OCAS-DRI-CIB-19-15
NEW CAR ASSESSMENT PROGRAM
CRASH IMMINENT BRAKE SYSTEM CONFIRMATION TEST

2018 Tesla Model 3

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18 November 2019

Final Report

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

U. S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Office of Crash Avoidance Standards
1200 New Jersey Avenue, SE
West Building, 4th Floor (NRM-200)
Washington, DC 20590

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16. Abstract

These tests were conducted on the subject in accordance with the specifications of the Office of Crash Avoidance Standards 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.

17. Key Words	18. Distribution Statement
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Section I
OVERVIEW AND TEST SUMMARY

Crash Imminent Brake (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 Brake system installed on a 2018 Tesla Model 3. This test is part of the New Car Assessment Program to assess Crash Imminent Brake 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 BRAKE

DATA SHEET 1: TEST RESULTS SUMMARY

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2018 Tesla Model 3

SUMMARY RESULTS

VIN: *5YJ3E1EB9JF0xxxx*

Test Date: *5/14/2019*

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 BRAKE

DATA SHEET 2: VEHICLE DATA

(Page 1 of 2)

2018 Tesla Model 3

TEST VEHICLE INFORMATION

VIN: *5YJ3E1EB9JF0xxxx*

Body Style: *Sedan* Color: *Pearl White Multi Coat*

Date Received: *5/1/2019* Odometer Reading: *1396 mi*

Engine: *Electric*

Transmission: *Automatic*

Final Drive: *AWD*

Is the vehicle equipped with:

ABS	**X**	Yes		No
Adaptive Cruise Control	**X**	Yes		No
Collision Mitigating Brake System	**X**	Yes		No

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Tesla, inc.*

Date of manufacture: *08/18*

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: *235/40R19*

Rear: *235/40R19*

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

Rear: *290 kPa (42 psi)*

CRASH IMMINENT BRAKE

DATA SHEET 2: VEHICLE DATA

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2018 Tesla Model 3

TIRES

Tire manufacturer and model: *Continental Procontact RX*

Front tire size: *235/40R19*

Rear tire size: *235/40R19*

VEHICLE ACCEPTANCE

Verify the following before accepting the vehicle:

X All options listed on the "window sticker" are present on the test vehicle.

X Tires and wheel rims are the same as listed.

X There are no dents or other interior or exterior flaws.

X The vehicle has been properly prepared and is in running condition.

X Verify that spare tire, jack, lug wrench, and tool kit (if applicable) is located in the vehicle cargo area.

CRASH IMMINENT BRAKE

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2018 Tesla Model 3

GENERAL INFORMATION

Test date: *5/14/2019*

AMBIENT CONDITIONS

Air temperature: *29.4 C (85 F)*

Wind speed: *4.1 m/s (9.2 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: *290 kPa (42 psi)*

Rear: *290 kPa (42 psi)*

CRASH IMMINENT BRAKE

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2018 Tesla Model 3

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*501.2 kg (1105 lb)*	Right Front	*499.0 kg (1100 lb)*
Left Rear	*495.8 kg (1093 lb)*	Right Rear	*485.8 kg (1071 lb)*
		Total:	*1981.7 kg (4369 lb)*

CRASH IMMINENT BRAKE

DATA SHEET 4: CRASH IMMINENT BRAKE SYSTEM OPERATION

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2018 Tesla Model 3

Name of the CIB option, option package, etc.

Automatic Emergency Brake (AEB)

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

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

7 mph (10 kph) (Per manufacturer supplied information)

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

90 mph (150 kph) (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

Before some features can be used for the first time, some cameras must complete a self-calibration process. Calibration typically completes after driving 20-25 miles (32-40 km), but the distance varies depending on road and environmental conditions. Driving on a straight road with highly-visible lane lines allows Model 3 to calibrate quicker. When calibration is complete, the features are available for use.

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

The system should not deactivate or reduce effectiveness due to repeated AEB activations. However, radar blindness can sometimes occur due to periods of inactivity. When that happens, user will not be able to engage Adaptive Cruise Control. System can be restored by power cycling the vehicle.

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

- **X** Warning light*
- **X** Buzzer or audible alarm
- ____ Vibration
- ____ Other

* The sensor used to detect the visual alerts was saturated by the brightness of the screen and therefore unable to detect the onset of the visual alert.

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.

Alerts are shown on the left side of center screen.

Forward Collision Warning is designed to sound a chime and highlight the vehicle in front of you in red on the touchscreen (Figure A14).

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

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.

Automatic Emergency Braking enabled by default. To disable it use touch controls:

> Autopilot

> Settings

> Automatic Emergency Braking

> Off

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

X No

If yes, please provide a full description.

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.

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 radar sensor is obstructed (dirty, covered, etc.).*
- *The windshield is obstructing the view of the camera(s) (fogged over, dirty, covered by a sticker, etc.).*

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

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.

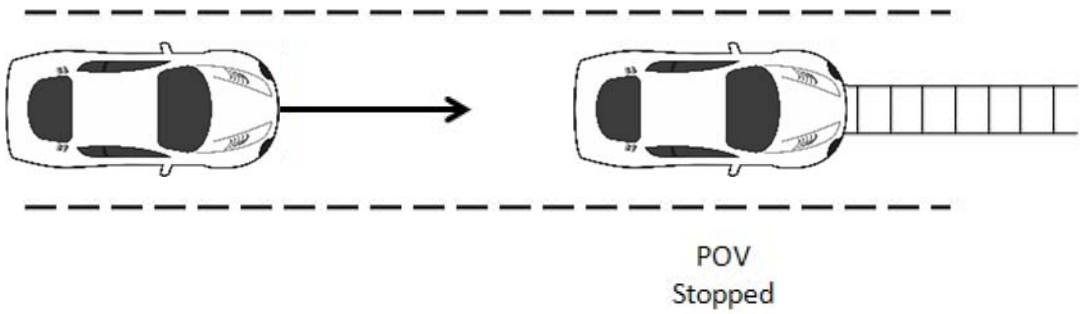


Figure 1. Depiction of Test 1

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 kph) 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 kph) 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.

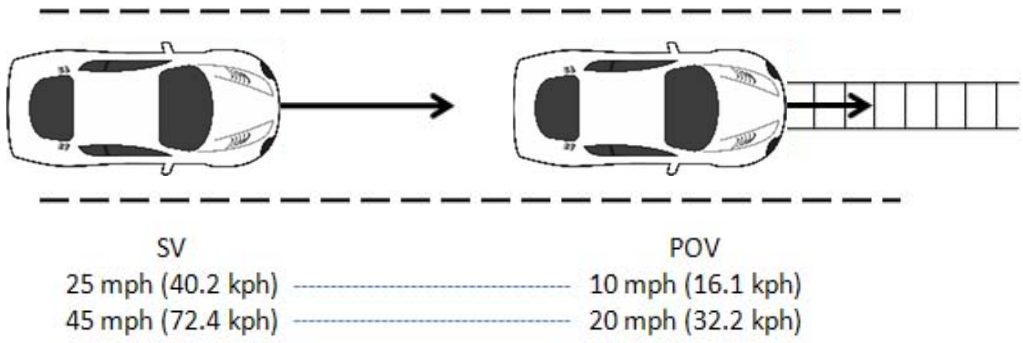


Figure 2. Depiction of Test 2

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 kph) in the center of the lane of travel while the SV was driven at 25.0 mph (40.2kph), 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 kph) in the center of the lane of travel while the SV was driven at 45.0 mph (72.4 kph), 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.

1. 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}.

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

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

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

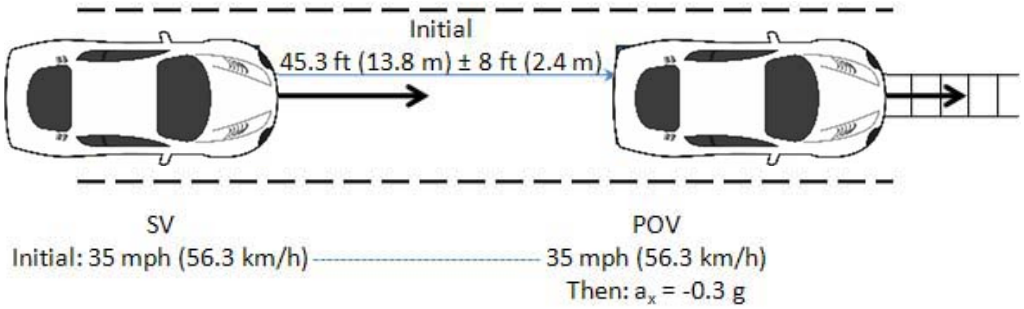


Figure 3. Depiction of Test 3 with POV Decelerating

a. Procedure

The SV ignition was cycled prior to each test run. For this test scenario, both the POV and SV were driven at a constant 35.0 mph (56.3 kph) 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 kph) 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.

1. 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}.

2. 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 kph) 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 bandpass 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	Pass-Band 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 0.25g.
- The SV driver did not apply any force to the brake pedal during the applicable validity period.
- The lateral distance between the centerline of the SV and the centerline of the POV or STP did not deviate more than ±1 ft (0.3 m) during the applicable validity period.

3. Validity Period

The valid test interval began:

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

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

Test 3: 3 seconds before the onset of POV braking

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

The valid test interval ended:

Test 1: When either of the following occurred:

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

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

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

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

4. Static Instrumentation Calibration

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

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

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

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

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

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

5. Number of Trials

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

6. Transmission

All trials were performed with SV automatic transmissions in ''Drive'' or with manual transmissions in the highest gear capable of sustaining the desired test speed. Manual transmission clutches remained engaged during all maneuvers. The brake lights of the POV were not illuminated.

C. Principal Other Vehicle

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

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

- POV element, whose requirements are to:
  - Provide an accurate representation of a real vehicle to CIB sensors, including cameras, radar and lidar.
  - Be resistant to damage and inflict little or no damage to the SV as a result of repeated SV-to-POV impacts.

- POV delivery system whose requirements 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.

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

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: 6/21/2018 Due: 6/21/2019
Platform Scales	Vehicle Total, Wheel, and Axle Load	1200 lb/platform 5338 N/	0.5% of applied load	Intercomp SWI	1110M206352	By: DRI Date: 1/3/2019 Due: 1/3/2020
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;	Accels ± 10g, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +		By: Oxford Technical Solutions
					2182	Date: 10/16/2017 Due: 10/16/2019

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
	Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles				2176	Date: 4/11/2018 Due: 4/11/2020

TABLE 2. TEST INSTRUMENTATION AND EQUIPMENT

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

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
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: 1/2/2019 Due: 1/2/2020

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)

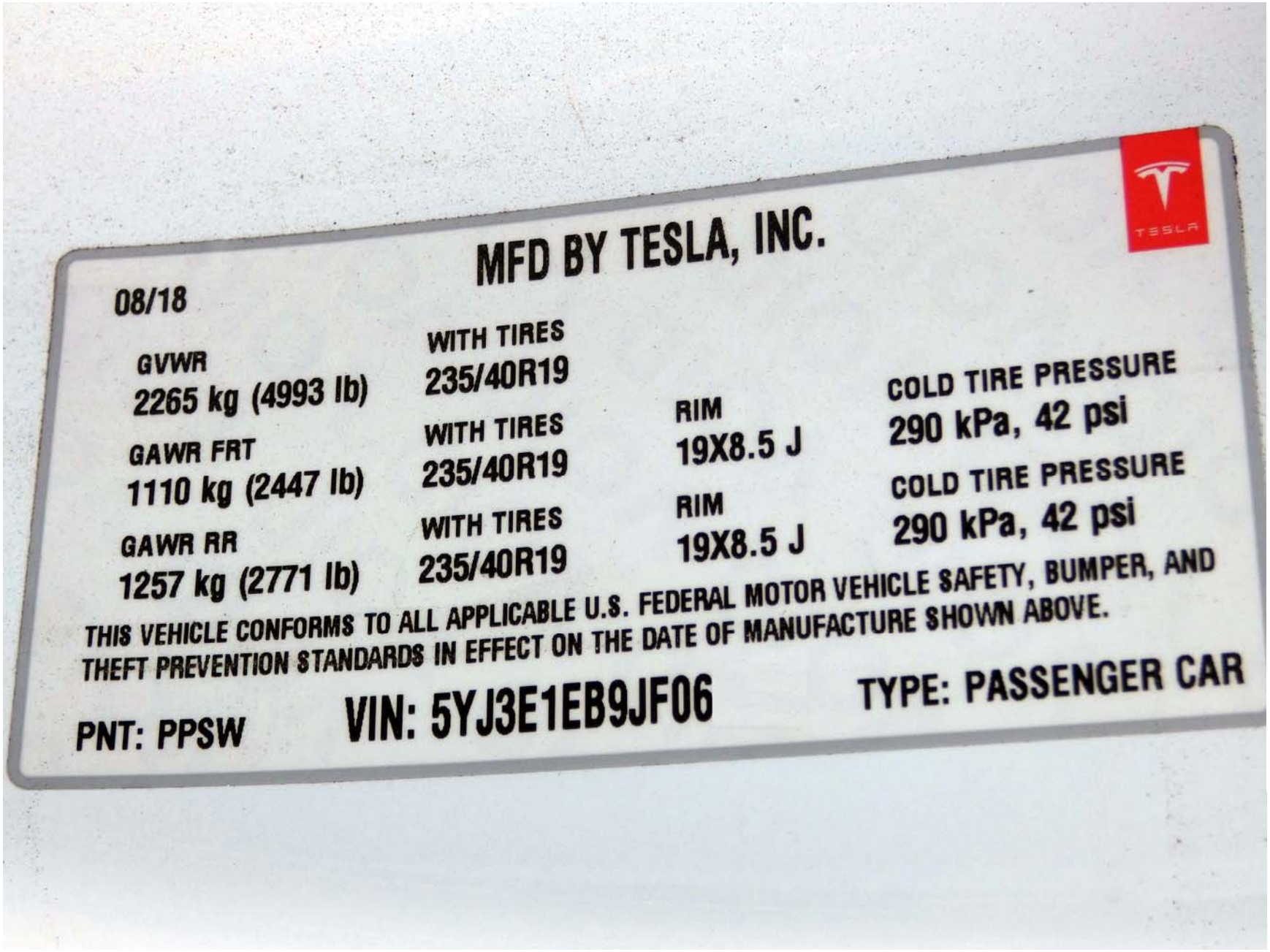


Figure A4. Vehicle Certification Label

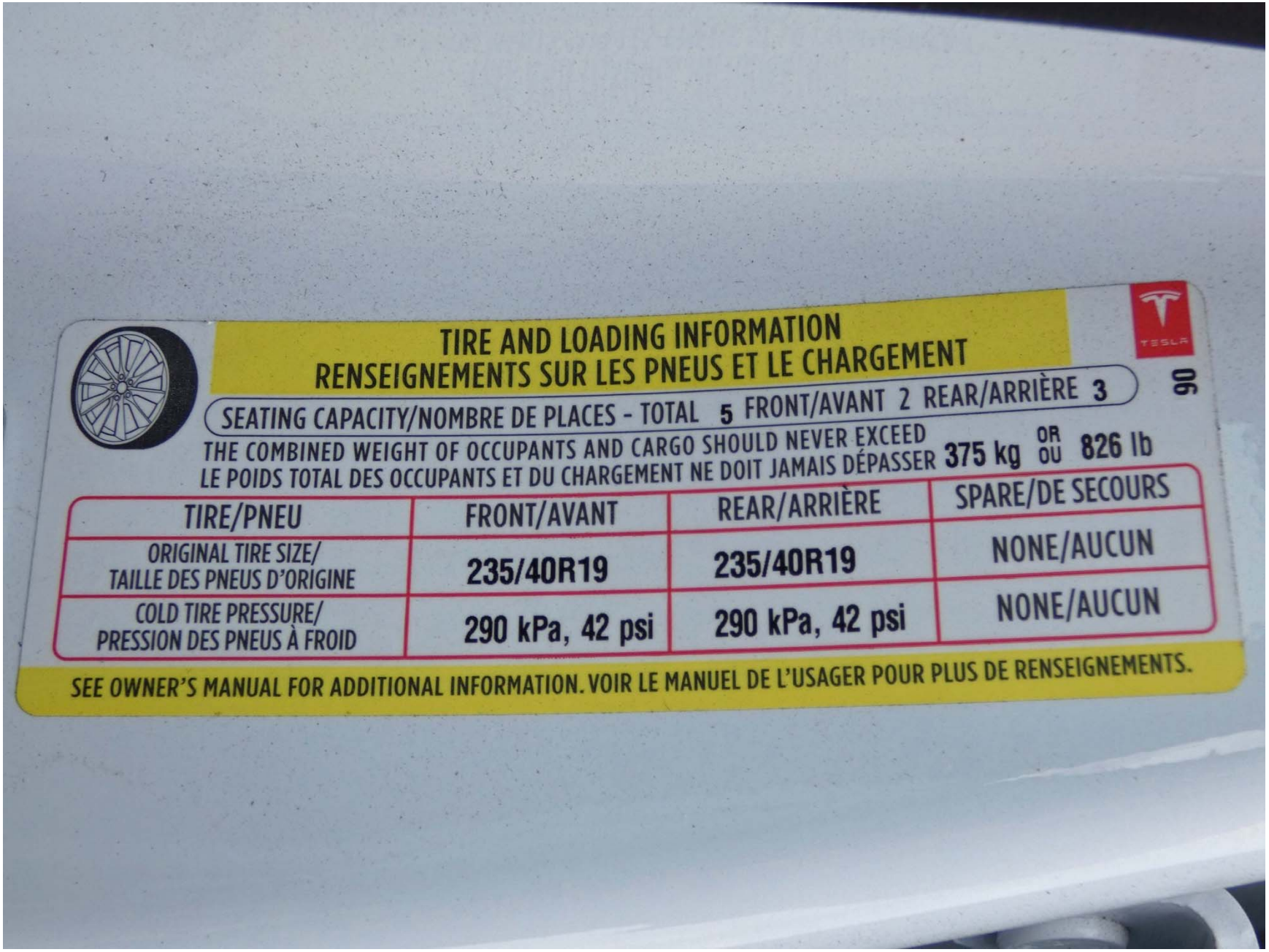


Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

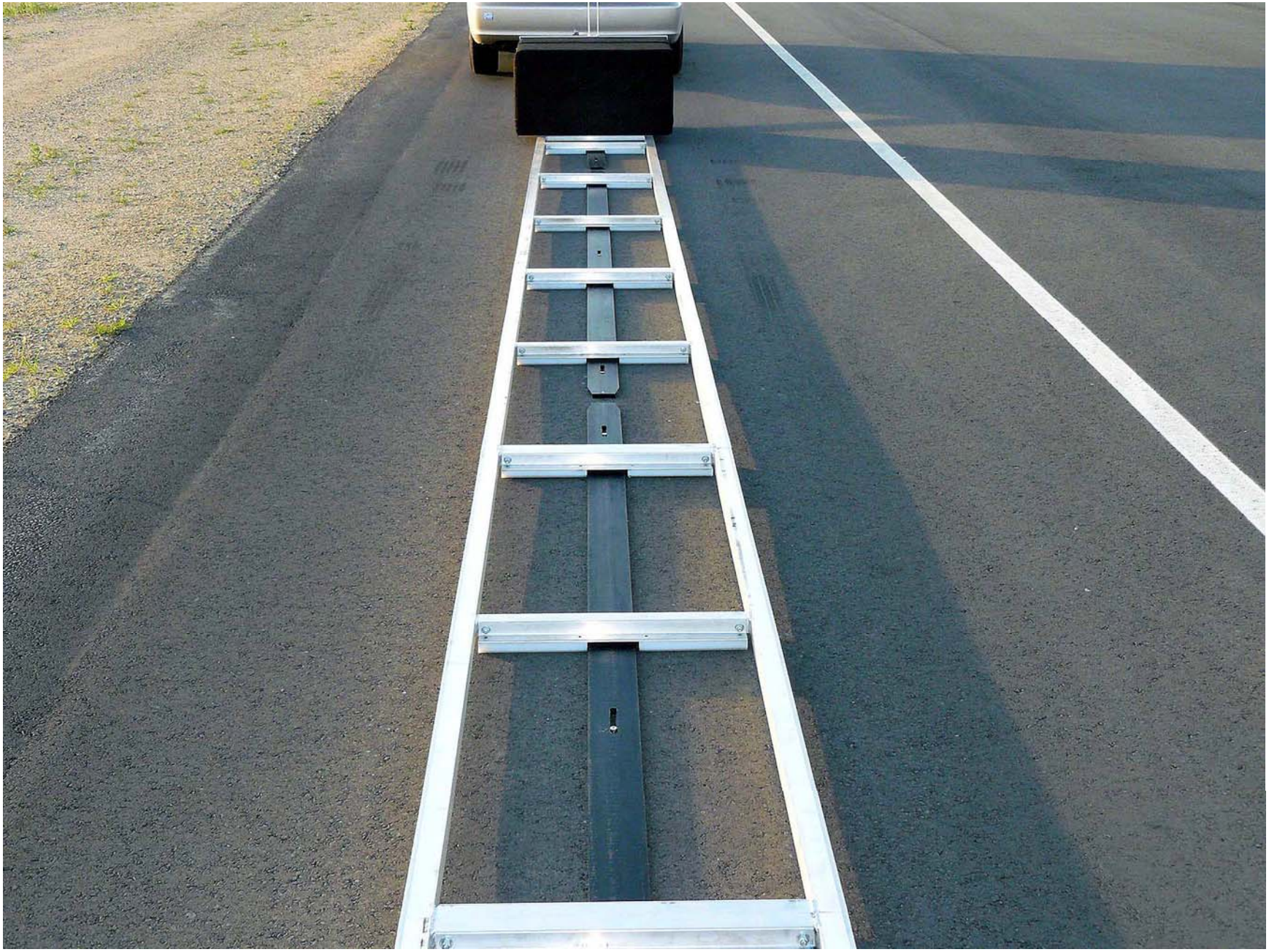


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

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

Figure A11. Sensor for Detecting Auditory Alerts

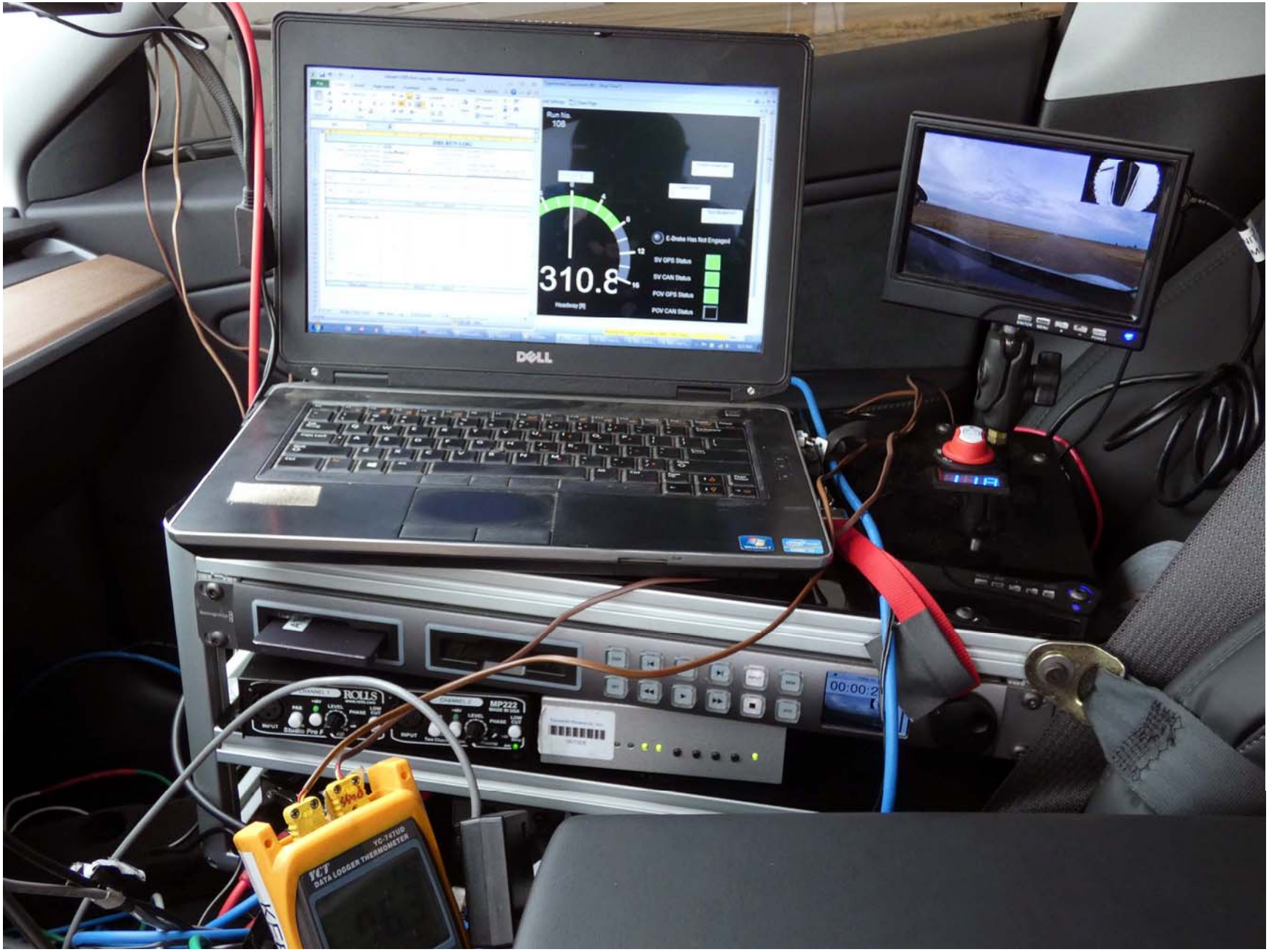


Figure A12. Computer Installed in Subject Vehicle

Figure A13. Brake Actuator Installed in POV System

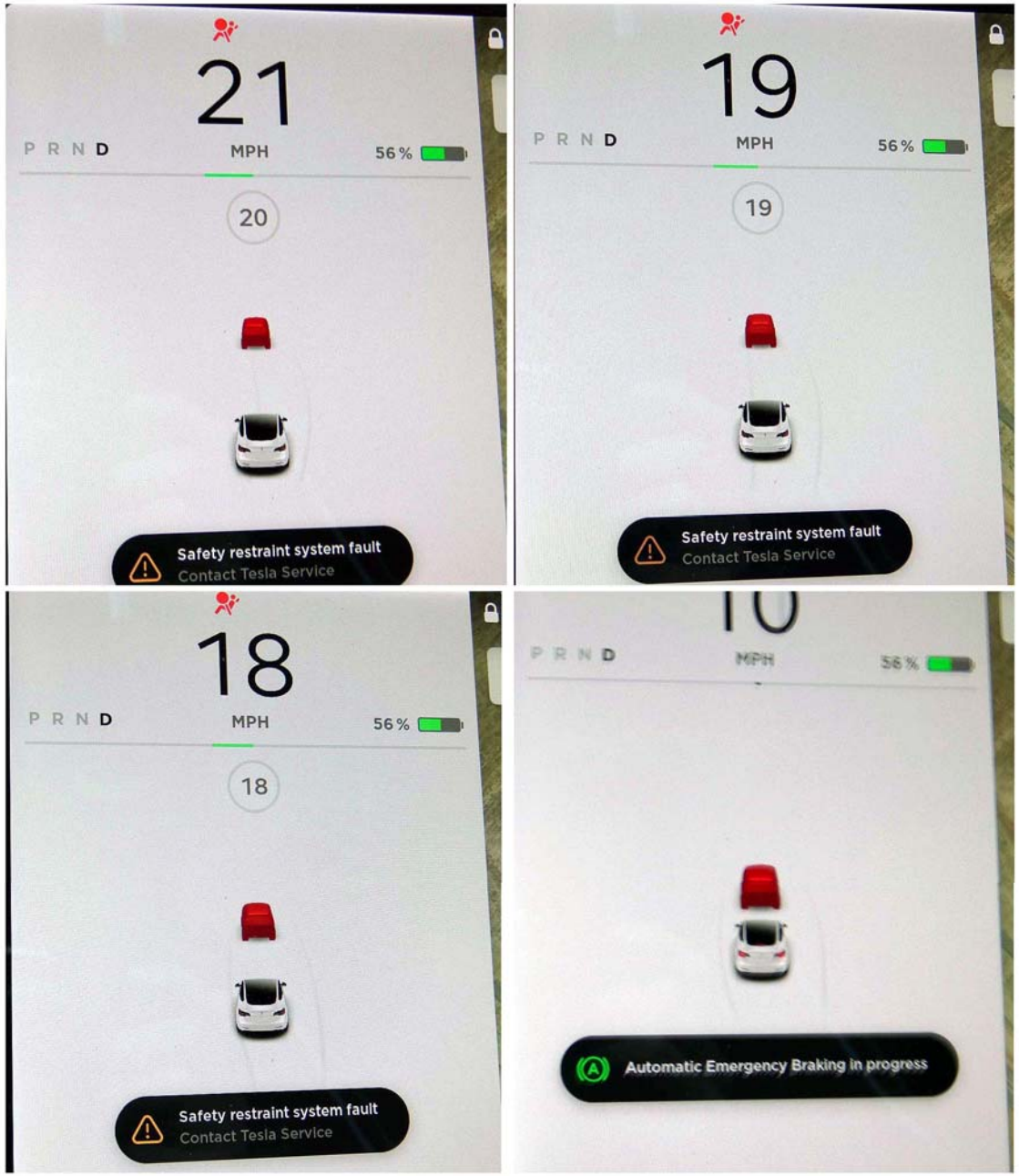


Figure A14. AEB Visual Alert

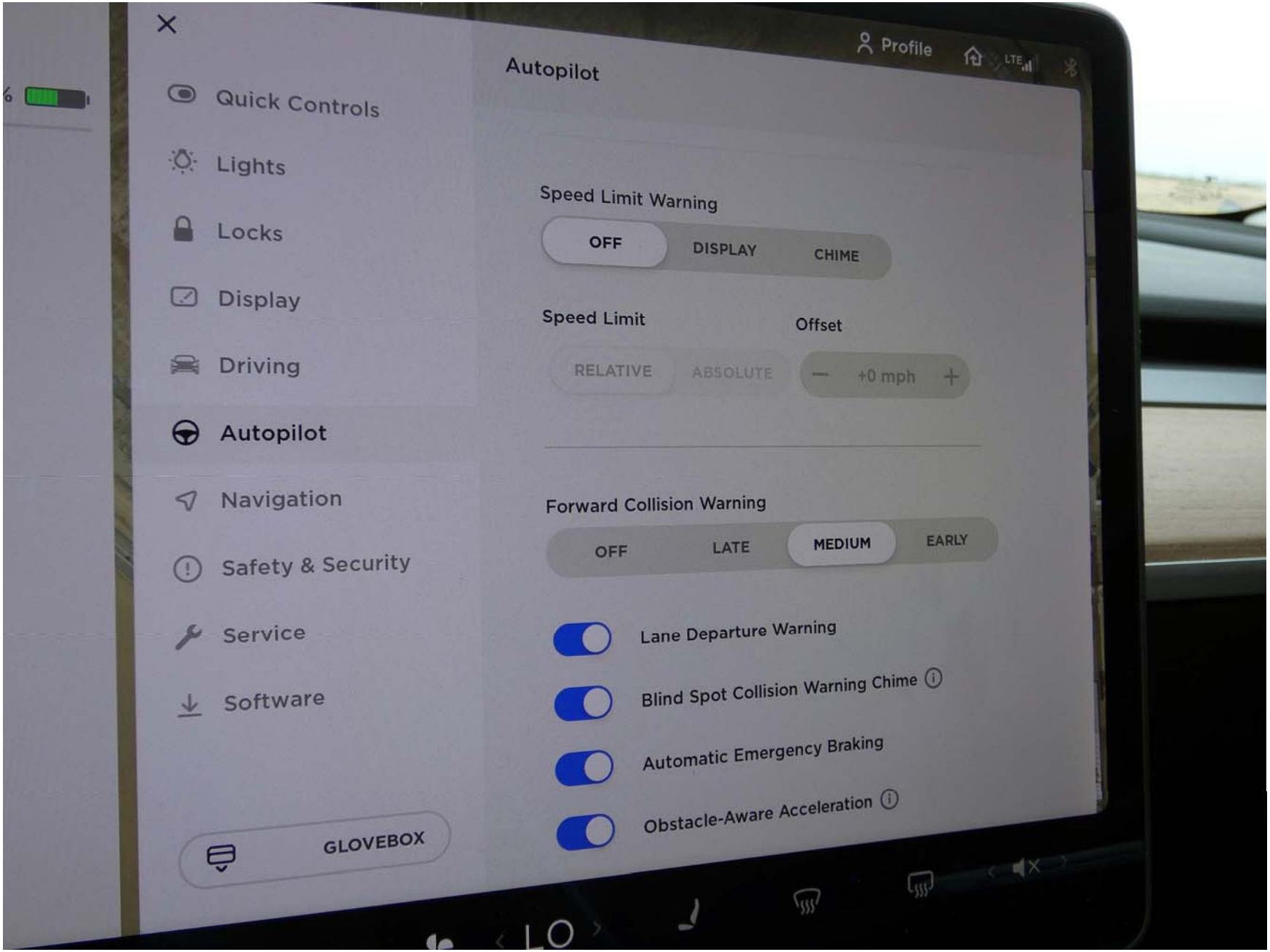


Figure A15. AEB Setup Menu

APPENDIX B

Excerpts from Owner's Manual

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 86).
- **Automatic Emergency Braking** - automatically applies braking to reduce the impact of a frontal collision (see Automatic Emergency Braking on page 87).
- **Obstacle-Aware Acceleration** - reduces acceleration if Model 3 detects an object in its immediate driving path (see Obstacle-Aware Acceleration on page 88).

