NEW CAR ASSESSMENT PROGRAM
CRASH IMMINENT BRAKING SYSTEM CONFIRMATION TEST
NCAP-DRI-CIB-20-11

2020 Mazda Mazda6 Sport

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Final Report

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

U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
New Car Assessment Program
1200 New Jersey Avenue, SE
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16. Abstract These tests were conducted on the subject 2020 Mazda Mazda6 Sport 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 track[1] 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 Mazda Mazda6 Sport. 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 Mazda Mazda6 Sport

SUMMARY RESULTS

VIN: *JM1GL1UM1L151xxxx*

Test Date: *4/14/2020*

Crash Imminent Braking System setting: *Far*

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 Mazda Mazda6 Sport

TEST VEHICLE INFORMATION

VIN: *JM1GL1UM1L151xxxx*

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

Date Received: *4/6/2020* Odometer Reading: *5 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *MAZDA MOTOR CORPORATION*

Date of manufacture: *10/19*

Vehicle Type: *Passenger Car*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *P225/55 R17*

Rear: *P225/55 R17*

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

Rear: *250 kPa (36 psi)*

TIRES

Tire manufacturer and model: *Yokohama Advan A83*

Front tire designation: *P225/55 R17 95V*

Rear tire designation: *P225/55 R17 95V*

Front tire DOT prefix: *FDUPV24*

Rear tire DOT prefix: *FDUPV24*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

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2020 Mazda Mazda6 Sport

GENERAL INFORMATION

Test date: *4/14/2020*

AMBIENT CONDITIONS

Air temperature: *23.3 C (74 F)*

Wind speed: *2.1 m/s (4.6 mph)*

X Windspeed ≤ 10 m/s (22 mph)

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

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

VEHICLE PREPARATION

Verify the following:

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

Fuel tank is full: **X**

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

Front: *250 kPa (36 psi)*

Rear: *250 kPa (36 psi)*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2020 Mazda Mazda6 Sport

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*490.3 kg (1081 lb)*	Right Front:	*470.4 kg (1037 lb)*
Left Rear:	*350.6 kg (773 lb)*	Right Rear:	*332.9 kg (734 lb)*
		Total:	*1644.2 kg (3625 lb)*

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

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2020 Mazda Mazda6 Sport

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

Smart Brake Support (SBS)

Type and location of sensors the system uses:

Radar and mono camera.

The Forward Sensing Camera (FSC) is installed at the top of the windshield near the rearview mirror.

The radar sensor (front) is mounted behind the radiator grille.

System setting used for test (if applicable): *Far*

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

16 km/h (10 mph) (Per manufacturer supplied information)

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

None stated. (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

X Yes

___ No

If yes, please provide a full description.

Drive more than 4 km (2.5 mile) of straight road with lane markings on both sides at a speed between 25 and 30 mph. Does not have to be continuous, can start and turn around.

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

X Yes

___ No

If yes, please provide a full description.

Deactivation can be avoided by cycling the ignition after each AEB activation.

How is the Crash Imminent Braking System alert presented to the driver?

(Check all that apply)

X Warning light

X 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 warning, located in the instrument cluster: Symbol & Word, Red color, Flashes on/off. See Appendix A, Figure A16.

Audible warning: Repeated Beep, High Pitch

Is there a way to deactivate the system?

X Yes

___ No

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

A touchscreen located in the center of the dash panel provides an interface to the settings (Appendix A, Figure A15). The hierarchy is:

Settings

Safety - Select SBS/SCBS

System - Select on or off (check or uncheck)

When the SBS system is turned off, the SBS OFF indicator light turns on. When the engine is restarted, the system becomes operational.

Is the vehicle equipped with a control whose purpose is to adjust the range setting or otherwise influence the operation of CIB?	**X**	Yes
		No

If yes, please provide a full description.

A touchscreen located in the center of the dash panel provides an interface to the settings (Appendix A, Figure A15). The hierarchy is:

- *Settings*
  - *Safety - Select SBS/SCBS*
    - *Warning Distance- Select Far, Med., Near*
    - *Warning Volume- Select High, Low, Off*

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

If yes, please provide a full description.

System limitations are described in the Owner's Manual, Pages 4-181 and 4-182. These pages are reproduced in Appendix B, Pages B-9 and B-10.

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

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.

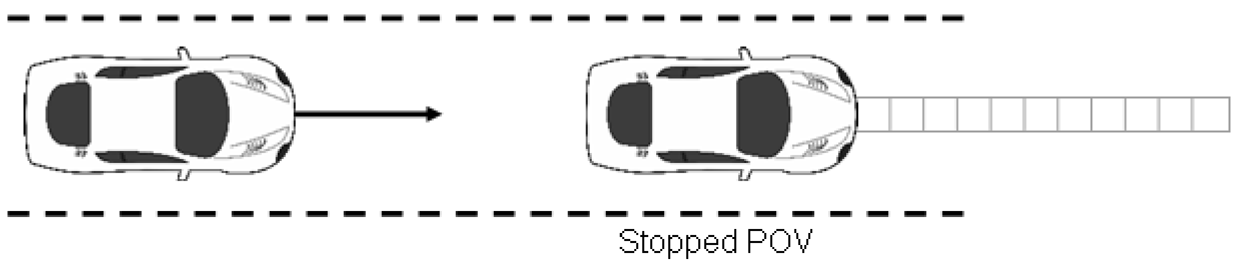


Figure 1. Depiction of Test 1

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.

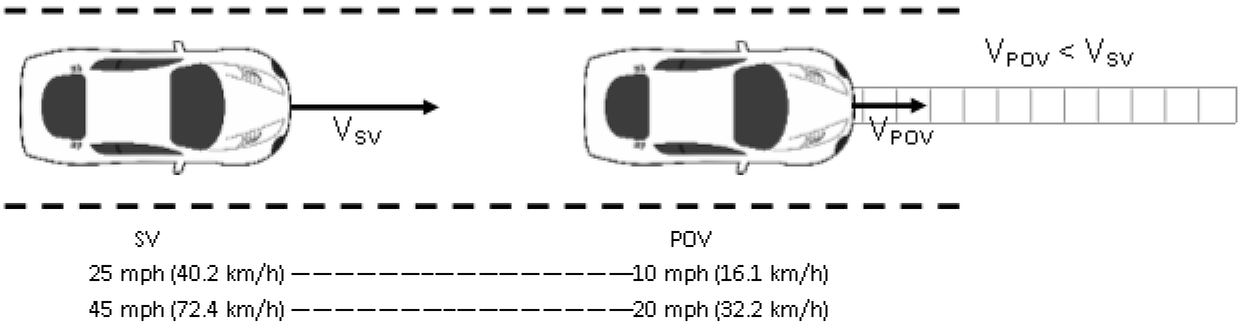


Figure 2. Depiction of Test 2

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 tFCW-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. <u>TEST 3 – SUBJECT VEHICLE ENCOUNTERS DECELERATING PRINCIPAL OTHER VEHICLE</u>

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.

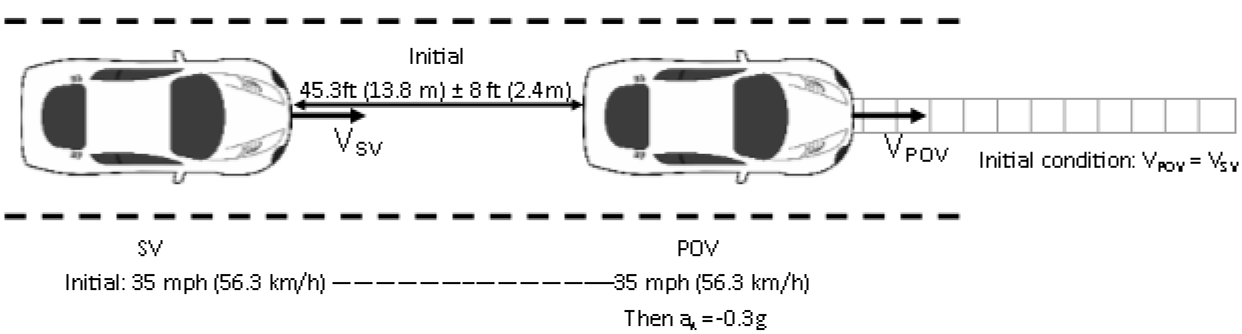


Figure 3. Depiction of Test 3 with POV Decelerating

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) ± 8 ft (2.4 m). Once these conditions were met, the POV tow vehicle brakes were applied to achieve 0.3 ± 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 ±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 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 ±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 ±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 ±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 ≥ 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	5th	3 dB	60 dB	Identified Center Frequency ± 5%
Tactile	5th	3 dB	60 dB	Identified Center Frequency ± 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 0.25 g.
- 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
					2258	Date: 5/3/2019 Due: 5/3/2021
					2182	Date: 9/16/2019 Due: 9/16/2021

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

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

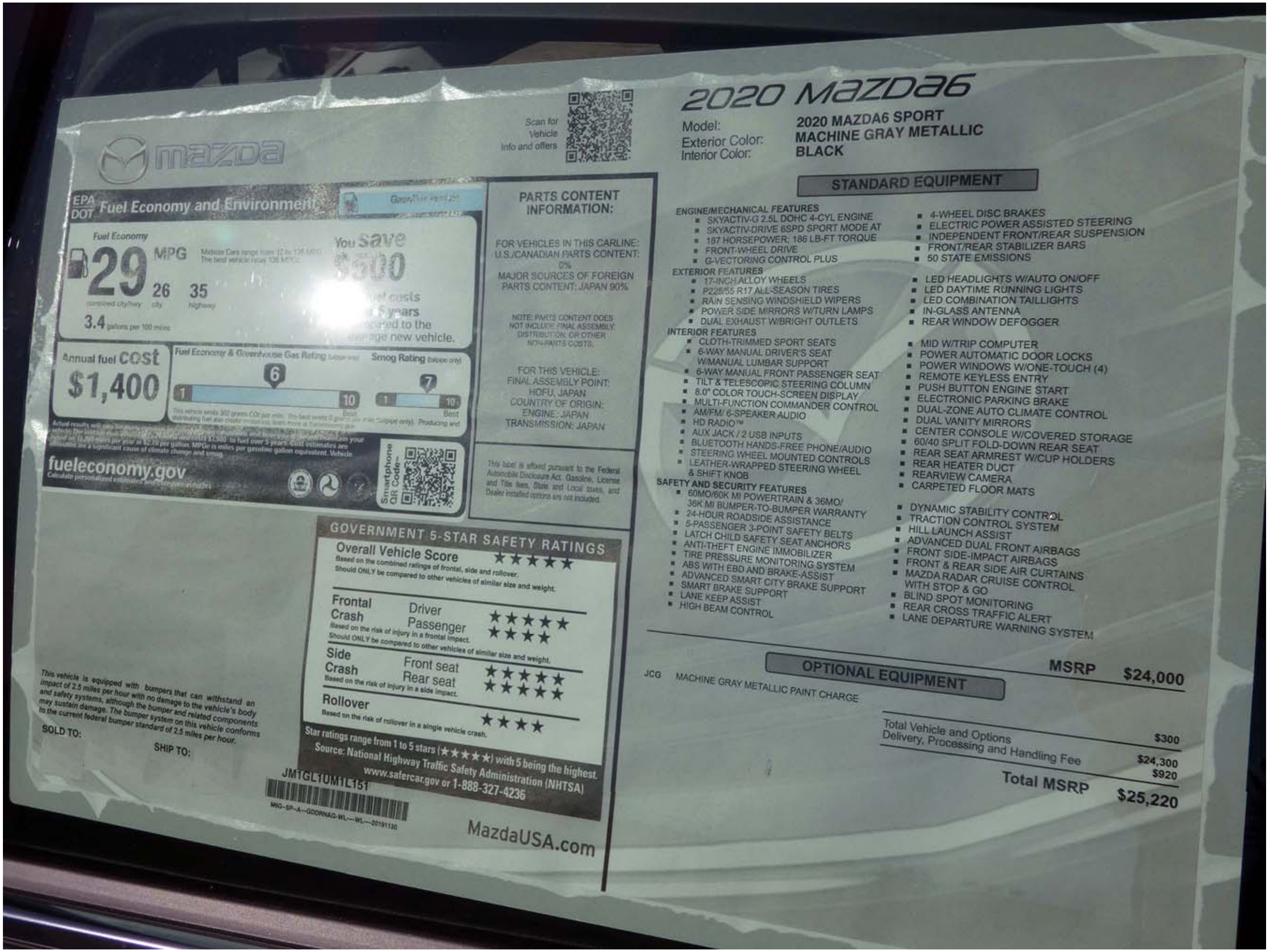


Figure A3. Window Sticker (Monroney Label)

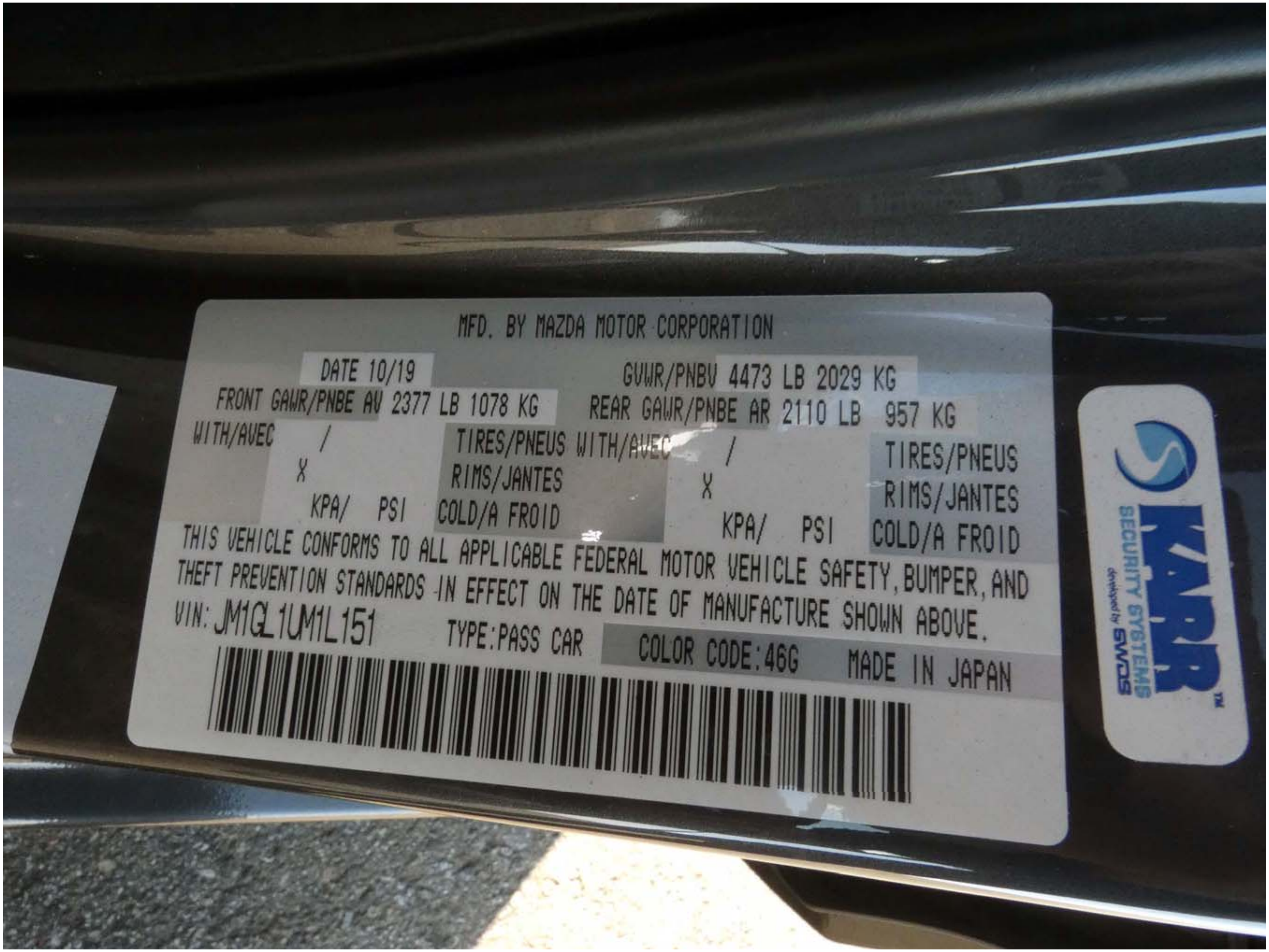


Figure A4. Vehicle Certification Label

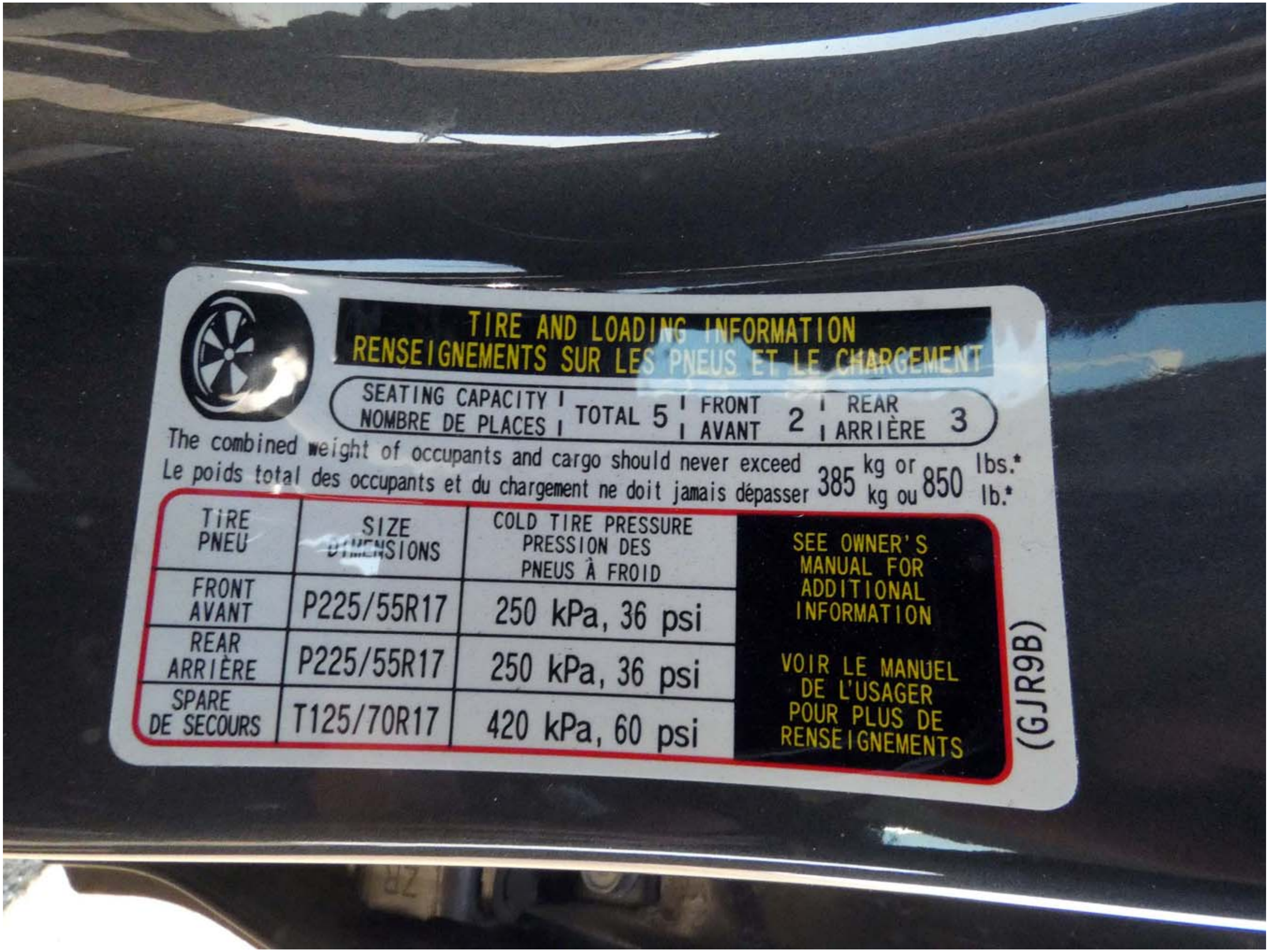


Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

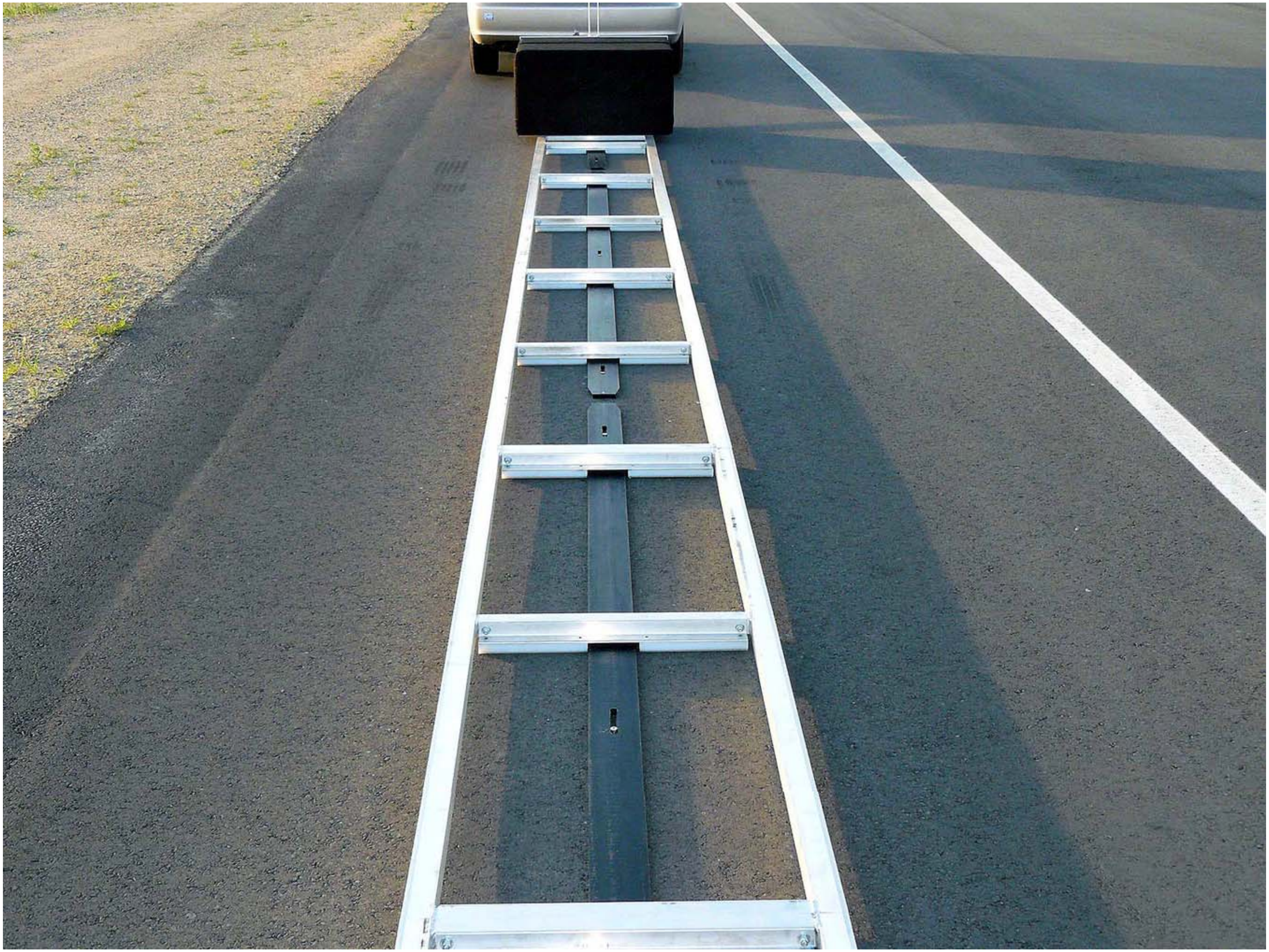


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

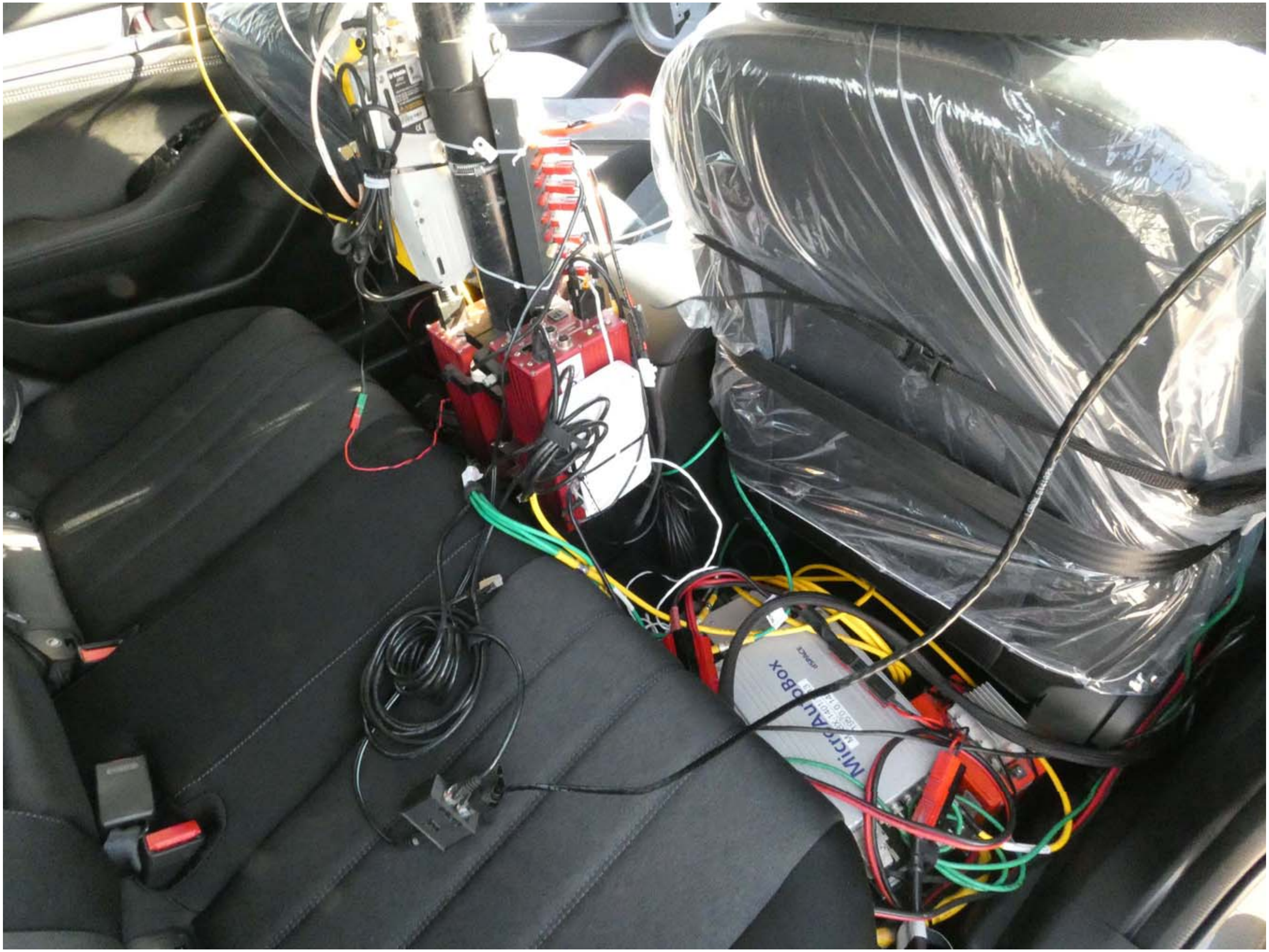


Figure A10. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle

Figure A11. Sensor for Detecting Auditory Alerts

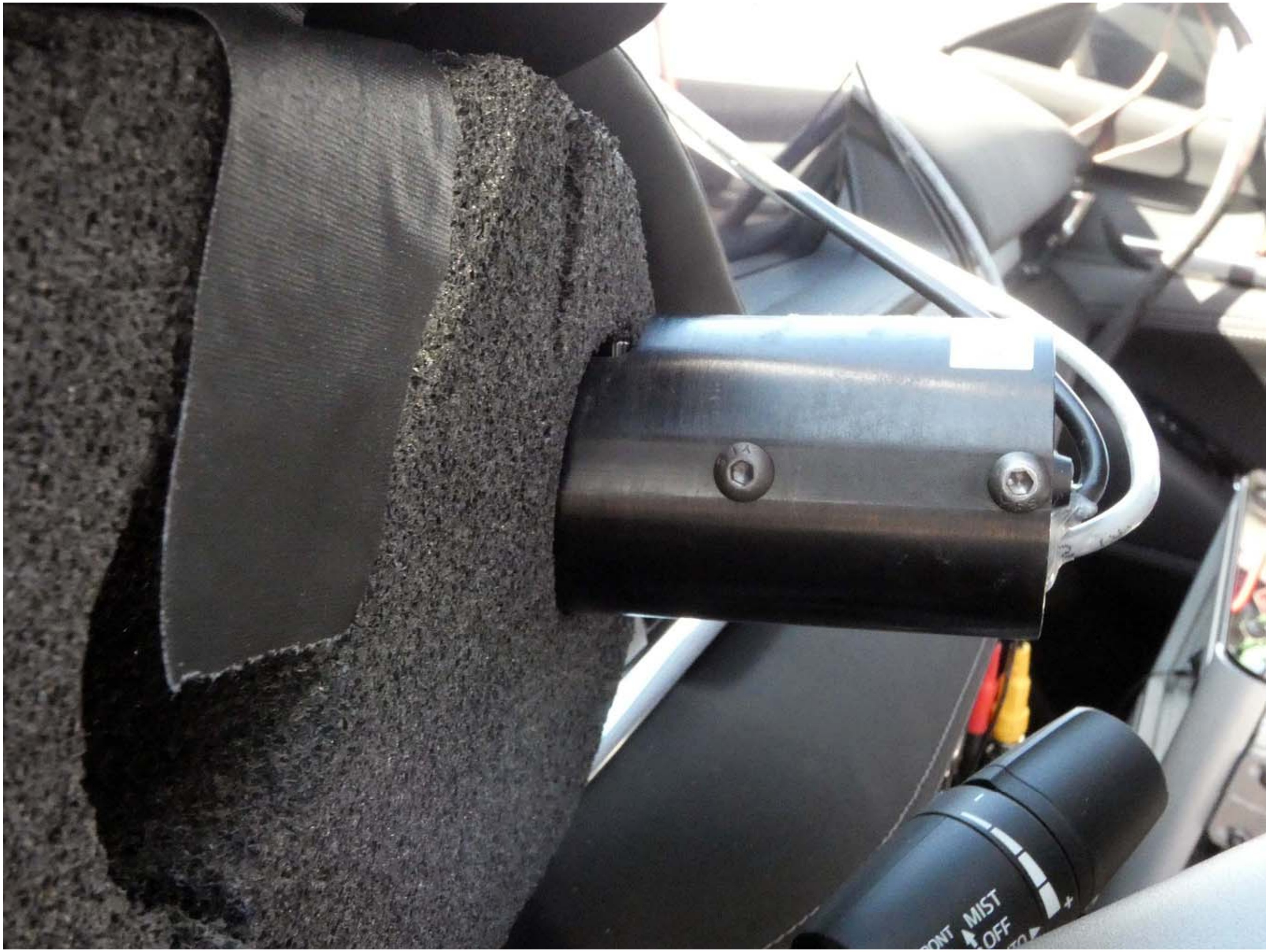


Figure A12. Sensor for Detecting Visual Alerts

Figure A13. Computer Installed in Subject Vehicle

Figure A14. Brake Actuator Installed in POV System

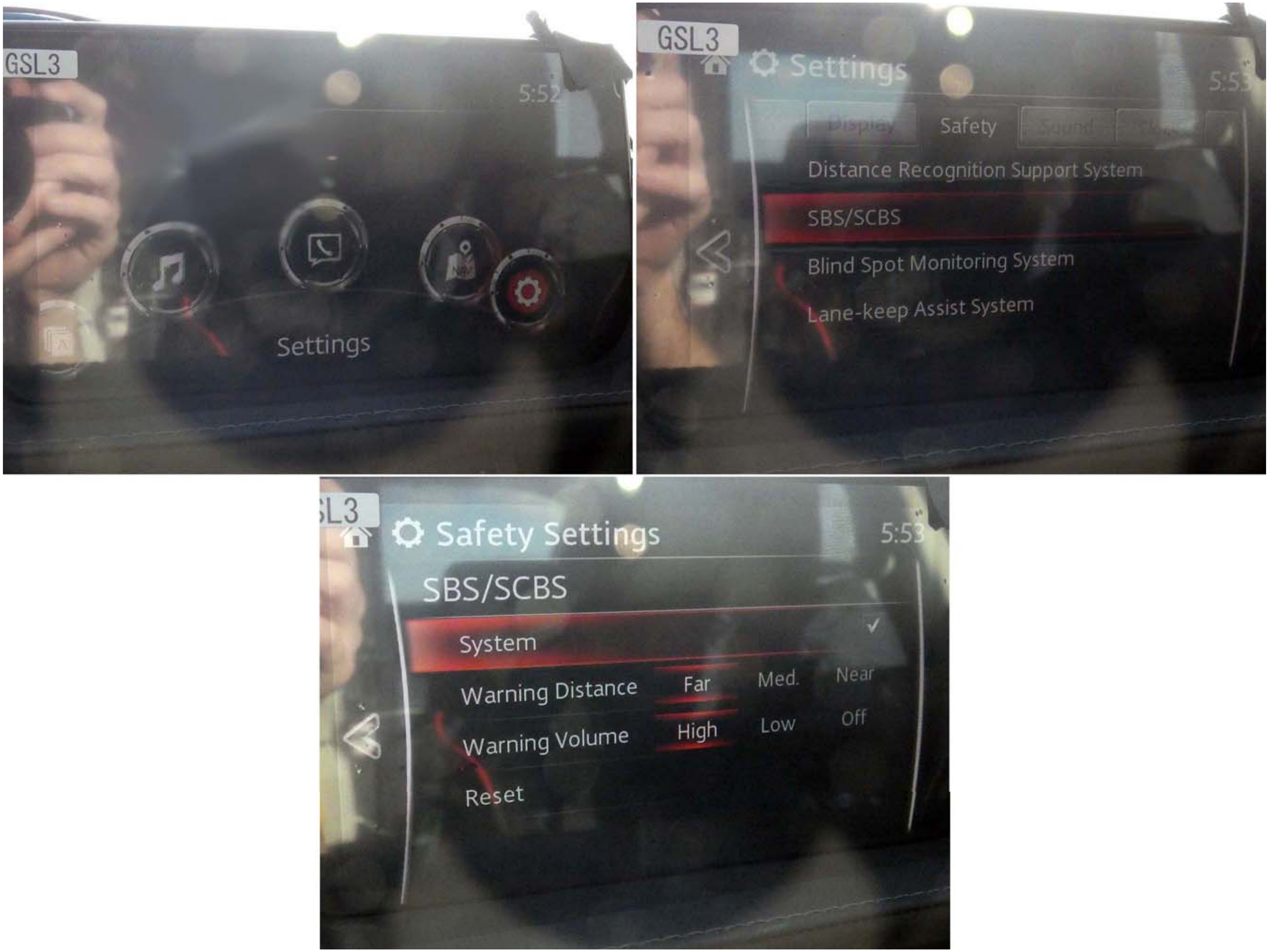
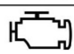
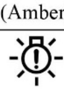
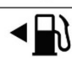


