CRASH IMMINENT BRAKING SYSTEM RESEARCH TEST
NCAP-DRI-CIBHS-20-07

2020 Toyota Corolla LE

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Draft Report

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16. Abstract These research tests were conducted on the subject 2020 Toyota Corolla LE 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 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 58 out of 58 valid test runs.			
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TABLE OF CONTENTS

Section I

INTRODUCTION

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

The method prescribed by the National Highway Traffic Safety Administration (NHTSA) in the New Car Assessment Program's (NCAP's) Crash Imminent Brake System Test Procedure (dated October 2015)[1] to evaluate CIB performance on the test track involves three rear-end type crash configurations and a "false positive" test. In the rear-end scenarios, a subject vehicle (SV) approaches a stopped, slower-moving, or decelerating principal other vehicle (POV) in the same lane of travel. For these tests, the POV is a strikeable object with the characteristics of a compact passenger car. The false positive scenarios are used to evaluate the propensity of a CIB system to inappropriately activate in a non-critical driving scenario that does not involve a forward vehicle or present a safety risk to the SV occupant(s).

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

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

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

[1] NHTSA-2015-0006-0025; Crash Imminent Brake System Performance Evaluation for the New Car Assessment Program, October 2015.
[2] A detailed description of the SSV system can be found in the NHTSA report: NHTSA'S STRIKEABLE SURROGATE VEHICLE PRELIMINARY DESIGN+OVERVIEW, May 2013.

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

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

Section II

DATA SHEETS

CRASH IMMINENT BRAKING

DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2020 Toyota Corolla LE

VIN: *JTDEPRAE1LJ11xxxx* Test Date: *4/24/2020*

Crash Imminent Braking System setting: *Far (Early)*

		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:	*4*	*0*	*4*
Test 2 –	**Subject Vehicle Encounters Slower Principal Other Vehicle**			
	SV 25 mph POV 10 mph:	*7*	*0*	*7*
	SV 45 mph POV 20 mph:	*7*	*0*	*7*
Test 3 –	**Subject Vehicle Encounters Decelerating Principal Other Vehicle**			
	SV 35 mph POV 35 mph, 0.3 g decel:	*7*	*0*	*7*
	SV 35 mph POV 35 mph, 0.5 g decel:	*5*	*0*	*5*
	SV 45 mph POV 45 mph, 0.3 g decel:	*5*	*0*	*5*
	Overall:	***57***	***0***	***57***

Notes:
The system met the acceptability criteria for 58 out of 58 valid test runs.

[3] The acceptability criteria listed herein are used only as a guide to gauge vehicle performance and are identical to the Pass/Fail criteria given in the New Car Assessment Program's most current Test Procedure in docket NHTSA-2015-0006-0025; CRASH IMMINENT BRAKE SYSTEM PERFORMANCE EVALUATION FOR THE NEW CAR ASSESSMENT PROGRAM, October 2015.

CRASH IMMINENT BRAKING

DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2020 Toyota Corolla LE

TEST VEHICLE INFORMATION

VIN: *JTDEPRAE1LJ11xxxx*

Body Style: *Sedan* Color: *Black Sand Pearl*

Date Received: *4/13/2020* Odometer Reading: *22 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Toyota Motor Corporation*

Date of manufacture: *02/20*

Vehicle Type: *Passenger Car*

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: *205/55 R16*

Rear: *205/55 R16*

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

Rear: *230 kPa (33 psi)*

TIRES

Tire manufacturer and model: *Dunlop Enasave 01A/S*

Front tire designation: *205/55 R16 91H*

Rear tire designation: *205/55 R16 91H*

Front tire DOT prefix: *EU8K 3MMR*

Rear tire DOT prefix: *EU8K 3MMR*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Toyota Corolla LE

GENERAL INFORMATION

Test date: *4/24/2020*

AMBIENT CONDITIONS

Air temperature: *28.3 C (83 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: *230 kPa (33 psi)*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2020 Toyota Corolla LE

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*447.7 kg (987 lb)*	Right Front:	*420.9 kg (928 lb)*
Left Rear:	*299.8 kg (661 lb)*	Right Rear:	*294.4 kg (649 lb)*
		Total:	*1462.8 kg (3225 lb)*

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

(Page 1 of 3)

2020 Toyota Corolla LE

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

Pre-Collision System (PCS) as part of Toyota Safety Sense 2.0 (TSS 2.0)

Type and location of sensors the system uses:

Millimeter wave Radar located behind the front emblem (or grille) and mono camera located behind the windshield near the rearview mirror.

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

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

10 km/h (7 mph) (Per manufacturer supplied information)

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

180 km/h (110 mph) (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure? **X** Yes

____ No

If yes, please provide a full description.

Sensor calibration is necessary which can be done by the following procedure:

- *Driving along a marked lane for more than 1 km driving at a speed at greater than 35 mph.*
- *1km distance driving is not necessarily continuous driving, but split driving in total of 1km distance is OK.*
- *Lane markings should be present on both sides of the vehicle; it does not matter whether it is a solid line or dotted line.*
- *It is ideal to put several vehicles (2-3 vehicles) beside the driving lane to be detected by camera.*
- *No sensor calibration completed indication will be displayed to the driver.*
- *Please make sure engine is not shut off after sensor calibration is completed. If an ignition cycle occurs again, sensor calibration needs*

to be done again.

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

(Page 2 of 4)

2020 Toyota Corolla LE

Will the system deactivate due to repeated CIB activations, impacts or near-misses? ___ Yes / **X** No

If yes, please provide a full description.

No deactivation or reduction of CIB will happen after repeated CIB activation.

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

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

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

When the system determines that the possibility of a frontal collision is high, a buzzer will sound and a warning message will be displayed on the multi-information display. The visual alert is presented in the display area adjacent to the speedometer and displays BRAKE! In white on a red background.

The auditory alert is presented as a pulsed tone of 2389 Hz pulsed at approximately five times per second.

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.

Buttons on the left side of the steering wheel are used to interact with the system menus. The hierarchy is:

Settings

Vehicle

PCS (Pre-Collision System) - Select "On" or "Off"

See Appendix A, Figures A12 and A13, also Appendix B, Pages B-20 and B-21.

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.

Buttons on the left side of the steering wheel are used to interact with the system menus. The hierarchy is:

Settings

Vehicle

PCS (Pre-Collision System)

Adjust alert timing - Select "Far", "Middle" or "Near"

("Early", "Middle", or "Late)

See Appendix A, Figures A15 and A16, also Appendix B, Pages B-20 and B-21.

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.

Limitations of the system are described in the Owner's Manual, Pages 188 and 189 shown in Appendix B, Pages B-13 and B-14.

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.

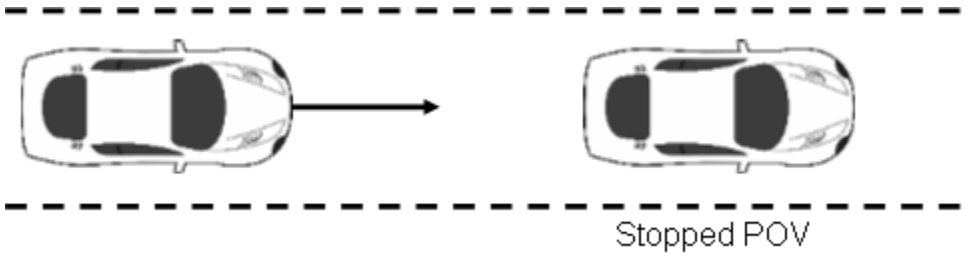


Figure 1. Depiction of Test 1

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.

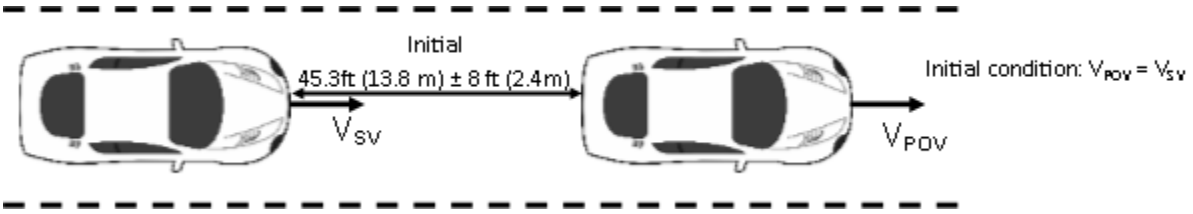


Figure 2. Depiction of Test 2

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.

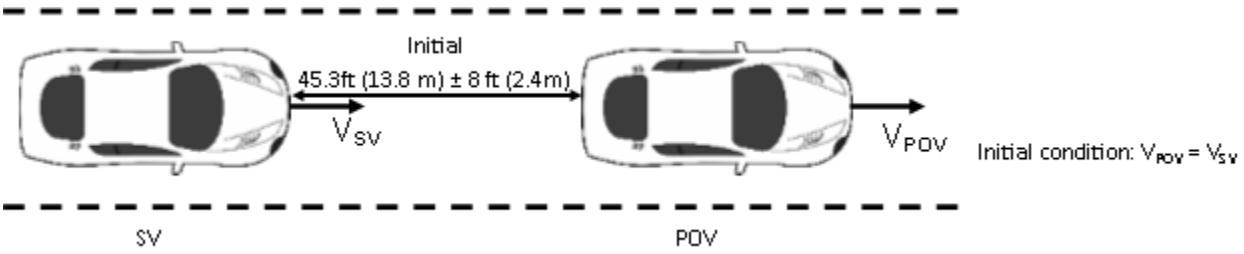


Figure 3. Depiction of Test 3 with POV Decelerating with V_0 =35 mph (56.3 km/h)

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 GVT secured to a low profile robotic vehicle (LPRV).

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

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

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

The key requirements of the POV element are to:

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

The key requirements of the POV delivery system are to:

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

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

D. Automatic Braking System

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

In some cases, the SV is also equipped with an automatic braking system (E-brake) for the purpose of slowing the SV before impact with the SSV in cases where the subject vehicle is likely to fail a test. The system fires when TTC is below 0.7 sec. It is typically enabled when an SV has already impacted the SSV one or two times in prior runs of the same test.

E. Instrumentation

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

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

Table 6. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	< 1% error between 20 and	Omega DPG8001	17042707002	By: DRI Date: 7/3/2019 Due: 7/3/2020
Platform Scales	Vehicle Total, Wheel, and Axle Load	1500 lb/platform	0.5% of applied load	Intercomp SW500	0828MA19001	By: DRI Date: 9/12/2019 Due: 9/12/2020
Linear (string) encoder	Throttle pedal travel	10 in 254 mm	0.1 in 2.54 mm	UniMeasure LX-EP	45040532	By: DRI Date: 5/10/2019 Due: 5/10/2020
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	NA
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	Latitude: ±90º Longitude	Position: ±2 cm Velocity	Oxford xNAV 550	015477	By: Oxford Technical Solutions Date: 9/12/2018 Due: 9/12/2020
POV Multi-Axis Inertial Sensing System		Latitude: ±90º Longitude	Position: ±2 cm Velocity	Oxford PinPoint 2G	24504	By: Oxford Technical Solutions Date: 7/18/2019 Due: 7/18/2021

Table 6. Test Instrumentation and Equipment (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Coordinate Measurement Machine	Inertial Sensing System Coordinates	0-8 ft 0-2.4 m	±.0020 in. ±.051 mm (Single point articulation accuracy)	Faro Arm, Fusion	UO8-05-08-06636	By: DRI Date: 1/6/2020 Due: 1/6/2021
Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW)	Distance and Velocity to lane markings (LDW) and POV (FCW)	Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	NA
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	NA	NA
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	NA	NA
Accelerometer	Acceleration (to measure time at alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	NA	NA

Type	Description	Mfr, Model	Serial Number
Data Acquisition System	Data acquisition is achieved using a dSPACE MicroAutoBox II. Data from the Oxford IMU, including Longitudinal, Lateral, and Vertical Acceleration, Roll, Yaw, and Pitch Rate, Forward and Lateral Velocity, Roll and Pitch Angle are sent over Ethernet to the MicroAutoBox. The Oxford IMUs are calibrated per the manufacturer's recommended schedule (listed above).	dSPACE Micro-Autobox II 1401/1513	
		Base Board	549068
		I/O Board	588523

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

Figure A3. Window Sticker (Monroney Label)

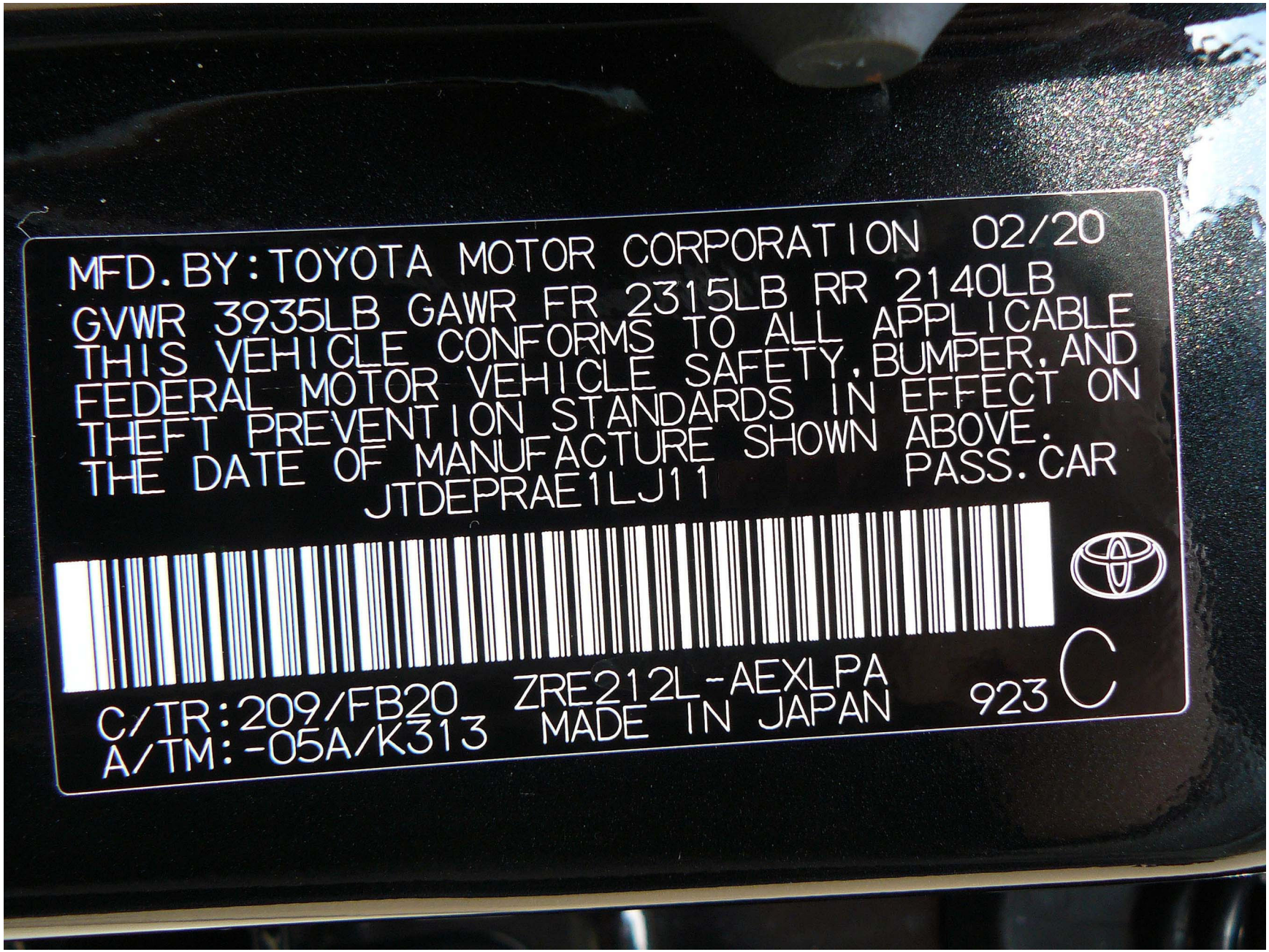


Figure A4. Vehicle Certification Label

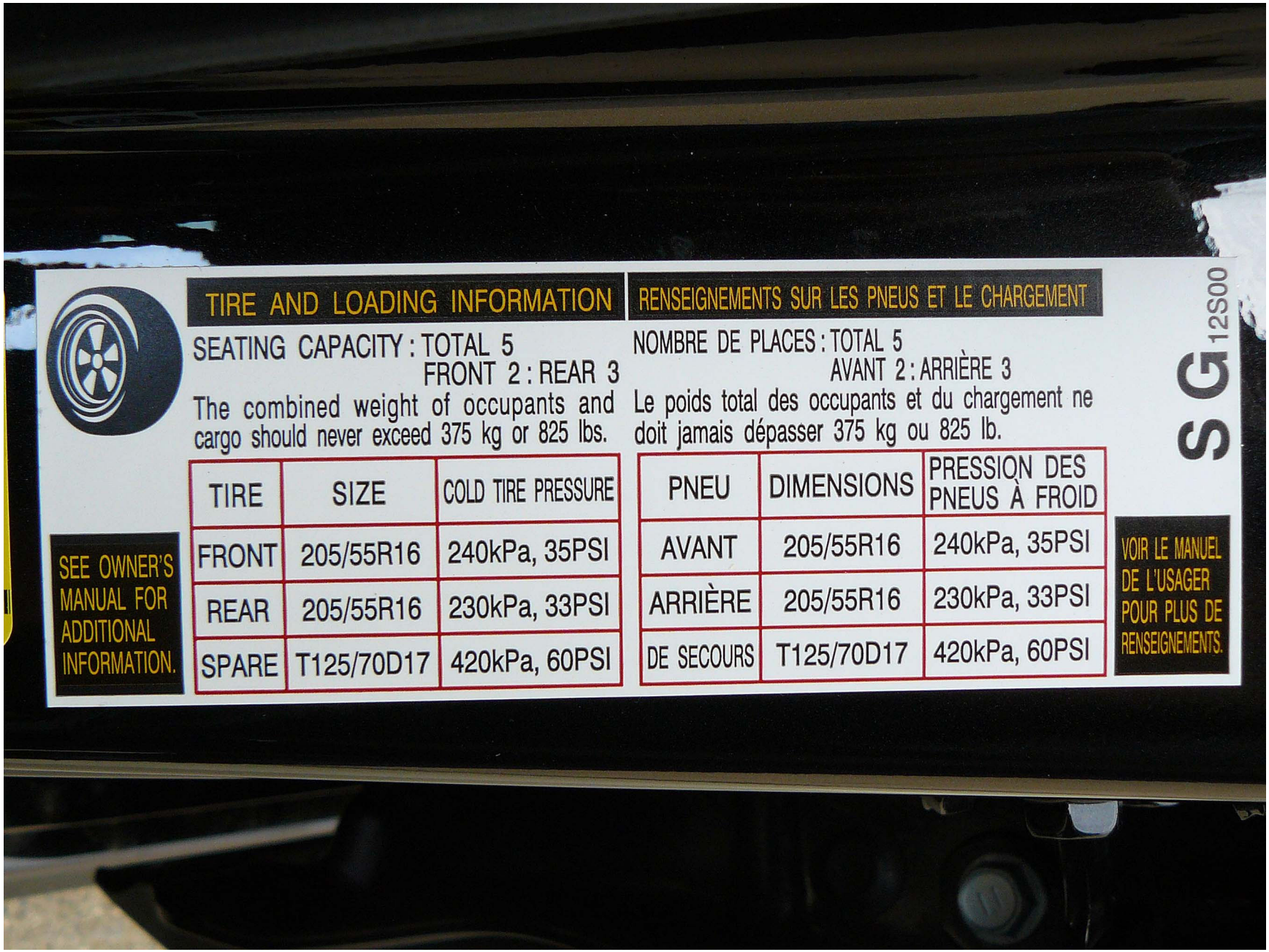


Figure A5. Tire Placard

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

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

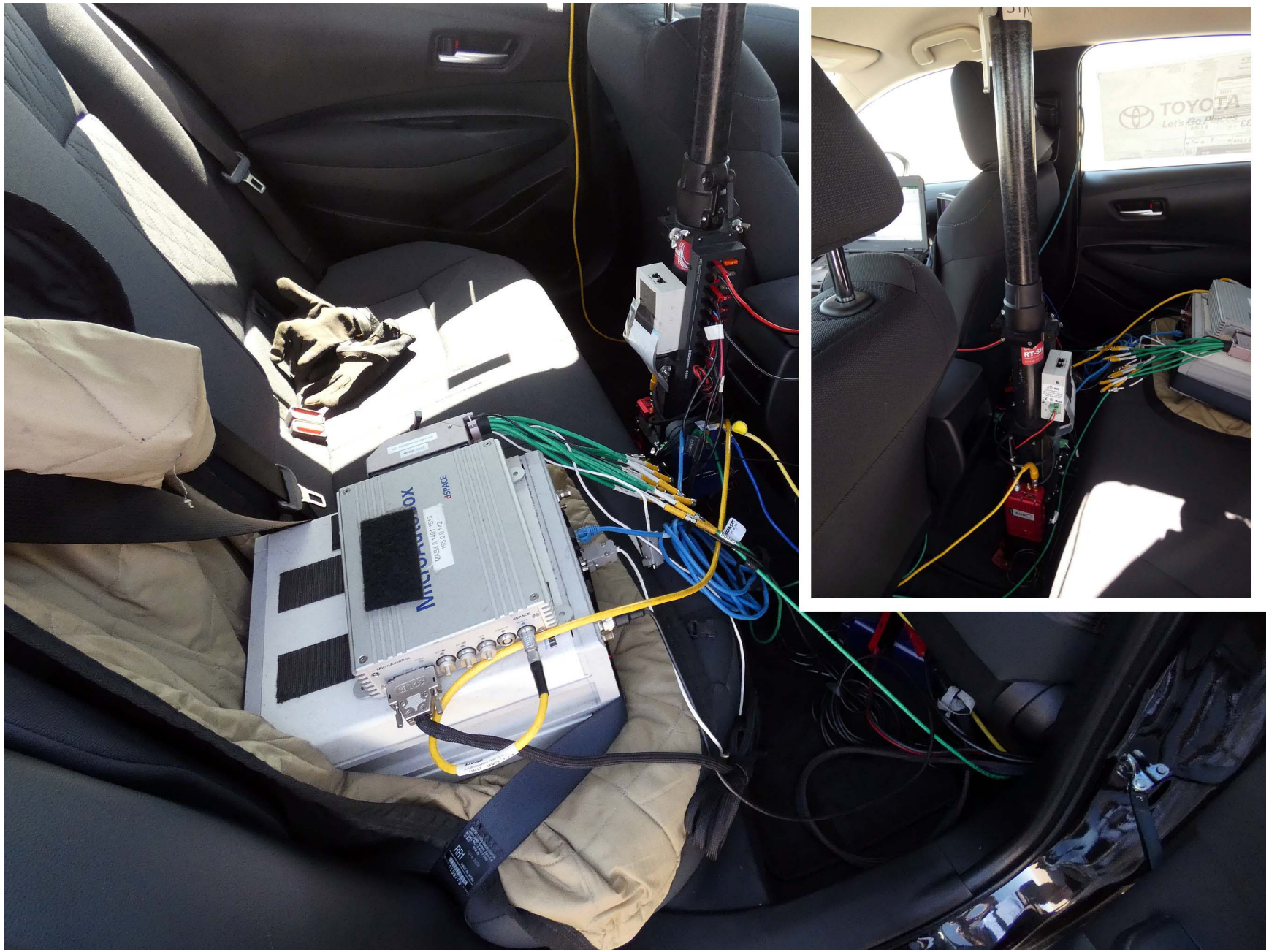


Figure A8. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle

Figure A9. Sensors for Detecting Auditory Alerts

Figure A10. Sensors for Detecting Visual Alerts

Figure A11. Computer Installed in Subject Vehicle

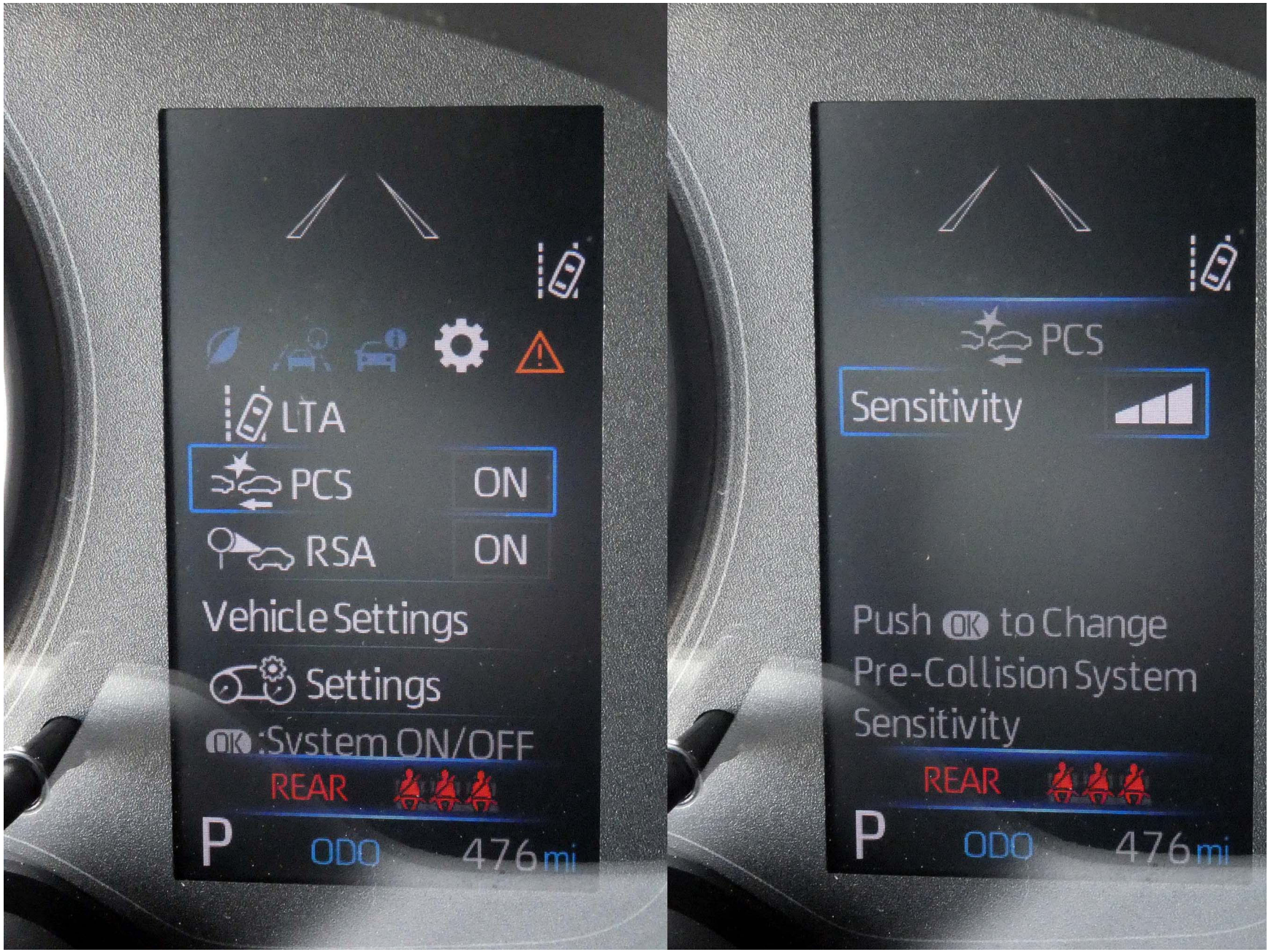


Figure A12. System Setup Menus

Figure A13. Controls for System Setup

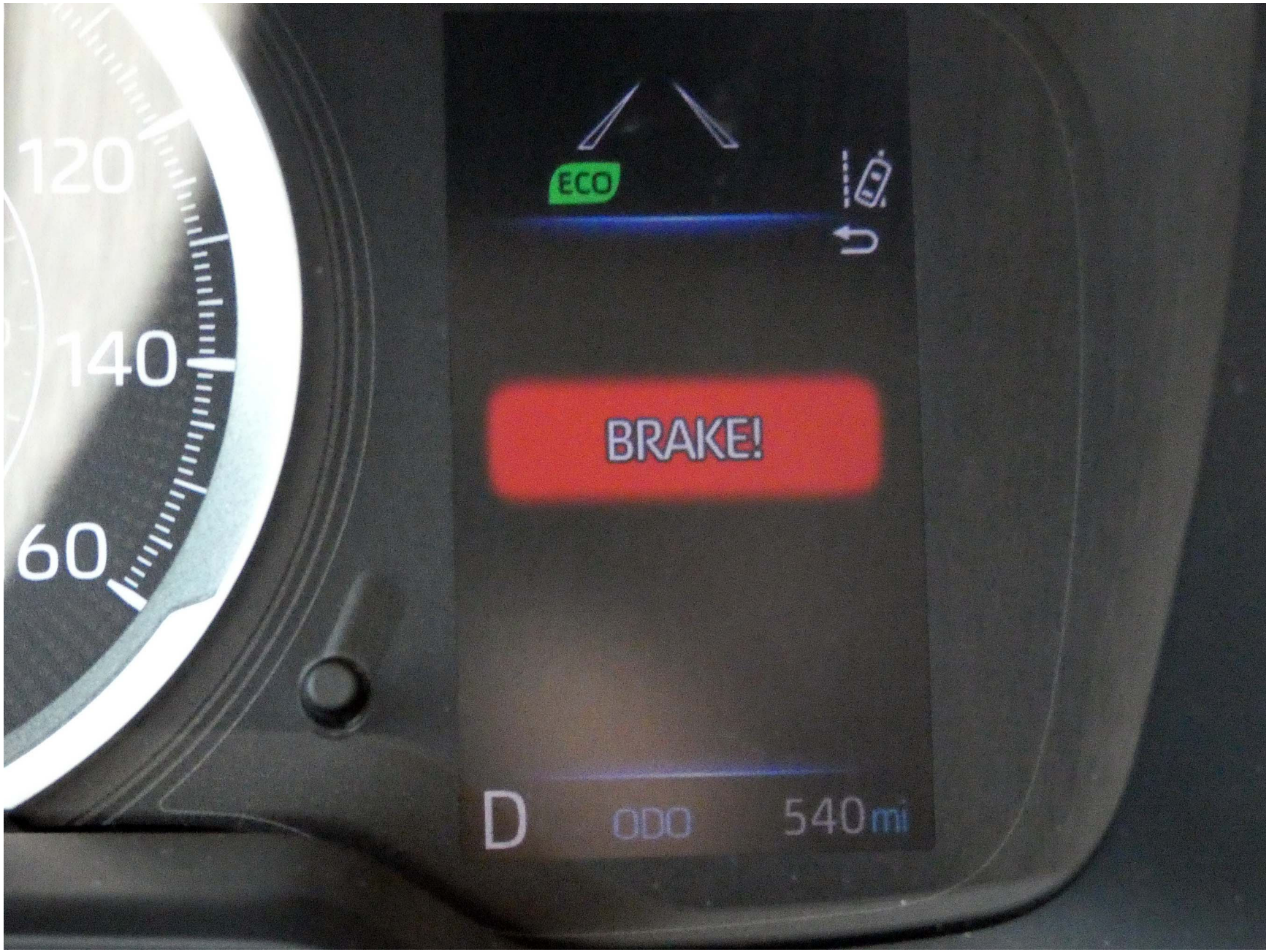
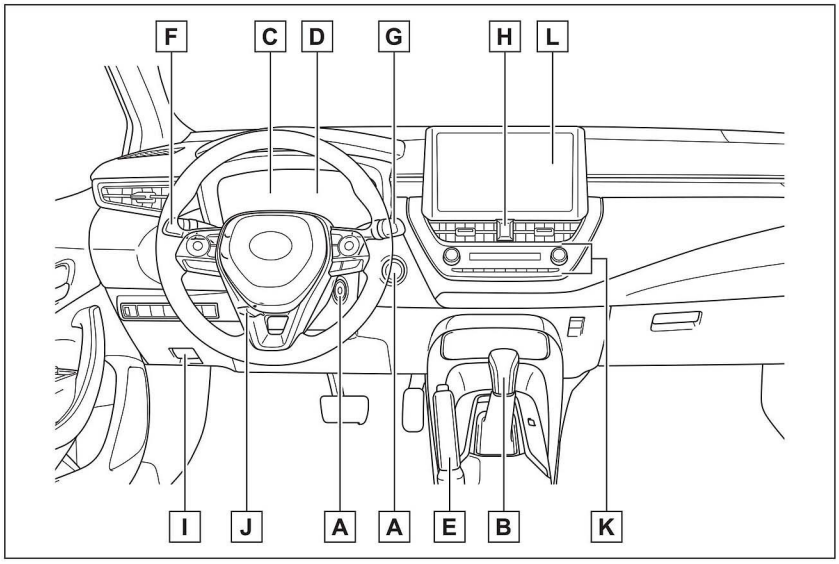


Figure A14. Visual Alert

APPENDIX B

Excerpts from Owner’s Manual

■Instrument panel



▶ 7-inch display (when digital speedometer is displayed)

Warning lights

Warning lights inform the driver of malfunctions in the indicated vehicle's systems.

BRAKE (U.S.A.) Brake system warning light*1 (→P.481)

(Red) (Canada) Brake system warning light*1 (→P.481)

(Yellow) Brake system warning light*1 (→P.481)

High coolant temperature warning light*2 (→P.481)

Charging system warning light*1 (→P.482)

Low engine oil pressure warning light*2 (→P.482)

CHECK (U.S.A.) Malfunction indicator lamp*1 (→P.482)

(Canada) Malfunction indicator lamp*1 (→P.482)

SRS warning light*1 (→P.482)

ABS (U.S.A.) ABS warning light*1 (→P.483)

(Canada) ABS warning light*1 (→P.483)

Brake Override System warning light/Drive-Start Control warning light*2 (→P.483)

(Red) Electric power steering system warning light*1 (→P.484)

(Yellow) Electric power steering system warning light*1 (→P.484)

Low fuel level warning light (→P.484)

Driver's and front passenger's seat belt reminder light (→P.484)

2 Vehicle status information and indicators

Rear passengers' seat belt reminder lights (→P.485)


Tire pressure warning light*1 (if equipped) (→P.485)


(Orange)
LTA indicator (if equipped) (→P.485)
LDA indicator (if equipped) (→P.485)

(Flashes or illuminates)
PCS warning light*1 (→P.486)


Slip indicator*1 (→P.486)

(Flashes) (U.S.A.)
Parking brake indicator (→P.486)


(Flashes) (Canada)
Parking brake indicator (→P.486)

(Flashes)
Brake hold operated indicator*1 (if equipped) (→P.487)

(Orange)
iMT indicator*1 (if equipped) (→P.487)

*1: These lights come on when the engine switch is turned to ON to indicate that a system check is being performed. They will turn off after the engine is started, or after a few seconds. There may be a malfunction in a system if the lights do not come on, or turn off. Have the vehicle inspected by your Toyota dealer.

*2: This light illuminates on the multi-information display.

WARNING

■ If a safety system warning light does not come on

Should a safety system light such as the ABS and SRS warning light not come on when you start the engine, this could mean that these systems are not available to help protect you in an accident, which could result in death or serious injury. Have the vehicle inspected by your Toyota dealer immediately if this occurs.

Indicators

The indicators inform the driver of the operating state of the vehicle's various systems.


Turn signal indicator (→P.162)


(U.S.A.)
Headlight indicator (→P.170)


(Canada)
Tail light indicator (→P.170)


Headlight high beam indicator (→P.172)


Automatic High Beam indicator (→P.173)

PCS warning light*1, 2 (→P.189)


Cruise control indicator (→P.213, 223)

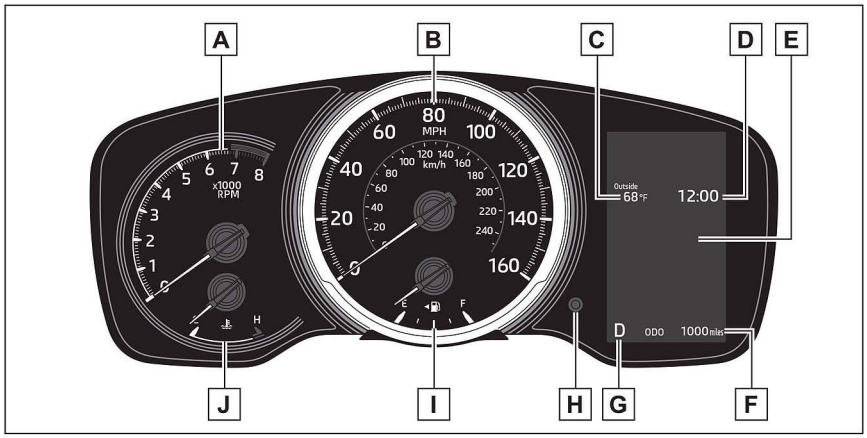

Dynamic radar cruise control indicator (→P.213, 223)

Cruise control "SET" indicator (→P.213, 223)

Gauges and meters (4.2-inch display)

Meter display

■ Locations of gauges and meters



The units of measure may differ depending on the intended destination of the vehicle.

A Tachometer

Displays the engine speed in revolutions per minute

B Speedometer

C Outside temperature

Displays the outside temperature within the range of -40°F (-40°C) to 122°F (50°C)

D Clock (→P.79)

E Multi-information display

Presents the driver with a variety of vehicle data (→P.86)
Displays warning messages if a malfunction occurs (→P.490)

F Odometer and trip meter display (→P.78)

G Shift position indicator (→P.153)

H Display change button (→P.78)

I Fuel gauge

Displays the quantity of fuel remaining in the tank

J Engine coolant temperature gauge

Displays the engine coolant temperature

Toyota Safety Sense 2.0

The Toyota Safety Sense 2.0 consists of the following drive assist systems and contributes to a safe and comfortable driving experience:

Driving assist system

■ **PCS (Pre-Collision System)**

→P.187

■ **LTA (Lane Tracing Assist)***

→P.195

*: If equipped

■ **LDA (Lane Departure Alert with steering control)***

→P.205

*: If equipped

■ **Automatic High Beam**

→P.173

■ **RSA (Road Sign Assist)***

→P.233

*: If equipped

■ **Dynamic radar cruise control with full-speed range***

→P.213

*: If equipped

■ **Dynamic radar cruise control***

→P.223

*: If equipped

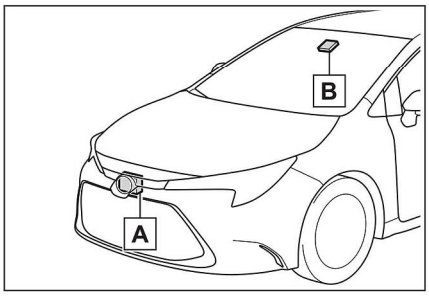
WARNING

■ **Toyota Safety Sense 2.0**

The Toyota Safety Sense 2.0 is designed to operate under the assumption that the driver will drive safely, and is designed to help reduce the impact to the occupants and the vehicle in the case of a collision or assist the driver in normal driving conditions.
As there is a limit to the degree of recognition accuracy and control performance that this system can provide, do not overly rely on this system. The driver is always responsible for paying attention to the vehicle's surroundings and driving safely.

Sensors

Two types of sensors, located behind the front grille and windshield, detect information necessary to operate the drive assist systems.



A Radar sensor

B Front camera

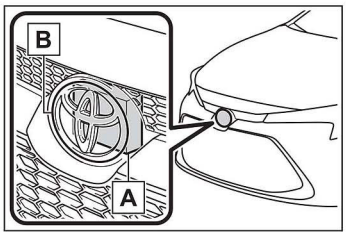
WARNING

■To avoid malfunction of the radar sensor

Observe the following precautions.
Otherwise, the radar sensor may not operate properly, possibly leading to an accident resulting in death or serious injury.

