CRASH IMMINENT BRAKING SYSTEM RESEARCH TEST
NCAP-DRI-CIBHS-20-03

2020 Ford F-150 4X4 SuperCrew

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10 August 2020

Final Report

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

U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
1200 New Jersey Avenue, SE
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These research tests were conducted on the subject 2020 Ford F-150 4X4 SuperCrew 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, with modifications to include use of the Global Vehicle Target (GVT) and additional test speeds or deceleration rates to assess system performance and point of failure.
The system met the acceptability criteria for 57 out of 57 valid test runs.</td></tr>
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TABLE OF CONTENTS

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) in the New Car Assessment Program's (NCAP's) Crash Imminent Brake System Test Procedure (dated October 2015)[1] to evaluate CIB performance on the test track 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).

This report describes the results of research tests conducted in accordance with the NHTSA test procedure, but several modifications were made to the specified test matrix and an alternative POV was used.

The modified test matrix replaces the "false positive" test condition in the standard CIB confirmation test with additional test speeds or deceleration rates, as indicated in Table 1.

The NHTSA test procedure does not specify a particular strikeable POV, but the New Car Assessment Program (NCAP) has been using the Strikeable Surrogate Vehicle (SSV) for the CIB confirmation tests.[2] However, the Global Vehicle Target (GVT) system, which is in general use worldwide, was used in these research tests instead of the SSV. A detailed description of the GVT system is given in Section III C.

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

[2] A detailed description of the SSV system can be found in the NHTSA report: NHTSA'S STRIKEABLE SURROGATE VEHICLE PRELIMINARY DESIGN+OVERVIEW, May 2013.

Table 1. Comparison of NCAP CIB Confirmation Test and Research Test Conditions

Test Scenario	Initial SV Speed mph (km/h)	Initial POV Speed mph (km/h)	POV Deceleration (g)	Standard NCAP CIB Confirmation Test Condition	Research Test Condition (Evaluated Herein)
1. Stopped POV	25 (40.2)	0	0	Yes	Yes
	30 (48.3)	0	0	Not Applicable	Yes
	35 (56.3)	0	0	Not Applicable	Yes
	40 (64.4)	0	0	Not Applicable	Yes
	45 (72.4)	0	0	Not Applicable	Yes
2. Slower Moving POV	25 (40.2)	10 (16.1)	0	Yes	Yes
	45 (72.4)	20 (32.2)	0	Yes	Yes
3. Decelerating POV	35 (56.3)	35 (56.3)	0.3	Yes	Yes
	35 (56.3)	35 (56.3)	0.5	Not Applicable	Yes
	45 (72.4)	45 (72.4)	0.3	Not Applicable	Yes
4. Steel Trench Plate	25 (40.2)	Not Applicable	Not Applicable	Yes	No
	45 (72.4)	Not Applicable	Not Applicable	Yes	No

Section II

DATA SHEETS

CRASH IMMINENT BRAKING

DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2020 Ford F-150 4X4 SuperCrew

VIN: *1FTEW1E42LFA1xxxx* Test Date: *5/22/2020*

Crash Imminent Braking System setting(s): *Pre-Collision: On, Alert Sensitivity: Normal, Distance Indication: On, Active Braking: On*

	Number of valid test runs for which acceptability[3] criteria were:		
Test 1 – Subject Vehicle Encounters Stopped Principal Other Vehicle	**Met**	**Not met**	**Valid Runs**
SV 25 mph:	6	0	6
SV 30 mph:	5	0	5
SV 35 mph:	5	0	5
SV 40 mph:	5	0	5
SV 45 mph:	5	0	5
Test 2 – Subject Vehicle Encounters Slower Principal Other Vehicle			
SV 25 mph POV 10 mph:	7	0	7
SV 45 mph POV 20 mph:	7	0	7
Test 3 – Subject Vehicle Encounters Decelerating Principal Other Vehicle			
SV 35 mph POV 35 mph, 0.3 g decel:	7	0	7
SV 35 mph POV 35 mph, 0.5 g decel:	5	0	5
SV 45 mph POV 45 mph, 0.3 g decel:	5	0	5
Overall:	**57**	**0**	**57**

3 The acceptability criteria listed herein are used only as a guide to gauge vehicle performance, and are identical to the Pass/Fail criteria given in 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.

CRASH IMMINENT BRAKING

DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2020 Ford F-150 4X4 SuperCrew

TEST VEHICLE INFORMATION

VIN: *1FTEW1E42LFA1xxxx*

Body Style: *4 door Crew Cab Pickup* Color: *Magnetic*

Date Received: *5/12/2020* Odometer Reading: *155 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Ford Motor Company*

Date of manufacture: *10/19*

Vehicle Type: *Truck*

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: *275/55R20 113T*

Rear: *275/55R20 113T*

Recommended cold tire pressure: Front: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

TIRES

Tire manufacturer and model: *Hankook Dynapro AT2*

Front tire designation: *275/55R20 113T*

Rear tire designation: *275/55R20 113T*

Front tire DOT prefix: *15M8D RN H0*

Rear tire DOT prefix: *15M8D RN H0*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Ford F-150 4X4 SuperCrew

GENERAL INFORMATION

Test date: *5/22/2020*

AMBIENT CONDITIONS

Air temperature: *18.3 C (65 F)*

Wind speed: *0.0 m/s (0.0 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: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*772.0 kg (1702 lb)*	Right Front:	*721.2 kg (1590 lb)*
Left Rear:	*572.0 kg (1261 lb)*	Right Rear:	*556.1 kg (1226 lb)*
		Total:	*2621.3 kg (5779 lb)*

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

(Page 1 of 4)

2020 Ford F-150 4X4 SuperCrew

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

Pre-Collision Assist

Type and location of sensors the system uses:

Mono camera, located behind the windshield near the rearview mirror

System setting used for test (if applicable): *Pre-Collision: on, Alert Sensitivity: Normal, Distance Indication: on, Active Braking: on*

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

5 km/h (3.1 mph) (Per manufacturer supplied information)

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

120 km/h (75 mph) (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

X Yes

___ No

If yes, please provide a full description.

Ensuring that the sensors are aligned before testing is very important. A 40 to 50 mile drive above 35 mph on a roadway with moving and stationary targets will confirm the sensors are fully aligned.

If Active Braking is enabled, the vehicle should require no other initialization.

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

X Yes

___ No

If yes, please provide a full description.

It is recommended to wait a minimum of 90 seconds between test runs, and to turn around when restaging as opposed to simply reversing in order to completely remove the target from the sensors field of view. The system effectiveness may reduce if too many AEB activations occur in quick succession. The message "Pre-Collision Assist Not Available" may also appear under repeated AEB activations/impacts. In this case, cycle the ignition to re-enable the Pre-Collision Assist feature.

How is the Forward Collision Warning System alert presented to the driver?

(Check all that apply)

X Warning light

X Buzzer or audible alarm

___ Vibration

___ Other ___________

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

The driver is provided with an audible and visual alert. The audible sound is a four-tone chime repeated three times. The visual alert is provided as a red and black flashing graphic in the cluster showing the text “Pre-Collision Assist.” or via a flashing red LED bar located in front of the driver below the windshield.

See Appendix A Figure A13.

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.

CIB and DBS are on by default after every ignition cycle. The CIB and DBS functionality can be turned off through a single checkbox in the cluster menu, accessed by means of buttons on the steering wheel. The hierarchy is:

Settings

- *Pre-Collision*
  - *Active Braking checkbox*

In a similar manner, the entire Pre-Collision Assist system can also be disabled. The hierarchy is

Settings

- *Pre-Collision*
  - *Pre-Collision Assist On/Off.*

If this has occurred, the driver will be prompted to re-enable the feature after an ignition cycle.

See the Owner's Manual, Pages 127, 131 and 277. These are shown in Appendix B, Pages B-2, B-3, and B-8.

See also Appendix A, Figures A11 and A12.

The Pre-Collision Assist system automatically disables when you select 4X4 LOW or when you manually disable AdvanceTrac.

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

____ No

If yes, please provide a full description.

The CIB and DBS functionality can be modified through the cluster menu, accessed by means of buttons on the steering wheel. The hierarchy is:

Settings

- *Pre-Collision*
  - *Alert Sensitivity –*
    - *Select High, Normal, or Low*
  - *Distance Indication - checkbox for on or off*
  - *Active Braking - checkbox for on or off*
  - *Pre-Collision - Select on or off*

See the Owner's Manual, Pages 127, 131 and 277. These are shown in Appendix B, Pages B-2, B-3, and B-8.

See also Appendix A, Figures A11 and A12.

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.

The limitations of the system are described in the Owner's Manual, Pages 274- 275 and 277-278. These are shown in Appendix B, Pages B-5 to B-6, and B-8 to B-9.

Notes:

Section III

TEST PROCEDURES

A. Test Procedure Overview

Three 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

An overview of each of the test procedures follows.

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

This test evaluates the ability of the CIB system to detect and respond to a stopped lead vehicle in the immediate forward path of the SV, as depicted in Figure 1. Test conditions for Test 1 are shown in Table 2.

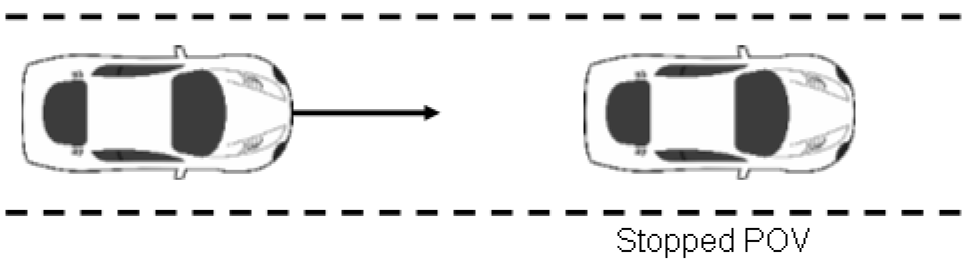

Figure 1. Depiction of Test 1

Table 2. Test Conditions for Stopped POV

Initial SV Speed mph (km/h)	**Initial POV Speed** mph (km/h)	**POV Deceleration** g
25 (40.2)	0	0
30 (48.3)	0	0
35 (56.3)	0	0
40 (64.4)	0	0
45 (72.4)	0	0

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 tests were conducted at five different SV nominal speeds. The nominal speeds were 25 mph (40.2 km/h), 30 mph (48.3 km/h), 35 mph (56.3 km/h), 40 mph (64.4 km/h), and 45 mph (72.4 km/h). The guideline for test speed was to start at the lowest speed and increase the test speed incrementally until a speed was reached at which the system performance was no longer acceptable. If the system performance became unacceptable before all the nominal speeds were completed, an additional series of tests was then conducted at a speed 2.5 mph less than the speed at which unacceptable performance was observed. The SV was driven at the nominal speed in the center of the lane of travel, toward the parked POV. The SV throttle pedal was released within 500 ms after t_{FCW}, i.e. within 500 ms of the FCW alert. The test concluded when either:

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

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

- The SV speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during an interval defined by a Time to Collision (TTC) = 5.1 seconds to t_{FCW}.

b. Criteria

If, at each nominal speed, the magnitude of the SV speed reduction attributable to CIB intervention was ≥ 9.8 mph (15.8 km/h) for at least three of five valid test trials the system performance was considered acceptable.

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. <u>TEST 2 – SUBJECT VEHICLE ENCOUNTERS SLOWER PRINCIPAL OTHER VEHICLE</u>

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. Test conditions for Test 2 are shown in Table 3.

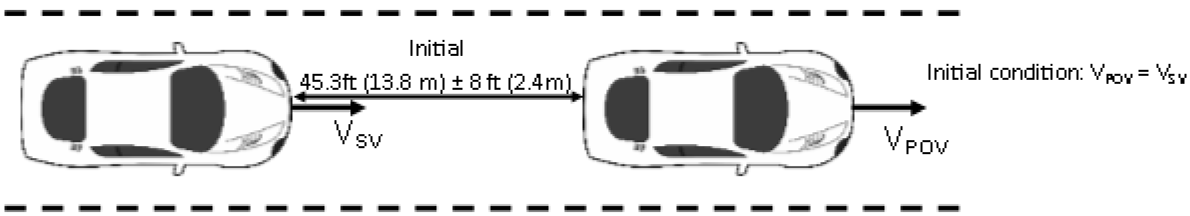

Figure 2. Depiction of Test 2

Table 3. Test Conditions for Slower POV

Initial SV Speed mph (km/h)	**Initial POV Speed** mph (km/h)	**POV Deceleration** g
25 (40.2)	10 (16.1)	0
45 (72.4)	20 (32.2)	0

a. Procedure

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

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

The SV driver then braked to a stop.

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

- The lateral distance between the centerline of the POV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.
- The lateral distance between the centerline of the SV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.
- The SV speed could not deviate more than ±1.0 mph (±1.6 km/h) during an interval defined by TTC = 5.0 seconds to t_{FCW}.
- The POV speed could not deviate more than ±1.0 mph (±1.6 km/h) during the validity period.

b. Criteria

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

To be considered acceptable for 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 three of five valid test trials. The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

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

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

This test evaluates the ability of the CIB system to detect and respond to a lead vehicle slowing with a constant deceleration in the immediate forward path of the SV, as depicted by the example in Figure 3. Test conditions for Test 3 are shown in Table 4.

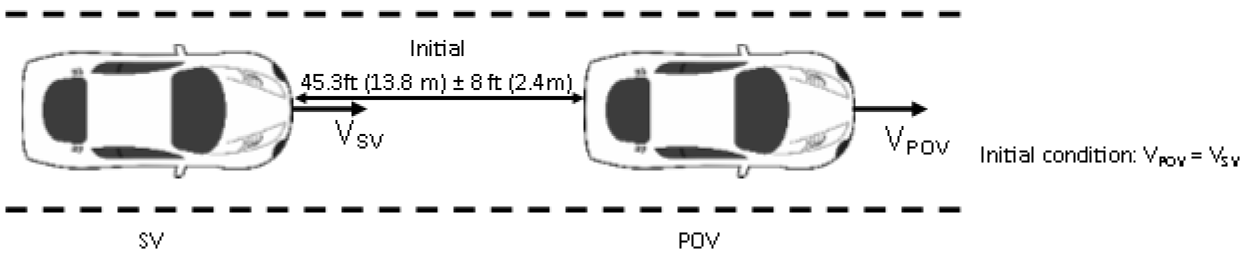

Figure 3. Depiction of Test 3 with POV Decelerating with V_0 =35 mph (56.3 km/h)

Table 4. Test Conditions for Decelerating POV

Initial SV Speed mph (km/h)	**Initial POV Speed** mph (km/h)	**POV Deceleration** g
35 (56.3)	35 (56.3)	0.3
35 (56.3)	35 (56.3)	0.5
45 (72.4)	45 (72.4)	0.3

a. Procedure

The SV ignition was cycled prior to each test run. This test scenario was conducted at three different combinations of nominal initial speeds (V_0) and deceleration levels ($-a_x$). The first two combinations comprised V_0 = 35.0 mph (56.3 km/h) with a_x = -0.3 ± 0.03 g and -0.5 ± 0.03 g respectively. The third combination comprised V_0 = 45 mph (72.4 km/h) and a_x = 0.3 ± 0.03 g. Both the POV and SV were driven at a constant V_0 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 for at least three seconds, the POV (GVT) brakes were applied to achieve the nominal level of deceleration ($-a_x$). The test concluded when either:

- The SV came into contact with the POV or
- For the decelerating POV, 1 second after minimal longitudinal SV-to-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 or 0.5 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

For the decelerating POV test series, in order to be considered acceptable, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 10.5 mph (16.9 km/h) for at least three of five valid test trials, for each combination of initial speeds and deceleration levels. 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}.

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 audible, visual, or haptic and the onset of the alert was determined by post-processing the test data.

For systems that implement audible or haptic alerts, part of the pre-test instrumentation verification process was to determine the tonal frequency of the audible warning or the vibration frequency of the tactile warning through use of the PSD (Power Spectral

Density) function in Matlab. This was accomplished in order to identify the center frequency around which a band-pass filter was applied to subsequent audible or tactile warning data so that the beginning of such warnings can be programmatically determined. The band-pass filter used for these warning signal types was a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 5.

Table 5. Audible and Tactile Warning Filter Parameters

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

2. GENERAL VALIDITY CRITERIA

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

- The SV driver seatbelt was latched.
- If any load had been placed on the SV front passenger seat (e.g., for instrumentation), the vehicle's front passenger seatbelt was latched.
- The SV was driven at the nominal speed in the center of the travel lane, toward the POV.
- The driver used the least amount of steering input necessary to maintain SV position in the center of the travel lane during the validity period; use of abrupt steering inputs or corrections was avoided.
- The yaw rate of the SV did not exceed ±1.0 deg/s from the onset of the validity period to the instant SV deceleration exceeded 0.25 g.
- The SV driver did not apply any force to the brake pedal during the applicable validity period.
- The lateral distance between the centerline of the SV and the centerline of the POV 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

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-to-POV distance occurred.

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 and POV (i.e., GVT and LPRV) were centered in the same travel lane with the same orientation (i.e., facing the same direction).

For these tests, the SV was also positioned such that it just contacted a vertical plane that defines the rearmost location of the POV. 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 five (5) valid trials were performed for each scenario. In cases where the test driver performed more than five trials, the first five 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 GVT secured to a low profile robotic vehicle (LPRV).

This GVT system was designed for a wide range of crash scenarios including scenarios that AEB systems address. The key components of the GVT system are:

- A soft Global Vehicle Target (GVT), which is visually and dimensionally similar to a 2013 Ford Fiesta hatchback. It is designed to appear realistic to the sensors used by automotive safety systems and automated vehicles: radar, camera, and lidar. Appropriate radar characteristics are achieved by using a combination of radar-reflective and radar-absorbing material enclosed within the GVT’s vinyl covers. Internally, the GVT consists of a vinyl-covered foam structure. If a test vehicle impacts the GVT at low speeds, it is designed to separate, and is typically pushed off and away from the supporting LPRV platform. At higher impact speeds, the GVT breaks apart as the SV essentially drives through it. The GVT can be repeatedly struck from any approach angle without harm to those performing the tests or the vehicles being evaluated. Reassembly of the GVT occurs on top of the robotic platform and takes a team of 3 to 5 people approximately 7 to 10 minutes to complete.
- An LPRV platform that supports the GVT and provides for precisely controlled GVT motion. The LPRV contains the batteries, drive motors, GPS receiver, and the control electronics for the system. It has a top speed of 50 mph (80 km/h); a maximum longitudinal acceleration and deceleration of 0.12g (1.18 m/s^2) and

0.8g (7.8 m/s^2), respectively; and a maximum lateral acceleration of 0.5 g (4.9 m/s^2). The LPRV is preprogrammed and allows the GVT's movement to be accurately and repeatedly choreographed with the test vehicle and/or other test equipment required by a pre-crash scenario using closed-loop control. The LPRV is designed to be safely driven over by the SV without damage if the GVT is struck by the SV.

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 45 mph (72.4 km/h).
- Accurately control the lateral position of the POV within the travel lane.

Operationally, the GVT body is attached to LPRV using Velcro hook and loop fasteners. The GVT and LPRV are designed to separate if the GVT is struck by the SV. The GVT/LPRV system is shown in Figures A6 and A7 in Appendix A and a detailed description can be found in the NHTSA report: "A Test Track Comparison of the Global Vehicle Target (GVT) and NHTSA's Strikeable Surrogate Vehicle (SSV)".[4]

D. Automatic Braking System

The LPRV includes an automatic braking system, which was used in Test 3. The braking system can provide for pre-programmed controlled deceleration up to 0.5 g (4.9 m/s^2).

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 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 in prior runs of the same test.

E. Instrumentation

Table 6 lists the sensors, signal conditioning, and data acquisition equipment used for these tests.

[4] Snyder, A.C., Forkenbrock, G.J., Davis, I.J., O'Harra, B.C., and Schnelle, S.C., A Test Track Comparison of the Global Vehicle Target (GVT) and NHTSA's Strikeable Surrogate Vehicle (SSV), DOT HS 812 698, Vehicle Research and Test Center, National Highway Traffic Safety Administration, Washington, DC, July 2019.

Table 6. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	< 1% error between 20 and	Omega DPG8001	17042707002	By: DRI Date: 7/3/2019 Due: 7/3/2020
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform	0.1% of reading	Intercomp SW wireless	0410MN20001	By: DRI Date: 4/20/2020 Due: 4/20/2021
Linear (string) encoder	Throttle pedal travel	10 in 254 mm	0.1 in 2.54 mm	UniMeasure LX-EP	49041189	By: DRI Date: 5/22/2020 Due: 5/22/2021
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	NA
SV Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +	2258	By: Oxford Technical Solutions Date: 5/3/2019 Due: 5/3/2021
POV Multi-Axis Inertial Sensing System		Latitude: ±90º Longitude	Position: ±2 cm Velocity	Oxford PinPoint 2G	24504	By: Oxford Technical Solutions Date: 7/18/2019 Due: 7/18/2021

Table 6. Test Instrumentation and Equipment (continued)

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: 1/6/2020 Due: 1/6/2021
Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW)	Distance and Velocity to lane markings (LDW) and POV (FCW)	Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	NA
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	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)

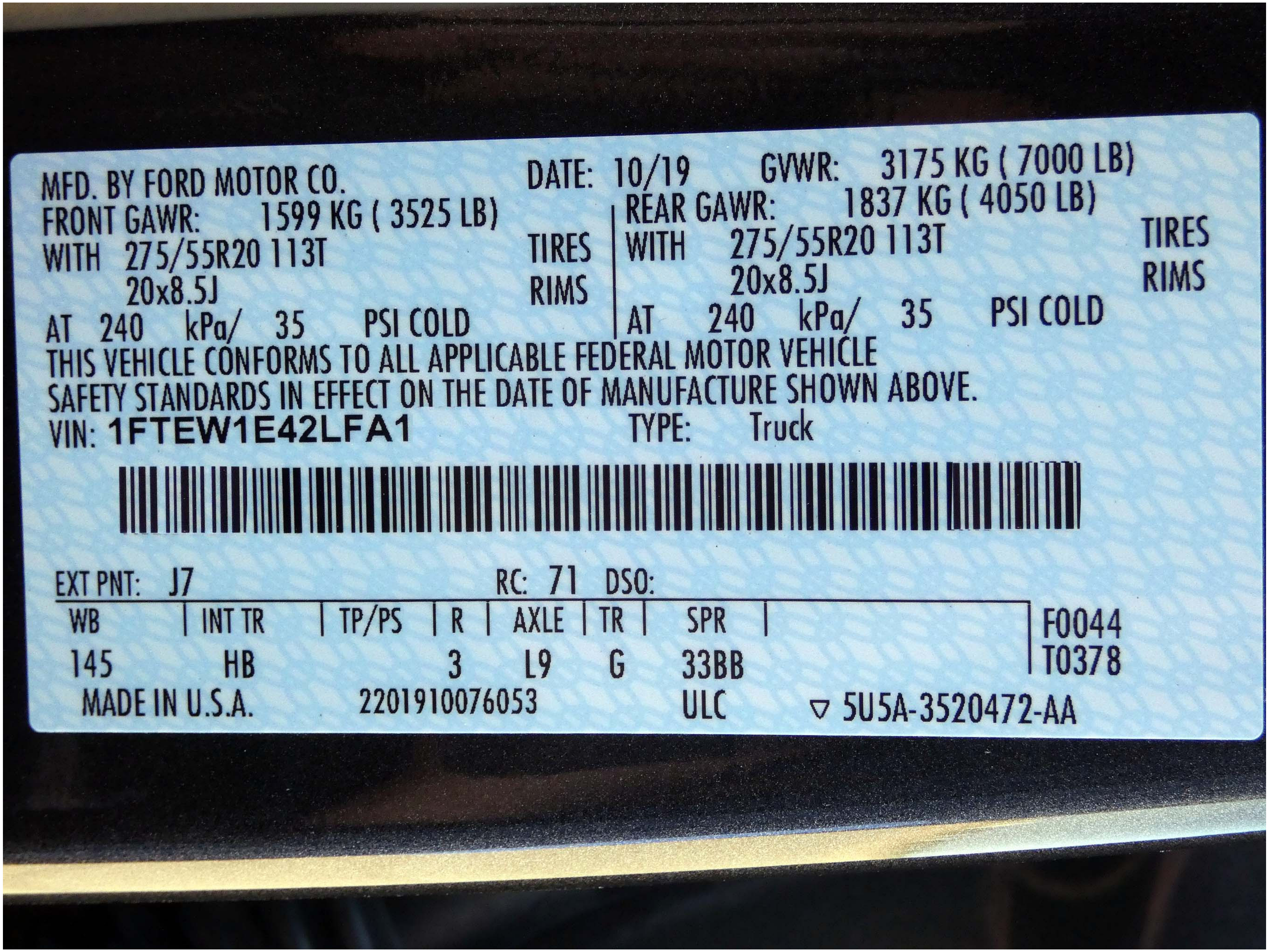

Figure A4. Vehicle Certification Label

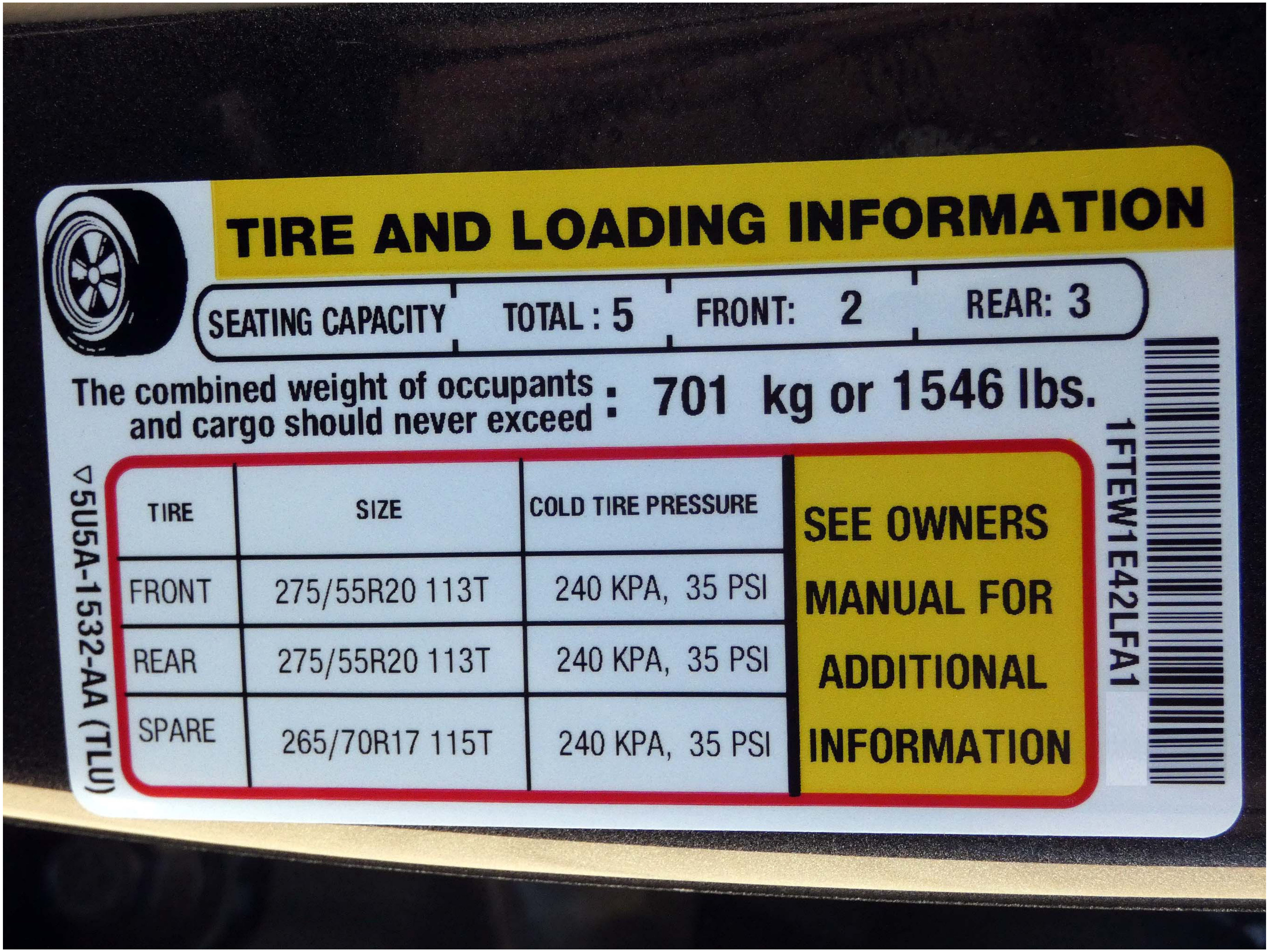

Figure A5. Tire Placard

Figure A6. Front View of Principal Other Vehicle: Global Vehicle Target

Figure A7. Rear View of Principal Other Vehicle: Global Vehicle Target

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

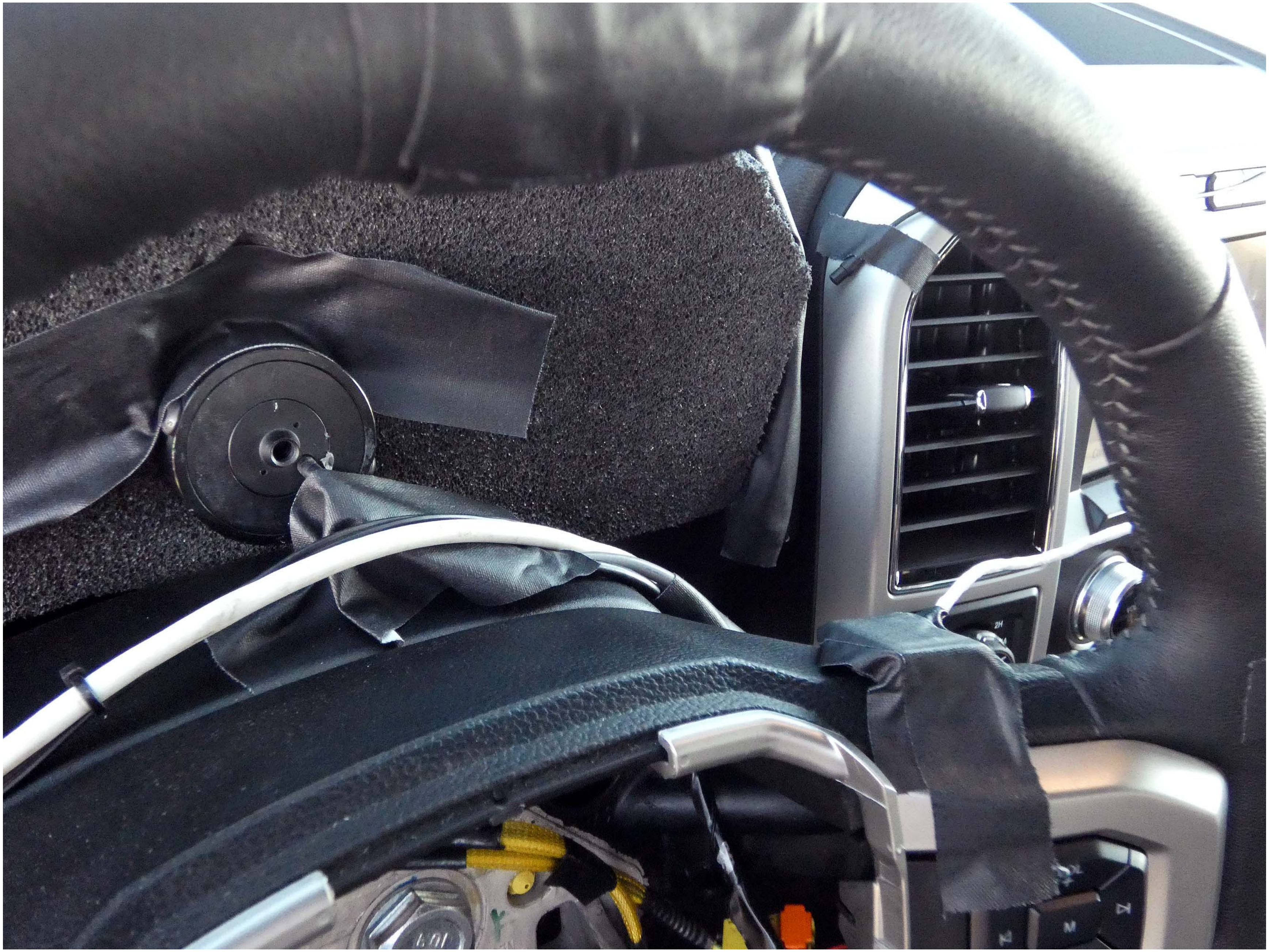

Figure A9. Sensors for Detecting Auditory Alerts

Figure A10. Sensors for Detecting Visual Alerts

Figure A11. Computer Installed in Subject Vehicle

Figure A12. System Setup Menus

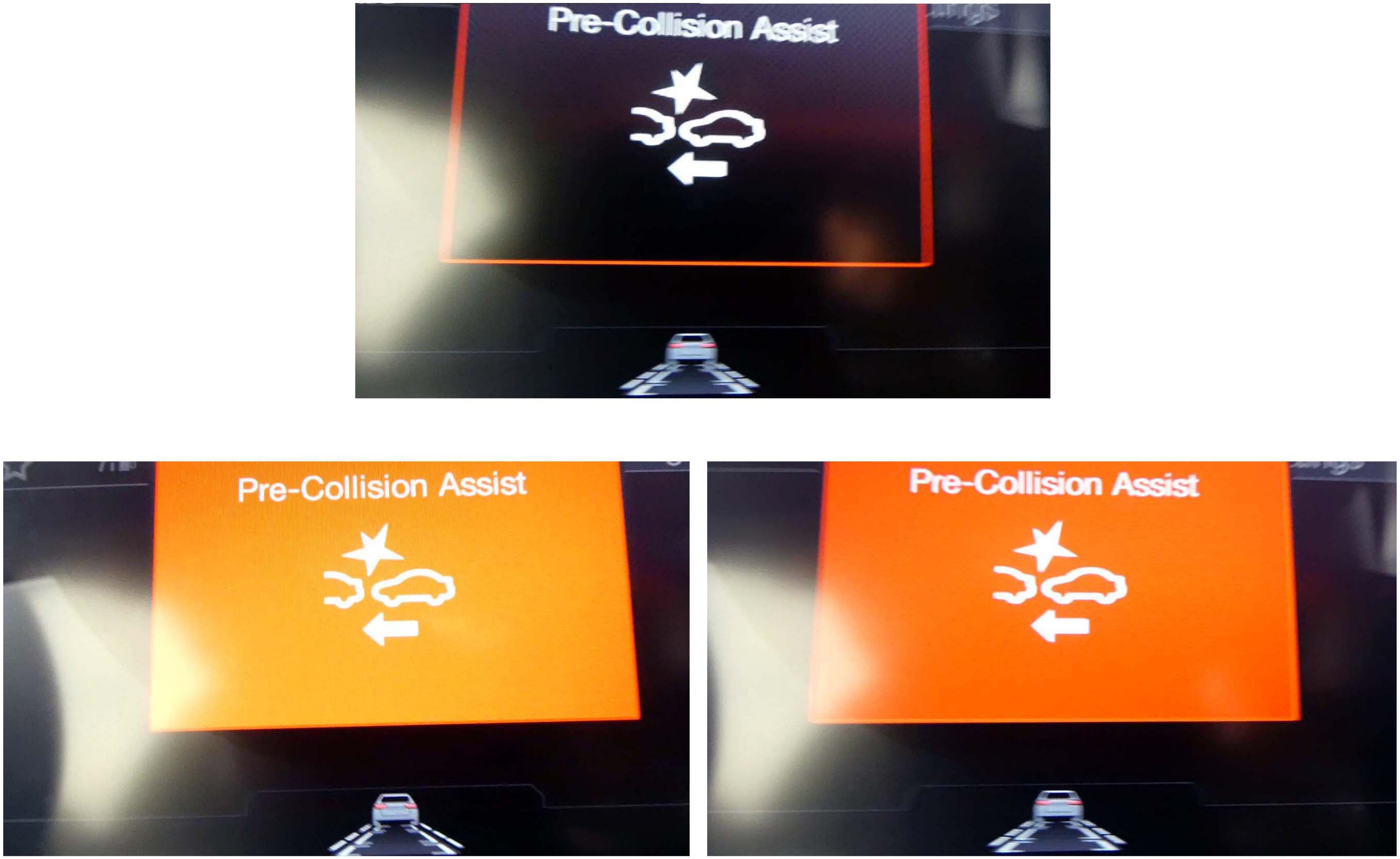

Figure A13. Controls for System Setup

APPENDIX B

Excerpts from Owner's Manual

Settings		
	MyKey	Enter the submenu and select your setting
	Display Setup	Units
		Temperature
		Tire Pressure
		Language

Information Display Controls (Type 3) (If Equipped)

E176093

- Press the up and down arrow buttons to scroll through and highlight the options within a menu.
- Press the right arrow button to enter a sub-menu.
- Press the left arrow button to exit a menu.
- Press the ***OK*** button to choose and confirm a setting or messages.

Main menu

You can access the menus using the information display control.


My View


Trip/Fuel


Truck Info


Towing


Off Road


Settings

My View


Use the arrow buttons to choose between the following My View options.

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Towing	
Connection Checklist	Conventional
	Fifth Wheel
	Gooseneck

Off Road

Use the arrow buttons to choose between the following off road options.

Off Road	
Off Road Status	Pitch, Steering Angle, Roll, Elocker and 4X4
Power Distribution	

Settings

Use the arrow buttons to configure different driver setting choices.

