NEW CAR ASSESSMENT PROGRAM
LANE DEPARTURE WARNING CONFIRMATION TEST
NCAP-DRI-LDW-22-07

2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG

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10 March 2022

Draft 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

Prepared for the Department of Transportation, National Highway Traffic Safety Administration, under Contract No. DTNH22-14-D-00333.

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Date: 10 March 2022

1. Report No. NCAP-DRI-LDW-22-07	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Draft Report of Lane Departure Warning Confirmation Test of a 2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG.		5. Report Date 10 March 2022	
		6. Performing Organization Code DRI	
7. Author(s) Stephen Rhim, Senior Engineer John Partridge, Staff Engineer		8. Performing Organization Report No. DRI-TM-21-132	
9. Performing Organization Name and Address Dynamic Research, Inc. 355 Van Ness Ave, STE 200 Torrance, CA 90501		10. Work Unit No.	
		11. Contract or Grant No. DTNH22-14-D-00333	
12. Sponsoring Agency Name and Address 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		13. Type of Report and Period Covered Draft Test Report March 2022	
		14. Sponsoring Agency Code NRM-110	
15. Supplementary Notes			
16. Abstract These tests were conducted on the subject 2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG in accordance with the specifications of the New Car Assessment Program's (NCAP's) 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.			
17. Key Words Lane Departure Warning, LDW, New Car Assessment Program, NCAP		18. Distribution Statement Copies of this report are available from the following: NHTSA Technical Reference Division National Highway Traffic Safety Administration 1200 New Jersey Avenue, SE Washington, DC 20590	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 136	22. Price

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Section I

INTRODUCTION

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.

The purpose of the testing reported herein was to objectively quantify the performance of a Lane Departure Warning system installed on a 2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG. This test is part of the New Car Assessment Program to assess Lane Departure Warning Systems sponsored by the National Highway Traffic Safety Administration under Contract No. DTNH22-14-D-00333.

Section II

DATA SHEETS

LANE DEPARTURE WARNING

DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG

VIN: *JM3KFBEM4N052xxxx*

Test start date: *3/3/2022*

Test end date: *3/7/2022*

Lane Departure Warning setting: *N/A*

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)

2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG

TEST VEHICLE INFORMATION

VIN: *JM3KFBEM4N052xxxx*

Body Style: *Crossover SUV* Color: *Eternal Blue Mica*

Date Received: *2/16/2022* Odometer Reading: *10 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *MAZDA MOTOR CORPORATION*

Date of manufacture: *12/21*

Vehicle Type: *MPV*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *P225/55R19*

Rear: *P225/55R19*

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

Rear: *240 kPa (35 psi)*

TIRES

Tire manufacturer and model: *Toyo A36 Toyo A36*

Front tire size: *P225/55R19 99V*

Rear tire size: *P225/55R19 99V*

Front tire DOT prefix: *N3T4 6ME*

Rear tire DOT prefix: *N3T4 6ME*

LANE DEPARTURE WARNING

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG

GENERAL INFORMATION

Test start date: *3/3/2022*

Test end date: *3/7/2022*

AMBIENT CONDITIONS

Air temperature: *18.9 C (66 F)*

Wind speed: *2.6 m/s (5.8 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)

2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*533.0 kg (1175 lb)*	Right Front:	*502.6 kg (1108 lb)*
Left Rear:	*410.0 kg (904 lb)*	Right Rear:	*391.5 kg (863 lb)*
		Total:	*1837.1 kg (4050 lb)*

LANE DEPARTURE WARNING

DATA SHEET 4: LANE DEPARTURE WARNING SYSTEM OPERATION

(Page 1 of 2)

2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG

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

Lane Departure Warning System

Type and location of sensor(s) used:

The LDW system uses a camera located at the top center of the windshield.

Lane Departure Warning Setting used in test:

N/A

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

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

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

The LDW system alerts the driver with a visual and auditory alert. The visual alert is displayed in the multi-information display and consists of two white lane lines. When the lane departure warning activates, the lane line corresponding to the side in which the vehicle crossed turns amber and flashes on/off. The auditory alert consists of five consecutive beeps with a primary frequency at approximately 2000 Hz.

LANE DEPARTURE WARNING

DATA SHEET 4: LANE DEPARTURE WARNING SYSTEM OPERATION

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2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG

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 LDW system can be turned on/off using a dedicated button on the dash to the left of the steering wheel. When the system is turned off, the LDW warning light is displayed on the right side of the instrument panel.

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

_____ Yes

__**X**__ No

If yes, please provide a full description.

Are there other driving modes or conditions that render LDW inoperable or reduce its effectiveness?

__**X**__ Yes

_____ No

If yes, please provide a full description.

Refer to the owner's manual pages 4-176 to 4-178 and 4-180 shown in Appendix B pages B-2 to B-4 and B-6.

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.

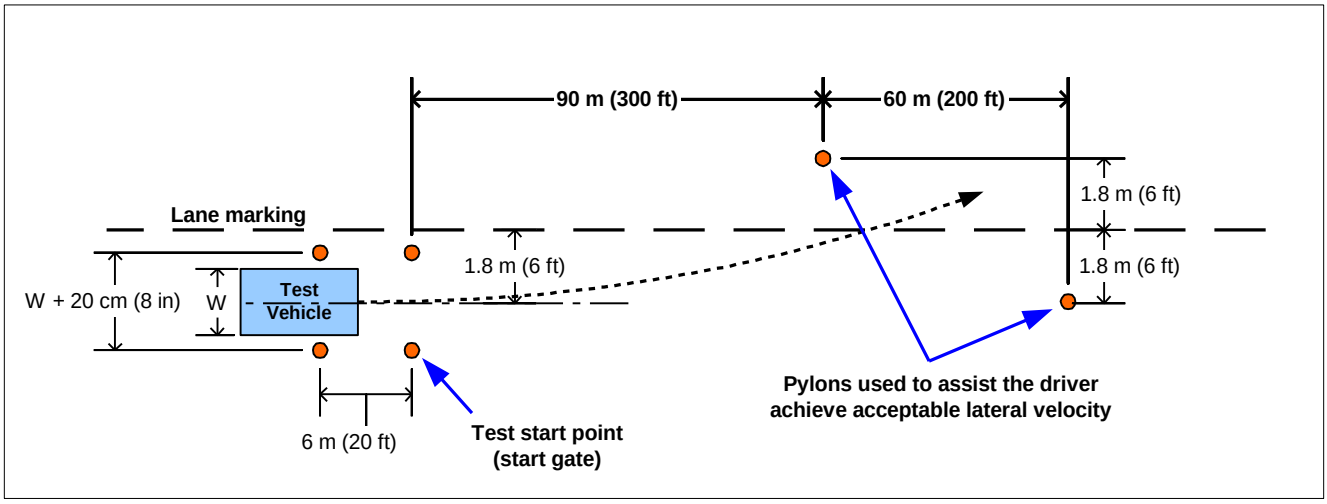


Figure 1. Position of Cones Used to Assist Driver

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.

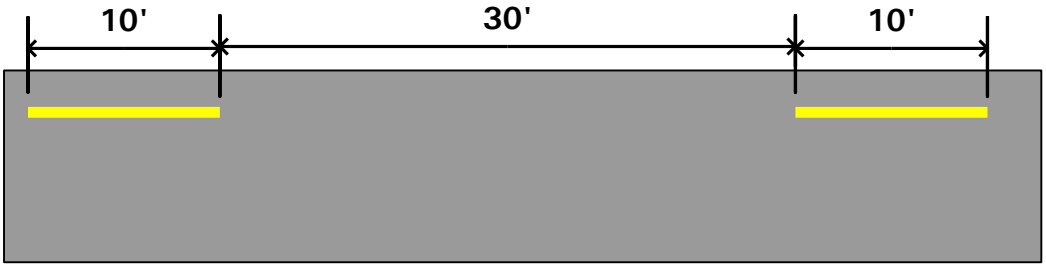


Figure 2. MUTCD Discontinuous Dashed Line Specifications

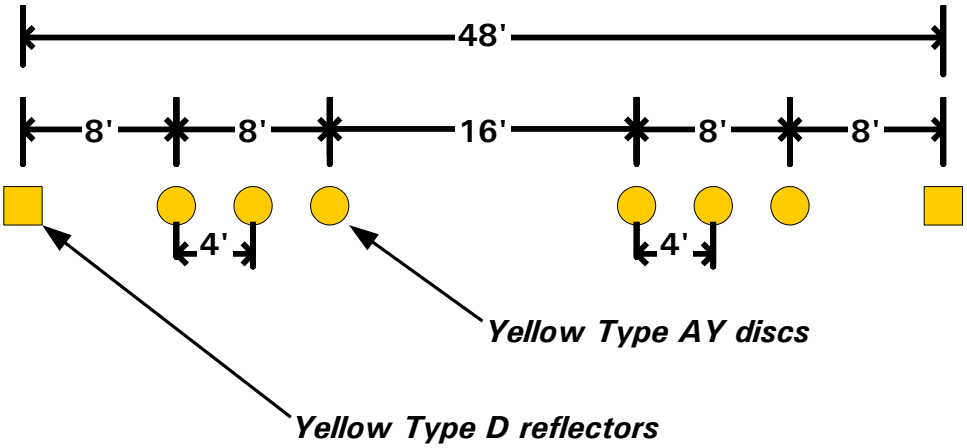


Figure 3. California Standard Plan A20A, Detail 4

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	< 1% error between 20 and 100 psi	Omega DPG8001	17042707002	By: DRI Date: 10/5/2021 Due: 10/5/2022
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform	0.1% of reading	Intercomp SW wireless	0410MN20001	By: DRI Date: 2/11/2022 Due: 2/11/2023
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	N/A
Multi-Axis Inertial Sensing System	Position: Longitudinal, Lateral, and Vertical Accels: Lateral, Longitudinal and Vertical Velocities: Roll, Pitch, Yaw Rates: Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +	2176	By: Oxford Technical Solutions[1] Date: 6/26/2020 Due: 6/26/2022
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	N/A

[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	N/A	N/A
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	N/A	N/A
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: 1/6/2022 Due: 1/6/2023

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 auditory or haptic alerts, part of the pre-test instrumentation verification process is to determine the tonal frequency of the auditory 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 auditory 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. Auditory and Tactile Warning Filter Parameters

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

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

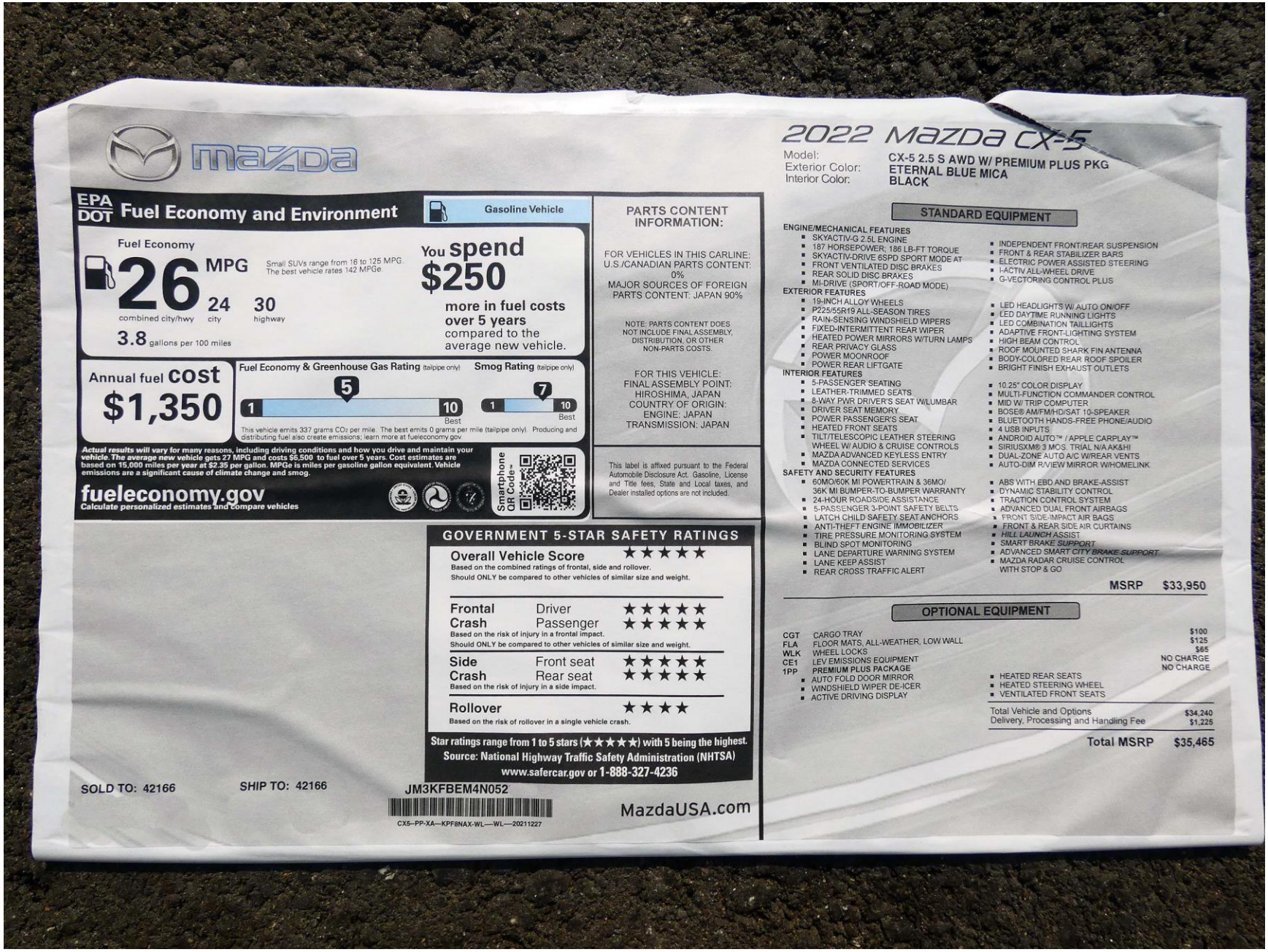


Figure A3. Window Sticker (Monroney Label)

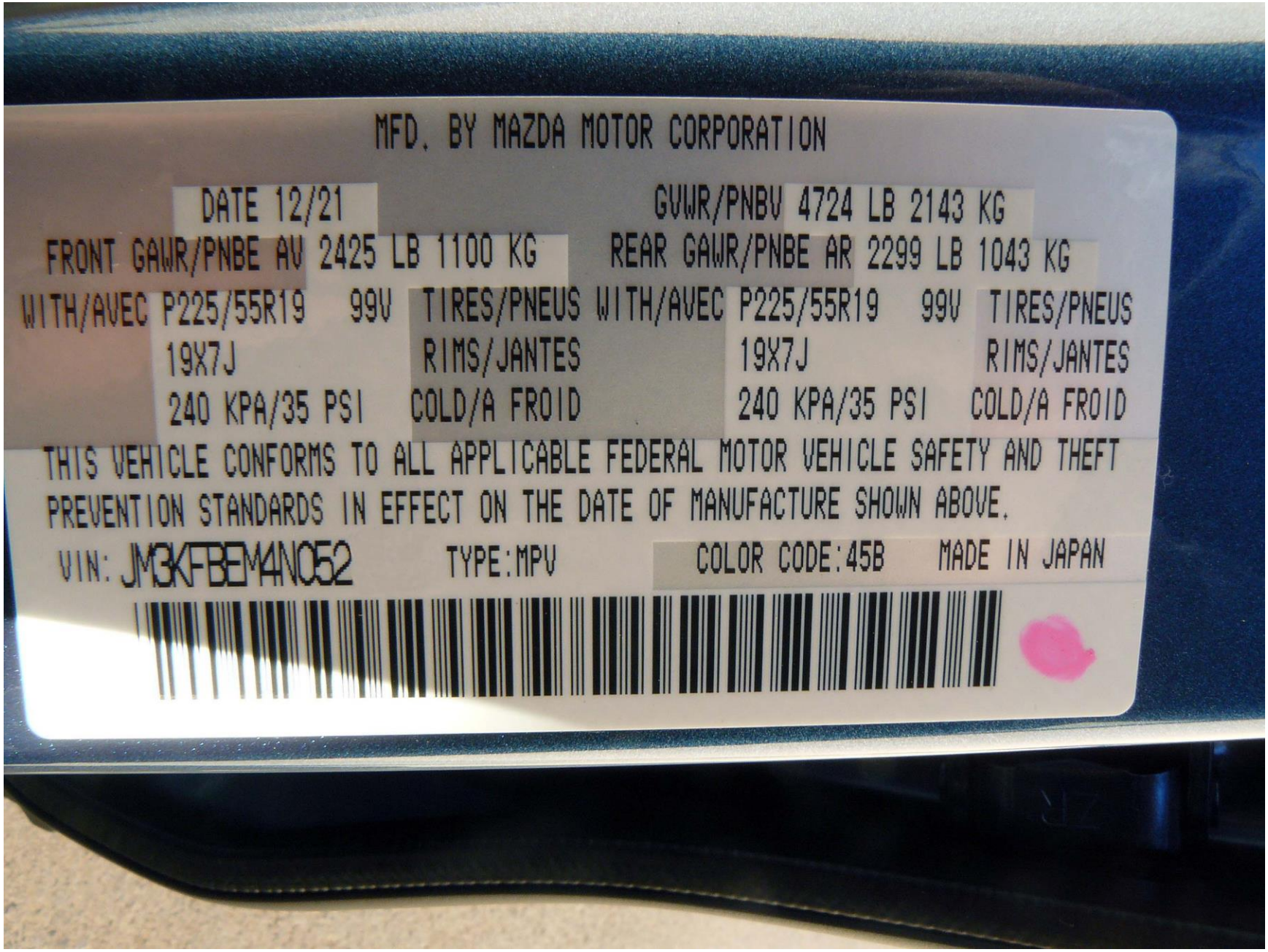


Figure A4. Vehicle Certification Label

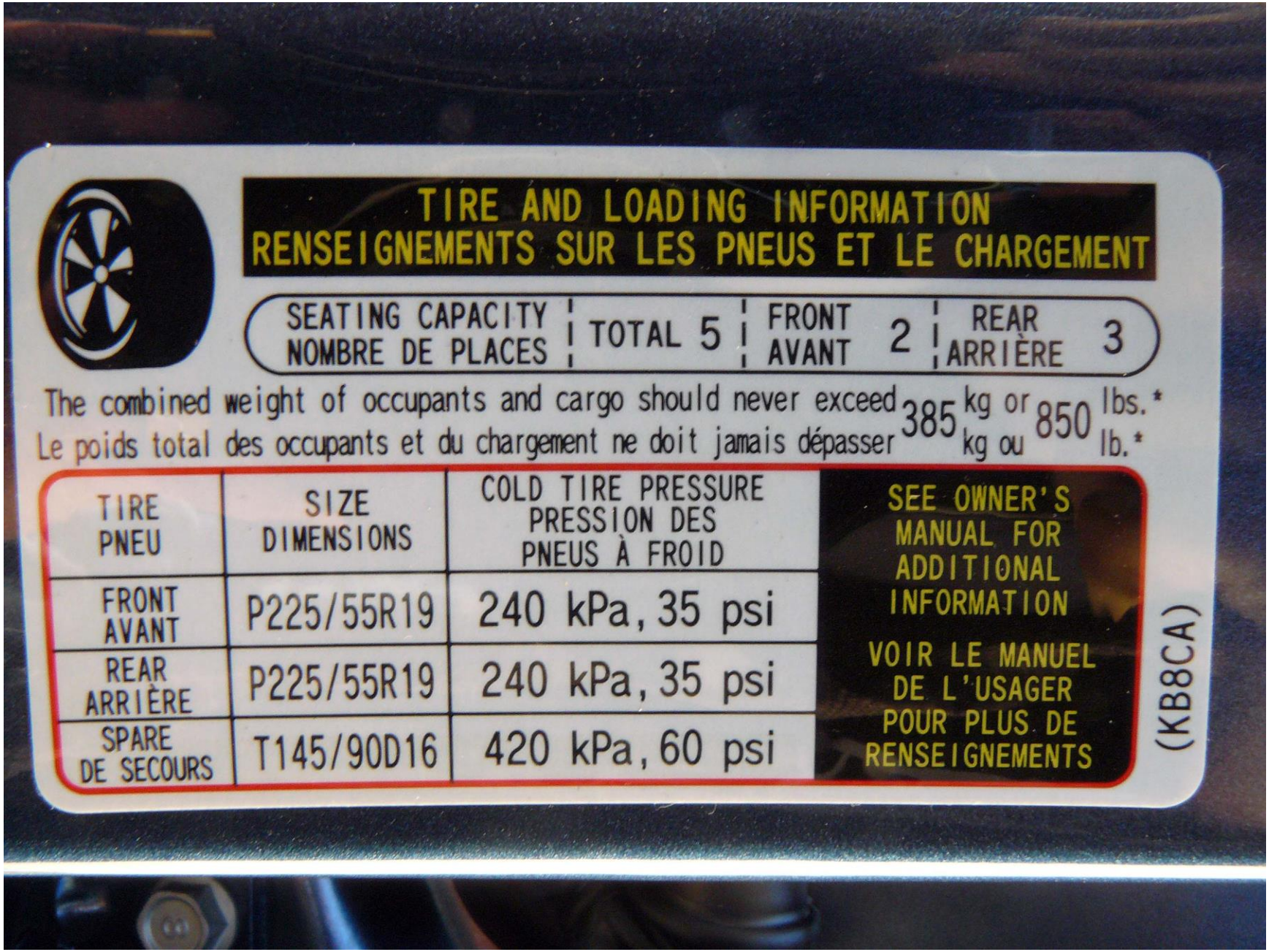


Figure A5. Tire Placard

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

Figure A7. Computer Installed in Subject Vehicle

Figure A8. Sensors for Detecting Visual and Auditory Alerts

Figure A9. Button for Accessing System Setup Menus

Figure A10. System Setup Menus and Alert Sensitivity

Figure A11. LDW Visual Alert

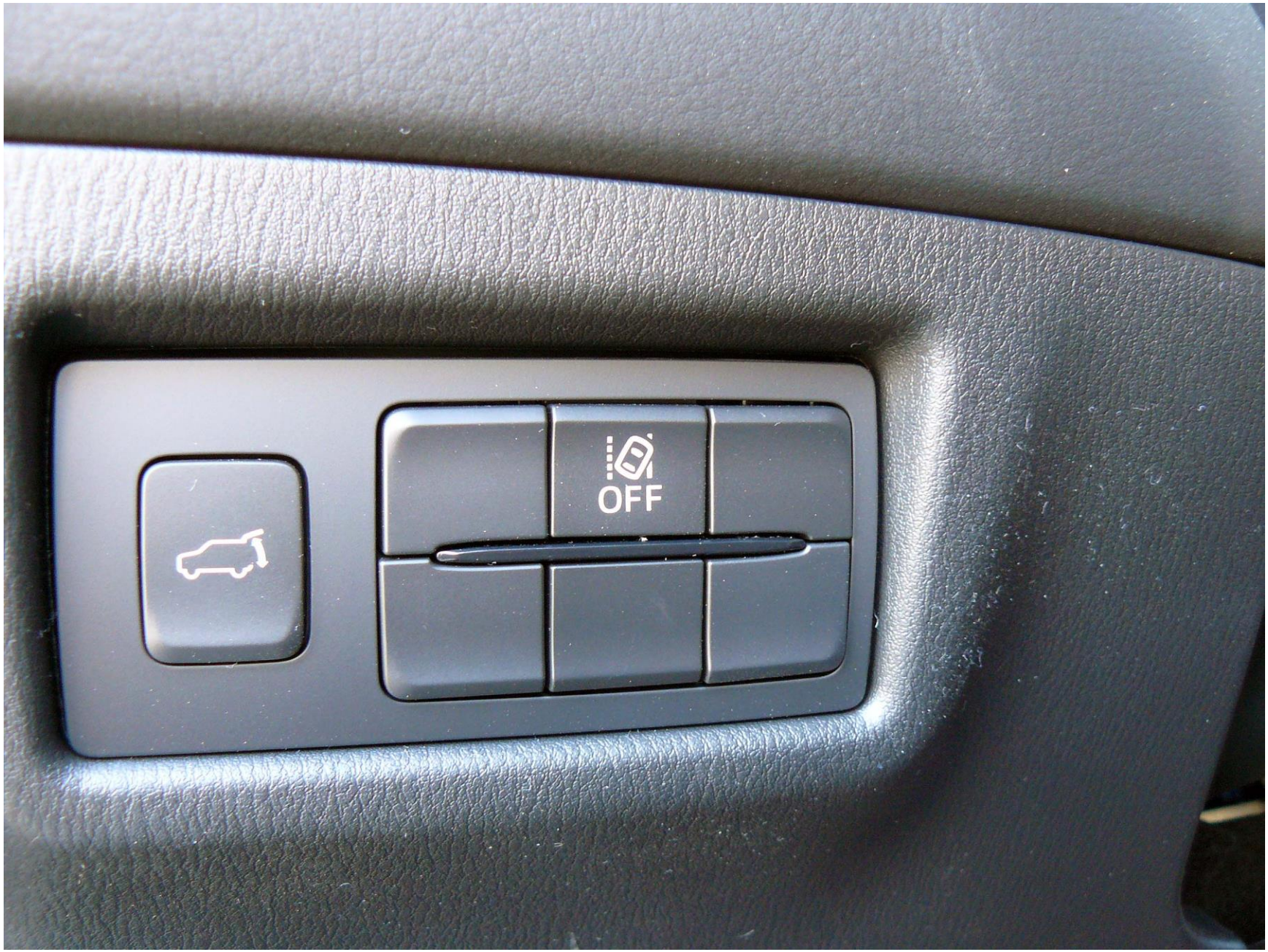


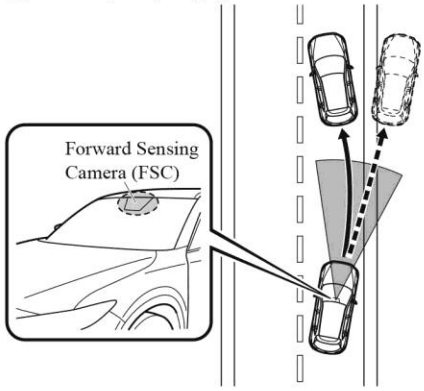
Figure A12. Button for turning LDW on/off

APPENDIX B

Excerpts from Owner’s Manual

Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS)*

The LAS & LDWS alerts the driver that the vehicle may be deviating from its lane and it provides steering assistance to help the driver stay within the vehicle lanes.
The Forward Sensing Camera (FSC) detects the white lines (yellow lines) of the vehicle lane in which the vehicle is traveling and if the system determines that the vehicle may deviate from its lane, it operates the electric power steering to assist the driver's steering operation. The system also alerts the driver by activating a lane departure warning sound, vibrating the steering wheel, and indicating an alert in the display. Use the system when you drive the vehicle on roads with white (yellow) lines such as expressways and highways.
Refer to Forward Sensing Camera (FSC) on page 4-256.



⚠ WARNING

Do not rely completely on the LAS & LDWS:

- *The LAS & LDWS is not an automatic driving system. In addition, the system is not designed to compensate for a driver's lack of caution, and over-reliance on the system could lead to an accident.*
- *The detection ability of the LAS & LDWS is limited. Always stay on course using the steering wheel and drive with care.*

Do not use the LAS & LDWS in the following cases:
The system may not operate adequately according to the actual driving conditions, resulting in an accident.

 *Some models.

- *Driving on roads with tight curves.*
- *Driving under bad weather conditions (rain, fog, and snow).*
- *Slippery roads such as ice or snow-bound roads.*
- *Roads with heavy traffic and insufficient distance between vehicles.*
- *Roads with no white (yellow) lane lines.*
- *Narrow roads resulting from road construction or lane closures.*
- *The vehicle is driven on a temporary lane or section with a closed lane resulting from road construction where there may be multiple white (yellow) lane lines or they are interrupted.*
- *Vehicle is driven on roads other than expressways and highways.*
- *The tire pressures are not adjusted to the specified pressure.*
- *The vehicle is being used to tow a camper or boat trailer.*
- *Tires of a different specified size are used, such as an emergency spare tire.*

⚠ CAUTION

Heed the following cautions so that the LAS & LDWS can operate normally.

- *Do not modify the suspensions.*
- *Always use wheels of the specified type and size for the front and rear wheels. Consult an Authorized Mazda Dealer for tire replacement.*

NOTE

- *When the turn signal lever is operated for a lane change, the LAS & LDWS is automatically disabled. The LAS & LDWS becomes operational again when the turn signal lever is returned and the system detects white (yellow) lane lines while the vehicle is being driven normally within its vehicle lane.*
- *If the steering wheel, accelerator pedal, or brake pedal is operated abruptly and the vehicle moves close to a white (yellow) line, the system determines that the driver is making a lane change and the LAS & LDWS operation is temporarily canceled. The LAS & LDWS becomes operational again when the system detects white (yellow) lane lines while the vehicle is being driven normally within its vehicle lane.*
- *If the vehicle deviates from its lane repeatedly within a short period of time, the LAS & LDWS may not operate.*
- *When white (yellow) lane lines are not detected, the LAS & LDWS does not operate.*
- *Under the following conditions, the LAS & LDWS may not be able to detect white (yellow) lane lines correctly and it may not operate normally.*
  - *If an object placed on the dashboard is reflected in the windshield and picked up by the camera.*
  - *Heavy luggage is loaded in the luggage compartment or on the rear seat and the vehicle is tilted.*

- *The tire pressures are not adjusted to the specified pressure.*
- *Tires other than conventional tires are equipped.*
- *Vehicle is driven on an intersection or junction, or on a forked road.*
- *The white (yellow) lane lines are less visible because of dirt or fading/patchiness.*
- *A vehicle in front of your vehicle is running near a white (yellow) lane line making it less visible.*
- *A white (yellow) lane line is less visible because of bad weather (rain, fog, or snow).*
- *The vehicle is driven on a temporary lane or section with a closed lane resulting from construction where there may be multiple white (yellow) lane lines or they are interrupted.*
- *A misleading line is picked up on the road such as a temporary line for construction, or because of shade, lingering snow, or grooves filled with water.*
- *The surrounding brightness suddenly changes such as when entering or exiting a tunnel.*
- *The illumination of the headlights is weakened because of dirt or the optical axis is deviated.*
- *The windshield is dirty or foggy.*
- *The windshield, camera is fogged (water droplets).*
- *Back-light is reflected off the road surface.*
- *The road surface is wet and shiny after rain, or there are puddles on the road.*
- *The shade of a guardrail parallel to a white (yellow) lane line is cast on the road.*
- *The width of the driving lane is narrow or wide.*
- *Driving on roads with tight curves.*
- *The road is excessively uneven.*
- *The vehicle is shaken after hitting a road bump.*
- *There are 2 or more adjacent white (yellow) lane lines.*
- *There are various road markings or lane markings of various shapes near an intersection.*

▼ System Operation

System operation

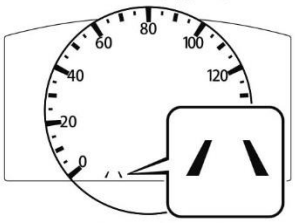
When the ignition is switched ON, the system goes on standby.
Drive the vehicle in the center of the vehicle lane while the system is on standby. When all of the following conditions are met, and the system becomes operational.

- The engine is running.
- The vehicle speed is about 64 km/h (40 mph) or faster.
- The system detects white (yellow) lane lines on both the right and left sides.
- The driver is operating the steering wheel.
- The driving lane is neither narrow nor wide.
- The steering assist function of the Traffic Jam Assist (TJA) is not operating.

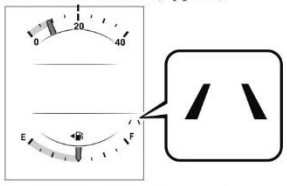
When the system becomes operational, the LAS & LDWS indication (white) is displayed on the multi-information display and active driving display.

Multi-information display (Basic display)

Instrument Cluster (Type A)



Instrument Cluster (Type B)



Multi-information display (i-ACTIVSENSE display)

Active driving display*

The LAS & LDWS goes on stand-by status in the following cases:

- The system cannot detect white (yellow) lane lines.
- The vehicle speed is less than about 56 km/h (35 mph).
- The ABS/TCS is operating.
- The TCS is turned off.
- The Off-Road Traction Assist is turned on.

*Some models.

- When Off-road mode is selected using Mazda intelligent Drive Select (Mi-Drive).
- The vehicle is making a sharp curve.
- The brake pedal is depressed.
- The steering wheel is operated abruptly.
- The width of a lane is excessively narrow or wide.
- The steering assist function of the TJA operated.

NOTE

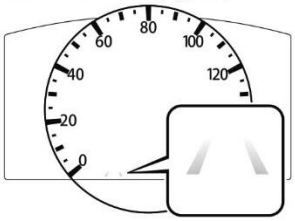
- *The LAS & LDWS does not operate until the system detects white (yellow) lane lines on either the left or right.*
- *When the system detects a white (yellow) lane line on one side only, the system will not operate the steering wheel operation assist and the warning for the lane line on the side that is not being detected. The steering wheel operation assist and the warning is only for a lane deviation on the side that is being detected.*
- *When the system determines that the driver is driving the vehicle with his or her hands off the steering wheel while the steering wheel operation assist is operating, and if the condition continues several times within a certain period of time, the warning sound is activated. The higher the number of times the steering wheel operation assist operates, the longer the period of time the warning sound is activated.*
- *The timing at which the lane departure warning is activated and the steering wheel operation assist is performed varies.*
- *The following settings for the LAS & LDWS can be changed. Refer to the Settings section in the Mazda Connect Owner's Manual.*
  - *Steering operation assist operational/non-operational*
  - ***(Mazda Connect (Type A) only)***
    Cancel sensitivity (likelihood of steering assist)

Vehicle lane line display

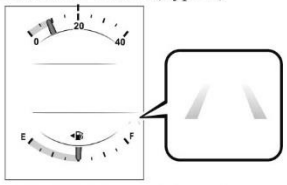
When the LAS & LDWS goes on standby, the vehicle lane lines are indicated on the multi-information display and the active driving display. When white (yellow) lines on both the left and right sides are detected and the system becomes operational, the vehicle lane lines indicated on the multi-information display and the active driving display change to white.

(Stand-by status)
Multi-information display (Basic display)

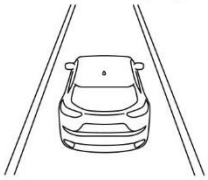
Instrument Cluster (Type A)



Instrument Cluster (Type B)



Multi-information display (i-ACTIVSENSE display)

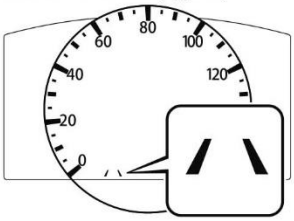


Active driving display*

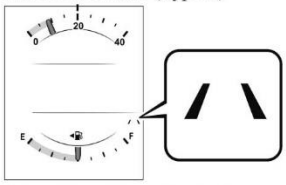
*Some models.

(Operational status)
Multi-information display (Basic display)

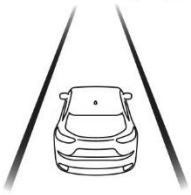
Instrument Cluster (Type A)



Instrument Cluster (Type B)



Multi-information display (i-ACTIVSENSE display)



Active driving display*

NOTE
When only one side of the white (yellow) lines is detected, only the detected vehicle lane line indicated on the multi-information display and the active driving display changes to white.

Auto cancel

In the following cases, the LAS & LDWS is automatically canceled, the LAS & LDWS warning indication (amber) turns on, and an alert is displayed. When the LAS & LDWS become operational, the system turns back on automatically.

- The temperature inside the camera is high or low.
- The windshield around the camera is foggy.
- The windshield around the camera is blocked by an obstruction, causing poor forward visibility.

Auto cancel of warning/steering assist

When the following operations are performed, the LAS & LDWS operation is canceled automatically. The LAS & LDWS resumes automatically after the operation.

- The steering wheel is operated abruptly.
- The brake pedal is operated.
- The accelerator pedal is operated.
  (Mazda Connect (Type A) only)
  (To cancel the automatic sensitivity cancel function, deselect “Cancel sensitivity” in the personalization features setting.)
- The turn signal lever is operated.
- The vehicle crosses a lane line.

NOTE

- *After the operation, the LAS & LDWS operation may not operate for a period of 5 seconds at the most until the lane lines are detected.*
- *Under the following conditions, the LAS & LDWS cancels the warning/steering assist automatically.*
  - *The TCS OFF switch is pressed to cancel the TCS.*
  - *The Off-Road Traction Assist switch is pressed to turn on the Off-Road Traction Assist.*
  - *When Off-road mode is selected using Mazda intelligent Drive Select (Mi-Drive).*

Steering wheel operation assist OFF (non-operational)

The steering wheel operation assist for the LAS & LDWS can be turned off. However, when driving the vehicle while the TJA function is in use, the steering wheel operation assist turns on automatically.
When the steering wheel operation assist has been turned off, only the lane departure warning is operational.
Refer to the Settings section in the Mazda Connect Owner's Manual.

System operation

Drive the vehicle in the center of the driving lane while the LAS & LDWS OFF indicator light in the instrument cluster is turned off.
The system becomes operational when all of the following conditions are met.

- The engine is running.

APPENDIX C

Run Log

Subject Vehicle: **2022 Mazda CX-5 AWD W/ PREMIUM PLUS PKG**

Test start date: **3/3/2022**

Test end date: **3/7/2022**

Driver: **John 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	**Botts**	**Left**	Y	-0.36	-0.47	Pass	
2			N				Data error
3			Y	-0.37	-0.48	Pass	
4			Y	-0.25	-0.41	Pass	
5			Y	-0.19	-0.30	Pass	
6			Y	-0.26	-0.37	Pass	
7			Y	-0.31	-0.42	Pass	
8			Y	-0.40	-0.50	Pass	
9	**Botts**	**Right**	N				Lateral velocity
10			Y	-0.13	-0.24	Pass	
11			Y	-0.23	-0.37	Pass	
12			Y	-0.29	-0.41	Pass	

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
13			Y	-0.45	-0.57	Pass	
14			Y	-1.31	-1.45	Fail	
15			Y	-0.29	-0.38	Pass	
16			Y	-0.34	-0.46	Pass	
17	**Solid**	**Right**	N				Data error
18			Y	-0.30	-0.39	Pass	
19			Y	-0.26	-0.36	Pass	
20			Y	-0.22	-0.32	Pass	
21			Y	-0.26	-0.37	Pass	
22			Y	-0.21	-0.30	Pass	
23			Y	-0.24	-0.36	Pass	
24			Y	-0.32	-0.44	Pass	
25	**Solid**	**Left**	Y	-0.02	-0.13	Pass	
26			N				Yaw rate
27			N				Yaw rate
28			N				Yaw rate
29			Y	-0.09	-0.18	Pass	

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
30			Y	-0.14	-0.23	Pass	
31			Y	-0.09	-0.23	Pass	
32	**Dashed**	**Left**	Y	-0.12	-0.26	Pass	
33			Y	-0.16	-0.26	Pass	
34			Y	-0.17	-0.26	Pass	
35			Y	-0.28	-0.35	Pass	
36			Y	-0.15	-0.26	Pass	
37			Y	-0.18	-0.28	Pass	
38			N				Yaw rate
39			Y	-0.16	-0.24	Pass	
40	**Dashed**	**Right**	Y	-0.72	-0.82	Pass	
41			N				Speed
42			Y	-0.32	-0.41	Pass	
43			Y	-0.18	-0.27	Pass	
44			Y	-0.36	-0.49	Pass	
45			Y	-0.37	-0.48	Pass	
46			Y	-0.31	-0.44	Pass	

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Auditory Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
47			Y	-0.38	-0.51	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.