- Keep the radar sensor and the grille cover clean at all times.

▶ 1.8 L 4-cylinder (2ZR-FAE) engine



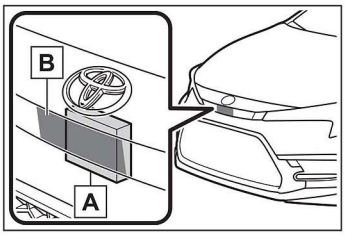
A Radar sensor

B Grille cover

If the front of the radar sensor or the front or back of the grille cover is dirty or covered with water droplets, snow, etc., clean it.

Clean the radar sensor and grille cover with a soft cloth to avoid damaging them.

▶ 2.0 L 4-cylinder (M20A-FKS) engine



A Radar sensor

B Grille cover

If the front of the radar sensor or the front or back of the grille cover is dirty or covered with water droplets, snow, etc., clean it.

Clean the radar sensor and grille cover with a soft cloth to avoid damaging them.

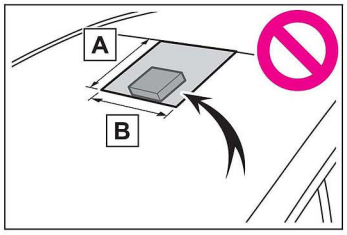
- Do not attach accessories, stickers (including transparent stickers) or other items to the radar sensor, grille cover or surrounding area.
- Do not subject the radar sensor or its surrounding area to a strong impact.
  If the radar sensor, front grille, or front bumper has been subjected to a strong impact, have the vehicle inspected by your Toyota dealer.
- Do not disassemble the radar sensor.
- Do not modify or paint the radar sensor or grille cover.
- If the radar sensor, front grille, or front bumper needs to be removed and installed, or replaced, contact your Toyota dealer.

WARNING

■ **To avoid malfunction of the front camera**

Observe the following precautions.
Otherwise, the front camera may not operate properly, possibly leading to an accident resulting in death or serious injury.

- Keep the windshield clean at all times.
  - If the windshield is dirty or covered with an oily film, water droplets, snow, etc., clean the windshield.
  - If a glass coating agent is applied to the windshield, it will still be necessary to use the windshield wipers to remove water droplets, etc. from the area of the windshield in front of the front camera.
  - If the inner side of the windshield where the front camera is installed is dirty, contact your Toyota dealer.
- Do not attach objects, such as stickers, transparent stickers, etc., to the outer side of the windshield in front of the front camera (shaded area in the illustration).



A From the top of the windshield to approximately 0.4 in. (1 cm) below the bottom of the front camera

B Approximately 7.9 in. (20 cm) (Approximately 4.0 in. [10 cm] to the right and left from the center of the front camera)

- If the part of the windshield in front of the front camera is fogged up or covered with condensation, or ice, use the windshield defogger to remove the fog, condensation, or ice. (→P.387, 392)
- If water droplets cannot be properly removed from the area of the windshield in front of the front camera by the windshield wipers, replace the wiper insert or wiper blade.

If the wiper inserts or wiper blades need to be replaced, contact your Toyota dealer.

- Do not attach window tint to the windshield.
- Replace the windshield if it is damaged or cracked.
  If the windshield needs to be replaced, contact your Toyota dealer.

WARNING

- Do not allow liquids to contact the front camera.
- Do not allow bright lights to shine into the front camera.
- Do not dirty or damage the front camera.
  When cleaning the inside of the windshield, do not allow glass cleaner to contact the lens of the front camera. Also, do not touch the lens.
  If the lens is dirty or damaged, contact your Toyota dealer.
- Do not subject the front camera to a strong impact.
- Do not change the installation position or direction of the front camera or remove it.
- Do not disassemble the front camera.
- Do not modify any components of the vehicle around the front camera (inside rear view mirror, etc.) or ceiling.
- Do not attach any accessories to the hood, front grille or front bumper that may obstruct the front camera. Contact your Toyota dealer for details.
- If a surfboard or other long object is to be mounted on the roof, make sure that it will not obstruct the front camera.
- Do not modify the headlights or other lights.

NOTE:
Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage; (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Cet équipement est conforme aux limites d'exposition aux rayonnements énoncées pour un environnement non contrôlé et respecte les règles d'exposition aux fréquences radioélectriques (RF) CNR-102 de l'IC.
Cet équipement doit être installé et utilisé en gardant une distance de 20 cm ou plus entre le dispositif rayonnant et le corps.

If a warning message is displayed on the multi-information display

A system may be temporarily unavailable or there may be a malfunction in the system.

- In the following situations, perform the actions specified in the table. When the normal operating conditions are detected, the message will disappear and the system will become operational.

If the message does not disappear, contact your Toyota dealer.

Situation	Actions
When the area around a sensor is covered with dirt, moisture (fogged up, covered with condensation, ice, etc.), or other foreign matter	To clean the part of the windshield in front of the front camera, use the windshield wipers or the windshield defogger of the air conditioning system (→P.387, 392).

Situation	Actions
When the temperature around the front camera is outside of the operational range, such as when the vehicle is in the sun or in an extremely cold environment	If the front camera is hot, such as after the vehicle had been parked in the sun, use the air conditioning system to decrease the temperature around the front camera. If a sunshade was used when the vehicle was parked, depending on its type, the sunlight reflected from the surface of the sunshade may cause the temperature of the front camera to become excessively high.
	If the front camera is cold, such after the vehicle is parked in an extremely cold environment, use the air conditioning system to increase the temperature around the front camera.
The area in front of the front camera is obstructed, such as when the hood is open or a sticker is attached to the part of the windshield in front of the front camera.	Close the hood, remove the sticker, etc. to clear the obstruction.

● In the following situations, if the situation has changed (or the vehicle has been driven for some time) and the normal operating conditions are detected, the message will disappear and the system will become operational.

If the message does not disappear, contact your Toyota dealer.

- When the temperature around the radar sensor is outside of the operational range, such as when the vehicle is in the sun or in an extremely cold environment
- When the front camera cannot detect objects in front of the vehicle, such as when driving in the dark, snow, or fog, or when bright lights are shining into the front camera

PCS (Pre-Collision System)

The pre-collision system uses a radar sensor and front camera to detect objects (→P.190) in front of the vehicle. When the system determines that the possibility of a frontal collision with an object is high, a warning operates to urge the driver to take evasive action and the potential brake pressure is increased to help the driver avoid the collision. If the system determines that the possibility of a frontal collision with an object is extremely high, the brakes are automatically applied to help avoid the collision or help reduce the impact of the collision.

The pre-collision system can be disabled/enabled and the warning timing can be changed. (→P.189)

Detectable objects

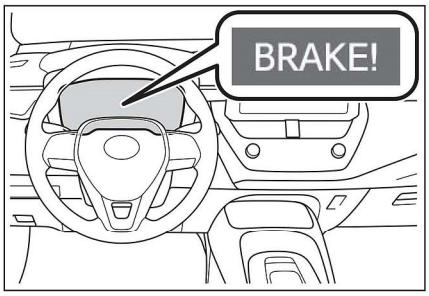
The system can detect the following:

- Vehicles
- Bicyclists
- Pedestrians

System functions

■ Pre-collision warning

When the system determines that the possibility of a frontal collision is high, a buzzer will sound and a warning message will be displayed on the multi-information display to urge the driver to take evasive action.



■ Pre-collision brake assist

When the system determines that the possibility of a frontal collision is high, the system applies greater braking force in relation to how strongly the brake pedal is depressed.

■ Pre-collision braking

If the system determines that the possibility of a frontal collision is extremely high, the brakes are automatically applied to help avoid the collision or reduce the impact of the collision.

WARNING

■Limitations of the pre-collision system

- The driver is solely responsible for safe driving. Always drive safely, taking care to observe your surroundings.
  Do not use the pre-collision system instead of normal braking operations under any circumstances. This system will not prevent collisions or lessen collision damage or injury in every situation. Do not overly rely on this system. Failure to do so may lead to an accident, resulting in death or serious injury.
- Although this system is designed to help avoid a collision or help reduce the impact of the collision, its effectiveness may change according to various conditions, therefore the system may not always be able to achieve the same level of performance.
  Read the following conditions carefully. Do not overly rely on this system and always drive carefully.
  - Conditions under which the system may operate even if there is no possibility of a collision: →P.191
  - Conditions under which the system may not operate properly: →P.192
- Do not attempt to test the operation of the pre-collision system yourself.
  Depending on the objects used for testing (dummies, cardboard objects imitating detectable objects, etc.), the system may not operate properly, possibly leading to an accident.

■Pre-collision braking

- When the pre-collision braking function is operating, a large amount of braking force will be applied.
- If the vehicle is stopped by the operation of the pre-collision braking function, the pre-collision braking function operation will be canceled after approximately 2 seconds. Depress the brake pedal as necessary.
- The pre-collision braking function may not operate if certain operations are performed by the driver. If the accelerator pedal is being depressed strongly or the steering wheel is being turned, the system may determine that the driver is taking evasive action and possibly prevent the pre-collision braking function from operating.
- In some situations, while the pre-collision braking function is operating, operation of the function may be canceled if the accelerator pedal is depressed strongly or the steering wheel is turned and the system determines that the driver is taking evasive action.
- If the brake pedal is being depressed, the system may determine that the driver is taking evasive action and possibly delay the operation timing of the pre-collision braking function.

■When to disable the pre-collision system

In the following situations, disable the system, as it may not operate properly, possibly leading to an accident resulting in death or serious injury:

- When the vehicle is being towed

WARNING

- When your vehicle is towing another vehicle
- When transporting the vehicle via truck, boat, train or similar means of transportation
- When the vehicle is raised on a lift with the engine running and the tires are allowed to rotate freely
- When inspecting the vehicle using a drum tester such as a chassis dynamometer or speedometer tester, or when using an on vehicle wheel balancer
- When a strong impact is applied to the front bumper or front grille, due to an accident or other reasons
- If the vehicle cannot be driven in a stable manner, such as when the vehicle has been in an accident or is malfunctioning
- When the vehicle is driven in a sporty manner or off-road
- When the tires are not properly inflated
- When the tires are very worn
- When tires of a size other than specified are installed
- When tire chains are installed
- When a compact spare tire or an emergency tire puncture repair kit is used
- If equipment (snow plow, etc.) that may obstruct the radar sensor or front camera is temporarily installed to the vehicle

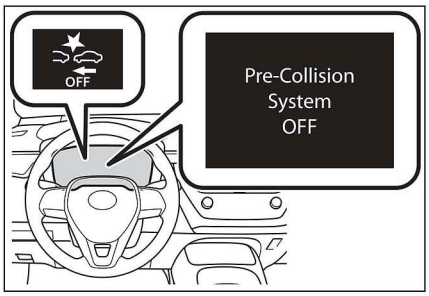
Changing settings of the pre-collision system

Enabling/disabling the pre-collision system

The pre-collision system can be enabled/disabled on  (→P.548) of the multi-information display.

The system is automatically enabled each time the engine switch is turned to ON.

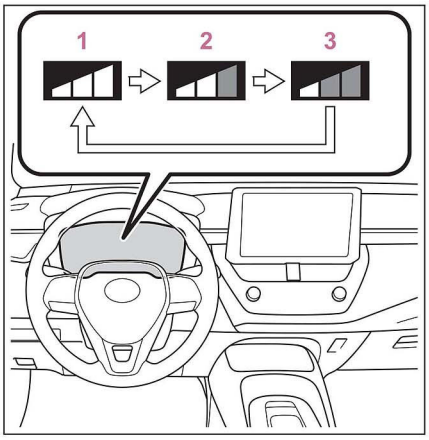
If the system is disabled, the PCS warning light will turn on and a message will be displayed on the multi-information display.



Changing the pre-collision warning timing

The pre-collision warning timing can be changed on  (→P.548) of the multi-information display.

The warning timing setting is retained when the engine switch is turned off. However, if the pre-collision system is disabled and re-enabled, the operation timing will return to the default setting (middle).



1 Early

2 Middle

This is the default setting.

3 Late

Operational conditions

The pre-collision system is enabled and the system determines that the possibility of a frontal collision with a detected object is high.
Each function is operational at the following speed

● Pre-collision warning

Detectable objects	Vehicle speed	Relative speed between your vehicle and object
Vehicles	Approx. 7 to 110 mph (10 to 180 km/h)	Approx. 7 to 110 mph (10 to 180 km/h)
Bicyclists and pedestrians	Approx. 7 to 50 mph (10 to 80 km/h)	Approx. 7 to 50 mph (10 to 80 km/h)

● Pre-collision brake assist

Detectable objects	Vehicle speed	Relative speed between your vehicle and object
Vehicles	Approx. 20 to 110 mph (30 to 180 km/h)	Approx. 20 to 110 mph (30 to 180 km/h)
Bicyclists and pedestrians	Approx. 20 to 50 mph (30 to 80 km/h)	Approx. 20 to 50 mph (30 to 80 km/h)

● Pre-collision braking

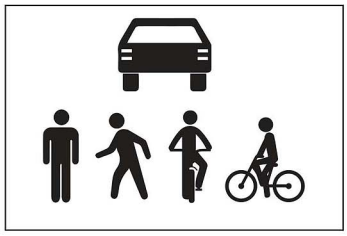
Detectable objects	Vehicle speed	Relative speed between your vehicle and object
Vehicles	Approx. 7 to 110 mph (10 to 180 km/h)	Approx. 7 to 110 mph (10 to 180 km/h)
Bicyclists and pedestrians	Approx. 7 to 50 mph (10 to 80 km/h)	Approx. 7 to 50 mph (10 to 80 km/h)

The system may not operate in the following situations:

- If a battery terminal has been disconnected and reconnected and then the vehicle has not been driven for a certain amount of time
- If the shift lever is in R
- When the VSC OFF indicator is illuminated (only the pre-collision warning function will be operational)

Object detection function

The system detects objects based on their size, profile, motion, etc. However, an object may not be detected depending on the surrounding brightness and the motion, posture, and angle of the detected object, preventing the system from operating properly. (→P.192)
The illustration shows an image of detectable objects.



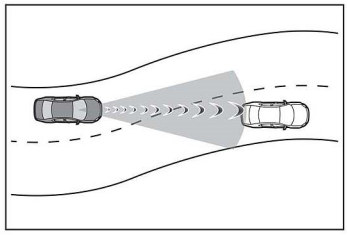
Cancelation of the pre-collision braking

If either of the following occur while the pre-collision braking function is operating, it will be canceled:

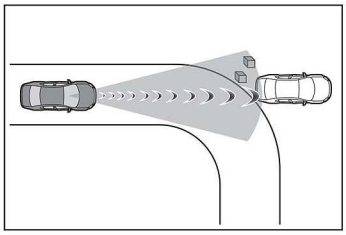
- The accelerator pedal is depressed strongly.
- The steering wheel is turned sharply or abruptly.

Conditions under which the system may operate even if there is no possibility of a collision

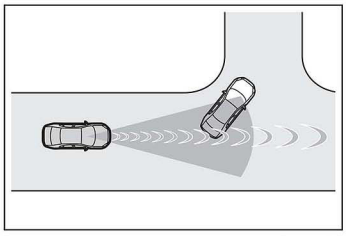
- In some situations such as the following, the system may determine that there is a possibility of a frontal collision and operate.
  - When passing a detectable object, etc.
  - When changing lanes while overtaking a detectable object, etc.
  - When approaching a detectable object in an adjacent lane or on the roadside, such as when changing the course of travel or driving on a winding road



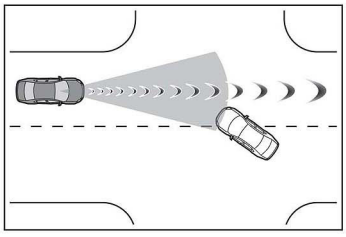
  - When rapidly closing on a detectable object, etc.
  - When approaching objects on the roadside, such as detectable objects, guardrails, utility poles, trees, or walls
  - When there is a detectable object or other object by the roadside at the entrance of a curve



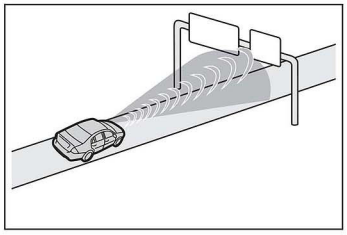
- When there are patterns or paint in front of your vehicle that may be mistaken for a detectable object
- When the front of your vehicle is hit by water, snow, dust, etc.
- When overtaking a detectable object that is changing lanes or making a right/left turn



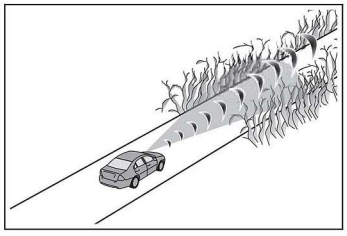
- When passing a detectable object in an oncoming lane that is stopped to make a right/left turn



- When a detectable object approaches very close and then stops before entering the path of your vehicle
- If the front of your vehicle is raised or lowered, such as when on an uneven or undulating road surface
- When driving on a road surrounded by a structure, such as in a tunnel or on an iron bridge
- When there is a metal object (manhole cover, steel plate, etc.), steps, or a protrusion in front of your vehicle
- When passing under an object (road sign, billboard, etc.)



- When approaching an electric toll gate barrier, parking area barrier, or other barrier that opens and closes
- When using an automatic car wash
- When driving through or under objects that may contact your vehicle, such as thick grass, tree branches, or a banner



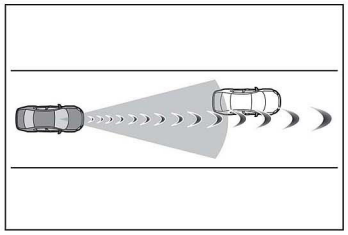
- When driving through steam or smoke
- When driving near an object that reflects radio waves, such as a large truck or guardrail
- When driving near a TV tower, broadcasting station, electric power plant, or other location where strong radio waves or electrical noise may be present

■ Situations in which the system may not operate properly

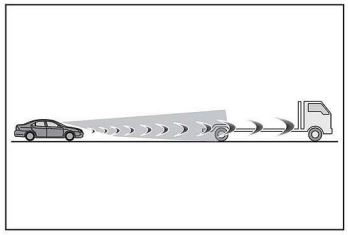
● In some situations such as the following, an object may not be detected by the radar sensor and front camera, preventing the system from operating properly:

- When a detectable object is approaching your vehicle
- When your vehicle or a detectable object is wobbling
- If a detectable object makes an abrupt maneuver (such as sudden

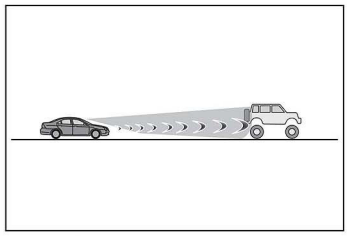
swerving, acceleration or deceleration)
- When your vehicle approaches a detectable object rapidly
- When a detectable object is not directly in front of your vehicle



- When a detectable object is near a wall, fence, guardrail, manhole cover, vehicle, steel plate on the road, etc.
- When a detectable object is under a structure
- When part of a detectable object is hidden by an object, such as large baggage, an umbrella, or guardrail
- When multiple detectable objects are close together
- If the sun or other light is shining directly on a detectable object
- When a detectable object is a shade of white and looks extremely bright
- When a detectable object appears to be nearly the same color or brightness as its surroundings
- If a detectable object cuts or suddenly emerges in front of your vehicle
- When the front of your vehicle is hit by water, snow, dust, etc.
- When a very bright light ahead, such as the sun or the headlights of oncoming traffic, shines directly into the front camera
- When approaching the side or front of a vehicle ahead
- If a vehicle ahead is a motorcycle
- If a vehicle ahead is narrow, such as a personal mobility vehicle
- If a preceding vehicle has a small rear end, such as an unloaded truck
- If a preceding vehicle has a low rear end, such as a low bed trailer

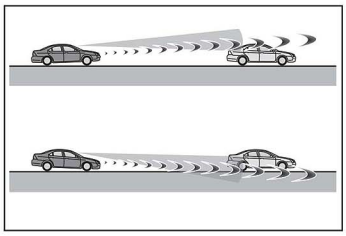


- If a vehicle ahead has extremely high ground clearance



- If a vehicle ahead is carrying a load which protrudes past its rear bumper
- If a vehicle ahead is irregularly shaped, such as a tractor or side car
- If a vehicle ahead is a child sized bicycle, a bicycle that is carrying a large load, a bicycle ridden by more than one person, or a uniquely shaped bicycle (bicycle with a child seat, tandem bicycle, etc.)
- If a pedestrian/or the riding height of a bicyclist ahead is shorter than approximately 3.2 ft. (1 m) or taller than approximately 6.5 ft. (2 m)
- If a pedestrian/bicyclist is wearing oversized clothing (a rain coat, long skirt, etc.), making their silhouette obscure
- If a pedestrian is bending forward or squatting or bicyclist is bending forward
- If a pedestrian/bicyclist is moving fast
- If a pedestrian is pushing a stroller, wheelchair, bicycle or other vehicle
- When driving in inclement weather such as heavy rain, fog, snow or a sandstorm

- When driving through steam or smoke
- When the surrounding area is dim, such as at dawn or dusk, or while at night or in a tunnel, making a detectable object appear to be nearly the same color as its surroundings
- When driving in a place where the surrounding brightness changes suddenly, such as at the entrance or exit of a tunnel
- After the engine has started the vehicle has not been driven for a certain amount of time
- While making a left/right turn and for a few seconds after making a left/right turn
- While driving on a curve and for a few seconds after driving on a curve
- If your vehicle is skidding
- If the front of the vehicle is raised or lowered



- If the wheels are misaligned
- If a wiper blade is blocking the front camera
- The vehicle is being driven at extremely high speeds
- When driving on a hill
- If the radar sensor or front camera is misaligned

● In some situations such as the following, sufficient braking force may not be obtained, preventing the system from performing properly:

- If the braking functions cannot operate to their full extent, such as when the brake parts are extremely cold, extremely hot, or wet
- If the vehicle is not properly maintained (brakes or tires are excessively worn, improper tire inflation pressure, etc.)
- When the vehicle is being driven on a gravel road or other slippery surface

■ If VSC is disabled

● If VSC is disabled (→P.252), the pre-collision brake assist and pre-collision braking functions are also disabled.

● The PCS warning light will turn on and “VSC Turned OFF Pre-Collision Brake System Unavailable” will be displayed on the multi-information display.

Customizable features

Your vehicle includes a variety of electronic features that can be personalized to suit your preferences. The settings of these features can be changed using the multi-information display, the audio system screen, or at your Toyota dealer.

Customizing vehicle features

■ Changing by using the audio system screen

1 Press the “MENU” button.

2 Select “Setup” on the “Menu” screen.

3 Select “General” or “Vehicle” on the “Setup” screen.

Various setting can be changed. Refer to the list of settings that can be changed for details.

■ Changing by using the meter control switches

1 Press ❮ or ❯ of the meter control switch to select ⚙.

2 Press ^ or ⌄ of the meter control switch to select the desired item to be customized.

3 Press or press and hold OK .

The available settings will differ depending on if OK is pressed or pressed and held. Follow the instructions on the display.

⚠ WARNING

■ During customization

As the engine needs to be running during customization, ensure that the vehicle is parked in a place with adequate ventilation. In a closed area such as a garage, exhaust gases including harmful carbon monoxide (CO) may collect and enter the vehicle. This may lead to death or a serious health hazard.

⚠ NOTICE

■ During customization

To prevent battery discharge, ensure that the engine is running while customizing features.

Customizable features

Some function settings are changed simultaneously with other functions being customized. Contact your Toyota dealer for further details.

A Settings that can be changed using the audio system screen

B Settings that can be changed using the meter control switches

■ **Lights (→P.170)**

Function	Default setting	Customized setting	A	B	C
Daytime running light system	On	Off*1	O	—	O
AFS (Adaptive Front-lighting System)*2	On	Off	—	—	O

*1: Except for Canada

*2: If equipped

■ **PCS (Pre-Collision System) (→P.187)**

Function	Default setting	Customized setting	A	B	C
PCS (Pre-Collision System)	On	Off	—	O	—
Adjust alert timing	Middle	Far	—	O	—
		Near			

■ **LTA (Lane Tracing Assist)*/LDA (Lane Departure Alert with steering control)* (→P.195, 205)**

Function	Default setting	Customized setting	A	B	C
Lane centering function*	On	Off	—	O	—
Steering assist function	On	Off	—	O	—
Alert sensitivity	High	Standard	—	O	—
Vehicle sway warning function	On	Off	—	O	—
Vehicle sway warning sensitivity	Standard	High	—	O	—
		Low			

*: If equipped

■ **RSA (Road Sign Assist)* (→P.233)**

Function	Default setting	Customized setting	A	B	C
RSA (Road Sign Assist)	On	Off	—	O	—

APPENDIX C

Run Log

Subject Vehicle: **2020 Toyota Corolla LE** Test Date: **4/24/2020**

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
1	Static Run								
45	**Stopped POV, 25**	Y	2.46	2.99	24.3	1.11	1.12	Yes	
46		Y	2.51	2.73	25.1	1.15	1.02	Yes	
47		Y	2.54	2.24	25.4	1.13	1.10	Yes	
48		Y	2.53	1.85	25.4	1.18	1.04	Yes	
49		Y	2.23	2.59	25.2	1.16	1.02	Yes	
50		Y	2.50	2.76	25.5	1.15	1.05	Yes	
51		Y	2.45	2.72	25.5	1.15	1.07	Yes	Video dropout at beginning of run
52	Static Run								
53	**Stopped POV, 30**	N							SV yaw
54		Y	2.75	2.10	30.0	1.16	1.12	Yes	
55		Y	2.63	2.36	29.6	1.17	1.10	Yes	
56		Y	2.75	2.04	30.2	1.18	1.11	Yes	
57		Y	2.73	2.45	30.3	1.18	1.08	Yes	
58		Y	2.43	2.22	29.8	1.18	1.12	Yes	
59	Static Run								

[5] 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.

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
60	**Stopped POV, 35**	Y	2.82	3.16	35.4	1.14	1.15	Yes	
61		Y	2.80	3.01	35.0	1.14	1.17	Yes	
62		Y	2.80	2.80	34.4	1.12	1.13	Yes	
63		Y	2.79	1.92	35.5	1.17	1.16	Yes	
64		Y	2.81	2.04	35.5	1.12	1.10	Yes	
65	Static Run								
66	**Stopped POV, 40**	Y	2.81	0.95	40.8	1.01	1.13	Yes	
67		Y	2.81	2.49	39.9	1.14	1.19	Yes	
68		Y	2.76	0.85	40.4	1.07	1.11	Yes	
69		Y	2.80	1.87	39.7	1.04	1.14	Yes	
70		Y	2.79	1.96	39.3	1.07	1.14	Yes	
71	Static Run								
72	**Stopped POV, 45**	Y	2.80	0.00	22.4	1.07	0.91	Yes	
73		Y	2.79	0.00	21.1	1.08	0.89	Yes	
74		N							Communication dropouts
75		Y	2.79	0.00	23.0	1.09	0.92	Yes	
76		Y	2.83	0.00	16.7	1.05	0.78	Yes	
77	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
2	**Slower POV, 25 vs 10**	Y	2.31	6.68	15.7	1.10	0.88	Yes	
3		N							Lateral Offset
4		Y	2.30	4.83	15.2	1.07	0.87	Yes	
5		Y	2.36	4.19	16.0	1.04	0.91	Yes	
6		Y	2.30	3.79	15.6	1.09	0.87	Yes	
7		N							SV Speed
8		Y	2.34	4.61	14.7	1.08	0.89	Yes	
9		Y	2.30	6.69	15.4	1.00	0.85	Yes	
10		Y	2.64	4.08	15.2	1.07	0.86	Yes	
11	Static Run								
12	**Slower POV, 45 vs 20**	Y	2.75	1.28	25.5	1.09	1.06	Yes	
13		Y	2.88	2.06	24.6	1.09	1.09	Yes	
14		Y	2.85	1.36	25.5	1.10	1.11	Yes	
15		Y	2.89	2.10	25.3	1.07	1.09	Yes	
16		Y	2.84	1.02	24.7	1.07	1.05	Yes	
17		Y	2.81	1.97	25.1	1.09	1.08	Yes	
18		Y	2.85	1.68	24.8	1.09	1.06	Yes	video cutout at beginning
19	Static run								
20	**Decelerating POV, 35, 0.3g**	Y	1.96	3.92	24.2	1.14	0.96	Yes	
21		Y	1.97	1.50	25.9	1.07	0.94	Yes	
22		Y	1.89	3.23	24.8	1.08	0.98	Yes	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Acceptability Criteria met [5]	Notes
23		Y	1.87	5.87	22.6	1.06	0.92	Yes	
24		Y	1.94	1.66	26.1	1.03	0.97	Yes	
25		N							SV yaw
26		Y	1.91	4.48	23.1	1.11	0.93	Yes	
27		Y	1.88	3.27	24.0	1.10	0.94	Yes	
28	Static Run								
29	**Decelerating POV, 45, 0.3g**	Y	1.97	5.00	23.0	1.05	0.93	Yes	
30		Y	1.87	0.00	25.9	0.65	1.06	Yes	
31		Y	1.81	3.66	23.9	1.04	0.95	Yes	
32		Y	1.77	4.53	23.5	1.04	0.97	Yes	
33		N							Lateral Offset
34		Y	1.94	3.13	25.2	1.03	1.02	Yes	
35	Static Run								
36	**Decelerating POV, 35 .5g**	N							POV Speed
37		Y	1.59	0.00	29.9	0.78	1.14	Yes	
38		N							POV Speed
39		Y	1.61	2.10	35.6	1.17	1.10	Yes	
40		Y	1.59	2.01	35.7	1.11	1.17	Yes	
41		N							POV Decel
42		Y	1.46	1.55	35.1	1.15	1.04	Yes	
43		Y	1.47	1.87	35.1	1.15	1.15	Yes	
44	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.

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

Examples of time history plots for each test type (including passing, failing and invalid runs) are shown in Figures D1 through Figure D7. Figures D1 through D4 show passing runs for each of the 4 test types. Figures D5 and D6 show examples of invalid runs. Figure D7 shows an example of a valid test that failed the CIB requirements.

Time history data plots for the tests of the vehicle under consideration herein are provided beginning with Figure D8.