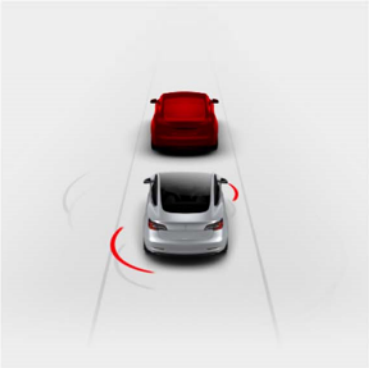
Warning: Forward Collision Warning is for guidance purposes only and is not a substitute for attentive driving and sound judgment. Keep your eyes on the road when driving and never depend on Forward Collision Warning to warn you of a potential collision. Several factors can reduce or impair performance, 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

The forward looking camera(s) and the radar sensor monitor the area in front of Model 3 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 87).

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 corrective action immediately.

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.

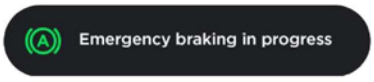
Warning: Forward Collision Warning operates only when driving between approximately 7 mph (10 km/h) and 90 mph (150 km/h).

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

Automatic Emergency Braking

The forward looking camera(s) and the radar sensor are designed to determine the distance from a detected object traveling in front of Model 3. When a frontal collision is considered unavoidable, Automatic Emergency Braking is designed to apply the brakes to reduce the severity of the impact.

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.



If driving 35 mph (56 km/h) or faster, the brakes are released after Automatic Emergency Braking has reduced your driving speed by 30 mph (50 km/h). For example, if Automatic Emergency Braking applies braking when driving 56 mph (90 km/h), it releases the brakes when your speed has been reduced to 26 mph (40 km/h).

Automatic Emergency Braking operates only when driving between approximately 7 mph (10 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 Tesla-supplied 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 if Model 3 detects an object in its driving path. 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**.

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.

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:

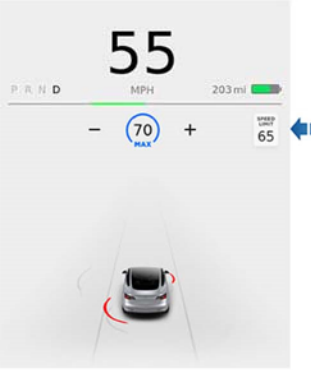
- The road has sharp curves.
- Visibility is poor (due to heavy rain, snow, fog, etc.).
- Bright light (such as from oncoming headlights or direct sunlight) is interfering with the view of the camera(s).
- The radar sensor is obstructed (dirty, covered, etc.).
- The windshield is obstructing the view of the camera(s) (fogged over, dirty, covered by a sticker, etc.).

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.

Caution: If a fault occurs with a Collision Avoidance Assist feature, Model 3 displays an alert. Contact Tesla Service.

How Speed Assist Works

When the Speed Limit Warning is turned on, the touchscreen displays a speed limit as determined by GPS data. You can touch this speed limit sign to automatically change the set speed to the detected speed limit (including any offsets that you have set). Warnings (described later) take effect when you exceed this limit.



In situations where Speed Assist is unable to determine a speed limit (for example, speed limit signs and GPS data are not available at the current location), or if Speed Assist is uncertain that an acquired speed limit is accurate (for example, although a speed limit sign was initially detected, some time has passed before a subsequent sign has been detected), the touchscreen may not display a speed limit sign and warnings do not take effect.

If you set the speed limit warning to **Display** (see Controlling Speed Assist on page 89) and exceed the determined speed limit, the speed limit sign on the touchscreen increases in size.

If you set the speed limit warning to **Chime** (see Controlling Speed Assist on page 89) and exceed the determined speed limit, the speed limit sign on the touchscreen increases in size and Model 3 also sounds a warning chime.

Note: Speed limit warnings go away after ten seconds, or when Model 3 slows down below the specified limit.

Warning: Do not rely on Speed Assist to determine the appropriate speed limit or driving speed. Always drive at a safe speed based on traffic and road conditions.

Controlling Speed Assist

To adjust the Speed Limit Warning setting, touch **Controls** > **Autopilot** > **Speed Limit Warning**, then choose one of these options:

- **Off** - Speed limit warnings do not display and chimes are not sounded.
- **Display** - Speed limit signs display on the touchscreen and the sign increases in size when you exceed the determined limit.
- **Chime** - In addition to the visual display, a chime is sounded whenever you exceed the determined speed limit.

You can also specify how the speed limit is determined:

- **Relative** - The speed limit is determined automatically based on detected traffic signs and GPS data. If desired, you can set a speed limit offset (+ or -) if you want to be alerted only when you exceed the offset speed limit by a specified amount. For example, you can increase the offset to +10 mph (10 km/h) if you only want to be warned when you exceed the speed limit by 10 mph (10 km/h).
- **Absolute** - Manually specify any speed limit between 20 and 140 mph (30 and 240 km/h).

Note: GPS data is not always accurate. The GPS can miscalculate a road's location and provide the speed limit for a directly adjacent road that may have a different speed limit. For example, the GPS can assume Model 3 is on a freeway or highway when it is actually on a nearby surface street, and vice versa.

Note: Your chosen setting is retained until you manually change it.

Limitations and Inaccuracies

Speed Assist may not be fully functional or may provide inaccurate information in these situations:

- The speed limits stored in the GPS database are incorrect or outdated.
- Model 3 is being driven in an area where GPS data is not available.
- A road or a speed limit has recently changed.

Warning: The list above does not represent an exhaustive list of situations

APPENDIX C

Run Log

Subject Vehicle: **2018 Tesla Model 3** Test Date: **5/14/2019**

Principal Other Vehicle: **SSV**

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
1	Static Run								
2	**Stopped POV**	Y	2.61	4.78	24.5	1.08	0.73	Pass	
3		Y	2.68	4.32	25.2	1.04	0.74	Pass	
4		Y	2.67	4.30	25.3	1.02	0.73	Pass	
5		Y	2.64	5.00	25.4	1.00	0.75	Pass	
6		Y	2.71	3.83	25.4	1.07	0.70	Pass	
7		Y	2.65	4.51	24.9	1.00	0.74	Pass	
8		N							Throttle
9		Y	2.65	3.30	24.8	1.04	0.69	Pass	
10	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
11	**Slower POV, 25 vs 10**	Y	2.53	2.02	14.2	1.06	0.45	Pass	
12		Y	2.62	2.59	15.0	1.01	0.50	Pass	
13		Y	2.59	1.11	15.0	0.96	0.37	Pass	
14		N							Post Processor error
15		Y	2.65	2.17	15.5	1.00	0.46	Pass	
16		Y	2.57	2.11	14.9	1.06	0.45	Pass	
17		Y	2.62	1.87	14.9	0.99	0.42	Pass	
18		N							Throttle
19		Y	2.65	2.08	15.1	0.99	0.44	Pass	
20	Static Run								
21	**Slower POV, 45 vs 20**	Y	3.07	3.71	25.3	1.04	0.68	Pass	
22		Y	3.03	3.59	25.1	1.04	0.66	Pass	
23		N							Yaw rate
24		Y	-	0.00	-	-	-	Fail	No warning, driver applied brakes at last minute. No AEB activation
25		Y	3.05	3.63	24.9	1.00	0.66	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
26		Y	3.02	4.52	25.9	1.03	0.70	Pass	
27		Y	3.01	3.44	25.5	1.09	0.65	Pass	
28		Y	2.95	3.59	25.2	1.06	0.69	Pass	
29		N							Throttle
30		Y	3.03	3.97	24.8	1.04	0.64	Pass	
31	Static run								
32	**Braking POV, 35**	N							POV speed
33		Y	1.69	0.00	20.1	1.03	0.50	Pass	
34		Y	2.00	0.00	29.3	1.04	0.54	Pass	
35		Y	1.91	0.00	26.2	0.99	0.54	Pass	
36		Y	1.95	0.00	28.1	1.07	0.57	Pass	
37		Y	1.98	0.00	20.8	1.04	0.50	Pass	
38		Y	1.82	0.00	21.8	1.03	0.53	Pass	
39		Y	1.64	0.00	21.3	1.05	0.52	Pass	
40	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
41	STP - Static Run								
42	**STP False Positive, 25**	Y				0.00		Pass	
43		Y				0.01		Pass	
44		Y				0.01		Pass	
45		Y				0.00		Pass	
46		Y				0.01		Pass	
47		Y				0.01		Pass	
48		Y				0.01		Pass	
49	STP - Static Run								
50	**STP False Positive, 45**	Y				0.01		Pass	
51		Y				0.01		Pass	
52		Y				0.03		Pass	
53		Y				0.01		Pass	
54		N							Speed
55		N							Lateral offset

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
56		Y				0.01		Pass	
57		Y				0.02		Pass	
58		Y				0.00		Pass	
59	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)
- Braking 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.

- 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. A green dot is displayed if the accelerator pedal was released within 0.5 seconds of the onset of the FCW warning.

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.

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

Examples of time history plots for each test type (including passing, failing and invalid runs) are shown in Figure 1 through Figure 9. Figures 1 through 6 show passing runs for each of the 6 test types. Figures 7 and 8 show examples of invalid runs. Figure 9 shows an example of a valid test that failed the CIB requirements.

