

**NEW CAR ASSESSMENT PROGRAM  
CRASH IMMINENT BRAKING SYSTEM CONFIRMATION TEST  
NCAP-DRI-CIB-22-15**

**2022 Tesla Model 3 AWD**

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**5 April 2022**

**Final Report**

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

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16. Abstract These tests were conducted on the subject 2022 Tesla Model 3 AWD 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 speeds.			
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## TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
I. INTRODUCTION .....	1
II. DATA SHEETS.....	2
Data Sheet 1: Test Results Summary .....	3
Data Sheet 2: Vehicle Data.....	4
Data Sheet 3: Test Conditions .....	5
Data Sheet 4: Crash Imminent Braking System Operation .....	7
III. TEST PROCEDURES .....	10
A. Test Procedure Overview.....	10
B. General Information .....	15
C. Principal Other Vehicle.....	18
D. Automatic Braking System .....	19
E. Instrumentation .....	19
APPENDIX A Photographs.....	A-1
APPENDIX B Excerpts from Owner's Manual .....	B-1
APPENDIX C Run Log.....	C-1
APPENDIX D Time Histories .....	D-1



## 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<sup>1</sup> 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 2022 Tesla Model 3 AWD. 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.

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<sup>1</sup> 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**

(Page 1 of 1)

2022 Tesla Model 3 AWD

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VIN: 5YJ3E1EB9NF17xxxx

Test start date: 3/22/2022

Test end date: 3/22/2022

Crash Imminent Braking System setting: Medium

**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)

**2022 Tesla Model 3 AWD**

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**TEST VEHICLE INFORMATION**

VIN: 5YJ3E1EB9NF17xxxx

Body Style: Sedan

Color: Midnight Silver

Date Received: 3/10/2022

Odometer Reading: 28 mi

**DATA FROM VEHICLE'S CERTIFICATON LABEL**

Vehicle manufactured by: TESLA, INC.

Date of manufacture: 02/22

Vehicle Type: Passenger Car

**DATA FROM TIRE PLACARD**

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

Rear: 235/45R18

Recommended cold tire pressure: Front: 290 kPa (42 psi)

Rear: 290 kPa (42 psi)

**TIRES**

Tire manufacturer and model: Michelin Primacy MXM4

Front tire designation: 235/45R18 98W

Rear tire designation: 235/45R18 98W

Front tire DOT prefix: B9EL 086X

Rear tire DOT prefix: B9EL 086X

**CRASH IMMINENT BRAKING**  
**DATA SHEET 3: TEST CONDITIONS**

(Page 1 of 2)

2022 Tesla Model 3 AWD

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**GENERAL INFORMATION**

Test start date: 3/22/2022

Test end date: 3/22/2022

**AMBIENT CONDITIONS**

Air temperature: 22.8 C (73 F)

Wind speed: 1.0 m/s (2.3 mph)

X Windspeed  $\leq$  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: 290 kPa (42 psi)

Rear: 290 kPa (42 psi)

**CRASH IMMINENT BRAKING**  
**DATA SHEET 3: TEST CONDITIONS**

(Page 2 of 2)

**2022 Tesla Model 3 AWD**

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**WEIGHT**

Weight of vehicle as tested including driver and instrumentation

Left Front: 492.1 kg (1085 lb)

Right Front: 487.2 kg (1074 lb)

Left Rear: 490.3 kg (1081 lb)

Right Rear: 480.4 kg (1059 lb)

Total: 1950.0 kg (4299 lb)



**CRASH IMMINENT BRAKING**

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

(Page 2 of 3)

**2022 Tesla Model 3 AWD**

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How is the Forward Collision Warning system alert presented to the driver?  Warning light  
(Check all that apply)  Buzzer or auditory alarm  
 Vibration  
 Other

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

The AEB system alerts the driver with a visual and auditory alert. The visual alert consists of an animation of the SV behind the POV shown in real time. When the visual alert activates, the POV turns red. The auditory alert consists of repeated beeps with a primary frequency of approximately 1100 Hz.

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.

The AEB system can be turned on/off using the touch screen display in the center console. The procedure is as follows:

1. Select "Controls".
  2. Select "Autopilot".
  3. Select "Automatic Emergency Braking" to turn the AEB system on/off.
- The system is automatically enabled each time the engine switch is turned on.



**CRASH IMMINENT BRAKING**

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

(Page 3 of 3)

**2022 Tesla Model 3 AWD**

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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 AEB system sensitivity/performance cannot be adjusted per manufacturer supplied information. But the range setting of the FCW system can be adjusted using the touch screen display in the center console. The procedure is as follows:

1. Select "Controls".
2. Select "Autopilot".
3. Select between "Late", "Medium", "Early".

The range setting is retained when the engine switch is turned off.

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 AEB system cannot always detect all objects, vehicles, bicycles, or pedestrians and may miss warnings or exhibit unnecessary, inaccurate, or invalid warnings. Possible reasons for this are listed in the examples below:

1. The road has sharp curves.
2. Visibility is poor (due to heavy rain, snow, fog, etc.).
3. Bright light (such as from oncoming headlights or direct sunlight) is interfering with the view of the camera(s).
4. The camera sensor is obstructed (dirty, covered, fogged over, covered by a sticker, etc.).
5. Weather conditions (heavy rain, snow, fog, or extremely hot or cold temperatures) are interfering with its operation.

Refer to the owner's manual page 114 shown in Appendix B page B-4 for additional information.

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.

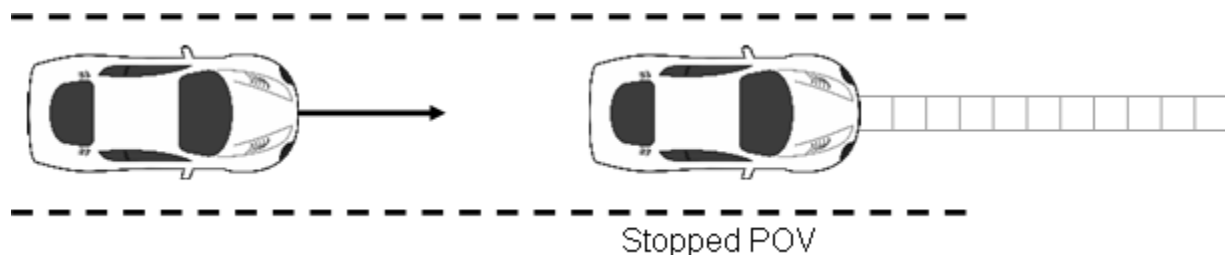


Figure 1. Depiction of Test 1

##### 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 lateral distance between the centerline of the SV to the center of the travel lane could not deviate more than  $\pm 1$  ft (0.3 m) during the validity period.
- The yaw rate of the SV could not deviate more than  $\pm 1$  deg/sec during the validity period.
- The SV speed could not deviate from the nominal speed by more than  $\pm 1.0$  mph ( $\pm 1.6$  km/h) during an interval defined by a Time to Collision (TTC) = 5.1 seconds to  $t_{FCW}$  or impact if no FCW alert was given.

b. Criteria

In order to pass the test, the magnitude of the SV speed reduction attributable to CIB intervention must have been  $\geq 9.8$  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.

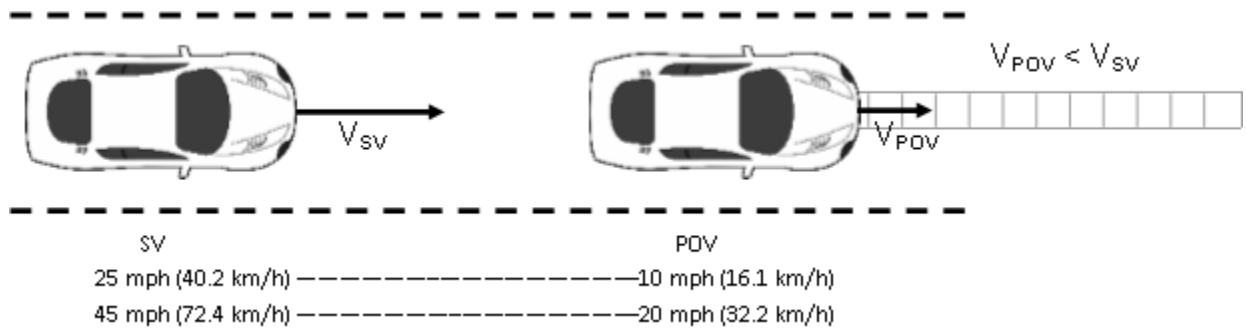


Figure 2. Depiction of Test 2

#### 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 SV and POV to the center of the travel lane could not deviate more than  $\pm 1$  ft (0.3 m) during the validity period.
- The yaw rate of the SV and POV could not deviate more than  $\pm 1$  deg/sec during the validity period.
- The SV speed could not deviate more than  $\pm 1.0$  mph ( $\pm 1.6$  km/h) during an interval defined by  $TTC = 5.0$  seconds to  $t_{FCW}$  or impact if no FCW alert was given.
- The POV speed could not deviate more than  $\pm 1.0$  mph ( $\pm 1.6$  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-to-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  $\geq 9.8$  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-to-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.

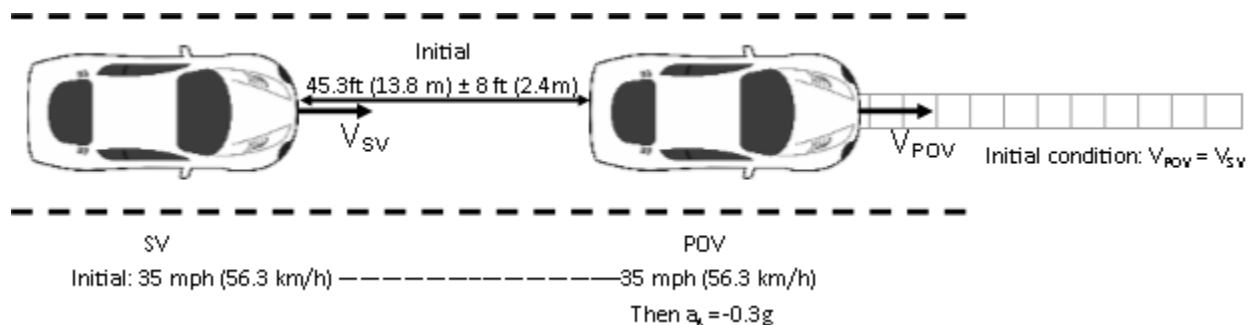


Figure 3. Depiction of Test 3

#### 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  $0.3 \pm 0.03$  g of deceleration within  $1.5 \pm 0.1$  sec. The test concluded when either:

- The SV came into contact with the POV or
- 1 second after minimum longitudinal SV-to-POV distance has occurred.

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 SV and POV to the center of the travel lane could not deviate more than  $\pm 1$  ft (0.3 m) during the validity period.
- The yaw rate of the SV and POV could not deviate more than  $\pm 1$  deg/sec during the validity period.
- The SV speed could not deviate more than  $\pm 1.0$  mph (1.6 km/h) during an interval defined by 3.0 seconds before the onset of POV braking to  $t_{FCW}$  or impact if no FCW alert was given.
- The POV speed could not deviate more than  $\pm 1.0$  mph (1.6 km/h) during an interval of 3.0 seconds before 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 lateral distance between the centerline of the SV to the center of the travel lane could not deviate more than  $\pm 1$  ft (0.3 m) during the validity period.
- The yaw rate of the SV could not deviate more than  $\pm 1$  deg/sec during the validity period.
- 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  $\pm 1.0$  mph ( $\pm 1.6$  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  $\leq 0.50$  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 visual, haptic or auditory, and the onset of the alert was determined by post-processing the test data.

For systems that implement auditory or haptic alerts, part of the pre-test instrumentation verification process was to determine the tonal frequency of the auditory warning or the vibration frequency of the tactile warning through use of the PSD (Power Spectral Density) function in Matlab. This was accomplished in order to identify the center frequency around which a band-pass filter was applied to subsequent auditory or tactile warning data so that the beginning of such warnings can be programmatically determined. The band-pass filter used for these warning signal types was a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 1.

**Table 1. Auditory and Tactile Warning Filter Parameters**

<b>Warning Type</b>	<b>Filter Order</b>	<b>Peak-to-Peak Ripple</b>	<b>Minimum Stop Band Attenuation</b>	<b>Passband Frequency Range</b>
Auditory	5 <sup>th</sup>	3 dB	60 dB	Identified Center Frequency $\pm$ 5%
Tactile	5 <sup>th</sup>	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  $\pm 1.0$  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  $\pm 1$  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 minimum longitudinal SV-to-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, and immediately after each of the test series.

For Tests 1, 2, and 3, the SV, POV, 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.”

If the zero position reported by the data acquisition system was found to differ by more

than  $\pm 2$  in ( $\pm 5$  cm) from that measured during collection of the pre-test static calibration data file, the pre-test offset was adjusted to output zero, another pre-test static calibration data file was collected, and the test series was repeated.

## 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 CIB 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 SV-to-POV 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 SV is also equipped with an automatic braking system (E-brake) for the purpose of slowing the SV before impact with the SSV in cases where the SV 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 100 psi	Omega DPG8001	17042707002	By: DRI Date: 10/5/2021 Due: 10/5/2022
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform	0.1% of reading	Intercomp SW wireless	0410MN20001	By: DRI Date: 2/11/2022 Due: 2/11/2023
Linear (string) encoder	Throttle pedal travel	10 in	0.1 in	UniMeasure LX-EP	50060727	By: DRI Date: 4/15/2021 Due: 4/15/2022
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	N/A
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +		By: Oxford Technical Solutions
					2176	Date: 6/26/2020 Due: 6/26/2022
					2258	Date: 4/28/2021 Due: 4/28/2023

**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 POV	Distance and Velocity to lane markings (LDW) and POV (FCW)	Lateral Lane Dist: $\pm 30$ m Lateral Lane Velocity: $\pm 20$ m/sec Longitudinal Range to POV: $\pm 200$ m Longitudinal Range Rate: $\pm 50$ m/sec	Lateral Distance to Lane Marking: $\pm 2$ cm Lateral Velocity to Lane Marking: $\pm 0.02$ m/sec Longitudinal Range: $\pm 3$ cm Longitudinal Range Rate: $\pm 0.02$ m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	N/A
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	N/A	N/A
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	N/A	N/A
Accelerometer	Acceleration (to measure time at alert)	$\pm 5g$	$\leq 3\%$ of full range	Silicon Designs, 2210-005	N/A	N/A
Coordinate Measurement Machine	Inertial Sensing System Coordinates	0-8 ft 0-2.4 m	$\pm 0.020$ in. $\pm 0.51$ mm (Single point articulation accuracy)	Faro Arm, Fusion	UO8-05-08-06636	By: DRI Date: 1/6/2022 Due: 1/6/2023
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

	Page
Figure A1. Front View of Subject Vehicle .....	A-3
Figure A2. Rear View of Subject Vehicle .....	A-4
Figure A3. Window Sticker (Monroney Label) .....	A-5
Figure A4. Vehicle Certification Label .....	A-6
Figure A5. Tire Placard .....	A-7
Figure A6. Rear View of Principal Other Vehicle (SSV) .....	A-8
Figure A7. Load Frame/Slider of SSV .....	A-9
Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track .....	A-10
Figure A9. Steel Trench Plate .....	A-11
Figure A10. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle .....	A-12
Figure A11. Sensor for Detecting Auditory and Visual Alerts .....	A-13
Figure A12. Computer Installed in Subject Vehicle .....	A-14
Figure A13. Brake Actuator Installed in POV System .....	A-15
Figure A14. AEB System Setup Menus .....	A-16
Figure A15. Visual Alert .....	A-17
Figure A16. Stopping Mode .....	A-18
Figure A17. Software Version .....	A-19





Figure A1. Front View of Subject Vehicle





Figure A2. Rear View of Subject Vehicle



# TESLA MODEL 3 Long Range AWD

Vehicle Identification Number 5YJ3E1EB9NF17  
 Date Of Manufacture 02/2022  
 Transportation Method Truck  
 Delivered to TESLA MOTORS, INC.  
 Fremont, California,  
 USA

## STANDARD FEATURES

### TECHNICAL

Three phase, four pole, induction motor (Front)  
 Three phase, six pole, internal permanent magnet motor (Rear)  
 Drive inverter with regenerative braking system  
 Microprocessor controlled, lithium-ion battery  
 Onboard charger and mobile connector  
 120 volt and J1772 charging adapters

### SAFETY

Eight cameras and twelve ultrasonic sensors  
 Six front row and two side curtain airbags  
 Three point safety belts with belt-reminders for driver and four passengers  
 Two LATCH (Lower Anchors and Tethers for Children) attachments in second row  
 Electronic stability and traction control  
 Four wheel antilock disc brakes with electronic parking brake  
 Child safety locks and manual cargo door release mechanisms  
 Anti-Theft Alarm System

### INTERIOR

15 inch capacitive touchscreen  
 Onboard maps and navigation  
 WiFi and Mobile network connectivity  
 FM and Internet streaming radio  
 Hands free talking with Bluetooth  
 Voice activated controls  
 High definition backup camera  
 One touch power windows  
 Dual zone climate control  
 12 volt power outlet and four USB ports

### EXTERIOR

Full LED lighting

## AS CONFIGURED

Model 3	\$35,000
Model 3 Long Range AWD	\$15,990
Premium Interior	INCLUDED
Midnight Silver Metallic Paint	INCLUDED
18" Pinwheel Refresh Wheels	INCLUDED
All Black Premium Interior	INCLUDED
Full Self-Driving Capability	\$12,000
Base Autopilot	INCLUDED

Destination and Regulatory Doc Fee \$1,200  
**Total vehicle price \$64,190**

## GOVERNMENT 5-STAR SAFETY RATINGS

### Overall Vehicle Score

Based on the combined ratings of frontal, side and rollover.  
 Should ONLY be compared to other vehicles of similar size and weight. ★★★★★

**Frontal Crash**  
 Driver ★★★★★  
 Passenger ★★★★★

Based on the risk of injury in a frontal impact.  
 Should ONLY be compared to other vehicles of similar size and weight.

**Side Crash**  
 Front seat ★★★★★  
 Rear seat ★★★★★

Based on the risk of injury in a side impact.

**Rollover** ★★★★★  
 Based on the risk of rollover in a single-vehicle crash.

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

## PARTS CONTENT INFORMATION

FOR THIS VEHICLE:

US/CANADIAN PARTS CONTENT: 65%  
 MAJOR SOURCES OF FOREIGN PARTS CONTENT MEXICO: 20%

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

FOR THIS VEHICLE:

FINAL ASSEMBLY POINT: FREMONT, CA  
 COUNTRY OF ORIGIN:  
 MOTOR ASSEMBLY: USA  
 GEARBOX/TRANSMISSION: USA

## ADDITIONAL ASSEMBLY INFORMATION

FOR THIS VEHICLE:

BATTERY FINAL ASSEMBLY POINT:  
 FREMONT, CA, USA  
 ON-BOARD CHARGER FINAL ASSEMBLY POINT:  
 FREMONT, CA, USA

## EPA DOT Fuel Economy and Environment Electric Vehicle

**Fuel Economy** These estimates reflect new EPA methods beginning with 2017 models. Midsize cars range from 14 to 41 MPGe. The best vehicle rates 141 MPGe. **You save \$4,000 in fuel costs over 5 years** compared to the average new vehicle.

**131 MPGe** combined city/hwy  
 134 city 126 highway 26 kW-hr per 100 miles

**Driving Range**  
 When fully charged, vehicle can travel about: **358 miles**

**Charge Time: 10 hours (240V)**

**Annual fuel COST \$500**

**Fuel Economy & Greenhouse Gas Rating** (tailpipe only) **10** Best  
**1** 10 Best

**Smog Rating** (tailpipe only) **10** Best  
**1** 10 Best

This vehicle emits 0 grams CO<sub>2</sub> per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also create emissions; learn more at [fuelconomy.gov](http://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 \$ 6,500 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at 0.13 per kW-hr. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

**fuelconomy.gov**  
 Calculate personalized estimates and compare vehicles


Smartphone QR Code 

Figure A3. Window Sticker (Monroney Label)



**MFD BY TESLA, INC.**

**02/22**

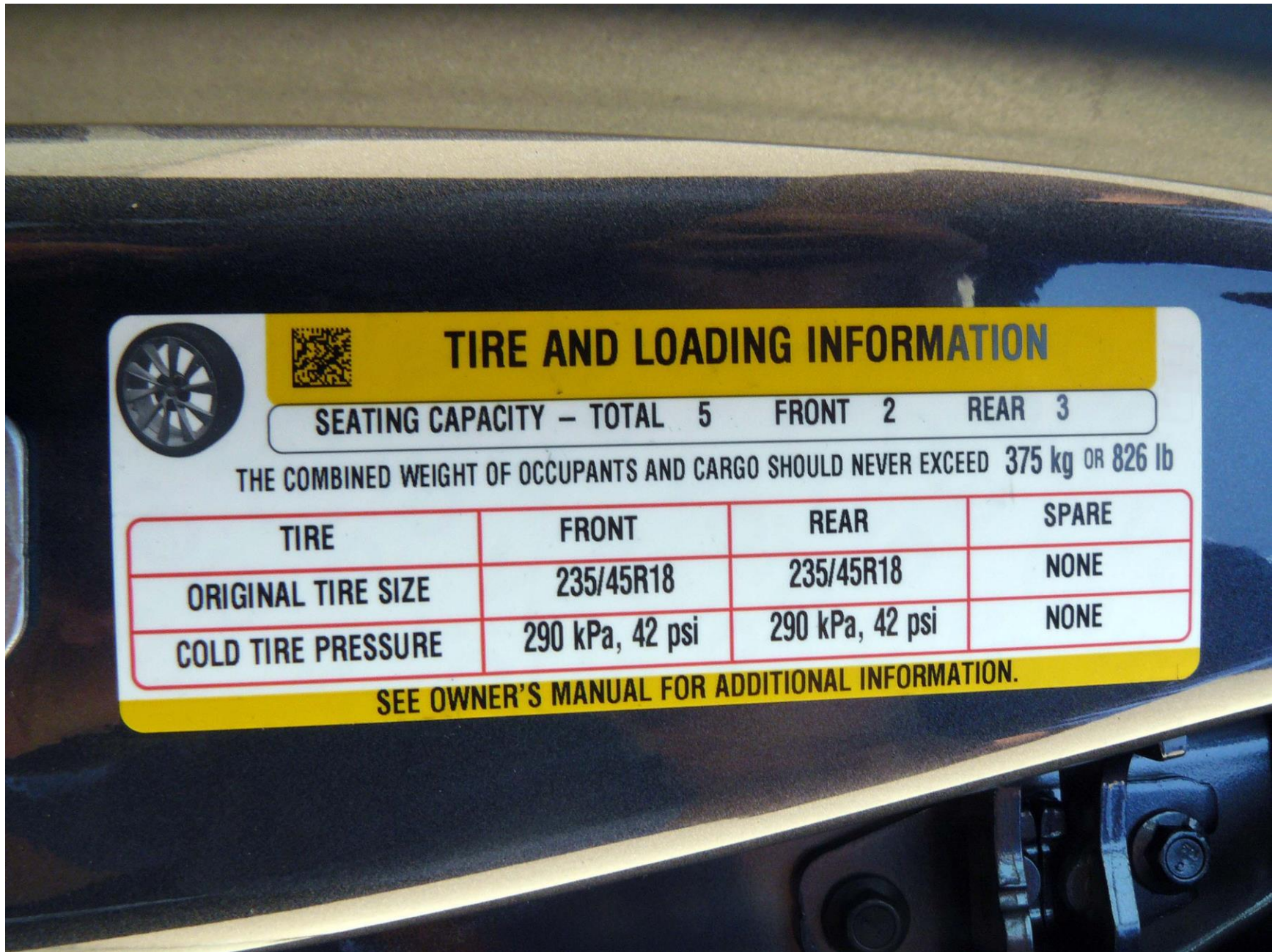
<b>GVWR</b>	<b>WITH TIRES</b>		
2207 kg (4866 lb)	235/45R18		
<b>GAWR FRT</b>	<b>WITH TIRES</b>	<b>RIM</b>	<b>COLD TIRE PRESSURE</b>
1110 kg (2447 lb)	235/45R18	18X8.5J	290 kPa, 42 psi
<b>GAWR RR</b>	<b>WITH TIRES</b>	<b>RIM</b>	<b>COLD TIRE PRESSURE</b>
1257 kg (2771 lb)	235/45R18	18X8.5J	290 kPa, 42 psi

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

**PNT: PMNG      VIN: 5YJ3E1EB9NF17      TYPE: PASSENGER CAR**

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 375 kg OR 826 lb

TIRE	FRONT	REAR	SPARE
ORIGINAL TIRE SIZE	235/45R18	235/45R18	NONE
COLD TIRE PRESSURE	290 kPa, 42 psi	290 kPa, 42 psi	NONE

SEE OWNER'S MANUAL FOR ADDITIONAL INFORMATION.