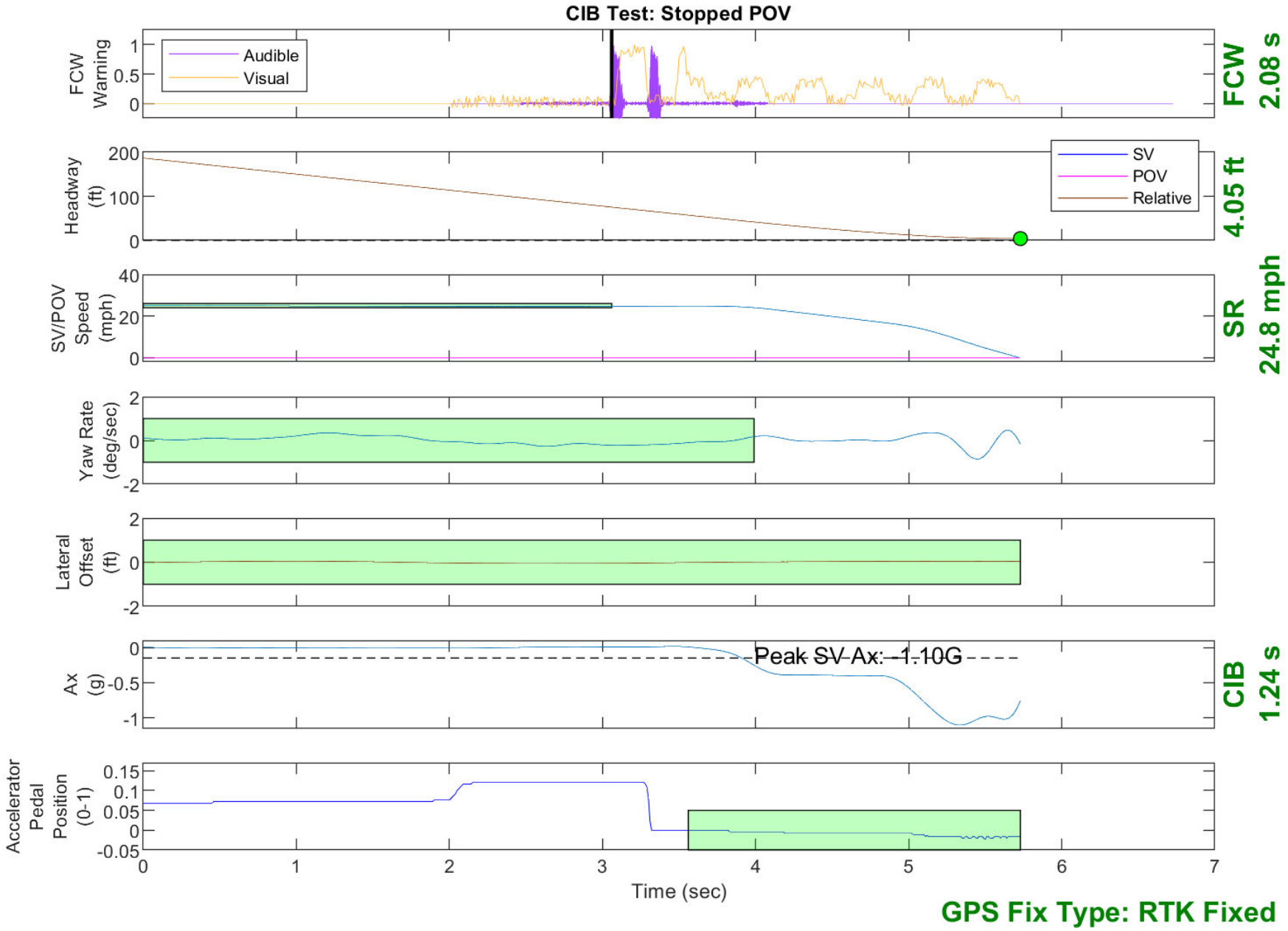


Figure D1. Example Time History for Stopped POV, Passing

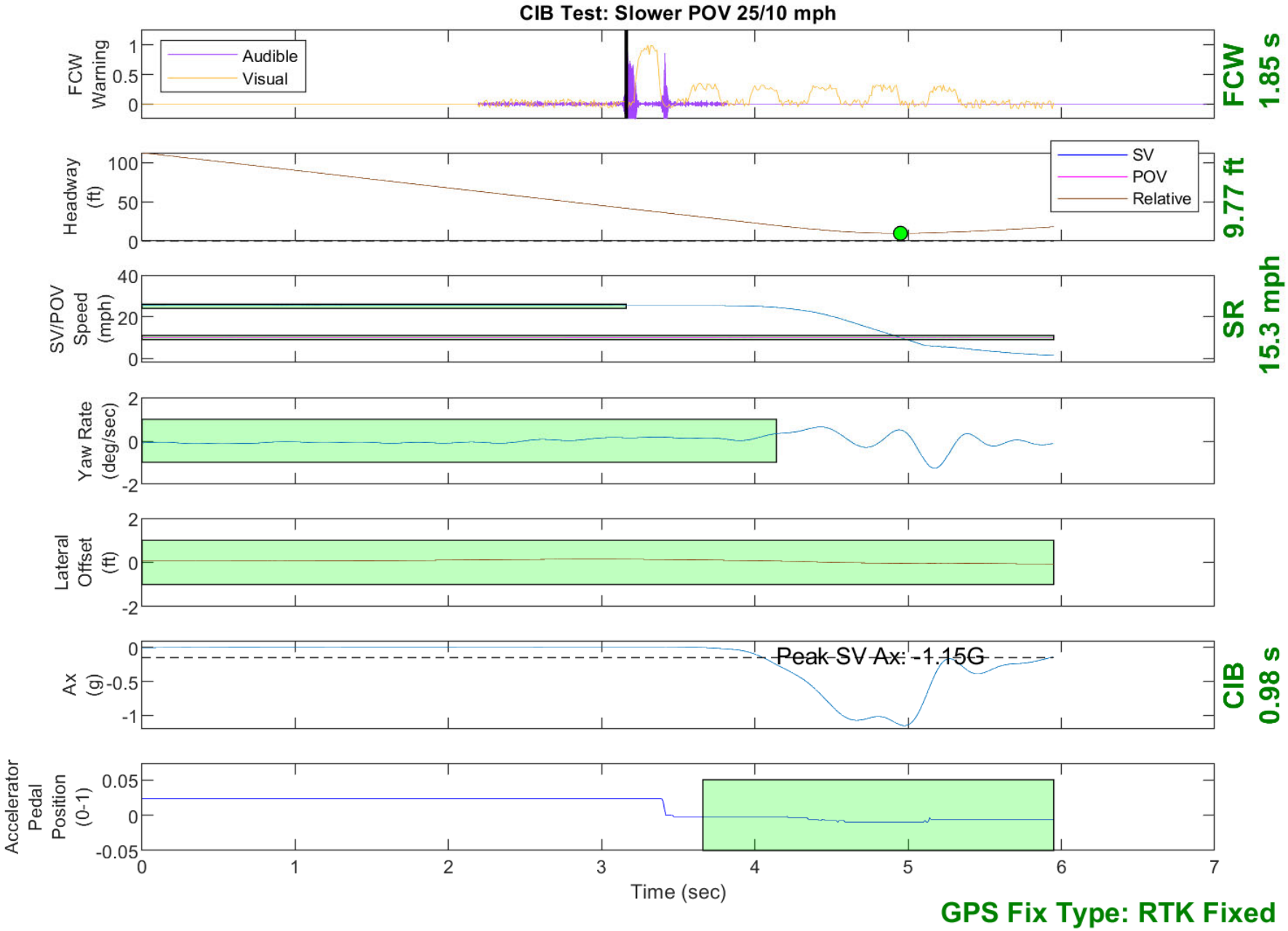


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

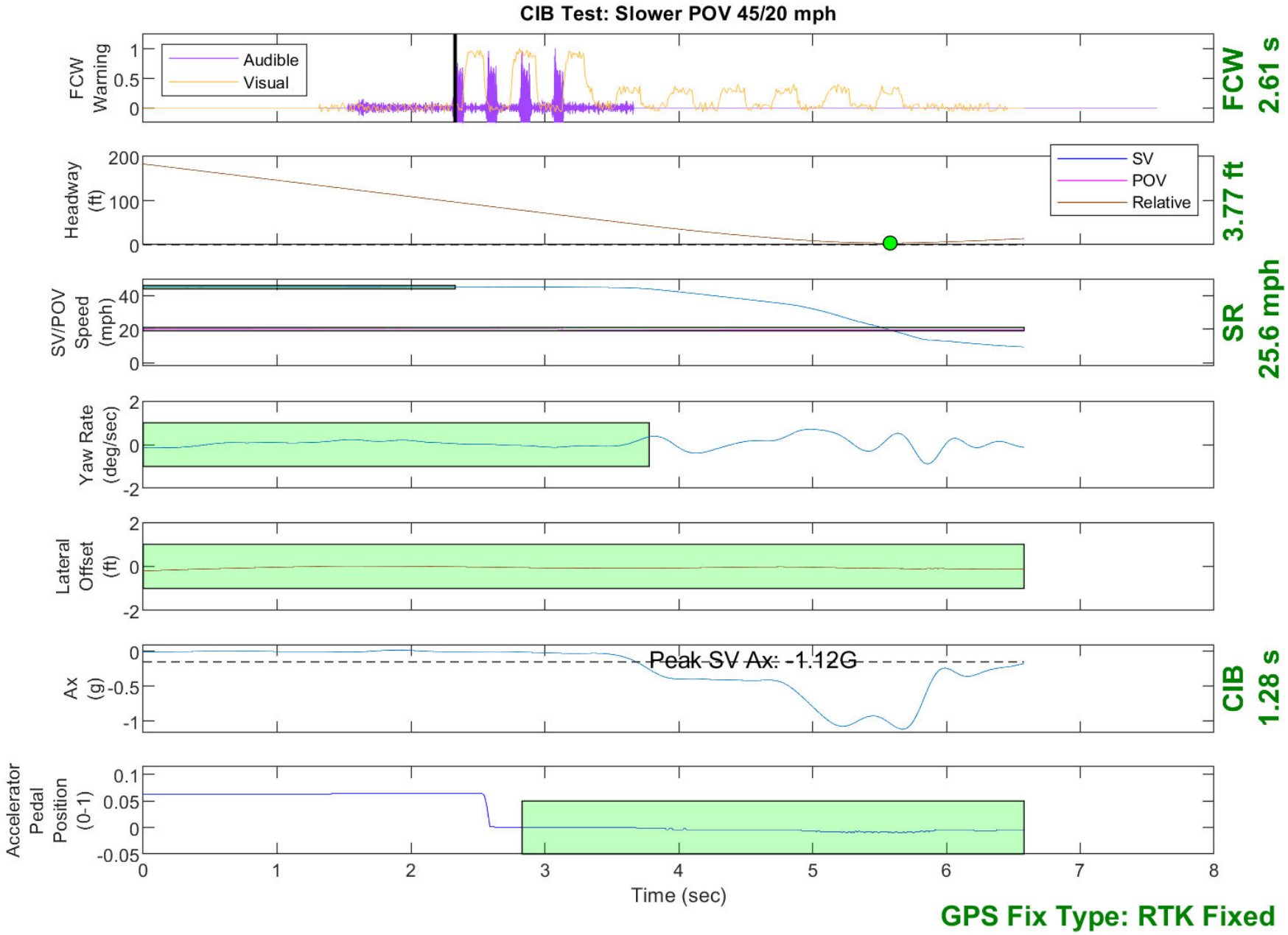


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

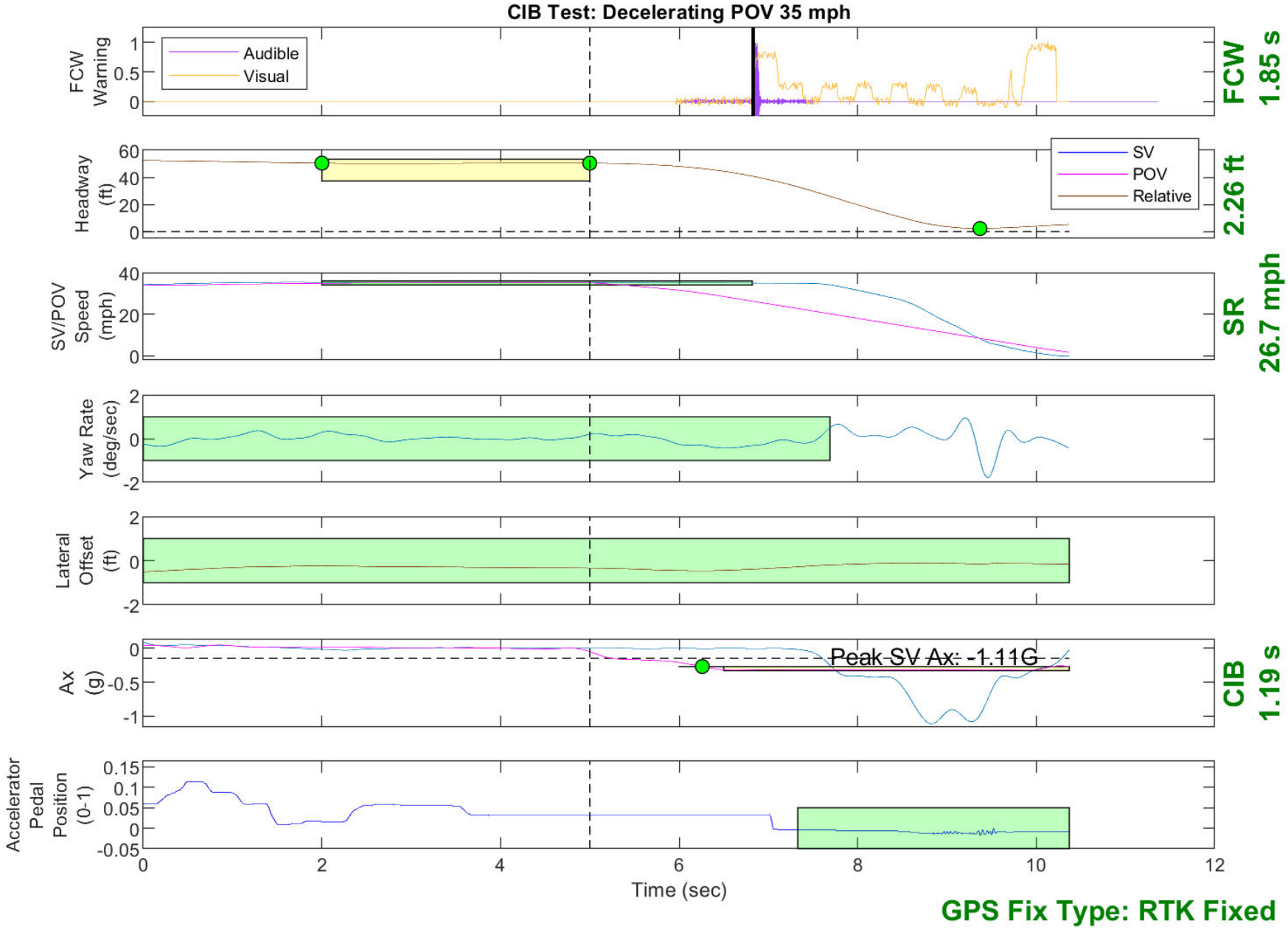


Figure D4. Example Time History for Decelerating POV 35, Passing

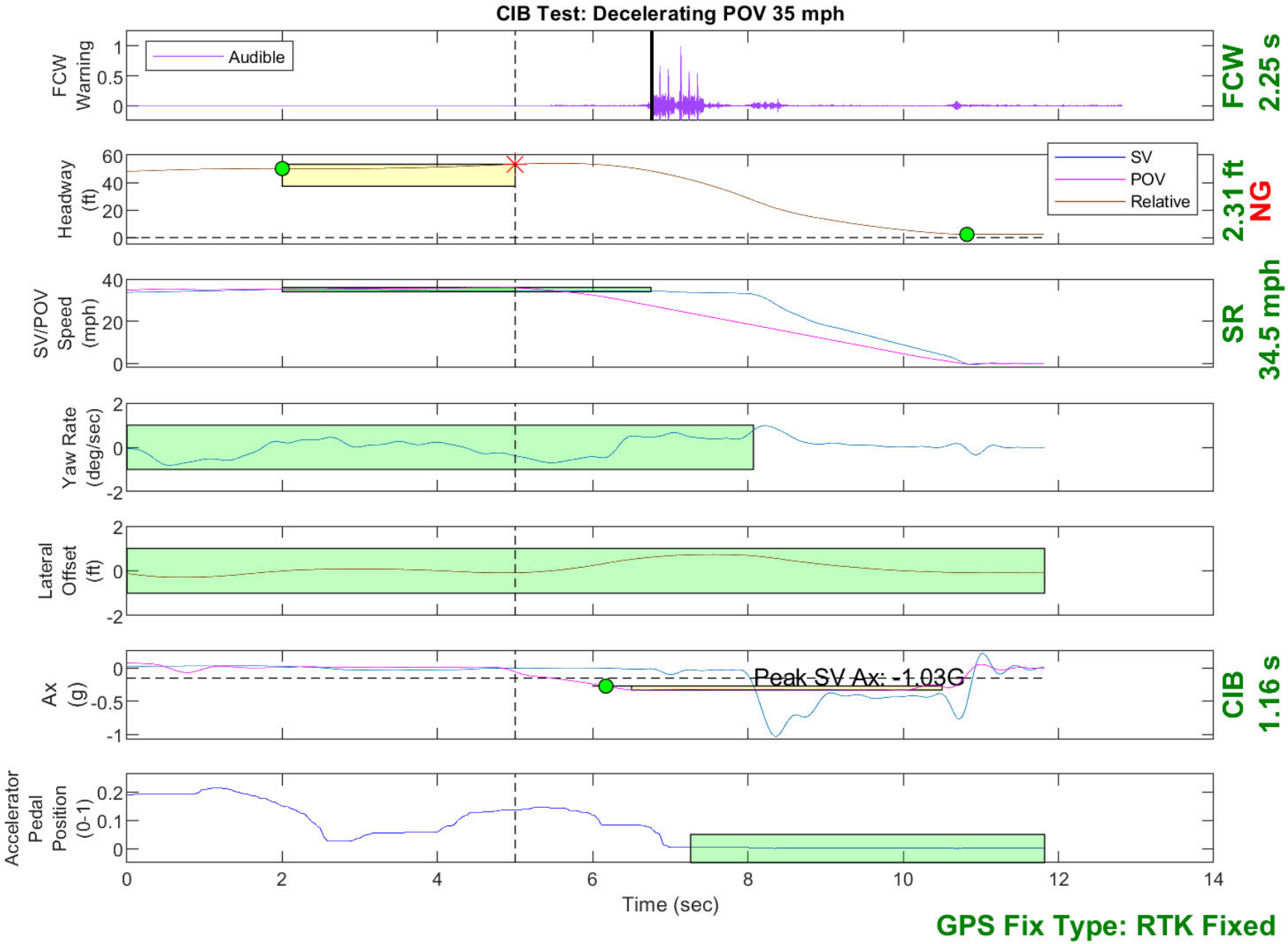


Figure D5. Example Time History Displaying Invalid Headway Criteria

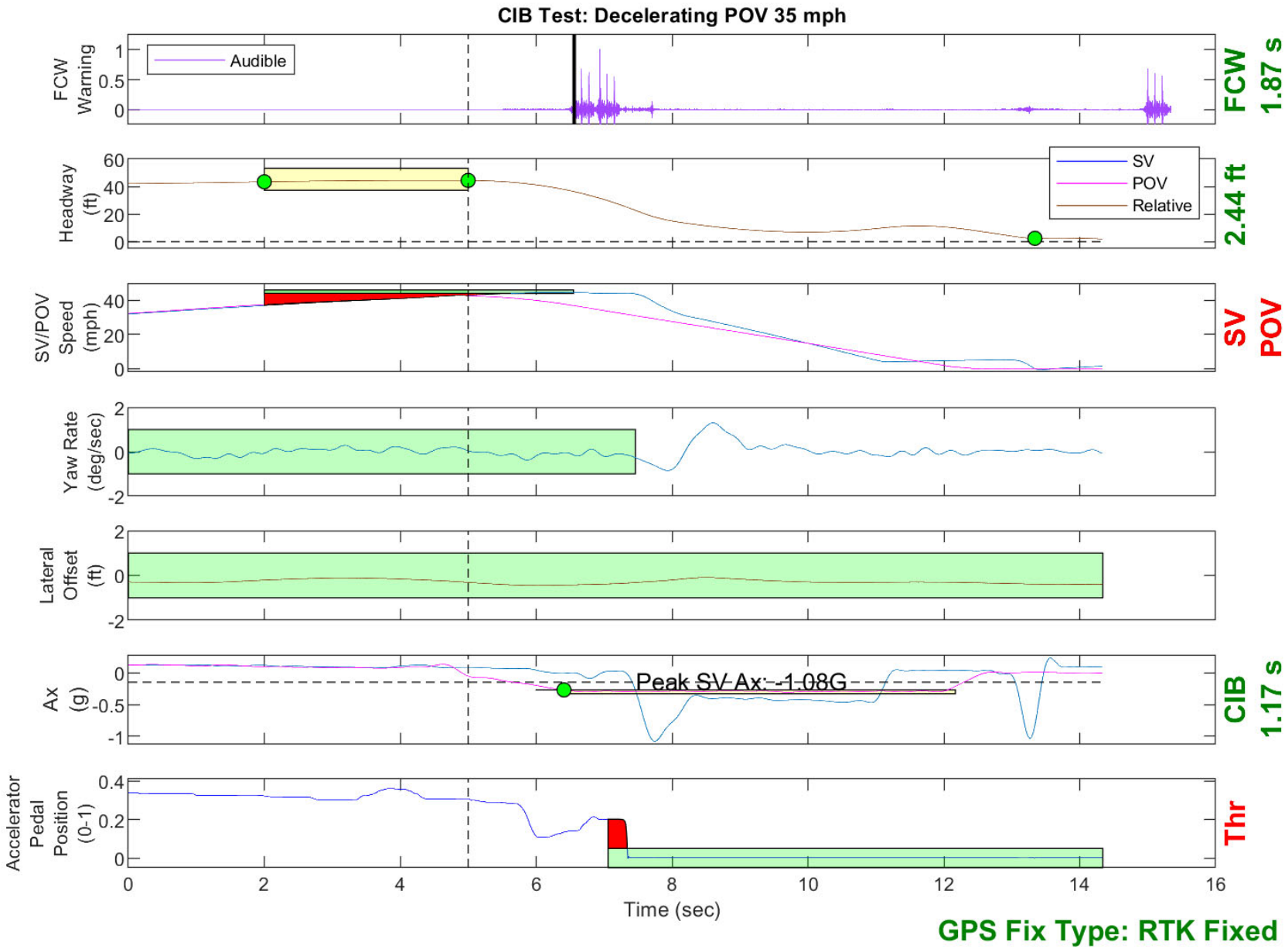


Figure D6. Example Time History Displaying Various Other Invalid Criteria

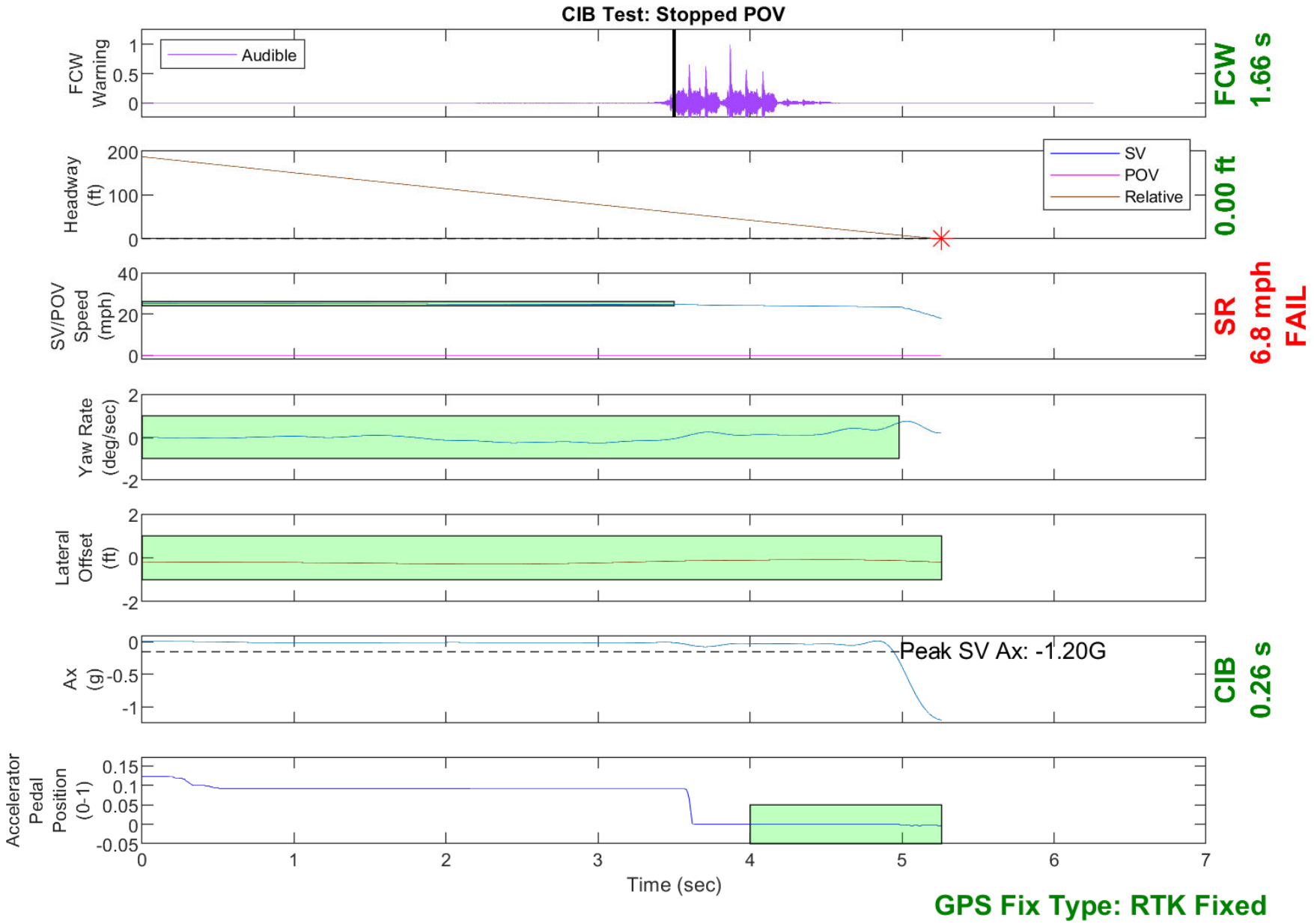


Figure D7. Example Time History for a Failed Run

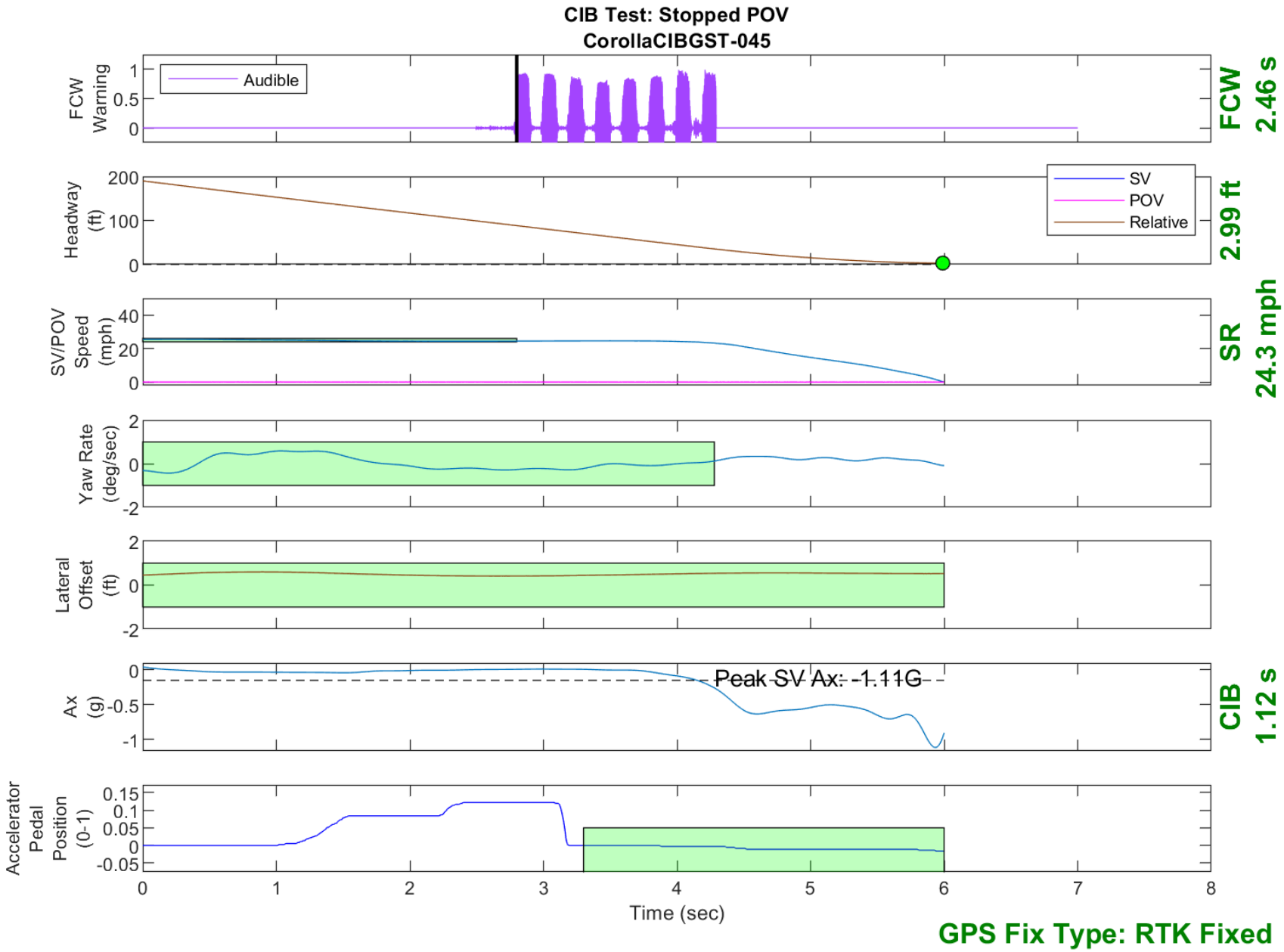


Figure D8. Time History for CIB Run 45, Stopped POV, 25 mph

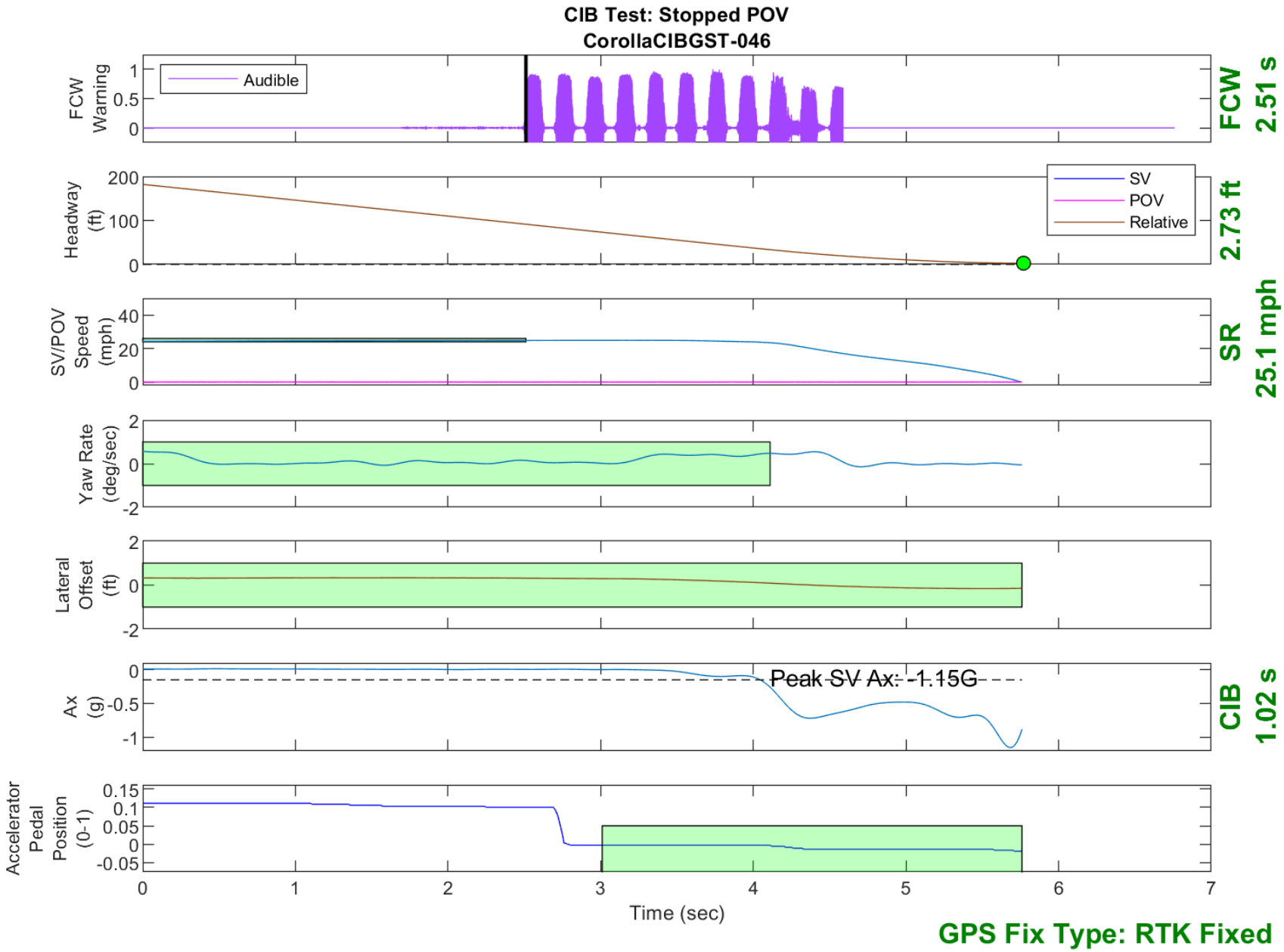


Figure D9. Time History for CIB Run 46, Stopped POV, 25 mph

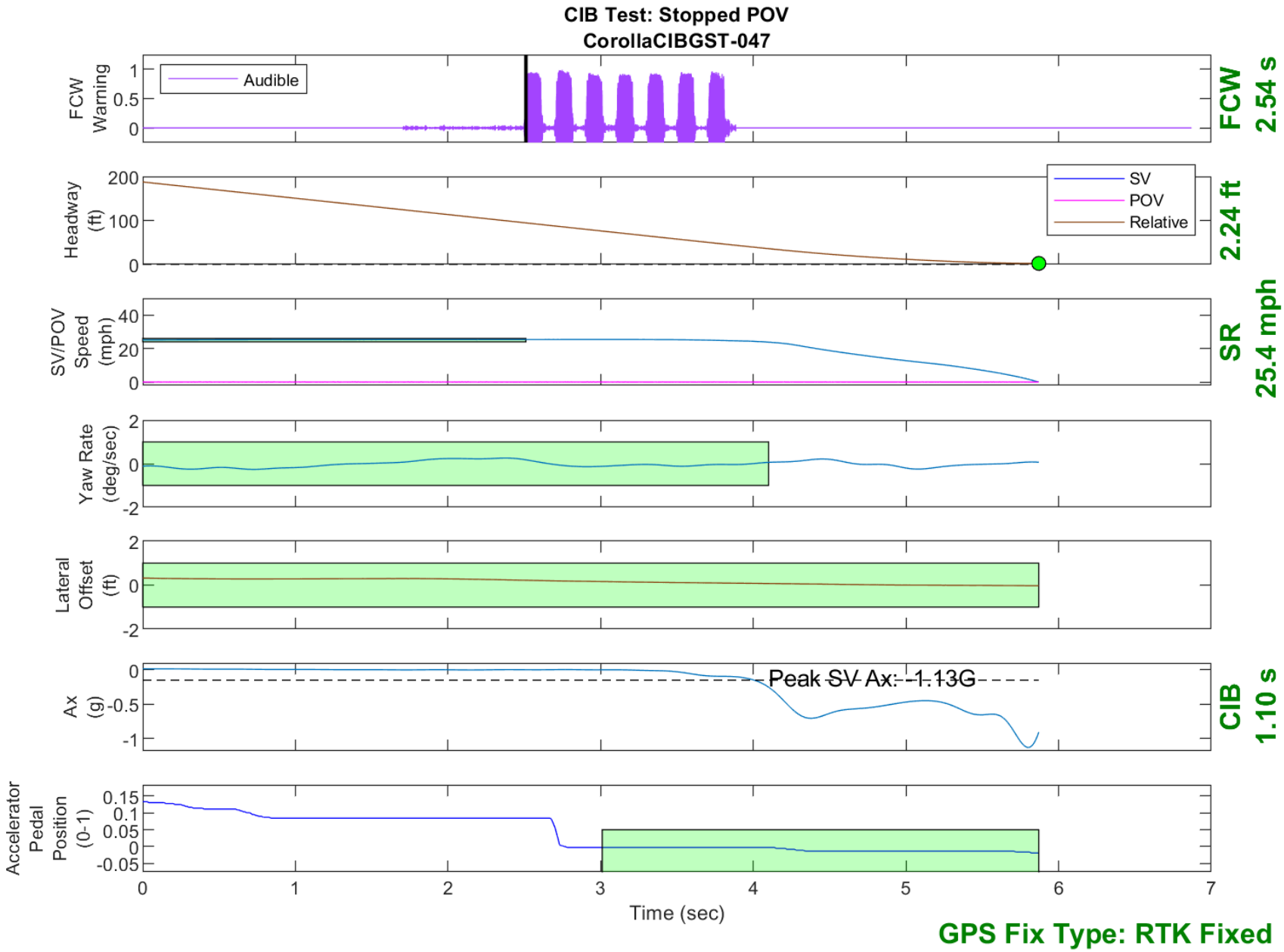


Figure D10. Time History for CIB Run 47, Stopped POV, 25 mph

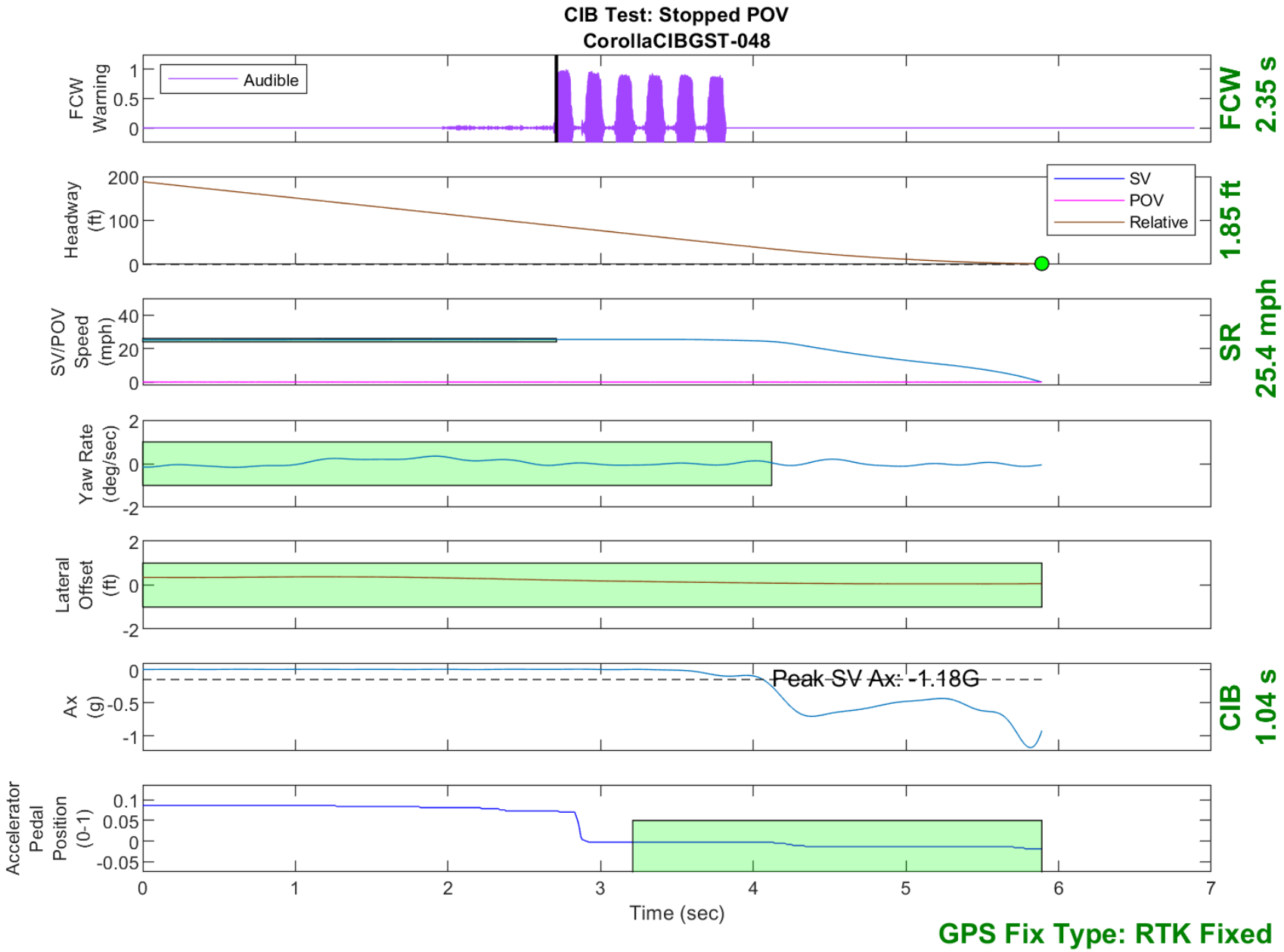


Figure D11. Time History for CIB Run 48, Stopped POV, 25 mph