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

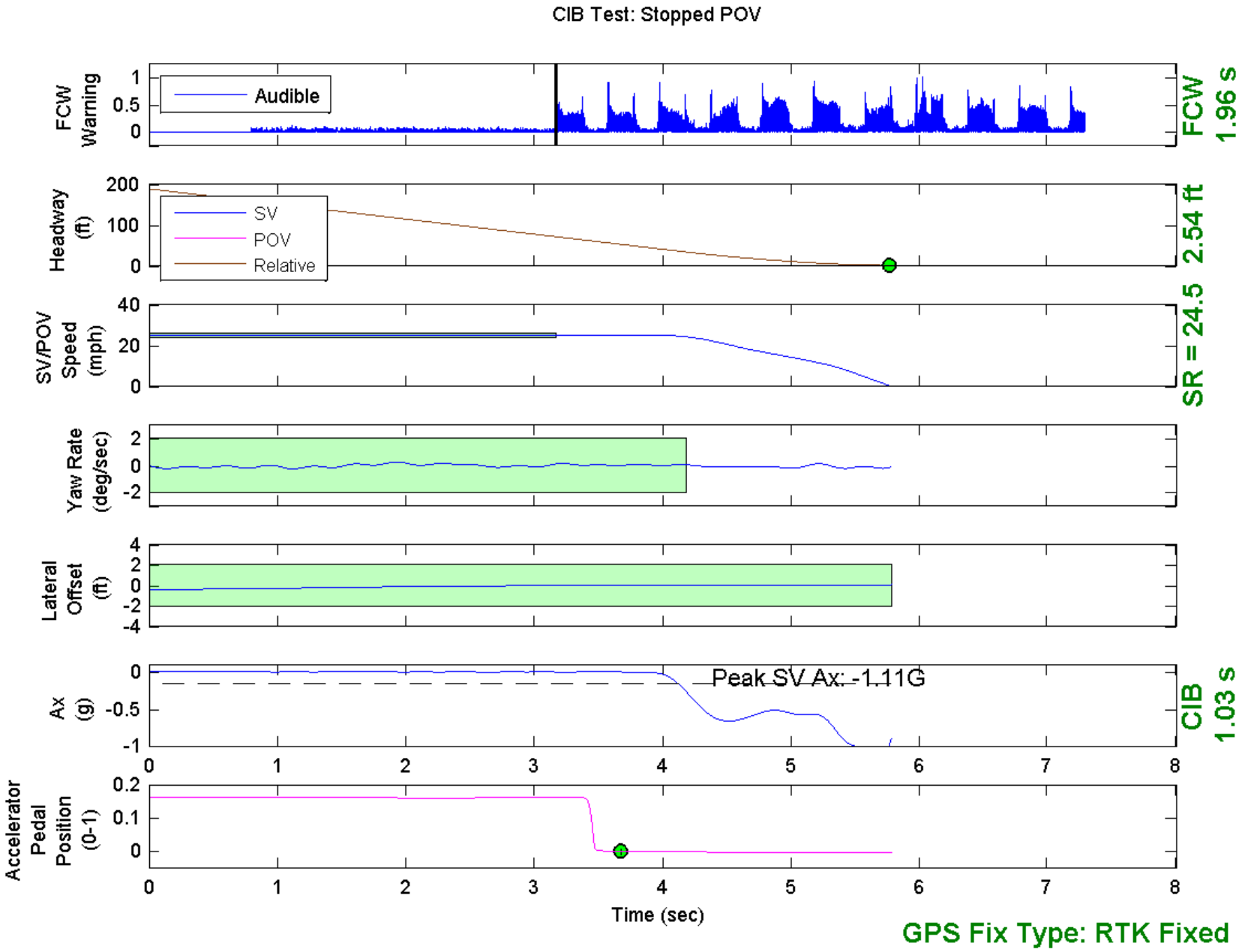


Figure D1. Example Time History for Stopped POV, Passing

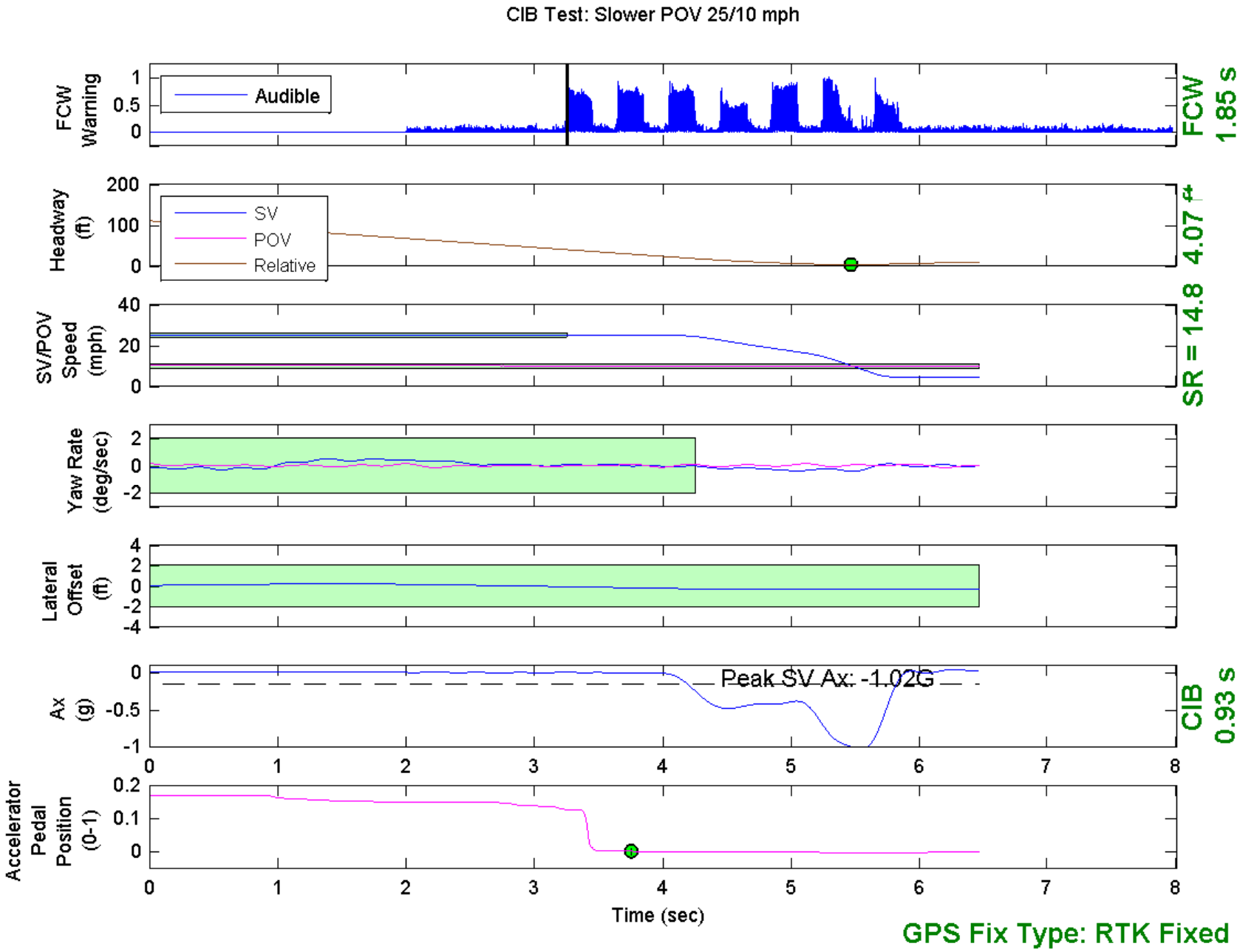


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

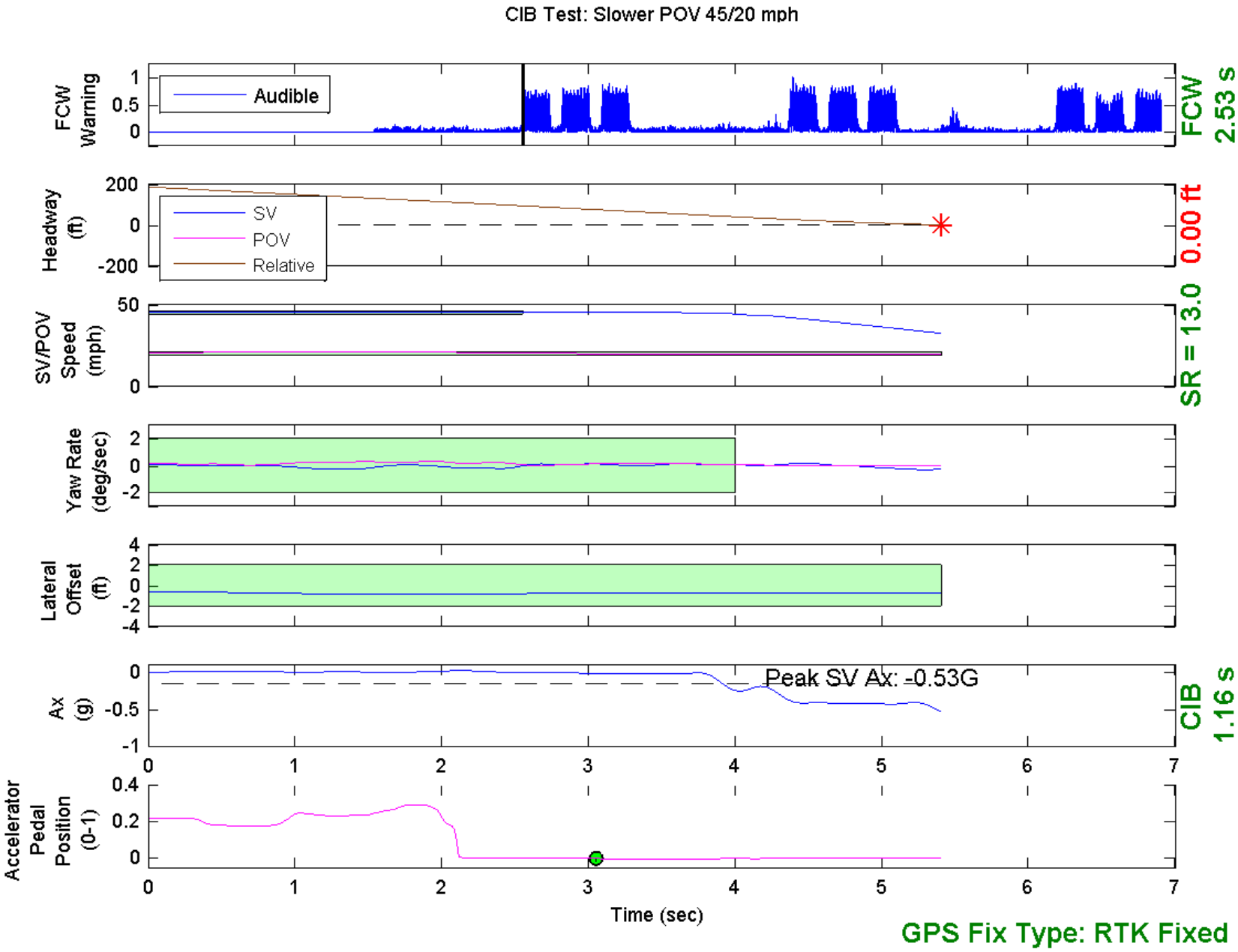


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

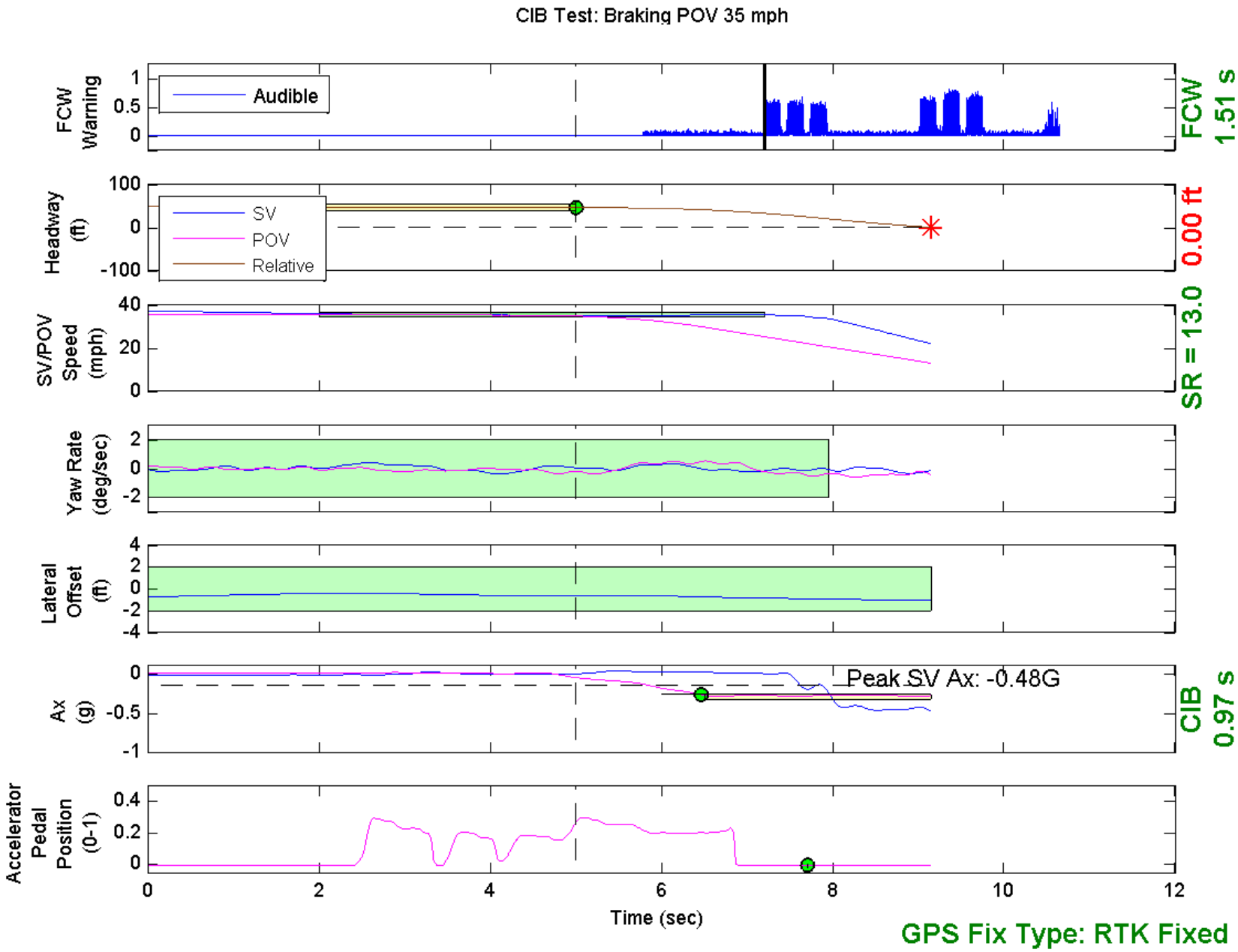


Figure D4. Example Time History for Braking POV 35, Passing

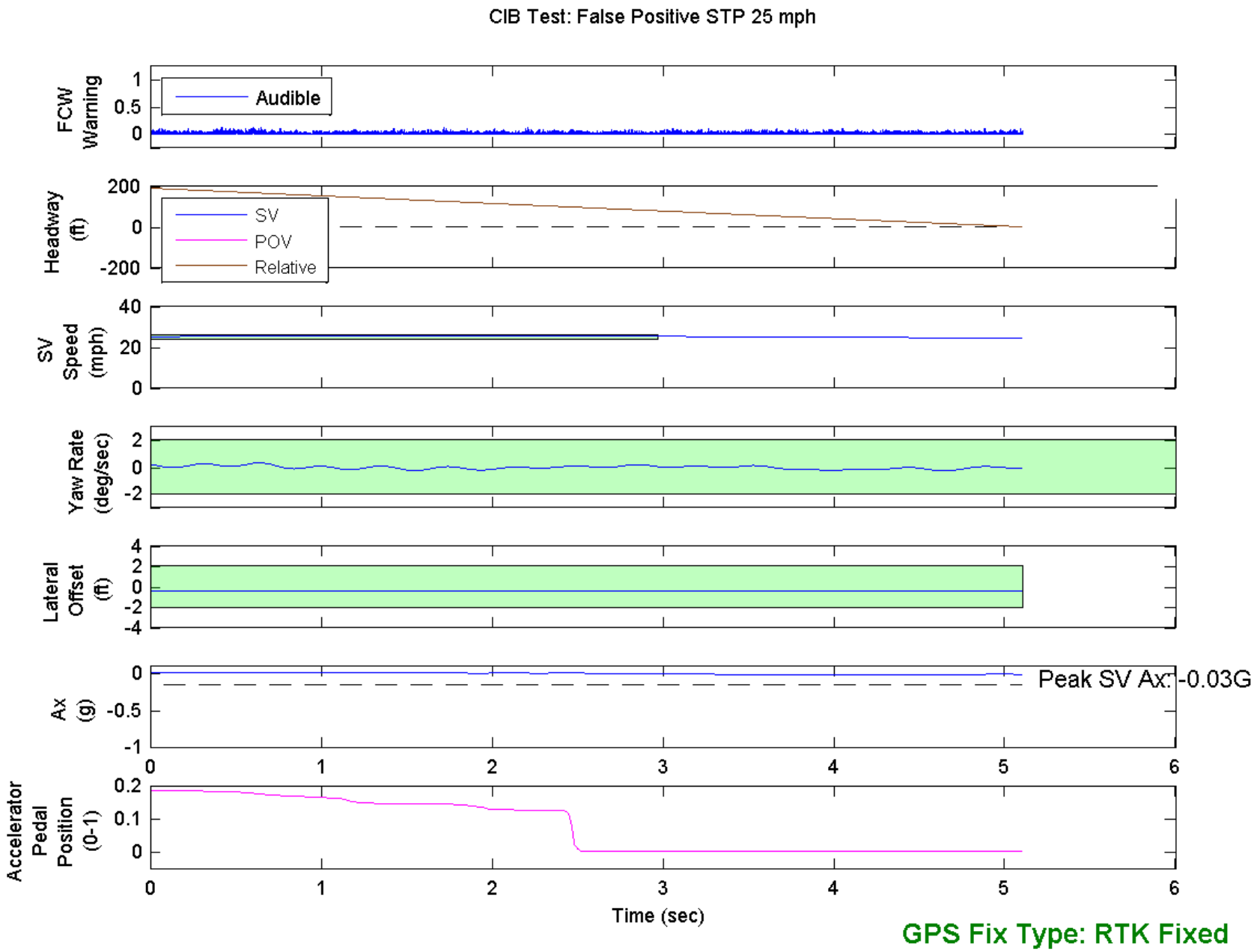


Figure D5. Example Time History for False Positive STP 25, Passing

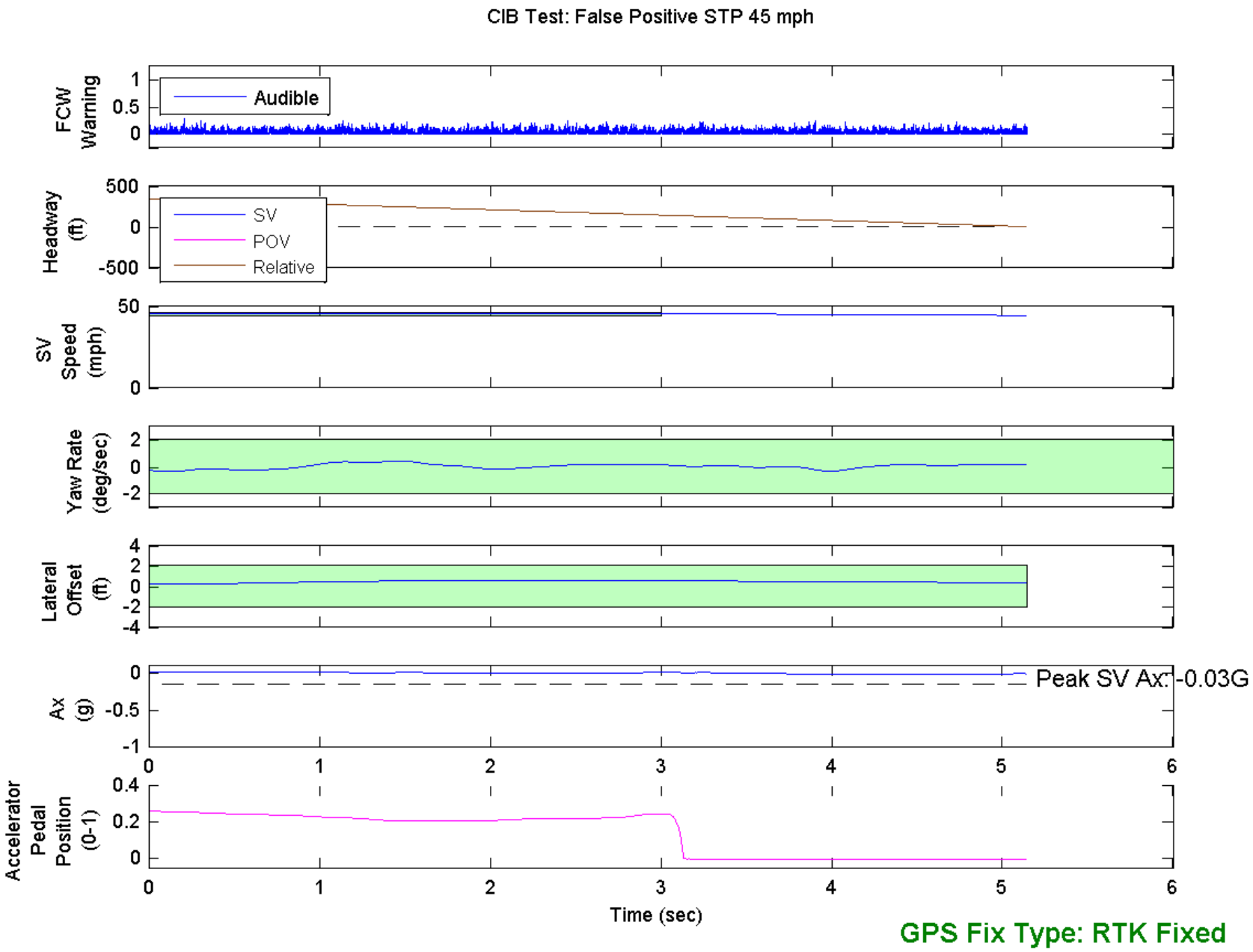


Figure D6. Example Time History for False Positive STP 45, Passing

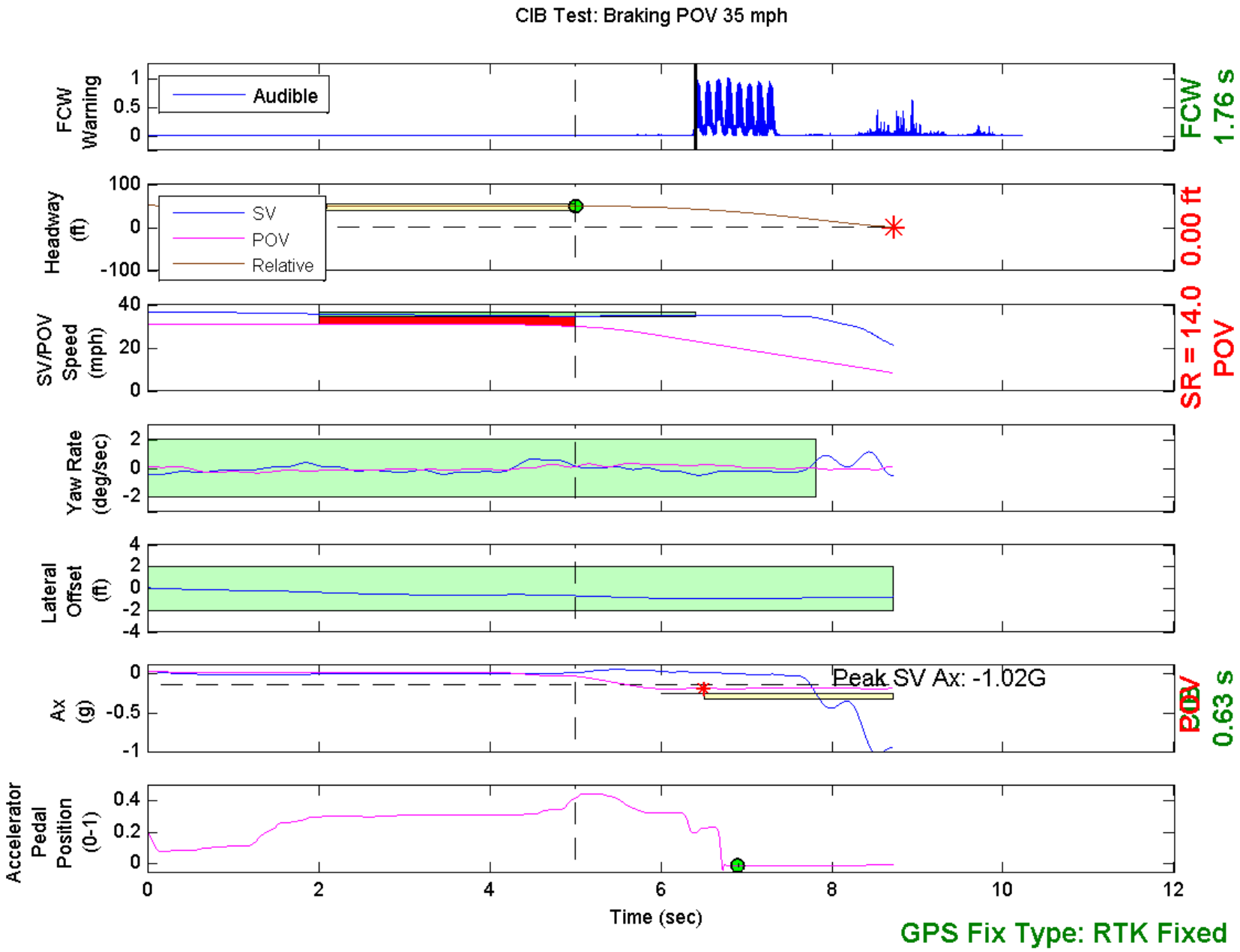


Figure D7. Example Time History Displaying Various Invalid Criteria

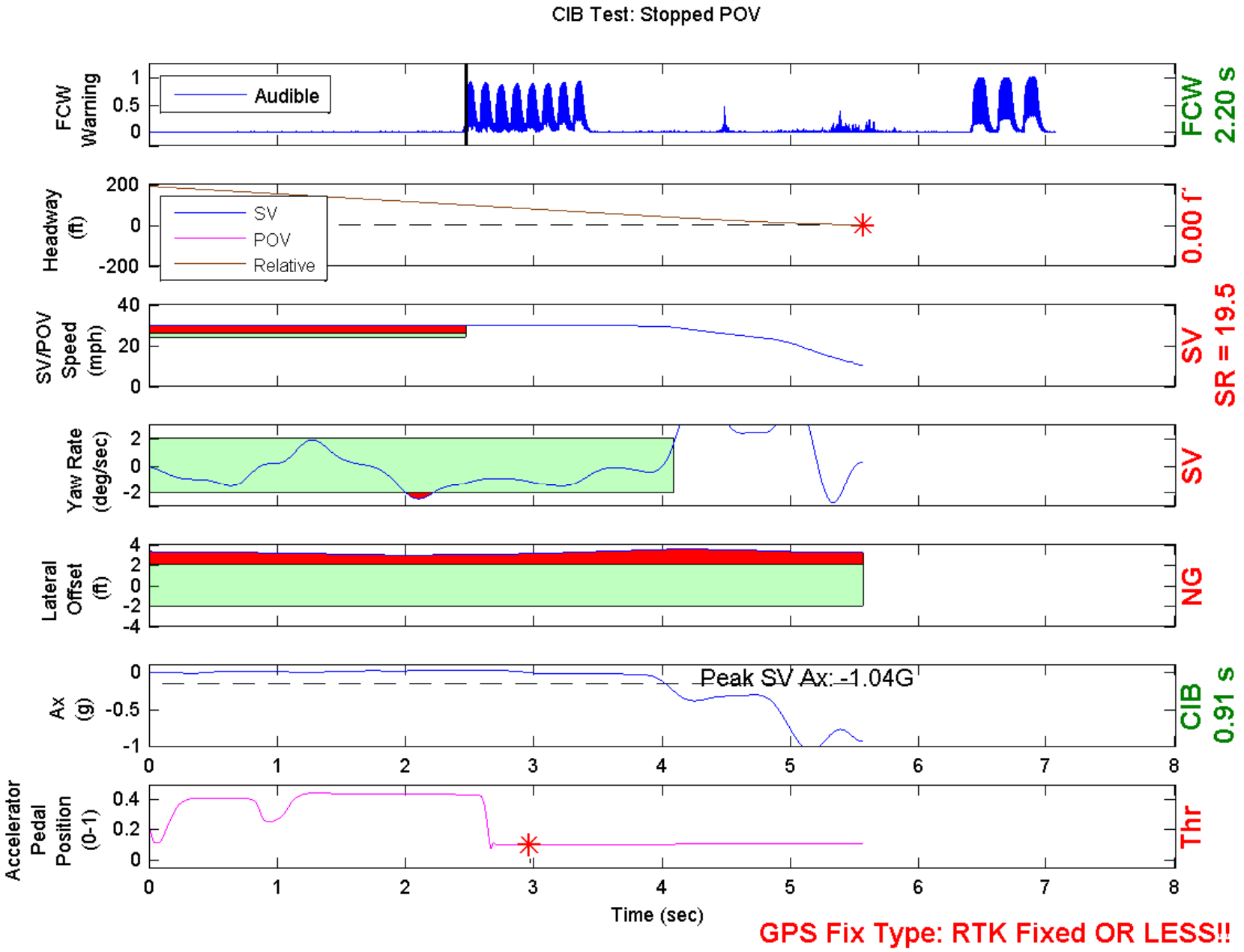


Figure D8. Example Time History Displaying Various Invalid Criteria

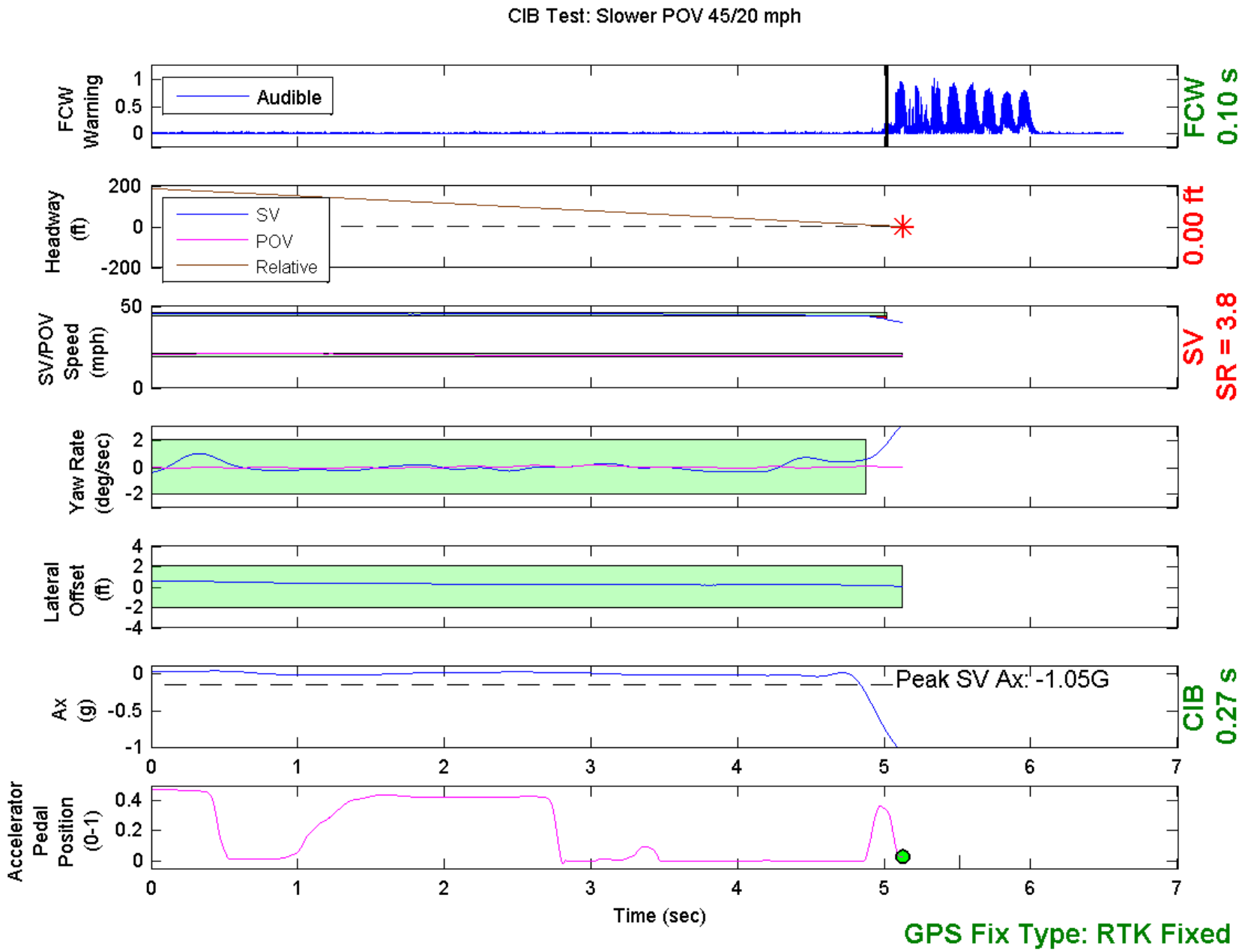


Figure D9. Example Time History for a Failed Run

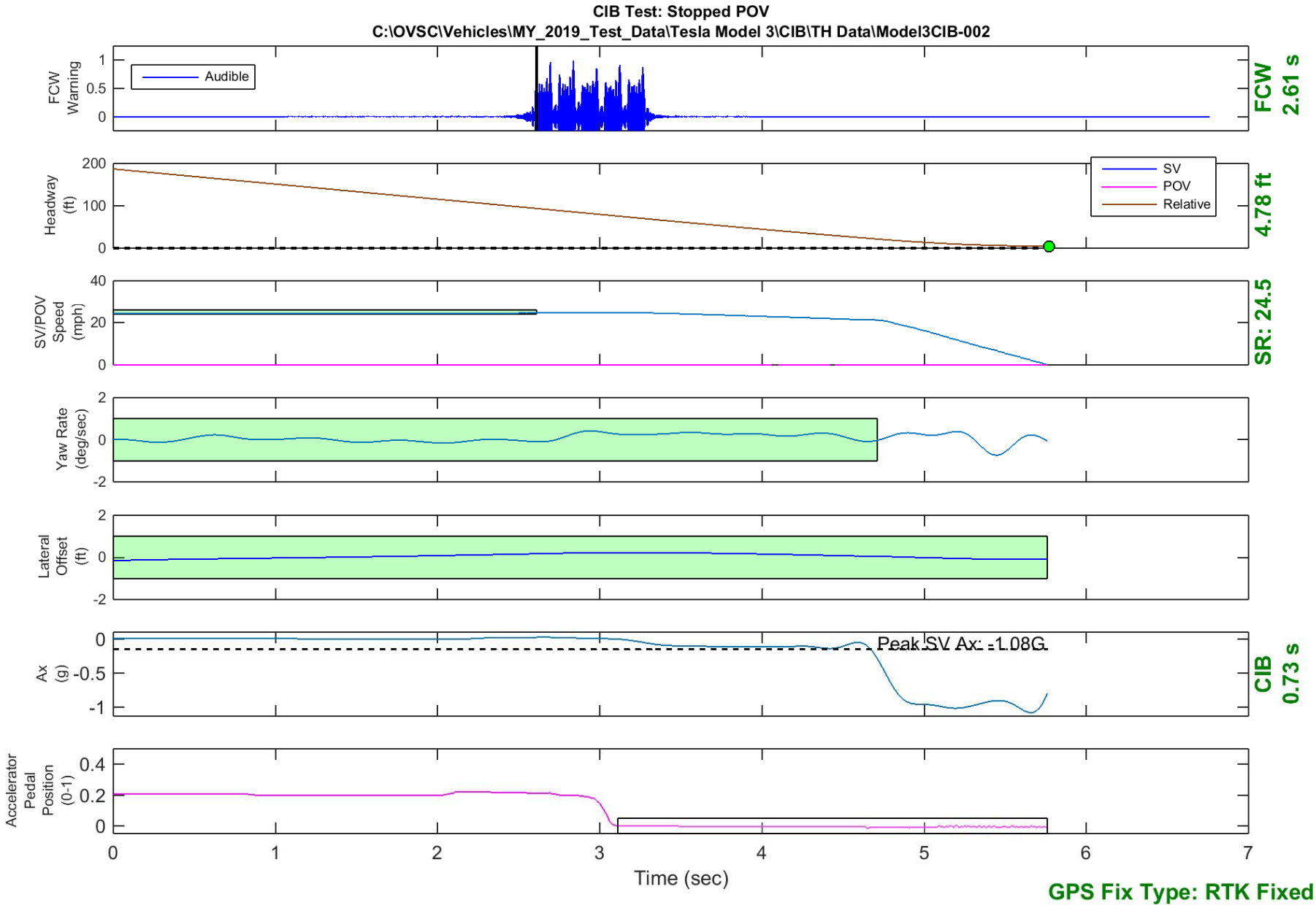


Figure D10. Time History for CIB Run 2, SV Encounters Stopped POV

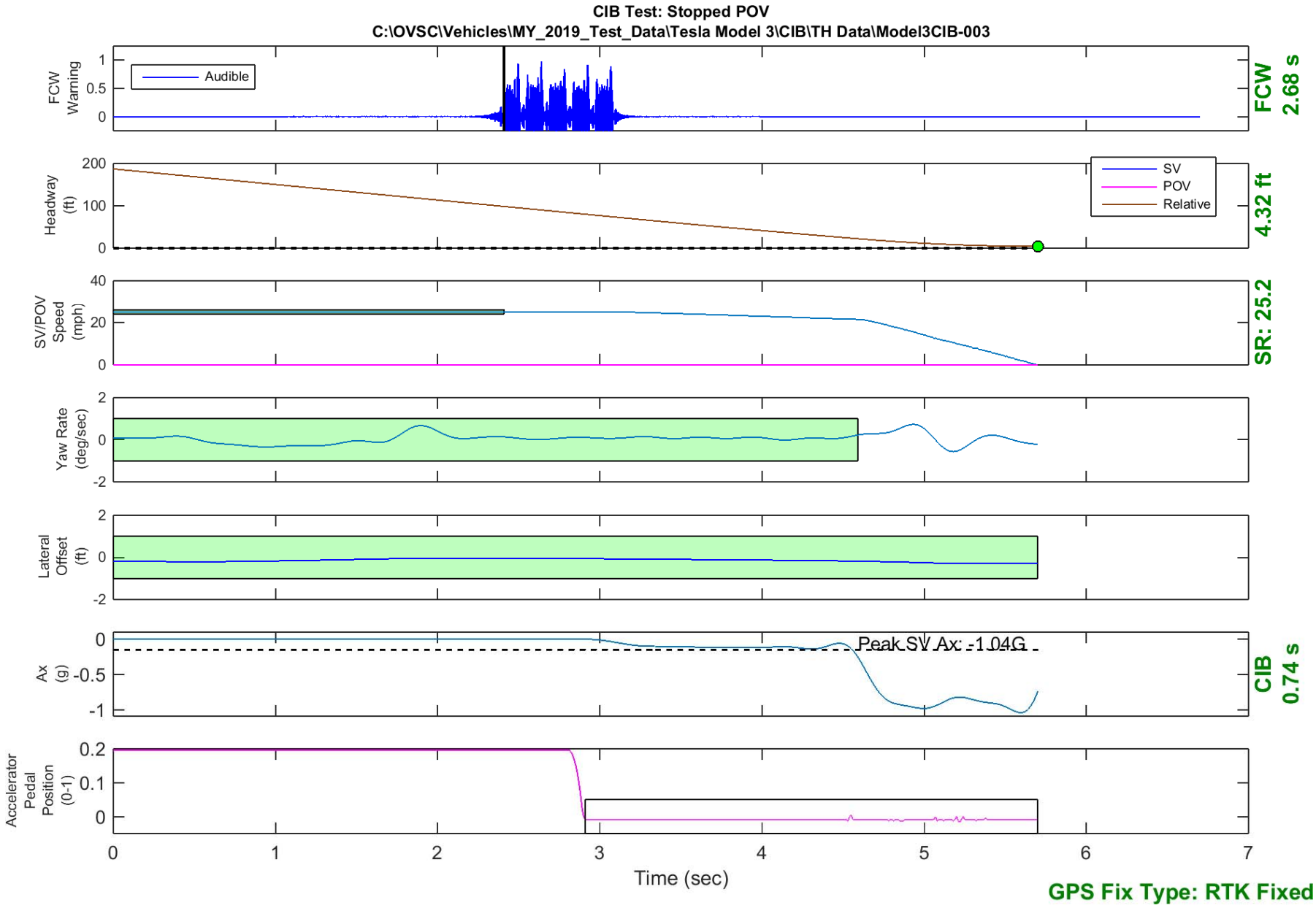


Figure D11. Time History for CIB Run 3, SV Encounters Stopped POV

