NEW CAR ASSESSMENT PROGRAM
FORWARD COLLISION WARNING CONFIRMATION TEST
NCAP-DRI-FCW-21-04

2021 Ford Bronco Sport Badlands 4x4

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5 April 2021

Draft Report

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National Highway Traffic Safety Administration
New Car Assessment Program
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Date: 5 April 2021

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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-2006-26555-0134 to confirm the performance of a Forward Collision Warning system. The vehicle passed the requirements of the test for all three FCW test scenarios.			
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Section I

INTRODUCTION

This test evaluates the ability of a Forward Collision Warning (FCW) system to detect and alert drivers to potential hazards in the path of the vehicle as specified in the New Car Assessment Program's "Forward Collision Warning Confirmation" test procedure, dated February 2013. Three driving scenarios are utilized to assess this technology. In the first test, a Subject Vehicle (SV) approaches a stopped Principal Other Vehicle (POV) in the same lane of travel. The second test begins with the SV initially following the POV at the same constant speed. After a short while, the POV stops suddenly. The third test consists of the SV, traveling at a constant speed, approaching a slower moving POV, which is also being driven at a constant speed.

Section II

DATA SHEETS

FORWARD COLLISION WARNING

DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2021 Ford Bronco Sport Badlands 4x4

VIN: *3FMCR9D95MRA0xxxx*

Test Date: *3/24/2021*

Forward Collision Warning setting: *High Sensitivity*

Test 1 –	Subject Vehicle Encounters Stopped Principal Other Vehicle:	***Pass***
Test 2 –	Subject Vehicle Encounters Decelerating Principal Other Vehicle:	***Pass***
Test 3 –	Subject Vehicle Encounters Slower Principal Other Vehicle:	***Pass***

Overall: ***Pass***

Notes:

FORWARD COLLISION 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 specification: *235/65R17 104H*

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

Front tire DOT prefix: *1R8L8 3MDR*

Rear tire DOT prefix: *1R8L8 3MDR*

FORWARD COLLISION 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)*

FORWARD COLLISION 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)*

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

(Page 1 of 3)

2021 Ford Bronco Sport Badlands 4x4

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

Pre-Collision Assist with Automatic Emergency Braking, which is part of Ford Co-Pilot360.

Type and location of sensor(s) the system uses:

*Camera-only sensing: Top center of windshield (camera) (**tested**)*

OR

Radar-camera (fusion) sensing: Top center of windshield (camera), left side of front bumper & right side of front bumper (radars)

Forward Collision Warning Setting used in test: *High Sensitivity*

How is the Forward Collision 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 visual warning is displayed in the center of the instrument panel. See Appendix A, Figure A13. The words "Pre-Collision Assist" are displayed above a crashing vehicle icon with a red background that flashes on and off.

An auditory warning comprising repeated four pulse bursts of an 1800 Hz tone is also provided.

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

(Page 2 of 3)

2021 Ford Bronco Sport Badlands 4x4

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

____ Yes

X No

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

Only the active braking portion of the system can be disabled, i.e. when Active Braking is disabled, FCW is still functional.

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

X Yes

____ No

If yes, please provide a full description.

A center mounted touchscreen is used to interact with system menus. The hierarchy is:

Settings

Driver Assistance

Pre-Collision Assist

Alert Sensitivity

Choose from "High", "Normal", or "Low"

See Appendix A, Figure A12.

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

(Page 3 of 3)

2021 Ford Bronco Sport Badlands 4x4

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

If yes, please provide a full description.

System limitations are described on page 218 of the Owner's Manual, shown in Appendix B, page B-4.

Notes:

The 2021 Ford Bronco Sport Badlands 4x4 is available with two types of AEB systems. One of these uses a camera-only system and the other uses a fusion of camera and forward-facing radar system. The vehicle covered in this report was equipped with the camera-only system.

Section III

TEST PROCEDURES

A. Test Procedure Overview

Three test procedures were used, as follows:

Test 1. Subject Vehicle (SV) Encounters Stopped Principal Other Vehicle (POV)

Test 2. Subject Vehicle Encounters Decelerating Principal Other Vehicle

Test 3. Subject Vehicle Encounters Slower Principal Other Vehicle

With the exception of trials associated with Test 1, all trials were performed with SV and POV automatic transmissions in ‘‘Drive’’ or with manual transmissions in the highest gear capable of sustaining the desired test speed. Manual transmission clutches remained engaged during all maneuvers. Except for Test 2, the brake lights of the POV were not illuminated.

In order to pass the test, if the FCW system provides a warning timing adjustment for the driver, at least one setting must meet the criterion of the test procedure. Therefore, if the vehicle was equipped with a warning timing adjustment, only the most “conservative” (earliest warning) setting was tested.

An overview of each of the test procedures follows.

1. <u>TEST 1 – SUBJECT VEHICLE ENCOUNTERS STOPPED PRINCIPAL OTHER VEHICLE ON A STRAIGHT ROAD</u>

This test evaluates the ability of the FCW function to detect a stopped lead vehicle, as depicted in Figure 1.

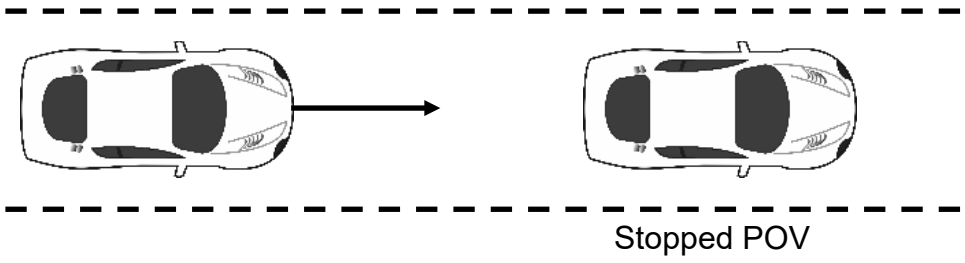

Figure 1. Depiction of Test 1

a. Alert Criteria

In order to pass the test, the FCW alert must be issued when the time-to-collision (TTC) is at least 2.1 seconds. The TTC for this test was calculated by considering the speeds of the SV and the POV at the time of the FCW alert (i.e., when the SV and POV speeds are nominally equal to 45 and 0 mph (72.4 and 0 km/h), respectively).

b. Procedure

The POV was parked in the center of a travel lane, with its longitudinal axis oriented parallel to the roadway edge and facing the same direction as the SV so that the SV approaches the rear of the POV.

The SV was driven at a nominal speed of 45 mph (72.4 km/h) in the center of the lane of travel, toward the parked POV. The test began when the SV was 492 ft (150 m) from the POV and ended when either of the following occurred:

- The required FCW alert occurred.
- The TTC to the POV fell to less than 90% of the minimum allowable range (i.e., TTC = 1.9 sec) for the onset of the required FCW alert.

The SV driver then steered and/or braked to keep the SV from striking the POV.

For an individual test trial to be valid, the following was required throughout the test:

- The SV vehicle speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) for a period of three seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90% of the minimum allowable range for onset of the required FCW alert.
- The SV driver could not apply any force to the brake pedal before (1) the required FCW alert occurred or (2) the range fell to less than 90% of the minimum allowable range for onset of the required FCW alert.
- The lateral distance between the centerline of the SV, relative to the centerline of the POV, in road coordinates, could not exceed 2.0 ft (0.6 m).
- The yaw rate of the SV could not exceed ±1 deg/sec during the test.

Nominally, the Test 1 series was comprised of seven individual trials. The FCW system must satisfy the TTC alert criteria for at least five of the seven test trials.

2. TEST 2 – SUBJECT VEHICLE ENCOUNTERS DECELERATING PRINCIPAL OTHER VEHICLE

The SV in this test initially followed the POV at a constant time gap and then the POV suddenly decelerated, as depicted in Figure 2. The test evaluates the ability of the FCW to recognize a decelerating lead vehicle and to issue an alert to SV driver in a timely manner.

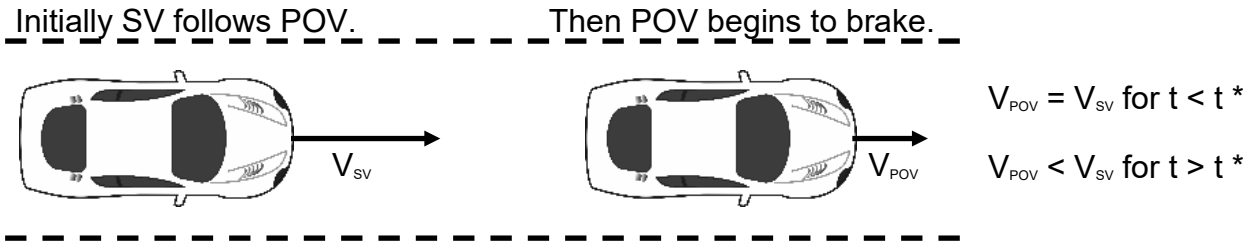

Figure 2. Depiction of Test 2

a. Alert Criteria

In order to pass the test, the FCW alert must be issued when TTC is at least 2.4 seconds. The TTC for this test, a prediction of the time it would take for the SV to collide with the POV, was calculated by considering three factors at the time of the FCW alert: (1) the speed of the SV, (2) the speed of the POV, and (3) the deceleration of the POV[1].

b. Procedure

Test 2 began with the SV and the POV traveling on a straight, flat road at a constant speed of 45.0 mph (72.4 km/h), in the center of the lane of travel. The headway from the SV to the POV was nominally maintained at 98.4 ft (30 m) until the POV braking was initiated.

The test began approximately 7 seconds before the driver of the POV started a braking maneuver in which the POV brakes were rapidly applied and modulated such that a constant deceleration of 0.3 g was achieved within 1.5 seconds after braking is initiated. The test ended when either of the following conditions was satisfied:

- The required FCW alert occurred.
- The TTC to the POV fell to less than 90% of the minimum allowable range (i.e., TTC = 2.2 sec) for the onset of the required FCW alert.

The SV driver then steered and/or braked to keep the SV from striking the POV.

[1]To simplify calculation of the TTC for Test 2, the deceleration of the POV is assumed to remain constant from the time of the FCW alert until the POV comes to a stop (i.e., a “constant” rate of slowing is assumed).

For an individual test trial to be valid, the following was required throughout the test:

- The initial POV vehicle speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) for a period of 3 seconds prior to the initiation of POV braking.
- The speed of the SV could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) for a period of 3 seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90% of the minimum allowable range for onset of the required FCW alert.
- The lateral distance between the centerline of the SV, relative to the centerline of the POV, in road coordinates, could not exceed 2.0 ft (0.6 m).
- The yaw rates of the SV and POV could not exceed ±1 deg/sec during the test.
- The POV deceleration level was nominally required to be 0.3 g within 1.5 seconds after initiation of POV braking. The acceptable error magnitude of the POV deceleration was ±0.03 g, measured at the time the FCW alert first occurred. An initial overshoot beyond the deceleration target was acceptable, however the first local deceleration peak observed during an individual trial could not exceed 0.375 g for more than 50 ms. Additionally, the deceleration could not exceed 0.33 g over a period defined from 500 ms after the first local deceleration peak occurs, to the time when the FCW alert first occurred.
- The tolerance for the headway from the SV to the POV was ±8.2 ft (±2.5 m), measured at two instants in time: (1) three seconds prior to the time the POV brake application was initiated and (2) at the time the POV brake application was initiated.
- SV driver could not apply any force to the brake pedal before (1) the required FCW alert occurred or (2) the range fell to less than 90% of the minimum allowable range for onset of the required FCW alert.

Nominally, the Test 2 series was comprised of seven individual trials. The FCW system must satisfy the TTC alert criteria for at least five of the seven test trials.

3. TEST 3 – SUBJECT VEHICLE ENCOUNTERS SLOWER PRINCIPAL OTHER VEHICLE

This test examines the ability of the FCW system to recognize a slower lead vehicle being driven with a constant speed and to issue a timely alert. As depicted in Figure 3, the scenario was conducted with a closing speed equal to 25.0 mph (40.2 km/h).

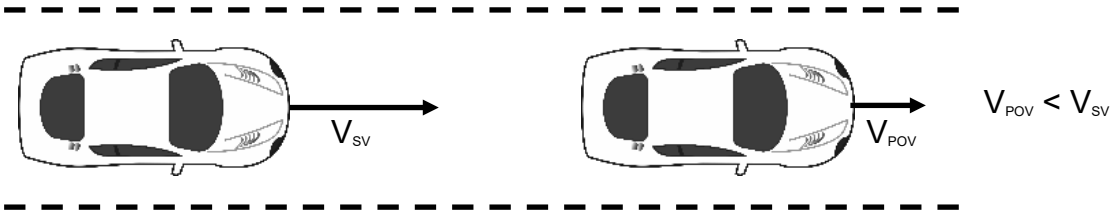

Figure 3. Depiction of Test 3

a. Alert Criteria

In order to pass the test, the FCW alert must be issued when TTC is at least 2.0 seconds. The TTC for this test, a prediction of the time it would take for the SV to collide with the POV, was calculated by considering the speeds of the SV and POV at the time of the FCW alert.

b. Procedure

Throughout the test, the POV was driven at a constant 20.0 mph (32.2 km/h) in the center of the lane of travel.

The SV was driven at 45.0 mph (72.4 km/h), in the center lane of travel, toward the slow-moving POV.

The test began when the headway from the SV to the POV was 329 ft (100 m) and ended when either of the following occurred:

- The required FCW alert occurred.
- The TTC to the POV fell to less than 90% of the minimum allowable range (i.e., TT = 1.8 sec) for the onset of the required FCW alert.

The SV driver then steered and/or braked to keep the SV from striking the POV.

For an individual test trial to be valid, the following was required throughout the test:

- The SV vehicle speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) for a period of 3 seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90% of the minimum allowable range for onset of the required FCW alert.
- Speed of the POV could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during the test.
- The lateral distance between the centerline of the SV, relative to the centerline of the POV, in road coordinates, could not exceed 2.0 ft (0.6 m).
- The yaw rates of the SV and POV could not exceed ±1 deg/sec during the test.
- SV driver could not apply any force to the brake pedal before (1) the required

FCW alert occurred or (2) before the range fell to less than 90% of the minimum allowable range for onset of the required FCW alert.

Nominally, the Test 3 series was comprised of seven individual trials. The FCW system must satisfy the TTC alert criteria for at least five of the seven test trials.

B. Principal Other Vehicle

The vehicle used as the Principal Other Vehicle (POV) was a 2006 Acura RL. This satisfied the test requirement that the POV be a mid-size sedan. The vehicle had a rear license plate in order to provide a suitable representative radar profile. Vehicle loading consisted of the driver plus equipment and instrumentation.

C. Automatic Braking System

The POV was equipped with an automatic braking system, which was used in Test 2. The braking system consisted of the following components:

- High pressure nitrogen bottle, strapped to the front passenger seat, with regulator and pressure gauges
- Pneumatic piston-type actuator, with solenoid valve
- “Pickle” switch to activate brakes

D. Instrumentation

Table 1 lists the sensors, signal conditioning, and data acquisition equipment used for these tests.

Table 1. 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: 8/18/2020 Due: 8/18/2021
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform	0.1% of reading	Intercomp SW wireless	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	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			By: Oxford Technical Solutions
				SV: Oxford Inertial +	2258	Date: 5/3/2019 Due: 5/3/2021
				POV:	2182	Date: 9/16/2019 Due: 9/16/2021
Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW)	Distance and Velocity to lane markings (LDW) and POV (FCW)	Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	N/A

Table 1. Test Instrumentation and Equipment (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Microphone	Sound (to measure time at auditory 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 visual alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	N/A	N/A
Accelerometer	Acceleration (to measure time at haptic alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	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).	dSPACE 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 2.

Table 2. 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)

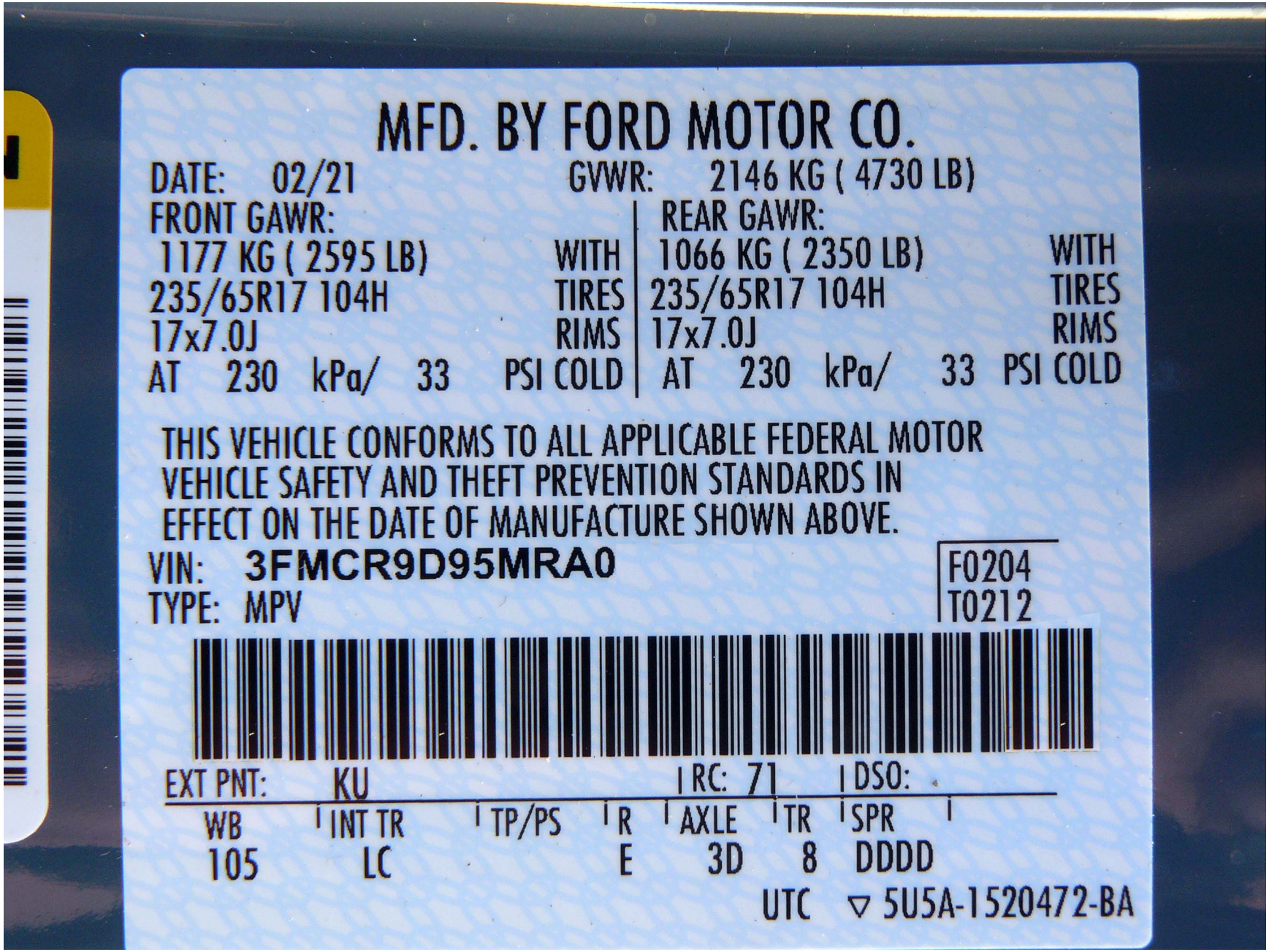

Figure A4. Vehicle Certification Label

Figure A5. Tire Placard

Figure A6. Front View of Principal Other Vehicle

Figure A7. Rear View of Principal Other Vehicle

Figure A8. DGPS and Inertial Measurement Unit Installed in Subject Vehicle

Figure A9. Sensors for Detecting Auditory and Visual Alerts

Figure A10. Computer Installed in Subject Vehicle

Figure A11. Brake Actuation System Installed in Principal Other Vehicle

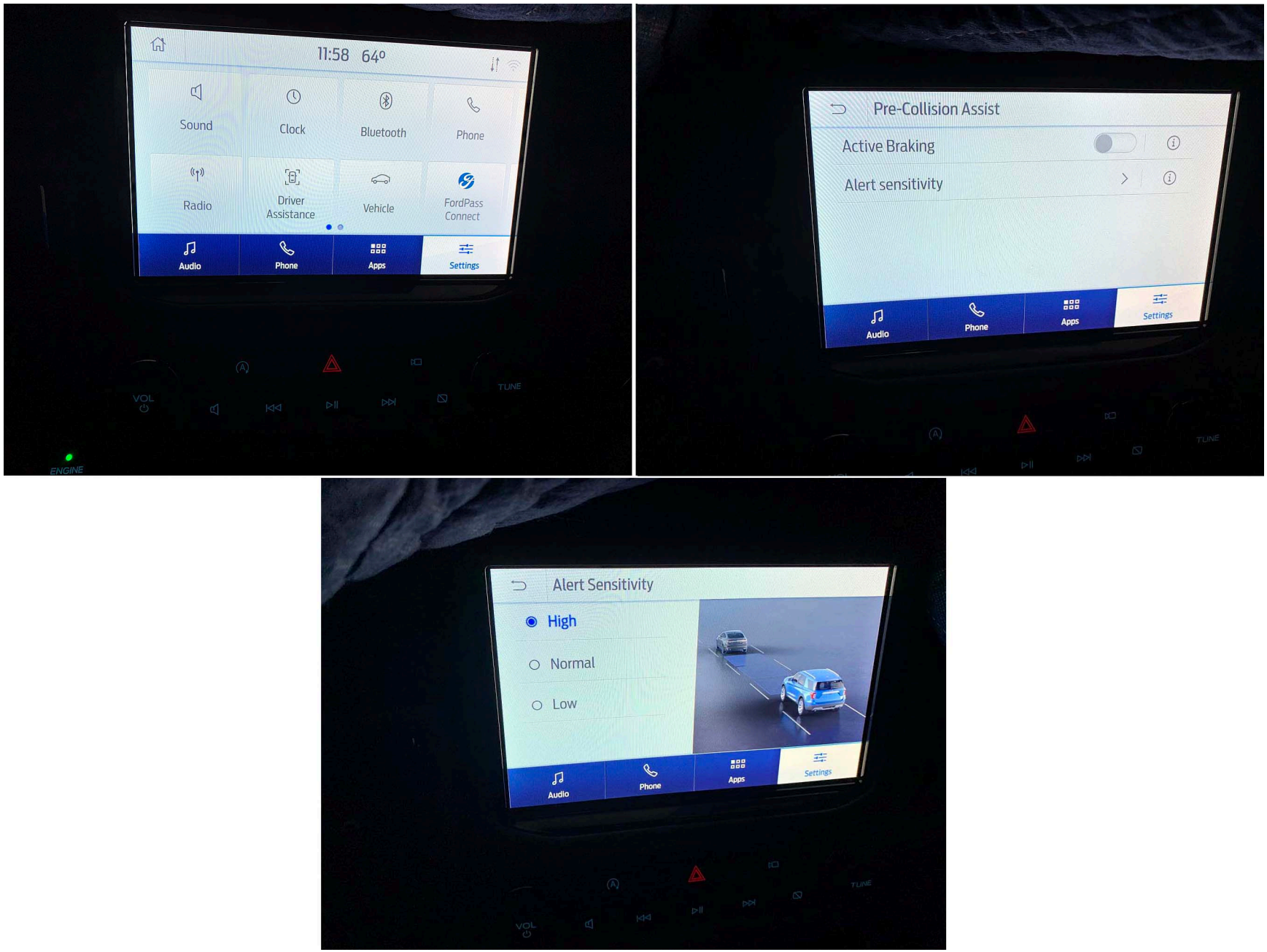

Figure A12. System Setup Menus

Figure A13. FCW Visual Alert

APPENDIX B

Excerpts from Owner’s Manual

Message	Action
Park Brake Limited Function Service Required	The electric park brake system has detected a condition that requires service. Some functionality may still be available. Contact your authorized dealer.
Park Brake Malfunction Service Now	The electric parking brake system has detected a condition that requires service. Contact your authorized dealer.
Park Brake System Overheated	Numerous park brake applies have overheated the system. Wait 2 minutes before attempting to apply again.

Power Steering

Message	Action
Steering Fault Service Now	The power steering system has detected a condition that requires service. See an authorized dealer.
Steering Loss Stop Safely	The power steering system is not working. Stop your vehicle in a safe place. Contact an authorized dealer.
Steering Assist Fault Service Required	The power steering system has detected a condition within the power steering system or passive entry or passive start system requires service. Contact an authorized dealer.
Steering Lock Malfunction Service Now	The steering lock system has detected a condition that requires service. See an authorized dealer.

Pre-Collision Assist

Message	Action
Pre-Collision Assist Not Available Sensor Blocked	You have a blocked sensor due to bad weather, ice, mud or water in front of the radar sensor. You can typically clean the sensor to resolve.
Pre-Collision Assist Not Available	A fault with the system has occurred. Contact an authorized dealer as soon as possible.

Remote Start

Message	Action
To Drive: Press Brake and Gear Shift Button	Displays as a reminder to apply the brake and push the gear shift button to drive the vehicle after a remote start.

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

STEERING

Electric Power Steering

WARNING: The electric power steering system has diagnostic checks that continuously monitor the system. If a fault is detected, a message displays in the information display. Stop your vehicle as soon as it is safe to do so. Switch the ignition off. After at least 10 seconds, switch the ignition on and watch the information display for a steering system warning message. If a steering system warning message returns, have the system checked as soon as possible.

WARNING: If the system detects an error, you may not feel a difference in the steering, however a serious condition may exist. Have your vehicle checked as soon as possible. Failure to do so may result in loss of steering control.

Your vehicle is equipped with an electric power-assisted steering system. There is no fluid reservoir to check or fill.

If your vehicle loses electrical power while you are driving (or if the ignition is turned off), you can steer the vehicle manually, but it takes more effort. You must adapt your speed and driving behavior to reduced steering assist. Extreme continuous steering may increase the effort it takes for you to steer. This occurs to prevent internal overheating and permanent damage to your steering system. If this should occur, you will neither lose the ability to steer the vehicle manually nor will it cause permanent damage. Typical steering and driving maneuvers will allow the system to cool down and steering assist will return to normal.

Steering Tips

If the steering wanders or pulls, check for:

- An improperly inflated tire.
- Uneven tire wear.
- Loose or worn suspension components.
- Loose or worn steering components.
- Improper vehicle alignment.

A high crown in the road or high crosswinds may also make the steering seem to wander or pull.

PRE-COLLISION ASSIST

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: The system does not detect vehicles that are driving in a different direction, cyclists or animals. Apply the brakes when necessary. Failure to follow this instruction could result in the loss of control of your vehicle, personal injury or death.

WARNING: The system does not operate during hard acceleration or steering. Failure to take care may lead to a crash or personal injury.

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WARNING: The system may fail or operate with reduced function during cold and severe weather conditions. Snow, ice, rain, spray and fog can adversely affect the system. Keep the front camera and radar free of snow and ice. Failure to take care may result in the loss of control of your vehicle, serious personal injury or death.

WARNING: Some situations and objects prevent hazard detection. For example low or direct sunlight, inclement weather, unconventional vehicle types, and pedestrians. Apply the brakes when necessary. Failure to follow this instruction could result in the loss of control of your vehicle, personal injury or death.

WARNING: The system cannot help prevent all crashes. Do not rely on this system to replace driver judgment and the need to maintain a safe distance and speed.

Using the Pre-Collision Assist System

The system is active at speeds above 3 mph (5 km/h) and pedestrian detection is active at speeds up to 50 mph (80 km/h).

