NEW CAR ASSESSMENT PROGRAM
LANE DEPARTURE WARNING CONFIRMATION TEST
NCAP-DRI-LDW-21-05

2021 Ford Bronco Sport Badlands 4x4

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16 April 2021

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 2021 Ford Bronco Sport Badlands 4x4 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 2021 Ford Bronco Sport Badlands 4x4. The LDW system for this vehicle provides a visual alert in addition to a haptic alert implemented via a vibration felt in the steering wheel. 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)

2021 Ford Bronco Sport Badlands 4x4

VIN: *3FMCR9D95MRA0xxxx*

Test Date: *3/24/2021*

Lane Departure Warning settings: *Lane Keeping Mode: Alert*
Alert Intensity: High

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)

2021 Ford Bronco Sport Badlands 4x4

TEST VEHICLE INFORMATION

VIN: *3FMCR9D95MRA0xxxx*

Body Style: *SUV* Color: *Area 51*

Date Received: *3/16/2021* Odometer Reading: *4 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *FORD MOTOR CO.*

Date of manufacture: *02/21*

Vehicle Type: *MPV*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *235/65R17 104H*

Rear: *235/65R17 104H*

Recommended cold tire pressure: Front: *230 kPa (33 psi)*

Rear: *230 kPa (33 psi)*

TIRES

Tire manufacturer and model: *Falken Wildpeak A/T AT3W*

Front tire size: *235/65R17 104H*

Rear tire size: *235/65R17 104H*

Front tire DOT prefix: *1R8L8 3MDR*

Rear tire DOT prefix: *1R8L8 3MDR*

LANE DEPARTURE WARNING

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2021 Ford Bronco Sport Badlands 4x4

GENERAL INFORMATION

Test date: *3/24/2021*

AMBIENT CONDITIONS

Air temperature: *18.9 C (66 F)*

Wind speed: *1.5 m/s (3.5 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: *230 kPa (33 psi)*

Rear: *230 kPa (33 psi)*

LANE DEPARTURE WARNING

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2021 Ford Bronco Sport Badlands 4x4

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*539.3 kg (1189 lb)*	Right Front:	*504.8 kg (1113 lb)*
Left Rear:	*399.6 kg (881 lb)*	Right Rear:	*384.6 kg (848 lb)*
		Total:	*1828.3 kg (4031 lb)*

LANE DEPARTURE WARNING

DATA SHEET 4: LANE DEPARTURE WARNING SYSTEM OPERATION

(Page 1 of 3)

2021 Ford Bronco Sport Badlands 4x4

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

The Lane Keeping System is part of the CoPilot 360 package. Copilot 360 is standard on the Badlands model.

Type and location of sensor(s) used:

Mono camera located behind the windshield near the rearview mirror

Lane Departure Warning Setting used in test:

Lane Keeping Mode: Alert

Alert Intensity: High

How is the Lane Departure Warning presented to the driver?

(Check all that apply)

- **X** Warning light
- _____ Buzzer or auditory 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, auditory, vibration, or combination), etc.

The visual alert is located in the center of the instrument panel. It depicts left and right lane lines. If the system is active and lane lines are not detected, the lane lines are shown in gray. When the system is active and detecting lanes, the lane lines are displayed in white. When the system detects that the vehicle is nearing a lane line, the lane line on that side of the display is shown in red, and the steering wheel vibrates.

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.

A switch located on the end of the turn signal stalk can be used to switch the system on and off. See Appendix A, Figure A10.

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.

A center mounted touchscreen is used to interact with system menus. For Lane-Keeping mode the hierarchy is:

Settings

Driver Assistance

Lane-Keeping System

Lane-Keeping Mode

Select: "Alert", "Aid", or "Alert + Aid"

For Alert Intensity the hierarchy is:

Settings

Driver Assistance

Lane-Keeping System

Alert Intensity

Select: "High", "Normal", or "Low"

See Appendix A, Figure A9.

LANE DEPARTURE WARNING

DATA SHEET 4: LANE DEPARTURE WARNING SYSTEM OPERATION

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2021 Ford Bronco Sport Badlands 4x4

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.

System limitations are described on page 206 of the Owner's Manual, Shown in Appendix B, page B-4.

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.

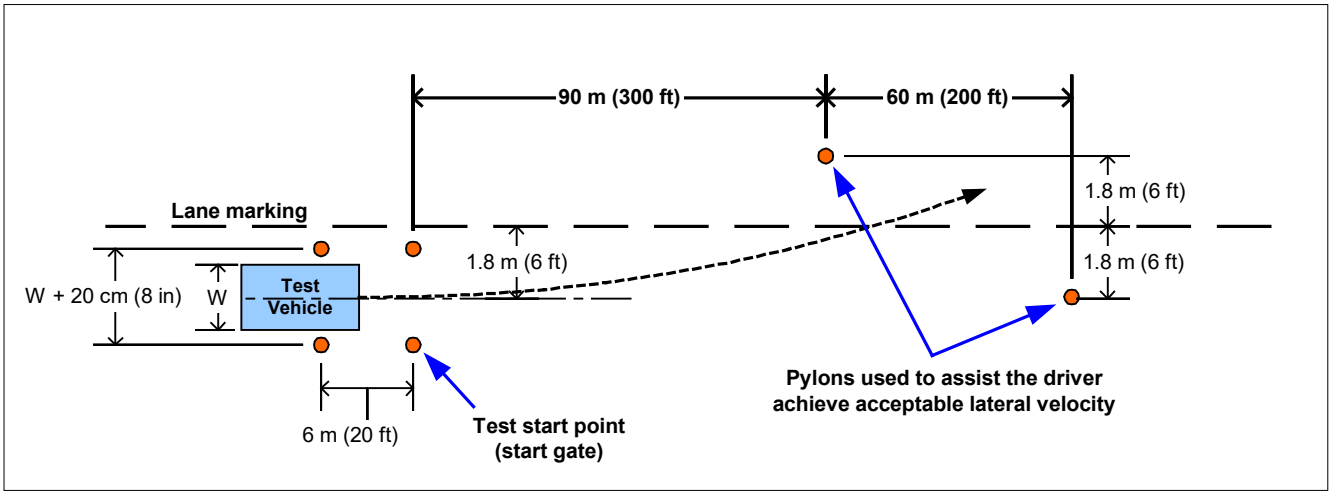

Figure 1. Position of Cones Used to Assist Driver

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.

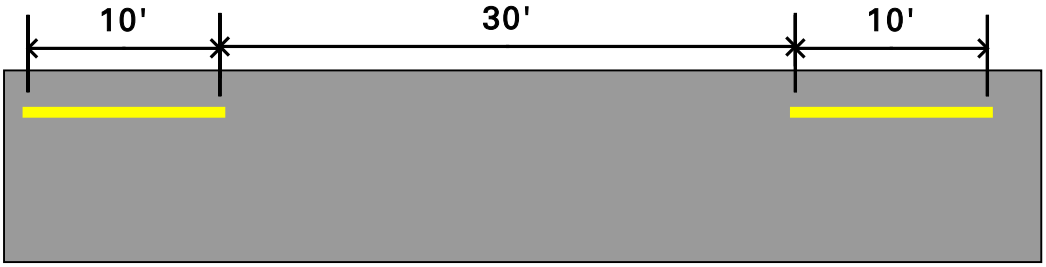

Figure 2. MUTCD Discontinuous Dashed Line Specifications

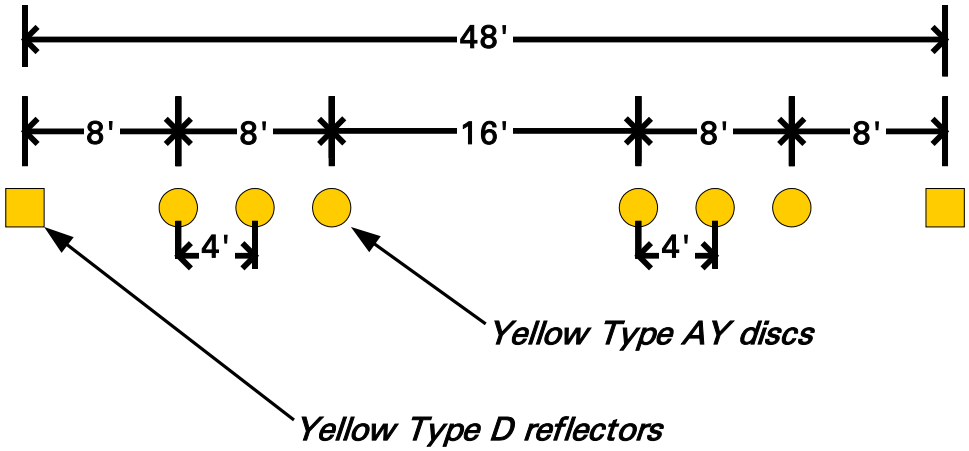

Figure 3. California Standard Plan A20A, Detail 4

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: 8/18/2020 Due: 8/18/2021
Platform Scales	Vehicle Total, Wheel, and Axle Load	8000 lb 35.6 kN	±1.0% of applied load	Intercomp, SWII	0410MN20001	By: DRI Date: 2/10/2021 Due: 2/10/2022
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	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	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: 1/6/2021 Due: 1/6/2022

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)

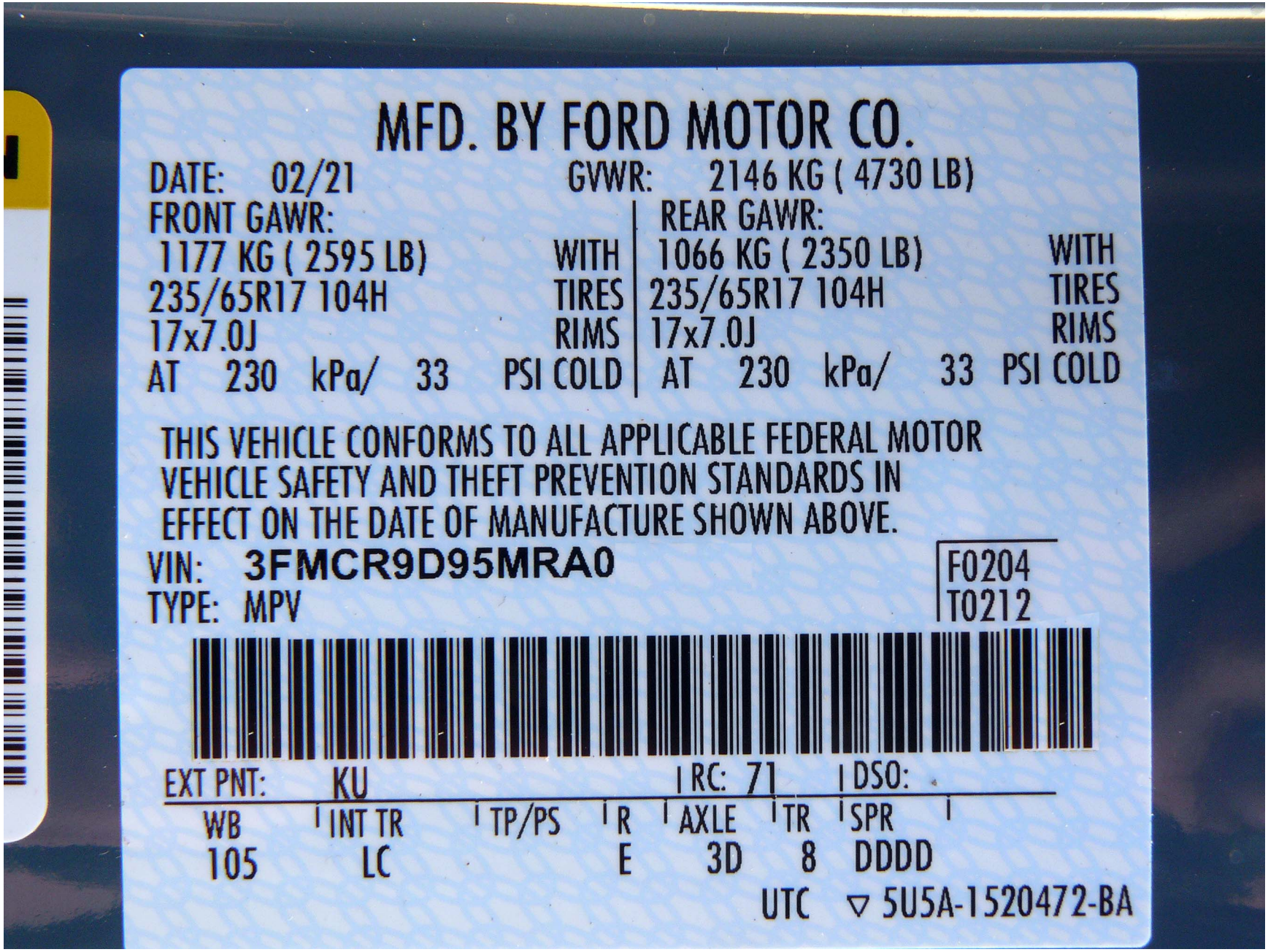

Figure A4. Vehicle Certification Label

Figure A5. Tire Placard

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

Figure A7. Sensors for Detecting Visual and Haptic Alerts

Figure A8. Computer Installed in Subject Vehicle

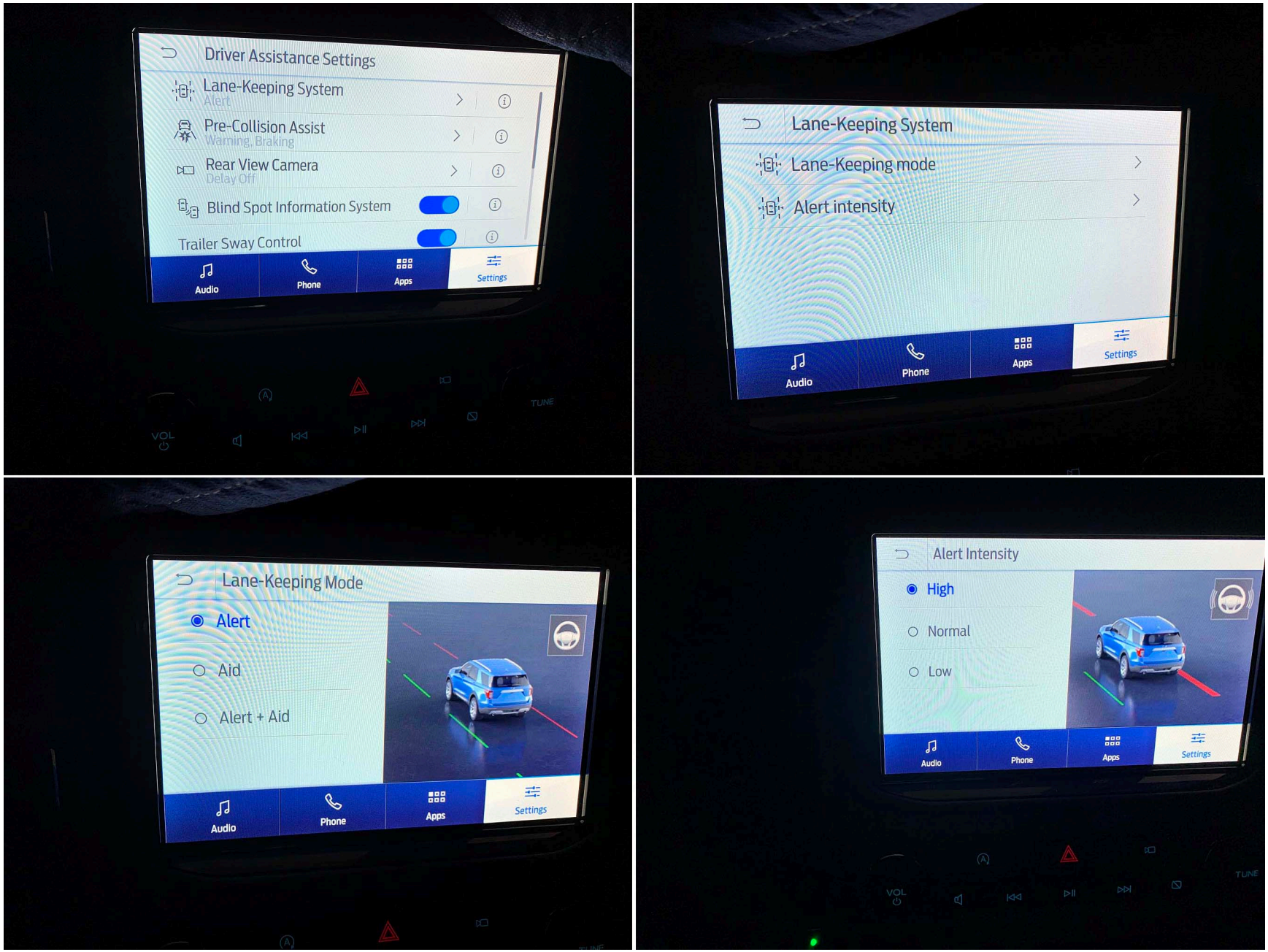

Figure A9. LDW Menus

Figure A10. LDW On/Off Switch

Figure A11. LDW Status Indicator/Visual Alert

APPENDIX B

Excerpts from Owner’s Manual

Message	Action
Restart Now or Key is Needed	Appears when you need to press the Start Stop button to shut off the engine when the system does not detect an Intelligent Access key inside your vehicle.
Full Accessory Power Active	Your vehicle is in the accessory ignition state.
Starting System Fault	There is a problem with your vehicle's starting system. See an authorized dealer for service.
Key Program Successful	During spare key programming, an intelligent access key is programmed to the system.
Max Number of Keys Learned	During spare key programming, the maximum number of keys have been programmed.
Key Program Failure	Displayed during spare key programming, when an intelligent access key has failed to be programmed.
Not Enough Keys Learned	Displayed during spare key programming when not enough keys have been programmed.
Key Battery Low Replace Soon	Displays when the key battery is low. Change the battery as soon as possible.
Vehicle Switched Off	Displays when the vehicle is switched off.

Lane Keeping System

Message	Action
Lane Keeping Sys. Malfunction Service Required	The system has malfunctioned. Contact an authorized dealer as soon as possible.
Front Camera Temporarily Not Available	The system has detected a condition that has caused the system to be temporarily unavailable.
Front Camera Low Visibility Clean Screen	The system has detected a condition that requires the windshield to be cleaned to operate properly.
Front Camera Malfunction Service Required	The system has malfunctioned. Contact an authorized dealer as soon as possible.
Keep Hands on Steering Wheel	The system requests the driver to keep their hands on the steering wheel.

Bronco Sport (CHD) Canada/United States of America, enUSA, Edition date: 202007, First-Printing

MyKey

Message	Action
MyKey not Created	You cannot program a MyKey.
MyKey Active Drive Safely	MyKey is active.
Speed Limited to XX MPH/km/h	When switching on your vehicle and MyKey is in use, displays that the MyKey speed limit is on.
Near Vehicle Top Speed	MyKey is in use and the MyKey speed limit is on and the vehicle speed is approaching 81 mph (130 km/h).
Vehicle at Top Speed of MyKey Setting	You have reached the speed limit set for your MyKey.
Check Speed Drive Safely	You have an active MyKey with a programmed set speed limit.
Buckle Up to Unmute Audio	Belt-Minder turns on with a MyKey in use.
AdvanceTrac On - MyKey Setting	With a MyKey in use, AdvanceTrac turns on.
Traction Control On - MyKey Setting	With a MyKey in use, traction control turns on.
MyKey Park Aid Cannot be Deactivated	With a MyKey in use, park aid is always on.
Lane Keeping Alert On MyKey Setting	With a MyKey in use, lane keeping alert turns on.

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The warning system is in two stages. At first the system issues a temporary warning that you need to take a rest. This message only appears for a short time. If the system detects further reduction in driving alertness, another warning could be issued which remains in the information display for a longer time. Press OK on the steering wheel control to clear the warning. When active the system runs in the background and only issues a warning if required.

Resetting the System

You can reset the system by either:

- Switching the ignition off and on.
- Stopping the vehicle and then opening and closing the driver door.

LANE KEEPING SYSTEM

WARNING: You are responsible for controlling your vehicle at all times. The system is designed to be an aid and does not relieve you of your responsibility to drive with due care and attention. Failure to follow this instruction could result in the loss of control of your vehicle, personal injury or death.

WARNING: Always drive with due care and attention when using and operating the controls and features on your vehicle.

WARNING: In cold and severe weather conditions the system may not function. Rain, snow and spray can all limit sensor performance.

WARNING: Large contrasts in outside lighting can limit sensor performance.

WARNING: The system will not operate if the sensor cannot track the road lane markings.

WARNING: The sensor may incorrectly track lane markings as other structures or objects. This can result in a false or missed warning.

WARNING: The system may not operate properly if the sensor is blocked. Keep the windshield free from obstruction.

WARNING: If damage occurs in the immediate area surrounding the sensor, have your vehicle checked as soon as possible.

WARNING: The system may not correctly operate if your vehicle is fitted with a suspension kit not approved by us.

Note: *The system works above 40 mph (64 km/h).*

Note: *The system works as long as the camera can detect one lane marking or road edge.*

Note: *When you select aid or alert + aid mode and the system detects no steering activity for a short period, the system alerts you to put your hands on the steering wheel.* ***The system may detect a light grip or touch on the steering wheel as hands off driving.***

Note: *The system may not function if the camera is blocked, or if the windshield is damaged or dirty.*

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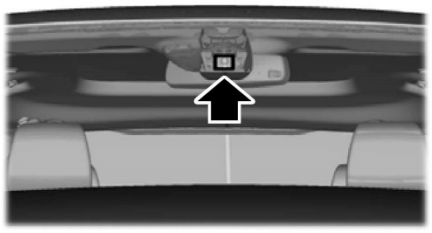

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When you switch the system on and it detects an unintentional drift out of your lane is likely to occur, the system notifies or assists you to stay in your lane through the steering system and information display. In alert mode, the system provides a warning by vibrating the steering wheel. In aid mode, the system provides steering assistance by gently counter steering your vehicle back into the lane.

When the system is functioning in the combined alert and aid mode, the system first provides steering assistance by gently counter steering your vehicle back into the lane, followed by a warning that vibrates the steering wheel if the vehicle is still out of the lane markings.

Switching the System On and Off

E288067

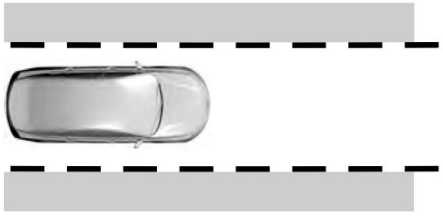
Press the button on the direction indicator stalk to switch the system on or off.

Note: *The on or off setting is stored until it is manually changed, unless a MyKey is detected. If the system detects a MyKey, it defaults to on and the mode sets to alert.*

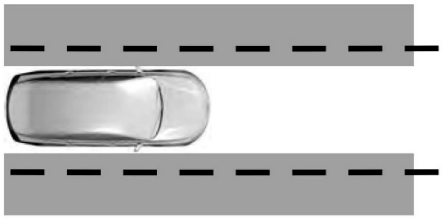
System Settings

The system has optional setting menus available. The system stores the last known selection for each of these settings. You do not need to readjust your settings each time you switch the system on.

Mode: This setting allows you to select which of the system features you can enable.



Alert only – Provides a steering wheel vibration when the system detects an unintended lane departure.



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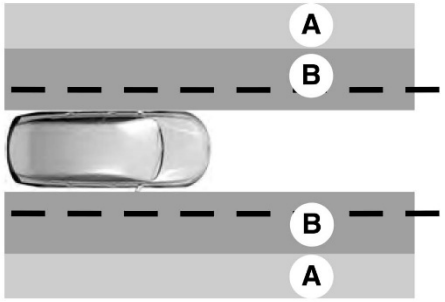
Aid only – Provides steering assistance toward the lane center when the system detects an unintended lane departure.



A Alert.

B Aid.

Alert + Aid – Provides steering assistance toward the lane center.

If your vehicle continues drifting out of the lane after the lane keeping aid corrects the vehicle, the system provides a steering wheel vibration.

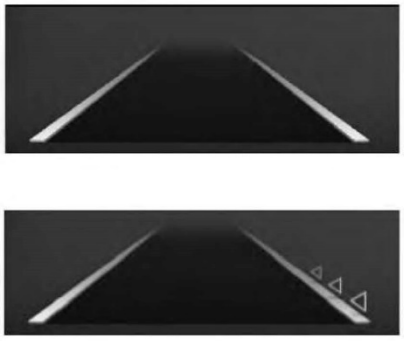
If your vehicle stays to one side of the lane after the lane keeping aid corrects your vehicle and then subsequently drifts out of the lane again, the system only provides an alert at the steering wheel.

Note: *The alert and aid diagrams illustrate general zone coverage. They do not provide exact zone parameters.*

Intensity: This setting affects the intensity of the steering wheel vibration used for the alert and alert + aid modes. **This setting does not affect the aid mode.**

- Low.
- Normal.
- High.

System Display



When you switch the system on, an image of lane markings appears in the information display.

When you switch the system off, the lane marking images do not display.

While the system is on, the color of the lane markings change to indicate the system status. These colors represent the following:

Gray: Indicates that the system is temporarily unable to provide a warning or intervention on the indicated side. This may be because:

- Your vehicle is under the activation speed.
- The direction indicator is active.
- Your vehicle is in a dynamic maneuver.
- The road has no or poor lane markings in the camera field-of-view.
- The camera is obscured or unable to detect the lane markings due to environmental, traffic or vehicle conditions. For example, significant sun angles, shadows, snow, heavy rain or fog, following a large vehicle that is blocking or shadowing the lane or poor headlamp illumination.

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See **Troubleshooting** for additional information.

White: Indicates that the system is available or ready to provide a warning or intervention on the indicated side.

Note: *If your vehicle has lane centering assist and the system is active, the walls appear green instead of white.*

Yellow: Indicates that the system is providing or has just provided a lane keeping aid intervention.

Red: Indicates that the system is providing or has just provided a lane keeping alert warning.

The system can be temporarily suppressed at any time by the following:

- Quick braking.
- Fast acceleration.
- Using the direction indicator.
- Evasive steering maneuver.
- Driving too close to the lane markings.

Troubleshooting

Why is the feature not available, line markings are gray, when I can see the lane markings on the road?
Your vehicle speed is outside the operational range of the feature.
The sun is shining directly into the camera lens.
A quick intentional lane change has occurred.
Your vehicle stays too close to the lane markings.
Driving at high speeds in curves.
The last alert warning or aid intervention occurred a short time ago.
Ambiguous lane markings, for example in construction zones.
Rapid transition from light to dark, or from dark to light.
Sudden offset in lane markings.
ABS or AdvanceTrac™ is active.
There is a camera blockage due to dirt, grime, fog, frost or water on the windshield.
You are driving too close to the vehicle in front of you.
Transitioning between no lane markings to lane markings or vice versa.
There is standing water on the road.
Faint lane markings, for example partial yellow lane markings on concrete roads.

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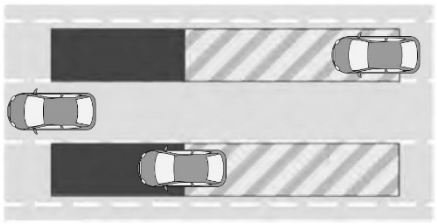
Why is the feature not available, line markings are gray, when I can see the lane markings on the road?
Lane width is too narrow or too wide.
The camera has not been calibrated after a windshield replacement.
Driving on tight roads or on uneven roads.

Why does the vehicle not come back toward the middle of the lane, as expected, in the aid or aid + alert mode?
High cross winds are present.
There is a large road crown.
Rough roads, grooves or shoulder drop-offs.
Heavy uneven loading of the vehicle or improper tire inflation pressure.
The tires have been changed, or the suspension has been modified.

BLIND SPOT INFORMATION SYSTEM

WARNING: Do not use the blind spot information system as a replacement for using the interior and exterior mirrors or looking over your shoulder before changing lanes. The blind spot information system is not a replacement for careful driving.

WARNING: The system may not operate properly during severe weather conditions, for example snow, ice, heavy rain and spray. Always drive with due care and attention. Failure to take care may result in a crash.



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The system is designed to detect vehicles that may have entered the blind spot zone. The detection area is on both sides of your vehicle, extending rearward from the exterior mirrors to approximately 13 ft (4 m) beyond the rear bumper. The detection area extends to approximately 59 ft (18 m) beyond the rear bumper when the vehicle speed is greater than 30 mph (48 km/h) to alert you of faster approaching vehicles.

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APPENDIX C

Run Log

Subject Vehicle: **2021 Ford Bronco Sport Badlands 4x4** Test Date: **3/24/2021**

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

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Haptic Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
1	**Solid**	**Left**	Y	0.12	0.15	Pass	
2			Y	0.03	0.12	Pass	
3			Y	-0.13	-0.13	Pass	
4			Y	0.11	0.15	Pass	
5			Y	0.03	0.06	Pass	
6			Y	0.13	0.15	Pass	
7			Y	0.05	0.09	Pass	
8	**Solid**	**Right**	N				Bad haptic signal
9			Y	0.12	0.13	Pass	
10			Y	0.16	0.14	Pass	
11			Y	0.12	0.21	Pass	
12			Y	0.12	0.17	Pass	
13			Y	0.21	0.19	Pass	
14			Y	0.17	0.15	Pass	
15			Y	0.17	0.13	Pass	
16	**Dashed**	**Right**	Y	0.14	0.11	Pass	
17			Y	0.13	0.12	Pass	
18			Y	0.16	0.19	Pass	

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Haptic Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
19	**Dashed**	**Right**	N				Cone hit
20			Y	0.20	0.19	Pass	
21			Y	0.09	0.09	Pass	
22			Y	0.19	0.14	Pass	
23			Y	0.16	0.17	Pass	
24	**Dashed**	**Left**	Y	0.09	0.12	Pass	
25			Y	-0.07	-0.04	Pass	
26			Y	-0.01	-0.01	Pass	
27			Y	-0.01	0.03	Pass	
28			Y	-0.06	0.02	Pass	
29			Y	0.03	0.05	Pass	
30			Y	0.00	0.05	Pass	
31	**Botts**	**Left**	Y	0.10	0.07	Pass	
32			Y	0.13	0.16	Pass	
33			N				SV speed, SV yaw rate
34			Y	0.22	0.28	Pass	
35			Y	0.32	0.30	Pass	
36			Y	0.09	0.12	Pass	
37			Y	0.21	0.26	Pass	
38			Y	0.22	0.18	Pass	
39	**Botts**	**Right**	Y	0.27	0.34	Pass	
40			Y	0.47	0.52	Pass	
41			Y	0.35	0.36	Pass	

Run	Lane Marking Type	Departure Direction	Valid Run?	Distance at Haptic Alert (ft)	Distance at Visual Alert (ft)	Pass/Fail	Notes
42	**Botts**	**Right**	Y	0.29	0.32	Pass	
43			Y	0.45	0.51	Pass	
44			Y	0.27	0.36	Pass	
45			Y	0.46	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.

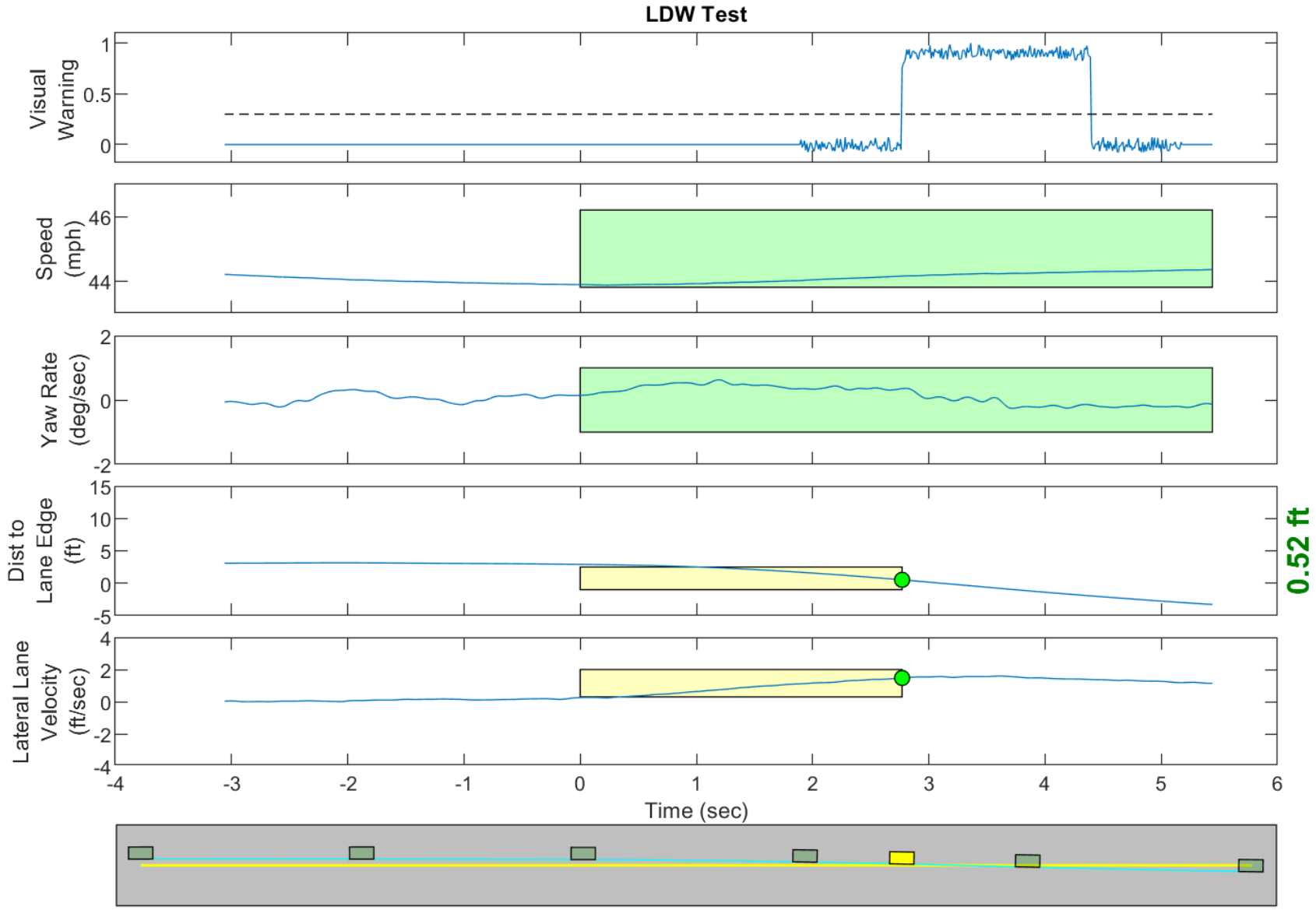

Figure D1. Example Time History for Lane Departure Warning Test, Passing

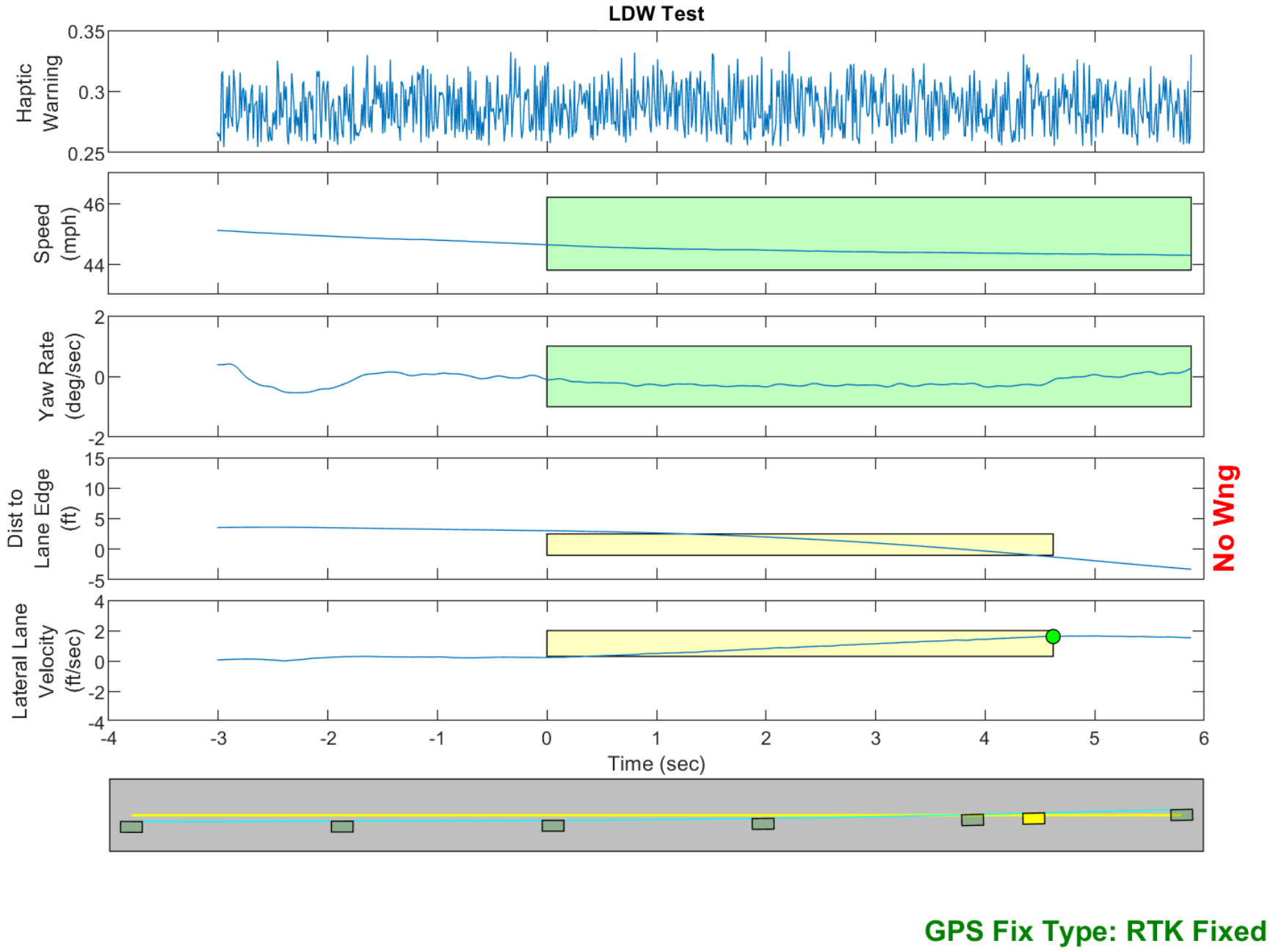

Figure D2. Example Time History for Lane Departure Warning Test, Failing, No Warning Issued

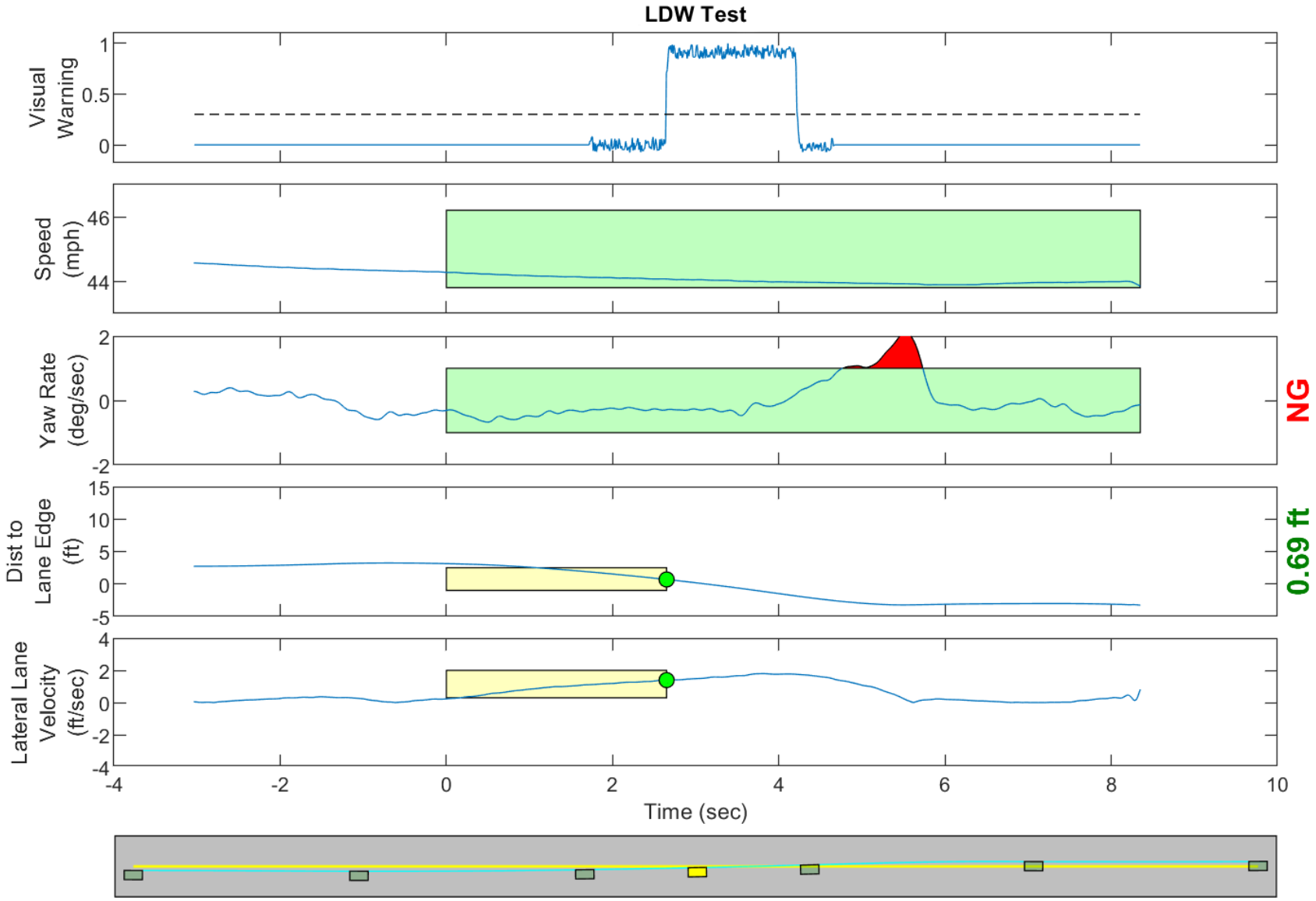

Figure D3. Example Time History for Lane Departure Warning Test, Invalid Run Due to Subject Vehicle Yaw Rate

