NEW CAR ASSESSMENT PROGRAM
FORWARD COLLISION WARNING CONFIRMATION TEST
NCAP-DRI-FCW-20-20

2020 Volvo S60 T6 AWD Momentum

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10 June 2020

Final Report

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

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

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16. Abstract These tests were conducted on the subject 2020 Volvo S60 T6 AWD Momentum 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 principle 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

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2020 Volvo S60 T6 AWD Momentum

VIN: *7JRA22TKXLG03xxxx*

Test Date: *2/4/2020*

Forward Collision Warning setting: *Early*

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)

2020 Volvo S60 T6 AWD Momentum

TEST VEHICLE INFORMATION

VIN: *7JRA22TKXLG03xxxx*

Body Style: *Sedan* Color: *Osmium Grey Metallic*

Date Received: *1/27/2020* Odometer Reading: *10 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *VOLVO CAR CORPORATION*

Date of manufacture: *08/19*

Vehicle Type: *PC (Passenger Car)*

DATA FROM TIRE PLACARD

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

Rear: *235/45 R18*

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

Rear: *250 kPa (36 psi)*

TIRES

Tire manufacturer and model: *Continental ProContact TX*

Front tire specification: *235/45 R18 98H*

Rear tire specification: *235/45 R18 98H*

Front tire DOT prefix: *VYFUWCCO*

Rear tire DOT prefix: *VYFUWCCO*

FORWARD COLLISION WARNING

DATA SHEET 3: TEST CONDITIONS

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2020 Volvo S60 T6 AWD Momentum

GENERAL INFORMATION

Test date: *2/4/2020*

AMBIENT CONDITIONS

Air temperature: *6.1 C (43 F)*

Wind speed: *2.3 m/s (5.2 mph)*

X Wind speed ≤ 10 m/s (22 mph).

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

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

VEHICLE PREPARATION

Verify the following:

All non-consumable fluids at 100% capacity: **X**

Fuel tank is full: **X**

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

Front: *250 kPa (36 psi)*

Rear: *250 kPa (36 psi)*

FORWARD COLLISION WARNING

DATA SHEET 3: TEST CONDITIONS

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2020 Volvo S60 T6 AWD Momentum

WEIGHT

Weight of vehicle as tested including driver and instrumentation:

Left Front:	*548.4 kg (1209 lb)*	Right Front:	*523.9 kg (1155 lb)*
Left Rear:	*436.8 kg (963 lb)*	Right Rear:	*421.8 kg (930 lb)*
		Total:	*1930.9 kg (4257 lb)*

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

(Page 1 of 3)

2020 Volvo S60 T6 AWD Momentum

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

City Safety (standard equipment)

Forward Collision Warning Setting used in test: *Early*

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

Radar and mono camera (fusion). Both located in the mid-upper part of the windshield.

How is the Forward Collision Warning presented to the driver? (Check all that apply)

- [X] Warning light
- [X] Buzzer or audible alarm
- [X] Vibration
- [ ] Other _____

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

Visual alert – The first visual alert will be a collision warning in the instrument panel. If City Safety applies the brakes, a text message will appear in the instrument panel to notify the driver that the function is/was activated. See Appendix A Figure A-14.

Auditory alert – Repeated beeps.

Haptic alert – Short brake pulses (the pulsation varies according to the vehicle's speed). The seat belt pretensioner may be activated when the AEB function is triggered.

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

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2020 Volvo S60 T6 AWD Momentum

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.

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.

The warnings distance can be adjusted in three level of distances: Early-Normal-Late.

This can be done in the center panel.

1) At start the center panel will display the Home View.

2) There is a tab in the upper part of the display that you could pull down to access the Top View. In this view you will be able to select Settings in the upper left corner.

3) In Settings you then select My Car.

4) In My Car view select IntelliSafe.

5) In IntelliSafe view you will see City Safety Warning and the three option of timing for the collision warning. Late – Normal – Early.

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

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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.

The potential limitations of the system sensors are described in the 301-303 of the Owner's Manual shown in Appendix B pages B-4 to B-6.

Notes:

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. TEST 1 – SUBJECT VEHICLE ENCOUNTERS STOPPED PRINCIPAL OTHER VEHICLE ON A STRAIGHT ROAD

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

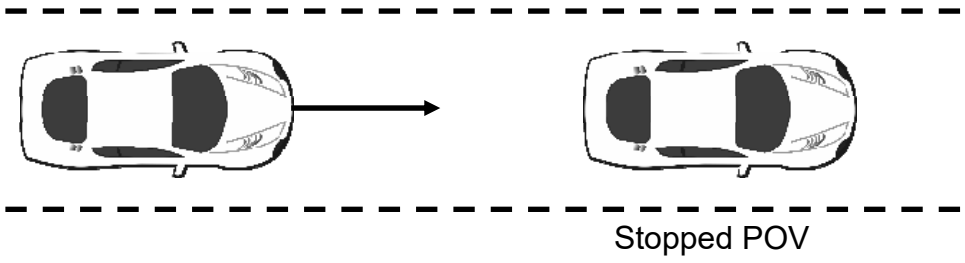


Figure 1. Depiction of Test 1

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.

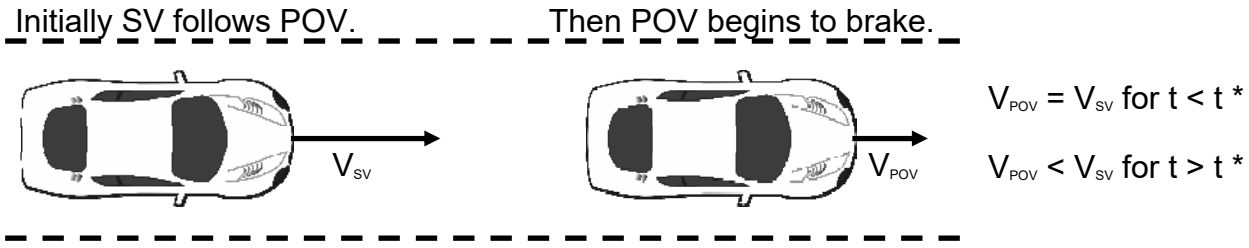


Figure 2. Depiction of Test 2

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 ±0.03g, 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).

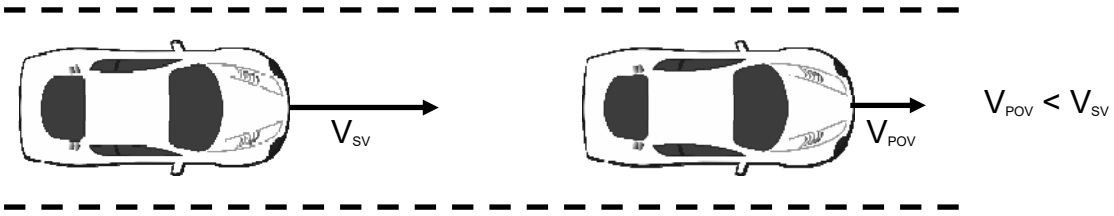


Figure 3. Depiction of Test 3

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	Omega DPG8001	17042707002	By: DRI Date: 7/3/2019 Due: 7/3/2020
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform 5338 N/	0.5% of applied load	Intercomp SWI	1110M206352	By: DRI Date: 1/6/2020 Due: 1/6/2021
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	NA
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +		By: Oxford Technical Solutions
					2176	Date: 4/11/2018 Due: 4/11/2020
					2258	Date: 5/3/2019 Due: 5/3/2021
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	NA

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	NA	NA
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	NA	NA
Accelerometer	Acceleration (to measure time at haptic alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	NA	NA
Coordinate Measurement Machine	Inertial Sensing System Coordinates	0-8 ft 0-2.4 m	±.0020 in. ±.051 mm (Single point articulation accuracy)	Faro Arm, Fusion	UO8-05-08-06636	By: DRI Date: 1/6/2020 Due: 1/6/2021

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 audible or haptic alerts, part of the pre-test instrumentation verification process is to determine the tonal frequency of the audible warning or the vibration frequency of the tactile warning through use of the PSD (Power Spectral Density) function in Matlab. This is accomplished in order to identify the center frequency around which a band-pass filter is applied to subsequent audible or tactile warning data so that the beginning of such warnings can be programmatically determined. The band-pass filter used for these warning signal types is a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 2.

Table 2. Audible and Tactile Warning Filter Parameters

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

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

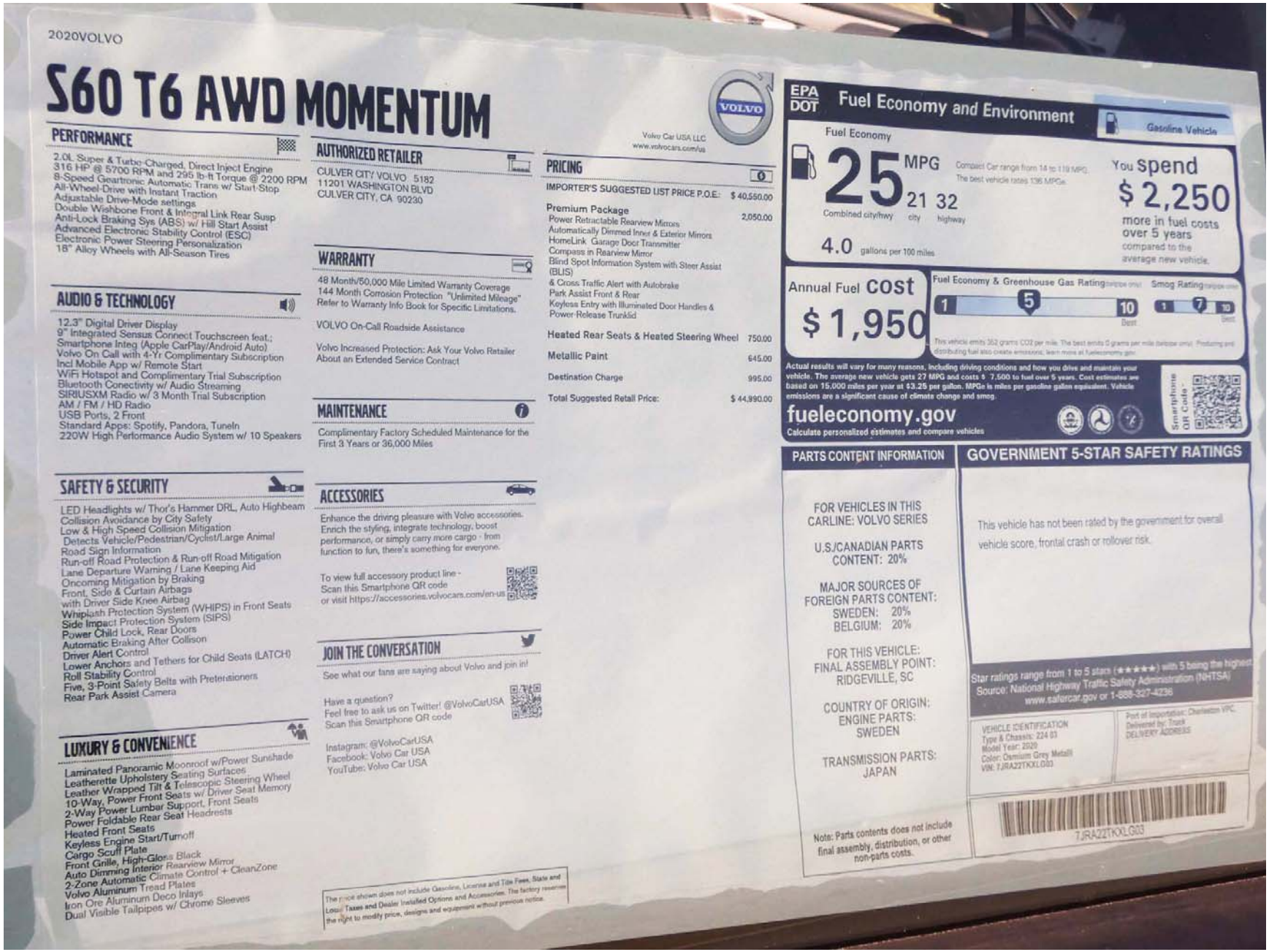


Figure A3. Window Sticker (Monroney Label)

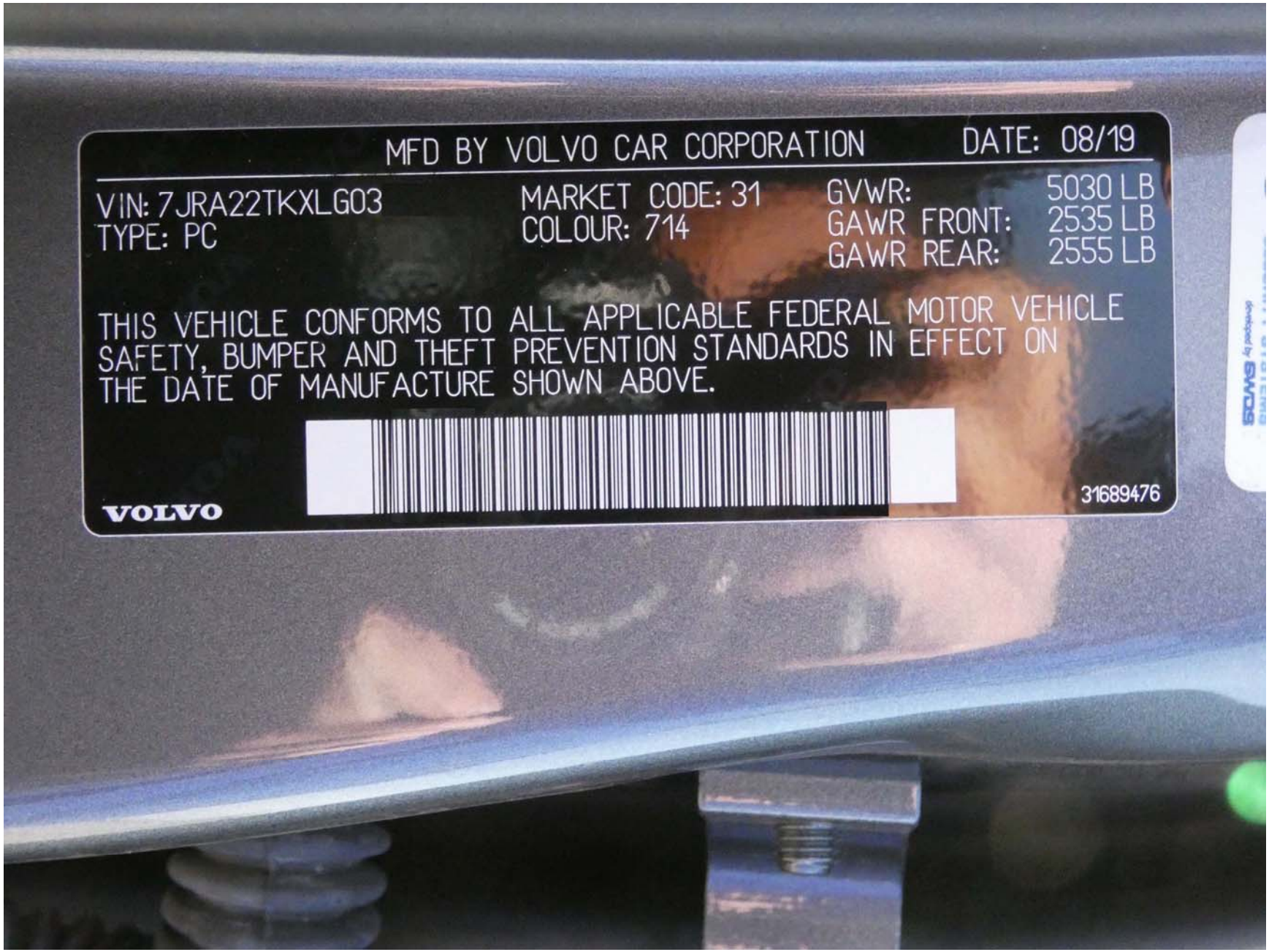


Figure A4. Vehicle Certification Label

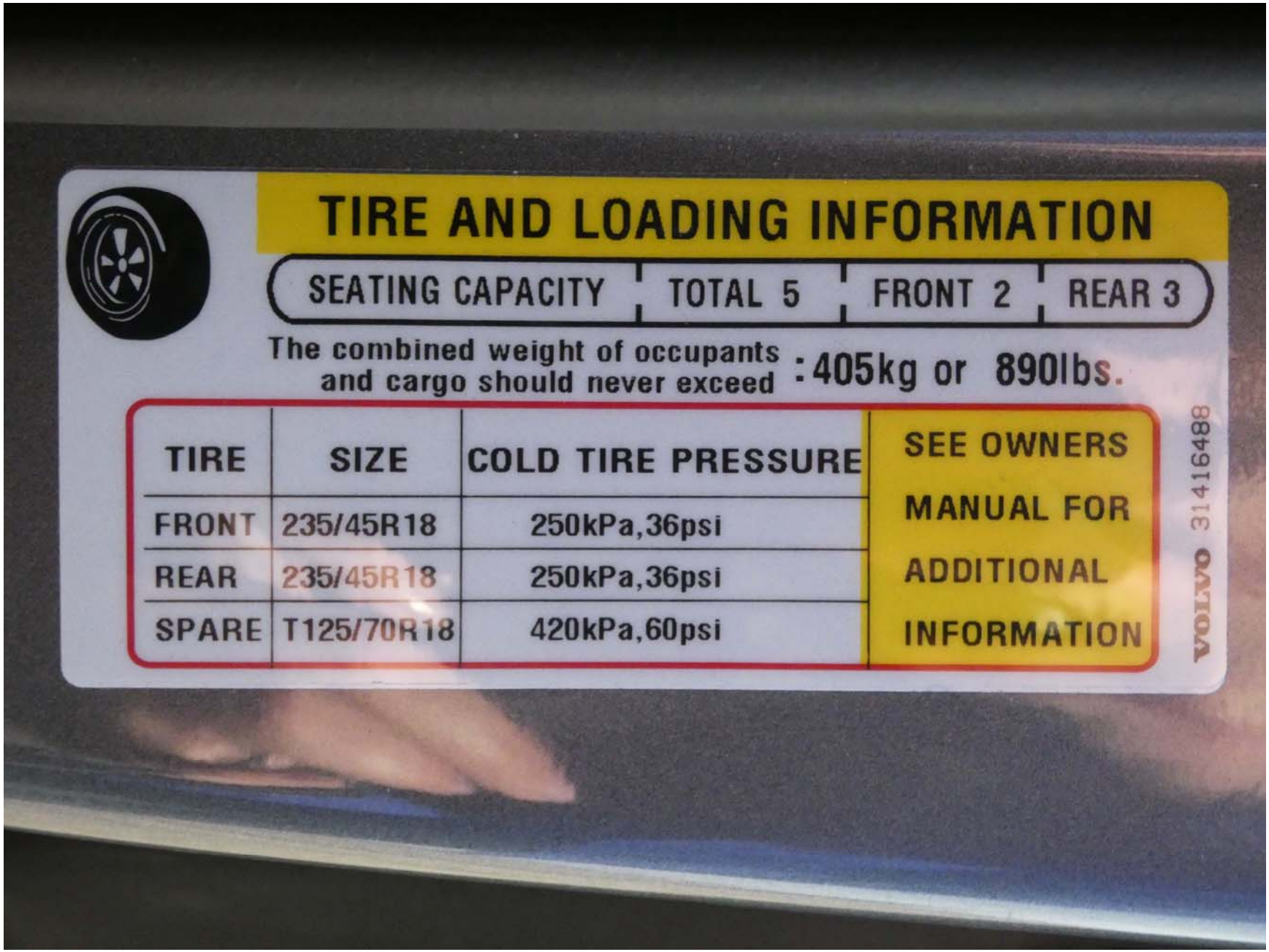


Figure A5. Tire Placard

Figure A6. Front View of Principal Other Vehicle

Figure A7. Rear View of Principal Other Vehicle

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

Figure A9. Sensor for Detecting Visual Alerts

Figure A10. Sensor for Detecting Auditory Alerts

Figure A11. Computer Installed in Subject Vehicle

Figure A12. Brake Actuation System Installed in Principal Other Vehicle

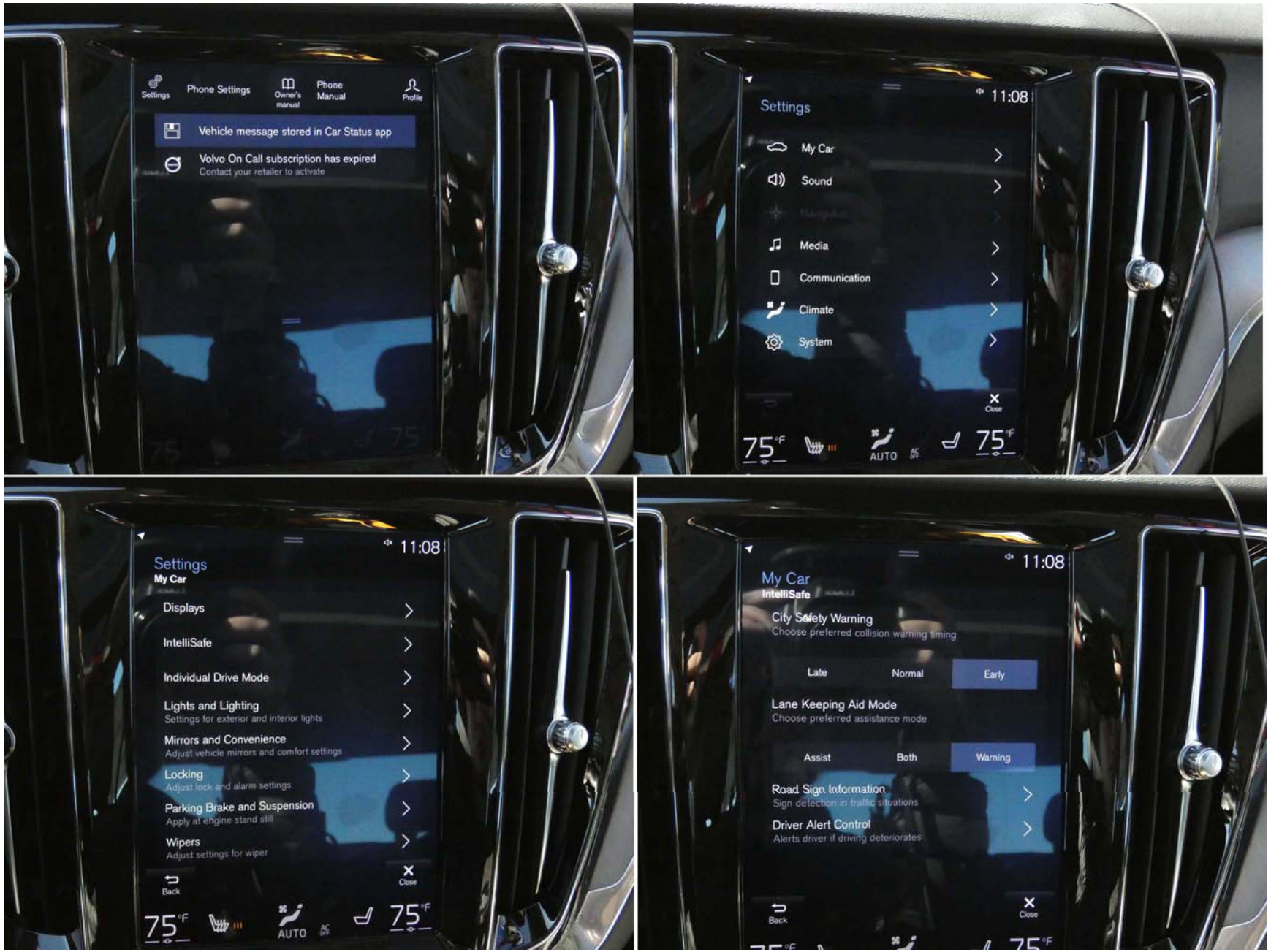


Figure A13. System Setting Menus

Figure A14. FCW Visual Alert

APPENDIX B

Excerpts from Owner’s Manual

⚠ WARNING

The driver should be aware that if conditions suddenly change when using Passing Assistance, the function may implement an undesired acceleration in certain conditions.

Some situations should be avoided, e.g. if:

- the vehicle is approaching an exit in the same direction as passing would normally occur
- the vehicle ahead slows before your vehicle has had time to switch to the passing lane
- traffic in the passing lane slows down

Situations of this type can be avoided by temporarily putting Adaptive Cruise Control or Pilot Assist in standby mode.

Related information

- Passing assistance (p. 296)
- Adaptive Cruise Control* (p. 270)
- Pilot Assist* (p. 279)
- Adaptive Cruise Control* standby mode (p. 274)
- Pilot Assist* standby mode (p. 284)

Radar sensor

The radar sensor is used by several driver support systems to detect other vehicles.

Location of radar sensor.

The radar sensor is used by the following functions:

- Distance Alert*
- Adaptive Cruise Control*
- Pilot Assist*
- Lane Keeping Aid
- City Safety

Any modifications to the radar sensor may make its use illegal.

Related information

- Driver support systems (p. 260)
- Camera/radar sensor limitations (p. 301)
- Recommended camera and radar sensor maintenance (p. 305)
- Radar sensor type approval (p. 298)

Camera

The camera is used by several driver support systems to e.g. detect lane marker lines or road signs.

Location of the camera.

The camera is used by the following functions:

- Adaptive Cruise Control*
- Pilot Assist*
- Lane Keeping Aid*
- Steering assistance at risk of collision
- City Safety
- Driver Alert Control*
- Road Sign Information*
- Active high beams*
- Park Assist*

Related information

- Driver support systems (p. 260)
- Camera/radar sensor limitations (p. 301)
- Recommended camera and radar sensor maintenance (p. 305)

* Option/accessory.

Camera/radar sensor limitations

The camera and radar sensor used by several of the driver support functions has certain limitations, which also affect the functions using the camera and radar sensor. The driver should be aware of the following limitations:

Camera and radar

Obstructed camera

The area marked in the illustration must be cleaned regularly and kept free of decals, objects, solar film, etc.

The camera is located on the upper interior section of the windshield along with the radar sensor.

Do not place, affix or mount anything on the inside or outside of the windshield, or in front of or around the camera and radar sensor – this could disrupt camera and radar-based functions. It could cause functions to be reduced, deactivated completely or to produce an incorrect function response.

If this symbol and the message "**Windscreen sensor Sensor blocked, see Owner's manual**" is displayed in the instrument panel, it means that the camera and radar sensor are unable to detect other vehicles, cyclists, pedestrians and large animals in front of the vehicle and that the vehicle's camera and radar-based functions may be obstructed.

The following table shows some of the situations that can cause the message to be displayed, and suggested actions:

Cause	Action
The area of the windshield in front of the camera/radar sensor is dirty or covered by ice or snow.	Clean the windshield in front of the camera/radar sensor and remove dirt, ice and snow.
Thick fog, heavy rain or snow is blocking the radar signals or the camera's range of visibility.	No action. Heavy precipitation may sometimes prevent the camera/radar sensor from functioning.

▸▸

Cause	Action
Water or snow is spraying/swirling up and blocking the radar signals or the camera's range of visibility.	No action. Very wet or snow-covered roads may sometimes prevent the camera/radar sensor from functioning.
There is dirt between the inside of the windshield and the camera/radar sensor.	Consult a workshop to have the area of the windshield on the inside of the camera's casing cleaned. An authorized Volvo workshop is recommended.
Bright sunlight.	No action. The camera/radar sensor will reset automatically when lighting conditions improve.

High temperatures
If the temperature in the passenger compartment is very high, the camera/radar sensor will switch off temporarily for approx. 15 minutes after the engine is started to protect its electronic components. When the temperature has cooled sufficiently, the camera/radar sensor will automatically restart.

Damaged windshield

NOTE

Failure to take action could result in reduced performance for the driver support systems that use the camera and radar unit. It could cause functions to be reduced, deactivated completely or to produce an incorrect function response.

To avoid the risk of malfunction of the driver support systems that use the radar sensor, the following also apply:

- If there are cracks, scratches or stone chips on the windshield in front of any of the camera and radar sensor "windows" and this covers an area of about 0.5 × 3.0 mm (0.02 × 0.12 in.) or more, contact a workshop to have the windshield replaced[53].
- Volvo advises **against** repairing cracks, scratches or stone chips in the area in front of the camera and radar sensor – the entire windshield should instead be replaced.
- Before replacing the windshield, contact a workshop[53] to verify that the right windshield has been ordered and installed.
- The same type of windshield wipers or wipers approved by Volvo should be used for replacement.
- If the windshield is replaced, the camera and radar sensor must be recalibrated by a workshop[53] to help ensure proper functioning of all of the vehicle's camera and radar-based systems.

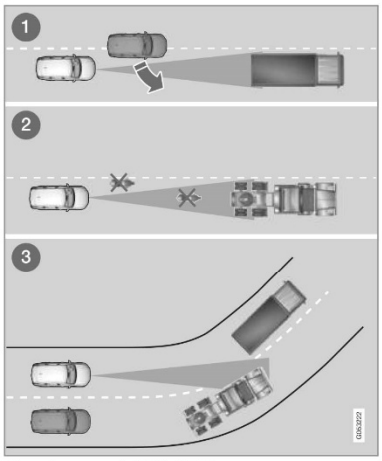
Radar

Vehicle speed
The radar sensor's ability to detect a vehicle ahead is significantly reduced if the speed of the vehicle ahead differs greatly from your vehicle's speed.

[53] An authorized Volvo workshop is recommended.

Limited field of vision

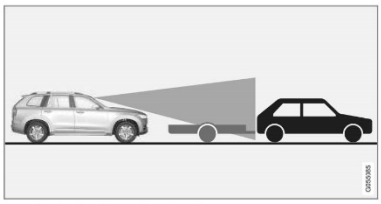
The radar sensor has a limited field of vision. In some situations, it may detect a vehicle later than expected or not at all.



The radar sensor's field of vision.