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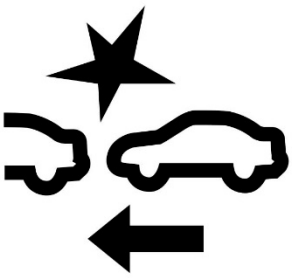
If your vehicle is rapidly approaching another stationary vehicle, a vehicle traveling in the same direction as yours, or a pedestrian within your driving path, the system provides three levels of functionality:

1. Alert.
2. Brake support.
3. Active braking.



Alert: When active, a flashing visual warning appears and an audible warning tone sounds.

Brake support: The system helps reduce the impact speed by preparing the brakes for rapid braking. Brake support does not automatically apply the brakes. If you press the brake pedal, the system could apply additional braking up to maximum braking force, even if you lightly press the brake pedal.

Active braking: It activates if the system determines that a collision is about to occur. The system may help the driver reduce impact damage or completely avoid the crash.

Note: *Brake support and active braking are active at speeds up to 75 mph (120 km/h). If your vehicle is equipped with a radar sensor, included with adaptive cruise control, then brake support and active braking are active up to the maximum speed of your vehicle.*

Note: *If you perceive pre-collision assist alerts as being too frequent or disturbing, you can reduce the alert sensitivity, though we recommend using the highest sensitivity setting where possible. Setting lower sensitivity would lead to fewer and later system warnings.*

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Note: *The system turns off when you manually disable AdvanceTrac™.*

Distance Indication and Alert (If Equipped)

This feature provides the driver with a graphical indication of the time gap to other preceding vehicles traveling in the same direction. The information display screen shows one of the images that follow.

Note: *Distance indication and alert deactivates and the images do not display when adaptive cruise control is active.*

Speed	Sensitivity	Images	Distance Gap	Time Gap
62 mph (100 km/h)	Normal	Grey	>82 ft (25 m)	>0.9sec
62 mph (100 km/h)	Normal	Yellow	56–82 ft (17–25 m)	0.6sec — 0.9sec
62 mph (100 km/h)	Normal	Red	<56 ft (17 m)	<0.6sec

Evasive Steering Assist (If Equipped)

If your vehicle is rapidly approaching a stationary vehicle or a vehicle traveling in the same direction as your vehicle, the system helps you steer around the vehicle.

The system only activates when all of the following occur:

- The pre-collision assist system detects a vehicle ahead and starts to apply active braking.
- You turn the steering wheel in an attempt to steer around the vehicle.

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After you turn the steering wheel, the system applies additional steering torque to help you steer around the vehicle. After you pass the vehicle, the system applies steering torque in the opposite direction to encourage you to steer back into the lane. The system deactivates after you fully pass the vehicle.

Note: *The system does not automatically steer around a vehicle. If you do not turn the steering wheel, the system does not activate.*

Note: *The system does not activate if the distance to the vehicle ahead is too small and a crash cannot be avoided.*

Adjusting the Pre-Collision Assist Settings

Depending on your vehicle options, the pre-collision assist settings may be in the following:

- Information display. See **General Information** (page 98).
- Touchscreen. See **Settings** (page 376).

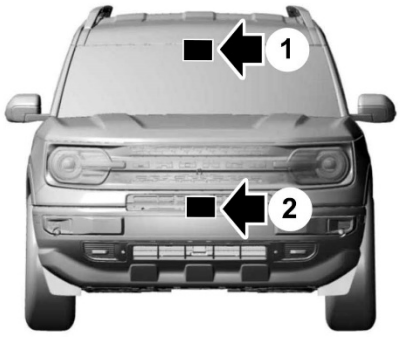
You can adjust the following settings:

- Change alert and distance alert sensitivity to one of three possible settings.
- Switch distance indication and alert on or off.
- If required, switch active braking on or off.
- If required, switch evasive steering assist on or off.

Note: *Active braking and evasive steering assist turn on every time you switch the ignition on.*

Note: *If you switch active braking off, evasive steering assist turns off.*

Blocked Sensors



1 Camera.
2 Radar sensor (if equipped).

If a message regarding a blocked sensor or camera appears in the information display, the radar signals or camera images are obstructed. If your vehicle is equipped with a radar sensor, it is behind the fascia cover in the center of the lower grille. With a blocked sensor or camera, the pre-collision assist system may not operate or performance may reduce. The following table lists possible causes and actions for when this message displays.

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Camera Troubleshooting

Cause	Action
The windshield in front of the camera is dirty or obstructed in some way.	Clean the outside of the windshield in front of the camera.
The windshield in front of the camera is clean but the message remains in the display screen.	Wait a short time. It could take several minutes for the camera to detect that there is no obstruction.

Radar Troubleshooting (If Equipped)

Cause	Action
The surface of the radar in the grille is dirty or obstructed in some way.	Clean the grille surface in front of the radar or remove the object causing the obstruction.
The surface of the radar in the grille is clean but the message remains in the display screen.	Wait a short time. It could take several minutes for the radar to detect that there is no obstruction.
Heavy rain, spray, snow or fog is interfering with the radar signals.	The pre-collision assist system is temporarily disabled. Pre-collision assist reactivates a short time after the weather conditions improve.
Swirling water, snow or ice on the surface of the road may interfere with the radar signals.	The pre-collision assist system is temporarily disabled. Pre-collision assist reactivates a short time after the weather conditions improve.
Radar is out of alignment due to a front-end impact.	Have the radar checked for proper coverage and operation.

Note: *Proper system operation requires a clear view of the road by the camera. Have any windshield damage in the area of the camera's field of view repaired.*

Note: *If something hits the front end of your vehicle or damage occurs and your vehicle is equipped with a radar sensor, the radar sensing zone may change. This could cause missed or false detections. Have the radar checked for proper coverage and operation.*

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APPENDIX C

Run Log

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

Principal Other Vehicle: **2006 Acura RL**

Run	Test Type	Valid Run?	TTCW Sound (sec)	TTCW Light (sec)	TTCW Margin (sec)	Pass/Fail	Notes
1	**Stopped POV**	Y	2.57	2.23	0.47	Pass	
2		Y	2.61	2.28	0.51	Pass	
3		Y	2.42	2.16	0.32	Pass	
4		Y	2.66	2.33	0.56	Pass	
5		Y	2.87	2.57	0.77	Pass	
6		Y	2.42	2.09	0.32	Pass	
7		Y	2.58	2.28	0.48	Pass	
15	**Decelerating POV**	Y	2.85	2.60	0.45	Pass	
16		Y	2.82	2.51	0.42	Pass	
17		Y	3.03	2.71	0.63	Pass	
18		Y	2.85	2.55	0.45	Pass	
19		Y	2.81	2.49	0.41	Pass	
20		Y	2.92	2.64	0.52	Pass	
21		Y	2.78	2.47	0.38	Pass	
8	**Slower POV**	Y	2.75	2.48	0.75	Pass	
9		Y	2.77	2.50	0.77	Pass	
10		Y	2.70	2.36	0.70	Pass	

Run	Test Type	Valid Run?	TTCW Sound (sec)	TTCW Light (sec)	TTCW Margin (sec)	Pass/Fail	Notes
11	**Slower POV**	Y	2.60	2.33	0.60	Pass	
12		Y	2.60	2.30	0.60	Pass	
13		Y	2.62	2.31	0.62	Pass	
14		Y	2.84	2.60	0.84	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 both the Subject Vehicle (SV) and the Principal Other Vehicle (POV), 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 indicating to which vehicle the data pertain.

Each time history plot consists of data pertinent to the test type under consideration, and therefore the data channels plotted vary according to test type. The test types (shown in the plot titles) include:

- FCW Test 1 – Stopped POV (SV at 45 mph)
- FCW Test 2 – Decelerating POV (Both vehicles at 45 mph with a 30 m gap, POV brakes at 0.3 g)
- FCW Test 3 – Slower Moving POV (SV at 45 mph, POV at 20 mph)

Time history figures include the following sub-plots:

- Warning – Displays the Forward Collision Warning Alert (which can be auditory, visual, or haptic). Depending on the type of FCW alert or instrumentation used to measure the alert, this can be any of the following:
    - Filtered, rectified, and normalized sound signal. The vertical scale is 0 to 1.
    - Filtered, rectified, and normalized acceleration (e.g., haptic alert, such as steering wheel vibration). The vertical scale is 0 to 1.
    - Light sensor signal.

- TTC (sec) – Indicates the Time to Collision as calculated up to the point of FCW alert issuance. The value of TTCW (Time to Collision at Warning) is given numerically on the right side of the figure. A passing value is indicated in green, while a failing value is indicated in red.

- SV Speed (mph) – Speed of the Subject Vehicle

- POV Speed (mph) – Speed of the Principal Other Vehicle

- Yaw Rate (deg/sec) – Yaw rate of both the Subject Vehicle and Principal Other Vehicle

- Lateral Offset (ft) – Lateral offset within the lane from the Subject Vehicle to the Principal Other Vehicle
- Ax (g) – Longitudinal acceleration of both the Subject Vehicle and Principal Other Vehicle
- Headway (ft) – Longitudinal separation between front of Subject Vehicle to rear of Principal Other Vehicle (Exclusive to test type 2)

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 left and/or right ends. Exceedances at the left or right extent of a yellow envelope are indicated by red asterisks.

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

For the TTC plot, a dashed black threshold line indicates the minimum allowable TTC for the given test scenario. If the FCW alert occurs before this minimum allowable TTC, a green dot appears. However, if there is no alert or the alert occurs after the minimum allowable TTC, a red asterisk is shown on the plot.

For the Ax plot, a dashed black threshold line is given for at a value of -0.05 g. For a test run to be valid, the longitudinal acceleration of the Subject Vehicle must not fall below this threshold (i.e. the driver cannot apply any brakes). Additionally, for test type 2, the plot indicating the longitudinal acceleration of the Principal Other Vehicle includes a yellow envelope indicating the deceleration (0.3 g ± 0.03 g) allowed while braking. Exceedance of this threshold is indicated with red asterisks at the beginning and/or end of the threshold boundary.

Color Codes

Color codes have been adopted to easily identify which data correspond to which vehicle, as well as to indicate the types of envelopes and thresholds used in the plots.

Color codes can be broken into four categories:

1. Time-varying data
2. Validation envelopes and thresholds
3. Instantaneous samplings
4. Text

1. Time-varying data color codes:
   - Blue = Subject Vehicle data
   - Magenta = Principal Other Vehicle data
   - Brown = Relative data between SV and POV (i.e., TTC, lateral offset and headway distance)

2. 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 left and/or right ends
   - 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, TTC thresholds, and acceleration thresholds

3. 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

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

Other Notations

- ENV – For Ax plots only, indicates that the envelope for the POV braking was exceeded.
- NG – Indicates that the value for that variable was outside of bounds and therefore “No Good”.
- No Wng – No warning was detected.
- POV – Indicates that the value for the Principal Other Vehicle was out of bounds.
- SV – Indicates that the value for the Subject Vehicle was out of bounds.
- SR – Shows the speed reduction value.
- Thr – Indicates that the requirements for the throttle were not met.

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 for each test type (including passing, failing and invalid runs) are shown in Figure D1 through Figure D6. Actual time history data plots for the vehicle under consideration are provided subsequently.

Notes

When vehicles provide more than one type of alert, and when it is possible to measure the timing of these alerts, plots will be shown of each alert for each run. Because alert timing nearly always differs between alert types, a plot may indicate a valid run for one of the alerts and invalid for another. Test run validity is based on the validity window of the earliest alert, but validity determination for each individual alert is based on the timing of that alert alone. As an example, a vehicle has both visual and auditory alerts. For a particular run, the auditory alert occurs first followed by the visual alert. The validity period for the run ends when the auditory alert occurs, at which time the driver steers and/or brakes to avoid the POV. Since the visual alert occurs after the auditory alert, the run is essentially already over by the time the visual alert occurs. Depending on the relative timing gap between alerts, it may be expected that the validity criteria (yaw rate, speed, etc.) based on the timing of the visual alert could indicate an invalid run.