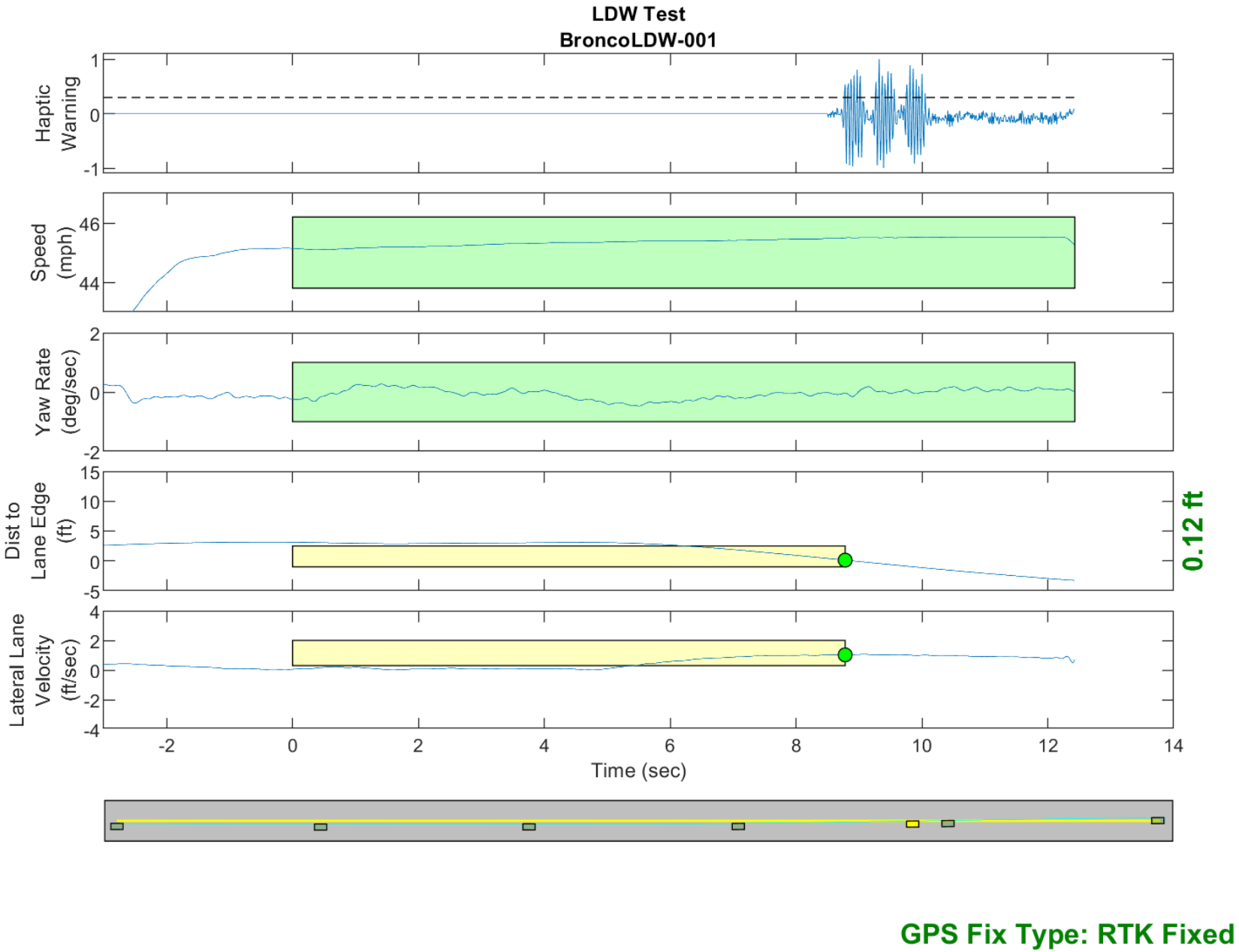

Figure D4. Time History for Run 01, Solid Line, Left Departure, Haptic Warning

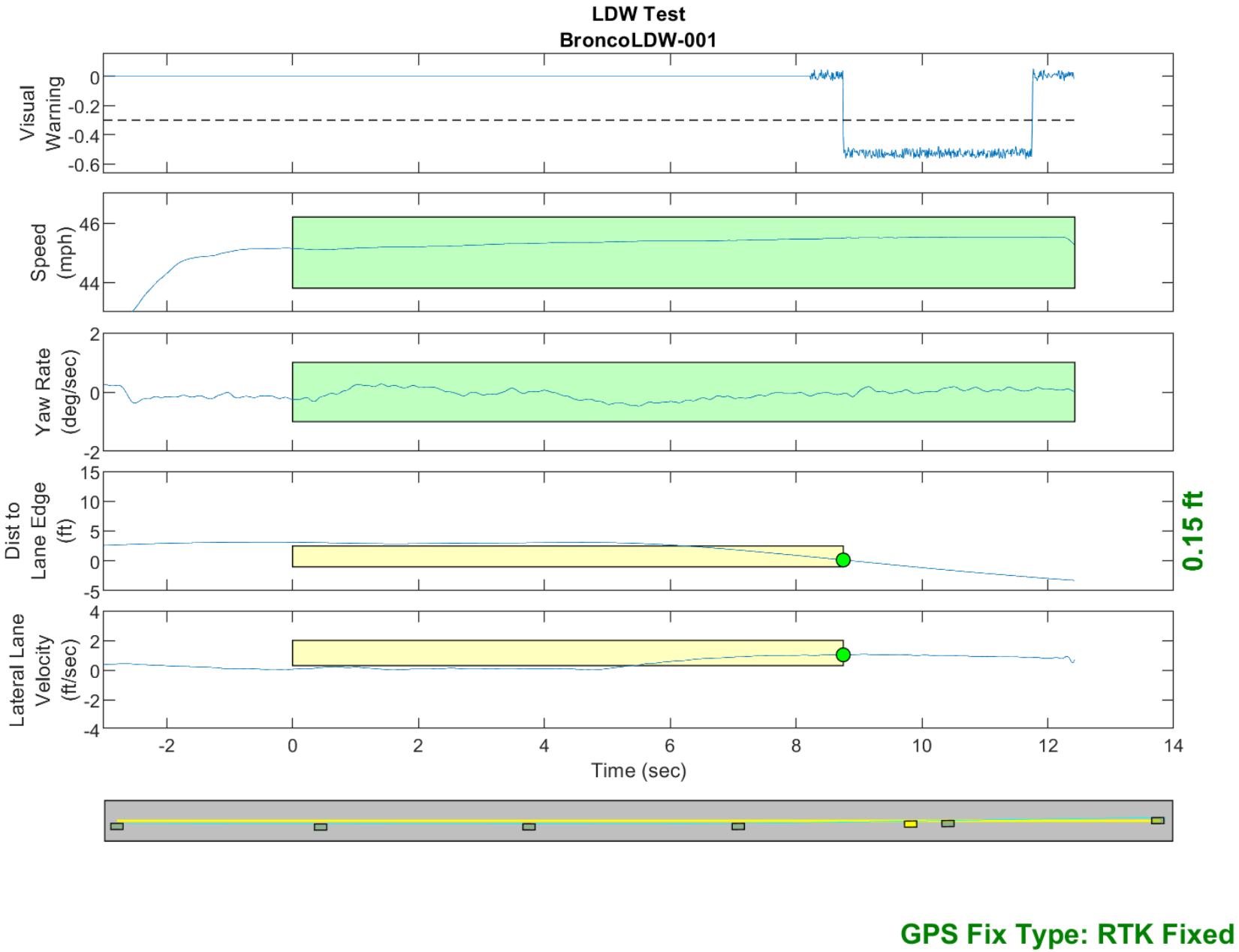

Figure D5. Time History for Run 01, Solid Line, Left Departure, Visual Warning

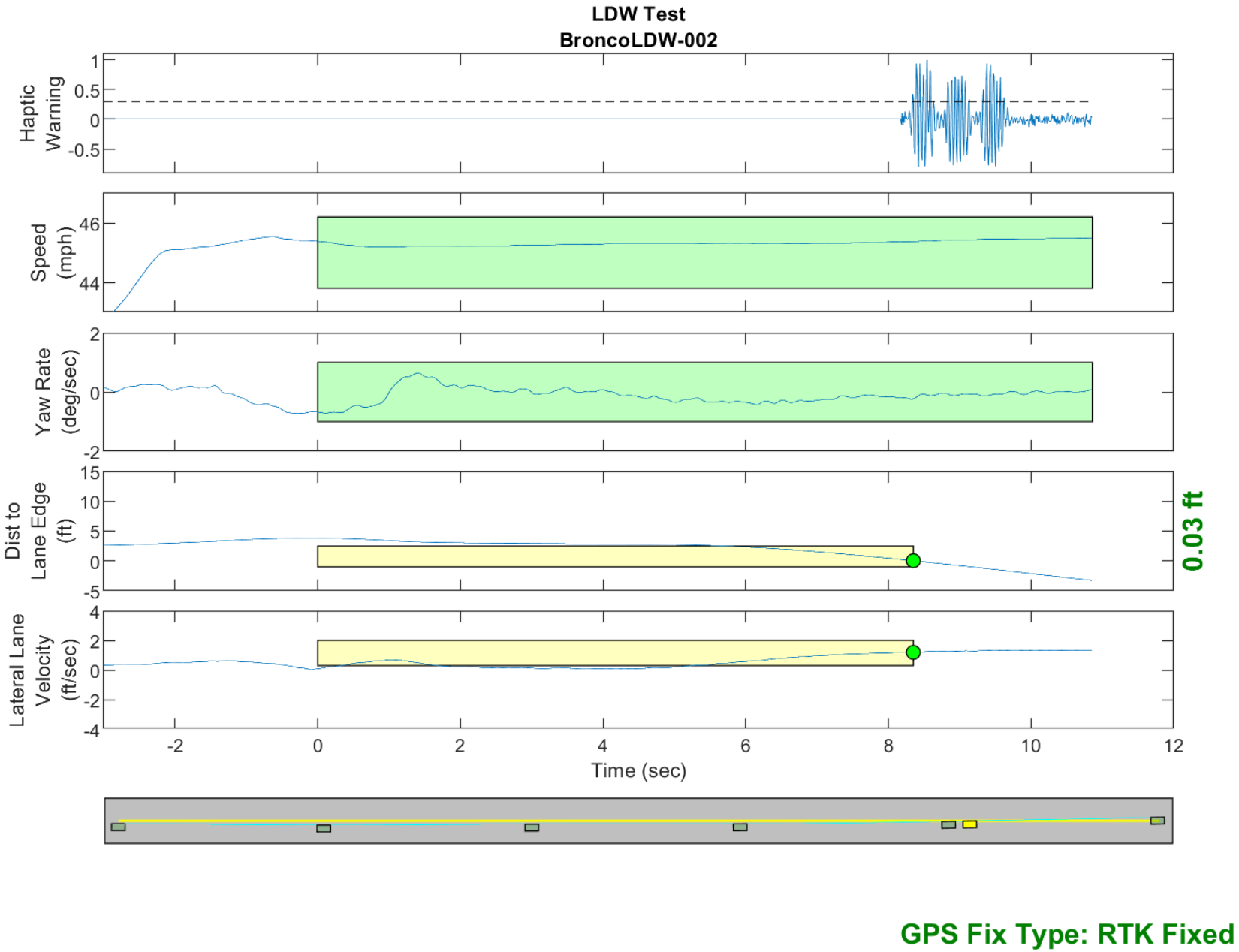

Figure D6. Time History for Run 02, Solid Line, Left Departure, Haptic Warning

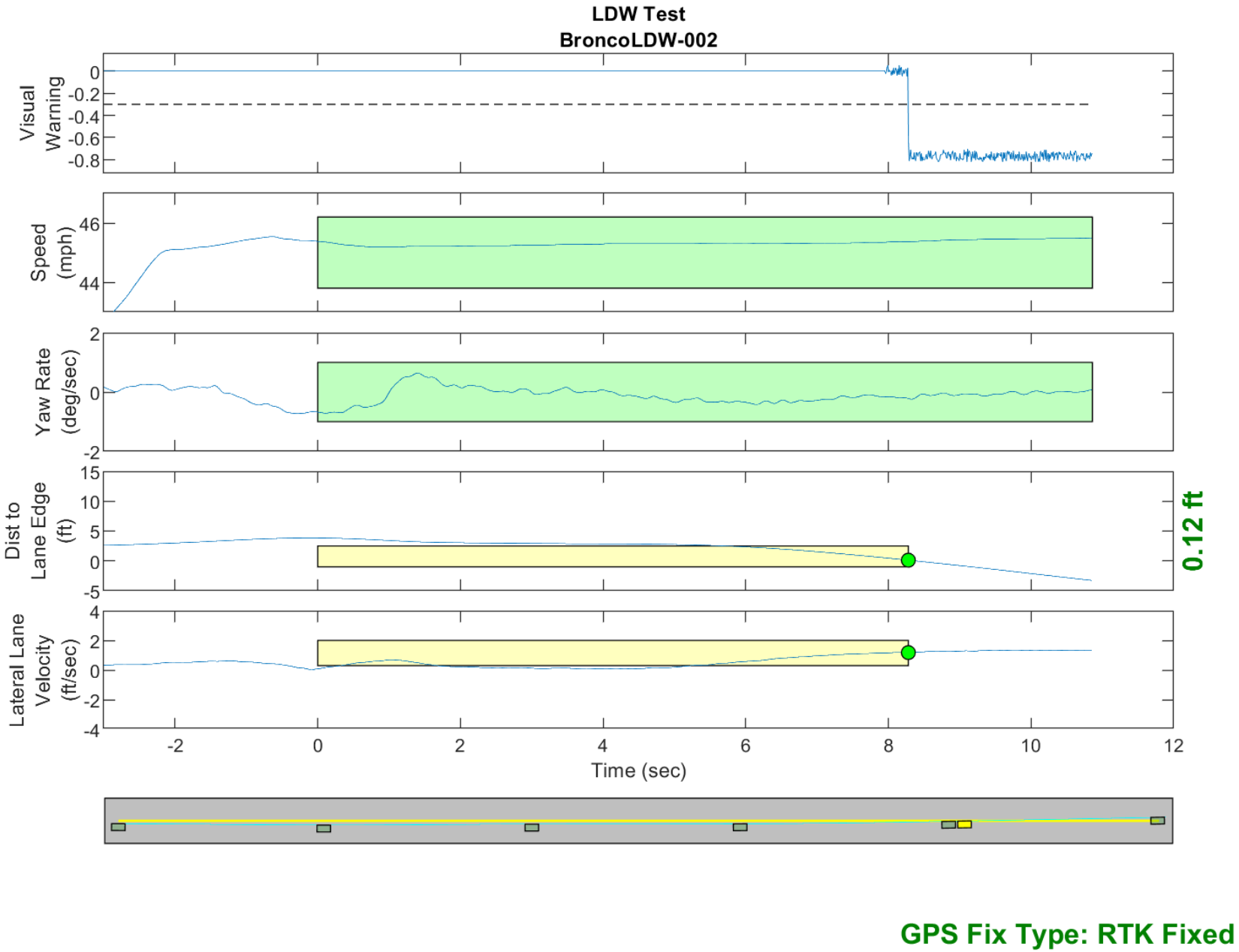

Figure D7. Time History for Run 02, Solid Line, Left Departure, Visual Warning

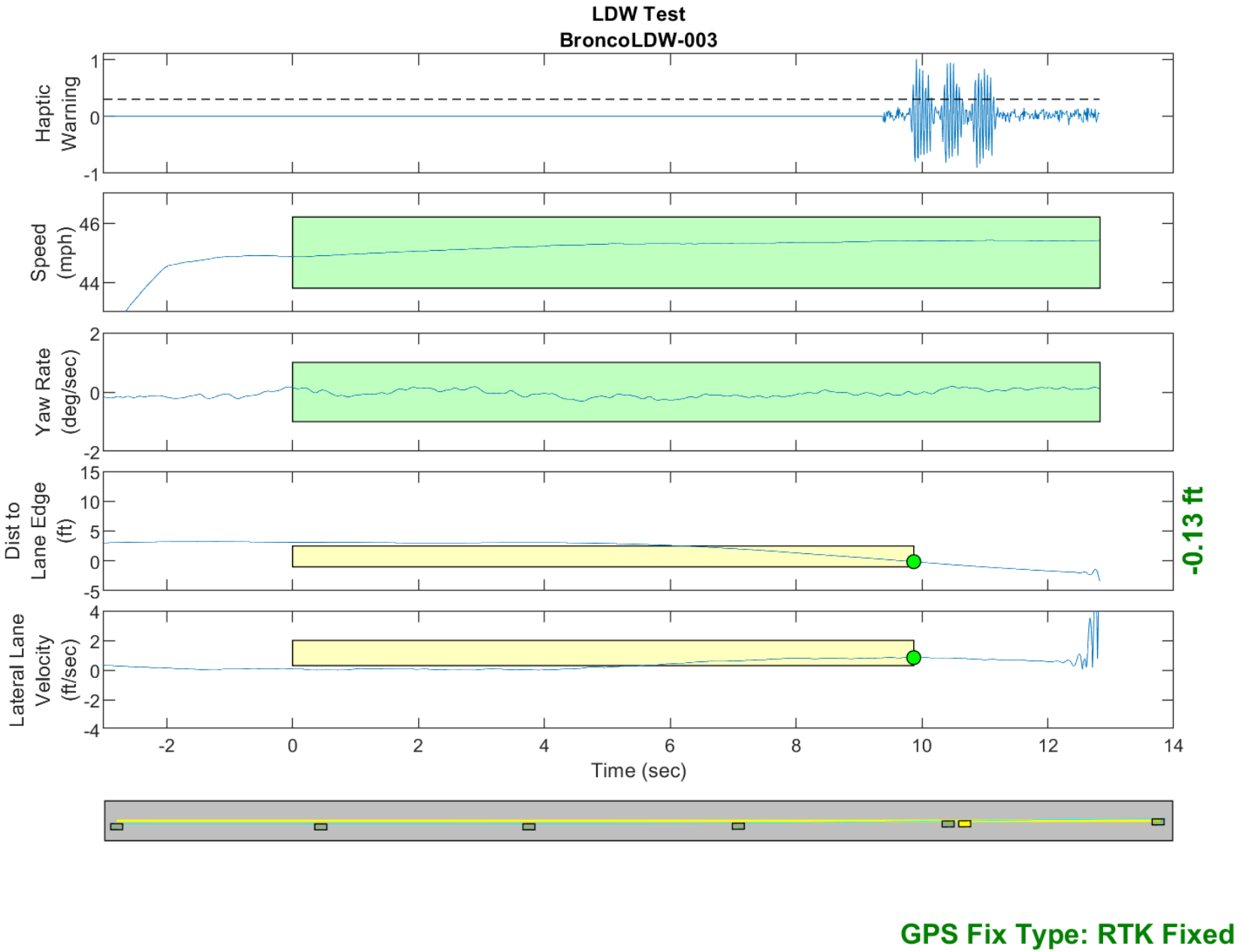

Figure D8. Time History for Run 03, Solid Line, Left Departure, Haptic Warning

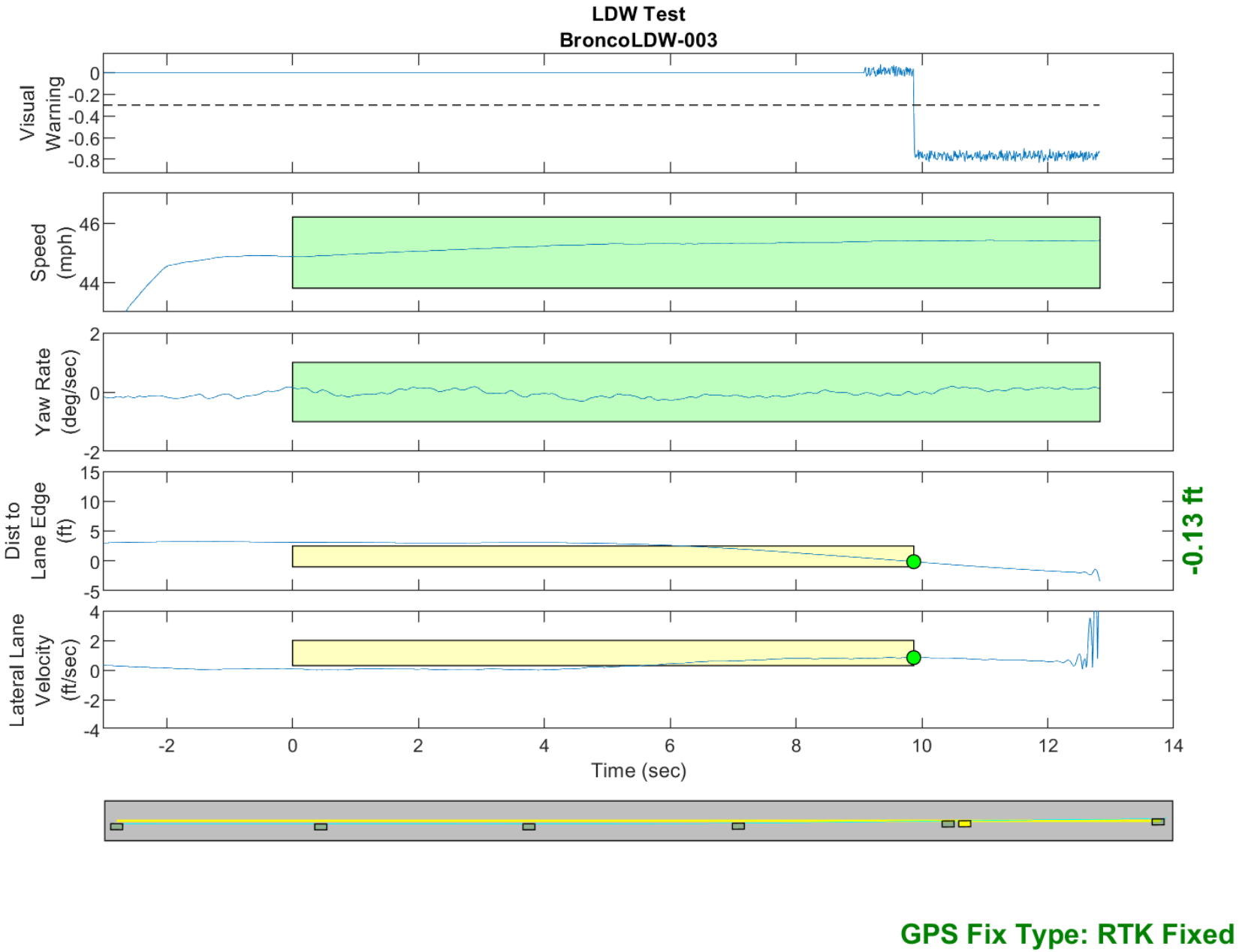

Figure D9. Time History for Run 03, Solid Line, Left Departure, Visual Warning

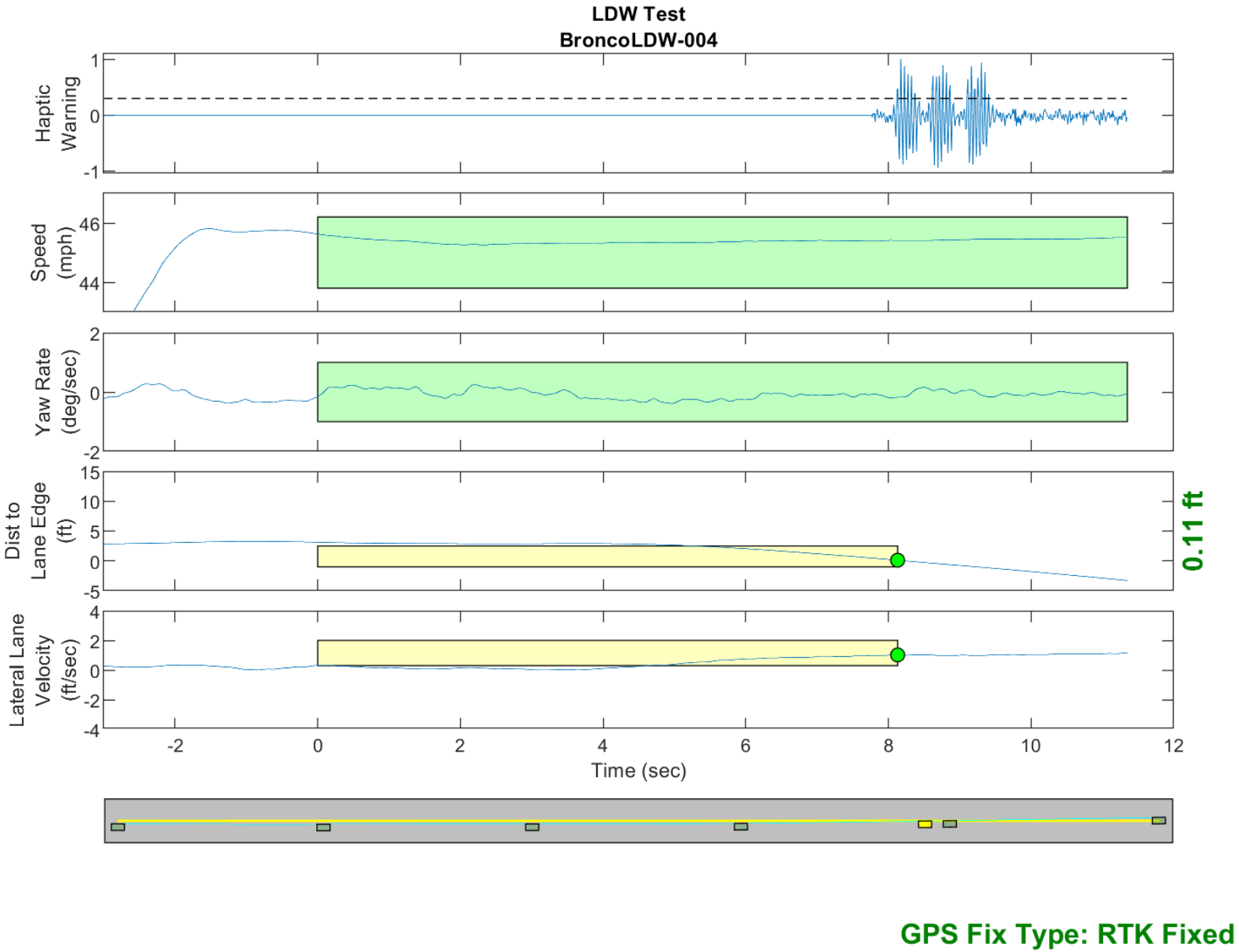

Figure D10. Time History for Run 04, Solid Line, Left Departure, Haptic Warning

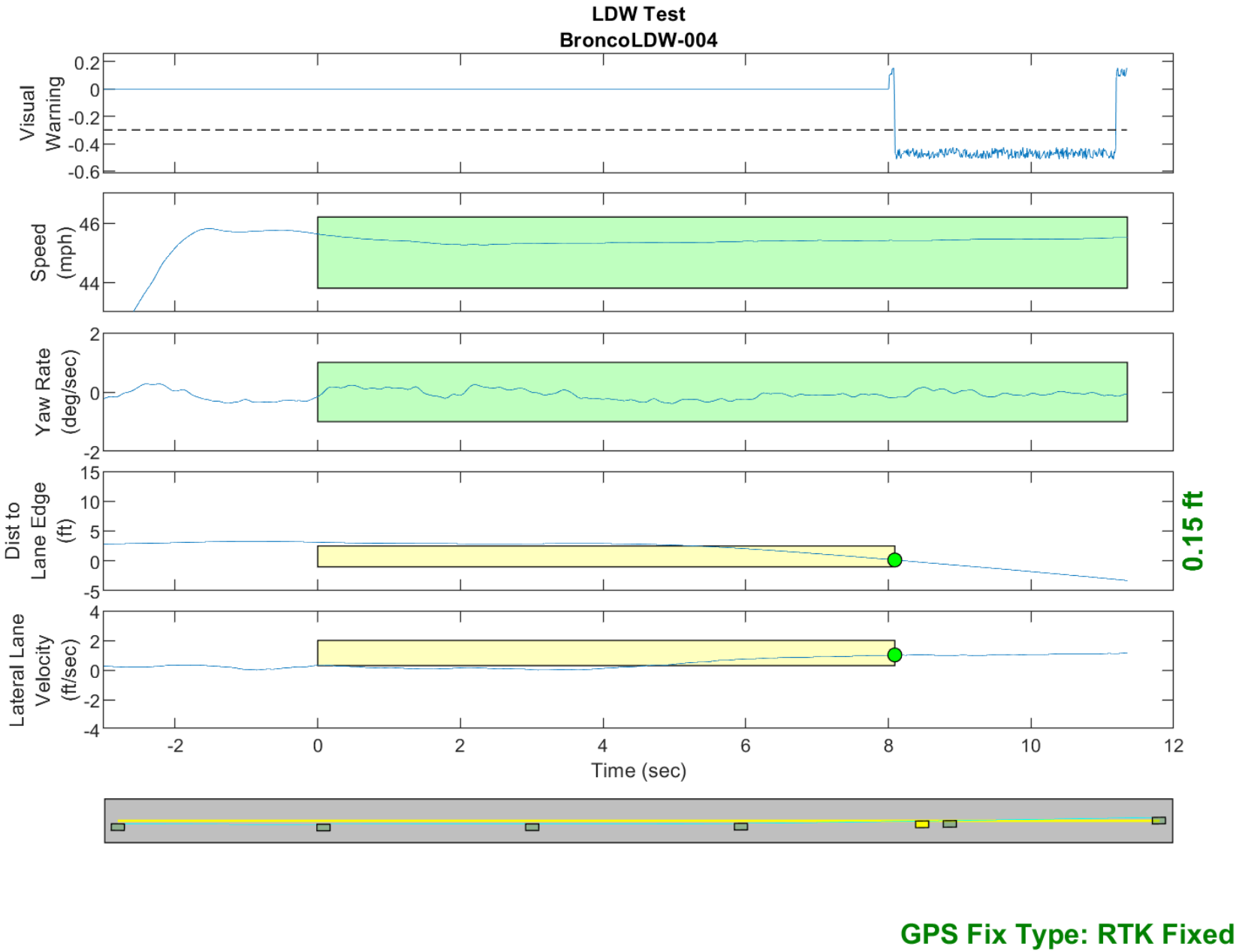

Figure D11. Time History for Run 04, Solid Line, Left Departure, Visual Warning

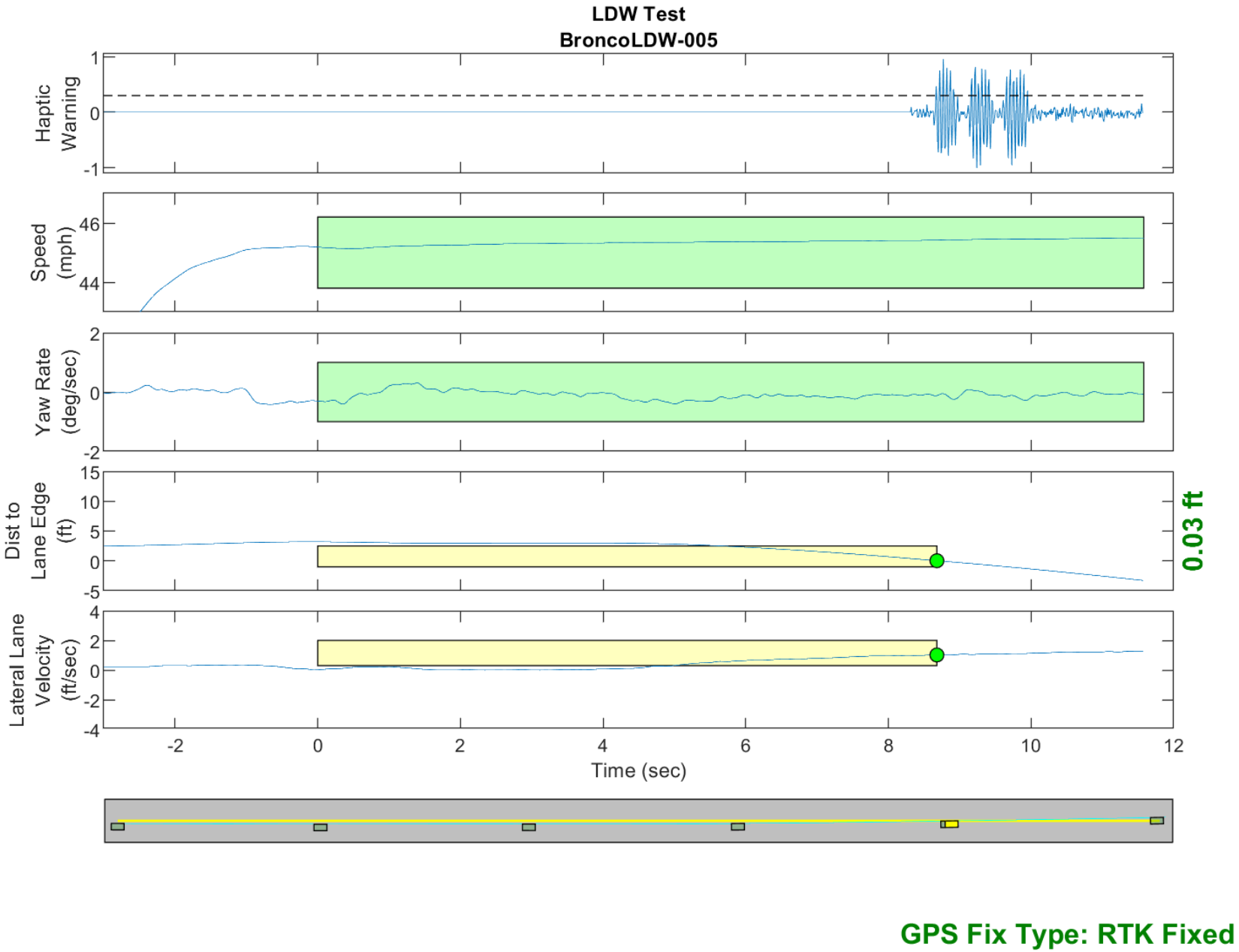

Figure D12. Time History for Run 05, Solid Line, Left Departure, Haptic Warning

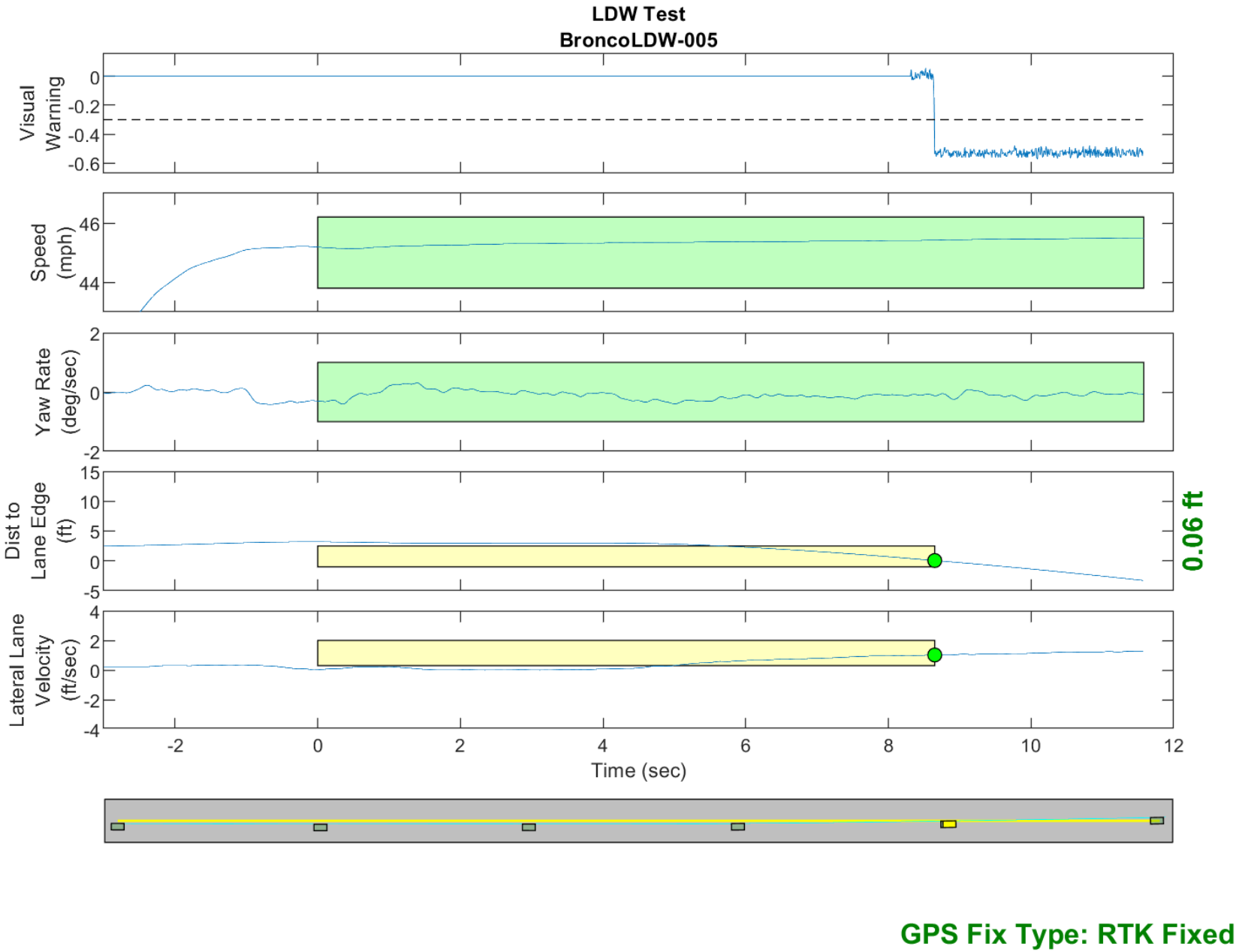

Figure D13. Time History for Run 05, Solid Line, Left Departure, Visual Warning

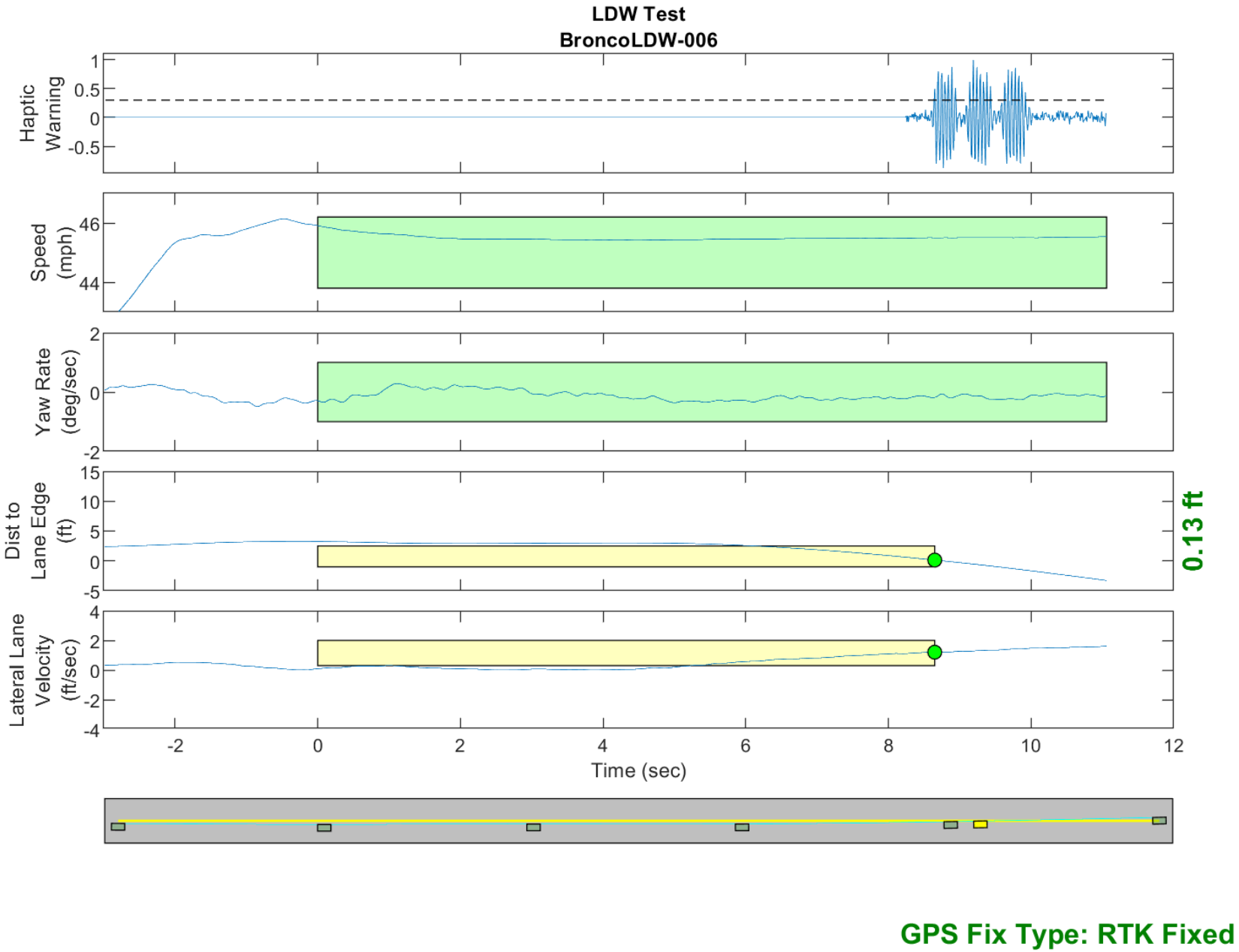

Figure D14. Time History for Run 06, Solid Line, Left Departure, Haptic Warning

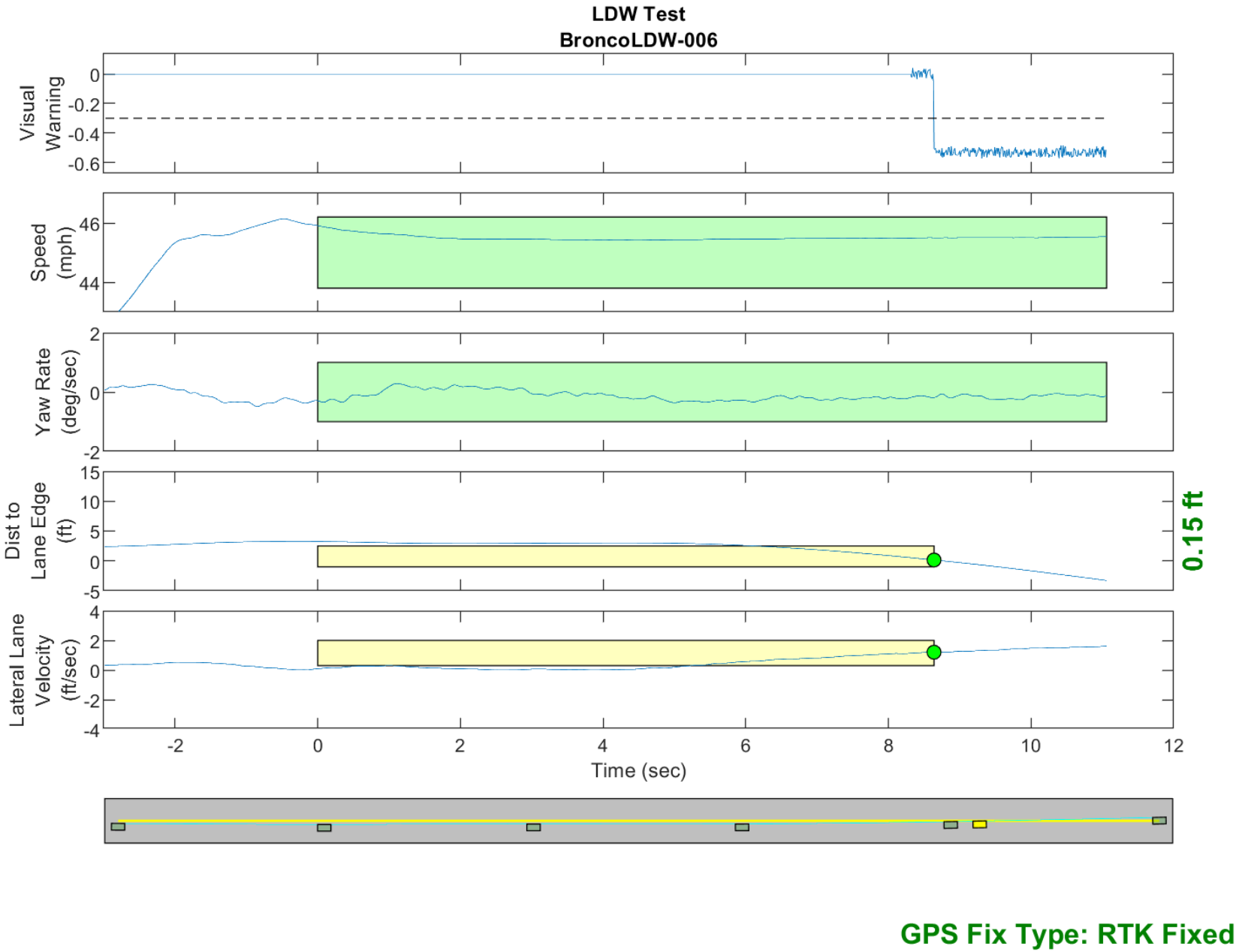

Figure D15. Time History for Run 06, Solid Line, Left Departure, Visual Warning