1. The radar sensor's detection of vehicles very close to your vehicle may be delayed in certain situations, e.g. if a vehicle pulls in between your vehicle and the vehicle directly ahead.
2. Small vehicles, such as motorcycles, or vehicles that are not driving in the center of the lane may remain undetected.
3. In curves, the radar may detect the wrong vehicle or lose sight of a target vehicle.

Low trailers



Low trailer in the radar shadow.

Low trailers may also be difficult or even impossible for the radar to detect. The driver should be extra alert when driving behind vehicles towing low trailers when Adaptive Cruise Control* or Pilot Assist* is activated.

Camera

Reduced visibility

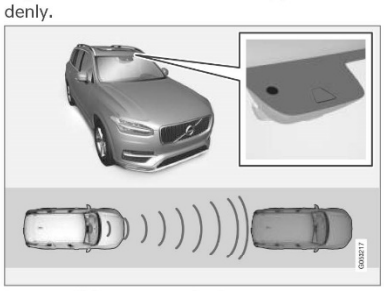
Cameras have the same limitations as the human eye. In other words, their "vision" is impaired by adverse weather conditions such as heavy snowfall/rain, dense fog, swirling dust/snow, etc. These conditions may reduce the function of systems that depend on the camera or cause these systems to temporarily stop functioning.

Strong sunlight, reflections from the road surface, ice or snow covering the road, a dirty road surface, or unclear lane marker lines may drastically reduce the camera's ability to detect the side of a lane, a pedestrian, a cyclist, a large animal or another vehicle.

▸▸

City Safety™

City Safety[54] can alert the driver with light, sound and pulsations in the brake pedal to help the driver detect pedestrians, cyclists, large animals and vehicles that appear suddenly.



Location of the camera and radar sensor.

City Safety can help prevent a collision or lower the vehicle's speed at the point of impact.

City Safety is an aid intended to assist the driver if a collision with a pedestrian, large animal, cyclist or vehicle is imminent.

City Safety can help the driver avoid a collision when e.g. driving in stop-and-go traffic, when changes in the traffic ahead and driver distraction could lead to an incident.

The function assists the driver by automatically applying the brakes if there is an imminent risk of a collision and the driver does not react in time by braking and/or steering away.

City Safety activates a brief, forceful braking in an attempt to stop your vehicle immediately behind the vehicle or object ahead.

City Safety is activated in situations in which the driver should have applied the brakes much earlier, which means that the system will not be able to assist the driver in all situations.

City Safety is designed to be activated as late as possible to help avoid unnecessary intervention. Automatic braking will only be applied after or during a collision warning.

Normally, the occupants of the vehicle will not be aware of City Safety except when the system intervenes when a collision is imminent.

⚠ WARNING

- The function is supplementary driver support intended to facilitate driving and help make it safer – it cannot handle all situations in all traffic, weather and road conditions.
- The driver is advised to read all sections in the Owner's Manual about this function to learn of its limitations, which the driver must be aware of before using the function.
- Driver support functions are not a substitute for the driver's attention and judgment. The driver is always responsible for ensuring the vehicle is driven in a safe manner, at the appropriate speed, with an appropriate distance to other vehicles, and in accordance with current traffic rules and regulations.

Related information

- Driver support systems (p. 260)
- City Safety sub-functions (p. 307)
- Setting a warning distance for City Safety (p. 309)
- Detecting obstacles with City Safety (p. 310)

54 This function is not available on all markets.

- City Safety braking for oncoming vehicles (p. 315)
- Automatic braking during delayed evasive maneuvers with City Safety (p. 315)
- City Safety in crossing traffic (p. 312)
- City Safety steering assistance for evasive maneuver (p. 314)
- City Safety limitations (p. 316)
- City Safety messages (p. 319)

City Safety sub-functions

City Safety[55] can help the driver avoid a collision with a vehicle, cyclist or large animal ahead by reducing the vehicle's speed using its automatic braking function.
If the difference in speed is greater than the speeds specified below, the City Safety auto-brake function cannot prevent a collision, but it can help mitigate its effects.

Vehicles
City Safety can help prevent a collision with a vehicle ahead by reducing your vehicle's speed by up to 60 km/h (37 mph).

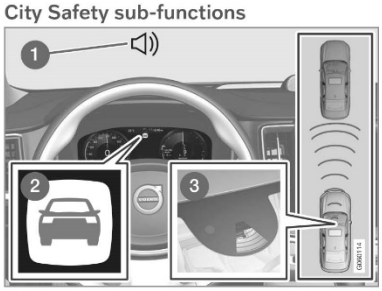
Cyclists
City Safety can help prevent a collision with a cyclist ahead by reducing your vehicle's speed by up to 50 km/h (30 mph).

Pedestrians
City Safety can help prevent a collision with a pedestrian ahead by reducing your vehicle's speed by up to 45 km/h (28 mph).

Large animals
If there is a risk of colliding with a large animal, City Safety can help reduce your vehicle's speed by up to 15 km/h (9 mph).

The braking function for large animals is primarily intended to mitigate the force of a collision at higher speeds. Braking is most effective at speeds above 70 km/h (43 mph) and less effective at lower speeds.

City Safety sub-functions



Function overview.

1. Acoustic collision warning signal
2. Collision warning symbol
3. Camera/radar sensor distance monitoring

City Safety carries out three steps in the following order:

1. Collision warning
2. Brake assistance
3. Auto-brake

Descriptions of what happens in these three steps are provided below.

55 This function is not available on all markets.

▸▸

1 - Collision warning
The driver is first alerted to the risk of an imminent collision.

In vehicles equipped with a head-up display*, a flashing warning symbol will be displayed on the windshield.

Collision warning symbol on the windshield.

NOTE

Visual warnings on the windshield may be difficult to notice in cases of strong sunlight, reflections, extreme light contrasts, or if the driver is wearing sunglasses or is not looking straight ahead.

City Safety can detect pedestrians, cyclists or vehicles that are stationary, are moving in the same direction as your vehicle and are ahead of your vehicle. City Safety can also detect pedestrians, cyclists or large animals that are crossing the road in front of your vehicle.

If there is a risk of a collision with a pedestrian, large animal, cyclist or another vehicle, the driver will be alerted with light, sound and pulsations in the brake pedal. At lower speeds, during hard braking or if the accelerator pedal is pressed, the brake pedal pulsation warning will not be given. The intensity of the brake pedal pulsations varies according to the vehicle's speed.

2 - Brake assistance
If the risk of a collision increases after the collision warning, brake support will be activated.

If the system determines that the pressure the driver is exerting on the brake pedal is insufficient to prevent the collision, brake support will increase pressure.

3 - Auto-brake
The automatic braking function is activated at the last moment.

If the driver has not taken evasive action by this stage and a collision is imminent, the automatic braking function will be triggered. This occurs whether or not the driver is pressing the brake pedal. Full braking force will be applied to reduce the speed at impact or reduced braking effect will be applied if this is sufficient to avoid the collision.

The seat belt tensioner may be activated when the automatic braking function is triggered.

In certain situations, auto-braking may begin with a limited braking force before applying full braking force.

If City Safety has prevented a collision, the vehicle will be kept at a standstill until the driver takes action. If the vehicle has slowed to avoid colliding with a slower-moving vehicle ahead, your speed will be reduced to that vehicle's speed.

Auto-braking can always be cancelled if the driver presses hard on the accelerator pedal.

NOTE

When City Safety activates the brakes, the brake lights come on.

When City Safety applies the brakes, a text message will appear in the instrument panel to notify the driver that the function is/was activated.

WARNING

City Safety may not be used to change how the driver operates the vehicle. The driver must not only rely on City Safety to brake the vehicle.

* Option/accessory.

Related information

- City Safety™ (p. 306)
- City Safety in crossing traffic (p. 312)
- City Safety braking for oncoming vehicles (p. 315)
- City Safety limitations (p. 316)
- Head-up display* (p. 139)
- Seat belt tensioners (p. 50)

Setting a warning distance for City Safety

City Safety[56] is always active, but the function's warning distance can be adjusted.

NOTE

The City Safety function cannot be deactivated. It is activated automatically each time the engine/electric motor is started.

The alert distance determines the sensitivity of the system and regulates the distance at which the light, sound and brake pulsations will be activated.

To select warning distance:

1. Select **Settings** → **My Car** → **IntelliSafe** in the center display's Top view.
2. Under **City Safety Warning**, tap **Late**, **Normal** or **Early** to set the desired warning distance.

If the driver feels that the **Early** setting is giving too many warnings or finds them irritating, the **Normal** or **Late** warning distance settings can be selected instead.

If the driver feels that the warnings are too frequent and distracting, the warning distance can be reduced. This will reduce the total number of warnings, but it will also result in City Safety providing warnings at a later stage.

The **Late** warning distance setting should therefore only be used in exceptional cases, such as when a more dynamic driving style is preferred.

56 This function is not available on all markets.

▸▸

WARNING

- No automatic system can guarantee 100% correct function in all situations. You should therefore never test use of City Safety in the direction of people, animals or vehicles – this could lead to severe damage, serious personal injury or even death.
- City Safety warns the driver if there is a risk of collision, but the function cannot reduce the driver's reaction time.
- Even if the warning distance has been set to **Early**, warnings may be perceived as late in certain situations – e.g. when there are large speed differences or if the vehicle ahead suddenly brakes heavily.
- With the warning distance set to **Early**, warnings come further in advance. This may cause the warnings to come more frequently than with warning distance **Normal**, but is recommended since it can make City Safety more effective.

NOTE

The warning with direction indicators for Rear Collision Warning* is deactivated if the collision warning distance in the City Safety function is set to the lowest level "**Late**".

The seat belt tensioning and braking functions remain active.

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)
- Rear Collision Warning* (p. 320)

Detecting obstacles with City Safety

City Safety[57] can help the driver detect other vehicles, cyclists, large animals and pedestrians.

Vehicles

City Safety can detect most vehicles that are stationary or are moving in the same direction as your vehicle. In some cases, it can also detect oncoming vehicles and crossing traffic.

For City Safety to be able to detect a vehicle in the dark, its headlights and taillights must be on and clearly visible.

Cyclists

Examples of what City Safety would interpret to be a cyclist: clear body and bicycle shapes.

57 This function is not available on all markets.

* Option/accessory.

For good performance, the system's function for cyclist detection needs the clearest possible information about the contours of the bicycle and of the cyclist's head, arm, shoulders, legs, torso and lower body in combination with normal human movements.

If large portions of the cyclist's body or the bicycle itself are not visible to the function's camera, it will not be able to detect a cyclist.

The system can only detect adult cyclists riding on bicycles intended for adults.

⚠ WARNING

City Safety is supplementary driver support, but it cannot detect all cyclists in all situations and, for example, cannot see:

- partially obscured cyclists.
- cyclists if the background contrast of the cyclist is poor - warning and brake interventions may then be late or not occur at all.
- cyclists in clothing that hides their body contour.
- bikes loaded with large objects.

The driver is always responsible for ensuring that the vehicle is driven correctly and with a safety distance suitable for the speed.

Pedestrians

Examples of what the system considers to be a pedestrian: clear body contours.

For good performance, the system's function for pedestrian detection needs the clearest possible information about the contours of the pedestrian's head, arm, shoulders, legs, torso and lower body in combination with normal human movements.

In order to detect a pedestrian, there must be a contrast to the background, which could depend on clothing, weather conditions, etc. If there is little contrast, the person may be detected late or not at all, which may result in a delayed reaction from the system or no reaction at all.

City Safety can detect pedestrians even in dark conditions if they are illuminated by the vehicle's headlights.

⚠ WARNING

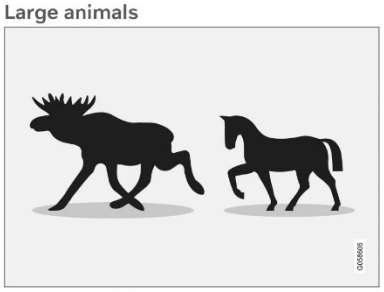
City Safety is supplementary driver support, but it cannot detect all pedestrians in all situations and, for example, cannot see:

- partially obscured pedestrians, people in clothing that hides their body contour or pedestrians shorter than 80 cm (32 in.).
- pedestrians if the background contrast of the pedestrians is poor - warning and brake interventions may then be late or not occur at all.
- pedestrians who are carrying large objects.

The driver is always responsible for ensuring that the vehicle is driven correctly and with a safety distance suitable for the speed.

▸▸

Large animals



Examples of what City Safety would interpret as a large animal: stationary or moving slowly and with clear body contours.

For good performance, the system's function for detecting large animals (e.g. moose, horses, etc.) needs the clearest possible information about body contours. This entails being able to detect the animal straight from the side in combination with normal movements for that animal.

If parts of the animal's body are not visible to the function's camera, the system will not be able to detect the animal.

City Safety can detect large animals even in dark conditions if they are illuminated by the vehicle's headlights.

WARNING

City Safety is supplementary driver support, but it cannot detect all large animals in all situations and, for example, cannot see:

- partially obscured larger animals.
- larger animals seen from the front or from behind.
- running or fast moving larger animals.
- larger animals if the contrast of the animal's background is poor - warning and brake interventions may then occur late or not at all.
- smaller animals such as cats and dogs.

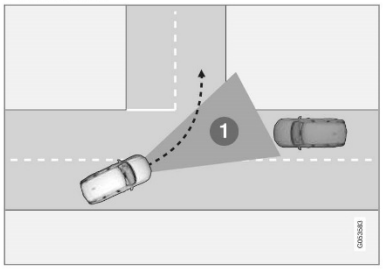
The driver is always responsible for ensuring that the vehicle is driven correctly and with a safety distance suitable for the speed.

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

City Safety in crossing traffic

City Safety[58] can assist the driver when turning into the path of an oncoming vehicle in an intersection.



1 Sector in which City Safety can detect an oncoming vehicle in crossing traffic.

In order for City Safety to detect an oncoming vehicle in situations where there is a risk of a collision, that vehicle must be within the sector in which City Safety can analyze the situation.

The following criteria must also be met:

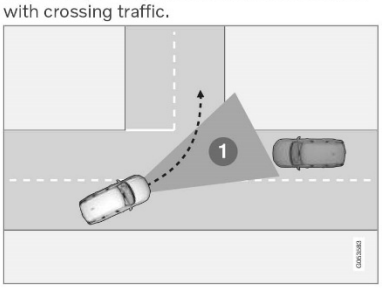
- your vehicle's speed must be at least 4 km/h (3 mph)
- your vehicle must be making a left turn
- the oncoming vehicle's headlights must be on

58 This function is not available on all markets.

Related information
- City Safety™ (p. 306)
- City Safety limitations (p. 316)

Limitations of City Safety in crossing traffic

In certain situations, it may be difficult for City Safety to help the driver avoid a collision with crossing traffic.



For example:

- on slippery roads when Electronic Stability Control (ESC) is actively operating
- if an approaching vehicle is detected at a late stage
- if the oncoming vehicle is partially obstructed by another vehicle or object
- if the oncoming vehicle's headlights are off
- if the oncoming vehicle is moving erratically and e.g. suddenly changes lanes at a late stage.

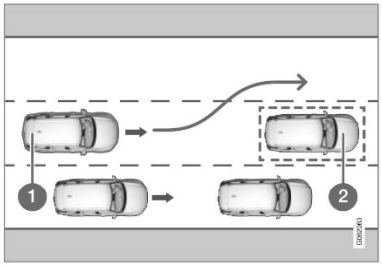
NOTE

The function uses the vehicle's camera and radar sensor, which has certain general limitations.

Related information
- City Safety in crossing traffic (p. 312)
- City Safety limitations (p. 316)
- Camera/radar sensor limitations (p. 301)

City Safety steering assistance for evasive maneuver

City Safety steering assistance can help the driver steer away from a vehicle/obstacle when it is not possible to avoid a collision by braking alone. City Safety steering assistance is always activated and cannot be switched off.



1. Your vehicle swerves away
2. Slow-moving/stationary vehicle or obstacle.

City Safety helps provide assistance by strengthening the driver's steering movements, but only if the driver has begun evasive action and the system detects that the driver's steering movements are not sufficient to avoid a collision.

The brake system is used simultaneously to further strengthen steering movements. The function also helps stabilize the vehicle after it has passed the obstacle.

City Safety steering assistance can detect:

- vehicles
- cyclists
- pedestrians
- large animals

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

City Safety steering assistance limitations during evasive maneuvers

City Safety steering assistance may have limited functionality in certain situations and not intervene, e.g.:

- at speeds outside the range of 50-100 km/h (30-62 mph)
- if the driver does not take evasive action
- if speed-dependent power steering wheel resistance is working at reduced power – e.g. during cooling due to overheating.

NOTE

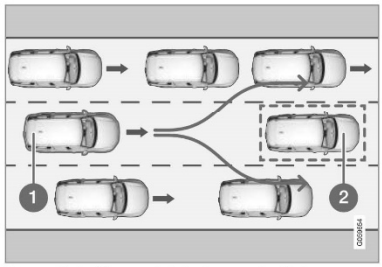
The function uses the vehicle's camera and radar sensor, which has certain general limitations.

Related information

- City Safety steering assistance for evasive maneuver (p. 314)
- City Safety limitations (p. 316)
- Speed-dependent steering wheel resistance (p. 260)
- Camera/radar sensor limitations (p. 301)

Automatic braking during delayed evasive maneuvers with City Safety

City Safety[59] can assist the driver by automatically braking the vehicle when it is not possible to avoid a collision by steering alone.
City Safety assists the driver by periodically attempting to predict possible "escape routes" to the sides of the vehicle in the event a slow-moving or stationary vehicle were to be detected at a late stage.



Your vehicle (1) cannot detect any potential escape routes for veering away from the vehicle ahead (2) and may therefore apply the brakes at an earlier stage.

1. Own vehicle
2. Slow-moving/stationary vehicles

City Safety will not intervene to automatically apply the brakes if it is possible for the driver to avoid a collision by steering the vehicle.

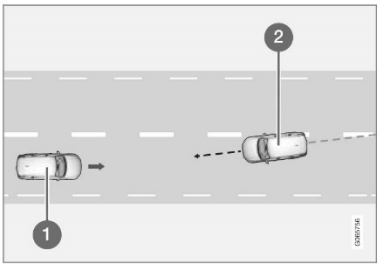
However, if City Safety determines that an evasive maneuver would not be possible due to traffic in the adjacent lane(s), the function can assist the driver by automatically starting to apply the brakes at an earlier stage.

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

City Safety braking for oncoming vehicles

City Safety can help you apply the brakes for an oncoming vehicle in your lane.
If an oncoming vehicle veers into your lane and a collision is unavoidable, City Safety can help reduce your vehicle's speed to attempt to mitigate the force of the collision.



1. Own vehicle
2. Oncoming vehicles

The following criteria must be met for the function to work:

- your vehicle's speed must be above 4 km/h (3 mph)
- the road must be straight

[59] This function is not available on all markets.

- your lane must have clear side lane markings
- your vehicle must be positioned straight in your lane
- the oncoming vehicle must be positioned within your vehicle's lane markings
- the oncoming vehicle's headlights must be on
- the function can only handle "front-to-front" collisions
- the function can only detect vehicles with four wheels.

WARNING

Warnings and brake interventions due to an imminent collision with an oncoming vehicle always come very late.

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

City Safety limitations

City Safety[60] functionality may be reduced in certain situations.

Surroundings

Low objects

Hanging objects, such as flags for overhanging loads or accessories such as auxiliary lights or front protective grids that extend beyond the height of the hood, may limit City Safety functionality.

Slippery road conditions

The extended braking distance on slippery roads may reduce City Safety's capacity to help avoid a collision. In these types of situations, the Anti-lock Braking System and Electronic Stability Control (ESC[61]) are designed for optimal braking power with maintained stability.

Backlighting

The visual warning signal in the windshield may be difficult to detect in bright sunlight, if there are reflections, or if the driver is wearing sunglasses or not looking straight ahead.

Heat

If the temperature in the passenger compartment is high due to e.g. bright sunlight, the visual warning signal in the windshield may be temporarily disabled.

Camera and radar sensor's field of vision

The camera's field of vision is limited and in certain situations, it may be unable to detect pedestrians, large animals, cyclists or vehicles, or it may detect them later than expected.

Vehicles that are dirty may be detected later than clean vehicles, and in dark conditions, motorcycles may be detected late or not at all.

If a text message displayed in the instrument panel indicates that the camera/radar sensor is obstructed, it may be difficult for City Safety to detect pedestrians, large animals, cyclists, vehicles or lane markings in front of the vehicle. City Safety functionality may therefore be reduced.

Text messages may not be displayed for all situations in which the windshield sensors are blocked. The driver must therefore always keep the windshield in front of the camera/radar sensor clean.

CAUTION

Only a workshop may perform maintenance on driver support components – an authorized Volvo workshop is recommended.

60 This function is not available on all markets.
61 Electronic Stability Control

Driver intervention

Backing up
City Safety is temporarily deactivated when the vehicle is backing up.

Low speed
City Safety is not activated at very low speeds under 4 km/h (3 mph). The system will therefore not intervene in situations in which your vehicle is approaching another vehicle very slowly, such as when parking.

Active driver
Action by the driver always has priority. City Safety will therefore not react or will react at a later stage with a warning or intervention in situations in which the driver is clearly steering and operating the accelerator pedal, even if a collision is unavoidable.

An active and aware driving style may therefore delay collision warnings and intervention in order to minimize unnecessary warnings.

Other limitations

⚠ WARNING

The driver support system only issues a warning for obstacles detected by its radar sensor – thus, a warning may come after a delay or not at all.

- Never wait for a warning or assistance. Apply the brakes when necessary.

⚠ WARNING

- Warnings and brake interventions can be triggered late or not at all if the traffic situation or external influences prevent the camera and radar unit from properly detecting pedestrians, cyclists, large animals or vehicles ahead of the vehicle.
- To be able to detect vehicles at night, its front and rear lights must work and illuminate clearly.
- The camera and radar unit have a limited range for pedestrians and cyclists – the system can provide effective warnings and brake interventions if the relative speed is lower than 50 km/h (30 mph). For stationary or slow-moving vehicles, warnings and brake interventions are effective at vehicle speeds of up to 70 km/h (43 mph). Speed reduction for large animals is less than 15 km/h (9 mph) and can be achieved at vehicle speeds over 70 km/h (43 mph). At lower speeds, the warning and brake intervention for large animals is less effective.
- Warnings for stationary or slow-moving vehicles and large animals can be disengaged due to darkness or poor visibility.
- Warnings and brake interventions for pedestrians and cyclists are disengaged at vehicle speeds over 80 km/h (50 mph).
- Do not place, affix or mount anything on the inside or outside of the windshield, or in front of or around the camera and radar unit – this could disrupt camera-based functions.
- Objects, snow, ice or dirt in the area of the camera sensor can reduce the function, disengage it completely or give an improper function response.

▸▸

WARNING

- The City Safety auto-brake function can prevent a collision or reduce collision speed, but to ensure full brake performance the driver should always depress the brake pedal – even when the car auto-brakes.
- The warning and steering assistance are only activated if there is a high risk of collision – you must therefore never wait for the collision warning or City Safety to intervene.
- Warnings and brake interventions for pedestrians and cyclists are disengaged at vehicle speeds over 80 km/h (50 mph).
- City Safety does not activate auto-braking intervention during heavy acceleration.

NOTE

The function uses the vehicle's camera and radar sensor, which has certain general limitations.

Market limitations

City Safety is not available in all countries. If City Safety is not shown in the center display's **Settings** menu, your vehicle is not equipped with this function.

In the center display's Top view, tap:

- **Settings ➔ My Car ➔ IntelliSafe**

Related information

- City Safety™ (p. 306)
- Camera/radar sensor limitations (p. 301)

City Safety messages

A number of messages related to City Safety may be displayed in the instrument panel. Several examples are provided below.

Message	Meaning
City Safety **Automatic intervention**	When City Safety is braking or has activated the automatic braking function, one or more symbols may illuminate in the instrument panel and a text message may be displayed.
City Safety **Reduced functionality Service required**	The system is not functioning as intended. Contact a workshop[A].

[A] An authorized Volvo workshop is recommended.

A text message can be erased by briefly pressing the ○ button in the center of the right-side steering wheel keypad.

If a message cannot be erased, contact a workshop[A].

Related information

- City Safety™ (p. 306)

WARNING

If the warning symbols for both brake fault and ABS fault are lit simultaneously, there may be a fault in the brake system.

- If the brake fluid reservoir level is normal when this occurs, drive carefully to the nearest workshop to have the brake system checked - an authorized Volvo workshop is recommended.
- If the brake fluid has fallen below the **MIN** level in the brake fluid reservoir, the vehicle should not be driven until the brake fluid has been filled. The reason for the brake fluid loss must be checked.

Related information

- Brake Assist System (p. 380)
- Auto-hold brakes (p. 385)
- Hill Start Assist (p. 386)
- Braking on wet roads (p. 380)
- Braking on salted roads (p. 381)
- Maintenance of the brake system (p. 381)
- Brake lights (p. 157)

Brake Assist System

The brake enhancing system, (BAS[3]), helps increase braking force and can thereby reduce braking distance.
The system monitors the driver's braking habits and increases braking force when necessary. Braking force can be increased up to the point at which the ABS intervenes. The function is deactivated when pressure on the brake pedal is decreased.

NOTE

When BAS is activated, the brake pedal will go down slightly more than usual. Press (hold) down the brake pedal as long as necessary.

When the brake pedal is released, all braking ceases.

Related information

- Brakes (p. 379)

Braking on wet roads

Prolonged driving in heavy rain without braking may cause braking effect to be slightly delayed the first time the brakes are applied.
This may also occur after washing the vehicle. It will then be necessary to apply greater pressure to the brake pedal. You should therefore maintain a greater distance to the vehicle ahead.

Firmly apply the brakes after washing the vehicle or driving on wet roads. This helps warm up the brake discs, enabling them to dry more quickly and protecting them against corrosion. Consider the current traffic situation when braking.

Related information

- Brakes (p. 379)
- Braking on salted roads (p. 381)

[3] Brake Assist System

APPENDIX C

Run Log

Subject Vehicle: **2020 Volvo S60 T6 AWD Momentum** Test Date: **2/4/2020**

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**	N					poor light signal
2		Y	3.54	3.47	1.44	Pass	
3		Y	3.20	3.14	1.10	Pass	
4		Y	3.51	3.45	1.41	Pass	
5		Y	3.05	2.99	0.95	Pass	
6		Y	2.77	2.69	0.67	Pass	
7		Y	3.51	3.45	1.41	Pass	
8		Y	3.05	2.95	0.95	Pass	
18	**Decelerating POV, 45**	Y	2.94	2.88	0.54	Pass	
19		N					lateral offset
20		Y	2.79	2.74	0.39	Pass	
21		Y	2.73	2.66	0.33	Pass	
22		Y	2.73	2.66	0.33	Pass	
23		Y	2.93	2.89	0.53	Pass	
24		Y	2.77	2.70	0.37	Pass	
25		Y	2.89	2.82	0.49	Pass	

Run	Test Type	Valid Run?	TTCW Sound (sec)	TTCW Light (sec)	TTCW Margin (sec)	Pass/Fail	Notes
9	**Slower POV, 45 vs 20**	Y	2.76	2.66	0.76	Pass	
10		Y	2.64	2.55	0.64	Pass	
11		Y	2.66	2.56	0.66	Pass	
12		N					POV speed
13		Y	2.61	2.53	0.61	Pass	
14		Y	2.62	2.55	0.62	Pass	
15		Y	2.71	2.61	0.71	Pass	
16		N					POV speed
17		Y	2.64	2.56	0.64	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 audible, 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)

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

Envelopes and Thresholds

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

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

Yellow envelopes indicate that the time-varying data should not exceed the envelope only at the 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.