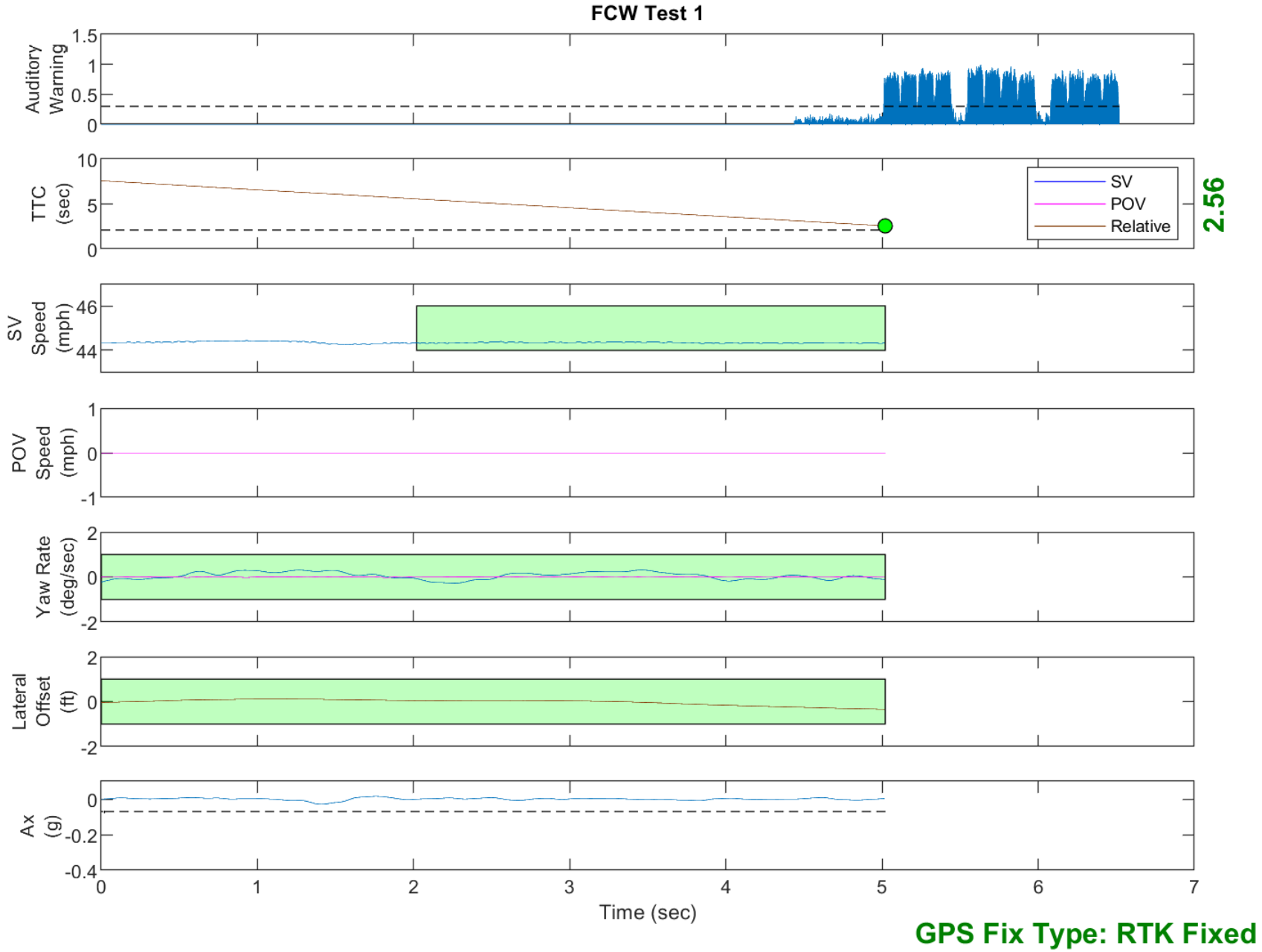

Figure D1. Example Time History for Test Type 1, Passing

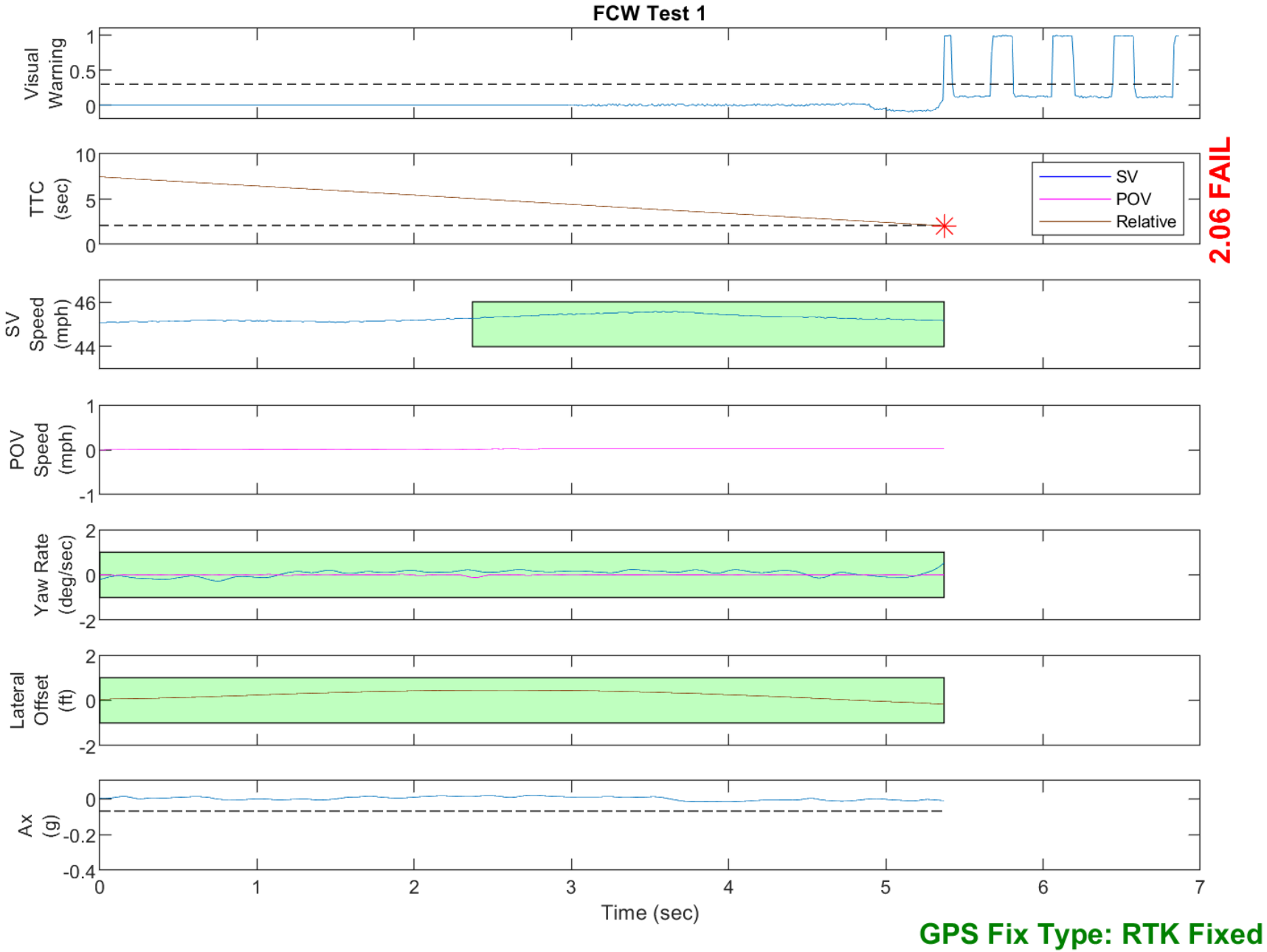

Figure D2. Example Time History for Test Type 1, Failing

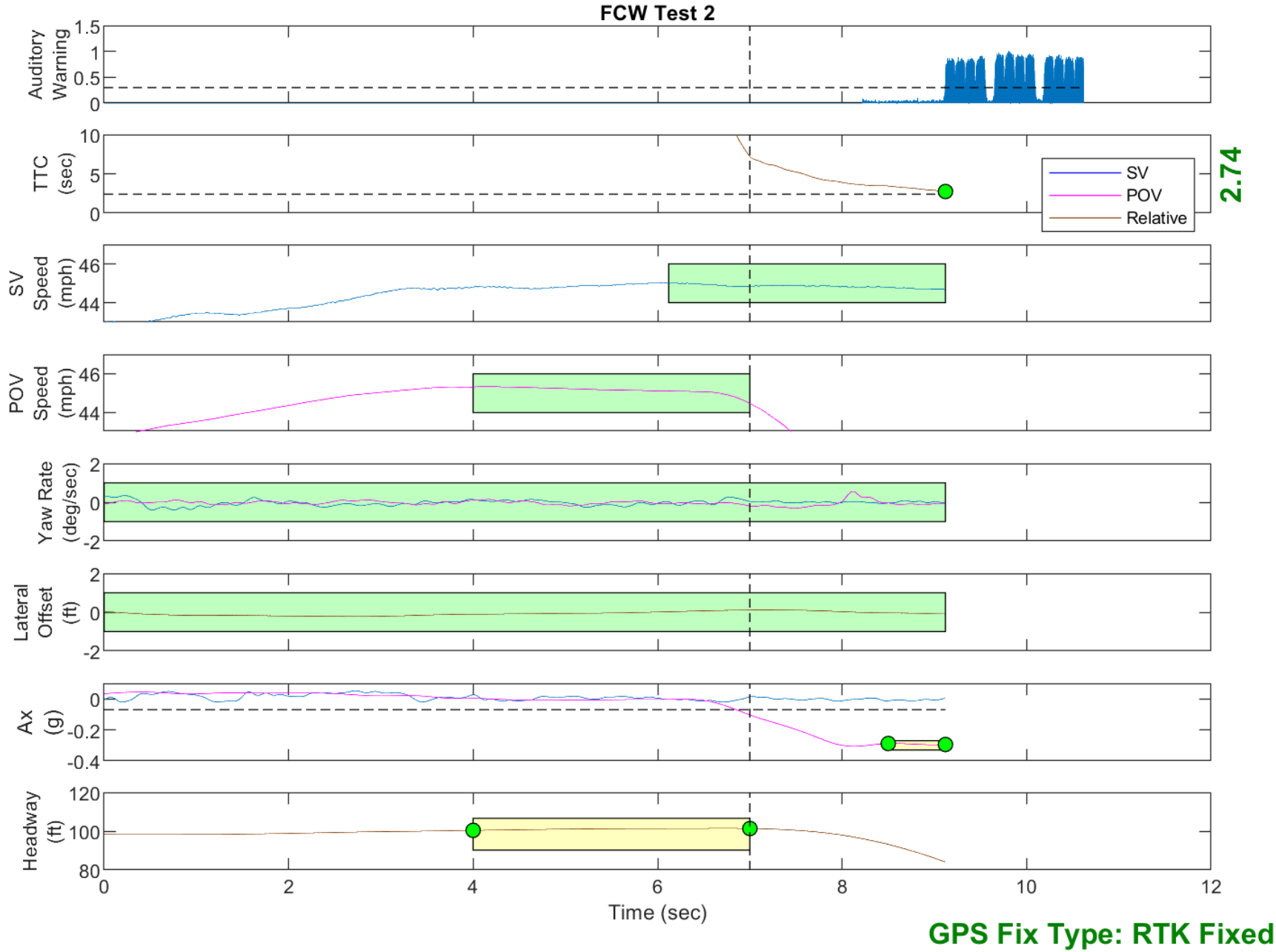

Figure D3. Example Time History for Test Type 2, Passing

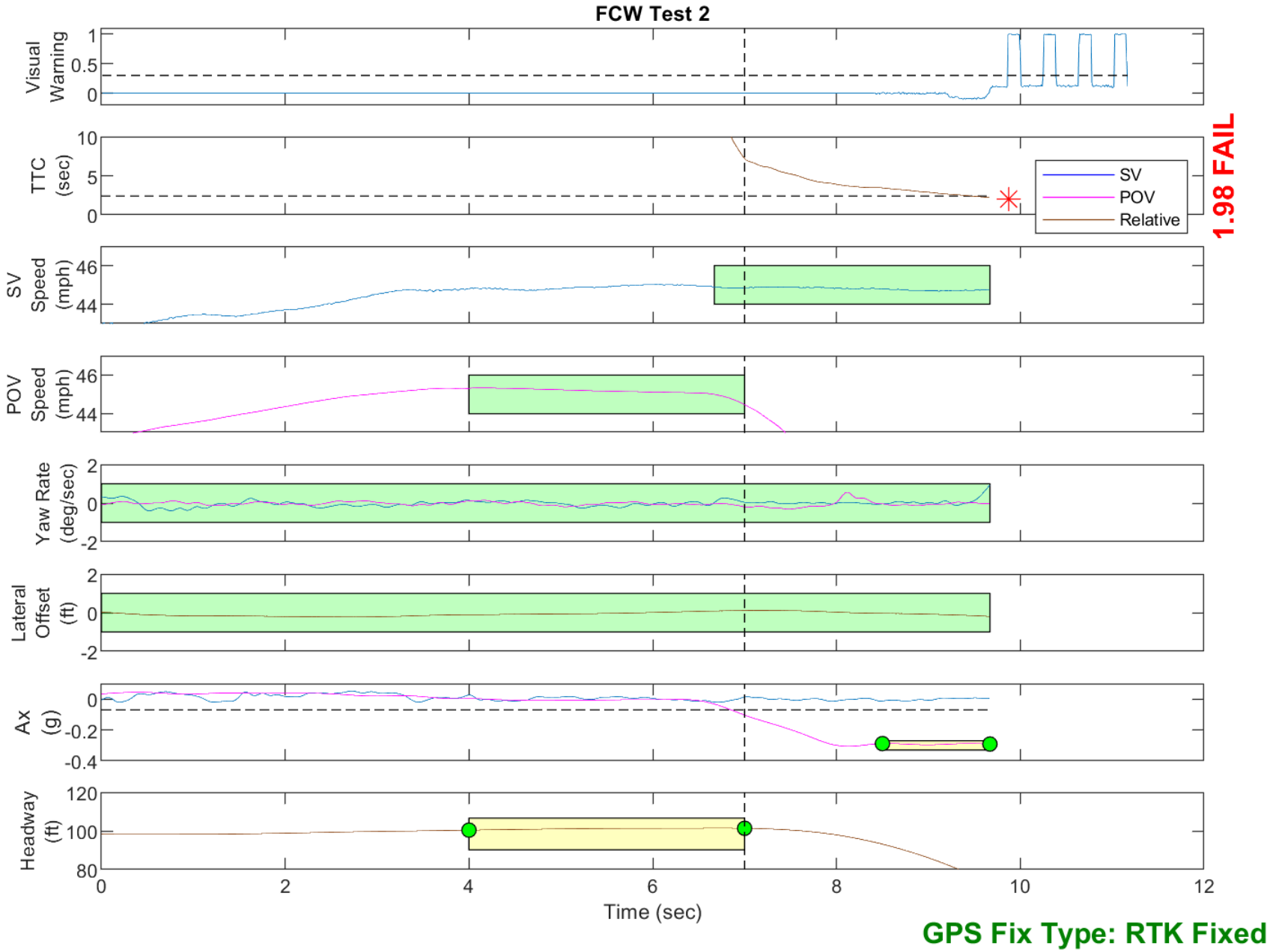

Figure D4. Example Time History for Test Type 2, Failing

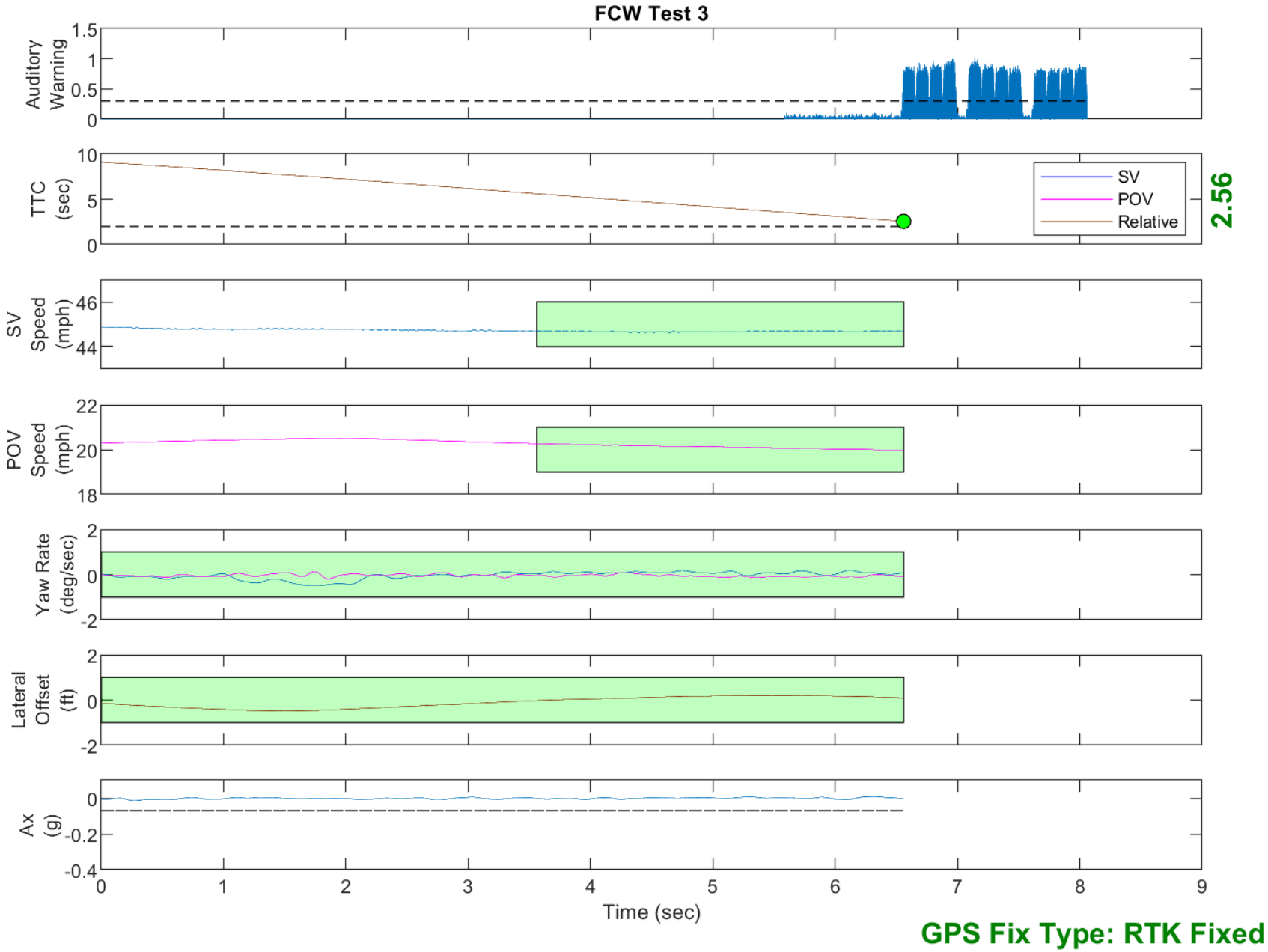

Figure D5. Example Time History for Test Type 3, Passing

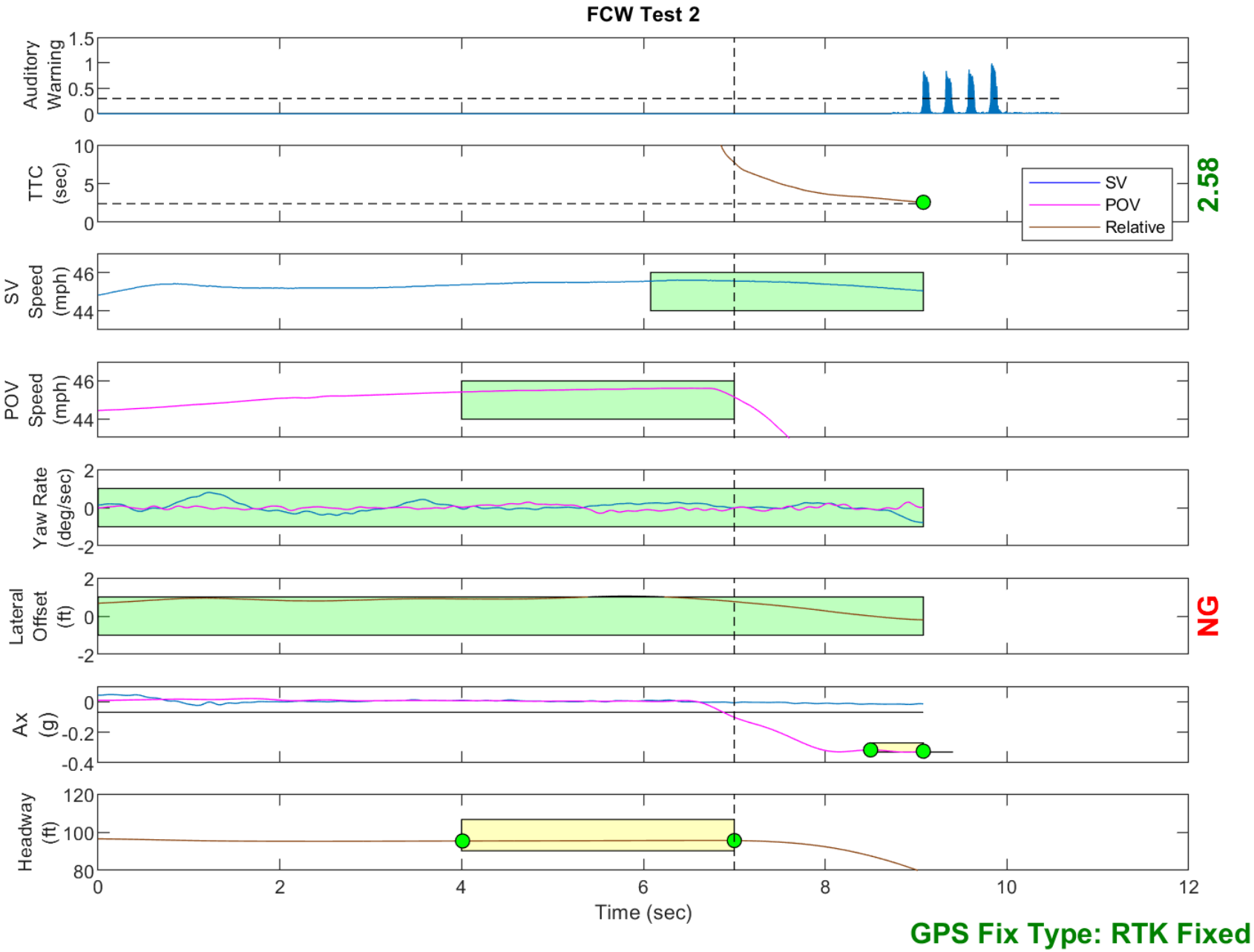

Figure D6. Example Time History Showing Invalid Lateral Offset Criteria

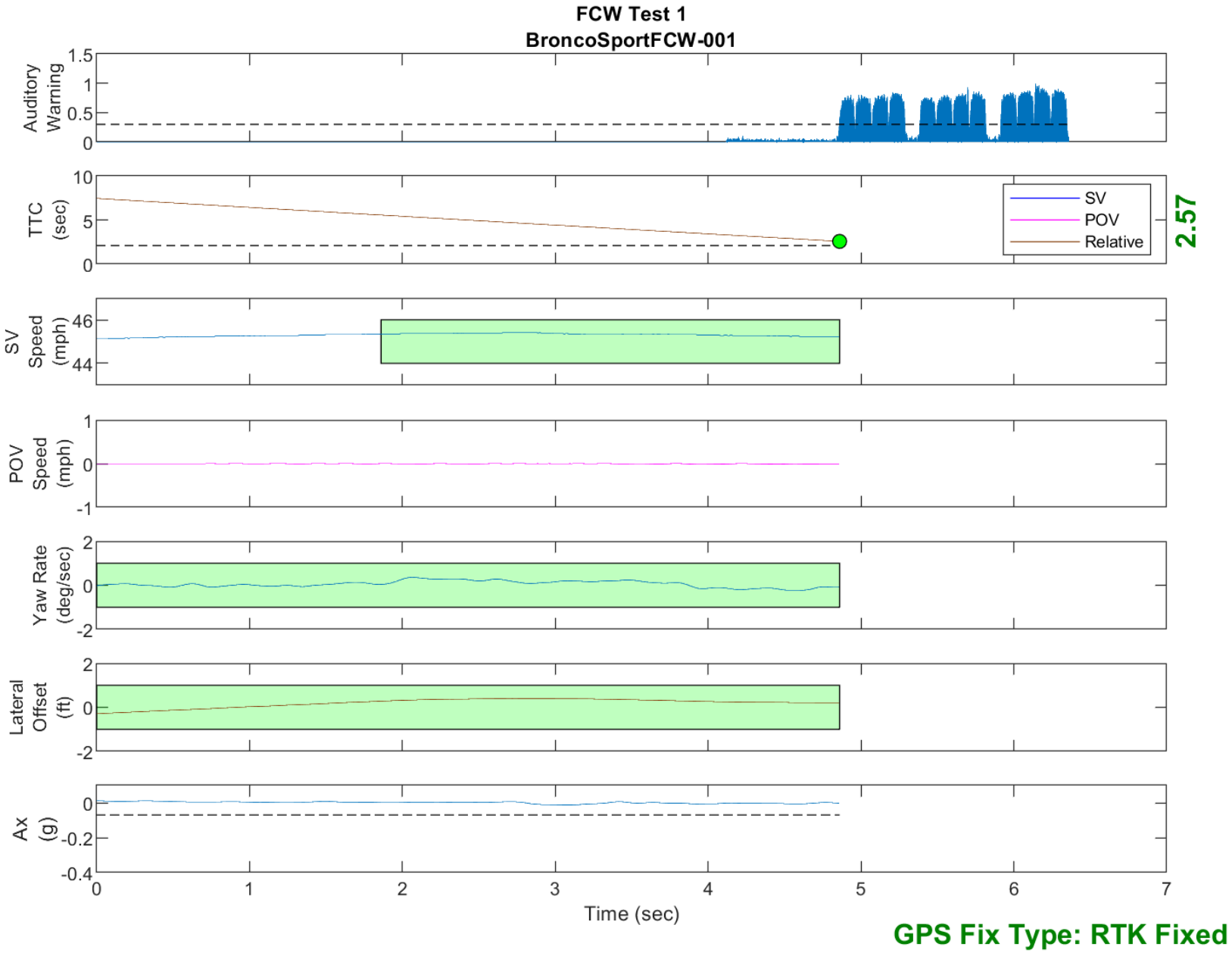

Figure D7. Time History for Run 1, FCW Test 1, Auditory Warning

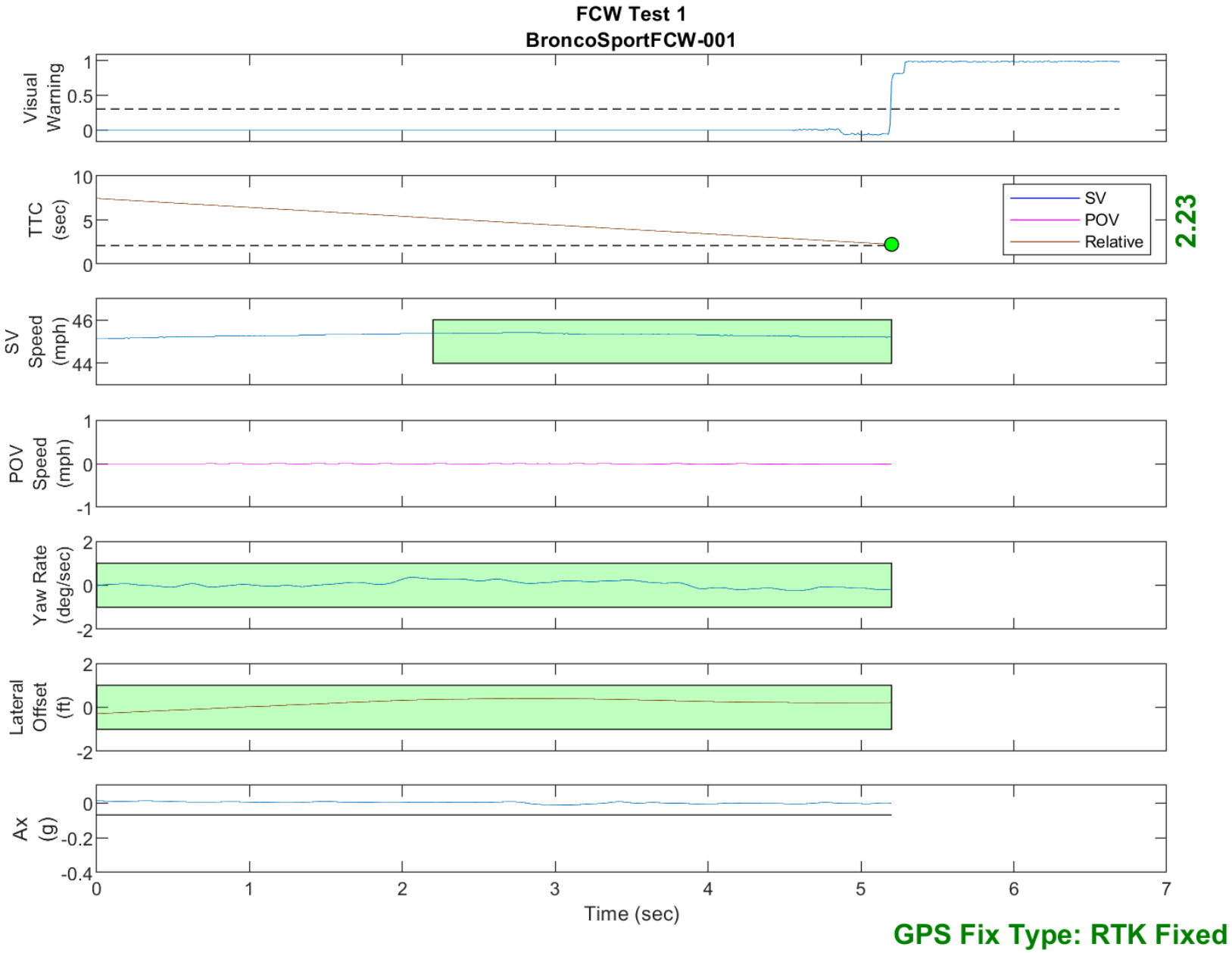

Figure D8. Time History for Run 1, FCW Test 1, Visual Warning

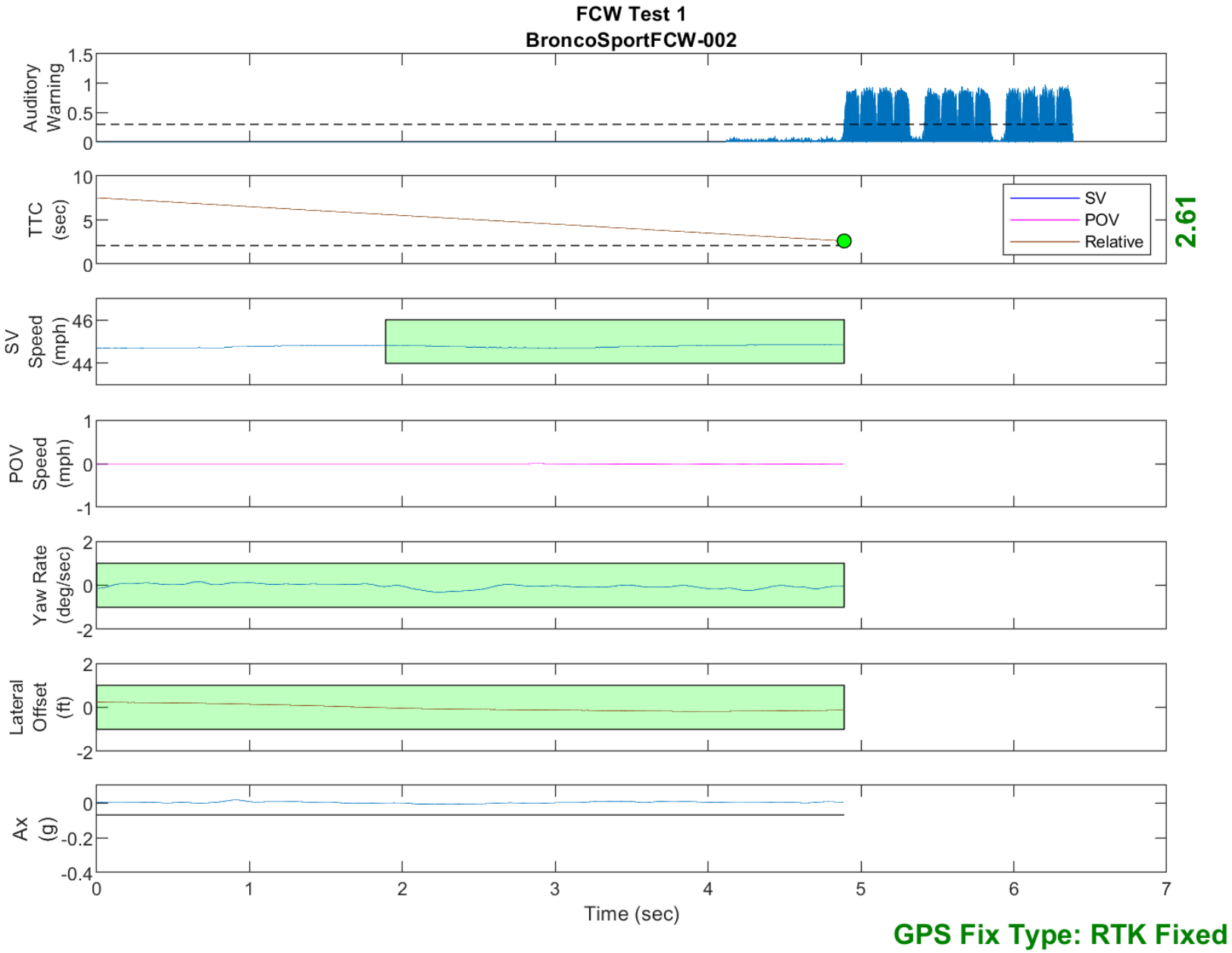

