NEW CAR ASSESSMENT PROGRAM
LANE DEPARTURE WARNING CONFIRMATION TEST
NCAP-DRI-LDW-20-12

2020 Lexus ES 350

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29 May 2020

Final Report

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

U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
New Car Assessment Program
1200 New Jersey Avenue, SE
West Building, 4th Floor (NRM-110)
Washington, DC 20590

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16. Abstract These tests were conducted on the subject 2020 Lexus ES 350 in accordance with the specifications of the New Car Assessment Program's (NCAP) 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 2020 Lexus ES 350 . The LDW system for this vehicle provides both visual and audible 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" dated 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, infrared, 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 RESULTS SUMMARY

(Page 1 of 1)

2020 Lexus ES 350

VIN: *58ADZ1B17LU06xxxx*

Test Date: *1/14/2020*

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*

Notes:

LANE DEPARTURE WARNING

DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2020 Lexus ES 350

TEST VEHICLE INFORMATION

VIN: *58ADZ1B17LU06xxxx*

Body Style: *4-door Sedan* Color: *Eminent White*

Date Received: *1/6/2020* Odometer Reading: *6 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

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

Date of manufacture: *11/19*

Vehicle Type: *PASS. CAR*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *235/45R18*

Rear: *235/45R18*

Recommended cold tire pressure: Front: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

TIRES

Tire manufacturer and model: *Michelin Energy Saver A/S*

Front tire size: *235/45R18 94V*

Rear tire size: *235/45R18 94V*

Front tire DOT prefix: *B9EL 02NX*

Rear tire DOT prefix: *B9EL 02NX*

LANE DEPARTURE WARNING

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Lexus ES 350

GENERAL INFORMATION

Test date: *1/14/2020*

AMBIENT CONDITIONS

Air temperature: *13.9 C (57 F)*

Wind speed: *1.3 m/s (2.9 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: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

LANE DEPARTURE WARNING

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2020 Lexus ES 350

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*551.6 kg (1216 lb)*	Right Front:	*545.2 kg (1202 lb)*
Left Rear:	*381.5 kg (841 lb)*	Right Rear:	*359.2 kg (792 lb)*
		Total:	*1837.5 kg (4051 lb)*

LANE DEPARTURE WARNING

DATA SHEET 4: LANE DEPARTURE WARNING SYSTEM OPERATION

(Page 1 of 4)

2020 Lexus ES 350

Name of the LDW option, option package, etc.:

Lane Tracing Assist (LTA) as part of the Lexus Safety System+ 2.0 (LSS+ 2.0) option

Lane Departure Warning Setting used in test: *High Sensitivity, Auditory Alert on*

Type of sensor(s) used: *Camera*

How is the Lane Departure Warning presented to the driver?

(Check all that apply)

- **X** Warning light
- **X** Buzzer or audible alarm
- **X** 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 system provides two type of visual warnings as well as an option for either an auditory or haptic alert. The haptic alert is presented as a vibration of the steering wheel and is the default setting. The auditory warning is presented as a series of beeps with a frequency of 1579 Hz approximately 2.5 times per second.

(continued next page)

The first of the visual displays is a Lane Tracing Alert (LTA) indicator located to the lower left of the tachometer. It depicts an overhead view of a vehicle crossing a lane line. The illumination condition of the indicator informs the driver of the system operation status.

Illuminated in white:

LTA system is operating.

Illuminated in green:

Steering wheel assistance of the steering assist function or lane centering function is operating.

Flashing in orange:

Lane departure alert function is operating.

The second visual alert is displayed when the multi-information display is switched to the driving assist system information screen. It depicts the front portion of a vehicle hood with lane lines on both sides. When the lines are white it indicates that the system is recognizing white (yellow) lines or a course. When the vehicle departs from its lane, the white line displayed on the side the vehicle departs from flashes orange. If the lanes are black, it indicates that the system is not able to recognize the lane lines or is temporarily cancelled.

See Appendix B, Pages B-10 and B 11 (Owner's Manual, Pages 187 and 188), and also Appendix A, Figure A12.

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 LTA (LDW) on/off switch is located on the right side of the steering wheel. See Figure A9 in Appendix A.

Press the LTA switch to turn the LTA system on. The LTA indicator illuminates and a message is displayed on the multi-information display.

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

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

Is the vehicle equipped with a control whose purpose is to adjust the range setting or otherwise influence the operation of LDW?	**X**	Yes
	_____	No

If yes, please provide a full description.

The LDW portion of the LTA systems allows the LDW to be switched between haptic or auditory alert and also allows selection of either Std or High sensitivity.

The menus are accessed using controls located on the left side of the steering wheel. The controls are shown in Figure A10 and the menus are shown in Figure A11 of Appendix A.

The < and > buttons are used to scroll across to the settings menu indicated by a gear. Selection brings up a list of settings including those for LDW Alert type and sensitivity.

For this test, the options chosen were auditory warning and High sensitivity. For testing, alert onset is generally more reliably detected from auditory warnings.

LANE DEPARTURE WARNING

DATA SHEET 4: LANE DEPARTURE WARNING SYSTEM OPERATION

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2020 Lexus ES 350

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.

Detailed descriptions of the limitations of the system are given on pages 182-185 of the Owner's Manual, shown in Appendix B pages B-5 through B-8.

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.

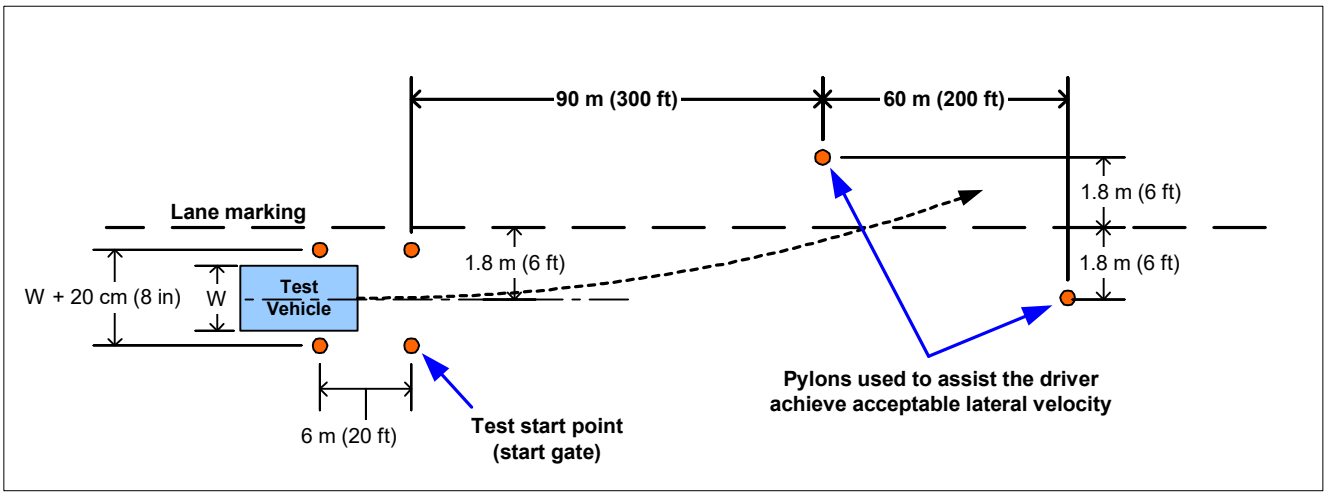


Figure 1. Position of Cones Used to Assist Driver

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 New Car Assessment Program's 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.

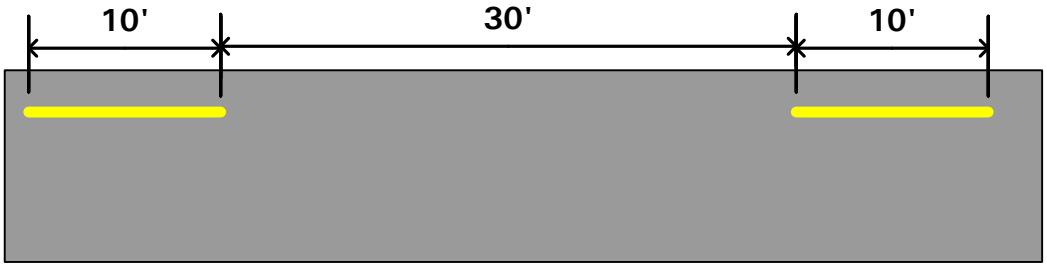


Figure 2. MUTCD Discontinuous Dashed Line Specifications

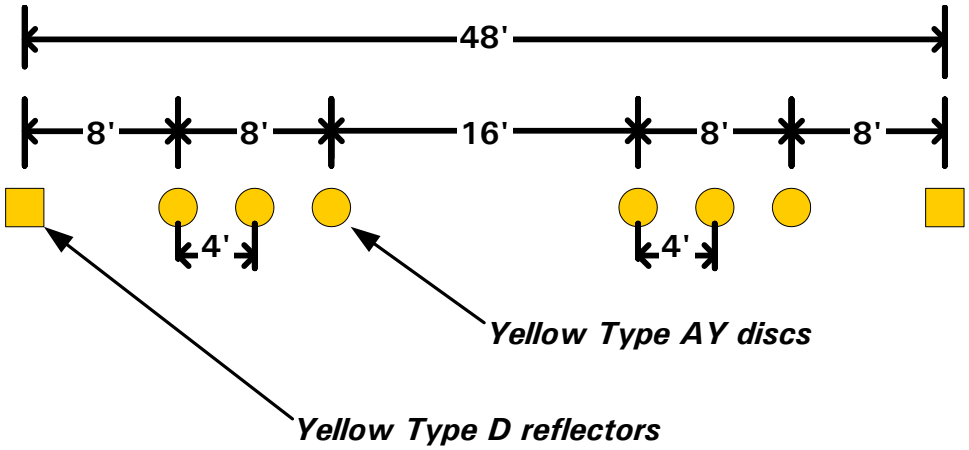


Figure 3. California Standard Plan A20A, Detail 4

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 close 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 the 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 not 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%), and pass 20 of the 30 trials overall (66%).

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: 7/3/2019 Due: 7/3/2020
Platform Scales	Vehicle Total, Wheel, and Axle Load	8000 lb 35.6 kN	±1.0% of applied load	Intercomp, SWII	1110M206352	By: DRI Date: 1/6/2020 Due: 1/6/2021
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+	2258	By: Oxford Technical Solutions[1] Date: 5/3/2019 Due: 5/3/2021
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 band-pass 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	Passband 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

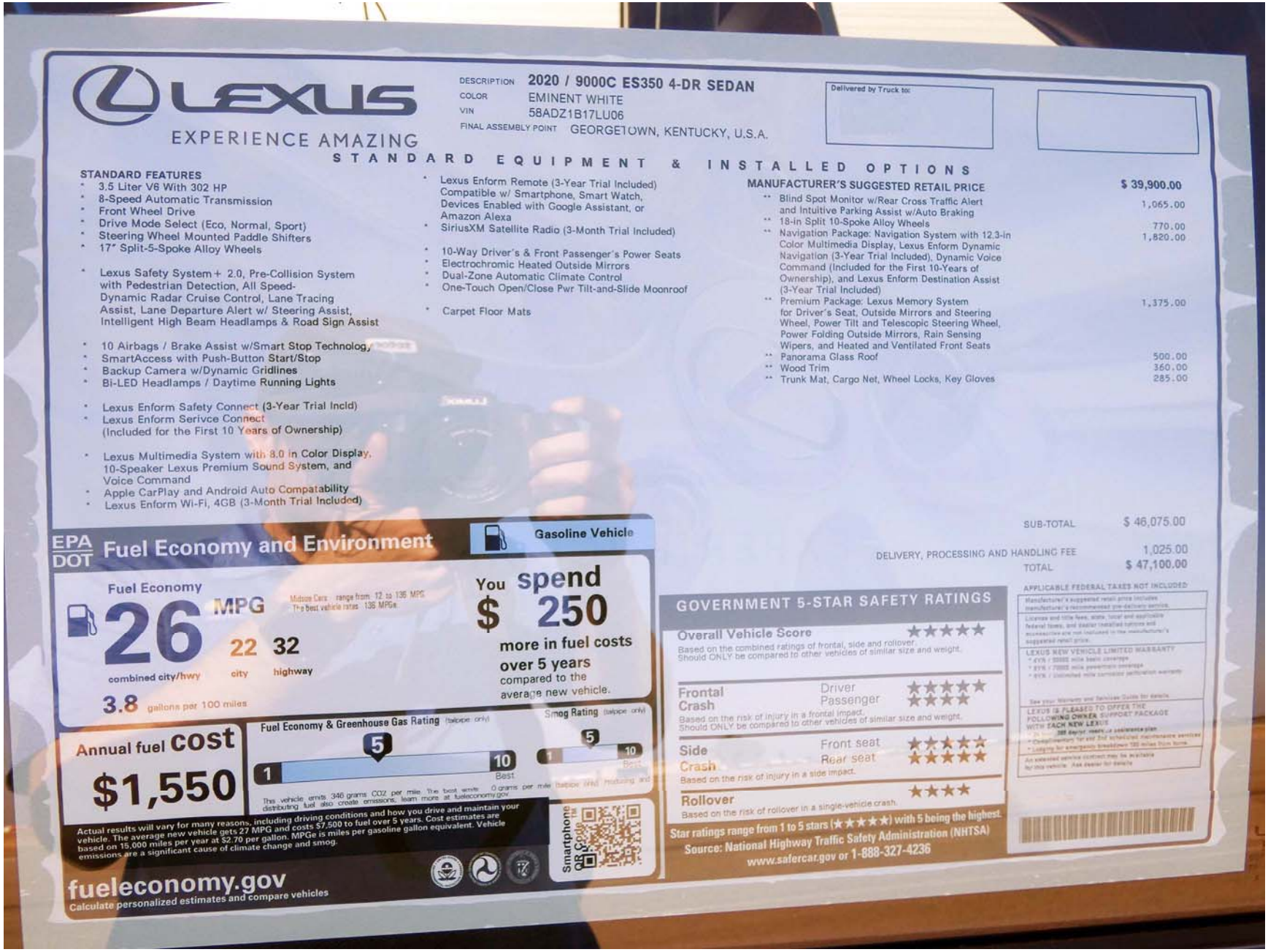


Figure A3. Window Sticker (Monroney Label)

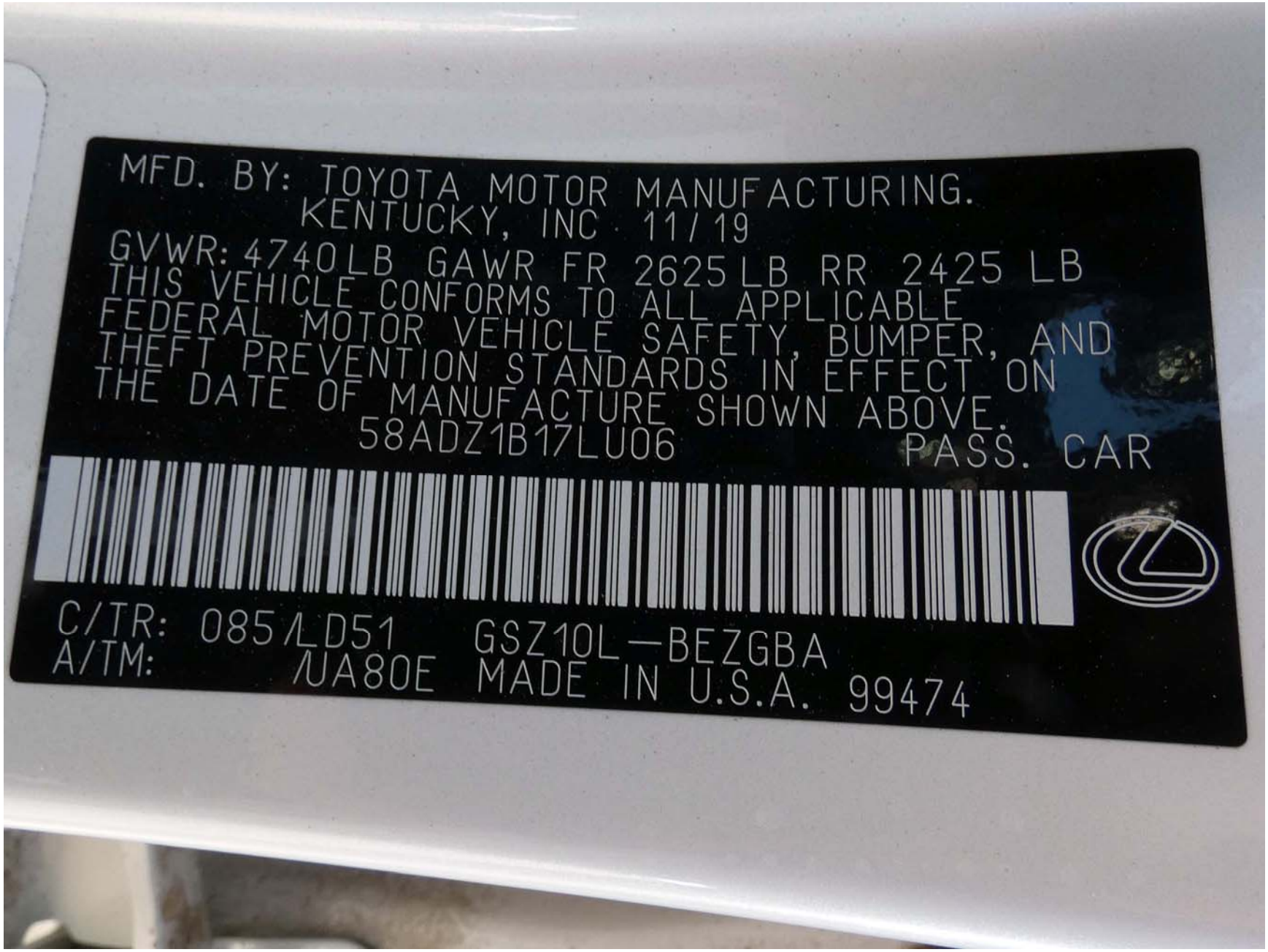


Figure A4. Vehicle Certification Label

Figure A5. Tire Placard

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

Figure A7. Sensor for Detecting Visual Alerts

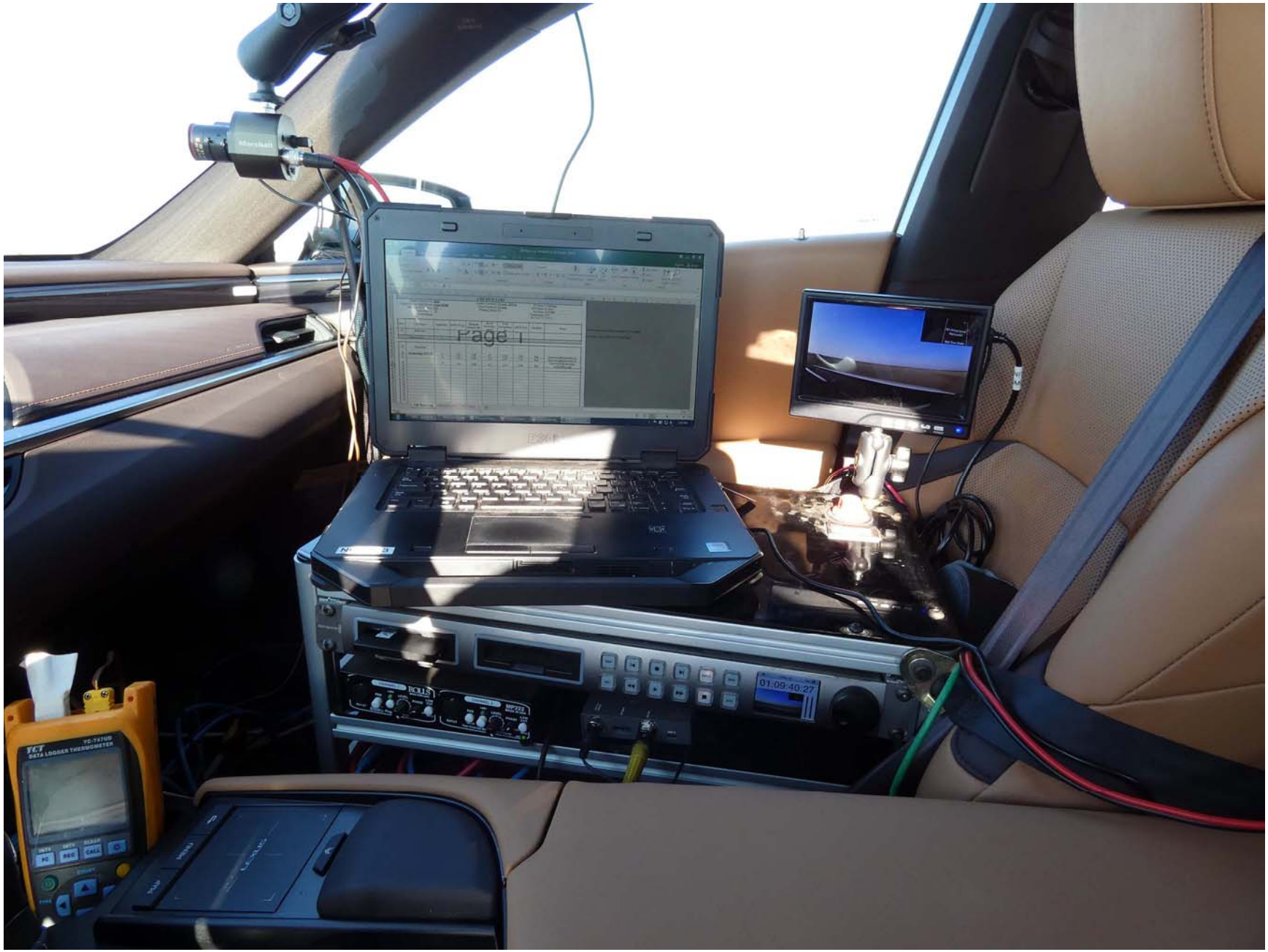


Figure A8. Computer Installed in Subject Vehicle

Figure A9. LTA (LDW)On/Off Switch

Figure A10. Controls for Interacting with LTA (LDW) Settings

Figure A11. LTA (LDW) Menus

Figure A12. LTA (LDW) Visual Alert

APPENDIX B

Excerpts from Owner’s Manual

Warning lights

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

(U.S.A.) Brake system warning light*1 (→P.352)


(red) (Canada) Brake system warning light*1 (→P.352)


(yellow) Brake system warning light*1 (→P.352)


High coolant temperature warning light*2 (→P.352)


Charging system warning light*2 (→P.353)


Low engine oil pressure warning light*2 (→P.353)

(U.S.A.) Malfunction indicator lamp*1 (→P.353)


(Canada) Malfunction indicator lamp*1 (→P.353)


SRS warning light*1 (→P.353)

(U.S.A.) ABS warning light*1 (→P.354)


(Canada) ABS warning light*1 (→P.354)


Brake Override System warning light/Drive-Start Control warning light*2 (→P.354)


(red) Electric power steering system warning light*1 (→P.354)


(yellow) Electric power steering system warning light*1 (→P.354)


Low fuel level warning light (→P.355)


Driver's and front passenger's seat belt reminder light (→P.355)

Rear passengers' seat belt reminder lights (→P.355)


Tire pressure warning light*1 (→P.356)


(orange) LTA indicator (→P.356)

(flashes) Intuitive parking assist OFF indicator*1 (if equipped) (→P.356)

(flashes) RCTA OFF indicator*1 (if equipped) (→P.357)

(flashes) RCD OFF indicator (if equipped) (→P.357)

(flashes) PKSB OFF indicator*1 (if equipped) (→P.357)

(flashes or illuminates) PCS warning light*1 (→P.358)


Slip indicator*1 (→P.358)

(flashes) (U.S.A.) Parking brake indicator (→P.358)


(flashes) (Canada) Parking brake indicator (→P.358)

HOLD (flashes) Brake hold operated indicator*1 (→P.359)

Master warning light*1 (→P.359)

*1: These lights come on when the engine switch is turned to IGNITION ON mode to indicate that a system check is being performed. They will go off after the engine is on, or after a few seconds. There may be a malfunction in a system if the lights do not come on, or go off. Have the vehicle inspected by your Lexus dealer.

*2: This light illuminates on the multi-information display.

WARNING

■ If a safety system warning light does not come on

Should a safety system light such as the ABS and SRS warning light not come on when you start the engine, this could mean that these systems are not available to help protect you in an accident, which could result in death or serious injury. Have the vehicle inspected by your Lexus dealer immediately if this occurs.

Indicators

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

Turn signal indicator (→P.151)

Headlight indicator (→P.156) (U.S.A.)

Tail light indicator (→P.156) (Canada)

Headlight high beam indicator (→P.158)

Automatic High Beam indicator (→P.159)

PCS warning light*1, 2 (→P.175)

Cruise control indicator (→P.193)

Dynamic radar cruise control indicator (→P.193)

SET Cruise control "SET" indicator (→P.193)

LTA indicator (→P.187) (white)

LTA indicator (→P.187) (green)

LTA indicator (→P.187) (orange) (flashes)

BSM outside rear view mirror indicators*1, 3 (if equipped) (→P.203, 218)

BSM BSM indicator (if equipped) (→P.203)

P OFF Intuitive parking assist OFF indicator*1, 2 (if equipped) (→P.212)

RCTA OFF RCTA OFF indicator*1, 2 (if equipped) (→P.218)

RCD OFF RCD OFF indicator*2 (if equipped) (→P.222)

OFF PKSB OFF indicator*1, 2 (if equipped) (→P.226)

Slip indicator*1 (→P.245) (flashes)

OFF VSC OFF indicator*1, 2 (→P.245)

Driving support system information display

Select to display the operational status of the following systems:

- LTA (Lane Tracing Assist) (→P.182)
- Dynamic radar cruise control with full-speed range (→P.193)
- RSA (Road Sign Assist) (if equipped) (→P.191)

Settings display

Meter display settings that can be changed

- Language

Select to change the language displayed.

- Units

Select to change the units of measure displayed.

- Speedometer display (except F SPORT models)

Select to set the display of the speedometer to digital or analog.

- Drive information 1/Drive information 2

Select to select up to 2 items (→P.79) that will be displayed on each Drive information screen (Drive information 1 screen and Drive information 2 screen) respectively.

- Clock

Select to switch between 12-hour display and 24-hour display.

- Pop-up display

Select to enable/disable some pop-up displays for each relevant system.

- Accent color

Select to change the accent color on the screen, such as the cursor color.

- Rev indicator (F SPORT models)

• Select to enable/disable the rev indicator.

• Select to set the engine speed at which the rev indicator (amber) will begin to be displayed.

- Rev peak (F SPORT models)

Select to enable/disable the rev peak.

- Eco Driving Indicator Light

Select to enable/disable the Eco Driving Indicator Light.

- Default setting

Select to reset the meter display settings to the default setting.

Vehicle functions and settings that can be changed

→P.404

Suspension of the settings display

- Some settings cannot be changed while driving. When changing settings, park the vehicle in a safe place.
- If a warning message is displayed, operation of the settings display will be suspended.

WARNING

Cautions during setting up the display

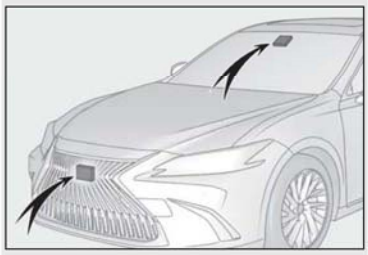
As the engine needs to be running during setting up the display, ensure that the vehicle is parked in a place with adequate ventilation. In a closed area such as a garage, exhaust gases including harmful carbon monoxide (CO) may collect and enter the vehicle. This may lead to death or a serious health hazard.

LTA (Lane Tracing Assist)

When driving on highways and freeways with white (yellow) lane lines, this function alerts the driver when the vehicle might depart from its lane or course* and provides assistance by operating the steering wheel to keep the vehicle in its lane or course*. Furthermore, the system provides steering assistance when dynamic radar cruise control with full-speed range is operating to keep the vehicle in its lane.

The LTA system recognizes white (yellow) lane lines or a course* using the front camera. Additionally, it detects preceding vehicles using the front camera and radar.

*: Boundary between asphalt and the side of the road, such as grass, soil, or a curb



WARNING

■ Before using LTA system

- Do not rely solely upon the LTA system. The LTA 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.
- When not using the LTA system, use the LTA switch to turn the system off.

■ Situations unsuitable for LTA system

In the following situations, use the LTA switch to turn the system off. Failure to do so may lead to an accident, resulting in death or serious injury.

- Vehicle is driven on a road surface which is slippery due to rainy weather, fallen snow, freezing, etc.
- Vehicle is driven on a snow-covered road.
- White (yellow) lines are difficult to see due to rain, snow, fog, dust, etc.
- Vehicle is driven in a temporary lane or restricted lane due to construction work.
- Vehicle is driven in a construction zone.
- A spare tire, tire chains, etc. are equipped.
- When the tires have been excessively worn, or when the tire inflation pressure is low.

WARNING

- When tires of a size other than specified are installed.
- Vehicle is driven in traffic lanes other than that highways and freeways.
- During emergency towing

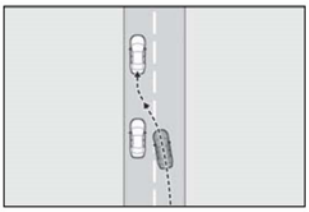
■ Preventing LTA system malfunctions and operations performed by mistake

- 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 Lexus 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 Lexus dealer.

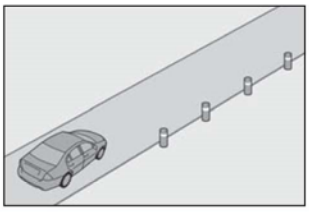
■ Conditions in which functions may not operate properly

In the following situations, the functions may not operate properly and the vehicle may depart from its lane. Drive safely by always paying careful attention to your surroundings and operate the steering wheel to correct the path of the vehicle without relying solely on the functions.

- When the follow-up cruising display is displayed (→P.187) and the preceding vehicle changes lanes. (Your vehicle may follow the preceding vehicle and also change lanes.)

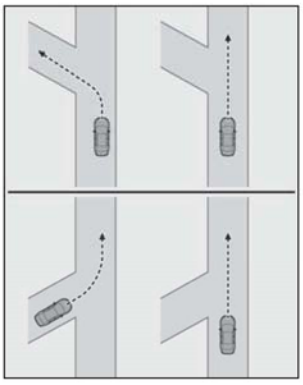


- When the follow-up cruising display is displayed (→P.187) and the preceding vehicle is swaying. (Your vehicle may sway accordingly and depart from the lane.)
- When the follow-up cruising display is displayed (→P.187) and the preceding vehicle departs from its lane. (Your vehicle may follow the preceding vehicle and depart from the lane.)
- When the follow-up cruising display is displayed (→P.187) and the preceding vehicle is being driven extremely close to the left/right lane line. (Your vehicle may follow the preceding vehicle and depart from the lane.)
- Vehicle is being driven around a sharp curve.
- Objects or patterns that could be mistaken for white (yellow) lines are present on the side of the road (guardrails, reflective poles, etc.).

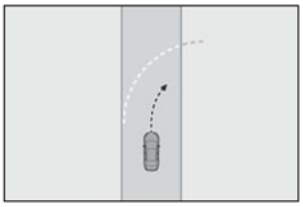


WARNING

- Vehicle is driven where the road diverges, merges, etc.



- Repair marks of asphalt, white (yellow) lines, etc. are present due to road repair.



- 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.
- If the edge of the road is not clear or straight.
- 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 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 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).
- When driving in a tunnel or at night with the headlights off or when a headlight is dim due to its lens being dirty or it being misaligned.
- The vehicle is struck by a crosswind.

WARNING

- The vehicle is affected by wind from a vehicle driven in a nearby lane.
- The vehicle has just changed lanes or crossed an intersection.
- Tires which differ by structure, manufacturer, brand or tread pattern are used.
- Snow tires, etc. are equipped.
- The vehicle is being driven at extremely high speeds.

Functions included in LTA system

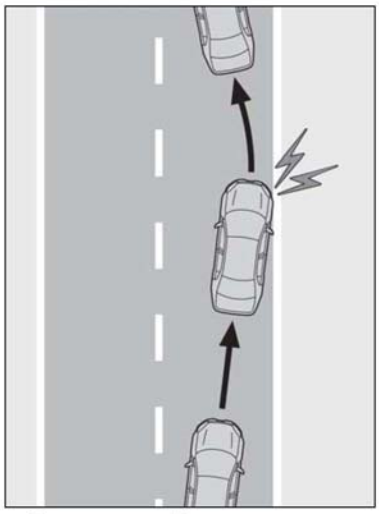
■ Lane departure alert function

When the system determines that the vehicle might depart from its lane or course*, a warning is displayed on the multi-information display, and either a warning buzzer will sound or the steering wheel will vibrate to alert the driver.

When the warning buzzer sounds or the steering wheel vibrates, check the area around your vehicle and carefully operate the steering wheel to move the vehicle back to the center of the lane.

Vehicle with BSM: When the system determines that the vehicle might depart from its lane and that the possibility of a collision with an overtaking vehicle in the adjacent lane is high, the lane departure alert will operate even if the turn signals are operating.

*: Boundary between asphalt and the side of the road, such as grass, soil, or a curb



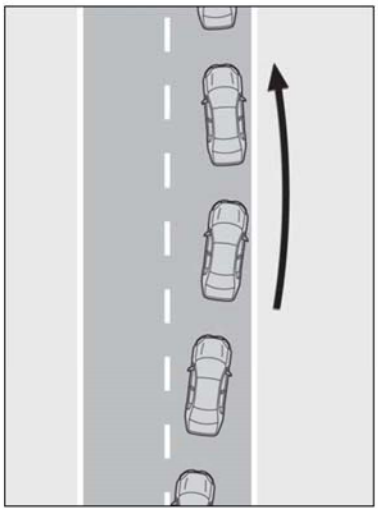
■ Steering assist function

When the system determines that the vehicle might depart from its lane or course*, 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 function is temporarily canceled.

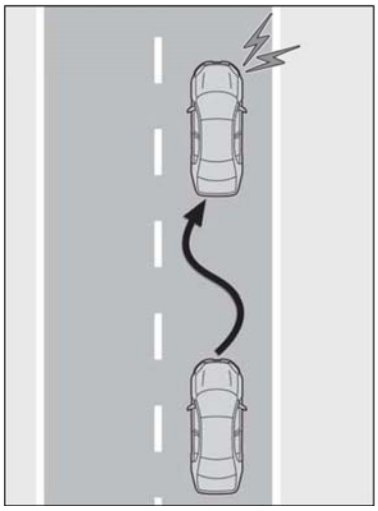
Vehicle with BSM: When the system determines that the vehicle might depart from its lane and that the possibility of a collision with an overtaking vehicle in the adjacent lane is high, the steering assist function will operate even if the turn signals are operating.

*: Boundary between asphalt and the side of the road, such as grass, soil, or a curb



■ Vehicle sway warning function

When the vehicle is swaying within a lane, the warning buzzer will sound and a message will be displayed on the multi-information display to alert the driver.



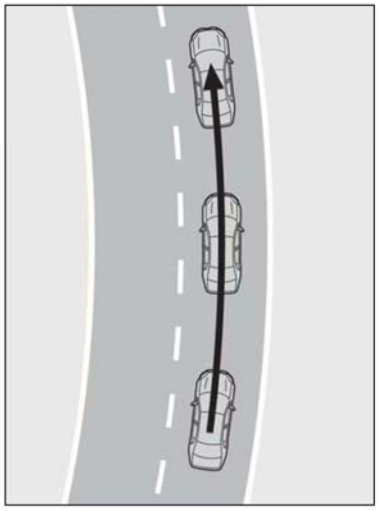
■ Lane centering function

This function is linked with dynamic radar cruise control with full-speed range and provides the required assistance by operating the steering wheel to keep the vehicle in its current lane.

When dynamic radar cruise control with full-speed range is not operating, the lane centering function does not operate.

In situations where the white (yellow) lane lines are difficult to see or are not visible, such as when in a traffic jam, this function will operate to help follow a preceding vehicle by monitoring the position of the preceding vehicle.

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 function is temporarily canceled.



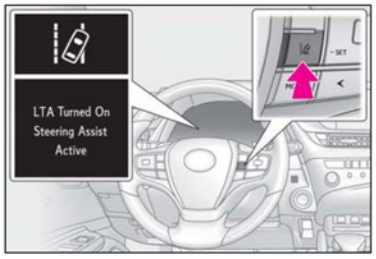
Turning LTA system on

Press the LTA switch to turn the LTA system on.

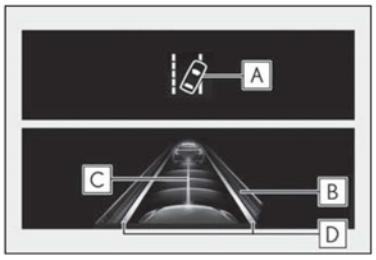
The LTA indicator illuminates and a message is displayed on the multi-information display.

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

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



Indications on multi-information display



A LTA indicator

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

Illuminated in white:
LTA system is operating.

Illuminated in green:
Steering wheel assistance of the steering assist function or lane centering function is operating.

Flashing in orange:
Lane departure alert function is operating.

B Operation display of steering wheel operation support

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

Indicates that steering wheel assistance of the steering assist function or lane centering function is operating.

Both outer sides of the lane are displayed:
Indicates that steering wheel assist of the lane centering function is operating.

One outer side of the lane is displayed:
Indicates that steering wheel assist of the steering assist function is operating.

Both outer sides of the lane are flashing:
Alerts the driver that their input is necessary to stay in the center of the lane (lane centering function).

C Follow-up cruising display

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

Indicates that steering assist of the lane centering function is operating by monitoring the position of a preceding vehicle.

When the follow-up cruising display is displayed, if the preceding vehicle moves, your vehicle may move in the same way. Always pay careful attention to your surroundings and operate the steering wheel as necessary to correct the path of the vehicle and ensure safety.

D Lane departure alert function display

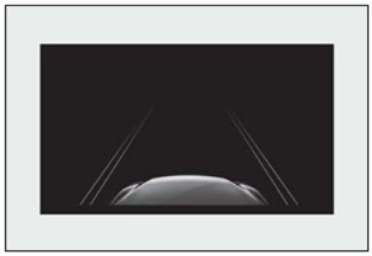
Displayed when the multi-information dis-

play is switched to the driving assist system information screen.

▶ Inside of displayed lines is white

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

▶ Inside of displayed lines is black



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

*: Boundary between asphalt and the side of the road, such as grass, soil, or a curb

■ Operation conditions of each function

● Lane departure alert function

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

- LTA is turned on.
- Vehicle speed is approximately 32 mph (50 km/h) or more.*1
- System recognizes white (yellow) lane lines or a course*2. (When a white [yellow] line or course*2 is recognized on only one side, the system will operate only for the recognized side.)
- Width of traffic lane is approximately 9.8 ft. (3 m) or more.
- Turn signal lever is not operated. (Vehicle with BSM: Except when another vehicle is in the lane on the side where the turn signal was operated)
- Vehicle is not being driven around a sharp curve.
- No system malfunctions are detected. (→P.190)

*1: The function operates even if the vehicle speed is less than approximately 32 mph (50 km/h) when the lane centering function is operating.

*2: Boundary between asphalt and the side of the road, such as grass, soil, or a curb

● Steering assist 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" in ⚙ of the multi-information display is set to "On". (→P.78)
- Vehicle is not accelerated or decelerated by a fixed amount or more.
- Steering wheel is not operated with a steering force level suitable for changing lanes.
- ABS, VSC, TRAC and PCS are not operating.
- TRAC or VSC is not turned off.
- Hands off steering wheel warning is not displayed. (→P.189)

● Vehicle sway warning function

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

- Setting for "Warning" in ⚙ of the multi-information display is set to "On". (→P.78)
- 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.190)

● Lane centering function

This function operates when all of the following conditions are met.
- LTA is turned on.
- Setting for "Steering Assist" and "Lane Center" in ⚙ of the multi-information display are set to "On". (→P.78)
- This function recognizes white (yellow) lane lines or the position of a preceding vehicle (except when the preceding vehicle is small, such as a motorcycle).
- The dynamic radar cruise control with full-speed range is operating in vehicle-to-vehicle distance control mode.
- Width of traffic lane is approximately 10 to 13 ft. (3 to 4 m).
- Turn signal lever is not operated.
- Vehicle is not being driven around a sharp curve.
- No system malfunctions are detected. (→P.190)
- Vehicle does not accelerate or decelerate by a fixed amount or more.
- Steering wheel is not operated with a steering force level suitable for changing lanes.
- ABS, VSC, TRAC and PCS are not operating.
- TRAC or VSC is not turned off.
- Hands off steering wheel warning is not displayed. (→P.189)
- The vehicle is being driven in the center of a lane.
- Steering assist function is not operating.

■ **Temporary cancelation of functions**

When 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.188)

If the operation conditions (→P.188) are no longer met while the lane centering function is operating, the steering wheel may vibrate and the buzzer may sound to indicate that the function has been temporarily canceled. However, if the "Steering wheel vibration" customization setting is set to on, the system will notify the driver by vibrating the steering wheel instead of sounding the buzzer.

■ **Steering assist function/lane centering 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.

● The steering control of the function is overridden by the driver's steering wheel operation.

● Do not attempt to test the operation of the steering assist function.

■ **Lane departure alert function**

● The warning buzzer may be difficult to hear due to external noise, audio playback, etc. Also, it may be difficult to feel steering wheel vibrations due to the road conditions, etc.

● If the edge of the course* is not clear or straight, the lane departure alert function may not operate.

● Vehicle with BSM: It may not be possible for the system to determine if there is a danger of a collision with a vehicle in an adjacent lane.

● Do not attempt to test the operation of the lane departure alert function.

*: Boundary between asphalt and the side of the road, such as grass, soil, or a curb

■ **Hands off steering wheel warning**

In the following situations, 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 to warn the driver. The warning stops when the system determines that the driver holds the steering wheel. Always keep your hands on the steering wheel when using this system, regardless of warnings.

● When the system determines that the driver is driving without holding the steering wheel while the system is operating

If the driver continues to keep their hands off of the steering wheel, the buzzer sounds, the driver is warned and the function is temporarily canceled. This warning also operates in the same way when the driver continuously operates the steering wheel only a small amount.

The buzzer also sounds even if the alert type is set to "Steering wheel vibration".

● When the system determines that the vehicle may not turn and instead depart from its lane while driving around a curve

Depending on the vehicle condition and road conditions, the warning may not operate. Also, if the system determines that the vehicle is driving around a curve, warnings will occur earlier than during straight-lane driving.

● When the system determines that the driver is driving without holding the steering wheel while the steering wheel assist of the steering assist function is operating.

If the driver continues to keep their hands off of the steering wheel and the steering wheel assist is operating, the buzzer sounds and the driver is warned. Each time the buzzer sounds, the continuing time of the buzzer becomes longer.

The buzzer also sounds even if the alert type is set to "Steering wheel vibration".

■ **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.

■ **Warning message**

If the following warning message is displayed on the multi-information display and the LTA indicator illuminates in orange, follow the appropriate troubleshooting procedure. Also, if a different warning message is displayed, follow the instructions displayed on the screen.

● "LTA Malfunction Visit Your Dealer"

The system may not be operating properly. Have the vehicle inspected by your Lexus dealer.

● "LTA Unavailable"

The system is temporarily canceled due to a malfunction in a sensor other than the front camera. Turn the LTA system off, wait for a little while, and then turn the LTA system back on.

● "LTA Unavailable at Current Speed"

The function cannot be used as the vehicle speed exceeds the LTA operation range. Drive slower.

■ **Customization**

Function settings can be changed.

(Customizable features:→P.404)

Winter driving tips

Carry out the necessary preparations and inspections before driving the vehicle in winter. Always drive the vehicle in a manner appropriate to the prevailing weather conditions.

Preparation for winter

- Use fluids that are appropriate to the prevailing outside temperatures.
  - Engine oil
  - Engine coolant
  - Washer fluid
- Have a service technician inspect the condition of the battery.
- Have the vehicle fitted with four snow tires or purchase a set of tire chains for the front tires.*

Ensure that all tires are the specified size and brand, and that chains match the size of the tires.

*: Tire chains cannot be mounted on vehicles with 18-inch/19-inch tires.

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 specified size.
- 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 (vehicles with 17-inch tires)

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 LTA (Lane Tracing Assist) system.

NOTICE

■ Repairing or replacing snow tires

Request repairs or replacement of snow tires from Lexus 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.

Before driving the vehicle

Perform the following according to the driving conditions:

- Do not try to forcibly open a window

■ Tire pressure warning light

Warning light	Details/Actions
	When the light comes on after blinking for approximately 1 minute: Malfunction in the tire pressure warning system → **Have the system checked by your Lexus dealer.** When the light comes on: Low tire inflation pressure such as ● Natural causes ● Flat tire → **Immediately stop the vehicle in a safe place.** **Handling method (→P.359)**

■ LTA indicator (warning buzzer)

Warning light	Details/Actions
 (orange)	Indicates a malfunction in the LTA (Lane Tracing Assist) → **Follow the instructions displayed on the multi-information display. (→P.190)**

■ Intuitive parking assist OFF indicator (warning buzzer)

Warning light	Details/Actions
 (flashes) (if equipped)	When a buzzer sounds: Indicates a malfunction in the intuitive parking assist function → **Have the vehicle inspected by your Lexus dealer immediately.** When a buzzer does not sound: Indicates that the system is temporarily unavailable, possibly due to a sensor being dirty or covered with ice, etc. → **Follow the instructions displayed on the multi-information display. (→P.214)**

76 ft•lbf (103 N•m, 10.5 kgf•m)

5 Stow the flat tire, tire jack and all tools.

■ **The compact spare tire**

- The compact spare tire is identified by the label "TEMPORARY USE ONLY" on the tire sidewall.
  Use the compact spare tire temporarily, and only in an emergency.
- Make sure to check the tire inflation pressure of the compact spare tire. (→P.391)

■ **After completing the tire change**

The tire pressure warning system must be reset. (→P.326)

■ **When using the compact spare tire**

As the compact spare tire is not equipped with a tire pressure warning valve and transmitter, low inflation pressure of the spare tire will not be indicated by the tire pressure warning system. Also, if you replace the compact spare tire after the tire pressure warning light comes on, the light remains on.

■ **When the compact spare tire is attached**

The vehicle becomes lower when driving with the compact spare tire compared to when driving with standard tires.