Figure A5. Tire Placard





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





Figure A7. Load Frame/Slider of SSV



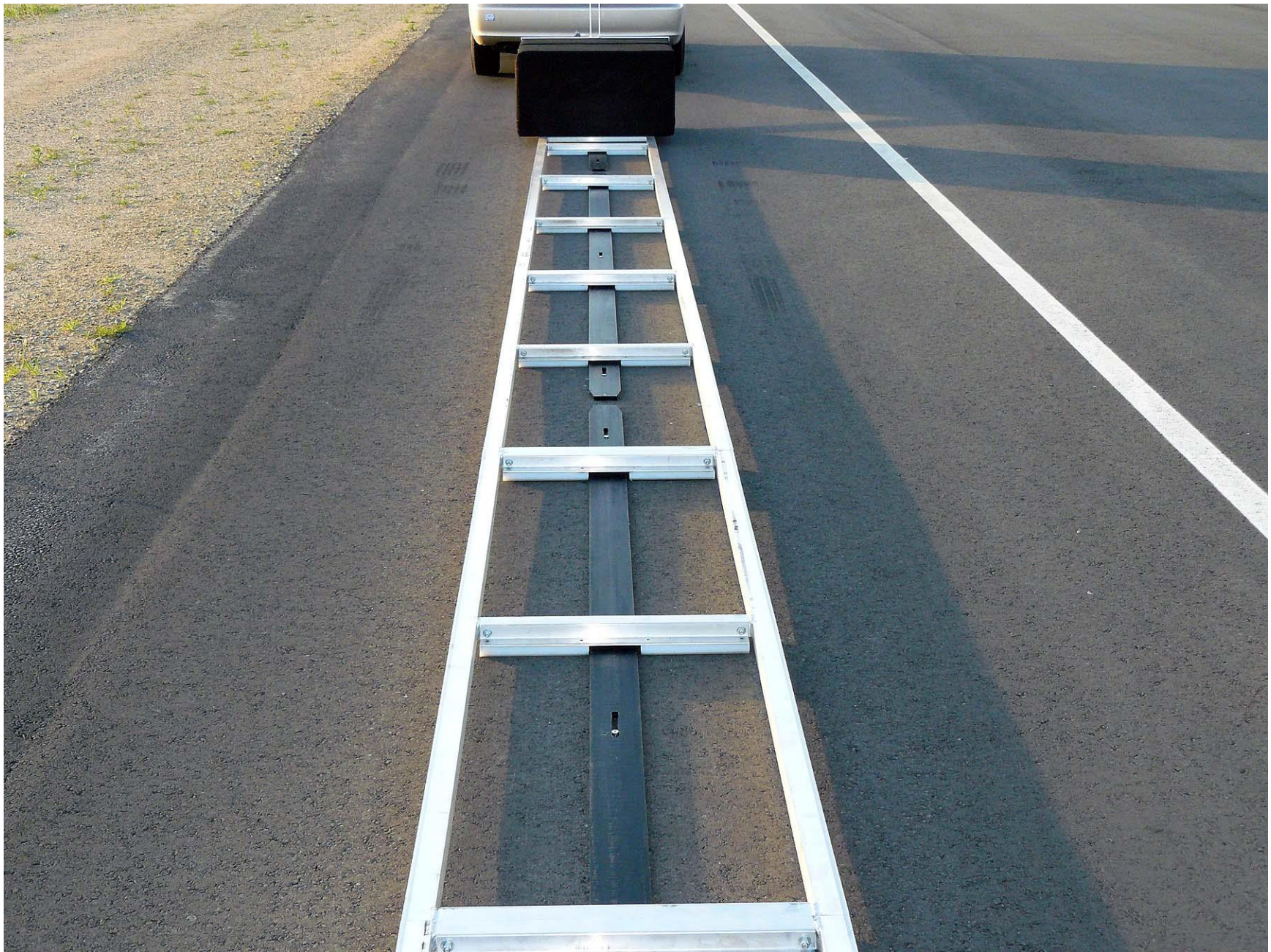


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track





Figure A9. Steel Trench Plate



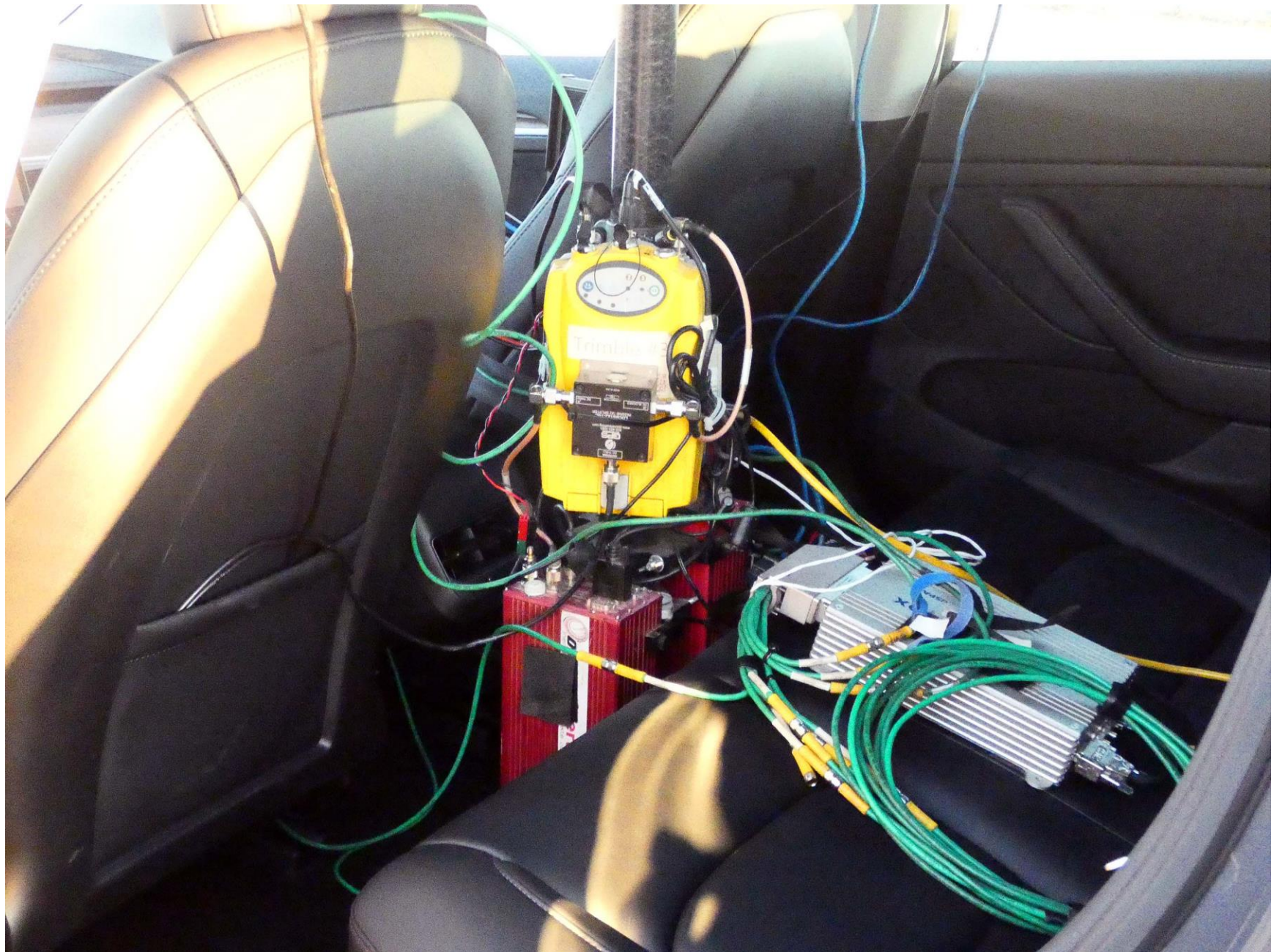


Figure A10. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle



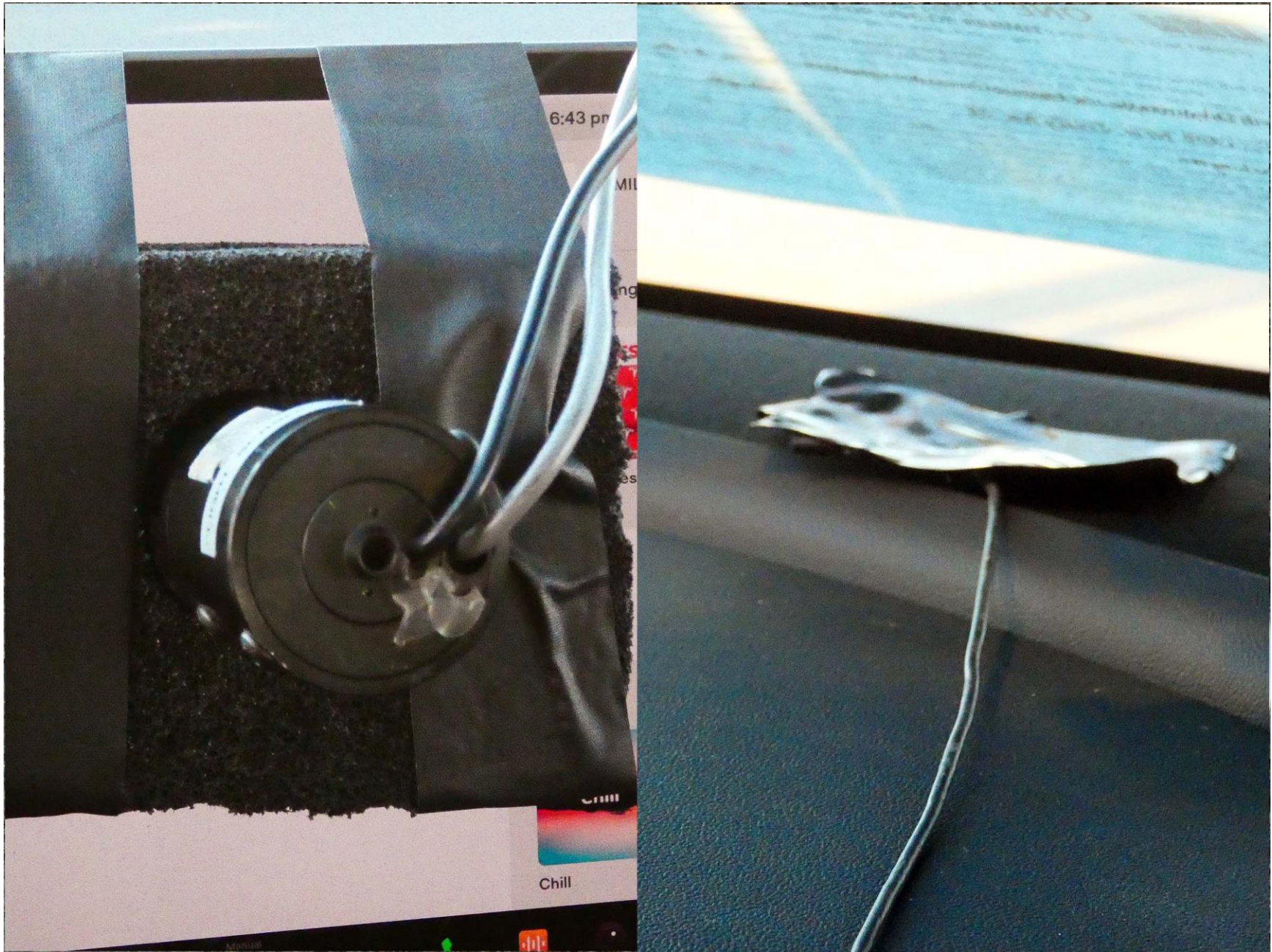


Figure A11. Sensor for Detecting Auditory and Visual Alerts





Figure A12. Computer Installed in Subject Vehicle



Figure A13. Brake Actuator Installed in POV System



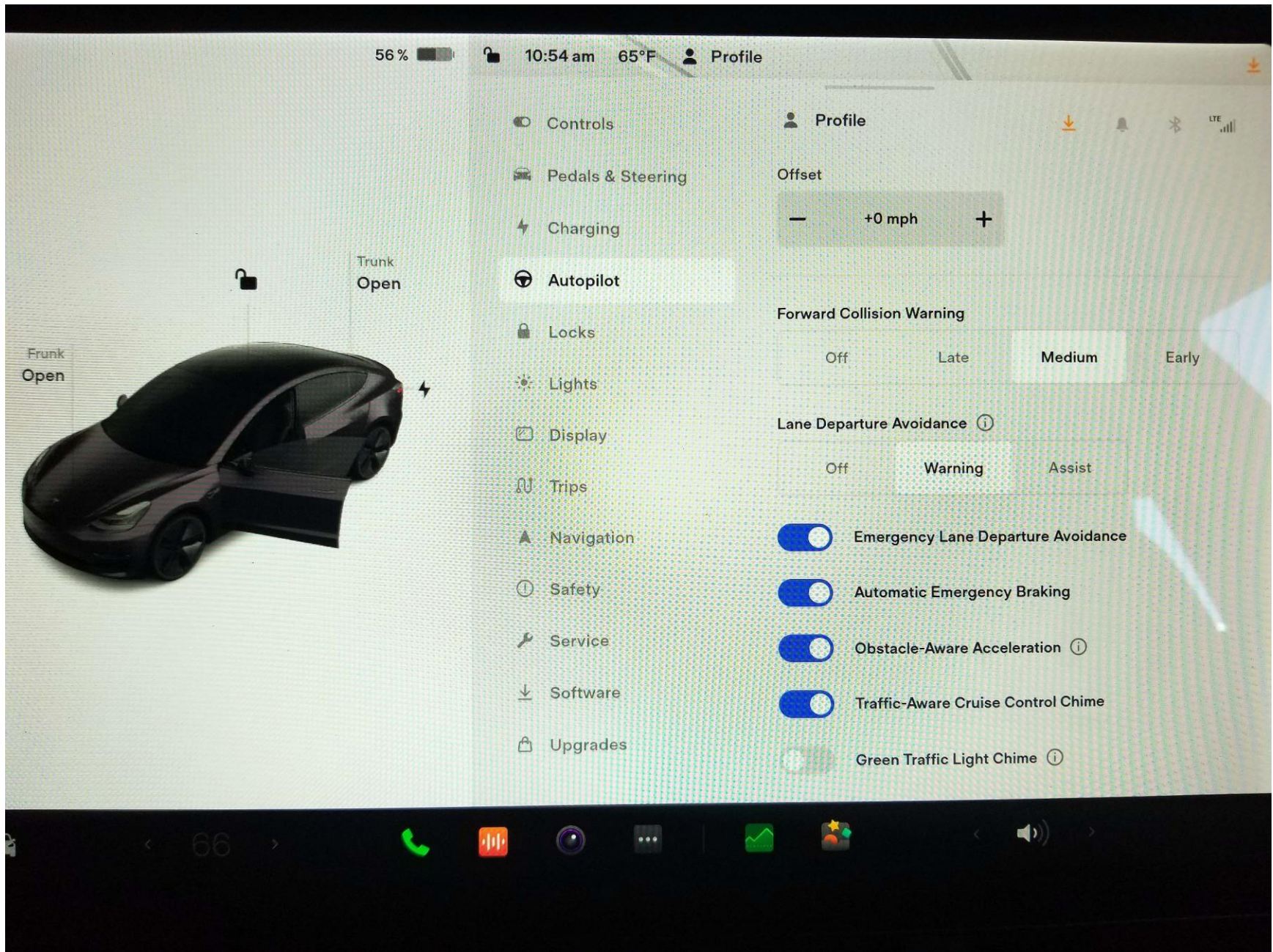


Figure A14. AEB System Setup Menus



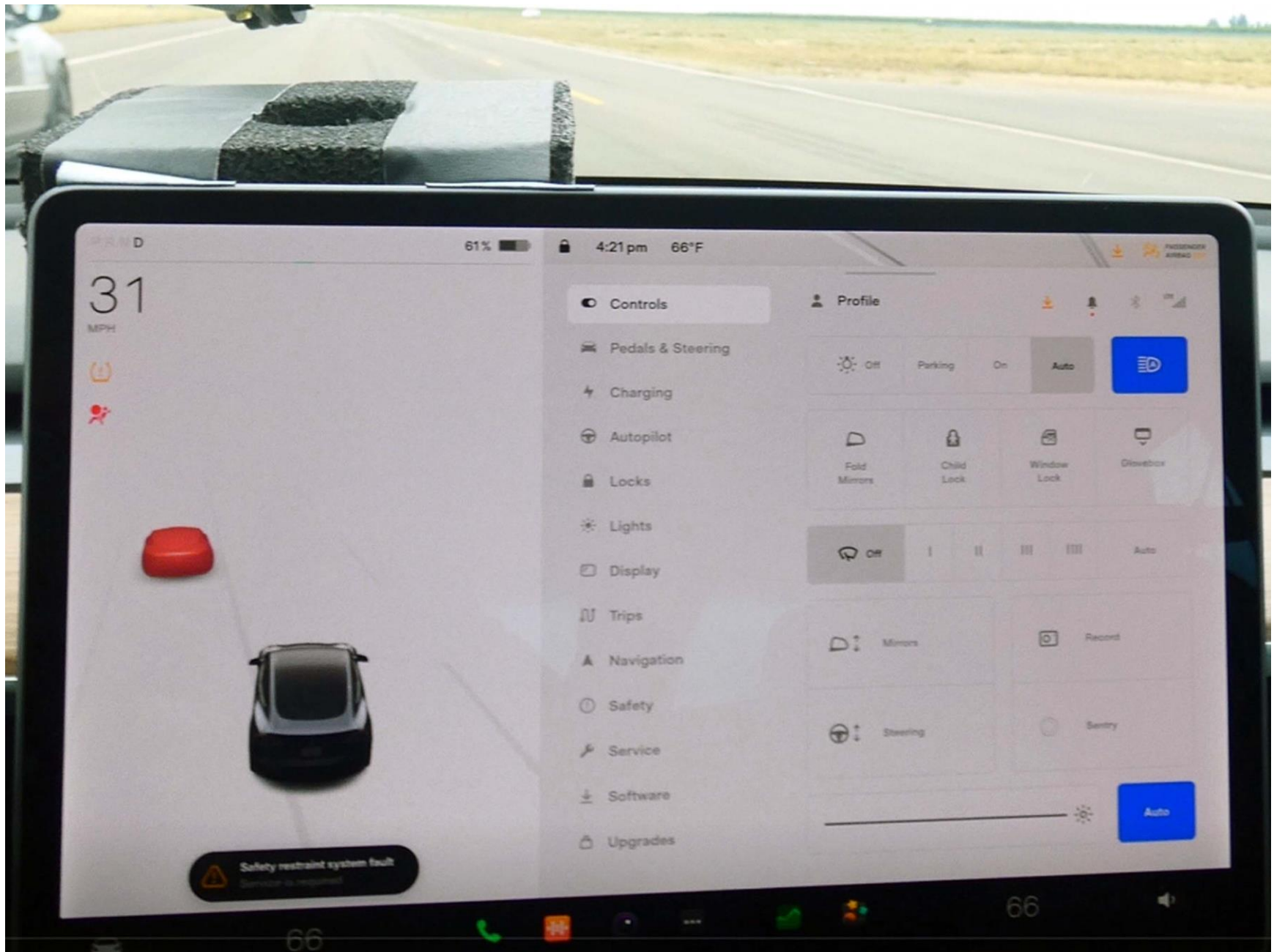


Figure A15. Visual Alert

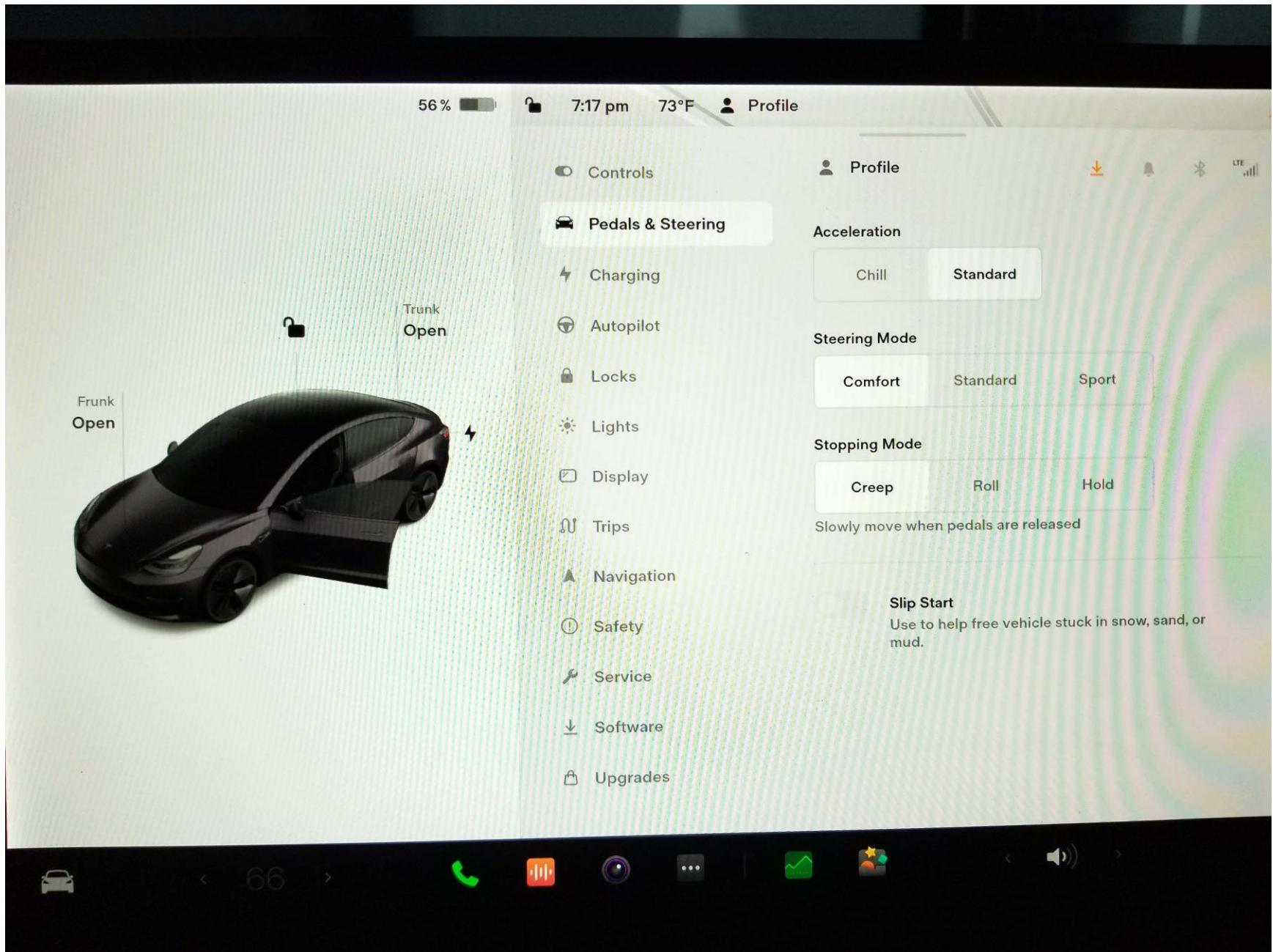


Figure A16. Stopping Mode



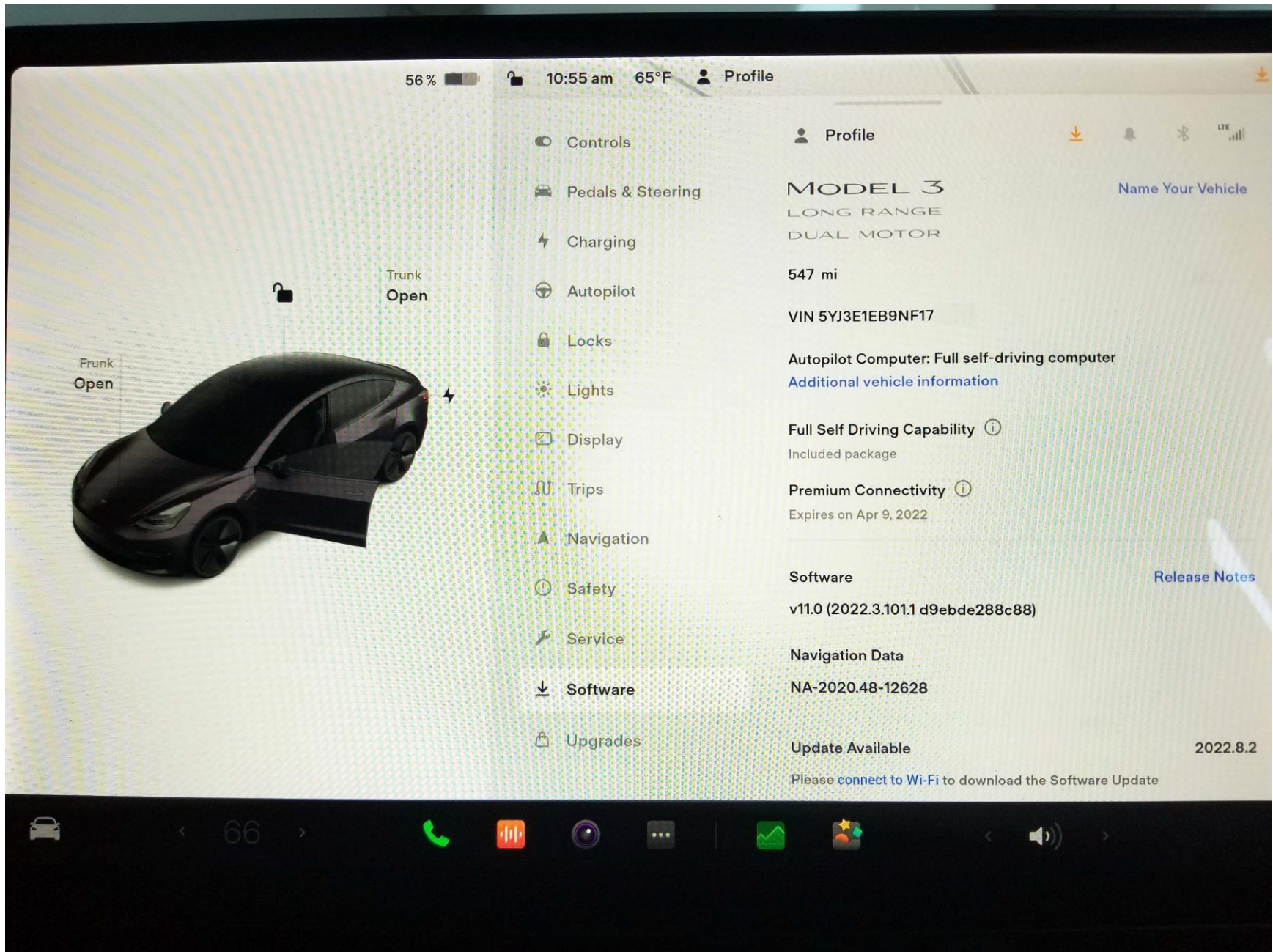


Figure A17. Software Version



## APPENDIX B

Excerpts from Owner's Manual



## Collision Avoidance Assist

The following collision avoidance features are designed to increase the safety of you and your passengers:

- **Forward Collision Warning** - provides visual and audible warnings in situations when Model 3 detects that there is a high risk of a frontal collision (see [Forward Collision Warning on page 112](#)).
- **Automatic Emergency Braking** - automatically applies braking to reduce the impact of a frontal collision (see [Automatic Emergency Braking on page 113](#)).
- **Obstacle-Aware Acceleration** - reduces acceleration if Model 3 detects an object in its immediate driving path (see [Obstacle-Aware Acceleration on page 113](#)).



**CAUTION:** Ensure all cameras and sensors are clean. Dirty cameras and sensors, as well as environmental conditions such as rain and faded lane markings, can affect performance.



**WARNING:** Forward Collision Warning is for guidance purposes only and is not a substitute for attentive driving and sound judgment. Keep your eyes on the road when driving and never depend on Forward Collision Warning to warn you of a potential collision. Several factors can reduce or impair performance, causing either unnecessary, invalid, inaccurate, or missed warnings. Depending on Forward Collision Warning to warn you of a potential collision can result in serious injury or death.



**WARNING:** Automatic Emergency Braking is not designed to prevent all collisions. In certain situations, it can minimize the impact of a frontal collision by attempting to reduce your driving speed. Depending on Automatic Emergency Braking to avoid a collision can result in serious injury or death.



**WARNING:** Obstacle-Aware Acceleration is not designed to prevent a collision. In certain situations, it can minimize the impact of a collision. Depending on Obstacle-Aware Acceleration to avoid a collision can result in serious injury or death.

### Forward Collision Warning

Model 3 monitors the area in front of it for the presence of an object such as a vehicle, motorcycle, bicycle, or pedestrian. If a collision is considered likely unless you take immediate corrective action, Forward Collision Warning is designed to sound a chime and highlight the vehicle in front of you in red on the touchscreen. If this happens, **TAKE IMMEDIATE CORRECTIVE ACTION!**



Warnings cancel automatically when the risk of a collision has been reduced (for example, you have decelerated or stopped Model 3, or the object in front of your vehicle has moved out of your driving path).

If immediate action is not taken when Model 3 issues a Forward Collision Warning, Automatic Emergency Braking (if enabled) may automatically apply the brakes if a collision is considered imminent (see [Automatic Emergency Braking on page 113](#)).

By default, Forward Collision Warning is turned on. To turn it off or adjust its sensitivity, touch **Controls > Autopilot > Forward Collision Warning**. Instead of the default warning level of **Medium**, you can turn the warning **Off**, or you can choose to be warned **Late** or **Early**.

**NOTE:** Your chosen setting for Forward Collision Warning is retained until you manually change it.



**WARNING:** The camera(s) and sensors associated with Forward Collision Warning are designed to monitor an approximate area of up to 525 feet (160 meters) in your driving path. The area being monitored by Forward Collision Warning can be adversely affected by road and weather conditions. Use appropriate caution when driving.



**WARNING:** Forward Collision Warning is designed only to provide visual and audible alerts. It does not attempt to apply the brakes or decelerate Model 3. When seeing and/or hearing a warning, it is the driver's responsibility to take immediate corrective action.



**⚠ WARNING:** Forward Collision Warning may provide a warning in situations where the likelihood of collision may not exist. Stay alert and always pay attention to the area in front of Model 3 so you can anticipate whether any action is required.

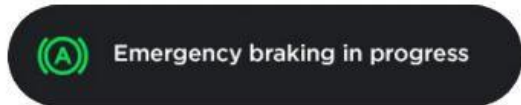
Forward Collision Warning operates only when driving between approximately 3 mph (5 km/h) and 90 mph (150 km/h).

**⚠ WARNING:** Forward Collision Warning does not provide a warning when the driver is already applying the brake.

### Automatic Emergency Braking

Model 3 is designed to determine the distance from a detected object traveling in front of it. When a frontal collision is considered unavoidable, Automatic Emergency Braking is designed to apply the brakes to reduce the vehicle's speed and therefore, the severity of the impact. The amount of speed that is reduced depends on many factors, including driving speed and environment.

When Automatic Emergency Braking applies the brakes, the touchscreen displays a visual warning and sounds a chime. You may also notice abrupt downward movement of the brake pedal. The brake lights turn on to alert other road users that you are slowing down.



Automatic Emergency Braking operates only when driving between approximately 3 mph (5 km/h) and 90 mph (150 km/h).

Automatic Emergency Braking does not apply the brakes, or stops applying the brakes, when:

- You turn the steering wheel sharply.
- You press and release the brake pedal while Automatic Emergency Braking is applying the brakes.
- You accelerate hard while Automatic Emergency Braking is applying the brakes.
- The vehicle, motorcycle, bicycle, or pedestrian is no longer detected ahead.

Automatic Emergency Braking is always enabled when you start Model 3. To disable it for your current drive, touch **Controls > Autopilot > Automatic Emergency Braking**.

**⚠ WARNING:** It is strongly recommended that you do not disable Automatic Emergency Braking. If you disable it, Model 3 does not automatically apply the brakes in situations where a collision is considered likely.

**⚠ WARNING:** Automatic Emergency Braking is designed to reduce the severity of an impact. It is not designed to avoid a collision.

**⚠ WARNING:** Several factors can affect the performance of Automatic Emergency Braking, causing either no braking or inappropriate or untimely braking, such as when a vehicle is partially in the path of travel or there is road debris. It is the driver's responsibility to drive safely and remain in control of the vehicle at all times. Never depend on Automatic Emergency Braking to avoid or reduce the impact of a collision.

**⚠ WARNING:** Automatic Emergency Braking is designed to reduce the impact of frontal collisions only and does not function when Model 3 is in Reverse.

**⚠ WARNING:** Automatic Emergency Braking is not a substitute for maintaining a safe traveling distance between you and the vehicle in front of you.

**⚠ WARNING:** The brake pedal moves downward abruptly during automatic braking events. Always ensure that the brake pedal can move freely. Do not place material under or on top of the driver's floor mat (including an additional mat) and always ensure that the driver's floor mat is properly secured. Failure to do so can impede the ability of the brake pedal to move freely.

### Obstacle-Aware Acceleration

Obstacle-Aware Acceleration is designed to reduce the impact of a collision by reducing motor torque and in some cases applying the brakes, if Model 3 detects an object in its driving path. The touchscreen displays a visual warning and sounds a chime when the brakes are automatically applied. For example, Model 3, while parked in front of a closed garage door with the Drive gear engaged, detects that you have pressed hard on the accelerator pedal. Although Model 3 still accelerates and hits the garage door, the reduced torque may result in less damage.

Obstacle-Aware Acceleration is designed to operate only when all of these conditions are simultaneously met:







- A driving gear is engaged (Drive or Reverse).
- Model 3 is stopped or traveling less than 10 mph (16 km/h).
- Model 3 detects an object in its immediate driving path.

To disable Obstacle-Aware Acceleration, touch **Controls > Autopilot > Obstacle-Aware Acceleration**.






## Collision Avoidance Assist

-  **WARNING:** Obstacle-Aware Acceleration is designed to reduce the severity of an impact. It is not designed to avoid a collision.
-  **WARNING:** Obstacle-Aware Acceleration may not limit torque in all situations. Several factors, including environmental conditions, distance from an obstacle, and a driver's actions, can limit, delay, or inhibit Obstacle-Aware Acceleration.
-  **WARNING:** Obstacle-Aware Acceleration may not limit torque when performing a sharp turn, such as into a parking space.
-  **WARNING:** Do not rely on Obstacle-Aware Acceleration to control acceleration or to avoid, or limit, the severity of a collision, and do not attempt to test Obstacle-Aware Acceleration. Doing so can result in serious property damage, injury, or death.
-  **WARNING:** Several factors can affect the performance of Obstacle-Aware Acceleration, causing an inappropriate or untimely reduction in motor torque. It is the driver's responsibility to drive safely and remain in control of Model 3 at all times.
-  **CAUTION:** If a fault occurs with a Collision Avoidance Assist feature, Model 3 displays an alert. Contact Tesla Service.

### Limitations and Inaccuracies

Collision Avoidance features cannot always detect all objects, vehicles, bikes, or pedestrians, and you may experience unnecessary, inaccurate, invalid, or missed warnings for many reasons, particularly if:

- The road has sharp curves.
- Visibility is poor (due to heavy rain, snow, fog, etc.).
- Bright light (such as from oncoming headlights or direct sunlight) is interfering with the view of the camera(s).
- The camera or radar sensor (if equipped) is obstructed (dirty, covered, fogged over, covered by a sticker, etc.).
- One or more of the ultrasonic sensors is damaged, dirty, or obstructed (such as by mud, ice, or snow, or by a vehicle bra, excessive paint, or adhesive products such as wraps, stickers, rubber coating, etc.).
- Weather conditions (heavy rain, snow, fog, or extremely hot or cold temperatures) are interfering with sensor operation.
- The sensors are affected by other electrical equipment or devices that generate ultrasonic waves.

-  **WARNING:** The limitations previously described do not represent an exhaustive list of situations that may interfere with proper operation of Collision Avoidance Assist features. These features may fail to provide their intended function for many other reasons. It is the driver's responsibility to avoid collisions by staying alert, paying attention, and taking corrective action as early as possible.

## APPENDIX C

### Run Log

Subject Vehicle: **2022 Tesla Model 3 AWD**

Test start date: **3/22/2022**

Principal Other Vehicle: **SSV**

Test end date: **3/22/2022**

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	<b>Stopped POV</b>	Y	2.62	3.25	25.3	1.05	0.58	Pass	
3		Y	2.60	4.05	24.7	1.08	0.61	Pass	
4		Y	2.61	4.55	25.6	1.12	0.63	Pass	
5		Y	2.59	3.95	25.0	1.11	0.60	Pass	
6		Y	2.65	4.45	25.4	1.03	0.64	Pass	
7		Y	2.58	3.61	24.9	1.10	0.59	Pass	
8		Y	2.59	3.92	24.7	1.03	0.61	Pass	
9	Static Run								
10	<b>Slower POV, 25 vs 10</b>	Y	2.71	13.39	14.4	0.22		Pass	No additional AEB
11		Y	2.67	8.71	15.3	0.22		Pass	No additional AEB
12		Y	2.65	10.06	14.6	0.22		Pass	No additional AEB
13		Y	2.52	6.61	14.5	0.22		Pass	No additional AEB
14		Y	2.65	7.41	15.6	0.22		Pass	No additional AEB
15		Y	2.58	8.73	14.4	0.22		Pass	No additional AEB
16		Y	2.65	7.15	15.8	0.22		Pass	No additional AEB
17	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
18	<b>Slower POV, 45 vs 20</b>	Y	2.85	8.01	24.9	0.98	0.79	Pass	
19		Y	2.77	13.74	25.5	0.95	1.02	Pass	
20		Y	2.84	8.29	25.1	0.94	0.82	Pass	
21		Y	2.99	7.52	25.7	0.96	0.77	Pass	
22		Y	2.87	7.22	25.2	0.96	0.75	Pass	
23		N							POV Speed
24		Y	3.04	1.99	24.2	1.04	0.44	Pass	
25		Y	2.94	6.24	25.3	0.96	0.72	Pass	
26		Static run							
27	<b>Decelerating POV, 35</b>	N							POV Brakes
28		Y	2.39	17.85	19.9	0.95	1.35	Pass	
29		Y	2.46	15.19	20.4	0.95	1.22	Pass	
30		Y	2.52	15.95	21.1	0.93	1.25	Pass	
31		Y	2.32	16.68	18.5	0.91	1.35	Pass	
32		Y	2.24	17.28	17.9	0.95	1.34	Pass	
33		Y	2.72	14.46	21.5	0.99	1.20	Pass	
34		Y	2.52	14.41	22.8	0.96	1.14	Pass	
35	Static Run								
36	STP - Static Run								
37		N							Yaw Rate

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
38	<b>STP False Positive, 25</b>	Y				0.01		Pass	
39		N							Lateral Offset, Yaw Rate
40		Y				0.02		Pass	
41		Y				0.01		Pass	
42		Y				0.01		Pass	
43		Y				0.01		Pass	
44		Y				0.01		Pass	
45		Y				0.01		Pass	
46	STP - Static Run								
47	<b>STP False Positive, 45</b>	N							SV Speed
48		N							SV Speed
49		N							Lane Offset
50		Y				0.02		Pass	
51		Y				0.01		Pass	
52		Y				0.02		Pass	
53		Y				0.00		Pass	
54		Y				0.03		Pass	
55		Y				0.01		Pass	
56		Y				0.00		Pass	
57	STP - Static Run								



## APPENDIX D

### Time History Plots

## LIST OF FIGURES

	Page
Figure D1. Example Time History for Stopped POV, Passing.....	D-9
Figure D2. Example Time History for Slower POV 25 vs. 10, Passing.....	D-10
Figure D3. Example Time History for Slower POV 45 vs. 20, Passing.....	D-11
Figure D4. Example Time History for Decelerating POV 35, Passing.....	D-12
Figure D5. Example Time History for False Positive STP 25, Passing.....	D-13
Figure D6. Example Time History for False Positive STP 45, Passing.....	D-14
Figure D7. Example Time History Displaying Invalid Headway Criteria.....	D-15
Figure D8. Example Time History Displaying Various Invalid Criteria.....	D-16
Figure D9. Example Time History for a Failed Run.....	D-17
Figure D10. Time History for CIB Run 2, Test 1 - Stopped POV.....	D-18
Figure D11. Time History for CIB Run 3, Test 1 - Stopped POV.....	D-19
Figure D12. Time History for CIB Run 4, Test 1 - Stopped POV.....	D-20
Figure D13. Time History for CIB Run 5, Test 1 - Stopped POV.....	D-21
Figure D14. Time History for CIB Run 6, Test 1 - Stopped POV.....	D-22
Figure D15. Time History for CIB Run 7, Test 1 - Stopped POV.....	D-23
Figure D16. Time History for CIB Run 8, Test 1 - Stopped POV.....	D-24
Figure D17. Time History for CIB Run 10, Test 2 - Slower Moving POV, 25/10 mph.....	D-25
Figure D18. Time History for CIB Run 11, Test 2 - Slower Moving POV, 25/10 mph.....	D-26
Figure D19. Time History for CIB Run 12, Test 2 - Slower Moving POV, 25/10 mph.....	D-27
Figure D20. Time History for CIB Run 13, Test 2 - Slower Moving POV, 25/10 mph.....	D-28
Figure D21. Time History for CIB Run 14, Test 2 - Slower Moving POV, 25/10 mph.....	D-29
Figure D22. Time History for CIB Run 15, Test 2 - Slower Moving POV, 25/10 mph.....	D-30
Figure D23. Time History for CIB Run 16, Test 2 - Slower Moving POV, 25/10 mph.....	D-31
Figure D24. Time History for CIB Run 18, Test 2 - Slower Moving POV, 45/20 mph.....	D-32
Figure D25. Time History for CIB Run 19, Test 2 - Slower Moving POV, 45/20 mph.....	D-33
Figure D26. Time History for CIB Run 20, Test 2 - Slower Moving POV, 45/20 mph.....	D-34
Figure D27. Time History for CIB Run 21, Test 2 - Slower Moving POV, 45/20 mph.....	D-35
Figure D28. Time History for CIB Run 22, Test 2 - Slower Moving POV, 45/20 mph.....	D-36
Figure D29. Time History for CIB Run 24, Test 2 - Slower Moving POV, 45/20 mph.....	D-37
Figure D30. Time History for CIB Run 25, Test 2 - Slower Moving POV, 45/20 mph.....	D-38
Figure D31. Time History for CIB Run 28, Test 3 - Decelerating POV 35 mph.....	D-39
Figure D32. Time History for CIB Run 29, Test 3 - Decelerating POV 35 mph.....	D-40
Figure D33. Time History for CIB Run 30, Test 3 - Decelerating POV 35 mph.....	D-41
Figure D34. Time History for CIB Run 31, Test 3 - Decelerating POV 35 mph.....	D-42
Figure D35. Time History for CIB Run 32, Test 3 - Decelerating POV 35 mph.....	D-43
Figure D36. Time History for CIB Run 33, Test 3 - Decelerating POV 35 mph.....	D-44
Figure D37. Time History for CIB Run 34, Test 3 - Decelerating POV 35 mph.....	D-45
Figure D38. Time History for CIB Run 38, Test 4 - False Positive STP, 25 mph.....	D-46
Figure D39. Time History for CIB Run 40, Test 4 - False Positive STP, 25 mph.....	D-47
Figure D40. Time History for CIB Run 41, Test 4 - False Positive STP, 25 mph.....	D-48
Figure D41. Time History for CIB Run 42, Test 4 - False Positive STP, 25 mph.....	D-49

Figure D42. Time History for CIB Run 43, Test 4 - False Positive STP, 25 mph.....	D-50
Figure D43. Time History for CIB Run 44, Test 4 - False Positive STP, 25 mph.....	D-51
Figure D44. Time History for CIB Run 45, Test 4 - False Positive STP, 25 mph.....	D-52
Figure D45. Time History for CIB Run 50, Test 4 - False Positive STP, 45 mph.....	D-53
Figure D46. Time History for CIB Run 51, Test 4 - False Positive STP, 45 mph.....	D-54
Figure D47. Time History for CIB Run 52, Test 4 - False Positive STP, 45 mph.....	D-55
Figure D48. Time History for CIB Run 53, Test 4 - False Positive STP, 45 mph.....	D-56
Figure D49. Time History for CIB Run 54, Test 4 - False Positive STP, 45 mph.....	D-57
Figure D50. Time History for CIB Run 55, Test 4 - False Positive STP, 45 mph.....	D-58
Figure D51. Time History for CIB Run 56, Test 4 - False Positive STP, 45 mph.....	D-59

## 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 auditory, 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 auditory 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.

