CRASH IMMINENT BRAKING SYSTEM RESEARCH TEST
NCAP-DRI-CIBHS-20-10

2020 Land Rover Range Rover Sport HSE

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8 December 2020

Final Report

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National Highway Traffic Safety Administration
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16. Abstract These research tests were conducted on the subject 2020 Land Rover Range Rover Sport HSE in accordance with the specifications of the New Car Assessment Program's most current Test Procedure in docket NHTSA-2015-0006-0025; CRASH IMMINENT BRAKE SYSTEM PERFORMANCE EVALUATION FOR THE NEW CAR ASSESSMENT PROGRAM, October 2015, with modifications to include use of the Global Vehicle Target (GVT) and additional test speeds or deceleration rates to assess system performance and point of failure. The system met the acceptability criteria for 61 out of 61 valid test runs.			
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Section I

INTRODUCTION

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

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

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

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

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

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

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

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

Section II

DATA SHEETS

CRASH IMMINENT BRAKING

DATA SHEET 1: TEST RESULTS SUMMARY

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2020 Land Rover Range Rover Sport HSE

VIN: *SALWR2SU9LA71xxxx* Test Date: *9/8/2020*

Crash Imminent Braking System setting: *System on, High Sensitivity*

		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:	*7*	*0*	*7*
	SV 35 mph:	*7*	*0*	*7*
	SV 40 mph:	*6*	*0*	*6*
	SV 45 mph:	*5*	*0*	*5*
Test 2 –	**Subject Vehicle Encounters Slower Principal Other Vehicle**			
	SV 25 mph POV 10 mph:	*7*	*0*	*7*
	SV 45 mph POV 20 mph:	*7*	*0*	*7*
Test 3 –	**Subject Vehicle Encounters Decelerating Principal Other Vehicle**			
	SV 35 mph POV 35 mph, 0.3 g decel:	*6*	*0*	*6*
	SV 35 mph POV 35 mph, 0.5 g decel:	*5*	*0*	*5*
	SV 45 mph POV 45 mph, 0.3 g decel:	*4*	*0*	*4*
	Overall:	***61***	***0***	***61***

Notes:
The system met the acceptability criteria for 61 out of 61 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

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2020 Land Rover Range Rover Sport HSE

TEST VEHICLE INFORMATION

VIN: *SALWR2SU9LA71xxxx*

Body Style: *SUV* Color: *Portofino Blue*

Date Received: *6/19/2020* Odometer Reading: *62 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Jaguar Land Rover Ltd.*

Date of manufacture: *01/20*

Vehicle Type: *MPV*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *275/45 R21*

Rear: *275/45 R21*

Recommended cold tire pressure: Front: *250 kPa (37 psi)*

Rear: *300 kPa (44 psi)*

TIRES

Tire manufacturer and model: *Pirelli Scorpion*

Front tire designation: *275/45 R21 110Y*

Rear tire designation: *275/45 R21 110Y*

Front tire DOT prefix: *XN 8M 325E*

Rear tire DOT prefix: *XN 8M 325E*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

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2020 Land Rover Range Rover Sport HSE

GENERAL INFORMATION

Test date: *9/8/2020*

AMBIENT CONDITIONS

Air temperature: *33.9 C (93 F)*

Wind speed: *5.1 m/s (11.5 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: *250 kPa (37 psi)*

Rear: *300 kPa (44 psi)*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

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2020 Land Rover Range Rover Sport HSE

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*700.3 kg (1544 lb)*	Right Front:	*576.5 kg (1271 lb)*
Left Rear:	*568.8 kg (1254 lb)*	Right Rear:	*669.5 kg (1476 lb)*
		Total:	*2515.1 kg (5545 lb)*

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

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2020 Land Rover Range Rover Sport HSE

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

Emergency Braking (Autonomous Emergency Braking (AEB) in Owner's Manual) comes standard on all trims. High Speed Emergency Braking is optional and is available in the 'Drive Pro Pack' and 'Driver Assist Pack' packages.