■ **If you have a flat front tire on a road covered with snow or ice**

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**

- 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 tire 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**

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 with full-speed range
- PCS (Pre-Collision System)
- EPS
- LTA (Lane Tracing Assist)
- Panoramic view monitor (if equipped)
- Lexus parking assist monitor (if equipped)
- Intuitive parking assist (if equipped)
- Navigation system (if equipped)
- BSM (Blind spot monitor) (if equipped)
- Automatic high Beam

Function	Default setting	Customized setting	A	B	C
Adjust alert timing	Middle	Early	—	O	—
		Late			

■ LTA (Lane Tracing Assist) (→P.182)

Function	Default setting	Customized setting	A	B	C
Lane centering function	On	Off	—	O	—
Steering assist function	On	Off	—	O	—
Alert type	Steering wheel vibration	Buzzer	—	O	—
Alert sensitivity	High	Standard	—	O	—
Vehicle sway warning function	On	Off	—	O	—
Vehicle sway warning sensitivity	Standard	High	—	O	—
		Low			

■ RSA (Road Sign Assist)* (→P.191)

Function	Default setting	Customized setting	A	B	C
RSA (Road Sign Assist)	On	Off	—	O	—
Excess speed notification method	Display only	No notification	—	O	—
		Display and buzzer			
Excess speed notification level	1 mph (2 km/h)	3 mph (5 km/h)	—	O	—
		5 mph (10 km/h)			
Other notifications method (No-entry notification)	Display only	No notification	—	O	—
		Display and buzzer			

*: If equipped

■ BSM (Blind Spot Monitor)* (→P.203)

Function	Default setting	Customized setting	A	B	C
BSM (Blind Spot Monitor)	On	Off	—	O	—
Outside rear view mirror indicator brightness	Bright	Dim	—	O	—

APPENDIX C

Run Log

Subject Vehicle: **2020 Lexus ES 350** Test Date: **1/14/2020**

Driver: **J. Partridge** **Note: For Distance at Warning positive values indicate inside the lane**

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
1	**Solid**	**Left**	N				Could not detect warning with post processor
2			N				Cone
3			Y	0.56		Pass	Unable to reliably detect visual alert
4			Y	0.11		Pass	Unable to reliably detect visual alert
5			Y	0.53	0.26	Pass	
6			Y	0.51	0.28	Pass	
7			Y	0.48	0.24	Pass	
8			Y	0.34	0.07	Pass	
9			Y	0.59	0.27	Pass	
10	**Solid**	**Right**	Y	0.89	0.66	Pass	
11			Y	0.45	0.22	Pass	
12			Y	0.63	0.43	Pass	
13			Y	0.97	0.71	Pass	
14			Y	0.53	0.34	Pass	
15			N				Lateral velocity
16			Y	0.26	0.11	Pass	

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
17			Y	0.70	0.46	Pass	
18	**Dashed**	**Right**	Y	0.44	0.18	Pass	
19			Y	0.50	0.24	Pass	
20			Y	0.54	0.31	Pass	
21			Y	0.16	-0.05	Pass	
22			N				Hit cone
23			Y	0.24	0.12	Pass	
24			Y	0.50	0.25	Pass	
25			Y	0.31	0.11	Pass	
26	**Dashed**	**Left**	N				Yaw rate
27			Y	0.92	0.62	Pass	
28			Y	0.62	0.33	Pass	
29			N				Yaw rate
30			Y	0.60	0.31	Pass	
31			N				Hit cone
32			Y	1.02	0.74	Pass	
33			Y	0.37	0.15	Pass	
34			Y	0.64	0.35	Pass	
35			Y	0.45	0.13	Pass	

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
36	**Botts**	**Left**	Y	0.39	0.16	Pass	
37			Y	0.36	0.17	Pass	
38			Y	0.57	0.25	Pass	
39			Y	0.70	0.38	Pass	
40			Y	0.48	0.21	Pass	
41			N				Lateral velocity
42			Y	-0.15	-0.38	Pass	
43			Y	0.41	0.15	Pass	
44	**Botts**	**Right**	Y	0.69	0.48	Pass	
45			Y	0.40	0.22	Pass	
46			Y	0.37	0.21	Pass	
47			Y	0.28	0.11	Pass	
48			Y	0.15	-0.05	Pass	
49			Y	0.18	0.00	Pass	
50			Y	0.40	0.18	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.

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

Other Notations

- NG – Indicates that the value for that variable was outside of bounds and therefore “No Good”.
- No Wng – No warning was detected.

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.

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.

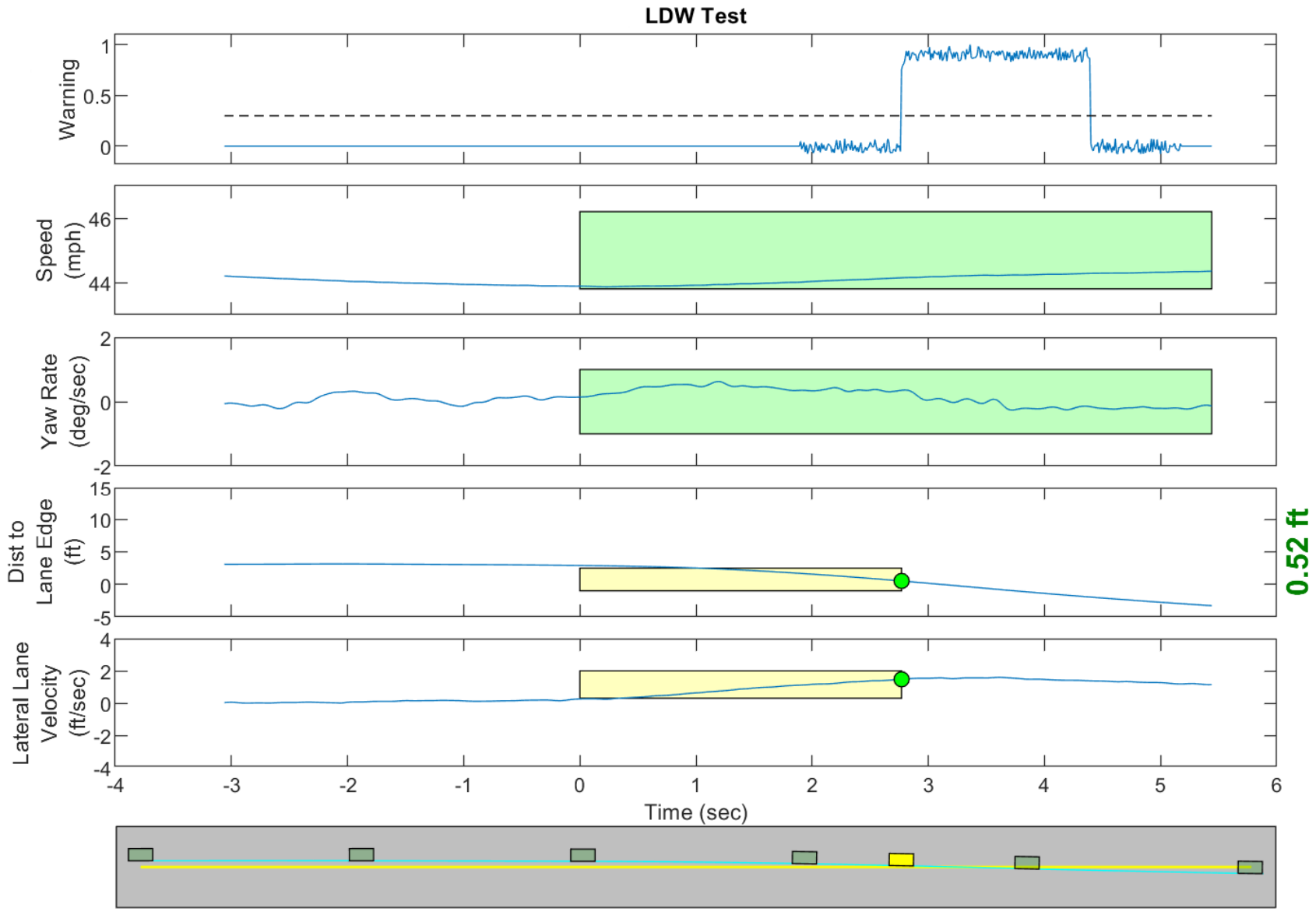


Figure D1. Example Time History for Lane Departure Warning Test, Passing

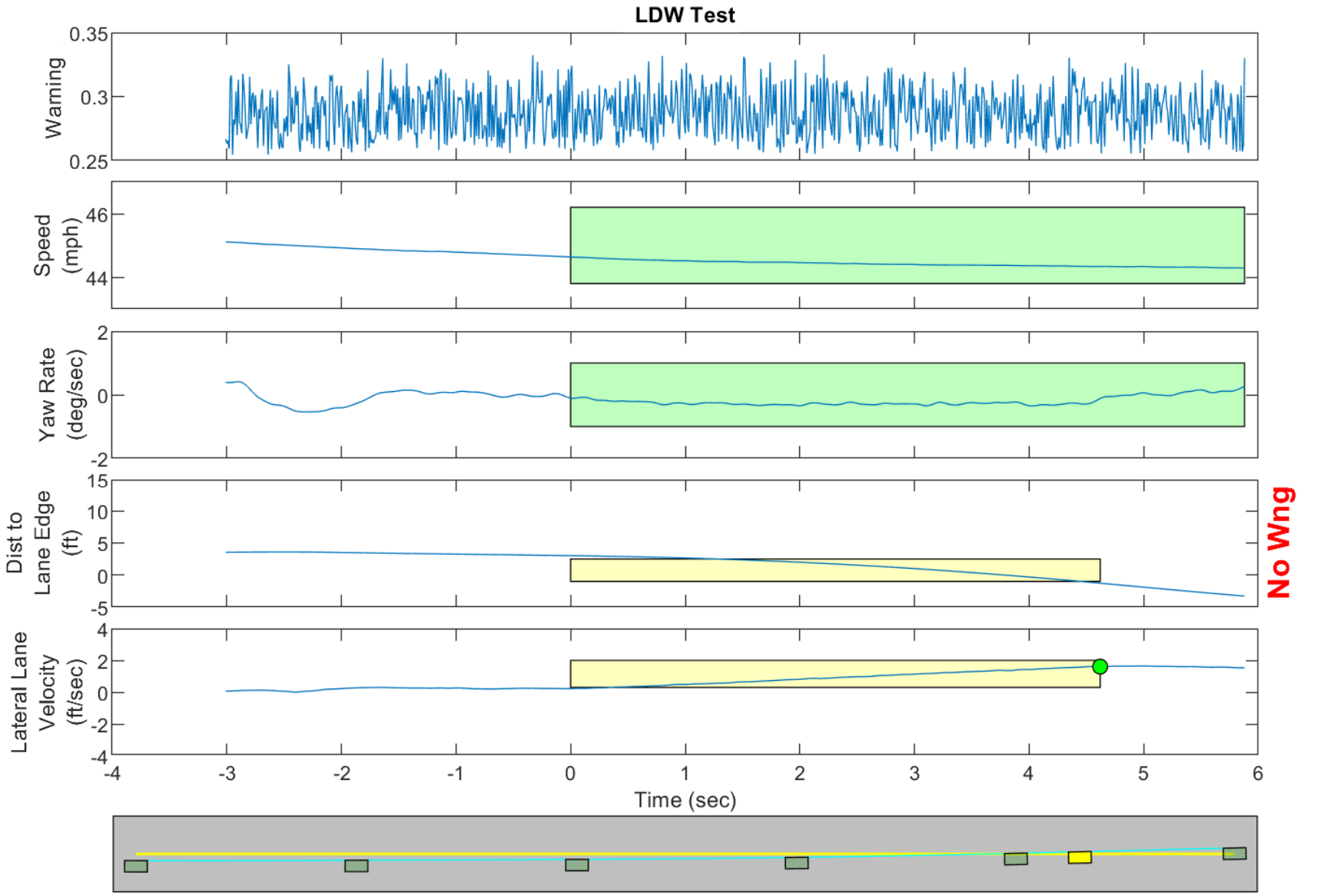


Figure D2. Example Time History for Lane Departure Warning Test, Failing, No Warning Issued

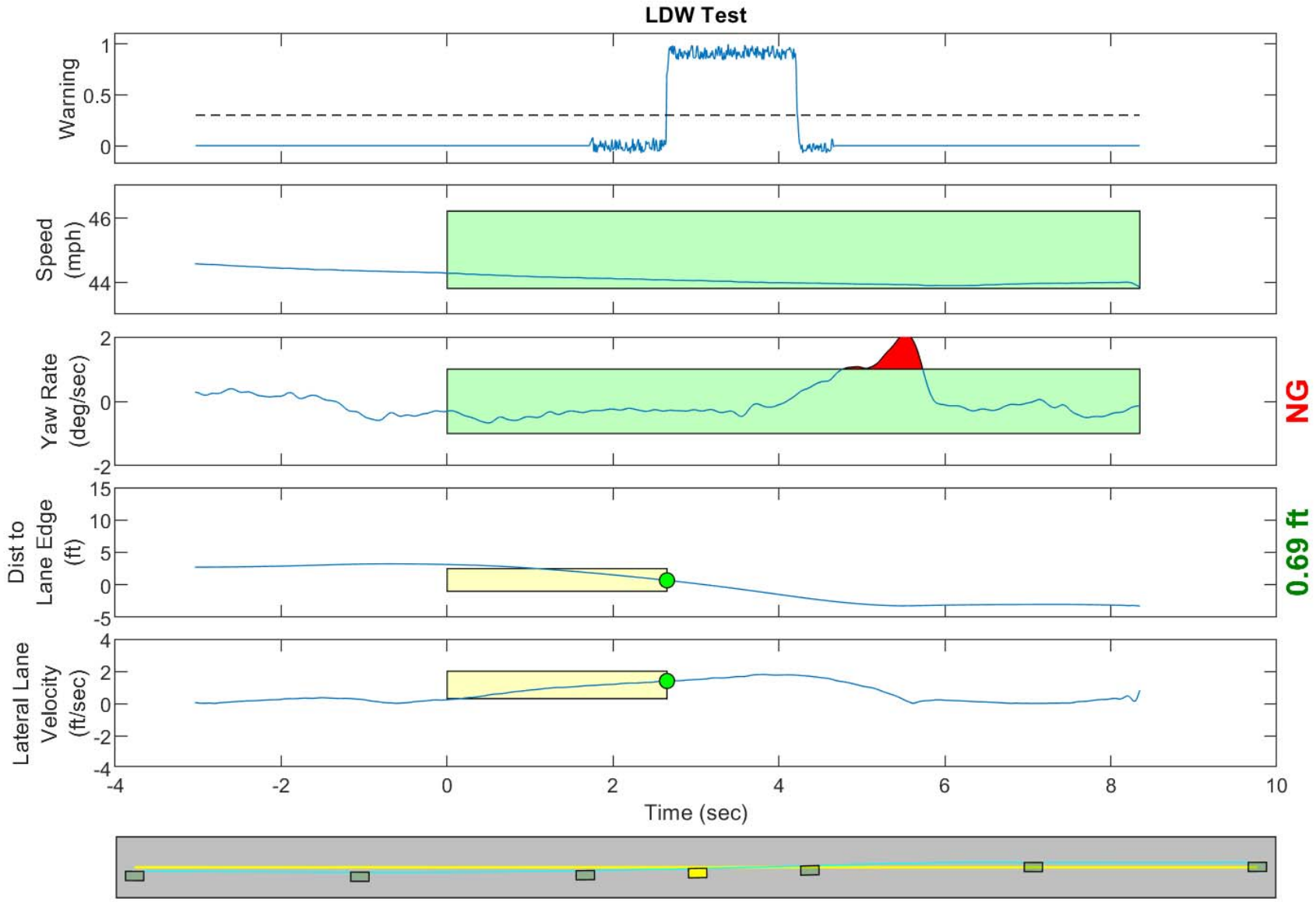


Figure D3. Example Time History for Lane Departure Warning Test, Invalid Run Due to Subject Vehicle Yaw Rate

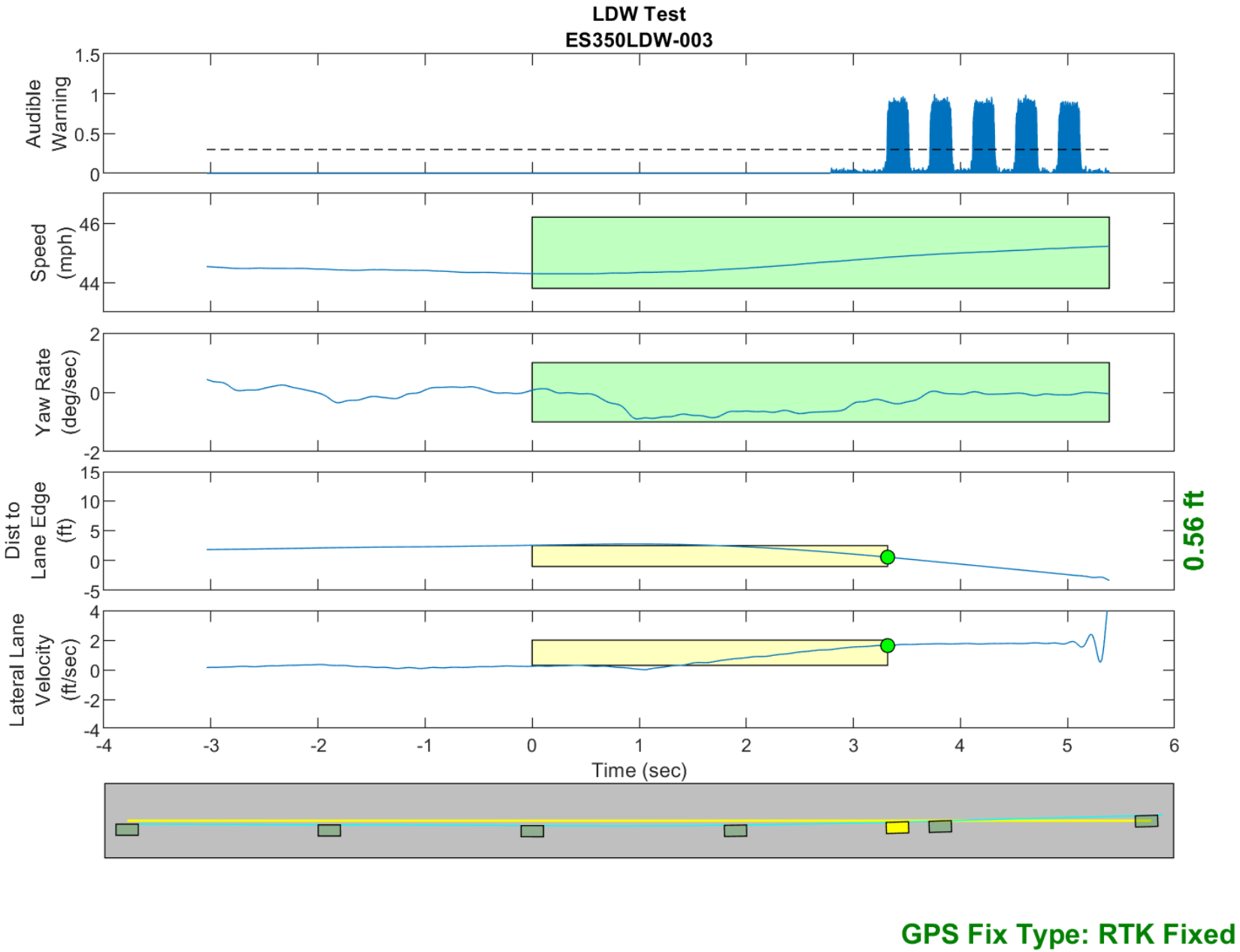


Figure D4. Time History for Run 03, Solid Line, Left Departure, Audible Warning

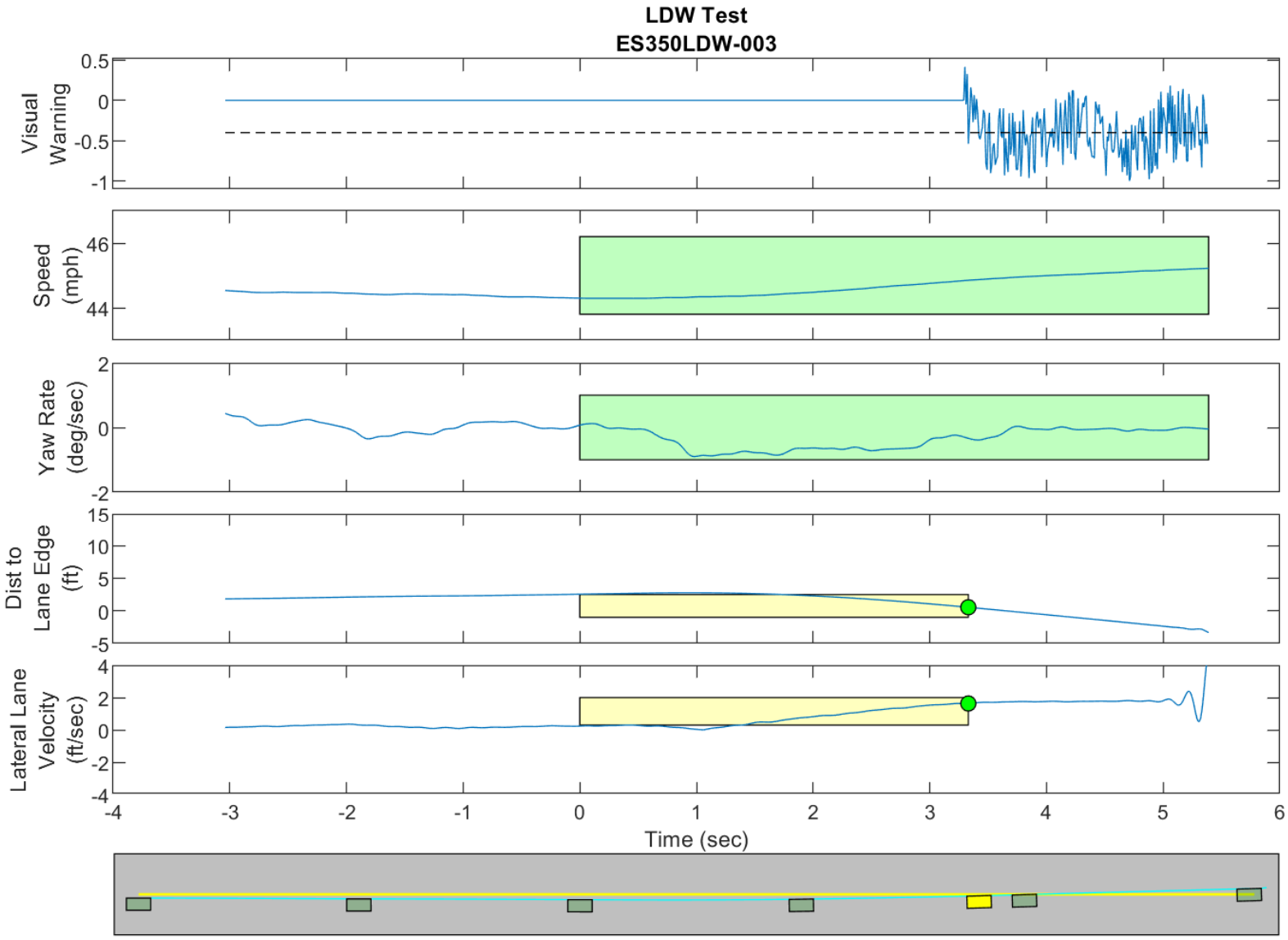


Figure D5. Time History for Run 03, Solid Line, Left Departure, Visual Warning

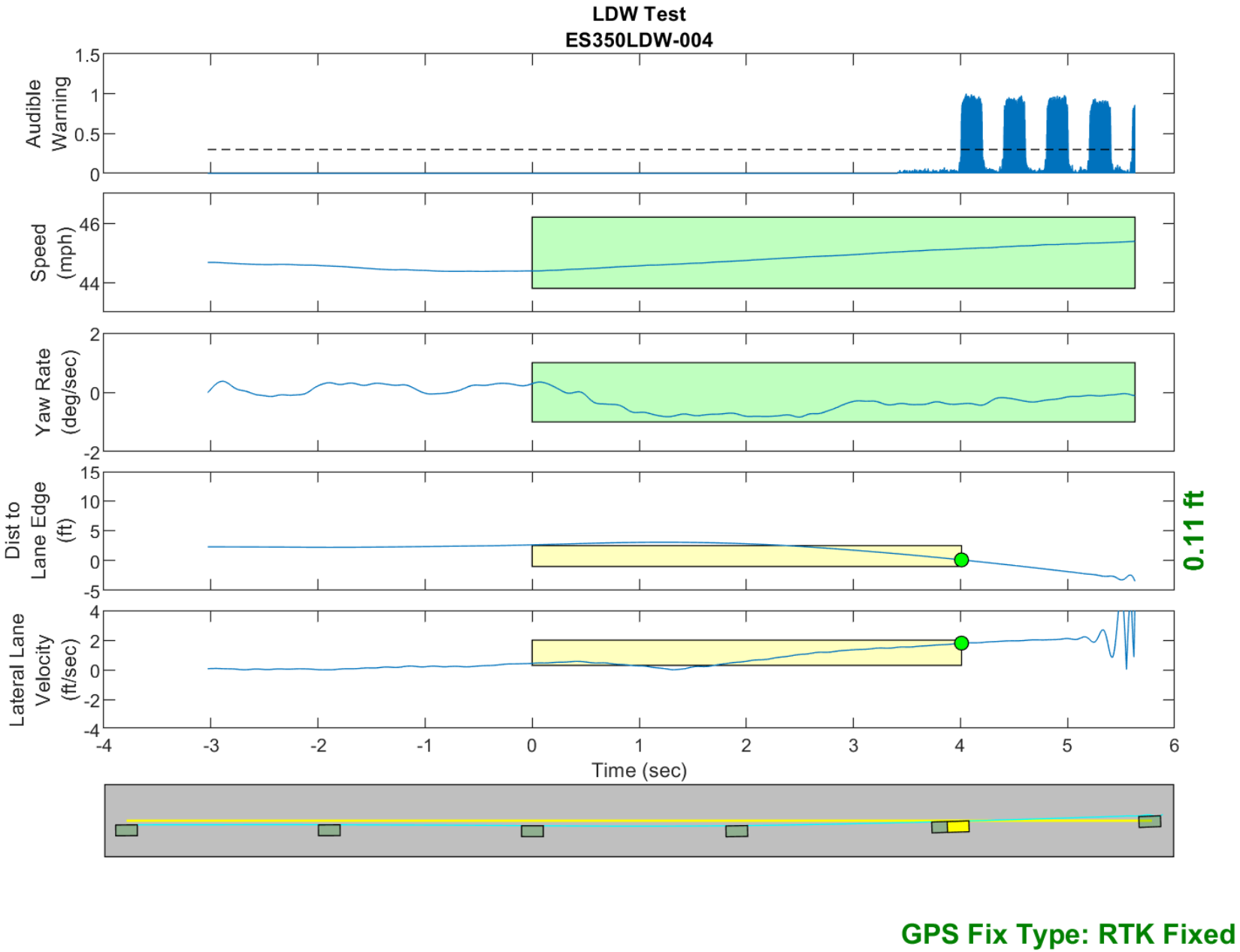
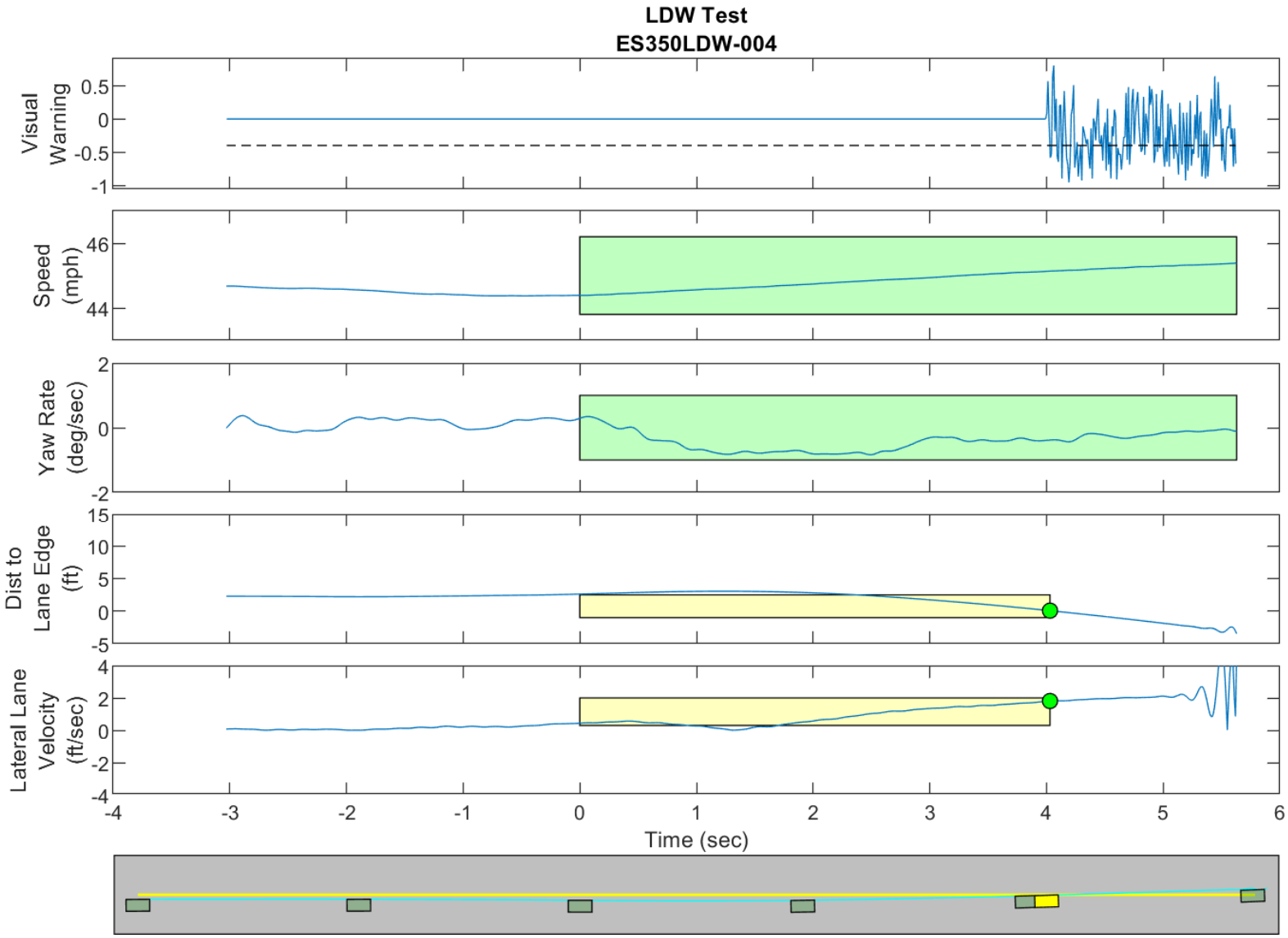