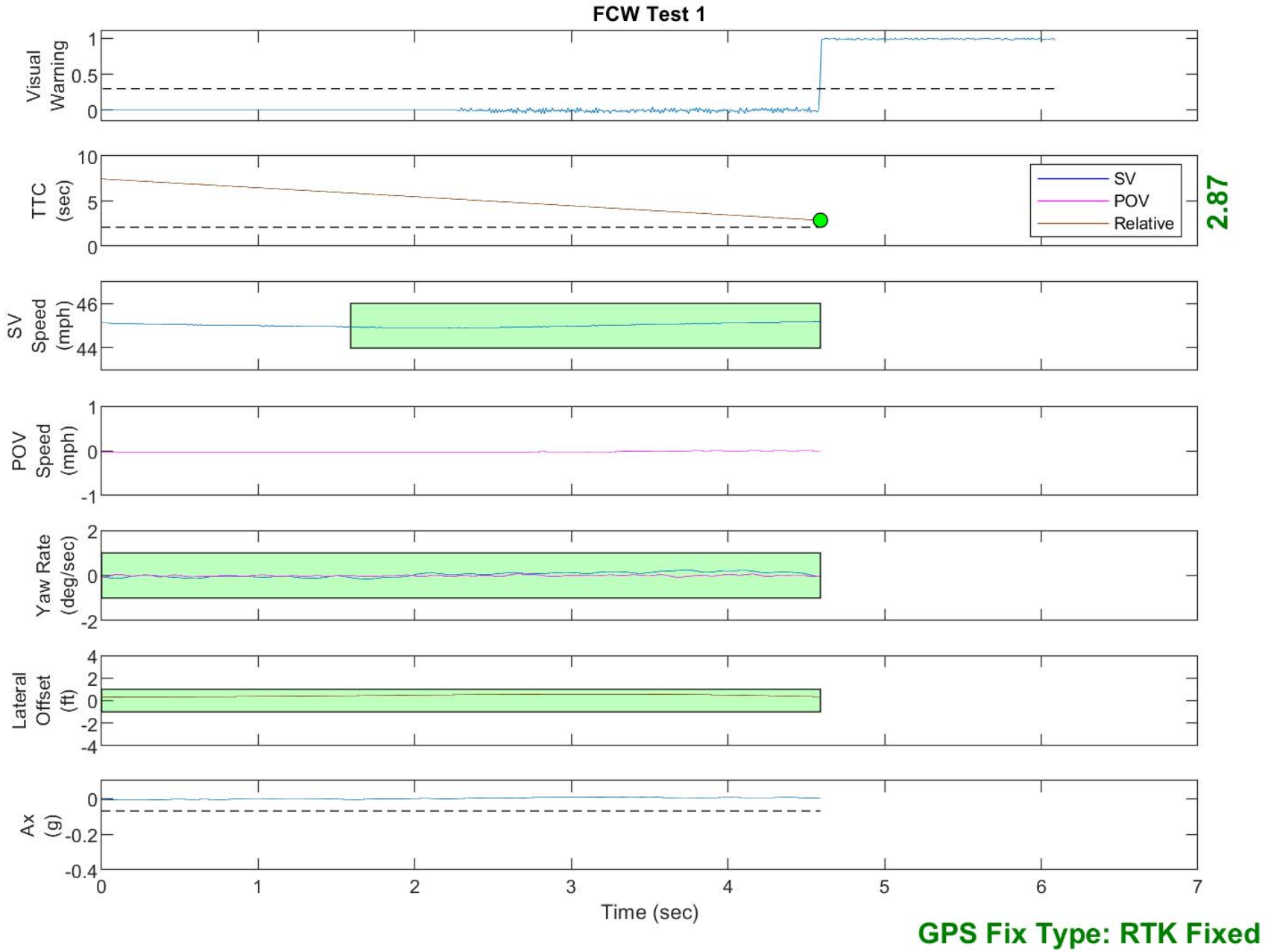


Figure D1. Example Time History for Test Type 1, Passing

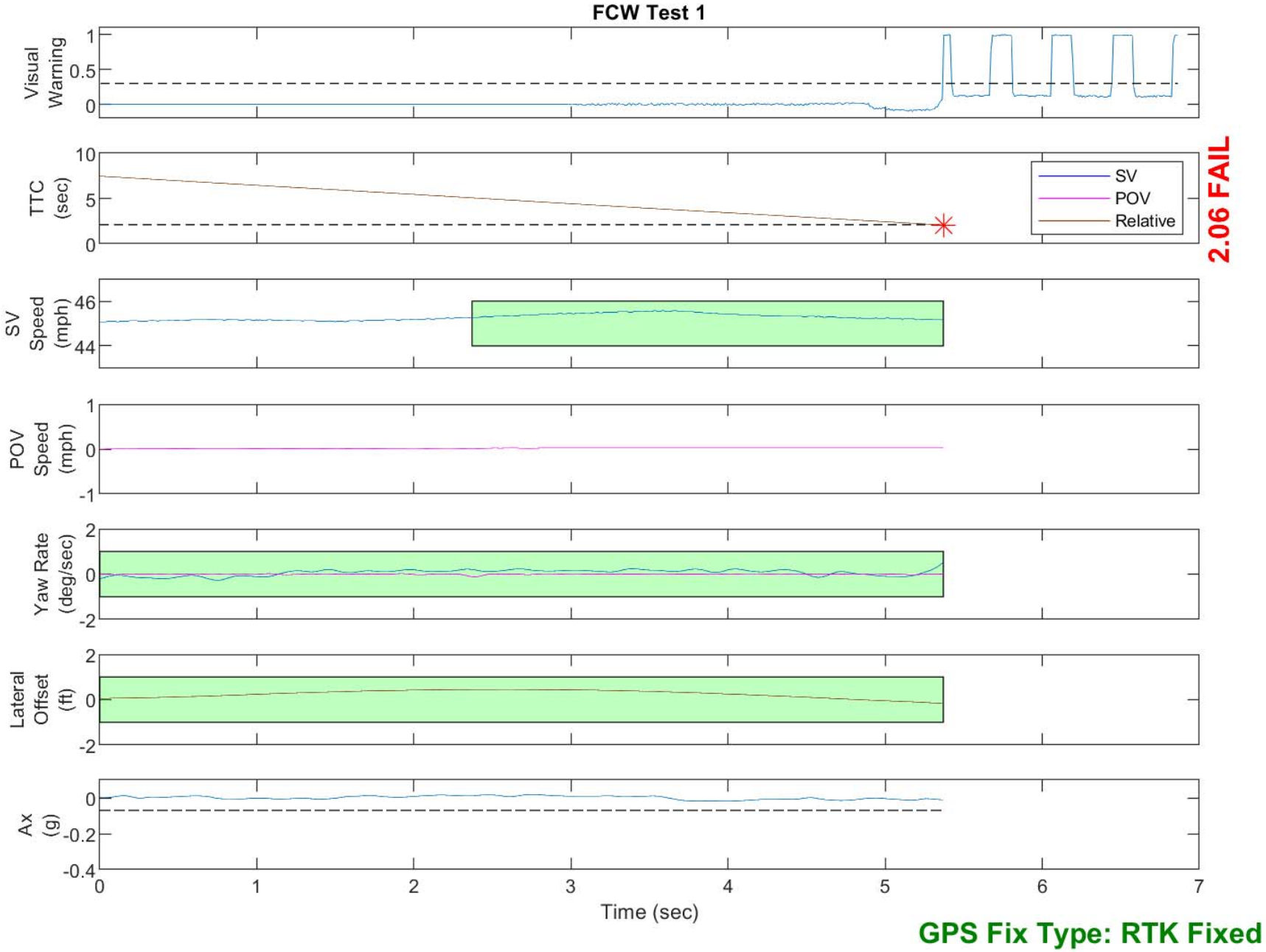


Figure D2. Example Time History for Test Type 1, Failing

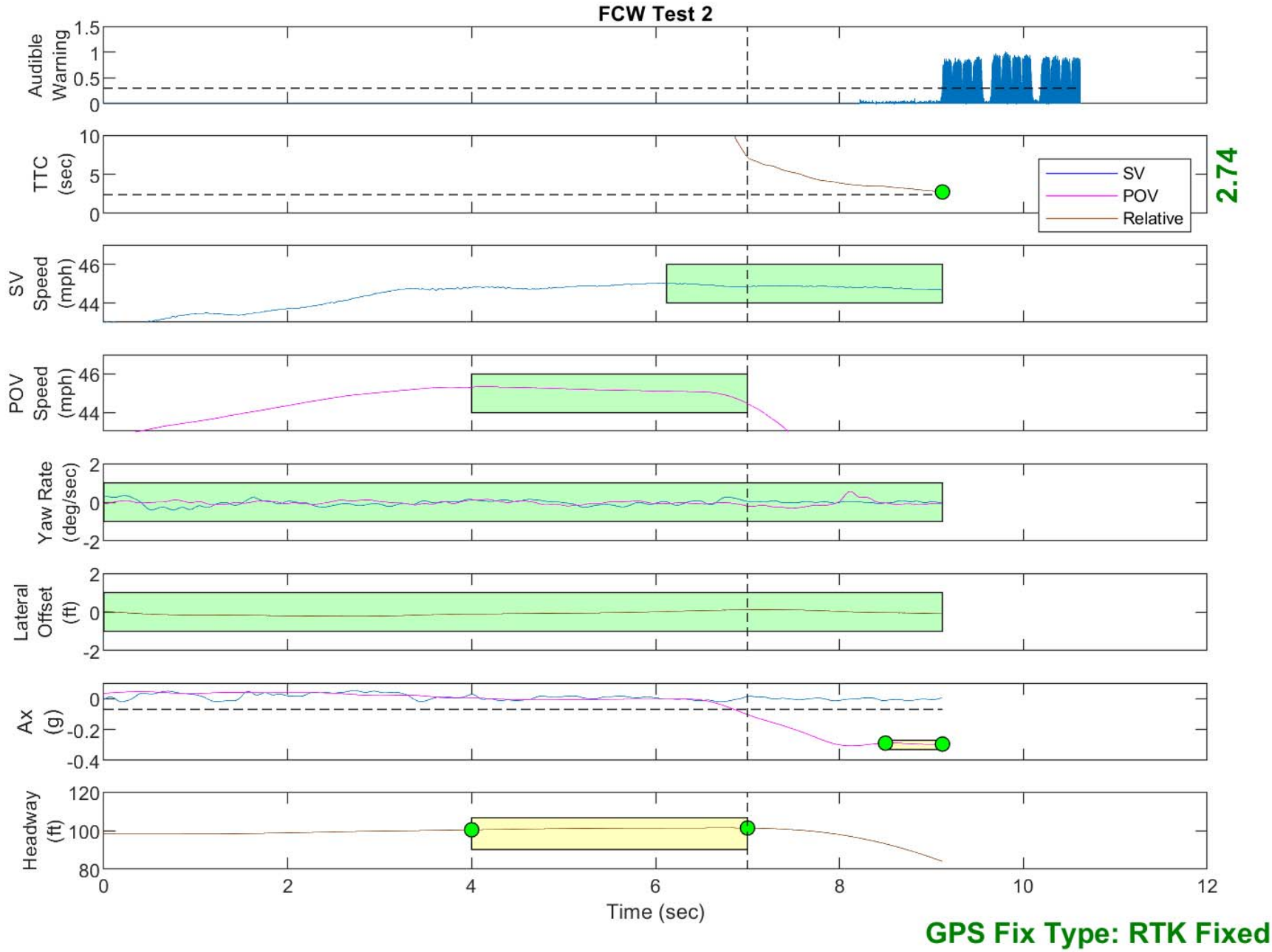


Figure D3. Example Time History for Test Type 2, Passing

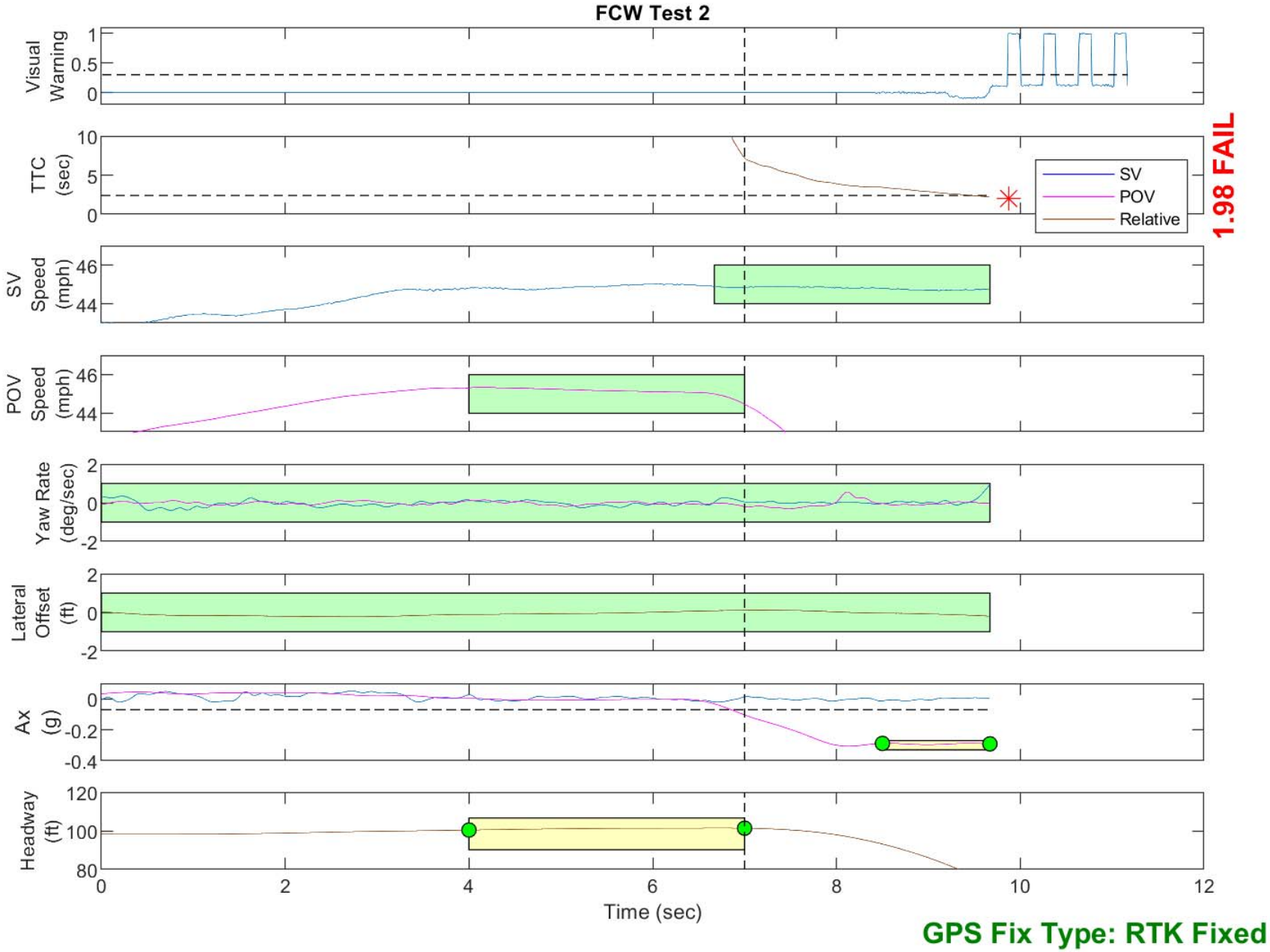


Figure D4. Example Time History for Test Type 2, Failing

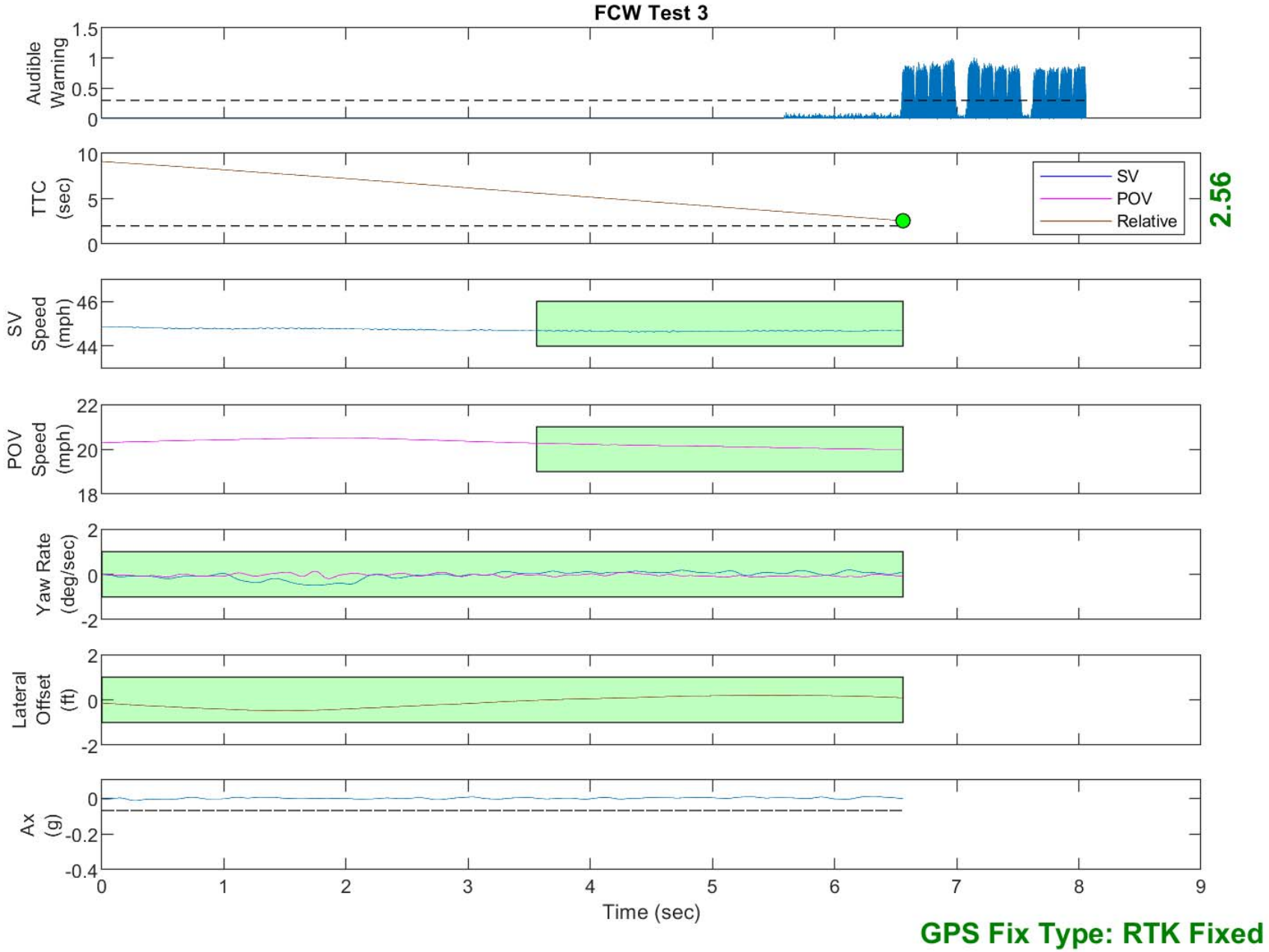


Figure D5. Example Time History for Test Type 3, Passing

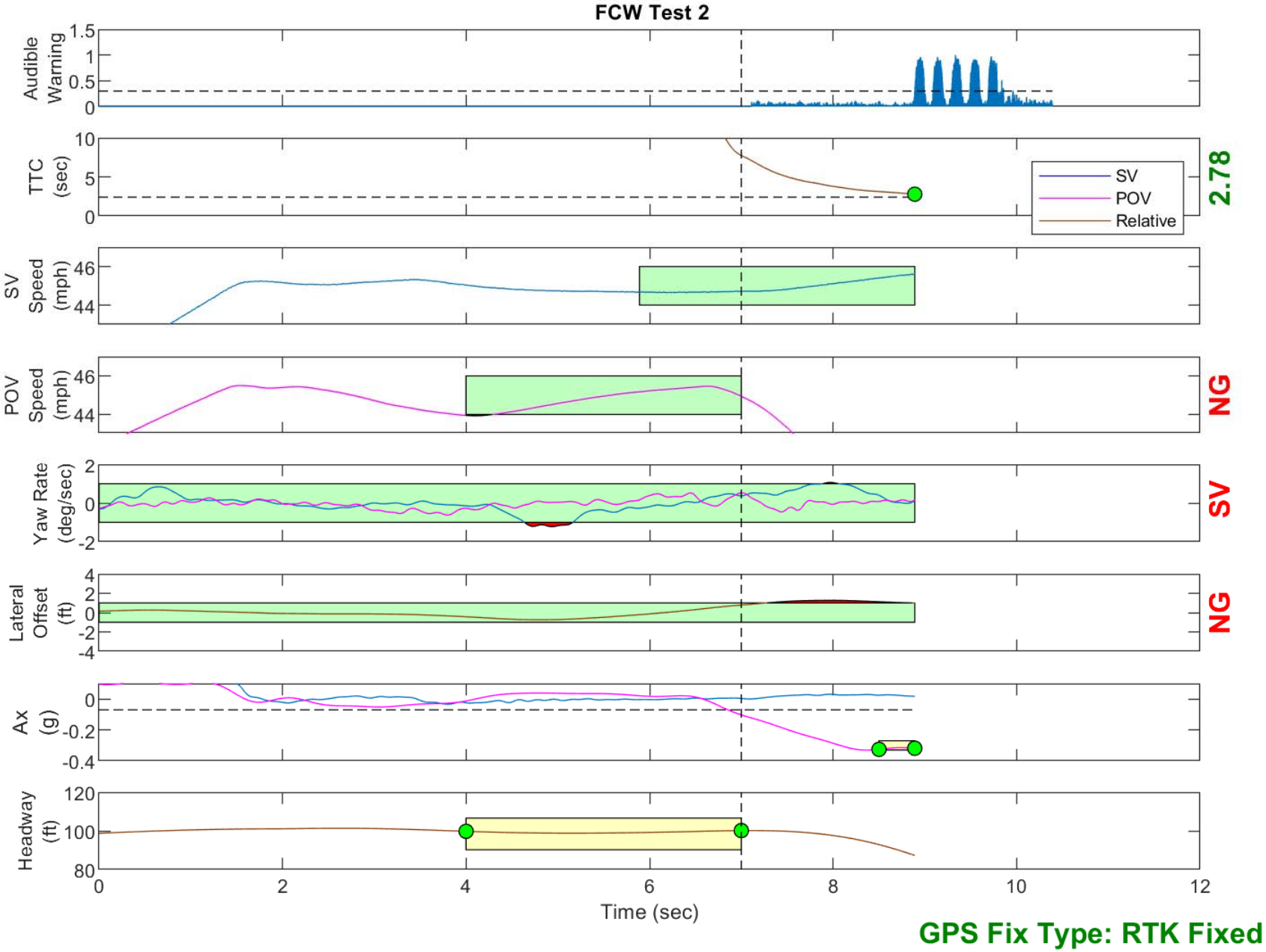


Figure D6. Example Time History Displaying Various Invalid Criteria

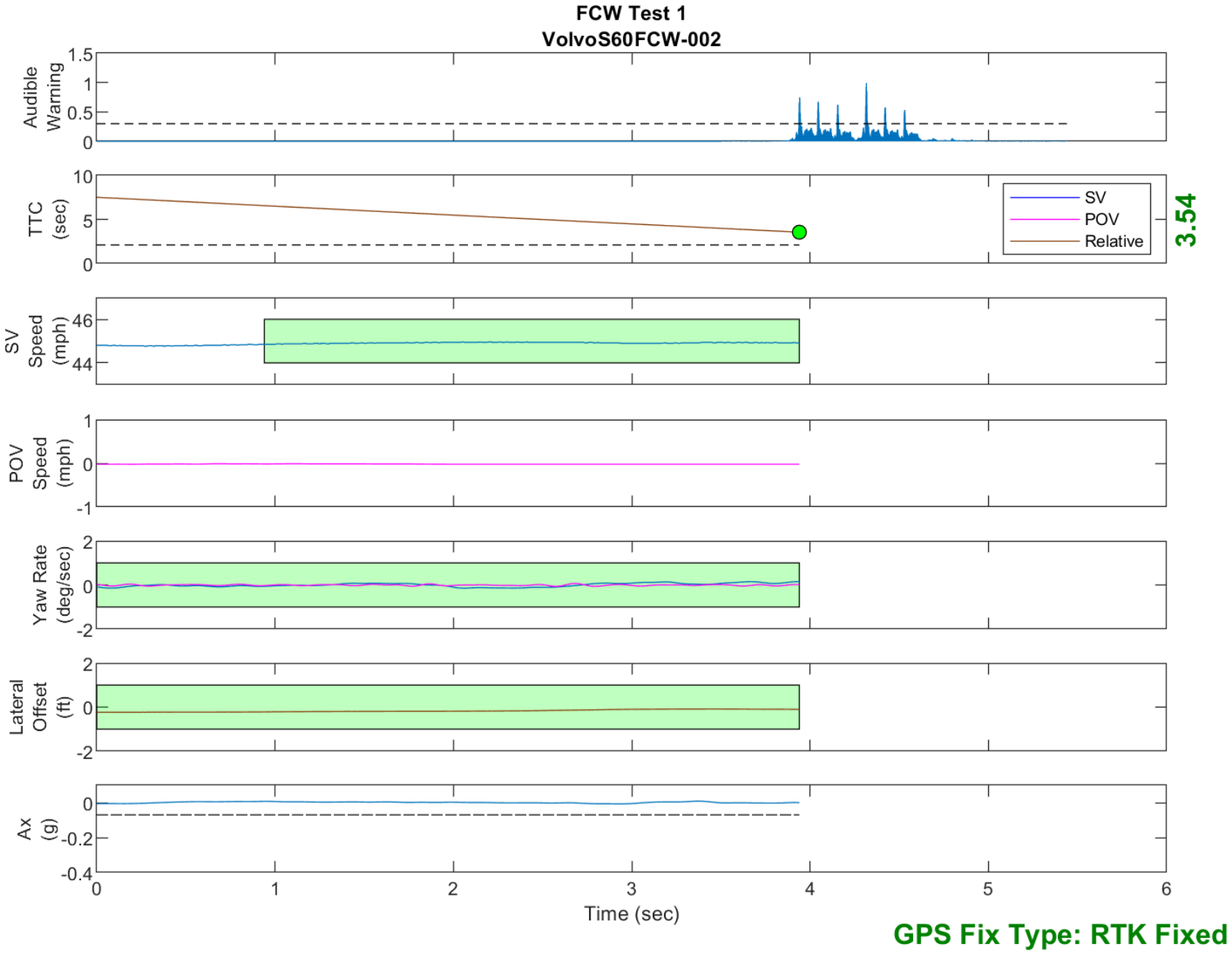


Figure D7. Time History for Run 2, FCW Test 1, Audible Warning

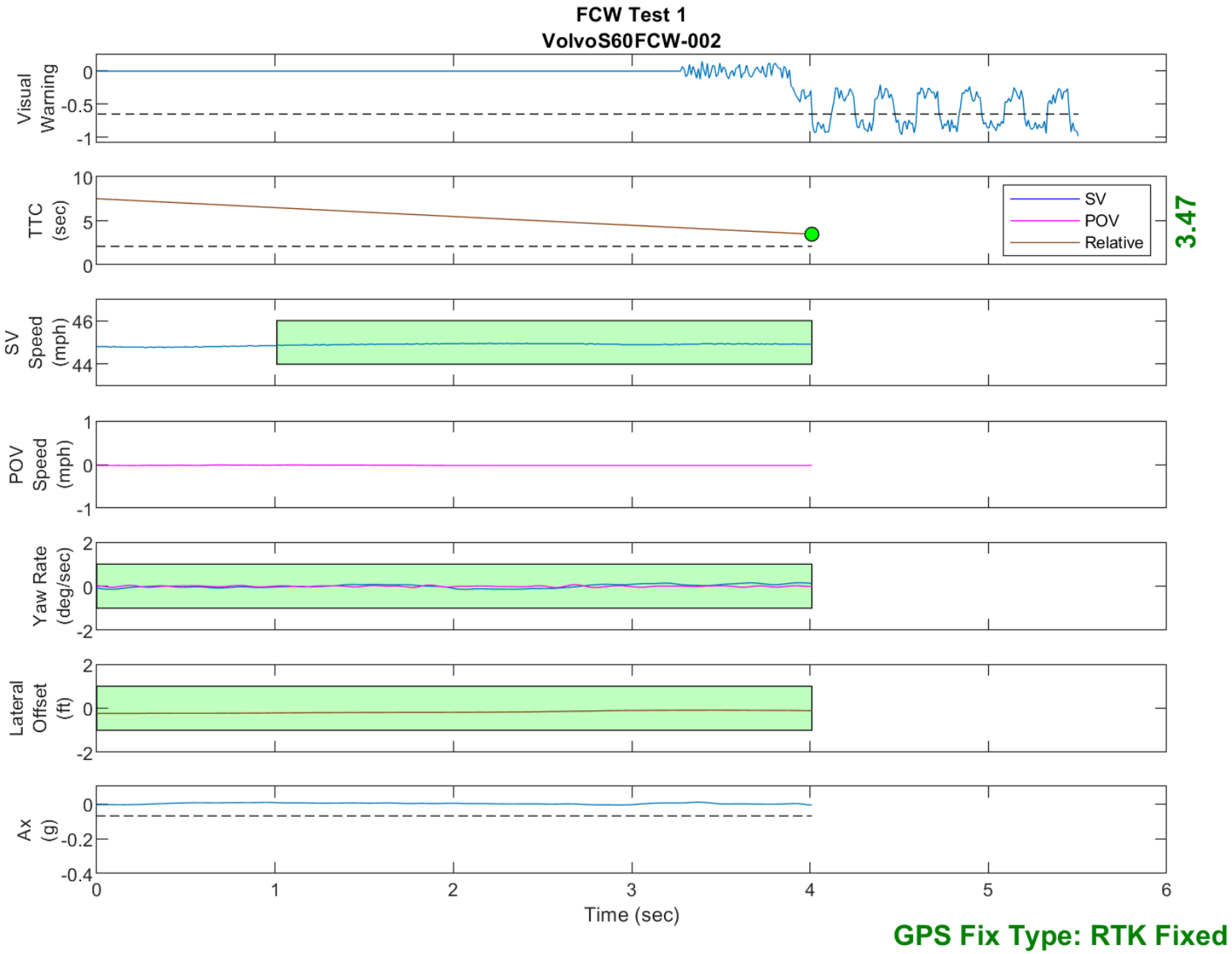


Figure D8. Time History for Run 2, FCW Test 1, Visual Warning

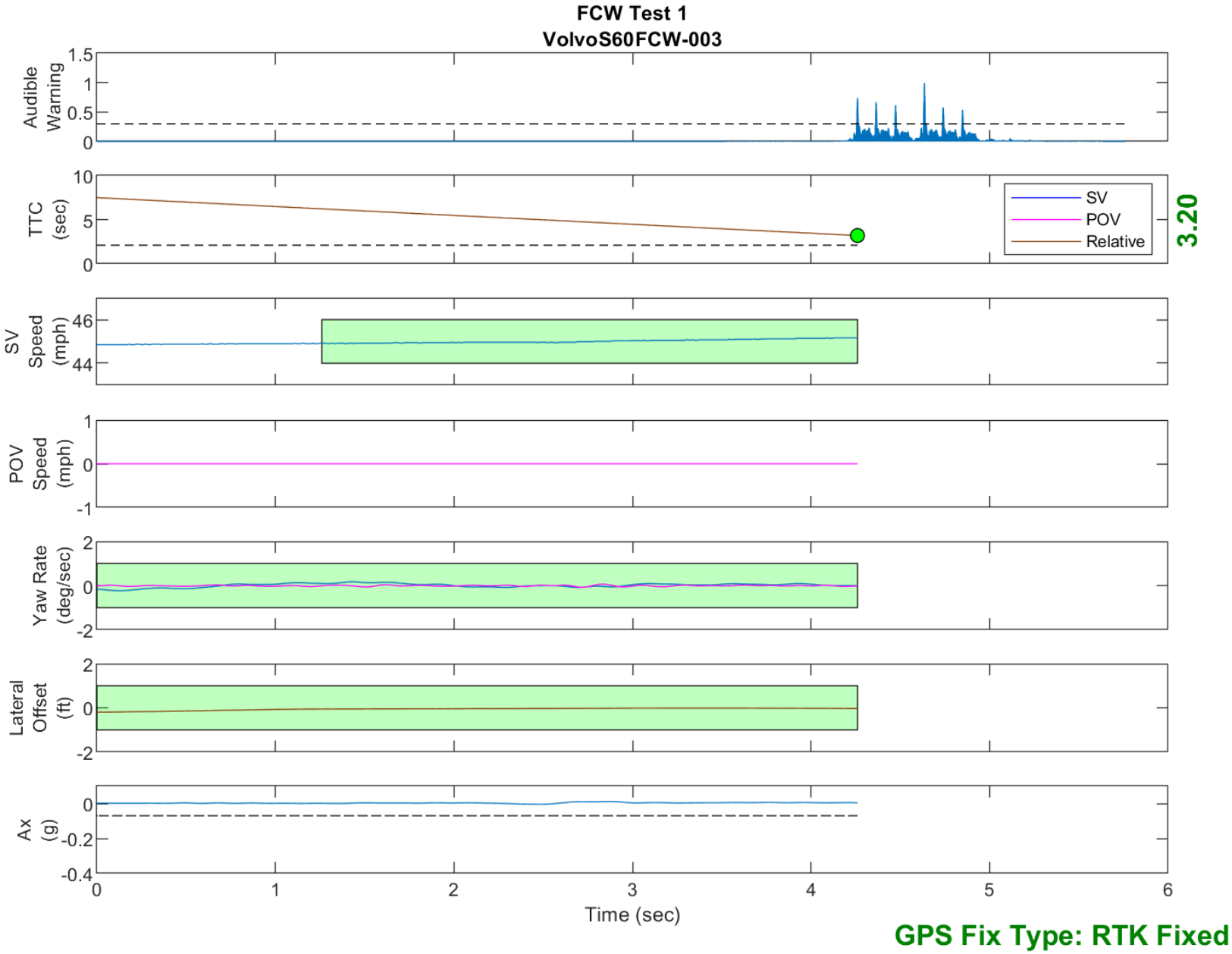