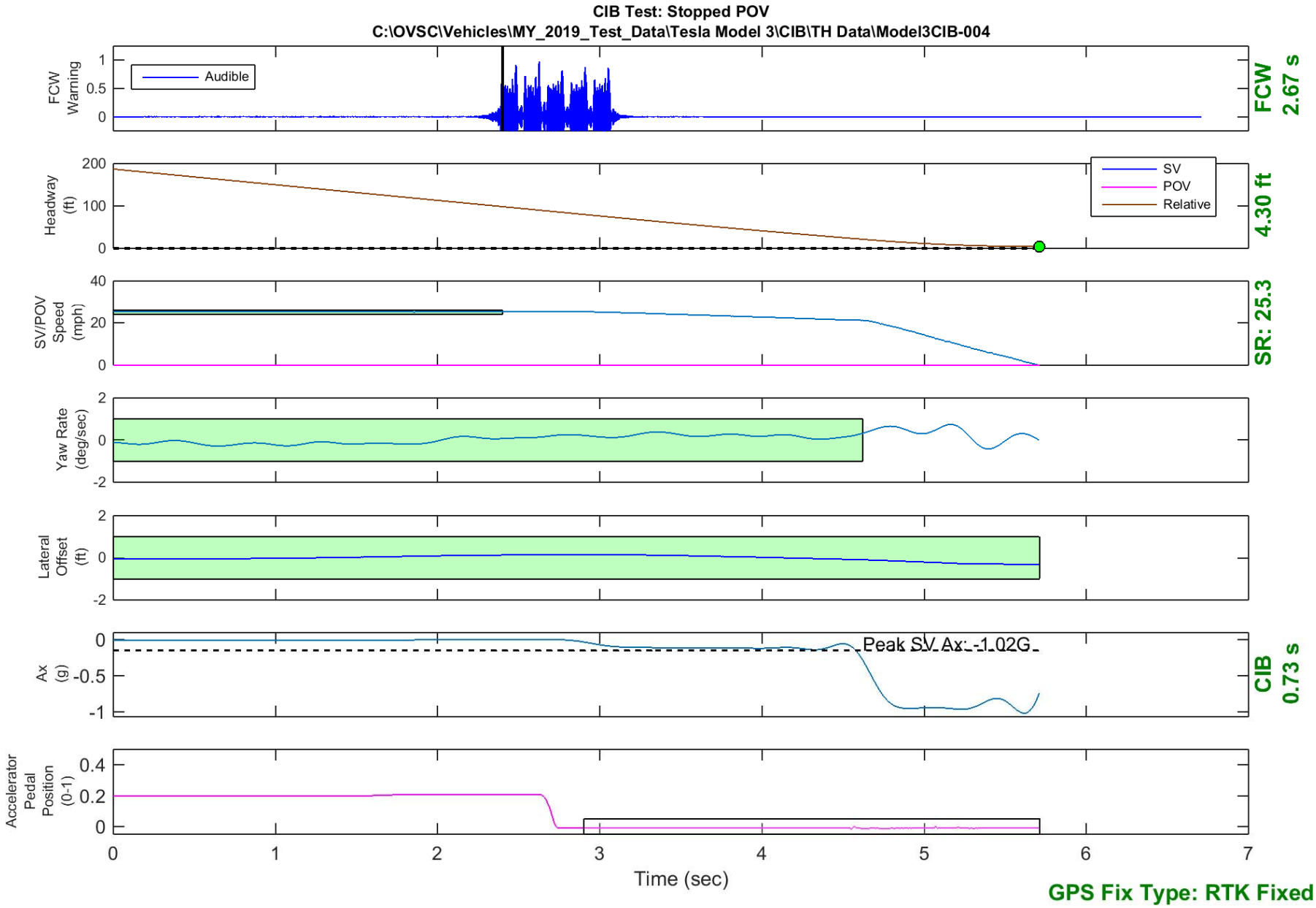


Figure D12. Time History for CIB Run 4, SV Encounters Stopped POV

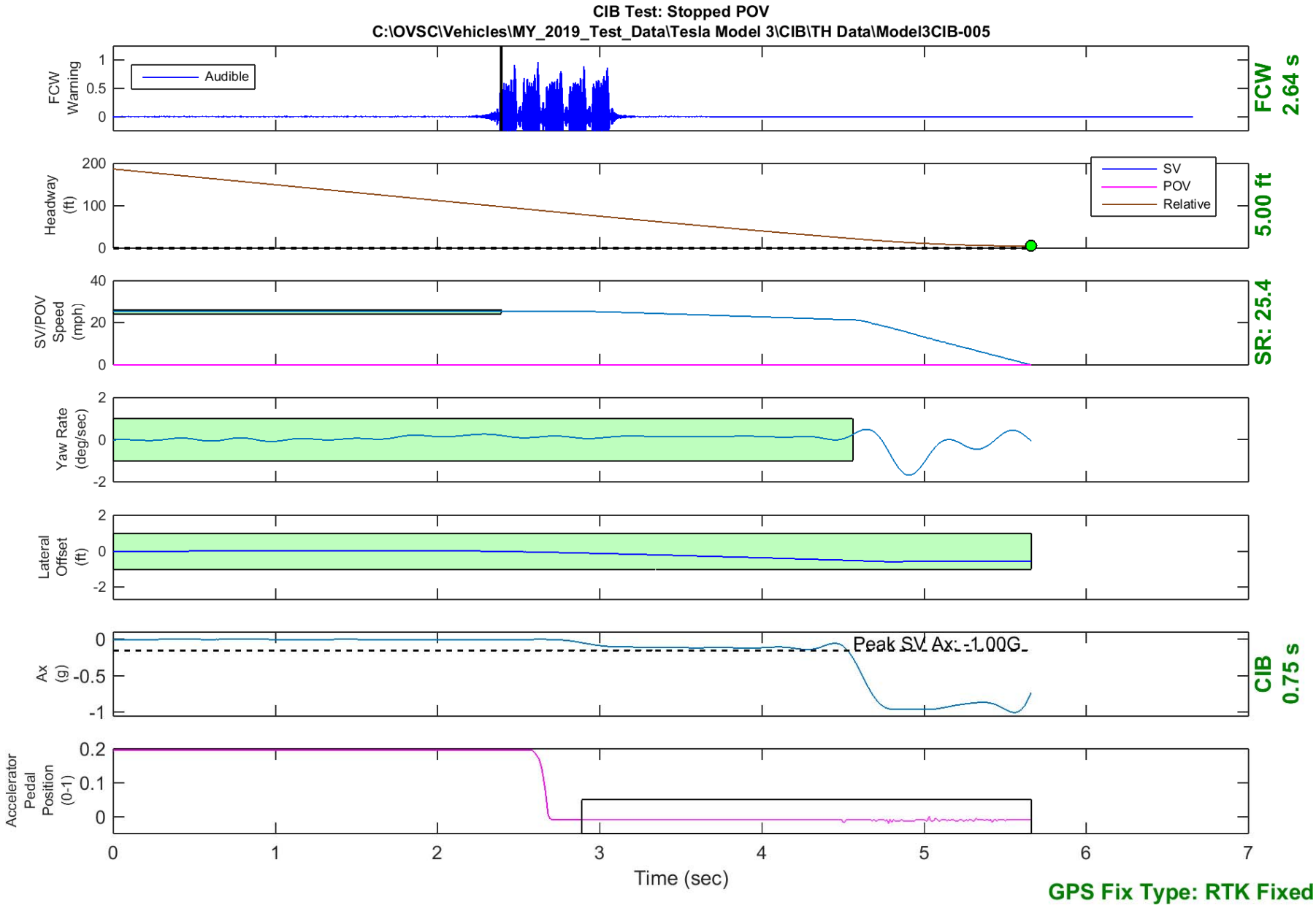


Figure D13. Time History for CIB Run 5, SV Encounters Stopped POV

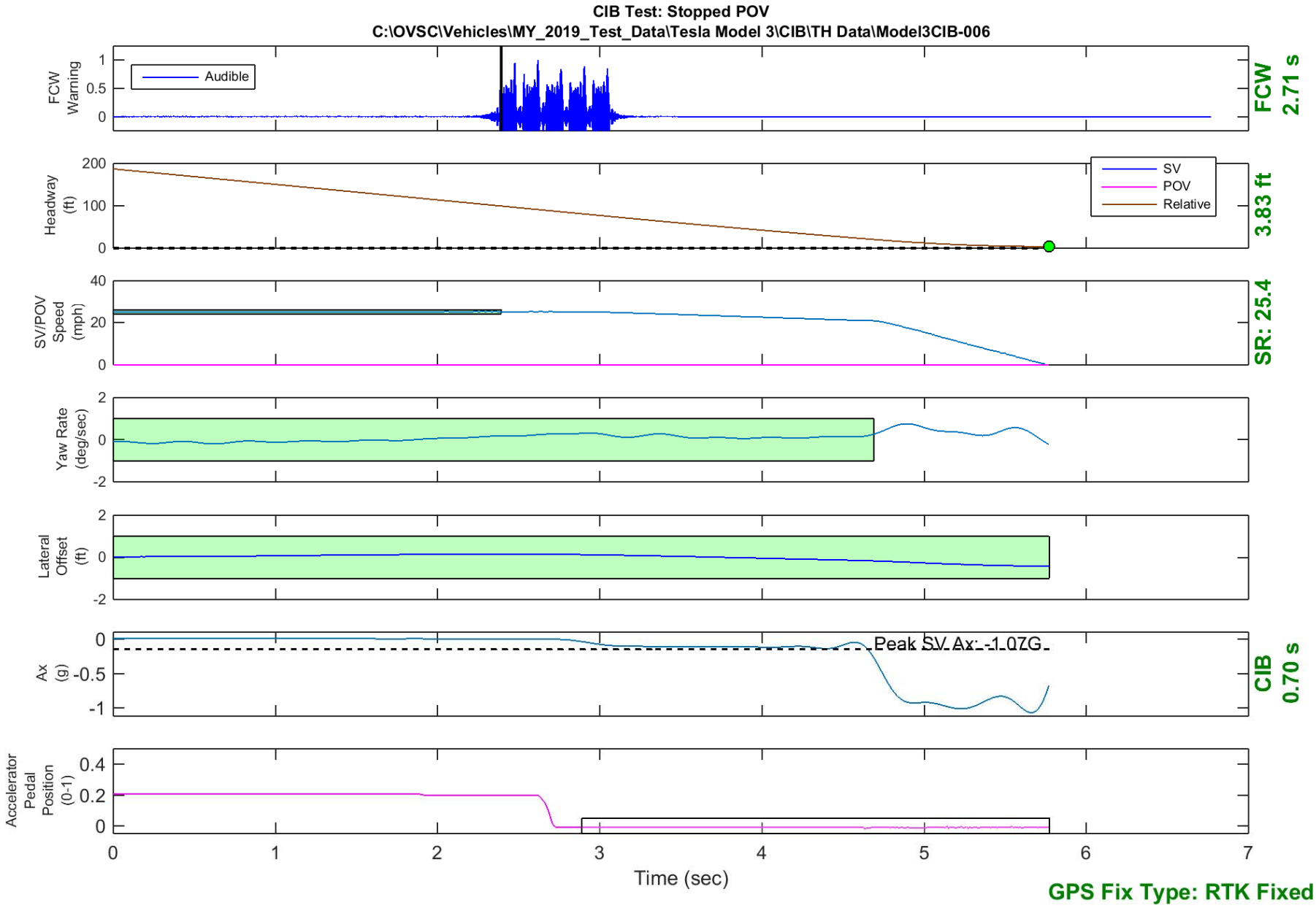


Figure D14. Time History for CIB Run 6, SV Encounters Stopped POV

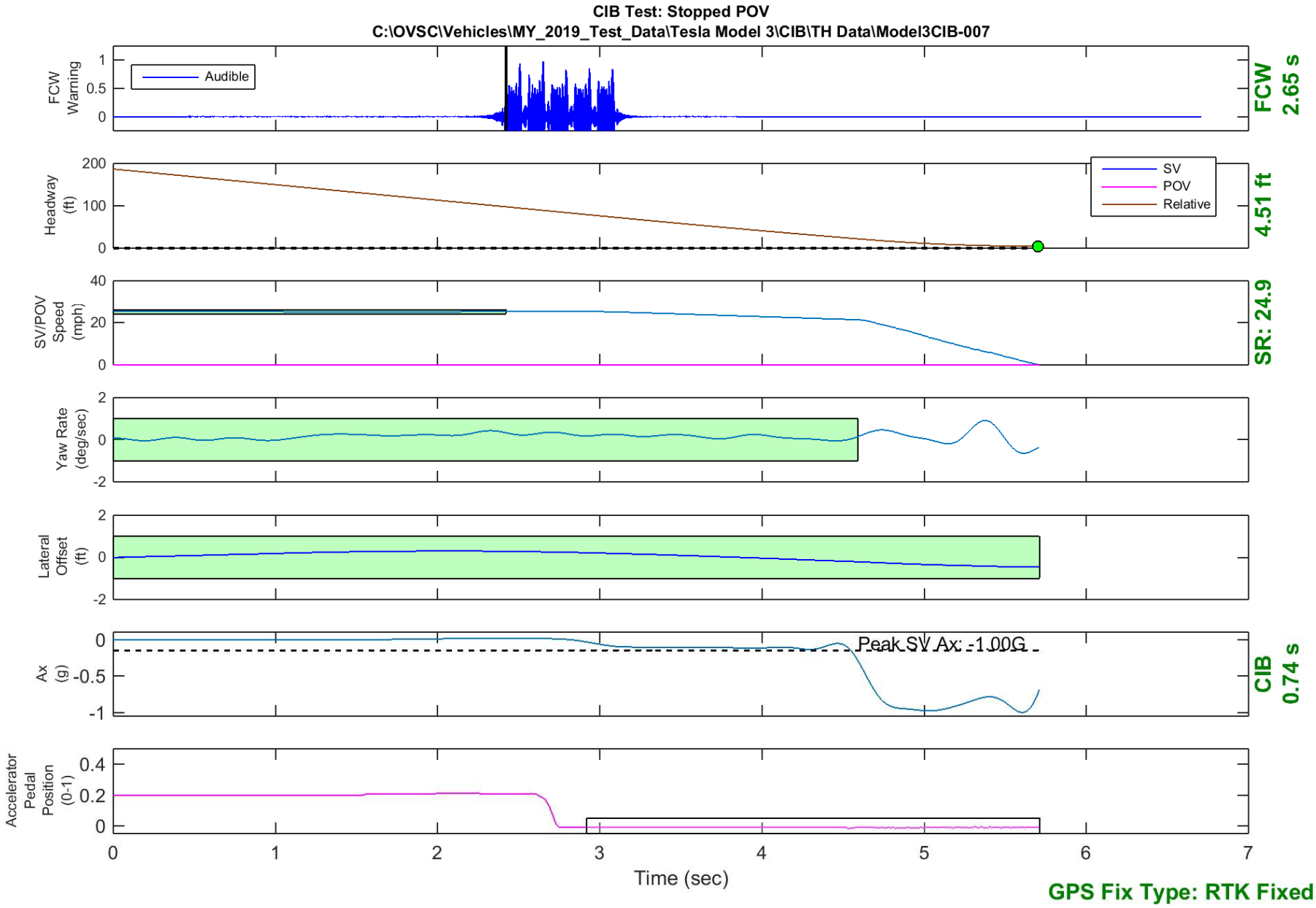


Figure D15. Time History for CIB Run 7, SV Encounters Stopped POV

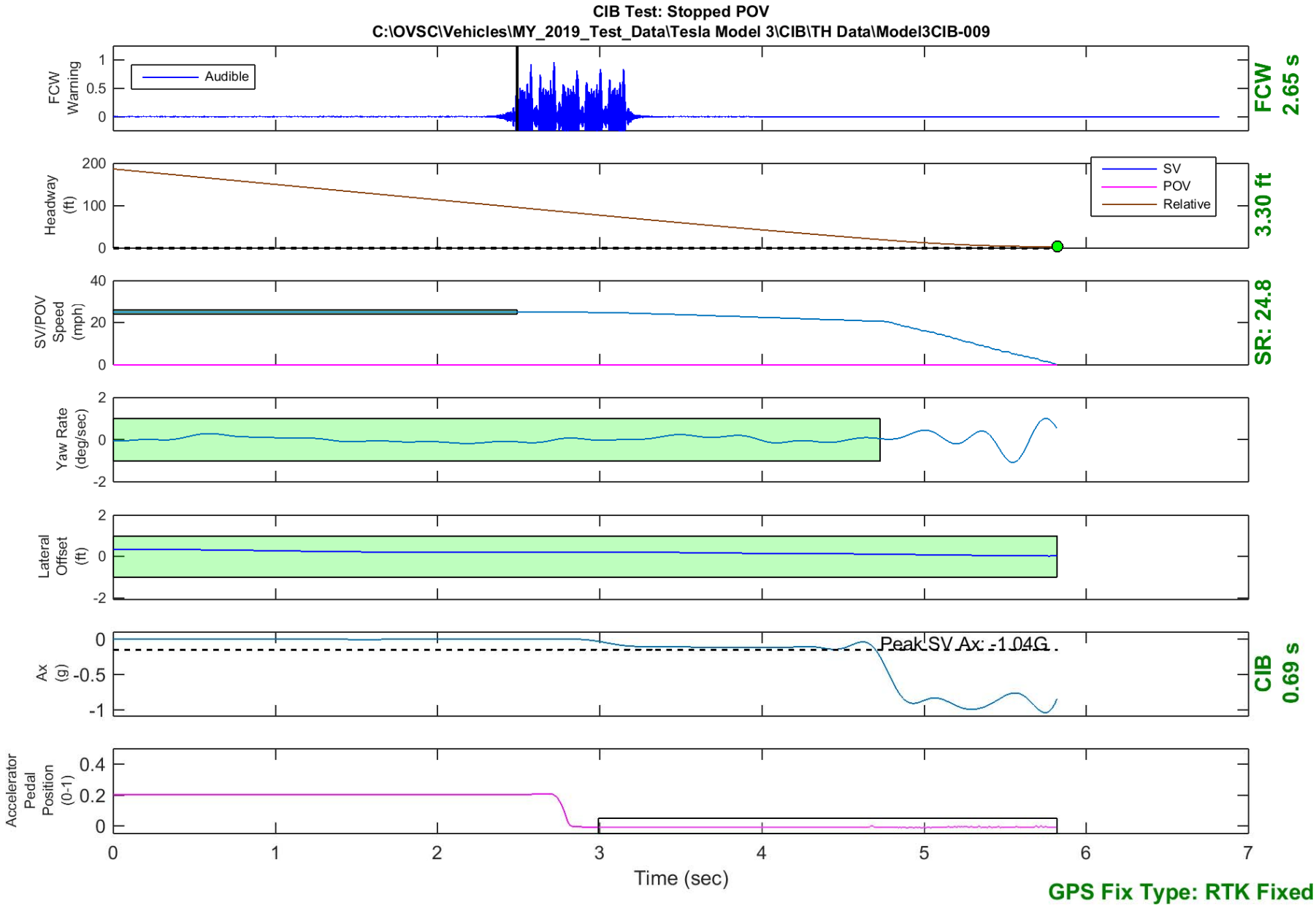


Figure D16. Time History for CIB Run 9, SV Encounters Stopped POV

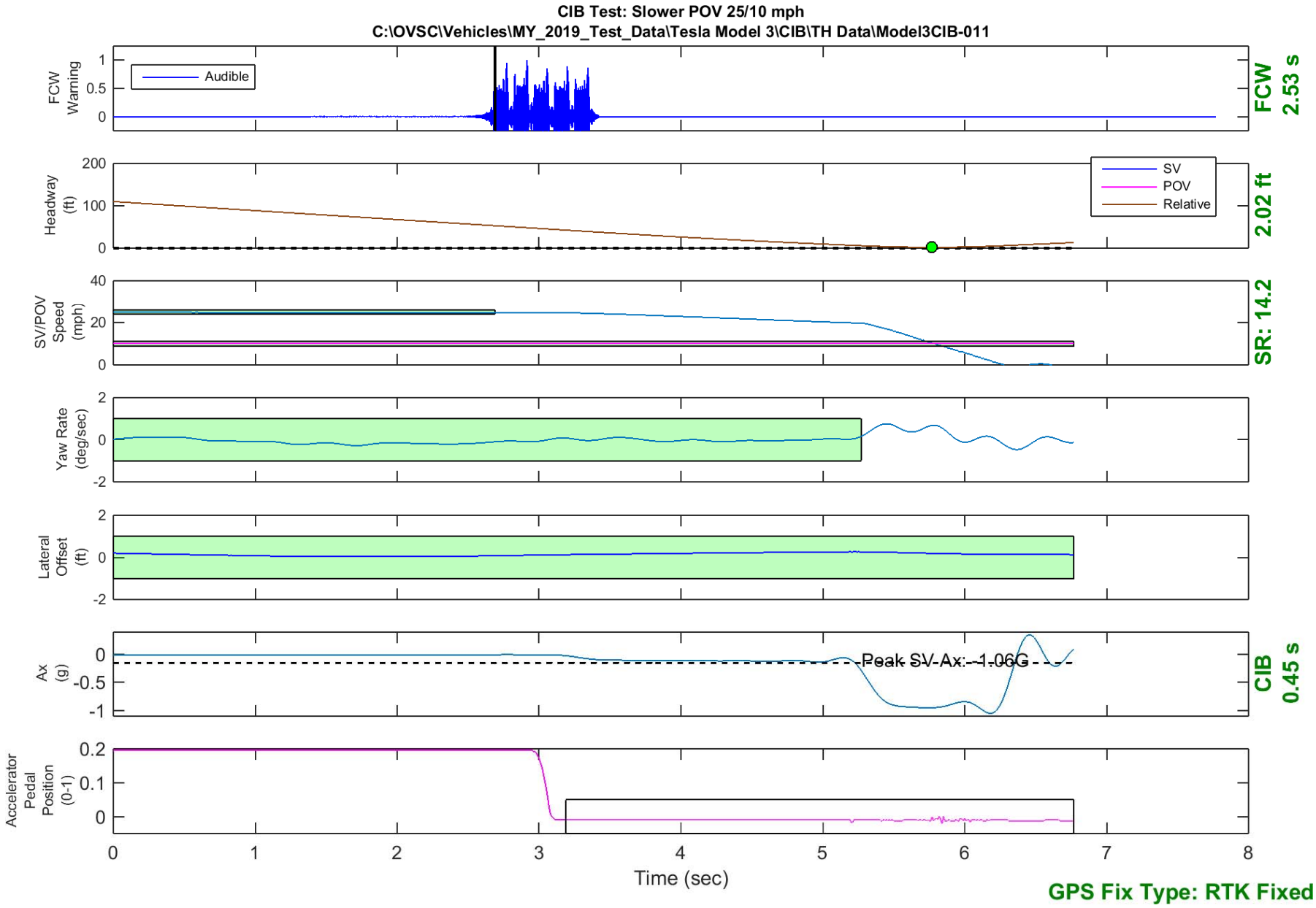


Figure D17. Time History for CIB Run 11, SV Encounters Slower POV, SV 25 mph, POV 10 mph

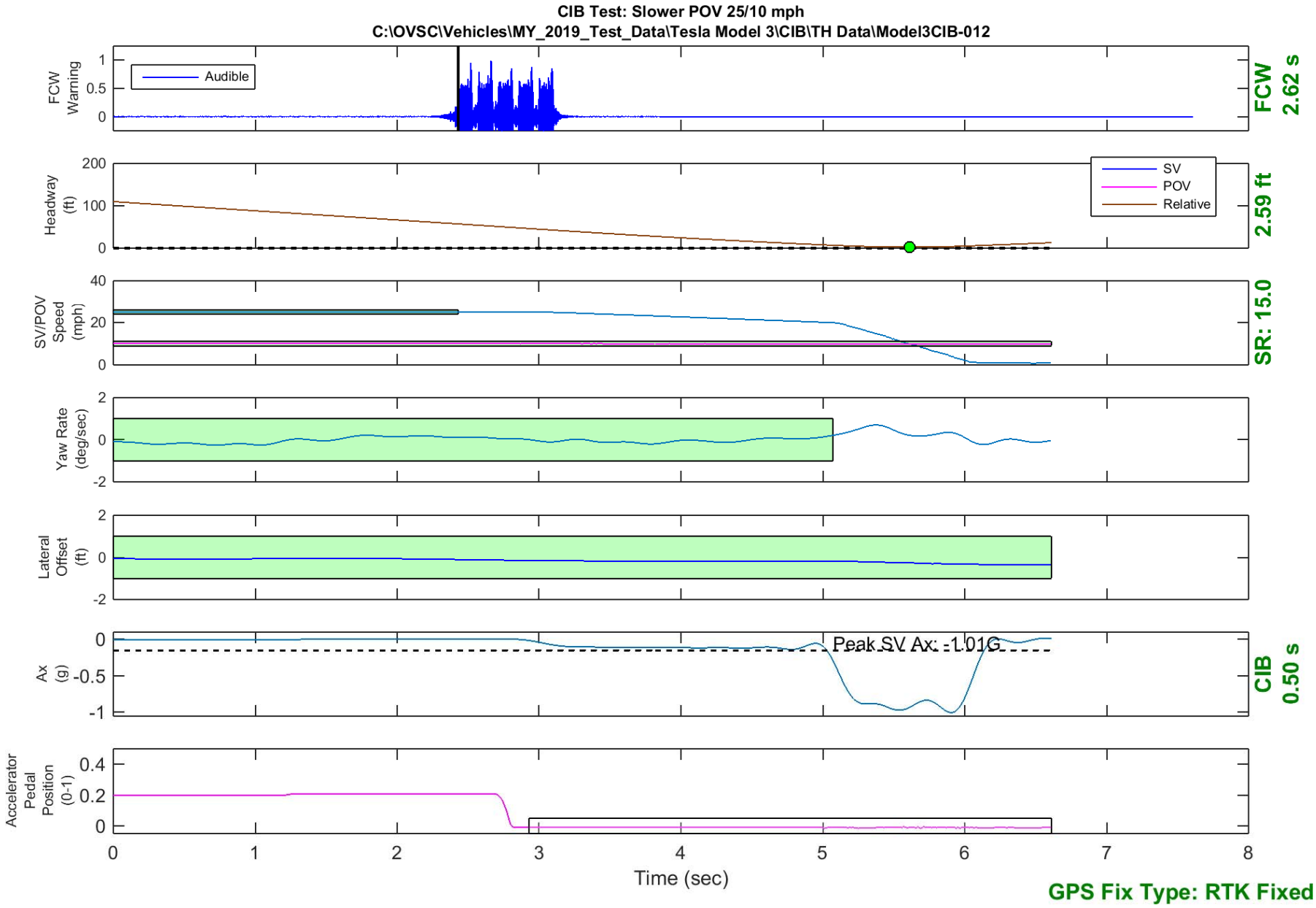


Figure D18. Time History for CIB Run 12, SV Encounters Slower POV, SV 25 mph, POV 10 mph

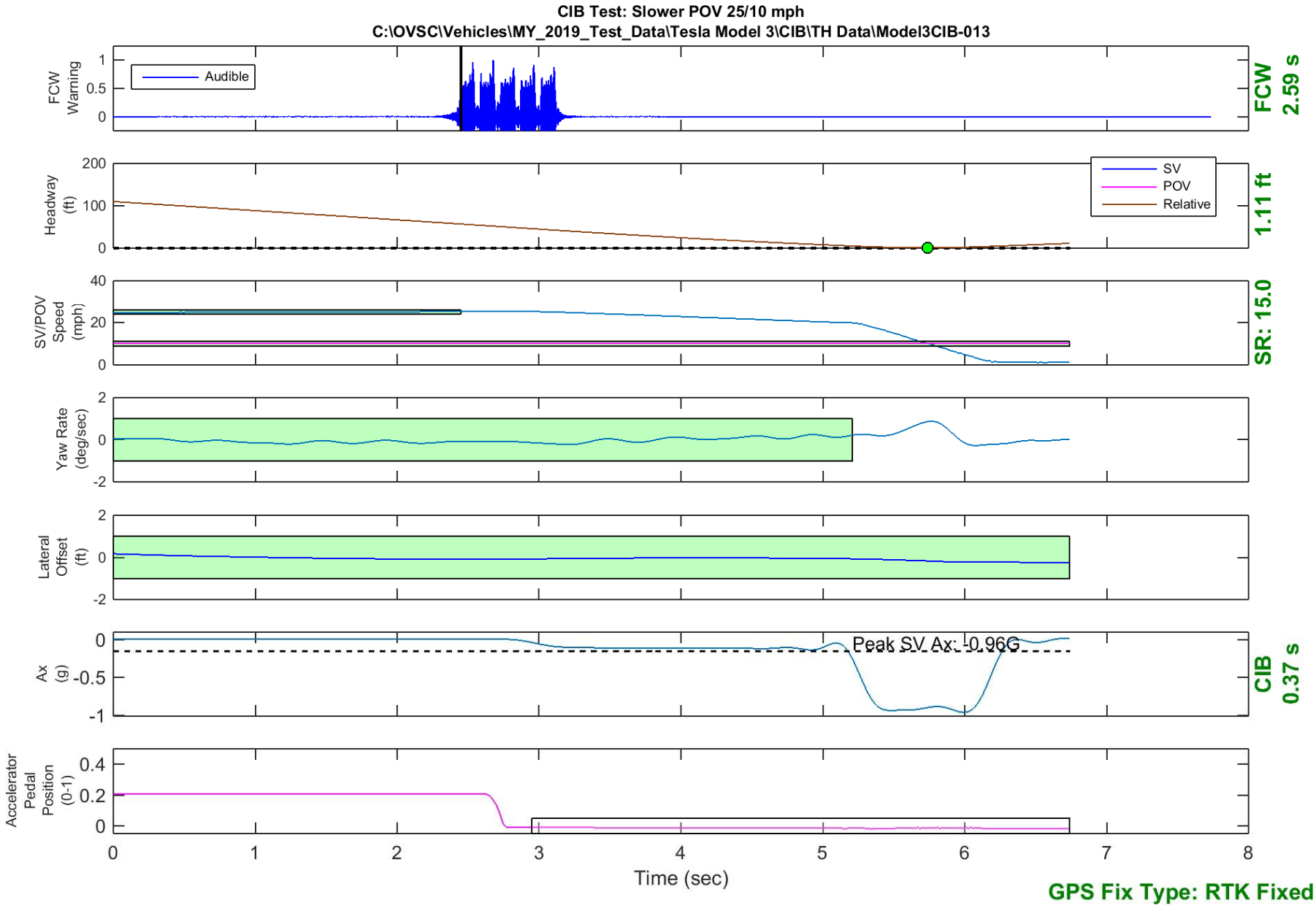


Figure D19. Time History for CIB Run 13, SV Encounters Slower POV, SV 25 mph, POV 10 mph

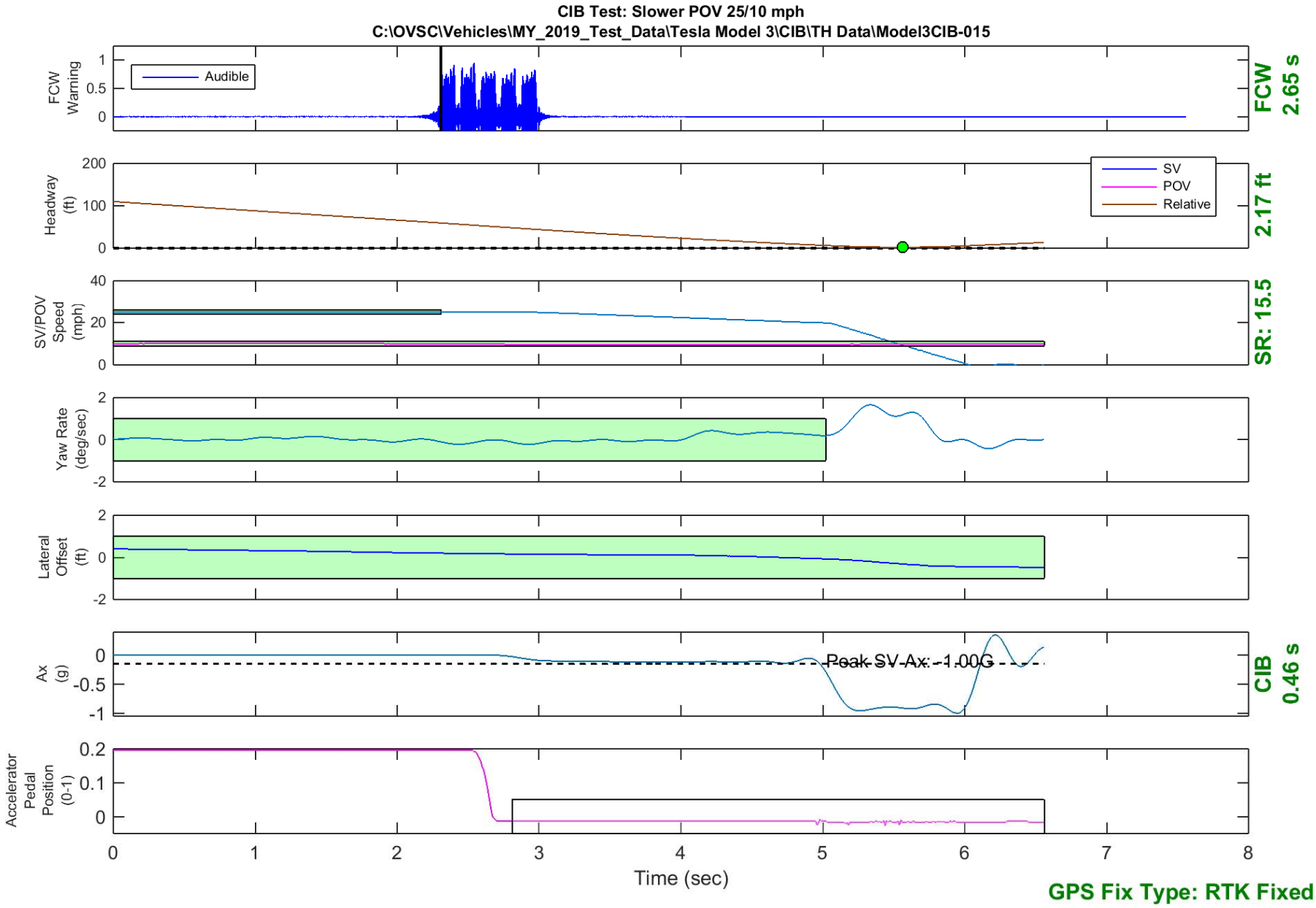


Figure D20. Time History for CIB Run 15, SV Encounters Slower POV, SV 25 mph, POV 10 mph

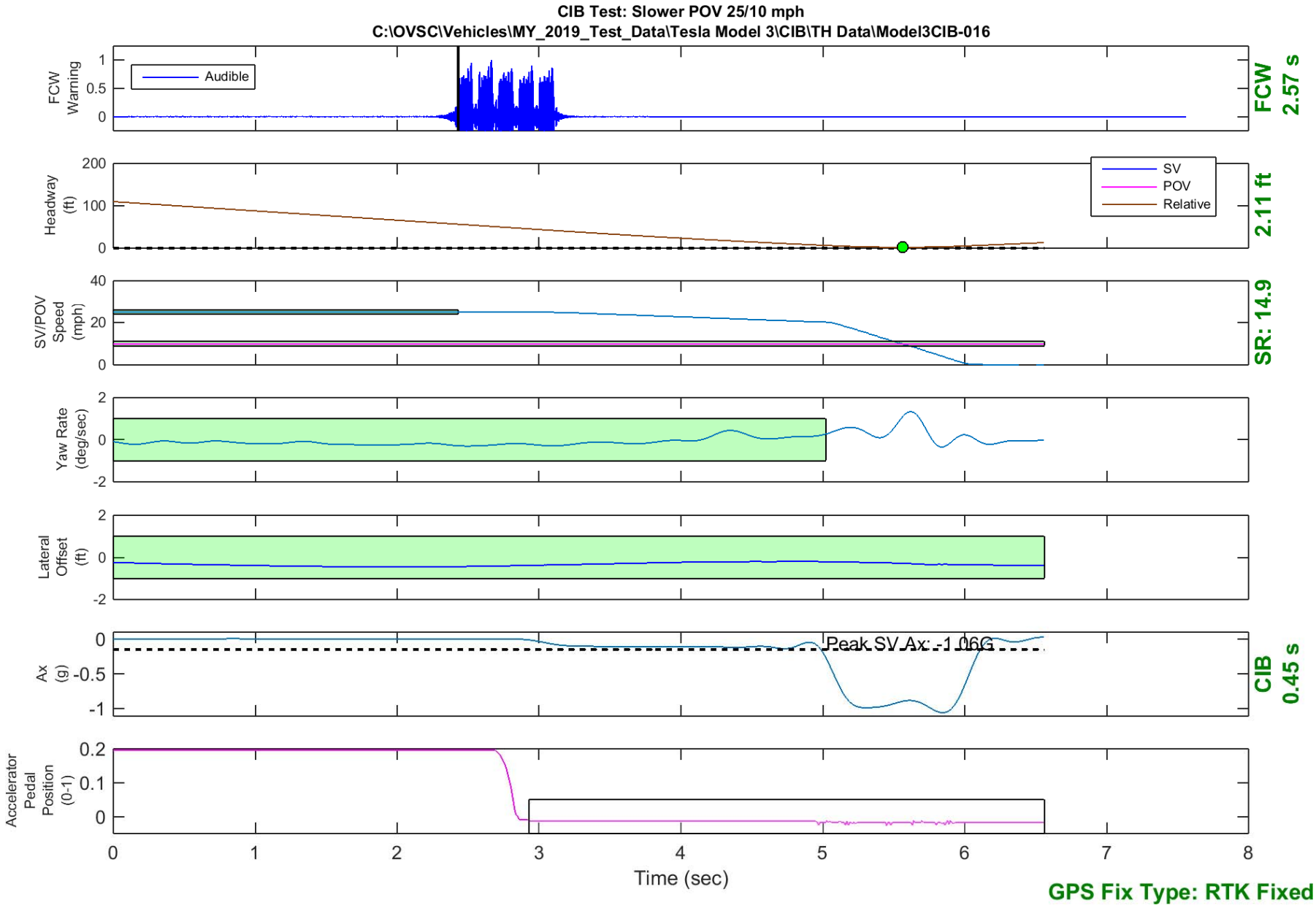


Figure D21. Time History for CIB Run 16, SV Encounters Slower POV, SV 25 mph, POV 10 mph

