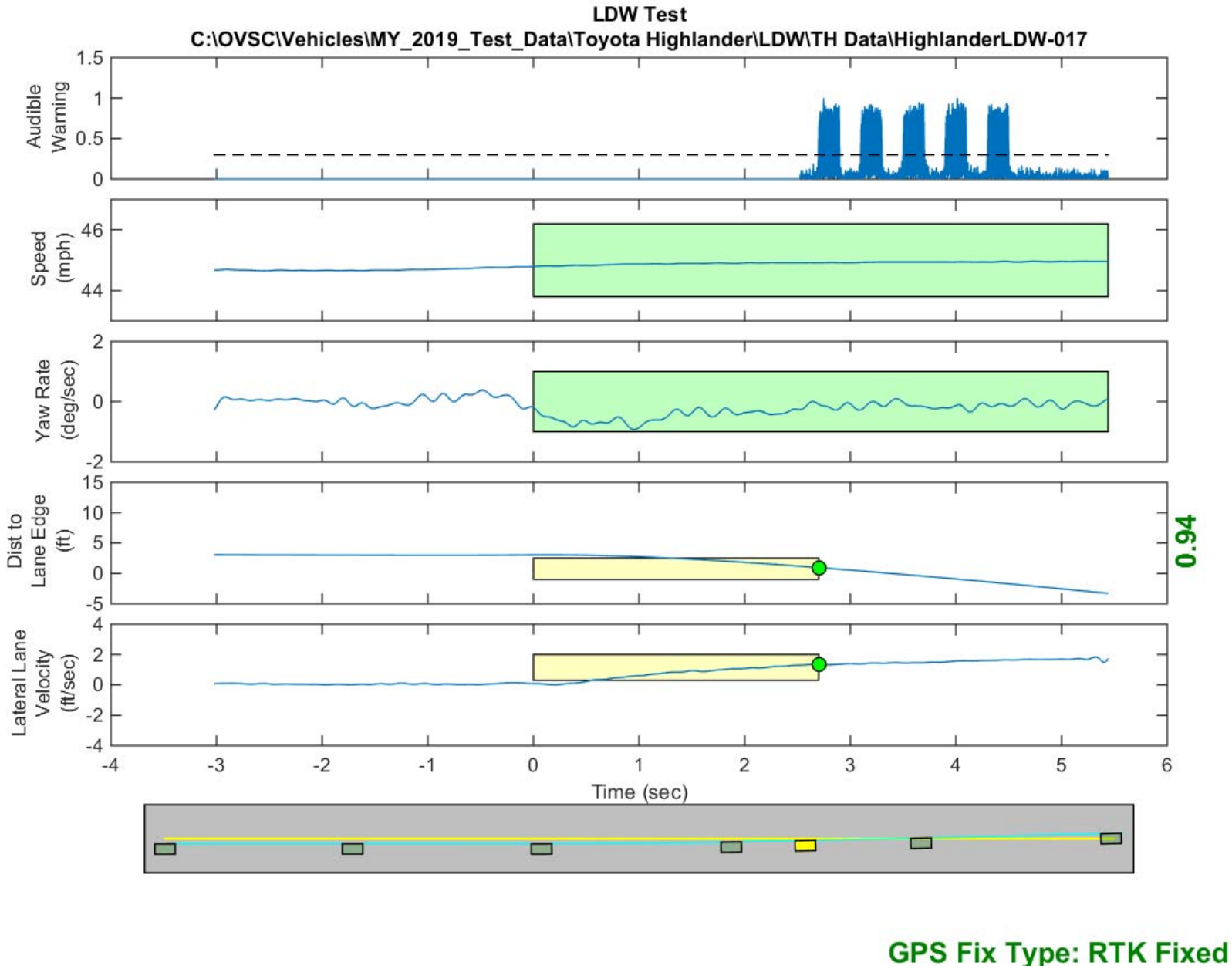


Figure D19. Time History for Run 17, Solid Line, Left Departure, Audible Warning

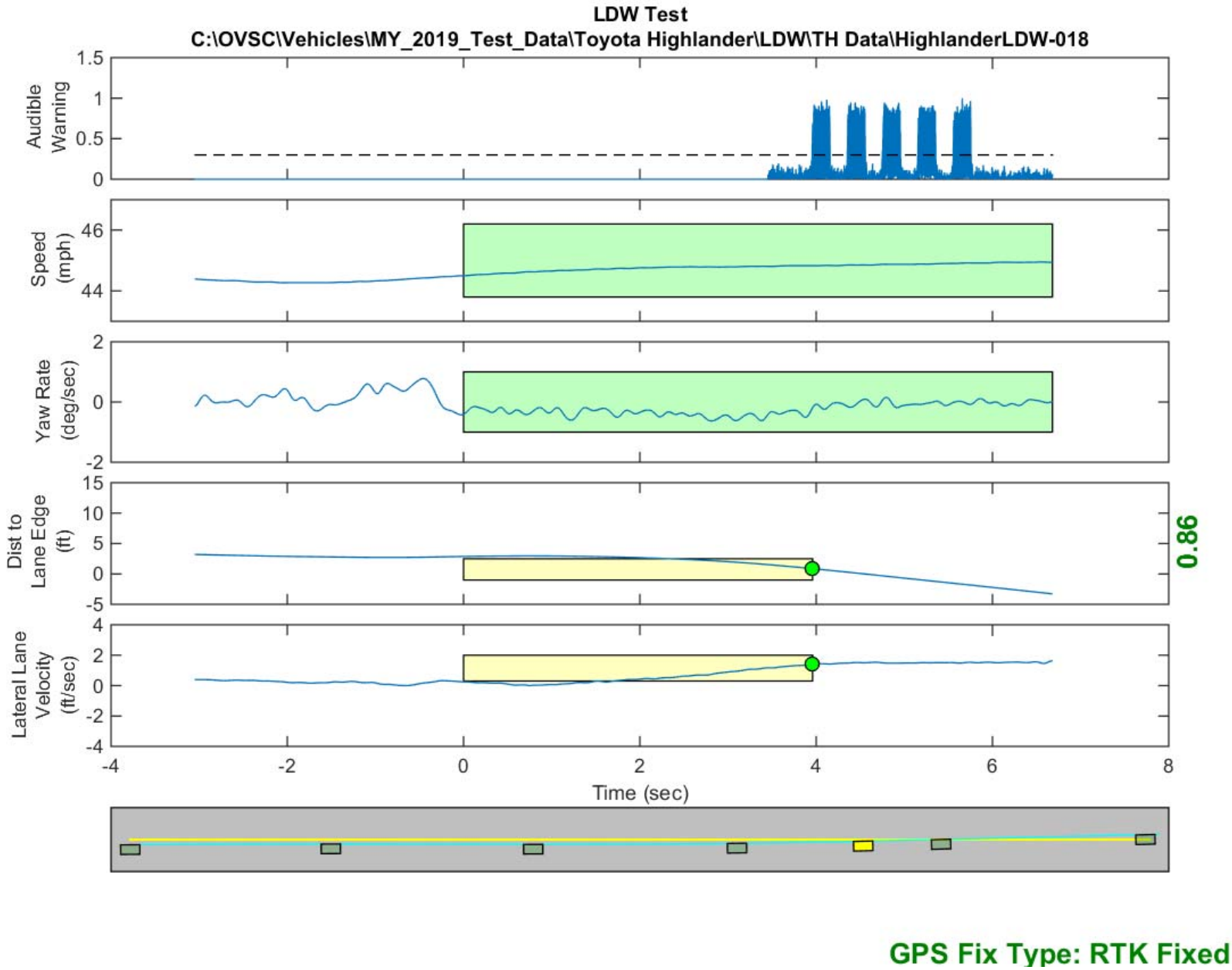


Figure D20. Time History for Run 18, Solid Line, Left Departure, Audible Warning

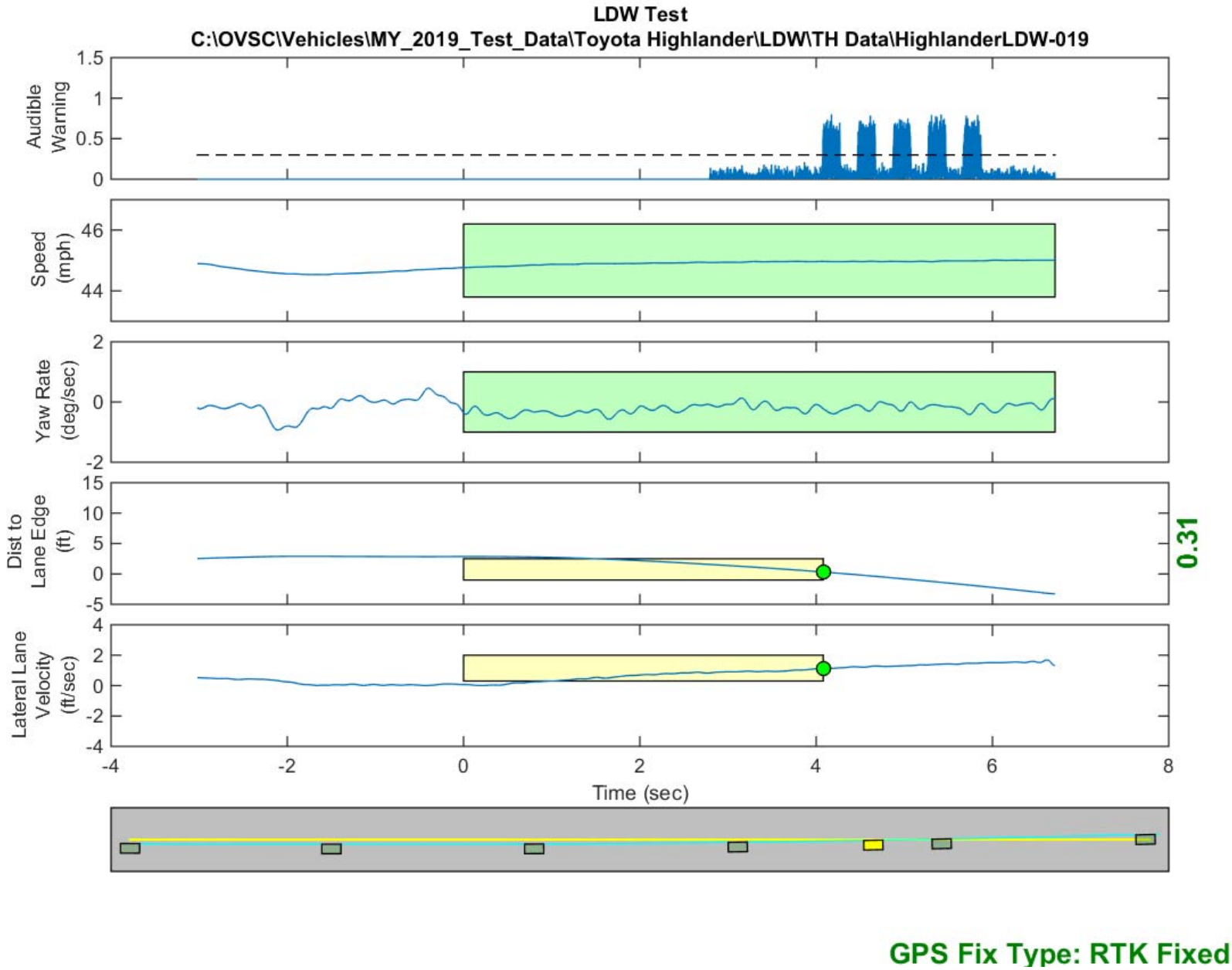


Figure D21. Time History for Run 19, Solid Line, Left Departure, Audible Warning

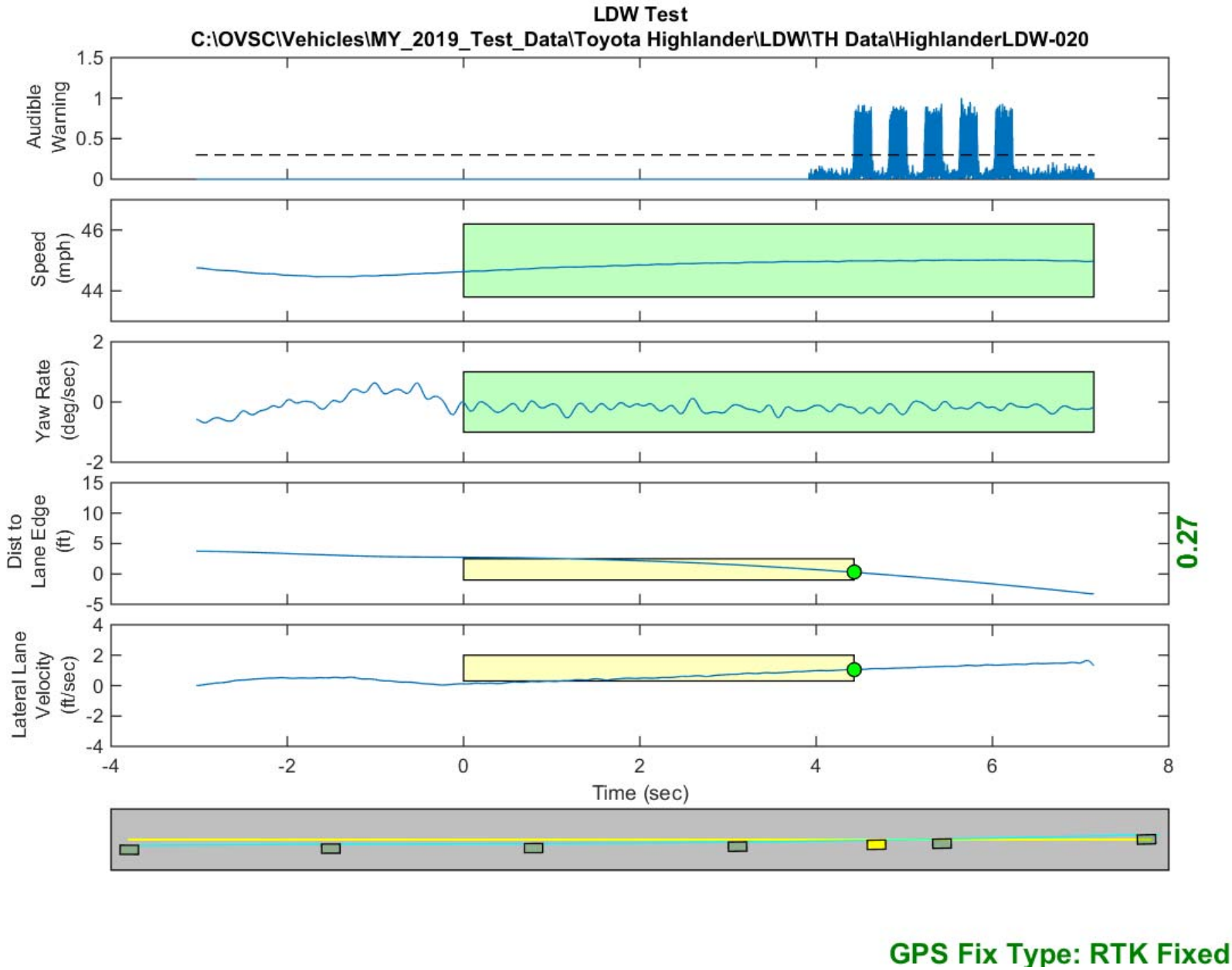