Figure D6. Time History for Run 04, Solid Line, Left Departure, Audible Warning



GPS Fix Type: RTK Fixed

Figure D7. Time History for Run 04, Solid Line, Left Departure, Visual Warning

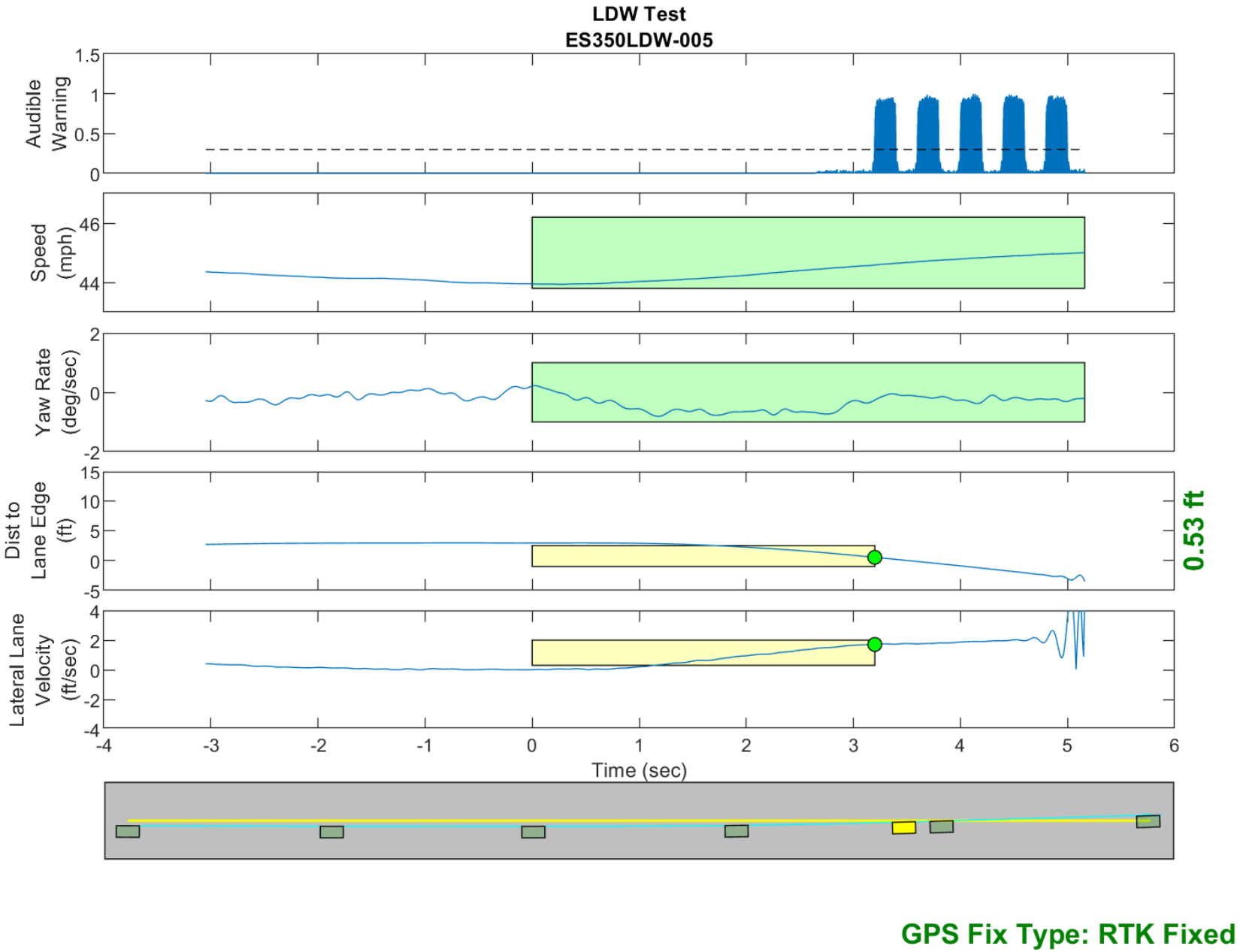


Figure D8. Time History for Run 05, Solid Line, Left Departure, Audible Warning

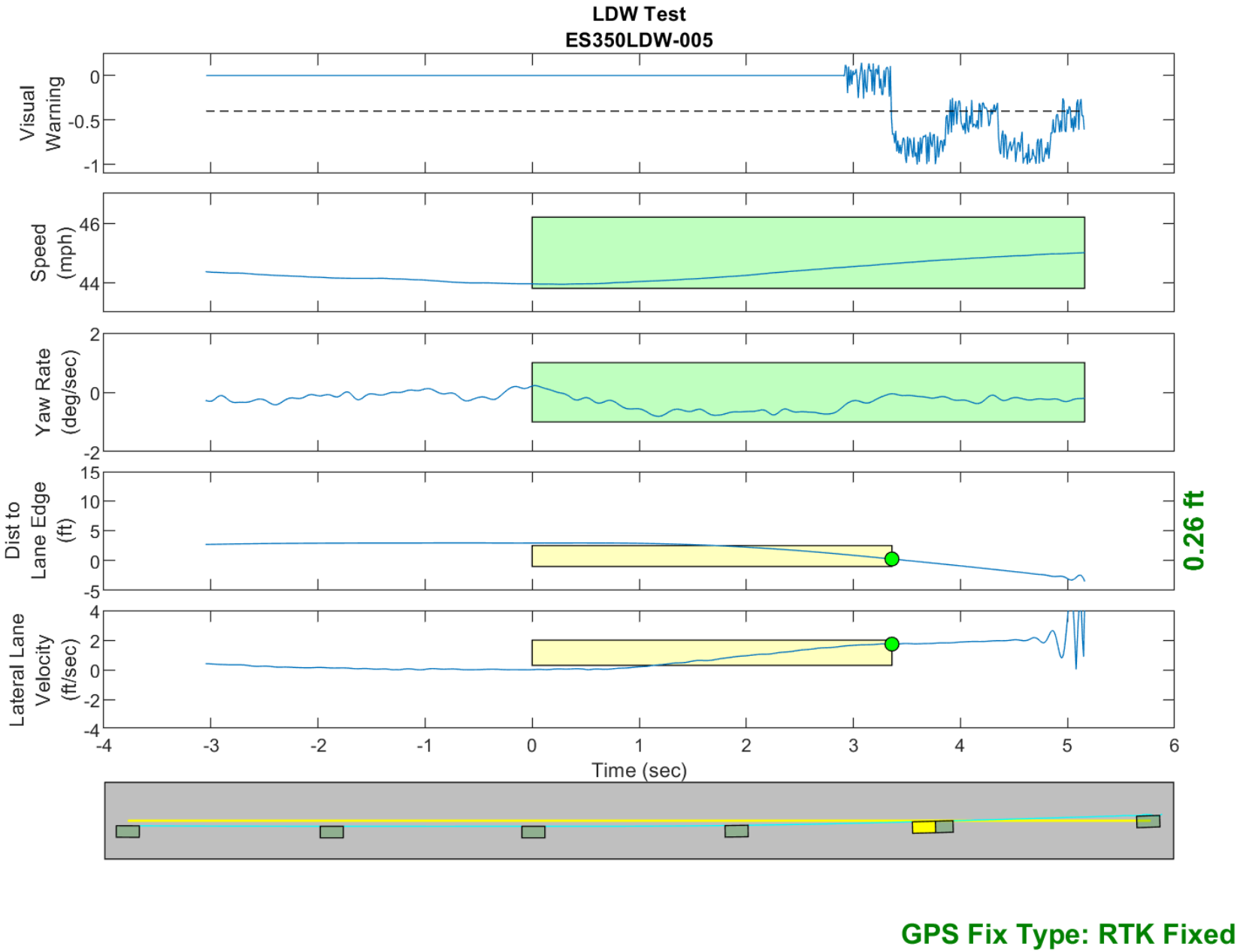


Figure D9. Time History for Run 05, Solid Line, Left Departure, Visual Warning

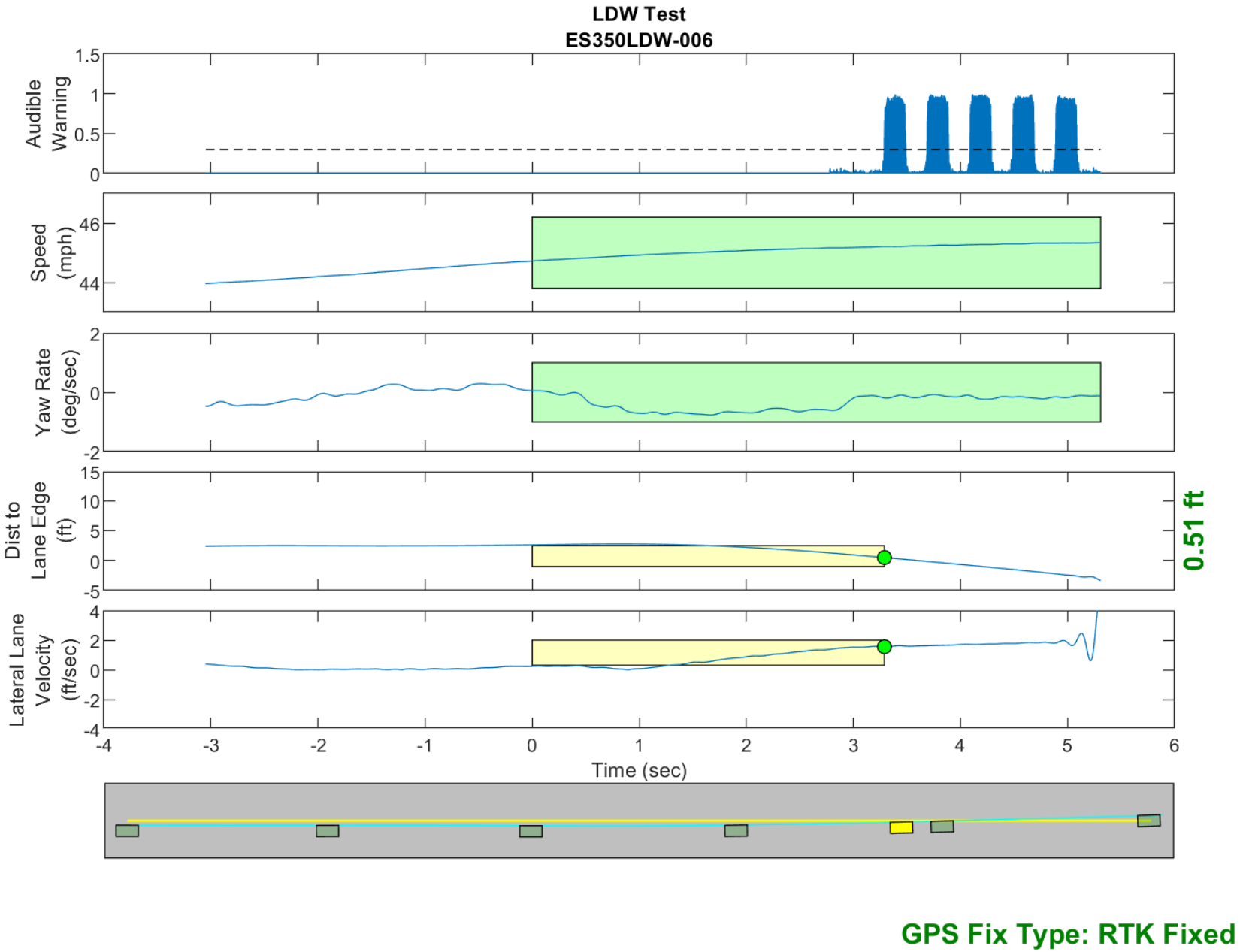


Figure D10. Time History for Run 06, Solid Line, Left Departure, Audible Warning

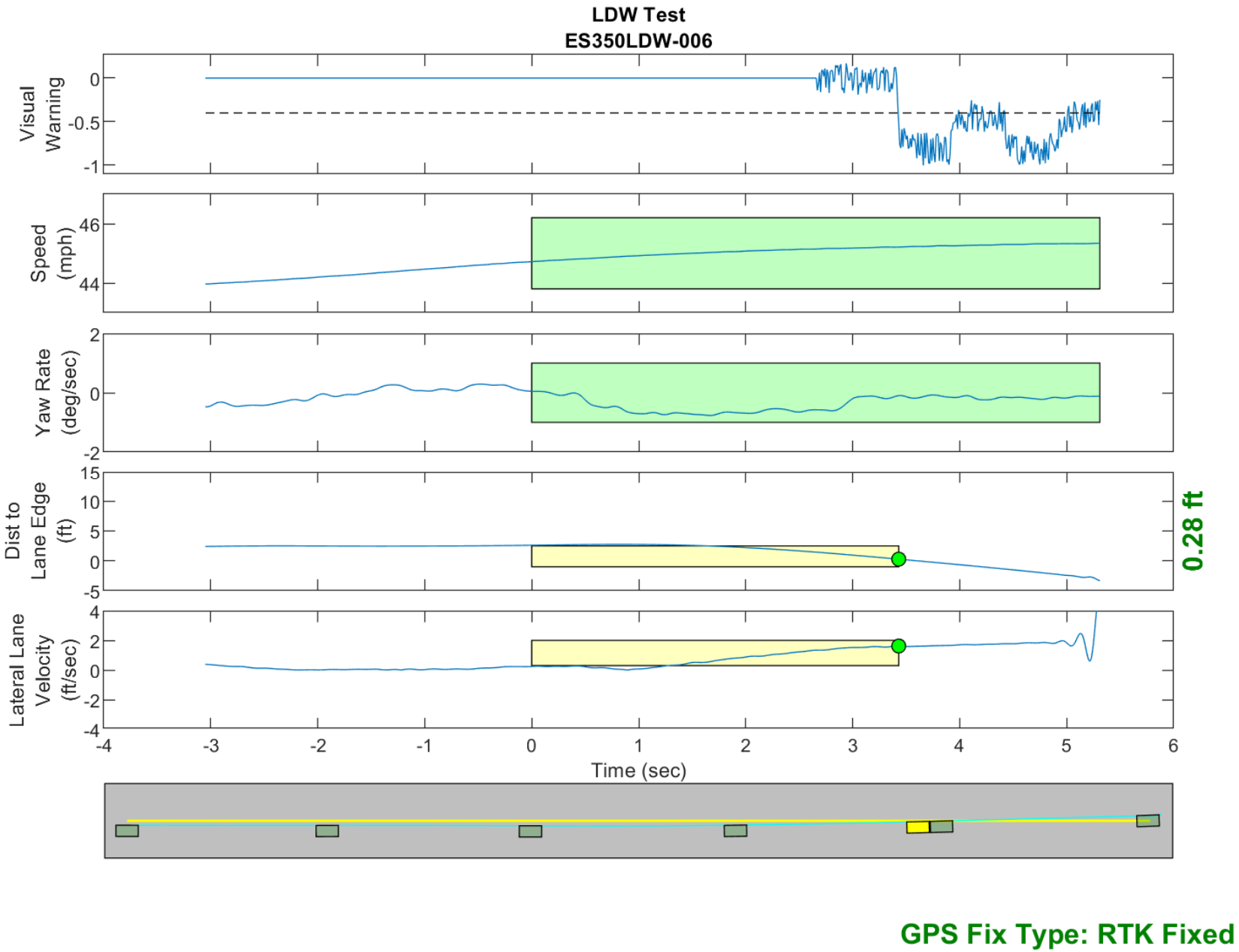


Figure D11. Time History for Run 06, Solid Line, Left Departure, Visual Warning

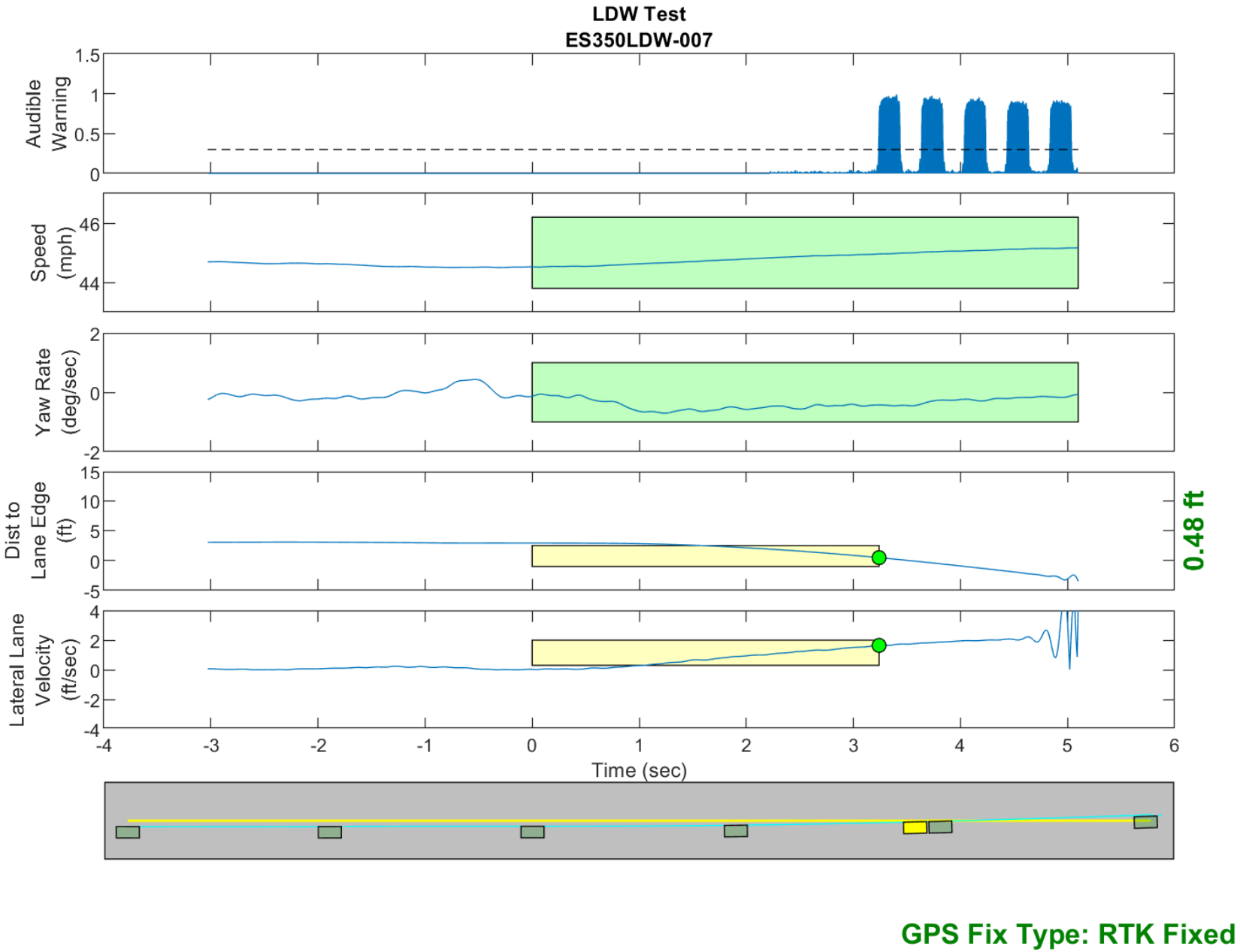


Figure D12. Time History for Run 07, Solid Line, Left Departure, Audible Warning

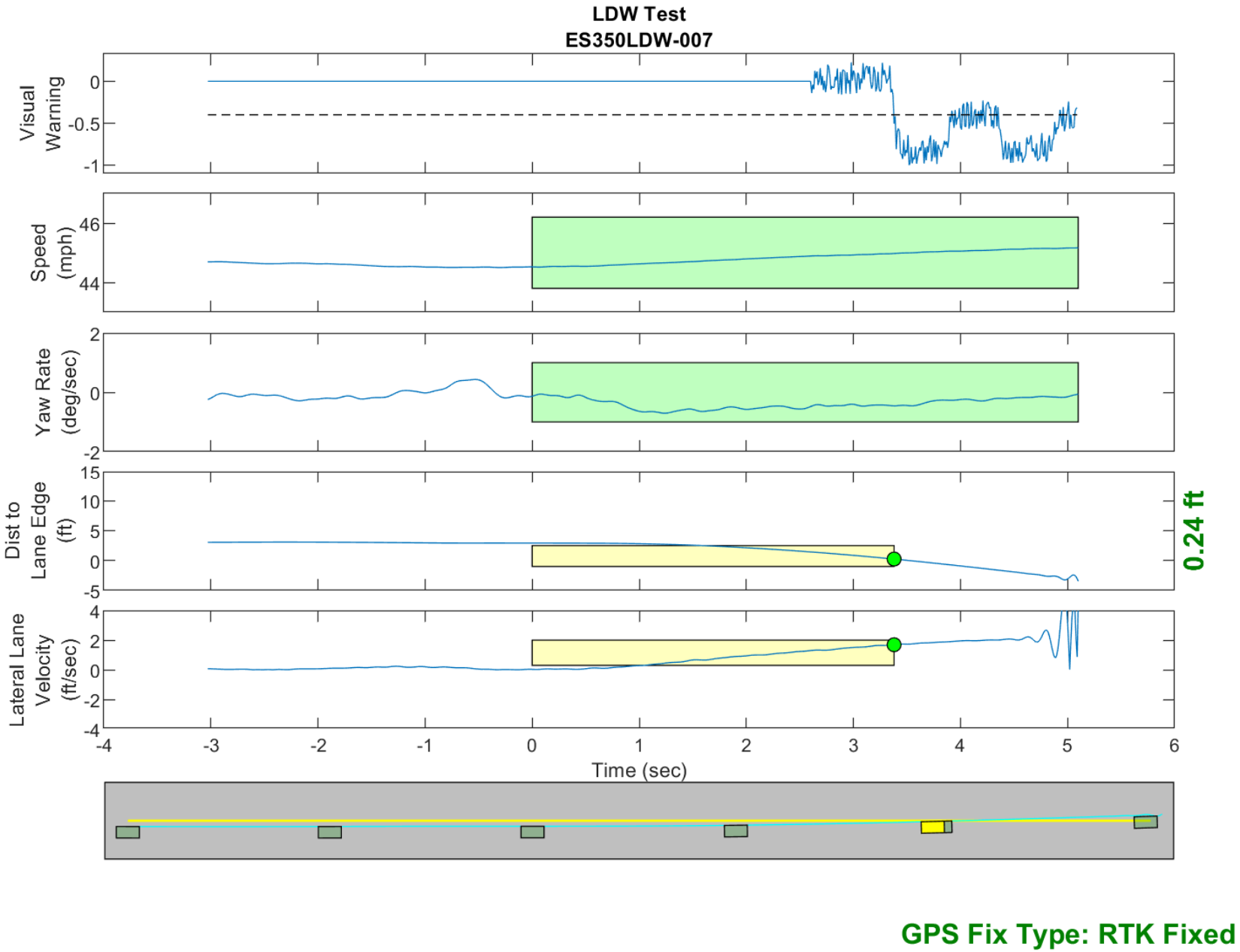


Figure D13. Time History for Run 07, Solid Line, Left Departure, Visual Warning

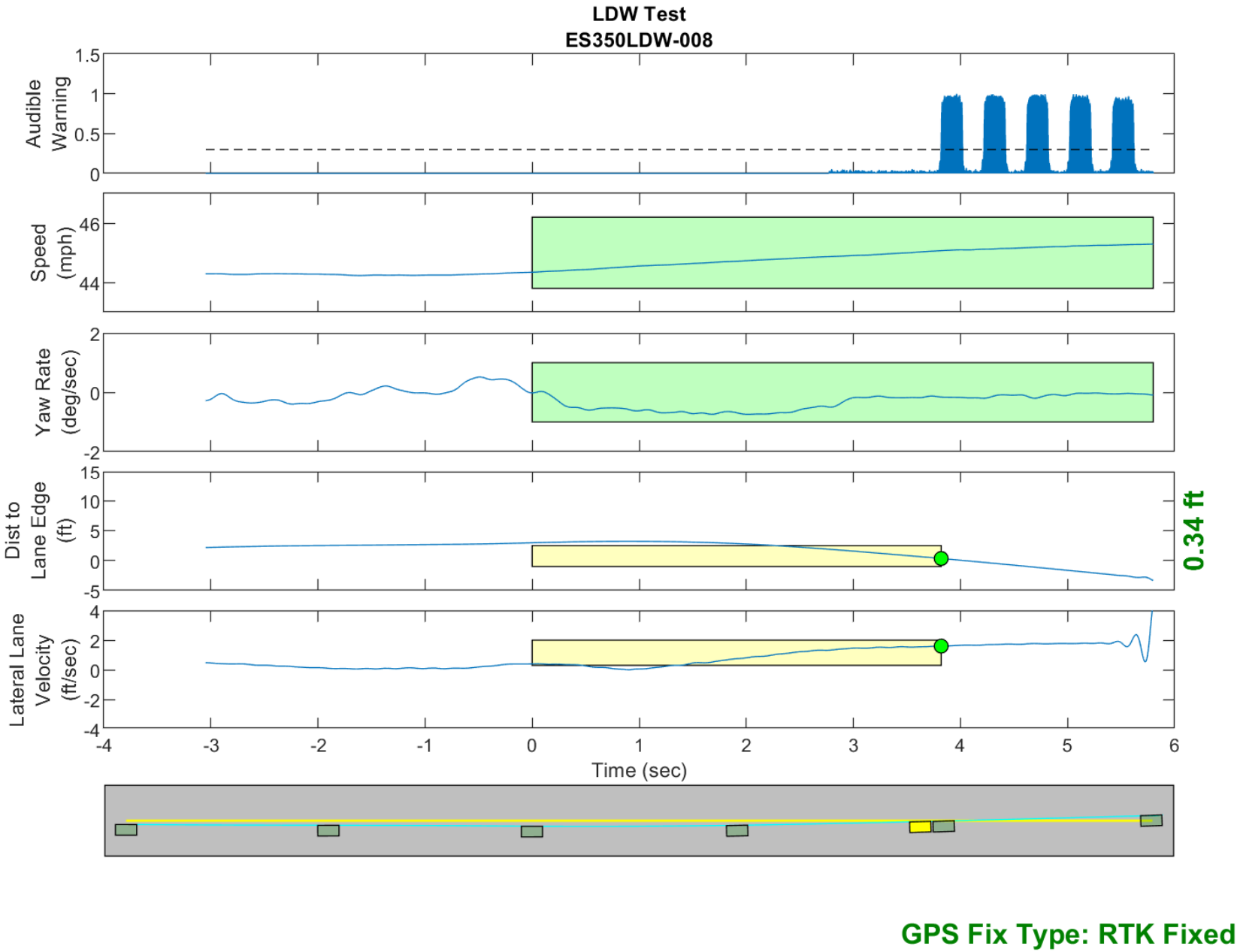


Figure D14. Time History for Run 08, Solid Line, Left Departure, Audible Warning

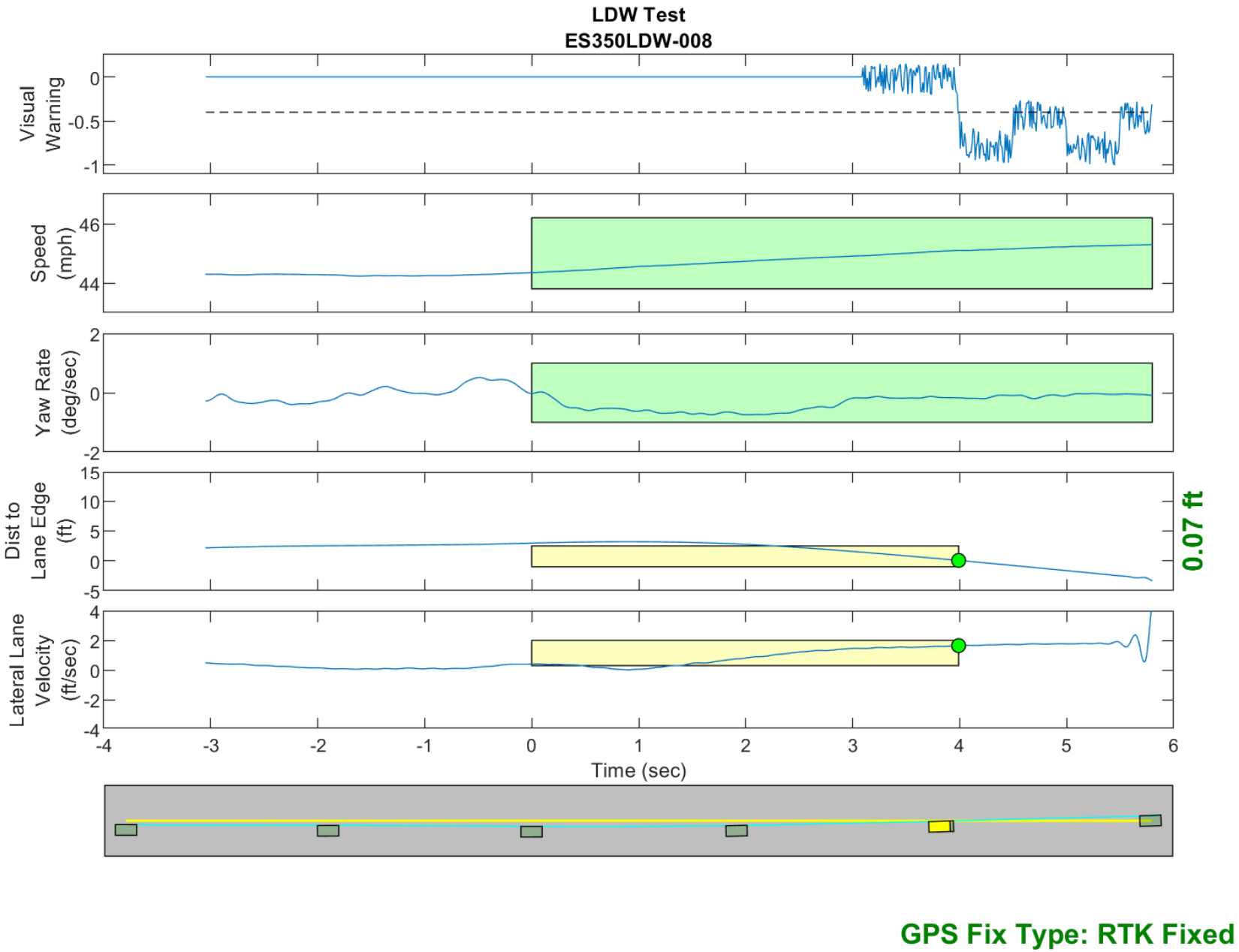


Figure D15. Time History for Run 08, Solid Line, Left Departure, Visual Warning

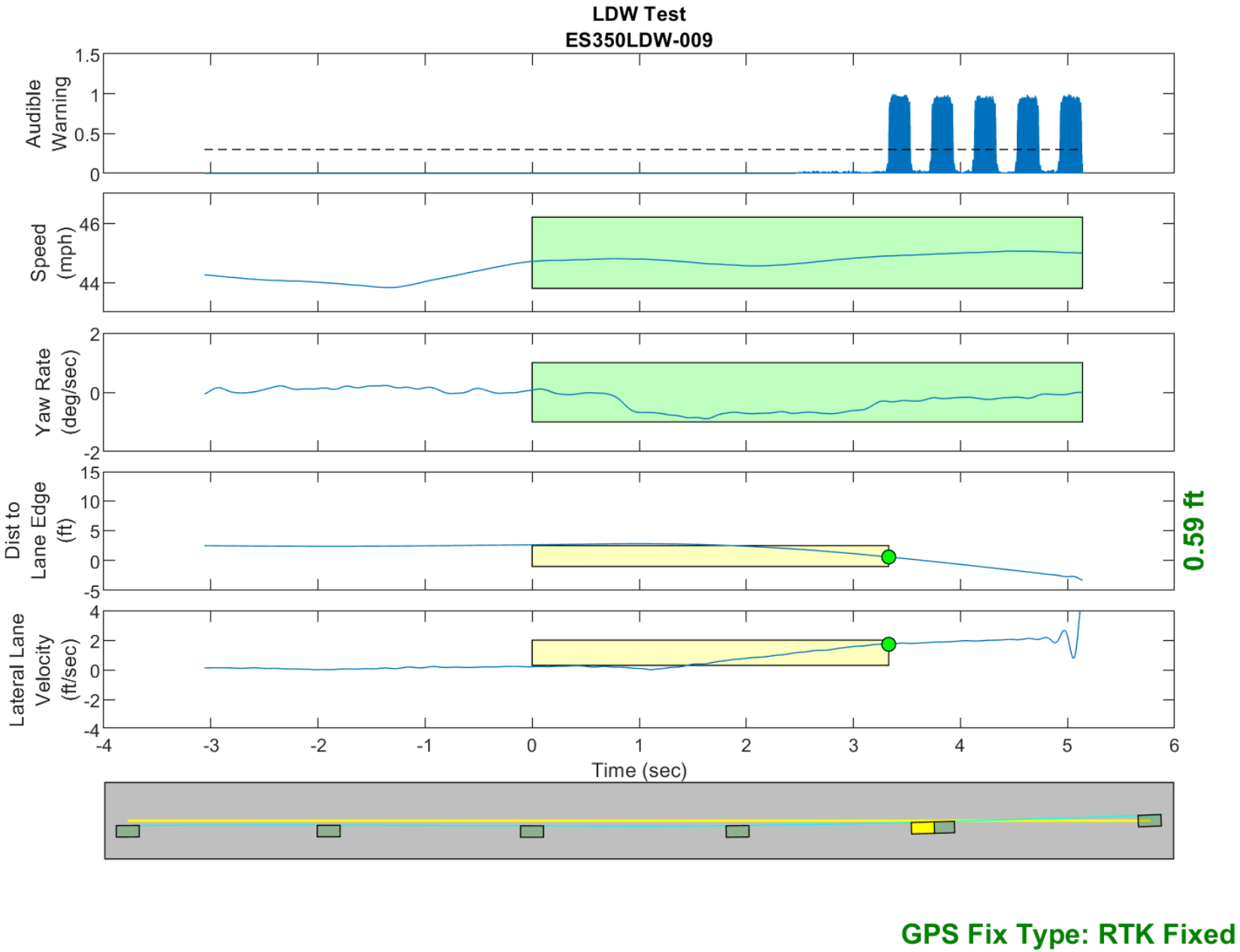


Figure D16. Time History for Run 09, Solid Line, Left Departure, Audible Warning

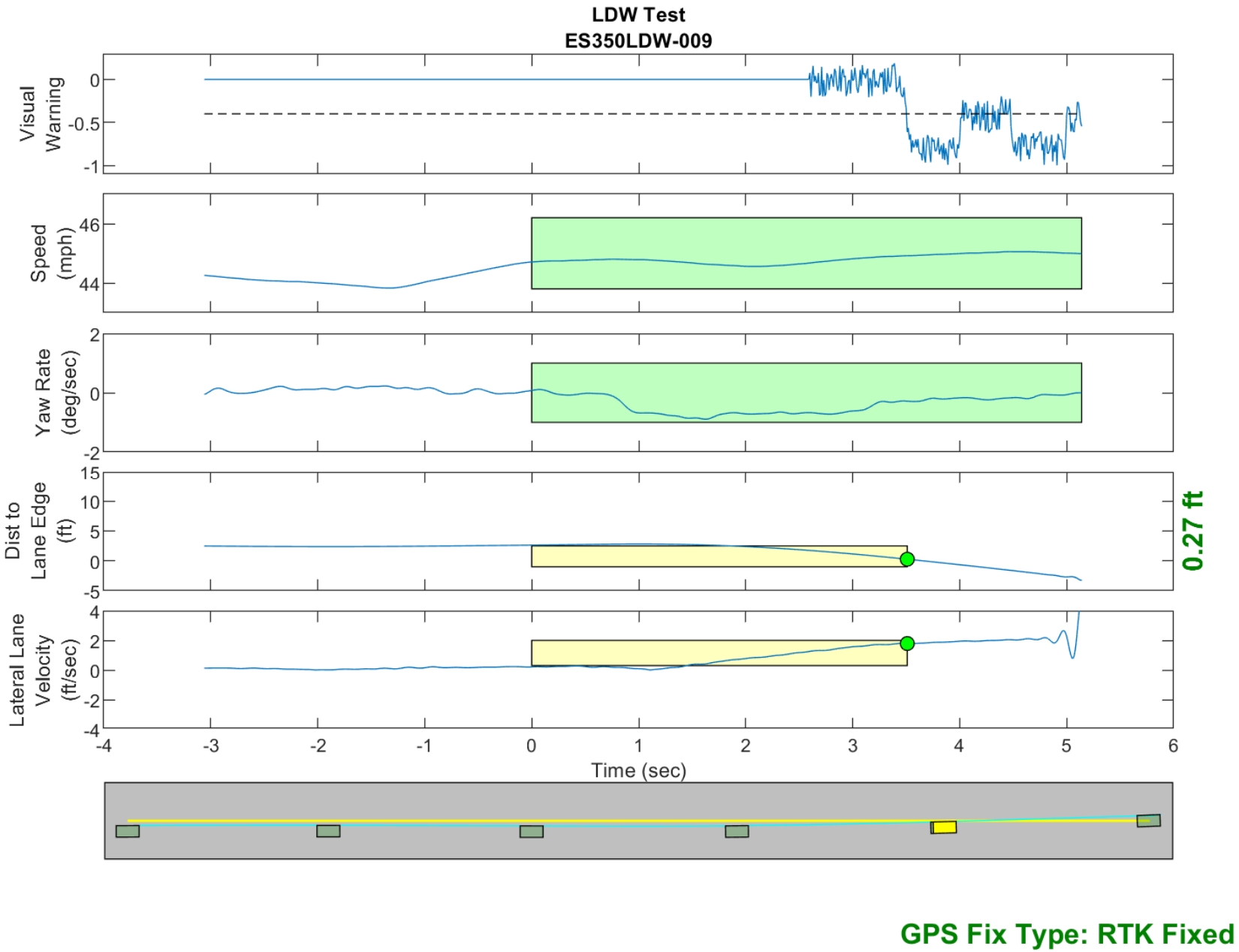


Figure D17. Time History for Run 09, Solid Line, Left Departure, Visual Warning

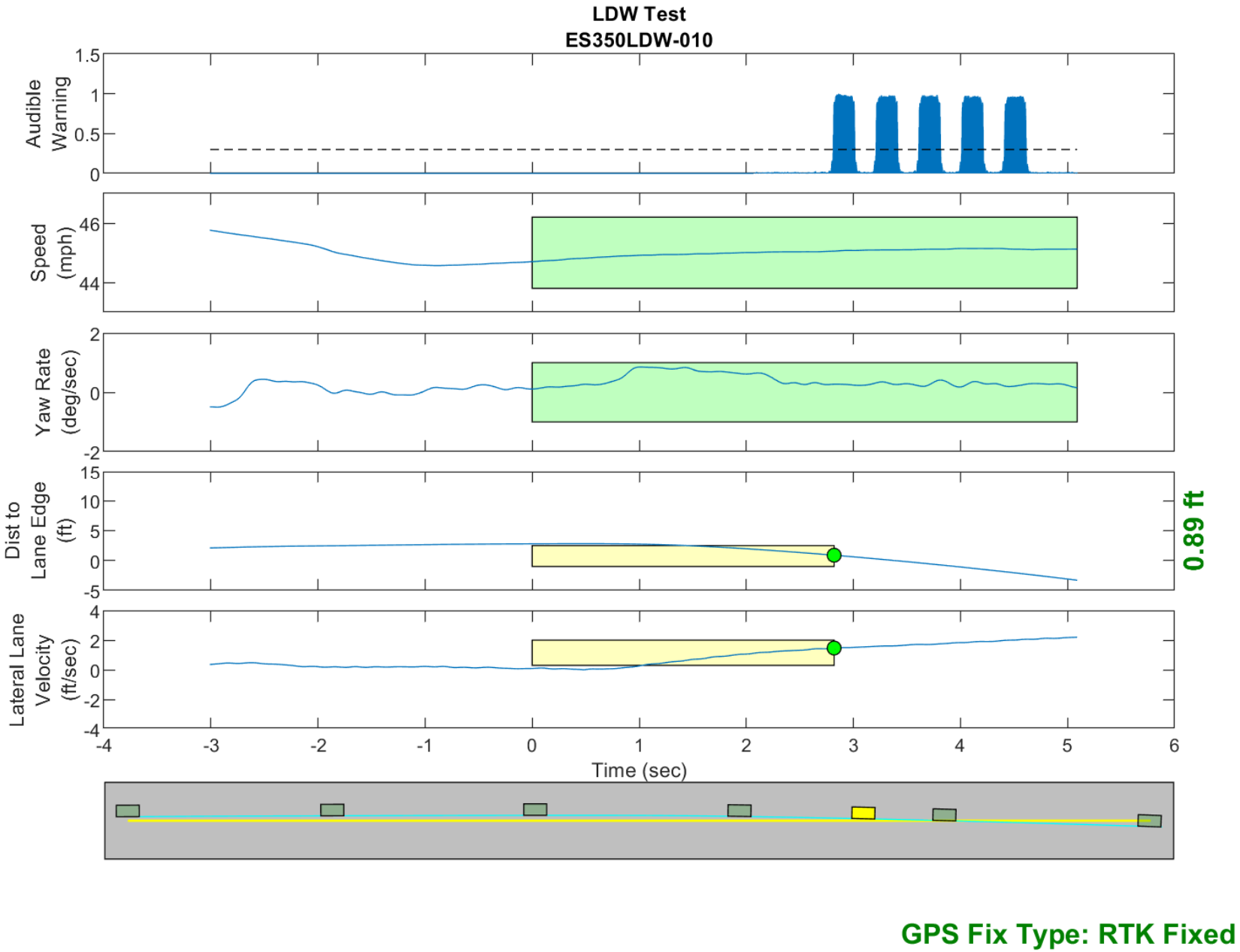


Figure D18. Time History for Run 10, Solid Line, Right Departure, Audible Warning

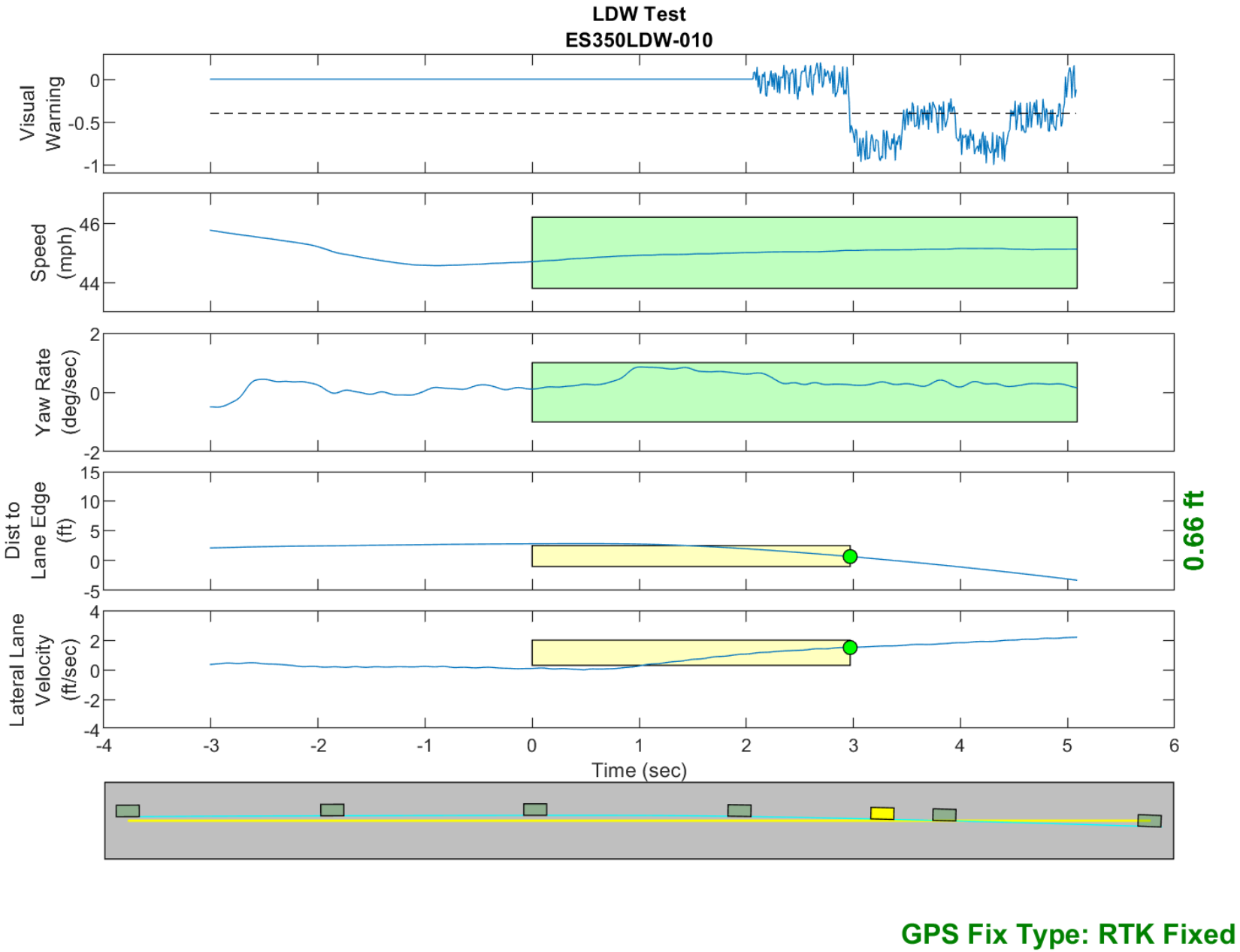


Figure D19. Time History for Run 10, Solid Line, Right Departure, Visual Warning

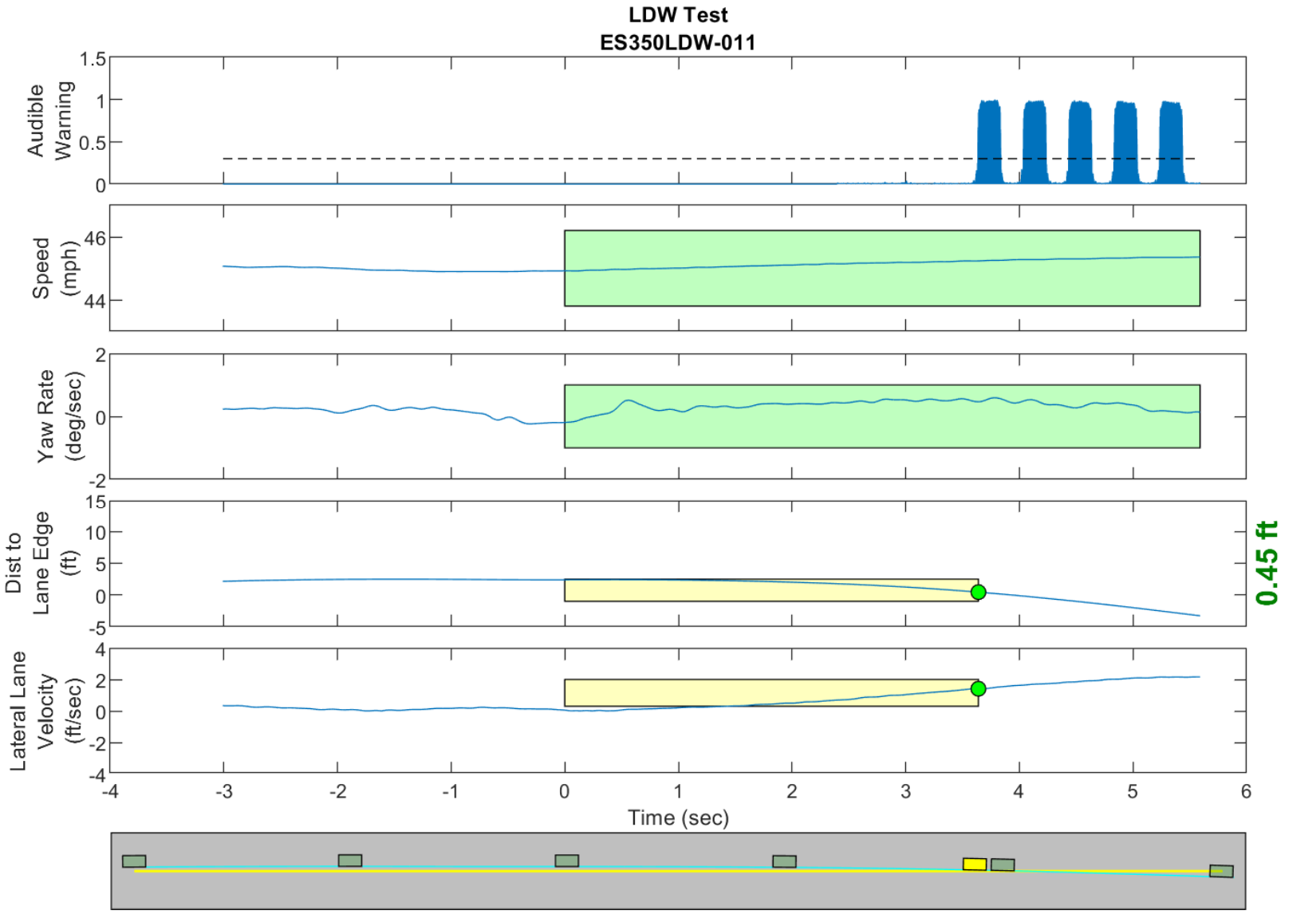


Figure D20. Time History for Run 11, Solid Line, Right Departure, Audible Warning

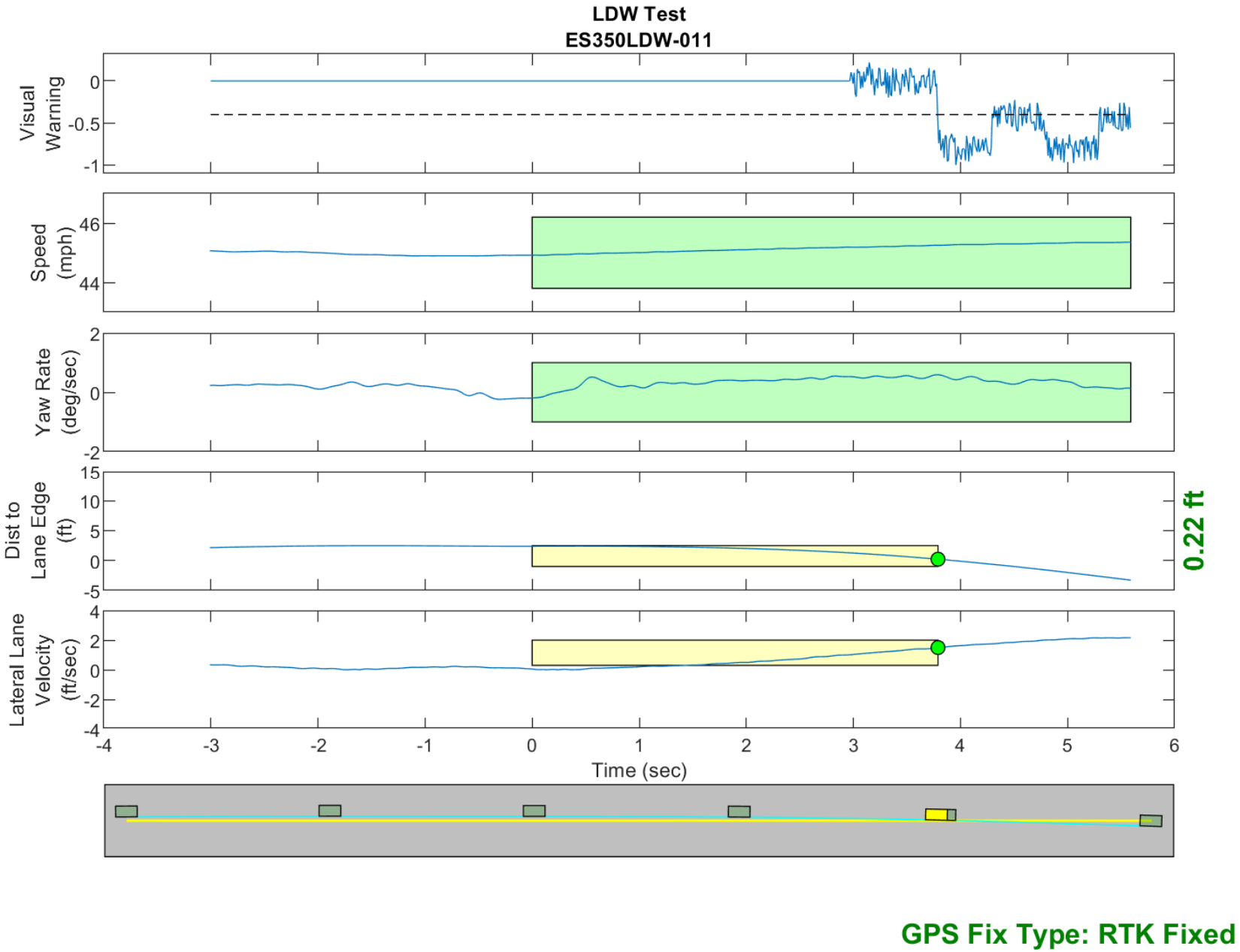


Figure D21. Time History for Run 11, Solid Line, Right Departure, Visual Warning

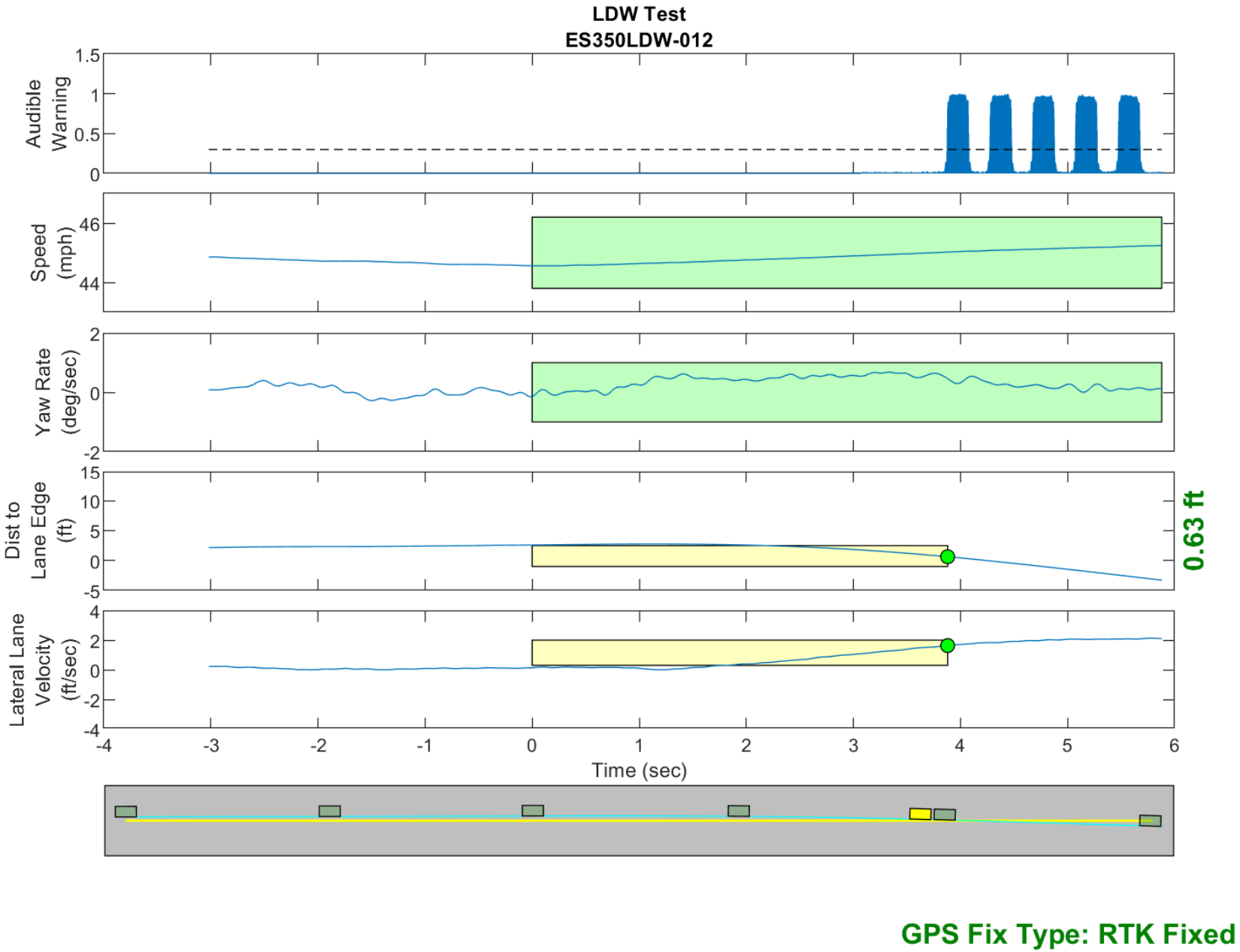


Figure D22. Time History for Run 12, Solid Line, Right Departure, Audible Warning

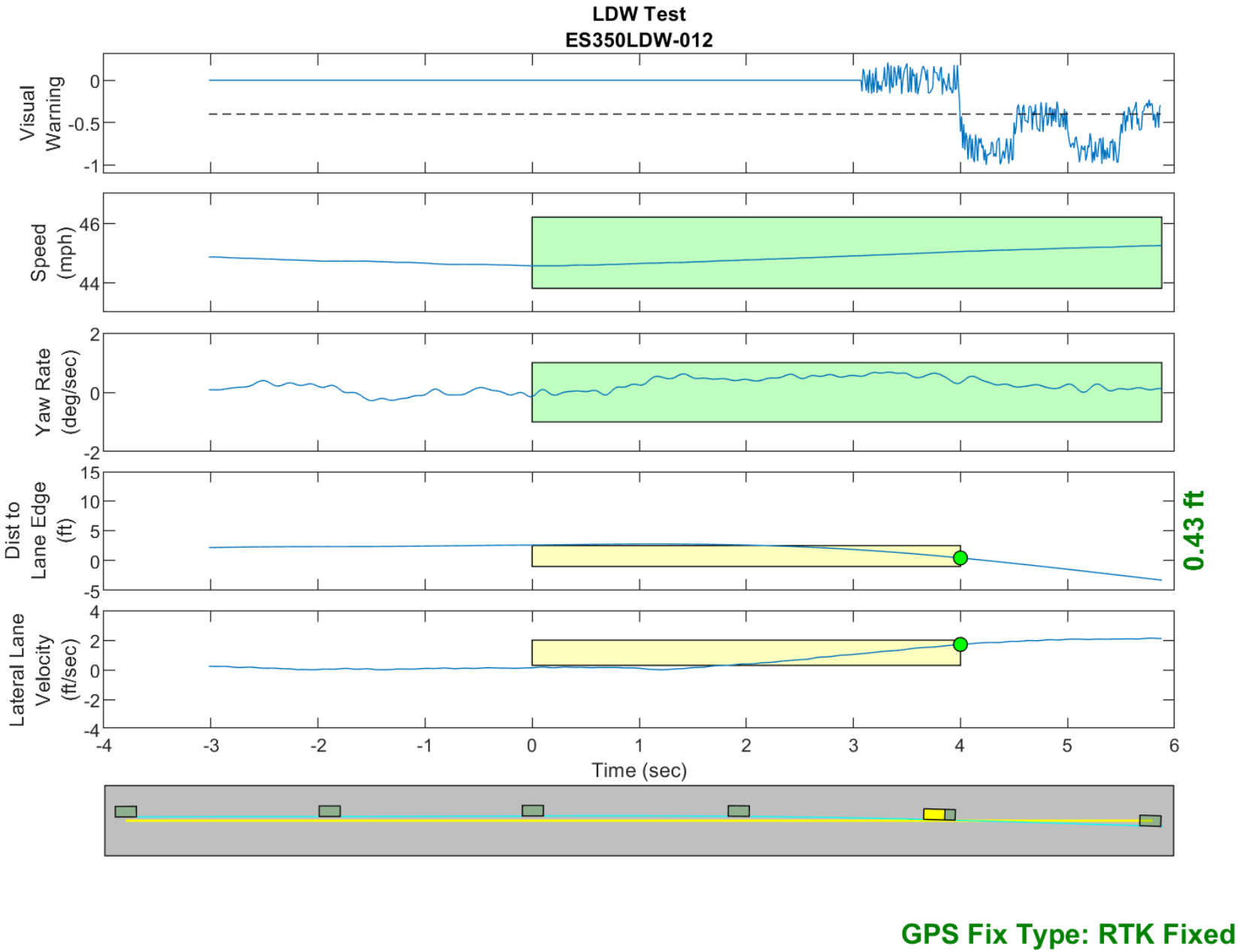


Figure D23. Time History for Run 12, Solid Line, Right Departure, Visual Warning

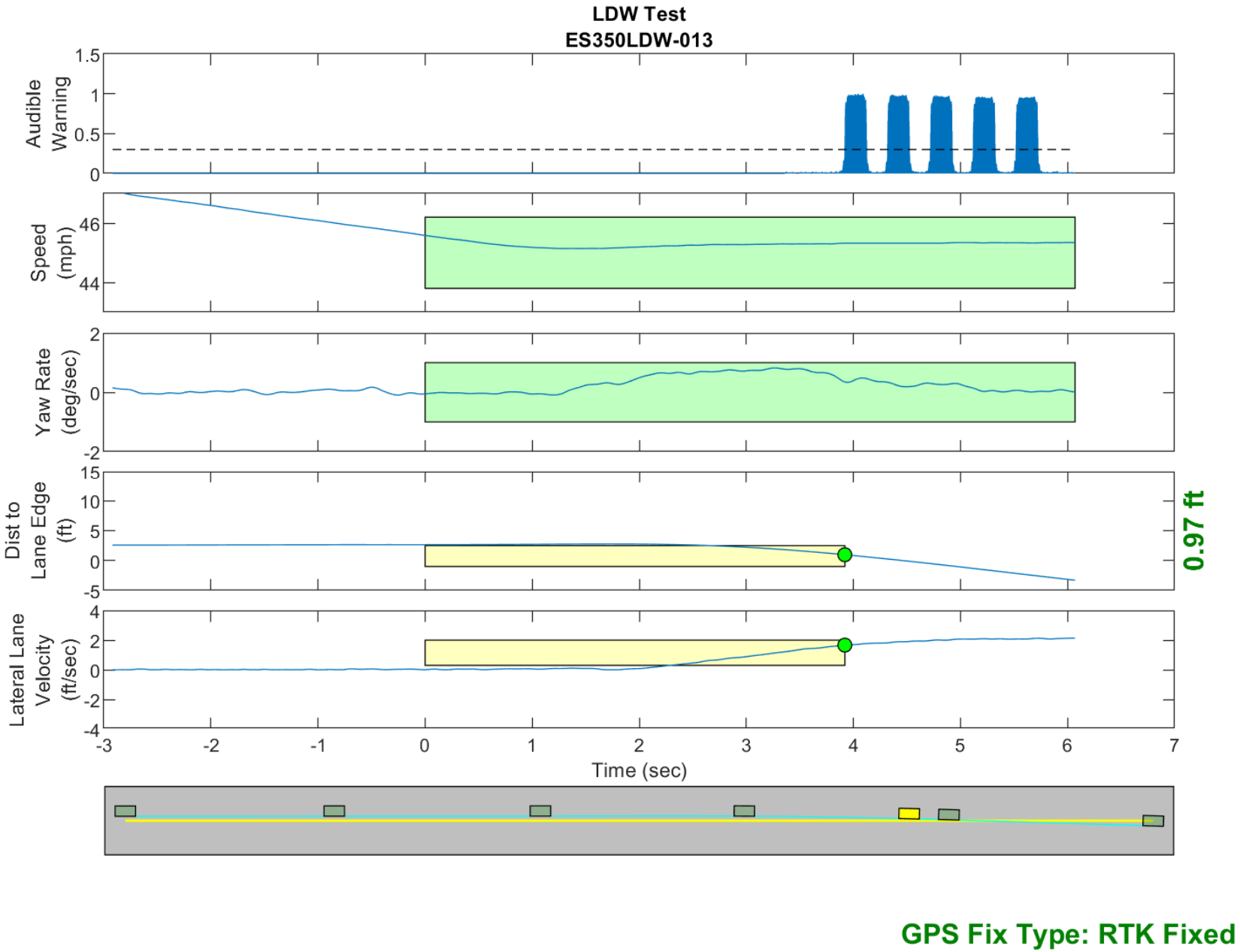


Figure D24. Time History for Run 13, Solid Line, Right Departure, Audible Warning