Settings	
Auto Regen	
Cross Traffic Alert	
Driver Alert	
Rear Park Aid	
Trailer Blind Spot	
Pre-Collision	Enter the submenu for items such as alert sensitivity, distance indication and active braking
Cruise Control	Enter the submenu and select your setting
DTE Calculation	Enter the submenu and select your setting

Message	Action
Park Brake Maintenance Mode	The electric park brake system has been put into a special mode that is used to allow service of the rear brakes. Contact an authorized dealer.
Park Brake Limited Function Service Required	The electric park brake system has detected a condition that requires service. Some functionality may still be available. Contact an authorized dealer.
Park Brake Malfunction Service Now	The electric park brake system has detected a condition that requires service. Contact an authorized dealer.

Power Steering

Message	Action
Steering Fault Service Now	The power steering system has detected a condition that requires service. See an authorized dealer.
Steering Loss Stop Safely	The power steering system is not working. Stop your vehicle in a safe place. Contact an authorized dealer.
Steering Assist Fault Service Required	The power steering system has detected a condition within the power steering system or passive entry or passive start system requires service. Contact an authorized dealer.
Steering Lock Malfunction Service Now	The steering lock system has detected a condition that requires service. See an authorized dealer.

Pre-Collision Assist

Message	Action
Pre-Collision Assist Not Available Sensor Blocked	You have a blocked sensor due to bad weather, ice, mud or water in front of the radar sensor. You can typically clean the sensor to resolve.
Pre-Collision Assist Not Available	A fault with the system has occurred. Contact an authorized dealer as soon as possible.

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Extreme continuous steering may increase the effort required for you to steer your vehicle, this increased effort prevents overheating and permanent damage to the steering system. You do not lose the ability to steer your vehicle manually. Typical steering and driving maneuvers allow the system to cool and return to normal operation.

Steering Tips

If the steering wanders or pulls, check for:

- Correct tire pressures.
- Uneven tire wear.
- Loose or worn suspension components.
- Loose or worn steering components.
- Improper vehicle alignment.

Note: *A high crown in the road or high crosswinds may also make the steering seem to wander or pull.*

Adaptive Learning (If Equipped)

The electronic power steering system adaptive learning helps correct road irregularities and improves overall handling and steering feel. It communicates with the brake system to help operate advanced stability control and accident avoidance systems. Additionally, whenever the battery is disconnected or a new battery installed, you must drive your vehicle a short distance before the system relearns the strategy and reactivates all systems.

PRE-COLLISION ASSIST

⚠ **WARNING:** You are responsible for controlling your vehicle at all times. The system is designed to be an aid and does not relieve you of your responsibility to drive with due care and attention. Failure to follow this instruction could result in the loss of control of your vehicle, personal injury or death.

⚠ **WARNING:** The system does not detect vehicles that are driving in a different direction, cyclists or animals. Failure to take care may result in the loss of control of your vehicle, serious personal injury or death.

⚠ **WARNING:** The system does not operate during hard acceleration or steering. Failure to take care may lead to a crash or personal injury.

⚠ **WARNING:** The system may fail or operate with reduced function during cold and severe weather conditions. Snow, ice, rain, spray and fog can adversely affect the system. Keep the front camera and radar free of snow and ice. Failure to take care may result in the loss of control of your vehicle, serious personal injury or death.

⚠ **WARNING:** In situations where the vehicle camera has limited detection capability, this may reduce system performance. These situations include but are not limited to direct or low sunlight, vehicles at night without tail lights, unconventional vehicle types, pedestrians with complex backgrounds,

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partly obscured pedestrians, or pedestrians that the system cannot distinguish from a group. Failure to take care may result in the loss of control of your vehicle, serious personal injury or death.

WARNING: The system cannot help prevent all crashes. Do not rely on this system to replace driver judgment and the need to maintain a safe distance and speed.

Using the Pre-Collision Assist System

The Pre-Collision Assist system is active at speeds above approximately 3 mph (5 km/h) and pedestrian detection is active at speeds up to 50 mph (80 km/h).


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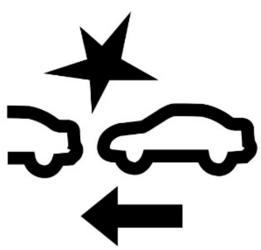
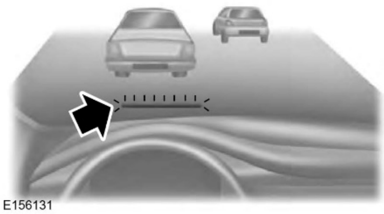
If your vehicle is rapidly approaching another stationary vehicle, a vehicle traveling in the same direction as yours, or a pedestrian within your driving path, the system provides three levels of functionality:

1. Alert
2. Brake Support
3. Active Braking


E255268


E156131

Alert: When active, a flashing visual warning appears and an audible warning tone sounds.

Brake Support: The system is designed to help reduce the impact speed by preparing the brakes for rapid braking. The system does not automatically apply the brakes. If you press the brake pedal, the system could apply additional braking up to maximum braking force, even if you lightly press the brake pedal.

Active Braking: Active braking may activate if the system determines that a collision is imminent. The system may help the driver reduce impact damage or avoid the crash completely.

Note: *Brake Support and Active Braking are active at speeds up to 75 mph (120 km/h). If the vehicle has a radar sensor or Adaptive Cruise Control, then Brake Support and Active Braking are active up to the maximum speed of the vehicle.*

Note: *If you perceive Pre-Collision Assist alerts as being too frequent or disturbing, then you can reduce the alert sensitivity, though the manufacturer recommends using the highest sensitivity setting where possible. Setting lower sensitivity would lead to fewer and later system warnings.*

Note: *The Pre-Collision Assist system automatically disables when you select **4X4 LOW** or when you manually disable AdvanceTrac™.*

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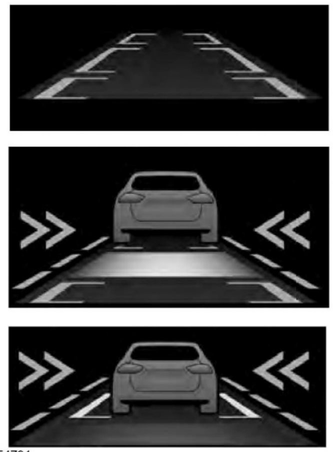
Distance Indication and Alert (If Equipped)

Distance Indication and Alert is a function that provides the driver with a graphical indication of the time gap to other preceding vehicles traveling in the same direction. The Distance Indication and Alert screen in the display screen shows one of the graphics that follow.



E254791

If the time gap to a preceding vehicle is small, a red visual indication displays.

Note: *Distance Indication and Alert deactivates and the graphics do not display when Adaptive Cruise Control is active.*

Speed	Sensitivity	Graphics	Distance Gap	Time Gap
62 mph (100 km/h)	Normal	Grey	>82 ft (25 m)	>0.9sec
62 mph (100 km/h)	Normal	Yellow	56–82 ft (17–25 m)	0.6sec — 0.9sec
62 mph (100 km/h)	Normal	Red	<56 ft (17 m)	<0.6sec

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Adjusting the Pre-Collision Assist Settings

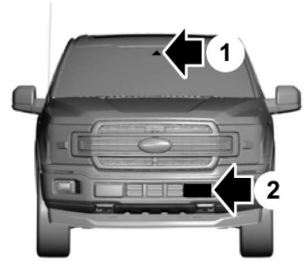
You can adjust the following settings by using the information display controls. See **General Information** (page 120).

- You can change Alert and Distance Alert sensitivity to one of three possible settings.
- You can switch Distance Indication and Alert on or off.
- If required, you can switch Active Braking on or off.
- If required, you can switch the entire Pre-Collision Assist feature on or off.

Note: *Active braking automatically turns on every time you switch the ignition on.*

Note: *If your vehicle has a radar sensor, we recommend that you switch the system off if you install a snow plow or similar object in such a way that it may block the radar sensor. Your vehicle remembers the selected setting across key cycles.*

Blocked Sensors



1 Camera.

2 Radar sensor (if equipped).

If a message regarding a blocked sensor or camera appears in the information display, the radar signals or camera images are obstructed. If your vehicle has a radar sensor, it is located behind the fascia cover in the center of the lower grille. With a blocked sensor or camera, the Pre-Collision Assist system may not function, or performance may reduce. The following table lists possible causes and actions for when this message displays.

Camera Troubleshooting

Cause	Action
The windshield in front of the camera is dirty or obstructed in some way.	Clean the outside of the windshield in front of the camera.
The windshield in front of the camera is clean but the message remains in the display screen.	Wait a short time. It may take several minutes for the camera to detect that there is no obstruction.

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Radar Troubleshooting (If Equipped)

Cause	Action
The surface of the radar in the grille is dirty or obstructed in some way.	Clean the grille surface in front of the radar or remove the object causing the obstruction.
The surface of the radar in the grille is clean but the message remains in the display screen.	Wait a short time. It may take several minutes for the radar to detect that there is no obstruction.
Heavy rain, spray, snow or fog is interfering with the radar signals.	The Pre-Collision Assist system is temporarily disabled. Pre-Collision Assist automatically reactivates a short time after the weather conditions improve.
Swirling water or snow or ice on the surface of the road may interfere with the radar signals.	The Pre-Collision Assist system is temporarily disabled. Pre-Collision Assist automatically reactivates a short time after the weather conditions improve.
Radar is out of alignment due to a front end impact.	Contact an authorized dealer to have the radar checked for proper coverage and operation.

Note: *Proper system operation requires a clear view of the road by the camera. Have any windshield damage in the area of the camera's field of view repaired.*

Note: *If something hits the front end of your vehicle or damage occurs and your vehicle has a radar sensor, the radar sensing zone may change. This could cause missed or false vehicle detections. Contact an authorized dealer to have the radar checked for proper coverage and operation.*

Note: *If your vehicle detects excessive heat at the camera or a potential misalignment condition, a message may display in the information display indicating temporary sensor unavailability. When operational conditions are correct, the message deactivates. For example, when the ambient temperature around the sensor decreases or the sensor automatically recalibrates successfully.*

DRIVE CONTROL

Selectable Drive Modes

This provides a single location to control multiple system performance settings such as steering, handling and powertrain response.

Changing the drive mode automatically changes the functionality of the following systems:

F-150 (TFC) Canada/United States of America, enUSA, Edition date: 201907, Third-Printing-

APPENDIX C

Run Log

Subject Vehicle: **2020 Ford F-150 4X4 SuperCrew** Test Date: **5/22/2020**

Principal Other Vehicle: **GVT**

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Acceptability Criteria met [5]	Notes
42	Static Run								
43	**Stopped POV, 25 mph**	Y	1.69	1.76	24.3	0.94	1.26	Yes	
44		Y	1.72	1.65	24.5	0.85	1.29	Yes	
45		Y	1.64	1.68	24.6	0.91	1.28	Yes	
46		Y	1.65	1.60	24.6	0.83	1.31	Yes	
47		Y	1.68	1.78	24.7	0.81	1.34	Yes	
56		Y	1.69	1.78	24.5	0.80	1.35	Yes	
57		Y	1.67	2.08	24.6	0.80	1.34	Yes	
58	Static Run								
48	Static Run								
49	**Stopped POV, 30 mph**	Y	1.80	1.91	29.9	1.05	1.24	Yes	
50		Y	1.80	2.22	30.1	1.06	1.27	Yes	
51		Y	1.84	0.00	26.1	1.01	1.24	Yes	
52		Y	1.77	0.95	29.5	1.02	1.20	Yes	
53		Y	1.88	0.00	28.0	1.01	1.22	Yes	
54	Static Run								
55	**Stopped POV, 35 mph**	Y	1.94	0.00	25.2	1.00	1.11	Yes	
59		Y	2.00	0.00	23.3	1.06	1.21	Yes	
60		Y	1.93	0.00	22.9	1.01	1.15	Yes	
61		Y	2.01	0.00	25.0	1.02	1.14	Yes	

[5] The acceptability criteria listed herein are used only a guide to gauge vehicle performance, and are identical to the Pass/Fail criteria given in 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.

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Acceptability Criteria met [5]	Notes
62		Y	2.01	0.00	22.3	1.00	1.13	Yes	
63	Static Run								
64	**Stopped POV, 40 mph**	Y	2.04	0.00	20.5	1.01	1.10	Yes	
65		Y	2.08	0.00	22.9	1.00	1.23	Yes	
66		Y	2.12	0.00	21.1	1.01	1.15	Yes	
67		Y	2.11	0.00	21.0	1.02	1.17	Yes	
68		N							Coms error
69		Y	2.07	0.00	19.9	0.98	1.09	Yes	
70	Static Run								
71	**Stopped POV, 45 mph**	Y	2.19	0.00	19.8	1.07	1.11	Yes	
72		Y	2.10	0.00	16.0	0.99	1.00	Yes	
73		Y	2.00	0.00	19.7	1.05	1.05	Yes	
74		Y	2.12	0.00	16.3	1.04	0.77	Yes	
75		Y	2.18	0.00	19.5	1.03	1.07	Yes	
76	Static Run								
1	Static Run								
2	**Slower POV, 25 mph**	Y	1.84	3.83	14.8	0.79	0.86	Yes	
3		Y	1.81	3.45	14.5	0.78	0.84	Yes	
4		N							Communication dropouts
5		N							Lateral offset
6		Y	1.82	3.29	14.9	0.78	0.86	Yes	
7		Y	1.87	4.84	14.8	0.82	0.87	Yes	
8		Y	1.83	4.22	14.8	0.79	0.84	Yes	
9		Y	1.80	3.35	14.8	0.77	0.83	Yes	
10	Static Run								

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Acceptability Criteria met [5]	Notes
11	**Slower POV, 45 mph**	Y	2.42	2.83	24.9	0.98	1.02	Yes	
12		Y	2.52	3.70	25.0	1.02	1.07	Yes	
13		Y	2.51	3.50	24.8	0.98	1.02	Yes	
14		Y	2.52	1.96	24.9	1.00	1.07	Yes	
15		Y	2.52	2.89	24.8	1.02	1.10	Yes	
16		Y	2.49	1.96	24.7	1.05	1.12	Yes	
17		N							POV GPS
18		Y	2.43	1.60	24.8	1.03	1.12	Yes	
19	Static Run								
20	**Decelerating POV, 0.3 g, 35 mph**	Y	1.75	0.00	27.0	0.93	1.10	Yes	
21		N							SV brakes
22		Y	1.71	0.00	27.8	0.87	1.16	Yes	
23		Y	1.80	3.17	24.0	1.02	1.13	Yes	
24		Y	1.75	0.00	31.3	1.00	1.20	Yes	
25		Y	1.79	0.49	35.1	1.06	1.17	Yes	
26		Y	1.73	0.00	30.0	1.00	1.20	Yes	
27		Y	1.75	0.55	34.7	1.08	1.26	Yes	
28	Static Run								
29	**Decelerating POV, 0.5 g, 35 mph**	Y	1.40	0.13	34.8	1.04	1.04	Yes	
30		Y	1.36	0.00	28.8	1.04	1.06	Yes	
31		Y	1.46	0.00	31.4	1.01	1.06	Yes	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Acceptability Criteria met [5]	Notes
32		Y	1.43	0.00	34.0	1.11	1.07	Yes	
33		Y	1.45	0.00	30.7	1.04	1.14	Yes	
34	Static Run								
35	**Decelerating POV, 0.3 g, 45 mph**	N							Lateral offset
36		Y	1.74	2.37	44.9	1.02	1.14	Yes	
37		N							SV brakes
38		Y	1.79	1.43	24.5	1.04	1.15	Yes	
39		Y	1.63	1.51	24.3	1.01	1.14	Yes	
40		Y	1.70	0.48	24.0	1.02	1.10	Yes	
41		Y	1.70	2.50	24.0	1.02	1.17	Yes	

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) -
Stopped POV (SV at 30 mph)
Stopped POV (SV at 35 mph)
Stopped POV (SV at 40 mph)
Stopped POV (SV at 45 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)
Decelerating POV 35 mph (Both vehicles at 35 mph with 13.8 m gap, POV brakes at 0.5 g)
Decelerating POV 45 mph (Both vehicles at 45 mph with 13.8 m gap, POV brakes at 0.3 g)

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 front-most point of the Subject Vehicle and the rearmost point of the Global Vehicle Target (GVT). 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. The lateral offset is defined to be the lateral distance between the centerline of the SV and the centerline of the POV.

- Ax (g) – Longitudinal acceleration of the Subject Vehicle and Principal Other Vehicle (if any). For CIB tests, the TTC (sec) at the moment of first CIB activation is displayed to the right of the subplot in green. Also, the peak value of Ax for the SV is shown on the subplot.

- Accelerator Pedal Position (0-1) – Normalized position of the accelerator pedal.

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

Envelopes and Thresholds

Some of the time history plot figures contain either green or yellow envelopes and/or black threshold lines. These envelopes and thresholds are used to programmatically and visually determine the validity of a given test run. Envelope and threshold exceedances are indicated with either red shading or red asterisks, and red text is placed to the right side of the plot indicating the type of exceedance. Such exceedances indicate either that the test was invalid or that the requirements of the test were not met (i.e., failure of the AEB system).

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

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

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

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

For the accelerator pedal position plot, a green envelope is given starting 500 ms after the onset of the FCW warning to ensure that the accelerator pedal was released at the correct time and remained off for the duration of the CIB event.

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 Figures D1 through Figure D7. Figures D1 through D4 show passing runs for each of the 4 test types. Figures D5 and D6 show examples of invalid runs. Figure D7 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 D8.