Figure D22. Time History for Run 20, Solid Line, Left Departure, Audible Warning

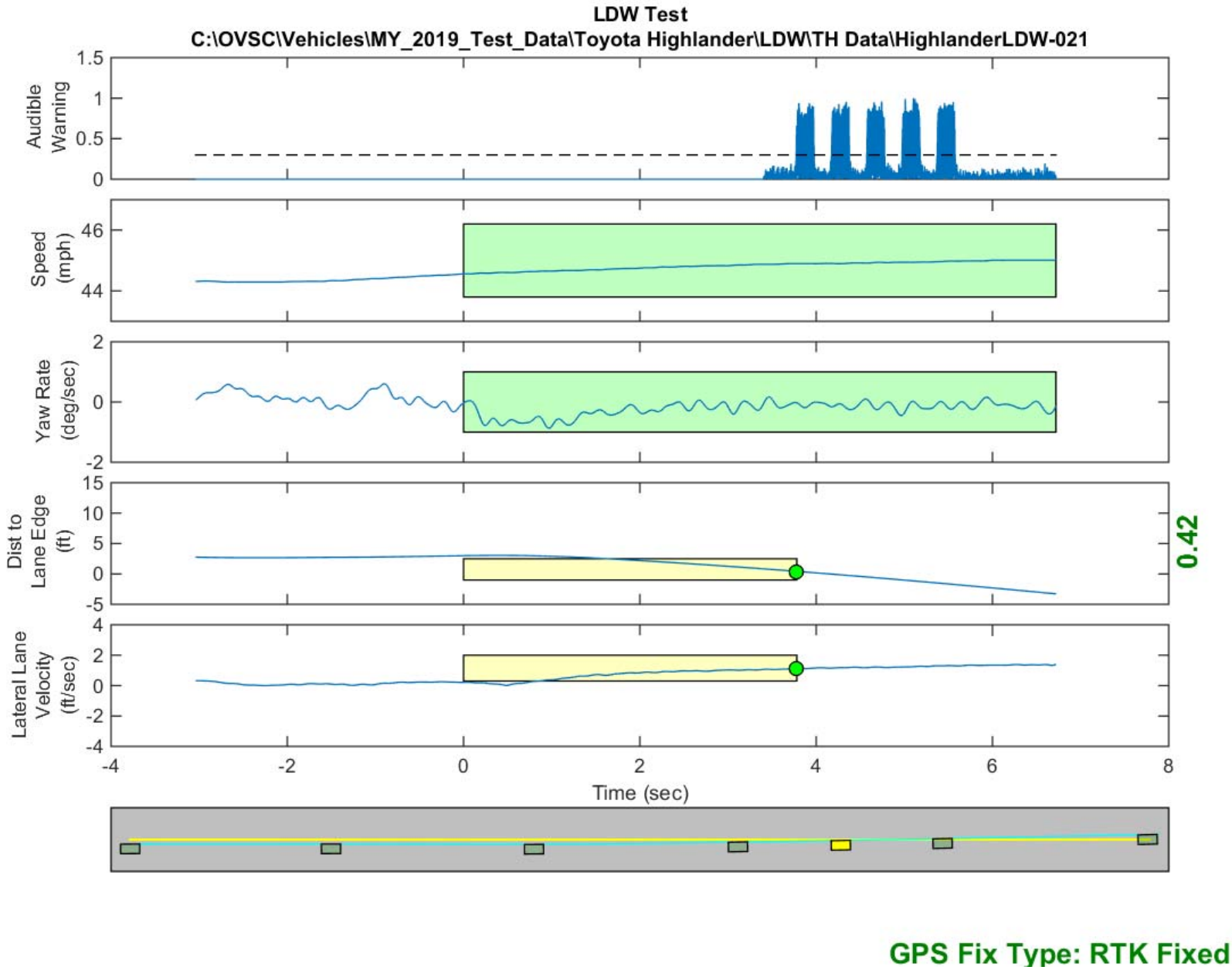


Figure D23. Time History for Run 21, Solid Line, Left Departure, Audible Warning

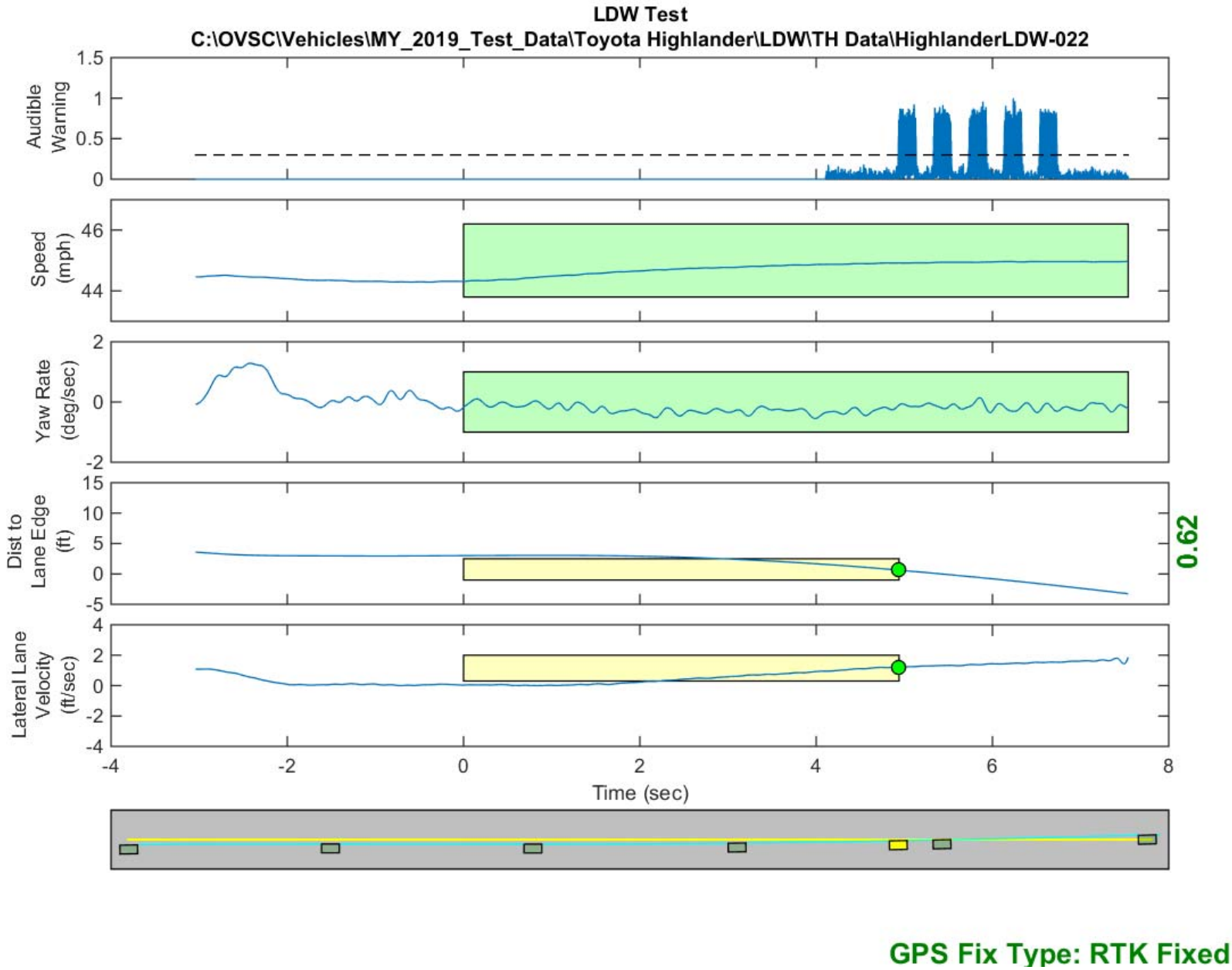


Figure D24. Time History for Run 22, Solid Line, Left Departure, Audible Warning

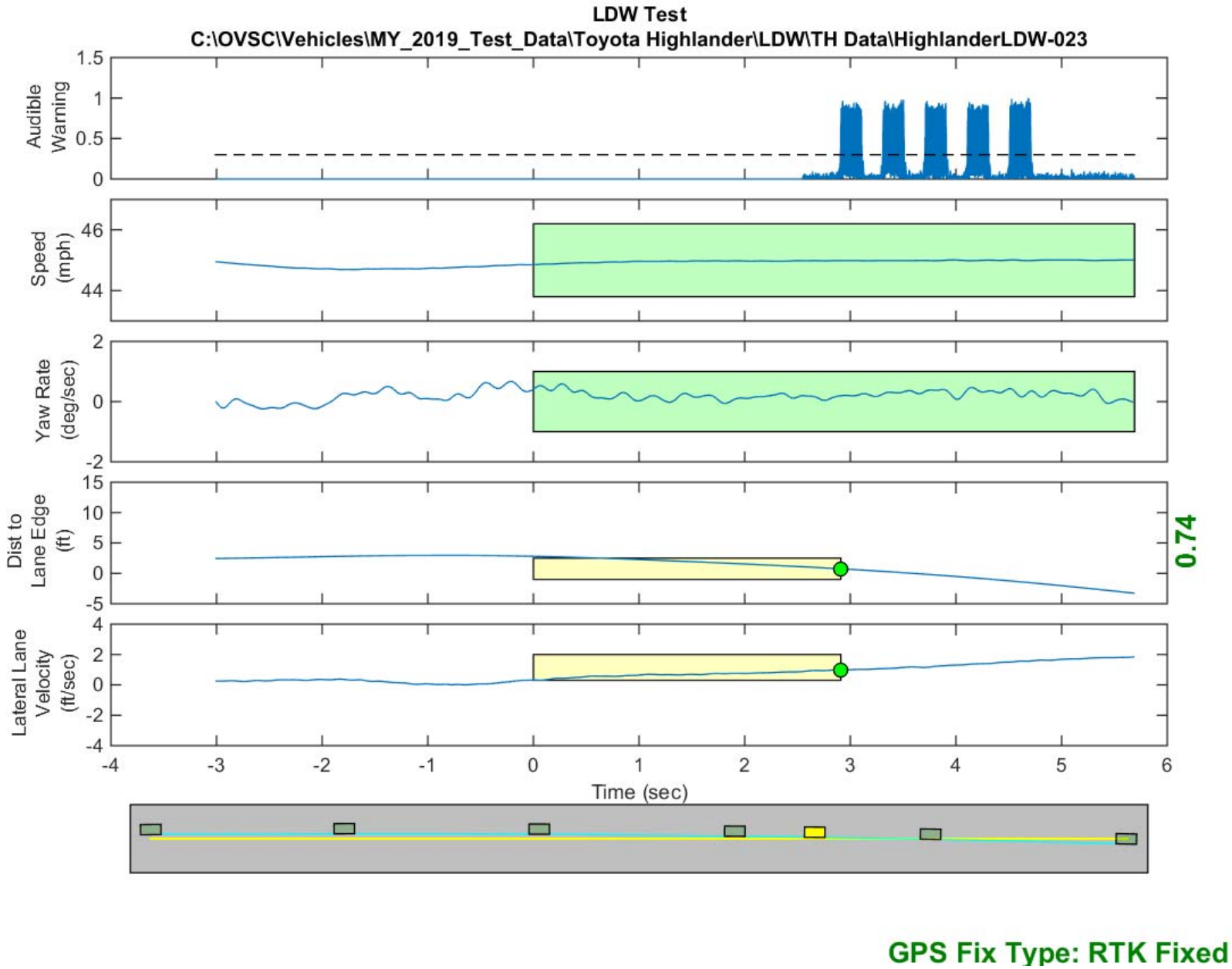


Figure D25. Time History for Run 23, Solid Line, Right Departure, Audible Warning