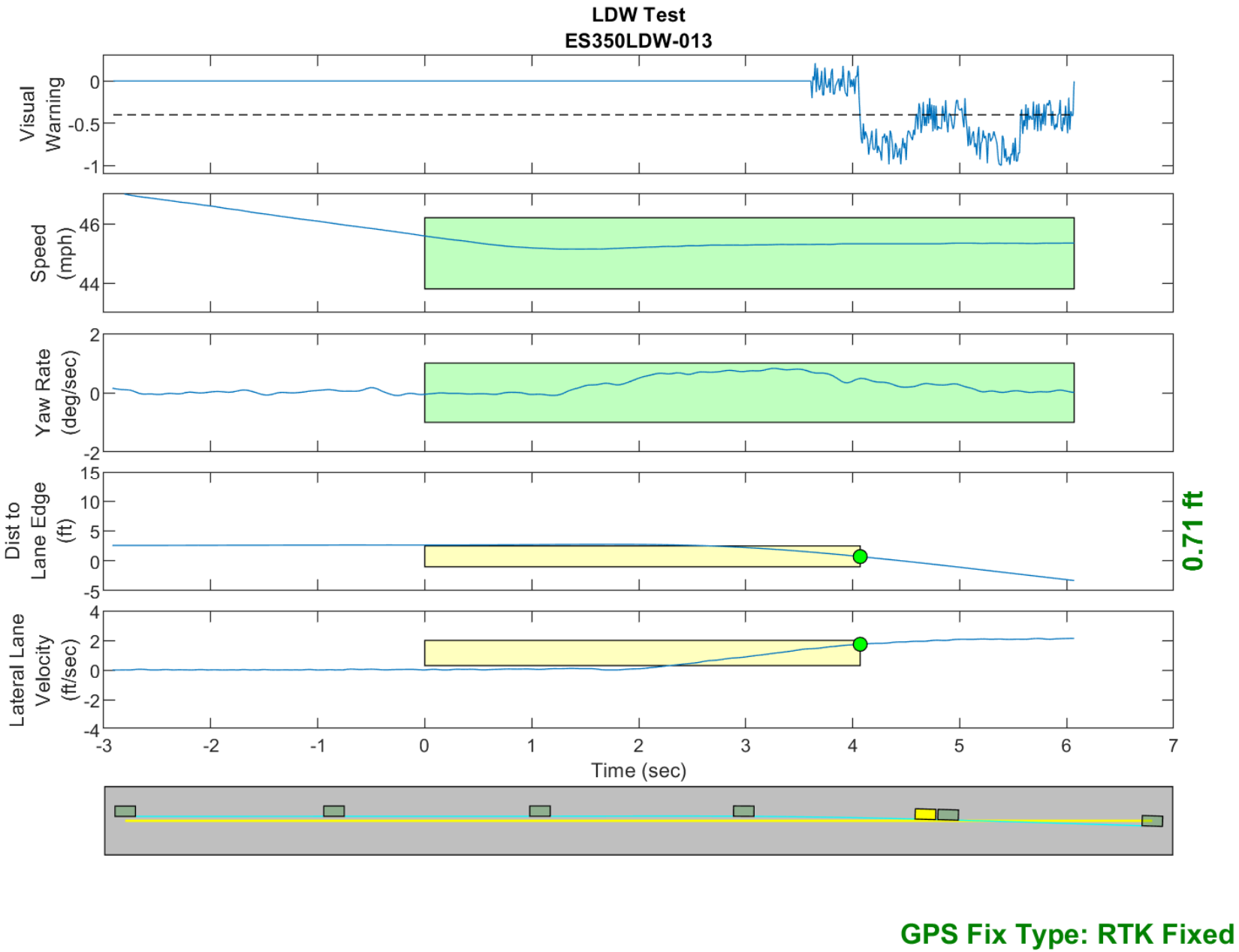


Figure D25. Time History for Run 13, Solid Line, Right Departure, Visual Warning

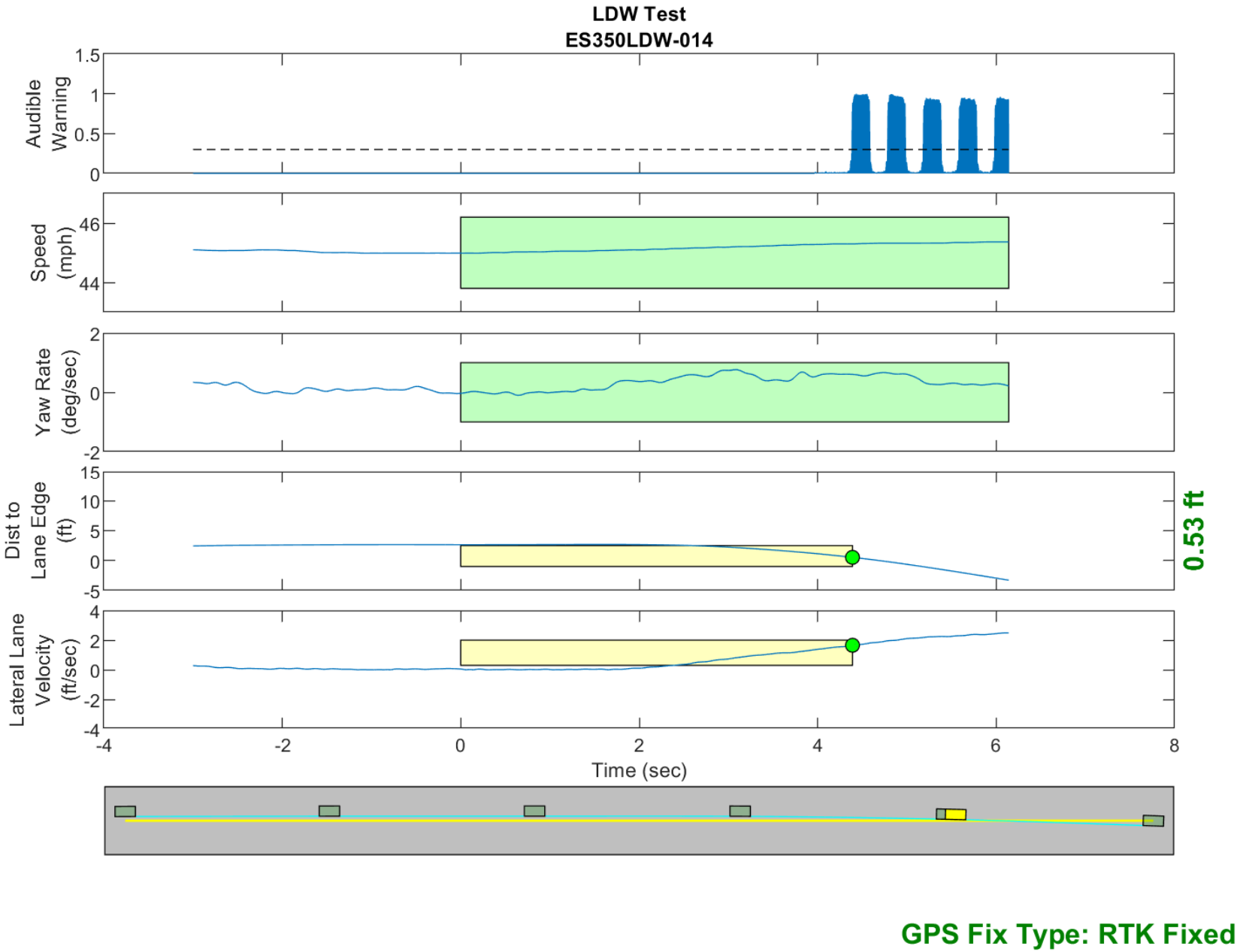


Figure D26. Time History for Run 14, Solid Line, Right Departure, Audible Warning

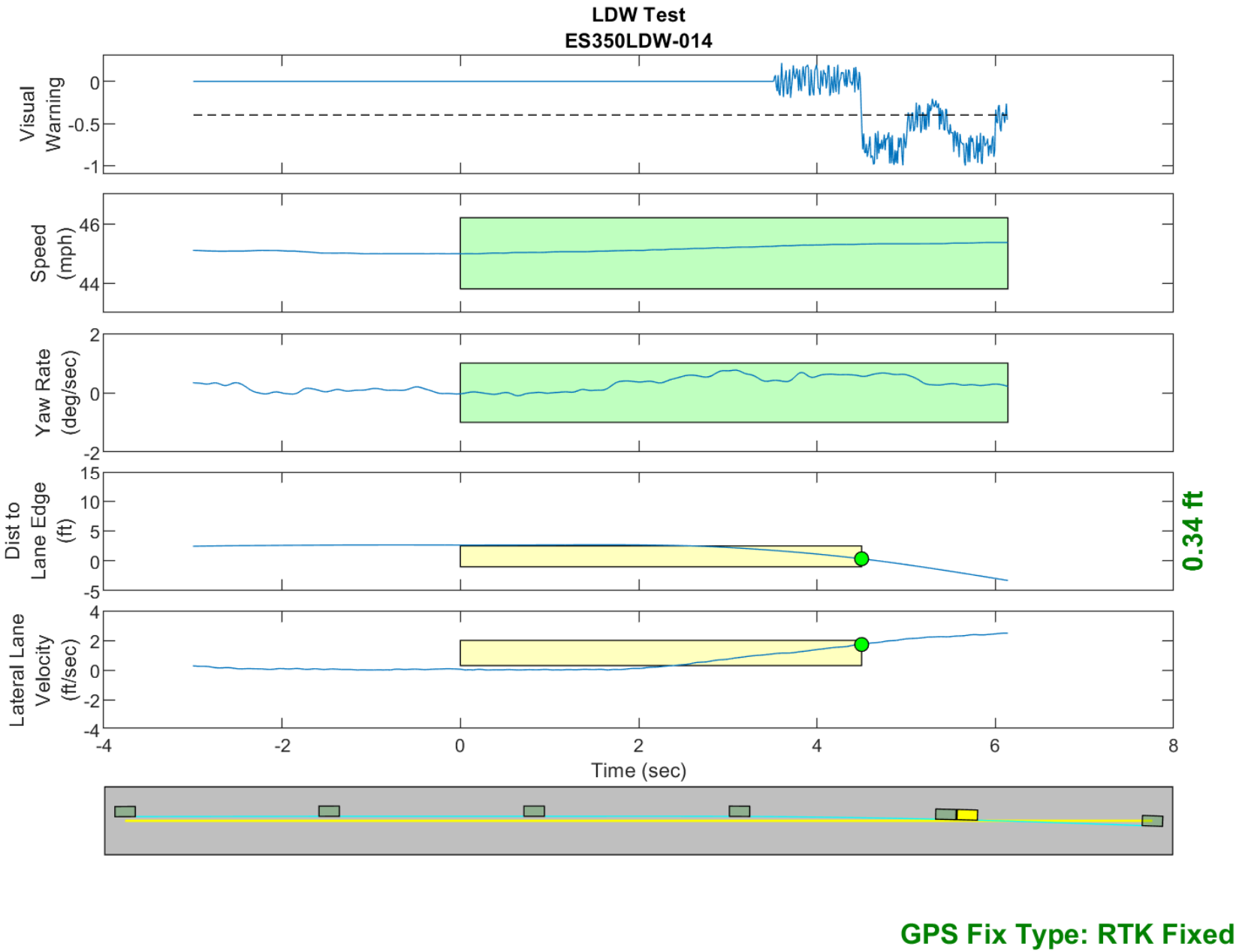


Figure D27. Time History for Run 14, Solid Line, Right Departure, Visual Warning

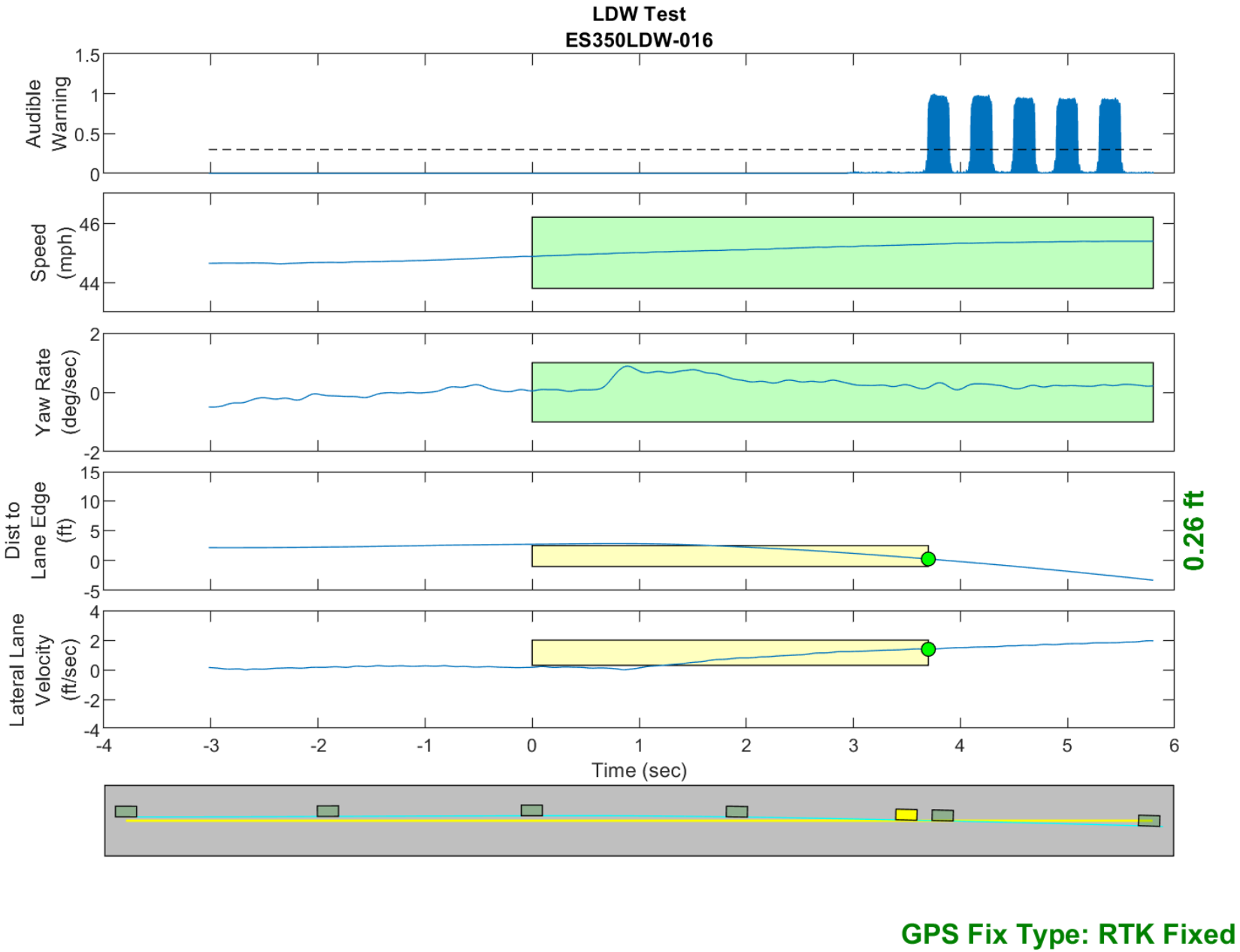


Figure D28. Time History for Run 16, Solid Line, Right Departure, Audible Warning

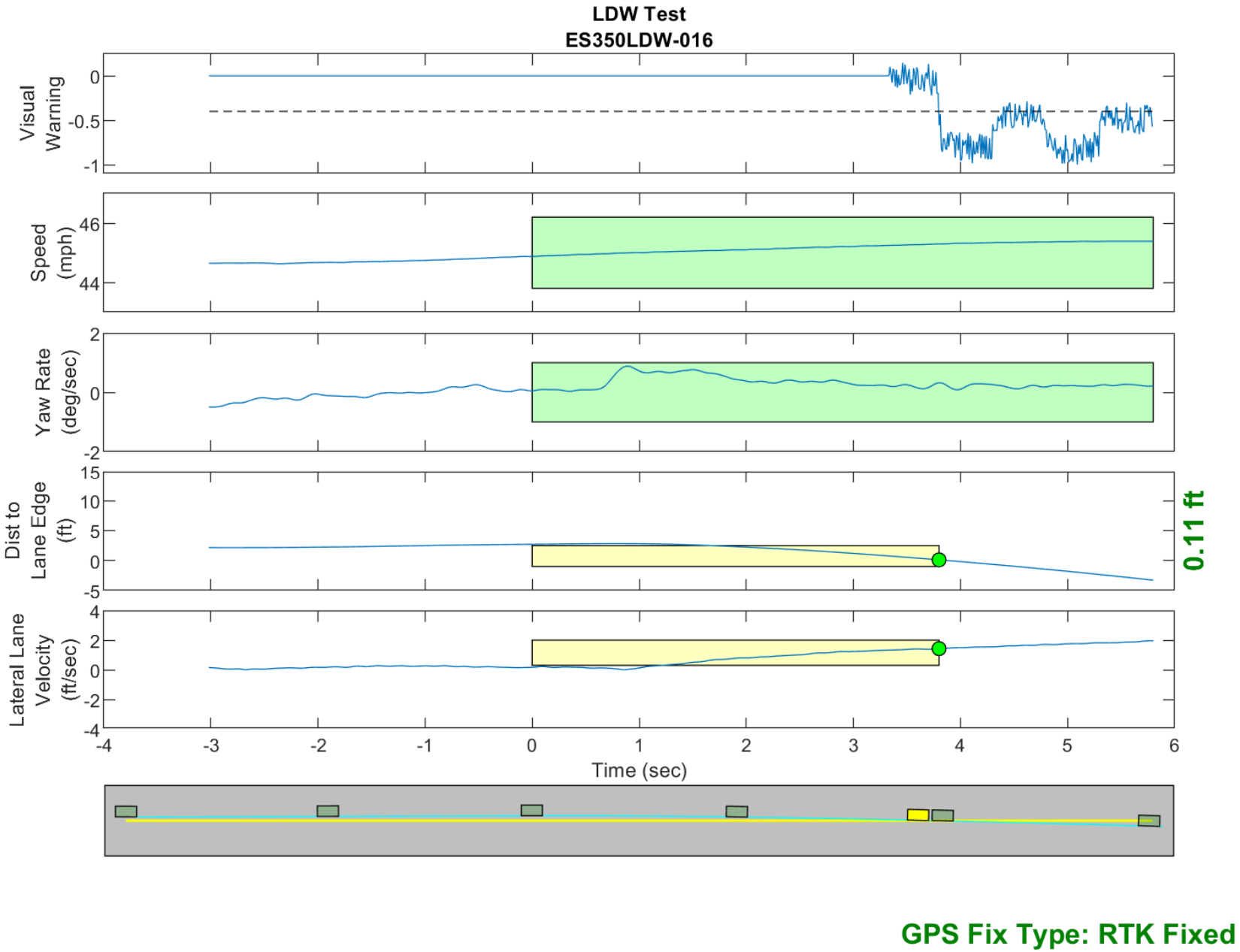


Figure D29. Time History for Run 16, Solid Line, Right Departure, Visual Warning

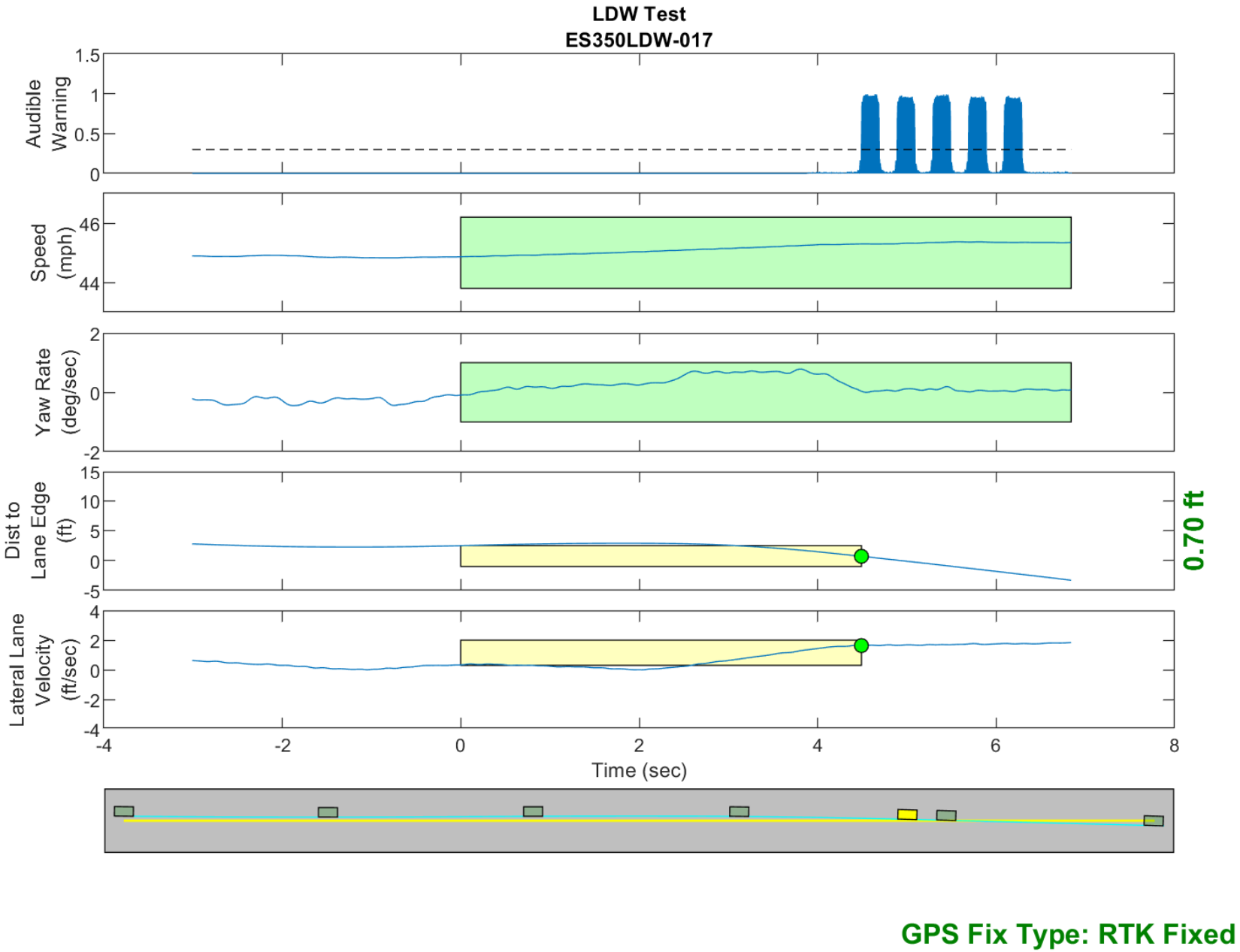


Figure D30. Time History for Run 17, Solid Line, Right Departure, Audible Warning

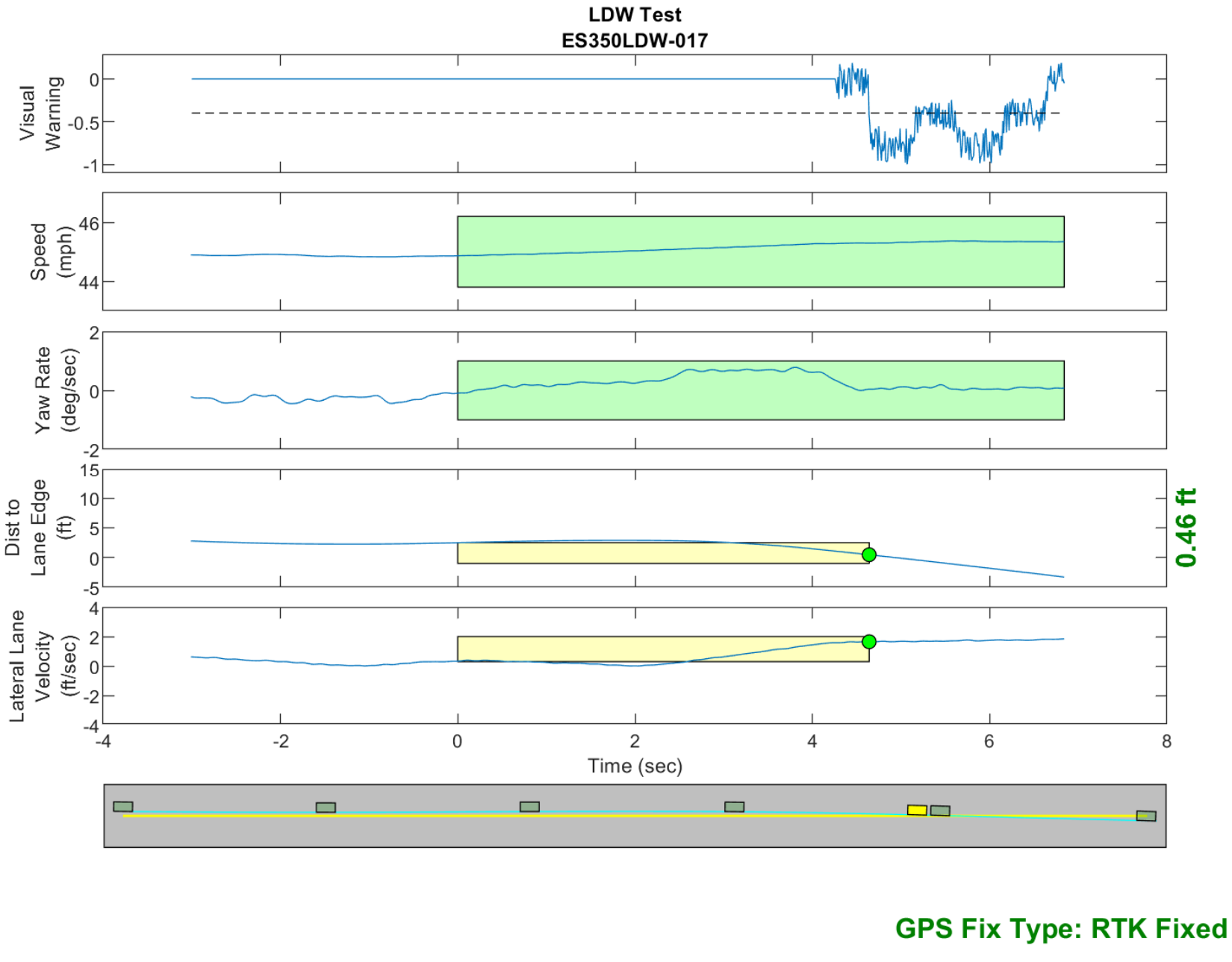


Figure D31. Time History for Run 17, Solid Line, Right Departure, Visual Warning

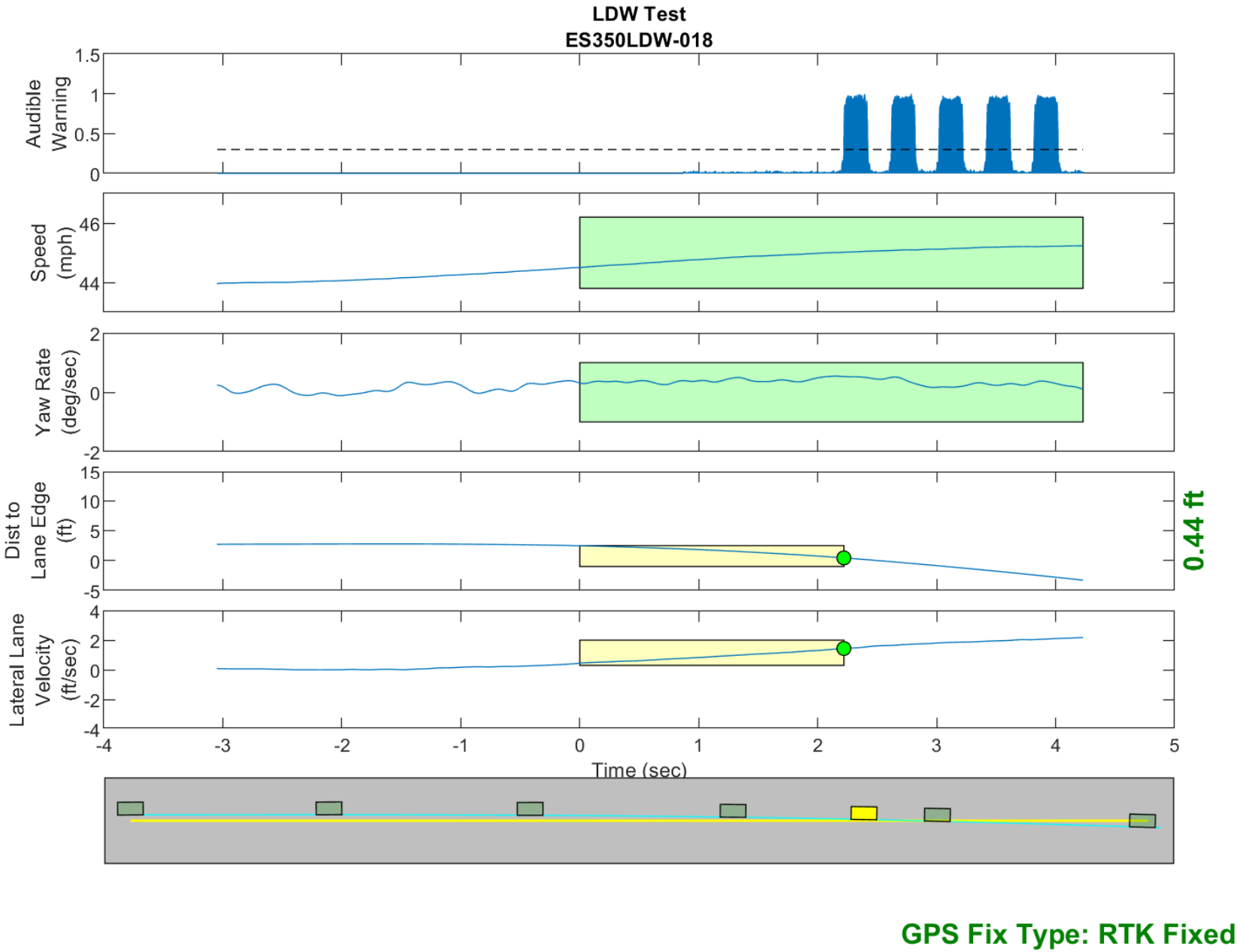


Figure D32. Time History for Run 18, Dashed Line, Right Departure, Audible Warning

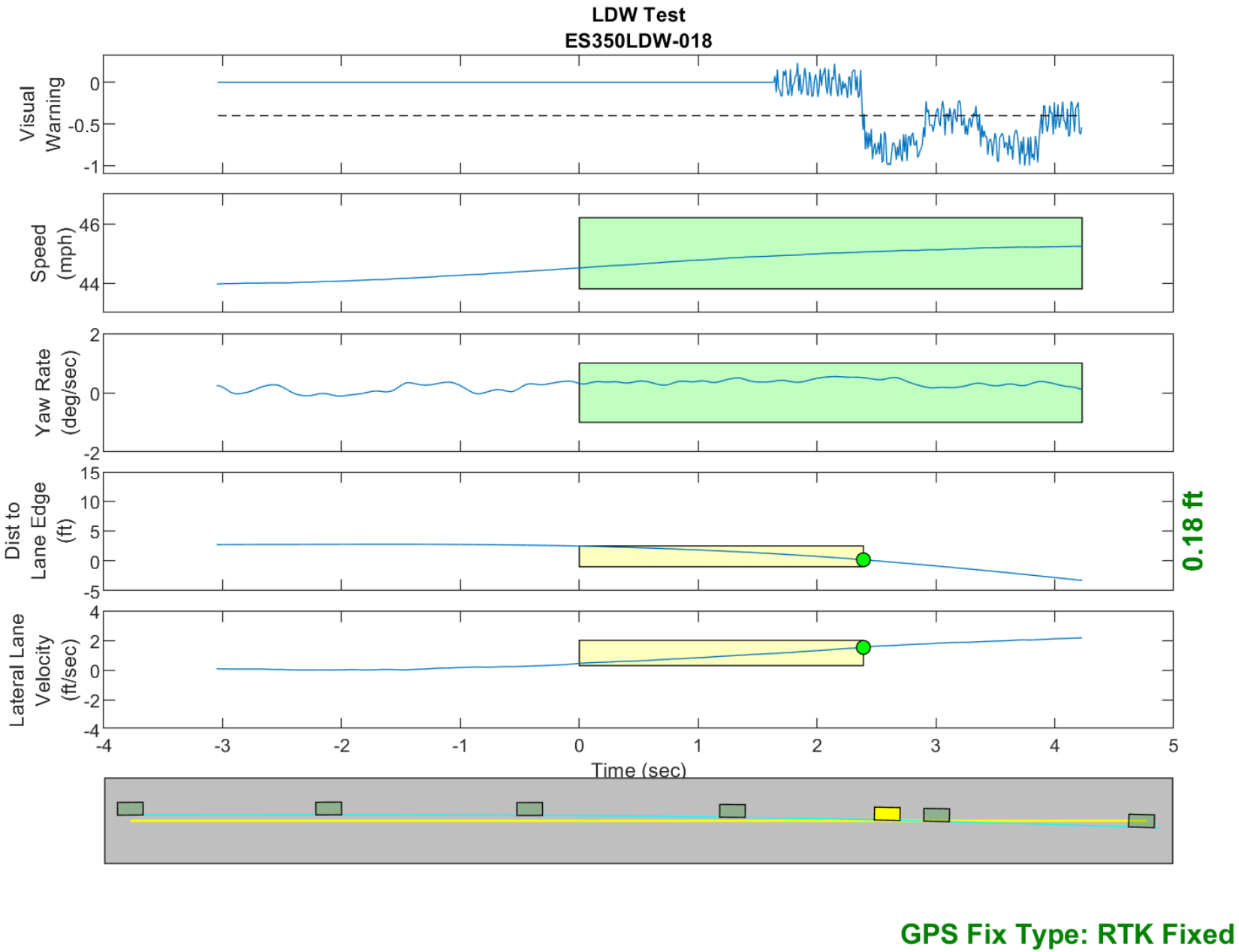


Figure D33. Time History for Run 18, Dashed Line, Right Departure, Visual Warning

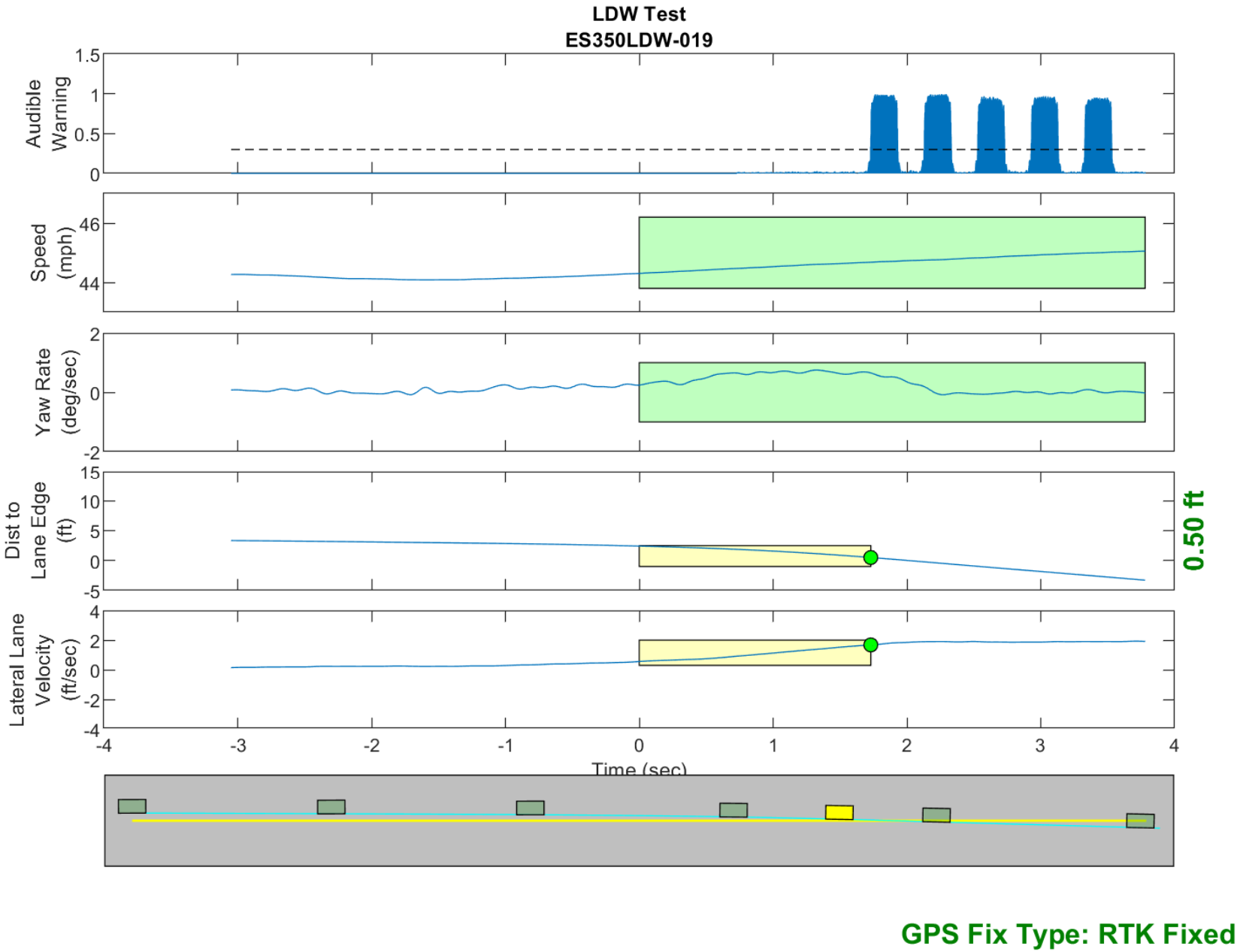


Figure D34. Time History for Run 19, Dashed Line, Right Departure, Audible Warning

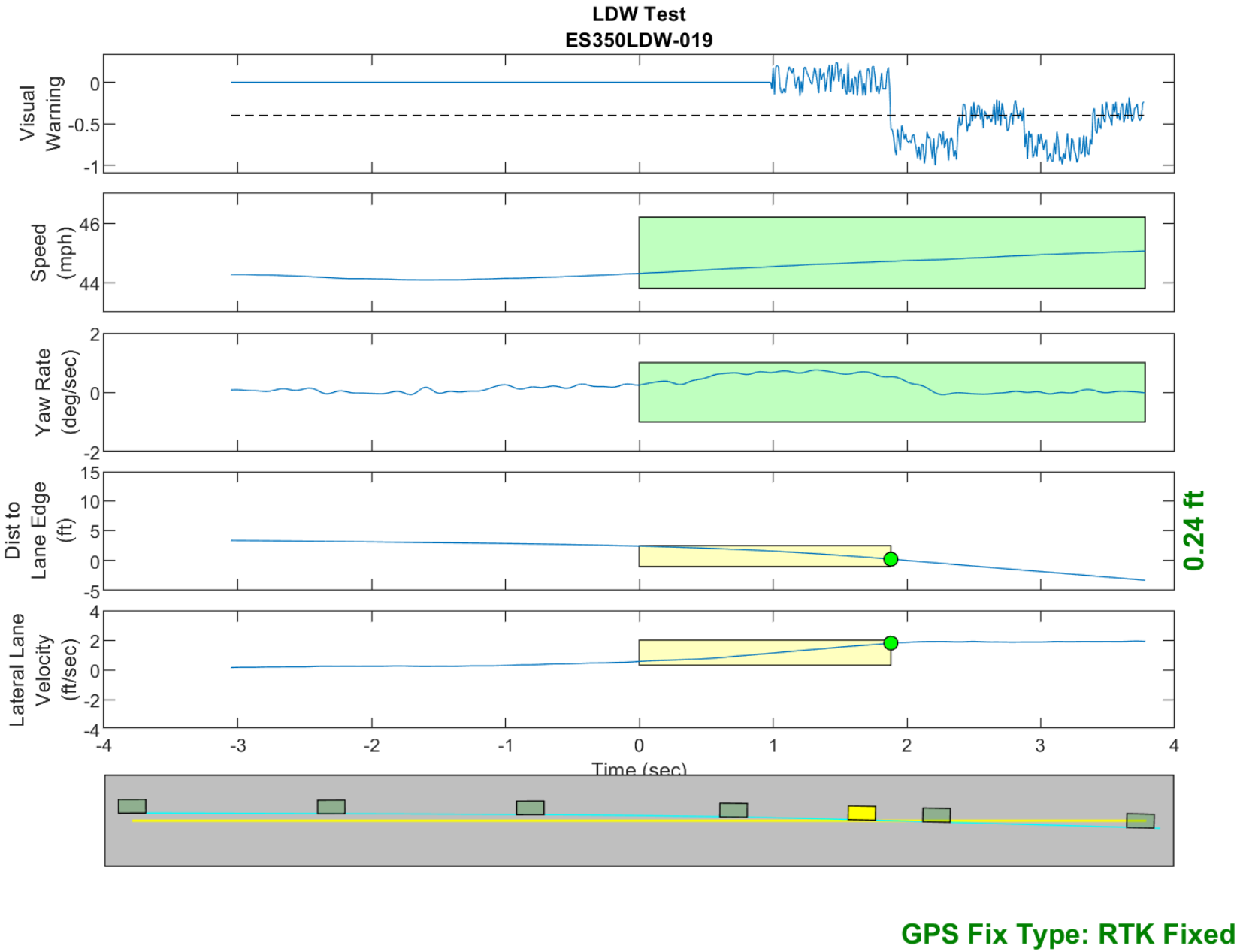


Figure D35. Time History for Run 19, Dashed Line, Right Departure, Visual Warning

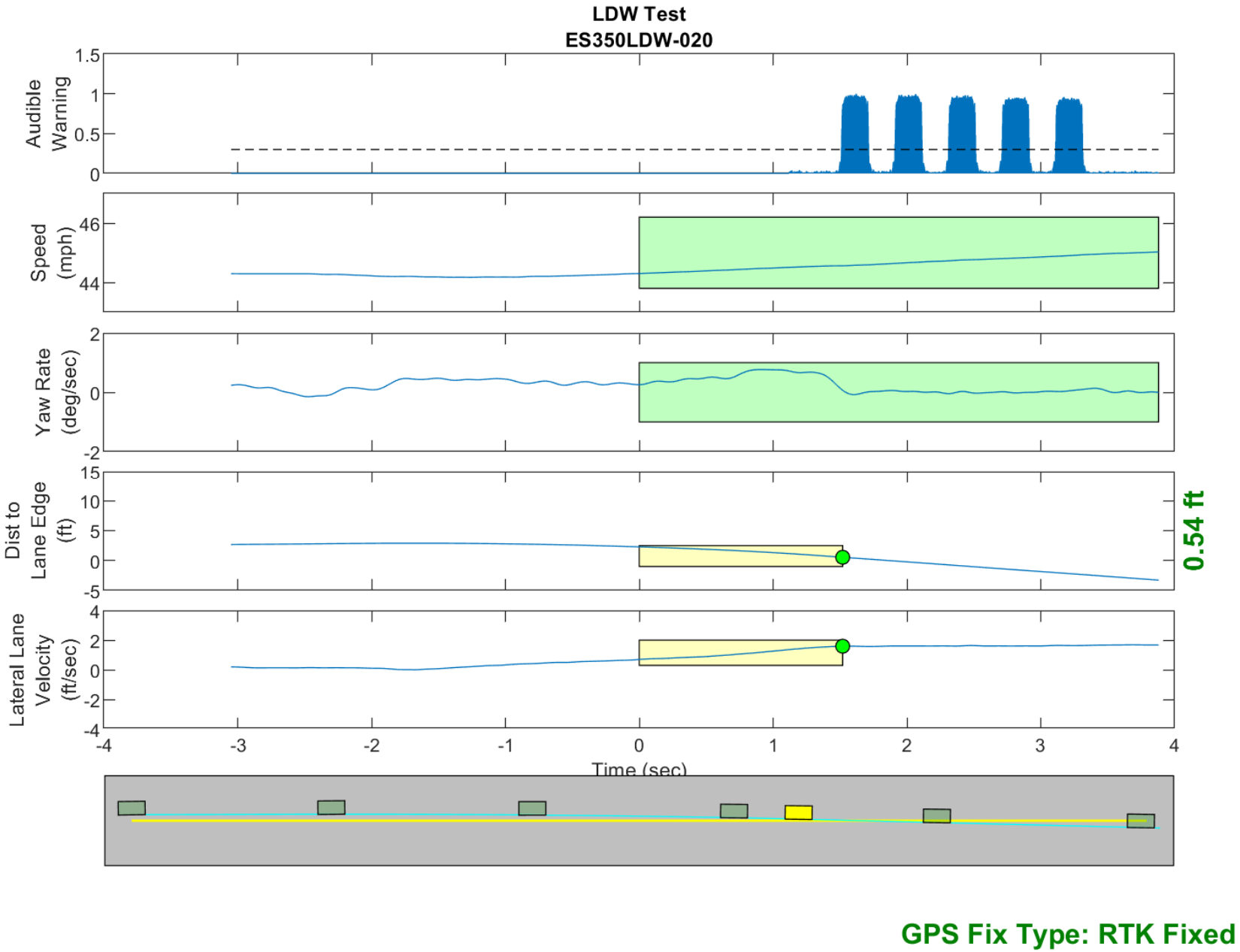


Figure D36. Time History for Run 20, Dashed Line, Right Departure, Audible Warning

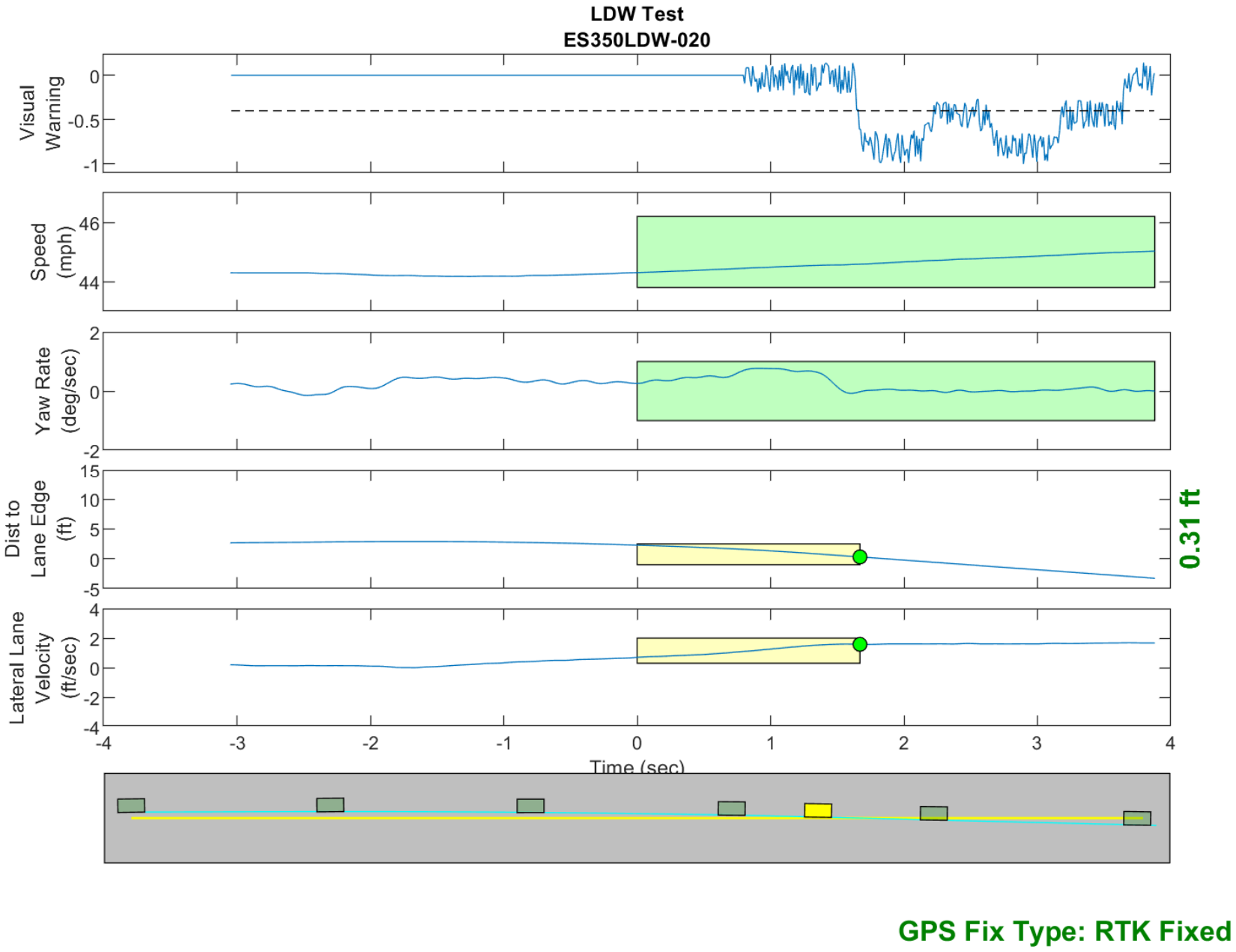


Figure D37. Time History for Run 20, Dashed Line, Right Departure, Visual Warning