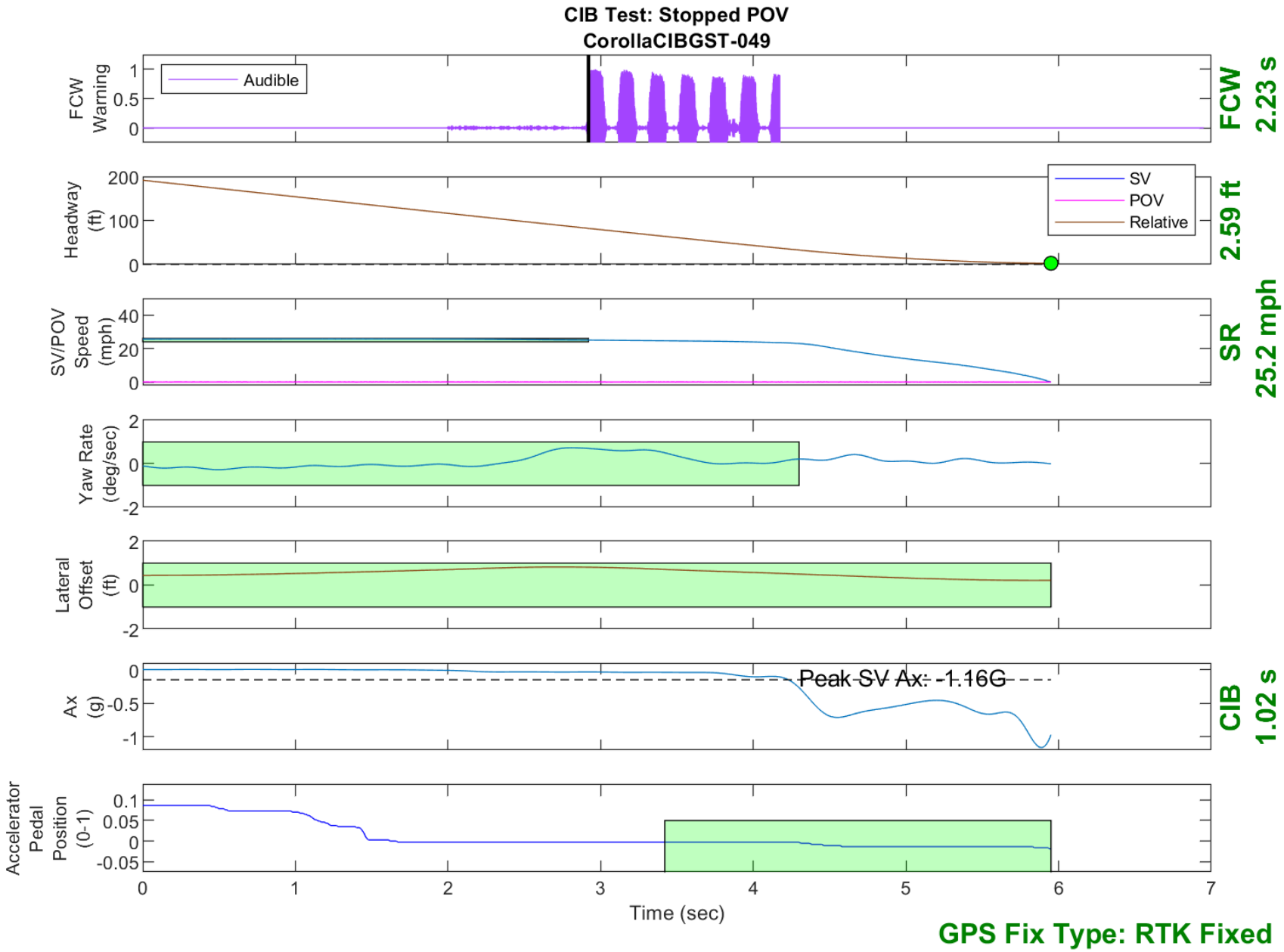


Figure D12. Time History for CIB Run 49, Stopped POV, 25 mph

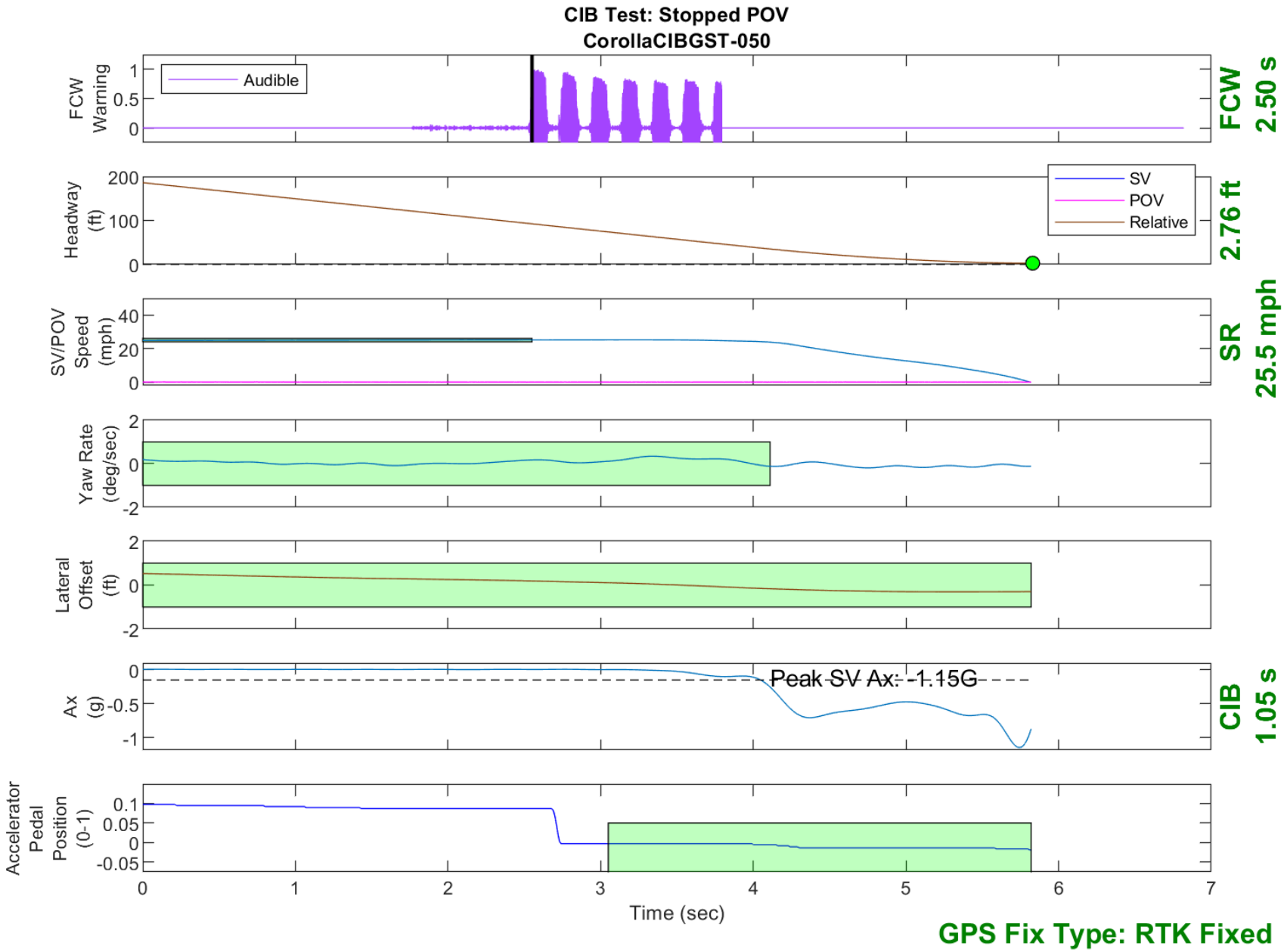


Figure D13. Time History for CIB Run 50, Stopped POV, 25 mph

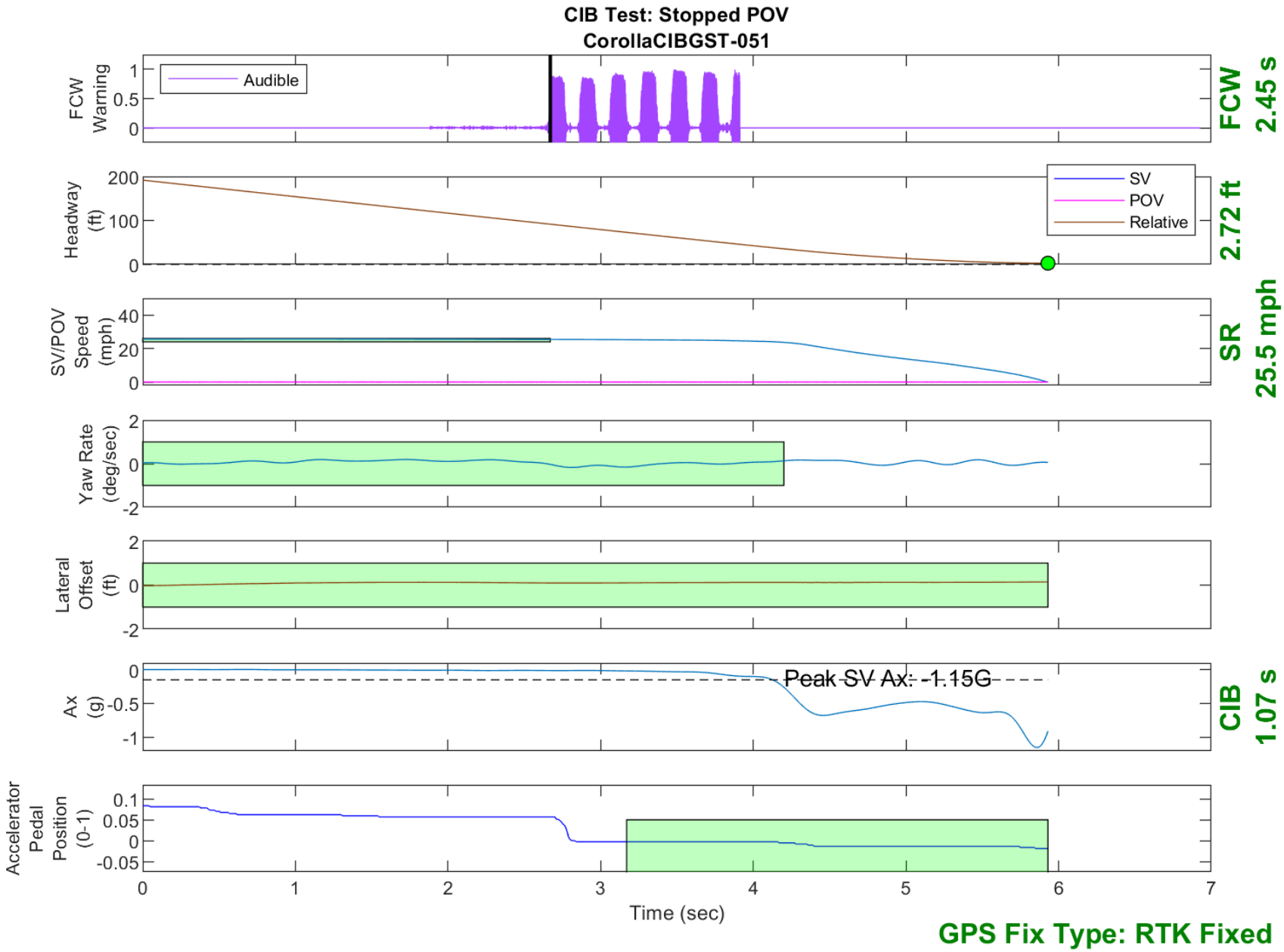


Figure D14. Time History for CIB Run 51, Stopped POV, 25 mph

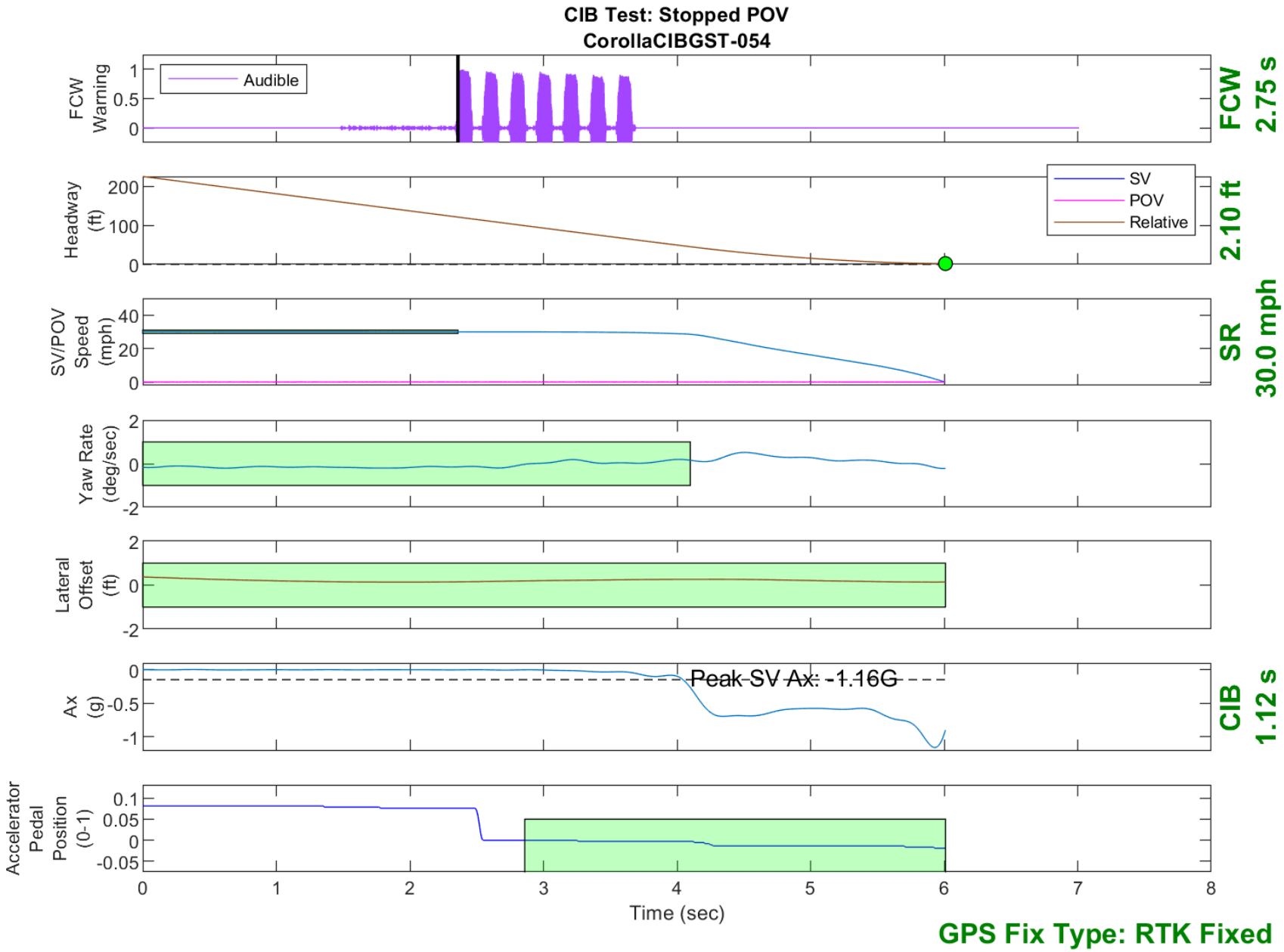


Figure D15. Time History for CIB Run 54, Stopped POV, 30 mph

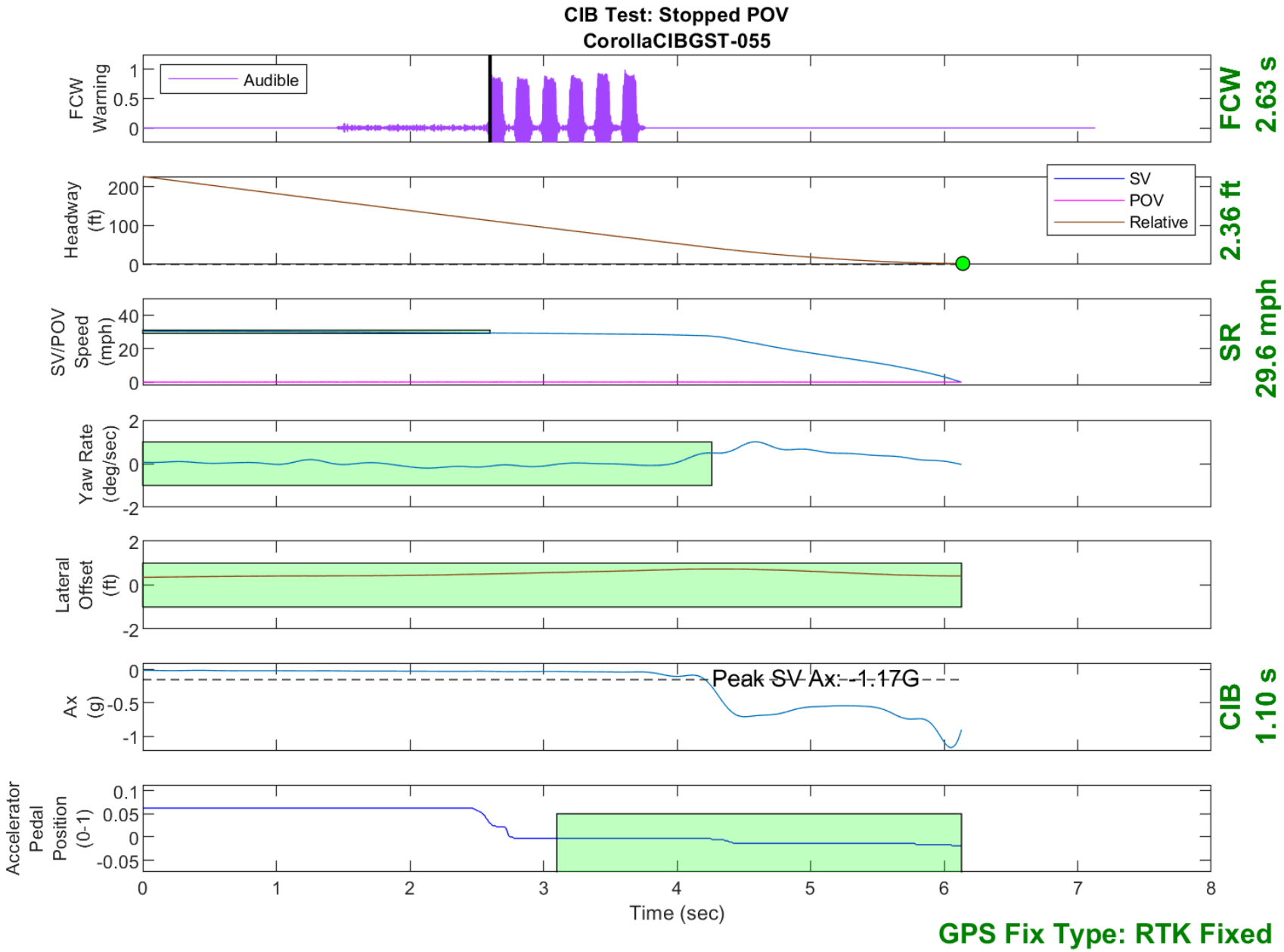


Figure D16. Time History for CIB Run 55, Stopped POV, 30 mph

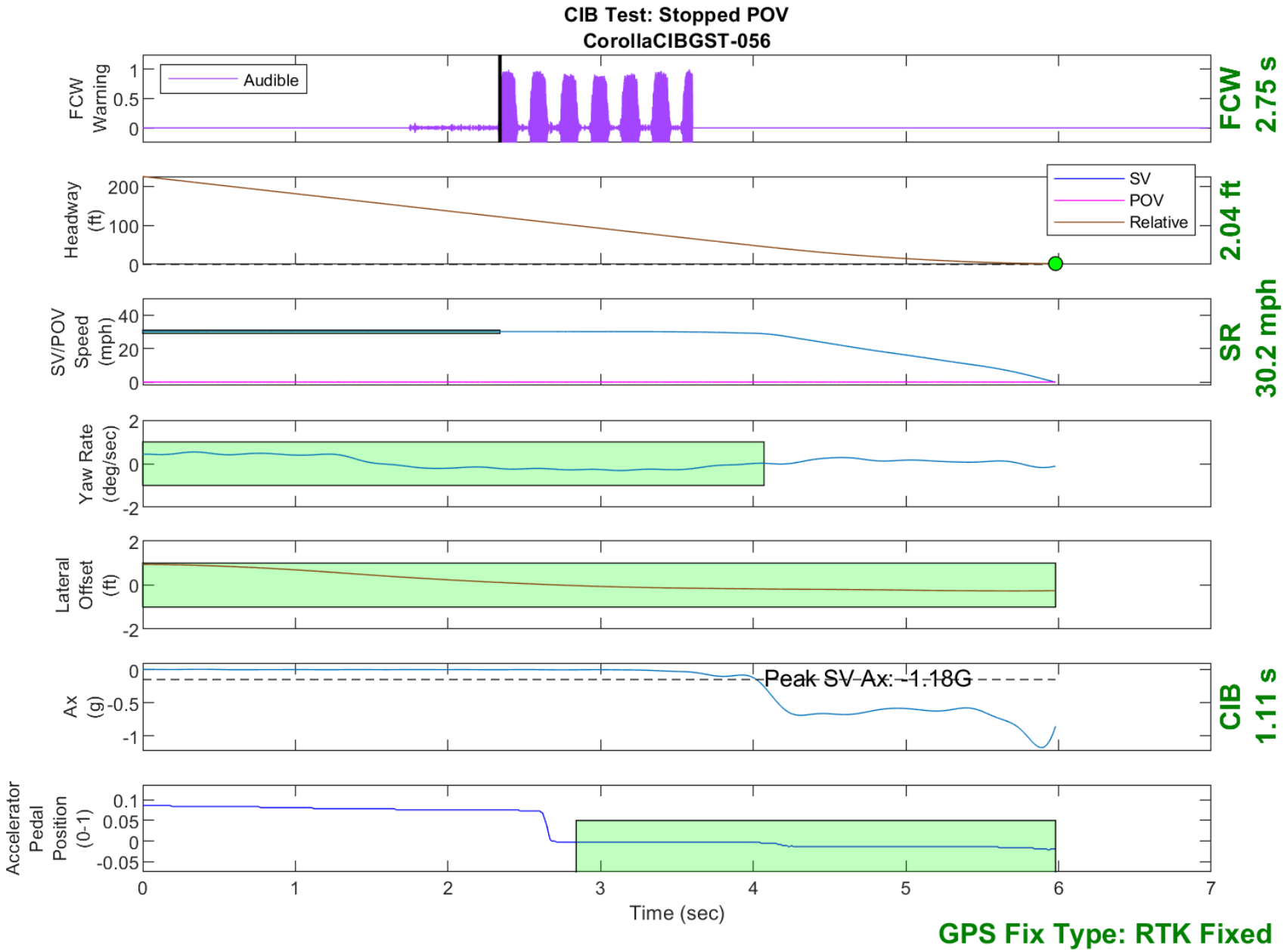


Figure D17. Time History for CIB Run 56, Stopped POV, 30 mph

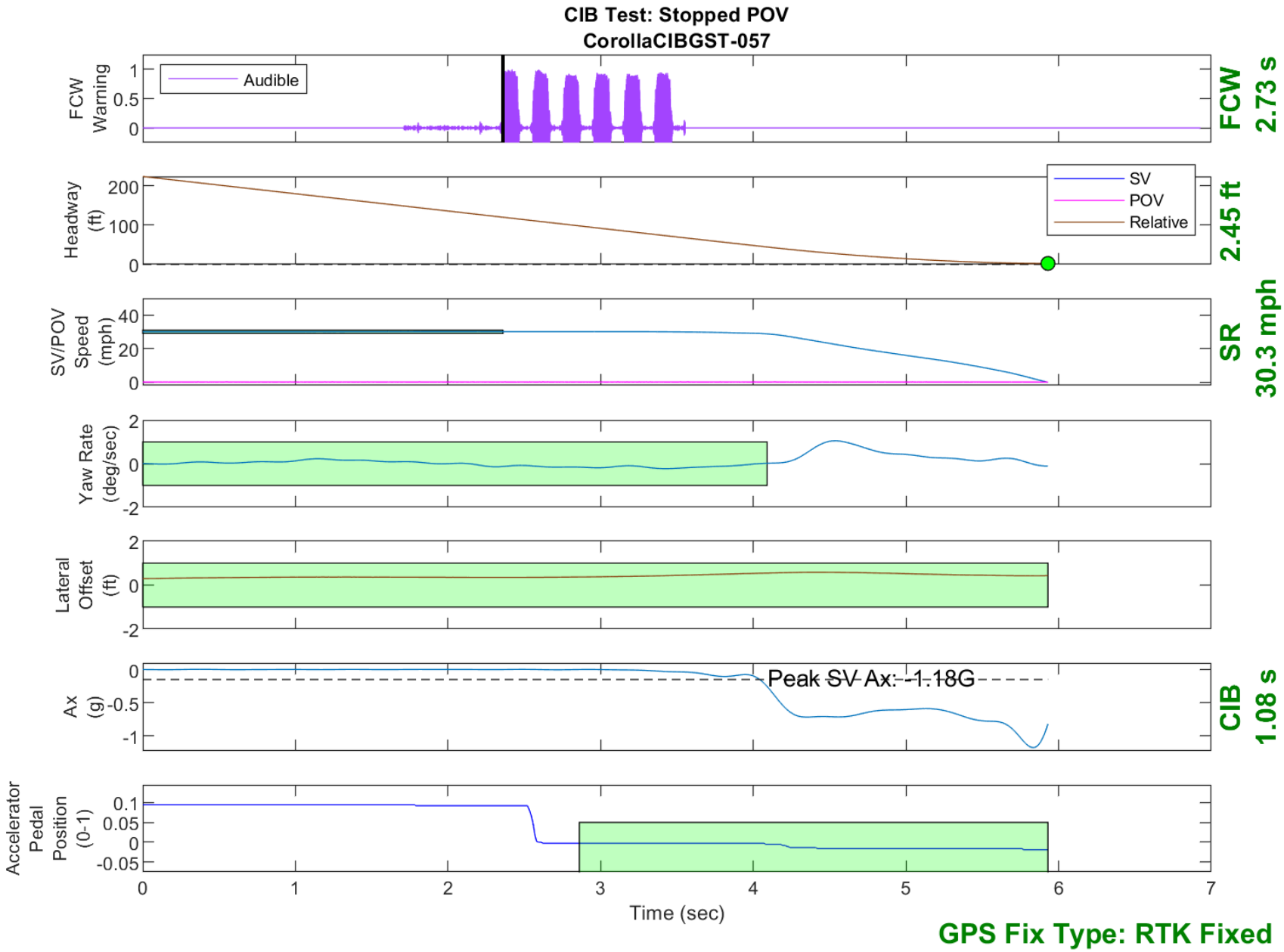


Figure D18. Time History for CIB Run 57, Stopped POV, 30 mph

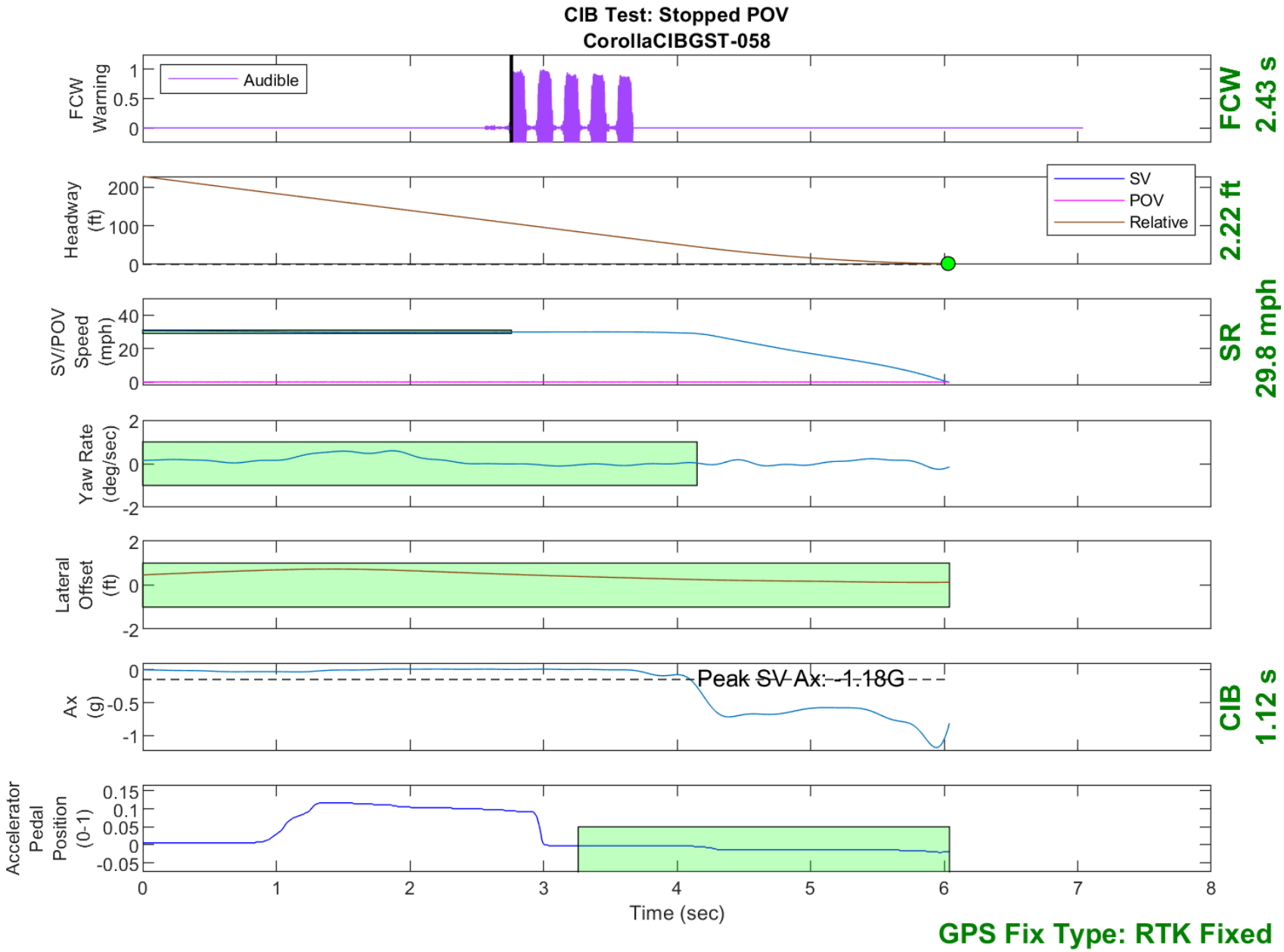


Figure D19. Time History for CIB Run 58, Stopped POV, 30 mph

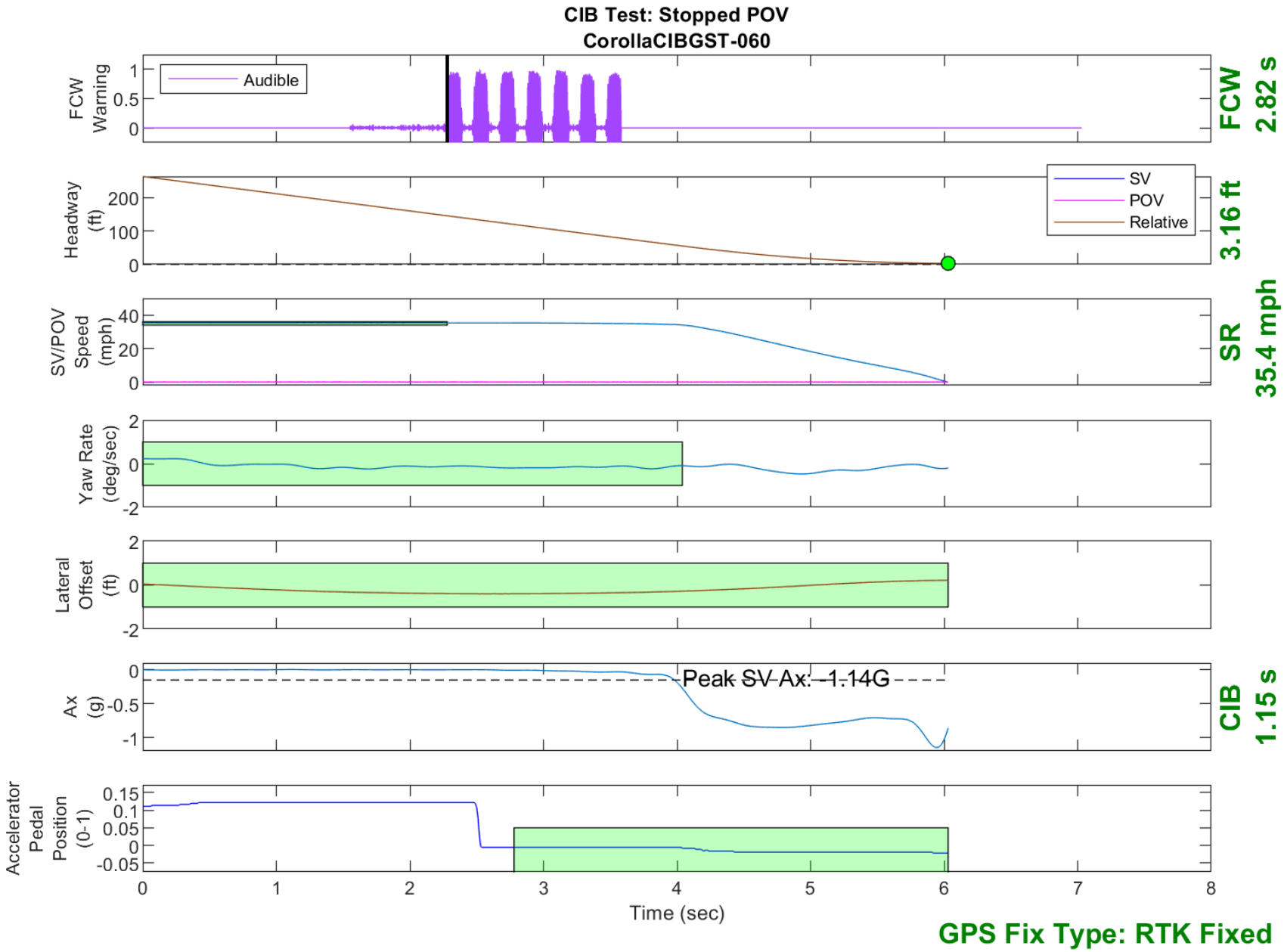


Figure D20. Time History for CIB Run 60, Stopped POV, 35 mph

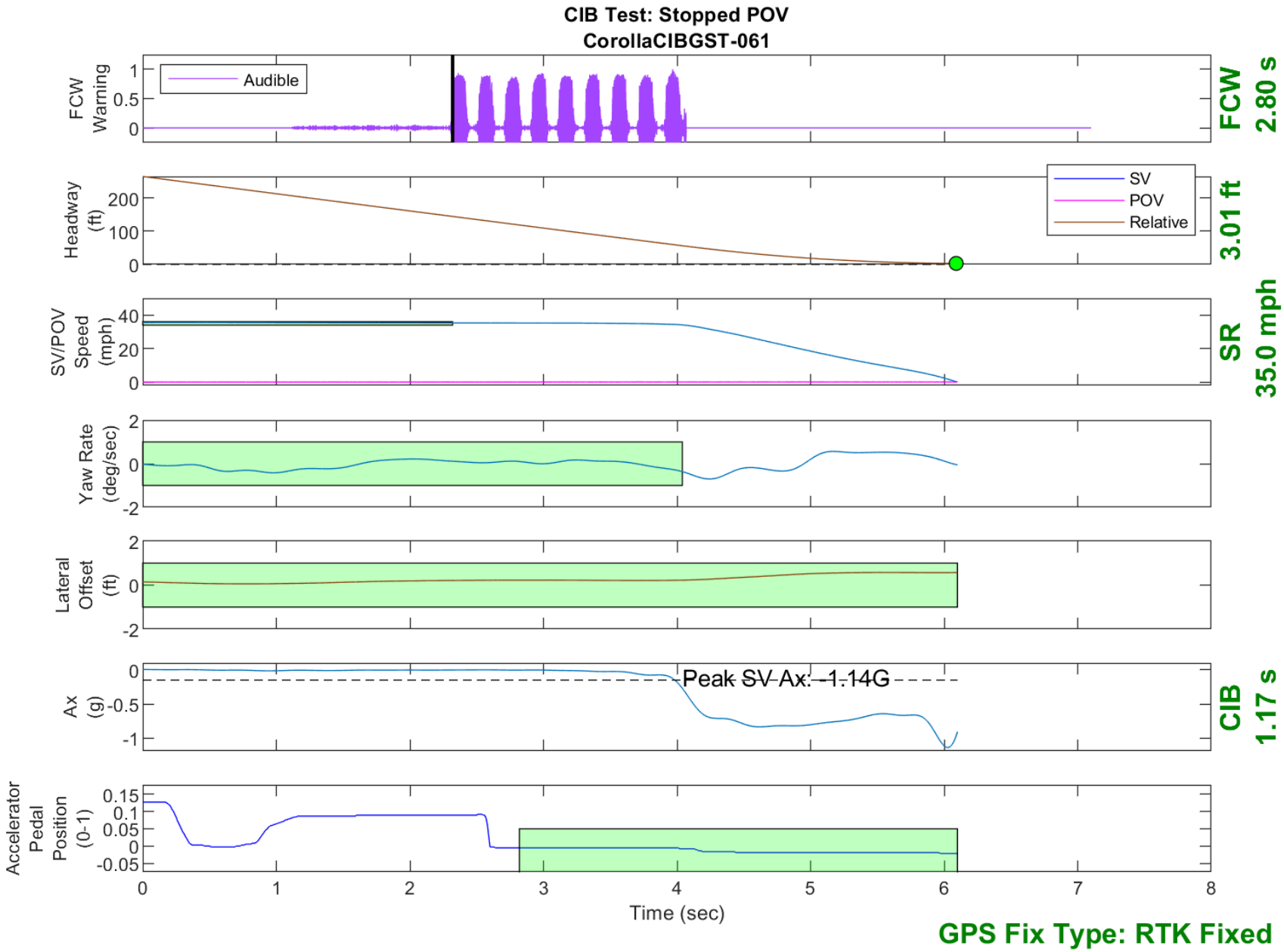


Figure D21. Time History for CIB Run 61, Stopped POV, 35 mph

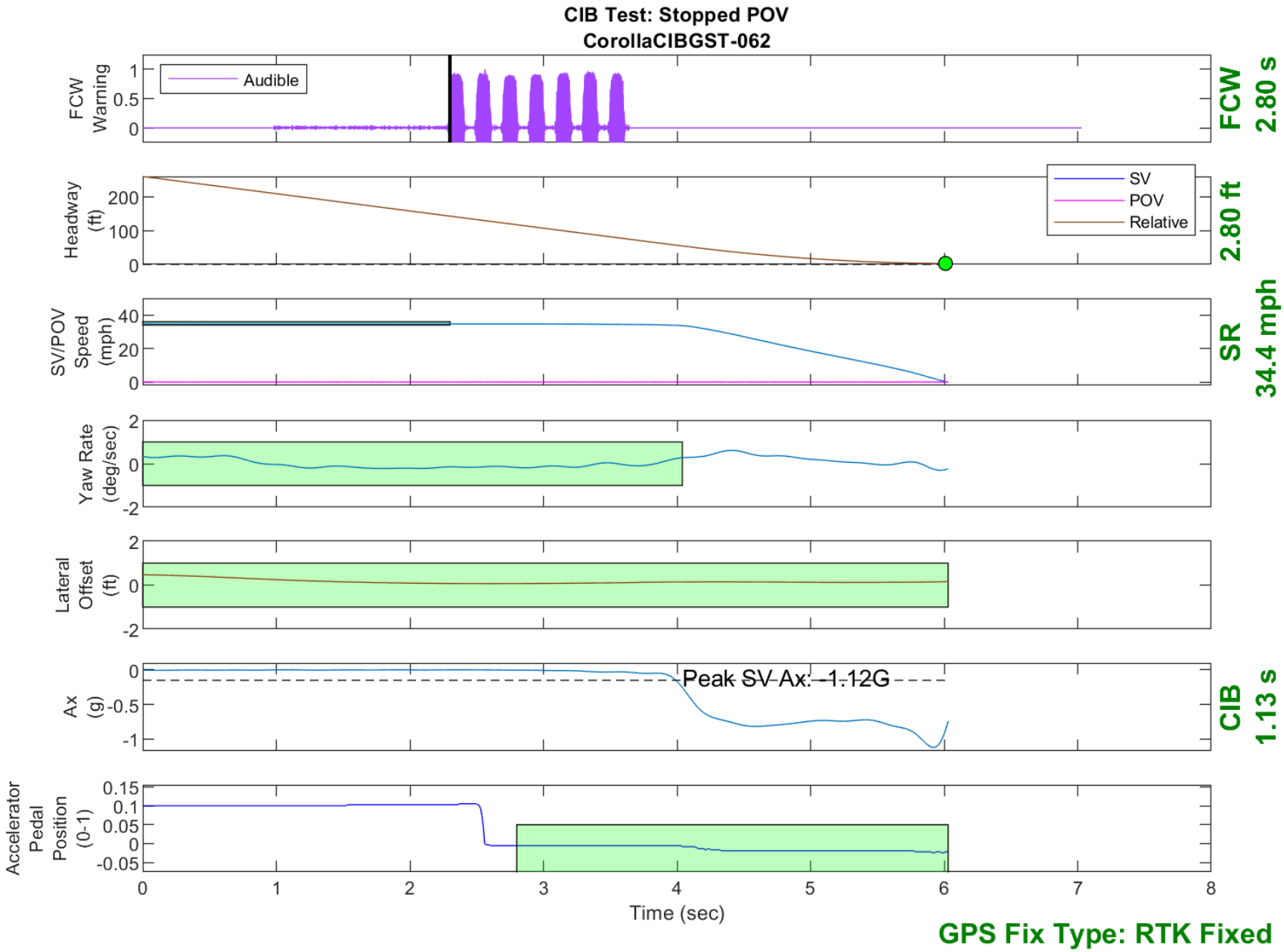


Figure D22. Time History for CIB Run 62, Stopped POV, 35 mph