## 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.



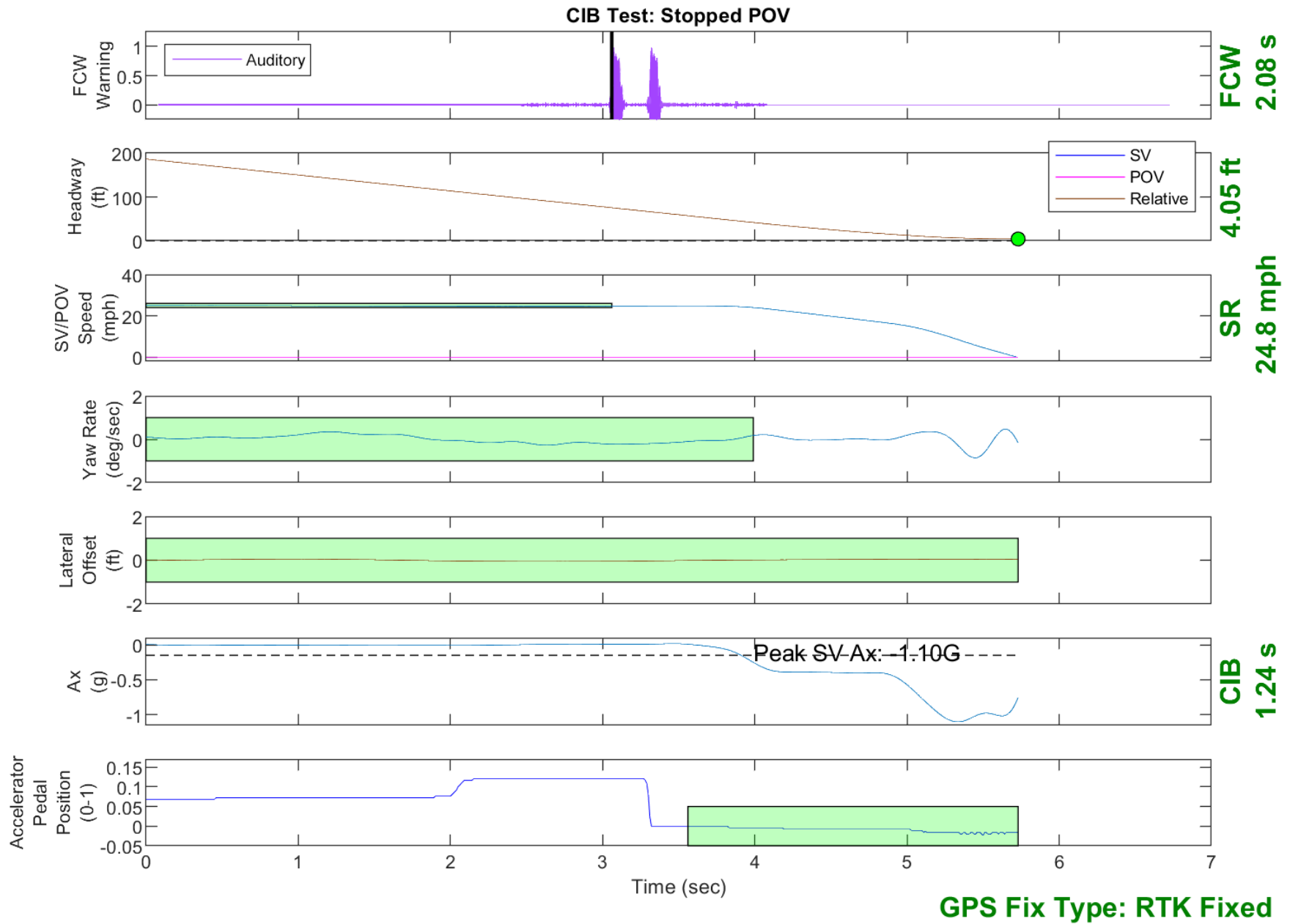


Figure D1. Example Time History for Stopped POV, Passing

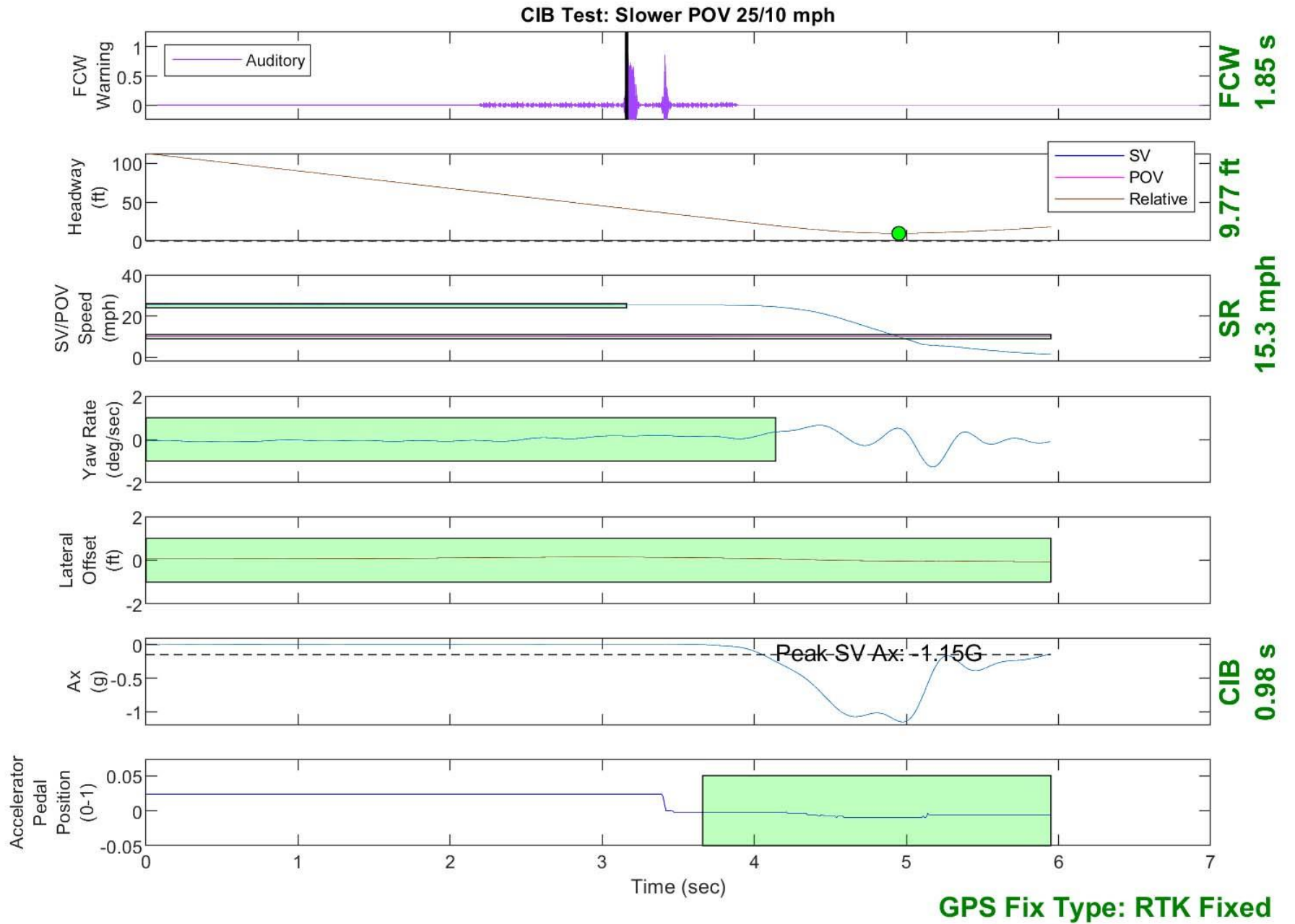


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

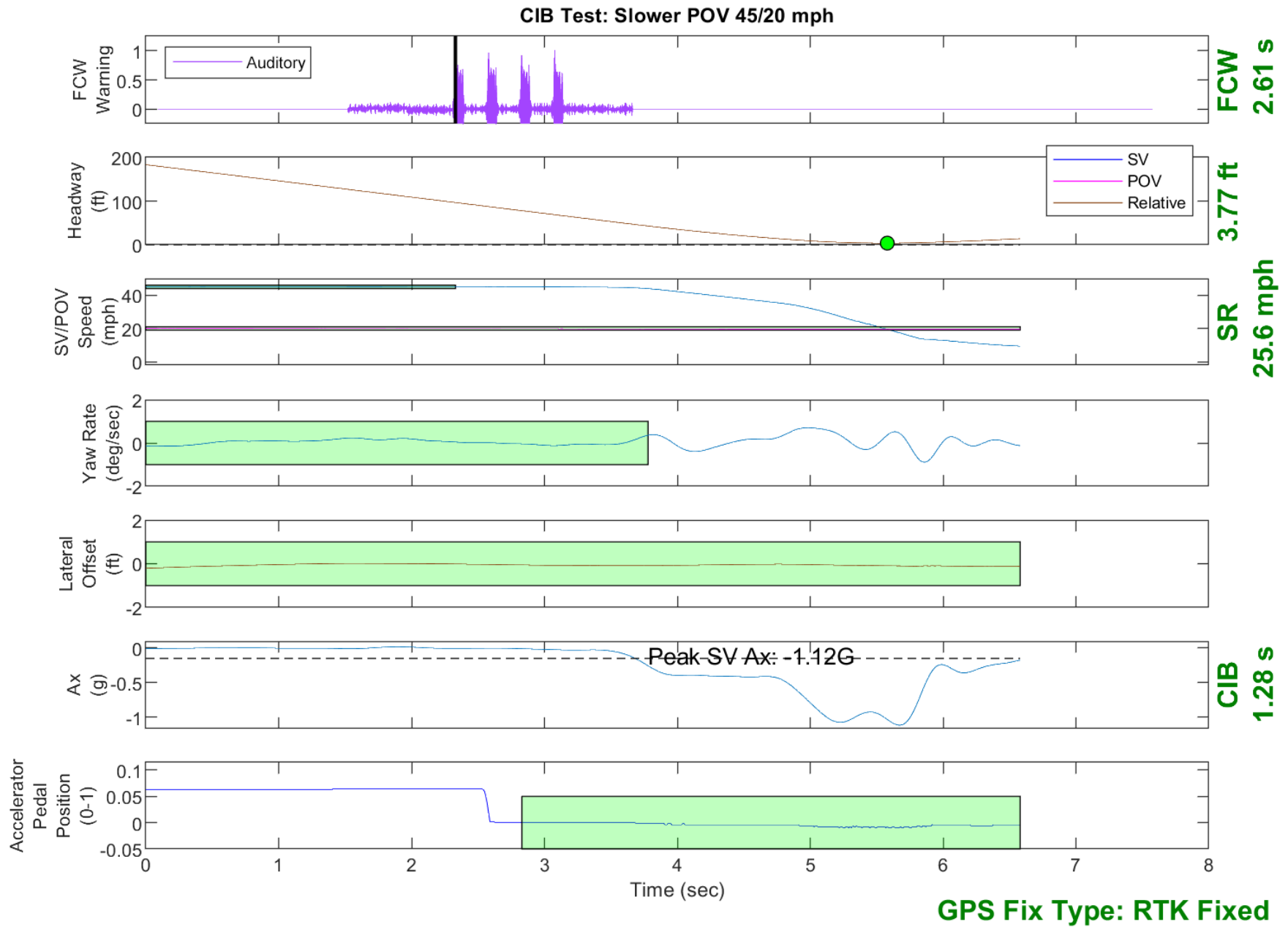


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

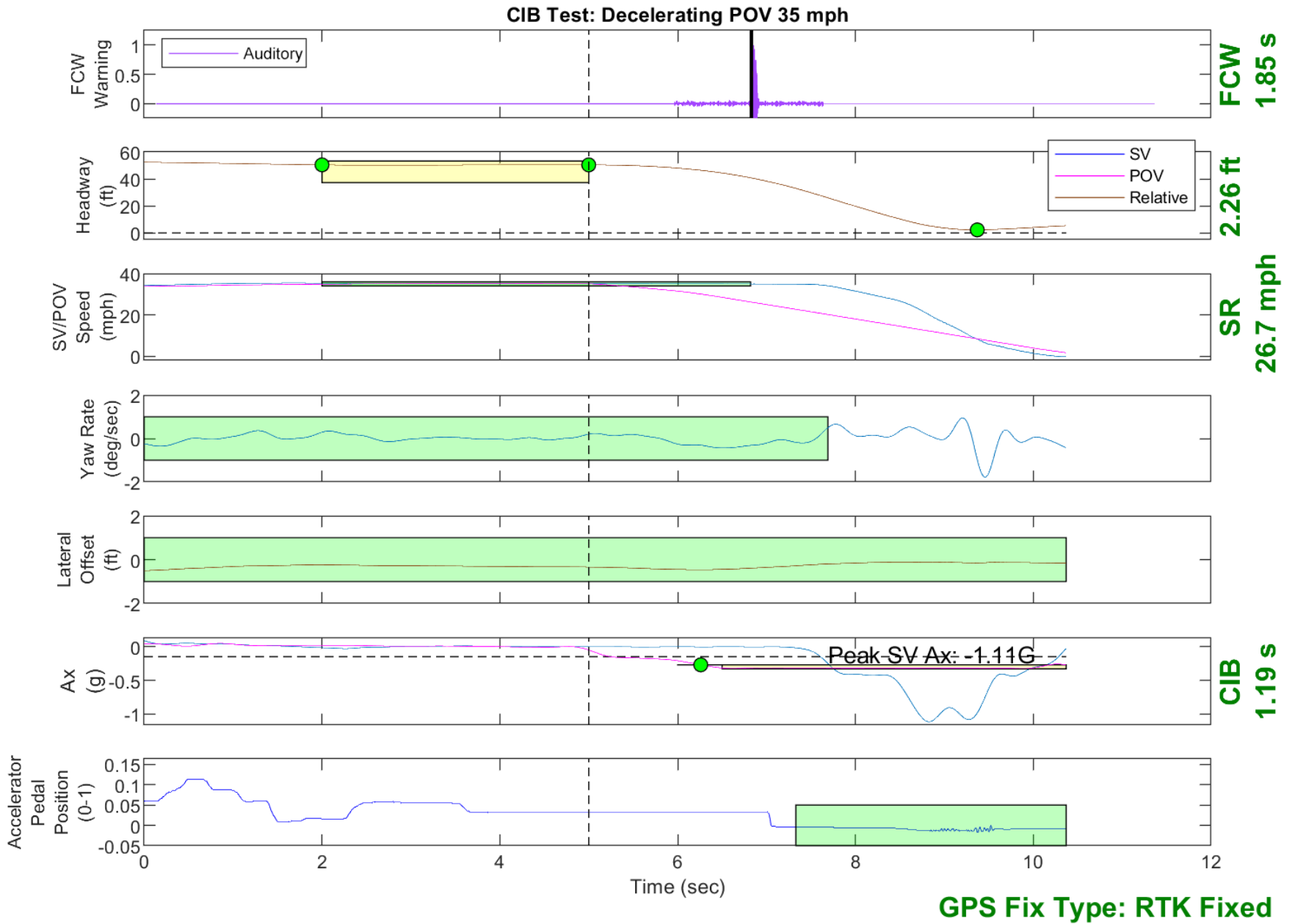


Figure D4. Example Time History for Decelerating POV 35, Passing

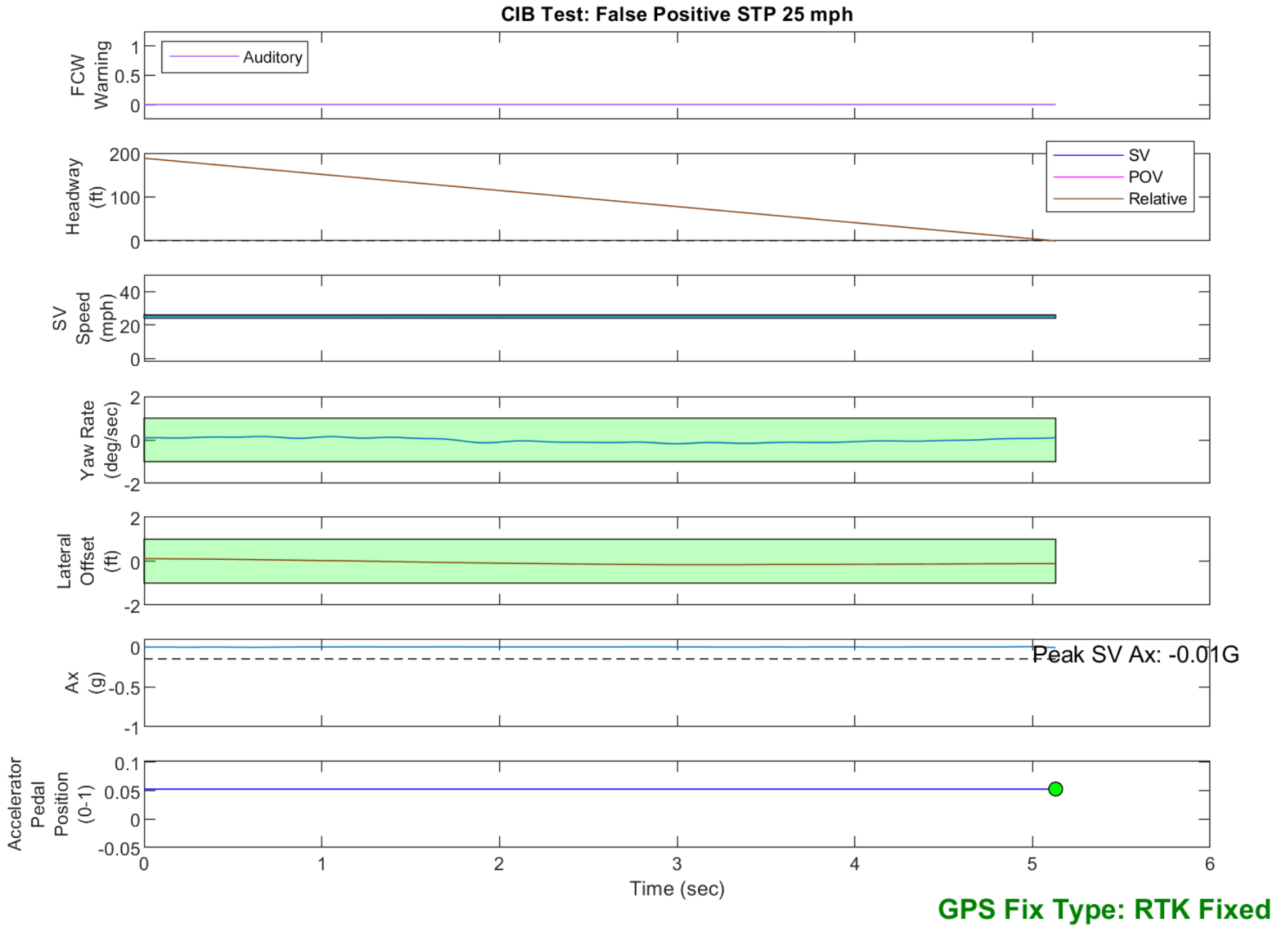


Figure D5. Example Time History for False Positive STP 25, Passing

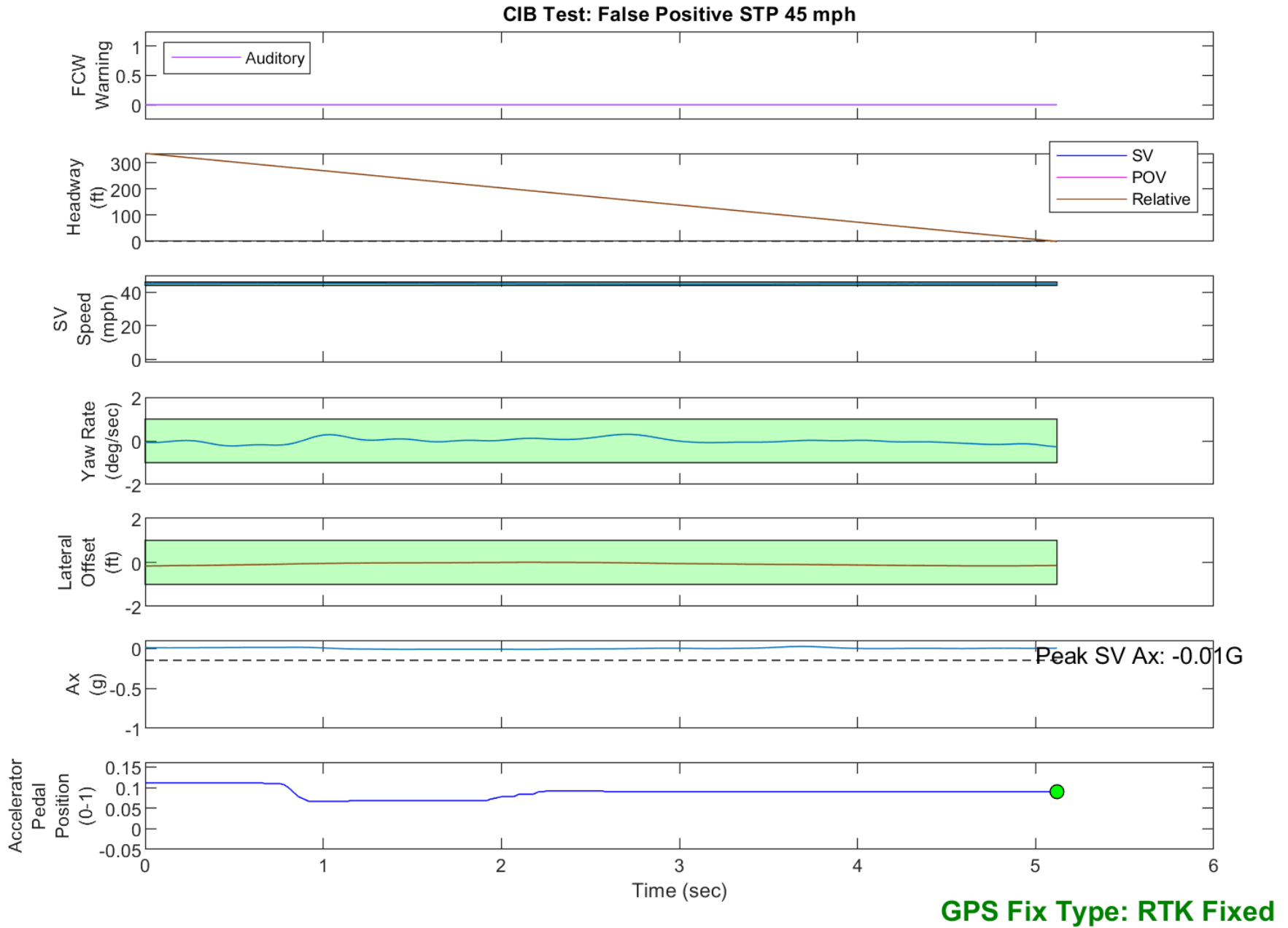


Figure D6. Example Time History for False Positive STP 45, Passing

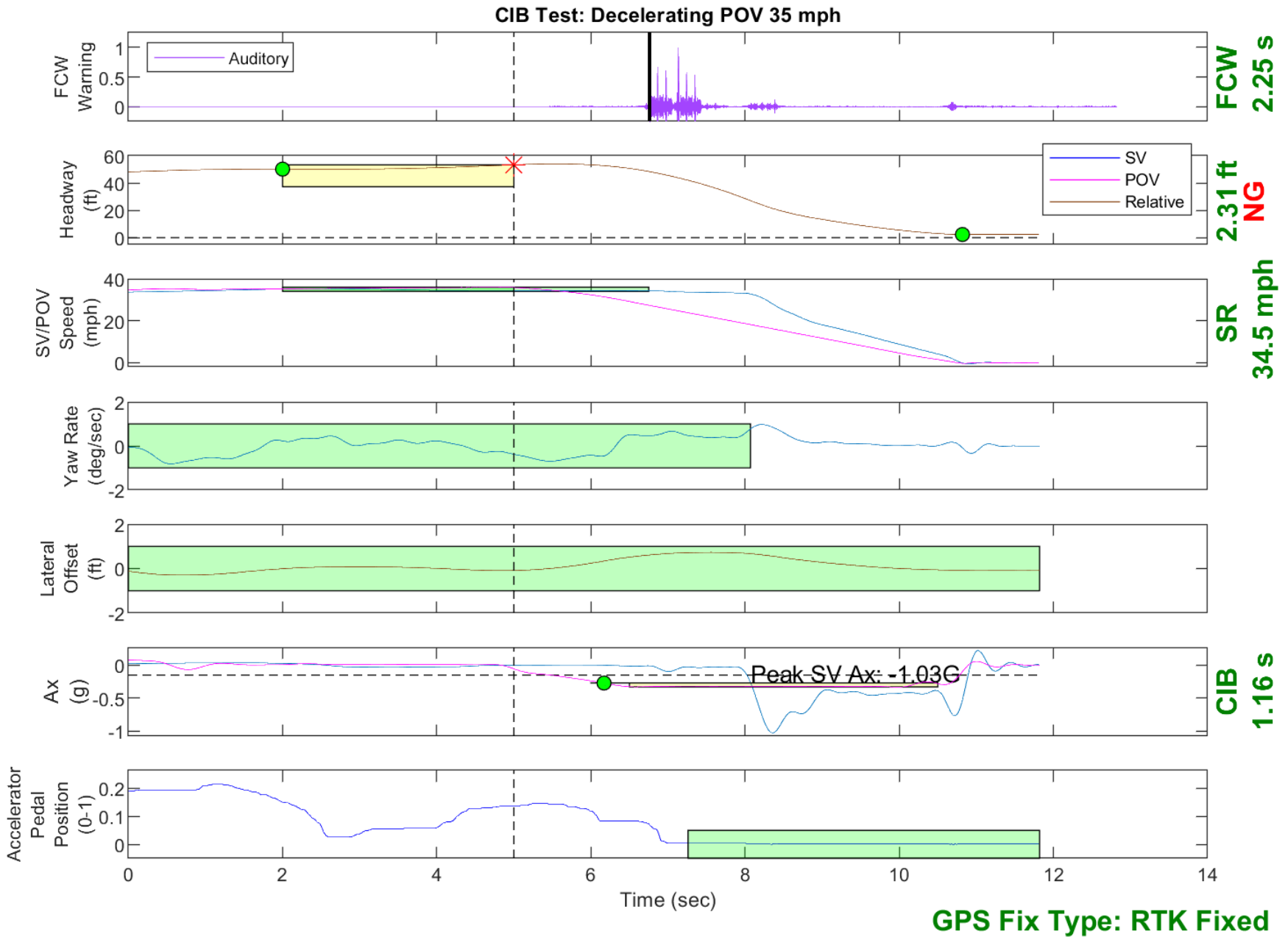


Figure D7. Example Time History Displaying Invalid Headway Criteria

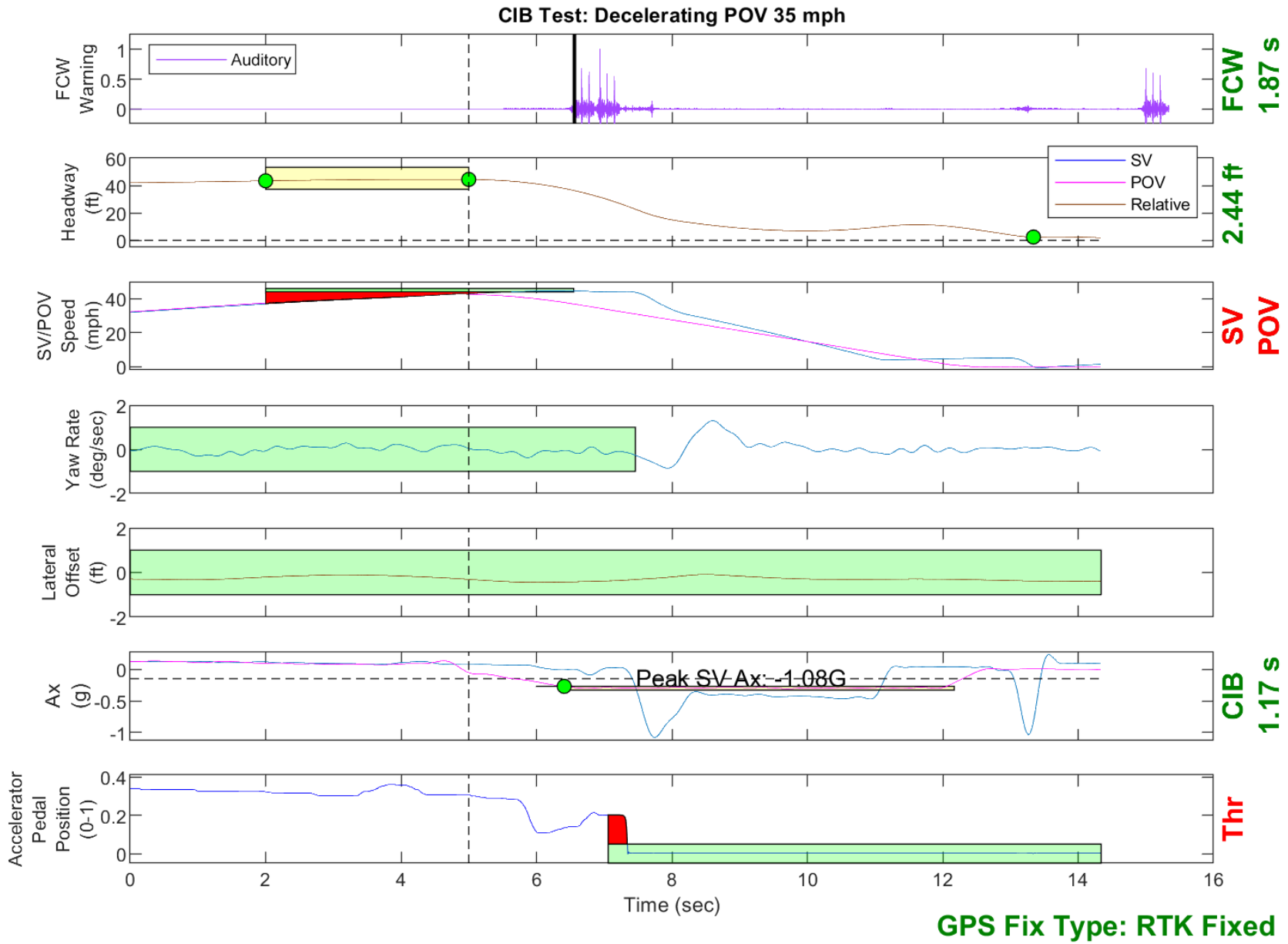


Figure D8. Example Time History Displaying Various Invalid Criteria



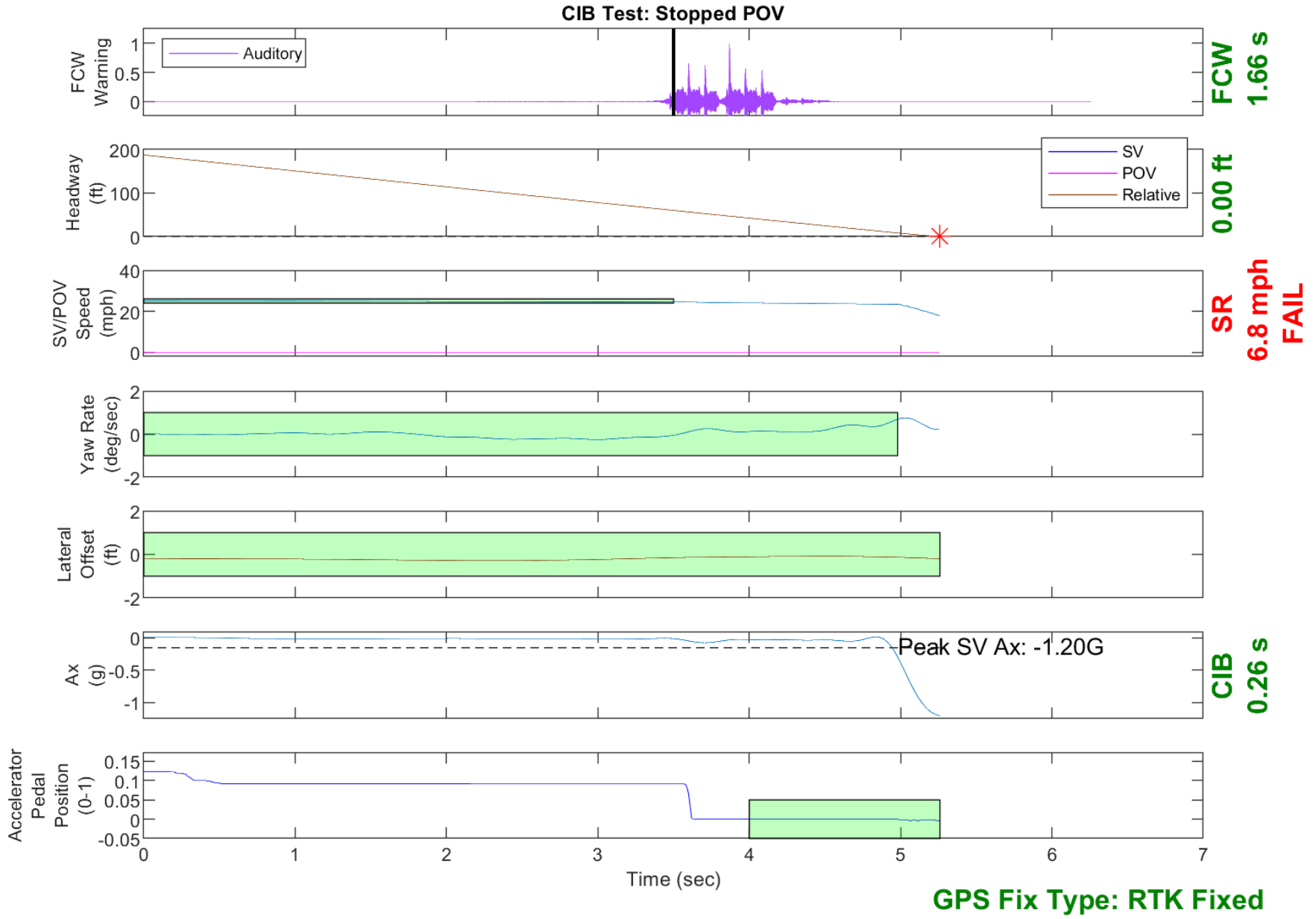


Figure D9. Example Time History for a Failed Run