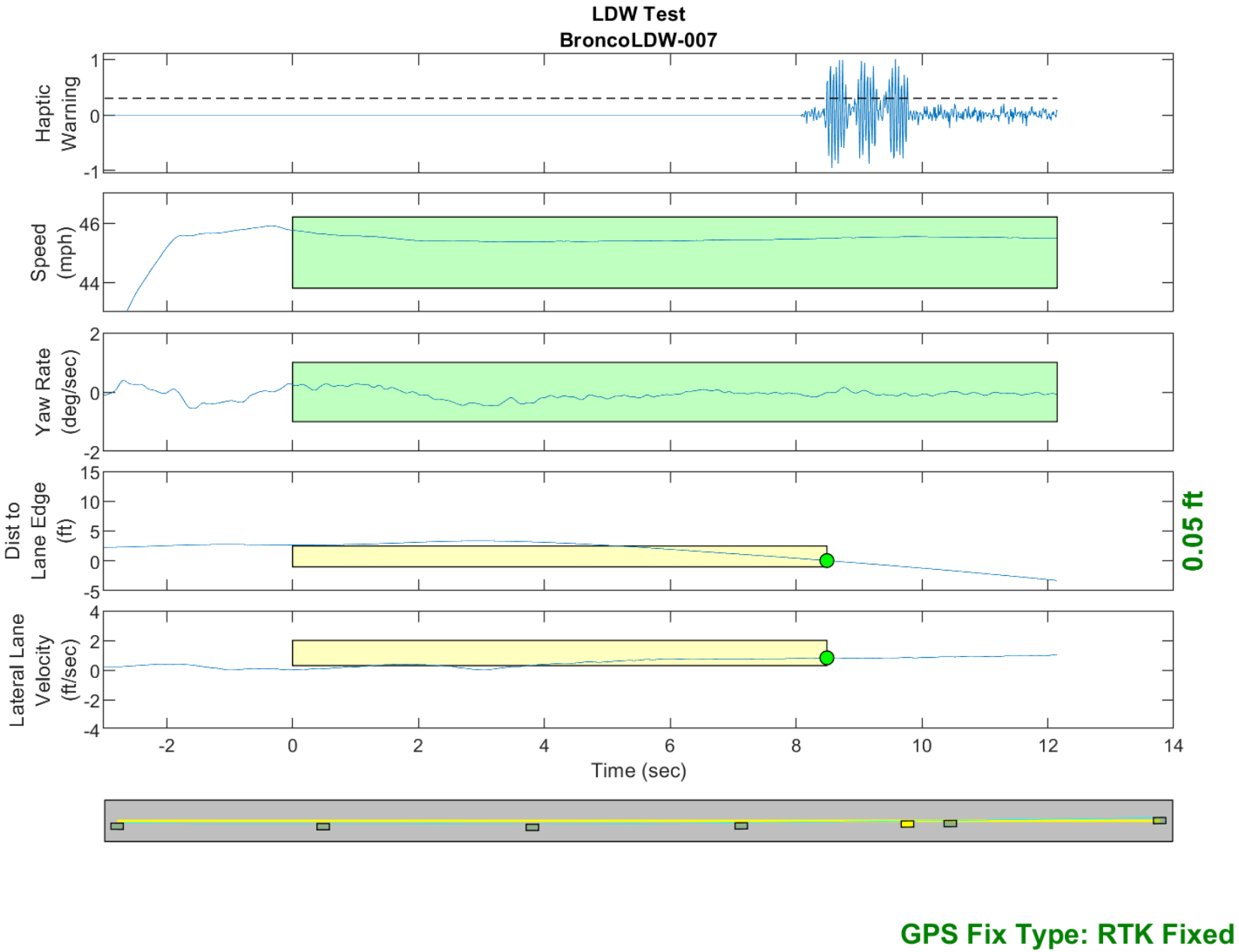

Figure D16. Time History for Run 07, Solid Line, Left Departure, Haptic Warning

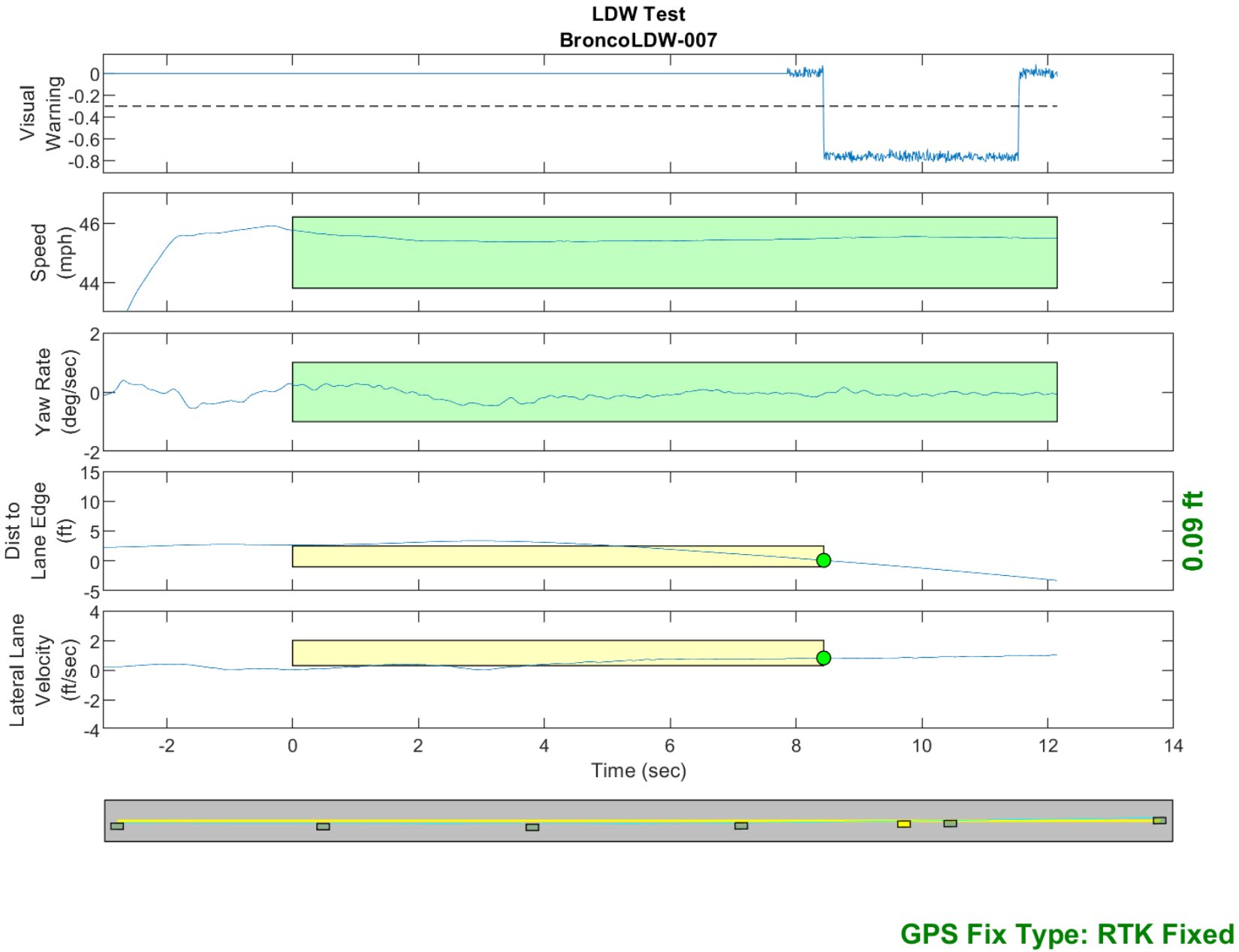

Figure D17. Time History for Run 07, Solid Line, Left Departure, Visual Warning

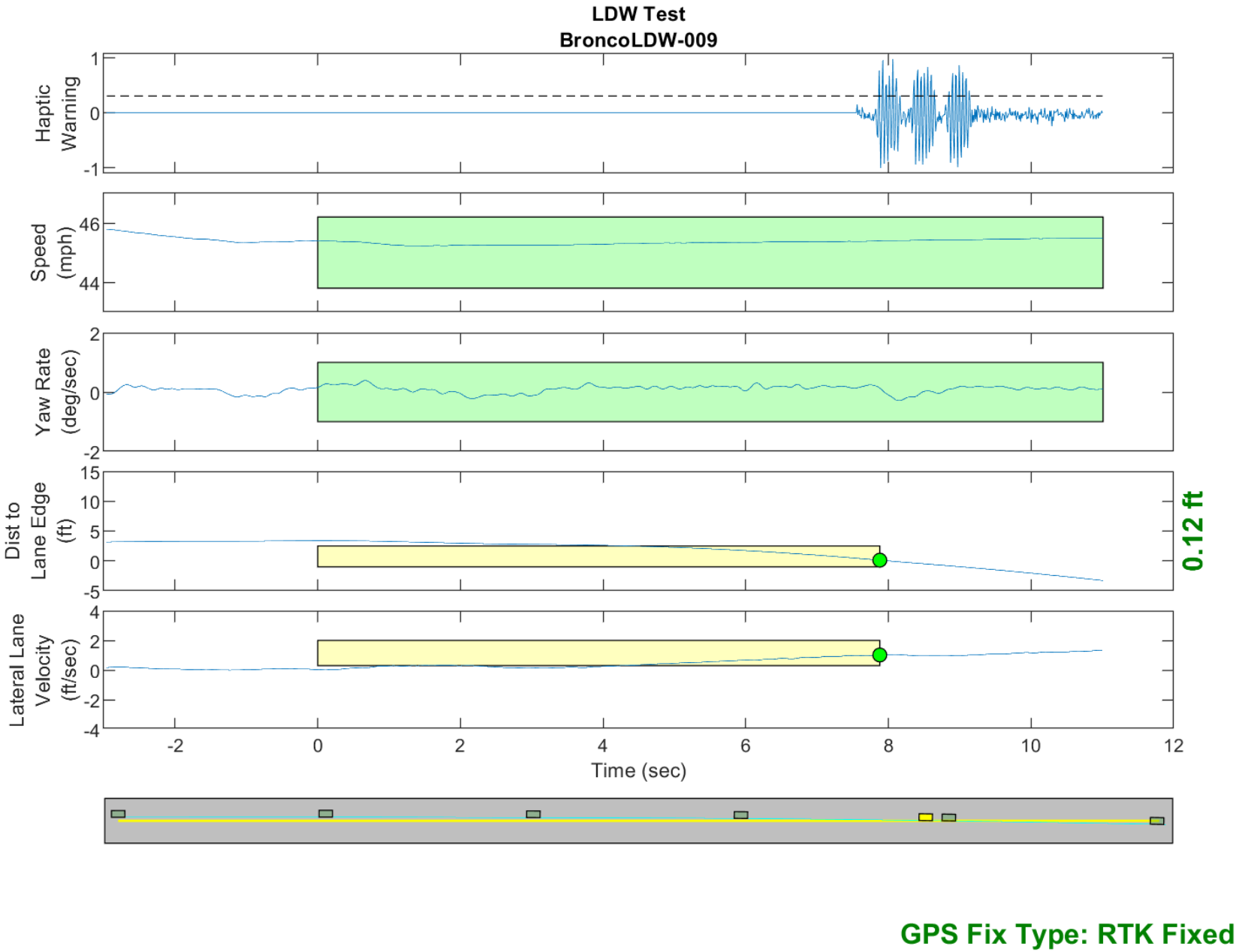

Figure D18. Time History for Run 09, Solid Line, Right Departure, Haptic Warning

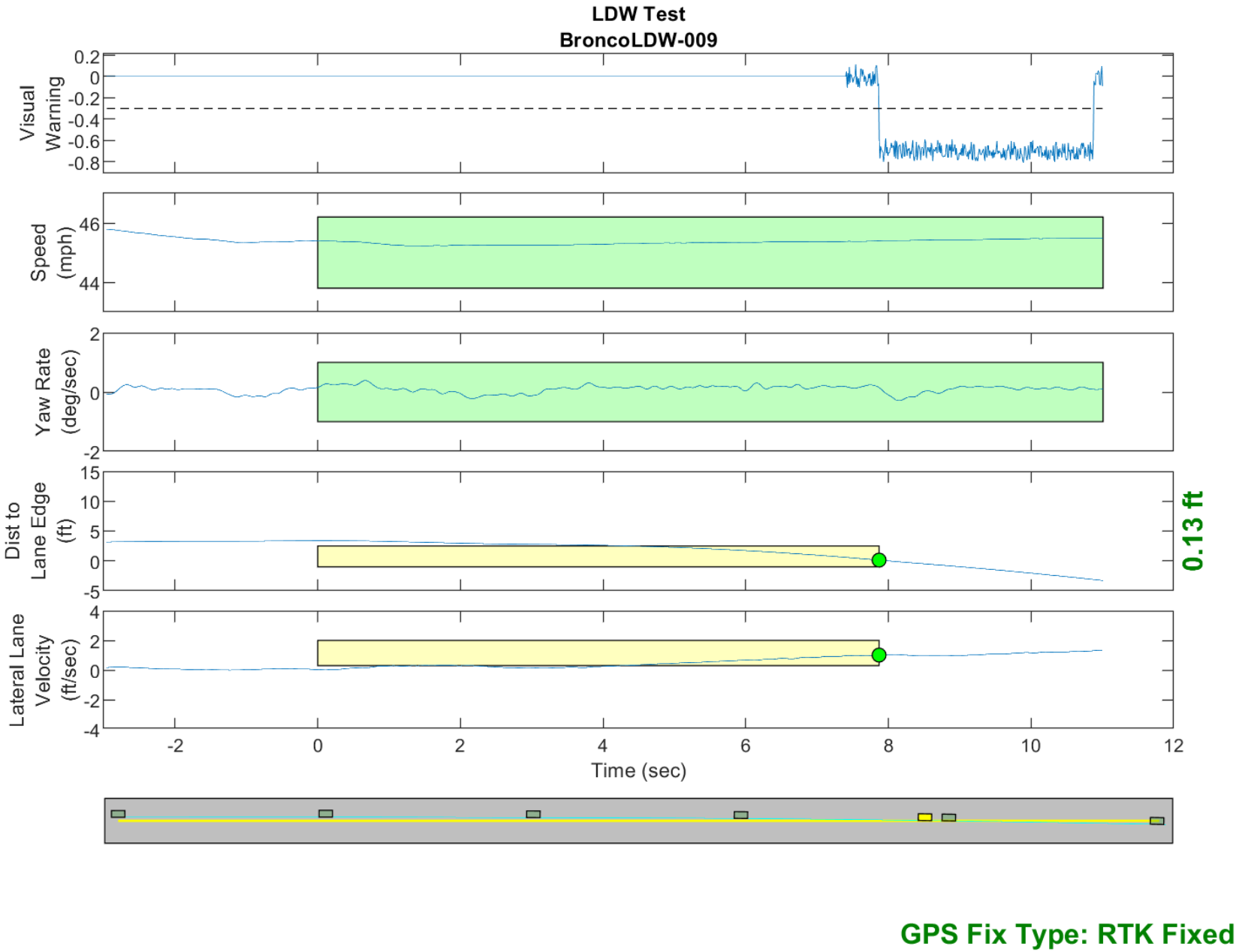

Figure D19. Time History for Run 09, Solid Line, Right Departure, Visual Warning

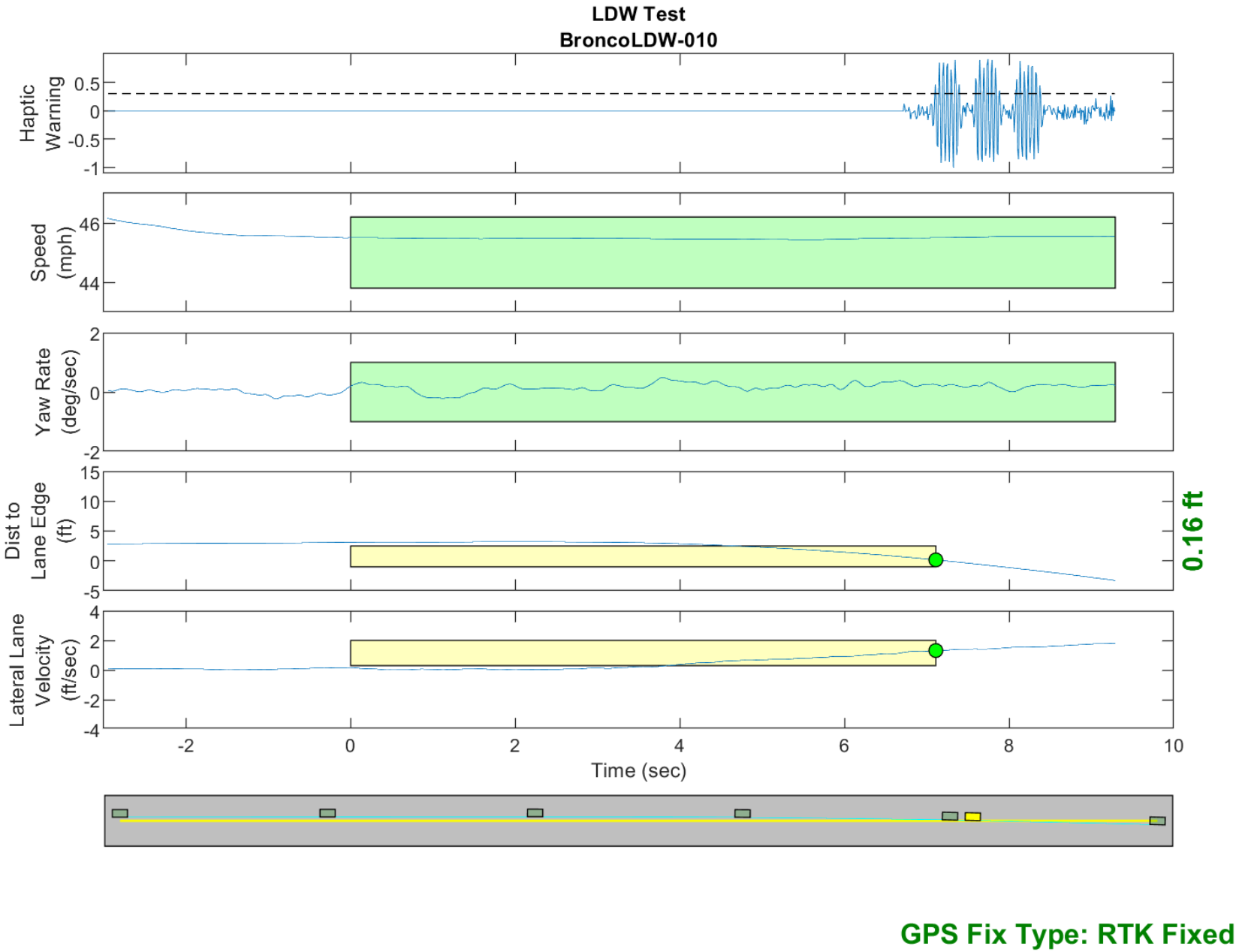

Figure D20. Time History for Run 10, Solid Line, Right Departure, Haptic Warning

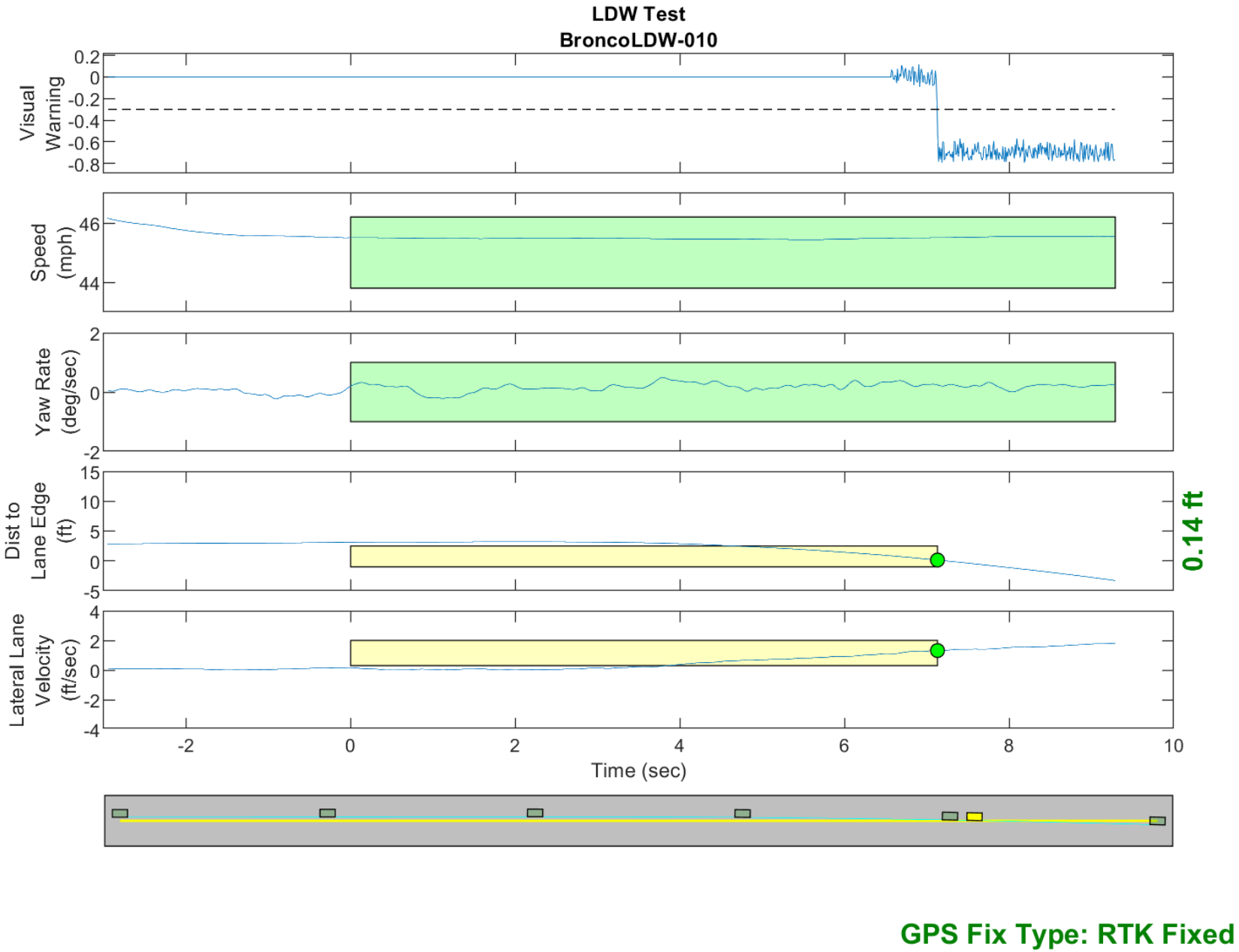

Figure D21. Time History for Run 10, Solid Line, Right Departure, Visual Warning

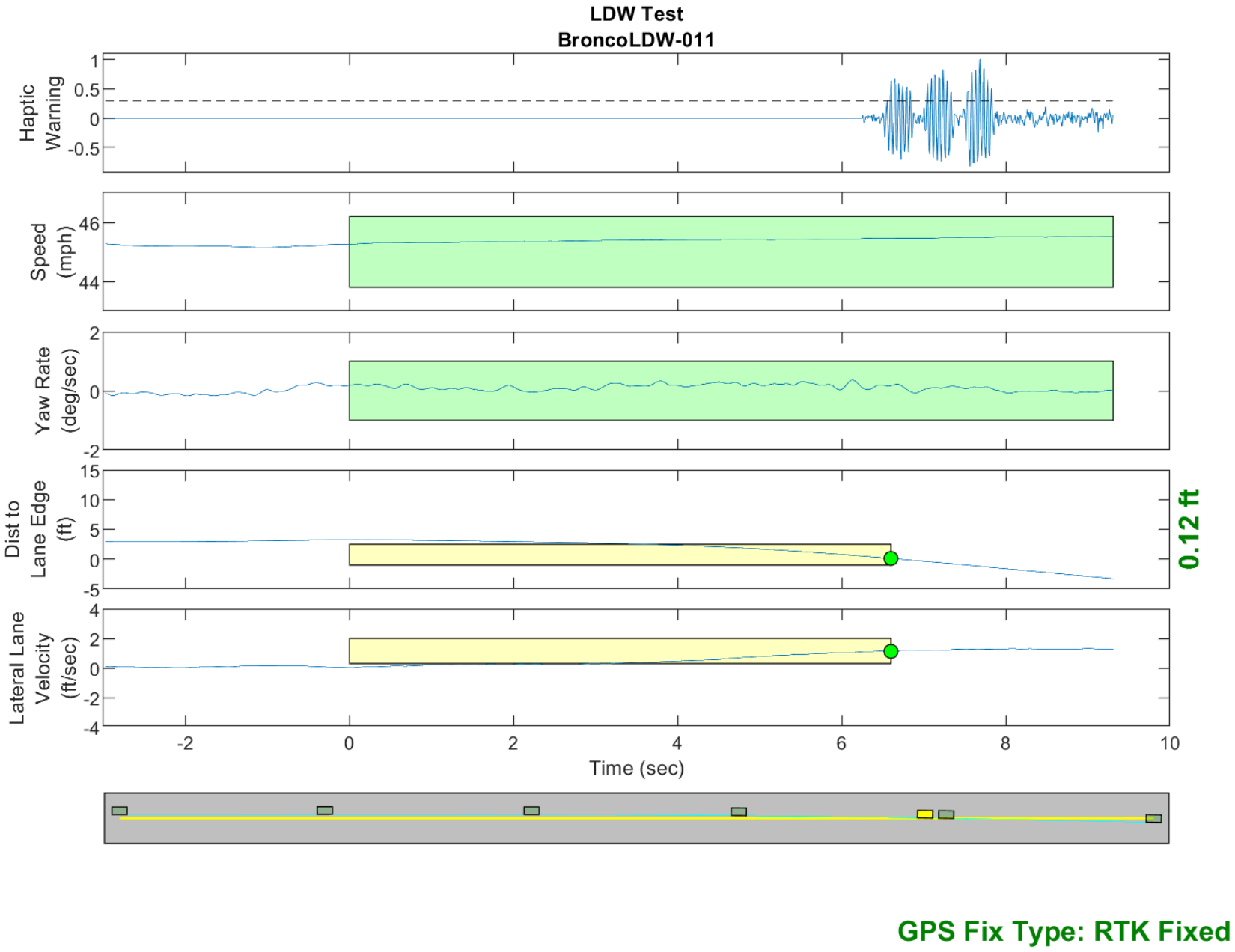

Figure D22. Time History for Run 11, Solid Line, Right Departure, Haptic Warning

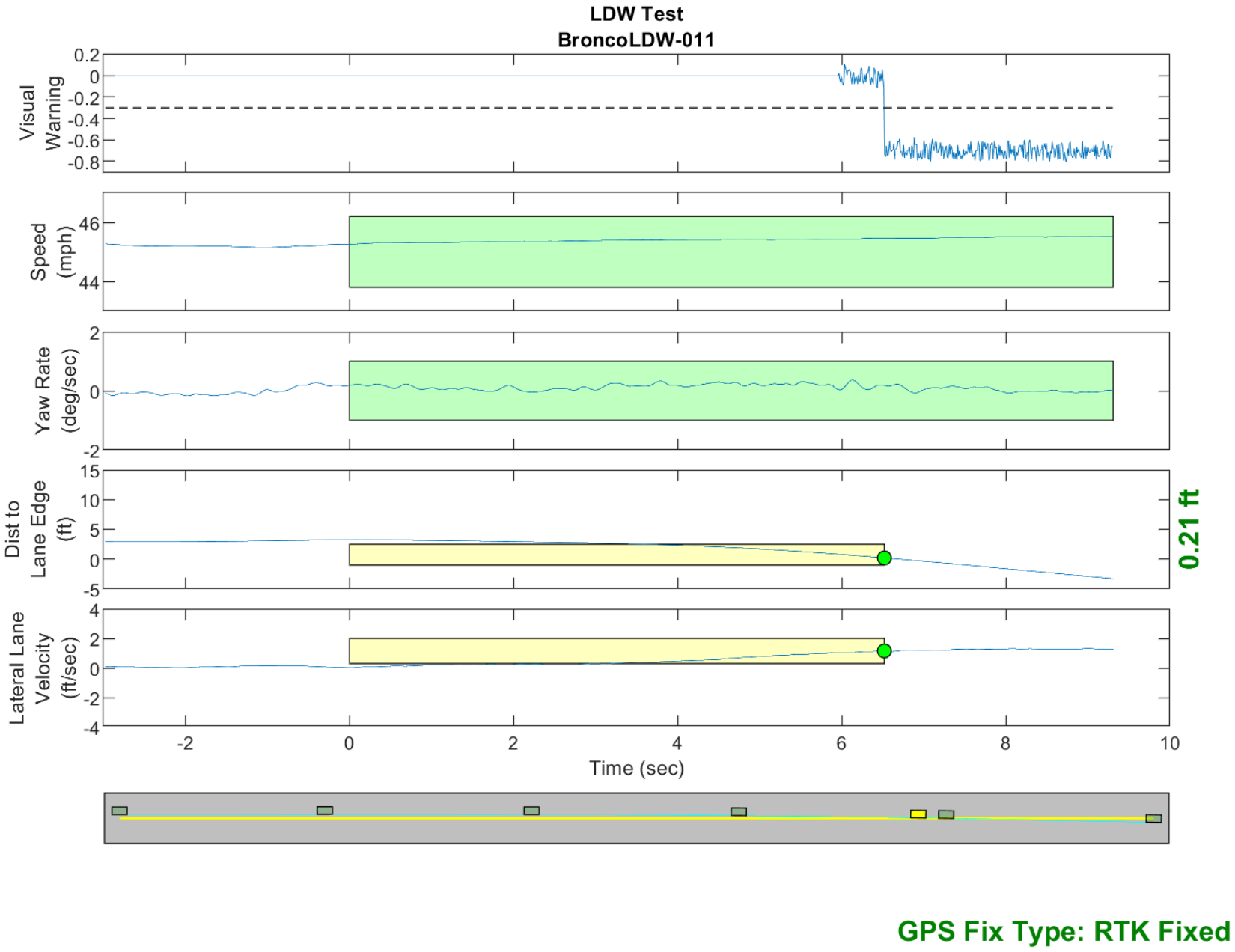

Figure D23. Time History for Run 11, Solid Line, Right Departure, Visual Warning

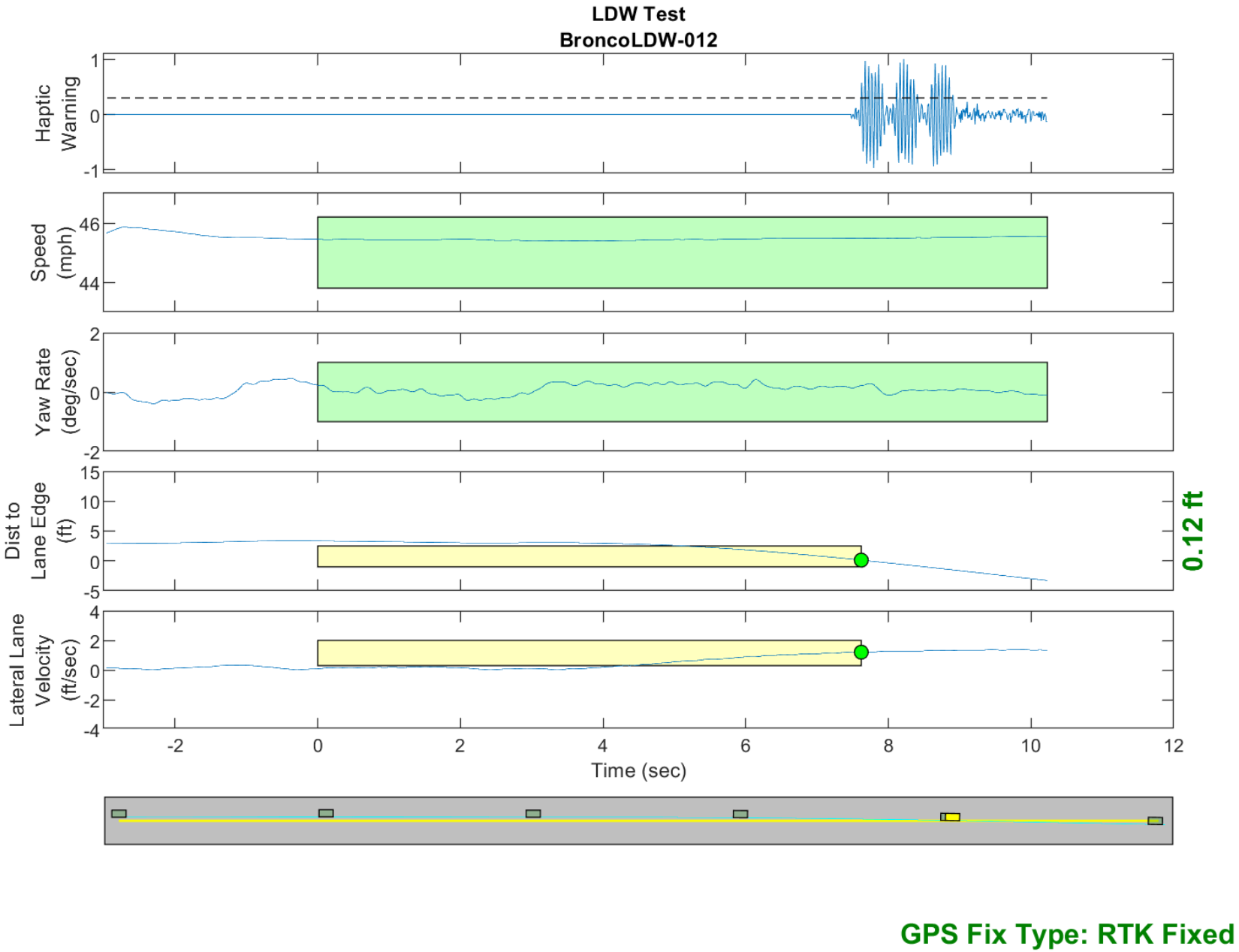

Figure D24. Time History for Run 12, Solid Line, Right Departure, Haptic Warning

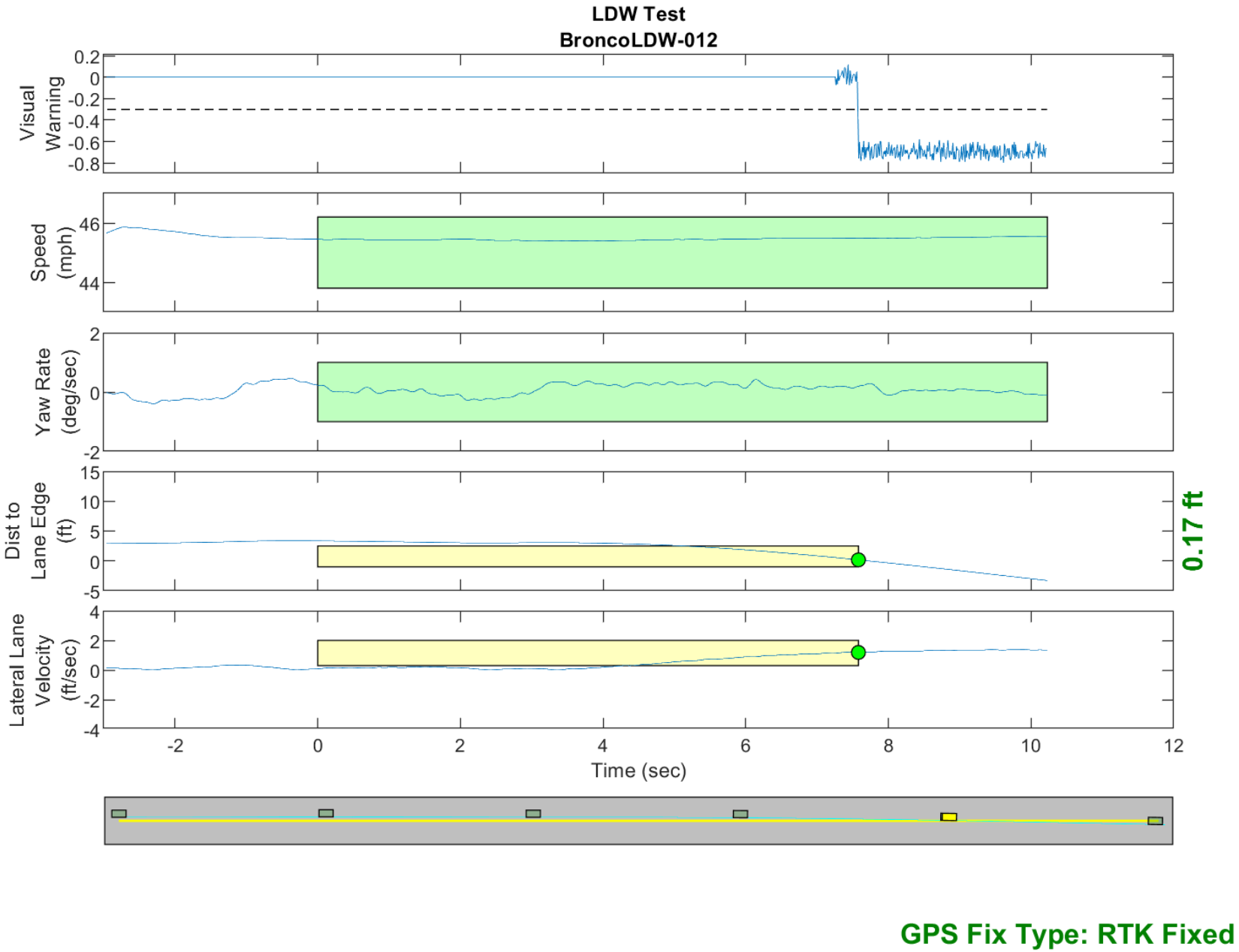

Figure D25. Time History for Run 12, Solid Line, Right Departure, Visual Warning

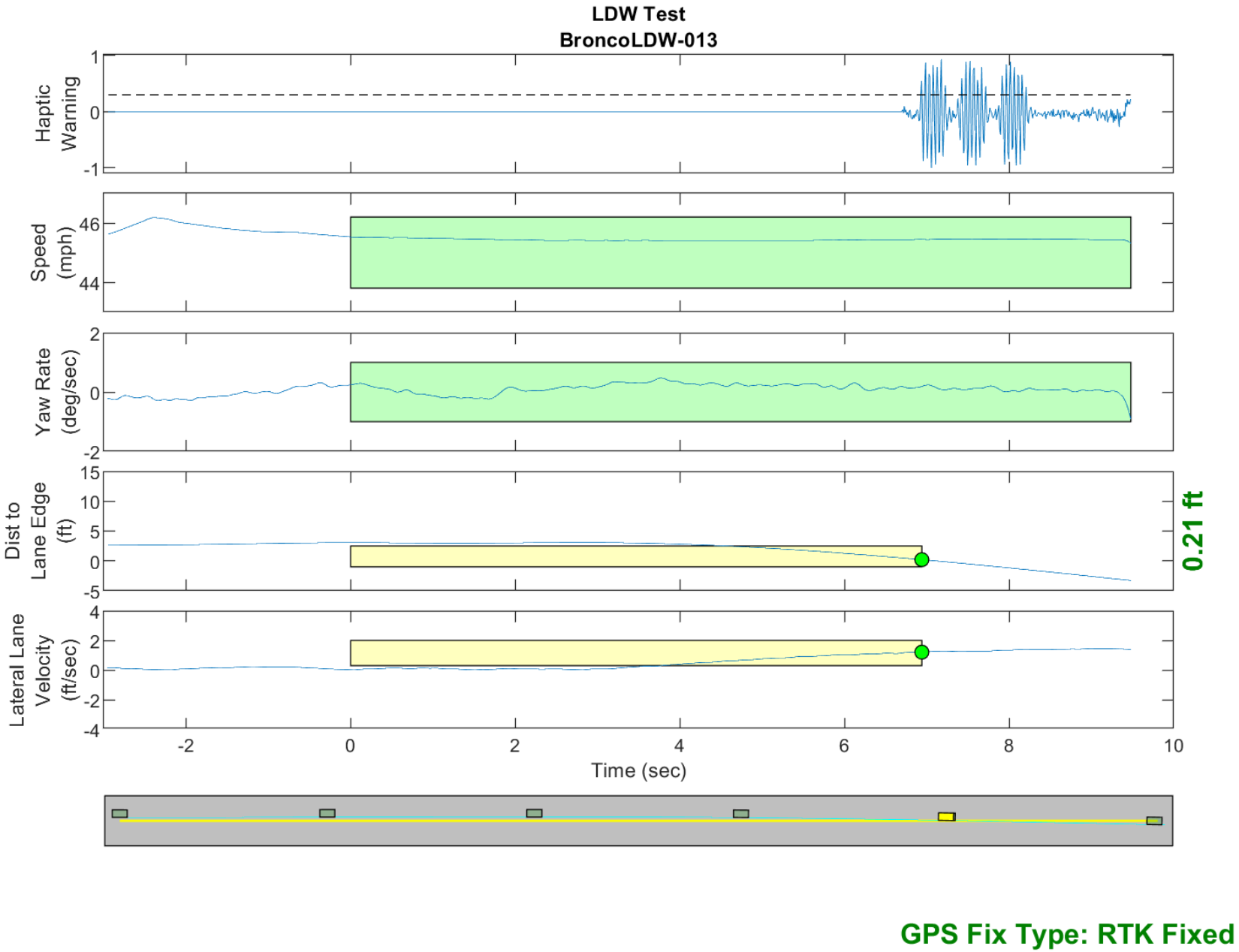

Figure D26. Time History for Run 13, Solid Line, Right Departure, Haptic Warning

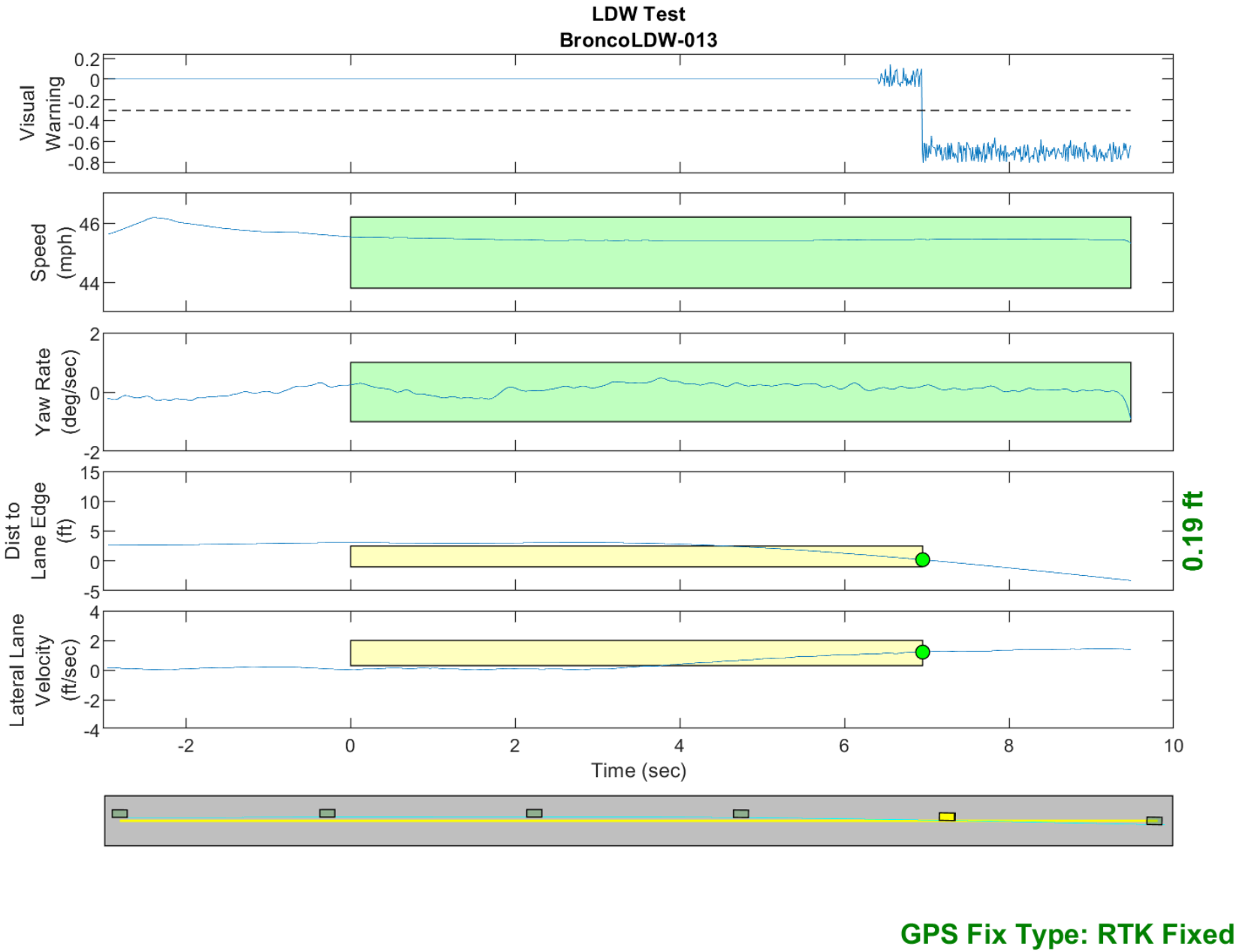

Figure D27. Time History for Run 13, Solid Line, Right Departure, Visual Warning