Figure D9. Time History for Run 3, FCW Test 1, Audible Warning

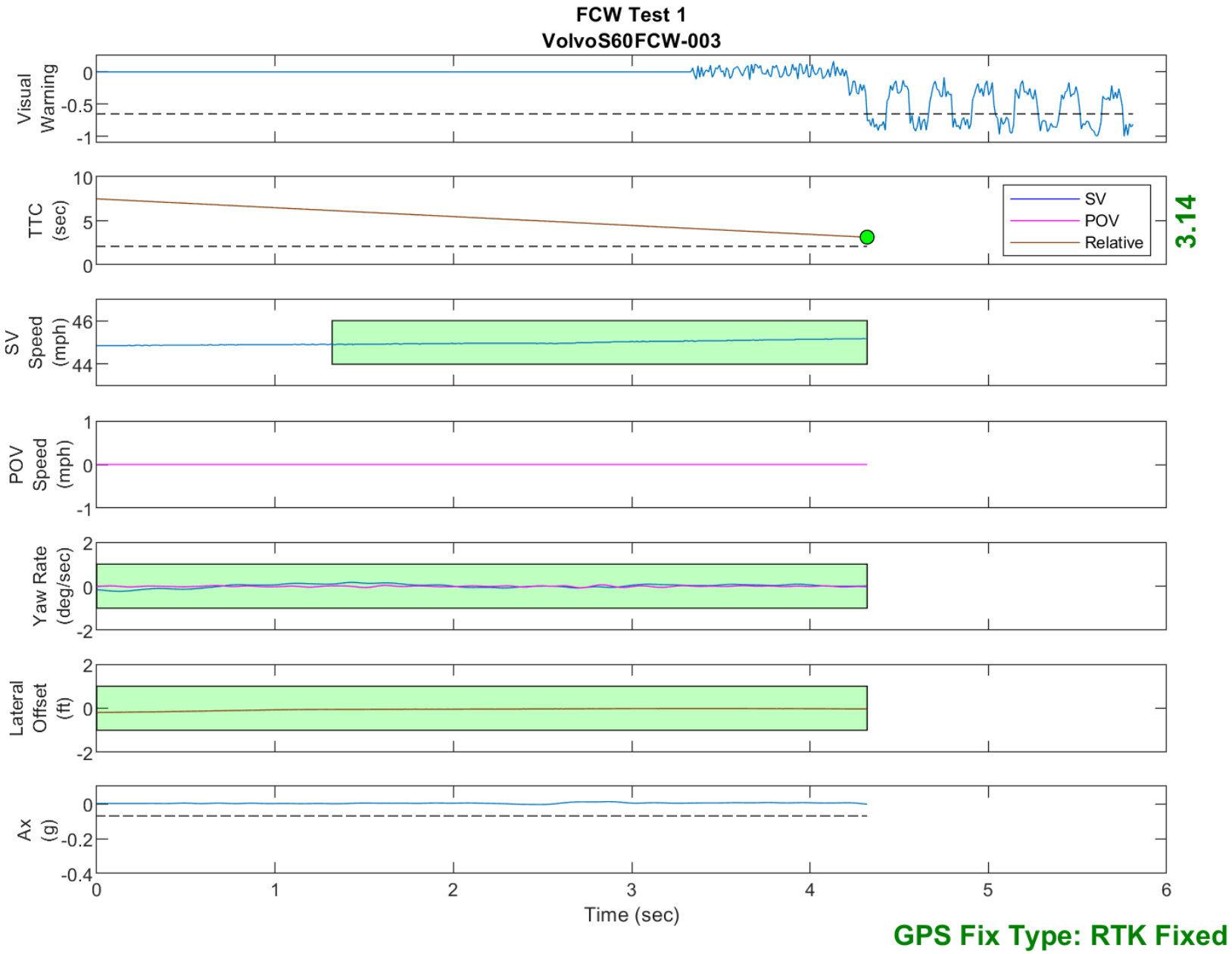


Figure D10. Time History for Run 3, FCW Test 1, Visual Warning

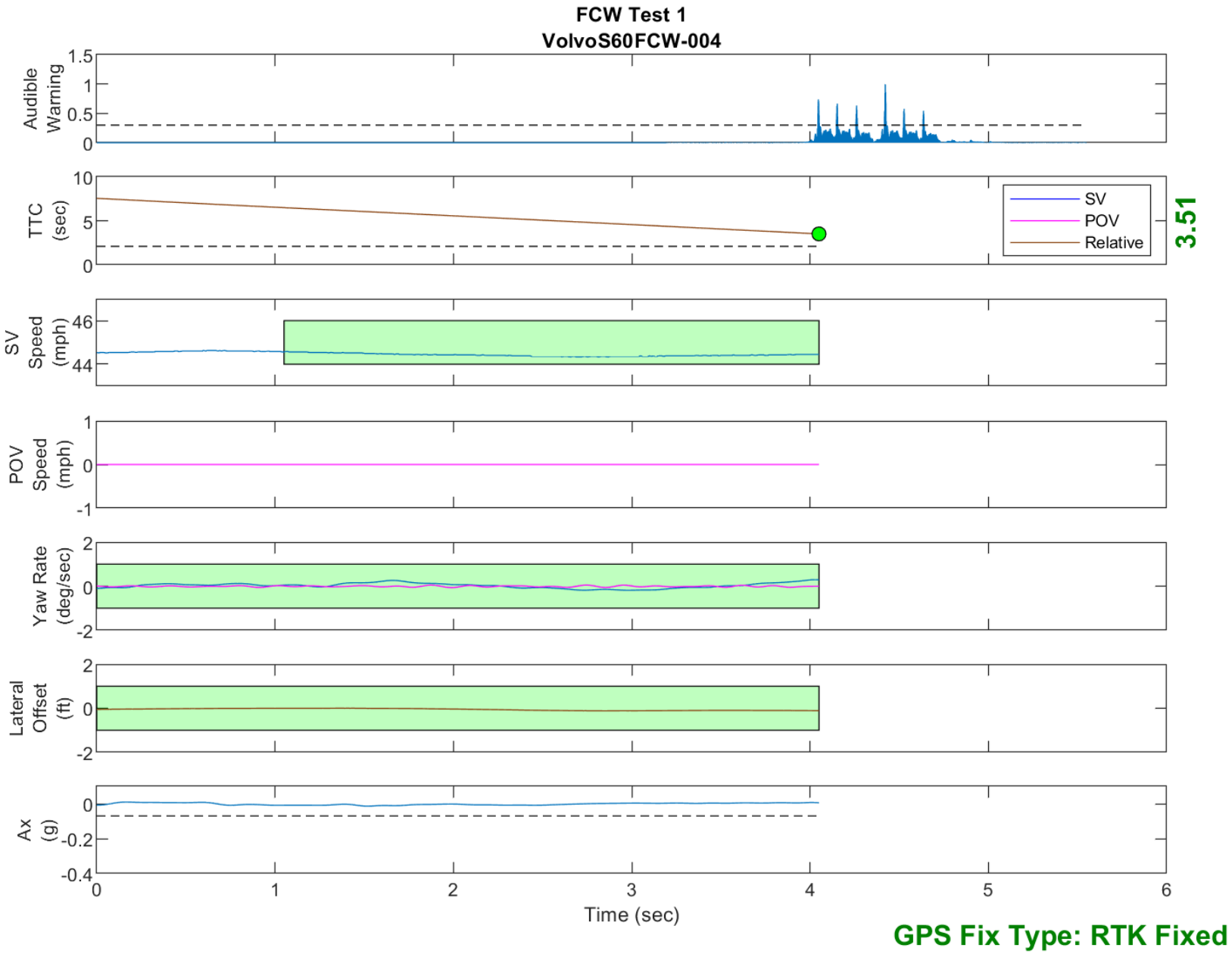


Figure D11. Time History for Run 4, FCW Test 1, Audible Warning

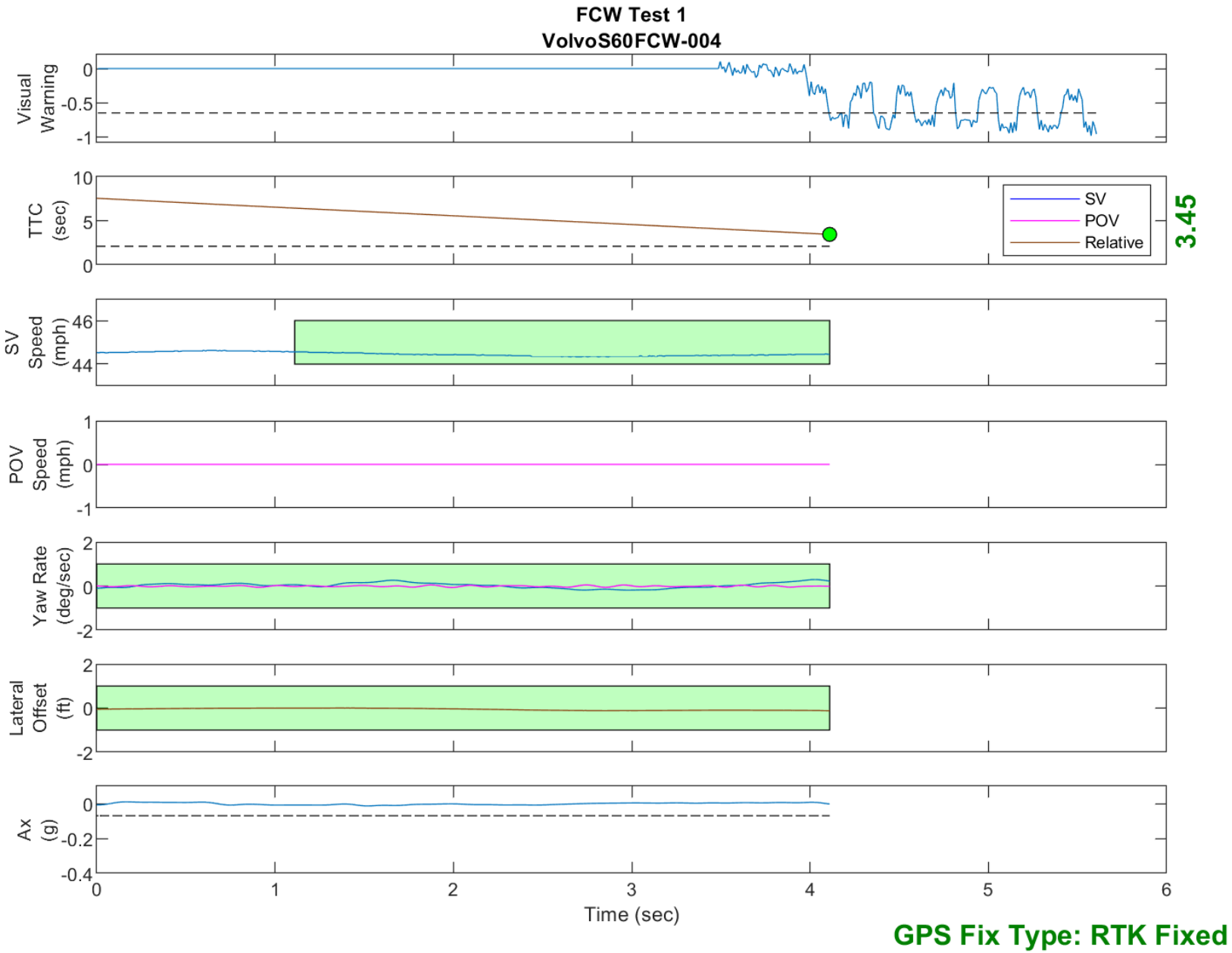


Figure D12. Time History for Run 4, FCW Test 1, Visual Warning

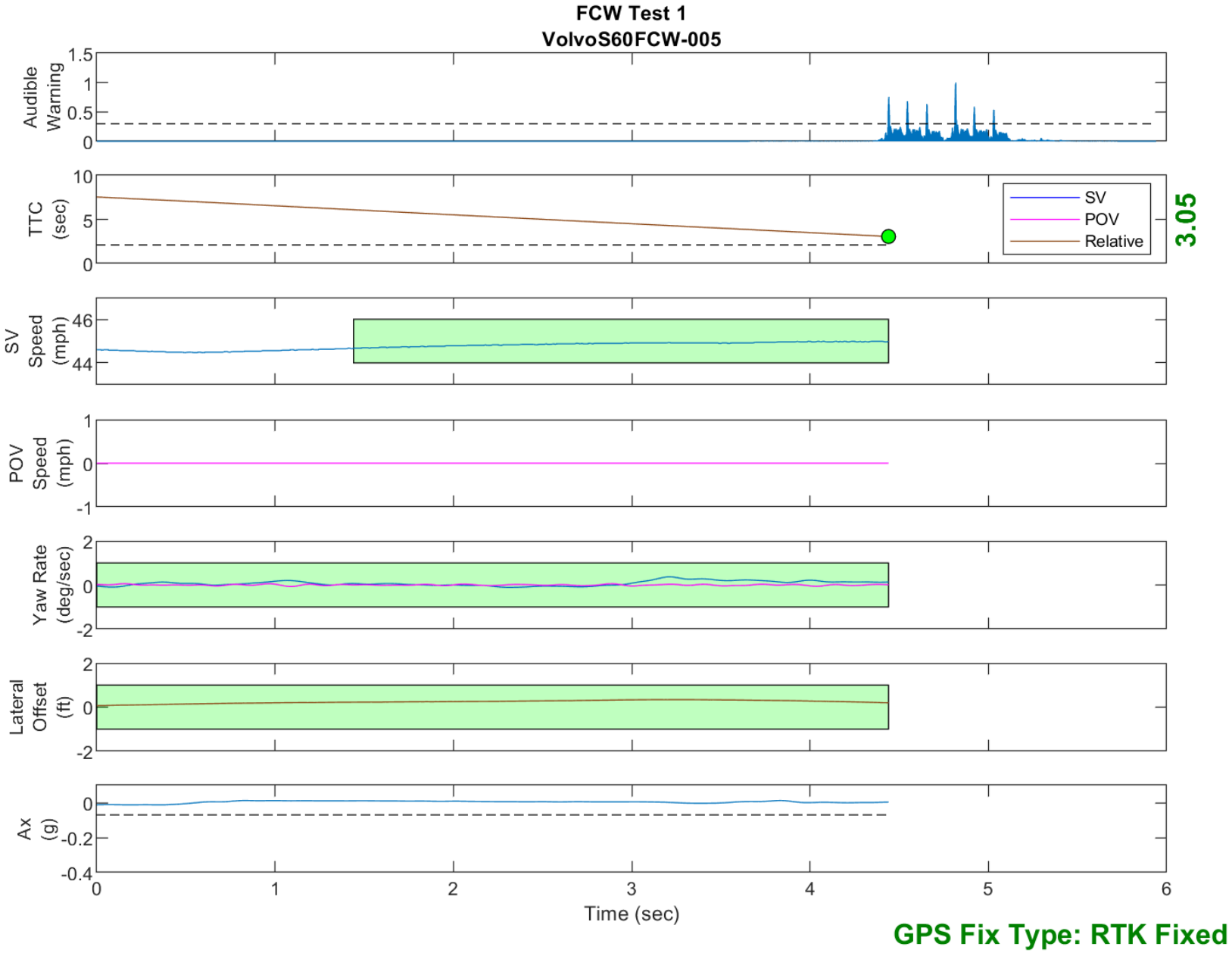


Figure D13. Time History for Run 5, FCW Test 1, Audible Warning

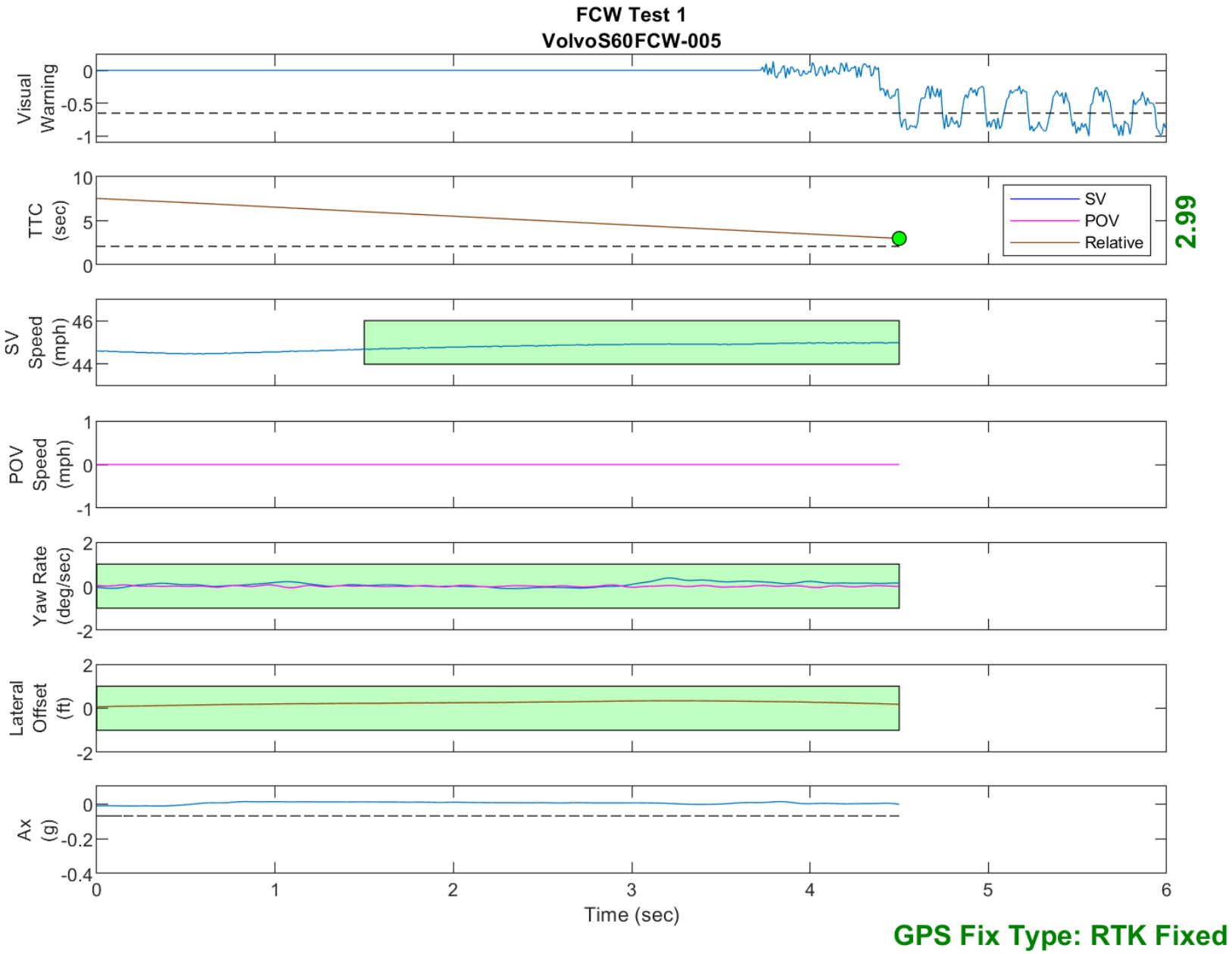


Figure D14. Time History for Run 5, FCW Test 1, Visual Warning

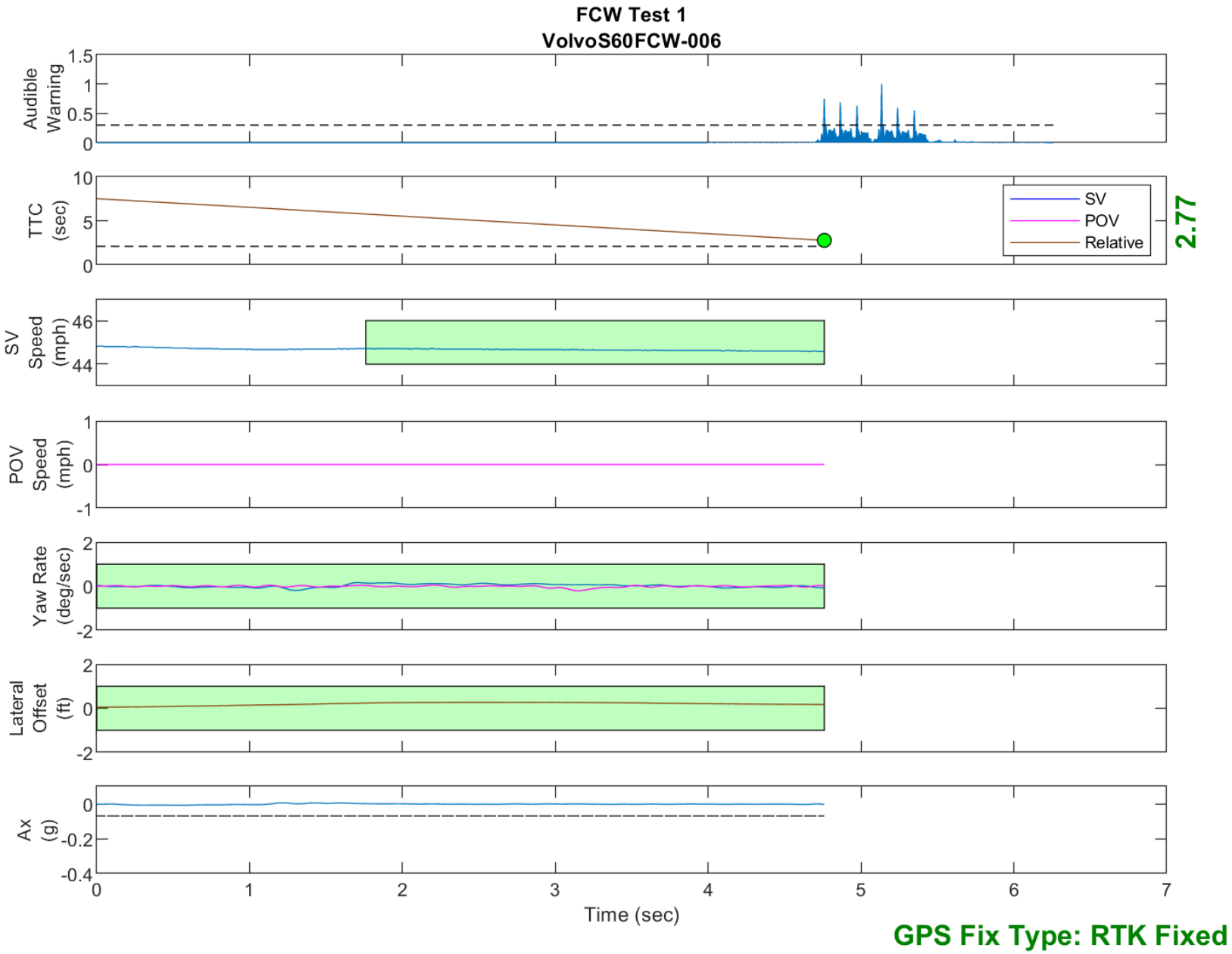


Figure D15. Time History for Run 6, FCW Test 1, Audible Warning

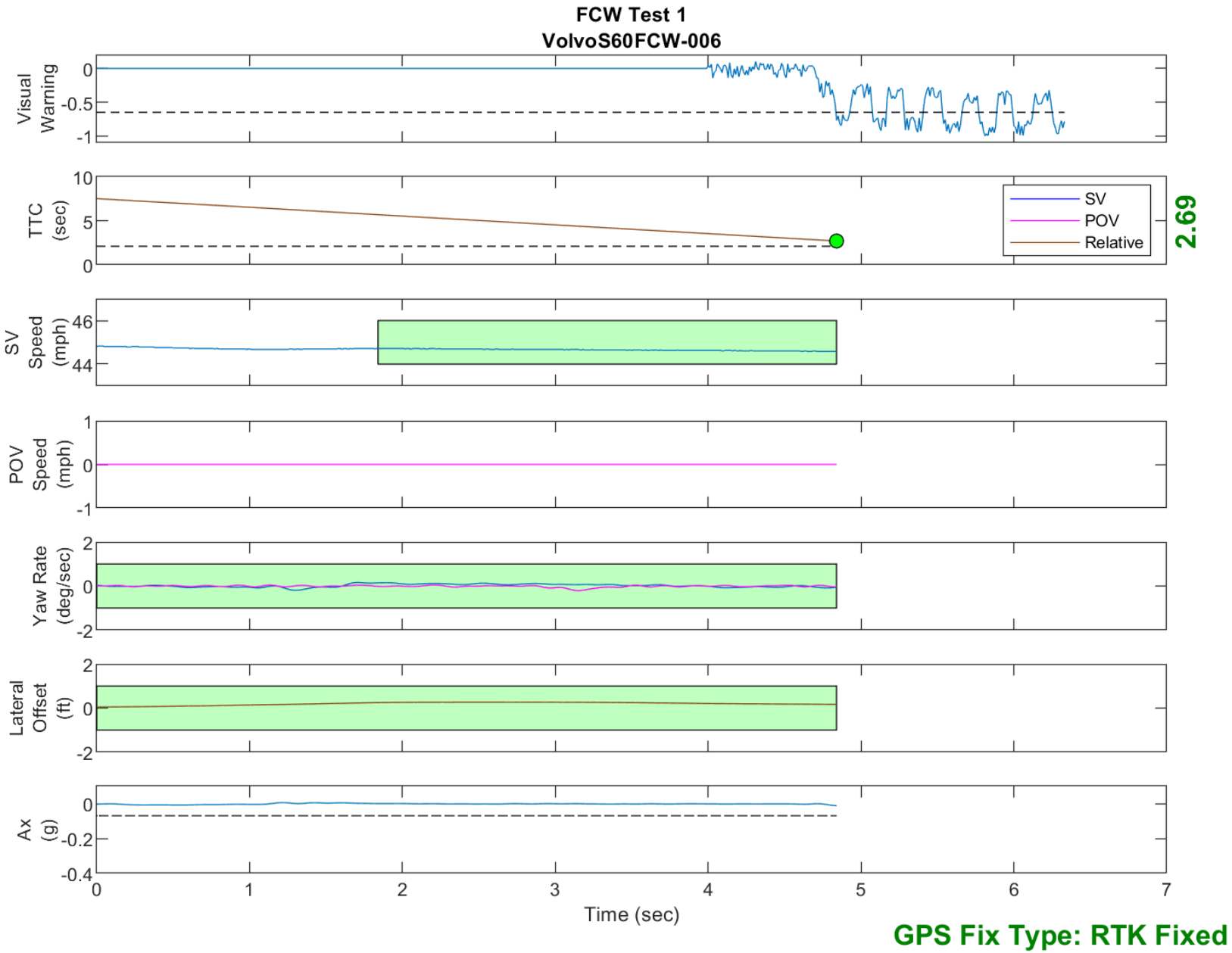


Figure D16. Time History for Run 6, FCW Test 1, Visual Warning

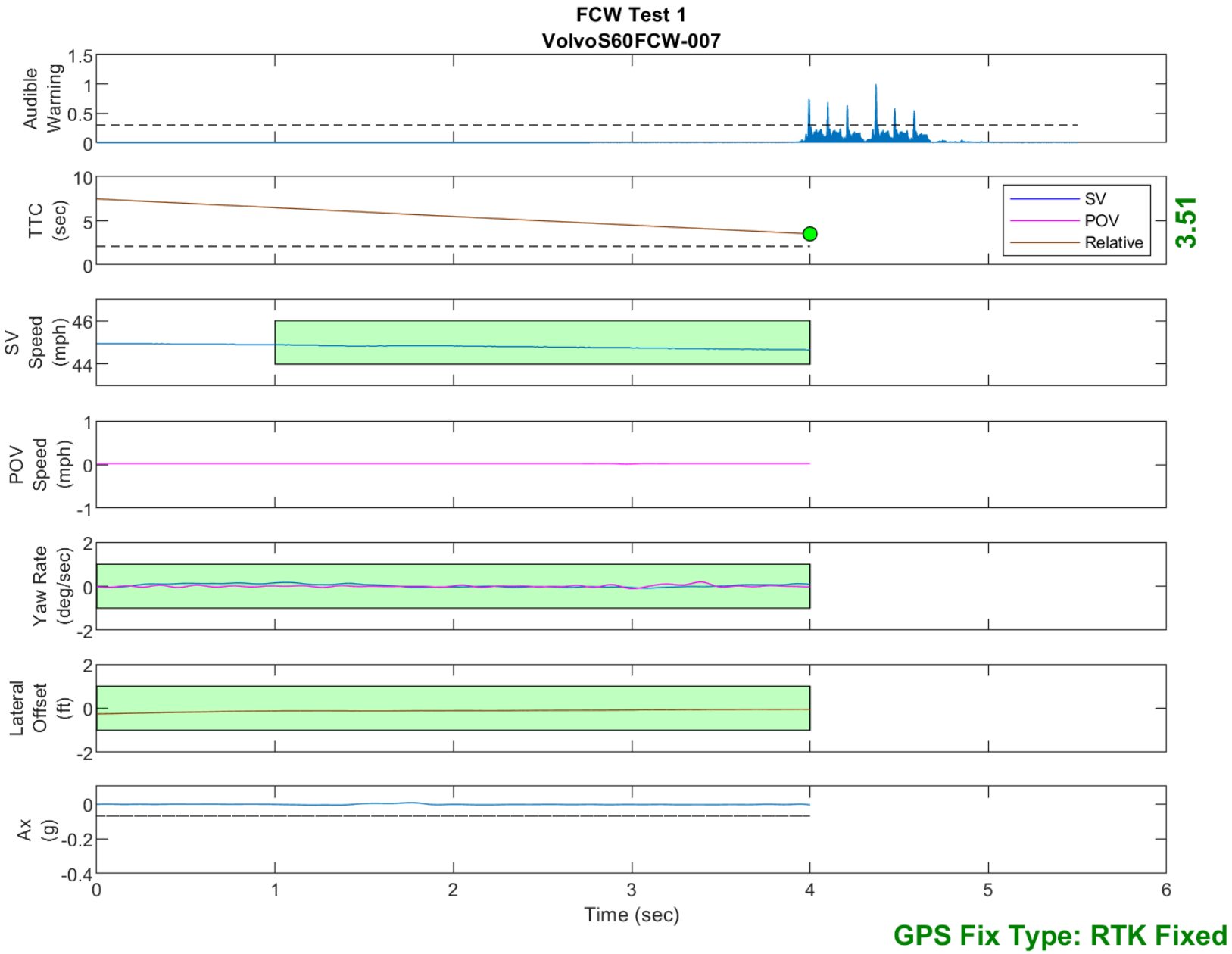