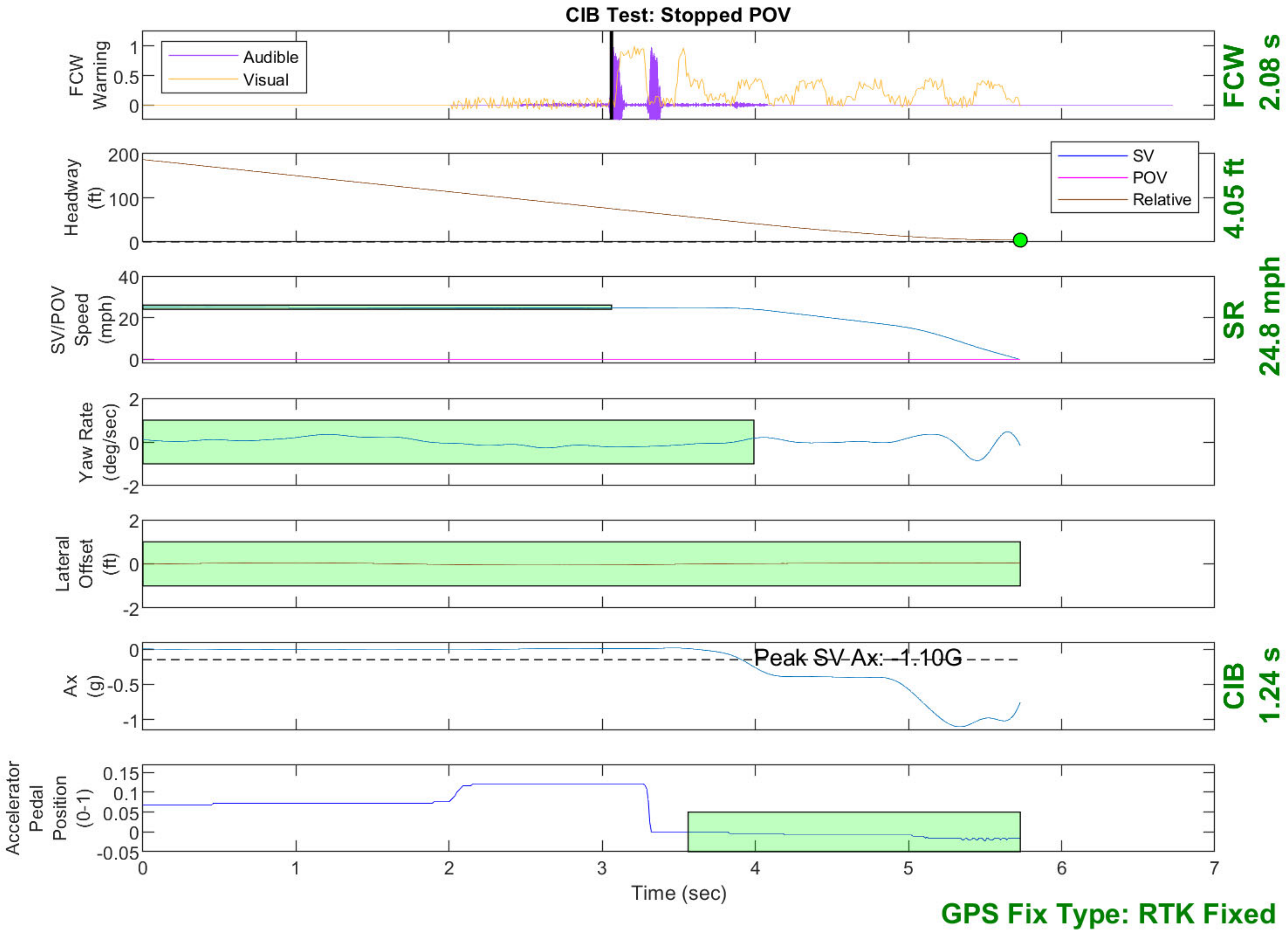

Figure D1. Example Time History for Stopped POV, Passing

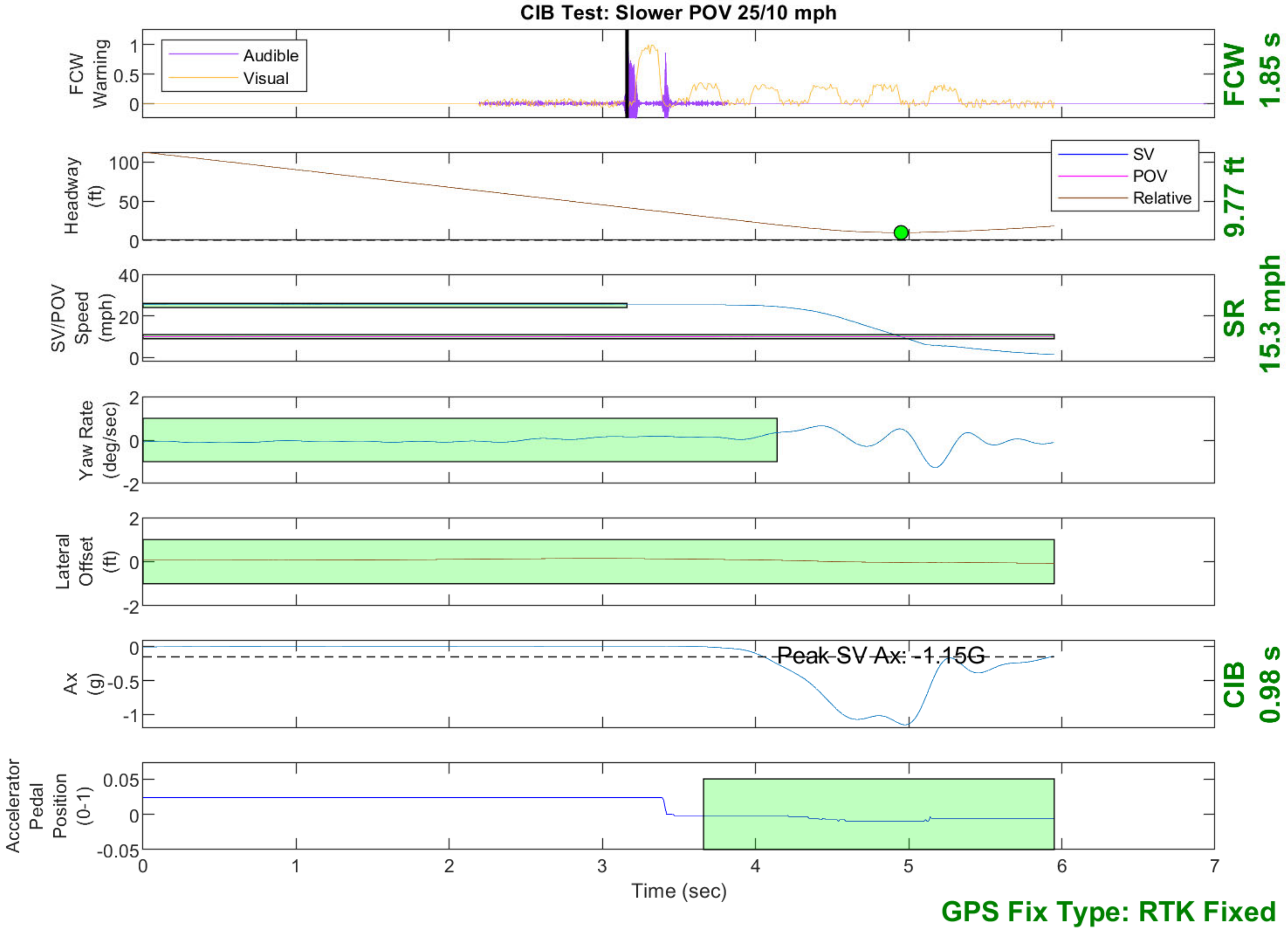

Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

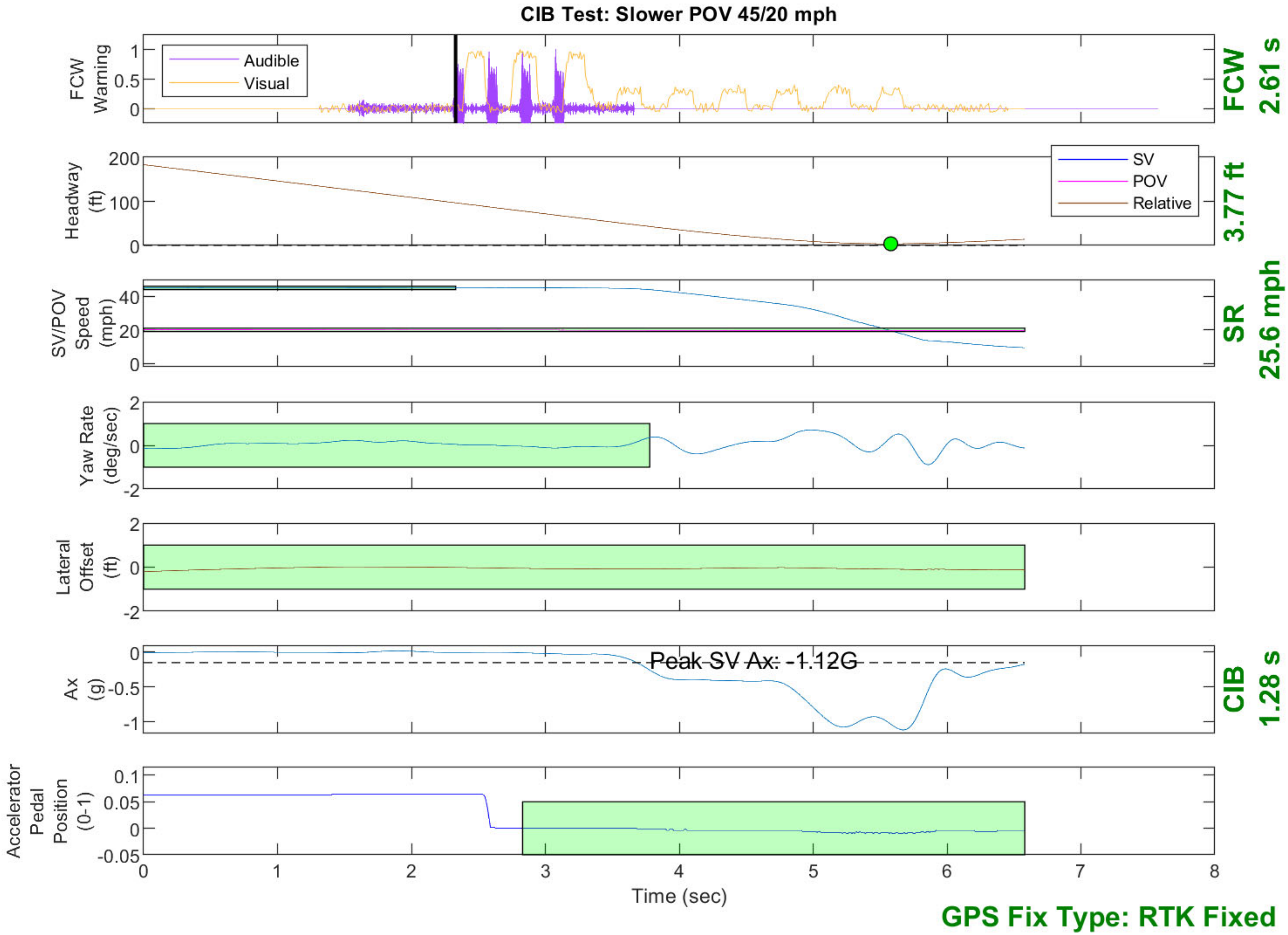

Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

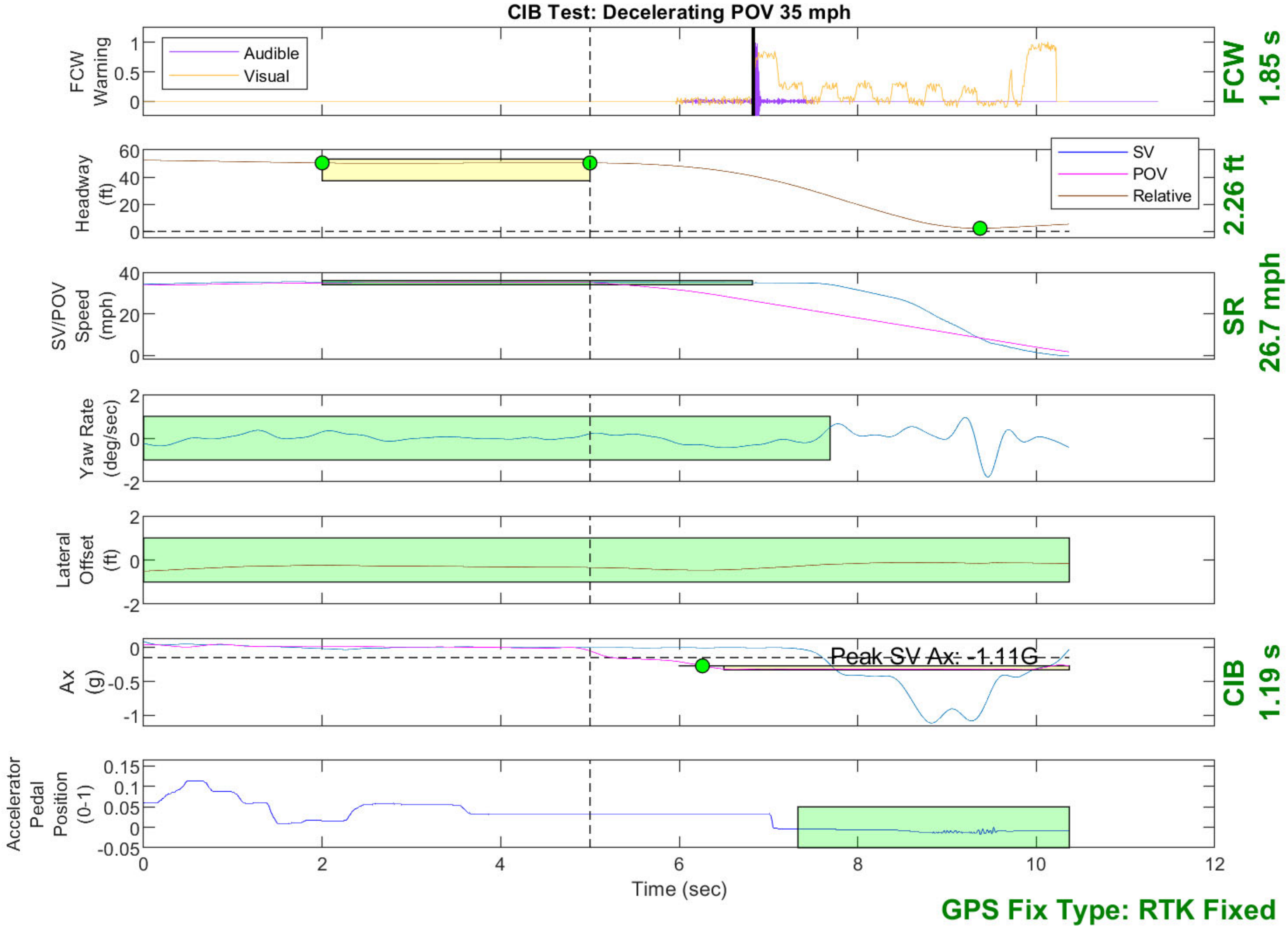

Figure D4. Example Time History for Decelerating POV 35, Passing

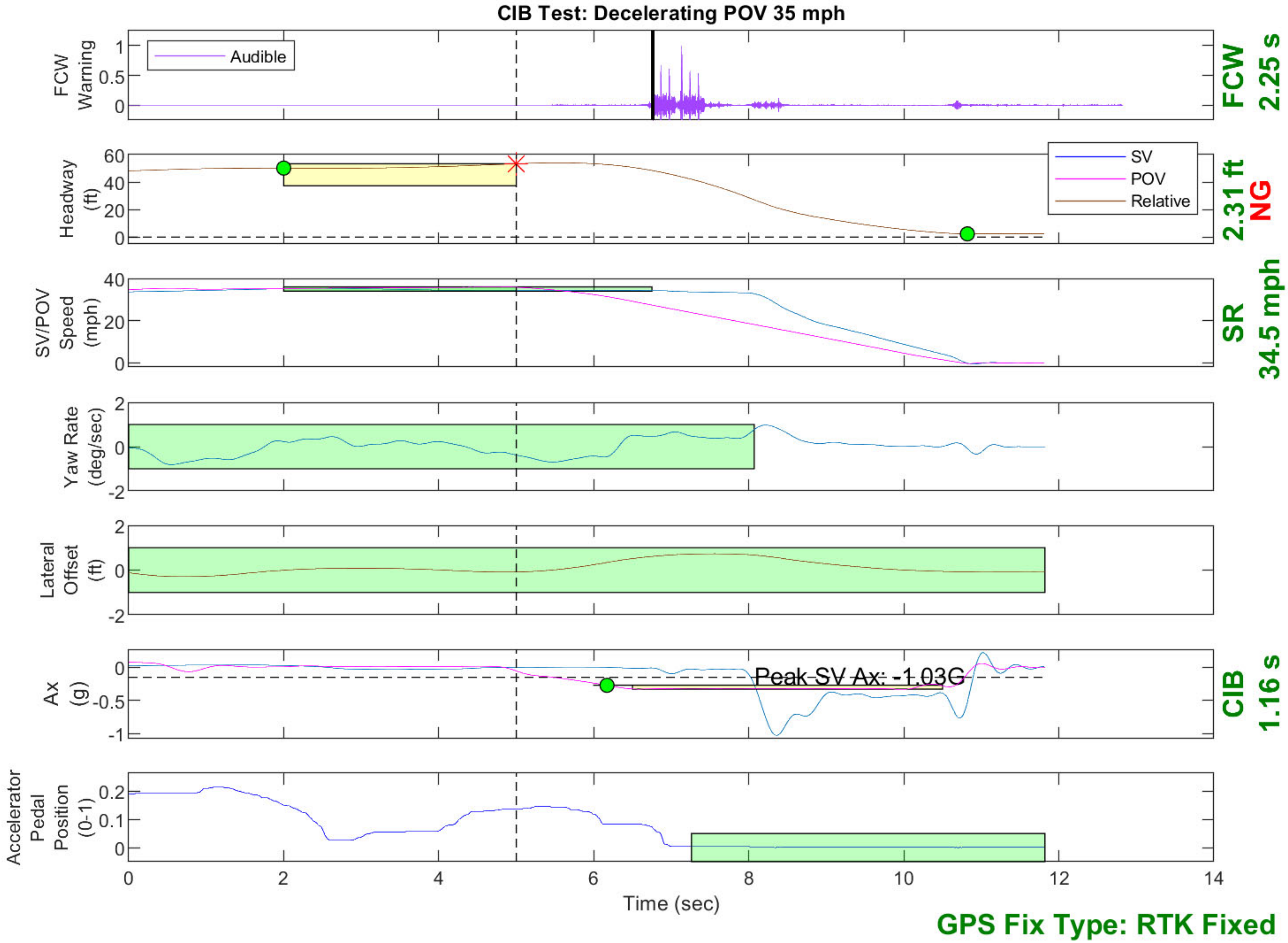

Figure D5. Example Time History Displaying Invalid Headway Criteria

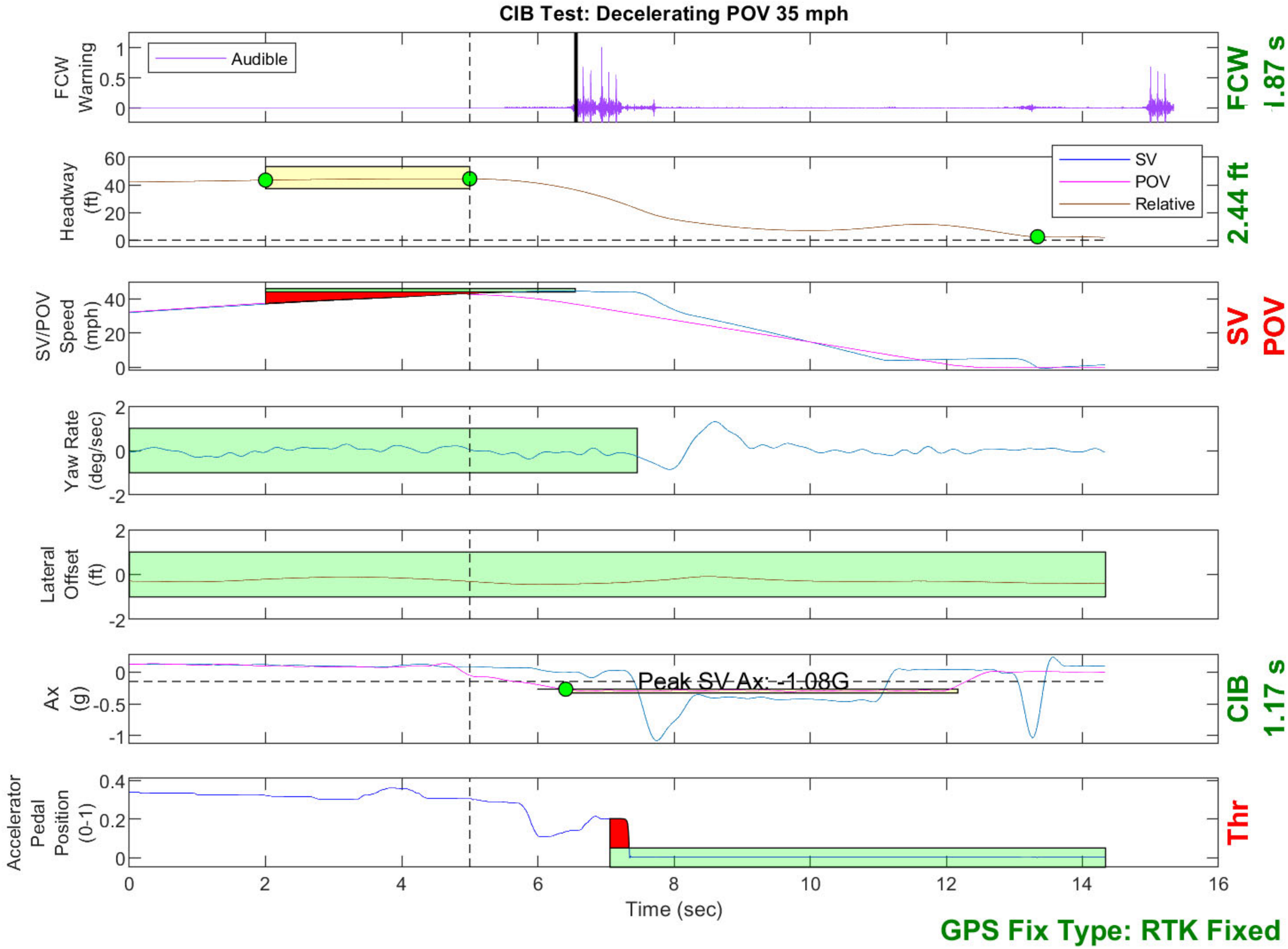

Figure D6. Example Time History Displaying Various Other Invalid Criteria

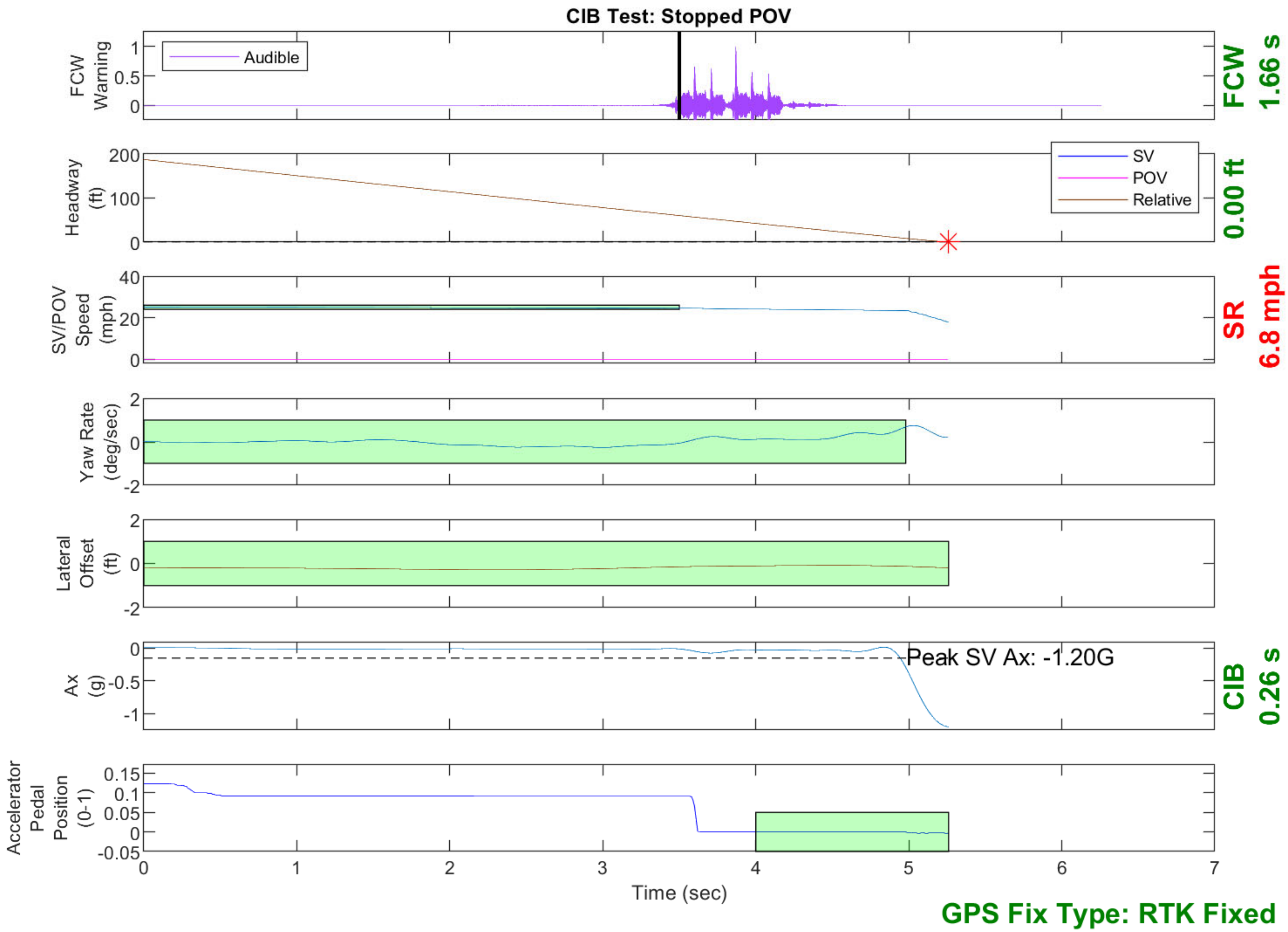

Figure D7. Example Time History for a Failed Run

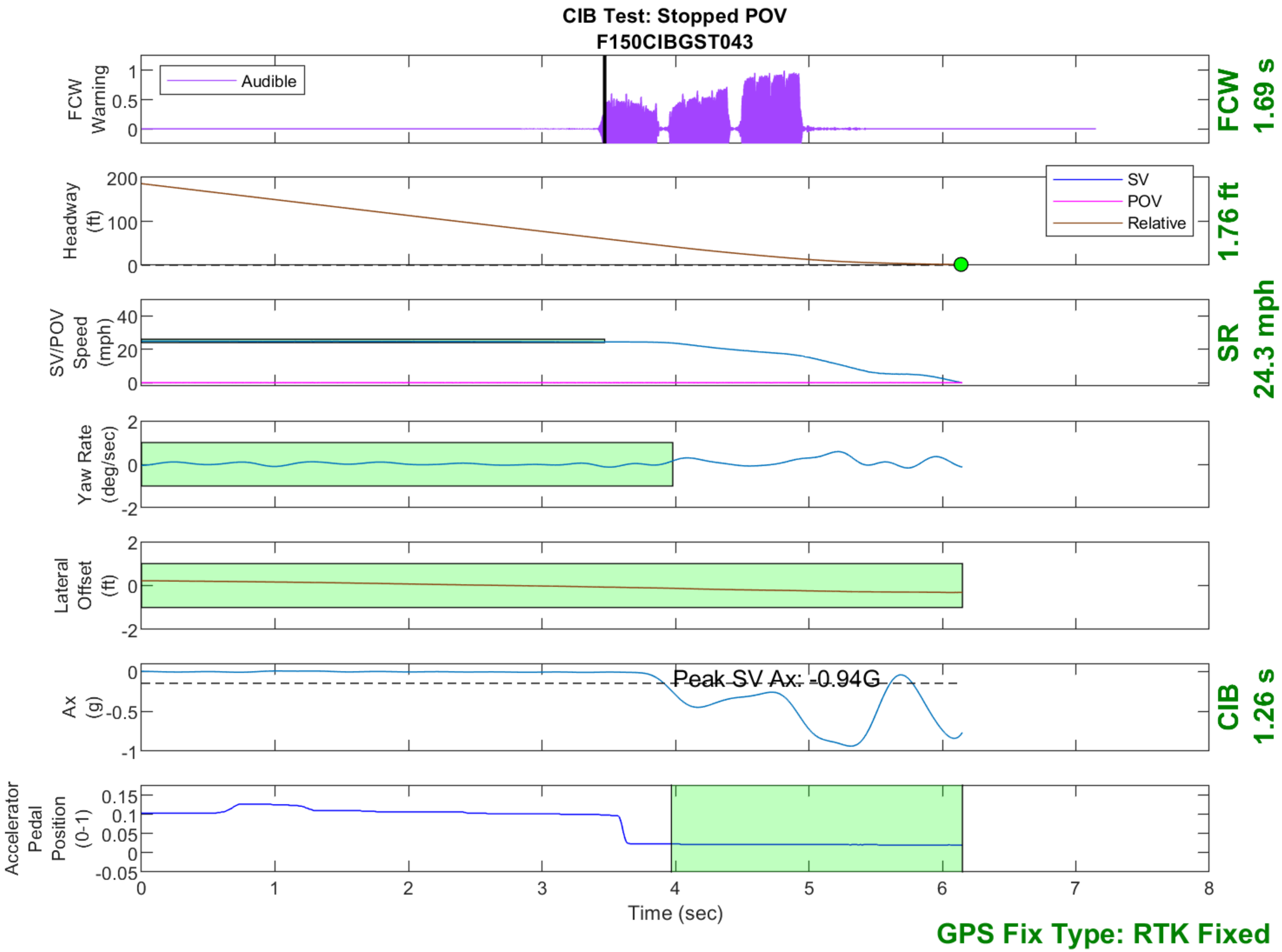

Figure D8. Time History for CIB Run 43, Stopped POV, 25 mph

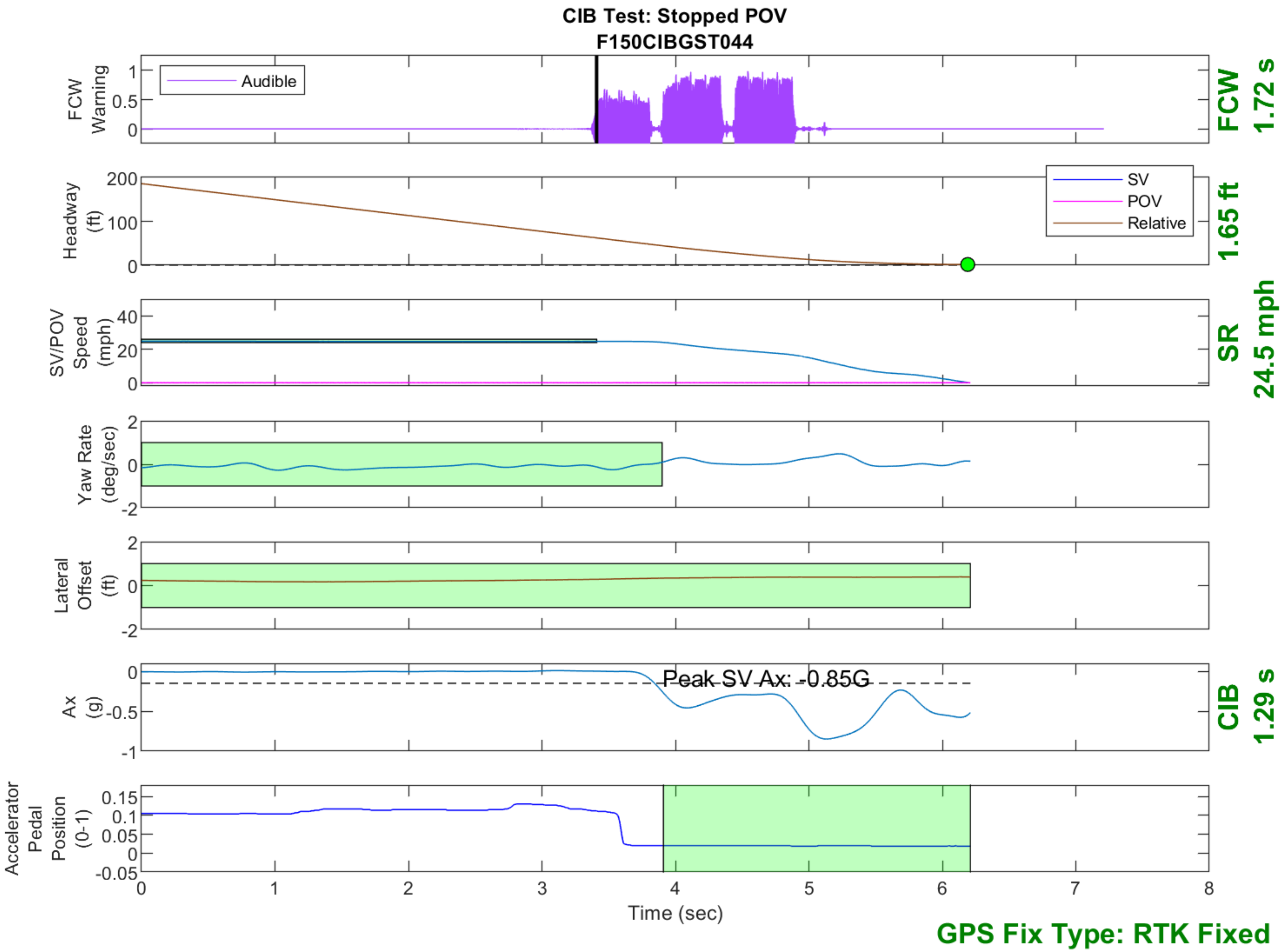

Figure D9. Time History for CIB Run 44, Stopped POV, 25 mph

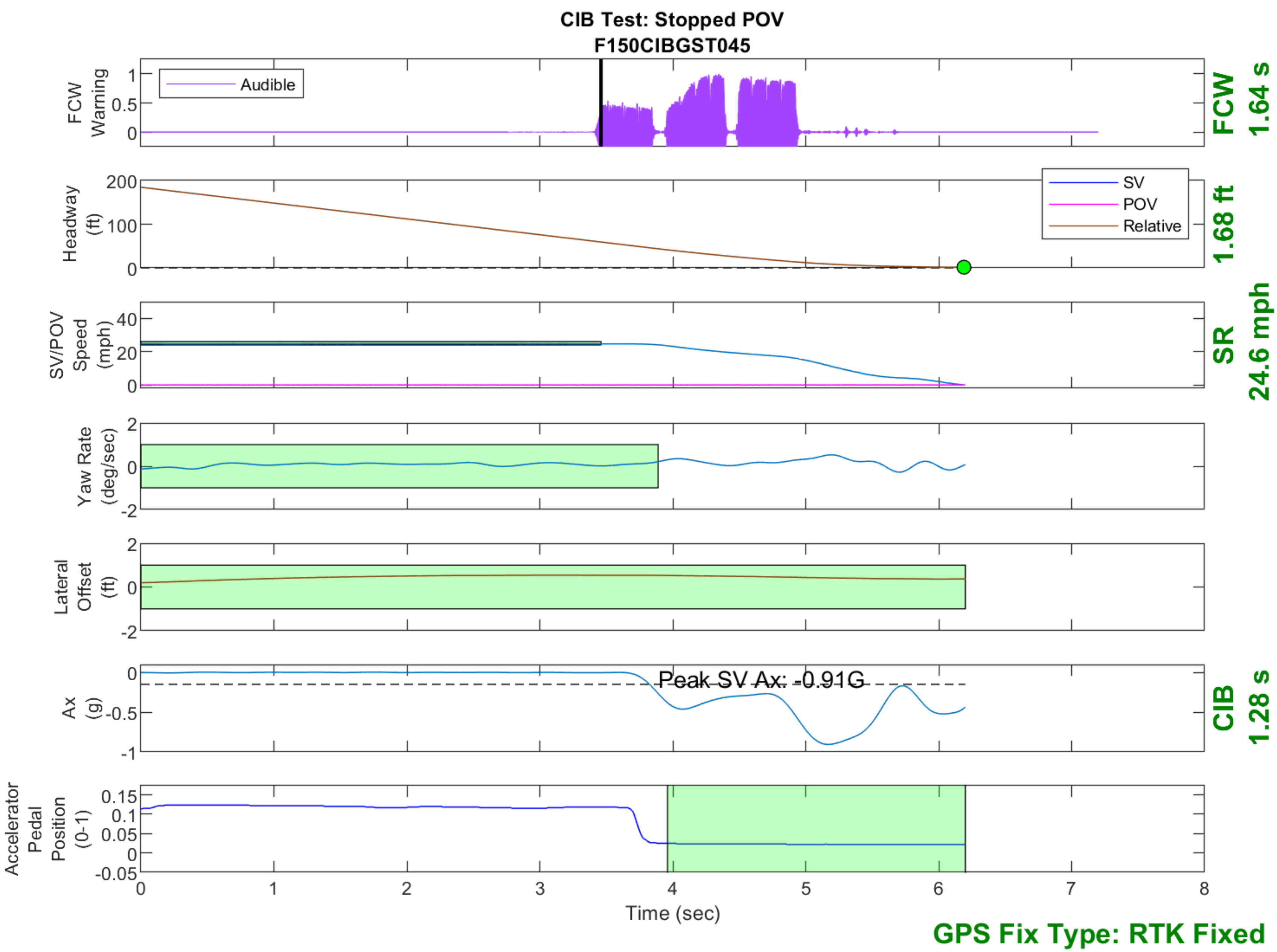

Figure D10. Time History for CIB Run 45, Stopped POV, 25 mph

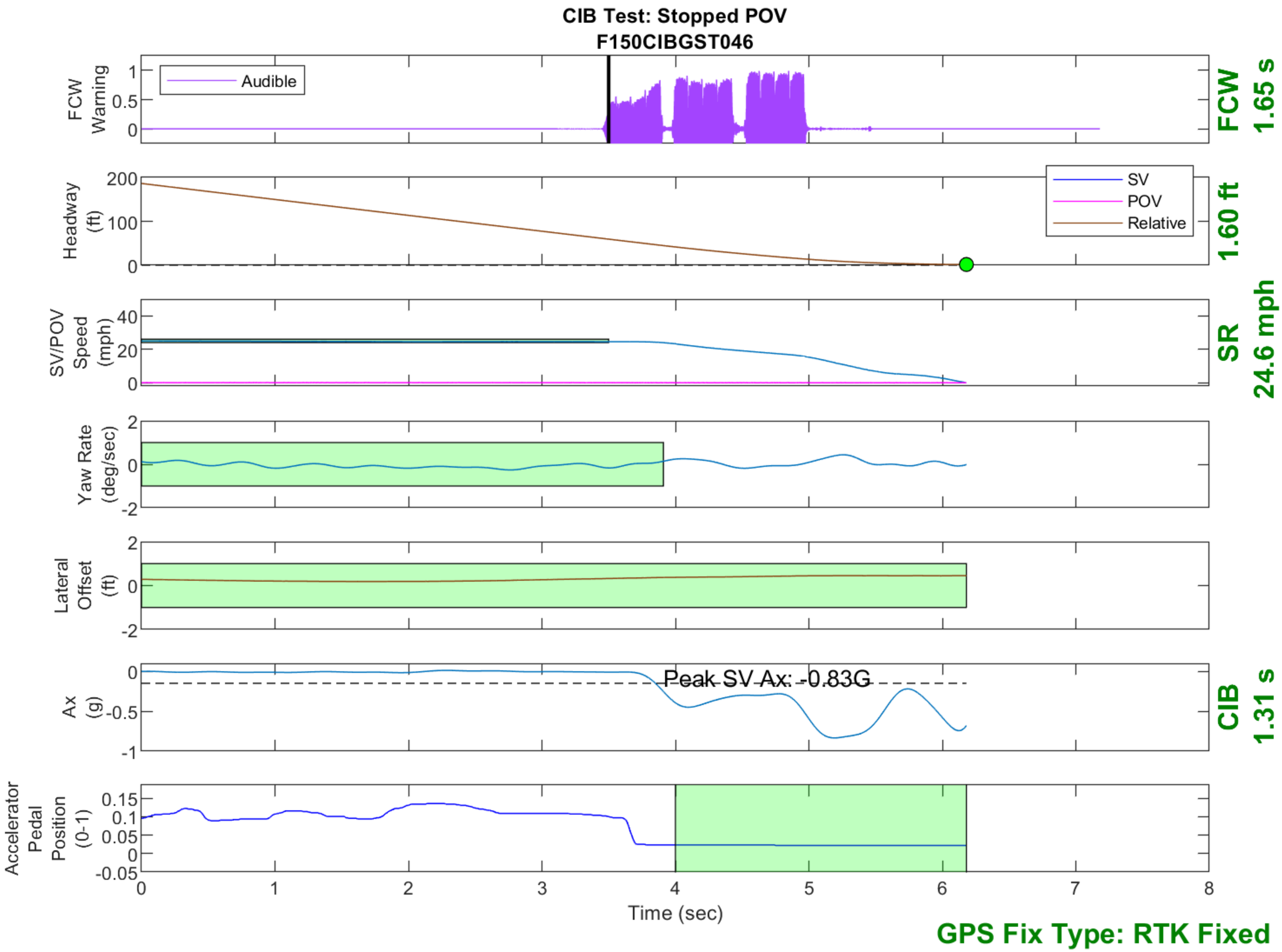

Figure D11. Time History for CIB Run 46, Stopped POV, 25 mph