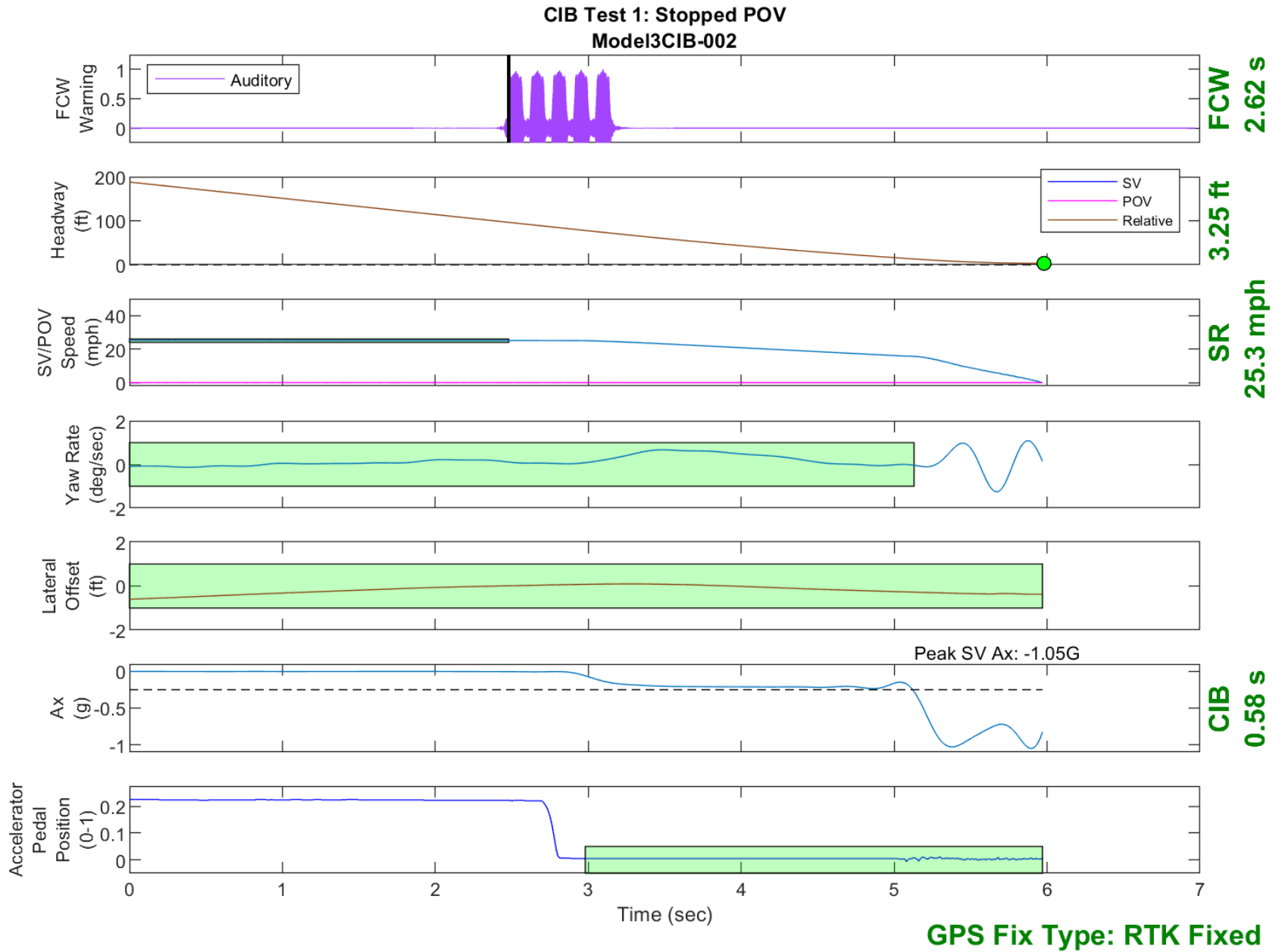


Figure D10. Time History for CIB Run 2, Test 1 - Stopped POV

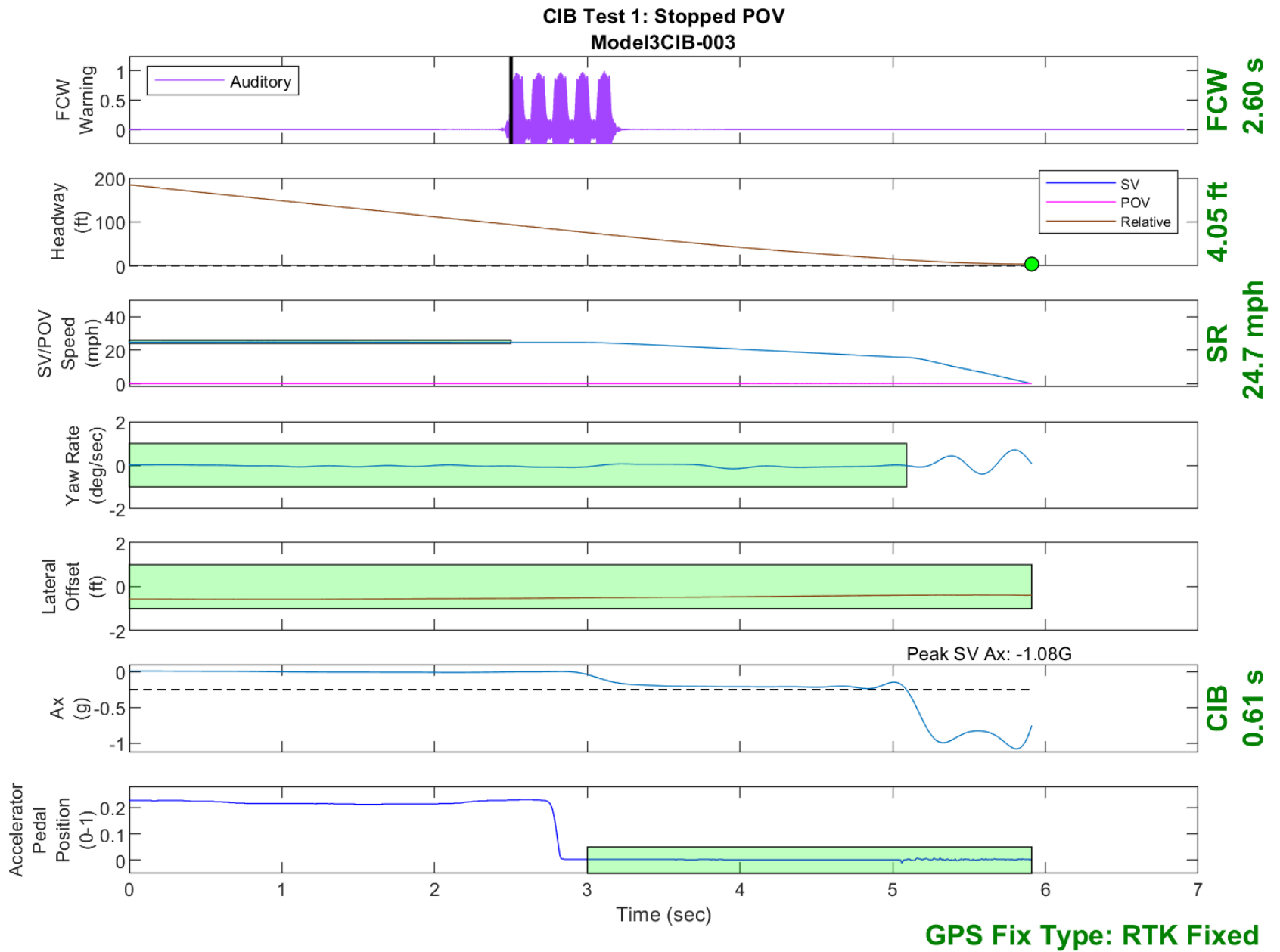


Figure D11. Time History for CIB Run 3, Test 1 - Stopped POV

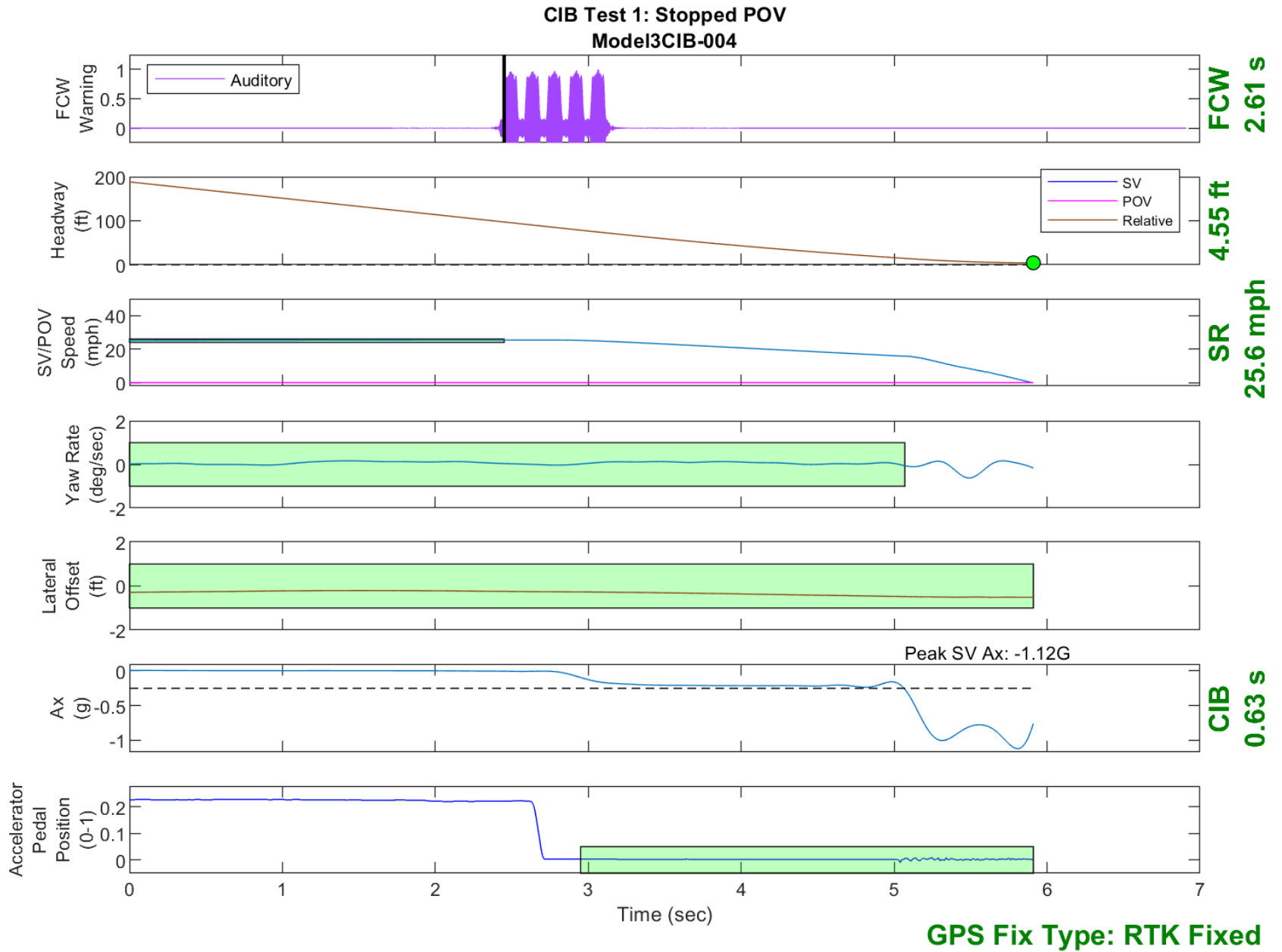


Figure D12. Time History for CIB Run 4, Test 1 - Stopped POV

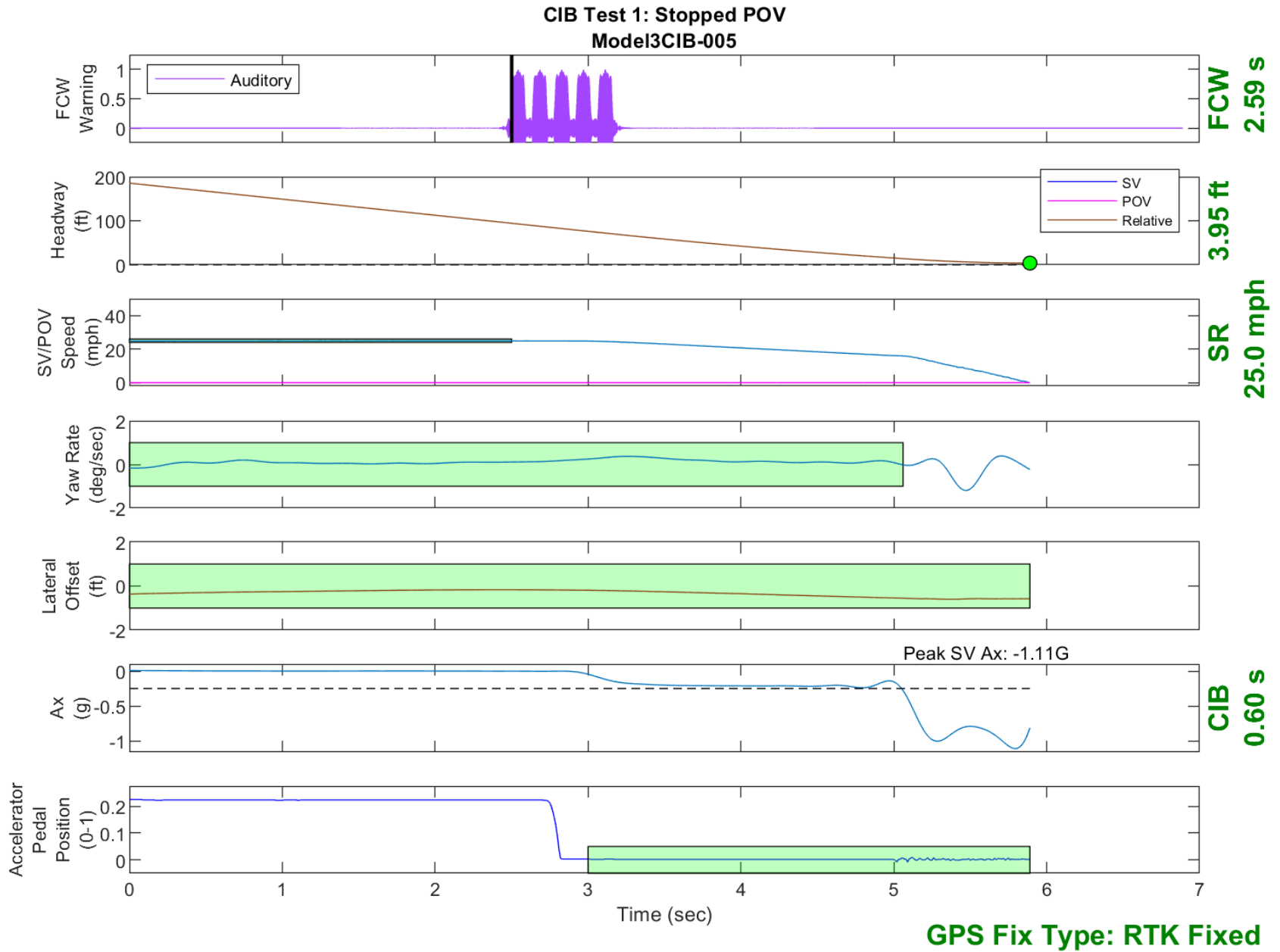


Figure D13. Time History for CIB Run 5, Test 1 - Stopped POV



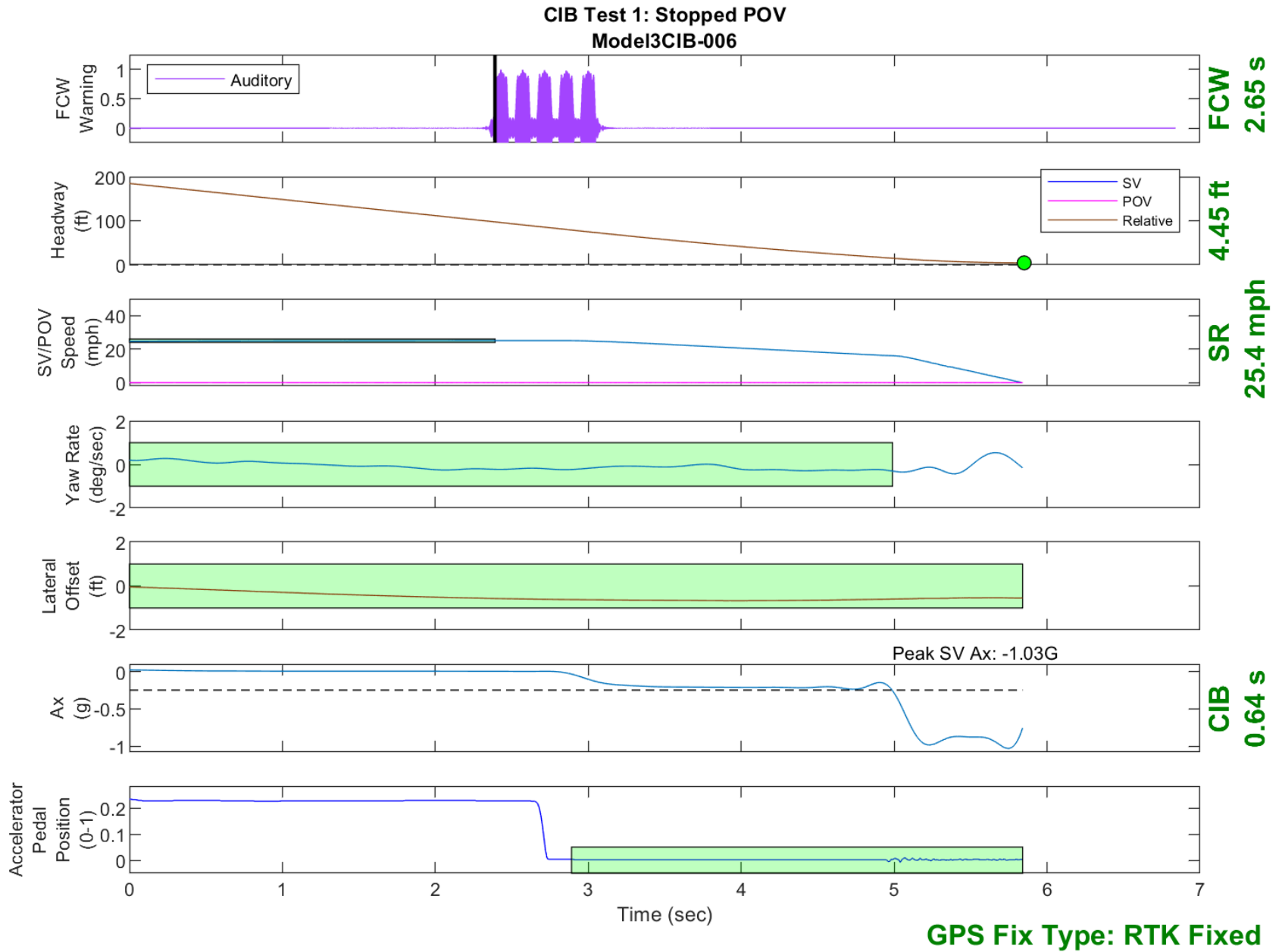


Figure D14. Time History for CIB Run 6, Test 1 - Stopped POV

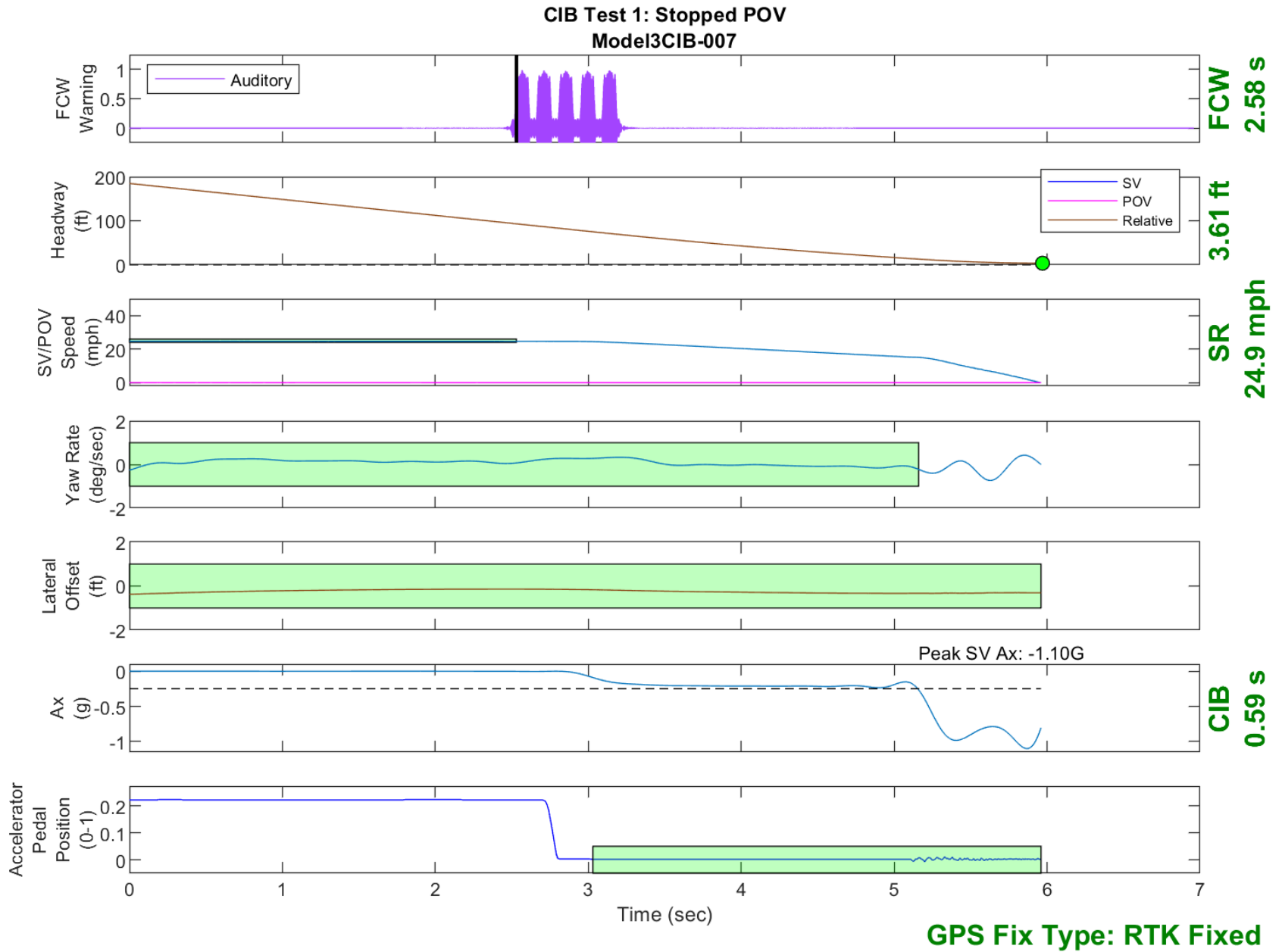


Figure D15. Time History for CIB Run 7, Test 1 - Stopped POV

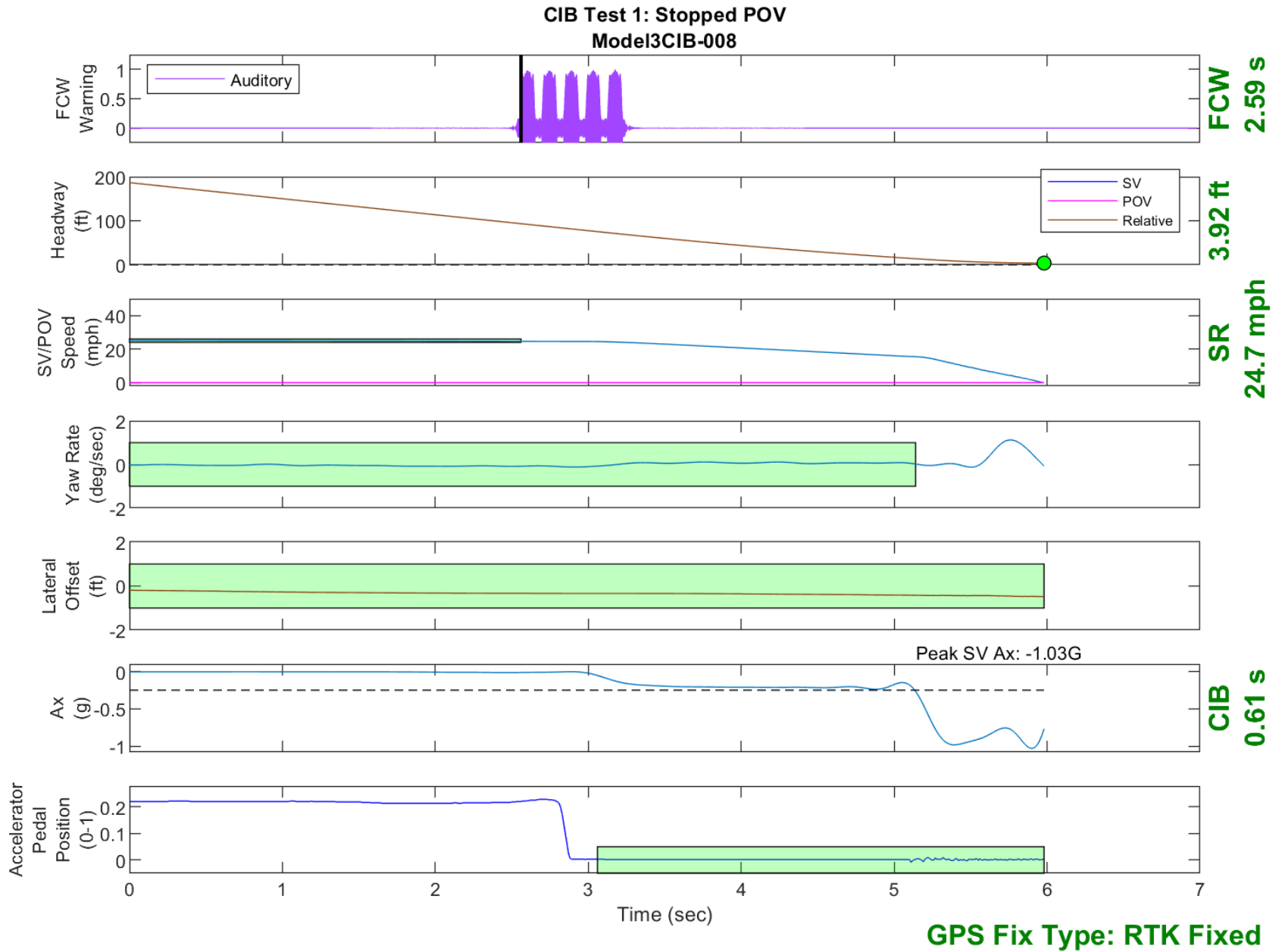


Figure D16. Time History for CIB Run 8, Test 1 - Stopped POV

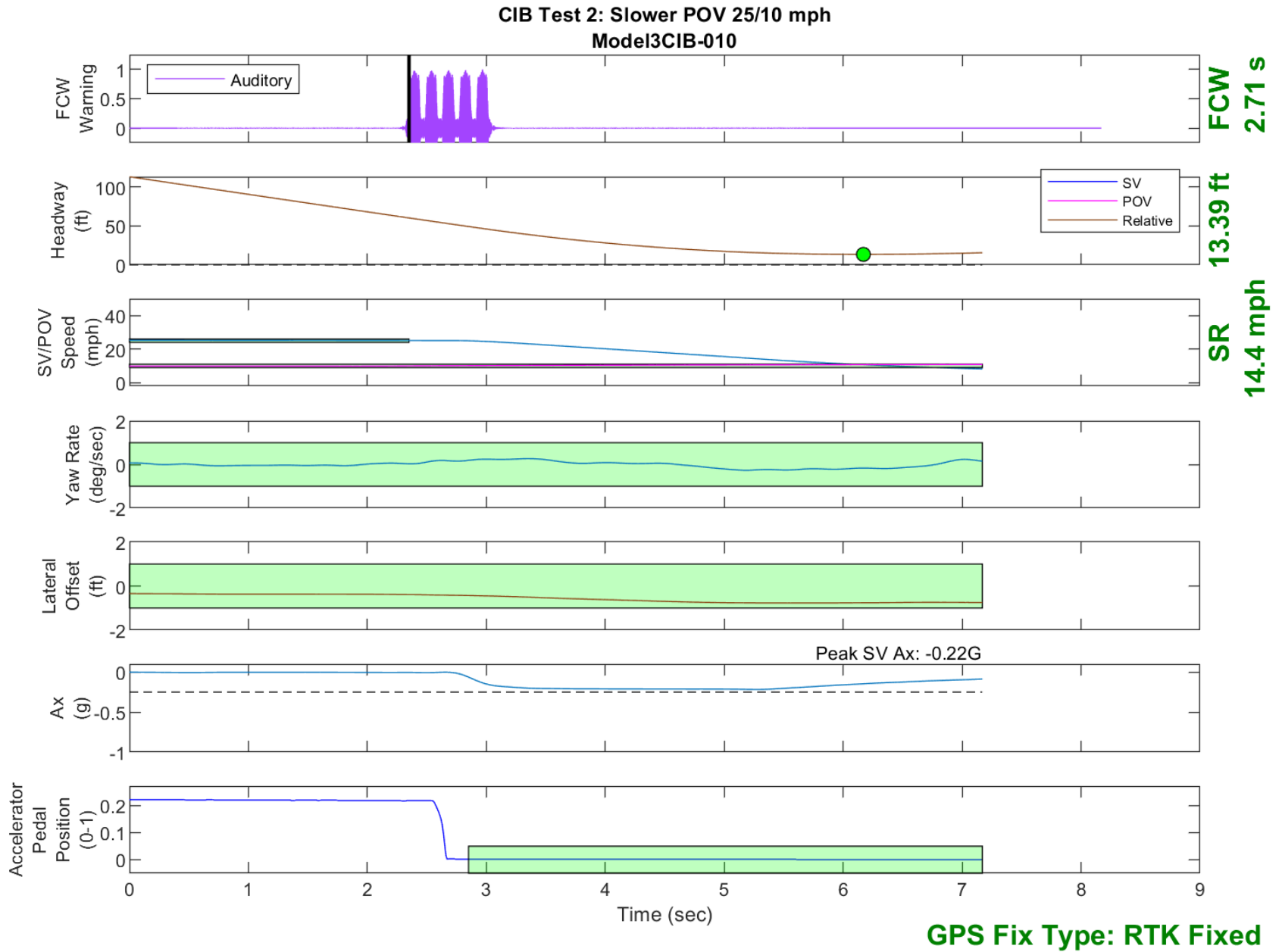


Figure D17. Time History for CIB Run 10, Test 2 - Slower Moving POV, 25/10 mph



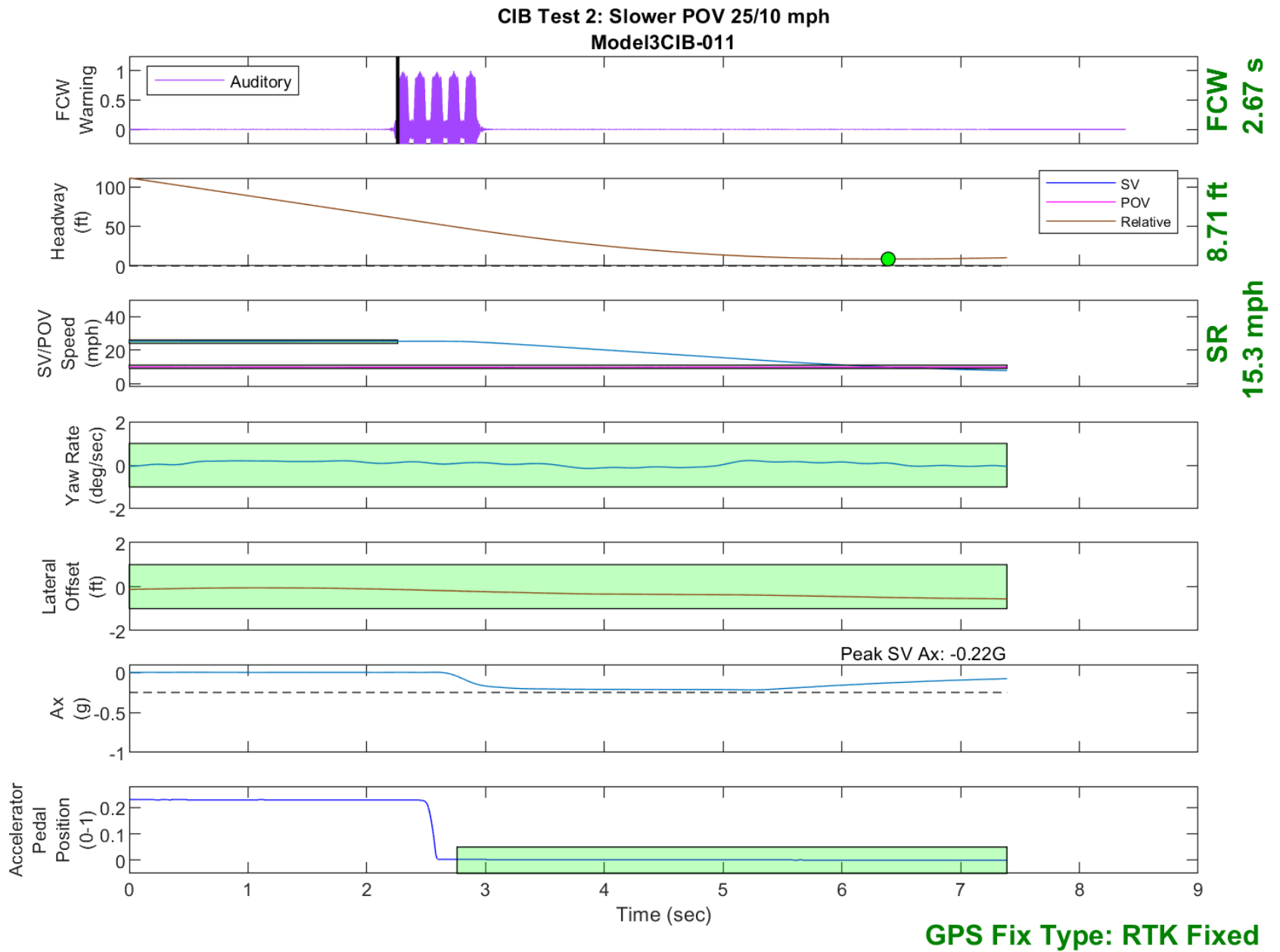


Figure D18. Time History for CIB Run 11, Test 2 - Slower Moving POV, 25/10 mph