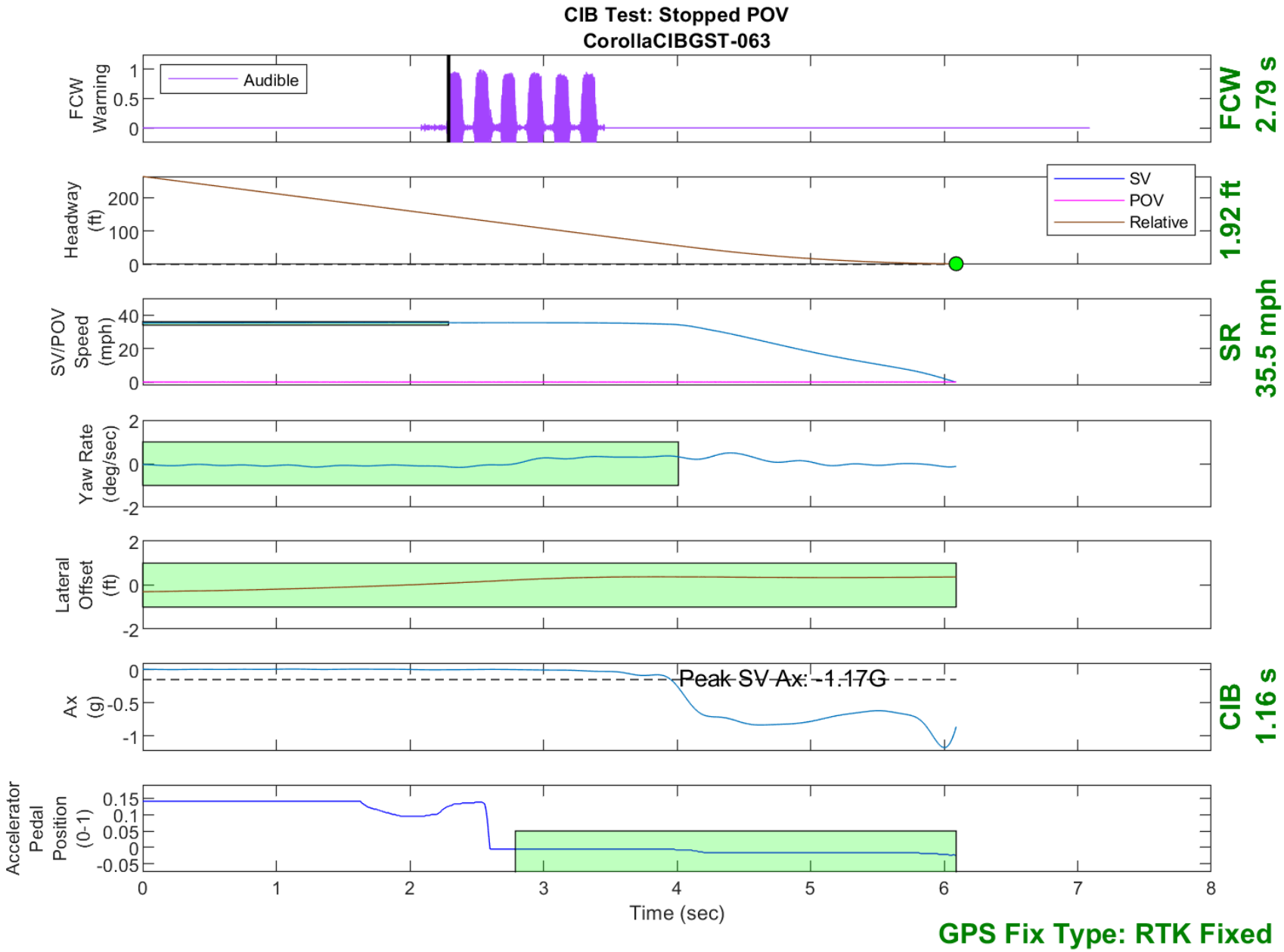


Figure D23. Time History for CIB Run 63, Stopped POV, 35 mph

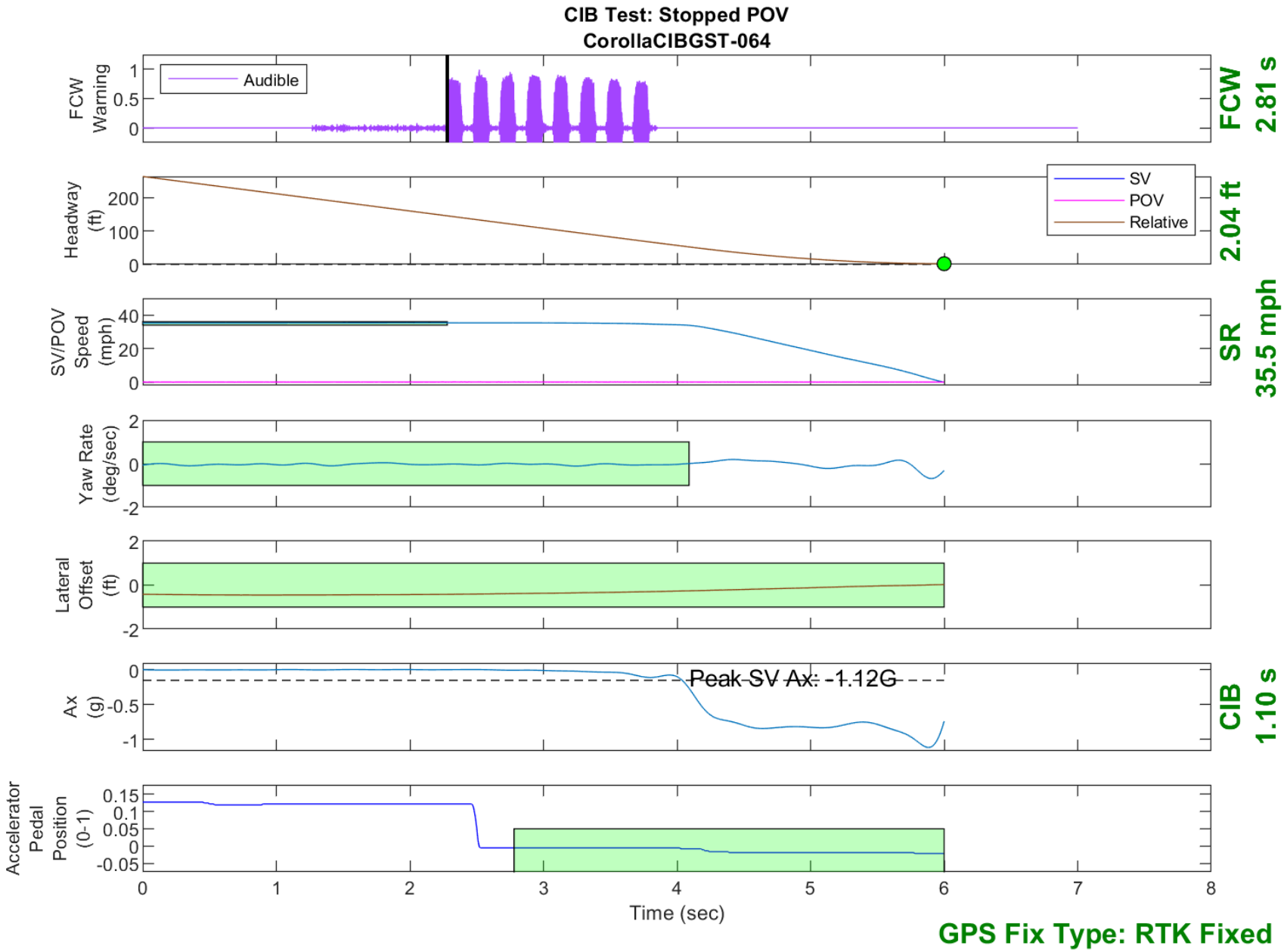


Figure D24. Time History for CIB Run 64, Stopped POV, 35 mph

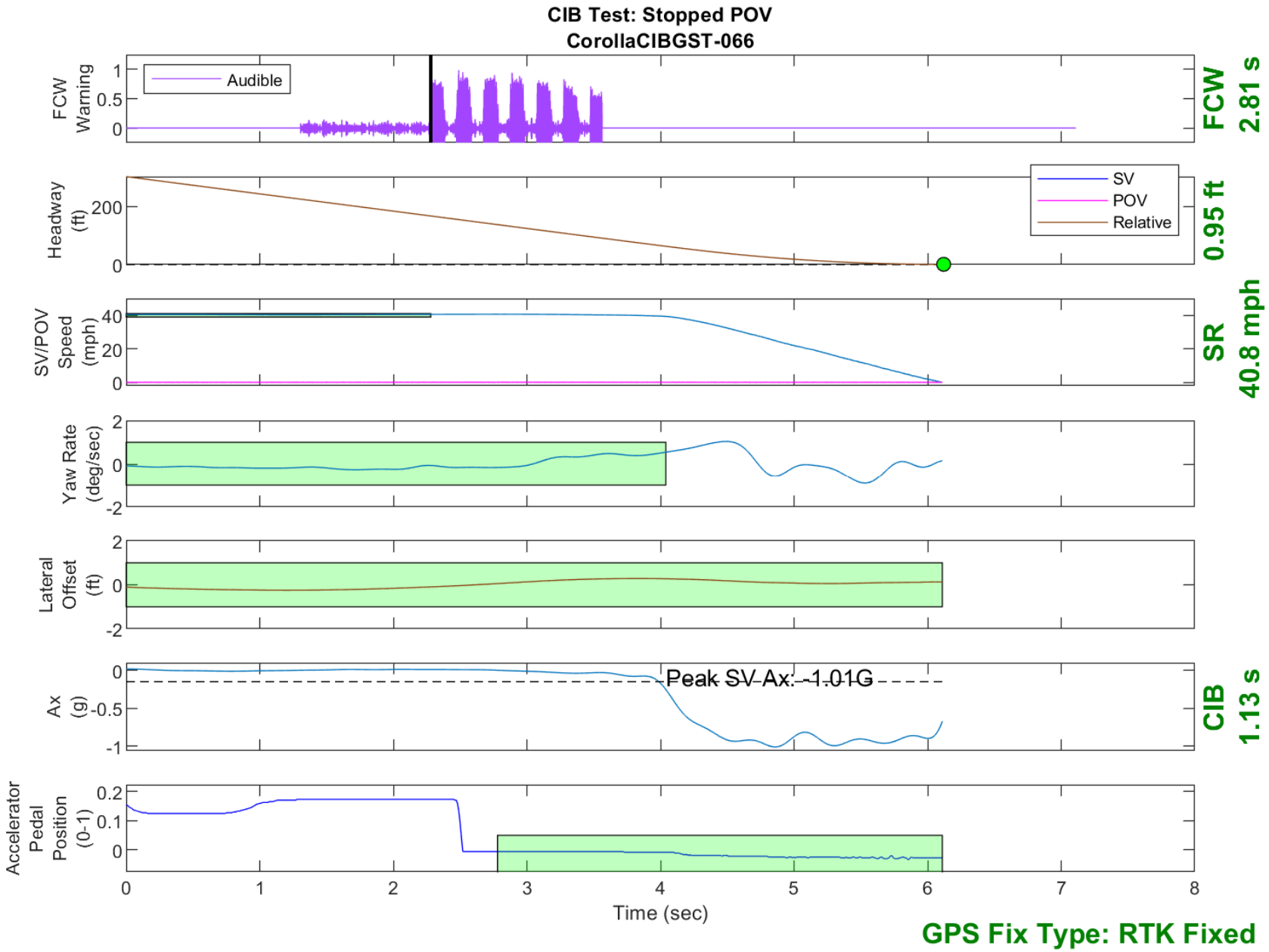


Figure D25. Time History for CIB Run 66, Stopped POV, 40 mph

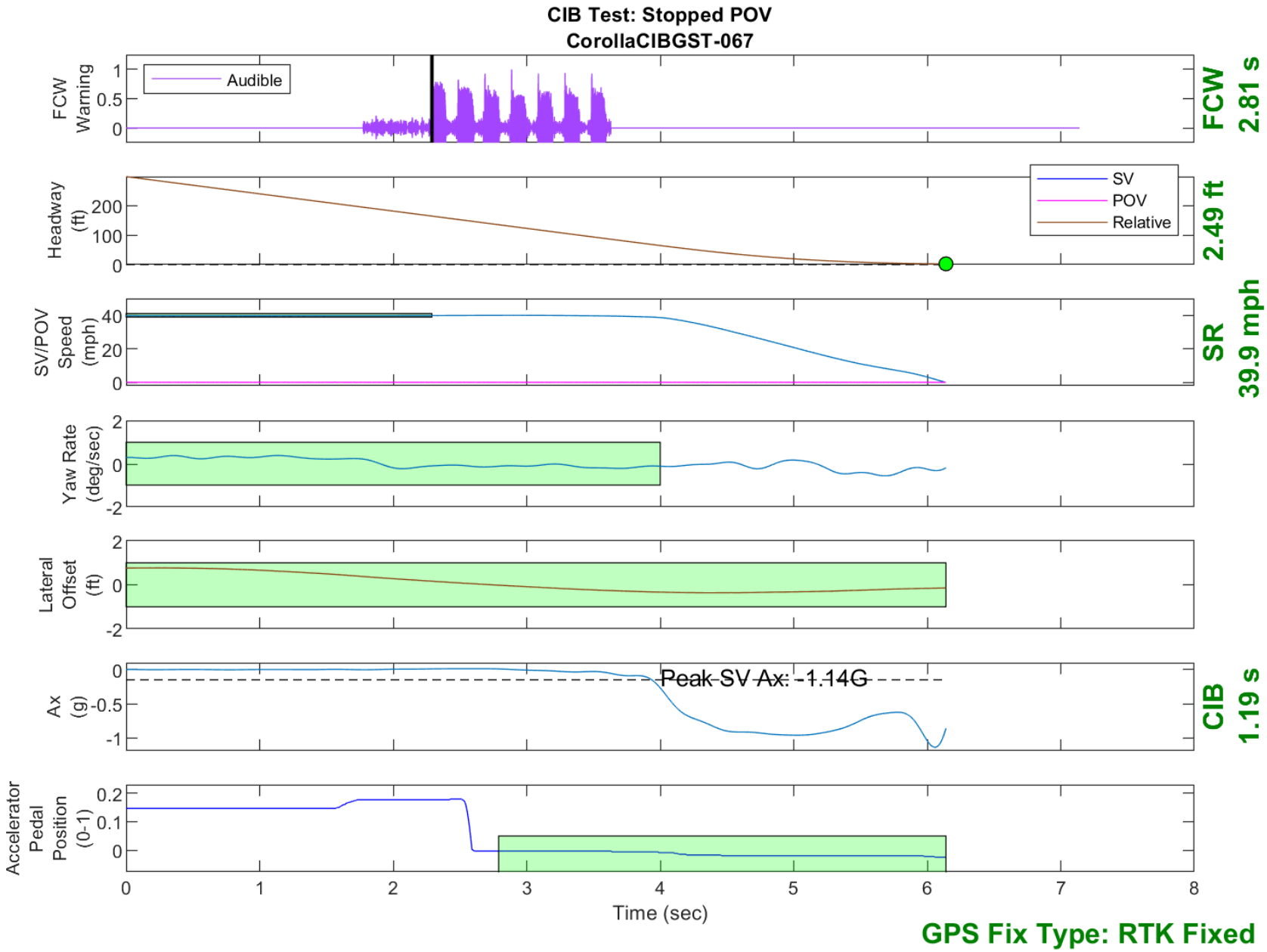


Figure D26. Time History for CIB Run 67, Stopped POV, 40 mph

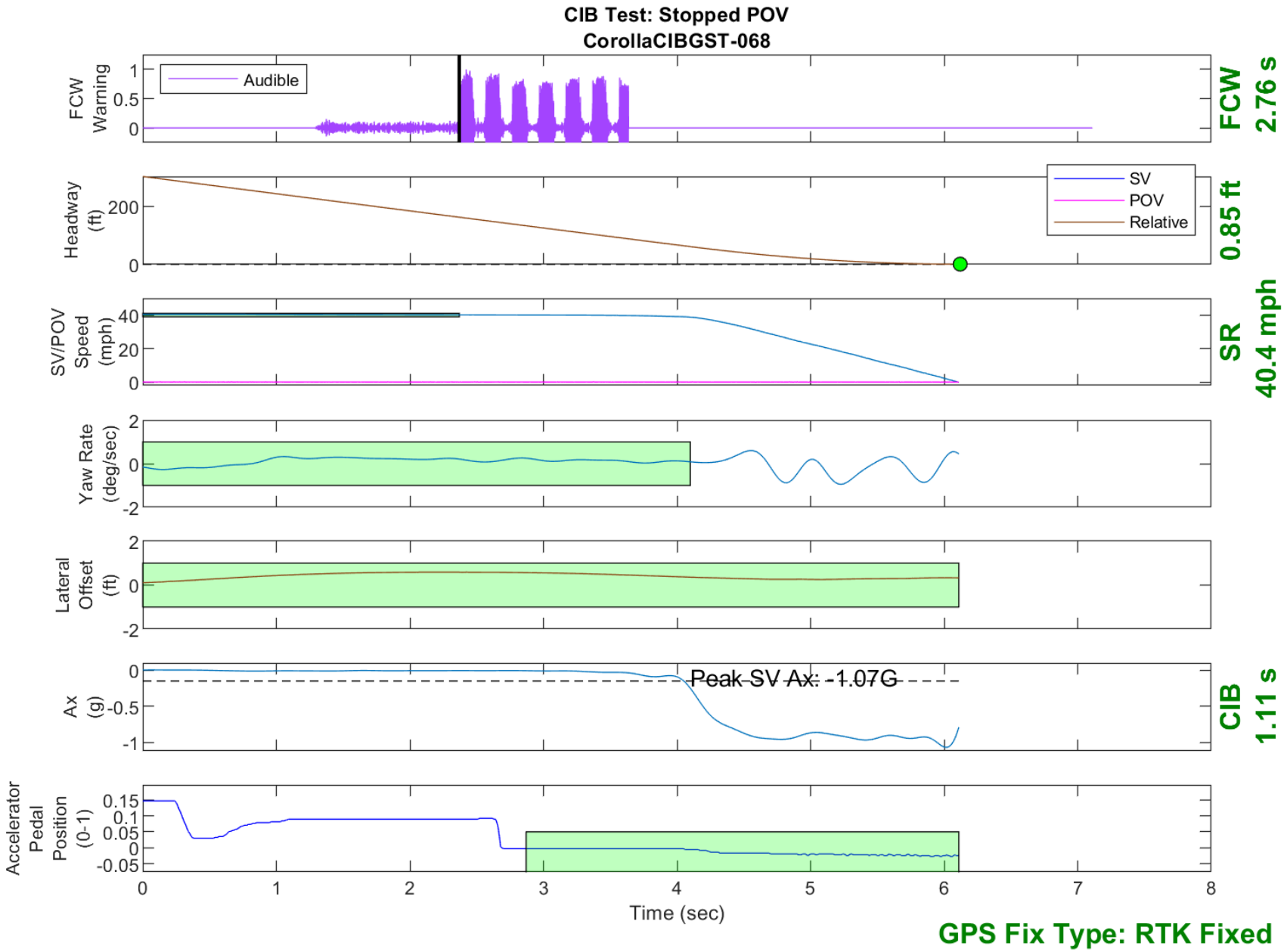


Figure D27. Time History for CIB Run 68, Stopped POV, 40 mph

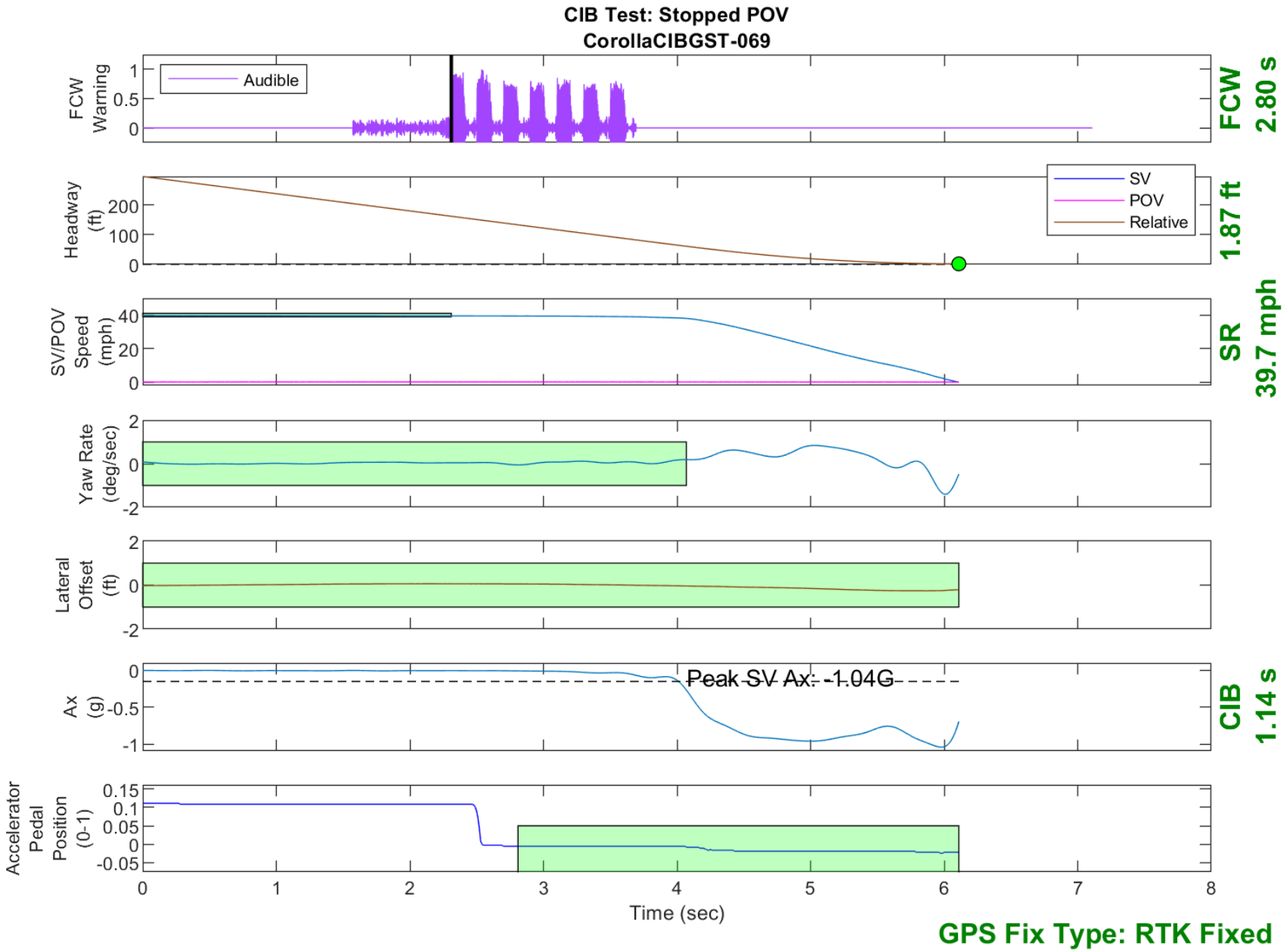


Figure D28. Time History for CIB Run 69, Stopped POV, 40 mph

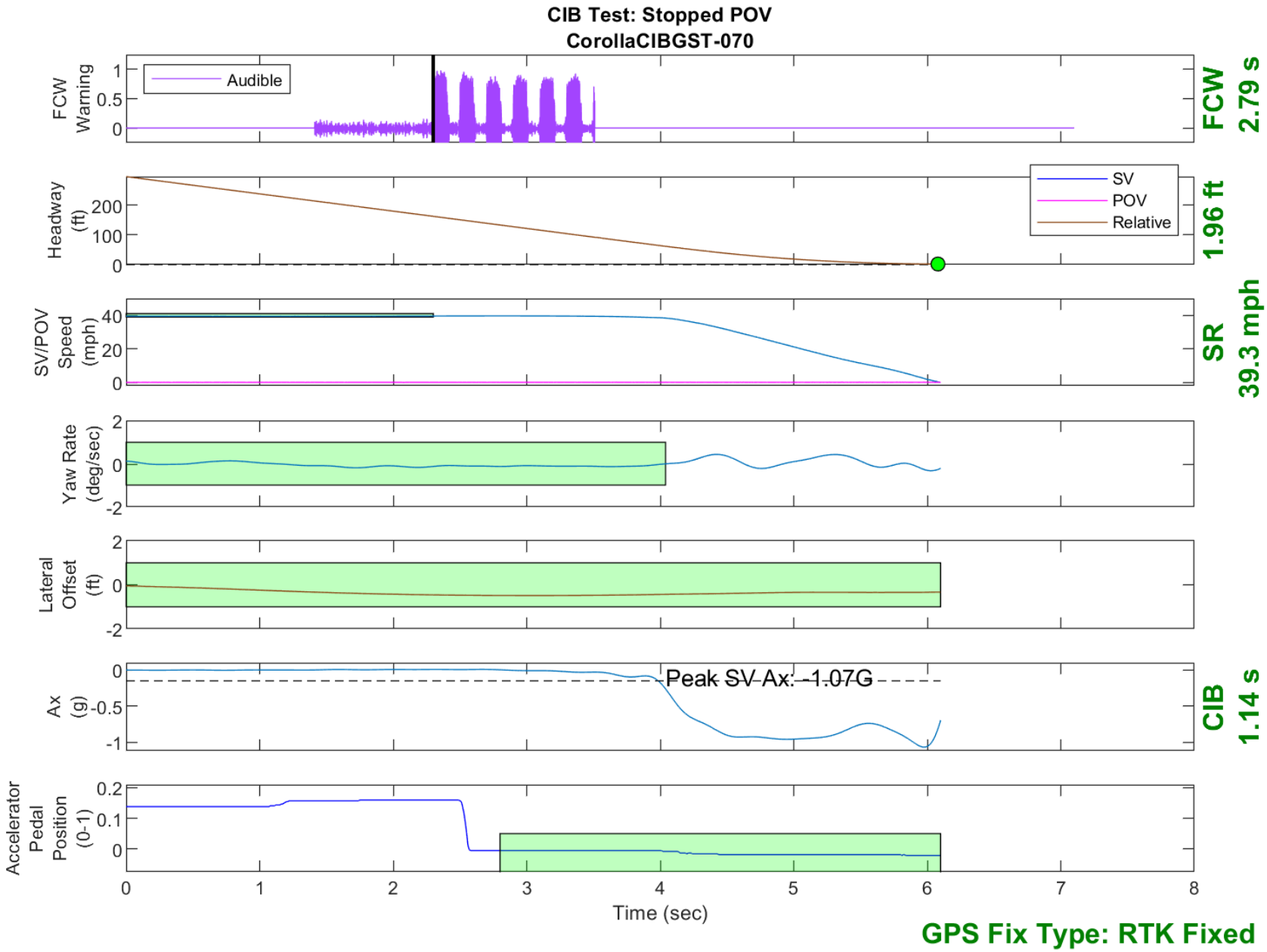


Figure D29. Time History for CIB Run 70, Stopped POV, 40 mph

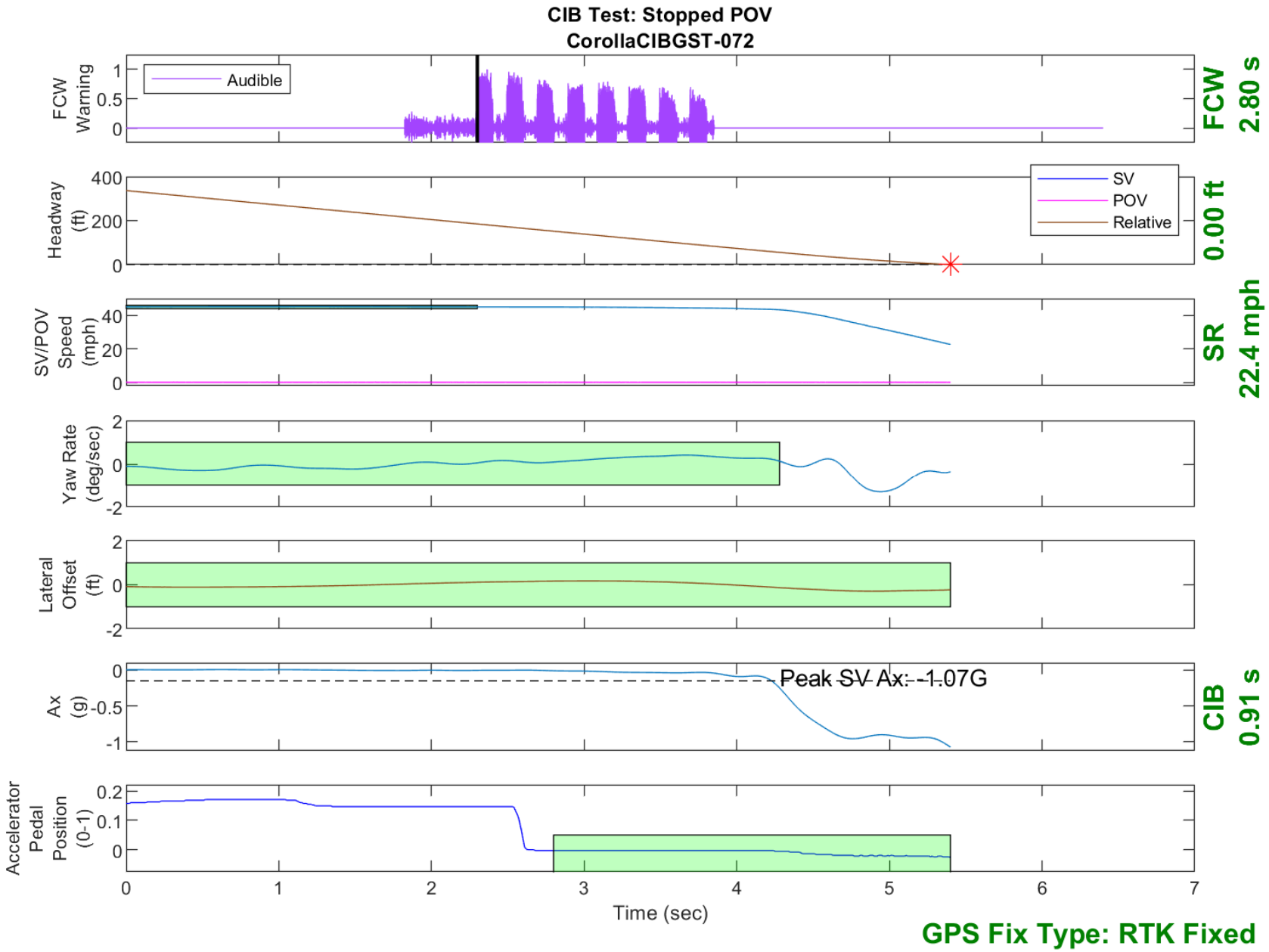


Figure D30. Time History for CIB Run 72, Stopped POV, 45 mph

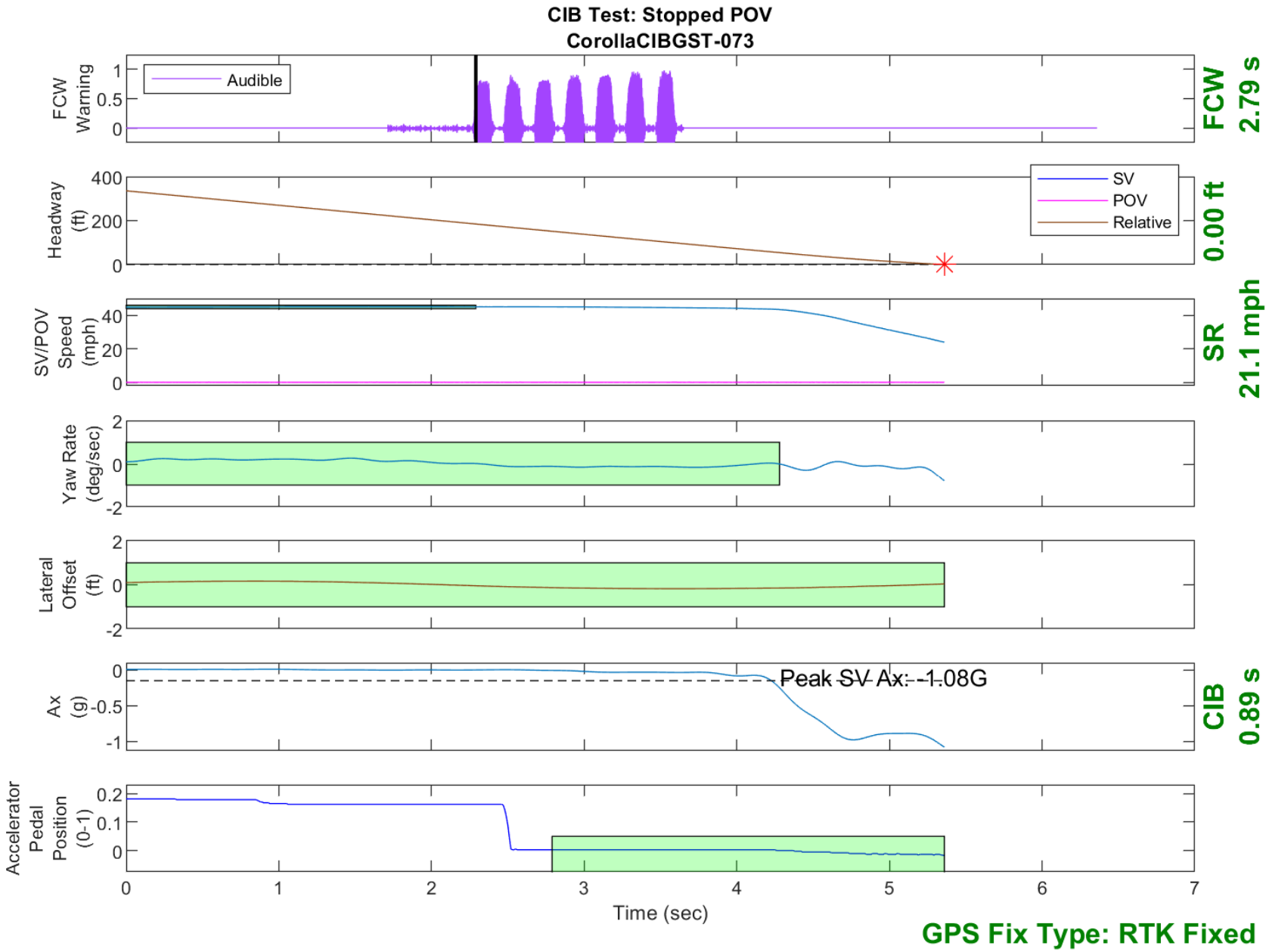


Figure D31. Time History for CIB Run 73, Stopped POV, 45 mph

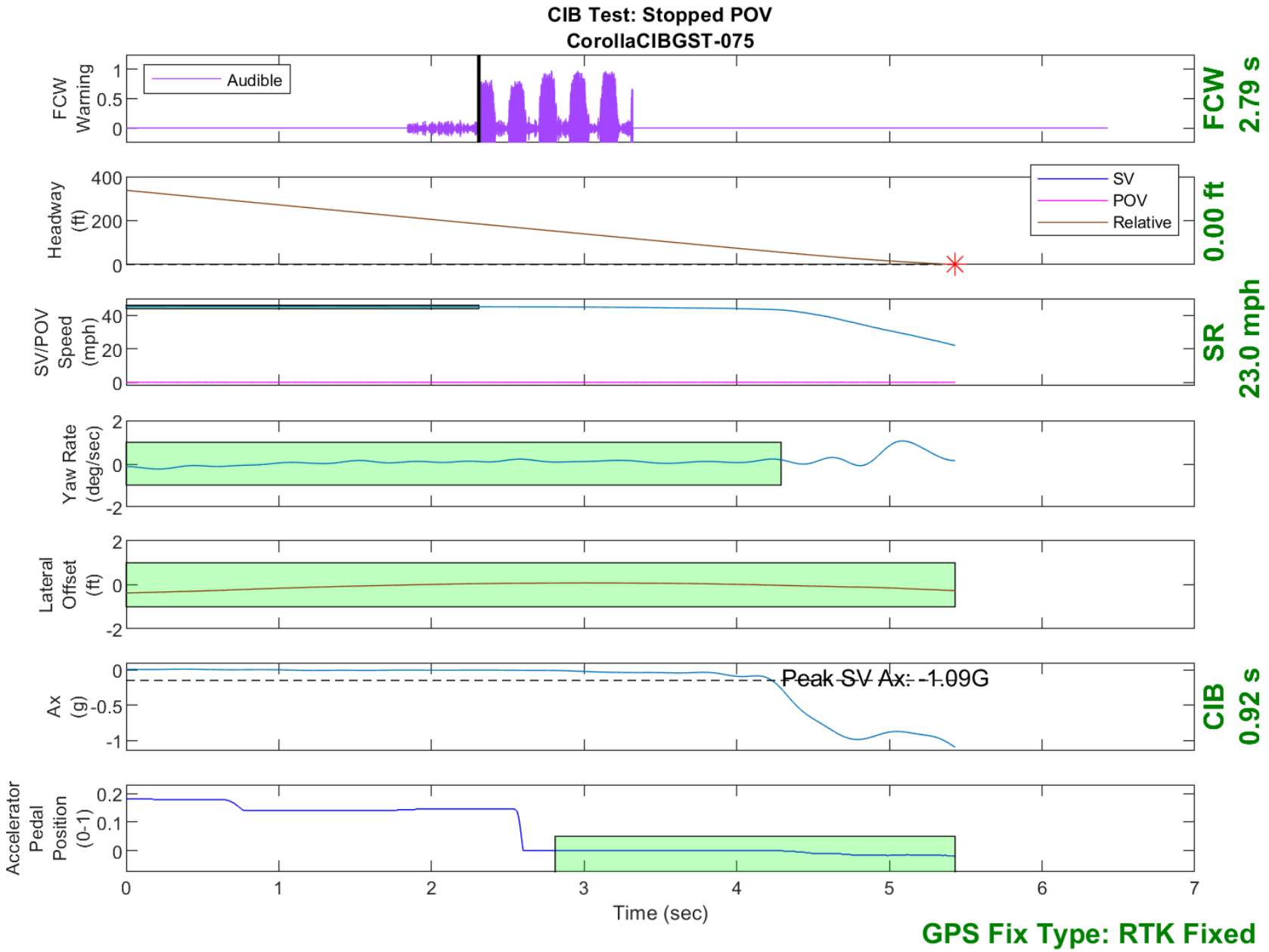


Figure D32. Time History for CIB Run 75, Stopped POV, 45 mph

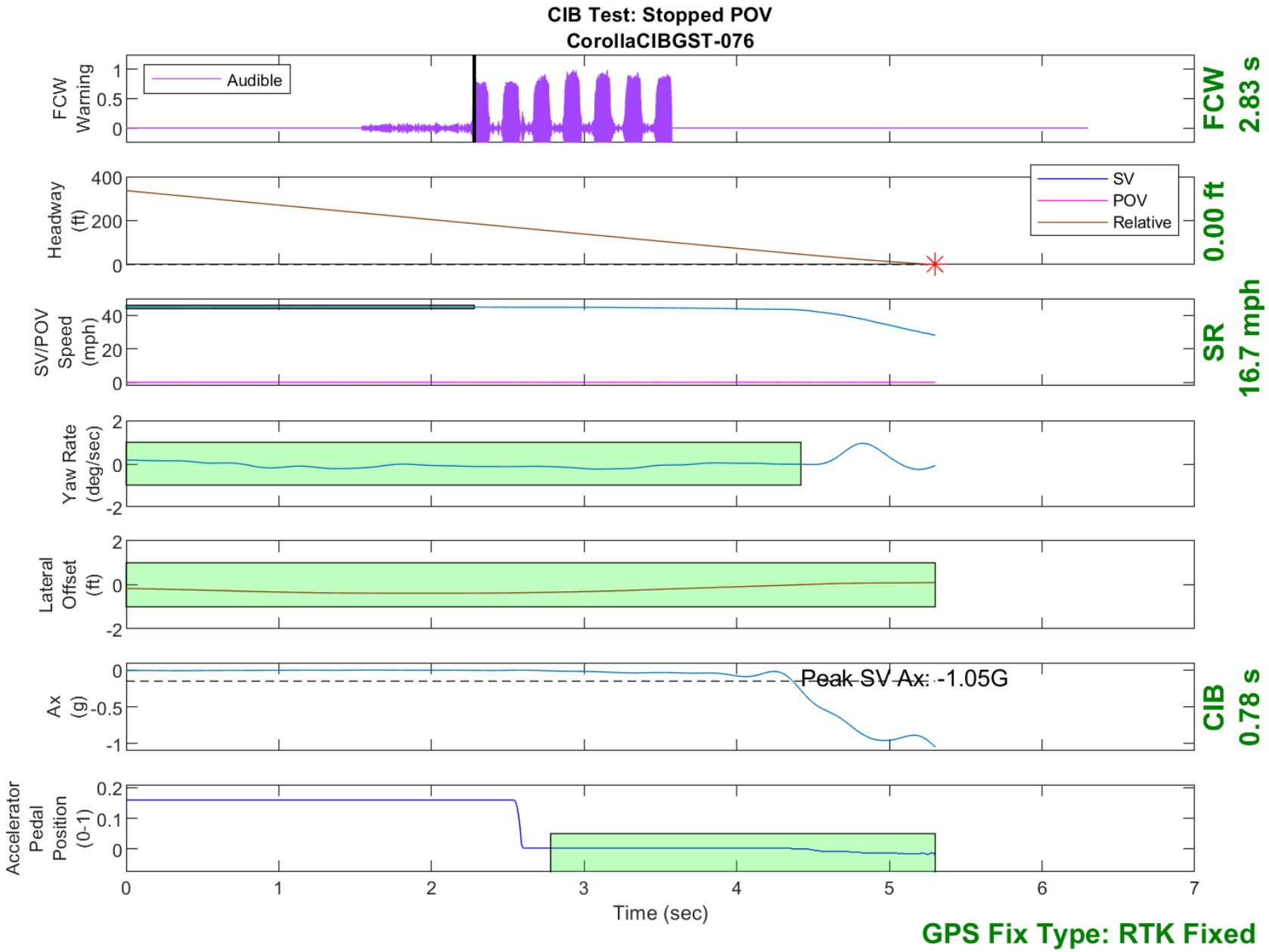


Figure D33. Time History for CIB Run 76, Stopped POV, 45 mph