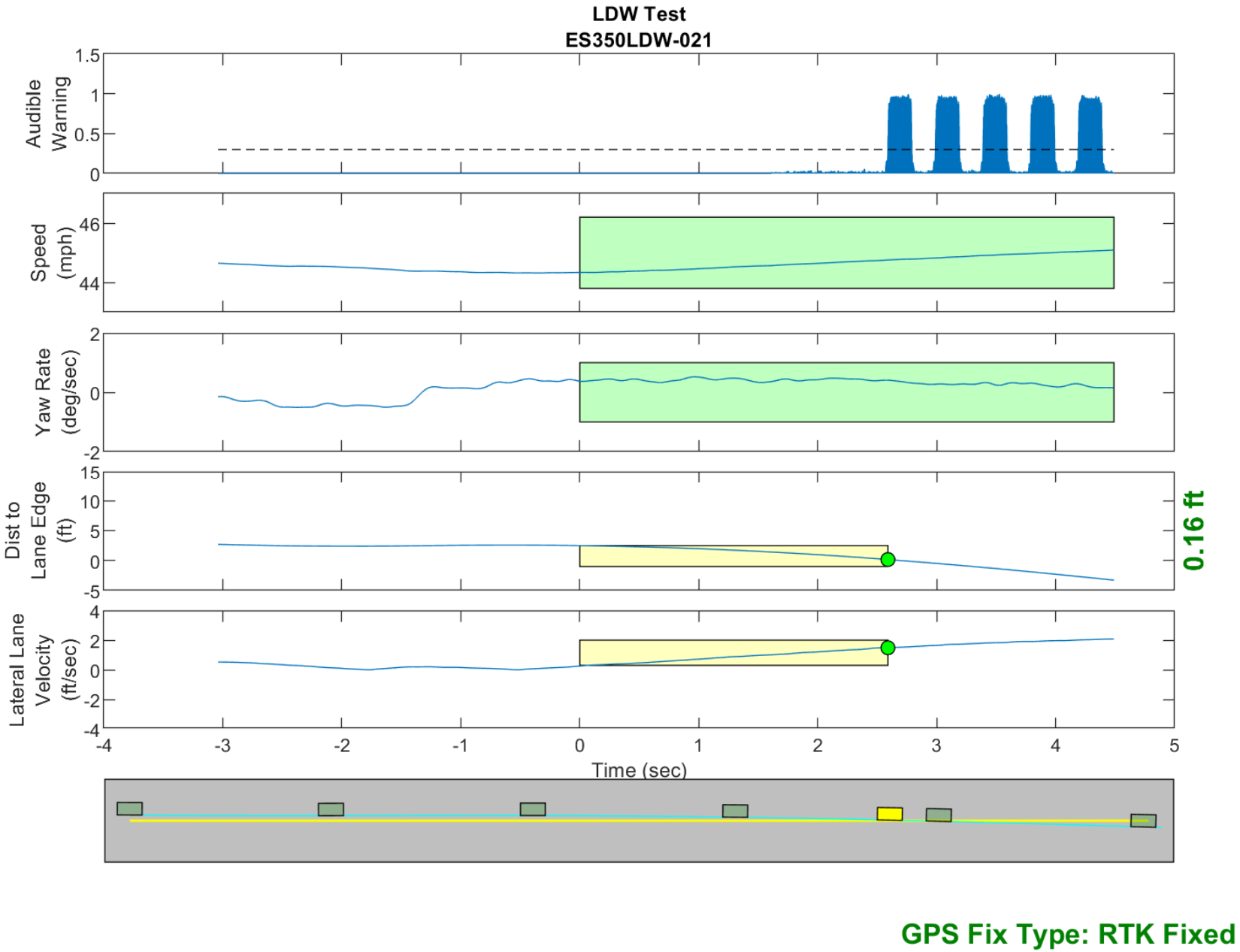


Figure D38. Time History for Run 21, Dashed Line, Right Departure, Audible Warning

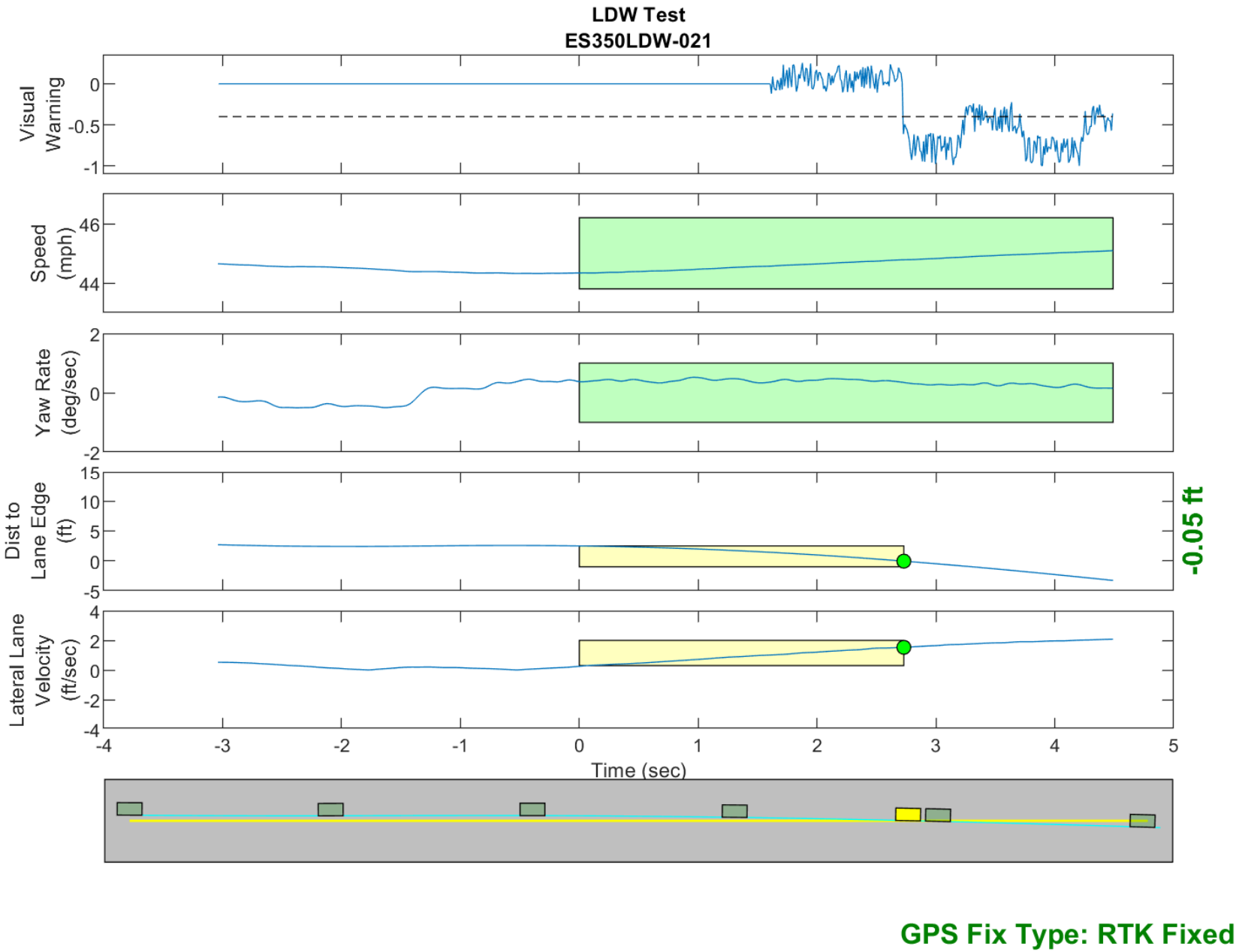


Figure D39. Time History for Run 21, Dashed Line, Right Departure, Visual Warning

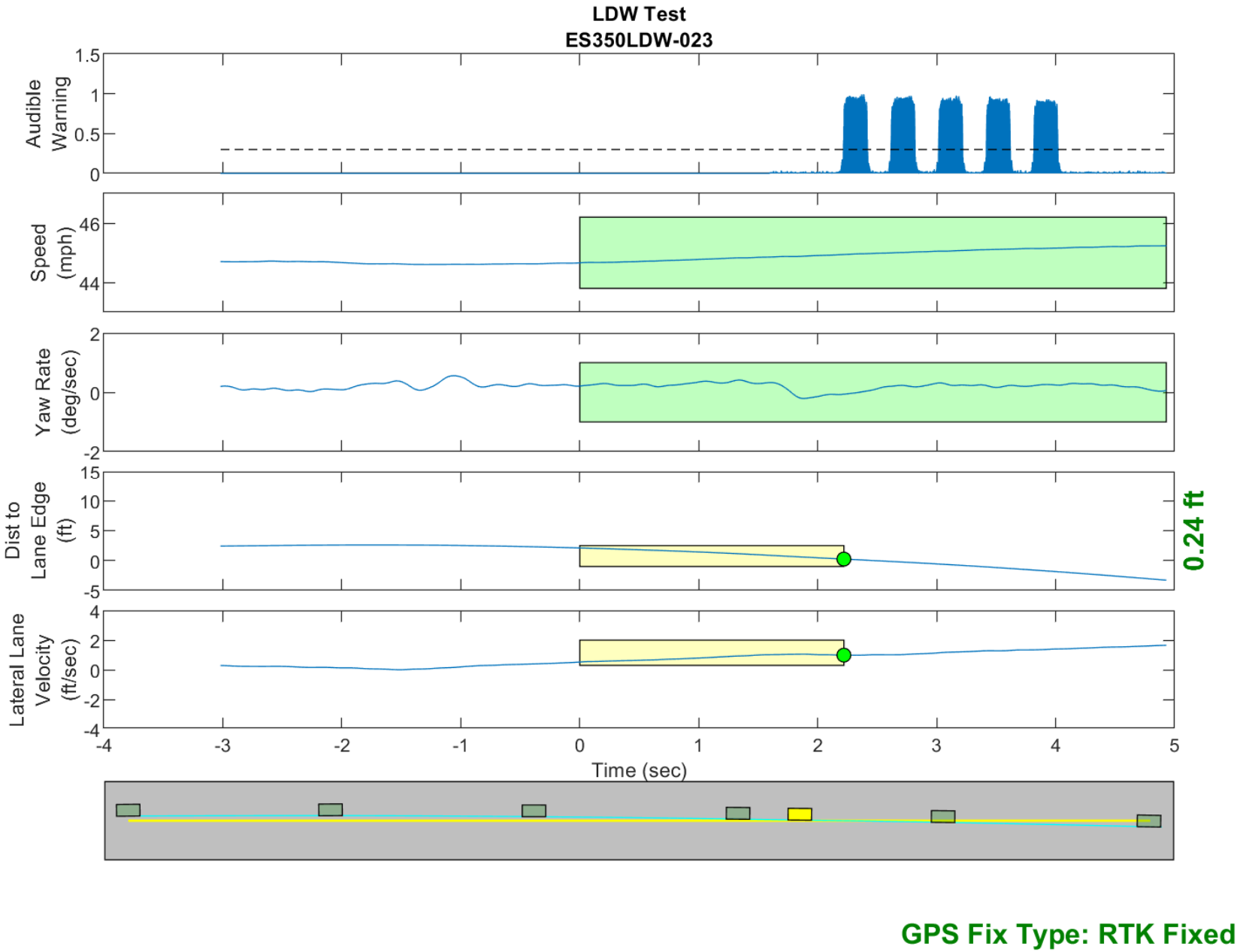


Figure D40. Time History for Run 23, Dashed Line, Right Departure, Audible Warning

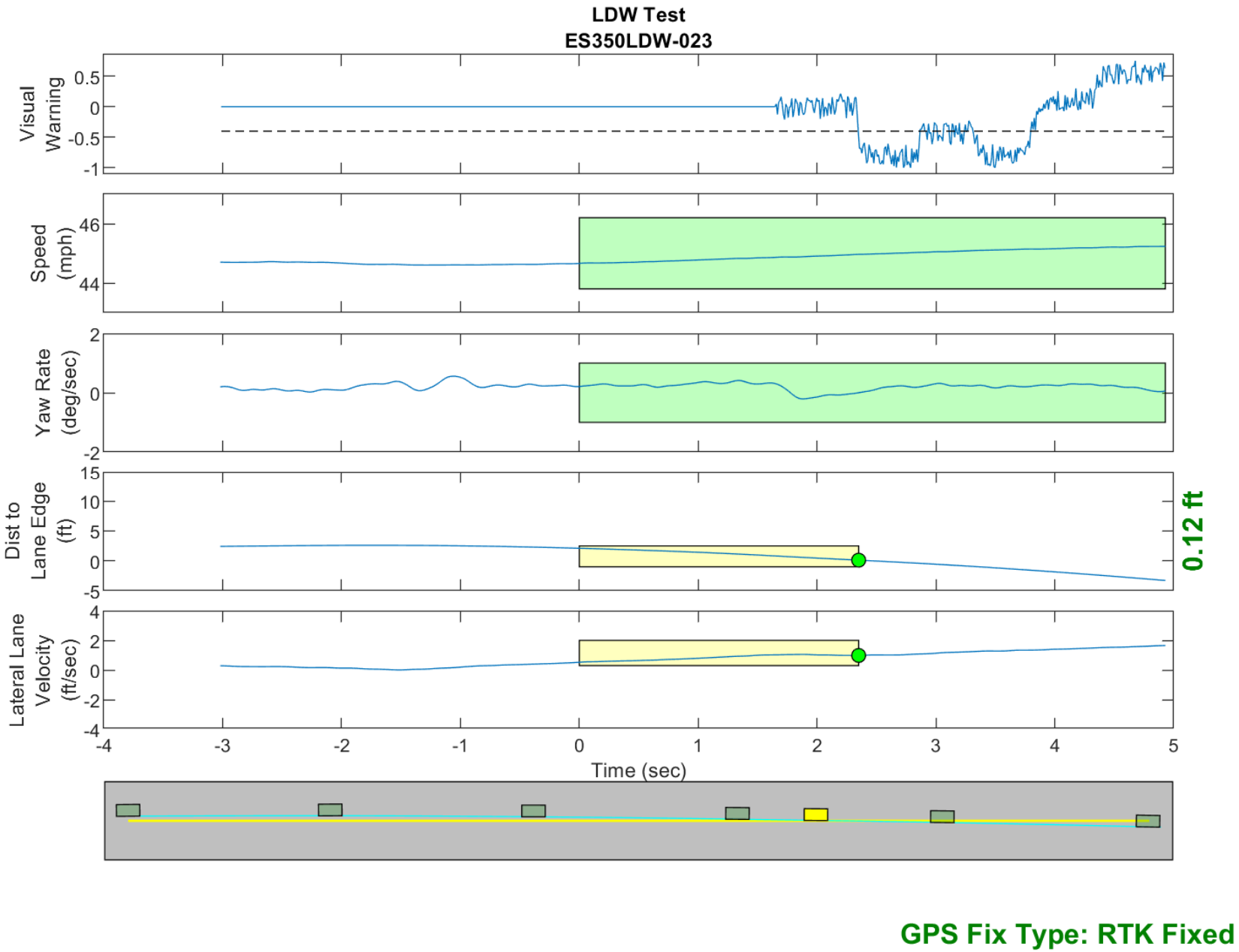


Figure D41. Time History for Run 23, Dashed Line, Right Departure, Visual Warning

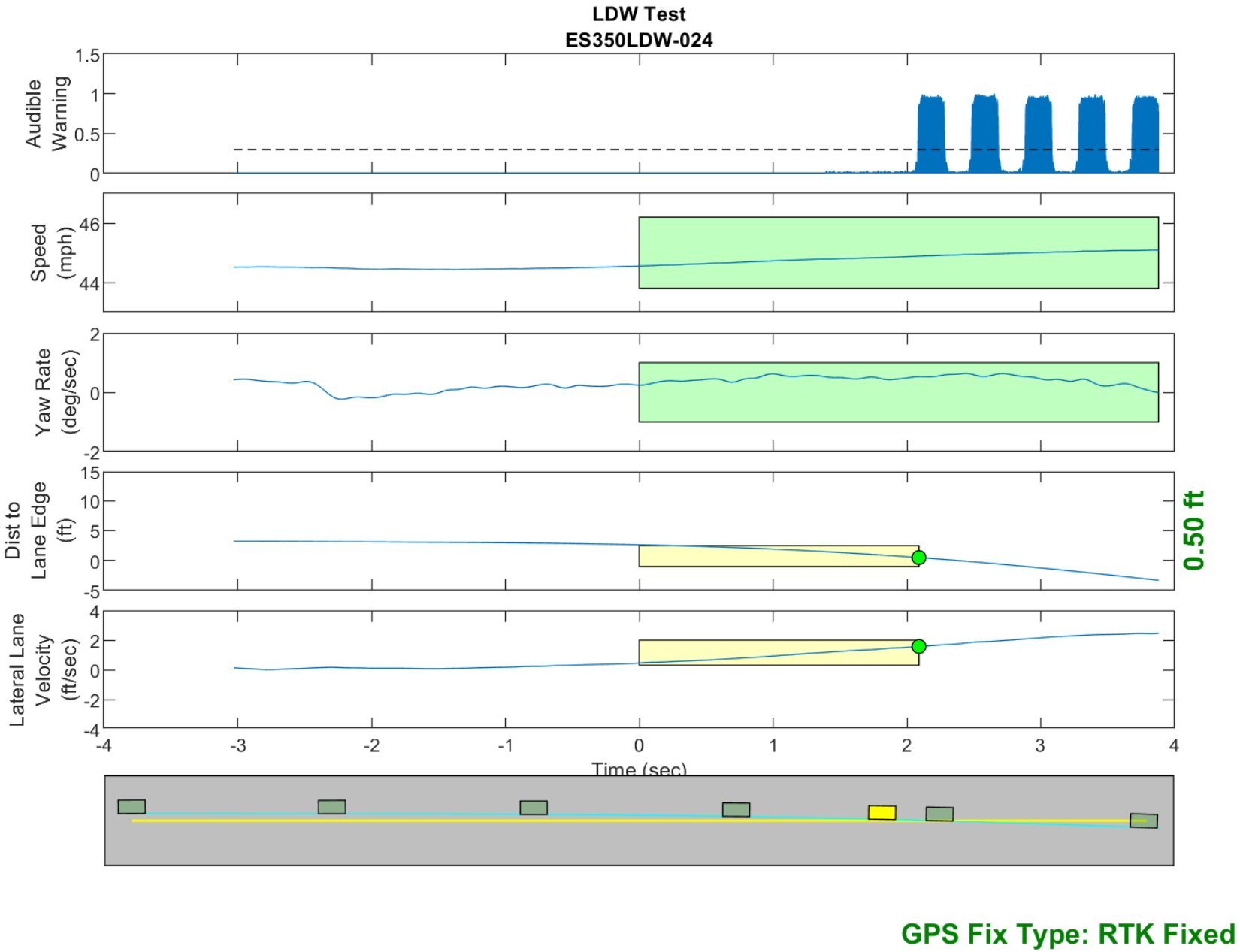


Figure D42. Time History for Run 24, Dashed Line, Right Departure, Audible Warning

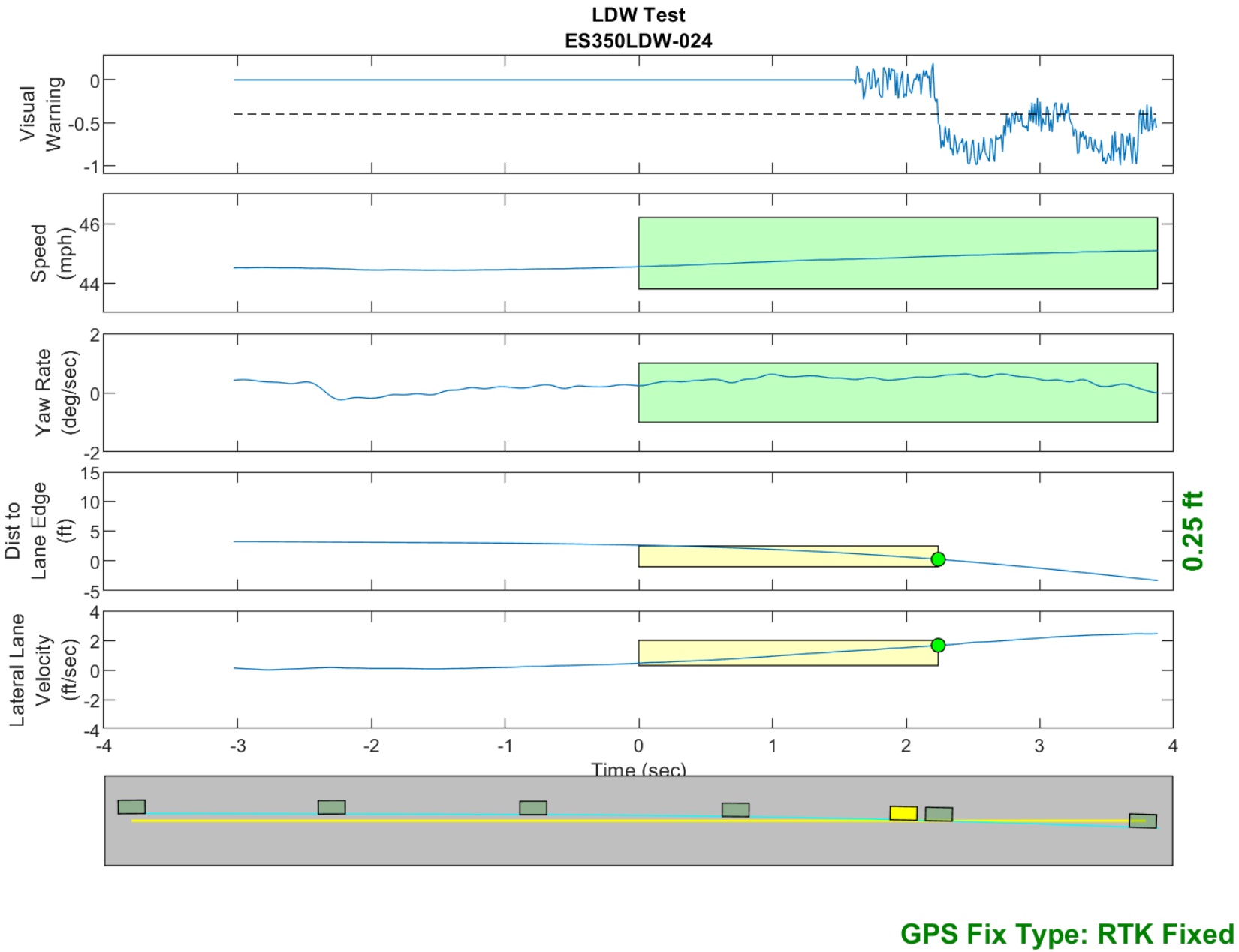


Figure D43. Time History for Run 24, Dashed Line, Right Departure, Visual Warning

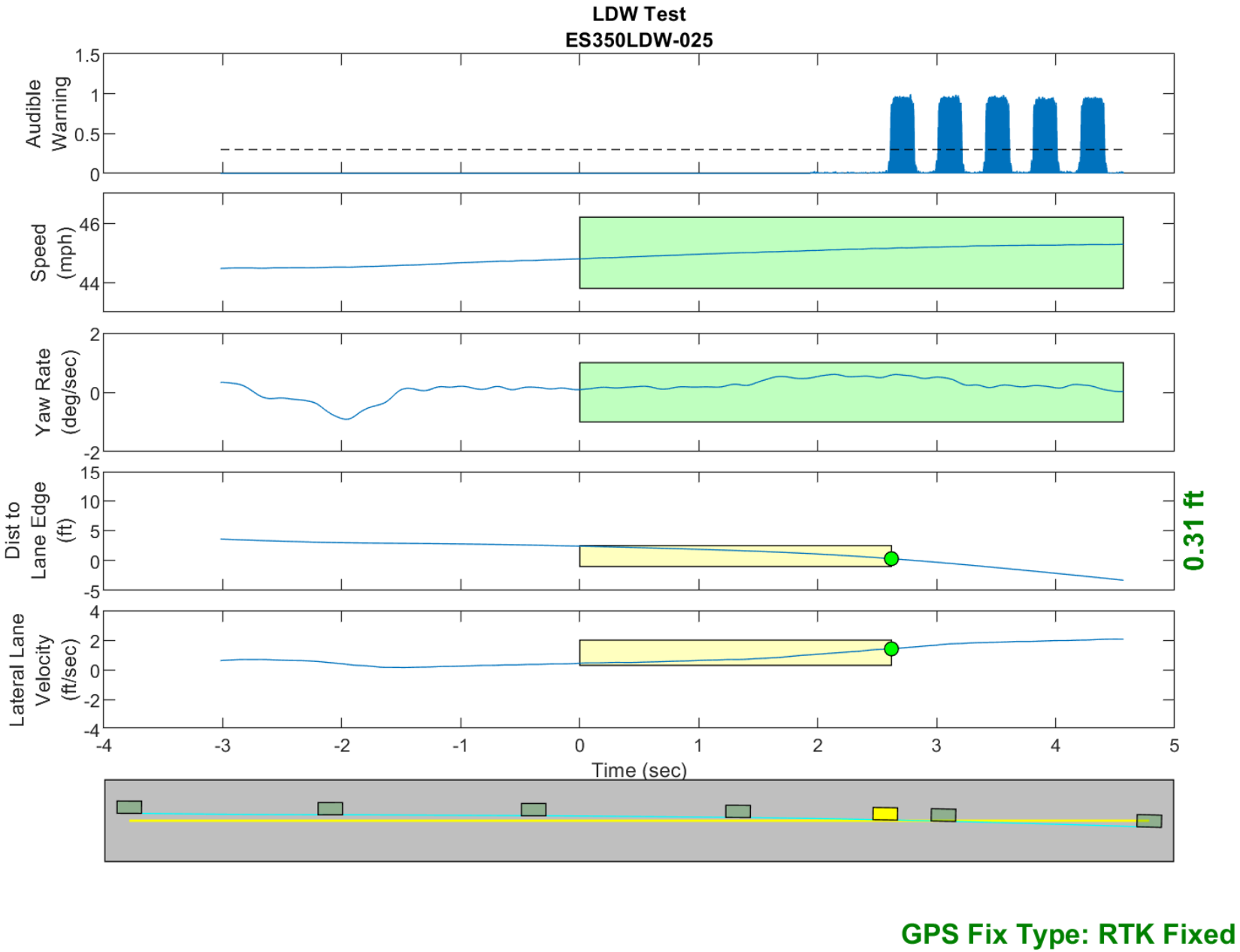


Figure D44. Time History for Run 25, Dashed Line, Right Departure, Audible Warning

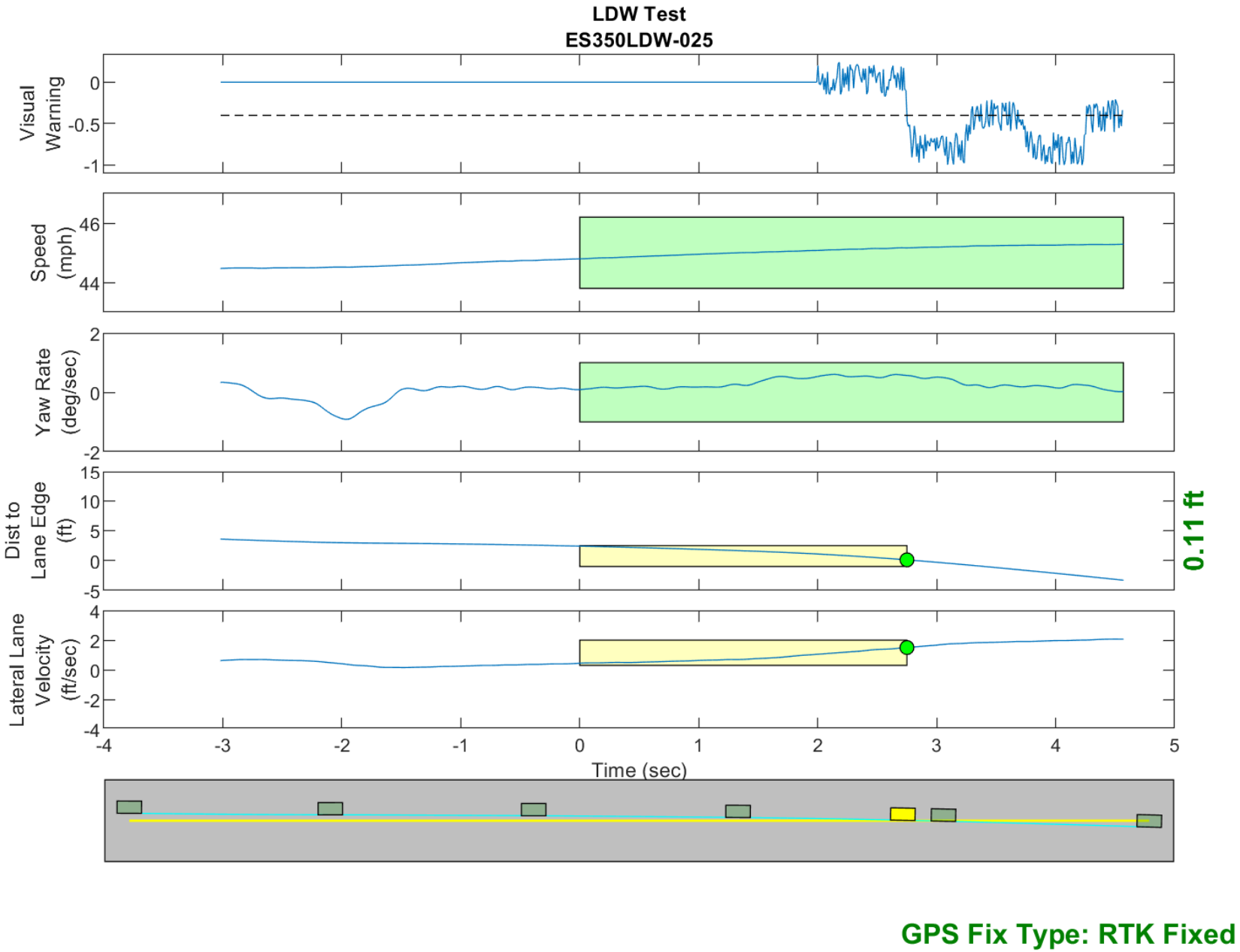


Figure D45. Time History for Run 25, Dashed Line, Right Departure, Visual Warning

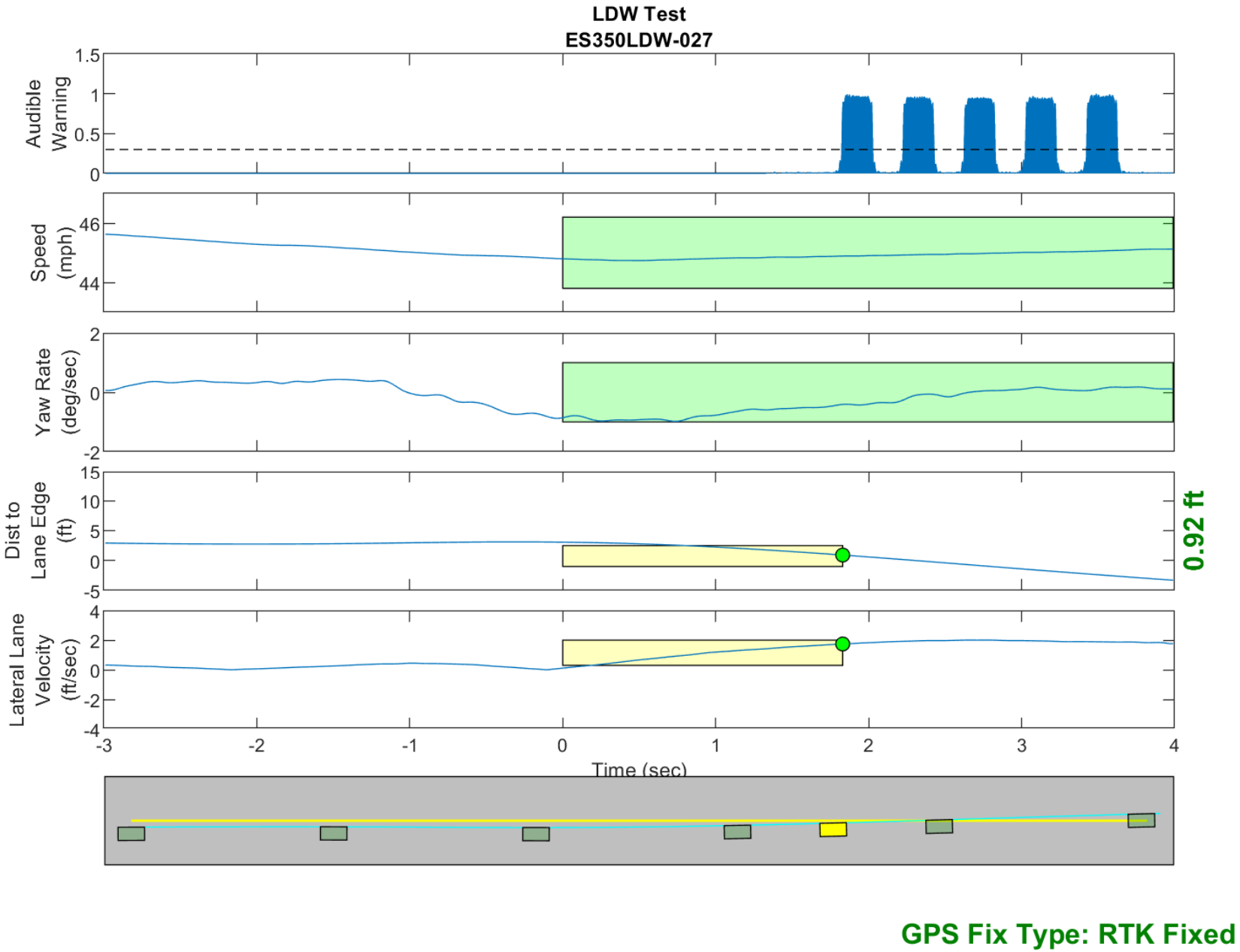


Figure D46. Time History for Run 27, Dashed Line, Left Departure, Audible Warning

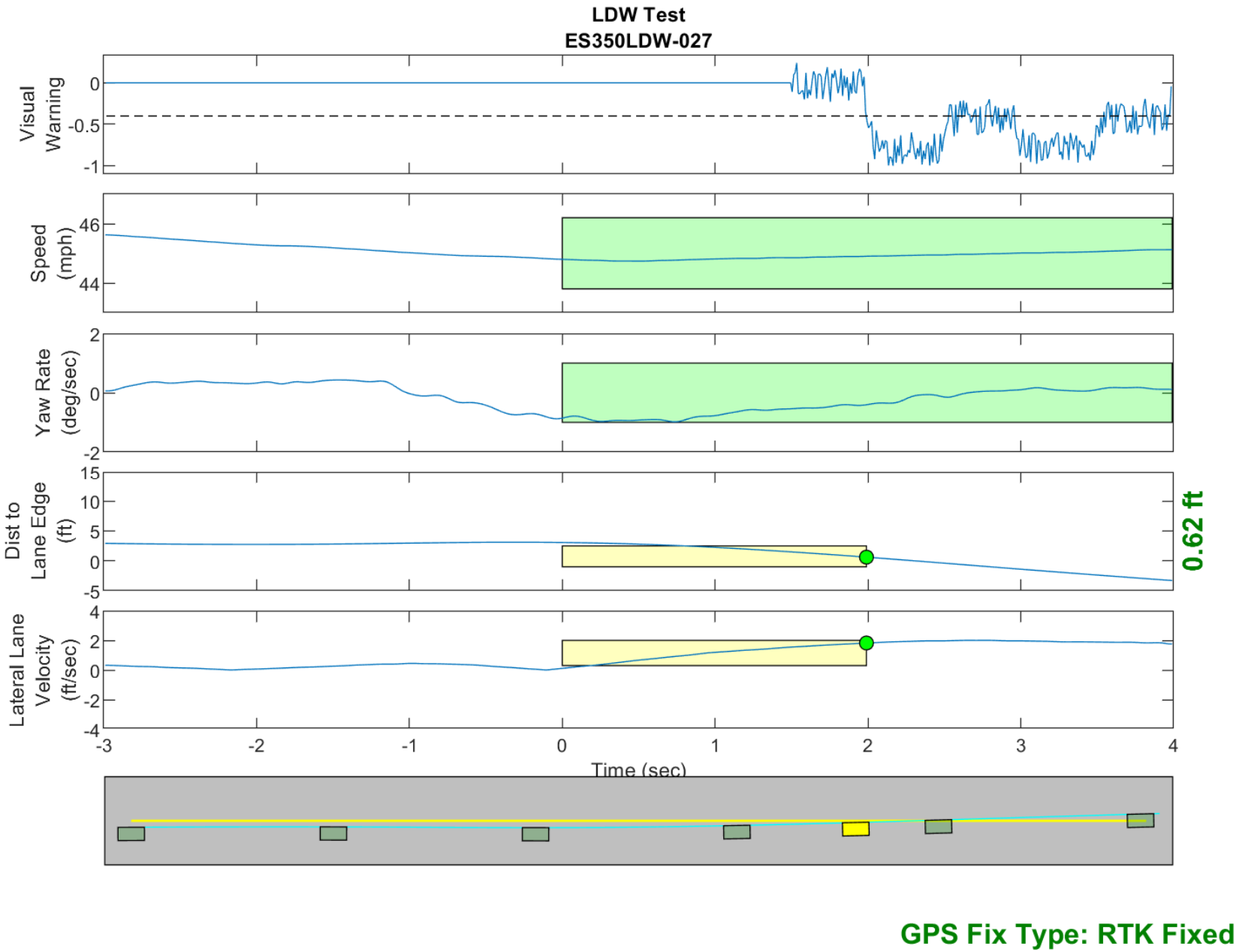


Figure D47. Time History for Run 27, Dashed Line, Left Departure, Visual Warning

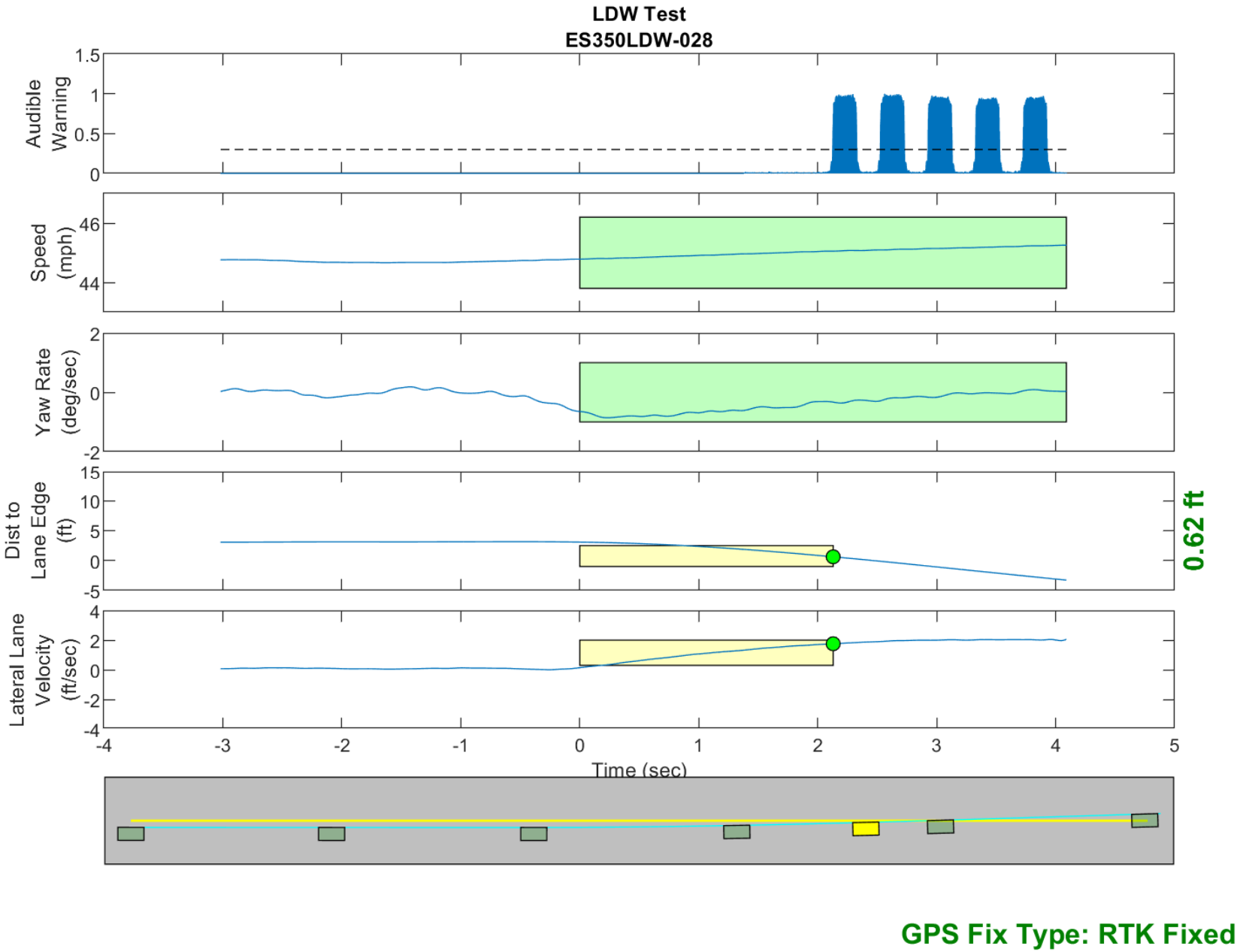


Figure D48. Time History for Run 28, Dashed Line, Left Departure, Audible Warning

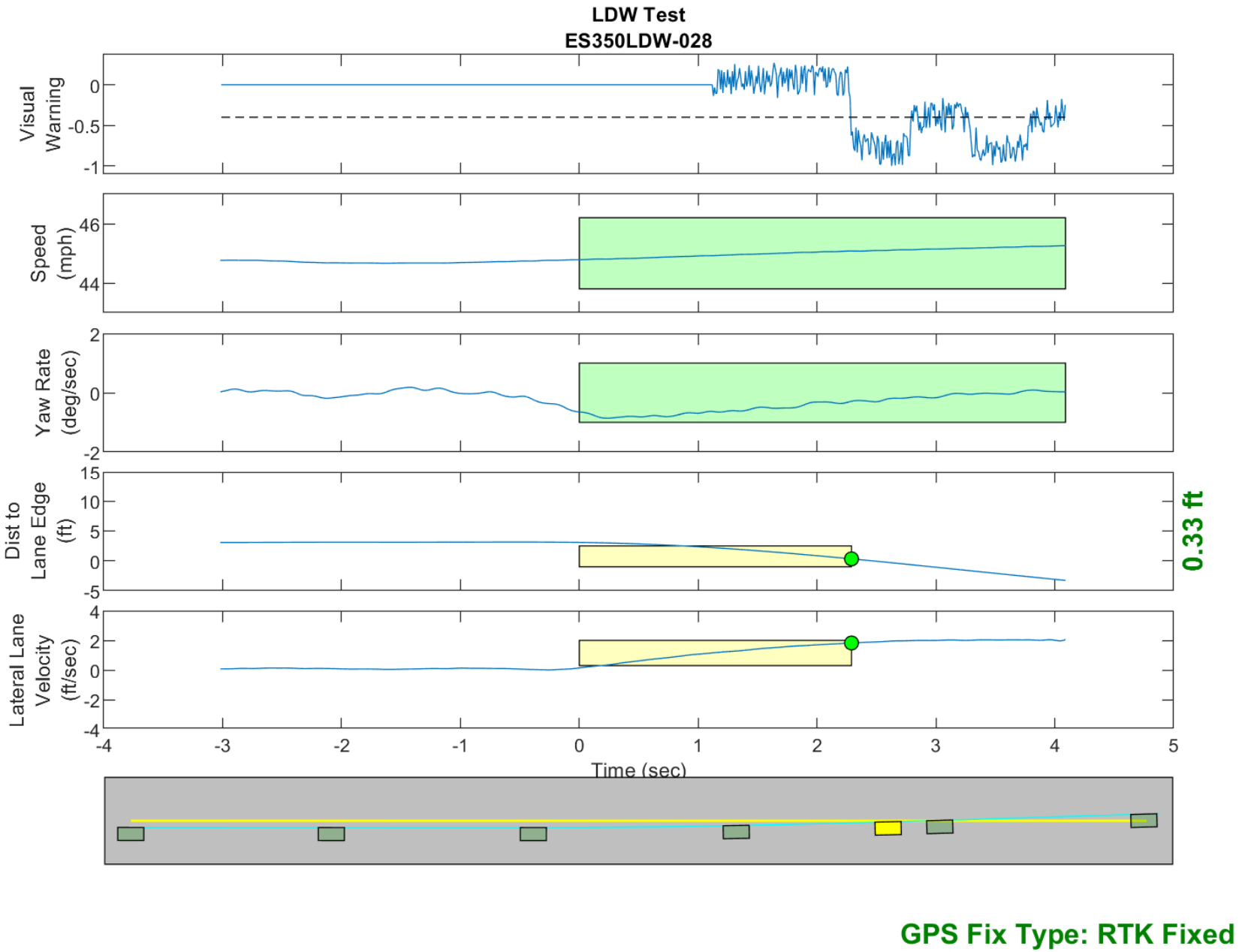


Figure D49. Time History for Run 28, Dashed Line, Left Departure, Visual Warning

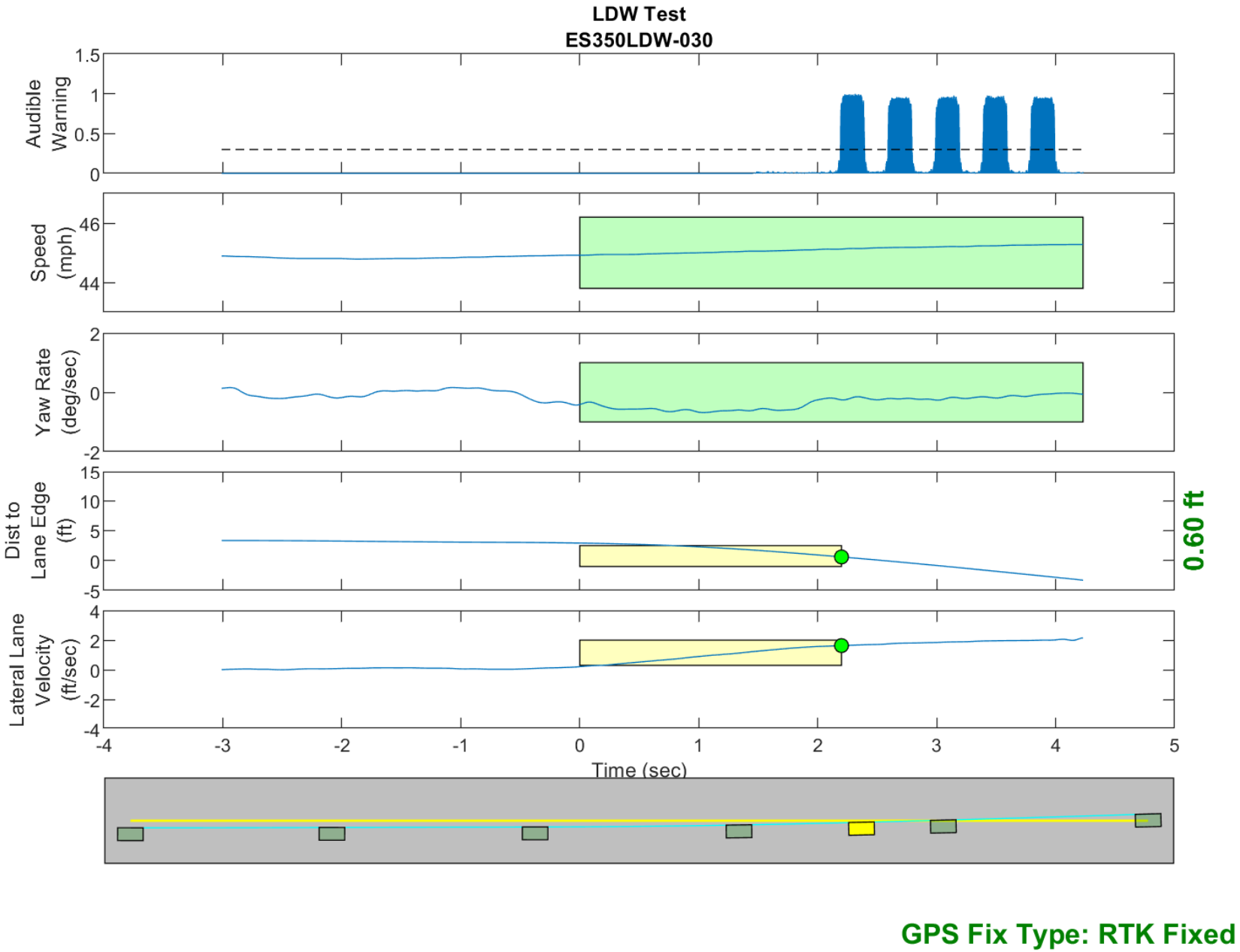


Figure D50. Time History for Run 30, Dashed Line, Left Departure, Audible Warning