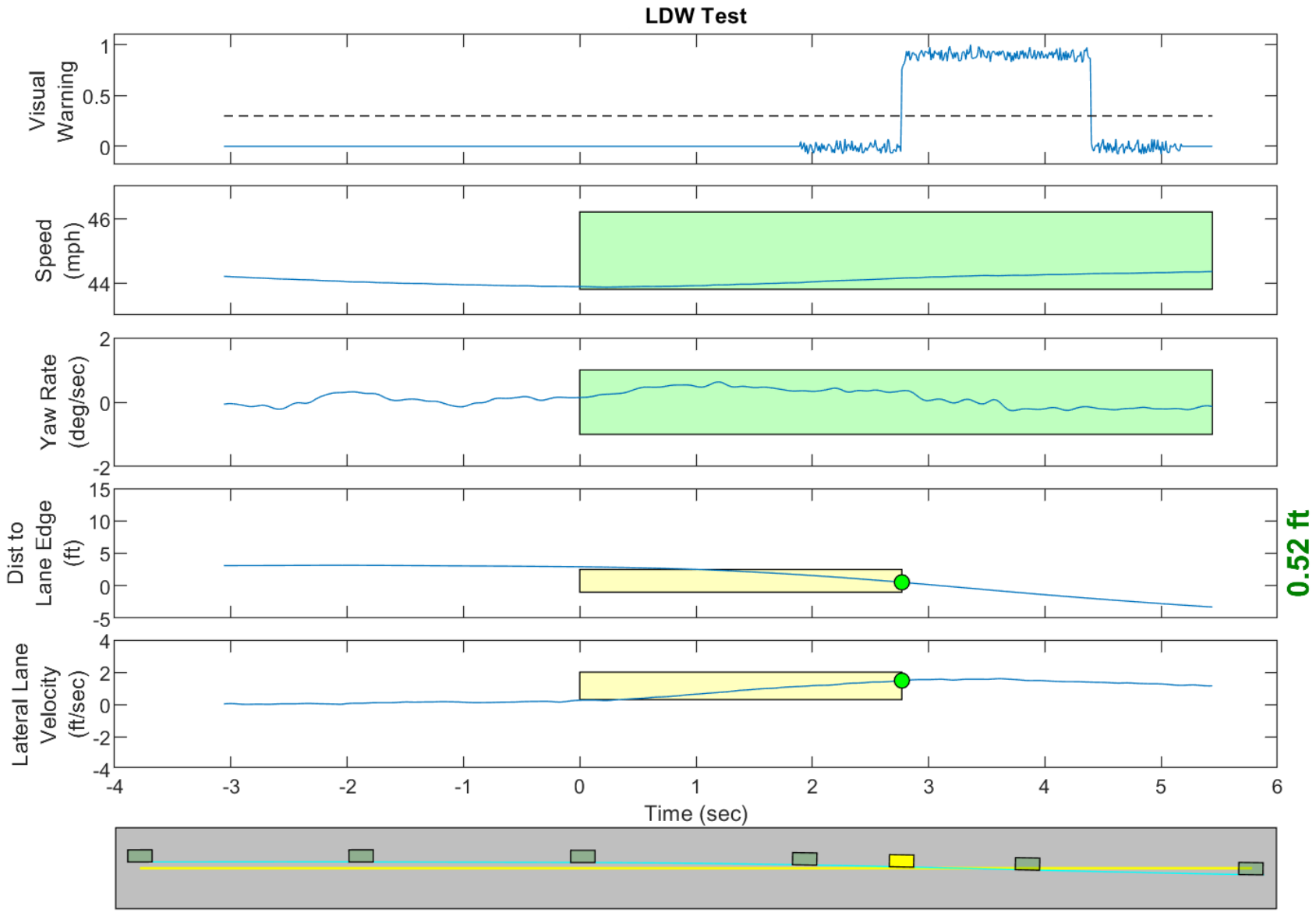


Figure D1. Example Time History for Lane Departure Warning Test, Passing

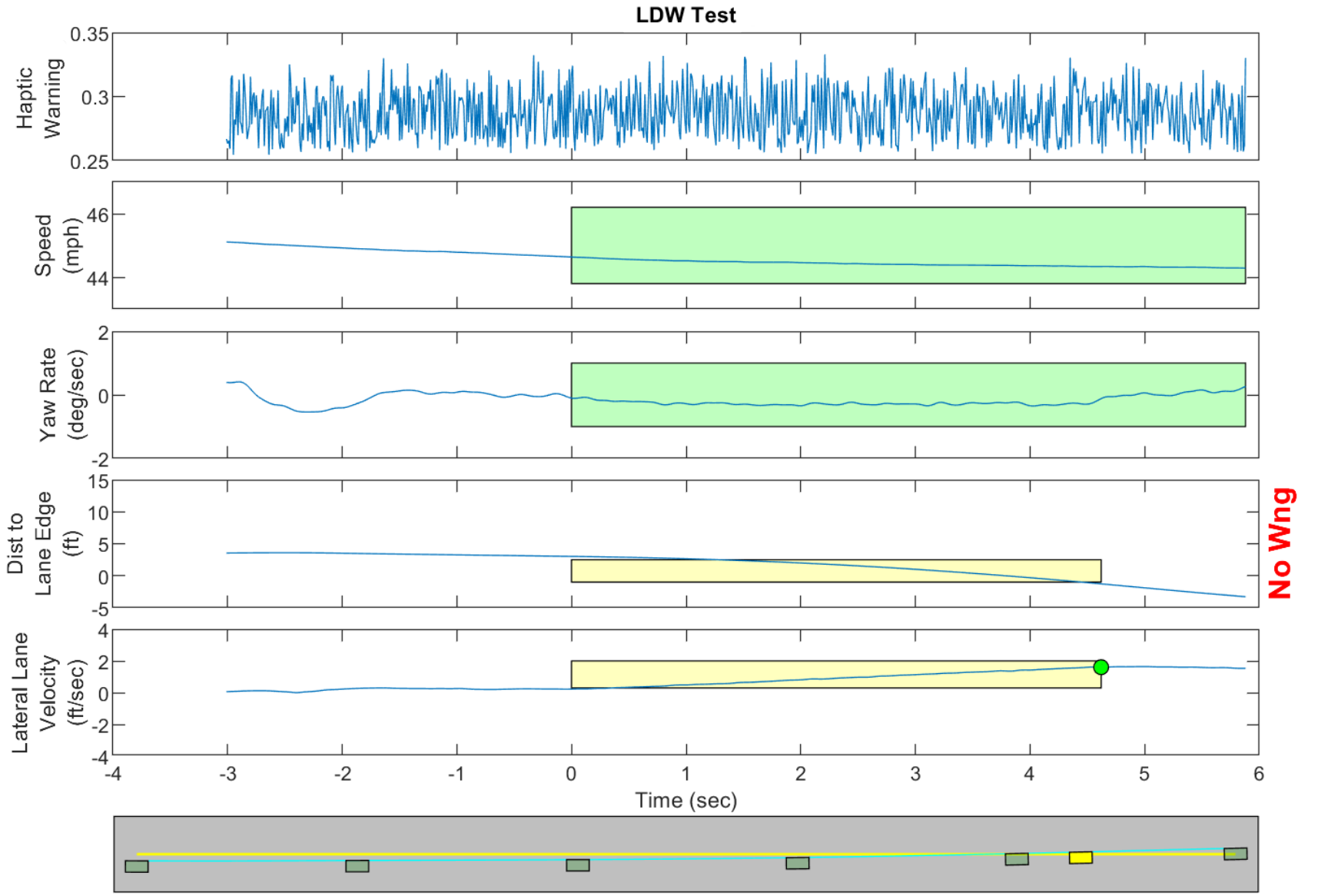


Figure D2. Example Time History for Lane Departure Warning Test, Failing, No Warning Issued

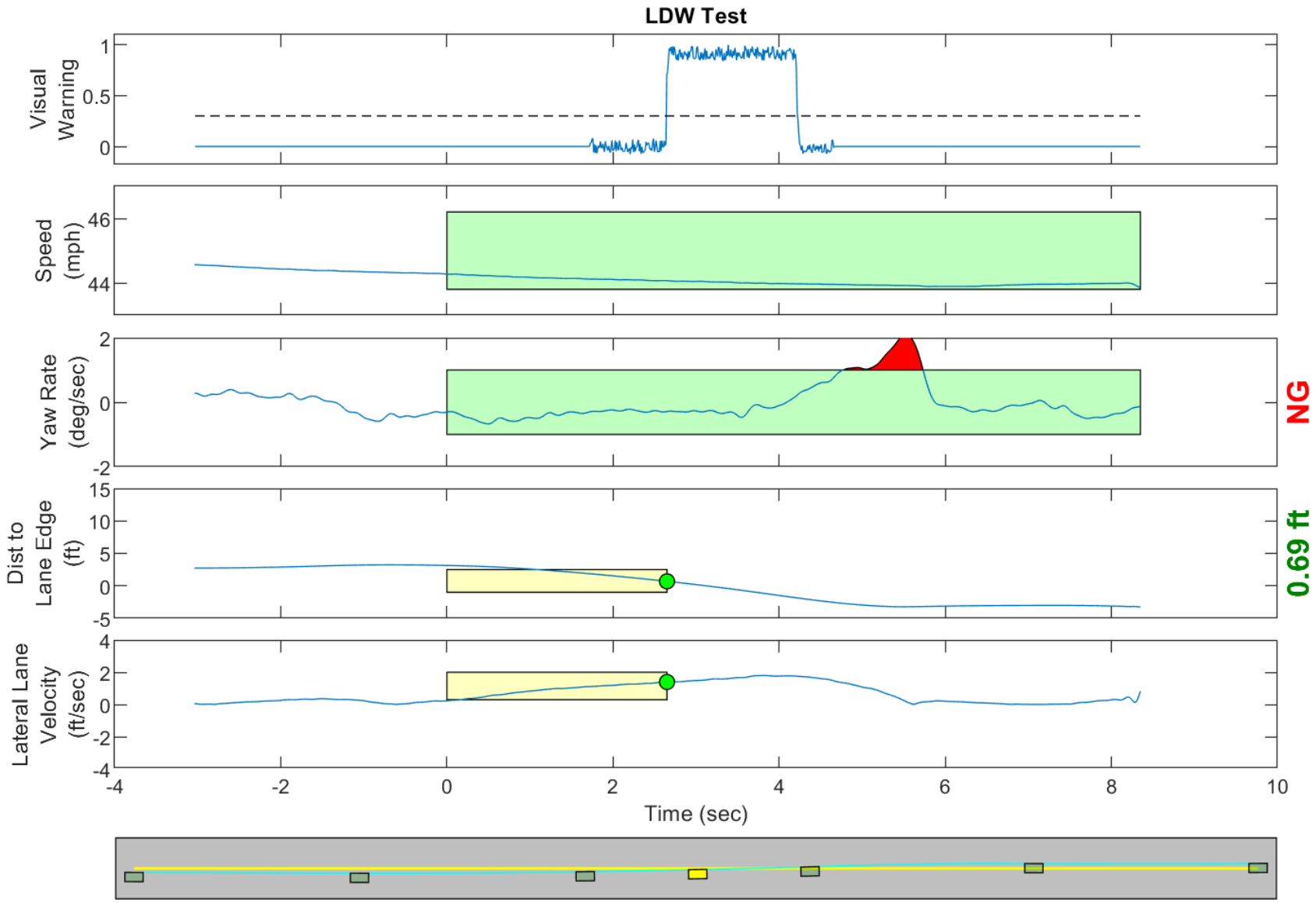


Figure D3. Example Time History for Lane Departure Warning Test, Invalid Run Due to Subject Vehicle Yaw Rate

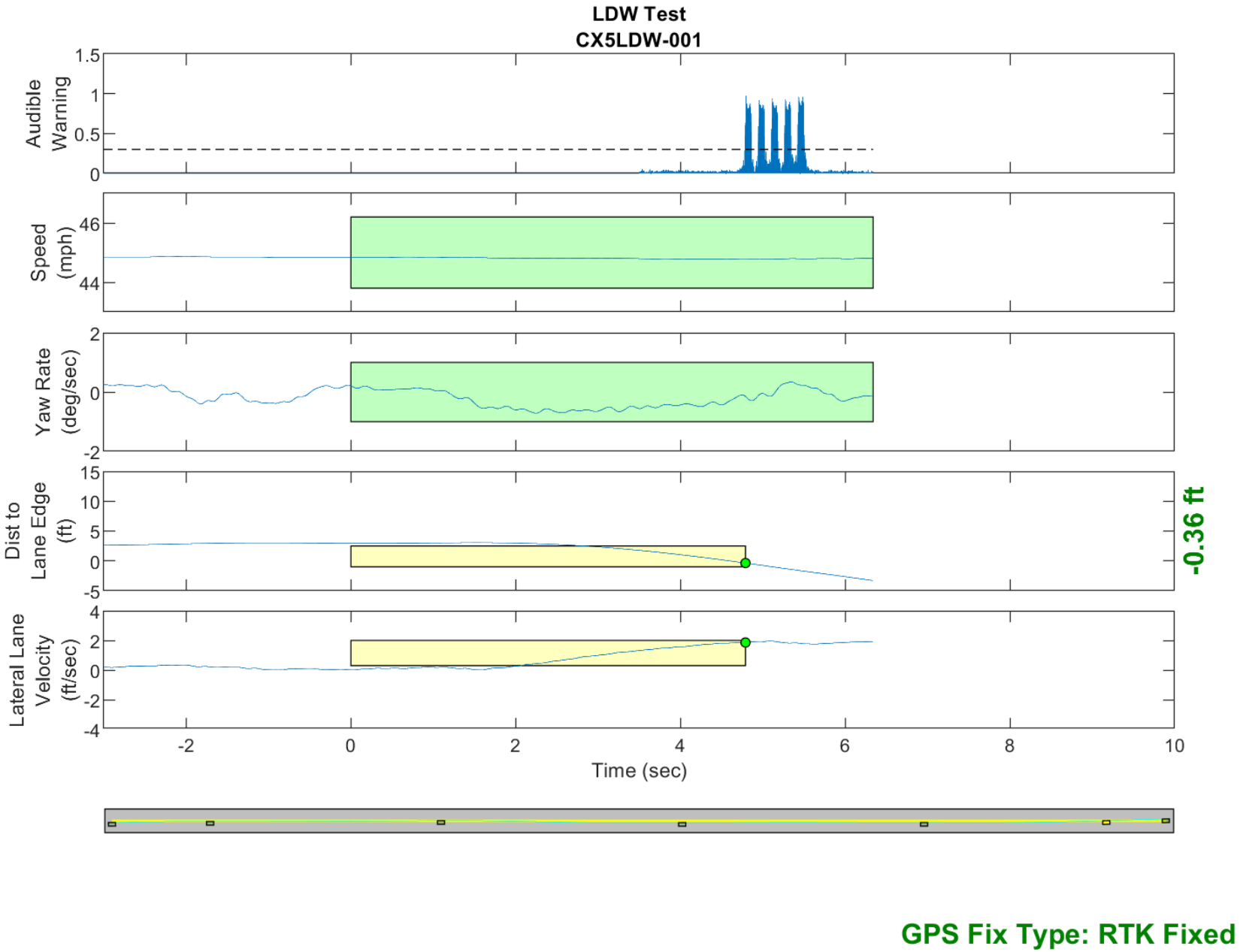


Figure D4. Time History for Run 01, Botts Dots, Left Departure, Auditory Warning

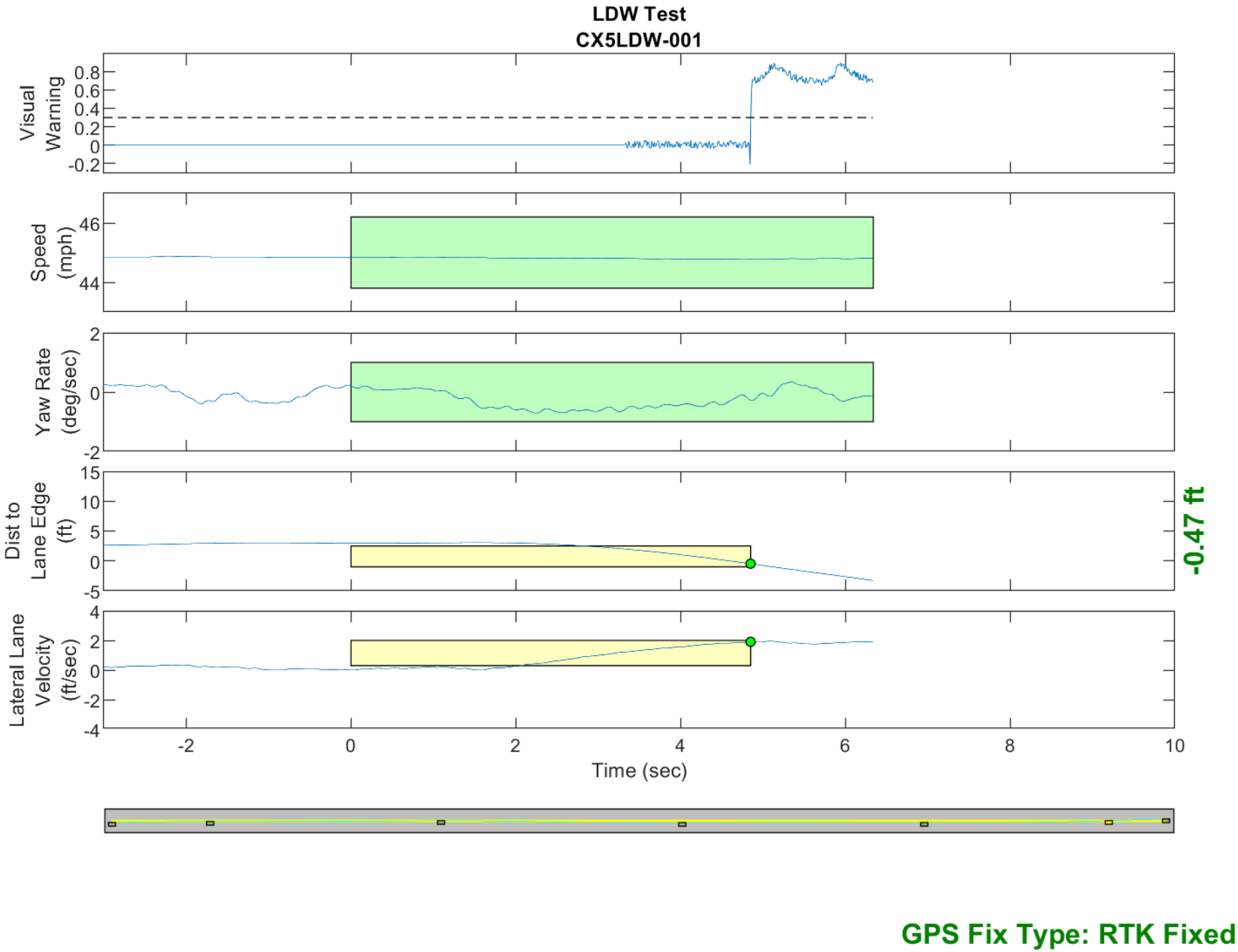


Figure D5. Time History for Run 01, Botts Dots, Left Departure, Visual Warning

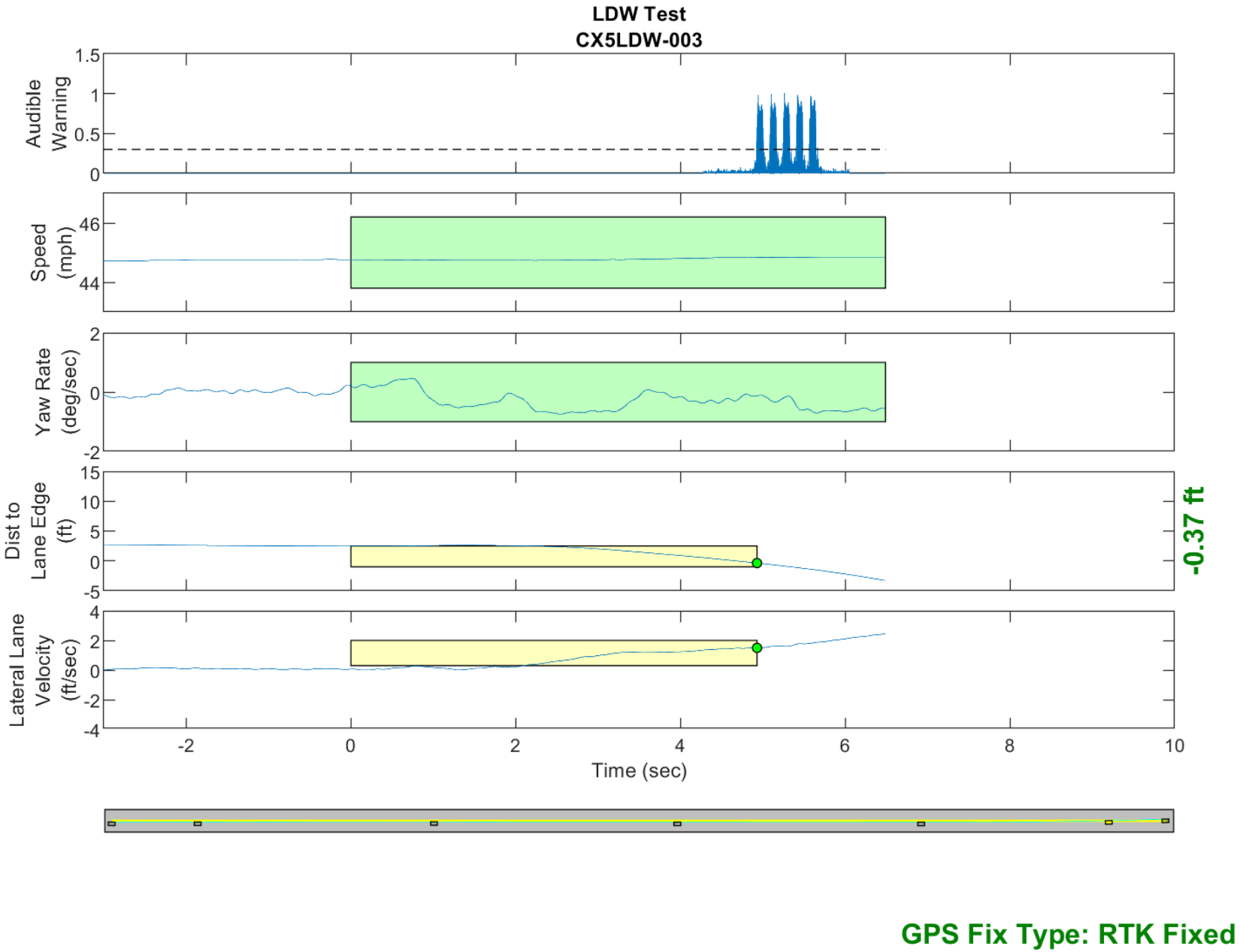


Figure D6. Time History for Run 03, Botts Dots, Left Departure, Auditory Warning

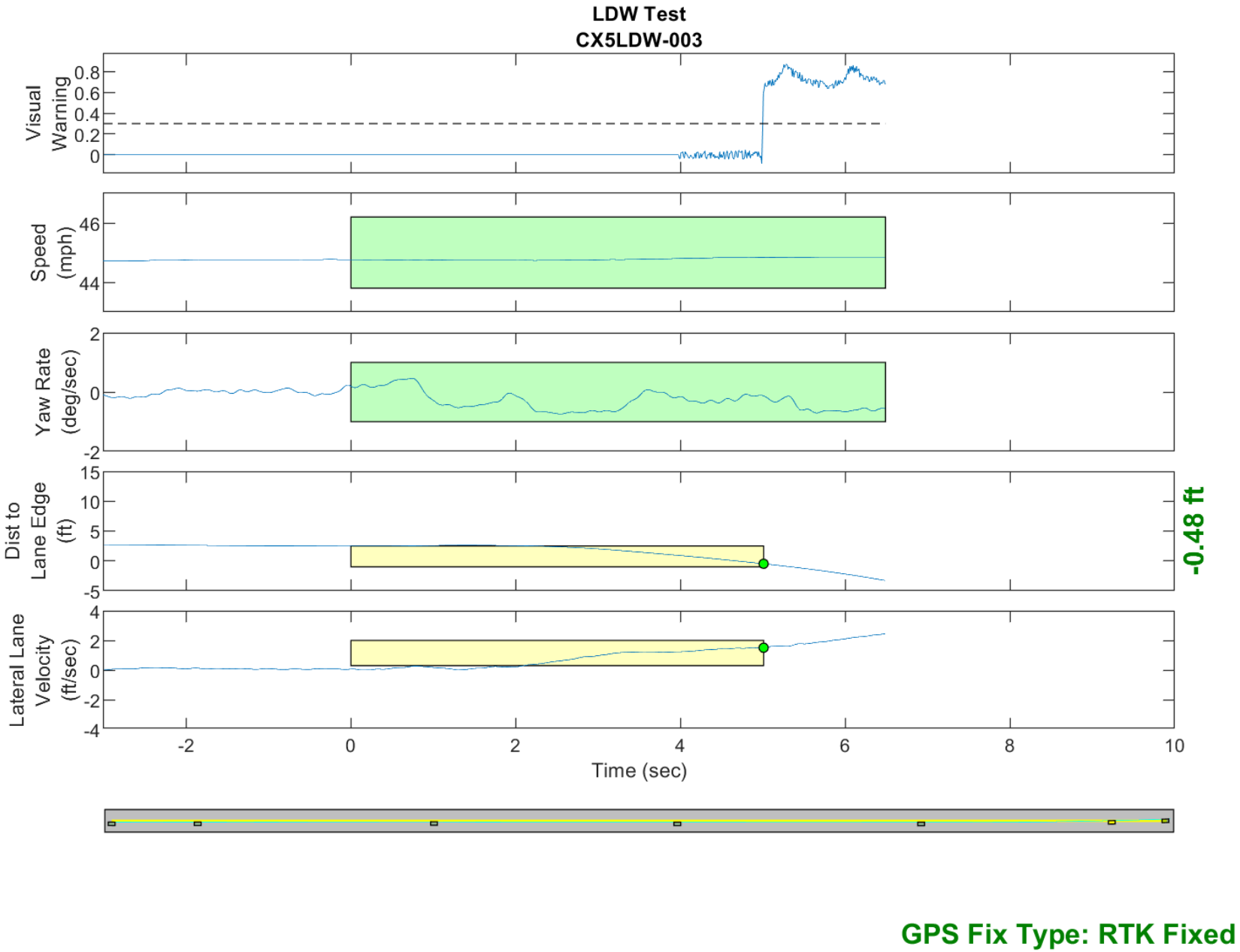


Figure D7. Time History for Run 03, Botts Dots, Left Departure, Visual Warning

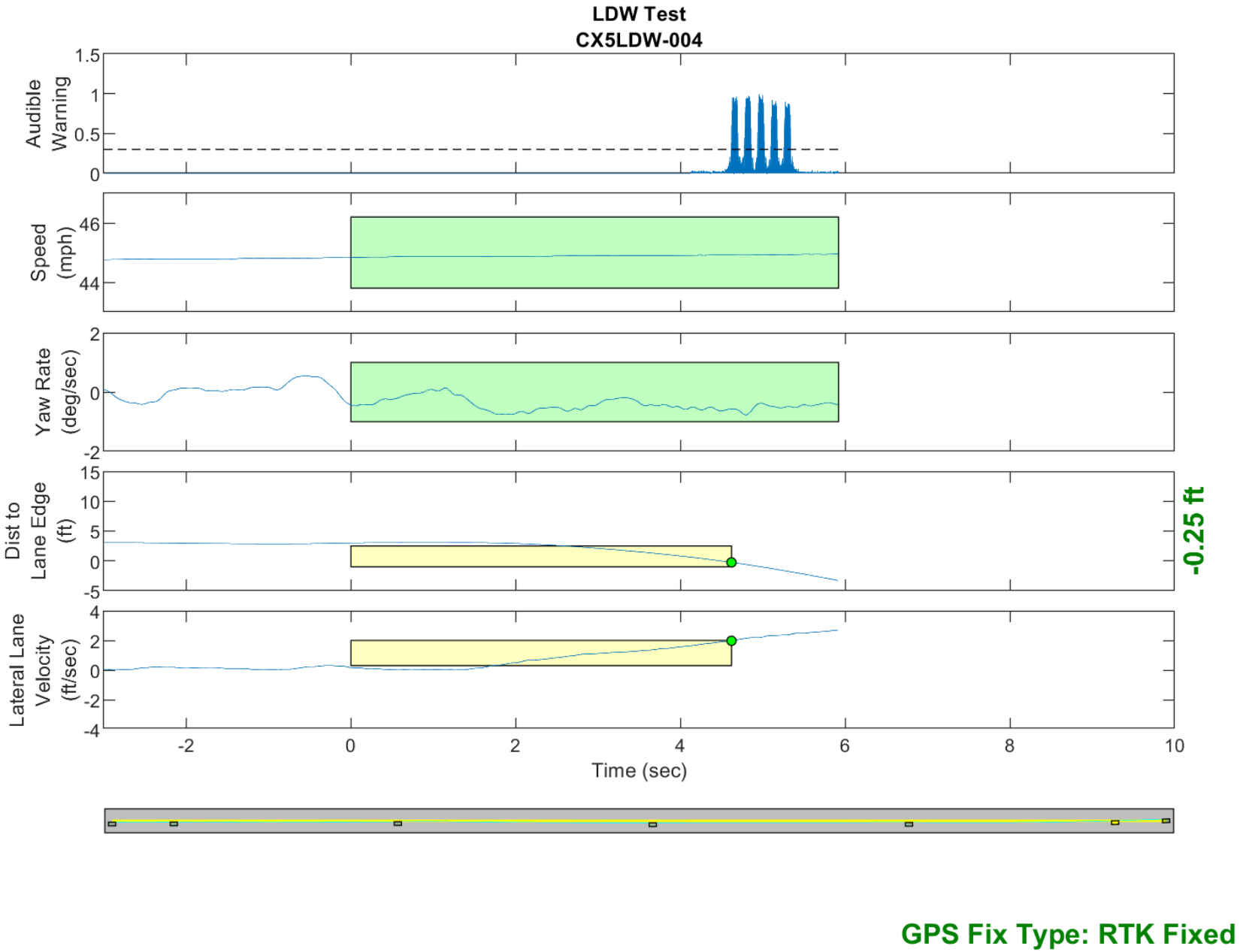


Figure D8. Time History for Run 04, Botts Dots, Left Departure, Auditory Warning

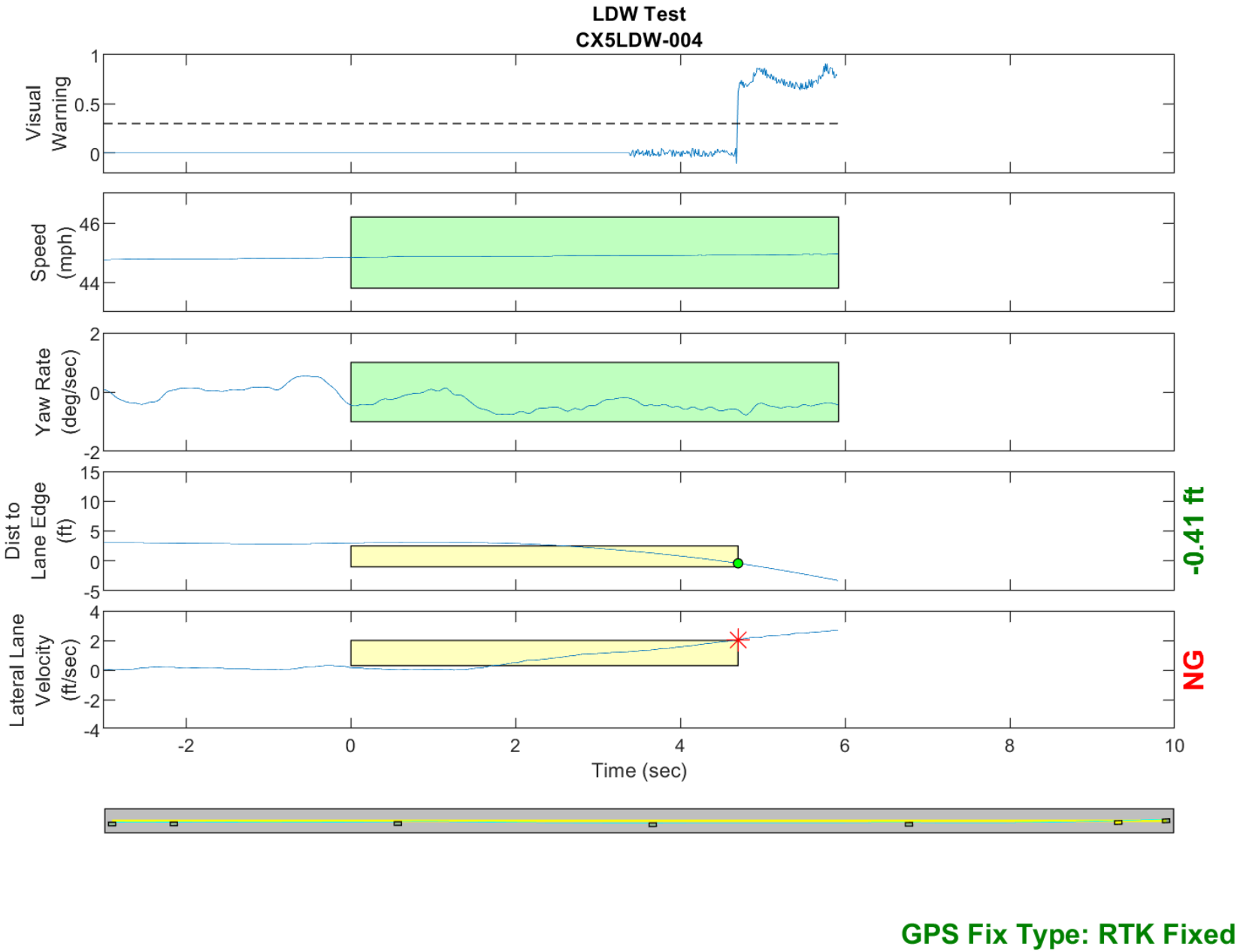


Figure D9. Time History for Run 04, Botts Dots, Left Departure, Visual Warning

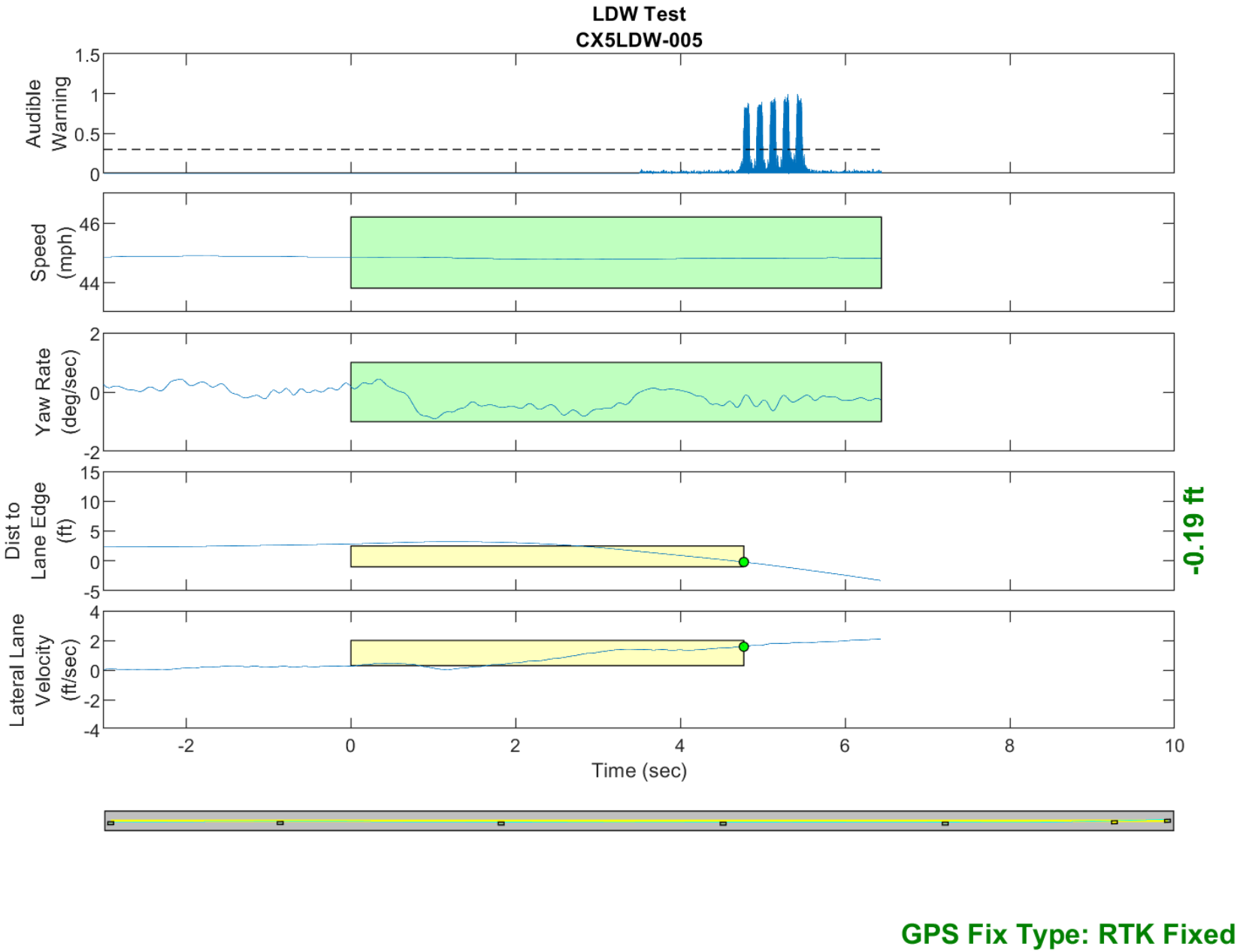


Figure D10. Time History for Run 05, Botts Dots, Left Departure, Auditory Warning

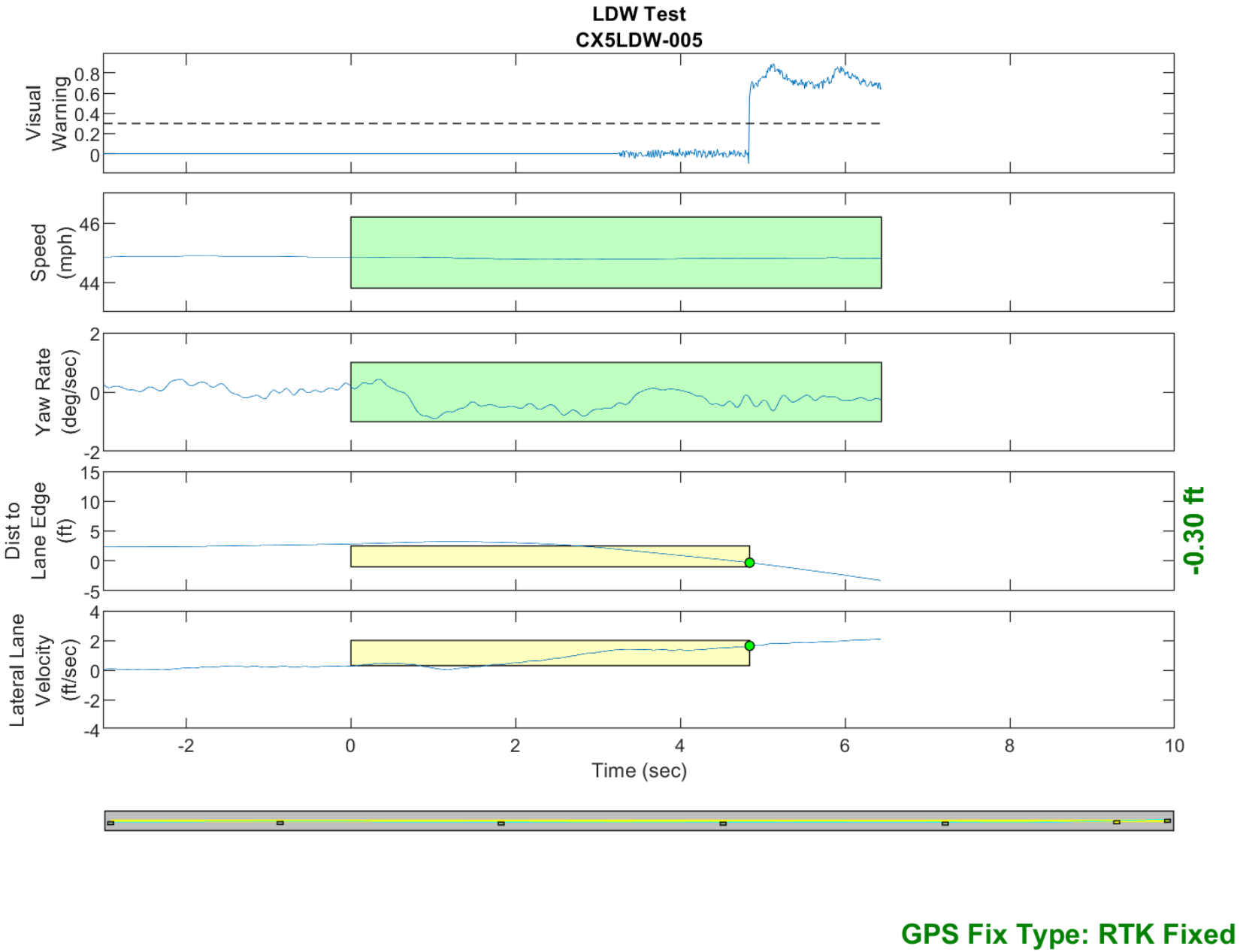


Figure D11. Time History for Run 05, Botts Dots, Left Departure, Visual Warning

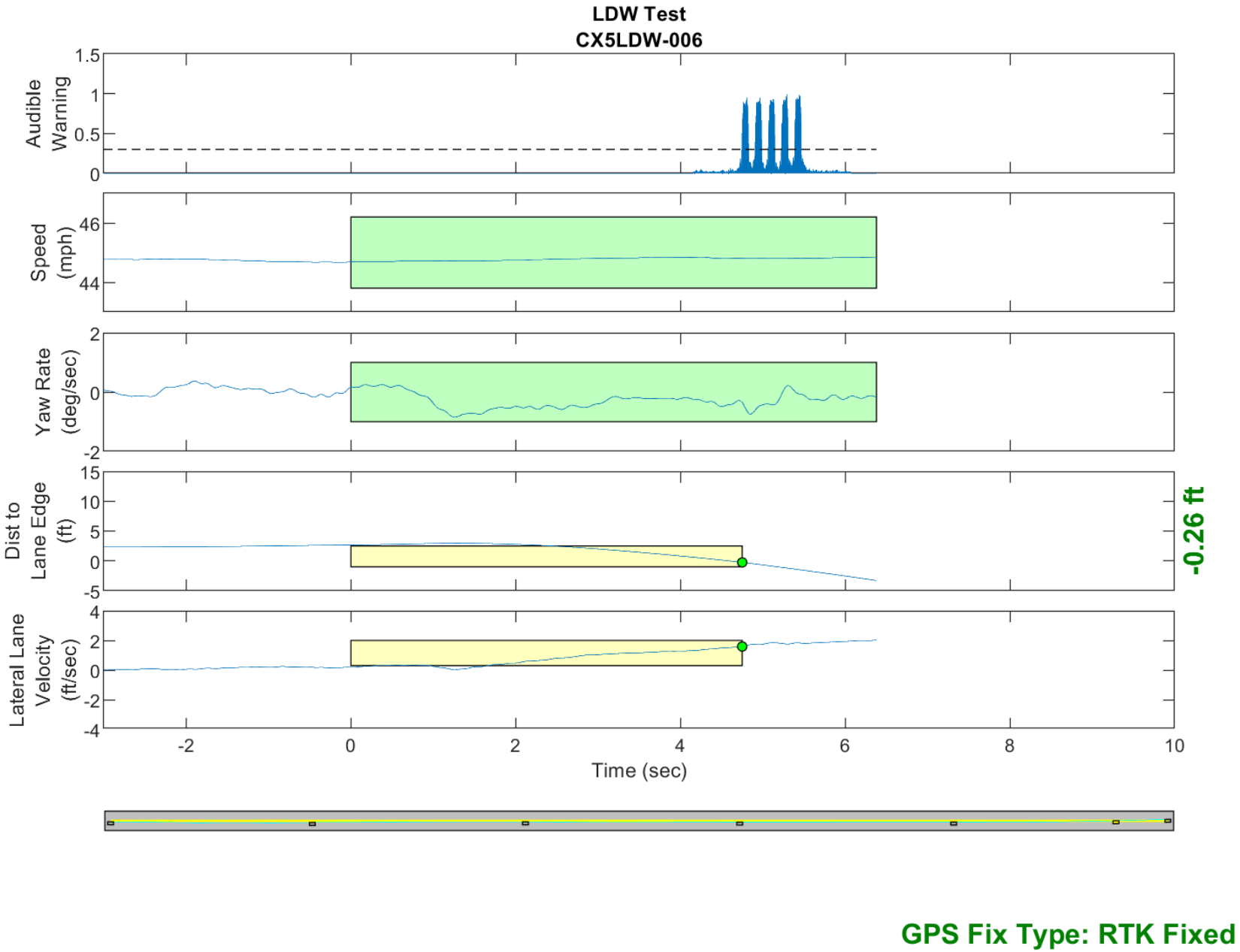


Figure D12. Time History for Run 06, Botts Dots, Left Departure, Auditory Warning