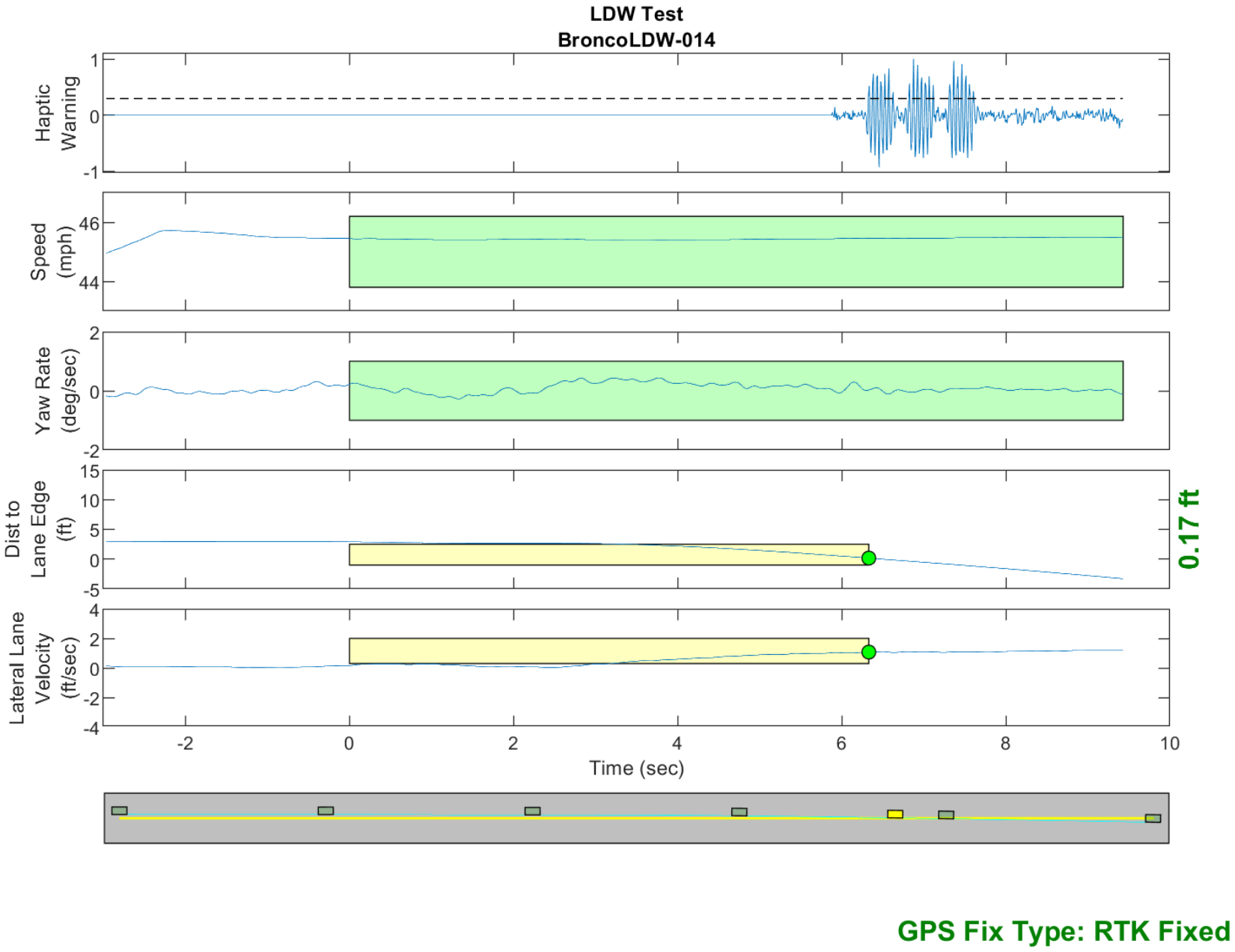

Figure D28. Time History for Run 14, Solid Line, Right Departure, Haptic Warning

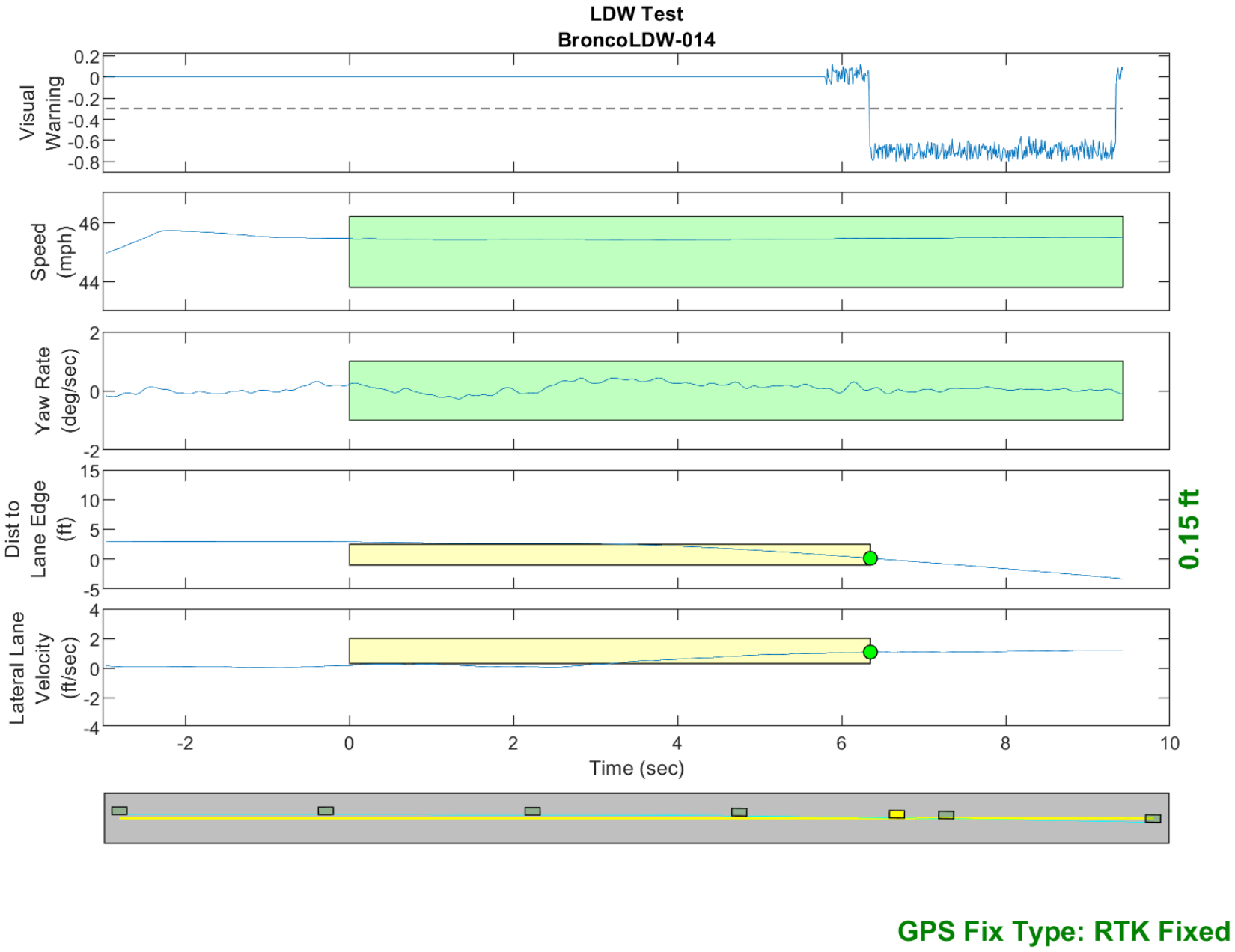

Figure D29. Time History for Run 14, Solid Line, Right Departure, Visual Warning

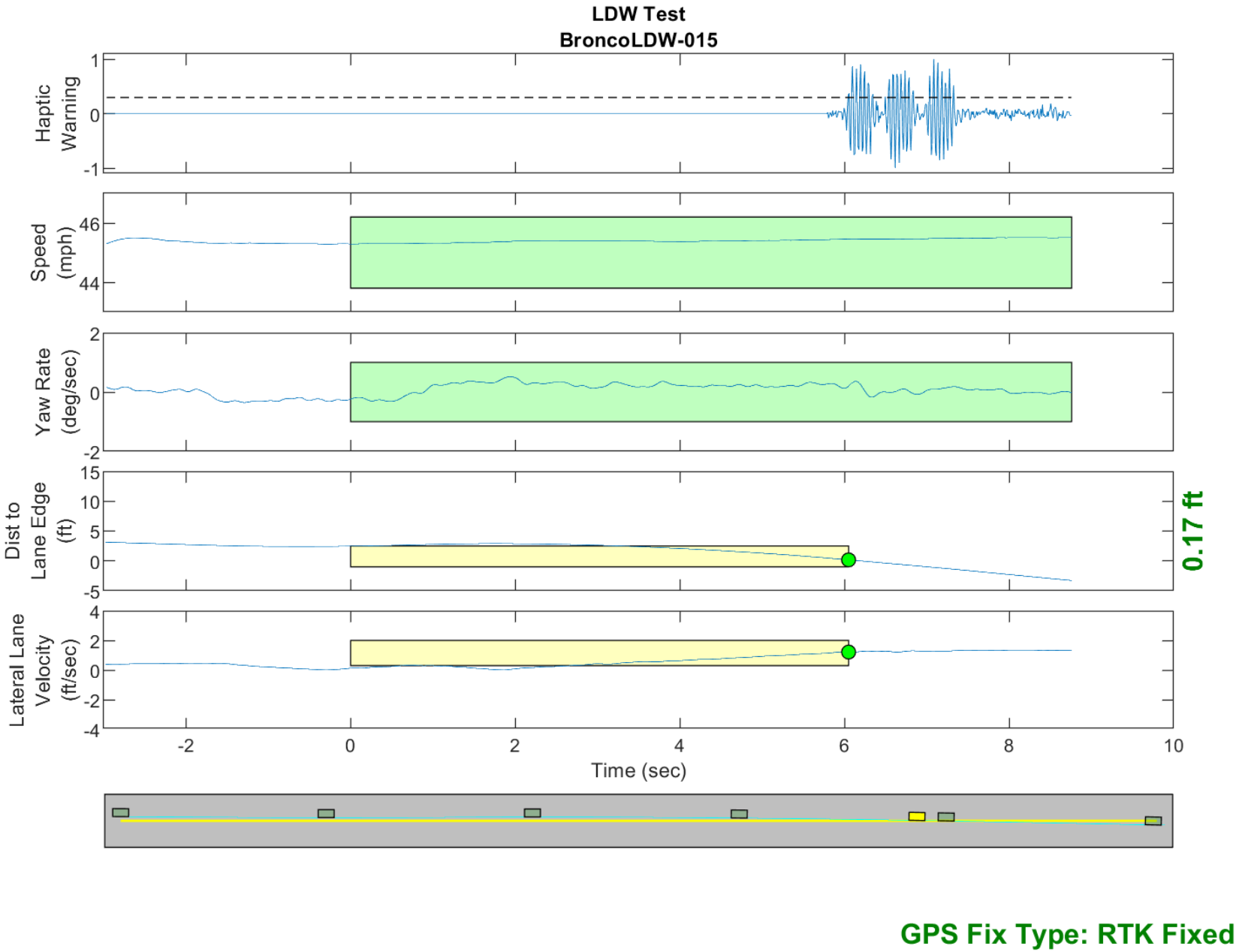

Figure D30. Time History for Run 15, Solid Line, Right Departure, Haptic Warning

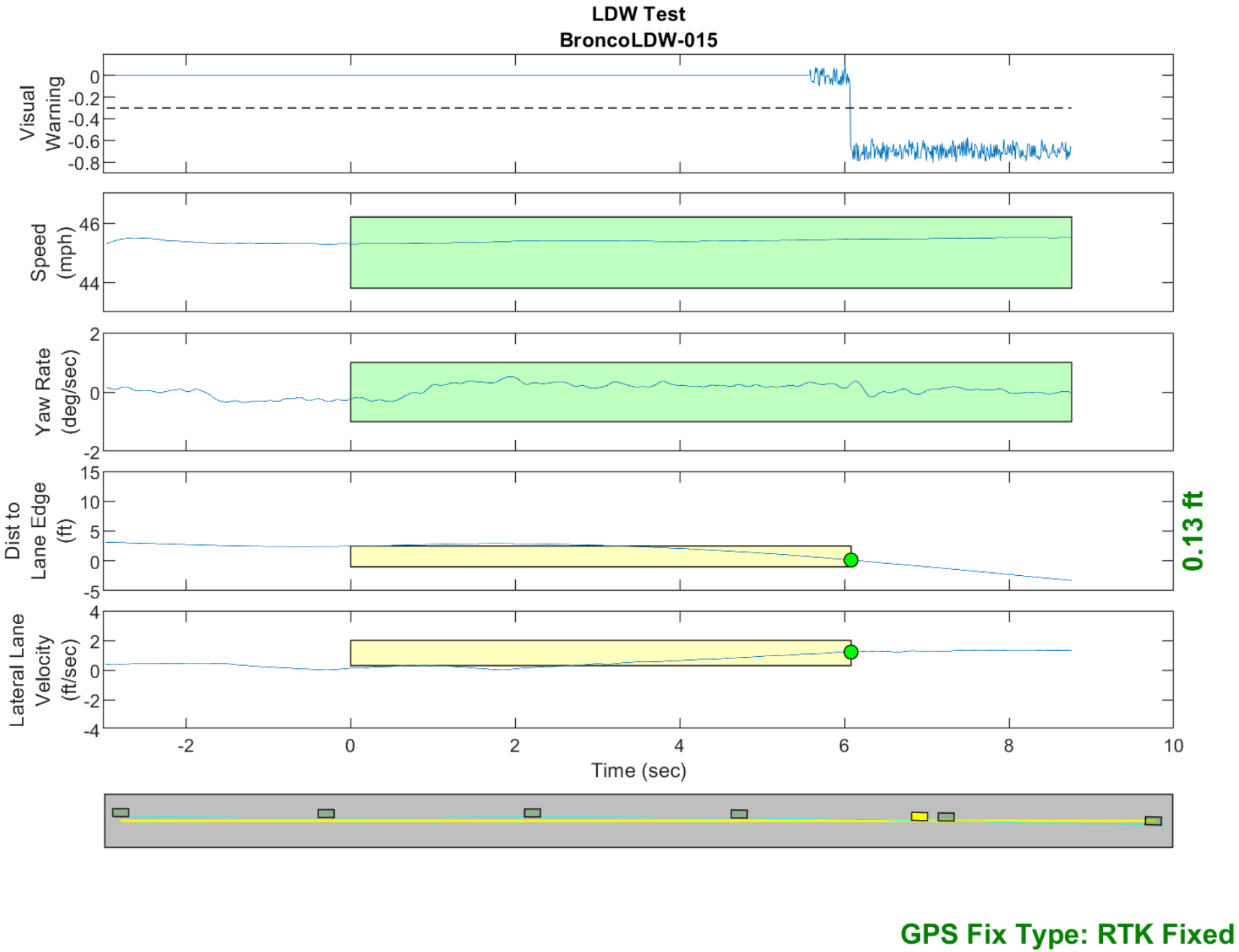

Figure D31. Time History for Run 15, Solid Line, Right Departure, Visual Warning

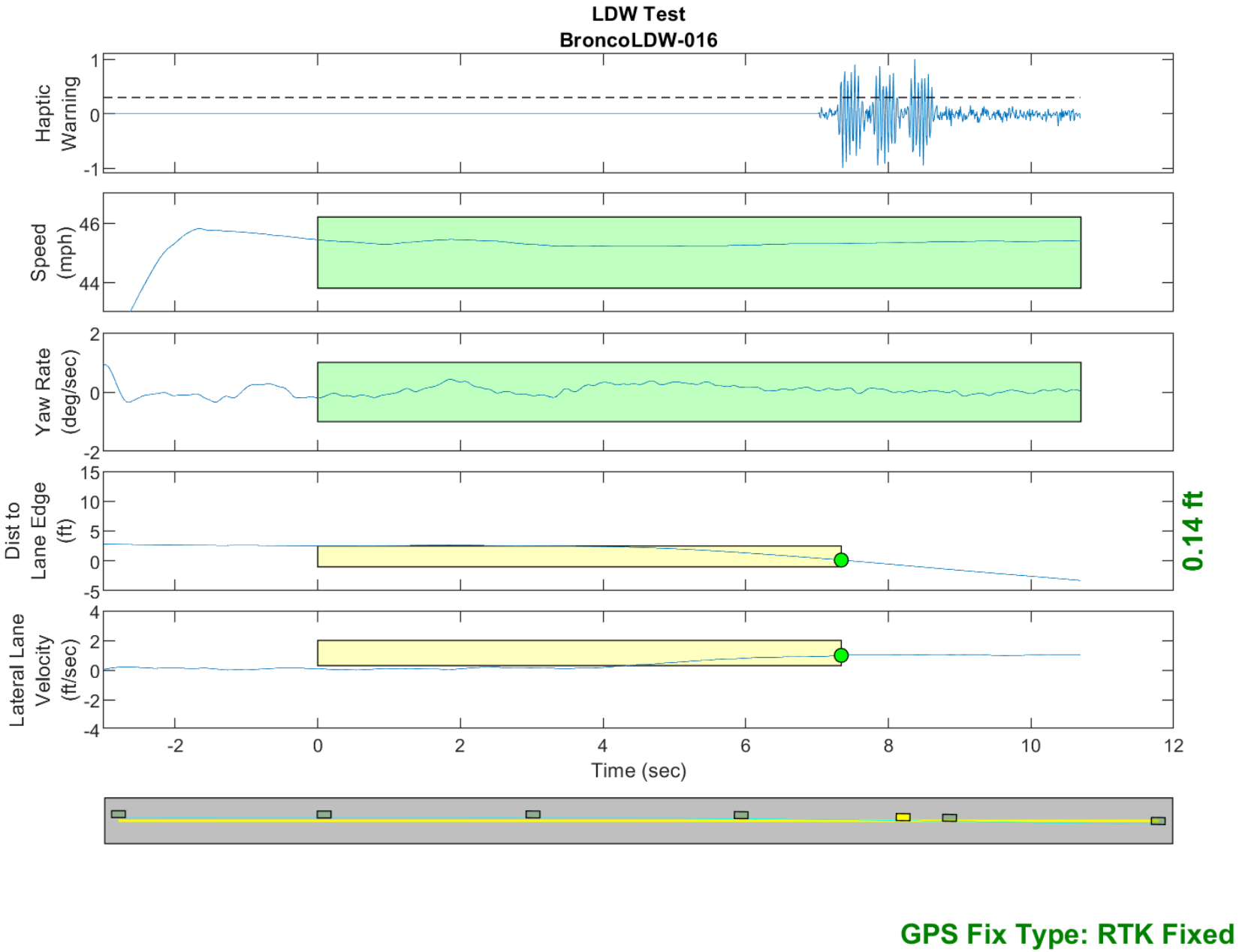

Figure D32. Time History for Run 16, Dashed Line, Right Departure, Haptic Warning

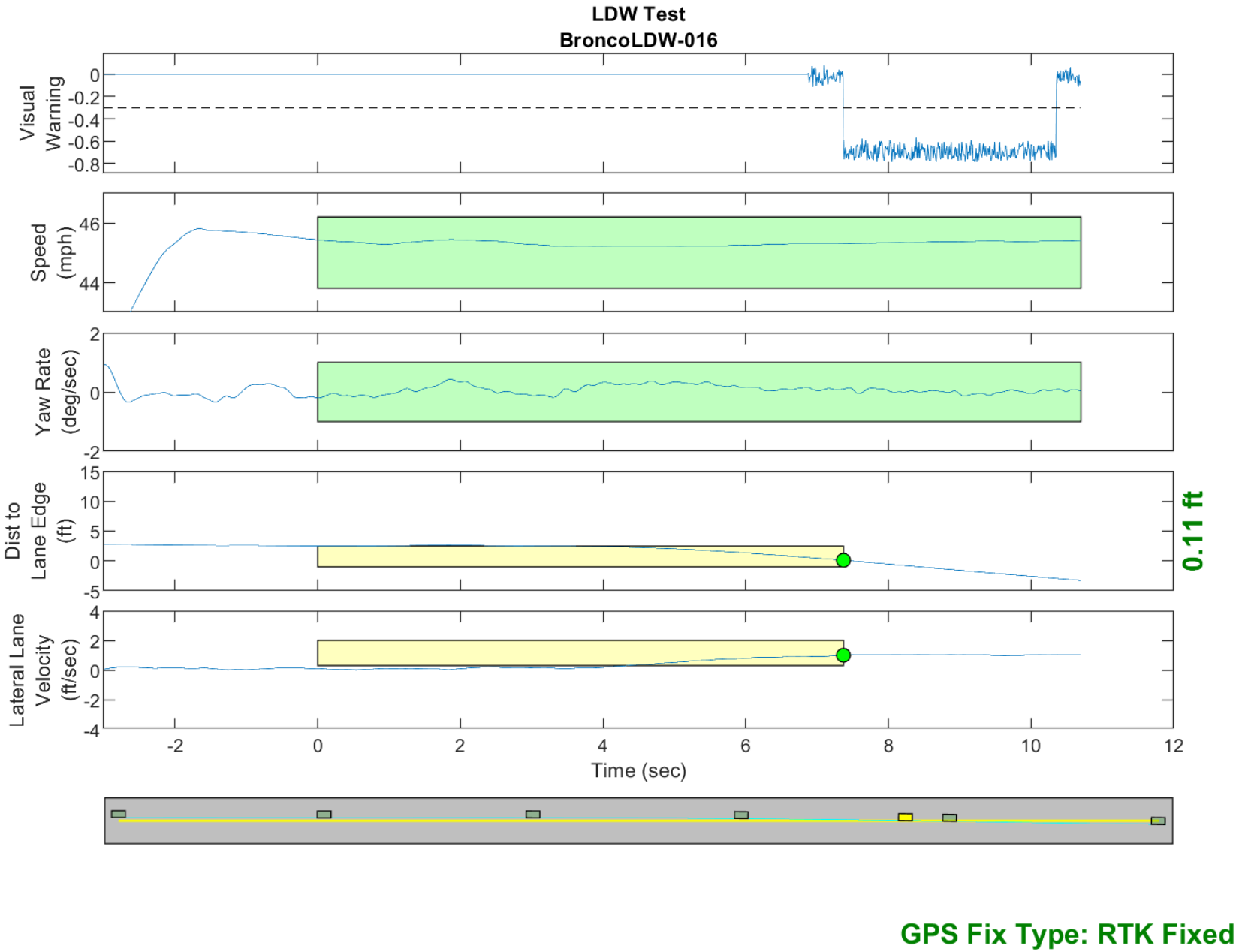

Figure D33. Time History for Run 16, Dashed Line, Right Departure, Visual Warning

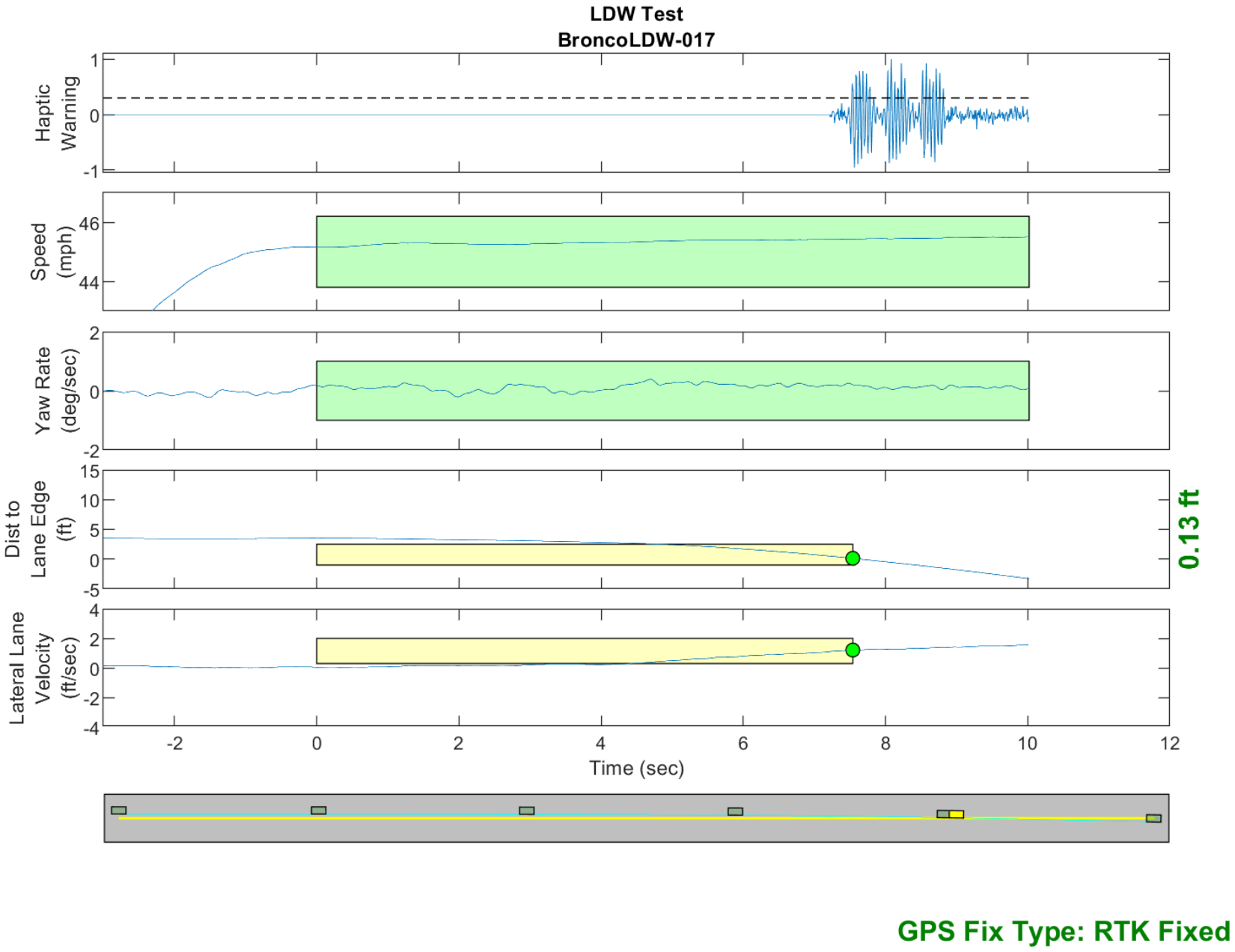

Figure D34. Time History for Run 17, Dashed Line, Right Departure, Haptic Warning

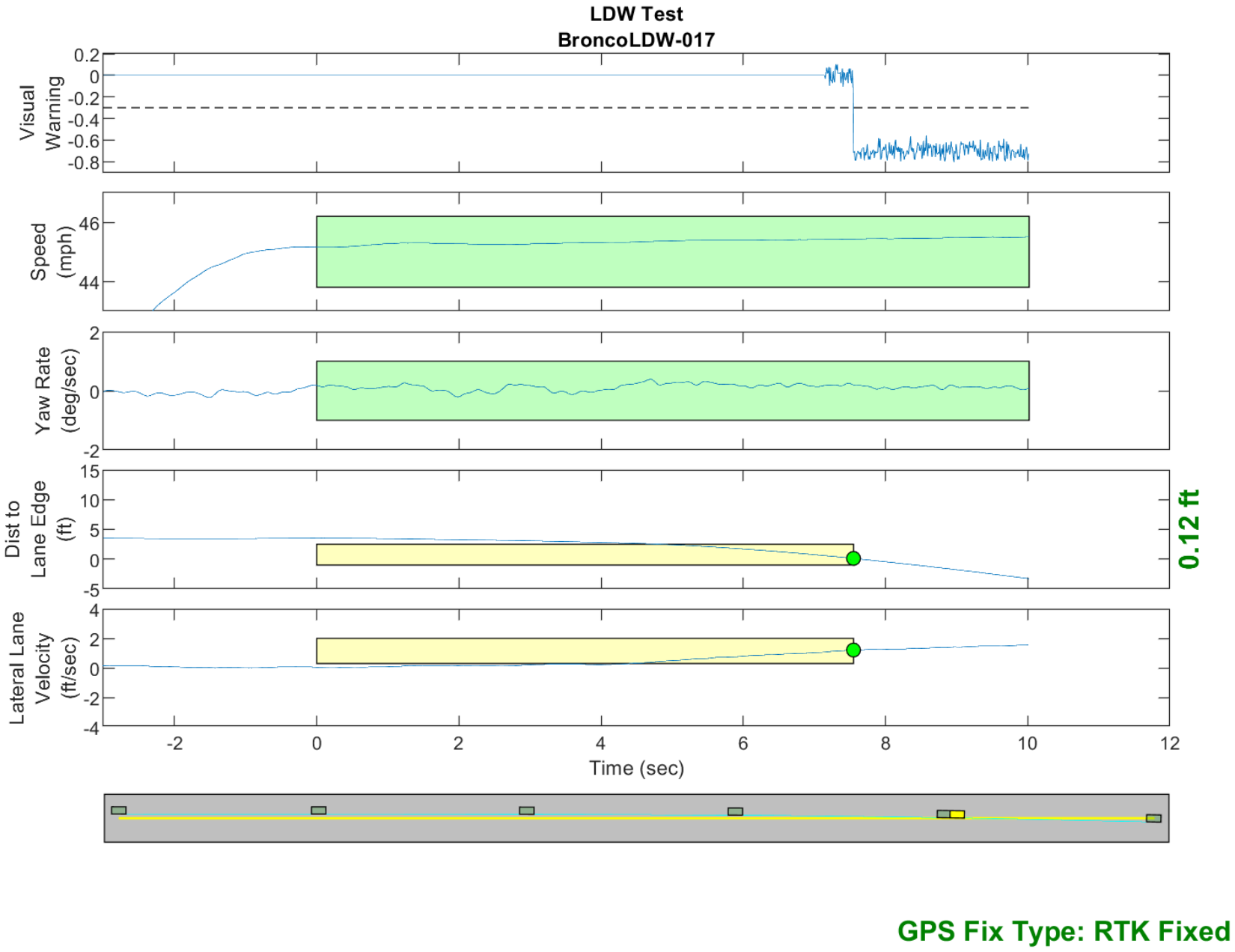

Figure D35. Time History for Run 17, Dashed Line, Right Departure, Visual Warning

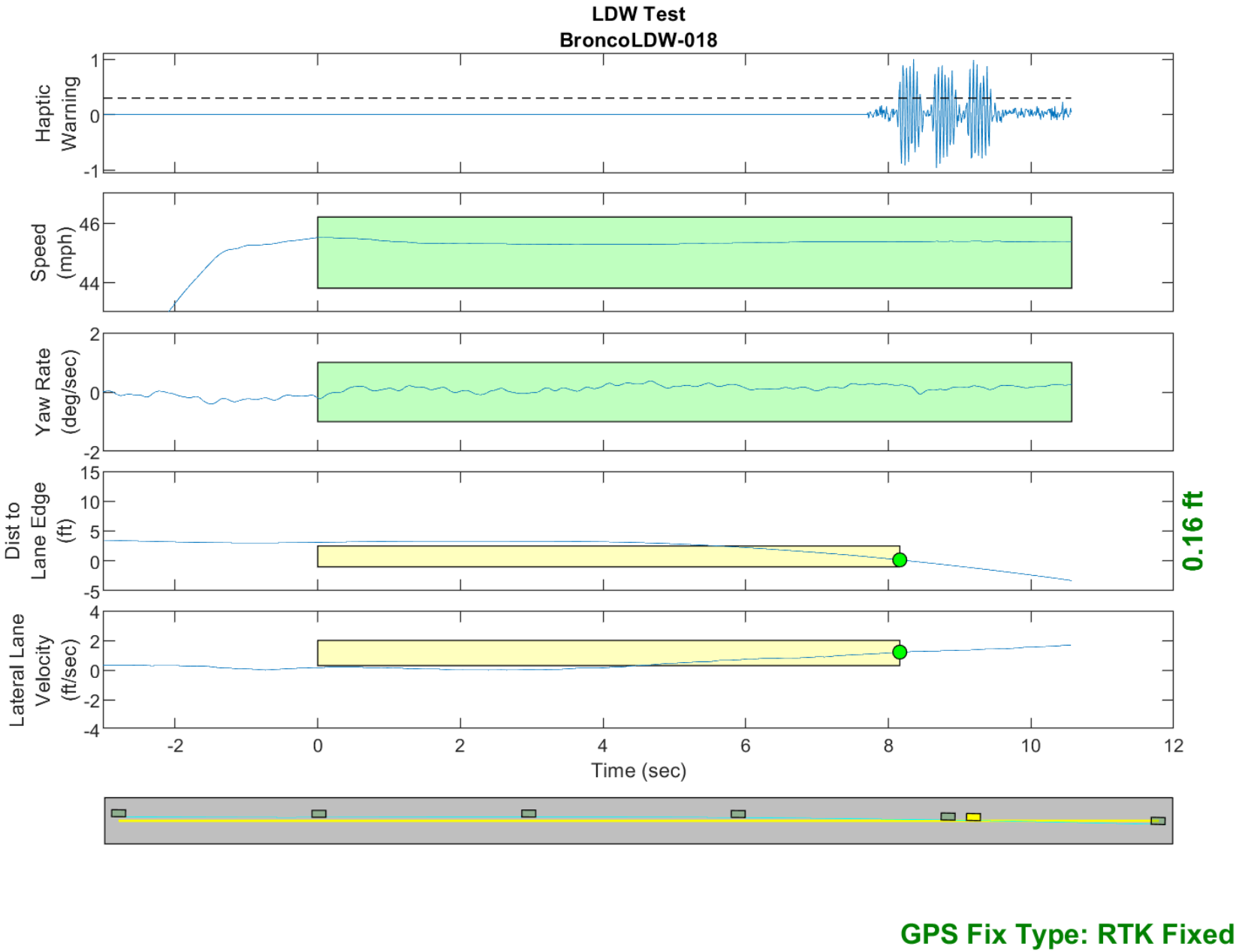

Figure D36. Time History for Run 18, Dashed Line, Right Departure, Haptic Warning

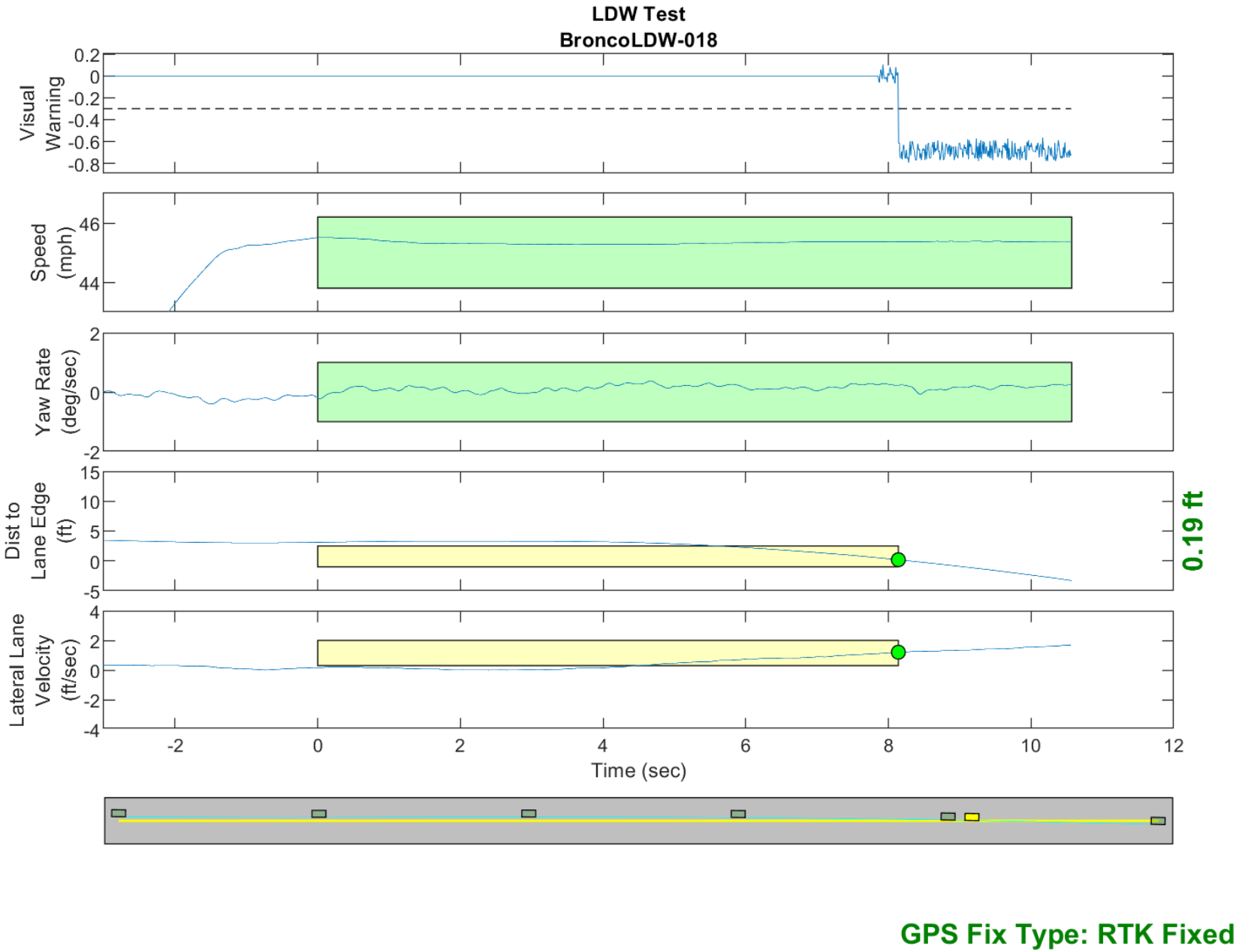

Figure D37. Time History for Run 18, Dashed Line, Right Departure, Visual Warning

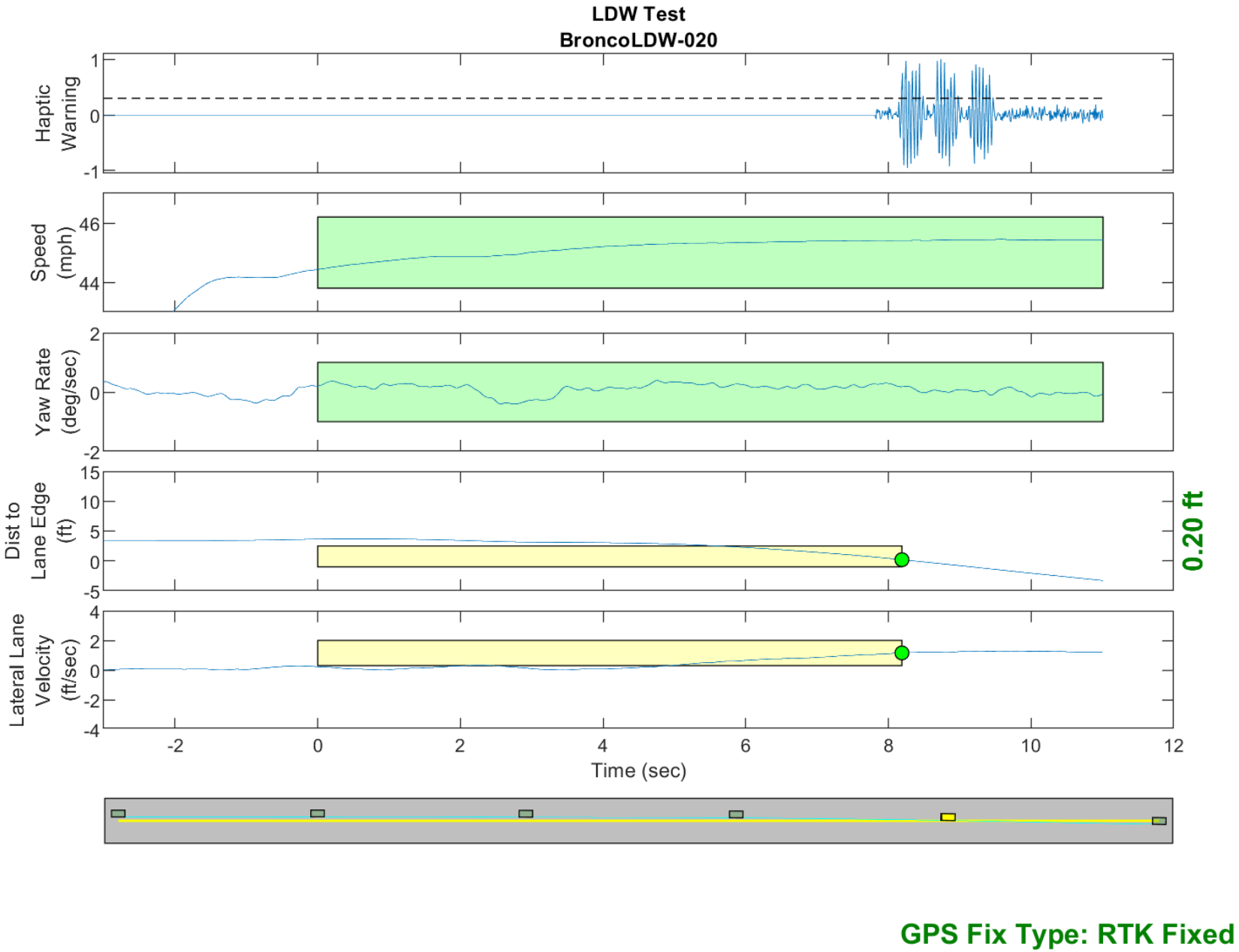

Figure D38. Time History for Run 20, Dashed Line, Right Departure, Haptic Warning

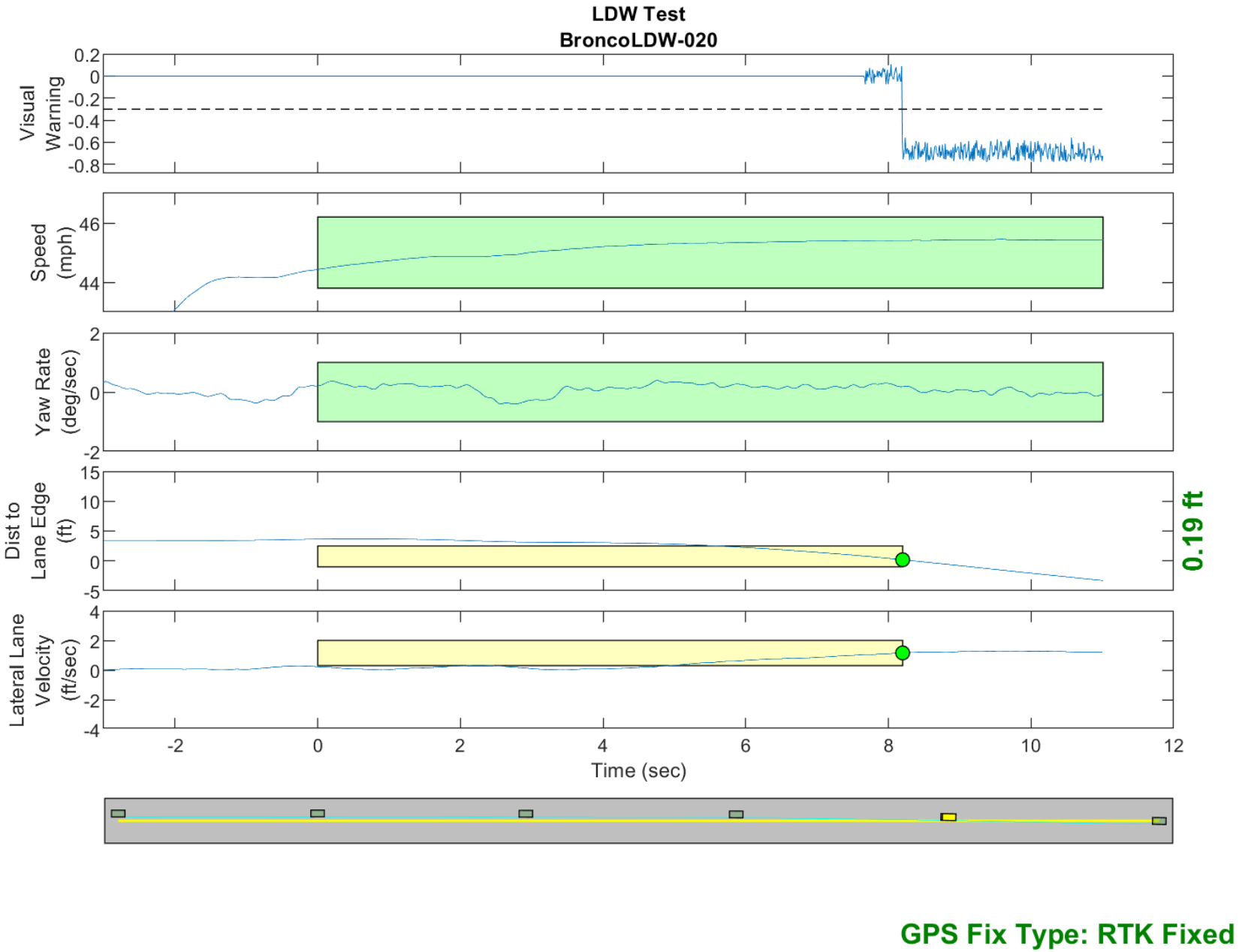

Figure D39. Time History for Run 20, Dashed Line, Right Departure, Visual Warning