Figure D9. Time History for Run 2, FCW Test 1, Auditory Warning

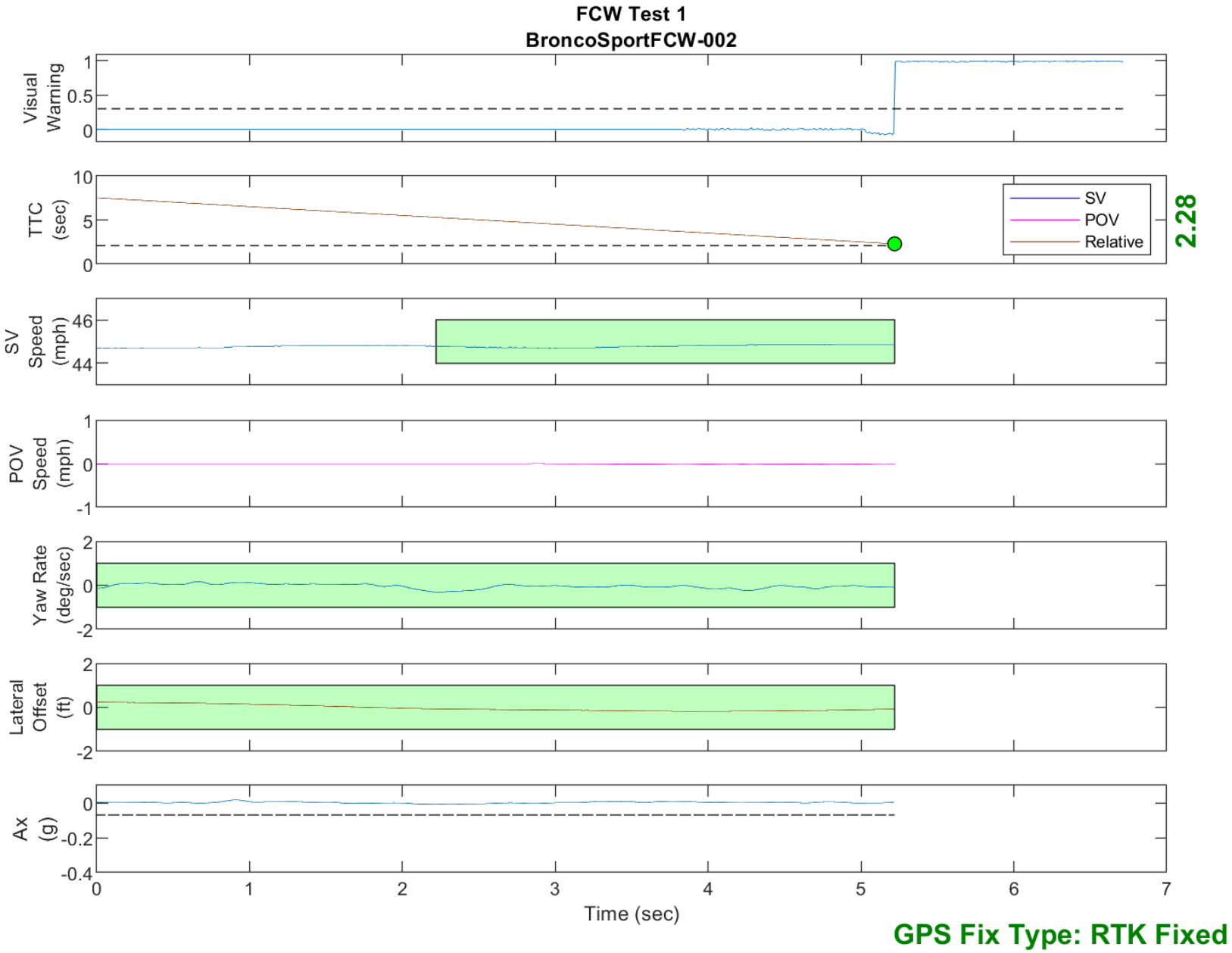

Figure D10. Time History for Run 2, FCW Test 1, Visual Warning

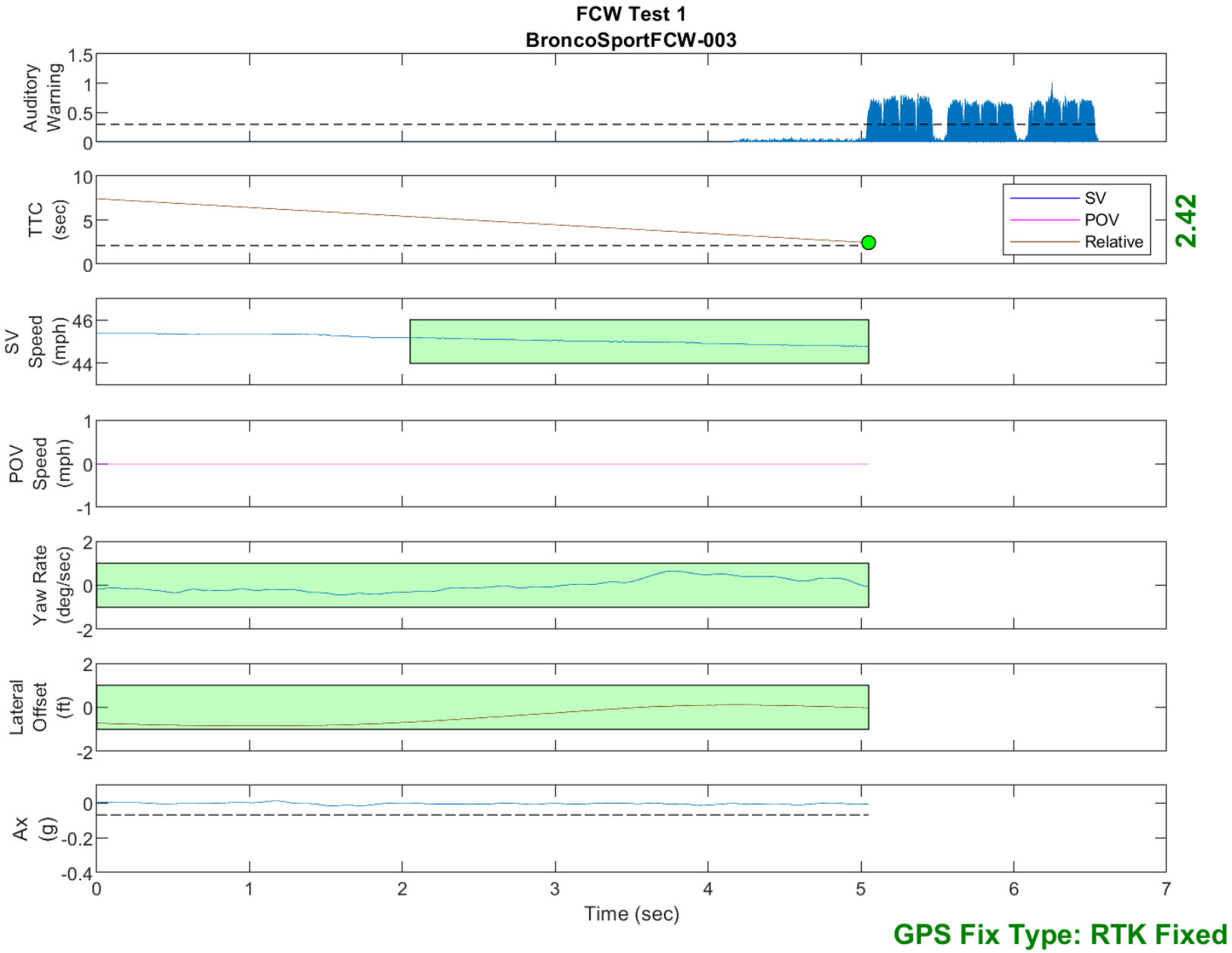

Figure D11. Time History for Run 3, FCW Test 1, Auditory Warning

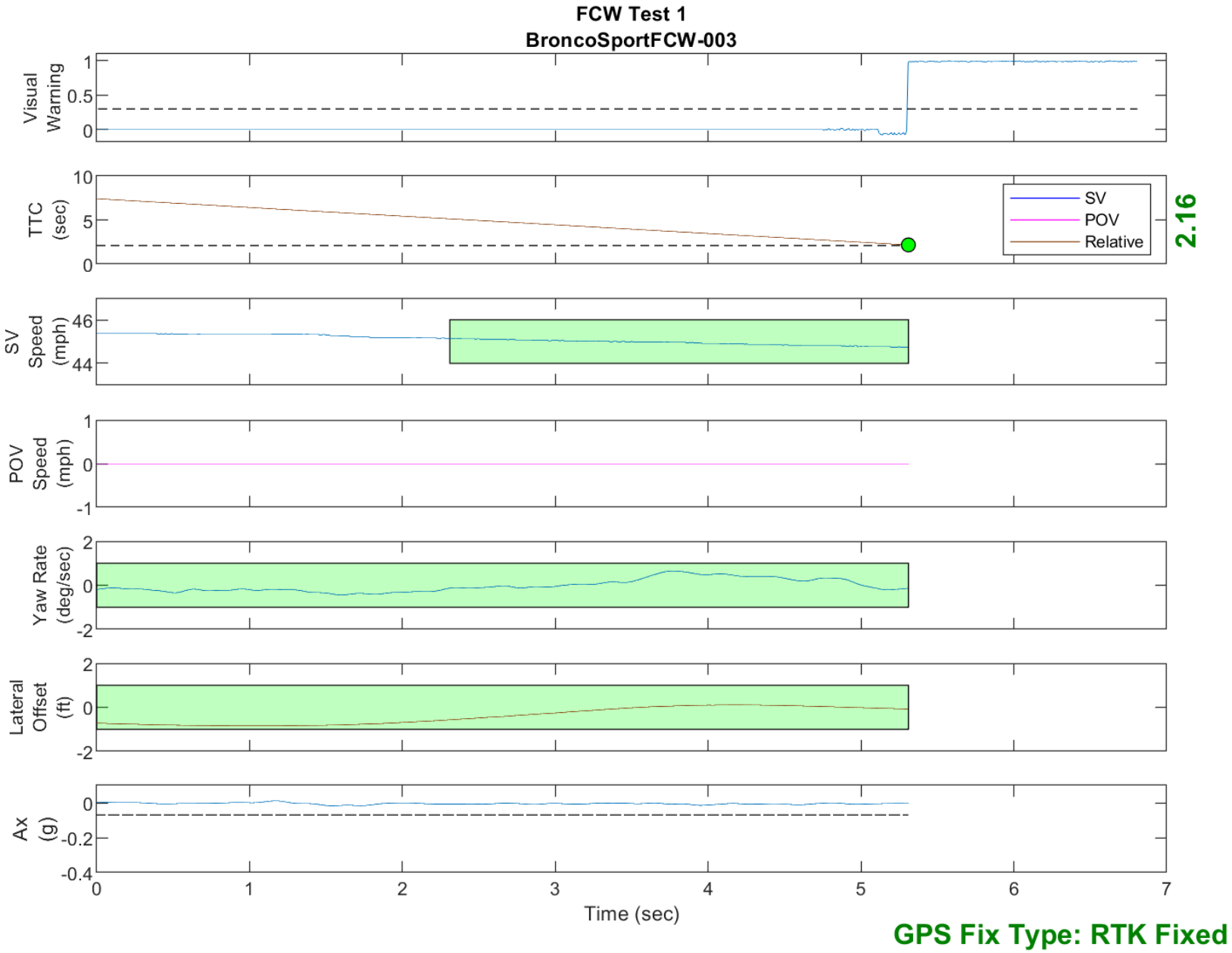

Figure D12. Time History for Run 3, FCW Test 1, Visual Warning

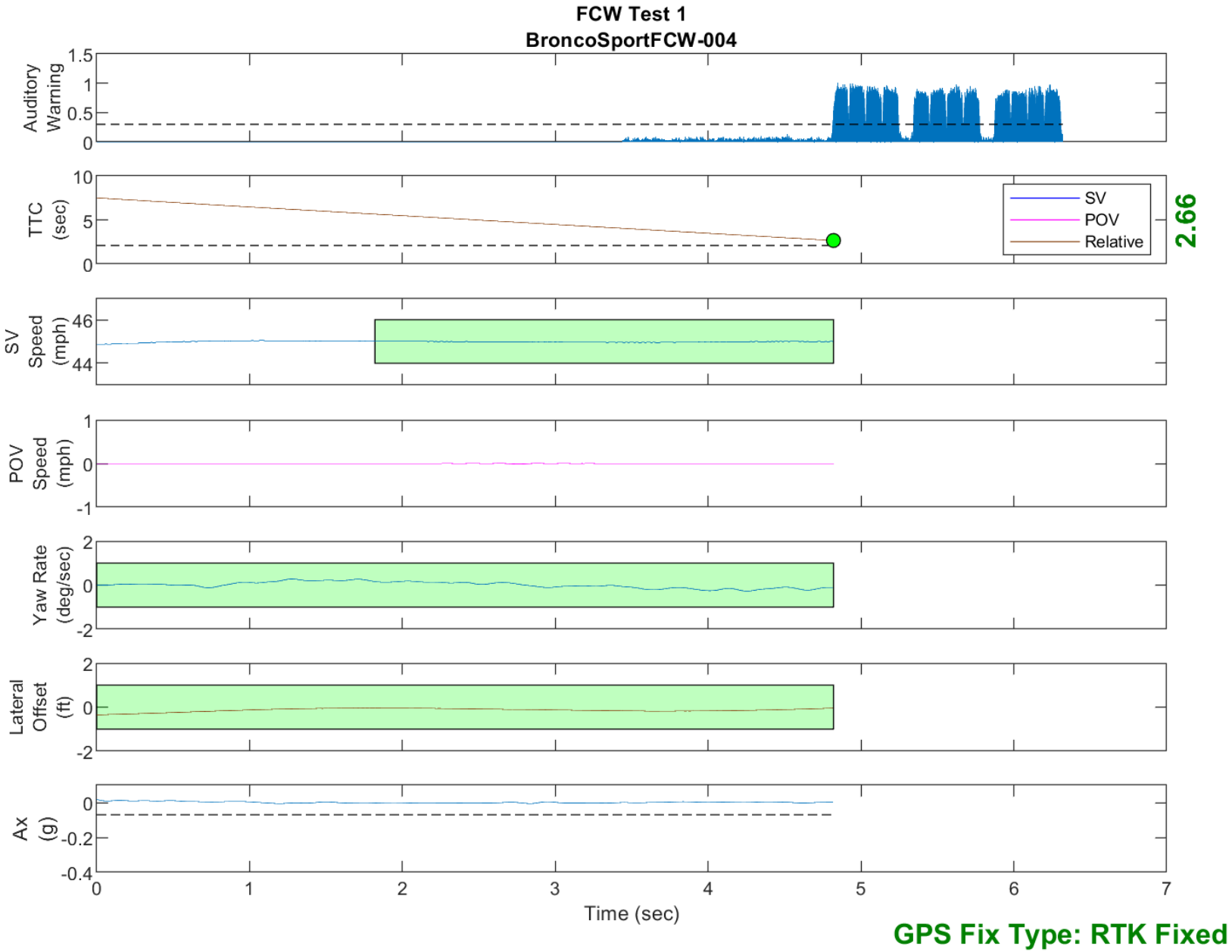

Figure D13. Time History for Run 4, FCW Test 1, Auditory Warning

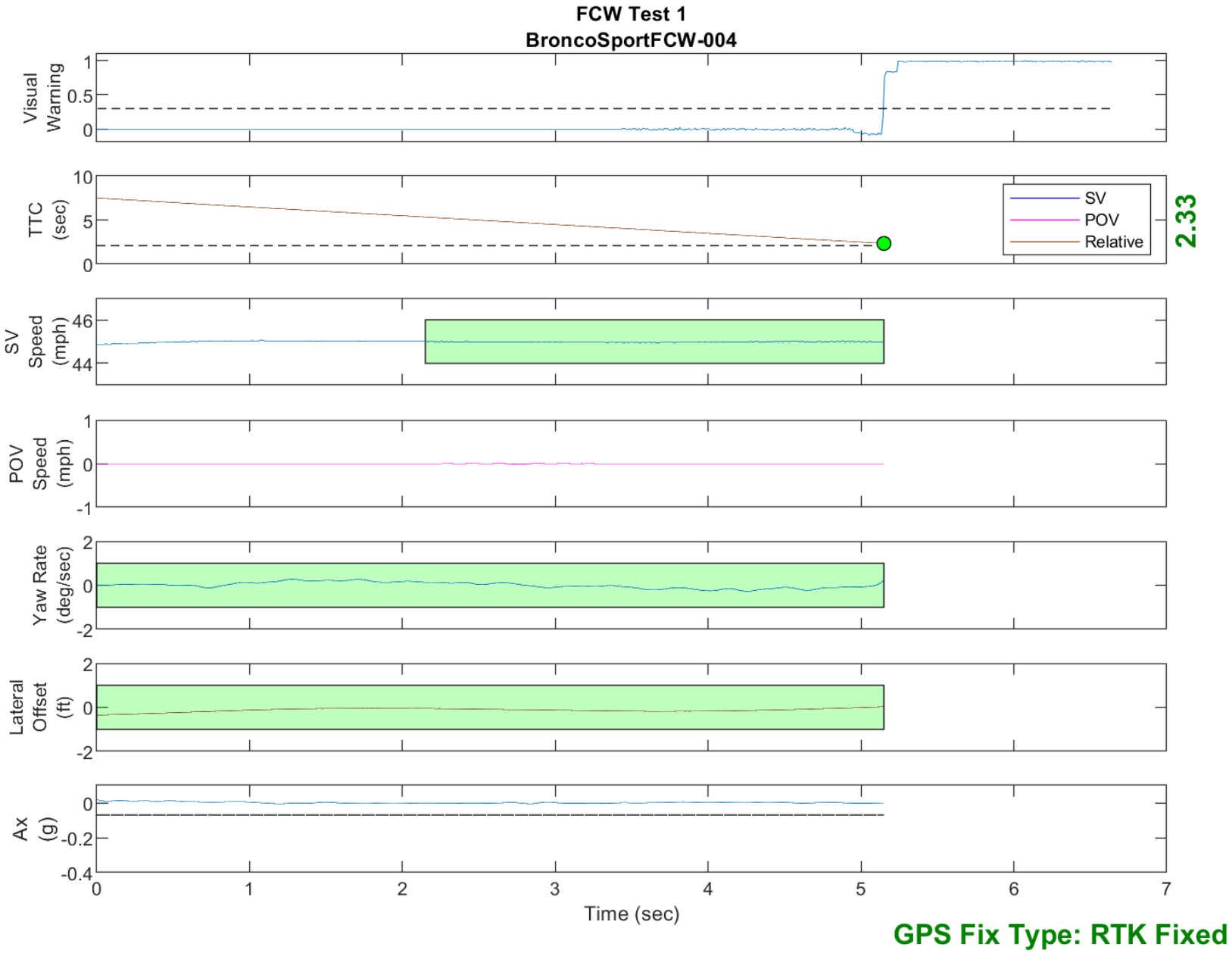

Figure D14. Time History for Run 4, FCW Test 1, Visual Warning

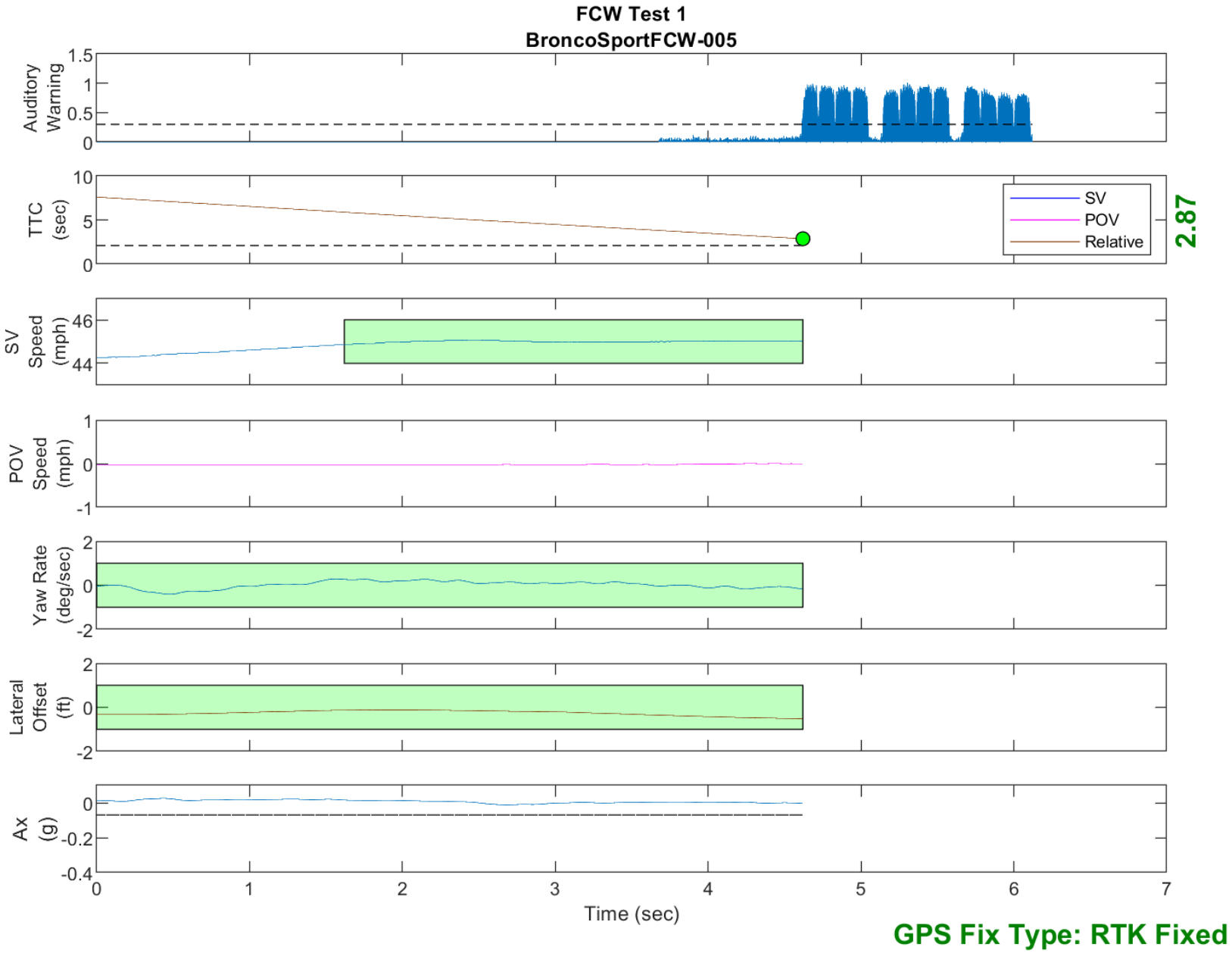

Figure D15. Time History for Run 5, FCW Test 1, Auditory Warning

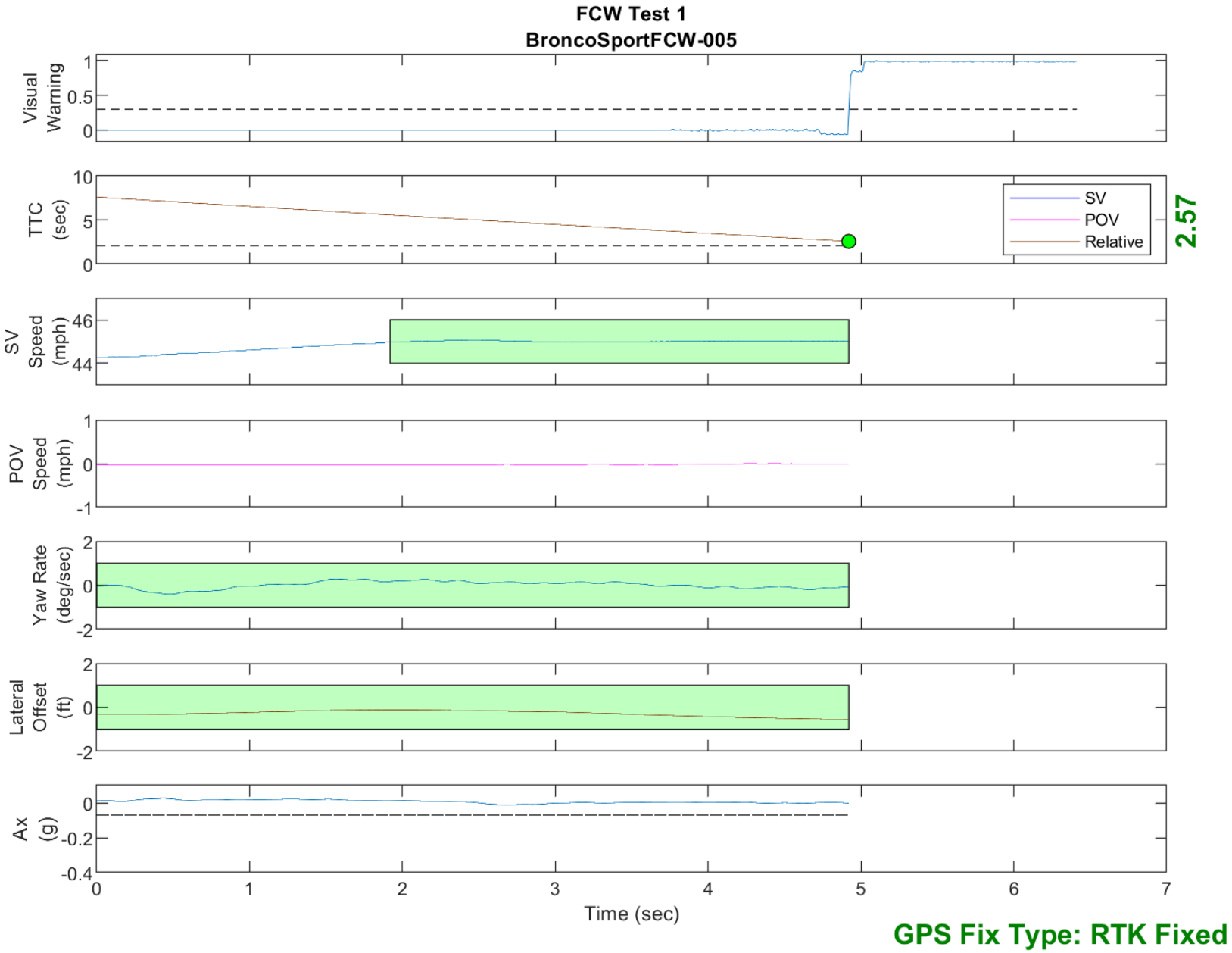

Figure D16. Time History for Run 5, FCW Test 1, Visual Warning

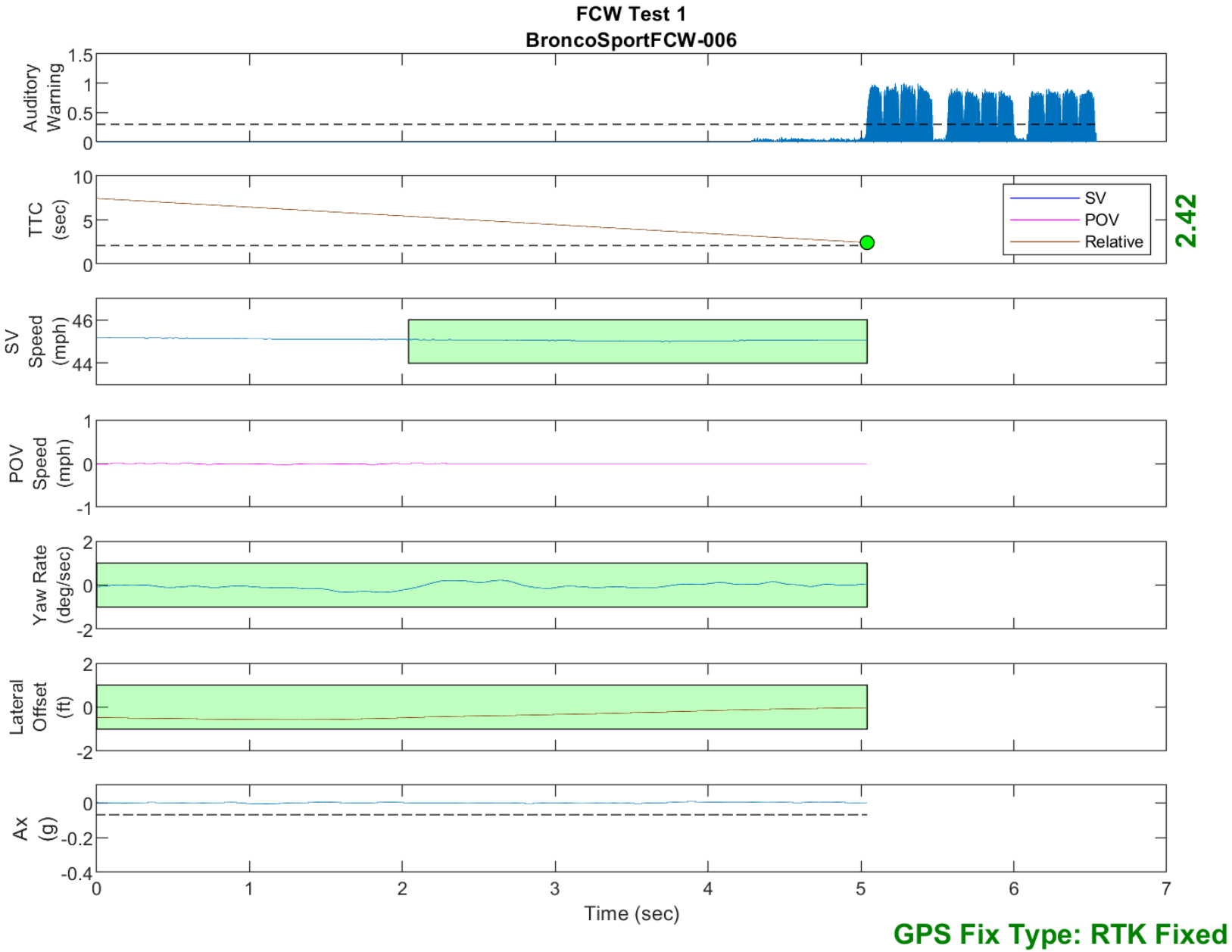