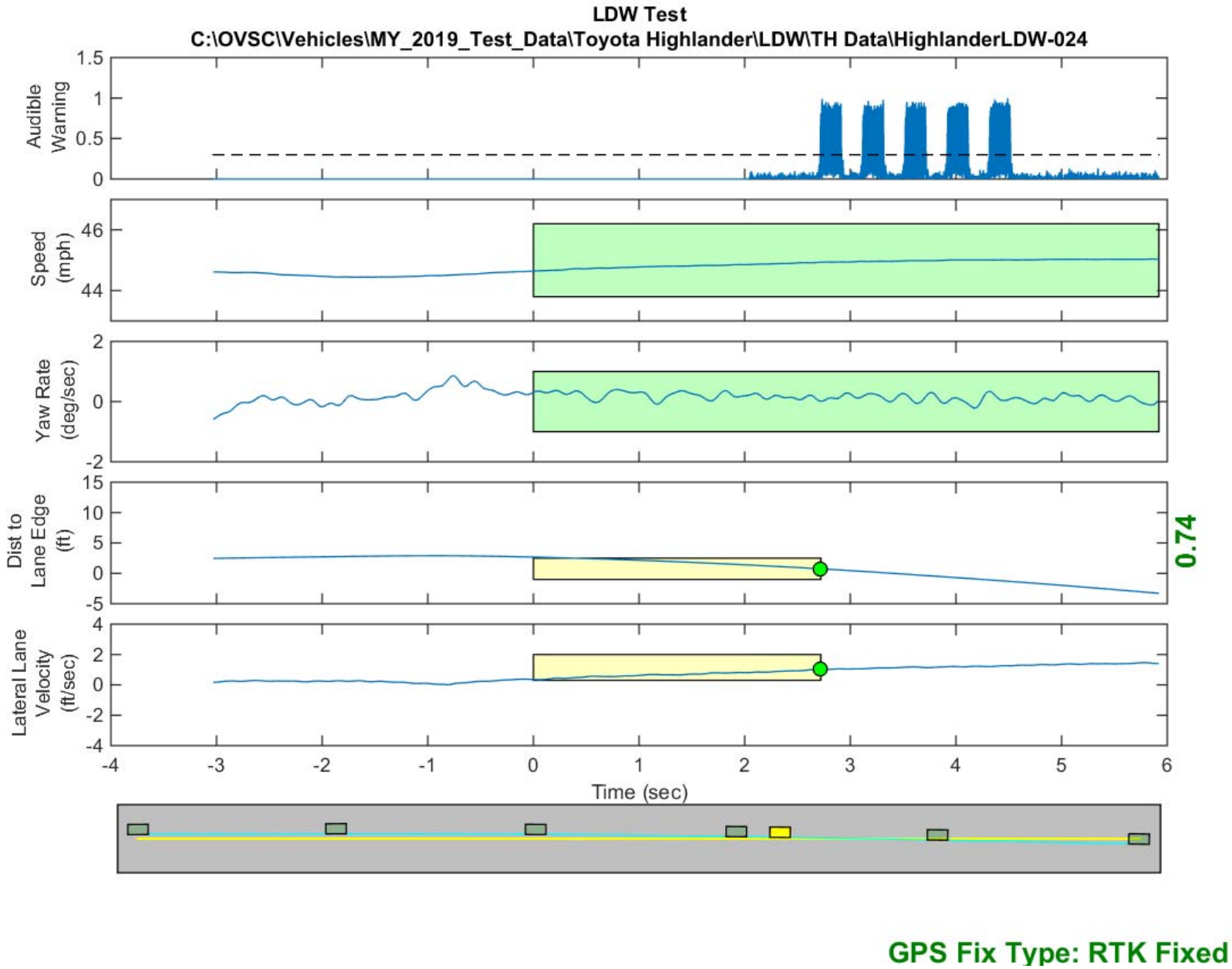


Figure D26. Time History for Run 24, Solid Line, Right Departure, Audible Warning

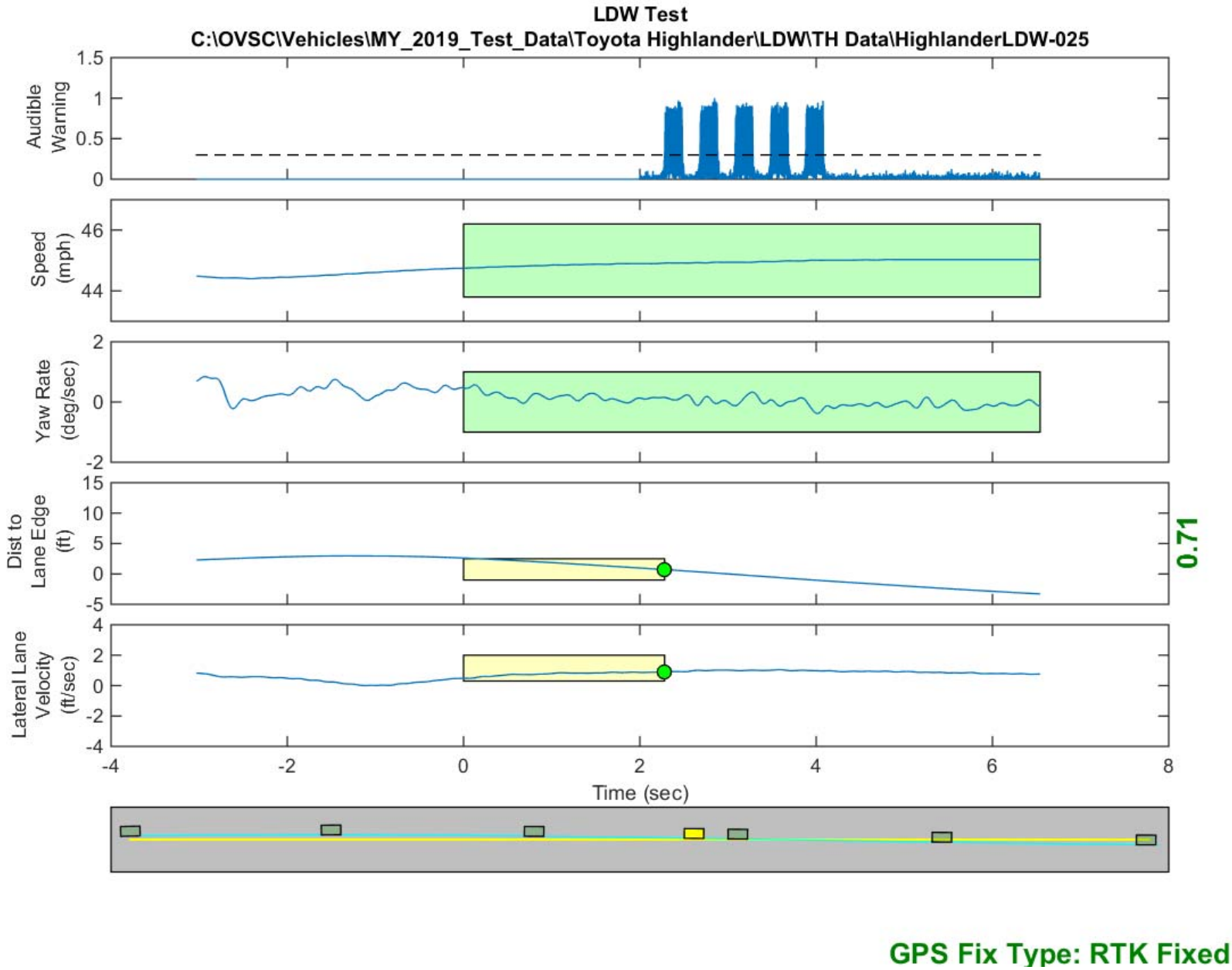


Figure D27. Time History for Run 25, Solid Line, Right Departure, Audible Warning

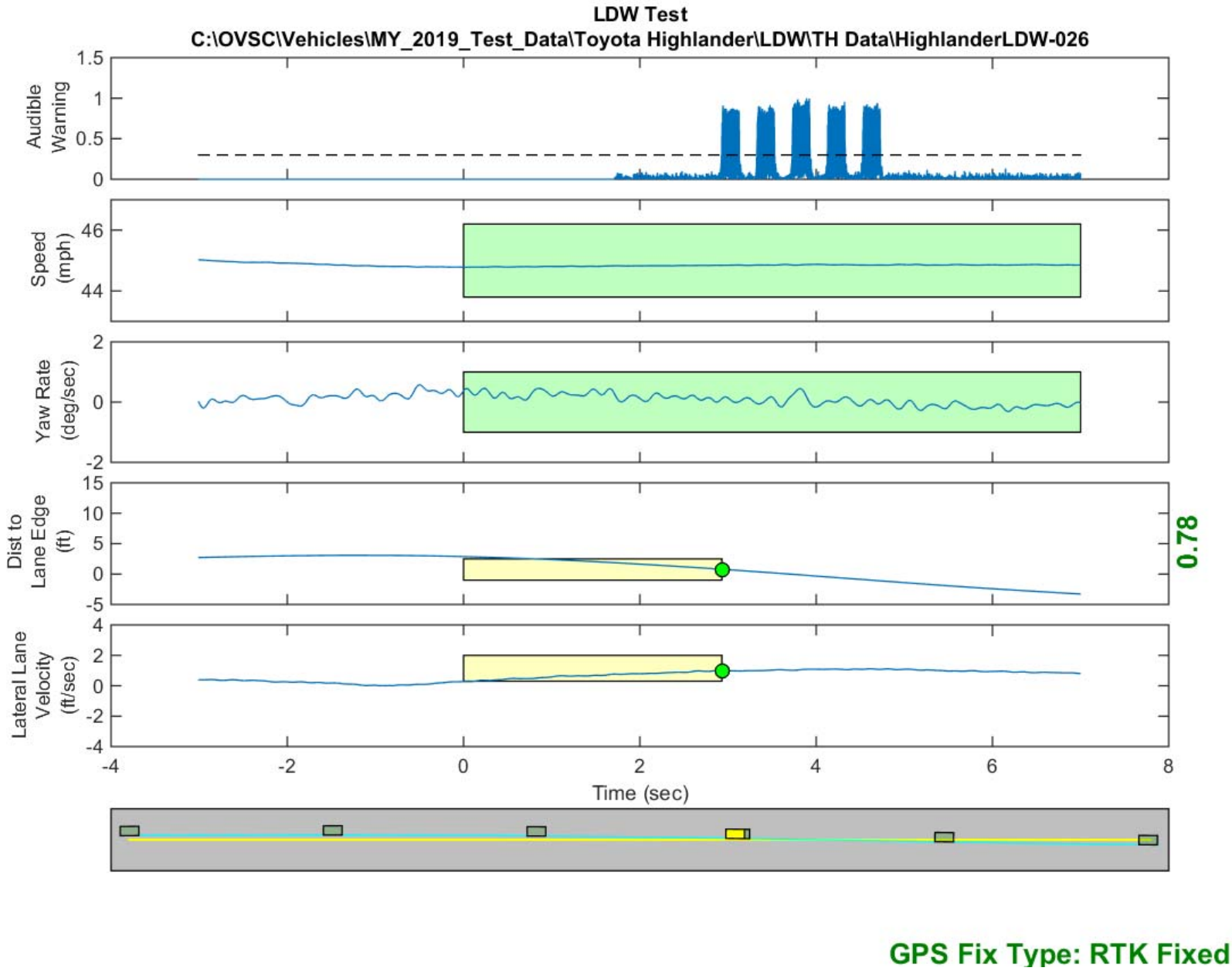


Figure D28. Time History for Run 26, Solid Line, Right Departure, Audible Warning