Figure A15. CIB (SBS) Setup Menus

Figure A16. CIB (SBS) Visual Alert

APPENDIX B

Excerpts from Owner's Manual

Signal	Warning	Page
	Master Warning Indication	7-28
	Electric Parking Brake (EPB) Warning Indication/Warning Light*1	7-28
	Check Engine Light*1	7-28
	*Selective Catalytic Reduction (SCR) system Warning Indication/Warning Light*1	7-28
AT	Automatic Transaxle Warning Indication	7-28
4WD	*AWD Warning Indication	7-28
	Air Bag/Front Seat Belt Pretensioner System Warning Light*1	7-28
	Tire Pressure Monitoring System Warning Light*1	Flashing 7-28 Turns on 7-35
 (Amber/White)	KEY Warning Indication	Amber 7-28 White 7-35
 (Amber)	High Beam Control System (HBC) Warning Indication/Warning Light*1	7-28
	Blind Spot Monitoring (BSM) Warning Indication	7-28
 (Amber)	*Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function) Warning Indication	7-28
 (Amber)	Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS) Warning Indication	7-28
	LED Headlight Warning Light*1	7-28
	*Smart Brake Support/Smart City Brake Support (SBS/SCBS) Warning Indication	7-35
	Low Fuel Warning Indication/Warning Light	7-35
	Check Fuel Cap Warning Indication/Warning Light*1	7-35

*Some models.

Instrument Cluster and Display

Signal	Indicator	Page
 (White)	*Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function) Main Indication	4-154
 (Green)	*Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function) Set Indication	4-154
	Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS) Indication	4-166
	*Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS) OFF Indicator Light*1	4-171
	Smart City Brake Support (SCBS) Indication	Advanced Smart City Brake Support (Advanced SCBS) 4-176 Smart City Brake Support (SCBS) 4-179
	*Smart Brake Support/Smart City Brake Support (SBS/SCBS) OFF Indicator Light*1	Advanced Smart City Brake Support (Advanced SCBS) 4-176 Smart City Brake Support (SCBS) 4-180 Smart Brake Support (SBS) System 4-182
 (White)	*Cruise Main Indication	4-222
 (Green)	*Cruise Set Indication	4-222

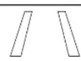
*1 The light turns on when the ignition is switched on for an operation check, and turns off a few seconds later or when the engine is started. If the light does not turn on or remains turned on, have the vehicle inspected at an Authorized Mazda Dealer.

 *Some models.

Instrument Cluster and Display

Signal	Warning	Page
	Power Steering Malfunction Indication	7-25
	Master Warning Indication	7-28
	Electric Parking Brake (EPB) Warning Indication/Warning Light[*1]	7-28
	Check Engine Light[*1]	7-28
	*Selective Catalytic Reduction (SCR) system Warning Indication/Warning Light[*1]	7-28
AT	Automatic Transaxle Warning Indication	7-28
4WD	*AWD Warning Indication	7-28
	Air Bag/Front Seat Belt Pretensioner System Warning Light[*1]	7-28
	Tire Pressure Monitoring System Warning Light[*1]	Flashing 7-28 Turns on 7-35
(Amber/White)	KEY Warning Indication	Amber 7-28 White 7-35
(Amber)	*High Beam Control System (HBC) Warning Indication/Warning Light[*1]	7-28
	*Blind Spot Monitoring (BSM) Warning Indication	7-28
(Amber)	*Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function) Warning Indication	7-28
	*Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS) Warning Indication	7-28
	LED Headlight Warning Light[*1]	7-28
(Amber)	*Smart Brake Support/Smart City Brake Support (SBS/SCBS) Warning Indication	7-35
	Low Fuel Warning Indication	7-35

*Some models.

Signal	Indicator	Page
	*Blind Spot Monitoring (BSM) OFF Indicator Light*1	Malfunction 7-28 Except malfunction 4-132
 (White)	*Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function) Main Indication	4-154
 (Green)	*Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function) Set Indication	4-154
	*Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS) Indication	4-166
	*Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS) OFF Indicator Light*1	4-171
	*Smart City Brake Support (SCBS) Indication	Advanced Smart City Brake Support (Advanced SCBS) 4-176 Smart City Brake Support (SCBS) 4-179
	*Smart Brake Support/Smart City Brake Support (SBS/SCBS) OFF Indicator Light*1	Advanced Smart City Brake Support (Advanced SCBS) 4-176 Smart City Brake Support (SCBS) 4-180 Smart Brake Support (SBS) System 4-182
 (White)	*Cruise Main Indication	4-222
 (Green)	*Cruise Set Indication	4-222

*Some models.

Collision damage reduction in low vehicle speed range

Forward driving

Smart City Brake Support (SCBS).. page 4-177
Advanced Smart City Brake Support (Advanced SCBS).......................................page 4-174

Collision damage reduction in medium/high speed range

Smart Brake Support (SBS)...page 4-180

▼ Camera and Sensors

Forward Sensing Camera (FSC)

The Forward Sensing Camera (FSC) detects lane indications and recognizes headlights, taillights and city lights during nighttime driving. In addition, it also detects the vehicle ahead, pedestrians, or obstructions. The following systems also use the Forward Sensing Camera (FSC).

- High Beam Control system (HBC)
- Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS)
- Traffic Sign Recognition System (TSR)
- Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function)
- Advanced Smart City Brake Support (Advanced SCBS)
- Smart City Brake Support (SCBS)
- Smart Brake Support (SBS)

The Forward Sensing Camera (FSC) is installed at the top of the windshield near the rearview mirror.
Refer to Forward Sensing Camera (FSC) on page 4-210.

Radar sensor (front)

The radar sensor (front) functions by detecting the radio waves reflected off a vehicle ahead sent from the radar sensor. The following systems also use the radar sensor (front).

- Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function)
- Distance Recognition Support System (DRSS)
- Smart Brake Support (SBS)

The radar sensor (front) is mounted behind the radiator grille.
Refer to Radar Sensor (Front) on page 4-215.

▼ Collision Warning

If there is the possibility of a collision with a vehicle ahead, the beep sounds continuously and a warning is indicated in the multi-information display or the active driving display.

BRAKE!

NOTE

The operation distance and volume of the collision warning can be changed. Refer to Safety Equipment on page 9-12.

▼ Automatic Brake Operation Display

The automatic brake operation display is indicated on the multi-information display after the Advanced SCBS is operated.

Smart City Brake Support Activated

NOTE

- *The collision warning beep sounds intermittently while the Advanced SCBS brake or brake assist (Advanced SCBS brake assist) is operating.*
- *If the vehicle is stopped by the Advanced SCBS operation and the brake pedal is not depressed, the warning beep sounds 1 time after about 2 seconds and the Advanced SCBS brake is automatically released.*

▼ Stopping the Advanced Smart City Brake Support (Advanced SCBS) System Operation

The Advanced SCBS system can be temporarily deactivated.
Refer to Safety Equipment on page 9-12.

When the Advanced SCBS system is turned off, the Smart City Brake Support (SCBS) OFF indicator light turns on.

When the engine is restarted, the system becomes operational.

NOTE

When the Advanced SCBS system is set to inoperable, the Smart Brake Support (SBS) are also set to inoperable.

▼ Stopping the Smart City Brake Support (SCBS) System Operation

The SCBS system can be temporarily deactivated.
Refer to Safety Equipment on page 9-12.
When the SCBS system is turned off, the Smart City Brake Support (SCBS) OFF indicator light turns on.

When the engine is restarted, the system becomes operational.

NOTE
When the SCBS system is set to inoperable, the Smart Brake Support (SBS) are also set to inoperable.

Smart Brake Support (SBS)*

The SBS system alerts the driver of a possible collision using a display and warning sound if the radar sensor (front) and the Forward Sensing Camera (FSC) determine that there is the possibility of a collision with a vehicle ahead while the vehicle is being driven at about 15 km/h or faster (10 mph or faster). Furthermore, if the radar sensor (front) and the Forward Sensing Camera (FSC) determines that a collision is unavoidable, the automatic brake control is performed to reduce damage in the event of a collision.
In addition, when the driver depresses the brake pedal, the brakes are applied firmly and quickly to assist. (Brake Assist (SBS brake assist))

⚠ WARNING

Do not rely completely on the SBS system and always drive carefully:
The SBS is designed to reduce damage in the event of a collision, not avoid an accident. The ability to detect an obstruction is limited depending on the obstruction, weather conditions, or traffic conditions. Therefore, if the accelerator pedal or brake pedal is mistakenly operated it could result in an accident. Always verify the safety of the surrounding area and depress the brake pedal or accelerator pedal while keeping a safer distance from vehicles ahead or on-coming vehicles.

*Some models.

⚠ CAUTION

In the following cases, turn the system off to prevent a mis-operation:

- *The vehicle is being towed or when towing another vehicle.*
- *The vehicle is on a chassis roller.*
- *When driving on rough roads such as in areas of dense grass or off-road.*

NOTE

- *The SBS system operates when all of the following conditions are met:*
  - *The ignition is switched ON.*
  - *The SBS system is on.*
  - *The vehicle speed is about 15 km/h or faster (10 mph or faster).*
  - *The relative speed between your vehicle and the vehicle ahead is about 15 km/h or faster (10 mph or faster).*
  - *The Dynamic Stability Control (DSC) is not operating.*
- *The SBS system may not operate under the following conditions:*
  - *If the vehicle is accelerated rapidly and it comes close to a vehicle ahead.*
  - *The vehicle is driven at the same speed as the vehicle ahead.*
  - *The accelerator pedal is depressed.*
  - *The brake pedal is depressed.*
  - *The steering wheel is being operated.*
  - *The selector lever is being operated.*
  - *The turn signal is being used.*
  - *When the vehicle ahead is not equipped with taillights or the taillights are turned off.*
  - *When warnings and messages, such as a dirty windshield, related to the Forward Sensing Camera (FSC) are being displayed in the multi-information display.*
- *Although the objects which activate the system are four-wheeled vehicles, the radar sensor (front) could detect the following objects, determine them to be an obstruction, and operate the SBS system.*
  - *Objects on the road at the entrance to a curve (including guardrails and snow banks).*
  - *A vehicle appears in the opposite lane while cornering or rounding a curve.*
  - *When crossing a narrow bridge.*
  - *When passing under a low gate or through a tunnel or narrow gate.*
  - *When entering an underground parking area.*
  - *Metal objects, bumps, or protruding objects on the road.*
  - *If you suddenly come close to a vehicle ahead.*
  - *When driving in areas where there is high grass or forage.*
  - *Two-wheeled vehicles such as motorbikes or bicycles.*
  - *Pedestrians or non-metallic objects such as standing trees.*
- *When the system operates, the user is notified by the multi-information display.*
- *If there is a problem with the SBS system, a message is displayed in the multi-information display. Check the center display to verify the problem and then have your vehicle inspected by an Authorized Mazda Dealer.*

Refer to Message Indicated on Display on page 7-43.

▼ Collision Warning

If there is the possibility of a collision with a vehicle ahead, the beep sounds continuously and a warning is indicated in the multi-information display and the active driving display.

BRAKE!

▼ Stopping The Smart Brake Support (SBS) System Operation

The SBS system can be temporarily deactivated.
Refer to Safety Equipment on page 9-12.
When the SBS system is turned off, the SBS OFF indicator light turns on.

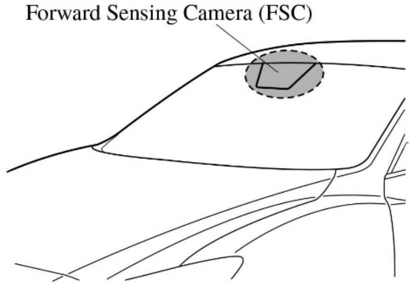
When the engine is restarted, the system becomes operational.

NOTE
If the SBS system operation is turned off, the Smart City Brake Support (SCBS) system operation is turned off simultaneously.

Forward Sensing Camera (FSC)*

Your vehicle is equipped with a Forward Sensing Camera (FSC). The Forward Sensing Camera (FSC) is positioned near the rearview mirror and used by the following systems.

- High Beam Control System (HBC)
- Lane-keep Assist System (LAS) & Lane Departure Warning System (LDWS)
- Traffic Sign Recognition System (TSR)
- Advanced Smart City Brake Support (Advanced SCBS)
- Smart City Brake Support (SCBS)
- Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function)
- Smart Brake Support (SBS)



The Forward Sensing Camera (FSC) determines the conditions ahead of the vehicle while traveling at night and detects traffic lanes. The distance in which the Forward Sensing Camera (FSC) can detect objects varies depending on the surrounding conditions.

WARNING

Do not modify the suspension:
If the vehicle height or inclination is changed, the system will not be able to correctly detect vehicles ahead. This will result in the system not operating normally or mistakenly operating, which could cause a serious accident.

CAUTION

- *Do not apply accessories, stickers or film to the windshield near the Forward Sensing Camera (FSC).*
  If the area in front of the Forward Sensing Camera (FSC) lens is obstructed, it will cause the system to not operate correctly. Consequently, each system may not operate normally which could lead to an unexpected accident.

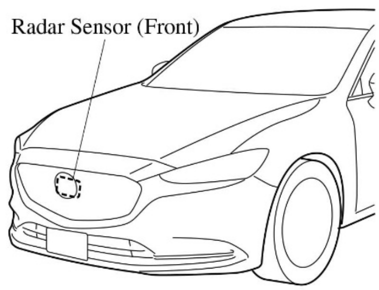
 *Some models.

Radar Sensor (Front)*

Your vehicle is equipped with a radar sensor (front).
The following systems also use the radar sensor (front).

- Distance Recognition Support System (DRSS)
- Mazda Radar Cruise Control with Stop & Go function (MRCC with Stop & Go function)
- Smart Brake Support (SBS)

The radar sensor (front) functions by detecting the radio waves reflected off a vehicle ahead or an obstruction sent from the radar sensor.
The radar sensor (front) is mounted behind the front emblem.



If "Front Radar Sensor Blocked" is displayed in the multi-information display of the instrument cluster, clean the area around the radar sensor (front).

CAUTION

Heed the following precautions to assure correct operation of each system.

- *Do not adhere stickers (including transparent stickers) to the surface of the radiator grille and front emblem in and around the radar sensor (front), and do not replace the radiator grille and front emblem with any product that is not a genuine product designed for use with the radar sensor (front).*
- *The radar sensor (front) includes a function for detecting soiling of the radar sensor's front surface and informing the driver, however, depending on the conditions, it may require time to detect or it may not detect plastic shopping bags, ice or snow. If this occurs, the system may not operate correctly, therefore always keep the radar sensor (front) clean.*
- *Do not install a grille guard.*
- *If the front part of the vehicle has been damaged in a vehicle accident, the position of the radar sensor (front) may have moved. Stop the system immediately and always have the vehicle inspected at an Authorized Mazda Dealer.*
- *Do not use the front bumper to push other vehicles or obstructions such as when pulling out of a parking space. Otherwise, the radar sensor (front) could be hit and its position deviated.*

*Some models.

▼ Taking Action

Take the appropriate action and verify that the warning light turns off.

Signal	Warning	Action to be taken
(Amber) Smart Brake Support/ Smart City Brake Support (SBS/SCBS) Warning Indication/ Warning Light*	The light turns on if the windshield or the radar sensor are dirty, or there is a malfunction in the system.	Verify the reason why the warning light is illuminated on the center display. If the reason why the warning light is illuminated is due to a dirty windshield, clean the windshield. If the warning light is illuminated because of a dirty radar sensor, clean the front emblem. For any other reasons, have the vehicle inspected at an Authorized Mazda Dealer.
Low Fuel Warning Indication/Warning Light	The light turns on when the remaining fuel is about 9.0 L (2.3 US gal, 1.9 Imp gal). ***NOTE*** *The light illumination timing may vary because fuel inside the fuel tank moves around according to the driving conditions and the vehicle posture.*	Add fuel.
Check Fuel Cap Warning Indication/Warning Light	If the check fuel cap warning light illuminates while driving, the fuel-filler cap may not be installed properly.	Stop the engine and reinstall the fuel-filler cap. Refer to Refueling on page 3-27.
Engine Oil Level Warning Light	This warning light indicates that the engine oil level is around the MIN mark (page 6-28).	Add 1 L (0.3 US gal, 0.2 Imp gal) of engine oil (page 6-25).

*Some models.

APPENDIX C

Run Log

Subject Vehicle: **2020 Mazda Mazda6 Sport** Test Date: **4/14/2020**

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								
13	**Stopped POV**	Y	2.12	10.42	25.4	0.95	1.07	Pass	
14		Y	2.10	0.00	11.4	0.56	0.91	Pass	
15		Y	2.14	8.54	24.5	0.91	0.97	Pass	
16		Y	2.09	10.27	24.5	0.92	1.04	Pass	
17		Y	2.46	8.27	24.5	0.91	0.98	Pass	
18		Y	2.21	9.78	24.1	0.94	1.00	Pass	
19		Y	2.31	9.26	24.5	0.91	0.99	Pass	Video cutout early
20	Static Run								
21	**Slower POV, 25 vs 10**	Y	2.28	4.27	15.9	0.94	0.74	Pass	
22		Y	2.29	4.61	15.2	0.95	0.73	Pass	
23		Y	2.25	4.40	15.0	0.94	0.75	Pass	
24		Y	2.23	5.69	15.7	0.92	0.74	Pass	
25		Y	2.32	4.77	15.5	0.94	0.78	Pass	
26		Y	2.24	4.42	15.0	0.92	0.70	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
27		Y	2.19	5.18	15.1	0.93	0.73	Pass	
28	Static Run								
29	**Slower POV, 45 vs 20**	Y	2.65	6.54	25.4	0.98	1.06	Pass	
30		Y	2.68	7.93	25.3	0.96	1.06	Pass	
31		Y	2.86	9.76	25.5	0.97	1.10	Pass	
32		Y	2.80	8.11	24.8	0.99	1.05	Pass	
33		Y	2.87	9.07	25.3	1.00	1.04	Pass	
34		Y	2.85	9.79	25.1	0.98	1.14	Pass	
35		Y	2.87	9.54	24.7	1.00	1.12	Pass	
36	Static run								
2	**Decelerating POV, 35**	N							Driver applied braking
3		N							POV speed
4		Y	1.98	8.02	22.5	0.94	0.98	Pass	
5		N							headway
6		Y	1.91	8.83	19.8	0.96	0.98	Pass	Video cutout early
7		Y	1.84	8.61	20.4	0.98	0.99	Pass	
8		Y	1.94	9.33	21.5	0.94	1.06	Pass	
9		Y	2.08	9.40	21.3	0.95	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
10		Y	1.88	7.19	24.2	0.72	1.11	Pass	
11		Y	1.97	8.49	21.7	1.01	0.96	Pass	
12	Static Run								
37	STP - Static Run								
38	**STP False Positive, 25**	Y				0.01		Pass	
39		Y				0.01		Pass	
40		Y				0.01		Pass	
41		Y				0.01		Pass	
42		Y				0.01		Pass	
43		Y				0.01		Pass	
44		Y				0.01		Pass	
45	STP - Static Run								
46	**STP False Positive, 45**	Y				0.02		Pass	
47		Y				0.03		Pass	
48		Y				0.04		Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
49		Y				0.06		Pass	
50		Y				0.04		Pass	
51		Y				0.05		Pass	
52		Y				0.02		Pass	
53	STP - Static Run								

APPENDIX D

Time History Plots

LIST OF FIGURES

Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from both the Subject Vehicle (SV) and the Principal Other Vehicle (POV), as well as pass/fail envelopes and thresholds. The following is a description of data types shown in the time history plots, as well as a description of the color 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 D1 through Figure D9. Figures D1 through D6 show passing runs for each of the 6 test types. Figures D7 and D8 show examples of invalid runs. Figure D9 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 D10.