Figure D17. Time History for Run 6, FCW Test 1, Auditory Warning

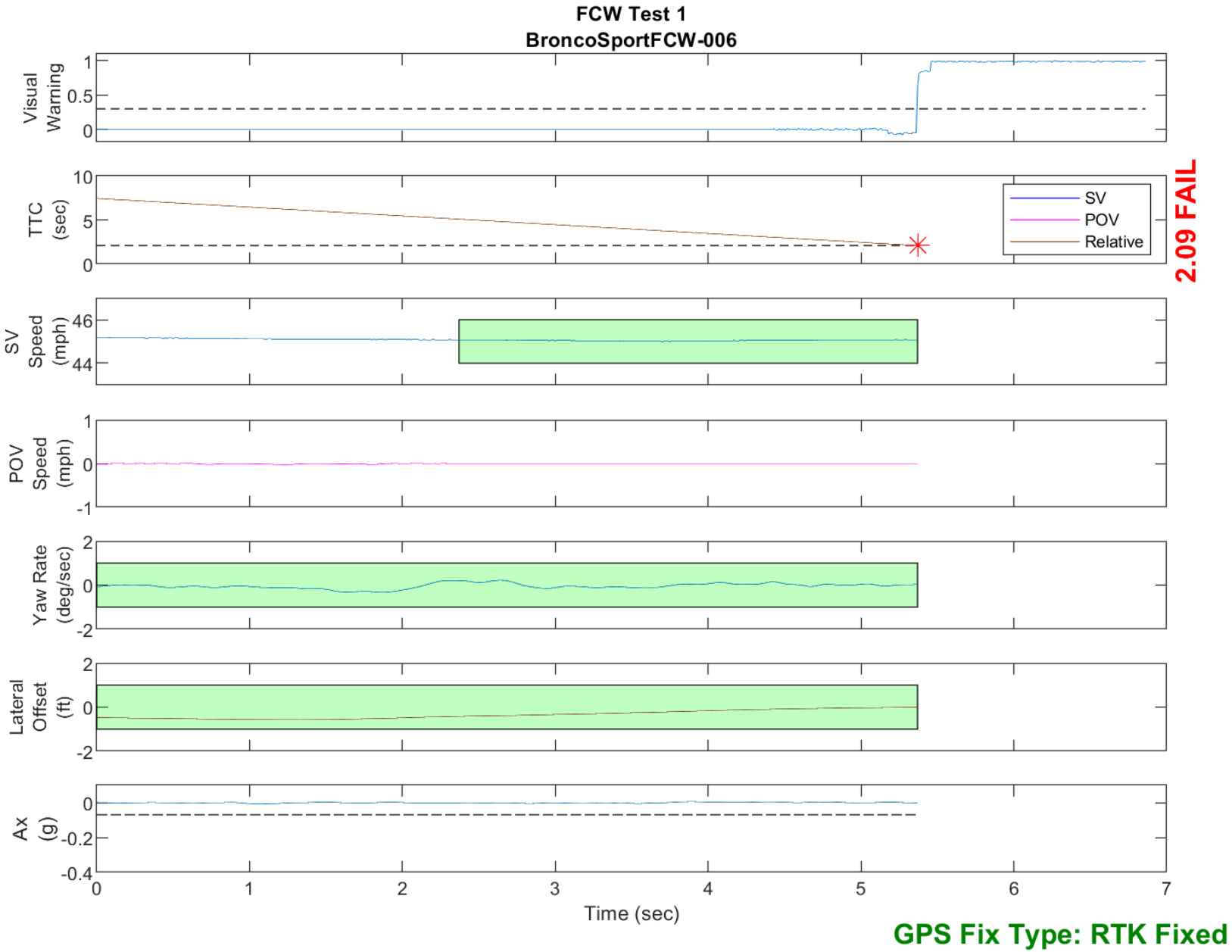

Figure D18. Time History for Run 6, FCW Test 1, Visual Warning

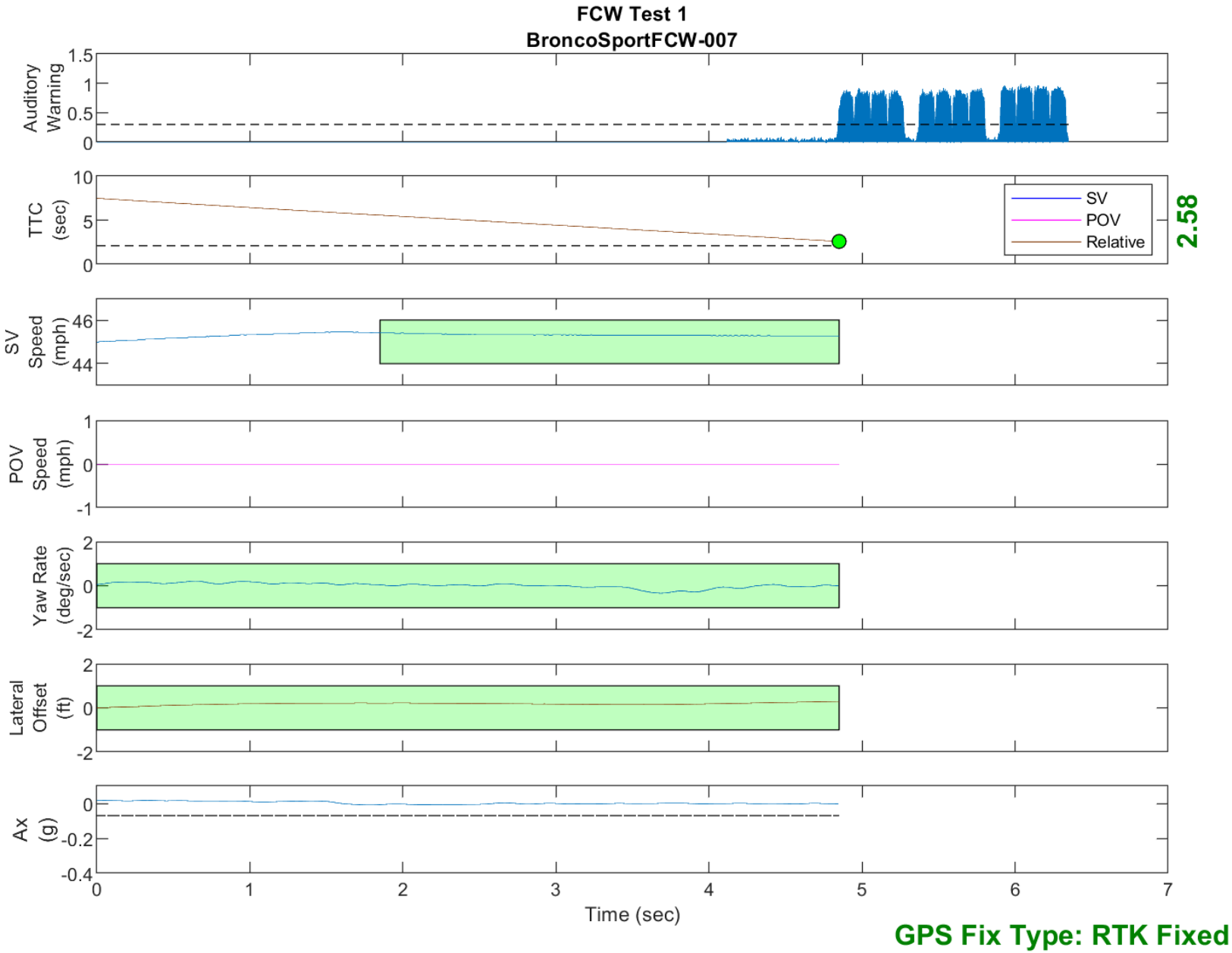

Figure D19. Time History for Run 7, FCW Test 1, Auditory Warning

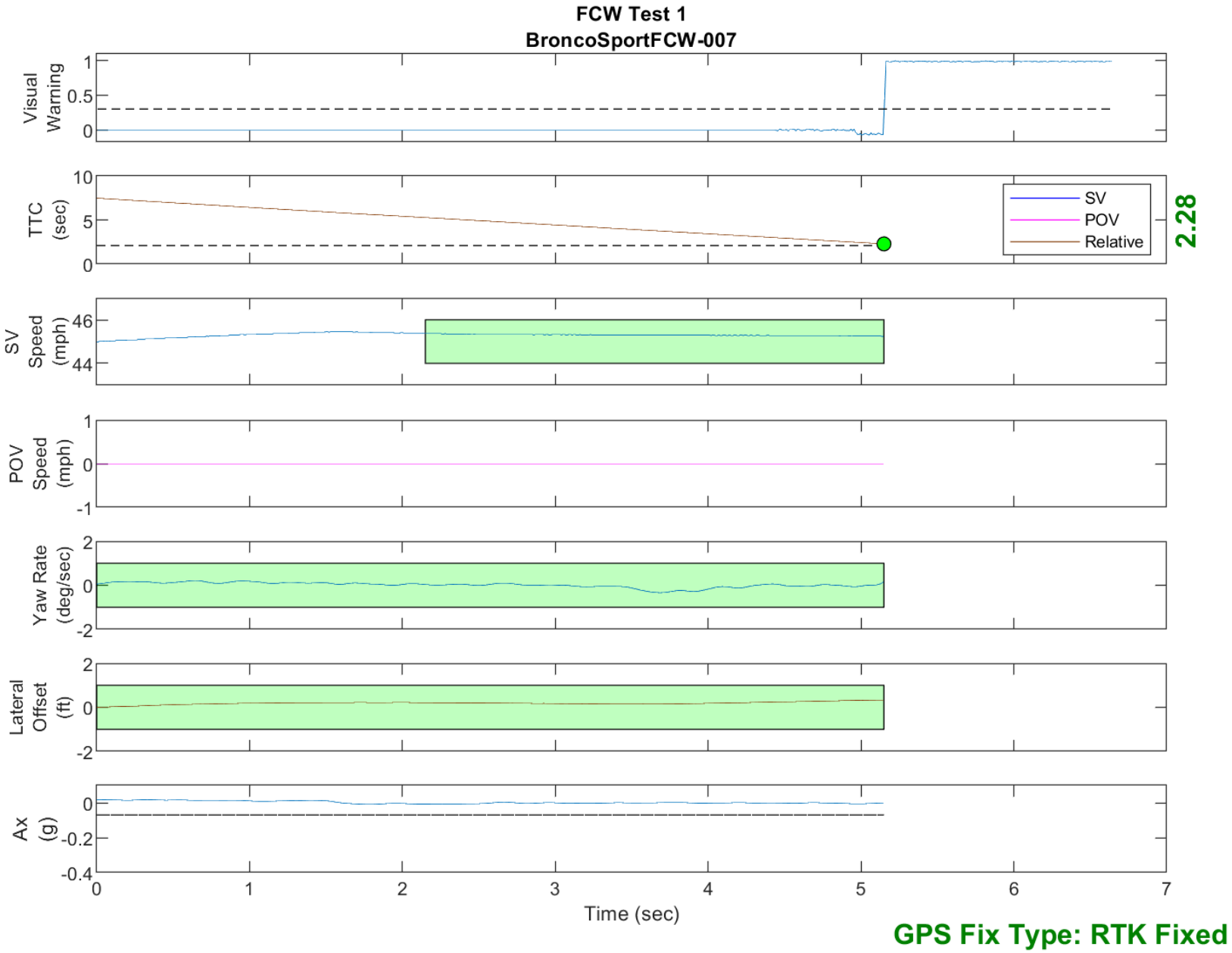

Figure D20. Time History for Run 7, FCW Test 1, Visual Warning

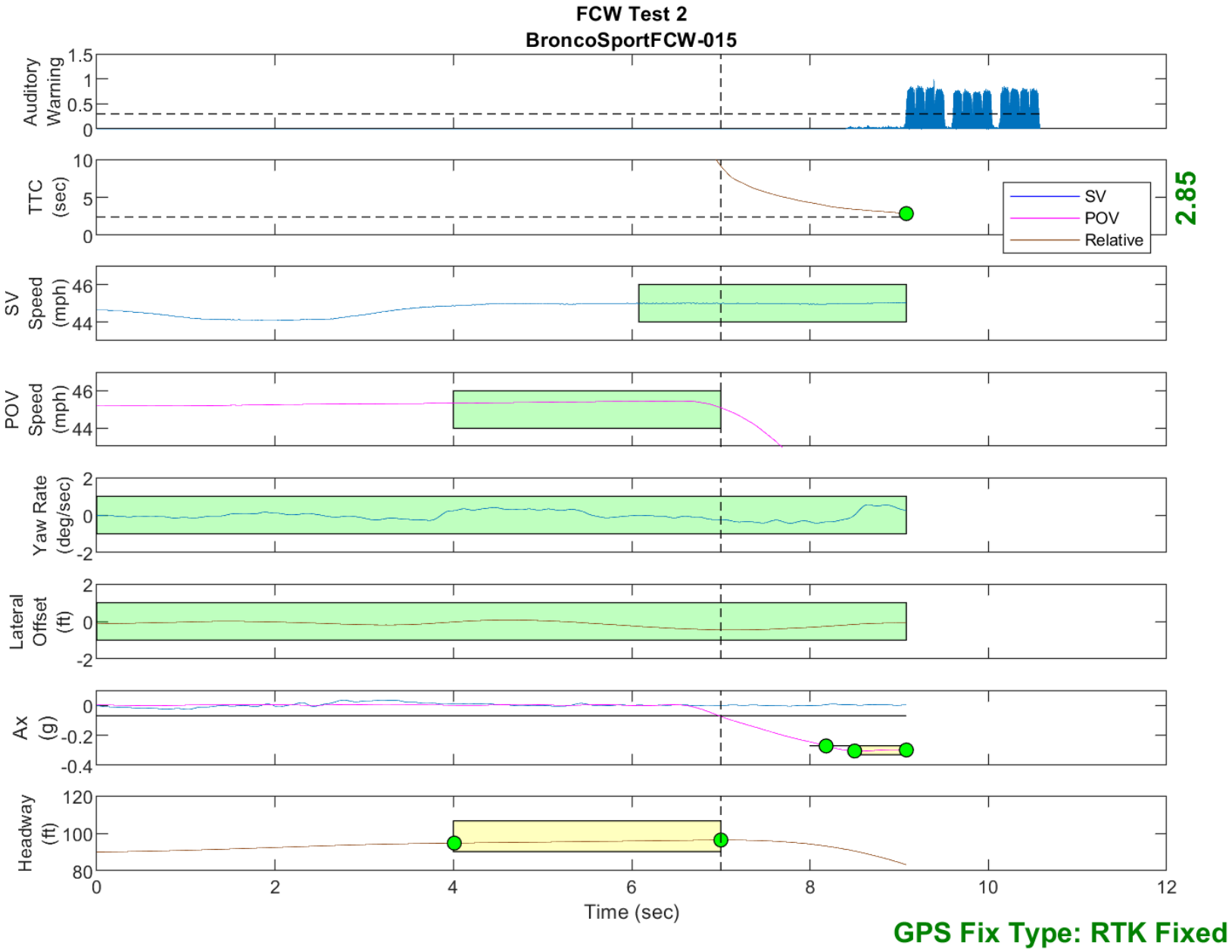

Figure D21. Time History for Run 15, FCW Test 2, Auditory Warning

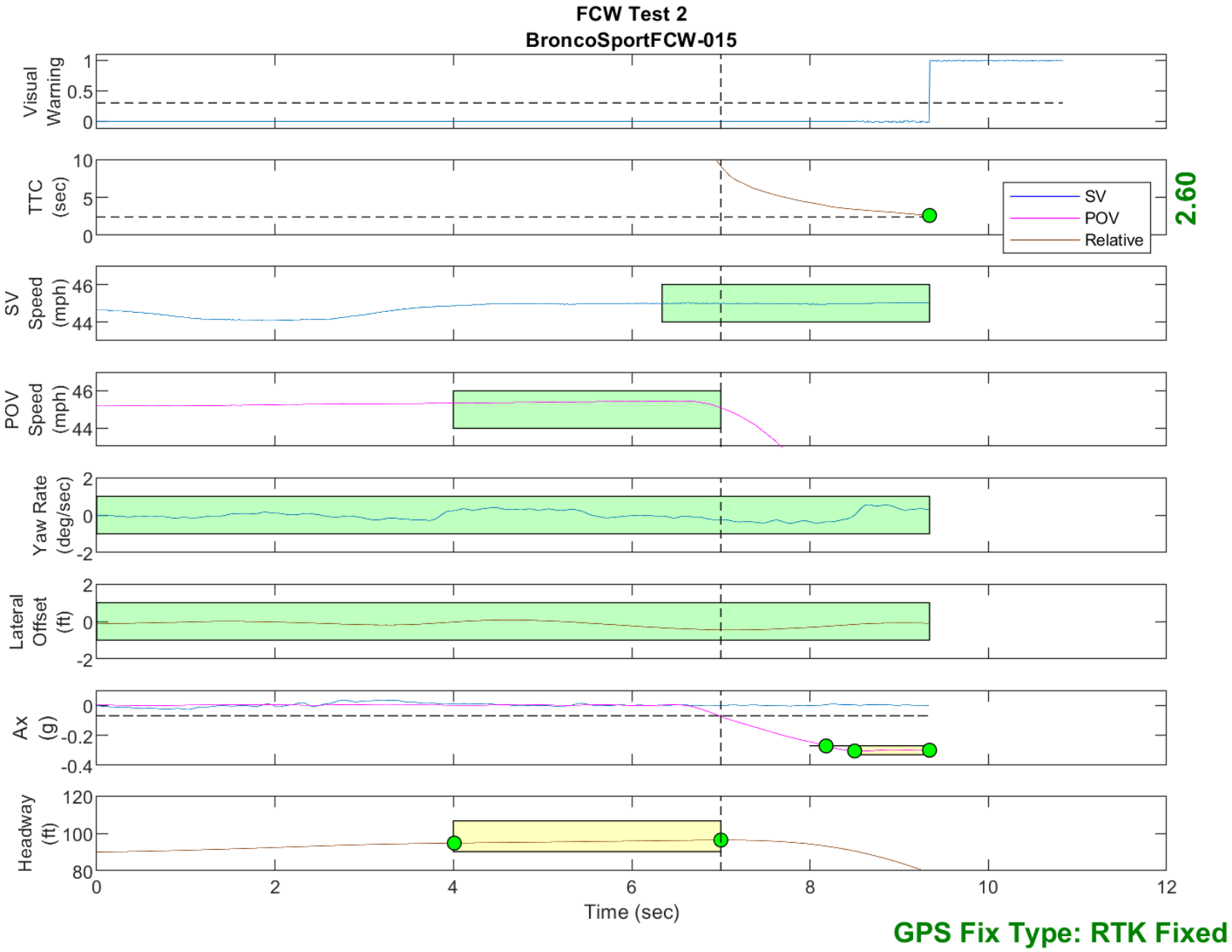

Figure D22. Time History for Run 15, FCW Test 2, Visual Warning

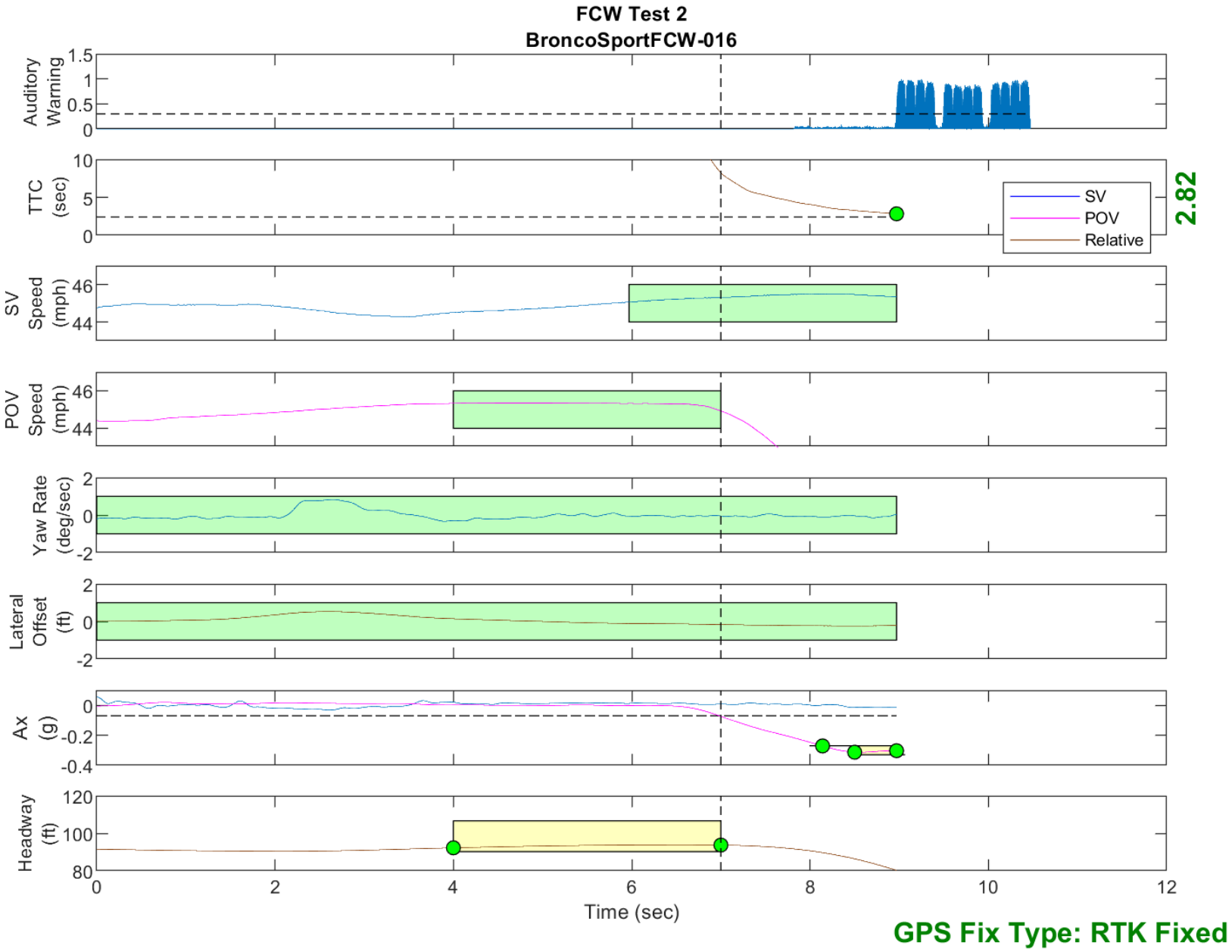

Figure D23. Time History for Run 16, FCW Test 2, Auditory Warning

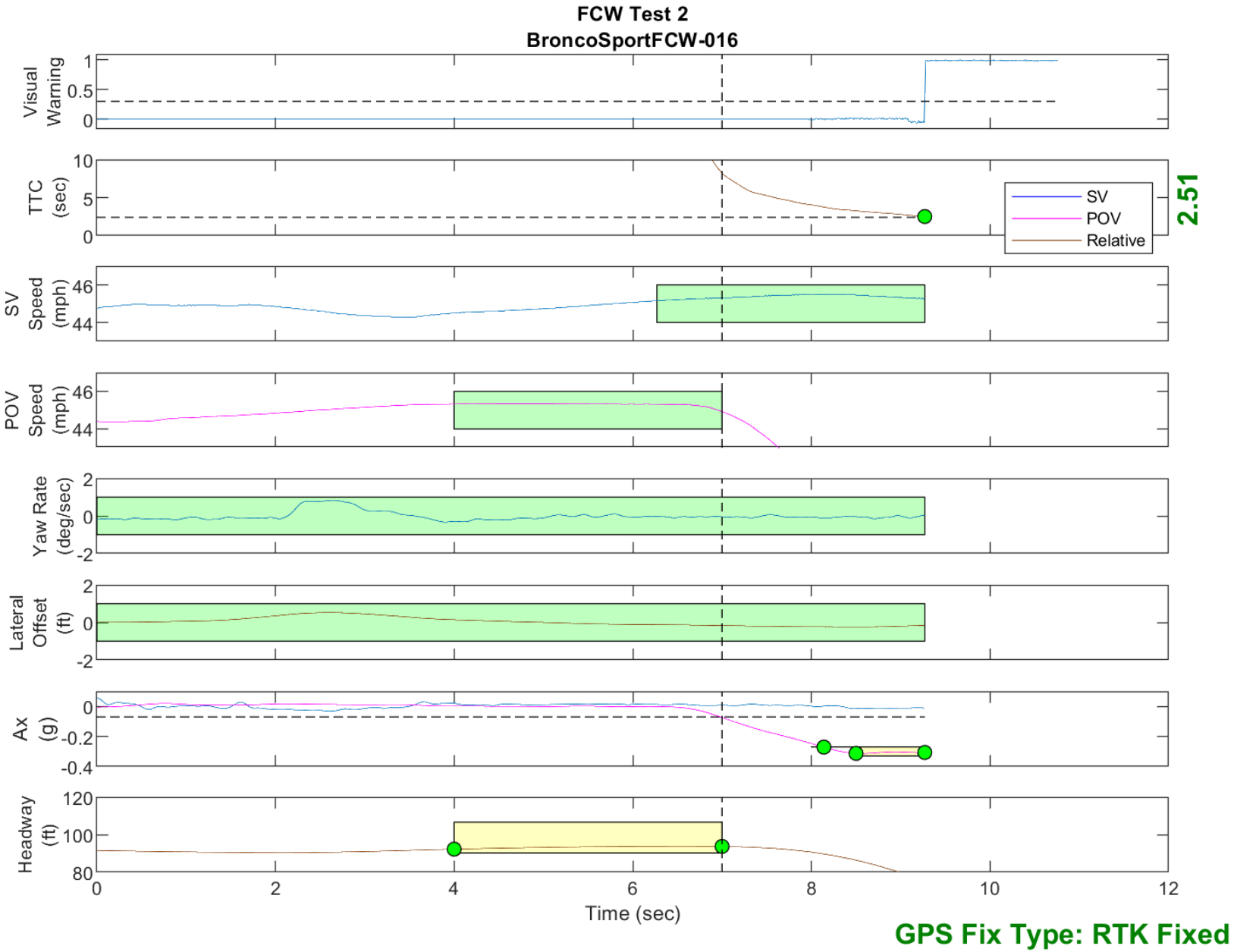

Figure D24. Time History for Run 16, FCW Test 2, Visual Warning

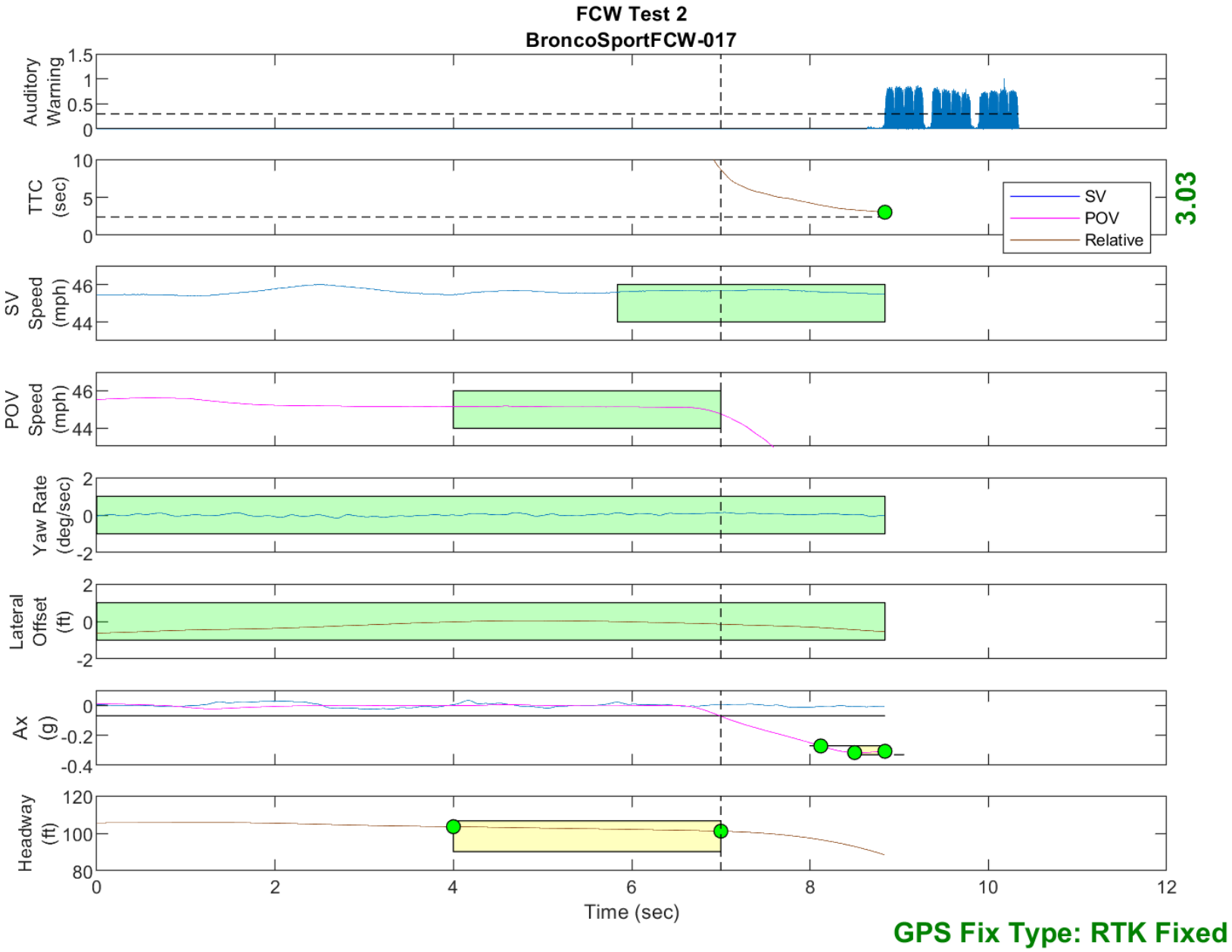