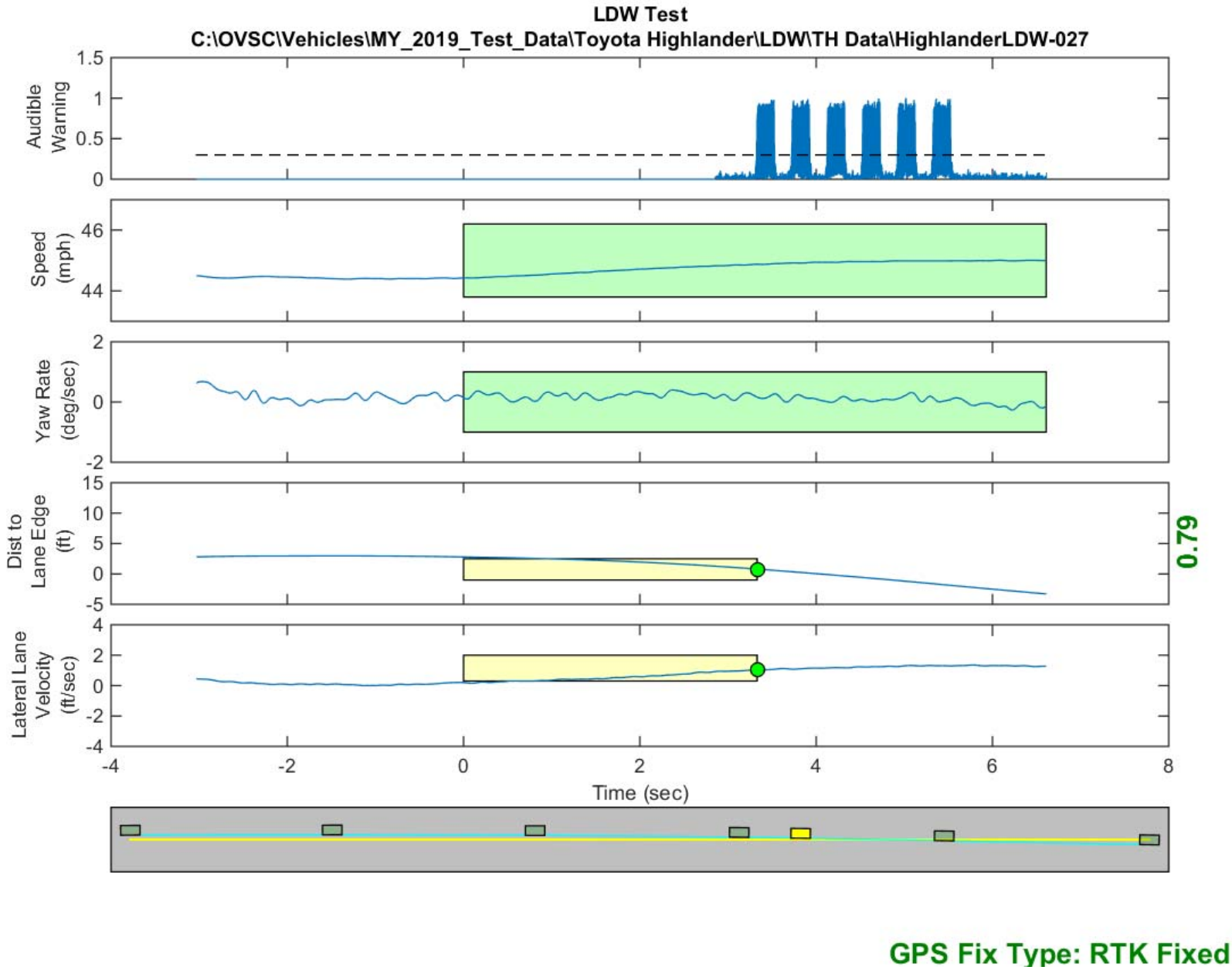


Figure D29. Time History for Run 27, Solid Line, Right Departure, Audible Warning

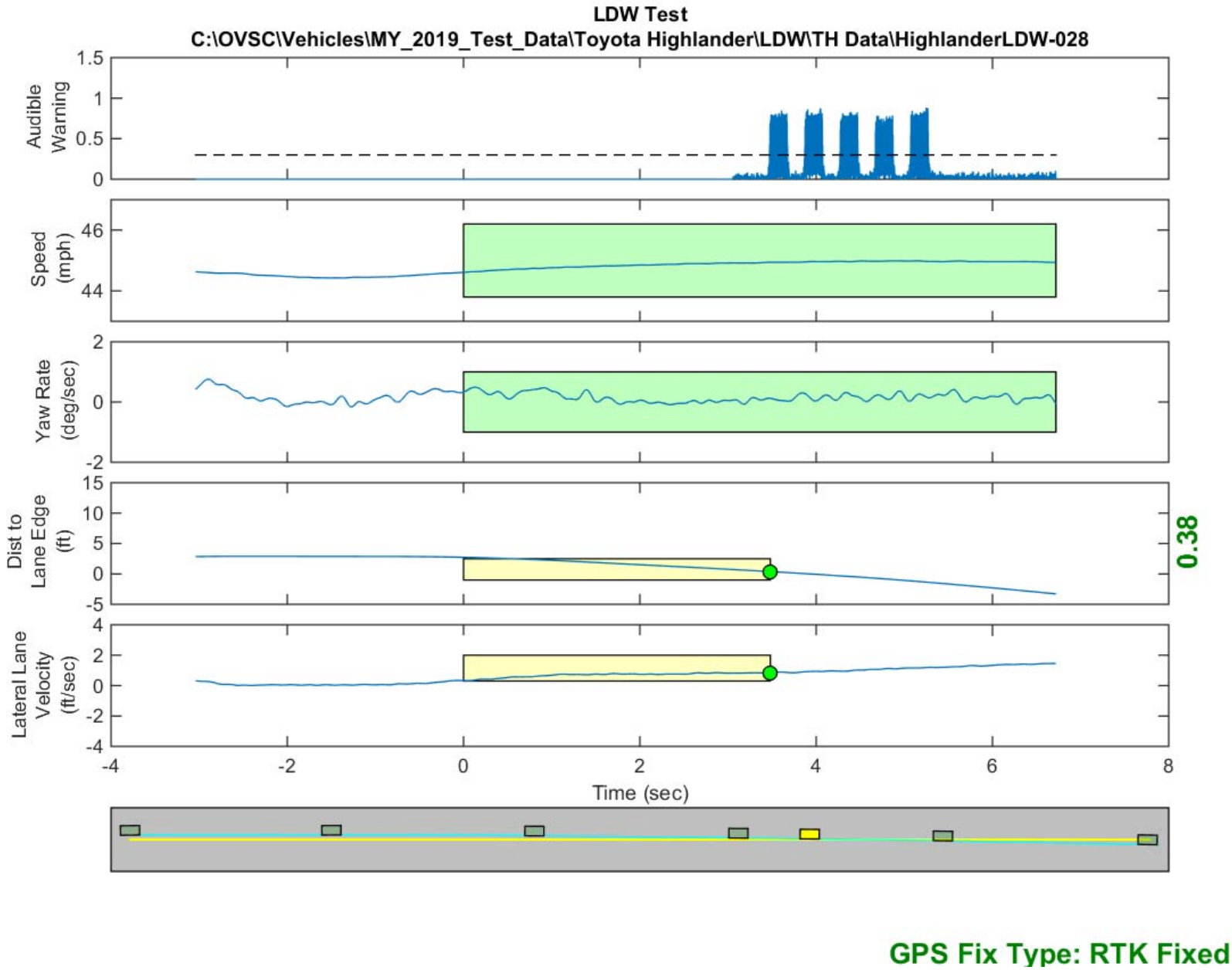


Figure D30. Time History for Run 28, Solid Line, Right Departure, Audible Warning

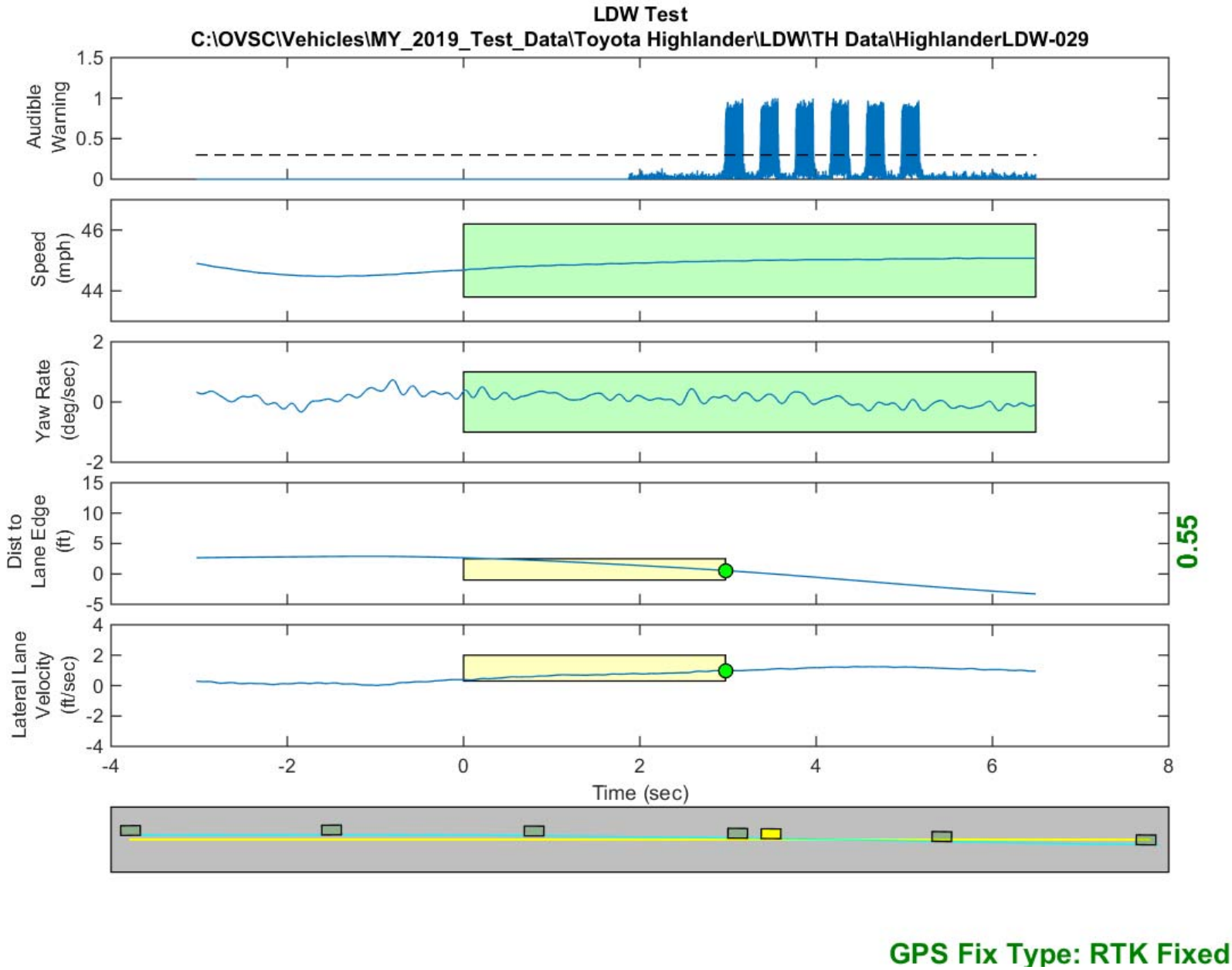


Figure D31. Time History for Run 29, Solid Line, Right Departure, Audible Warning

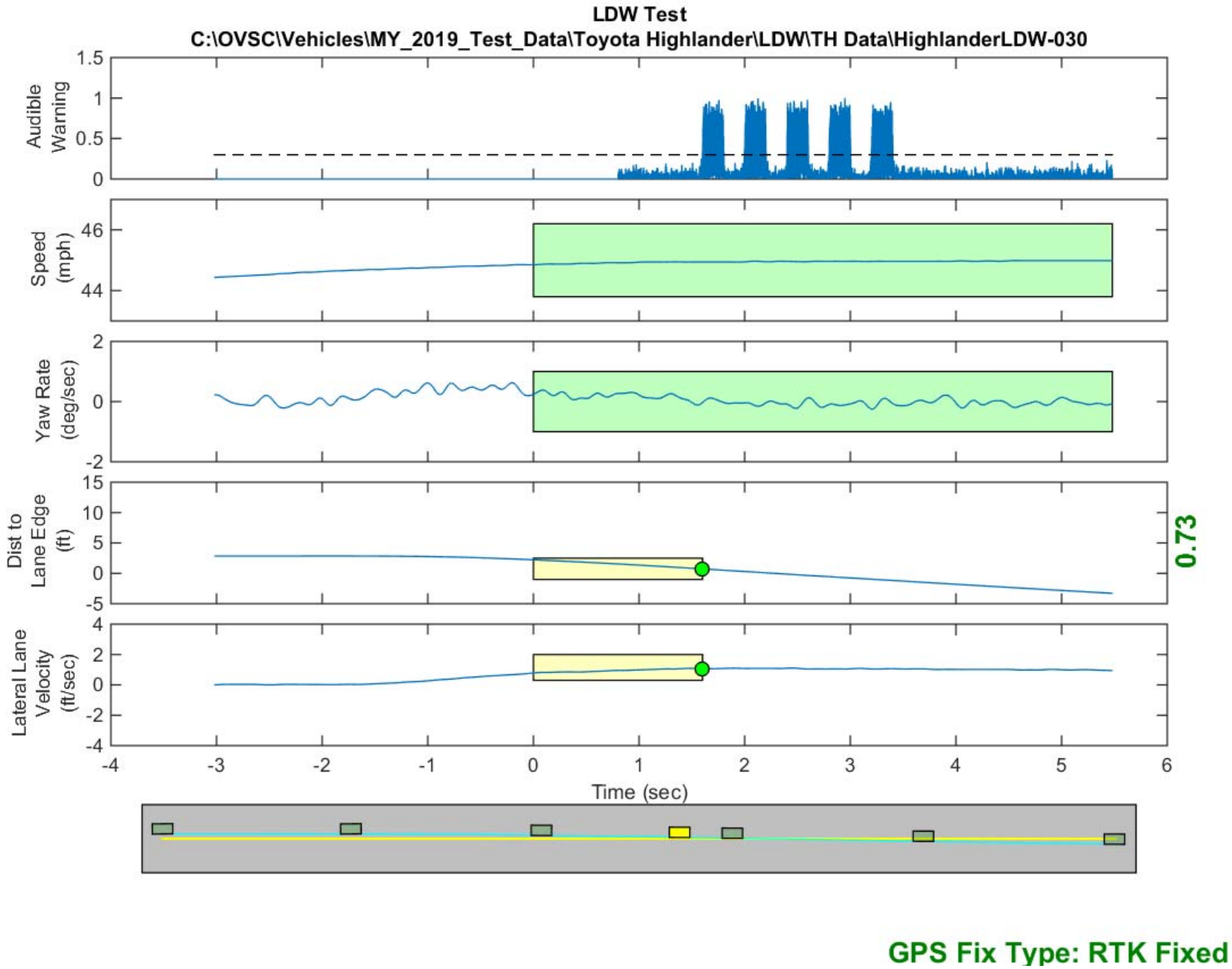


Figure D32. Time History for Run 30, Dashed Line, Right Departure, Audible Warning

