

**NEW CAR ASSESSMENT PROGRAM
CRASH IMMINENT BRAKING SYSTEM CONFIRMATION TEST
NCAP-DRI-CIB-20-15**

2020 Volvo S60 T6 AWD Momentum

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Final Report

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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 most current Test Procedure in docket NHTSA-2015-0006-0025; CRASH IMMINENT BRAKE SYSTEM PERFORMANCE EVALUATION FOR THE NEW CAR ASSESSMENT PROGRAM, October 2015. The vehicle passed the requirements of the test for all four CIB test scenarios and all speeds.			
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Section I

INTRODUCTION

Crash Imminent Braking (CIB) systems are a subset of Automatic Emergency Braking (AEB) systems. CIB systems are designed to avoid, or mitigate rear-end crashes, by automatically applying subject vehicle brakes when the system determines that, without intervention, a rear-end crash will occur. CIB systems typically work as an extension of Forward Collision Warning (FCW) systems, which alert the driver to the possibility of a collision unless driver action is taken. CIB systems employ sensors capable of detecting vehicles in the forward path. Current CIB technology typically involves RADAR, LIDAR, or vision-based (camera) sensors, and measurement of vehicle operating conditions such as speed, driver steering and brake application, etc. Algorithms in the system's Central Processing Unit (CPU) use this information to continuously monitor the likelihood of a rear-end crash and command a brake actuator to apply the brakes when necessary.

The method prescribed by the National Highway Traffic Safety Administration (NHTSA) to evaluate CIB performance on the test track¹ involves three rear-end type crash configurations and a "false positive" test. In the rear-end scenarios, a subject vehicle (SV) approaches a stopped, slower-moving, or decelerating principal other vehicle (POV) in the same lane of travel. For these tests, the POV is a strikeable object with the characteristics of a compact passenger car. The false positive scenarios are used to evaluate the propensity of a CIB system to inappropriately activate in a non-critical driving scenario that does not involve a forward vehicle or present a safety risk to the SV occupant(s).

The purpose of the testing reported herein was to objectively quantify the performance of a Crash Imminent Braking system installed on a 2020 Volvo S60 T6 AWD Momentum. This test is part of the New Car Assessment Program to assess Crash Imminent Braking Systems sponsored by the National Highway Traffic Safety Administration under Contract No. DTNH22-14-D-00333.

¹ NHTSA-2015-0006-0025; Crash Imminent Brake System Performance Evaluation for the New Car Assessment Program, October 2015.

Section II
DATA SHEETS

CRASH IMMINENT BRAKING
DATA SHEET 1: TEST RESULTS SUMMARY

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2020 Volvo S60 T6 AWD Momentum

SUMMARY RESULTS

VIN: 7JRA22TKXLG03xxxx

Test Date: 2/3/2020

Crash Imminent Braking System setting: Early

**Test 1 – Subject Vehicle Encounters
Stopped Principal Other Vehicle**

SV 25 mph: Pass

**Test 2 – Subject Vehicle Encounters
Slower Principal Other Vehicle**

SV 25 mph POV 10 mph: Pass

SV 45 mph POV 20 mph: Pass

**Test 3 – Subject Vehicle Encounters
Decelerating Principal Other Vehicle**

SV 35 mph POV 35 mph: Pass

**Test 4 – Subject Vehicle Encounters
Steel Trench Plate**

SV 25 mph: Pass

SV 45 mph: Pass

Overall: Pass

Notes:

CRASH IMMINENT BRAKING
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 designation: 235/45 R18 98H

Rear tire designation: 235/45 R18 98H

Front tire DOT prefix: VYFUWCCO

Rear tire DOT prefix: VYFUWCCO

CRASH IMMINENT BRAKING
DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Volvo S60 T6 AWD Momentum

GENERAL INFORMATION

Test date: 2/3/2020

AMBIENT CONDITIONS

Air temperature: 7.2 C (45 F)

Wind speed: 2.3 m/s (5.2 mph)

- Windspeed \leq 10 m/s (22 mph)
- Tests were not performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.
- 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)

CRASH IMMINENT BRAKING
DATA SHEET 3: TEST CONDITIONS
(Page 2 of 2)
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)

CRASH IMMINENT BRAKING
DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

(Page 1 of 3)

2020 Volvo S60 T6 AWD Momentum

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

City Safety (standard equipment)

Type and location of sensors the system uses:

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

System setting used for test (if applicable):

Early

What is the minimum vehicle speed at which the CIB system becomes active?

Minimum vehicle speed is 4 km/h (2.5 mph). (Per manufacturer supplied information)

What is the maximum vehicle speed at which the CIB system functions?

There is no maximum speed. (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

Yes

No

If yes, please provide a full description.

No initialization process required for the function to be active. It's recommended though that in addition to the procedure in CIB & DBS test protocols, the vehicle has been pre-conditioned with normal driving on public roads. Preferably multiple driving cycles with a total of 60 miles.

Will the system deactivate due to repeated CIB activations, impacts, or near-misses?

Yes

No

If yes, please provide a full description.

No deactivation occurs. There is a three second time-out after each intervention but after that the system is activated automatically again.

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

(Page 2 of 3)

2020 Volvo S60 T6 AWD Momentum

How is the Forward Collision Warning system alert presented to the driver? Warning light
(Check all that apply) Buzzer or audible 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, 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-16.

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.

Is there a way to deactivate the system? _____ Yes
 No

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

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

(Page 3 of 3)

2020 Volvo S60 T6 AWD Momentum

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

See Appendix A, Figure A15.

Are there other driving modes or conditions that render CIB inoperable or reduce its effectiveness? 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 through B-6.

Notes:

Section III

TEST PROCEDURES

A. Test Procedure Overview

Four test scenarios were used, as follows:

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

Test 2. Subject Vehicle Encounters Slower Principal Other Vehicle

Test 3. Subject Vehicle Encounters Decelerating Principal Other Vehicle

Test 4. Subject Vehicle Encounters Steel Trench Plate

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 CIB system to detect and respond to a stopped lead vehicle in the immediate forward path of the SV, as depicted in Figure 1.

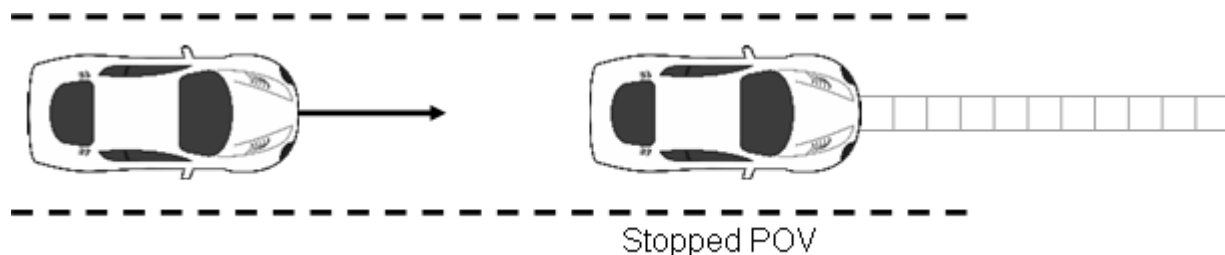


Figure 1. Depiction of Test 1

a. 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 approached the rear of the POV.

The SV ignition was cycled prior to each test run. The SV was driven at a nominal speed of 25 mph (40.2 km/h) in the center of the lane of travel, toward the parked POV. The SV throttle pedal was released within 500 ms after t_{FCW} , i.e. within 500 ms of the FCW alert. The test concluded when either:

- The SV came into contact with the POV or
- The SV came to a stop before making contact with the POV.

In addition to the general test validity criteria described below, for an individual test trial to be valid, the following was required throughout the test:

- The SV speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during an interval defined by a Time to Collision (TTC) = 5.1 seconds to t_{FCW} . For this test, TTC = 5.1 seconds is taken to occur at an SV-to-POV distance of 187 ft (57 m).

b. Criteria

In order to pass the test, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 9.8 mph (15.8 km/h) for at least five of seven valid test trials.

The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

- If SV-to-POV contact occurred during a test trial, the CIB speed reduction was calculated by subtracting the SV speed at the time of SV-to-POV contact (i.e., when longitudinal range became zero) from the average SV speed calculated from $t_{FCW}-100$ ms to t_{FCW} .
- If SV-to-POV contact did not occur during a test trial (i.e., CIB intervention prevented the crash), the SV speed at a time of SV-to-POV contact was taken to be zero. The speed reduction is therefore equal to the SV speed at t_{FCW} .

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

- This test evaluates the ability of the CIB system to detect and respond to a slower-moving lead vehicle traveling at a constant speed in the immediate forward path of the SV, as depicted in Figure 2.

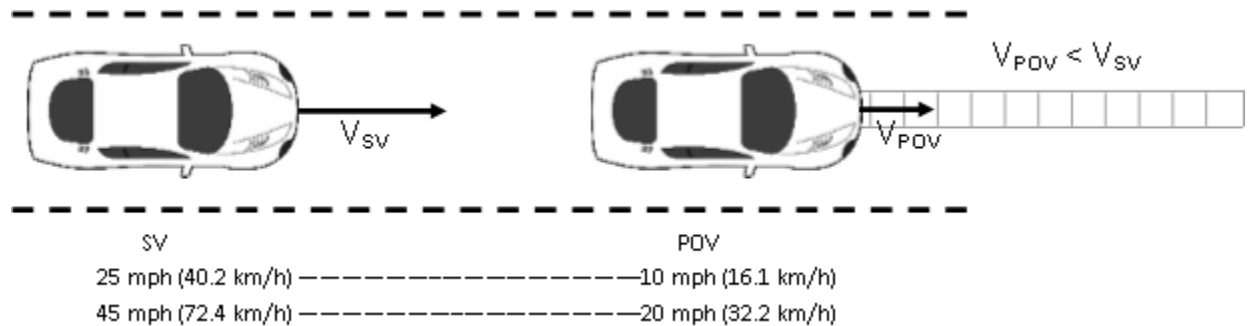


Figure 2. Depiction of Test 2

a. Procedure

The SV ignition was cycled prior to each test run. The tests were conducted two ways. In the first, the POV was driven at a constant 10.0 mph (16.1 km/h) in the center of the lane of travel while the SV was driven at 25.0 mph (40.2 km/h), in the center lane of travel, toward the slower-moving POV. In the second, the POV was driven at a constant 20.0 mph (32.2 km/h) in the center of the lane of travel while the SV was driven at 45.0 mph (72.4 km/h), in the center lane of travel, toward the slower-moving POV. In both cases, the SV throttle pedal was released within 500 ms after t_{FCW} , i.e. within 500 ms of the FCW alert. The test concluded when either:

- The SV came into contact with the POV or
- 1 second after the speed of the SV becomes less than or equal to that of the POV.

The SV driver then braked to a stop.

In addition to the general test validity criteria described below, for an individual test trial to be valid, the following was required throughout the test:

- The lateral distance between the centerline of the POV and the center of the travel lane could not deviate more than ± 1 ft (0.3 m) during the validity period.
- The lateral distance between the centerline of the SV and the center of the travel lane could not deviate more than ± 1 ft (0.3 m) during the validity period.

- The SV speed could not deviate more than ± 1.0 mph (± 1.6 km/h) during an interval defined by $TTC = 5.0$ seconds to t_{FCW} .
- The POV speed could not deviate more than ± 1.0 mph (± 1.6 km/h) during the validity period.

b. Criteria

For the test series in which the initial SV speed was 25 mph, the condition for passing was that there be no SV-POV impact for at least five of the seven valid test trials.

In order to pass the test series for which the initial speed of the SV was 45 mph, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 9.8 mph (15.8 km/h) for at least five of seven valid test trials. The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

- If SV-to-POV contact occurred during a test trial, the CIB speed reduction was calculated by subtracting the SV speed at the time of SV-to-POV contact (i.e., when longitudinal range became zero) from the average SV speed calculated from $t_{FCW}-100$ ms to t_{FCW} .
- If SV-to-POV contact did not occur during a test trial (i.e., CIB intervention prevented the crash), the CIB speed reduction was calculated by subtracting the SV speed at the minimum longitudinal SV-POV range during the validity period from the SV speed at t_{FCW} .

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

This test evaluates the ability of the CIB system to detect and respond to a lead vehicle slowing with a constant deceleration in the immediate forward path of the SV, as depicted in Figure 3.

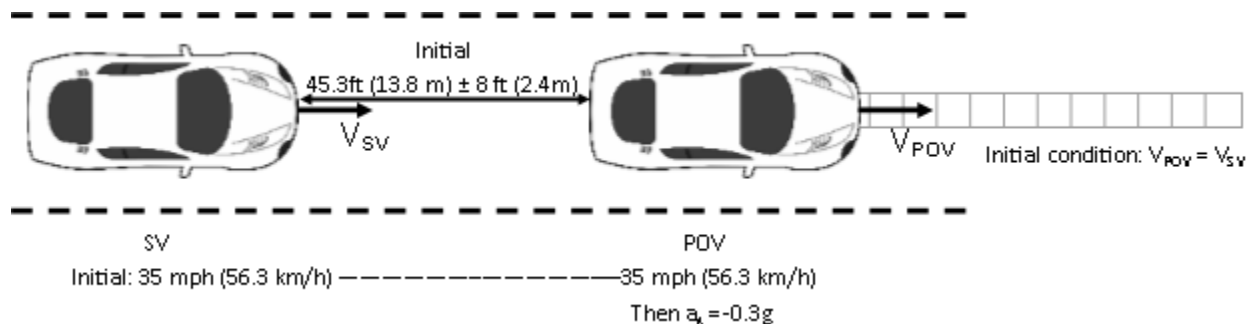


Figure 3. Depiction of Test 3 with POV Decelerating

a. Procedure

The SV ignition was cycled prior to each test run. For this test scenario, both the POV and SV were driven at a constant 35.0 mph (56.3 km/h) in the center of the lane, with a headway of 45.3 ft (13.8 m) \pm 8 ft (2.4 m). Once these conditions were met, the POV tow vehicle brakes were applied to achieve 0.3 \pm 0.03 g of deceleration. The test concluded when either:

- The SV came into contact with the POV or
- For the decelerating POV, 1 second after minimal longitudinal SV-POV distance occurred or
- For the POV decelerating to stop case, 1 second after the velocity of the SV became less than or equal to that of the POV.

The SV driver then braked to a stop.

In addition to the general test validity criteria described below, for an individual test trial to be valid, the following was required throughout the test:

- The lateral distance between the centerline of the POV and the center of the travel lane could not deviate more than \pm 1 ft (0.3 m) during the validity period.
- The lateral distance between the centerline of the SV and the center of the travel lane could not deviate more than \pm 1 ft (0.3 m) during the validity period.
- The headway between the SV and POV must have been constant from the onset of the applicable validity period to the onset of POV braking.
- The SV and POV speed could not deviate more than \pm 1.0 mph (1.6 km/h) during an interval defined by the onset of the validity period to the onset of POV braking.
- The SV- POV headway distance could not deviate more than \pm 8 ft (2.4 m) during an interval defined by the onset of the validity period to the onset of POV braking.
- The average POV deceleration could not deviate by more than \pm 0.03 g from the nominal 0.3 g deceleration during the interval beginning at 1.5 seconds after the onset of POV braking and ending either 250 ms prior to the POV coming to a stop or the SV coming into contact with the POV.

b. Criteria

In order to pass the decelerating POV test series, the magnitude of the SV speed reduction attributable to CIB intervention must have been \geq 10.5 mph (16.9 km/h) for at least five of seven valid test trials. The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

- If SV-to-POV contact occurred during a test trial, the CIB speed reduction was calculated by subtracting the SV speed at the time of SV-to-POV contact (i.e.,

when longitudinal range becomes zero) from the average SV speed calculated from $t_{FCW} - 100$ ms to t_{FCW} .

- If SV-to-POV contact did not occur during a test trial (i.e., CIB intervention prevents the crash), the CIB speed reduction was calculated by subtracting the SV speed at the minimum longitudinal SV-to-POV range during the applicable validity period from the SV speed at t_{FCW} .

4. TEST 4 – FALSE POSITIVE SUPPRESSION

The false positive suppression test series evaluates the ability of a CIB system to differentiate a steel trench plate (STP) from an object presenting a genuine safety risk to the SV. Although the STP is large and metallic, it is designed to be driven over without risk of injury to the driver or damage to the SV. Therefore, in this scenario, the automatic braking available from CIB is not necessary and should be suppressed. The test condition is nearly equivalent to that previously defined for Test 1, the stopped POV condition, but with an STP in the SV forward path in lieu of a POV.

a. Procedure

This test was conducted at two speeds, 25 mph (40.2 km/h) and 45 mph (72.4 km/h). The SV was driven directly towards, and over, the STP, which was positioned in the center of a travel lane, with its longest sides parallel to the road edge.

In addition to the general test validity criteria described below, for an individual test trial to be valid, the following was required throughout the test:

- The SV speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during an interval defined by a Time to Collision (TTC) = 5.1 seconds to t_{FCW} where:
 - For SV test speed of 25 mph, TTC = 5.1 seconds is taken to occur at an SV-to-STP distance of 187 ft (57 m).
 - For SV test speed of 45 mph, TTC = 5.1 seconds is taken to occur at an SV-to-STP distance of 337 ft (106 m).
- If the SV did not present an FCW alert before the end of the validity period, SV speed could not deviate more than ± 1.0 mph (± 1.6 km/h) from TTC = 5.1 s to the end of the validity period.

If an FCW alert was presented, the driver released the throttle pedal within 500 ms of the alert. If no alert was presented, the driver did not release the throttle pedal until the end of the validity period. The SV driver then braked to a stop.

b. Criteria

In order to pass the False Positive test series, the magnitude of the SV deceleration reduction attributable to CIB intervention must have been ≤ 0.50 g for at least five of seven valid test trials.

B. General Information

1. T_{FCW}

The time at which the Forward Collision Warning (FCW) activation flag indicates that the system has issued an alert to the SV driver is designated as t_{FCW} . FCW alerts are typically either haptic or audible, and the onset of the alert was determined by post-processing the test data.

For systems that implement audible or haptic alerts, part of the pre-test instrumentation verification process was 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 was accomplished in order to identify the center frequency around which a band-pass filter was 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 was a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 1.

Table 1. 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 \pm 5%
Tactile	5 th	3 dB	60 dB	Identified Center Frequency \pm 20%

2. GENERAL VALIDITY CRITERIA

In addition to any validity criteria described above for the individual test scenarios, for an individual trial to be valid, it must have met the following criteria throughout the test:

- The SV driver seatbelt was latched.
- If any load had been placed on the SV front passenger seat (e.g., for instrumentation), the vehicle's front passenger seatbelt was latched.
- The SV was driven at the nominal speed in the center of the travel lane, toward the POV or STP.
- The driver used the least amount of steering input necessary to maintain SV position in the center of the travel lane during the validity period; use of abrupt

steering inputs or corrections was avoided.

- The yaw rate of the SV did not exceed ± 1.0 deg/s from the onset of the validity period to the instant SV deceleration exceeded 0.25g.
- The SV driver did not apply any force to the brake pedal during the applicable validity period.
- The lateral distance between the centerline of the SV and the centerline of the POV or STP did not deviate more than ± 1 ft (0.3 m) during the applicable validity period.

3. VALIDITY PERIOD

The valid test interval began:

Test 1: When the SV-to-POV TTC = 5.1 seconds

Test 2: When the SV-to-POV TTC = 5.0 seconds

Test 3: 3 seconds before the onset of POV braking

Test 4: When the SV-to-STP TTC = 5.1 seconds

The valid test interval ended:

Test 1: When either of the following occurred:

- The SV came into contact with the POV (SV-to-POV contact was assessed by using GPS-based range data or by measurement of direct contact sensor output); or
- The SV came to a stop before making contact with the POV.

Tests 2 and 3: When either of the following occurred:

- The SV came into contact with the POV; or
- 1 second after the velocity of the SV became less than or equal to that of the POV.
- 1 second after minimal longitudinal SV-POV distance occurred.

Test 4: At the instant the front most part of SV reached a vertical plane defined by the leading edge of the STP first encountered by the SV (i.e., just before it was driven onto the STP).

4. STATIC INSTRUMENTATION CALIBRATION

To assist in resolving uncertain test data, static calibration data was collected prior to each of the test series.

For Tests 1, 2, and 3, the SV, POV, and POV moving platform and tow vehicle were centered in the same travel lane with the same orientation (i.e., facing the same direction). For Test 4, the SV and STP were centered in the same travel lane.

For Tests 1, 2, and 3, the SV was positioned such that it just contacted a vertical plane that defines the rearmost location of the POV. For Test 4, the front-most location of the SV was positioned such that it just reached a vertical plane defined by the leading edge of the STP first encountered by the SV (i.e., just before it is driven onto the STP). This is the “zero position.”

The zero position was documented prior to, and immediately after, conduct of each test series.

If the zero position reported by the data acquisition system was found to differ by more than ± 2 in (± 5 cm) from that measured during collection of the pre-test static calibration data file, the pre-test longitudinal offset was adjusted to output zero and another pre-test static calibration data file was collected. If the zero position reported by the data acquisition system was found to differ by more than ± 2 in (± 5 cm) from that measured during collection of the post-test static calibration data file, the test trials performed between collection of that post-test static calibration data file and the last valid pre-test static calibration data file were repeated.

Static data files were collected prior to, and immediately after, conducting each of the test series. The pre-test static files were reviewed prior to test conduct to confirm that all data channels were operational and were properly configured.

5. NUMBER OF TRIALS

A target total of seven (7) valid trials were performed for each scenario. In cases where the test driver performed more than seven trials, the first seven trials satisfying all test tolerances were used to assess the SV performance.

6. TRANSMISSION

All trials were performed with SV 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. The brake lights of the POV were not illuminated.

C. Principal Other Vehicle

CIB testing requires a POV that realistically represents typical vehicles, does not suffer damage or cause damage to a test vehicle in the event of collision, and can be accurately positioned and moved during the tests. The tests reported herein made use of the NHTSA developed Strikeable Surrogate Vehicle (SSV).

This SSV system was designed specifically for common rear-end crash scenarios which AEB systems address. The key components of the SSV system are:

- A POV shell which is a visually and dimensionally accurate representation of a passenger car.
- A slider and load frame assembly to which the shell is attached.
- A two-rail track on which the slider operates.
- A road-based lateral restraint track.
- A tow vehicle.

The key requirements of the POV element are to:

- Provide an accurate representation of a real vehicle to DBS sensors, including cameras and radar.
- Be resistant to damage and inflict little or no damage to the SV as a result of repeated SV-to-POV impacts.

The key requirements of the POV delivery system are to:

- Accurately control the nominal POV speed up to 35 mph (56 km/h).
- Accurately control the lateral position of the POV within the travel lane.
- Allow the POV to move away from the SV after an impact occurs.

Operationally, the POV shell is attached to the slider and load frame which includes rollers that allows the entire assembly to move longitudinally along the guide rail. The guide rail is coupled to a tow vehicle and guided by the lateral restraint track secured to the test track surface. The rail includes a provision for restraining the shell and roller assembly in the ward direction. In operation, the shell and roller assembly engage the rail assembly through detents to prevent relative motion during run-up to test speeds and deceleration of the tow vehicle. The combination of rearward stops and forward motion detents allows the test conditions, such as relative POV-SV headway distance, speed, etc., to be achieved and adjusted as needed in the preliminary part of a test. If during the test, the SV strikes the rear of the POV shell, the detents are overcome and the entire shell/roller assembly moves forward in a two-stage manner along the rail and away from the SV. The forward end of the rail has a cushioned stop to restrain forward motion of the shell/roller assembly. After impacting the SSV, the SV driver uses the steering wheel to maintain SV position in the center of the travel lane, thereby straddling

the two-rail track. The SV driver must manually apply the SV brakes after impact. The SSV system is shown in Figures A6 through A8 and a detailed description can be found in the NHTSA report: NHTSA'S STRIKEABLE SURROGATE VEHICLE PRELIMINARY DESIGN+OVERVIEW, May 2013.

D. Automatic Braking System

The POV was equipped with an automatic braking system, which was used in Test 3. The braking system consisted of the following components:

- Electronically controlled linear actuator, mounted on the seat rail and attached to the brake pedal. The actuator can be programmed for control of stroke and rate.
- PC module programmed for control of the stroke and rate of the linear actuator.
- Switch to activate actuator.

In some cases, the subject vehicle is also equipped with an automatic braking system (E-brake) for the purpose of slowing the subject vehicle before impact with the SSV in cases where the subject vehicle is likely to fail a test. The system fires when TTC is below 0.7 sec. It is typically enabled when an SV has already impacted the SSV one or two times.

E. Instrumentation

Table 2 lists the sensors, signal conditioning, and data acquisition equipment used for these tests.

Table 2. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	< 1% error between 20 and	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
Linear (string) encoder	Throttle pedal travel	10 in 254 mm	0.1 in 2.54 mm	UniMeasure LX-EP	45040532	By: DRI Date: 5/10/2019 Due: 5/10/2020
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

Table 2. Test Instrumentation and Equipment (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
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
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	NA	NA
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	NA	NA
Accelerometer	Acceleration (to measure time at 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

APPENDIX A

Photographs

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Figure A1. Front View of Subject Vehicle



Figure A2. Rear View of Subject Vehicle

2020VOLVO

S60 T6 AWD MOMENTUM



Volvo Car USA LLC
www.volvocars.com/us

PERFORMANCE

2.0L Super & Turbo-Charged, Direct Inject Engine
316 HP @ 5700 RPM and 295 lb-ft Torque @ 2200 RPM
8-Speed Geartronic Automatic Trans w/ Start-Stop
All-Wheel Drive with Instant Traction
Adjustable Drive-Mode settings
Double Washbone Front & Integral Link Rear Susp
Anti-Lock Braking Sys (ABS) w/ Hill Start Assist
Advanced Electronic Stability Control (ESC)
Electronic Power Steering Personalization
18" Alloy Wheels with All-Season Tires

AUDIO & TECHNOLOGY

12.3" Digital Driver Display
9" Integrated Sensus Connect Touchscreen feat. Smartphone Integ (Apple CarPlay/Android Auto)
Volvo On Call with 4-Yr Complimentary Subscription
Incl Mobile App w/ Remote Start
WiFi Hotspot and Complimentary Trial Subscription
Bluetooth Connectivity w/ Audio Streaming
SIRIUSXM Radio w/ 3 Month Trial Subscription
AM / FM / HD Radio
USB Ports, 2 Front
Standard Apps: Spotify, Pandora, TuneIn
220W High Performance Audio System w/ 10 Speakers

SAFETY & SECURITY

LED Headlights w/ Thor's Hammer DRL, Auto Highbeam
Collision Avoidance by City Safety
Low & High Speed Collision Mitigation
Detects Vehicle/Pedestrian/Cyclist/Large Animal
Road Sign Information
Run-off Road Protection & Run-off Road Mitigation
Lane Departure Warning / Lane Keeping Aid
Oncoming Mitigation by Braking
Front, Side & Curtain Airbags
with Driver Side Knee Airbag
Whiplash Protection System (WHIPS) in Front Seats
Side Impact Protection System (SIPS)
Power Child Lock, Rear Doors
Automatic Braking After Collision
Driver Alert Control
Lower Anchors and Tethers for Child Seats (LATCH)
Roll Stability Control
Five, 3-Point Safety Belts with Pretensioners
Rear Park Assist Camera

LUXURY & CONVENIENCE

Laminated Panoramic Moonroof w/Power Sunshade
Leatherette Upholstery Seating Surfaces
Leather Wrapped Tilt & Telescopic Steering Wheel
10-Way, Power Front Seats w/ Driver Seat Memory
2-Way Power Lumbar Support, Front Seats
Power Foldable Rear Seat Headrests
Heated Front Seats
Keyless Engine Start/Turnoff
Cargo Scoop Plate
Front Grille, High-Gloss Black
Auto Dimming Interior Rearview Mirror
2-Zone Automatic Climate Control + CleanZone
Volvo Aluminum Tread Plates
Iron Ore Aluminum Deco Inlays
Dual Visible Tailpipes w/ Chrome Sleeves

AUTHORIZED RETAILER

CULVER CITY VOLVO 5182
11201 WASHINGTON BLVD
CULVER CITY, CA 90230

WARRANTY

48 Month/50,000 Mile Limited Warranty Coverage
144 Month Corrosion Protection "Unlimited Mileage"
Refer to Warranty Info Book for Specific Limitations.

VOLVO On-Call Roadside Assistance

Volvo Increased Protection: Ask Your Volvo Retailer
About an Extended Service Contract

MAINTENANCE

Complimentary Factory Scheduled Maintenance for the
First 3 Years or 36,000 Miles

ACCESSORIES

Enhance the driving pleasure with Volvo accessories.
Enrich the styling, integrate technology, boost
performance, or simply carry more cargo - from
function to fun, there's something for everyone.

To view full accessory product line -
Scan this Smartphone QR code
or visit <https://accessories.volvocars.com/en-us>

JOIN THE CONVERSATION

See what our fans are saying about Volvo and join in!

Have a question?
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Facebook: Volvo Car USA
YouTube: Volvo Car USA

The price shown does not include Destination, License and Title Fees, State and
Local Taxes and Dealer Installed Options and Accessories. The factory reserves
the right to modify price, designs and equipment without previous notice.

PRICING

IMPORTER'S SUGGESTED LIST PRICE P.D.E.: \$ 40,550.00

Premium Package 2,050.00

Power Retractable Rearview Mirrors
Automatically Dimmed Inner & Exterior Mirrors
HomeLink Garage Door Transmitter
Compass in Rearview Mirror
Blind Spot Information System with Steer Assist
(BLIS)
& Cross Traffic Alert with Autobrake
Park Assist Front & Rear
Keyless Entry with Illuminated Door Handles &
Power Release Trunk/Lid

Heated Rear Seats & Heated Steering Wheel 750.00

Metallic Paint 645.00

Destination Charge 995.00

Total Suggested Retail Price: \$ 44,990.00

Fuel Economy and Environment

Fuel Economy

25 MPG
Combined city/hwy

Compact Car range from 14 to 119 MPG
The best vehicle rates 136 MPG.

You spend \$ 2,250
more in fuel costs
over 5 years
compared to the
average new vehicle.

4.0 gallons per 100 miles

Annual Fuel Cost \$ 1,950

Fuel Economy & Greenhouse Gas Rating (EPA est.) Smog Rating (EPA est.)

1 5 10 1 7 10

This vehicle emits 362 grams CO2 per mile. The best emits 0 grams per mile (tailpipe emit). Producing and distributing fuel also create emissions, learn more at fuelconomy.gov

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 27 MPG and costs \$ 7,500 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at \$ 3.25 per gallon. MPG is miles per gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fuelconomy.gov
Calculate personalized estimates and compare vehicles

PARTS CONTENT INFORMATION

FOR VEHICLES IN THIS CARLINE: VOLVO SERIES

U.S./CANADIAN PARTS CONTENT: 20%

MAJOR SOURCES OF FOREIGN PARTS CONTENT:
SWEDEN: 20%
BELGIUM: 20%

FOR THIS VEHICLE:
FINAL ASSEMBLY POINT:
RIDGEVILLE, SC

COUNTRY OF ORIGIN:
ENGINE PARTS:
SWEDEN

TRANSMISSION PARTS:
JAPAN

Note: Parts contents does not include final assembly, distribution, or other non-parts costs.

