CRASH IMMINENT BRAKING SYSTEM RESEARCH TEST
NCAP-DRI-CIBHS-20-11

2020 Hyundai Palisade SEL FWD

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Final Report

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National Highway Traffic Safety Administration
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16. Abstract These research tests were conducted on the subject 2020 Hyundai Palisade SEL FWD 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 59 out of 59 valid test runs. Contact did occur on all 5 of the 35 mph 0.5 G decel scenarios.			
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Section I

INTRODUCTION

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

The method prescribed by the National Highway Traffic Safety Administration (NHTSA) 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

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2020 Hyundai Palisade SEL FWD

VIN: *KM8R44HEXLU06xxxx* Test Date: *9/11/2020*

Crash Imminent Braking System setting: *Normal*

		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:	*7*	*0*	*7*
	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:	*8*	*0*	*8*
	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:	***59***	***0***	***59***

Notes:
The system met the acceptability criteria for 59 out of 59 valid test runs. Contact did occur on all 5 of the 35 mph 0.5 G decel scenarios.

[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

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2020 Hyundai Palisade SEL FWD

TEST VEHICLE INFORMATION

VIN: *KM8R44HEXLU06xxxx*

Body Style: *SUV* Color: *Becketts Black*

Date Received: *8/10/2020* Odometer Reading: *4038 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Hyundai Motor Company*

Date of manufacture: *AUG/14/19*

Vehicle Type: *MPV*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *245/50R20*

Rear: *245/50R20*

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

Rear: *240 kPa (35 psi)*

TIRES

Tire manufacturer and model: *Bridgestone Dueler H/P Sport AS*

Front tire designation: *245/50R20 120V*

Rear tire designation: *245/50/R20 120V*

Front tire DOT prefix: *DOT EJ KH CEC*

Rear tire DOT prefix: *DOT EJ KH CEC*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

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2020 Hyundai Palisade SEL FWD

GENERAL INFORMATION

Test date: *9/11/2020*

AMBIENT CONDITIONS

Air temperature: *32.2 C (90 F)*

Wind speed: *1.5 m/s (3.5 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)*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

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2020 Hyundai Palisade SEL FWD

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*567.0 kg (1250 lb)*	Right Front:	*601.9 kg (1327 lb)*
Left Rear:	*455.4 kg (1004 lb)*	Right Rear:	*430.5 kg (949 lb)*
		Total:	*2054.8 kg (4530 lb)*

CRASH IMMINENT BRAKE SYSTEM

DATA SHEET 4: CRASH IMMINENT BRAKE SYSTEM OPERATION

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2020 Hyundai Palisade

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

Forward Collision-Avoidance Assist (FCA)

Type of sensors the system uses:

The system uses a fusion type which includes radar and mono camera.

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

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

5 mph (8 km/h) (Per manufacturer supplied information)

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

50 mph (80 km/h) (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

The vehicle does not require an initialization sequence.

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

In general, the FCA does not deactivate due to repeated FCA activations or impacts. However, if the brake actuator or radar/camera sensors are damaged or have problems due to repeated activations or impacts, the FCA can deactivate. In this case, the system provides a diagnostic light to the driver.

CRASH IMMINENT BRAKE

DATA SHEET 4: CRASH IMMINENT BRAKE SYSTEM OPERATION

2020 Hyundai Palisade

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

- **X** Warning light
- **X** Buzzer or audible alarm
- **X** 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 alerted by a visual display (Figure A14), a repeated beep with a dominant frequency of 1506 Hz, and steering wheel vibration.

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.

The driver can deactivate the FCA via User Select Menu (USM) interface:
User Settings
Driver Assistance
Forward Safety
Off
The FCA is reactivated on each ignition cycle.
See Appendix A, Figure A11.

CRASH IMMINENT BRAKE

DATA SHEET 4: CRASH IMMINENT BRAKE SYSTEM OPERATION

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2020 Hyundai Palisade

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 driver can adjust the FCA via User Select Menu (USM) interface:
User Settings
Driver Assistance
Warning Timing
Normal
Later
Warning Volume
High
Medium
Low
Off
Forward Safety
Active Assist
Warning Only
Off
See Appendix A, Figures A11 through A13

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.

See pages 5-72 through 5-77 of the Owner's Manual shown in Appendix B, pages B-13 through B-18.

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. 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. Test conditions for Test 1 are shown in Table 2.

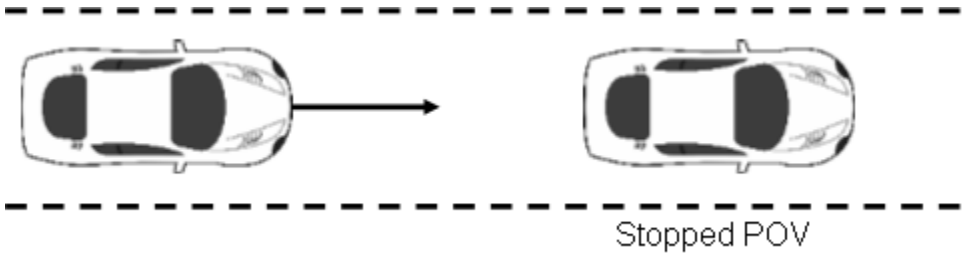


Figure 1. Depiction of Test 1

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

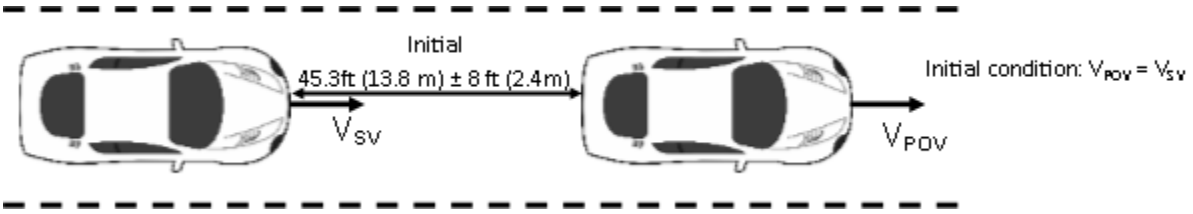


Figure 2. Depiction of Test 2

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. 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 by the example in Figure 3. Test conditions for Test 3 are shown in Table 4.

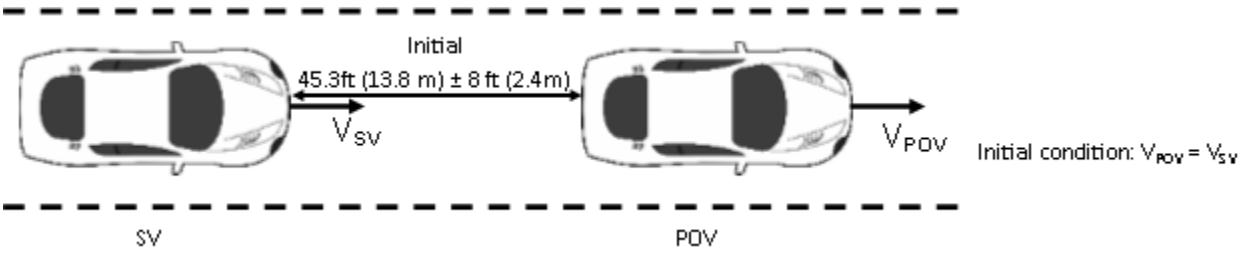


Figure 3. Depiction of Test 3 with POV Decelerating with V_0 =35 mph (56.3 km/h)

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 Global Vehicle Target (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 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 0.12 g (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 100 psi	Omega DPG8001	17042707002	By: DRI Date: 8/18/2020 Due: 8/18/2021
Platform Scales	Vehicle Total, Wheel, and Axle Load	1500 lb/platform	0.5% of applied load	Intercomp SW500	0410MN20001	By: DRI Date: 4/20/2020 Due: 4/20/2021
Linear (string) encoder	Throttle pedal travel	10 in	0.1 in	UniMeasure LX-EP	50060725	By: DRI Date: 6/19/2020 Due: 6/19/2021
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	N/A
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 Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +	2258	By: Oxford Technical Solutions Date: 5/3/2019 Due: 5/3/2021
POV Multi-Axis Inertial Sensing System		Accels ± 10g, Angular Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +	2176	By: Oxford Technical Solutions Date: 6/26/2020 Due: 6/26/2022

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	N/A
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	N/A	N/A
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	N/A	N/A
Accelerometer	Acceleration (to measure time at alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	N/A	N/A

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

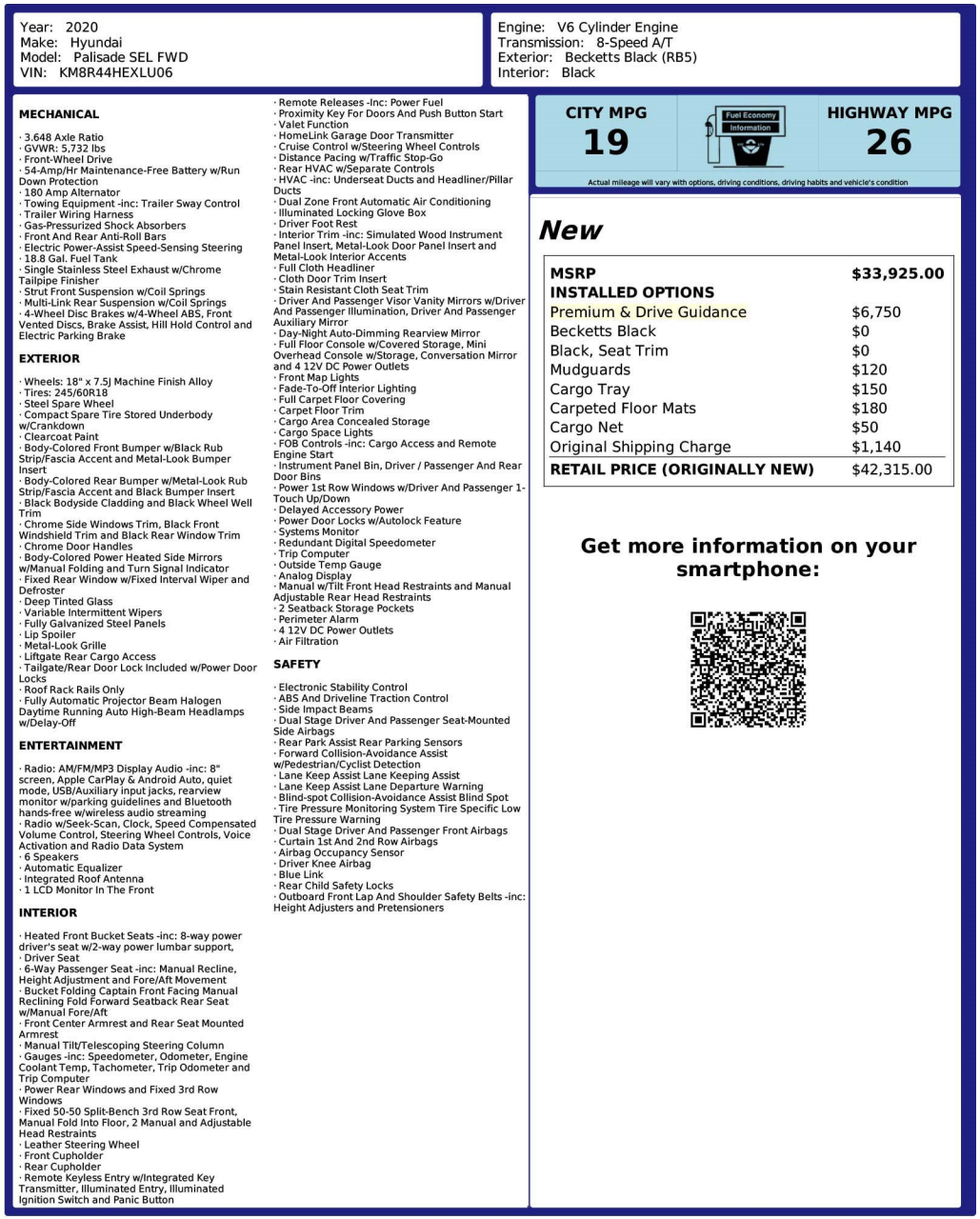
APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle



Year: 2020
Make: Hyundai
Model: Palisade SEL FWD
VIN: KM8R44HEXLU06

Engine: V6 Cylinder Engine
Transmission: 8-Speed A/T
Exterior: Becketts Black (RB5)
Interior: Black

MECHANICAL

· 3.648 Axle Ratio
· GVWR: 5,732 lbs
· Front-Wheel Drive
· 54-Amp/Hr Maintenance-Free Battery w/Run Down Protection
· 180 Amp Alternator
· Towing Equipment -inc: Trailer Sway Control
· Trailer Wiring Harness
· Gas-Pressurized Shock Absorbers
· Front And Rear Anti-Roll Bars
· Electric Power-Assist Speed-Sensing Steering
· 18.8 Gal. Fuel Tank
· Single Stainless Steel Exhaust w/Chrome Tailpipe Finisher
· Strut Front Suspension w/Coil Springs
· Multi-Link Rear Suspension w/Coil Springs
· 4-Wheel Disc Brakes w/4-Wheel ABS, Front Vented Discs, Brake Assist, Hill Hold Control and Electric Parking Brake

EXTERIOR

· Wheels: 18" x 7.5J Machine Finish Alloy
· Tires: 245/60R18
· Steel Spare Wheel
· Compact Spare Tire Stored Underbody w/Crankdown
· Clearcoat Paint
· Body-Colored Front Bumper w/Black Rub Strip/Fascia Accent and Metal-Look Bumper Insert
· Body-Colored Rear Bumper w/Metal-Look Rub Strip/Fascia Accent and Black Bumper Insert
· Black Bodyside Cladding and Black Wheel Well Trim
· Chrome Side Windows Trim, Black Front Windshield Trim and Black Rear Window Trim
· Chrome Door Handles
· Body-Colored Power Heated Side Mirrors w/Manual Folding and Turn Signal Indicator
· Fixed Rear Window w/Fixed Interval Wiper and Defroster
· Deep Tinted Glass
· Variable Intermittent Wipers
· Fully Galvanized Steel Panels
· Lip Spoiler
· Metal-Look Grille
· Liftgate Rear Cargo Access
· Tailgate/Rear Door Lock Included w/Power Door Locks
· Roof Rack Rails Only
· Fully Automatic Projector Beam Halogen Daytime Running Auto High-Beam Headlamps w/Delay-Off

ENTERTAINMENT

· Radio: AM/FM/MP3 Display Audio -inc: 8" screen, Apple CarPlay & Android Auto, quiet mode, USB/Auxiliary input jacks, rearview monitor w/parking guidelines and Bluetooth hands-free w/wireless audio streaming
· Radio w/Seek-Scan, Clock, Speed Compensated Volume Control, Steering Wheel Controls, Voice Activation and Radio Data System
· 6 Speakers
· Automatic Equalizer
· Integrated Roof Antenna
· 1 LCD Monitor In The Front

INTERIOR

· Heated Front Bucket Seats -inc: 8-way power driver's seat w/2-way power lumbar support,
· Driver Seat
· 6-Way Passenger Seat -inc: Manual Recline, Height Adjustment and Fore/Aft Movement
· Bucket Folding Captain Front Facing Manual Reclining Fold Forward Seatback Rear Seat w/Manual Fore/Aft
· Front Center Armrest and Rear Seat Mounted Armrest
· Manual Tilt/Telescoping Steering Column
· Gauges -inc: Speedometer, Odometer, Engine Coolant Temp, Tachometer, Trip Odometer and Trip Computer
· Power Rear Windows and Fixed 3rd Row Windows
· Fixed 50-50 Split-Bench 3rd Row Seat Front, Manual Fold Into Floor, 2 Manual and Adjustable Head Restraints
· Leather Steering Wheel
· Front Cupholder
· Rear Cupholder
· Remote Keyless Entry w/Integrated Key Transmitter, Illuminated Entry, Illuminated Ignition Switch and Panic Button
· Remote Releases -Inc: Power Fuel
· Proximity Key For Doors And Push Button Start
· Valet Function
· HomeLink Garage Door Transmitter
· Cruise Control w/Steering Wheel Controls
· Distance Pacing w/Traffic Stop-Go
· Rear HVAC w/Separate Controls
· HVAC -inc: Underseat Ducts and Headliner/Pillar Ducts
· Dual Zone Front Automatic Air Conditioning
· Illuminated Locking Glove Box
· Driver Foot Rest
· Interior Trim -inc: Simulated Wood Instrument Panel Insert, Metal-Look Door Panel Insert and Metal-Look Interior Accents
· Full Cloth Headliner
· Cloth Door Trim Insert
· Stain Resistant Cloth Seat Trim
· Driver And Passenger Visor Vanity Mirrors w/Driver And Passenger Illumination, Driver And Passenger Auxiliary Mirror
· Day-Night Auto-Dimming Rearview Mirror
· Full Floor Console w/Covered Storage, Mini Overhead Console w/Storage, Conversation Mirror and 4 12V DC Power Outlets
· Front Map Lights
· Fade-To-Off Interior Lighting
· Full Carpet Floor Covering
· Carpet Floor Trim
· Cargo Area Concealed Storage
· Cargo Space Lights
· FOB Controls -inc: Cargo Access and Remote Engine Start
· Instrument Panel Bin, Driver / Passenger And Rear Door Bins
· Power 1st Row Windows w/Driver And Passenger 1-Touch Up/Down
· Delayed Accessory Power
· Power Door Locks w/Autolock Feature
· Systems Monitor
· Redundant Digital Speedometer
· Trip Computer
· Outside Temp Gauge
· Analog Display
· Manual w/Tilt Front Head Restraints and Manual Adjustable Rear Head Restraints
· 2 Seatback Storage Pockets
· Perimeter Alarm
· 4 12V DC Power Outlets
· Air Filtration

SAFETY

· Electronic Stability Control
· ABS And Driveline Traction Control
· Side Impact Beams
· Dual Stage Driver And Passenger Seat-Mounted Side Airbags
· Rear Park Assist Rear Parking Sensors
· Forward Collision-Avoidance Assist w/Pedestrian/Cyclist Detection
· Lane Keep Assist Lane Keeping Assist
· Lane Keep Assist Lane Departure Warning
· Blind-spot Collision-Avoidance Assist Blind Spot
· Tire Pressure Monitoring System Tire Specific Low Tire Pressure Warning
· Dual Stage Driver And Passenger Front Airbags
· Curtain 1st And 2nd Row Airbags
· Airbag Occupancy Sensor
· Driver Knee Airbag
· Blue Link
· Rear Child Safety Locks
· Outboard Front Lap And Shoulder Safety Belts -inc: Height Adjusters and Pretensioners

CITY MPG 19

Fuel Economy Information

HIGHWAY MPG 26

Actual mileage will vary with options, driving conditions, driving habits and vehicle's condition

New

MSRP	**$33,925.00**
INSTALLED OPTIONS	
Premium & Drive Guidance	$6,750
Becketts Black	$0
Black, Seat Trim	$0
Mudguards	$120
Cargo Tray	$150
Carpeted Floor Mats	$180
Cargo Net	$50
Original Shipping Charge	$1,140
RETAIL PRICE (ORIGINALLY NEW)	$42,315.00

Get more information on your smartphone:

Figure A3. Window Sticker (Monroney Label)

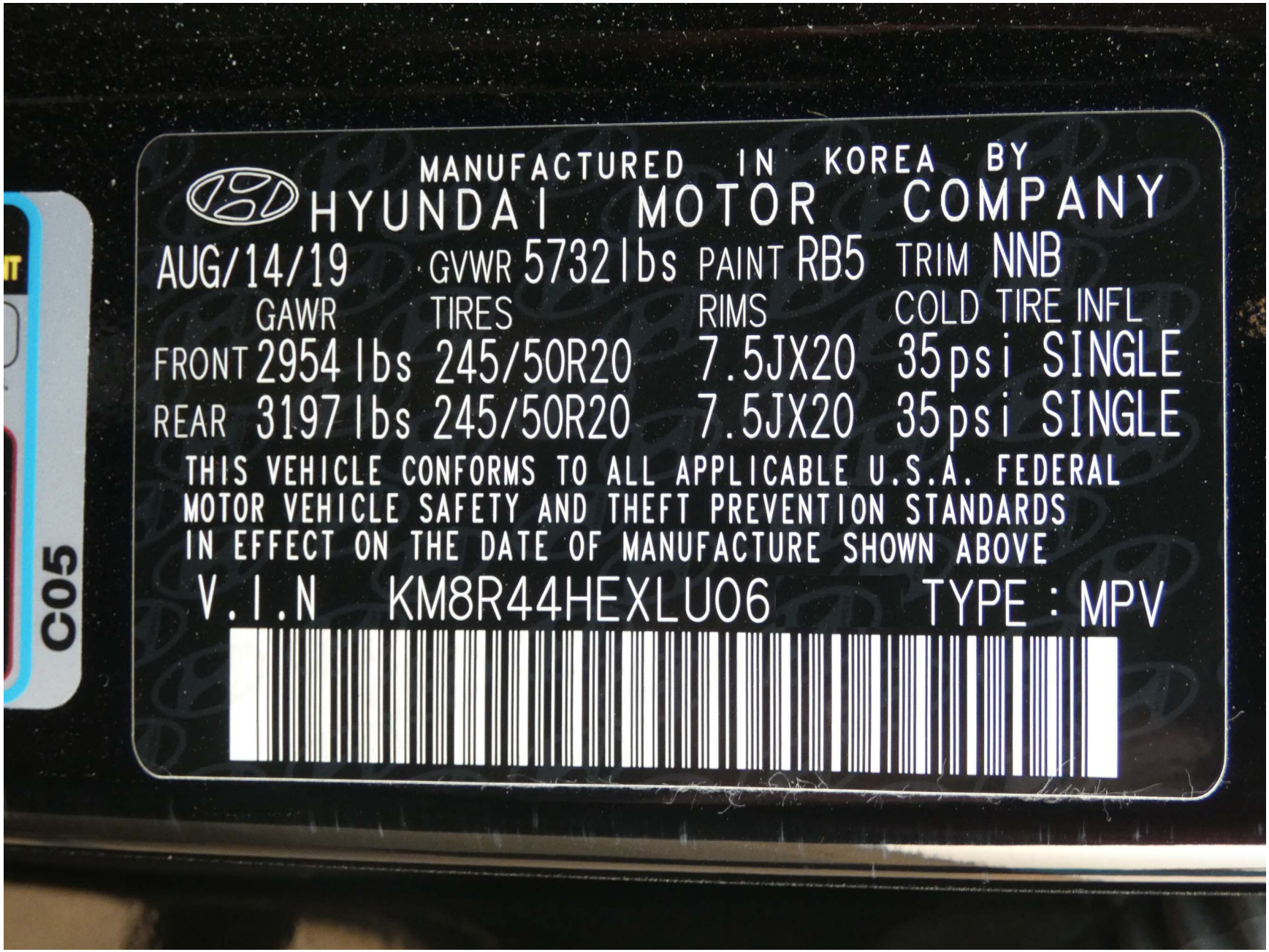


Figure A4. Vehicle Certification Label

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 and Visual Alerts

Figure A10. Computer Installed in Subject Vehicle

Figure A11. AEB Setup Menus (page 1 of 2)

Figure A12. AEB Setup Menus (page 2 of 2)

Figure A13. Controls for Driver Assistance Settings Menus

Figure A14. Visual Alert

APPENDIX B

Excerpts from Owner’s Manual

Forward Collision-Avoidance Assist (FCA) System Warning Light

This warning light illuminates:

- When you set the ignition switch or the Engine Start/Stop button to the ON position.
  - It illuminates for approximately 3 seconds and then goes off.
- When there is a malfunction with the FCA.

If this occurs, have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Forward Collision-Avoidance Assist (FCA) system" in chapter 5.

Lane Keeping Assist (LKA) System Indicator Light

This indicator light illuminates:

- [Green] When the system operating conditions are satisfied.
- [White] The system operating conditions are not satisfied.
- [Yellow] When there is a malfunction with the lane keeping assist system.

  If this occurs, have your vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Lane Keeping Assist (LKA) system" in chapter 5.

LED Headlight Warning Light (if equipped)

This warning light illuminates:

- When you set the ignition switch or the Engine Start/Stop button to the ON position.
- When there is a malfunction with the LED headlight.

  If this occurs, have the vehicle inspected by an authorized HYUNDAI dealer.

This warning light blinks:

When there is a malfunction with a LED headlight related part.

If this occurs, have the vehicle inspected by an authorized HYUNDAI dealer.

NOTICE

Continuous driving with the LED Headlight Warning Light on or blinking can reduce LED headlight life.

Check headlight (if equipped)

This warning message is displayed if the headlights are not operating properly. A headlight bulb may need to be replaced.

Information

Make sure to replace the burned out bulb with a new one of the same wattage rating.

Check turn signal (if equipped)

This warning message is displayed if the turn signal lamps are not operating properly. A lamp may need to be replaced.

Information

Make sure to replace the burned out bulb with a new one of the same wattage rating.

Check High Beam Assist (HBA) system (if equipped)

This warning message is displayed if there is a problem with the High Beam Assist (HBA) system. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "High Beam Assist (HBA) system" in chapter 3.

Check headlight LED (if equipped)

This warning message is displayed if there is a problem with the LED headlight. Have the vehicle inspected by an authorized HYUNDAI dealer.

Check Forward Collision-Avoidance Assist system (if equipped)

This warning message is displayed if there is a problem with the Forward Collision-Avoidance Assist (FCA) system. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Forward Collision-Avoidance Assist (FCA) system" in chapter 5.

Check Blind-Spot Collision Warning (BCW) system (if equipped)

This warning message is displayed if there is a problem with the Blind-Spot Collision Warning system. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Blind-Spot Collision Warning (BCW)/ Blind-Spot Collision-Avoidance Assist (BCA)" or "Rear Cross-Traffic Collision Warning (RCCW)/ Rear Cross-Traffic Collision-Avoidance Assist (RCCA)" System in chapter 5.

FORWARD COLLISION-AVOIDANCE ASSIST (FCA) SYSTEM

The Forward Collision-Avoidance Assist (FCA) system is designed to help detect and monitor the vehicle ahead or help detect a pedestrian in the roadway through radar signals and camera recognition to warn the driver that a collision is imminent, and if necessary, apply emergency braking.

⚠ WARNING

Take the following precautions when using the Forward Collision-Avoidance Assist (FCA) system:

- **This system is only a supplemental system and it is not intended to, nor does it replace the need for extreme care and attention of the driver. The sensing range and objects detectable by the sensors are limited. Pay attention to the road conditions at all times.**
- **Drive at posted speed limits and accordance to road conditions.**
- **Always drive cautiously to prevent unexpected and sudden situations from occurring. The Forward Collision-Avoidance system may not always stop the vehicle completely and is only intended to help mitigate a collision that is imminent.**

System Setting and Operation

System setting

OTMA058186

- Setting Forward Safety function

  The driver can activate the FCA by placing the ignition switch to the ON position and by selecting:

  'User Settings → Driver Assistance → Forward Safety'

  - If you select "Active Assist", the FCA system activates. The FCA produces warning messages and warning alarms in accordance with the collision risk levels. Braking assist will be applied in accordance with the collision risk.

- If you select 'Warning Only', the FCA system activates and produces only warning alarms in accordance with the collision risk levels. Braking assist will not be applied in this setting.
- If you select 'Off', the FCA system deactivates.

-  The warning light illuminates on the LCD display, when you cancel the FCA system. The driver can monitor the FCA ON/OFF status on the LCD display. Also, the warning light illuminates when the ESC (Electronic Stability Control) is turned off. If the warning light remains ON when the FCA is activated, have the system checked by an authorized HYUNDAI dealer.

OTMA058089

- Setting Warning Timing

  The driver can select the initial warning activation time on the LCD display.

  Go to the 'User Settings → Driver Assistance → Warning Timing → Normal/Later'.

The options for the initial Forward Collision Warning includes the following:

- Normal:

  When this option is selected, the initial Forward Collision Warning is activated sensitively. If you feel the warning activates too early, set the Forward Collision Warning to 'Later'.

  Even though, 'Normal' is selected if the front vehicle suddenly stops the initial warning activation time may not seem fast.

- Later:

  When this option is selected, the initial Forward Collision Warning is activated later than normal. This setting reduces the amount of distance between the vehicle, pedestrian ahead before the initial warning occurs.

  Select 'Later' when traffic is light and when driving speed is slow.

Information

If you change the warning timing, the warning time of other systems may change. Always be aware before changing the warning timing.

Prerequisite for activation

The FCA system is on and ready when 'Active Assist' or 'Warning Only' under Forward Safety is selected in the LCD display and when the following prerequisites are satisfied:

- ESC (Electronic Stability Control) is on.
- Vehicle speed is over 5 mph (8 km/h) (The FCA is only activated within a certain speed range.).
- The system detects a pedestrian or a vehicle in front, which may collide with your vehicle. However, FCA may not be activated or may only sound a warning alarm depending on the driving or vehicle conditions.

⚠ WARNING

- **To avoid driver distractions, do not attempt to set or cancel the FCA while driving the vehicle. Always completely stop the vehicle at a safe place before setting or canceling the system.**
- **FCA automatically activates upon placing the ignition switch to the ON position. The driver can deactivate FCA by canceling the system setting in the cluster LCD display.**
- **FCA automatically deactivates upon canceling ESC. When ESC is canceled, FCA cannot be activated in the cluster LCD display. In this situation, the FCA warning light will illuminate which is normal.**

FCA Warning Message and Brake Control

FCA produces warning messages, warning alarms, and emergency braking based on the level of risk of a frontal collision, such as when a vehicle ahead suddenly brakes, or when the system detects that a collision with a pedestrian is imminent.

Collision Warning (First and second warning)

OLX2059026N

- The warning message appears on the cluster LCD display with a warning chime.
- Your vehicle speed may decelerate moderately.
- If FCA detects a vehicle in front, the system operates when your vehicle speed is between 5 mph (8 km/h) and 100 mph (160km/h). Maximum vehicle speed may decrease depending on the condition of the vehicle ahead and surroundings.
- If FCA detects a pedestrian in front, the system operates when your vehicle speed is between 5 mph (8 km/h) and 55 mph (90 km/h). Maximum vehicle speed may decrease depending on the condition of the vehicle ahead and surroundings.
- If you select 'Warning only' for the system setting, the FCA system activates and produces only warning alarms in accordance with the collision risk levels. You should control the brake directly because the FCA system will not control the brake.

Emergency Braking (Third warning)

OLX2059027N

- The warning message appears on the cluster LCD display with a warning chime.
- Additionally, some vehicle system intervention occurs by the engine management system to help decelerate the vehicle.
- The brake control is maximized just before a collision, reducing impact when it strikes a forward vehicle.
- If FCA detects a vehicle in front, the system operates when your vehicle speed is above 5 mph (8 km/h) and 50 mph (80 km/h) or under. Maximum vehicle speed may decrease depending on the condition of the vehicle ahead and surroundings.
- If FCA detects a pedestrian in front, the system operates when your vehicle speed is 5 mph (8 km/h) or above and under 45 mph (70 km/h). Maximum vehicle speed may decrease depending on the condition of the vehicle ahead and surroundings.
- If you select 'Warning only' for the system setting, the FCA system activates and produces only warning alarms in accordance with the collision risk levels. You should control the brake directly because the FCA system do not control the brake.

Brake operation

- In an urgent situation, the braking system enters into the ready status for prompt reaction against the driver's depressing the brake pedal.
- The FCA provides additional braking power for optimum braking performance, when the driver depresses the brake pedal.
- The braking control is automatically deactivated, when the driver sharply depresses the accelerator pedal, or when the driver abruptly operates the steering wheel.
- The FCA braking control is automatically canceled, when risk factors disappear.

⚠ CAUTION

- **The driver should always use extreme caution while operating the vehicle, whether or not there is a warning message or alarm from the FCA system.**
- **After the brake control is activated, the driver must immediately depress the brake pedal and check the surroundings. The brake activation by the system lasts for about 2 seconds.**
- **If any other warning sound such as seat belt warning chime is already generated, the Forward Collision-Avoidance Assist (FCA) system warning may not sound.**
- **Playing the vehicle audio system at high volume may prevent occupants from hearing the system warning sounds.**

⚠ WARNING

The FCA braking control cannot completely stop the vehicle nor avoid all collisions. The driver should hold the responsibility to safely drive and control the vehicle.

⚠ WARNING

The FCA system logic operates within certain parameters, such as the distance from the vehicle, pedestrian ahead, the speed of the vehicle ahead, and the driver's vehicle speed. Certain conditions such as inclement weather and road conditions may affect the operation of the FCA system.

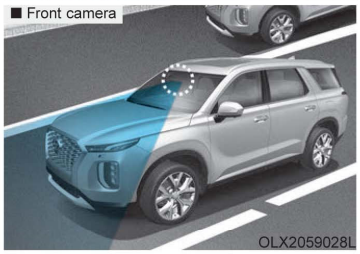
⚠ WARNING

Never deliberately drive dangerously to activate the system.

FCA Sensor (Front Radar/Front Camera)

■ Front radar

■ Front camera



In order for the FCA system to operate properly, always make sure the sensor cover or sensor is clean and free of dirt, snow, and debris.

Dirt, snow, or foreign substances on the sensor cover or sensor may adversely affect the sensing performance of the sensor.

NOTICE

- **Do not apply license plate frame or foreign objects such as a bumper sticker or a bumper guard near the sensor. Doing so may adversely affect the sensing performance of the radar.**
- **Always keep the sensor and cover clean and free of dirt and debris.**
- **Use only a soft cloth to wash the vehicle. Do not spray pressurized water directly on the sensor or sensor cover.**
- **Be careful not to apply unnecessary force on the sensor or sensor cover. If the sensor is forcibly moved out of proper alignment, the FCA system may not operate correctly. In this case, a warning message may not be displayed. Have the vehicle inspected by an authorized HYUNDAI dealer.**
- **If the front bumper becomes damaged in the area around the sensor, the FCA system may not operate properly. Have the vehicle inspected by an authorized HYUNDAI dealer.**
- **Use only genuine HYUNDAI parts to repair or replace a damaged sensor or sensor cover. Do not apply paint to the sensor cover.**

NOTICE

- **NEVER install any accessories or stickers on the front windshield, or tint the front windshield.**
- **NEVER place any reflective objects (i.e. white paper, mirror) over the crash pad. Any light reflection may prevent the system from functioning properly.**
- **Pay extreme caution to keep the camera dry.**
- **NEVER disassemble the camera assembly, or apply any impact on the camera assembly.**
- **If the sensor is forcibly moved out of proper alignment, the FCA system may not operate correctly. In this case, a warning message may not be displayed. Have the vehicle inspected by an authorized HYUNDAI dealer.**

Information

Have the system checked by an authorized HYUNDAI dealer when:

- **The windshield glass is replaced.**
- **The radar sensor or cover gets damaged or replaced.**

Warning message and warning light

OIK057090L

Forward Collision-Avoidance Assist (FCA) system disabled. Radar blocked

When the sensor cover is covered with dirt, snow, or debris, the FCA system operation may not be able to detect other vehicles. If this occurs, a warning message will appear on the LCD display.

The system will operate normally when such dirt, snow or debris is removed.

FCA may not properly operate in an area (e.g. open terrain) where any objects or vehicles are not detected after turning on the engine.

⚠ WARNING

The FCA system may not activate according to road conditions, inclement weather, driving conditions or traffic conditions.

System Malfunction

OIK057091L

Check Forward Collision-Avoidance Assist system

- When FCA is not working properly, the FCA warning light (⛐) will illuminate and the warning message will appear for a few seconds. After the message disappears, the master warning light (⚠) will illuminate. In this case, have the vehicle inspected by an authorized HYUNDAI dealer.
- The FCA warning message may appear along with the illumination of the ESC (Electronic Stability Control) warning light.

Both FCA warning light and warning message will disappear once the ESC warning light issue is resolved.

⚠ WARNING

- **FCA is only a supplemental system for the driver's convenience. It is the driver's responsibility to control the vehicle operation. Do not solely depend on the FCA system. Rather, maintain a safe braking distance, and, if necessary, depress the brake pedal to reduce the driving speed or to stop the vehicle.**
- **In certain instances and under certain driving conditions, the FCA system may activate prematurely. This initial warning message appears on the LCD display with a warning chime.**

Also due to sensing limitations, in certain situations, the front radar sensor or camera recognition system may not detect the vehicle, pedestrian ahead. The FCA system may not activate and the warning message may not be displayed.

- **If there is a malfunction with the FCA system, the Forward Collision avoidance assist system is not applied even though the braking system is operating normally.**
- **If the vehicle in front stops suddenly, you may have less control of the brake system. Therefore, always keep a safe distance between your vehicle and the vehicle in front of you.**
- **The FCA system may activate during braking and the vehicle may stop suddenly shifting loose objects toward the passengers. Always keep loose objects secured.**
- **The FCA system may not activate if the driver applies the brake pedal to avoid collision.**
- **The brake control may be insufficient, possibly causing a collision, if a vehicle in front abruptly stops. Always pay extreme caution.**
- **The FCA system may not activate according to the road conditions, inclement weather, driving conditions or traffic conditions.**
- **Occupants may get injured, if the vehicle abruptly stops by the activated FCA system. Pay extreme caution.**
- **The FCA system operates only to detect vehicles, pedestrian in front of the vehicle.**

⚠ WARNING

- **The FCA system operates only to help detect vehicles or pedestrians in front of the vehicle.**
- **The FCA system does not operate when the vehicle is in reverse.**
- **The FCA system is not designed to detect other objects on the road such as animals.**
- **The FCA system does not detect vehicles in the opposite lane.**
- **The FCA system does not detect cross traffic vehicles that are approaching.**
- **The FCA system cannot detect the cross traffic cyclist that are approaching.**
- **The FCA system cannot detect vehicles that are stopped vertically to your vehicle at a intersection or dead end street.**

In these cases, you must maintain a safe braking distance, and if necessary, depress the brake pedal to reduce the driving speed in order to maintain a safe distance or to stop the vehicle.

Limitations of the System

The Forward Collision Avoidance Assist (FCA) system is designed to monitor the vehicle ahead or a pedestrian on the roadway through radar signals and camera recognition to warn the driver that a collision is imminent, and if necessary, apply emergency braking.