Figure D17. Time History for Run 7, FCW Test 1, Audible Warning

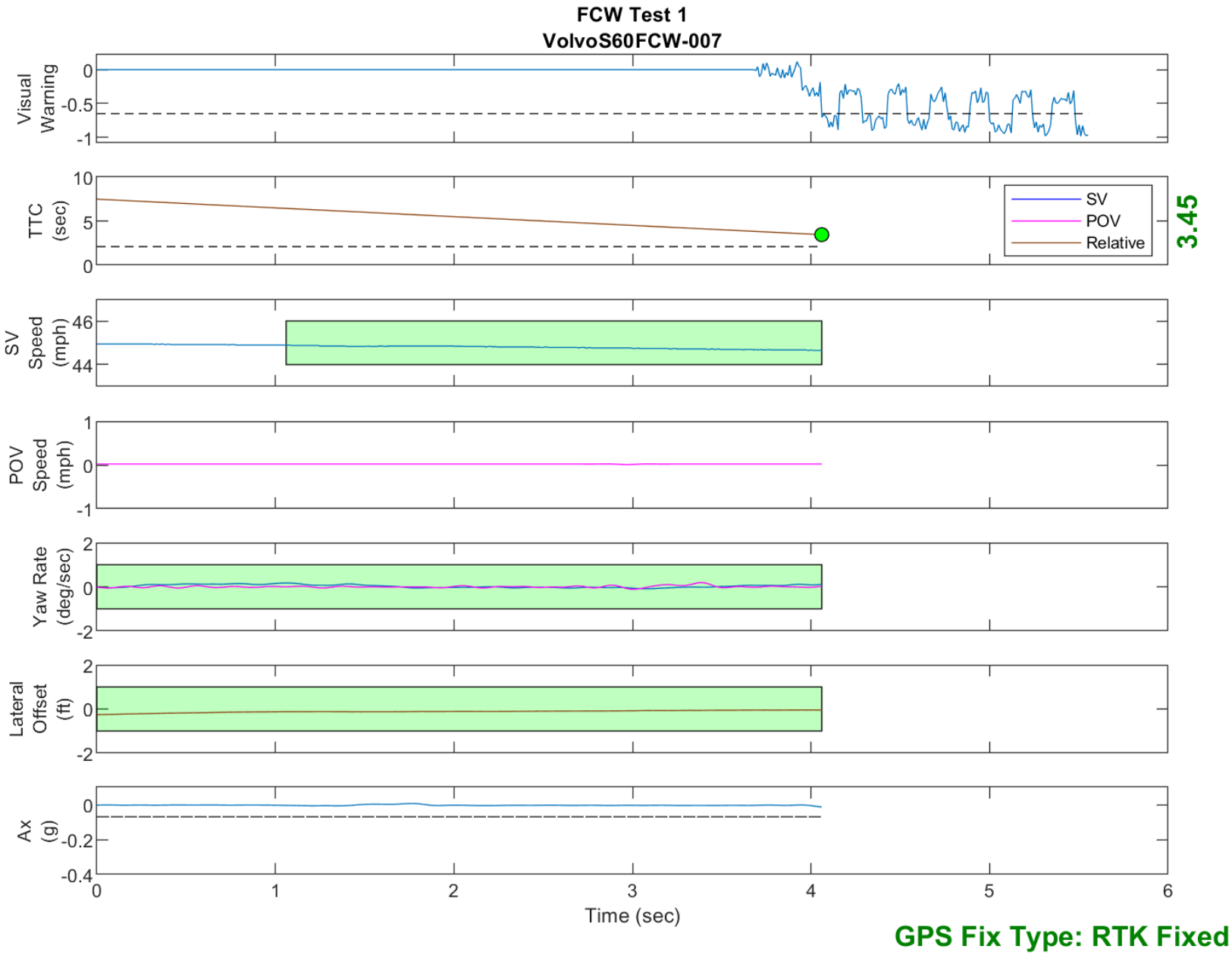


Figure D18. Time History for Run 7, FCW Test 1, Visual Warning

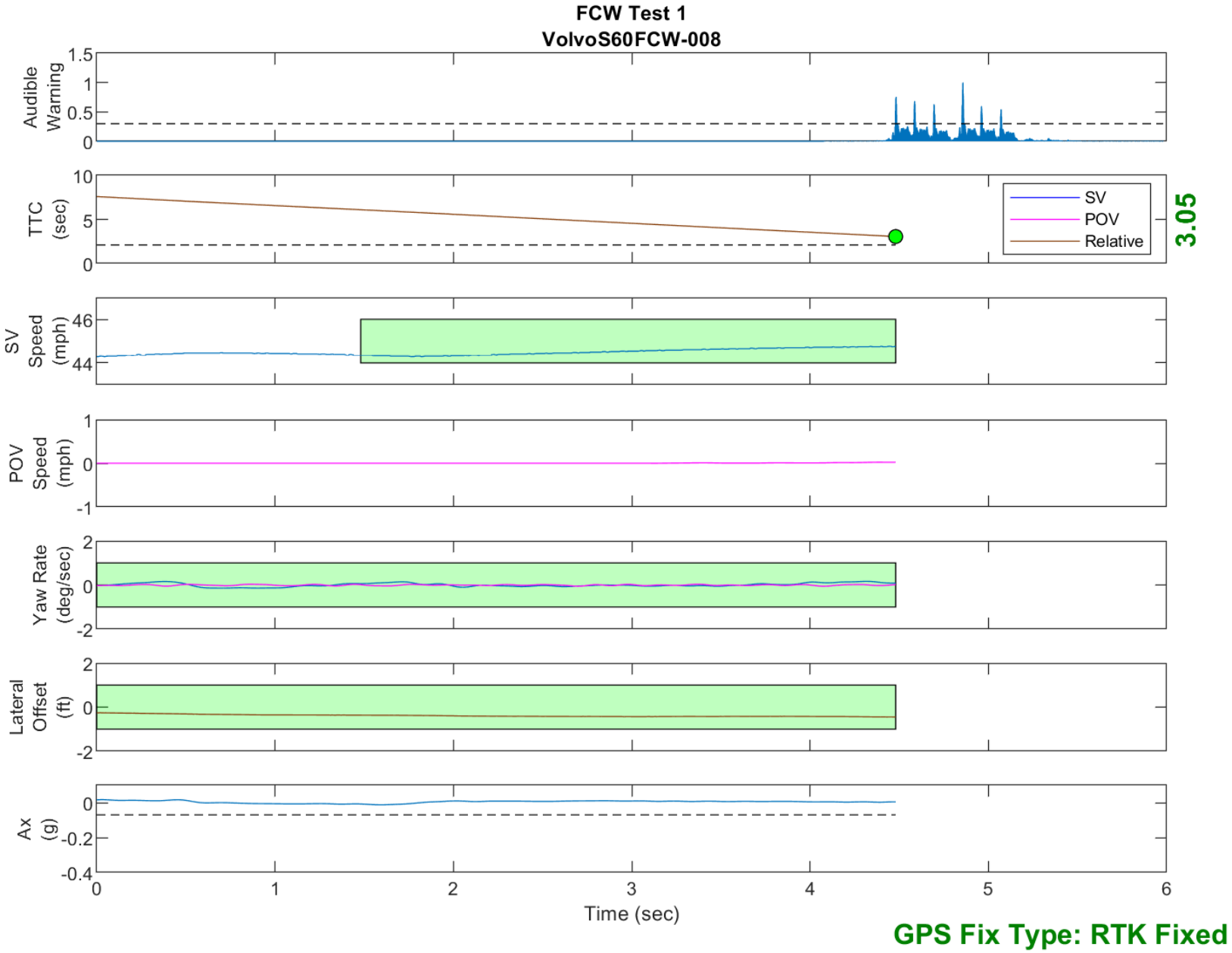


Figure D19. Time History for Run 8, FCW Test 1, Audible Warning

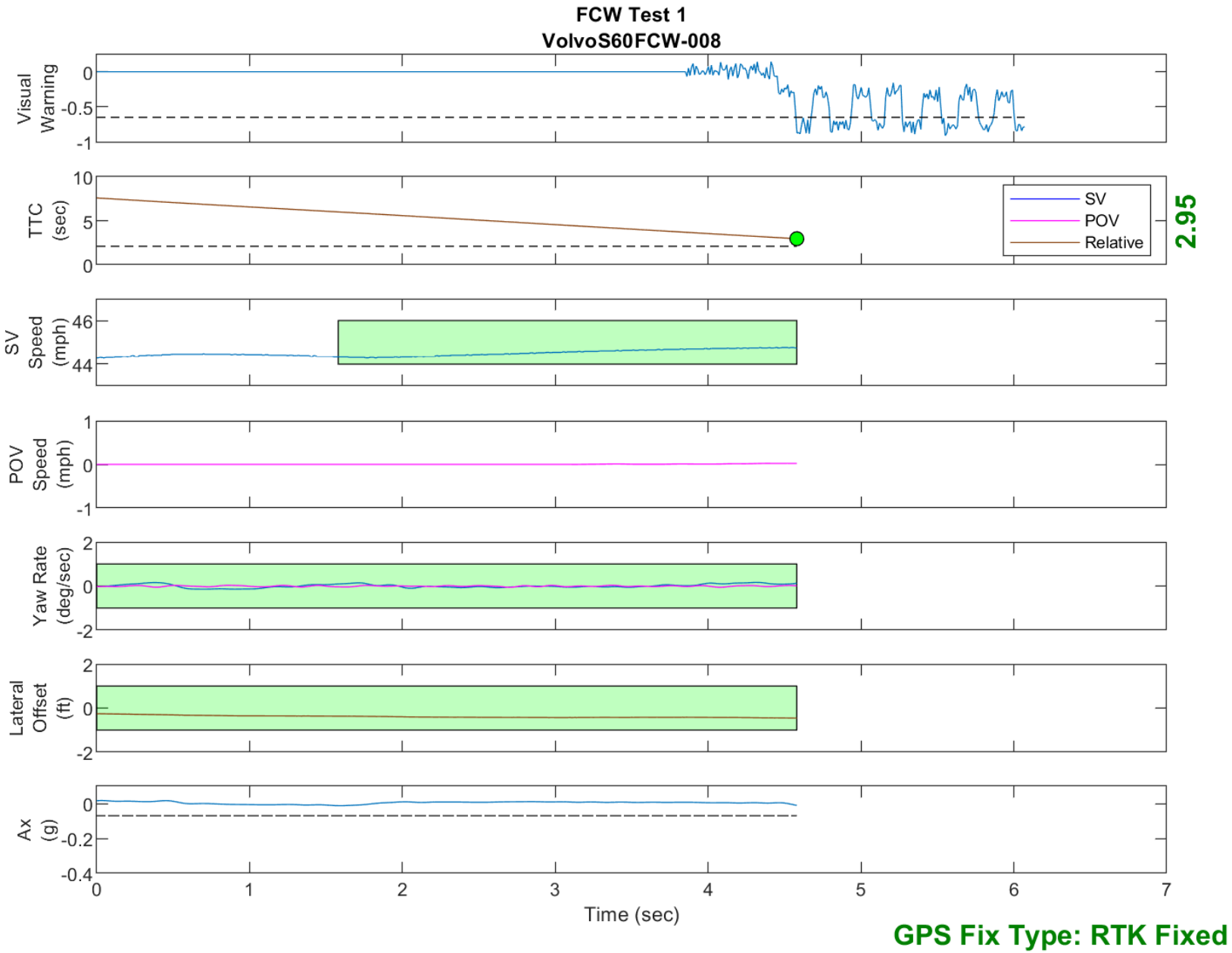


Figure D20. Time History for Run 8, FCW Test 1, Visual Warning

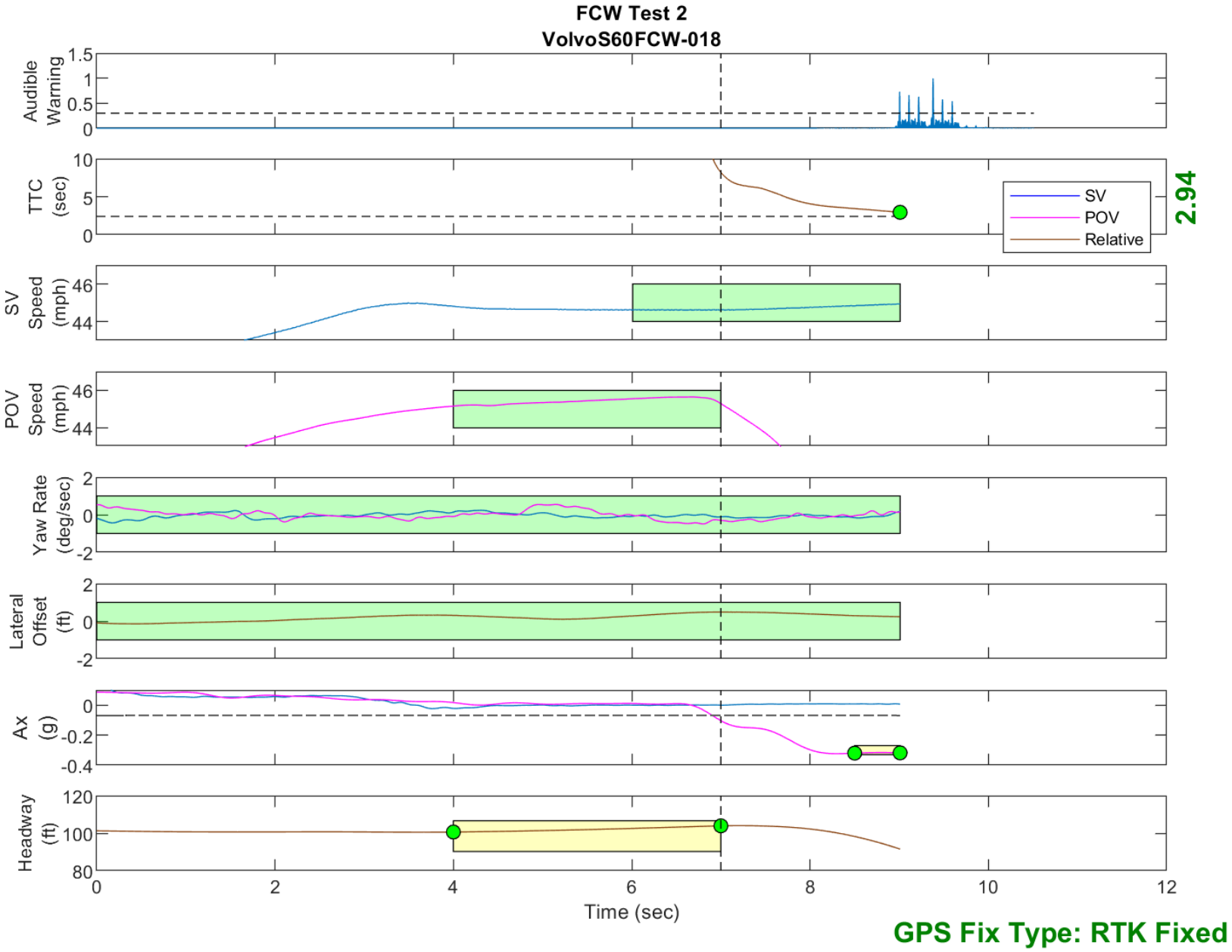


Figure D21. Time History for Run 18, FCW Test 2, Audible Warning

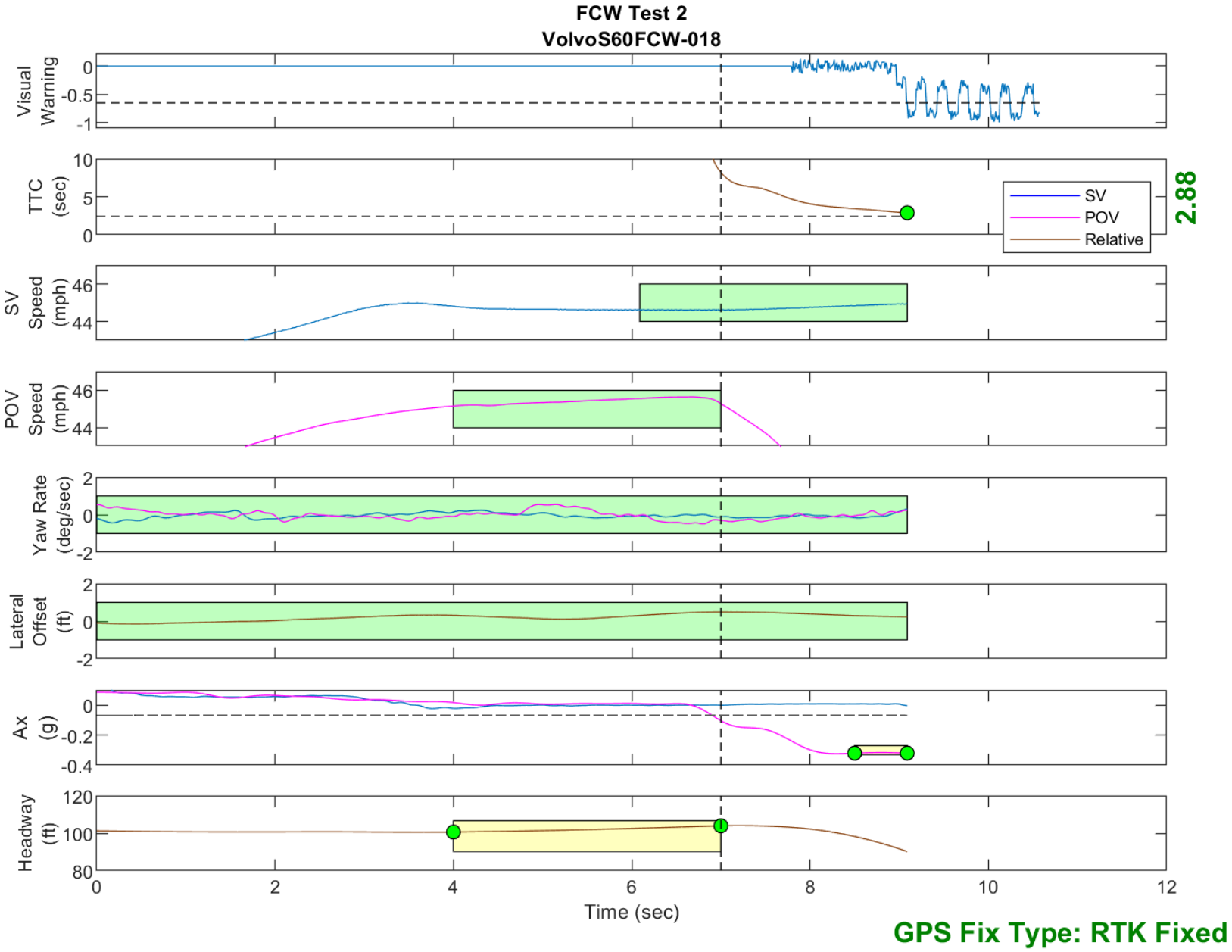


Figure D22. Time History for Run 18, FCW Test 2, Visual Warning

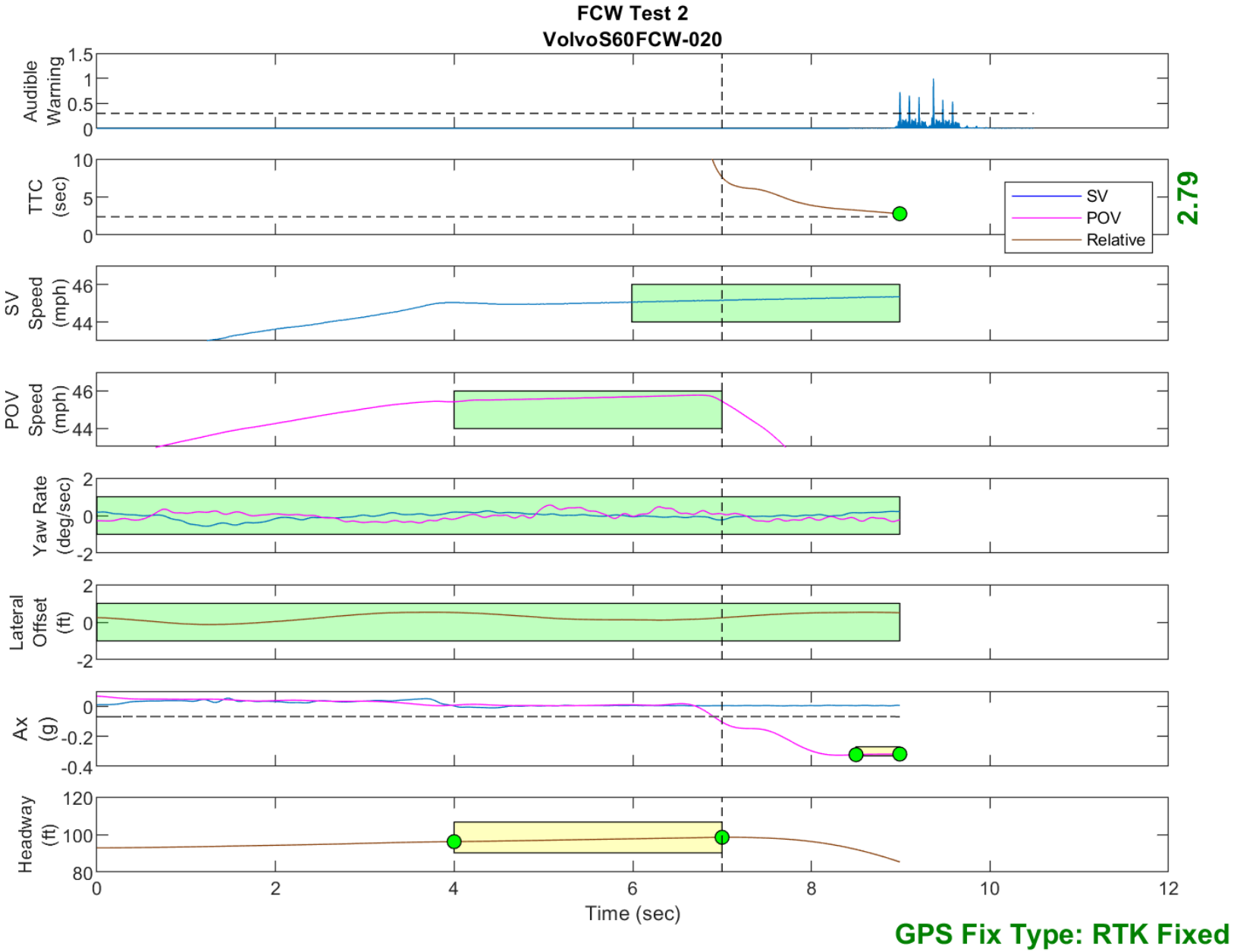


Figure D23. Time History for Run 20, FCW Test 2, Audible Warning

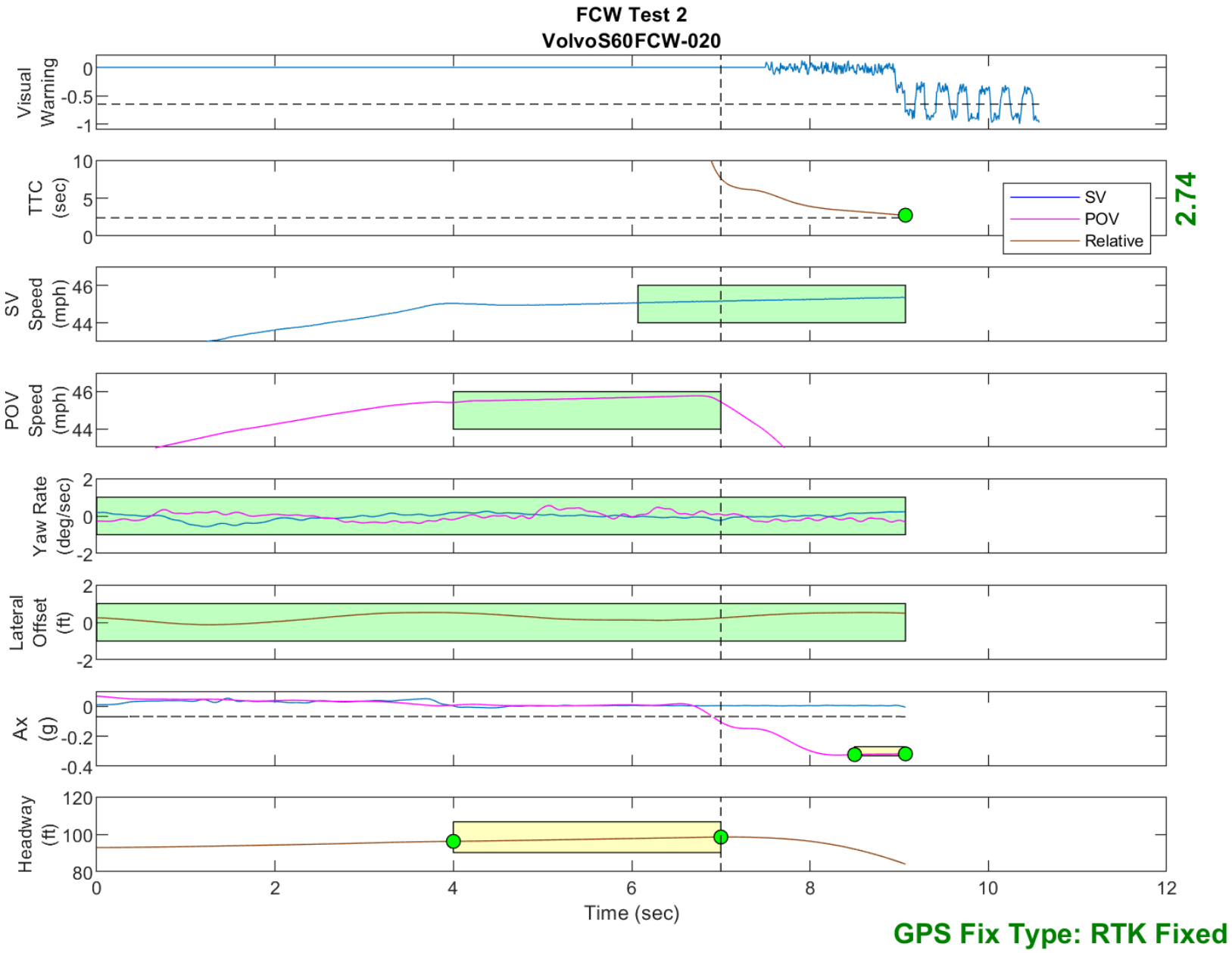


Figure D24. Time History for Run 20, FCW Test 2, Visual Warning

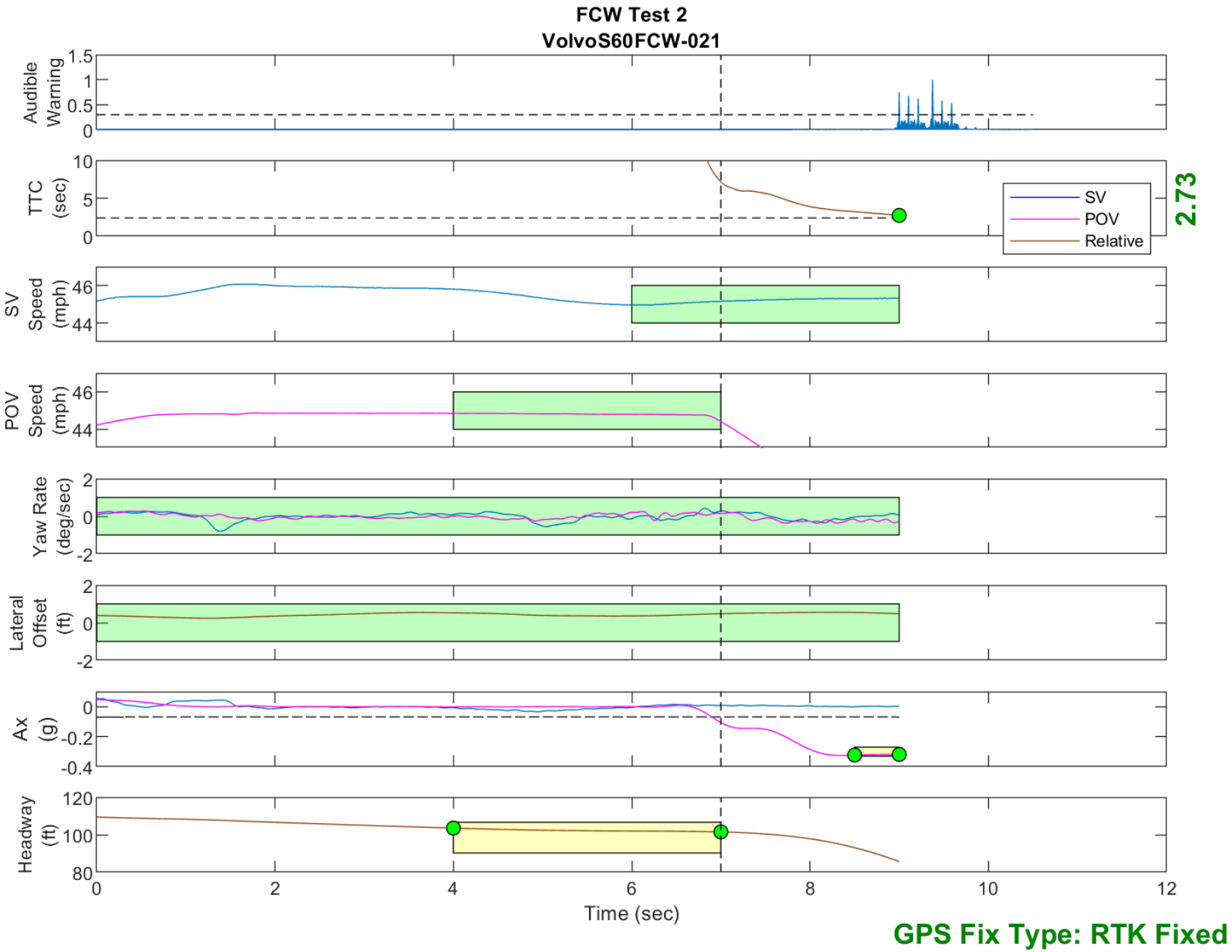