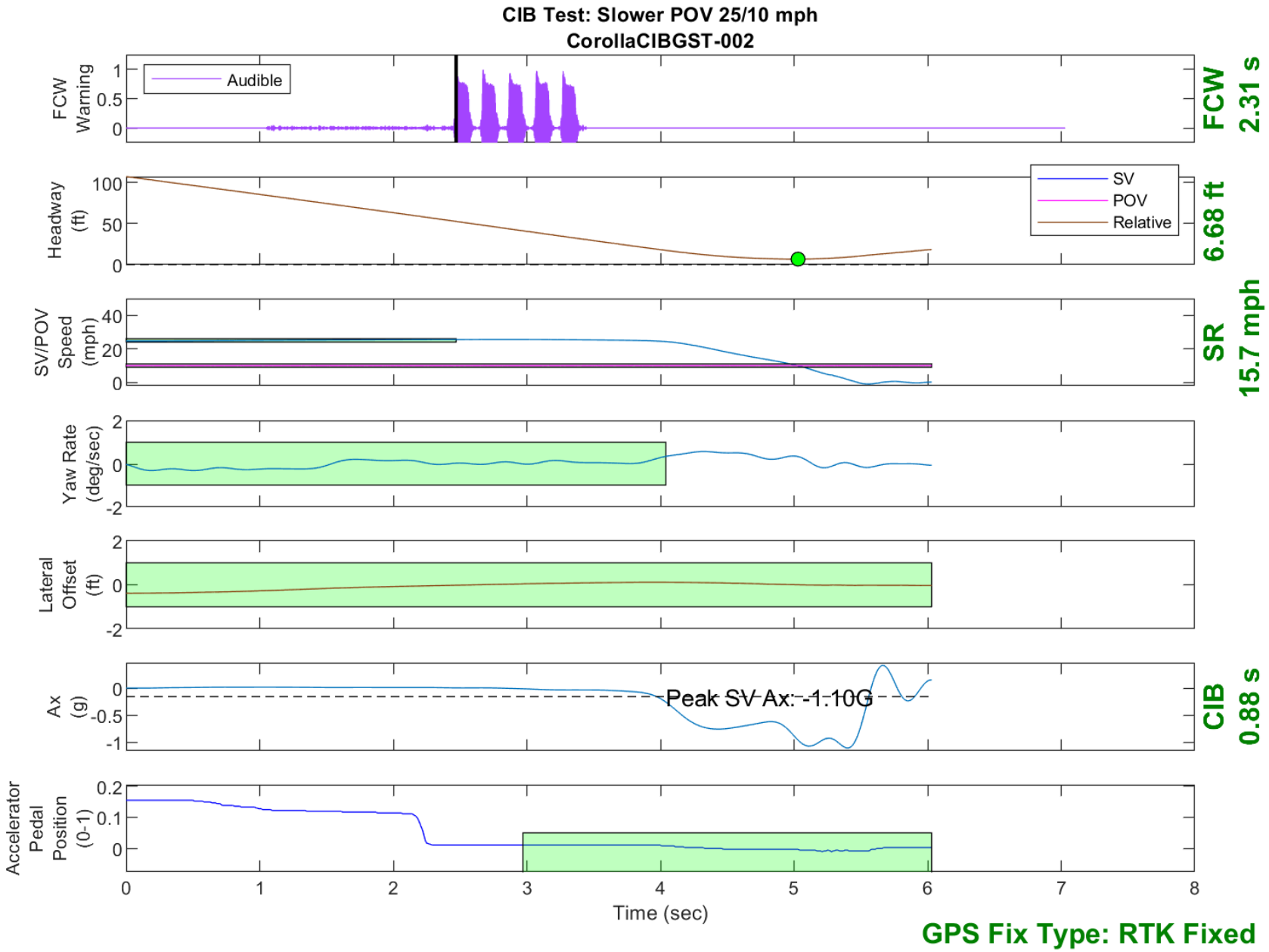


Figure D34. Time History for CIB Run 2, Slower POV, 25/10 mph

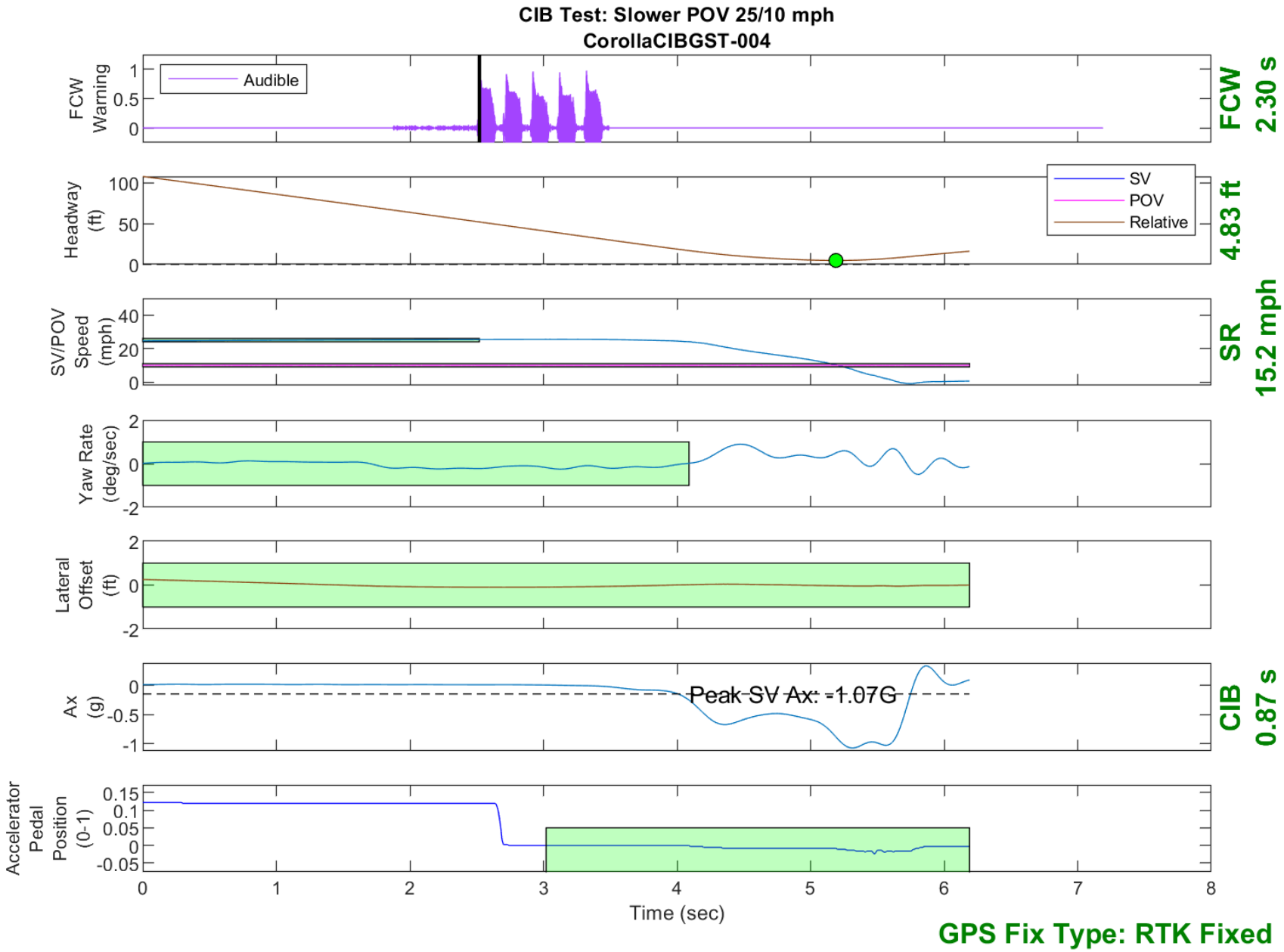


Figure D35. Time History for CIB Run 4, Slower POV, 25/10 mph

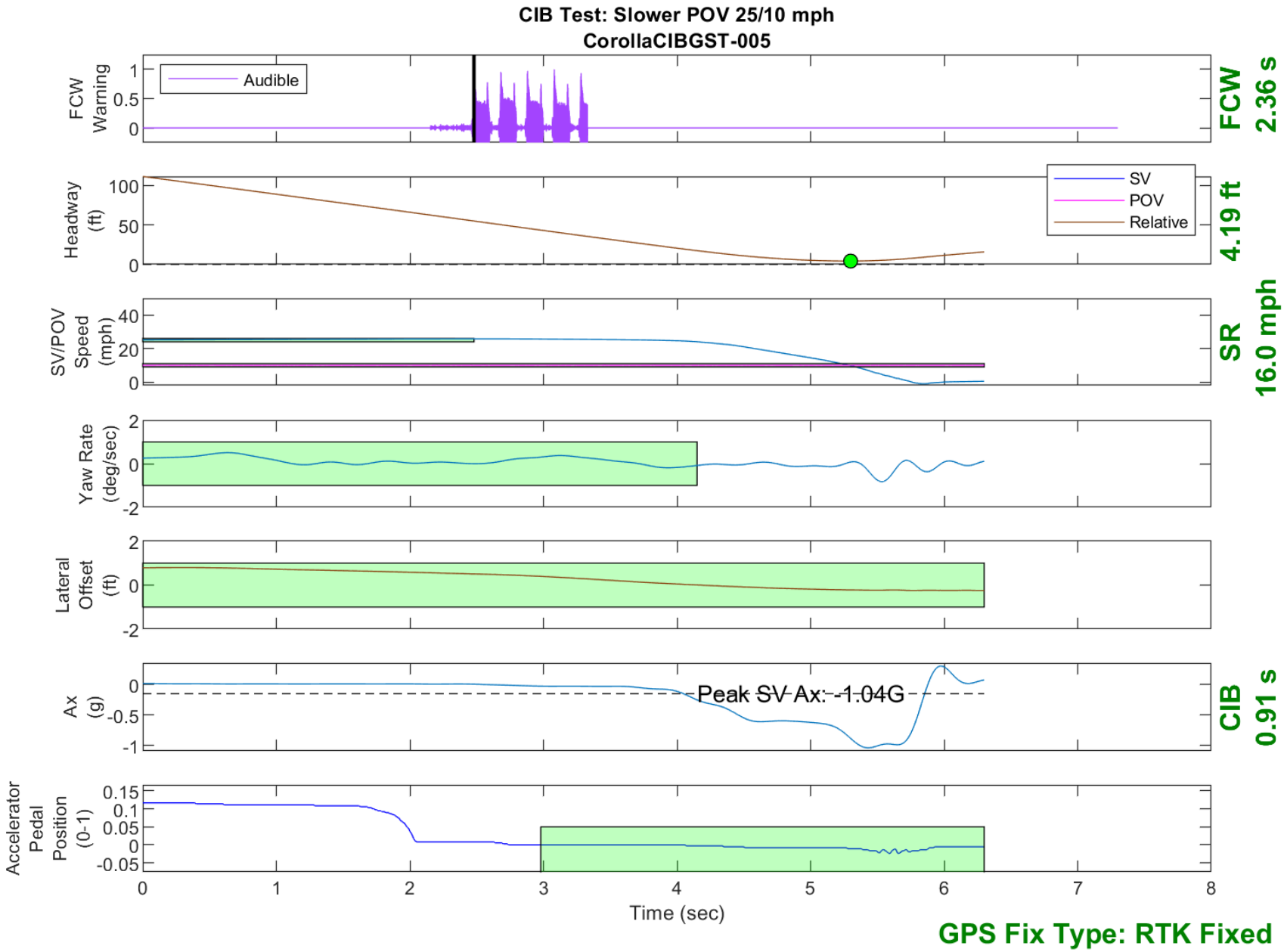


Figure D36. Time History for CIB Run 5, Slower POV, 25/10 mph

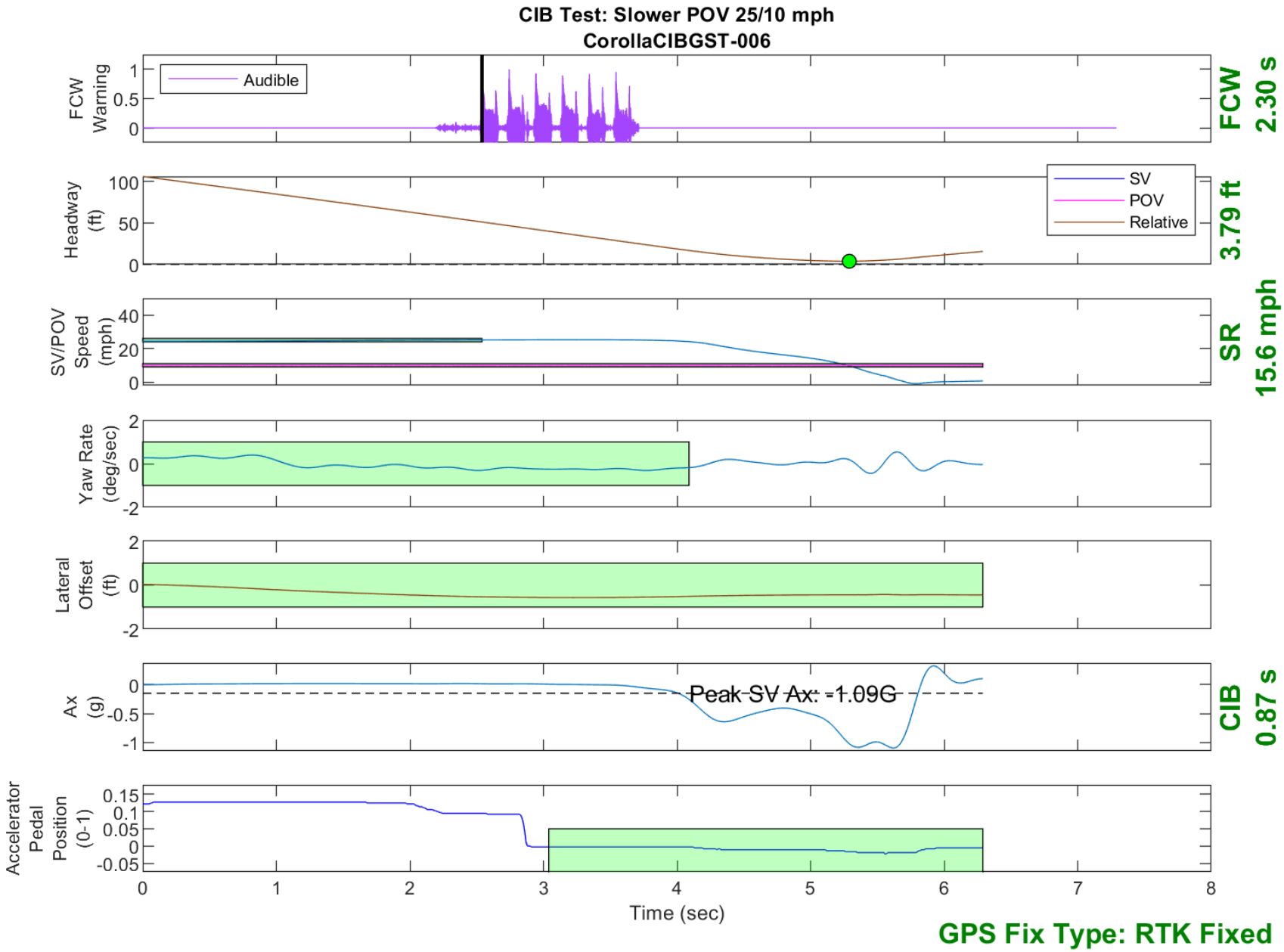


Figure D37. Time History for CIB Run 6, Slower POV, 25/10 mph

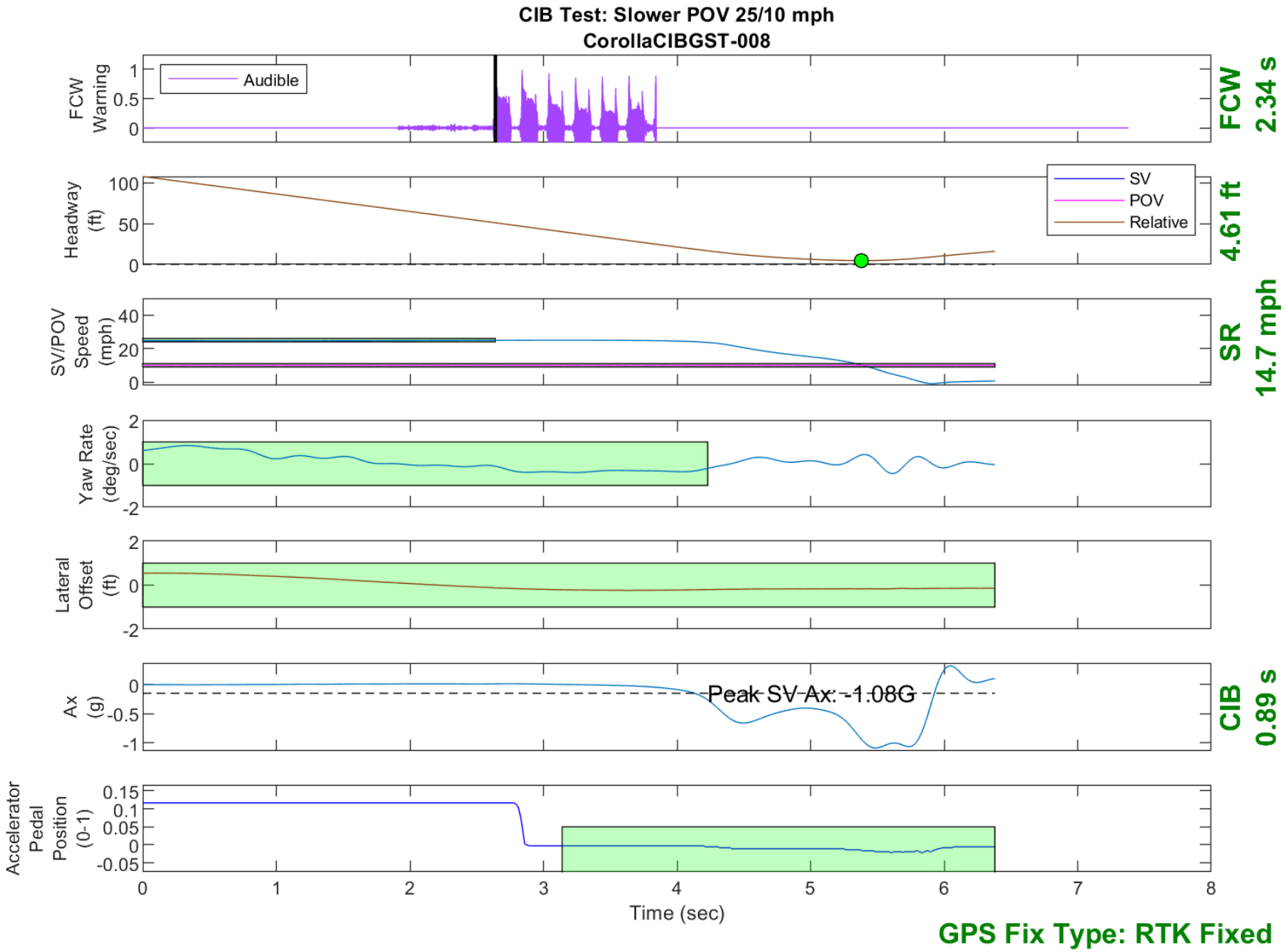


Figure D38. Time History for CIB Run 8, Slower POV, 25/10 mph

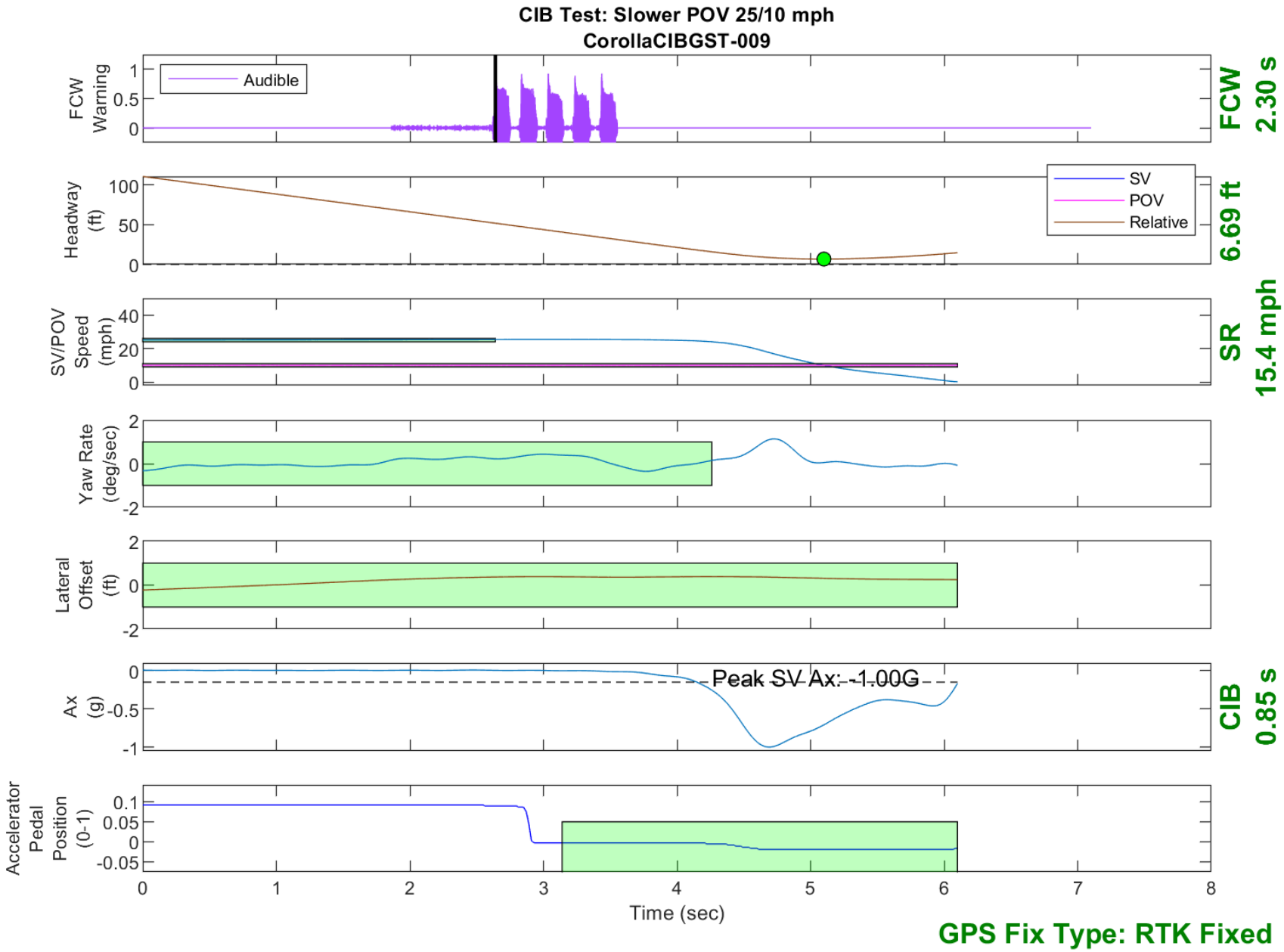


Figure D39. Time History for CIB Run 9, Slower POV, 25/10 mph

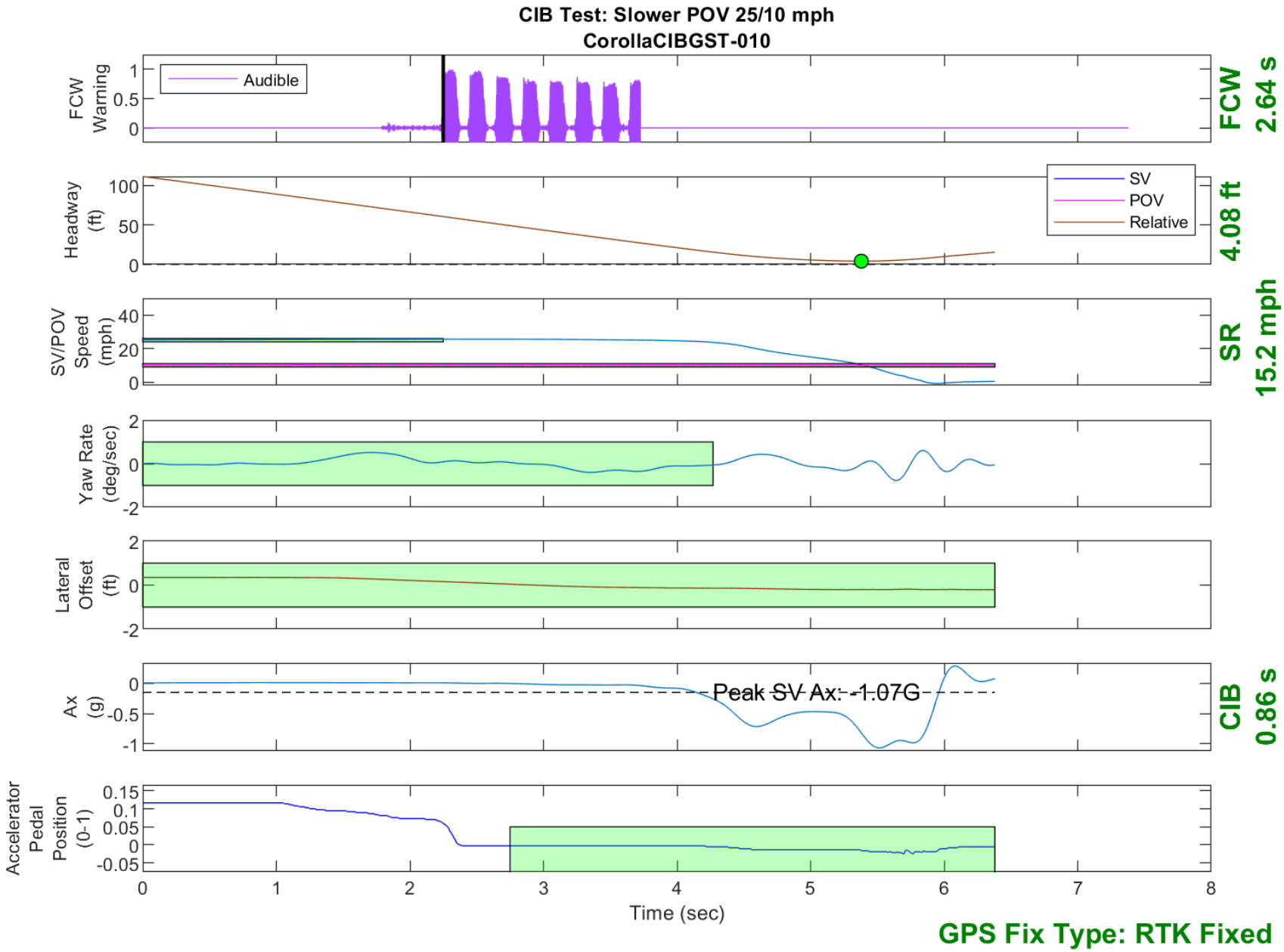


Figure D40. Time History for CIB Run 10, Slower POV, 25/10 mph

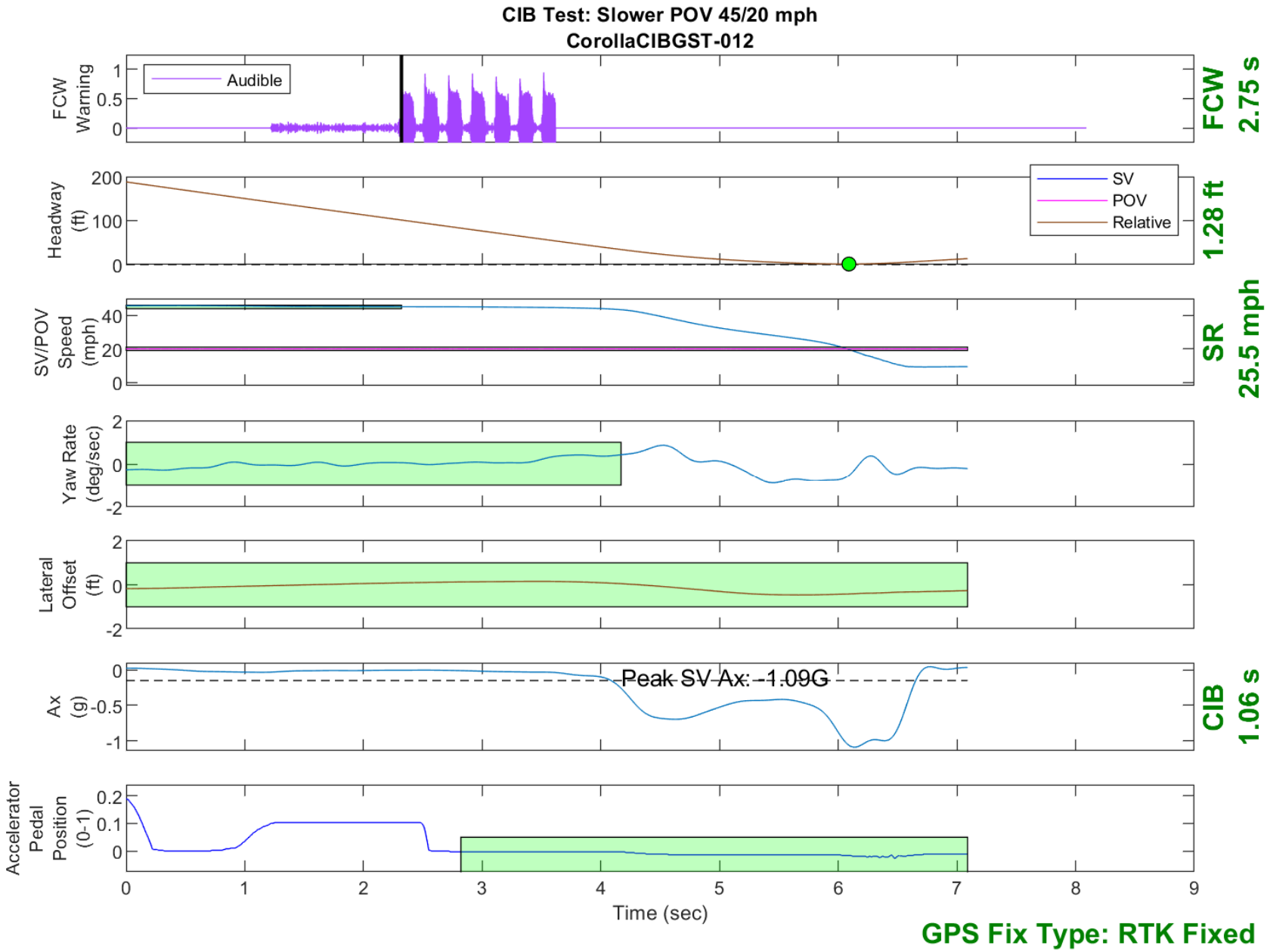


Figure D41. Time History for CIB Run 12, Slower POV, 45/20 mph

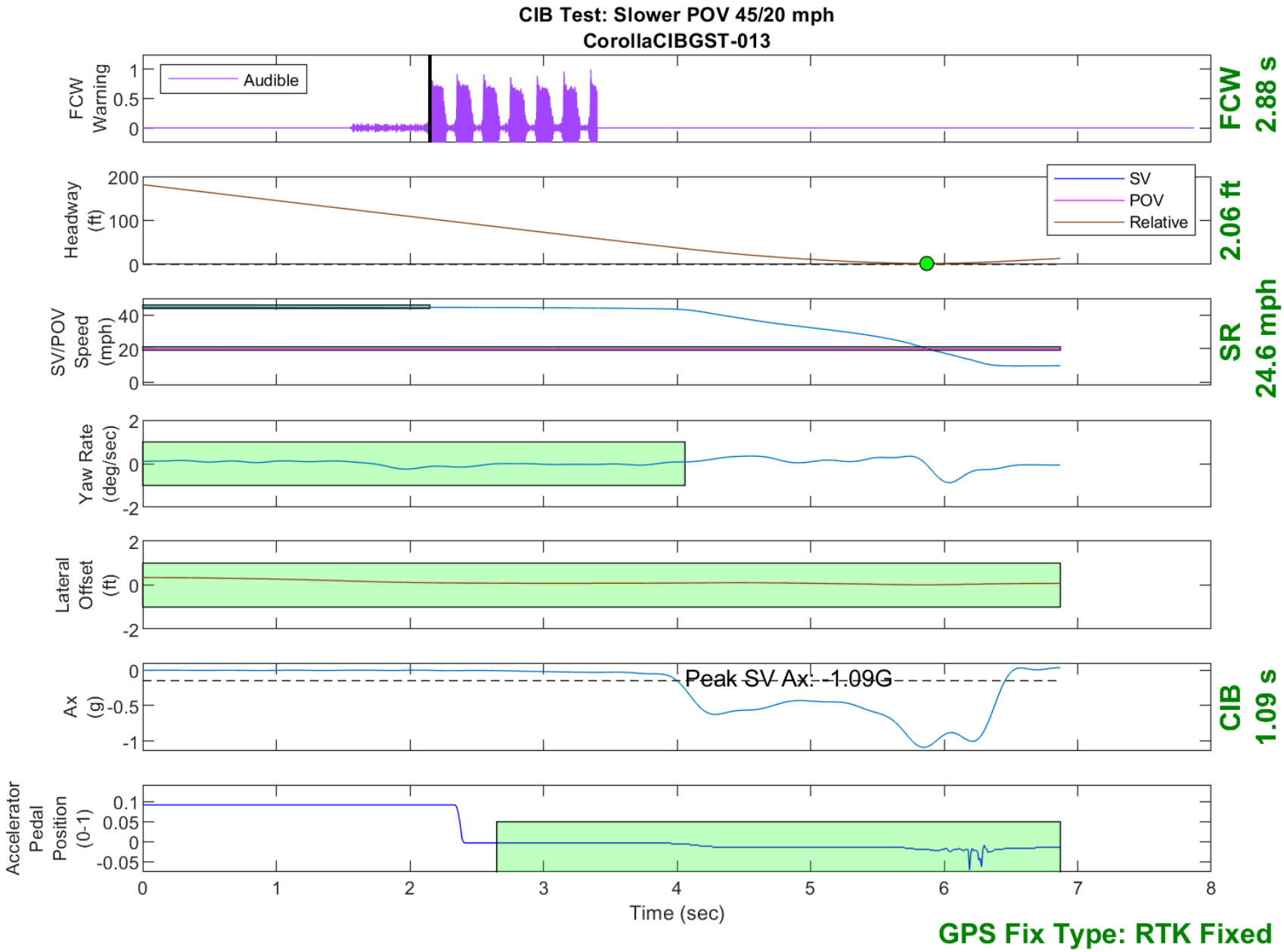


Figure D42. Time History for CIB Run 13, Slower POV, 45/20 mph

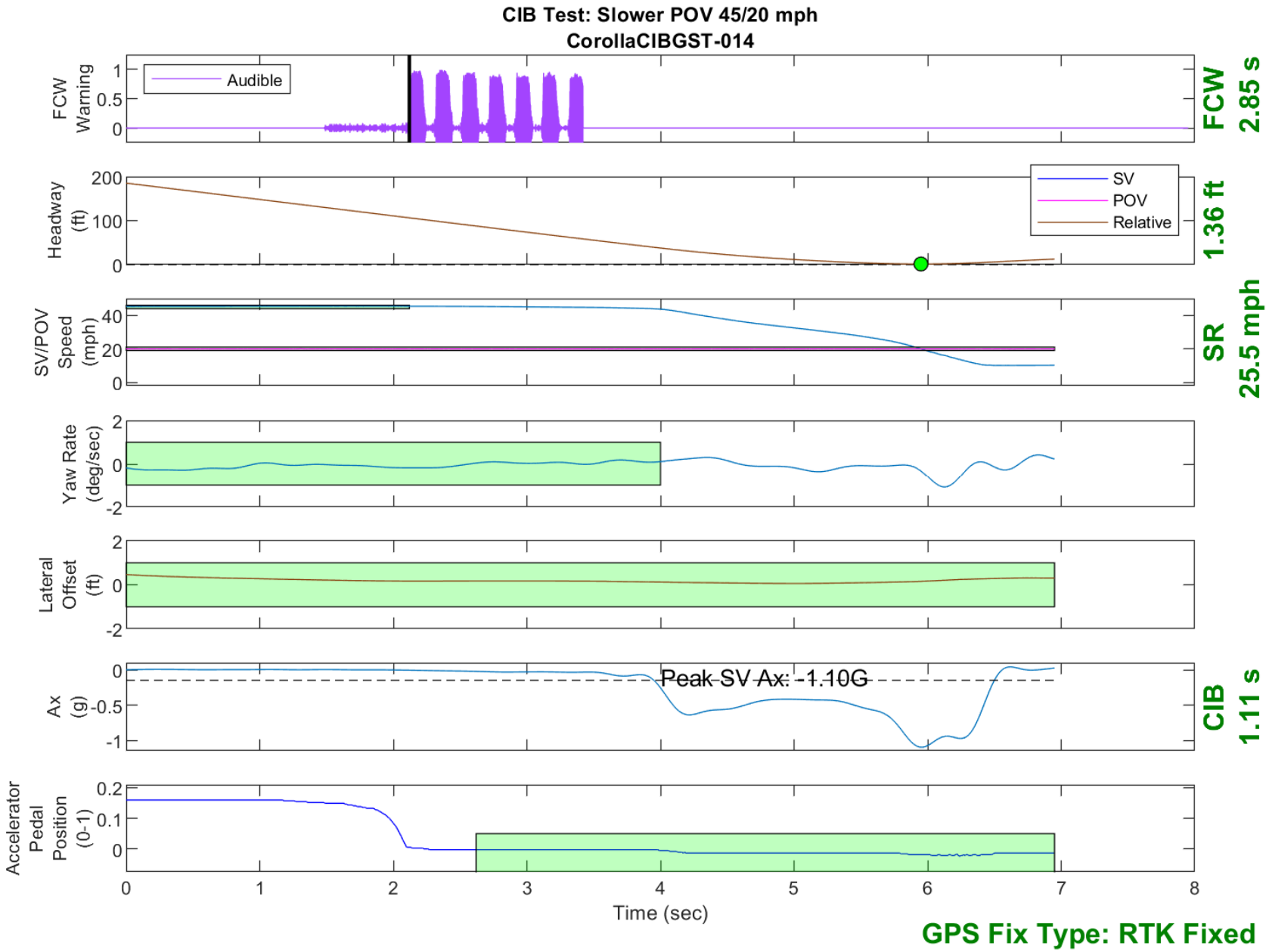


Figure D43. Time History for CIB Run 14, Slower POV, 45/20 mph

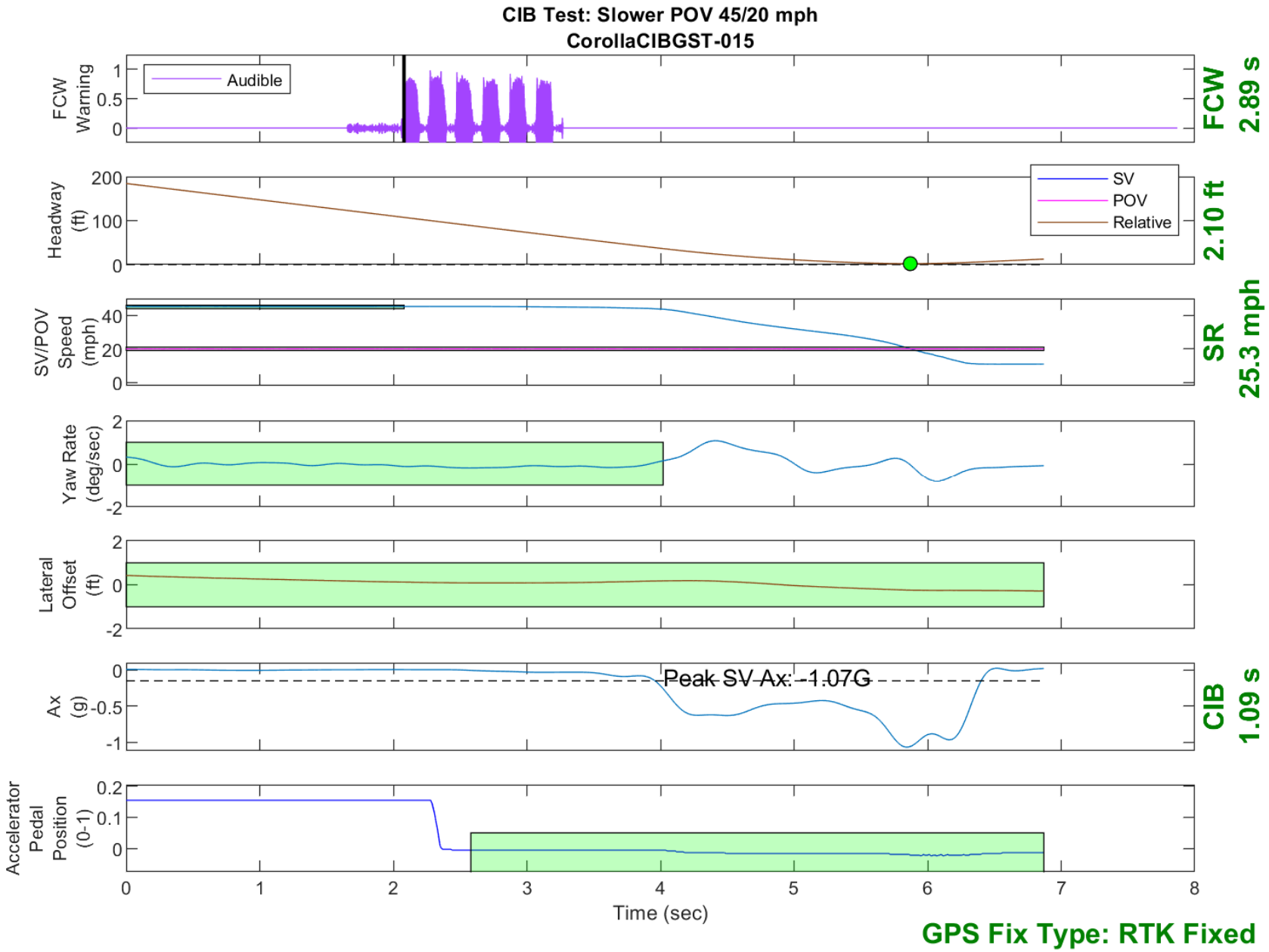


Figure D44. Time History for CIB Run 15, Slower POV, 45/20 mph