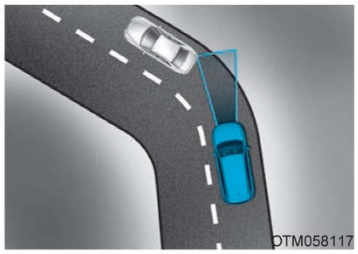
In certain situations, the radar sensor or the camera may not be able to detect the vehicle, pedestrian ahead. In these cases, the FCA system may not operate normally. The driver must pay careful attention in the following situations where the FCA operation may be limited.

Detecting vehicles

The sensor may be limited when:

- The system may not operate for 15 seconds after the engine is started or the camera is initialized
- The radar sensor or camera is covered with a foreign object or debris
- The camera lens is contaminated due to tinted, filmed or coated windshield, damaged glass, or stuck of foreign matter (sticker, bug, etc.) on the glass
- Inclement weather such as heavy rain or snow obscures the field of view of the radar sensor or camera
- There is interference by electromagnetic waves
- There is severe irregular reflection from the radar sensor
- The radar/camera sensor recognition is limited
- The vehicle in front is too small to be detected (for example a motorcycle or a bicycle, etc.)
- The vehicle in front is an oversize vehicle or trailer that is too big to be detected by the camera recognition system (for example a tractor trailer, etc.)
- The camera's field of view is not well illuminated (either too dark or too much reflection or too much backlight that obscures the field of view)
- The vehicle in front does not have their rear lights properly turned ON or their rear lights are located unusually
- The outside brightness changes suddenly, for example when entering or exiting a tunnel
- Light coming from a street light or an oncoming vehicle is reflected on a wet road surface such as a puddle in the road
- The field of view in front is obstructed by sun glare
- The windshield glass is fogged up; a clear view of the road is obstructed
- The vehicle in front is driving erratically
- The vehicle is on unpaved or uneven rough surfaces, or road with sudden gradient changes
- The vehicle is driven near areas containing metal substances as a construction zone, railroad, etc.
- The vehicle drives inside a building, such as a basement parking lot
- The camera does not recognize the entire vehicle in front
- The camera is damaged
- The brightness outside is too low such as when the headlamps are not on at night or the vehicle is going through a tunnel
- The shadow is on the road by a median strip, trees, etc.
- The vehicle drives through a tollgate.
- The rear part of the vehicle in front is not normally visible (the vehicle turns in other direction or the vehicle is overturned.)
- The adverse road conditions cause excessive vehicle vibrations while driving

- The sensor recognition changes suddenly when passing over a speed bump
- The vehicle in front is moving vertically to the driving direction
- The vehicle in front is stopped vertically
- The vehicle in front is driving towards your vehicle or reversing
- You are on a roundabout and the vehicle in front circles



- Driving on a curve

  The performance of the FCA system may be limited when driving on a curved road.

  In certain instances on a curved road, the FCA system may activate prematurely.

  Also, in certain instances the front radar sensor or camera recognition system may not detect the vehicle traveling on a curved road.

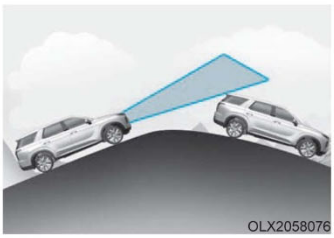
  In these cases, the driver must maintain a safe braking distance, and if necessary, depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

The FCA system may recognize a vehicle in the next lane when driving on a curved road.

In this case, the system may unnecessarily alarm the driver and apply the brake.

Always pay attention to road and driving conditions, while driving. If necessary, depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

Also, when necessary depress the accelerator pedal to prevent the system from unnecessarily decelerating your vehicle.

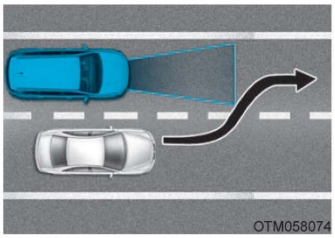

OLX2058076

- Driving on a slope

  The performance of the FCA decreases while driving upward or downward on a slope, not recognizing the vehicle in front in the same lane. It may unnecessarily produce the warning message and the warning alarm, or it may not produce the warning message and the warning alarm at all.

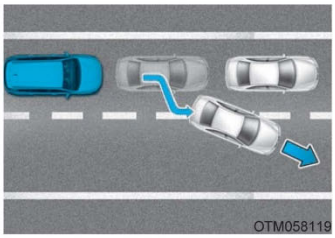
  When the FCA suddenly recognizes the vehicle in front while passing over a slope, you may experience sharp deceleration.

  Always keep your eyes forward while driving upward or downward on a slope, and, if necessary, depress the brake pedal to reduce your driving speed in order to maintain distance.

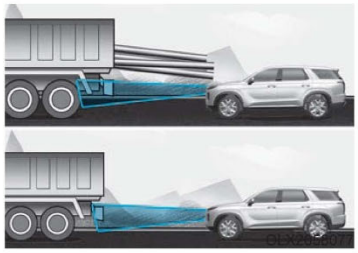

OTM058074

- Changing lanes

  When a vehicle changes lanes in front of you, the FCA system may not immediately detect the vehicle, especially if the vehicle changes lanes abruptly. In this case, you must maintain a safe braking distance, and if necessary, depress the brake pedal to reduce your driving speed in order to maintain a safe distance.


OTM058119

When driving in stop-and-go traffic, and a vehicle in front of you merges out of the lane, the FCA system may not immediately detect the new vehicle that is now in front of you. In this case, you must maintain a safe braking distance, and if necessary, depress the brake pedal to reduce your driving speed in order to maintain a safe distance.



- Detecting the vehicle in front of you

  If the vehicle in front of you has cargo that extends rearward from the cab, or when the vehicle in front of you has higher ground clearance, additional special attention is required. The FCA system may not be able to detect the cargo extending from the vehicle. In these instances, you must maintain a safe braking distance from the rearmost object, and if necessary, depress the brake pedal to reduce your driving speed in order to maintain distance.

Detecting pedestrians

The sensor may be limited when:

- The pedestrian is not fully detected by the camera recognition system, for example, if the pedestrian is leaning over or is not fully walking upright
- The pedestrian is moving very quickly or appears abruptly in the camera detection area
- The pedestrian is wearing clothing that easily blends into the background, making it difficult to be detected by the camera recognition system
- The outside lighting is too bright (e.g. when driving in bright sunlight or in sun glare) or too dark (e.g. when driving on a dark rural road at night)
- It is difficult to detect and distinguish the pedestrian from other objects in the surroundings, for example, when there is a group of pedestrians or a large crowd
- There is an item similar to a person's body structure
- The pedestrian is small
- The pedestrian has impaired mobility
- The sensor recognition is limited
- The radar sensor or camera is covered with a foreign object or debris
- The camera lens is contaminated due to tinted, filmed or coated windshield, damaged glass, or stuck of foreign matter (sticker, bug, etc.) on the glass
- The brightness outside is too low such as when the headlamps are not on at night or the vehicle is going through a tunnel
- Inclement weather such as heavy rain or snow obscures the field of view of the radar sensor or camera
- Light coming from a street light or an oncoming vehicle is reflected on a wet road surface such as a puddle in the road
- The field of view in front is obstructed by sun glare
- The windshield glass is fogged up; a clear view of the road is obstructed

- The adverse road conditions cause excessive vehicle vibrations while driving
- The sensor recognition changes suddenly when passing over a speed bump
- You are on a roundabout
- When the pedestrian suddenly interrupts in front of the vehicle
- When there is any other electromagnetic interference
- When the construction area, rail or other metal object is near the cyclist

⚠ WARNING

- **Do not use the Forward Collision Avoidance Assist (FCA) system when towing a vehicle. Application of the FCA system while towing may adversely affect the safety of your vehicle or the towing vehicle.**
- **Use extreme caution when the vehicle in front of you has cargo that extends rearward from the cab, or when the vehicle in front of you has higher ground clearance.**
- **The FCA system is designed to help detect and monitor the vehicle ahead to help detect a pedestrian in the roadway through radar signals and camera recognition. It is not designed to detect bicycles, motorcycles, or smaller wheeled objects such as luggage bags, shopping carts, or strollers.**
- **Never try to test the operation of the FCA system. Doing so may cause severe injury or death.**

Information

In some instances, the FCA system may be canceled when subjected to electromagnetic interference.

Information

This device complies with Part 15 of the FCC rules.

Operation is subject to the following two conditions:

1. **This device may not cause harmful interference.**
2. **This device must accept any interference received, including interference that may cause undesired operation.**

APPENDIX C

Run Log

Subject Vehicle: **2020 Hyundai Palisade SEL FWD** Test Date: **9/11/2020**

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
52	Static Run								
53	**Stopped POV, 25 mph**	Y	2.01	10.26	24.5	1.16	1.14	Yes	
54		Y	2.10	9.84	25.3	1.20	1.09	Yes	
55		Y	2.04	10.60	24.3	1.16	1.07	Yes	
56		Y	2.05	9.53	25.1	1.20	1.11	Yes	
57		Y	2.08	10.32	24.8	1.11	1.11	Yes	
58		Y	2.05	9.66	24.9	1.09	1.10	Yes	
59		Y	2.13	10.98	25.0	1.11	1.12	Yes	
60	Static Run								
61	**Stopped POV, 30 mph**	Y	2.31	9.06	30.3	1.11	1.20	Yes	
62		Y	2.24	8.75	29.6	1.11	1.21	Yes	
63		Y	2.27	9.90	30.1	1.11	1.24	Yes	
64		Y	2.28	10.50	30.3	1.13	1.24	Yes	
65		Y	2.27	10.73	29.7	1.10	1.22	Yes	
66	Static Run								
67	**Stopped POV, 35 mph**	Y	2.45	7.76	34.6	1.11	1.38	Yes	
68		Y	2.41	9.56	34.5	1.13	1.36	Yes	
69		Y	2.40	10.09	34.1	1.17	1.34	Yes	
70		Y	2.41	10.29	34.9	1.14	1.40	Yes	
71		Y	2.43	8.48	34.9	1.14	1.39	Yes	
72	Static Run								

[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
73	**Stopped POV, 40 mph**	Y	2.53	7.45	39.3	1.13	1.53	Yes	
74		Y	2.64	3.92	39.8	1.14	1.51	Yes	
75		Y	2.50	5.83	39.7	1.14	1.53	Yes	
76		Y	2.19	6.03	39.9	1.14	1.53	Yes	
77		Y	2.54	6.38	38.9	1.14	1.54	Yes	
78	Static Run								
79	**Stopped POV, 45 mph**	Y	2.73	3.70	44.9	1.14	1.54	Yes	
80		Y	2.75	1.44	45.2	1.12	1.54	Yes	
81		Y	2.74	2.26	45.1	1.16	1.52	Yes	
82		Y	2.71	3.42	45.0	1.16	1.53	Yes	
83		Y	2.67	2.53	45.1	1.15	1.50	Yes	
84	Static Run								
1	Static Run								
2	**Slower POV, 25/10 mph**	Y	1.81	9.44	15.1	0.99	0.89	Yes	
3		Y	1.84	10.55	15.2	1.00	0.93	Yes	
4		Y	1.78	9.99	15.3	1.04	1.01	Yes	
5		Y	1.83	10.38	15.6	1.06	0.93	Yes	
6		Y	1.74	10.00	14.6	1.03	0.92	Yes	
7		Y	1.77	10.44	14.9	1.06	0.94	Yes	
8		Y	1.80	10.66	15.2	1.10	0.96	Yes	
9	Static Run								
10	**Slower POV, 45/20 mph**	N							POV speed
11		Y	2.29	14.82	24.9	1.06	1.29	Yes	
12		Y	2.30	16.89	25.2	1.09	1.31	Yes	
13		Y	2.30	15.81	25.1	1.12	1.33	Yes	
14		Y	2.32	16.56	25.3	1.07	1.31	Yes	
15		Y	2.28	15.87	24.9	1.11	1.25	Yes	
16		N							Driver error

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
17		Y	2.31	15.93	24.9	1.08	1.28	Yes	
18		Y	2.32	15.67	25.5	1.08	1.31	Yes	
19	Static Run								
20	Static Run								
21	**Decelerating POV, 0.3g 35mph**	N							POV lateral and yaw
22		Y	1.53	8.07	22.1	1.06	1.07	Yes	
23		N							POV braking
24		N							POV braking
25		Y	1.55	7.25	22.1	1.06	0.98	Yes	
26		N							POV braking
27		Y	1.61	7.63	21.9	1.03	1.02	Yes	
28		Y	1.67	7.73	21.6	1.03	1.08	Yes	
29		Y	1.57	6.78	22.4	1.07	0.99	Yes	
30		Y	1.56	7.69	21.5	1.07	1.06	Yes	
31		N							GPS lost
32		N							POV braking
33		Y	1.53	7.68	21.9	1.04	1.04	Yes	
34		Y	1.58	9.15	21.3	1.02	1.17	Yes	
35	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
36	Static Run								
37	**Decelerating POV, 0.5g 35 mph**	Y	1.51	0.00	29.2	1.09	1.03	Yes	
38		Y	1.55	0.00	28.5	1.04	1.07	Yes	
39		Y	1.49	0.00	25.6	1.02	0.99	Yes	
40		Y	1.51	0.00	23.0	1.07	1.02	Yes	
41		N							GPS type
42		Y	1.55	0.00	27.0	1.05	1.08	Yes	
43	Static Run								
44	**Decelerating POV, 0.3g 45 mph**	N							Throttle encoder fell off
45		Y	1.65	9.44	21.6	1.04	0.95	Yes	
46		Y	1.69	10.11	22.1	0.99	1.09	Yes	
47		N							POV decel
48		Y	1.55	9.93	21.6	1.06	0.98	Yes	
49		Y	1.73	10.08	21.7	1.01	1.05	Yes	
50		Y	1.66	10.93	21.3	1.04	1.08	Yes	
51	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)
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.

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.