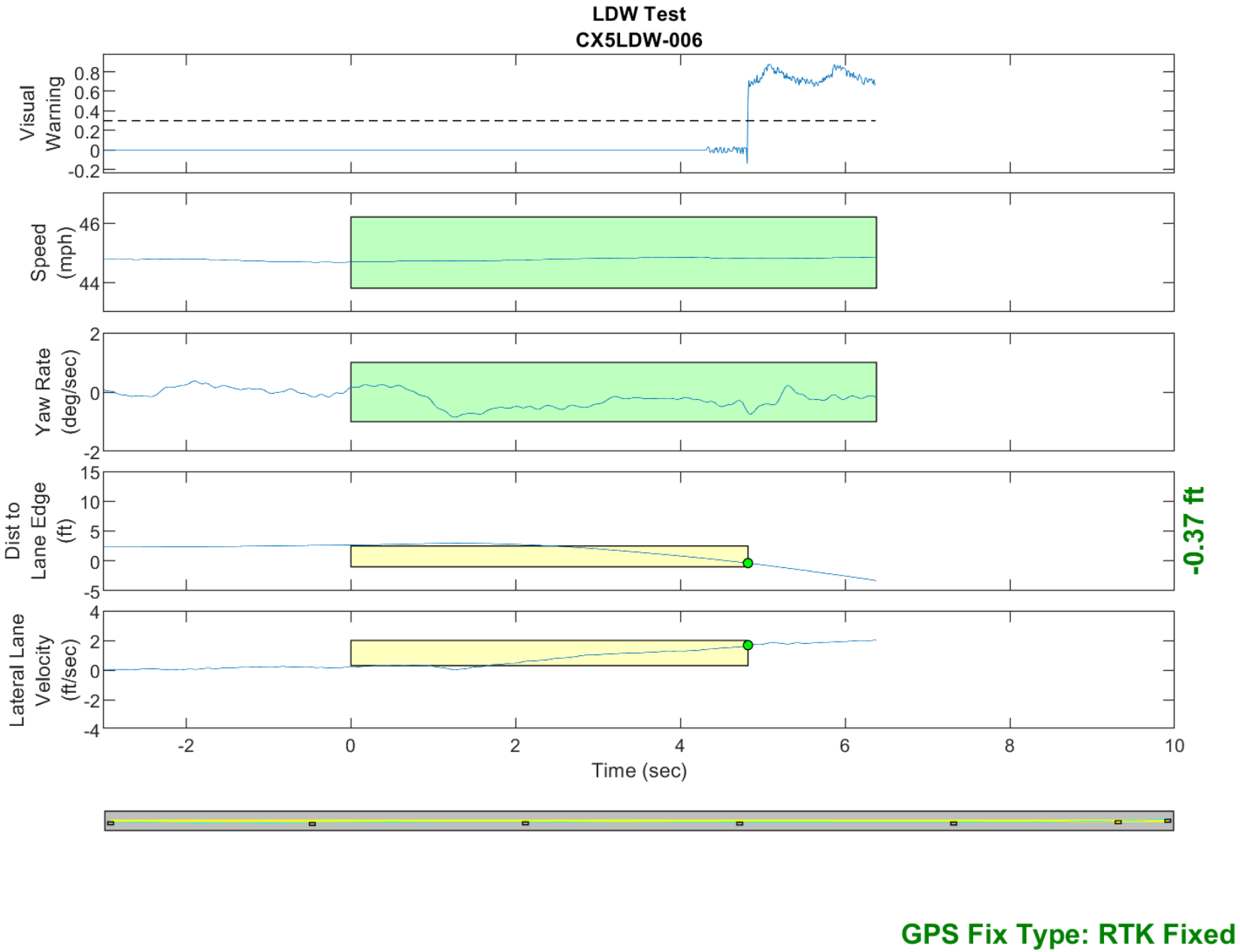


Figure D13. Time History for Run 06, Botts Dots, Left Departure, Visual Warning

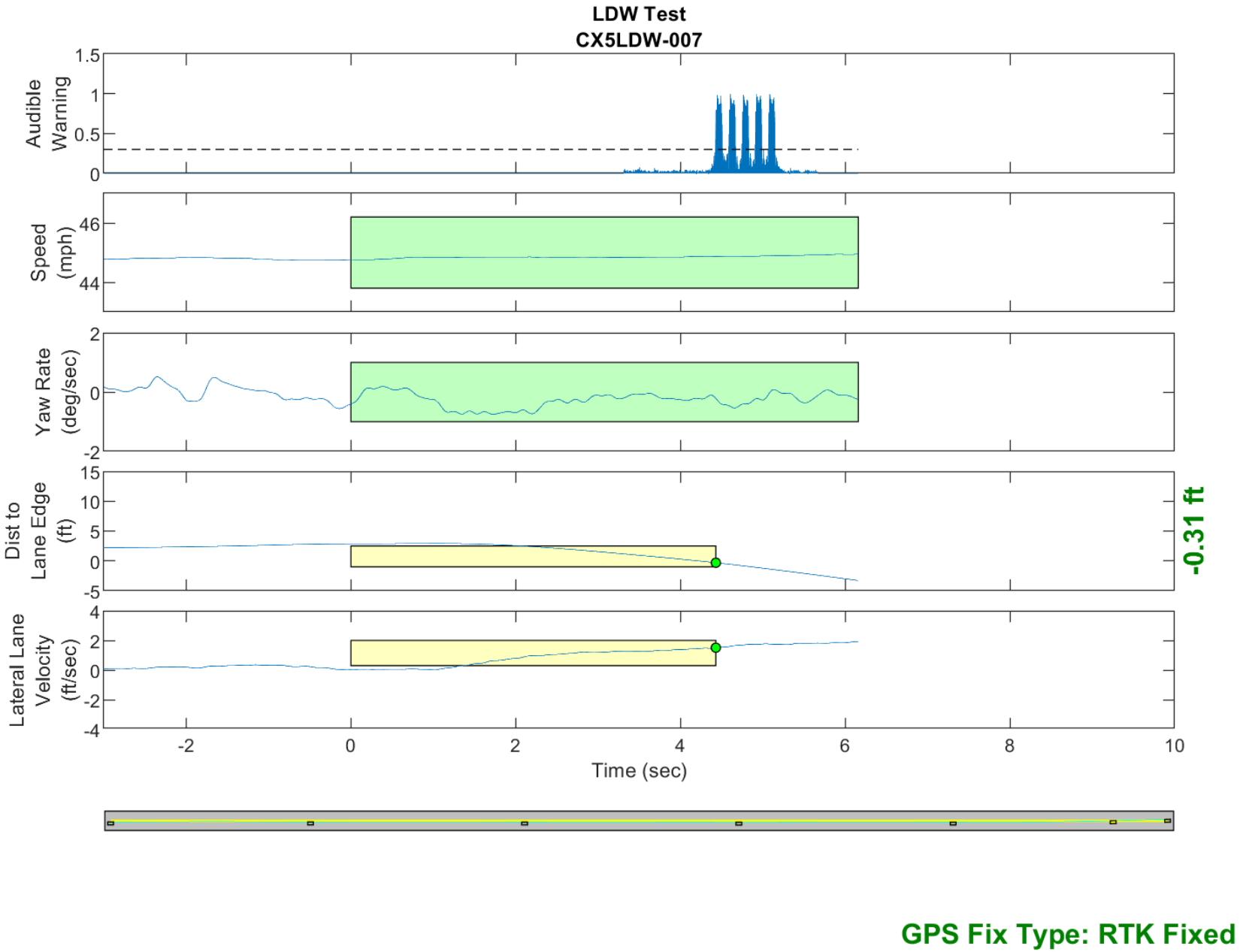


Figure D14. Time History for Run 07, Botts Dots, Left Departure, Auditory Warning

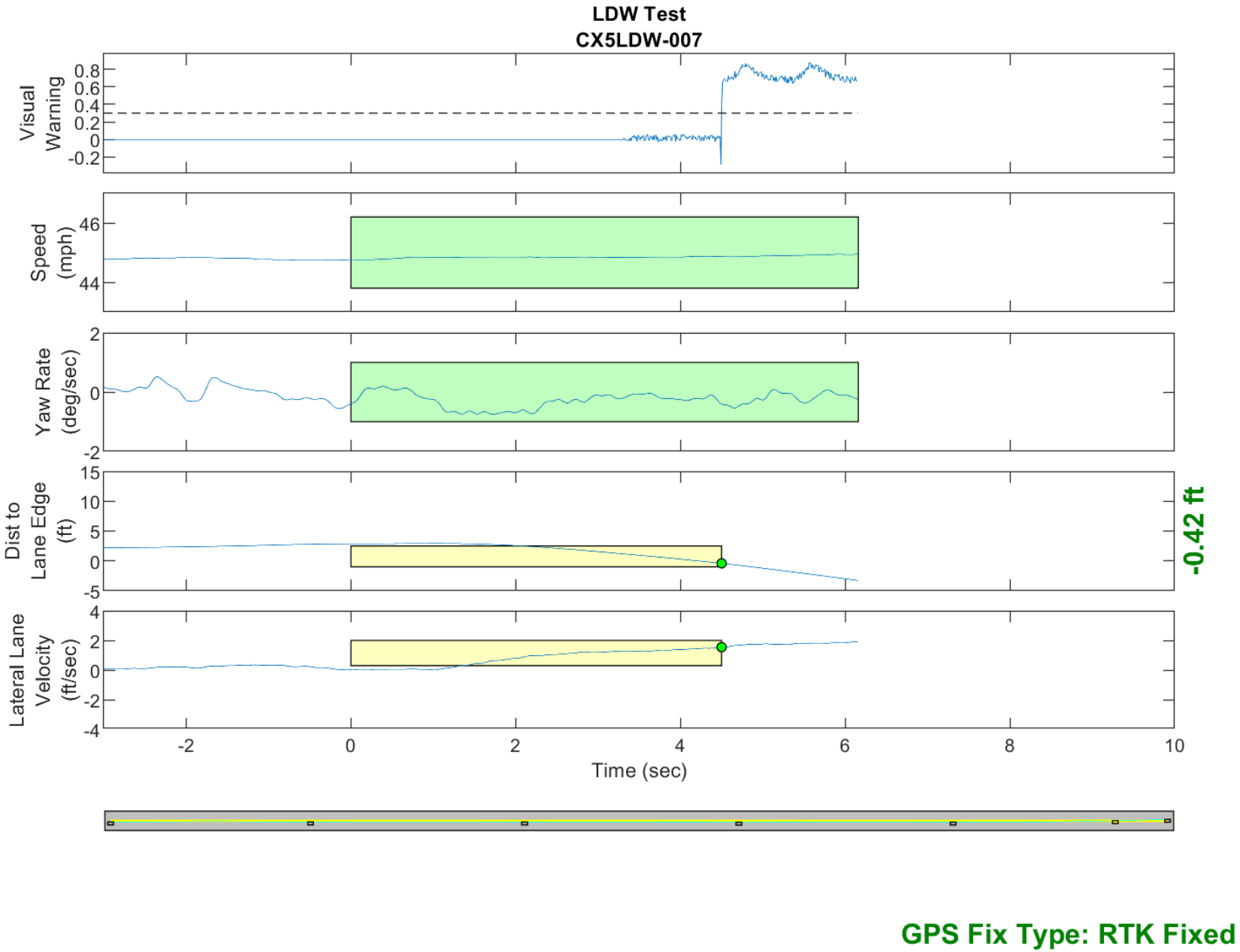


Figure D15. Time History for Run 07, Botts Dots, Left Departure, Visual Warning

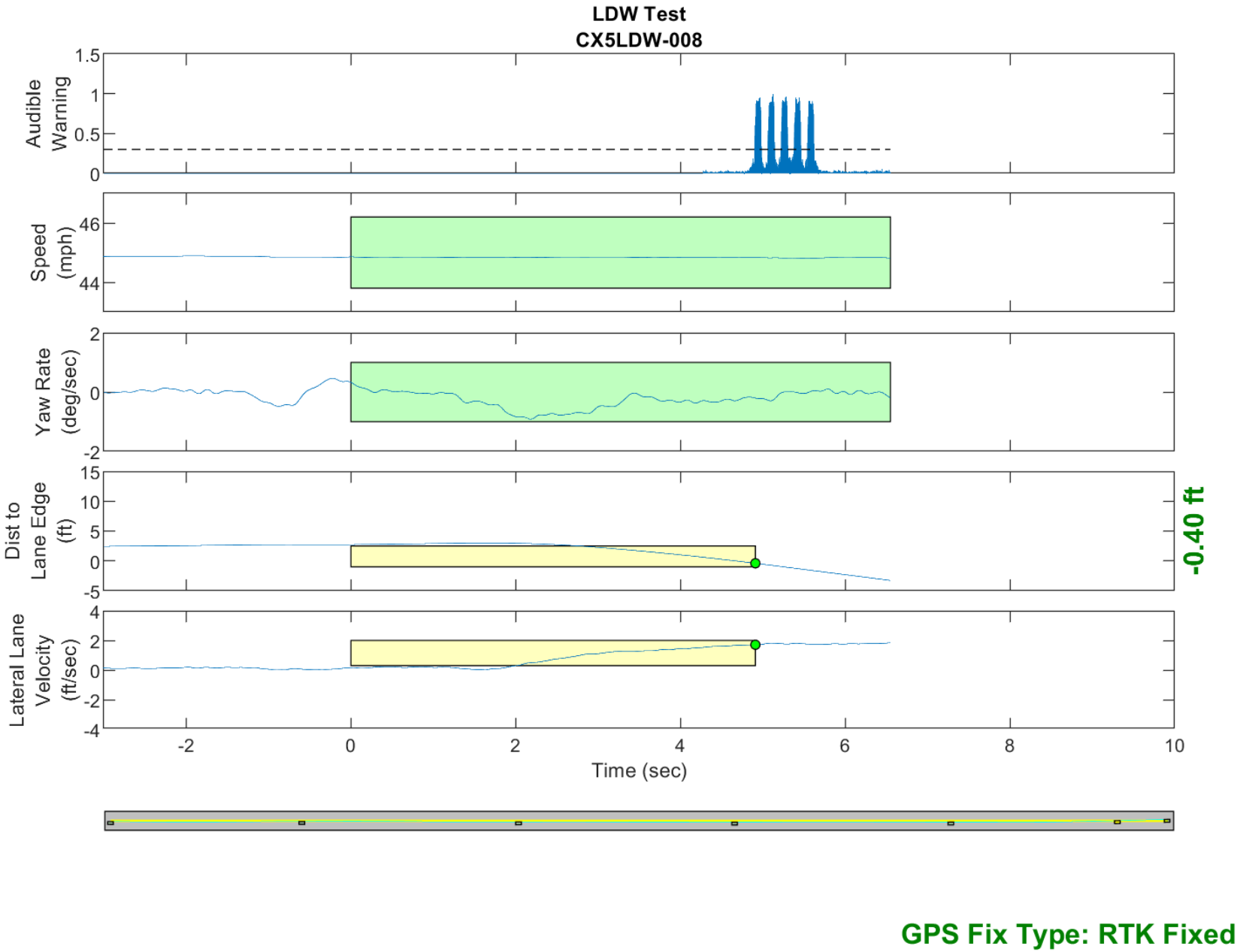


Figure D16. Time History for Run 08, Botts Dots, Left Departure, Auditory Warning

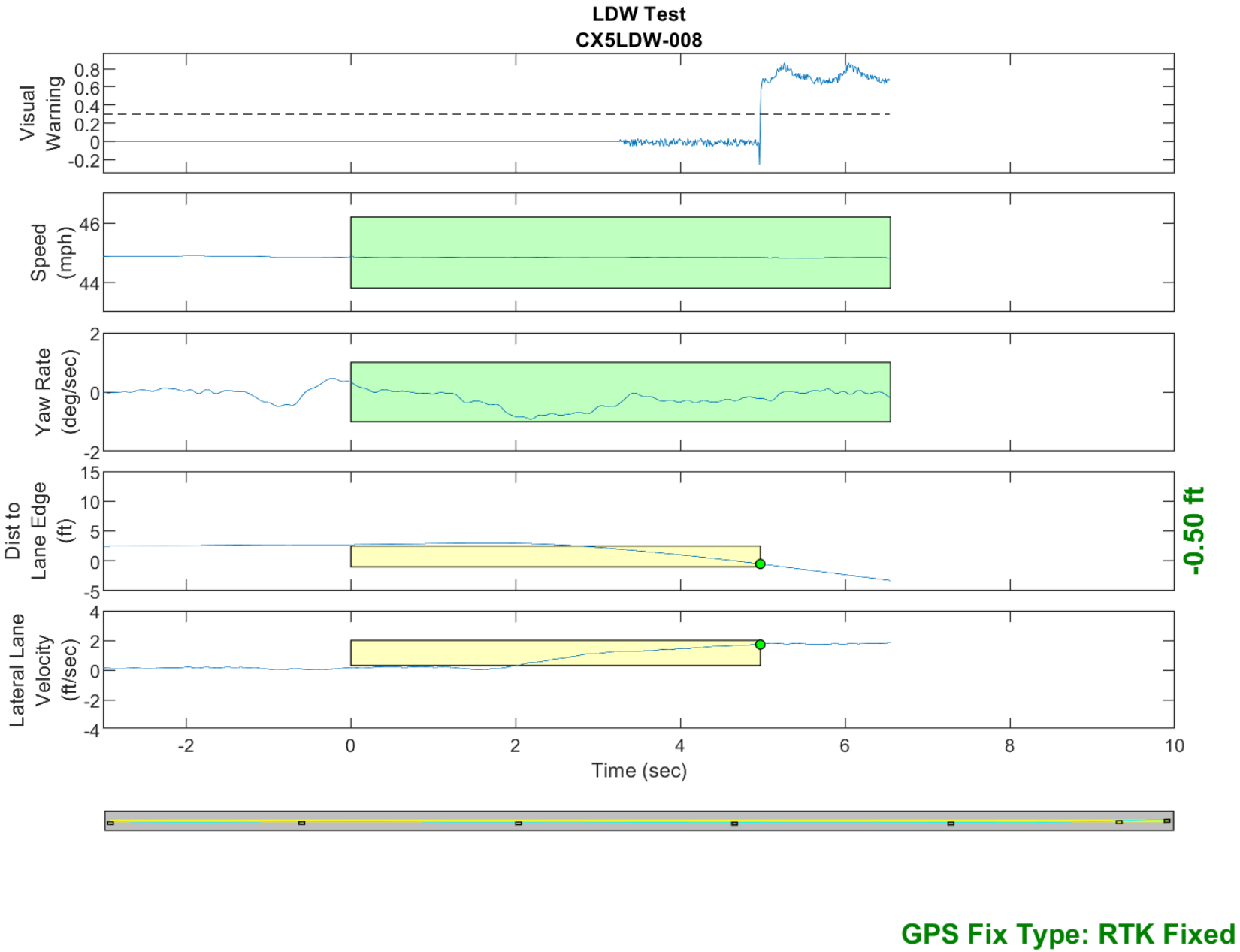


Figure D17. Time History for Run 08, Botts Dots, Left Departure, Visual Warning

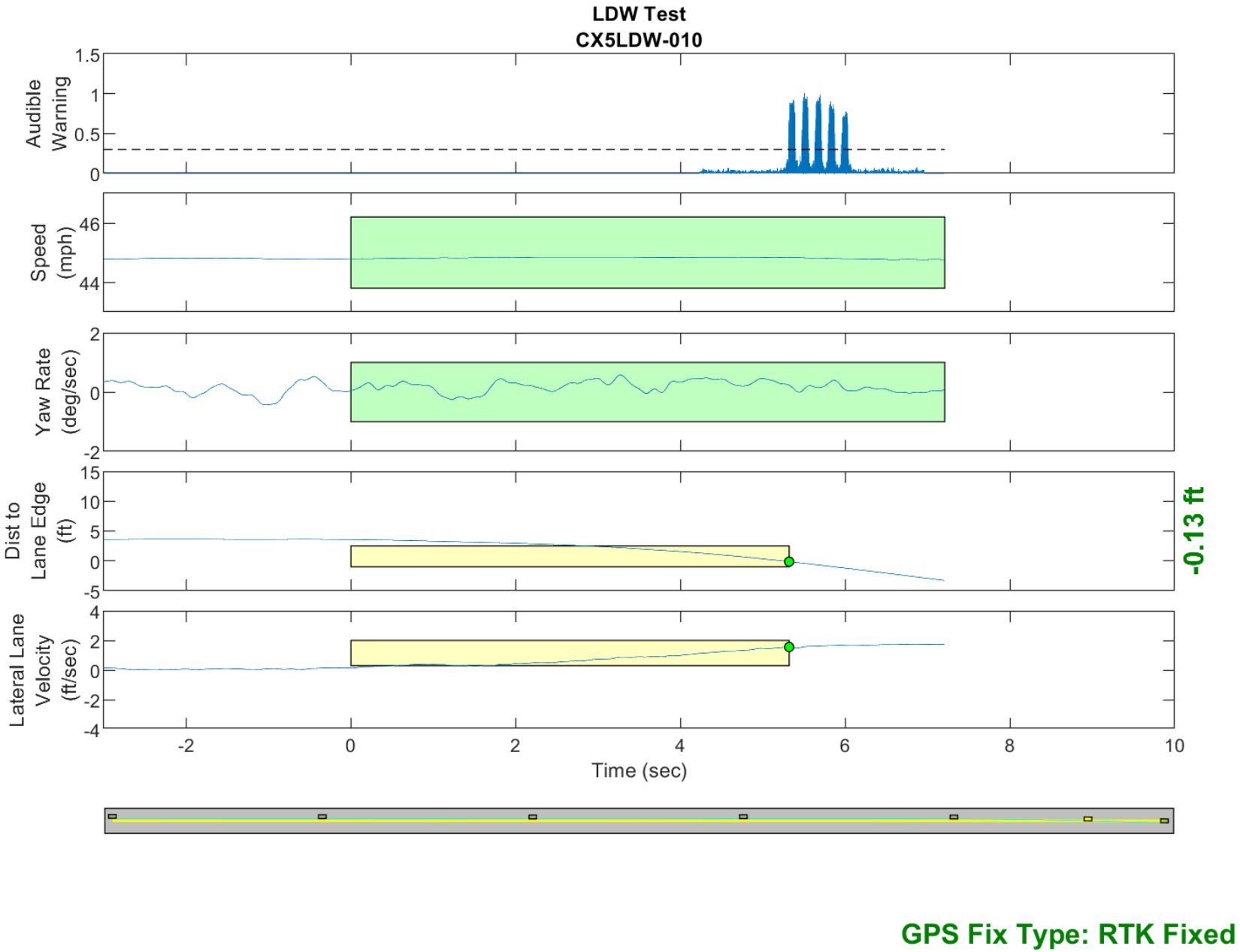


Figure D18. Time History for Run 10, Botts Dots, Right Departure, Auditory Warning

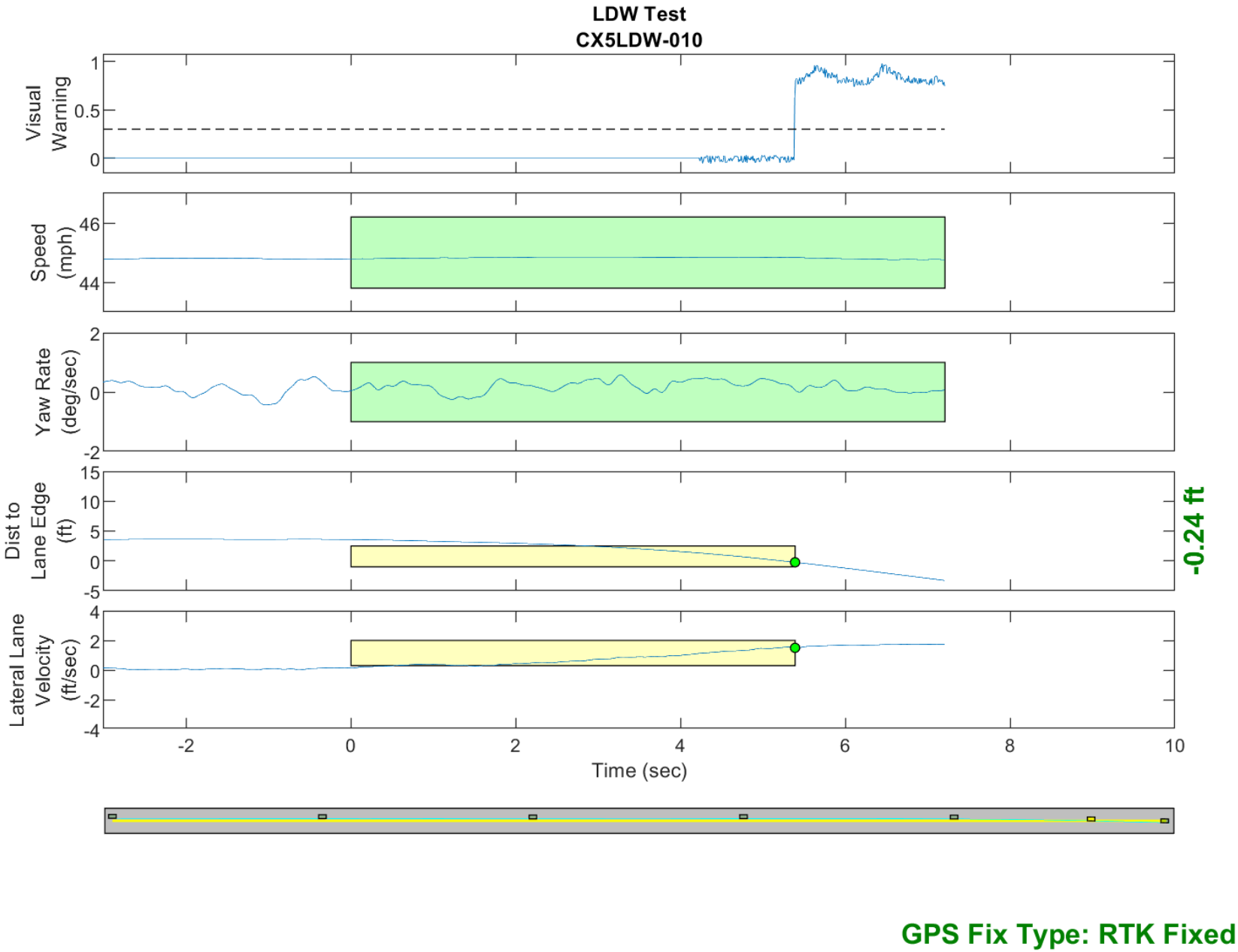


Figure D19. Time History for Run 10, Botts Dots, Right Departure, Visual Warning

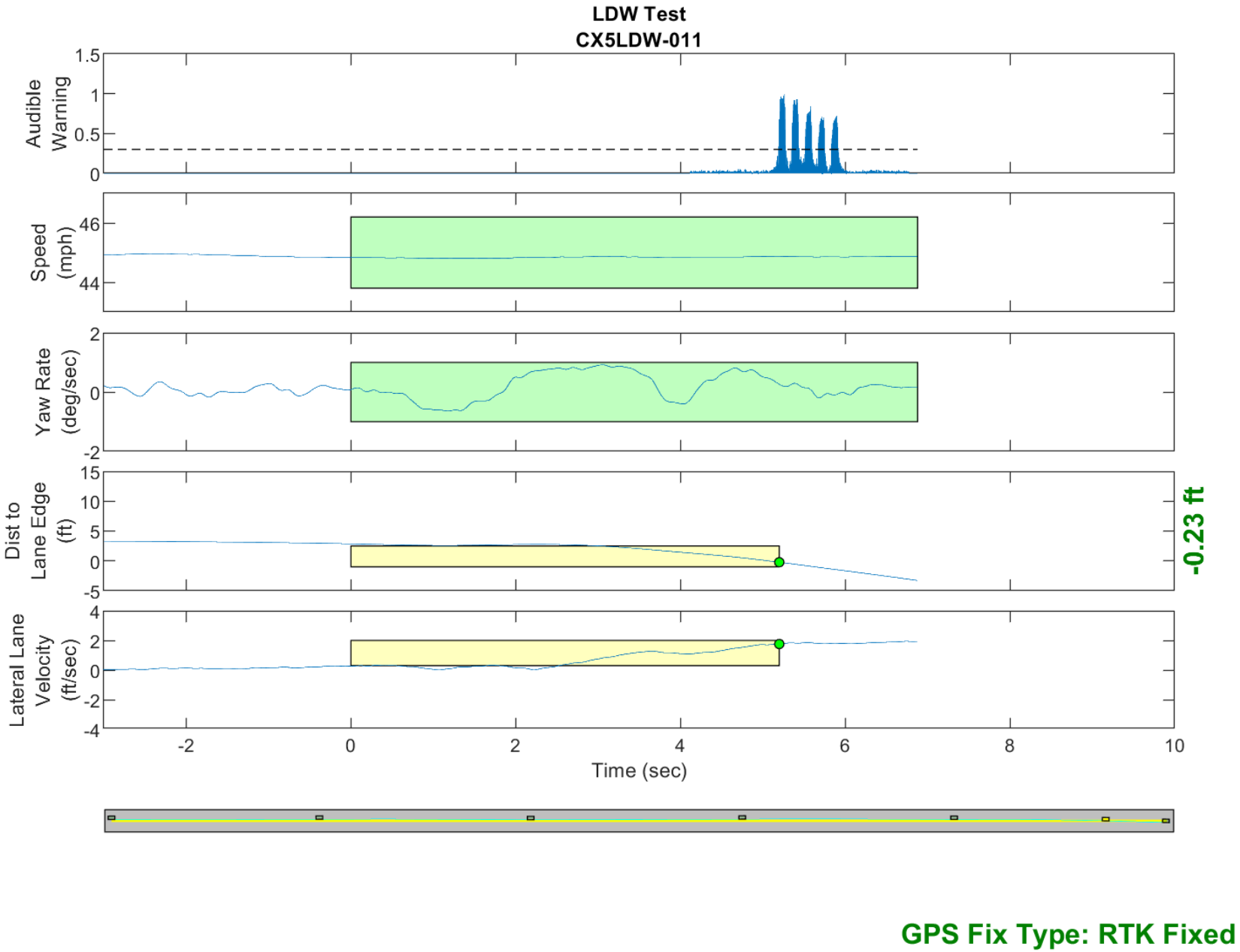


Figure D20. Time History for Run 11, Botts Dots, Right Departure, Auditory Warning

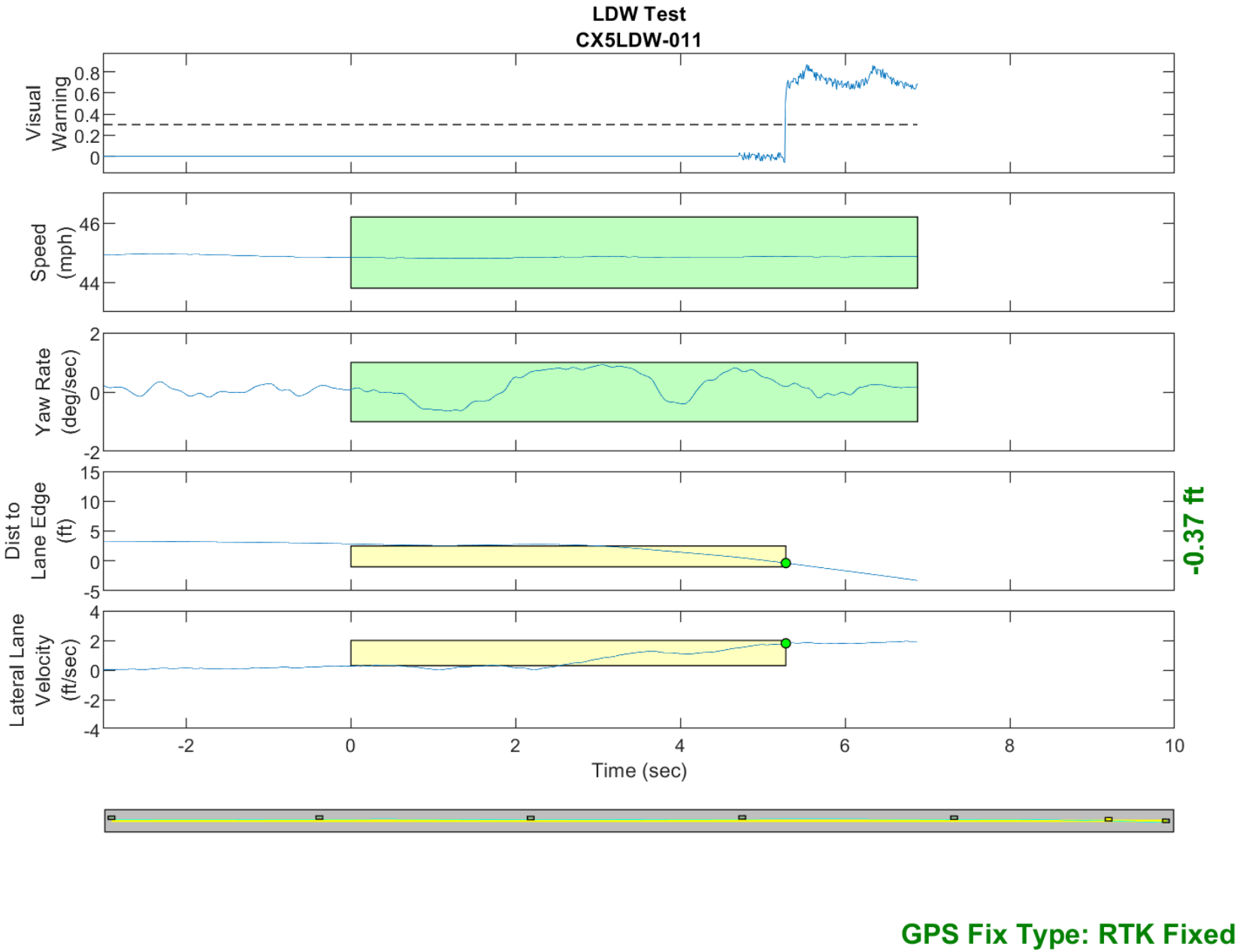


Figure D21. Time History for Run 11, Botts Dots, Right Departure, Visual Warning

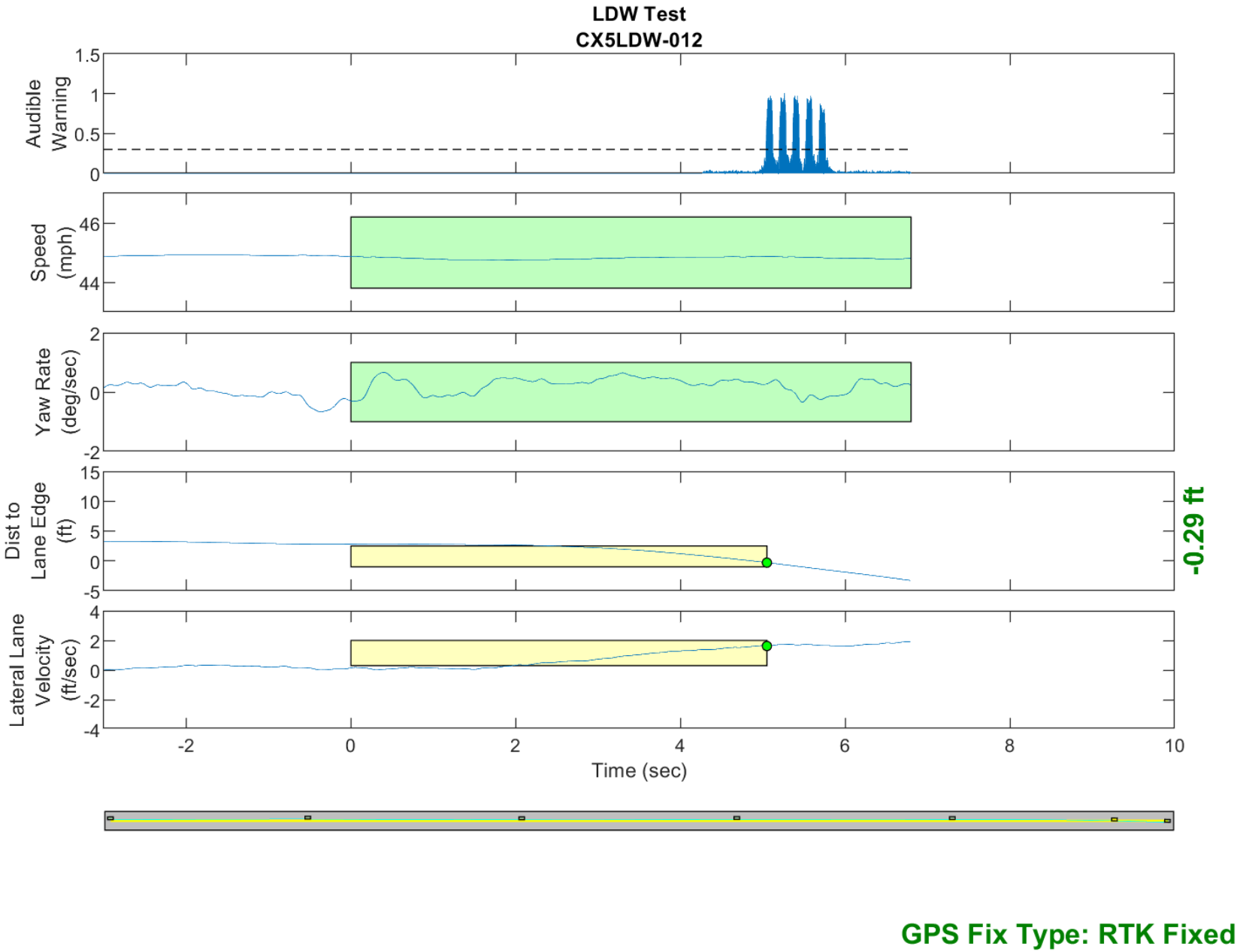


Figure D22. Time History for Run 12, Botts Dots, Right Departure, Auditory Warning

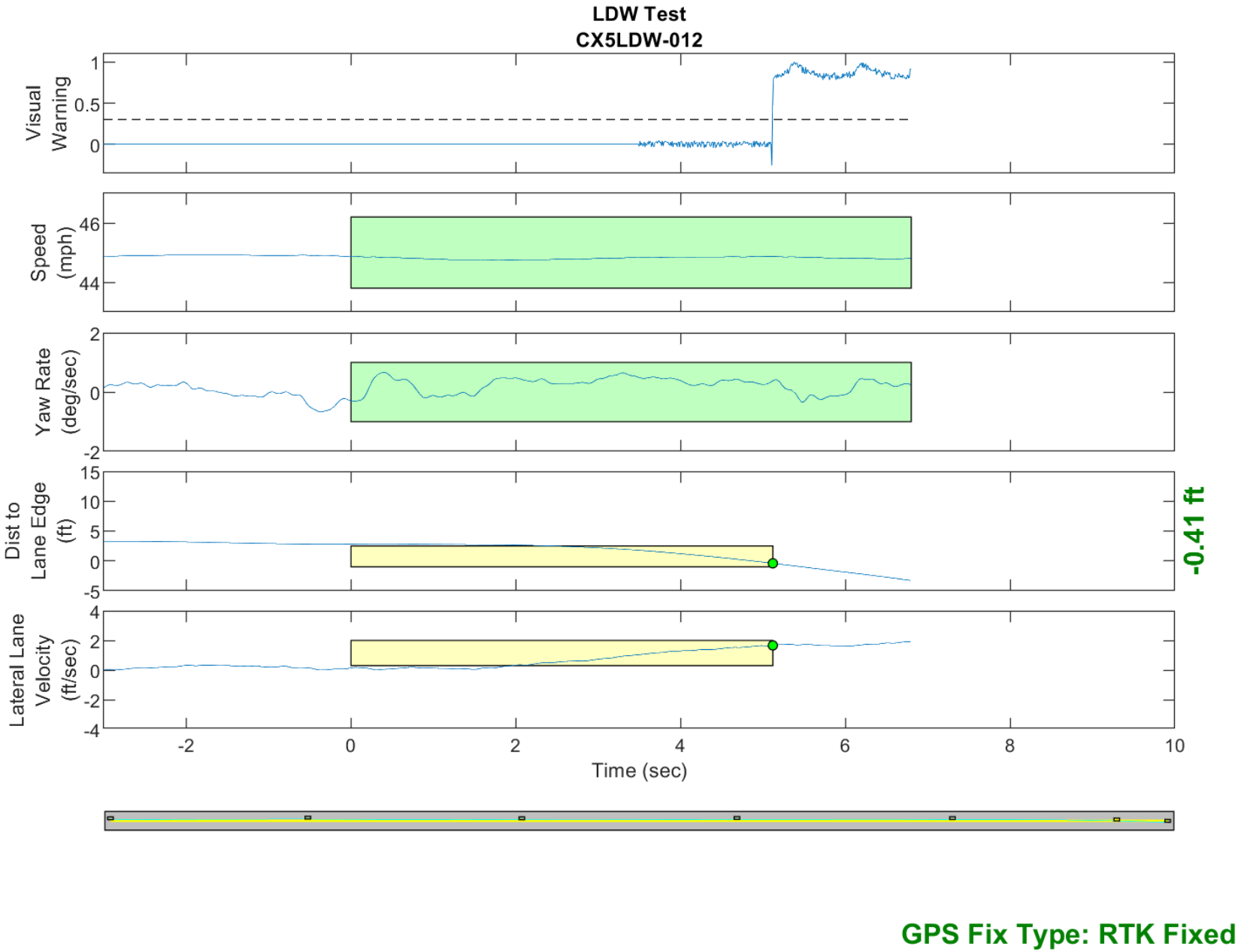


Figure D23. Time History for Run 12, Botts Dots, Right Departure, Visual Warning

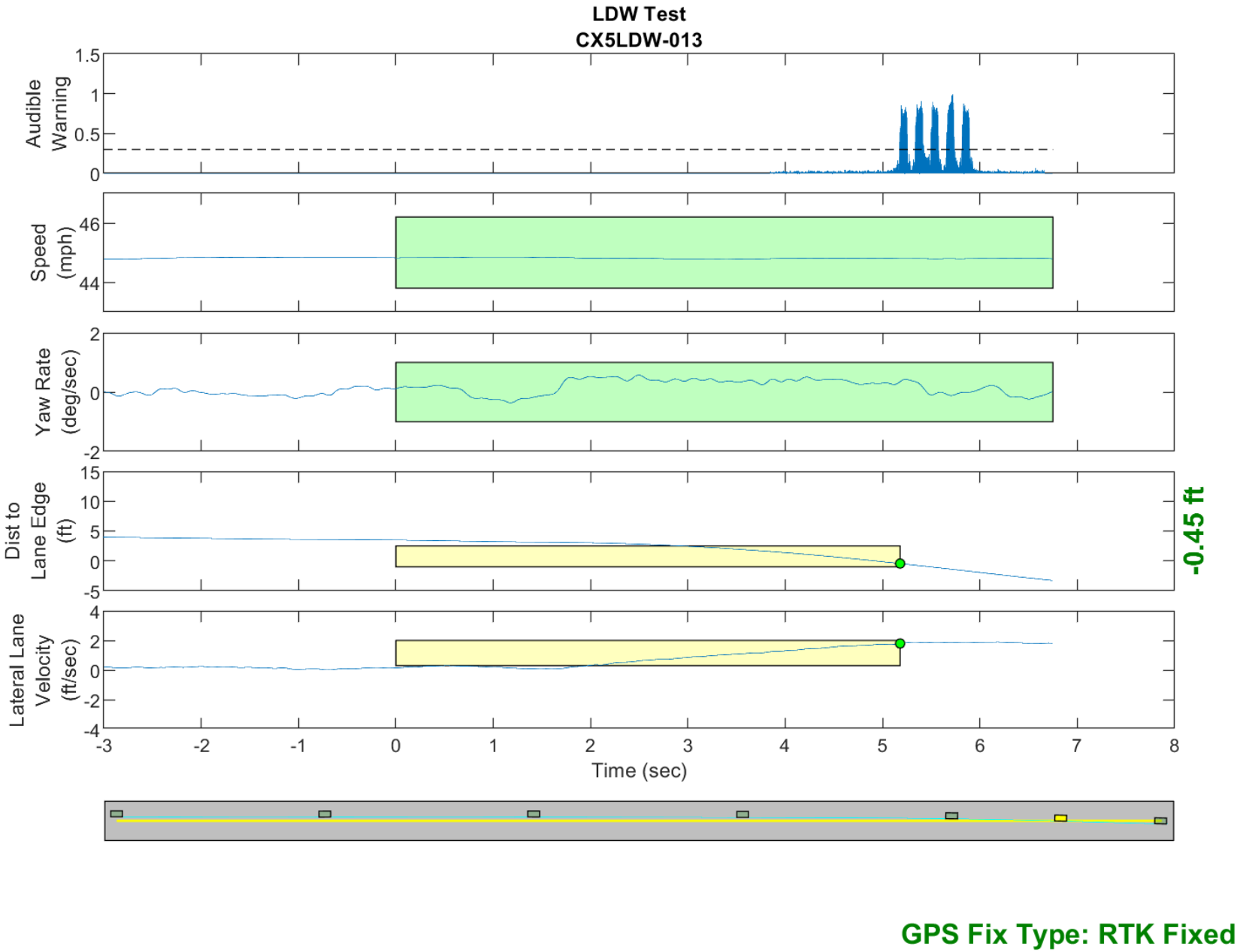


Figure D24. Time History for Run 13, Botts Dots, Right Departure, Auditory Warning