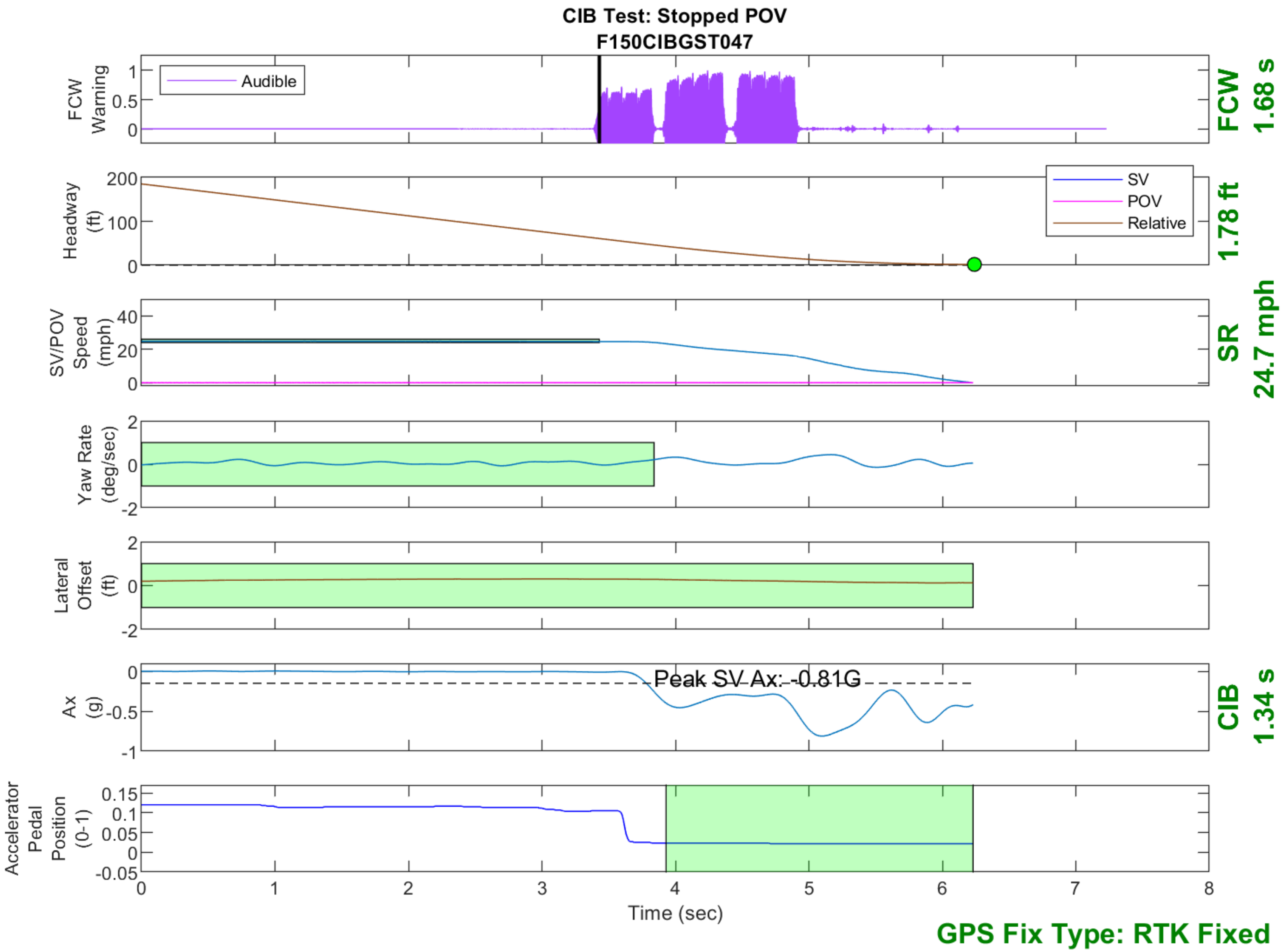

Figure D12. Time History for CIB Run 47, Stopped POV, 25 mph

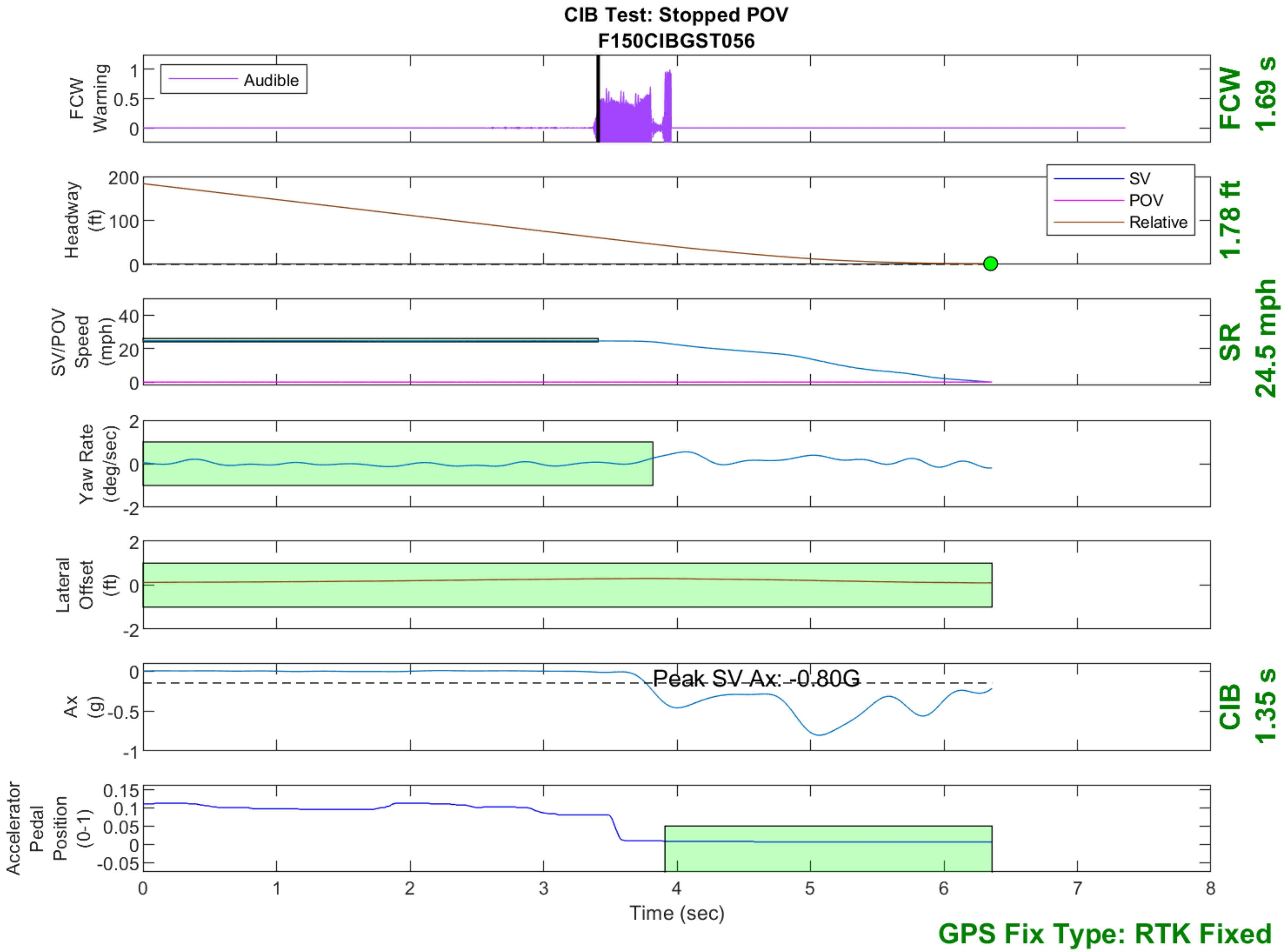

Figure D13. Time History for CIB Run 56, Stopped POV, 25 mph

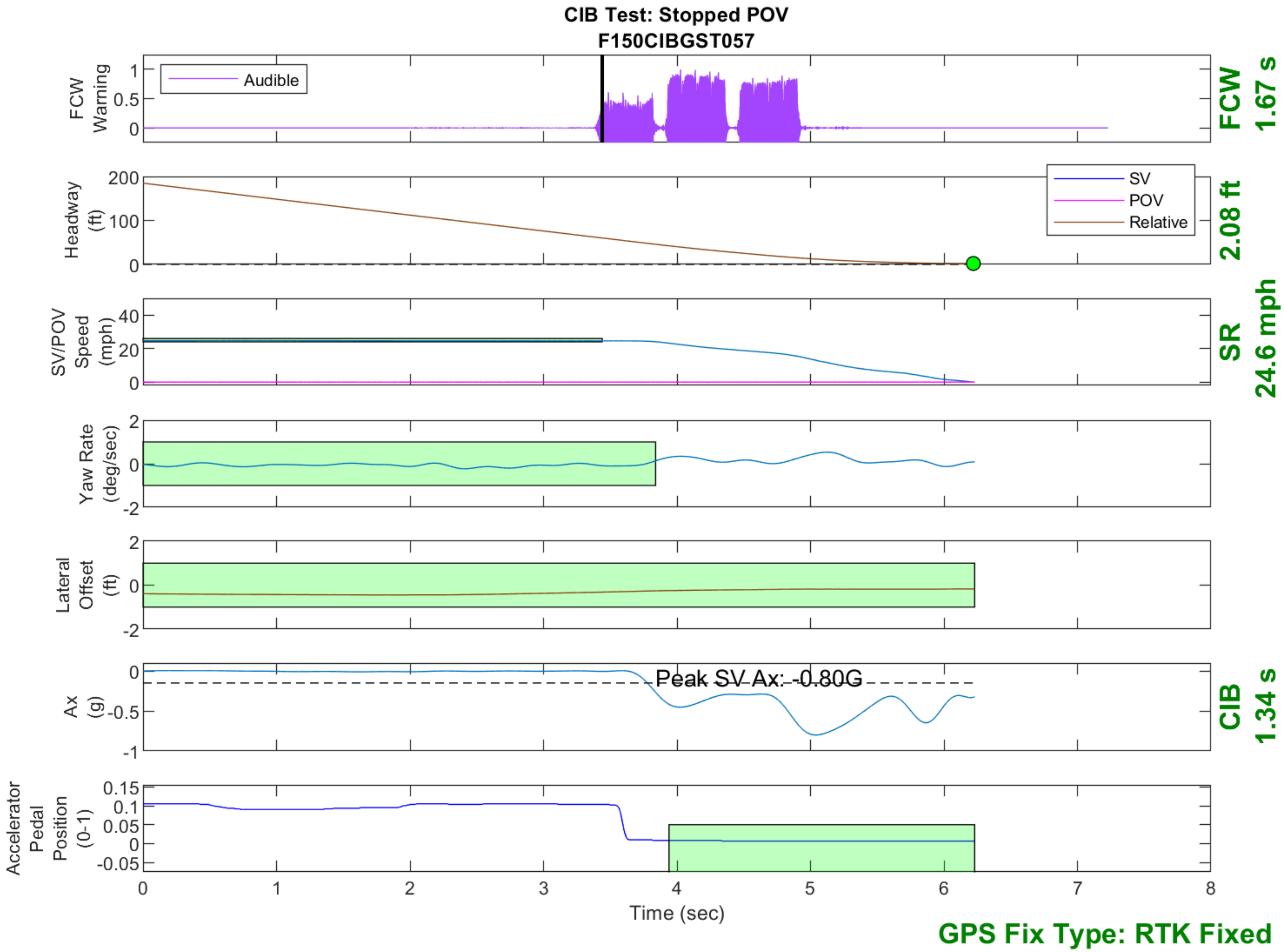

Figure D14. Time History for CIB Run 57, Stopped POV, 25 mph

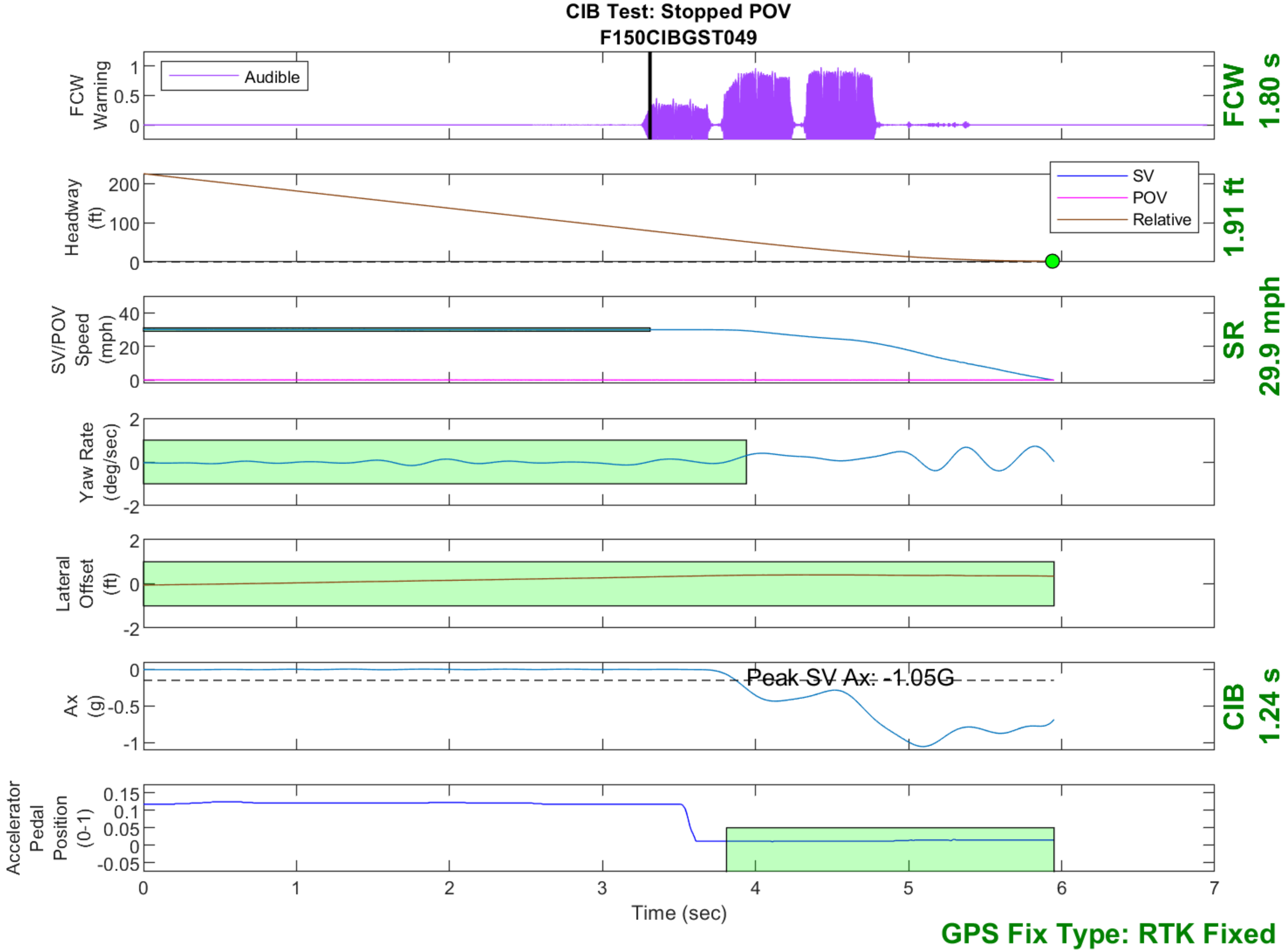

Figure D15. Time History for CIB Run 49, Stopped POV, 30 mph

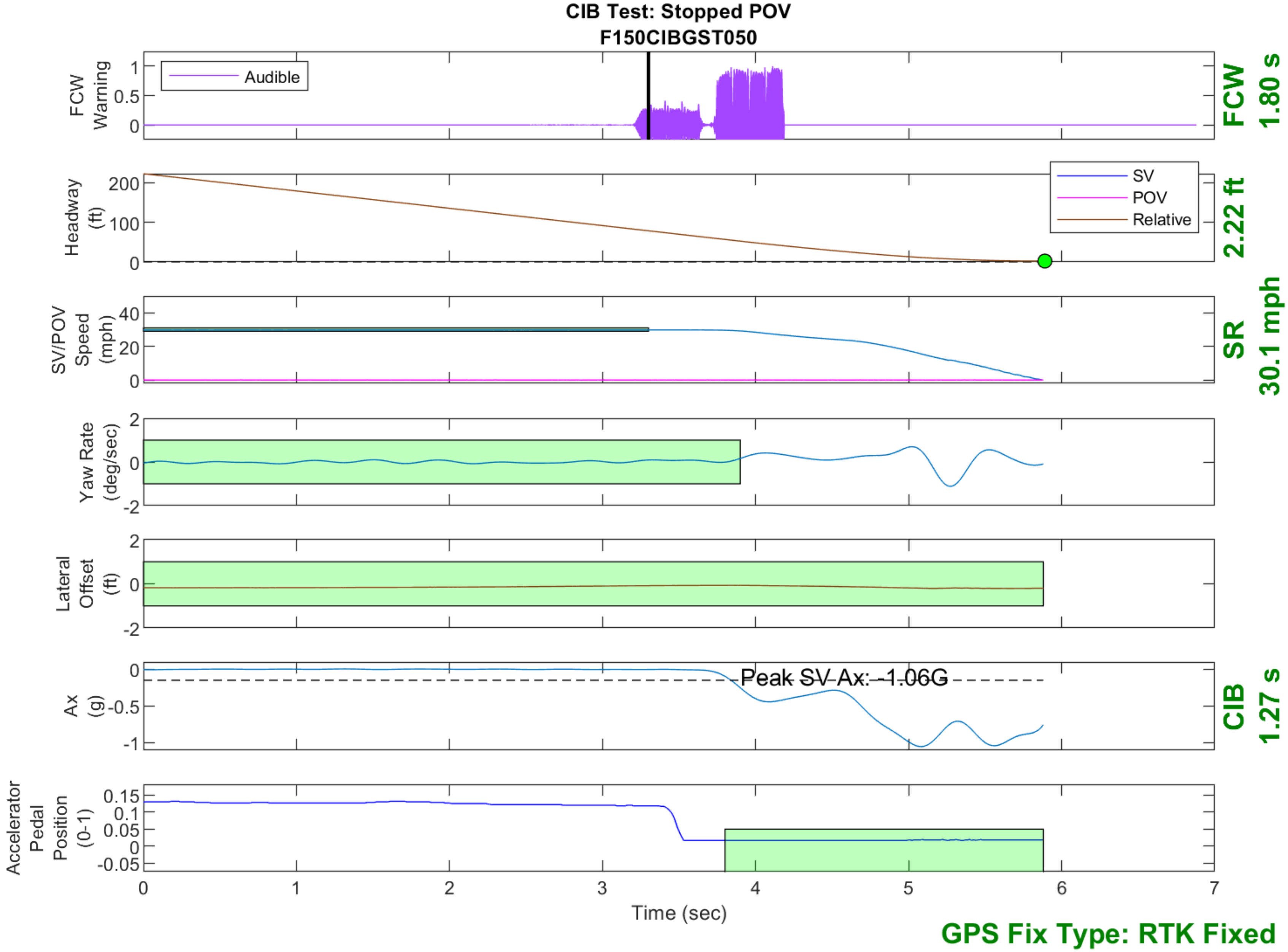

Figure D16. Time History for CIB Run 50, Stopped POV, 30 mph

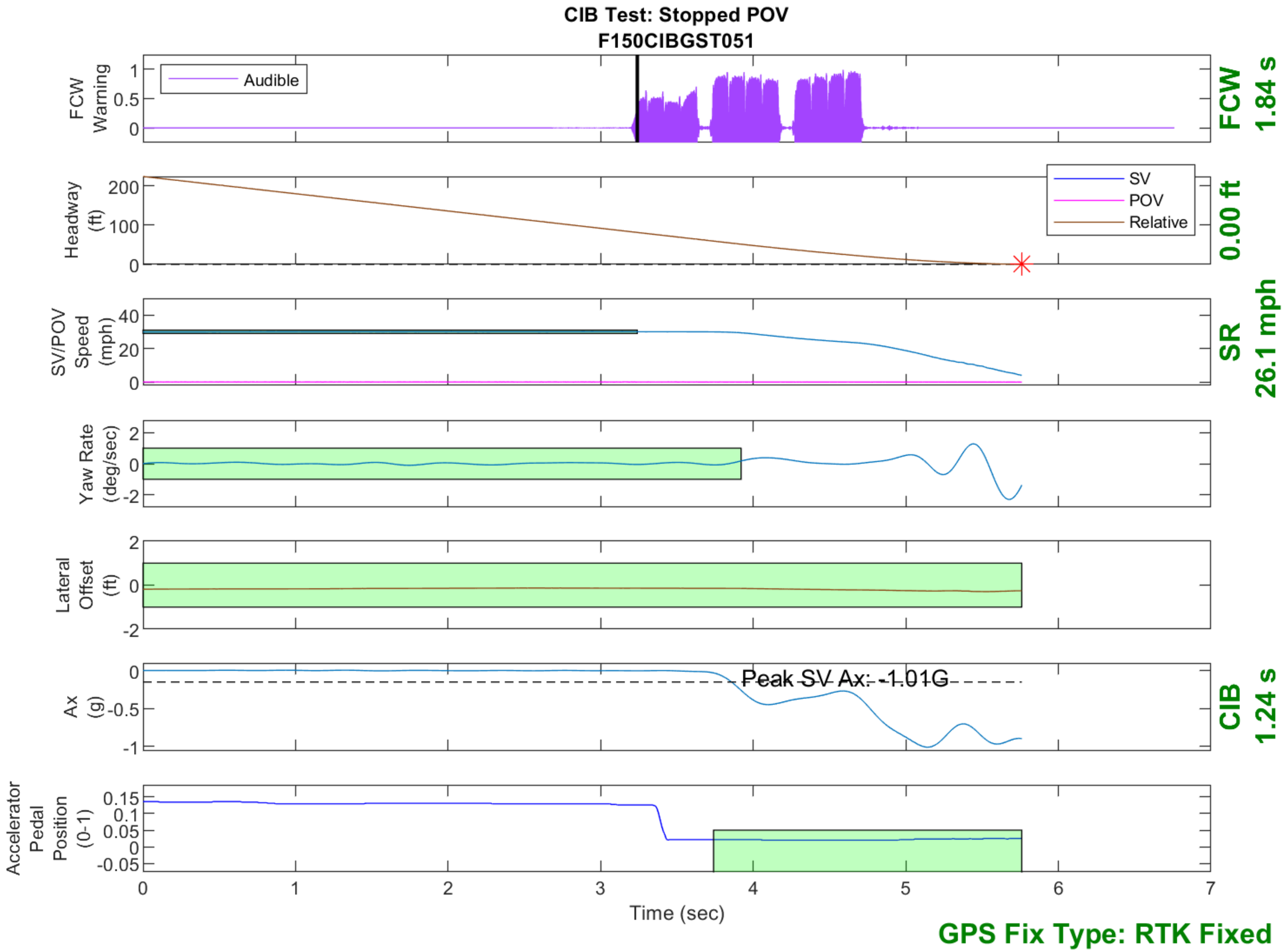

Figure D17. Time History for CIB Run 51, Stopped POV, 30 mph

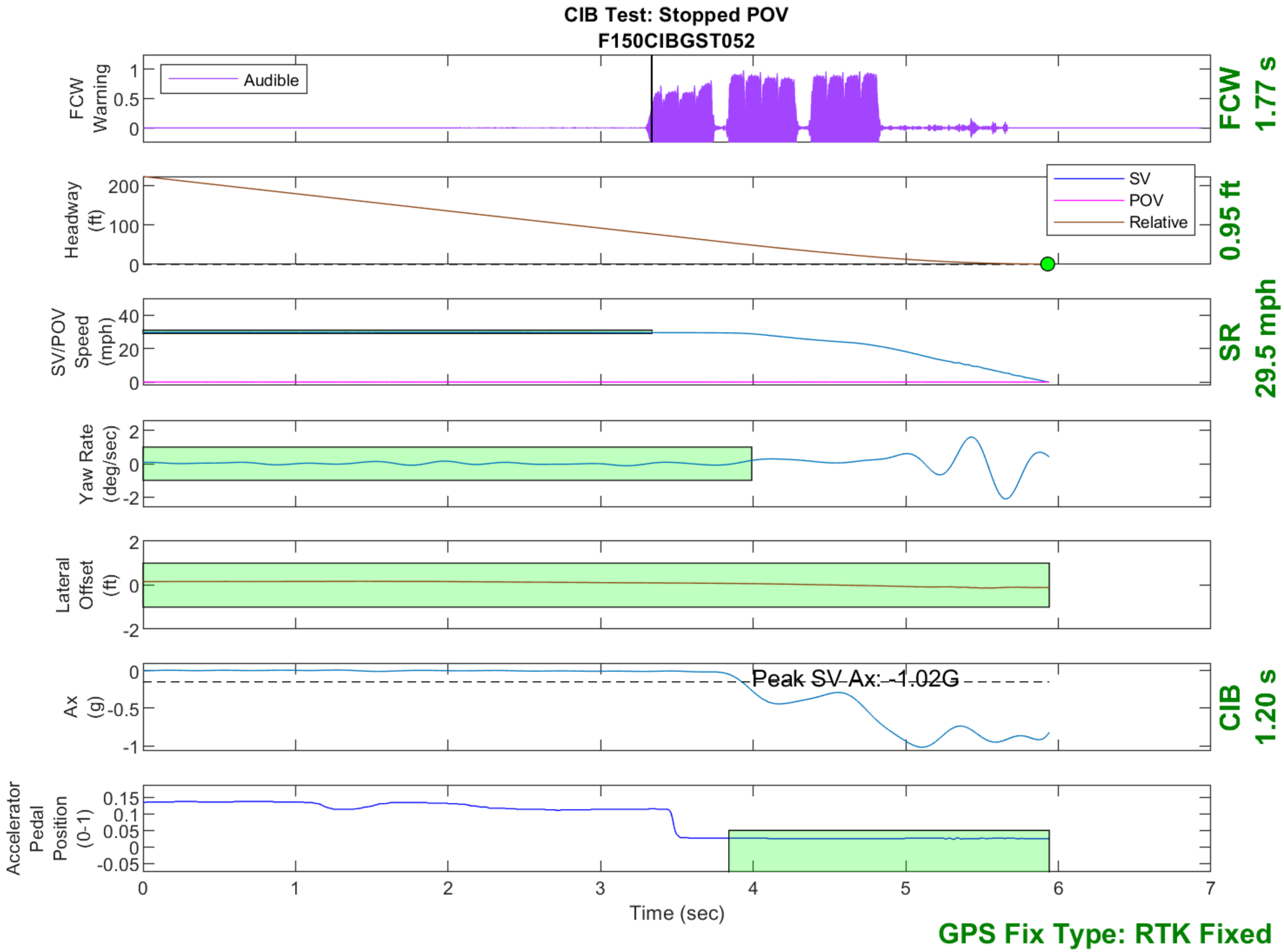

Figure D18. Time History for CIB Run 52, Stopped POV, 30 mph

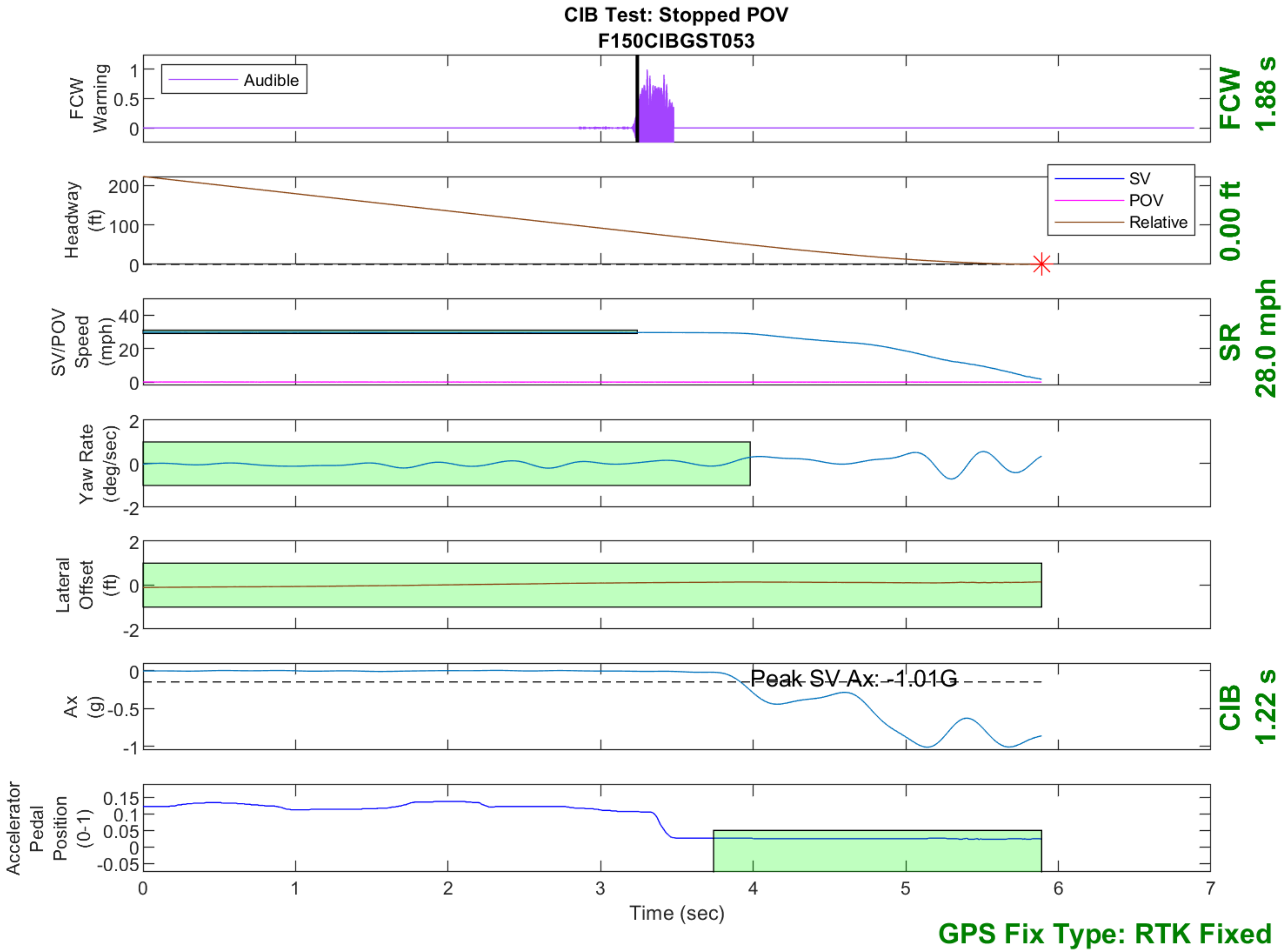

Figure D19. Time History for CIB Run 53, Stopped POV, 30 mph

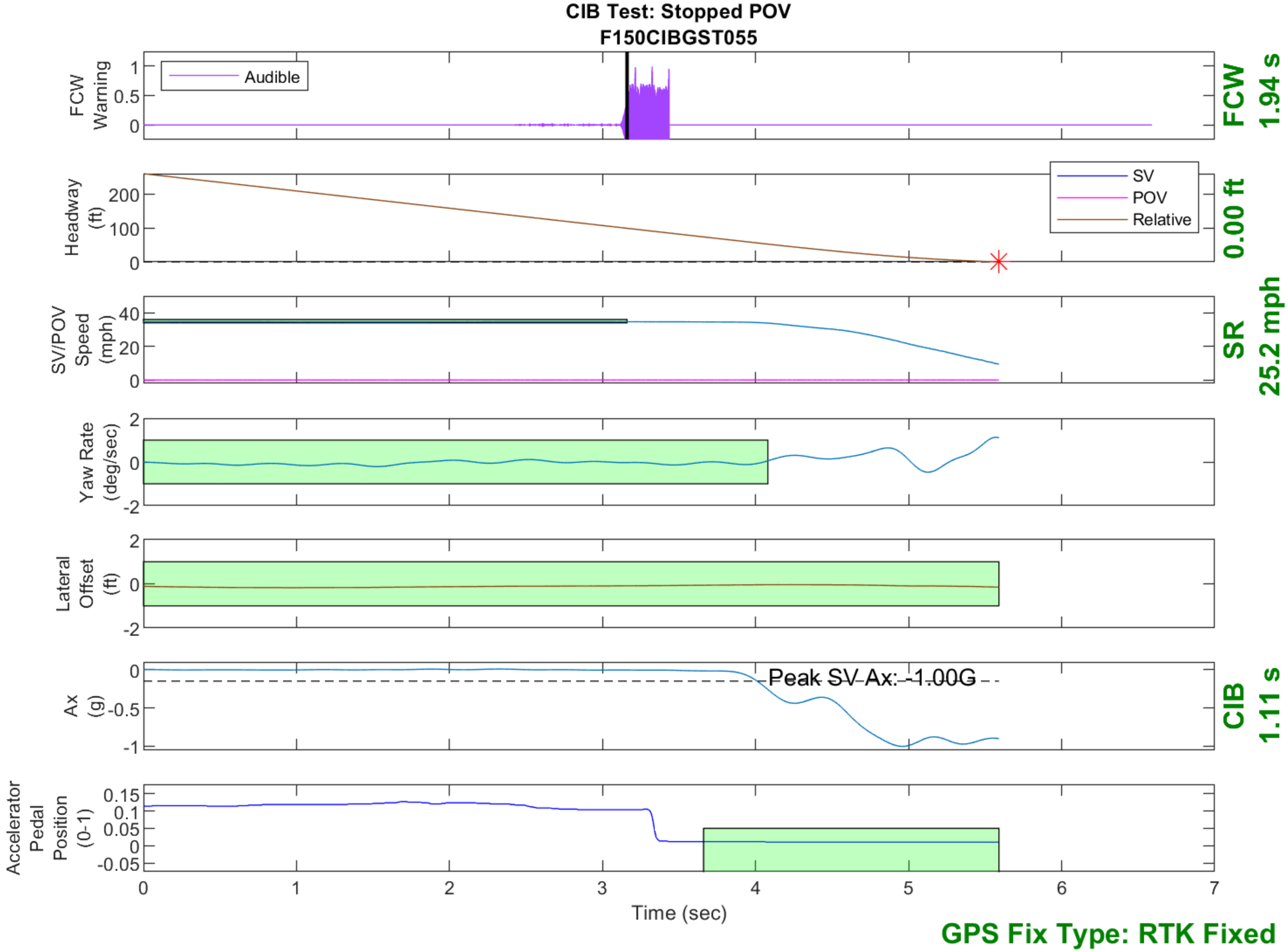

Figure D20. Time History for CIB Run 55, Stopped POV, 35 mph

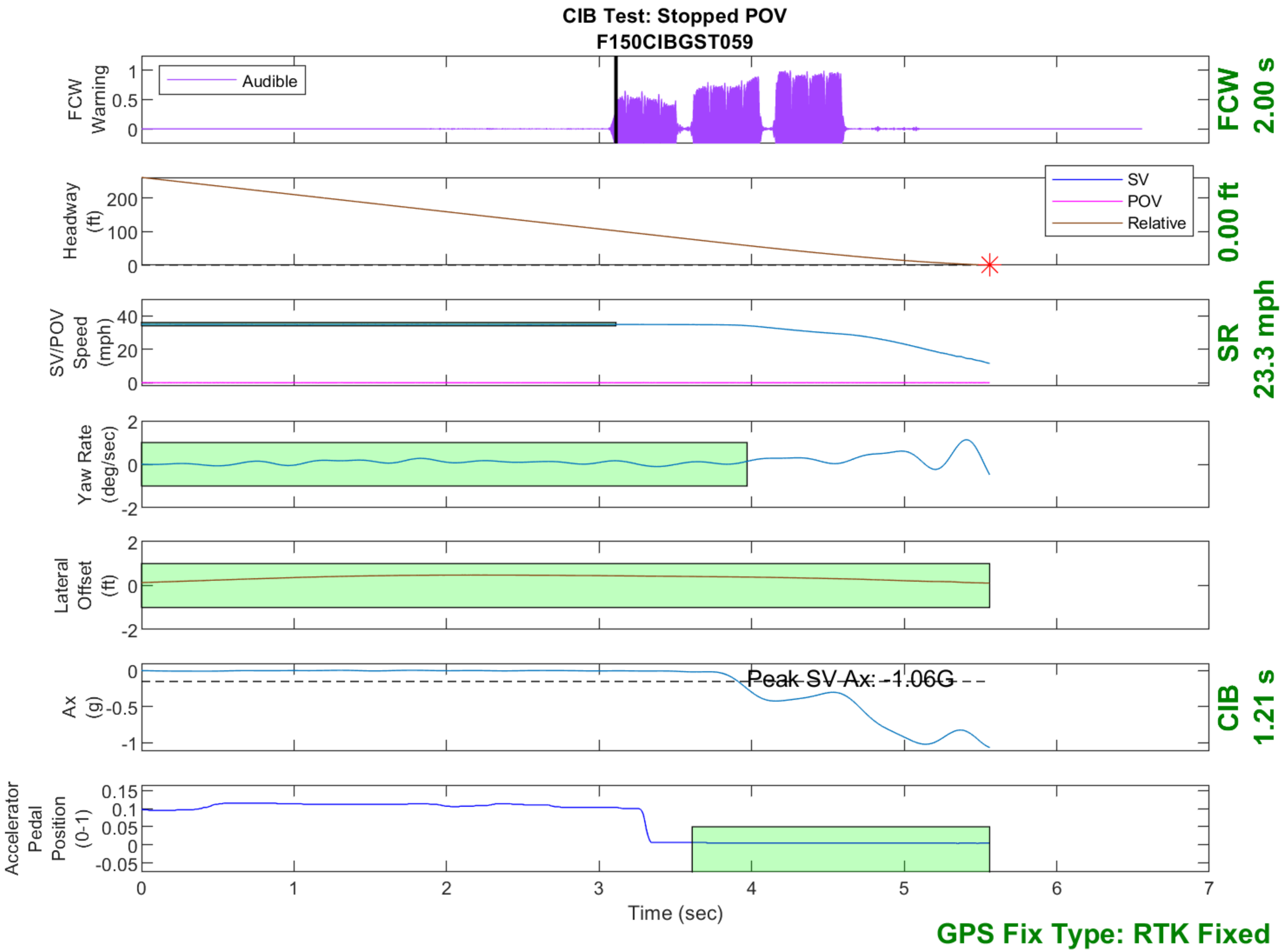

Figure D21. Time History for CIB Run 59, Stopped POV, 35 mph

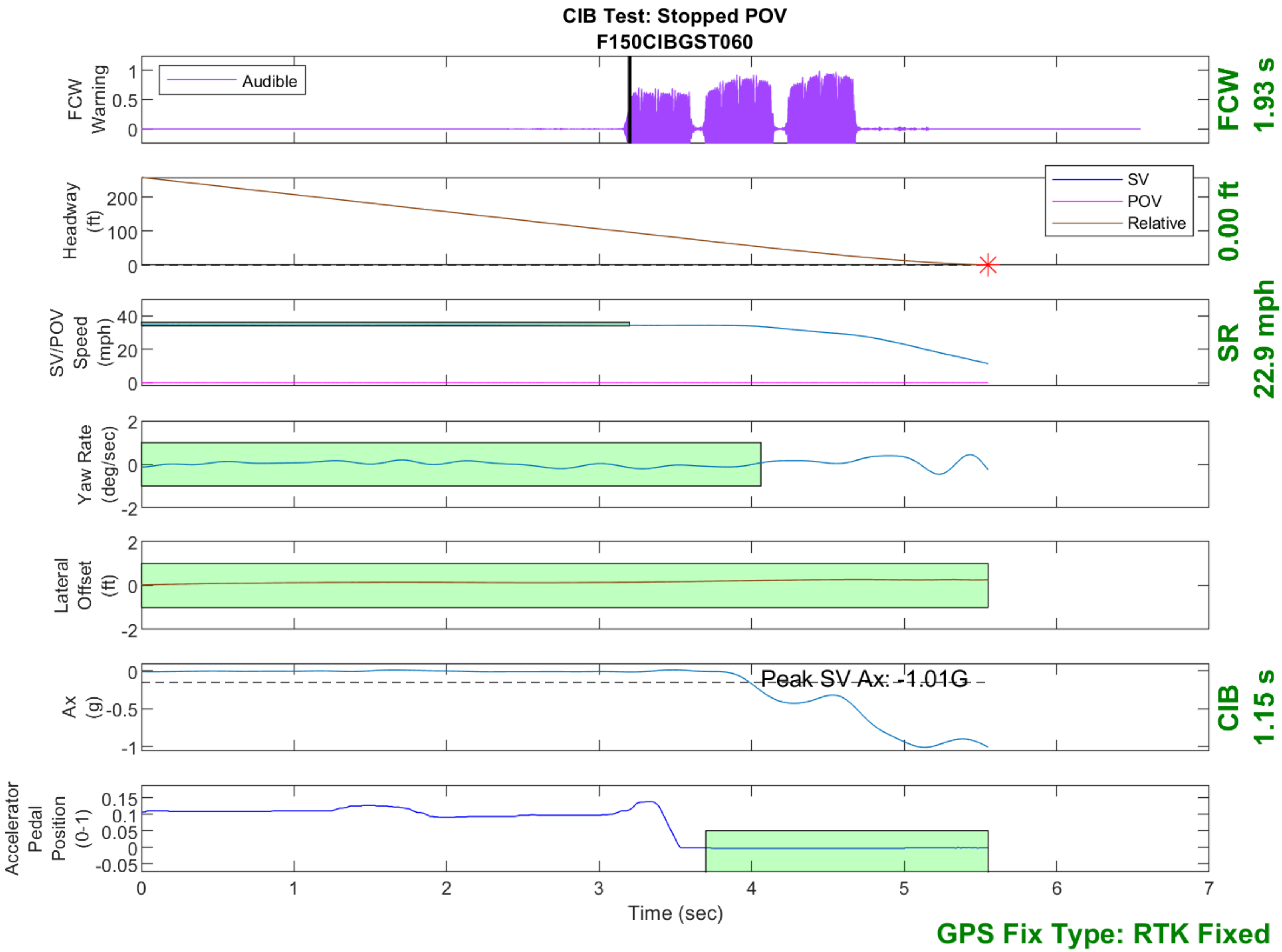

Figure D22. Time History for CIB Run 60, Stopped POV, 35 mph