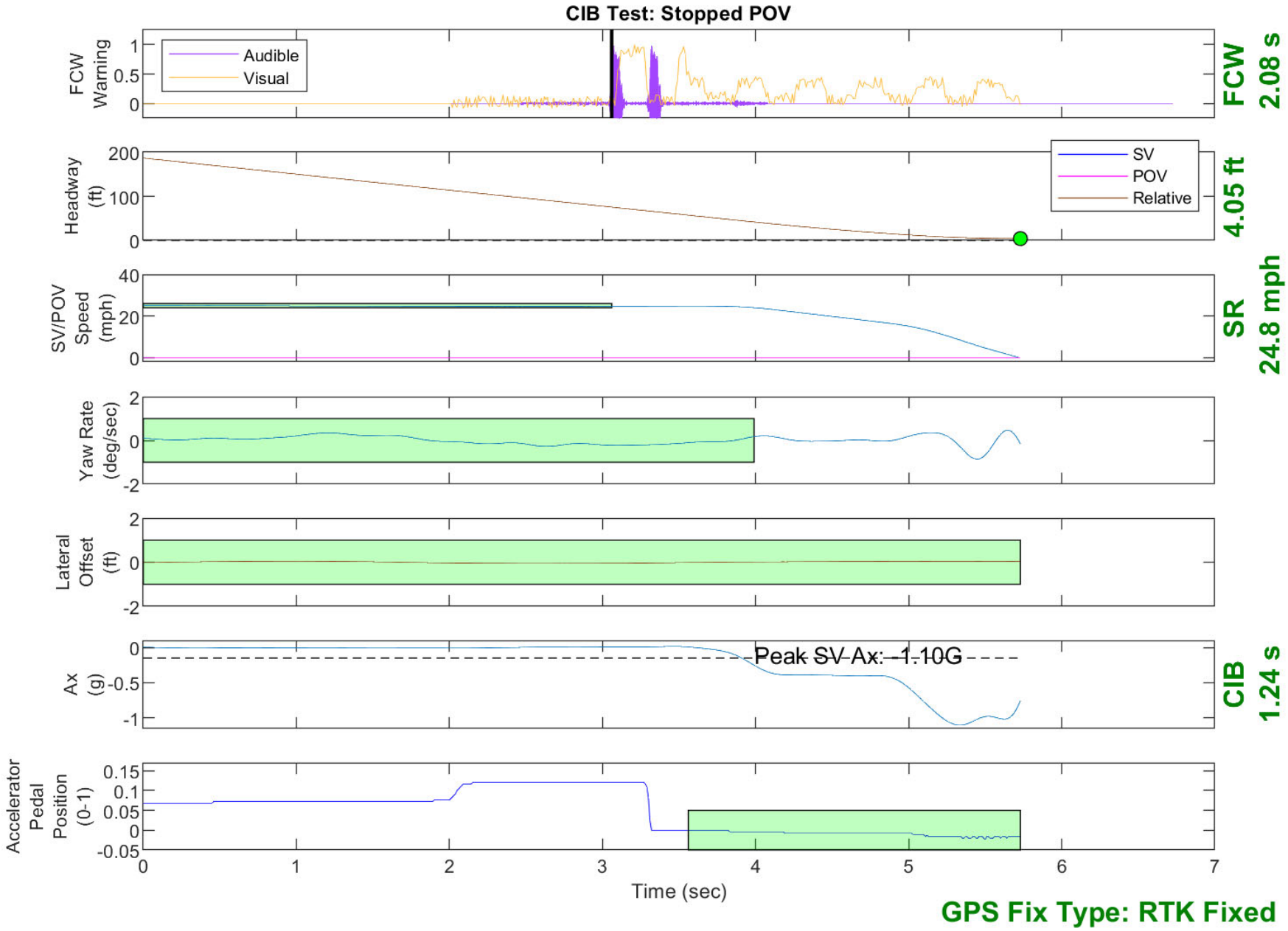


Figure D1. Example Time History for Stopped POV, Passing

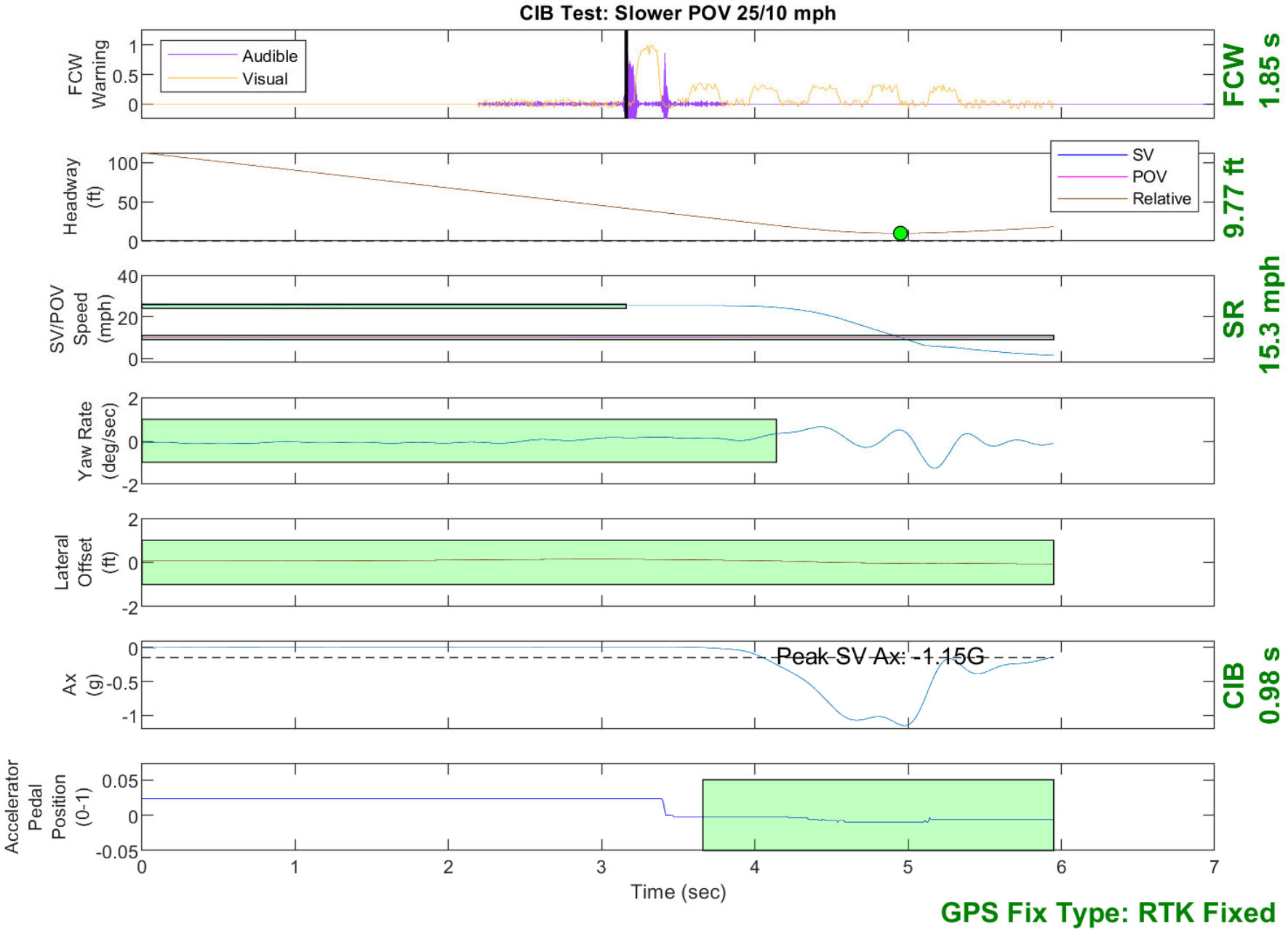


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

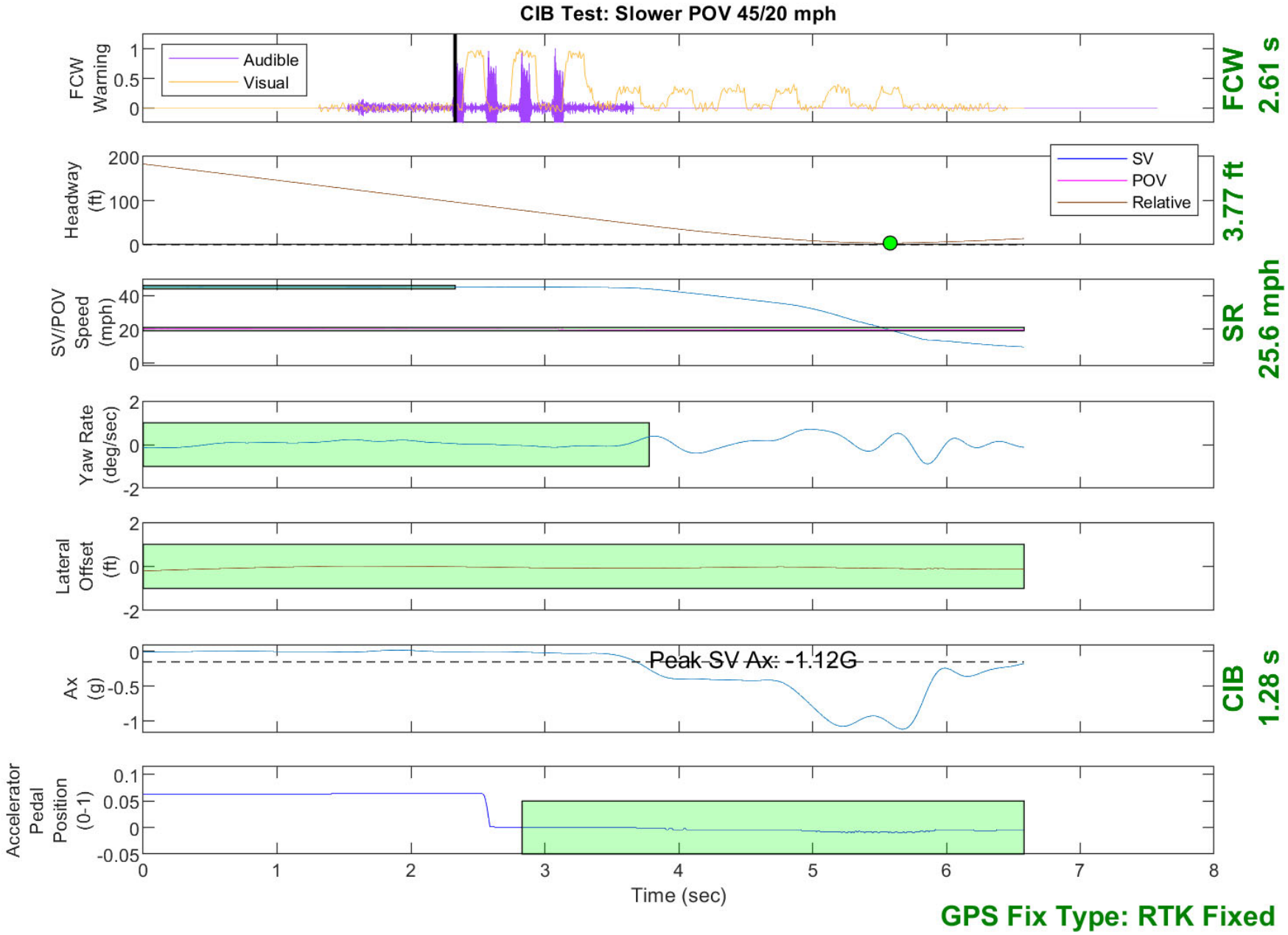


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

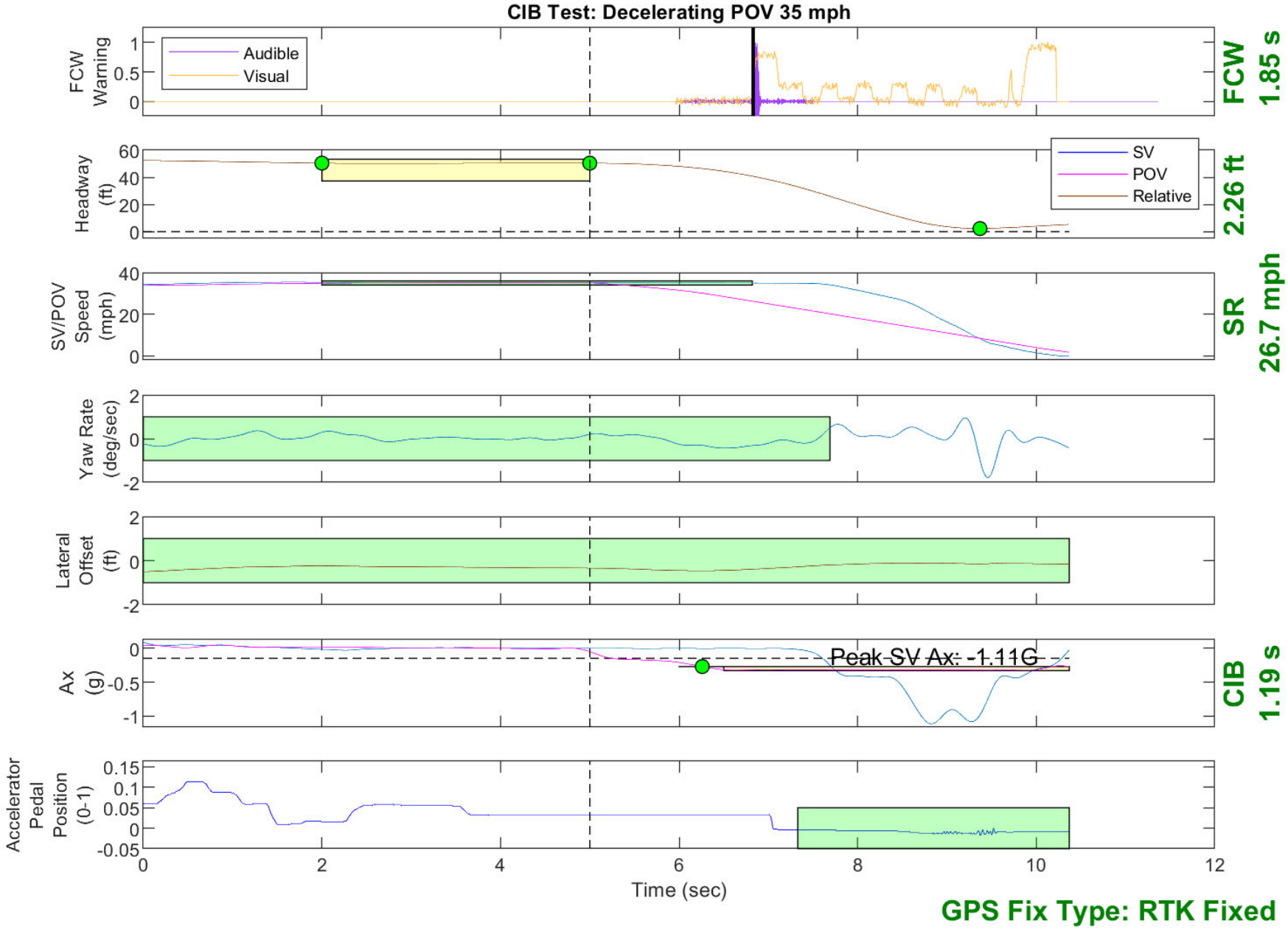


Figure D4. Example Time History for Decelerating POV 35, Passing

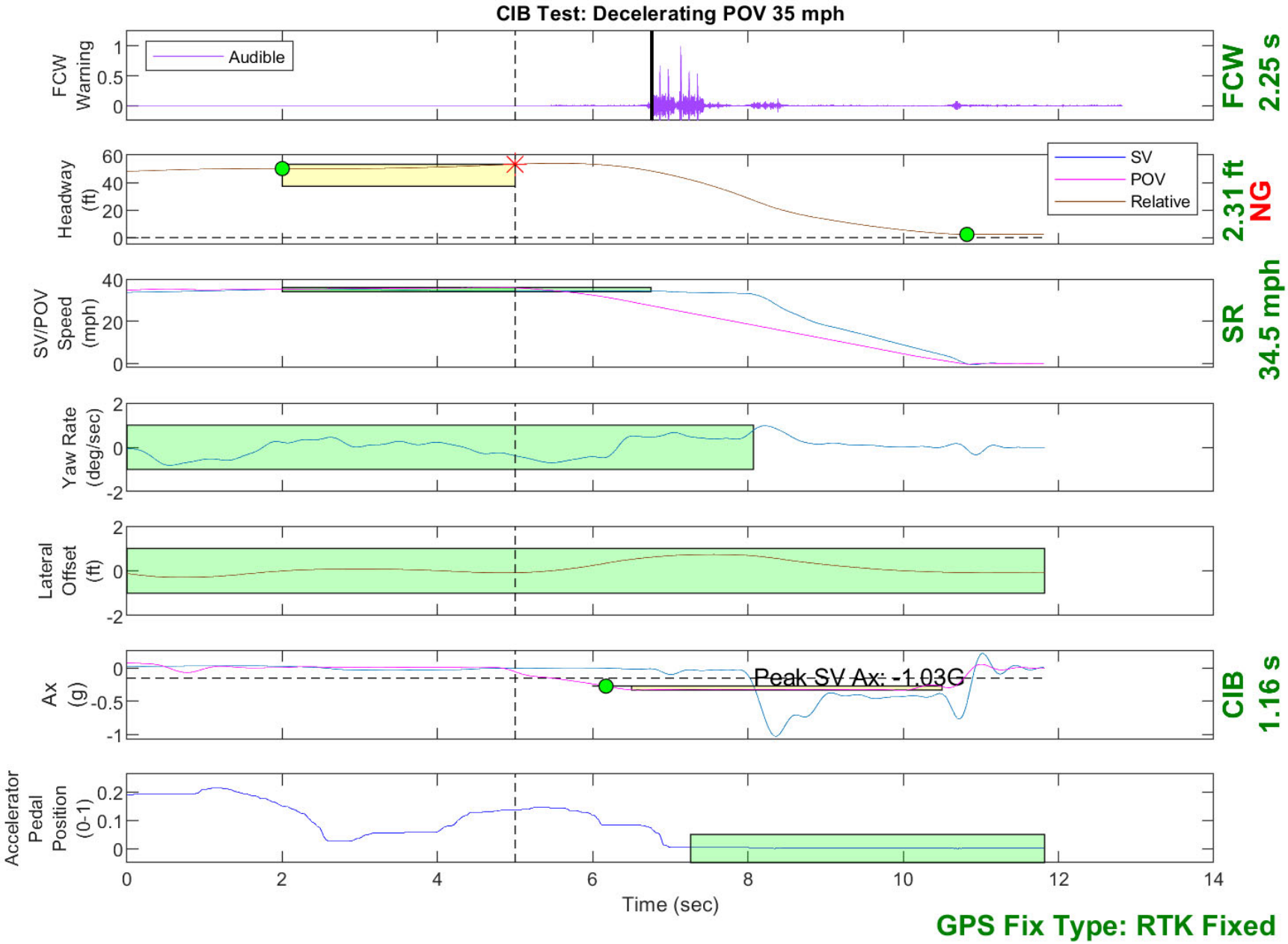


Figure D5. Example Time History Displaying Invalid Headway Criteria

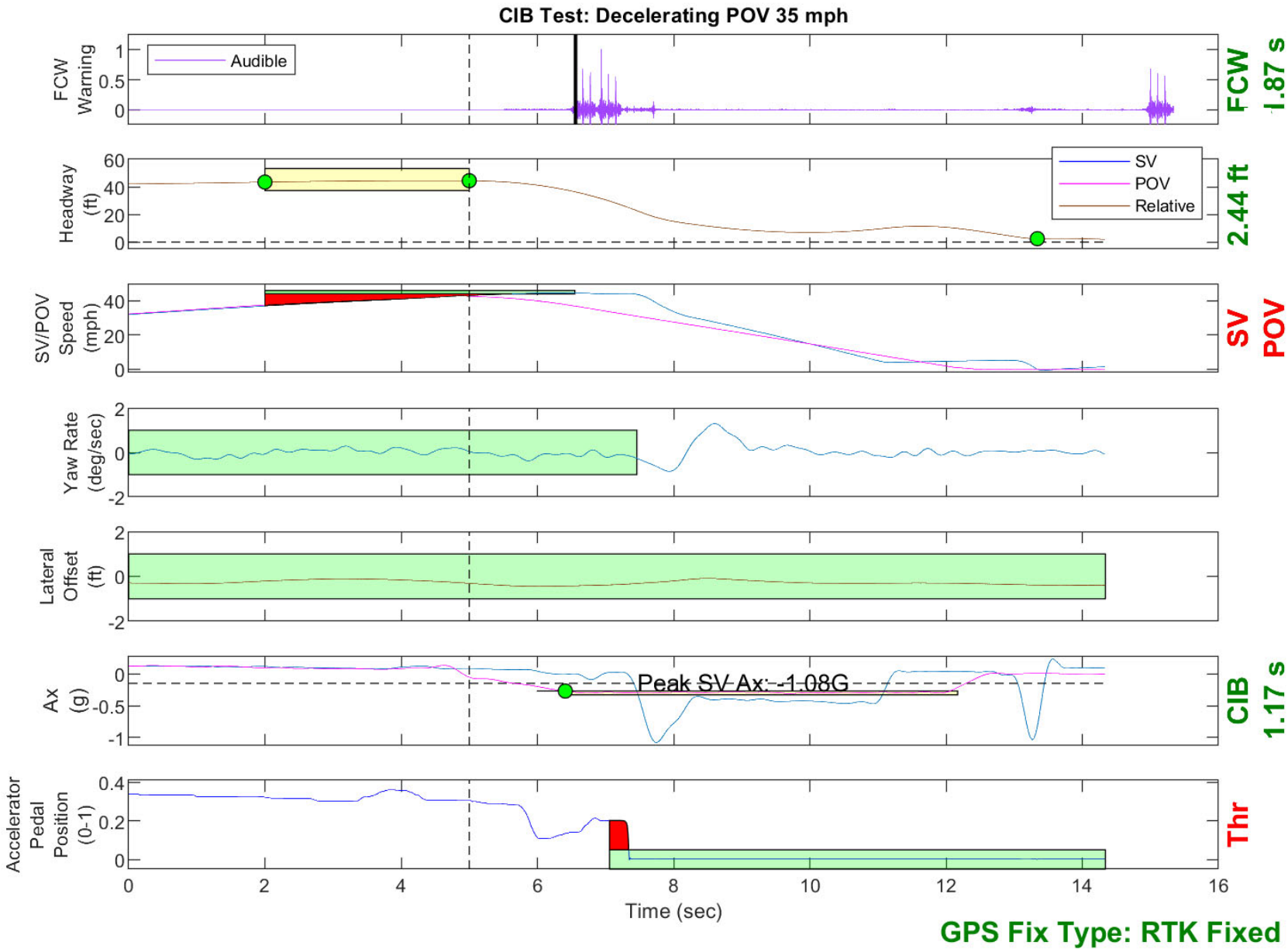


Figure D6. Example Time History Displaying Various Other Invalid Criteria

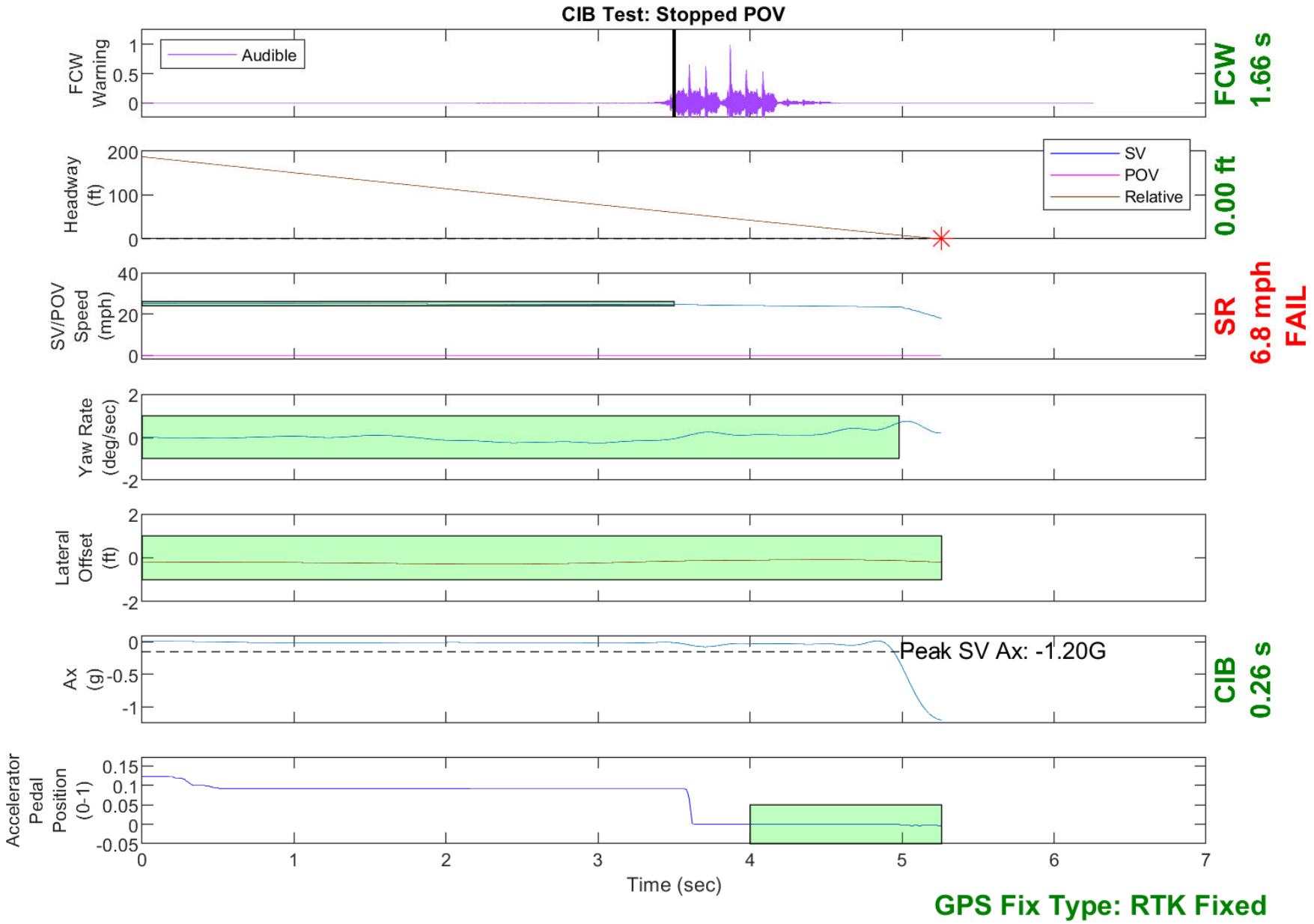


Figure D7. Example Time History for a Failed Run

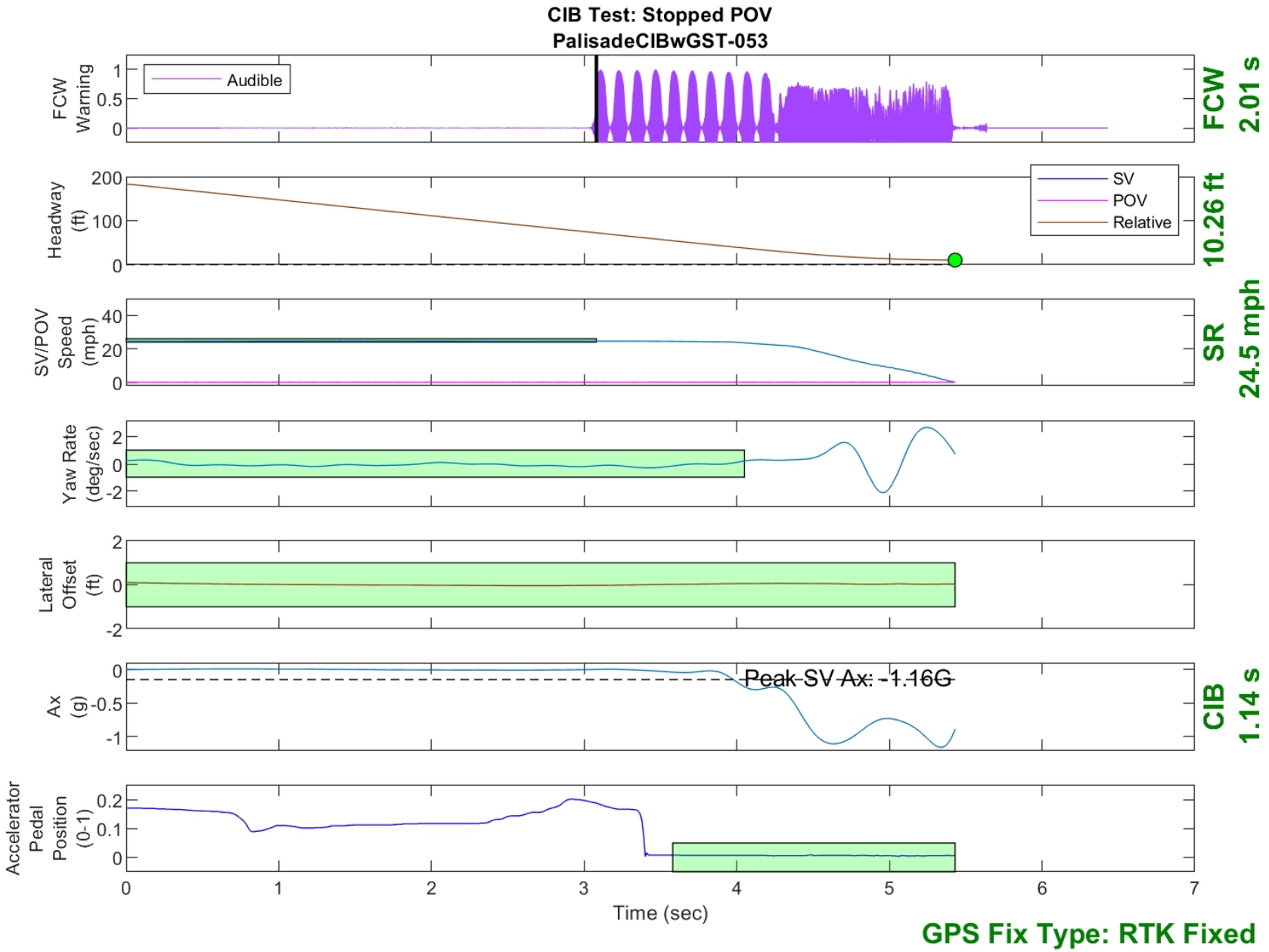


Figure D8. Time History for CIB Run 53, Stopped POV, 25 mph

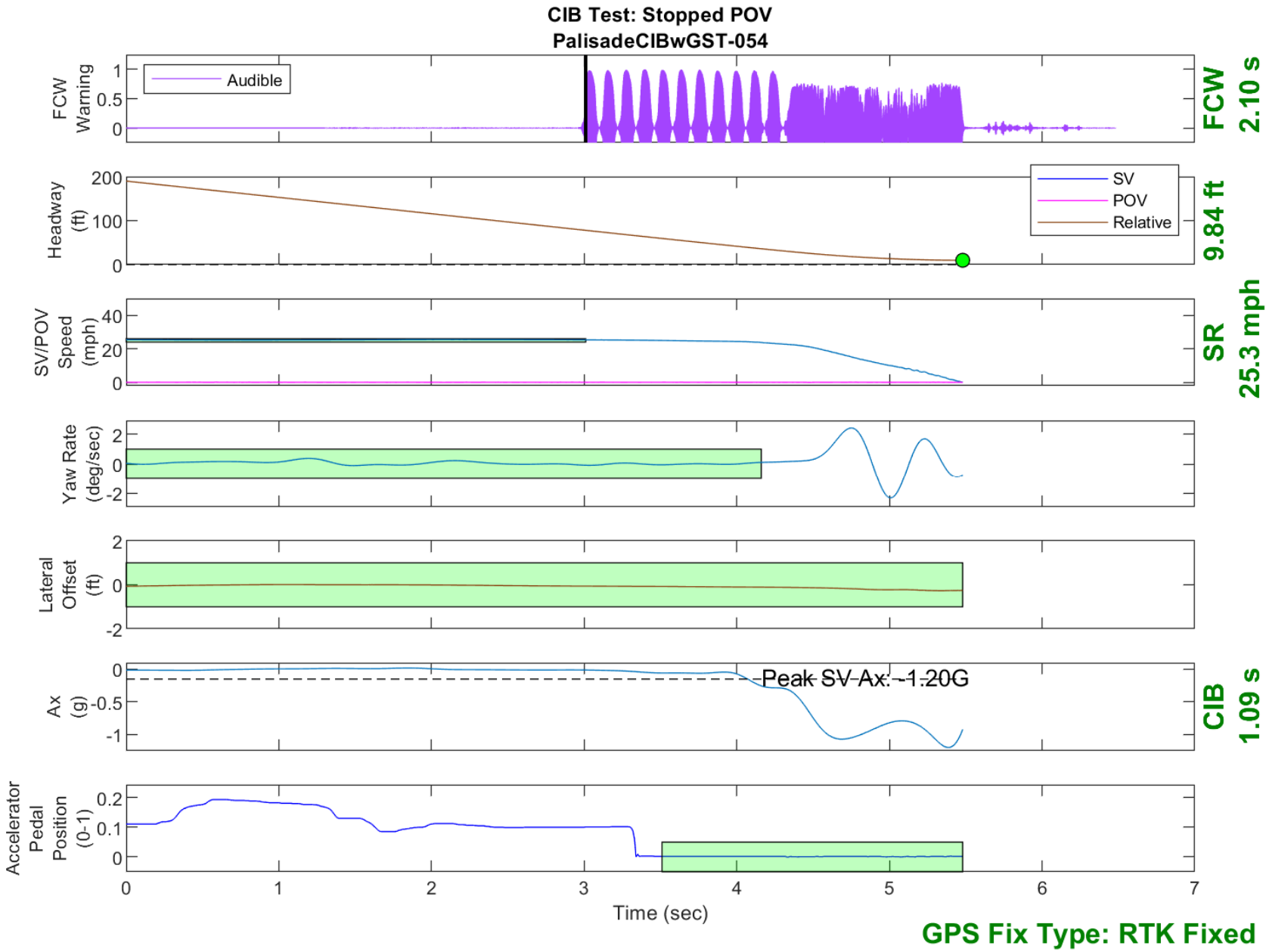


Figure D9. Time History for CIB Run 54, Stopped POV, 25 mph

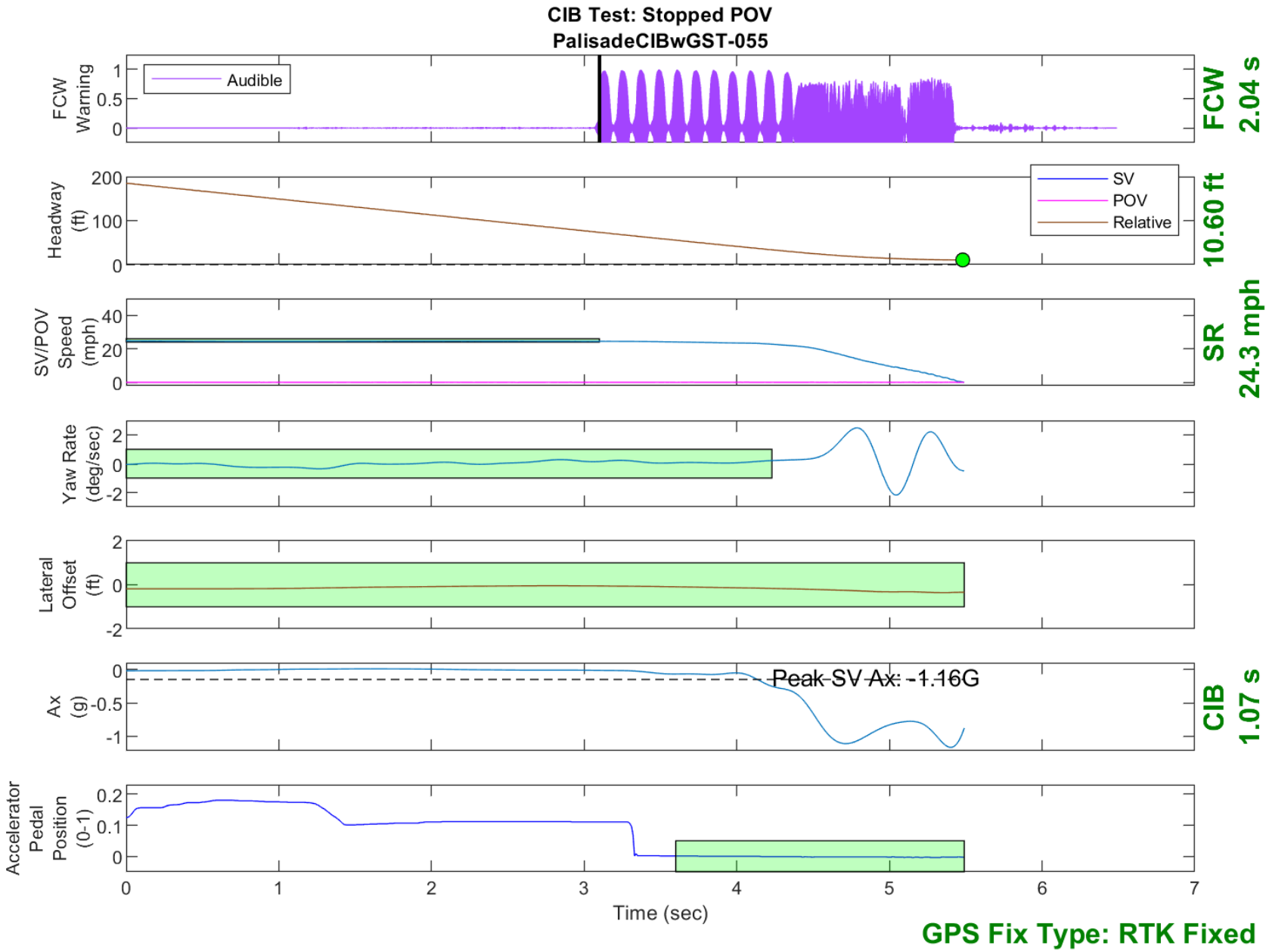


Figure D10. Time History for CIB Run 55, Stopped POV, 25 mph

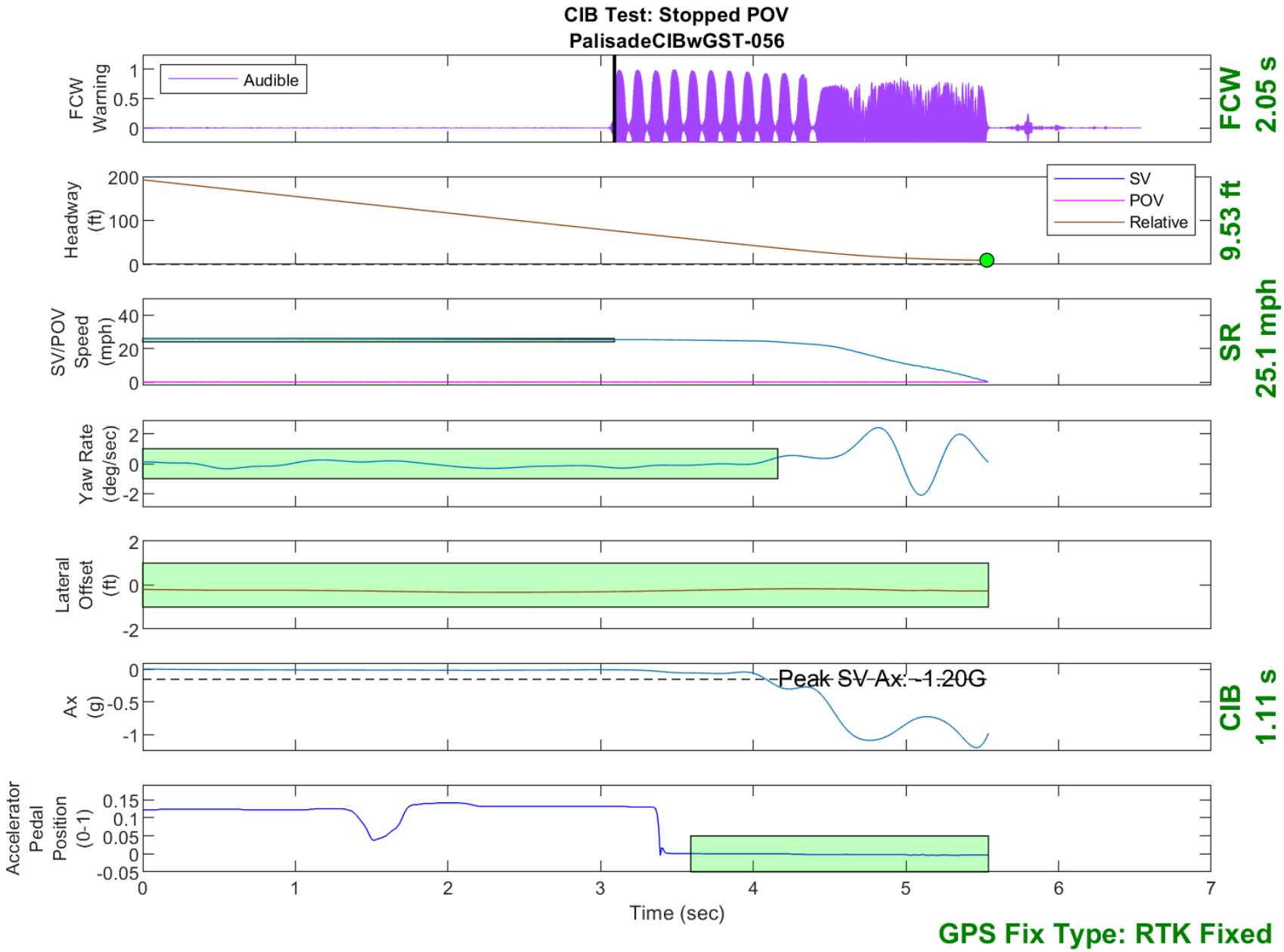


Figure D11. Time History for CIB Run 56, Stopped POV, 25 mph

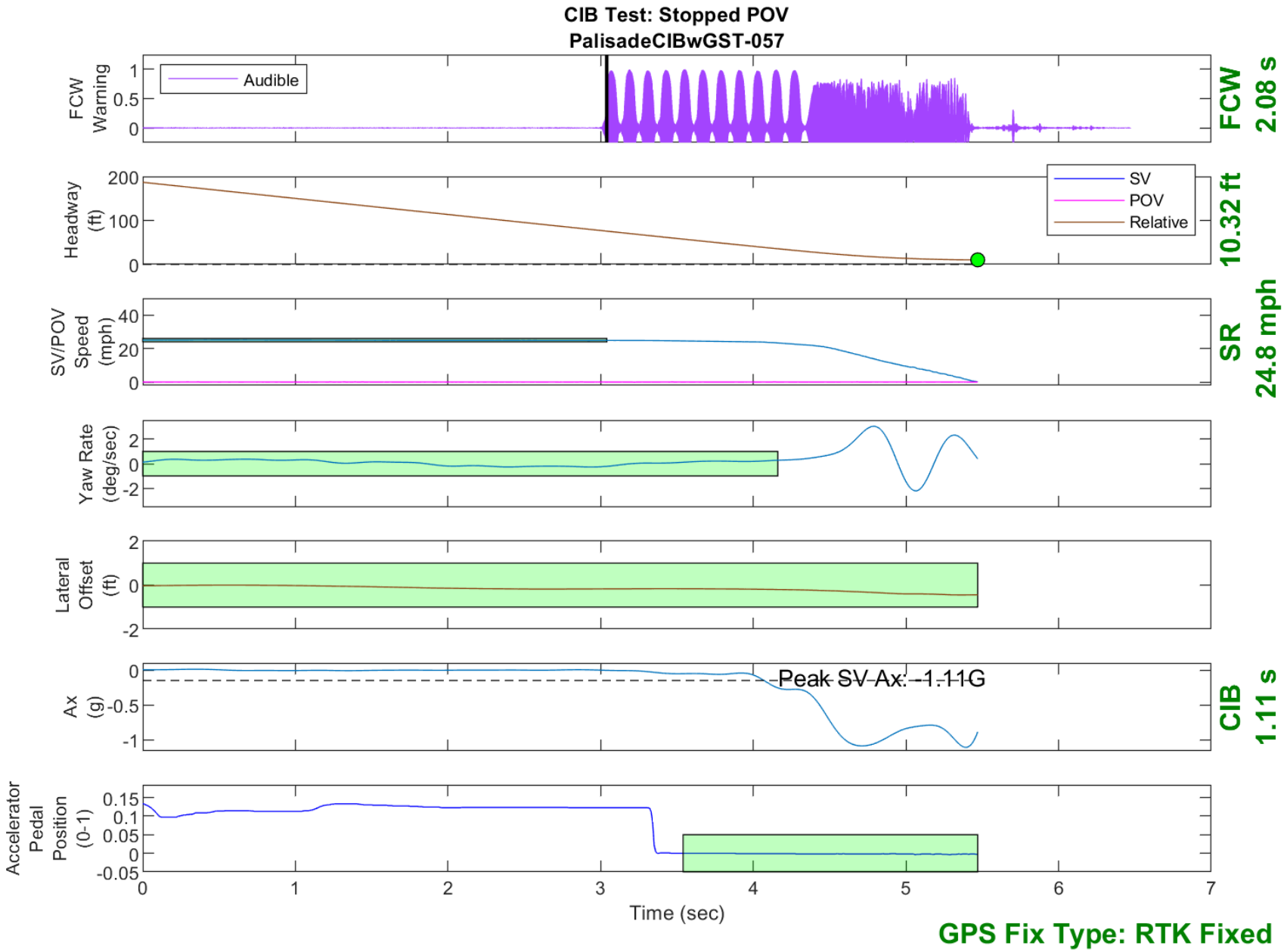