Figure D25. Time History for Run 17, FCW Test 2, Auditory Warning

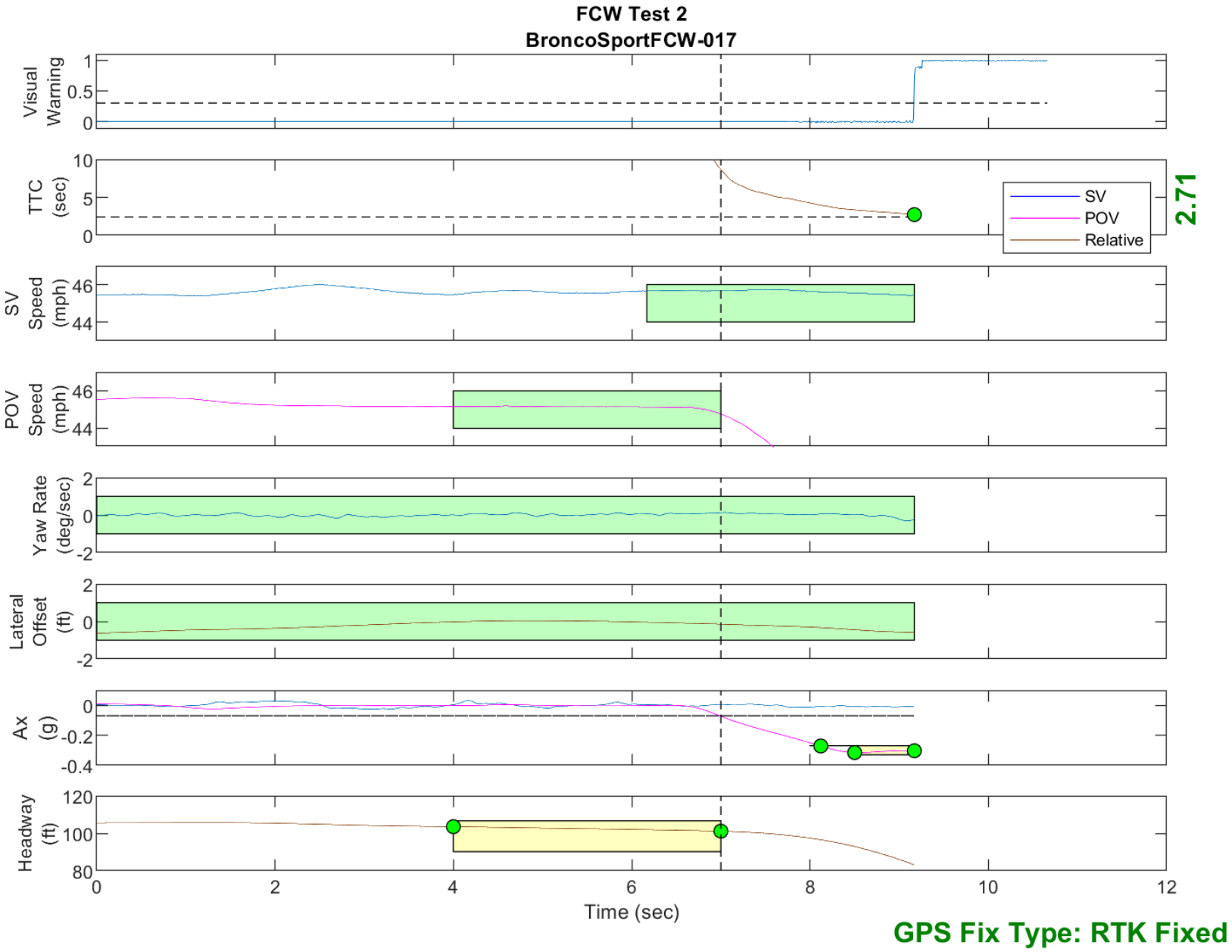

Figure D26. Time History for Run 17, FCW Test 2, Visual Warning

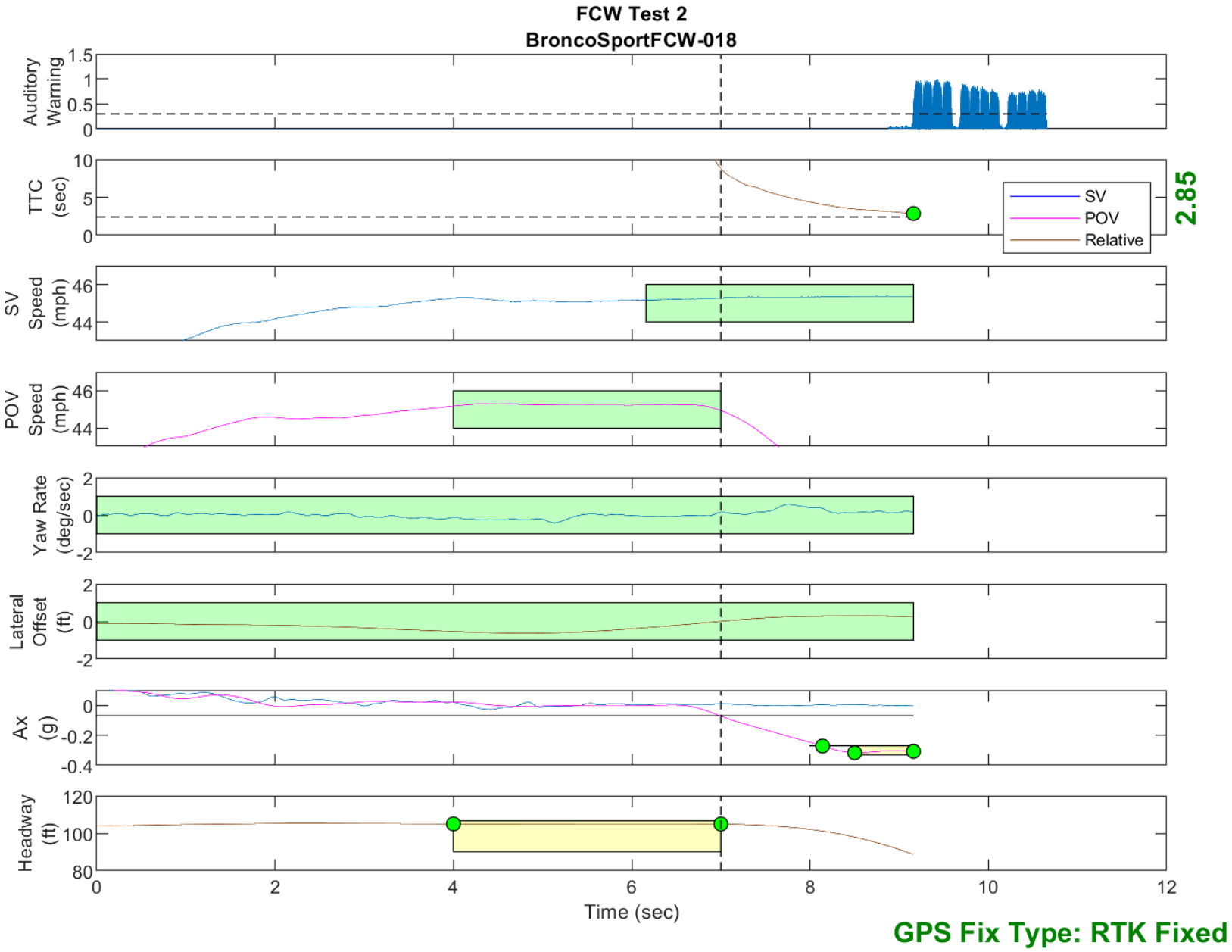

Figure D27. Time History for Run 18, FCW Test 2, Auditory Warning

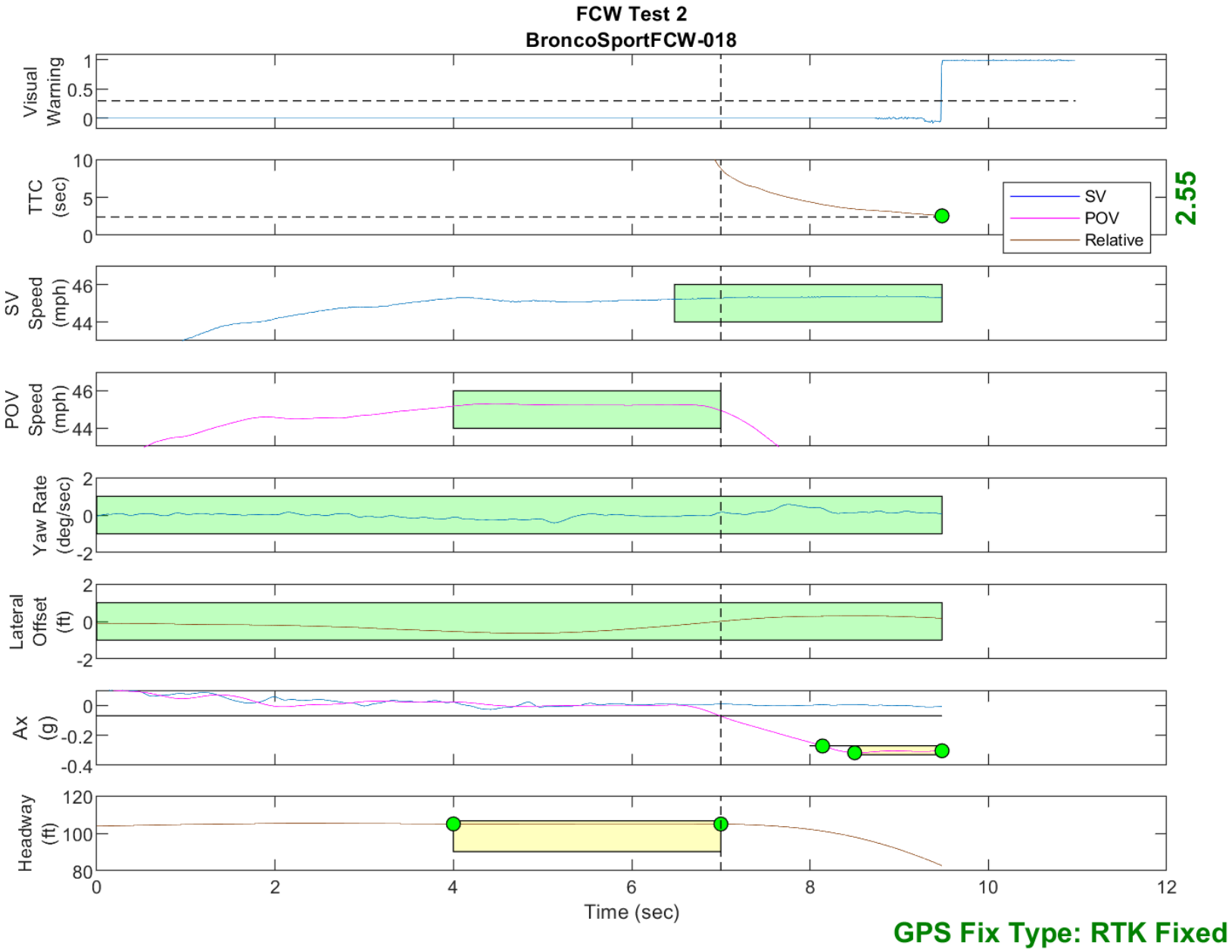

Figure D28. Time History for Run 18, FCW Test 2, Visual Warning

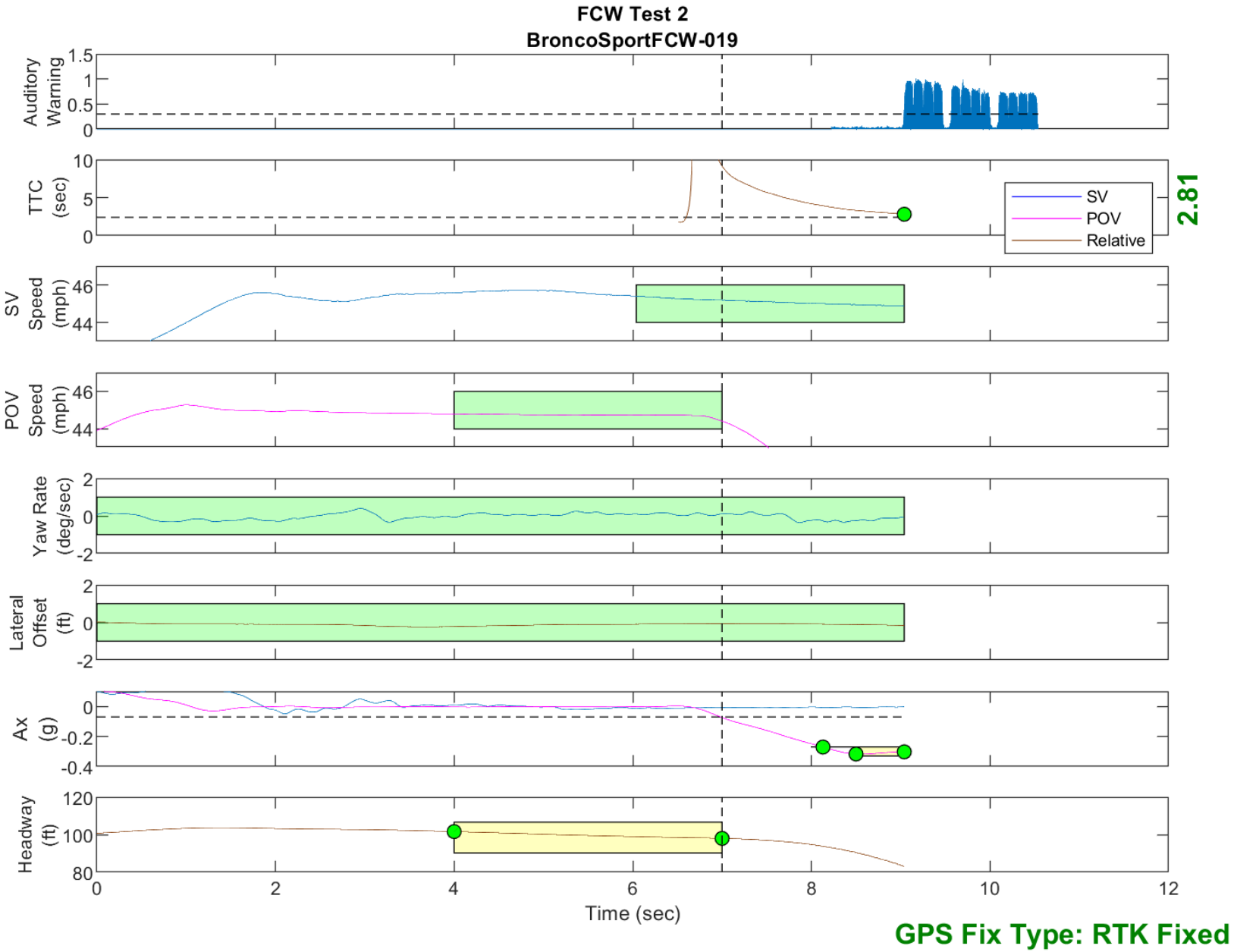

Figure D29. Time History for Run 19, FCW Test 2, Auditory Warning

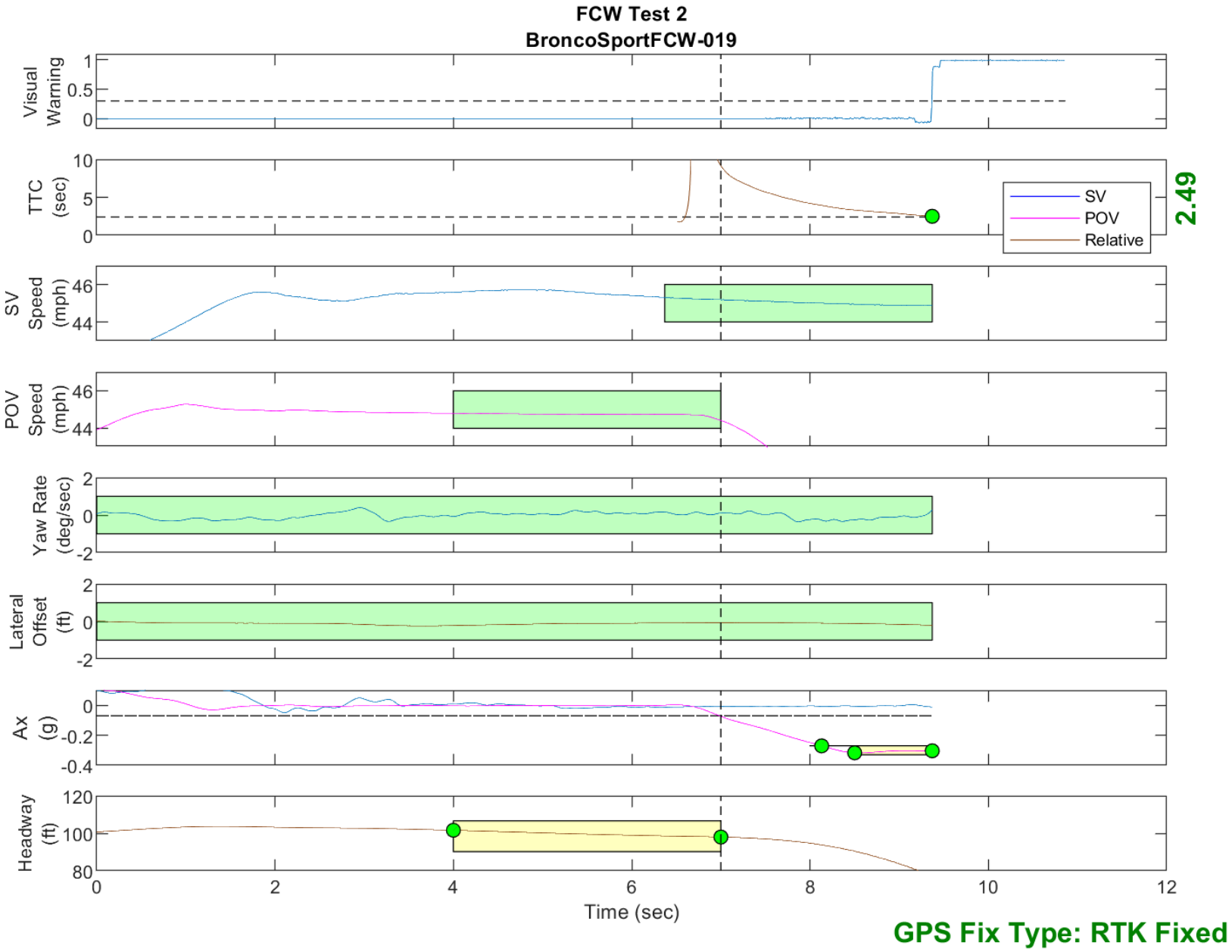

Figure D30. Time History for Run 19, FCW Test 2, Visual Warning

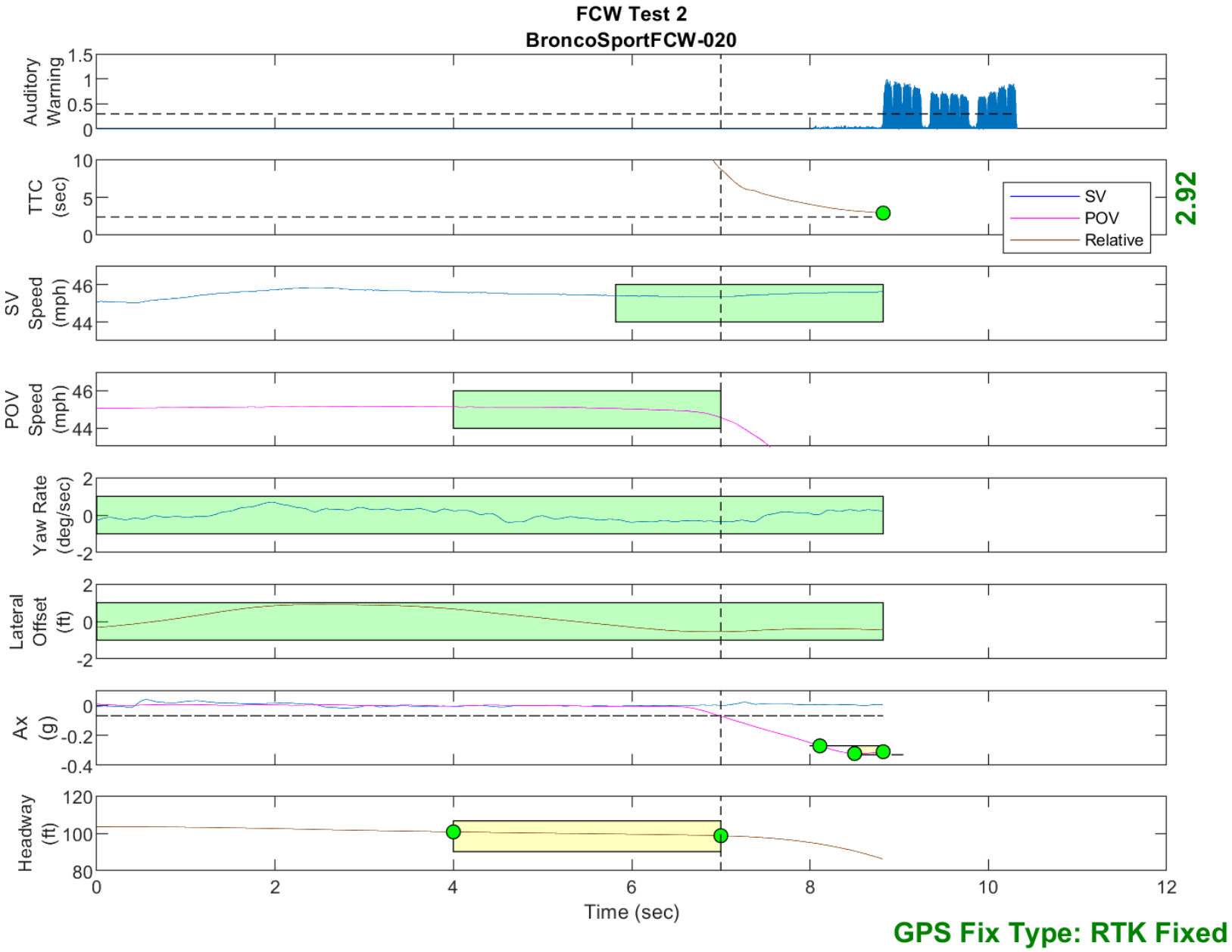

Figure D31. Time History for Run 20, FCW Test 2, Auditory Warning

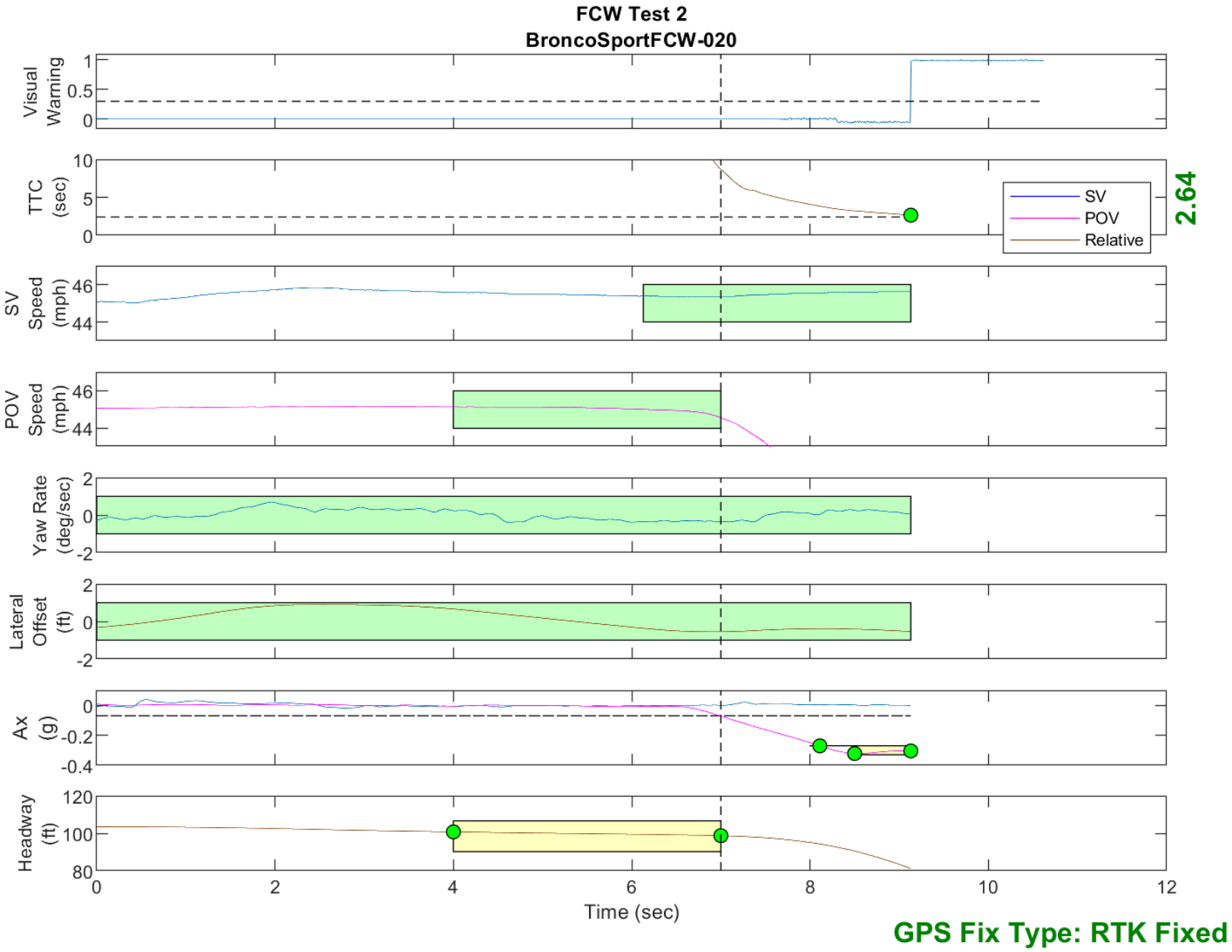

Figure D32. Time History for Run 20, FCW Test 2, Visual Warning