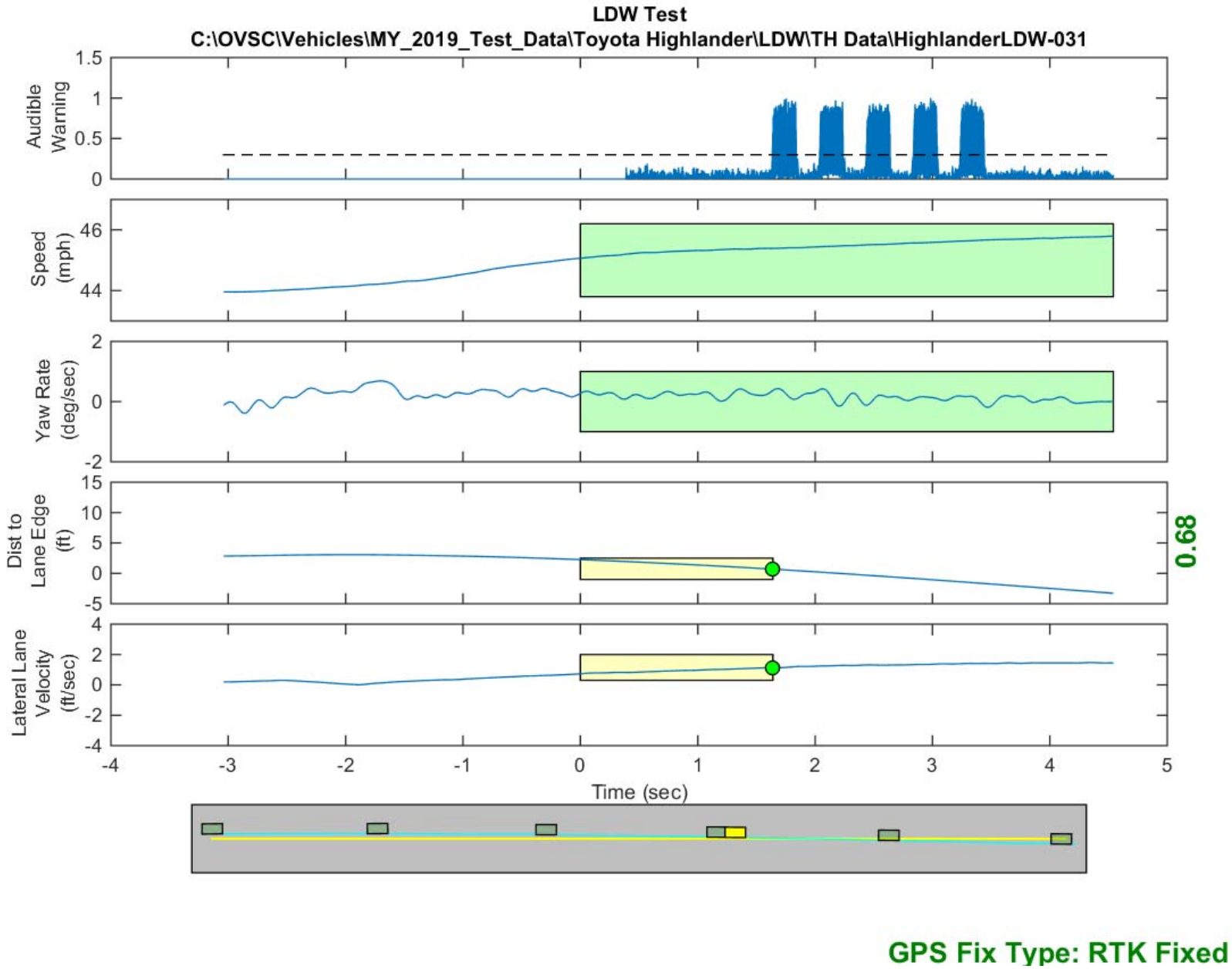


Figure D33. Time History for Run 31, Dashed Line, Right Departure, Audible Warning

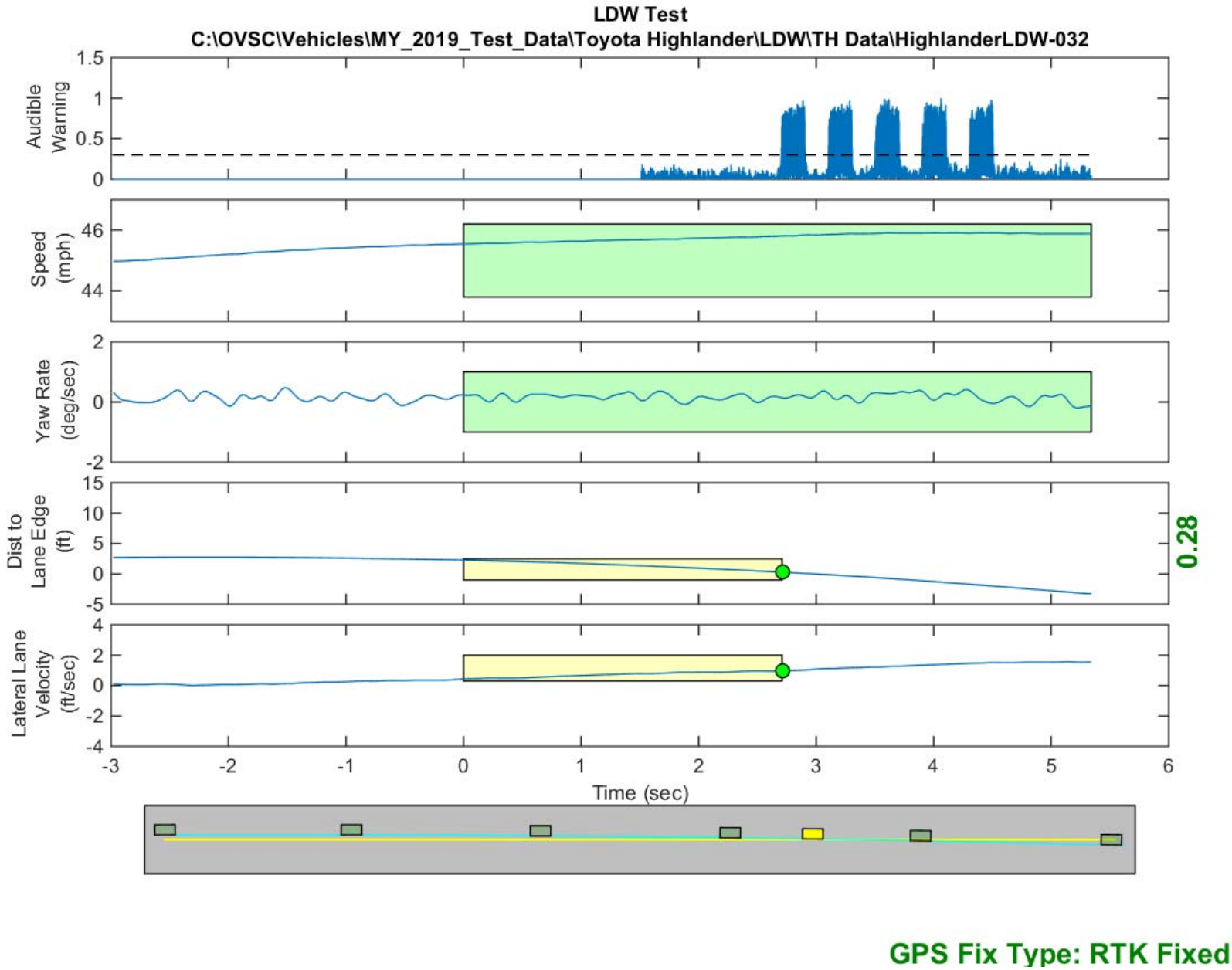


Figure D34. Time History for Run 32, Dashed Line, Right Departure, Audible Warning

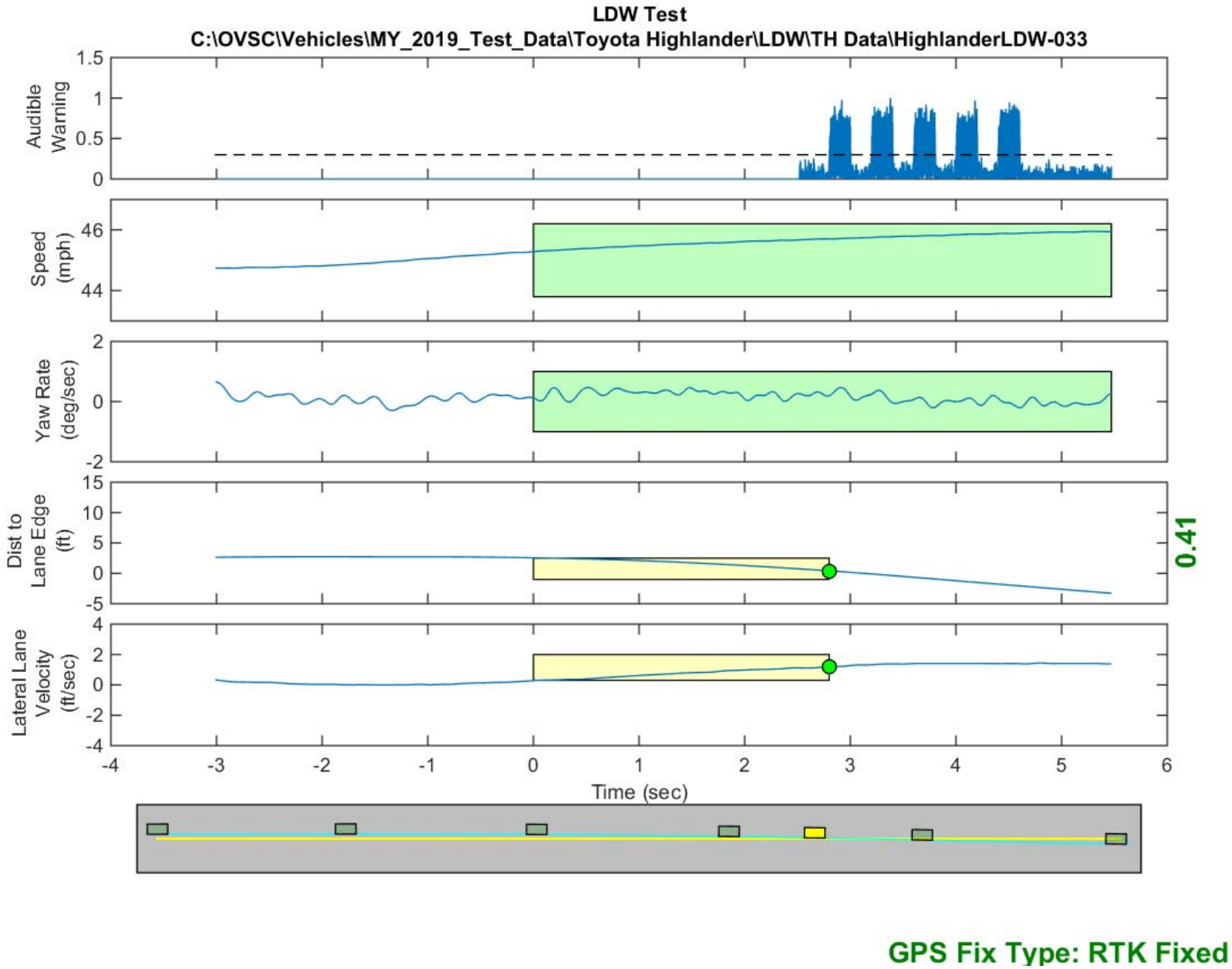


Figure D35. Time History for Run 33, Dashed Line, Right Departure, Audible Warning