Figure D25. Time History for Run 21, FCW Test 2, Audible Warning

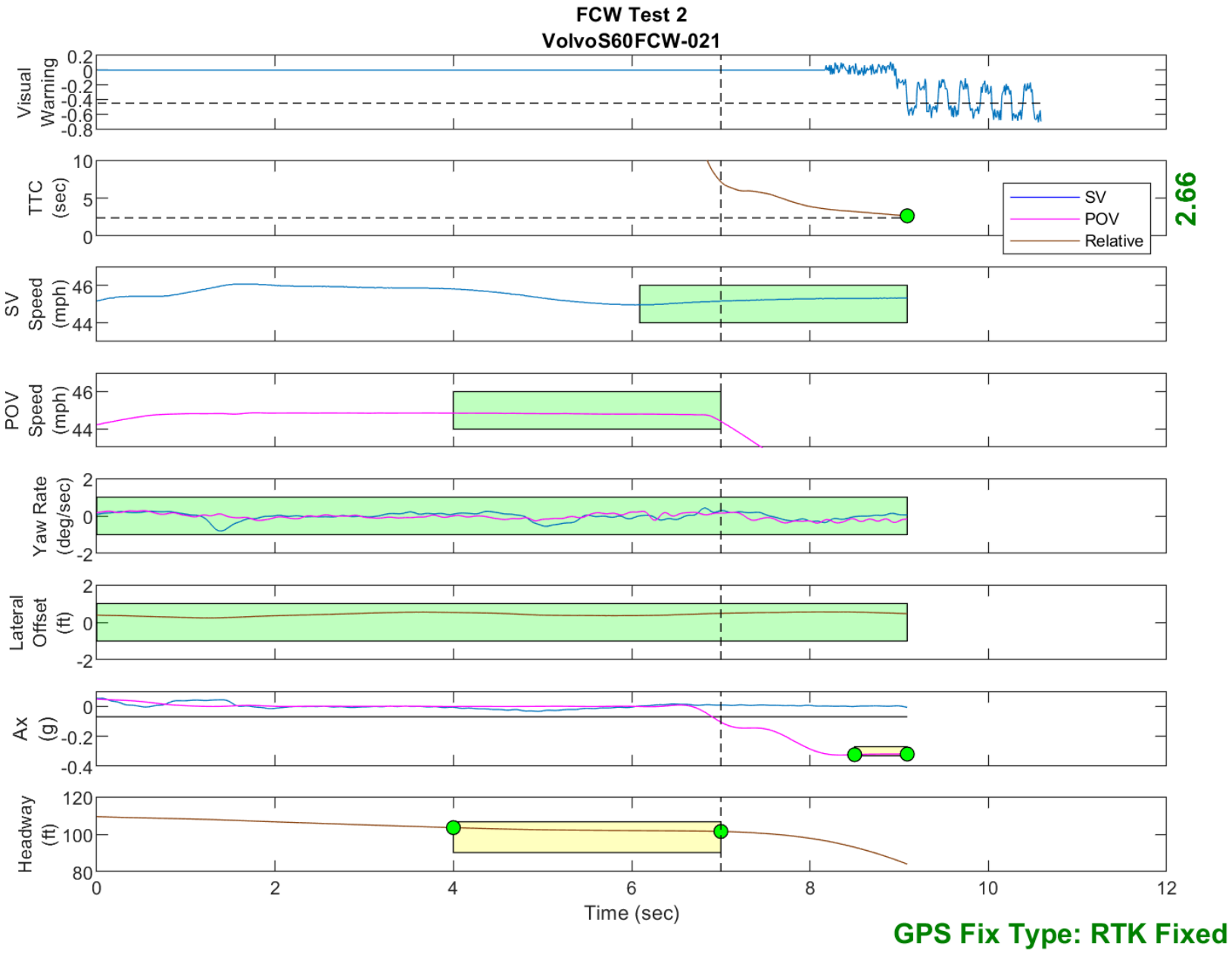


Figure D26. Time History for Run 21, FCW Test 2, Visual Warning

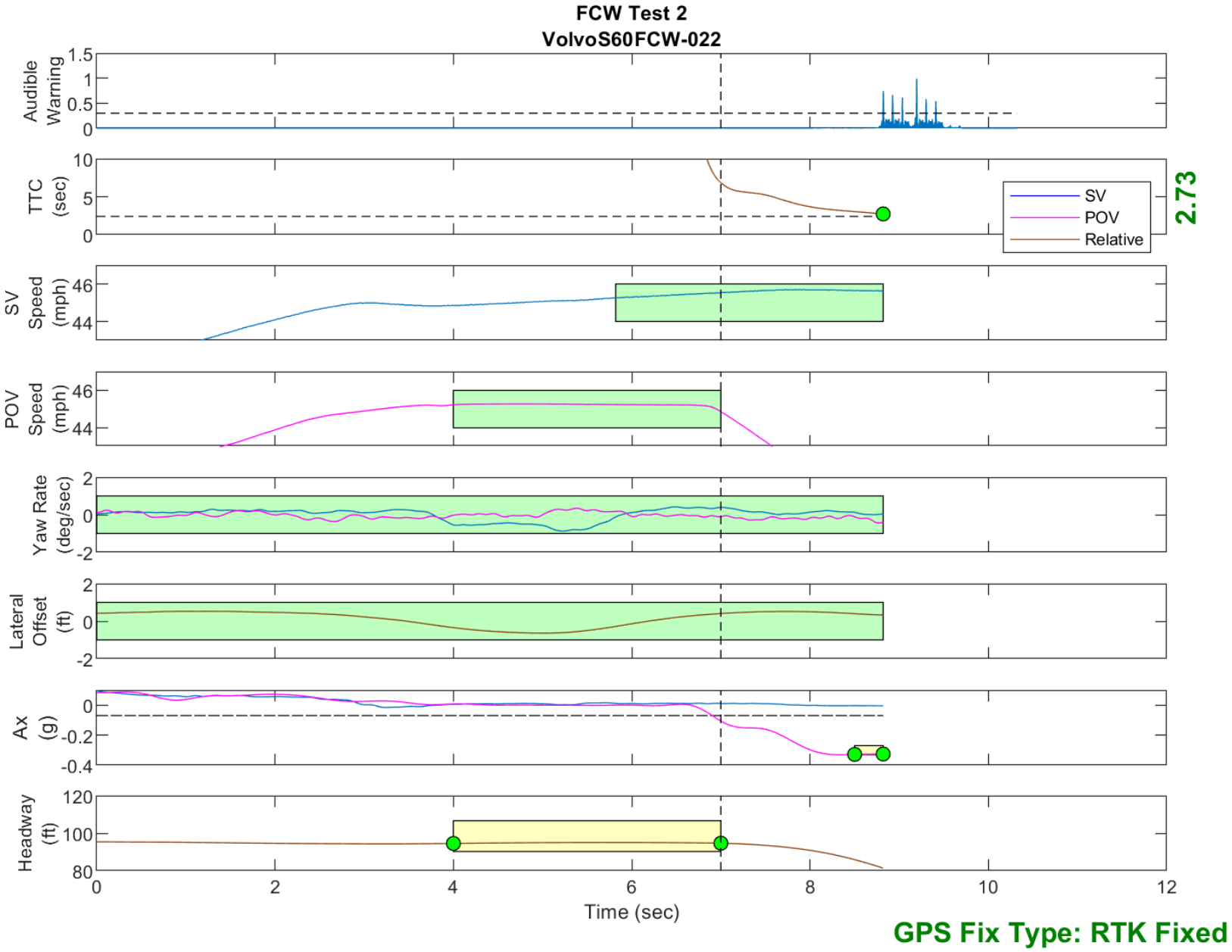


Figure D27. Time History for Run 22, FCW Test 2, Audible Warning

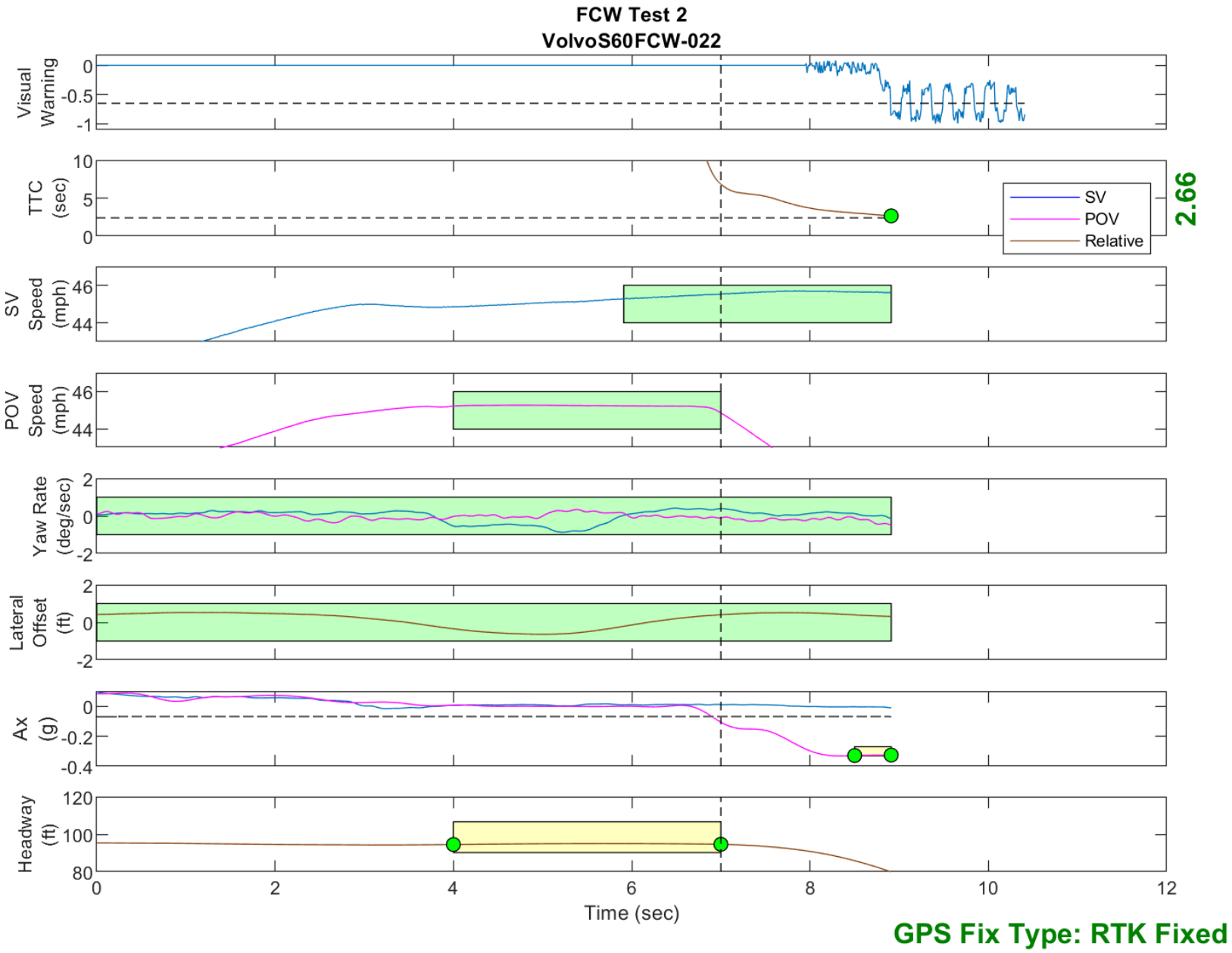


Figure D28. Time History for Run 22, FCW Test 2, Visual Warning

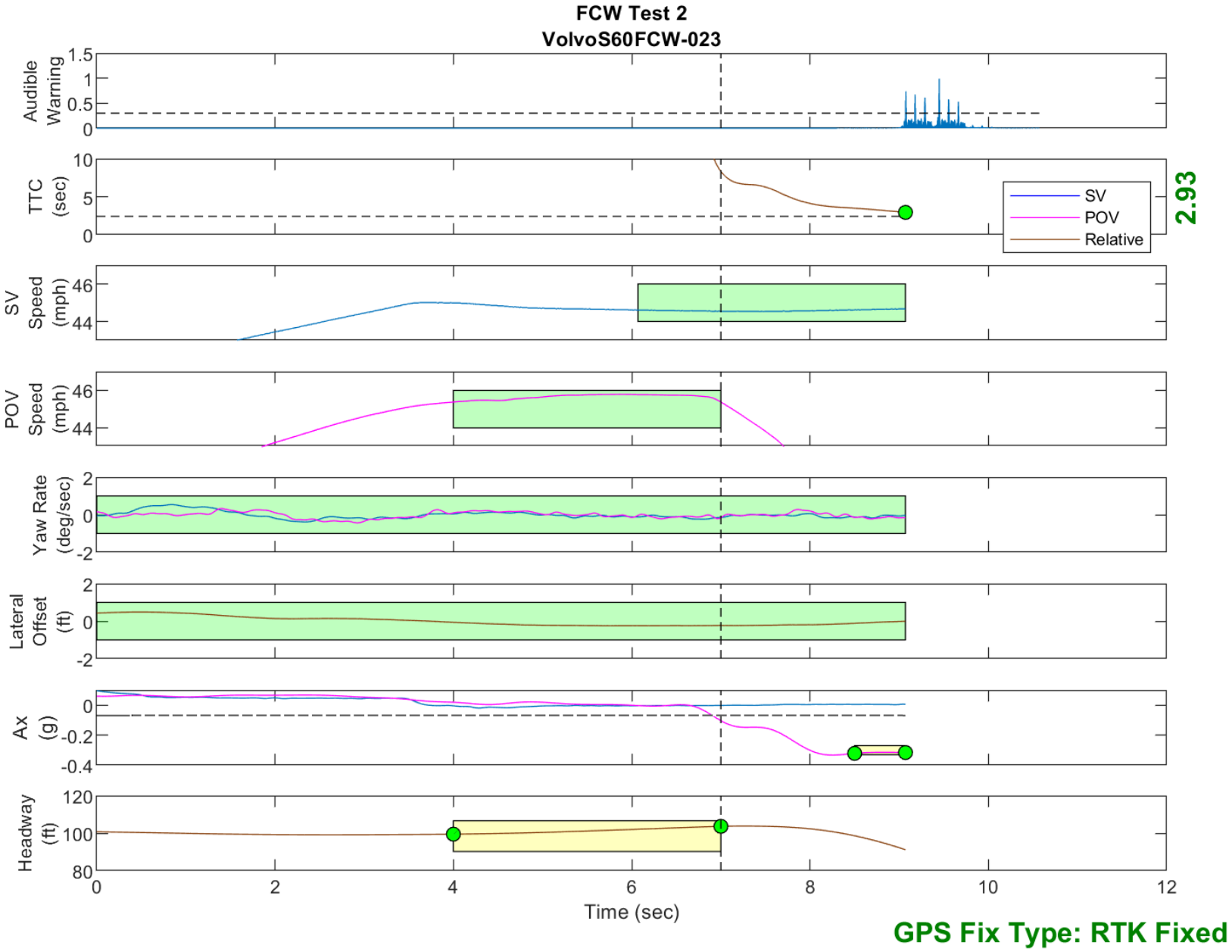


Figure D29. Time History for Run 23, FCW Test 2, Audible Warning

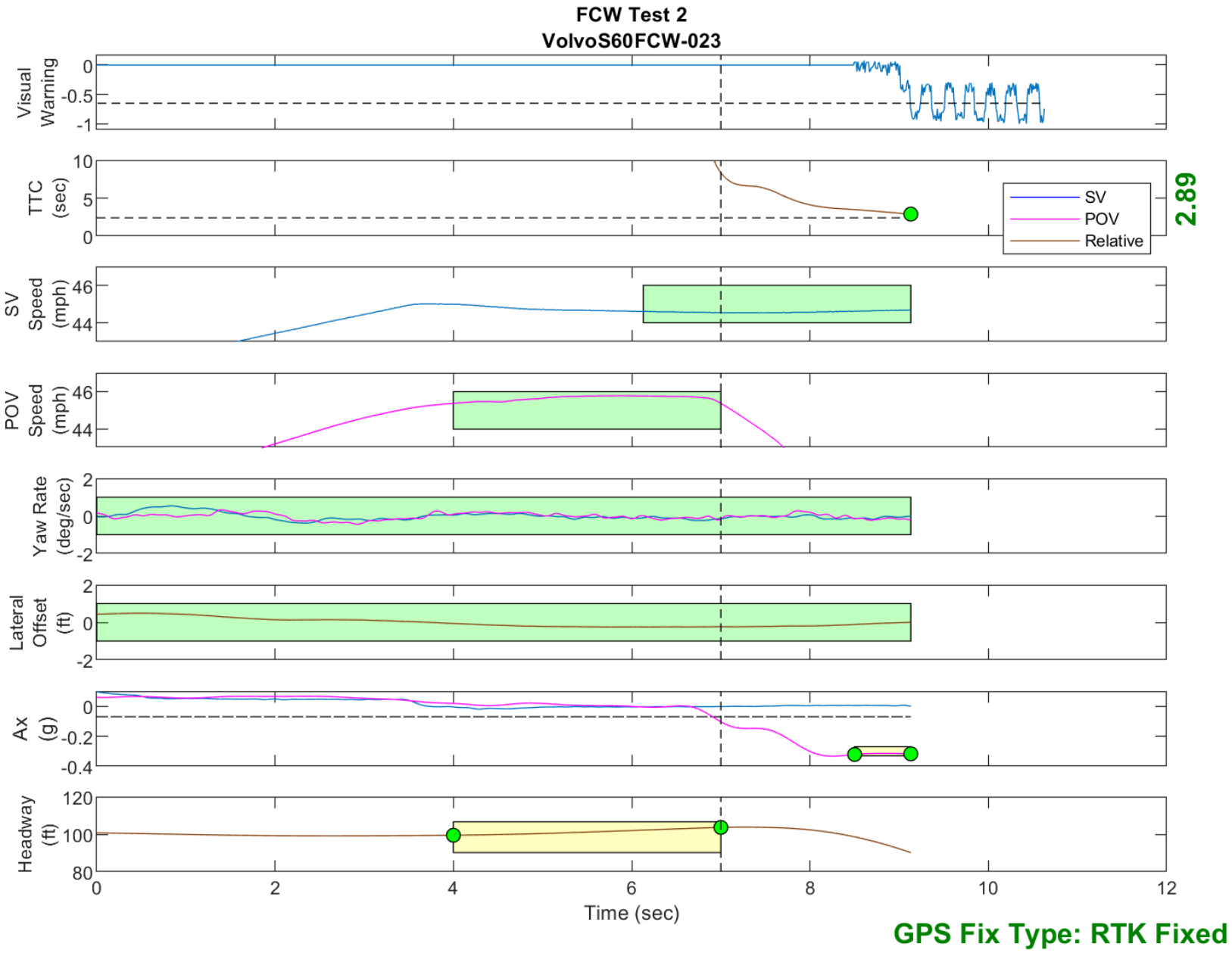


Figure D30. Time History for Run 23, FCW Test 2, Visual Warning

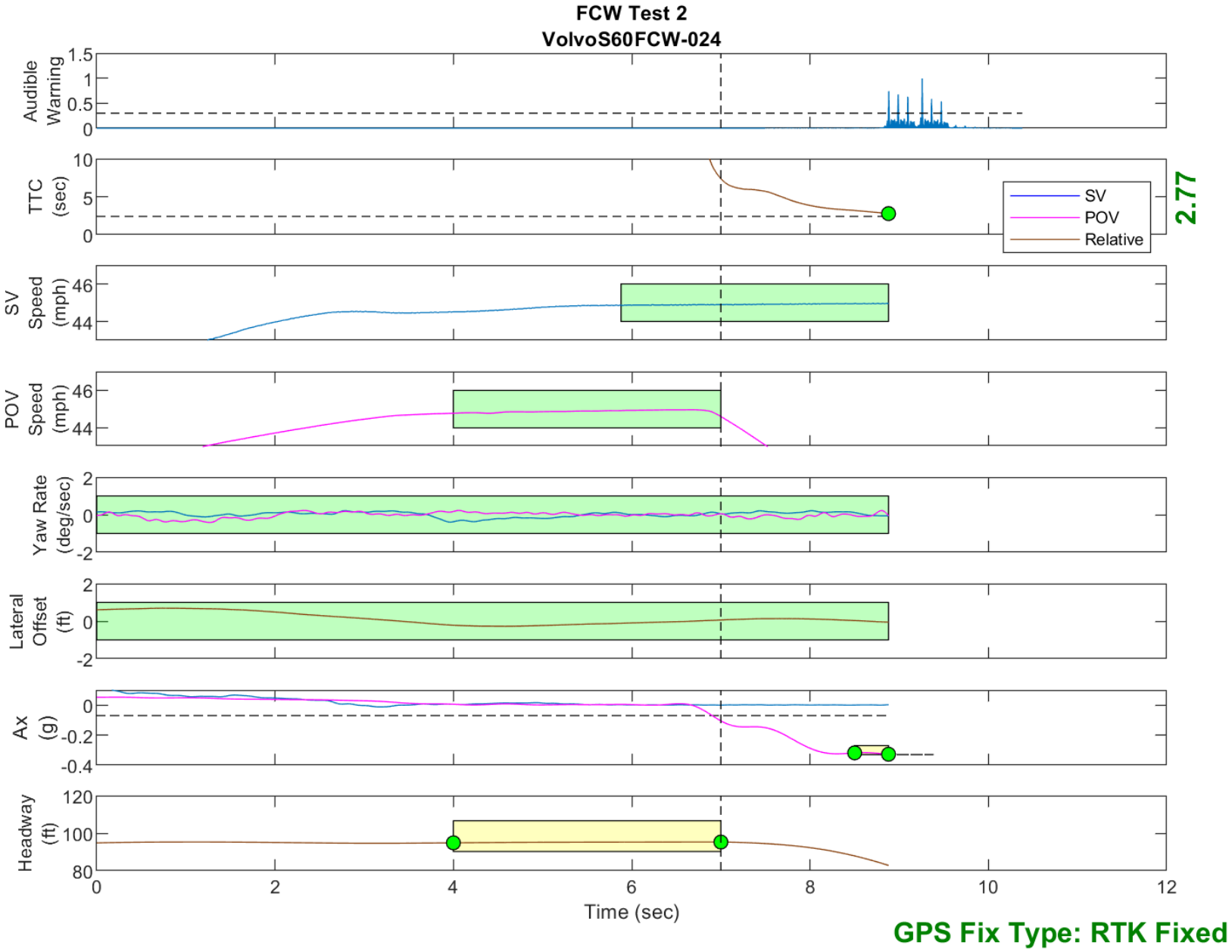


Figure D31. Time History for Run 24, FCW Test 2, Audible Warning

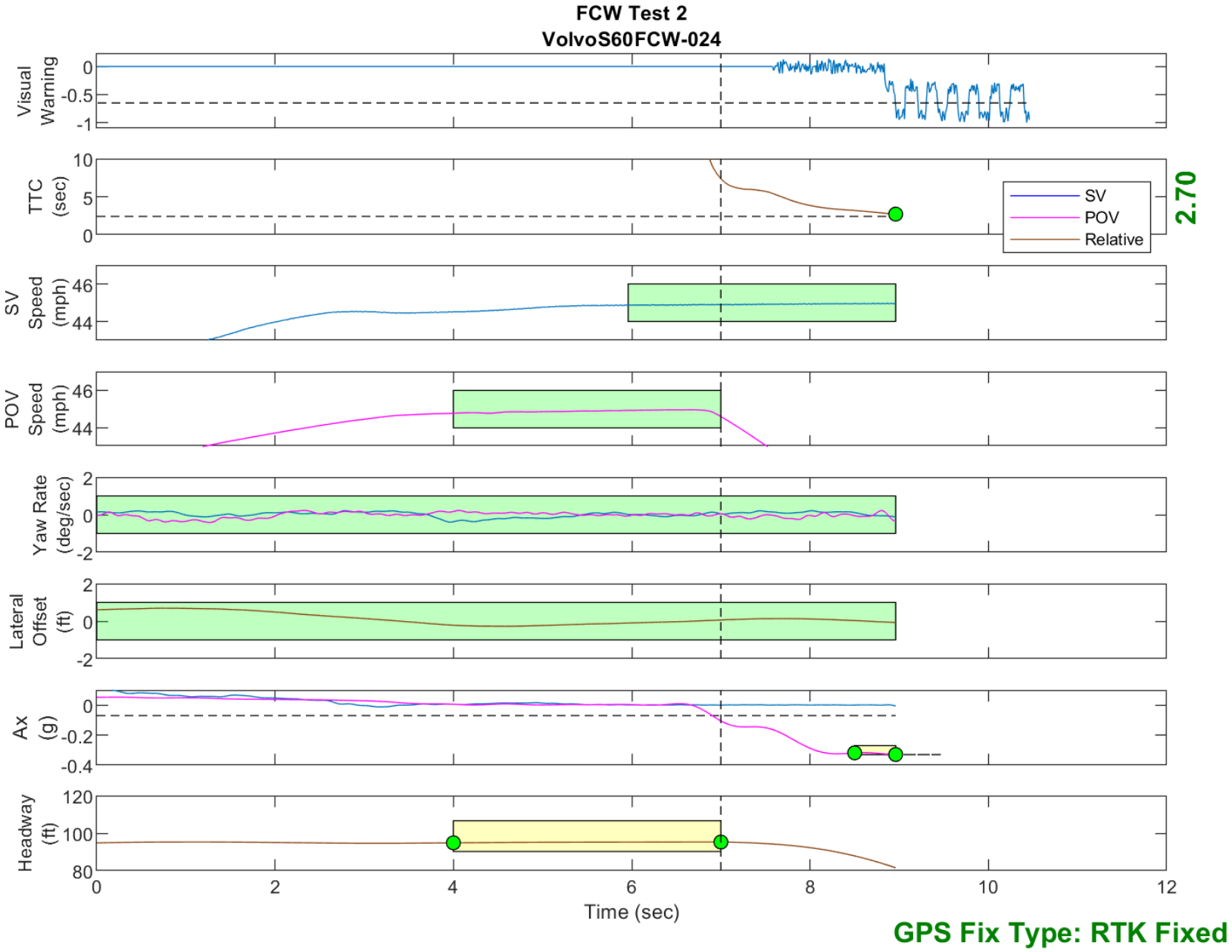


Figure D32. Time History for Run 24, FCW Test 2, Visual Warning