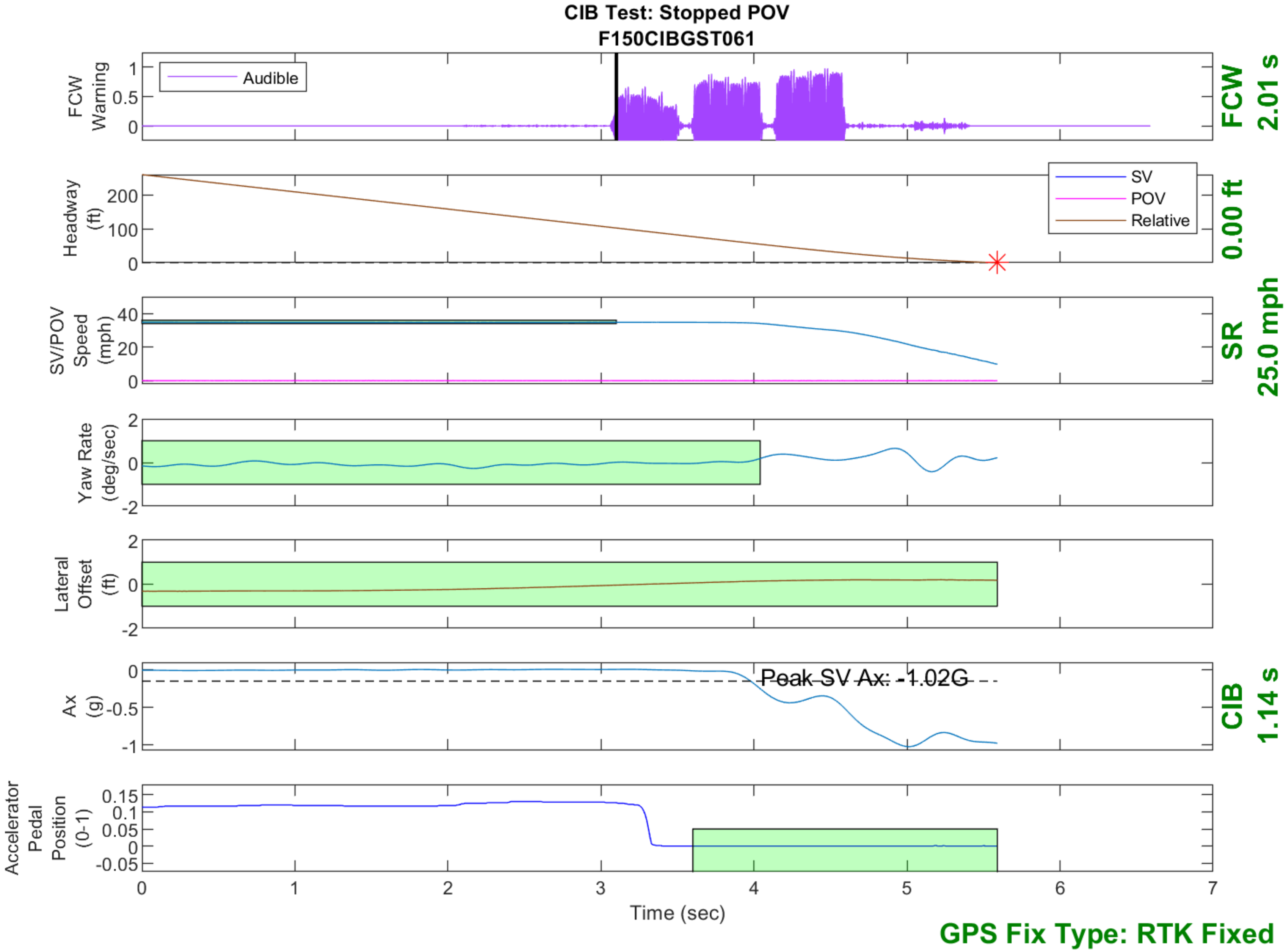

Figure D23. Time History for CIB Run 61, Stopped POV, 35 mph

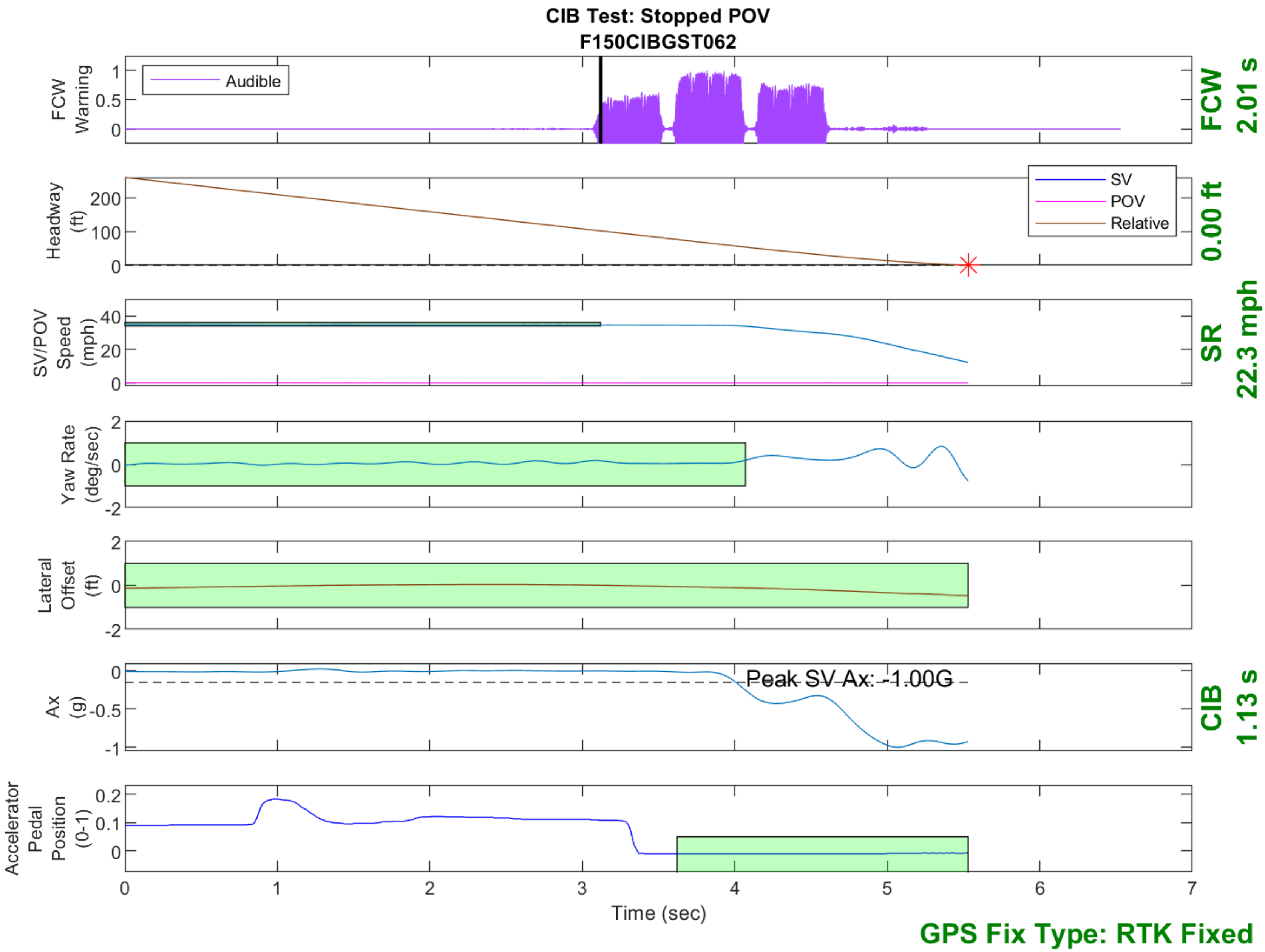

Figure D24. Time History for CIB Run 62, Stopped POV, 35 mph

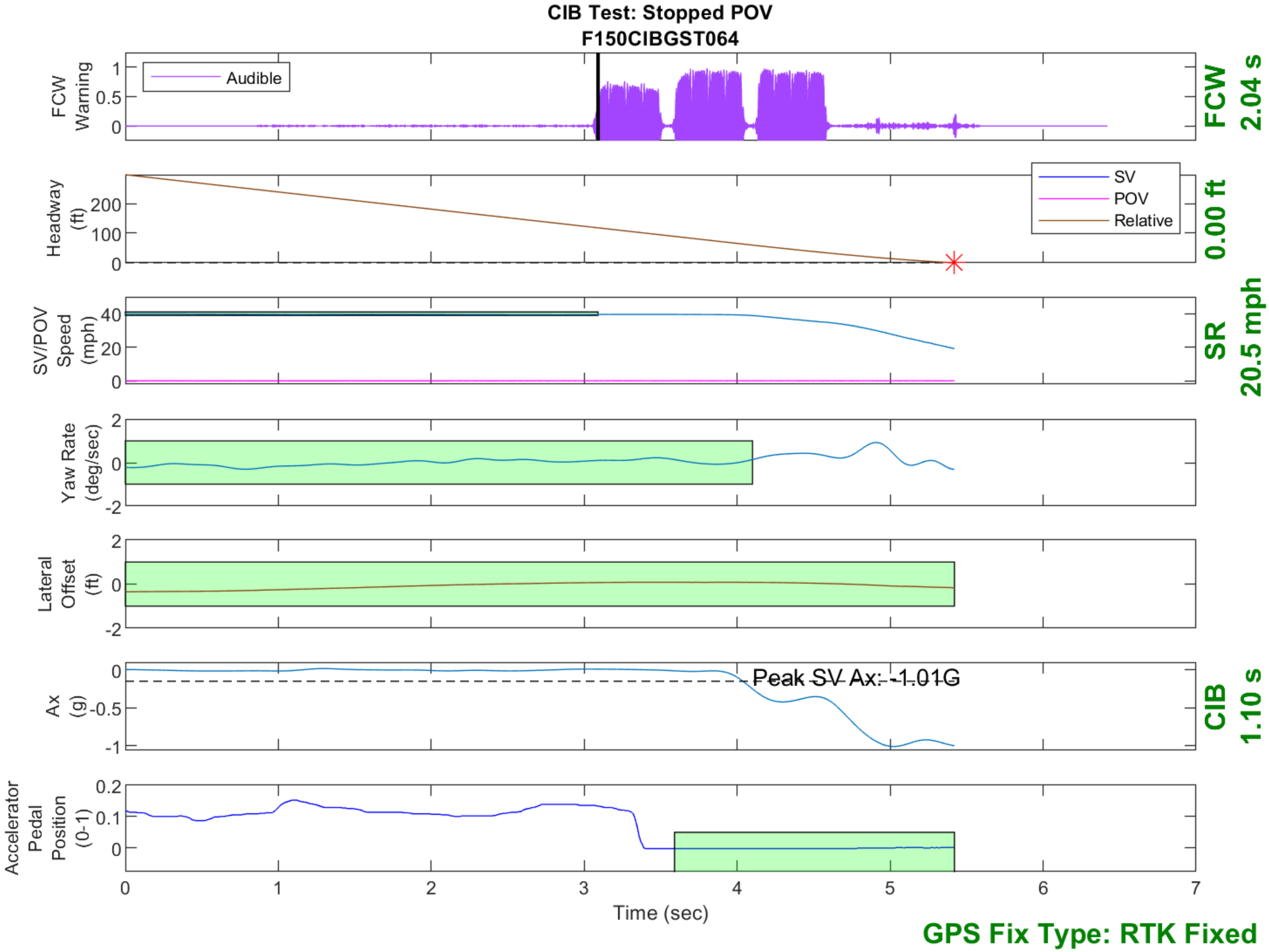

Figure D25. Time History for CIB Run 64, Stopped POV, 40 mph

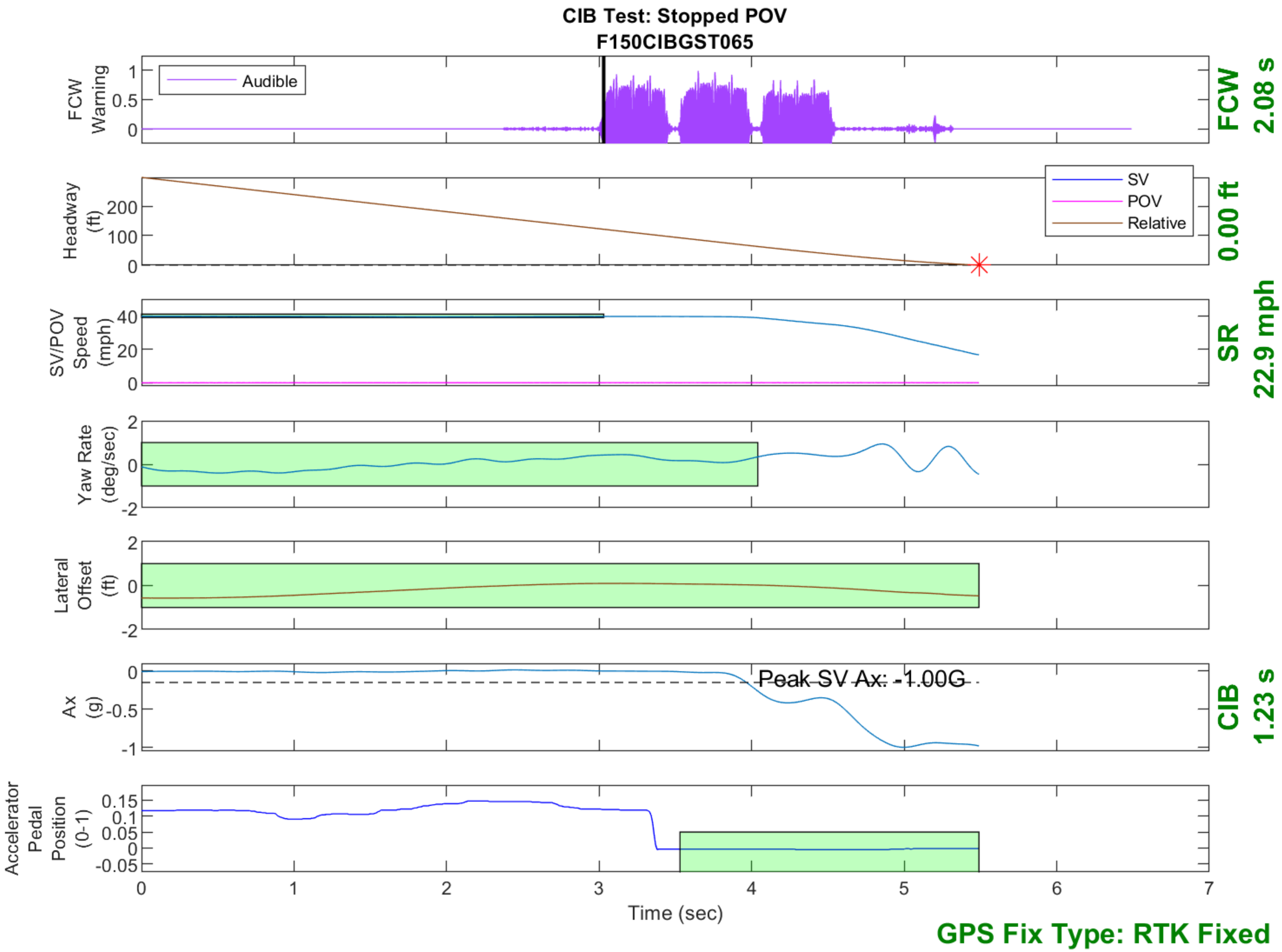

Figure D26. Time History for CIB Run 65, Stopped POV, 40 mph

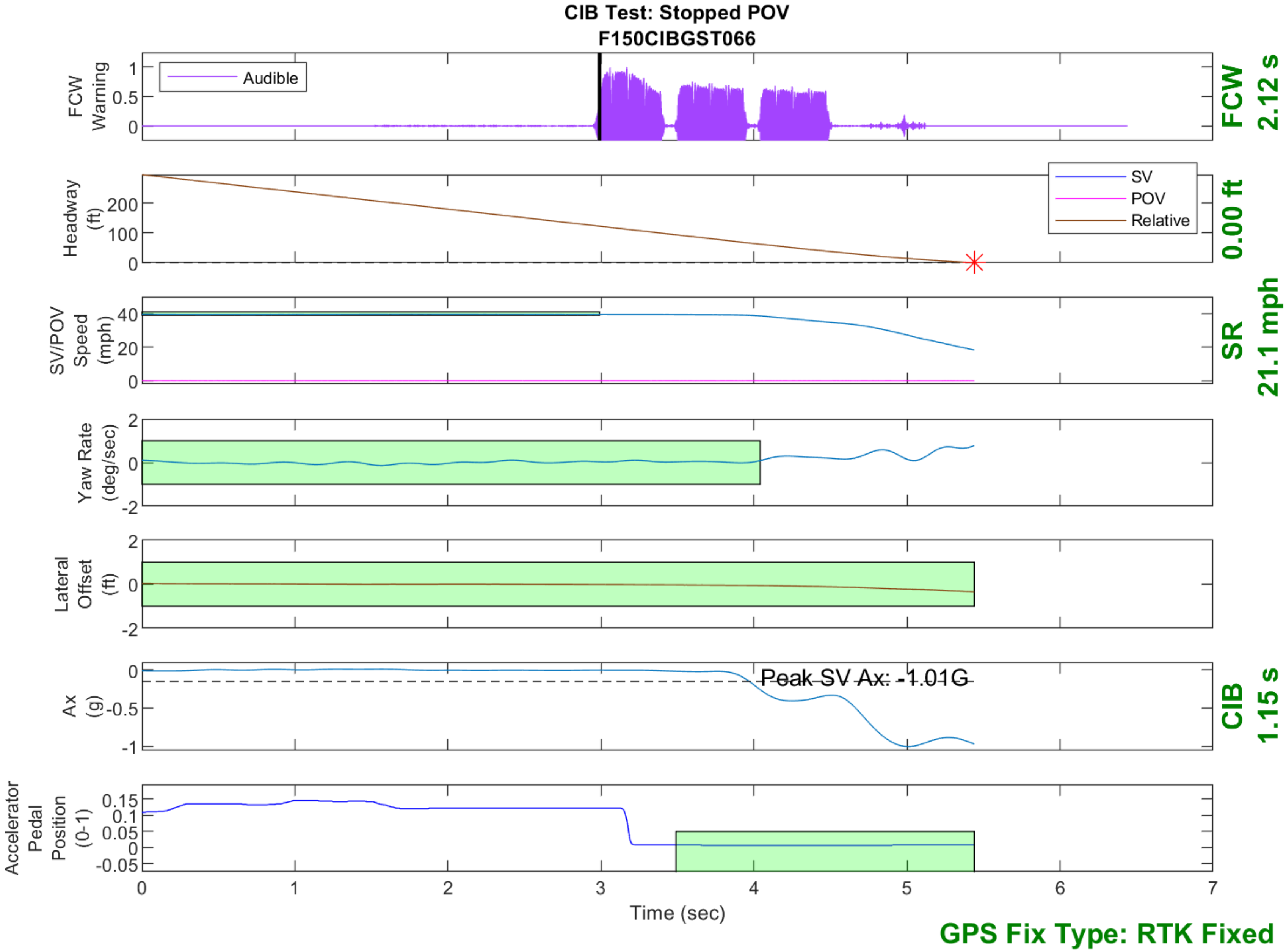

Figure D27. Time History for CIB Run 66, Stopped POV, 40 mph

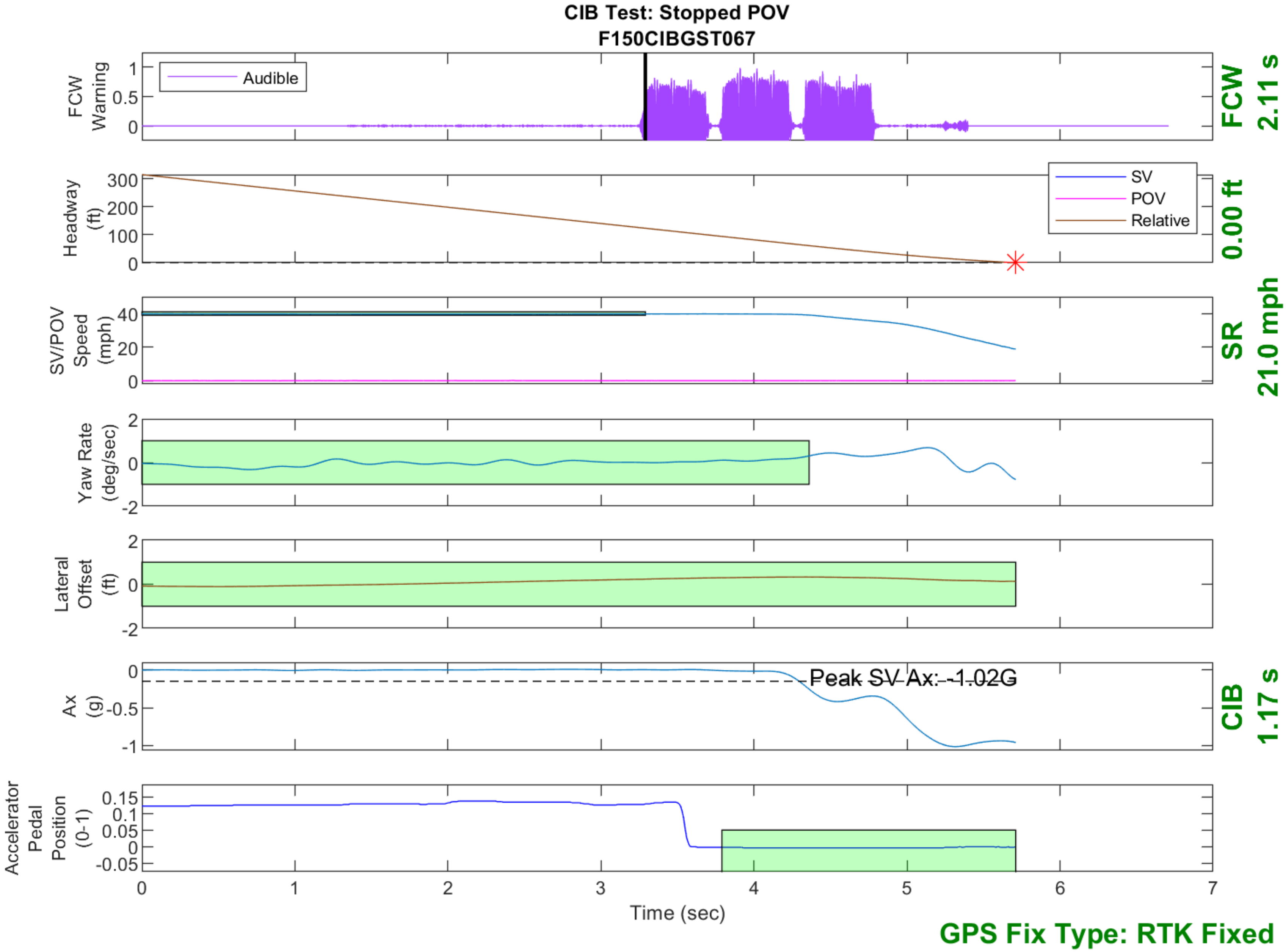

Figure D28. Time History for CIB Run 67, Stopped POV, 40 mph

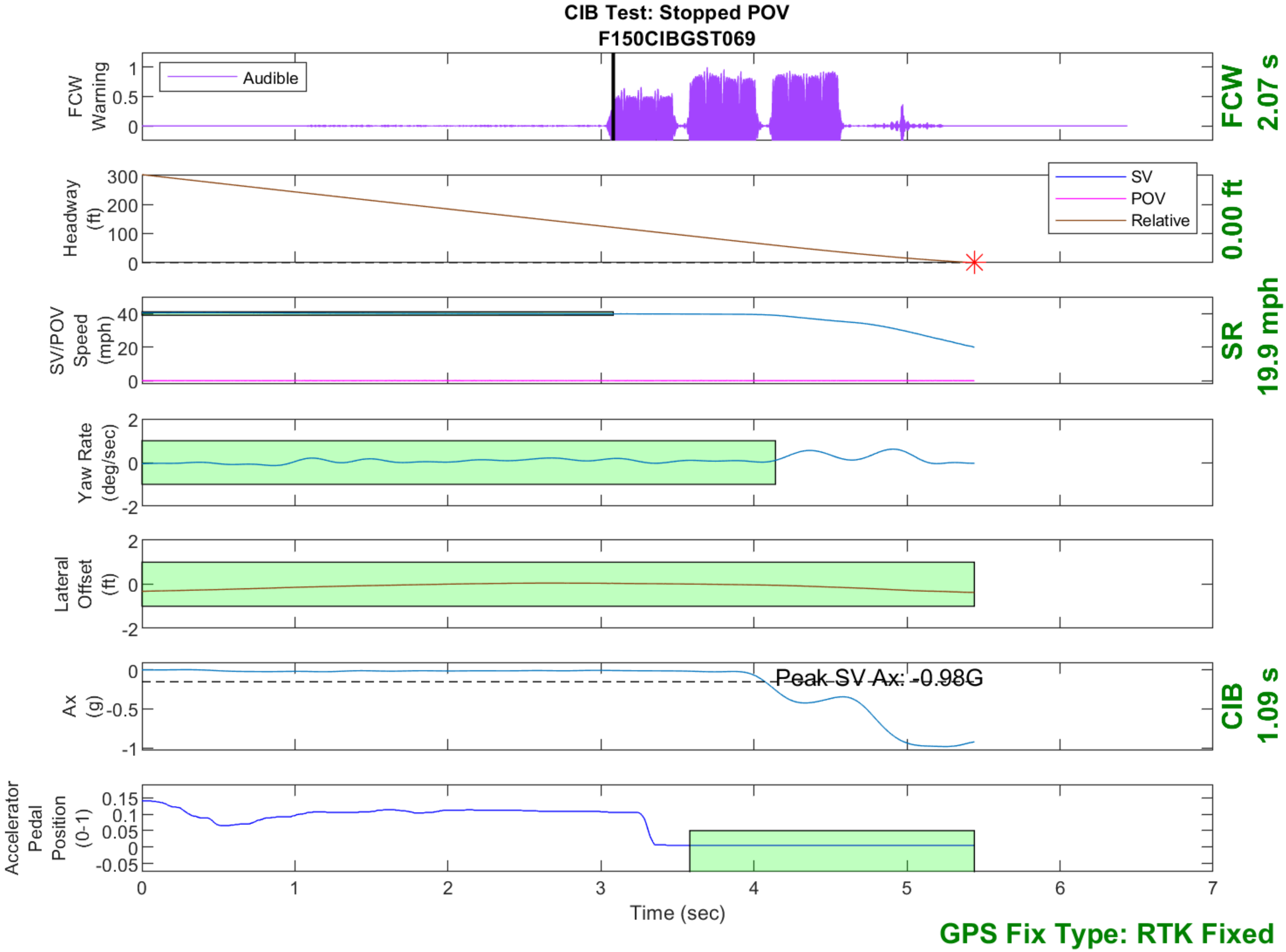

Figure D29. Time History for CIB Run 69, Stopped POV, 40 mph

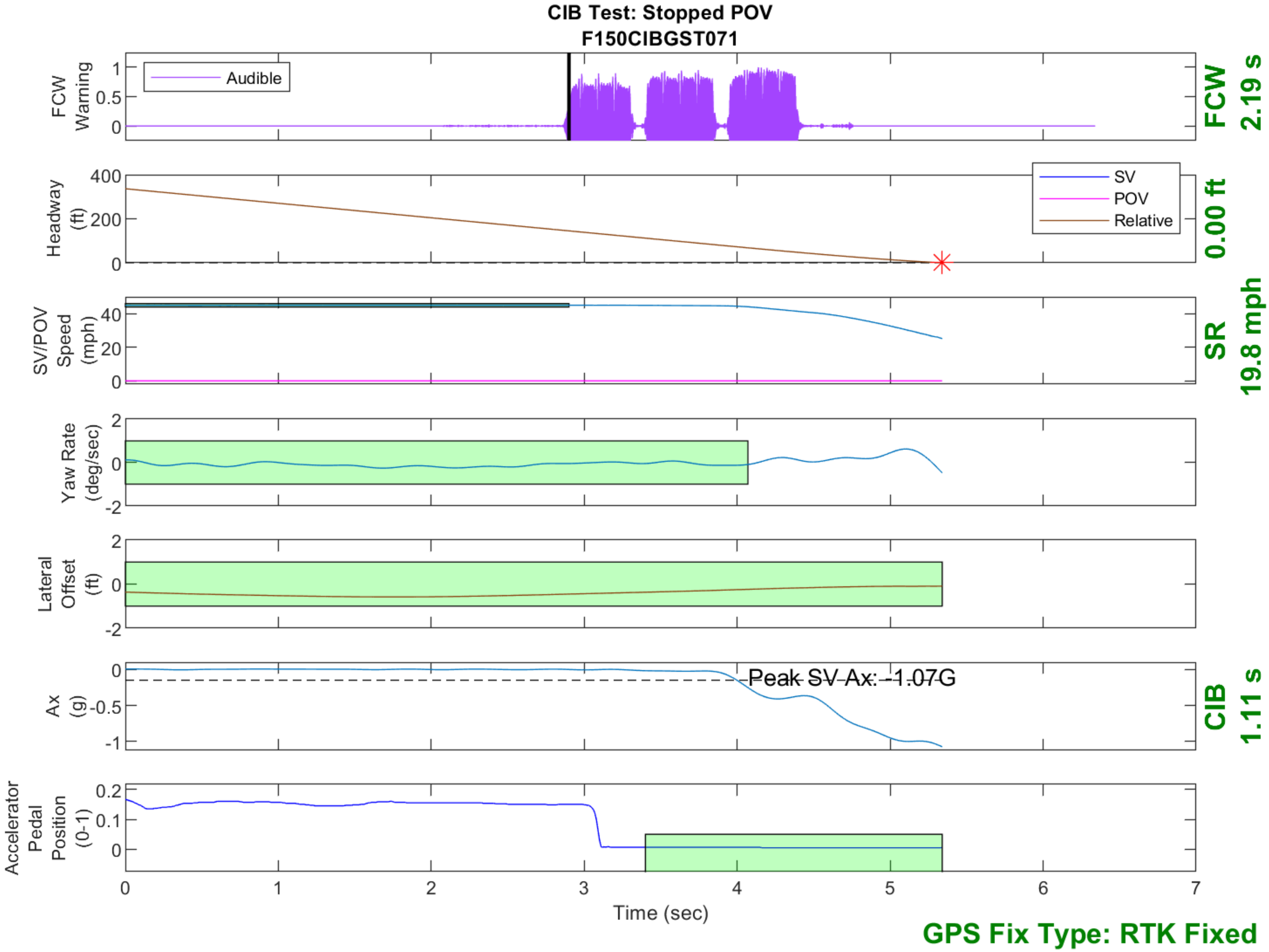

Figure D30. Time History for CIB Run 71, Stopped POV, 45 mph

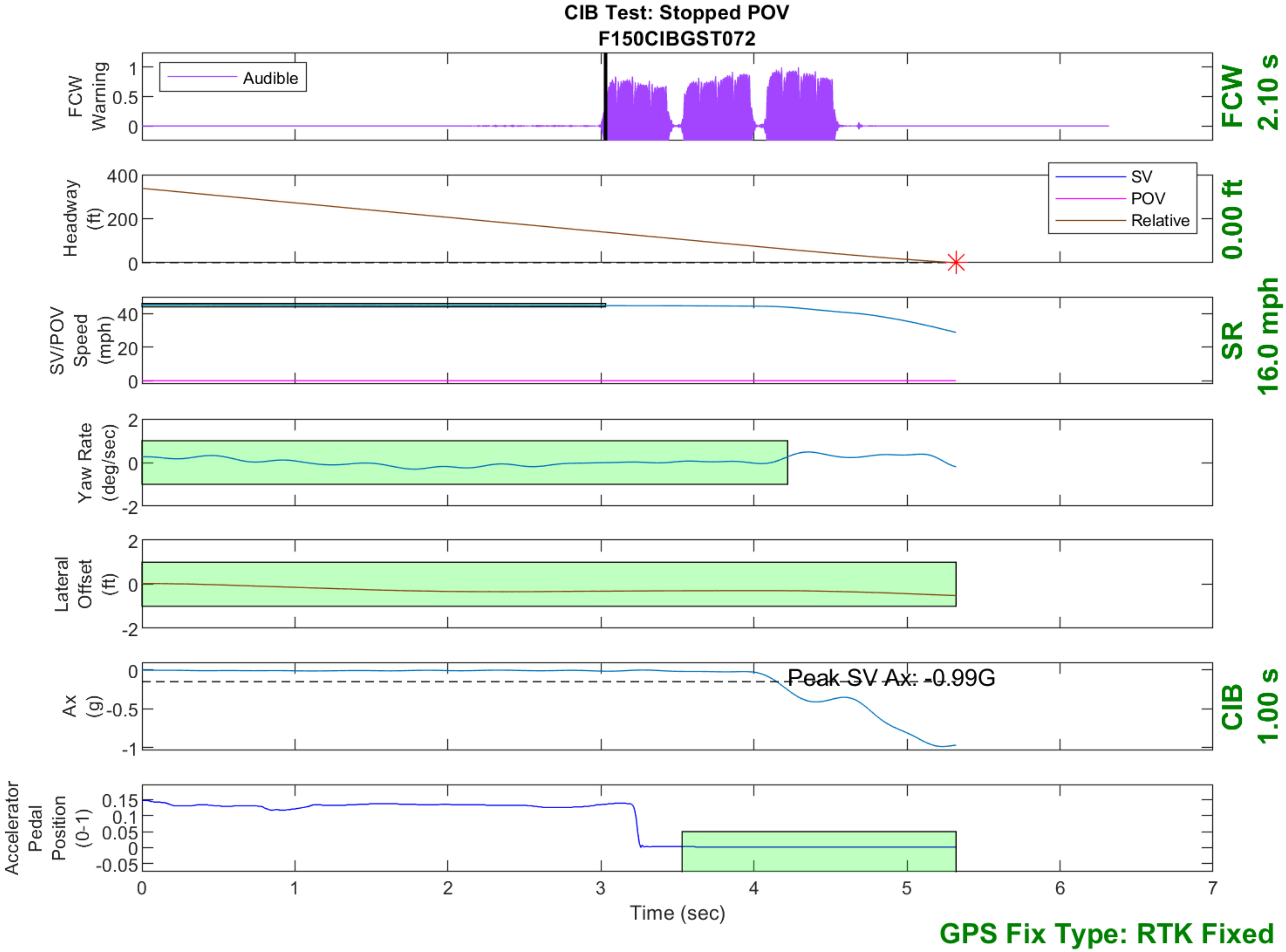

Figure D31. Time History for CIB Run 72, Stopped POV, 45 mph

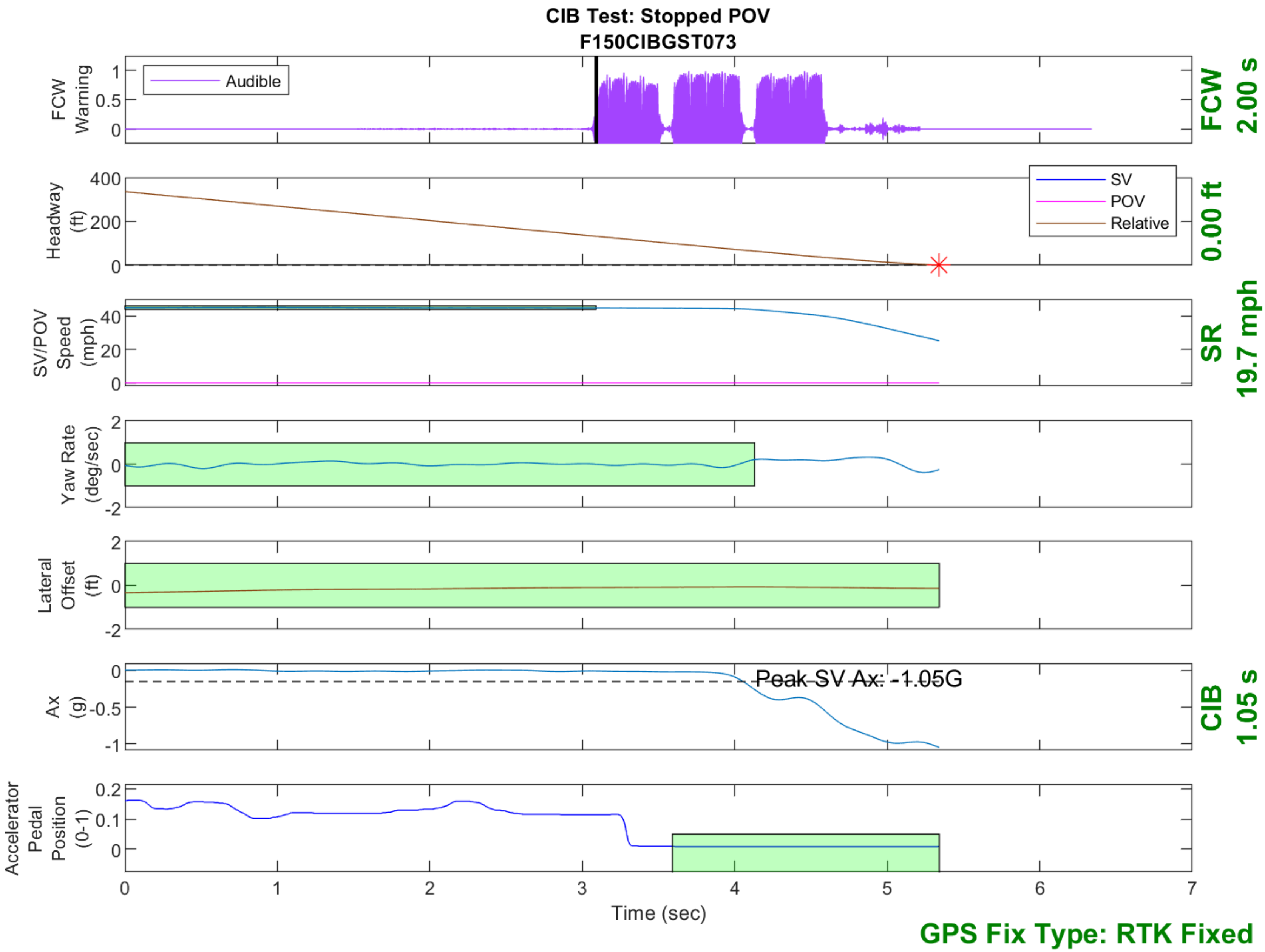

Figure D32. Time History for CIB Run 73, Stopped POV, 45 mph

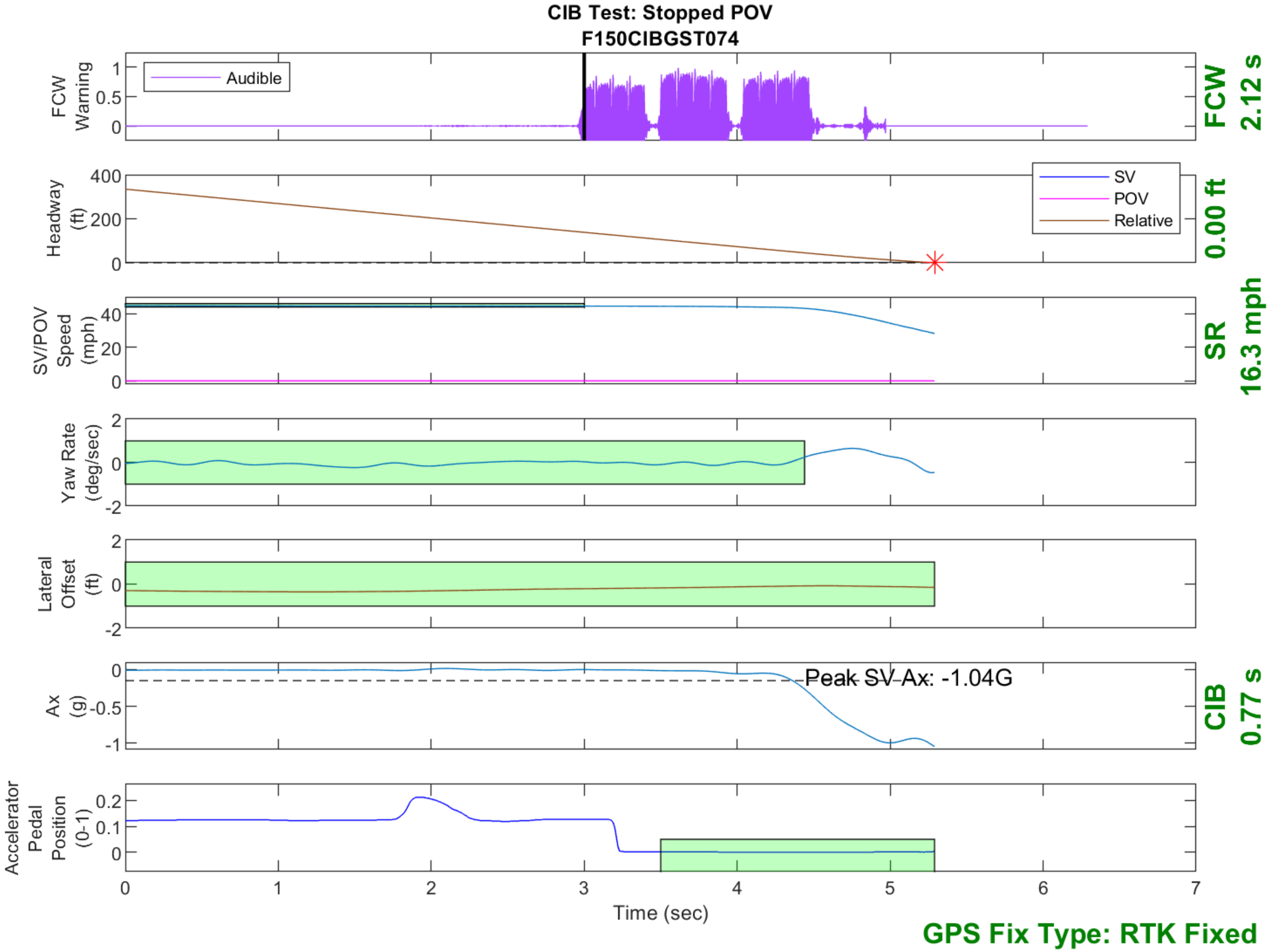

Figure D33. Time History for CIB Run 74, Stopped POV, 45 mph