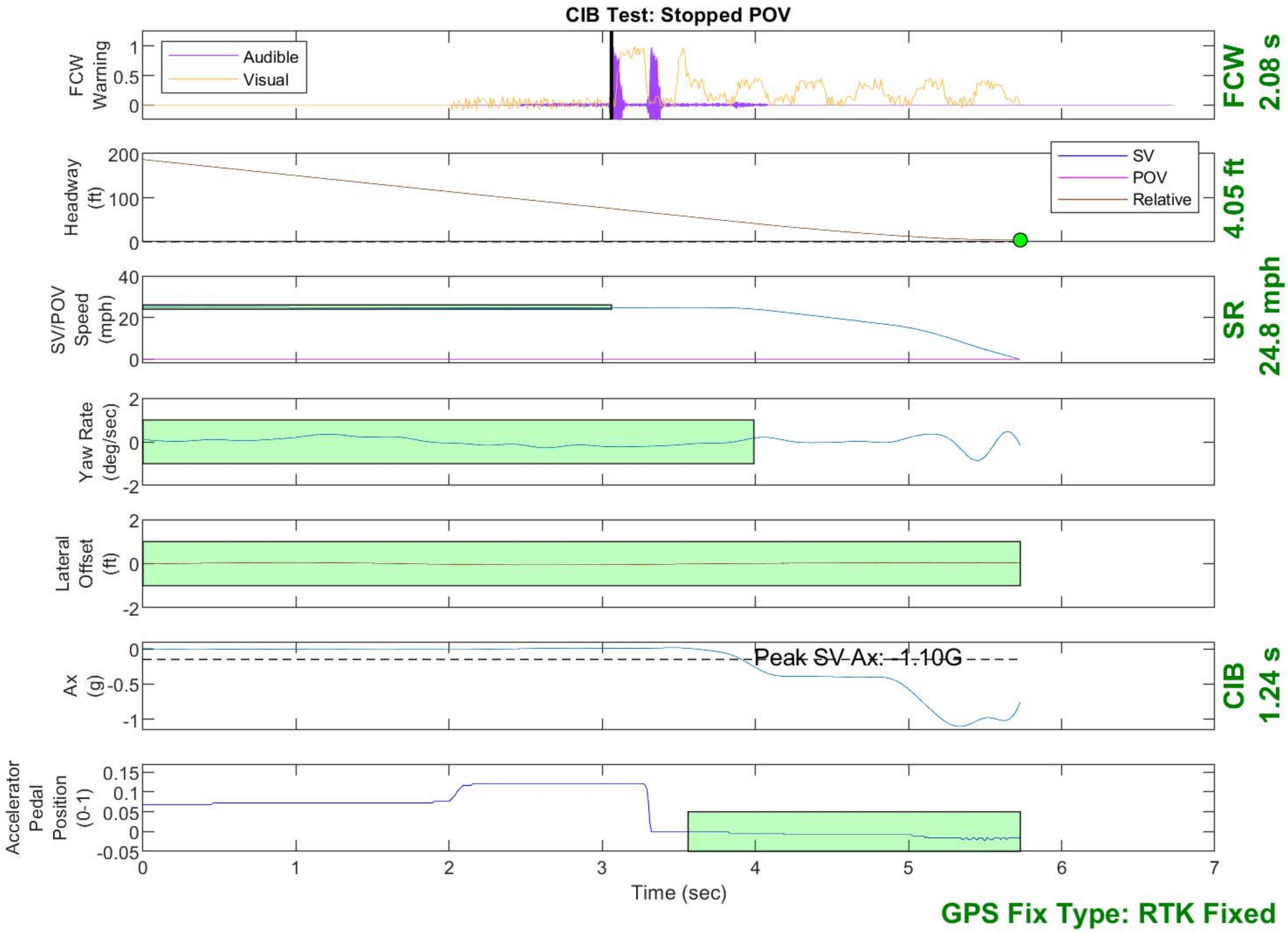


Figure D1. Example Time History for Stopped POV, Passing

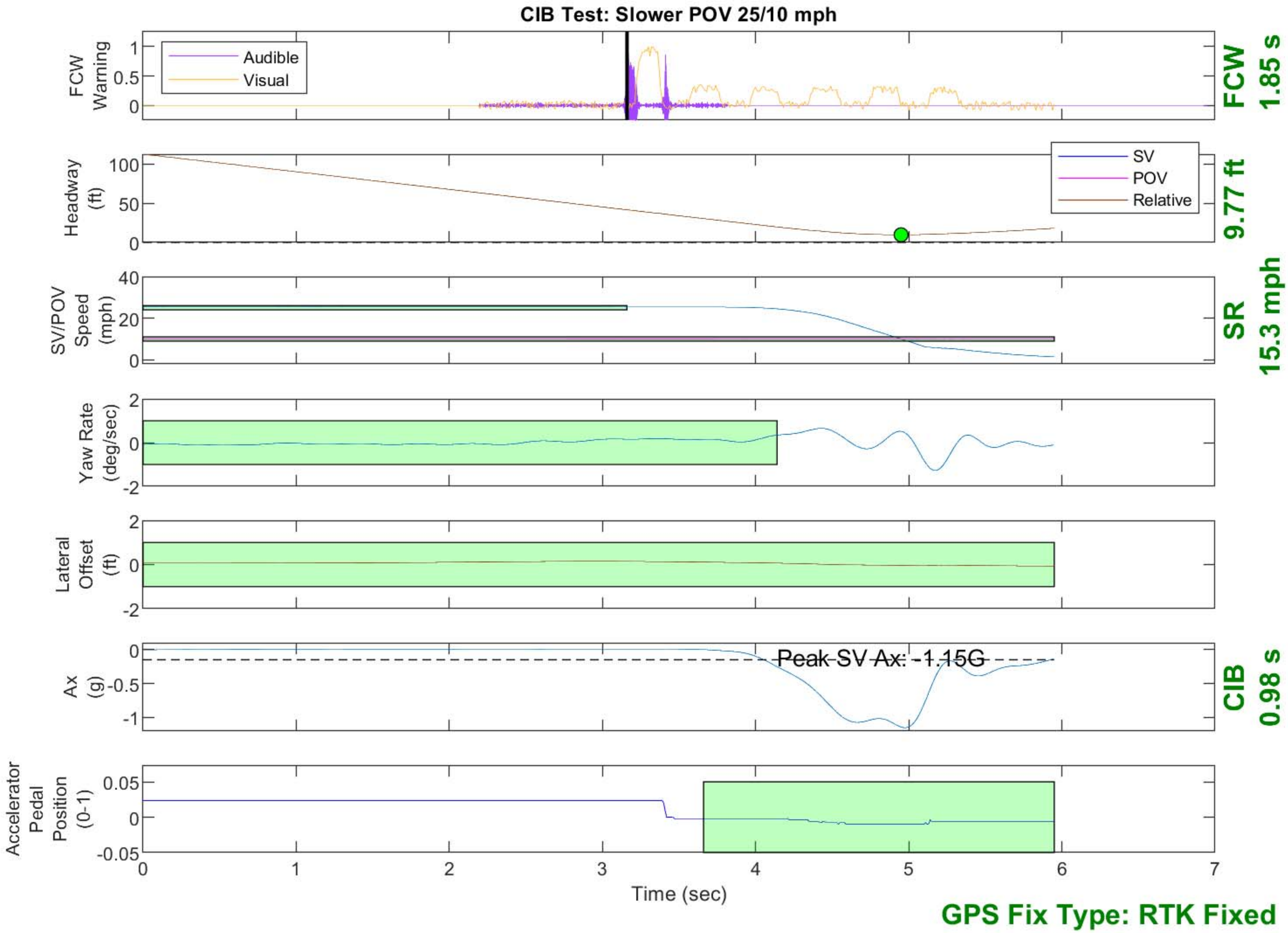


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

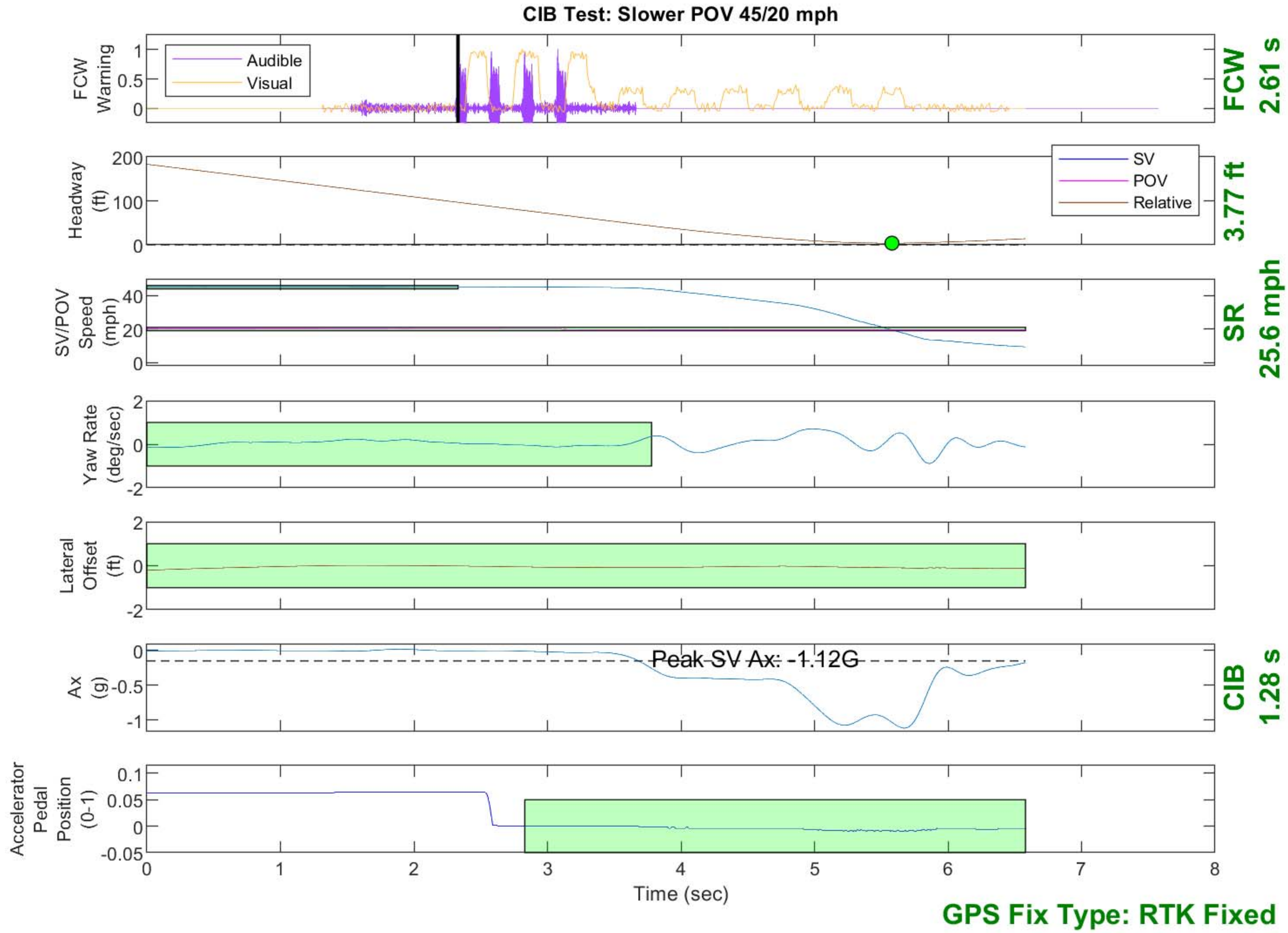


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

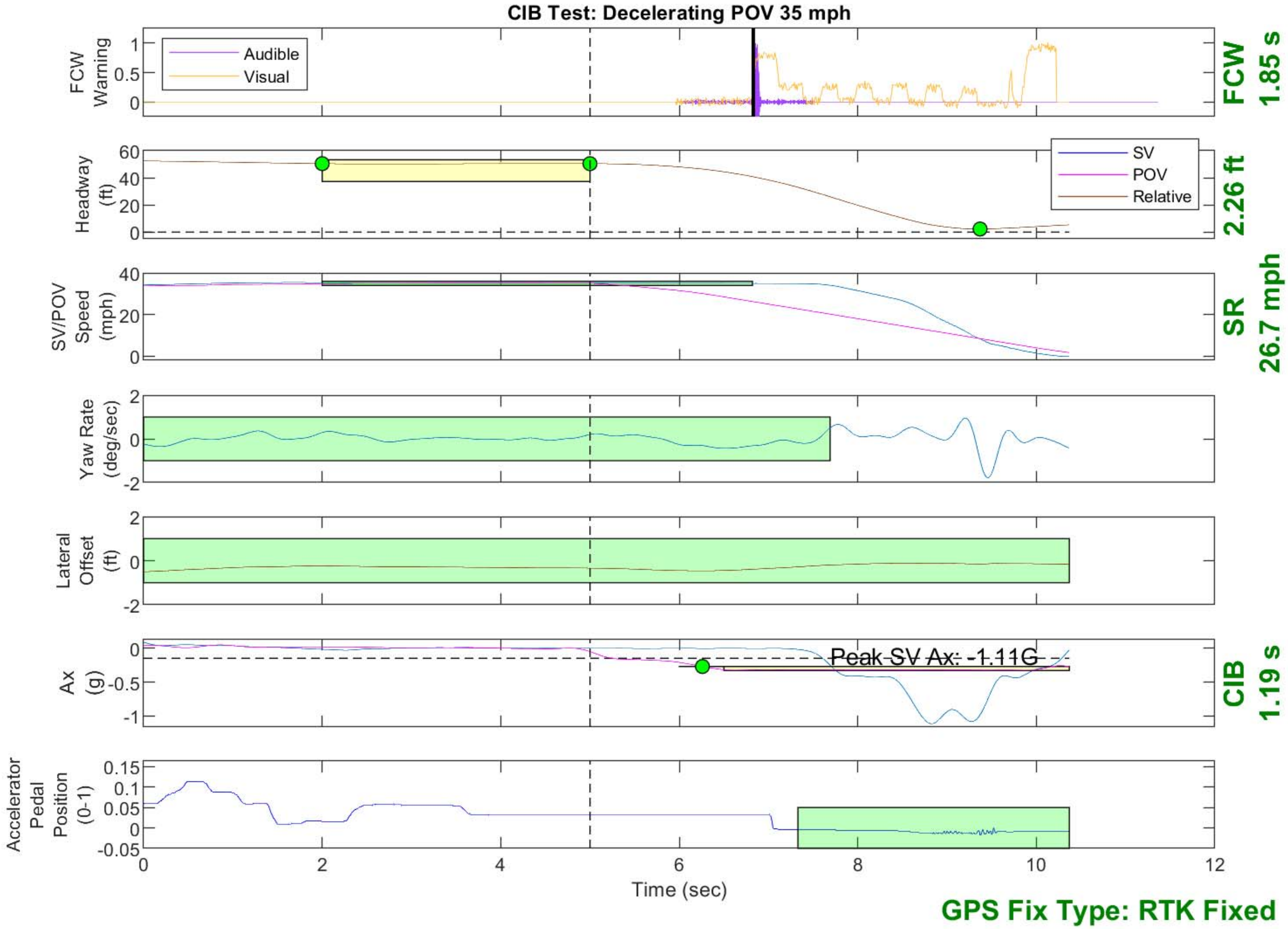


Figure D4. Example Time History for Decelerating POV 35, Passing

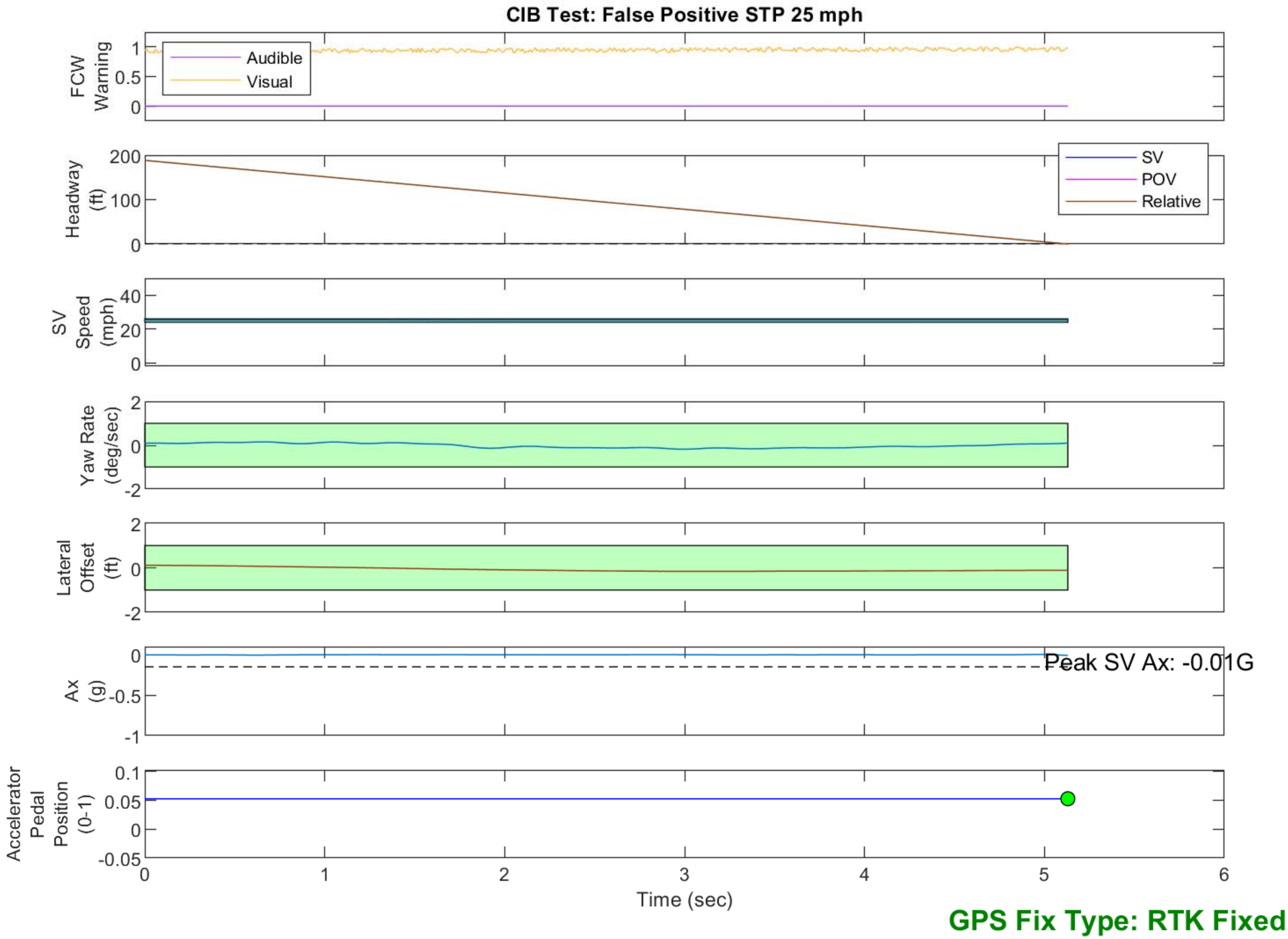


Figure D5. Example Time History for False Positive STP 25, Passing

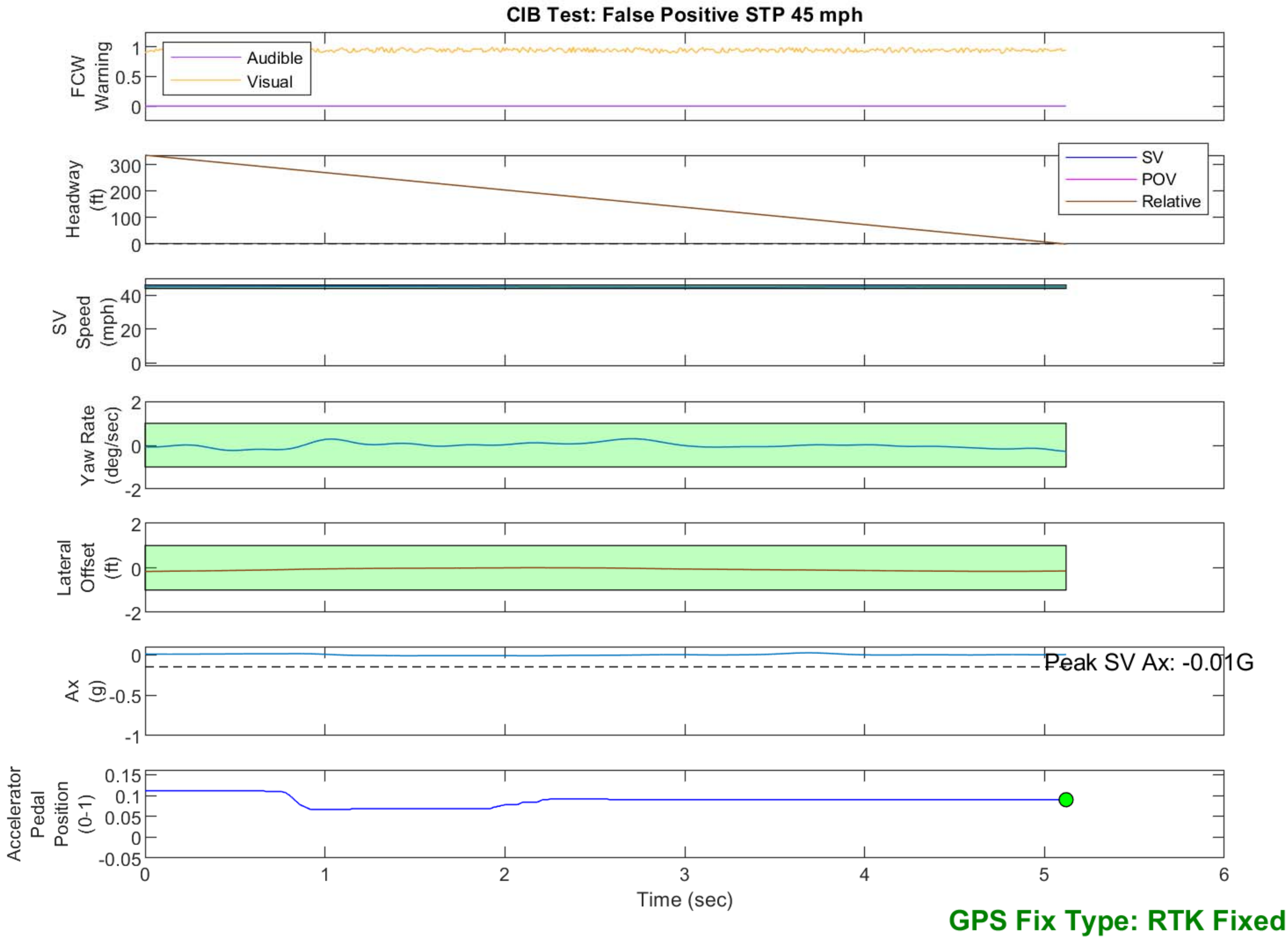


Figure D6. Example Time History for False Positive STP 45, Passing

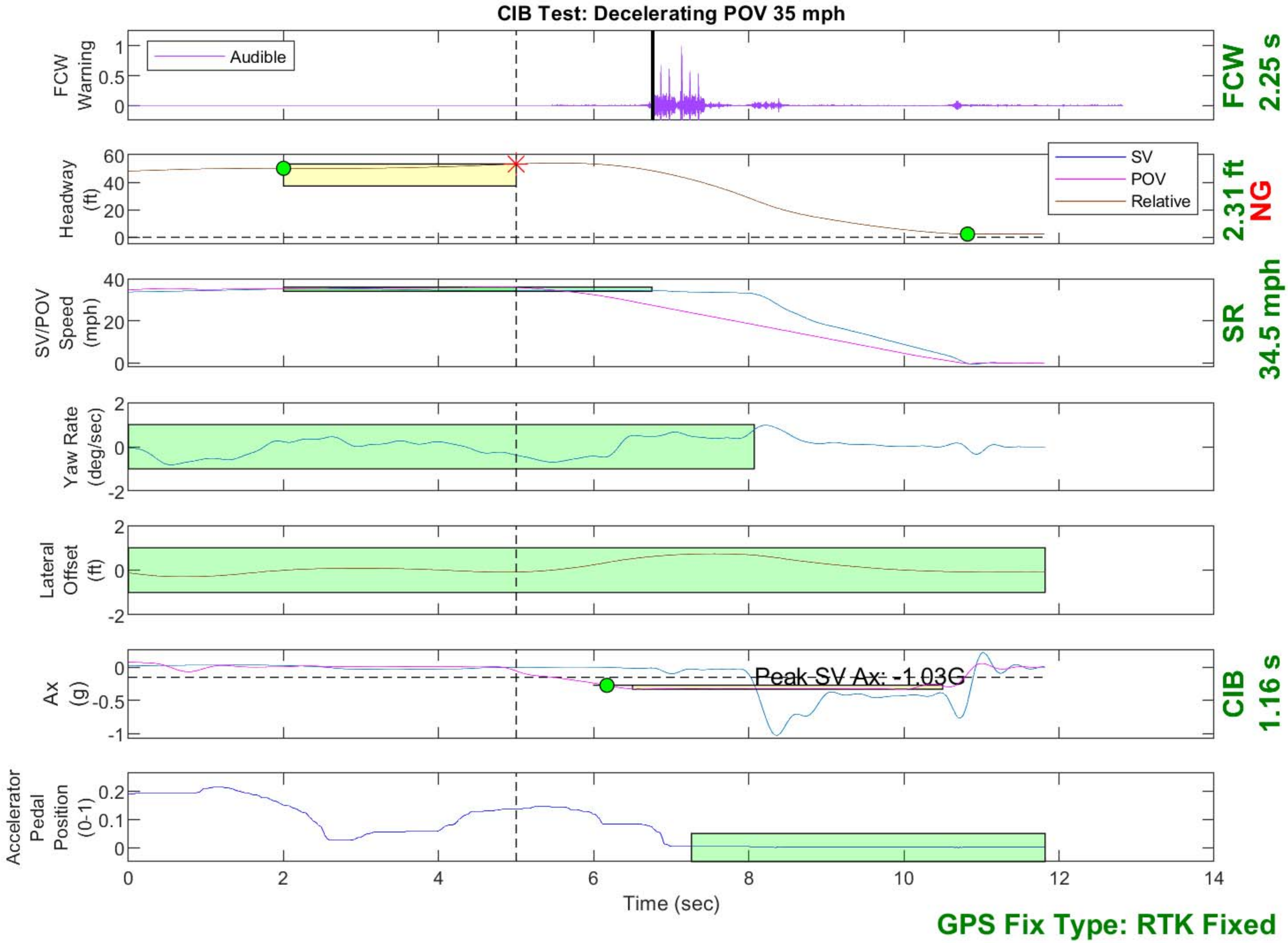


Figure D7. Example Time History Displaying Invalid Headway Criteria

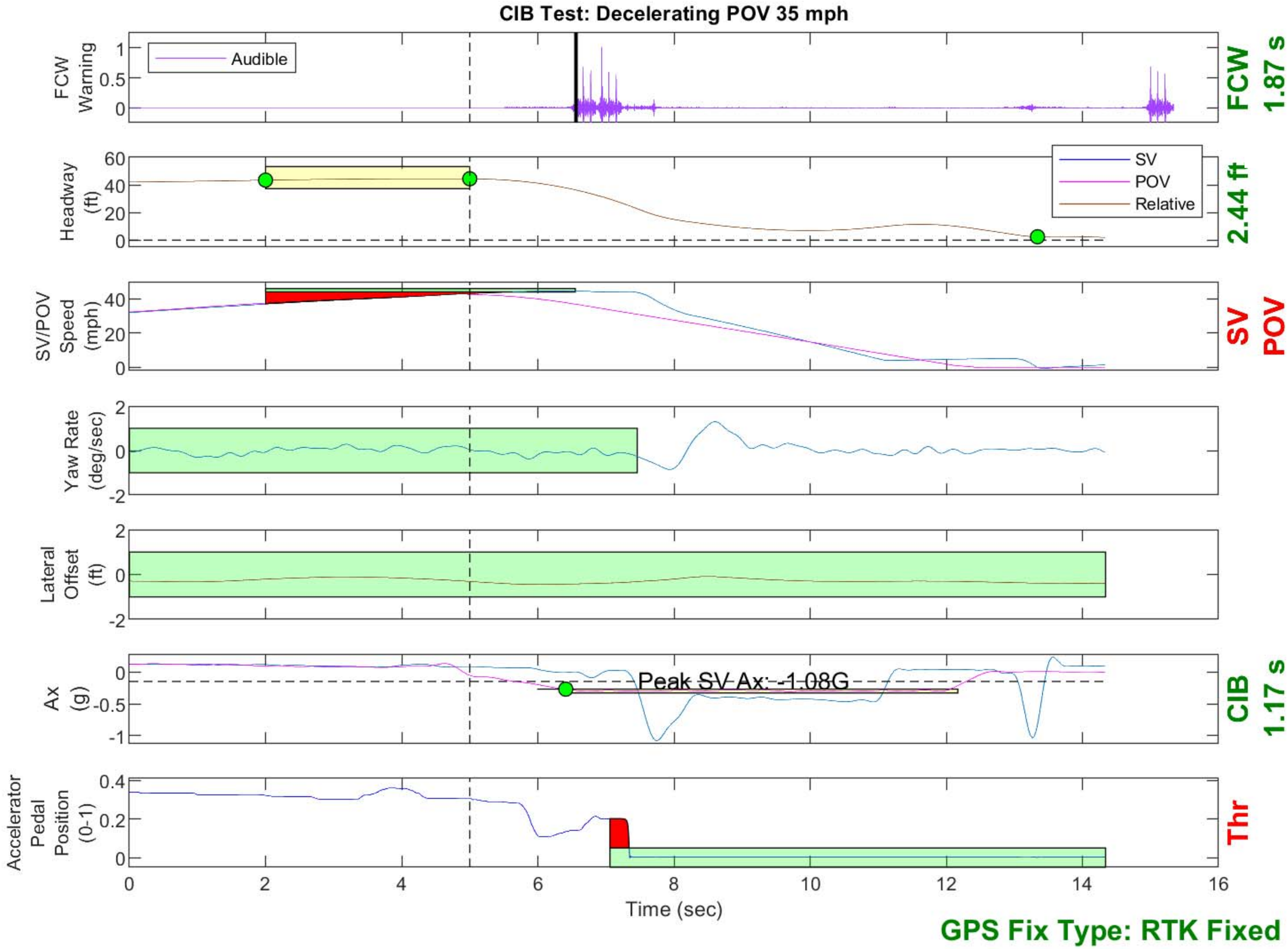


Figure D8. Example Time History Displaying Various Invalid Criteria

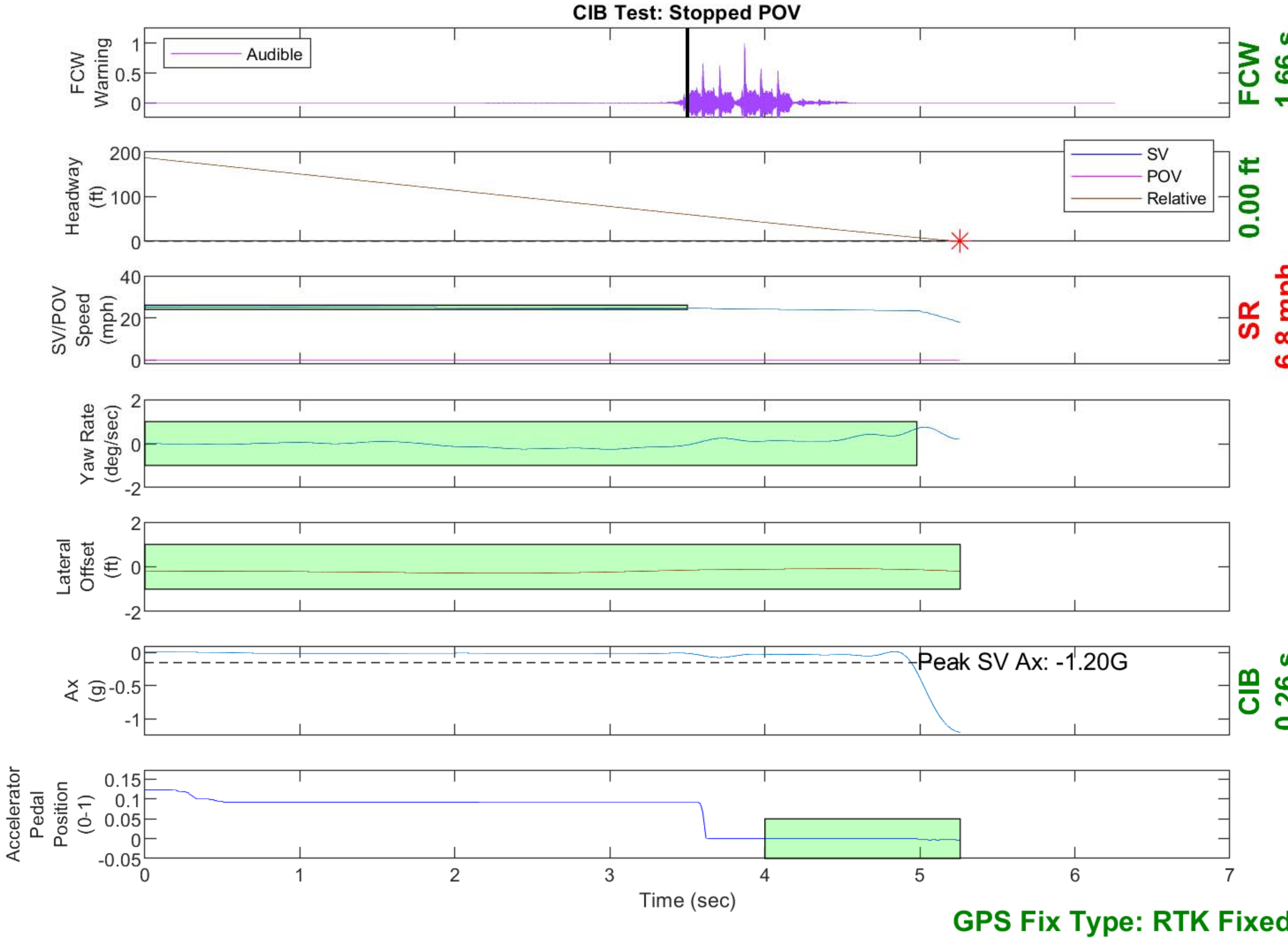


Figure D9. Example Time History for a Failed Run

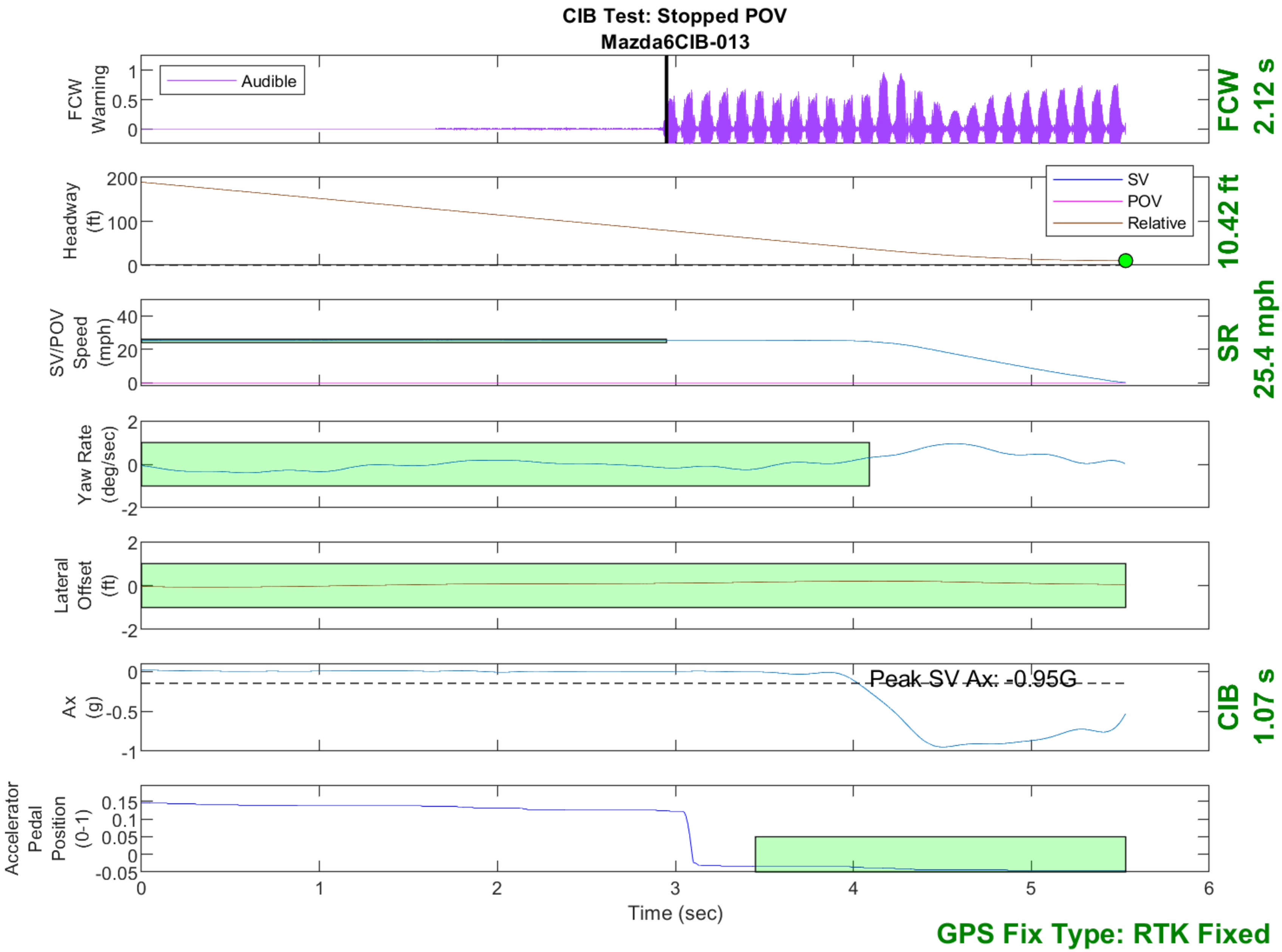