Figure D12. Time History for CIB Run 57, Stopped POV, 25 mph

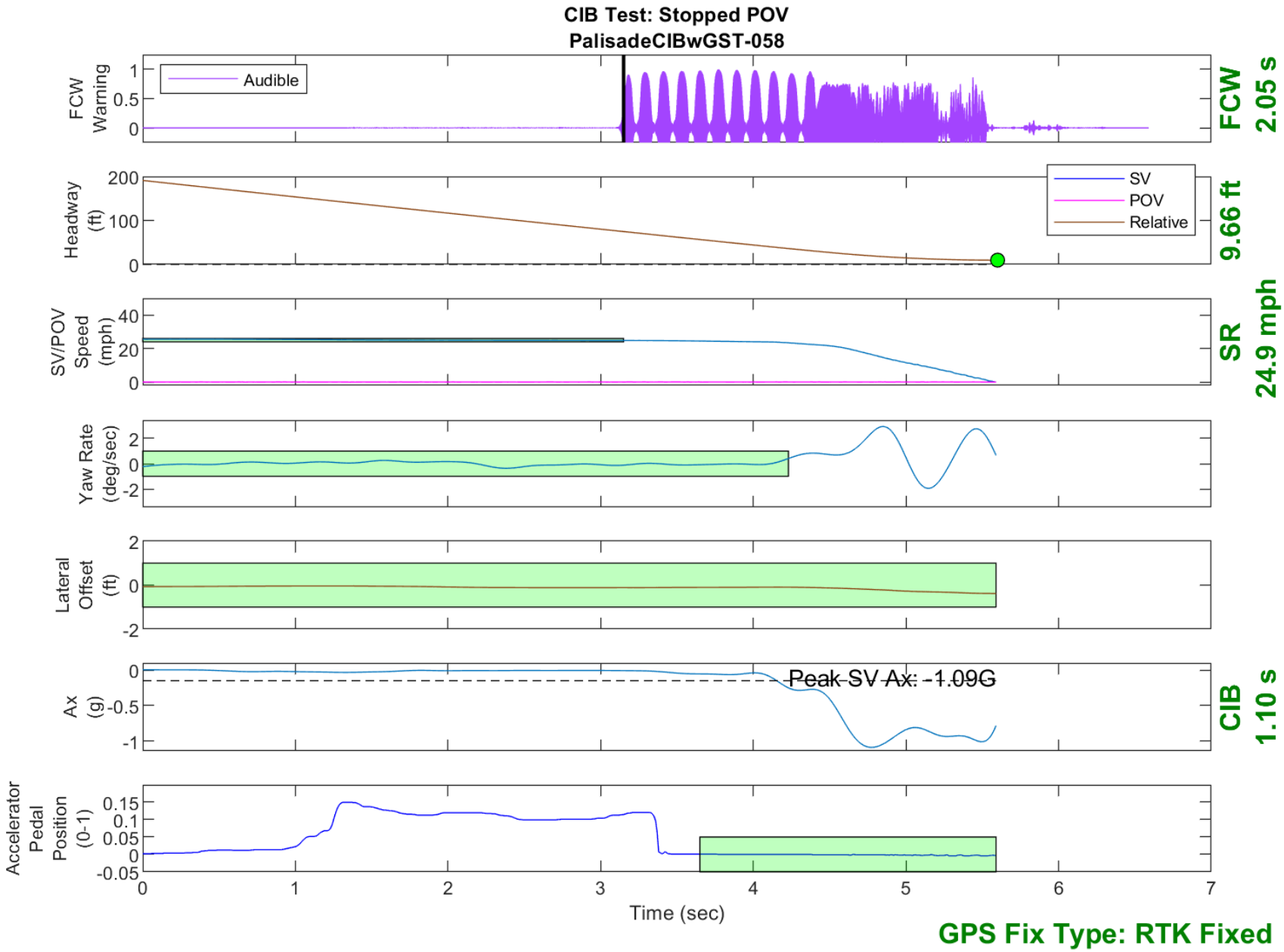


Figure D13. Time History for CIB Run 58, Stopped POV, 25 mph

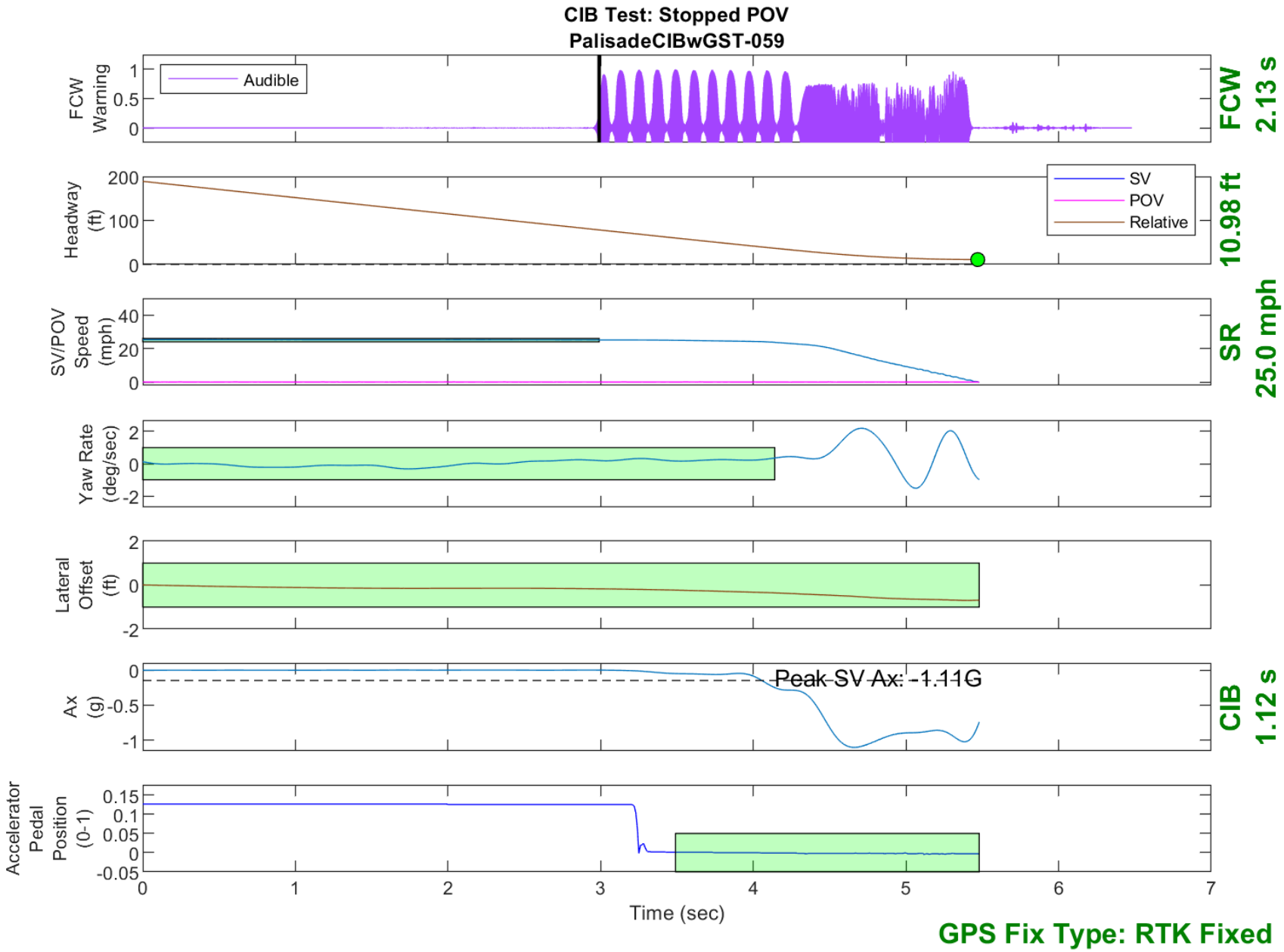


Figure D14. Time History for CIB Run 59, Stopped POV, 25 mph

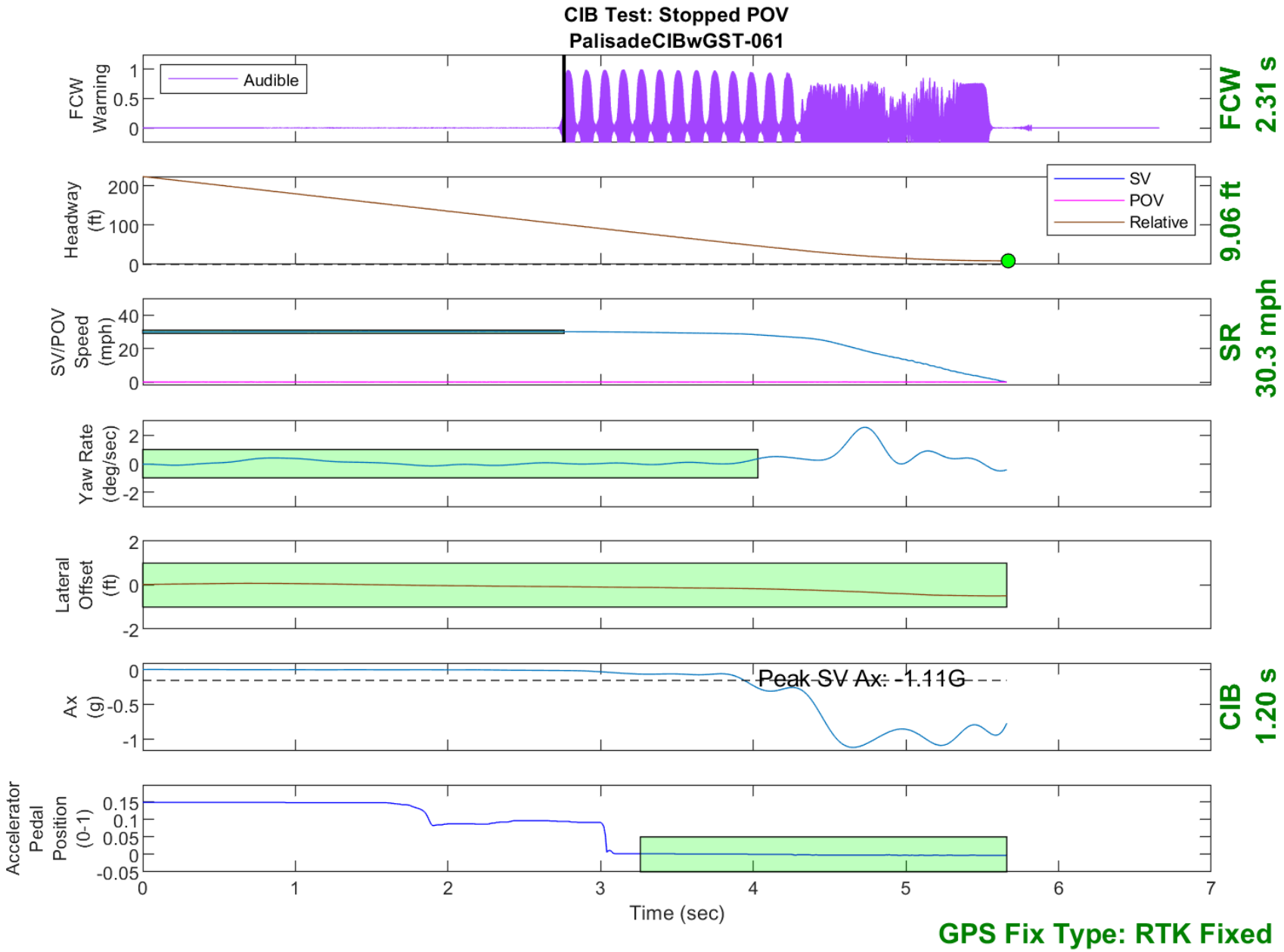


Figure D15. Time History for CIB Run 61, Stopped POV, 30 mph

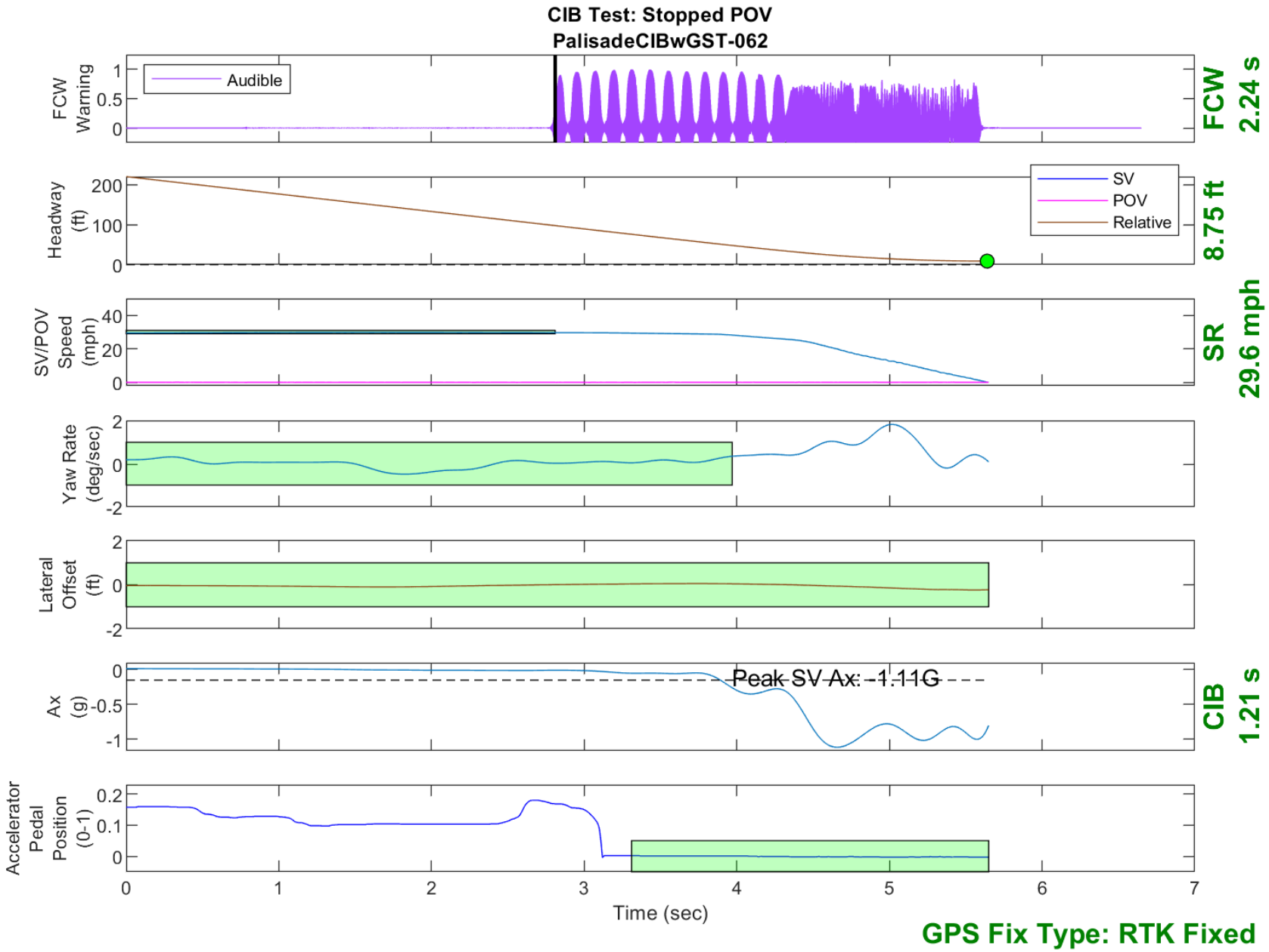


Figure D16. Time History for CIB Run 62, Stopped POV, 30 mph

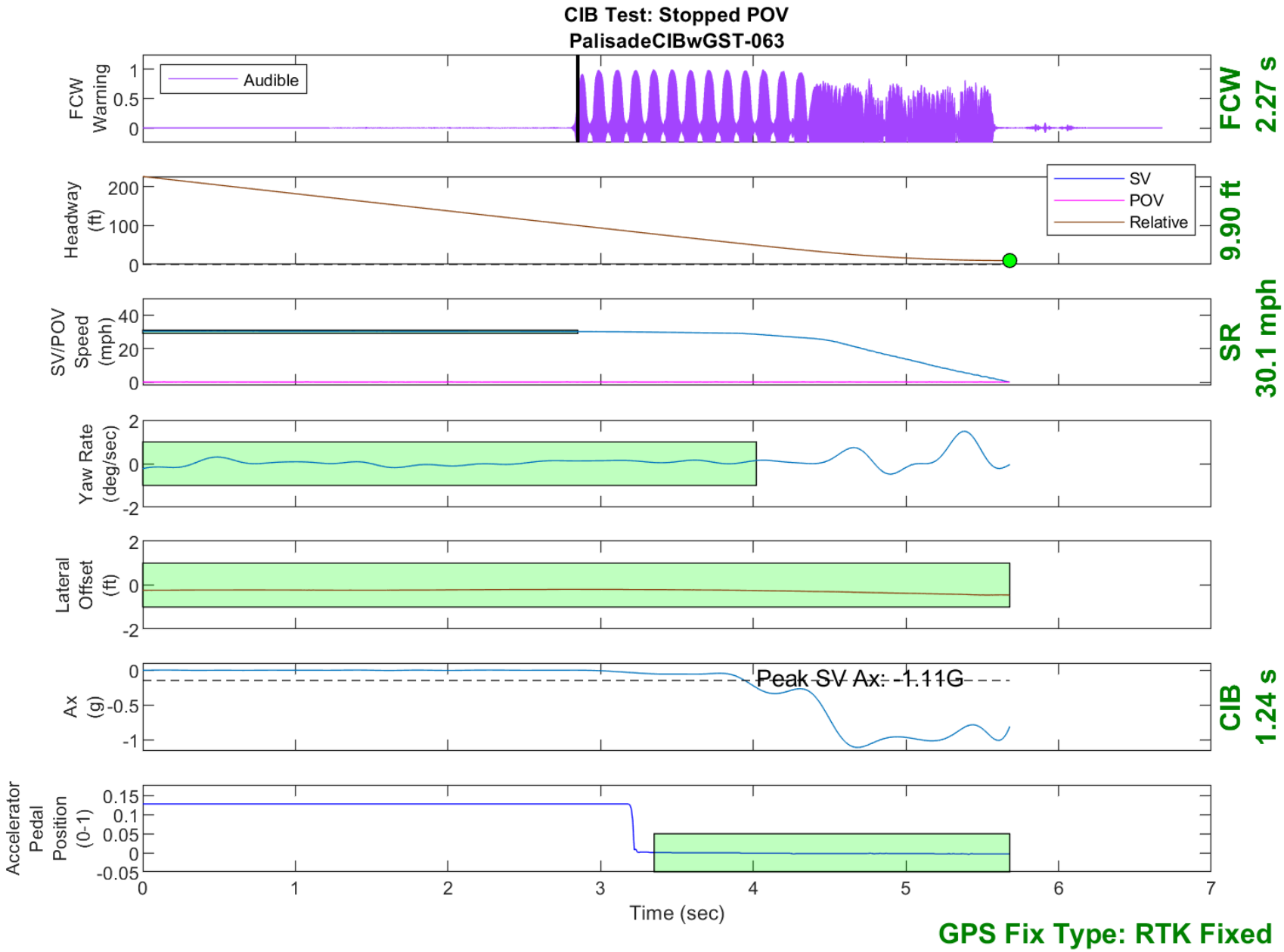


Figure D17. Time History for CIB Run 63, Stopped POV, 30 mph

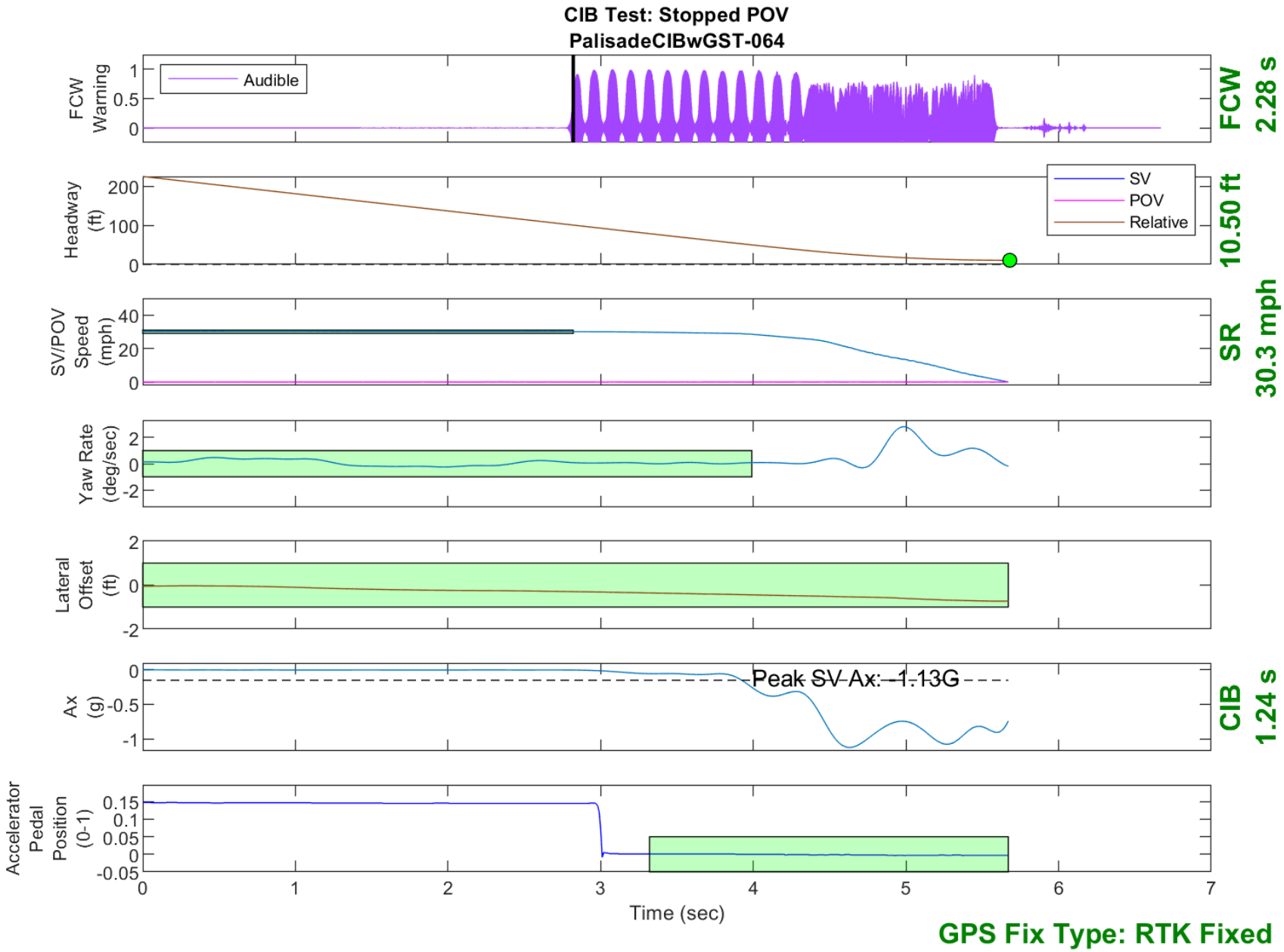


Figure D18. Time History for CIB Run 64, Stopped POV, 30 mph

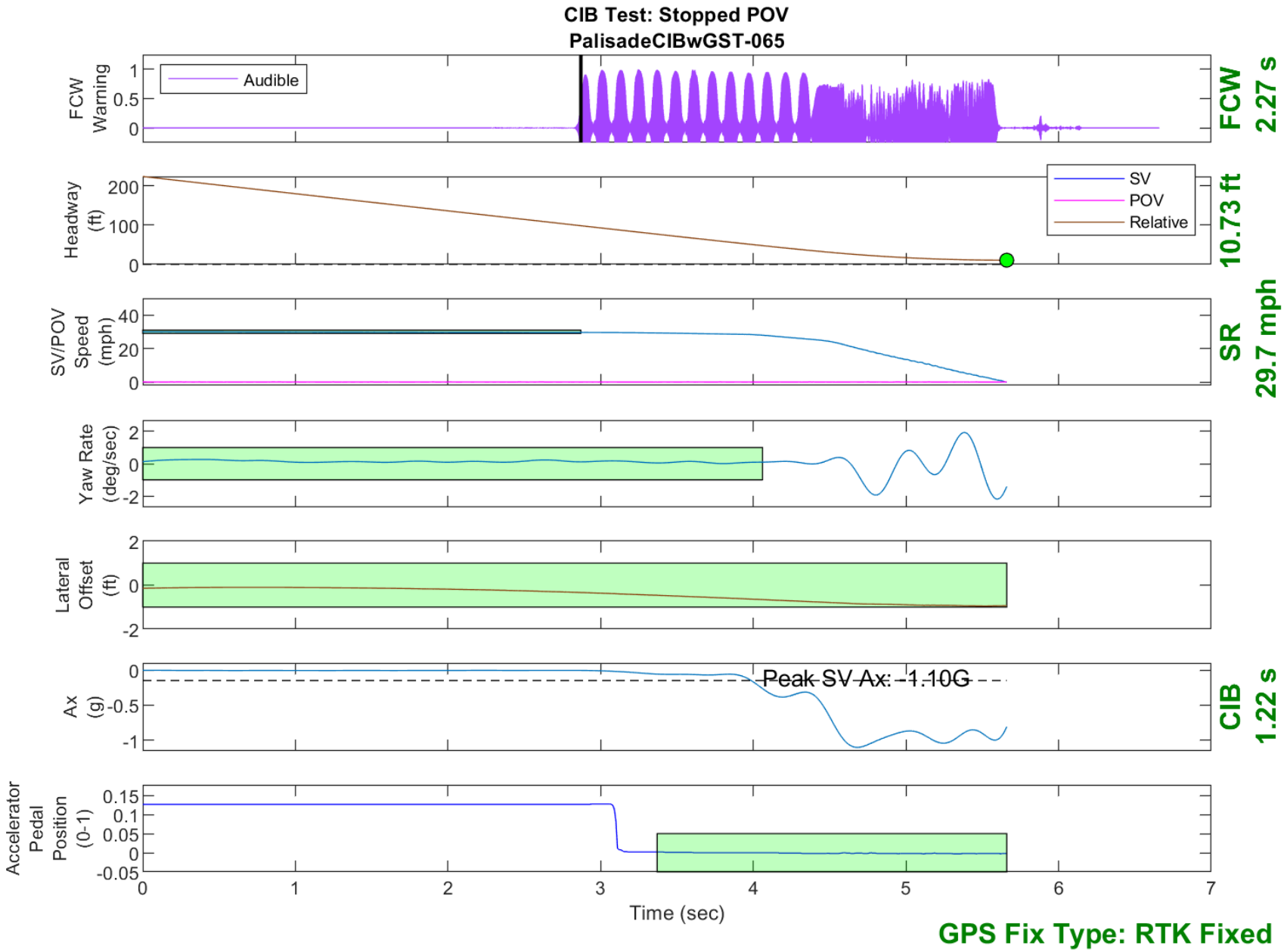


Figure D19. Time History for CIB Run 65, Stopped POV, 30 mph

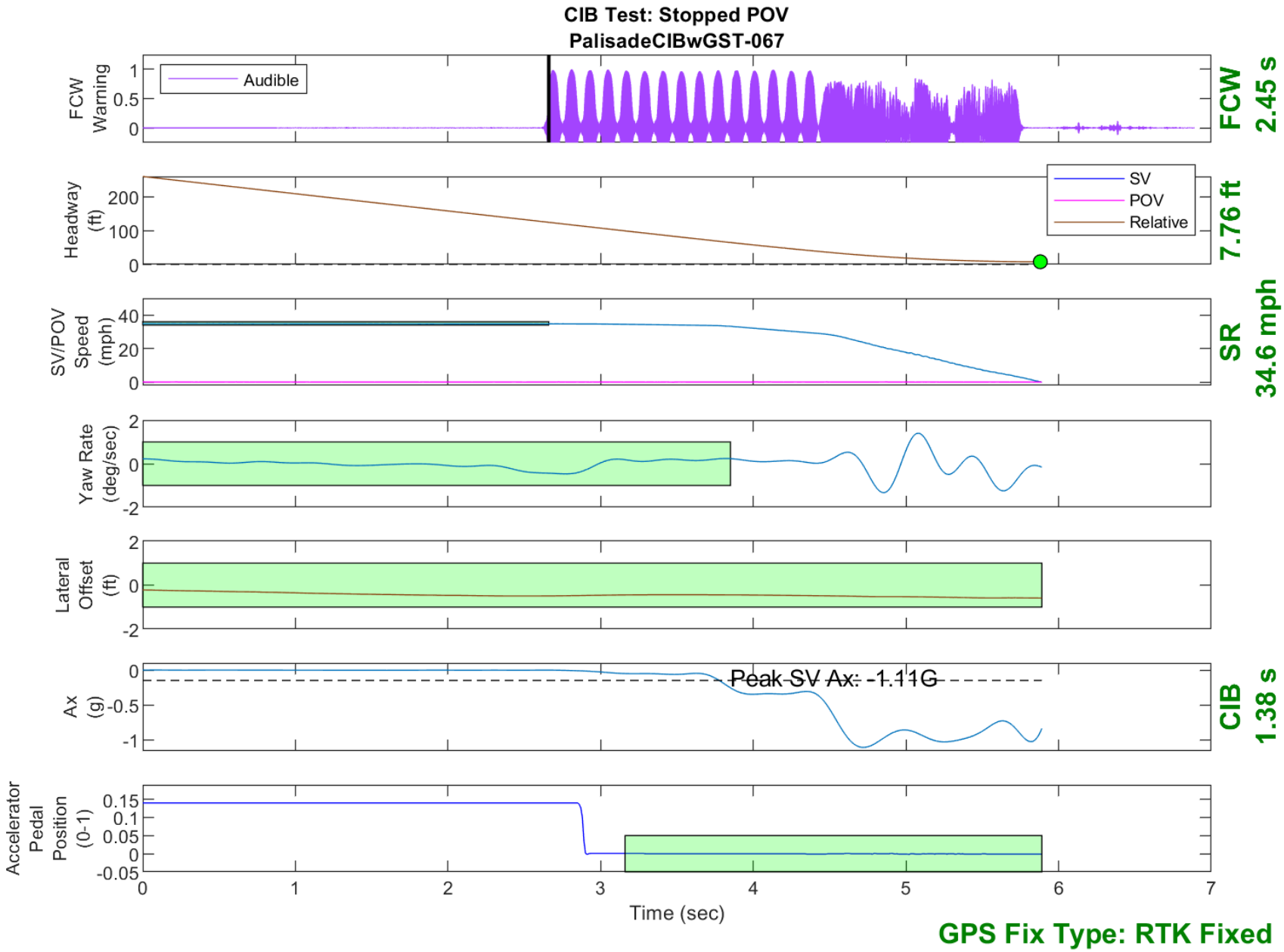


Figure D20. Time History for CIB Run 67, Stopped POV, 35 mph

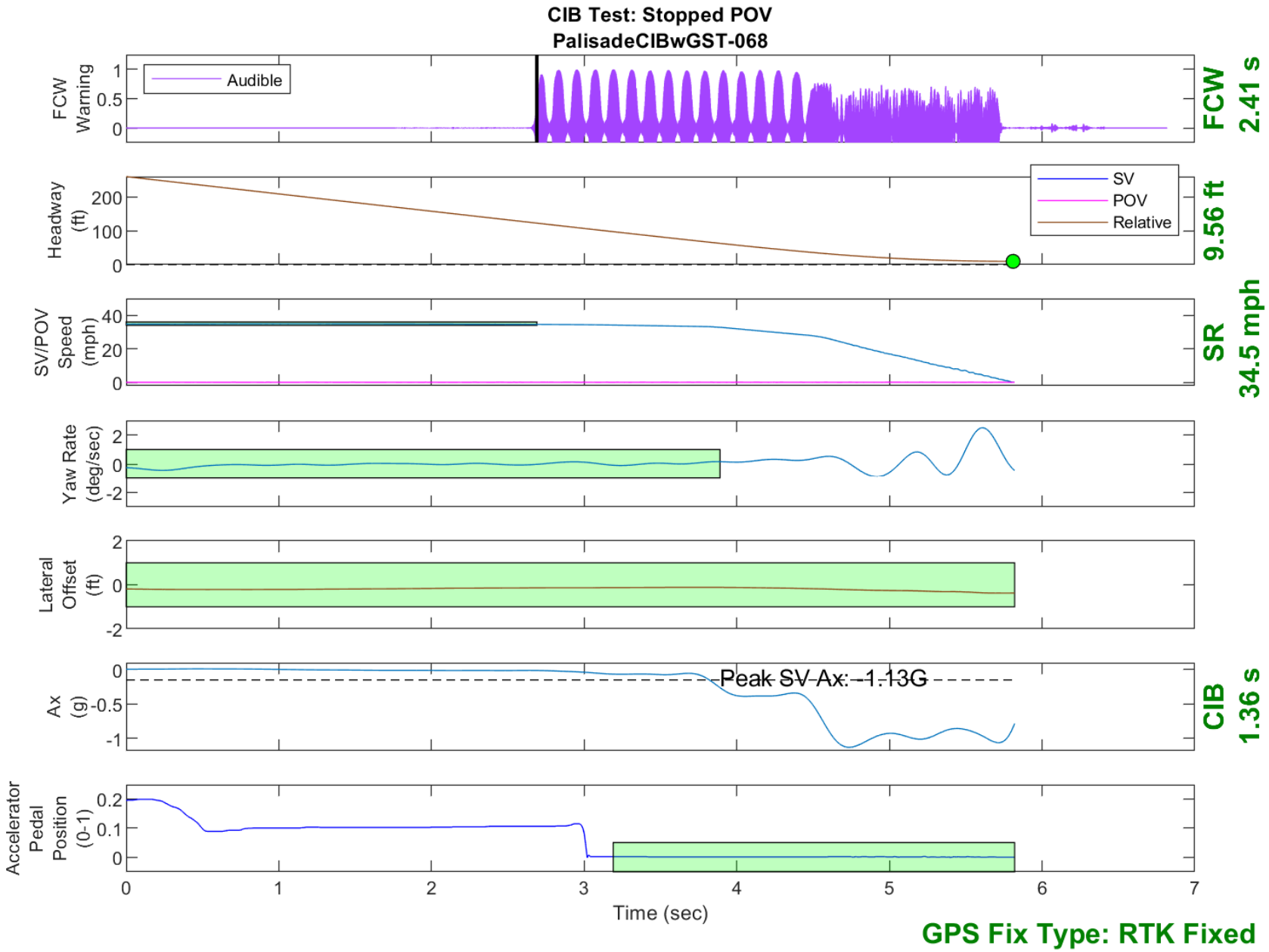


Figure D21. Time History for CIB Run 68, Stopped POV, 35 mph

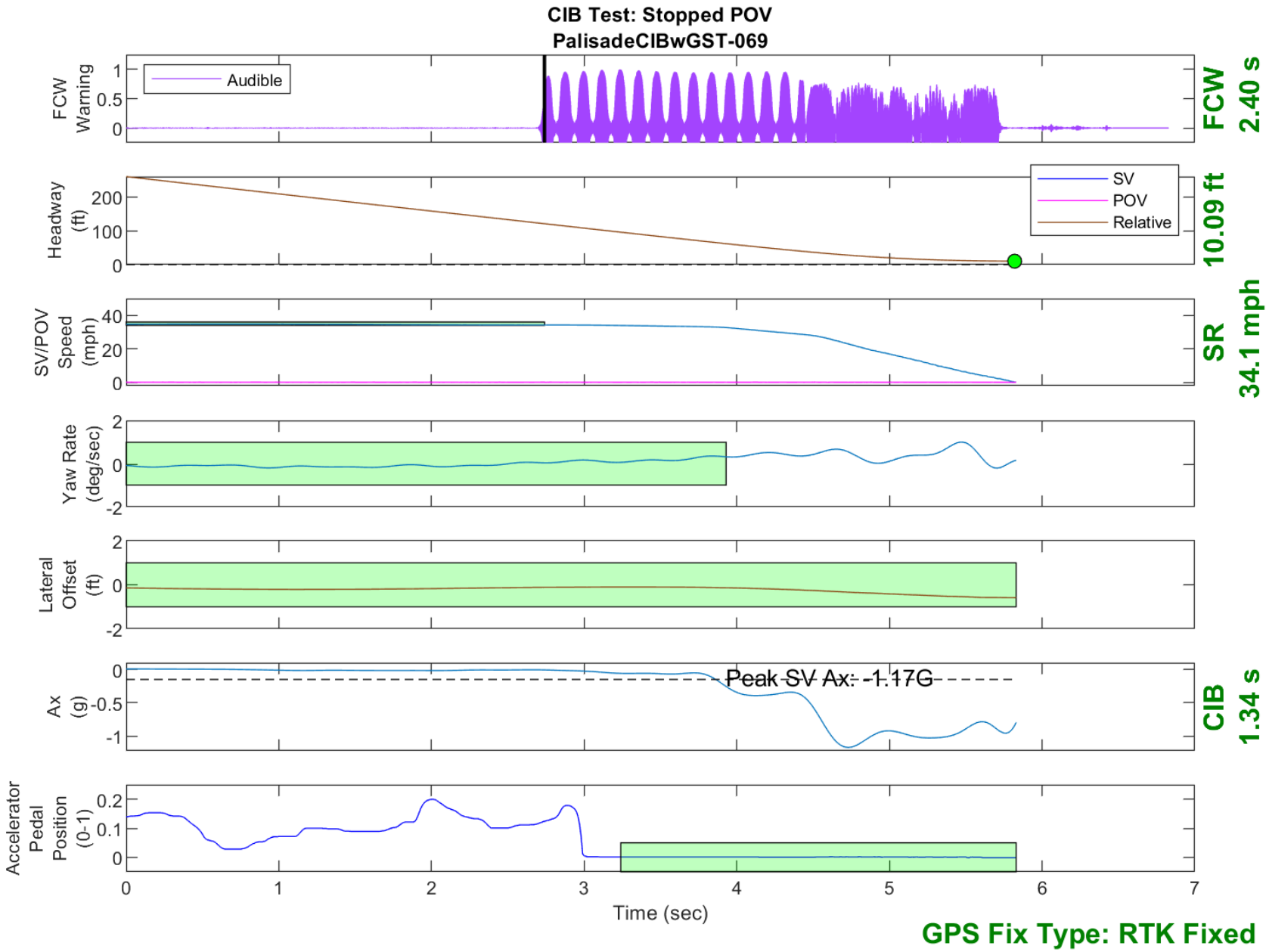


Figure D22. Time History for CIB Run 69, Stopped POV, 35 mph

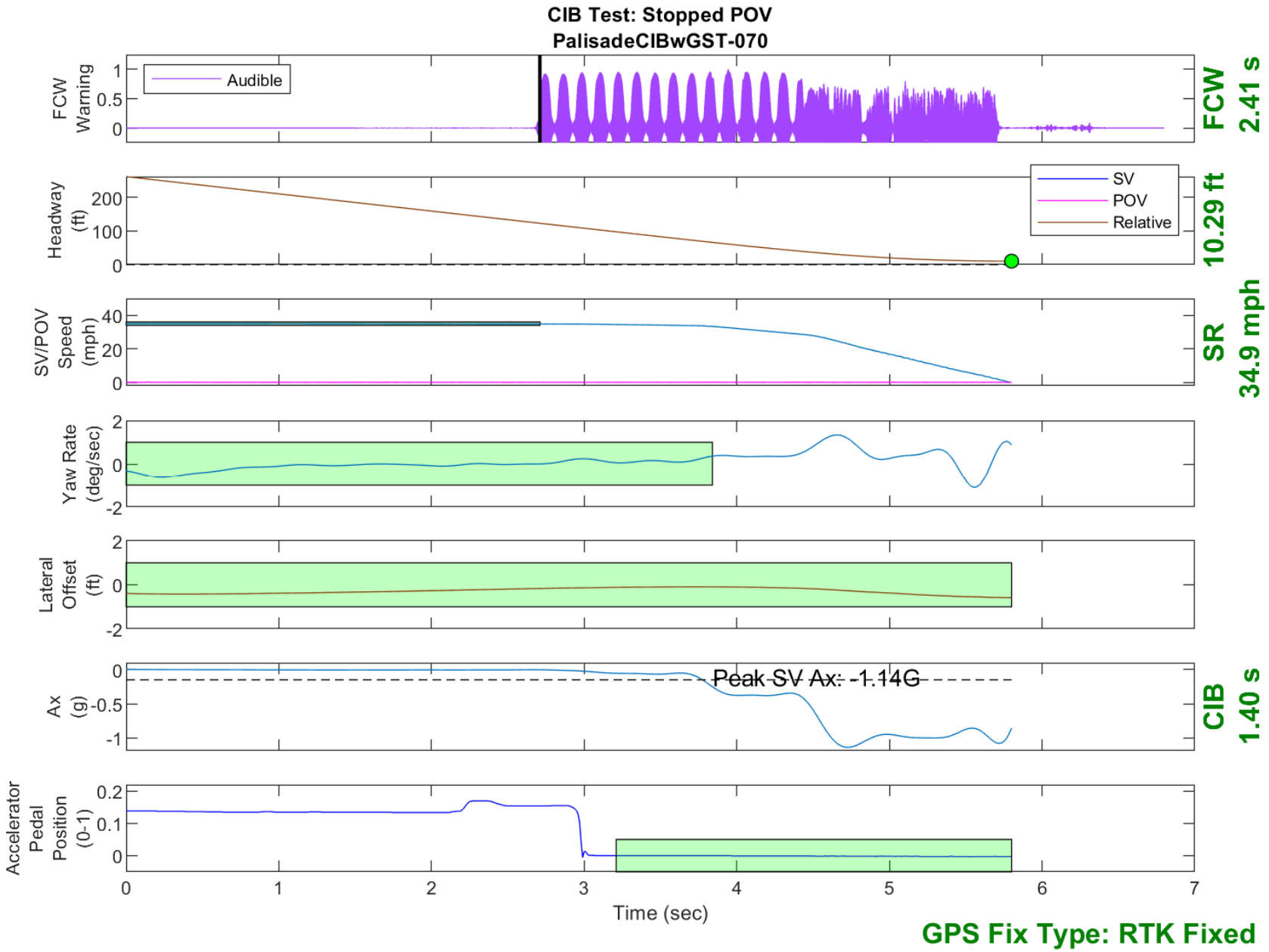