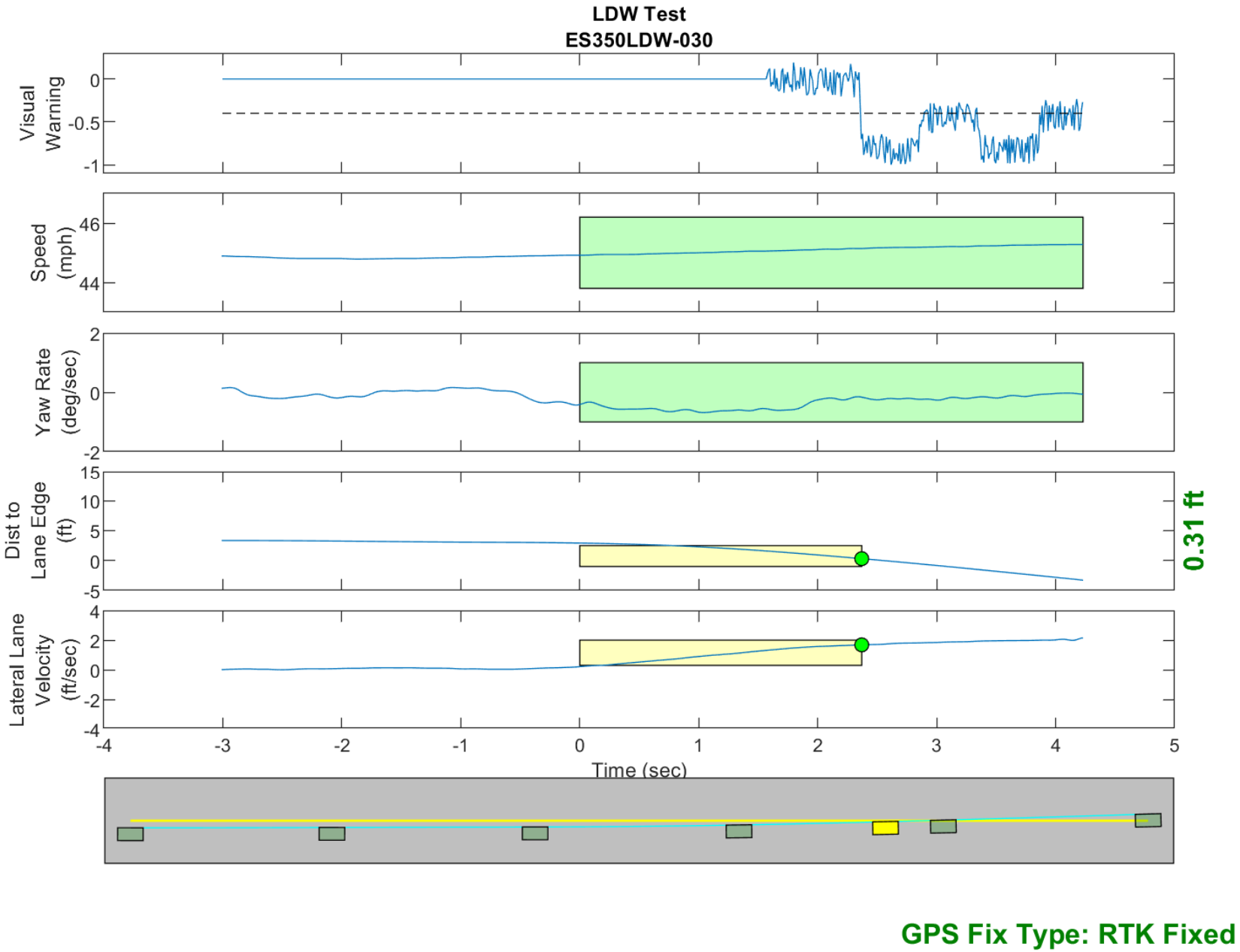


Figure D51. Time History for Run 30, Dashed Line, Left Departure, Visual Warning

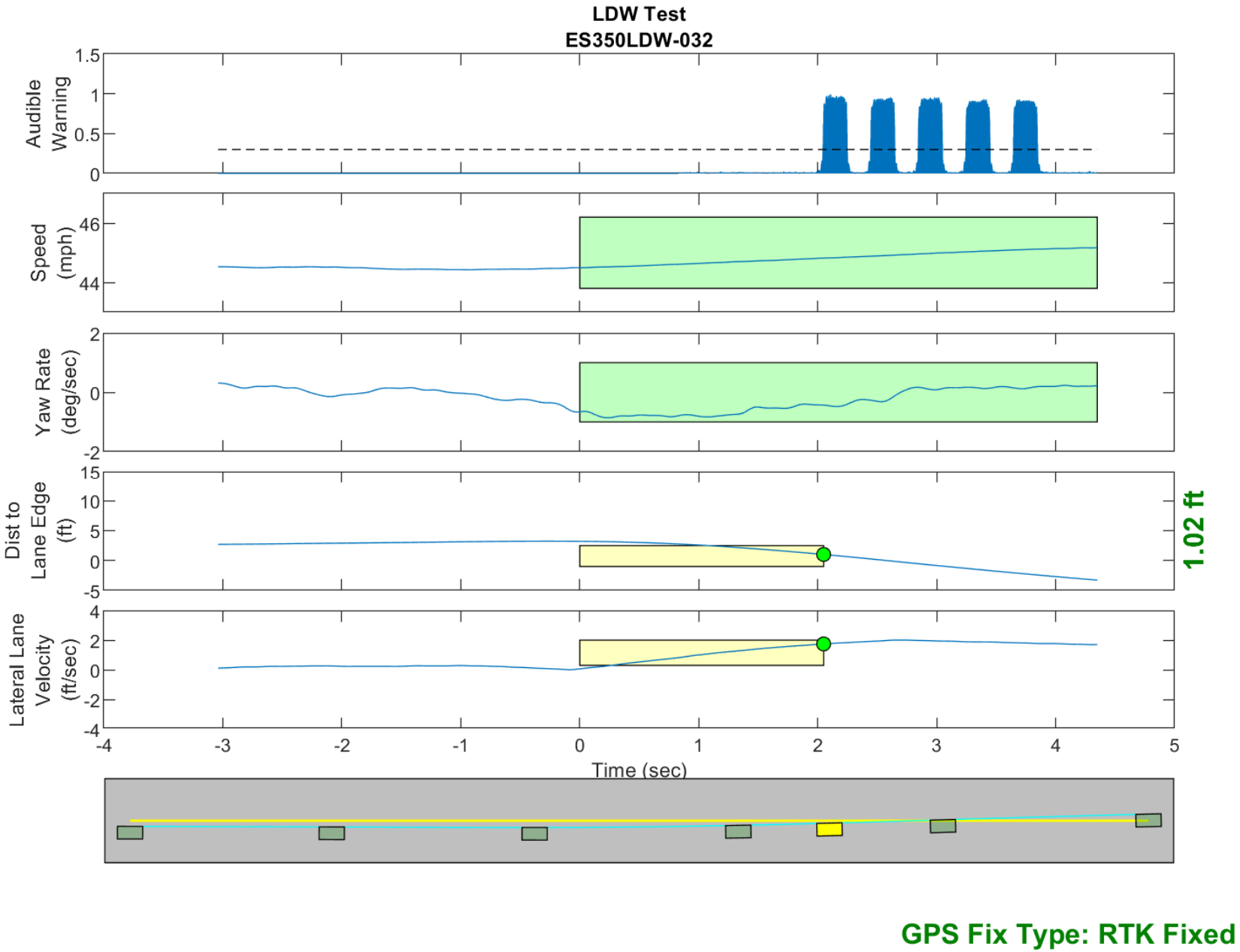


Figure D52. Time History for Run 32, Dashed Line, Left Departure, Audible Warning

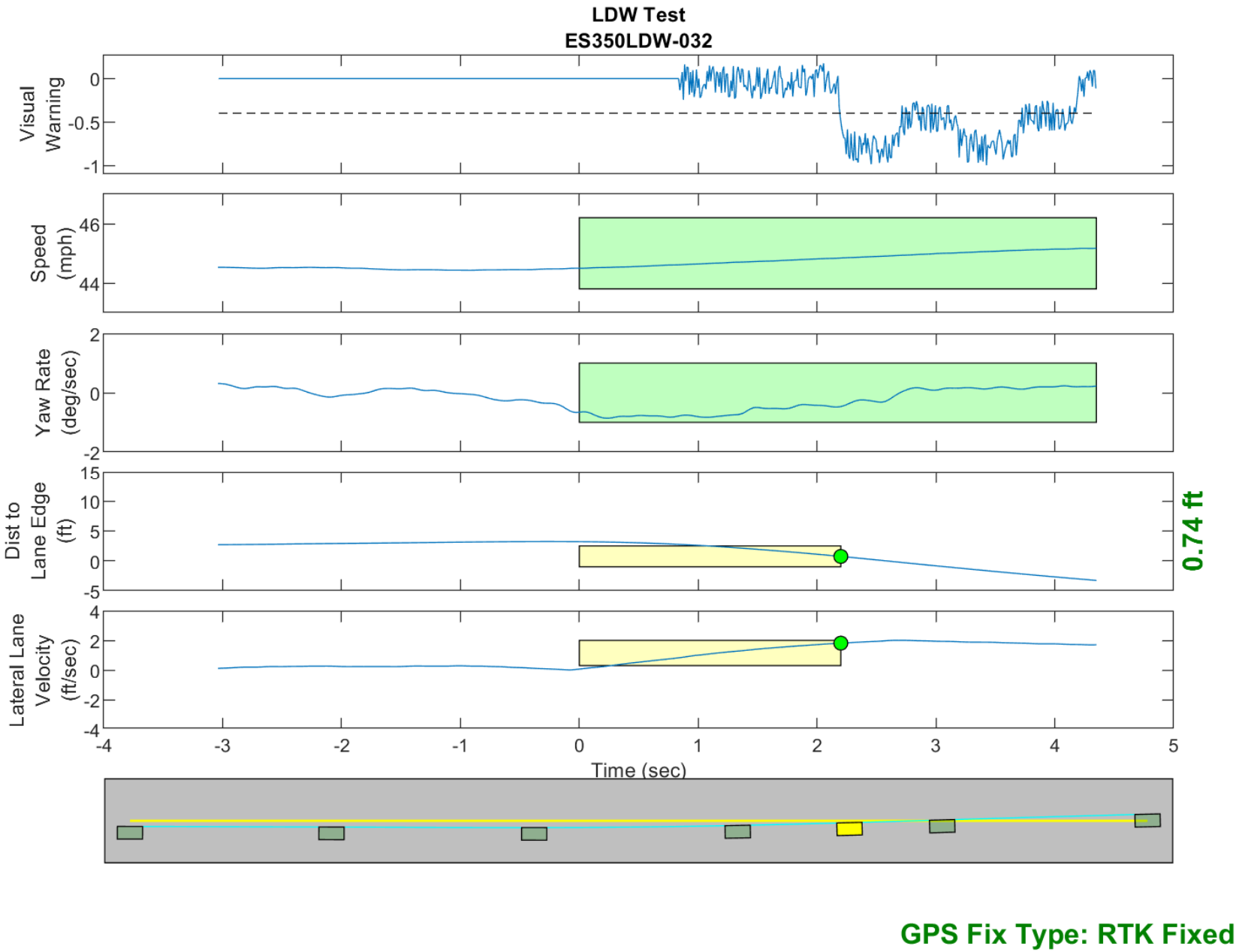


Figure D53. Time History for Run 32, Dashed Line, Left Departure, Visual Warning

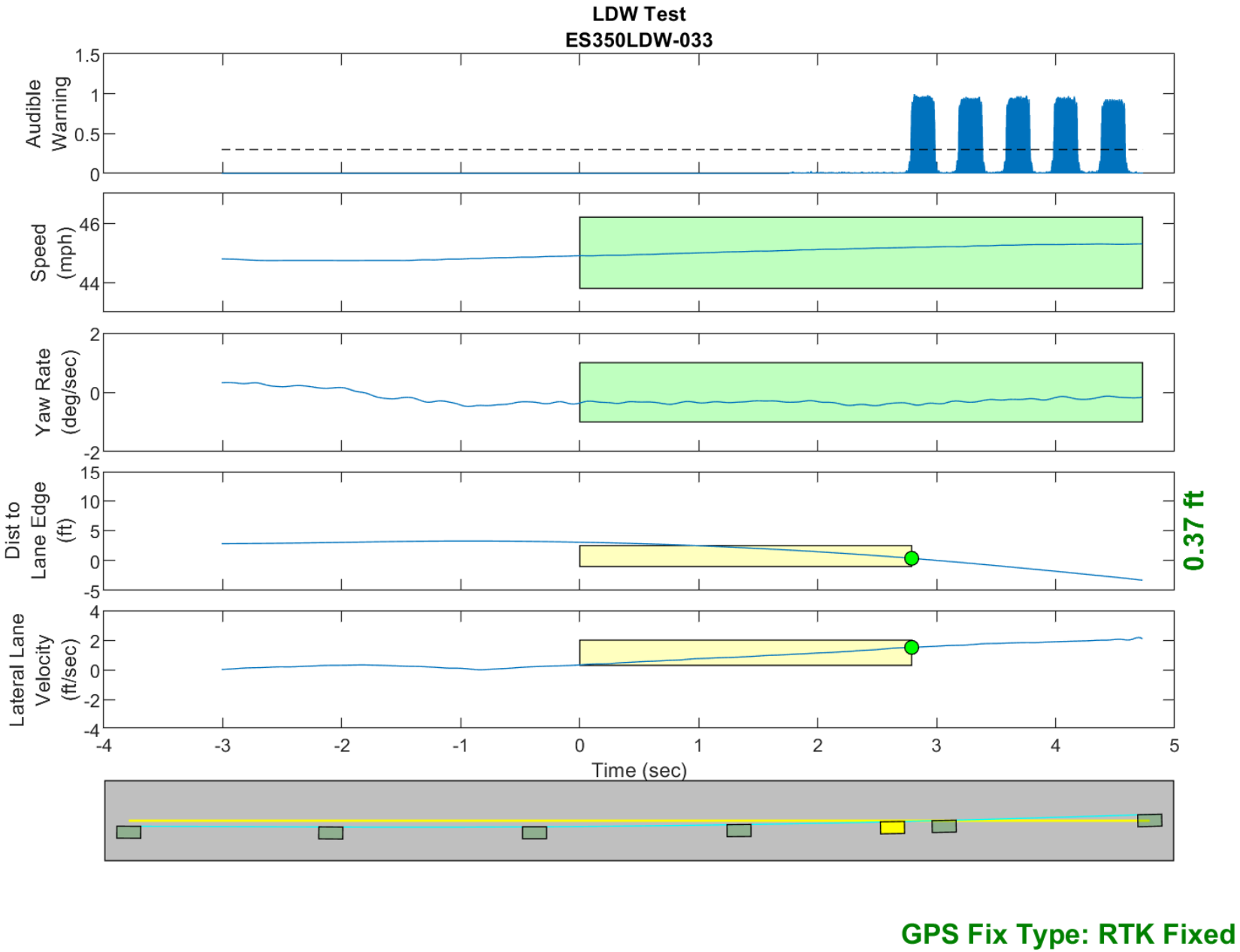


Figure D54. Time History for Run 33, Dashed Line, Left Departure, Audible Warning

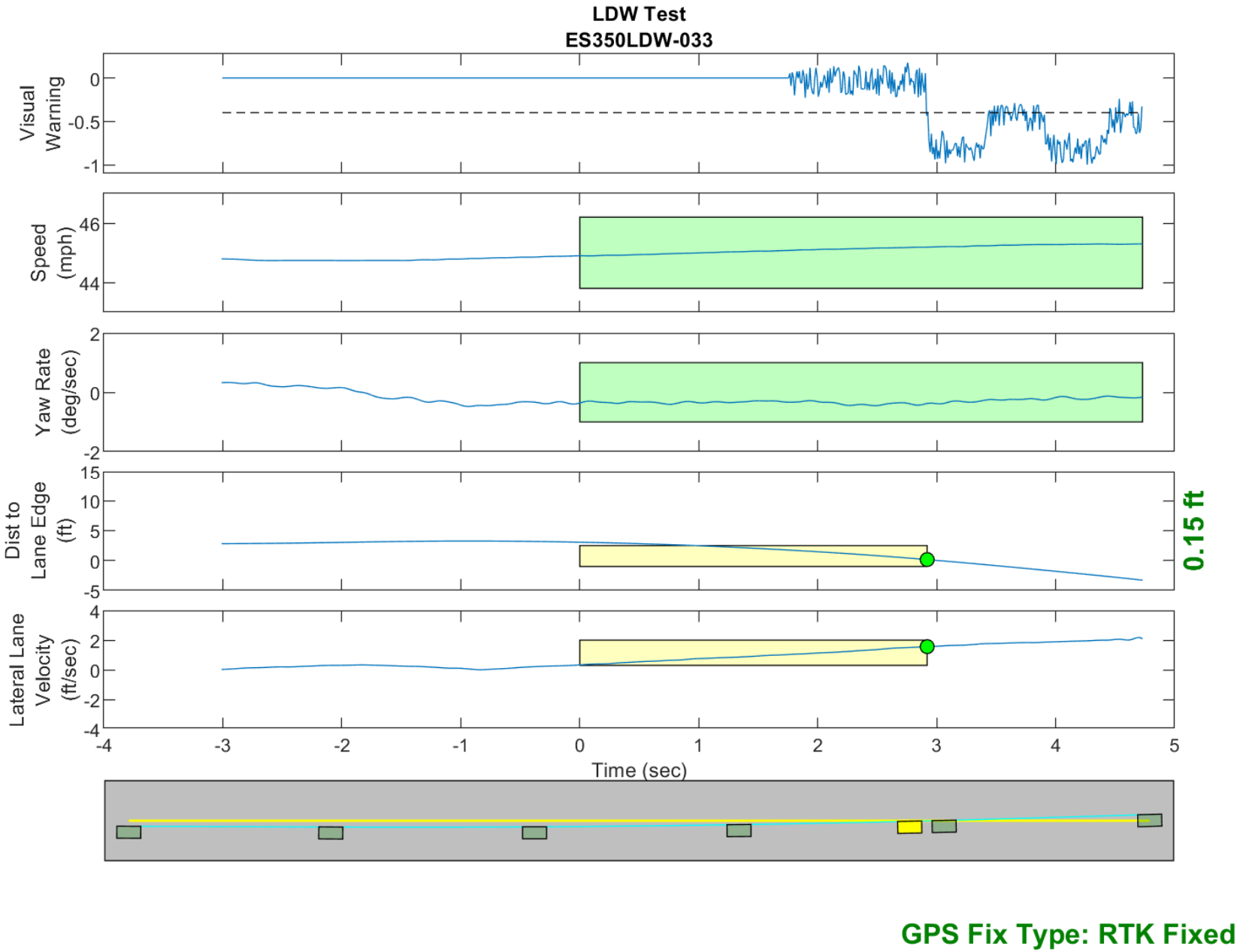


Figure D55. Time History for Run 33, Dashed Line, Left Departure, Visual Warning

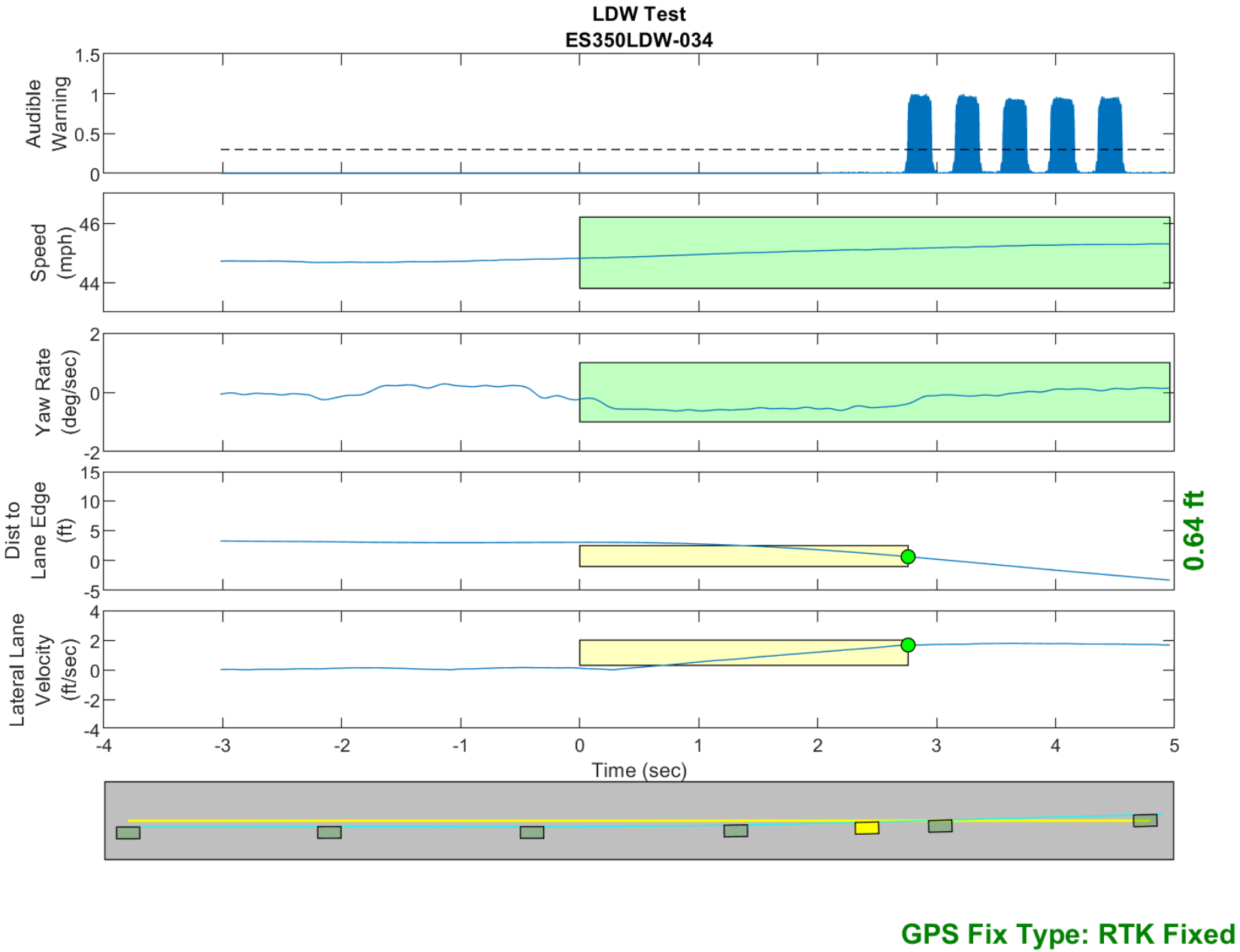


Figure D56. Time History for Run 34, Dashed Line, Left Departure, Audible Warning

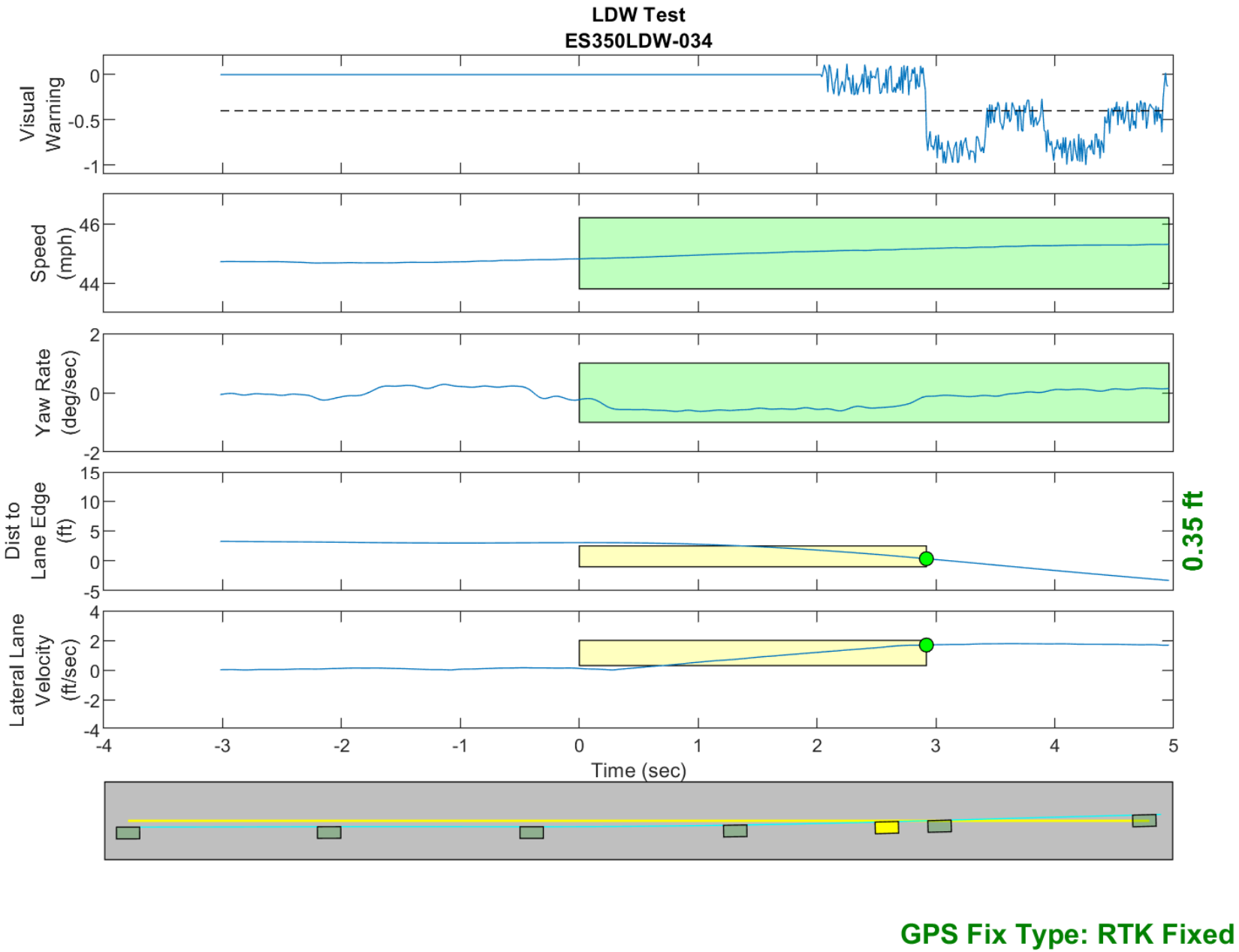


Figure D57. Time History for Run 34, Dashed Line, Left Departure, Visual Warning

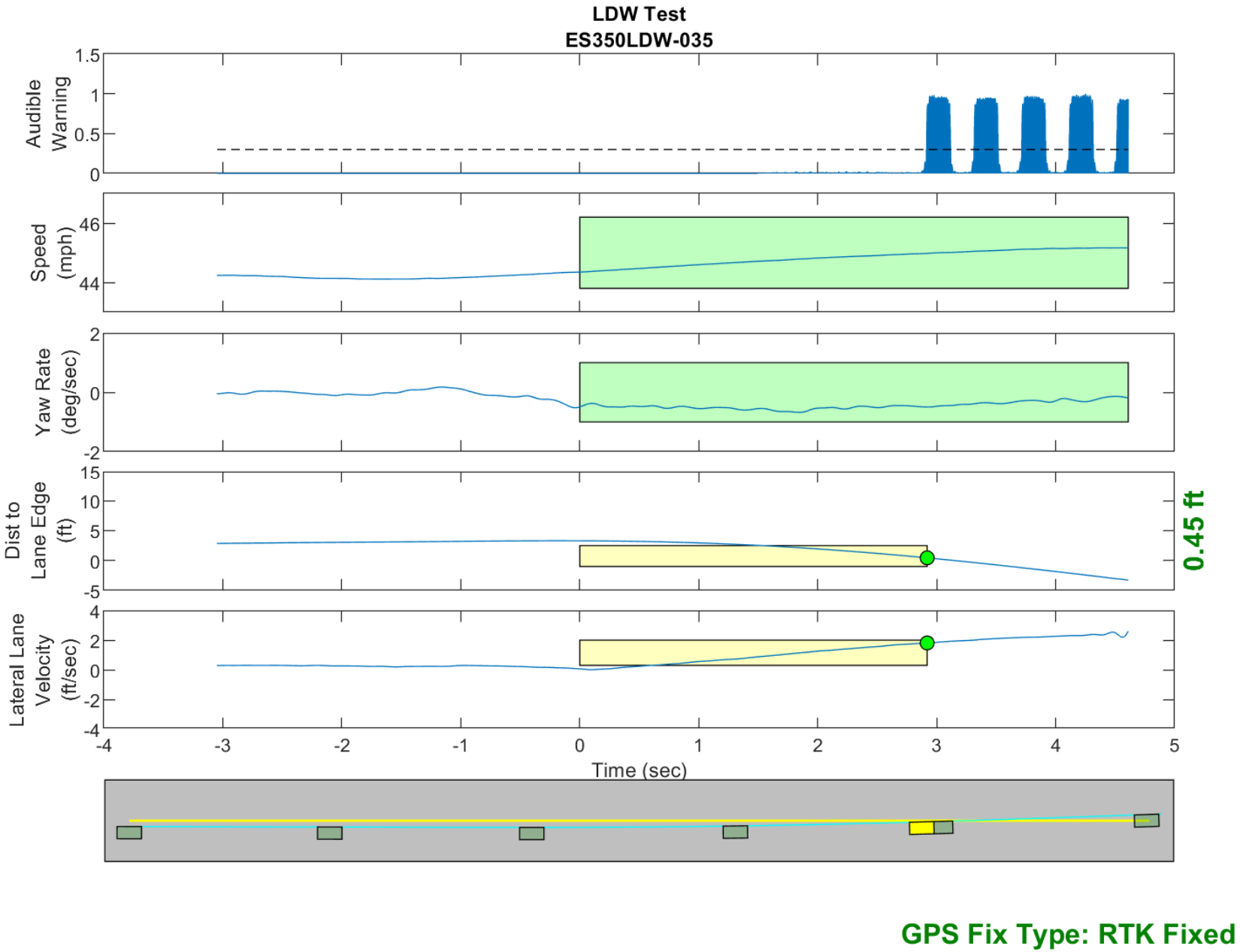


Figure D58. Time History for Run 35, Dashed Line, Left Departure, Audible Warning