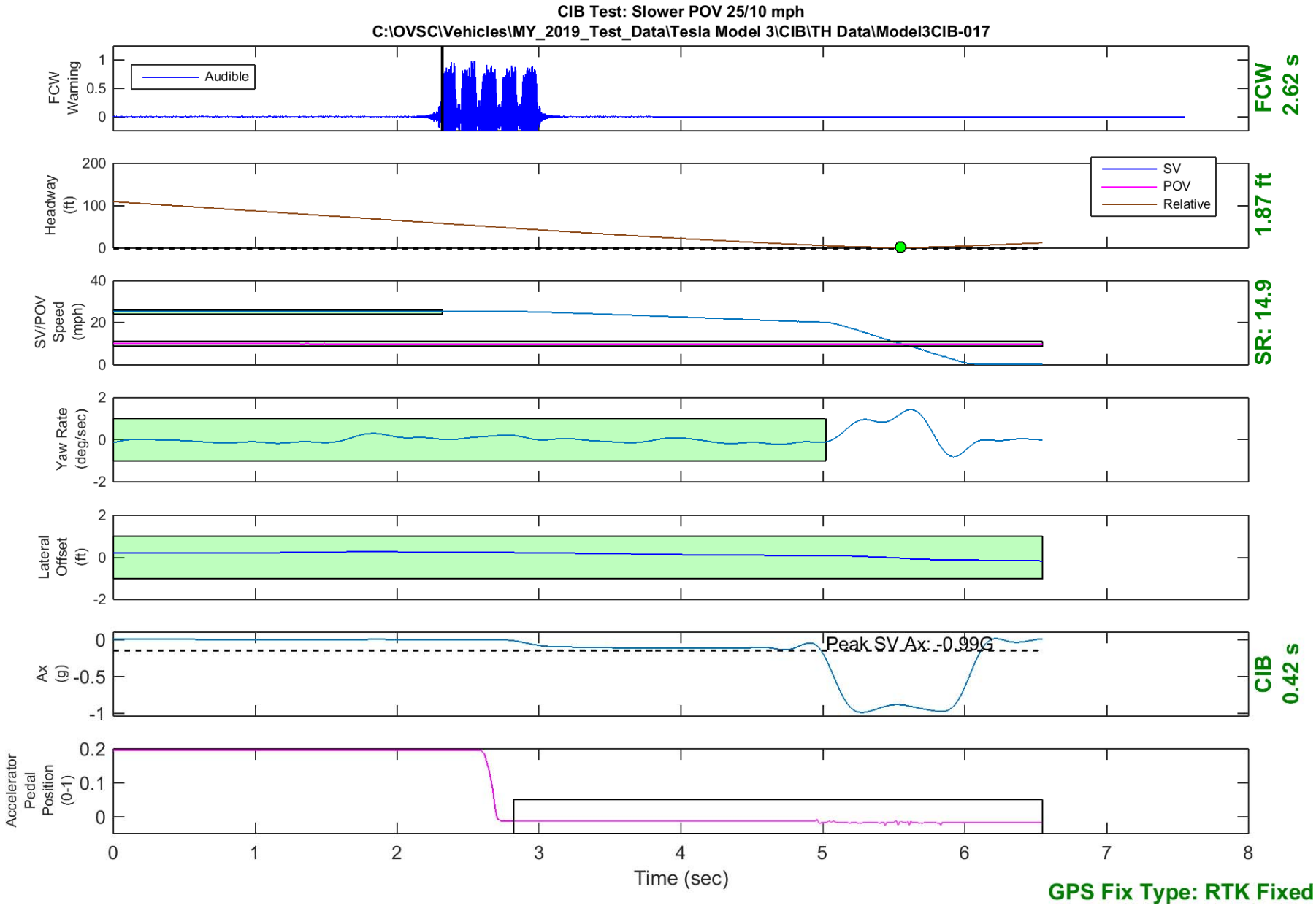


Figure D22. Time History for CIB Run 17, SV Encounters Slower POV, SV 25 mph, POV 10 mph

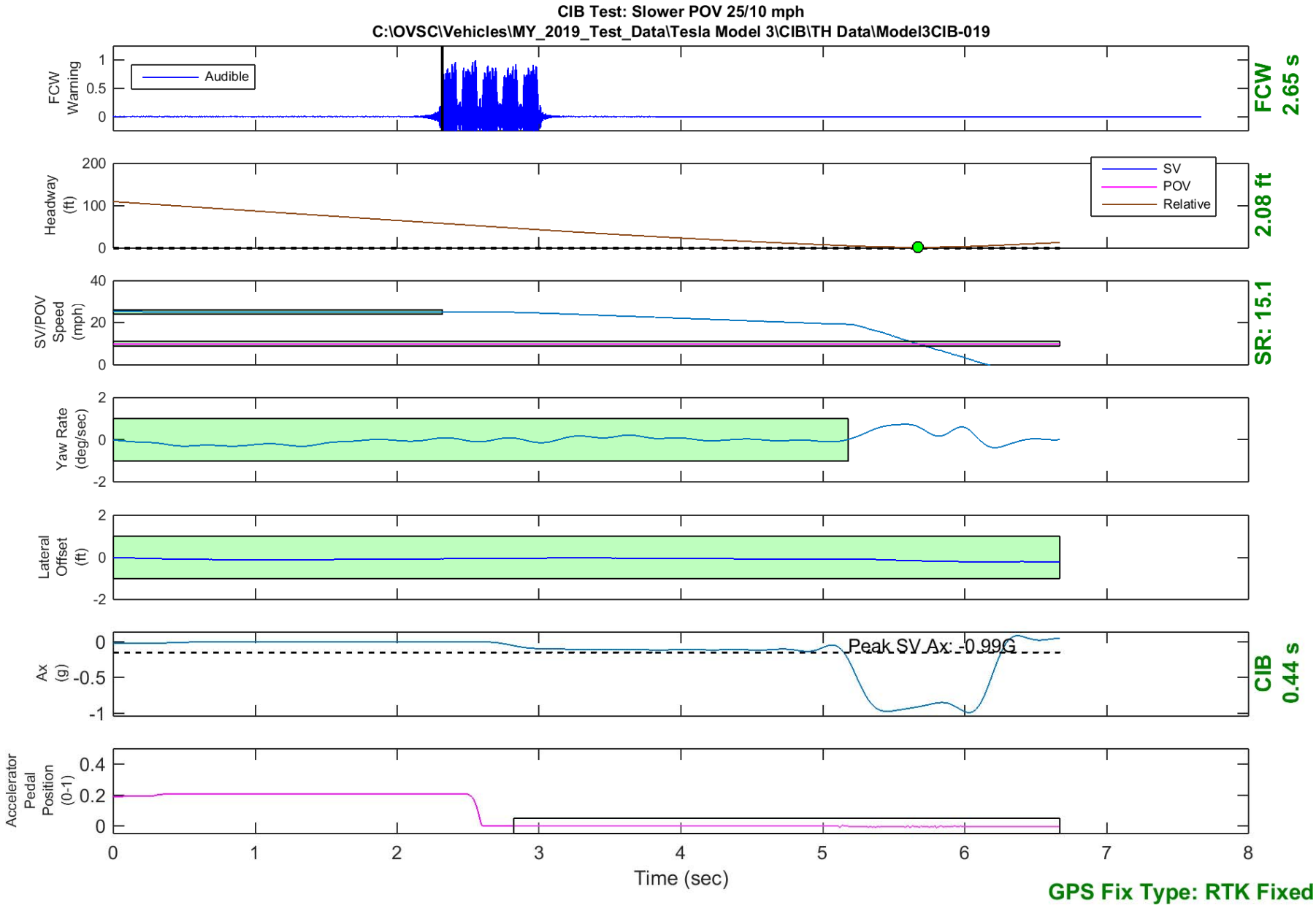


Figure D23. Time History for CIB Run 19, SV Encounters Slower POV, SV 25 mph, POV 10 mph

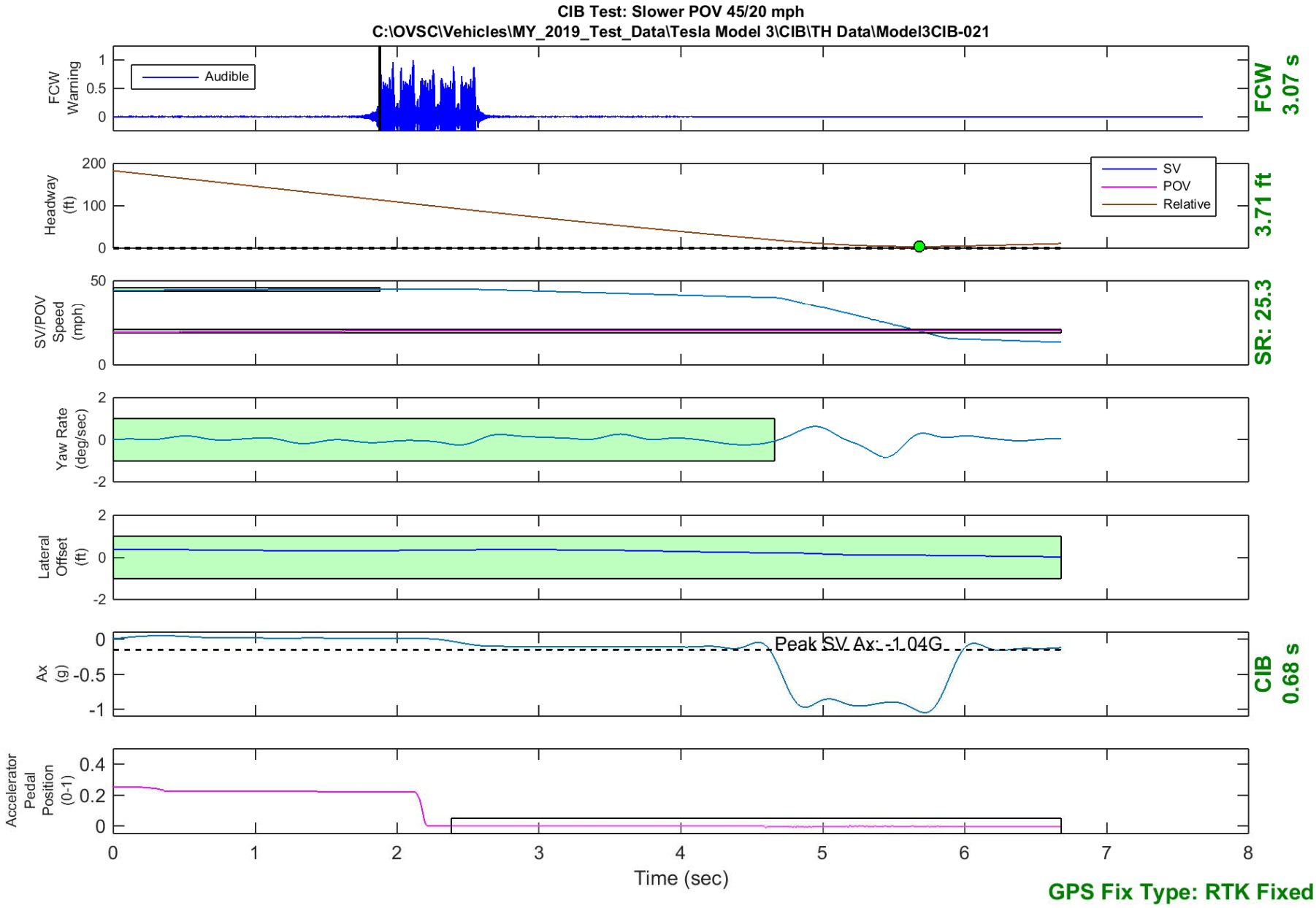


Figure D24. Time History for CIB Run 21, SV Encounters Slower POV, SV 45 mph, POV 20 mph

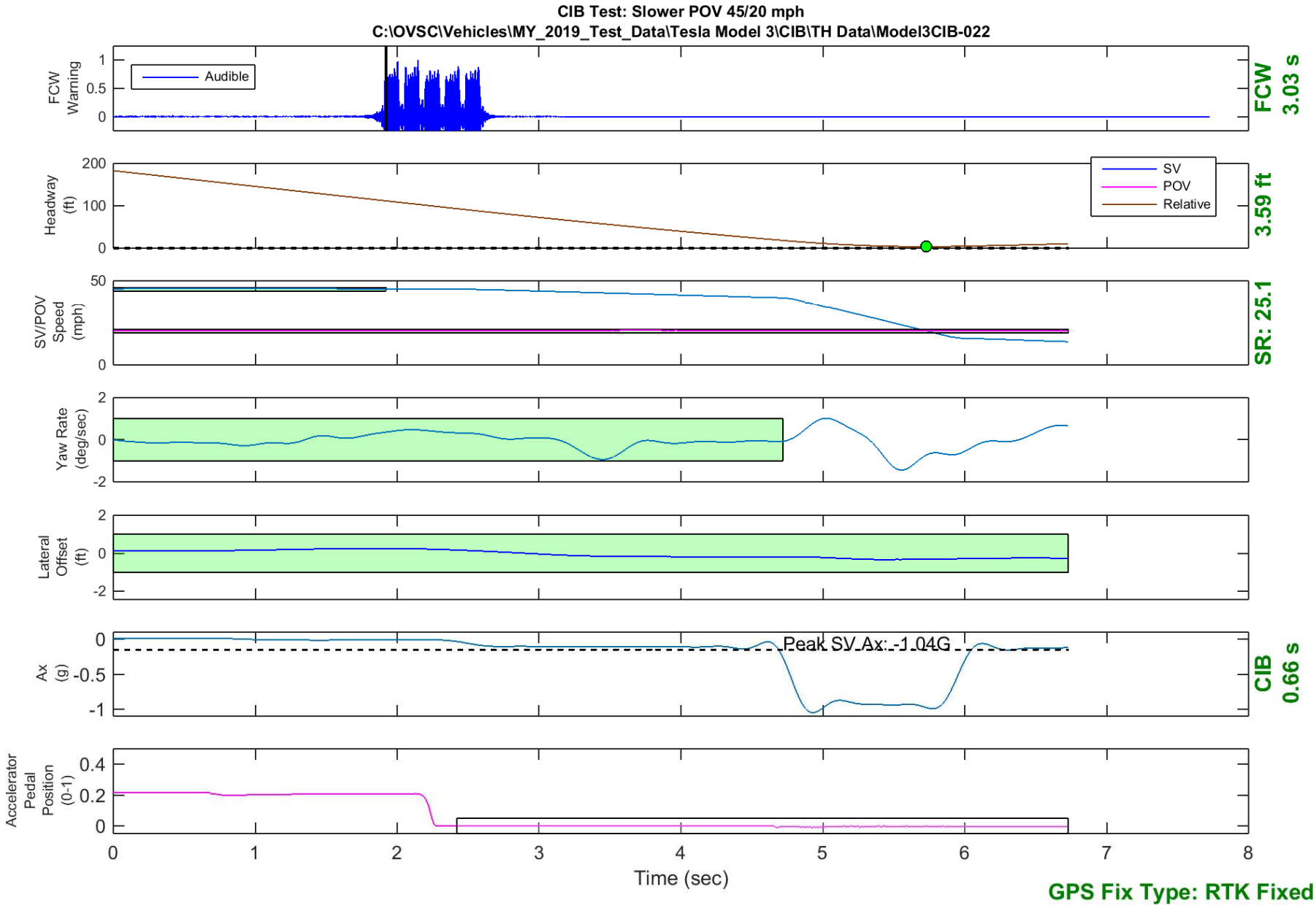


Figure D25. Time History for CIB Run 22, SV Encounters Slower POV, SV 45 mph, POV 20 mph

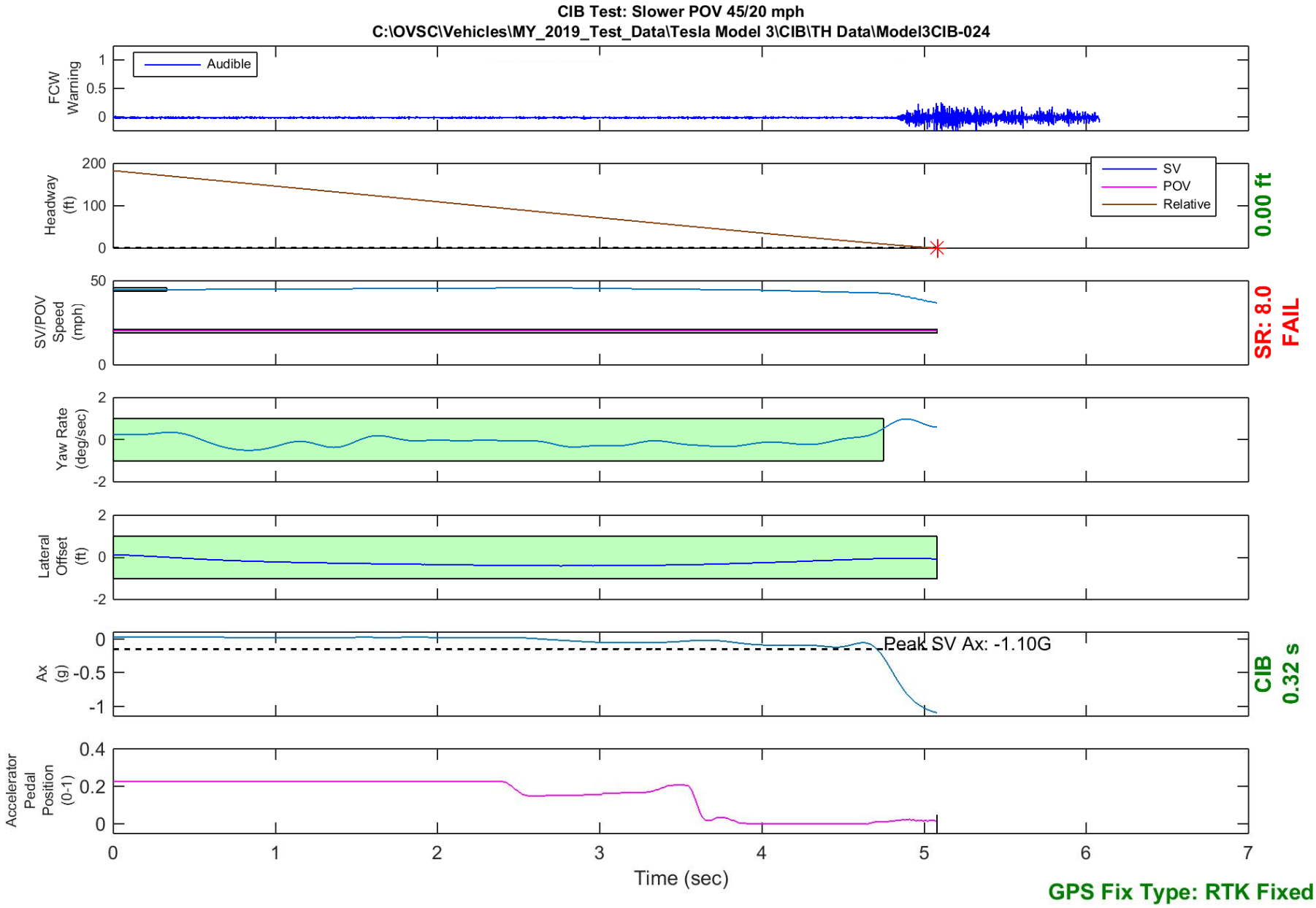


Figure D26. Time History for CIB Run 24, SV Encounters Slower POV, SV 45 mph, POV 20 mph

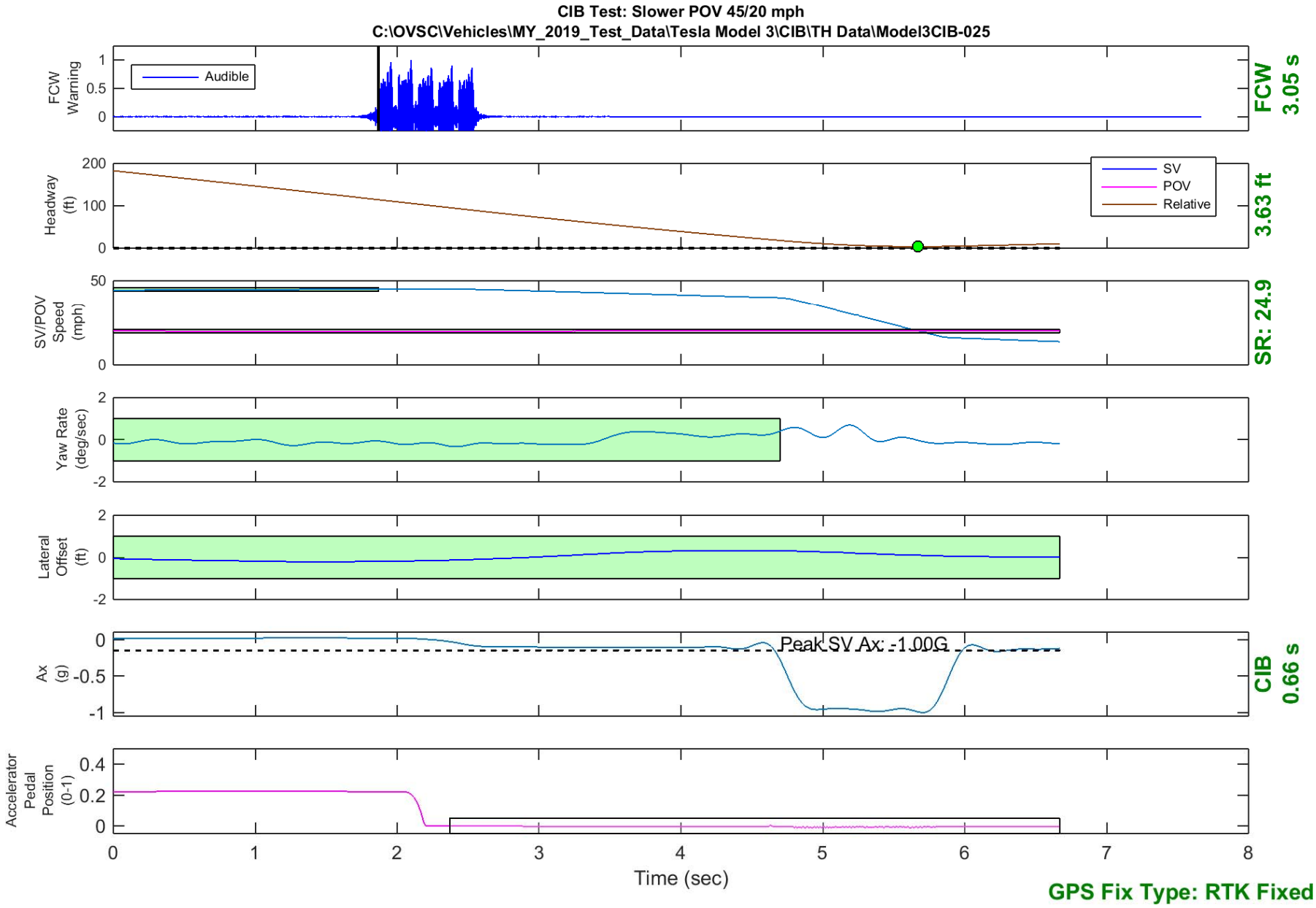


Figure D27. Time History for CIB Run 25, SV Encounters Slower POV, SV 45 mph, POV 20 mph

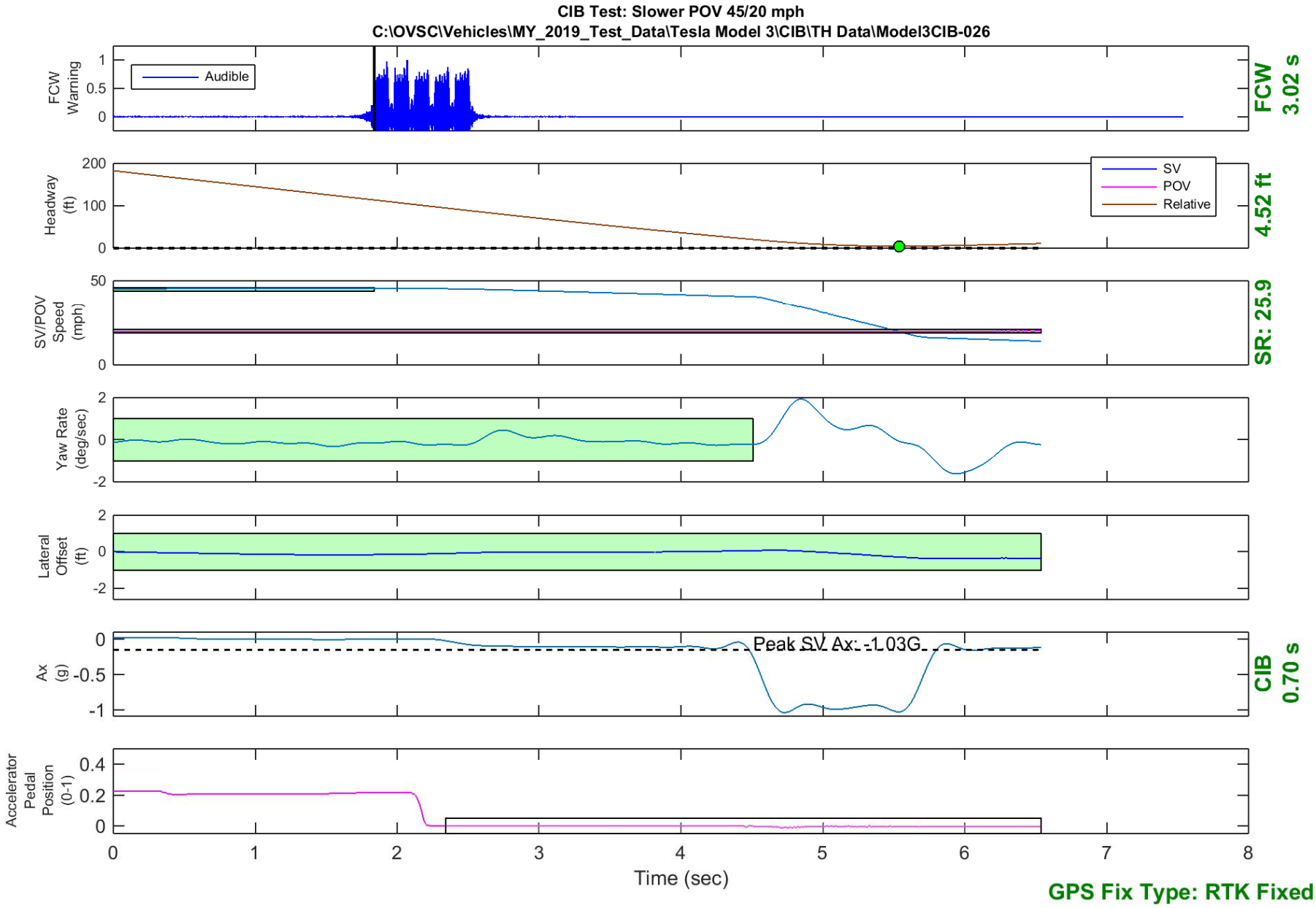


Figure D28. Time History for CIB Run 26, SV Encounters Slower POV, SV 45 mph, POV 20 mph