Figure D23. Time History for CIB Run 70, Stopped POV, 35 mph

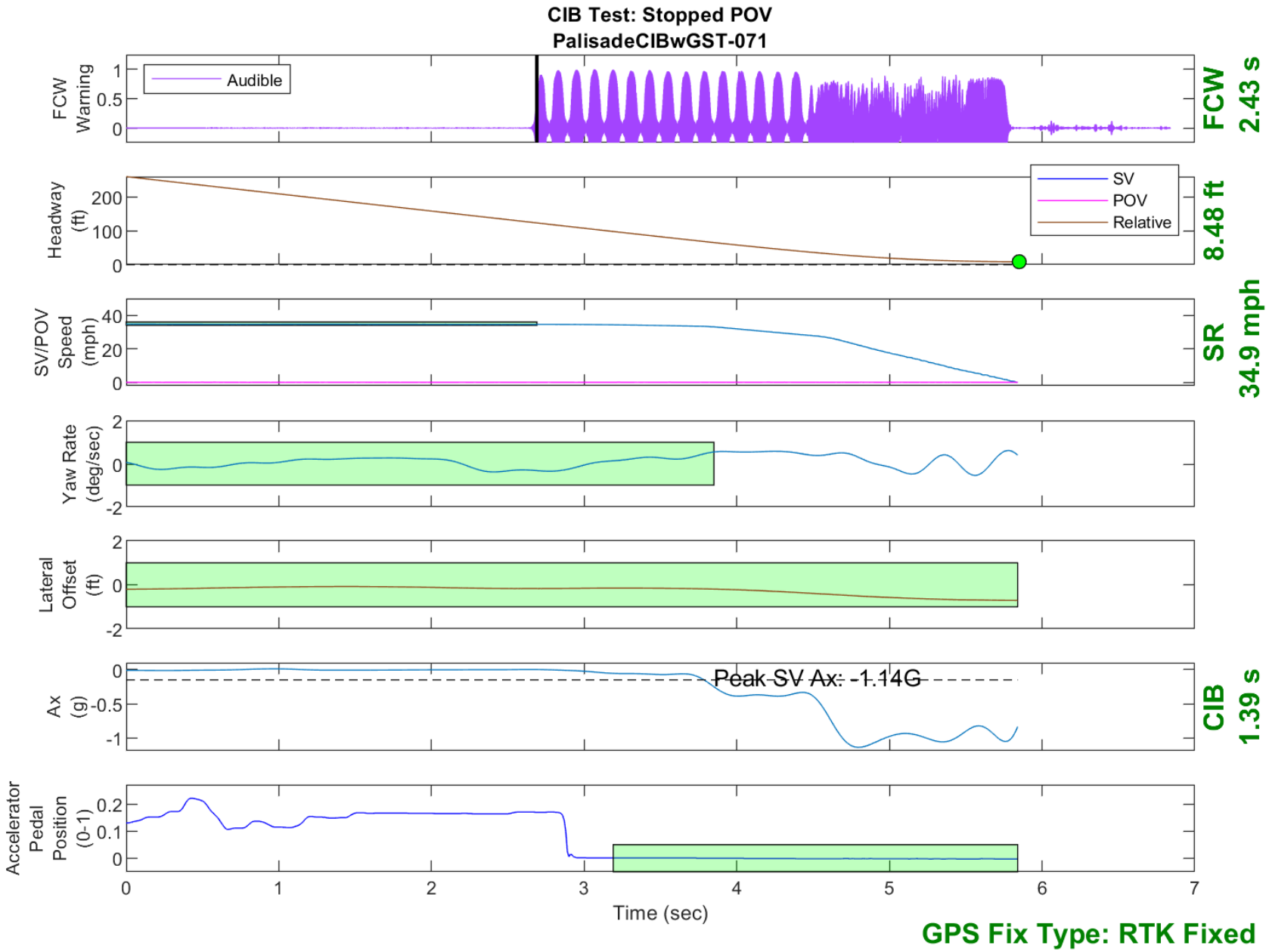


Figure D24. Time History for CIB Run 71, Stopped POV, 35 mph

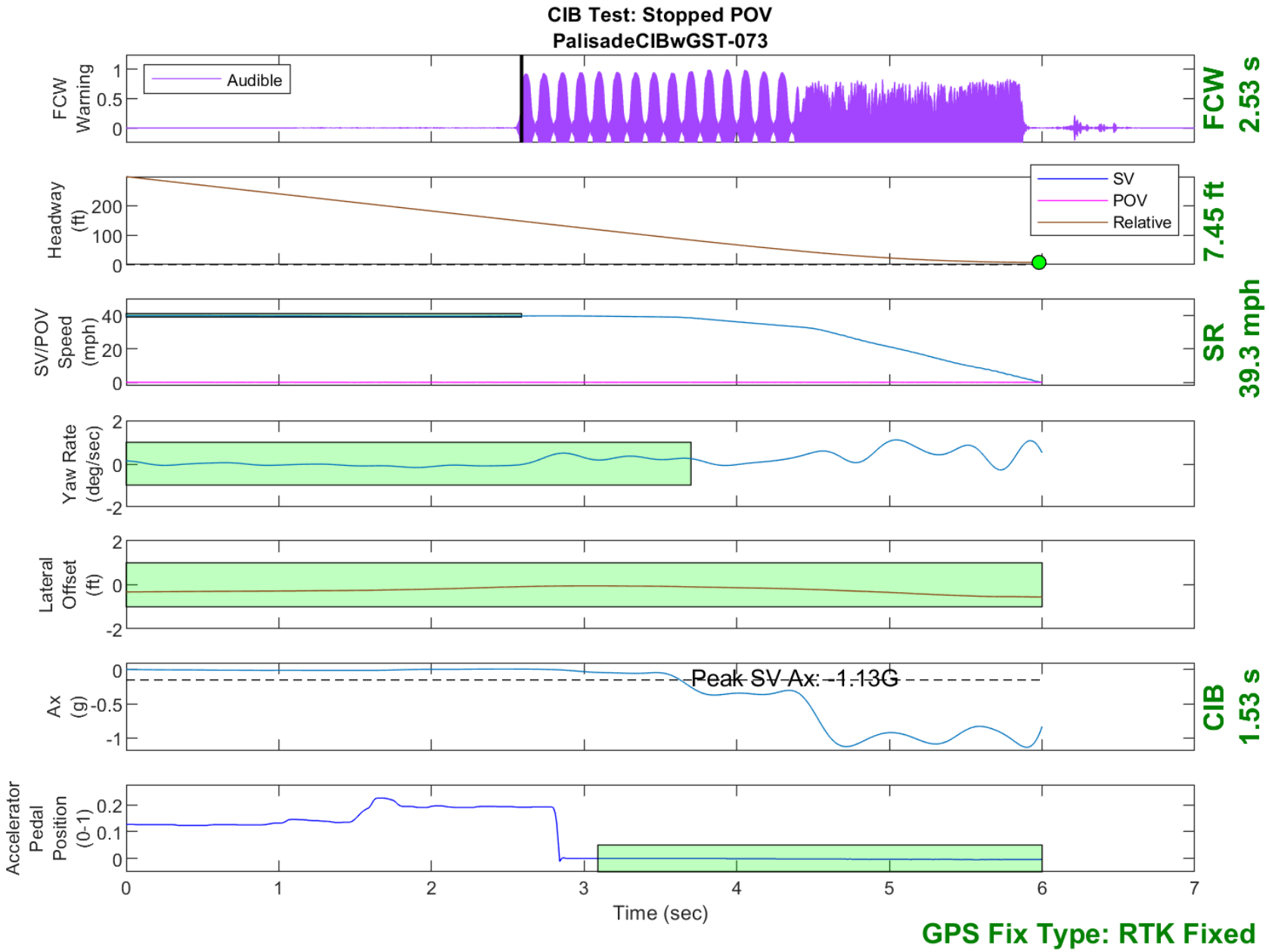


Figure D25. Time History for CIB Run 73, Stopped POV, 40 mph

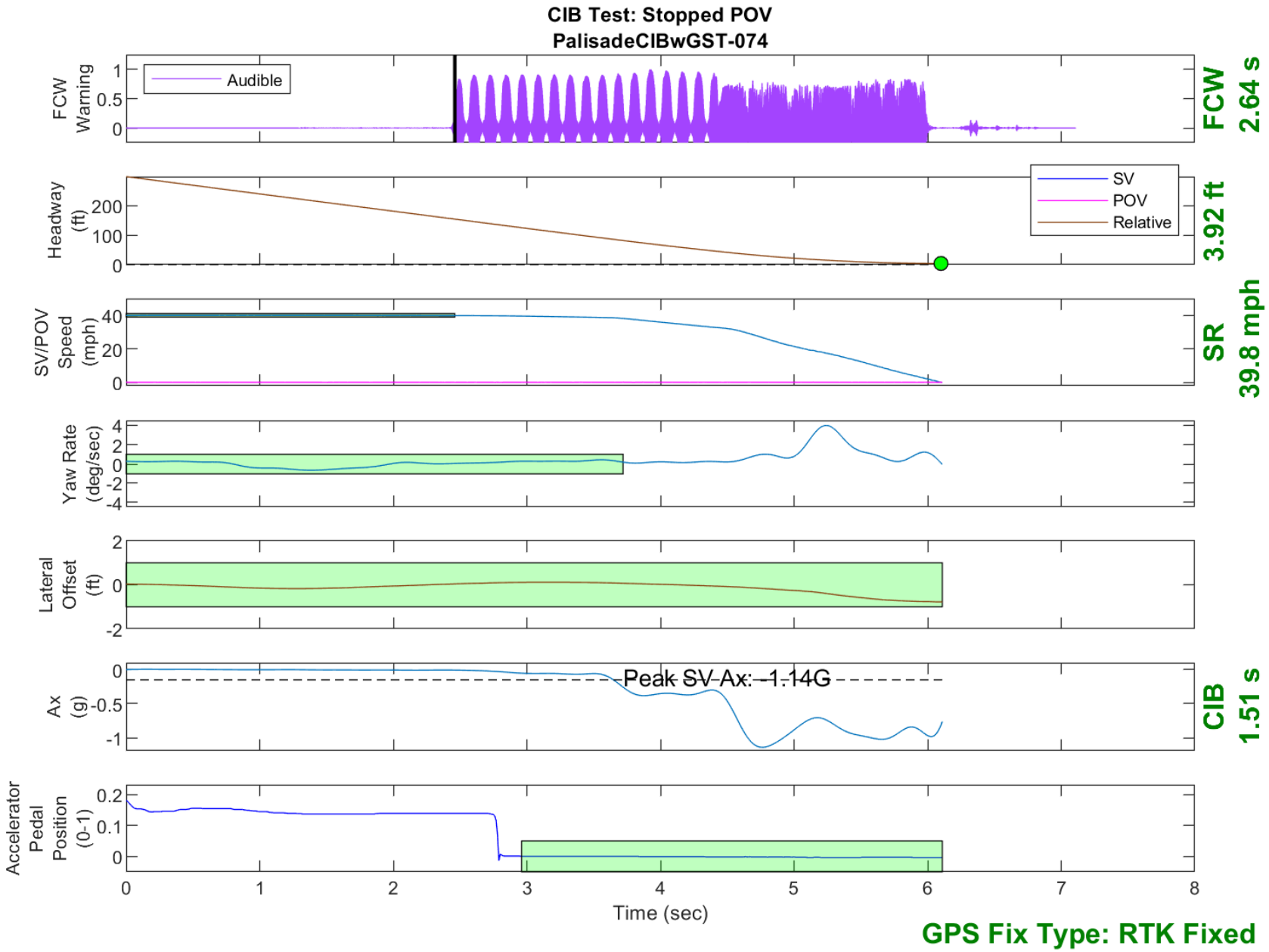


Figure D26. Time History for CIB Run 74, Stopped POV, 40 mph

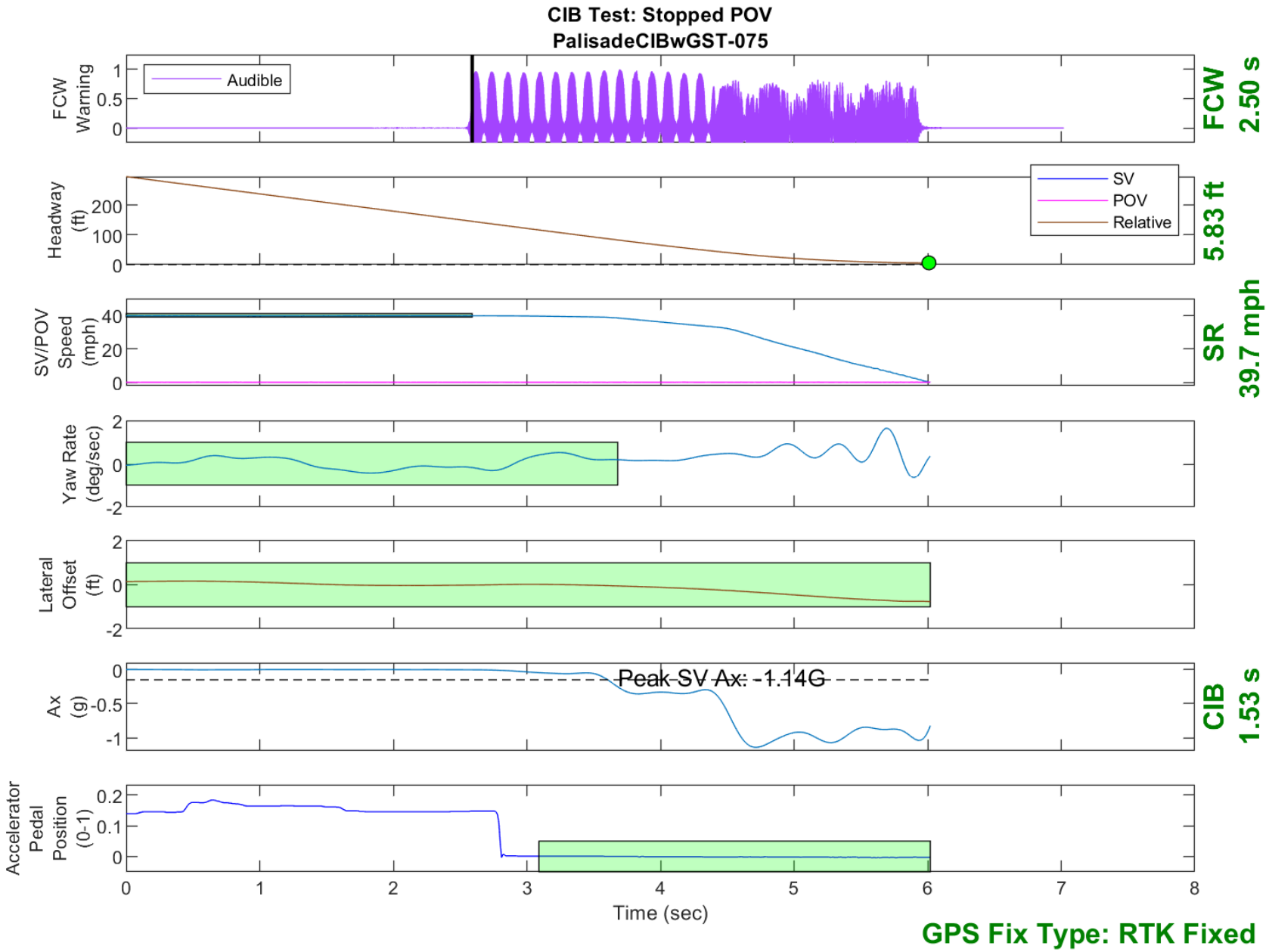


Figure D27. Time History for CIB Run 75, Stopped POV, 40 mph

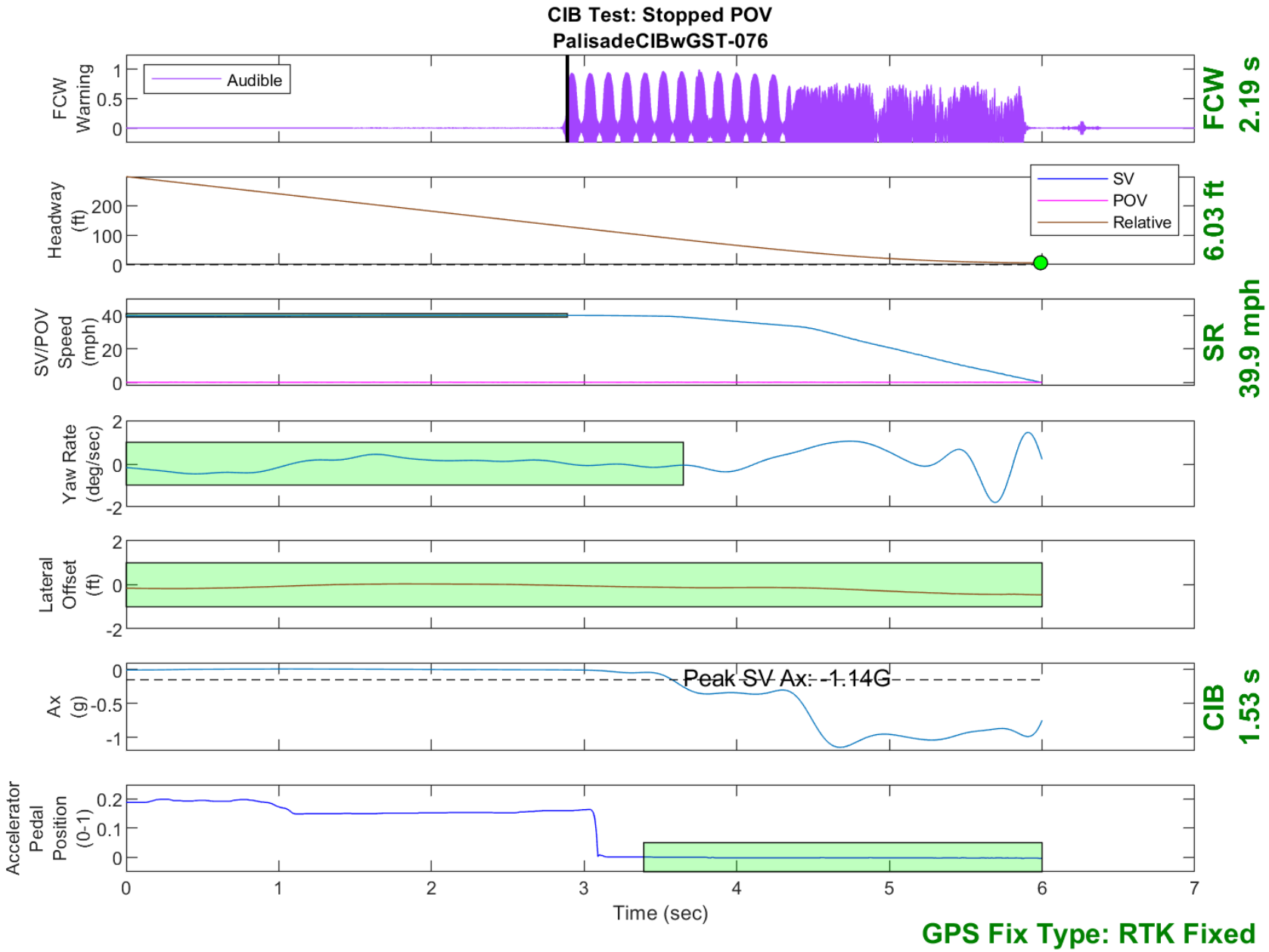


Figure D28. Time History for CIB Run 76, Stopped POV, 40 mph

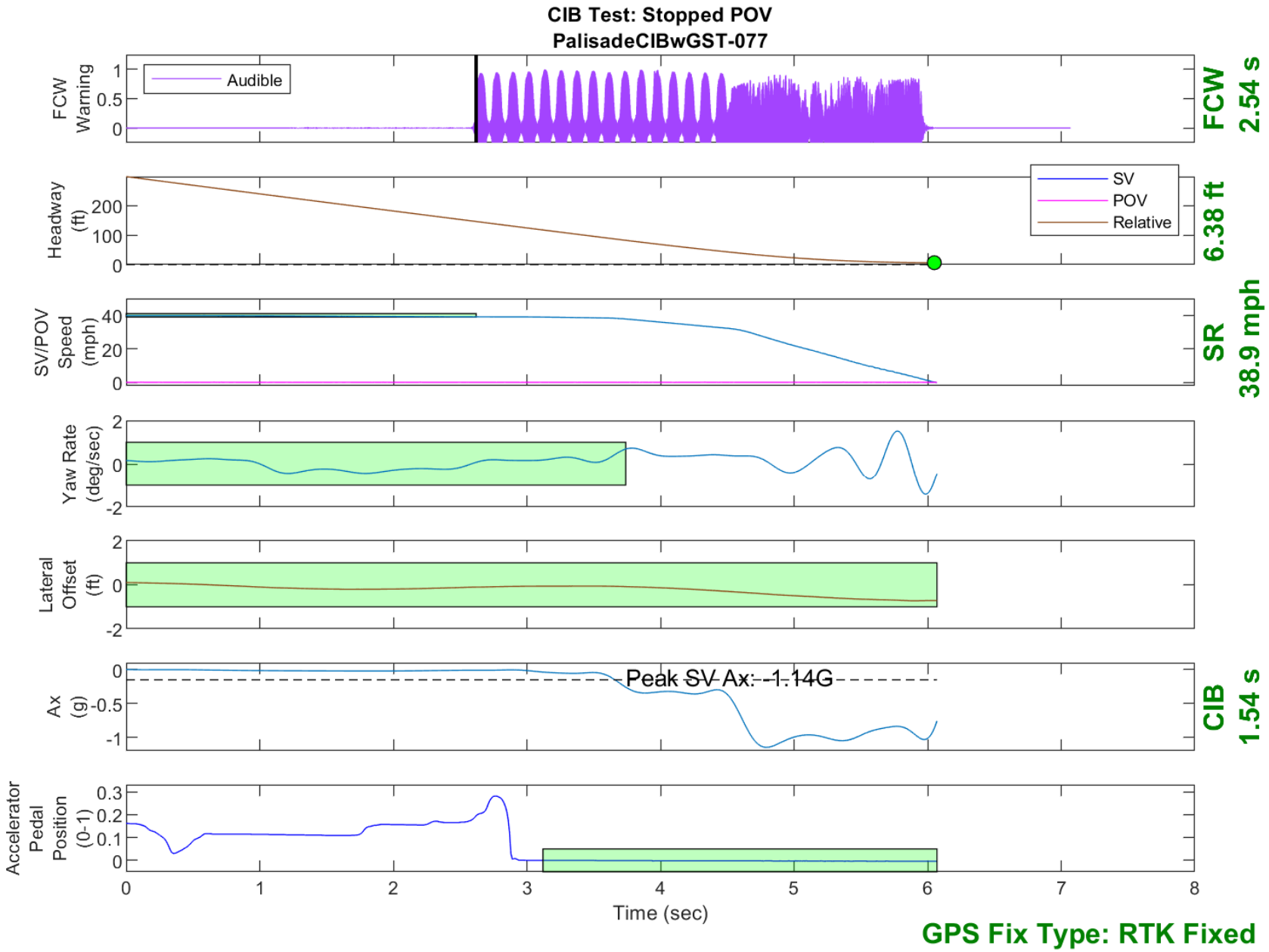


Figure D29. Time History for CIB Run 77, Stopped POV, 40 mph

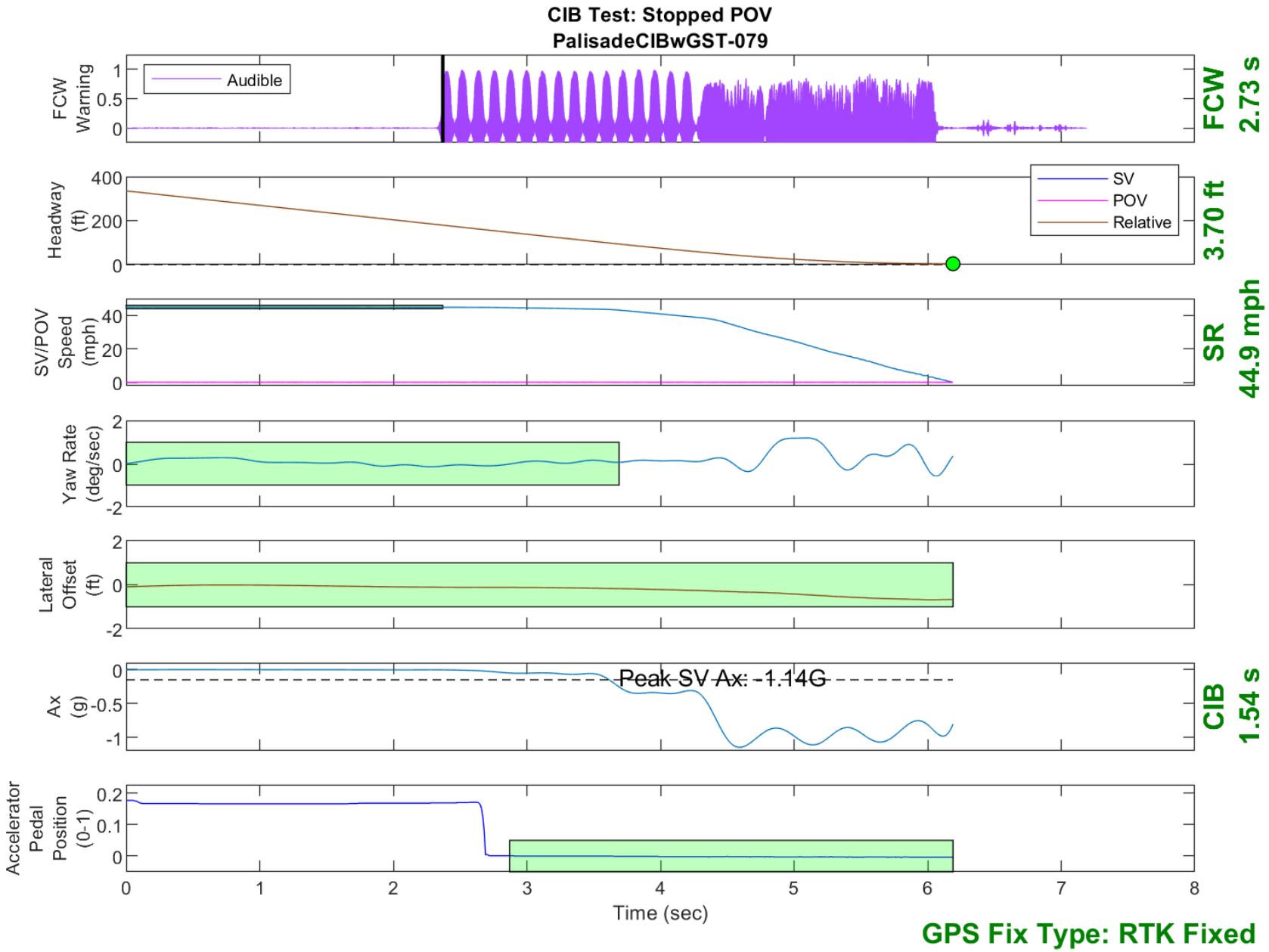


Figure D30. Time History for CIB Run 79, Stopped POV, 45 mph

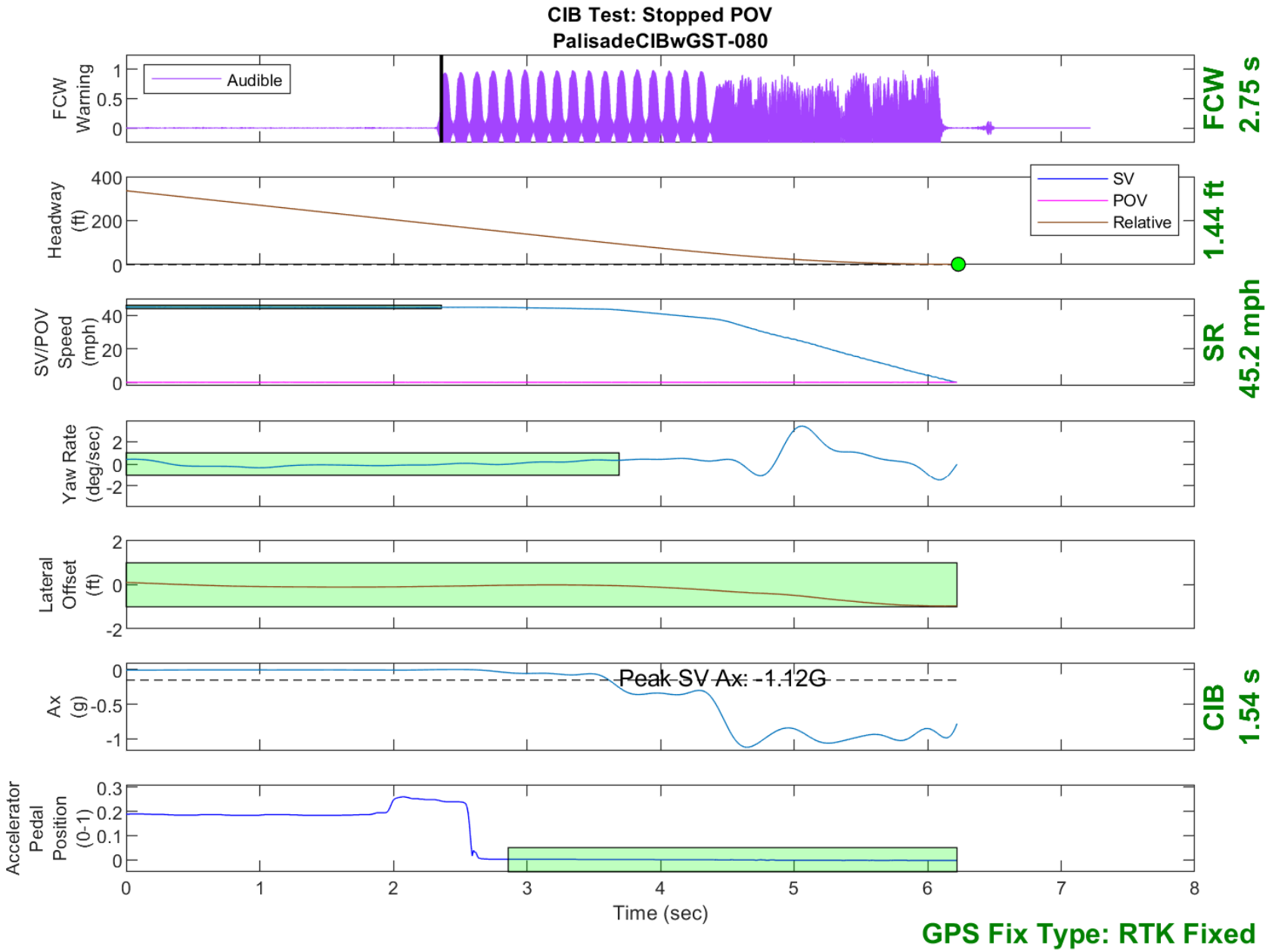


Figure D31. Time History for CIB Run 80, Stopped POV, 45 mph

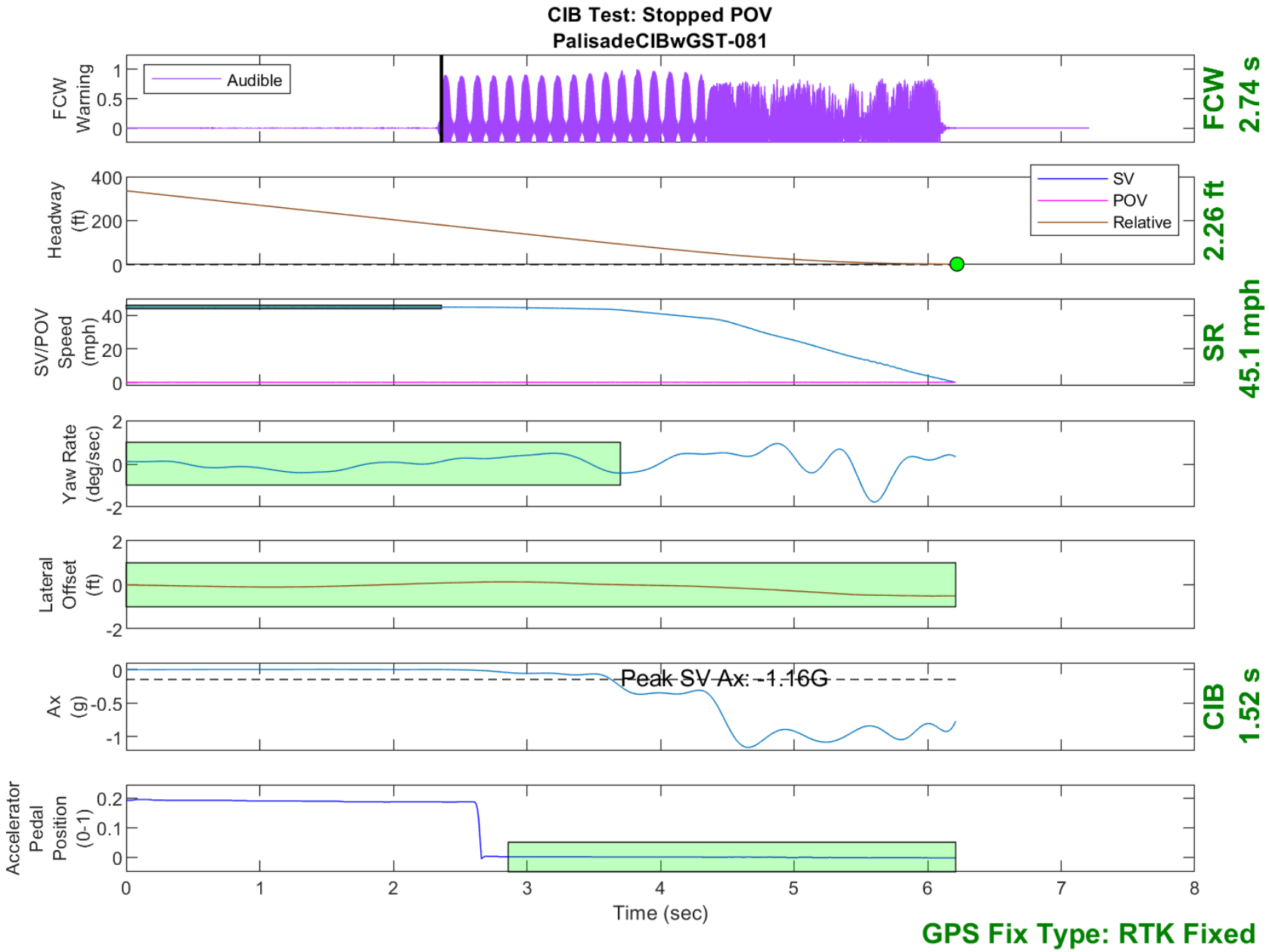


Figure D32. Time History for CIB Run 81, Stopped POV, 45 mph

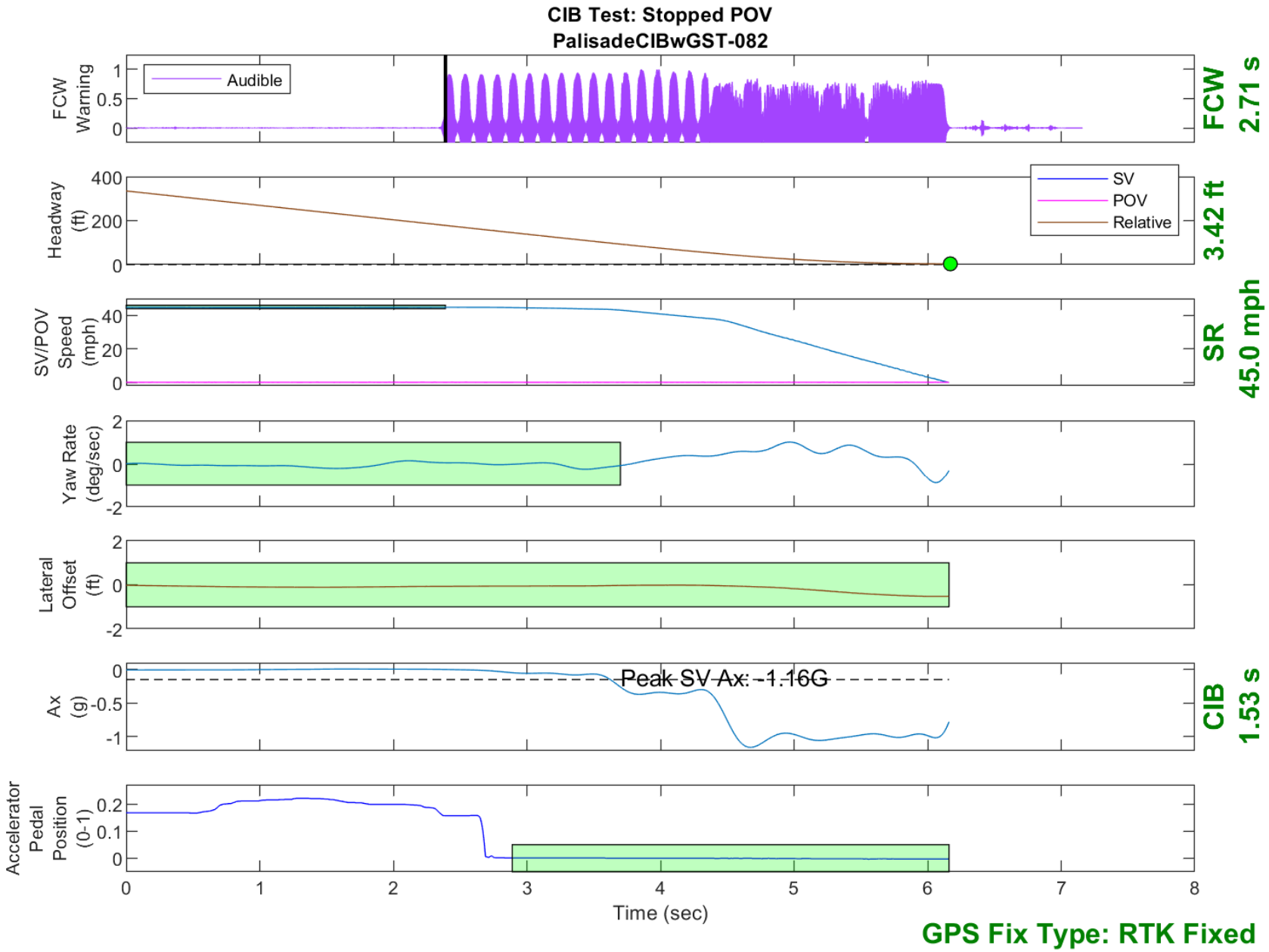


Figure D33. Time History for CIB Run 82, Stopped POV, 45 mph

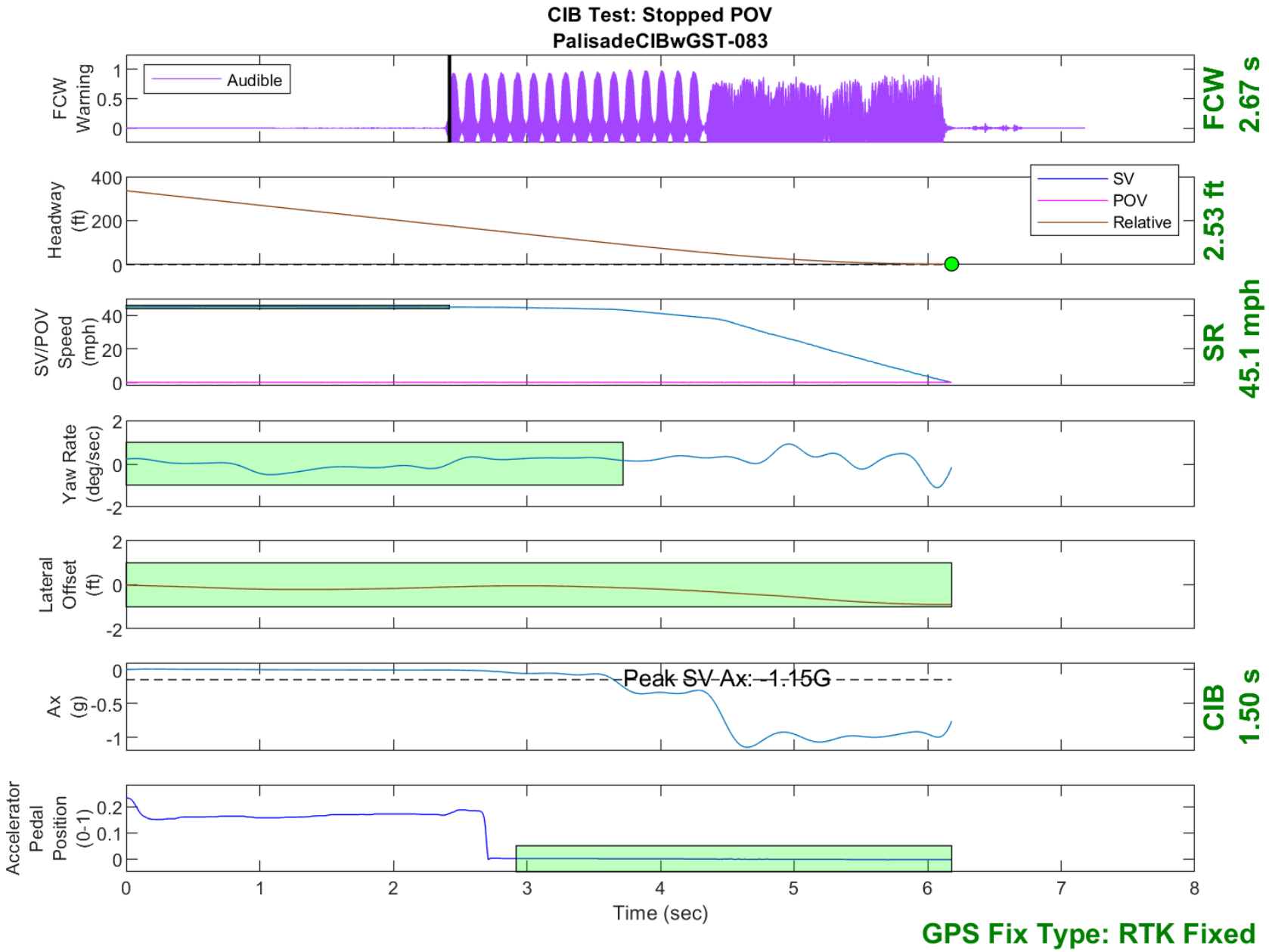


Figure D34. Time History for CIB Run 83, Stopped POV, 45 mph