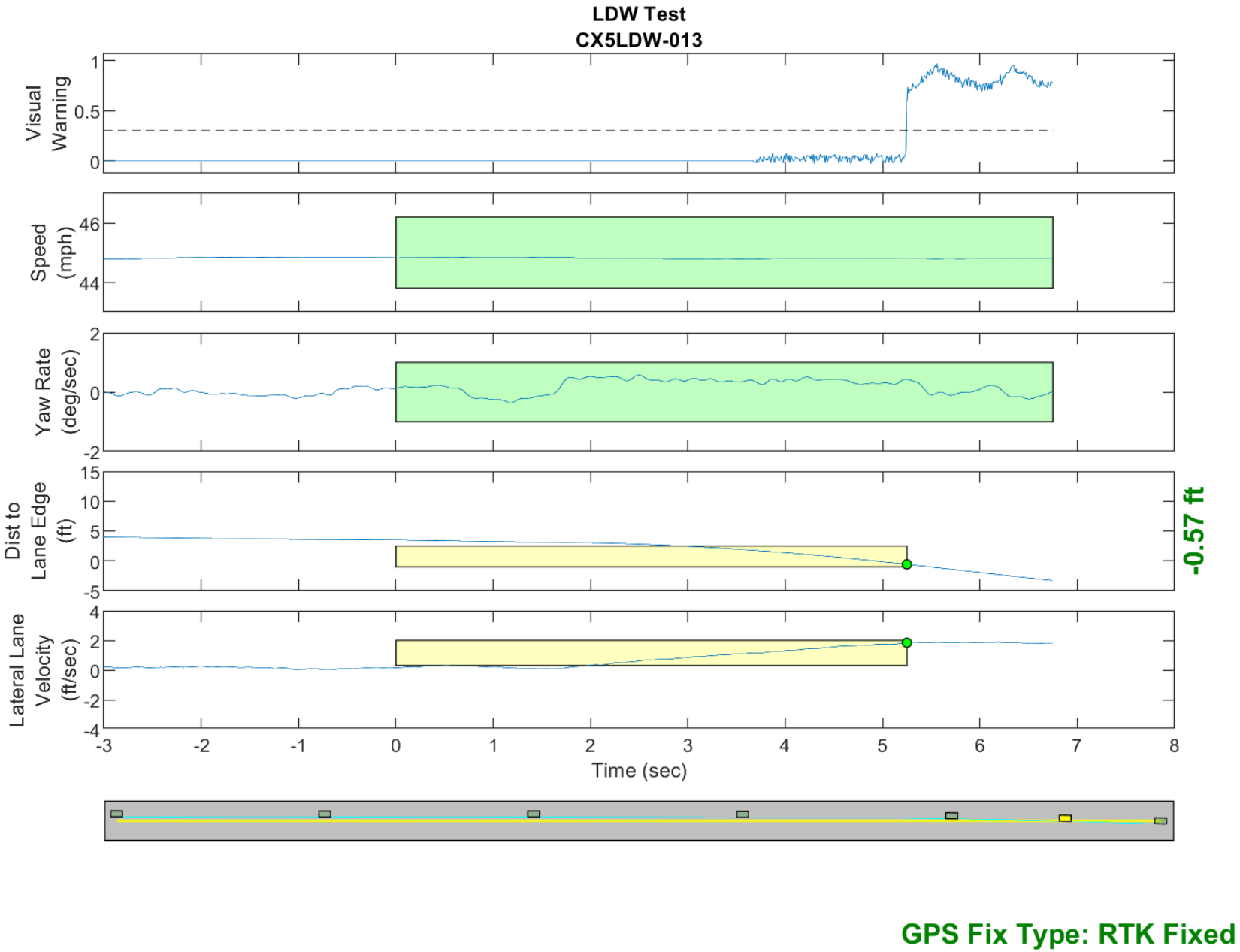


Figure D25. Time History for Run 13, Botts Dots, Right Departure, Visual Warning

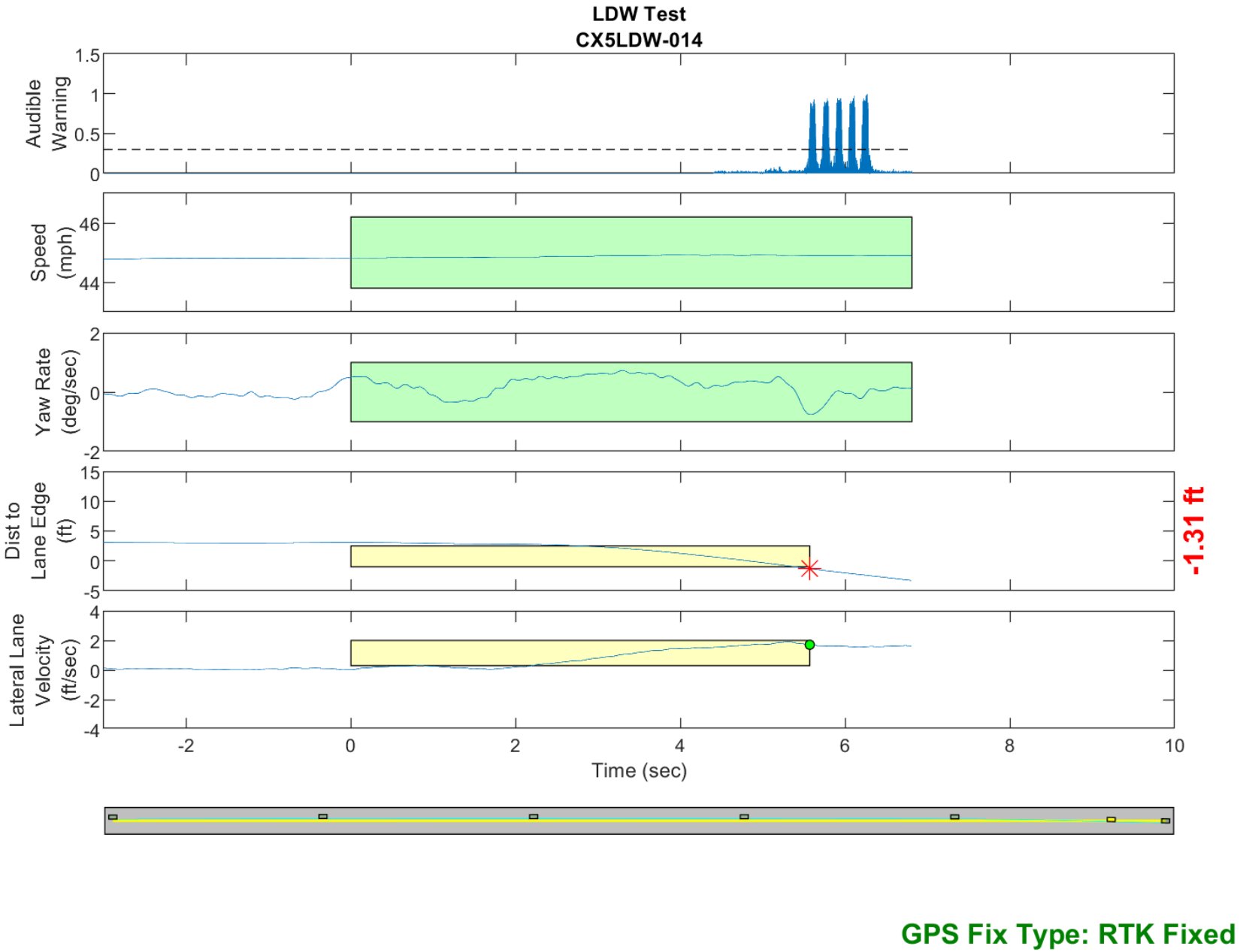


Figure D26. Time History for Run 14, Botts Dots, Right Departure, Auditory Warning

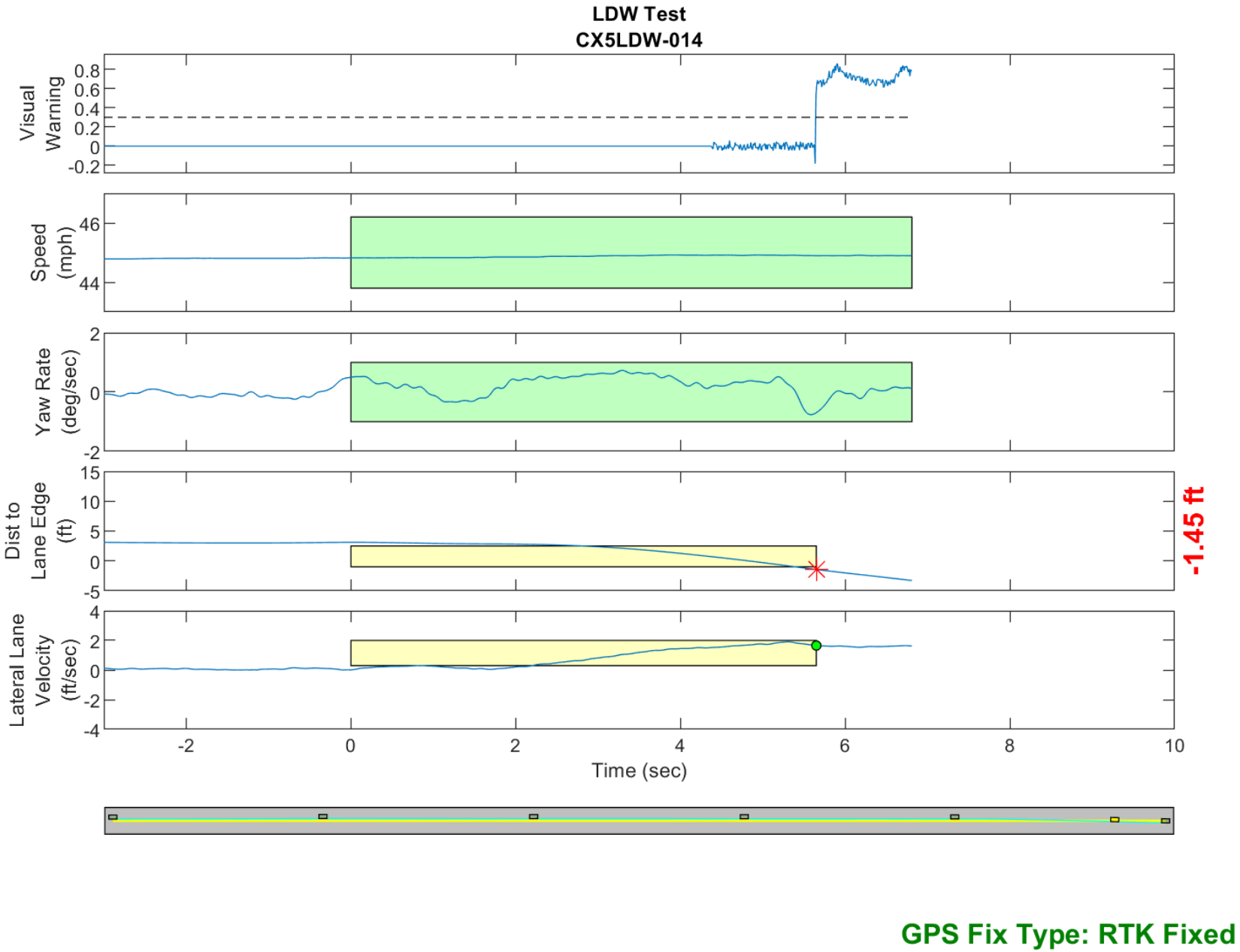


Figure D27. Time History for Run 14, Botts Dots, Right Departure, Visual Warning

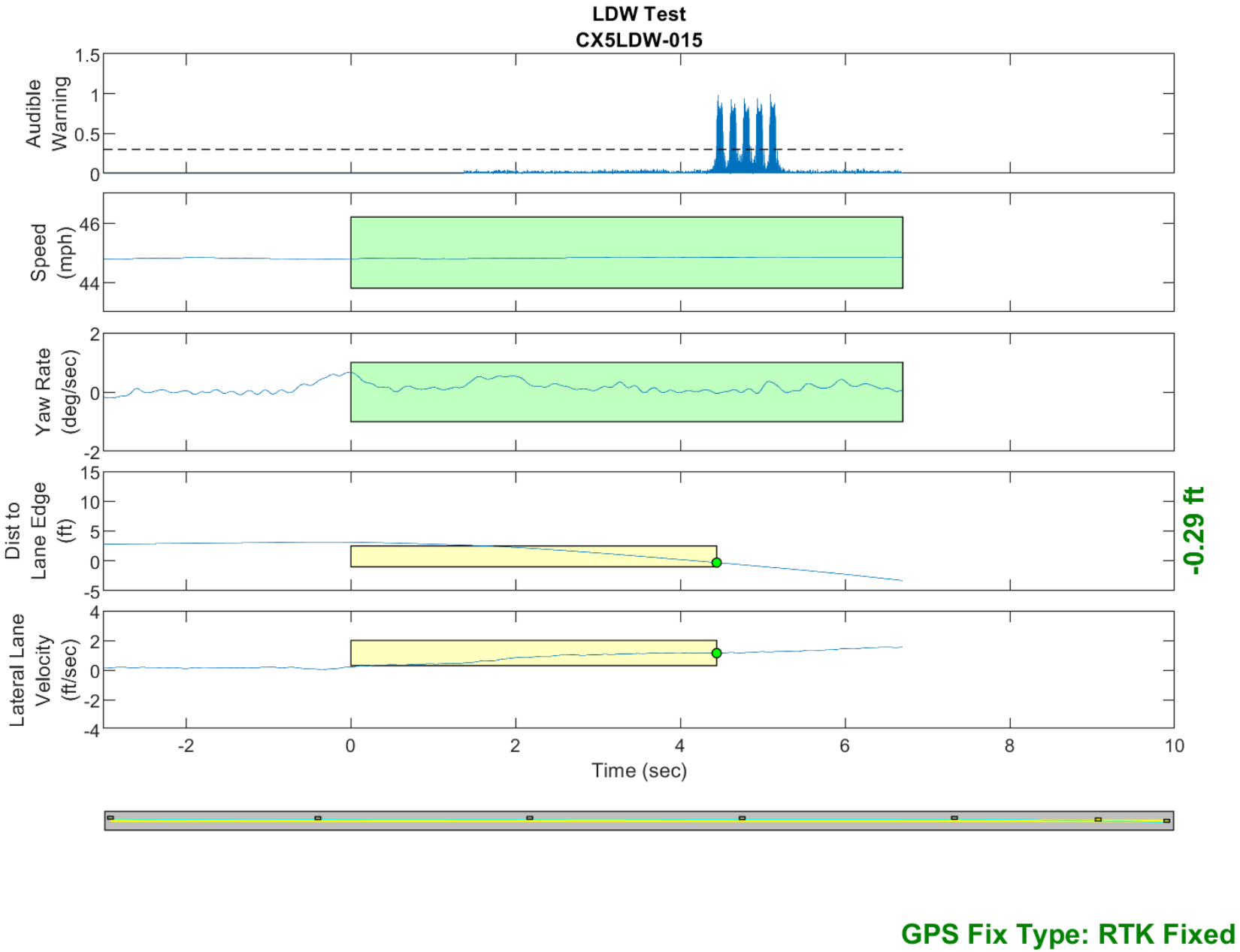


Figure D28. Time History for Run 15, Botts Dots, Right Departure, Auditory Warning

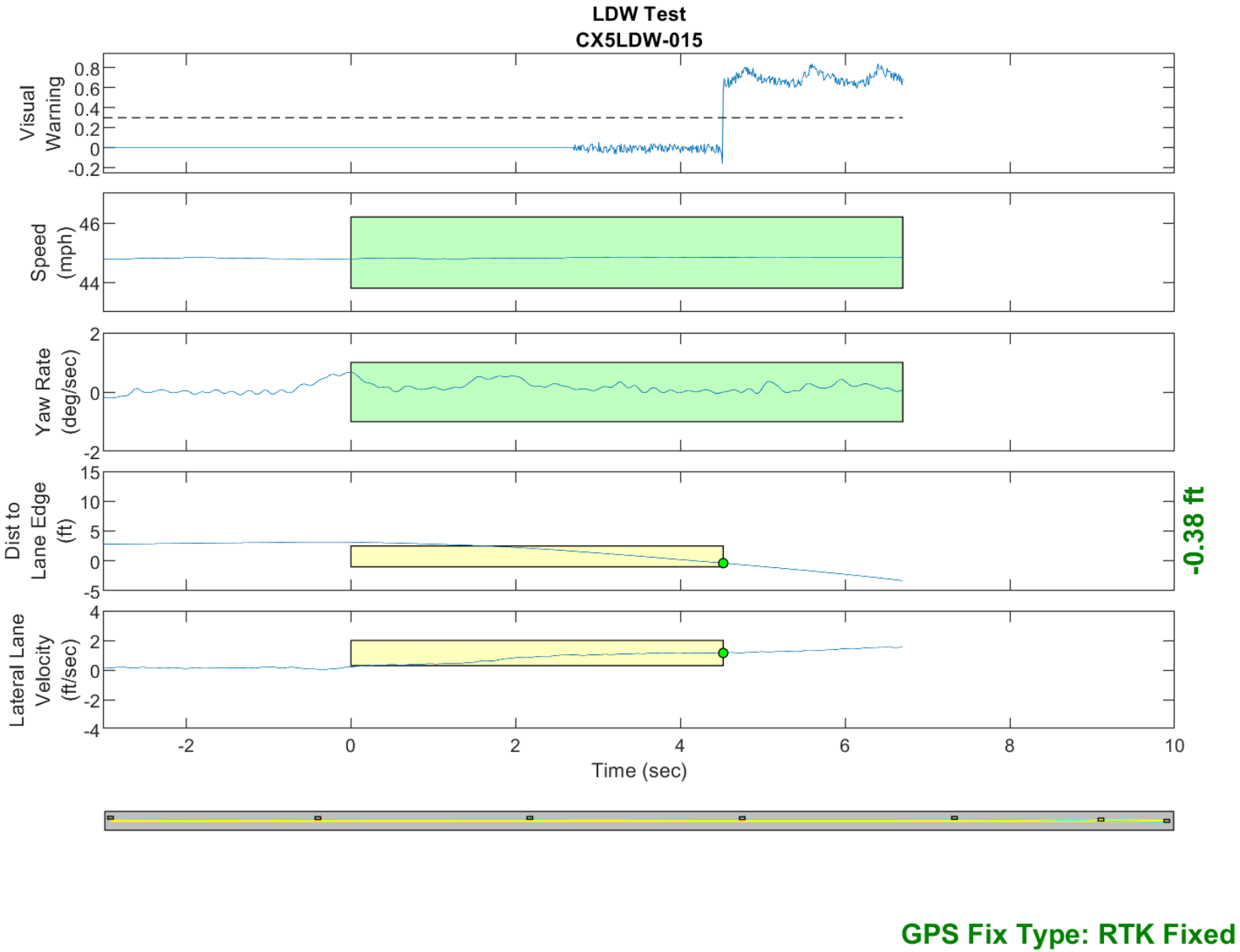


Figure D29. Time History for Run 15, Botts Dots, Right Departure, Visual Warning

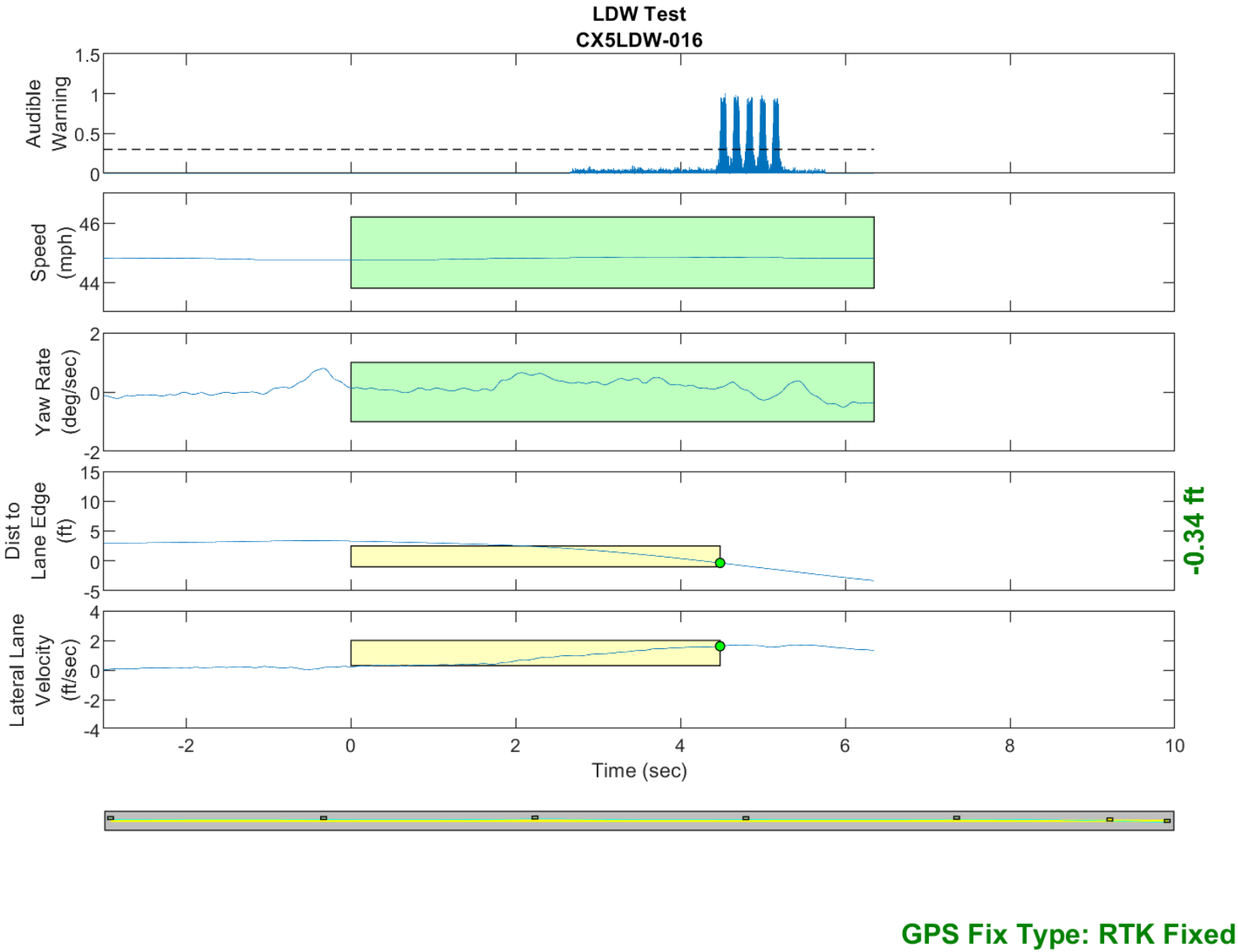


Figure D30. Time History for Run 16, Botts Dots, Right Departure, Auditory Warning

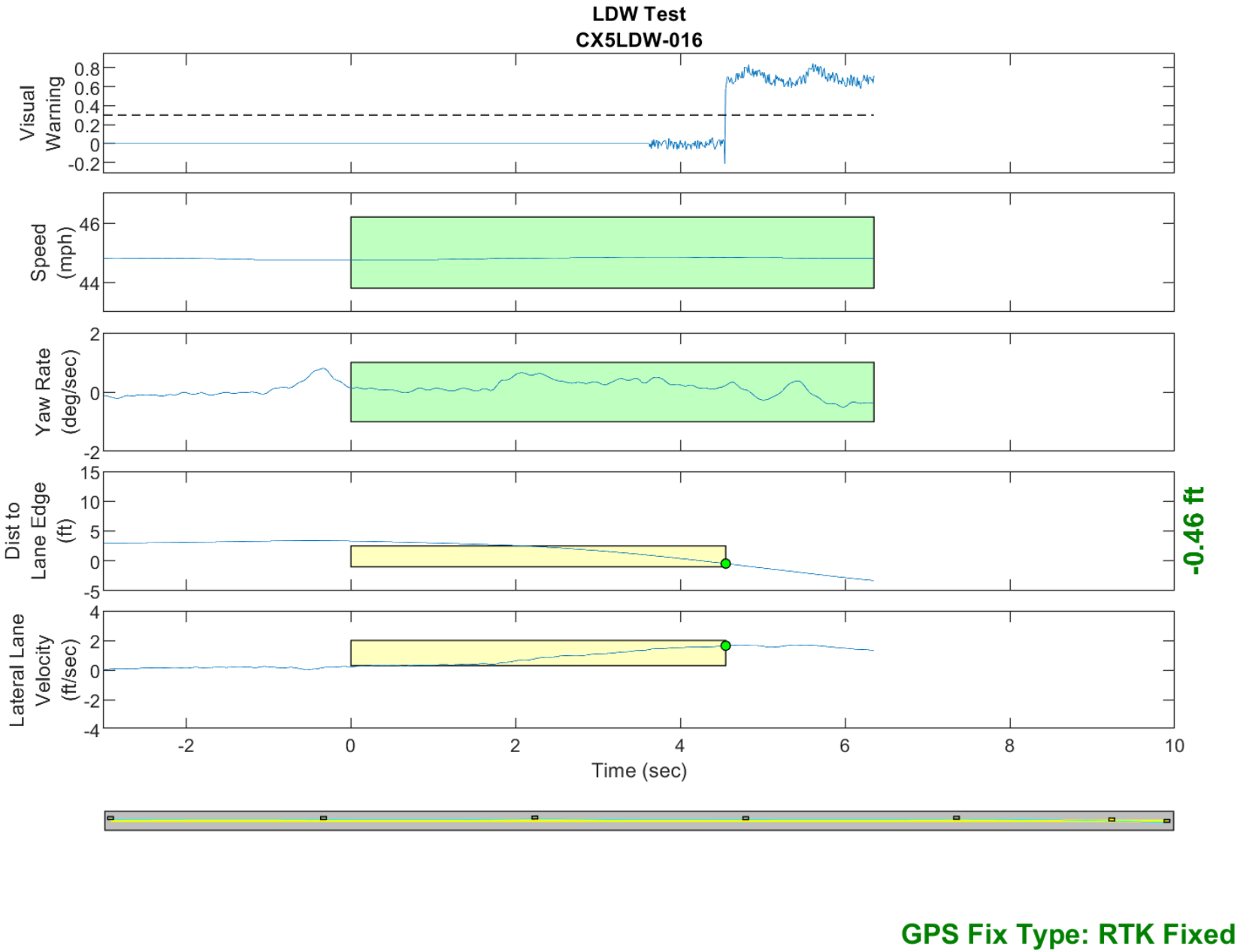


Figure D31. Time History for Run 16, Botts Dots, Right Departure, Visual Warning

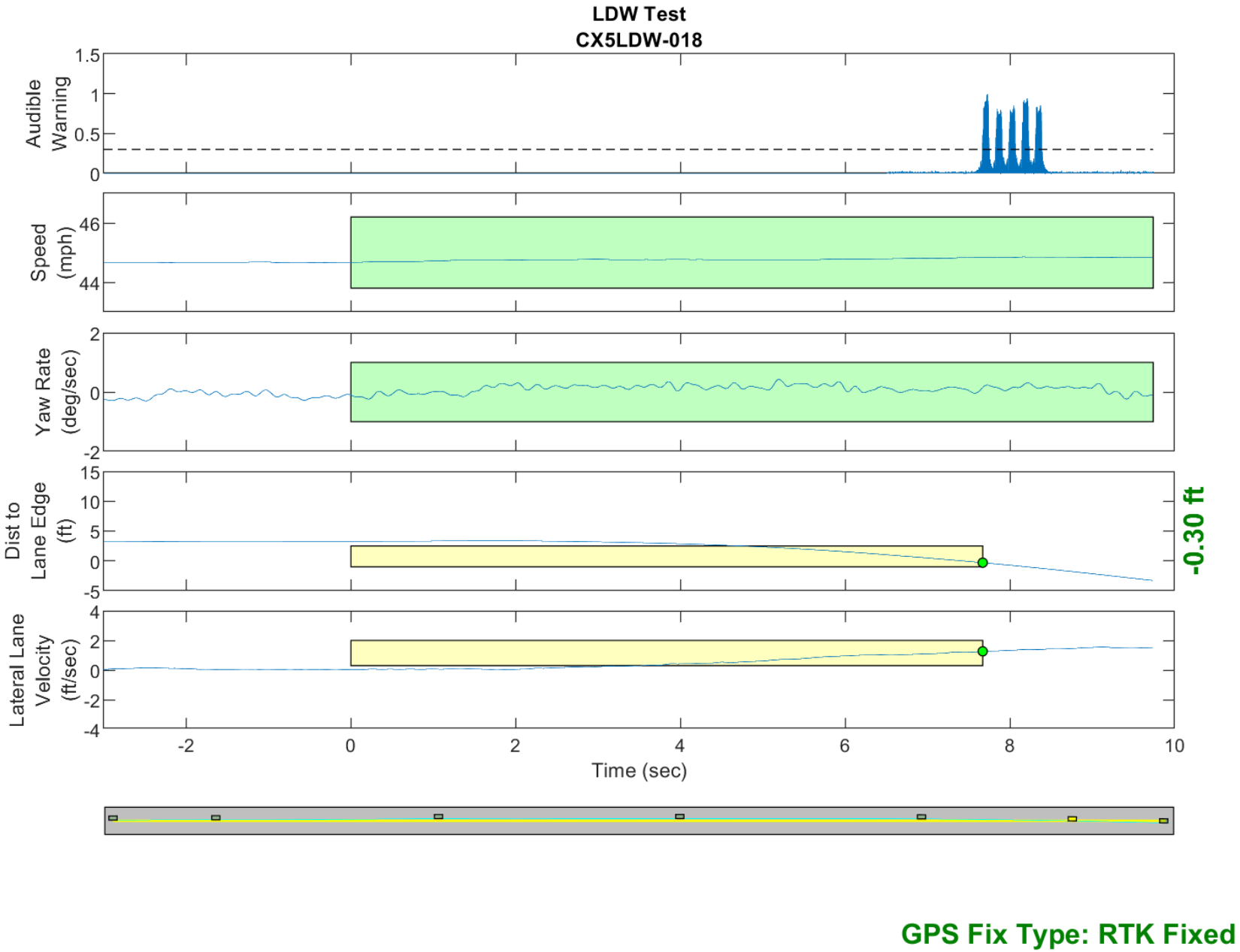


Figure D32. Time History for Run 18, Solid Line, Right Departure, Auditory Warning

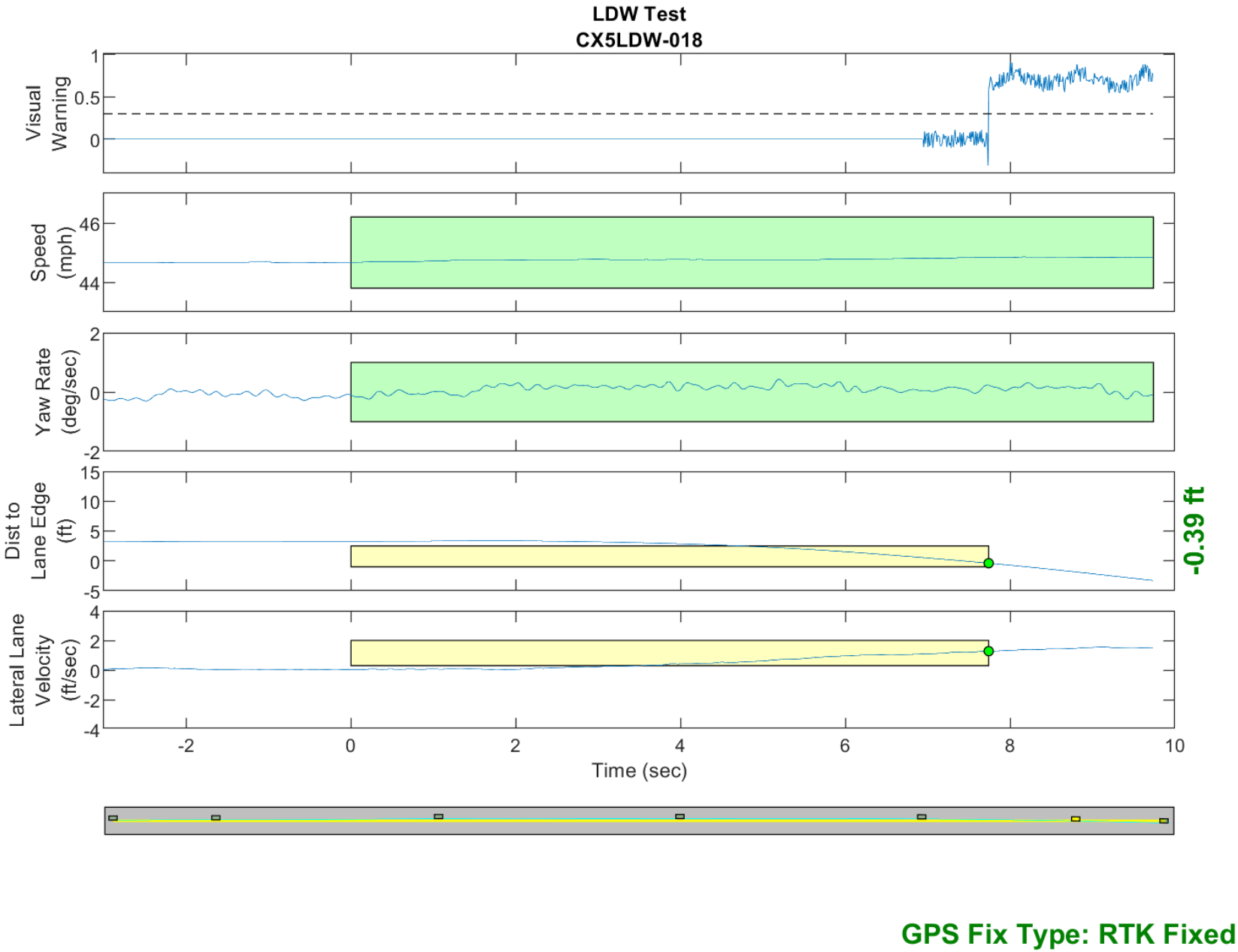


Figure D33. Time History for Run 18, Solid Line, Right Departure, Visual Warning

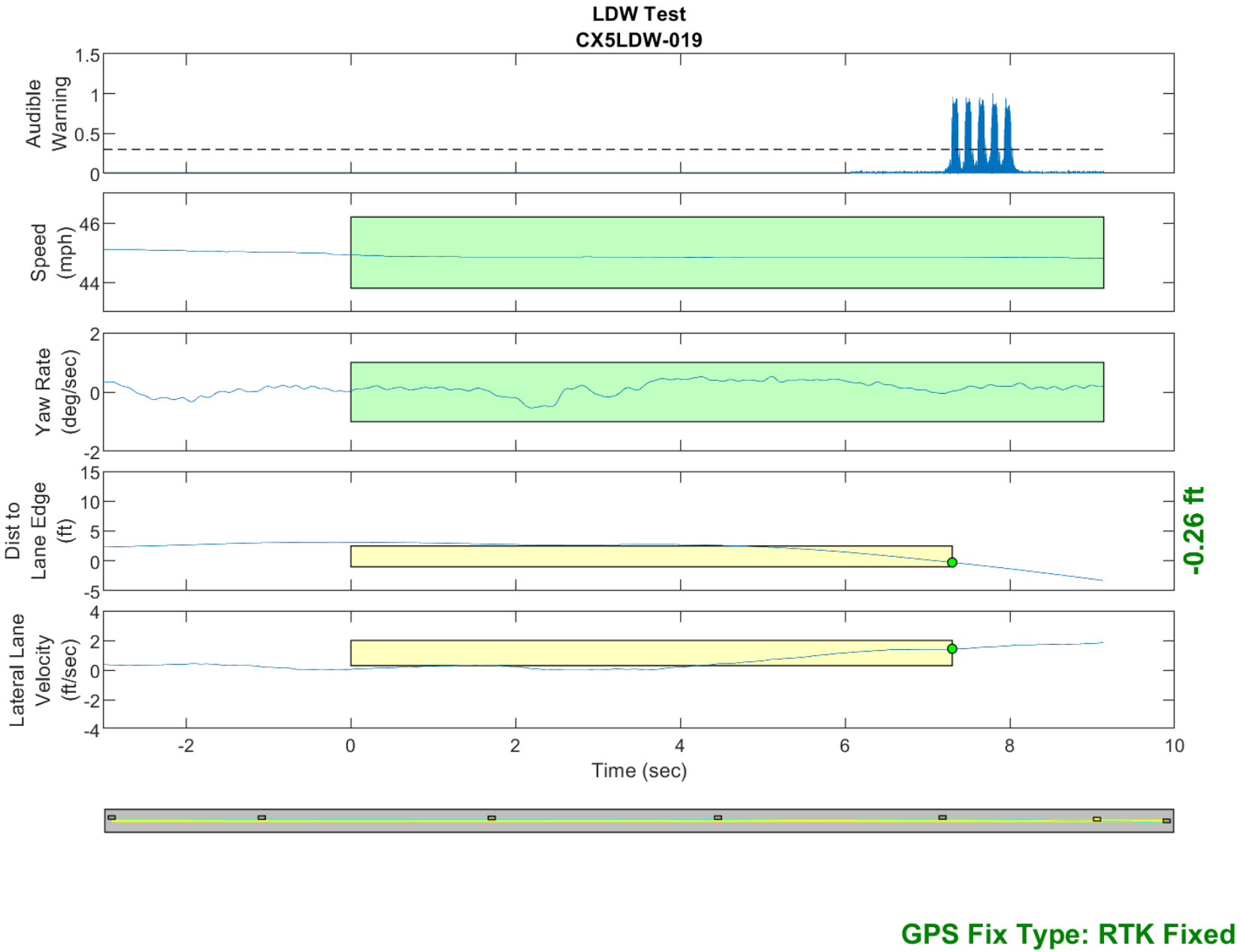


Figure D34. Time History for Run 19, Solid Line, Right Departure, Auditory Warning

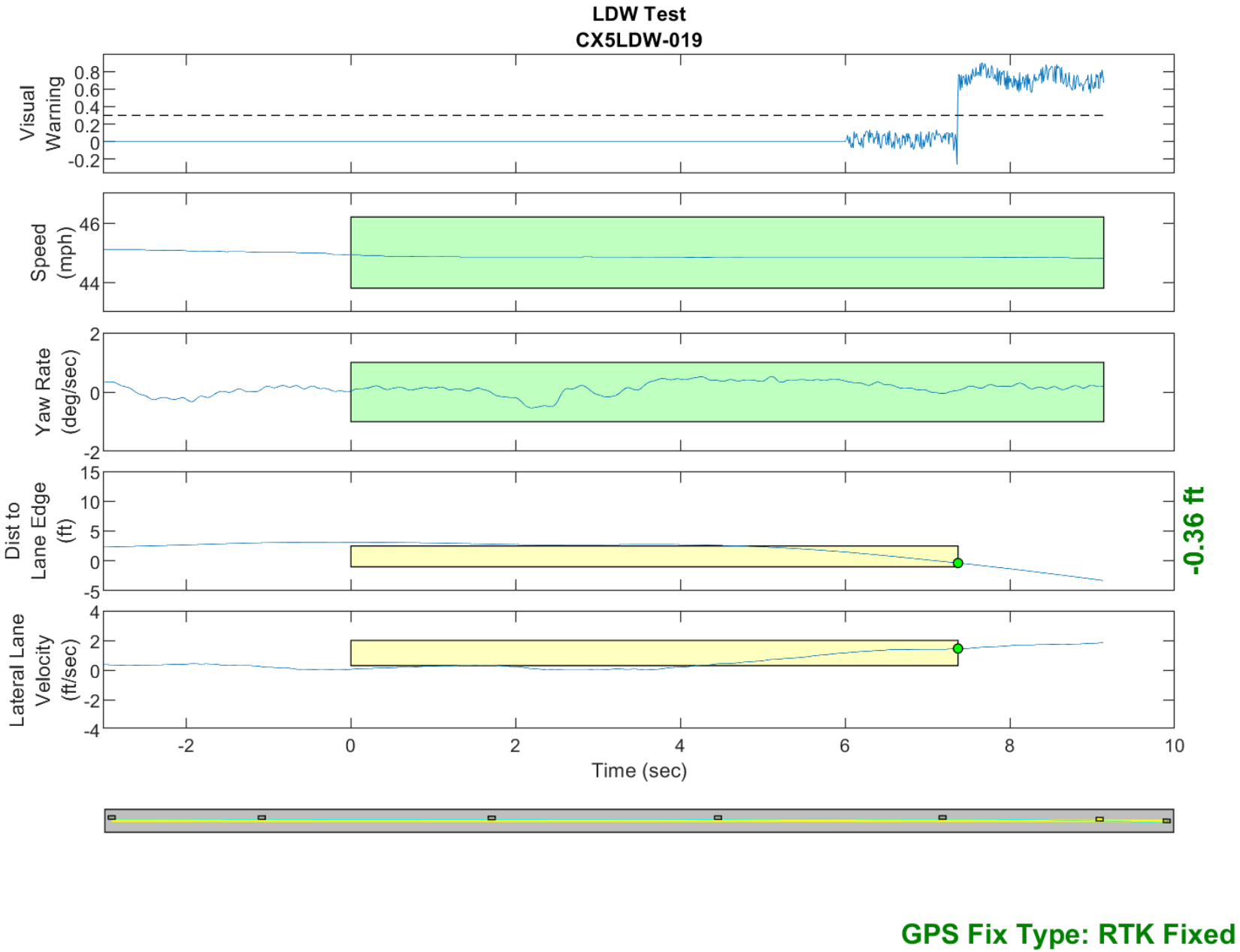


Figure D35. Time History for Run 19, Solid Line, Right Departure, Visual Warning

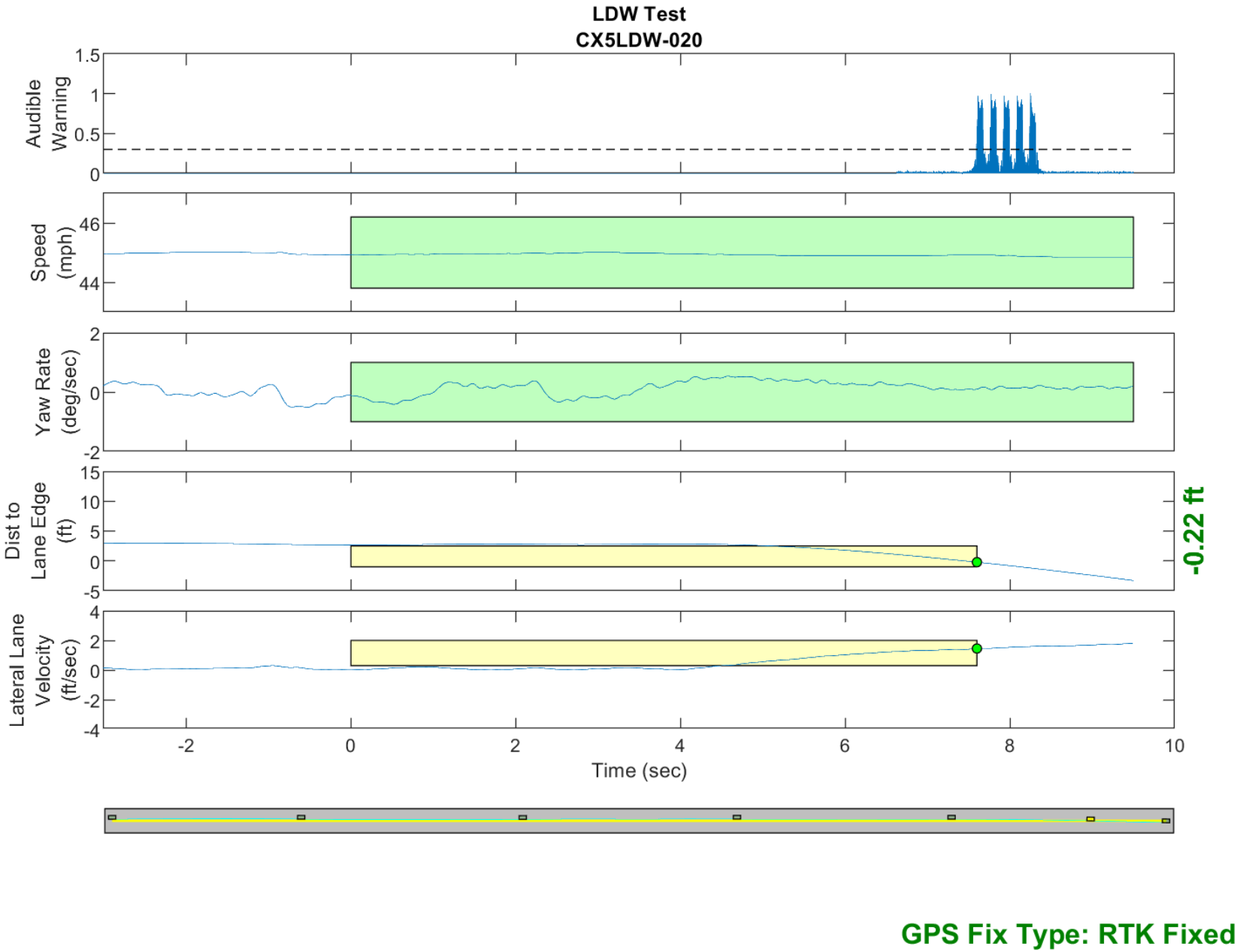


Figure D36. Time History for Run 20, Solid Line, Right Departure, Auditory Warning