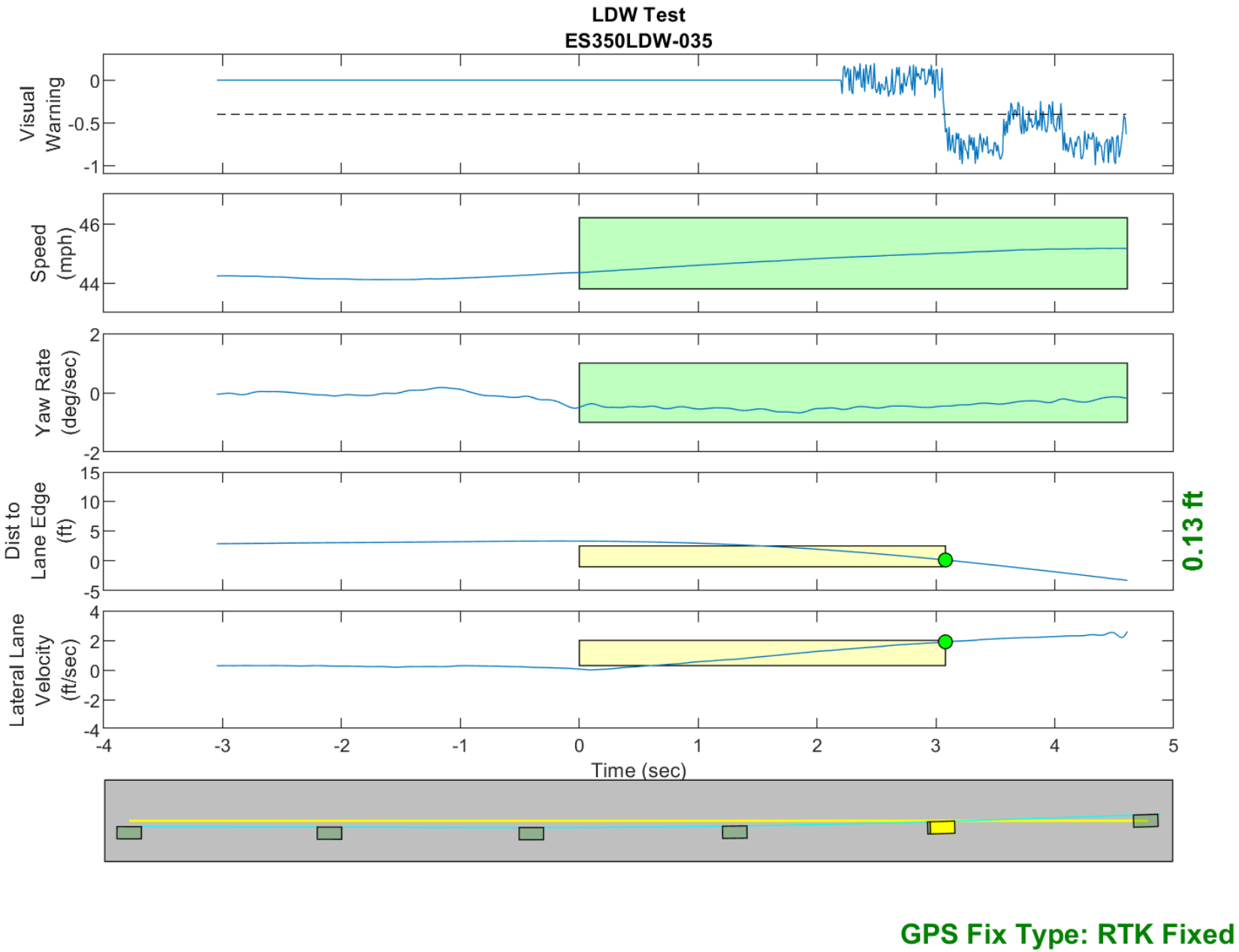


Figure D59. Time History for Run 35, Dashed Line, Left Departure, Visual Warning

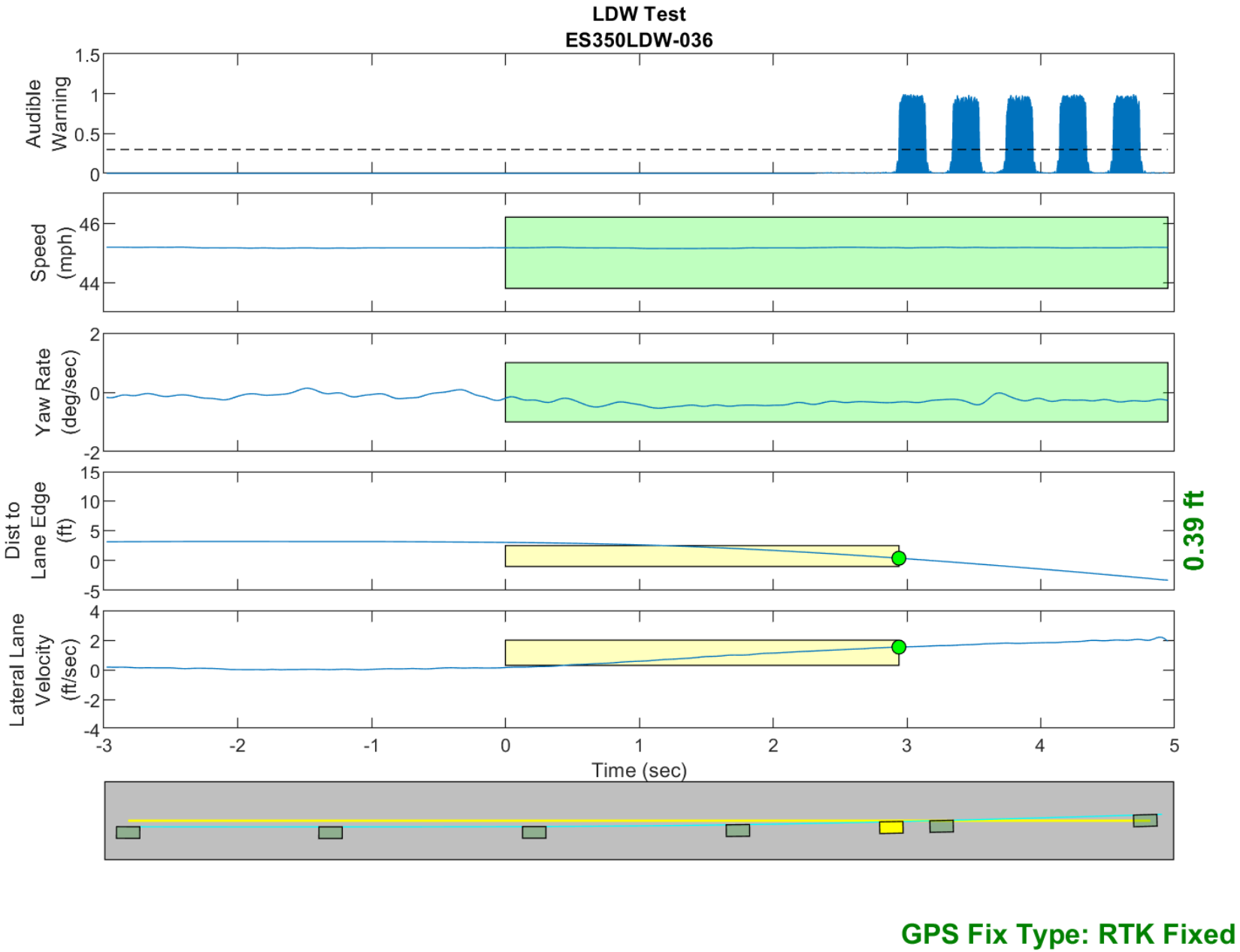


Figure D60. Time History for Run 36, Botts Dots, Left Departure, Audible Warning

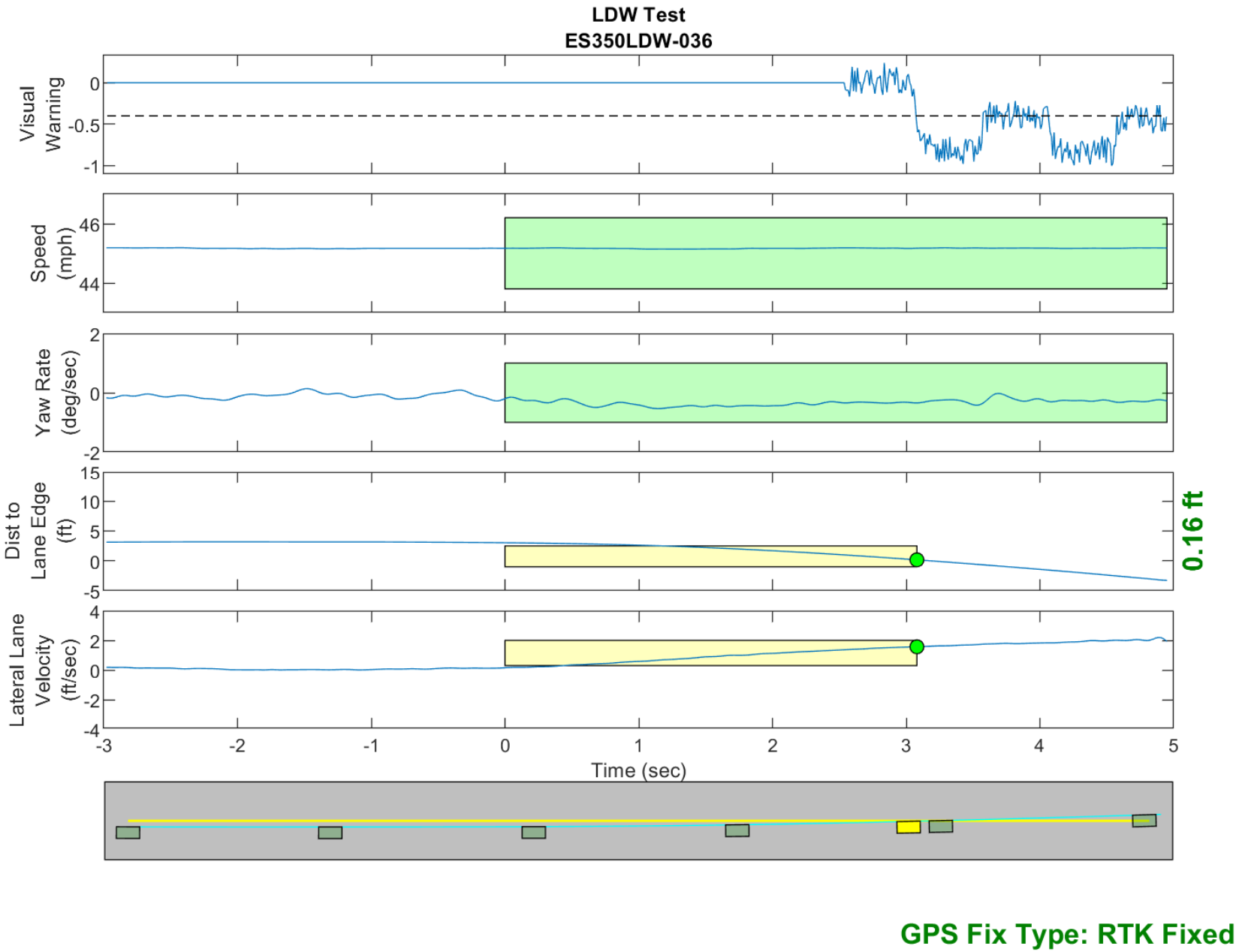


Figure D61. Time History for Run 36, Botts Dots, Left Departure, Visual Warning

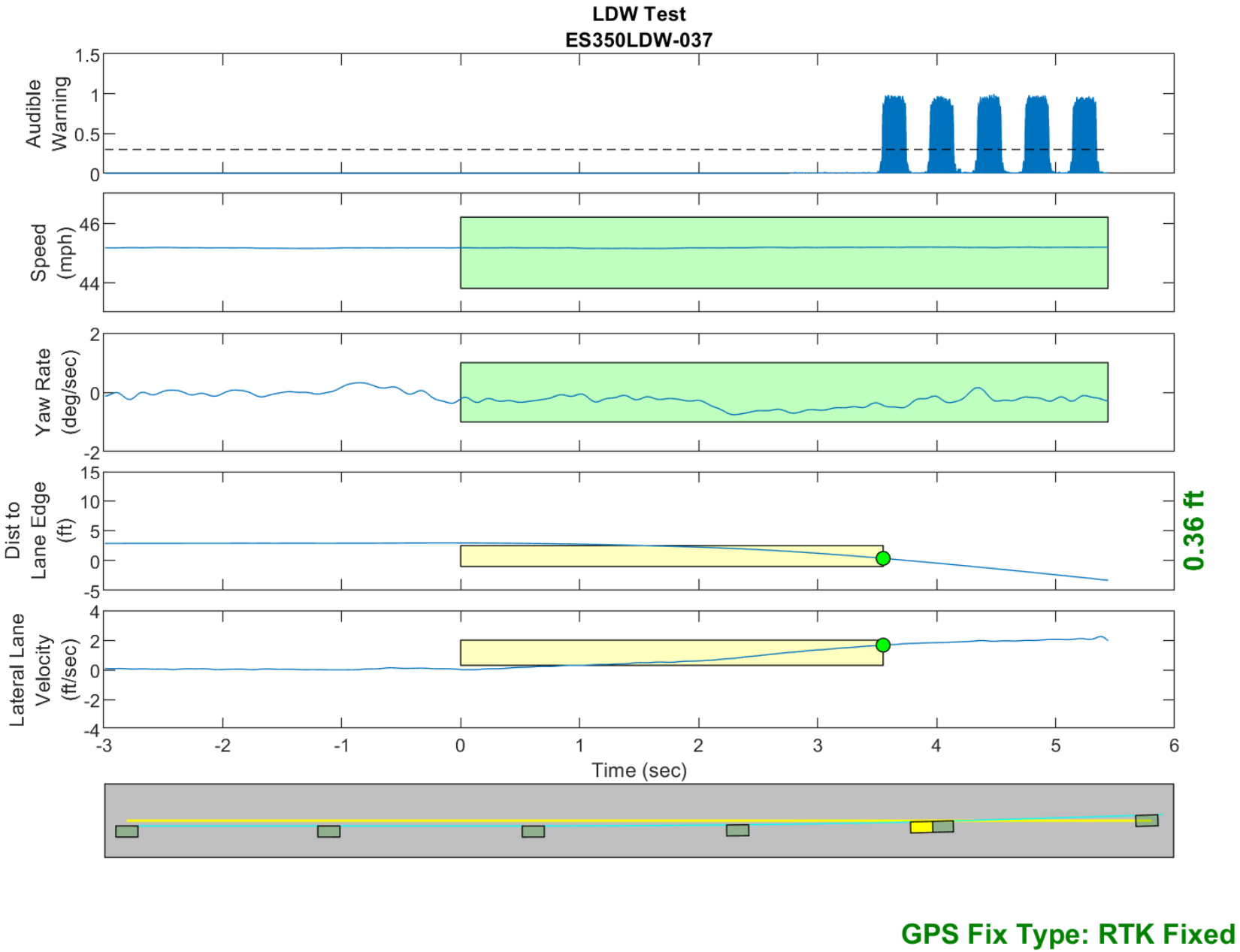


Figure D62. Time History for Run 37, Botts Dots, Left Departure, Audible Warning

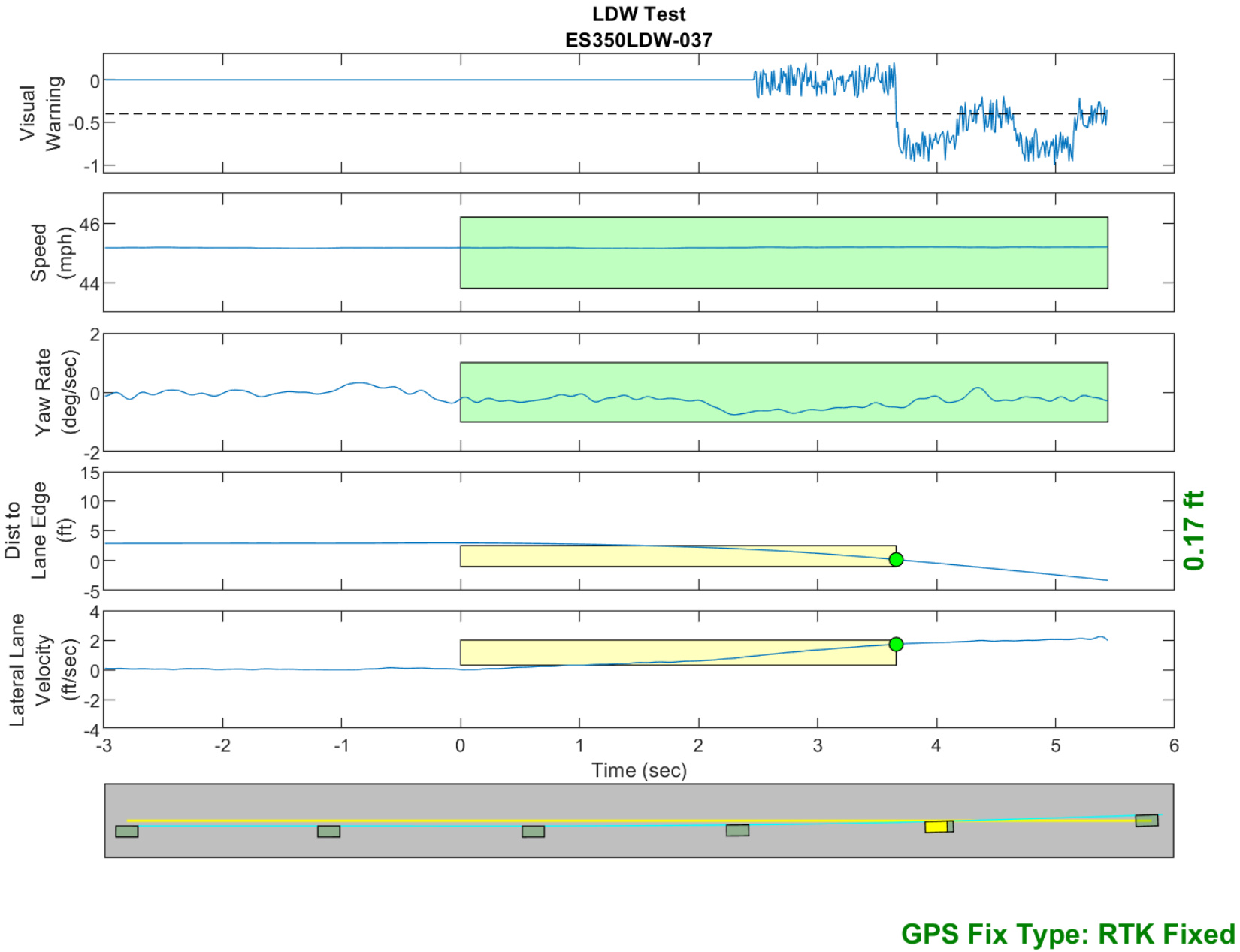


Figure D63. Time History for Run 37, Botts Dots, Left Departure, Visual Warning

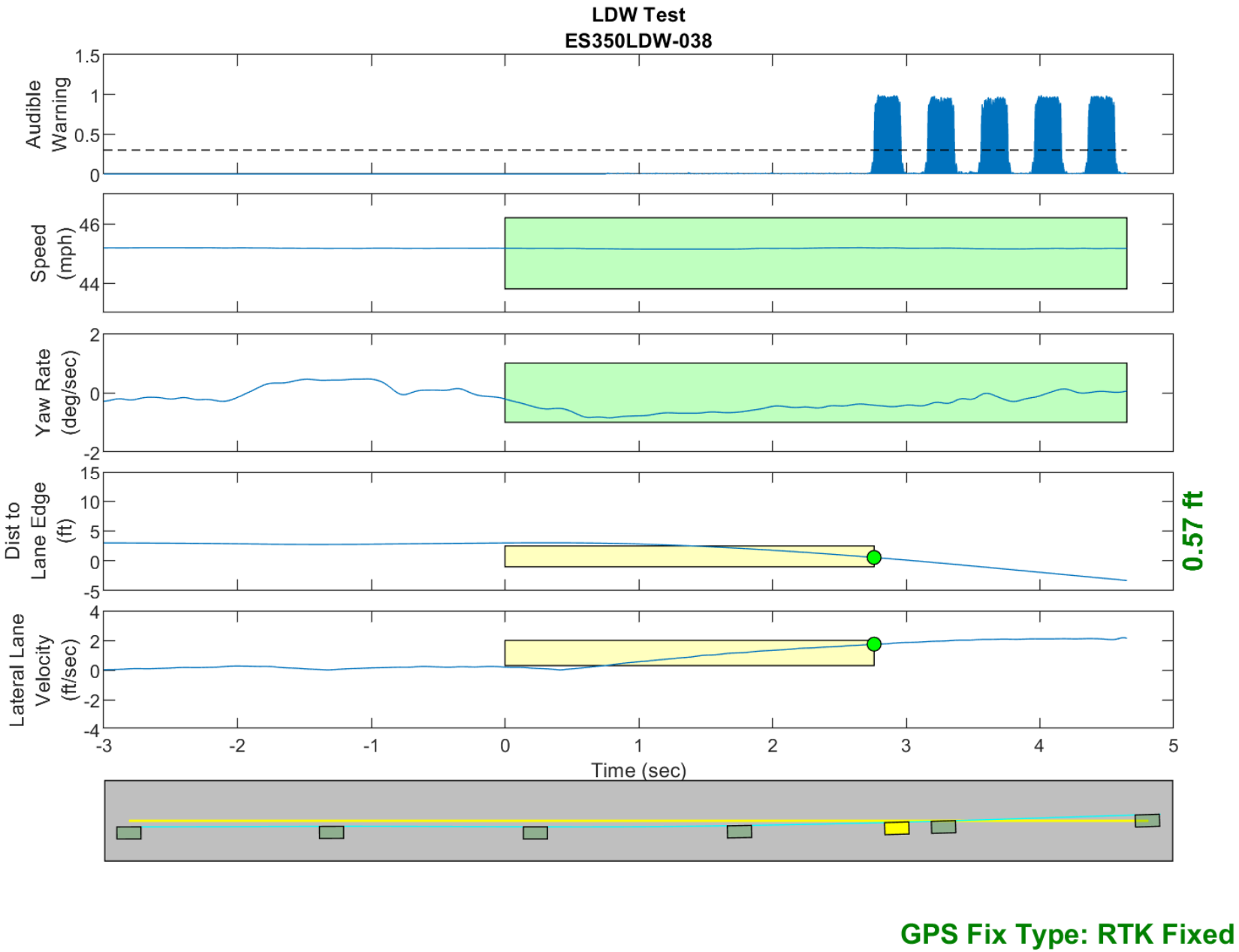


Figure D64. Time History for Run 38, Botts Dots, Left Departure, Audible Warning

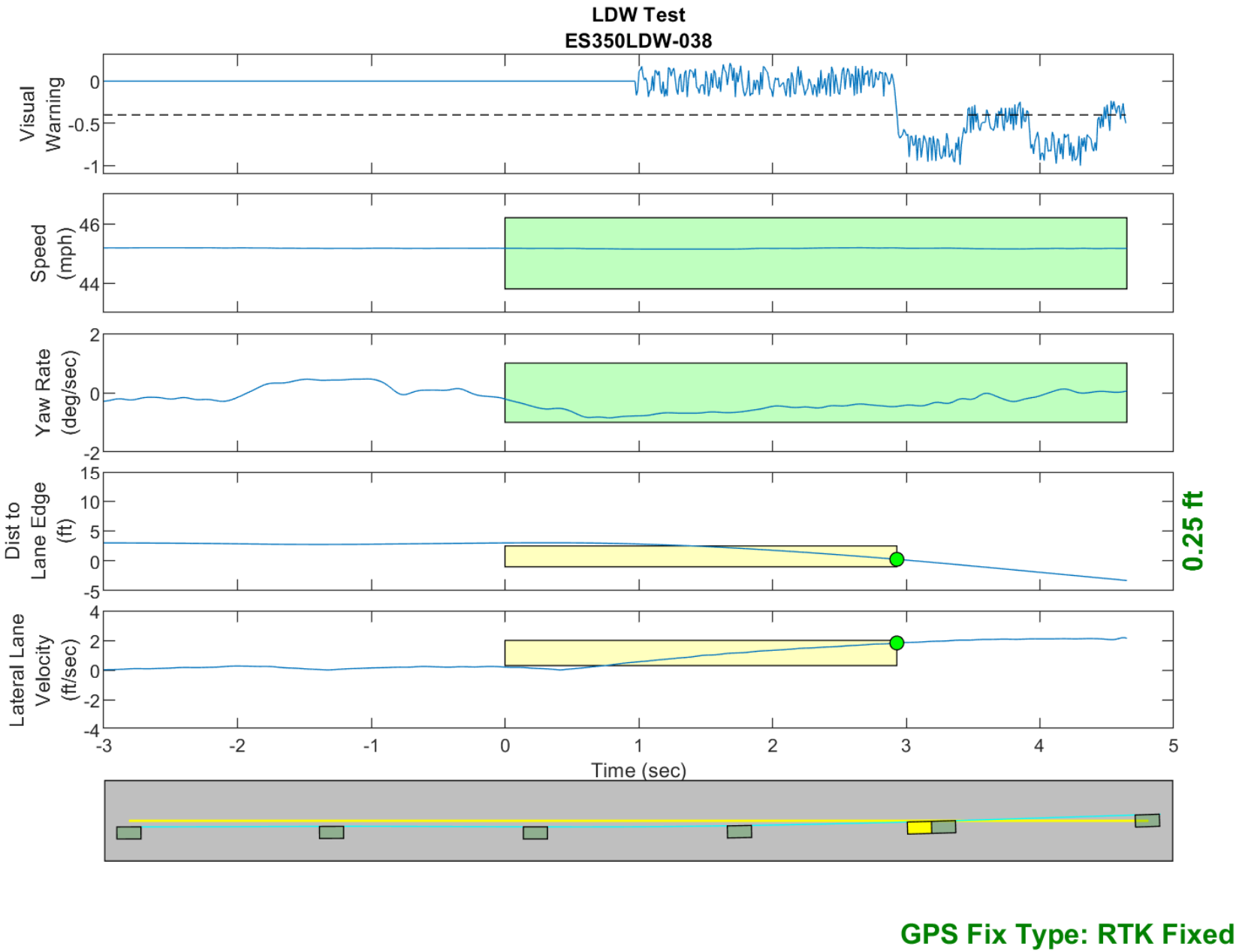


Figure D65. Time History for Run 38, Botts Dots, Left Departure, Visual Warning

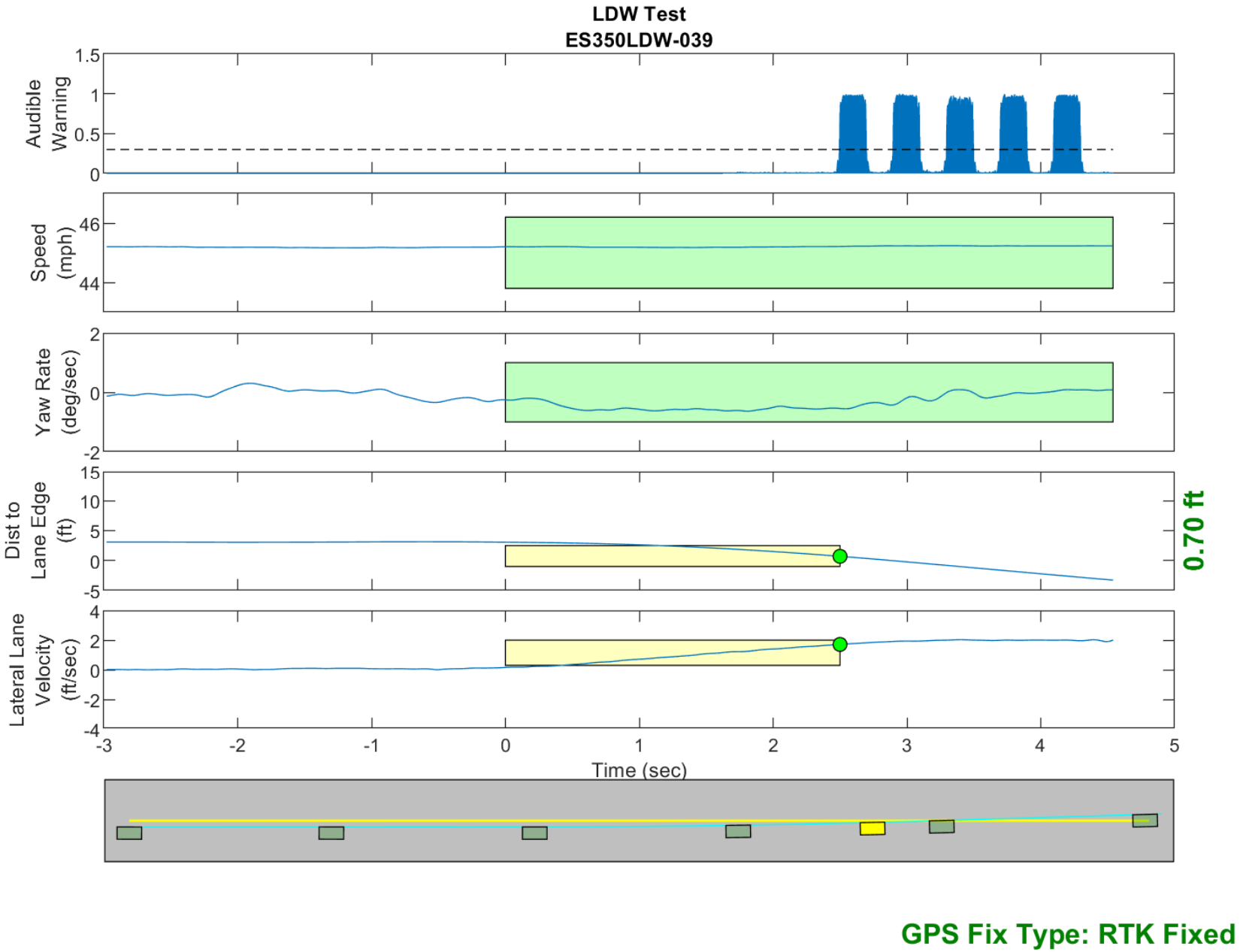


Figure D66. Time History for Run 39, Botts Dots, Left Departure, Audible Warning

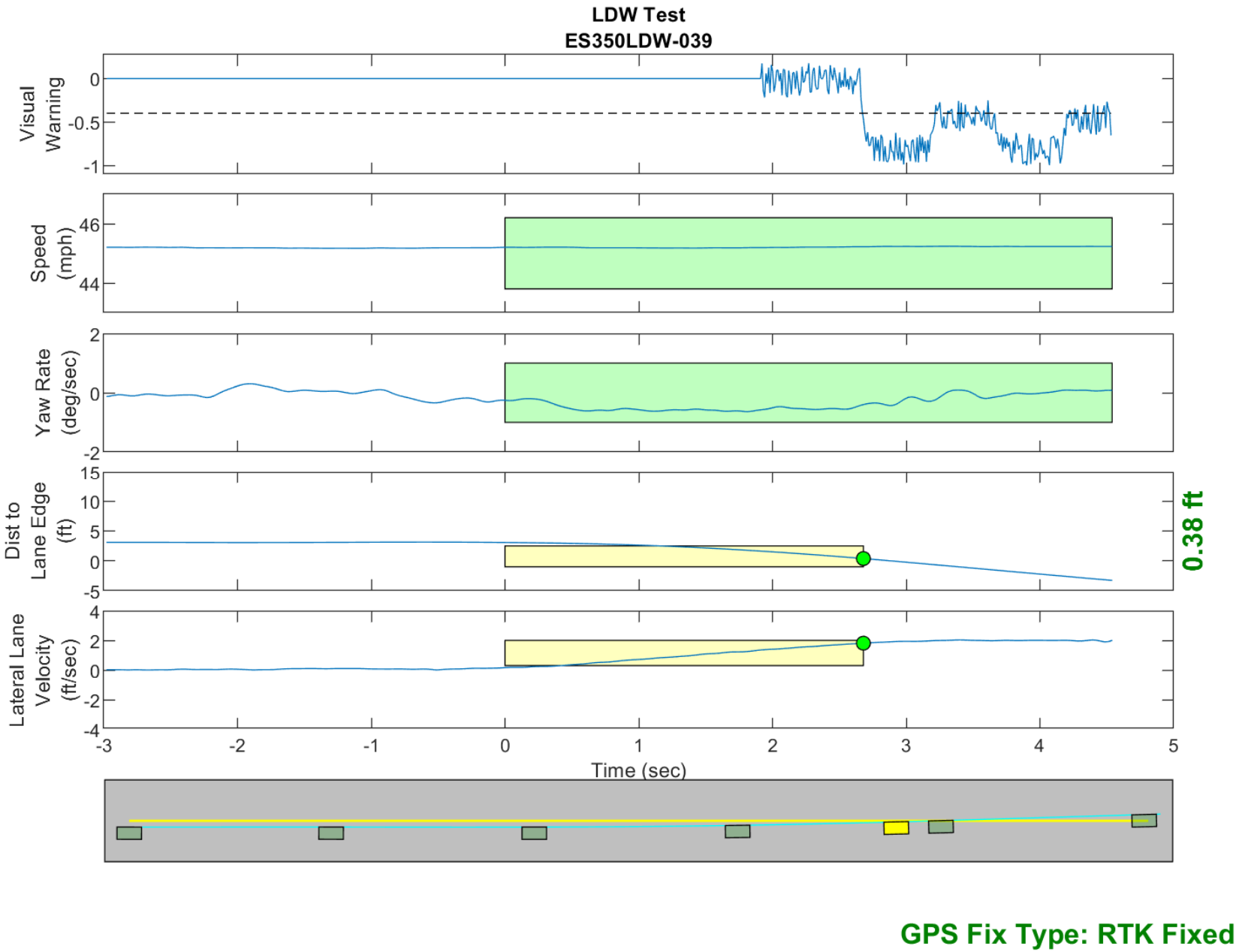


Figure D67. Time History for Run 39, Botts Dots, Left Departure, Visual Warning

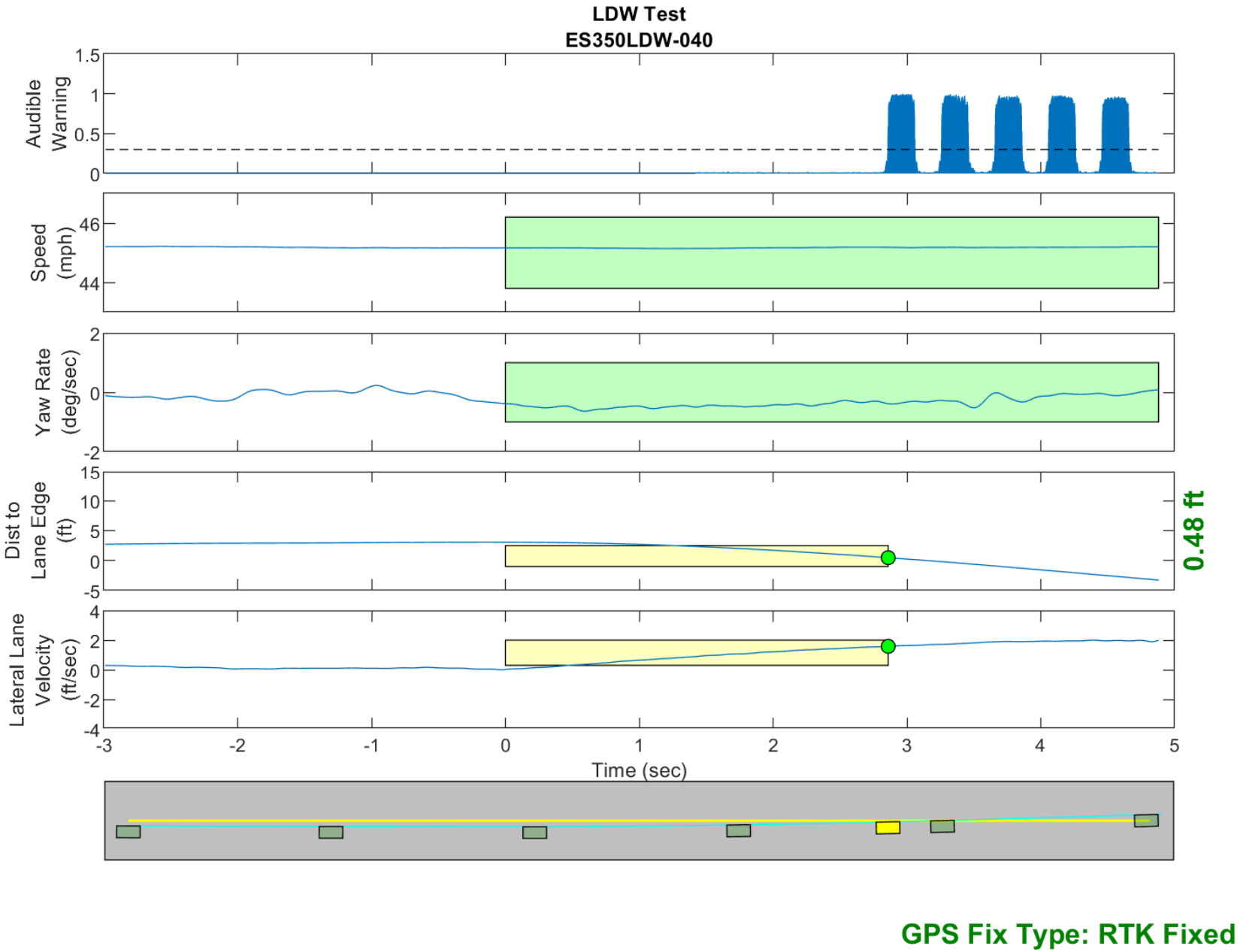


Figure D68. Time History for Run 40, Botts Dots, Left Departure, Audible Warning

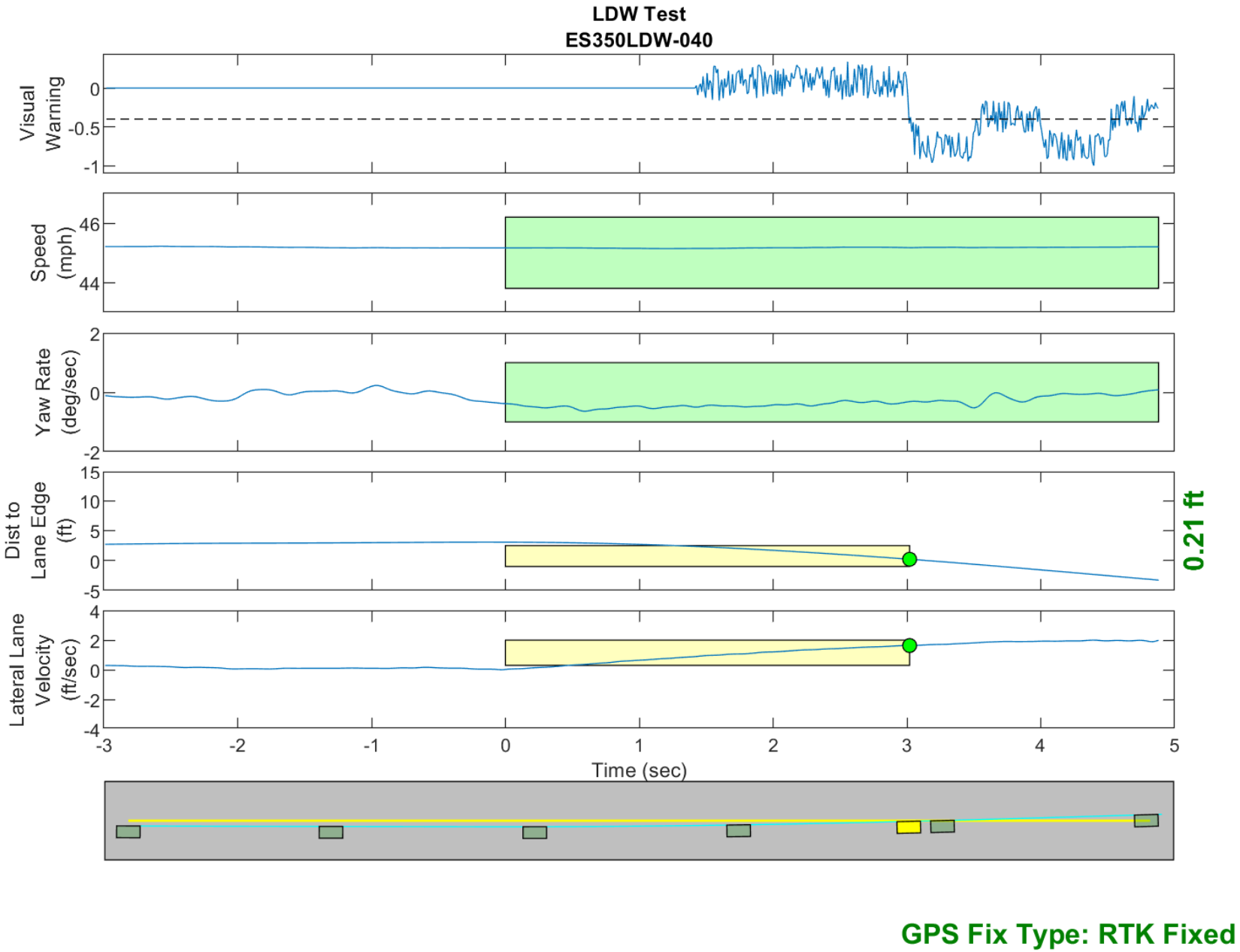


Figure D69. Time History for Run 40, Botts Dots, Left Departure, Visual Warning

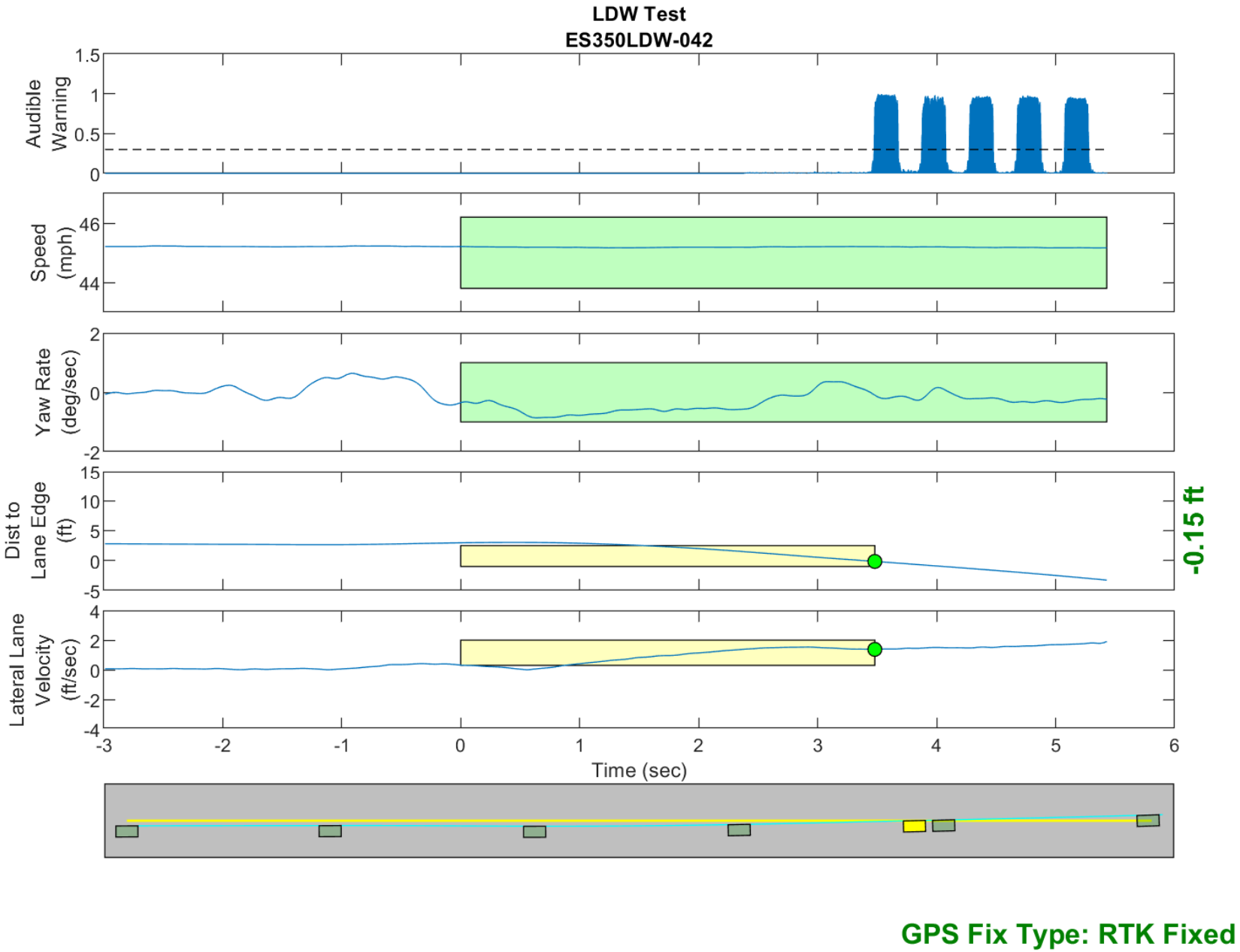


Figure D70. Time History for Run 42, Botts Dots, Left Departure, Audible Warning

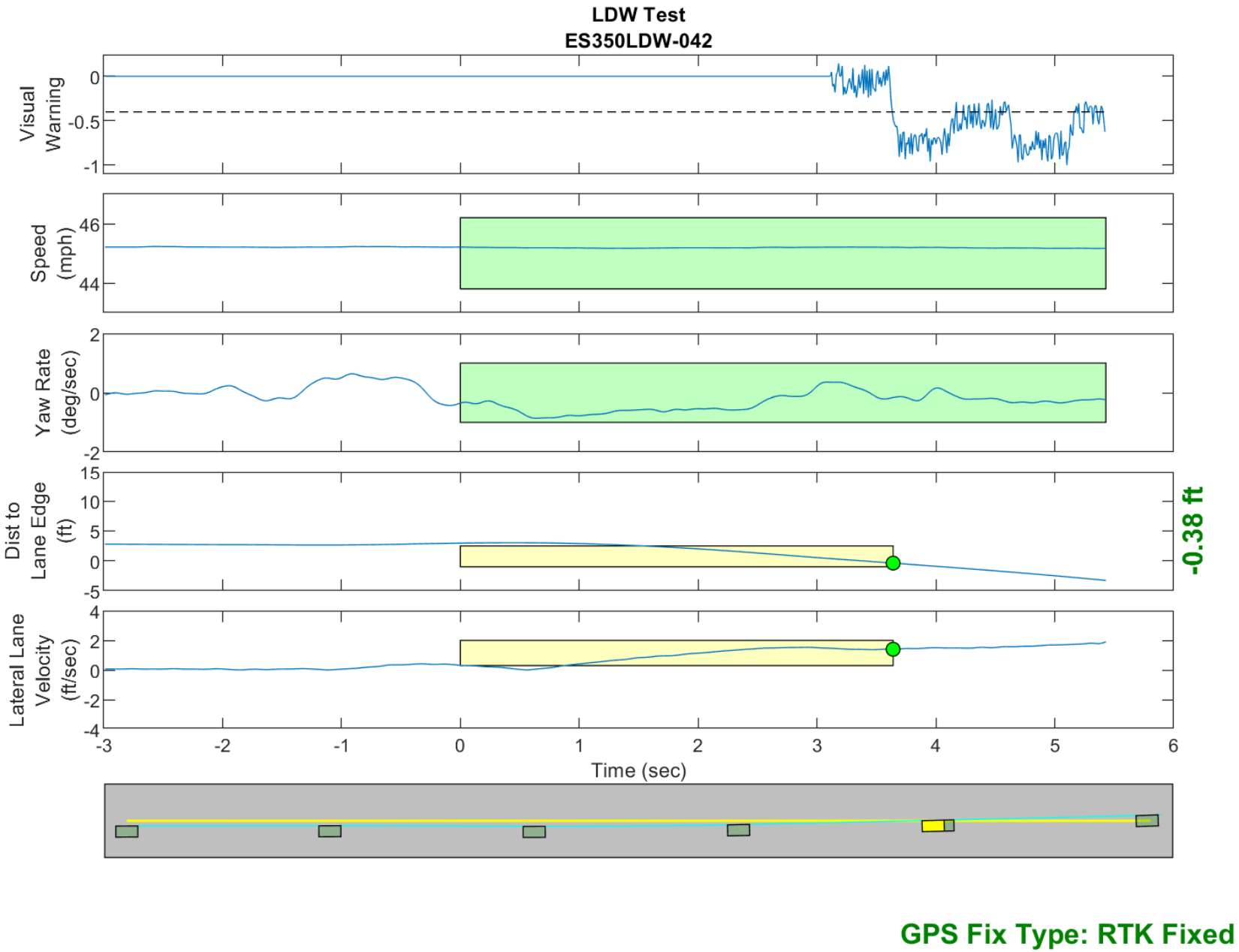


Figure D71. Time History for Run 42, Botts Dots, Left Departure, Visual Warning

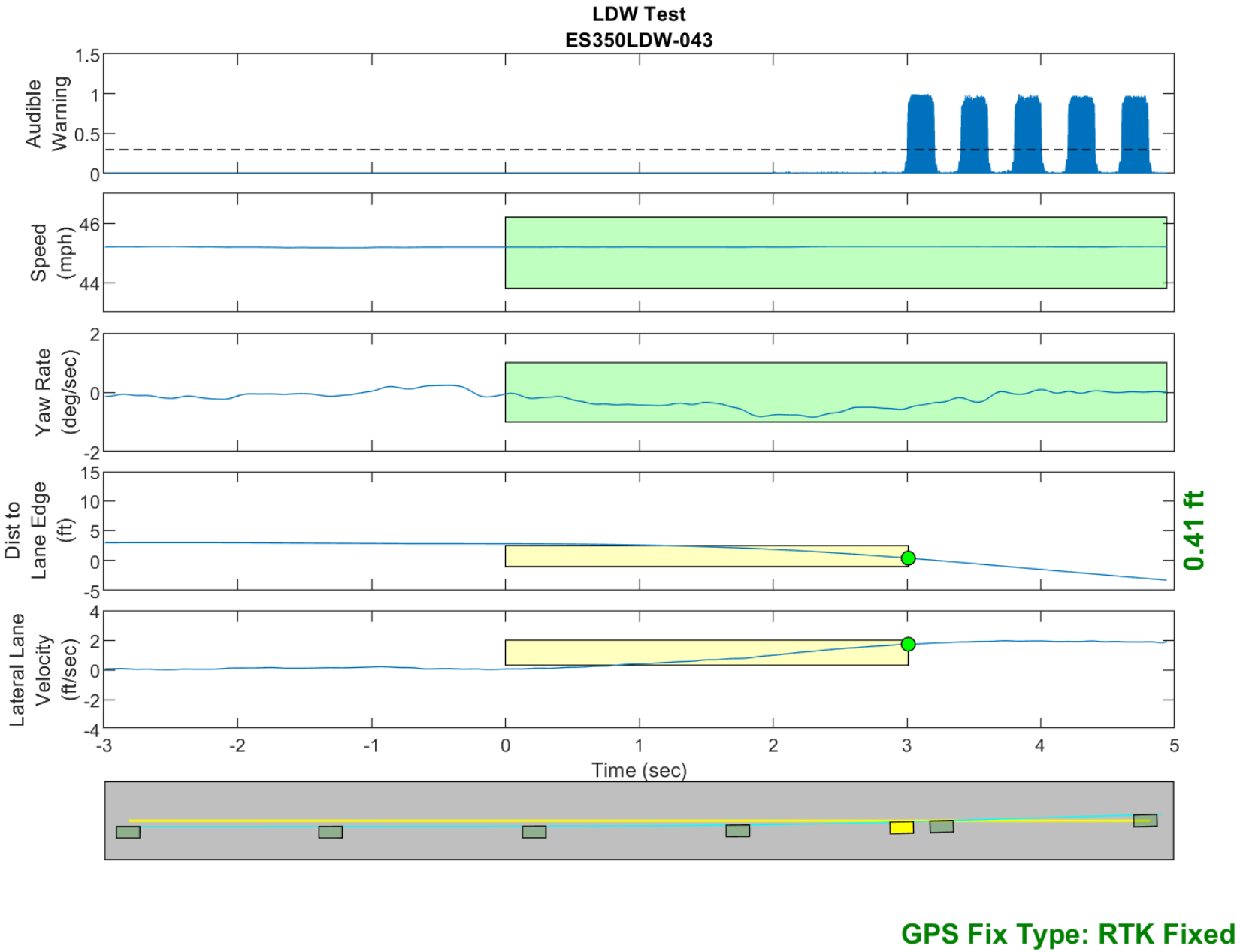


Figure D72. Time History for Run 43, Botts Dots, Left Departure, Audible Warning

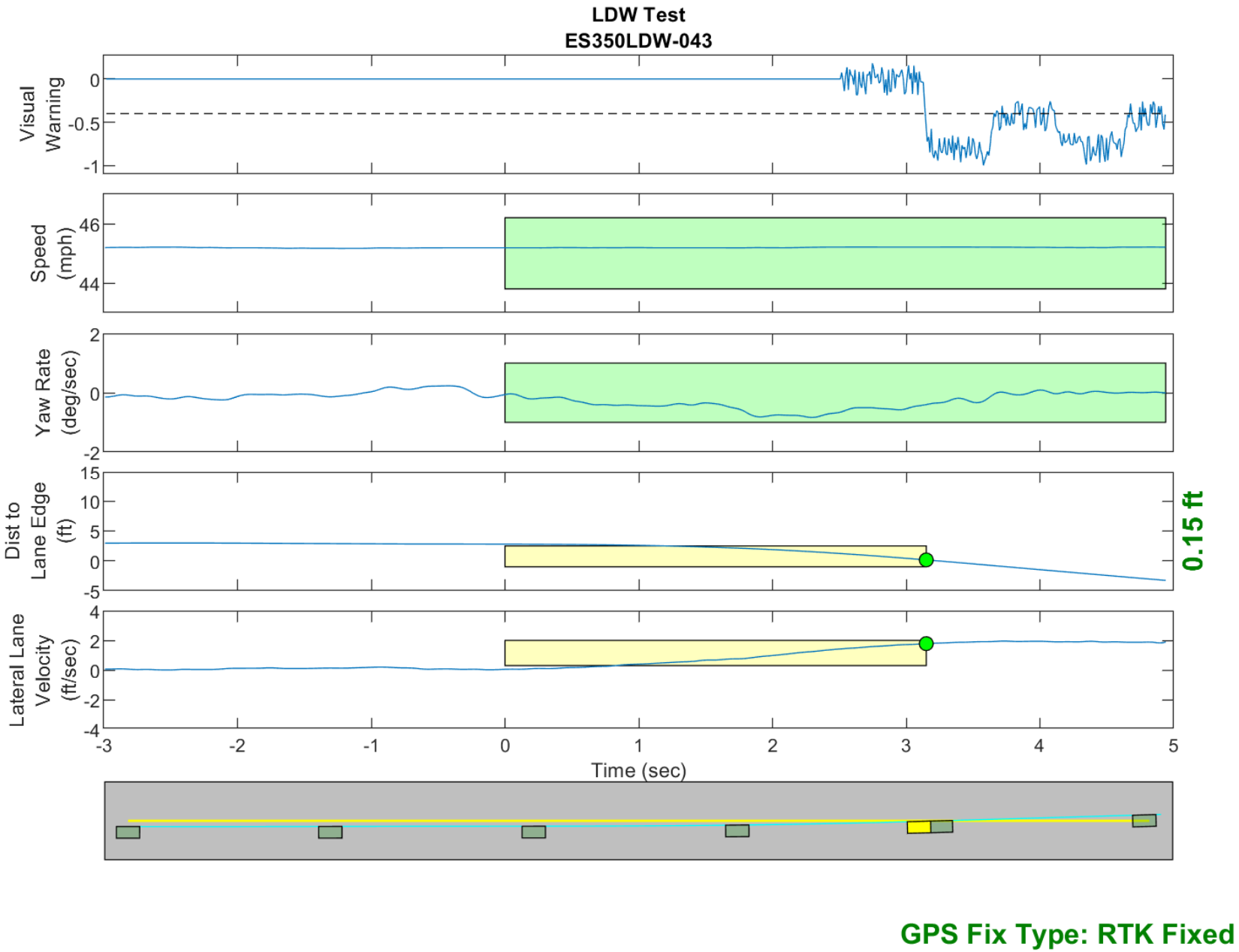


Figure D73. Time History for Run 43, Botts Dots, Left Departure, Visual Warning

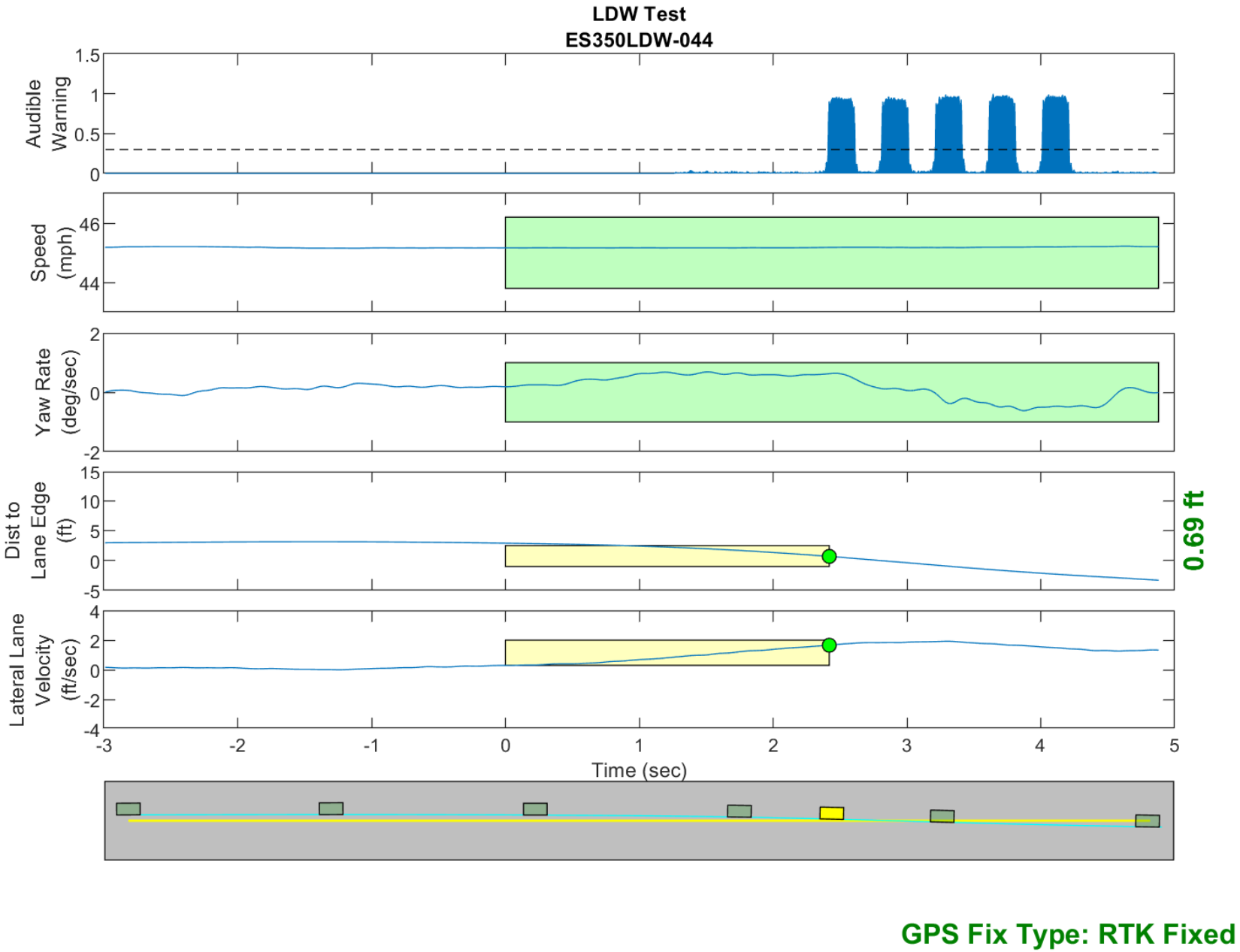


Figure D74. Time History for Run 44, Botts Dots, Right Departure, Audible Warning