GOVERNMENT 5-STAR SAFETY RATINGS

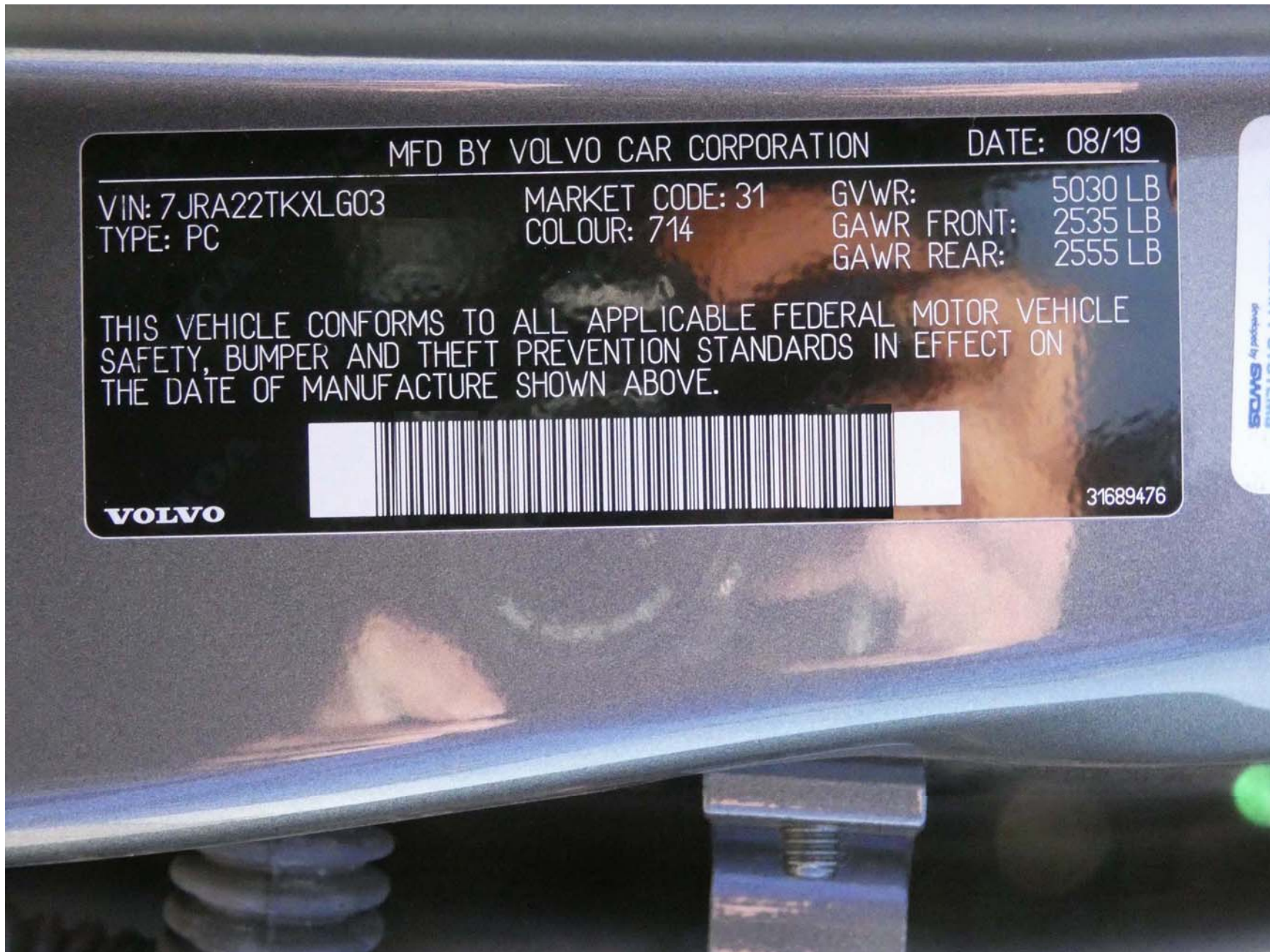
This vehicle has not been rated by the government for overall vehicle score, frontal crash or rollover risk.

Star ratings range from 1 to 5 stars (*****), with 5 being the highest.
Source: National Highway Traffic Safety Administration (NHTSA)
www.safercar.gov or 1-888-327-4236

VEHICLE IDENTIFICATION
Type & Chassis: 224 G3
Model Year: 2020
Color: Onyxium Grey Metallic
VIN: 7JRAZ2TKKLG3

Port of Importation: Charleston VFC
Delivered by: Truck
DELIVERY ADDRESS





MFD BY VOLVO CAR CORPORATION

DATE: 08/19

VIN: 7JRA22TKXLG03
TYPE: PC

MARKET CODE: 31
COLOUR: 714

GVWR: 5030 LB
GAWR FRONT: 2535 LB
GAWR REAR: 2555 LB

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY, BUMPER AND THEFT PREVENTION STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.



VOLVO

31689476

Figure A4. Vehicle Certification Label



TIRE AND LOADING INFORMATION

SEATING CAPACITY | TOTAL 5 | FRONT 2 | REAR 3

The combined weight of occupants and cargo should never exceed : **405kg or 890lbs.**

TIRE	SIZE	COLD TIRE PRESSURE	SEE OWNERS MANUAL FOR ADDITIONAL INFORMATION
FRONT	235/45R18	250kPa, 36psi	
REAR	235/45R18	250kPa, 36psi	
SPARE	T125/70R18	420kPa, 60psi	

VOLVO 31416488

Figure A5. Tire Placard



Figure A6. Rear View of Principal Other Vehicle (SSV)



Figure A7. Load Frame/Slider of SSV

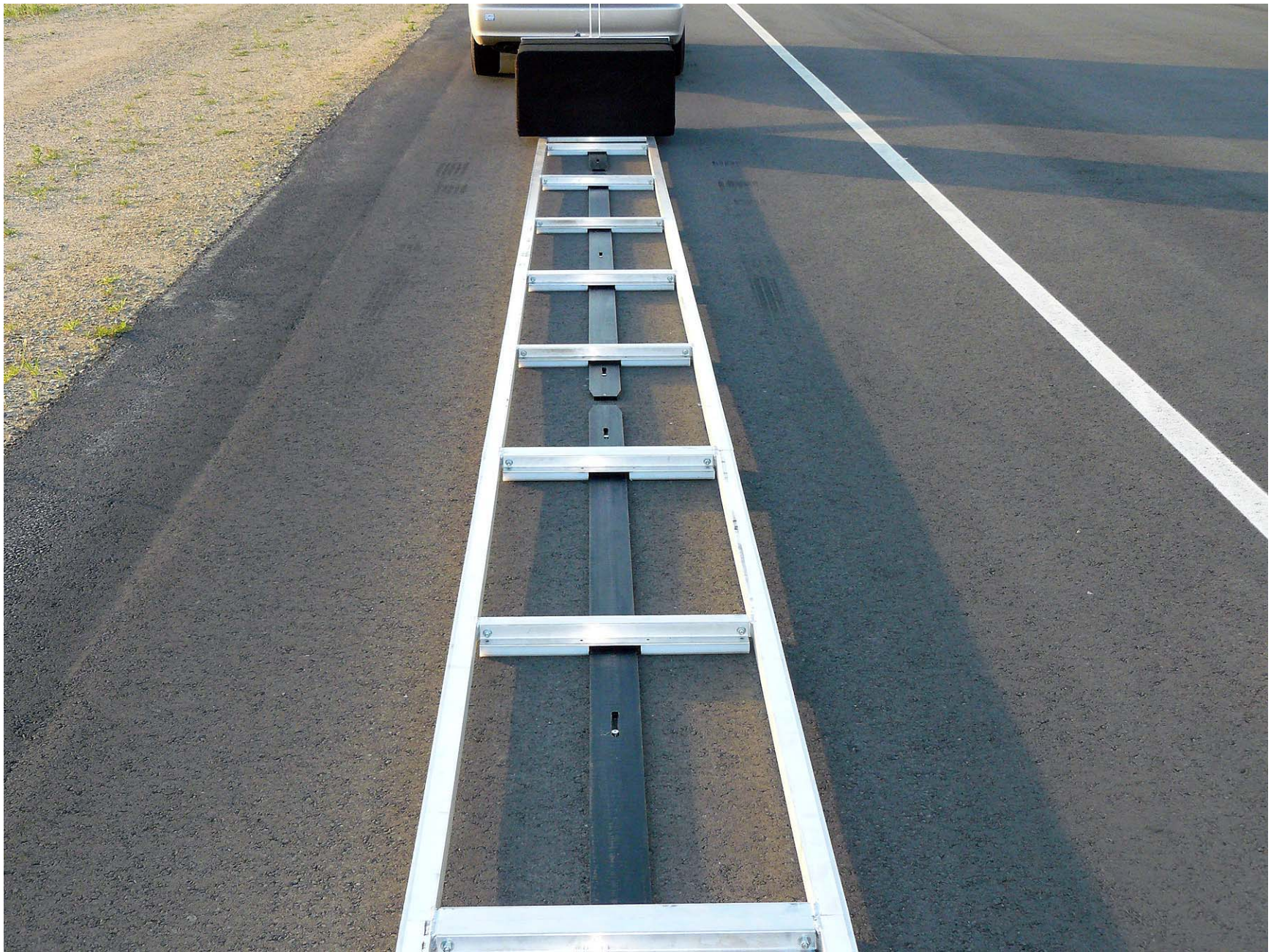


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track



Figure A9. Steel Trench Plate

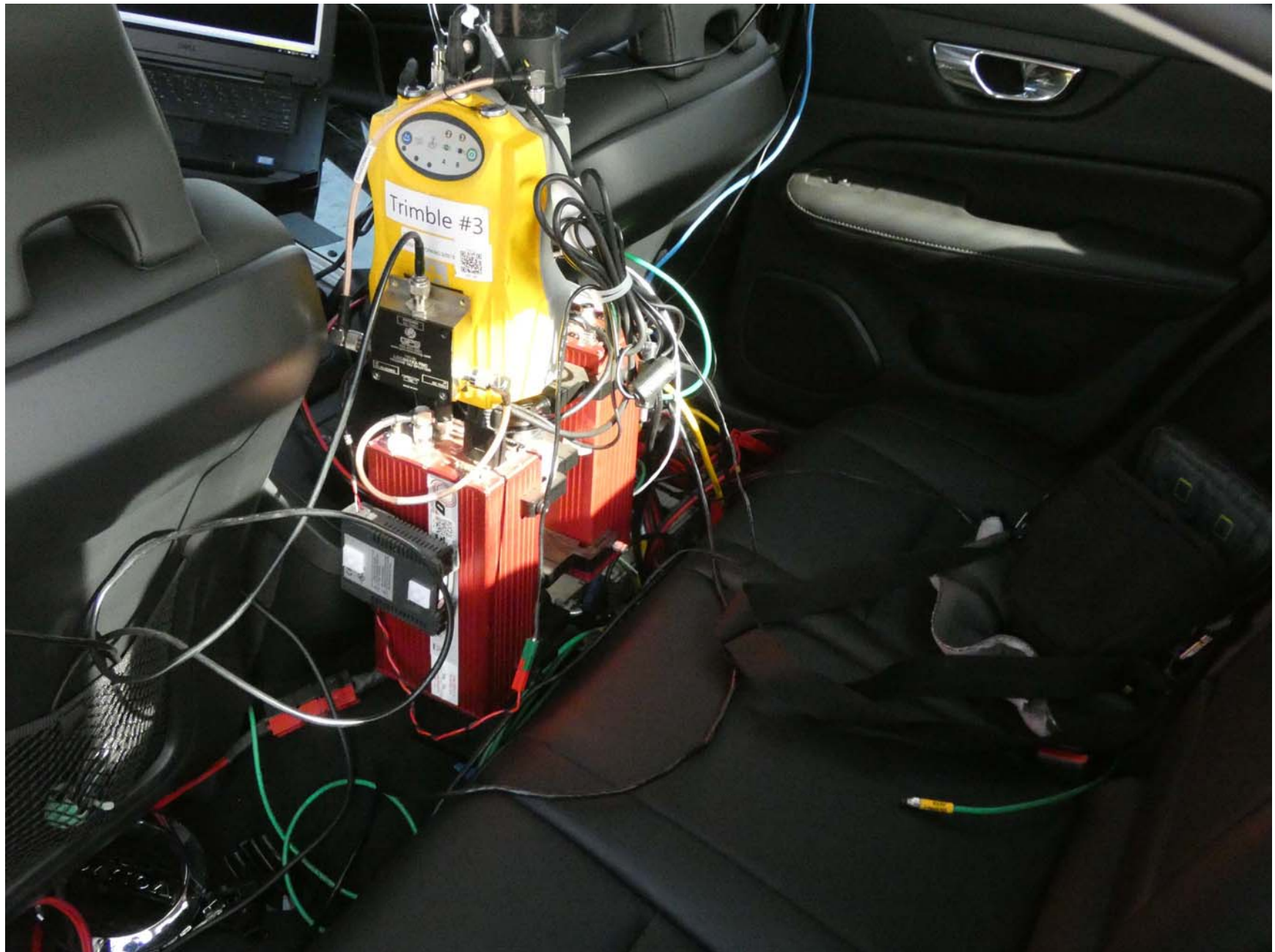


Figure A10. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle



Figure A11. Sensor for Detecting Visual Alerts



Figure A12. Sensor for Detecting Auditory Alerts



Figure A13. Computer Installed in Subject Vehicle



Figure A14. Brake Actuator Installed in POV System

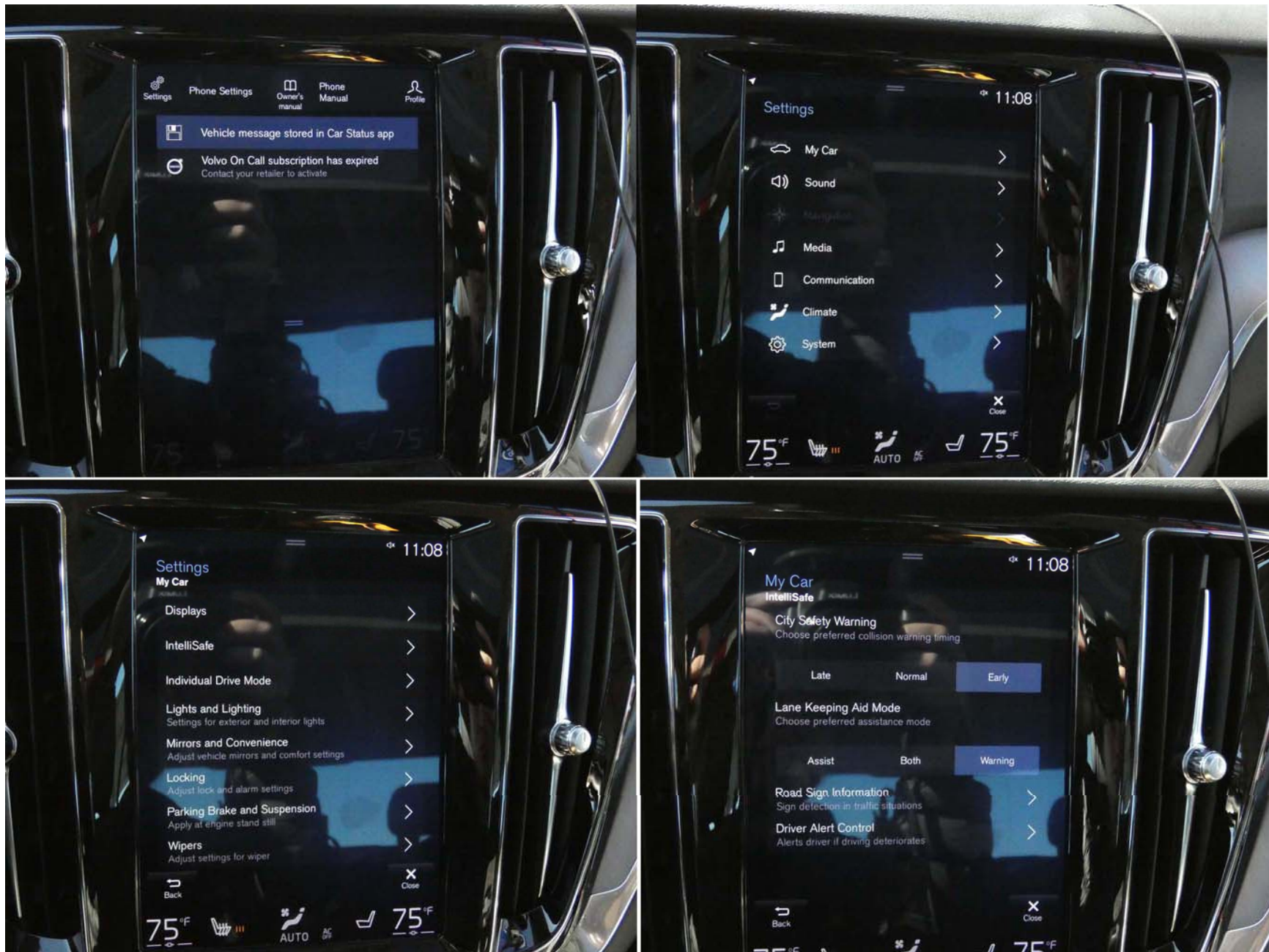


Figure A15. AEB Setup Menus



Figure A16. AEB 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)

* Option/accessory. 297

DRIVER SUPPORT

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)

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 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 replaced⁵³.
- 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 workshop⁵³ 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 workshop⁵³ to help ensure proper functioning of all of the vehicle's camera and radar-based systems.

Radar

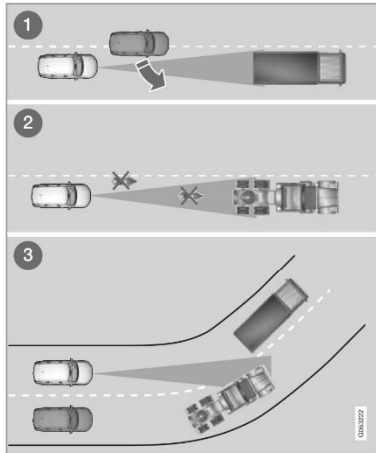
Vehicle speed

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.



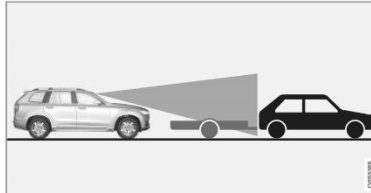
The radar sensor's field of vision.

- 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.

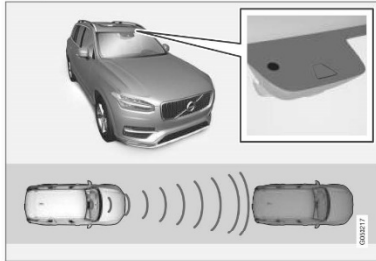
Strong sunlight, reflections from the road surface, ice or snow covering the road, a dirty road surface, or unclear lane marker lines may drastically reduce the camera's ability to detect the side of a lane, a pedestrian, a cyclist, a large animal or another vehicle.



* Option/accessory. 303

City Safety™

City Safety⁵⁴ 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.

⁵⁴ This function is not available on all markets.

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)

- 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 Safety⁵⁵ 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).

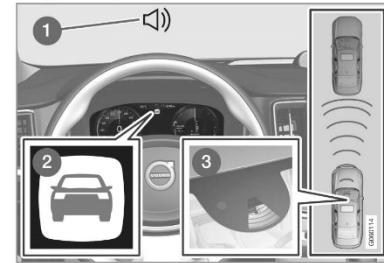
Large animals

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.

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 Safety⁵⁶ 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.



* Option/accessory. 309



⚠ 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.

ℹ 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 tensing 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 Safety⁵⁷ 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.

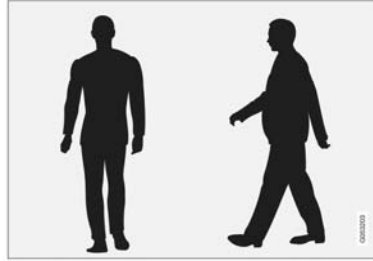
WARNING

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

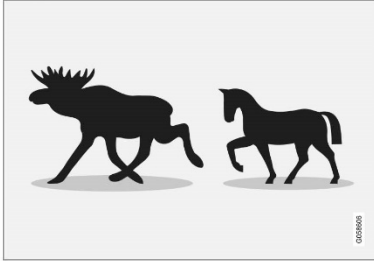
City Safety is supplementary driver support, but it cannot detect all pedestrians in all situations and, for example, cannot see:

- 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.

⁵⁸ This function is not available on all markets.

⚠ WARNING

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

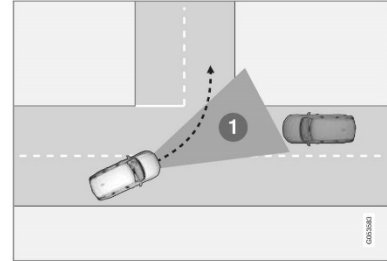
- partially obscured larger animals.
- larger animals seen from the front or from behind.
- running or fast moving larger animals.
- larger animals if the contrast of the animal's background is poor - warning and brake interventions may then occur late or not at all.
- smaller animals such as cats and 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 Safety⁵⁸ 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:

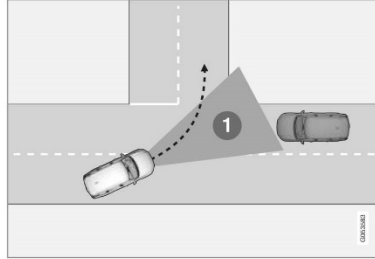
- your vehicle's speed must be at least 4 km/h (3 mph)
- your vehicle must be making a left turn
- the oncoming vehicle's headlights must be on

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

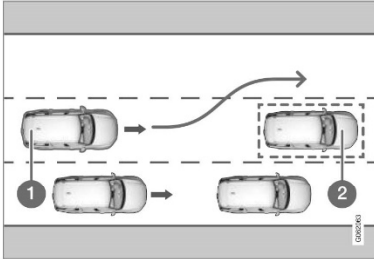
The function uses the vehicle's camera and radar sensor, which has certain general limitations.

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.

i NOTE

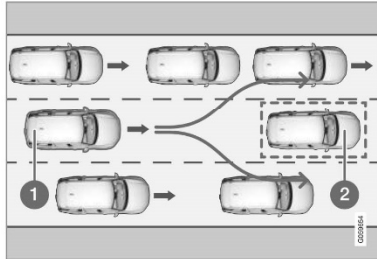
The function uses the vehicle's camera and radar sensor, which has certain general limitations.

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 Safety⁵⁹ 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

⁵⁹ This function is not available on all markets.

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.

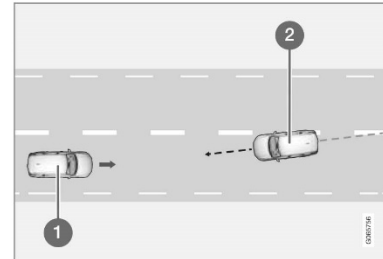
Related information

- 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

▶▶

- 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 Safety⁶⁰ 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 (ESC⁶¹) 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)

³ Brake Assist System

Brake Assist System

The brake enhancing system, (BAS³), 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)

APPENDIX C

Run Log

2020 Volvo S60 T6 AWDTest Date: **2/3/2020**Subject Vehicle: **Momentum**Principal Other Vehicle: **SSV**

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
1	Static Run								
2	Stopped POV	N							Video dropout
3		N							Video dropout
4		Y	2.52	2.08	24.9	1.09	0.88	Pass	
5		Y	2.55	0.74	24.8	1.08	0.85	Pass	
6		Y	1.66	0.00	6.8	1.20	0.26	Fail	Driver applied brakes at last second. Driver applied braking still resulted in failing speed reduction. Damage to front grille of vehicle. Vehicle manufacturer information found on Volvo website indicates that the radar and camera are both contained in the windshield of the vehicle. No indications that radar/camera system not operating as usual. Last Minute Braking turned on
7		N							Brake actuator fired due to incorrect settings
8		Y	2.53	2.61	24.2	1.06	0.97	Pass	
9		Y	2.50	2.29	24.5	1.04	0.87	Pass	
10		Y	2.51	2.43	24.5	1.08	0.97	Pass	
11		Y	2.49	2.31	24.6	1.06	0.93	Pass	
12	Static Run								

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
13	Slower POV, 25 vs 10	Y	1.91	1.16	14.5	1.11	0.82	Pass	
14		Y	1.99	5.12	14.4	0.84	0.80	Pass	
15		Y	1.84	5.03	13.9	0.91	0.75	Pass	
16		Y	1.95	4.87	14.7	0.78	0.82	Pass	
17		Y	1.92	6.26	14.6	0.92	0.86	Pass	
18		N							SV Speed
19		Y	1.93	4.97	14.1	1.01	0.76	Pass	
20		Y	1.97	5.29	14.3	0.93	0.79	Pass	
21	Static Run								
22	Slower POV, 45 vs 20	Y	2.64	2.39	24.4	1.01	1.14	Pass	
23		N							POV speed, GPS Fix Type
24		Y	2.59	3.86	24.8	0.85	1.10	Pass	
25		Y	2.73	2.43	24.6	1.07	1.13	Pass	
26		Y	2.58	1.39	24.5	1.05	1.16	Pass	
27		Y	2.72	1.34	24.2	0.97	1.02	Pass	
28		Y	2.56	2.13	25.2	1.05	1.14	Pass	
29		Y	2.61	3.24	25.6	1.08	1.14	Pass	
30	Static run								
31	Decelerating POV, 35	Y	1.45	1.27	34.8	0.98	1.04	Pass	
32		N							POV brakes
33		Y	2.11	1.05	30.9	1.17	1.14	Pass	
34		Y	2.03	3.13	27.0	1.12	1.12	Pass	
35		Y	2.01	2.09	32.5	1.17	1.05	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
36		Y	1.93	1.65	32.4	1.14	1.04	Pass	
37		N							Headway
38		Y	2.04	2.95	35.2	1.05	1.15	Pass	
39		Y	1.99	2.75	26.6	1.08	1.18	Pass	
40	Static Run								
41	STP - Static Run								
42	STP False Positive, 25	Y				0.01		Pass	
43		Y				0.01		Pass	
44		Y				0.01		Pass	
45		Y				0.01		Pass	
46		Y				0.01		Pass	
47		Y				0.02		Pass	
48		Y				0.01		Pass	
49	STP - Static Run								
50	STP False Positive, 45	N							yaw rate
51		Y				0.01		Pass	
52		Y				0.01		Pass	
53		Y				0.03		Pass	
54		Y				0.03		Pass	
55		Y				0.03		Pass	
56		Y				0.00		Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
57		Y				0.04		Pass	
58	STP - Static Run								

APPENDIX D

Time History Plots

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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 codes indicating to which vehicle the data pertain.

Time History Plot Description

Each time history plot consists of data relevant 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:

- Stopped POV (SV at 25 mph)
- Slower POV, 25/10 (SV at 25 mph, POV at 10 mph)
- Slower POV, 45/20 (SV at 45 mph, POV at 20 mph)
- Decelerating POV 35 mph (Both vehicles at 35 mph with 13.8 m gap, POV brakes at 0.3 g)
- False Positive STP 25 mph (Steel trench plate run over at 25 mph)
- False Positive STP 45 mph (Steel trench plate run over at 45 mph)

Time history figures include the following sub-plots:

- FCW 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 combination of the following:
 - Filtered, rectified, and normalized sound signal. The vertical scale is 0 to 1.
 - Filtered, rectified, and normalized acceleration (i.e., haptic alert, such as steering wheel vibration). The vertical scale is 0 to 1.
 - Normalized light sensor signal. The vertical scale is 0 to 1.

As only the audible or haptic alert is perceptible by the driver during a test run, the earliest of either of these alerts is used to define the onset of the FCW alert. A vertical black bar on the plot indicates the TTC (sec) at the first moment of the warning issued by the FCW system. The FCW TTC is displayed to the right of the subplot in green. For False Positive tests, when the FCW presents a warning “FCW” is shown in red at the right edge of the FCW plot.

- Headway (ft) – Longitudinal separation (gap) between the frontmost point of the Subject Vehicle and the rearmost point of the Strikeable Surrogate Vehicle (SSV) towed by the Principal Other Vehicle. The minimum headway during the run is displayed to the right of the subplot.
- SV/POV Speed (mph) – Speed of the Subject Vehicle and Principal Other Vehicle (if any). For CIB tests, the speed reduction experienced by the Subject Vehicle is displayed to the right of the subplot.
- Yaw Rate (deg/sec) – Yaw rate of the Subject Vehicle and Principal Other Vehicle (if any).
- Lateral Offset (ft) – Lateral offset within the lane of the Subject Vehicle to the center of the lane of travel. Note that for tests involving the Strikeable Surrogate Vehicle (SSV), the associated lateral restraint track is defined to be the center of the lane of travel. If testing is done with a different POV which does not have a lateral restraint track, lateral offset is defined to be the lateral offset between the SV and POV.
- Ax (g) – Longitudinal acceleration of the Subject Vehicle and Principal Other Vehicle (if any). For CIB tests, the TTC (sec) at the moment of first CIB activation is displayed to the right of the subplot in green. Also, the peak value of Ax for the SV is shown on the subplot.
- Accelerator Pedal Position (0-1) – Normalized position of the accelerator pedal.

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

Some of the time history plot figures 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. Such exceedances indicate either that the test was invalid or that the requirements of the test were not met (i.e., failure of the AEB system).

For plots with green envelopes, in order for the test to be valid, the time-varying data must not exceed the envelope boundaries at any time. Exceedances of a green envelope are indicated by red shading in the area between the measured time-varying data and the envelope boundaries.

For plots with yellow envelopes, in order for the test to be valid, the time-varying data must not exceed the envelope at the beginning (left edge of the boundary) and/or end (right edge), but may exceed the boundary during the time between the left and right edges. Exceedances at the left or right extent of a yellow envelope are indicated by red asterisks.

For the headway plot, a dashed black threshold line indicating a relative headway of zero is displayed. If no impact occurs, a green circle is displayed at the moment of minimum distance. If impact occurs, a red asterisk is displayed at the moment of impact.

For the Ax plot, if the scenario is an AEB brake-to-stop scenario, a vertical dashed black line is displayed for all plots indicating the moment of first POV braking. The yellow envelope in this case is relevant to the POV braking only. The left edge of the envelope is at 1.5 seconds after the first POV braking. A solid black threshold line extends horizontally 0.5 seconds to the left of the envelope. This threshold line represents the time during which the Ax of the Principal Other Vehicle must first achieve 0.27 g (the upper edge of the envelope). A green circle or red asterisk is displayed at the moment the POV brake level achieves 0.27 g. A green circle indicates that the test was valid (the threshold was crossed during the appropriate interval) and a red asterisk indicates that the test was invalid (the threshold was crossed outside of the appropriate interval). Additionally, for the CIB tests, a dashed black threshold line indicating an Ax of -0.15 g is given to define the onset of CIB activation. When the Subject Vehicle's Ax crosses this threshold, the CIB TTC is calculated and displayed.

For the accelerator pedal position plot, a green envelope is given starting 500 ms after the onset of the FCW warning to ensure that the accelerator pedal was released at the correct time and remained off for the duration of the CIB event. For false positive runs a green dot, rather than a green envelope is displayed. The green dot indicates that at the end of the run the accelerator pedal had not been released. If the accelerator had been released a red asterisk would appear.

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. Individual data points
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 cross this threshold in the time period shown in order to be valid
- Black threshold (Dashed) = for reference only – this can include warning level thresholds, TTC thresholds, and acceleration thresholds

3. Individual data point 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

- 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 1 through Figure 9. Figures 1 through 6 show passing runs for each of the 6 test types. Figures 7 and 8 show examples of invalid runs. Figure 9 shows an example of a valid test that failed the CIB requirements.

Time history data plots for the tests of the vehicle under consideration herein are provided beginning with Figure 10.