Figure D10. Time History for CIB Run 13, SV Encounters Stopped POV

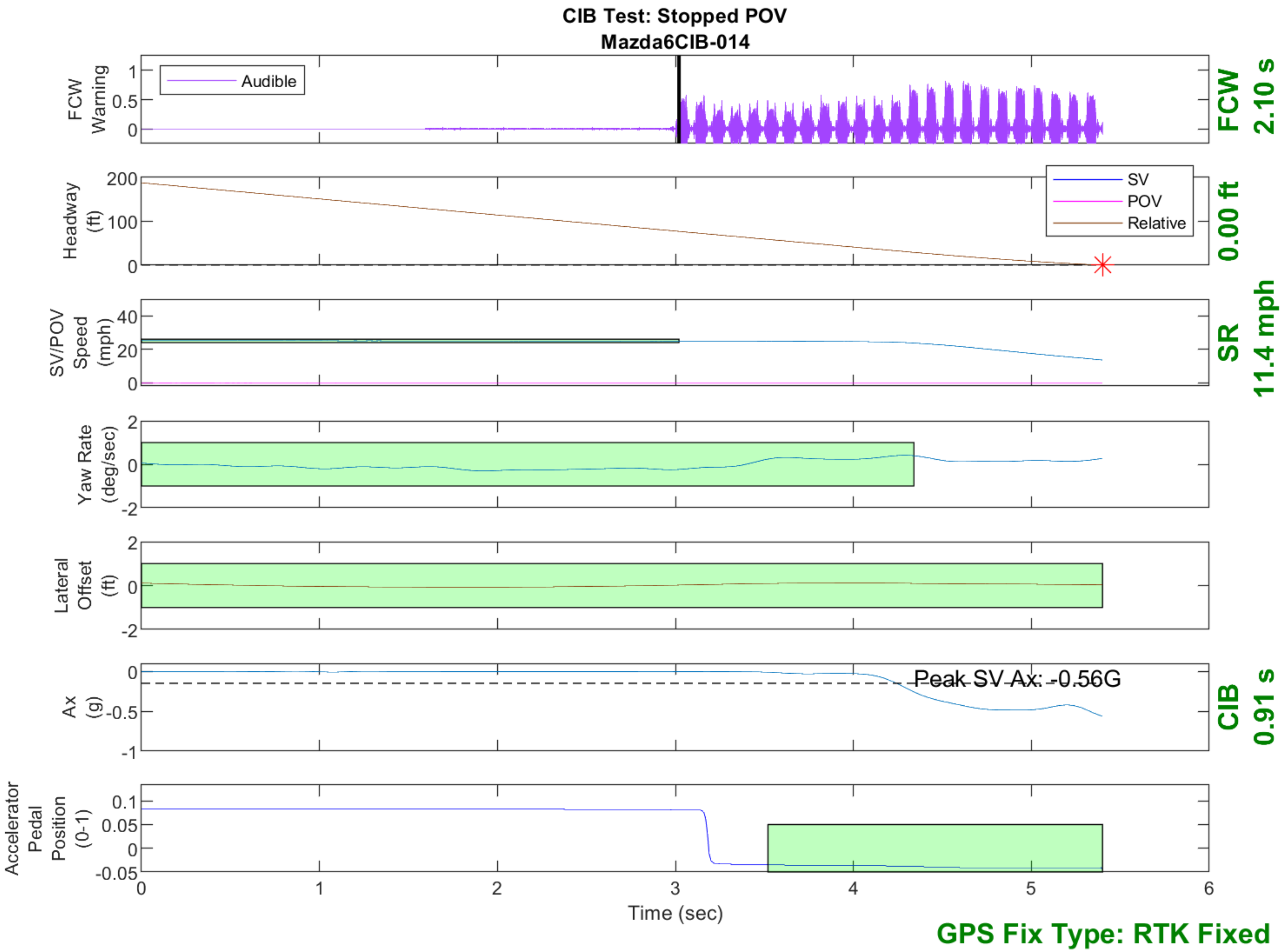


Figure D11. Time History for CIB Run 14, SV Encounters Stopped POV

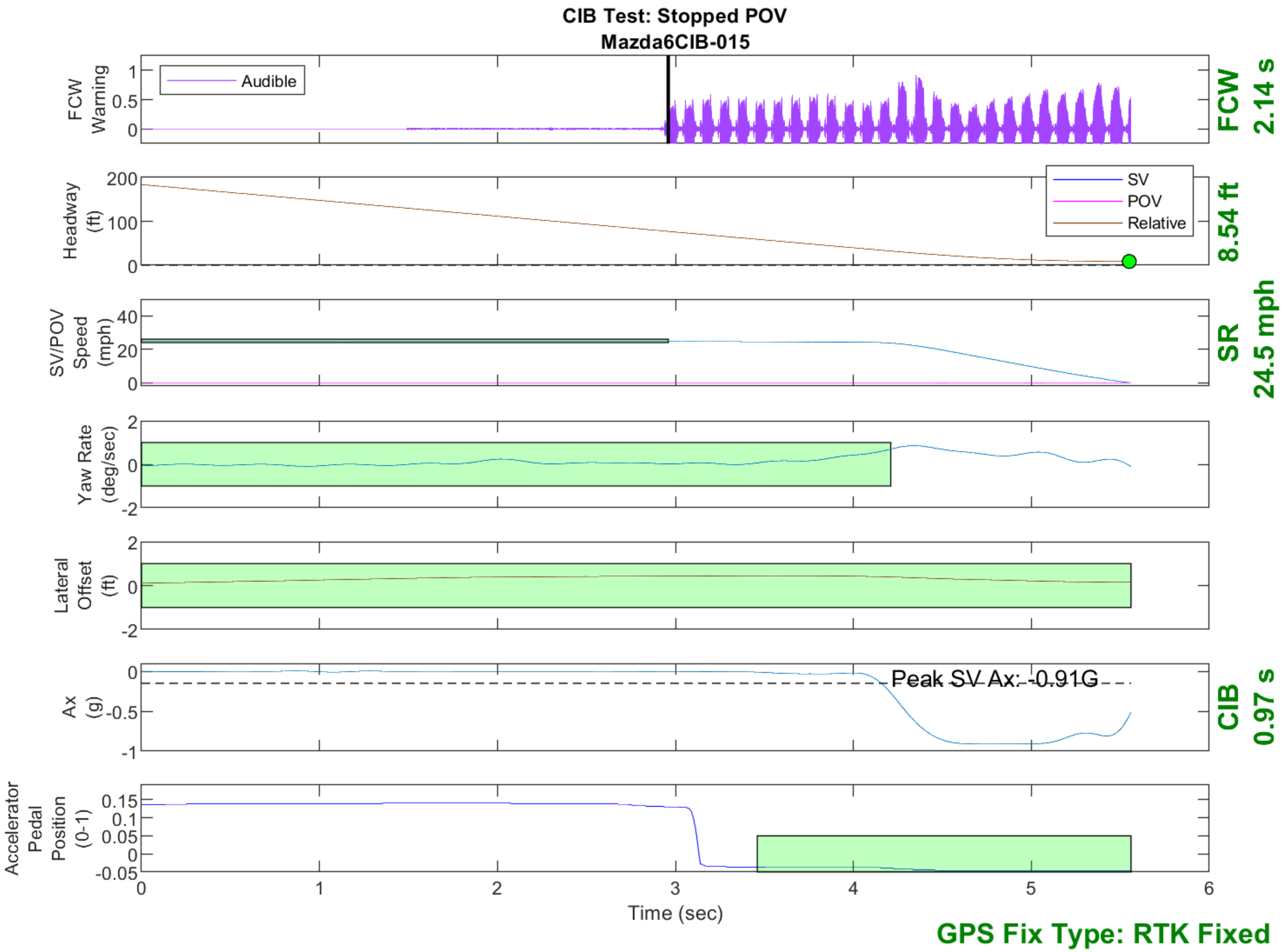


Figure D12. Time History for CIB Run 15, SV Encounters Stopped POV

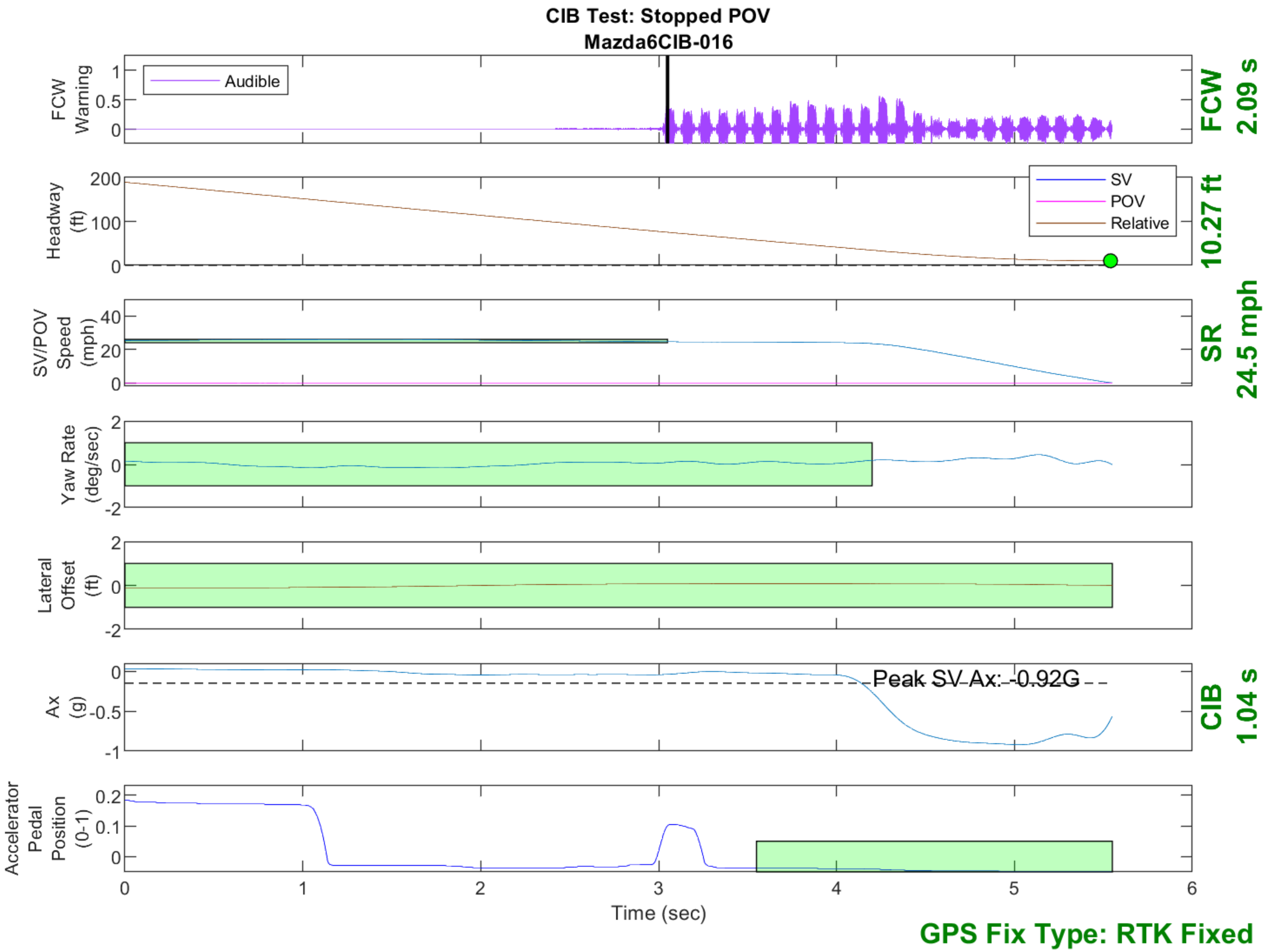


Figure D13. Time History for CIB Run 16, SV Encounters Stopped POV

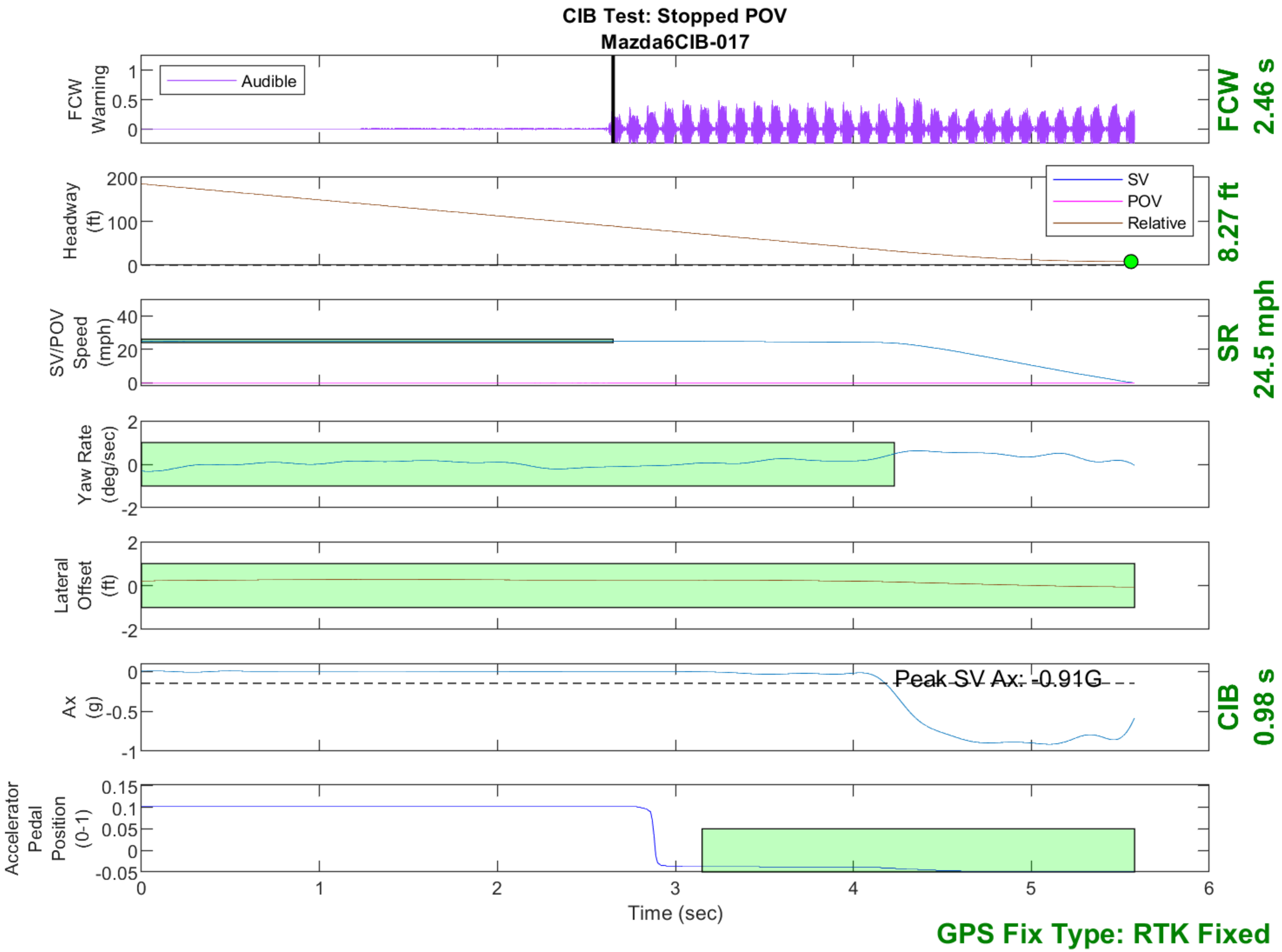


Figure D14. Time History for CIB Run 17, SV Encounters Stopped POV

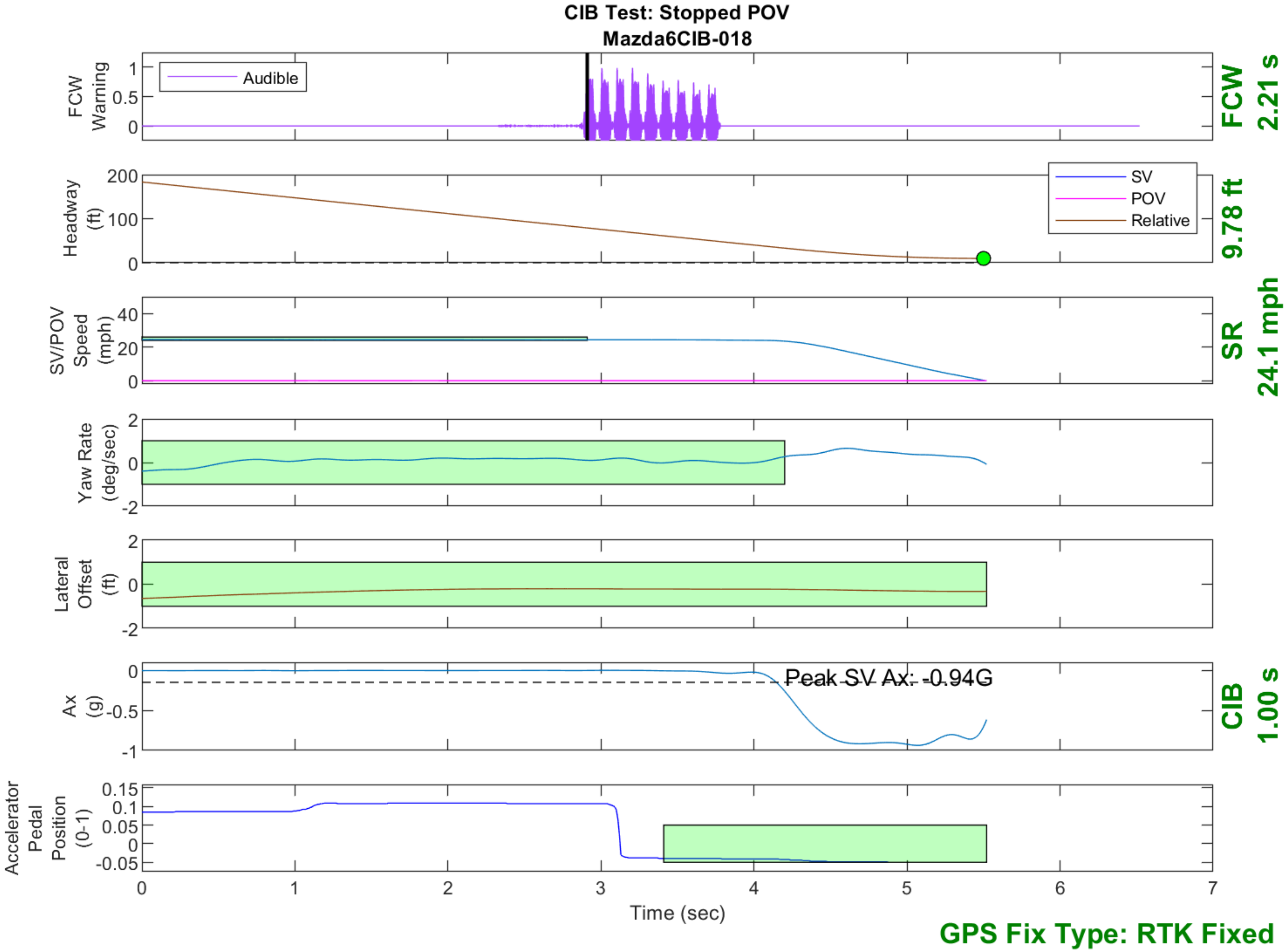


Figure D15. Time History for CIB Run 18, SV Encounters Stopped POV

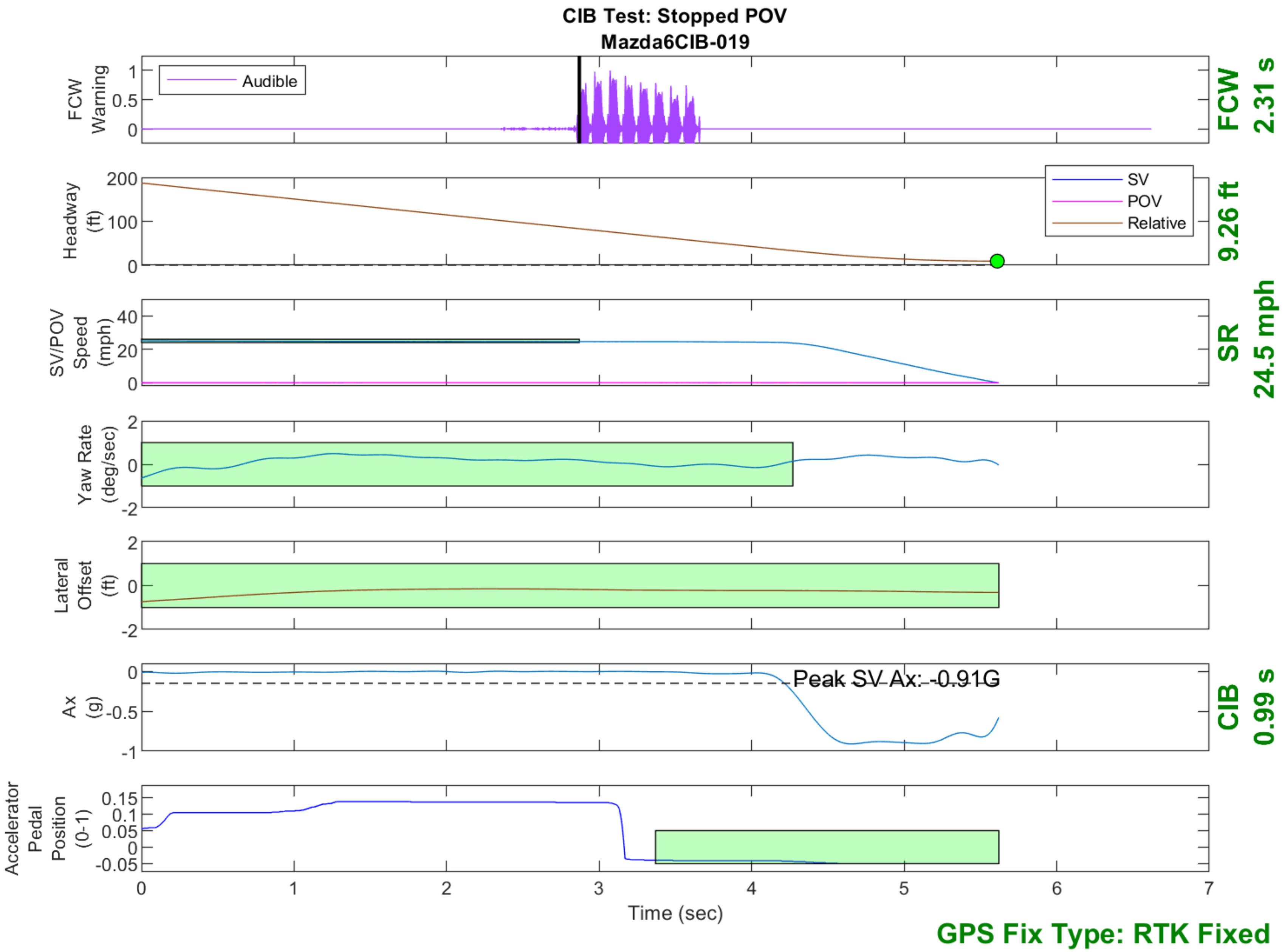


Figure D16. Time History for CIB Run 19, SV Encounters Stopped POV

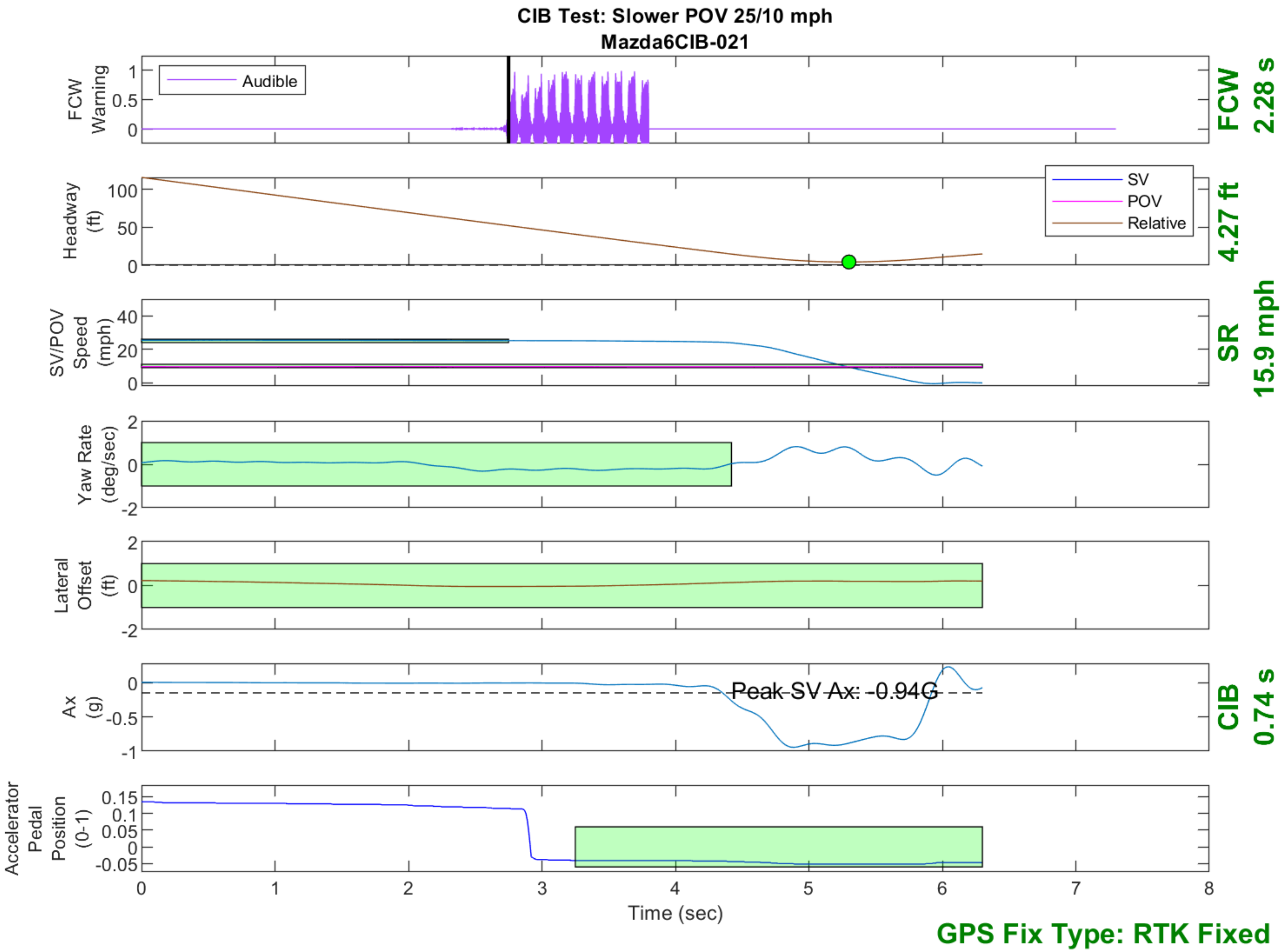


Figure D17. Time History for CIB Run 21, SV Encounters Slower POV, SV 25 mph, POV 10 mph

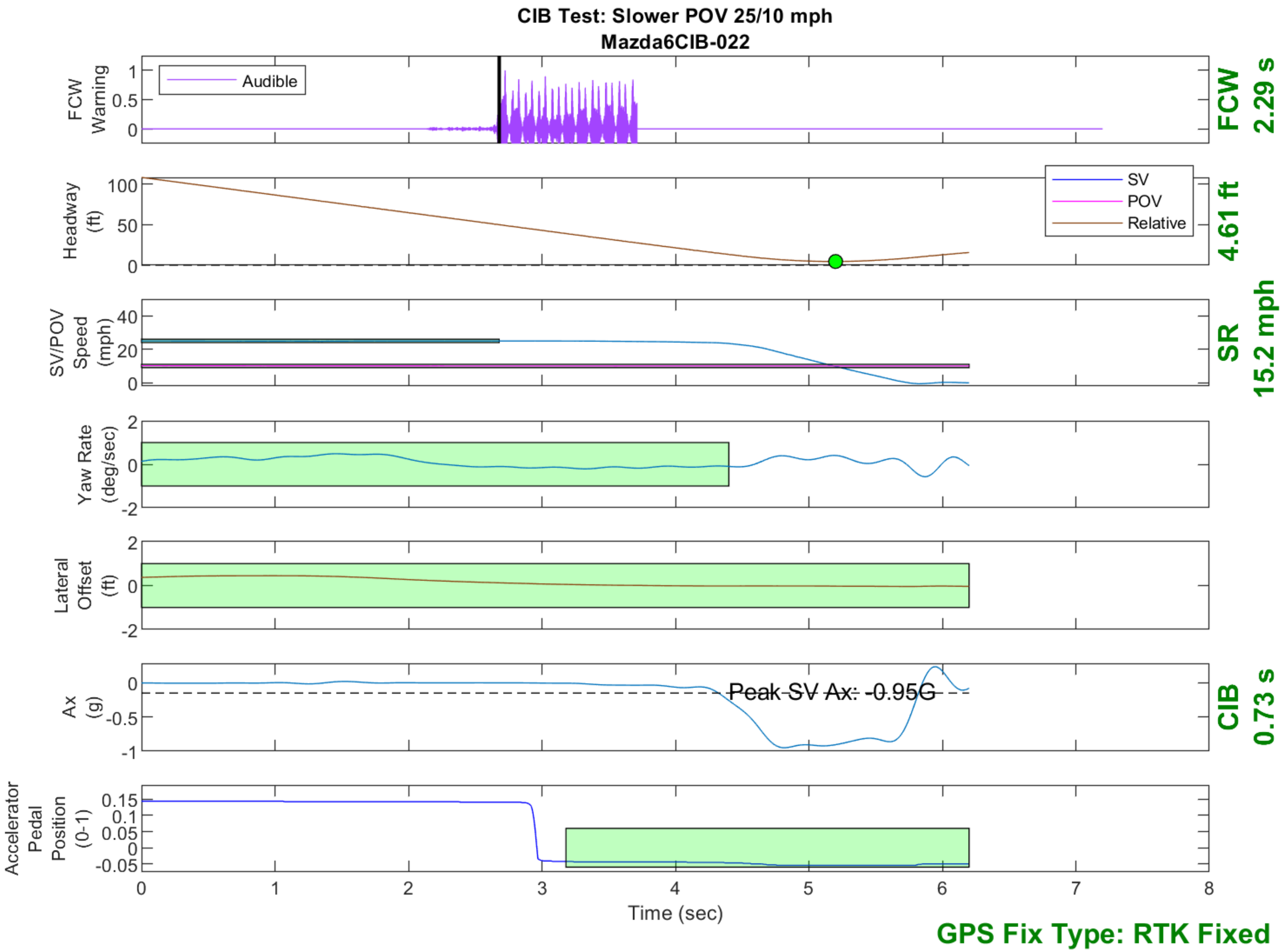


Figure D18. Time History for CIB Run 22, SV Encounters Slower POV, SV 25 mph, POV 10 mph