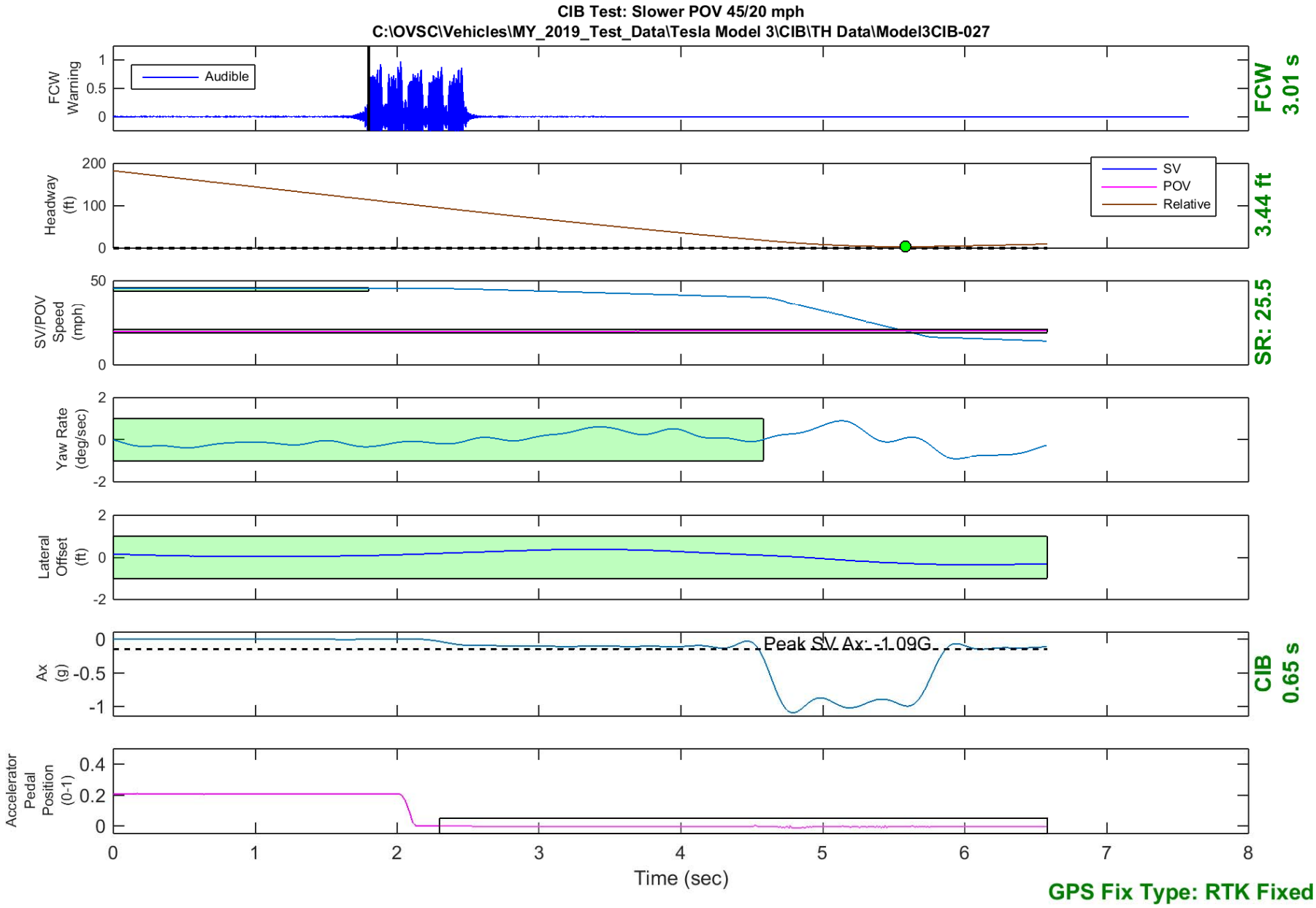


Figure D29. Time History for CIB Run 27, SV Encounters Slower POV, SV 45 mph, POV 20 mph

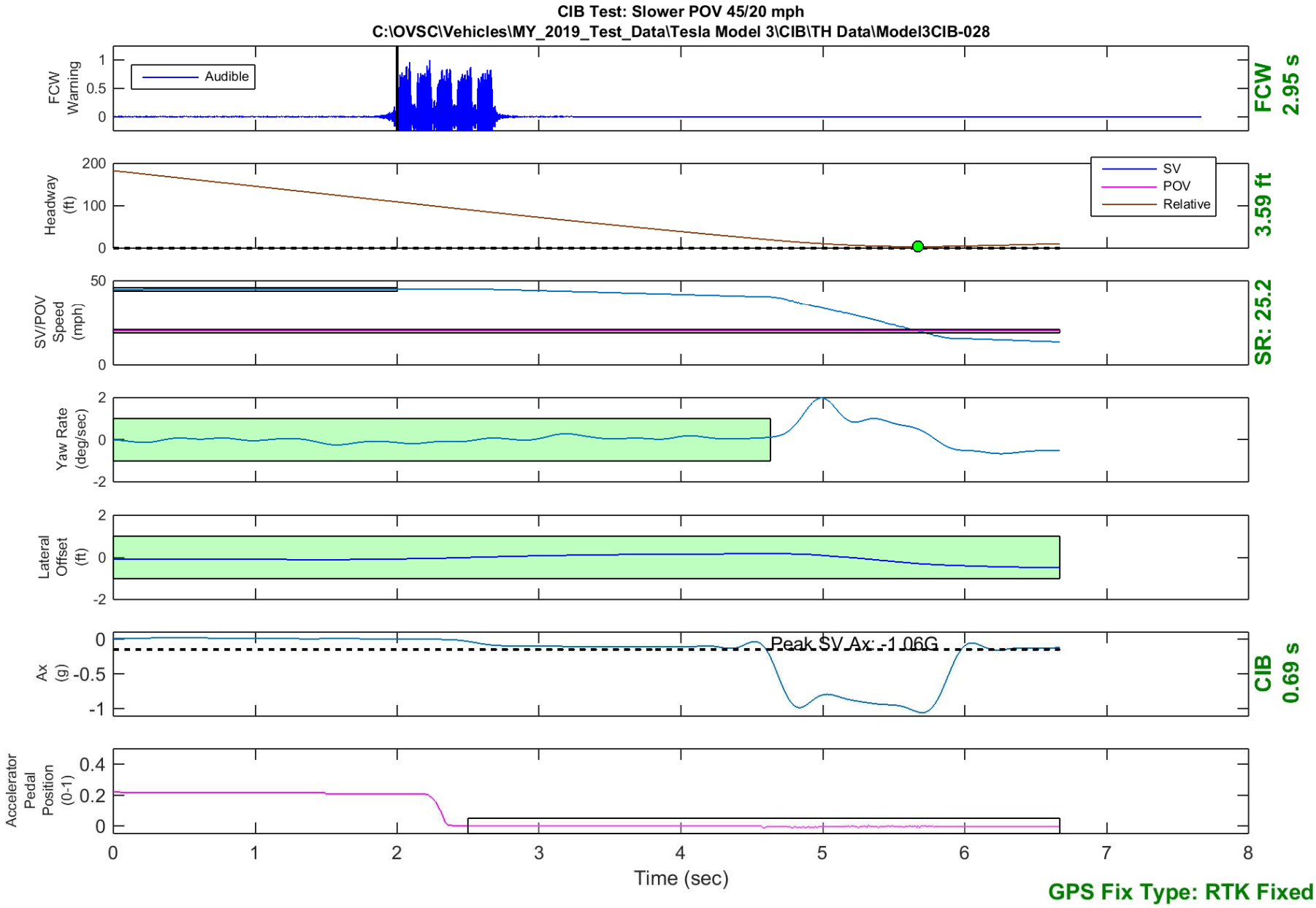


Figure D30. Time History for CIB Run 28, SV Encounters Slower POV, SV 45 mph, POV 20 mph

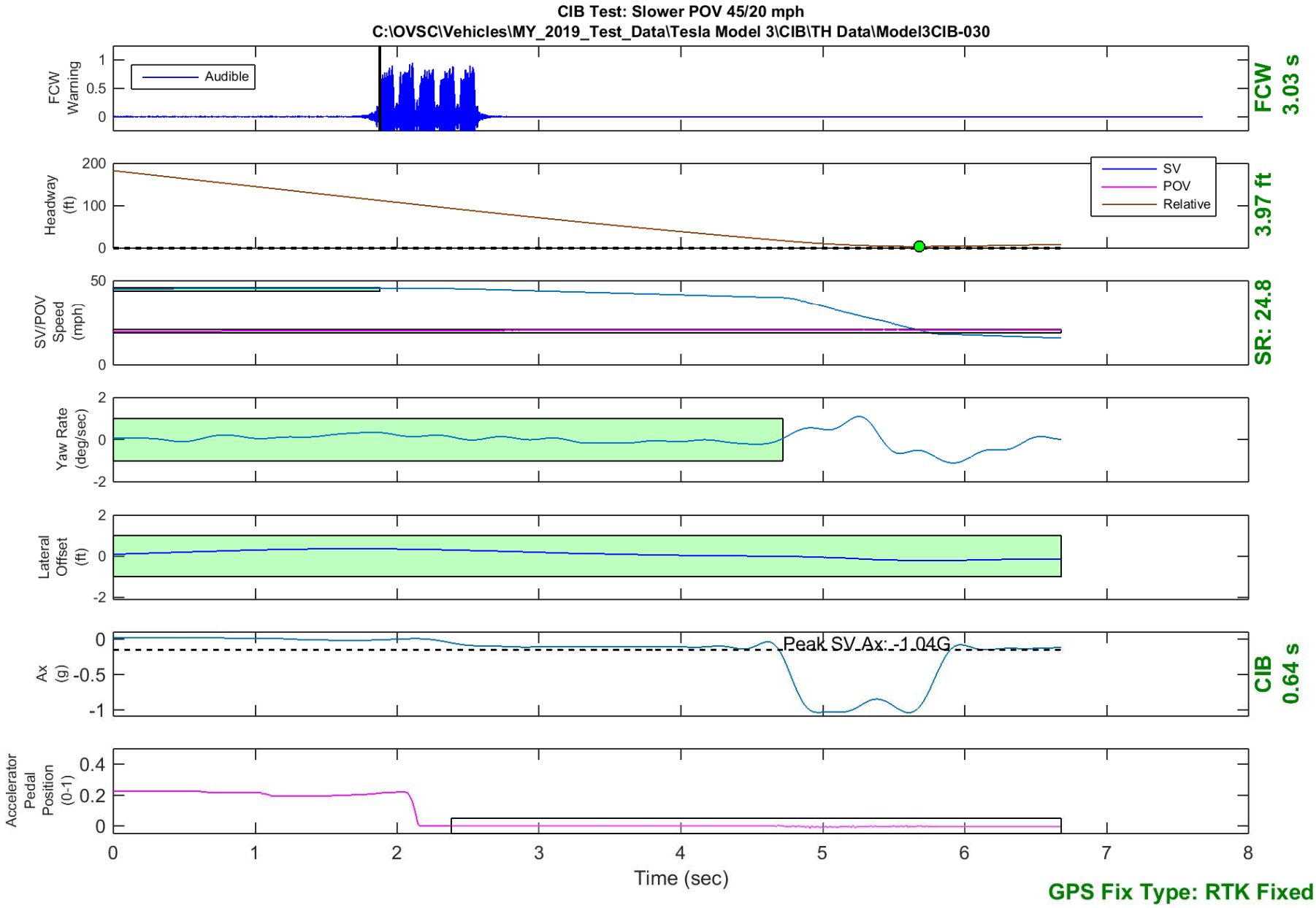


Figure D31. Time History for CIB Run 30, SV Encounters Slower POV, SV 45 mph, POV 20 mph

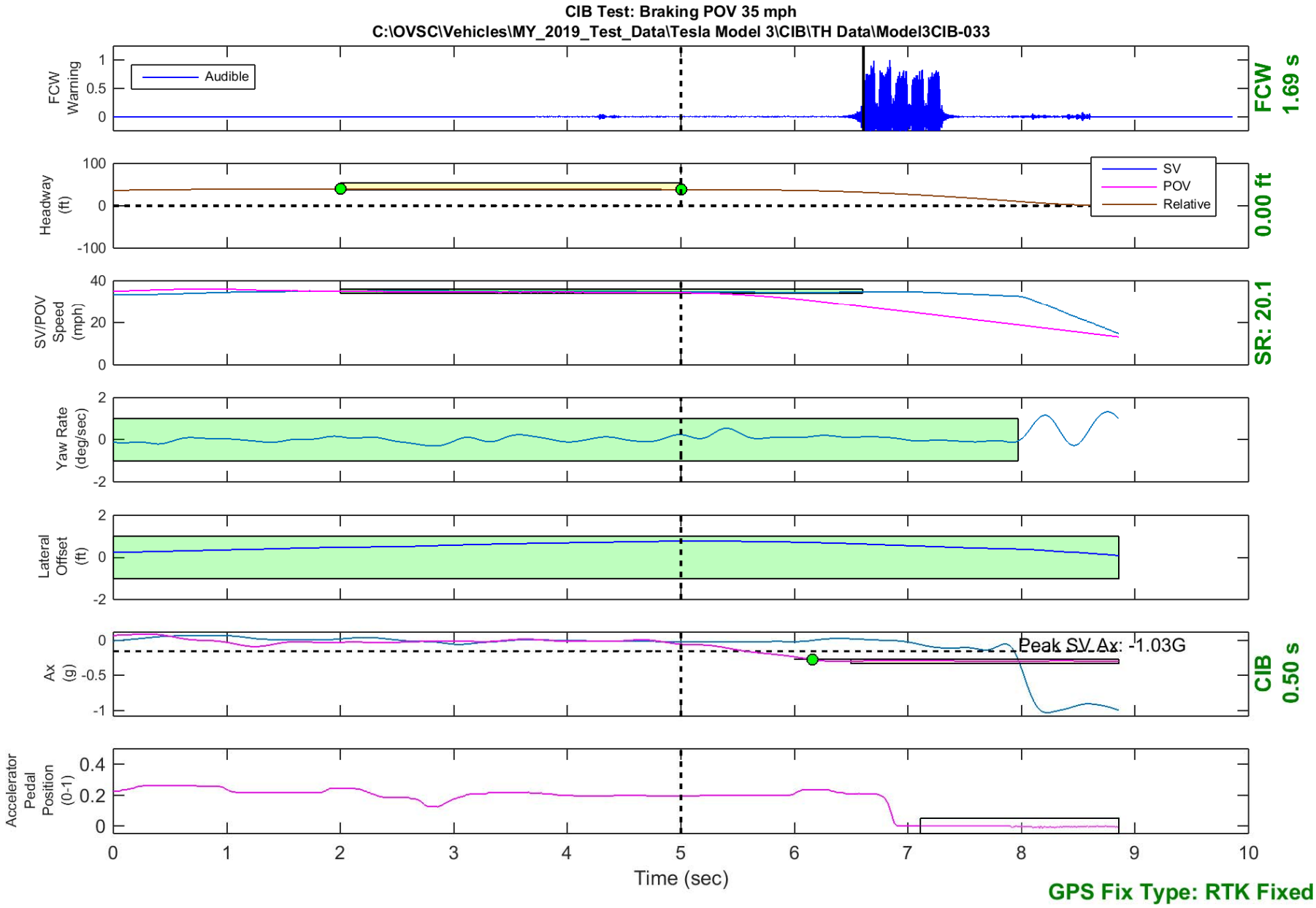


Figure D32. Time History for CIB Run 33, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

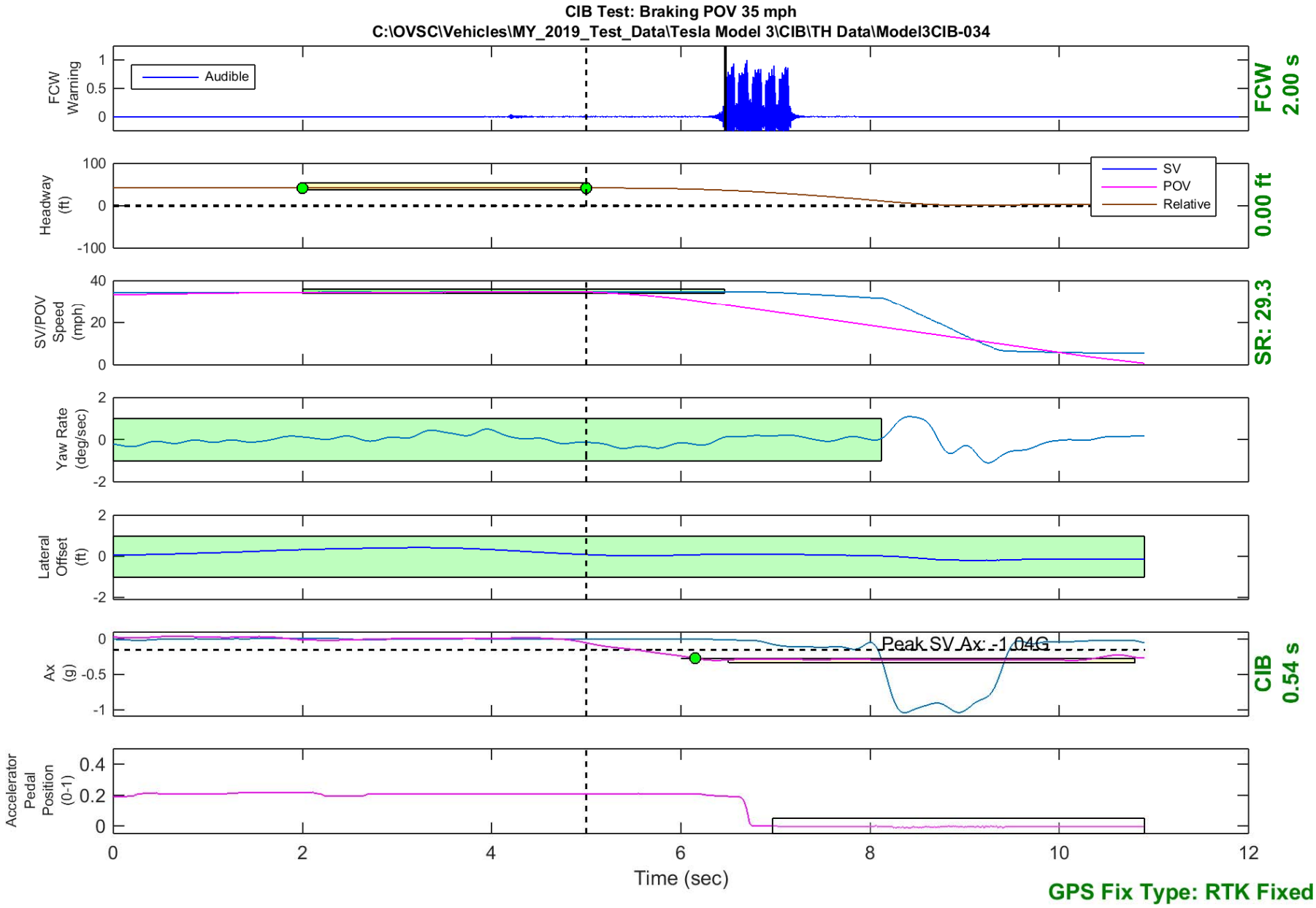


Figure D33. Time History for CIB Run 34, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

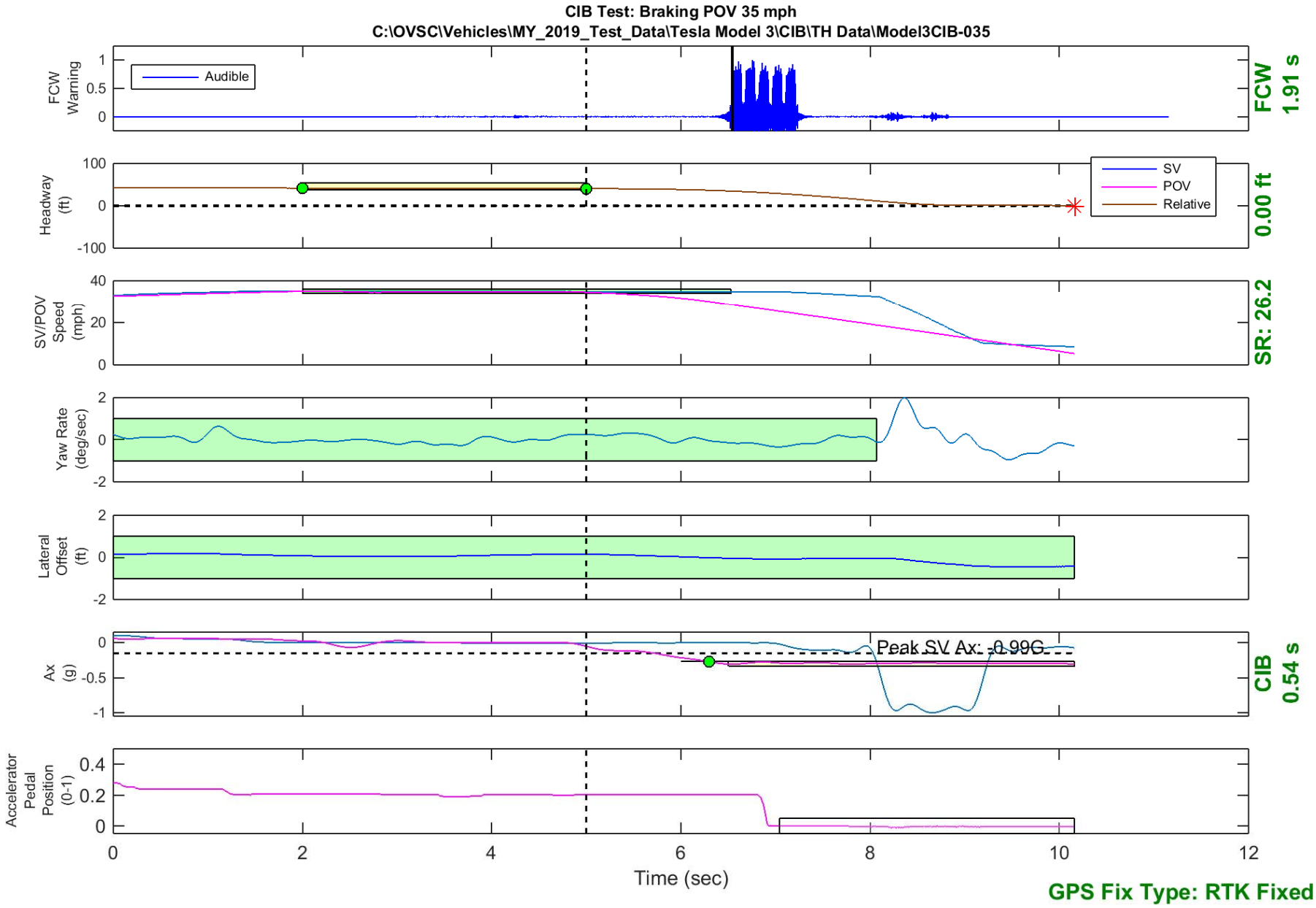


Figure D34. Time History for CIB Run 35, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

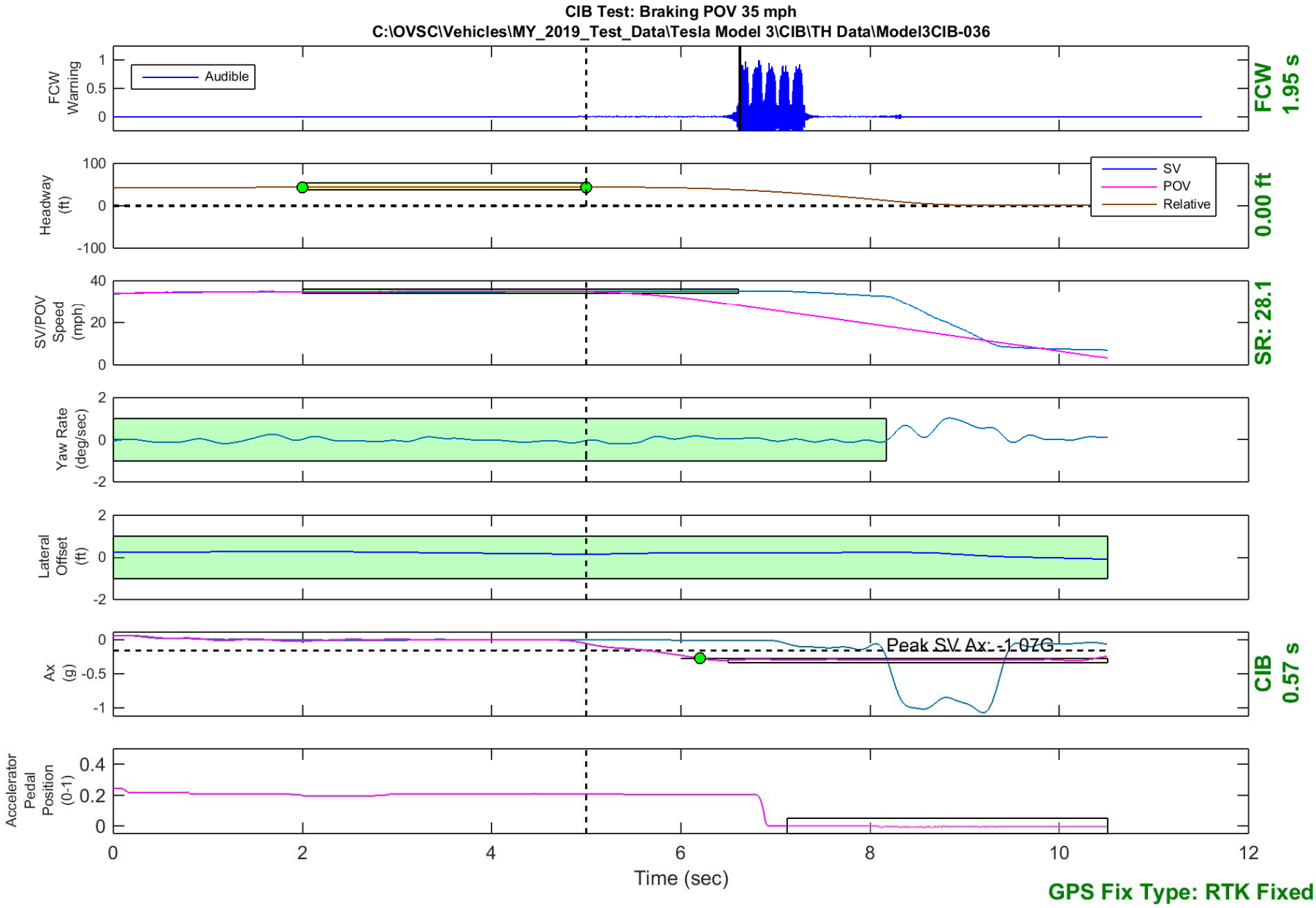


Figure D35. Time History for CIB Run 36, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

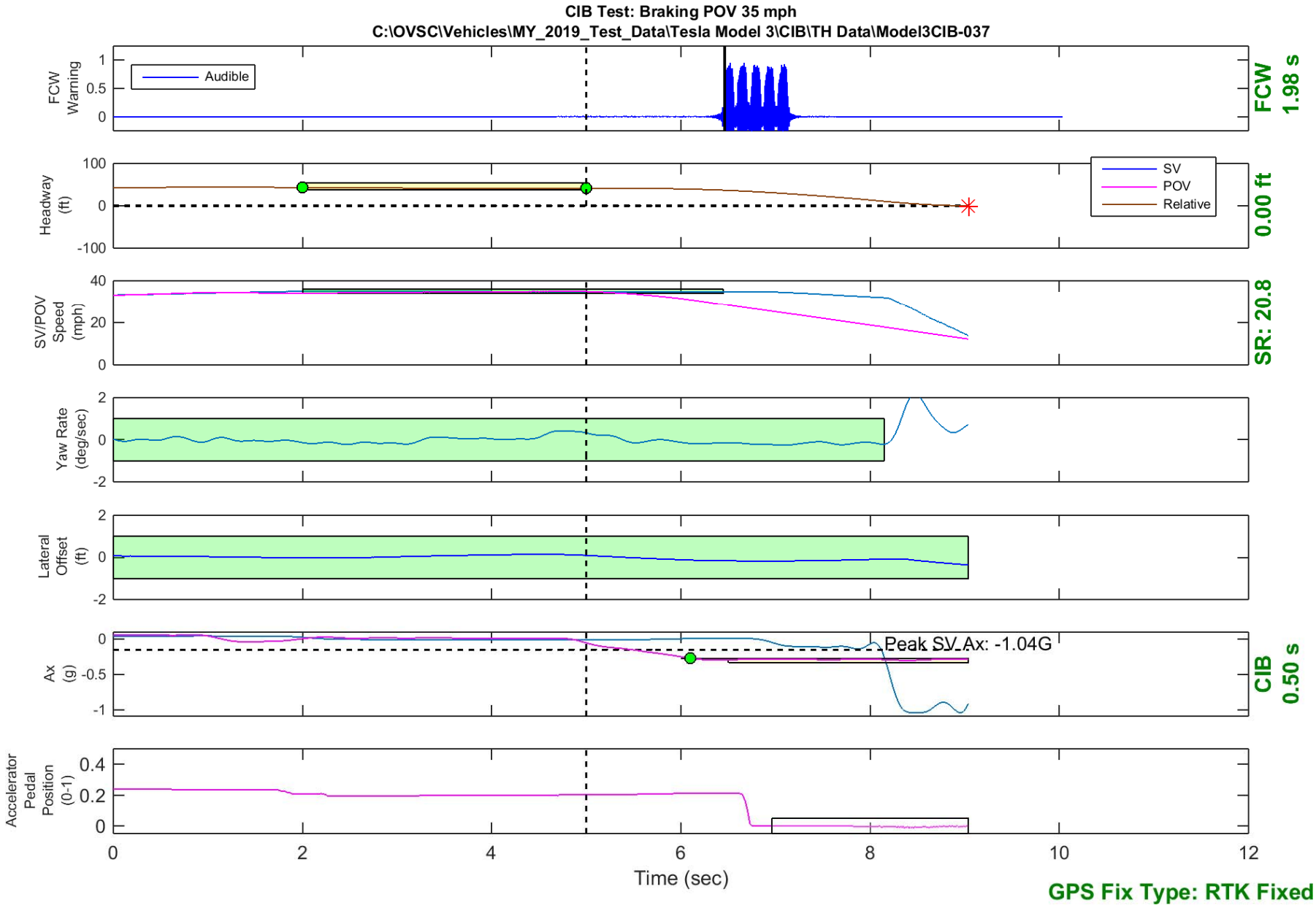


Figure D36. Time History for CIB Run 37, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