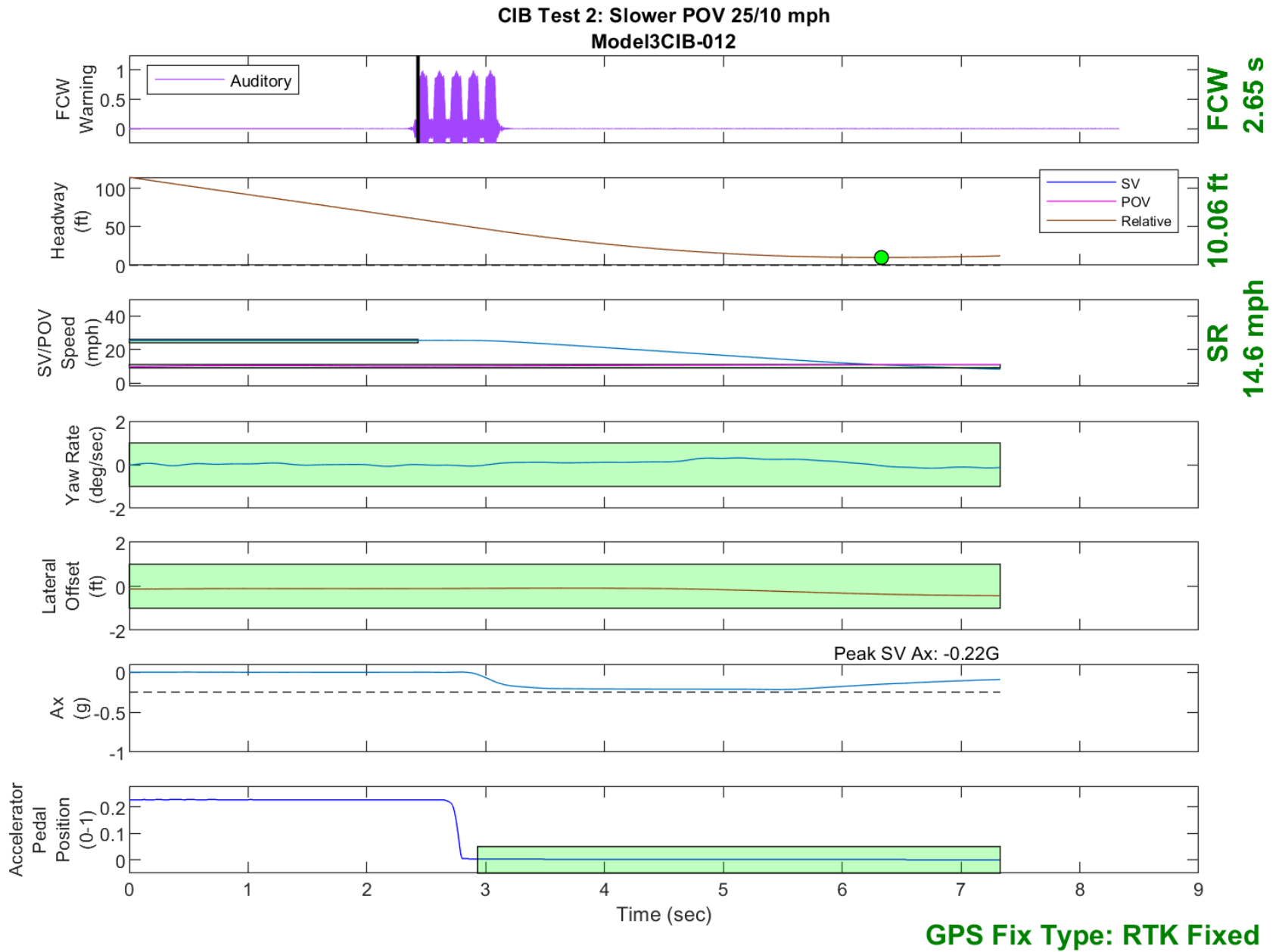


Figure D19. Time History for CIB Run 12, Test 2 - Slower Moving POV, 25/10 mph

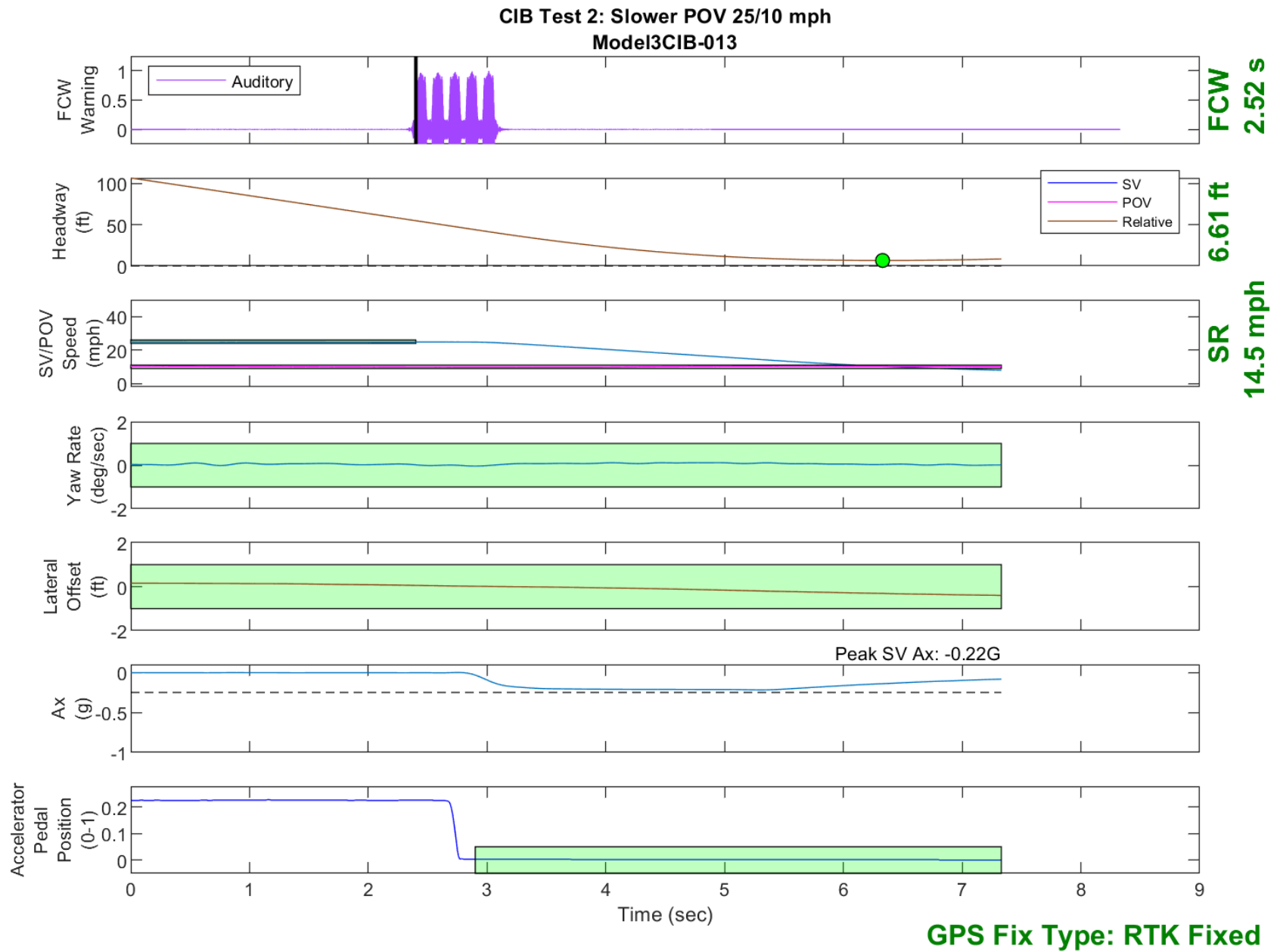


Figure D20. Time History for CIB Run 13, Test 2 - Slower Moving POV, 25/10 mph

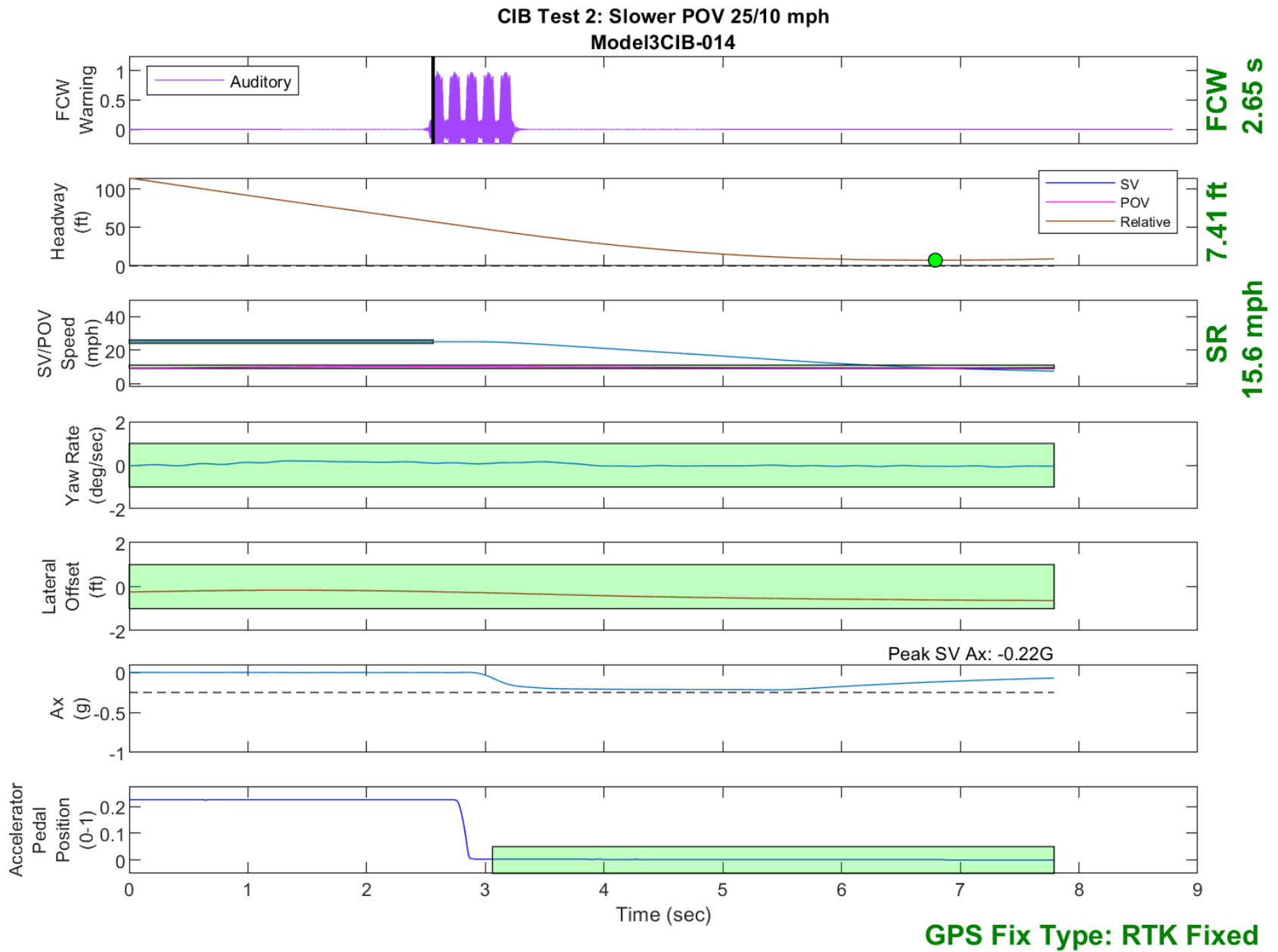


Figure D21. Time History for CIB Run 14, Test 2 - Slower Moving POV, 25/10 mph



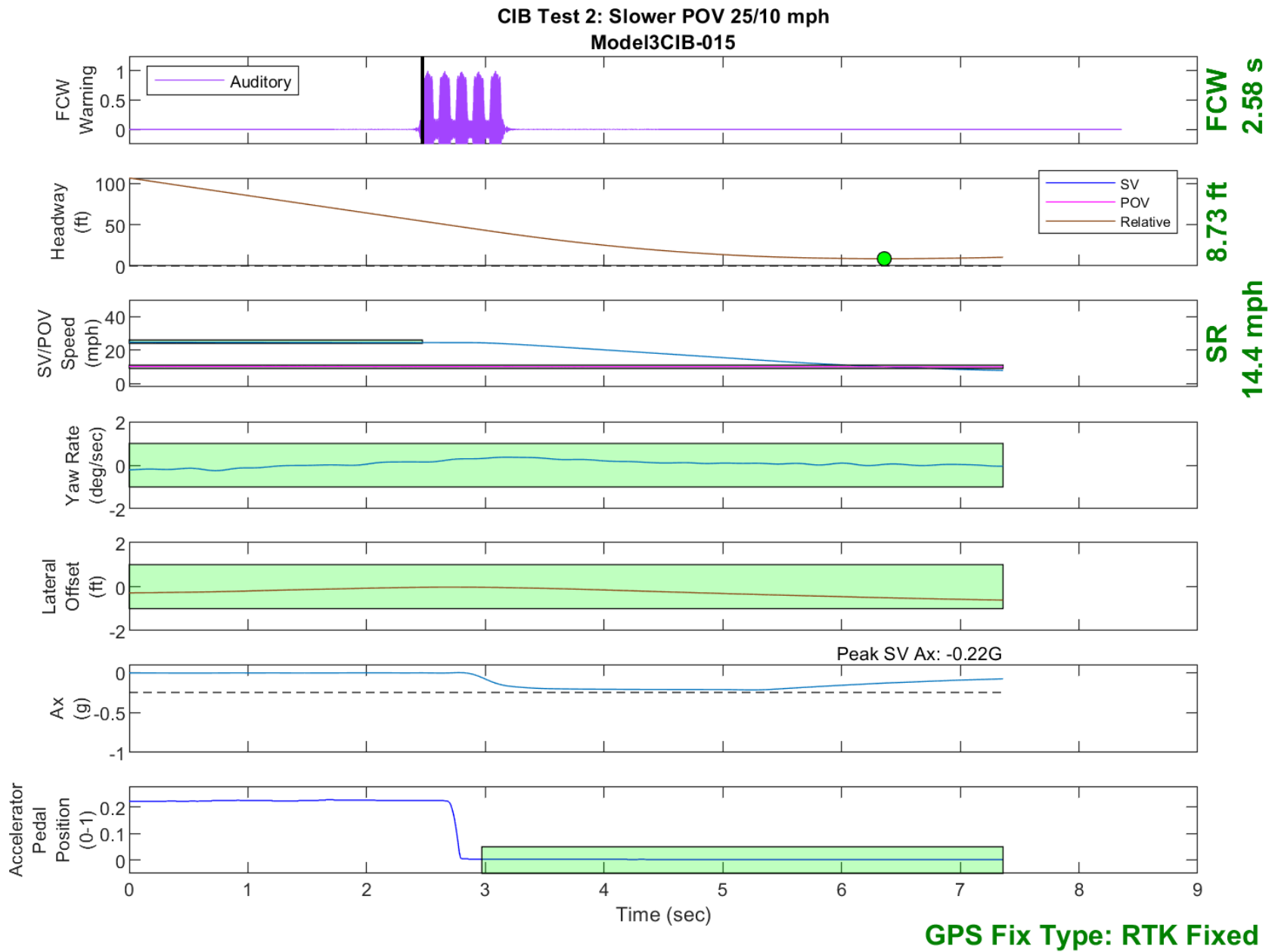


Figure D22. Time History for CIB Run 15, Test 2 - Slower Moving POV, 25/10 mph

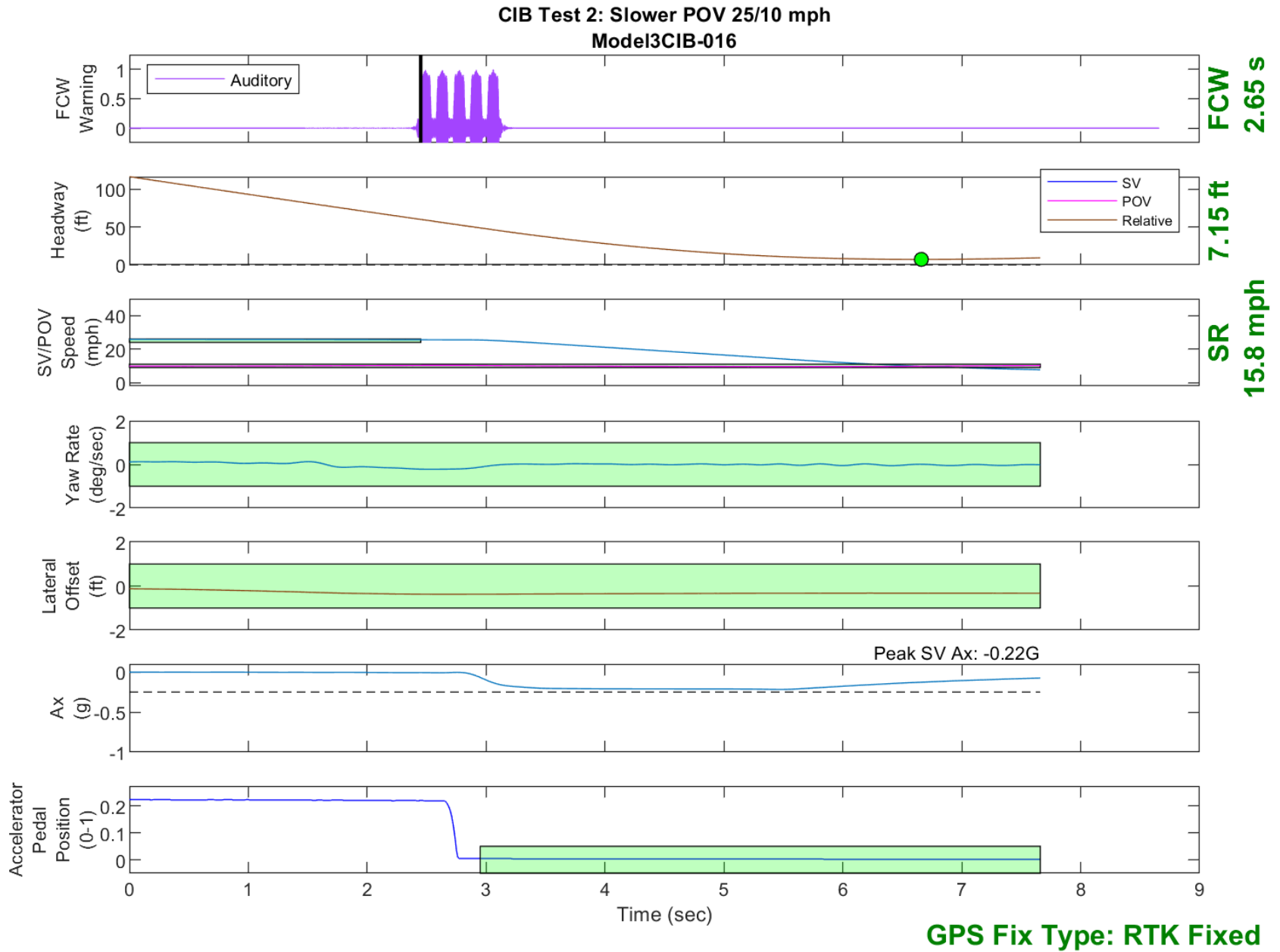


Figure D23. Time History for CIB Run 16, Test 2 - Slower Moving POV, 25/10 mph

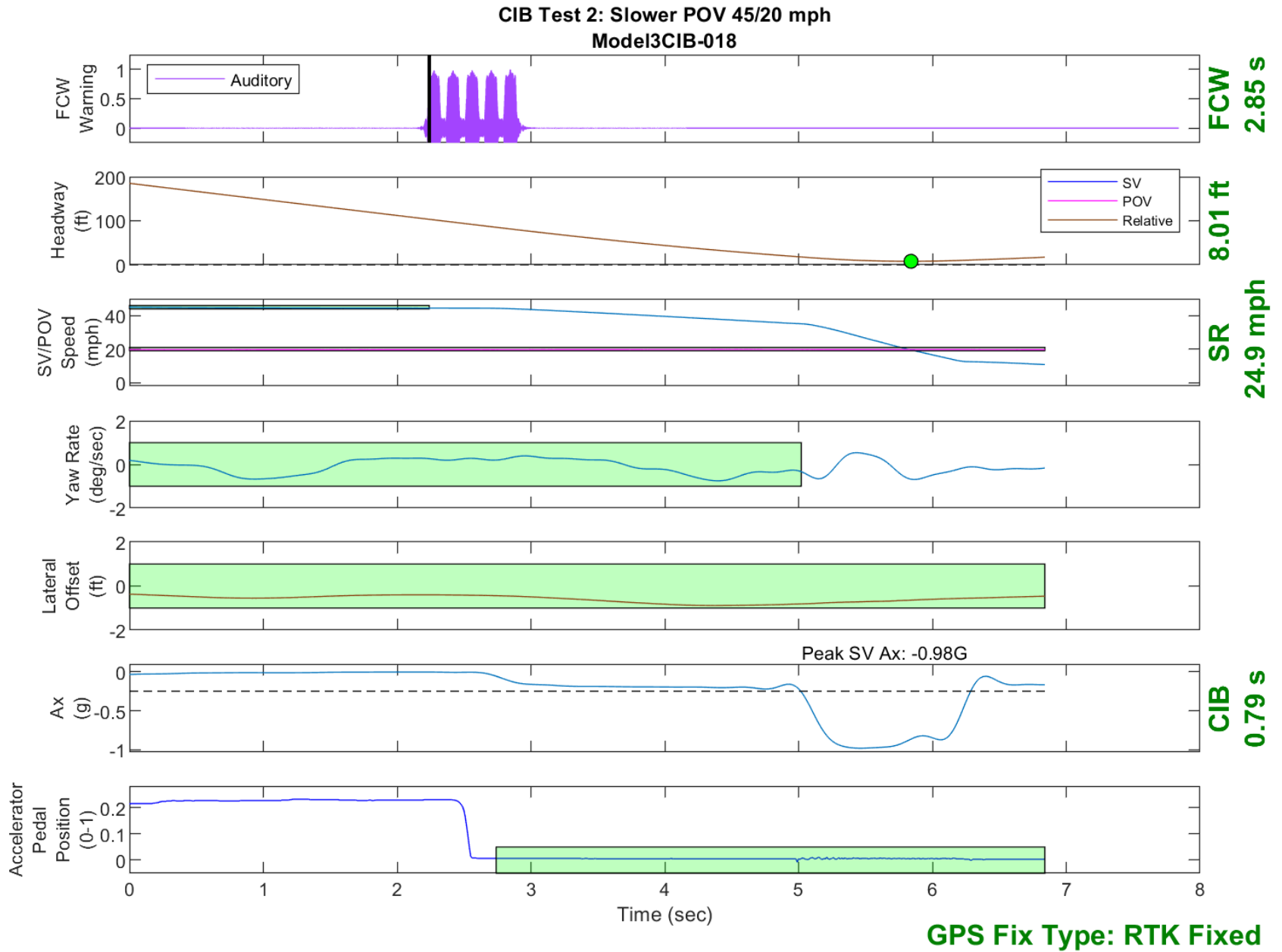


Figure D24. Time History for CIB Run 18, Test 2 - Slower Moving POV, 45/20 mph

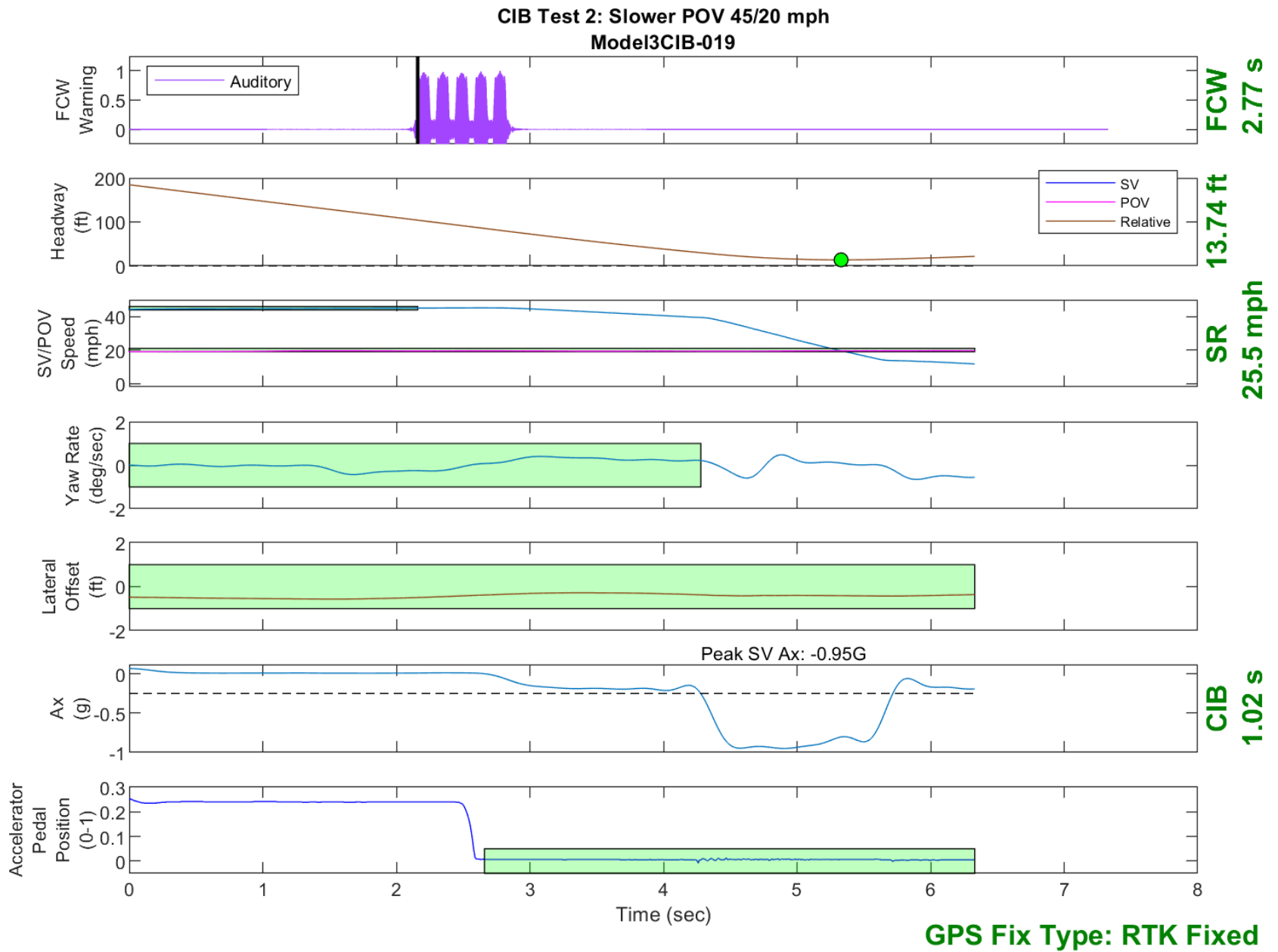


Figure D25. Time History for CIB Run 19, Test 2 - Slower Moving POV, 45/20 mph

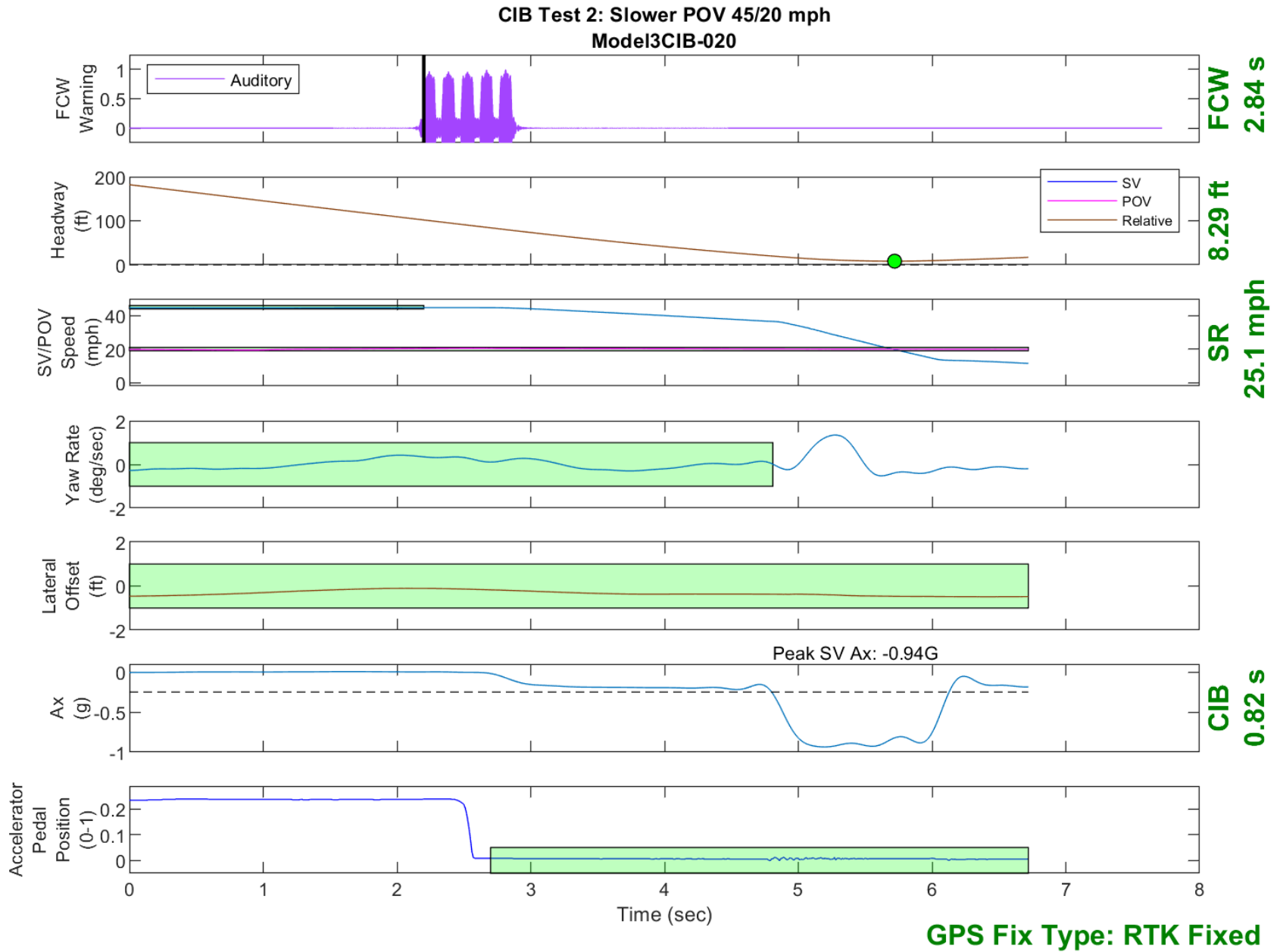


Figure D26. Time History for CIB Run 20, Test 2 - Slower Moving POV, 45/20 mph