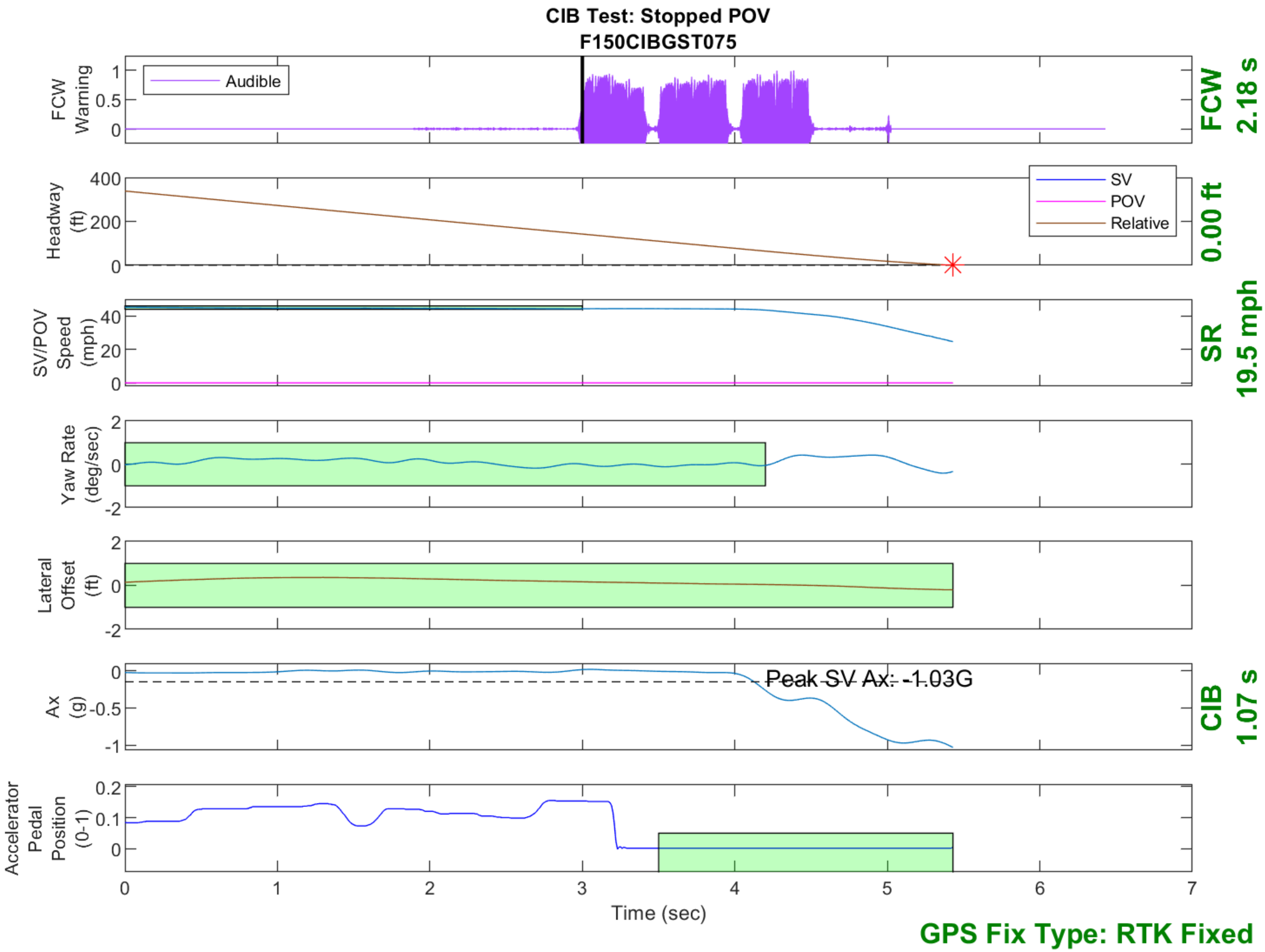

Figure D34. Time History for CIB Run 75, Stopped POV, 45 mph

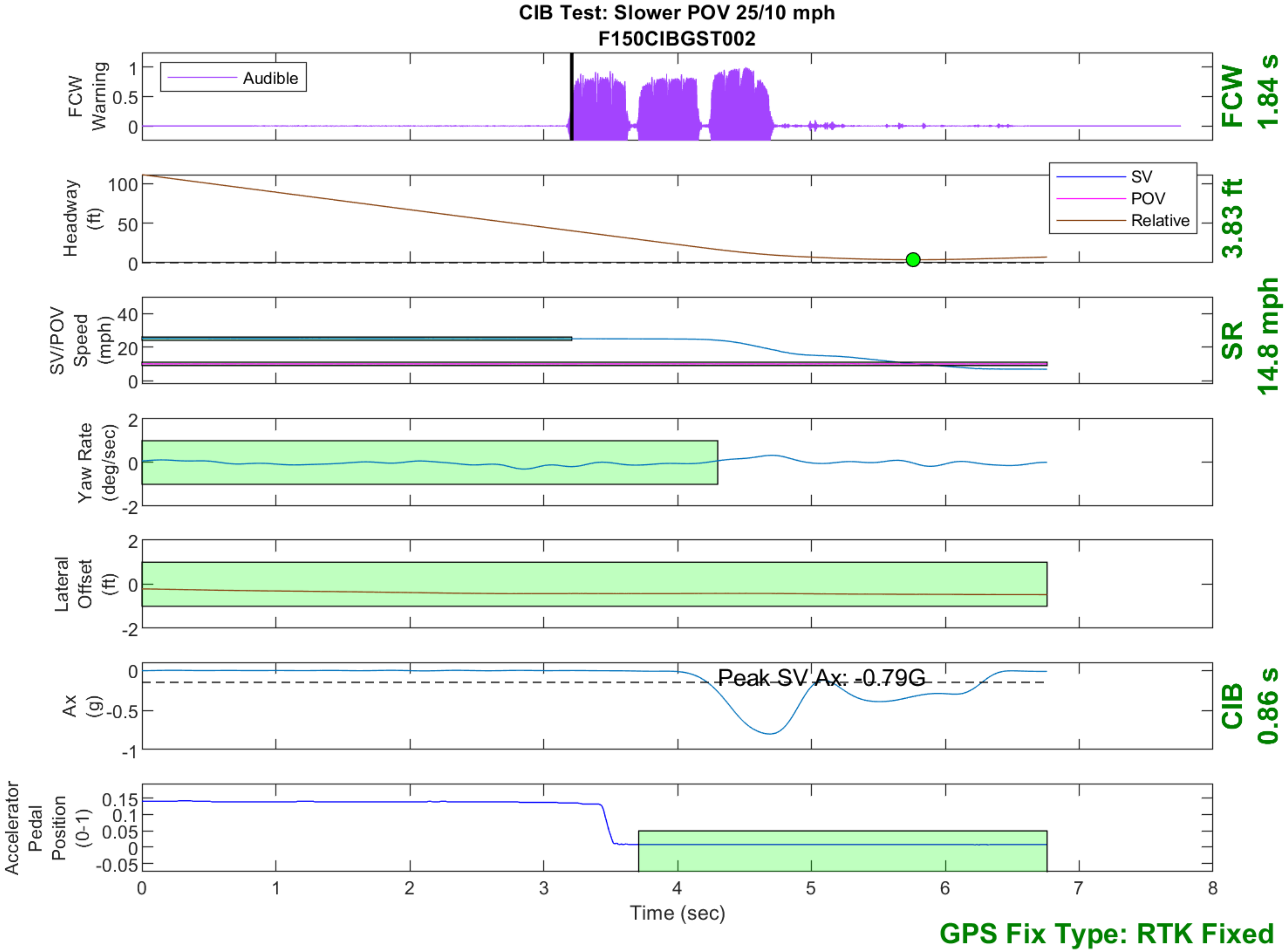

Figure D35. Time History for CIB Run 2, Slower POV, 25/10 mph

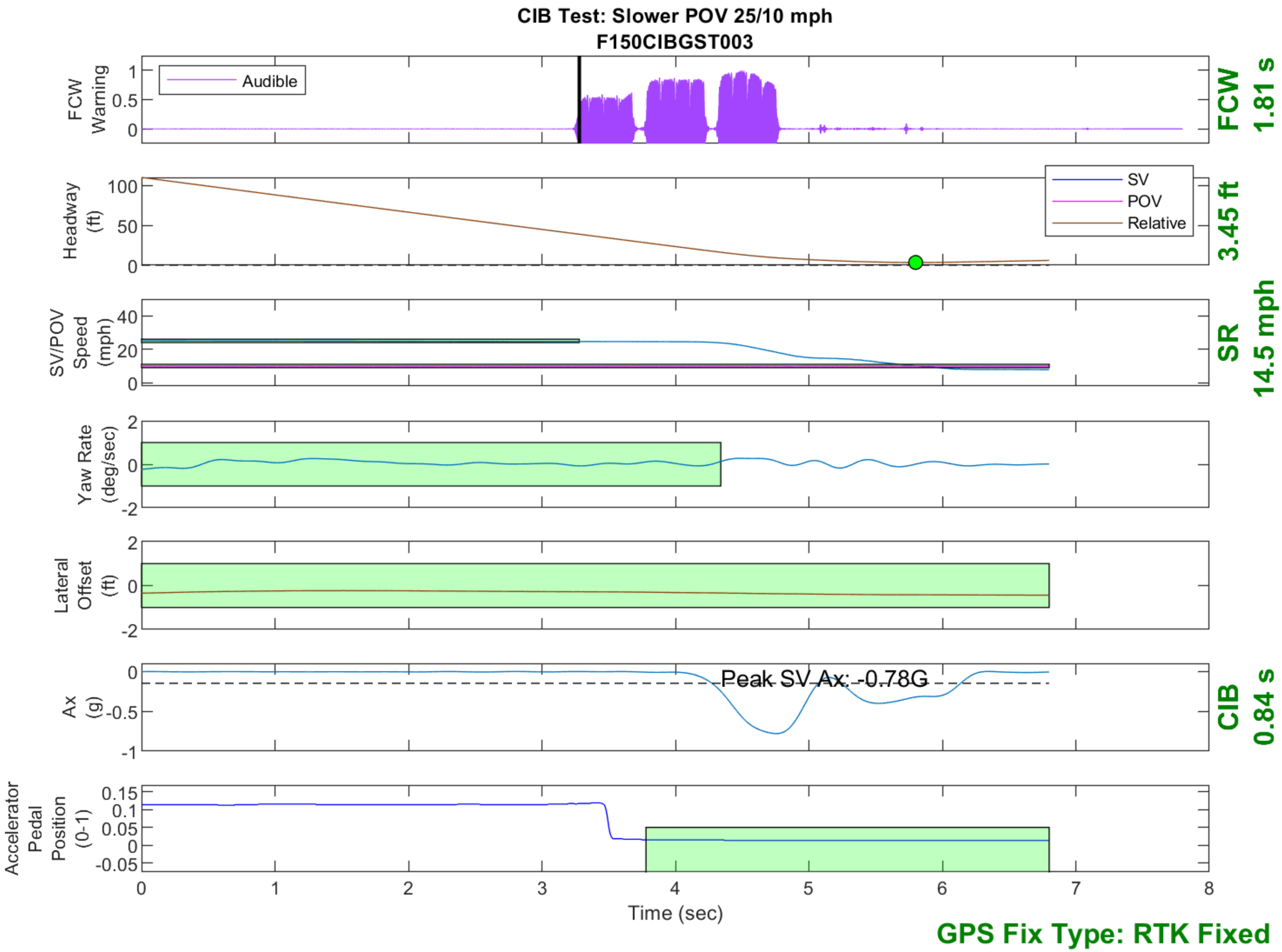

Figure D36. Time History for CIB Run 3, Slower POV, 25/10 mph

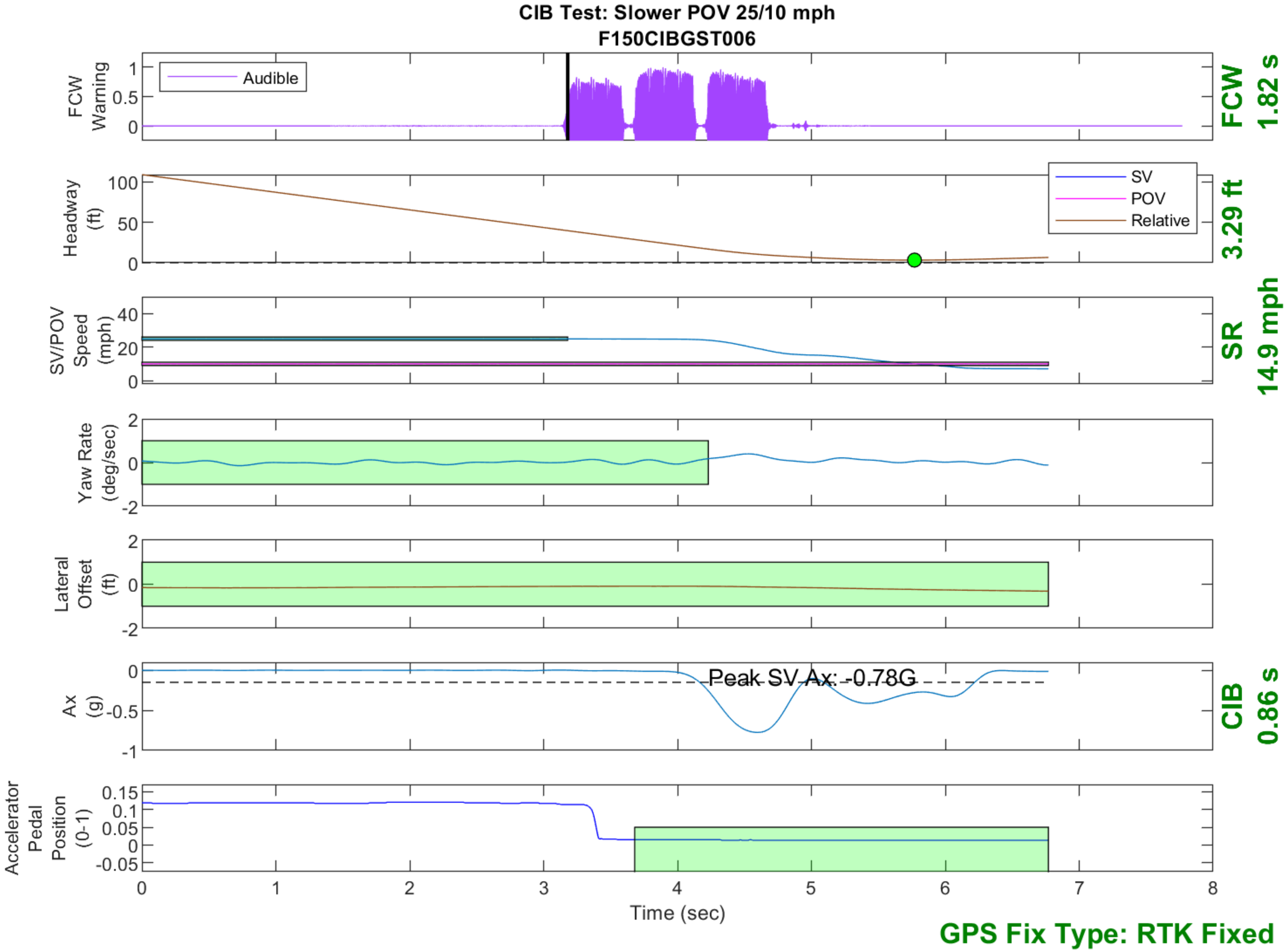

Figure D37. Time History for CIB Run 6, Slower POV, 25/10 mph

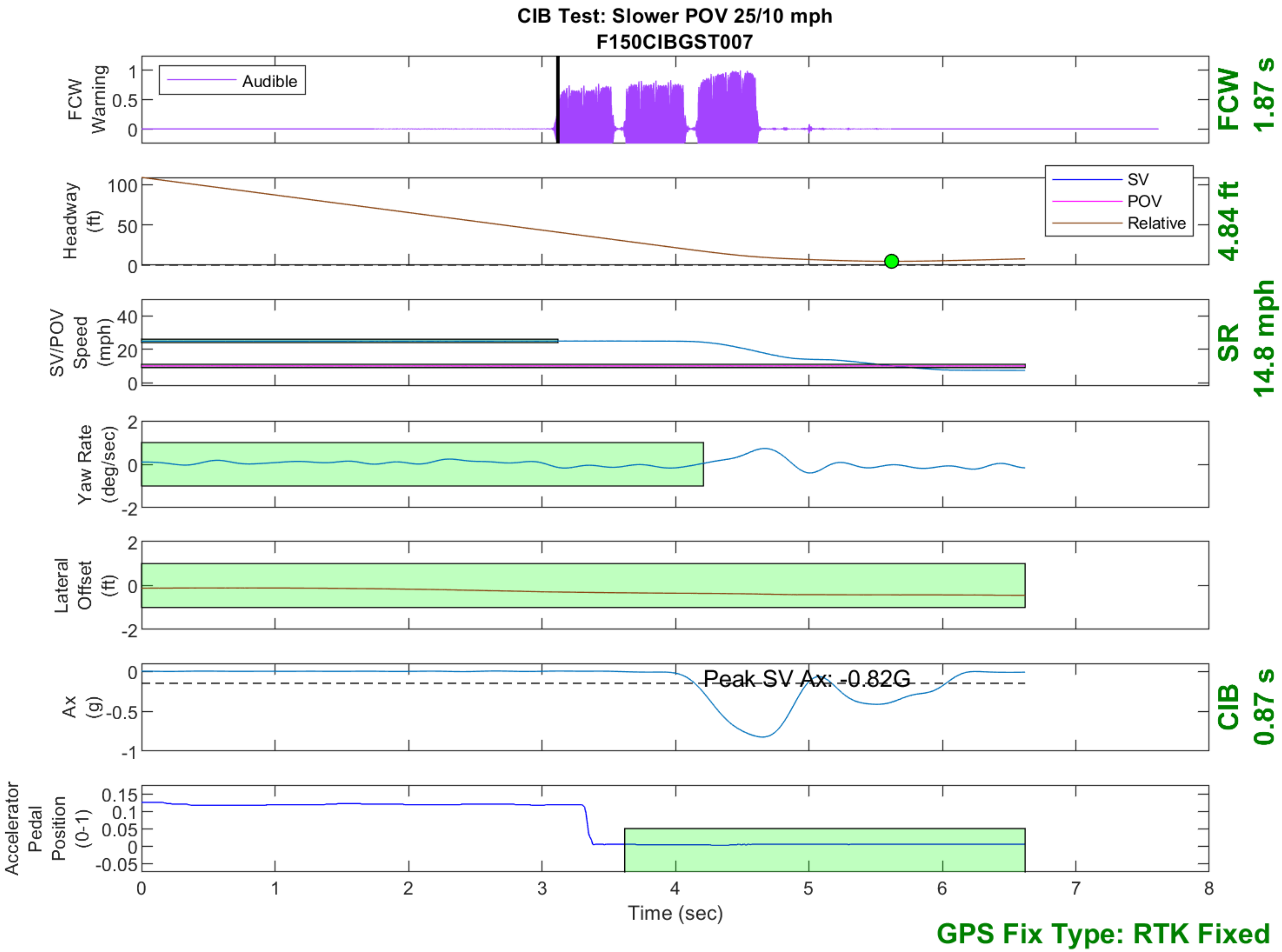

Figure D38. Time History for CIB Run 7, Slower POV, 25/10 mph

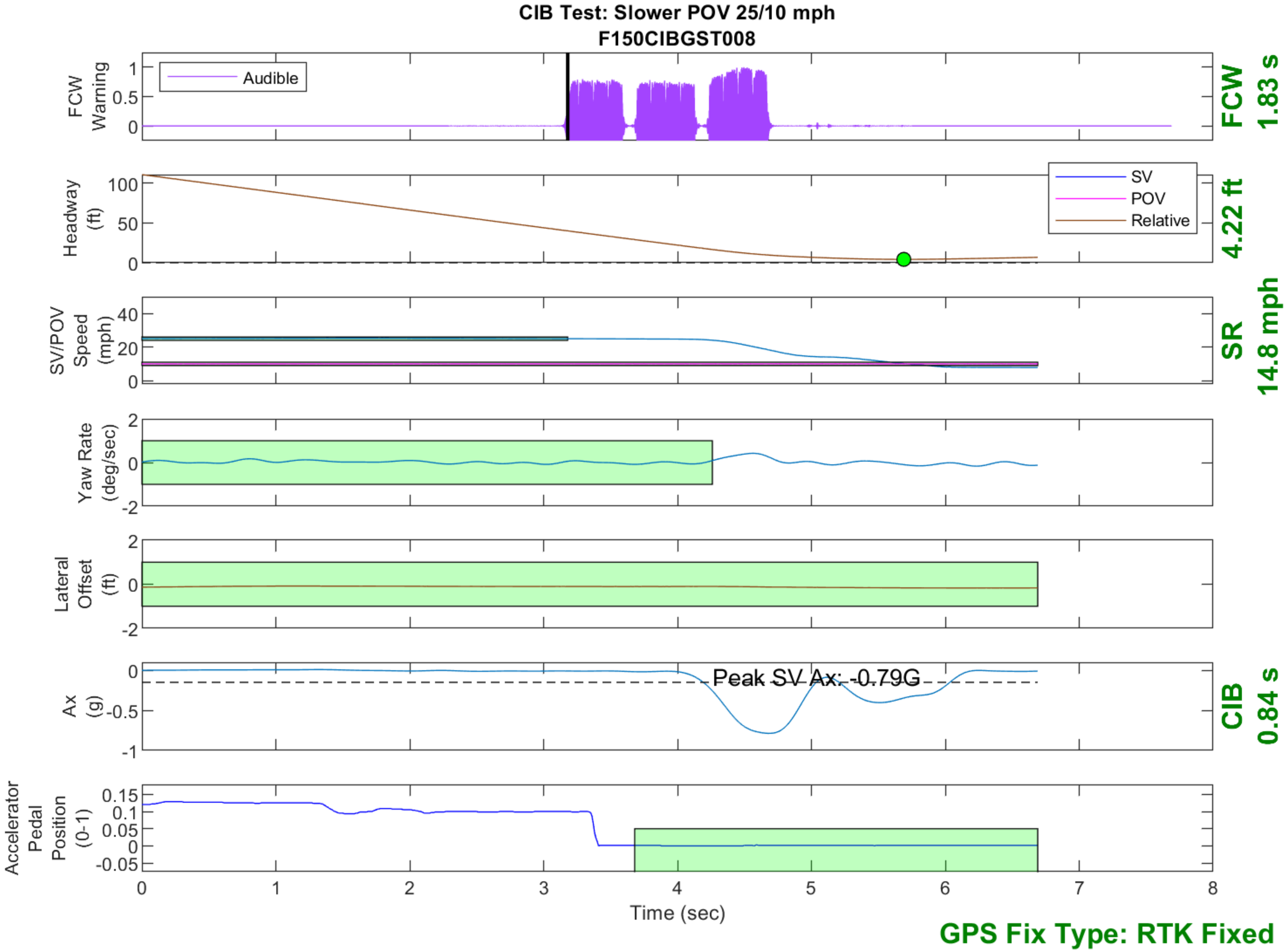

Figure D39. Time History for CIB Run 8, Slower POV, 25/10 mph

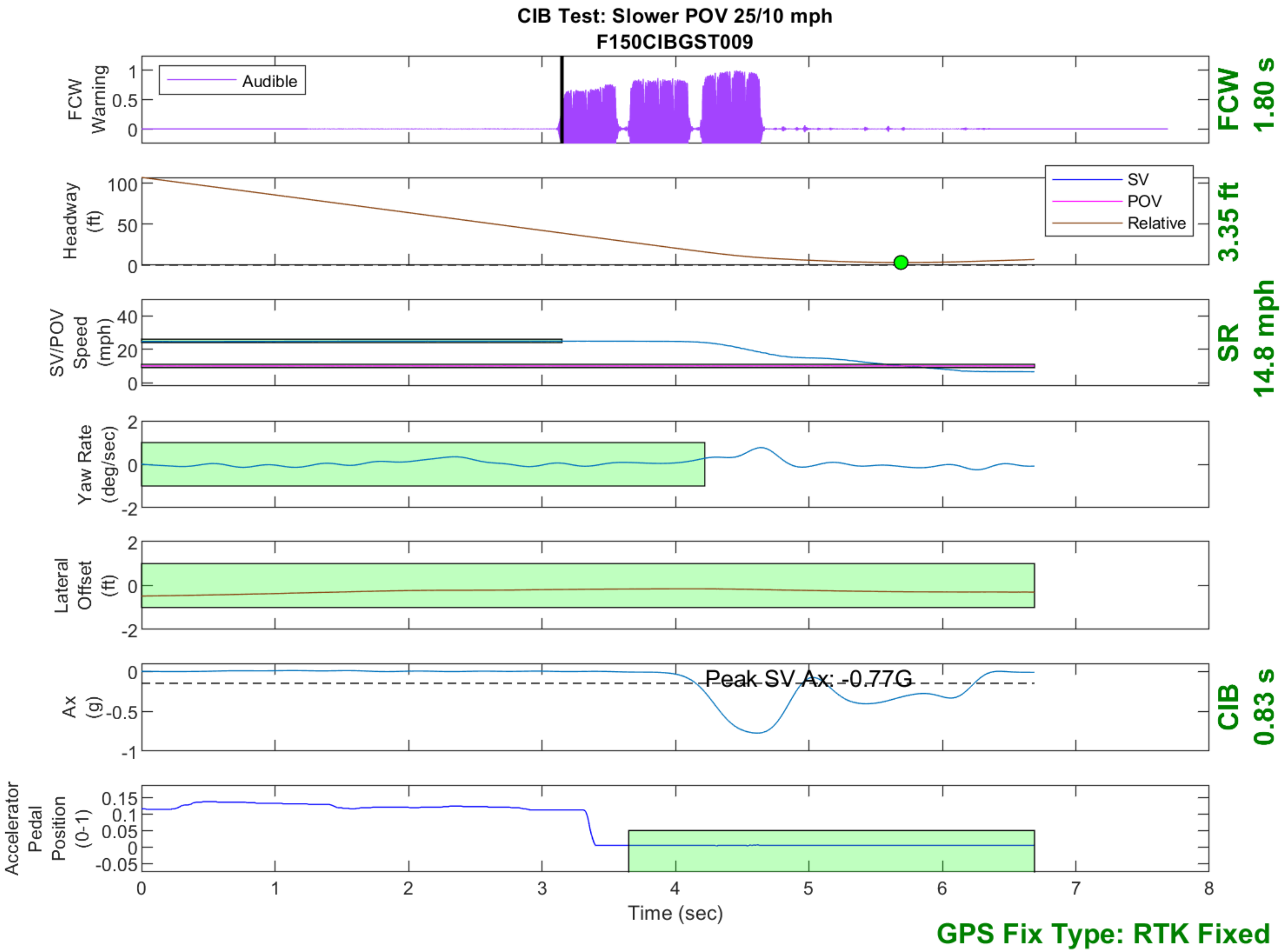

Figure D40. Time History for CIB Run 9, Slower POV, 25/10 mph

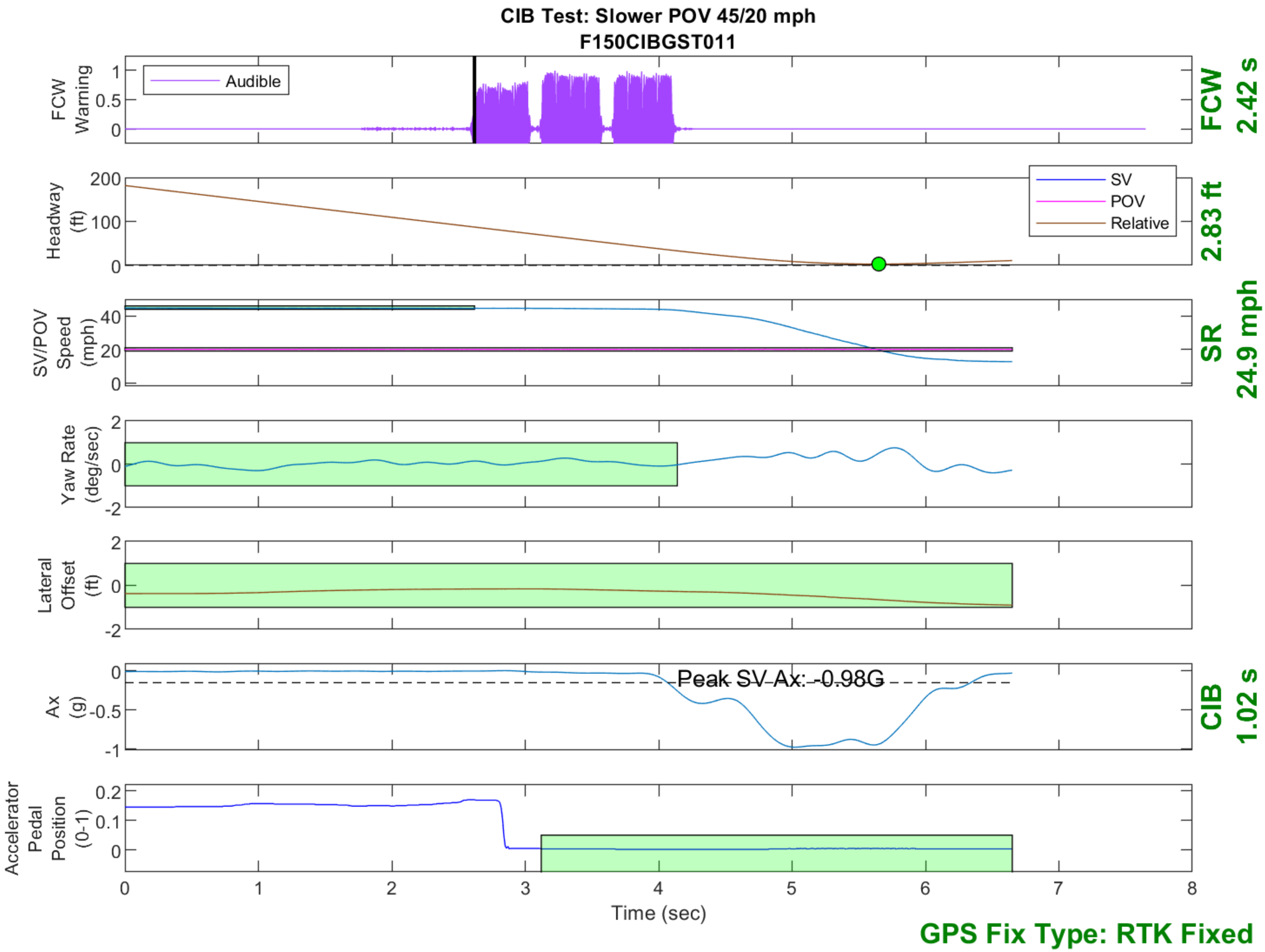

Figure D41. Time History for CIB Run 11, Slower POV, 45/20 mph

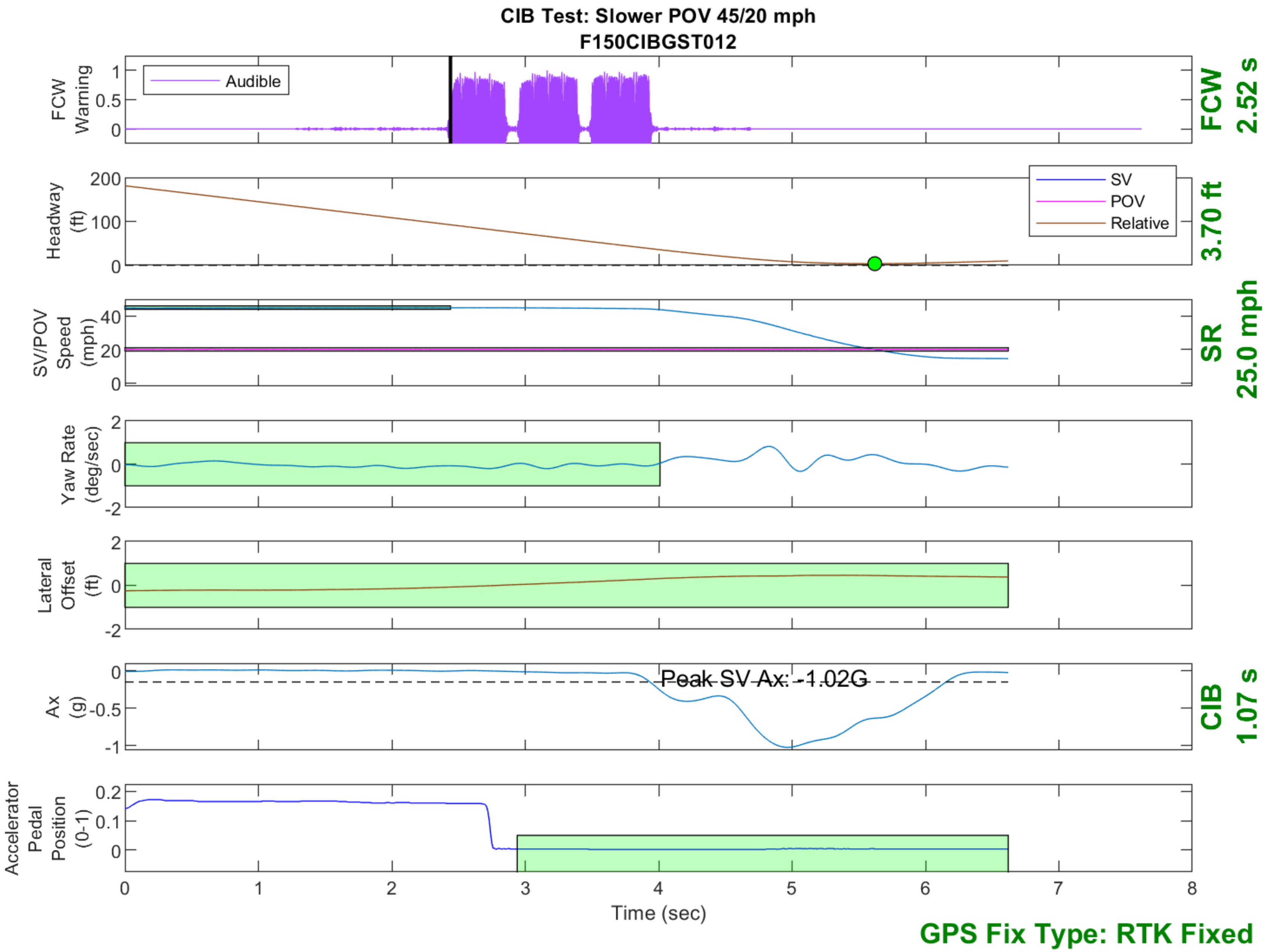

Figure D42. Time History for CIB Run 12, Slower POV, 45/20 mph

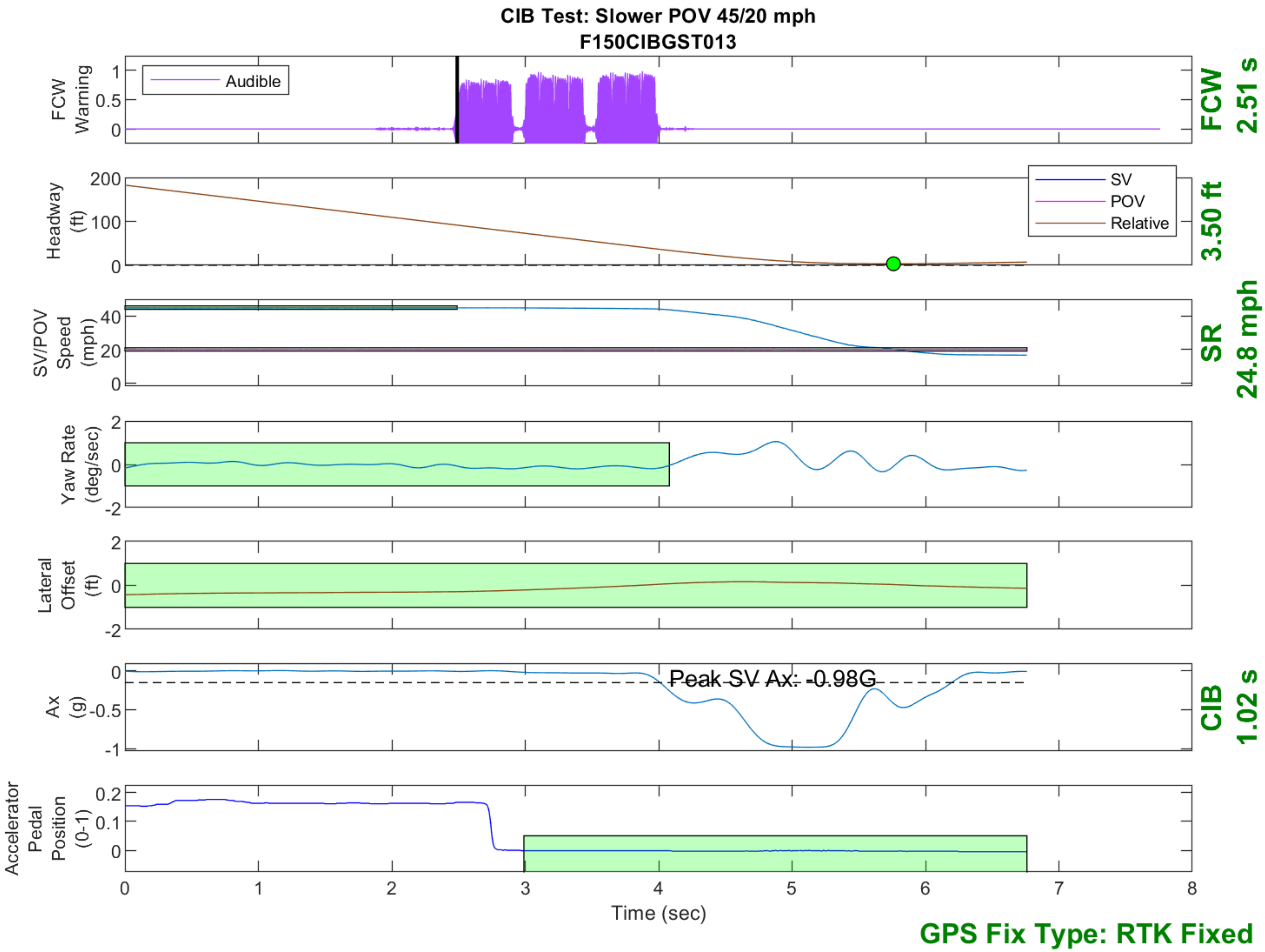

Figure D43. Time History for CIB Run 13, Slower POV, 45/20 mph

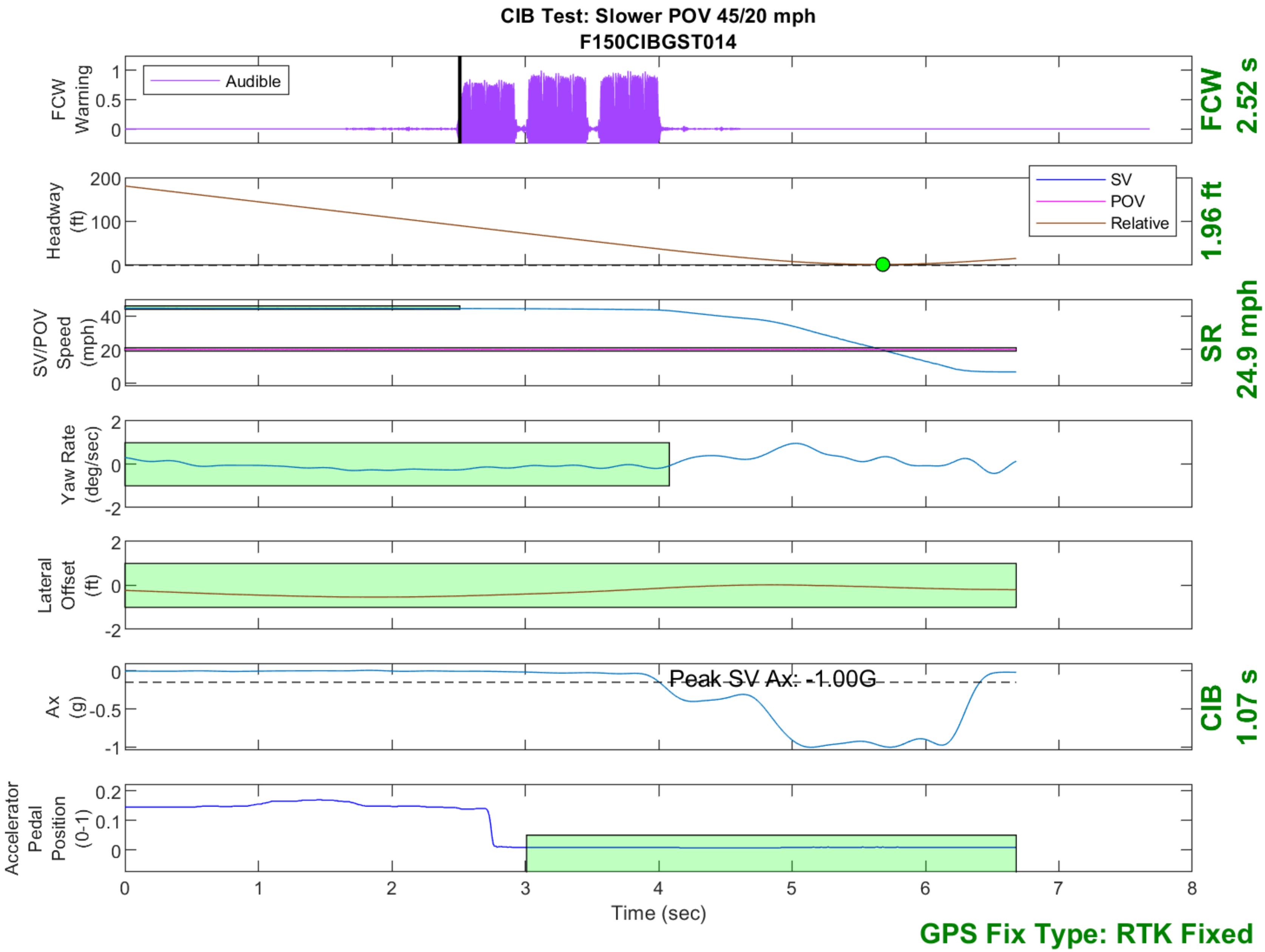

Figure D44. Time History for CIB Run 14, Slower POV, 45/20 mph