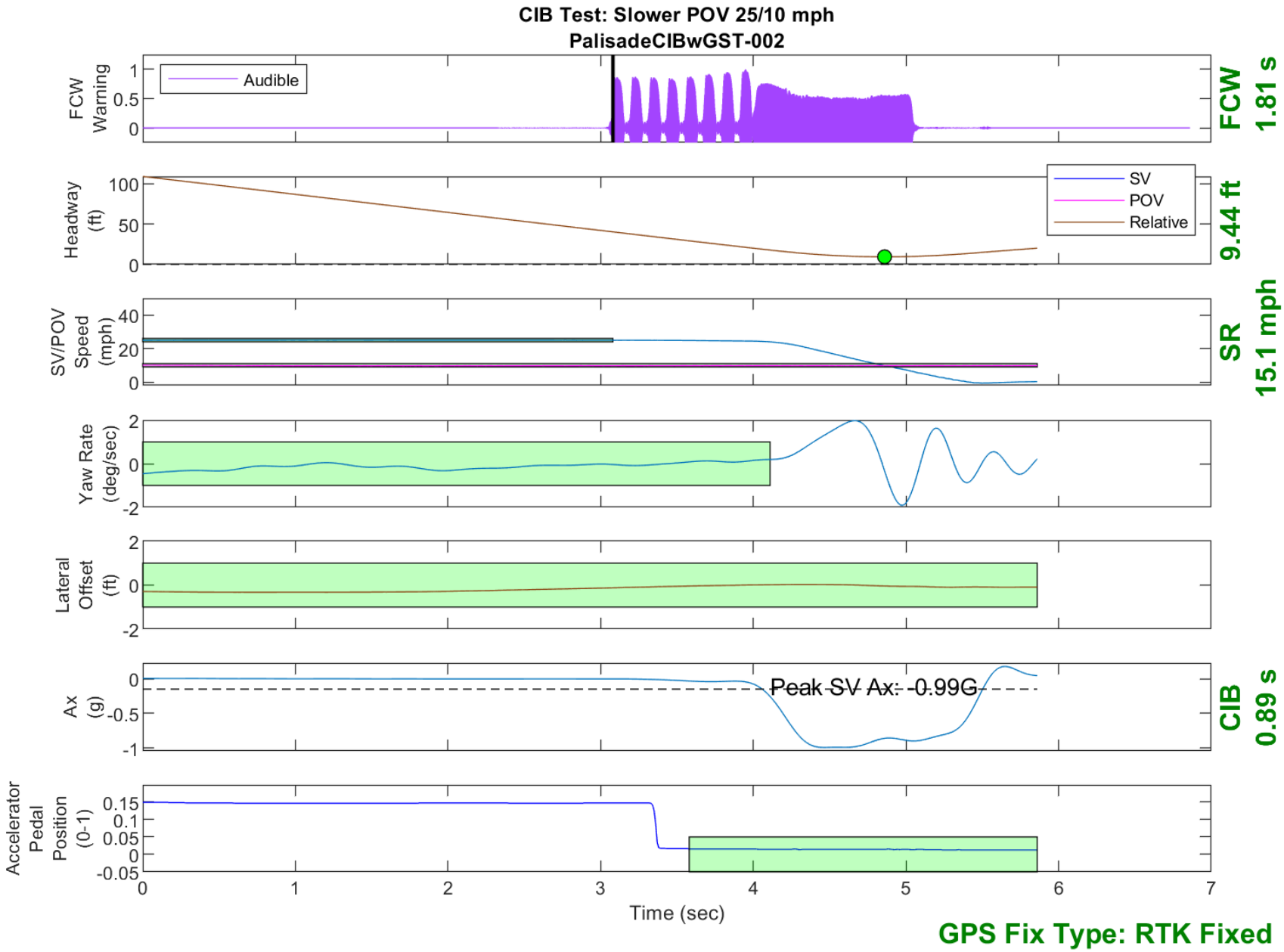


Figure D35. Time History for CIB Run 2, Slower POV, 25/10 mph

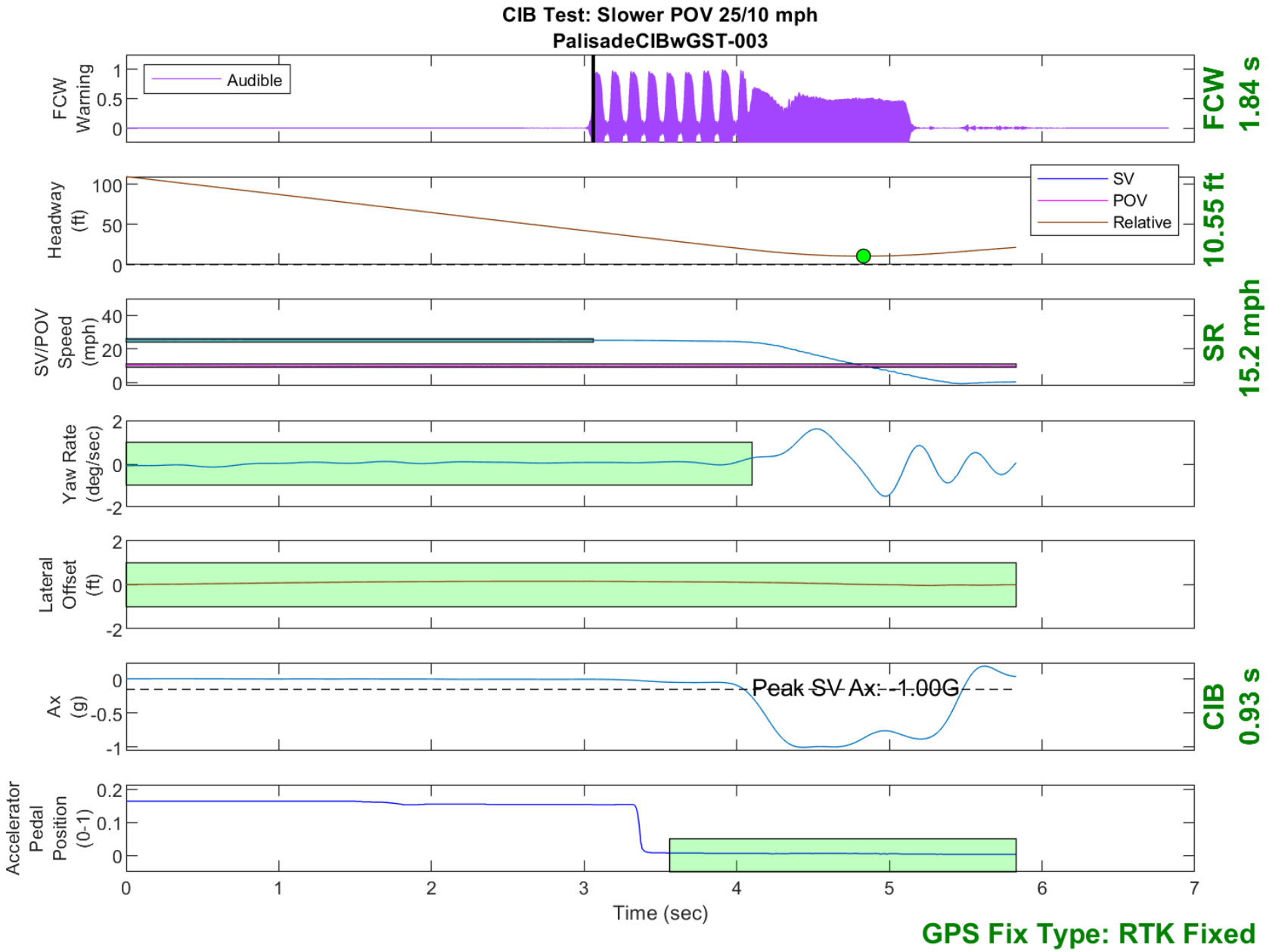


Figure D36. Time History for CIB Run 3, Slower POV, 25/10 mph

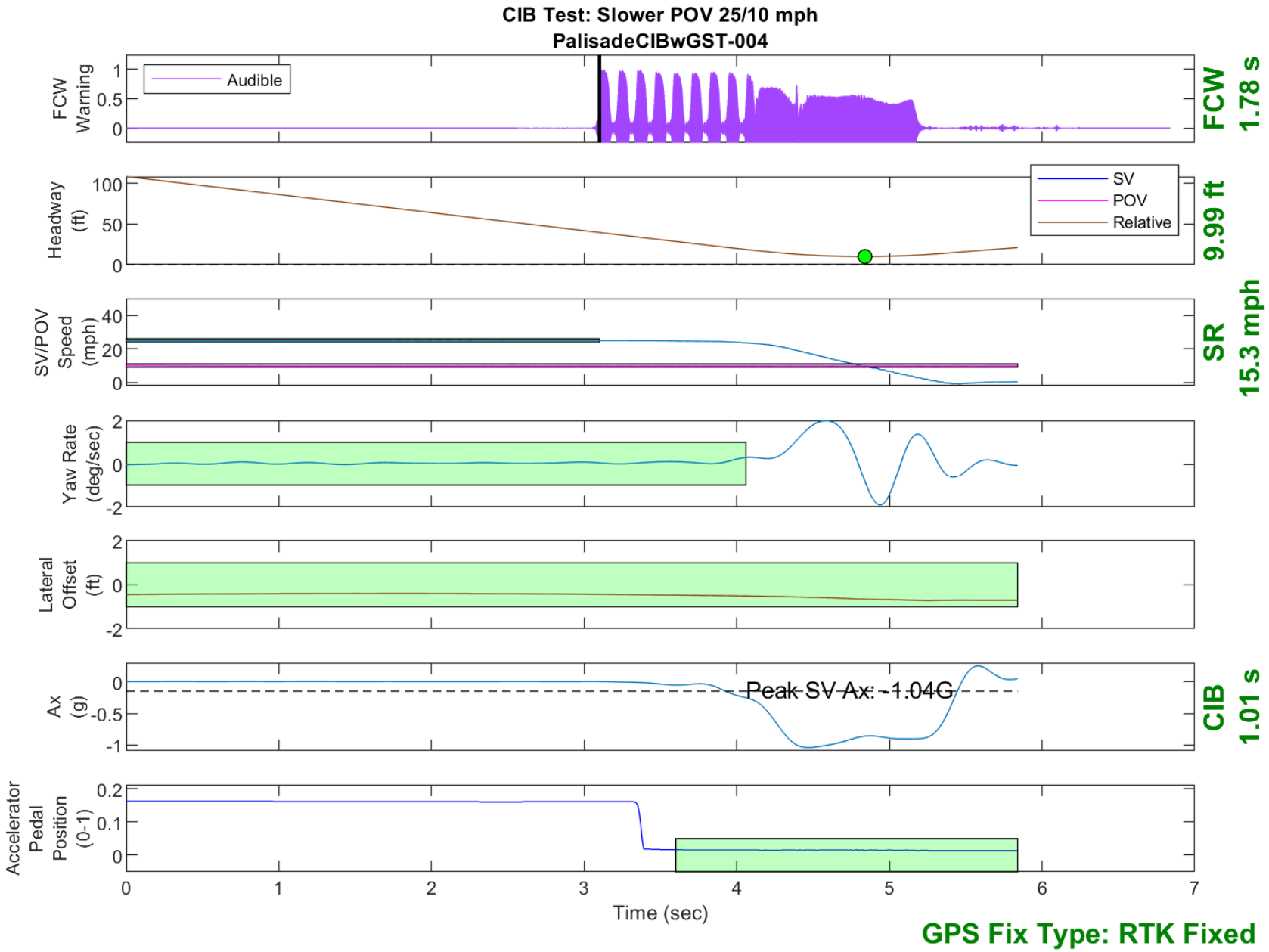


Figure D37. Time History for CIB Run 4, Slower POV, 25/10 mph

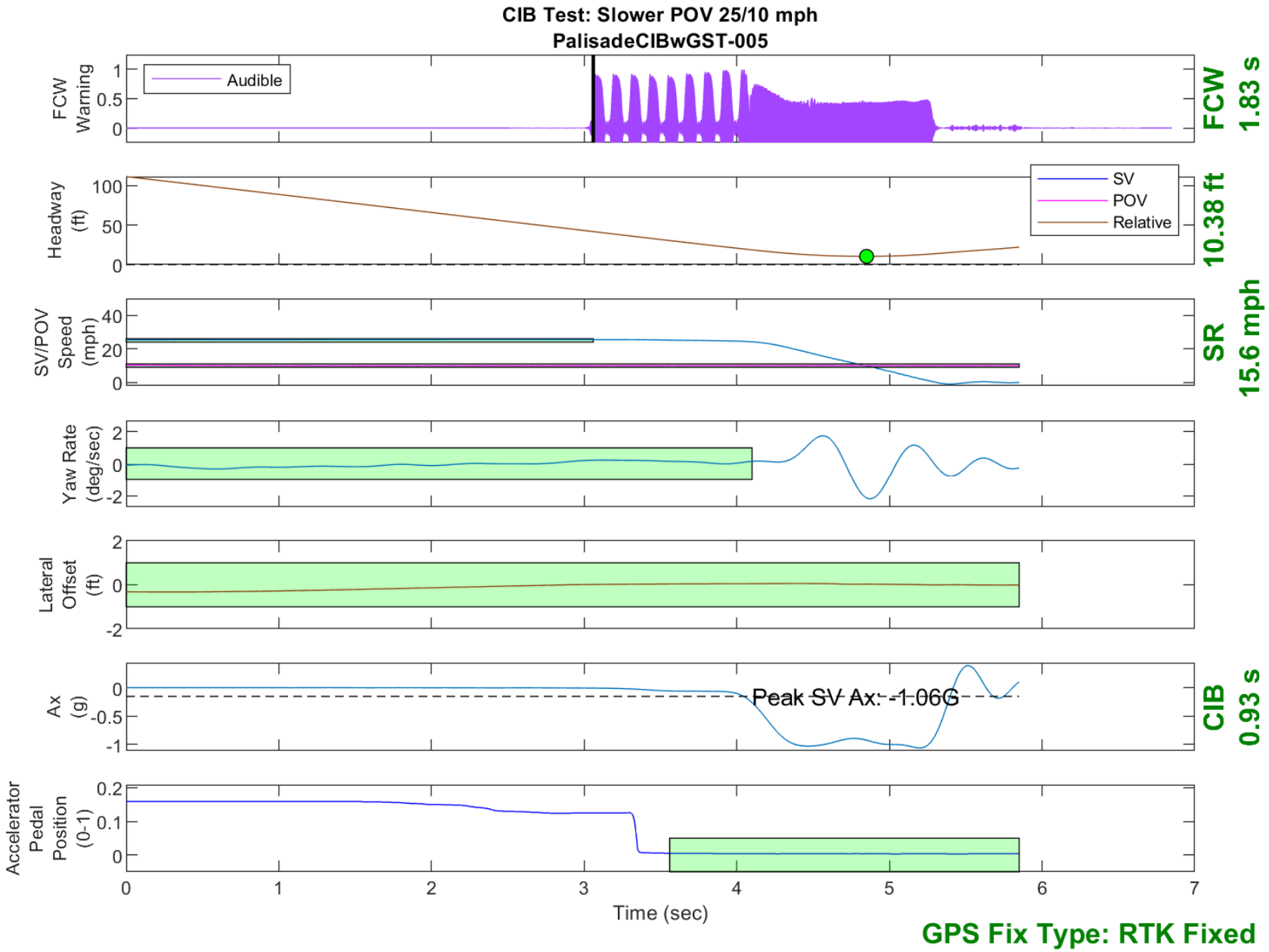


Figure D38. Time History for CIB Run 5, Slower POV, 25/10 mph

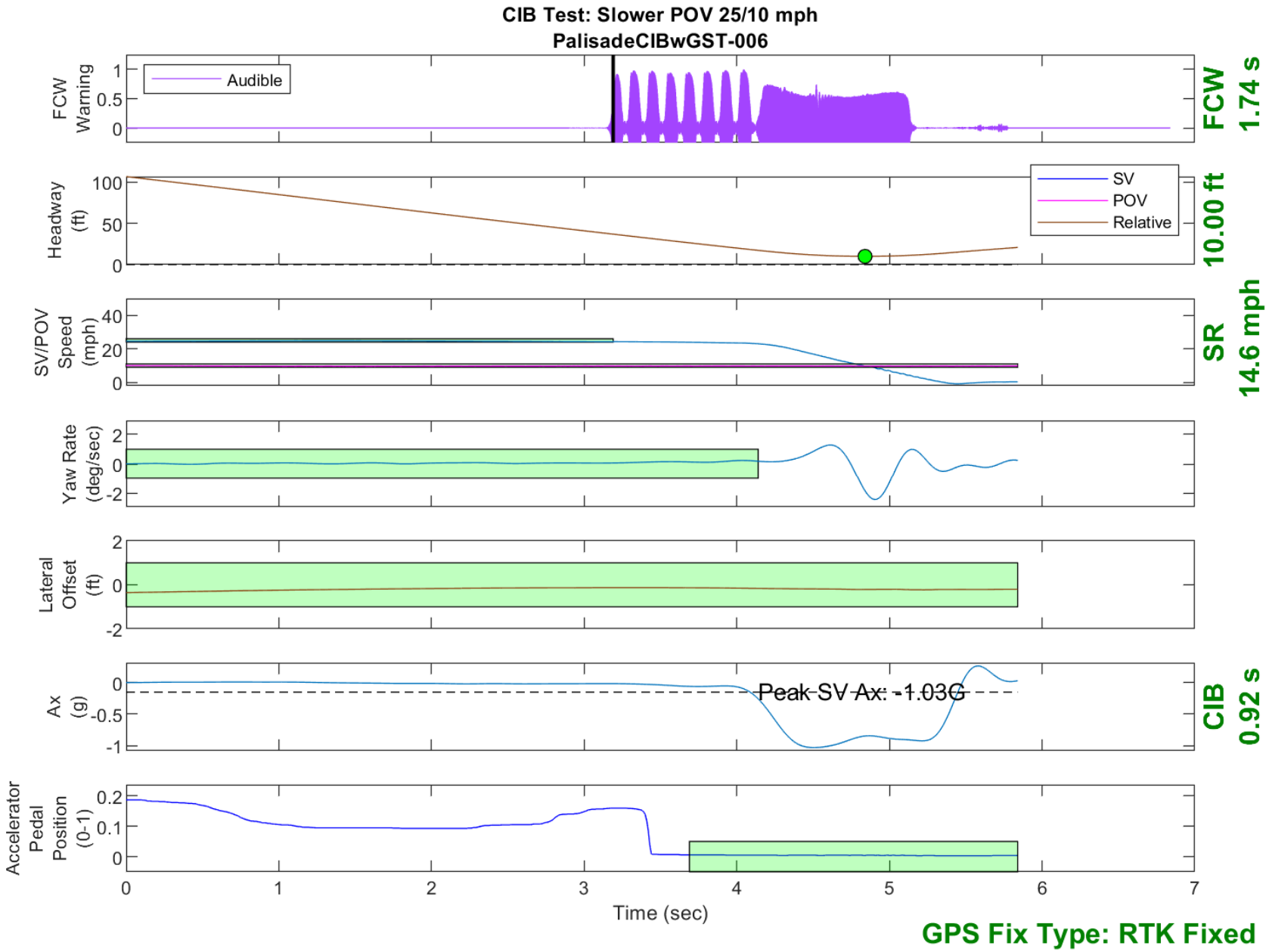


Figure D39. Time History for CIB Run 6, Slower POV, 25/10 mph

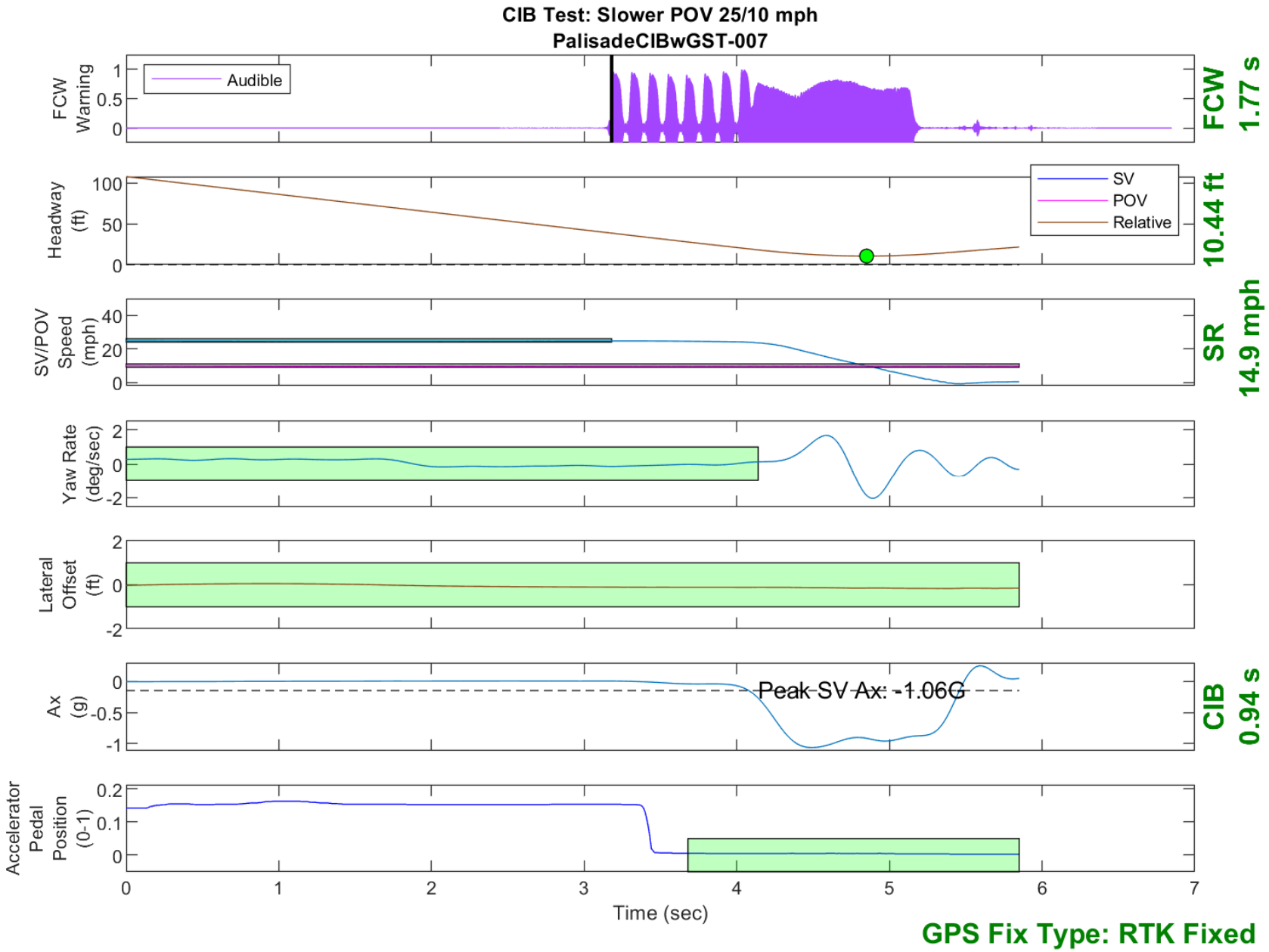


Figure D40. Time History for CIB Run 7, Slower POV, 25/10 mph

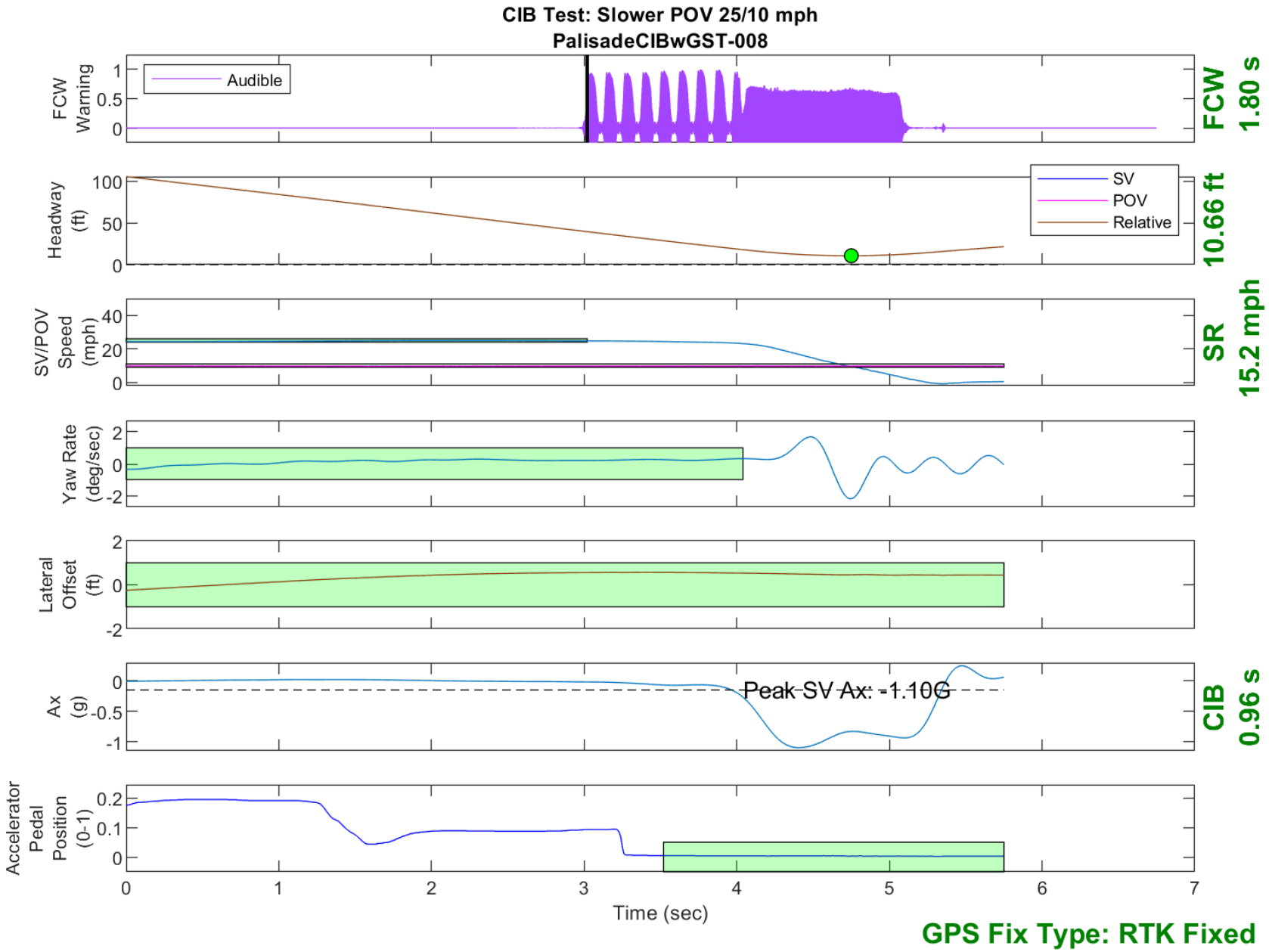


Figure D41. Time History for CIB Run 8, Slower POV, 25/10 mph

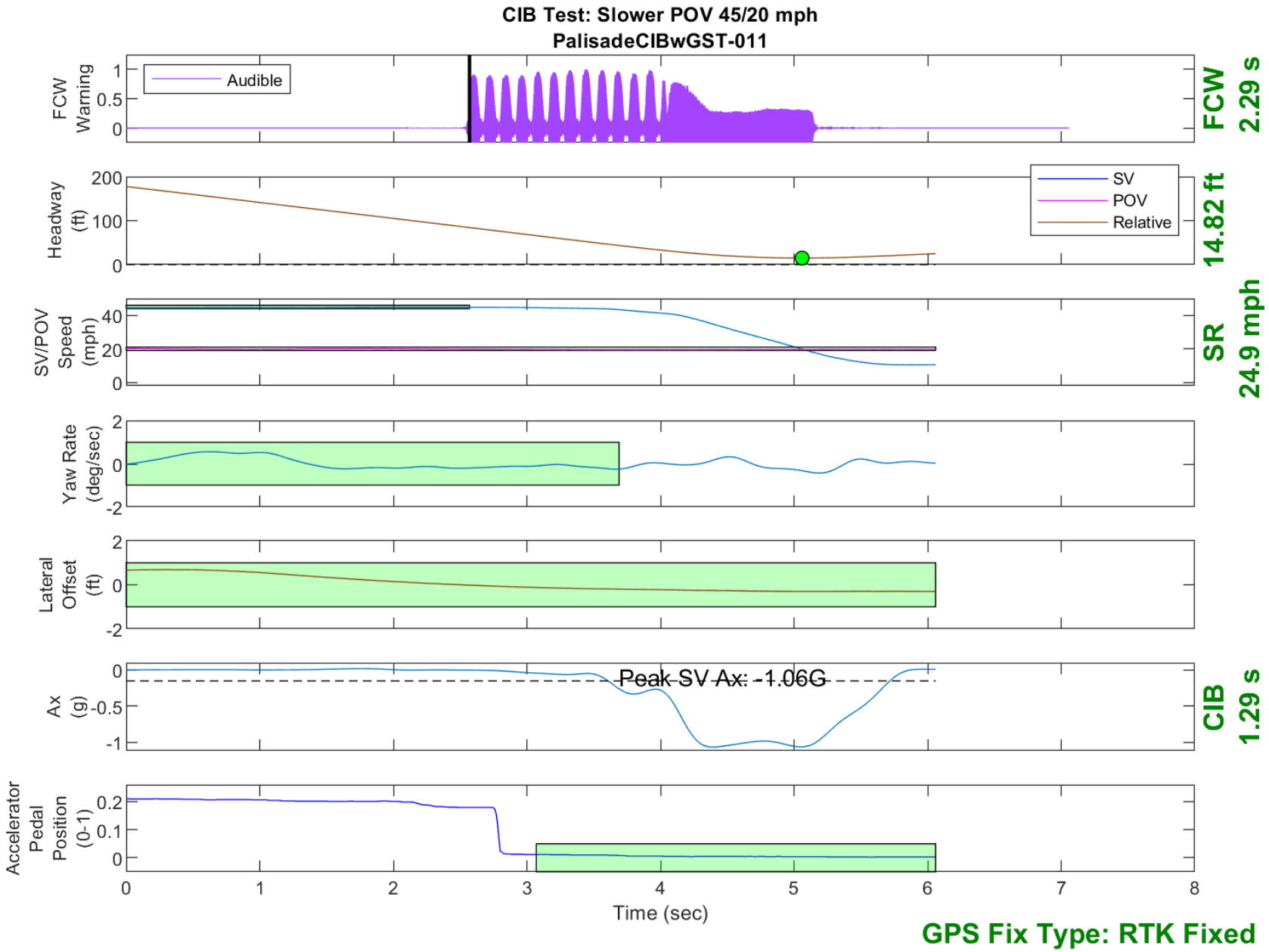


Figure D42. Time History for CIB Run 11, Slower POV, 45/20 mph

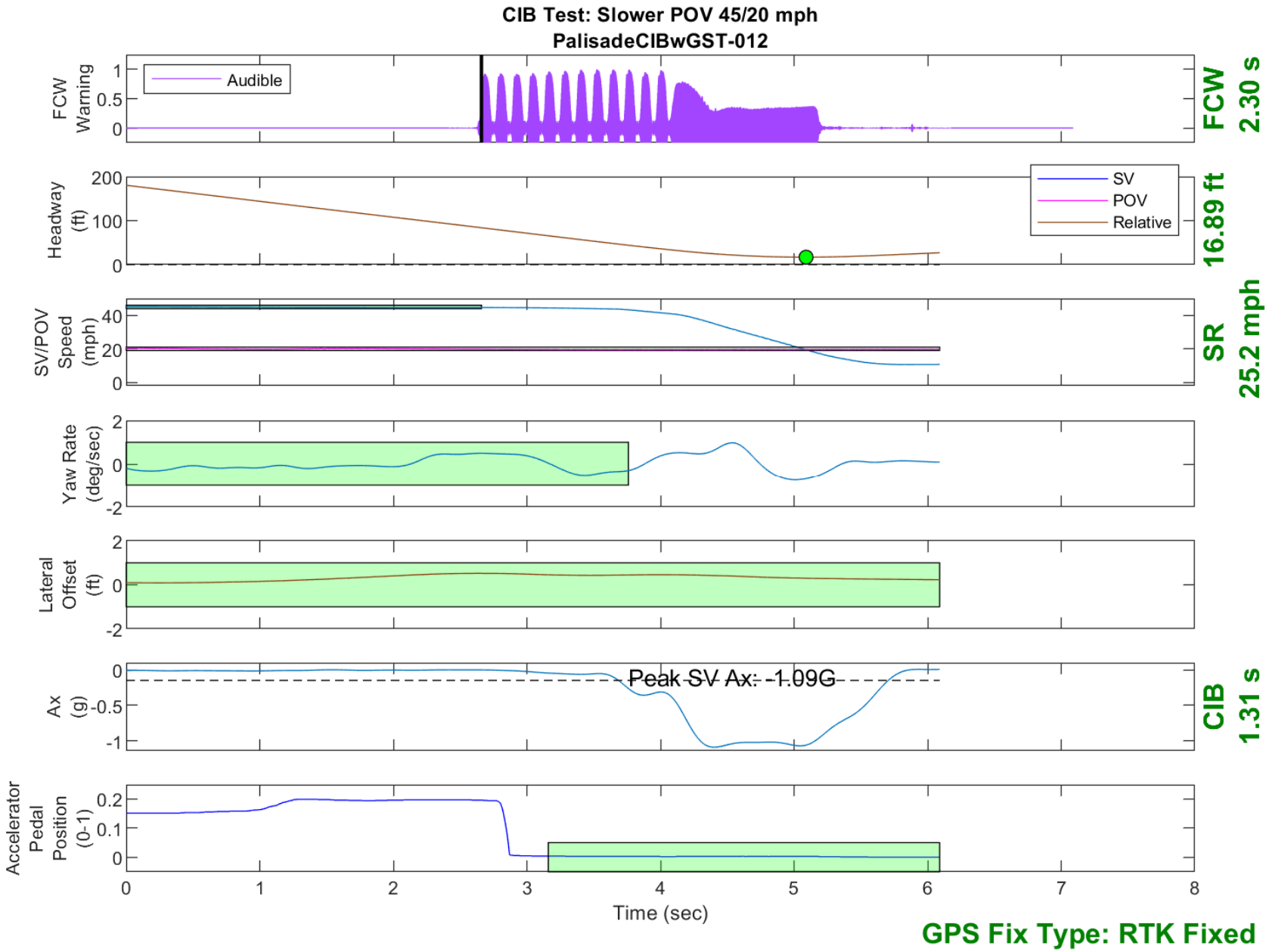


Figure D43. Time History for CIB Run 12, Slower POV, 45/20 mph

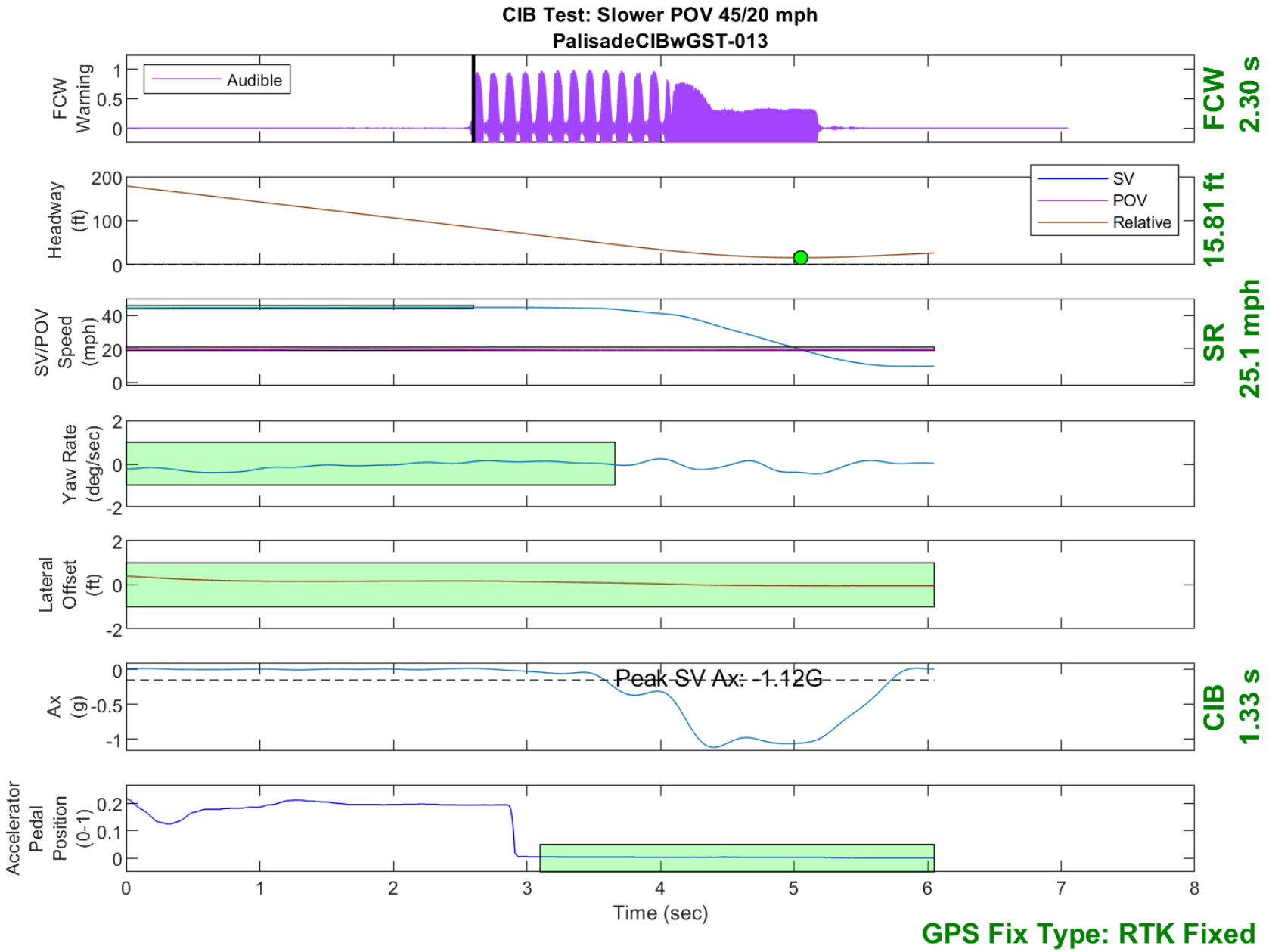


Figure D44. Time History for CIB Run 13, Slower POV, 45/20 mph

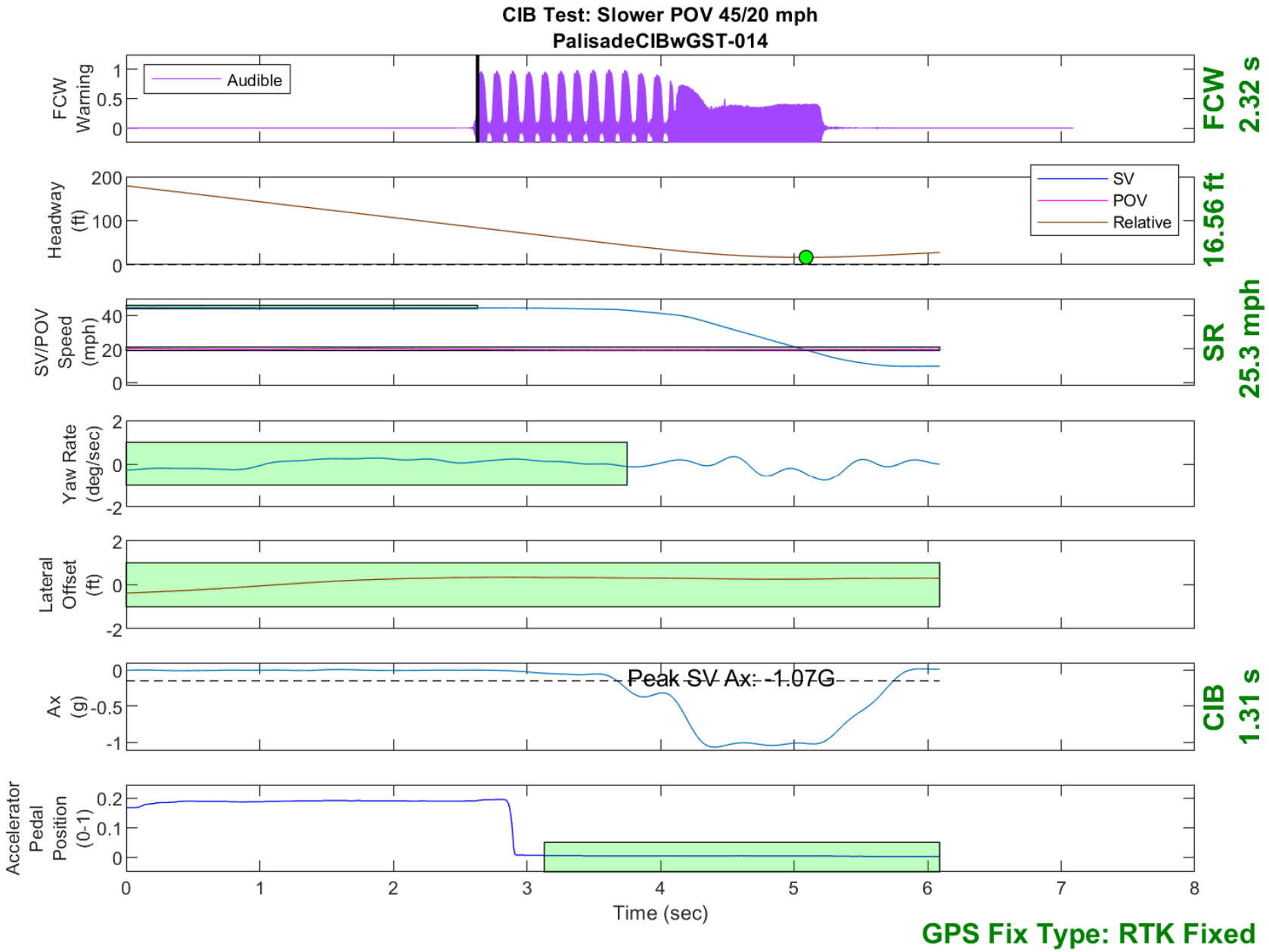


Figure D45. Time History for CIB Run 14, Slower POV, 45/20 mph