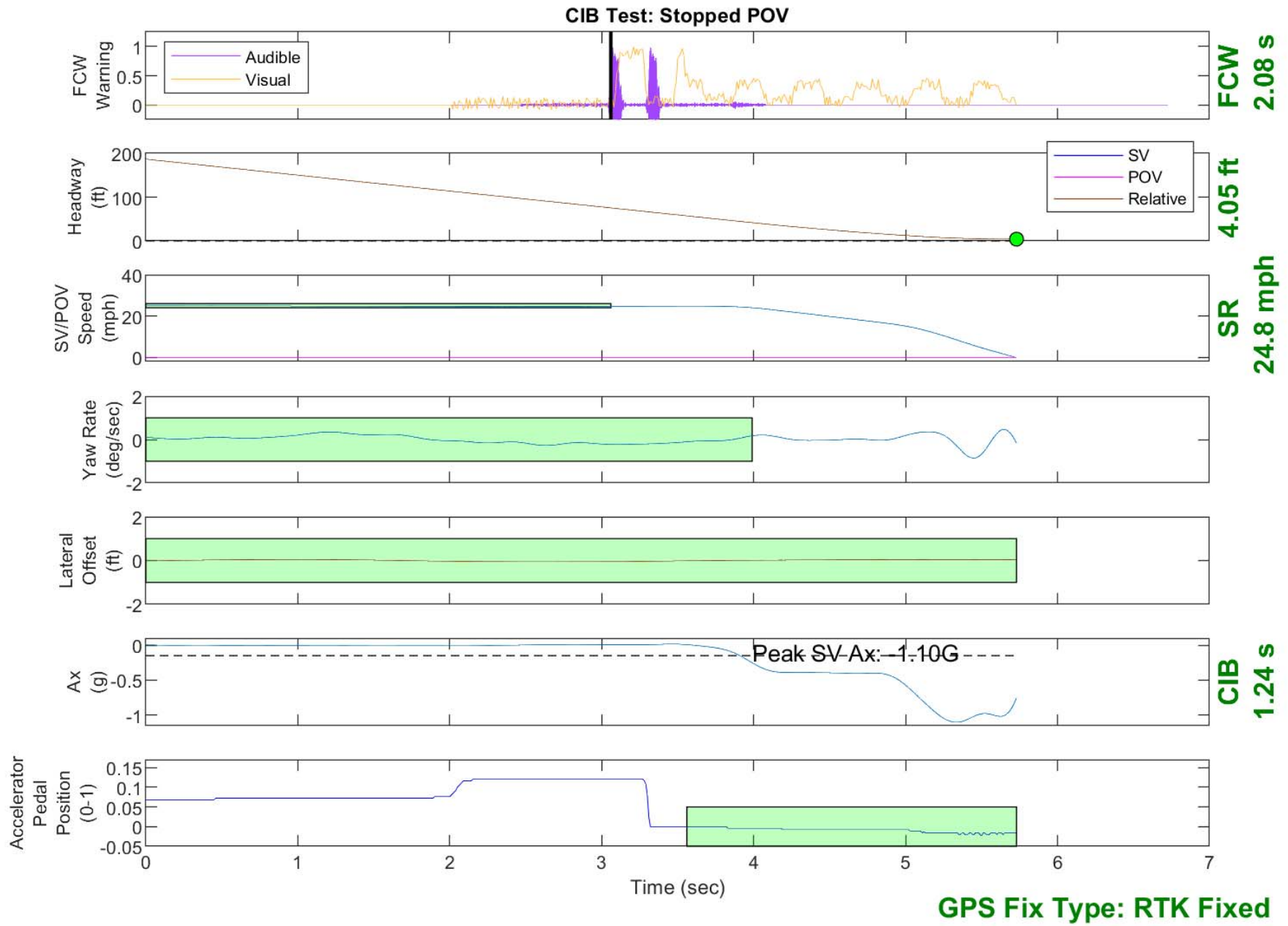


Figure D1. Example Time History for Stopped POV, Passing

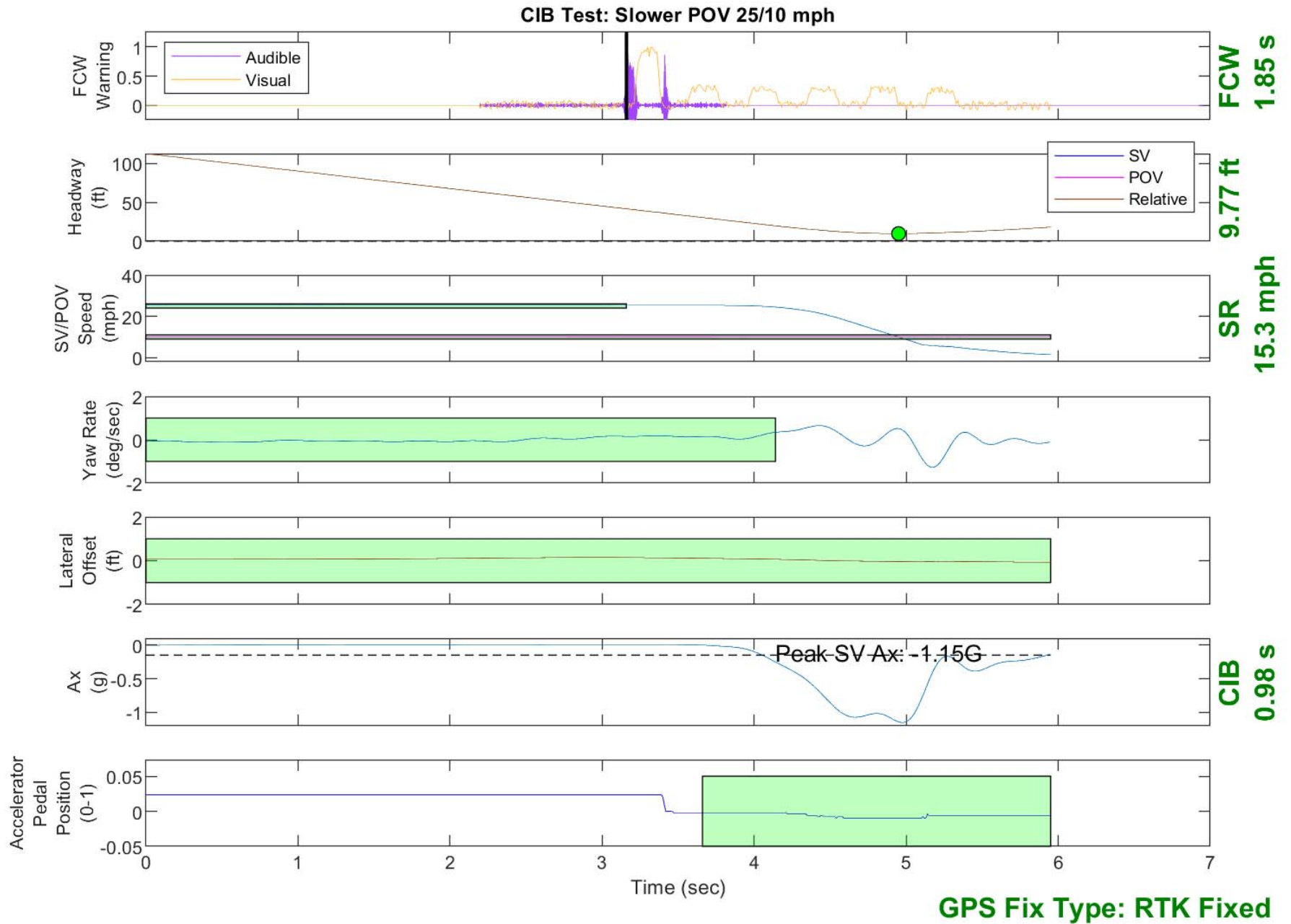


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

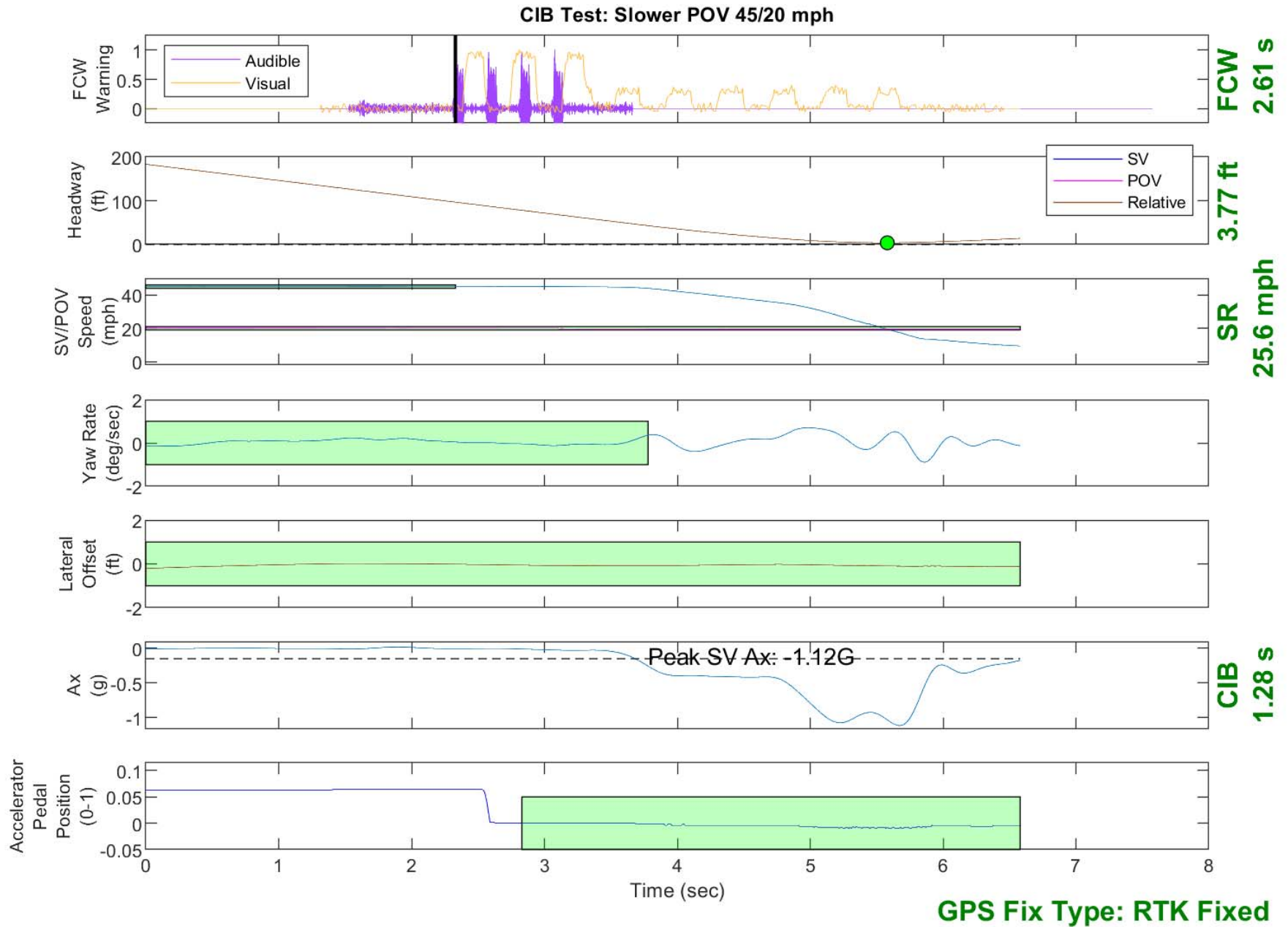


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

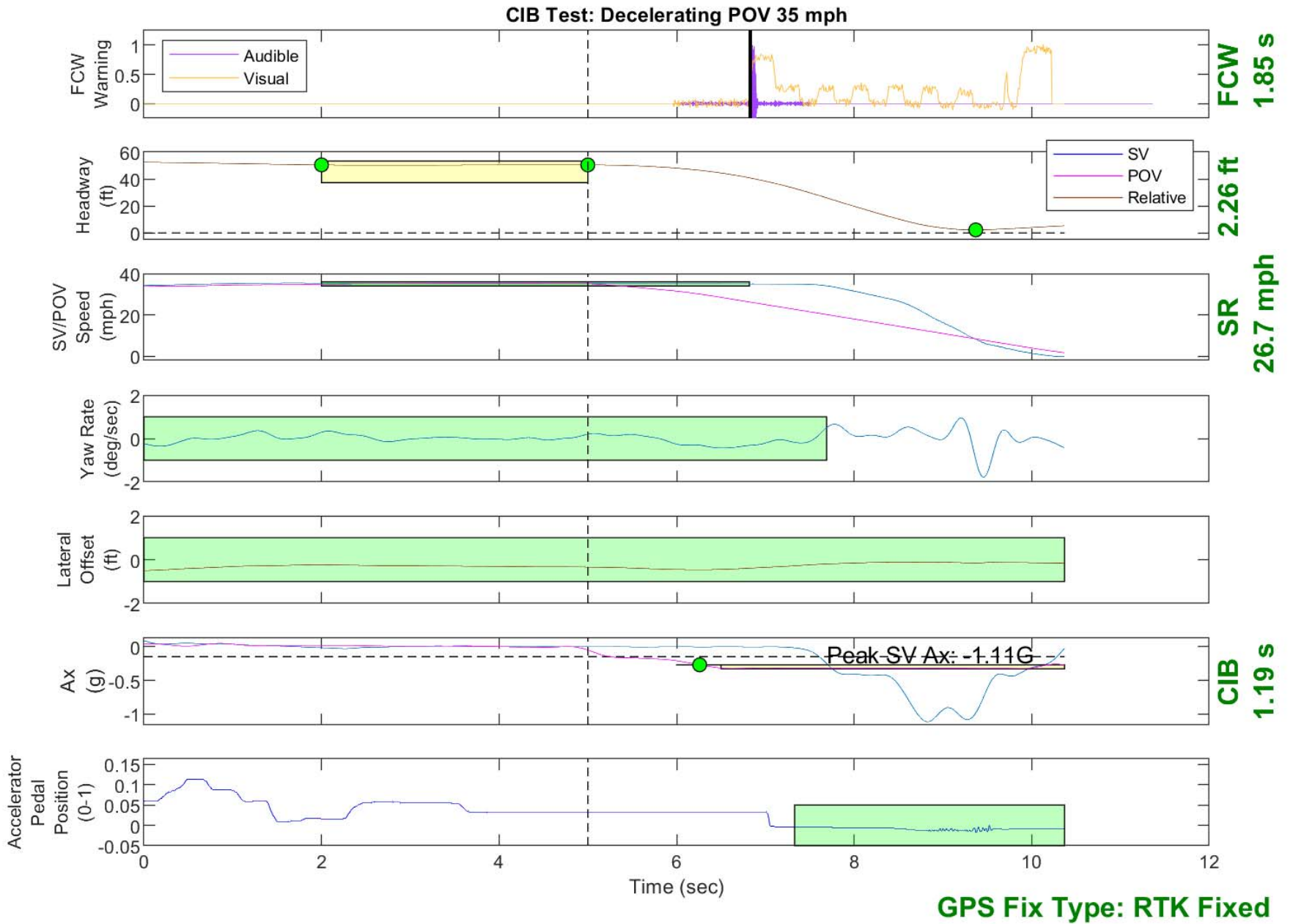


Figure D4. Example Time History for Decelerating POV 35, Passing

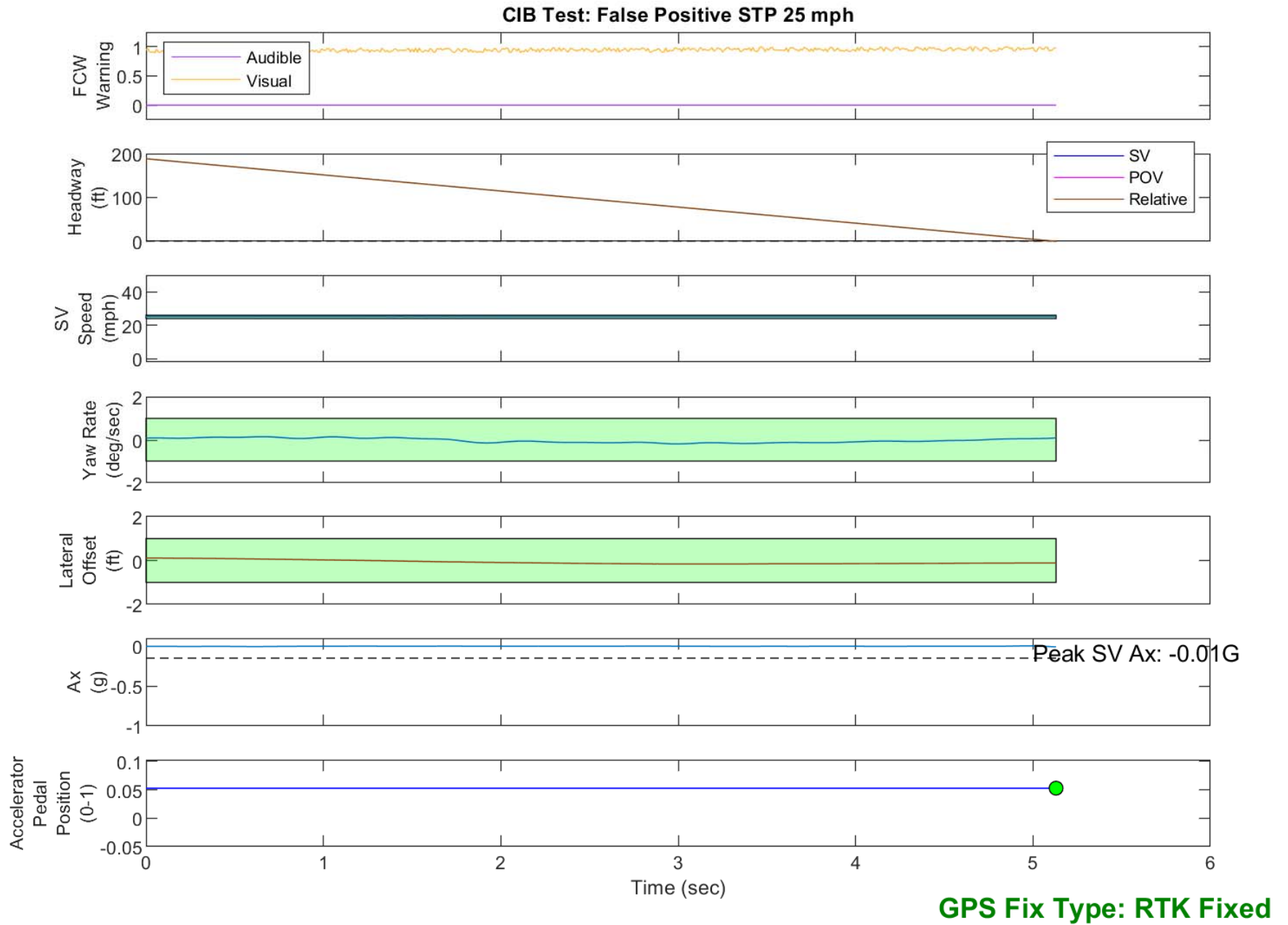


Figure D5. Example Time History for False Positive STP 25, Passing

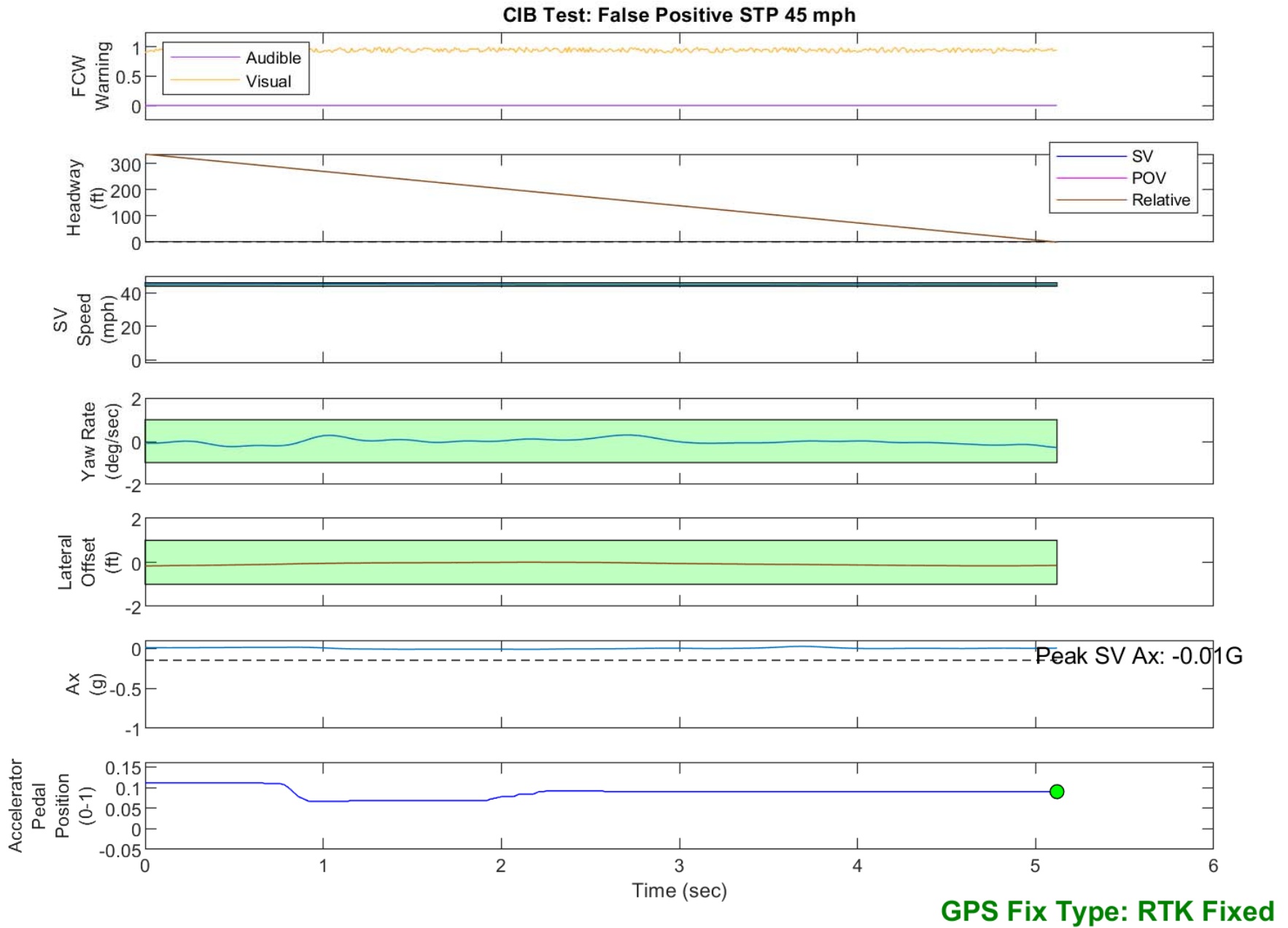


Figure D6. Example Time History for False Positive STP 45, Passing

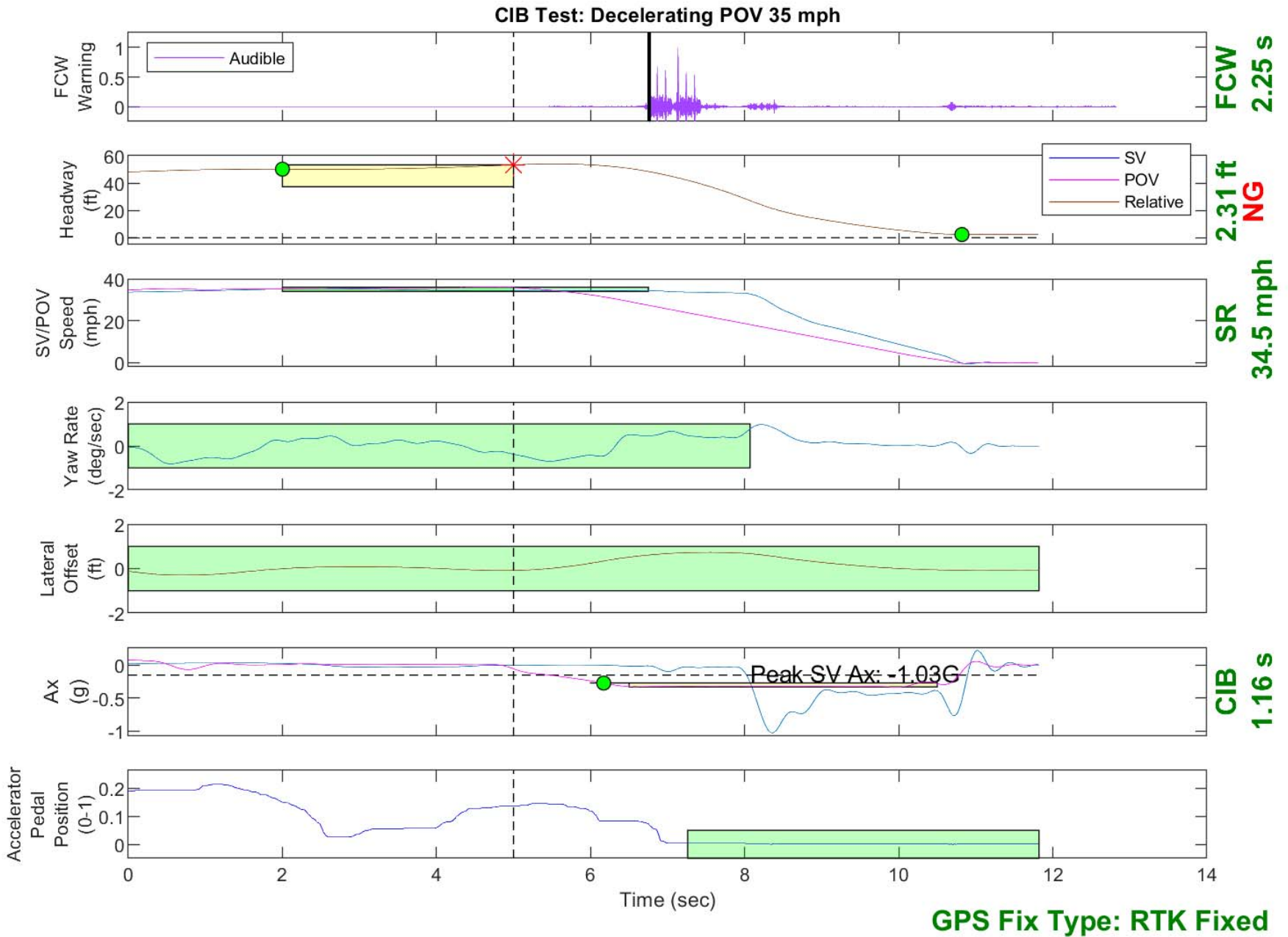


Figure D7. Example Time History Displaying Various Invalid Criteria

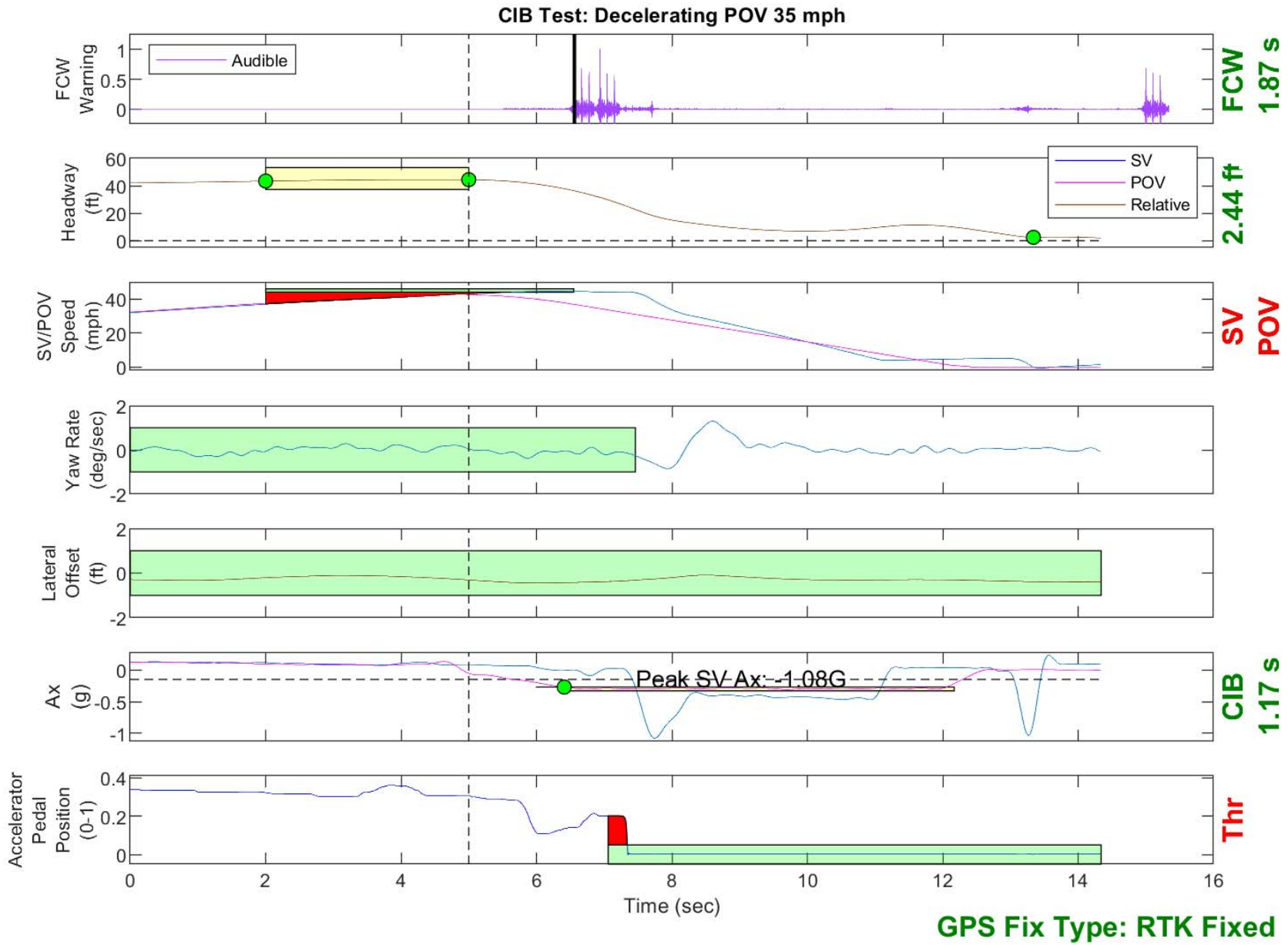


Figure D8. Example Time History Displaying Various Invalid Criteria

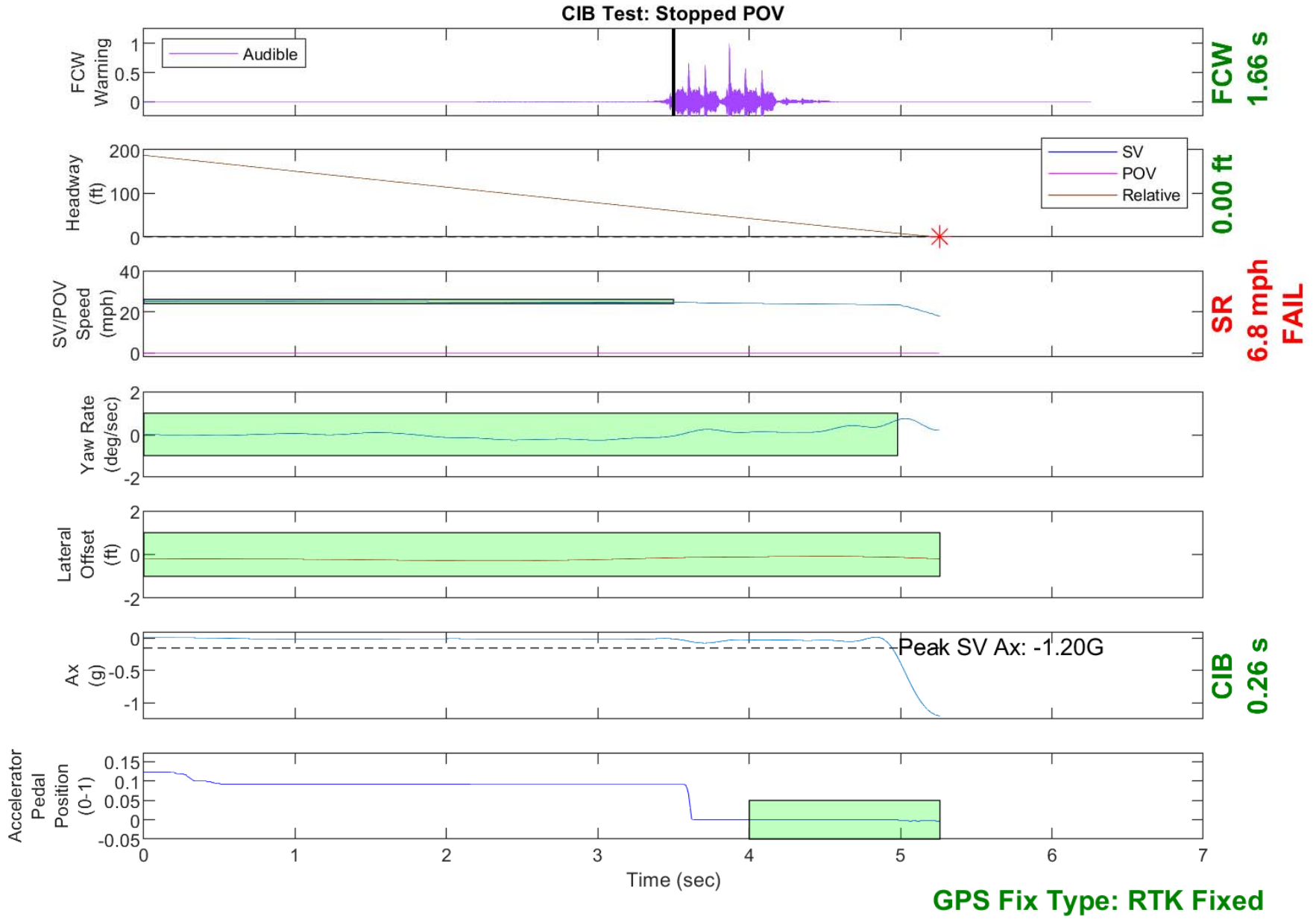


Figure D9. Example Time History for a Failed Run