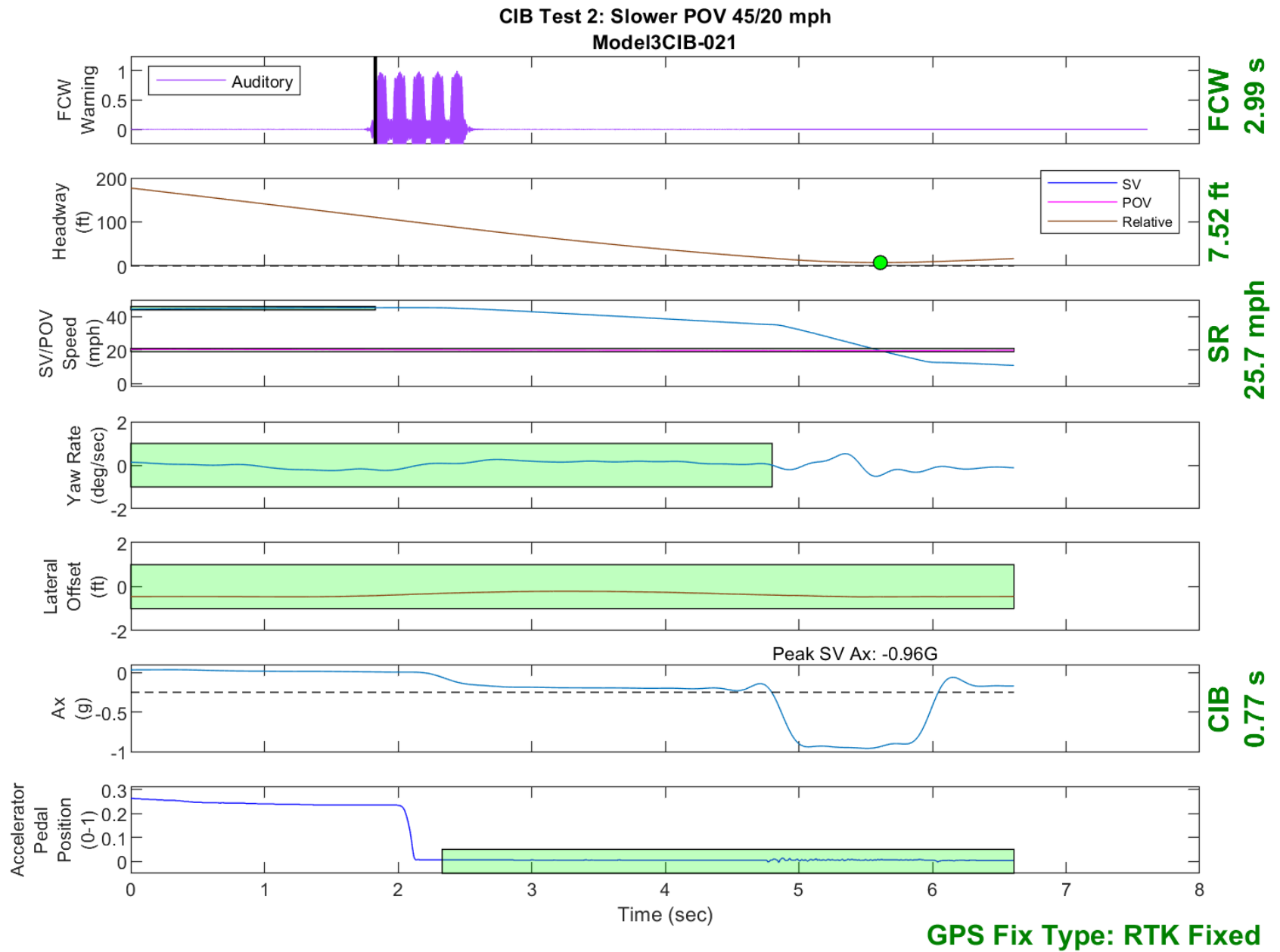


Figure D27. Time History for CIB Run 21, Test 2 - Slower Moving POV, 45/20 mph

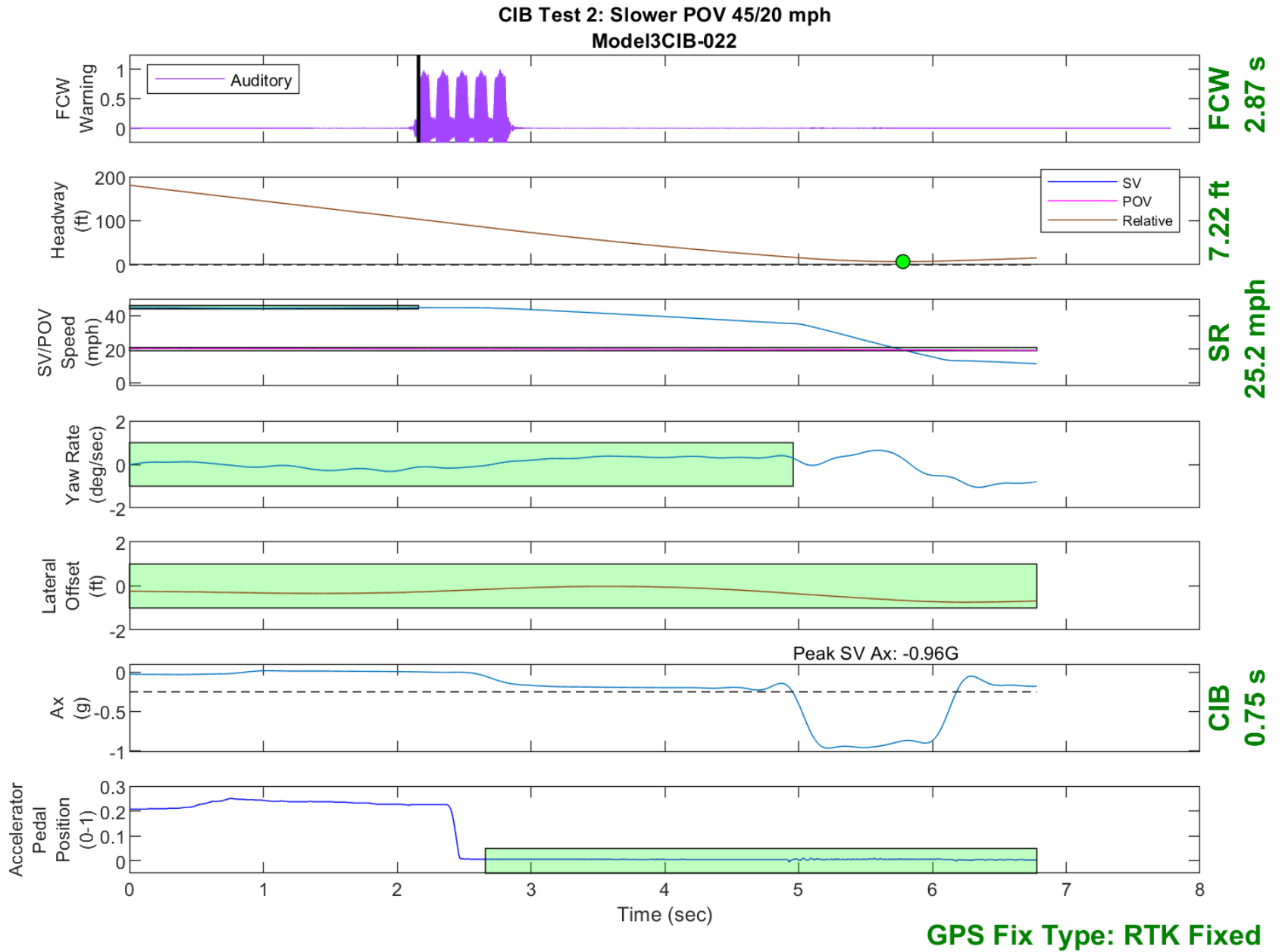


Figure D28. Time History for CIB Run 22, Test 2 - Slower Moving POV, 45/20 mph

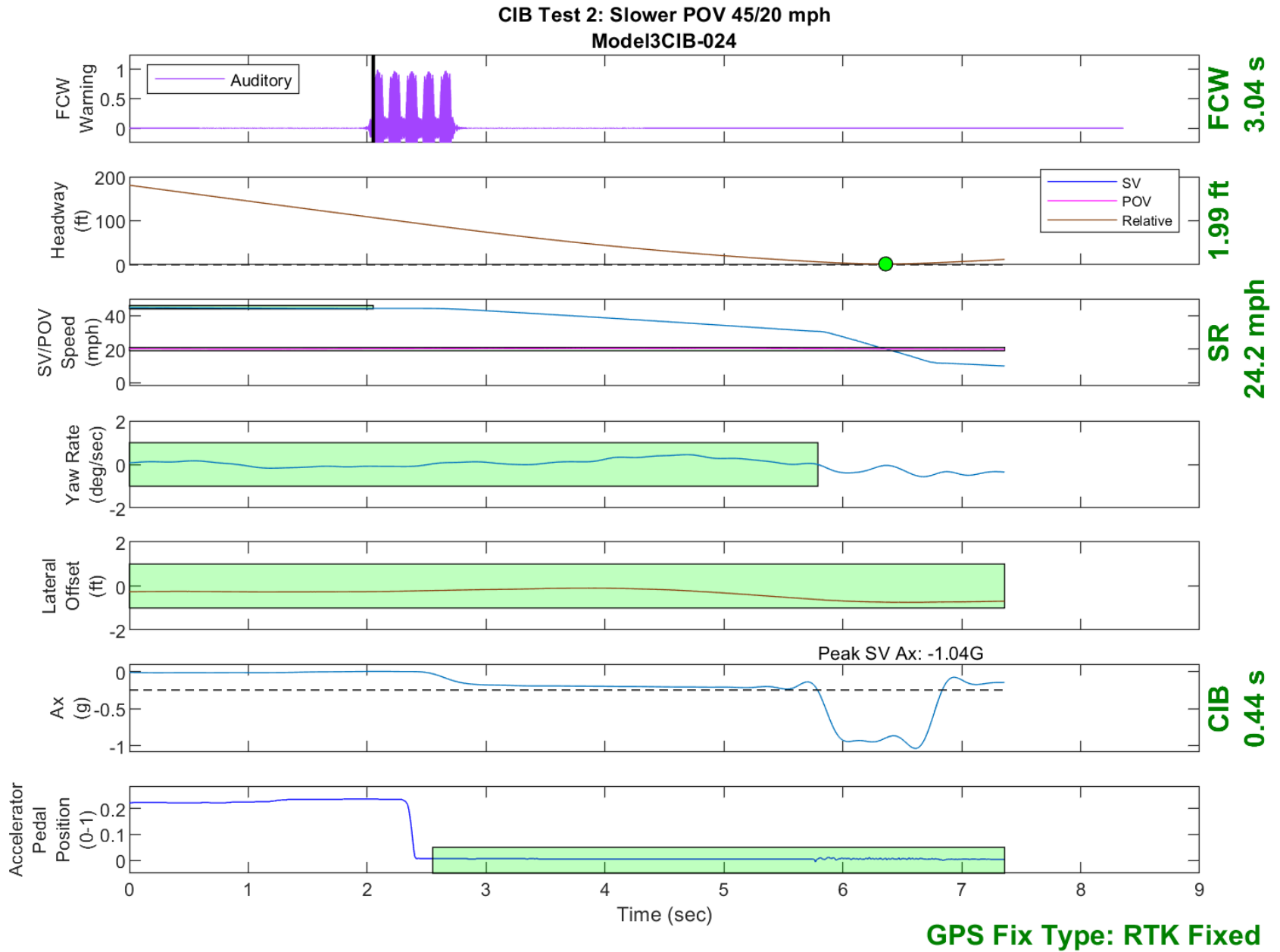


Figure D29. Time History for CIB Run 24, Test 2 - Slower Moving POV, 45/20 mph

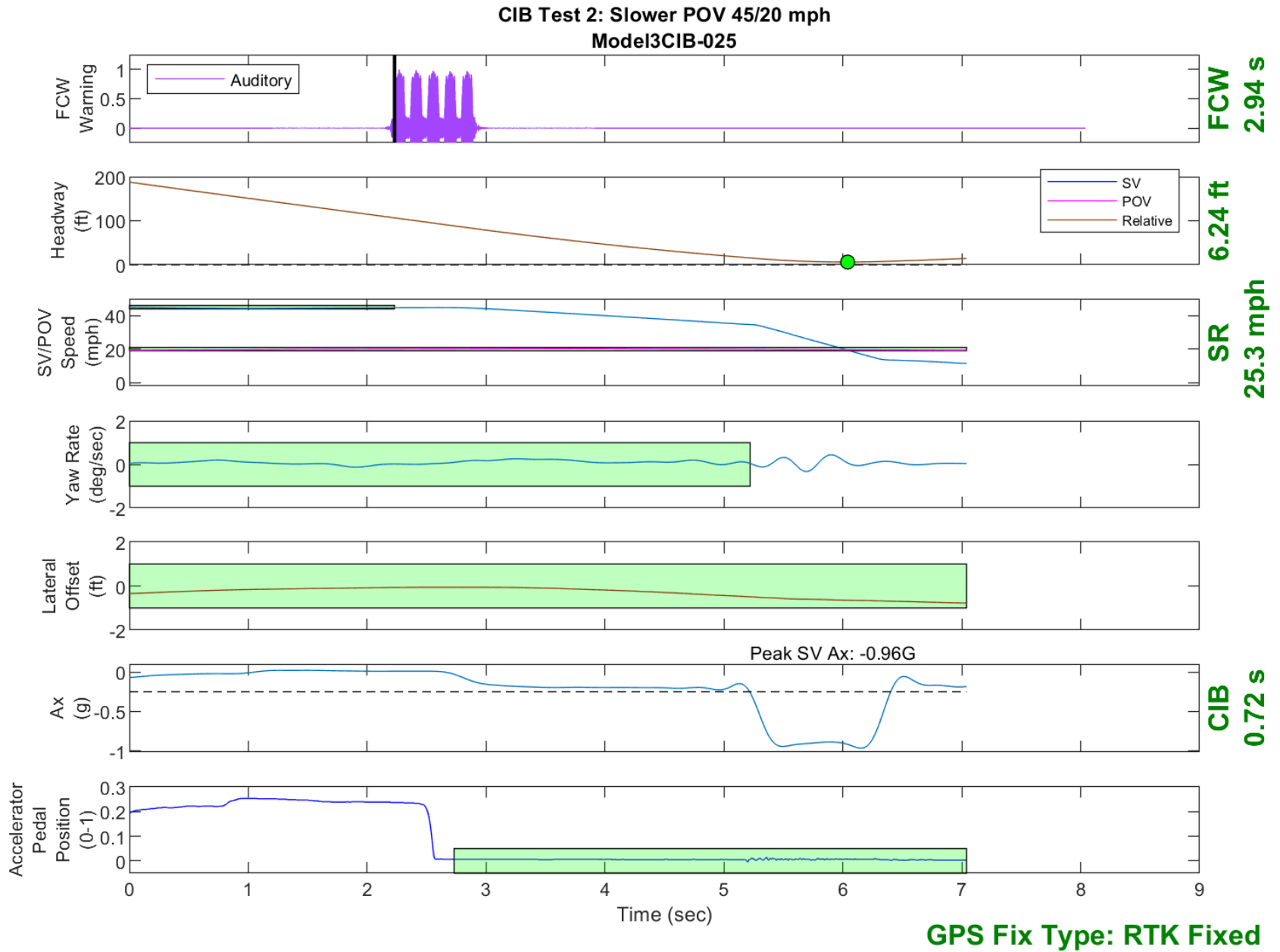


Figure D30. Time History for CIB Run 25, Test 2 - Slower Moving POV, 45/20 mph

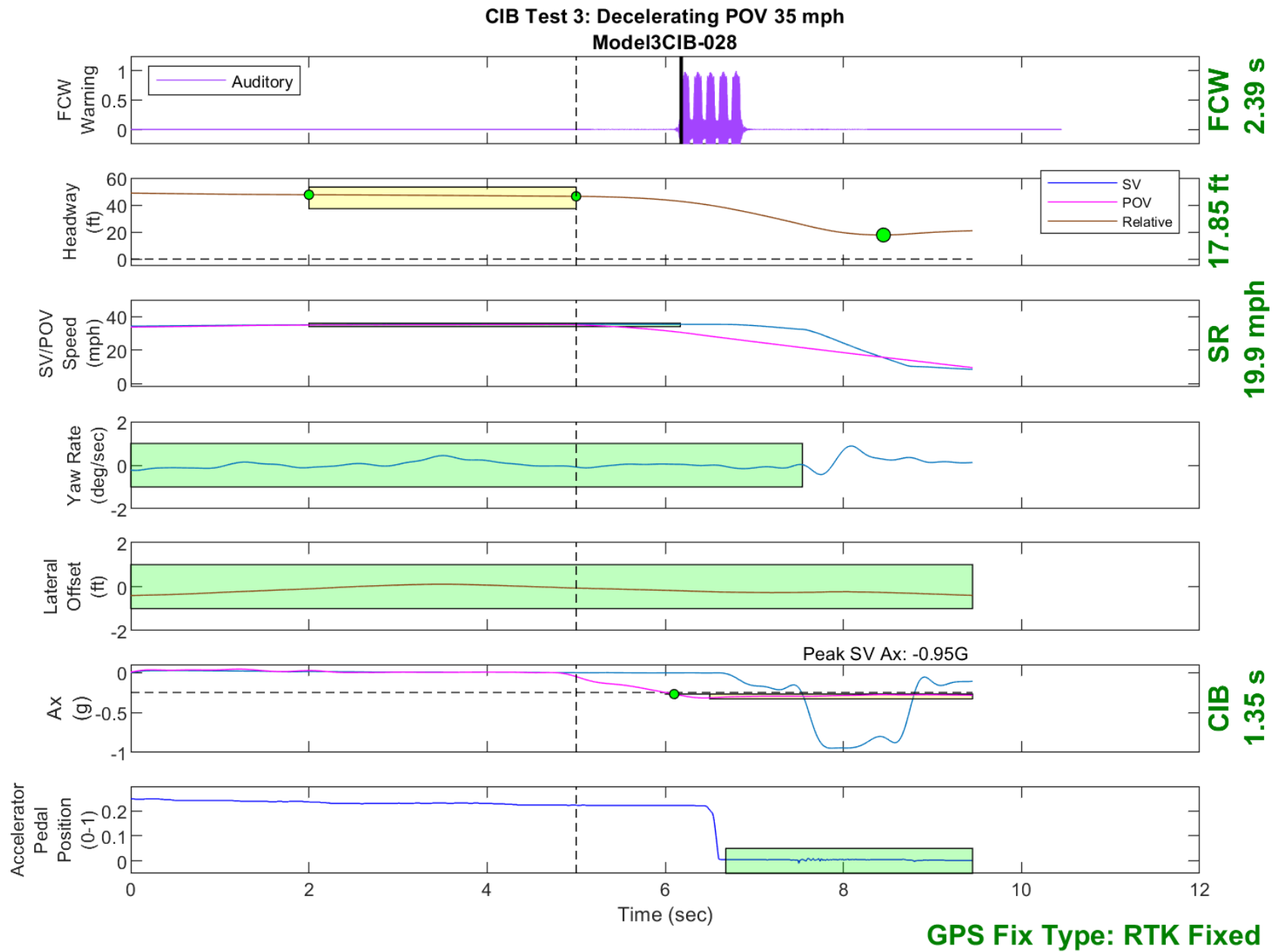


Figure D31. Time History for CIB Run 28, Test 3 - Decelerating POV 35 mph



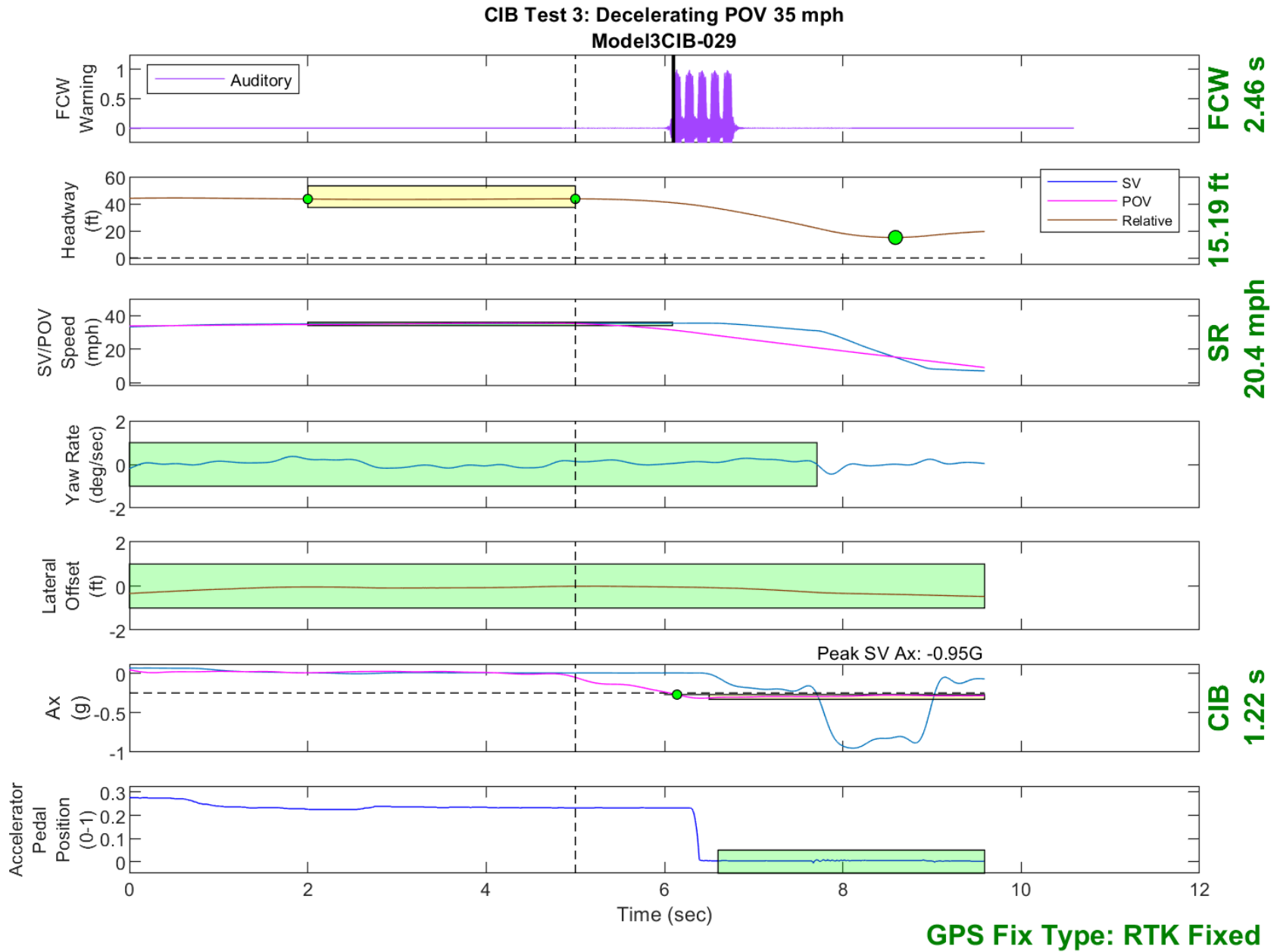


Figure D32. Time History for CIB Run 29, Test 3 - Decelerating POV 35 mph

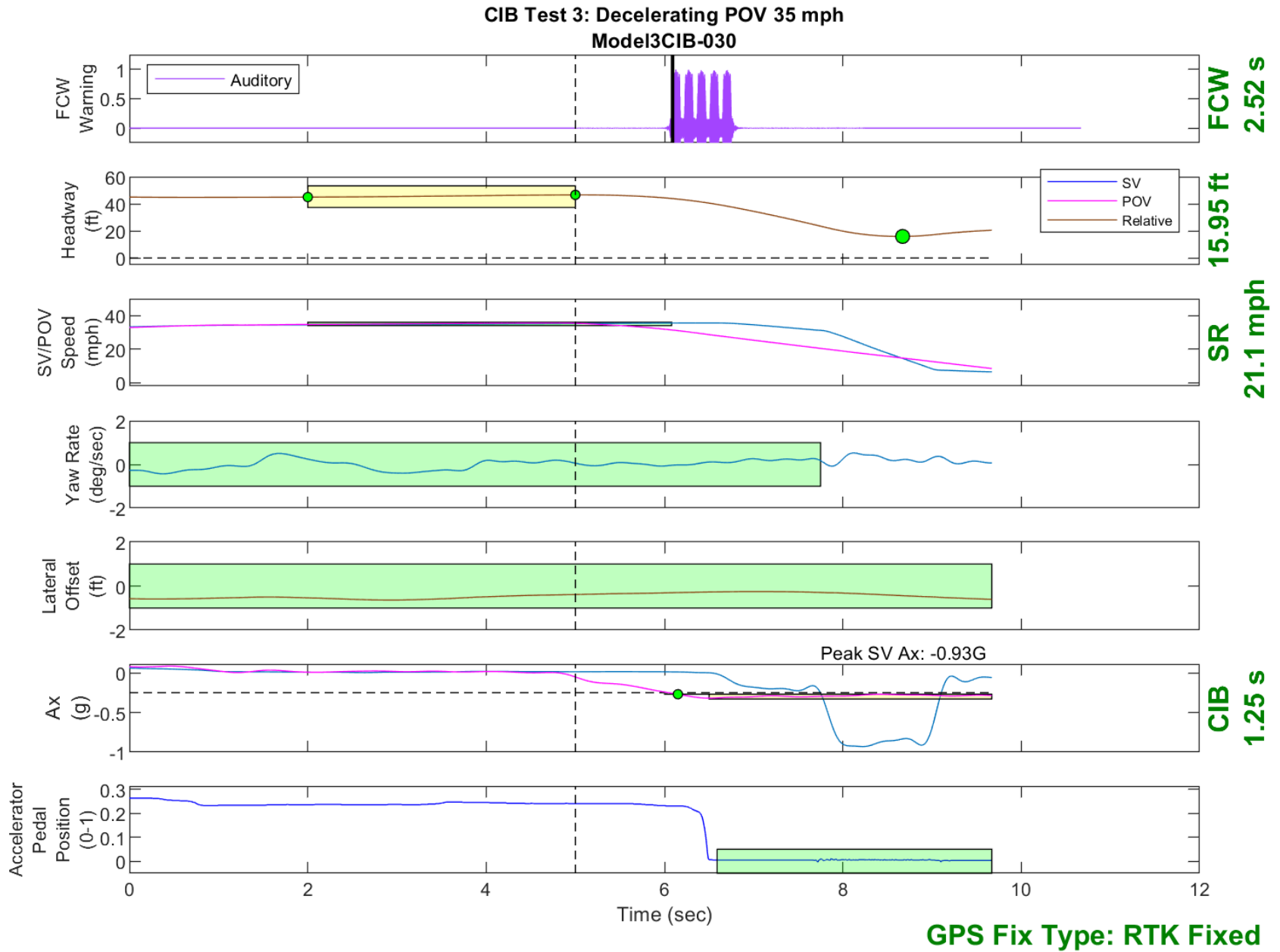


Figure D33. Time History for CIB Run 30, Test 3 - Decelerating POV 35 mph

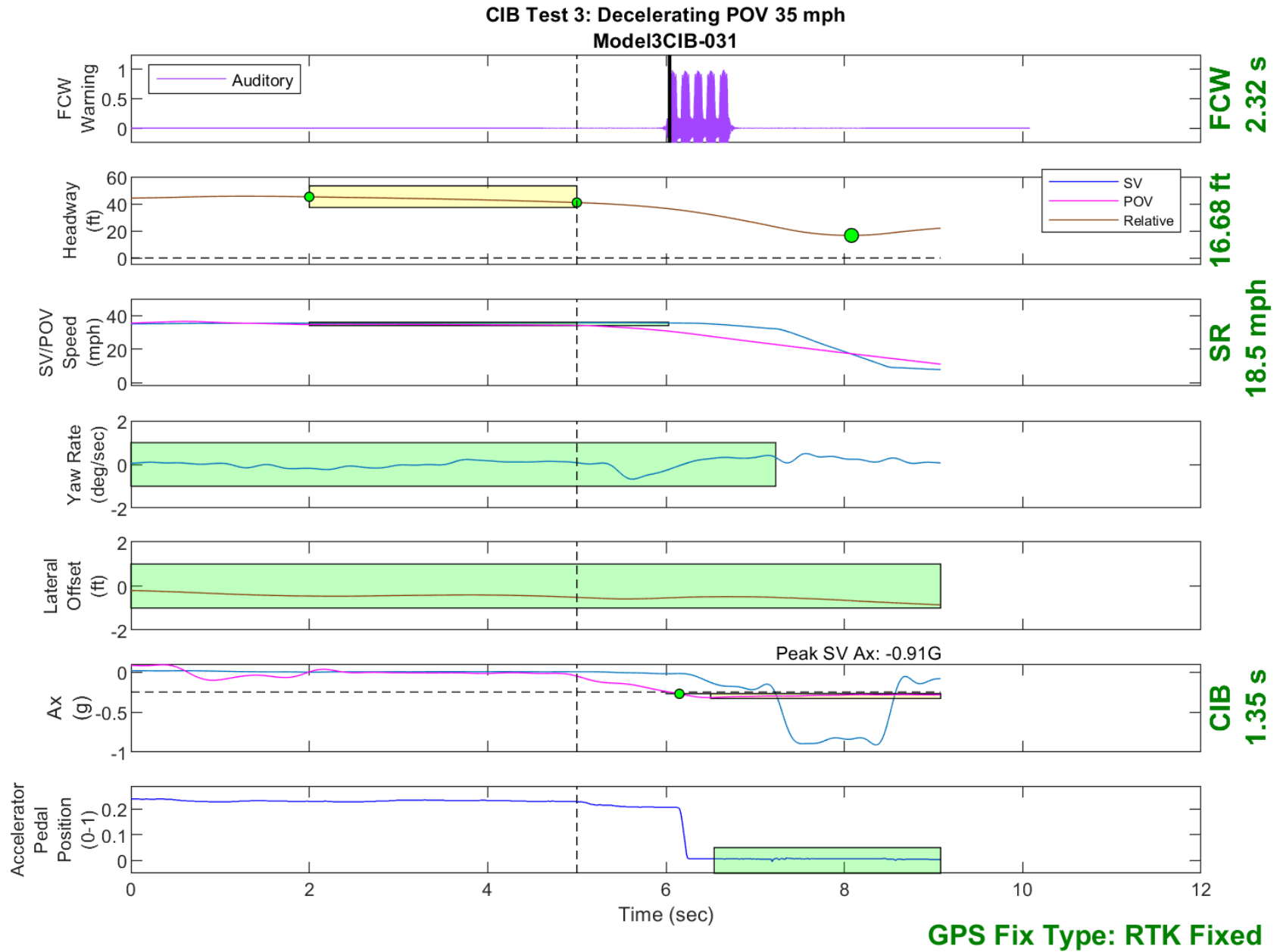


Figure D34. Time History for CIB Run 31, Test 3 - Decelerating POV 35 mph

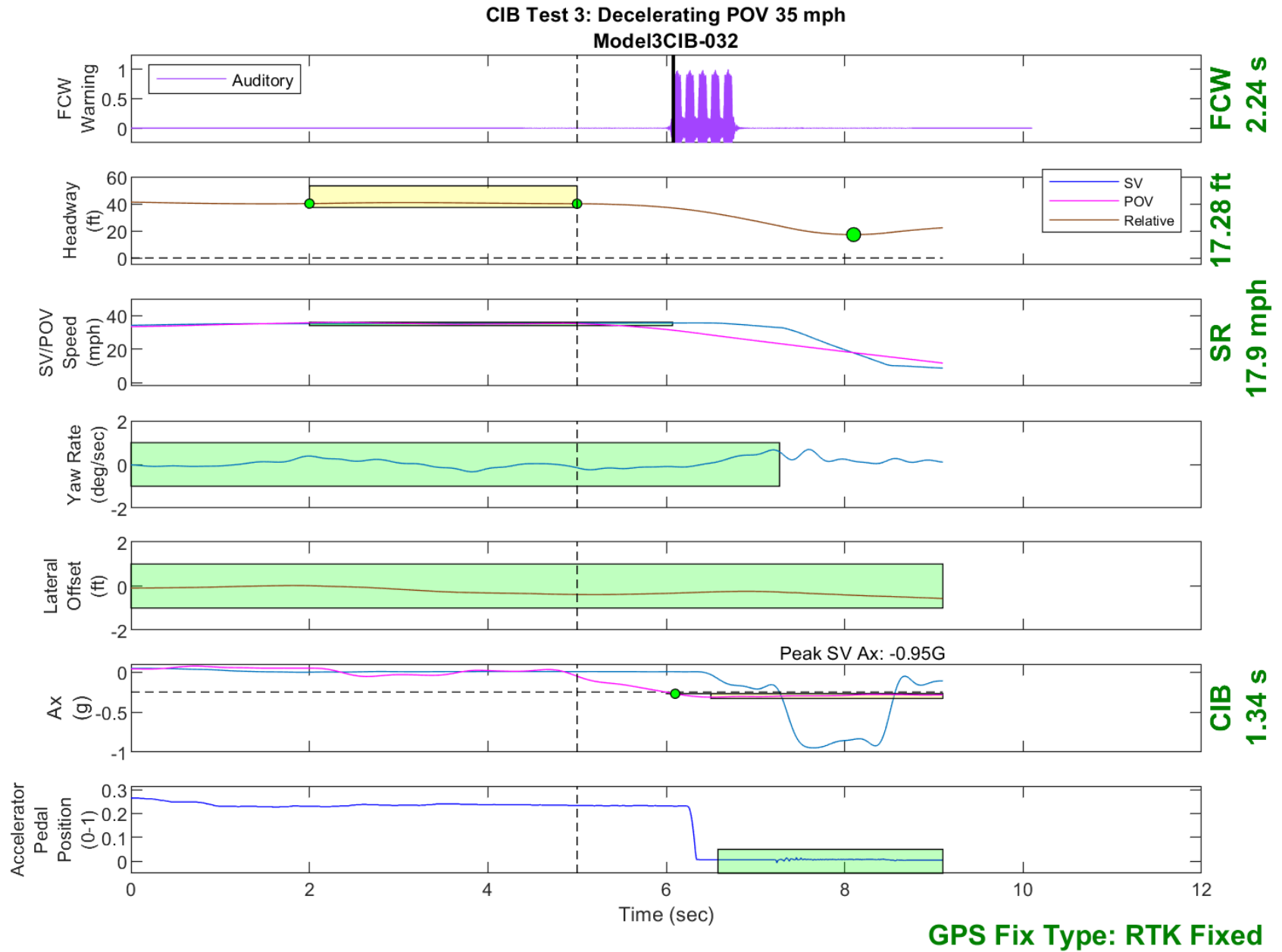