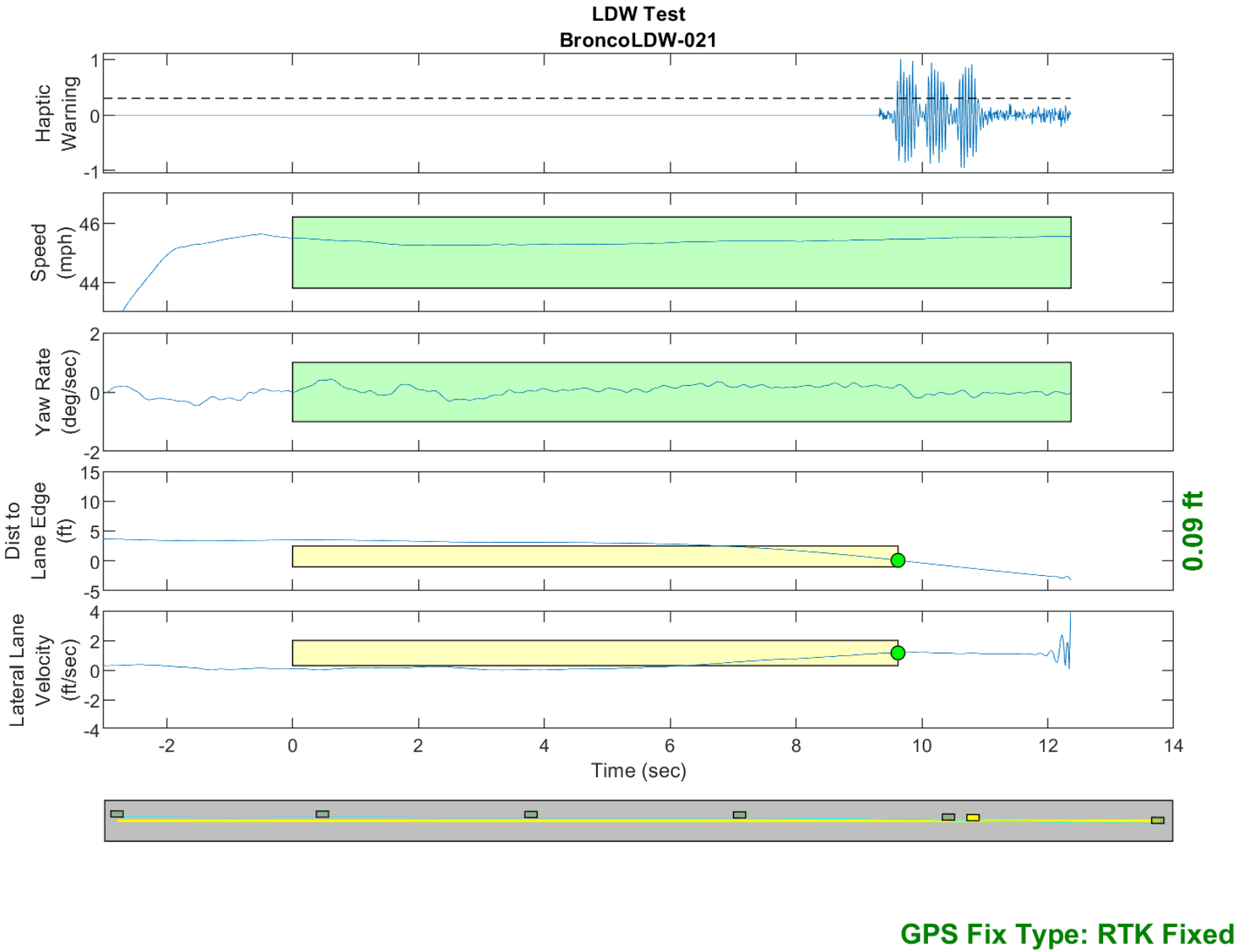

Figure D40. Time History for Run 21, Dashed Line, Right Departure, Haptic Warning

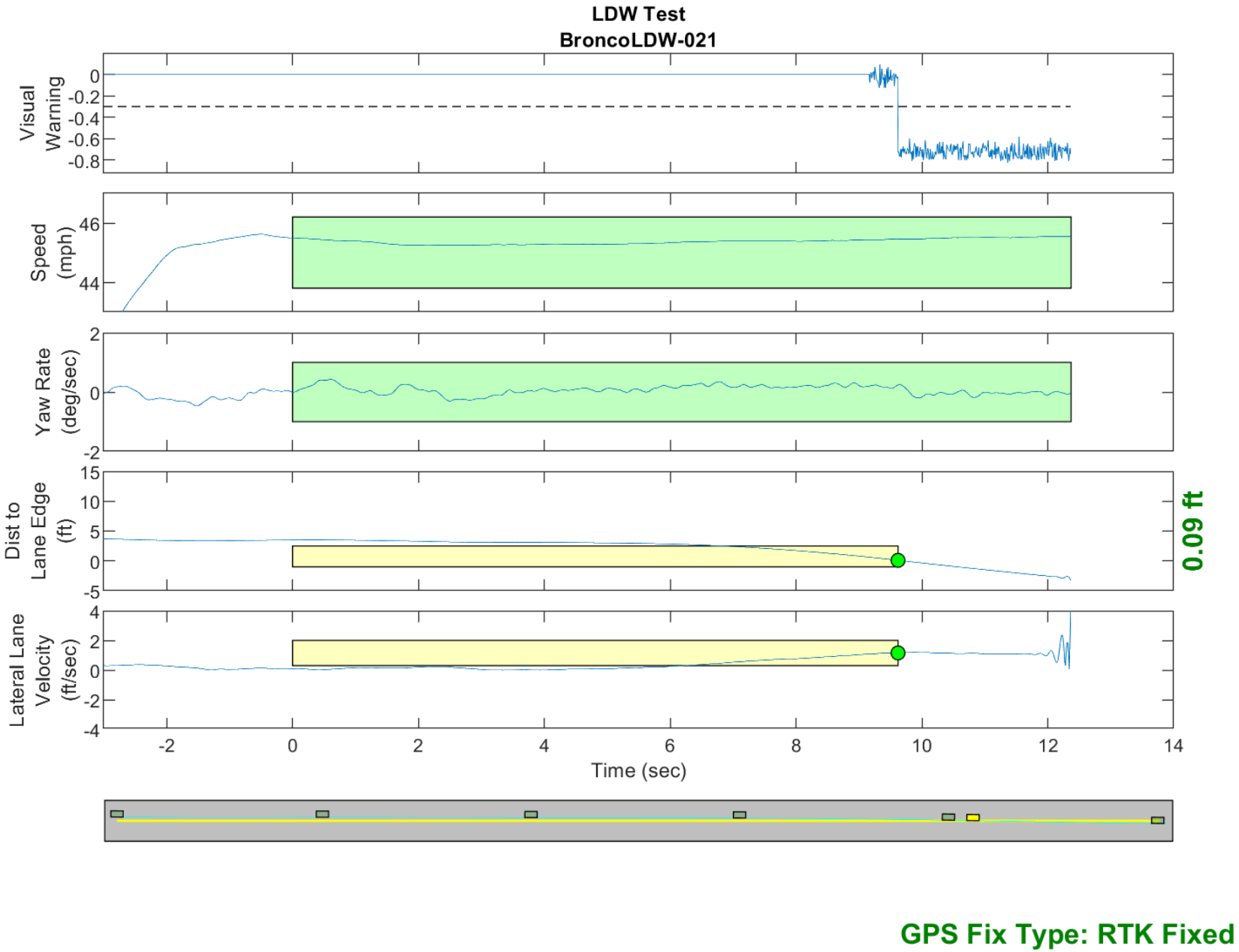

Figure D41. Time History for Run 21, Dashed Line, Right Departure, Visual Warning

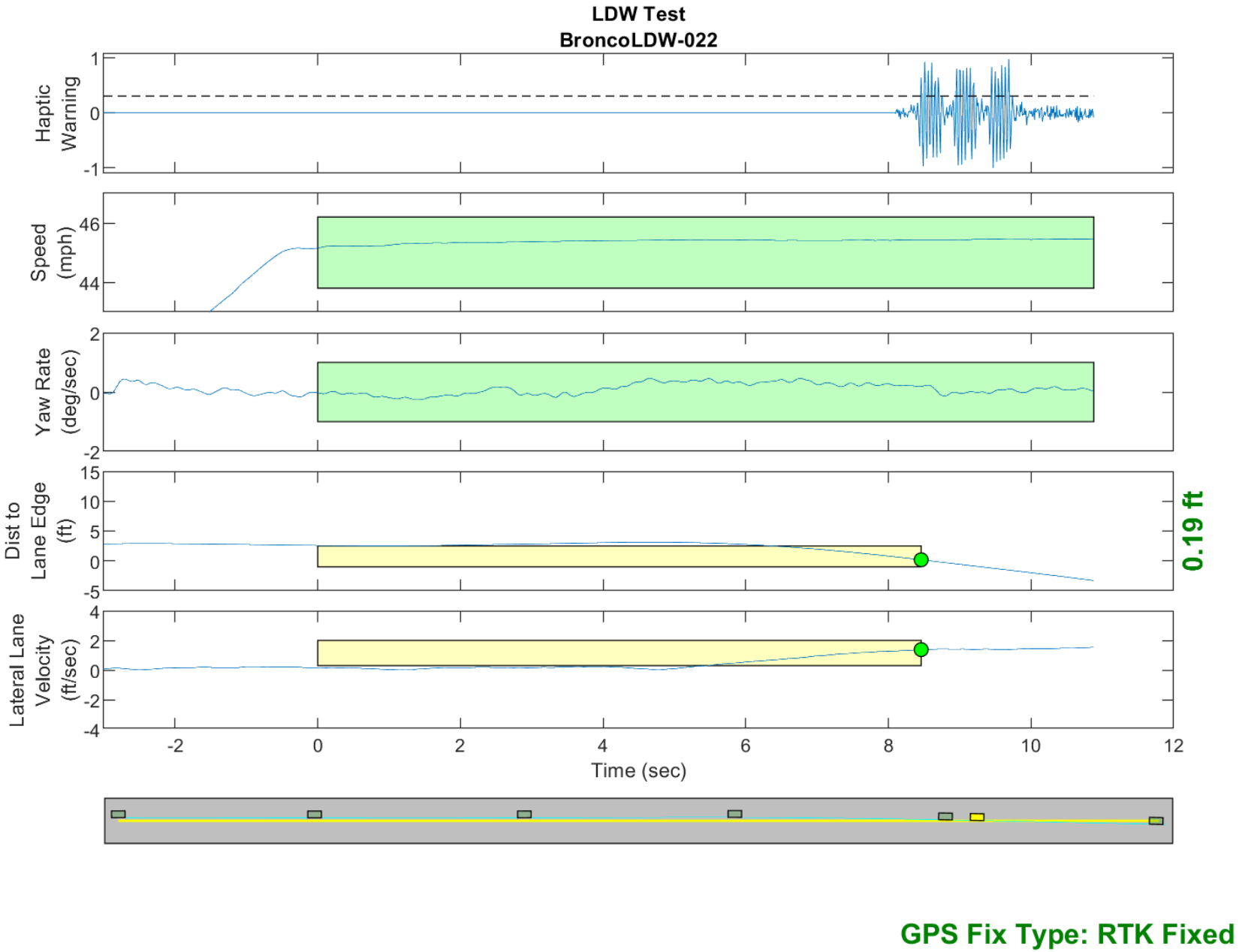

Figure D42. Time History for Run 22, Dashed Line, Right Departure, Haptic Warning

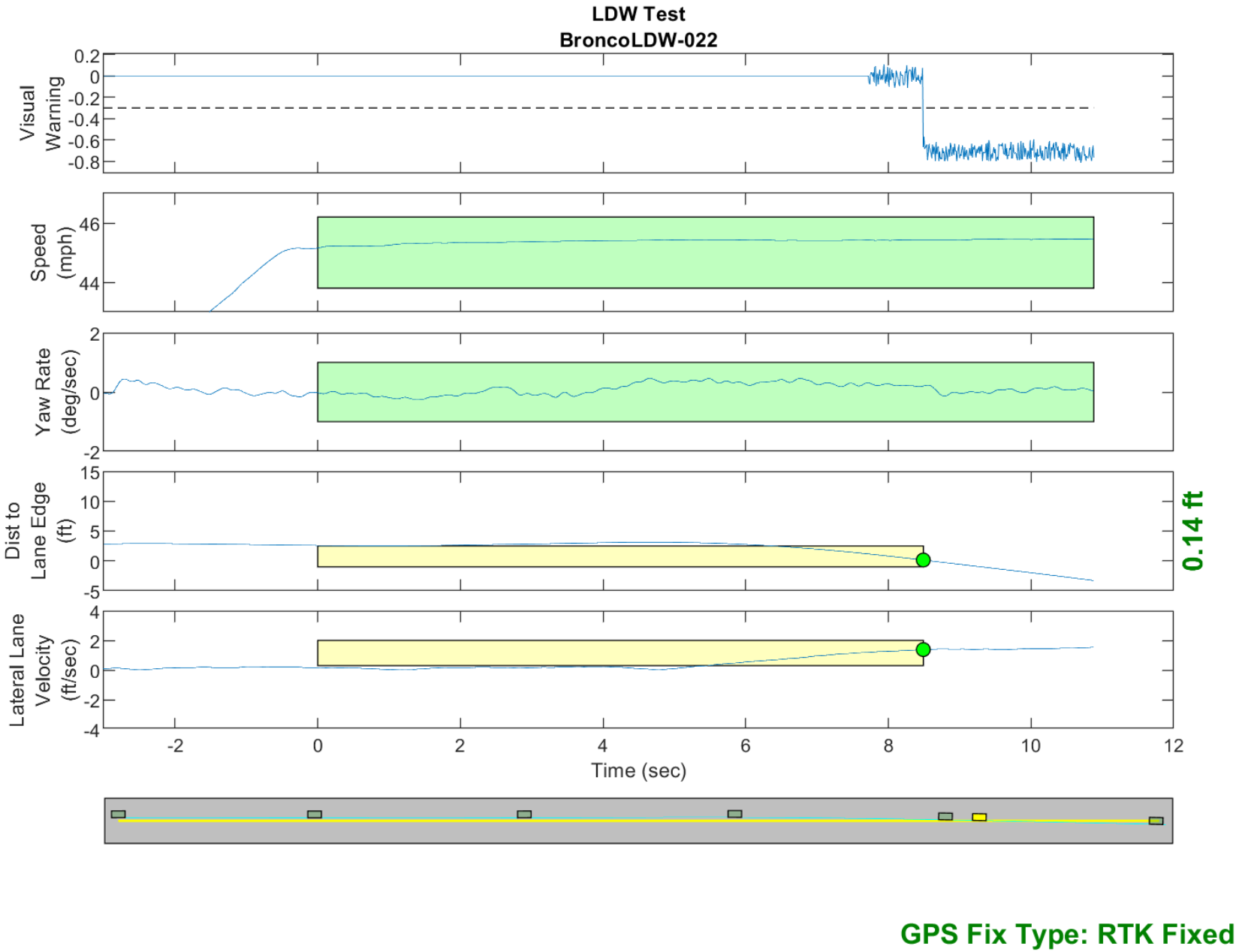

Figure D43. Time History for Run 22, Dashed Line, Right Departure, Visual Warning

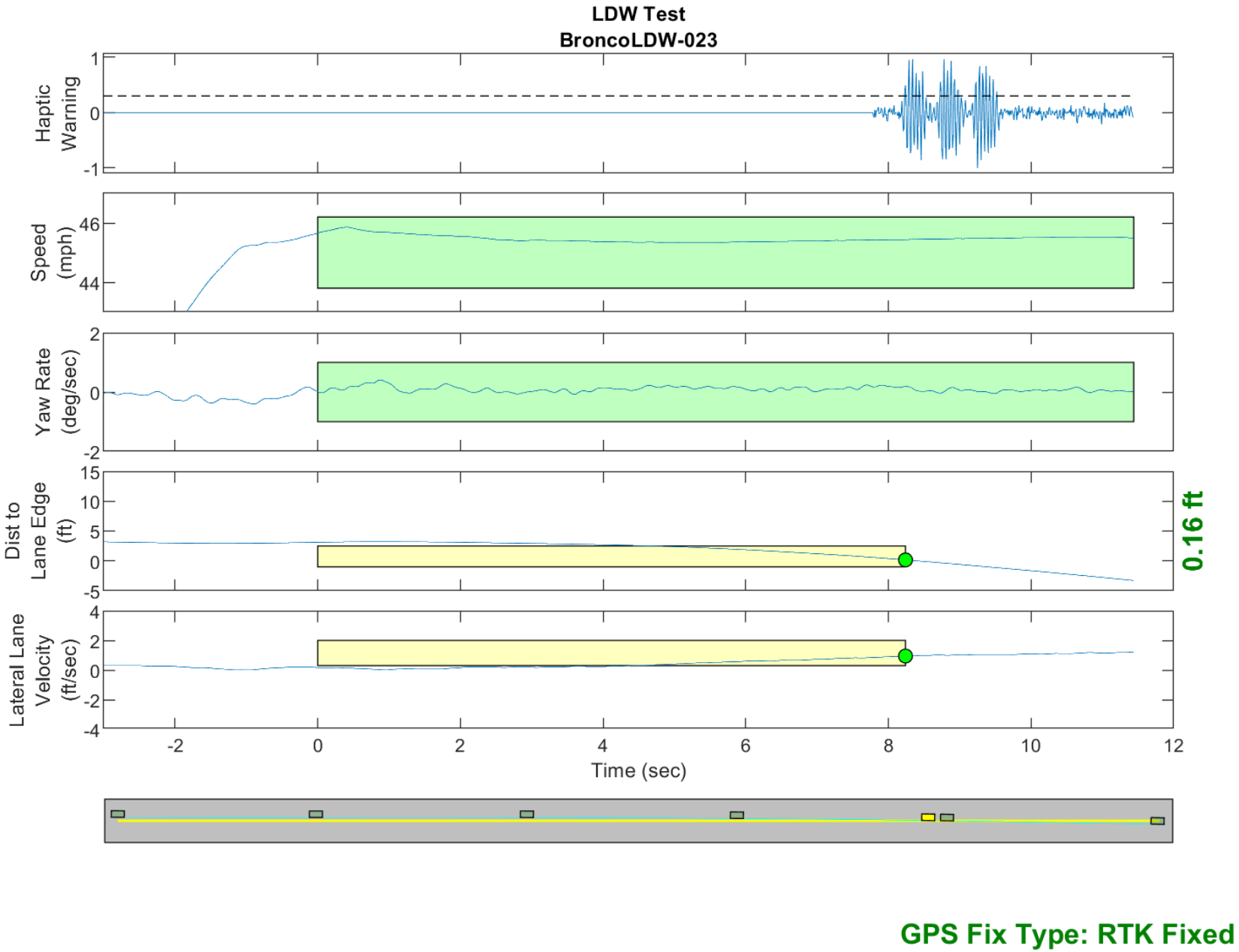

Figure D44. Time History for Run 23, Dashed Line, Right Departure, Haptic Warning

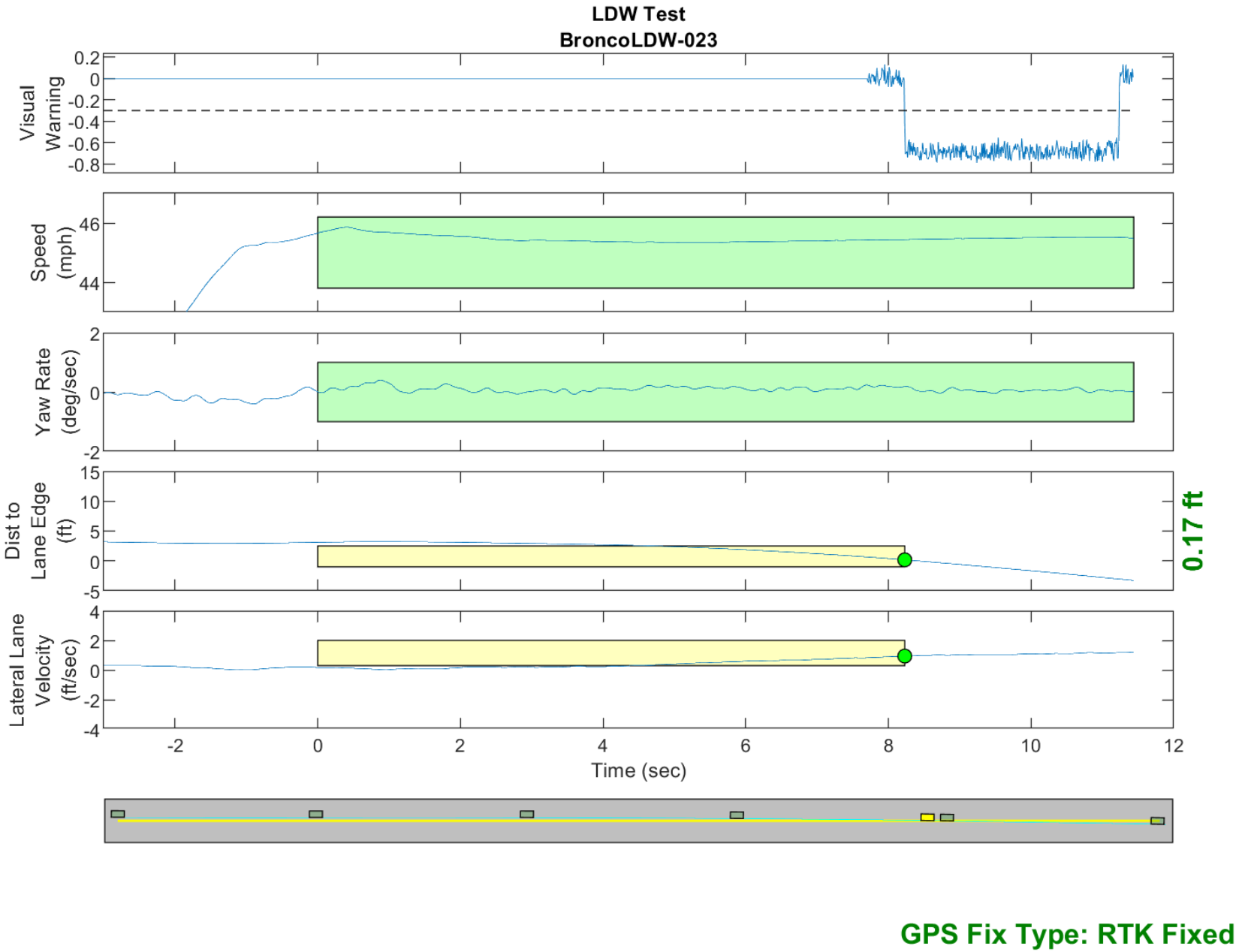

Figure D45. Time History for Run 23, Dashed Line, Right Departure, Visual Warning