Type and location of sensors the system uses:

Forward Facing Stereo Vision Camera located near rearview mirror – Standard

Forward looking radar mounted in the front bumper, where optional Adaptive Cruise Control (ACC) installed – Option available on all models)

System setting used for test (if applicable):

System on, High Sensitivity

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

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

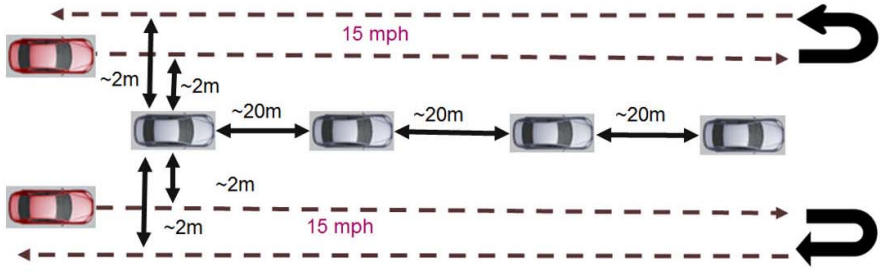
What is the maximum vehicle speed at which the CIB system functions?

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

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

____ No

If yes, please provide a full description.



- ❑ Left and right hand side drives alternately shall be repeated 10 times on each side.
- ❑ No braking, steering or anything that affects the Yaw of the car while objects are being studied by the camera.
- ❑ The entire calibration drives will not exceed 10minutes.

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

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2020 Land Rover Range Rover Sport HSE

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

If yes, please provide a full description.

AEB won't activate within 10 secs of previous 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.

A red symbol comprising a triangle with an exclamation point within is located in the instrument cluster message center. When the system detects a potential collision with a vehicle ahead, the symbol lights above the words "Collision Warning" (See Appendix A, Figure A14). A 1580 Hz audible alert also sounds, pulsing at approximately 4 times/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 located at the left side of the steering wheel are used to interact with system setup menus. The menu hierarchy is:

Driver Assistance

Collision Avoidance

Forward Alert - check or uncheck

See Appendix A, Figures A11 through A13

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 located at the left side of the steering wheel are used to interact with system setup menus. The menu hierarchy is:

Driver Assistance

Collision Avoidance

Forward Alert

+ Sensitivity - choose:

Normal

Medium

High

See Appendix A, Figures A11 through A13

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

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2020 Land Rover Range Rover Sport HSE

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.

Vehicle detection Autonomous Emergency Braking (AEB) does not operate if:

- *The vehicle is negotiating a tight corner.*
- *The forward-facing cameras are dirty or obscured.*
- *The vehicle's speed is below 3 mph (5 km/h), or above 50 mph (80 km/h).*
- *Visibility is impaired due to severe weather conditions, e.g., heavy rain, fog, or snow.*

See pages 196-197 of the Owner's Manual shown in Appendix B, pages B-6 through B-7.

Notes:

Section III

TEST PROCEDURES

A. Test Procedure Overview

Three test scenarios were used, as follows:

Test 1. Subject Vehicle (SV) Encounters Stopped Principal Other Vehicle (POV)

Test 2. Subject Vehicle Encounters Slower Principal Other Vehicle

Test 3. Subject Vehicle Encounters Decelerating Principal Other Vehicle

An overview of each of the test procedures follows.

1. TEST 1 – SUBJECT VEHICLE ENCOUNTERS STOPPED PRINCIPAL OTHER VEHICLE ON A STRAIGHT ROAD

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

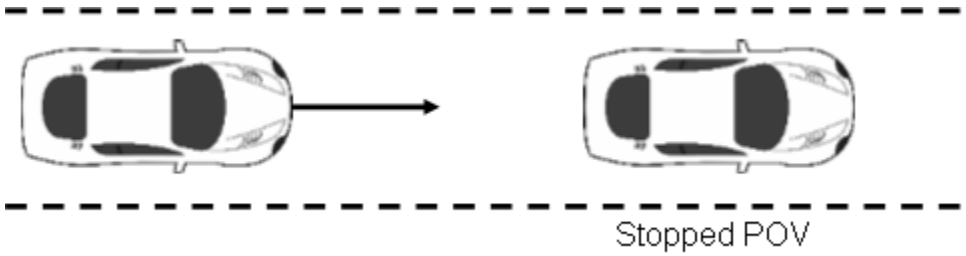


Figure 1. Depiction of Test 1

Table 2. Test Conditions for Stopped POV

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

a. Procedure

The POV was parked in the center of a travel lane, with its longitudinal axis oriented parallel to the roadway edge and facing the same direction as the SV so that the SV approached the rear of the POV.