Figure D35. Time History for CIB Run 32, Test 3 - Decelerating POV 35 mph

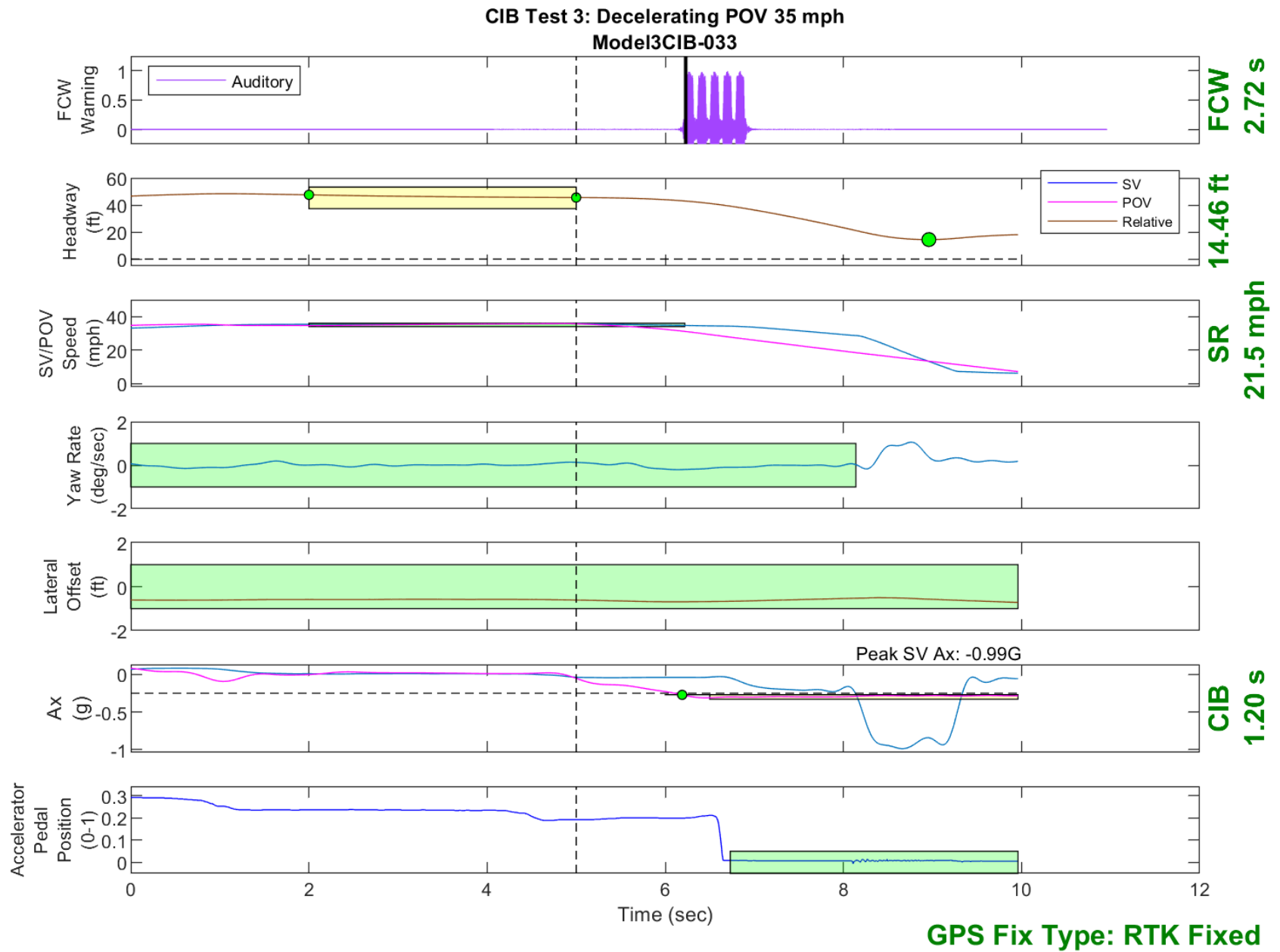


Figure D36. Time History for CIB Run 33, Test 3 - Decelerating POV 35 mph



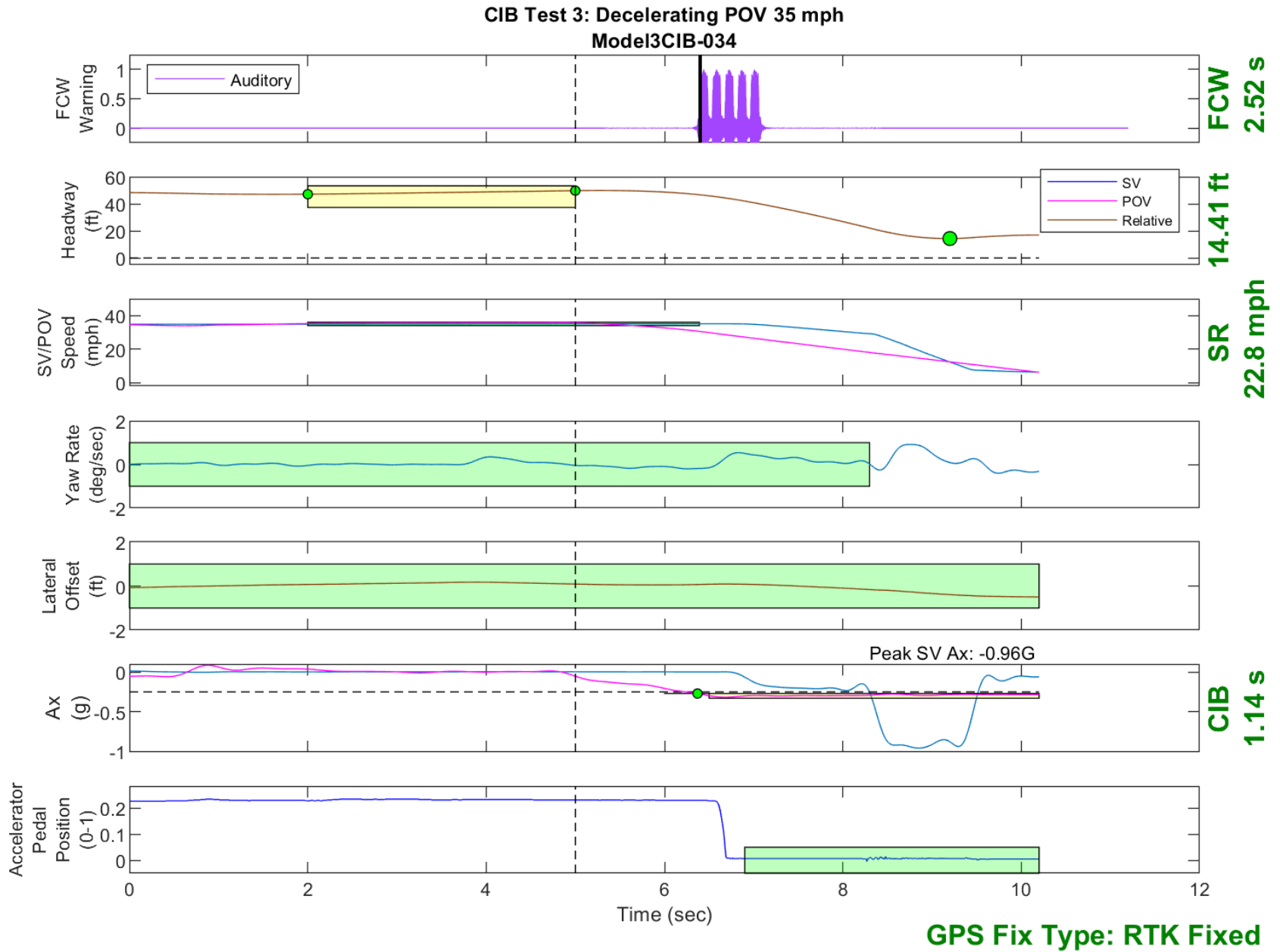


Figure D37. Time History for CIB Run 34, Test 3 - Decelerating POV 35 mph

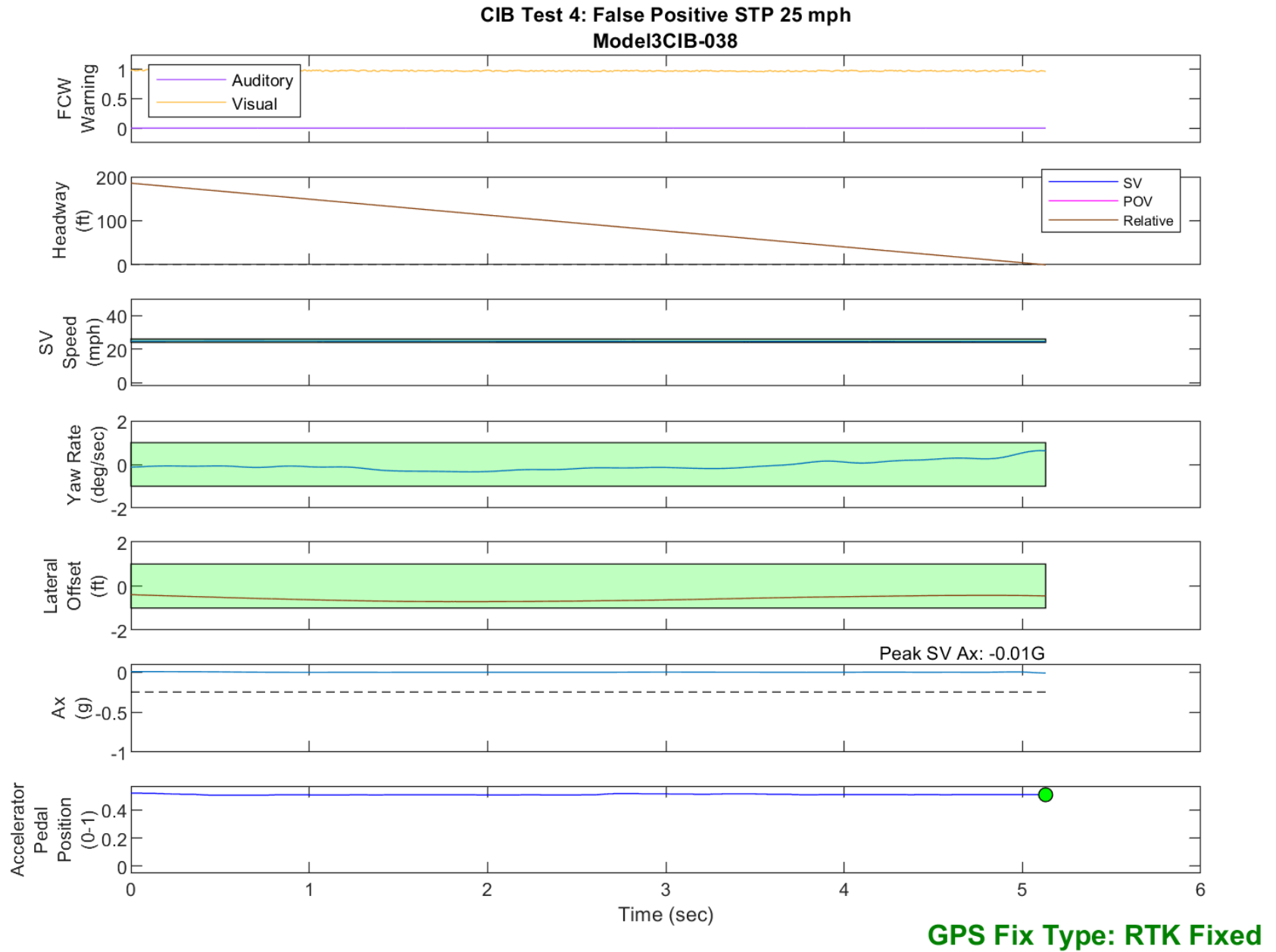


Figure D38. Time History for CIB Run 38, Test 4 - False Positive STP, 25 mph

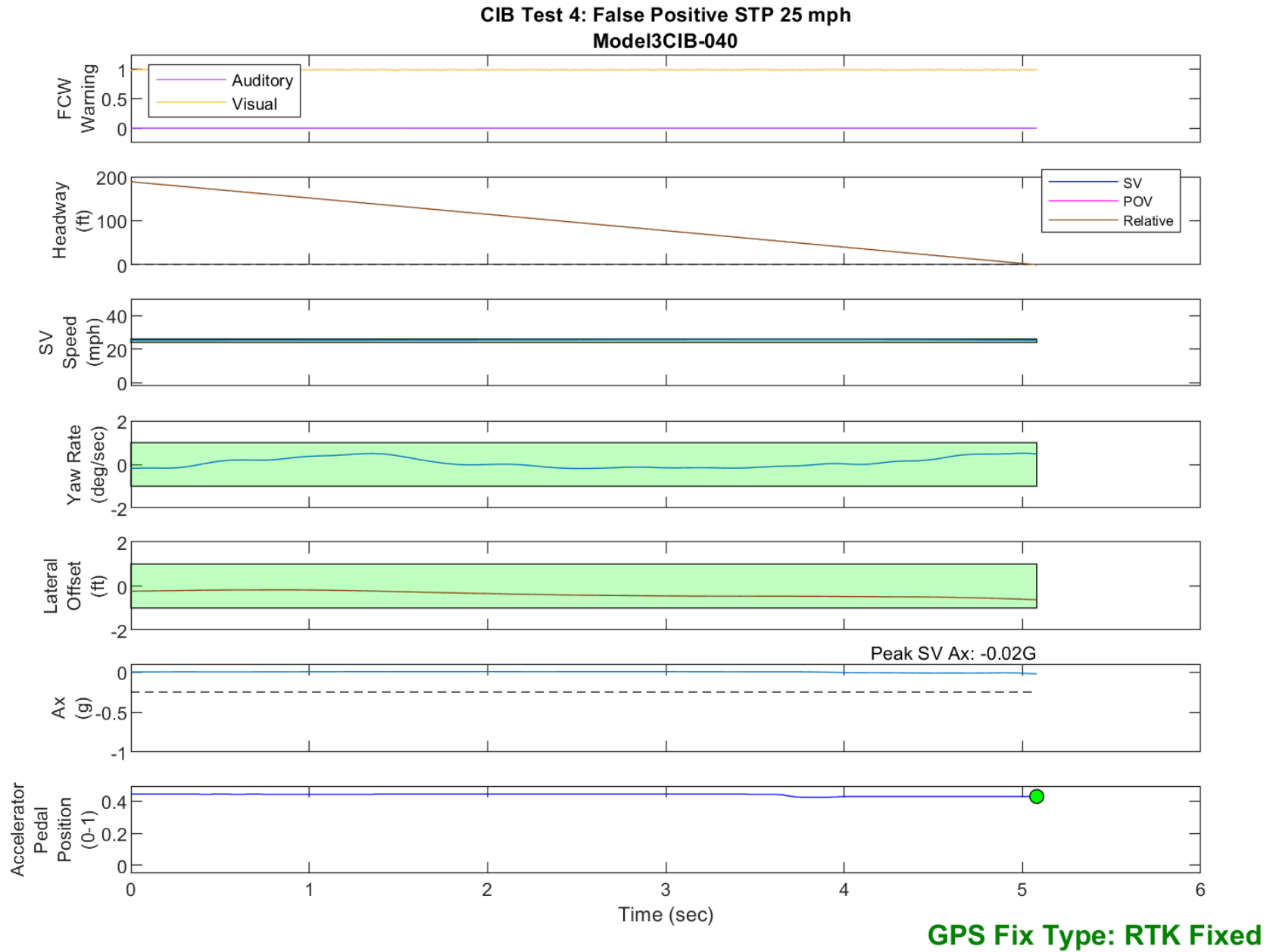


Figure D39. Time History for CIB Run 40, Test 4 - False Positive STP, 25 mph

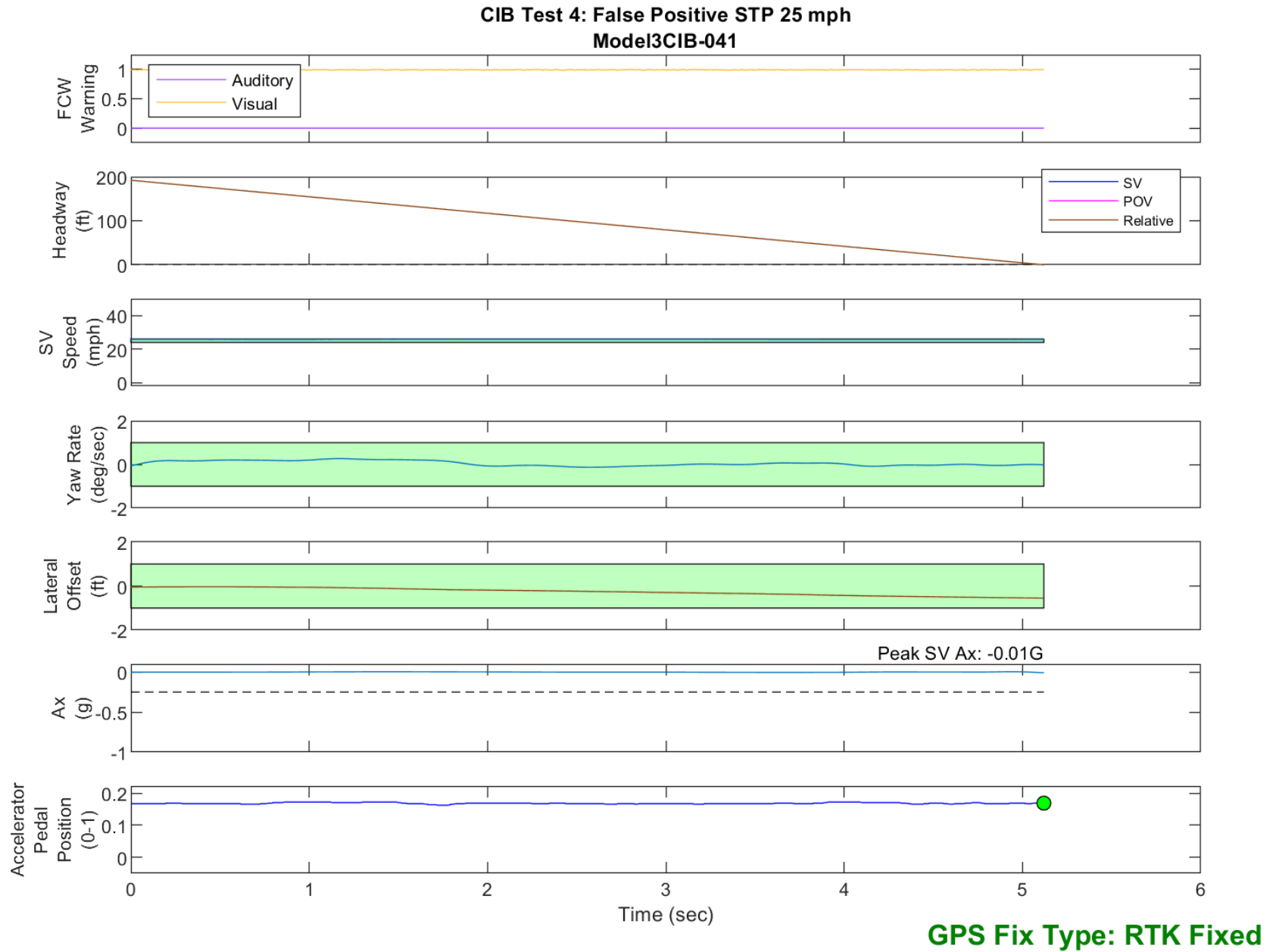


Figure D40. Time History for CIB Run 41, Test 4 - False Positive STP, 25 mph

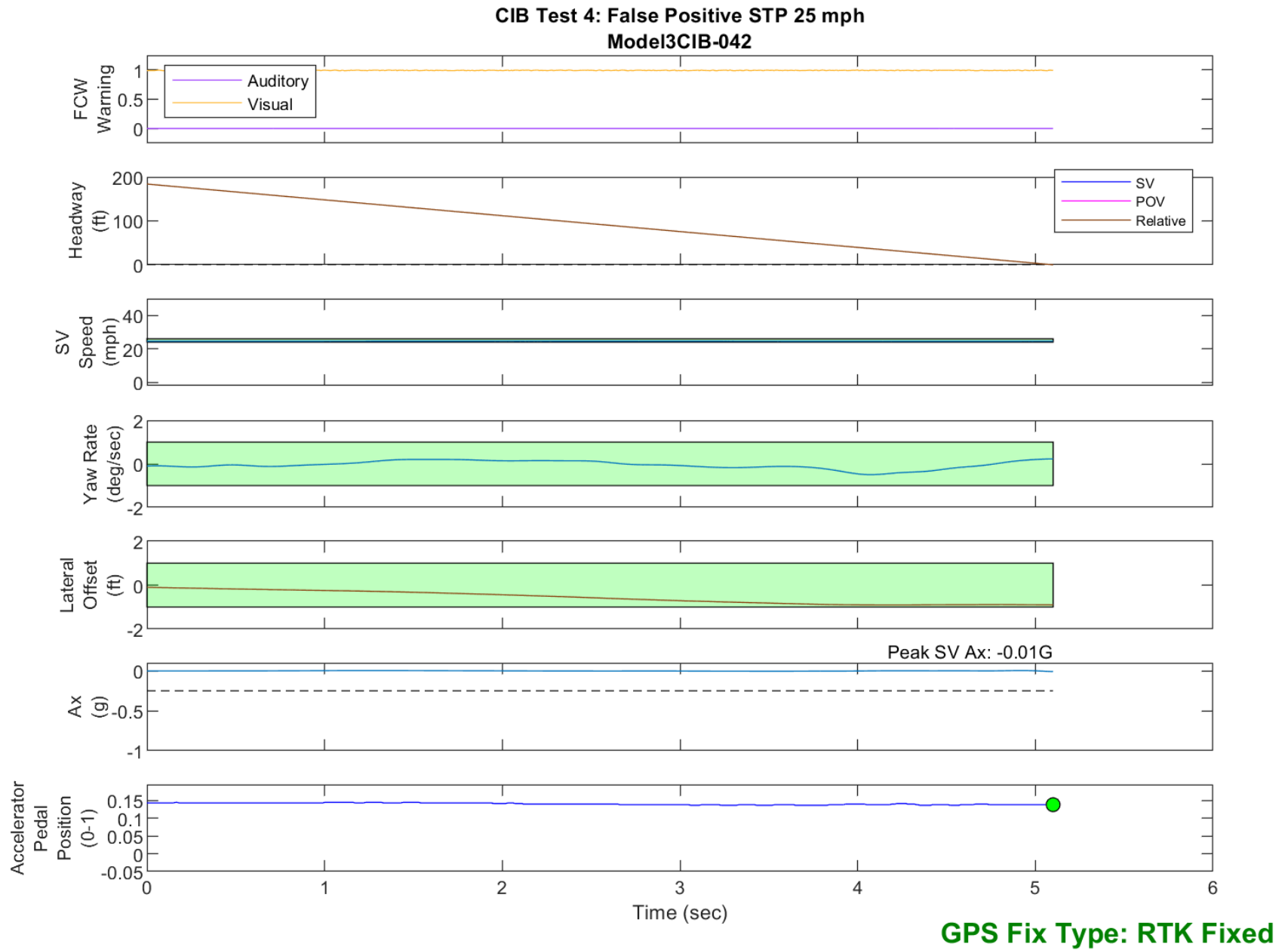


Figure D41. Time History for CIB Run 42, Test 4 - False Positive STP, 25 mph



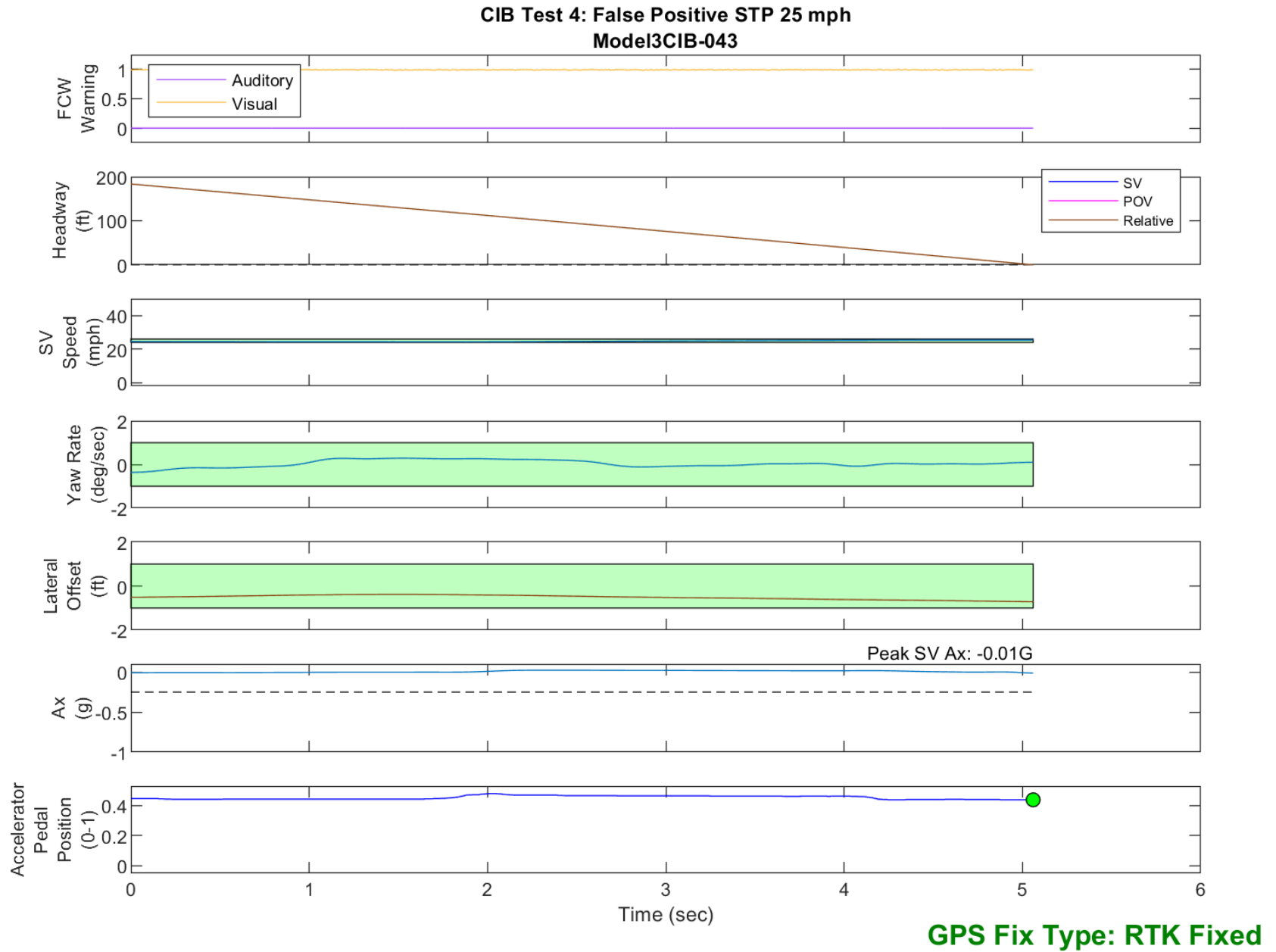


Figure D42. Time History for CIB Run 43, Test 4 - False Positive STP, 25 mph

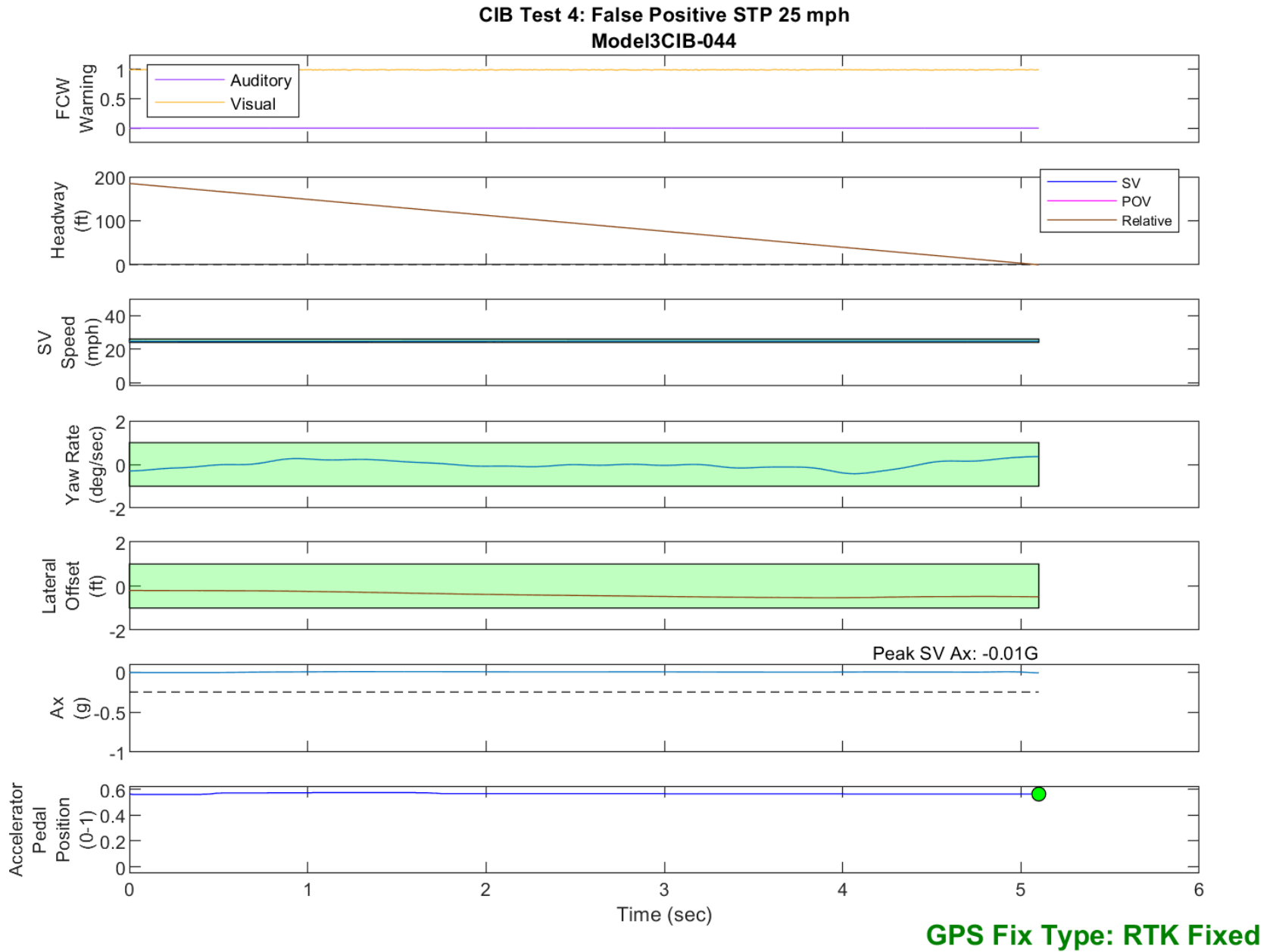


Figure D43. Time History for CIB Run 44, Test 4 - False Positive STP, 25 mph