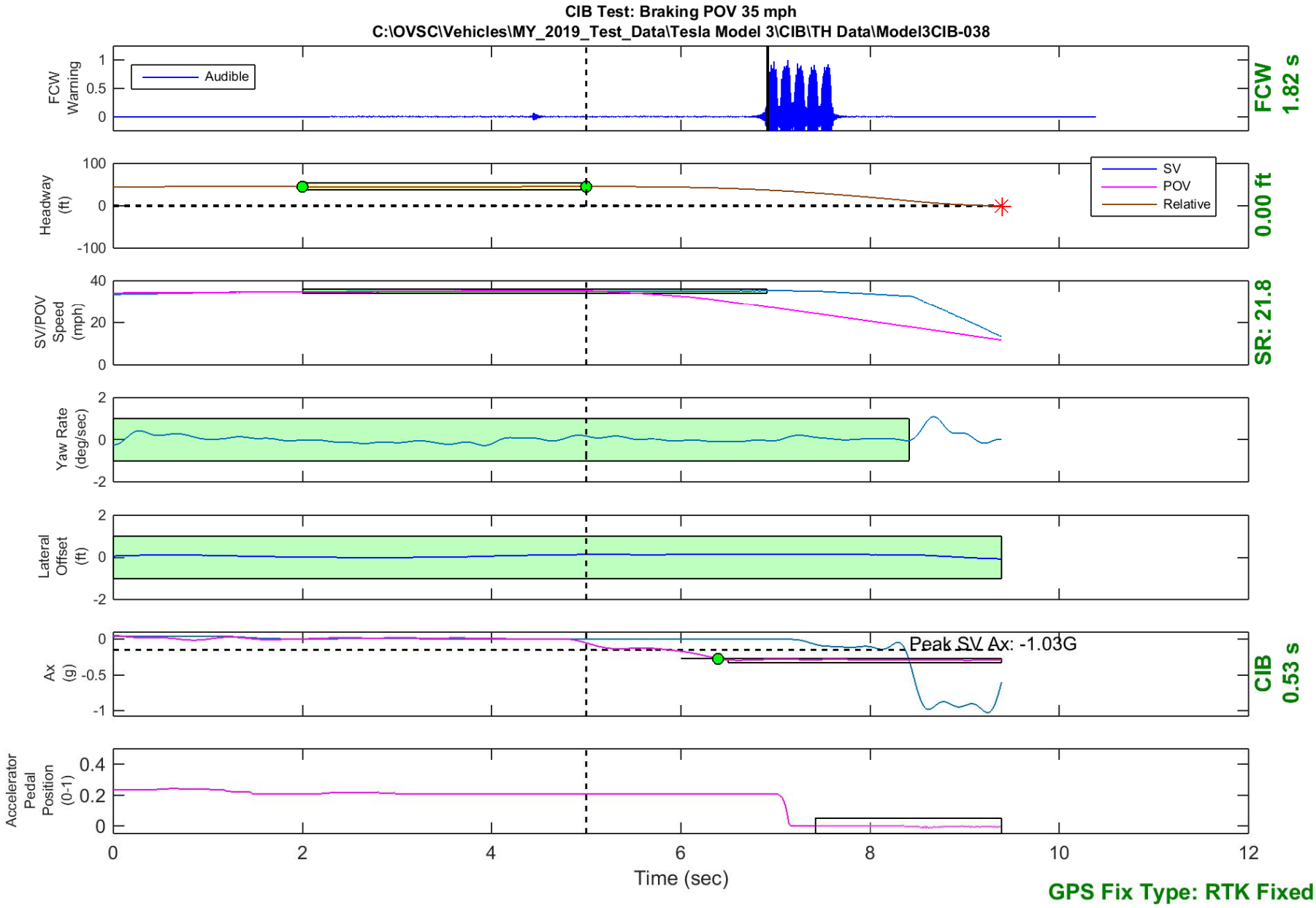


Figure D37. Time History for CIB Run 38, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

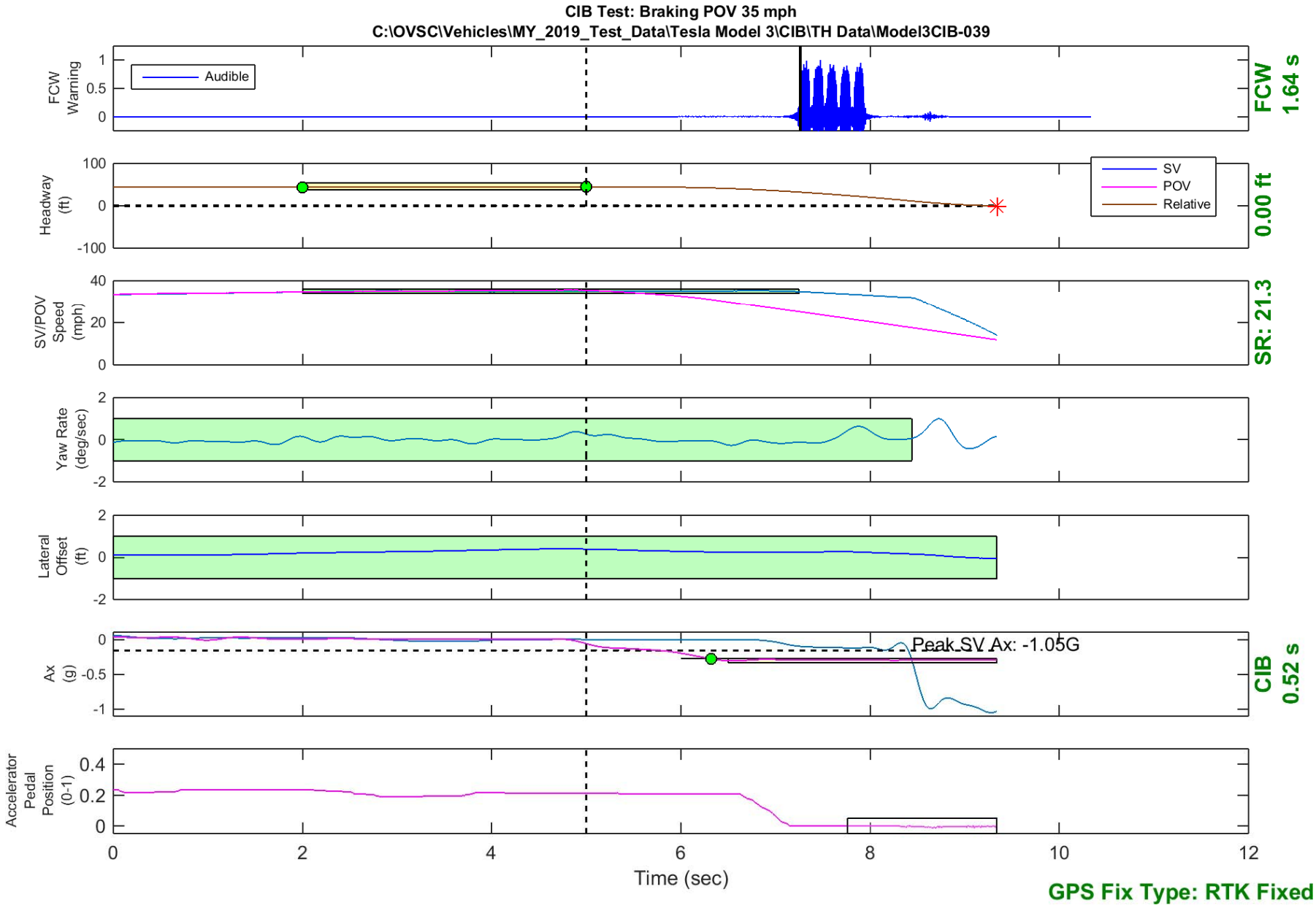


Figure D38. Time History for CIB Run 39, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

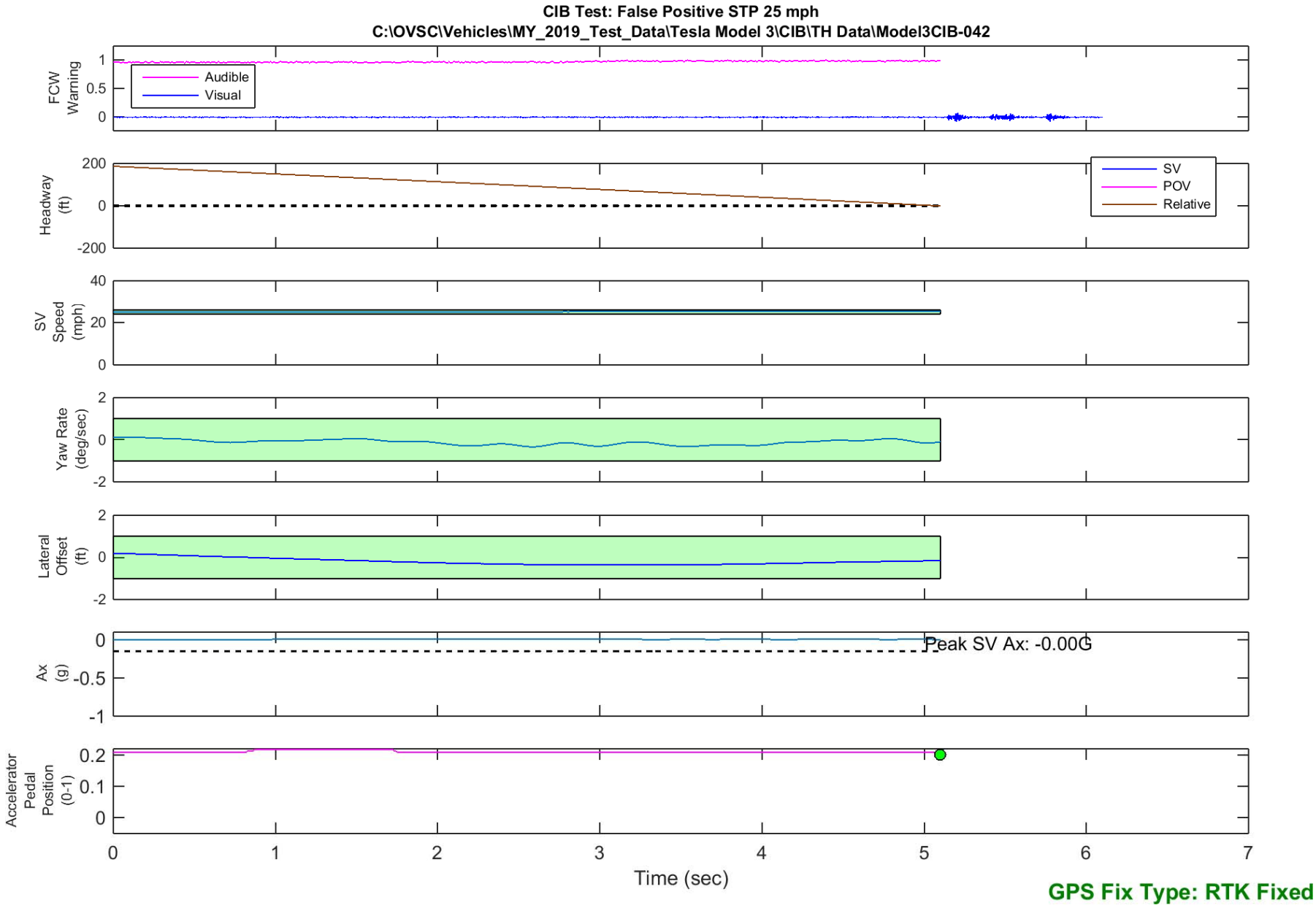


Figure D39. Time History for CIB Run 42, SV Encounters Steel Trench Plate, SV 25 mph

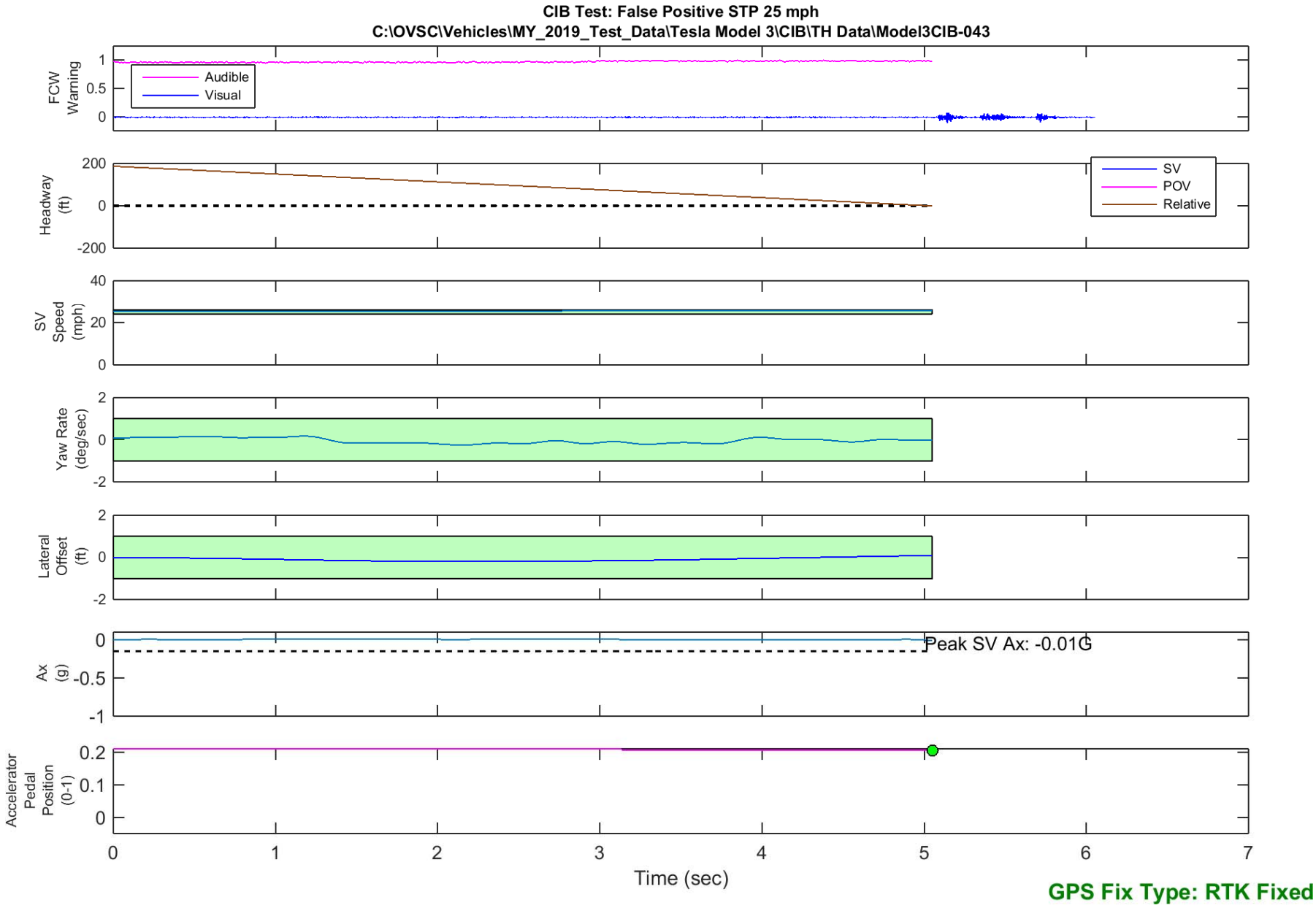


Figure D40. Time History for CIB Run 43, SV Encounters Steel Trench Plate, SV 25 mph

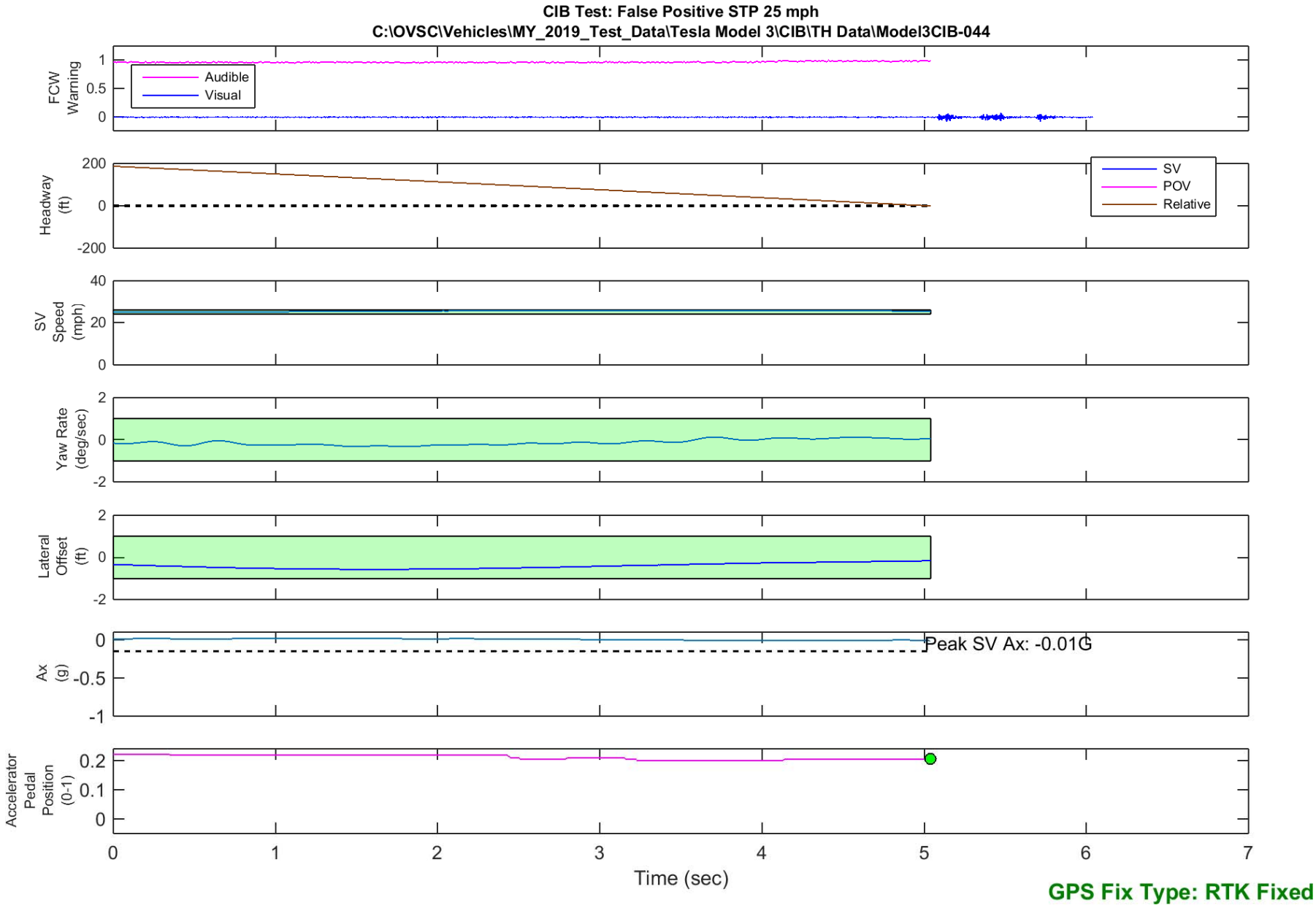


Figure D41. Time History for CIB Run 44, SV Encounters Steel Trench Plate, SV 25 mph

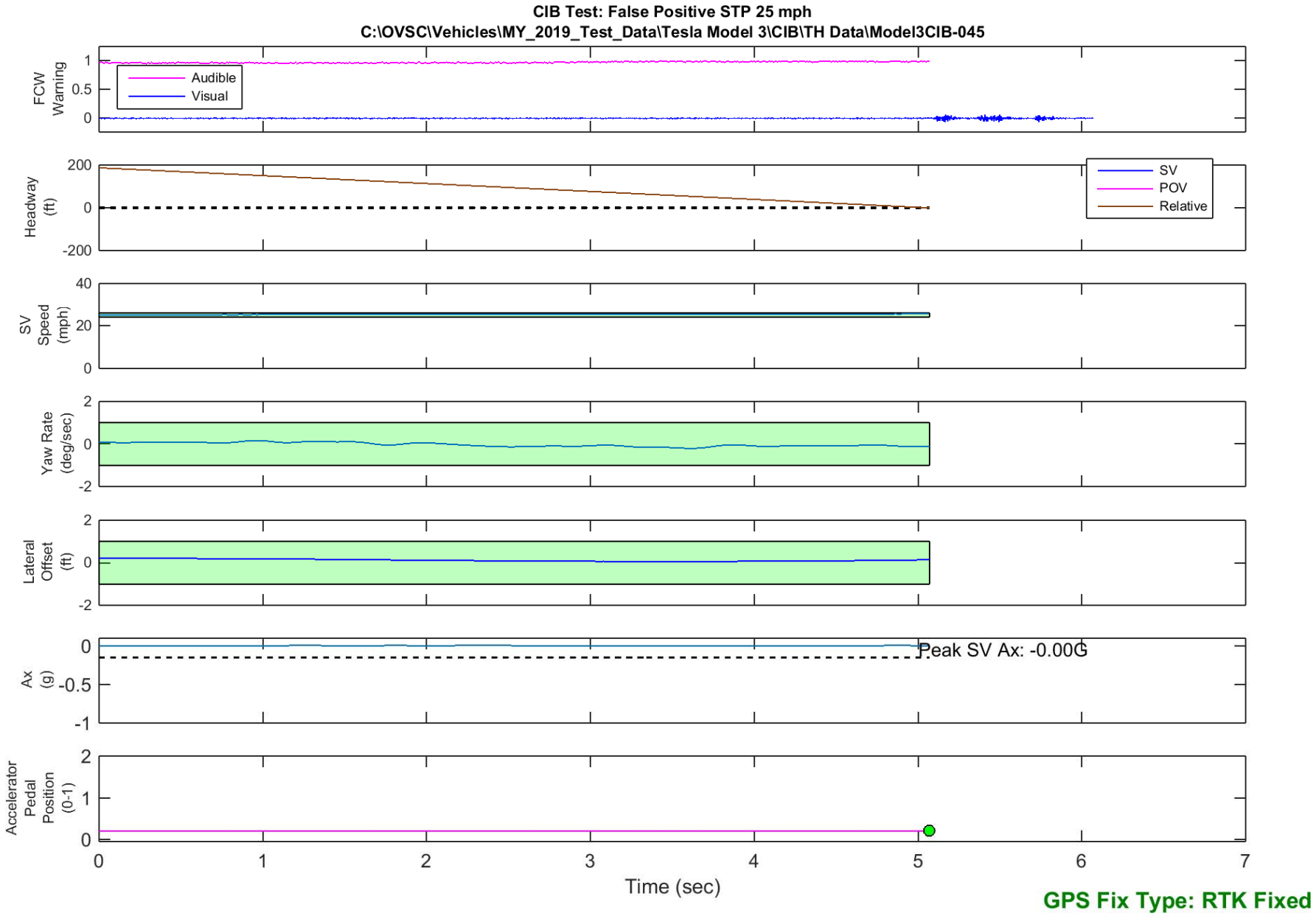


Figure D42. Time History for CIB Run 45, SV Encounters Steel Trench Plate, SV 25 mph

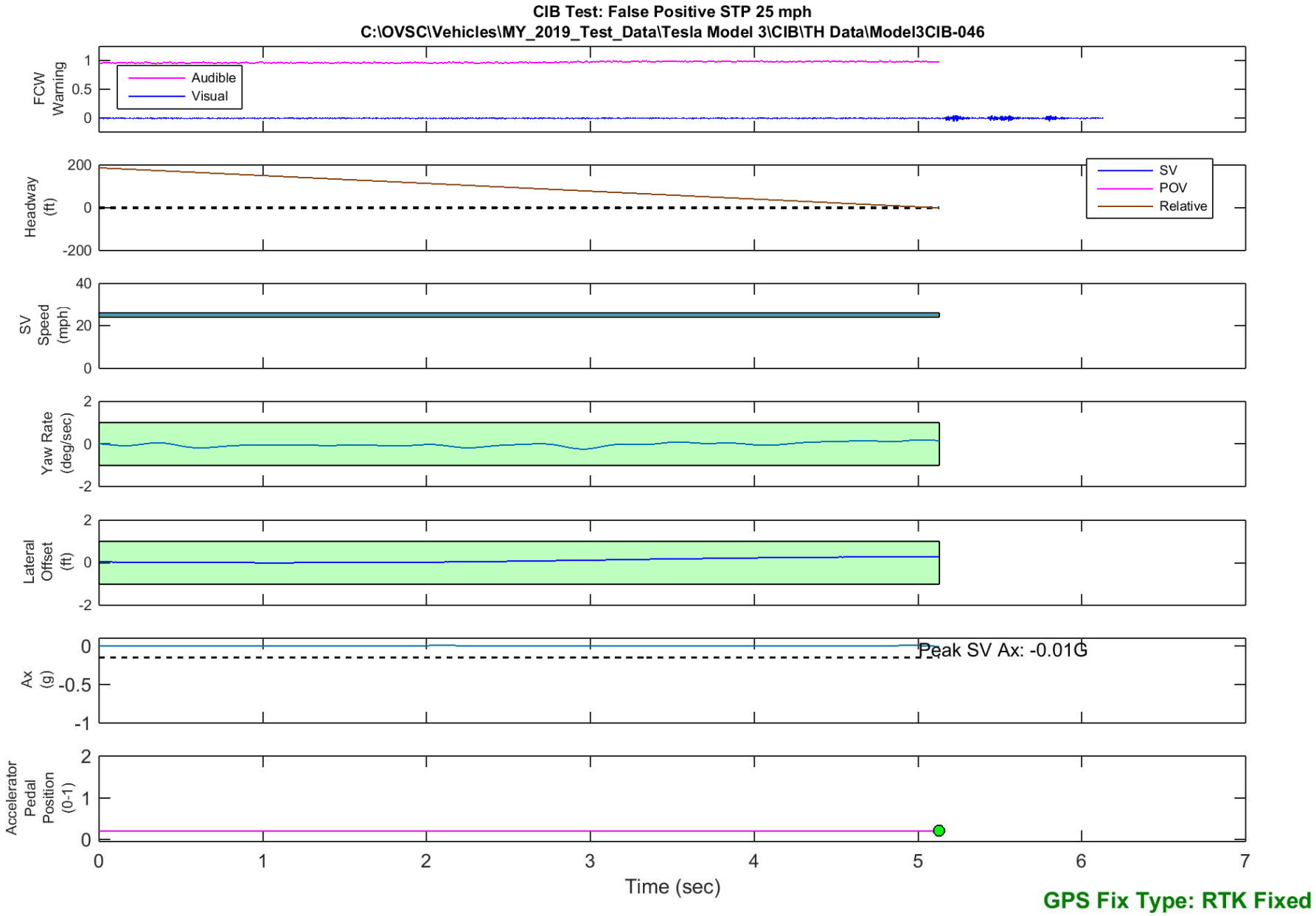


Figure D43. Time History for CIB Run 46, SV Encounters Steel Trench Plate, SV 25 mph

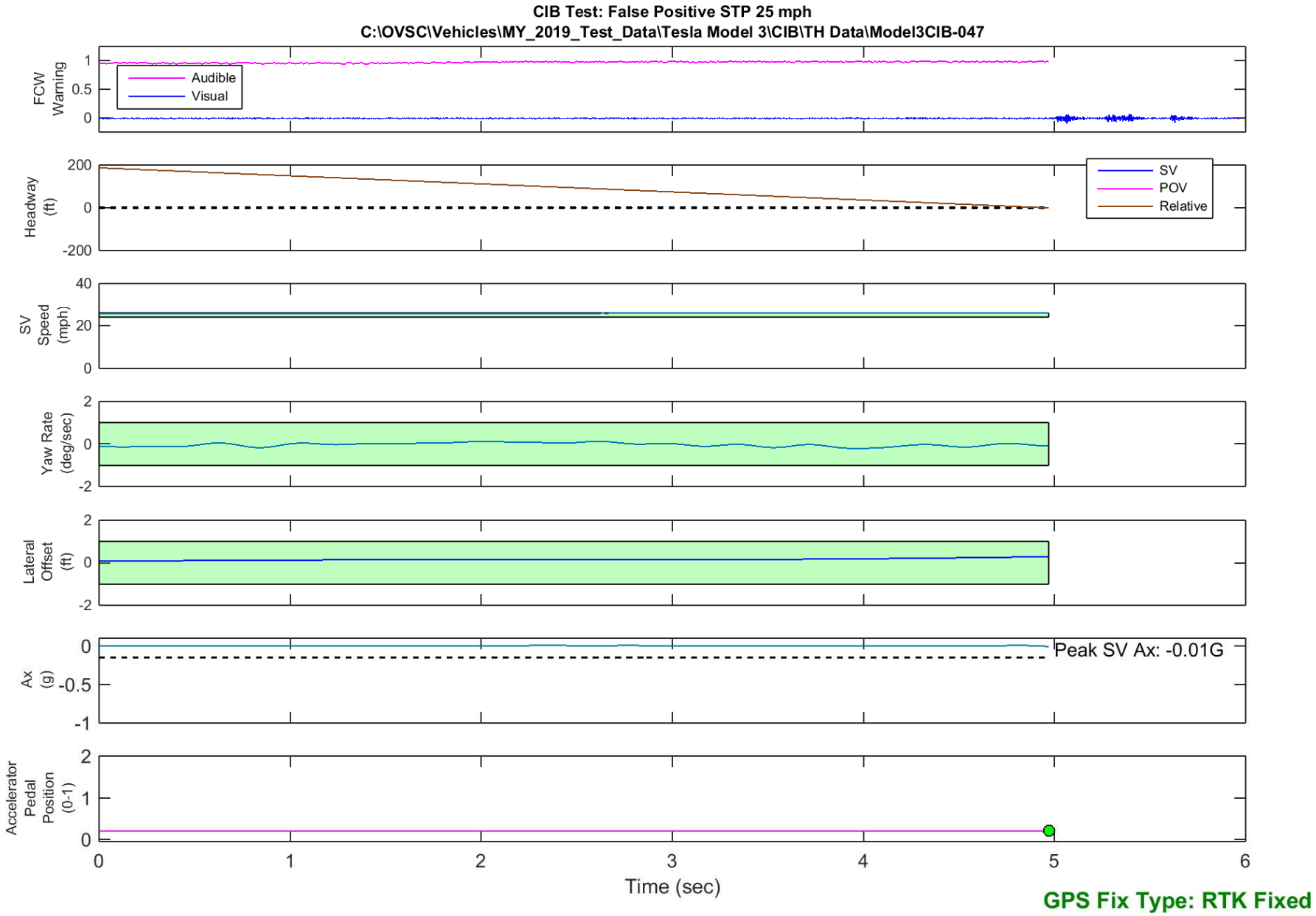


Figure D44. Time History for CIB Run 47, SV Encounters Steel Trench Plate, SV 25 mph