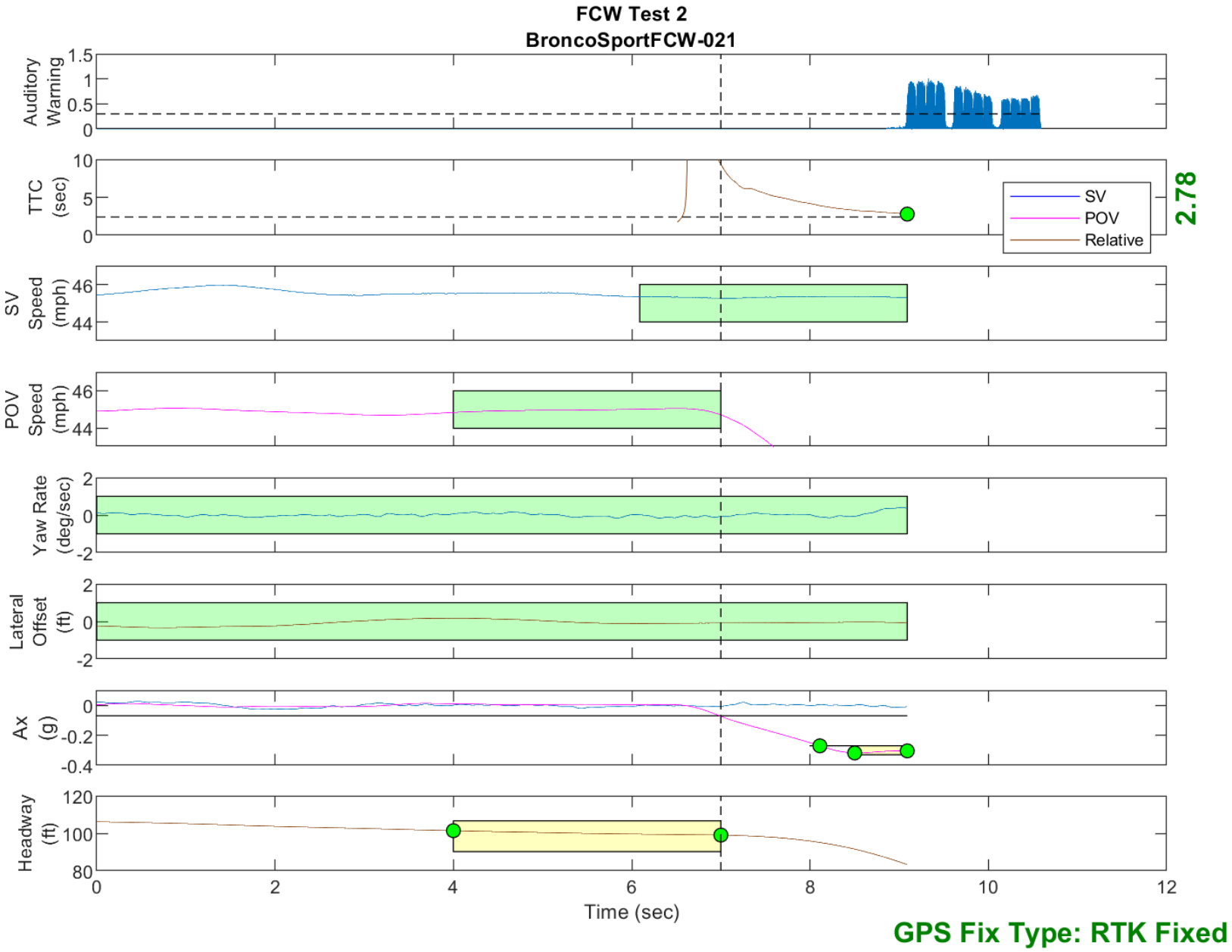

Figure D33. Time History for Run 21, FCW Test 2, Auditory Warning

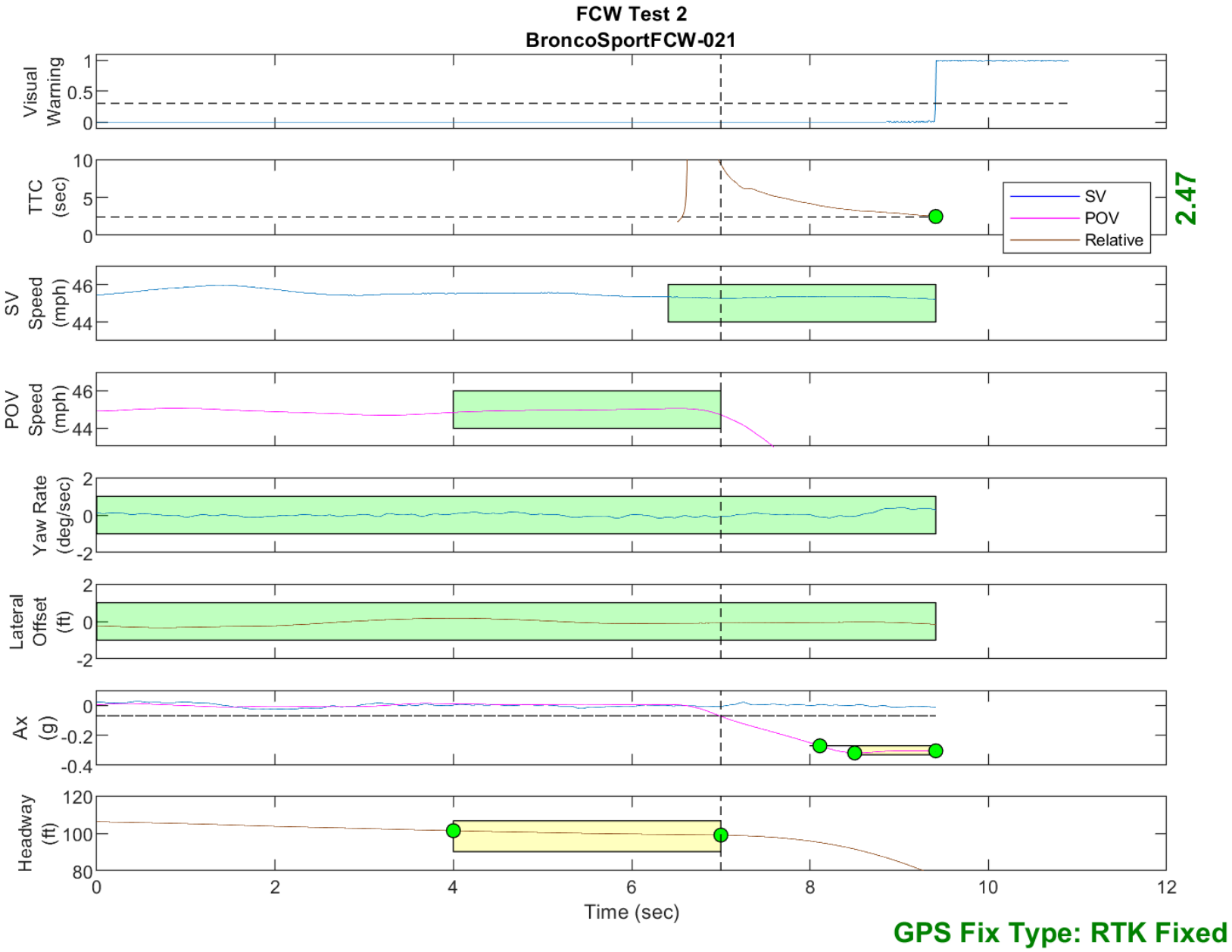

Figure D34. Time History for Run 21, FCW Test 2, Visual Warning

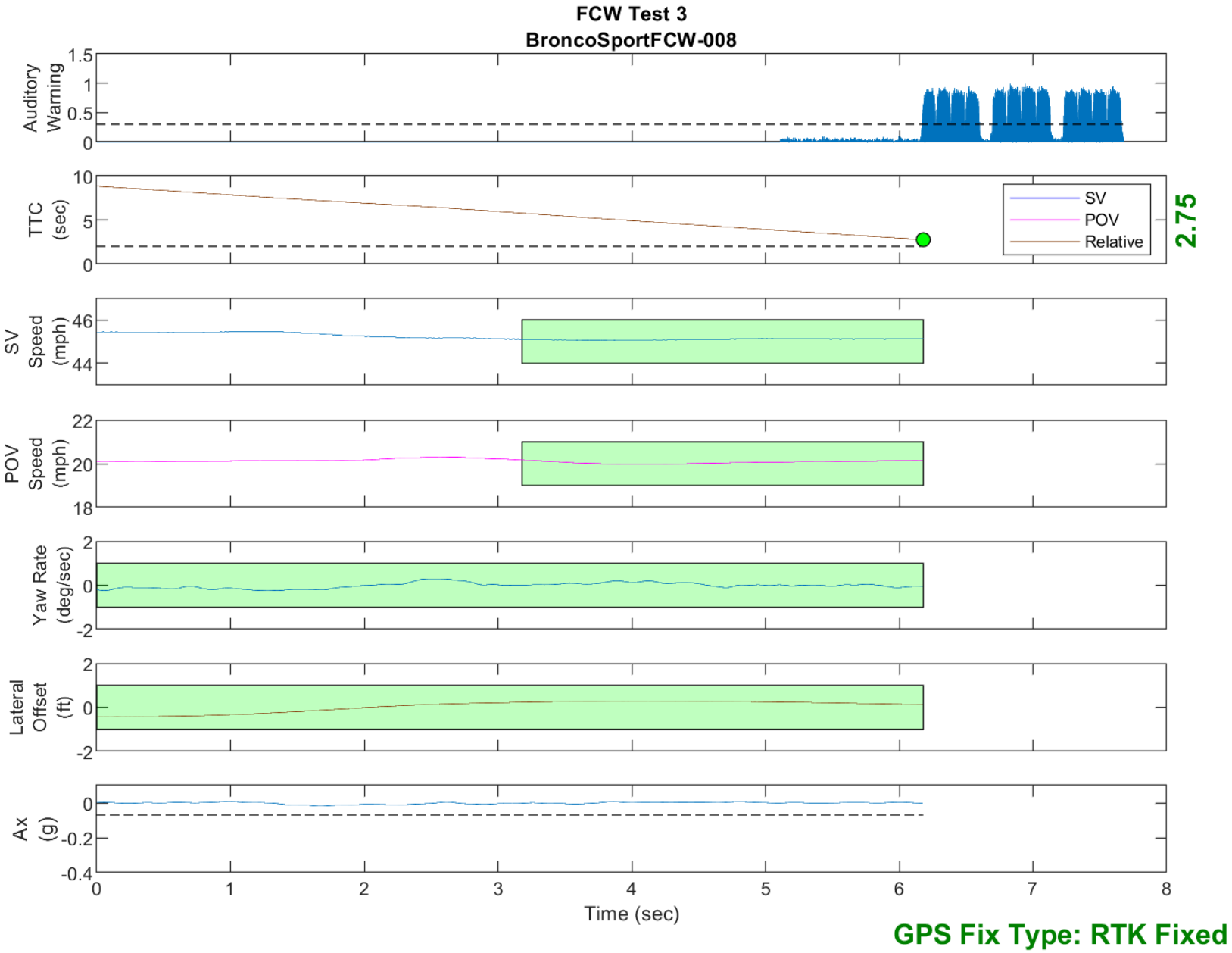

Figure D35. Time History for Run 8, FCW Test 3, Auditory Warning

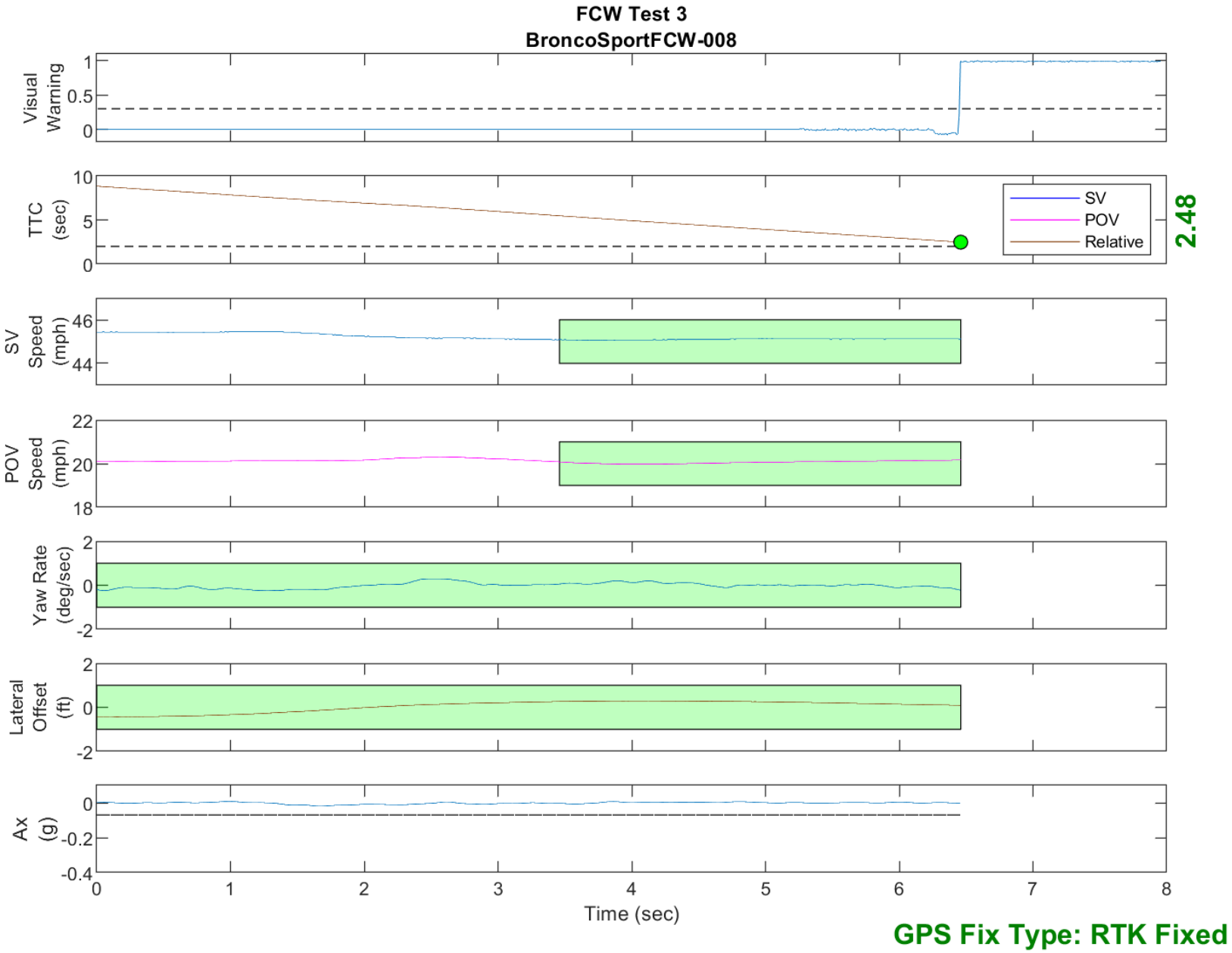

Figure D36. Time History for Run 8, FCW Test 3, Visual Warning

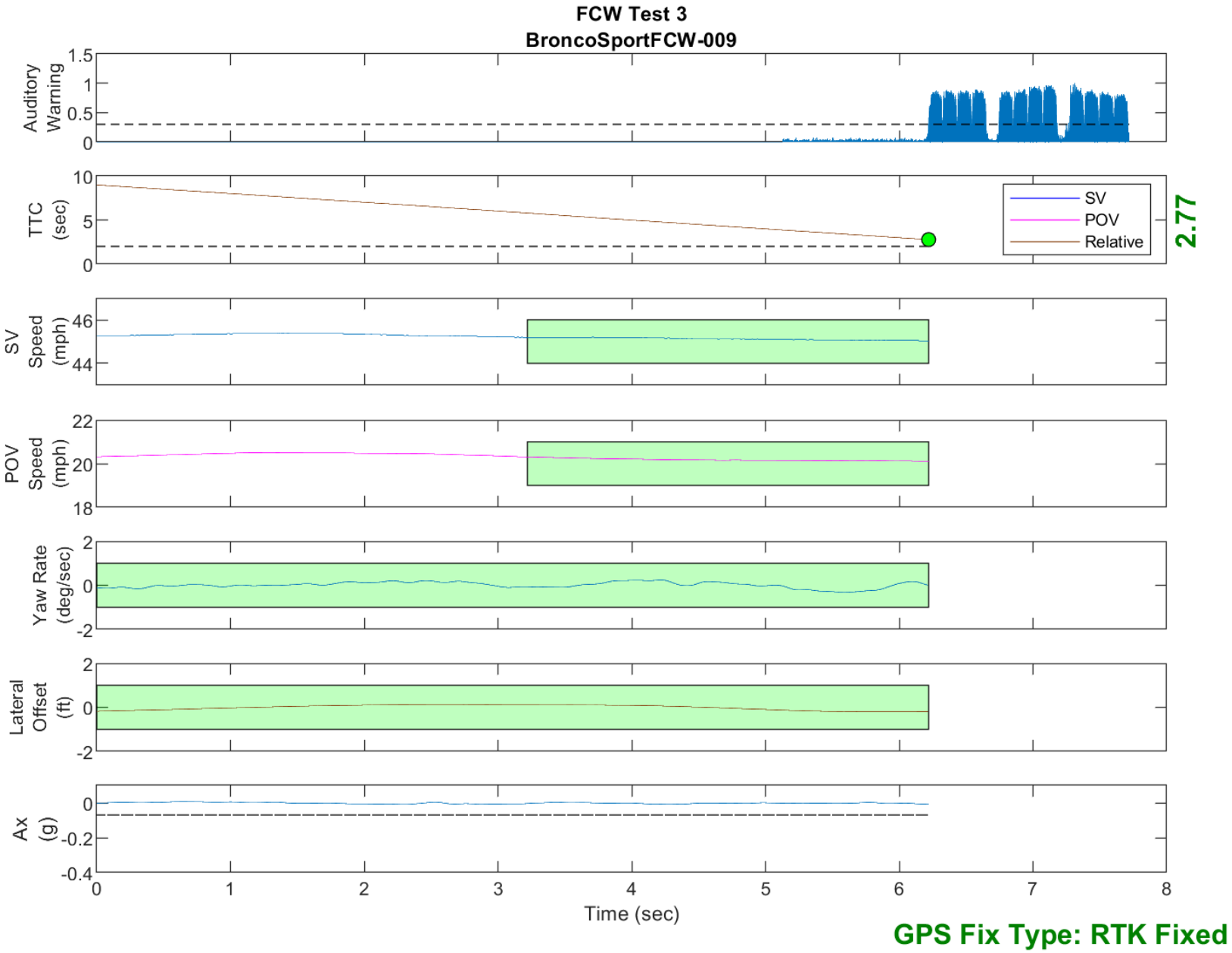

Figure D37. Time History for Run 9, FCW Test 3, Auditory Warning

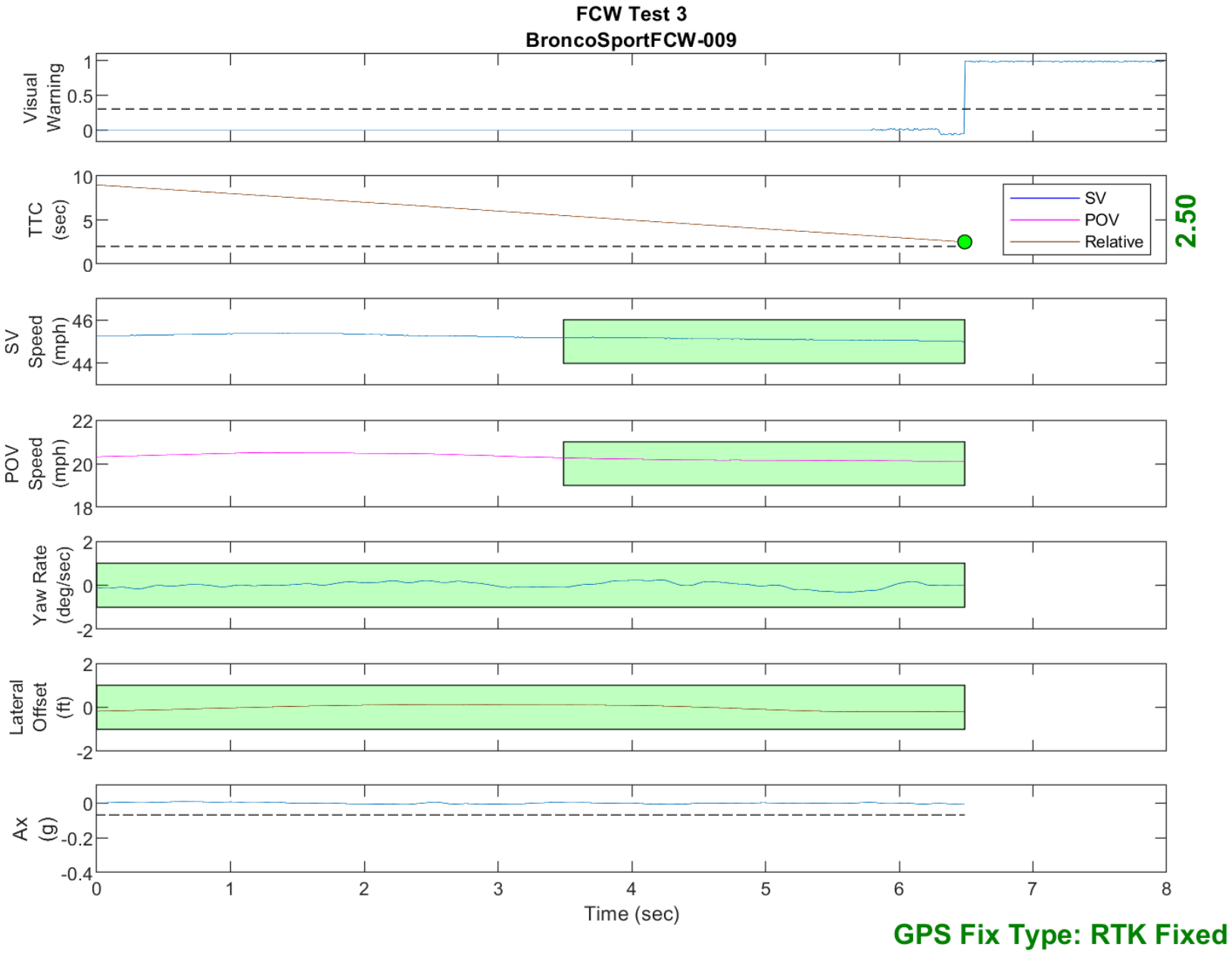

Figure D38. Time History for Run 9, FCW Test 3, Visual Warning

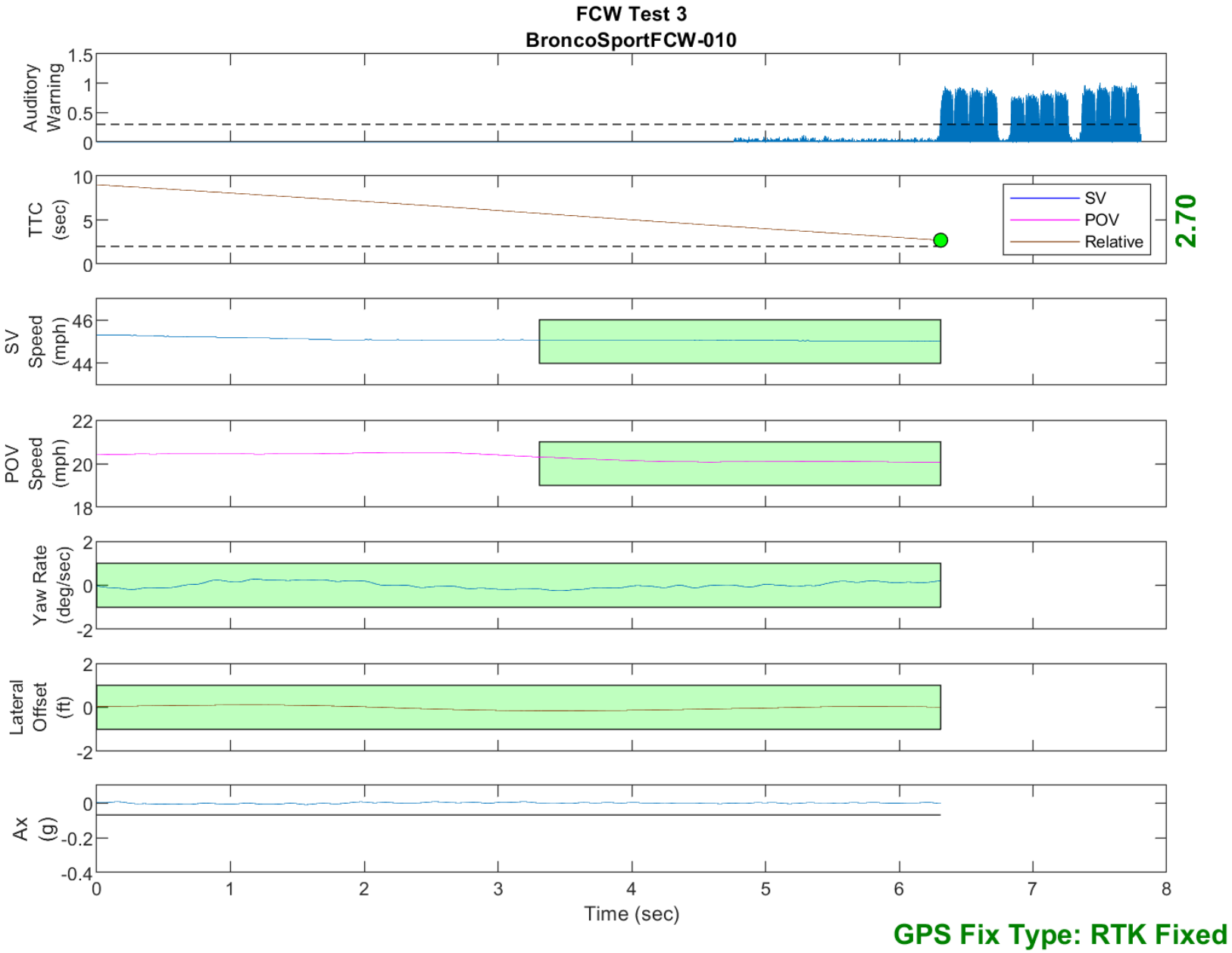

Figure D39. Time History for Run 10, FCW Test 3, Auditory Warning

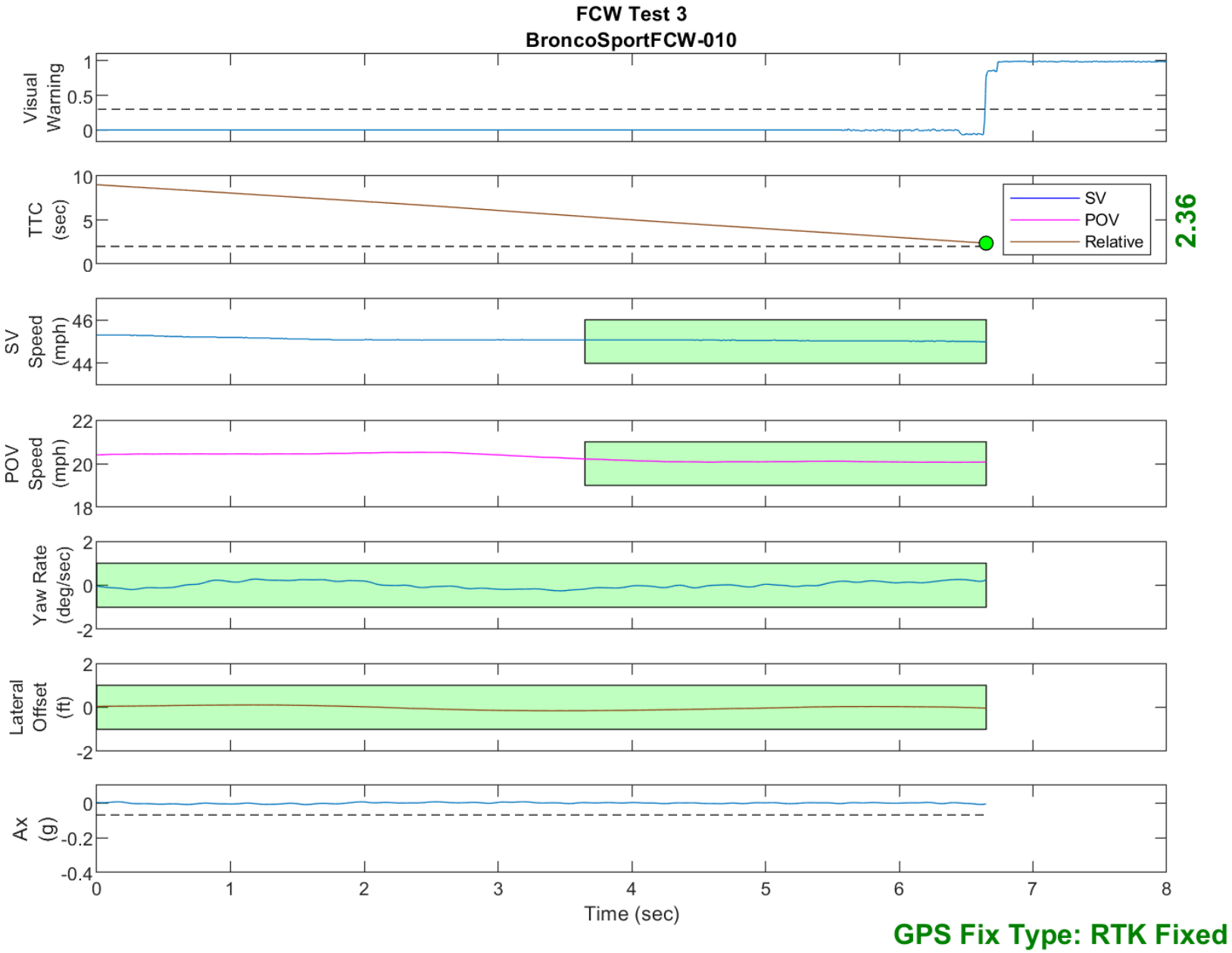

Figure D40. Time History for Run 10, FCW Test 3, Visual Warning