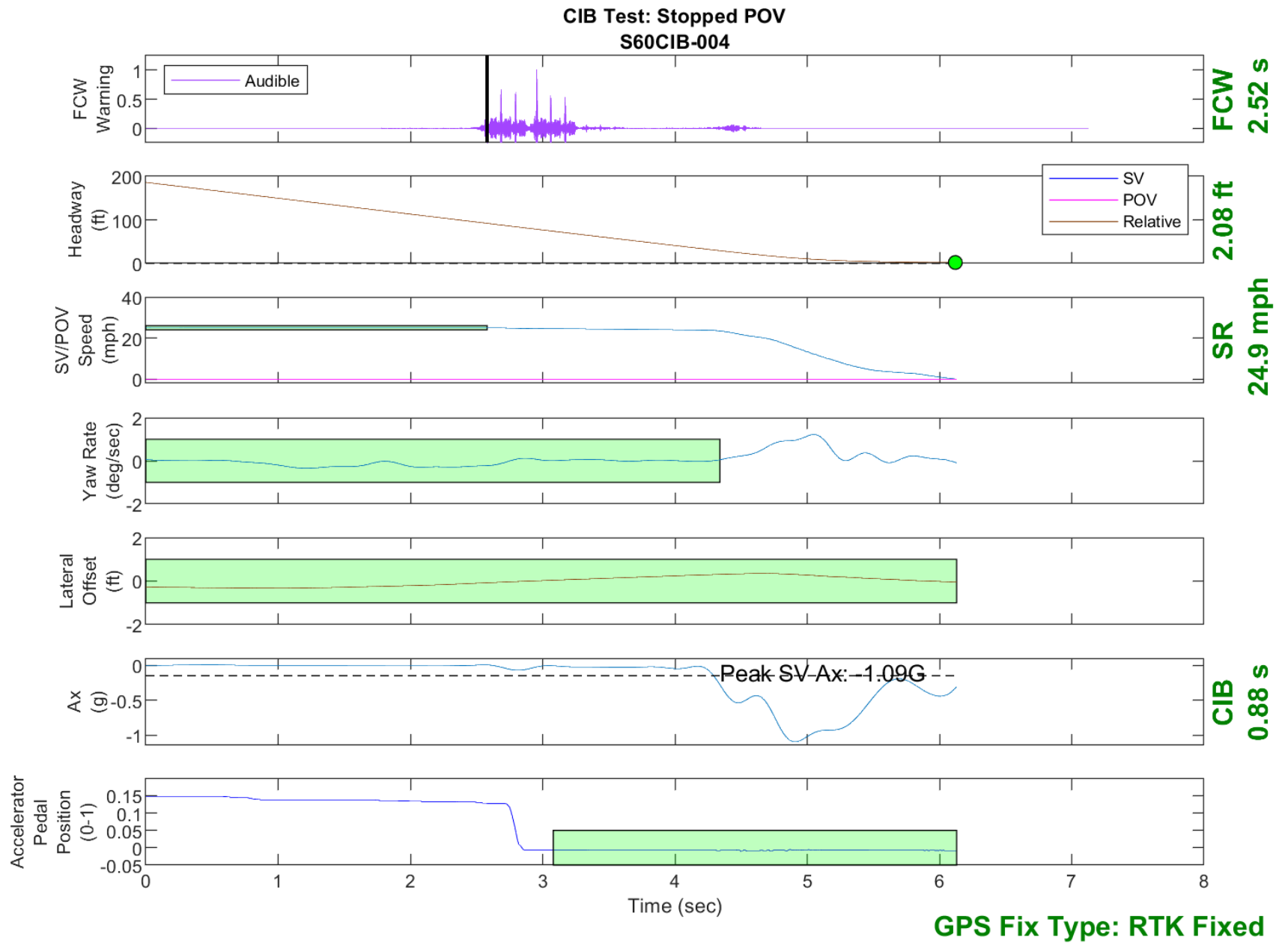


Figure D10. Time History for CIB Run 4, SV Encounters Stopped POV

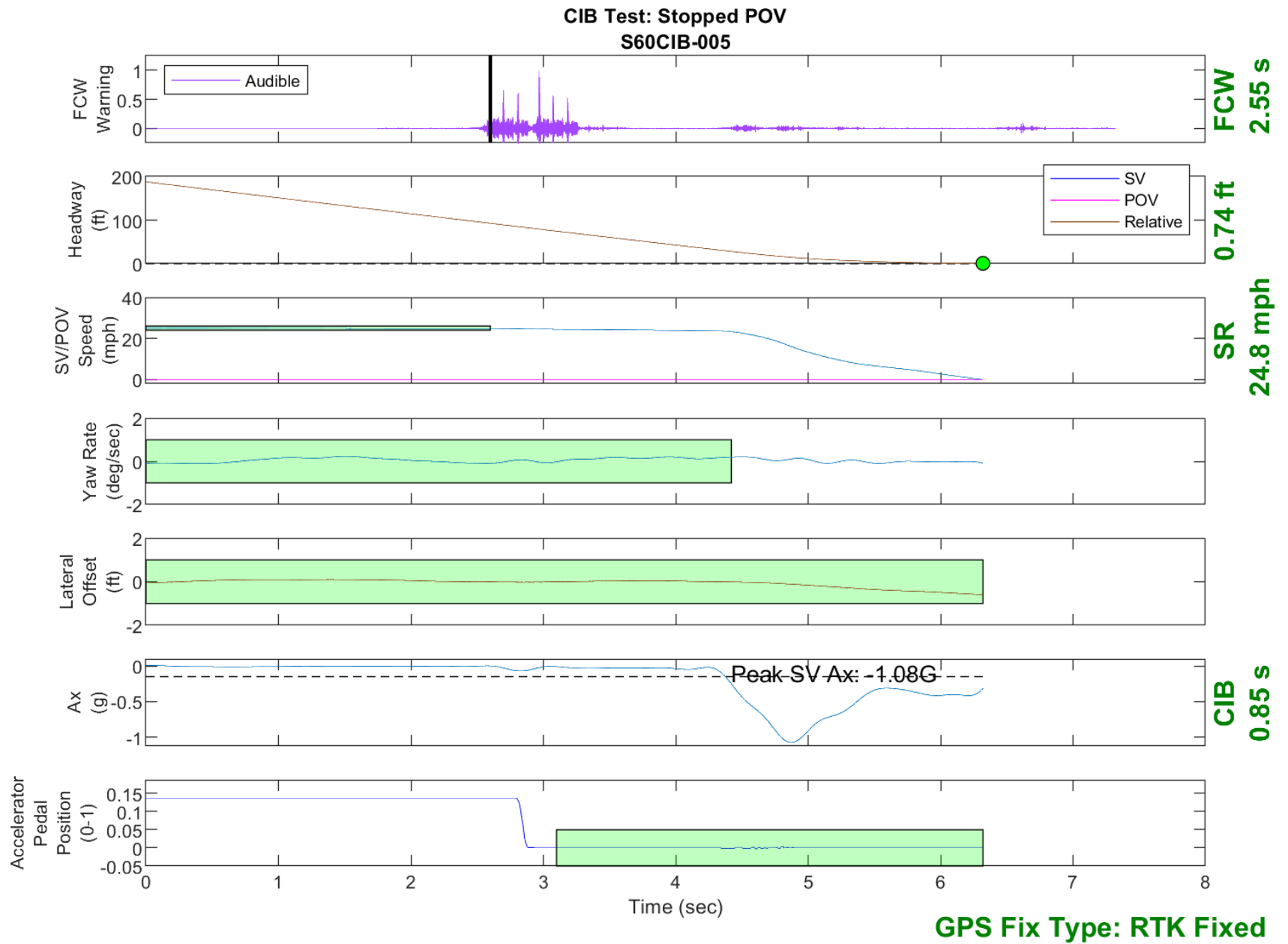


Figure D11. Time History for CIB Run 5, SV Encounters Stopped POV

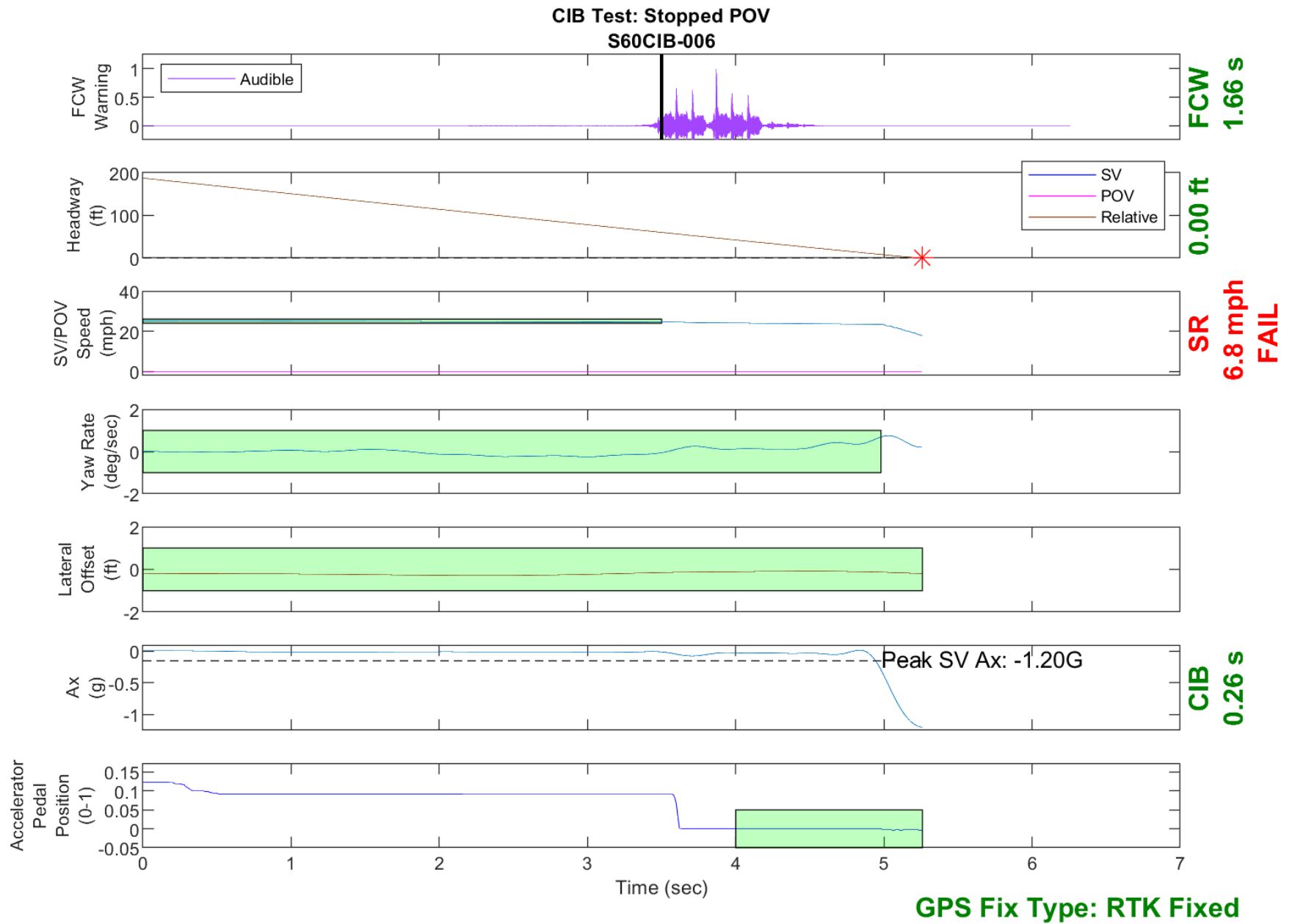


Figure D12. Time History for CIB Run 6, SV Encounters Stopped POV

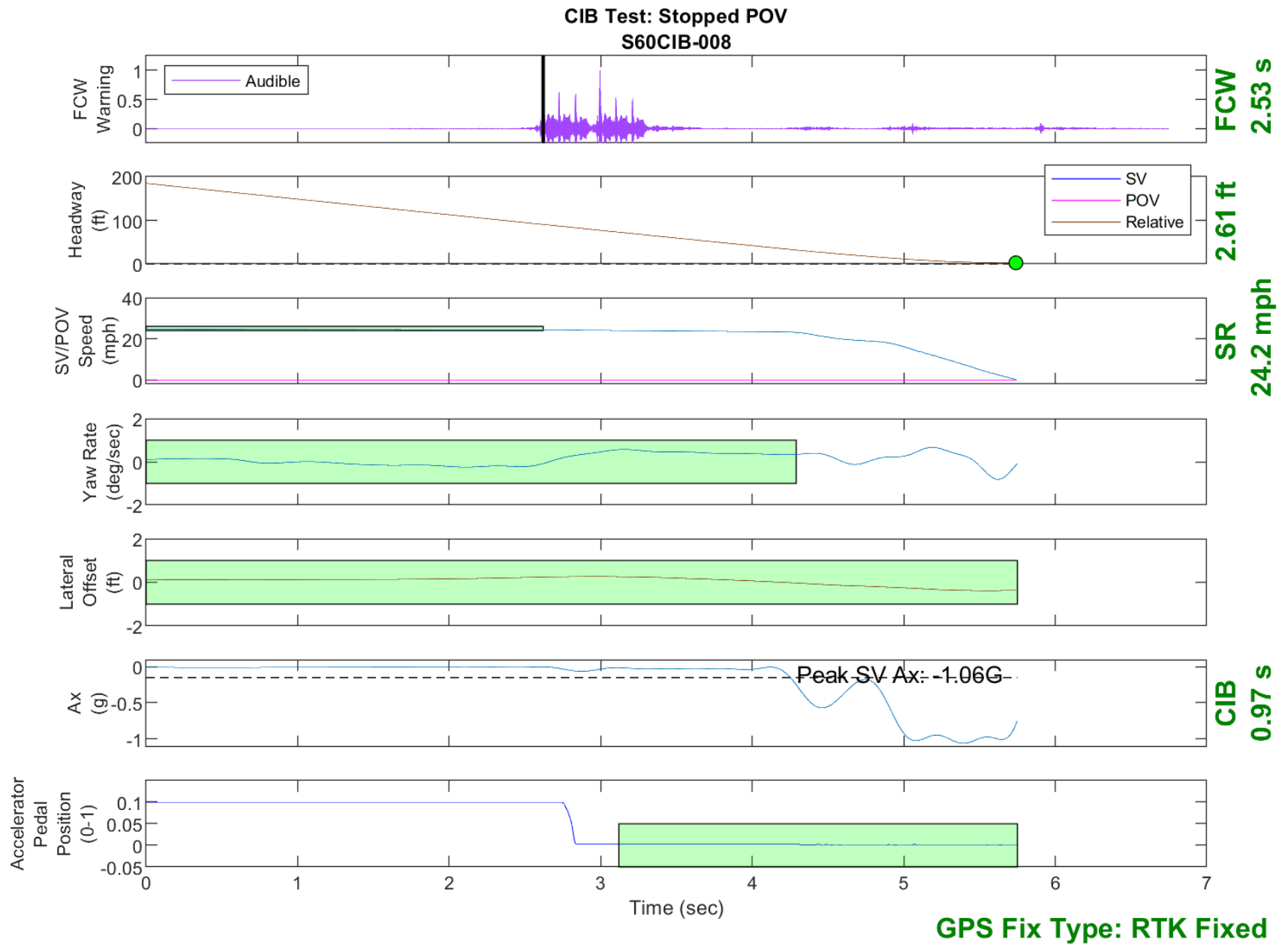


Figure D13. Time History for CIB Run 8, SV Encounters Stopped POV

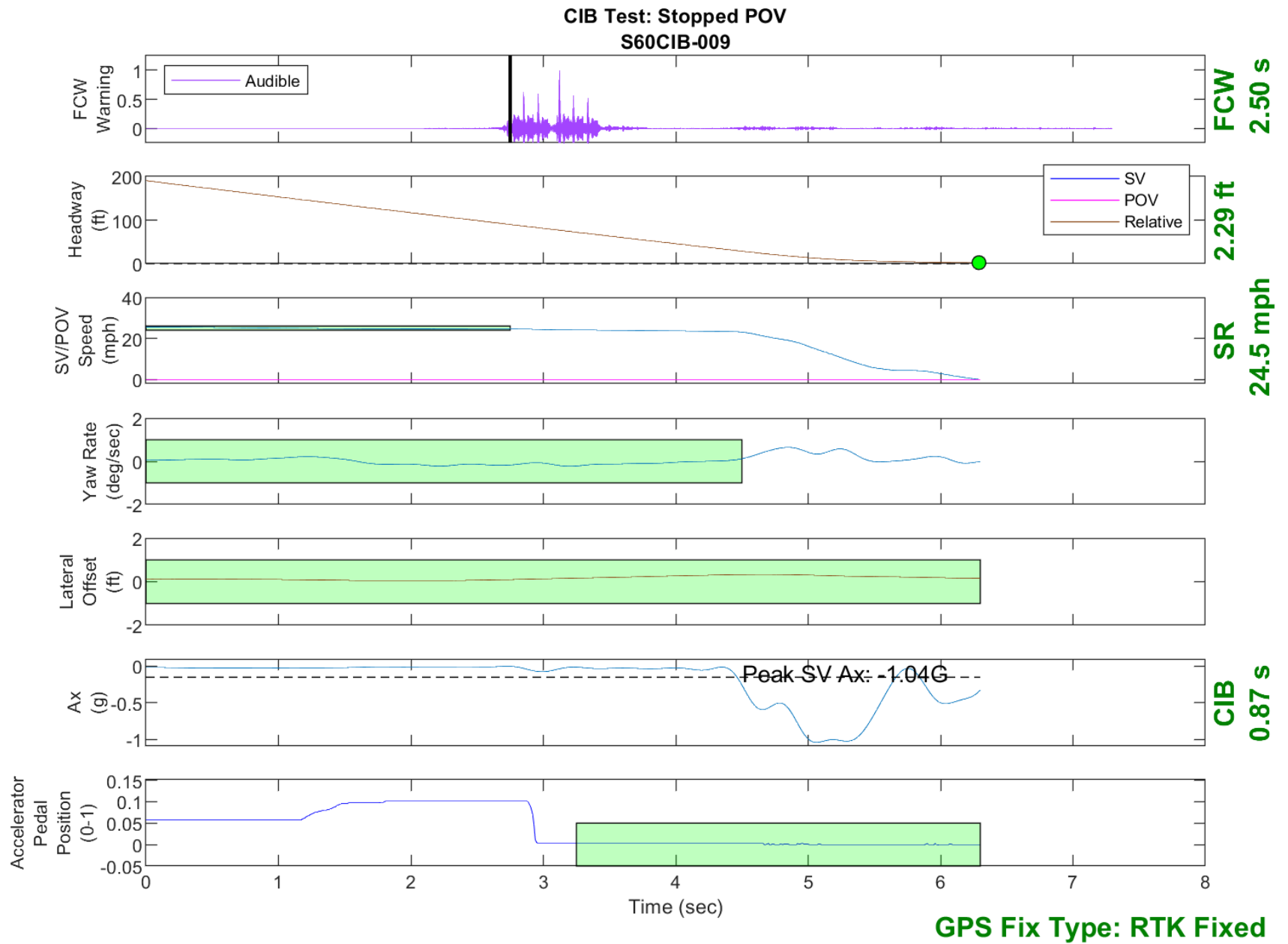


Figure D14. Time History for CIB Run 9, SV Encounters Stopped POV

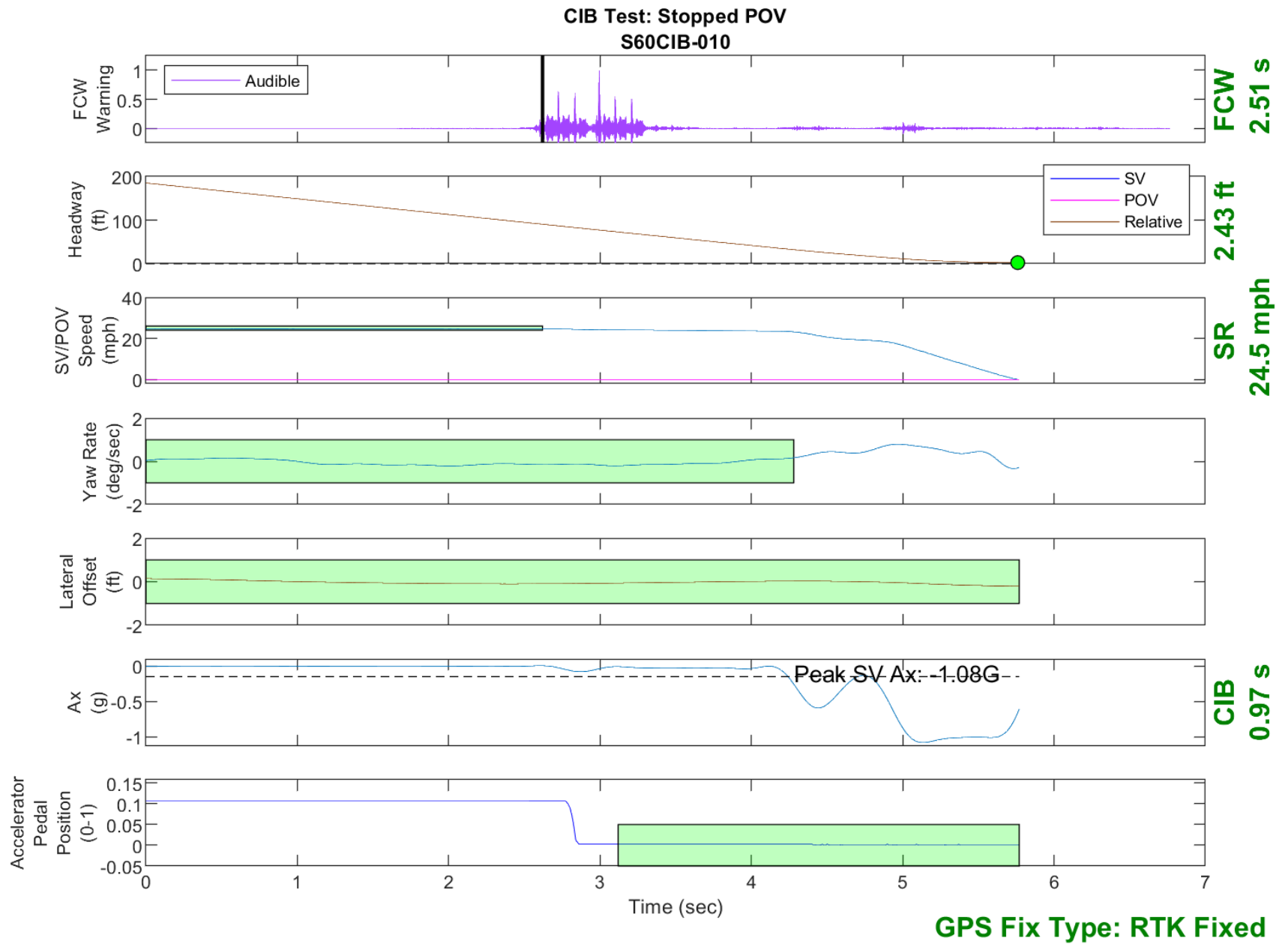


Figure D15. Time History for CIB Run 10, SV Encounters Stopped POV

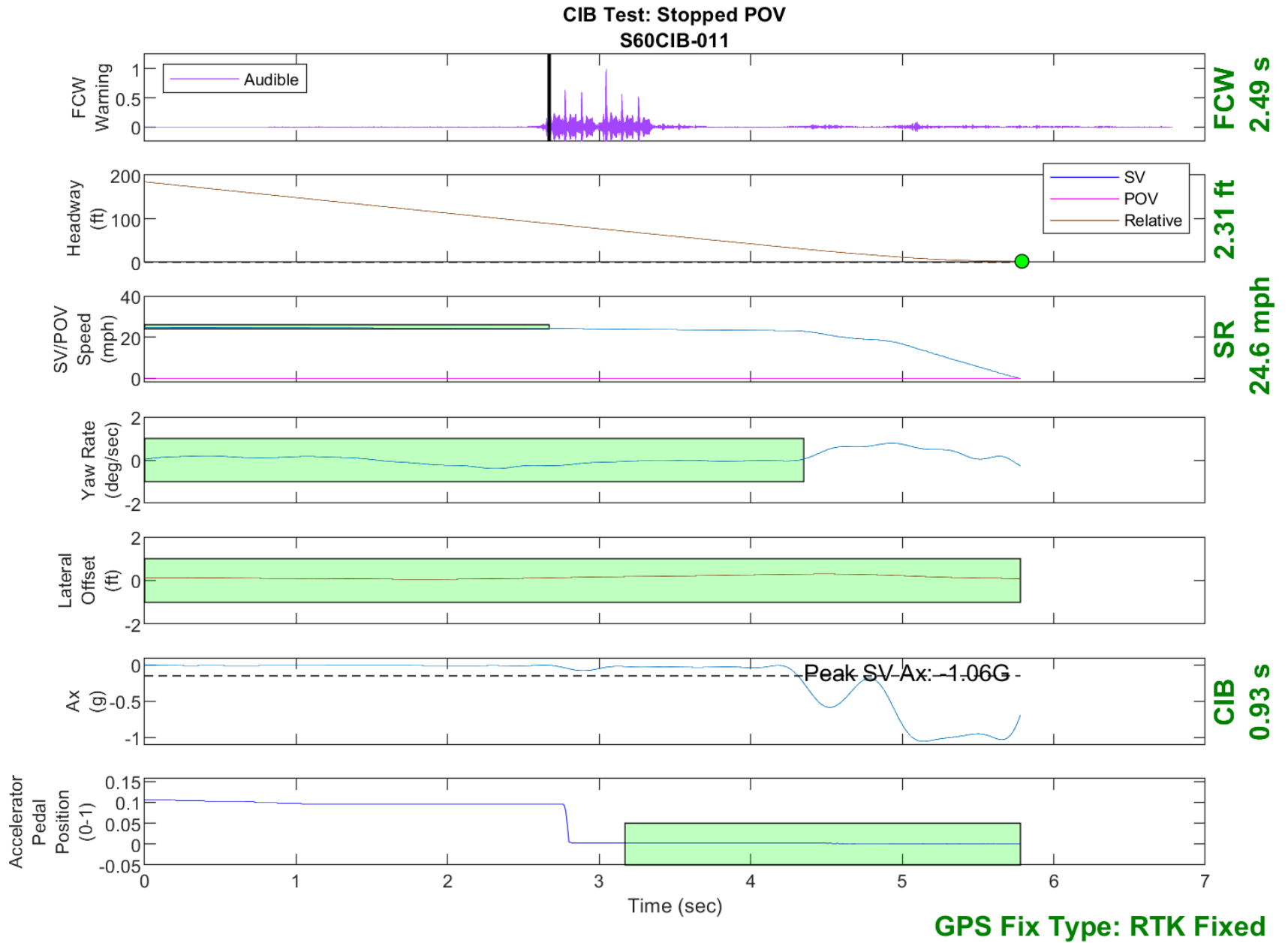


Figure D16. Time History for CIB Run 11, SV Encounters Stopped POV

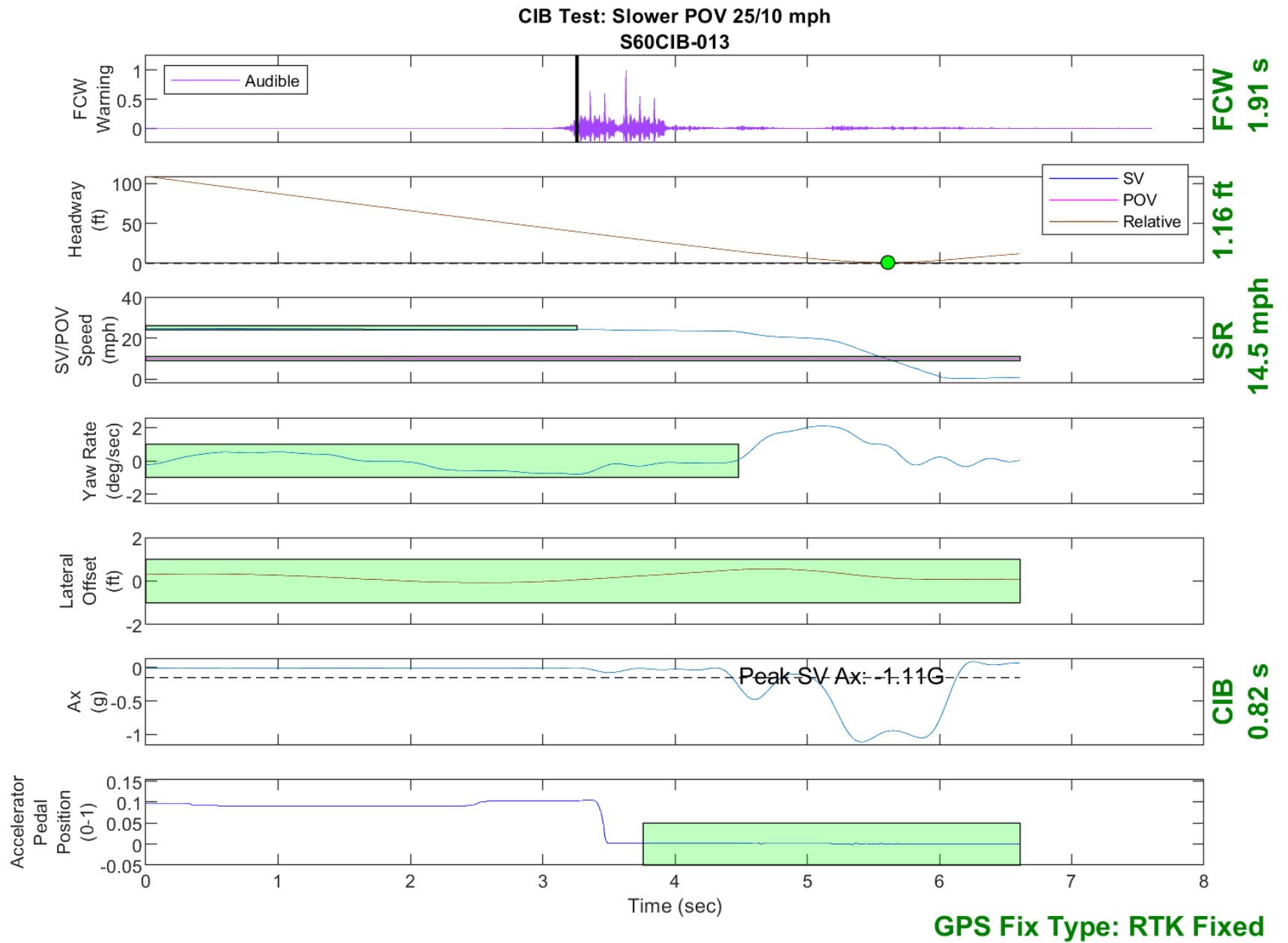


Figure D17. Time History for CIB Run 13, SV Encounters Slower POV, SV 25 mph, POV 10 mph