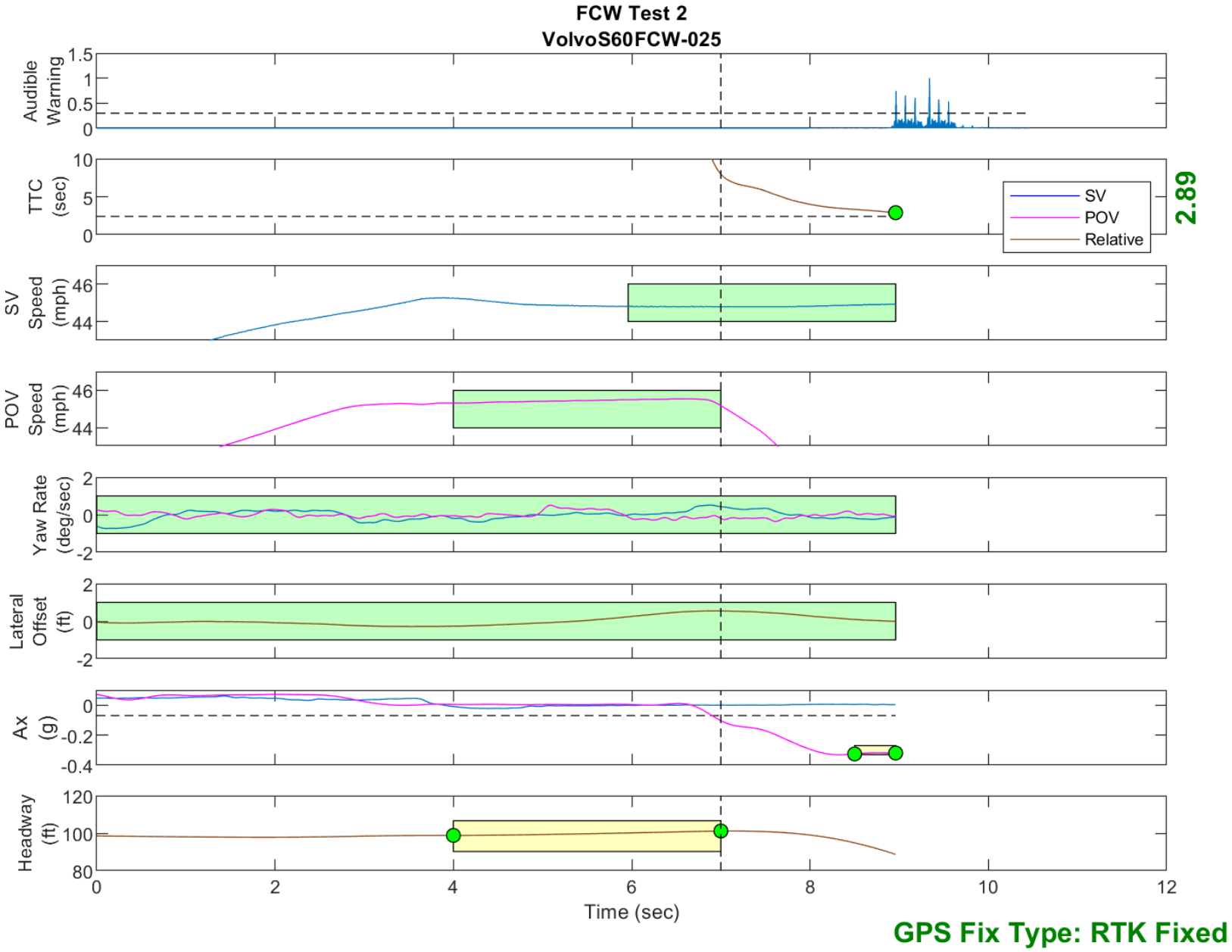


Figure D33. Time History for Run 25, FCW Test 2, Audible Warning

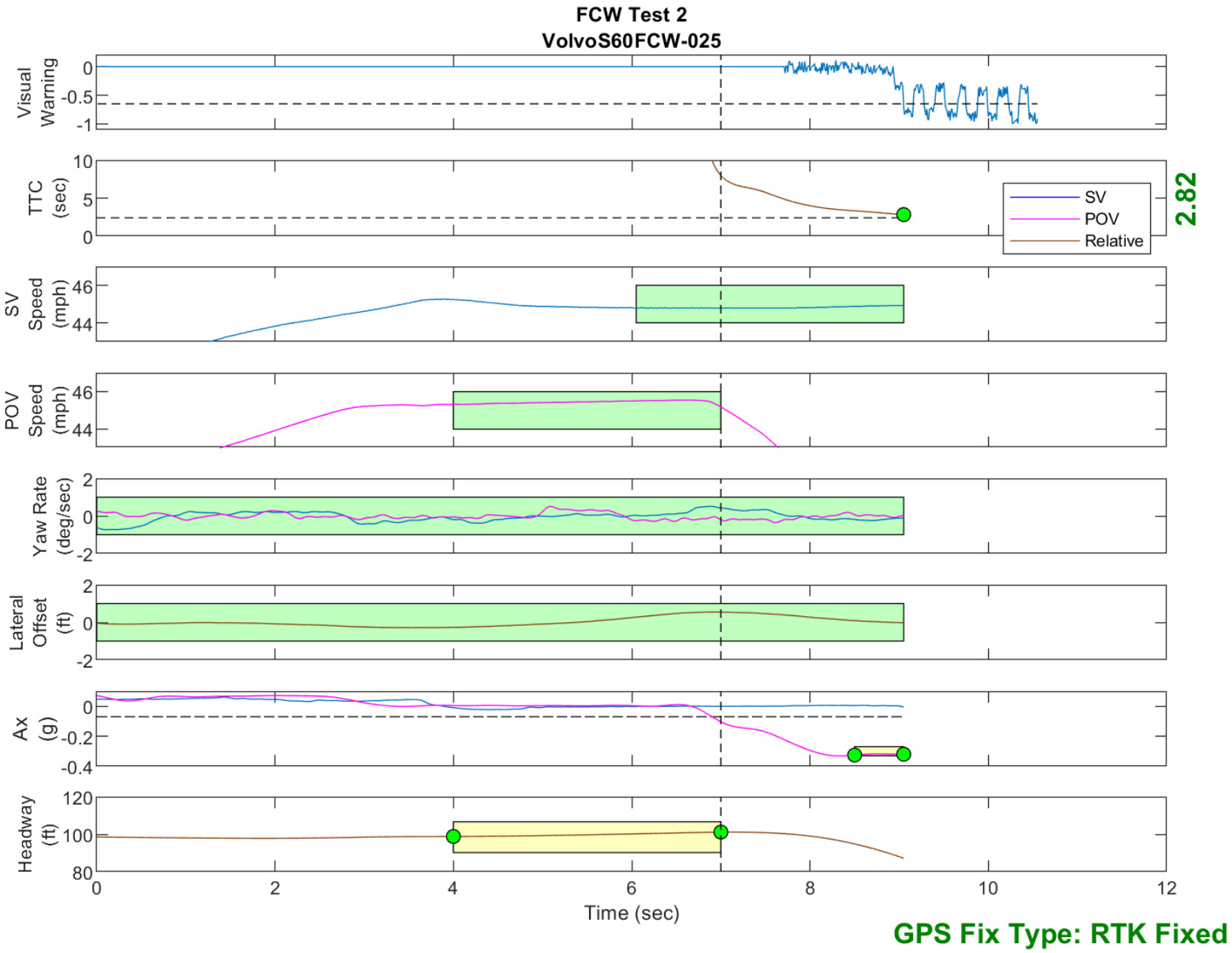


Figure D34. Time History for Run 25, FCW Test 2, Visual Warning

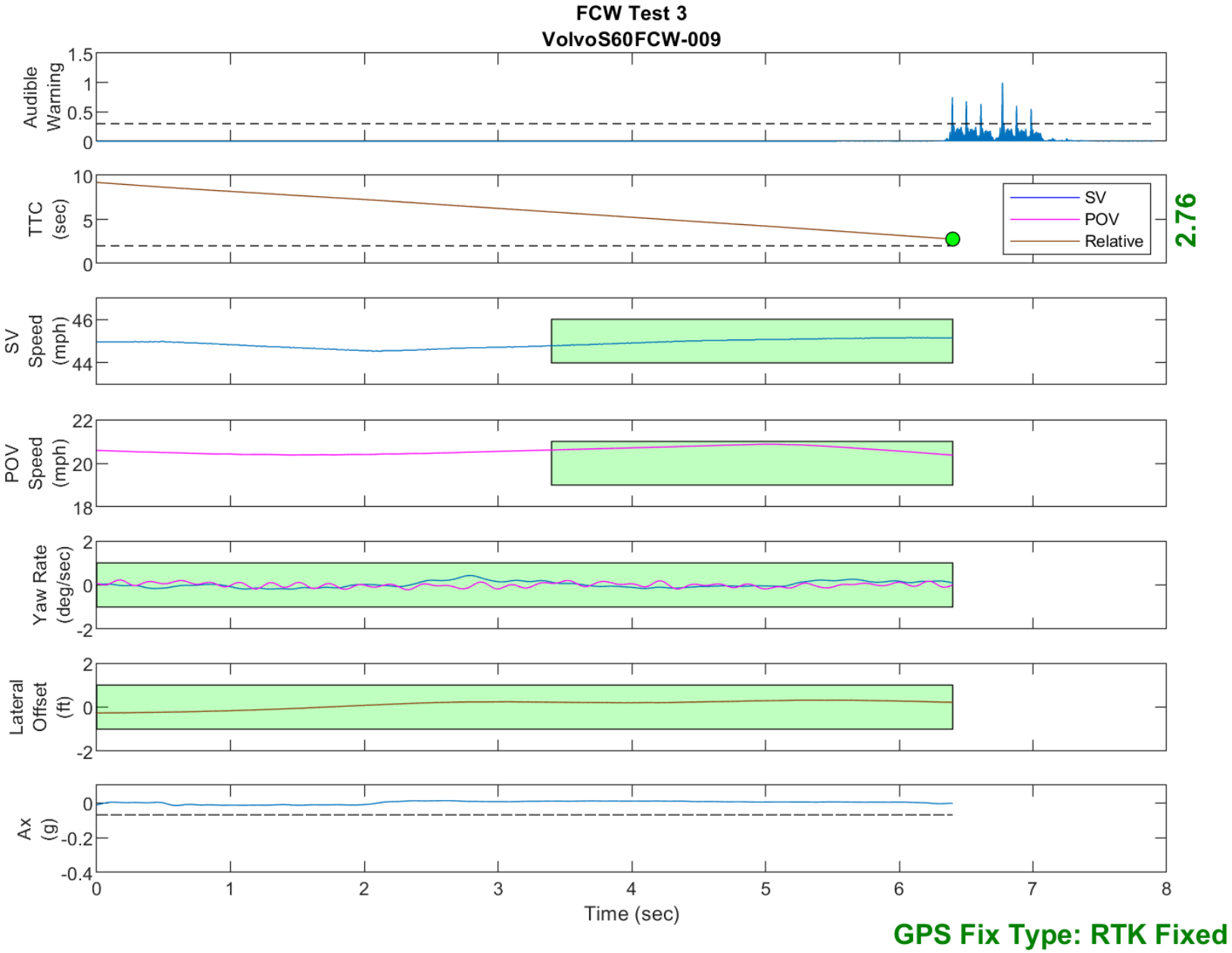


Figure D35. Time History for Run 9, FCW Test 3, Audible Warning

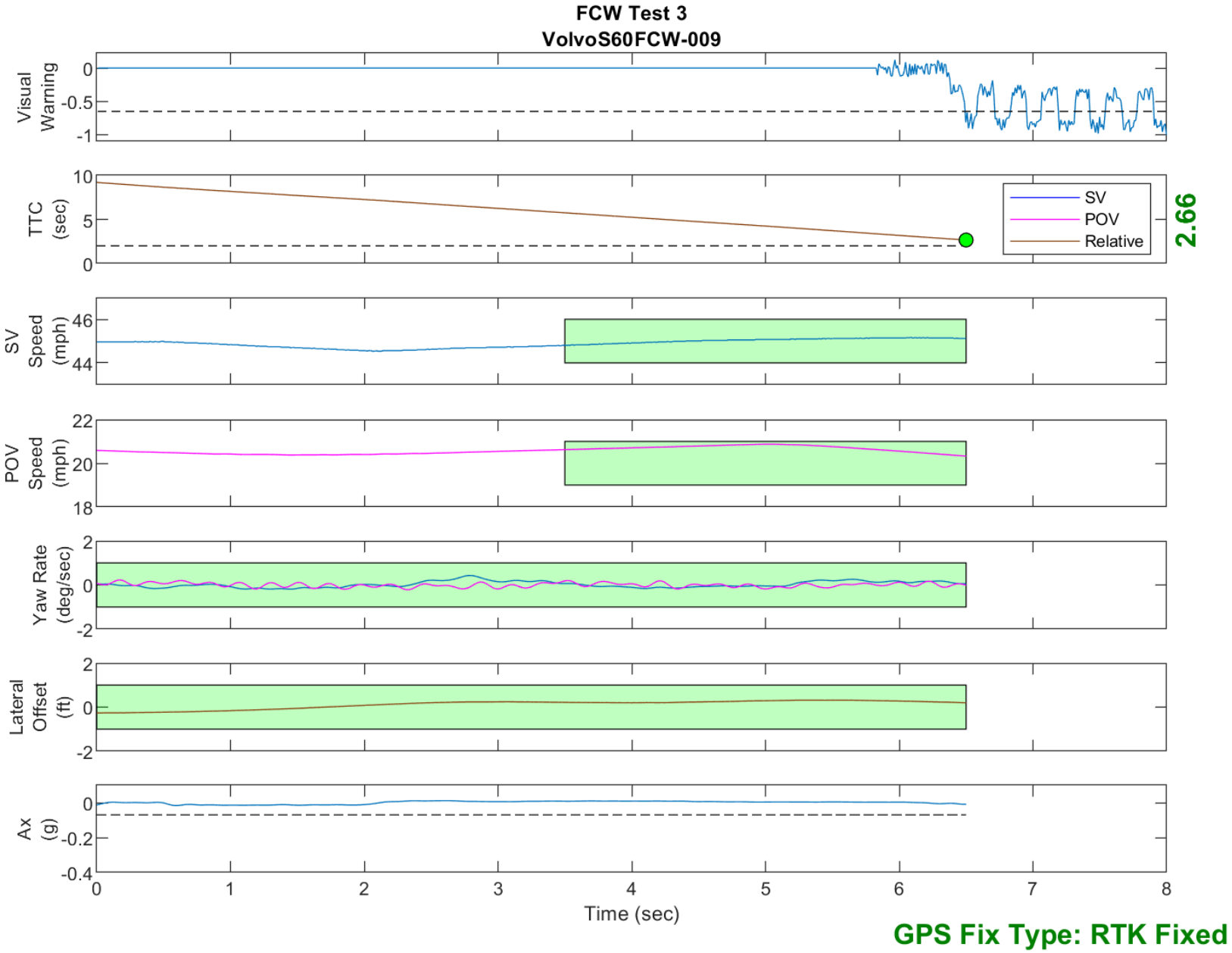


Figure D36. Time History for Run 9, FCW Test 3, Visual Warning

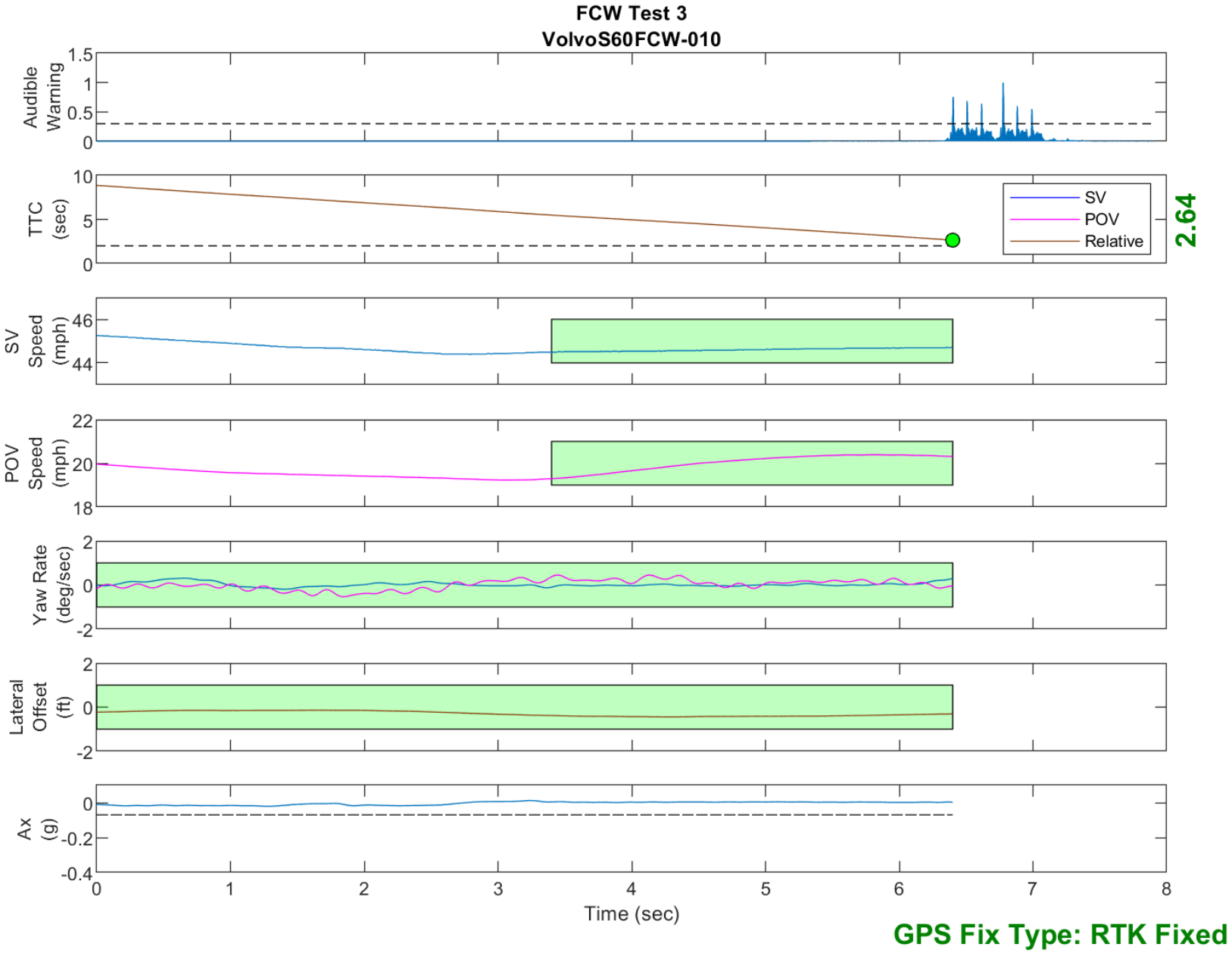


Figure D37. Time History for Run 10, FCW Test 3, Audible Warning

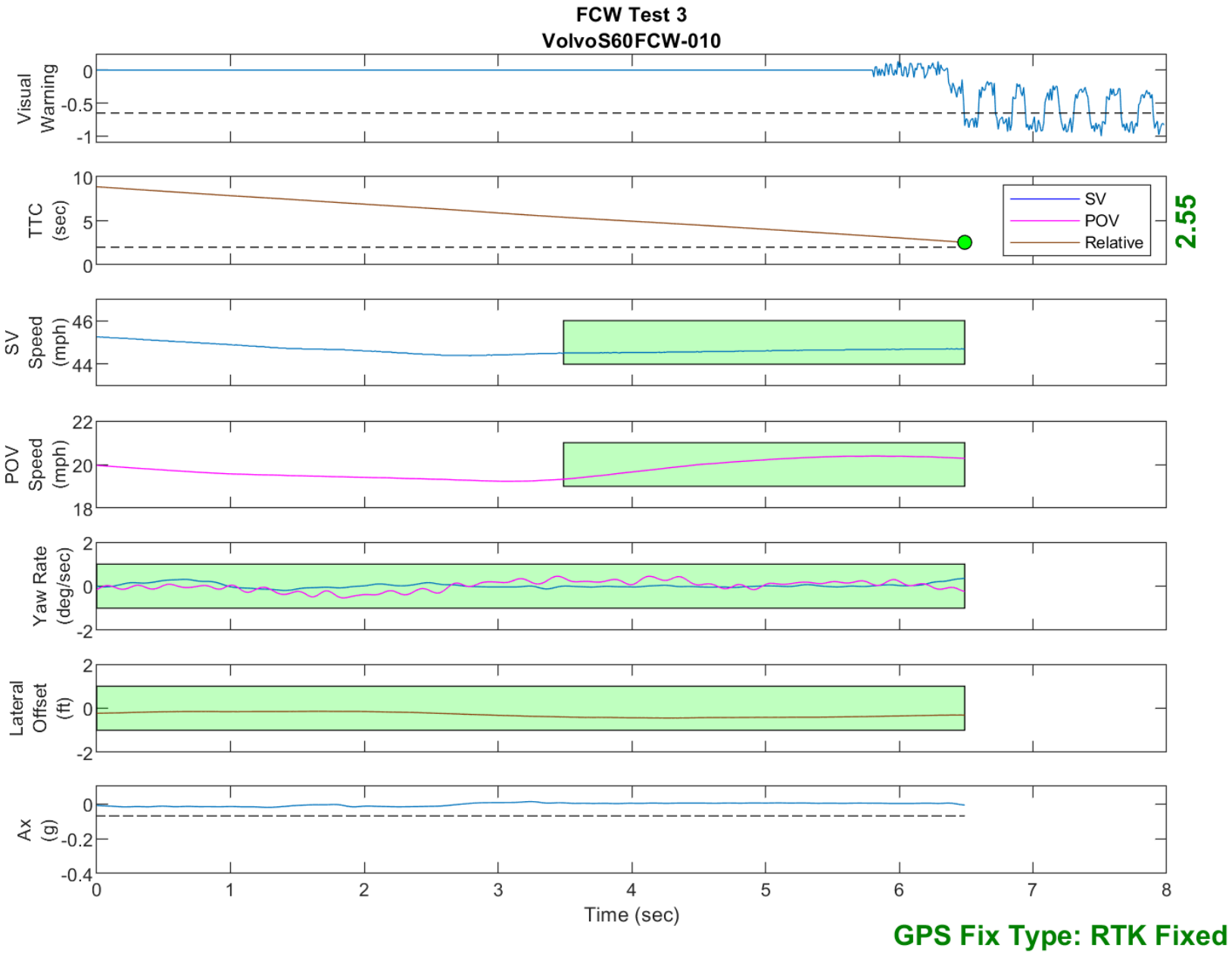


Figure D38. Time History for Run 10, FCW Test 3, Visual Warning

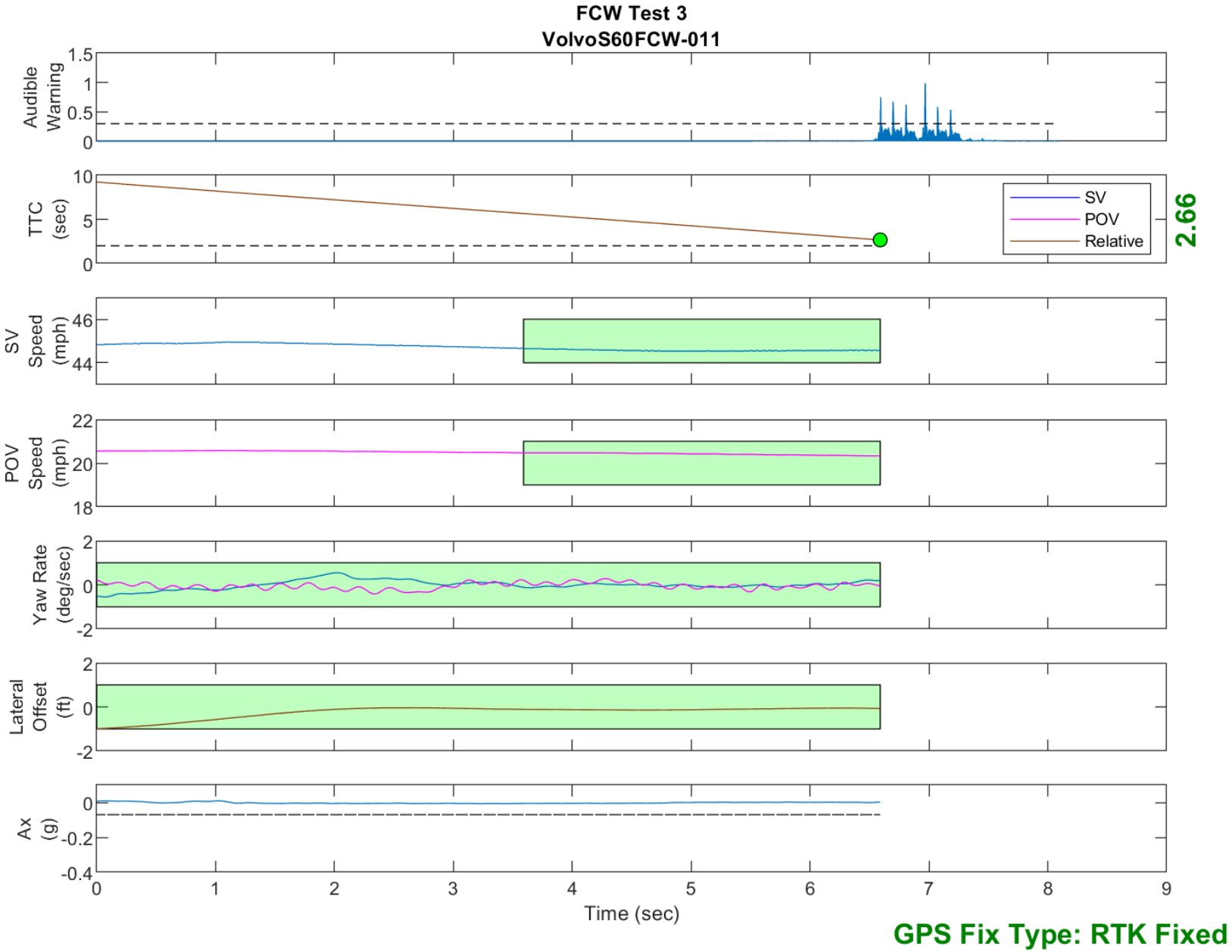


Figure D39. Time History for Run 11, FCW Test 3, Audible Warning

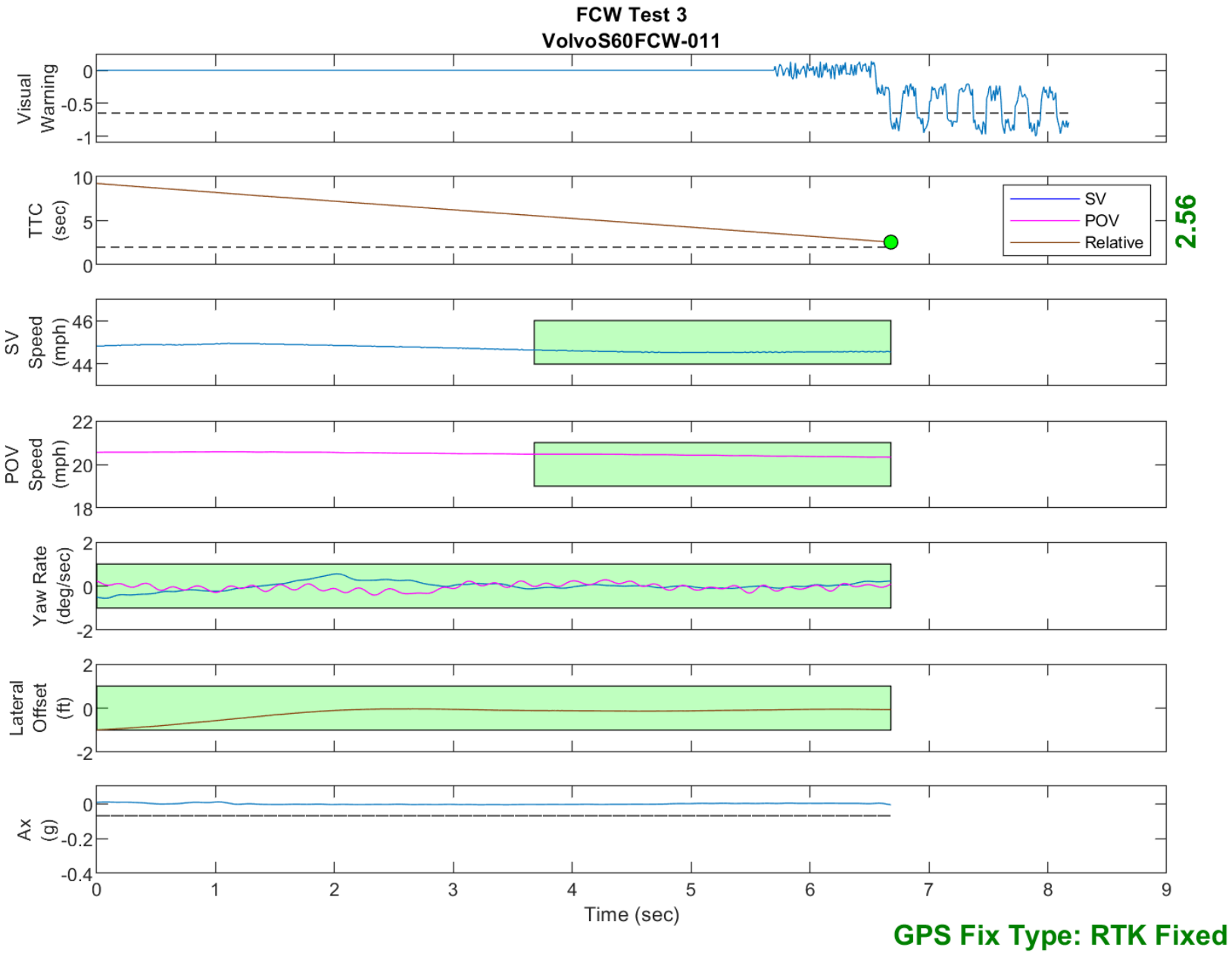


Figure D40. Time History for Run 11, FCW Test 3, Visual Warning