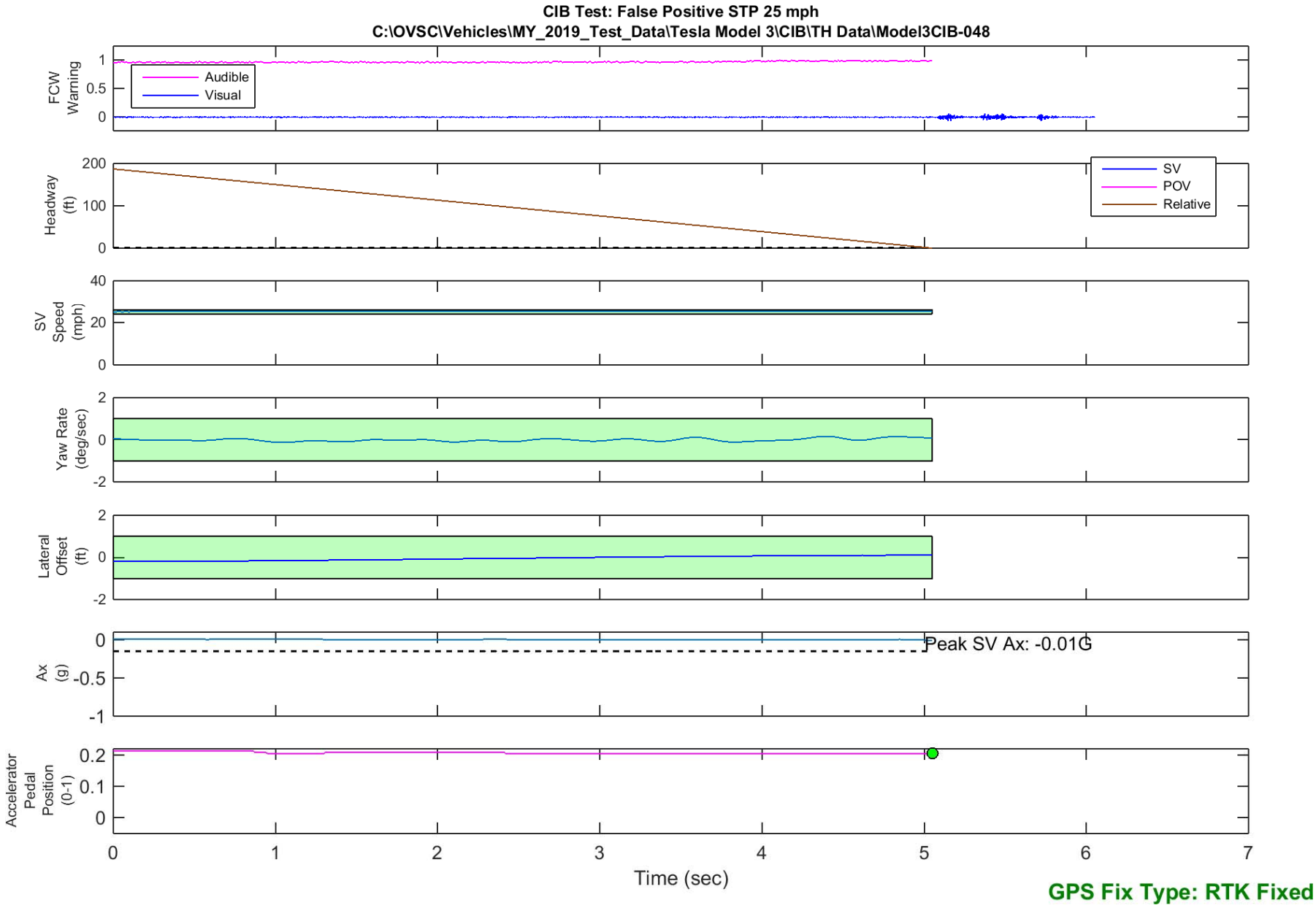


Figure D45. Time History for CIB Run 48, SV Encounters Steel Trench Plate, SV 25 mph

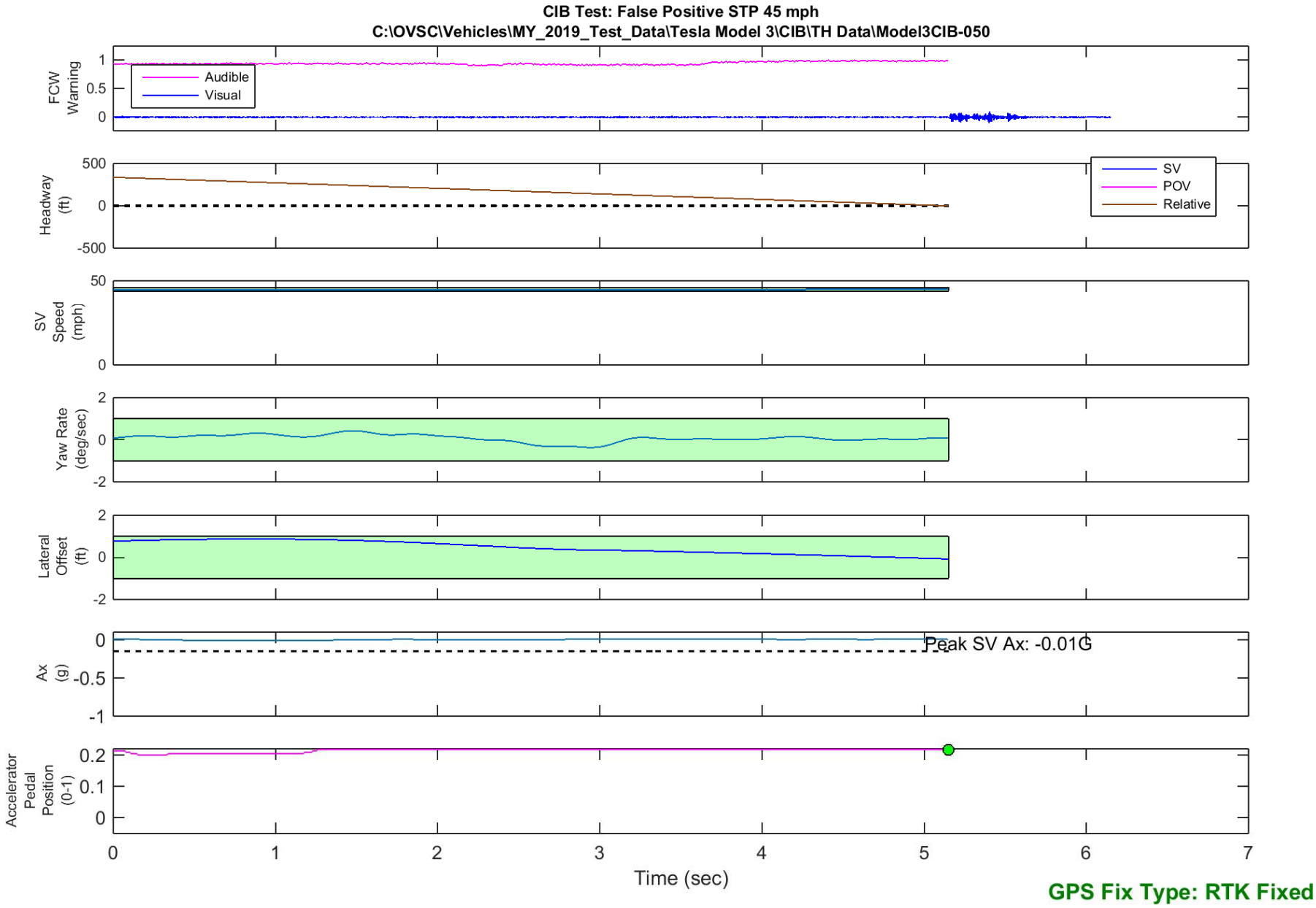


Figure D46. Time History for CIB Run 50, SV Encounters Steel Trench Plate, SV 45 mph

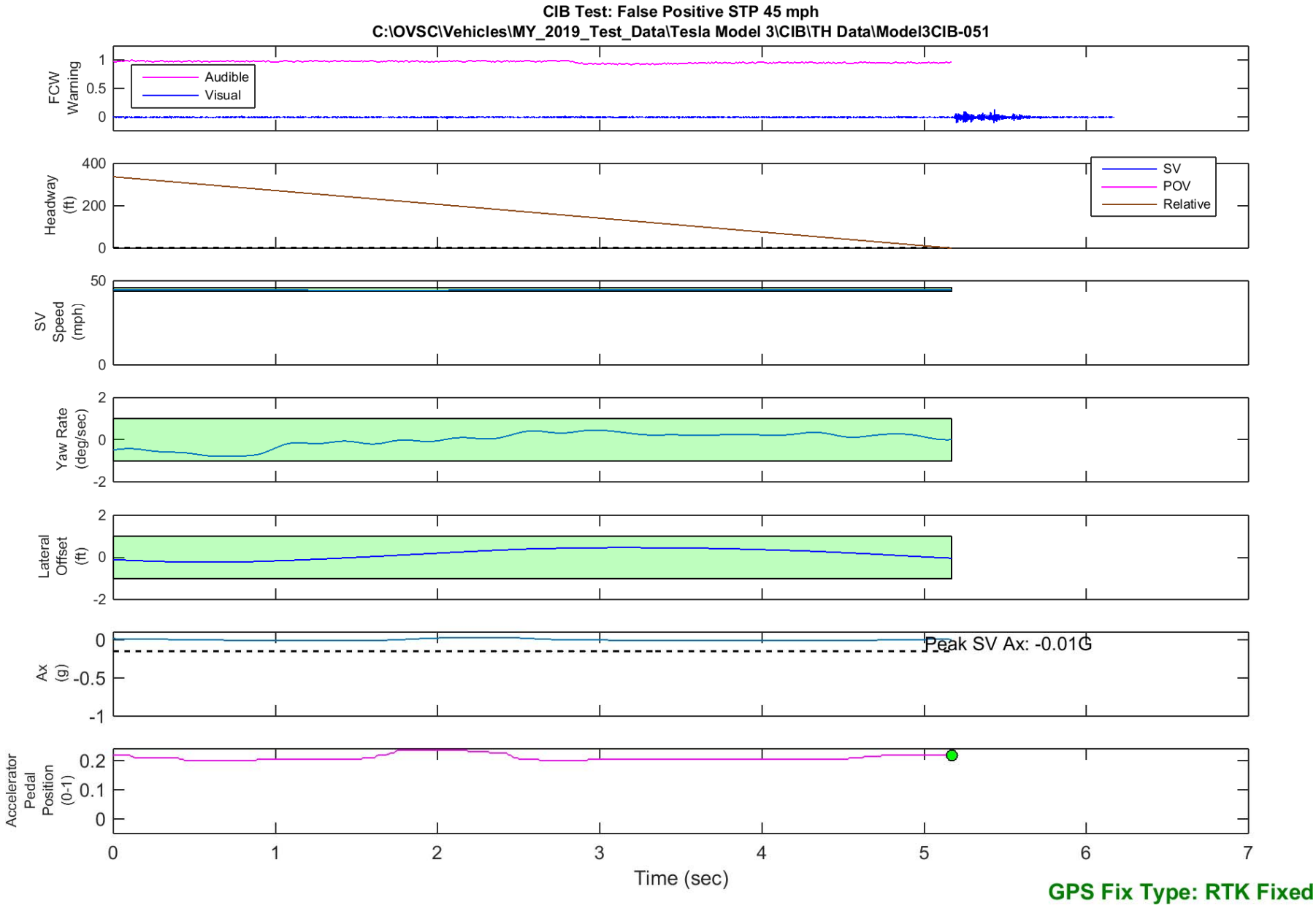


Figure D47. Time History for CIB Run 51, SV Encounters Steel Trench Plate, SV 45 mph

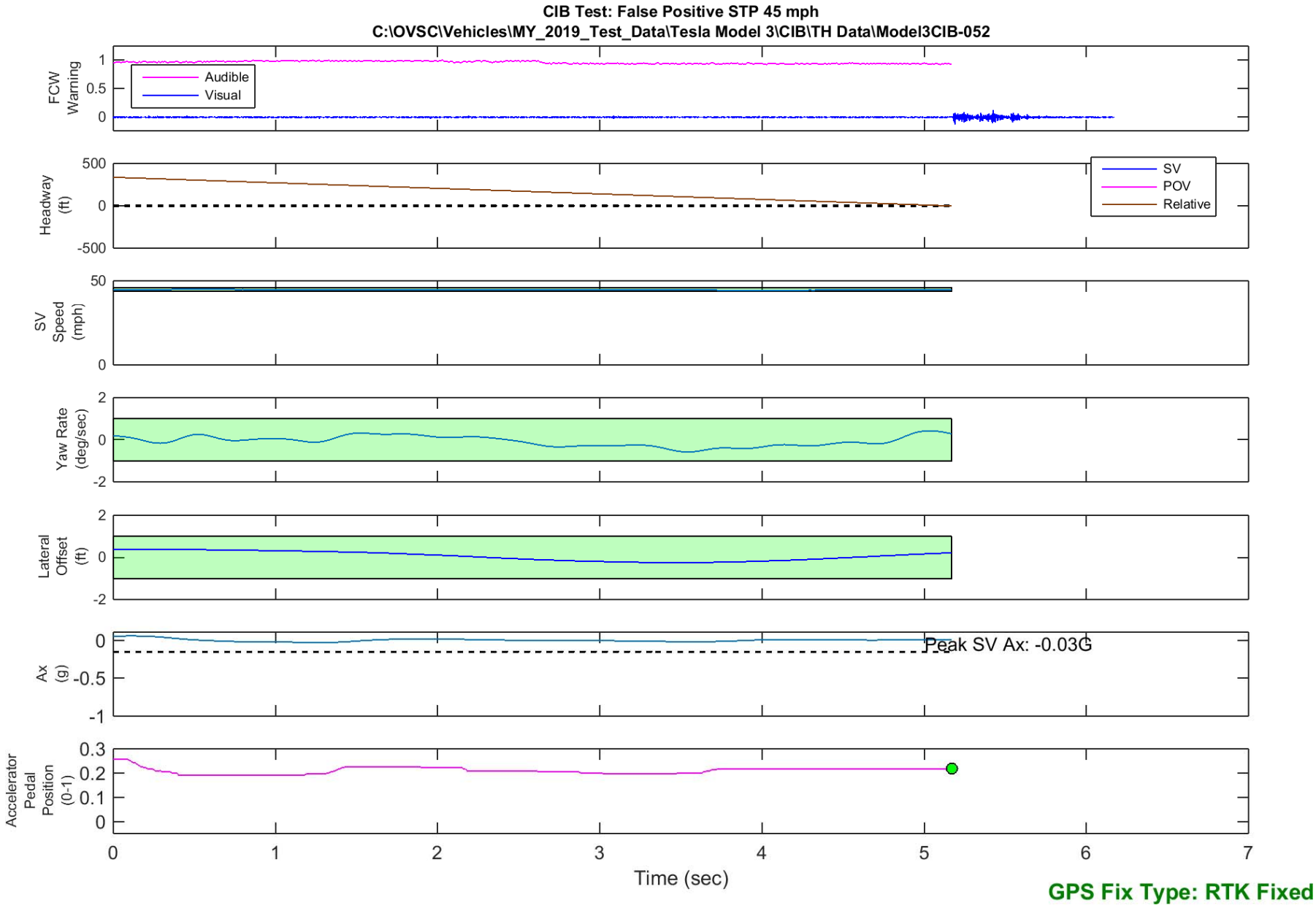


Figure D48. Time History for CIB Run 52, SV Encounters Steel Trench Plate, SV 45 mph

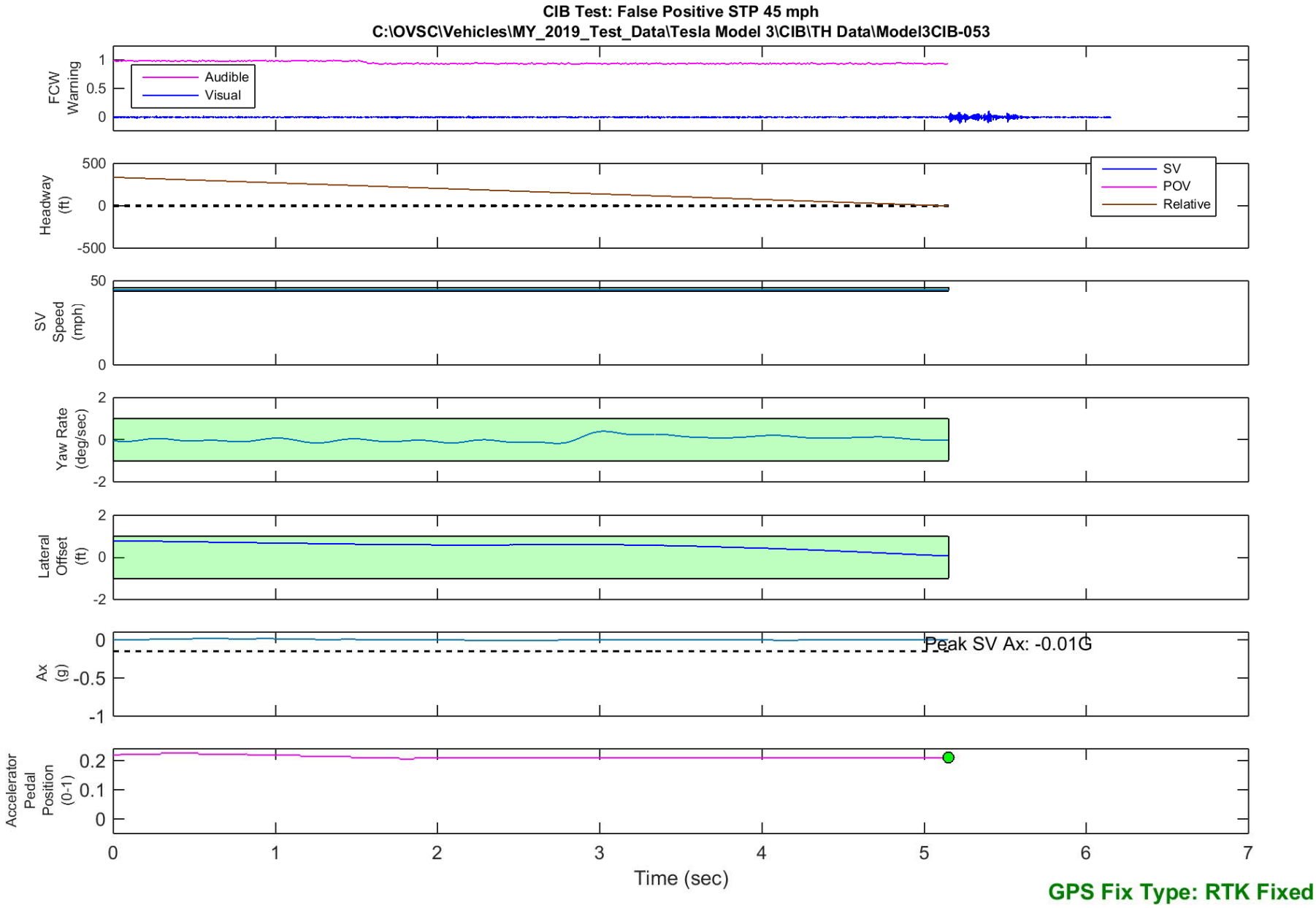


Figure D49. Time History for CIB Run 53, SV Encounters Steel Trench Plate, SV 45 mph

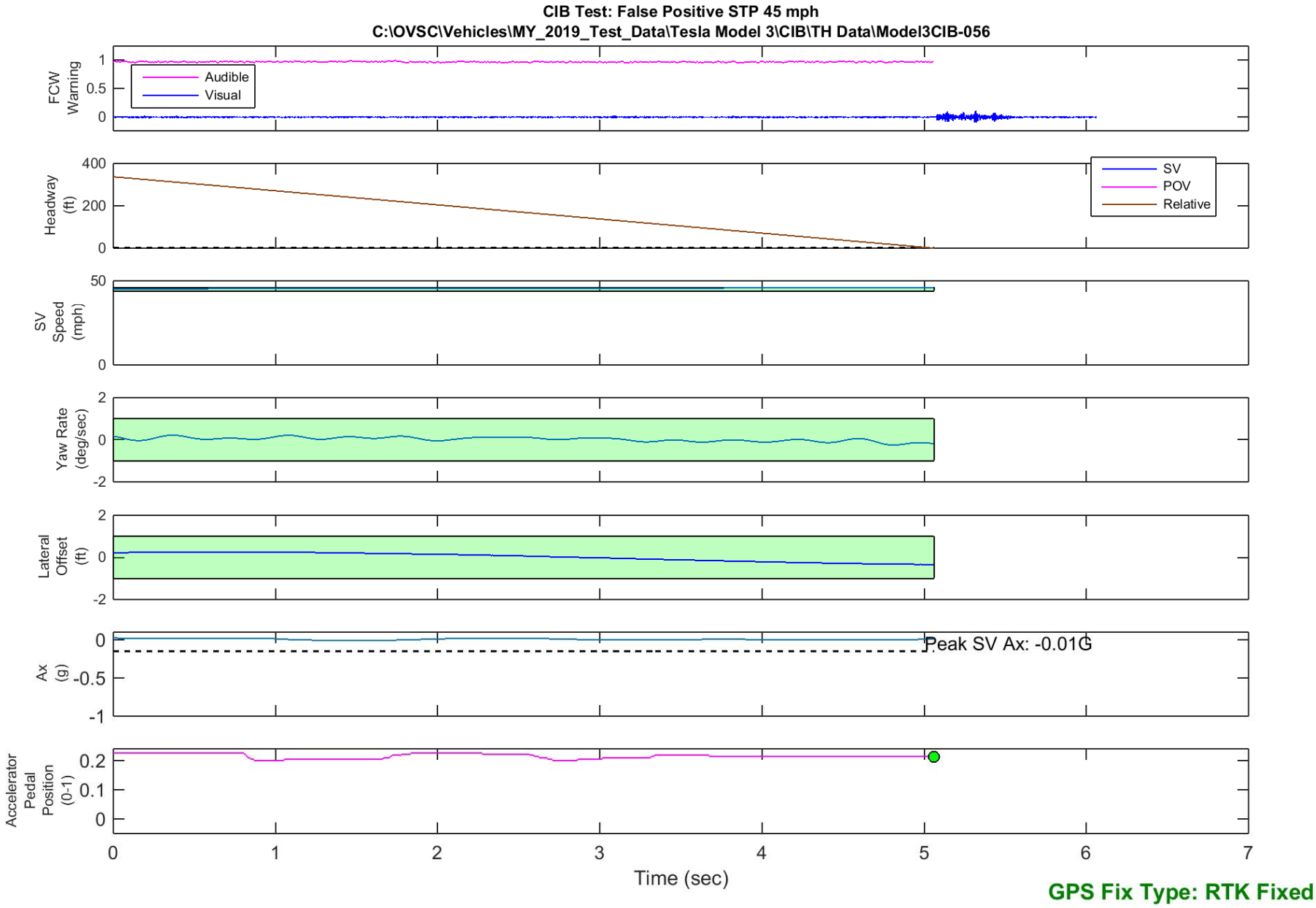


Figure D50. Time History for CIB Run 56, SV Encounters Steel Trench Plate, SV 45 mph

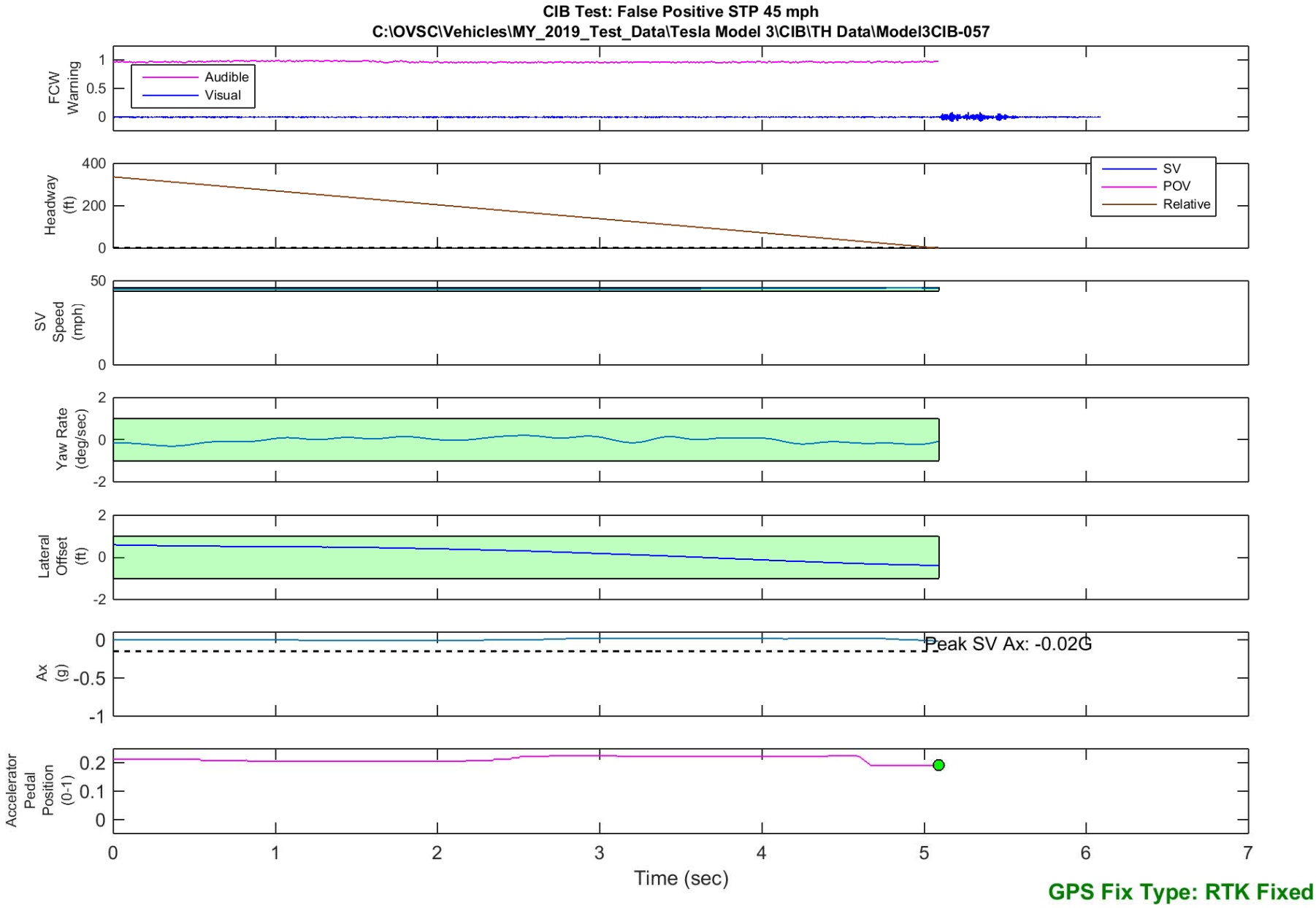


Figure D51. Time History for CIB Run 57, SV Encounters Steel Trench Plate, SV 45 mph

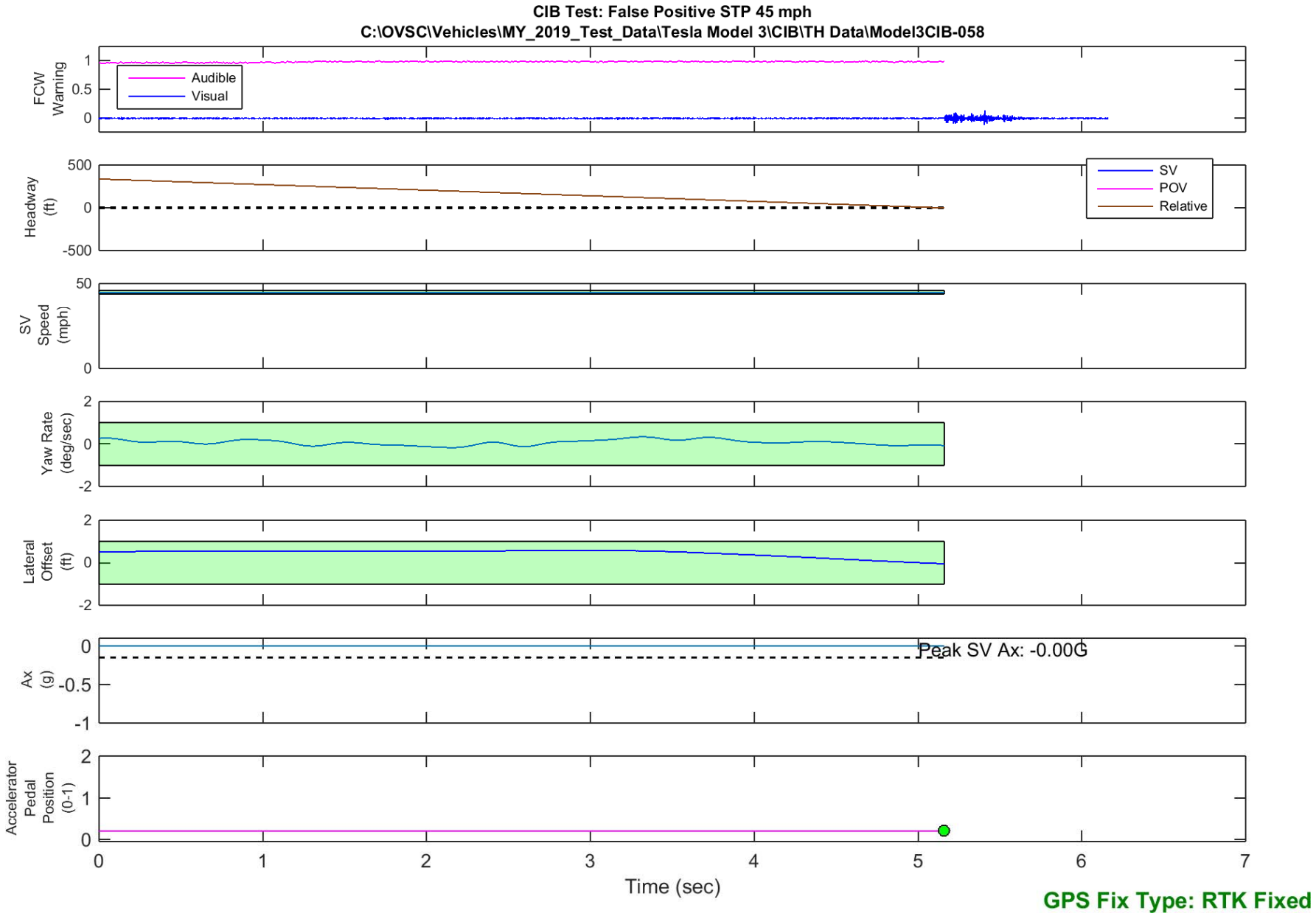


Figure D52. Time History for CIB Run 58, SV Encounters Steel Trench Plate, SV 45 mph