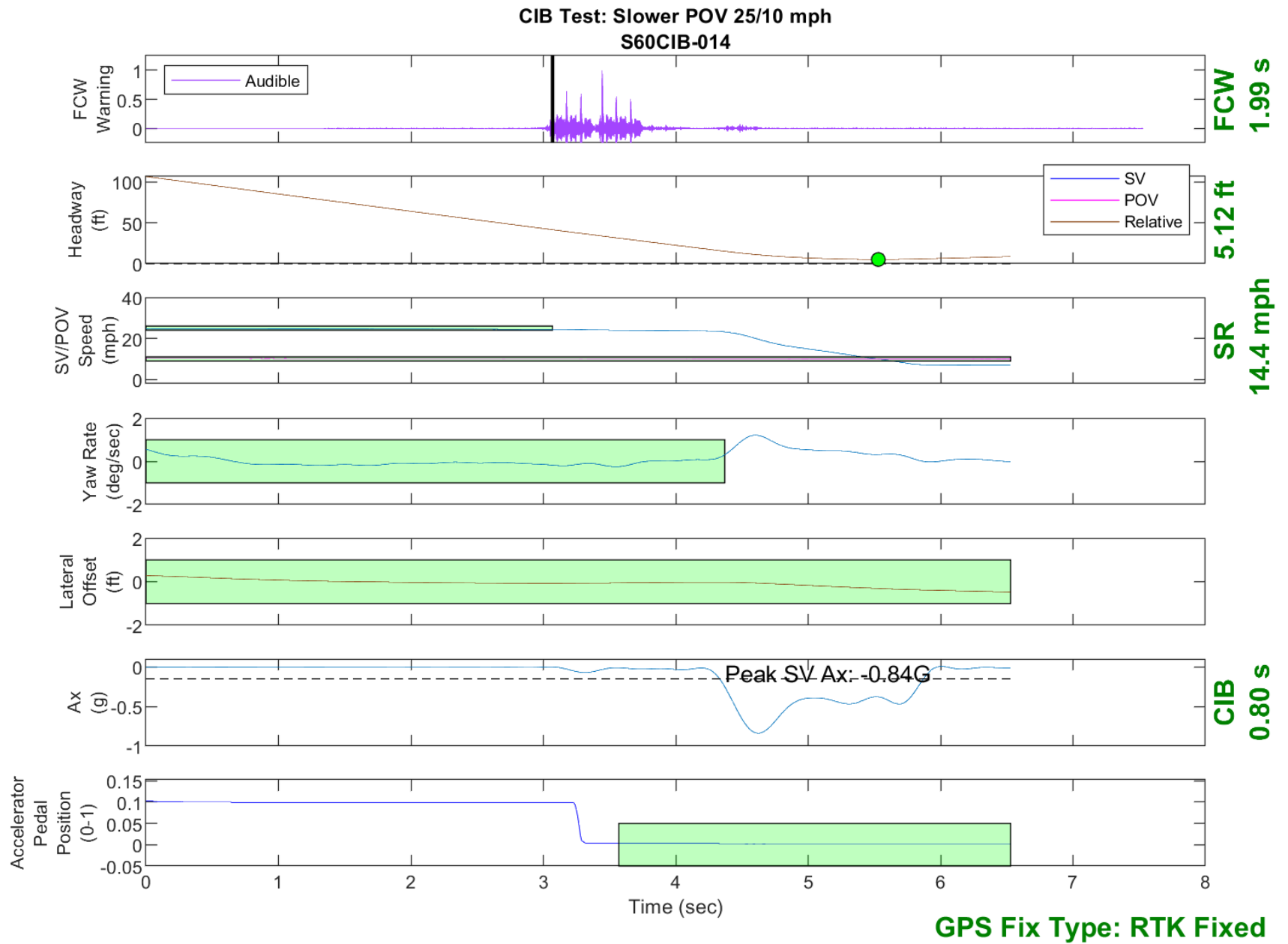


Figure D18. Time History for CIB Run 14, SV Encounters Slower POV, SV 25 mph, POV 10 mph

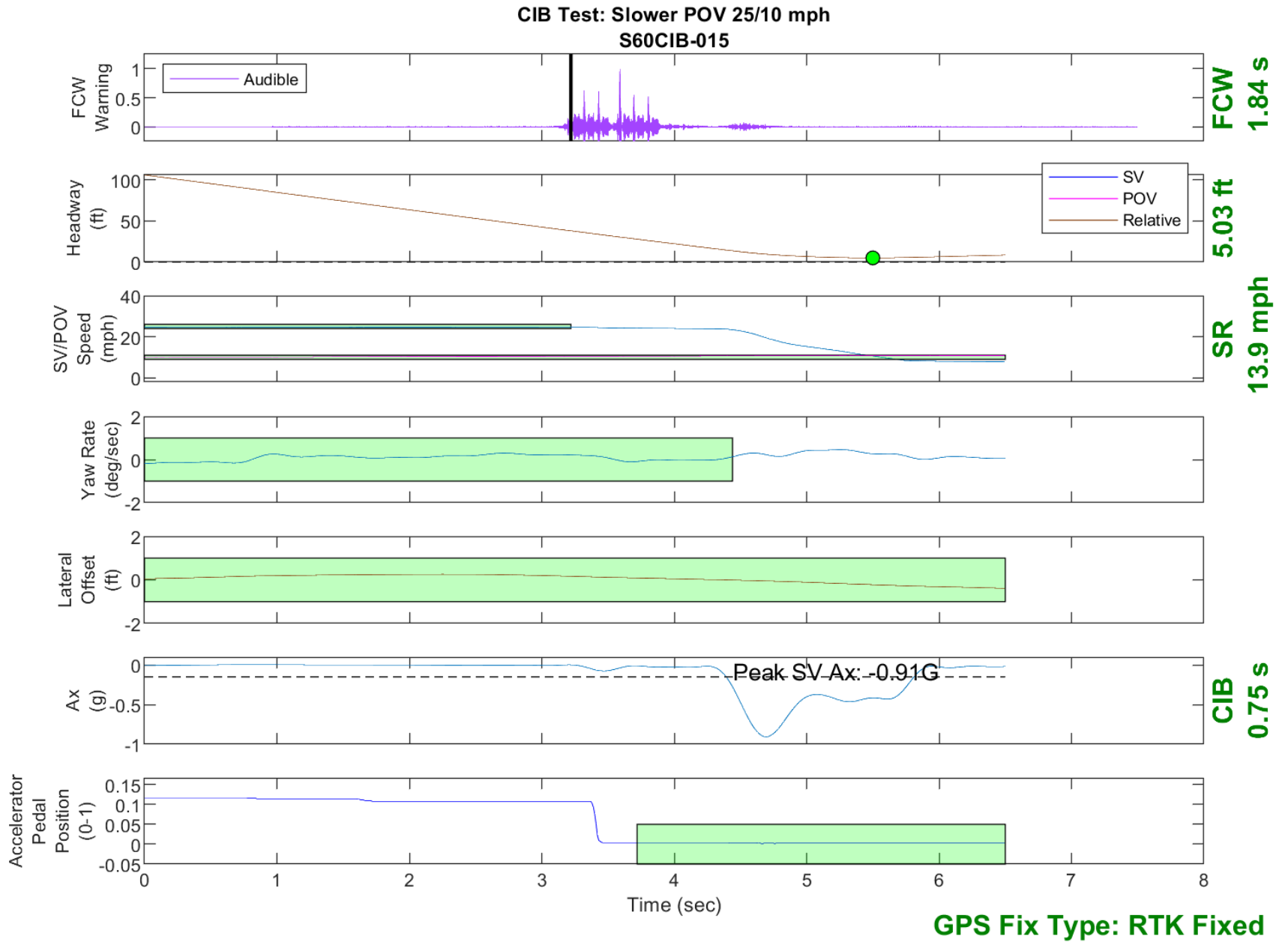


Figure D19. Time History for CIB Run 15, SV Encounters Slower POV, SV 25 mph, POV 10 mph

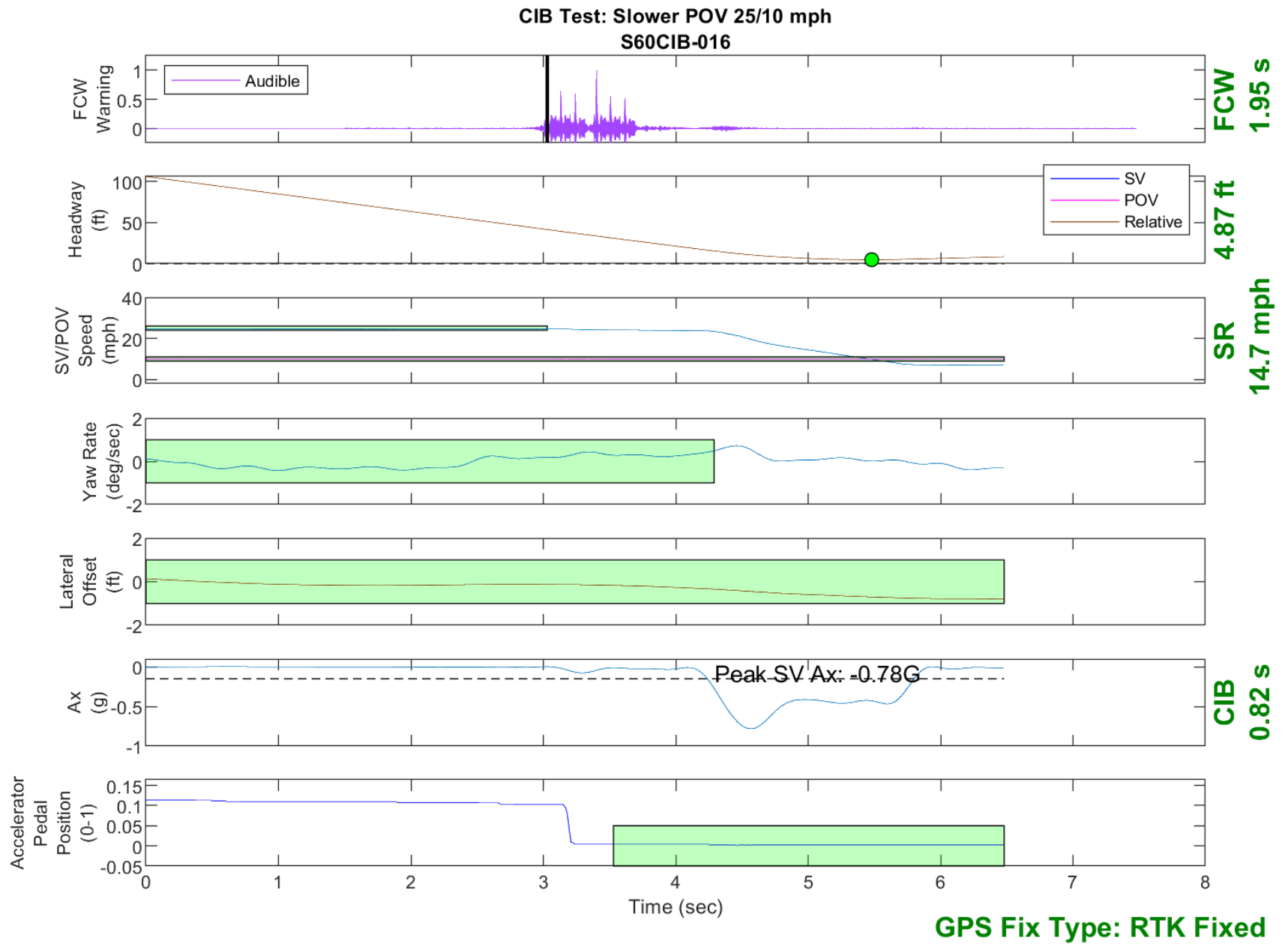


Figure D20. Time History for CIB Run 16, SV Encounters Slower POV, SV 25 mph, POV 10 mph

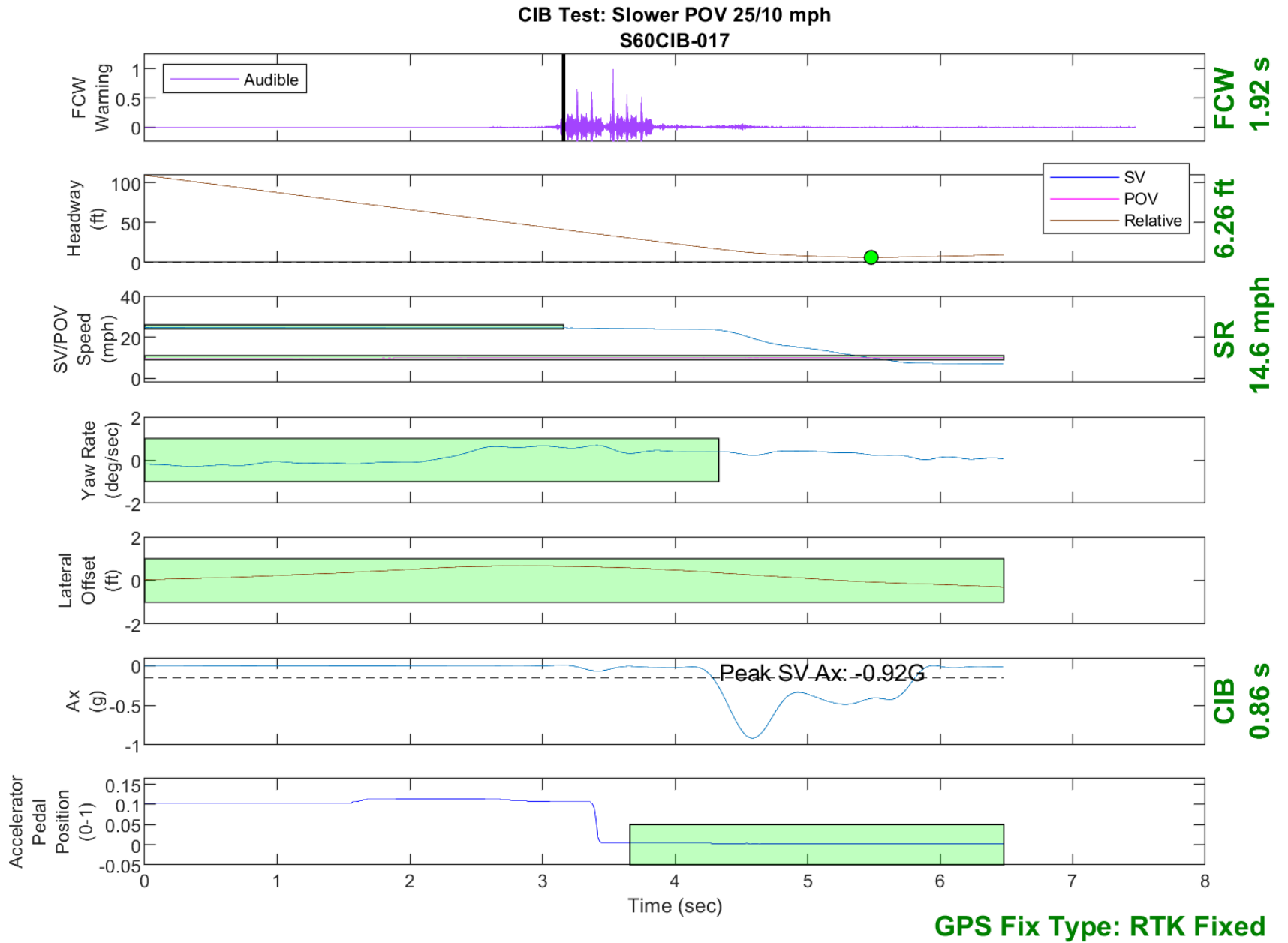


Figure D21. Time History for CIB Run 17, SV Encounters Slower POV, SV 25 mph, POV 10 mph

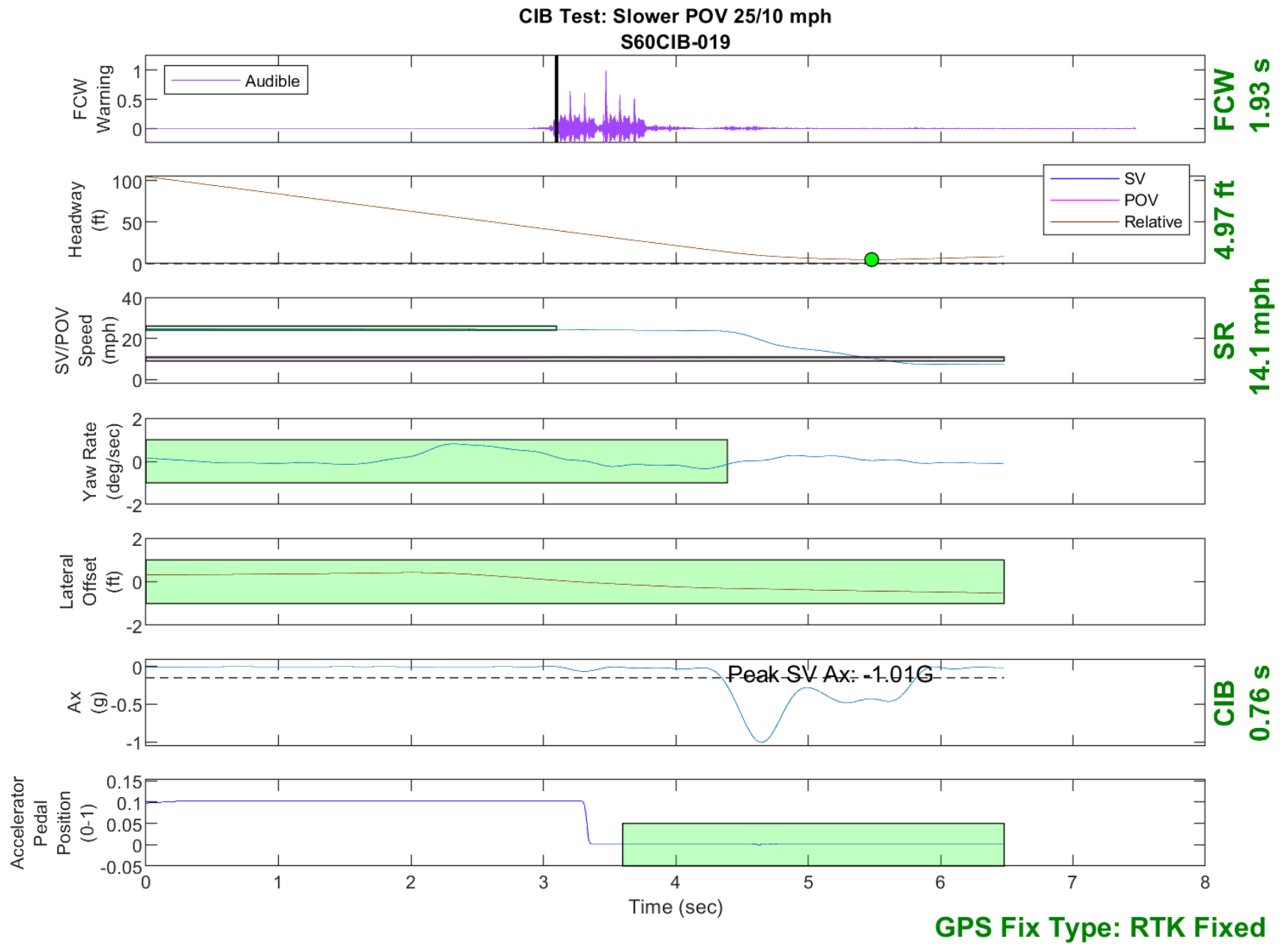


Figure D22. Time History for CIB Run 19, SV Encounters Slower POV, SV 25 mph, POV 10 mph

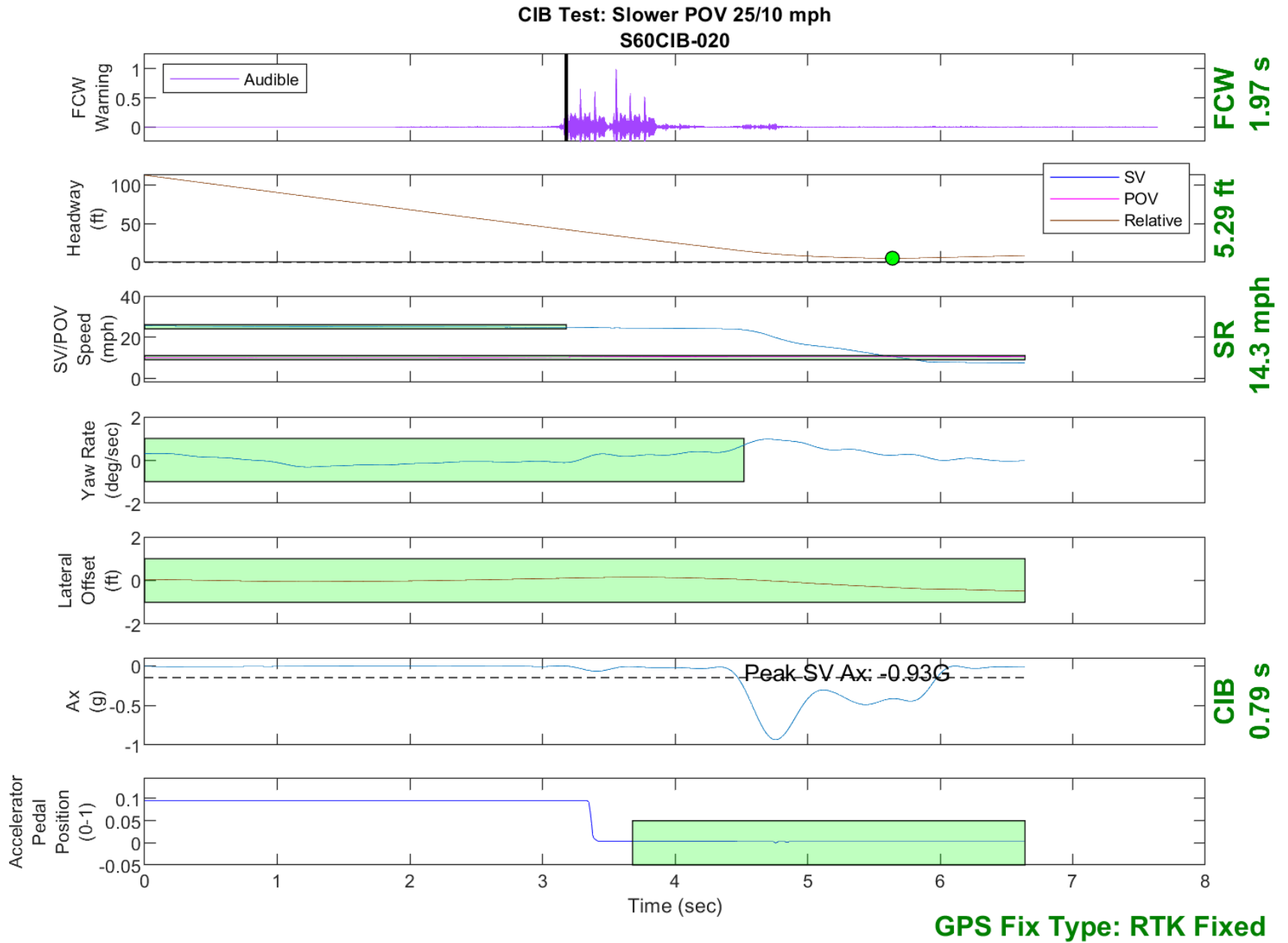


Figure D23. Time History for CIB Run 20, SV Encounters Slower POV, SV 25 mph, POV 10 mph

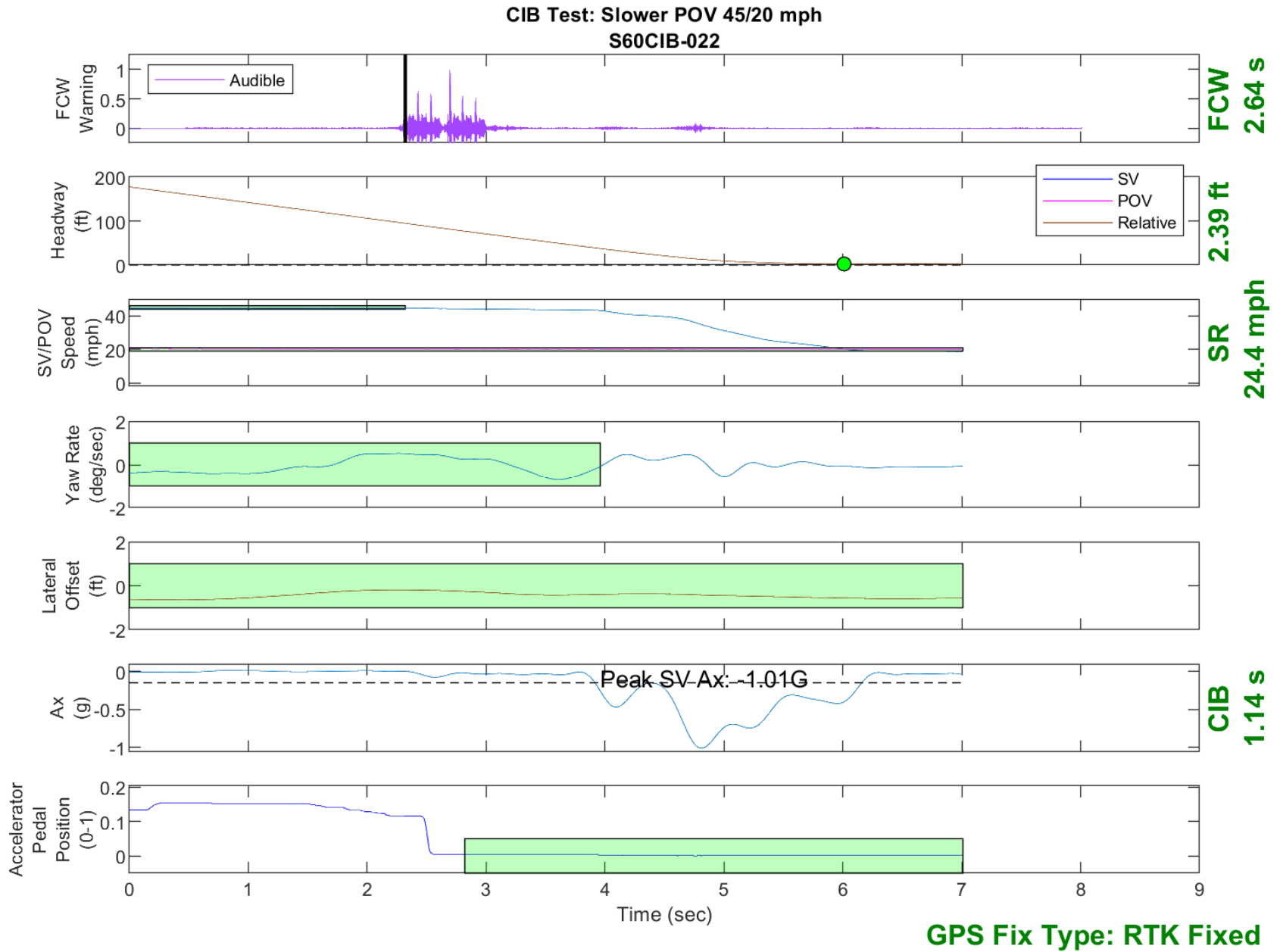


Figure D24. Time History for CIB Run 22, SV Encounters Slower POV, SV 45 mph, POV 20 mph

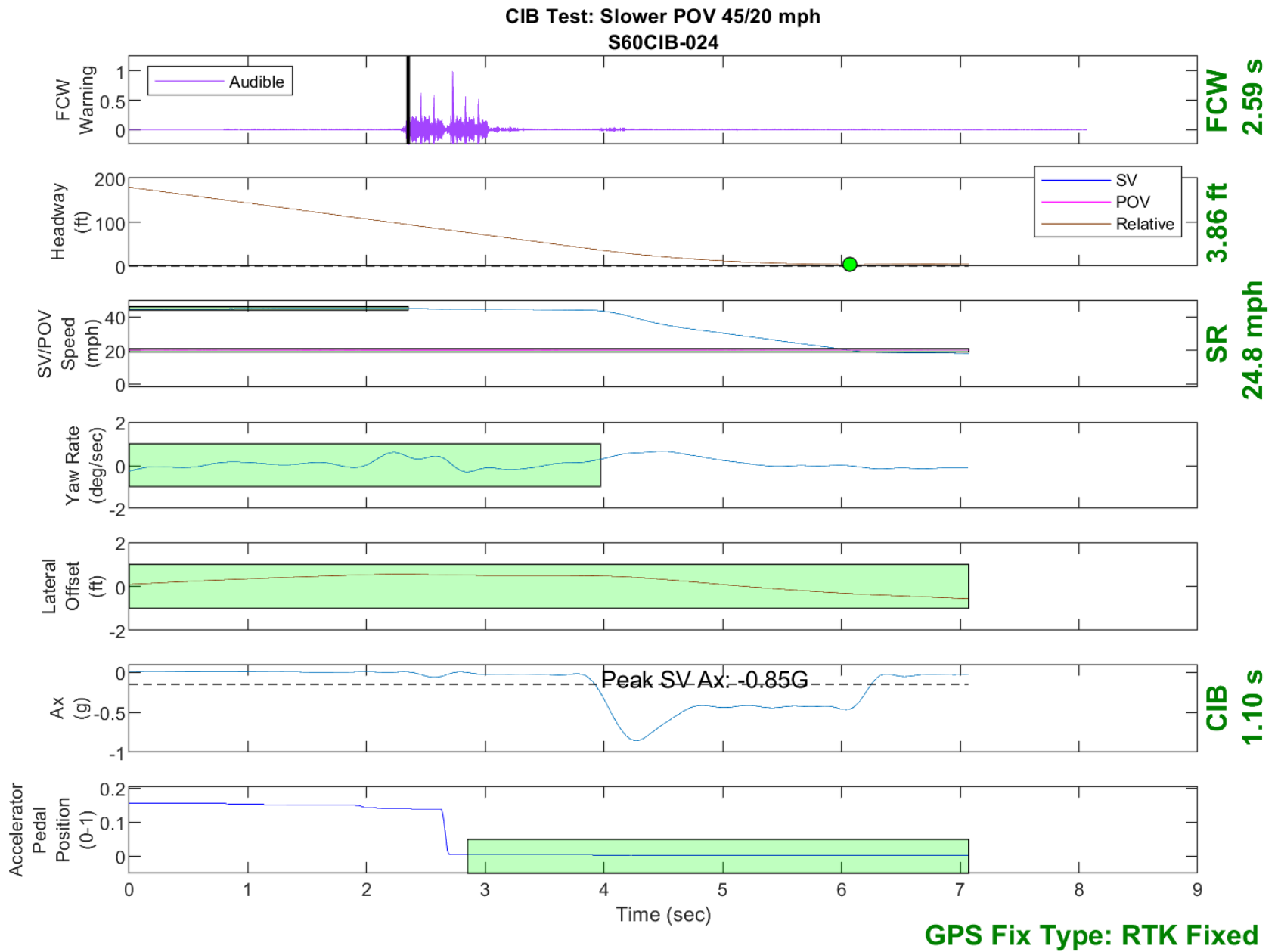


Figure D25. Time History for CIB Run 24, SV Encounters Slower POV, SV 45 mph, POV 20 mph

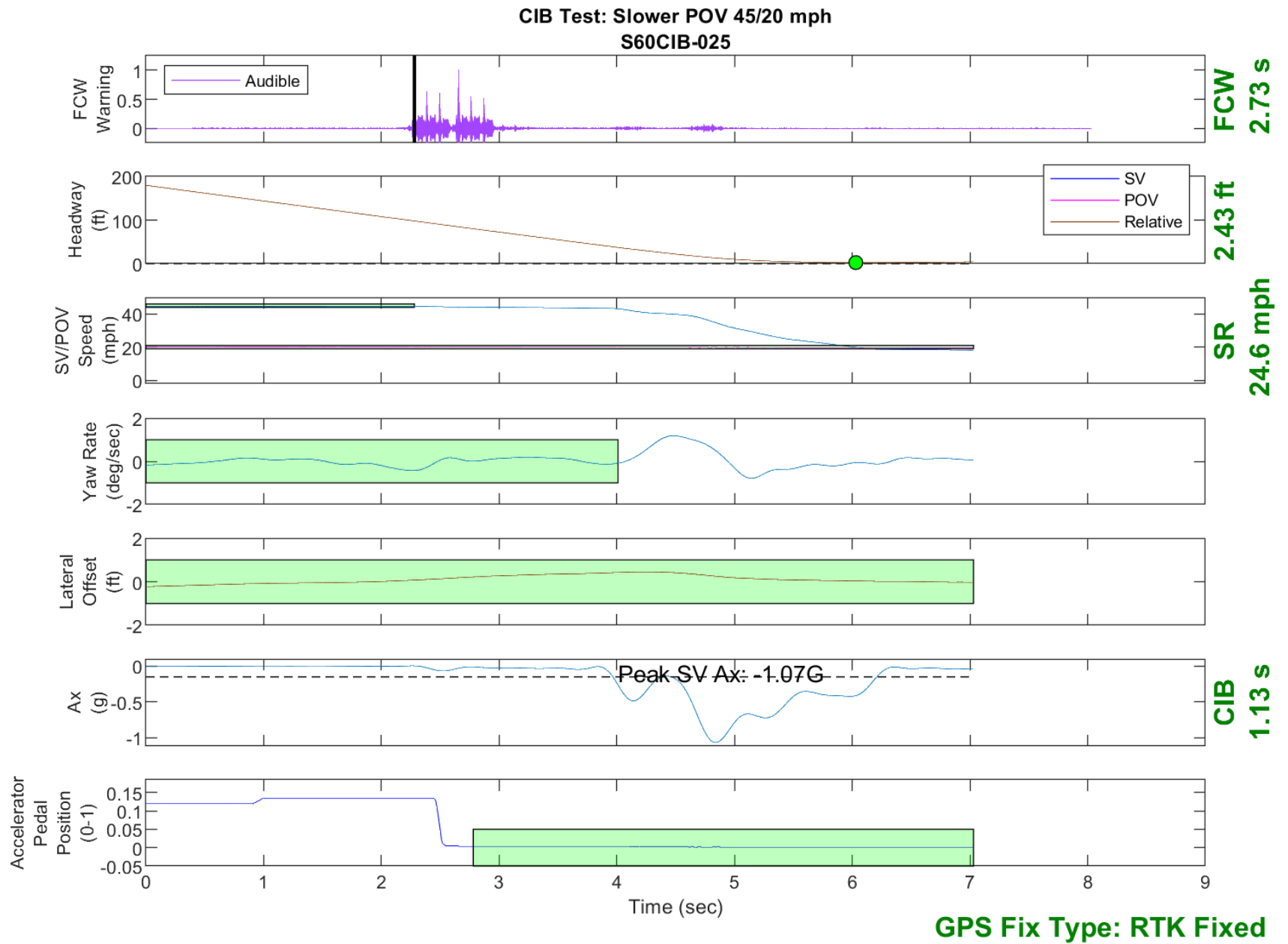


Figure D26. Time History for CIB Run 25, SV Encounters Slower POV, SV 45 mph, POV 20 mph