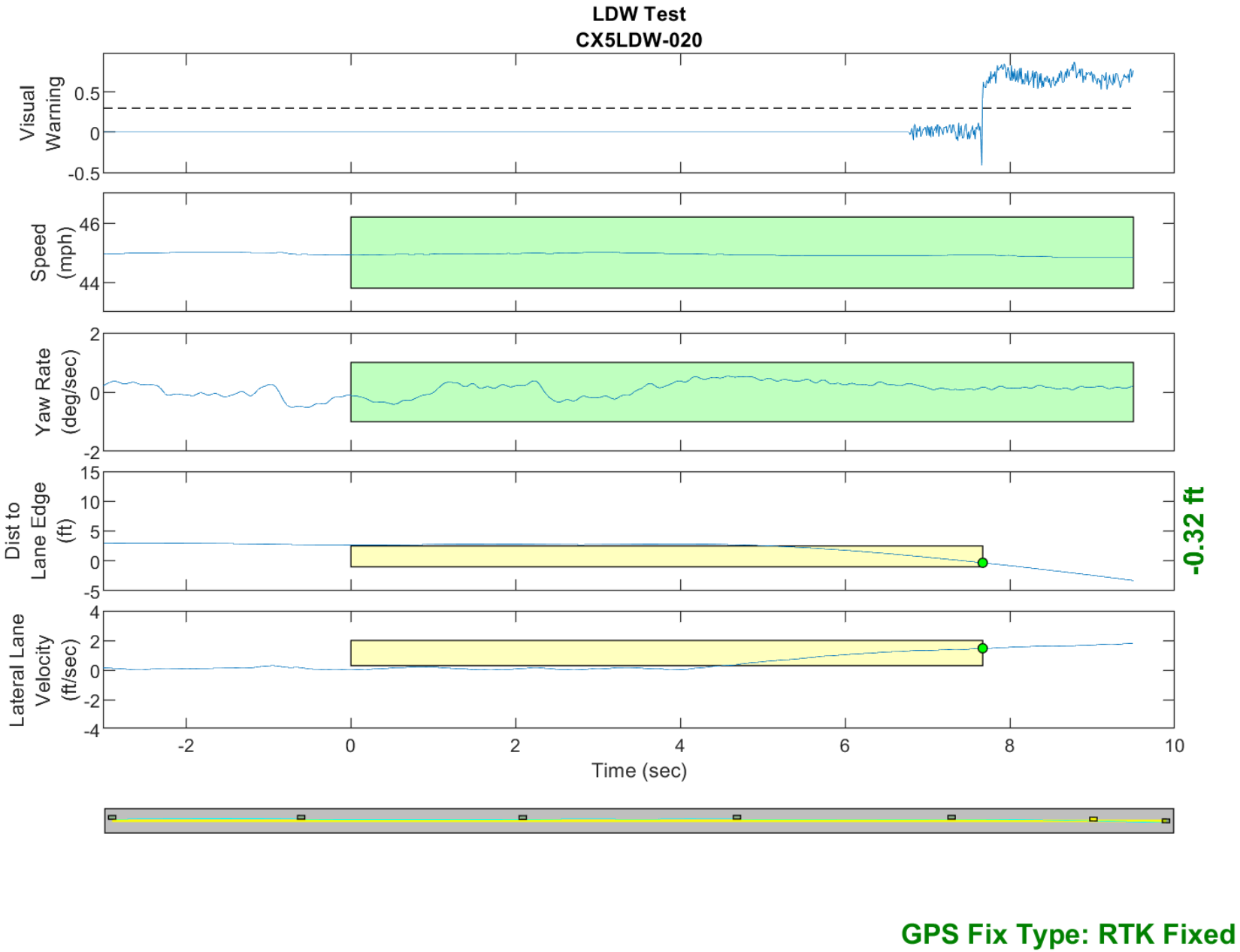


Figure D37. Time History for Run 20, Solid Line, Right Departure, Visual Warning

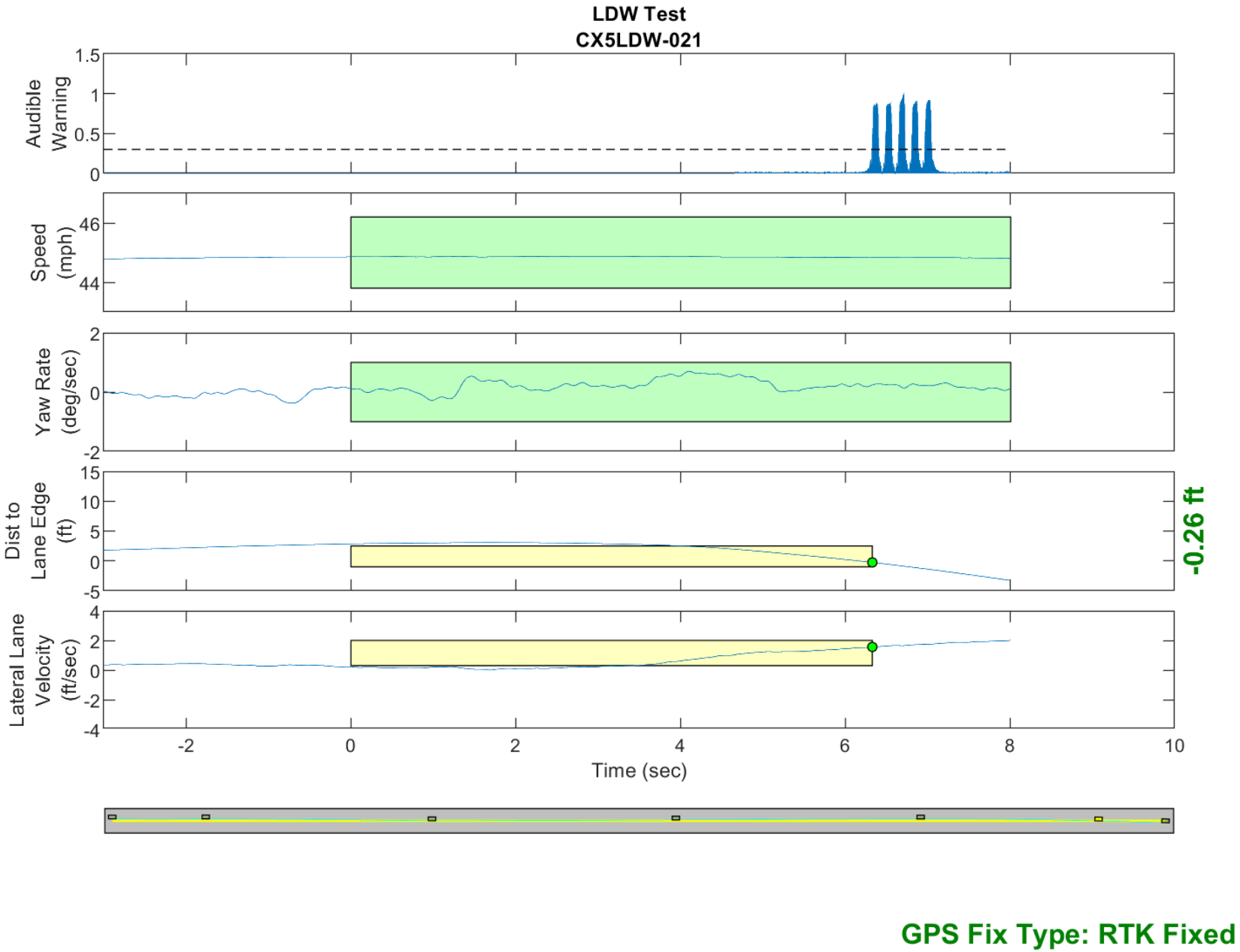


Figure D38. Time History for Run 21, Solid Line, Right Departure, Auditory Warning

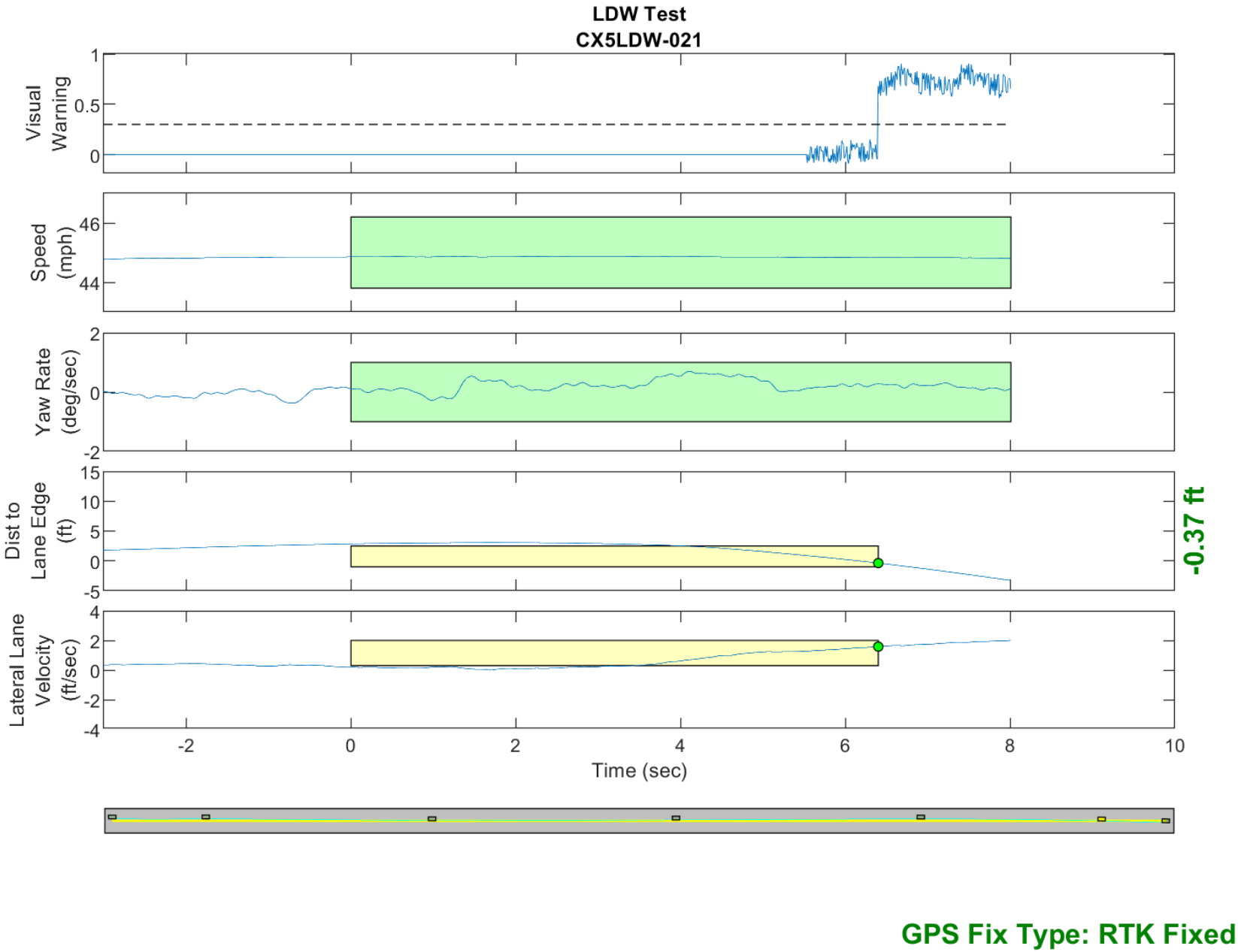


Figure D39. Time History for Run 21, Solid Line, Right Departure, Visual Warning

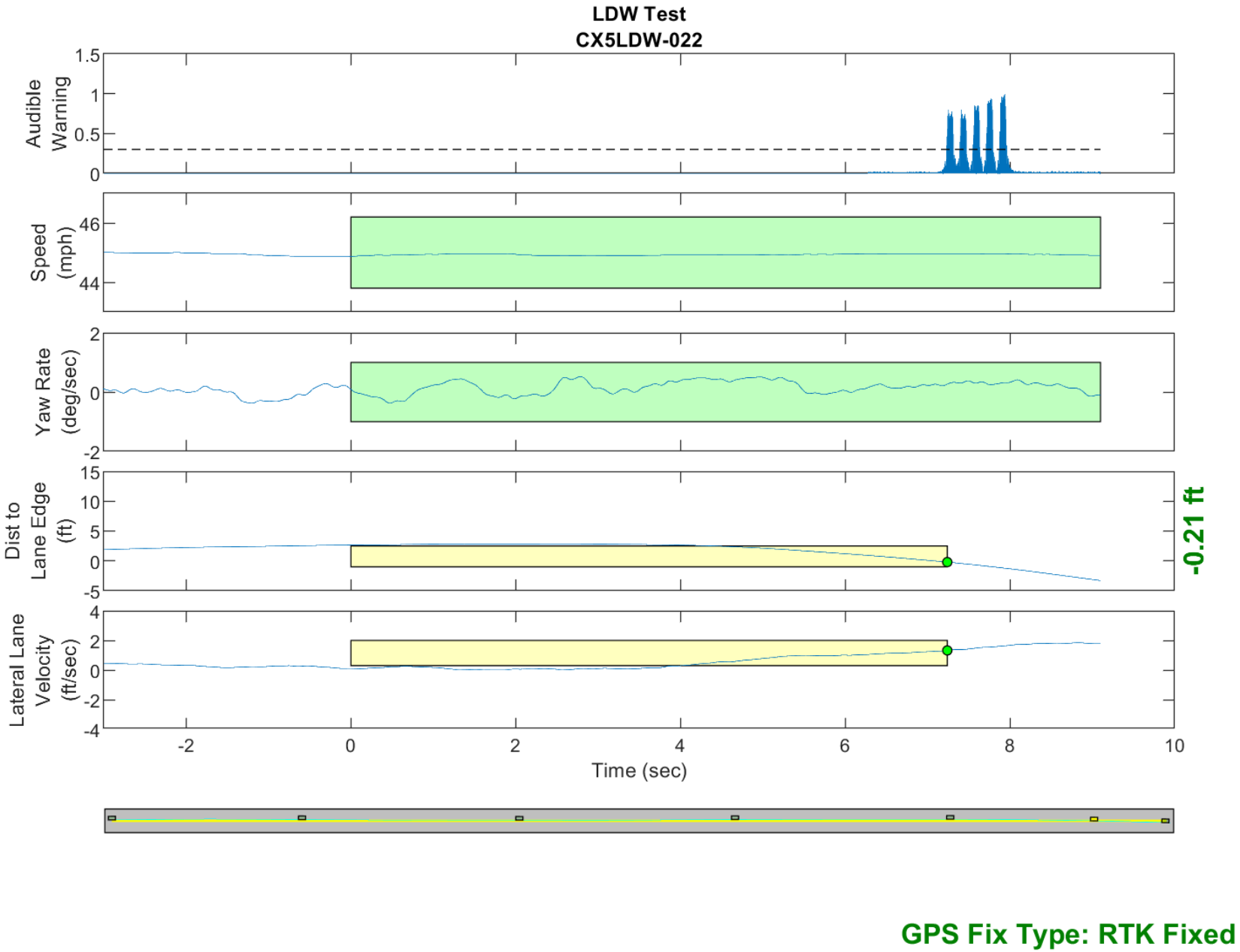


Figure D40. Time History for Run 22, Solid Line, Right Departure, Auditory Warning

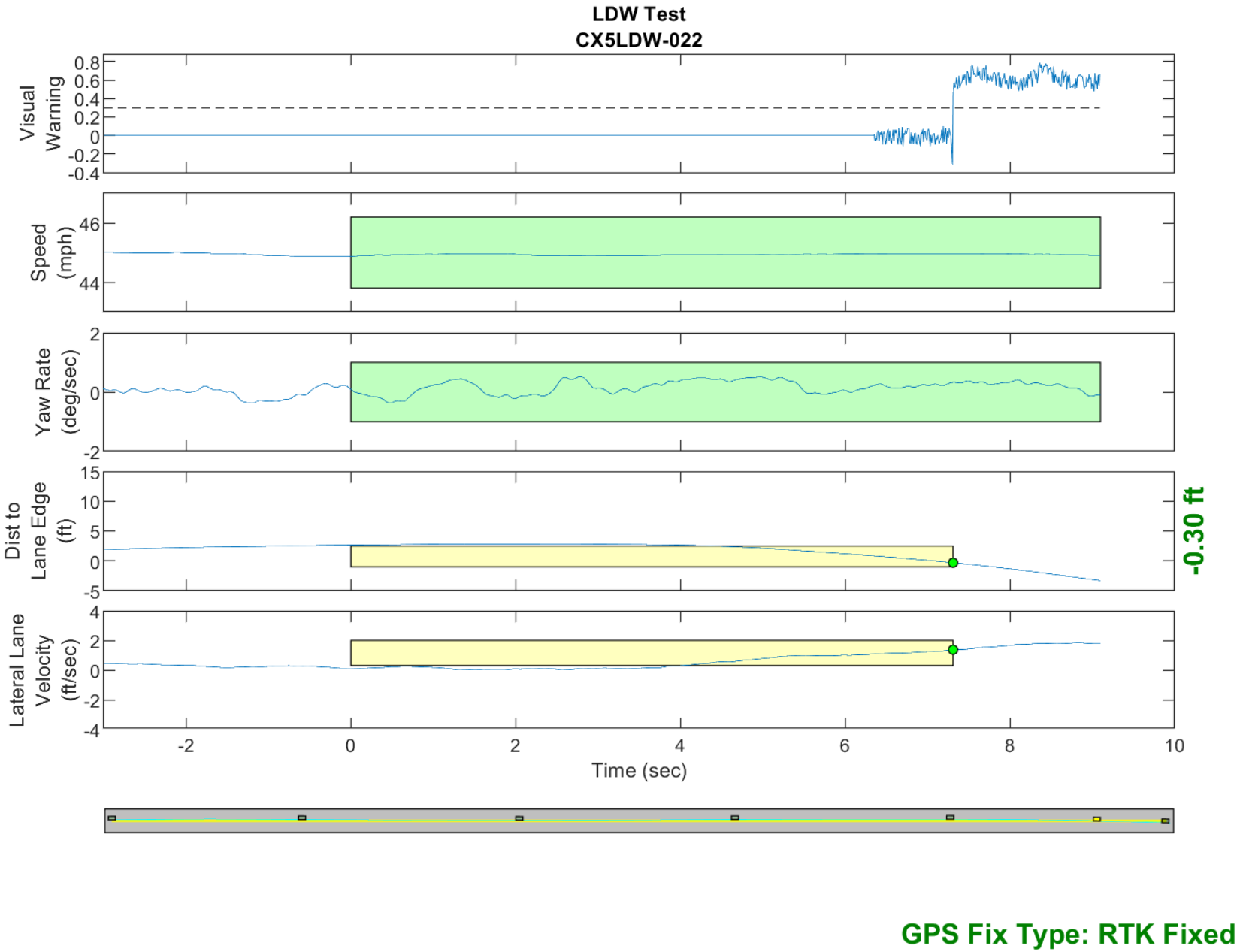


Figure D41. Time History for Run 22, Solid Line, Right Departure, Visual Warning

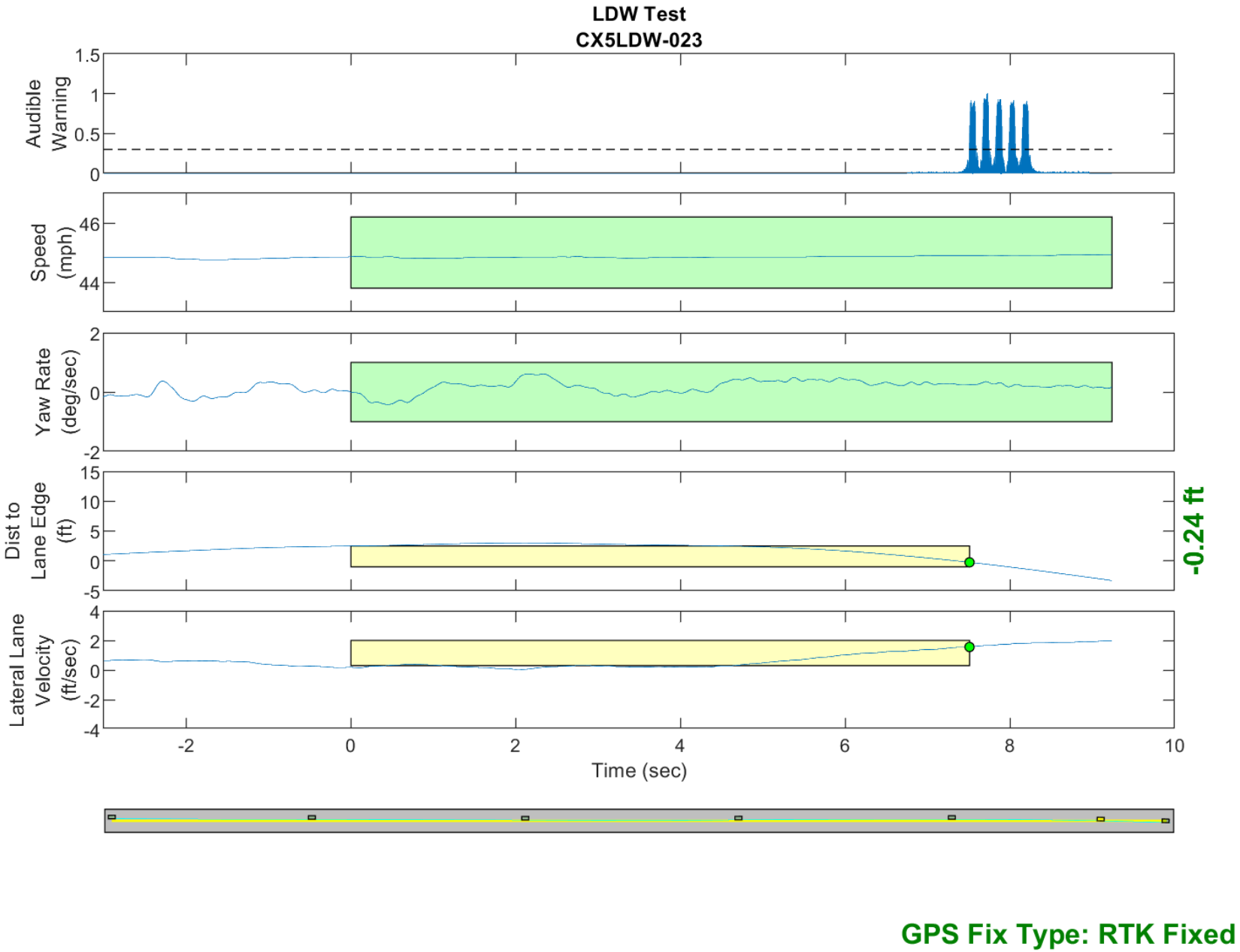
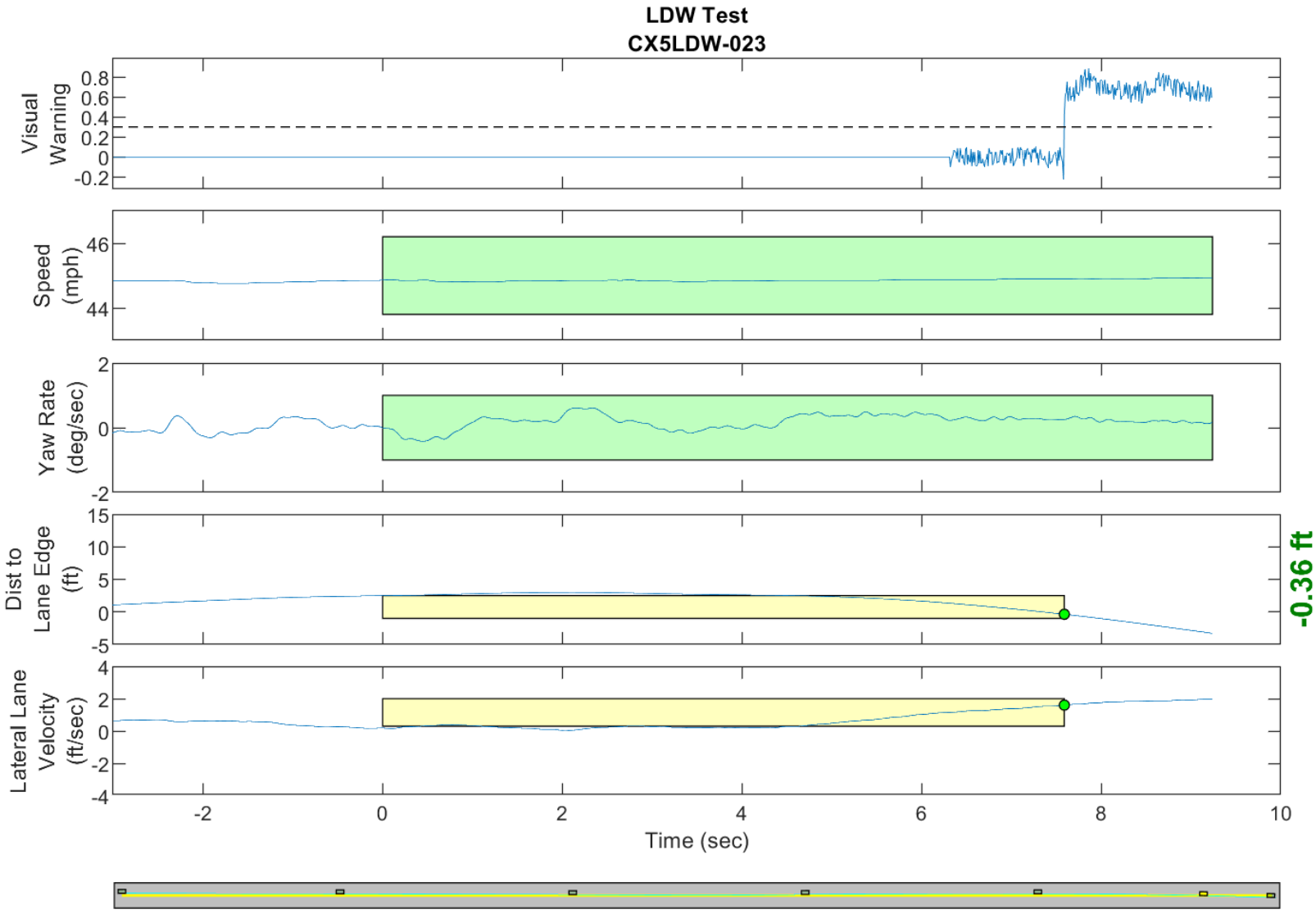


Figure D42. Time History for Run 23, Solid Line, Right Departure, Auditory Warning



GPS Fix Type: RTK Fixed

Figure D43. Time History for Run 23, Solid Line, Right Departure, Visual Warning

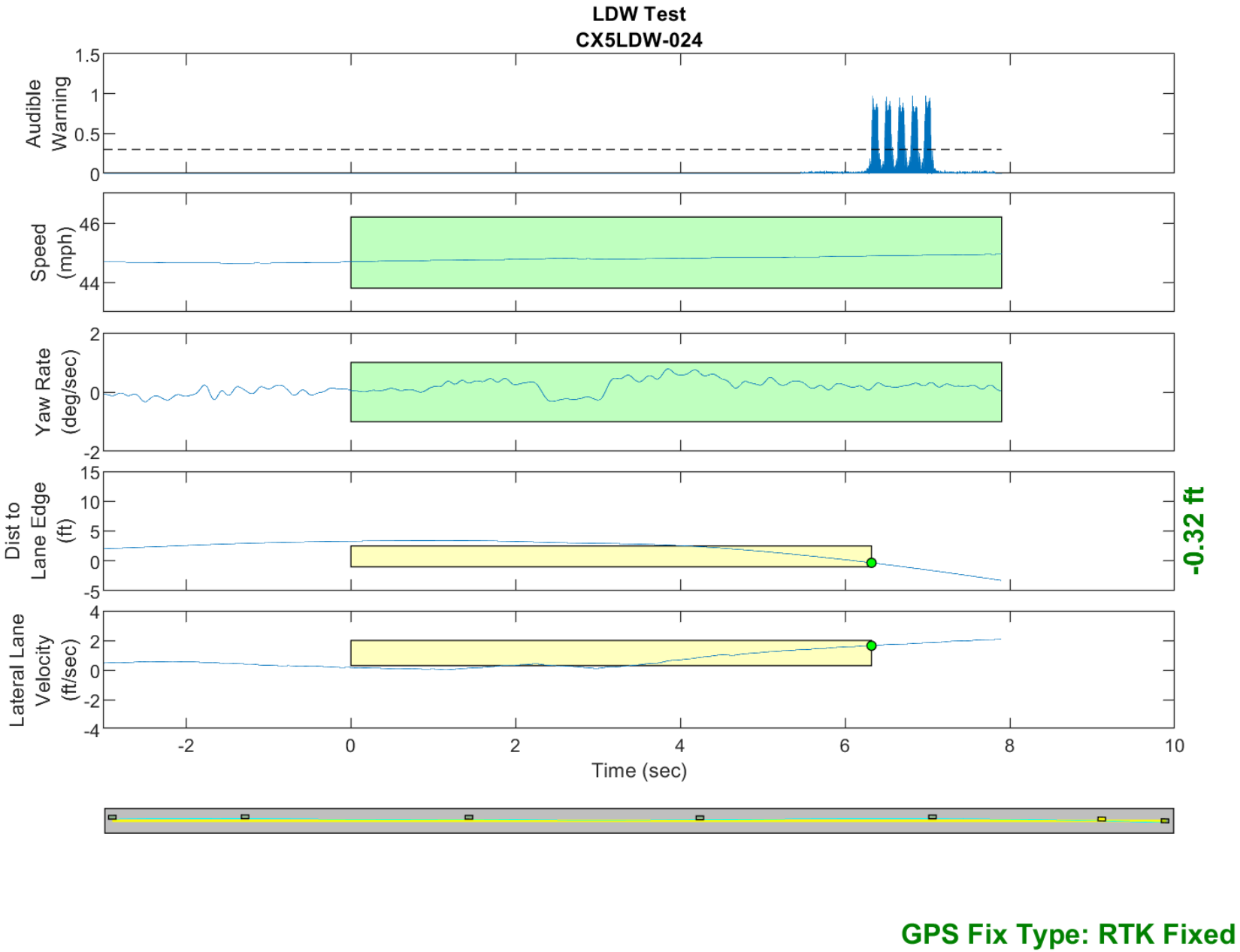


Figure D44. Time History for Run 24, Solid Line, Right Departure, Auditory Warning

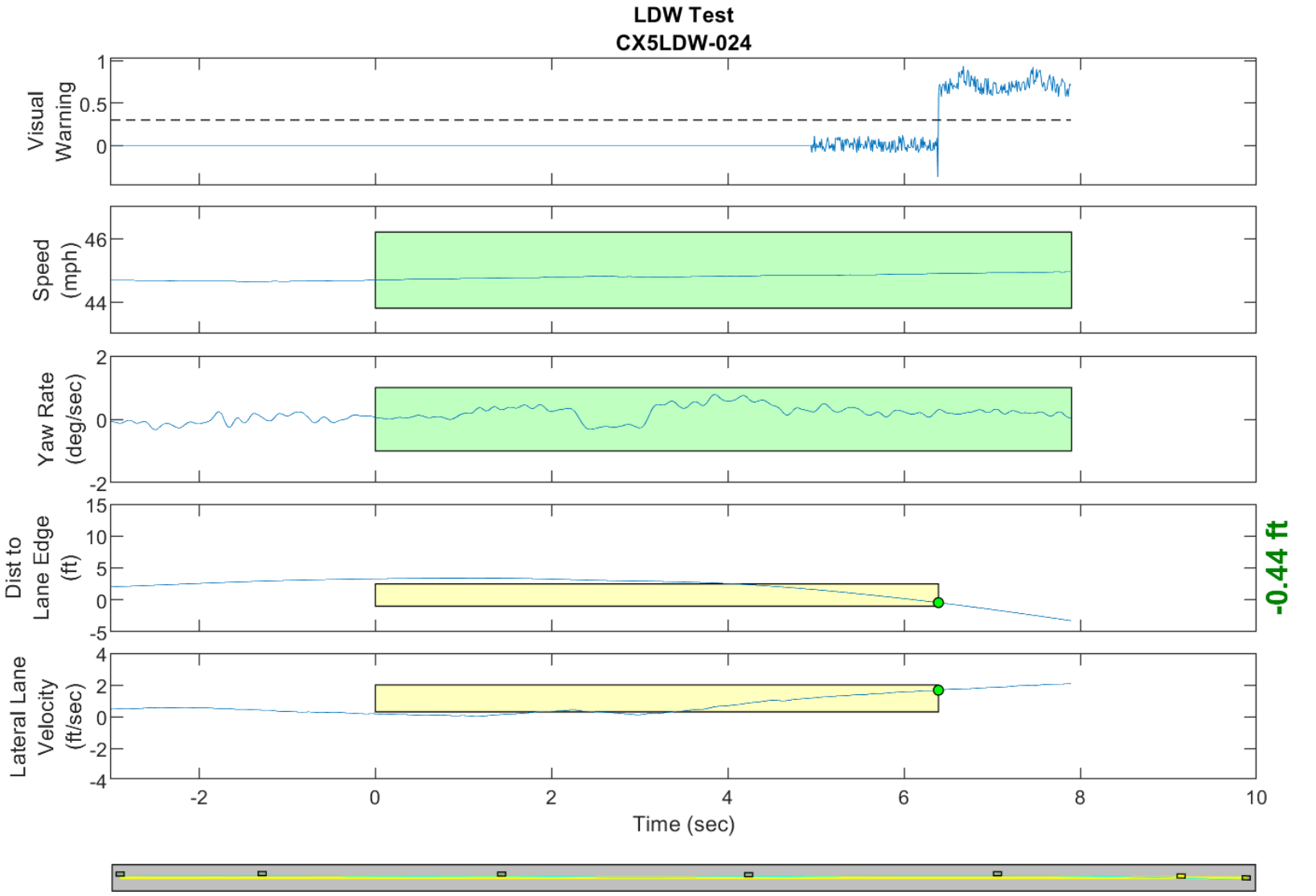


Figure D45. Time History for Run 24, Solid Line, Right Departure, Visual Warning

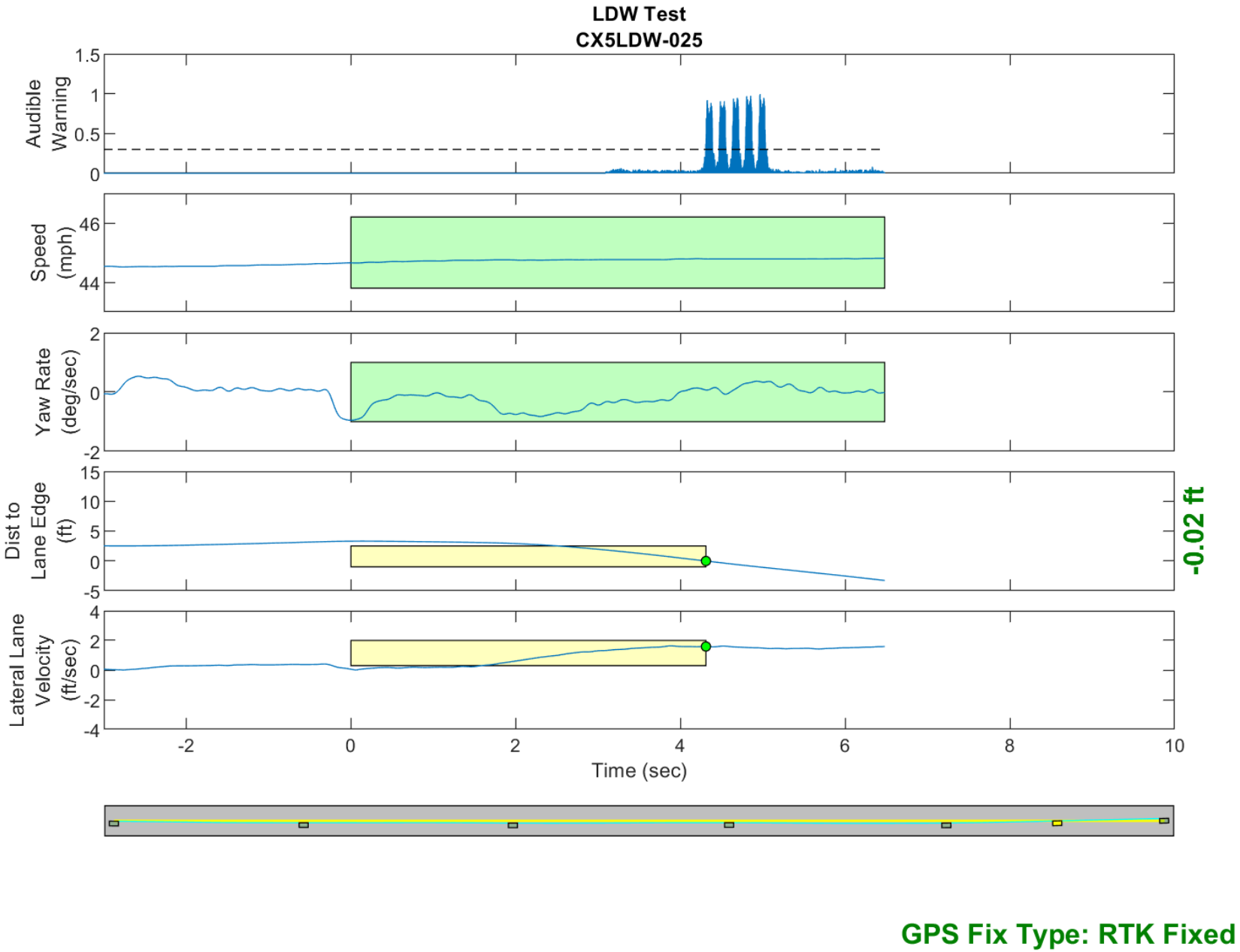


Figure D46. Time History for Run 25, Solid Line, Left Departure, Auditory Warning