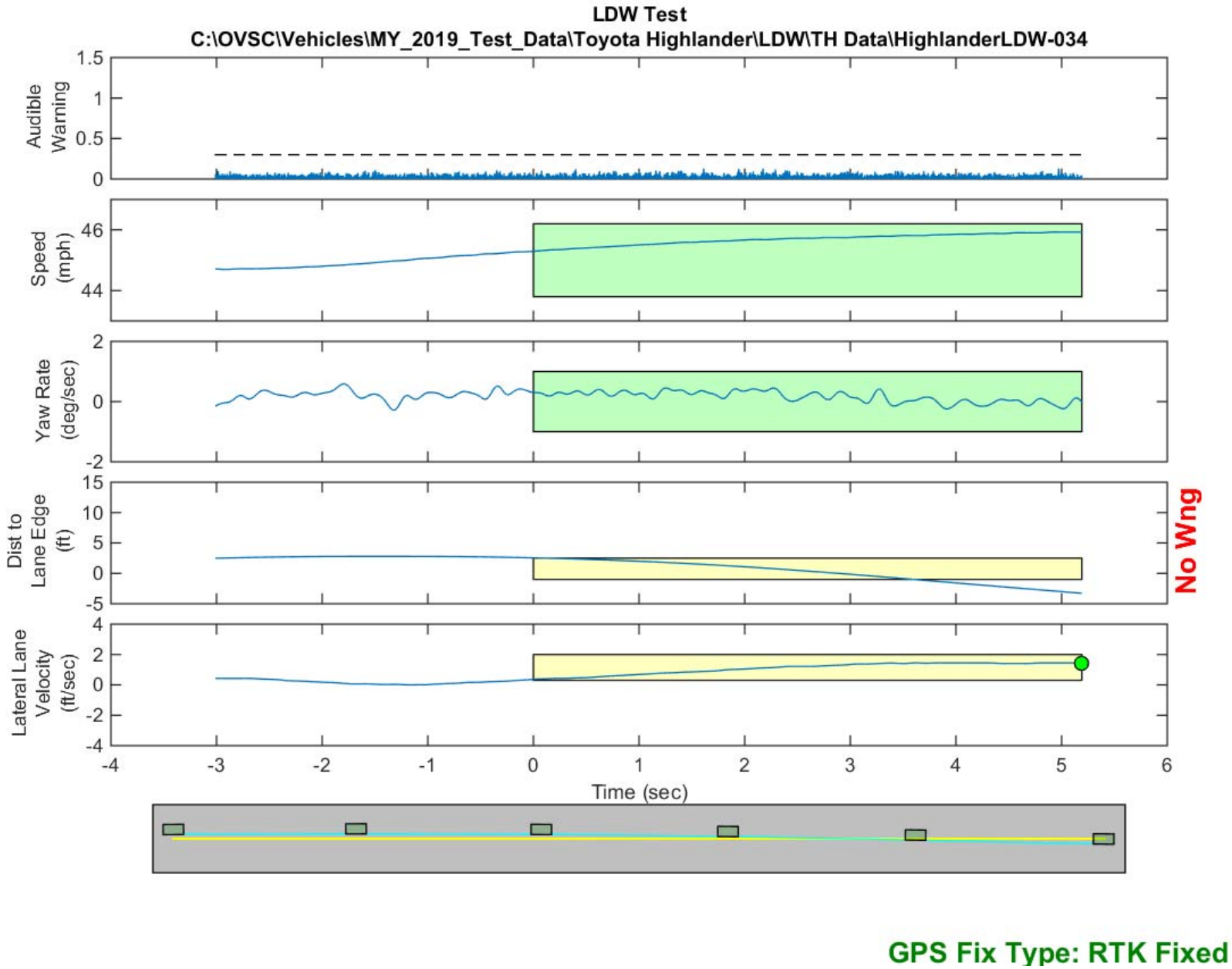


Figure D36. Time History for Run 34, Dashed Line, Right Departure, Audible Warning

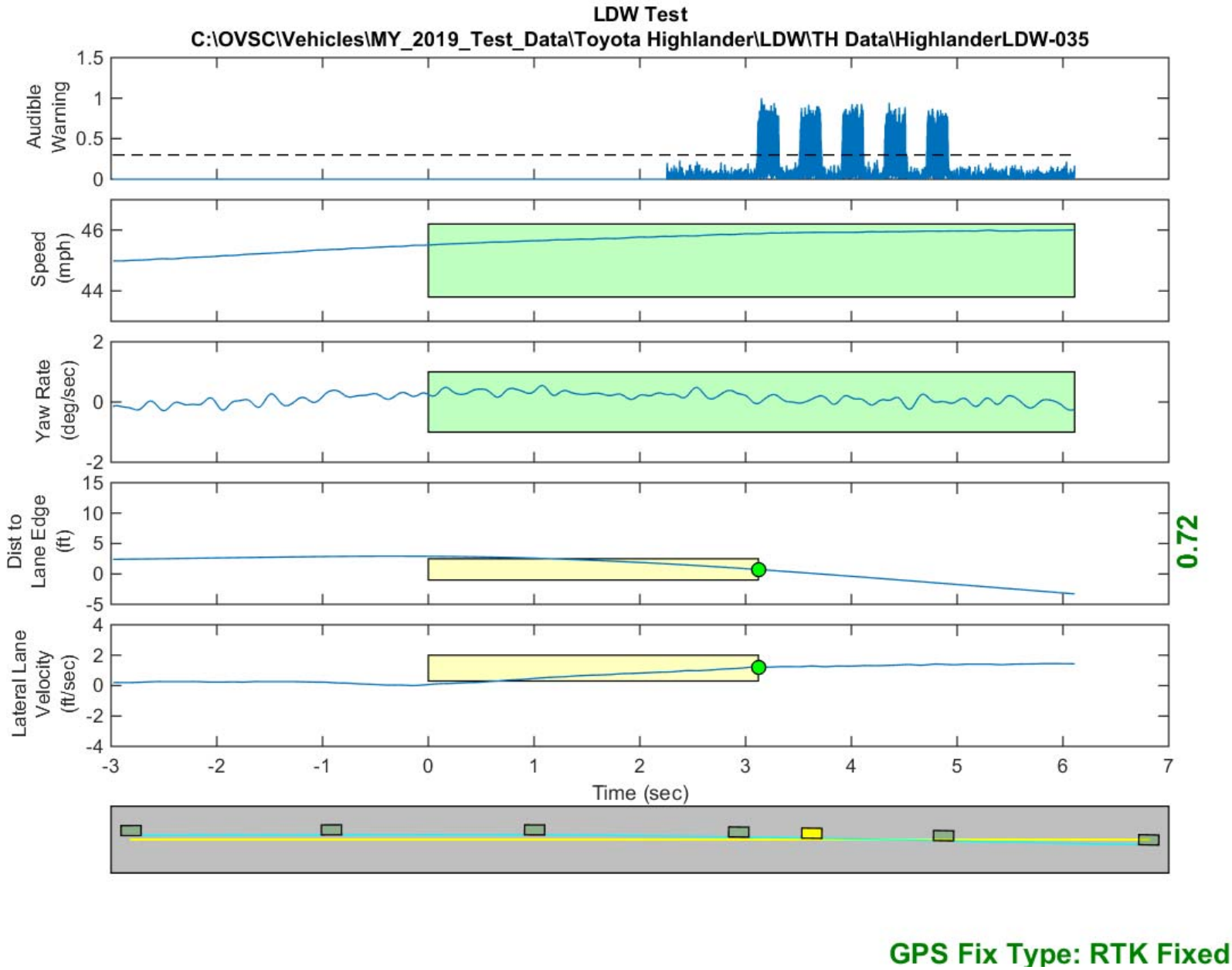


Figure D37. Time History for Run 35, Dashed Line, Right Departure, Audible Warning

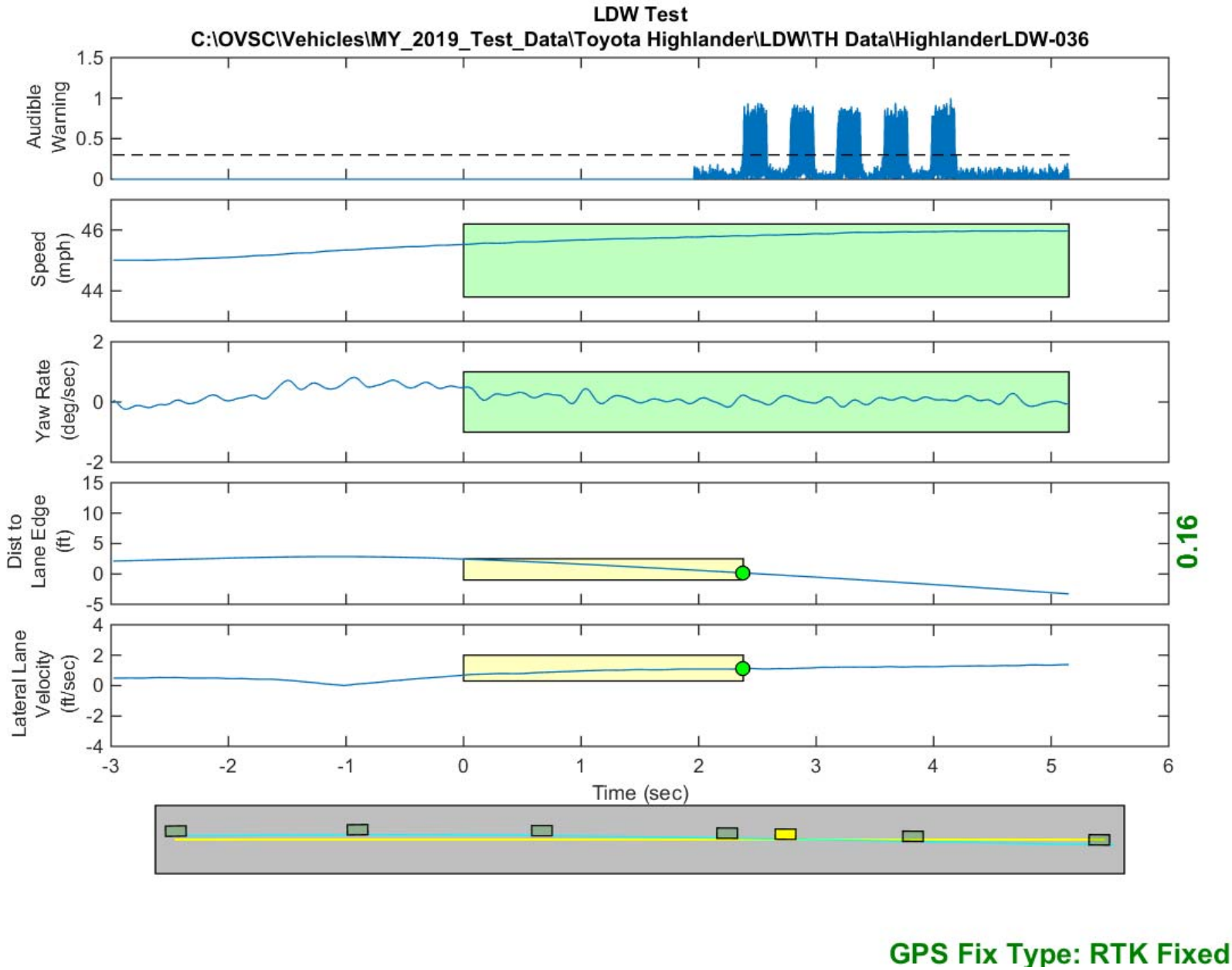


Figure D38. Time History for Run 36, Dashed Line, Right Departure, Audible Warning