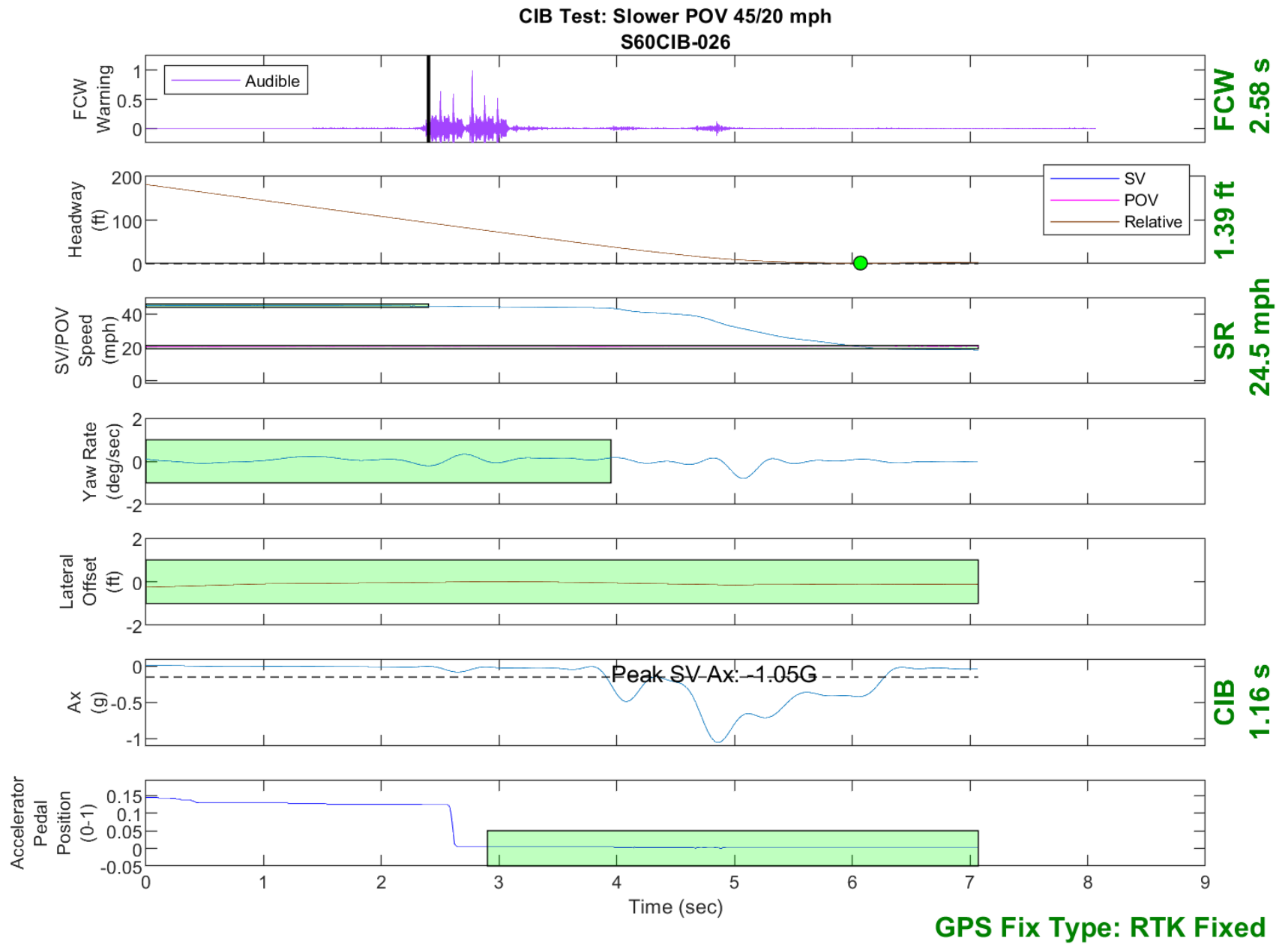


Figure D27. Time History for CIB Run 26, SV Encounters Slower POV, SV 45 mph, POV 20 mph

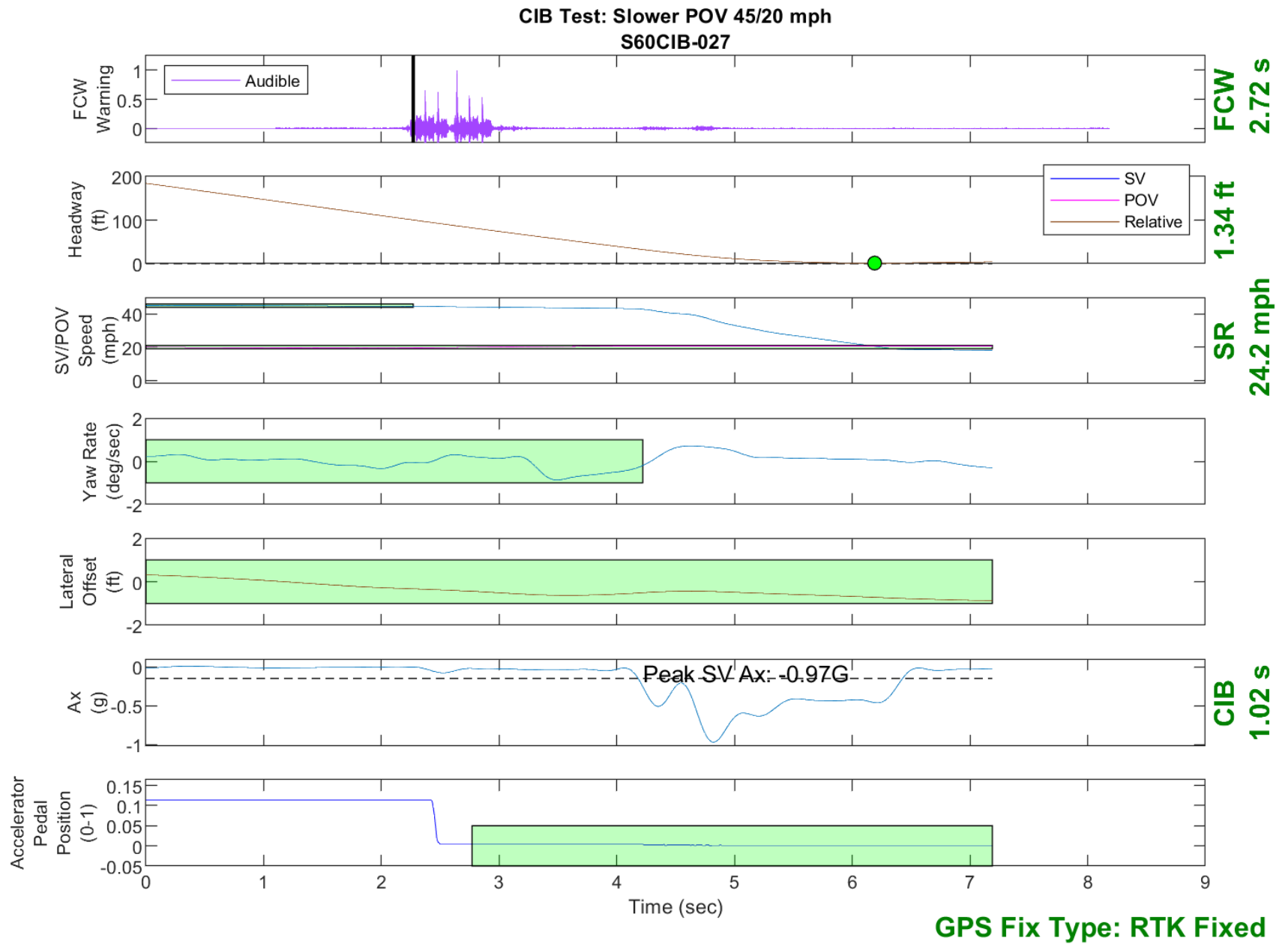


Figure D28. Time History for CIB Run 27, SV Encounters Slower POV, SV 45 mph, POV 20 mph

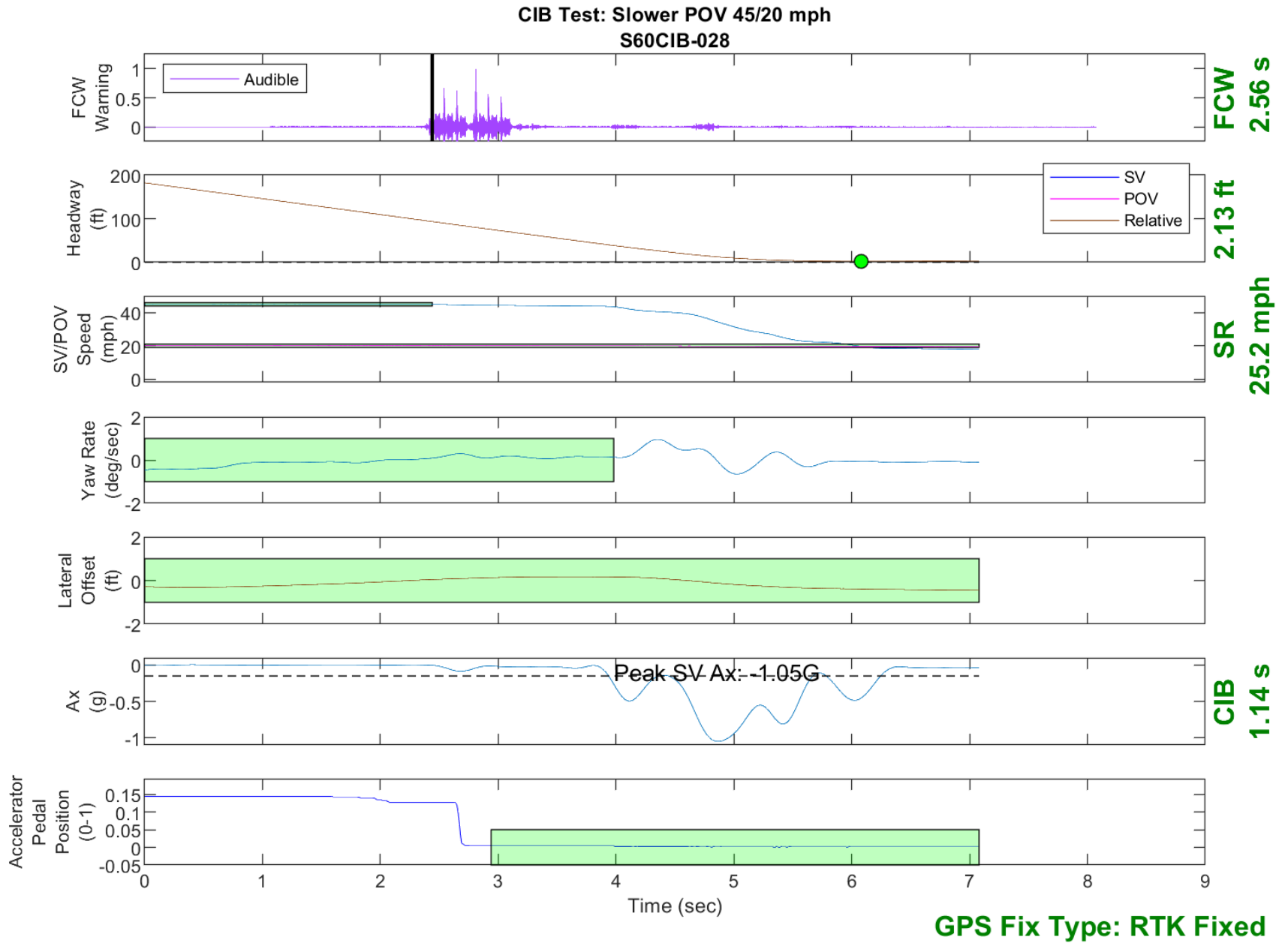


Figure D29. Time History for CIB Run 28, SV Encounters Slower POV, SV 45 mph, POV 20 mph

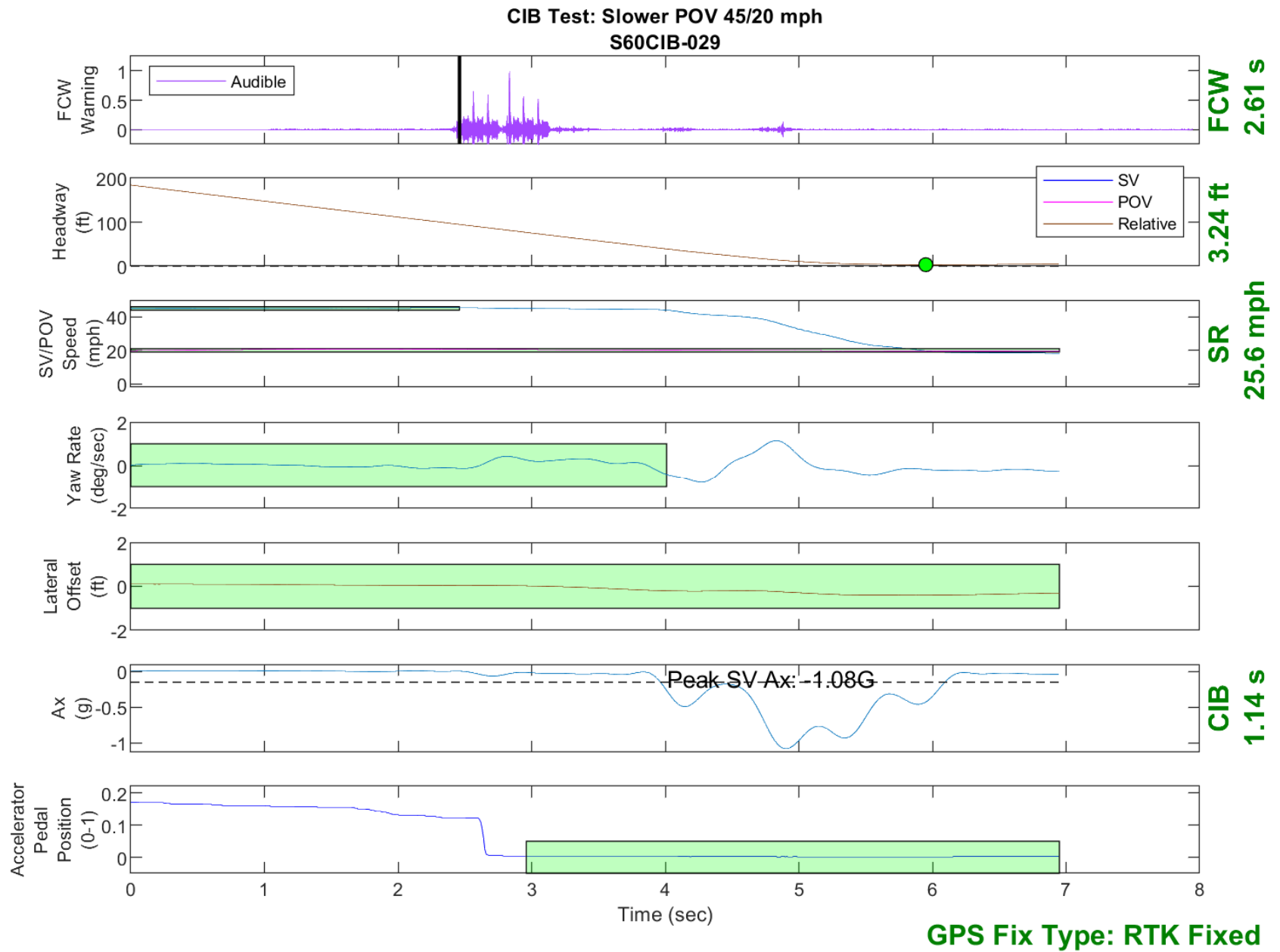


Figure D30. Time History for CIB Run 29, SV Encounters Slower POV, SV 45 mph, POV 20 mph

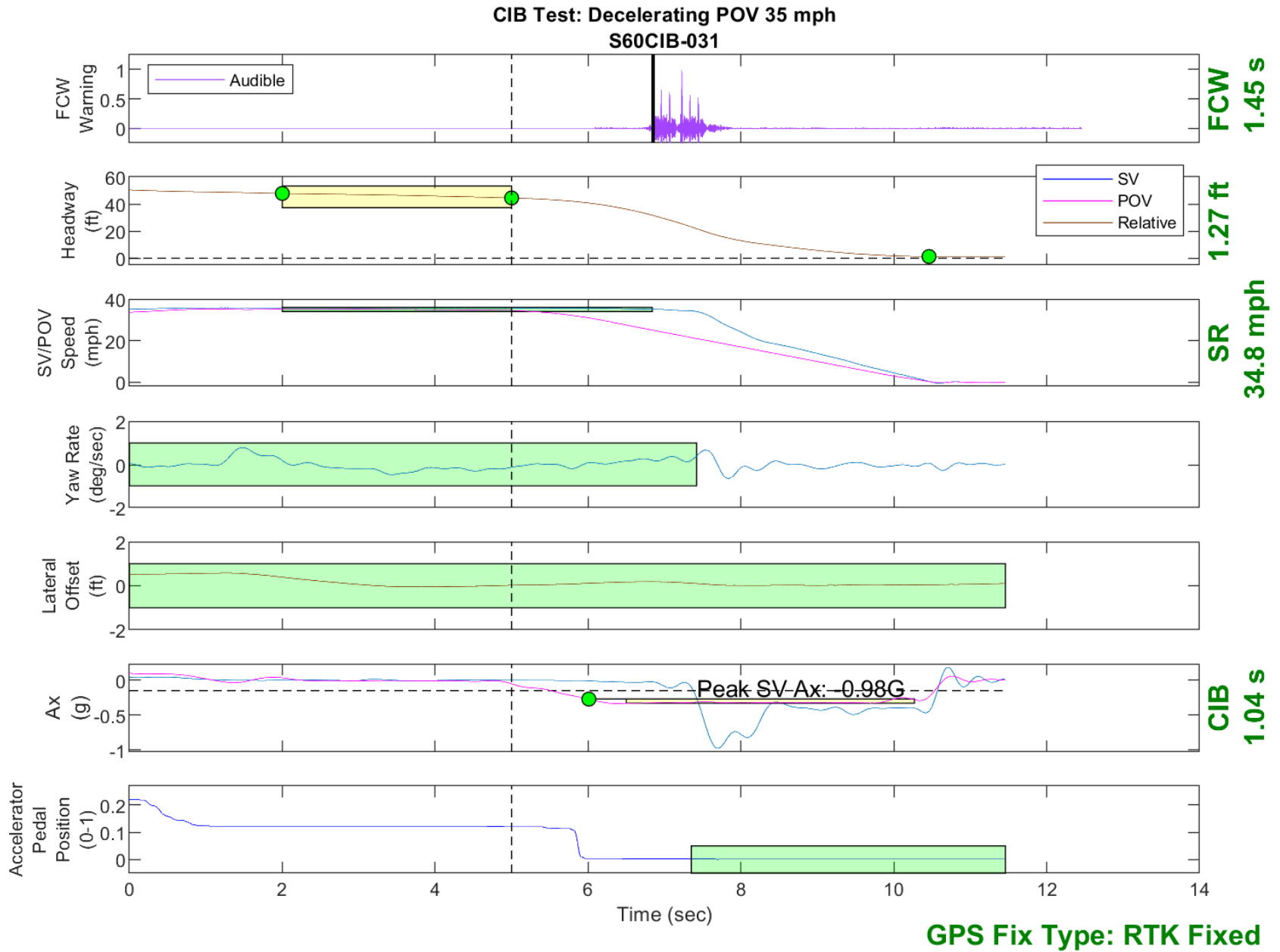


Figure D31. Time History for CIB Run 31, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

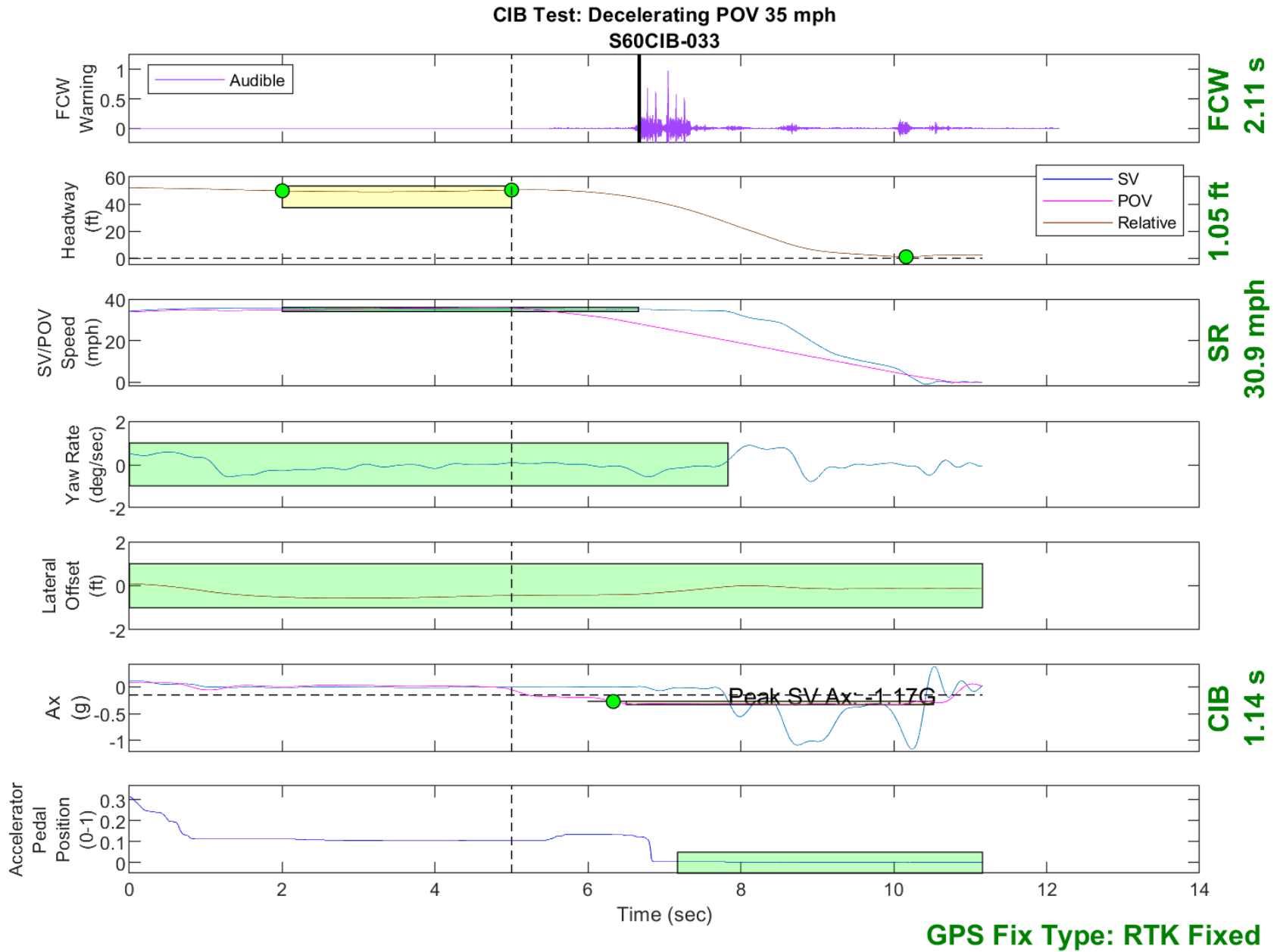


Figure D32. Time History for CIB Run 33, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

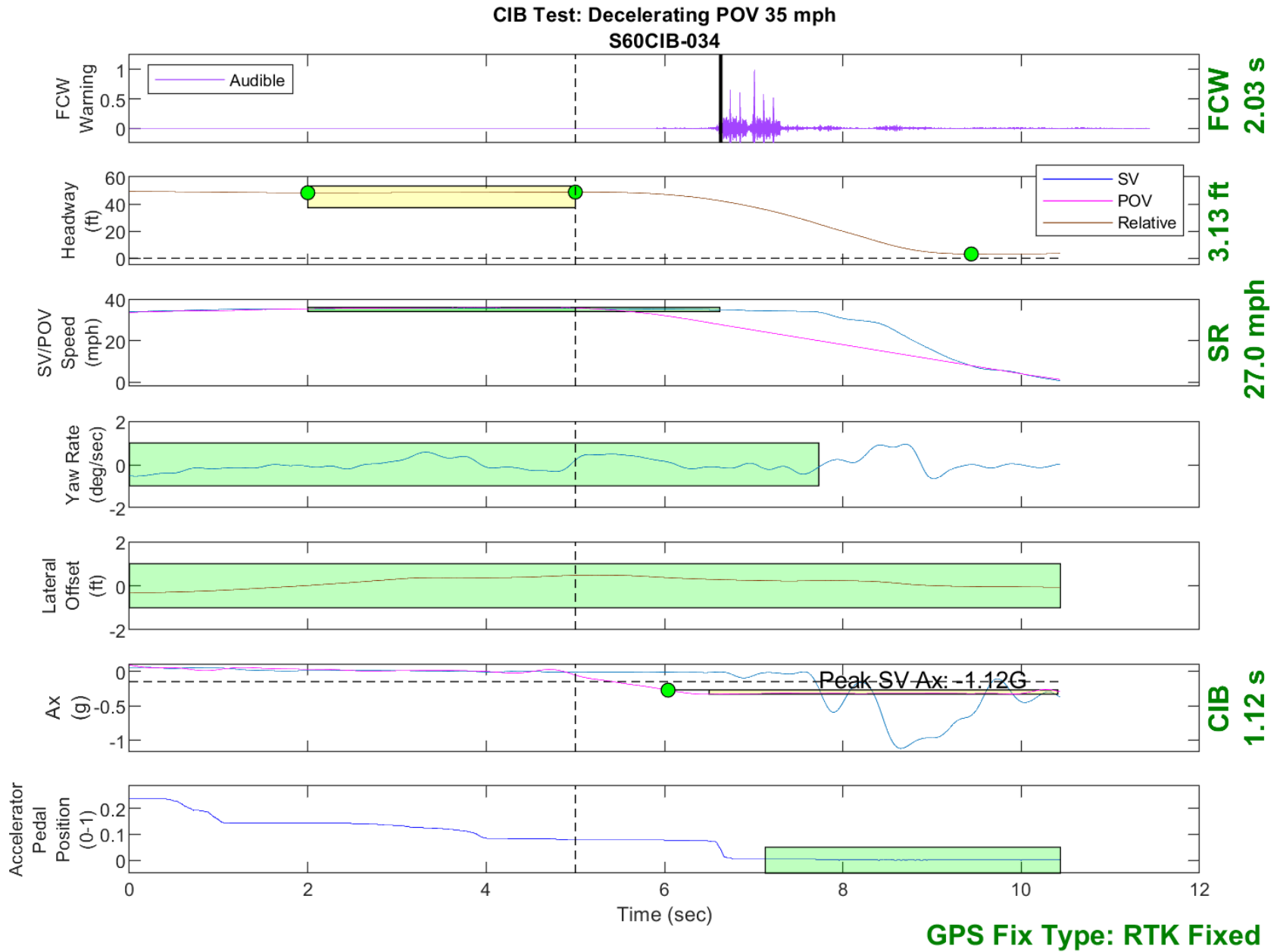


Figure D33. Time History for CIB Run 34, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

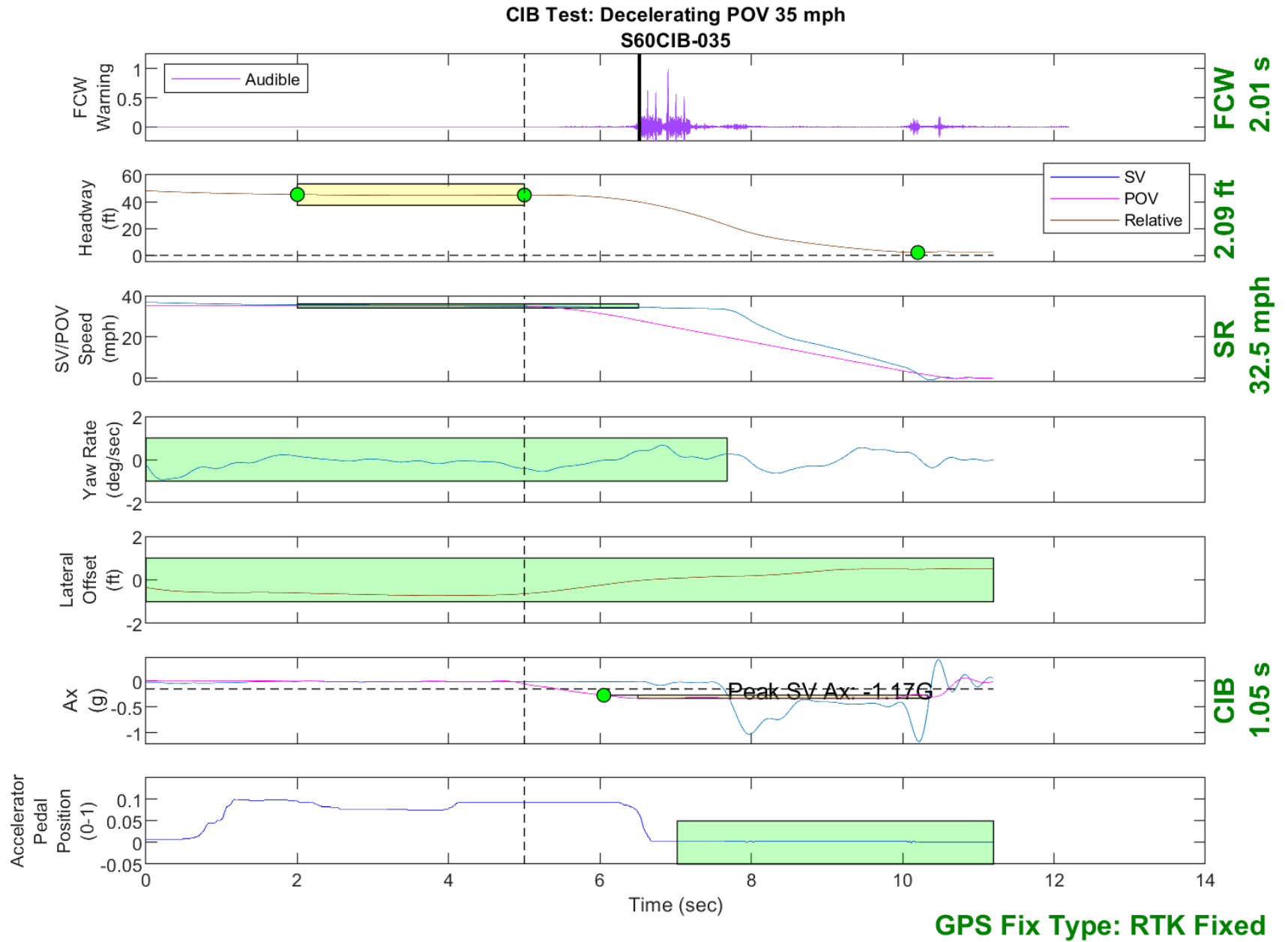


Figure D34. Time History for CIB Run 35, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