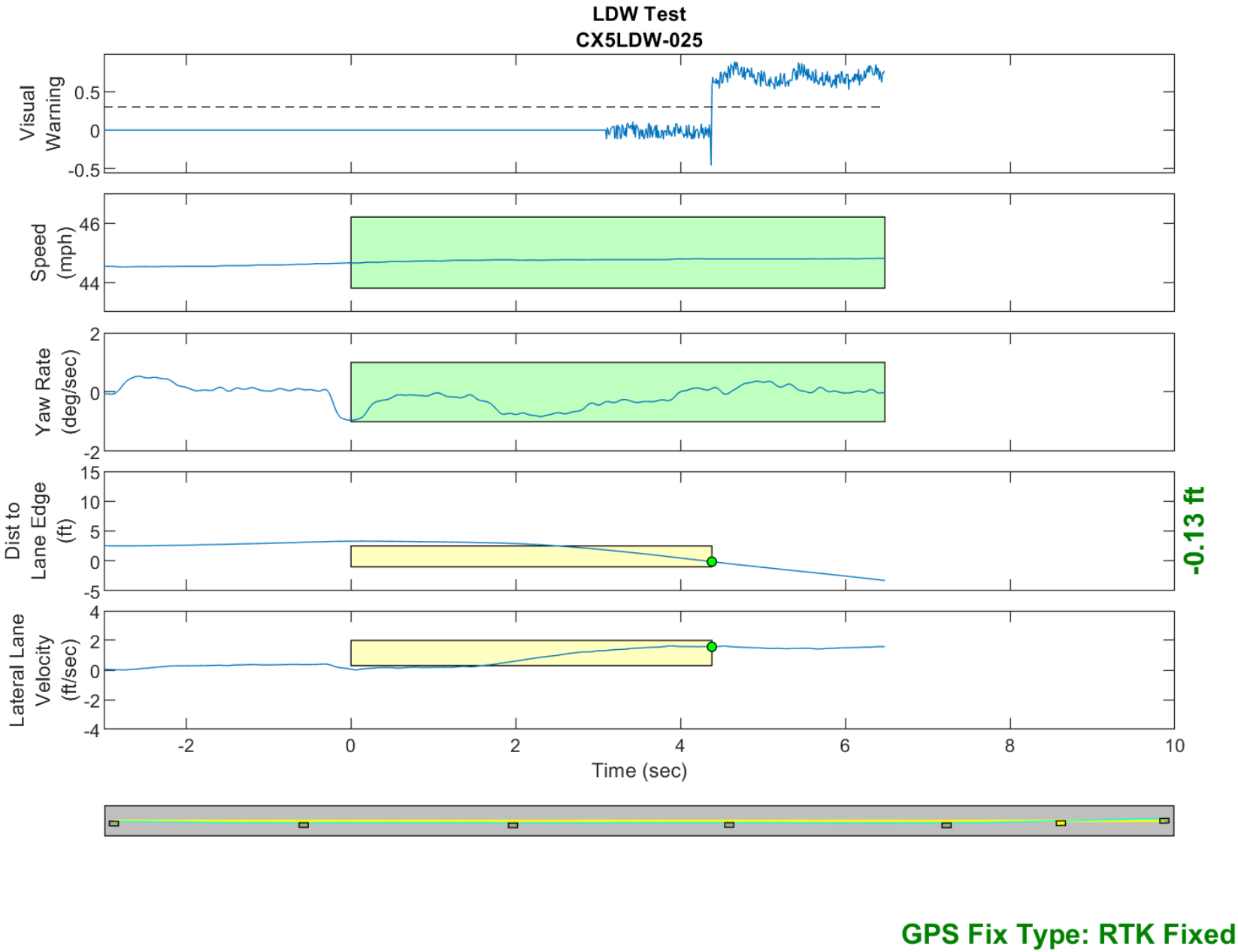


Figure D47. Time History for Run 25, Solid Line, Left Departure, Visual Warning

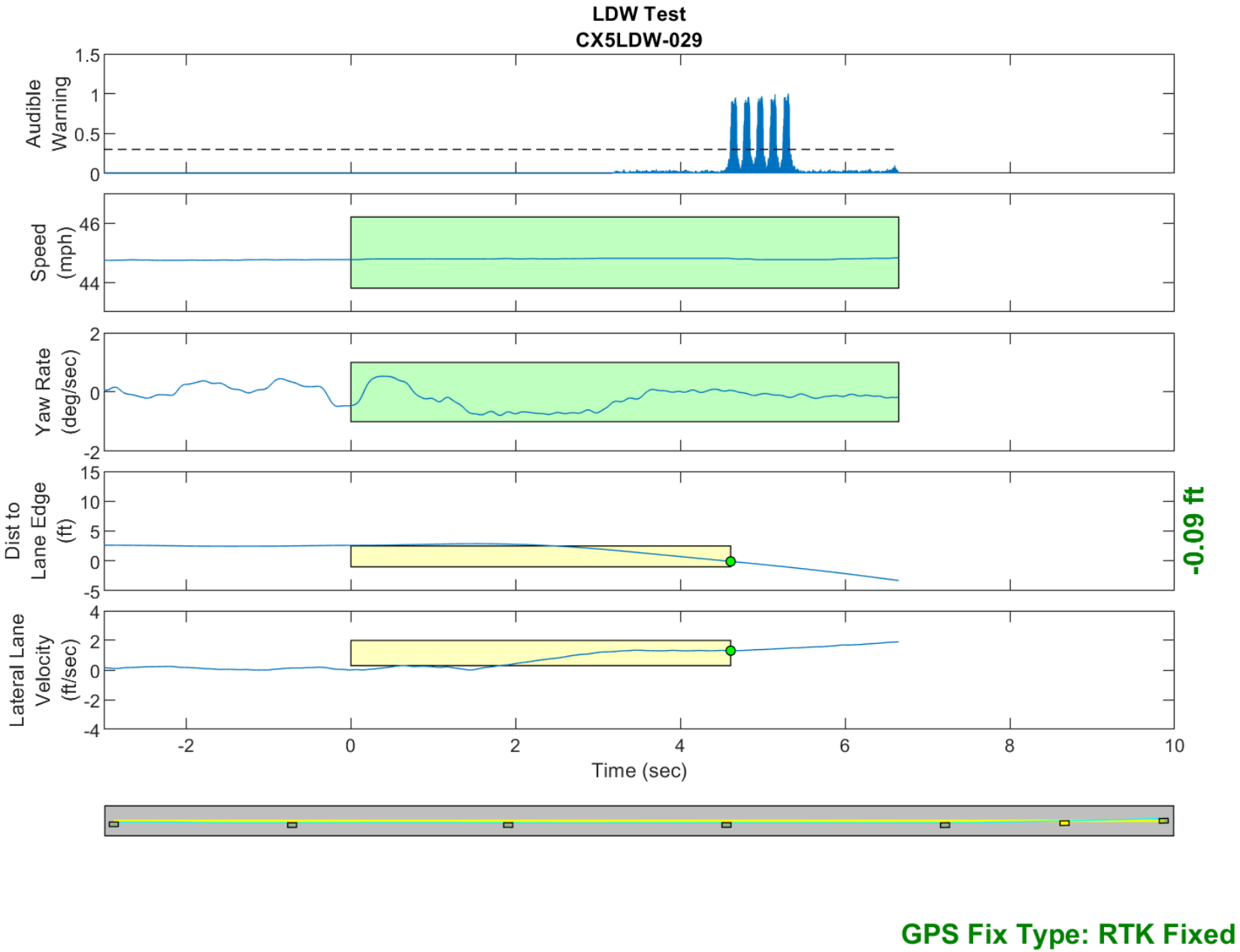


Figure D48. Time History for Run 29, Solid Line, Left Departure, Auditory Warning

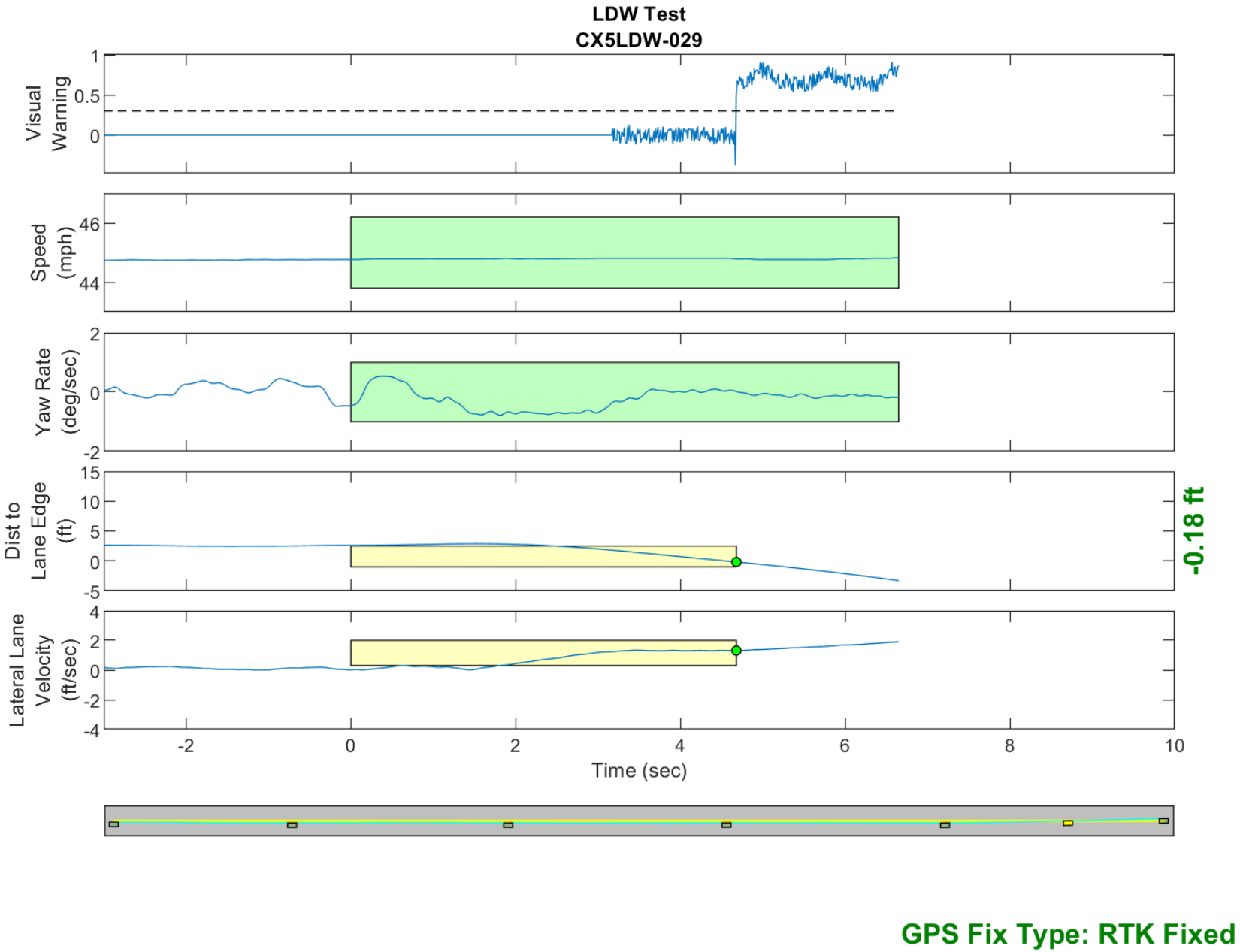


Figure D49. Time History for Run 29, Solid Line, Left Departure, Visual Warning

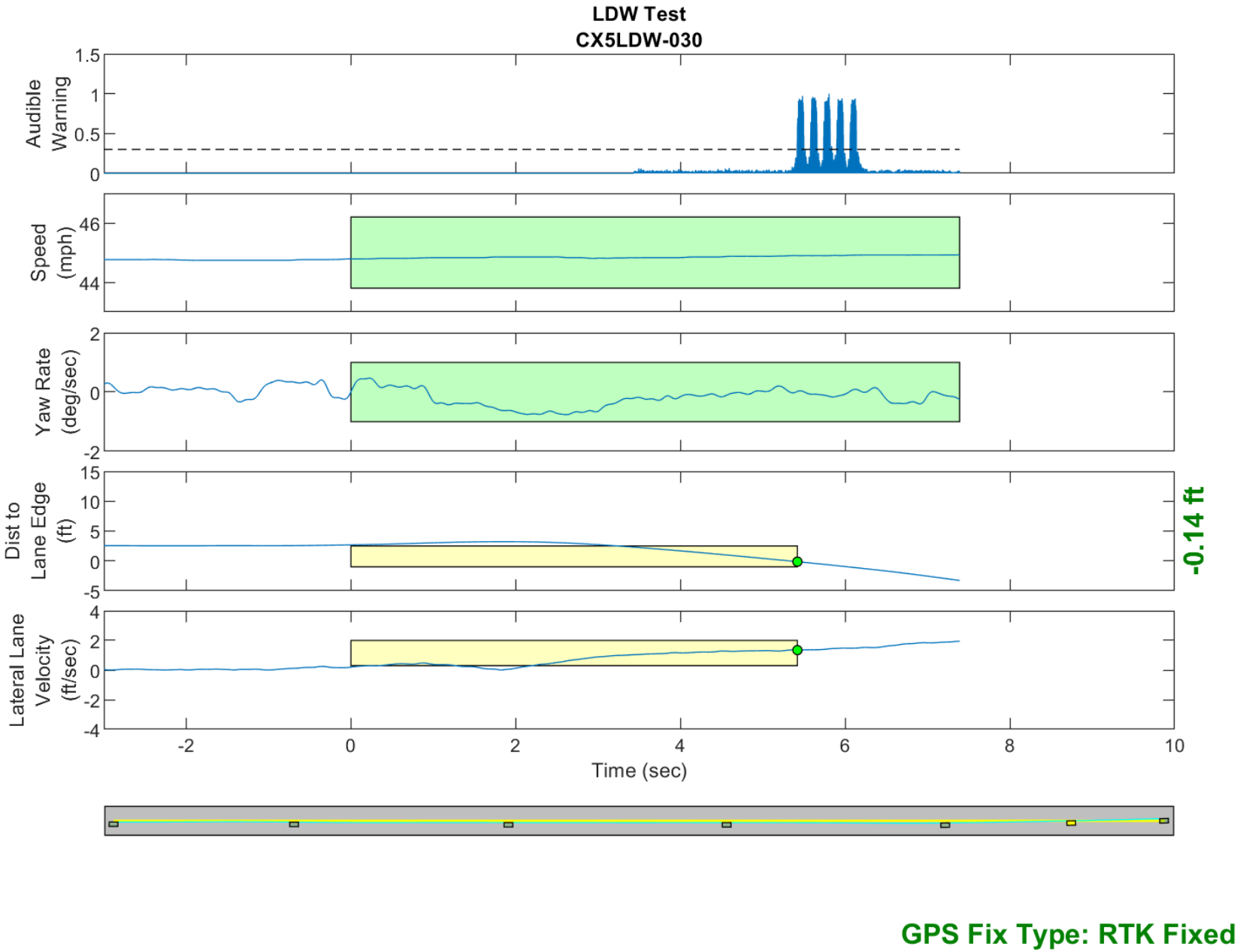


Figure D50. Time History for Run 30, Solid Line, Left Departure, Auditory Warning

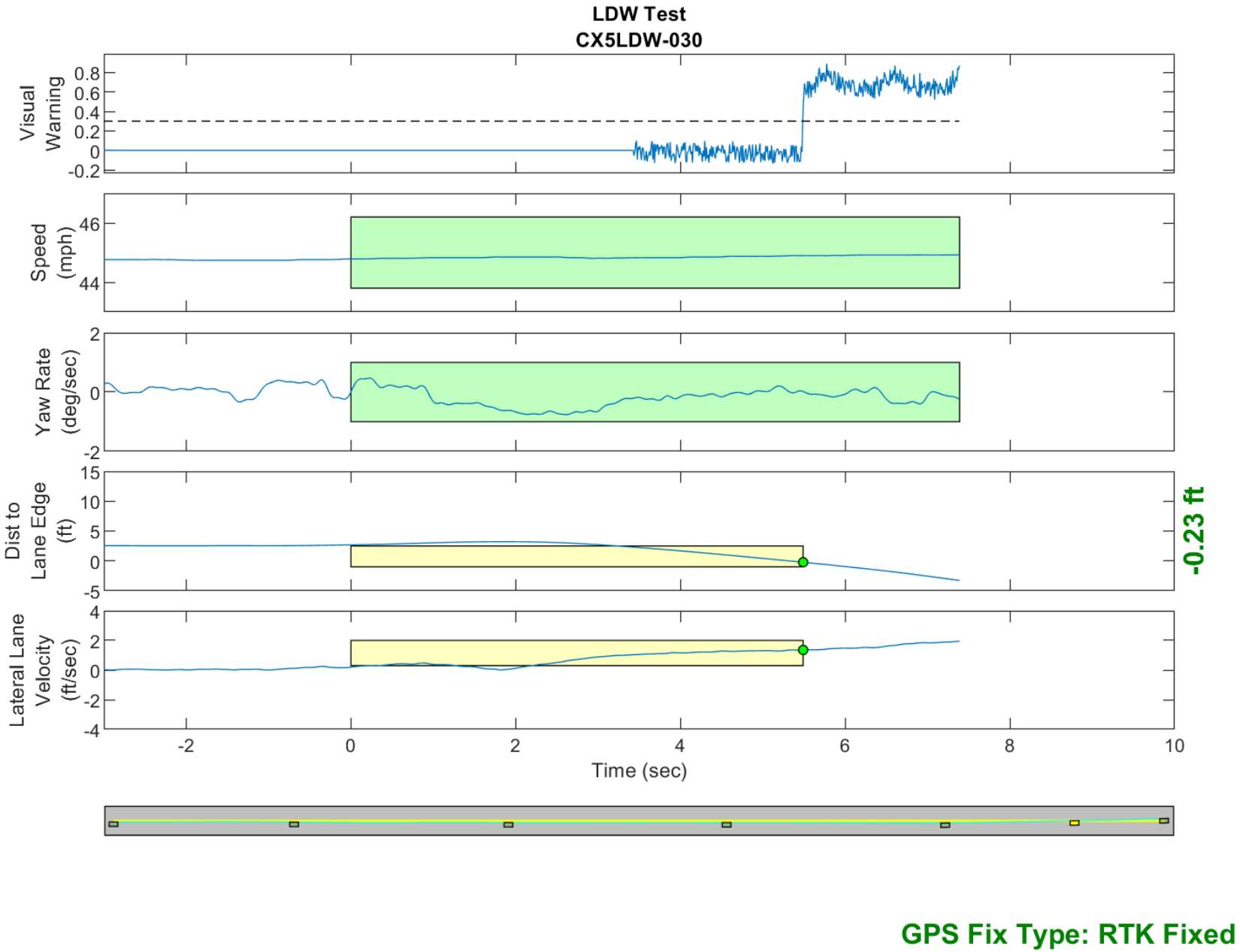


Figure D51. Time History for Run 30, Solid Line, Left Departure, Visual Warning

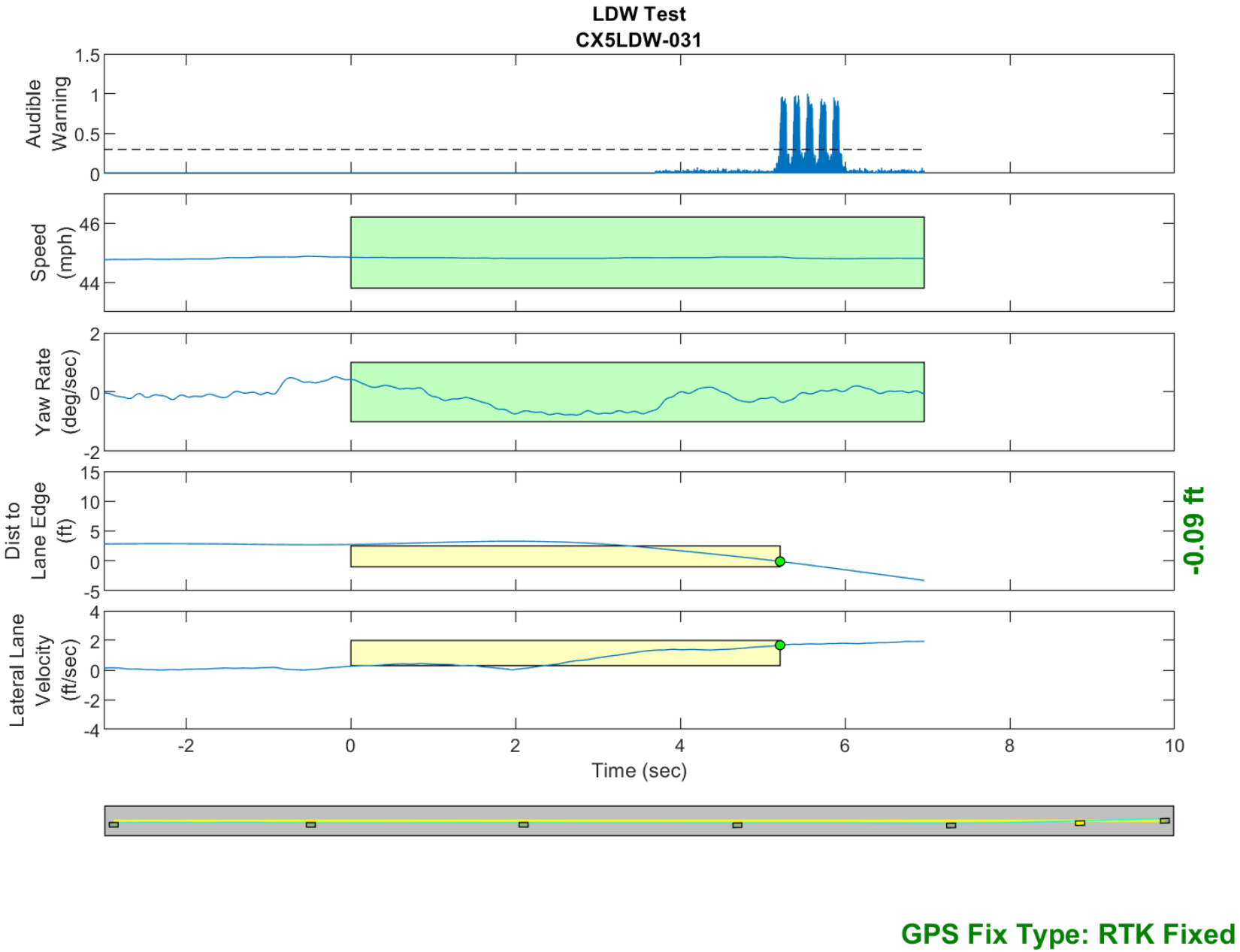


Figure D52. Time History for Run 31, Solid Line, Left Departure, Auditory Warning

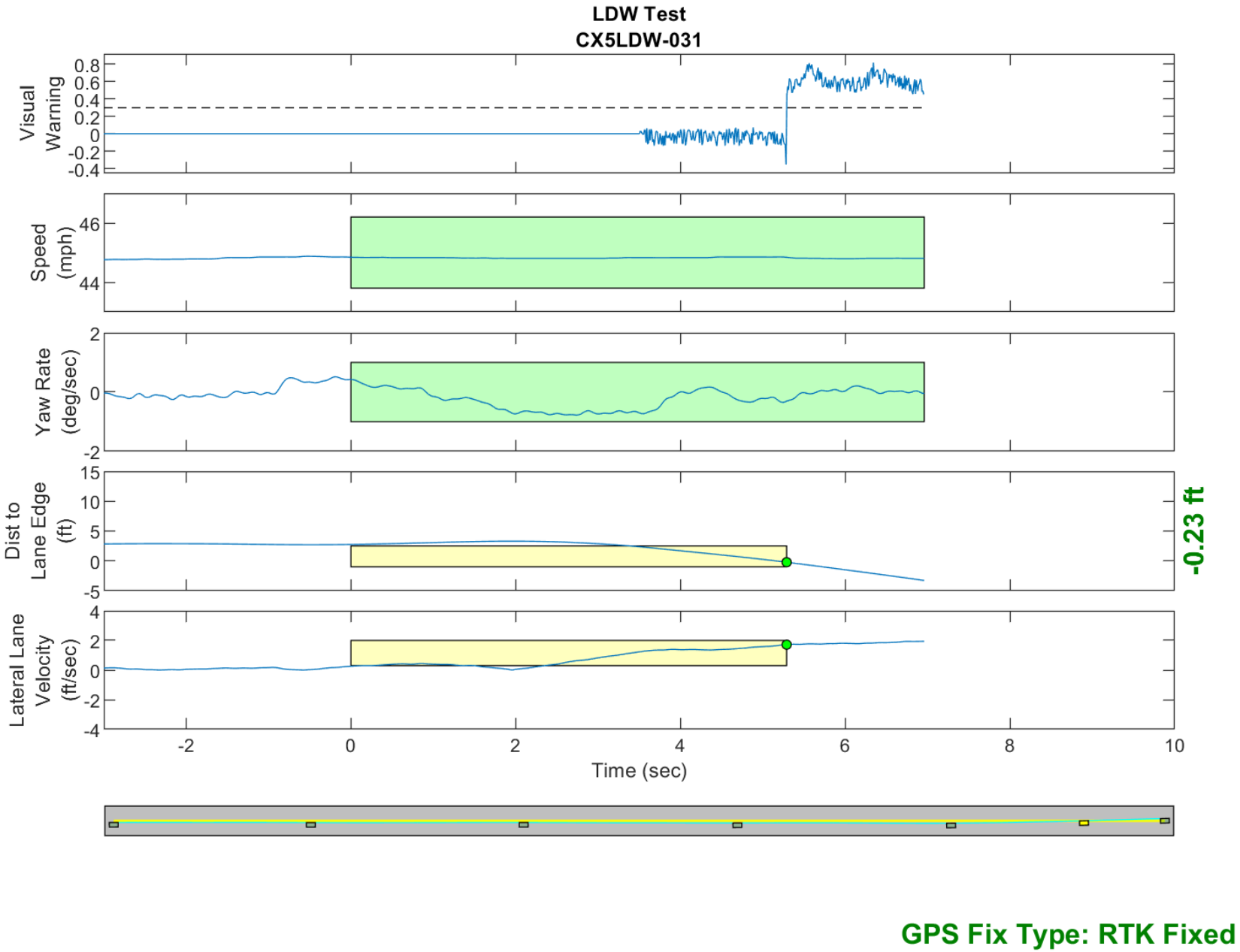


Figure D53. Time History for Run 31, Solid Line, Left Departure, Visual Warning

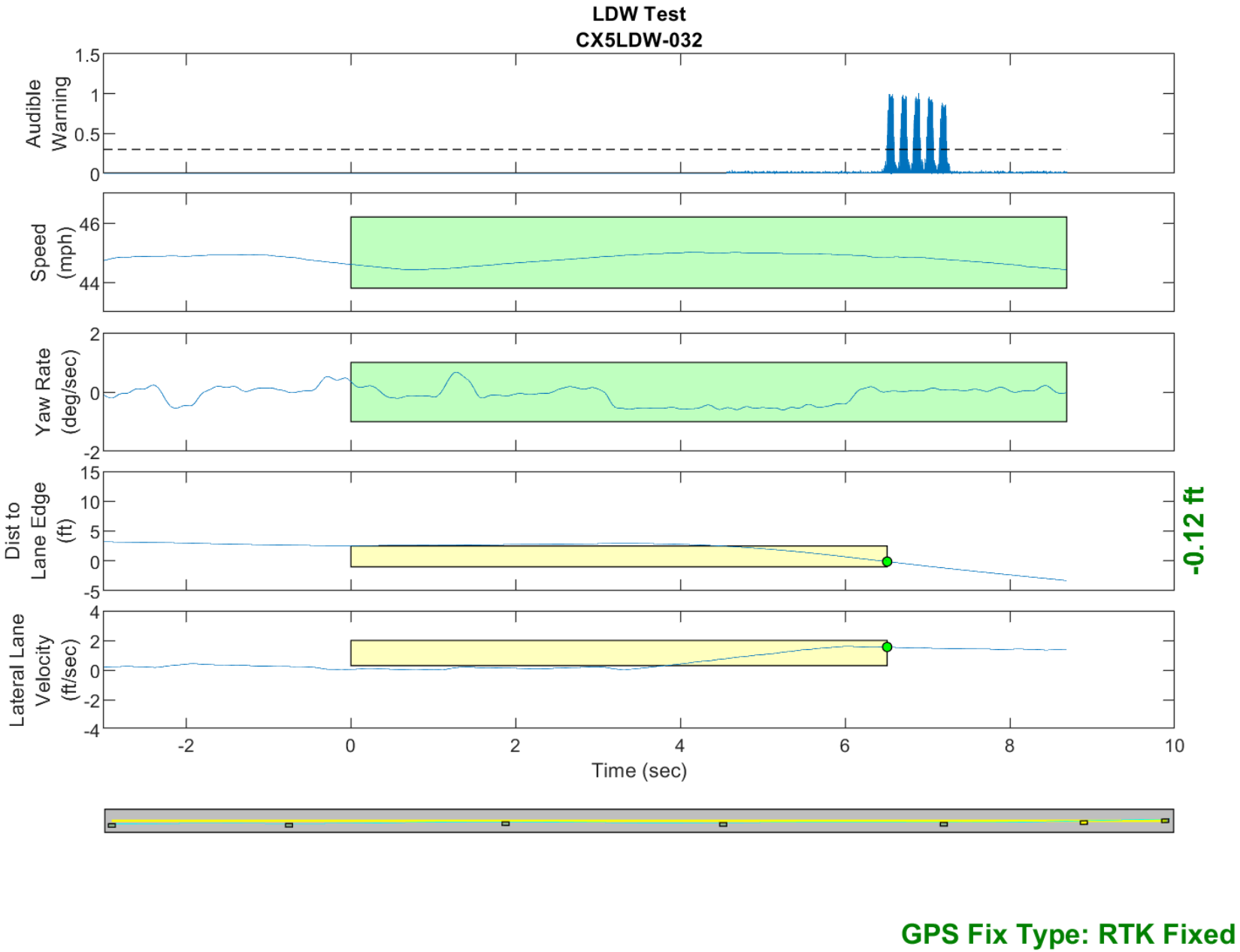


Figure D54. Time History for Run 32, Dashed Line, Left Departure, Auditory Warning

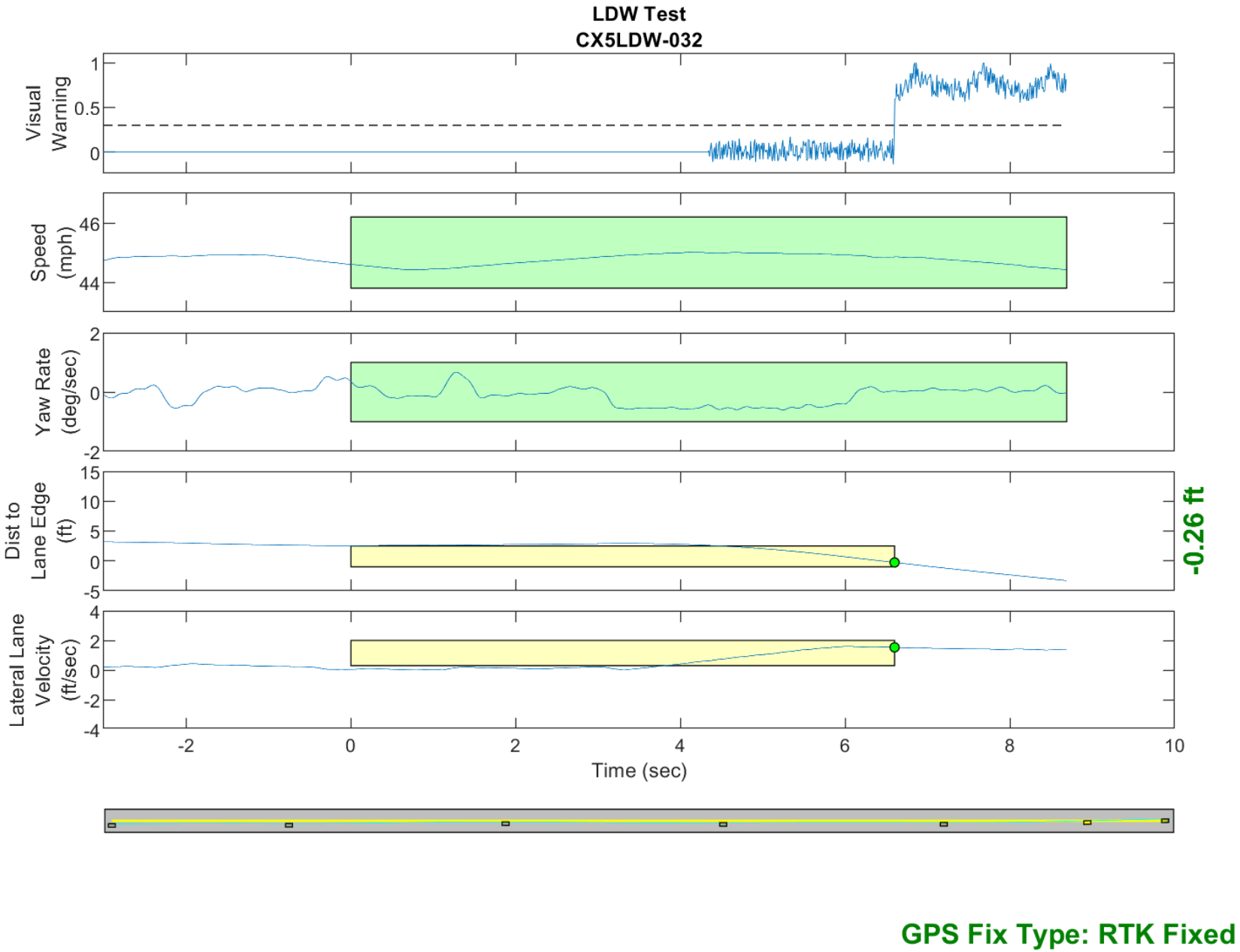


Figure D55. Time History for Run 32, Dashed Line, Left Departure, Visual Warning

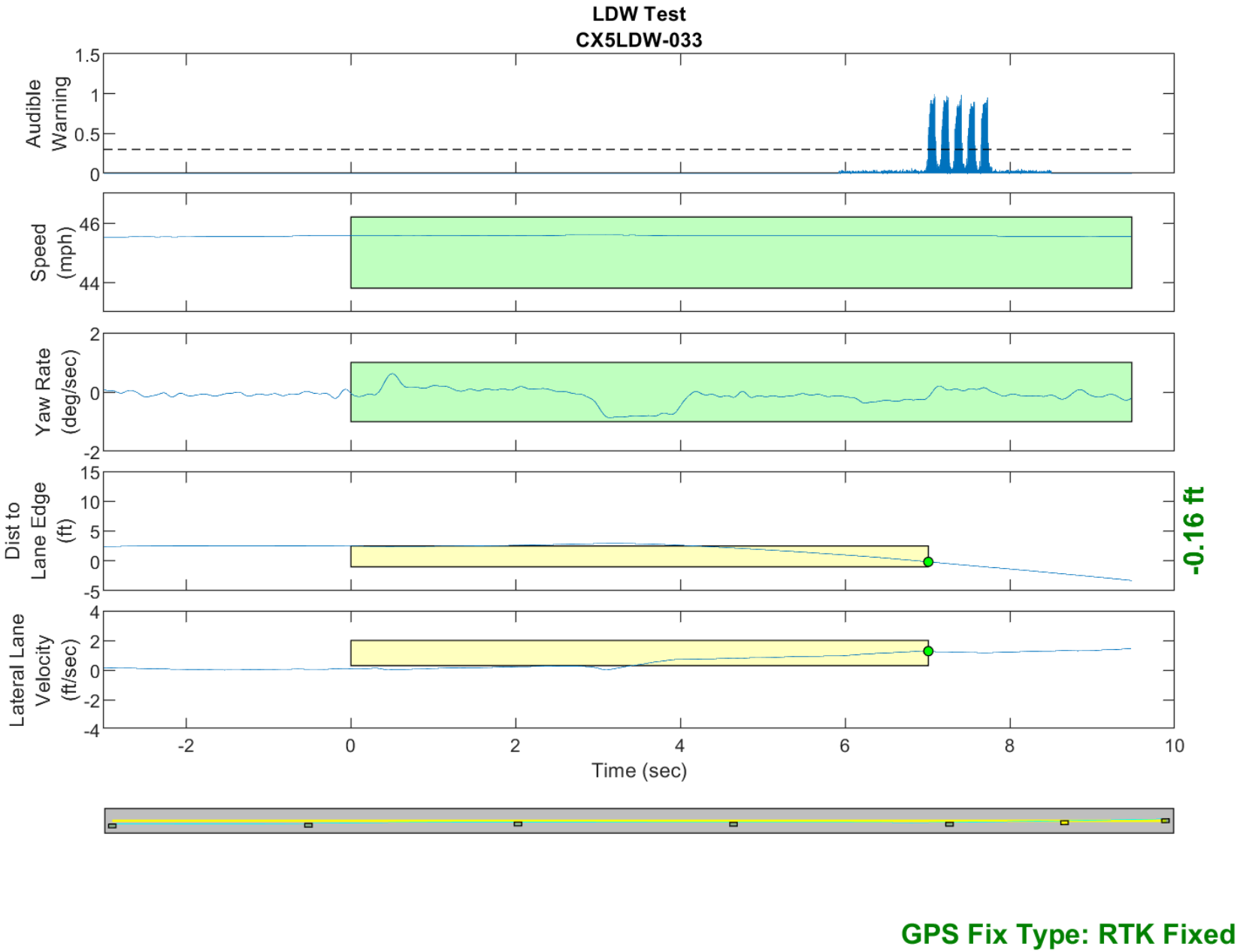


Figure D56. Time History for Run 33, Dashed Line, Left Departure, Auditory Warning

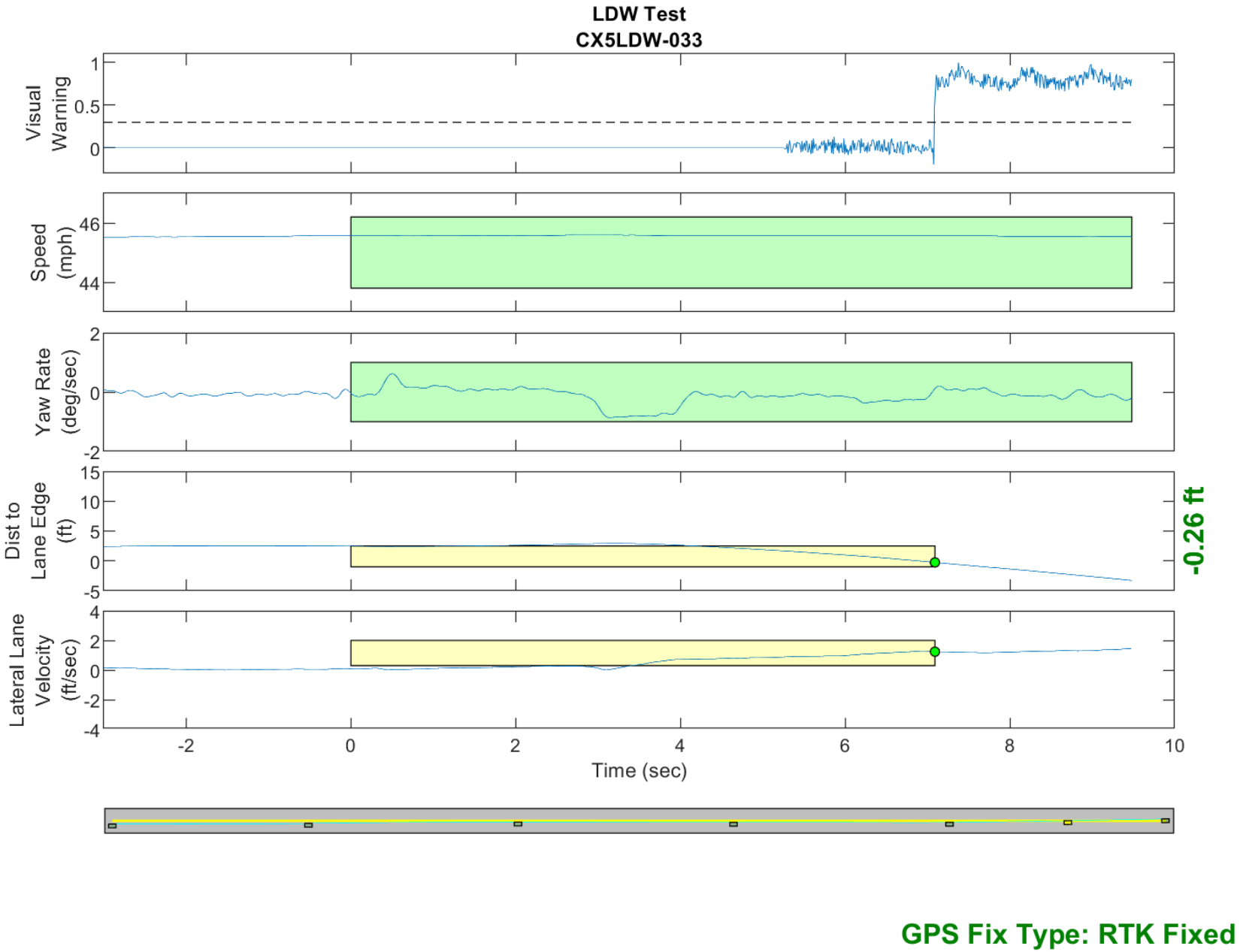


Figure D57. Time History for Run 33, Dashed Line, Left Departure, Visual Warning

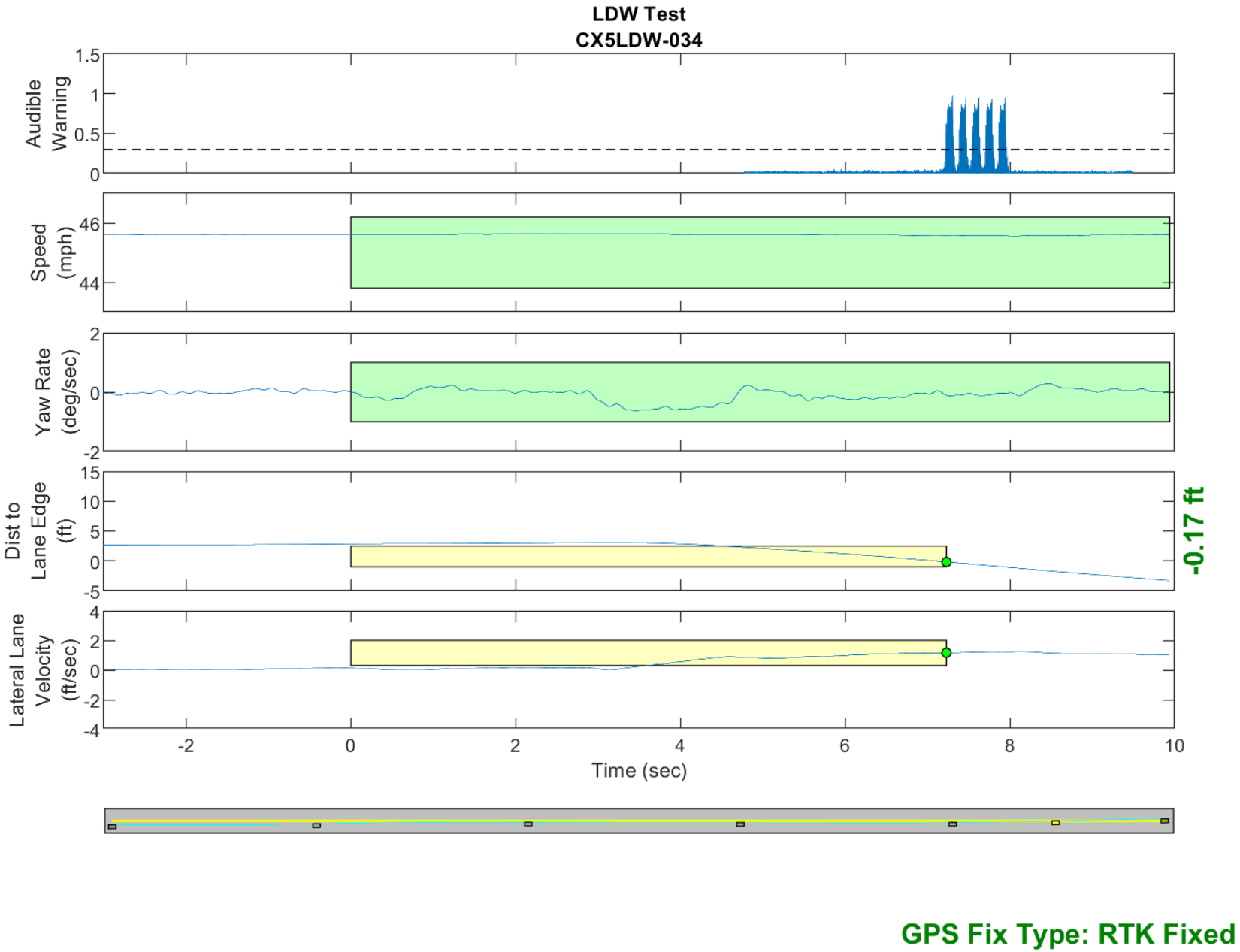


Figure D58. Time History for Run 34, Dashed Line, Left Departure, Auditory Warning