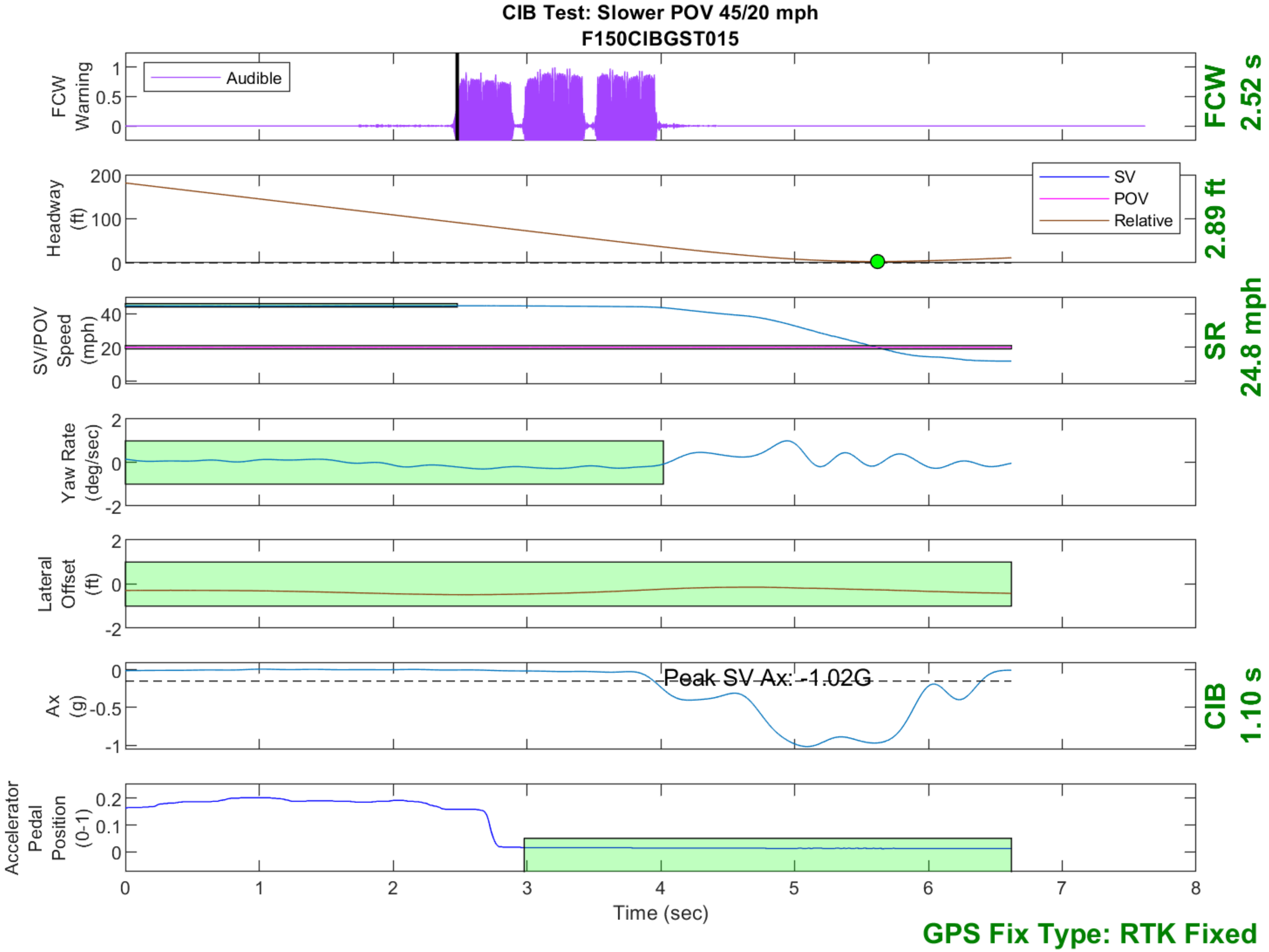

Figure D45. Time History for CIB Run 15, Slower POV, 45/20 mph

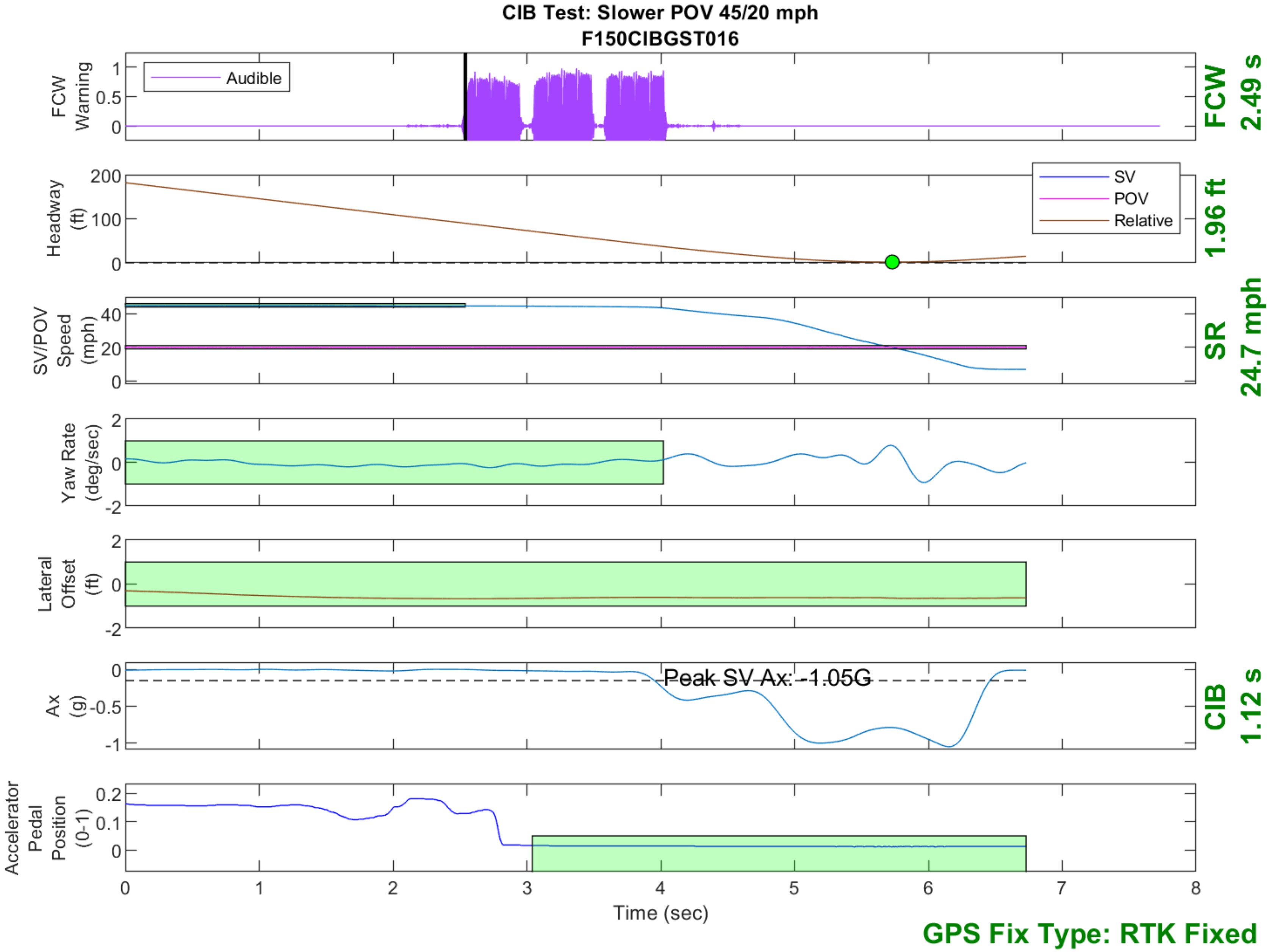

Figure D46. Time History for CIB Run 16, Slower POV, 45/20 mph

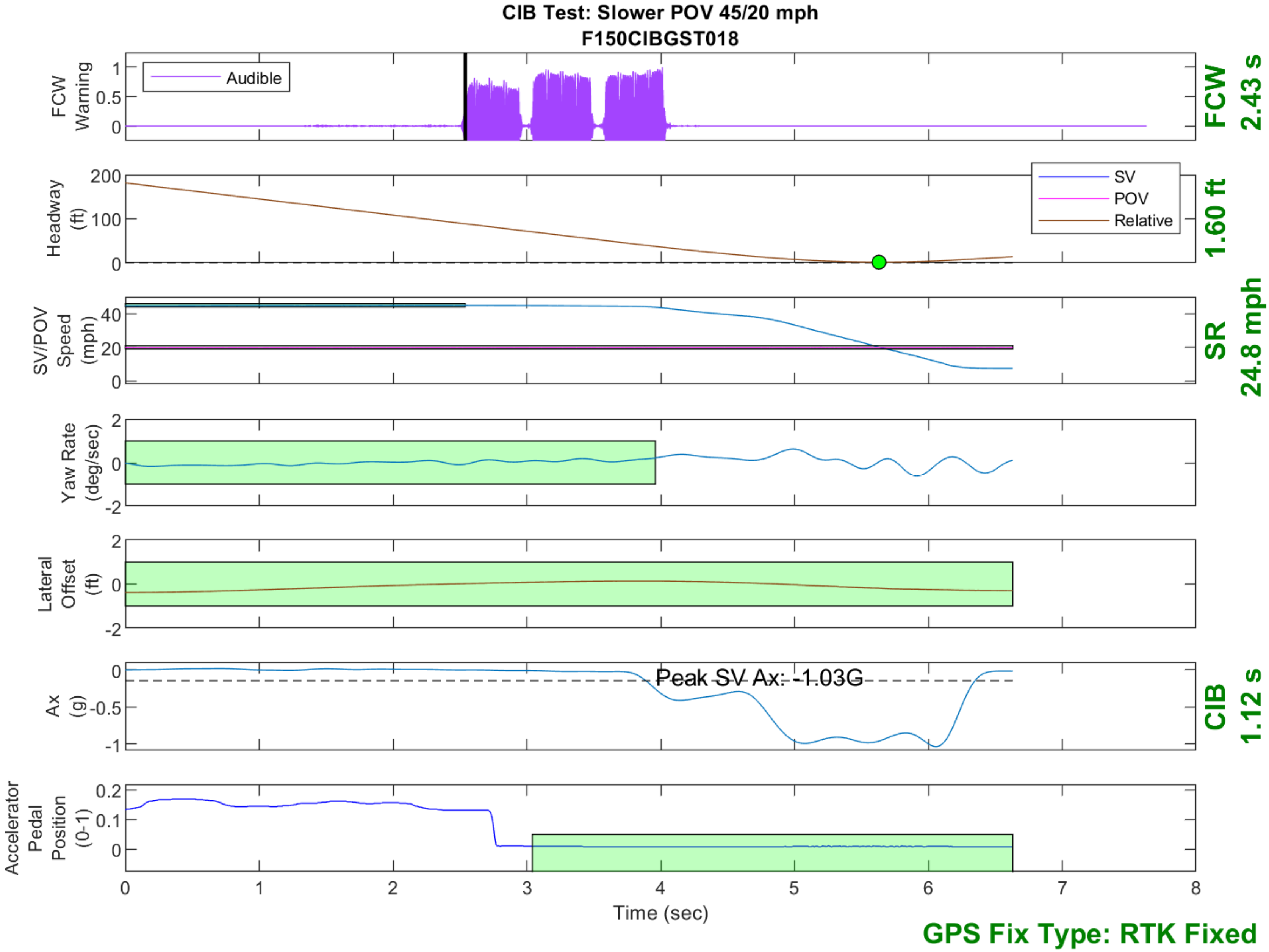

Figure D47. Time History for CIB Run 18, Slower POV, 45/20 mph

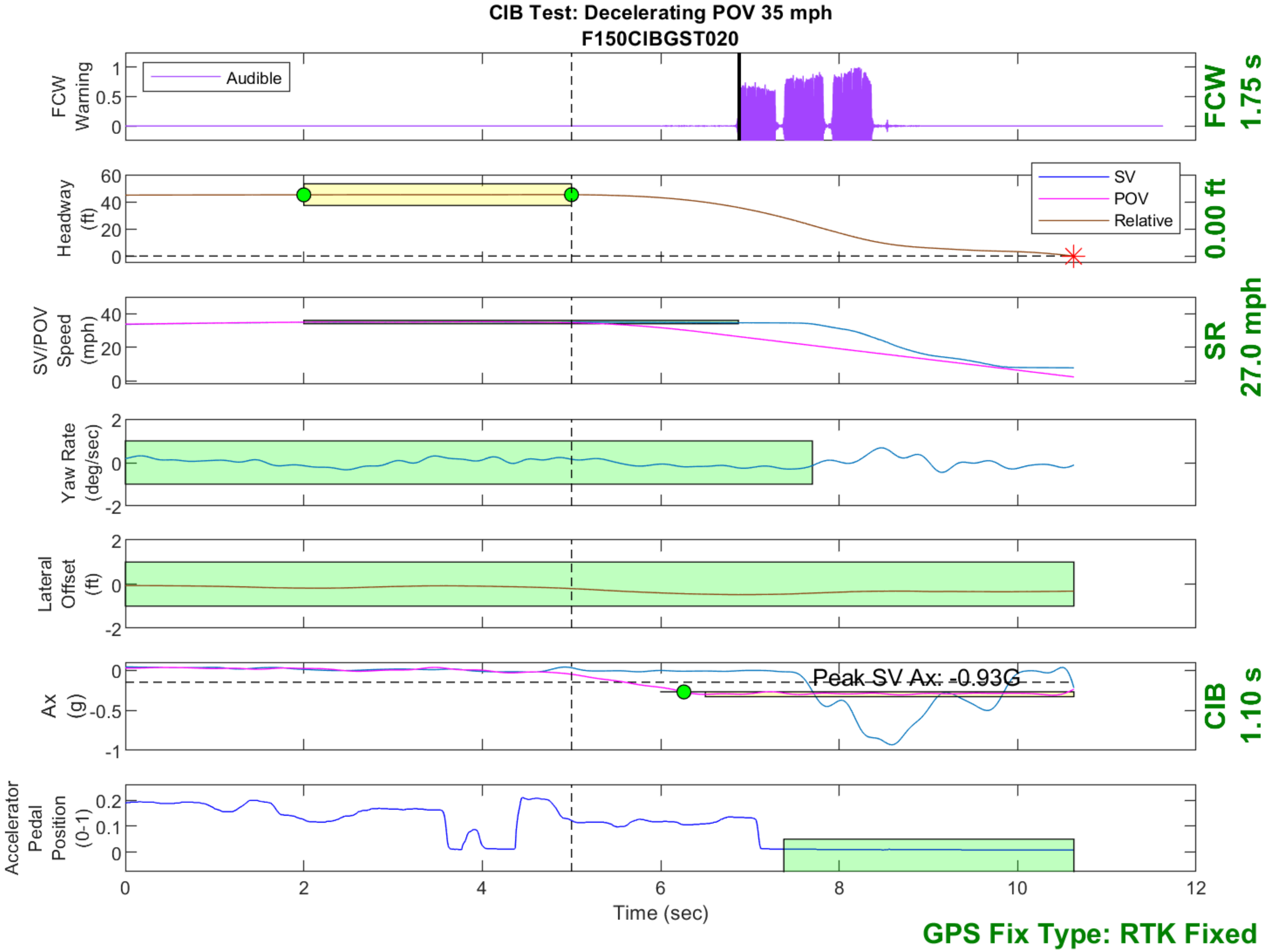

Figure D48. Time History for CIB Run 20, Decelerating POV, 35 mph 0.3 g

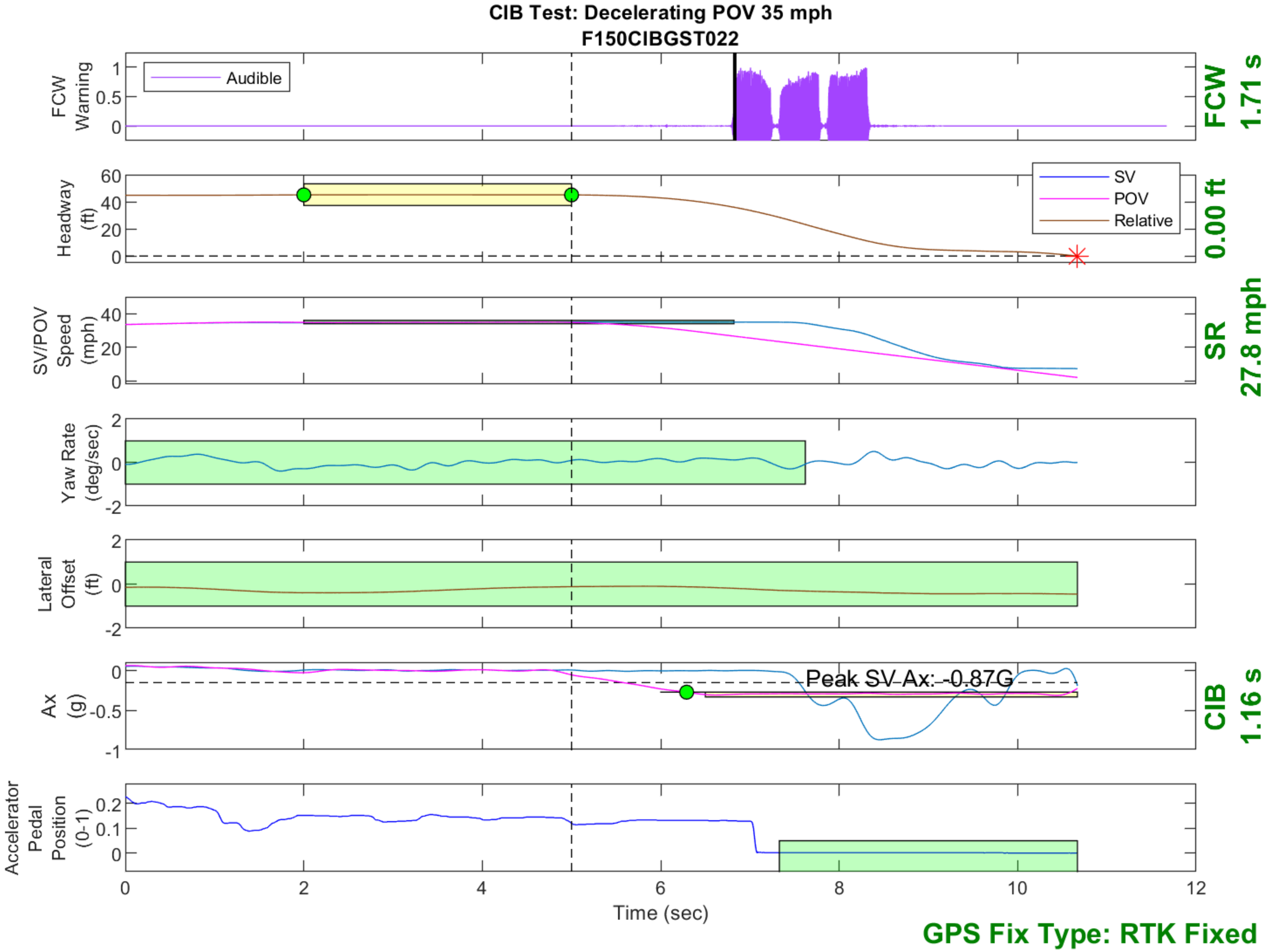

Figure D49. Time History for CIB Run 22, Decelerating POV, 35 mph 0.3 g

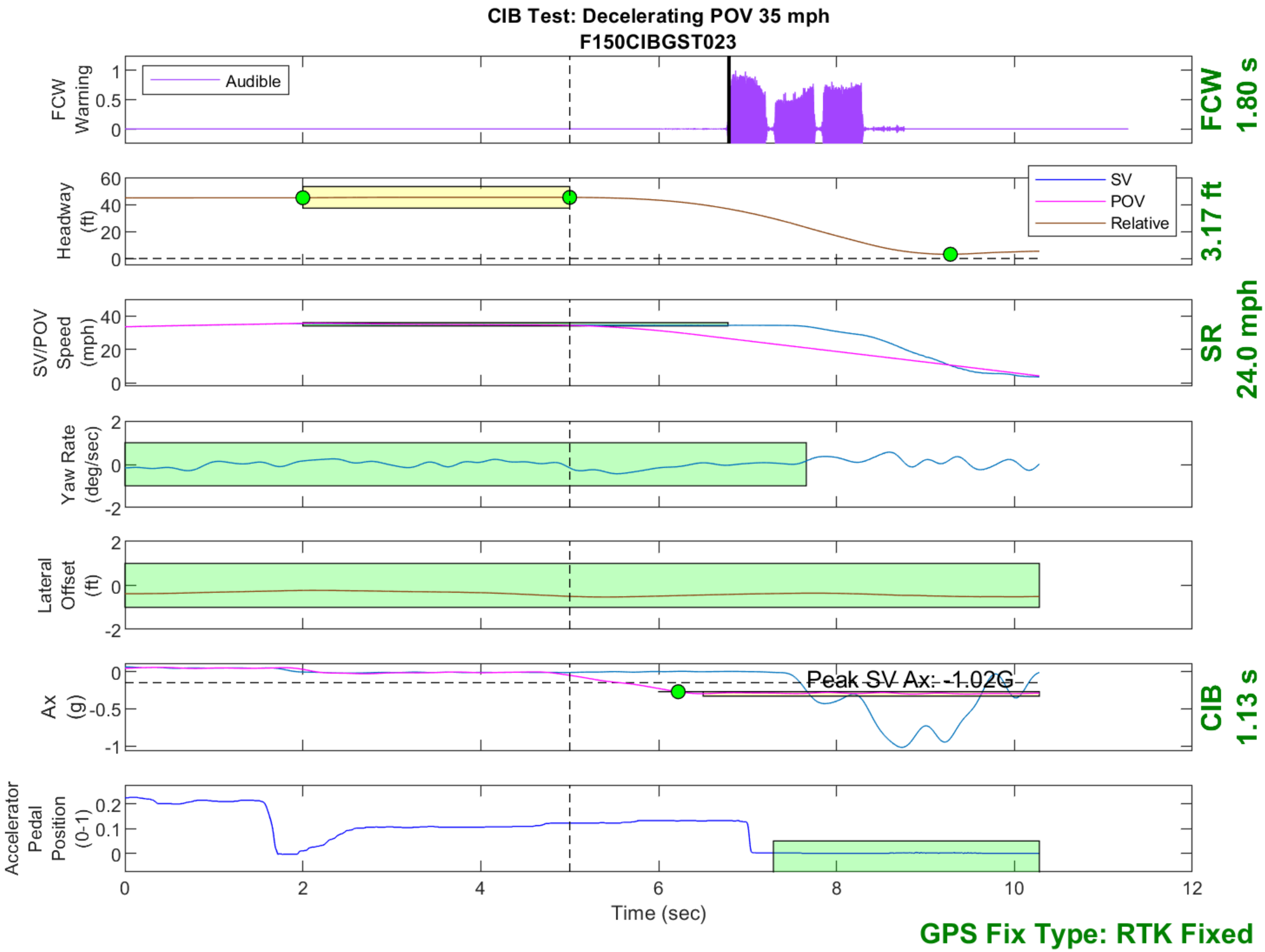

Figure D50. Time History for CIB Run 23, Decelerating POV, 35 mph 0.3 g

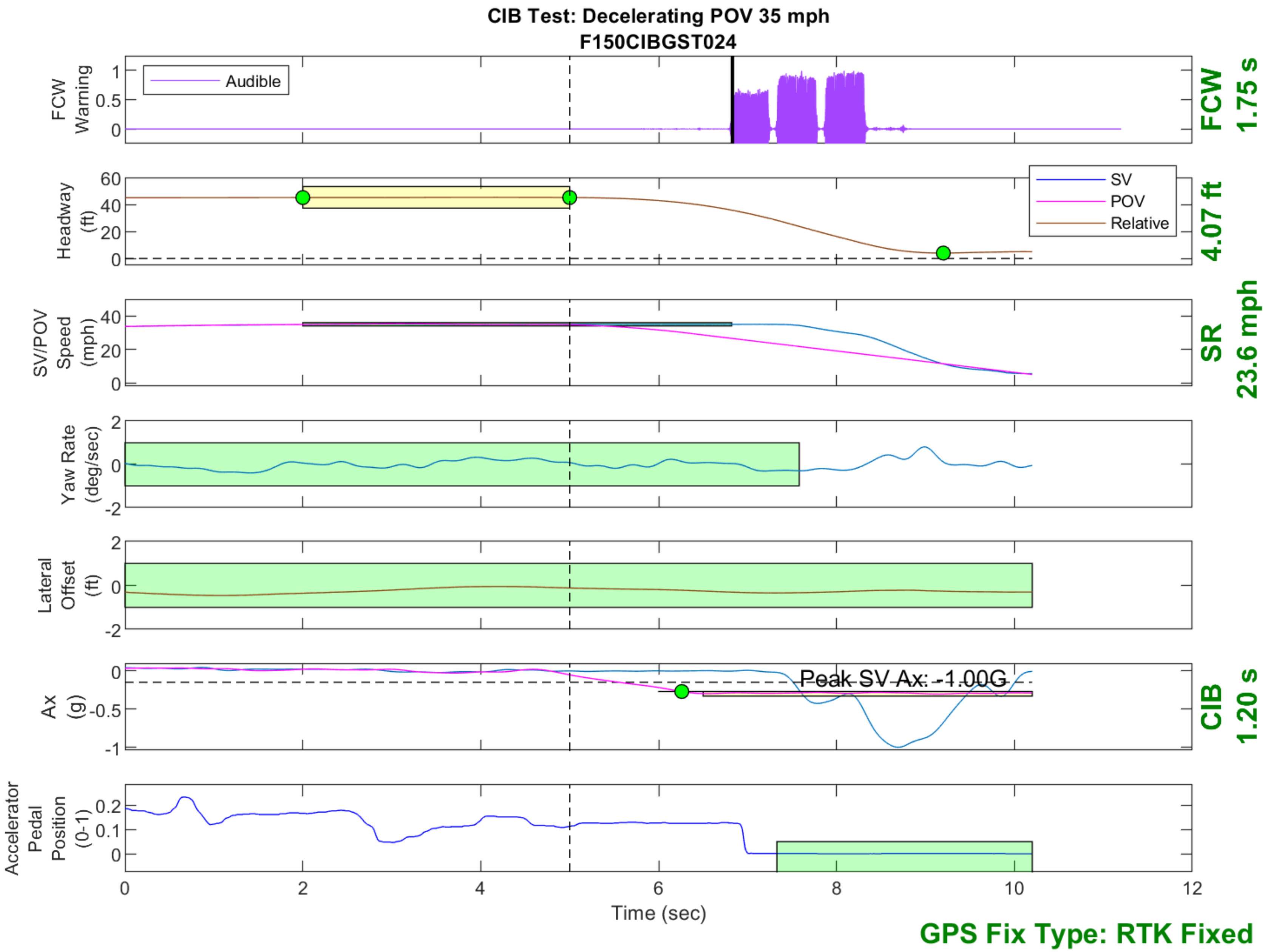

Figure D51. Time History for CIB Run 24, Decelerating POV, 35 mph 0.3 g

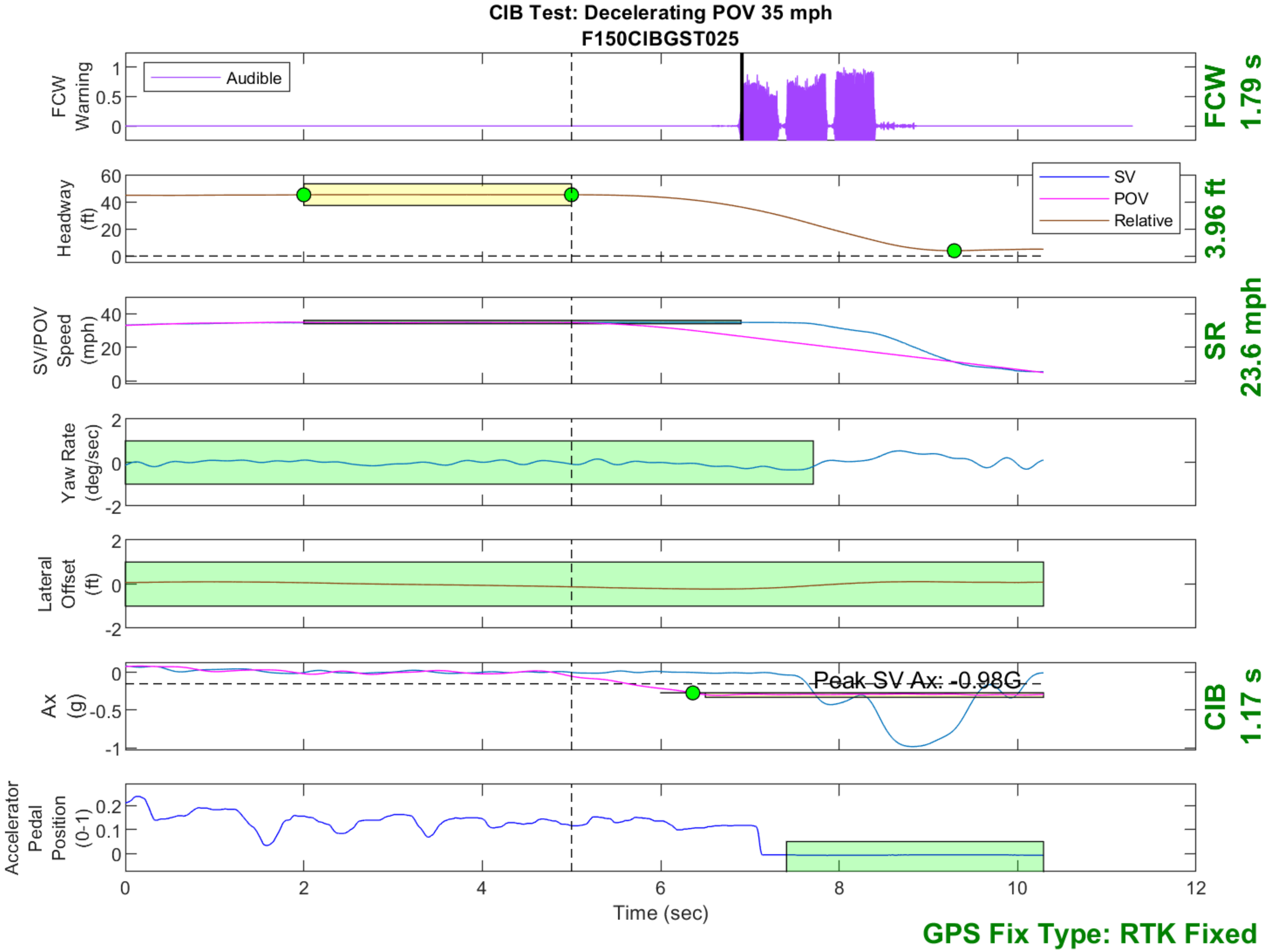

Figure D52. Time History for CIB Run 25, Decelerating POV, 35 mph 0.3 g

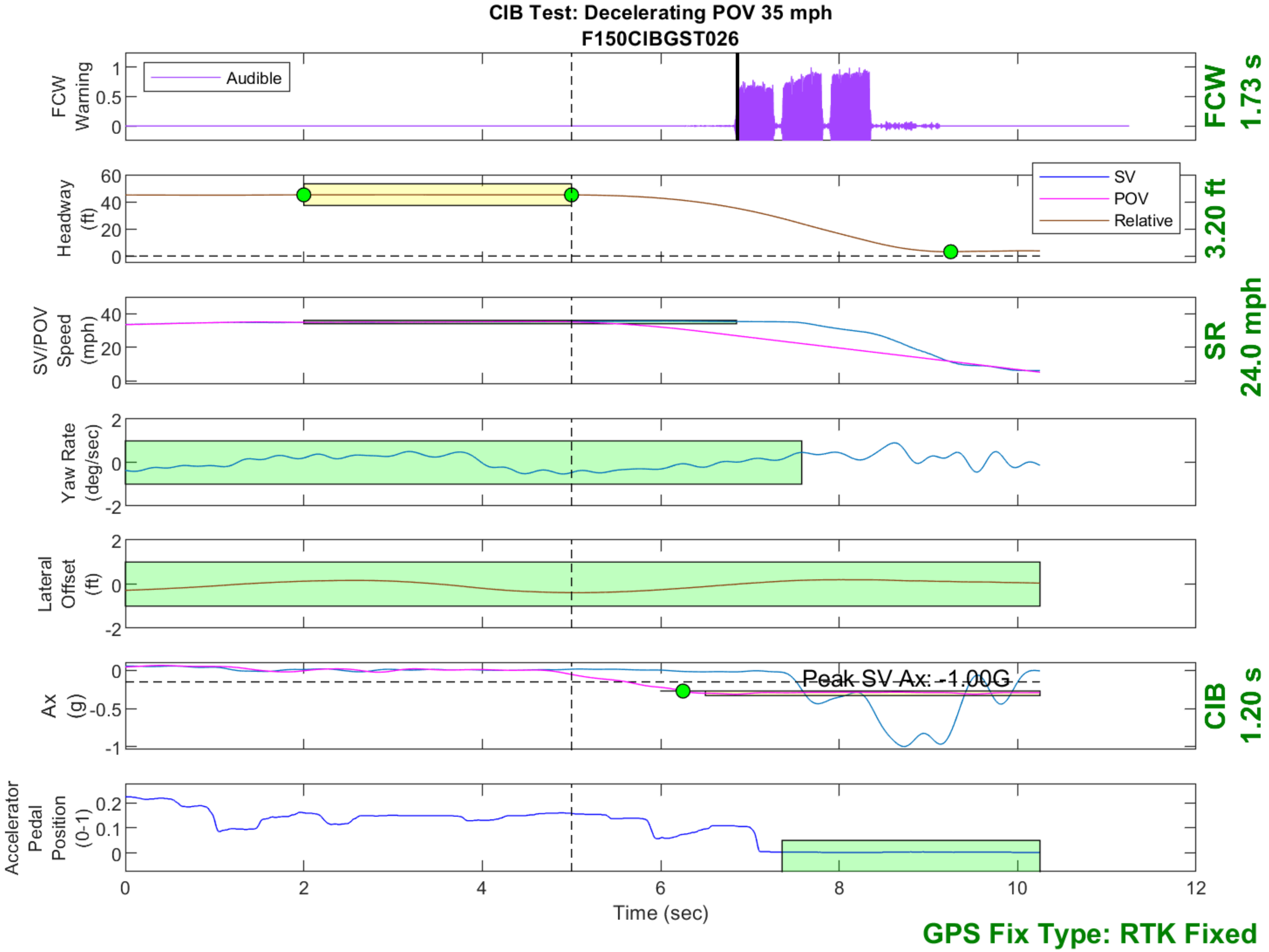

Figure D53. Time History for CIB Run 26, Decelerating POV, 35 mph 0.3 g

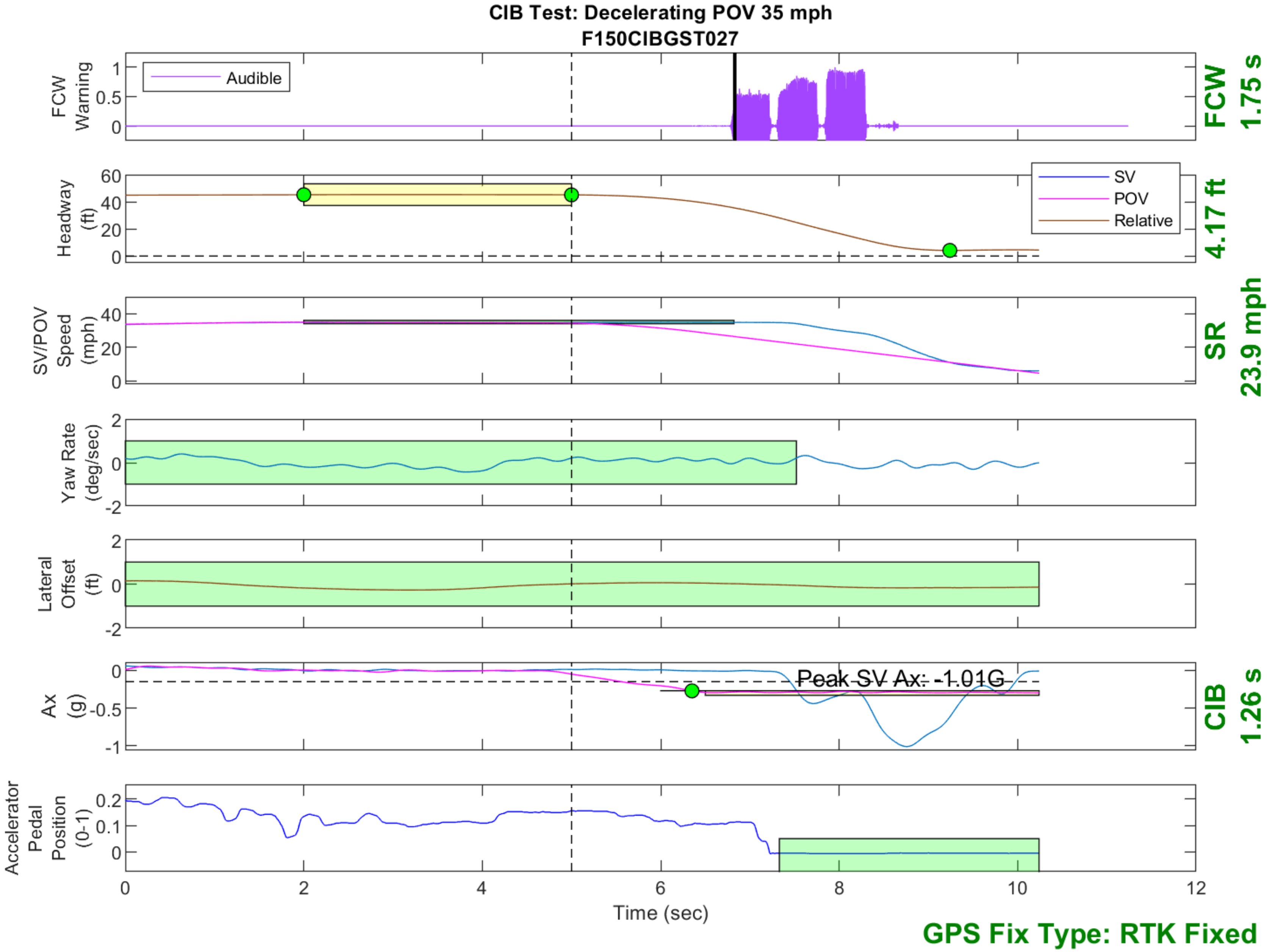

Figure D54. Time History for CIB Run 27, Decelerating POV, 35 mph 0.3 g