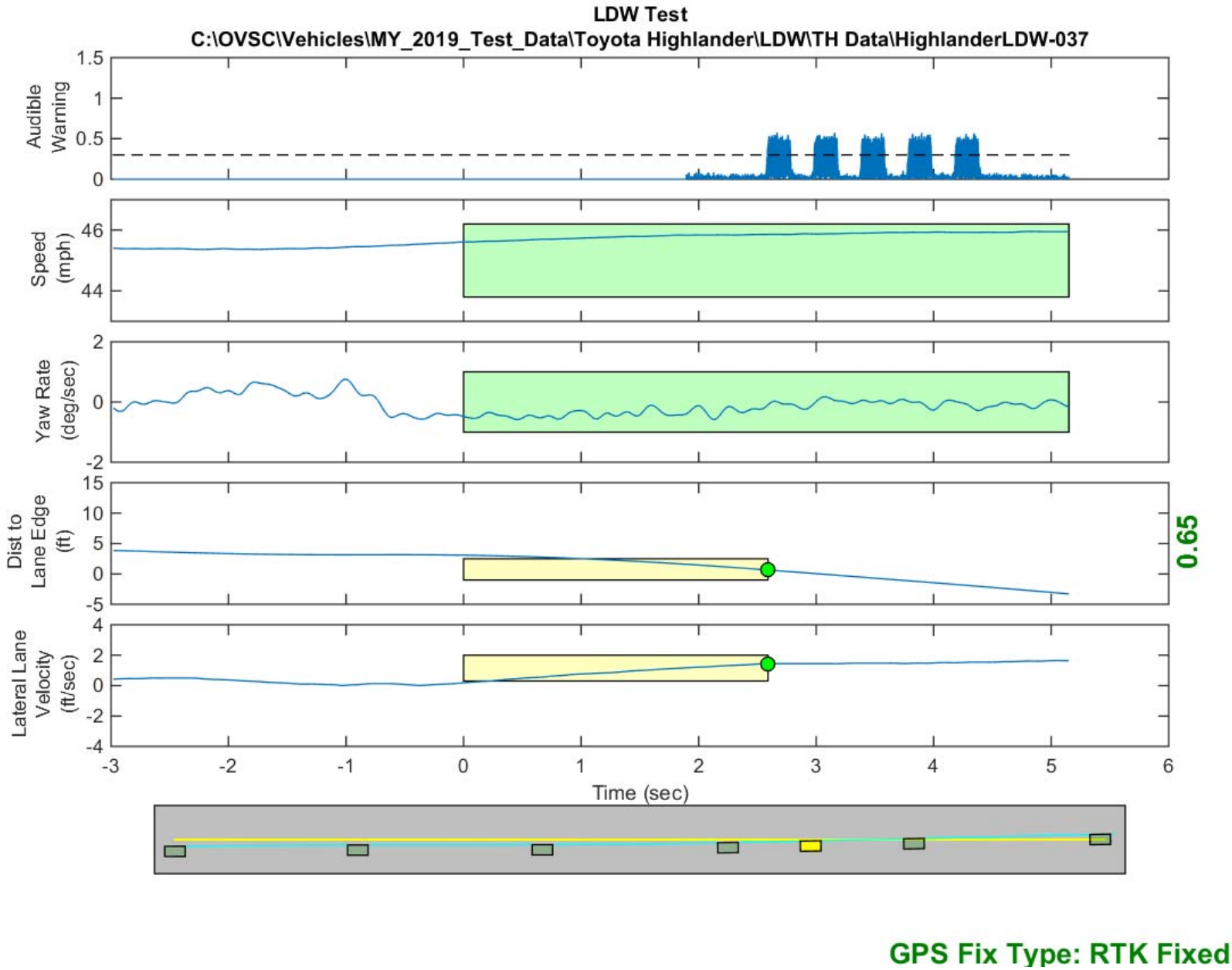


Figure D39. Time History for Run 37, Dashed Line, Left Departure, Audible Warning

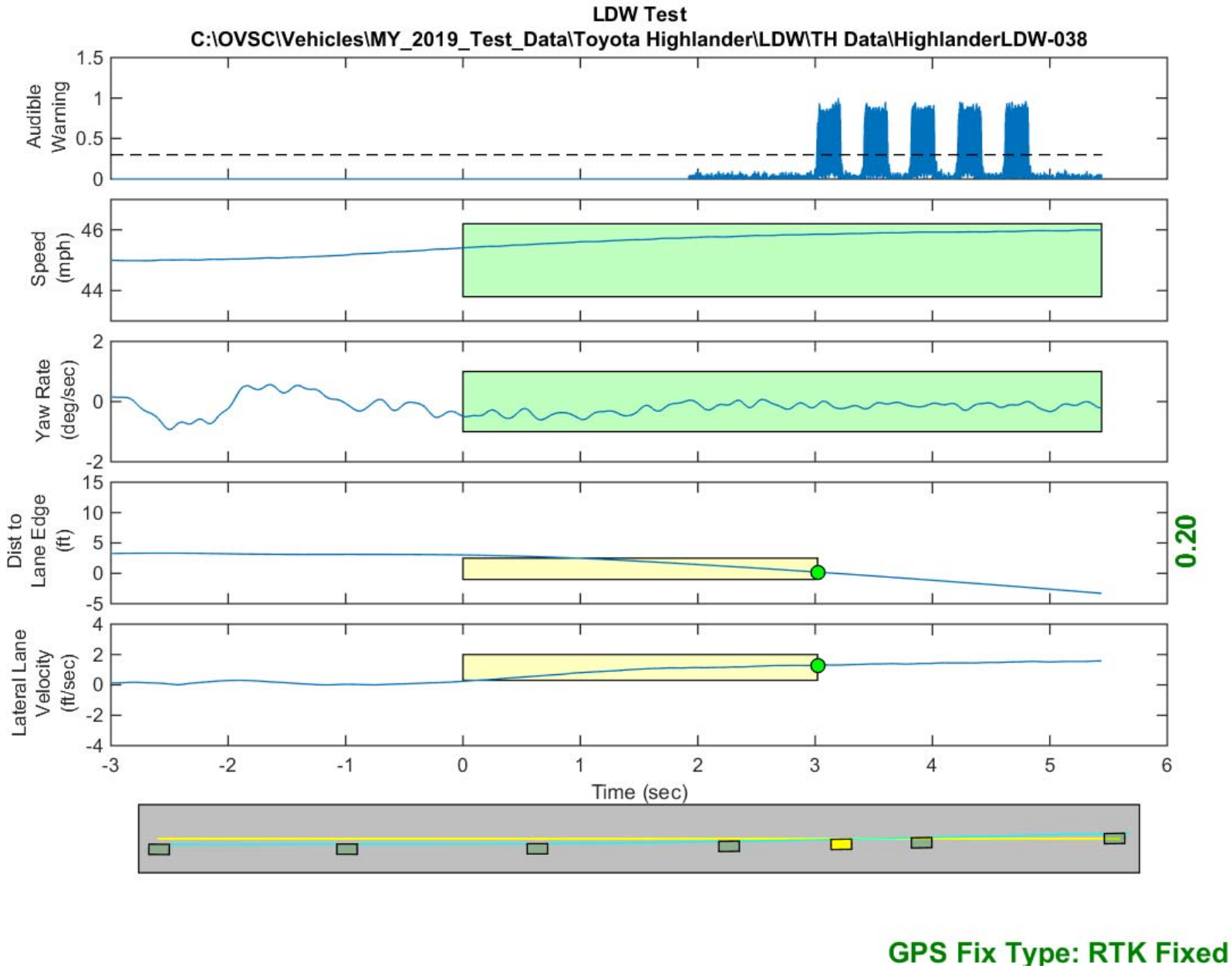


Figure D40. Time History for Run 38, Dashed Line, Left Departure, Audible Warning

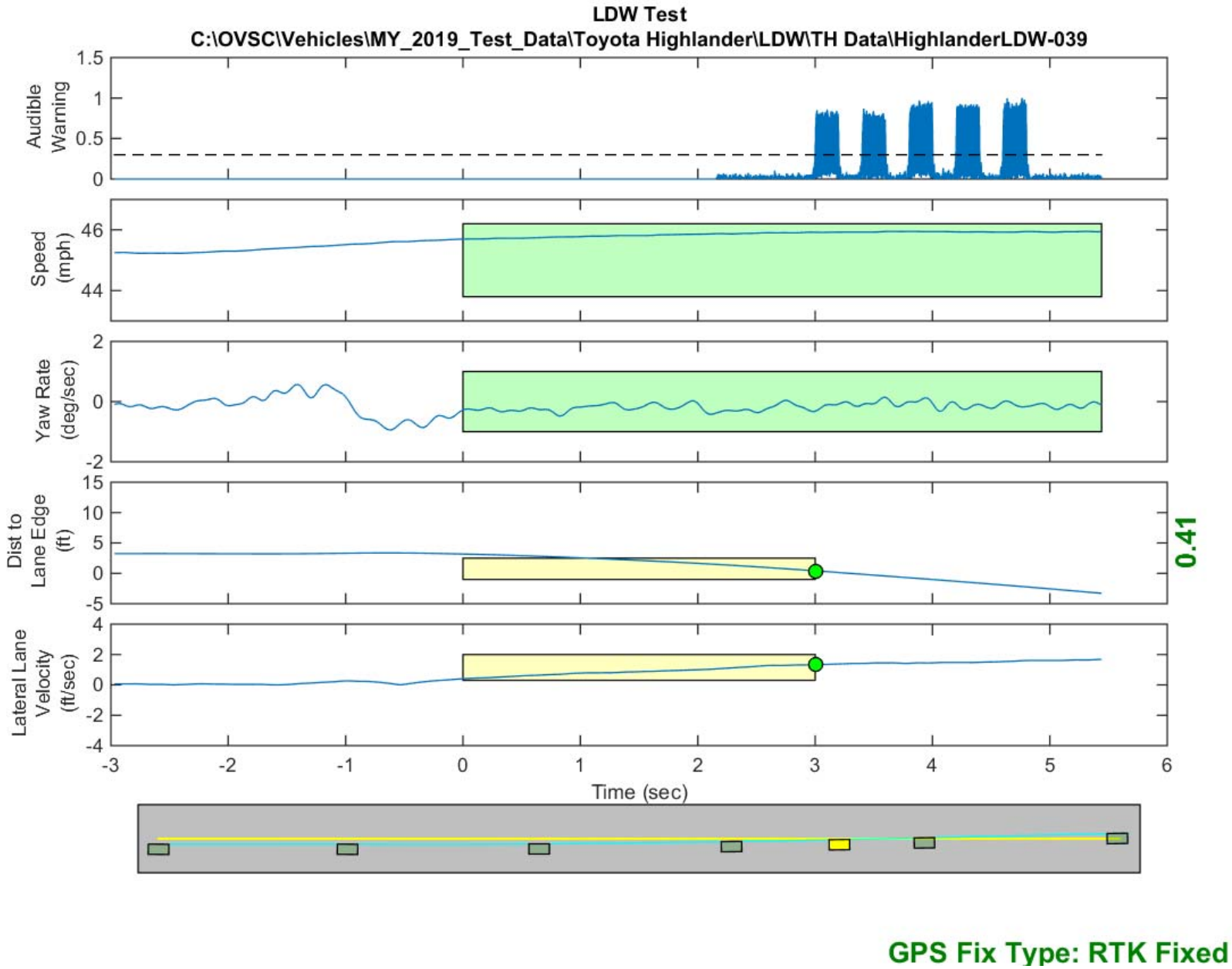


Figure D41. Time History for Run 39, Dashed Line, Left Departure, Audible Warning

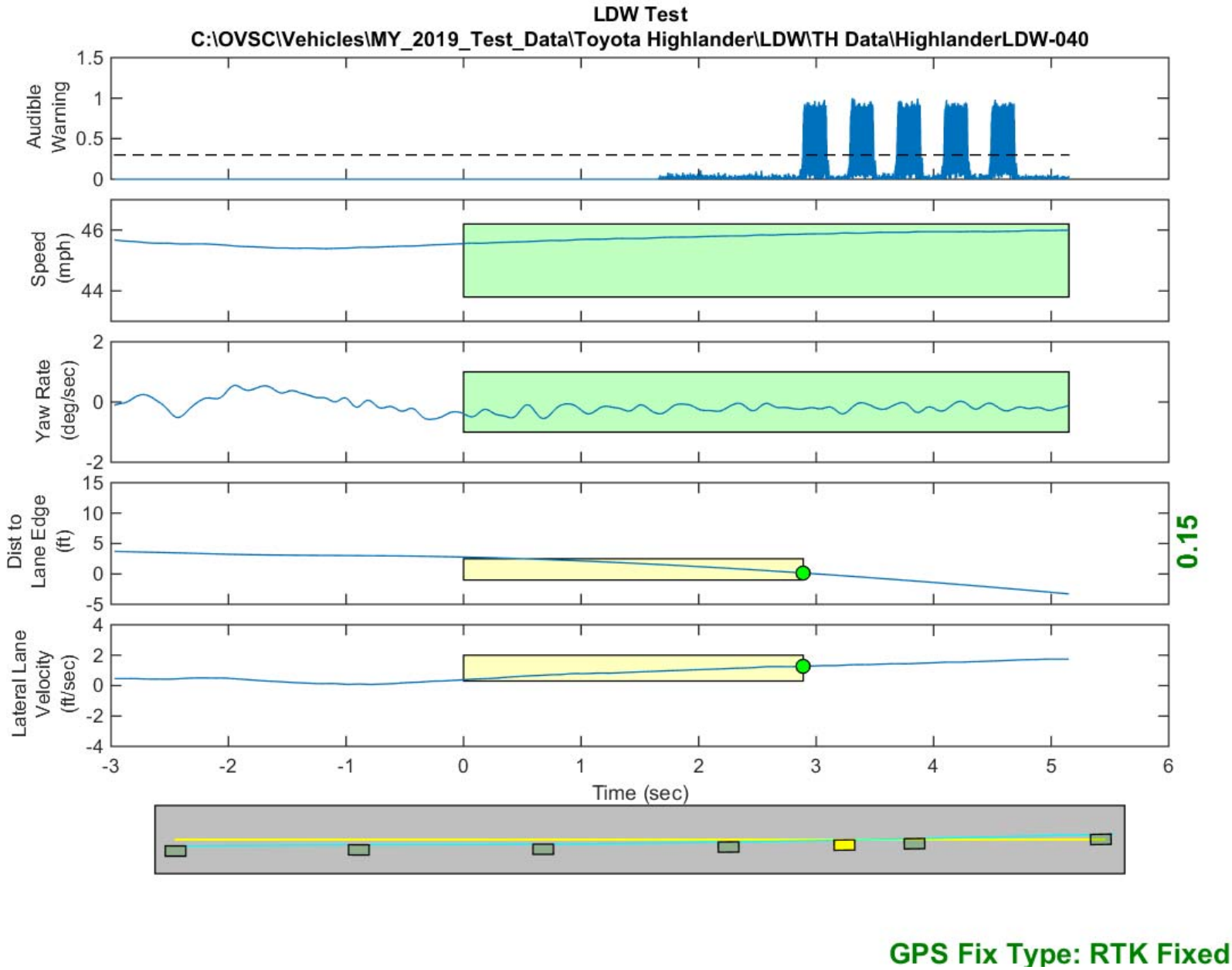


Figure D42. Time History for Run 40, Dashed Line, Left Departure, Audible Warning