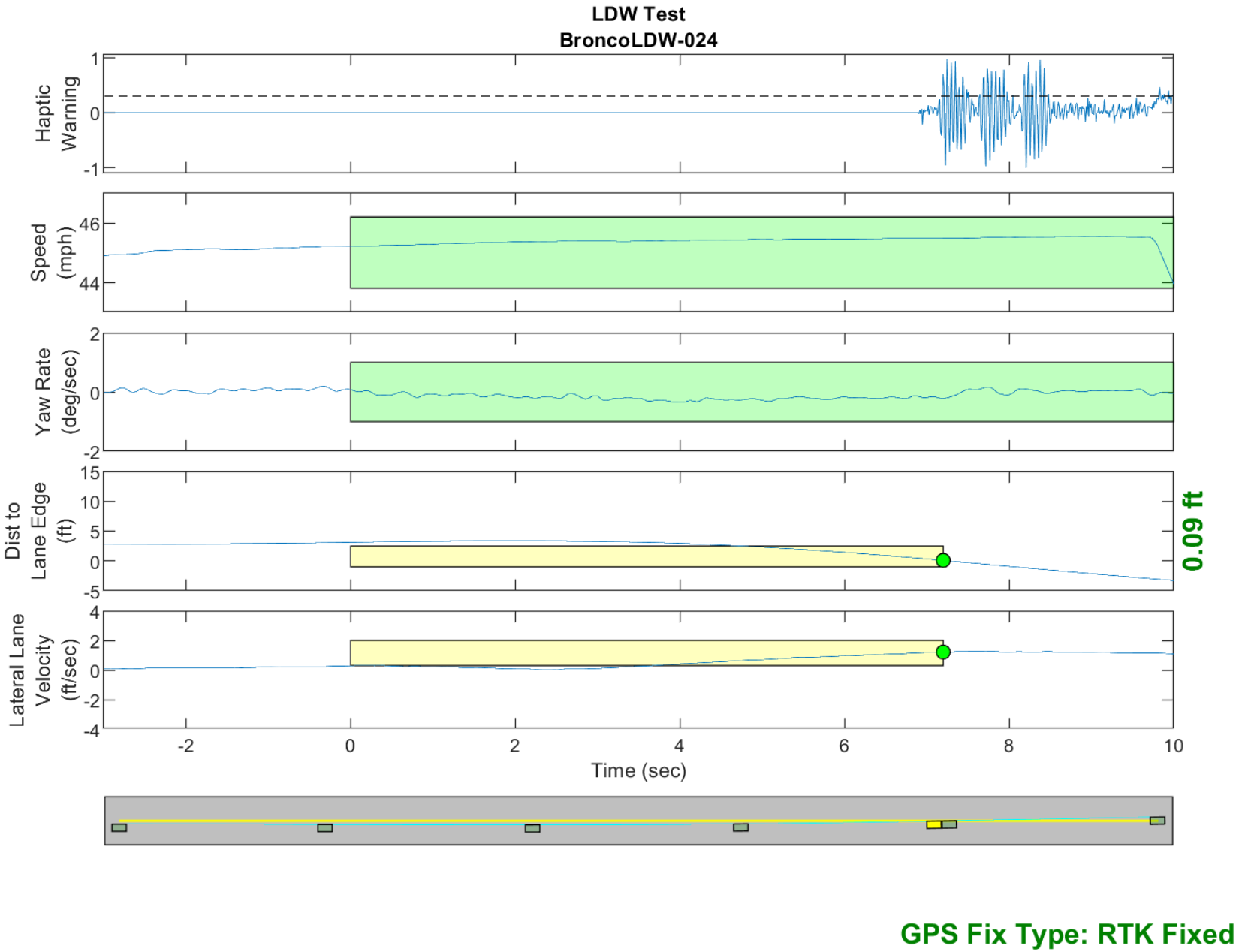

Figure D46. Time History for Run 24, Dashed Line, Left Departure, Haptic Warning

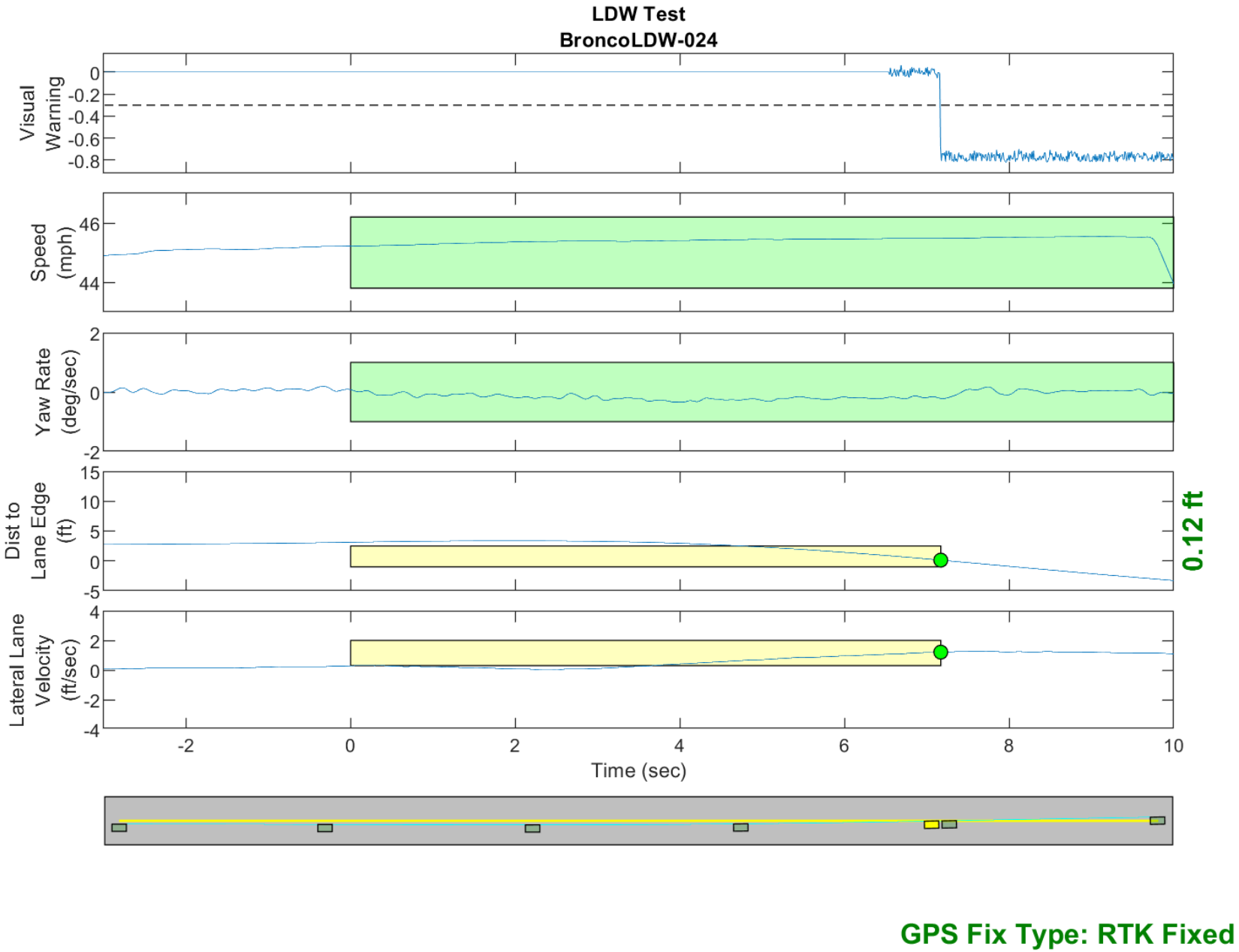

Figure D47. Time History for Run 24, Dashed Line, Left Departure, Visual Warning

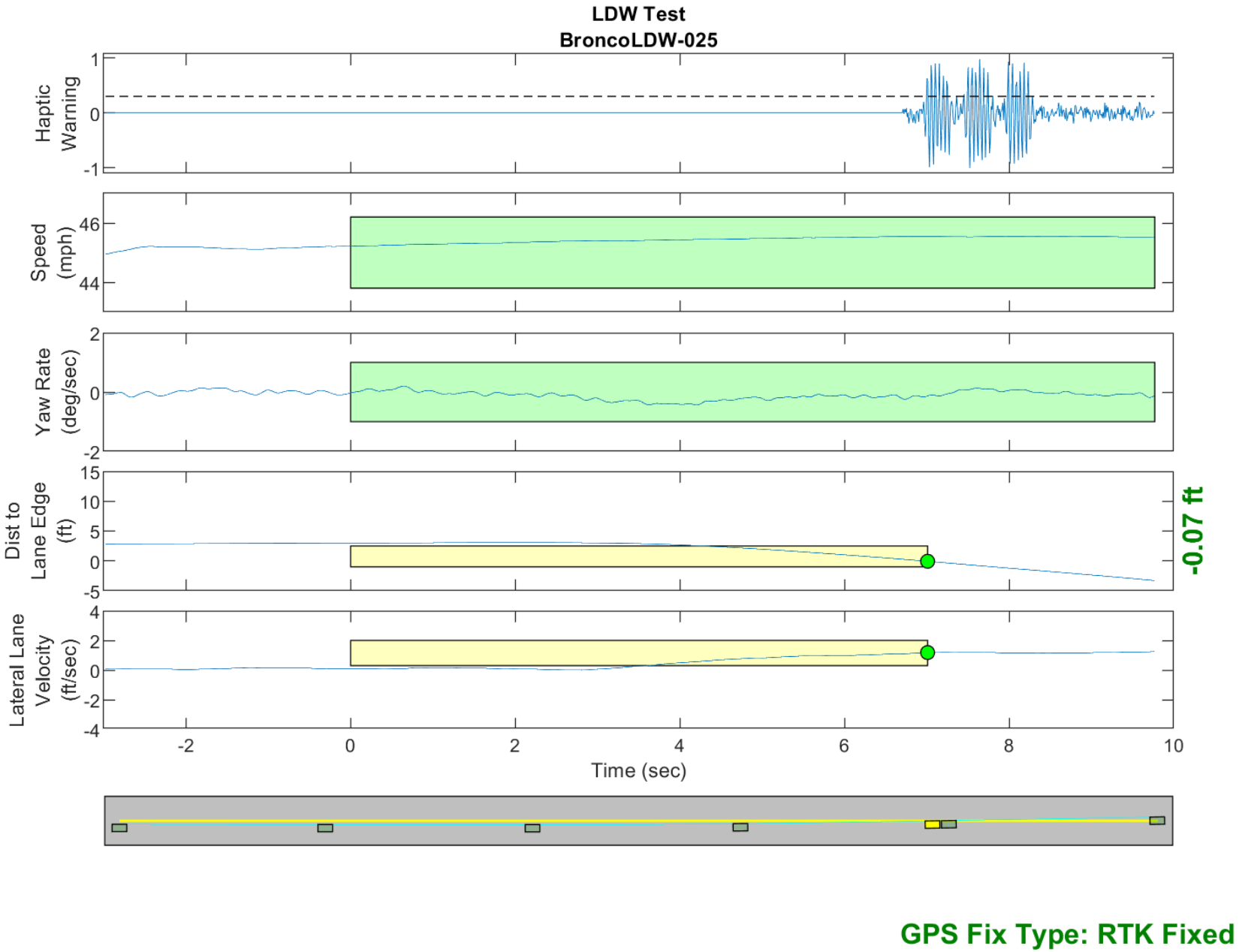

Figure D48. Time History for Run 25, Dashed Line, Left Departure, Haptic Warning

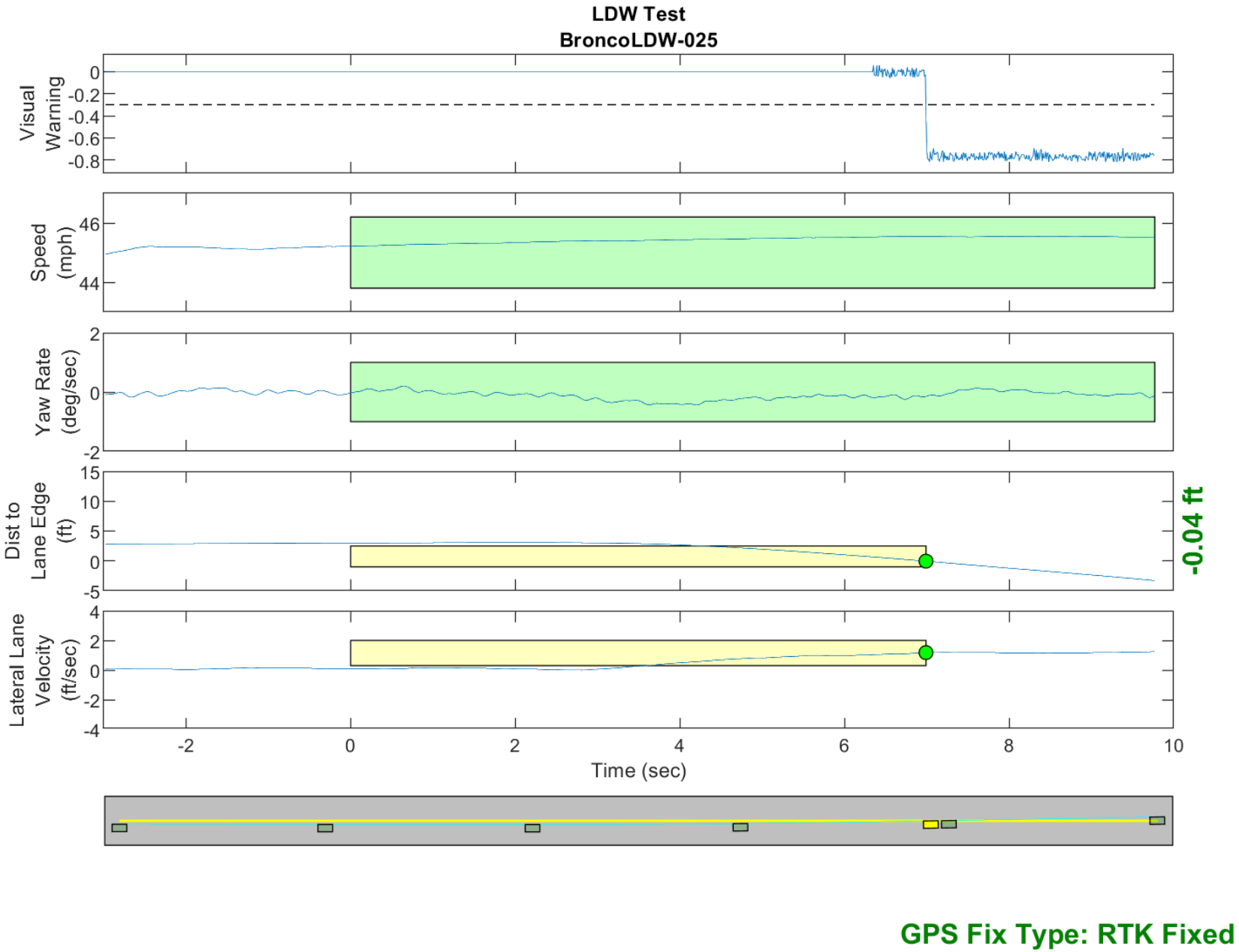

Figure D49. Time History for Run 25, Dashed Line, Left Departure, Visual Warning

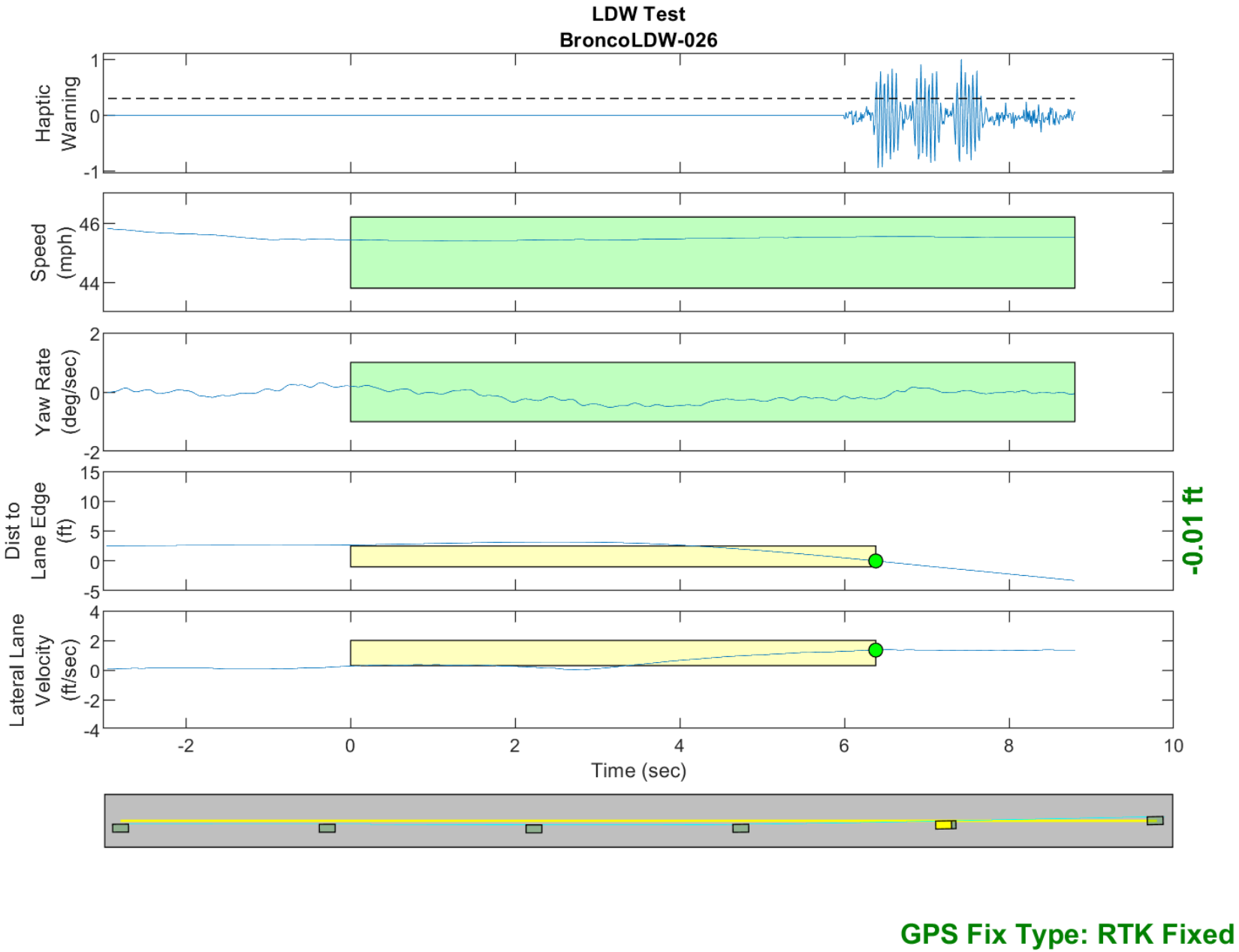

Figure D50. Time History for Run 26, Dashed Line, Left Departure, Haptic Warning

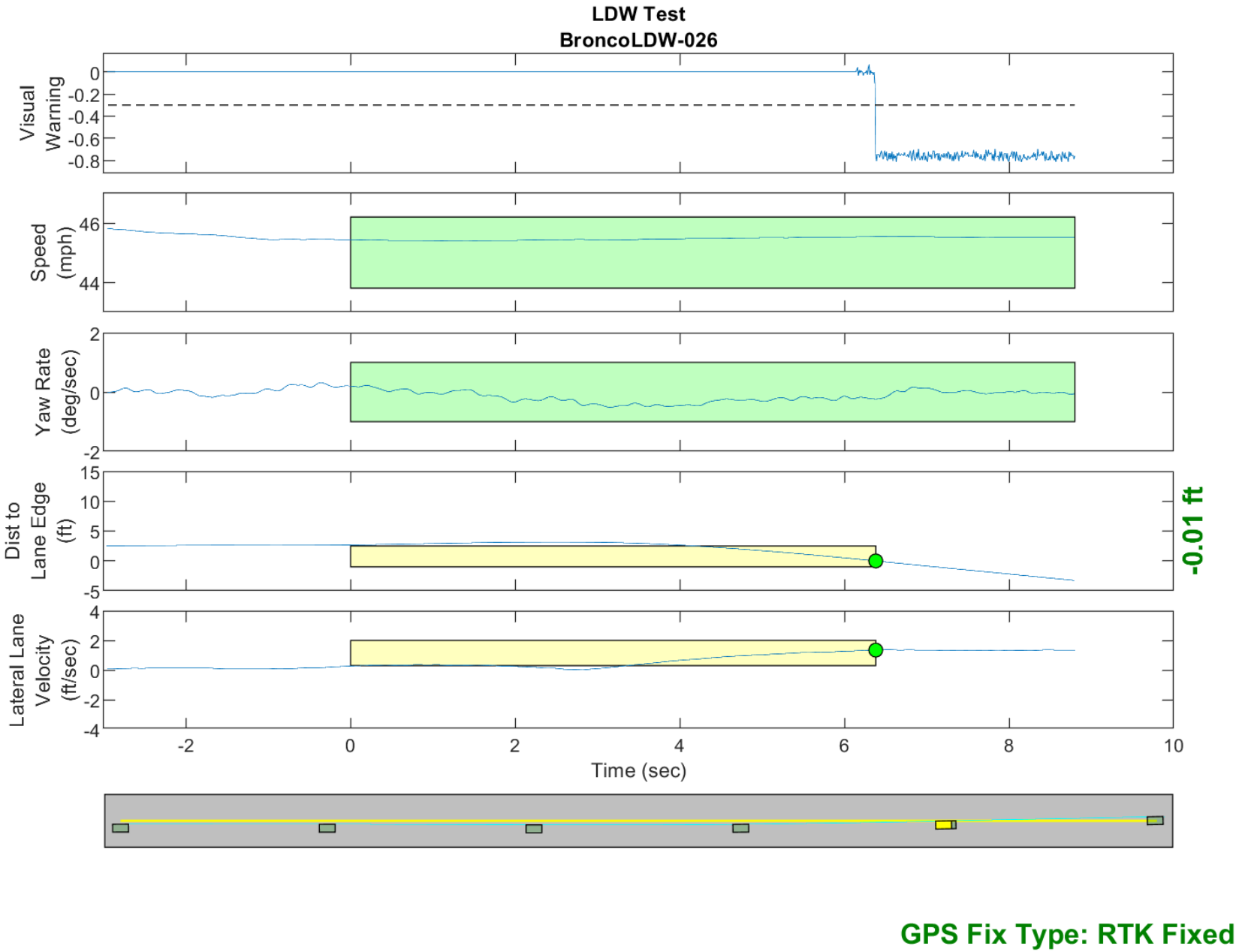

Figure D51. Time History for Run 26, Dashed Line, Left Departure, Visual Warning

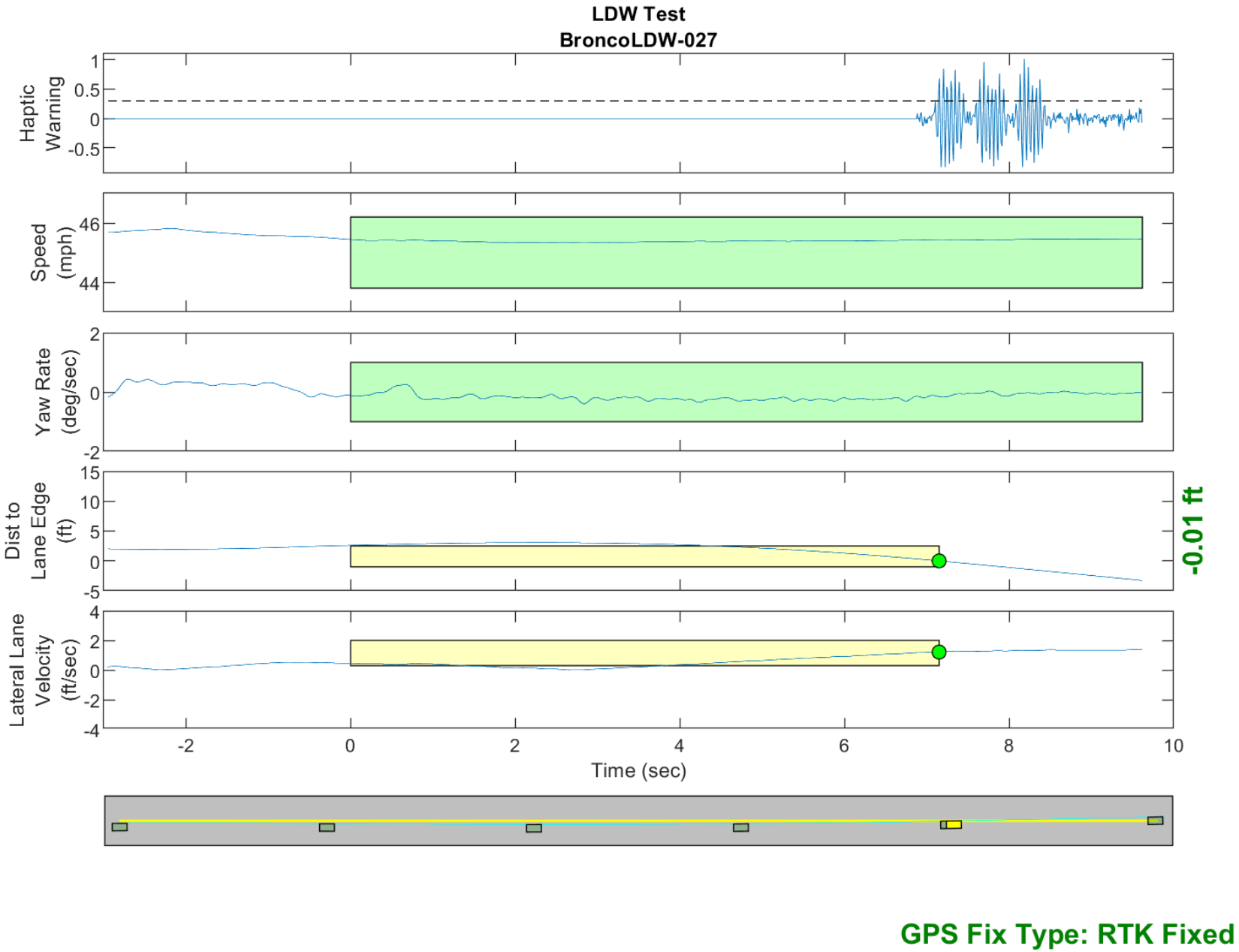

Figure D52. Time History for Run 27, Dashed Line, Left Departure, Haptic Warning

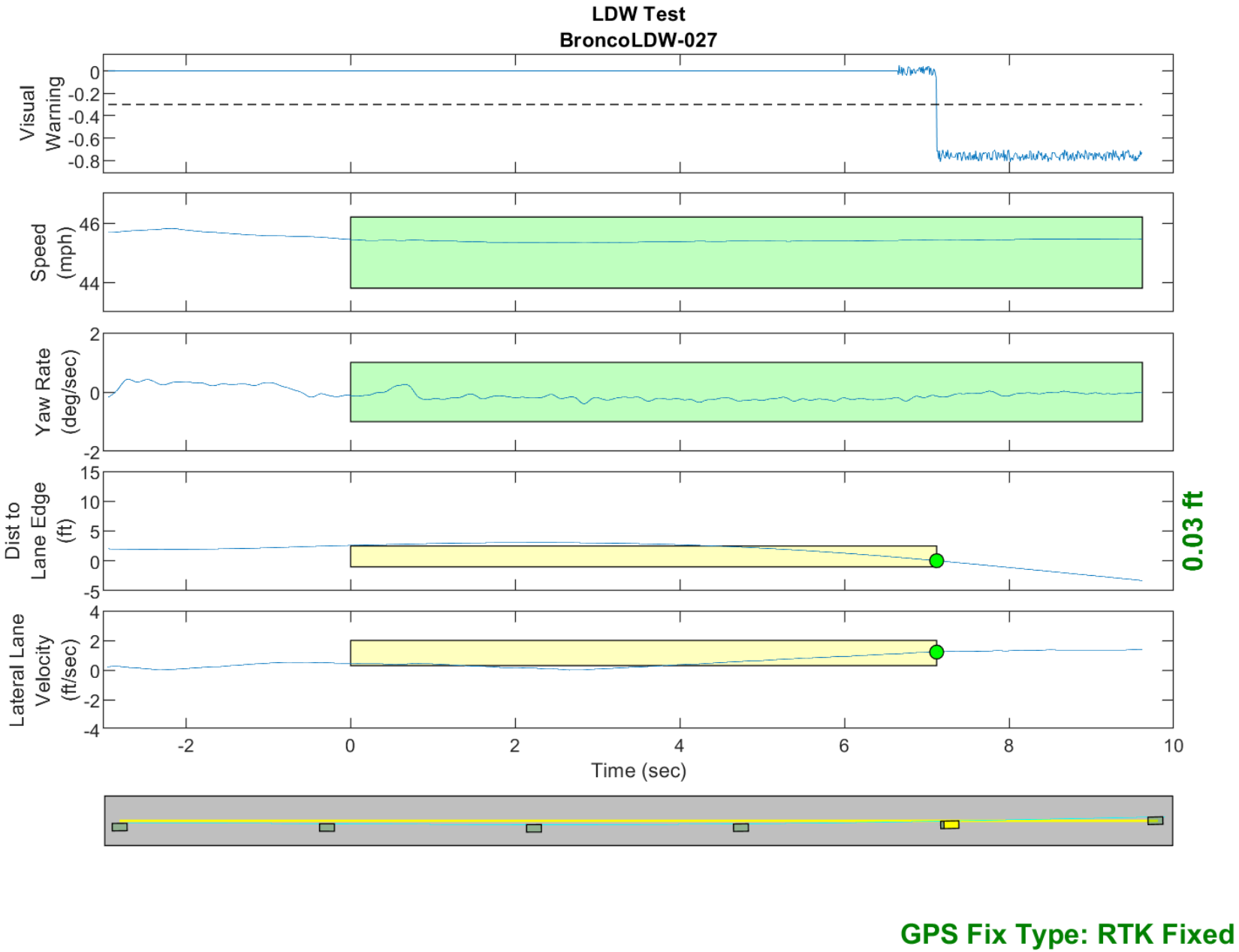

Figure D53. Time History for Run 27, Dashed Line, Left Departure, Visual Warning

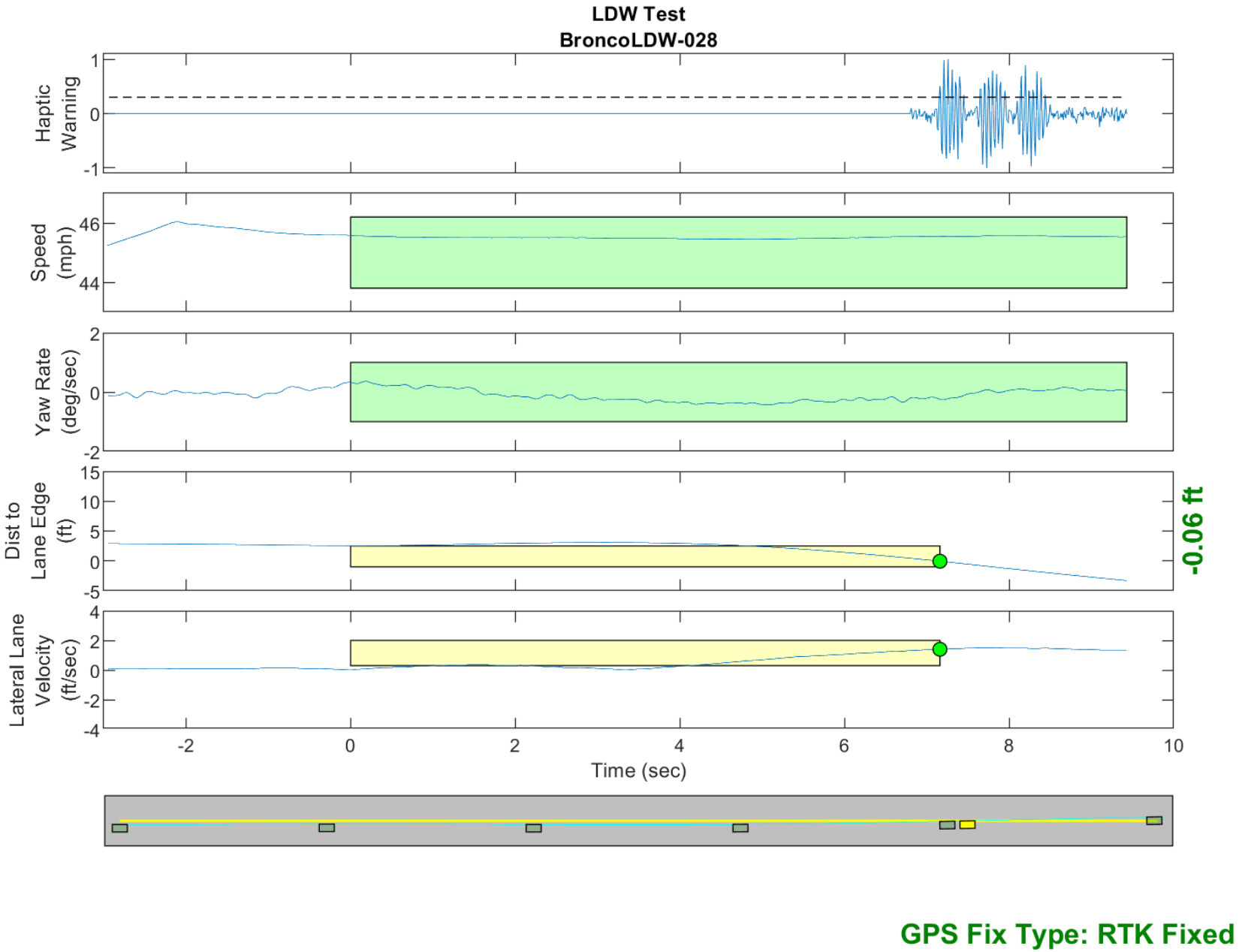

Figure D54. Time History for Run 28, Dashed Line, Left Departure, Haptic Warning

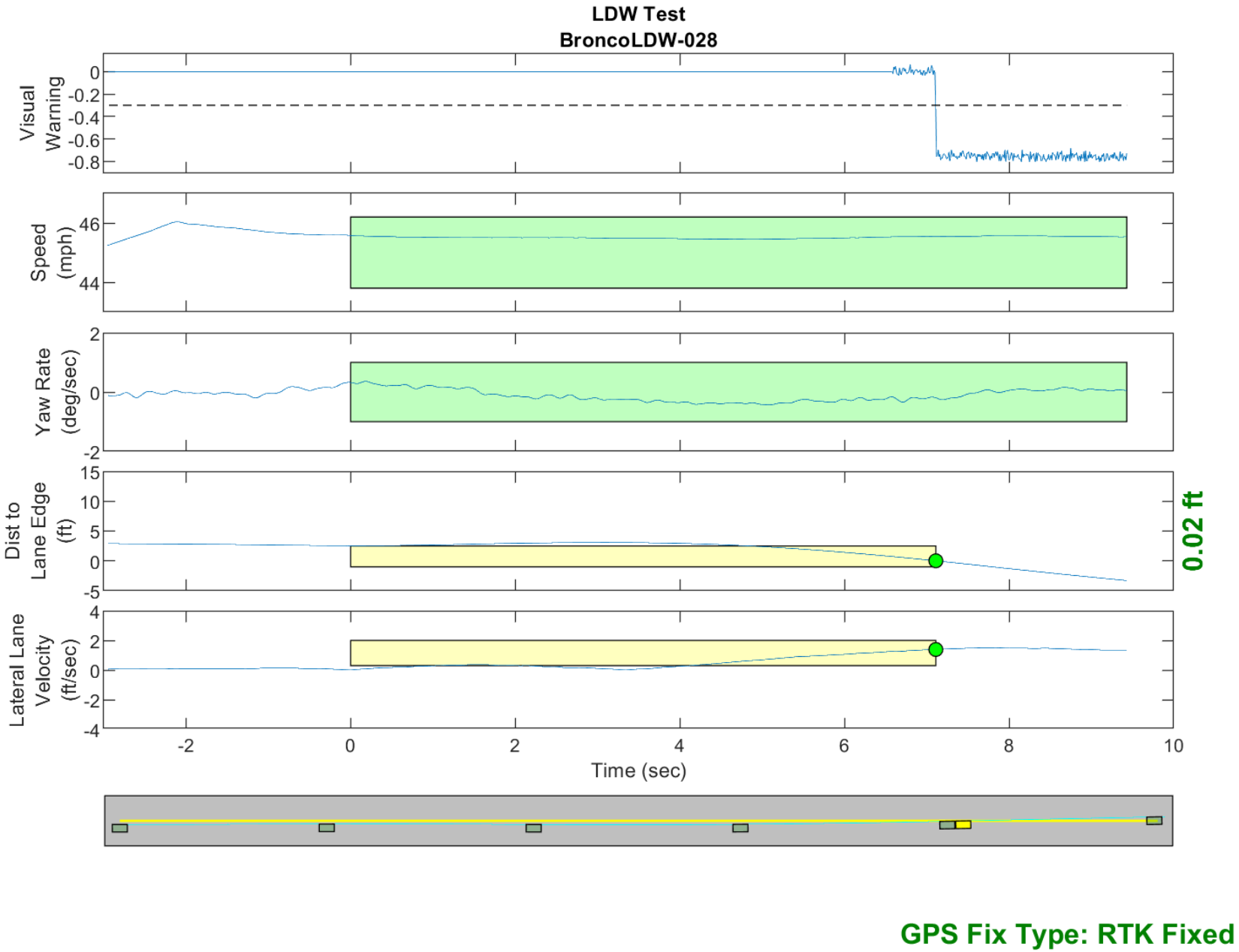

Figure D55. Time History for Run 28, Dashed Line, Left Departure, Visual Warning

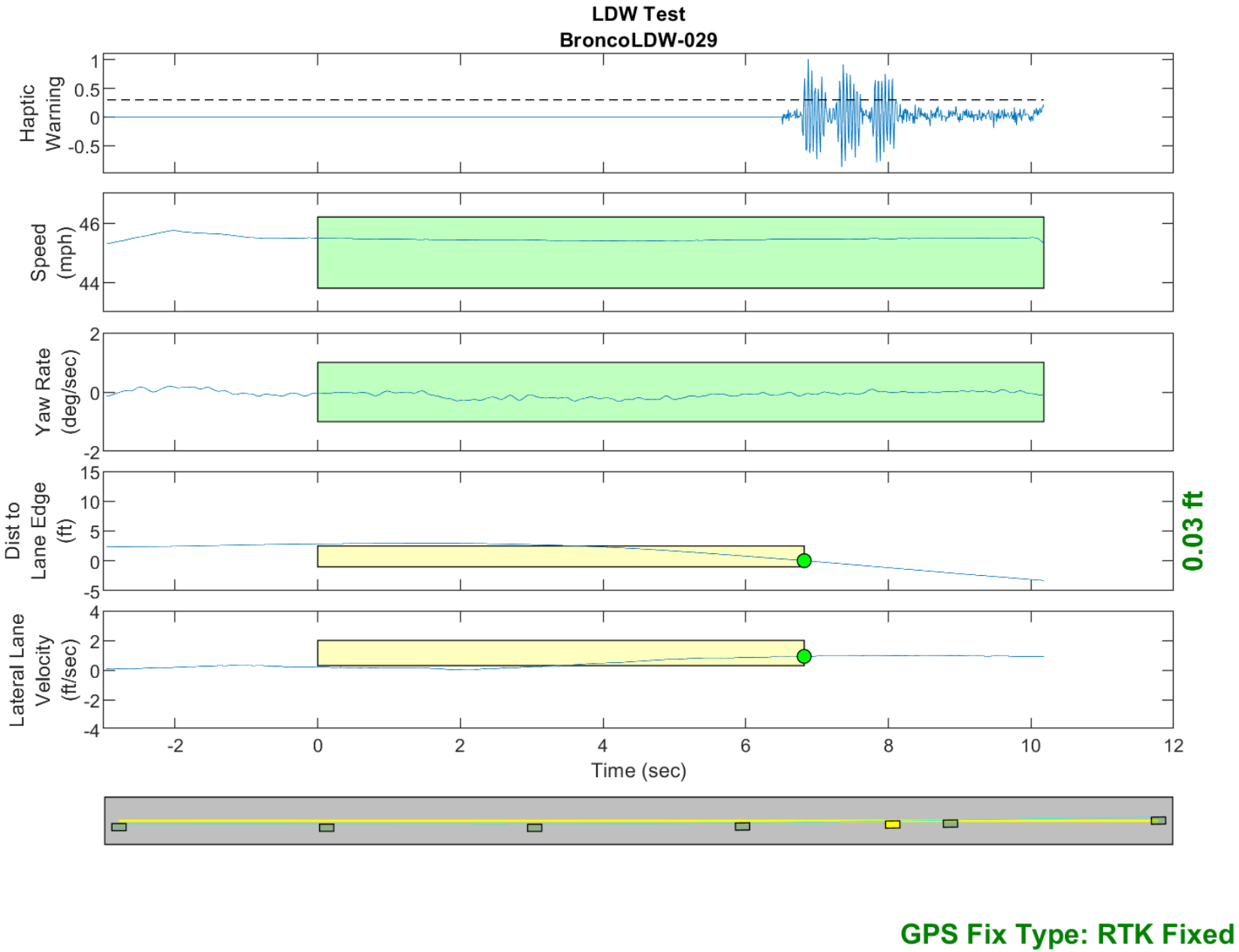

Figure D56. Time History for Run 29, Dashed Line, Left Departure, Haptic Warning

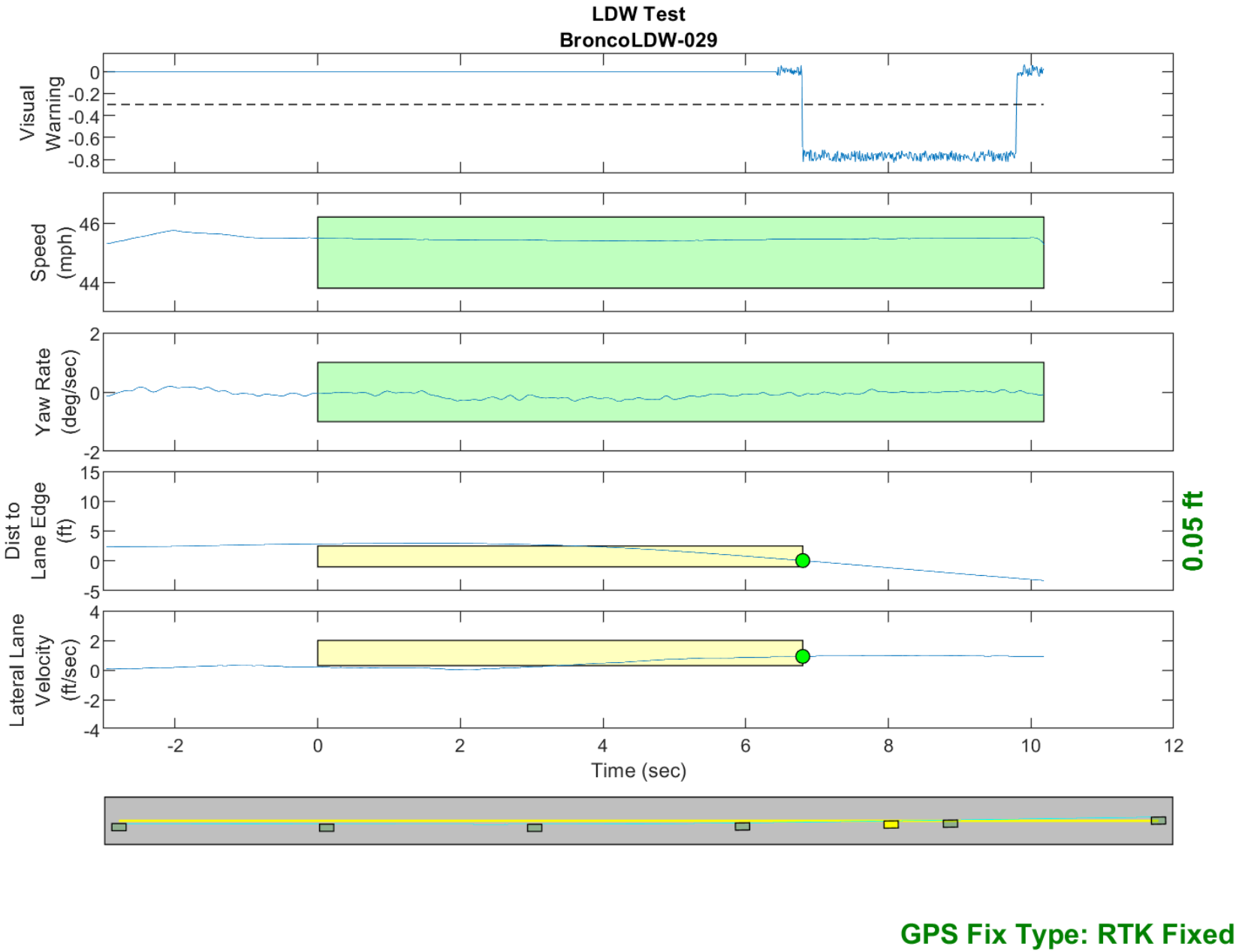

Figure D57. Time History for Run 29, Dashed Line, Left Departure, Visual Warning

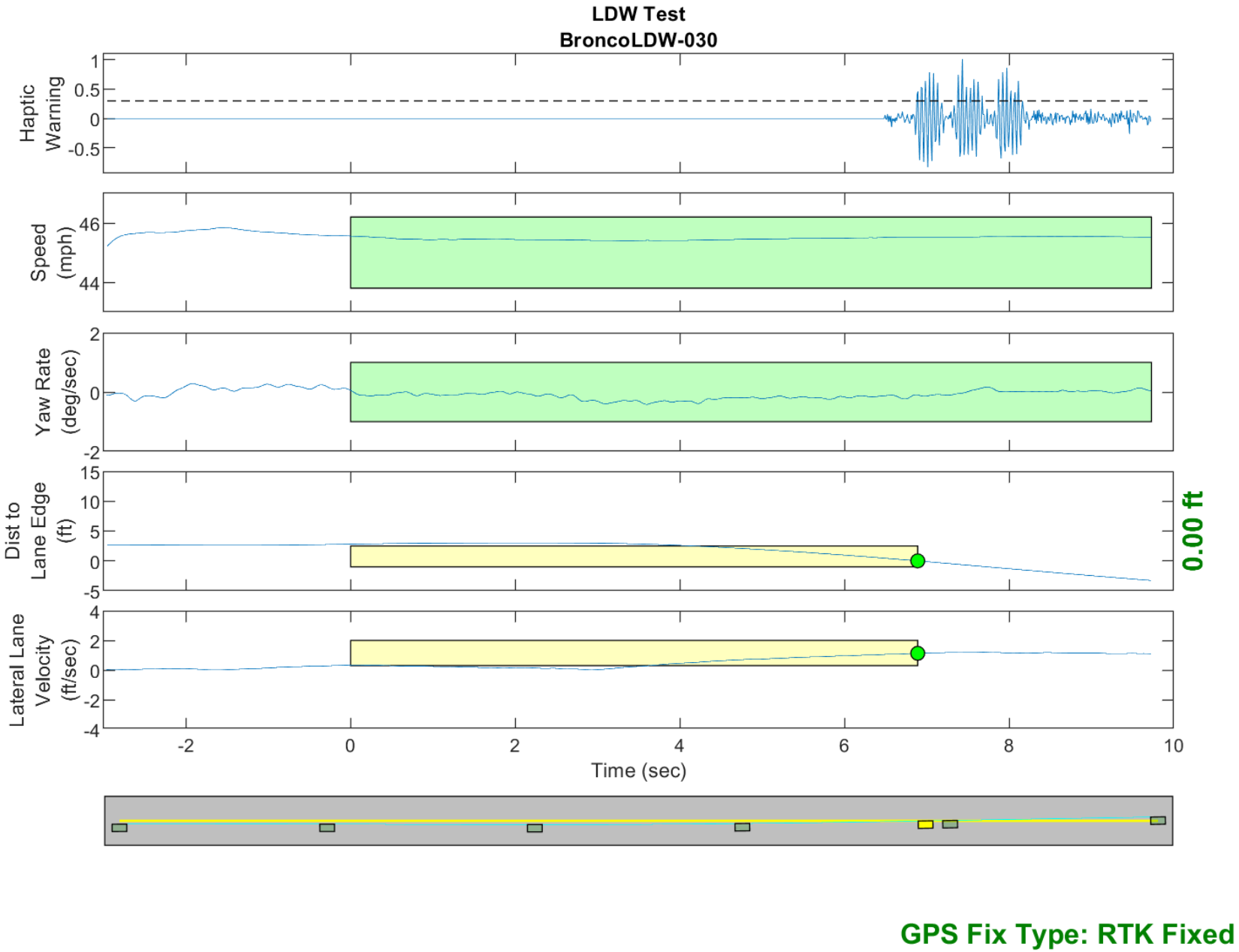

Figure D58. Time History for Run 30, Dashed Line, Left Departure, Haptic Warning

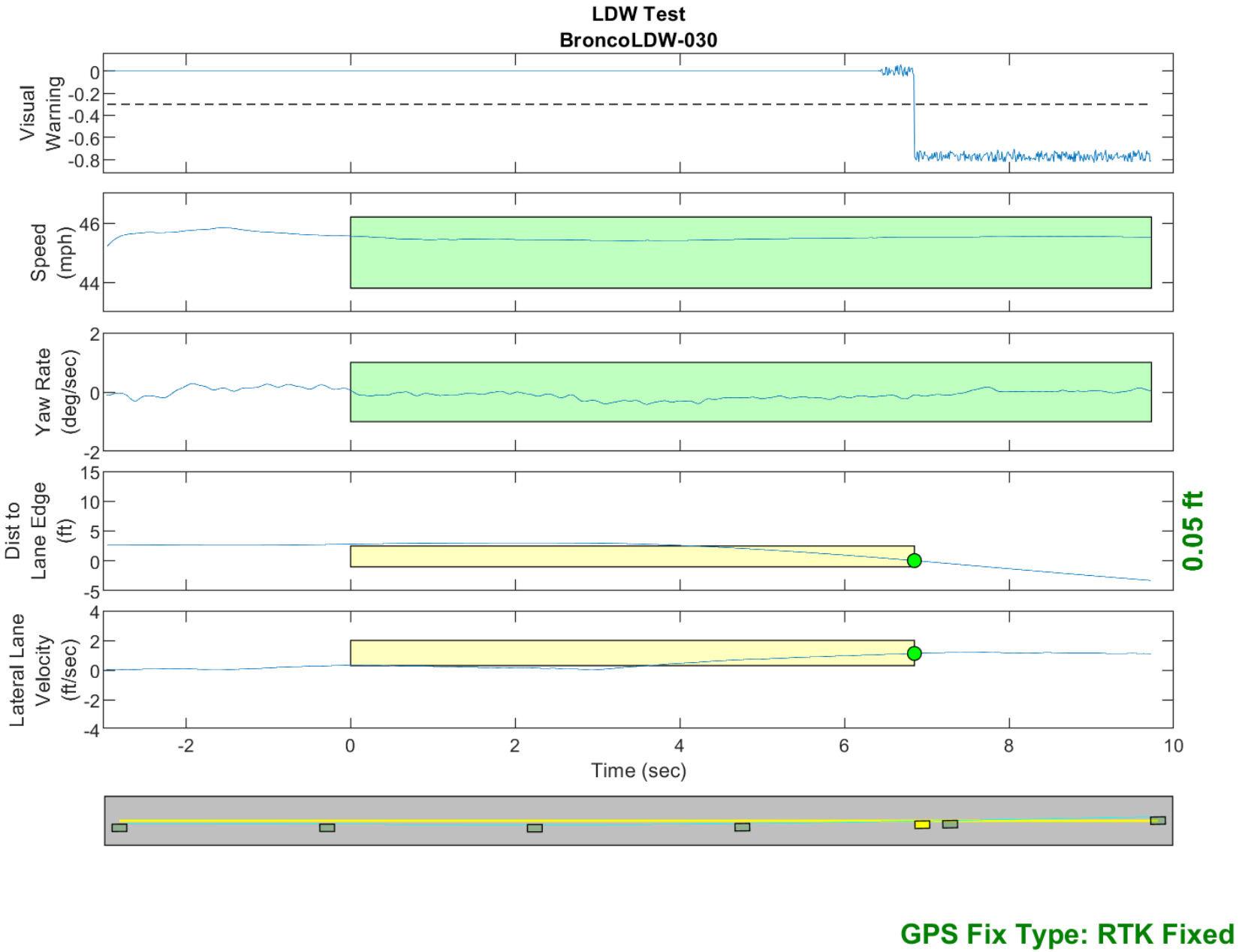

Figure D59. Time History for Run 30, Dashed Line, Left Departure, Visual Warning