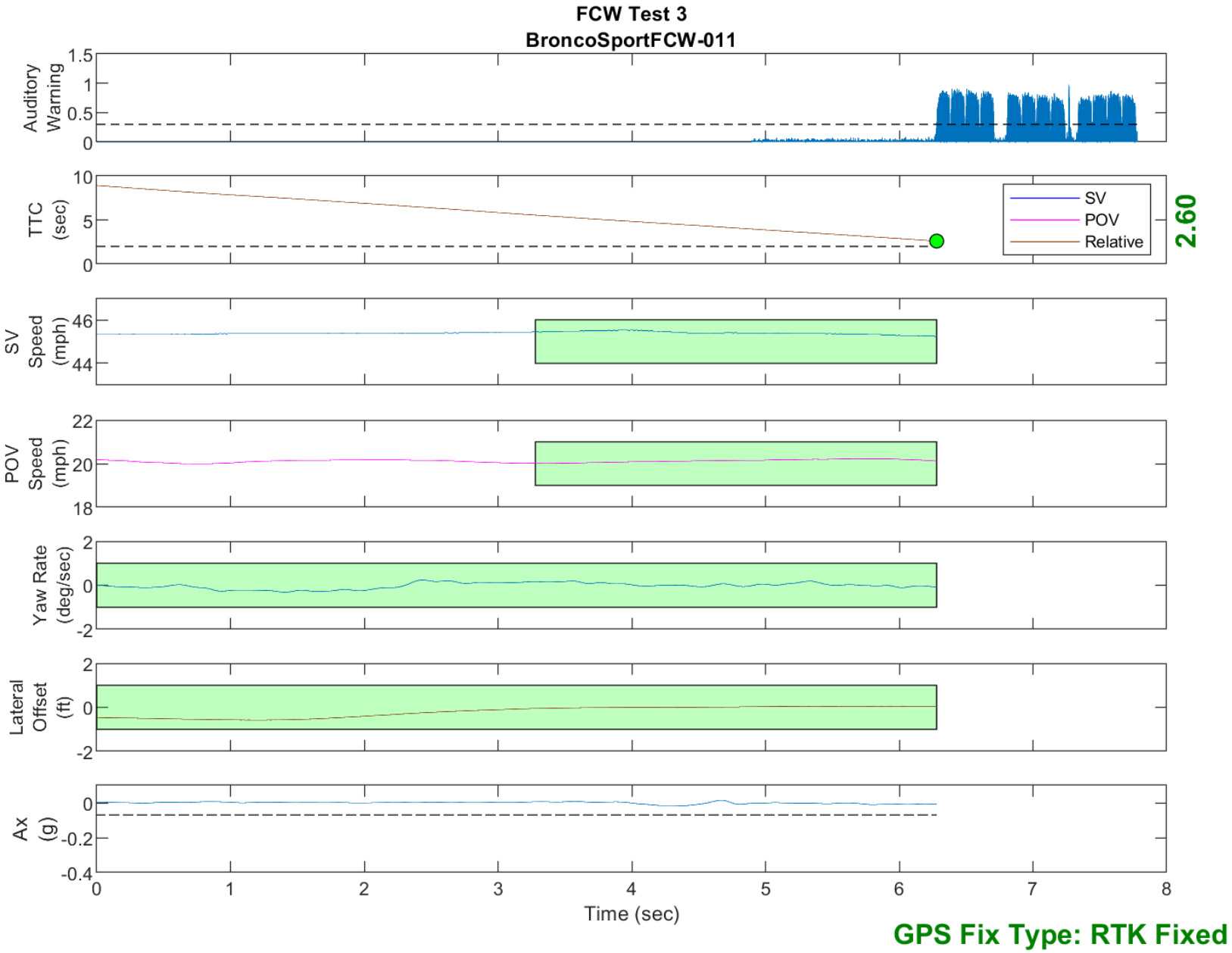

Figure D41. Time History for Run 11, FCW Test 3, Auditory Warning

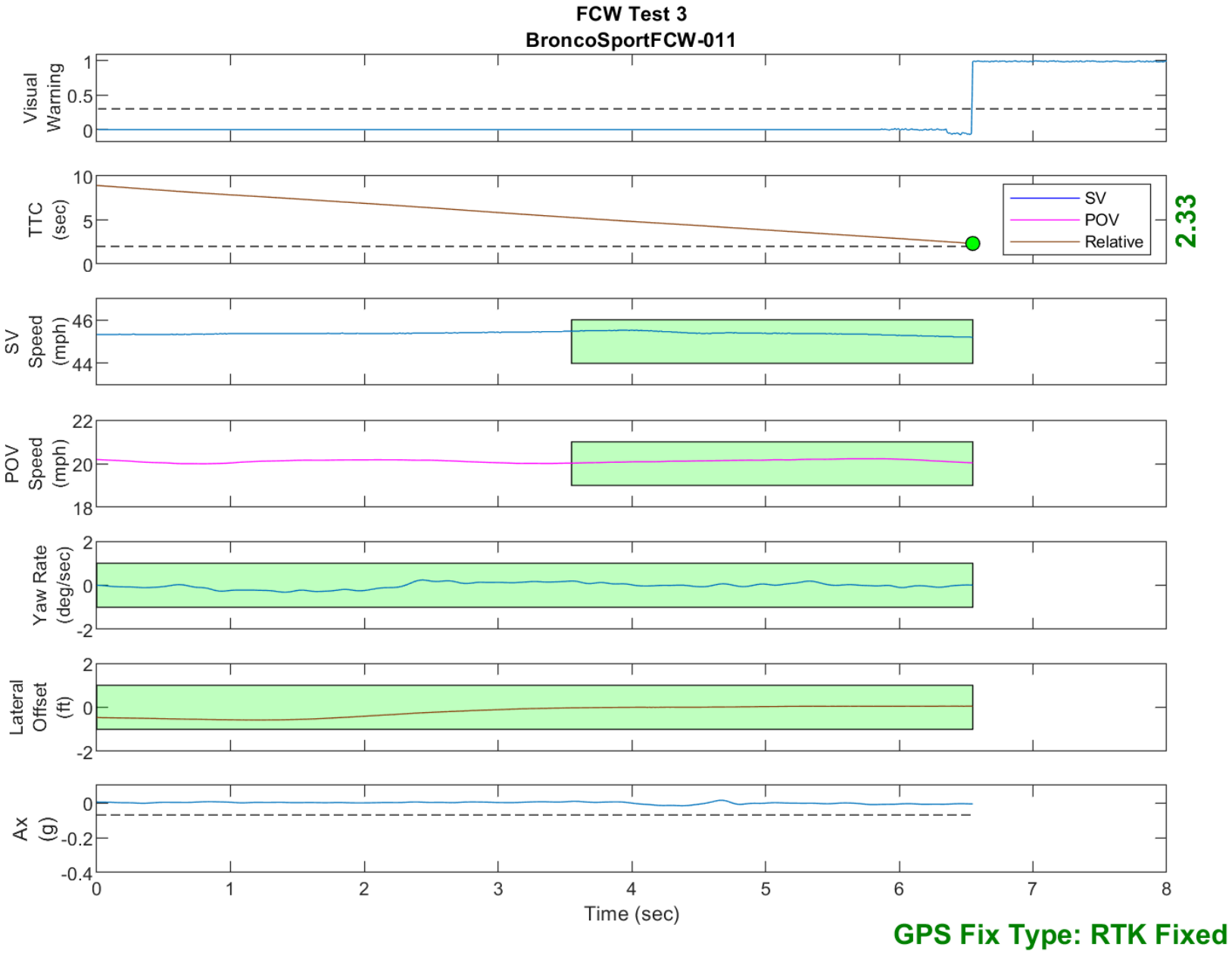

Figure D42. Time History for Run 11, FCW Test 3, Visual Warning

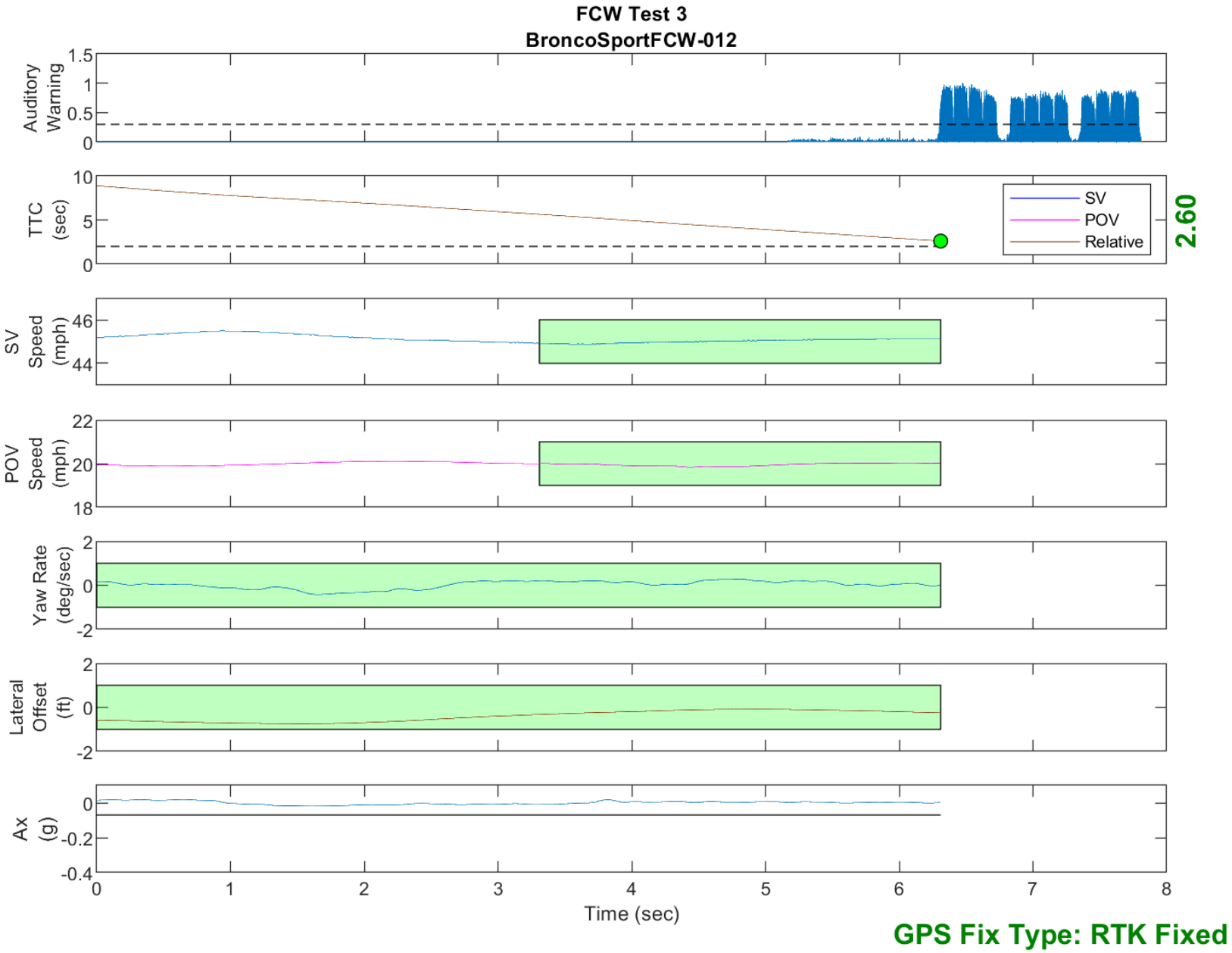

Figure D43. Time History for Run 12, FCW Test 3, Auditory Warning

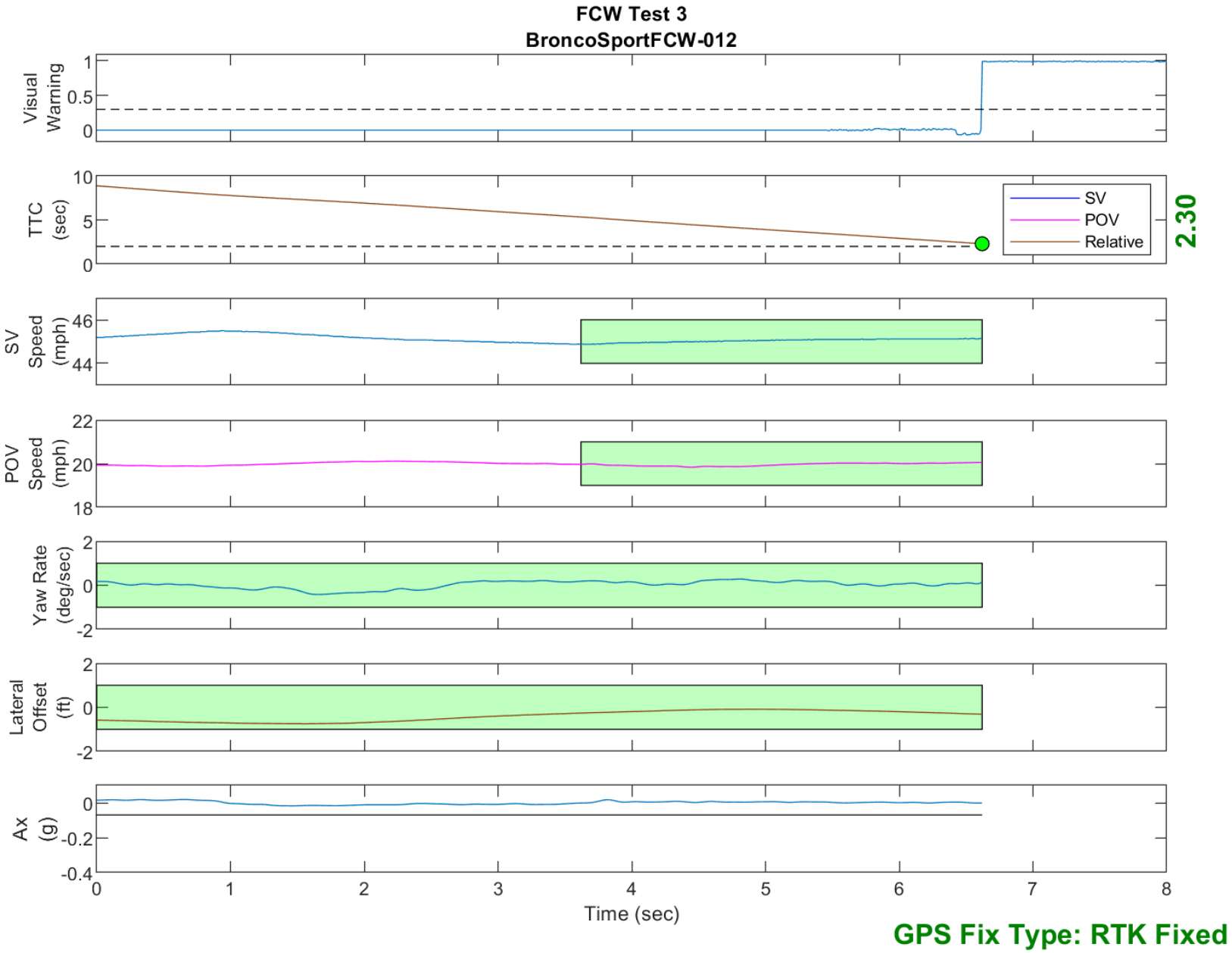

Figure D44. Time History for Run 12, FCW Test 3, Visual Warning

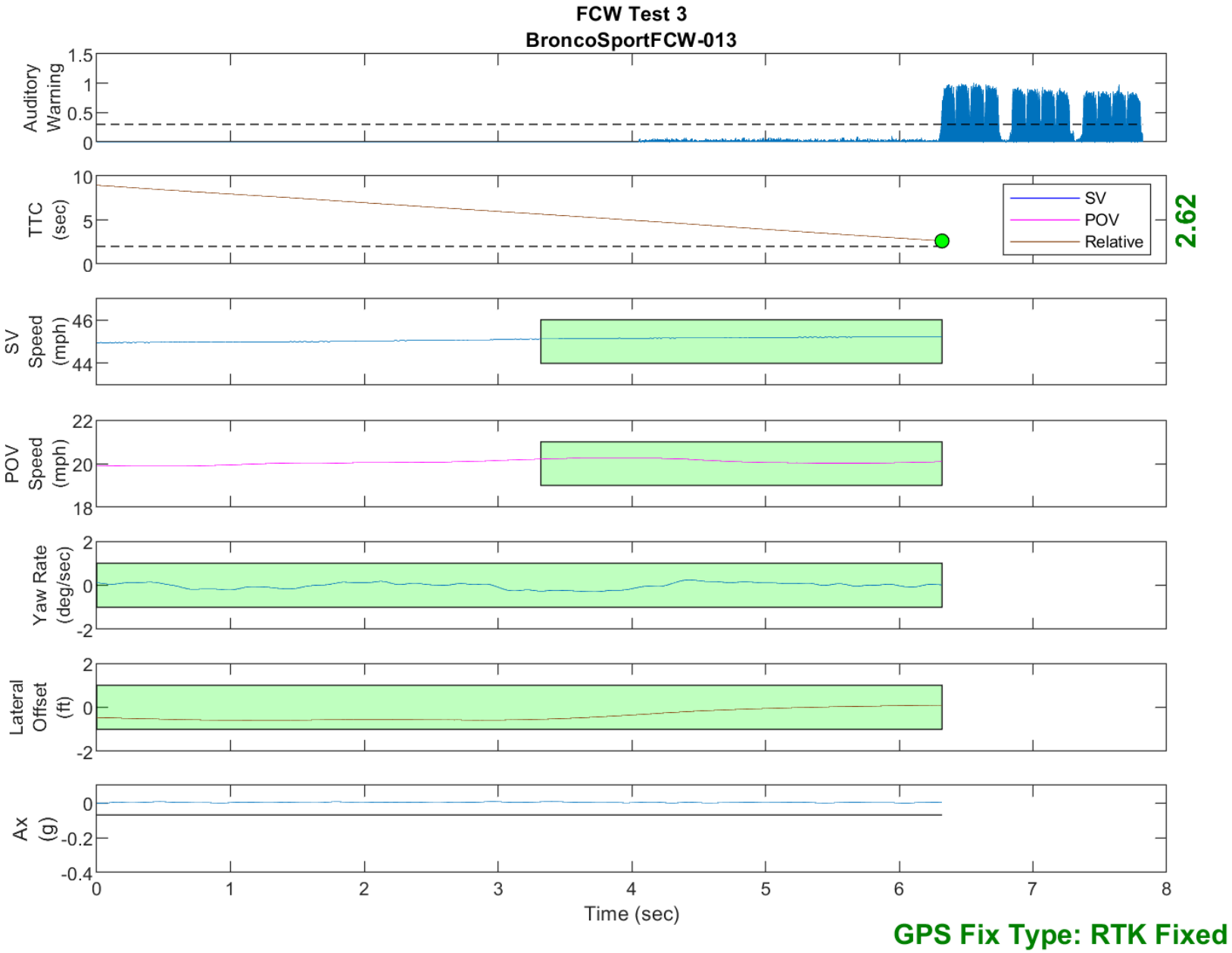

Figure D45. Time History for Run 13, FCW Test 3, Auditory Warning

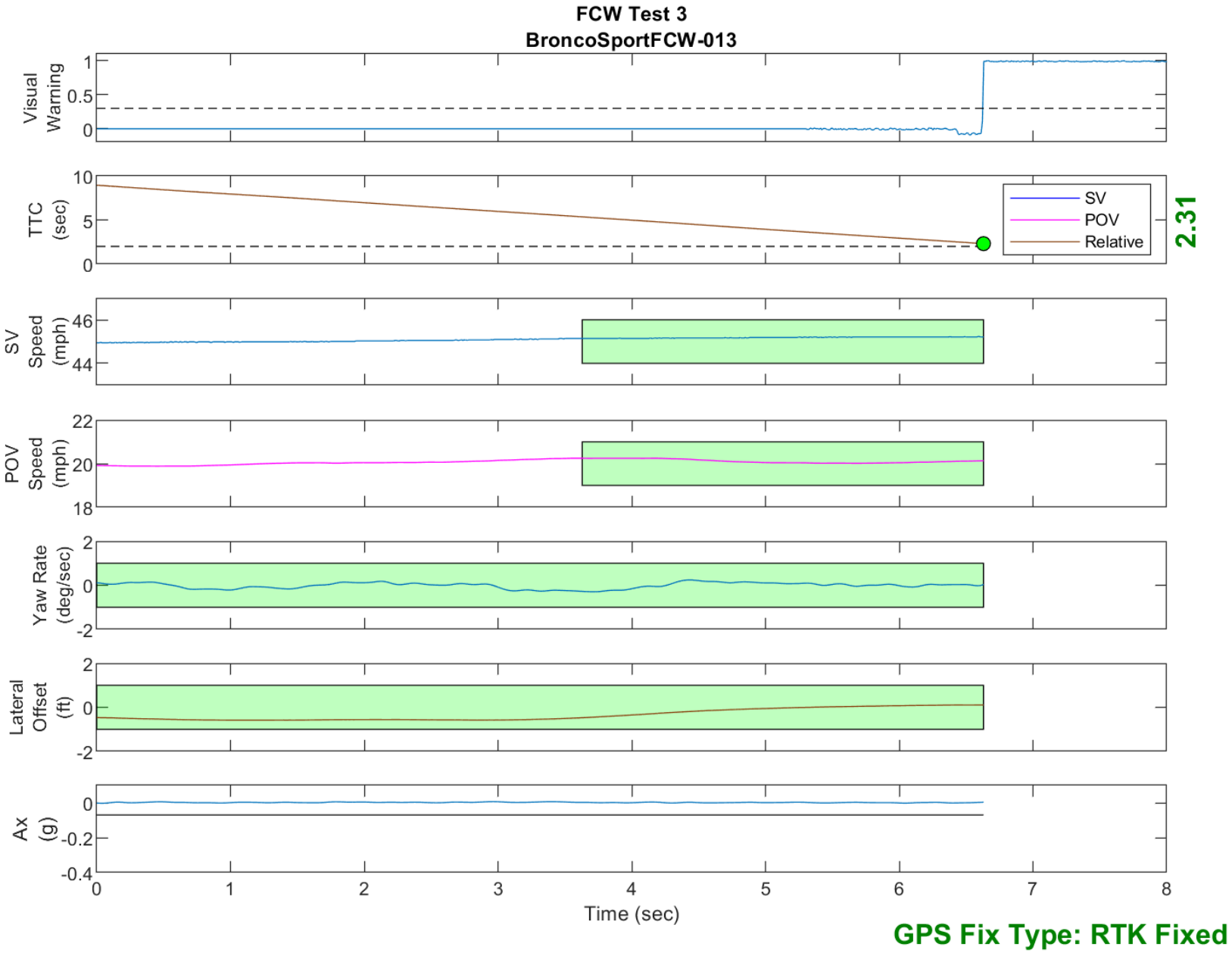

Figure D46. Time History for Run 13, FCW Test 3, Visual Warning

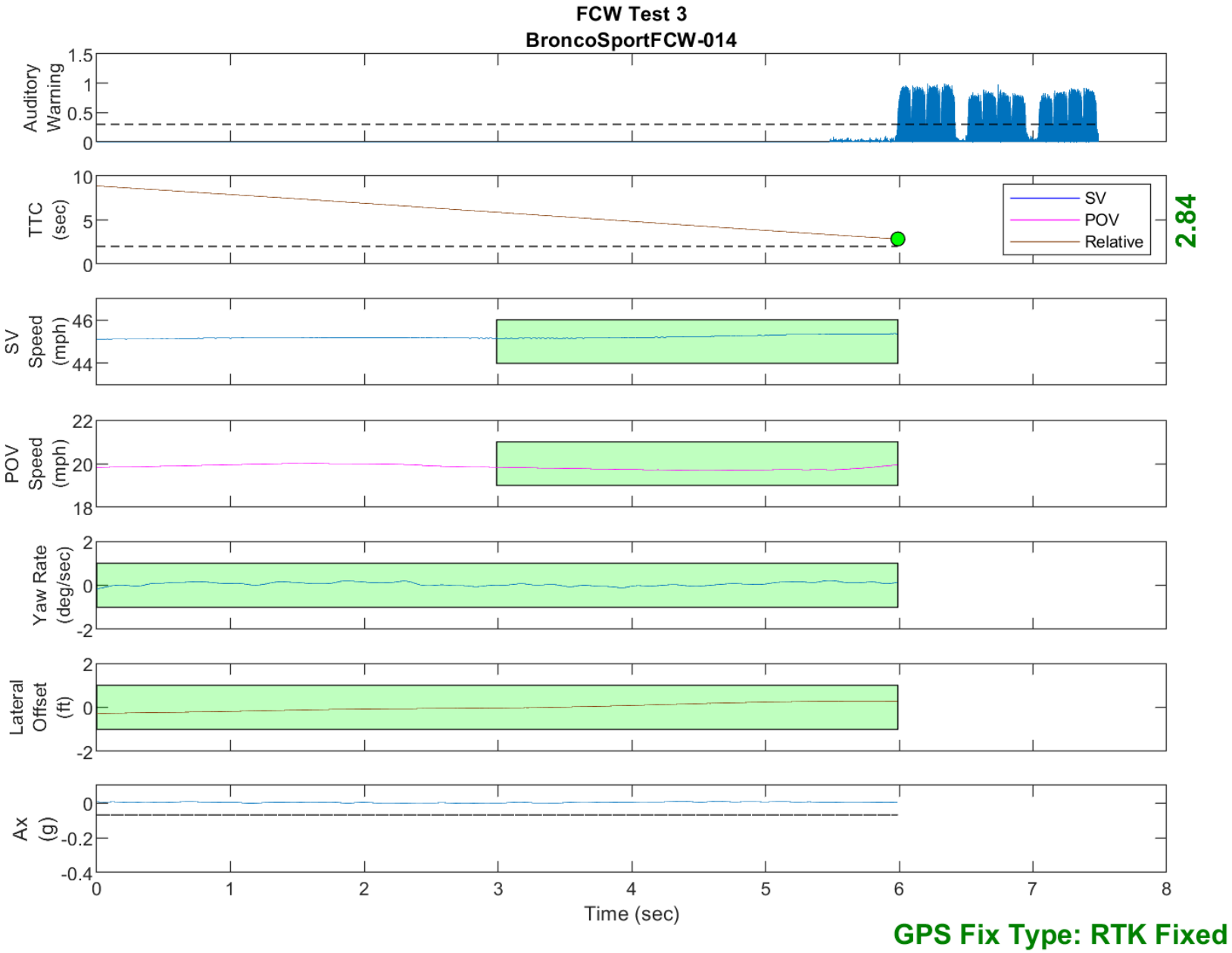

Figure D47. Time History for Run 14, FCW Test 3, Auditory Warning

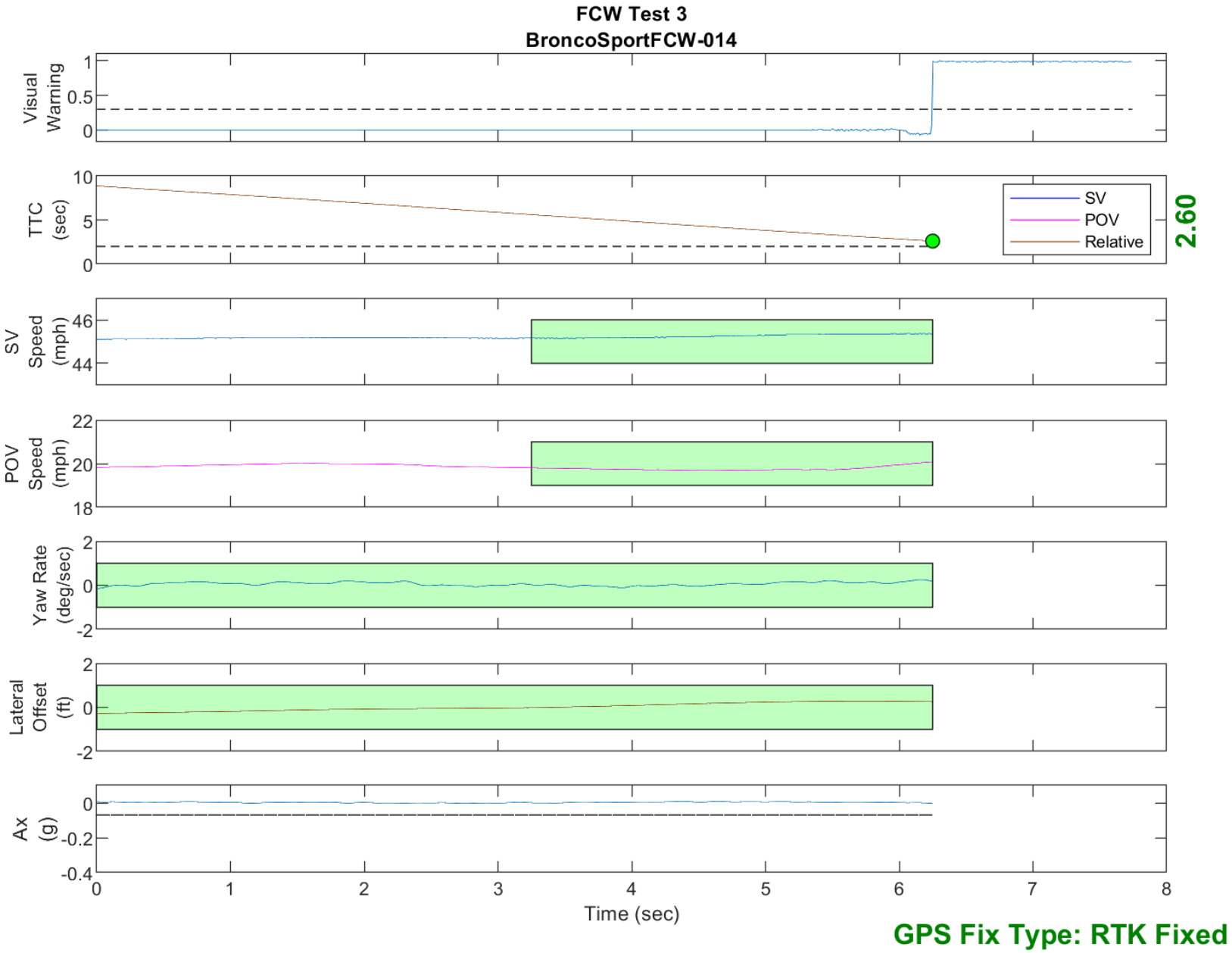

Figure D48. Time History for Run 14, FCW Test 3, Visual Warning