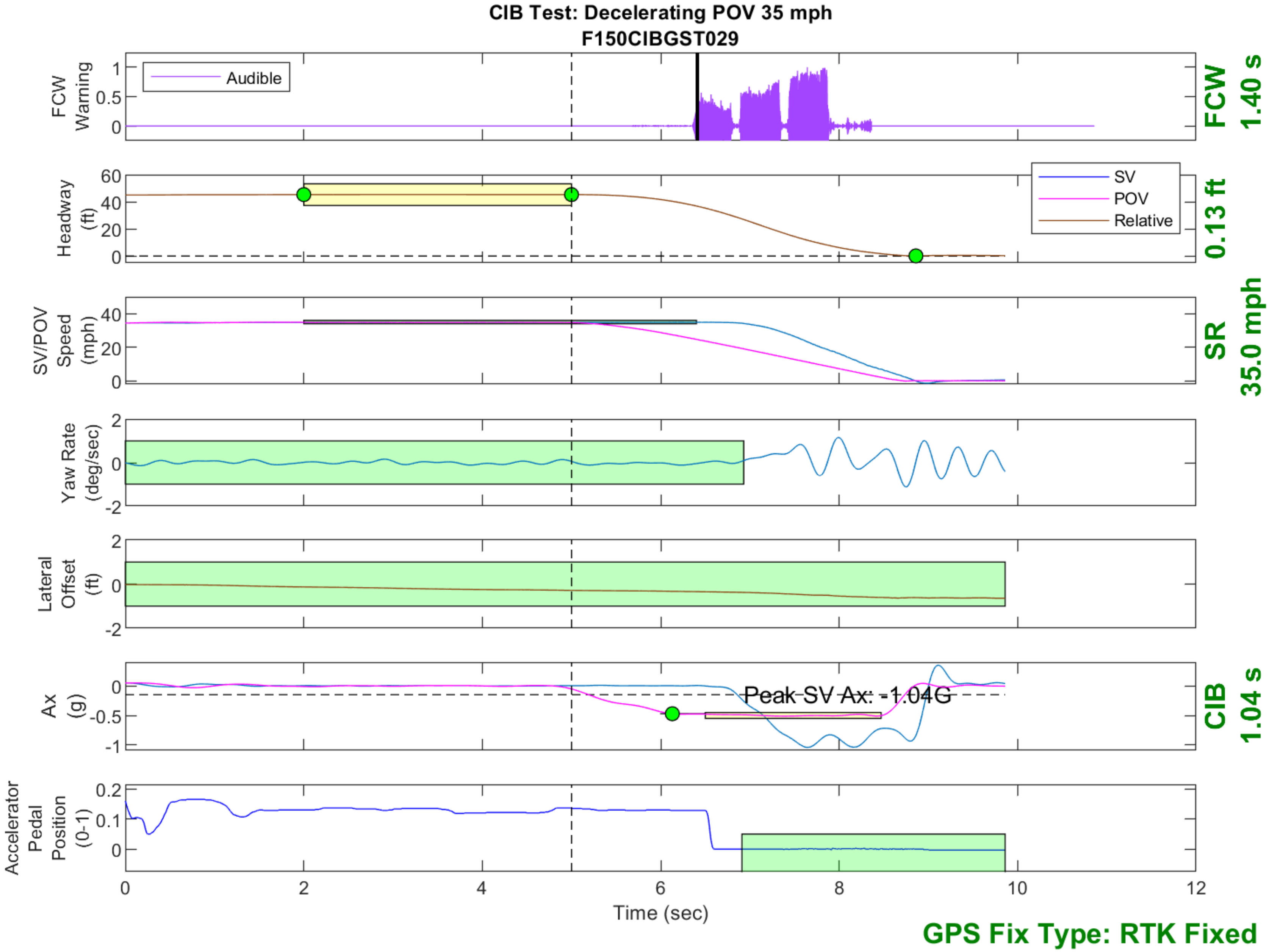

Figure D55. Time History for CIB Run 29, Decelerating POV, 35 mph 0.5 g

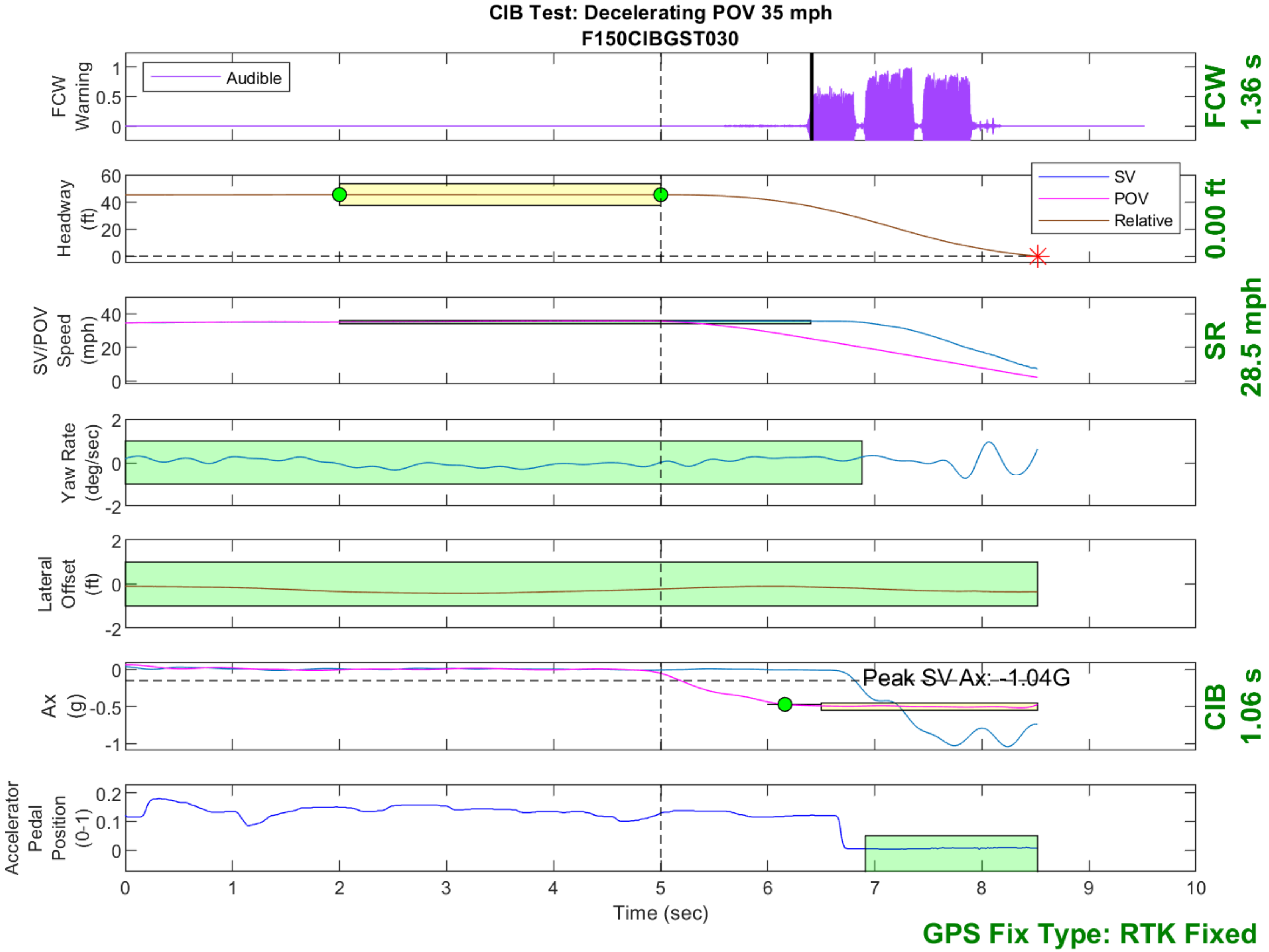

Figure D56. Time History for CIB Run 30, Decelerating POV, 35 mph 0.5 g

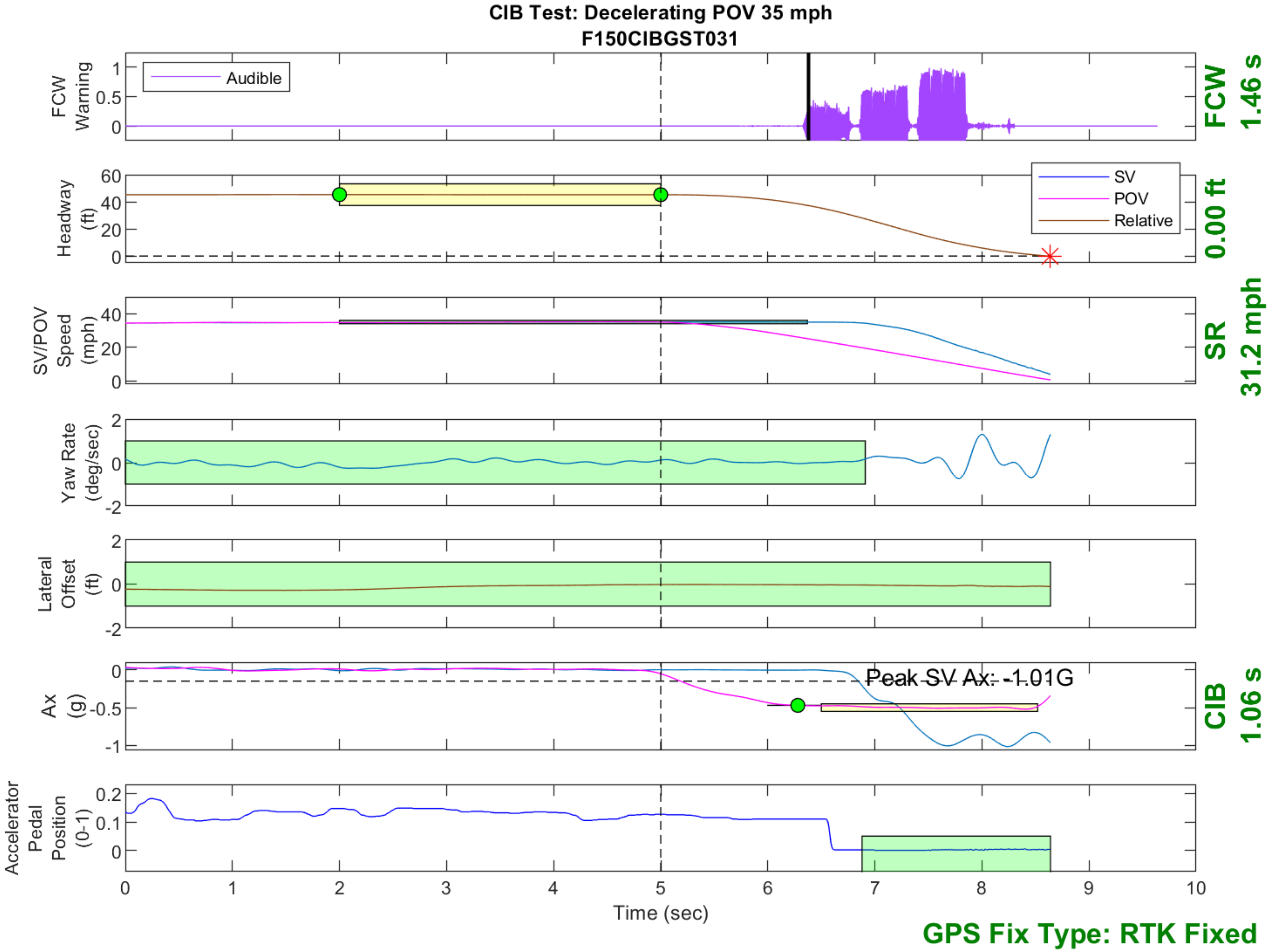

Figure D57. Time History for CIB Run 31, Decelerating POV, 35 mph 0.5 g

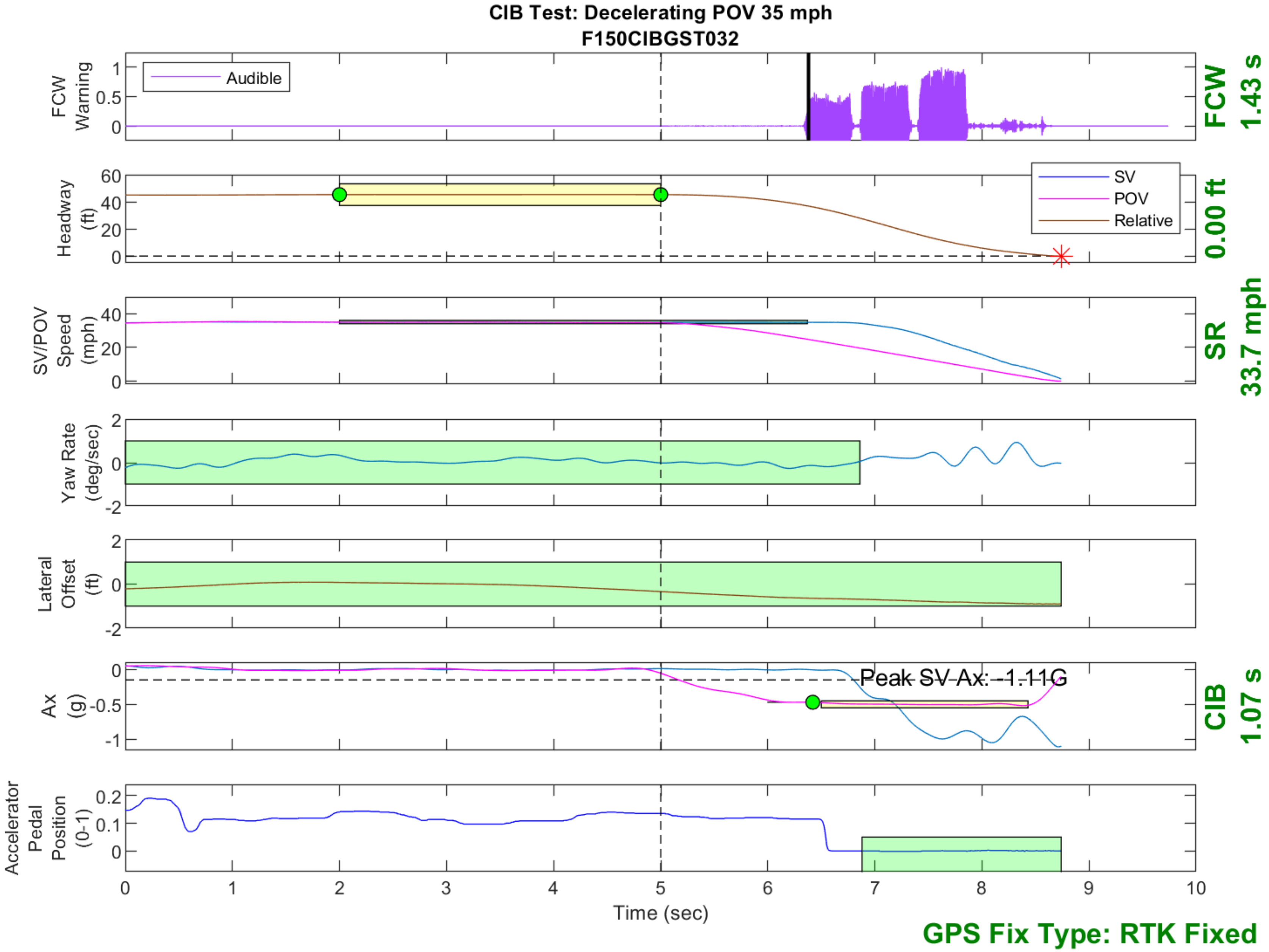

Figure D58. Time History for CIB Run 32, Decelerating POV, 35 mph 0.5 g

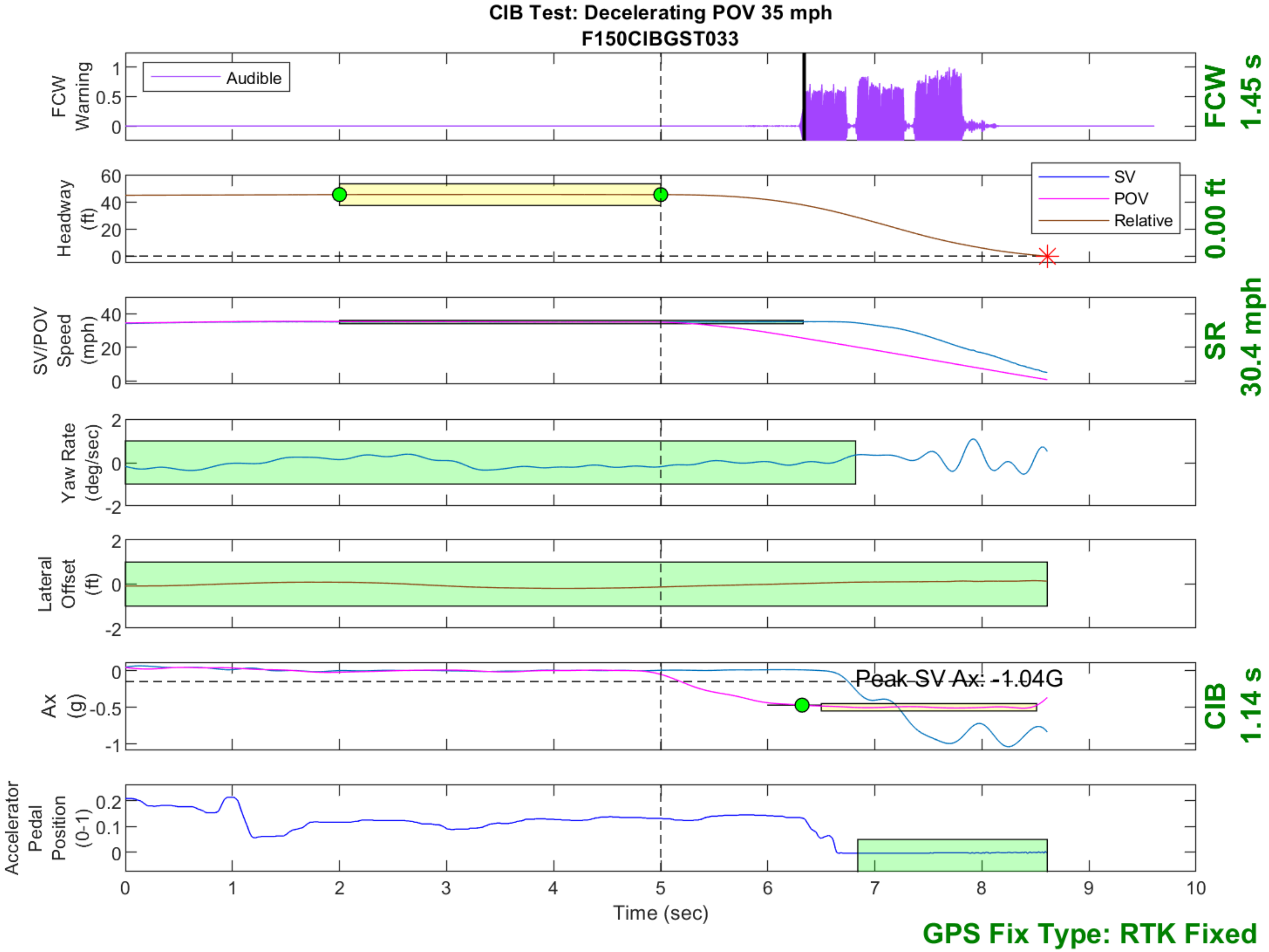

Figure D59. Time History for CIB Run 33, Decelerating POV, 35 mph 0.5 g

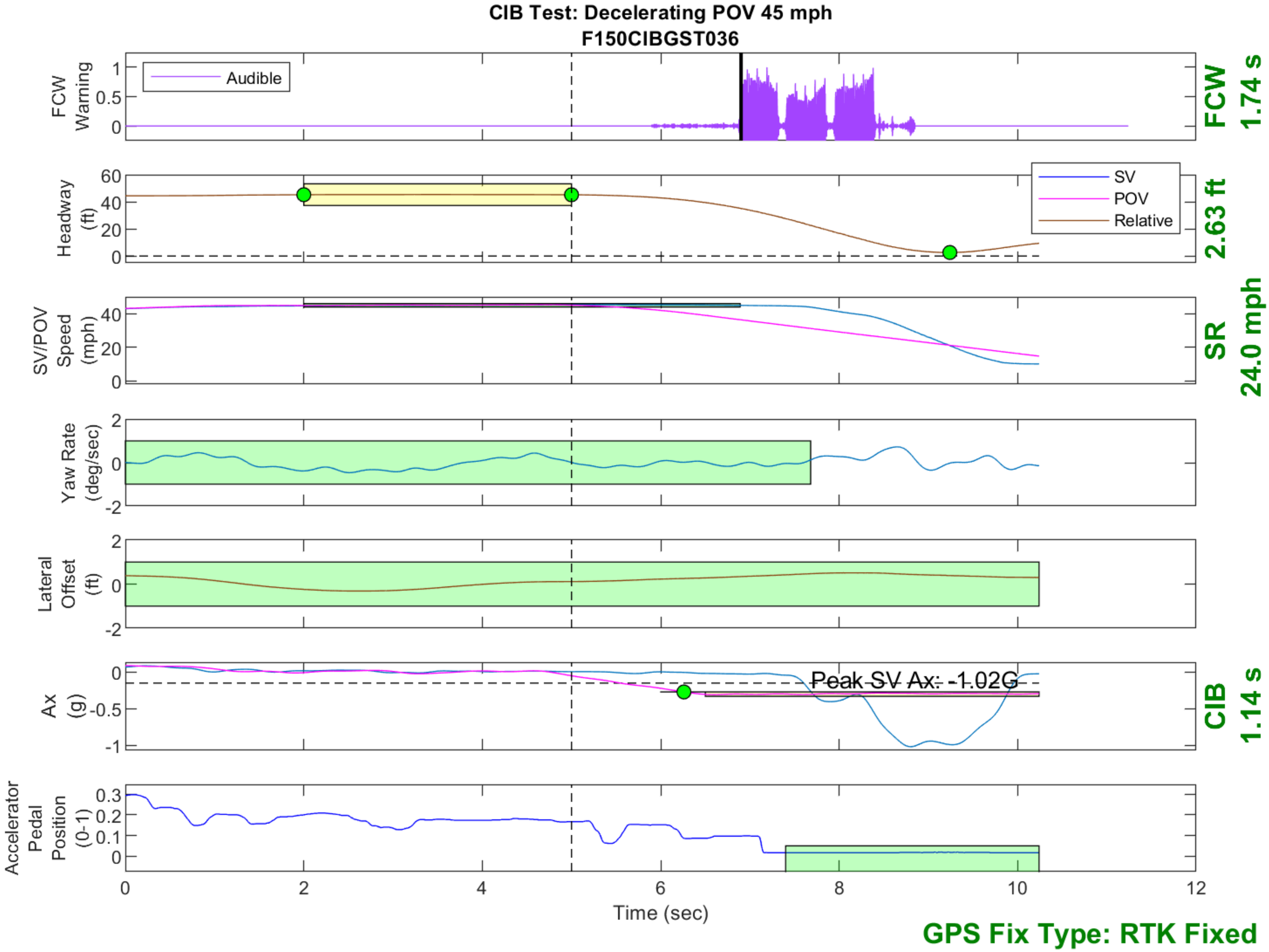

Figure D60. Time History for CIB Run 36, Decelerating POV, 45 mph 0.3 g

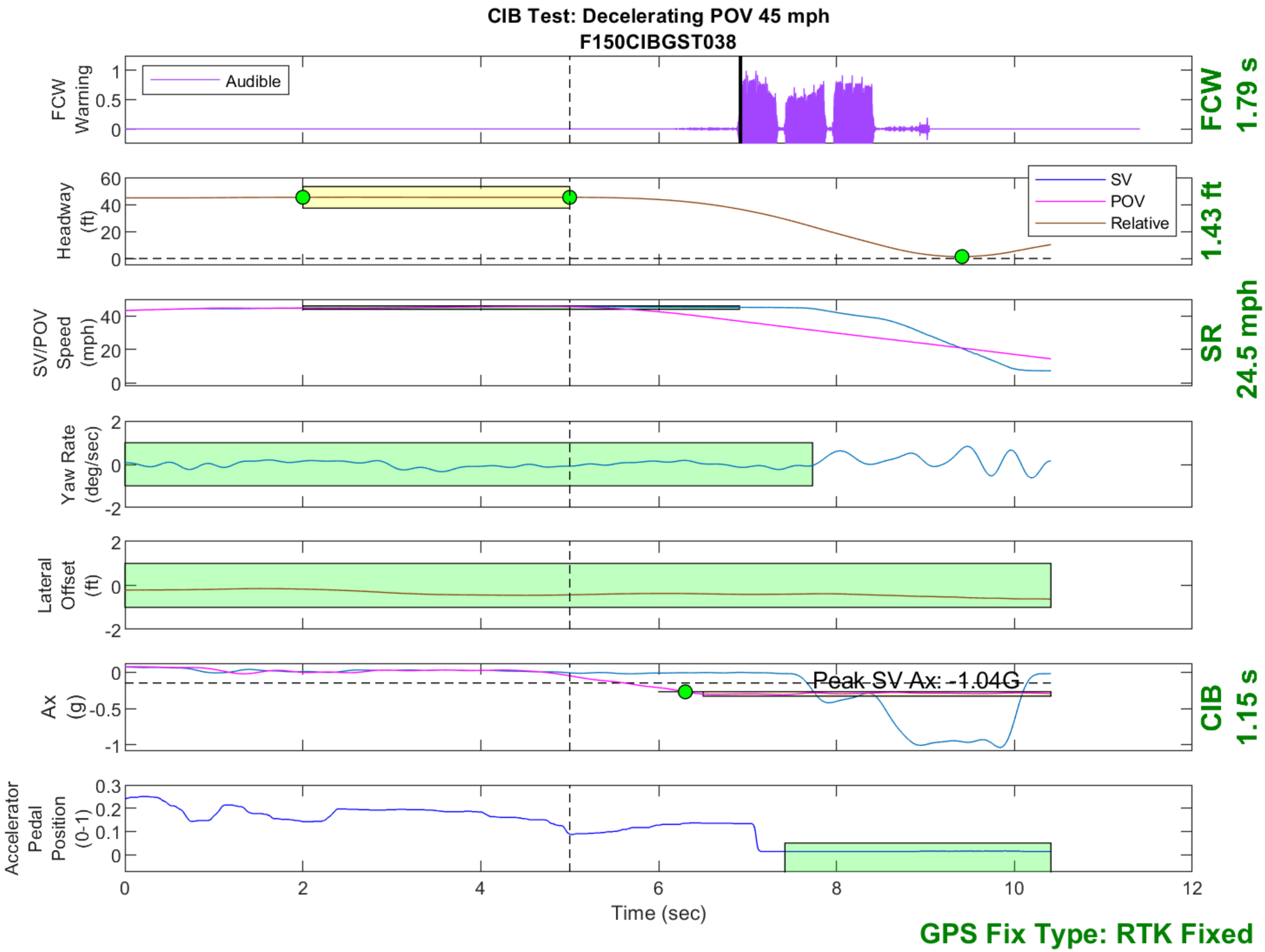

Figure D61. Time History for CIB Run 38, Decelerating POV, 45 mph 0.3 g

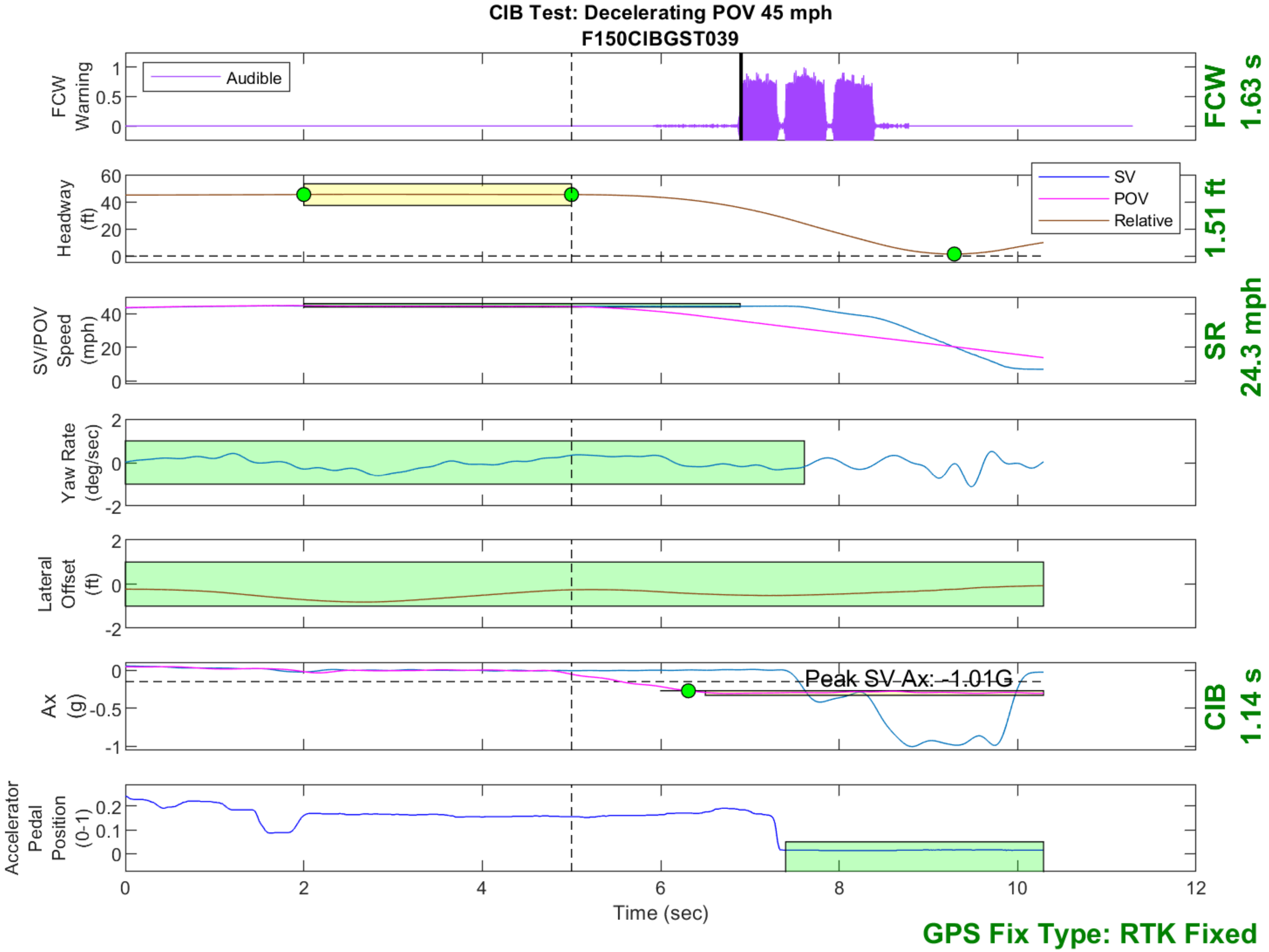

Figure D62. Time History for CIB Run 39, Decelerating POV, 45 mph 0.3 g

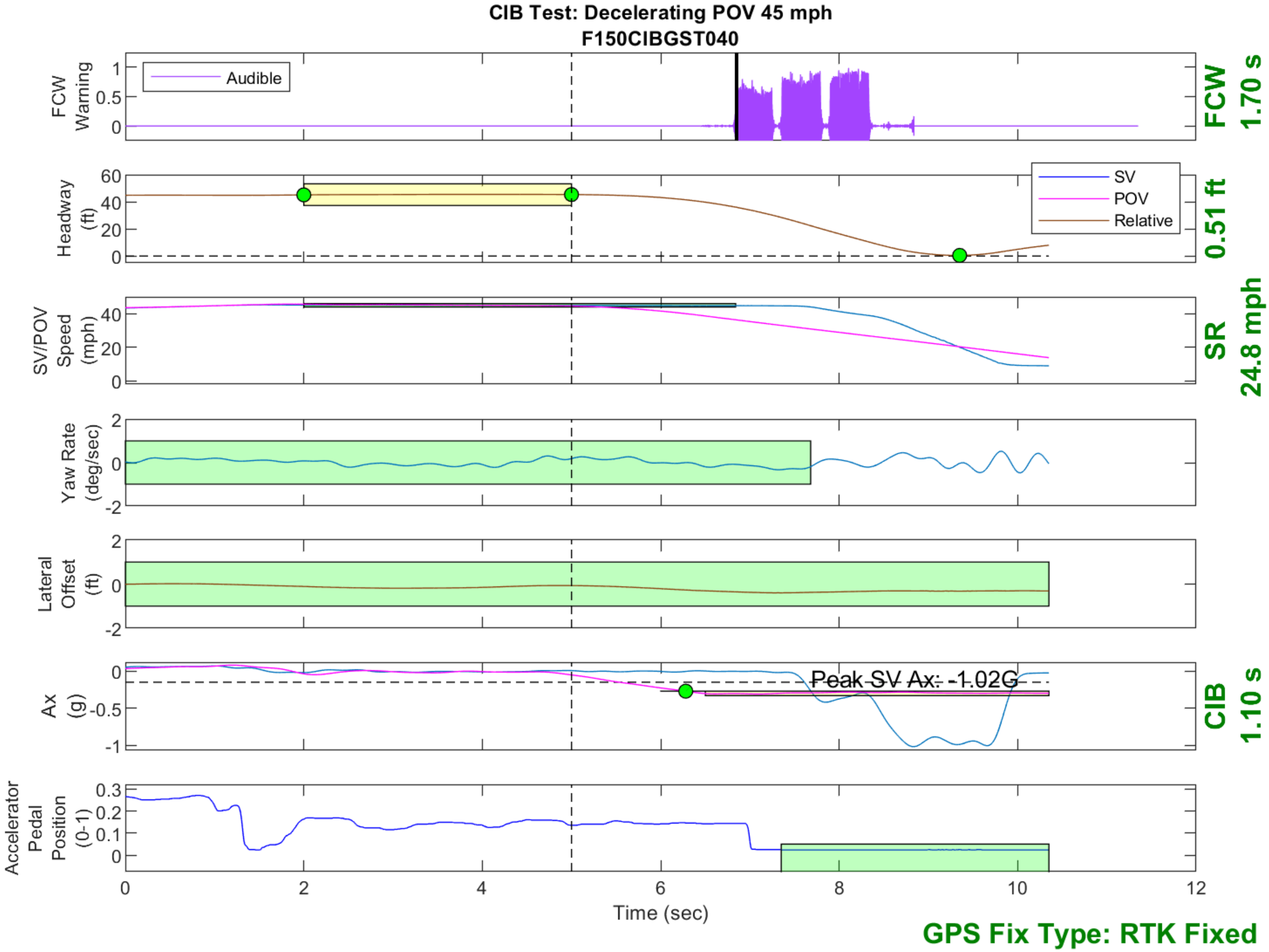

Figure D63. Time History for CIB Run 40, Decelerating POV, 45 mph 0.3 g

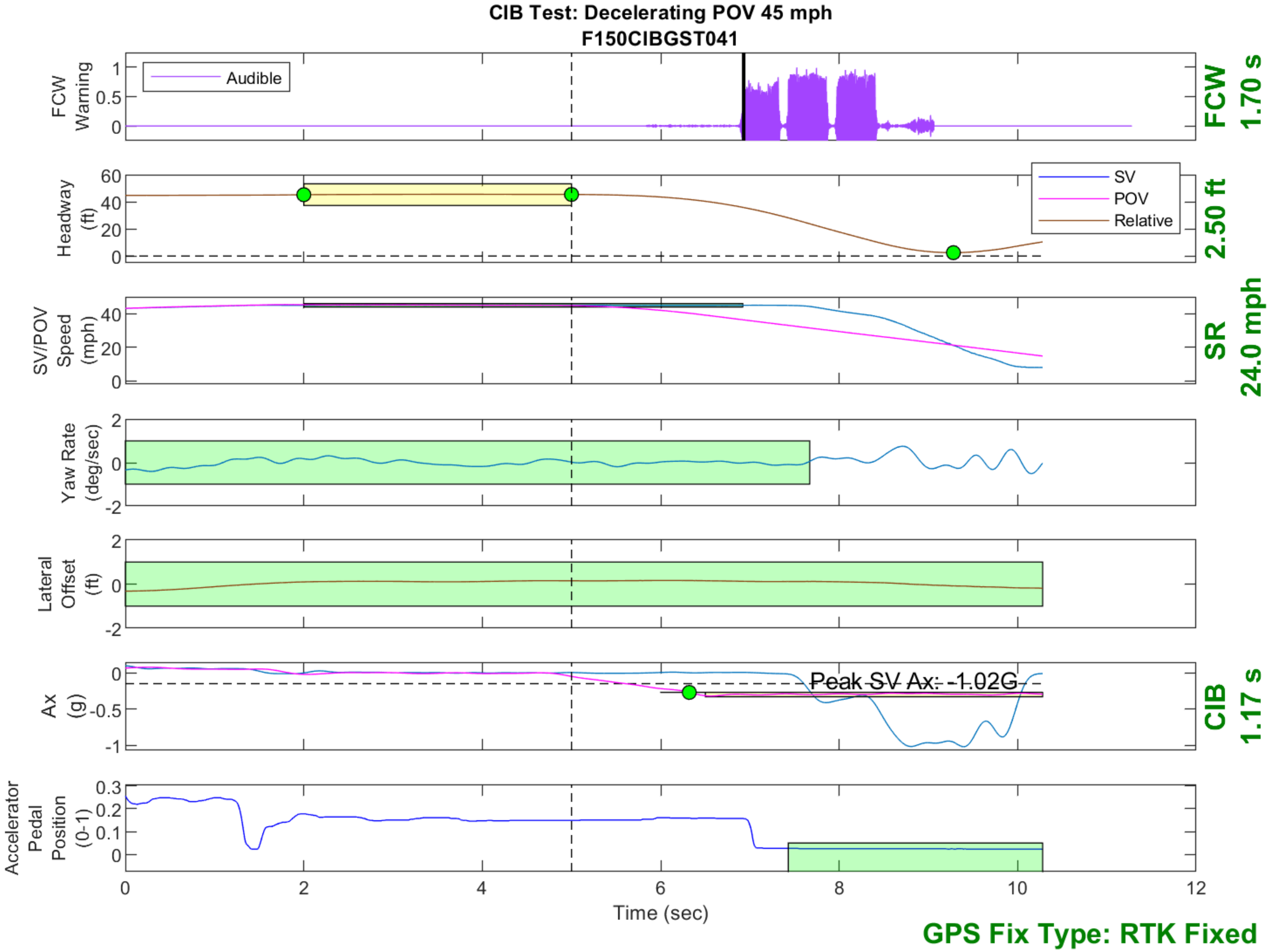

Figure D64. Time History for CIB Run 41, Decelerating POV, 45 mph 0.3 g