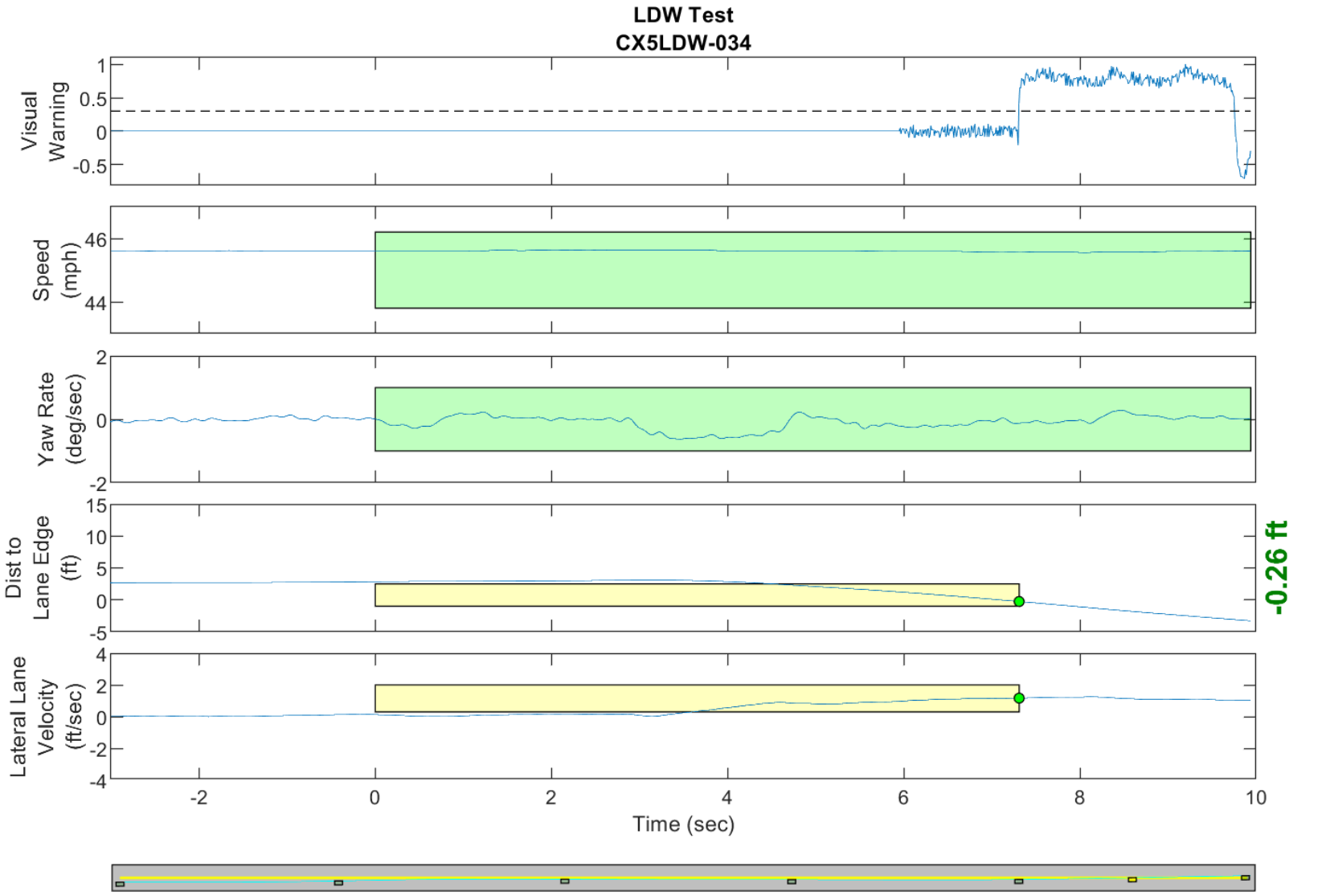


Figure D59. Time History for Run 34, Dashed Line, Left Departure, Visual Warning

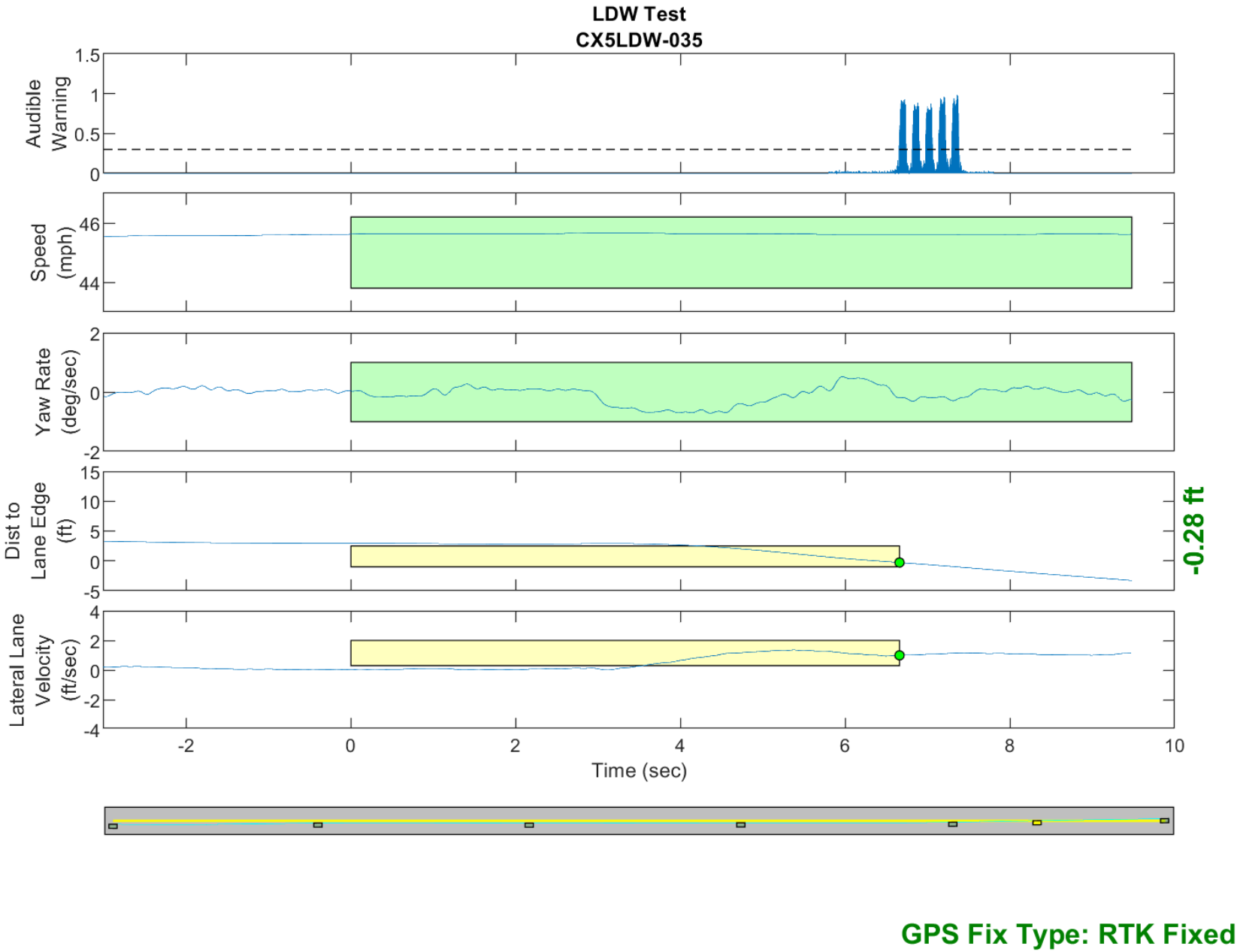


Figure D60. Time History for Run 35, Dashed Line, Left Departure, Auditory Warning

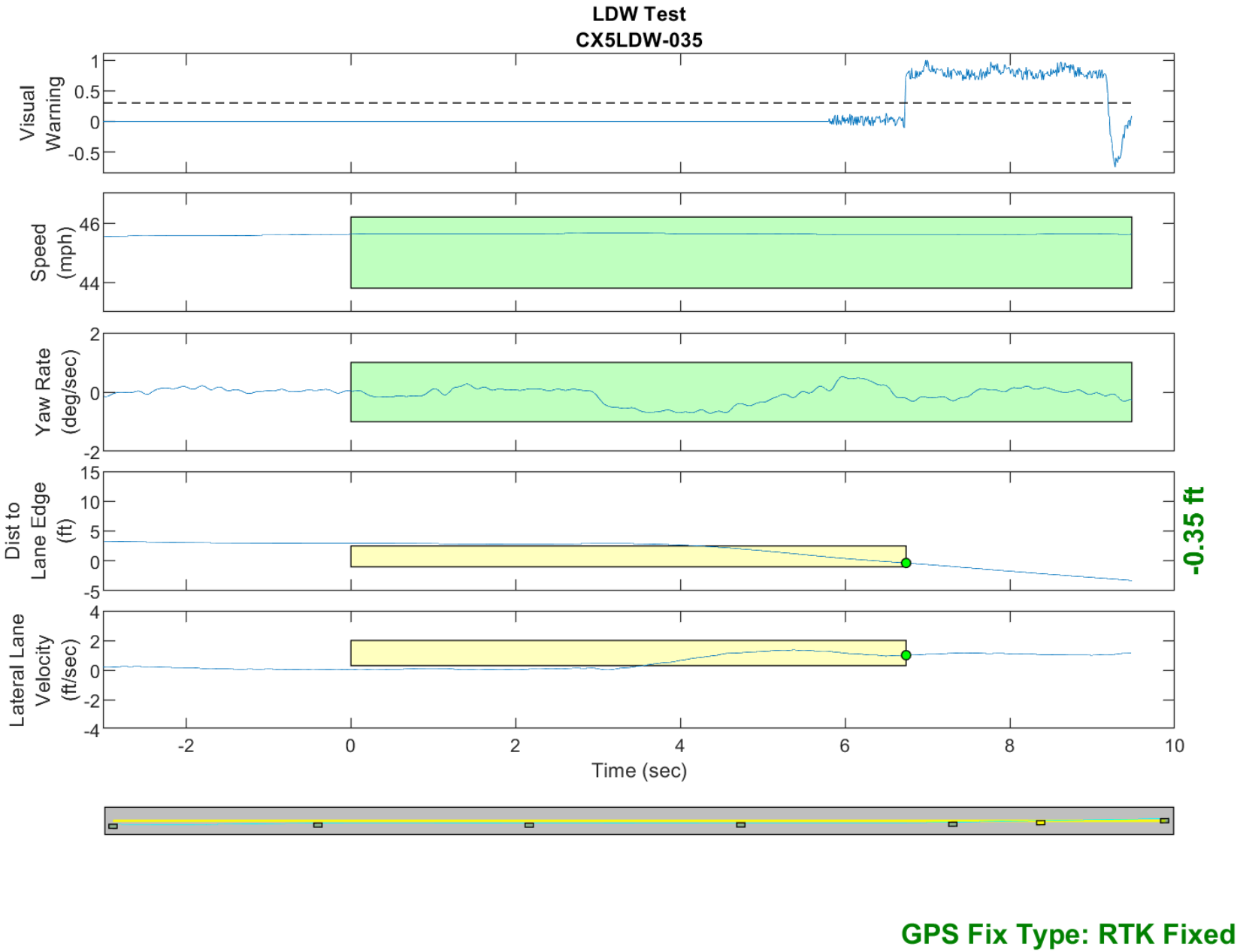


Figure D61. Time History for Run 35, Dashed Line, Left Departure, Visual Warning

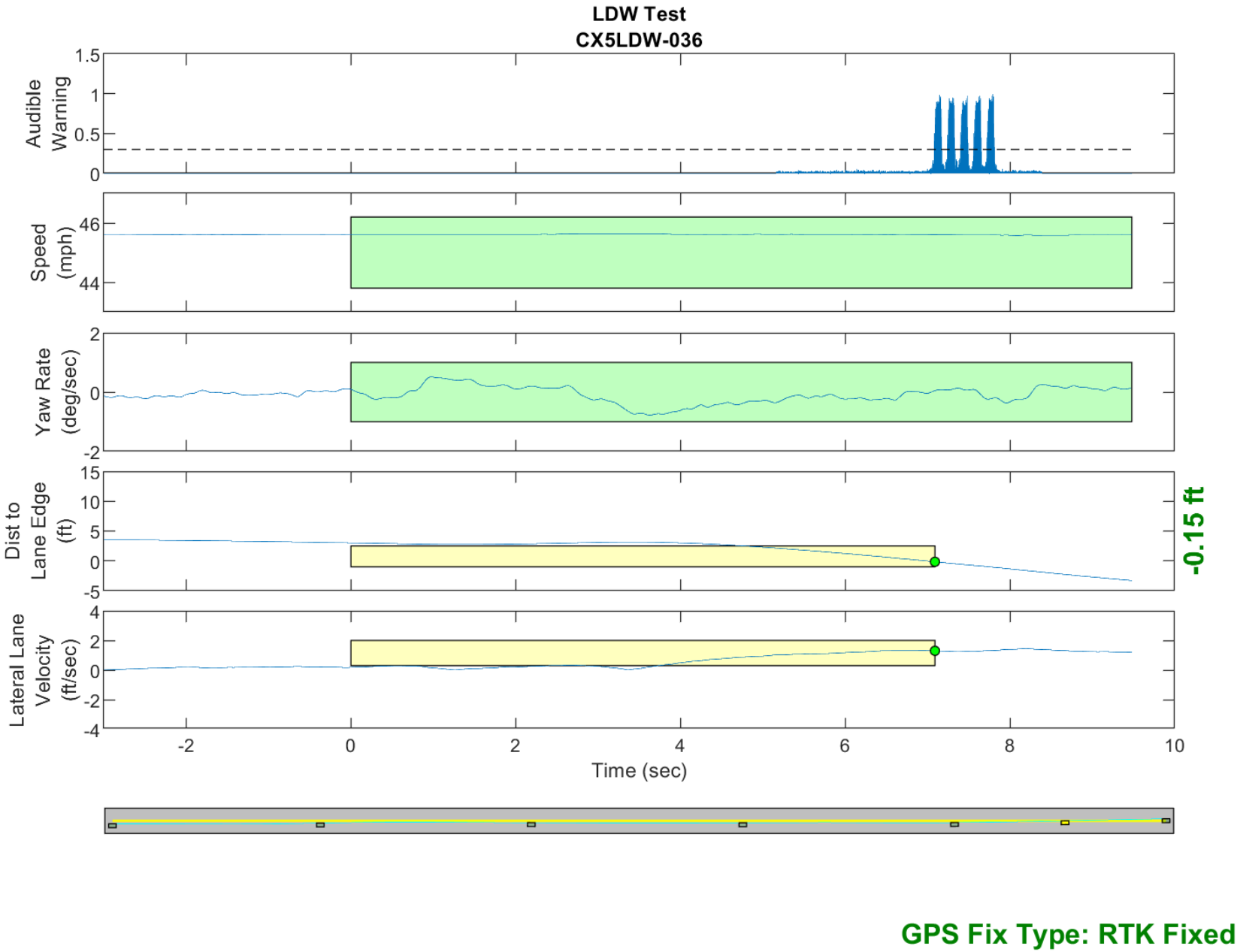


Figure D62. Time History for Run 36, Dashed Line, Left Departure, Auditory Warning

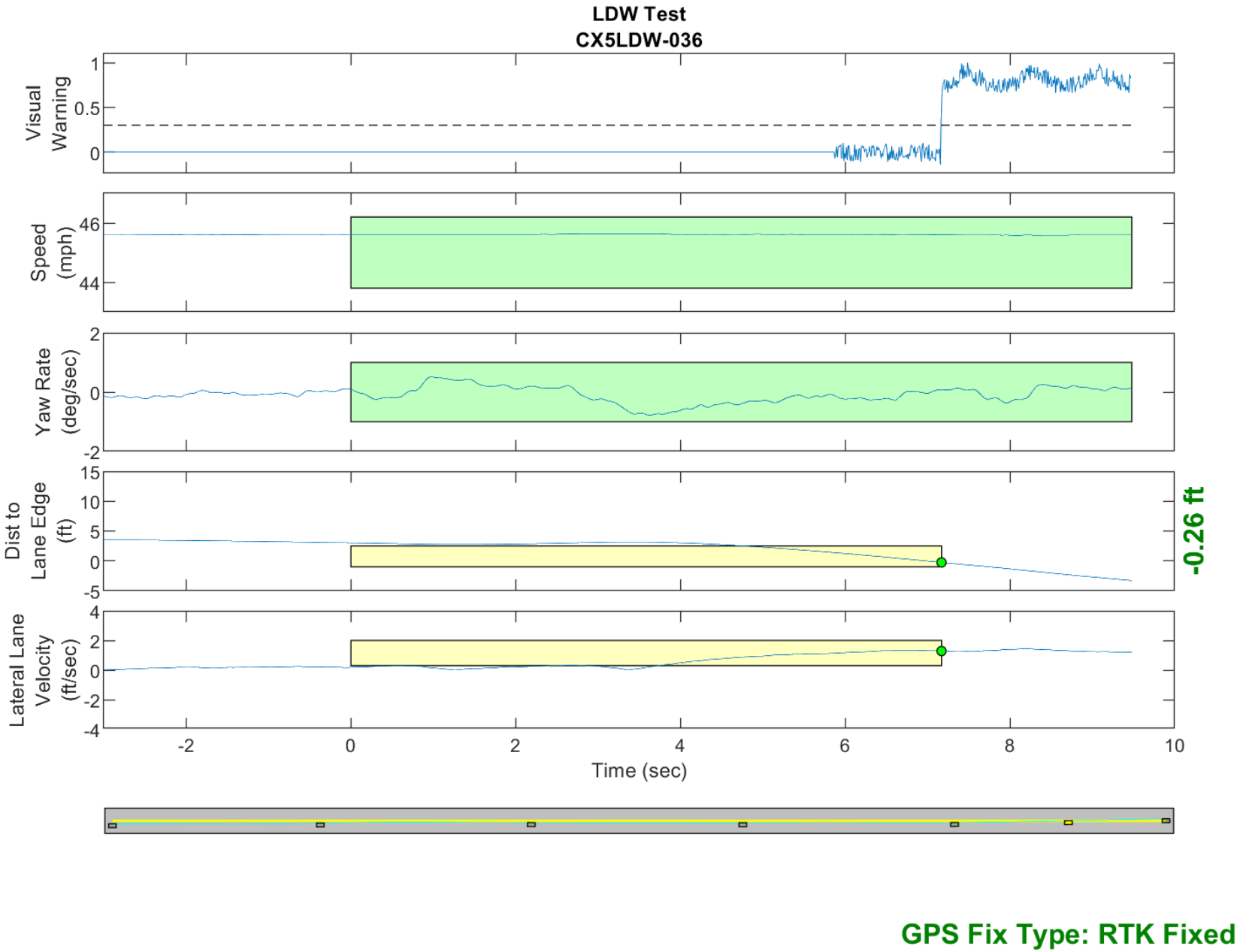


Figure D63. Time History for Run 36, Dashed Line, Left Departure, Visual Warning

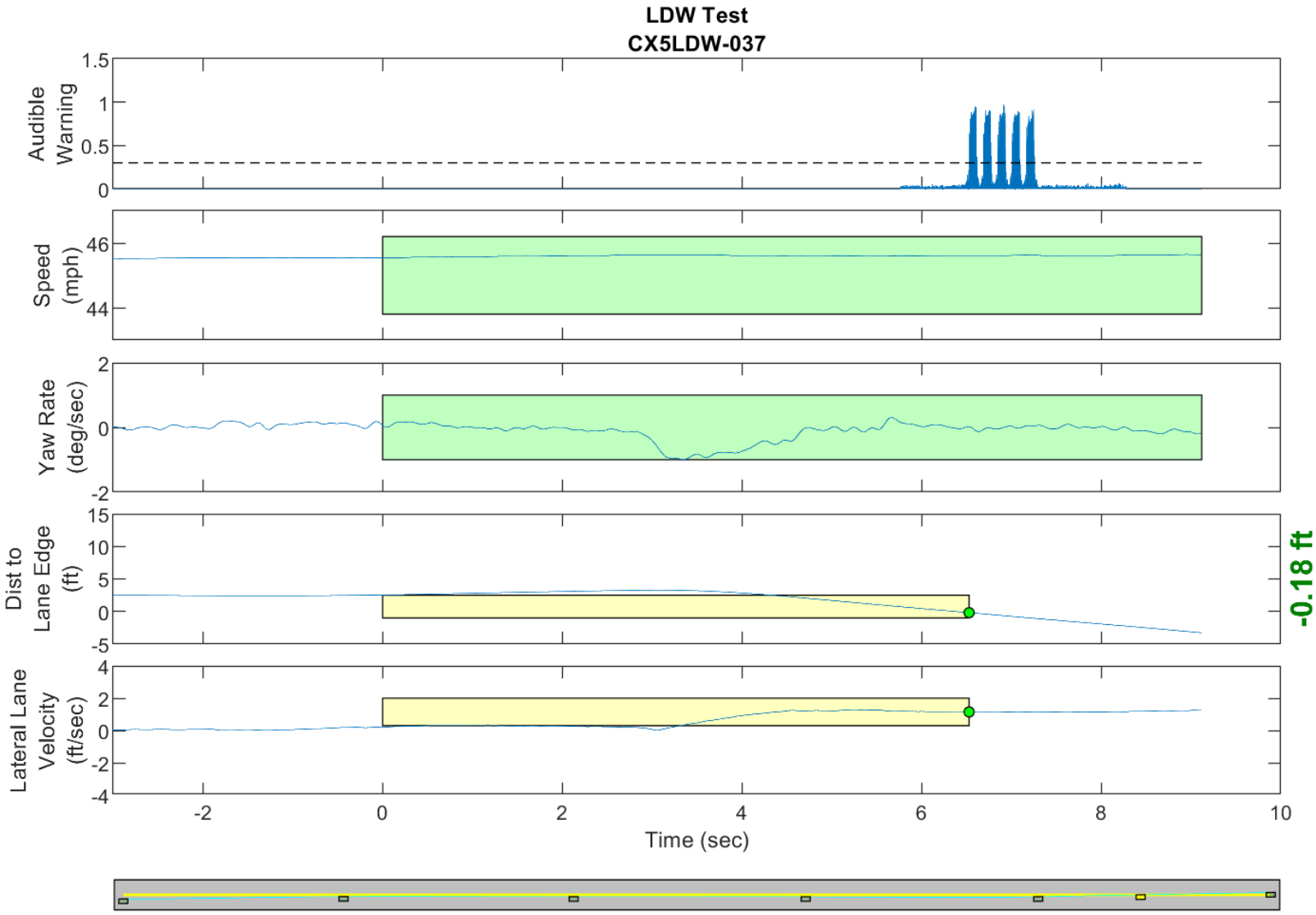


Figure D64. Time History for Run 37, Dashed Line, Left Departure, Auditory Warning

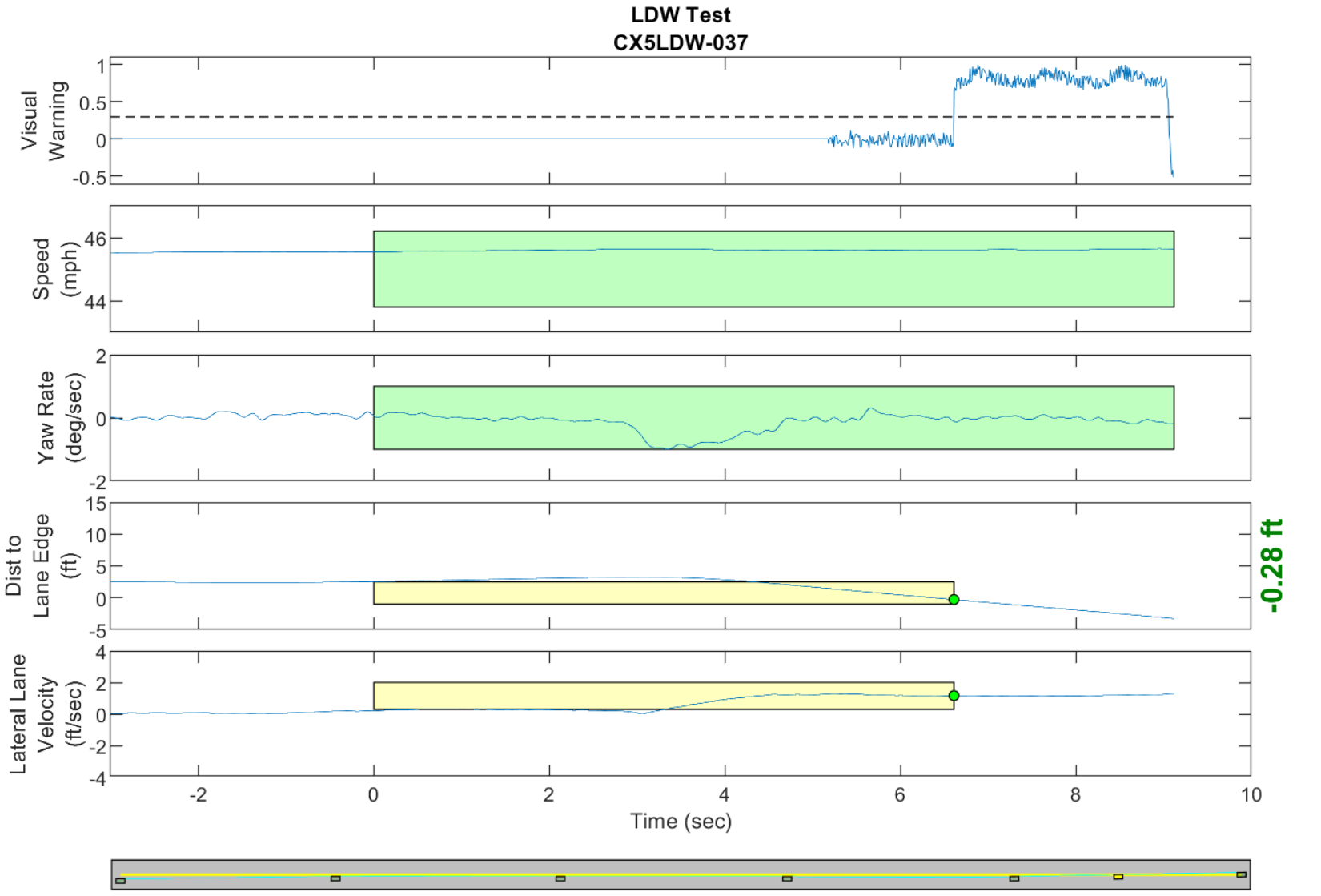


Figure D65. Time History for Run 37, Dashed Line, Left Departure, Visual Warning

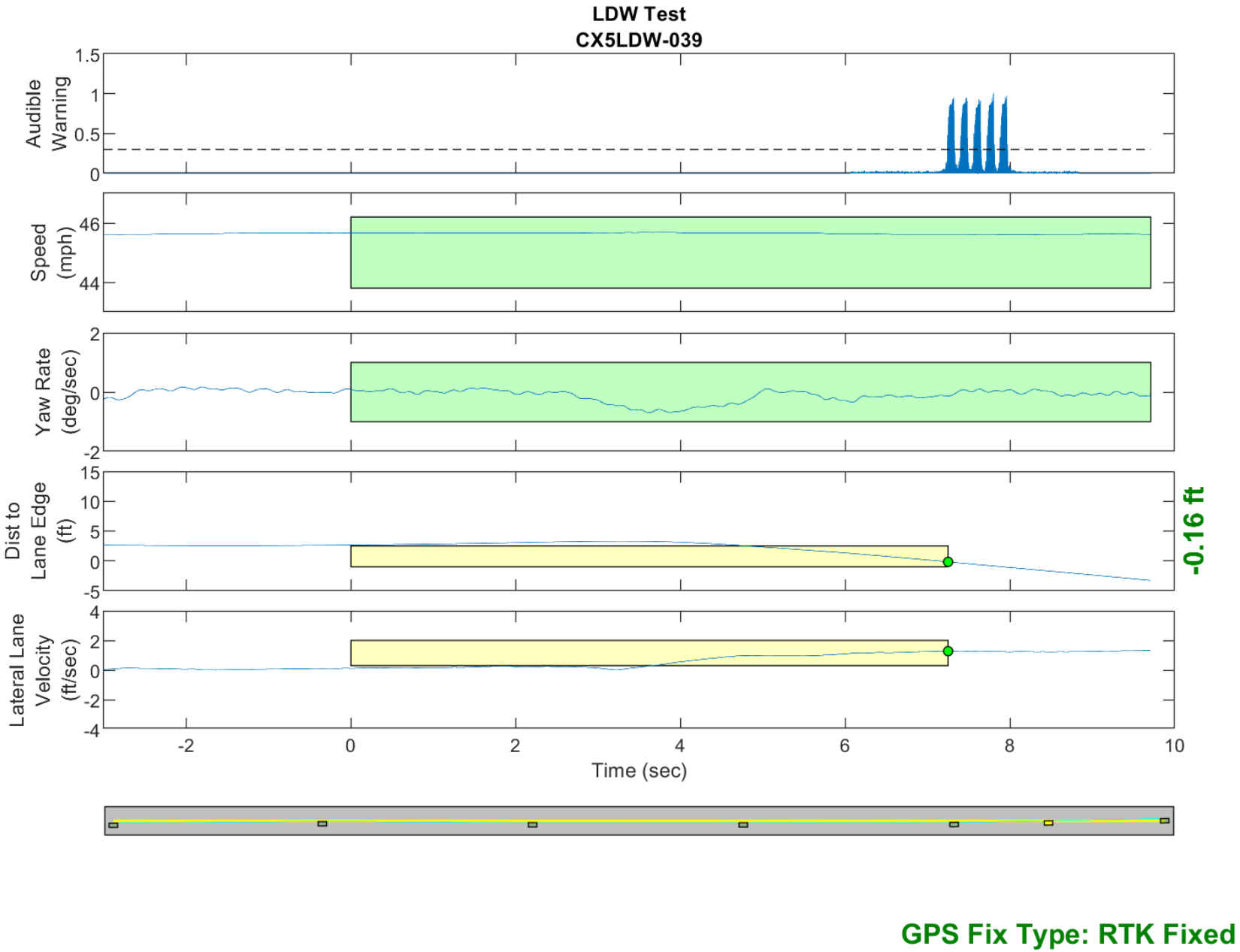


Figure D66. Time History for Run 39, Dashed Line, Left Departure, Auditory Warning

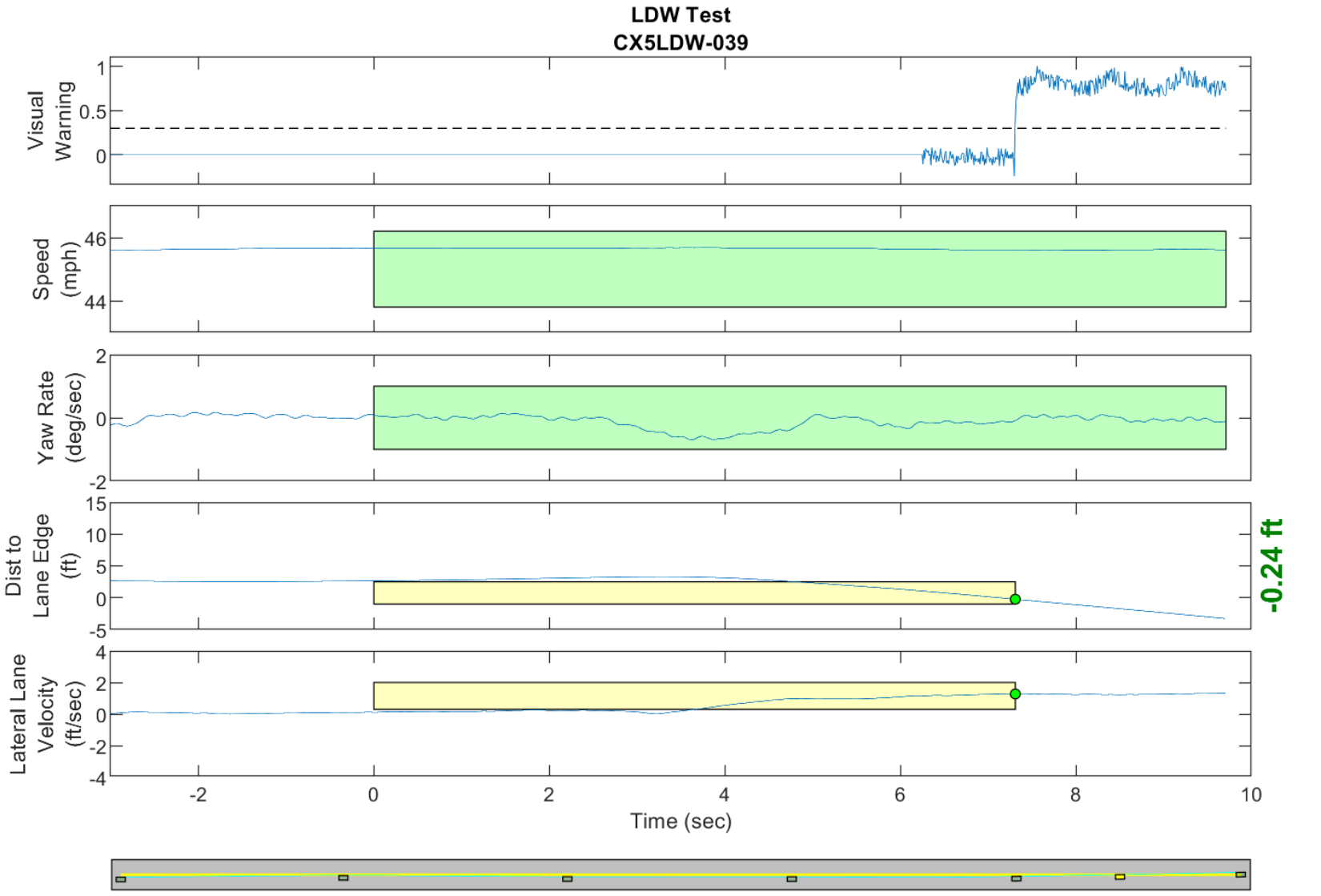


Figure D67. Time History for Run 39, Dashed Line, Left Departure, Visual Warning

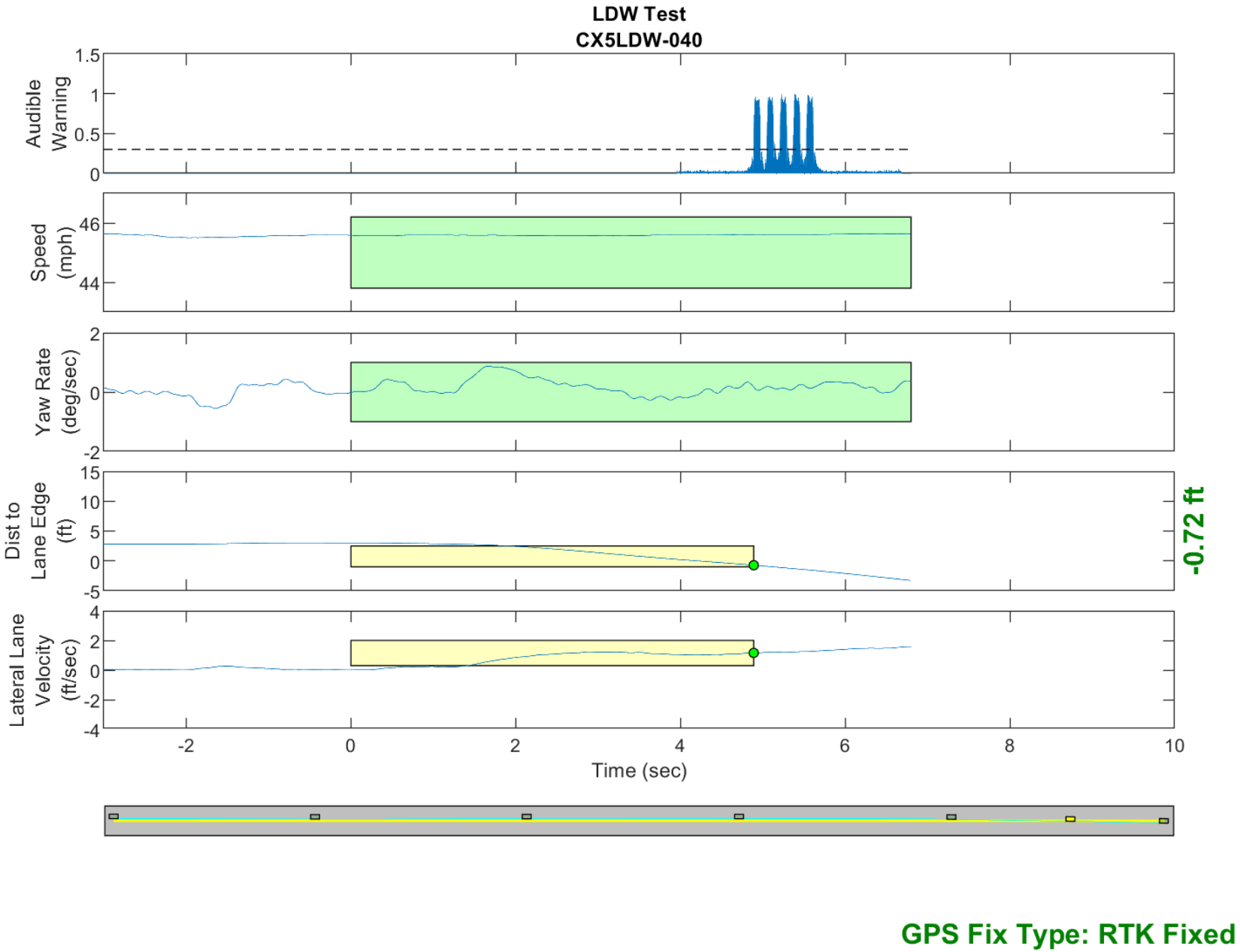


Figure D68. Time History for Run 40, Dashed Line, Right Departure, Auditory Warning

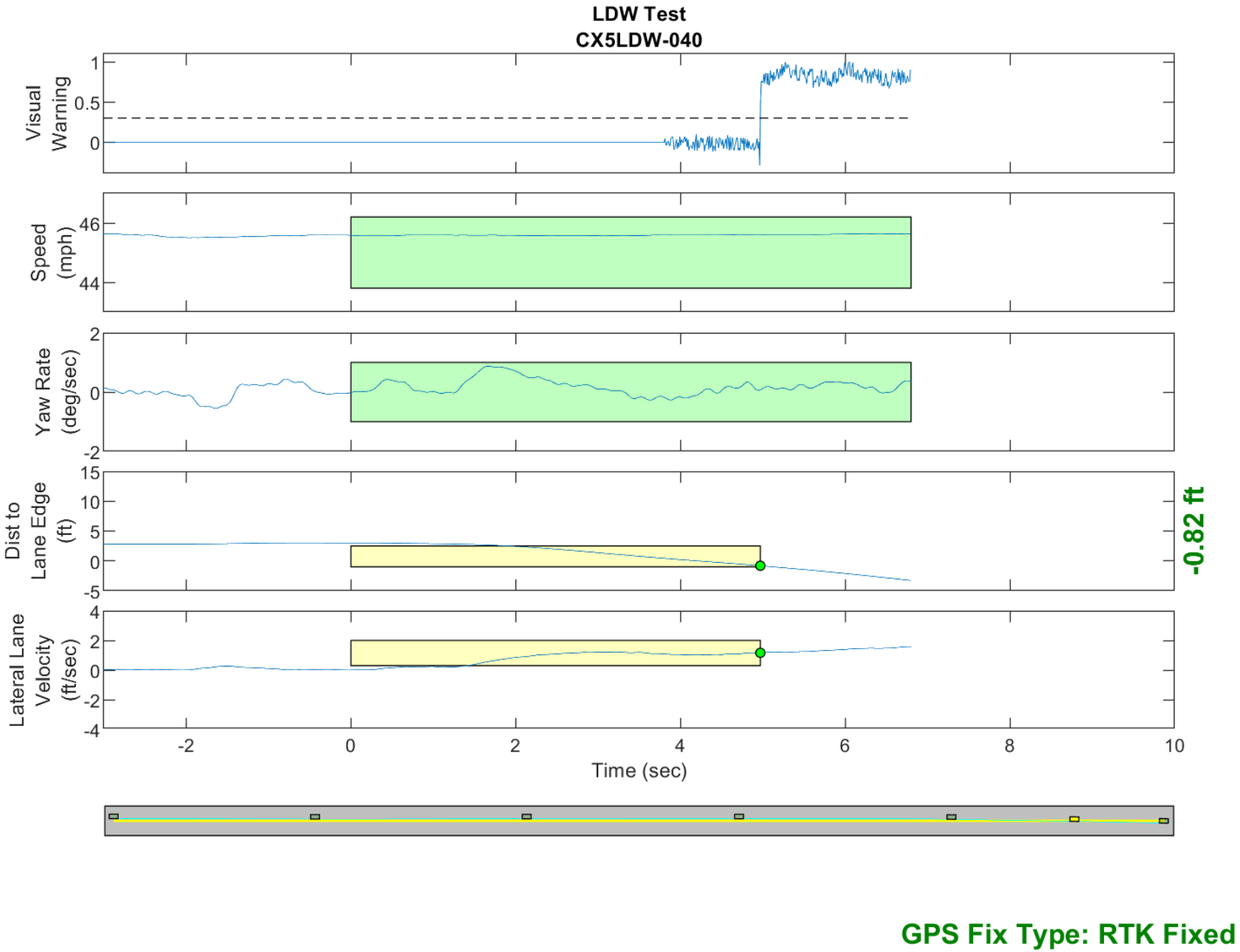


Figure D69. Time History for Run 40, Dashed Line, Right Departure, Visual Warning

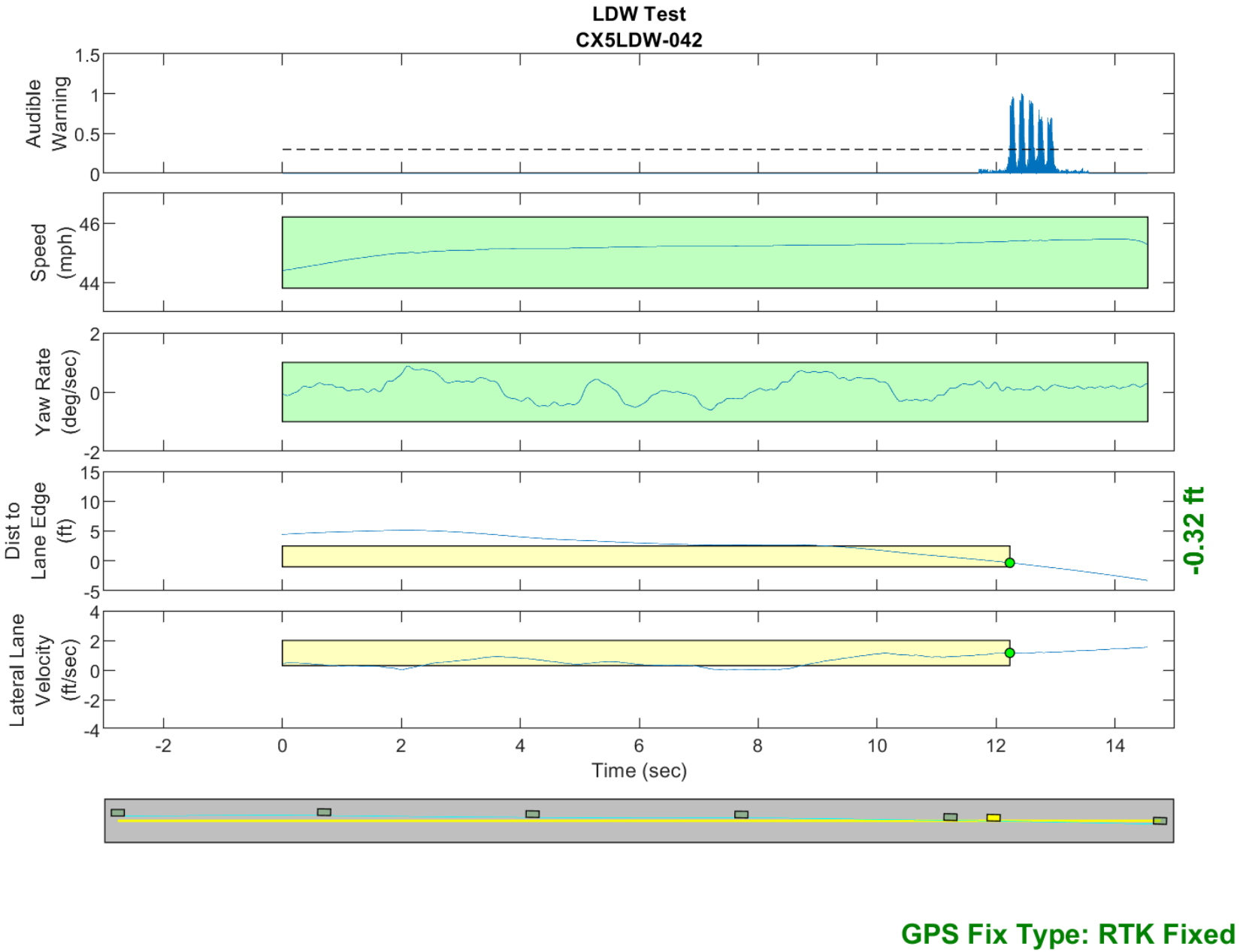


Figure D70. Time History for Run 42, Dashed Line, Right Departure, Auditory Warning