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

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

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

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

b. Criteria

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

The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

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

2. TEST 2 – SUBJECT VEHICLE ENCOUNTERS SLOWER PRINCIPAL OTHER VEHICLE

This test evaluates the ability of the CIB system to detect and respond to a slower-moving lead vehicle traveling at a constant speed in the immediate forward path of the SV, as depicted in Figure 2. Test conditions for Test 2 are shown in Table 3.

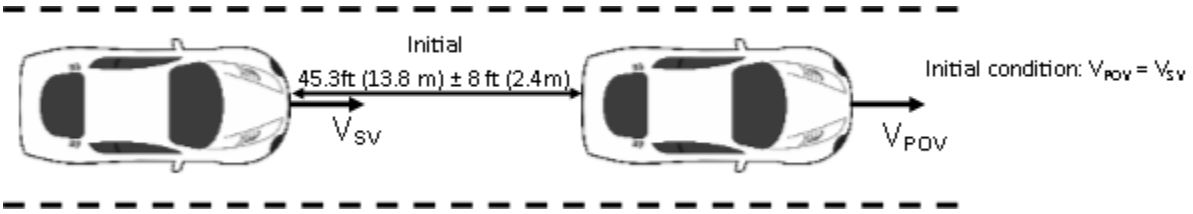


Figure 2. Depiction of Test 2

Table 3. Test Conditions for Slower POV

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

a. Procedure

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

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

The SV driver then braked to a stop.

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

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

b. Criteria

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

To be considered acceptable for the test series for which the initial speed of the SV was 45 mph, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 9.8 mph (15.8 km/h) for at least three of five valid test trials. The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

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

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

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

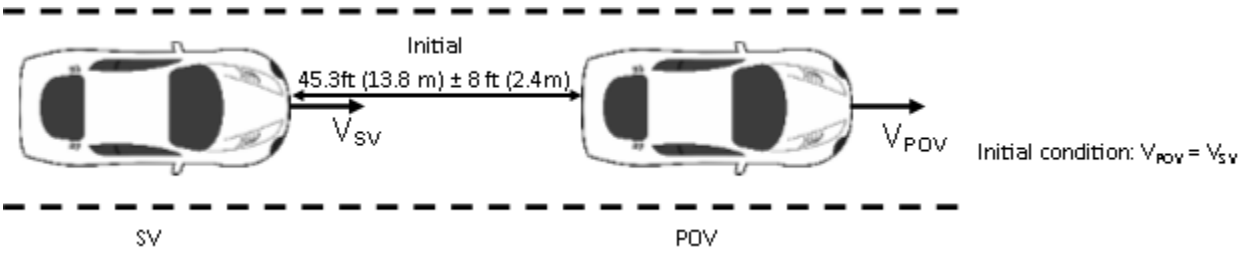


Figure 3. Depiction of Test 3 with POV Decelerating with V_0 =35 mph (56.3 km/h)

Table 4. Test Conditions for Decelerating POV

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

a. Procedure

The SV ignition was cycled prior to each test run. This test scenario was conducted at three different combinations of nominal initial speeds (V_0) and deceleration levels ($-a_x$). The first two combinations comprised V_0 = 35.0 mph (56.3 km/h) with a_x = -0.3 ± 0.03 g and -0.5 ± 0.03 g respectively. The third combination comprised V_0 = 45 mph (72.4 km/h) and a_x = 0.3 ± 0.03 g. Both the POV and SV were driven at a constant V_0 in the center of the lane, with a headway of 45.3 ft (13.8 m) ± 8 ft (2.4 m). Once these conditions were met for at least three seconds, the POV (GVT) brakes were applied to achieve the nominal level of deceleration ($-a_x$). The test concluded when either:

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

The SV driver then braked to a stop.

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

- The lateral distance between the centerline of the POV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.