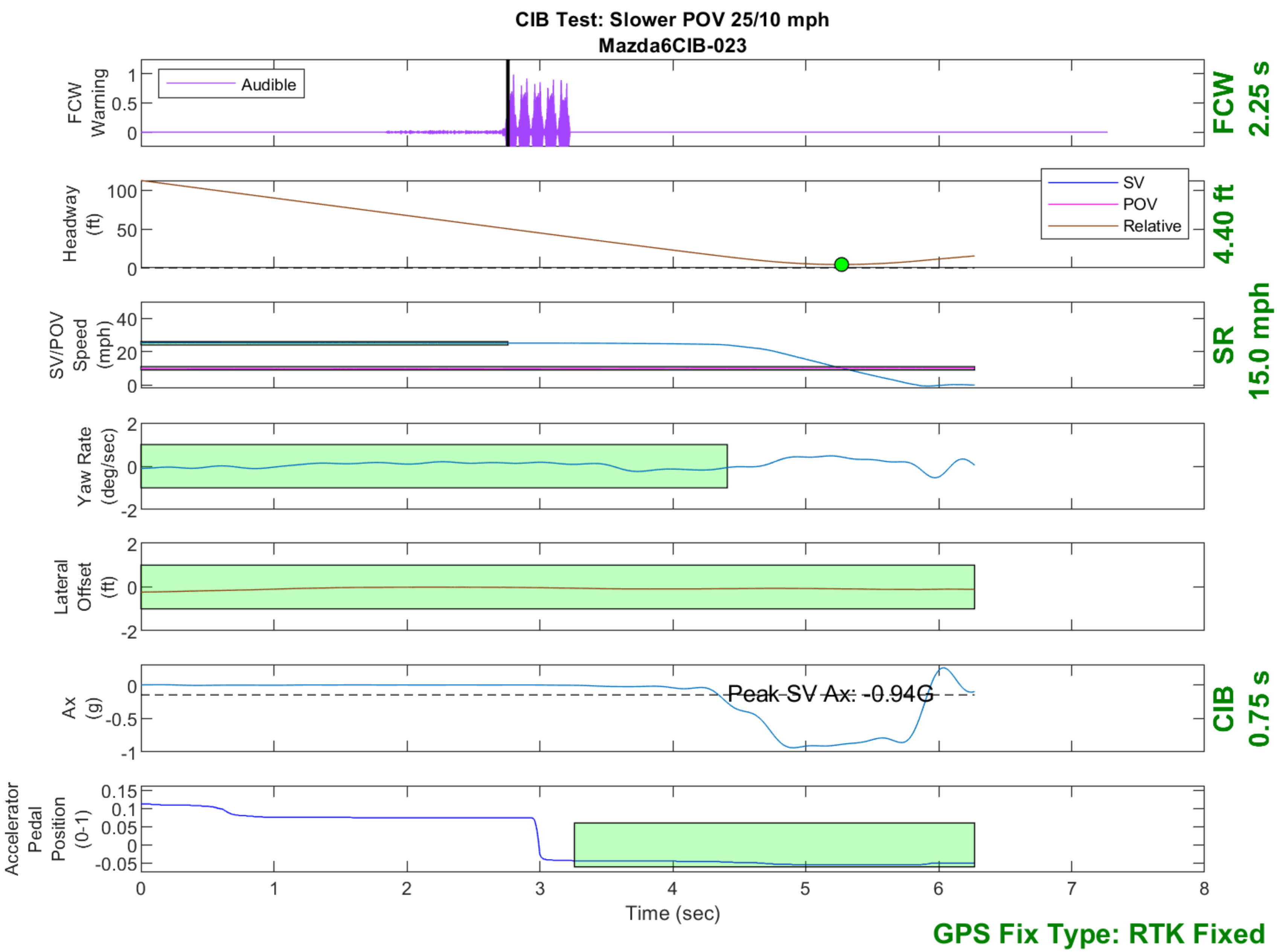


Figure D19. Time History for CIB Run 23, SV Encounters Slower POV, SV 25 mph, POV 10 mph

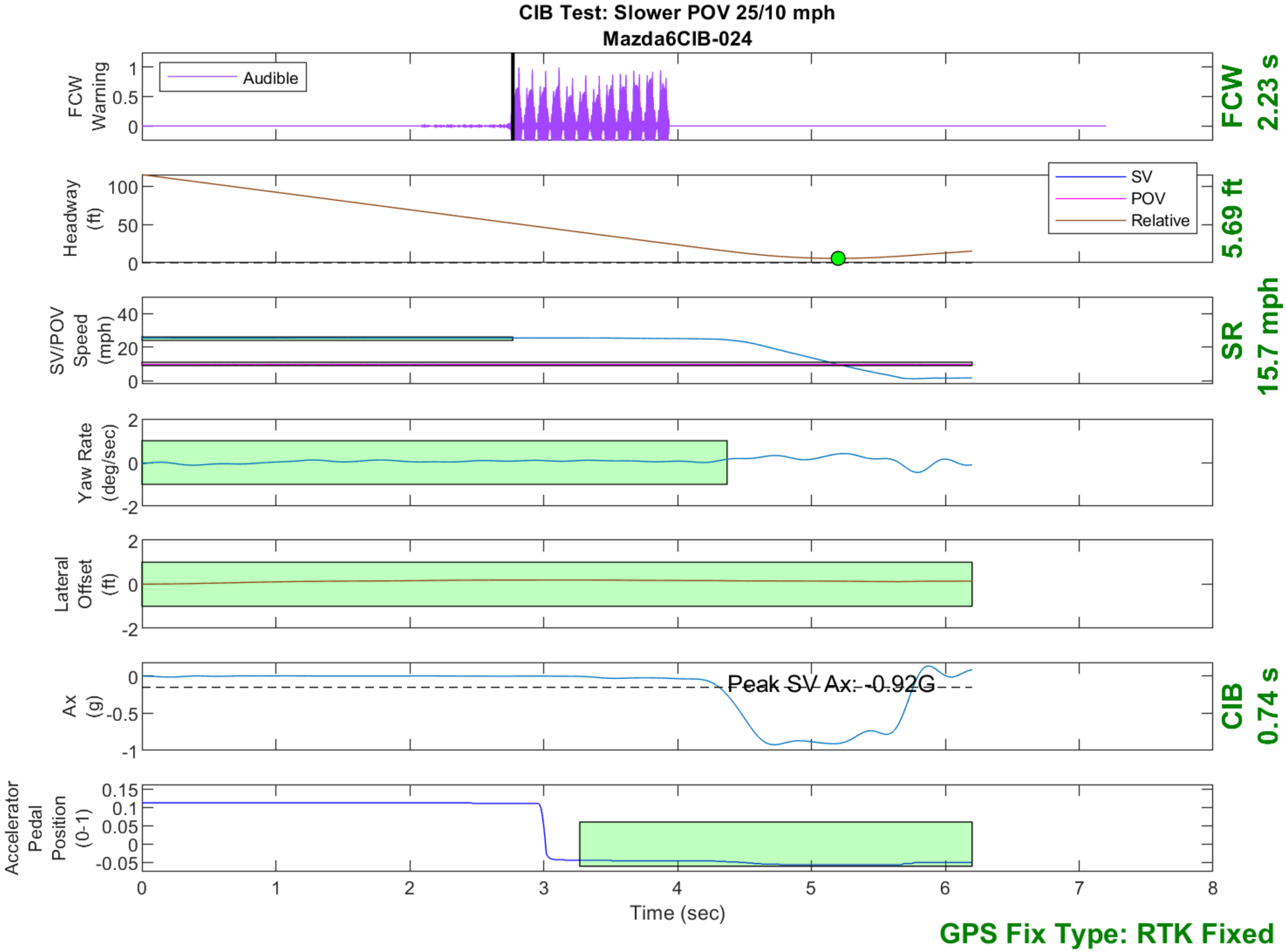


Figure D20. Time History for CIB Run 24, SV Encounters Slower POV, SV 25 mph, POV 10 mph

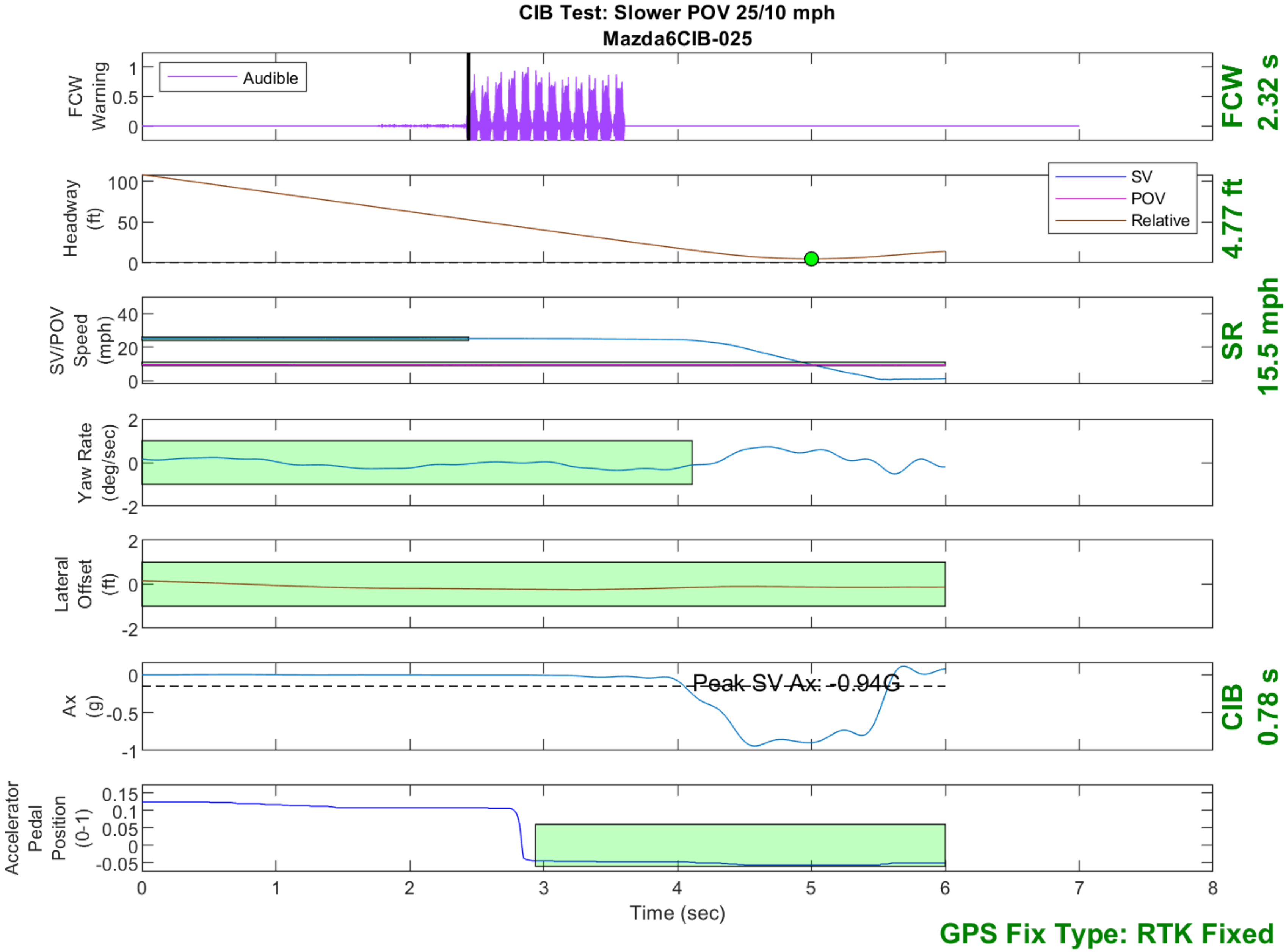


Figure D21. Time History for CIB Run 25, SV Encounters Slower POV, SV 25 mph, POV 10 mph

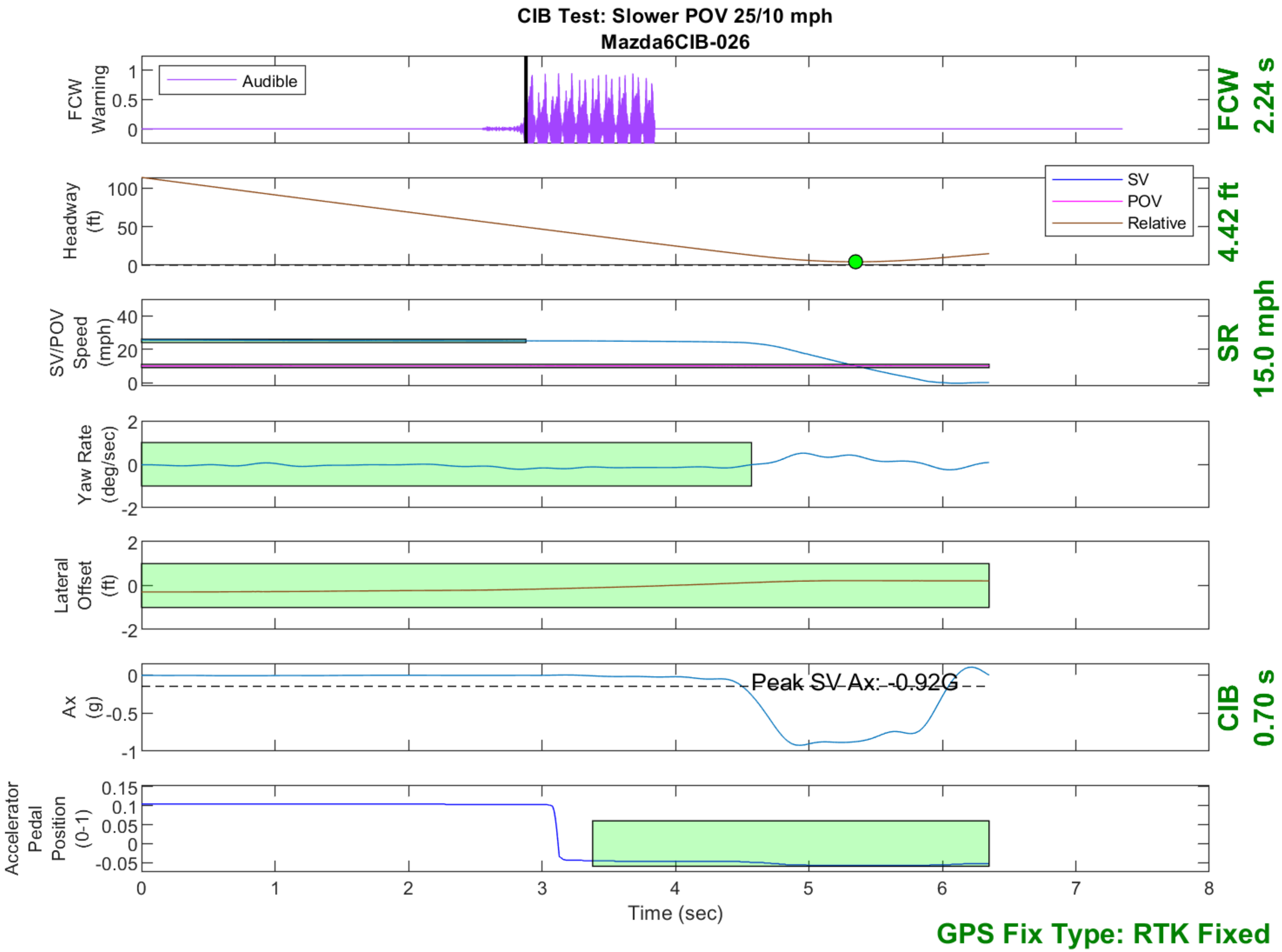


Figure D22. Time History for CIB Run 26, SV Encounters Slower POV, SV 25 mph, POV 10 mph

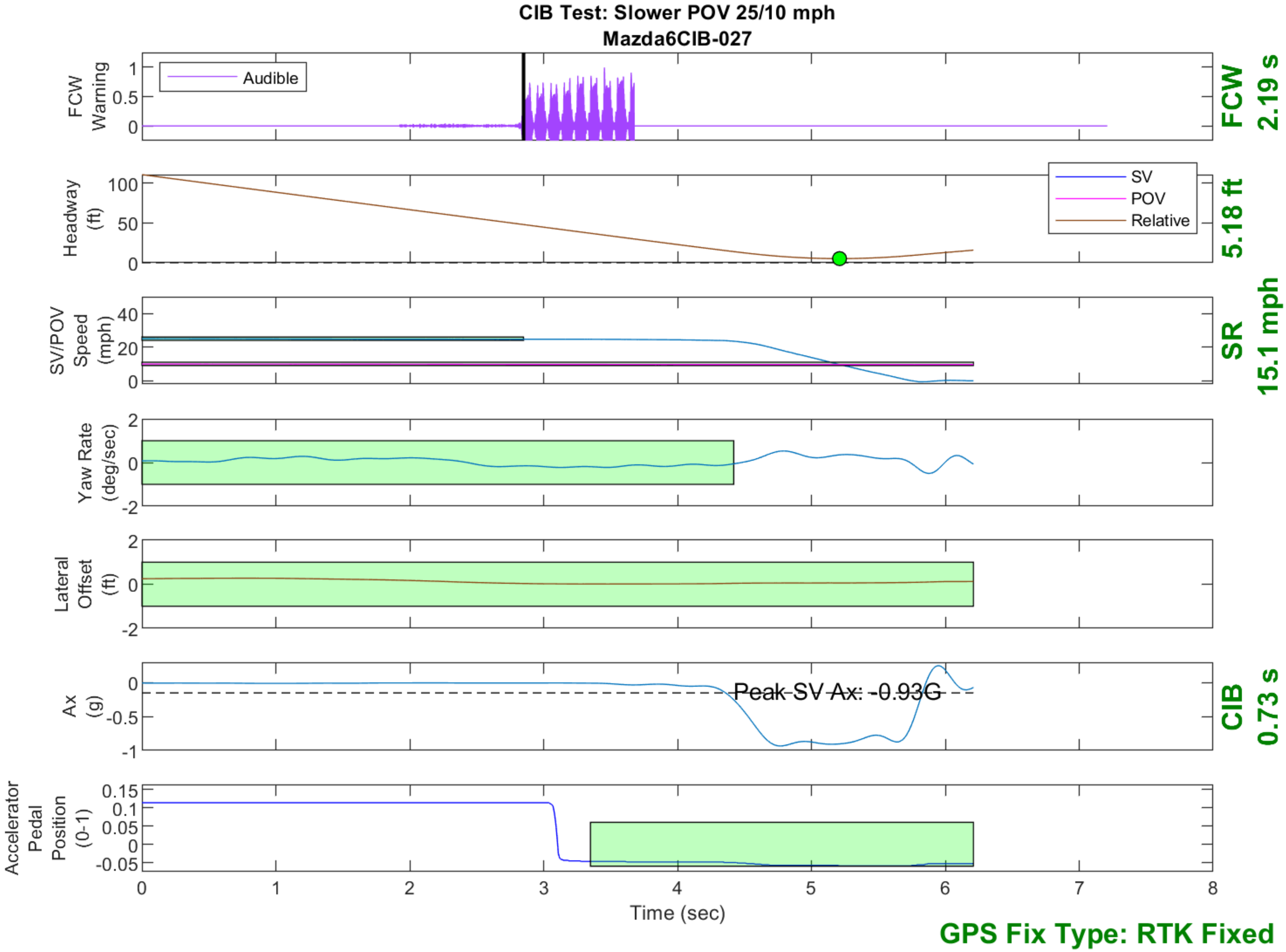


Figure D23. Time History for CIB Run 27, SV Encounters Slower POV, SV 25 mph, POV 10 mph

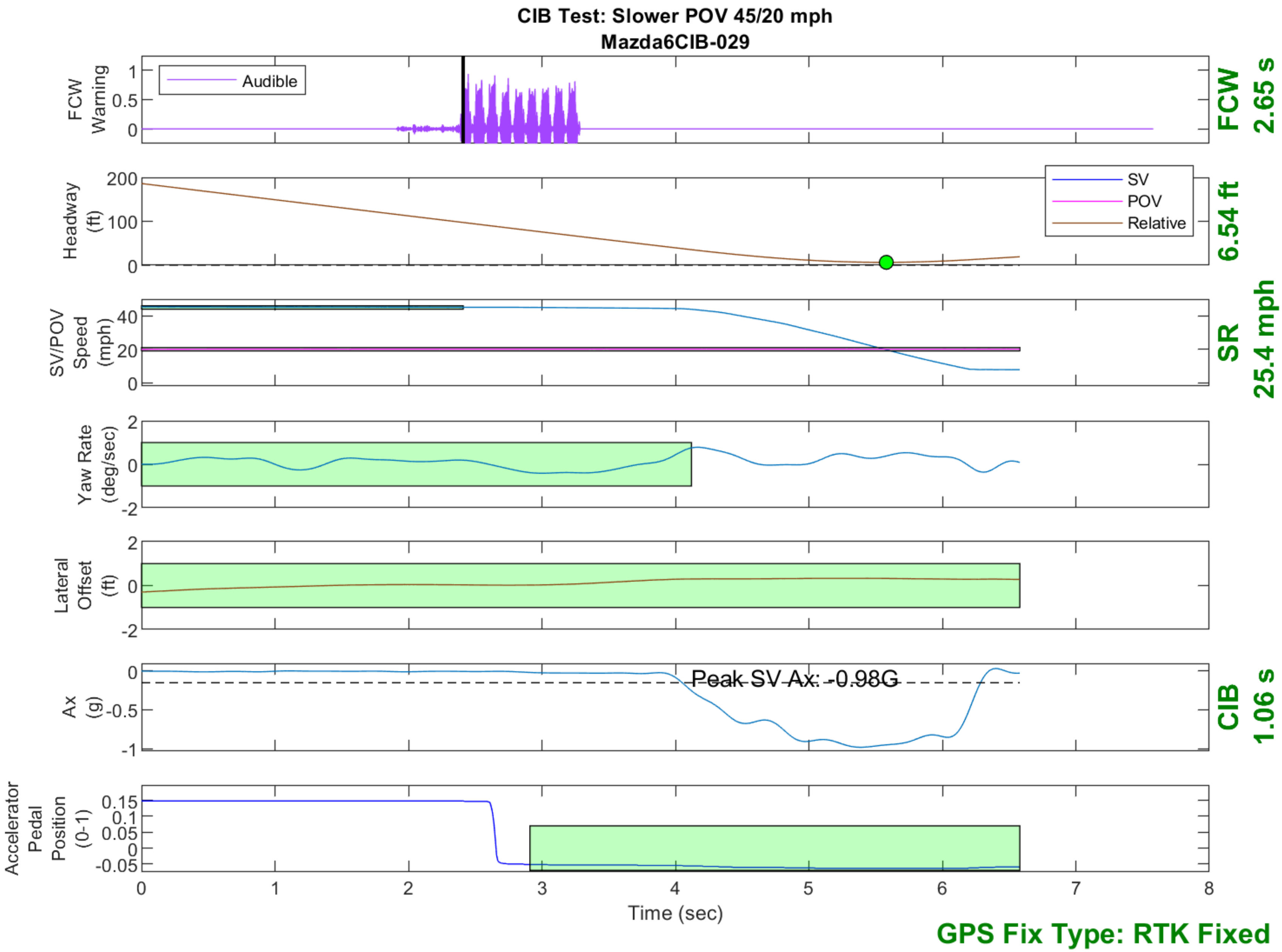


Figure D24. Time History for CIB Run 29, SV Encounters Slower POV, SV 45 mph, POV 20 mph

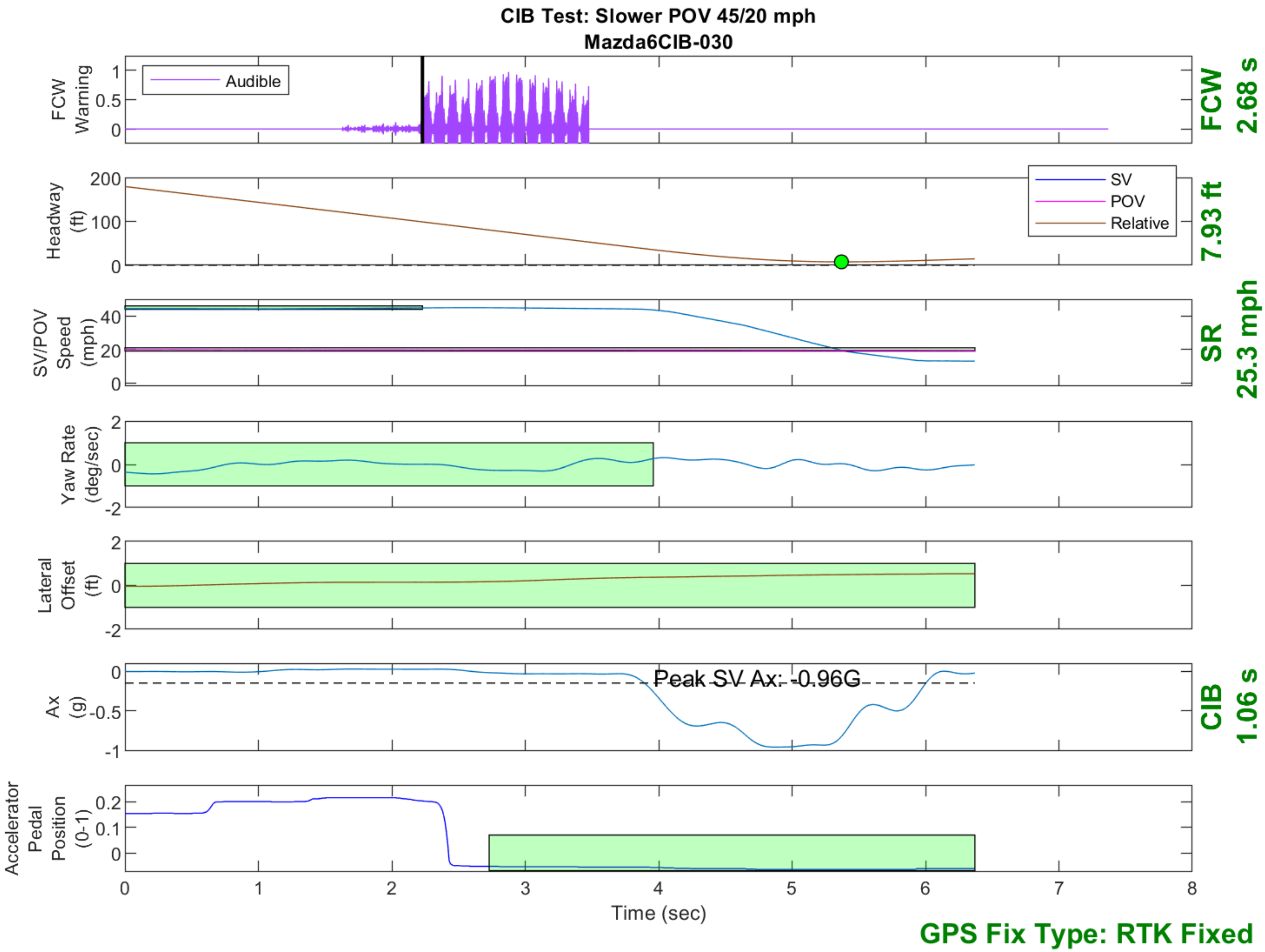


Figure D25. Time History for CIB Run 30, SV Encounters Slower POV, SV 45 mph, POV 20 mph

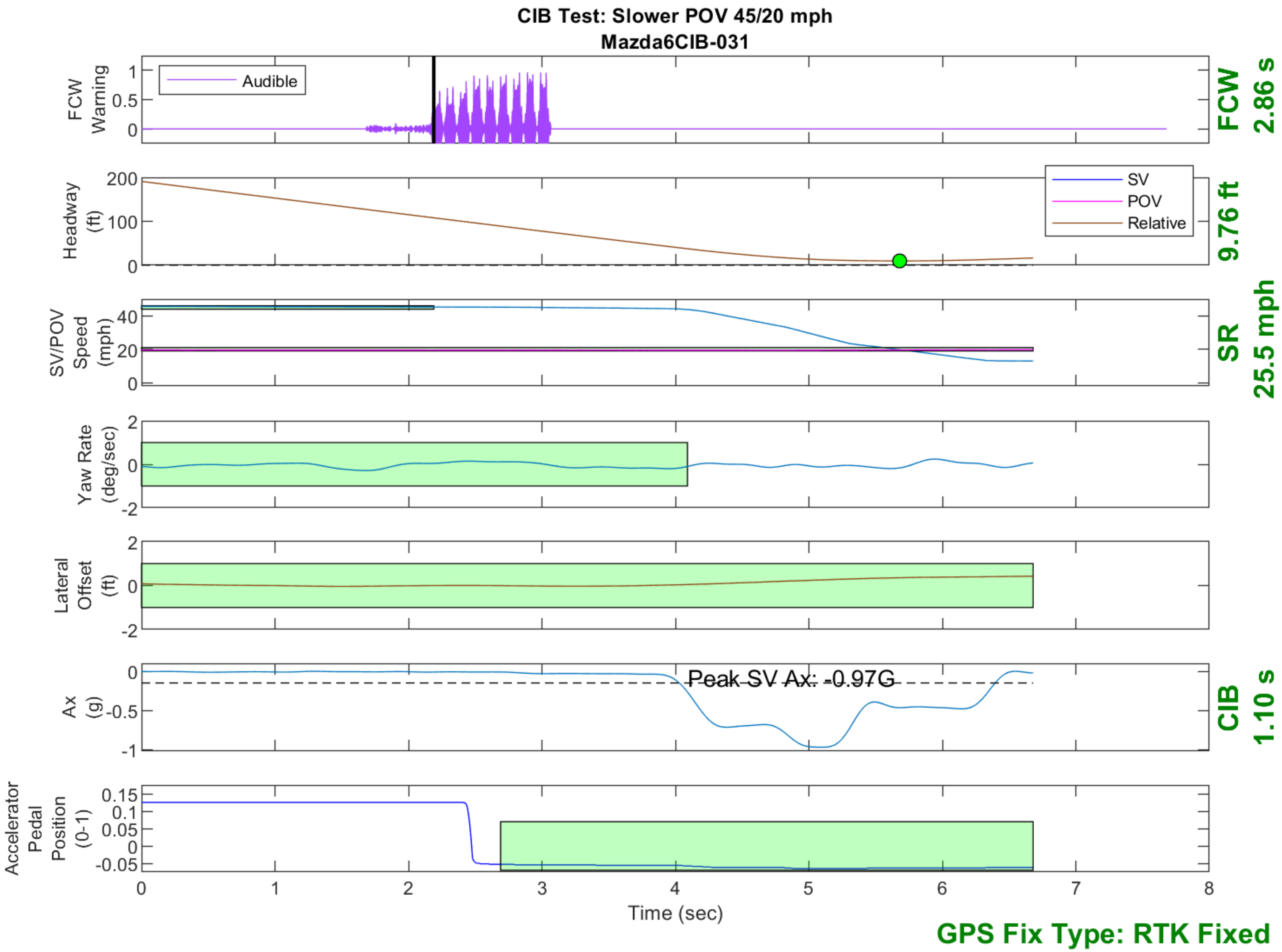


Figure D26. Time History for CIB Run 31, SV Encounters Slower POV, SV 45 mph, POV 20 mph