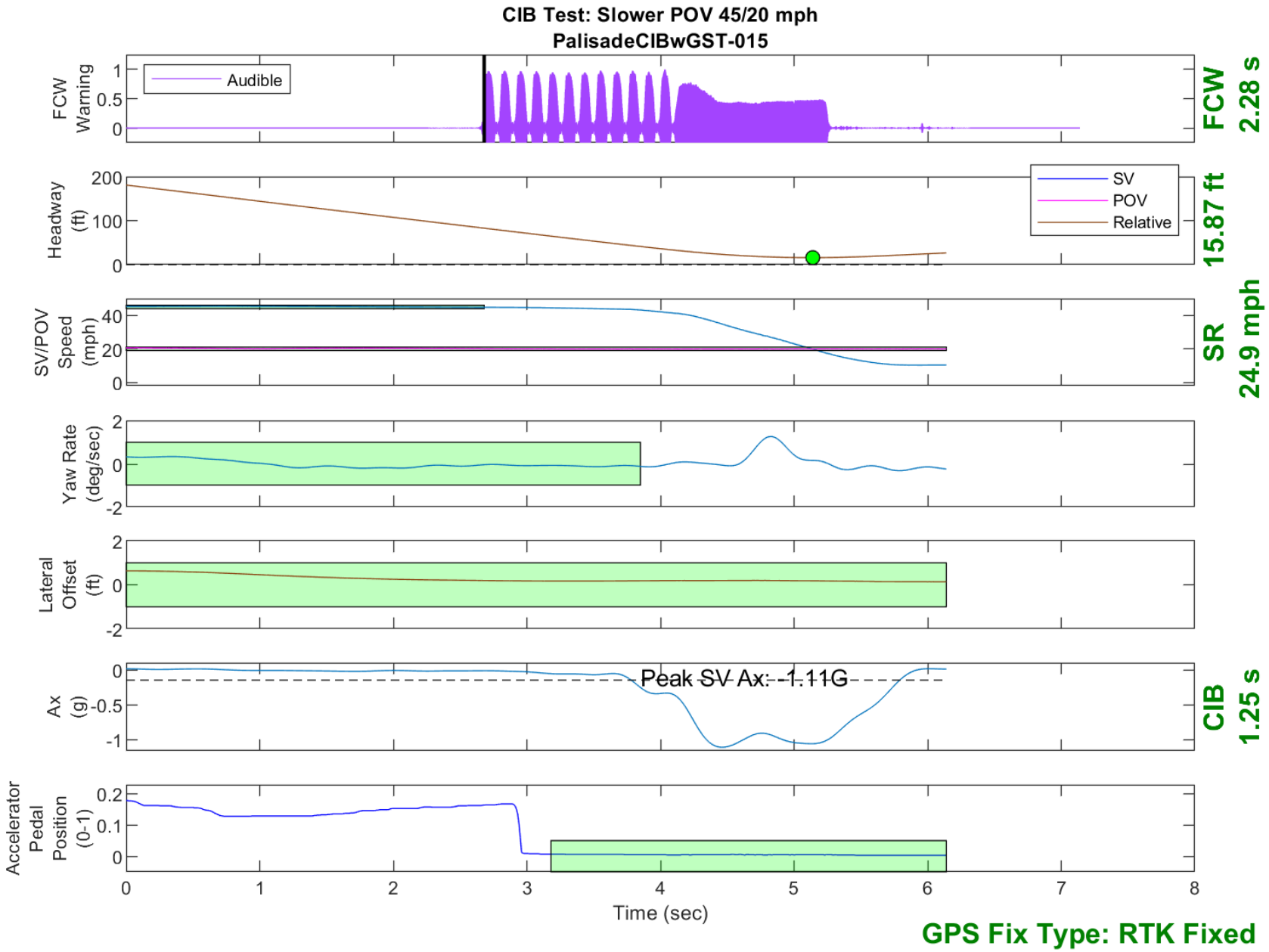


Figure D46. Time History for CIB Run 15, Slower POV, 45/20 mph

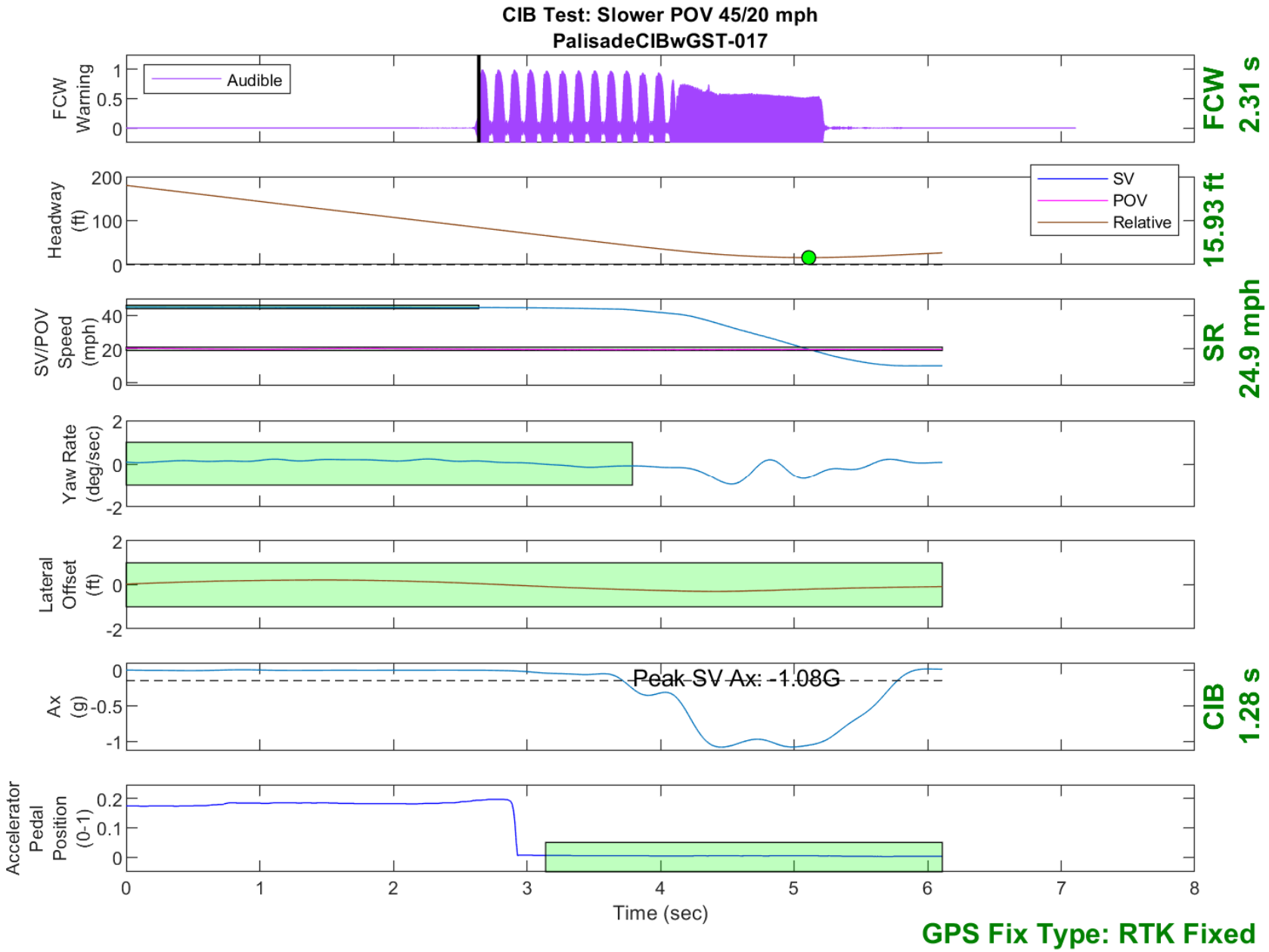


Figure D47. Time History for CIB Run 17, Slower POV, 45/20 mph

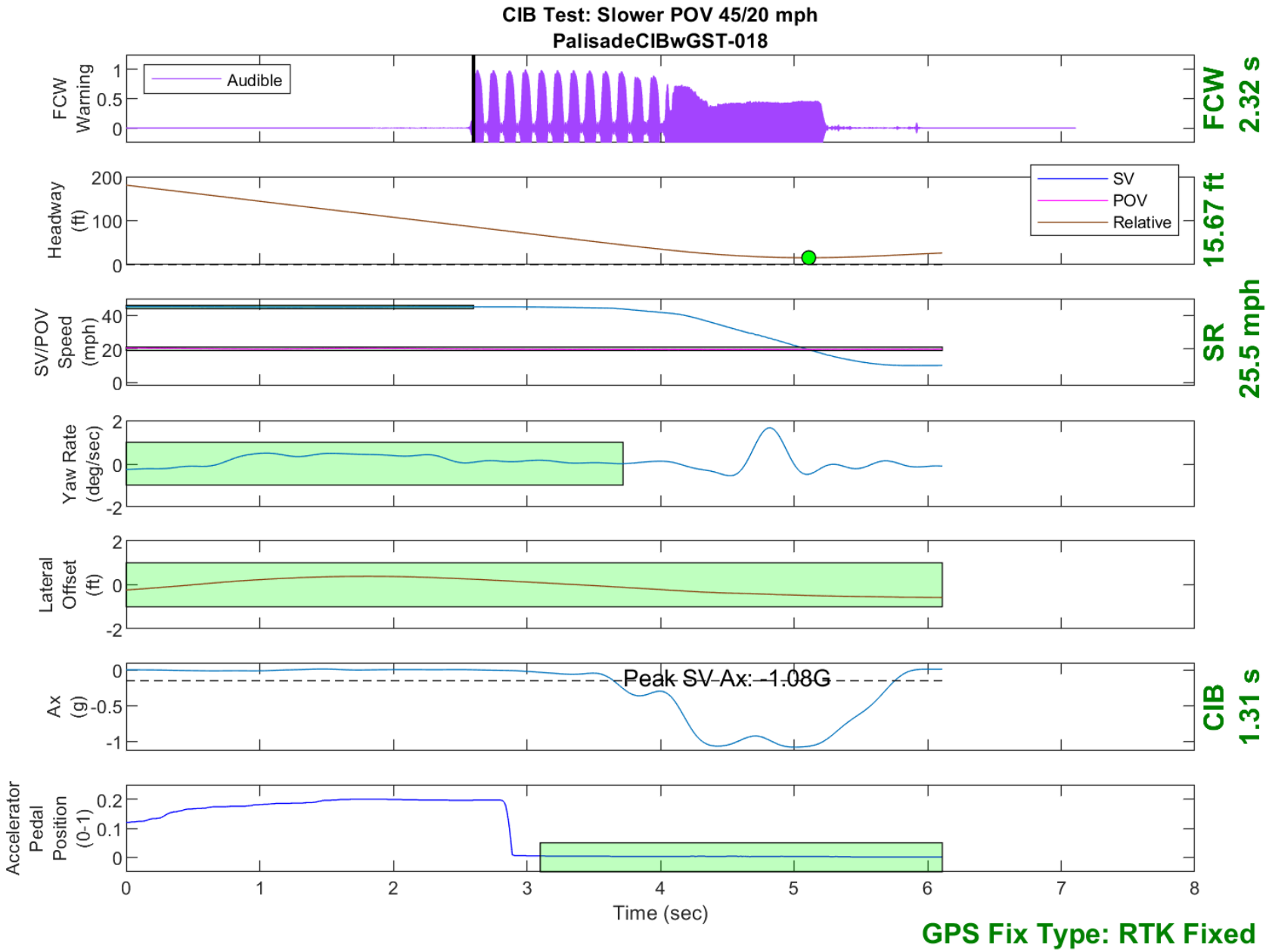


Figure D48. Time History for CIB Run 18, Slower POV, 45/20 mph

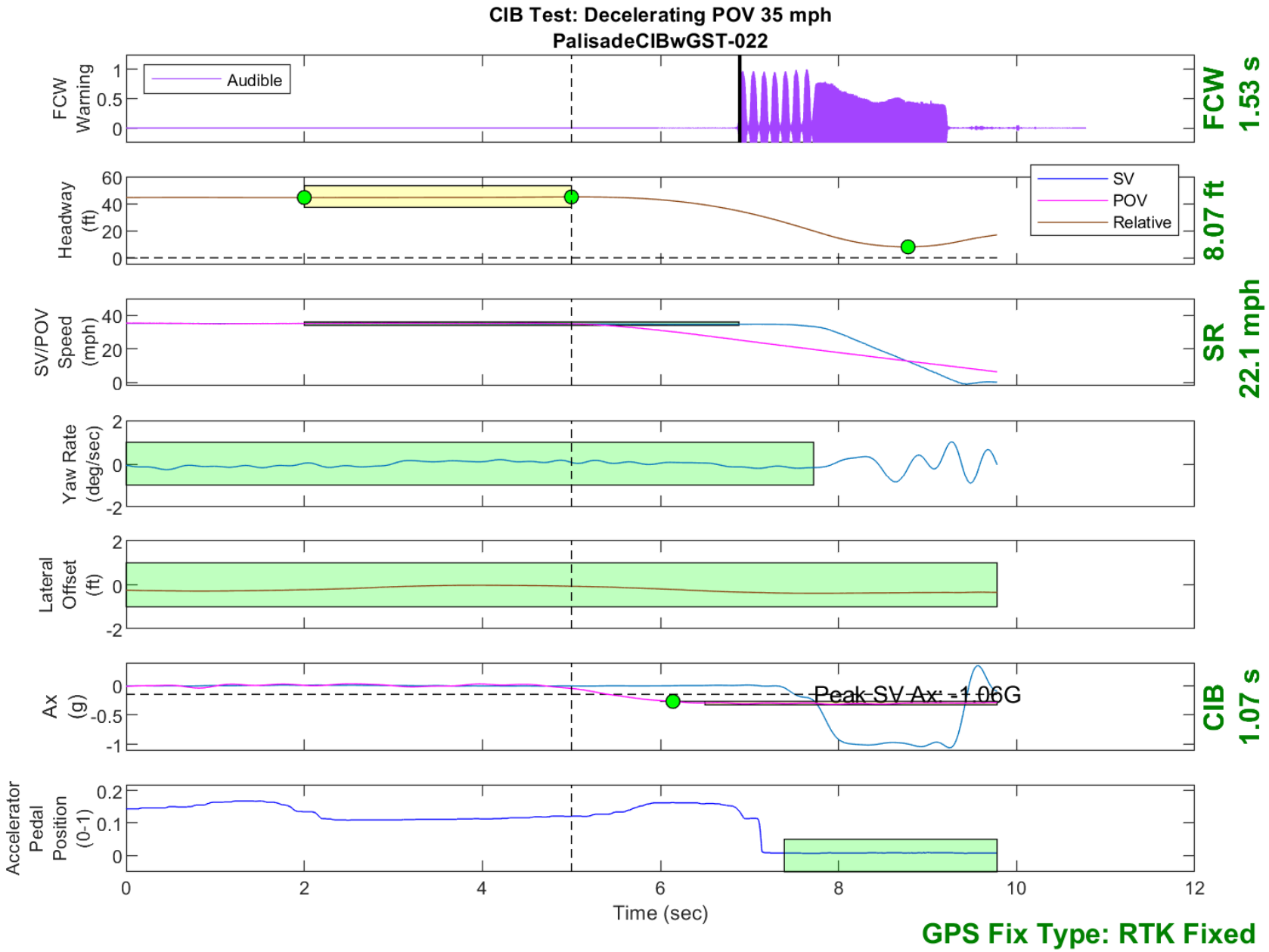


Figure D49. Time History for CIB Run 22, Decelerating POV, 35 mph 0.3g

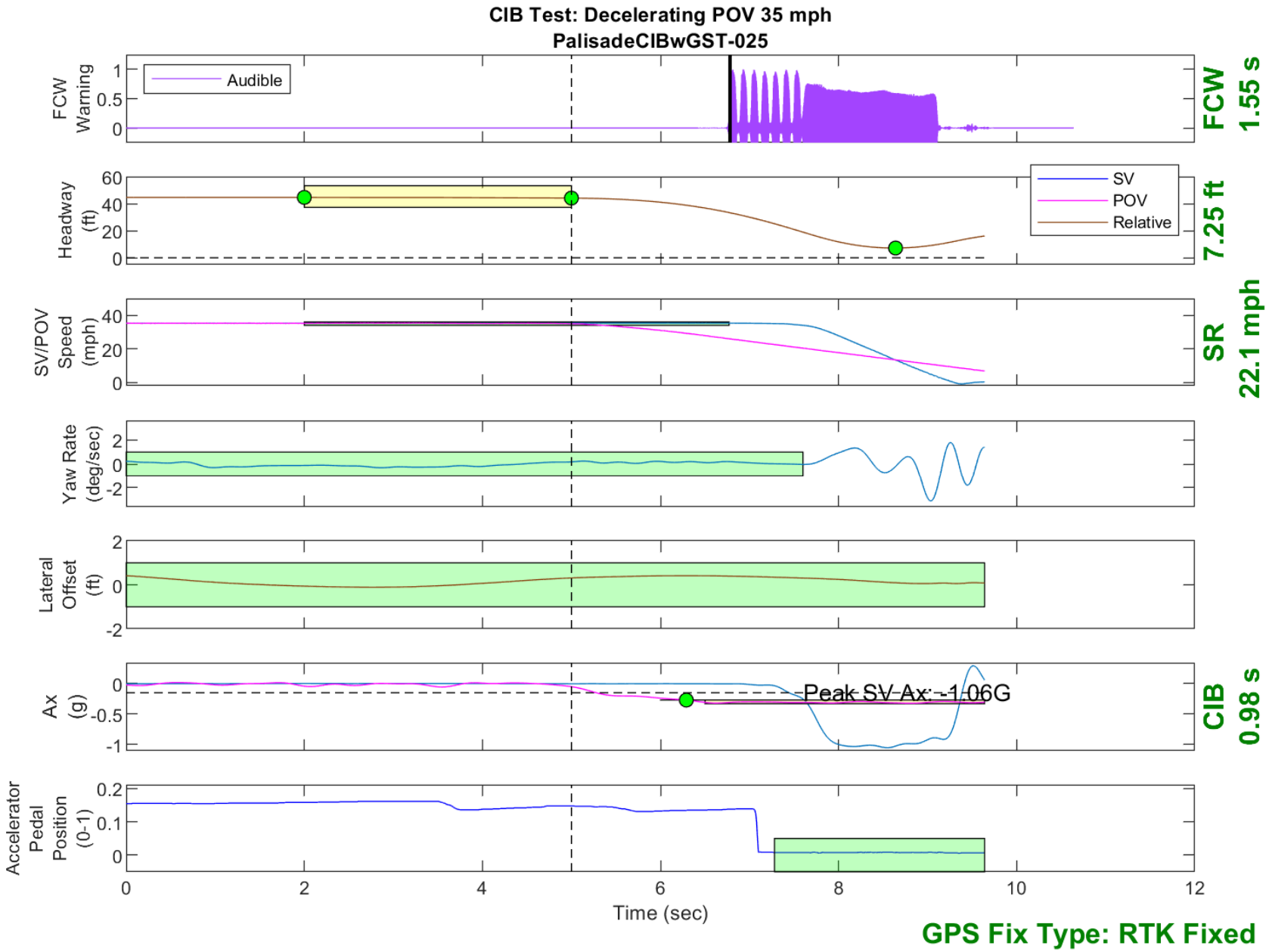


Figure D50. Time History for CIB Run 25, Decelerating POV, 35 mph 0.3g

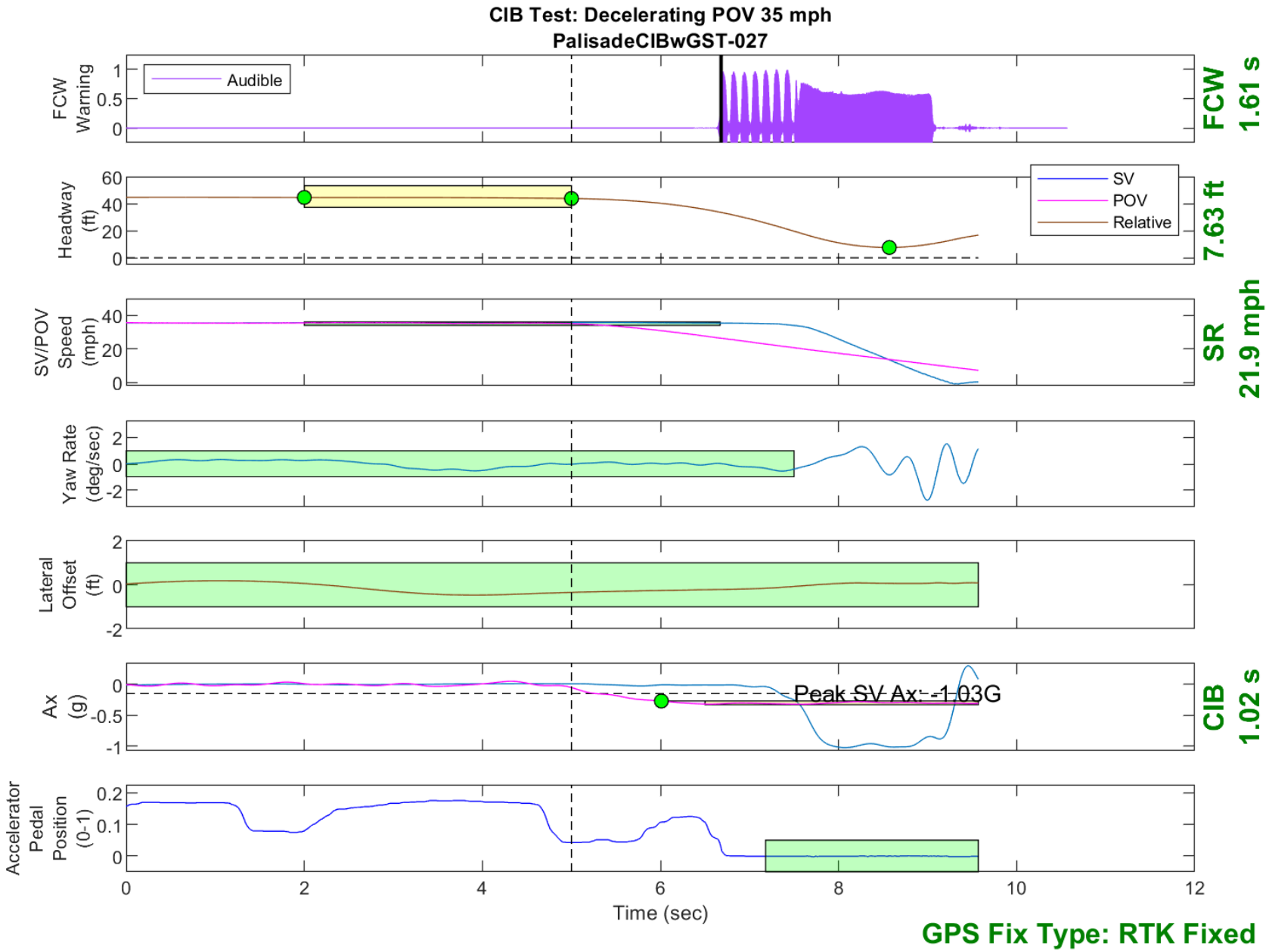


Figure D51. Time History for CIB Run 27, Decelerating POV, 35 mph 0.3g

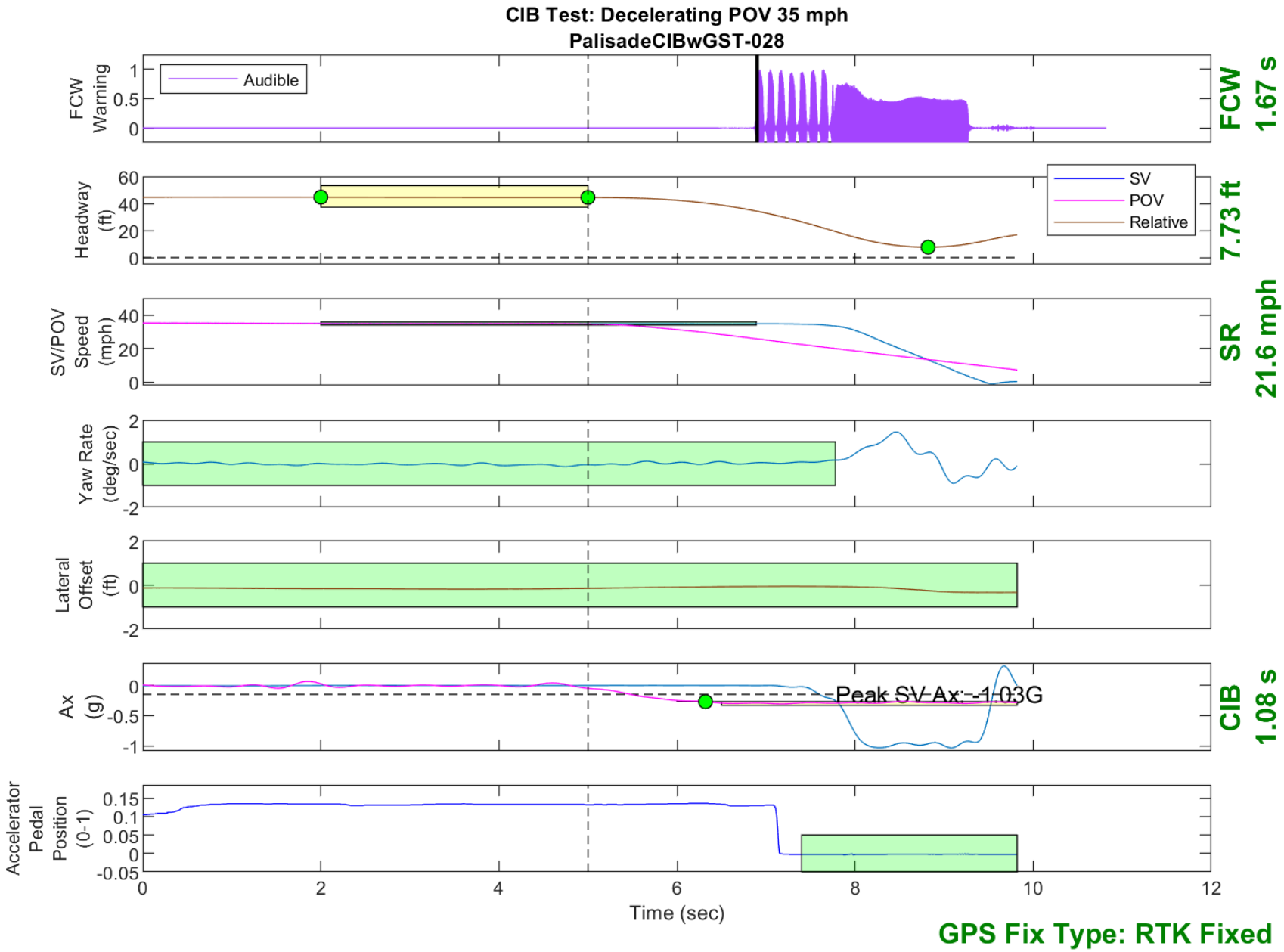


Figure D52. Time History for CIB Run 28, Decelerating POV, 35 mph 0.3g

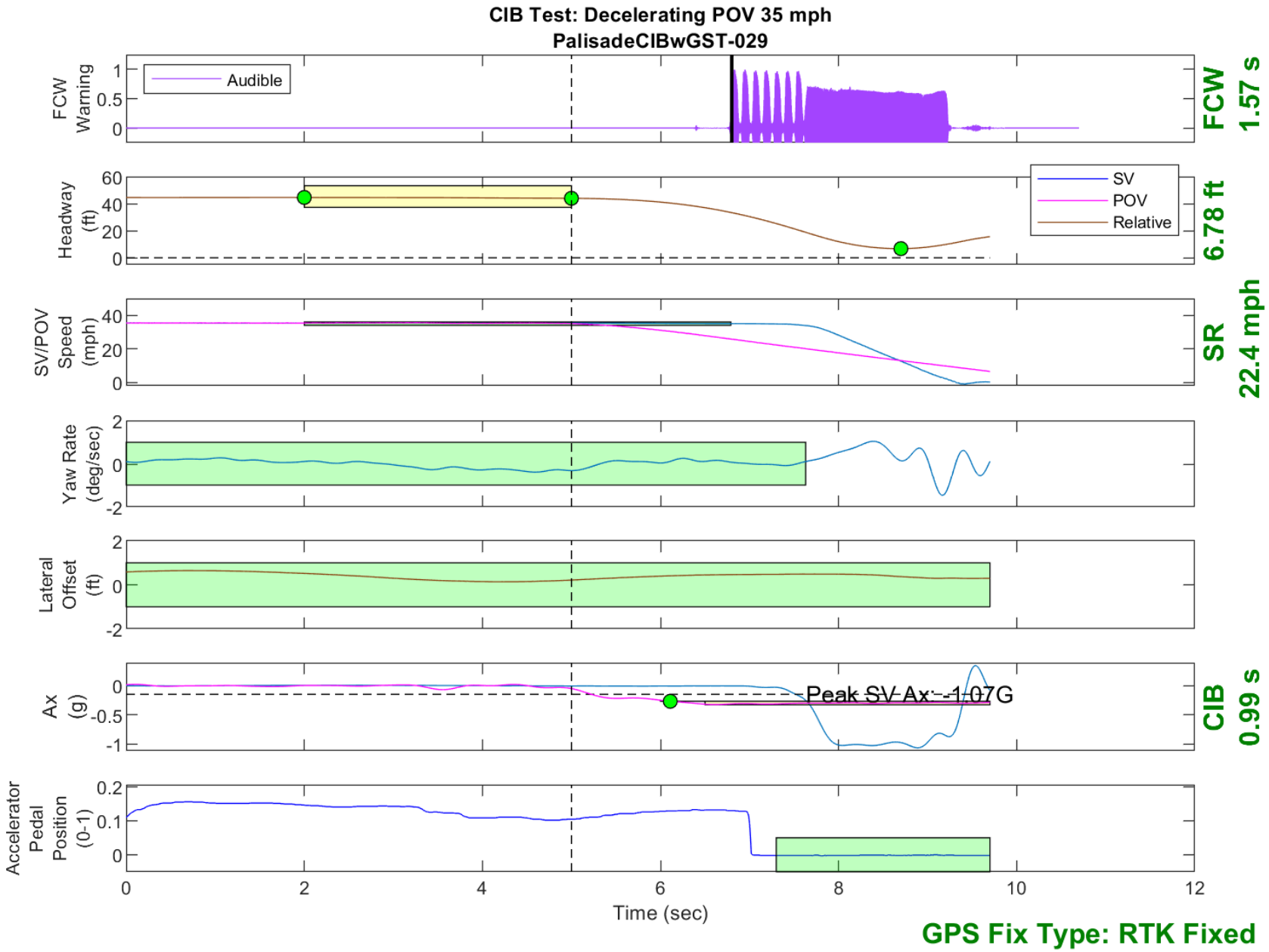


Figure D53. Time History for CIB Run 29, Decelerating POV, 35 mph 0.3g

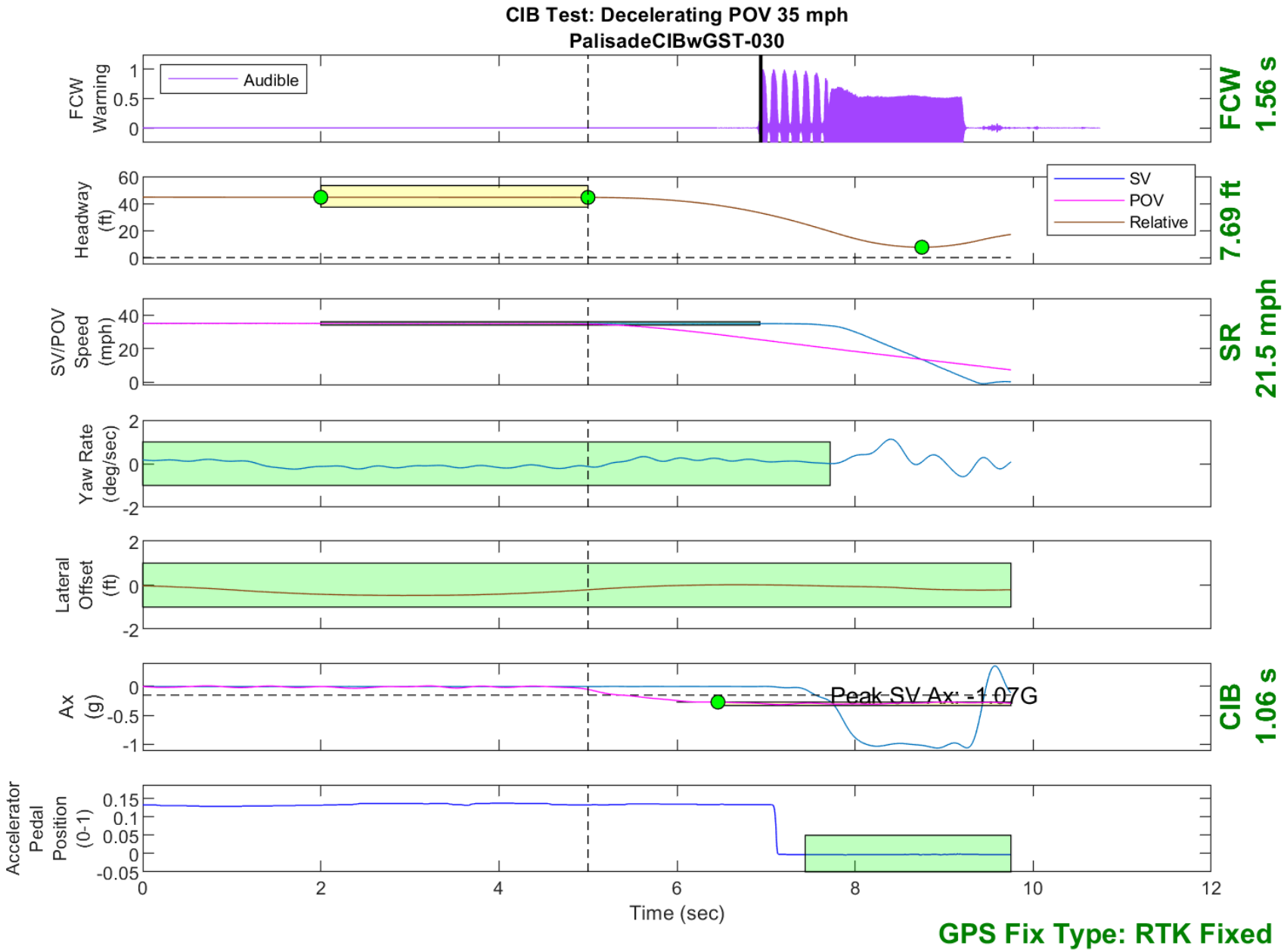


Figure D54. Time History for CIB Run 30, Decelerating POV, 35 mph 0.3g

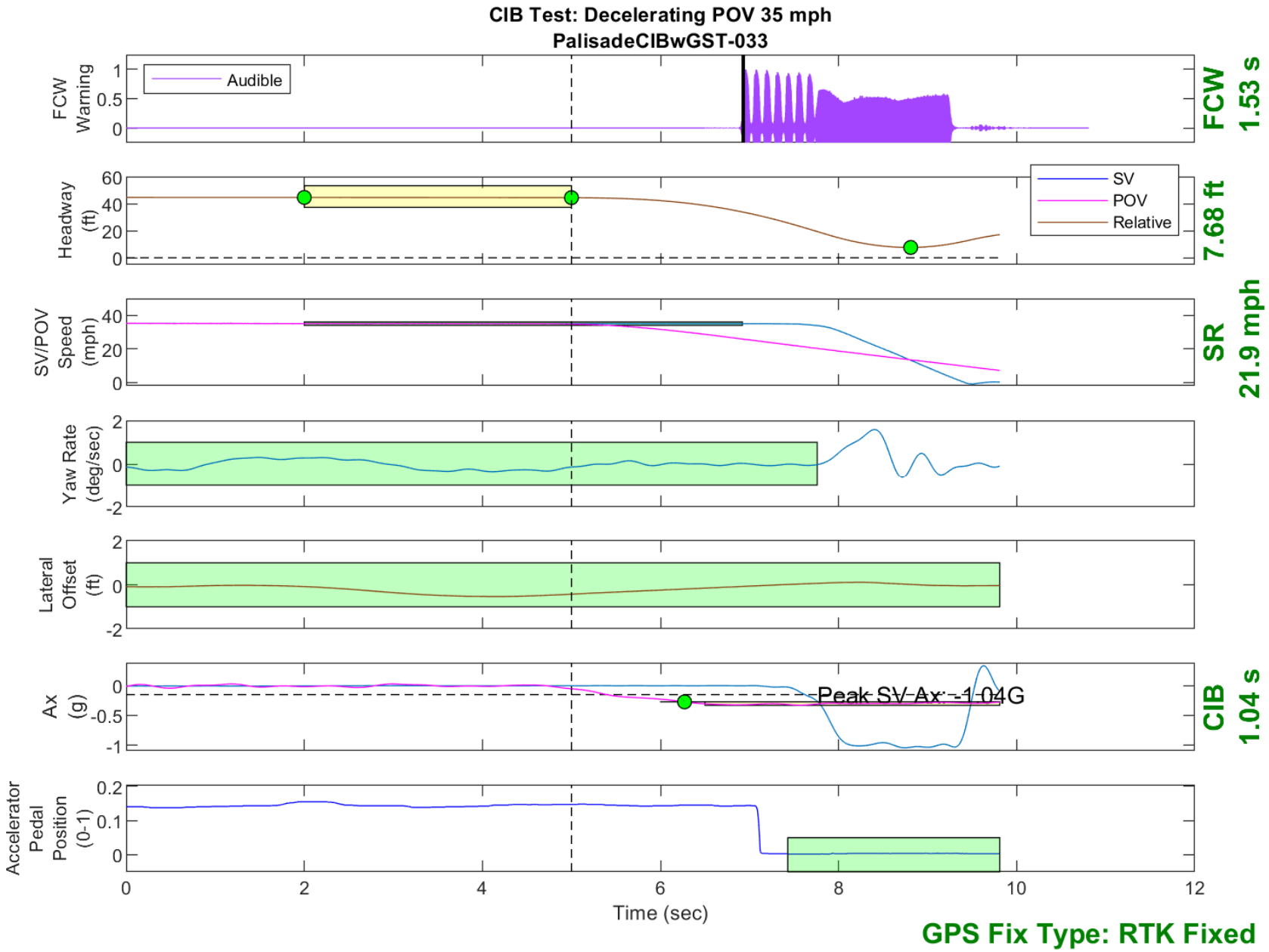


Figure D55. Time History for CIB Run 33, Decelerating POV, 35 mph 0.3g

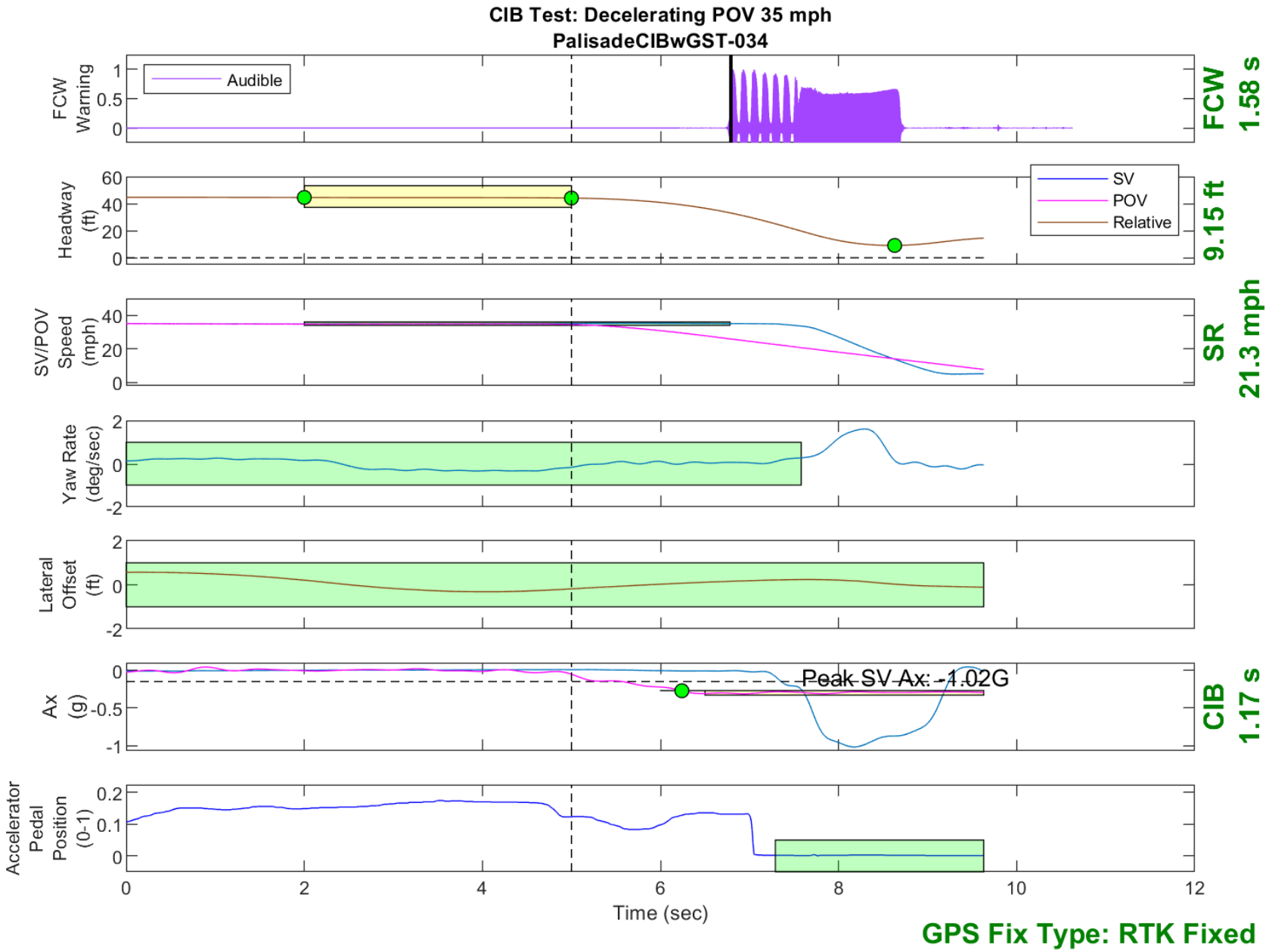