- The lateral distance between the centerline of the SV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.
- The headway between the SV and POV must have been constant from the onset of the applicable validity period to the onset of POV braking.
- The SV and POV speed could not deviate more than ±1.0 mph (1.6 km/h) during an interval defined by the onset of the validity period to the onset of POV braking.
- The SV- POV headway distance could not deviate more than ±8 ft (2.4 m) during an interval defined by the onset of the validity period to the onset of POV braking.
- The average POV deceleration could not deviate by more than ±0.03 g from the nominal 0.3 g deceleration or 0.5 g deceleration, during the interval beginning at 1.5 seconds after the onset of POV braking and ending either 250 ms prior to the POV coming to a stop or the SV coming into contact with the POV.

b. Criteria

For the decelerating POV test series, in order to be considered acceptable, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 10.5 mph (16.9 km/h) for at least three of five valid test trials, for each combination of initial speeds and deceleration levels. The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

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

B. General Information

1. T_{FCW}

The time at which the Forward Collision Warning (FCW) activation flag indicates that the system has issued an alert to the SV driver is designated as $t_{FCW.}$ FCW alerts are typically either audible, visual, or haptic and the onset of the alert was determined by post-processing the test data.

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

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

Table 5. Audible and Tactile Warning Filter Parameters

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

2. GENERAL VALIDITY CRITERIA

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

- The SV driver seatbelt was latched.
- If any load had been placed on the SV front passenger seat (e.g., for instrumentation), the vehicle's front passenger seatbelt was latched.
- The SV was driven at the nominal speed in the center of the travel lane, toward the POV.
- The driver used the least amount of steering input necessary to maintain SV position in the center of the travel lane during the validity period; use of abrupt steering inputs or corrections was avoided.
- The yaw rate of the SV did not exceed ±1.0 deg/s from the onset of the validity period to the instant SV deceleration exceeded 0.25 g.
- The SV driver did not apply any force to the brake pedal during the applicable validity period.
- The lateral distance between the centerline of the SV and the centerline of the POV did not deviate more than ±1 ft (0.3 m) during the applicable validity period.

3. VALIDITY PERIOD

The valid test interval began:

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

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

Test 3: 3 seconds before the onset of POV braking

The valid test interval ended:

Test 1: When either of the following occurred:

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

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

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

4. STATIC INSTRUMENTATION CALIBRATION

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

For Tests 1, 2, and 3, the SV and POV (i.e., GVT and LPRV) were centered in the same travel lane with the same orientation (i.e., facing the same direction).

For these tests, the SV was also positioned such that it just contacted a vertical plane that defines the rearmost location of the POV. This is the “zero position.”

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

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

between collection of that post-test static calibration data file and the last valid pre-test static calibration data file were repeated.

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

5. NUMBER OF TRIALS

A target total of five (5) valid trials were performed for each scenario. In cases where the test driver performed more than five trials, the first five trials satisfying all test tolerances were used to assess the SV performance.

6. TRANSMISSION

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

C. Principal Other Vehicle

CIB testing requires a POV that realistically represents typical vehicles, does not suffer damage or cause damage to a test vehicle in the event of collision, and can be accurately positioned and moved during the tests. The tests reported herein made use of the Global Vehicle Target (GVT) secured to a low profile robotic vehicle (LPRV).

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

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

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

The key requirements of the POV element are to:

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

The key requirements of the POV delivery system are to:

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

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

D. Automatic Braking System

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

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

E. Instrumentation

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

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

Table 6. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	< 1% error between 20 and 100 psi	Omega DPG8001	17042707002	By: DRI Date: 8/18/2020 Due: 8/18/2021
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform	0.1% of reading	Intercomp SW wireless	0410MN20001	By: DRI Date: 4/20/2020 Due: 4/20/2021
Linear (string) encoder	Throttle pedal travel	10 in 254 mm	0.1 in 2.54 mm	UniMeasure LX-EP	45040532	By: DRI Date: 7/2/2020 Due: 7/2/2021
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	N/A
SV Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +	2258	By: Oxford Technical Solutions Date: 5/3/2020 Due: 5/3/2021
POV Multi-Axis Inertial Sensing System		Accels ± 10g, Angular Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +	2176	By: Oxford Technical Solutions Date: 6/26/2020 Due: 6/26/2022