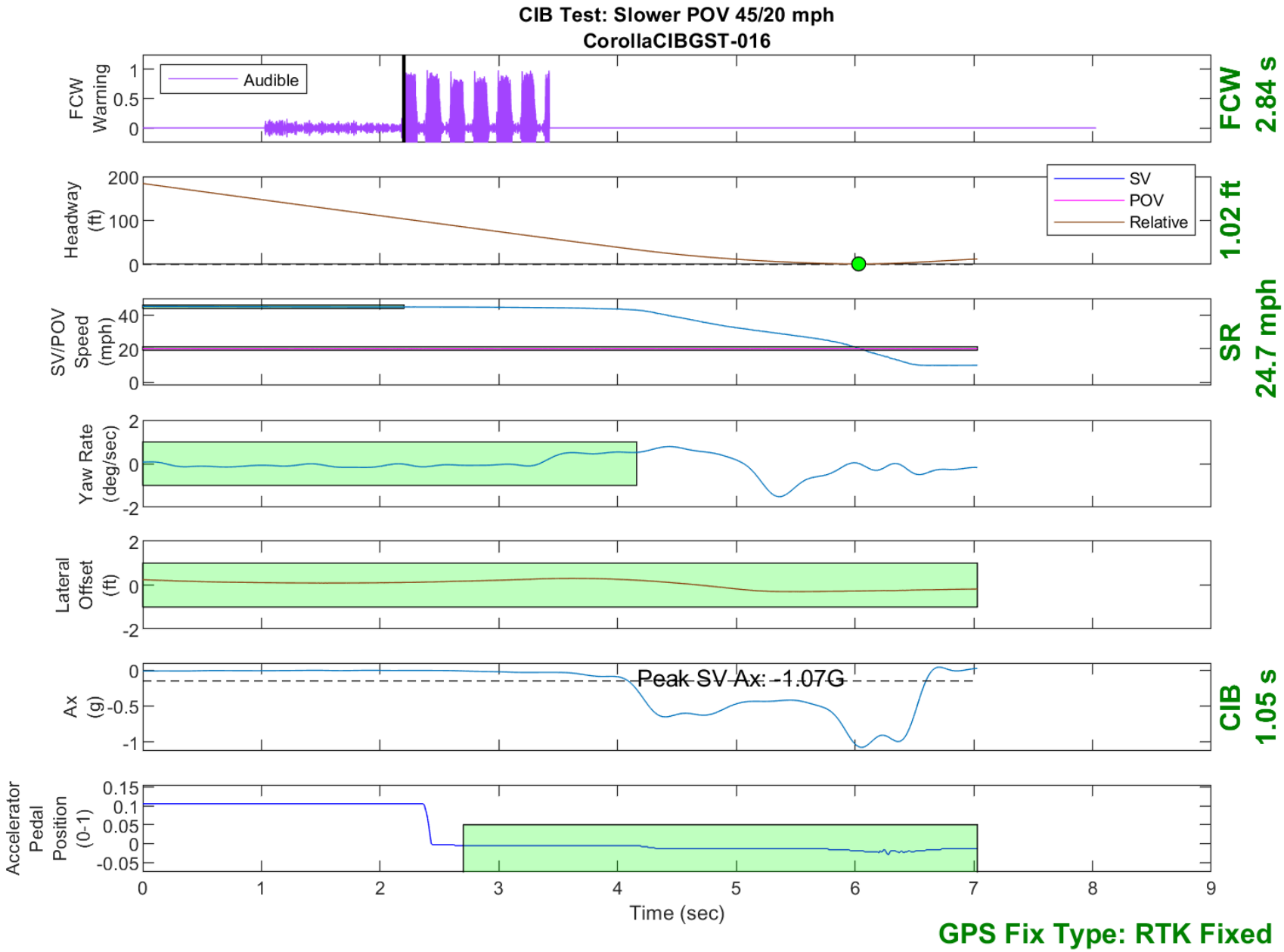


Figure D45. Time History for CIB Run 16, Slower POV, 45/20 mph

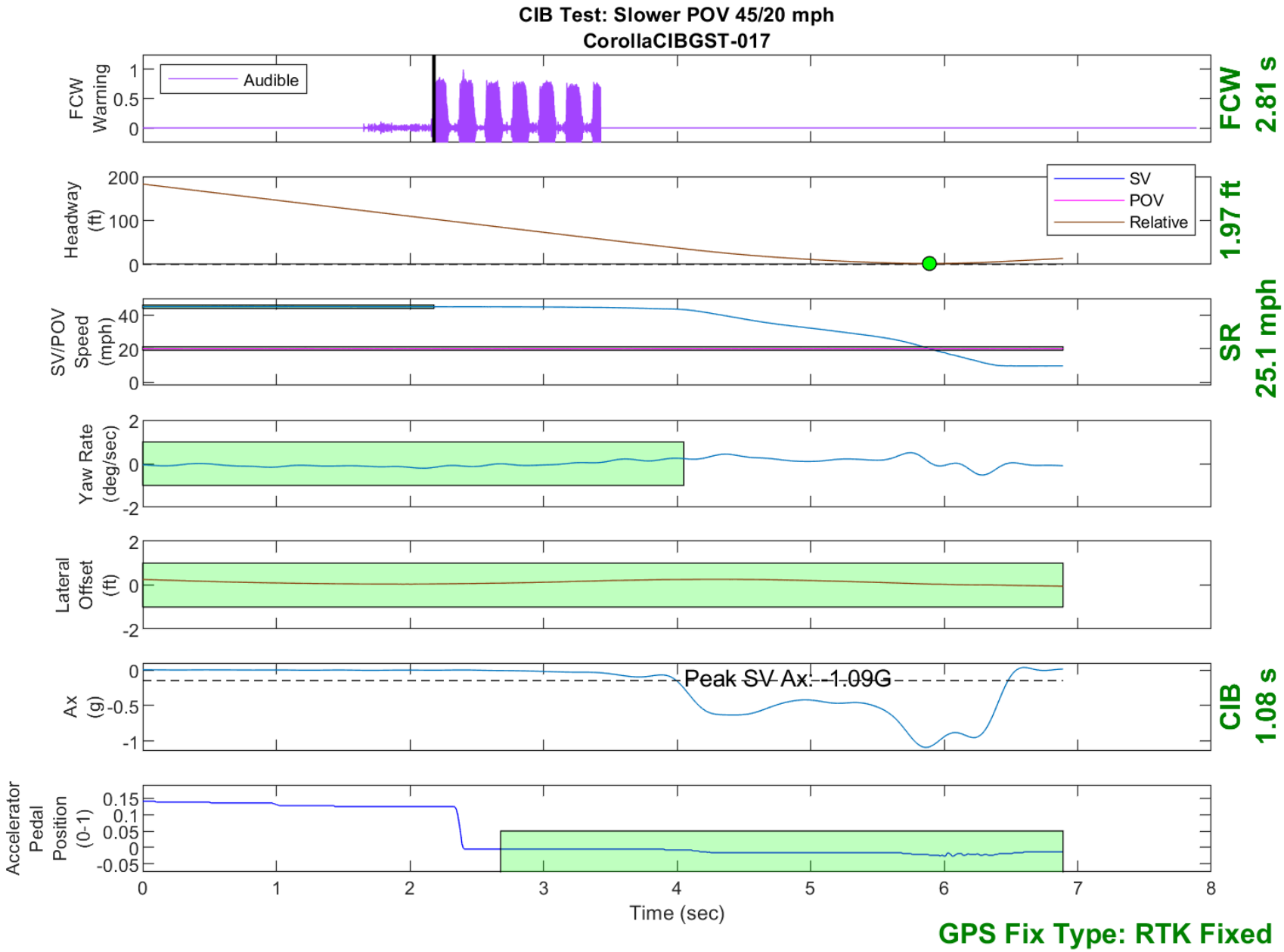


Figure D46. Time History for CIB Run 17, Slower POV, 45/20 mph

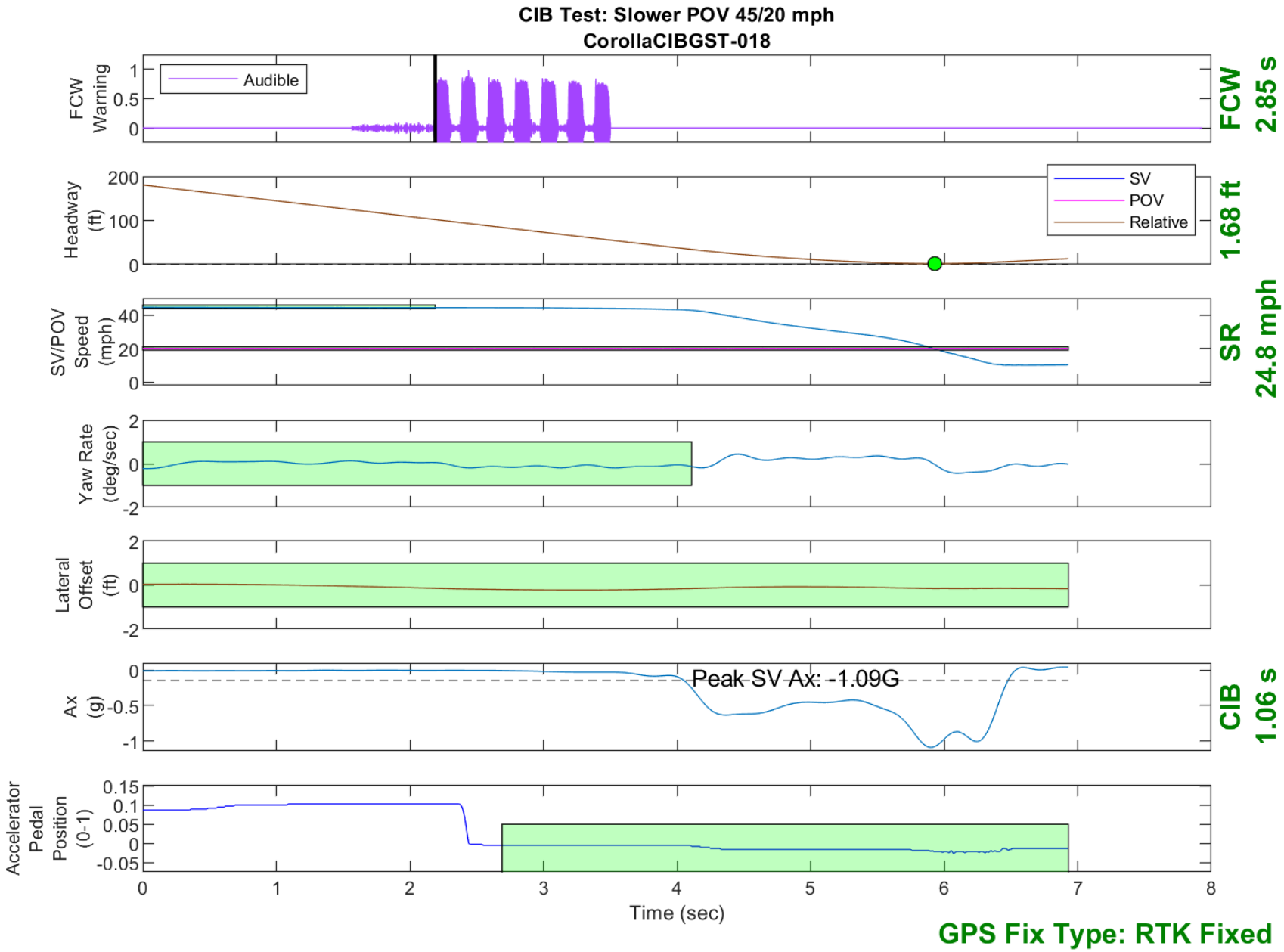


Figure D47. Time History for CIB Run 18, Slower POV, 45/20 mph

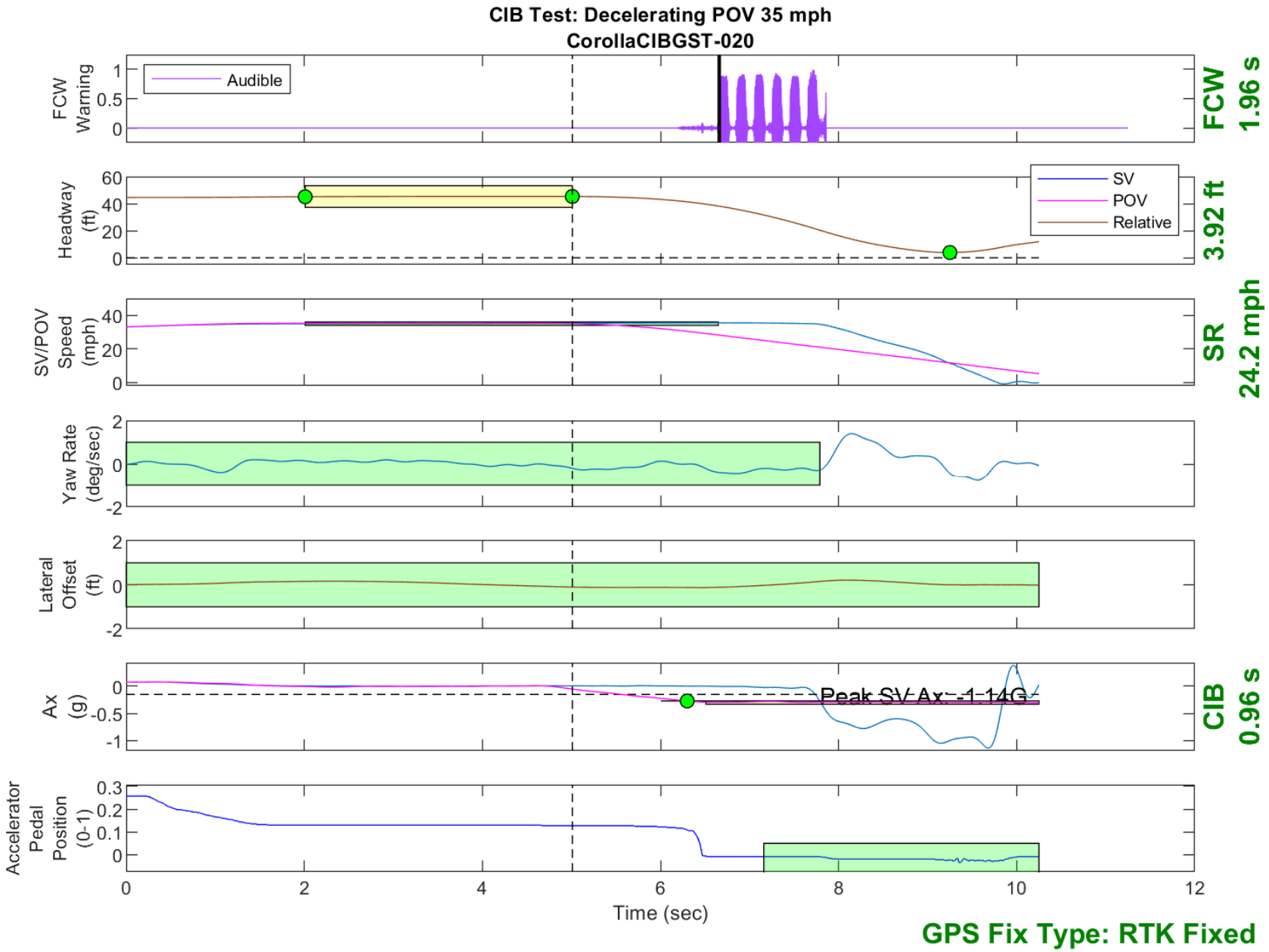


Figure D48. Time History for CIB Run 20, Decelerating POV, 35 mph 0.3g

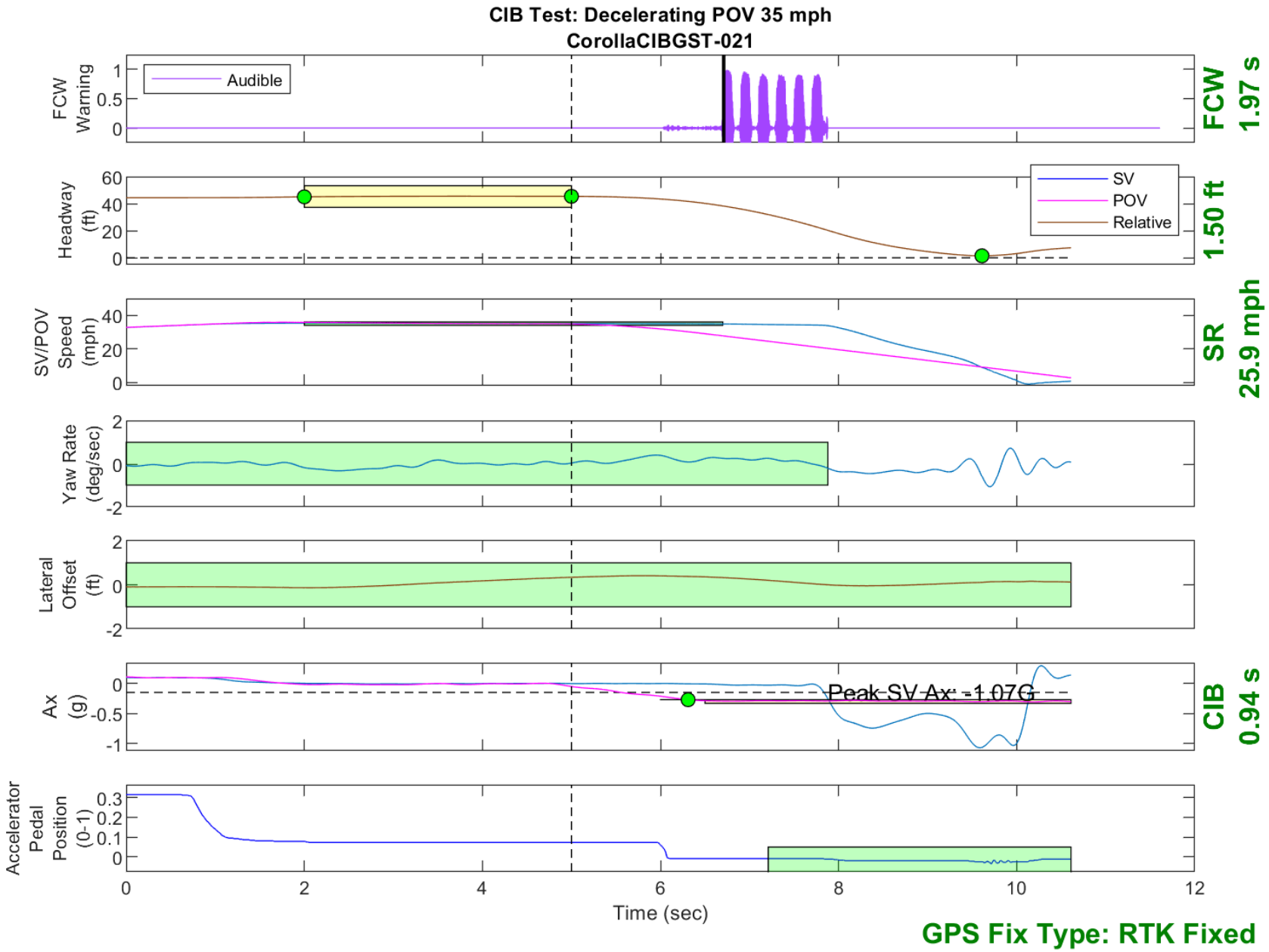


Figure D49. Time History for CIB Run 21, Decelerating POV, 35 mph 0.3g

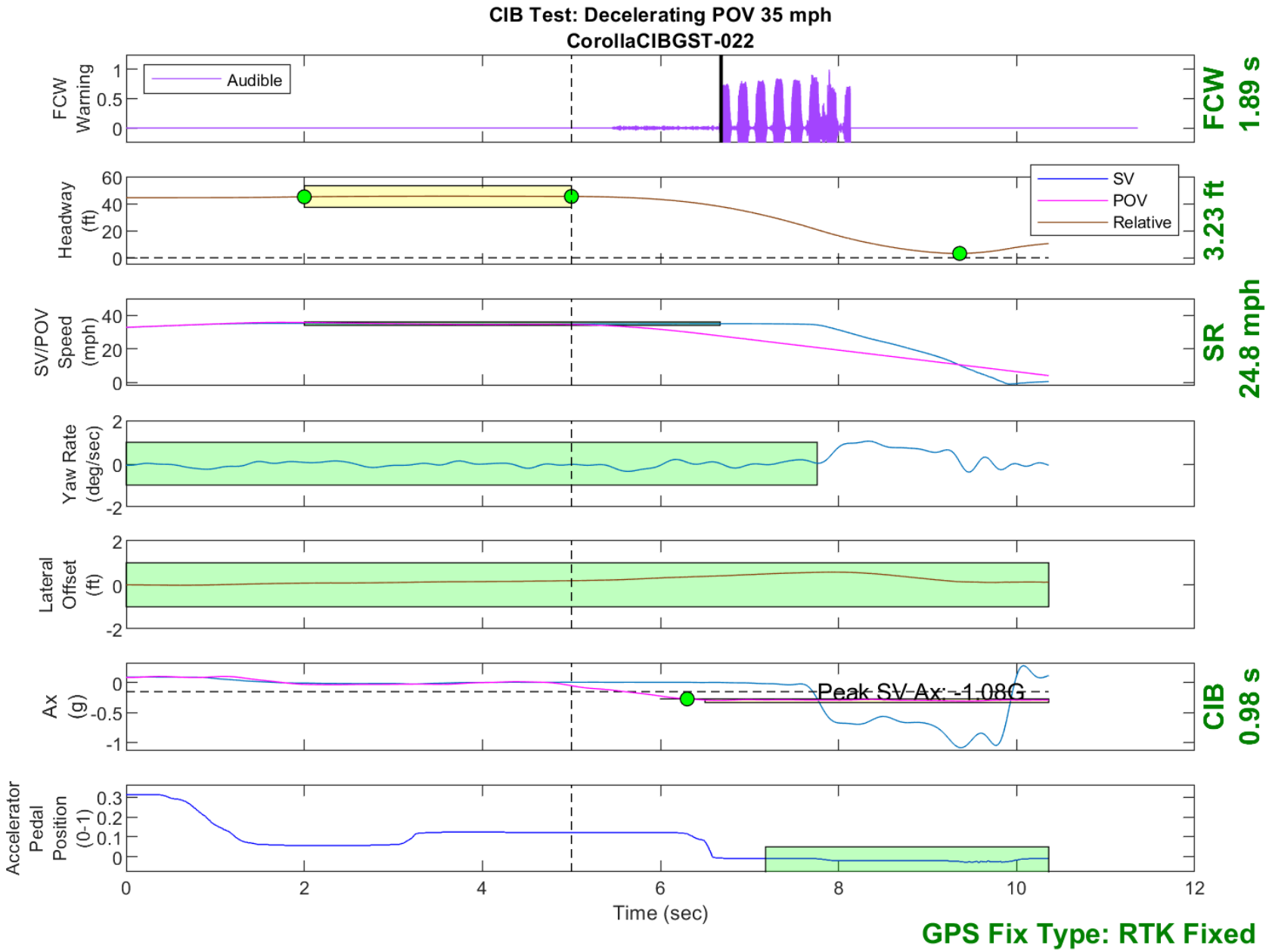


Figure D50. Time History for CIB Run 22, Decelerating POV, 35 mph 0.3g

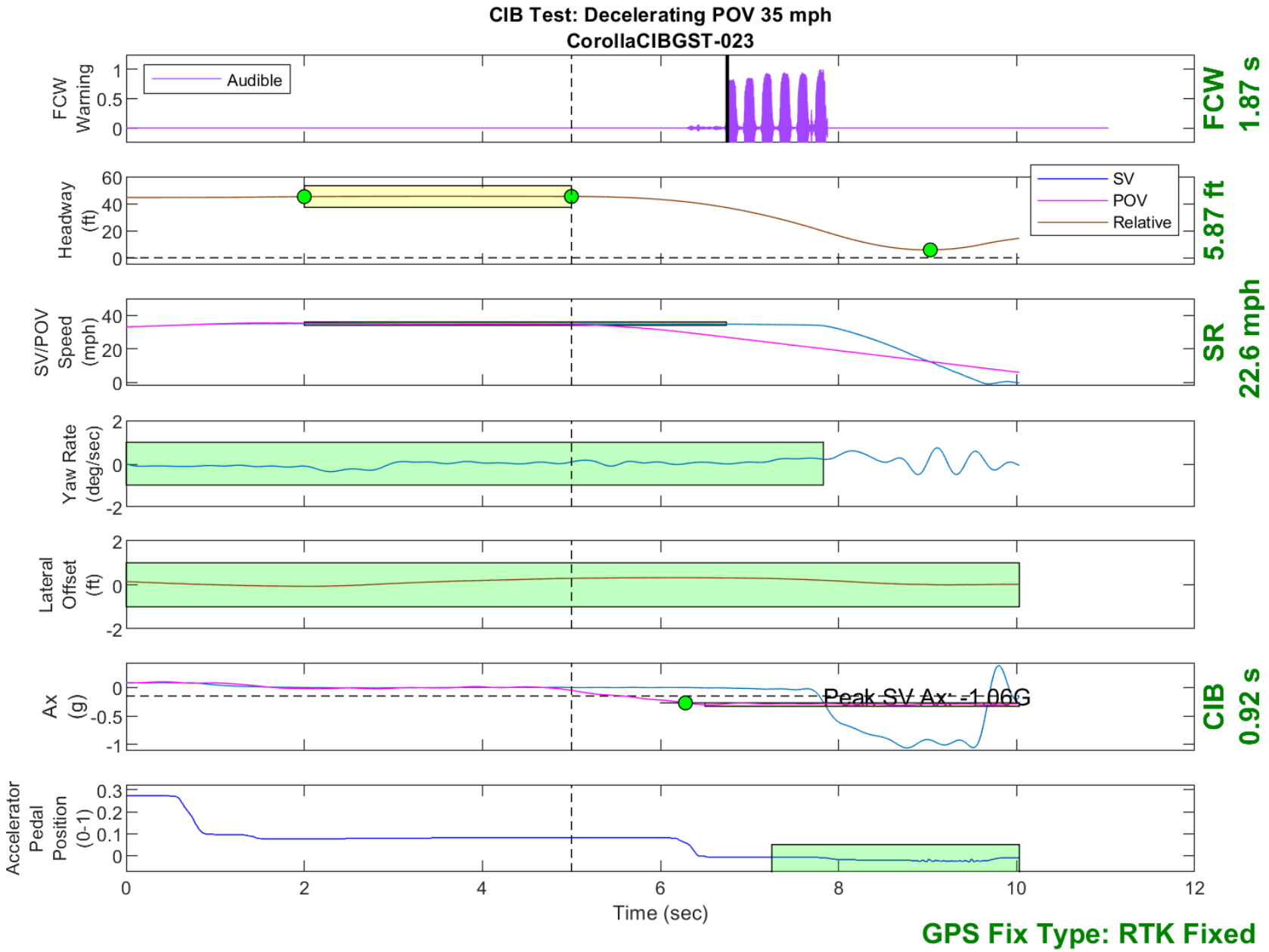


Figure D51. Time History for CIB Run 23, Decelerating POV, 35 mph 0.3g

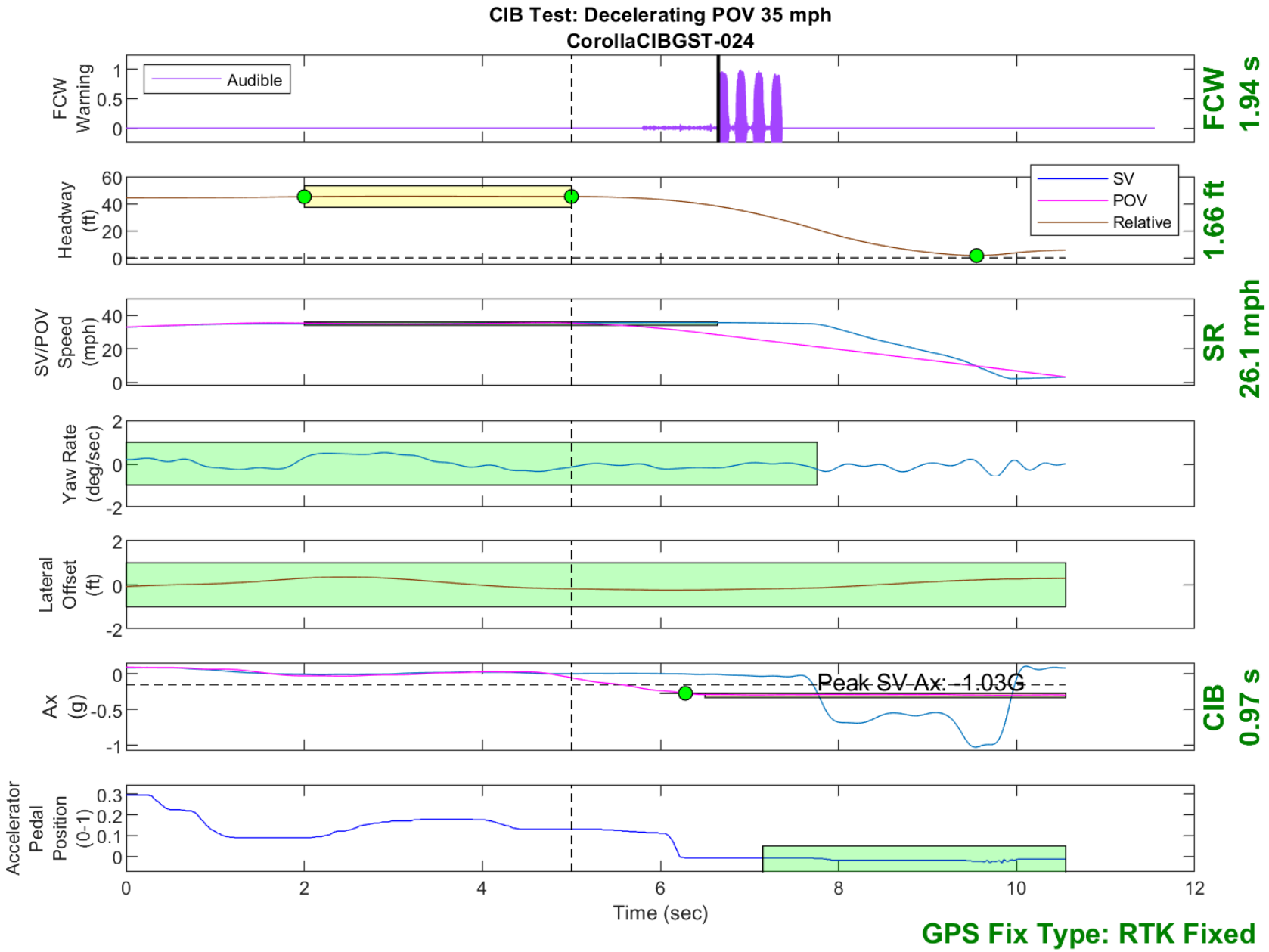


Figure D52. Time History for CIB Run 24, Decelerating POV, 35 mph 0.3g

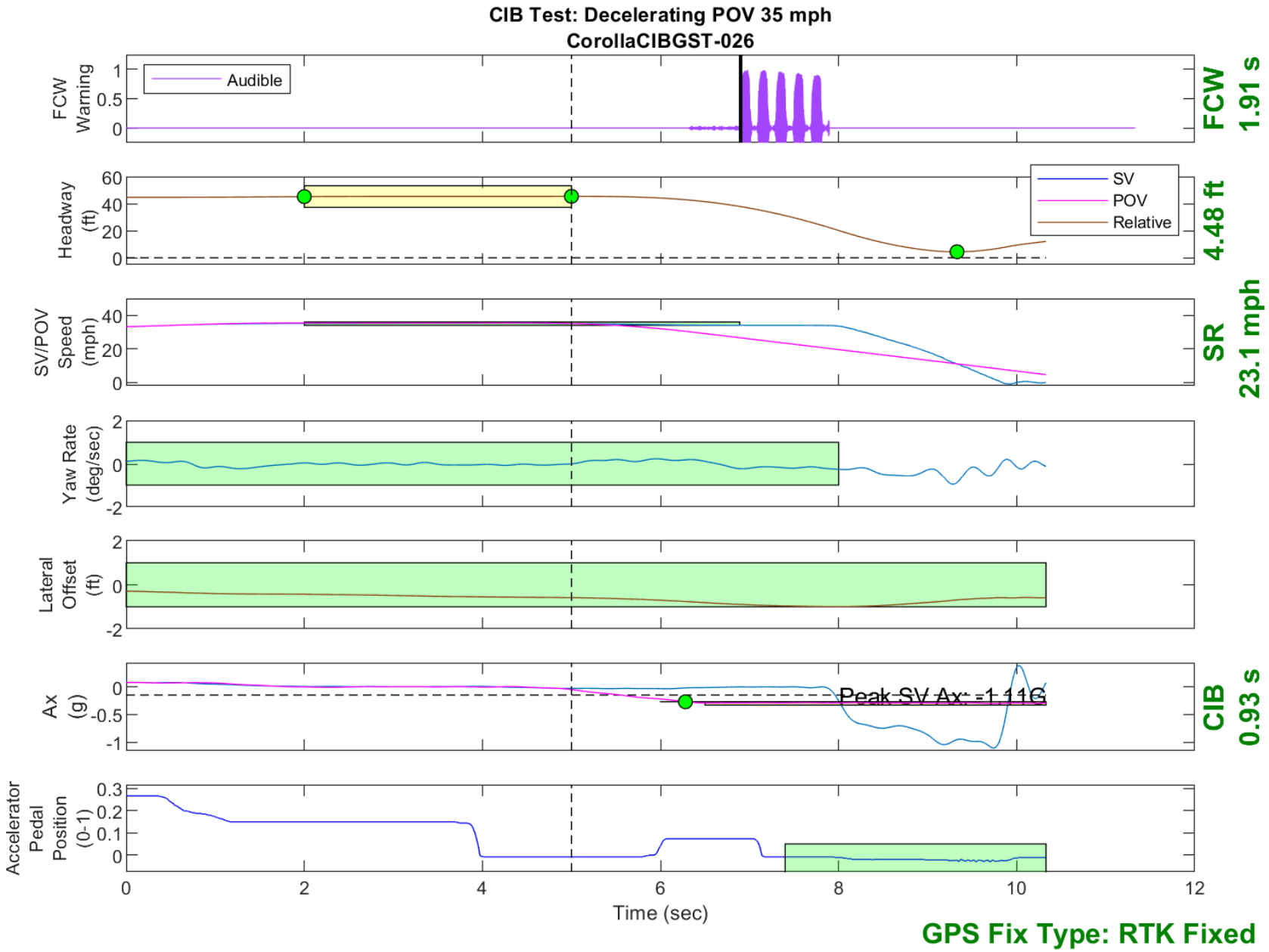


Figure D53. Time History for CIB Run 26, Decelerating POV, 35 mph 0.3g

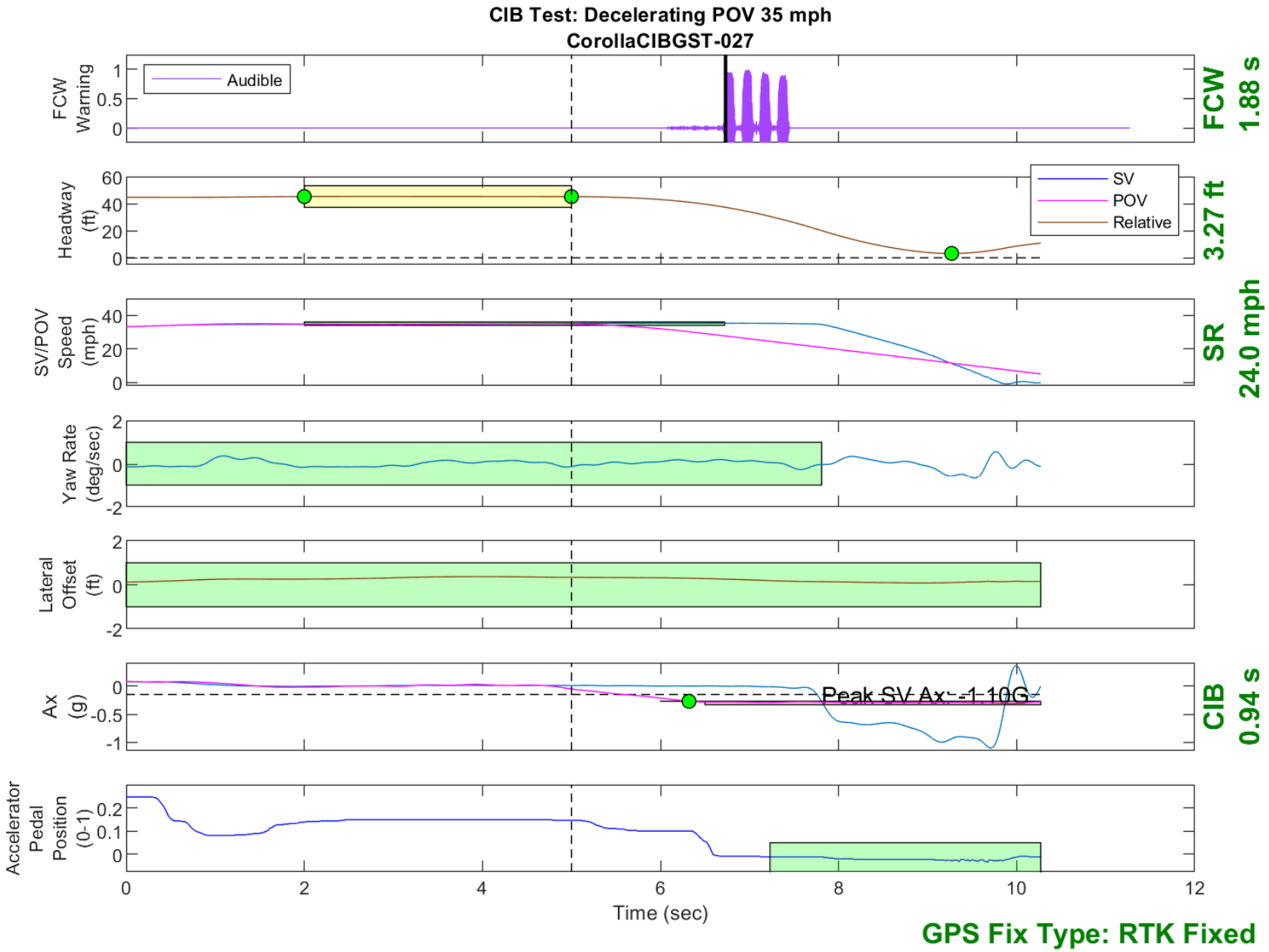


Figure D54. Time History for CIB Run 27, Decelerating POV, 35 mph 0.3g