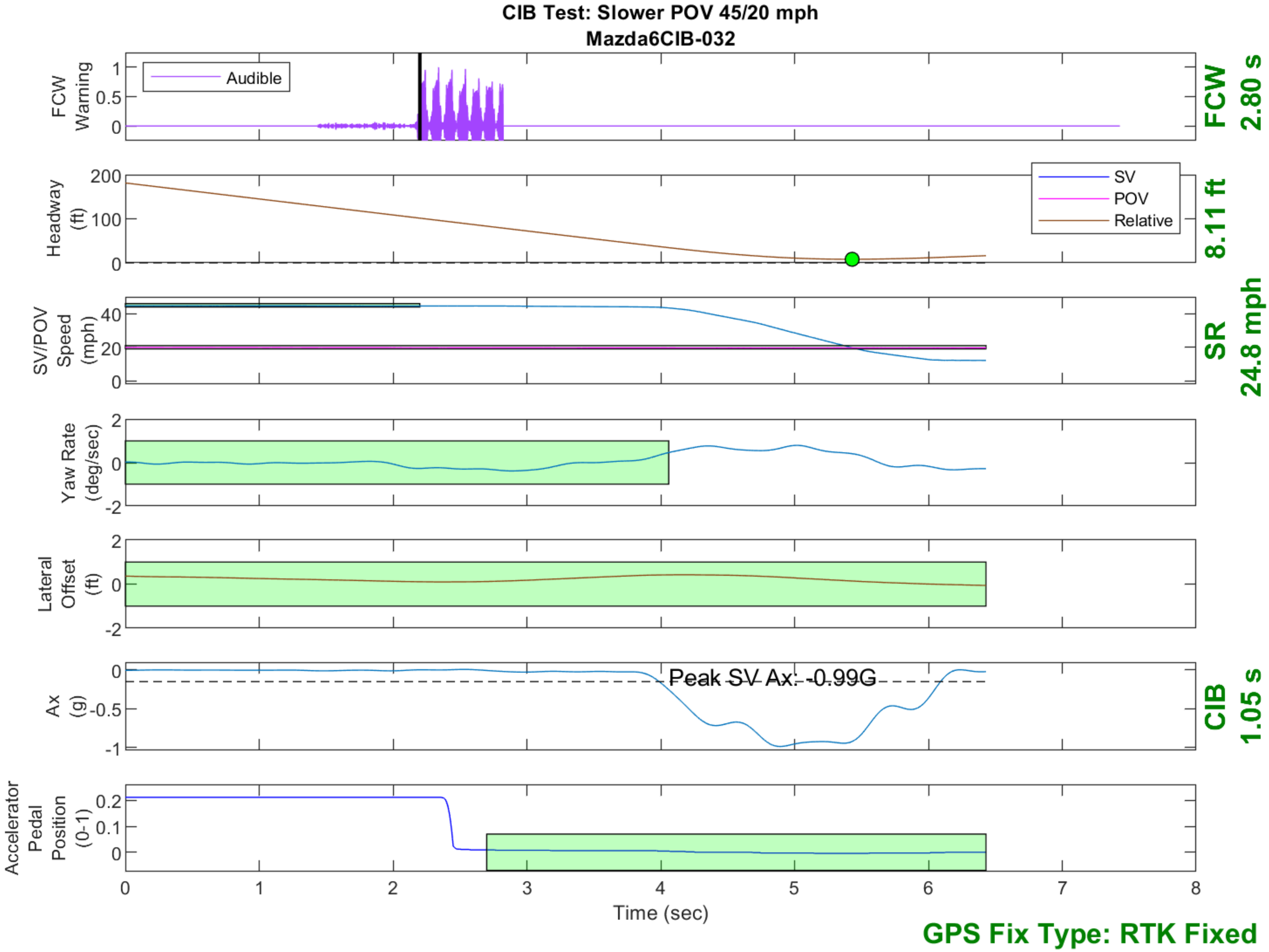


Figure D27. Time History for CIB Run 32, SV Encounters Slower POV, SV 45 mph, POV 20 mph

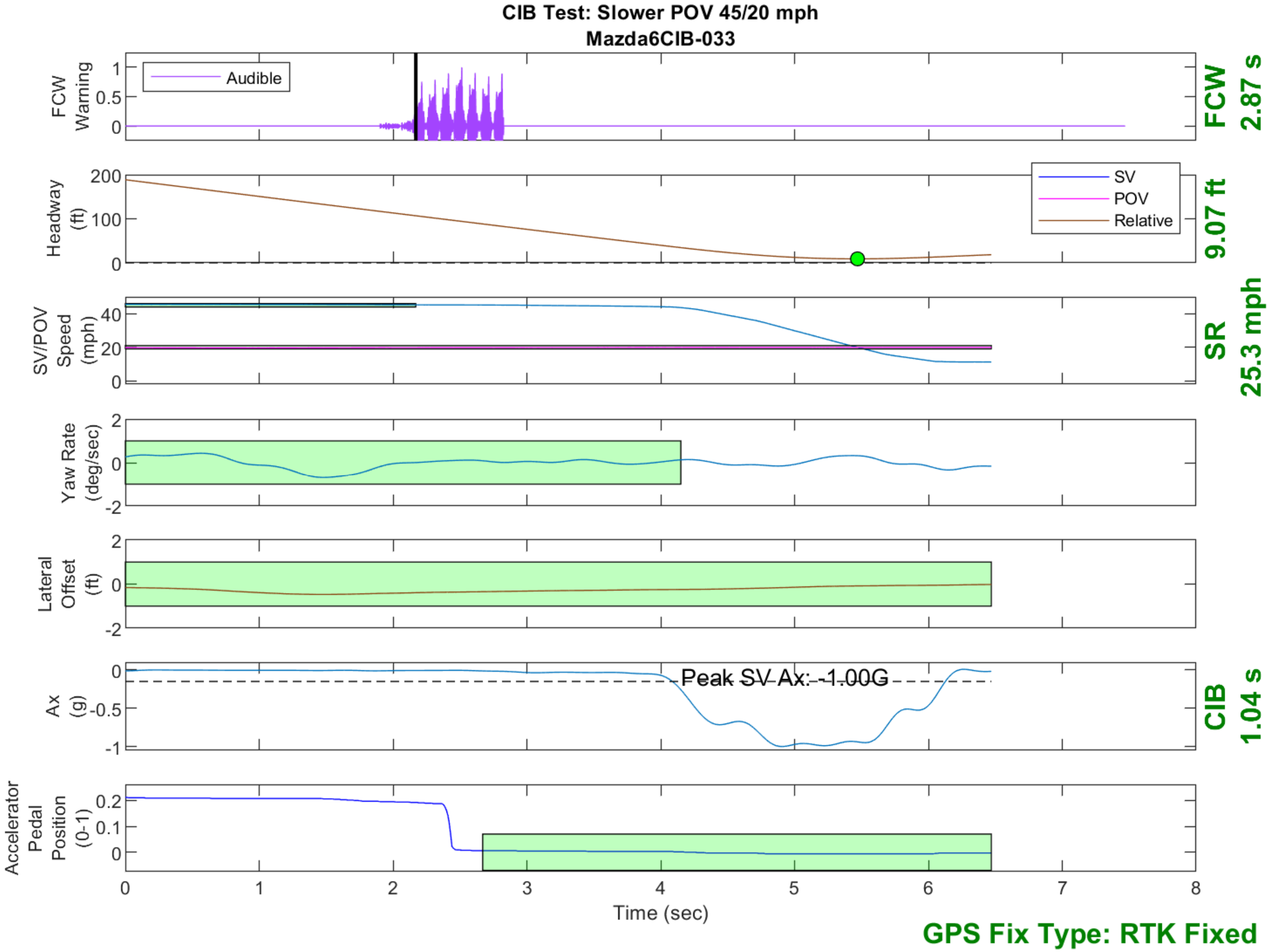


Figure D28. Time History for CIB Run 33, SV Encounters Slower POV, SV 45 mph, POV 20 mph

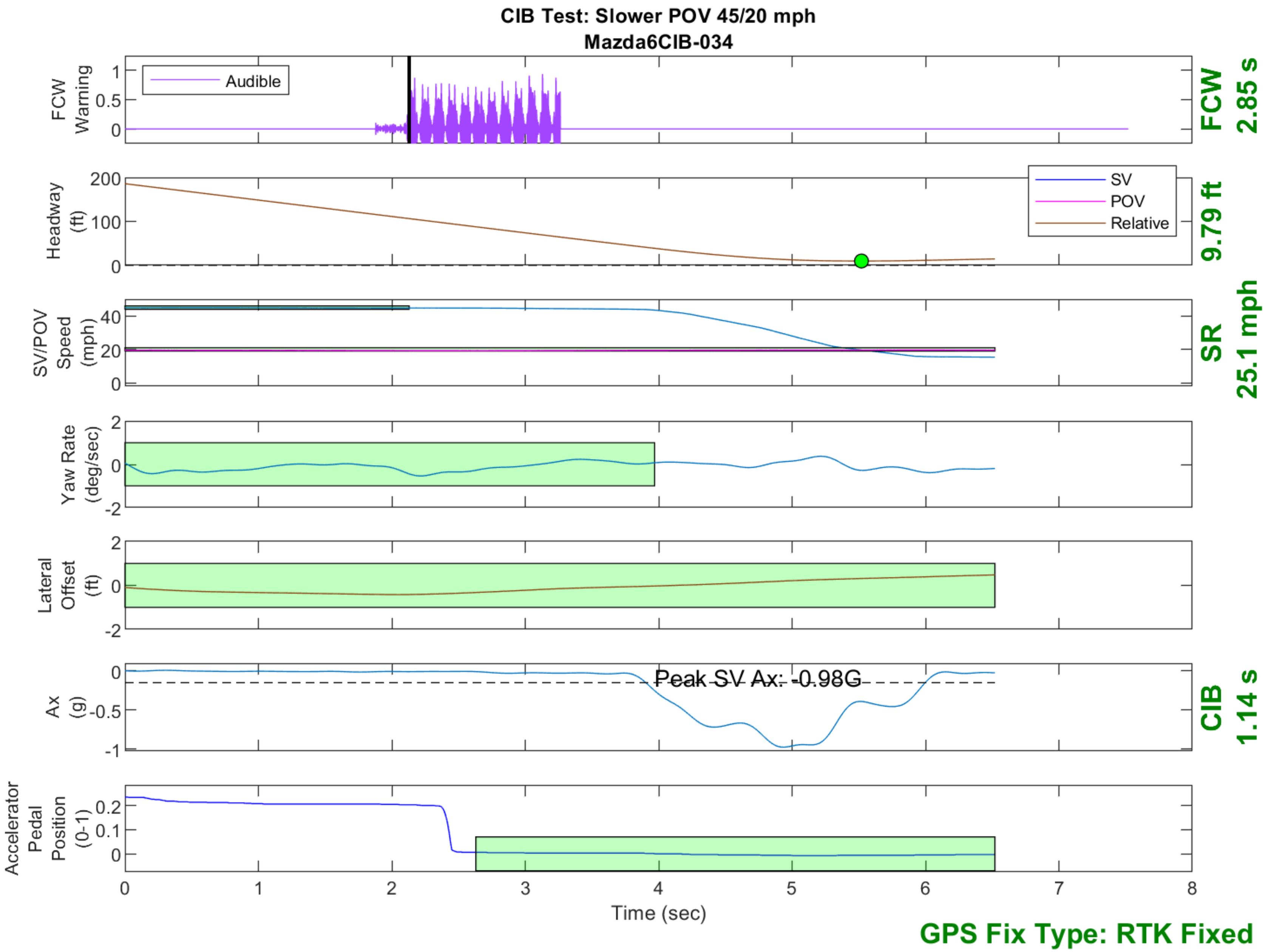


Figure D29. Time History for CIB Run 34, SV Encounters Slower POV, SV 45 mph, POV 20 mph

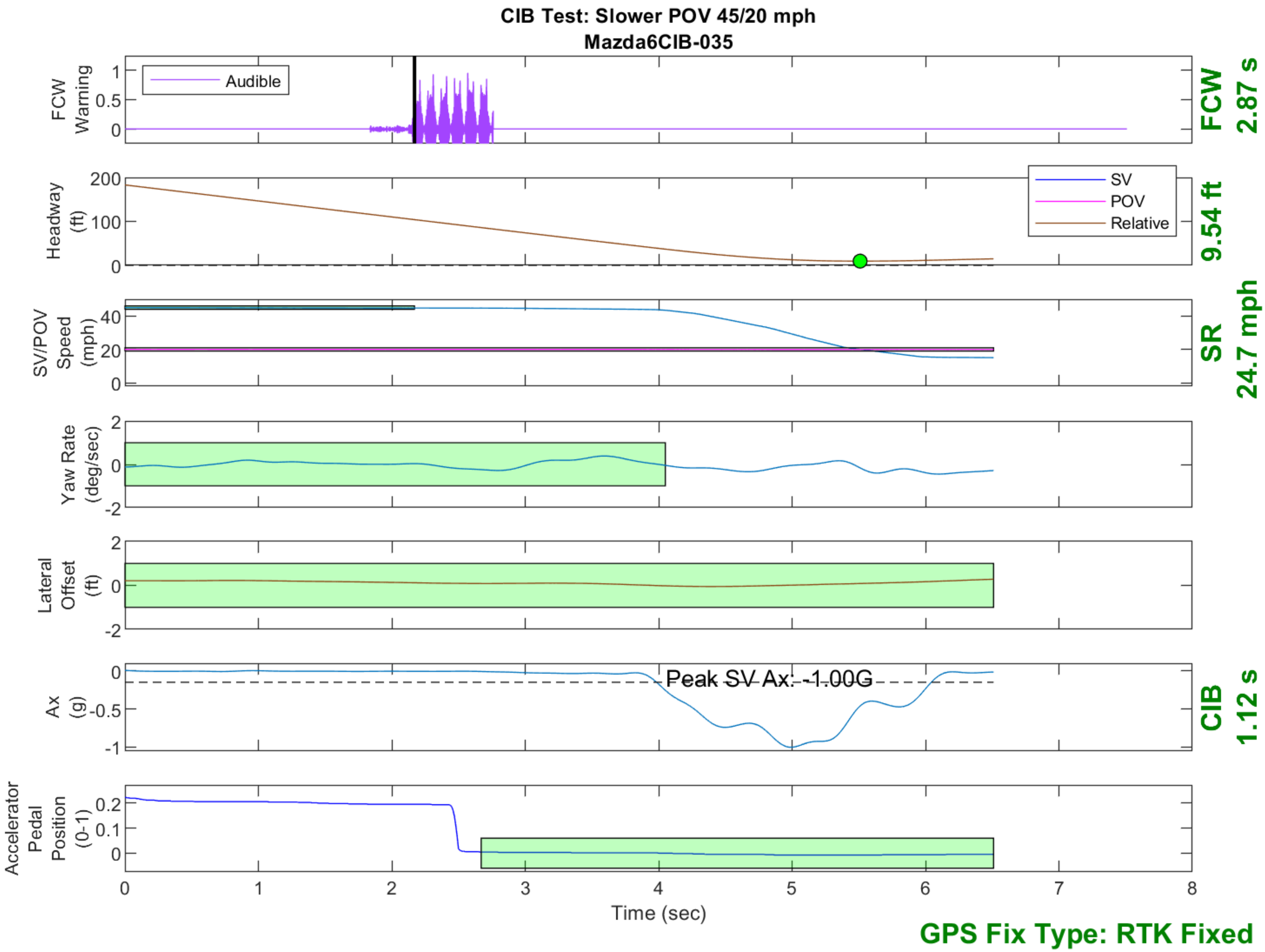


Figure D30. Time History for CIB Run 35, SV Encounters Slower POV, SV 45 mph, POV 20 mph

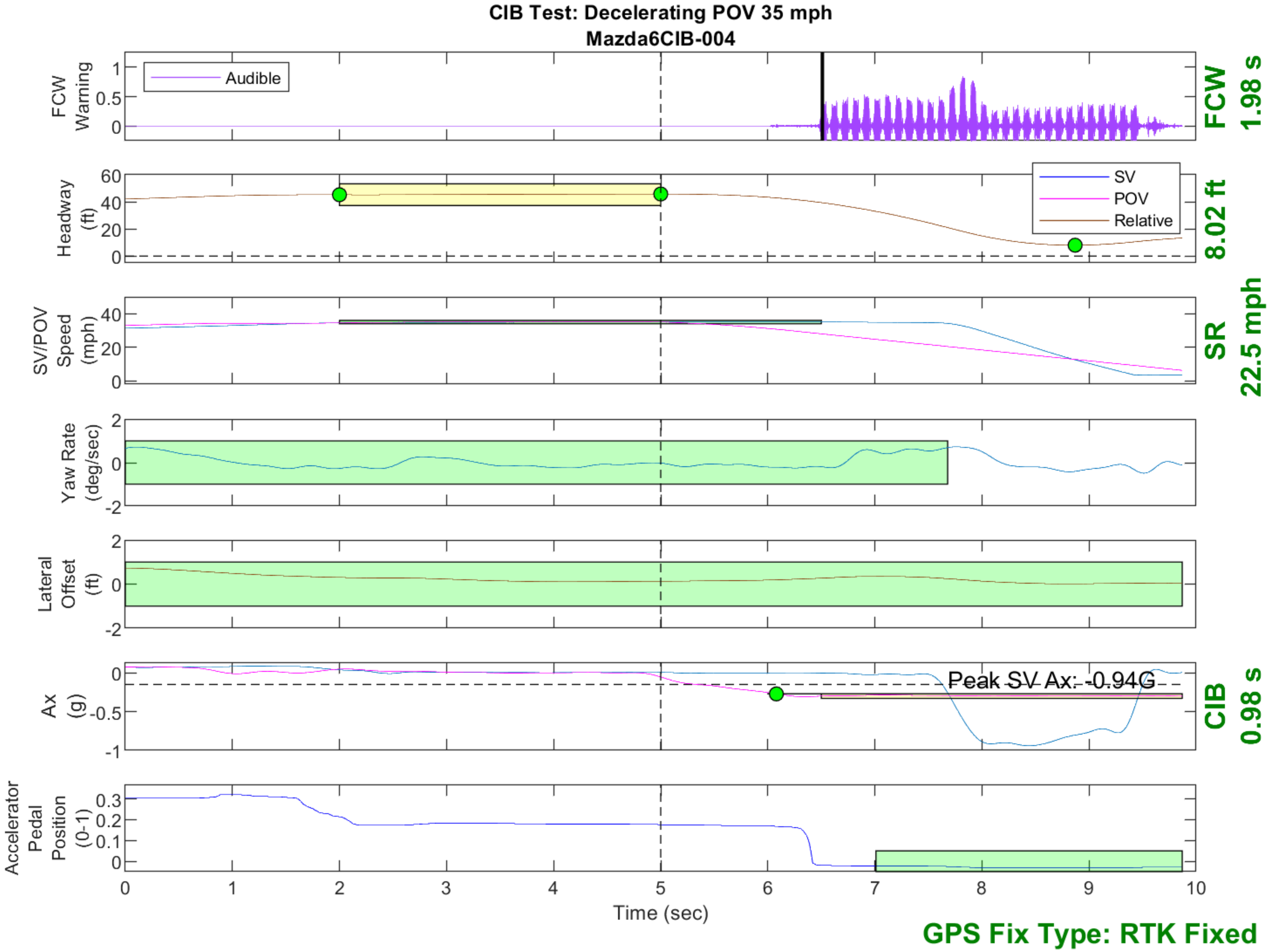


Figure D31. Time History for CIB Run 4, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

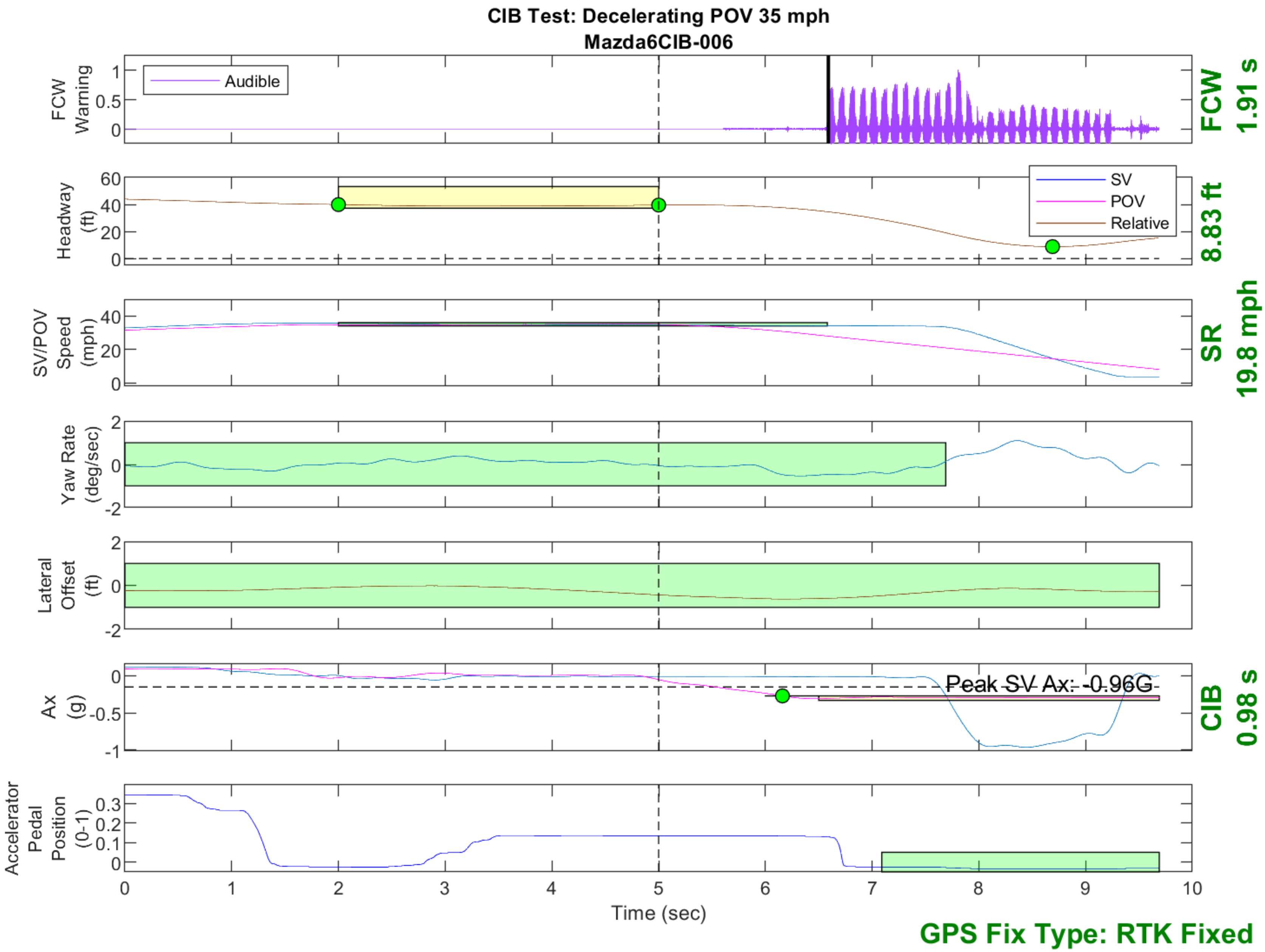


Figure D32. Time History for CIB Run 6, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

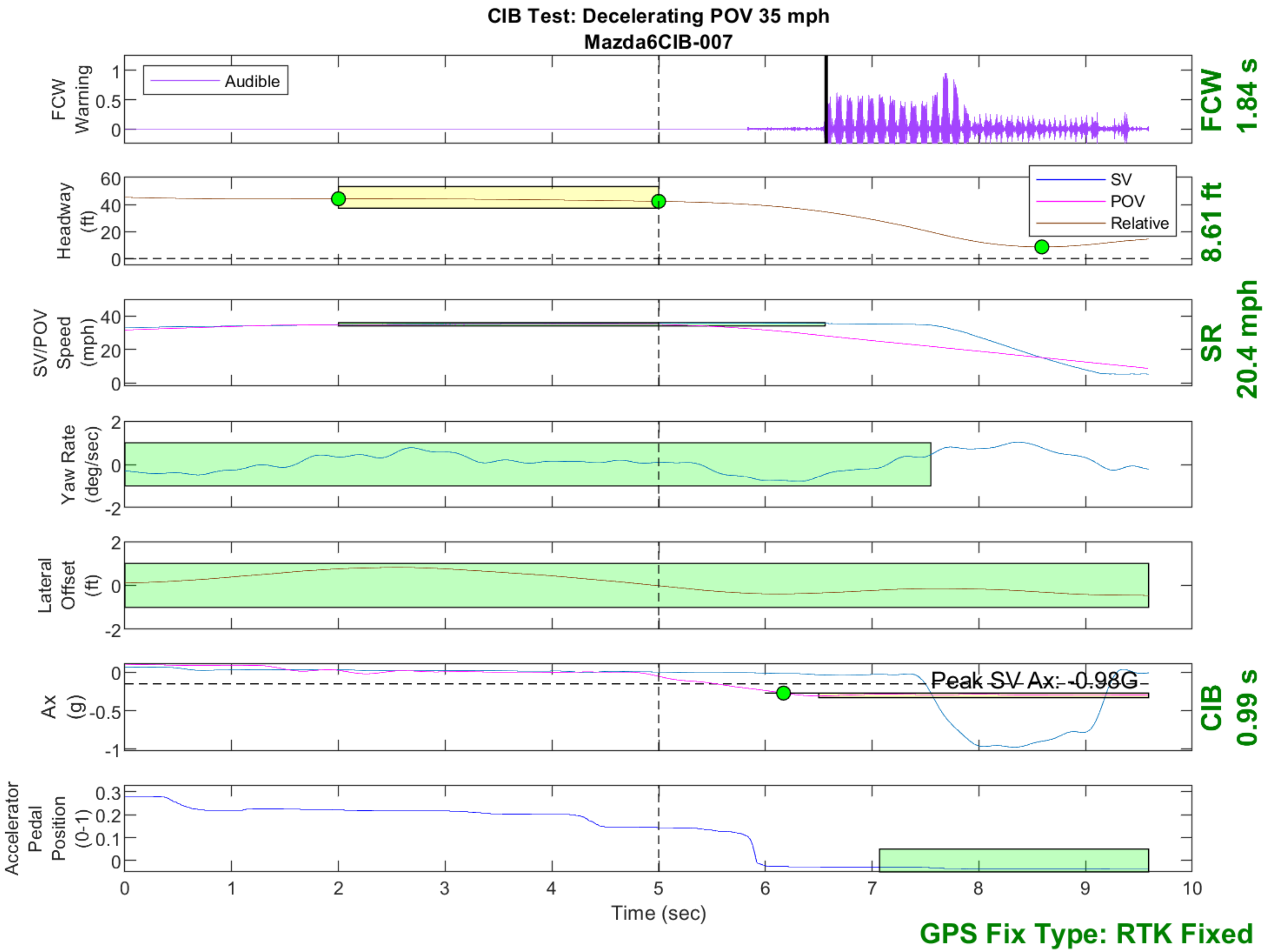


Figure D33. Time History for CIB Run 7, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

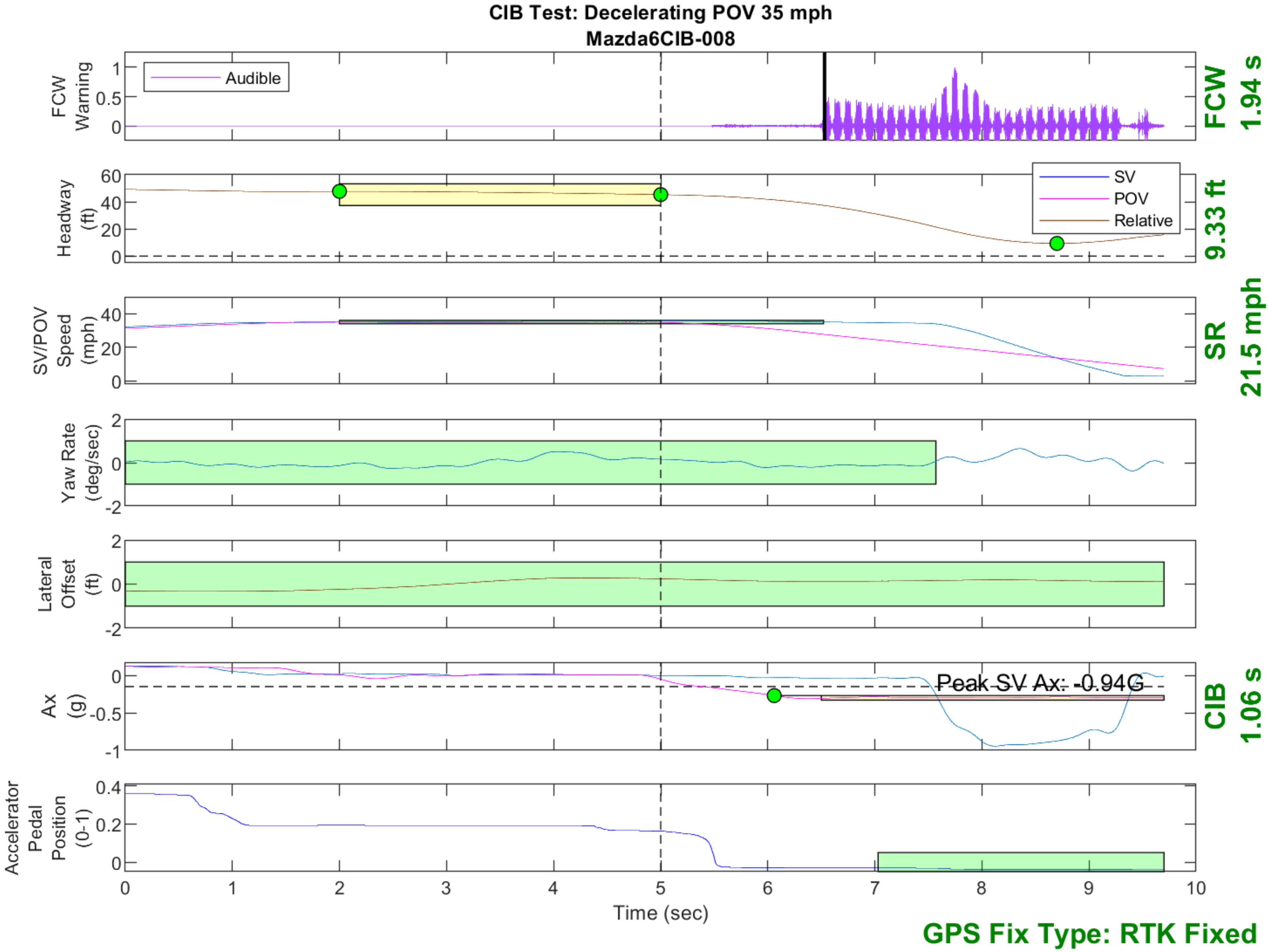


Figure D34. Time History for CIB Run 8, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

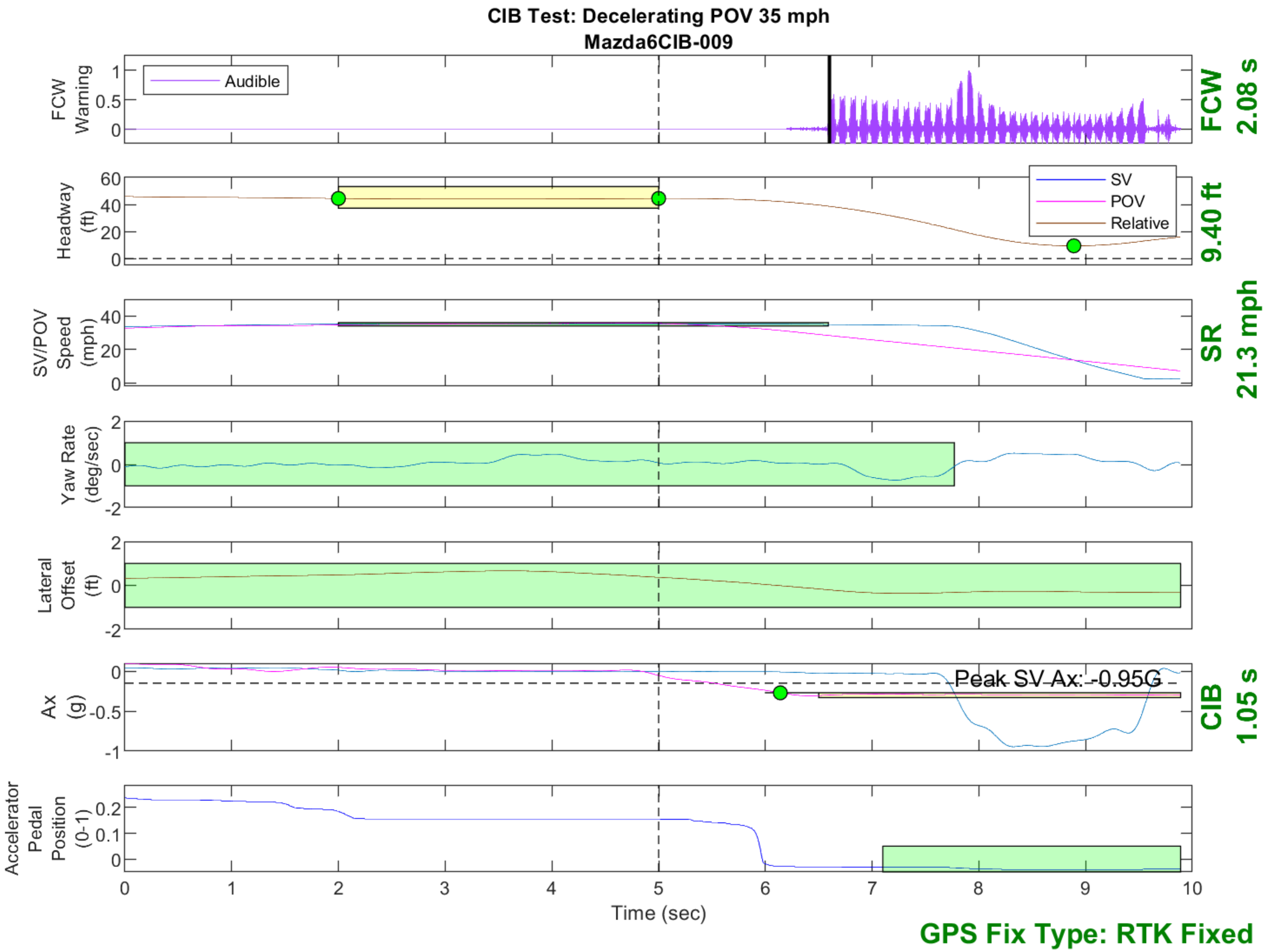


Figure D35. Time History for CIB Run 9, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