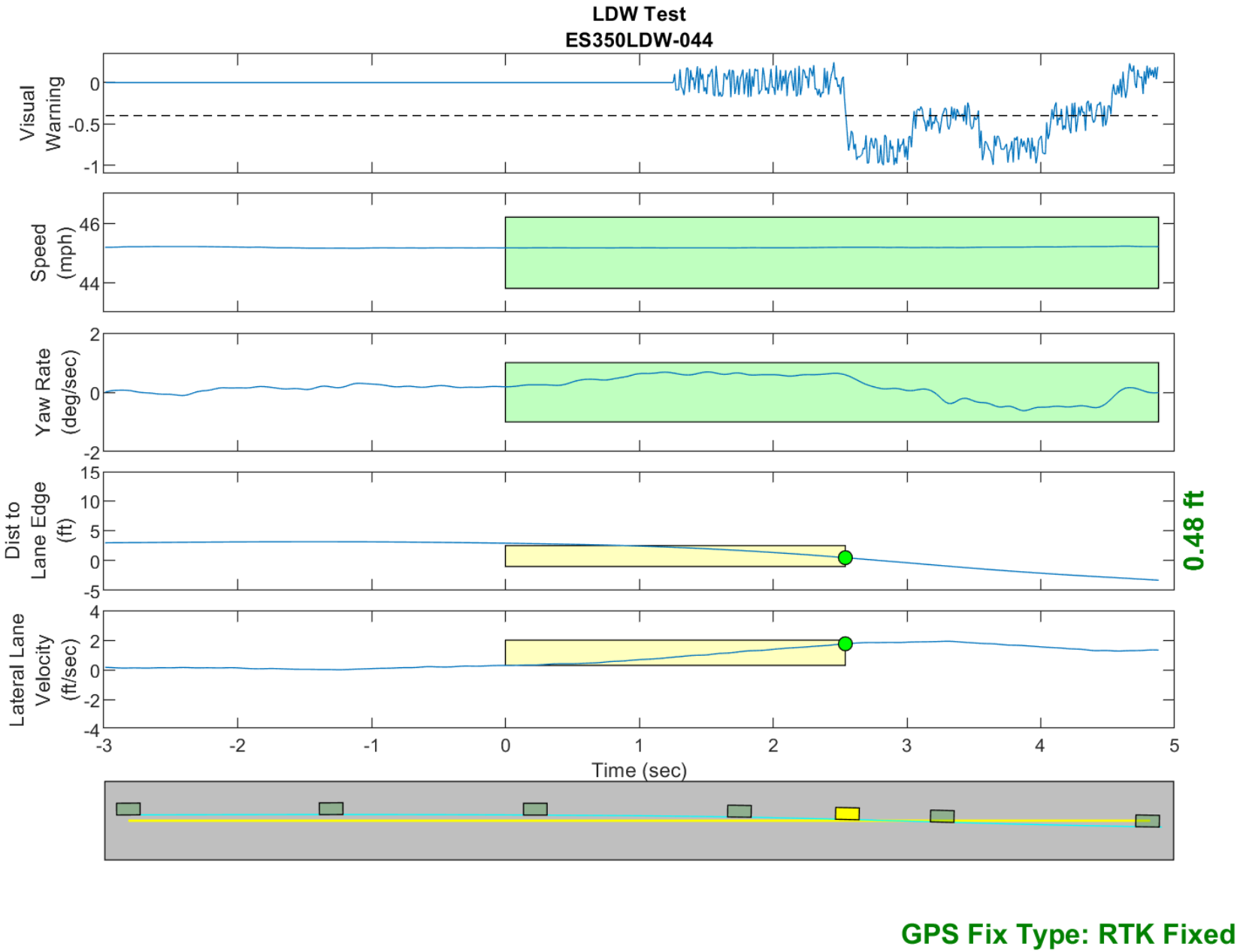


Figure D75. Time History for Run 44, Botts Dots, Right Departure, Visual Warning

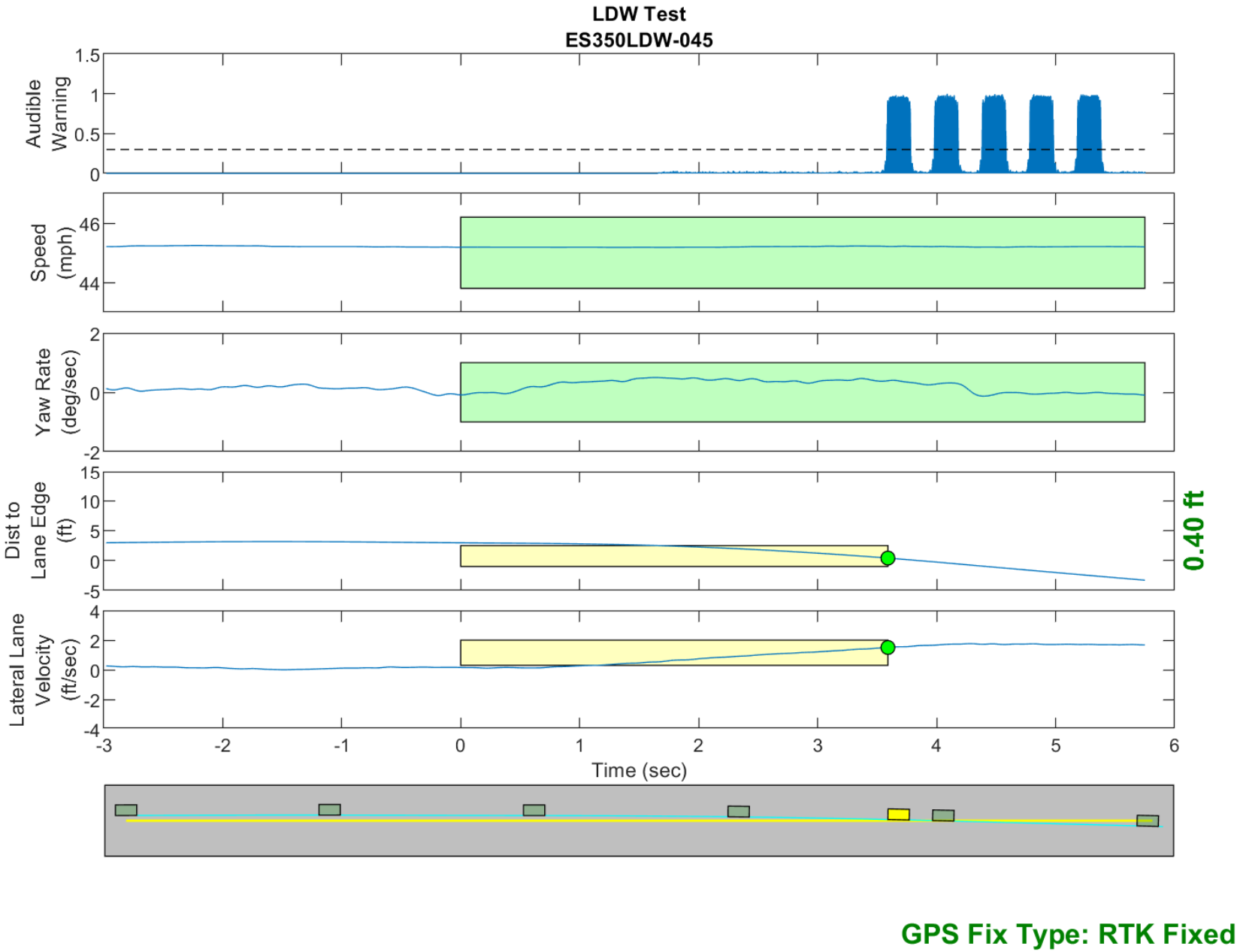


Figure D76. Time History for Run 45, Botts Dots, Right Departure, Audible Warning

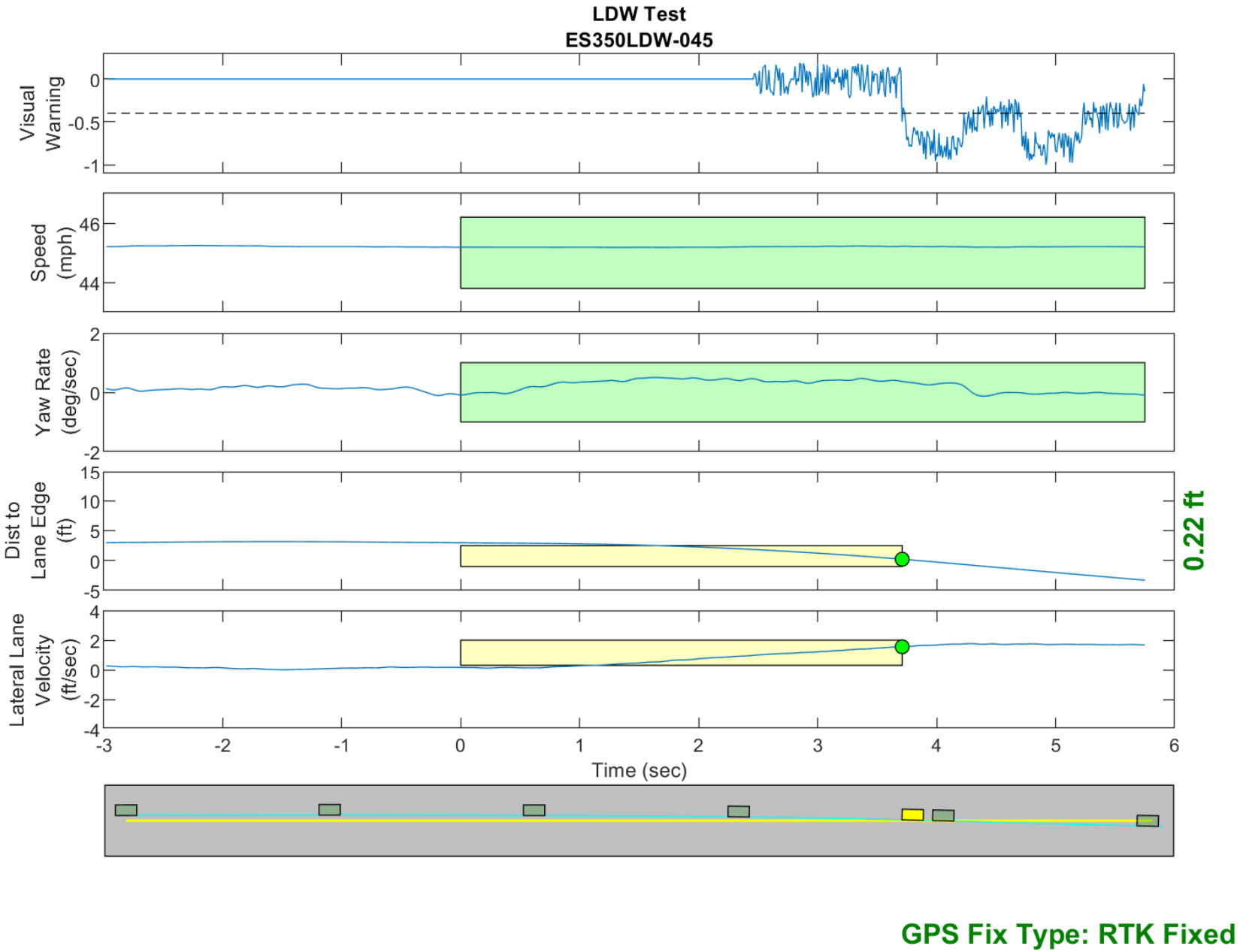


Figure D77. Time History for Run 45, Botts Dots, Right Departure, Visual Warning

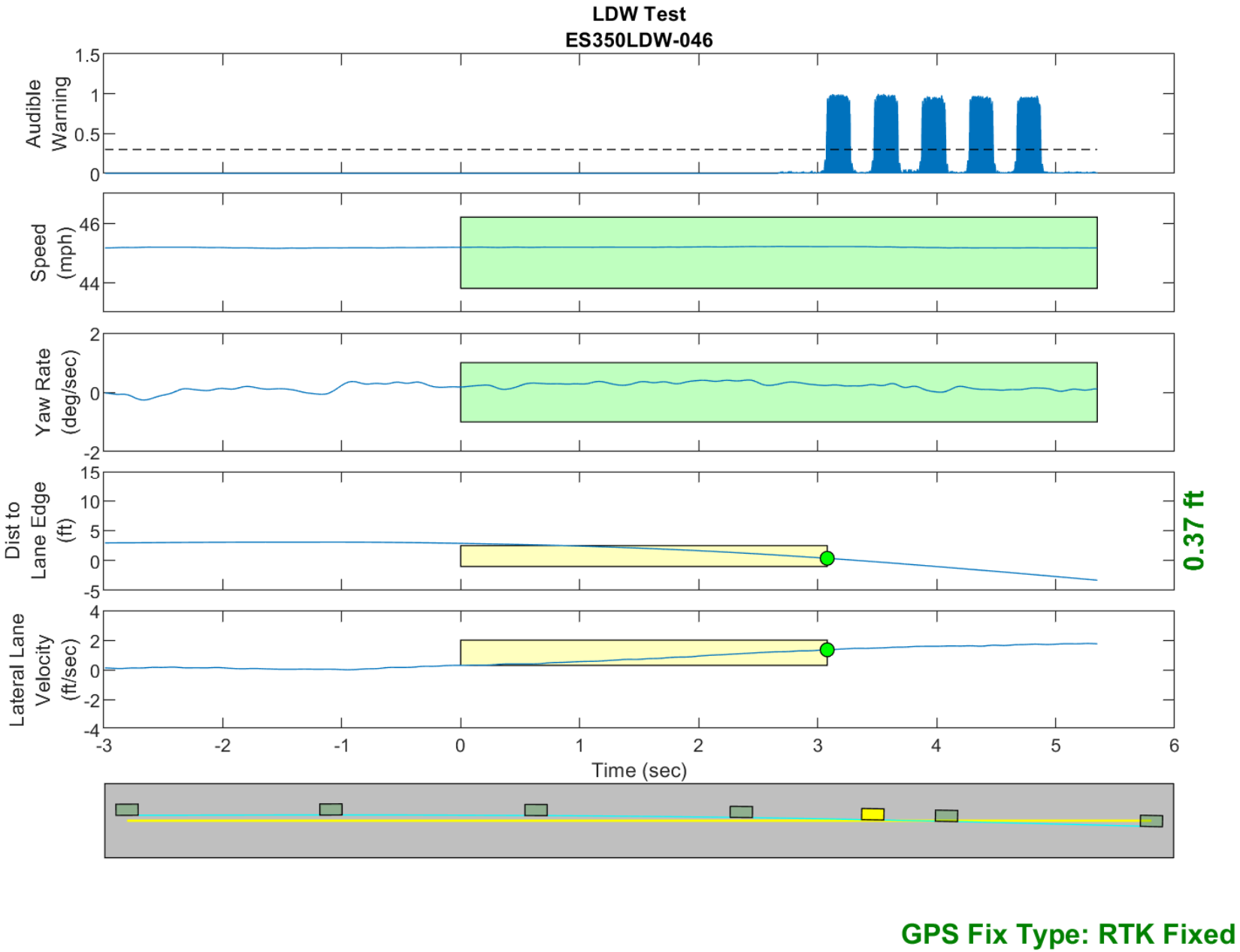


Figure D78. Time History for Run 46, Botts Dots, Right Departure, Audible Warning

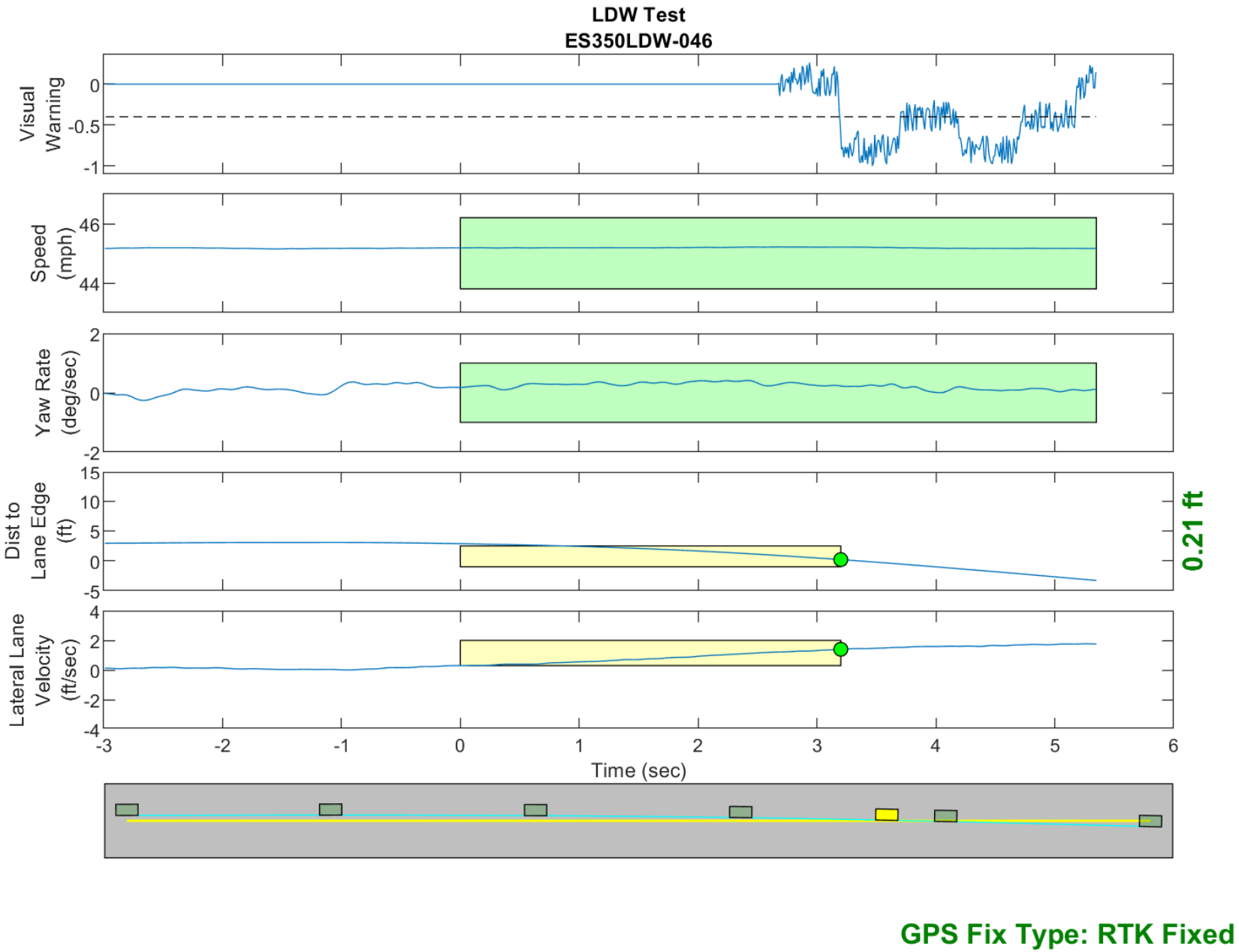


Figure D79. Time History for Run 46, Botts Dots, Right Departure, Visual Warning

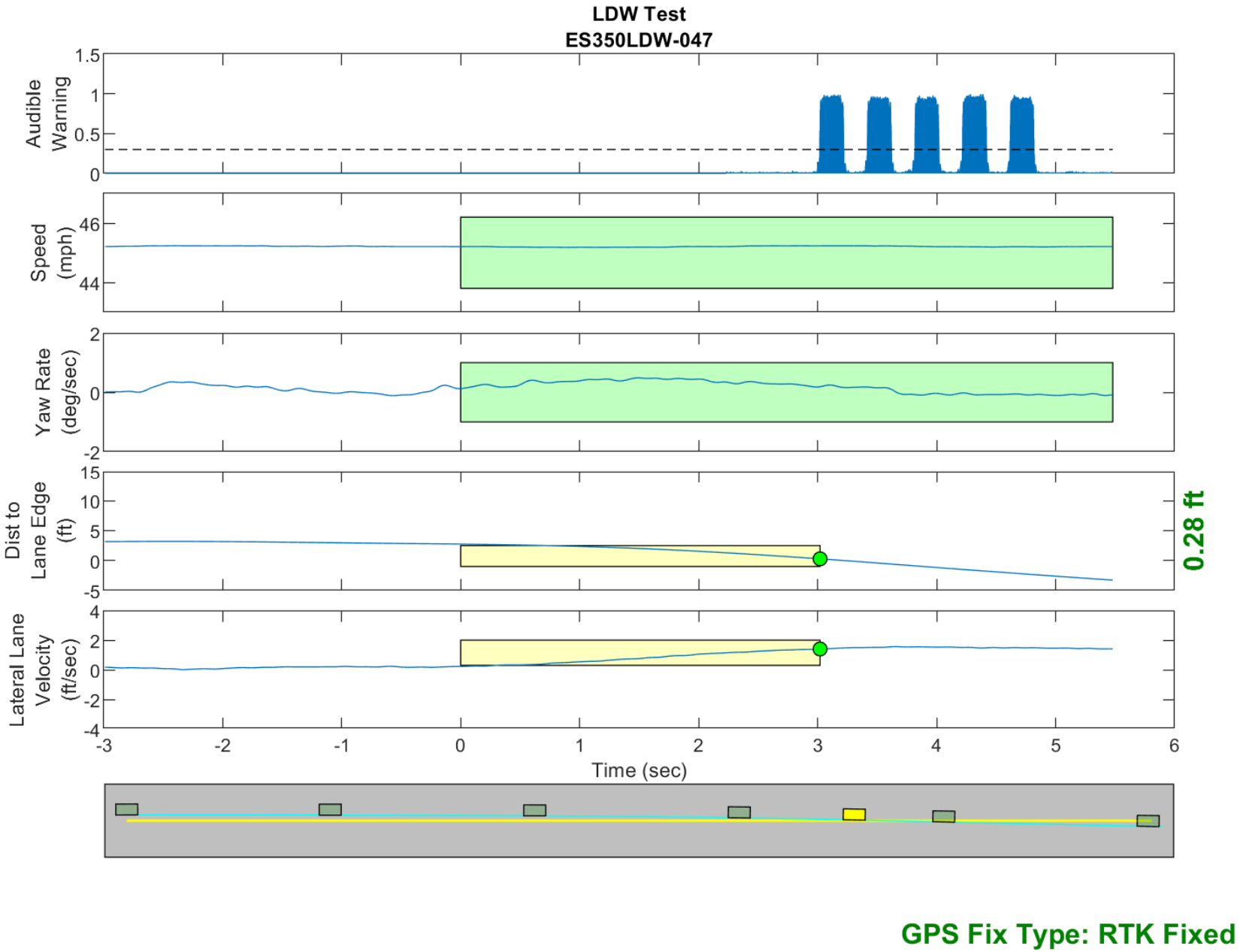


Figure D80. Time History for Run 47, Botts Dots, Right Departure, Audible Warning

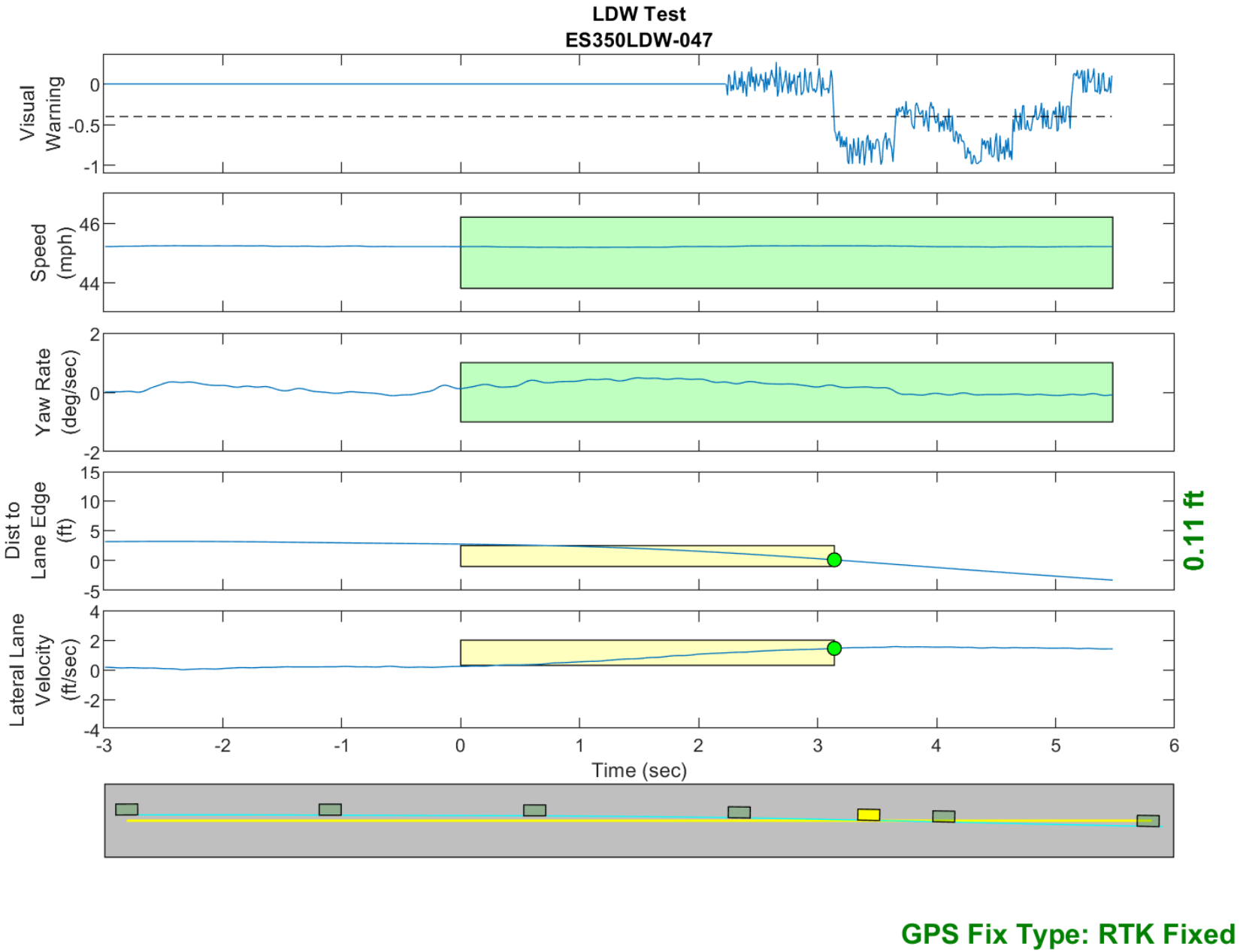


Figure D81. Time History for Run 47, Botts Dots, Right Departure, Visual Warning

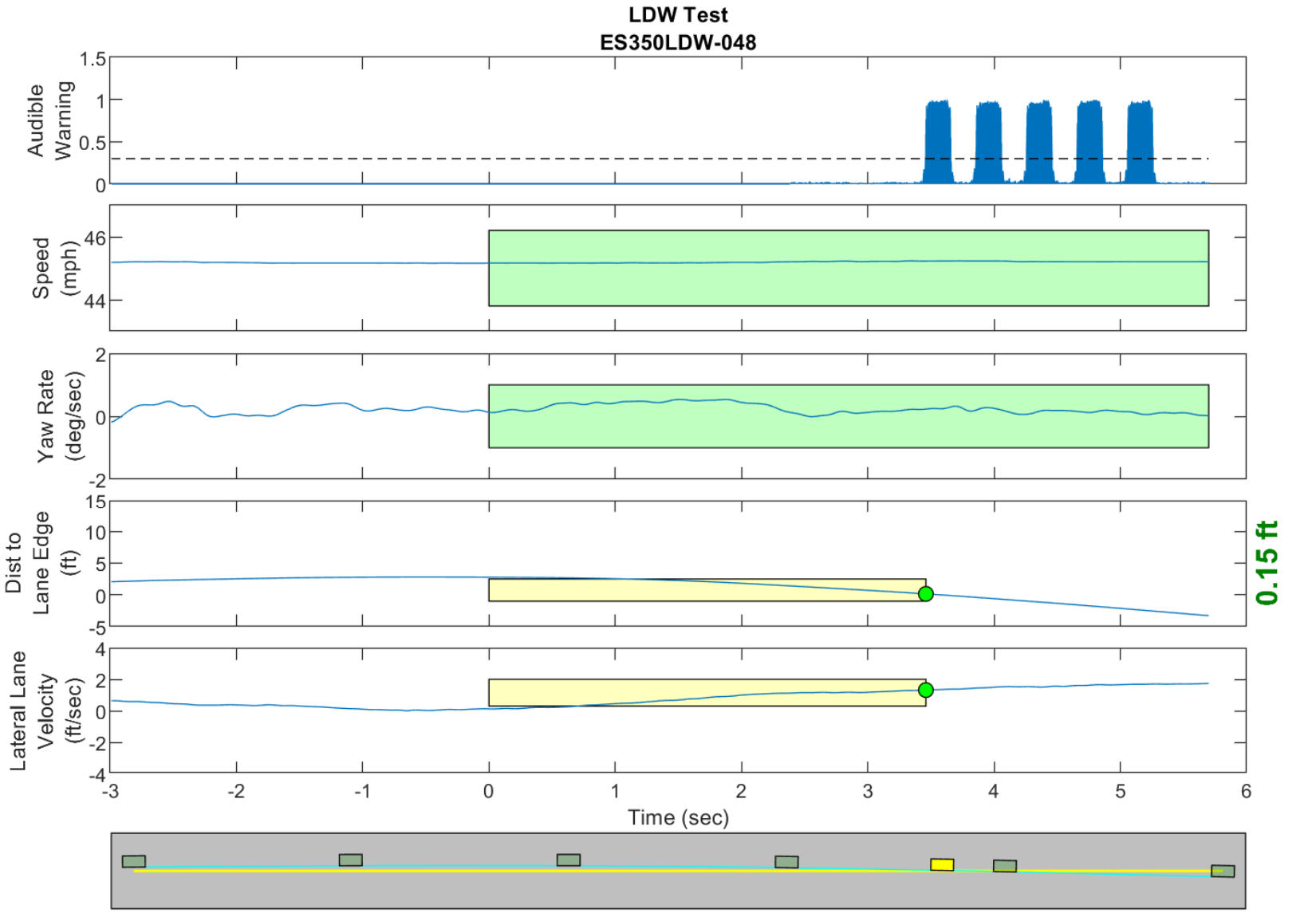


Figure D82. Time History for Run 48, Botts Dots, Right Departure, Audible Warning

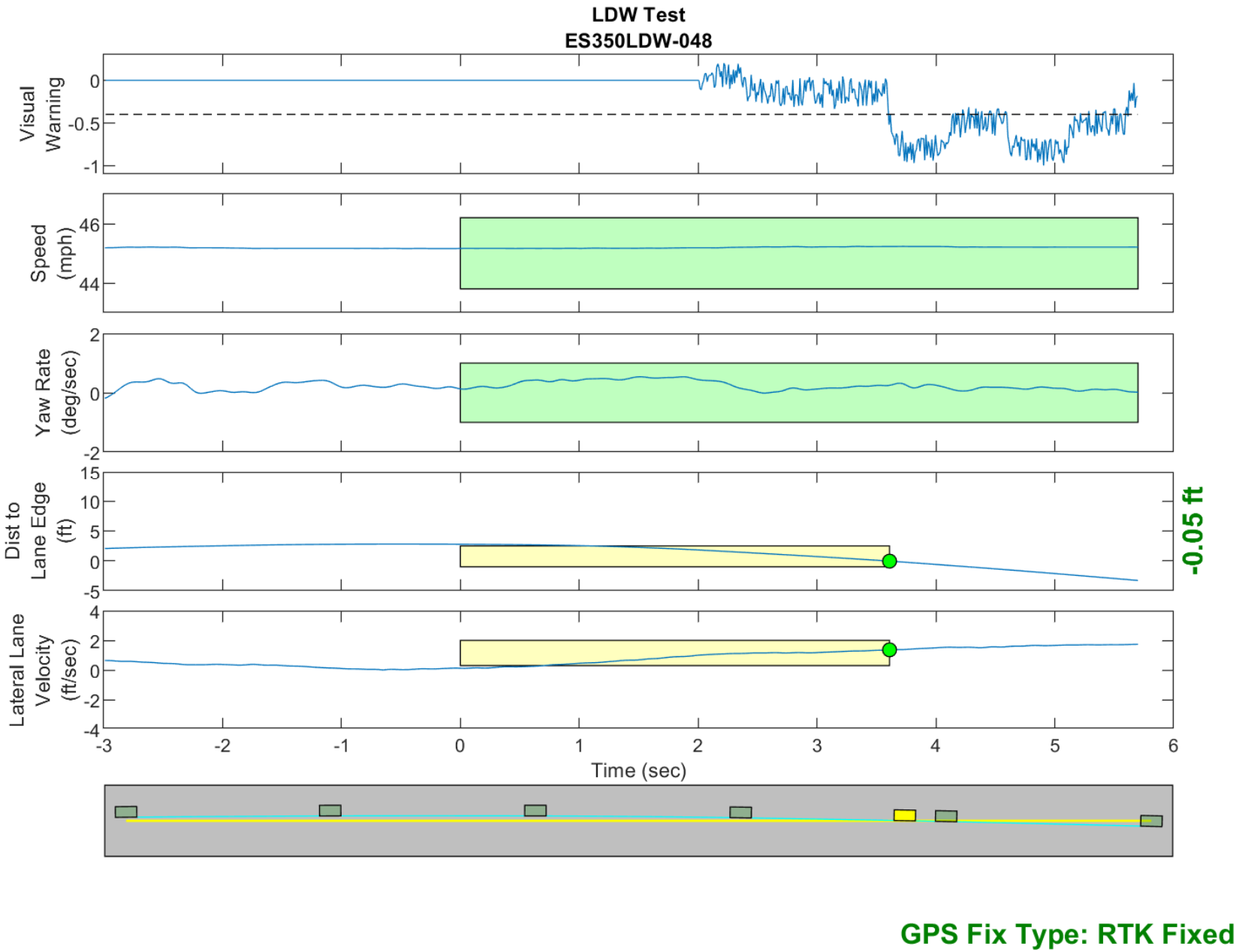


Figure D83. Time History for Run 48, Botts Dots, Right Departure, Visual Warning

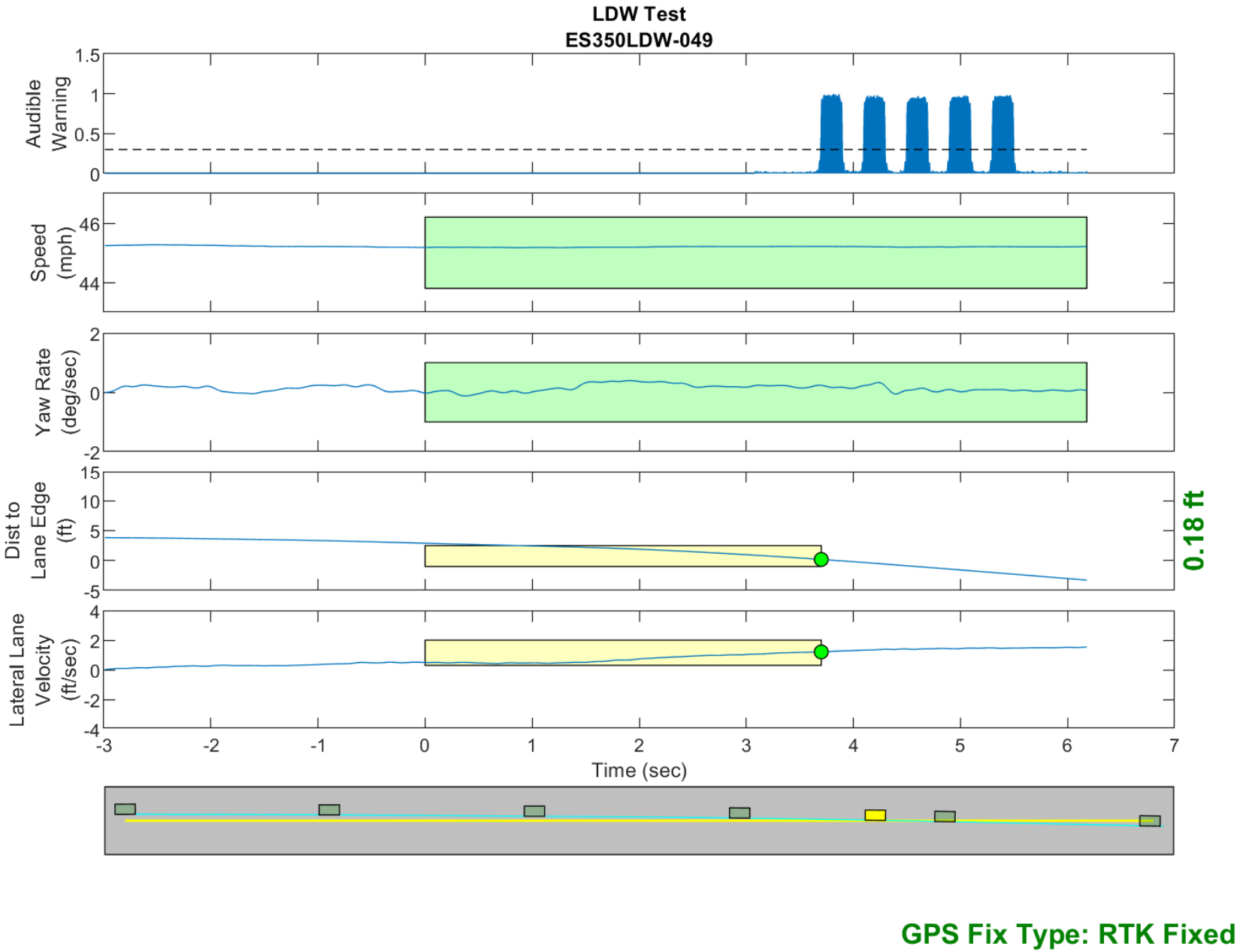


Figure D84. Time History for Run 49, Botts Dots, Right Departure, Audible Warning

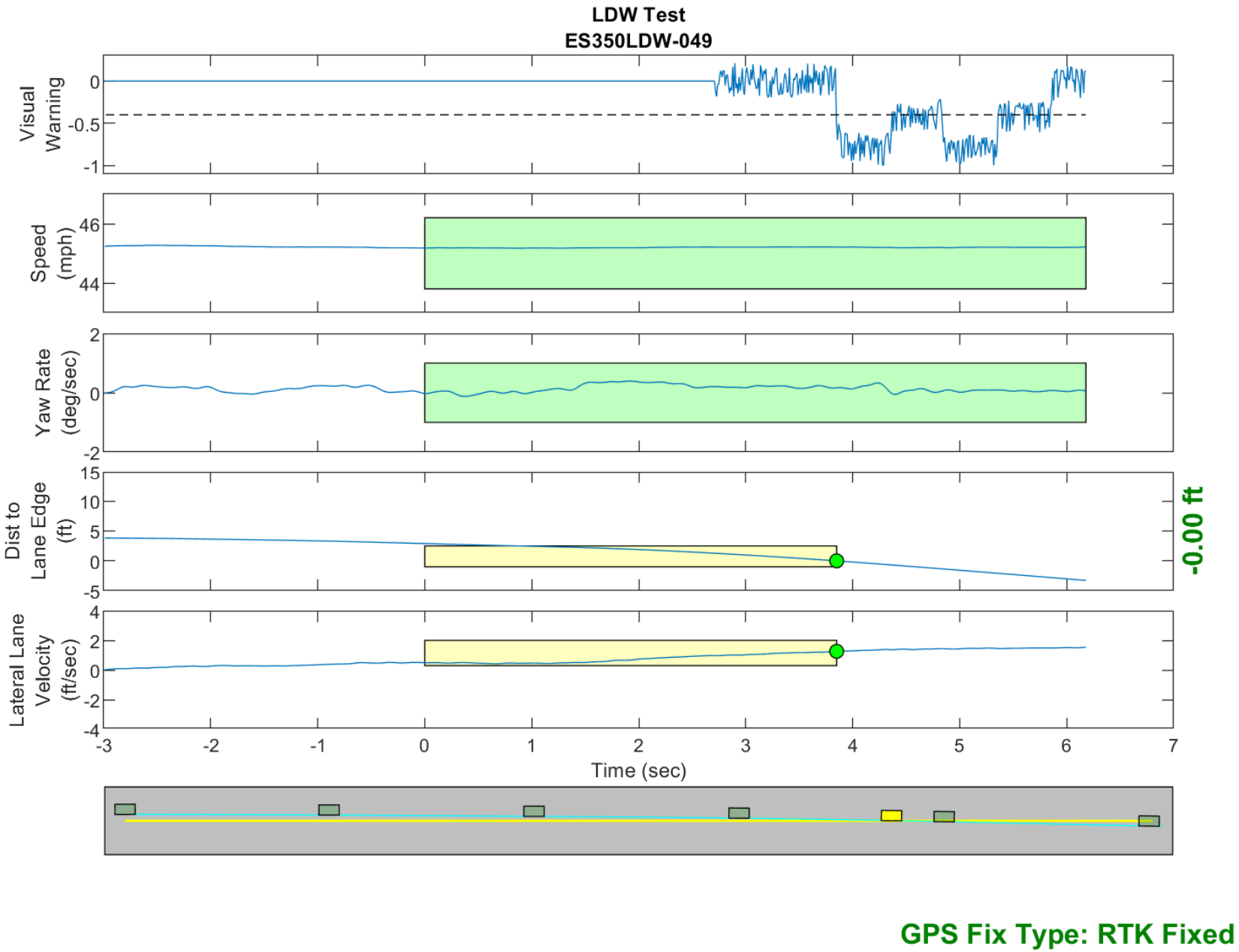


Figure D85. Time History for Run 49, Botts Dots, Right Departure, Visual Warning

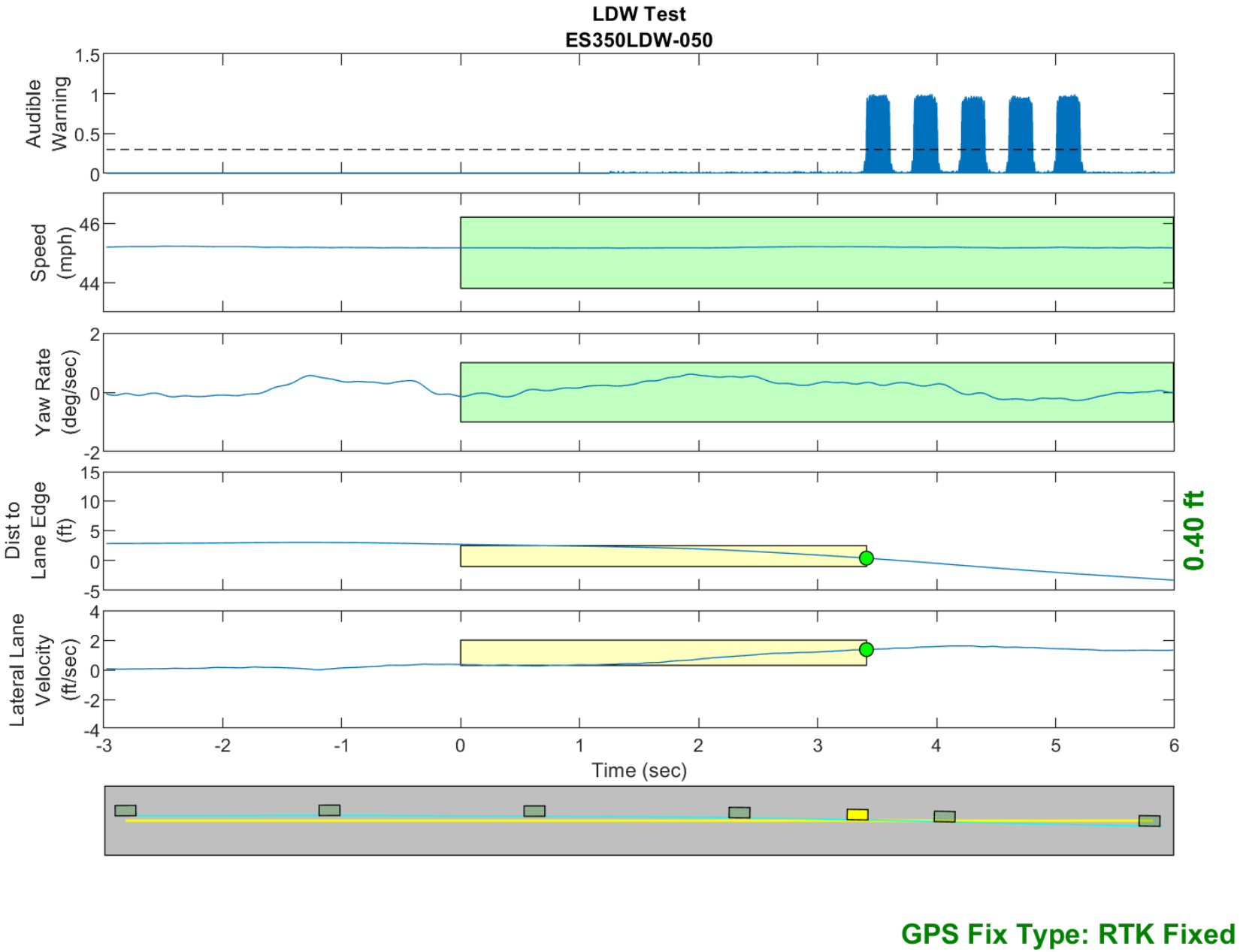


Figure D86. Time History for Run 50, Botts Dots, Right Departure, Audible Warning

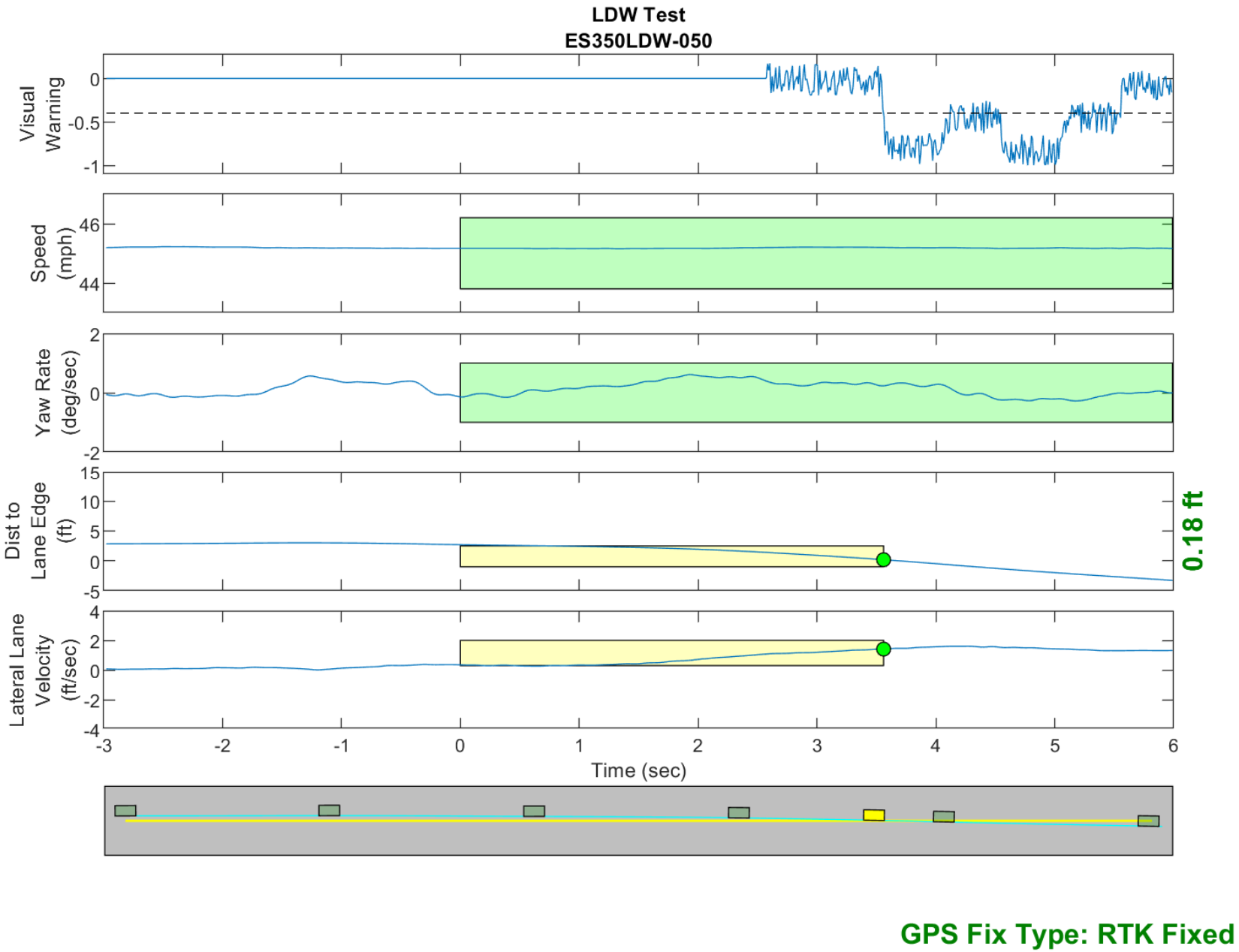


Figure D87. Time History for Run 50, Botts Dots, Right Departure, Visual Warning