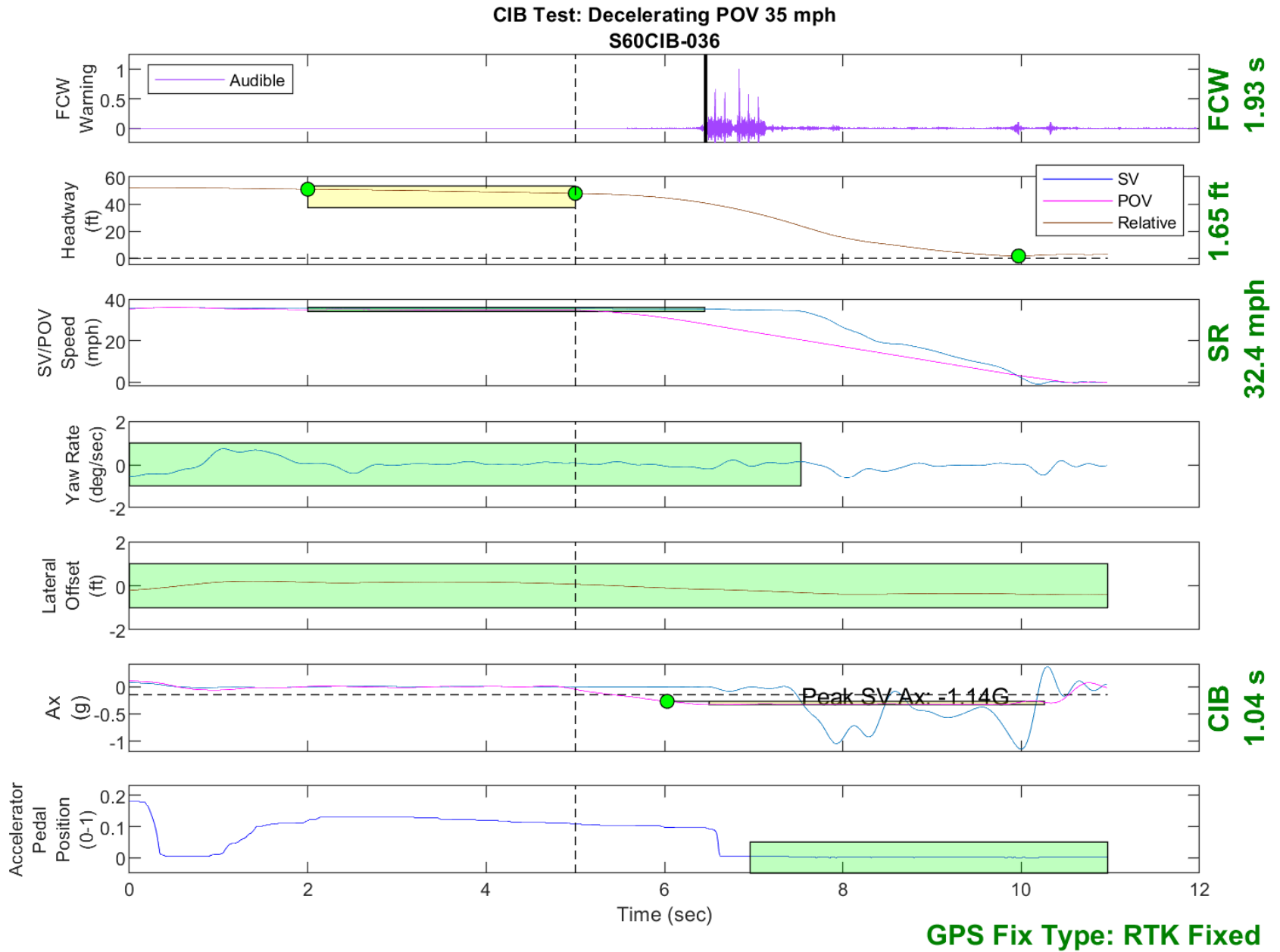


Figure D35. Time History for CIB Run 36, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

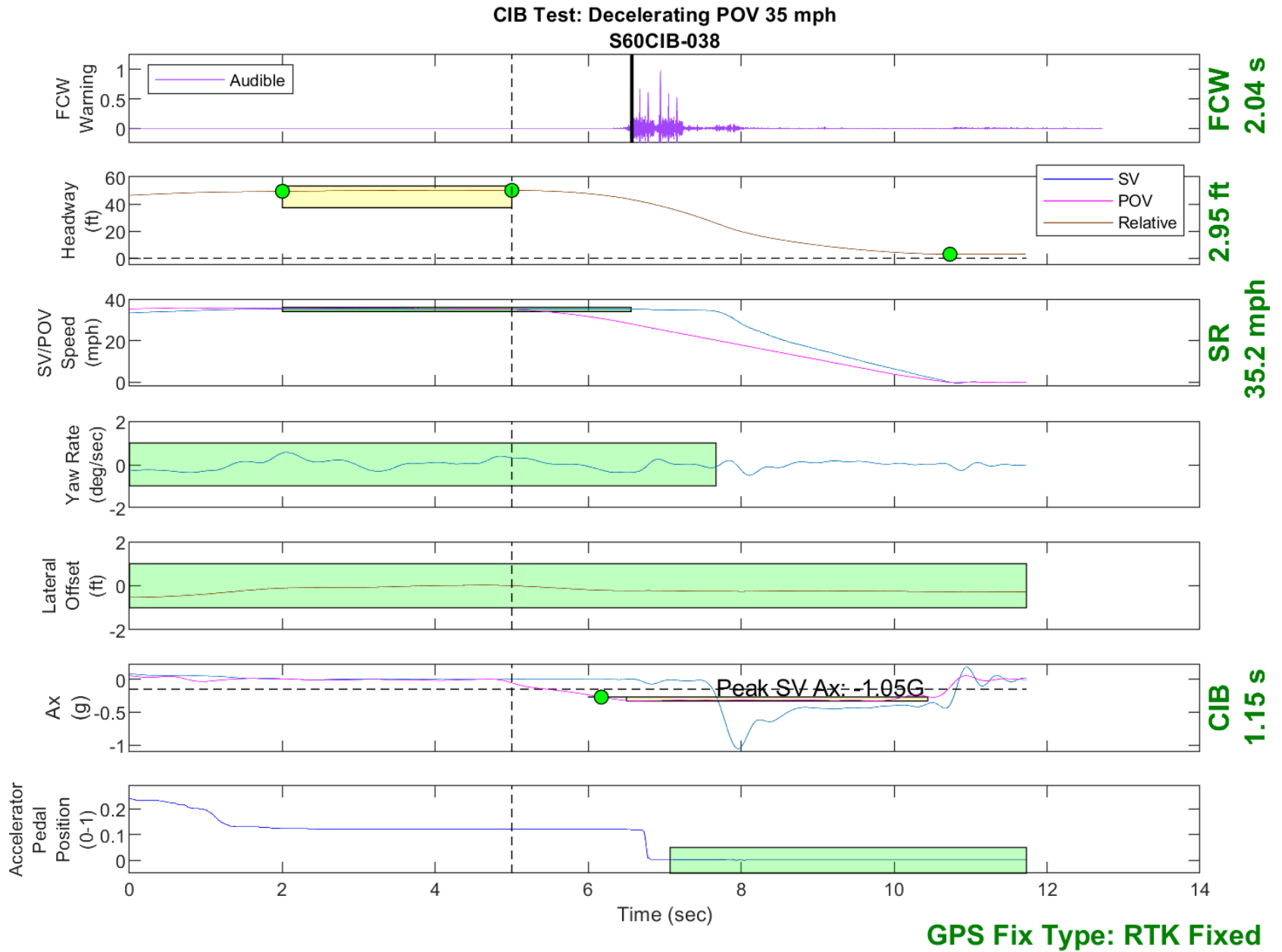


Figure D36. Time History for CIB Run 38, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

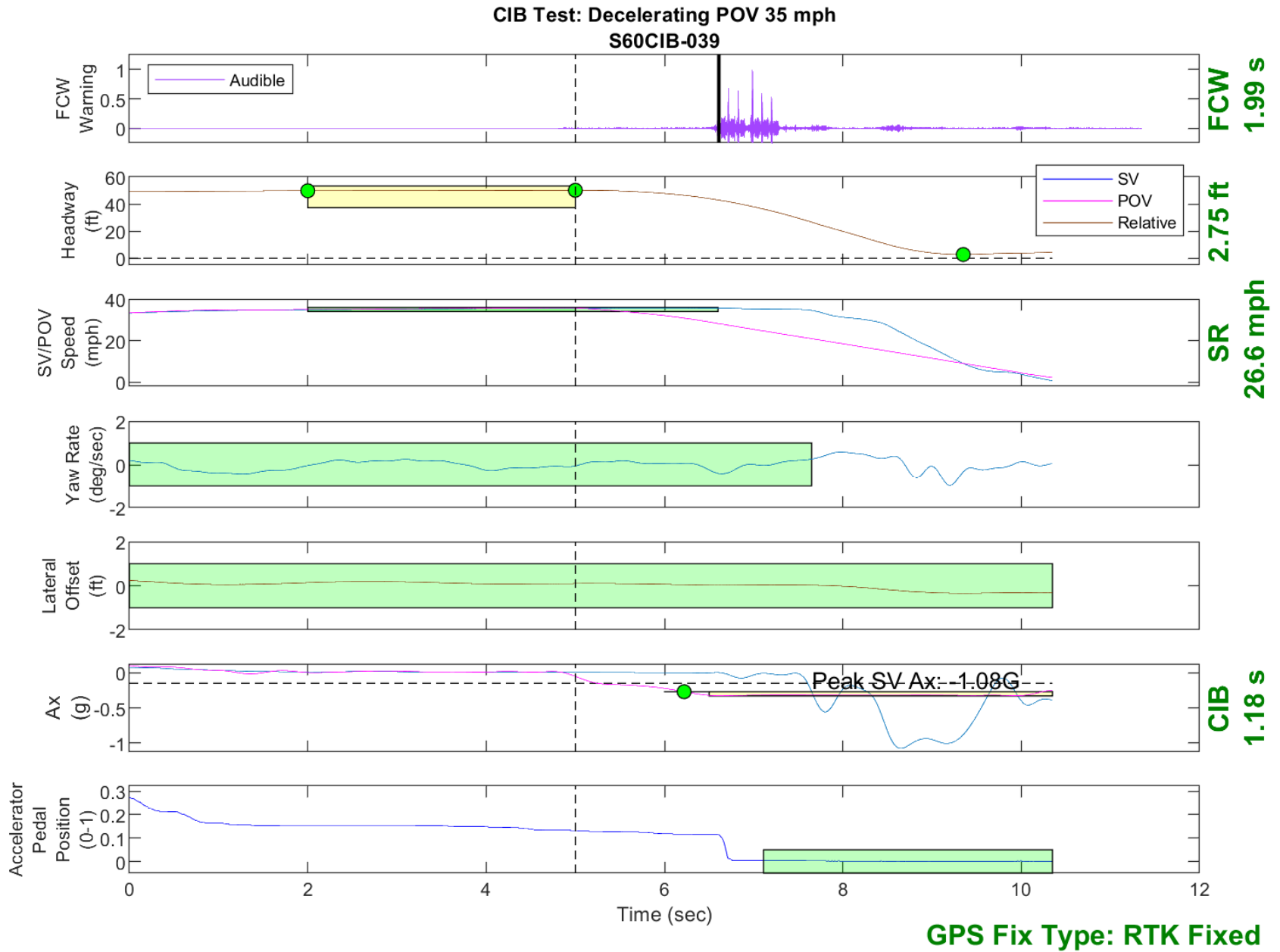


Figure D37. Time History for CIB Run 39, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

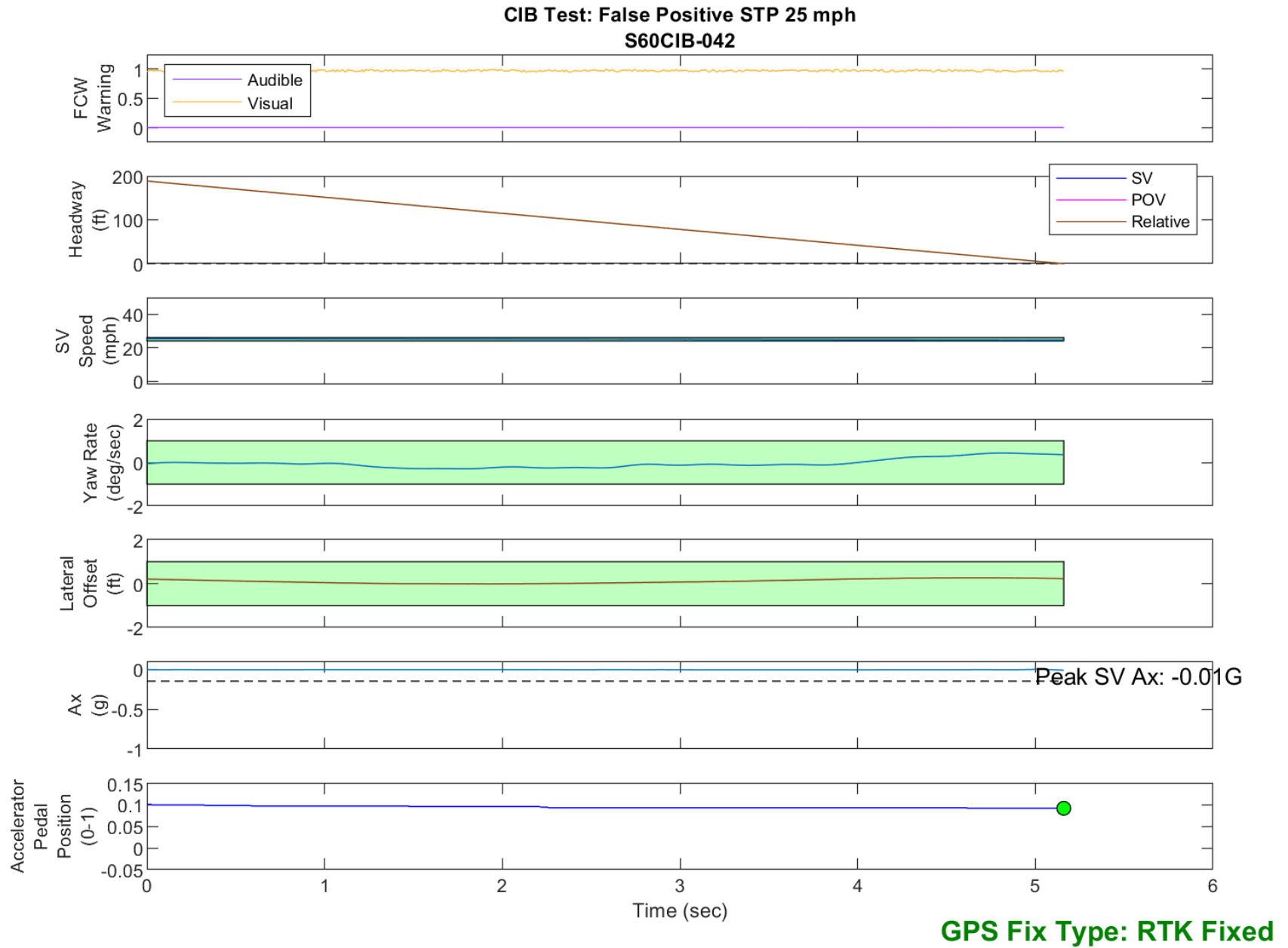


Figure D38. Time History for CIB Run 42, SV Encounters Steel Trench Plate, SV 25 mph

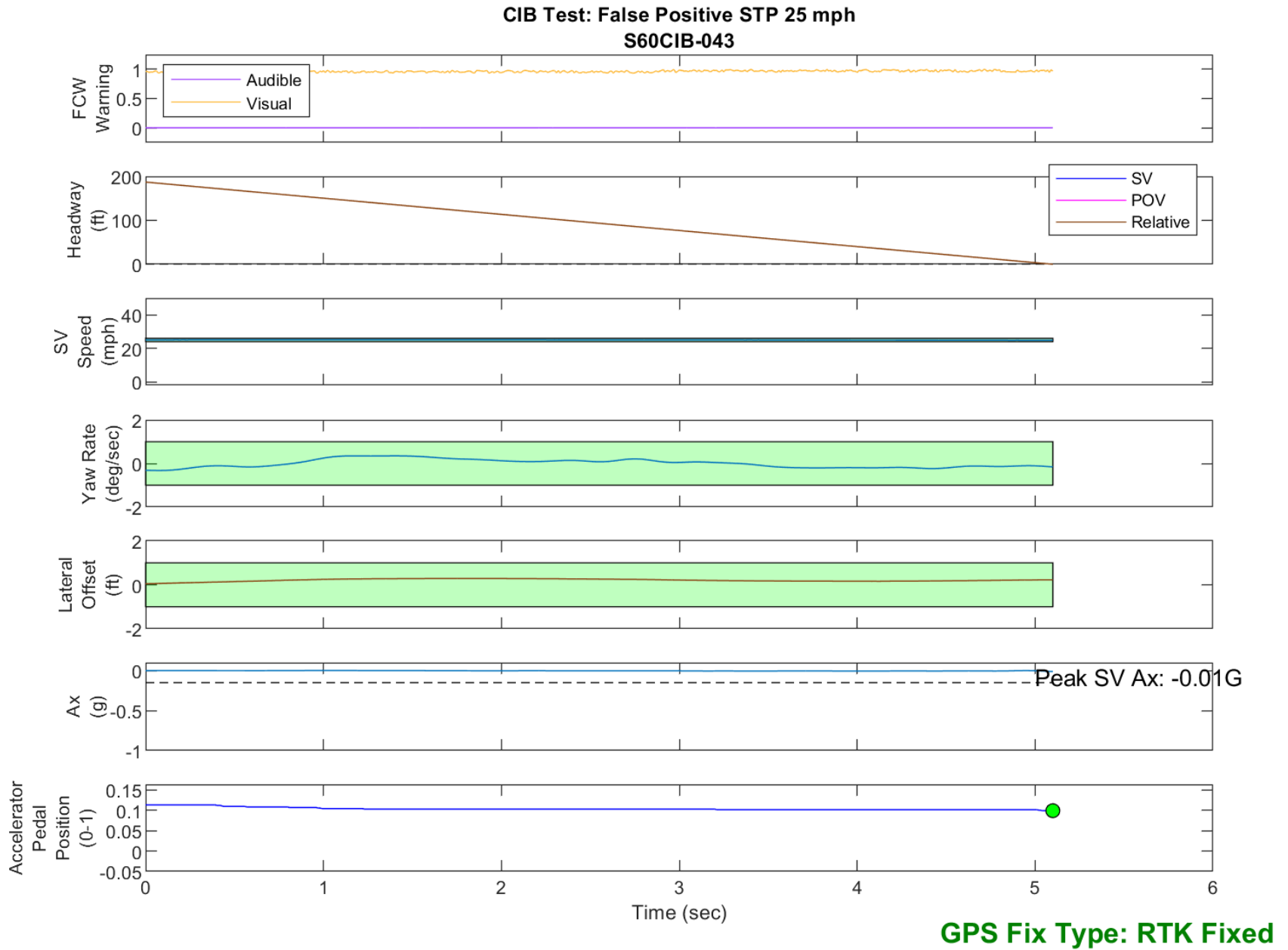


Figure D39. Time History for CIB Run 43, SV Encounters Steel Trench Plate, SV 25 mph

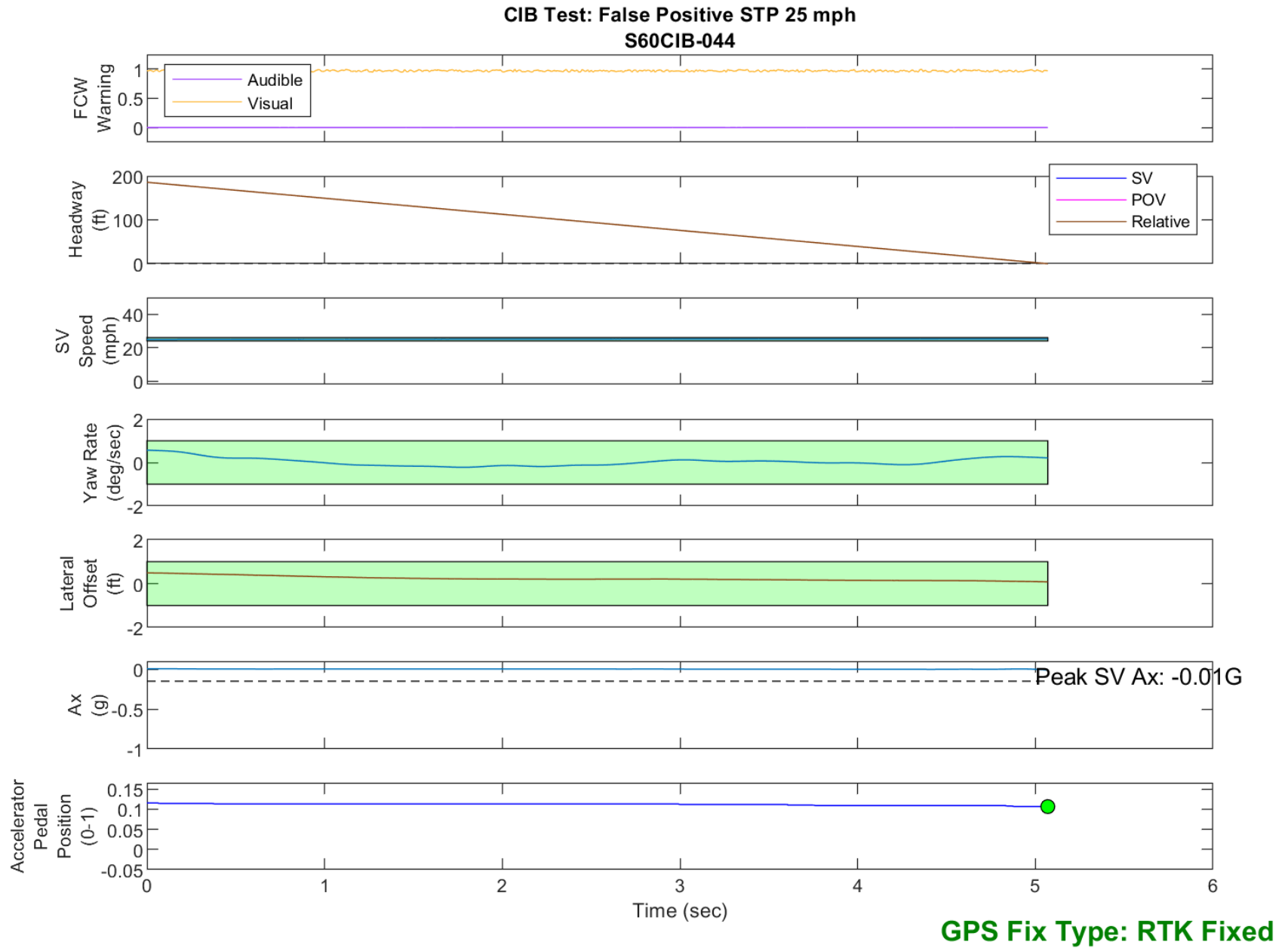


Figure D40. Time History for CIB Run 44, SV Encounters Steel Trench Plate, SV 25 mph

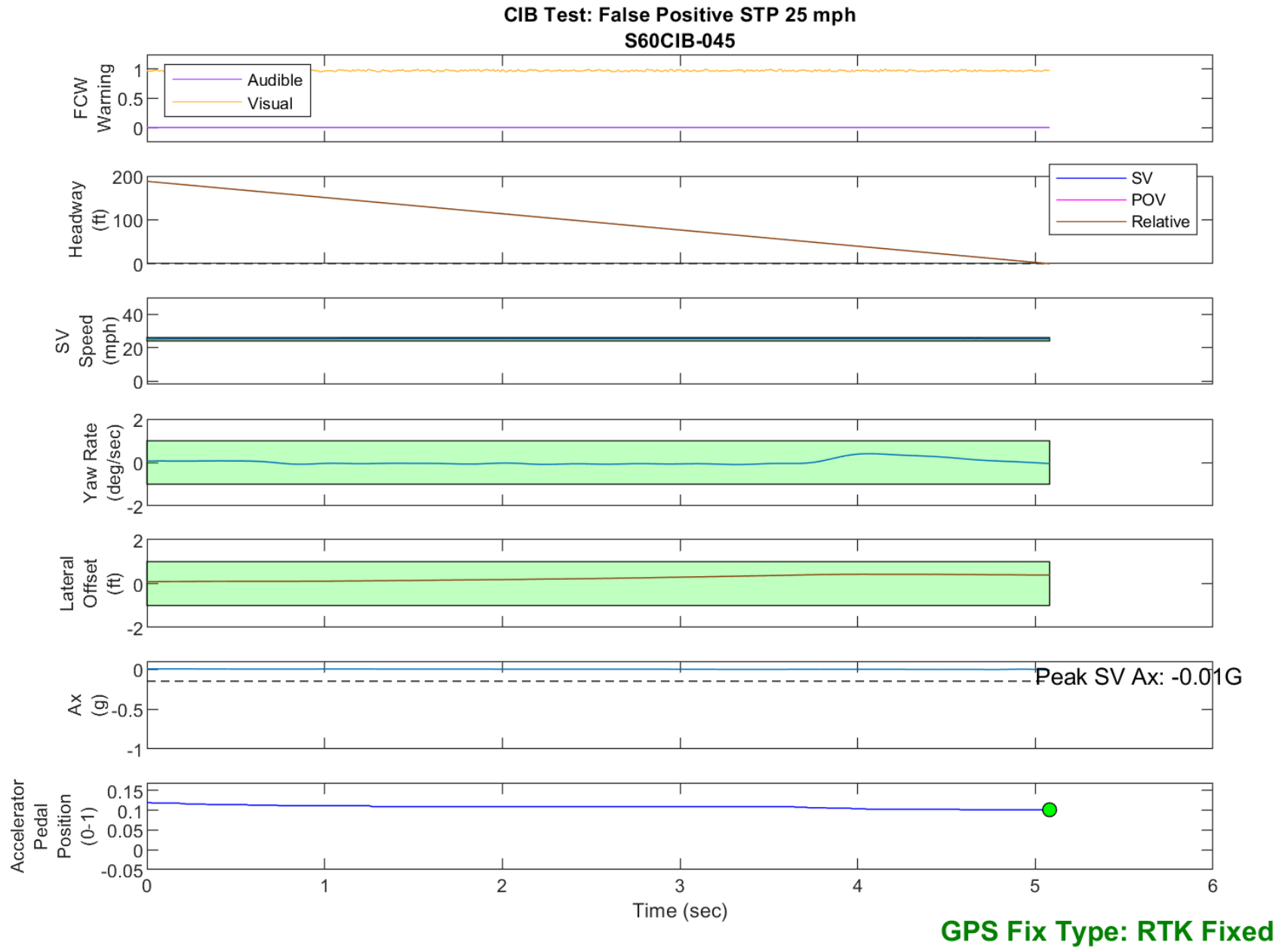


Figure D41. Time History for CIB Run 45, SV Encounters Steel Trench Plate, SV 25 mph

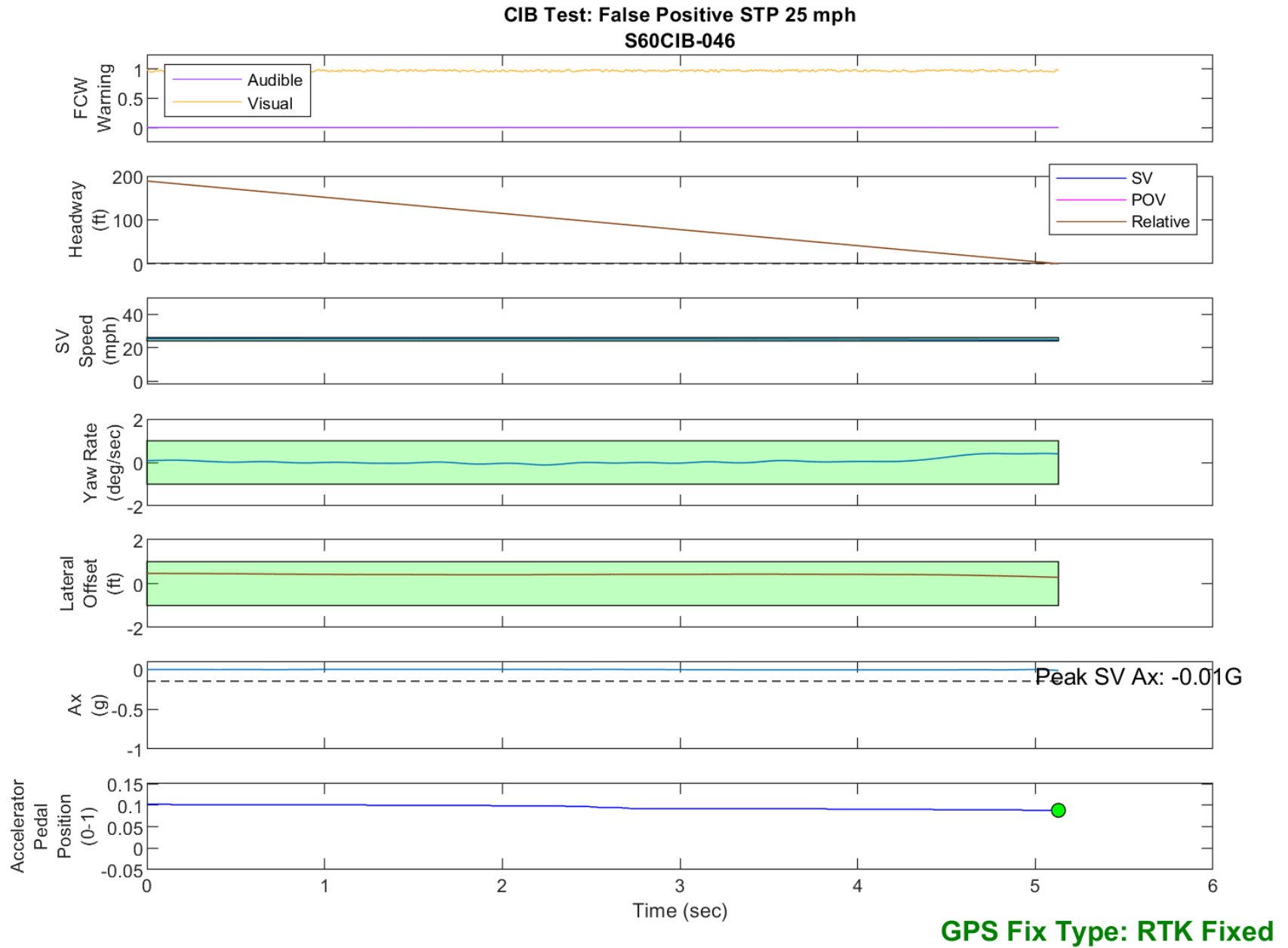


Figure D42. Time History for CIB Run 46, SV Encounters Steel Trench Plate, SV 25 mph

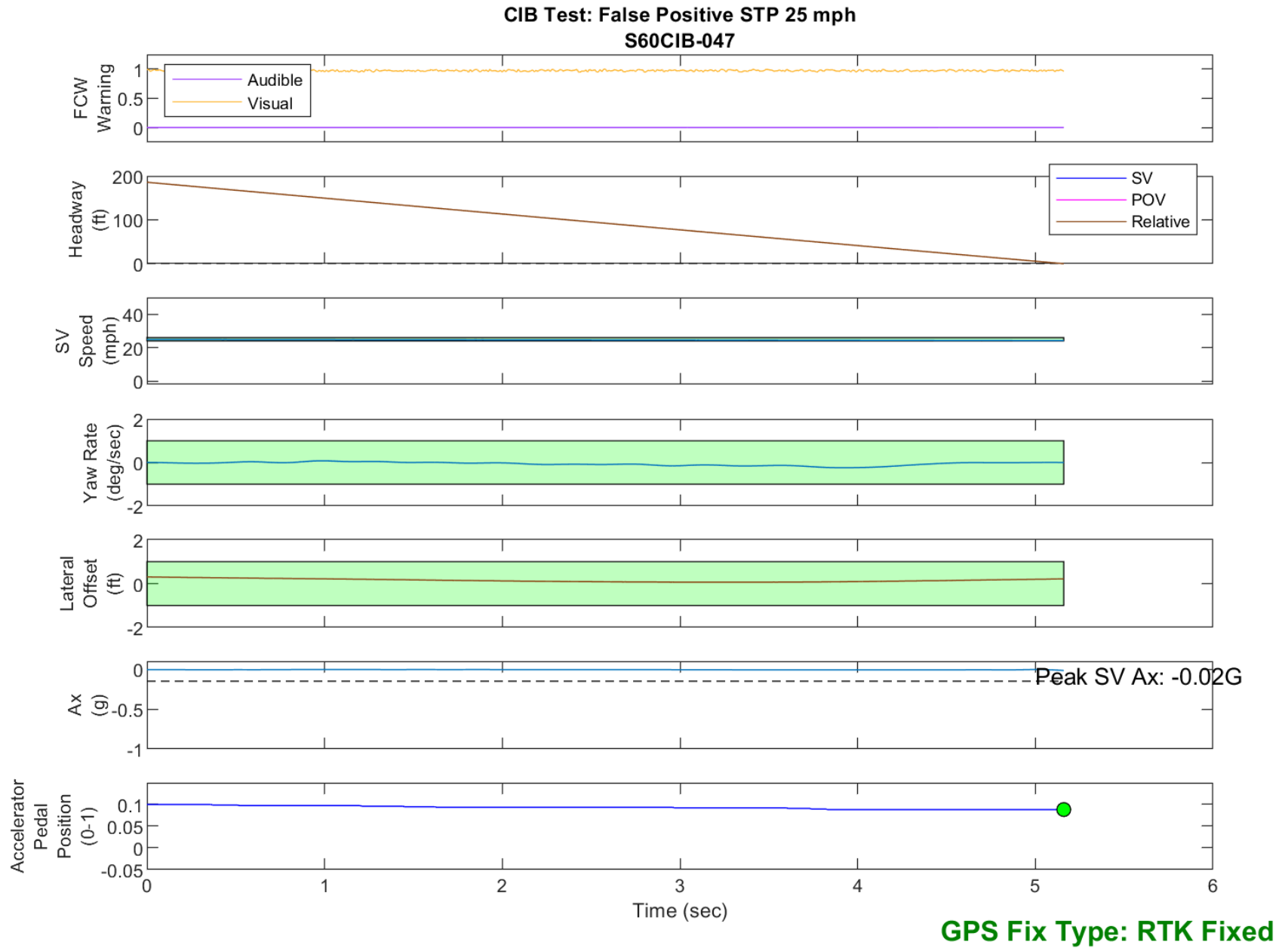


Figure D43. Time History for CIB Run 47, SV Encounters Steel Trench Plate, SV 25 mph