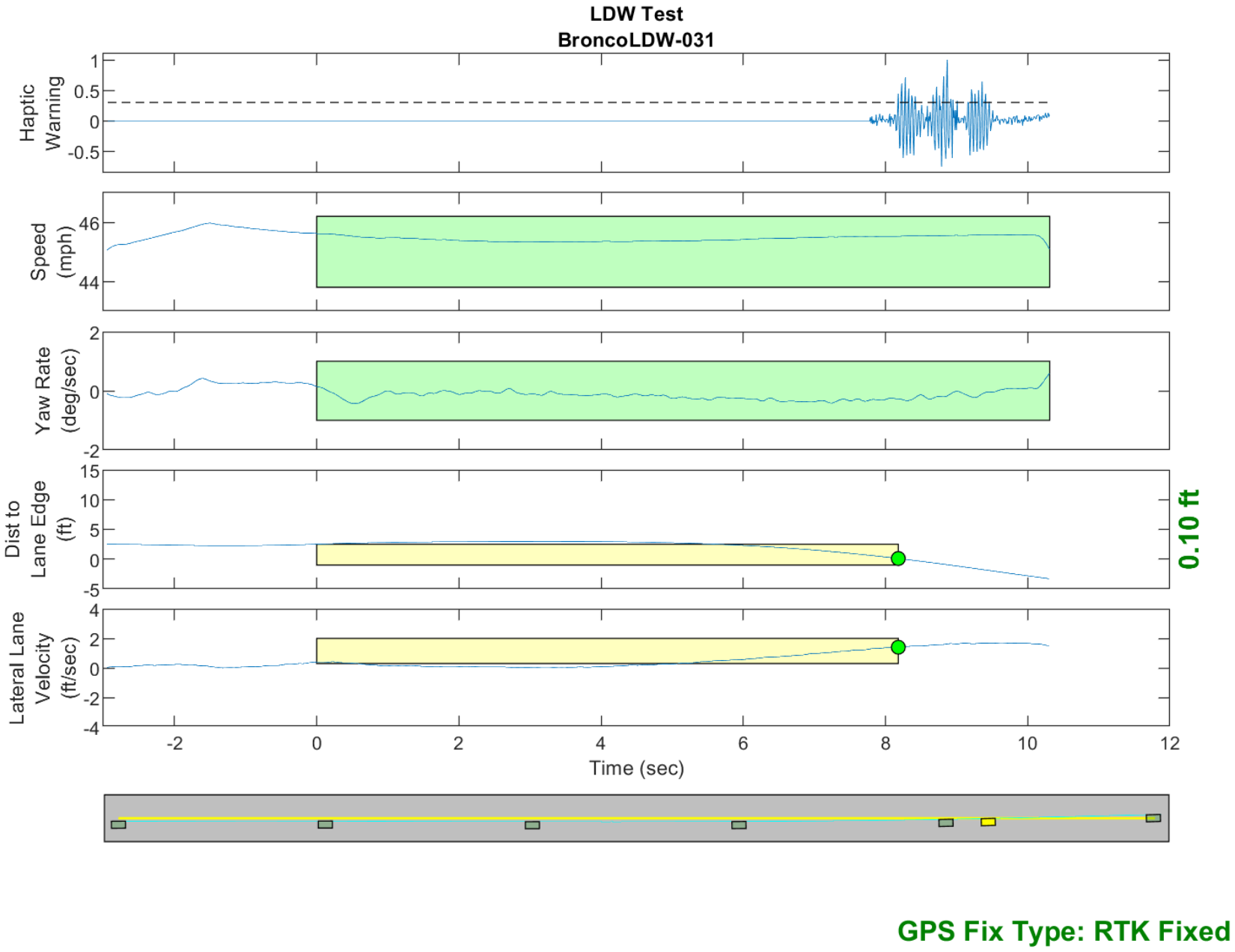

Figure D60. Time History for Run 31, Botts Dots, Left Departure, Haptic Warning

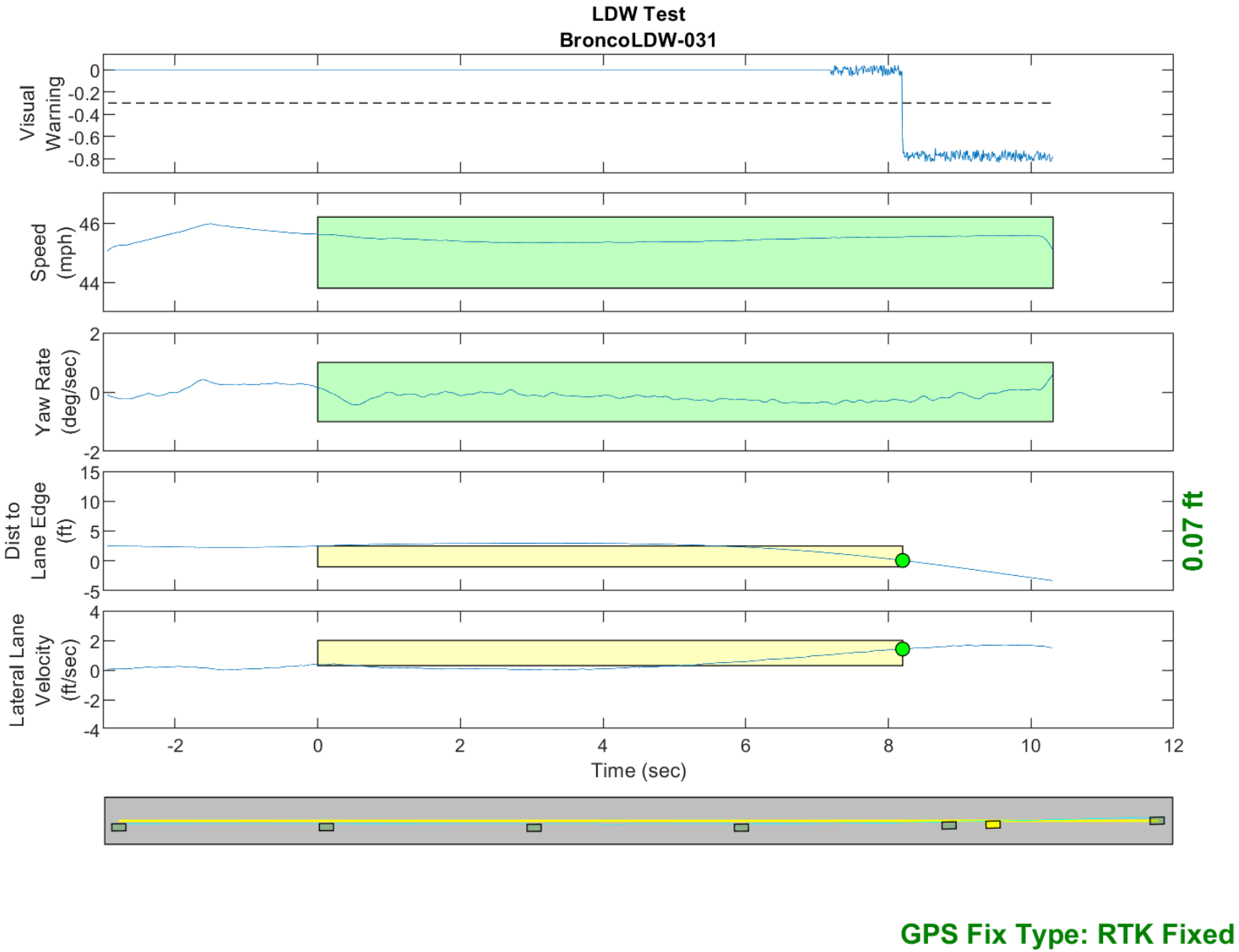

Figure D61. Time History for Run 31, Botts Dots, Left Departure, Visual Warning

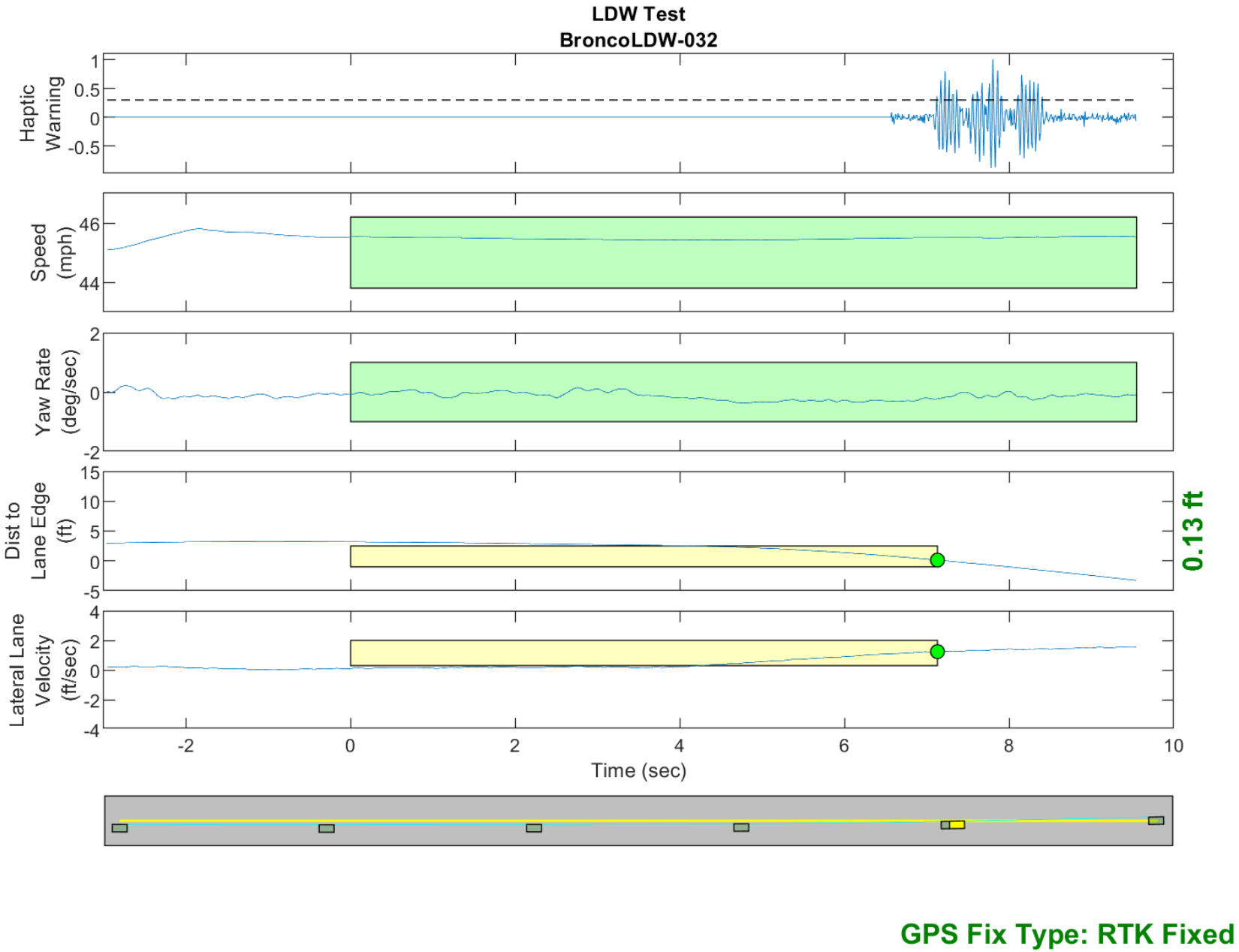

Figure D62. Time History for Run 32, Botts Dots, Left Departure, Haptic Warning

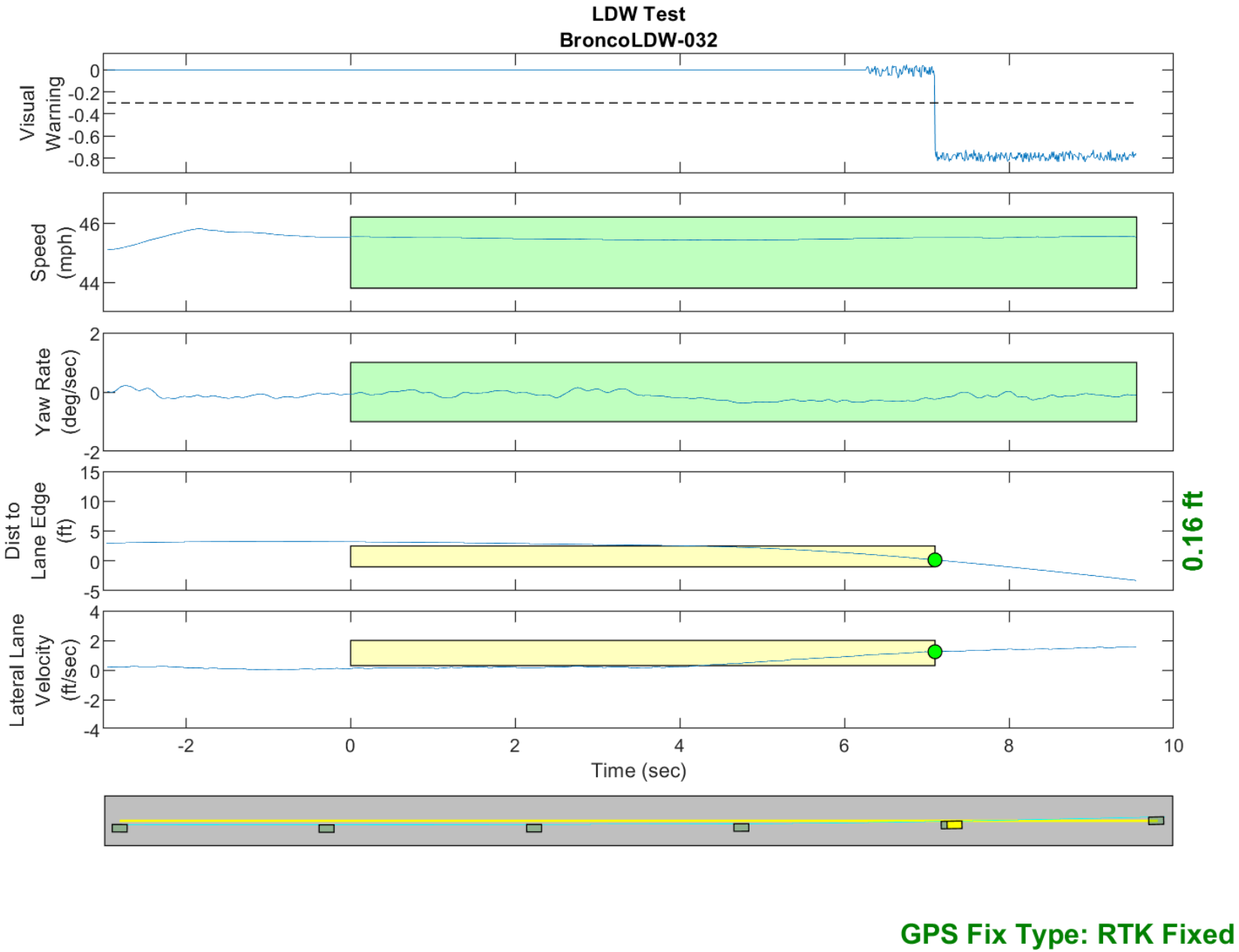

Figure D63. Time History for Run 32, Botts Dots, Left Departure, Visual Warning

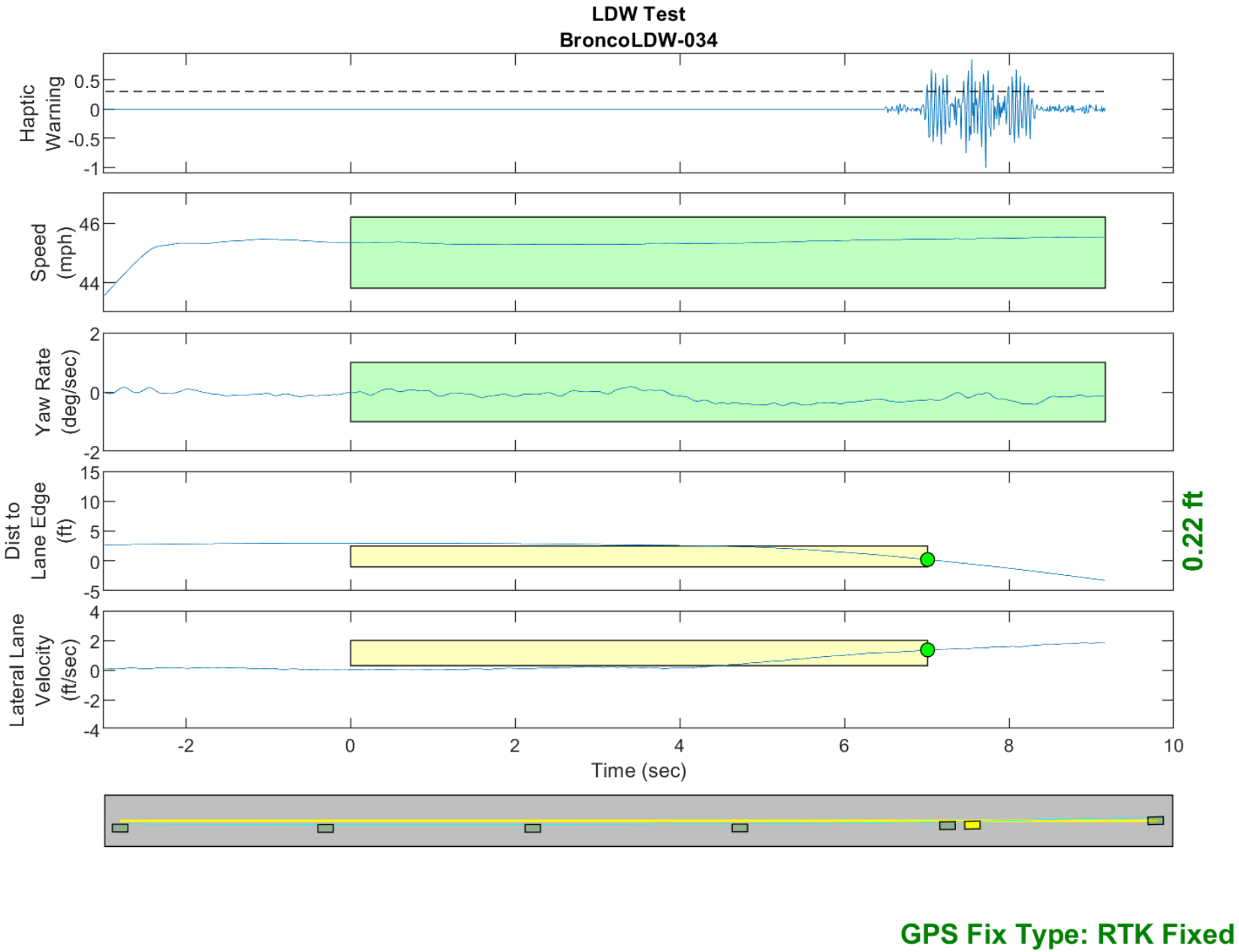

Figure D64. Time History for Run 34, Botts Dots, Left Departure, Haptic Warning

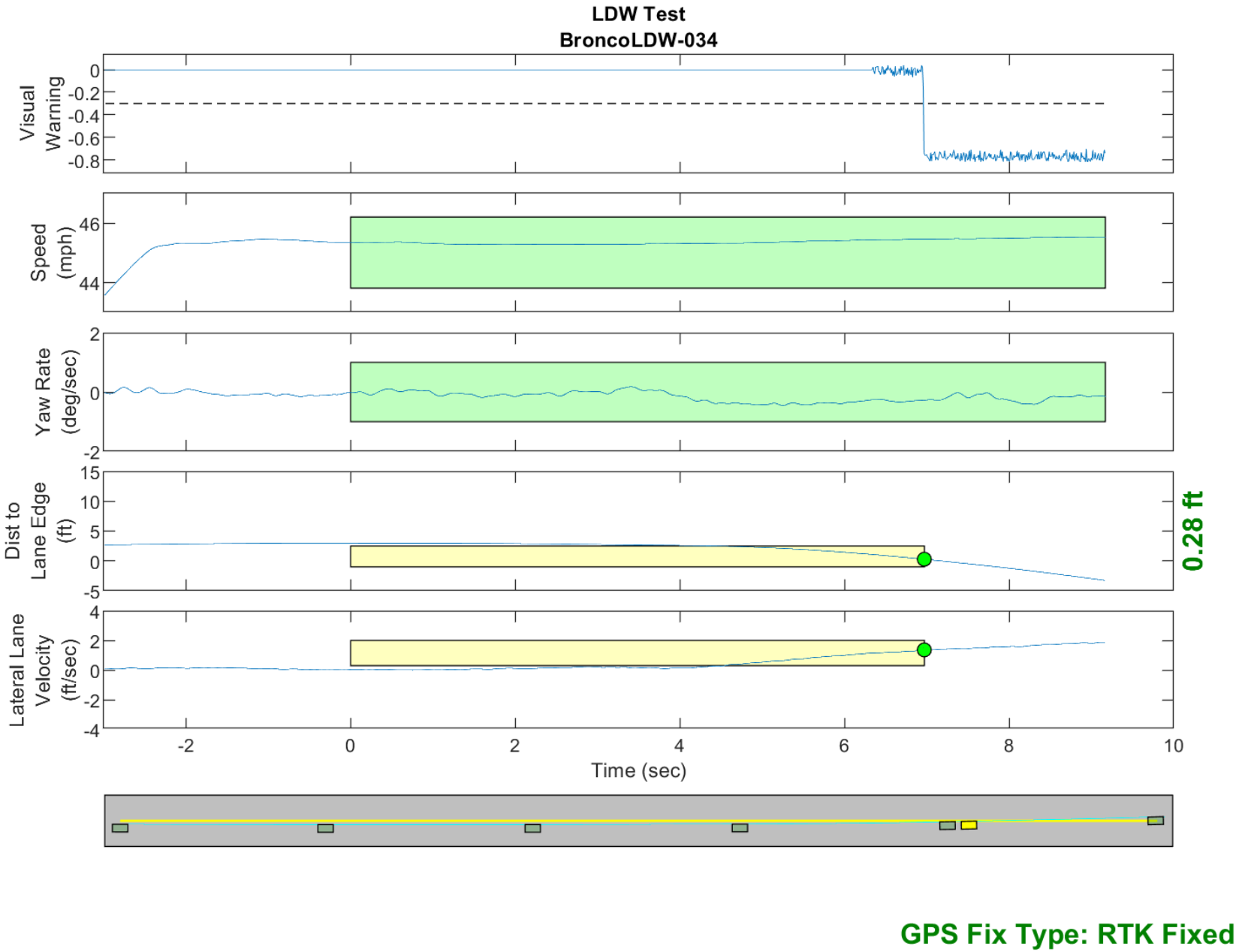

Figure D65. Time History for Run 34, Botts Dots, Left Departure, Visual Warning

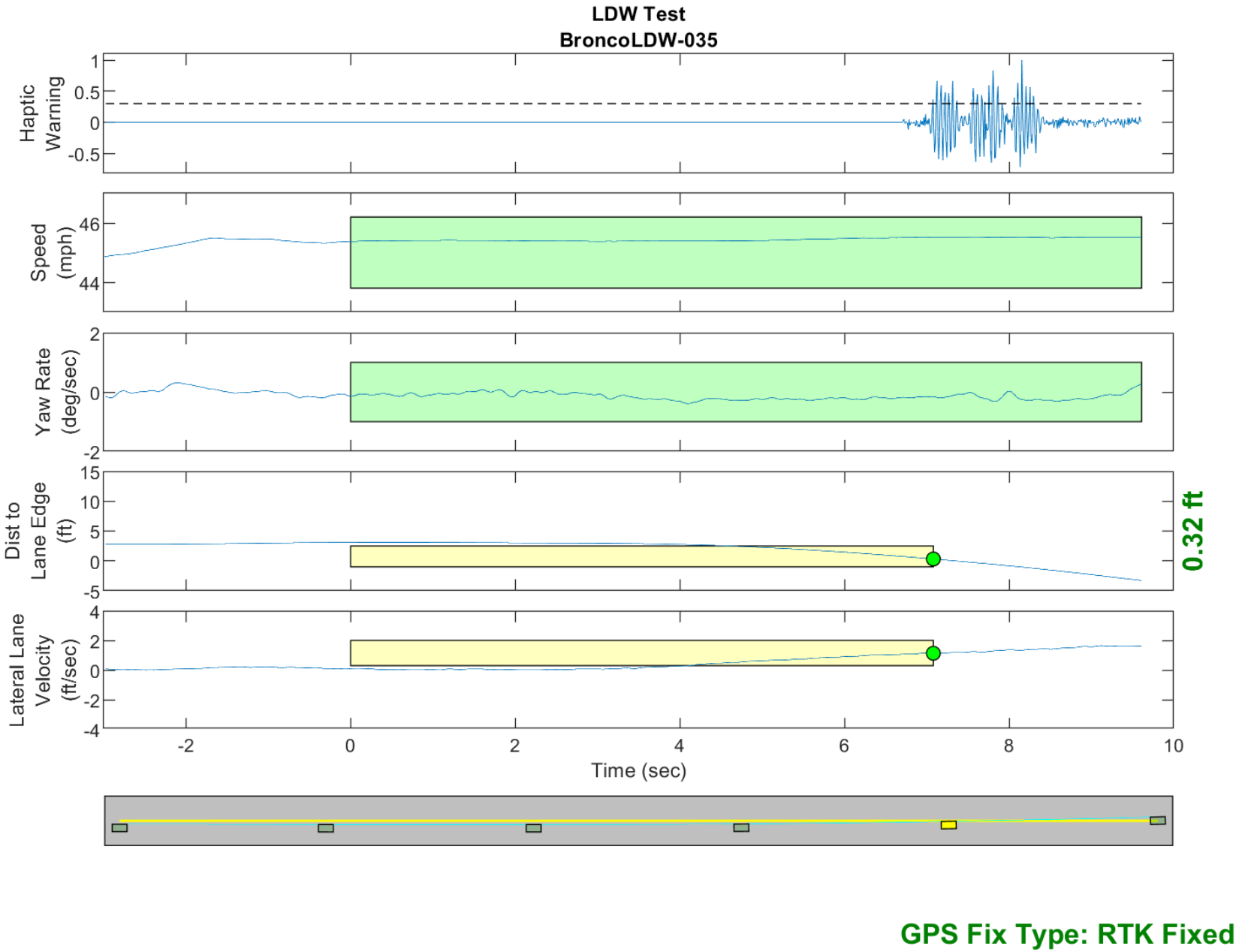

Figure D66. Time History for Run 35, Botts Dots, Left Departure, Haptic Warning

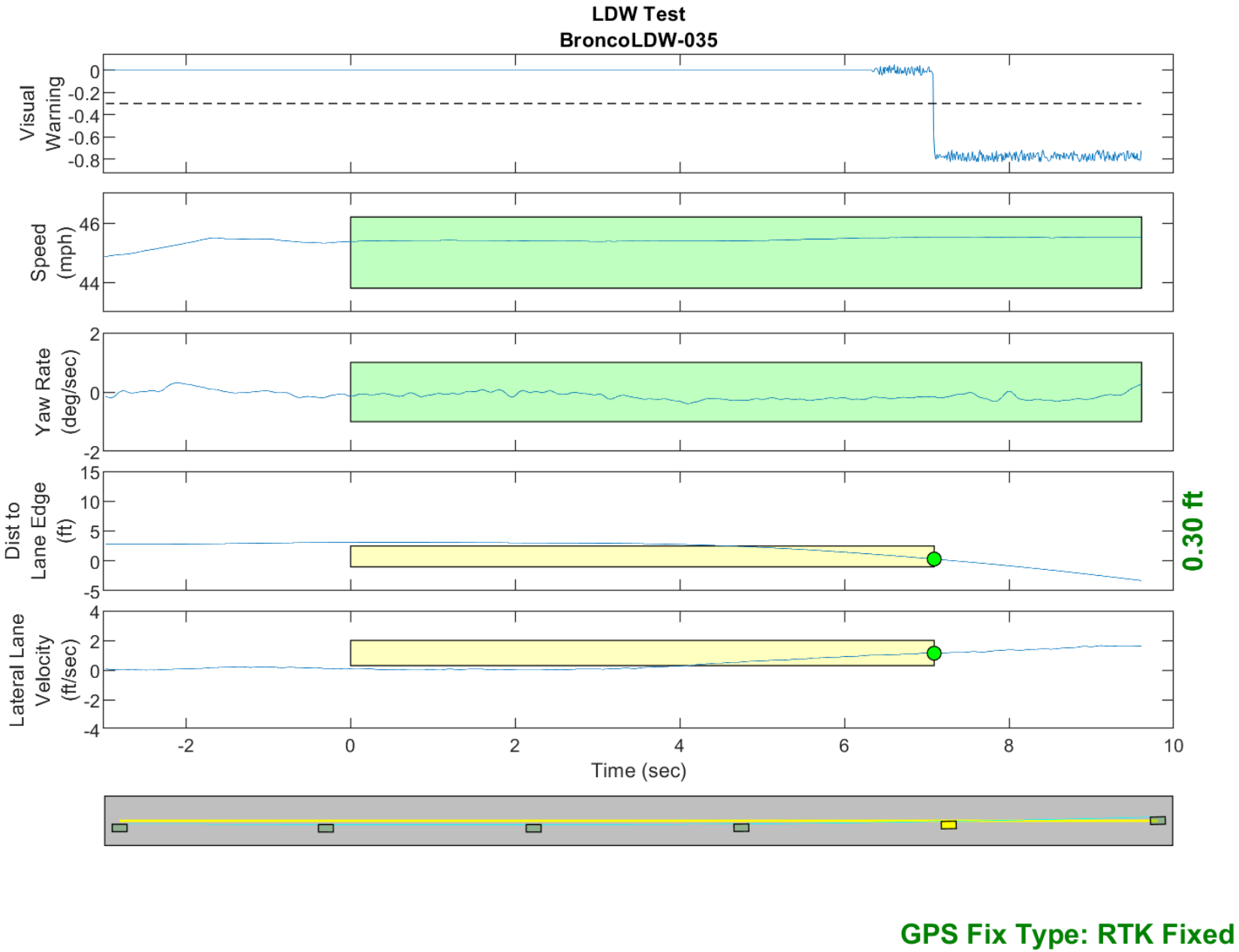

Figure D67. Time History for Run 35, Botts Dots, Left Departure, Visual Warning

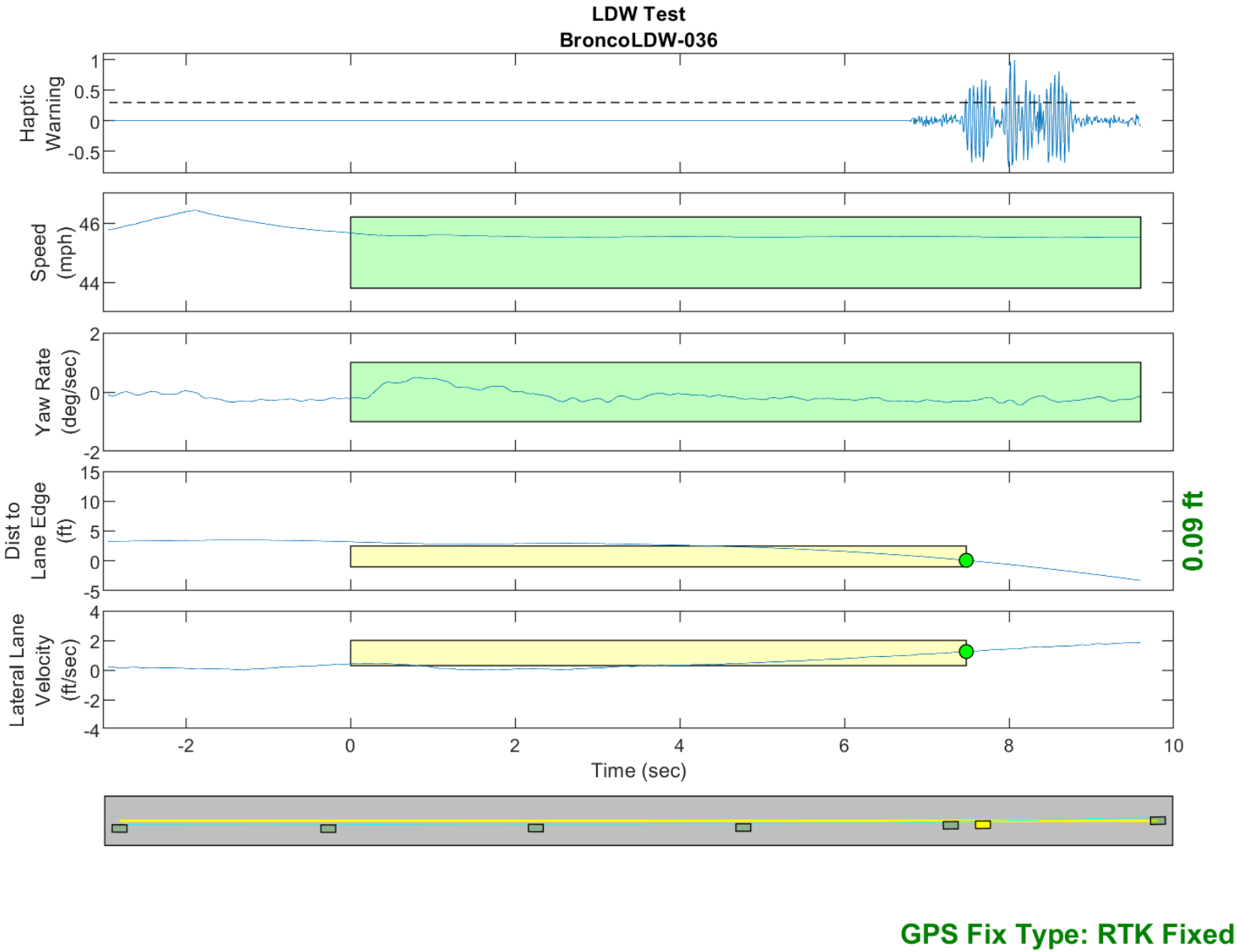

Figure D68. Time History for Run 36, Botts Dots, Left Departure, Haptic Warning

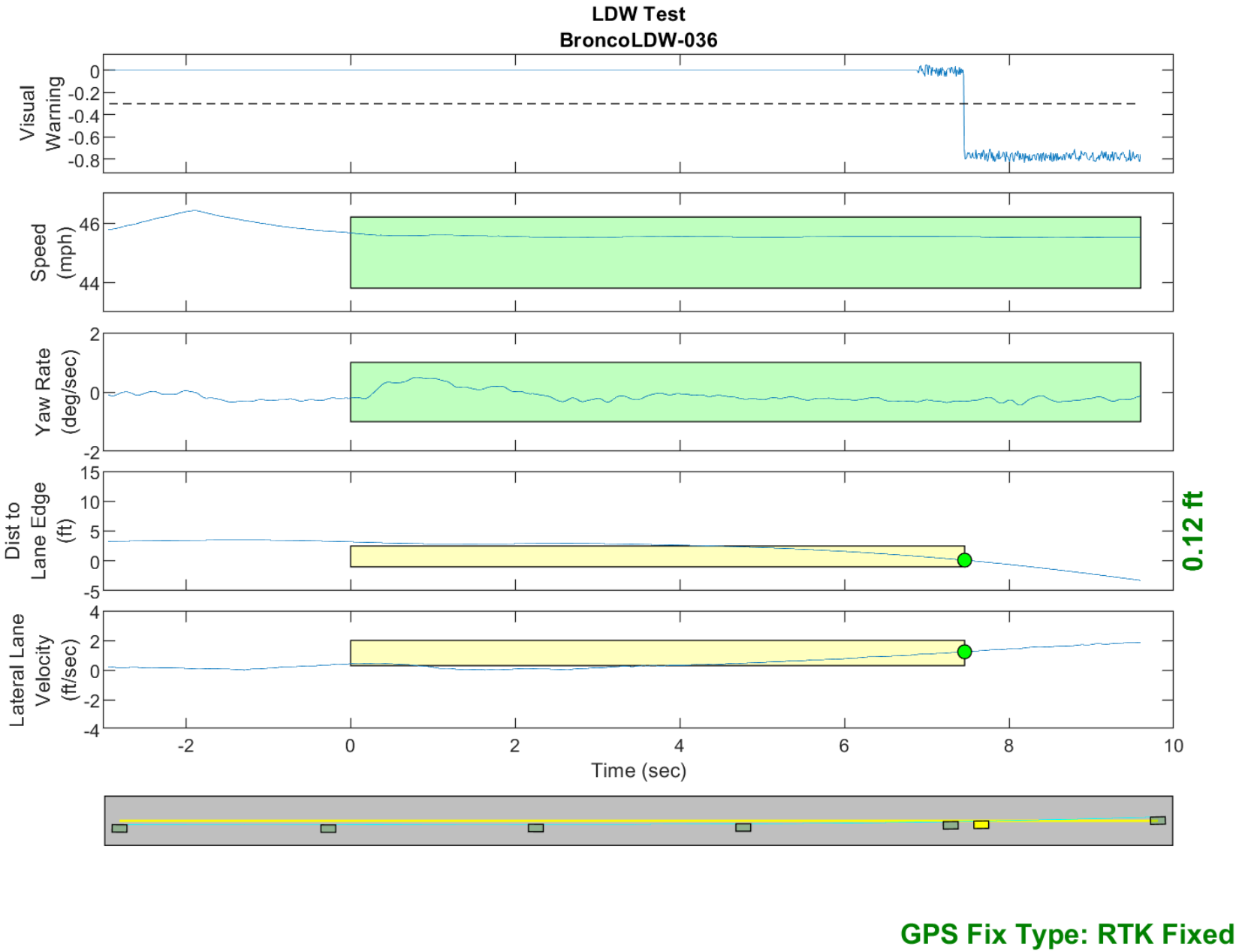

Figure D69. Time History for Run 36, Botts Dots, Left Departure, Visual Warning

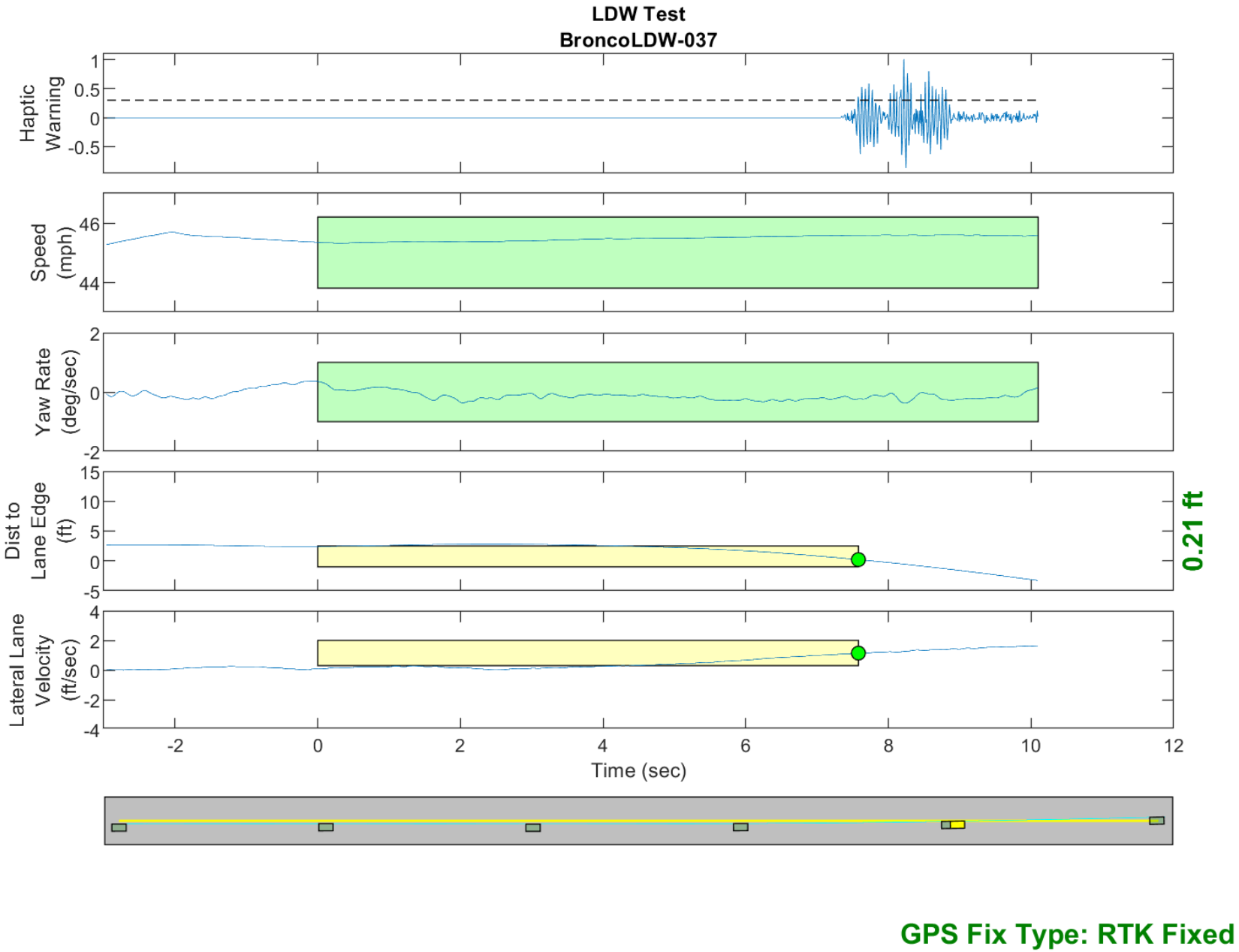

Figure D70. Time History for Run 37, Botts Dots, Left Departure, Haptic Warning

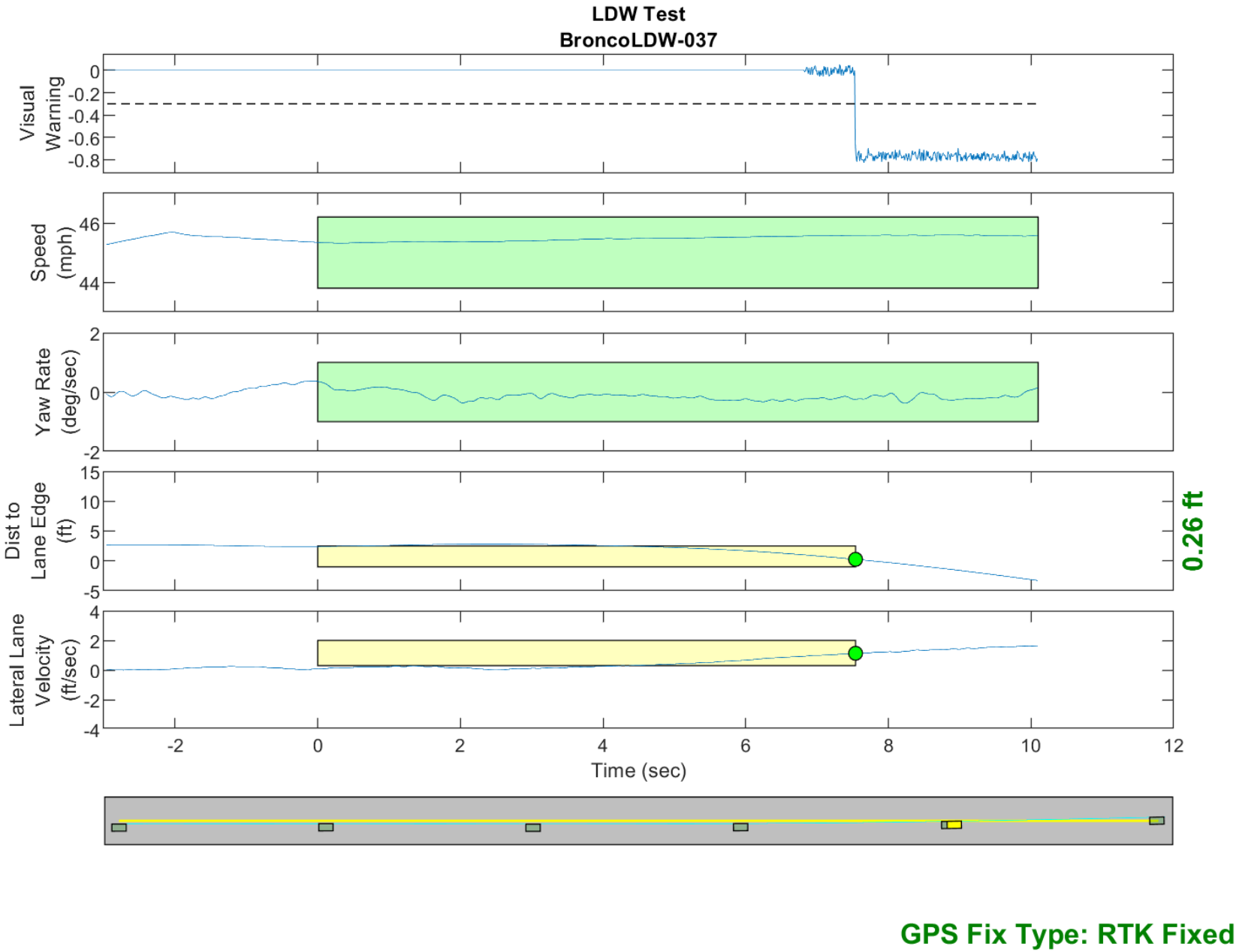

Figure D71. Time History for Run 37, Botts Dots, Left Departure, Visual Warning

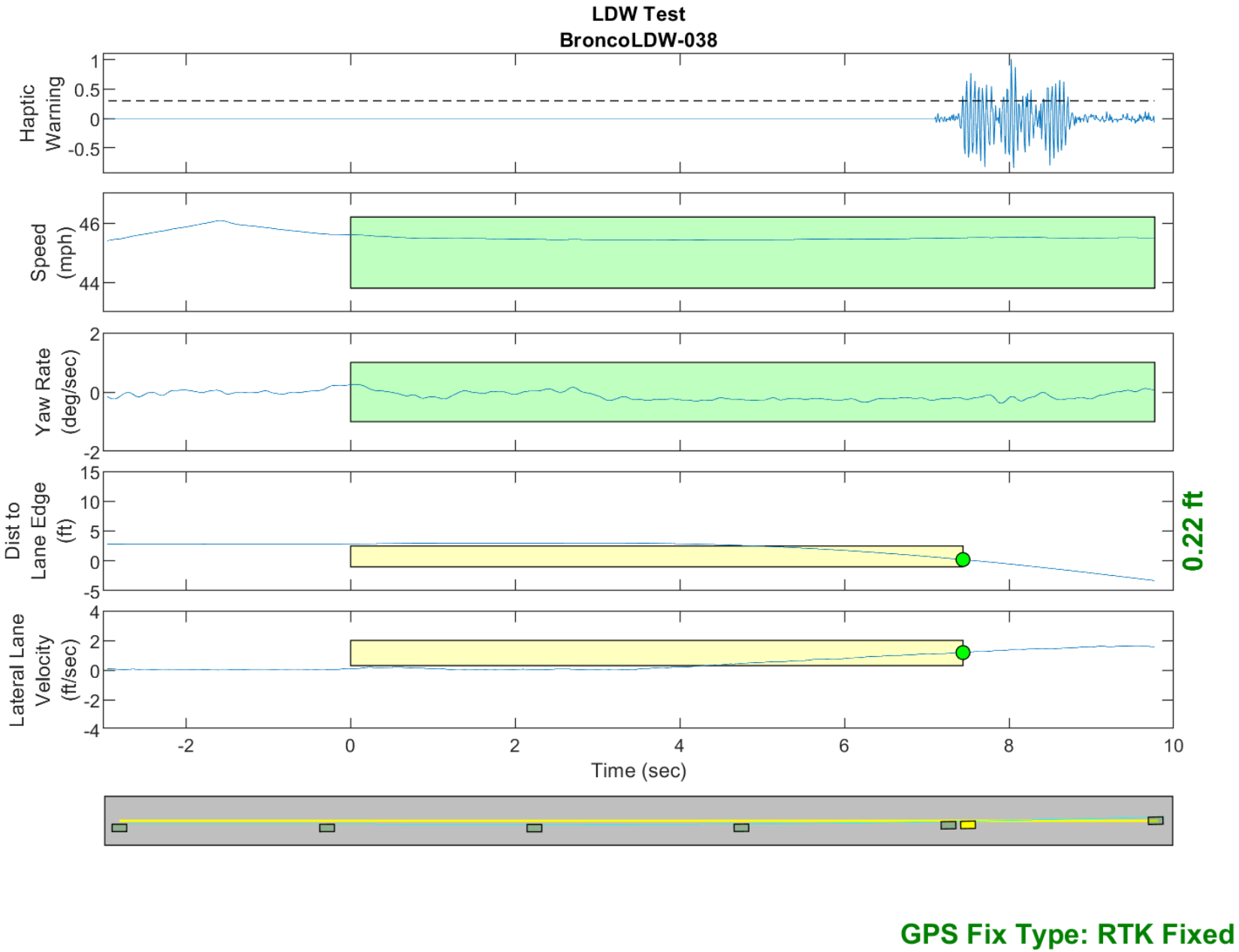

Figure D72. Time History for Run 38, Botts Dots, Left Departure, Haptic Warning

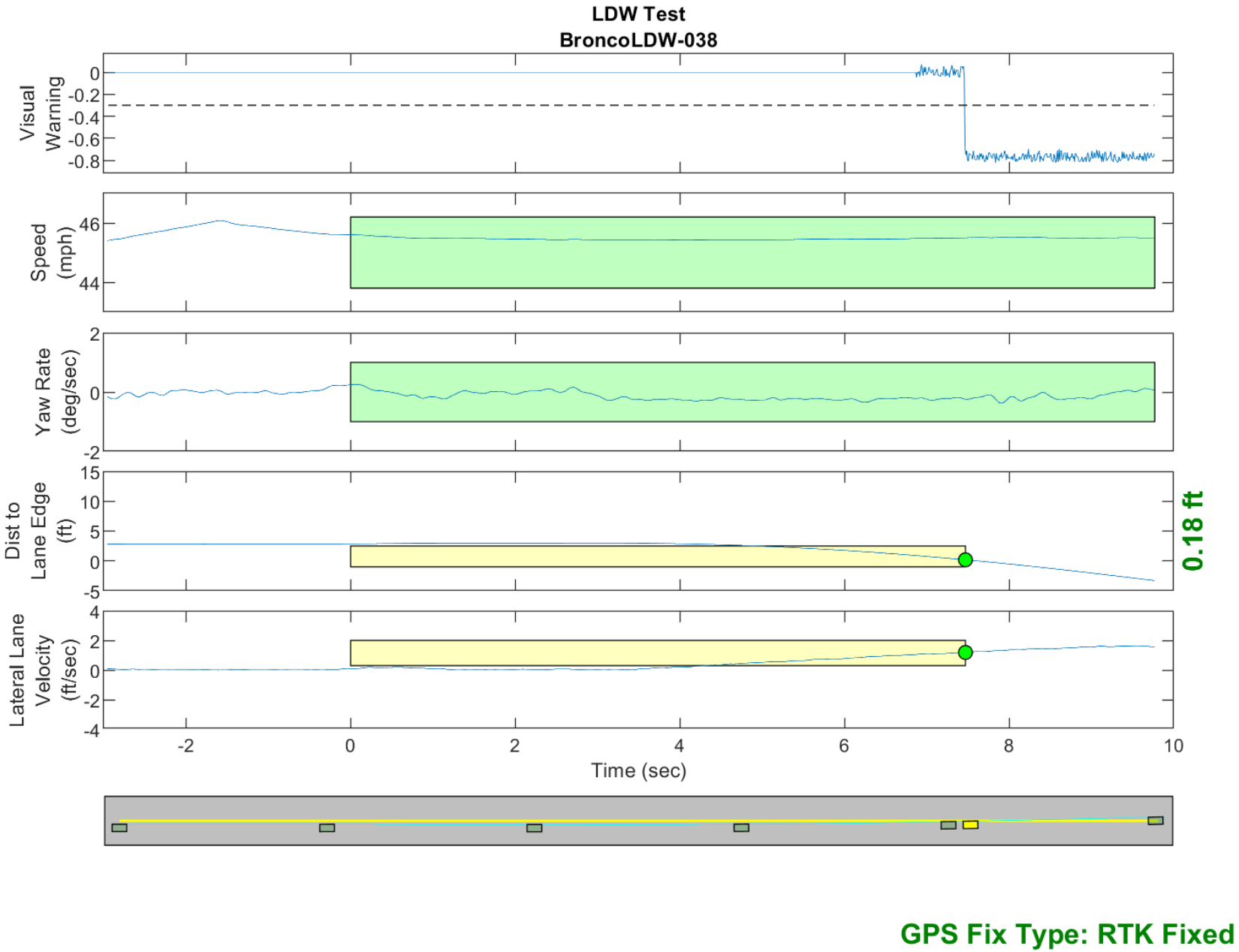

Figure D73. Time History for Run 38, Botts Dots, Left Departure, Visual Warning