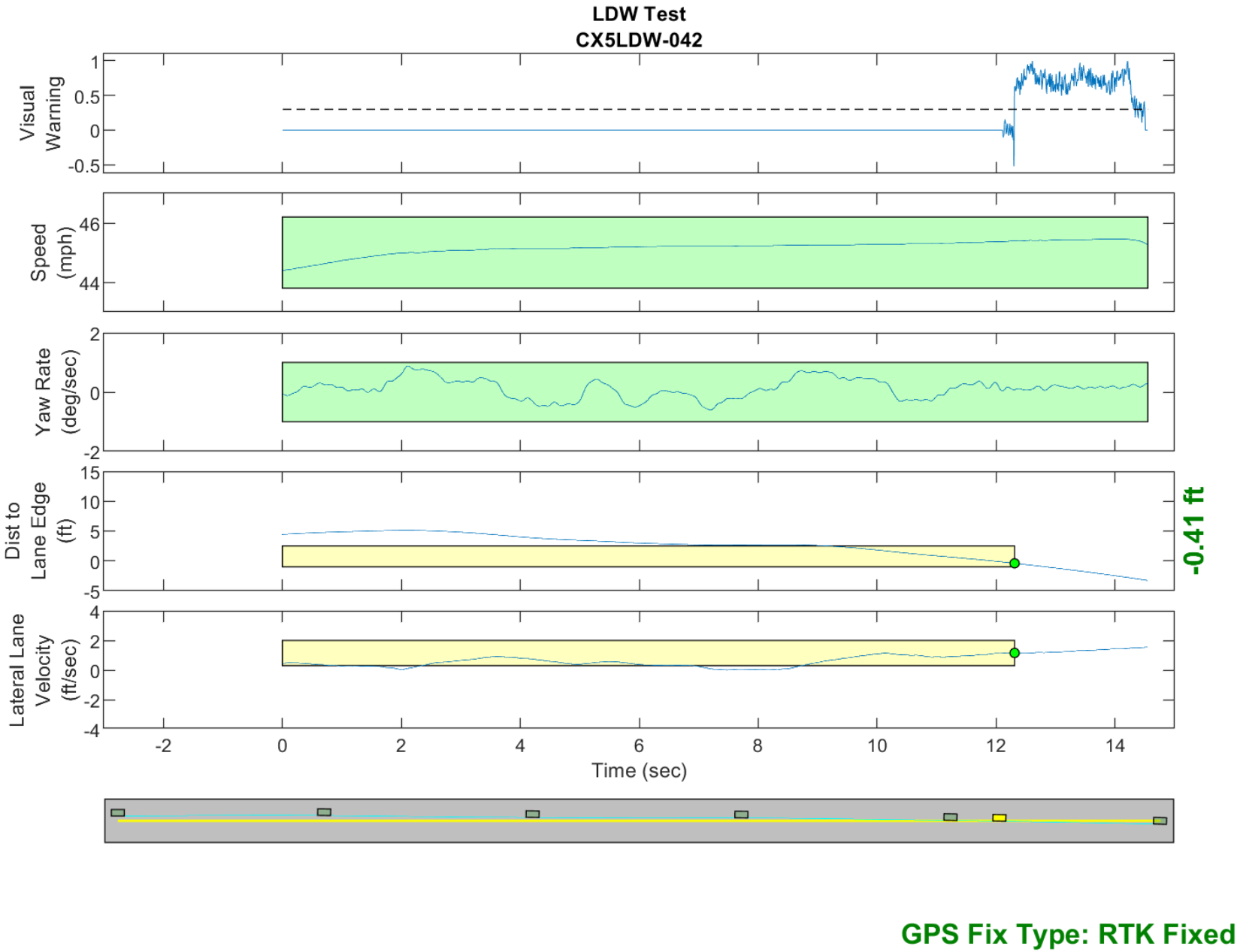


Figure D71. Time History for Run 42, Dashed Line, Right Departure, Visual Warning

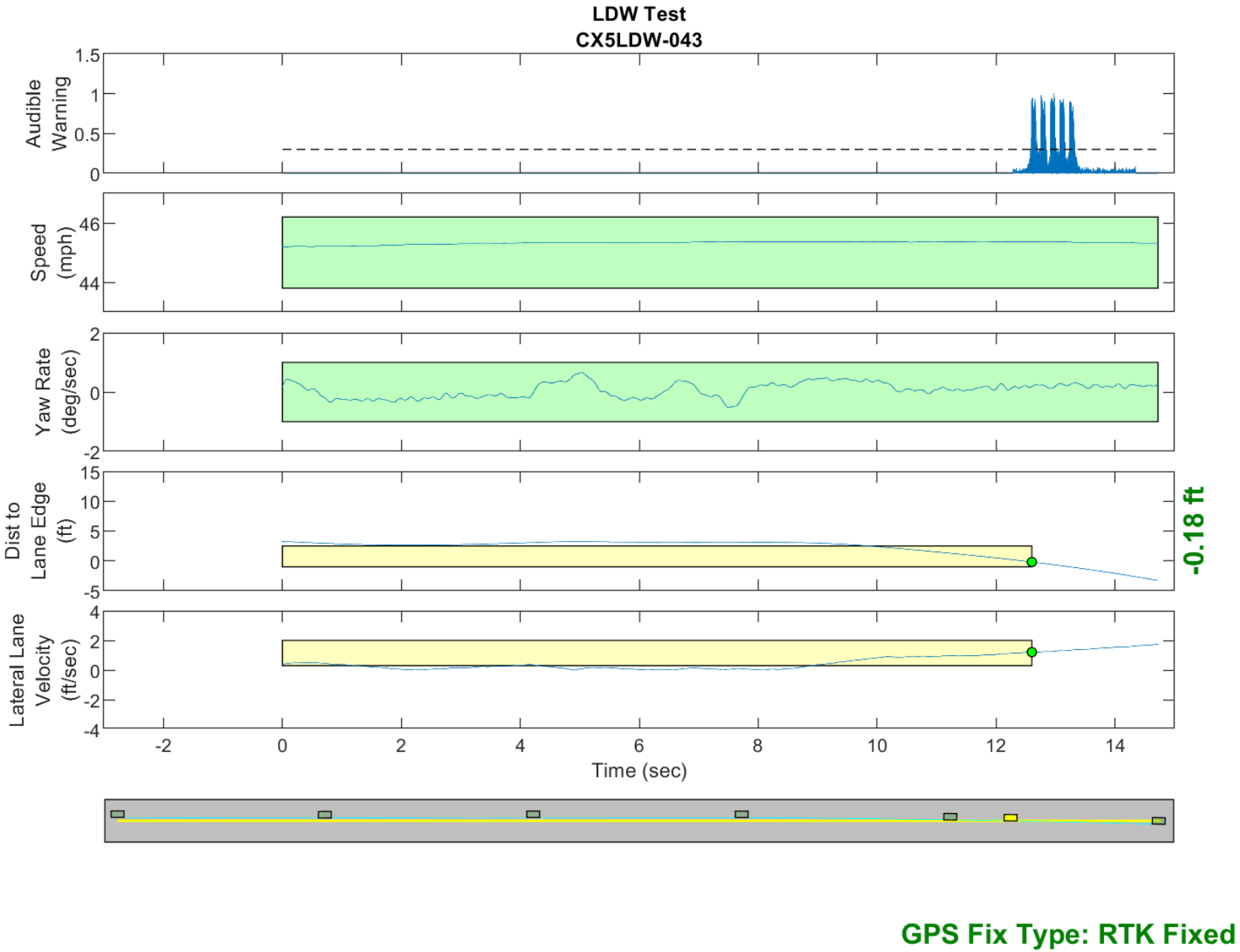


Figure D72. Time History for Run 43, Dashed Line, Right Departure, Auditory Warning

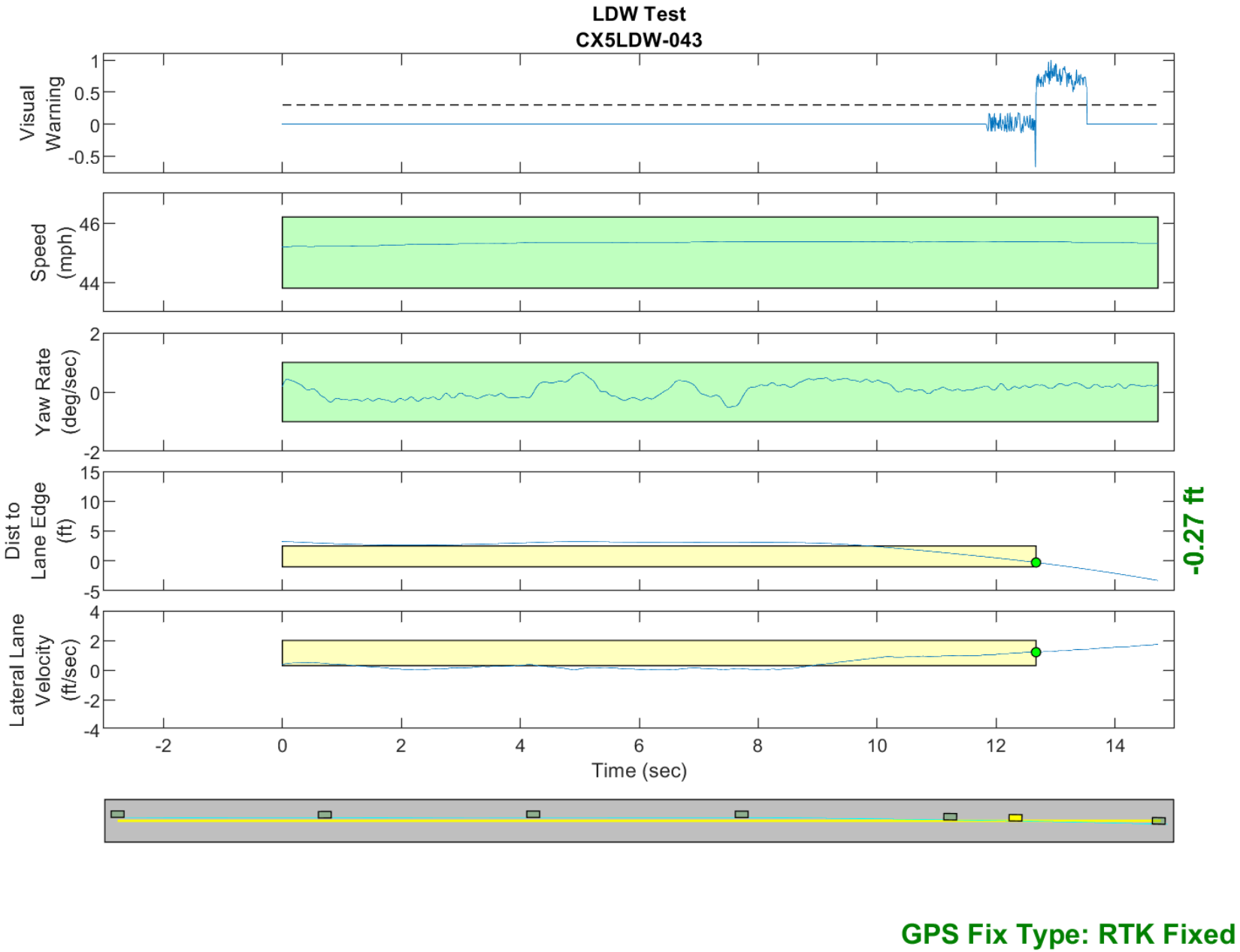


Figure D73. Time History for Run 43, Dashed Line, Right Departure, Visual Warning

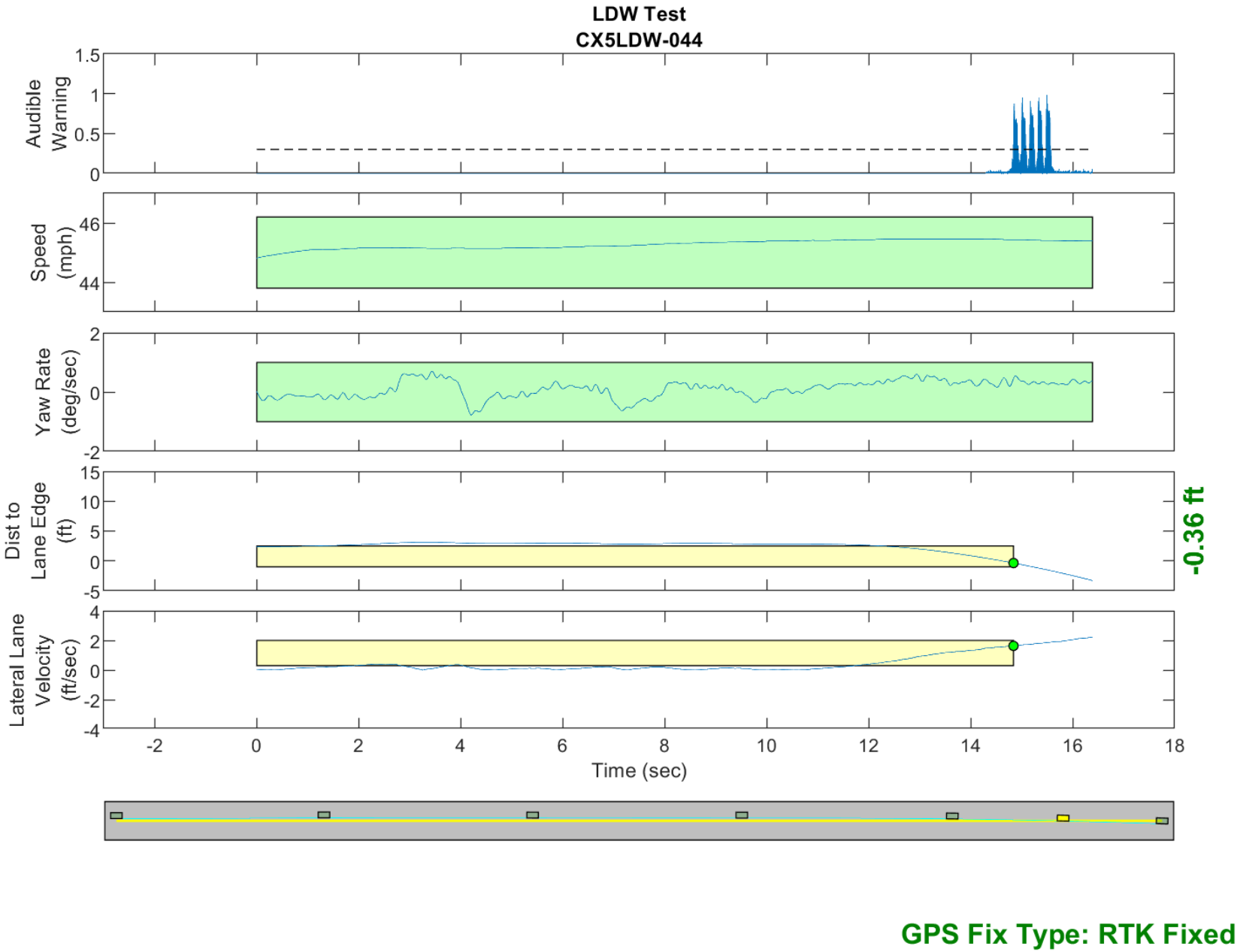


Figure D74. Time History for Run 44, Dashed Line, Right Departure, Auditory Warning

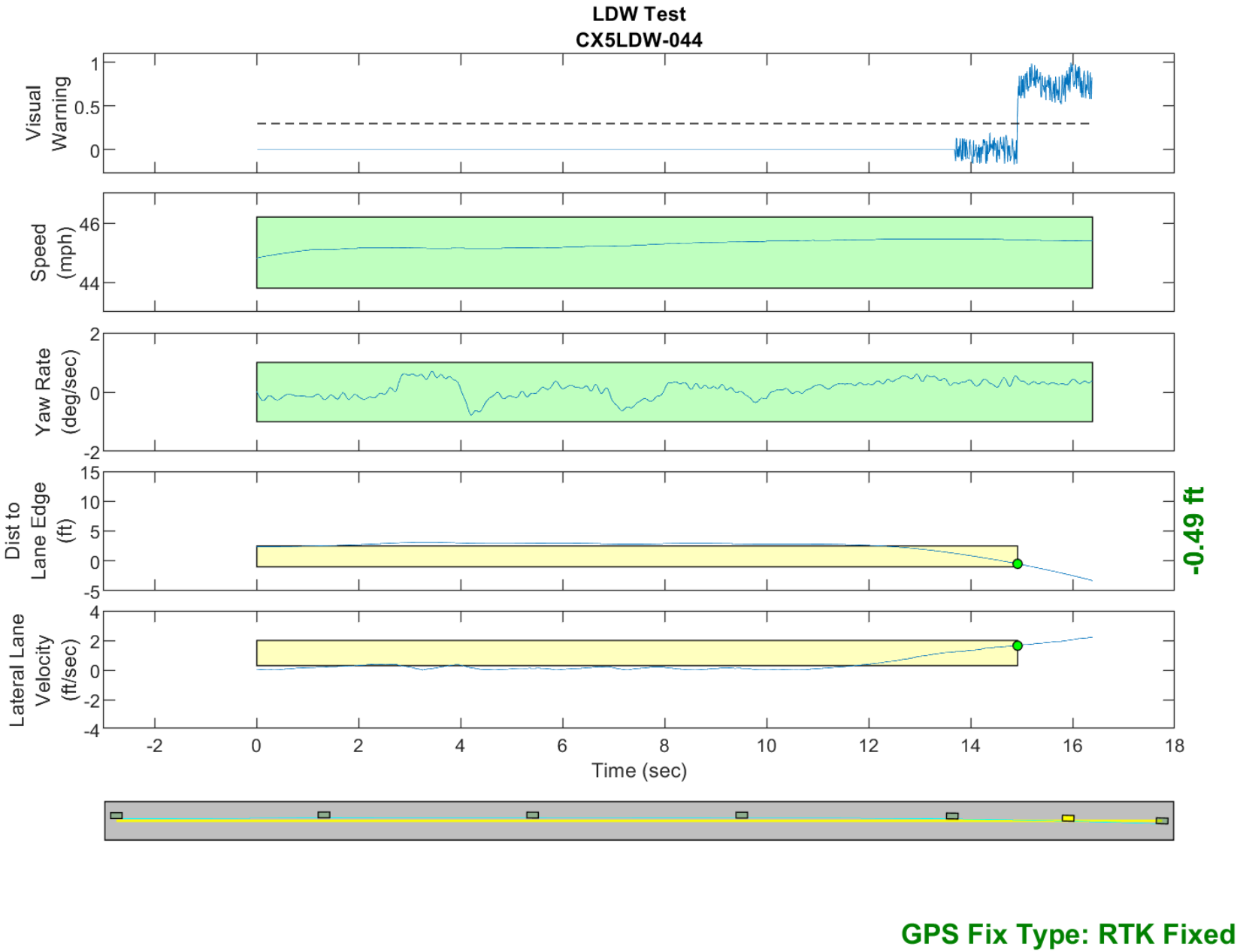


Figure D75. Time History for Run 44, Dashed Line, Right Departure, Visual Warning

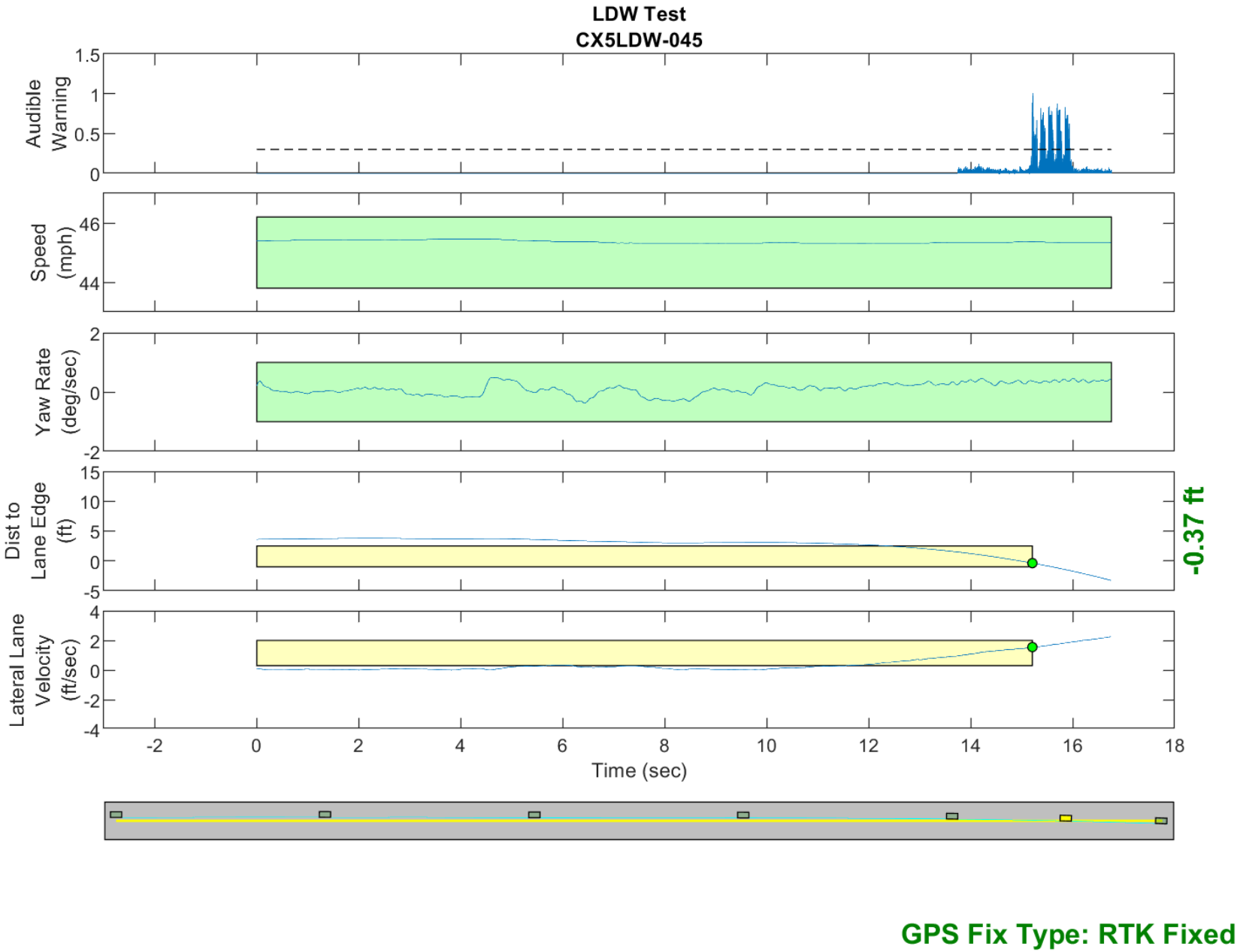


Figure D76. Time History for Run 45, Dashed Line, Right Departure, Auditory Warning

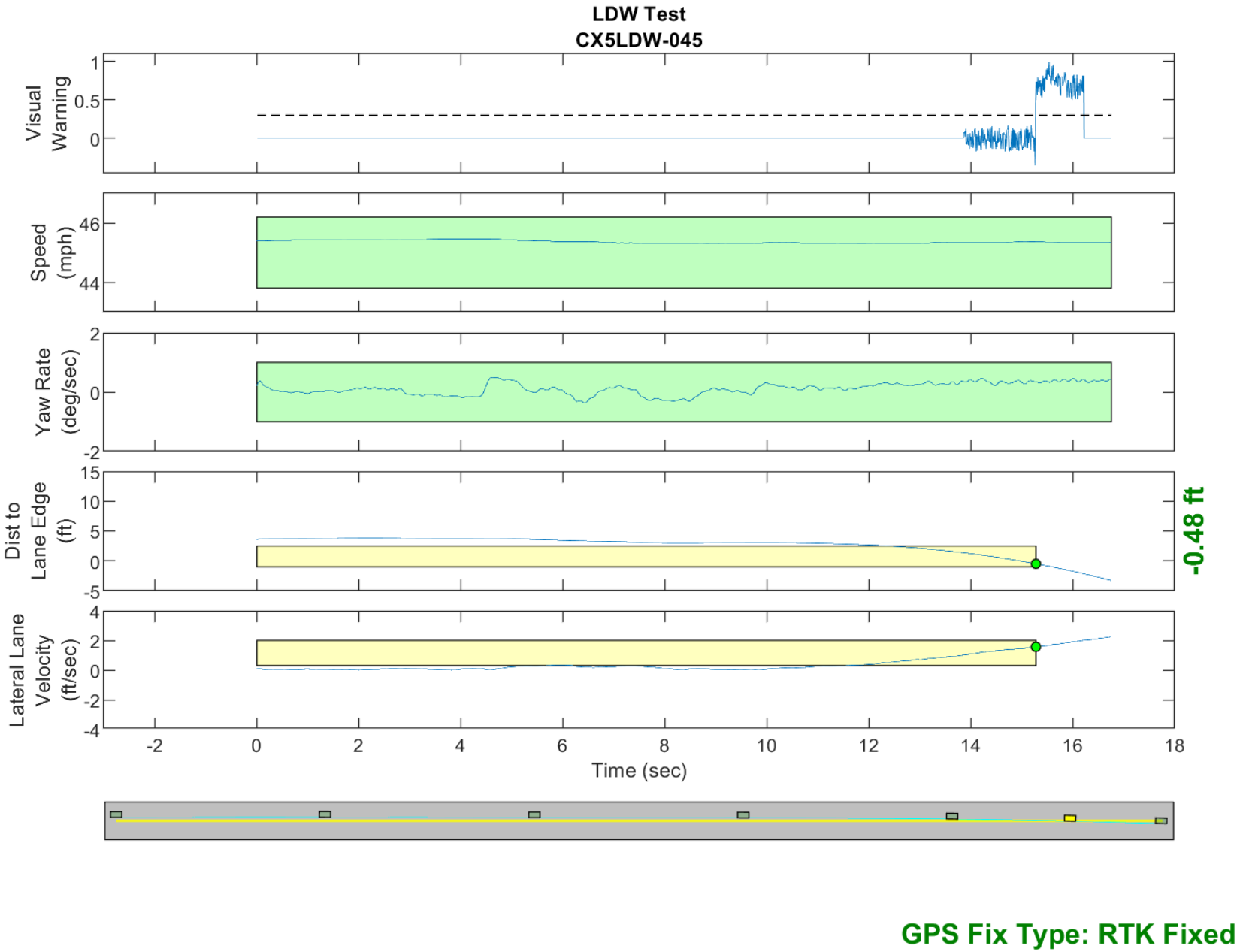


Figure D77. Time History for Run 45, Dashed Line, Right Departure, Visual Warning

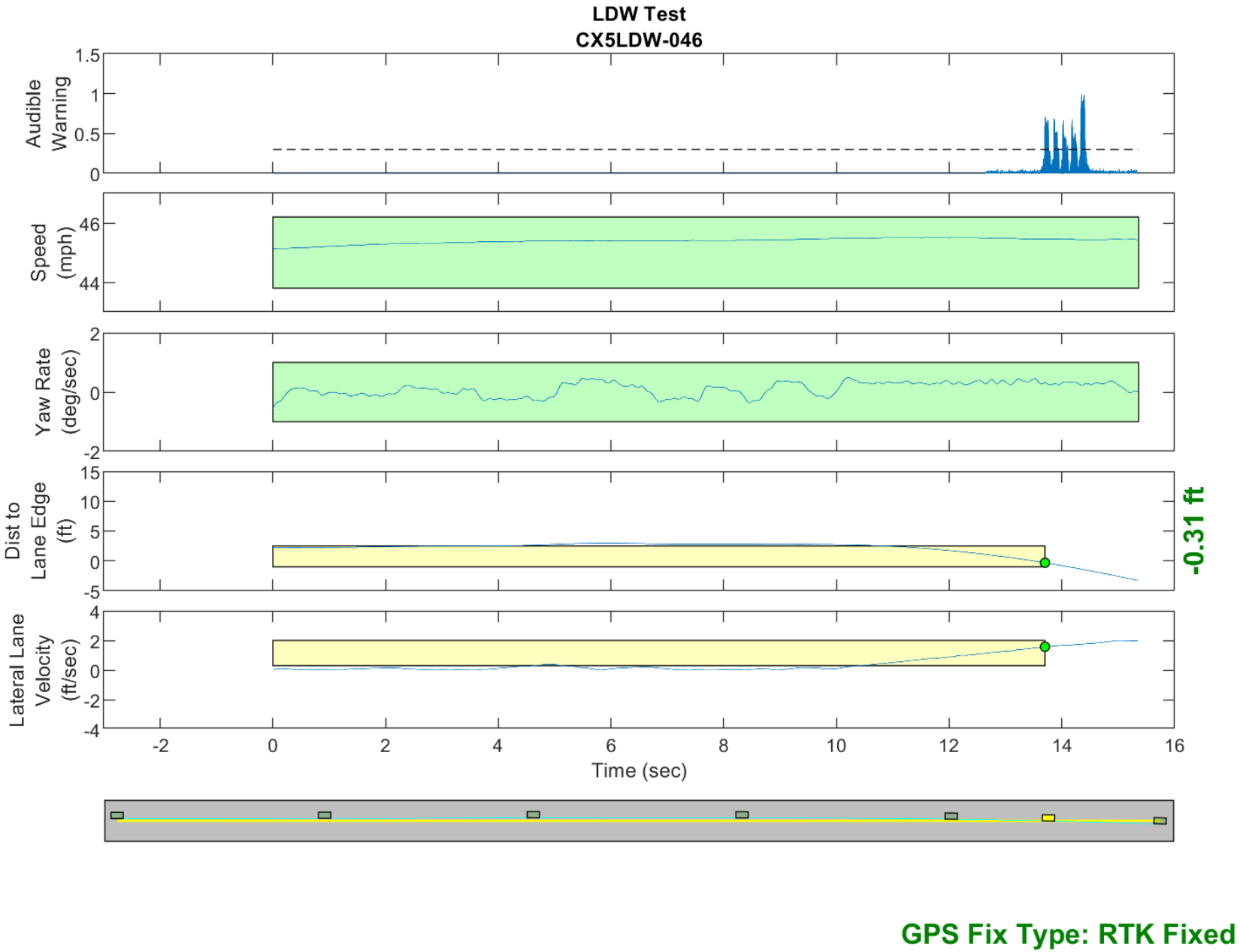


Figure D78. Time History for Run 46, Dashed Line, Right Departure, Auditory Warning

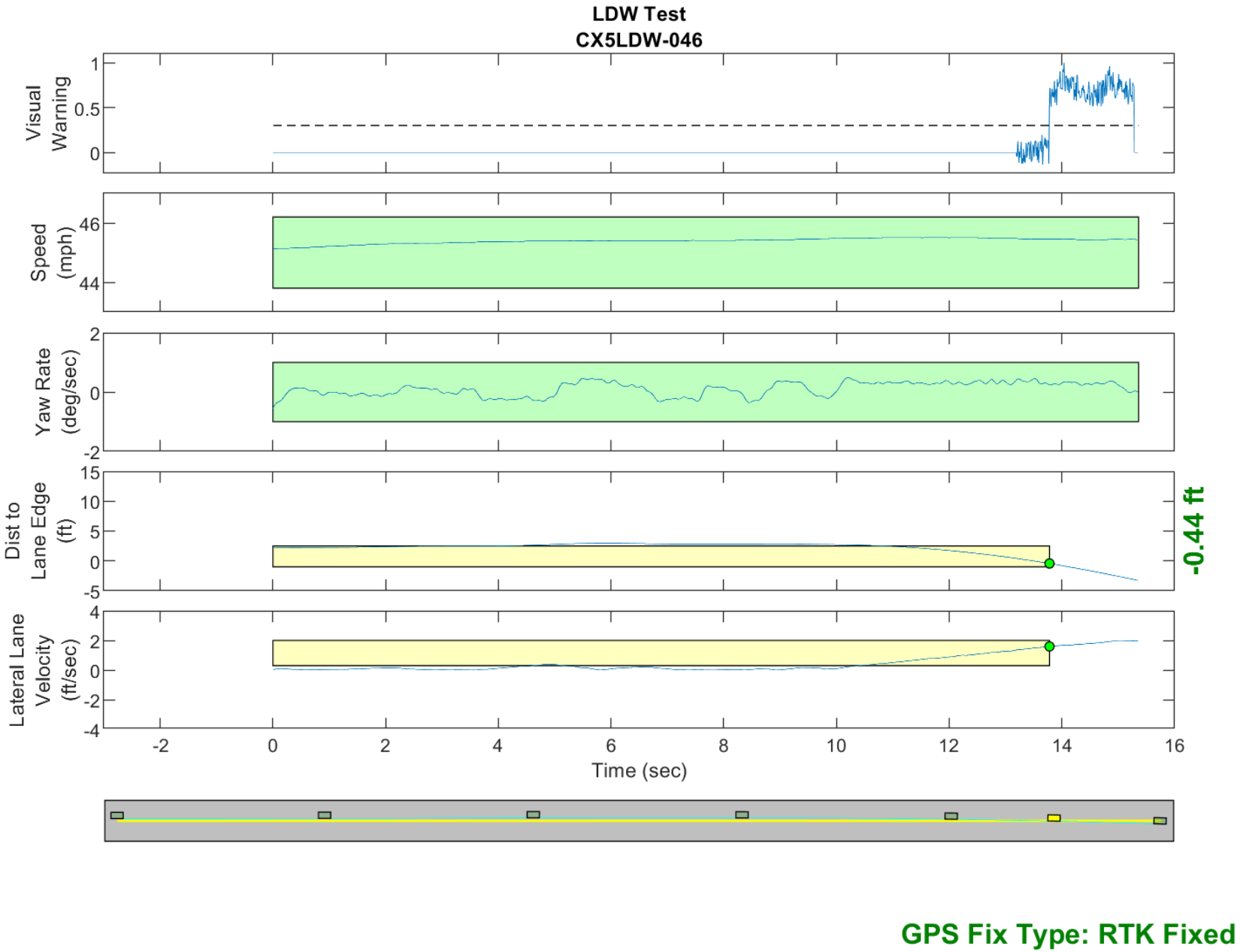


Figure D79. Time History for Run 46, Dashed Line, Right Departure, Visual Warning

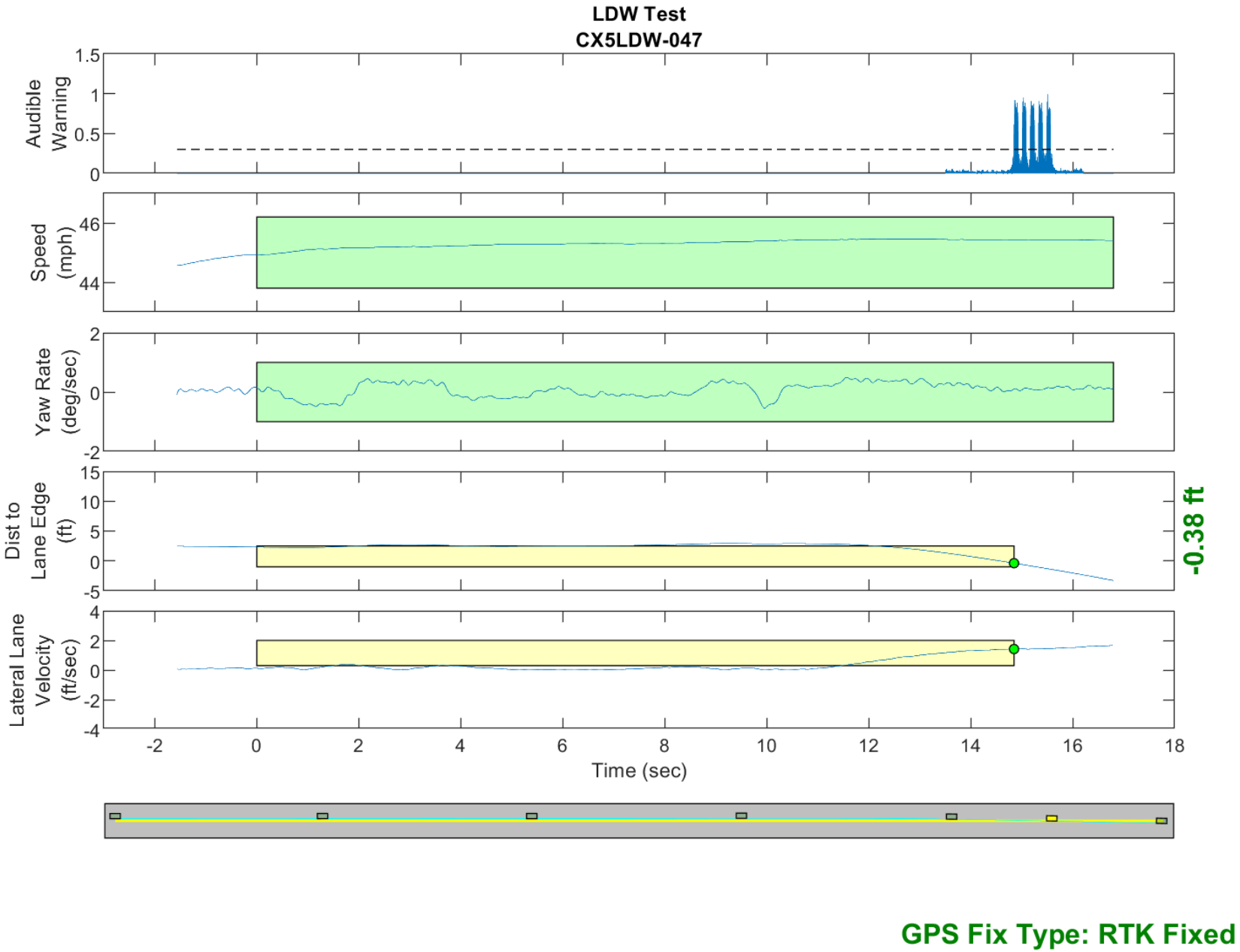


Figure D80. Time History for Run 47, Dashed Line, Right Departure, Auditory Warning

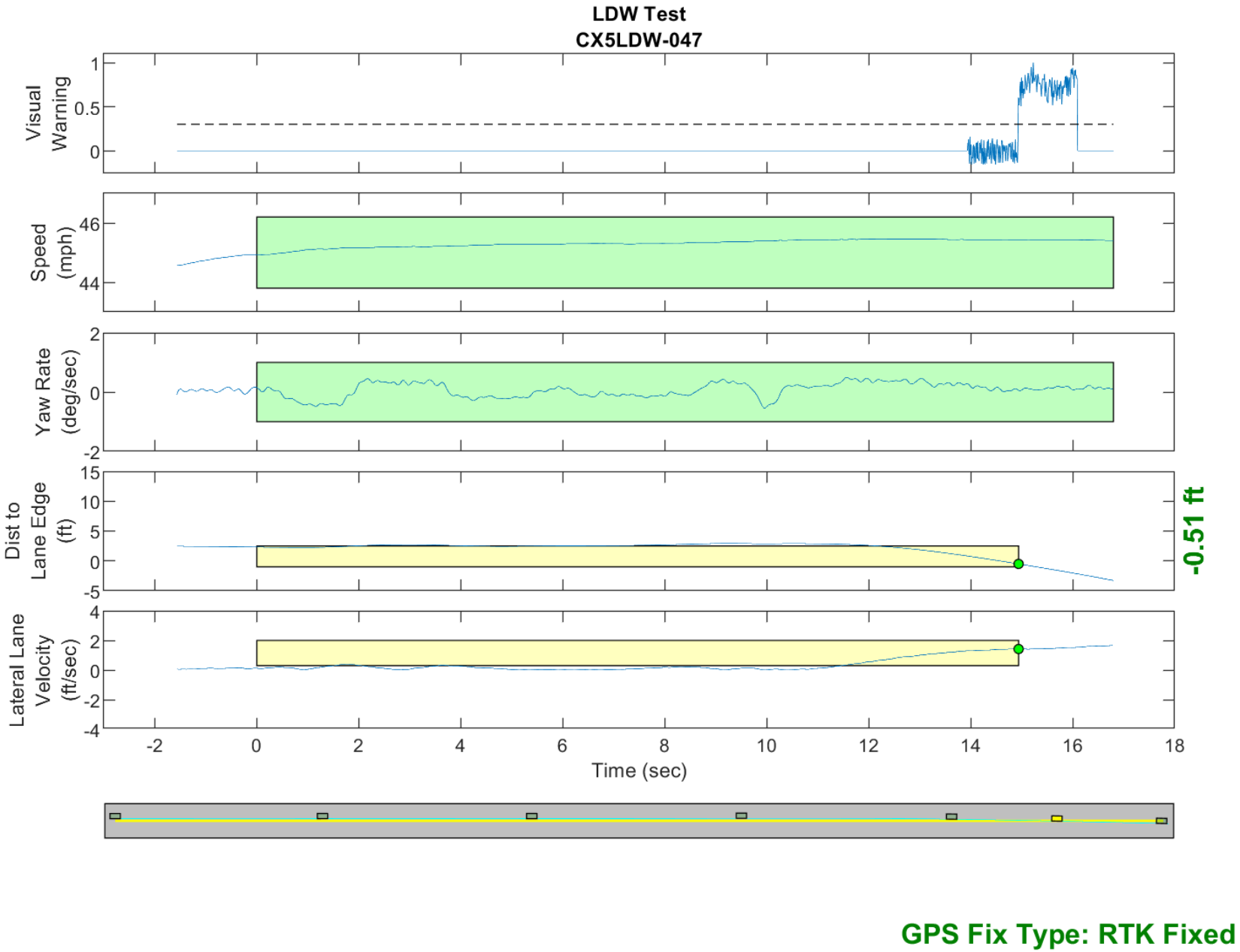


Figure D81. Time History for Run 47, Dashed Line, Right Departure, Visual Warning