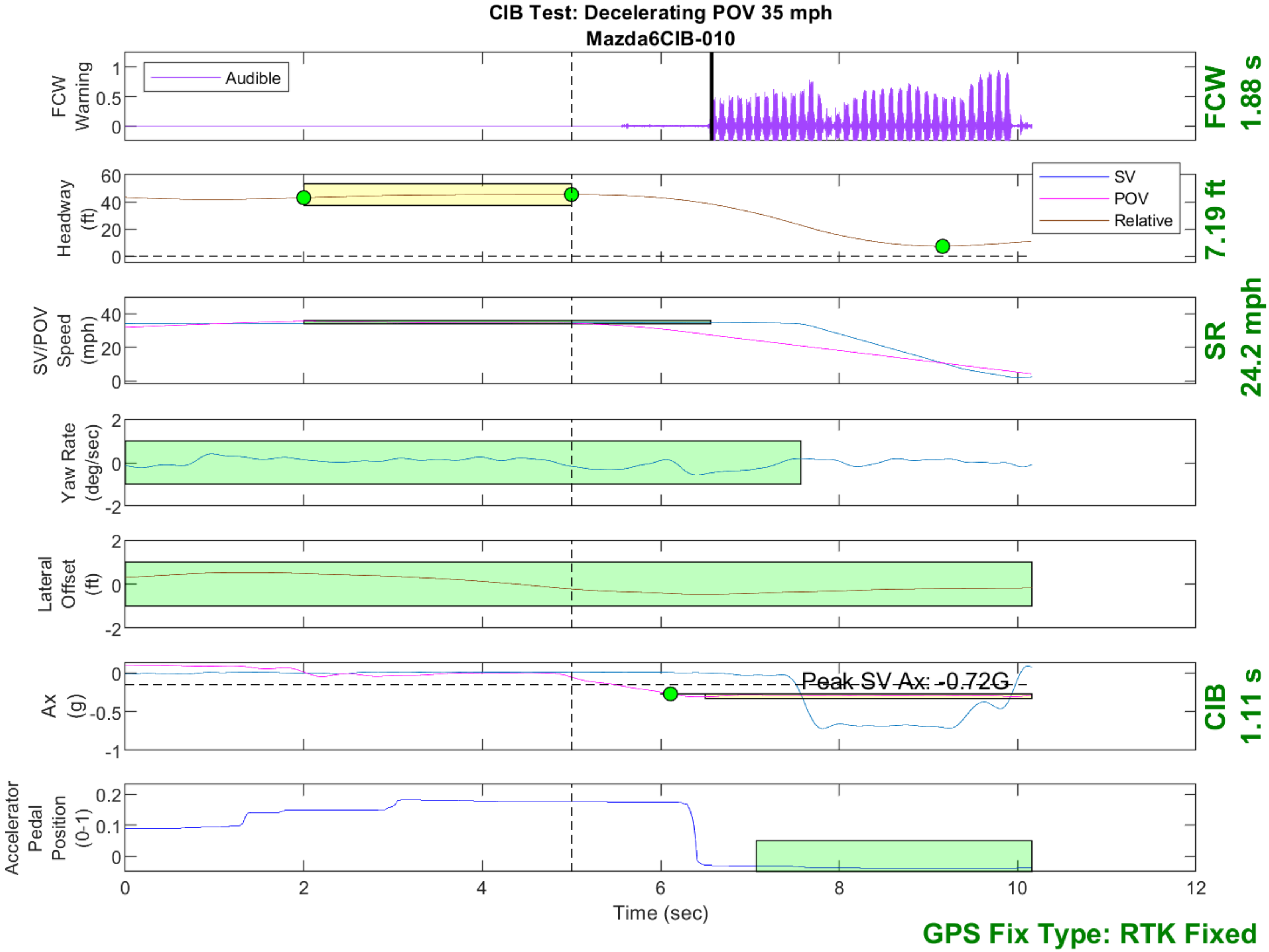


Figure D36. Time History for CIB Run 10, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

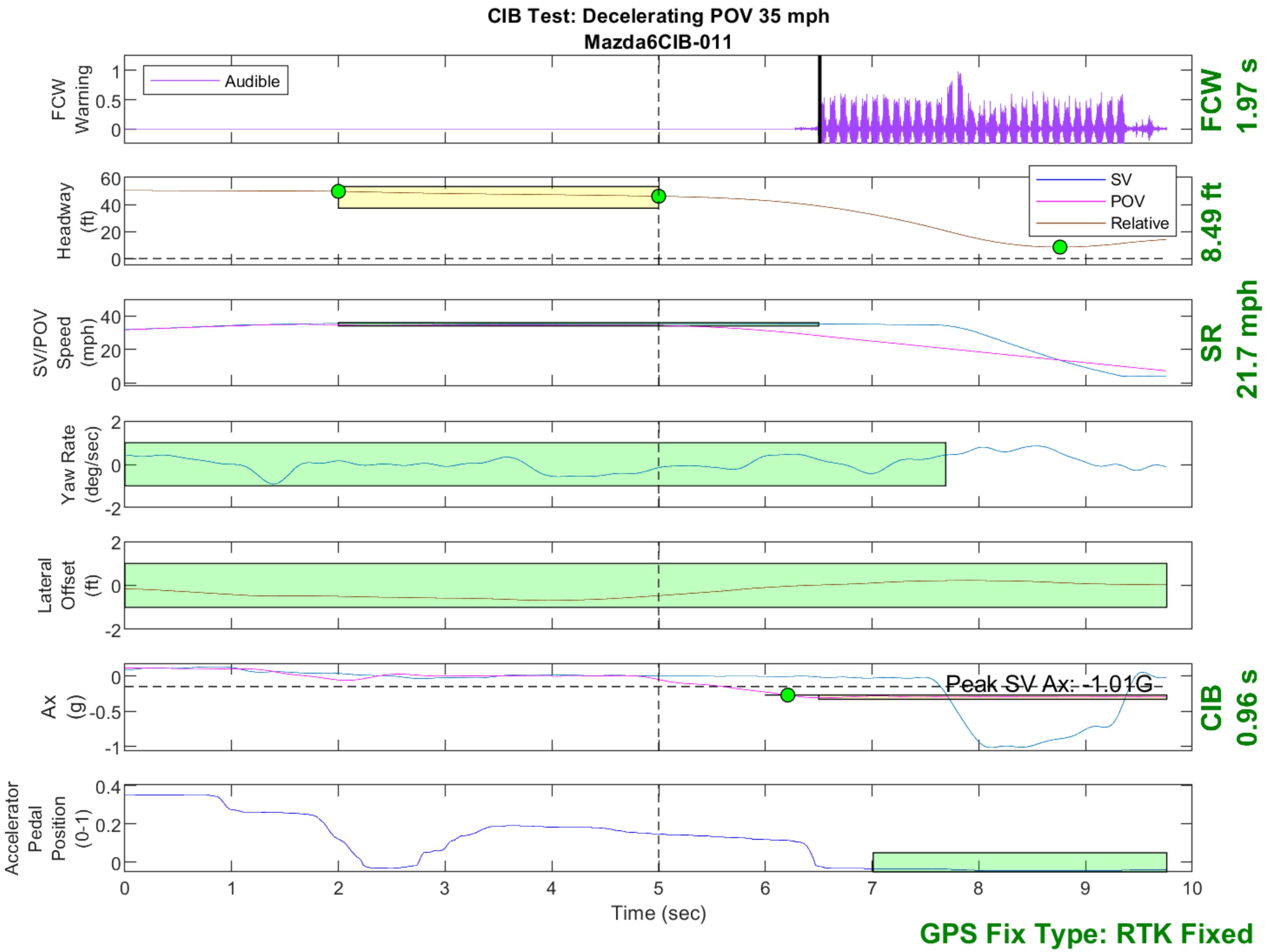


Figure D37. Time History for CIB Run 11, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

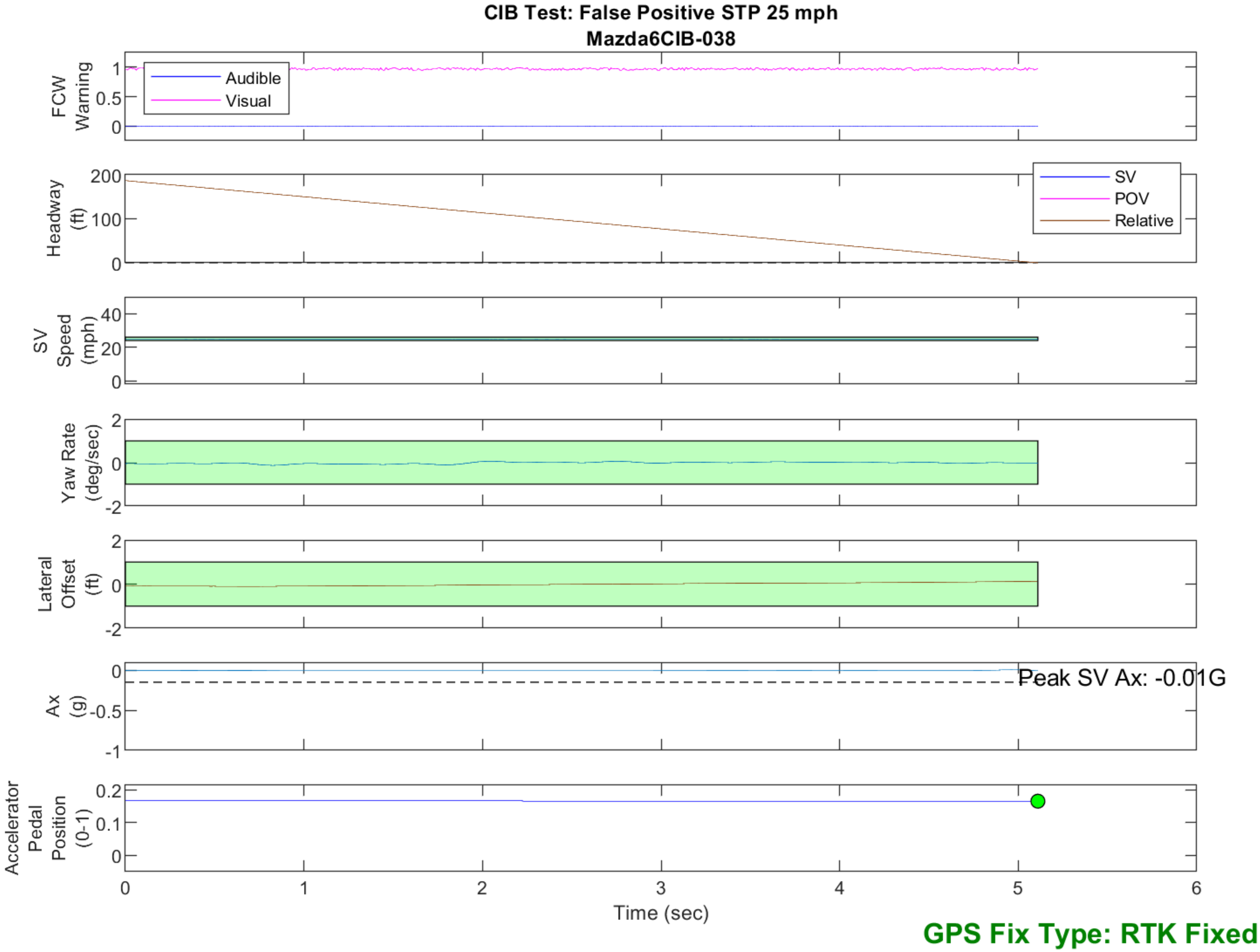


Figure D38. Time History for CIB Run 38, SV Encounters Steel Trench Plate, SV 25 mph

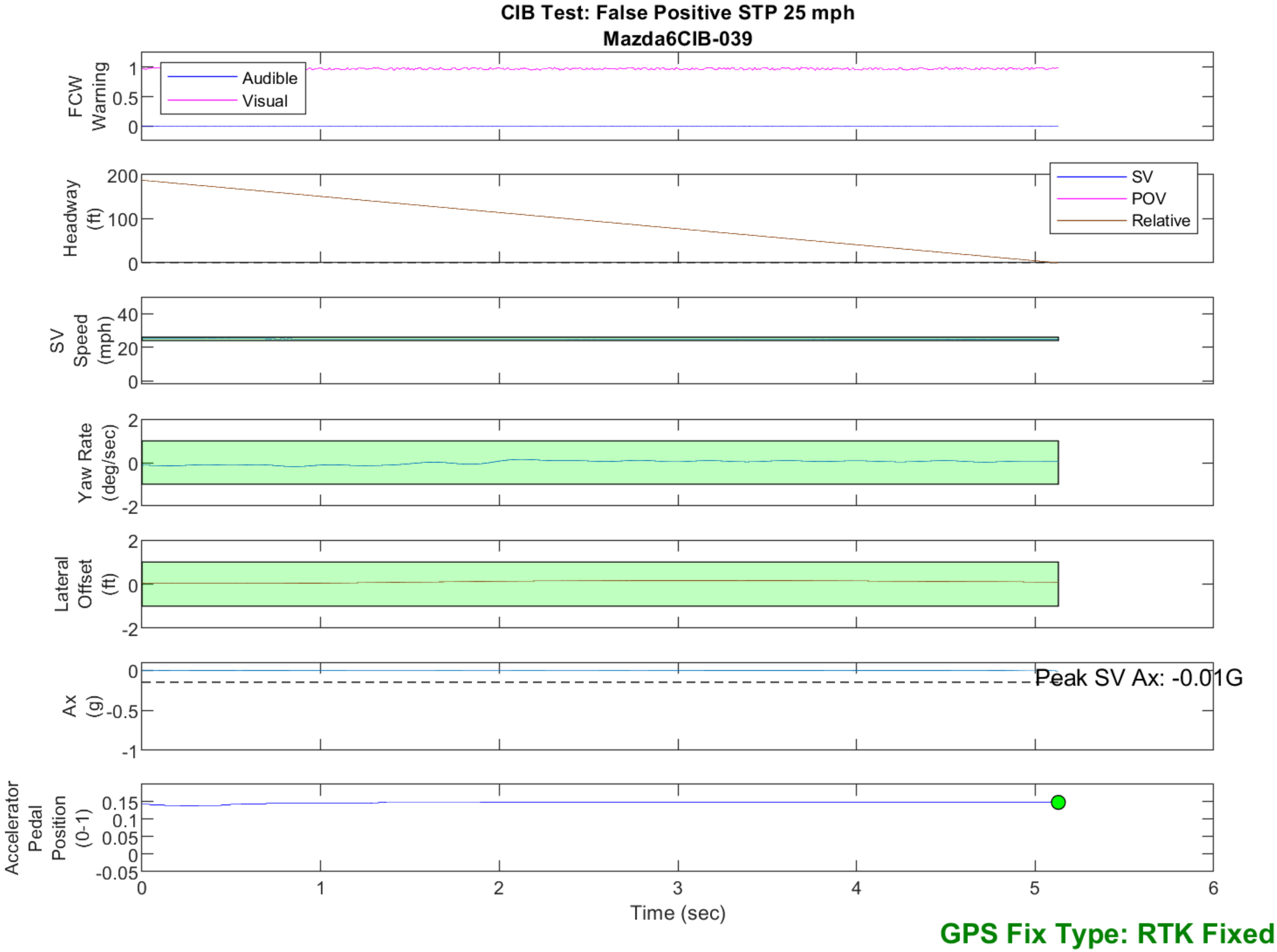


Figure D39. Time History for CIB Run 39, SV Encounters Steel Trench Plate, SV 25 mph

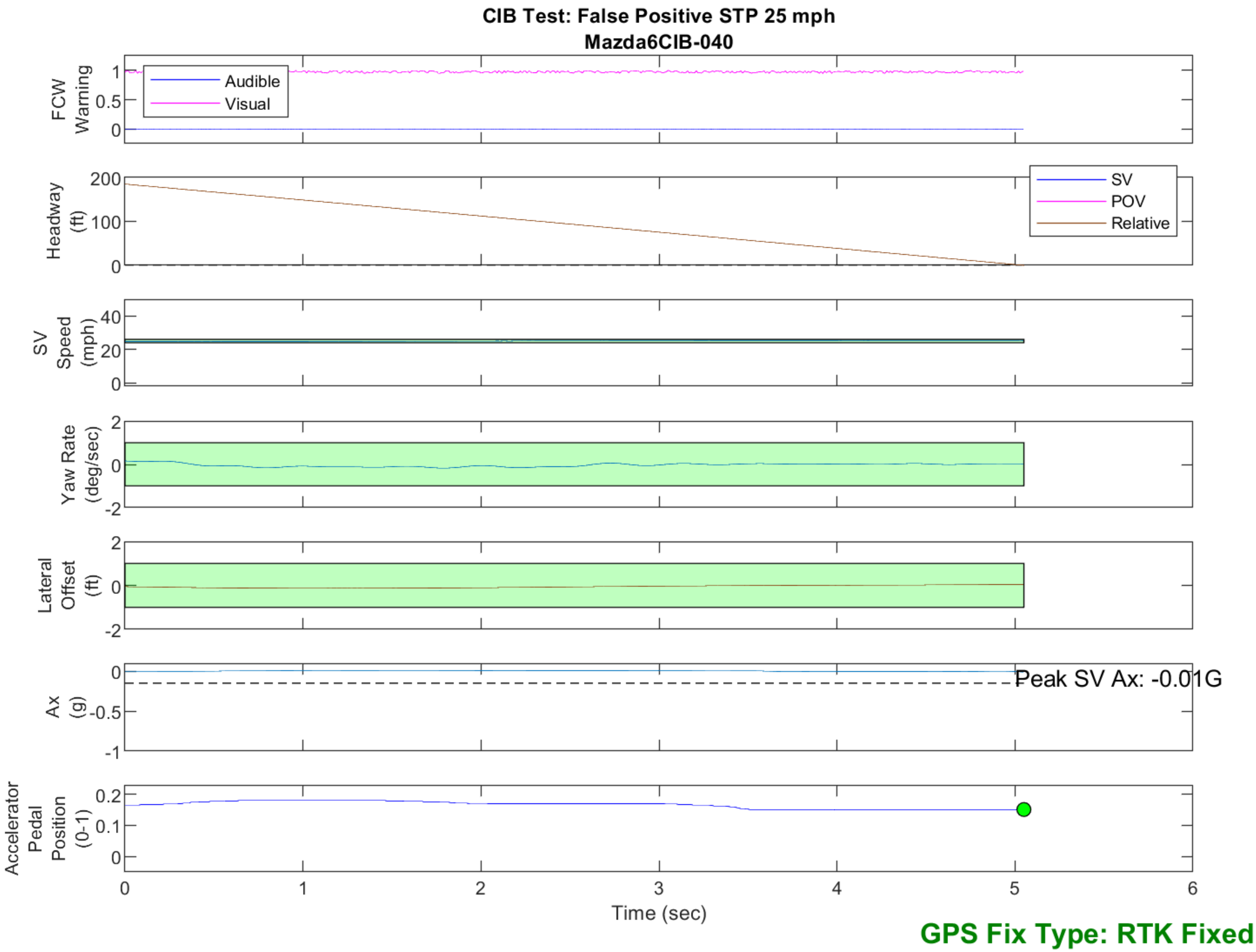


Figure D40. Time History for CIB Run 40, SV Encounters Steel Trench Plate, SV 25 mph

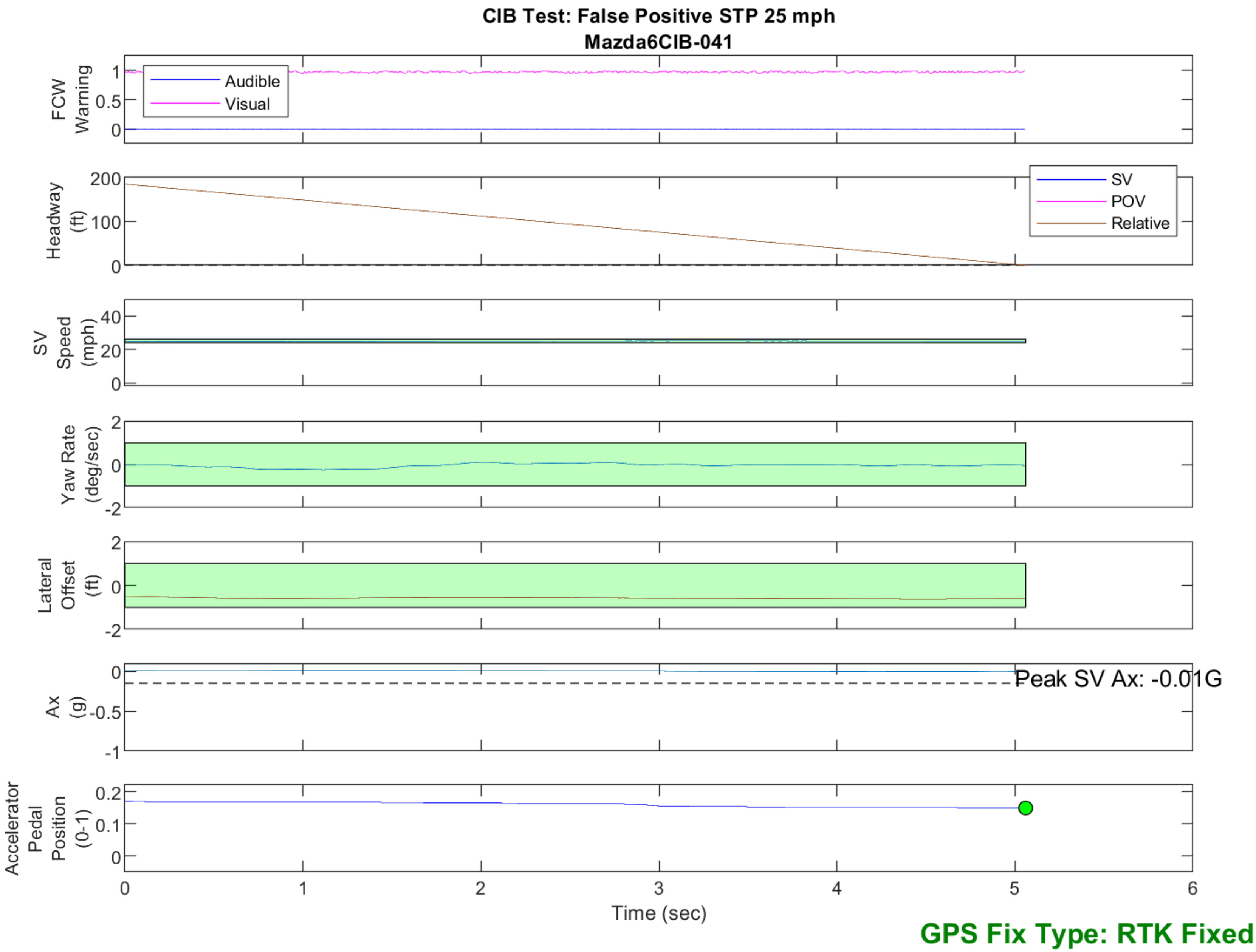


Figure D41. Time History for CIB Run 41, SV Encounters Steel Trench Plate, SV 25 mph

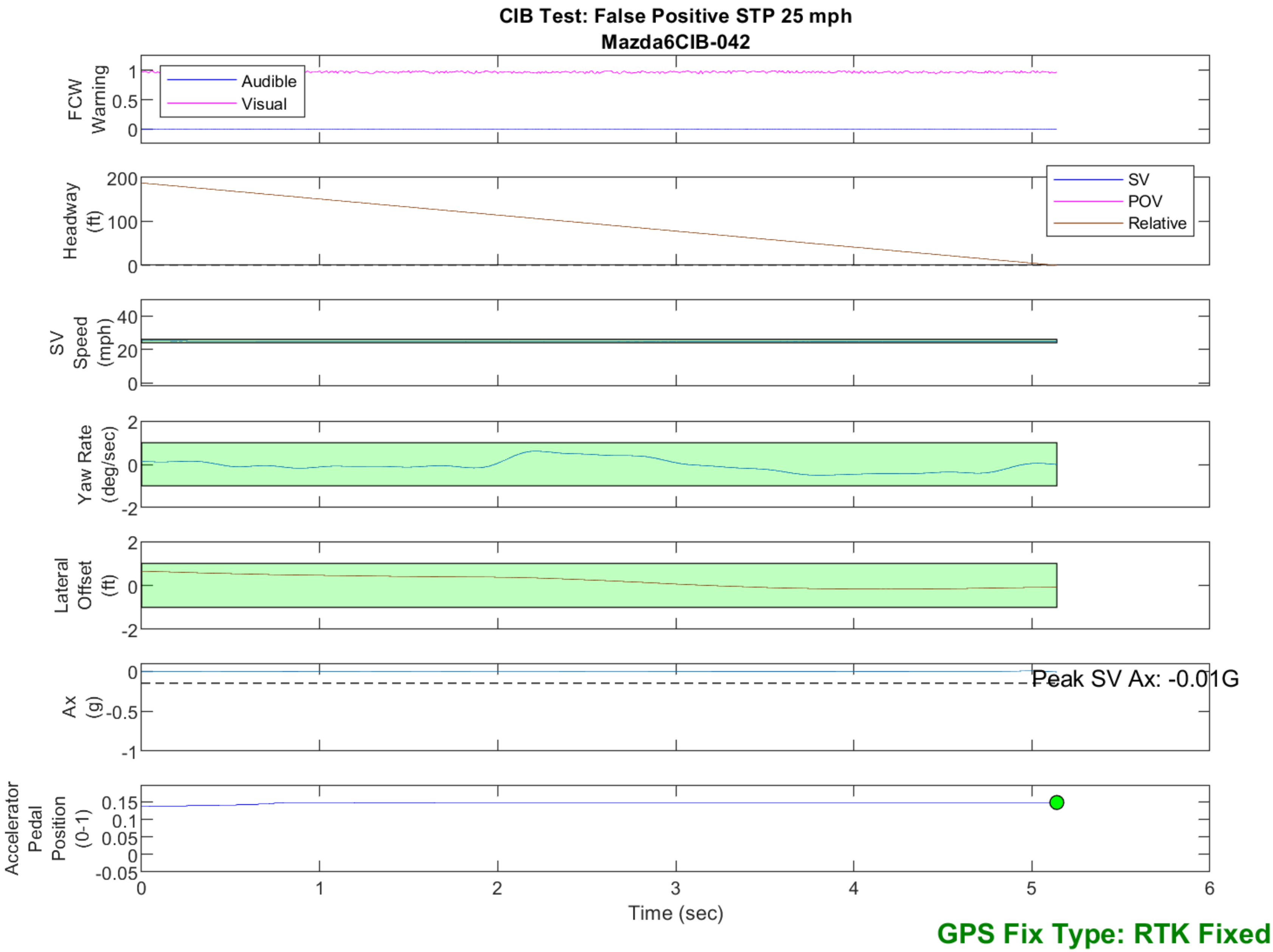


Figure D42. Time History for CIB Run 42, SV Encounters Steel Trench Plate, SV 25 mph

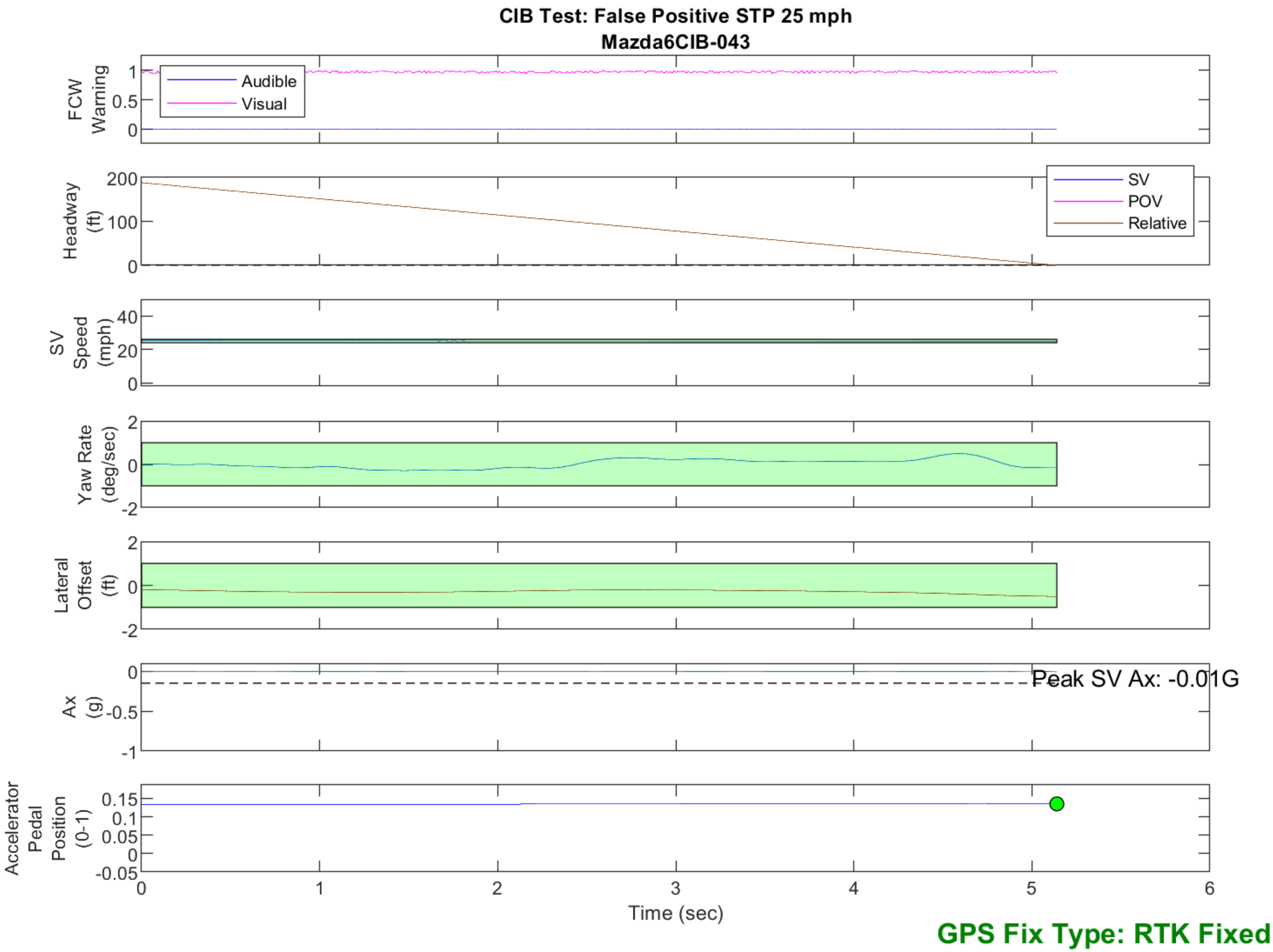


Figure D43. Time History for CIB Run 43, SV Encounters Steel Trench Plate, SV 25 mph