Figure D56. Time History for CIB Run 34, Decelerating POV, 35 mph 0.3g

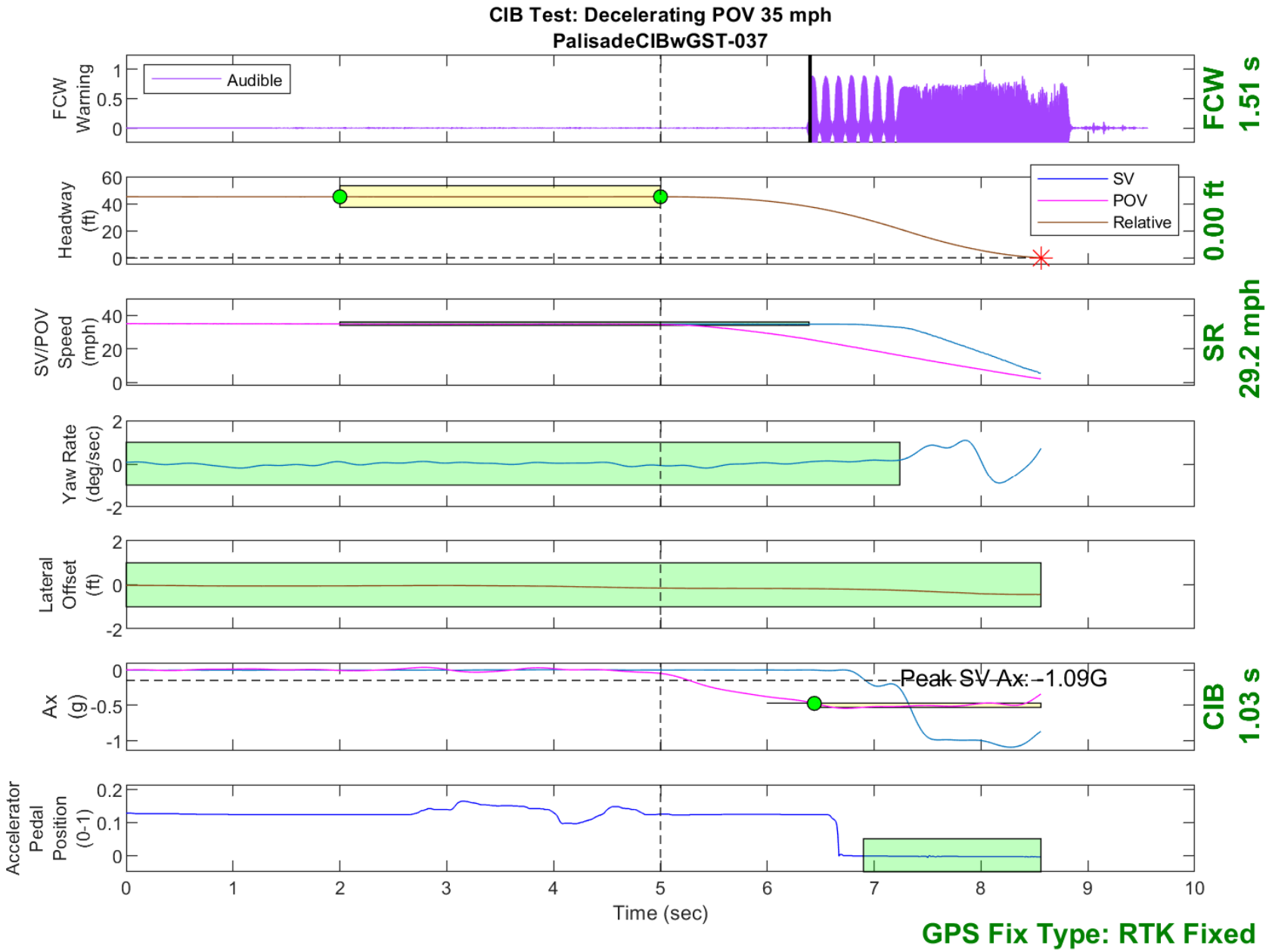


Figure D57. Time History for CIB Run 37, Decelerating POV, 35 mph 0.5g

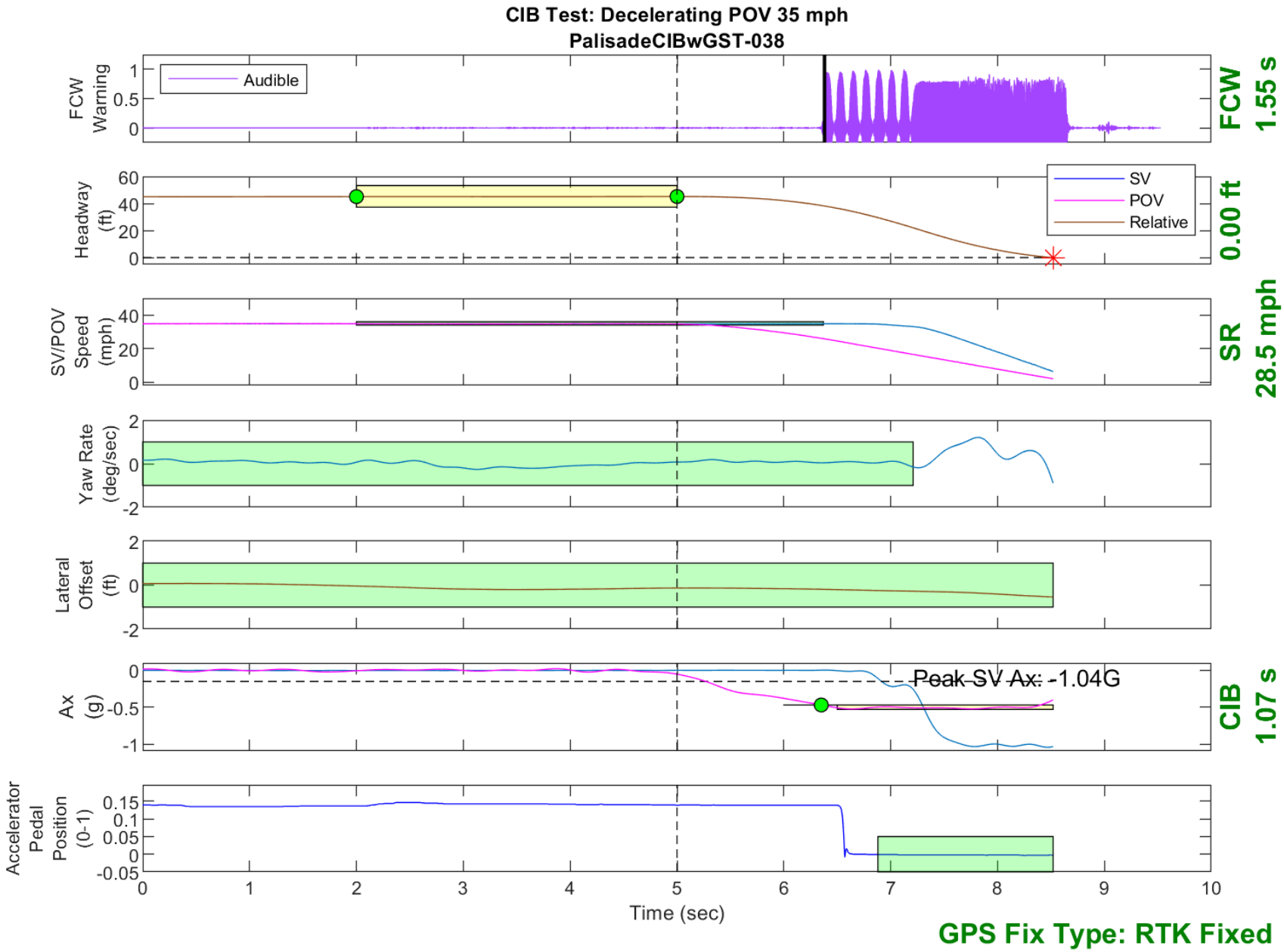


Figure D58. Time History for CIB Run 38, Decelerating POV, 35 mph 0.5g

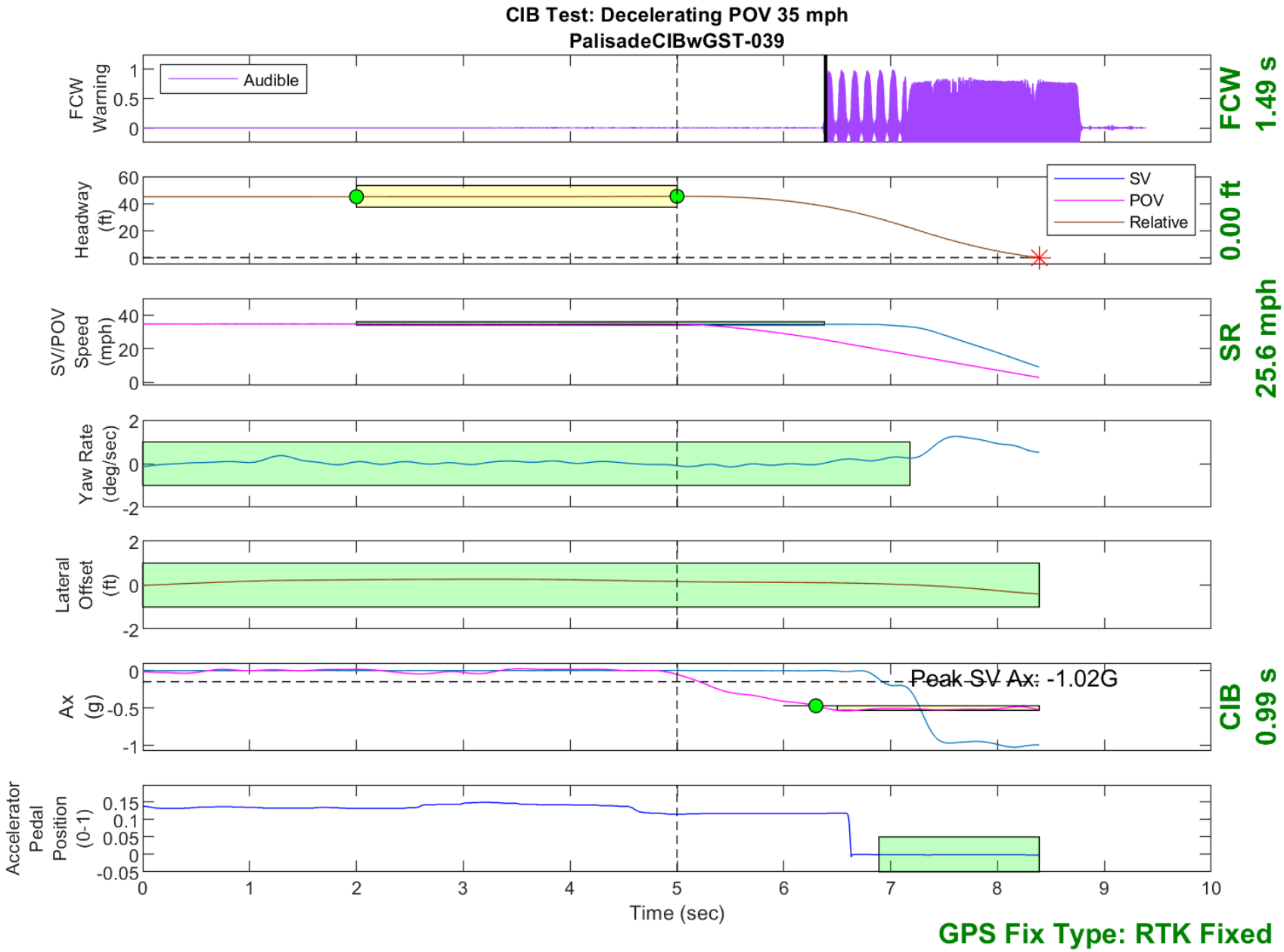


Figure D59. Time History for CIB Run 39, Decelerating POV, 35 mph 0.5g

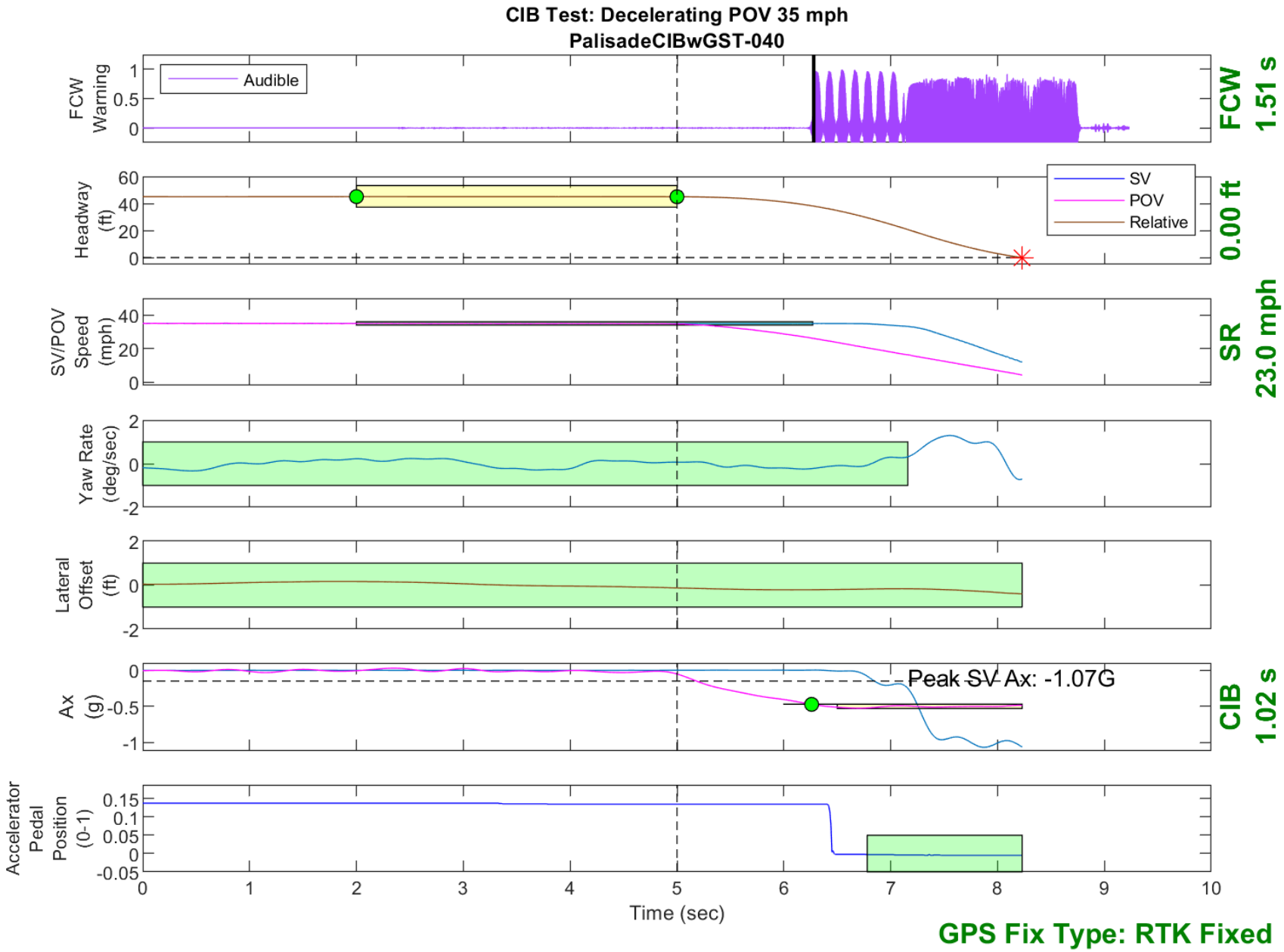


Figure D60. Time History for CIB Run 40, Decelerating POV, 35 mph 0.5g

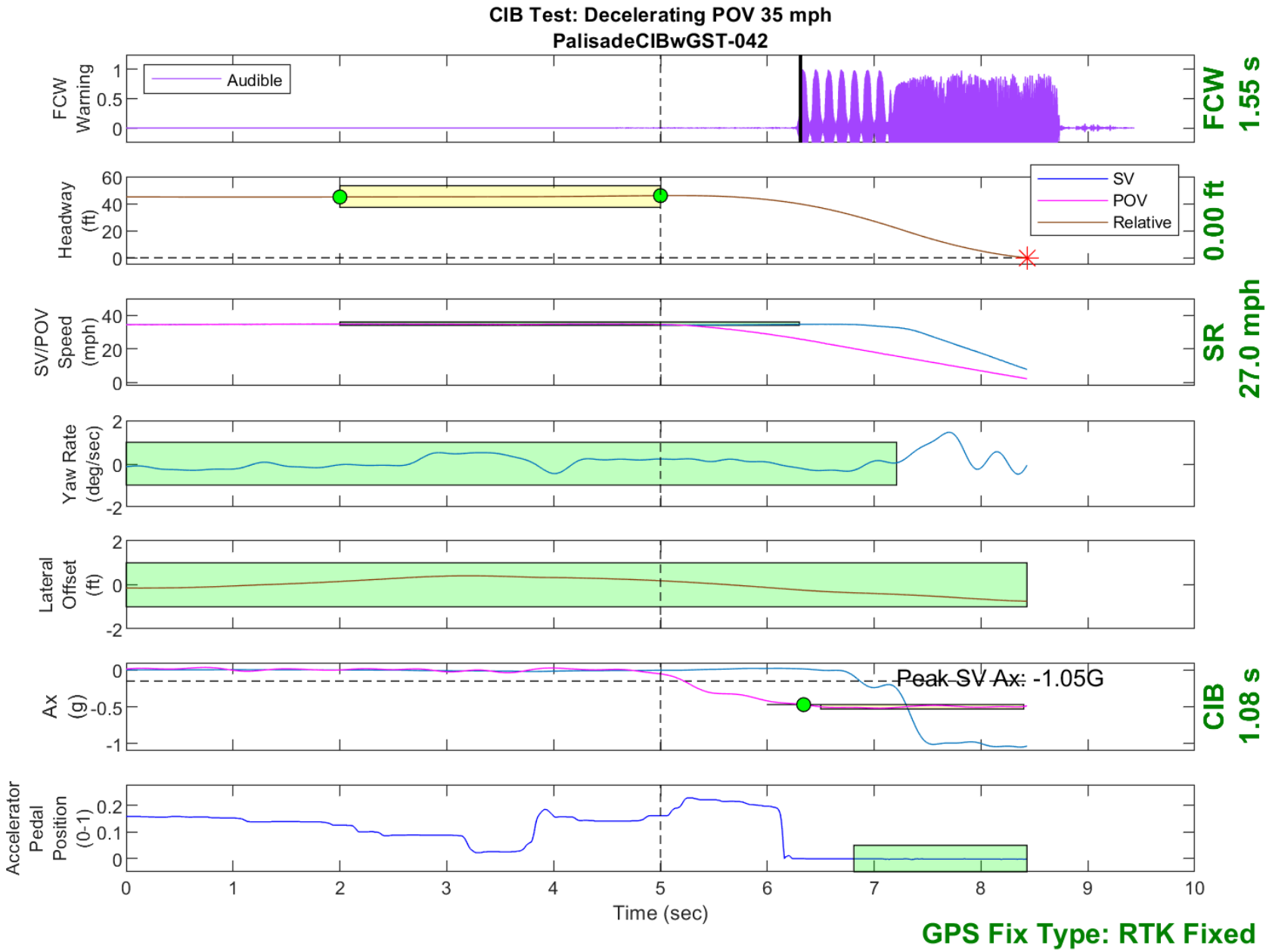


Figure D61. Time History for CIB Run 42, Decelerating POV, 35 mph 0.5g

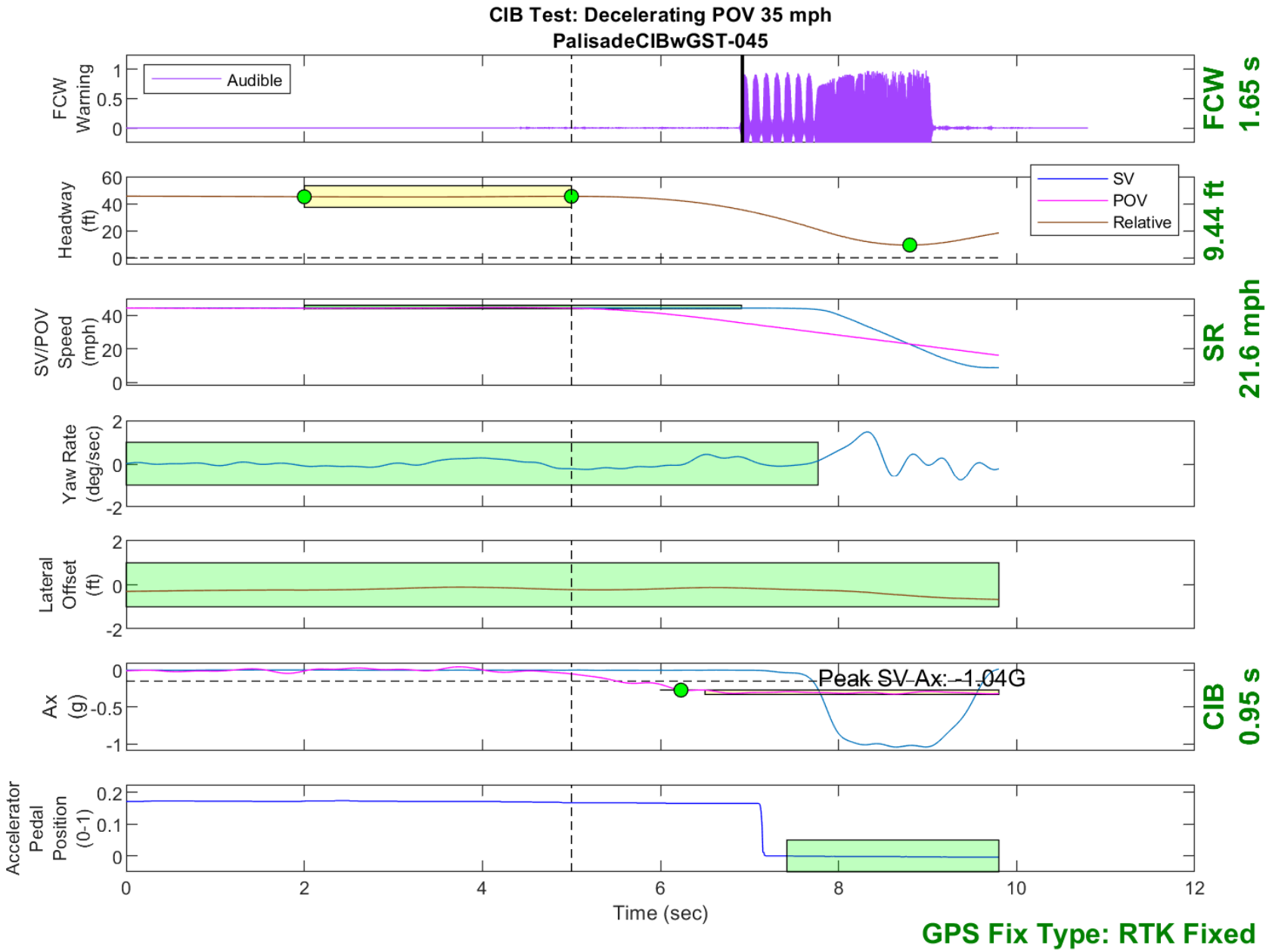


Figure D62. Time History for CIB Run 45, Decelerating POV, 45 mph 0.3g

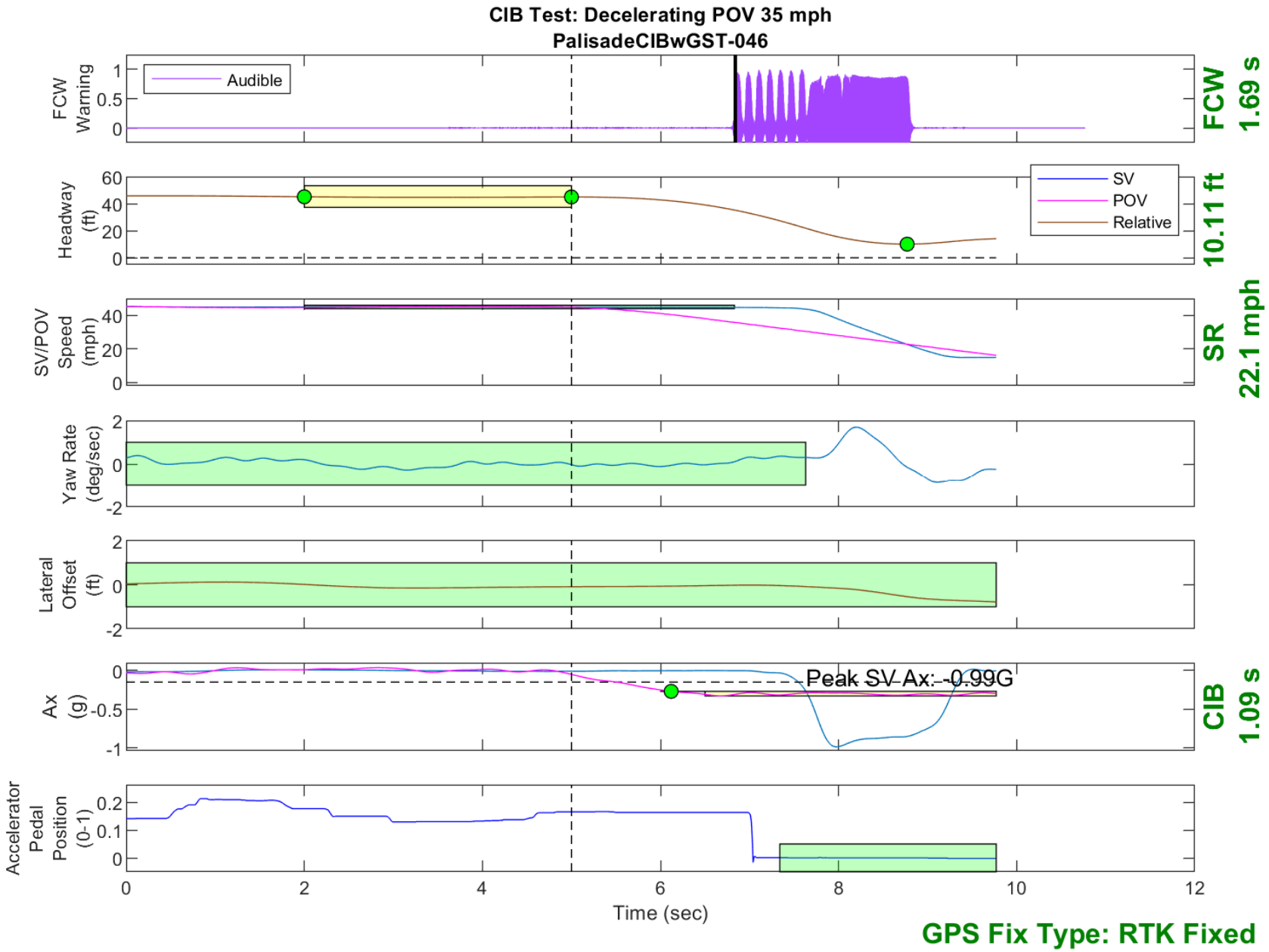


Figure D63. Time History for CIB Run 46, Decelerating POV, 45 mph 0.3g

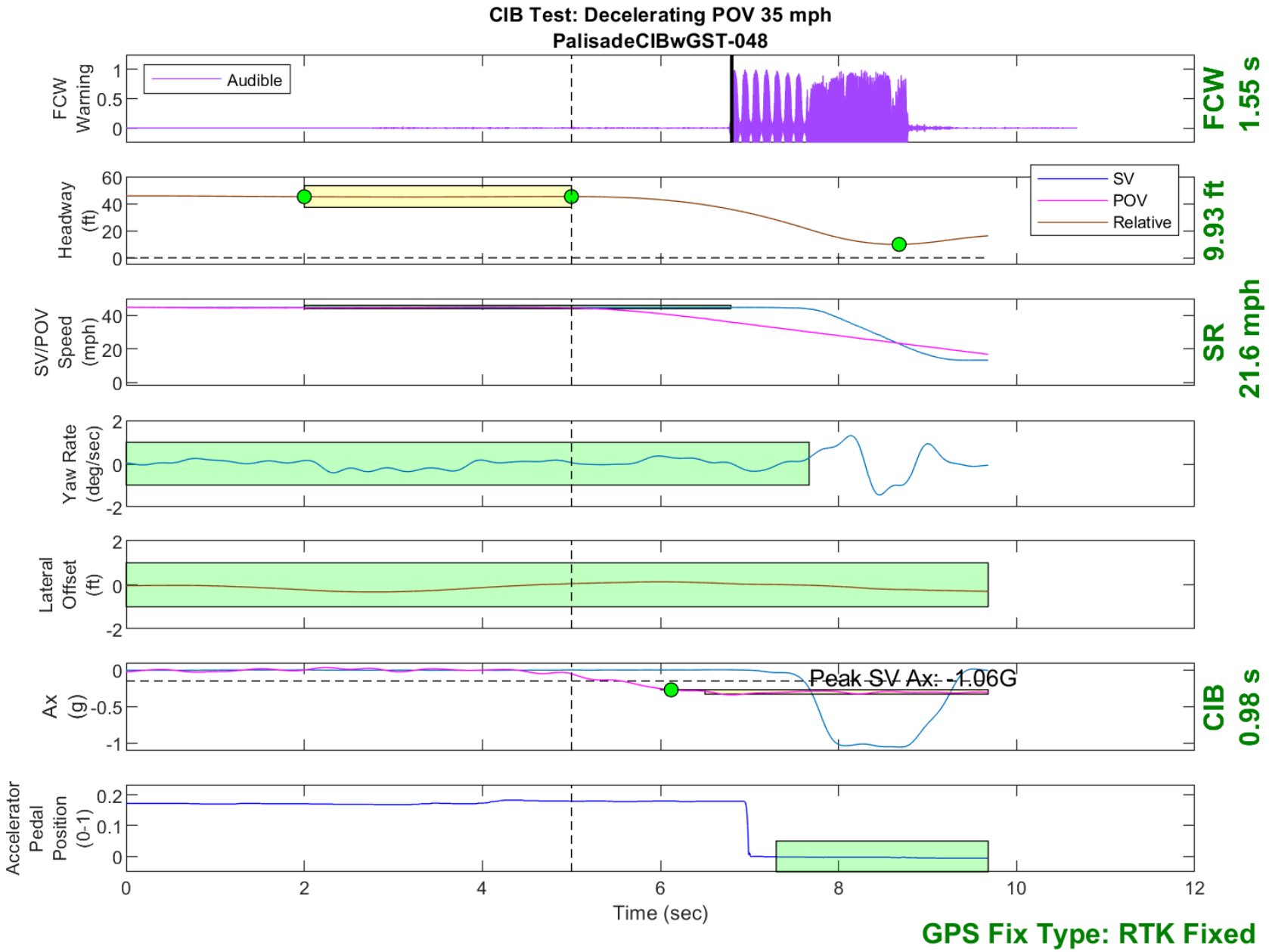


Figure D64. Time History for CIB Run 48, Decelerating POV, 45 mph 0.3g

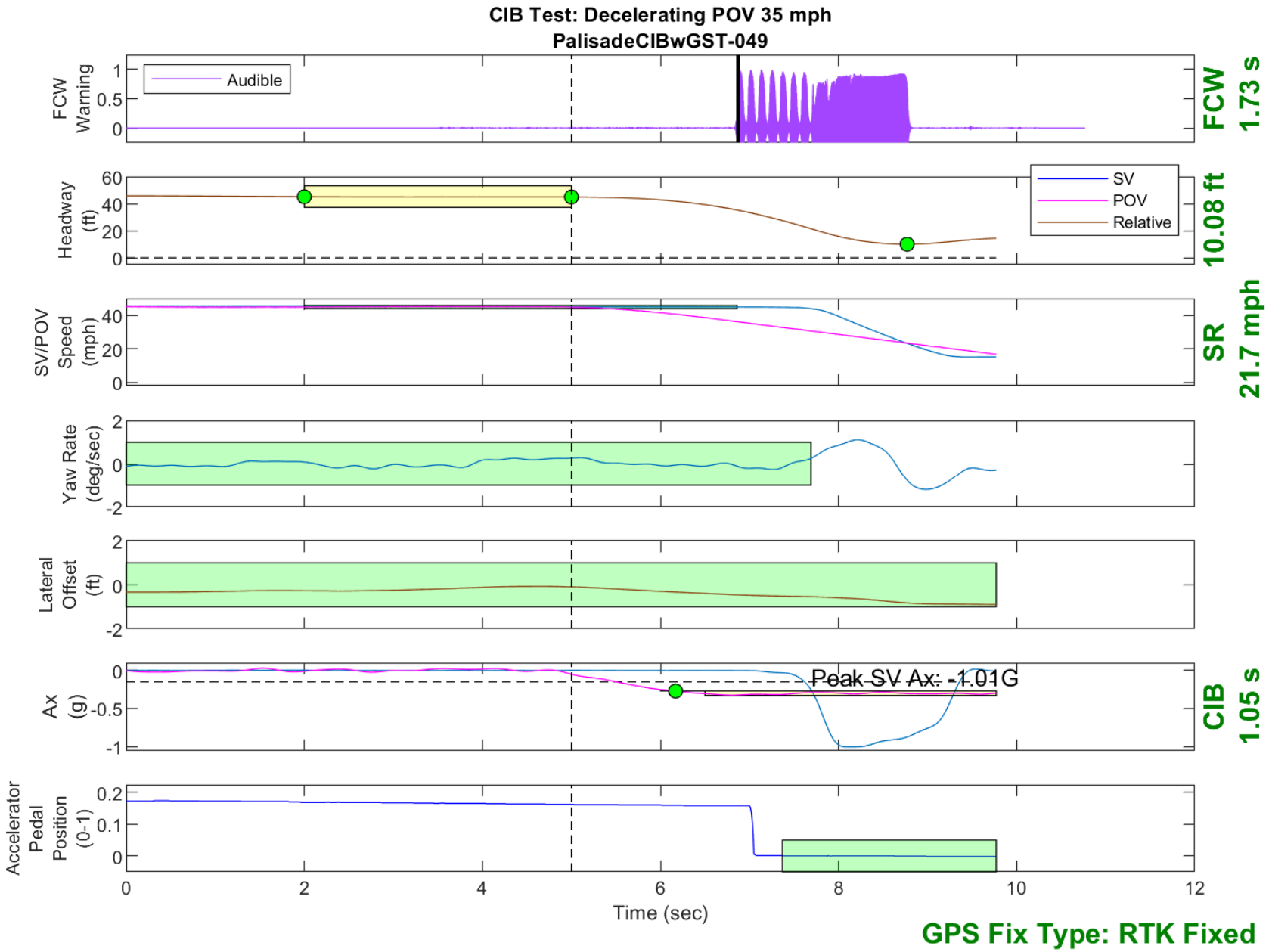


Figure D65. Time History for CIB Run 49, Decelerating POV, 45 mph 0.3g

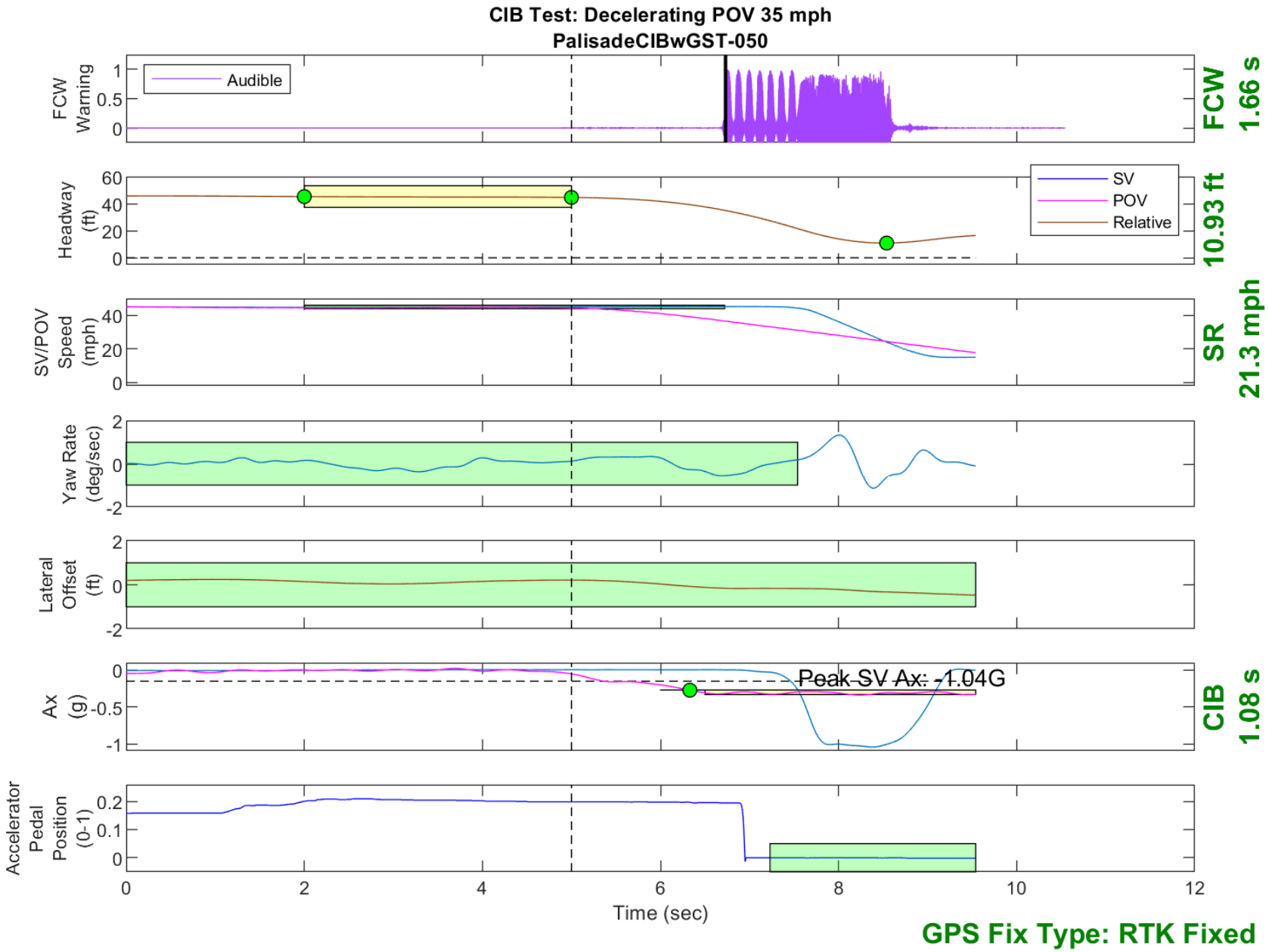


Figure D66. Time History for CIB Run 50, Decelerating POV, 45 mph 0.3g