Table 6. Test Instrumentation and Equipment (continued)

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

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

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

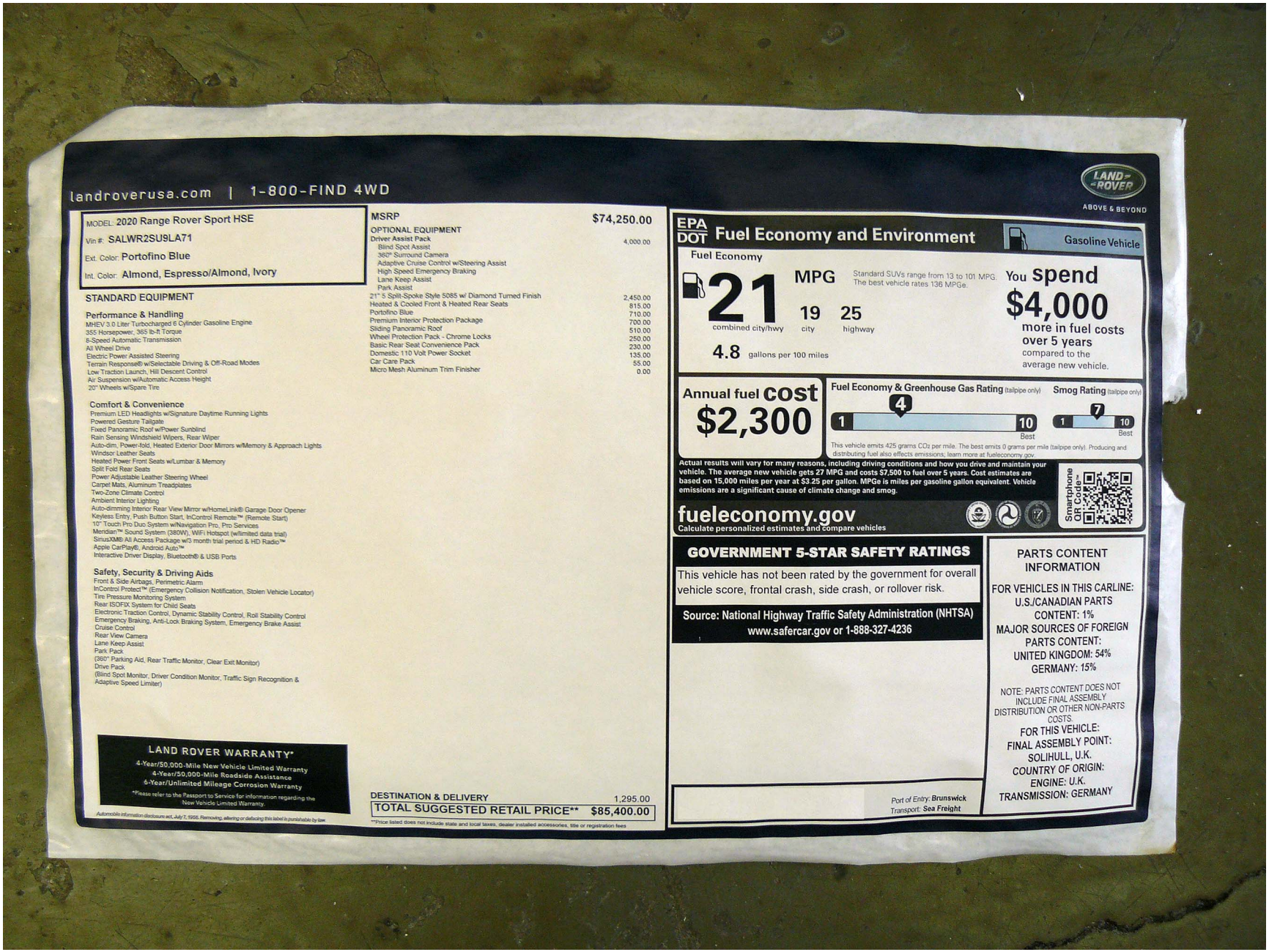


Figure A3. Window Sticker (Monroney Label)