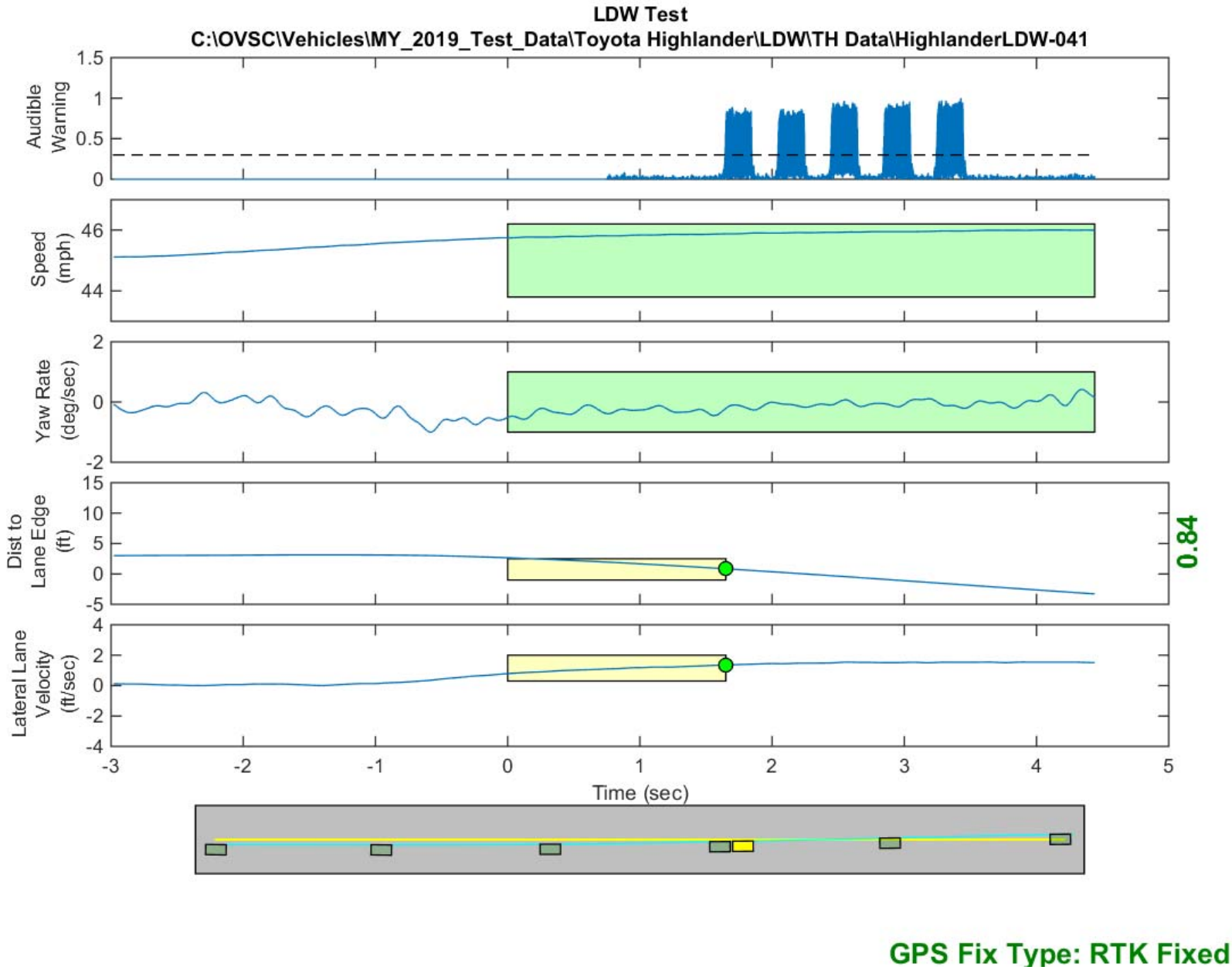


Figure D43. Time History for Run 41, Dashed Line, Left Departure, Audible Warning

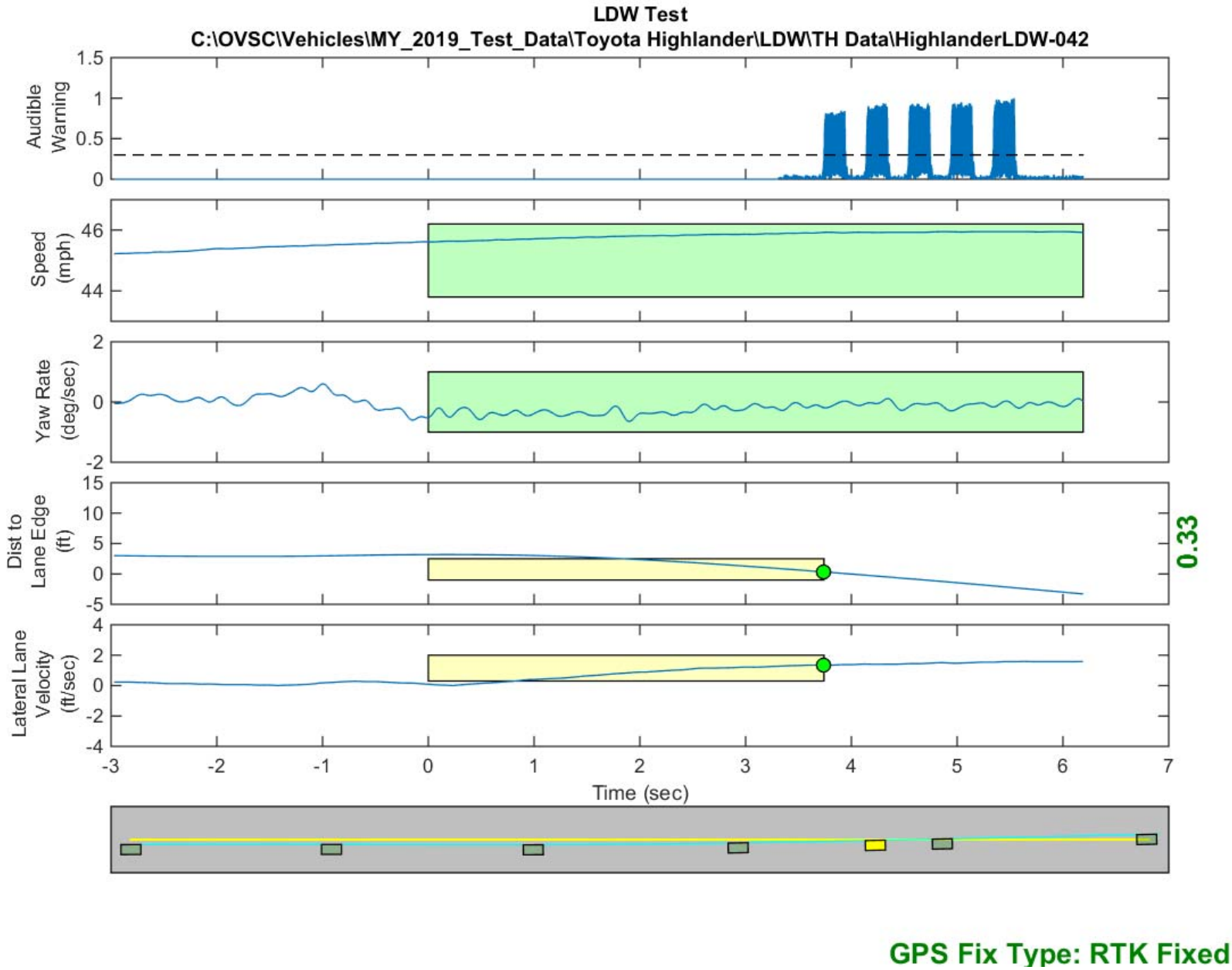


Figure D44. Time History for Run 42, Dashed Line, Left Departure, Audible Warning

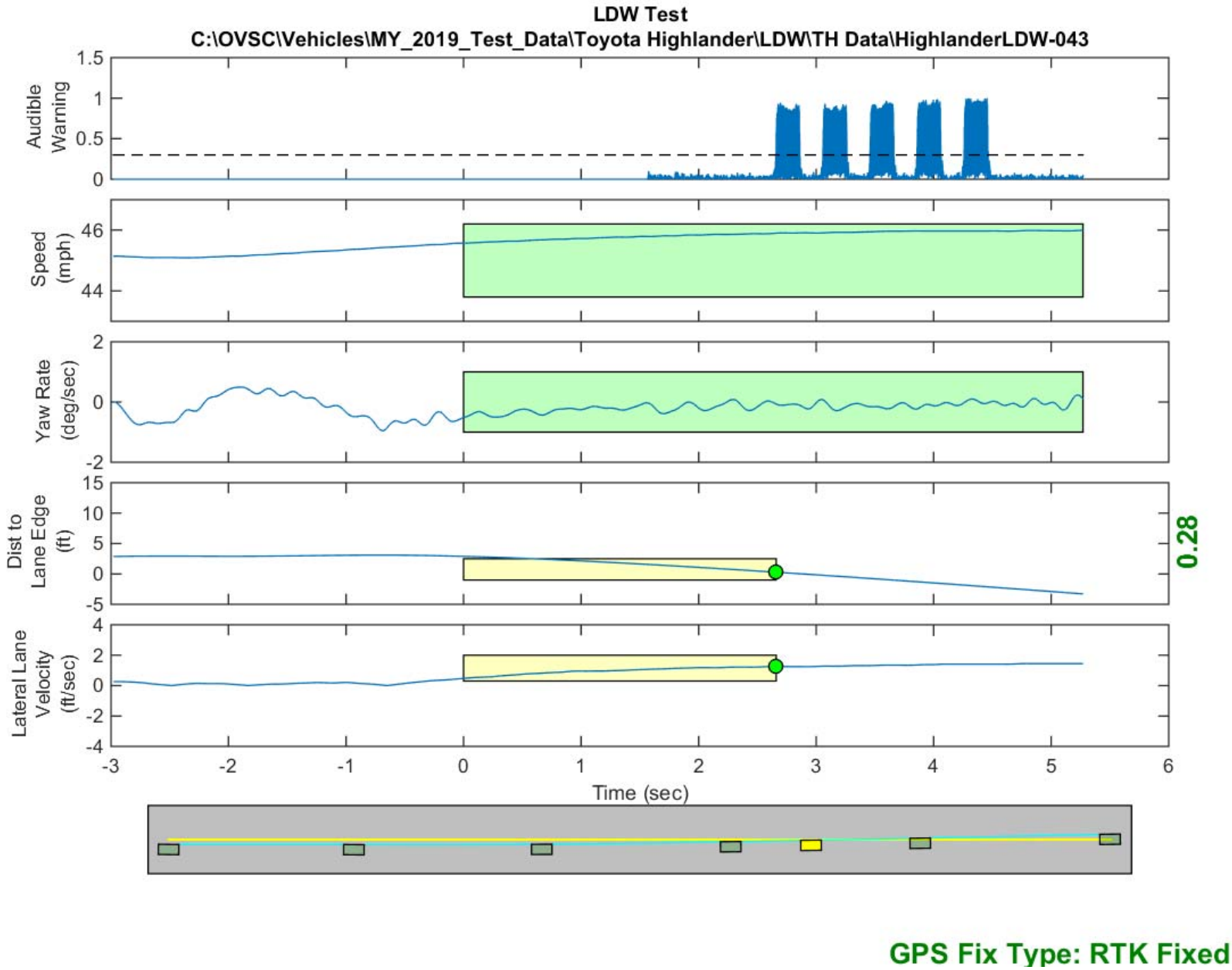


Figure D45. Time History for Run 43, Dashed Line, Left Departure, Audible Warning