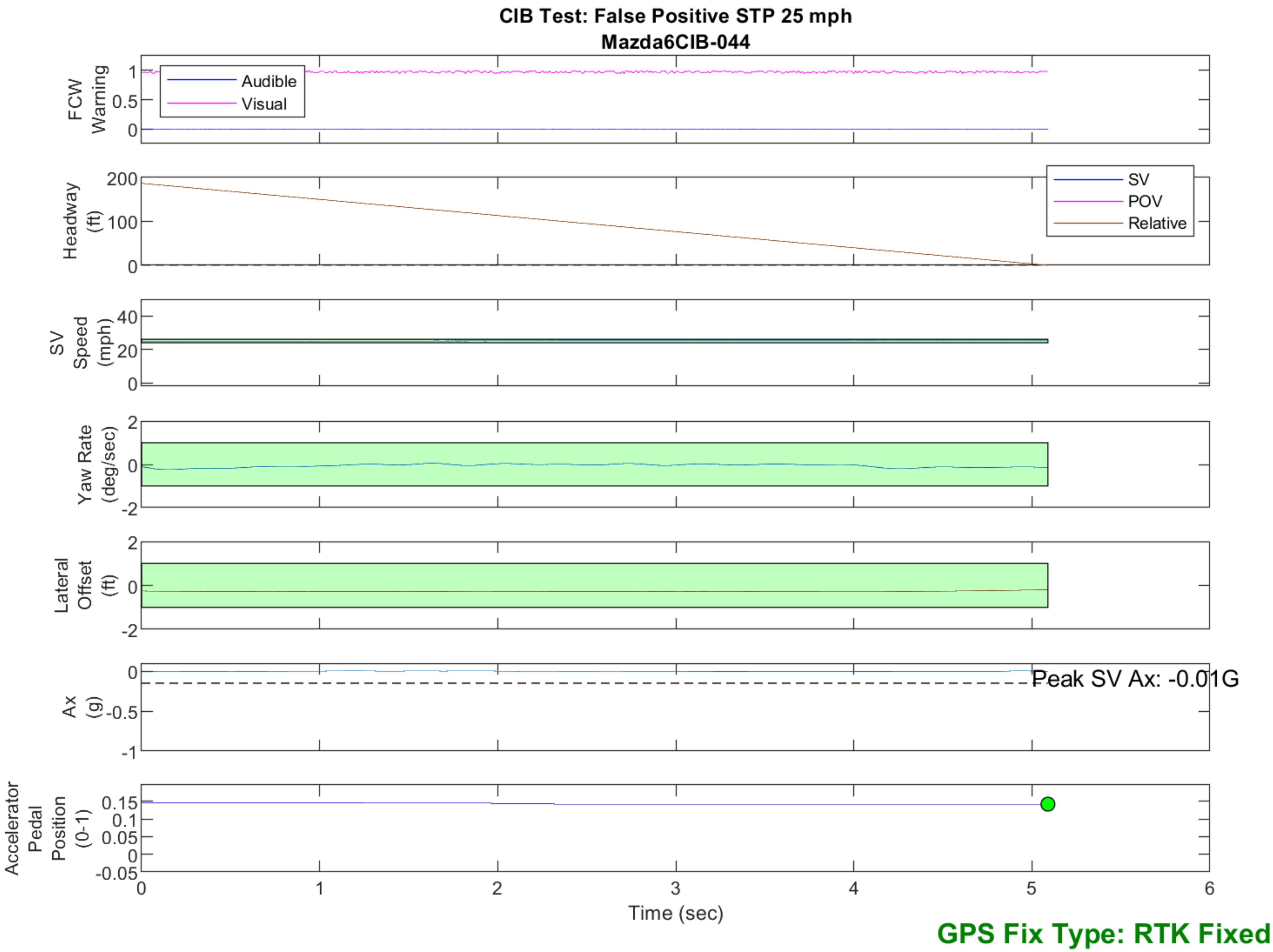


Figure D44. Time History for CIB Run 44, SV Encounters Steel Trench Plate, SV 25 mph

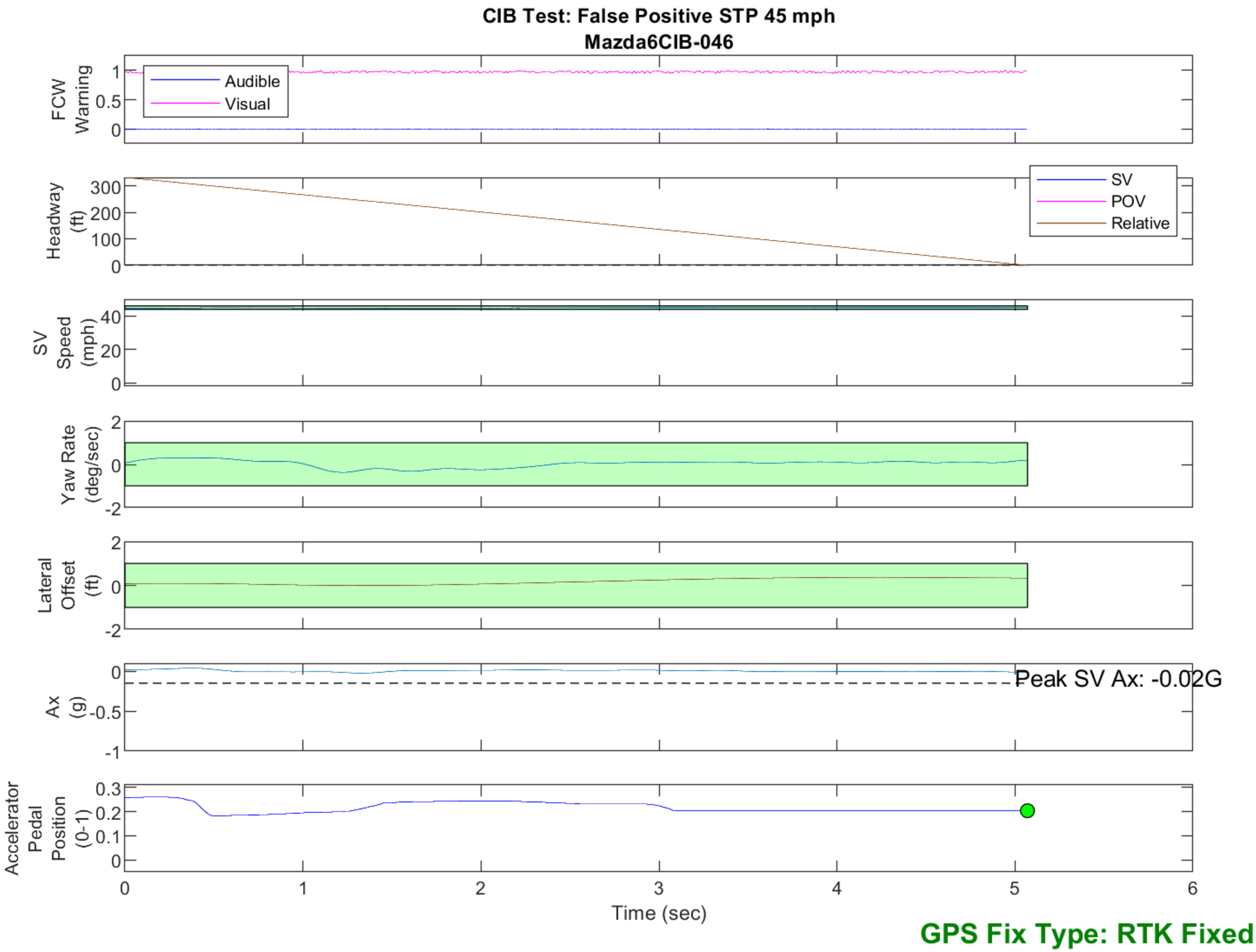


Figure D45. Time History for CIB Run 46, SV Encounters Steel Trench Plate, SV 45 mph

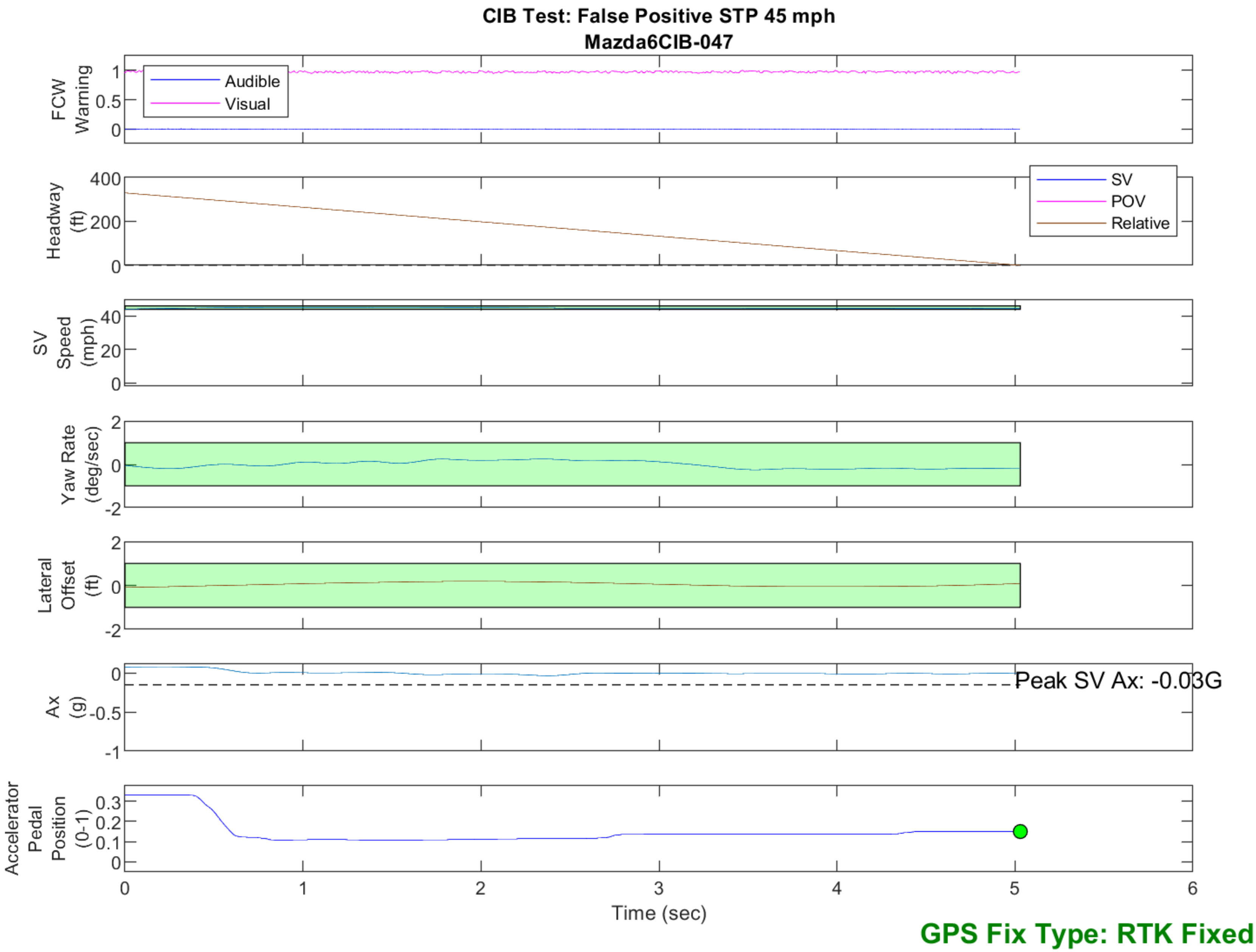


Figure D46. Time History for CIB Run 47, SV Encounters Steel Trench Plate, SV 45 mph

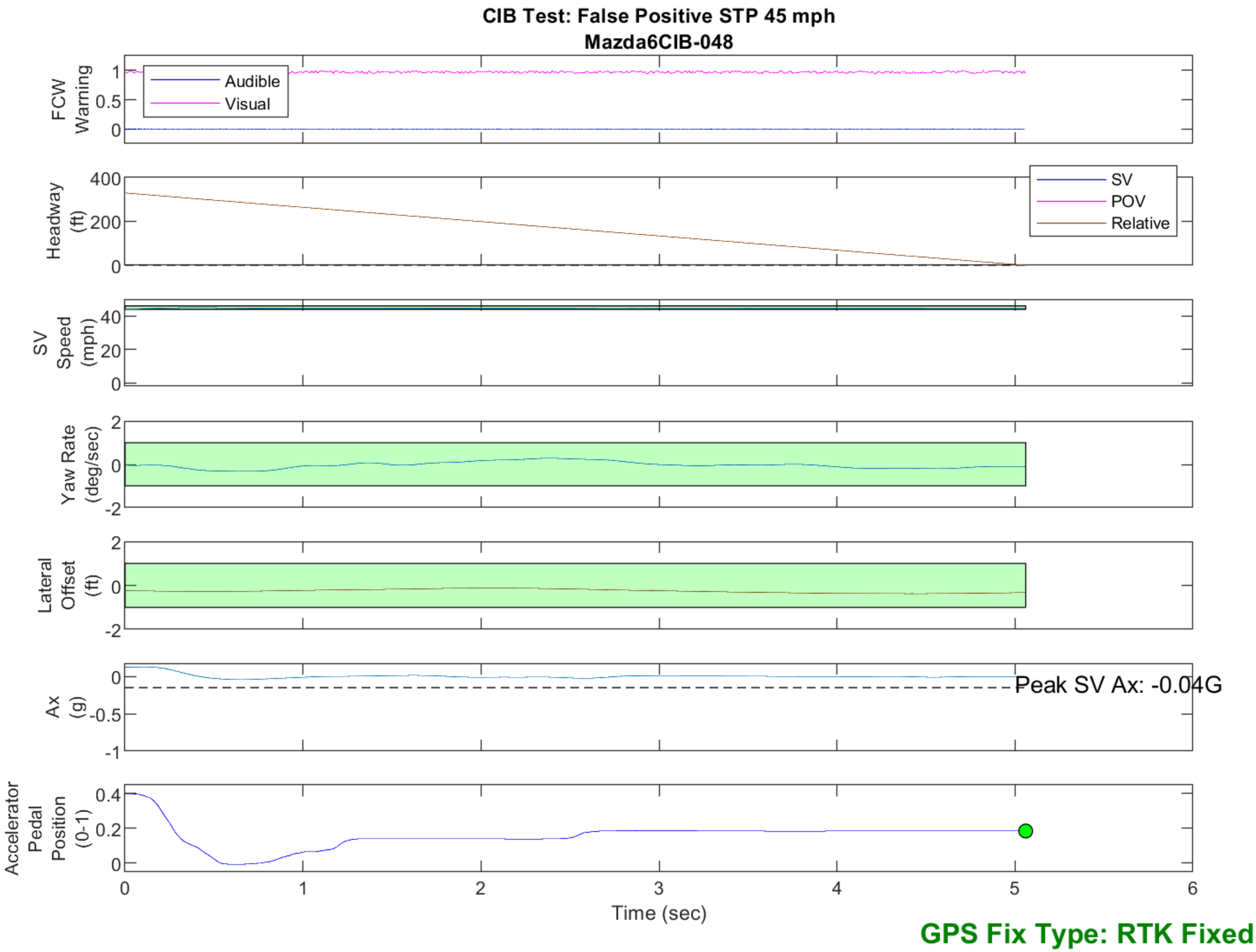


Figure D47. Time History for CIB Run 48, SV Encounters Steel Trench Plate, SV 45 mph

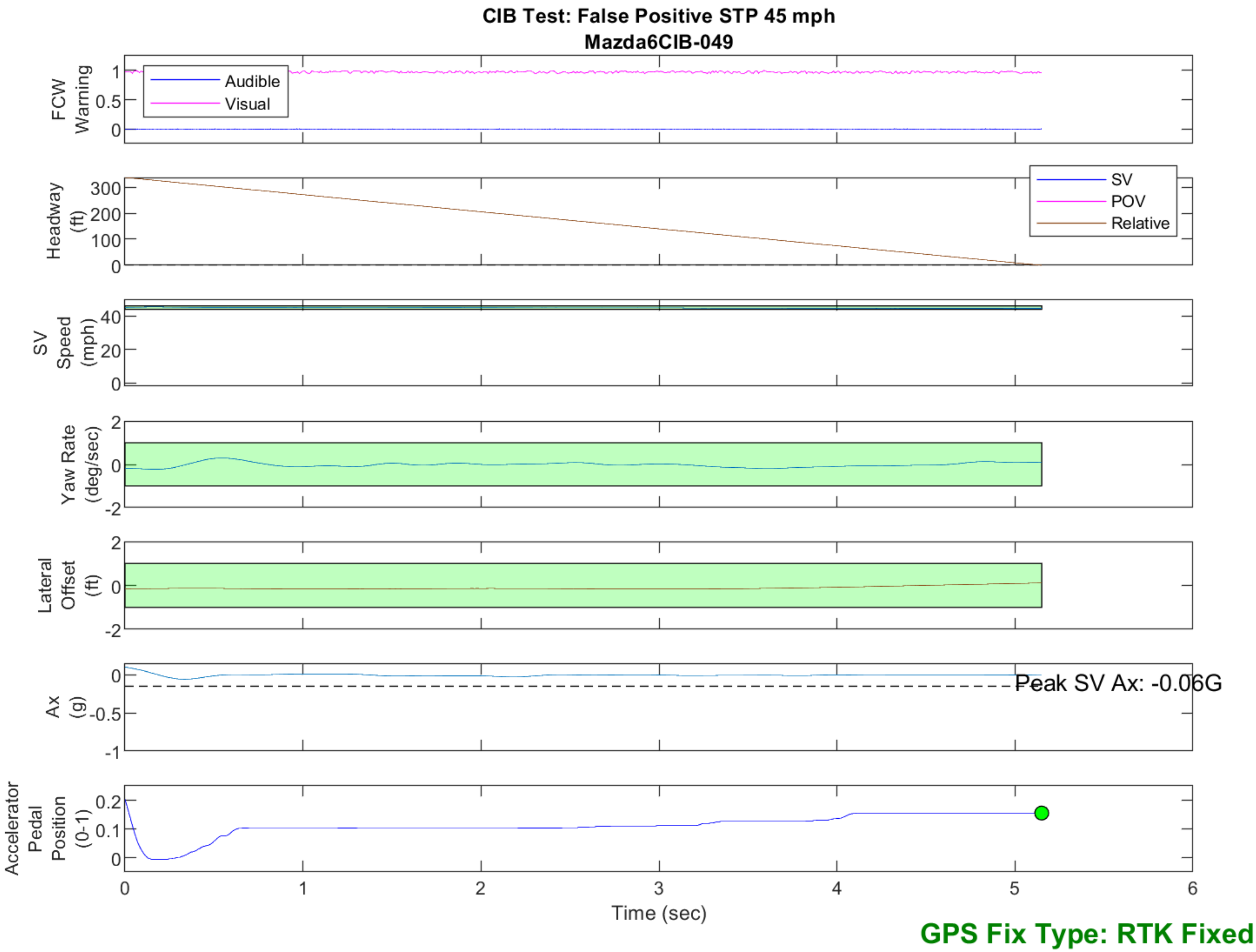


Figure D48. Time History for CIB Run 49, SV Encounters Steel Trench Plate, SV 45 mph

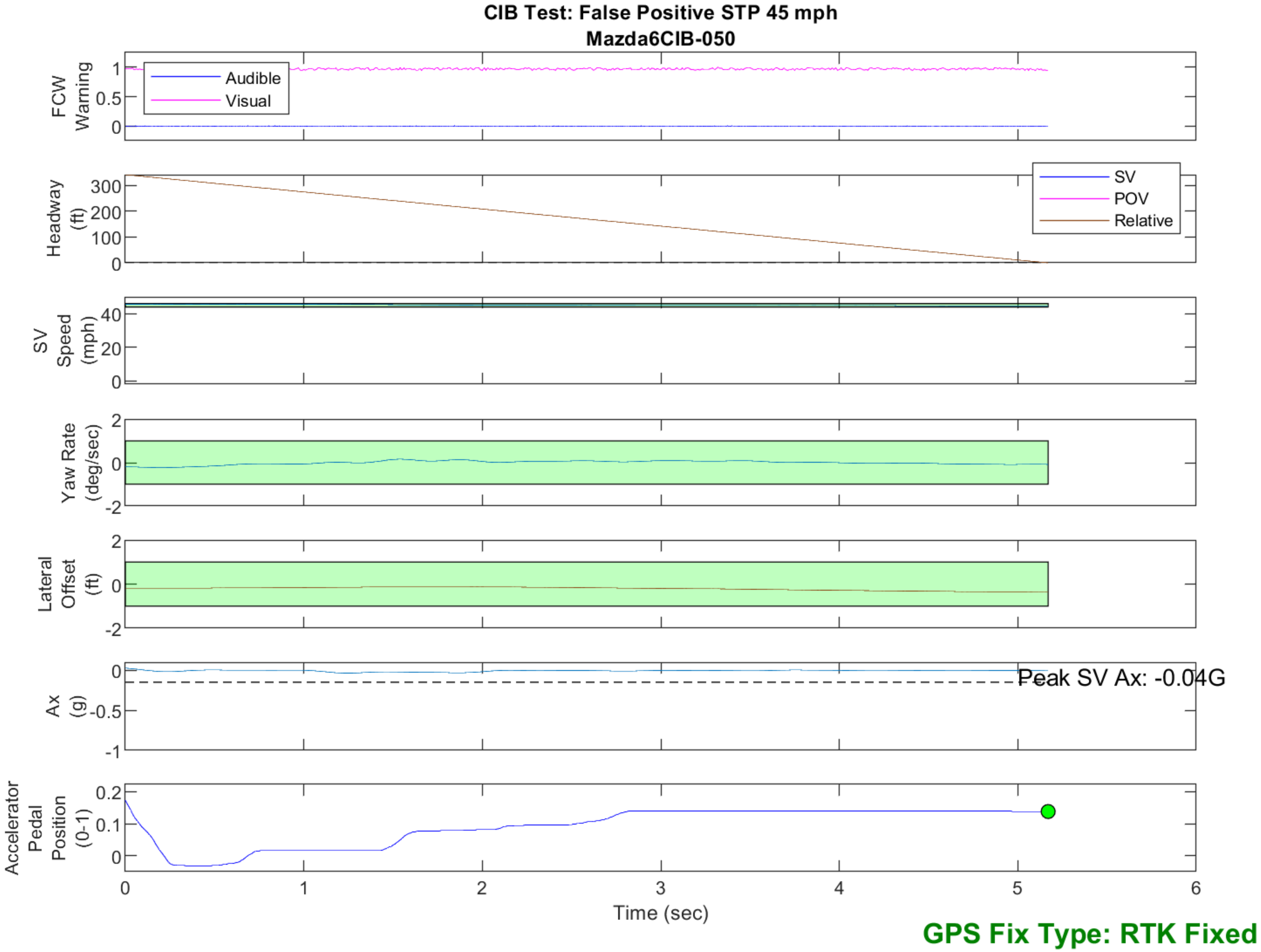


Figure D49. Time History for CIB Run 50, SV Encounters Steel Trench Plate, SV 45 mph

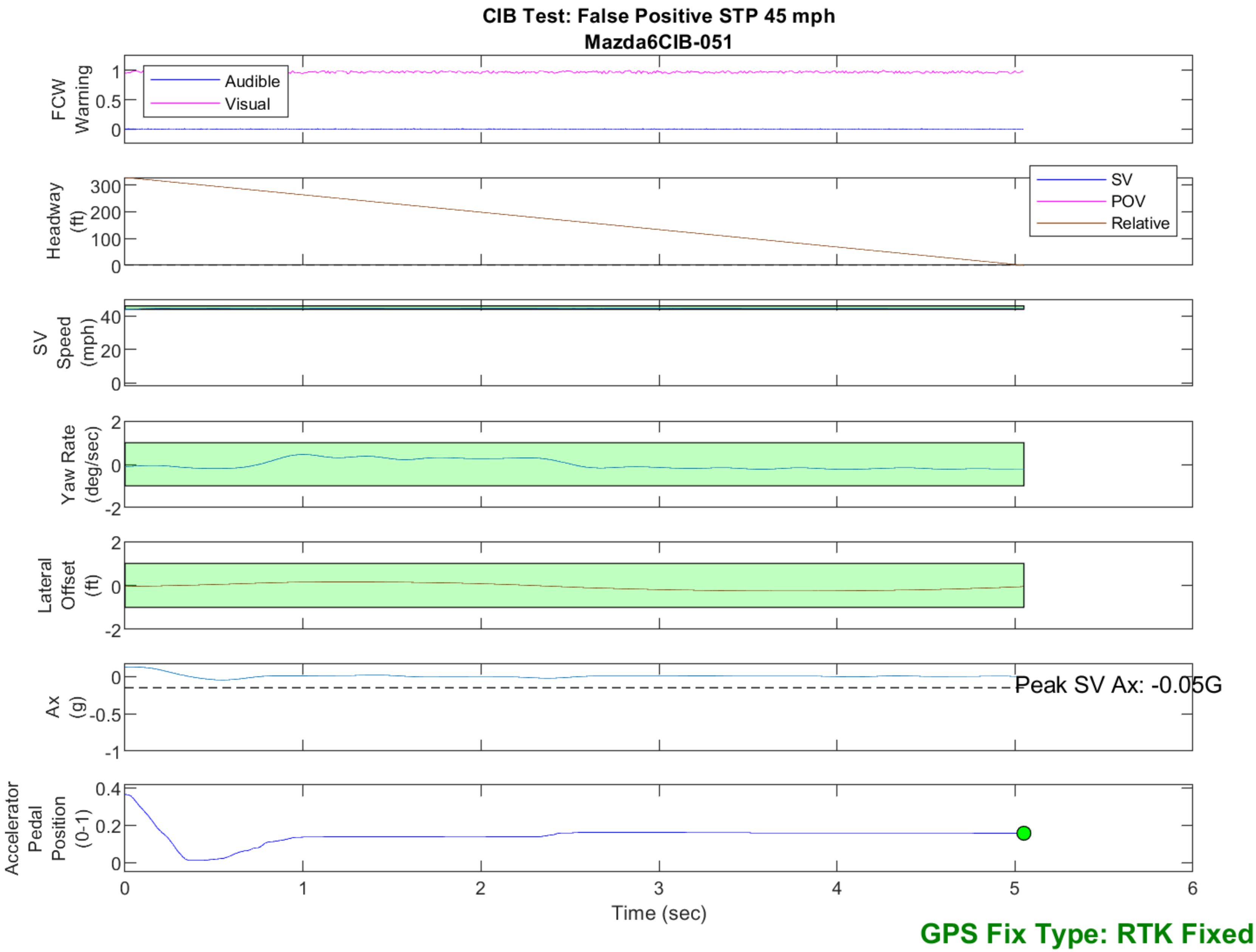


Figure D50. Time History for CIB Run 51, SV Encounters Steel Trench Plate, SV 45 mph

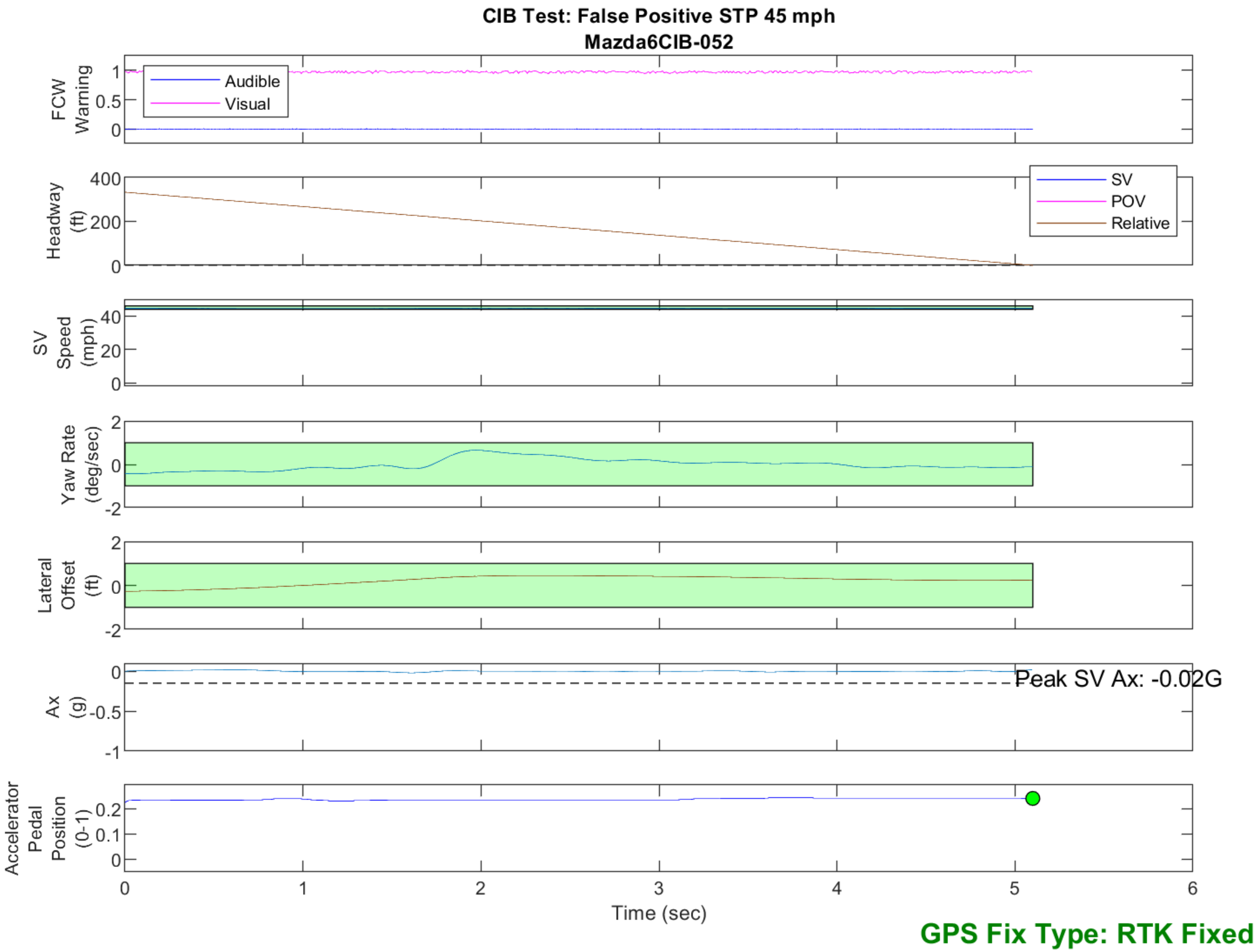


Figure D51. Time History for CIB Run 52, SV Encounters Steel Trench Plate, SV 45 mph