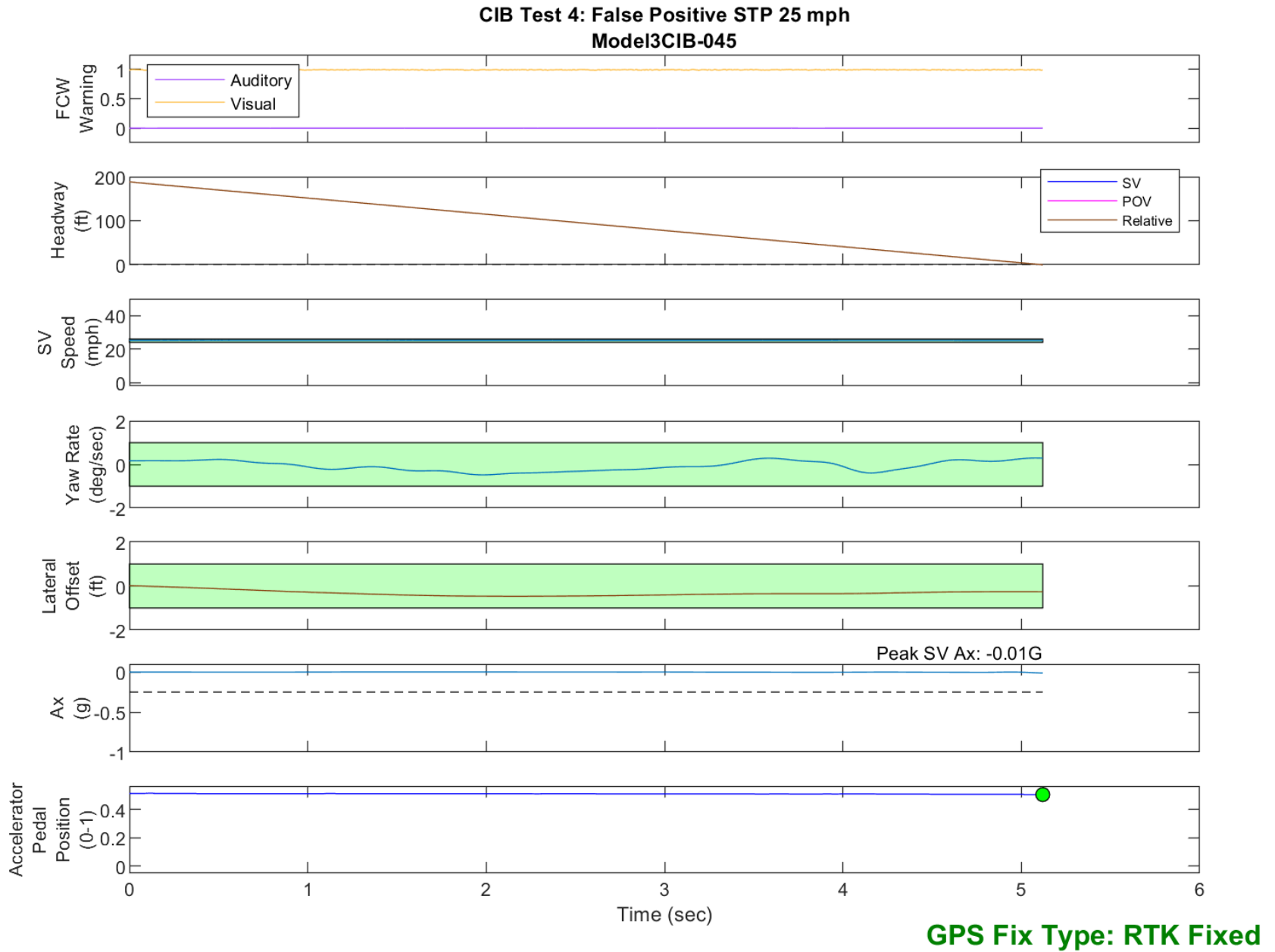


Figure D44. Time History for CIB Run 45, Test 4 - False Positive STP, 25 mph

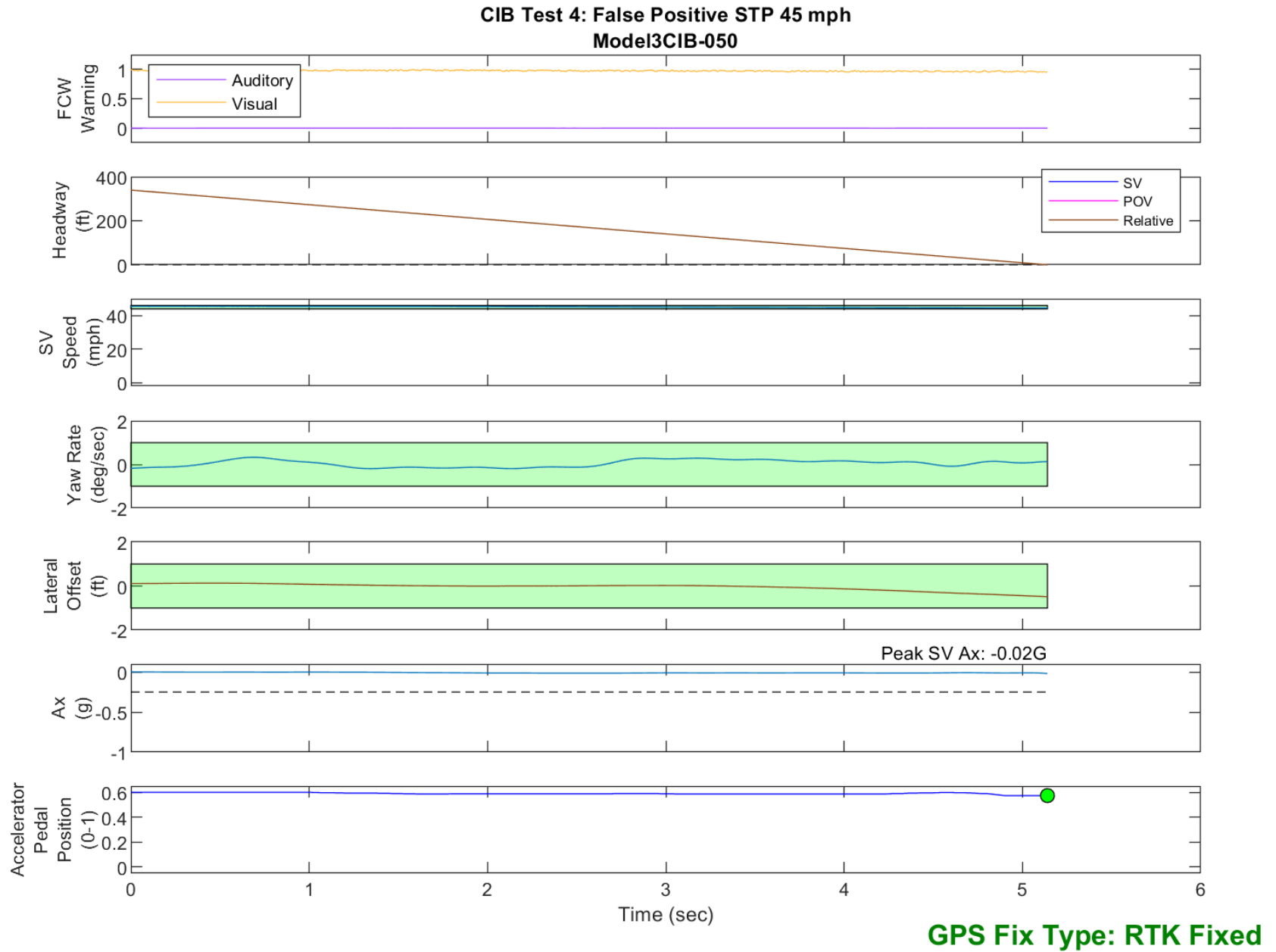


Figure D45. Time History for CIB Run 50, Test 4 - False Positive STP, 45 mph

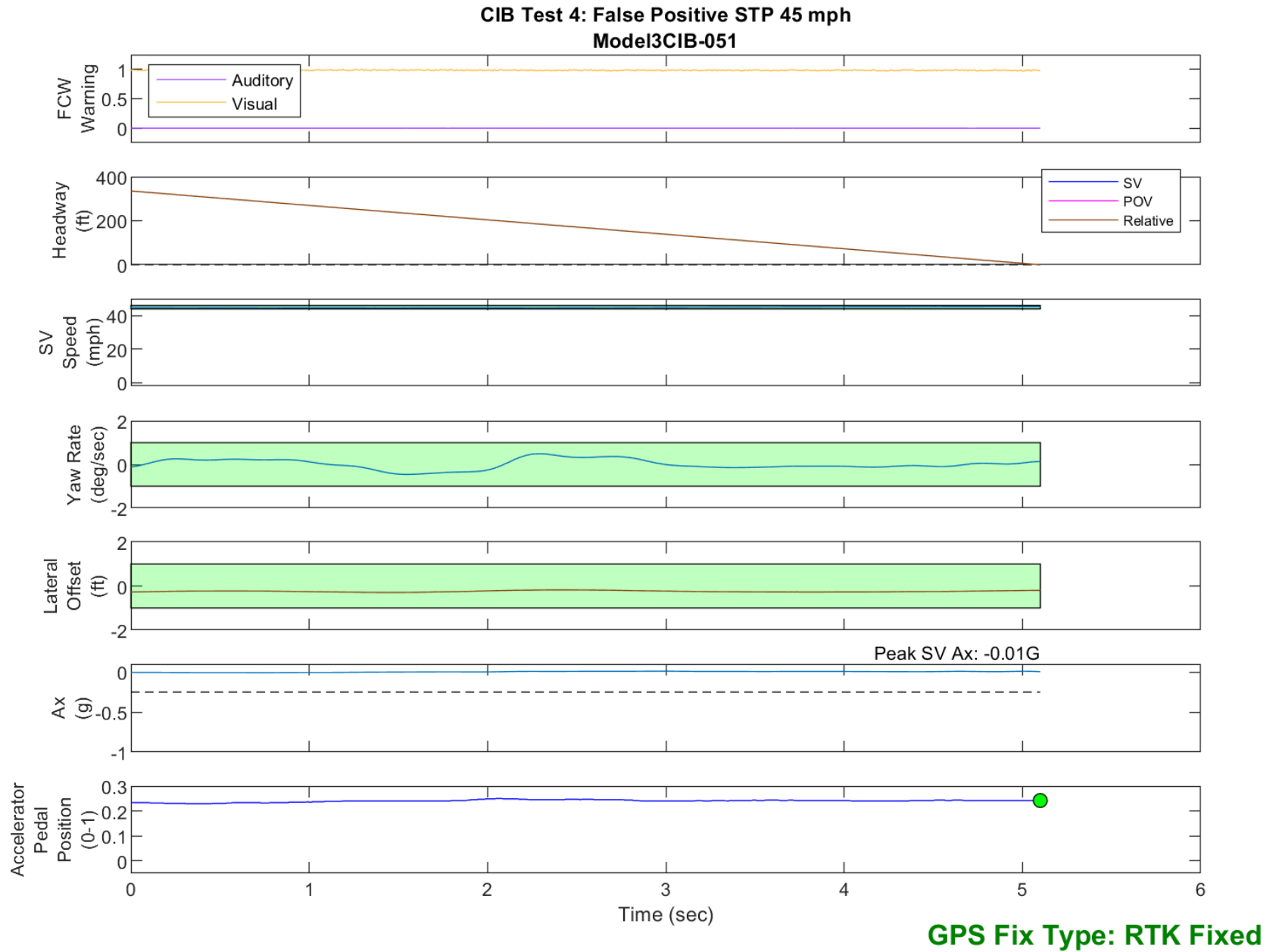


Figure D46. Time History for CIB Run 51, Test 4 - False Positive STP, 45 mph

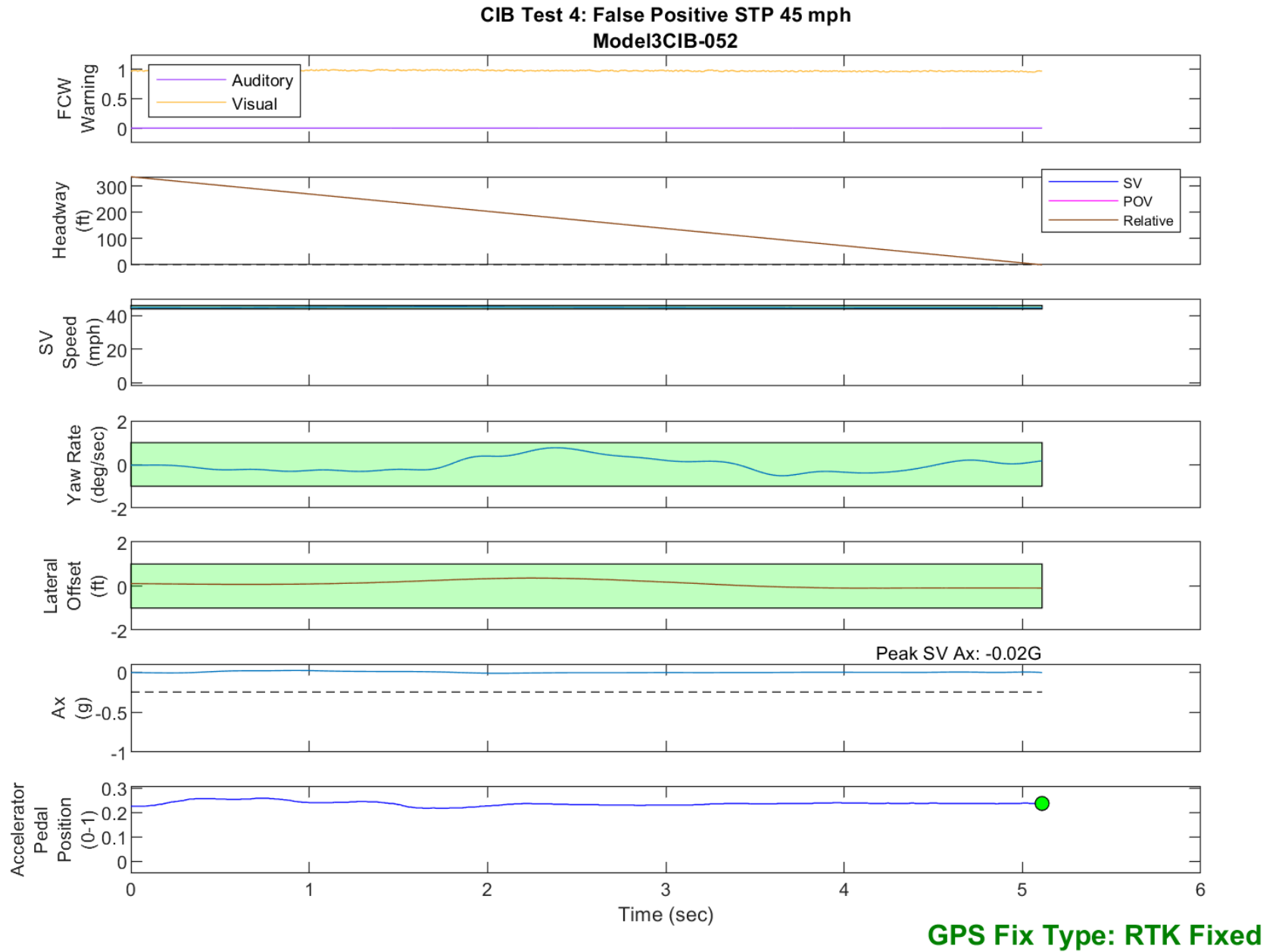


Figure D47. Time History for CIB Run 52, Test 4 - False Positive STP, 45 mph



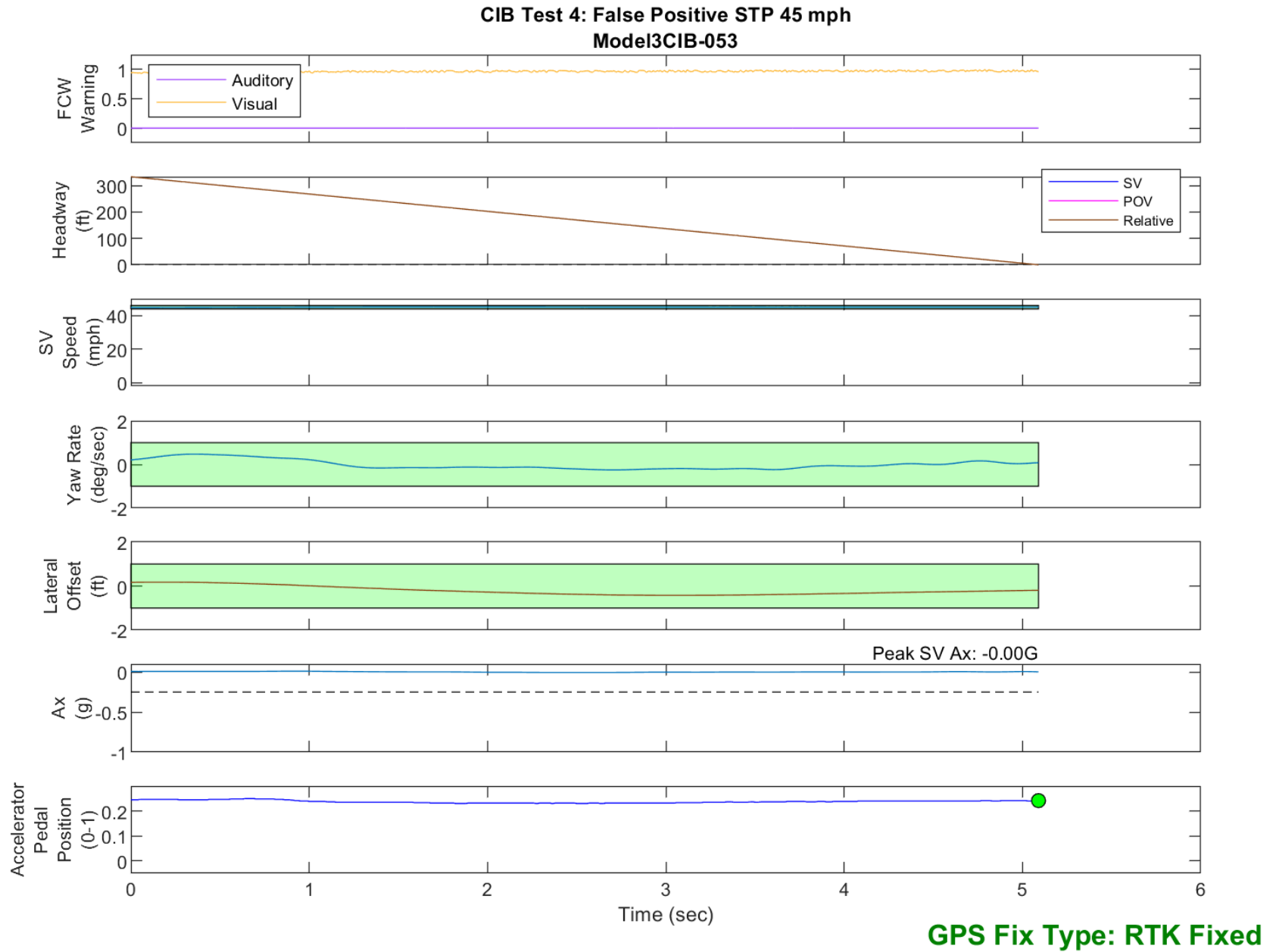


Figure D48. Time History for CIB Run 53, Test 4 - False Positive STP, 45 mph

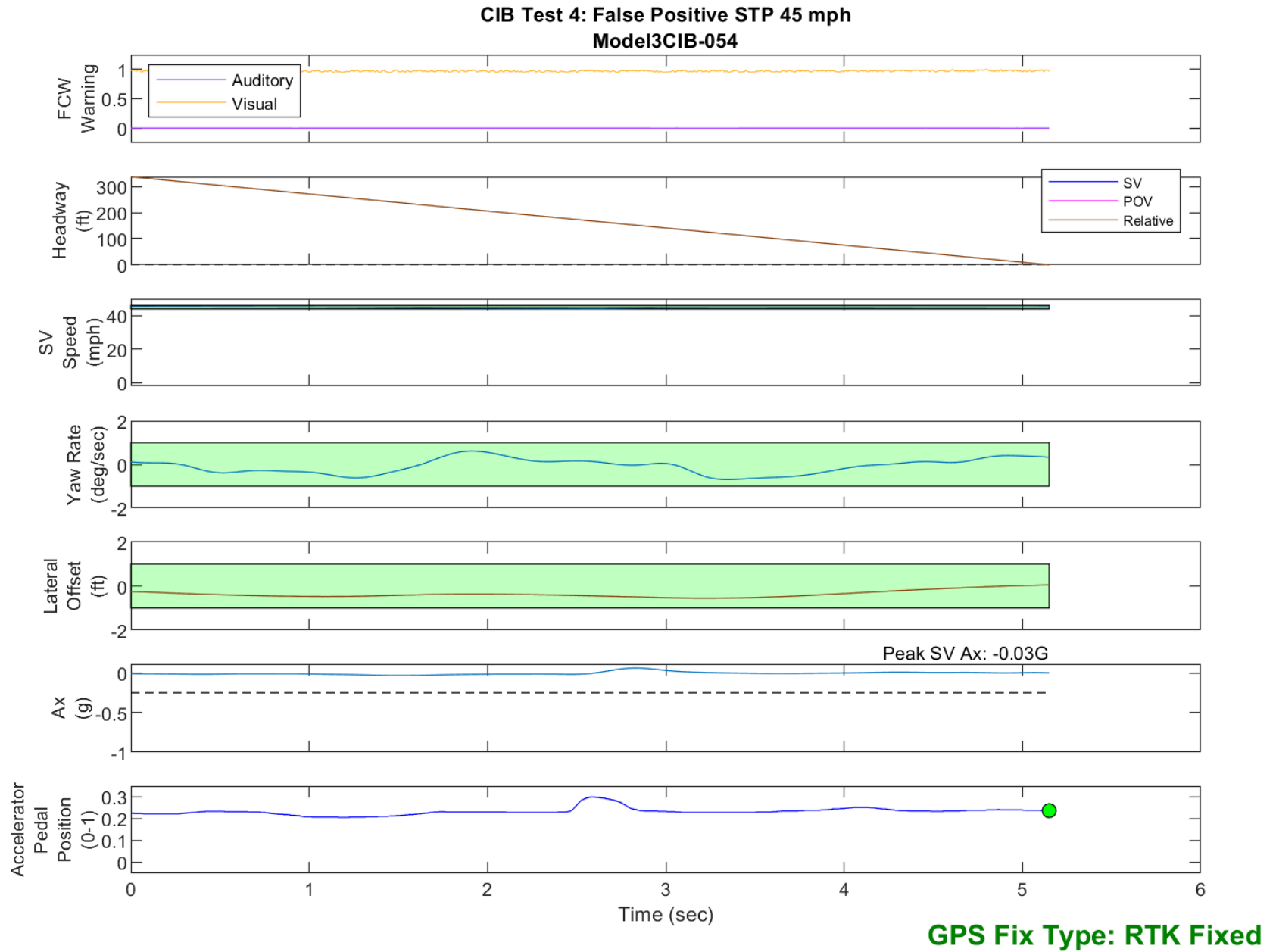


Figure D49. Time History for CIB Run 54, Test 4 - False Positive STP, 45 mph

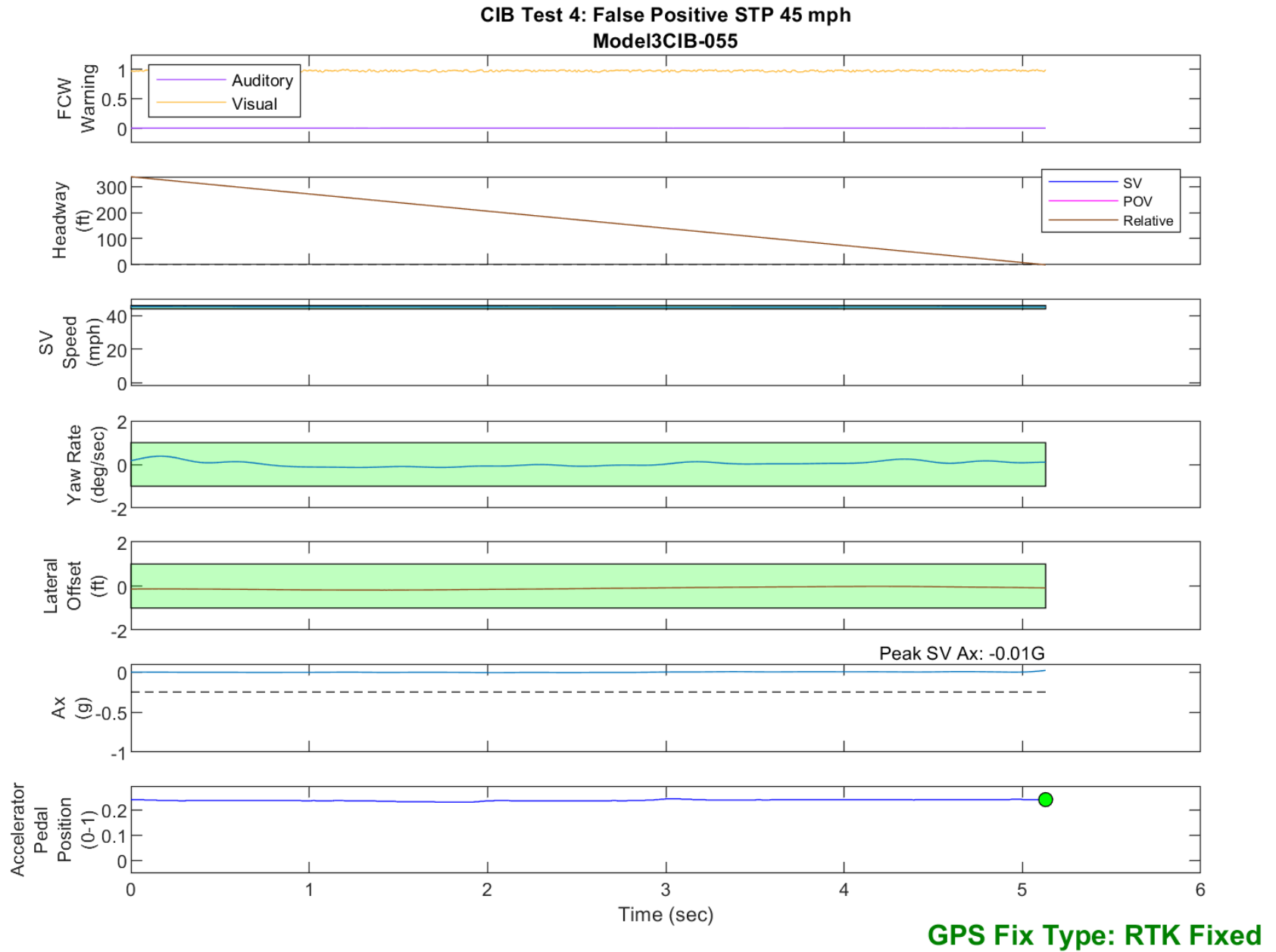


Figure D50. Time History for CIB Run 55, Test 4 - False Positive STP, 45 mph

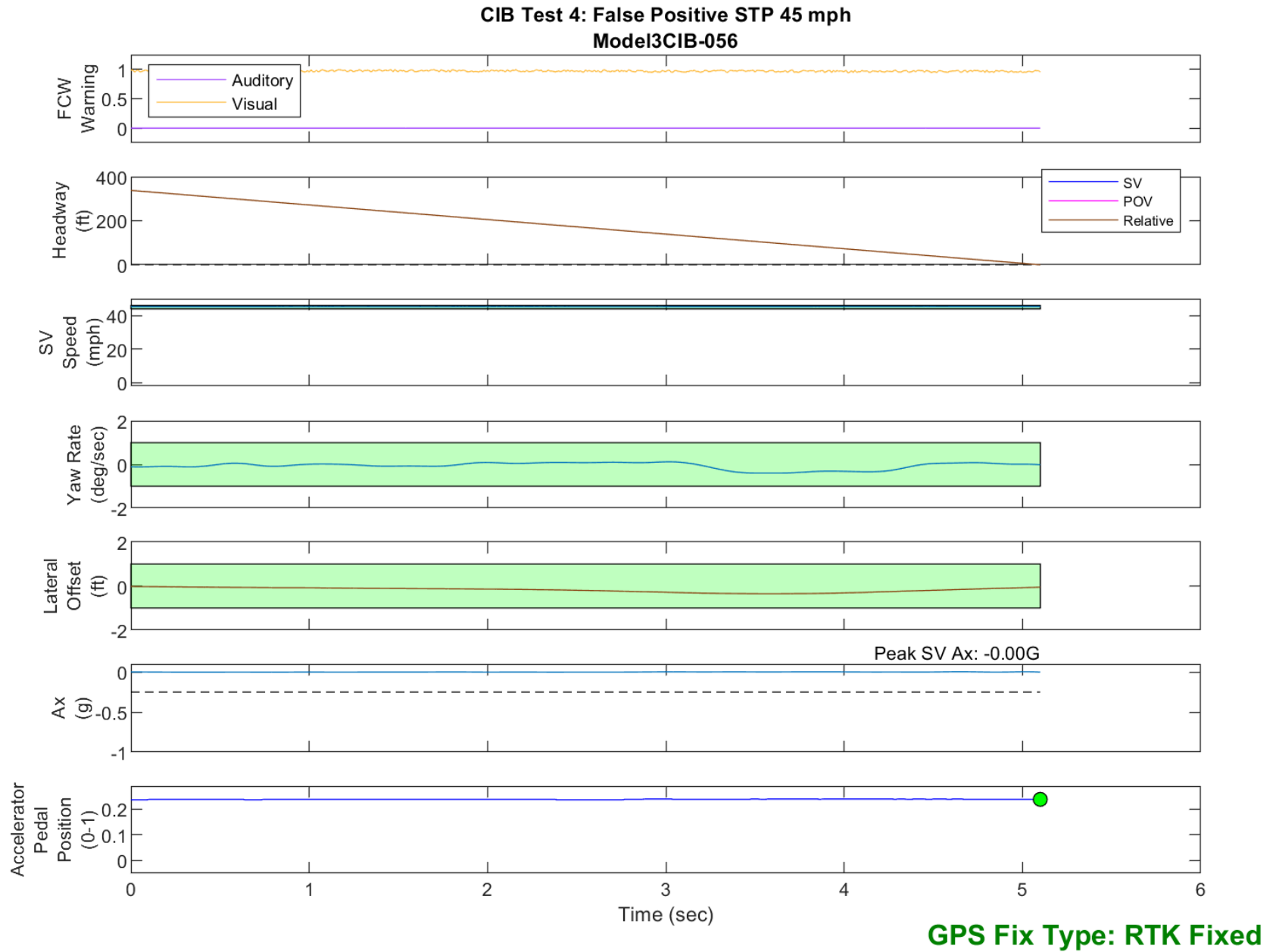


Figure D51. Time History for CIB Run 56, Test 4 - False Positive STP, 45 mph