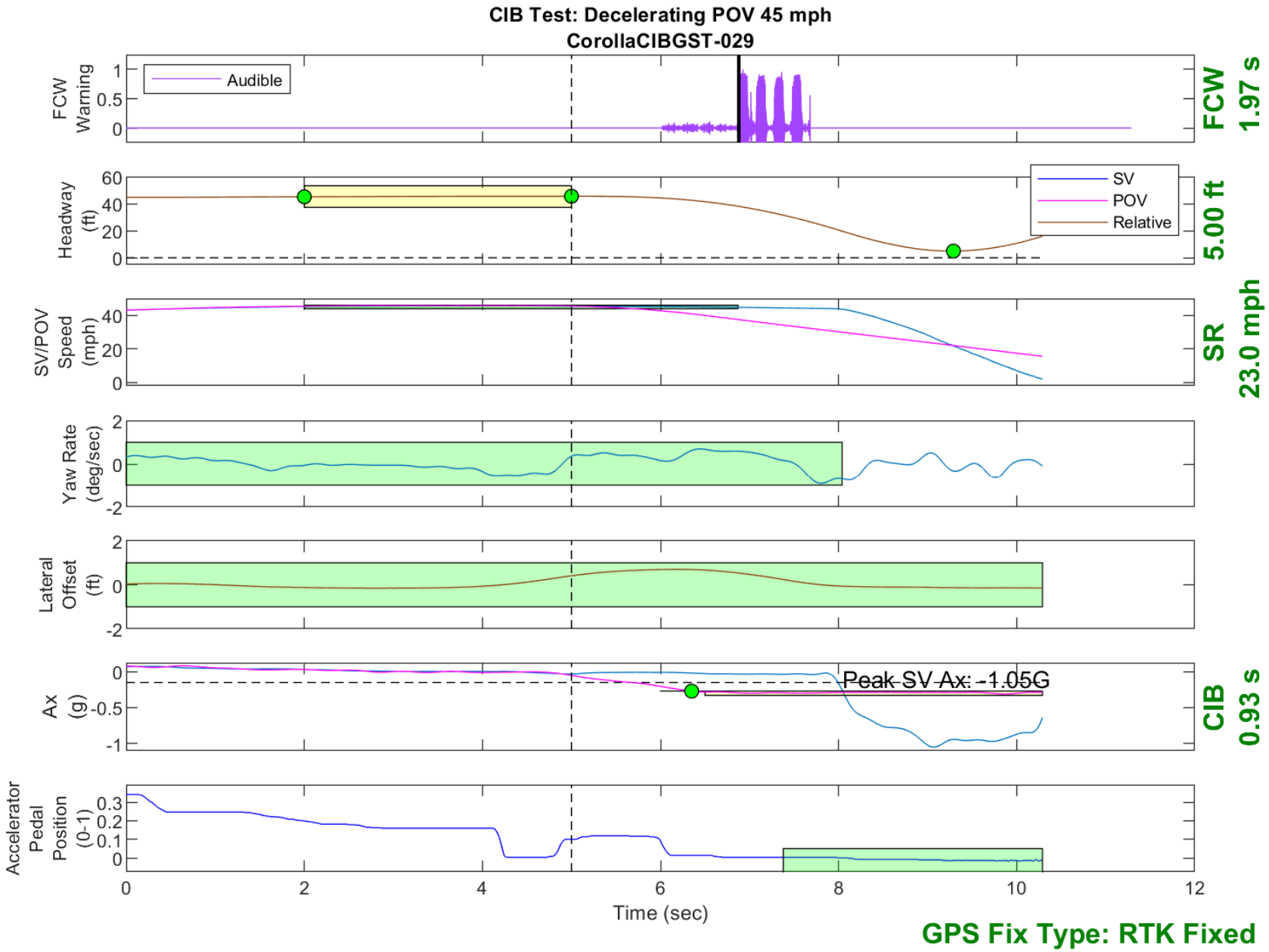


Figure D55. Time History for CIB Run 29, Decelerating POV, 45 mph 0.3g

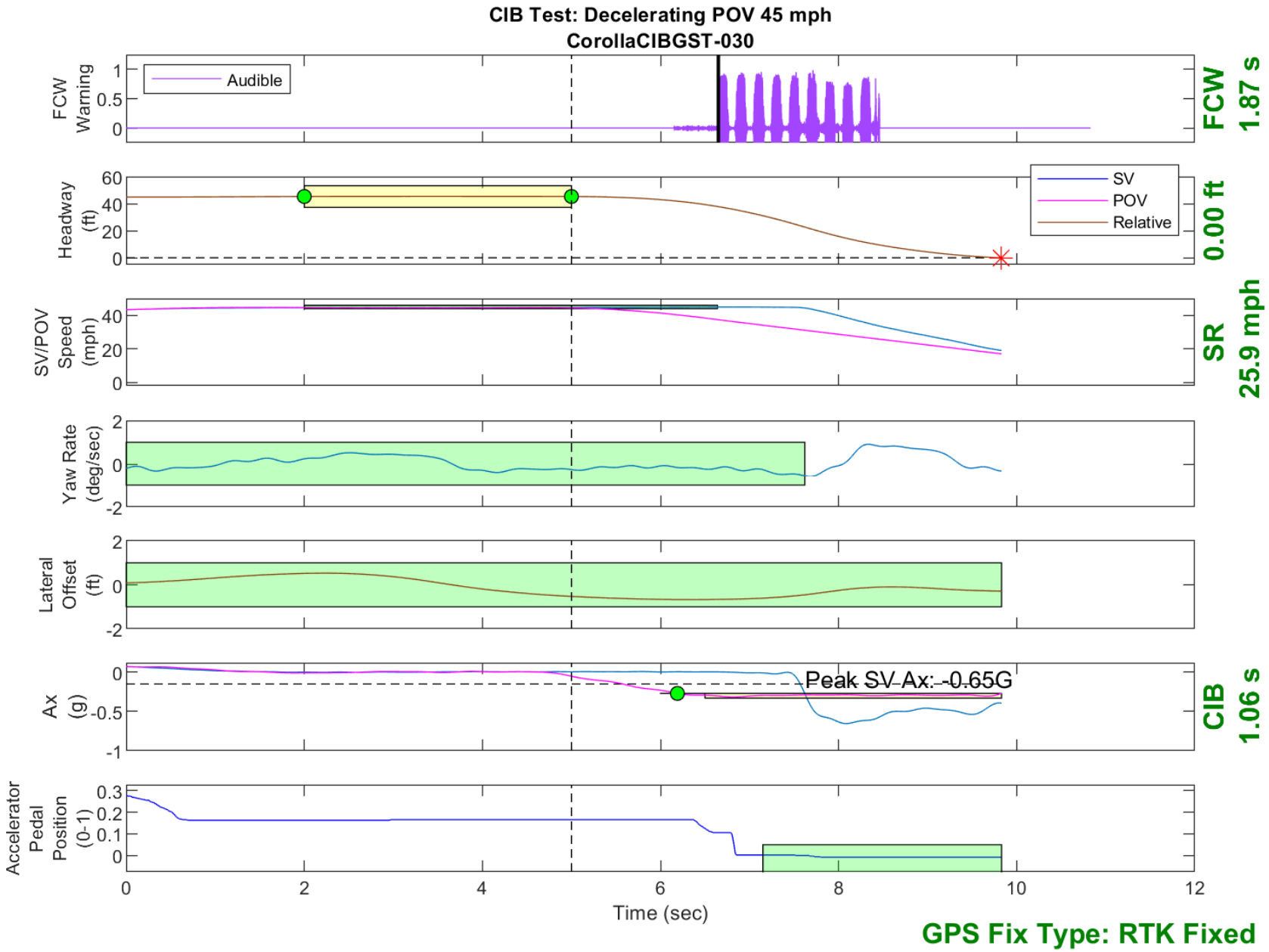


Figure D56. Time History for CIB Run 30, Decelerating POV, 45 mph 0.3g

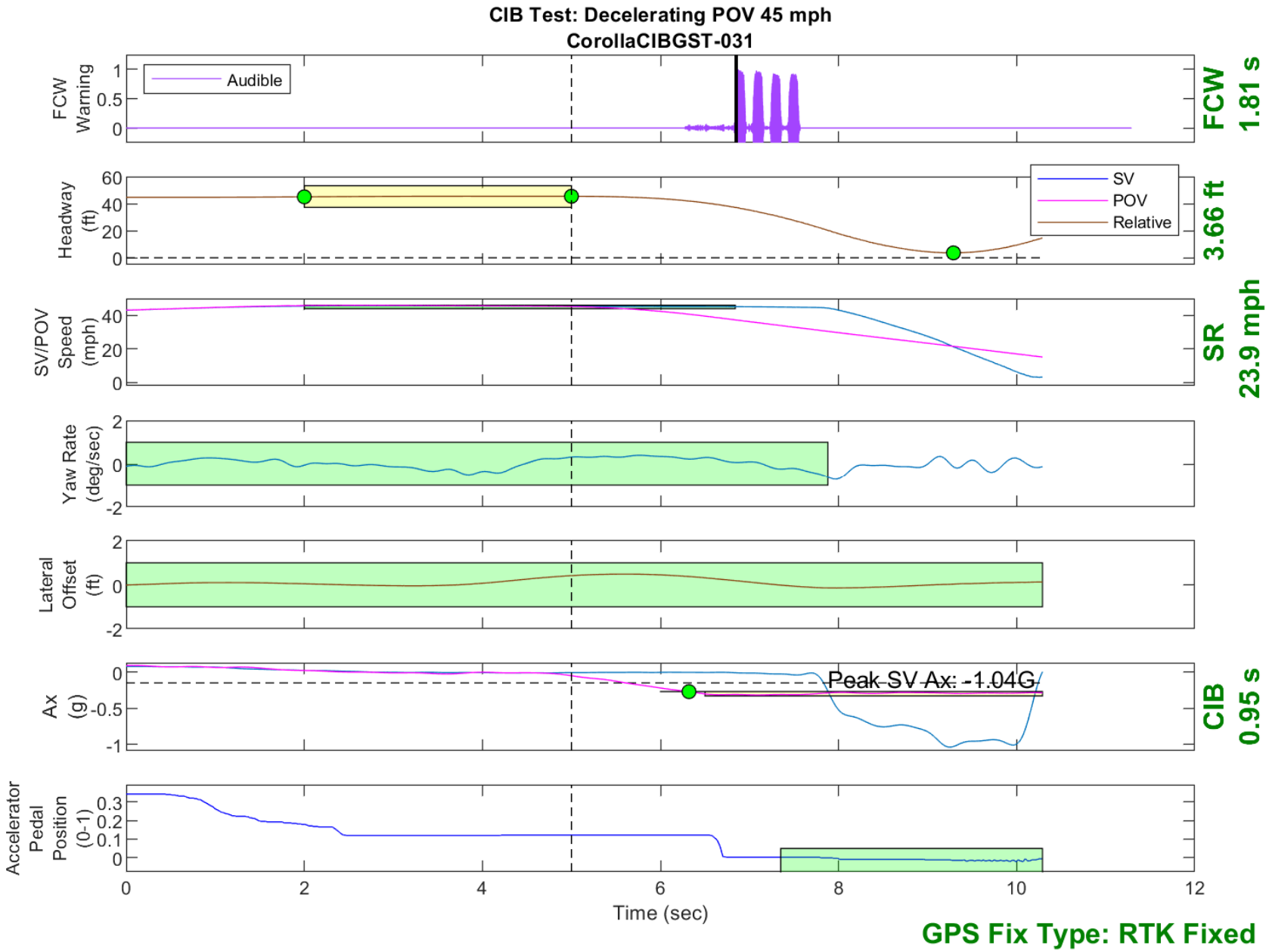


Figure D57. Time History for CIB Run 31, Decelerating POV, 45 mph 0.3g

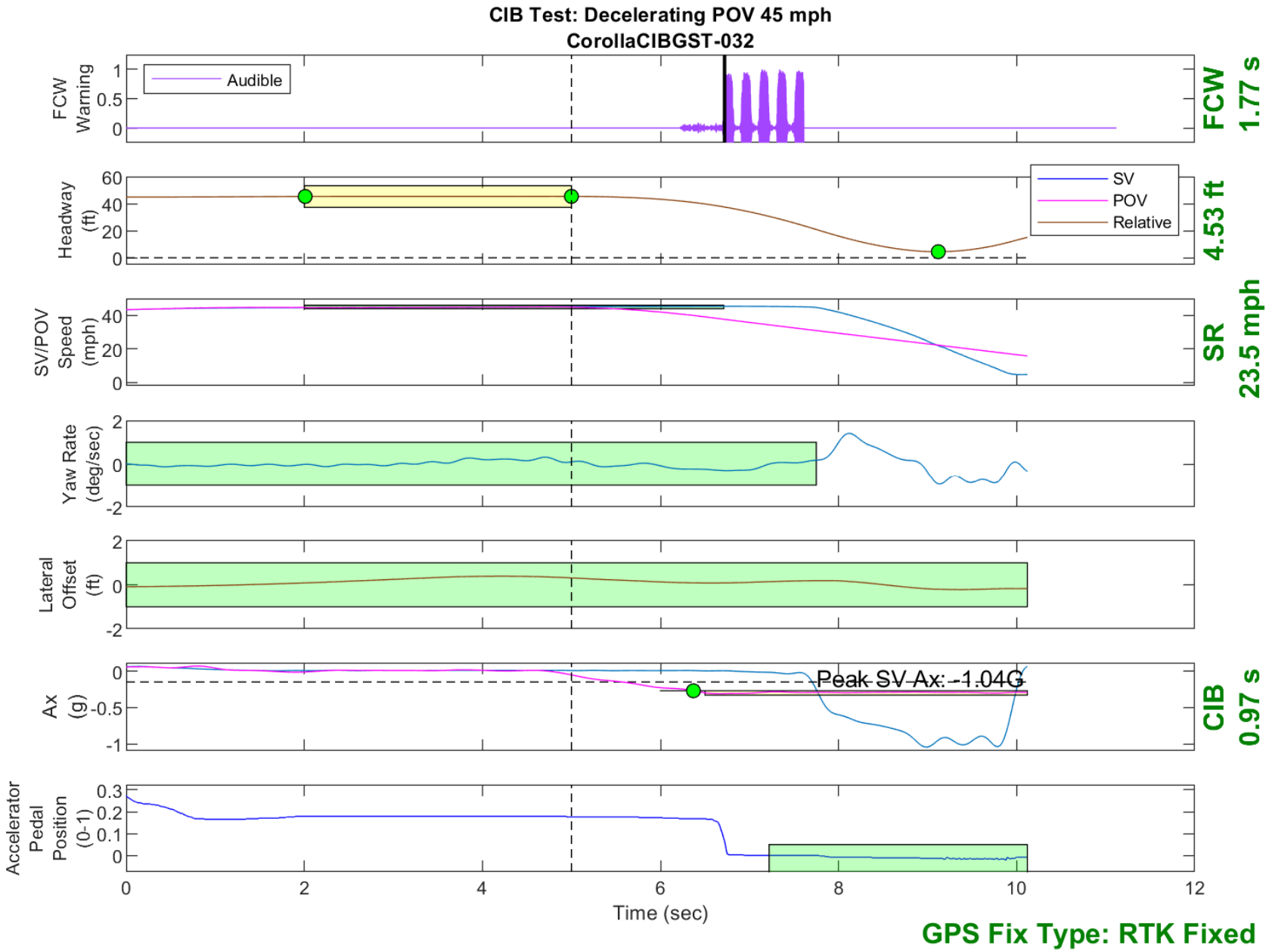


Figure D58. Time History for CIB Run 32, Decelerating POV, 45 mph 0.3g

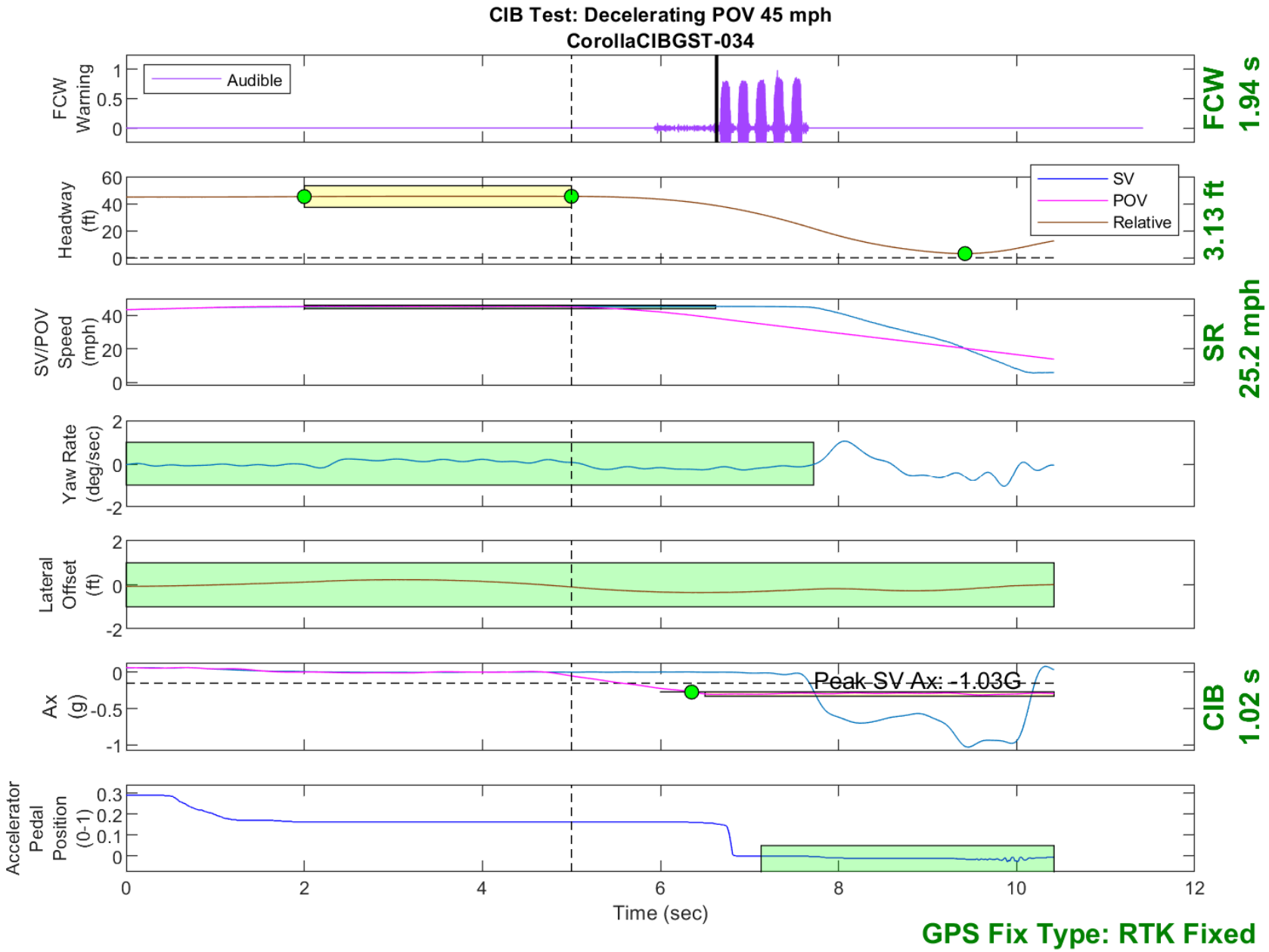


Figure D59. Time History for CIB Run 34, Decelerating POV, 45 mph 0.3g

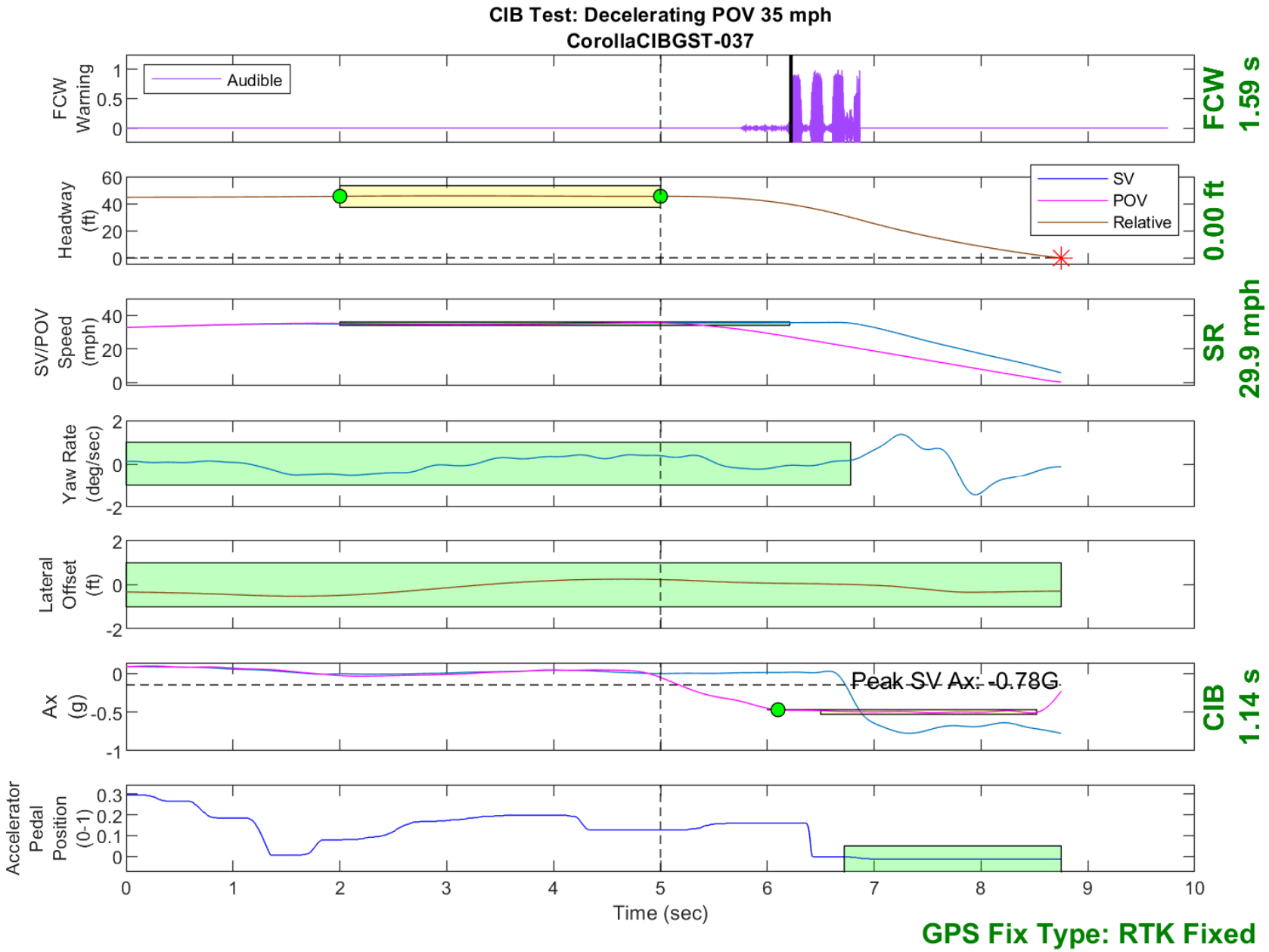


Figure D60. Time History for CIB Run 37, Decelerating POV, 35 mph 0.5g

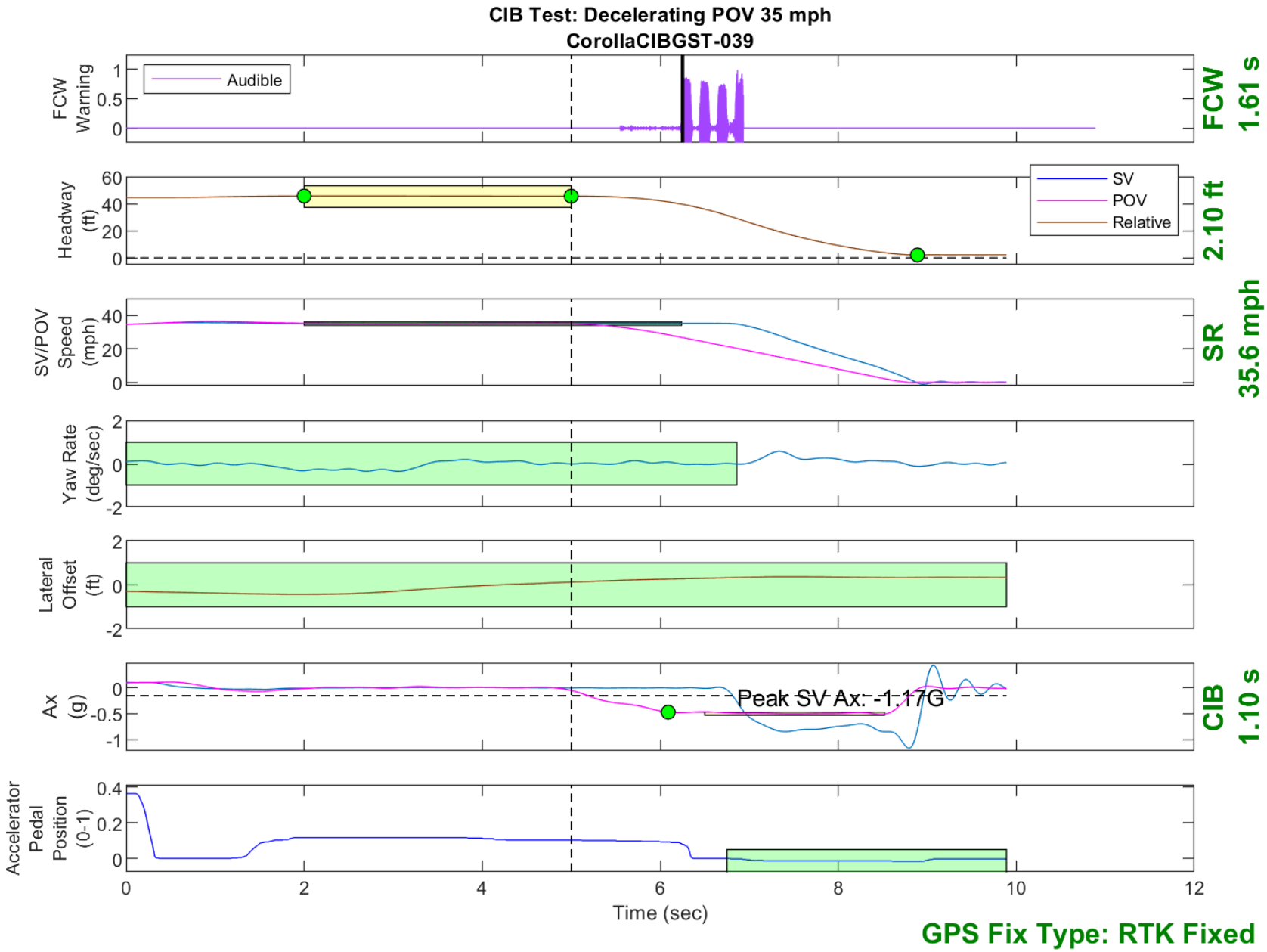


Figure D61. Time History for CIB Run 39, Decelerating POV, 35 mph 0.5g

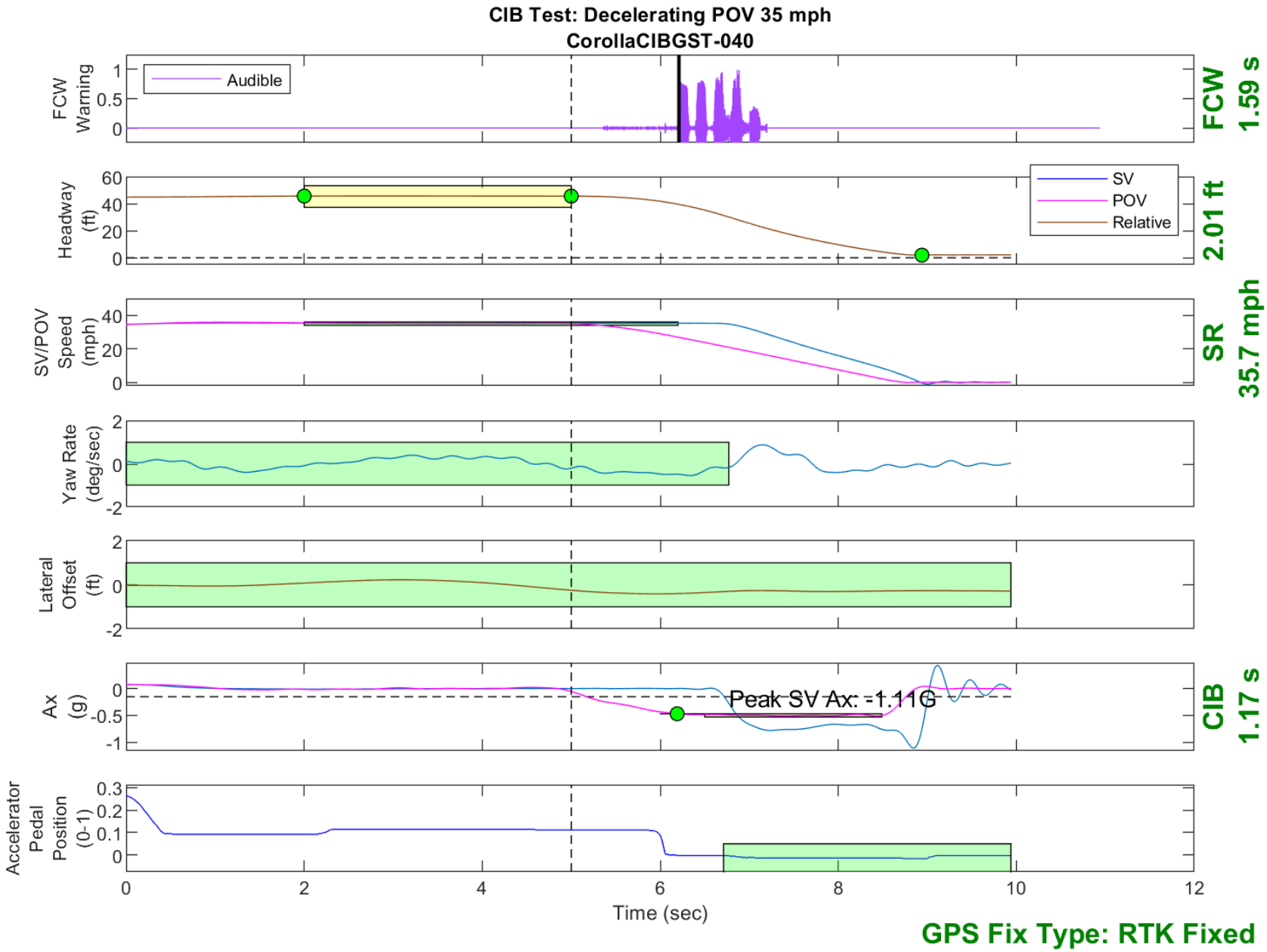


Figure D62. Time History for CIB Run 40, Decelerating POV, 35 mph 0.5g

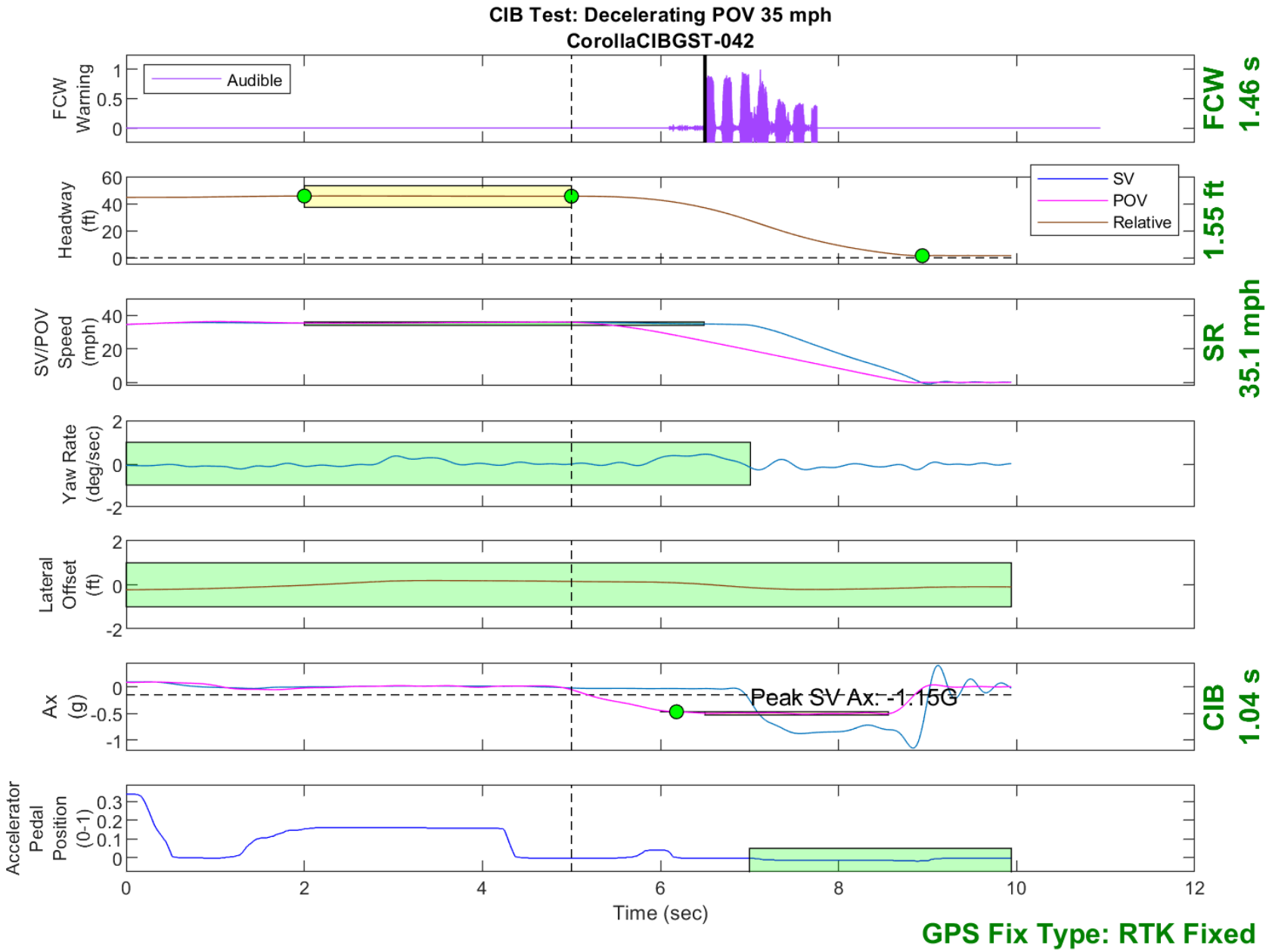


Figure D63. Time History for CIB Run 42, Decelerating POV, 35 mph 0.5g

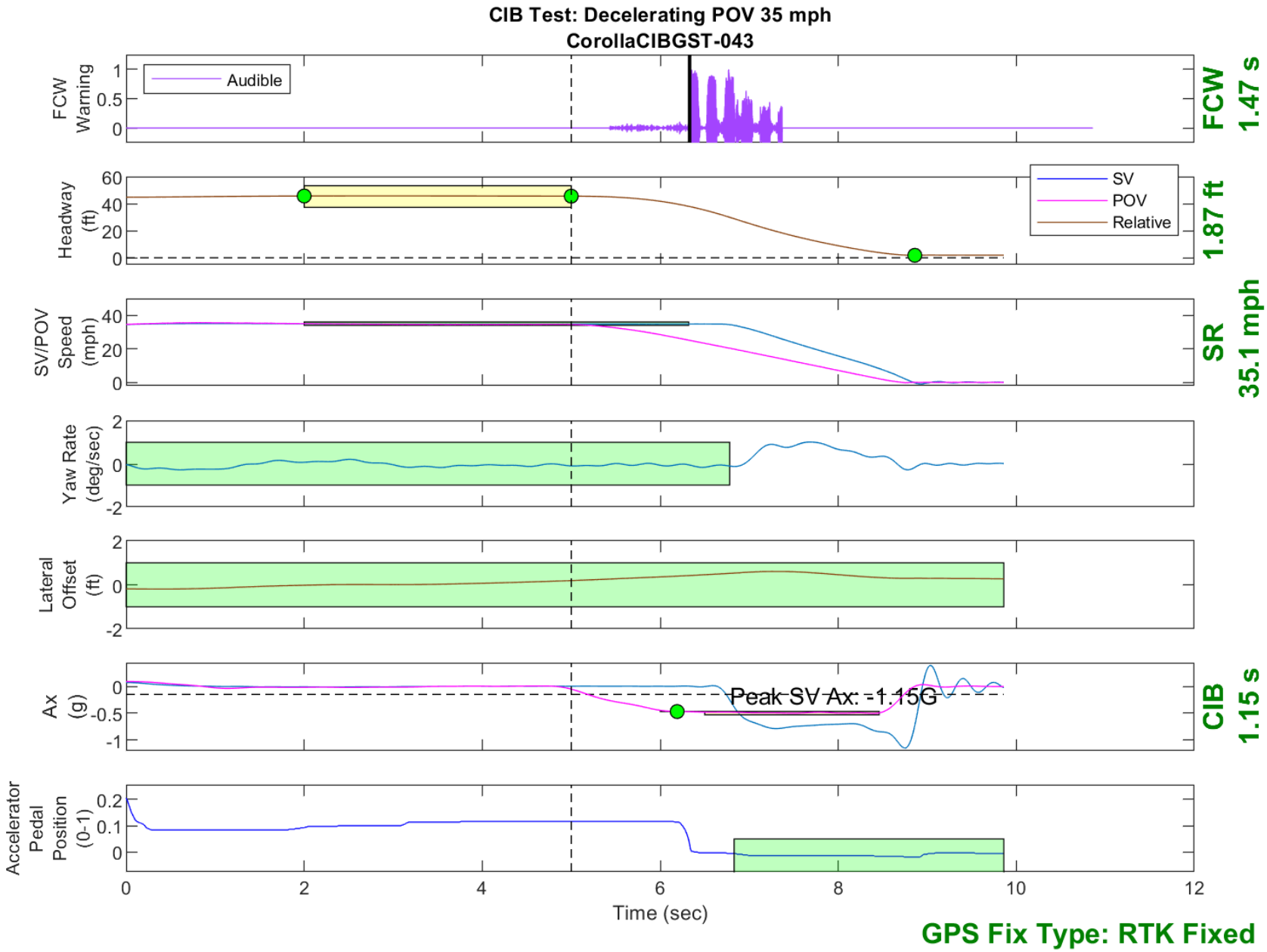


Figure D64. Time History for CIB Run 43, Decelerating POV, 35 mph 0.5g