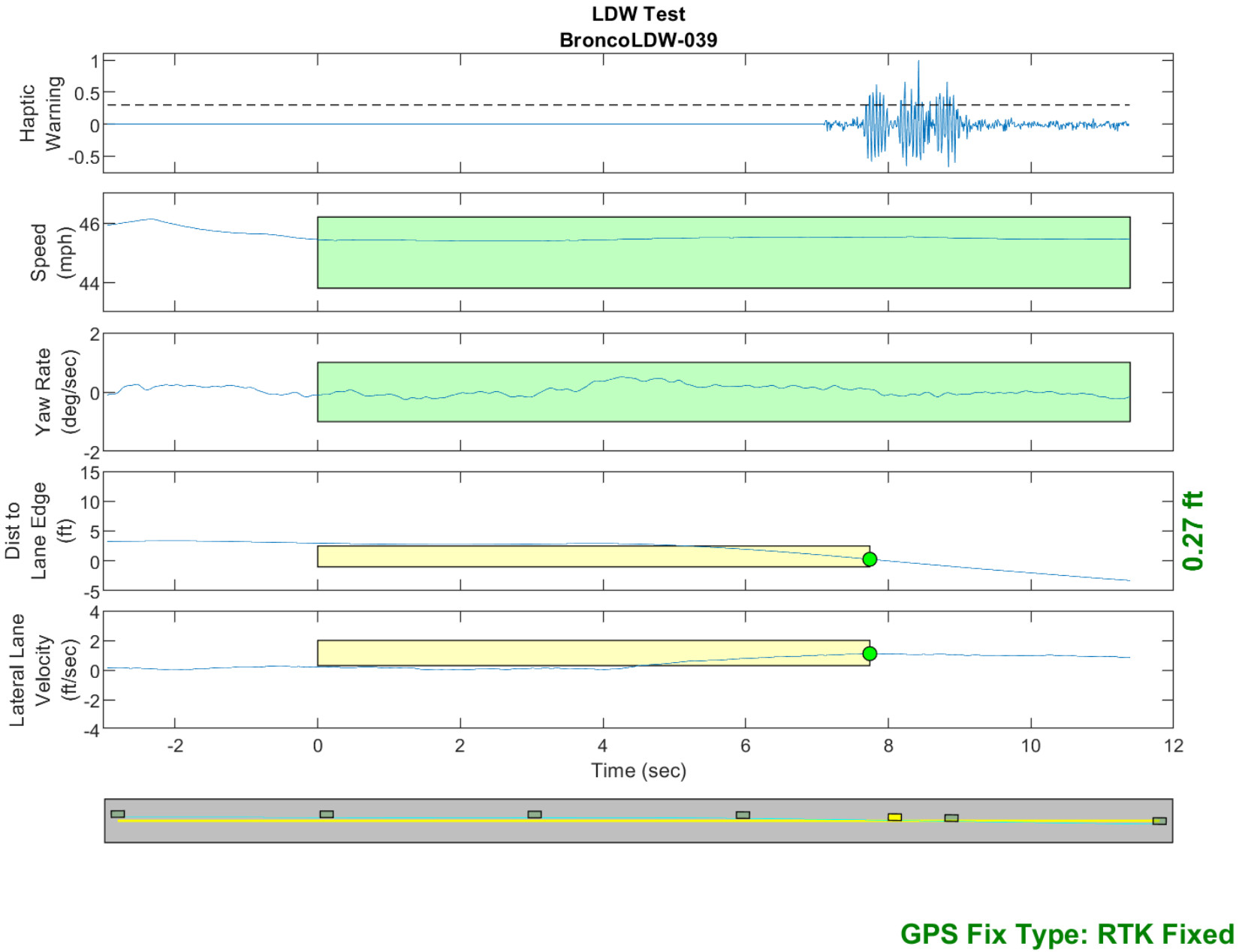

Figure D74. Time History for Run 39, Botts Dots, Right Departure, Haptic Warning

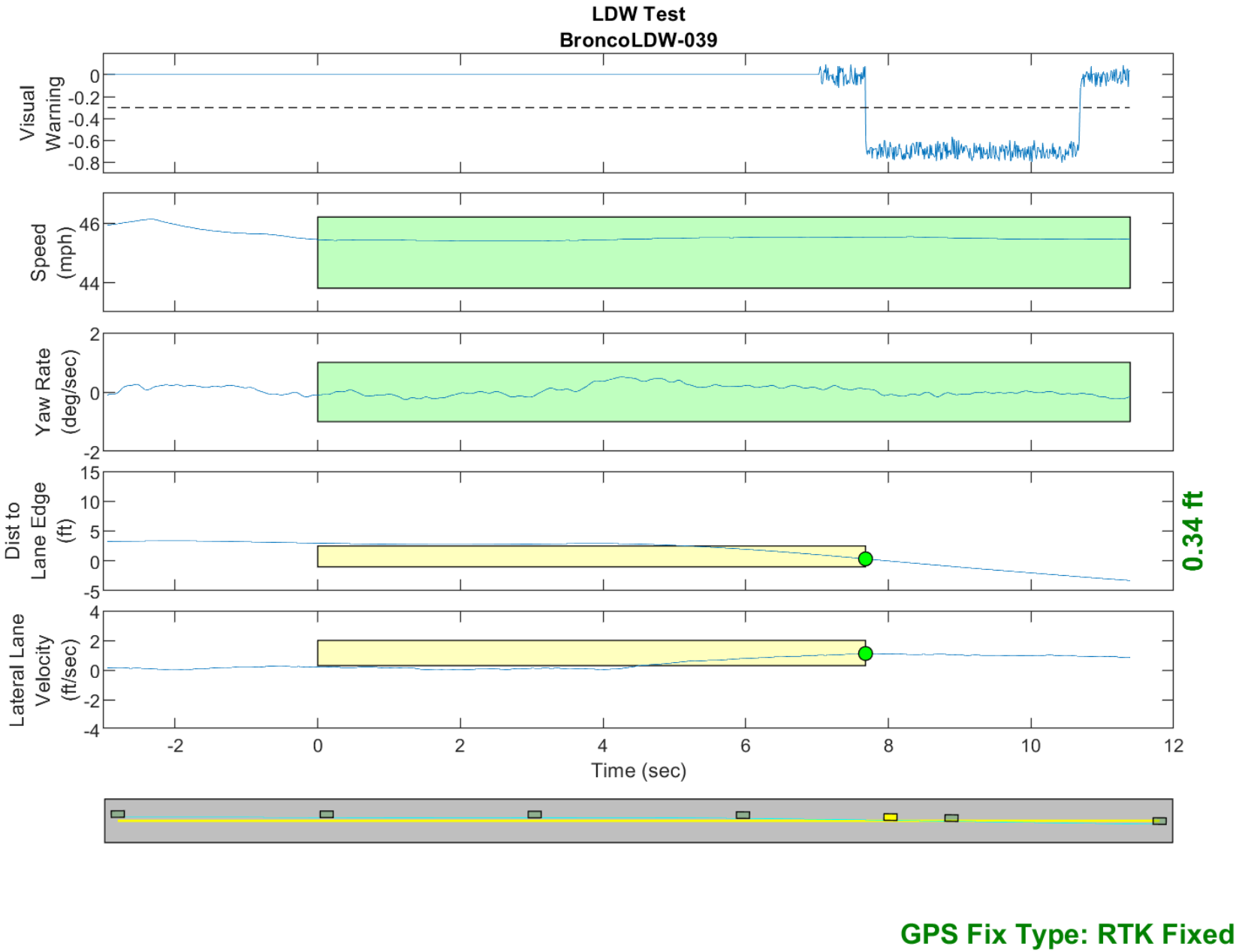

Figure D75. Time History for Run 39, Botts Dots, Right Departure, Visual Warning

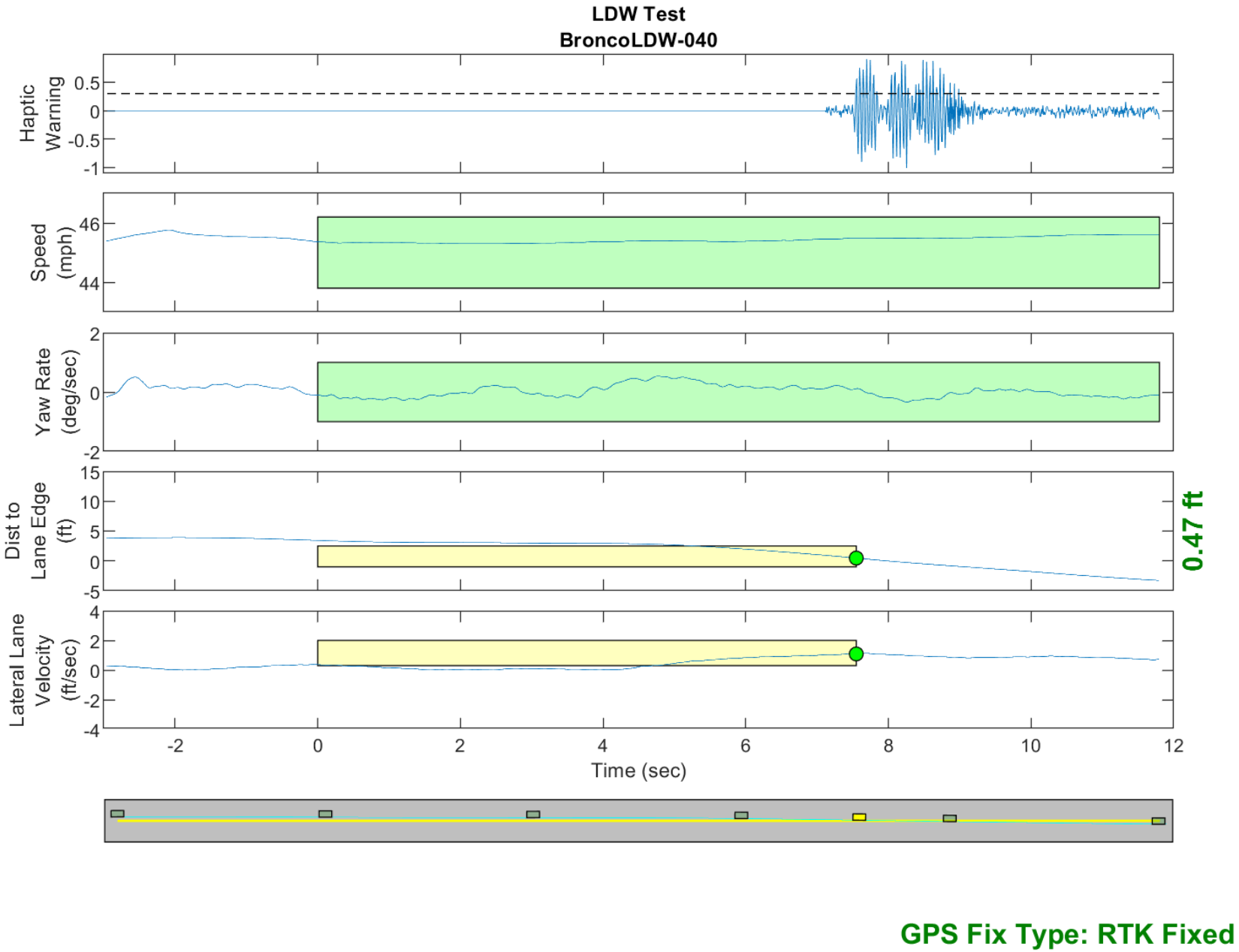

Figure D76. Time History for Run 40, Botts Dots, Right Departure, Haptic Warning

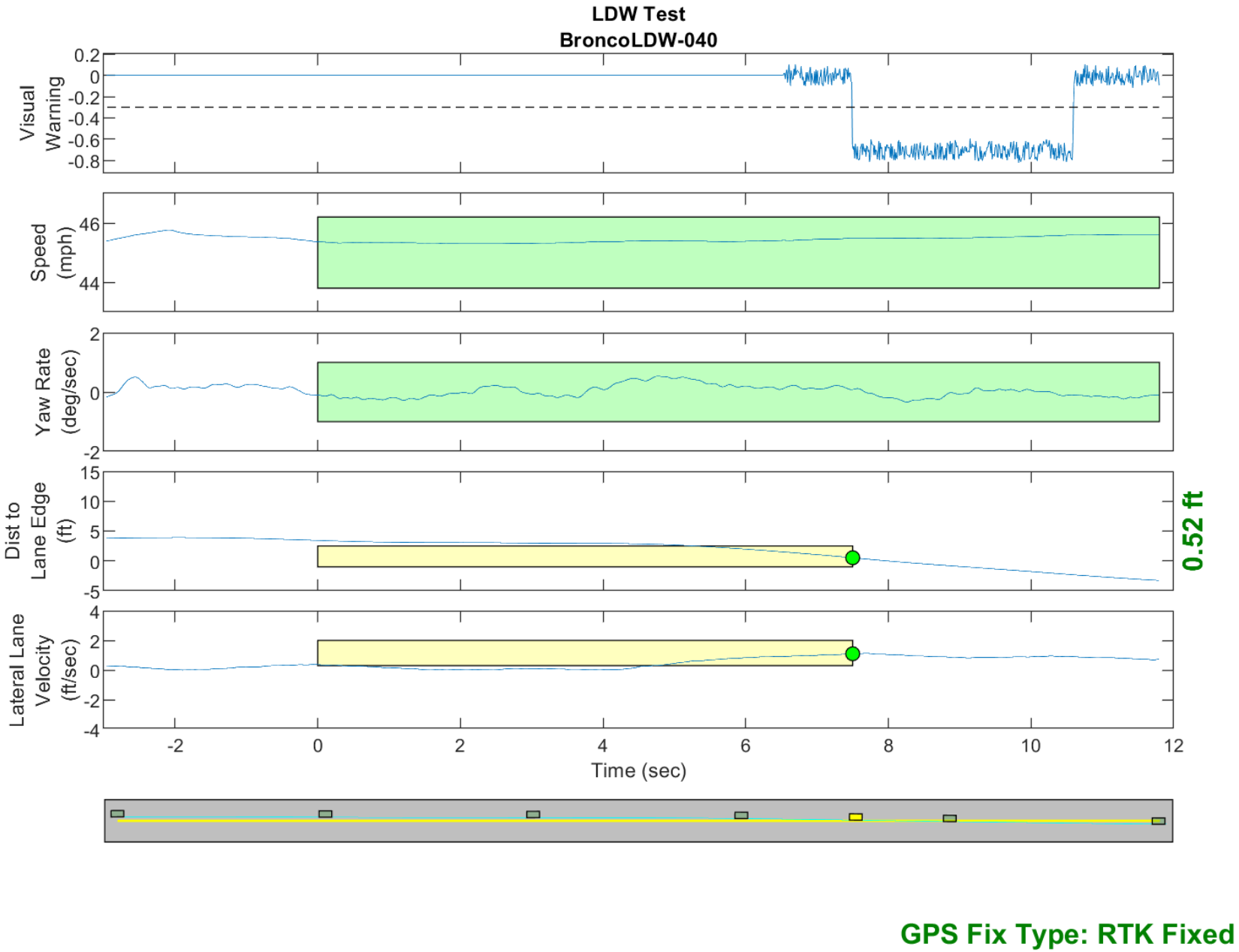

Figure D77. Time History for Run 40, Botts Dots, Right Departure, Visual Warning

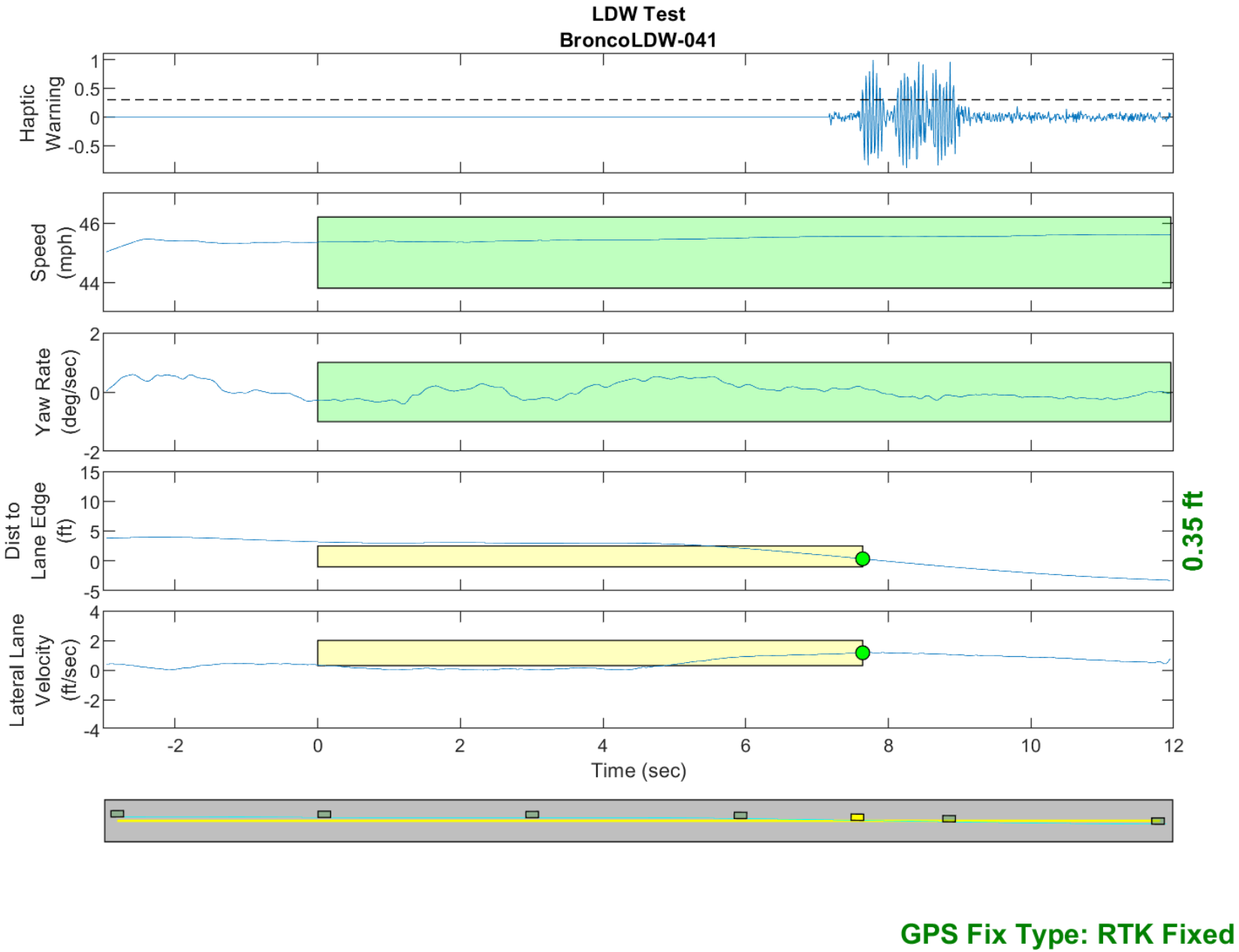

Figure D78. Time History for Run 41, Botts Dots, Right Departure, Haptic Warning

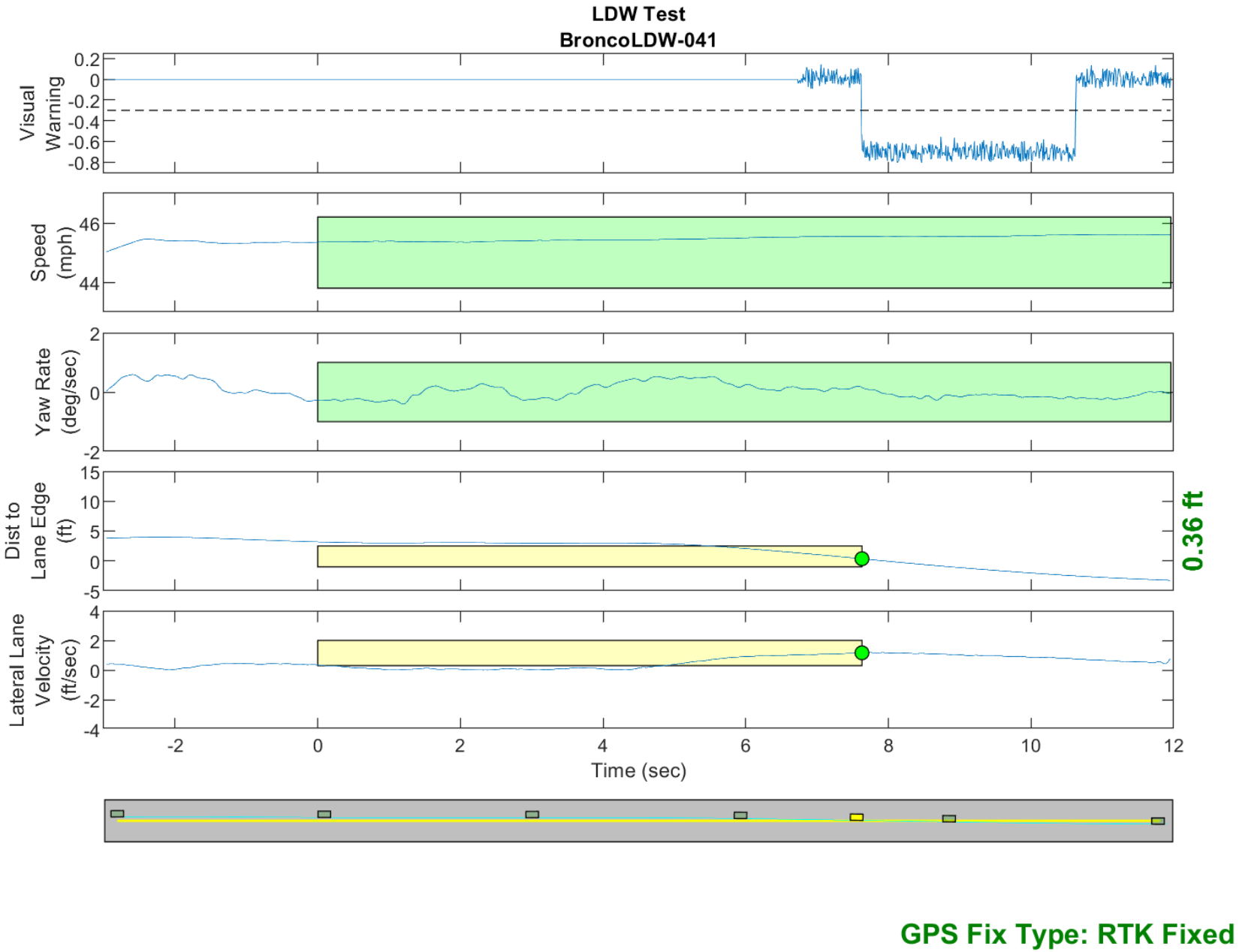

Figure D79. Time History for Run 41, Botts Dots, Right Departure, Visual Warning

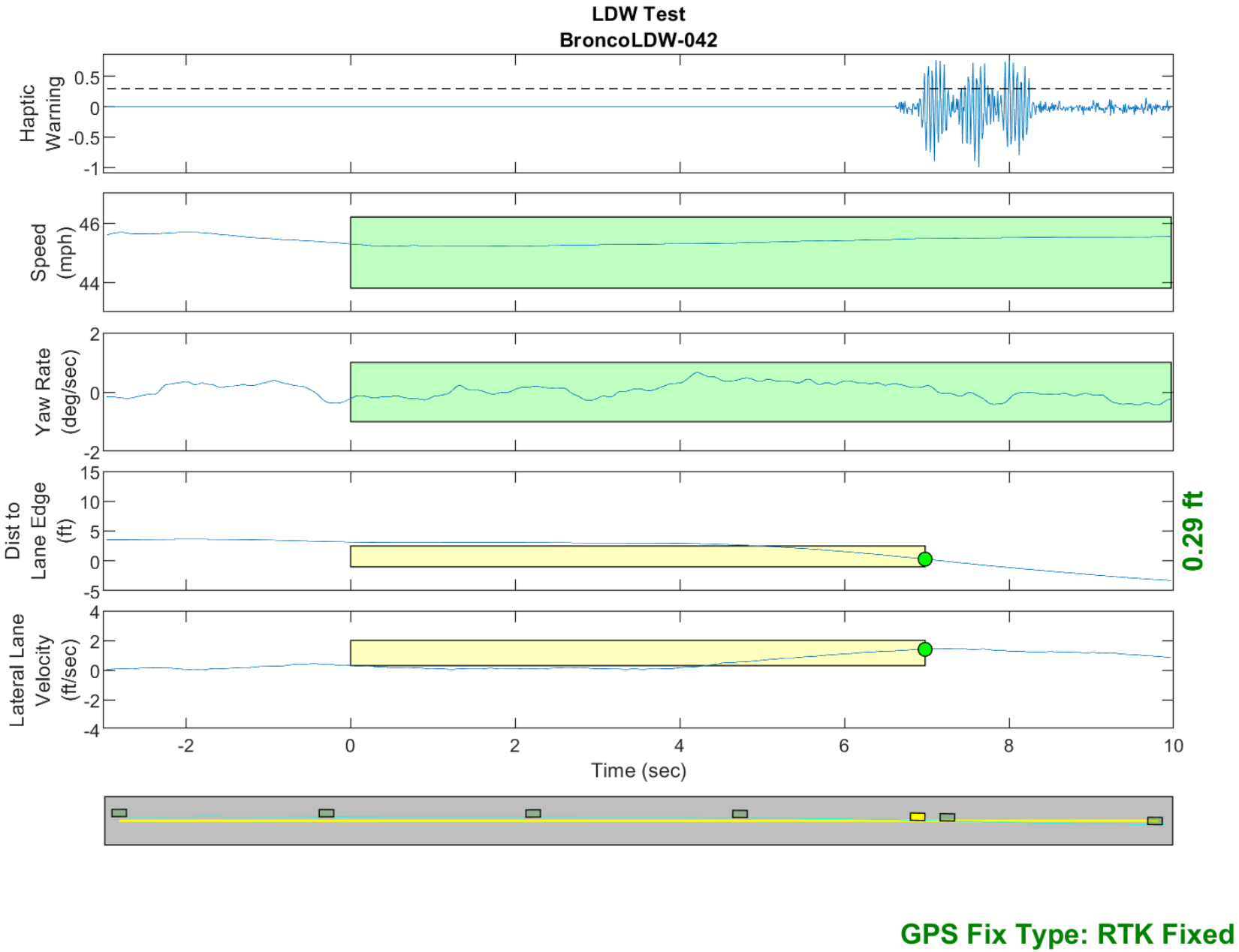

Figure D80. Time History for Run 42, Botts Dots, Right Departure, Haptic Warning

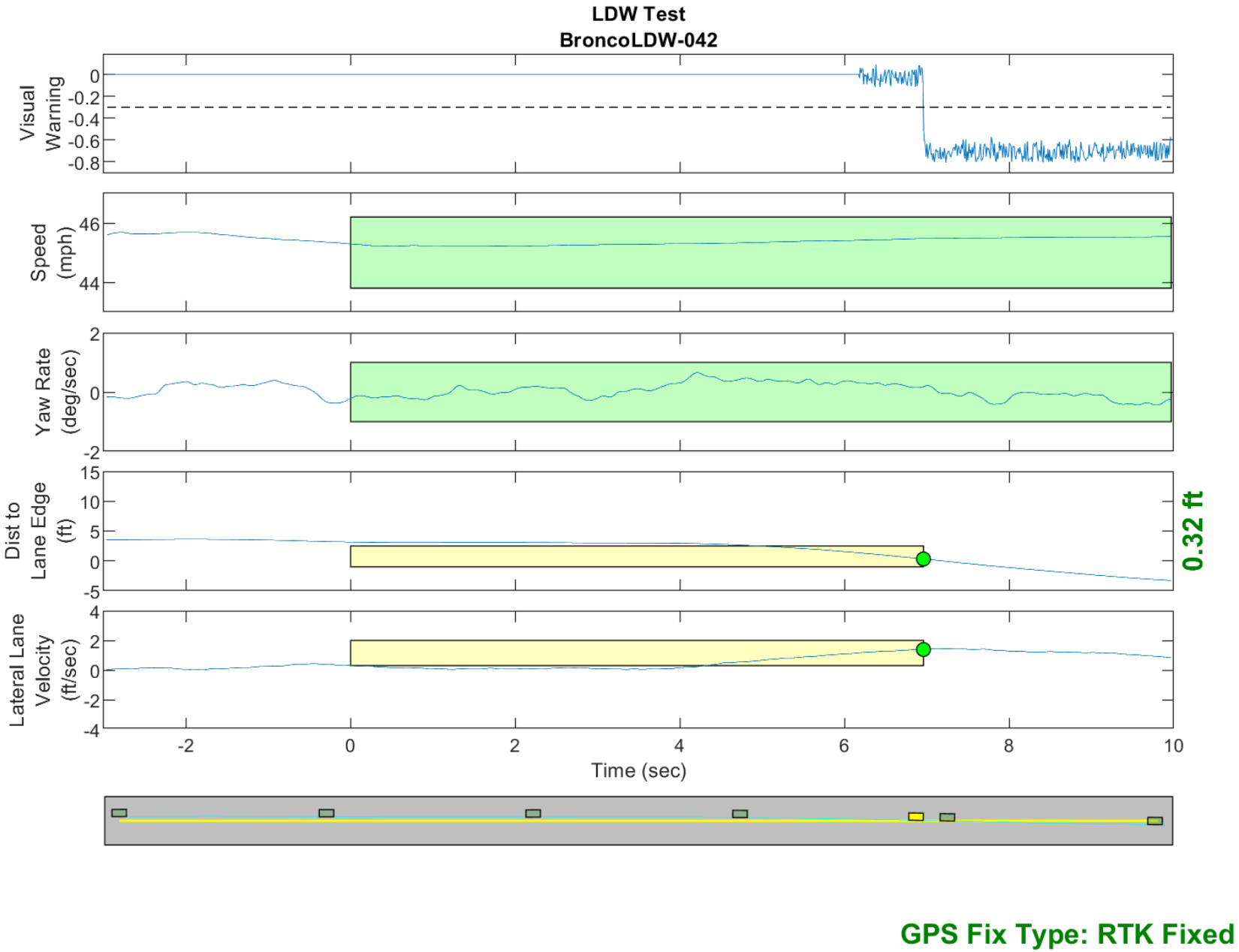

Figure D81. Time History for Run 42, Botts Dots, Right Departure, Visual Warning

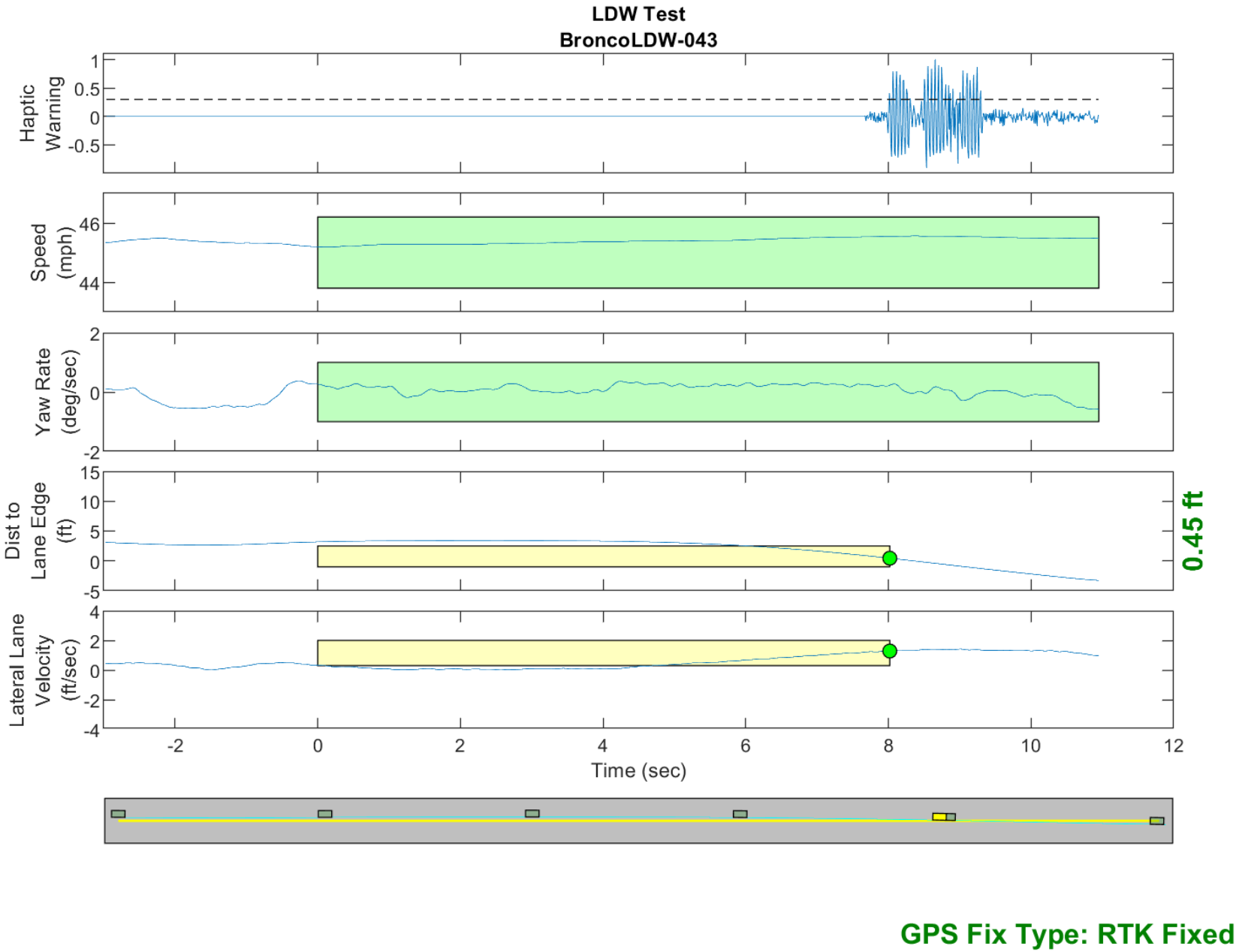

Figure D82. Time History for Run 43, Botts Dots, Right Departure, Haptic Warning

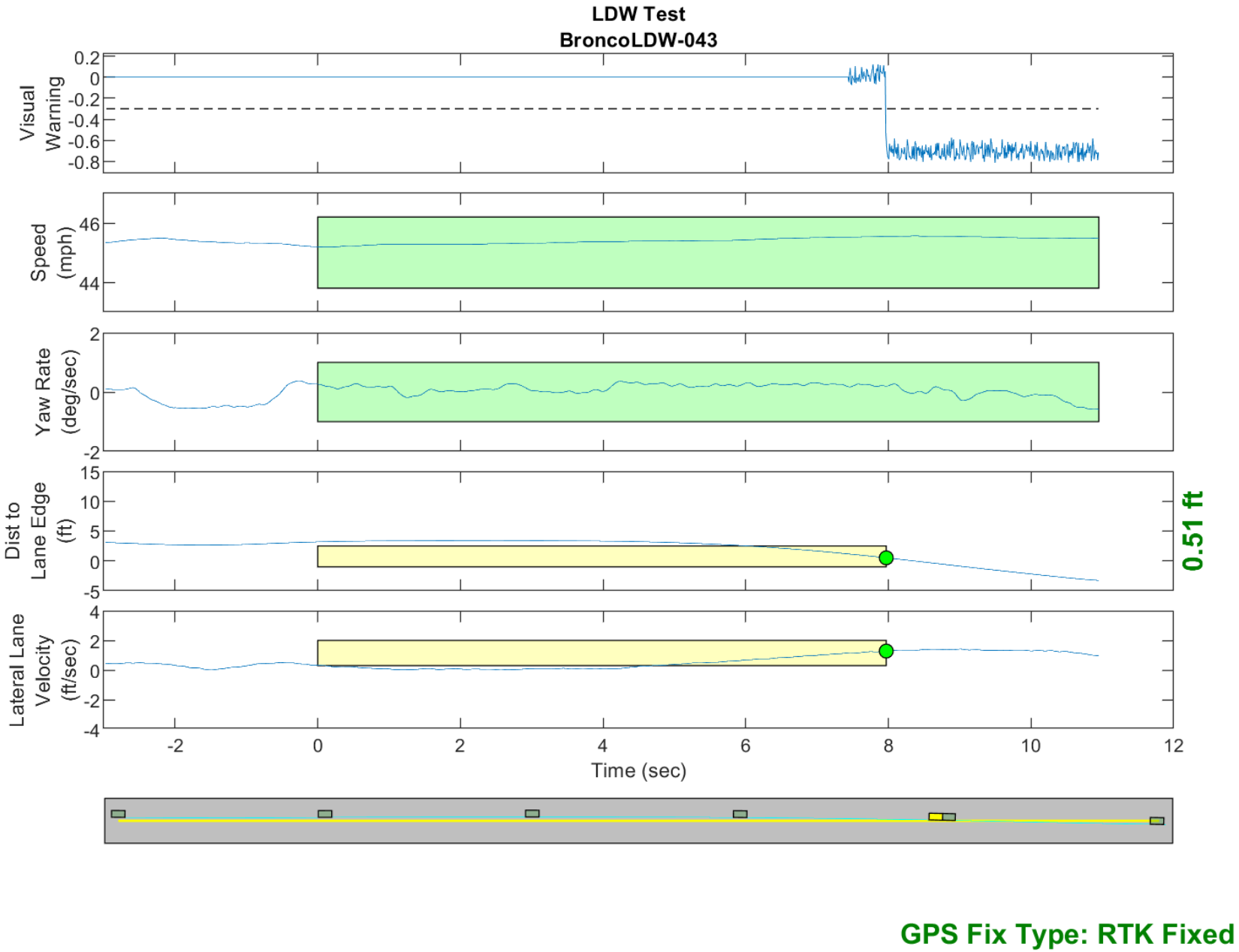

Figure D83. Time History for Run 43, Botts Dots, Right Departure, Visual Warning

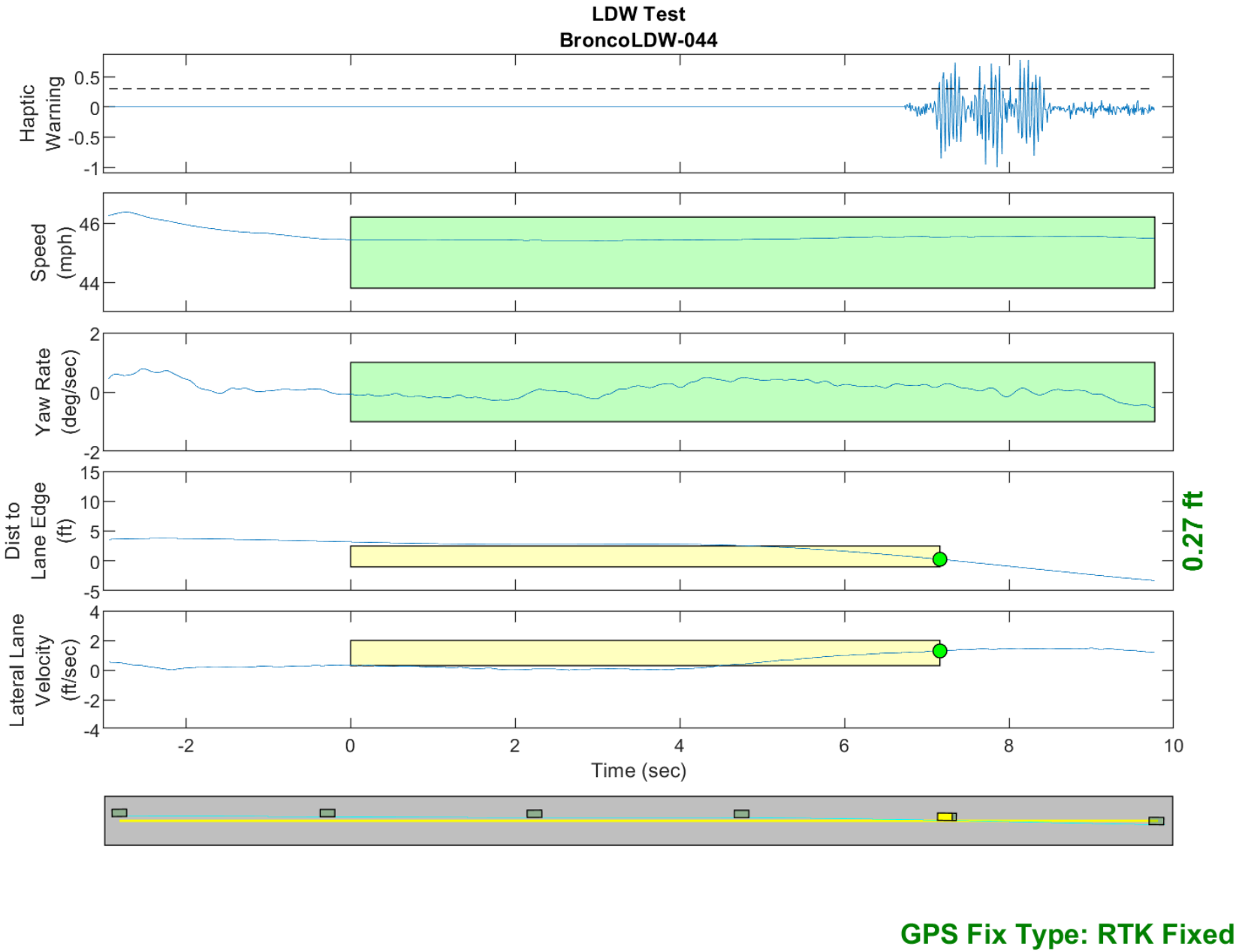

Figure D84. Time History for Run 44, Botts Dots, Right Departure, Haptic Warning

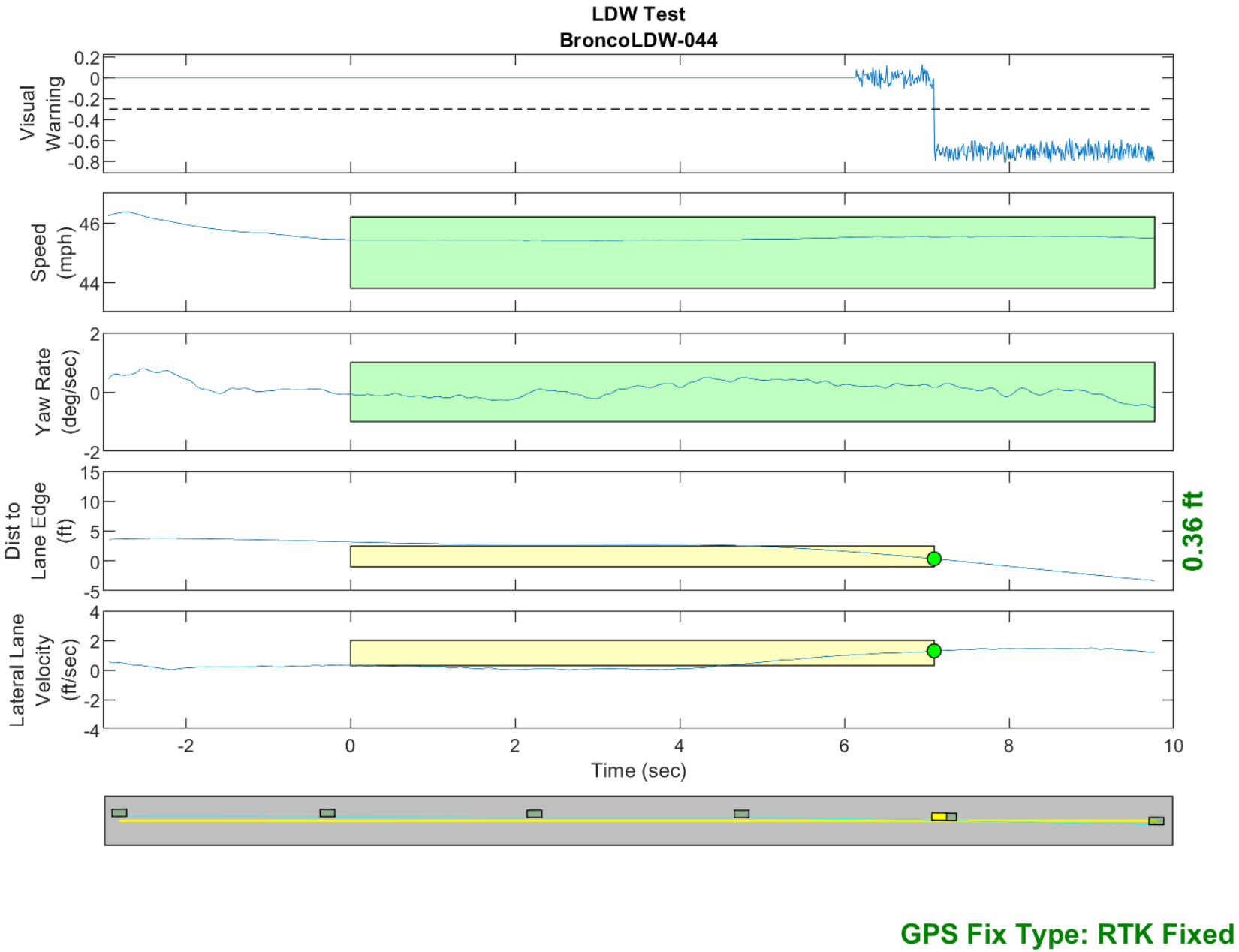

Figure D85. Time History for Run 44, Botts Dots, Right Departure, Visual Warning

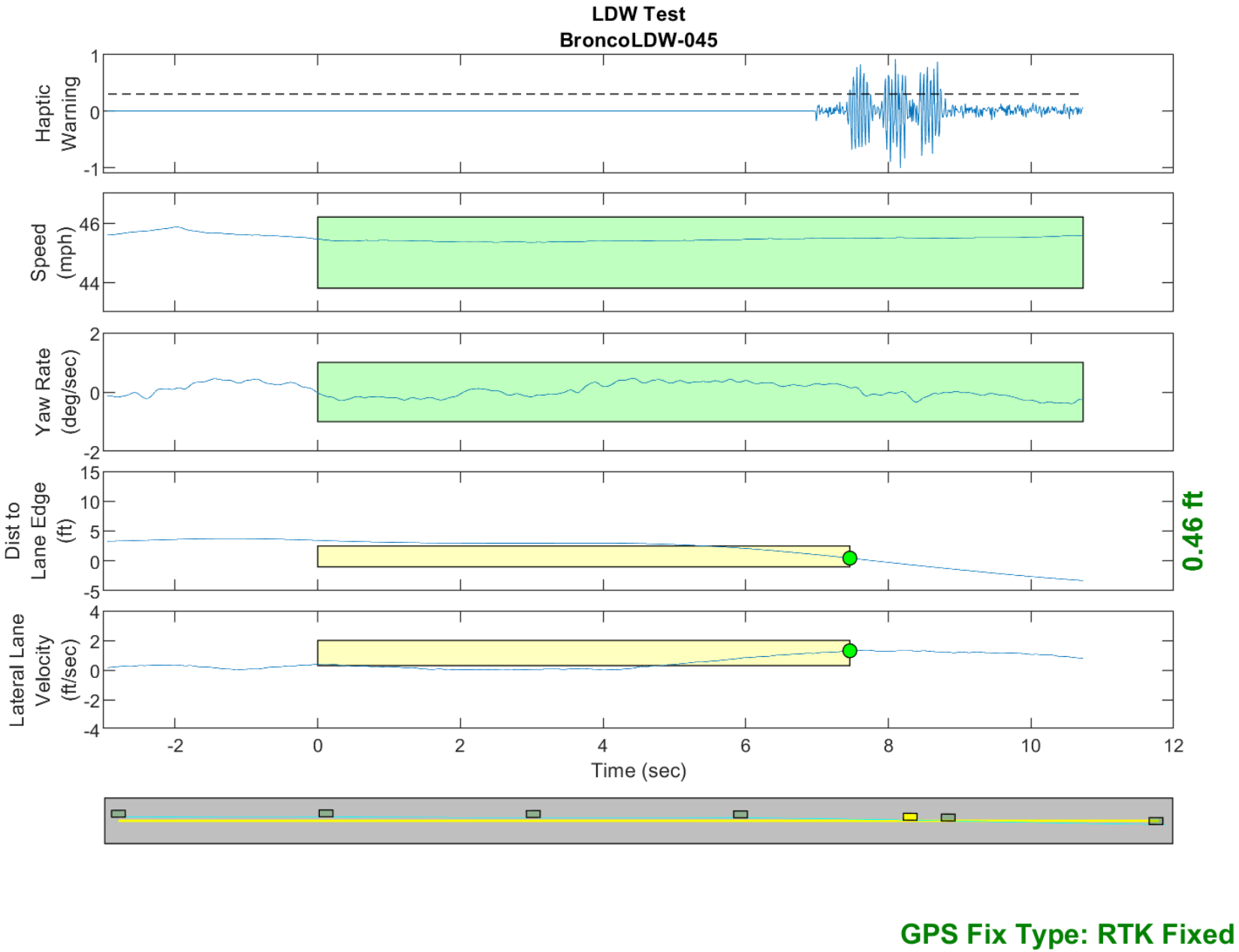

Figure D86. Time History for Run 45, Botts Dots, Right Departure, Haptic Warning

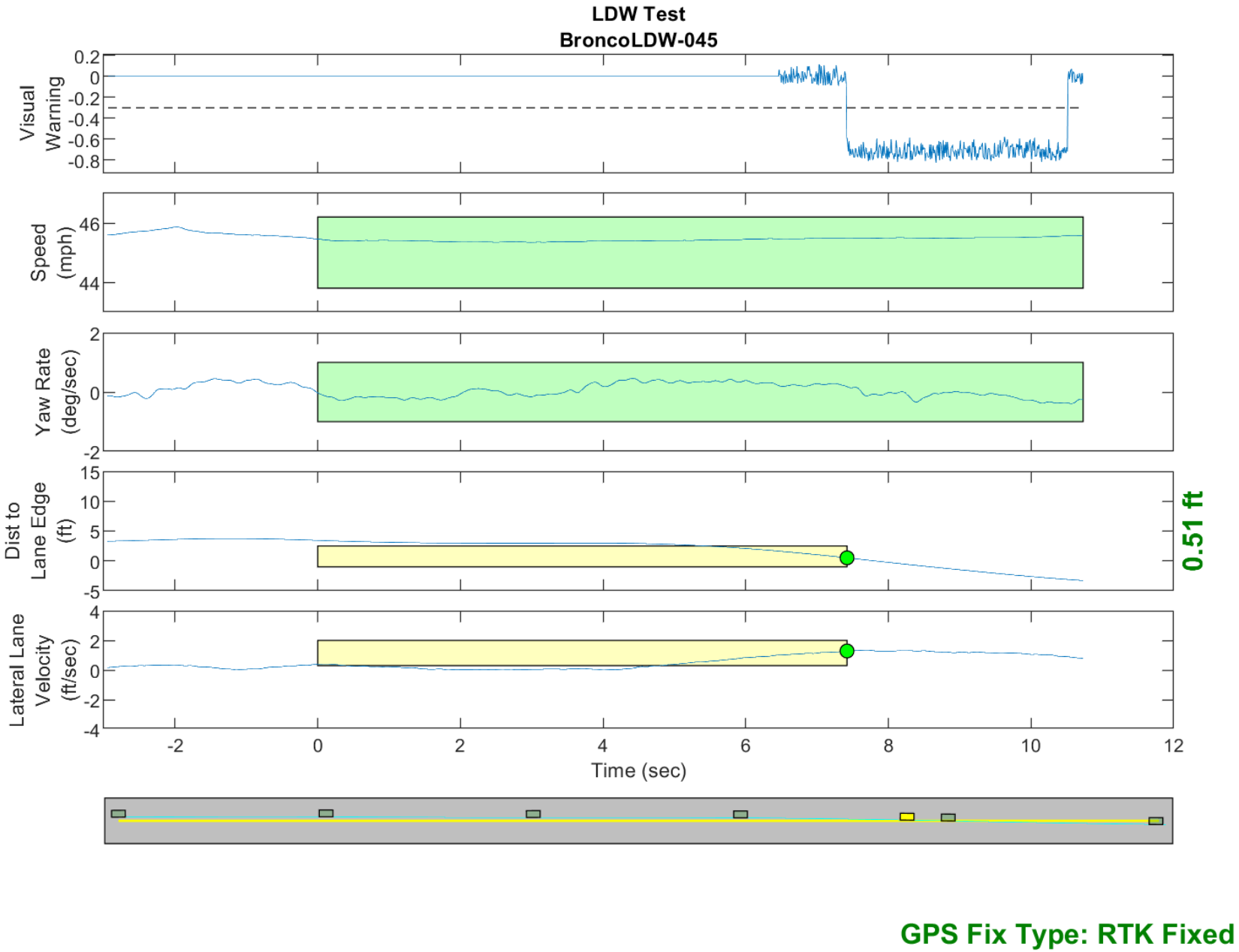

Figure D87. Time History for Run 45, Botts Dots, Right Departure, Visual Warning