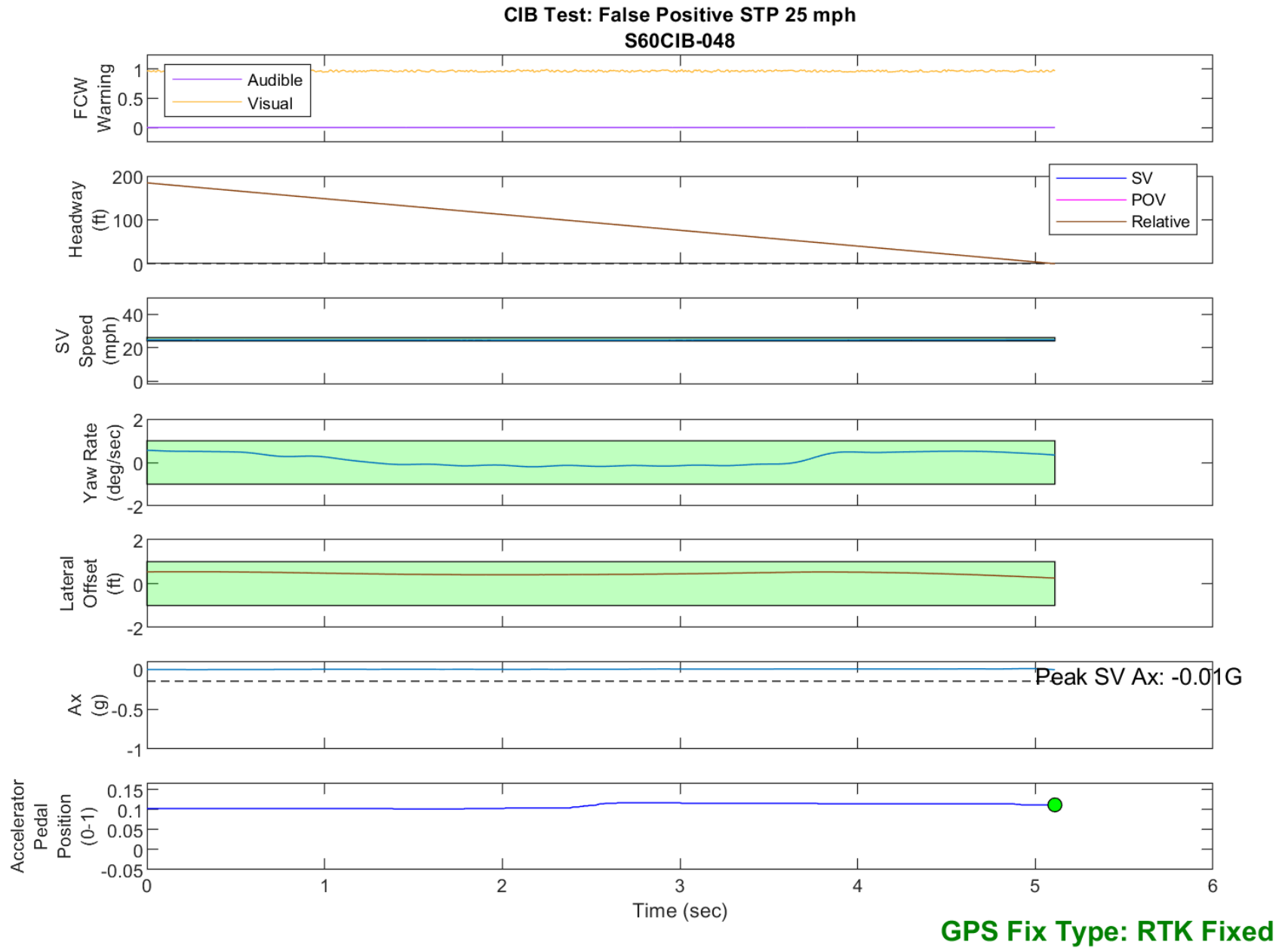


Figure D44. Time History for CIB Run 48, SV Encounters Steel Trench Plate, SV 25 mph

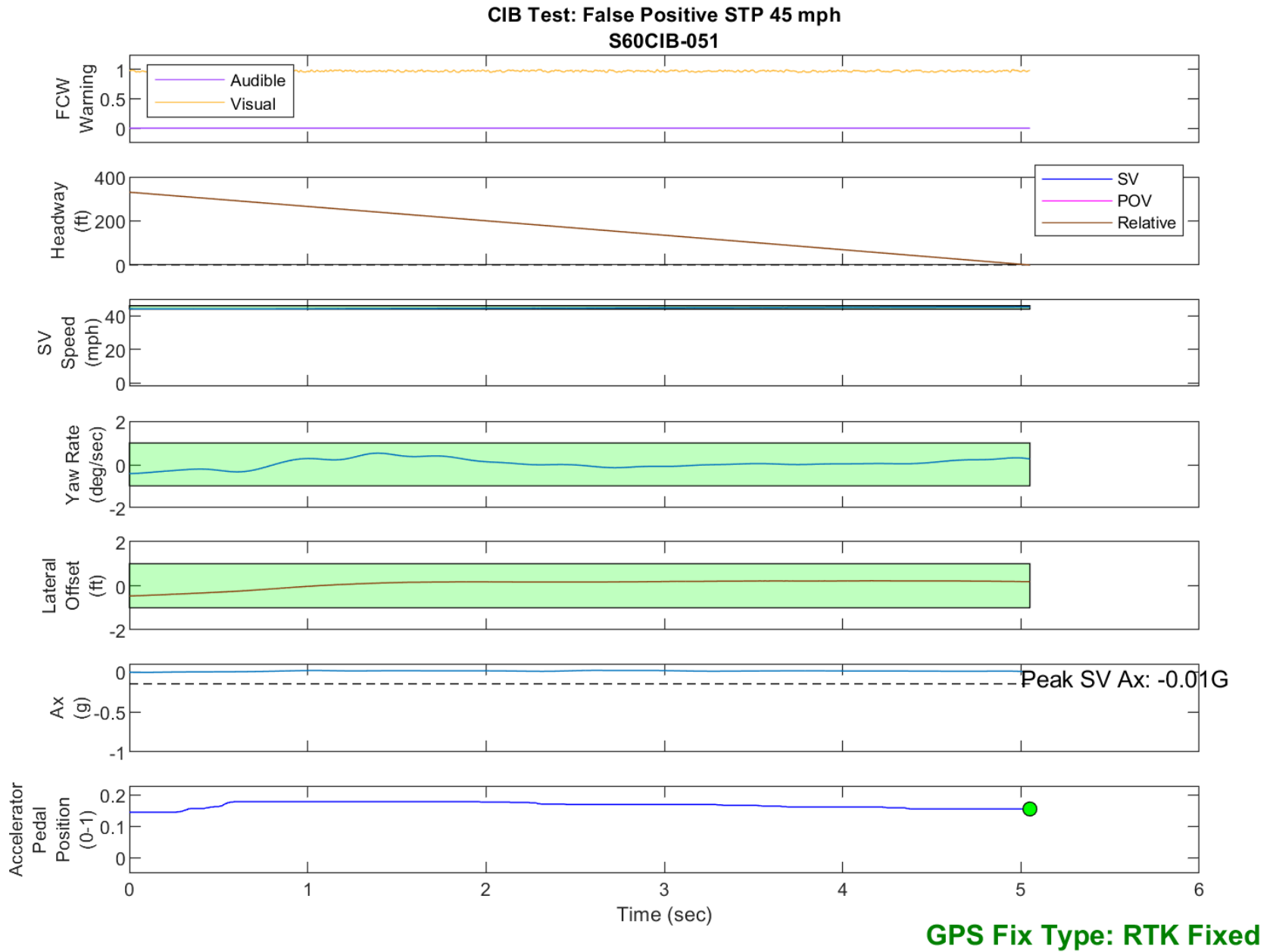


Figure D45. Time History for CIB Run 51, SV Encounters Steel Trench Plate, SV 45 mph

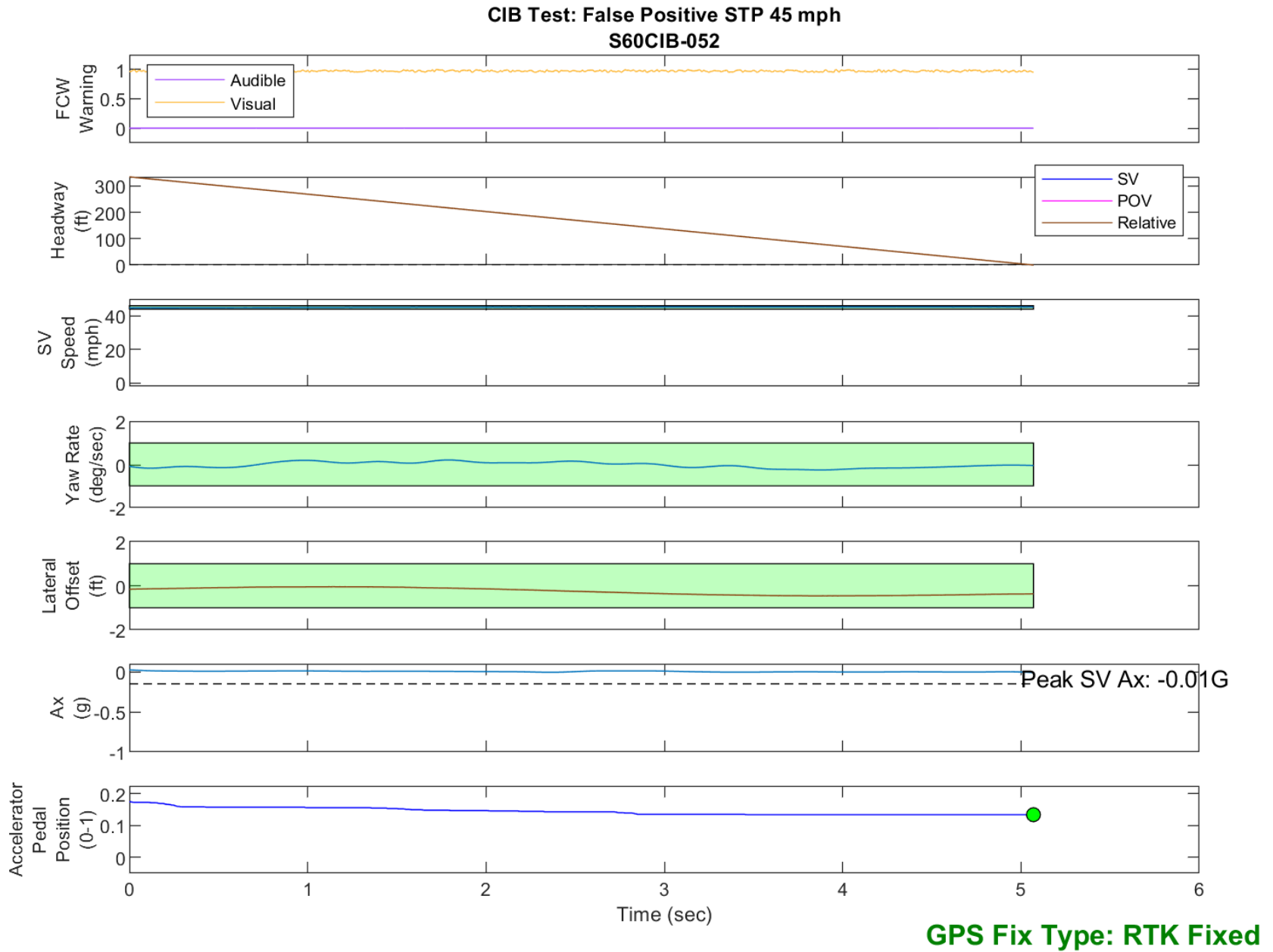


Figure D46. Time History for CIB Run 52, SV Encounters Steel Trench Plate, SV 45 mph

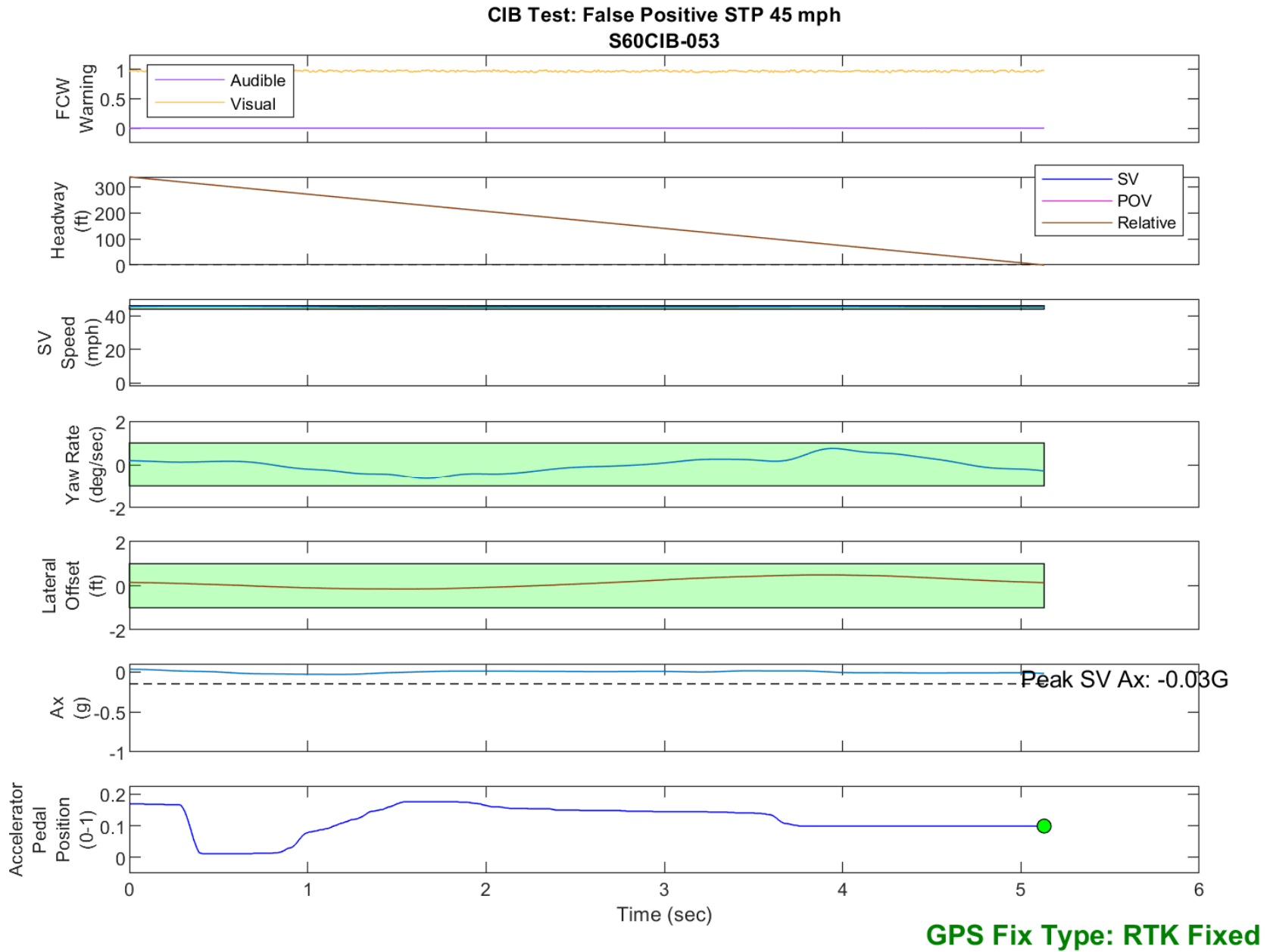


Figure D47. Time History for CIB Run 53, SV Encounters Steel Trench Plate, SV 45 mph

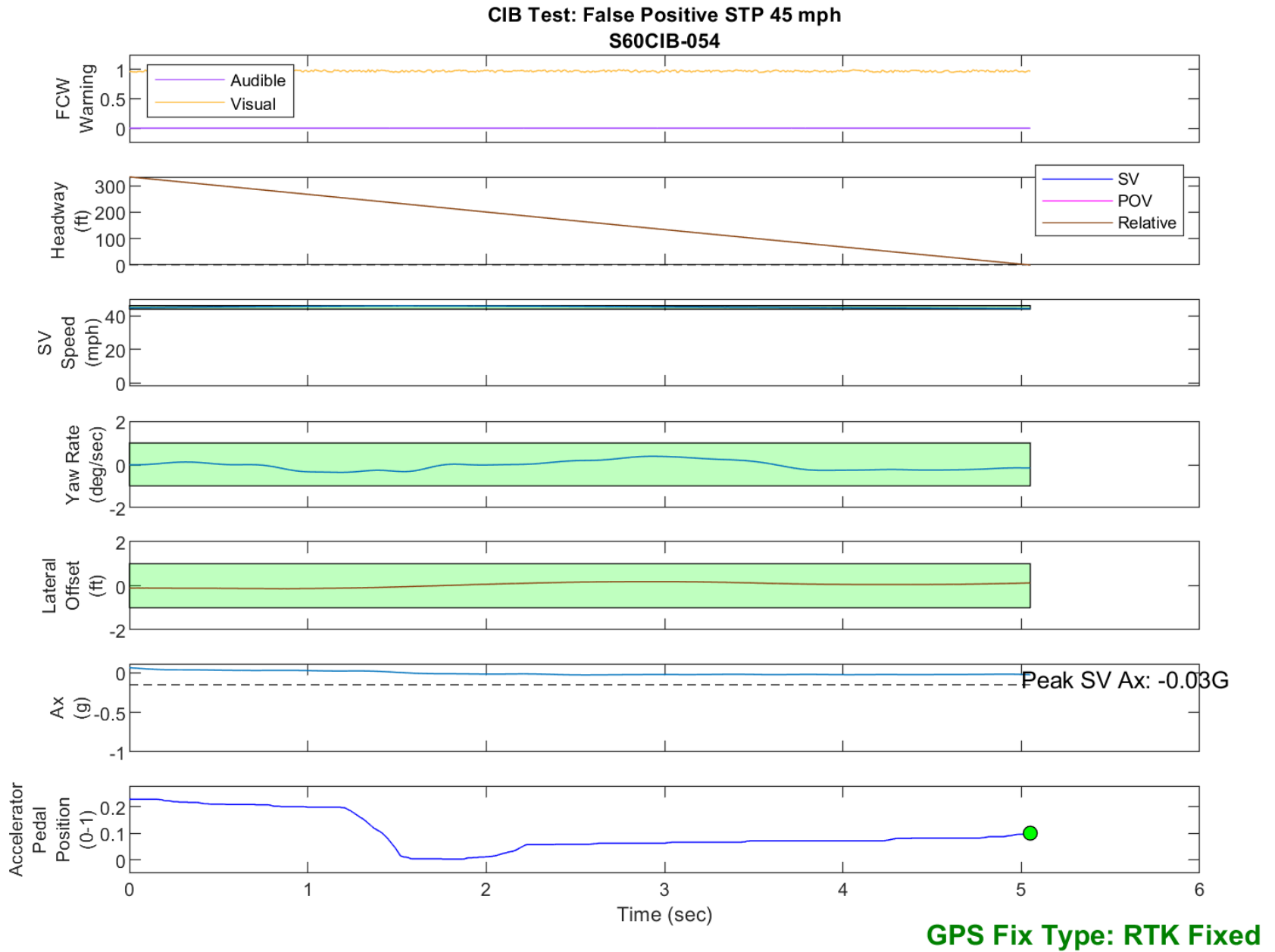


Figure D48. Time History for CIB Run 54, SV Encounters Steel Trench Plate, SV 45 mph

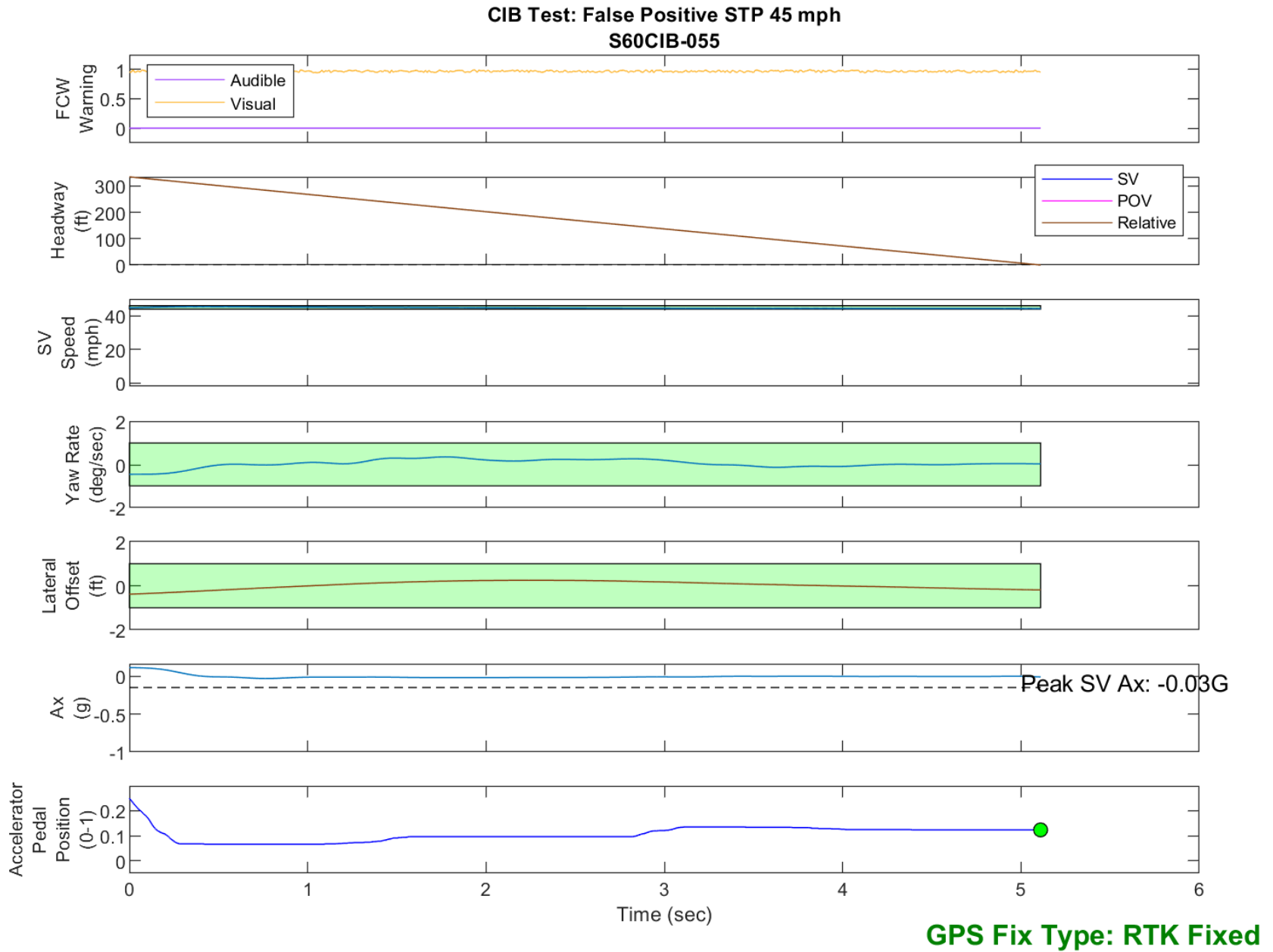


Figure D49. Time History for CIB Run 55, SV Encounters Steel Trench Plate, SV 45 mph

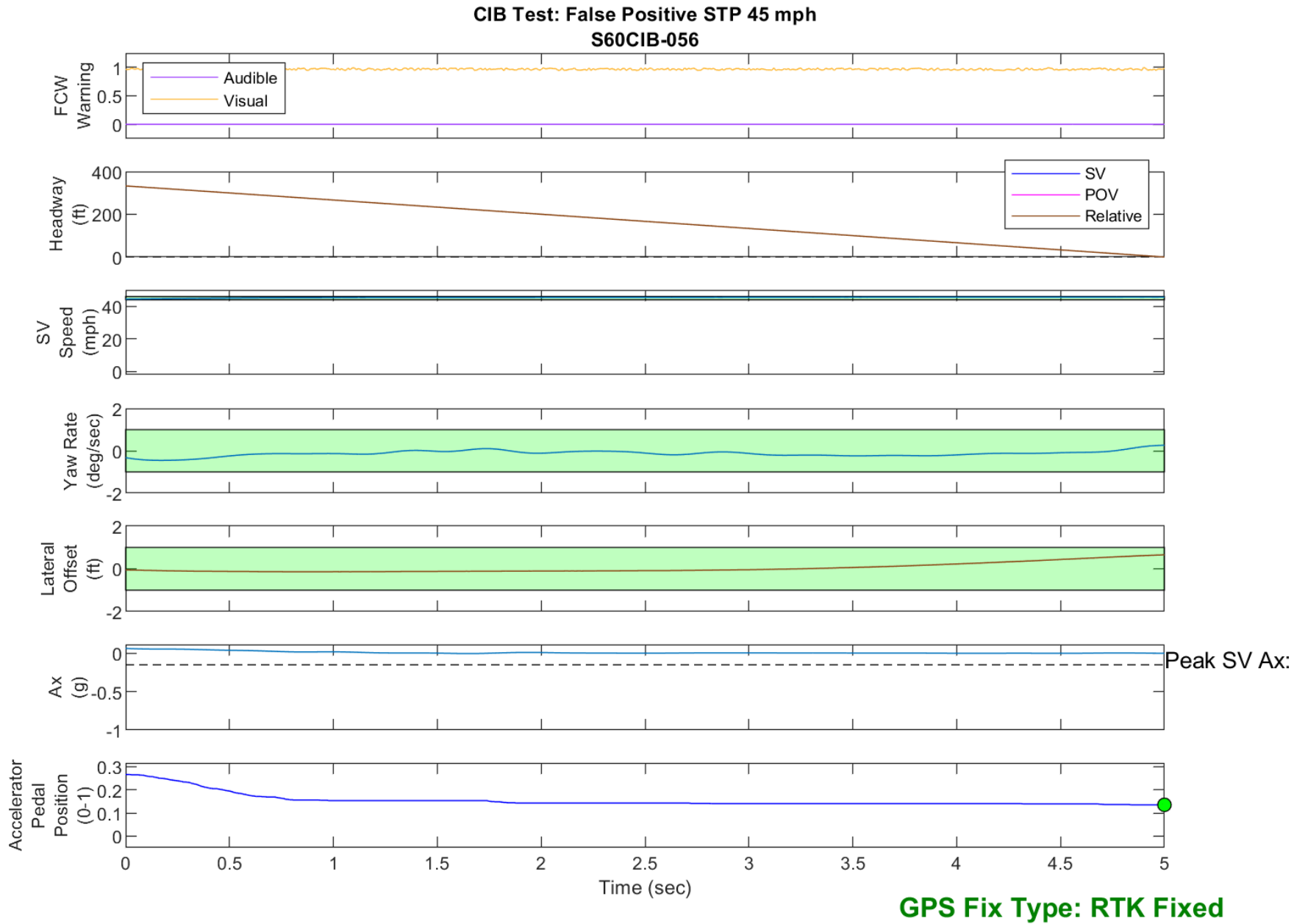


Figure D50. Time History for CIB Run 56, SV Encounters Steel Trench Plate, SV 45 mph

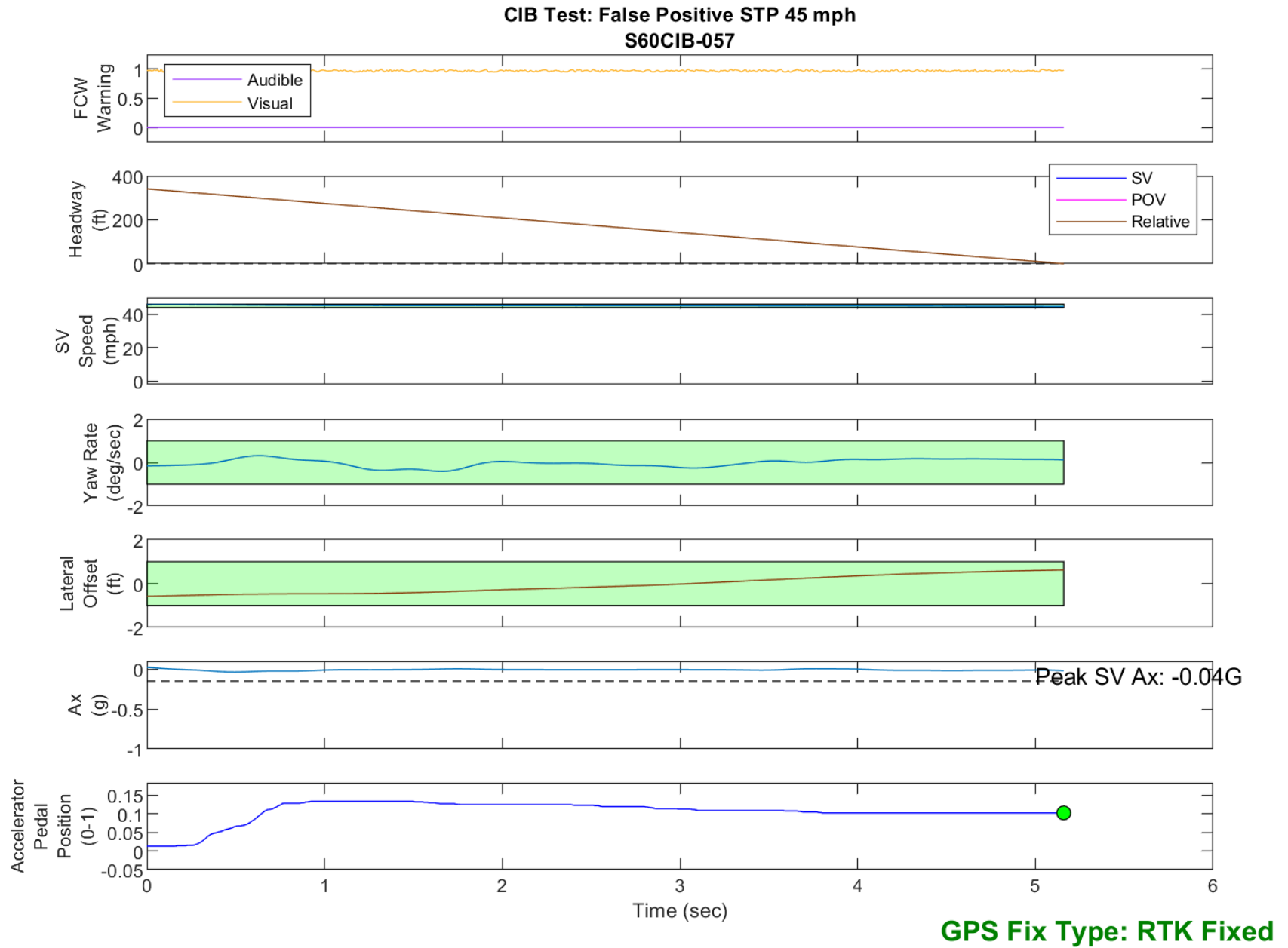


Figure D51. Time History for CIB Run 57, SV Encounters Steel Trench Plate, SV 45 mph