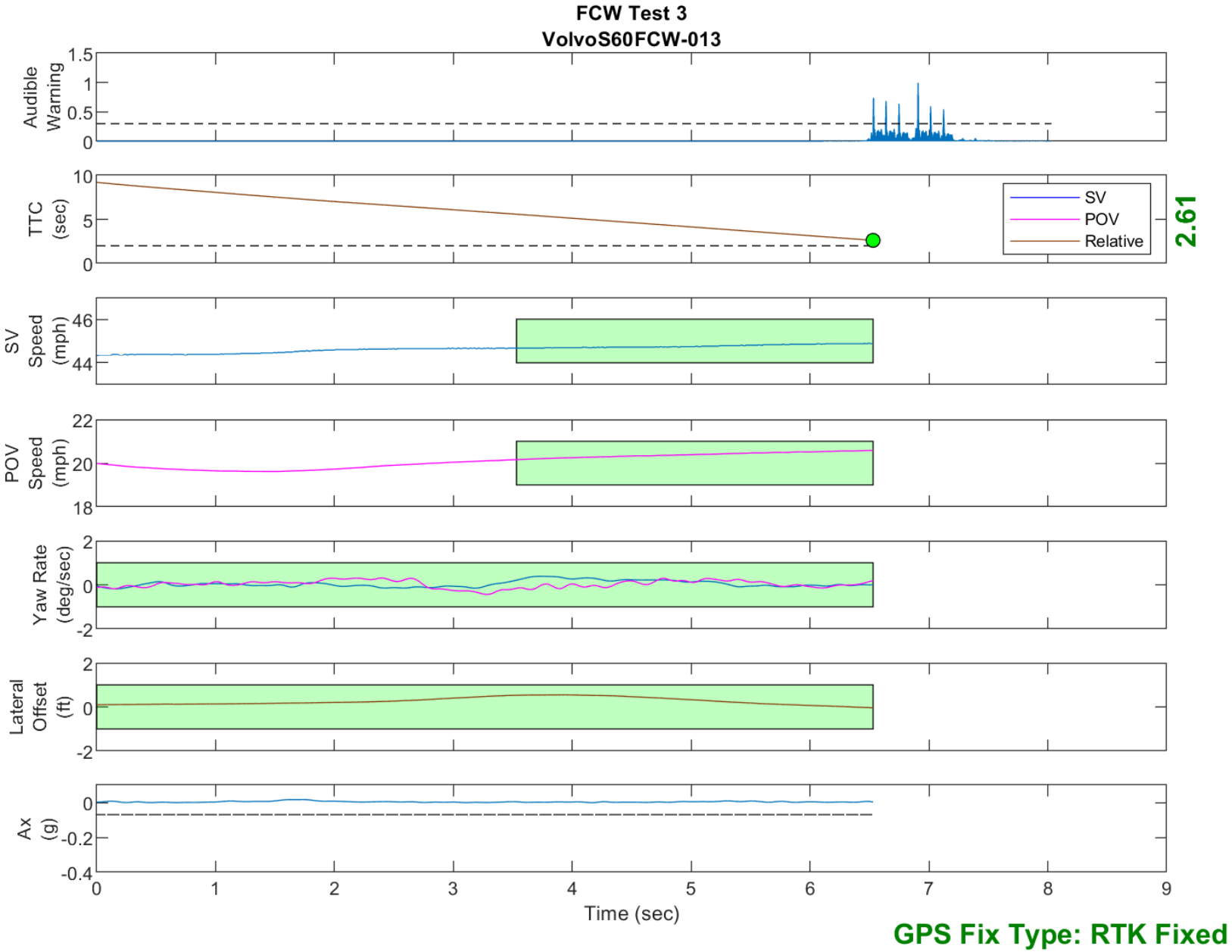


Figure D41. Time History for Run 13, FCW Test 3, Audible Warning

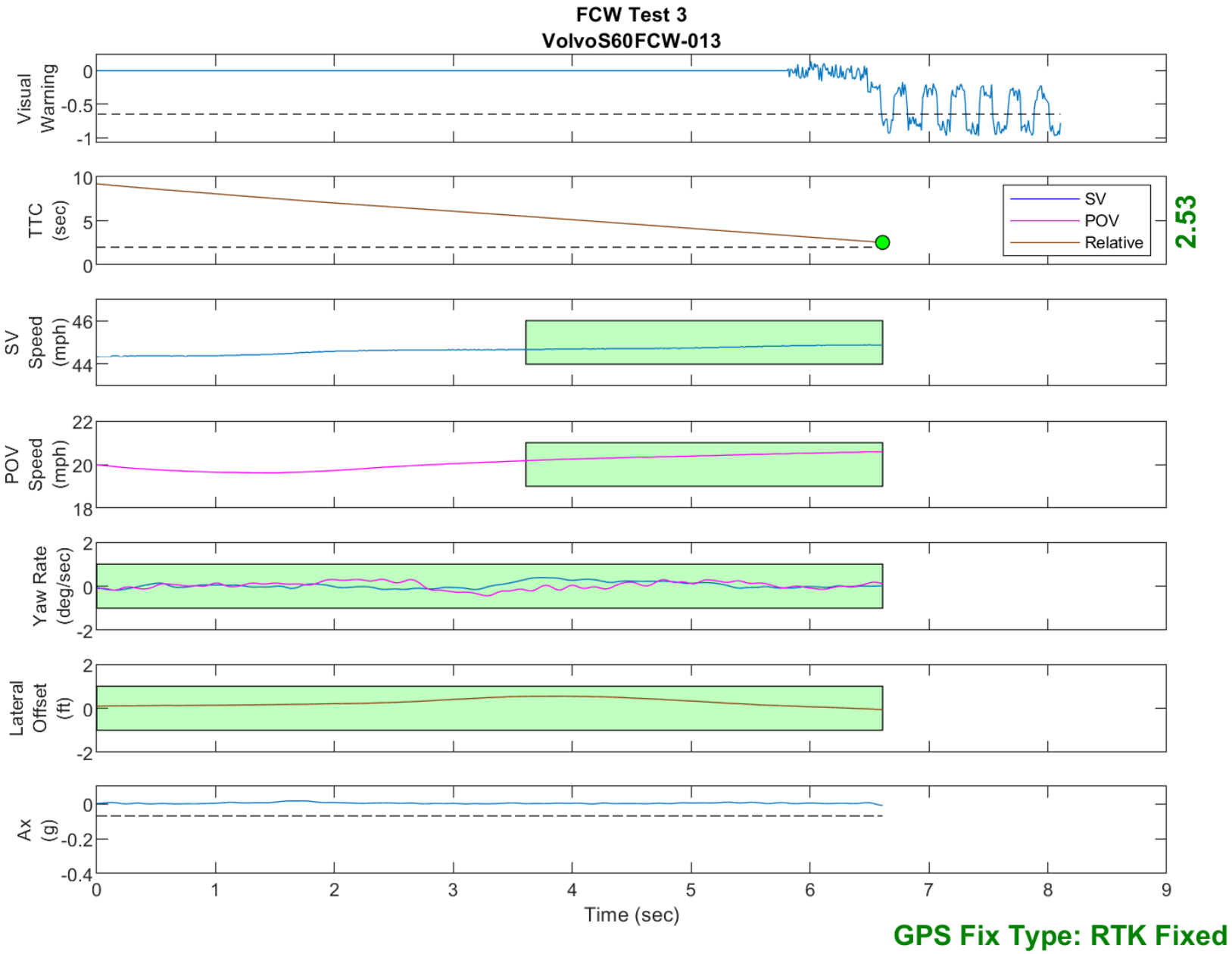


Figure D42. Time History for Run 13, FCW Test 3, Visual Warning

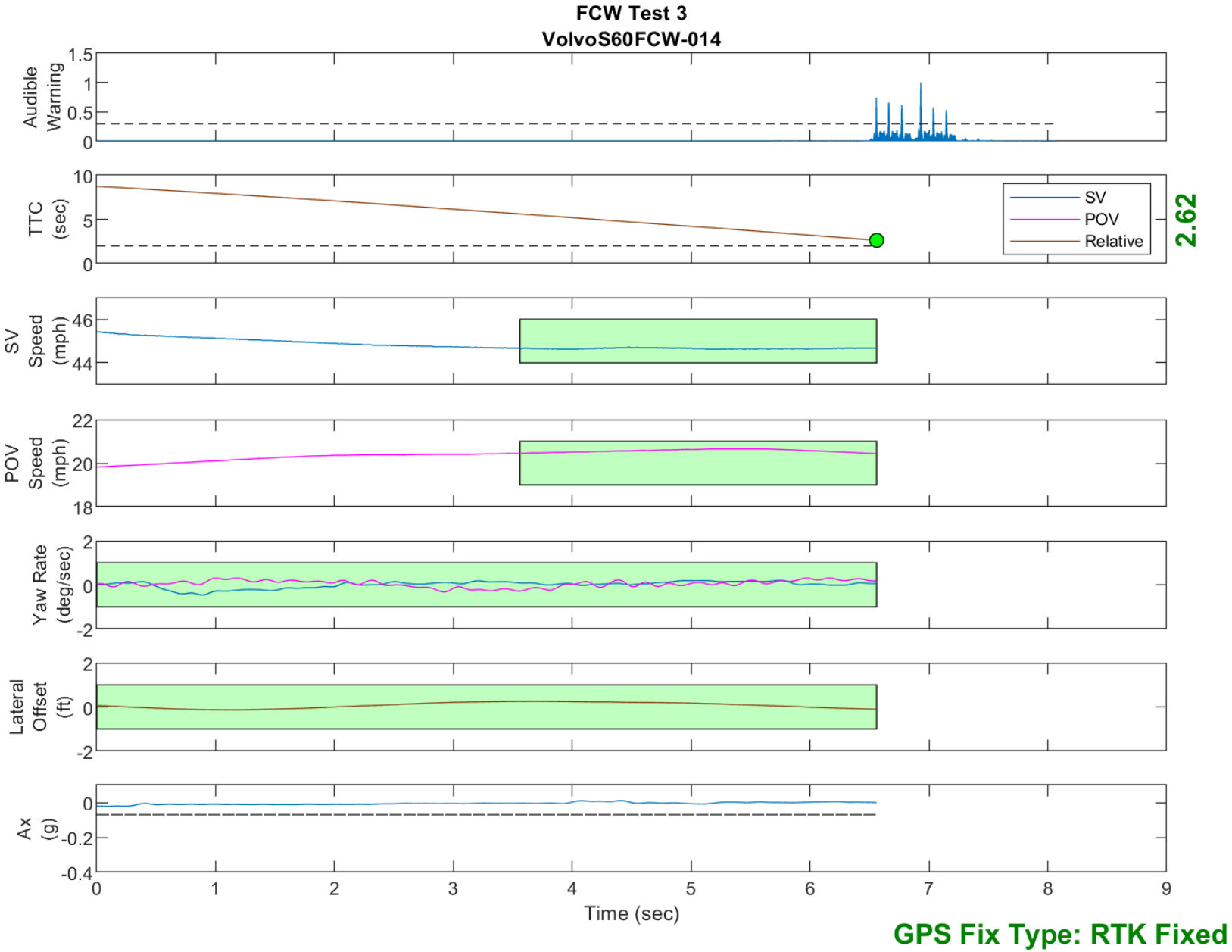


Figure D43. Time History for Run 14, FCW Test 3, Audible Warning

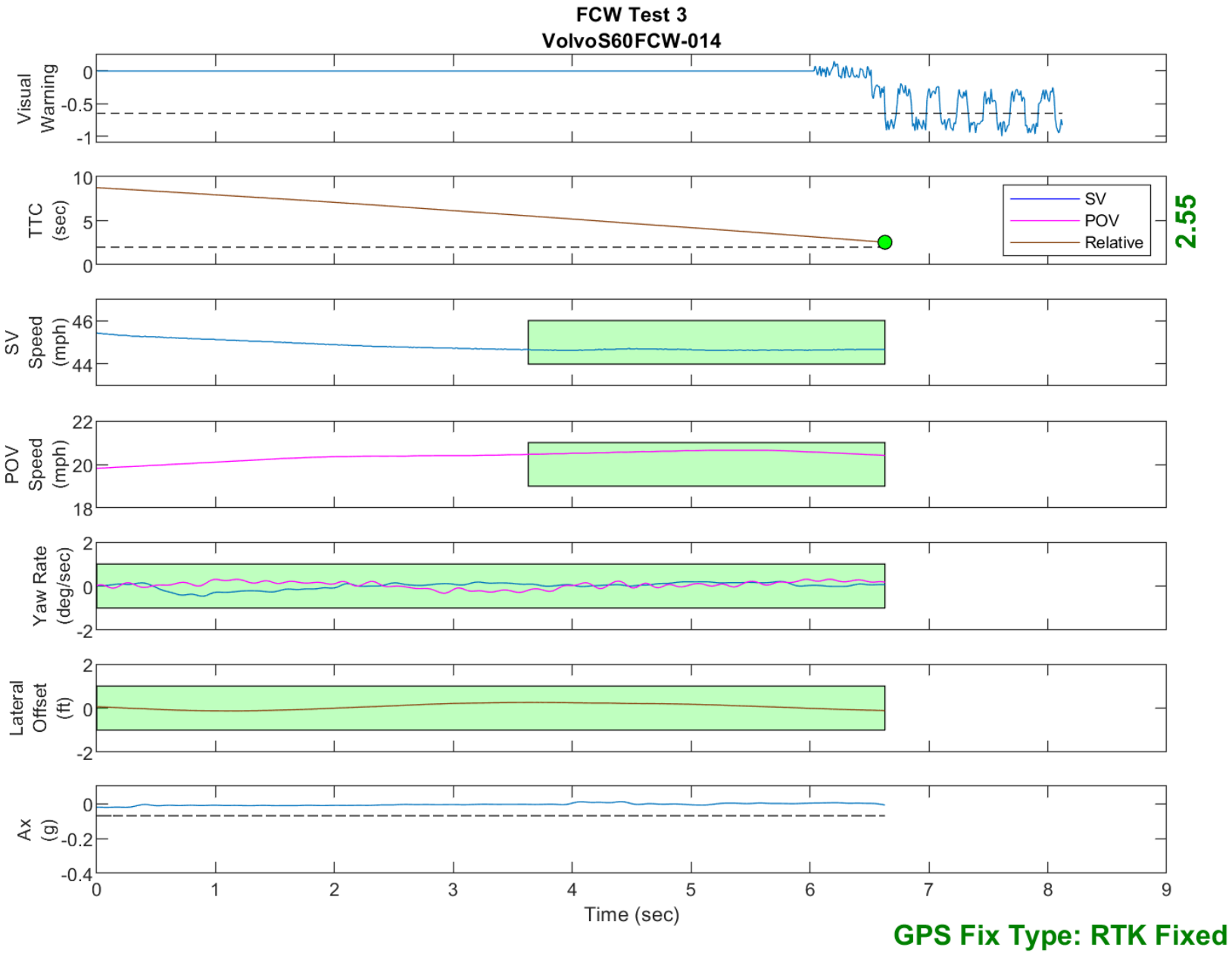


Figure D44. Time History for Run 14, FCW Test 3, Visual Warning

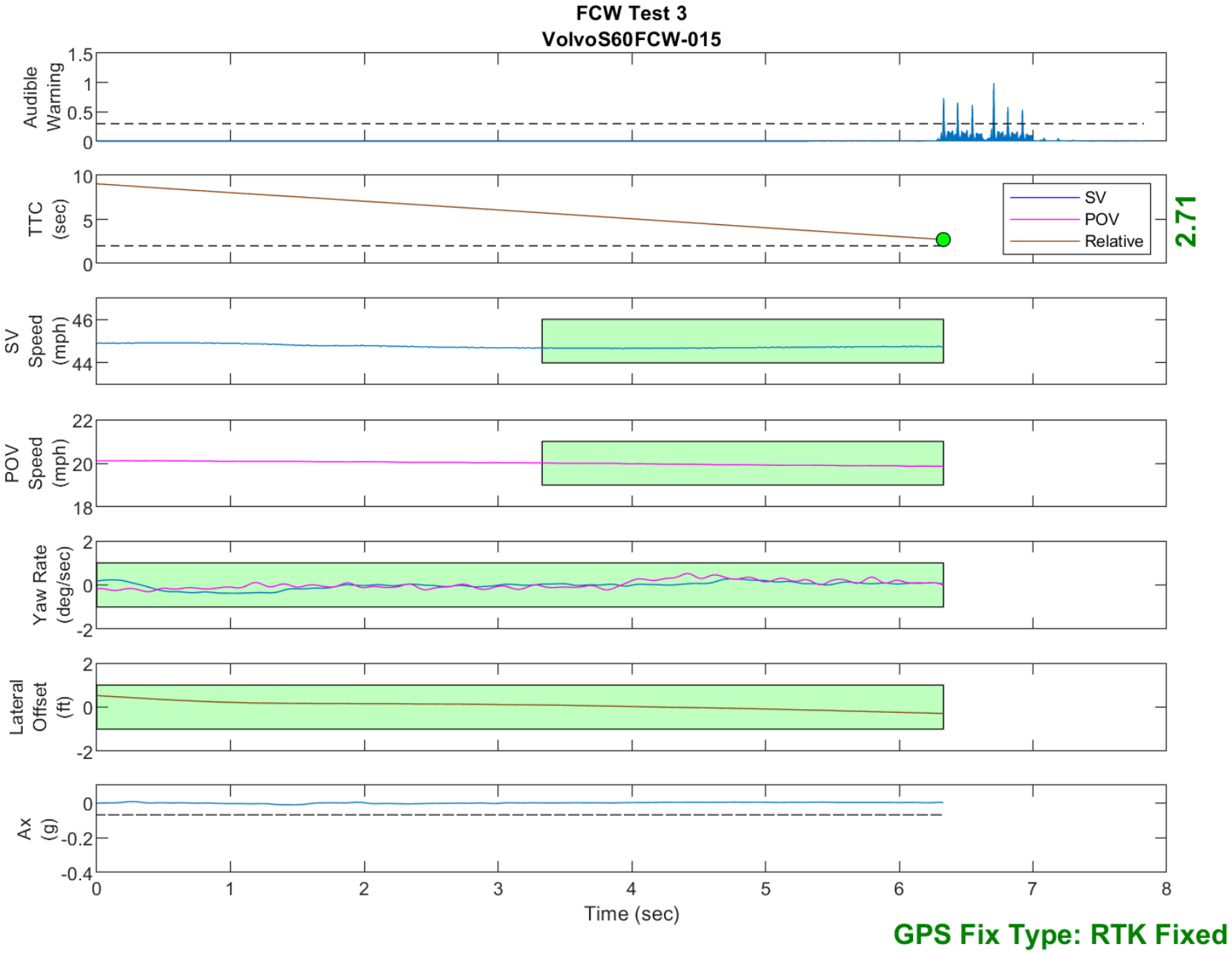


Figure D45. Time History for Run 15, FCW Test 3, Audible Warning

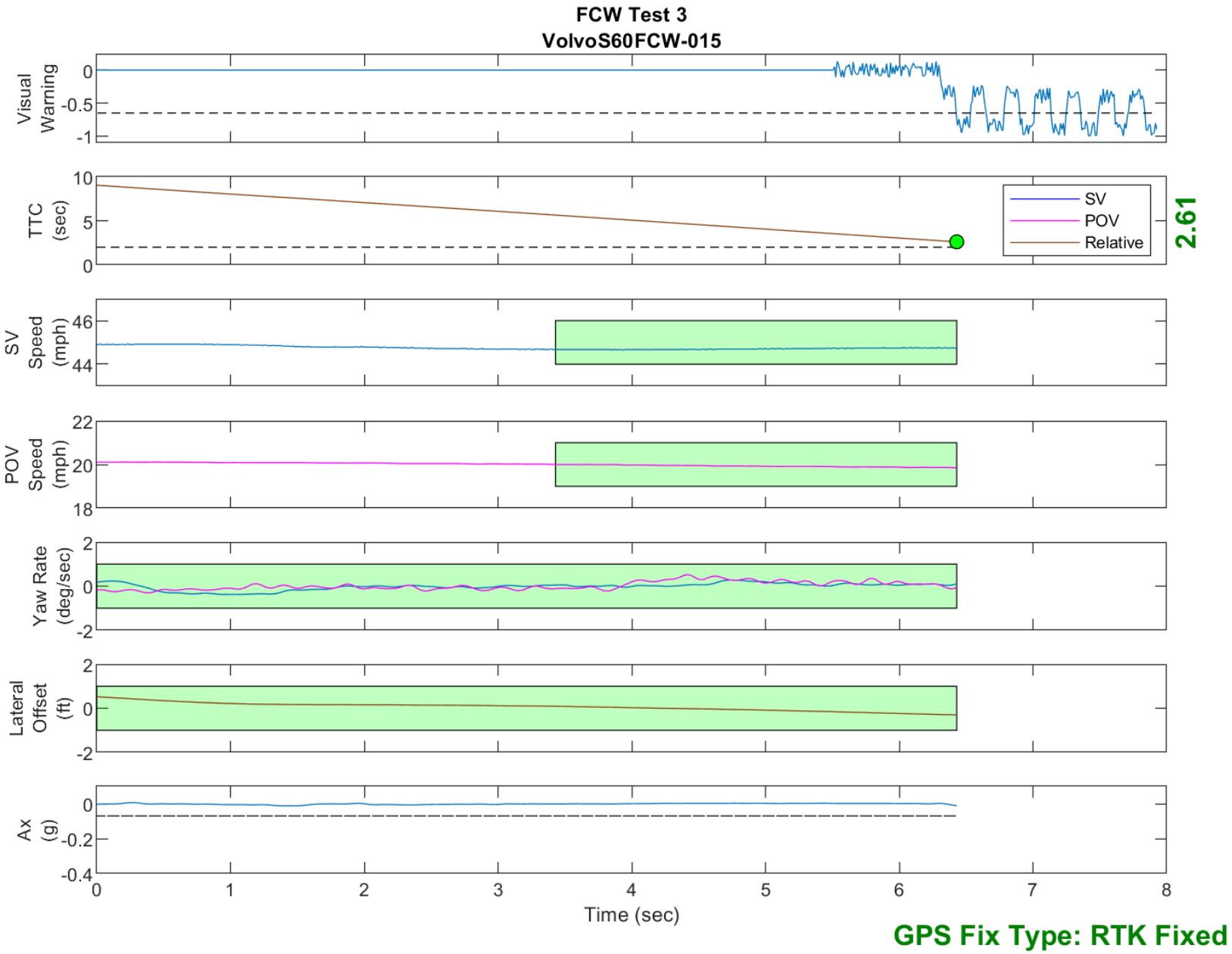


Figure D46. Time History for Run 15, FCW Test 3, Visual Warning

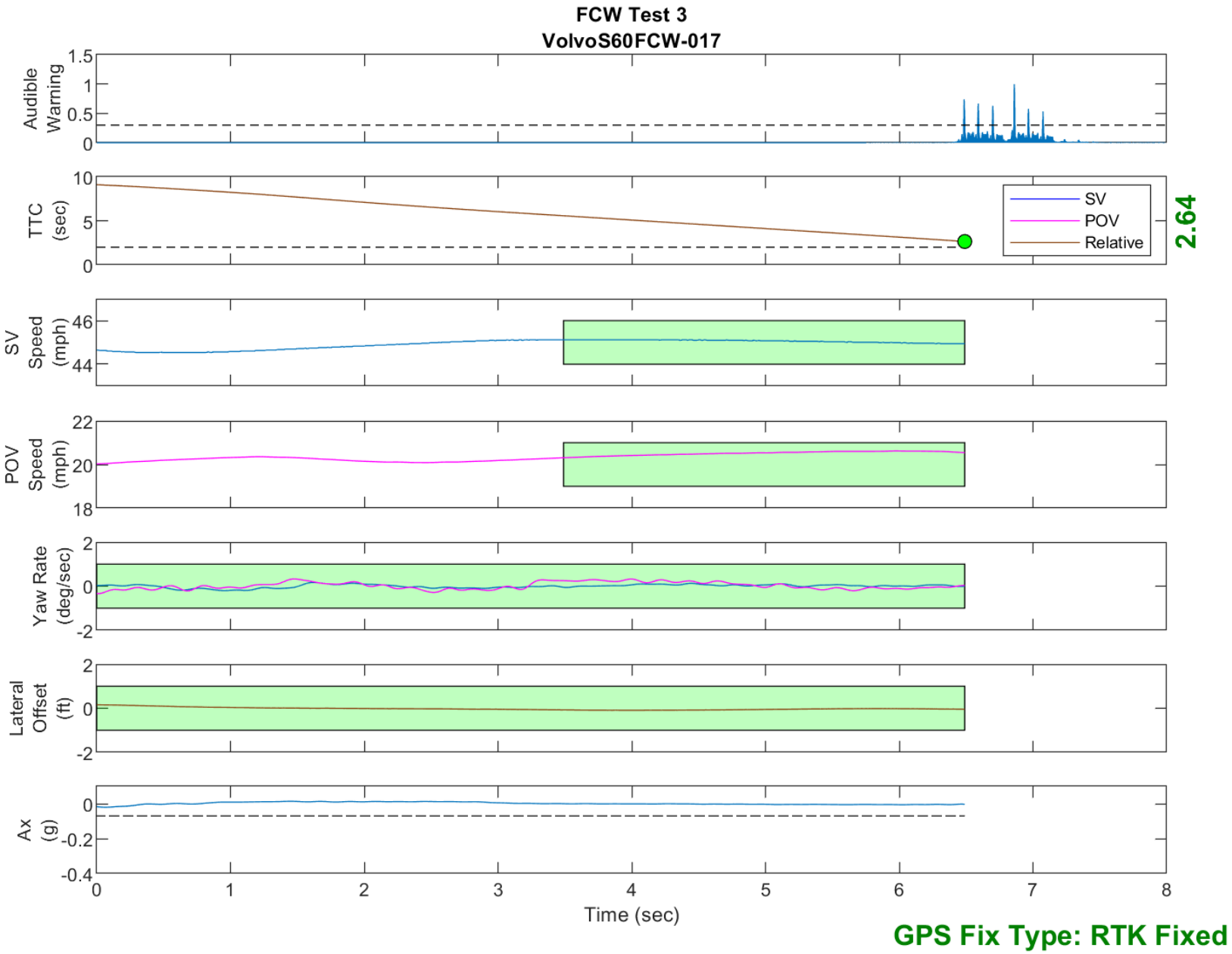


Figure D47. Time History for Run 17, FCW Test 3, Audible Warning

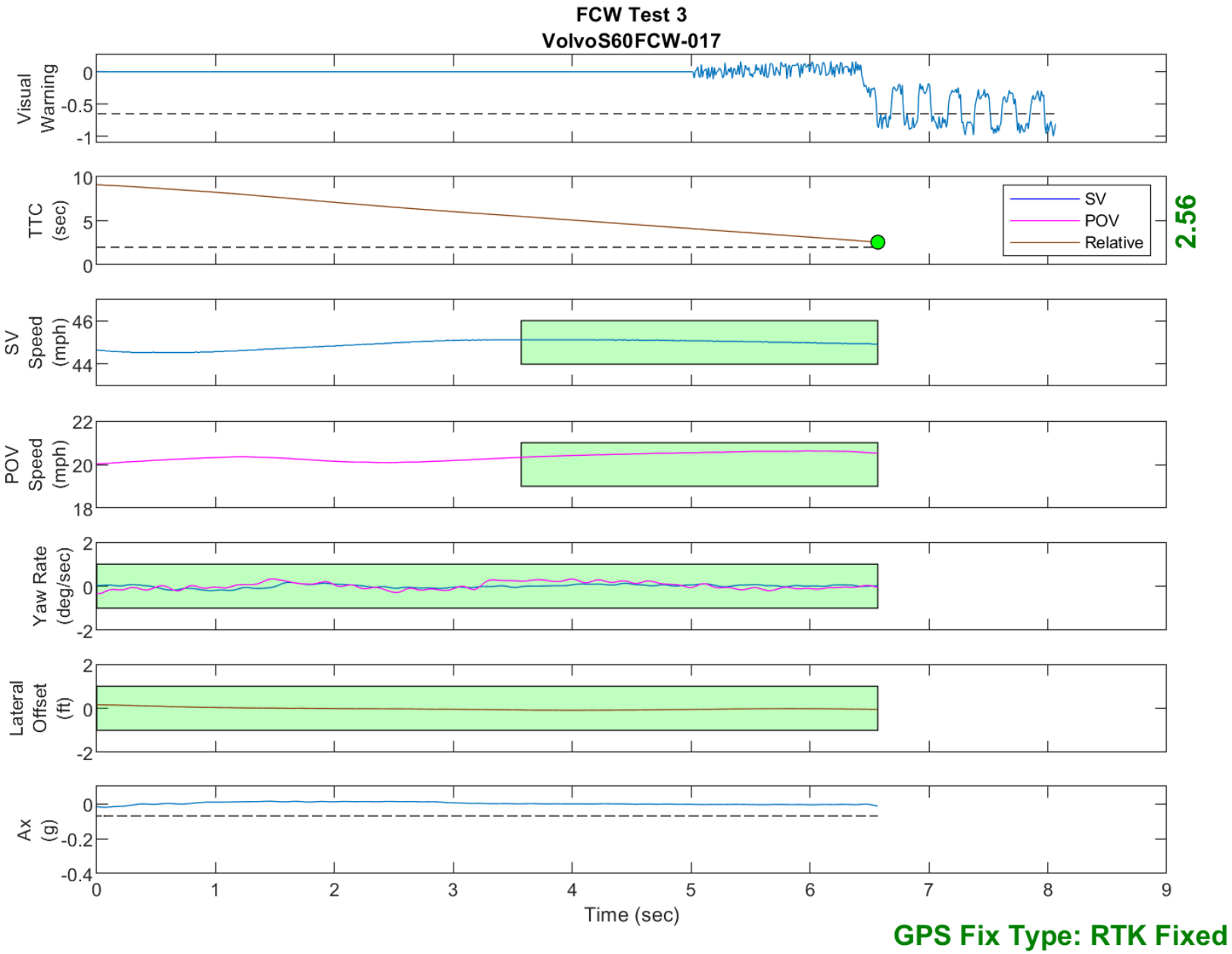


Figure D48. Time History for Run 17, FCW Test 3, Visual Warning