Figure A4. Vehicle Certification Label

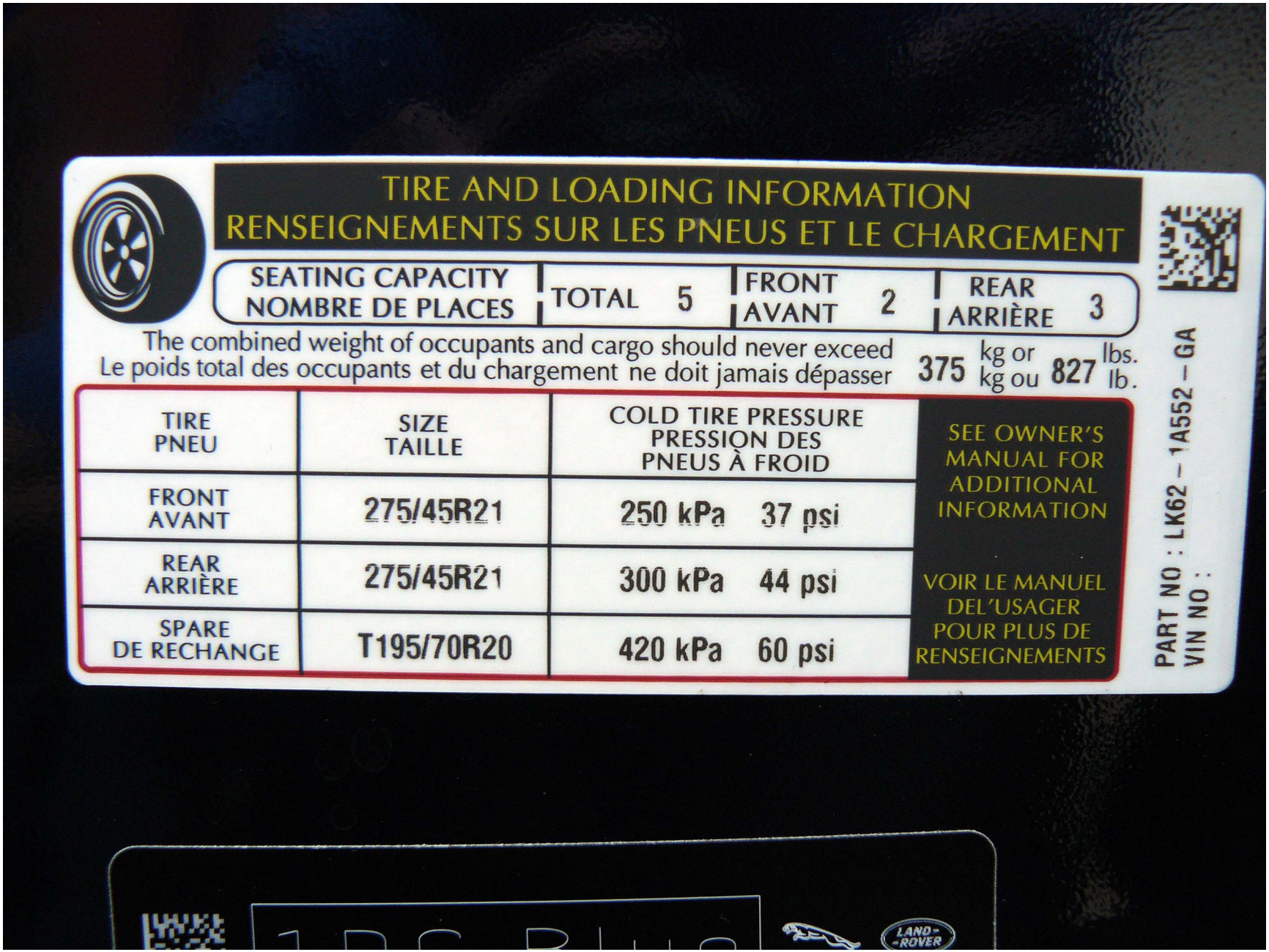


Figure A5. Tire Placard

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

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

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

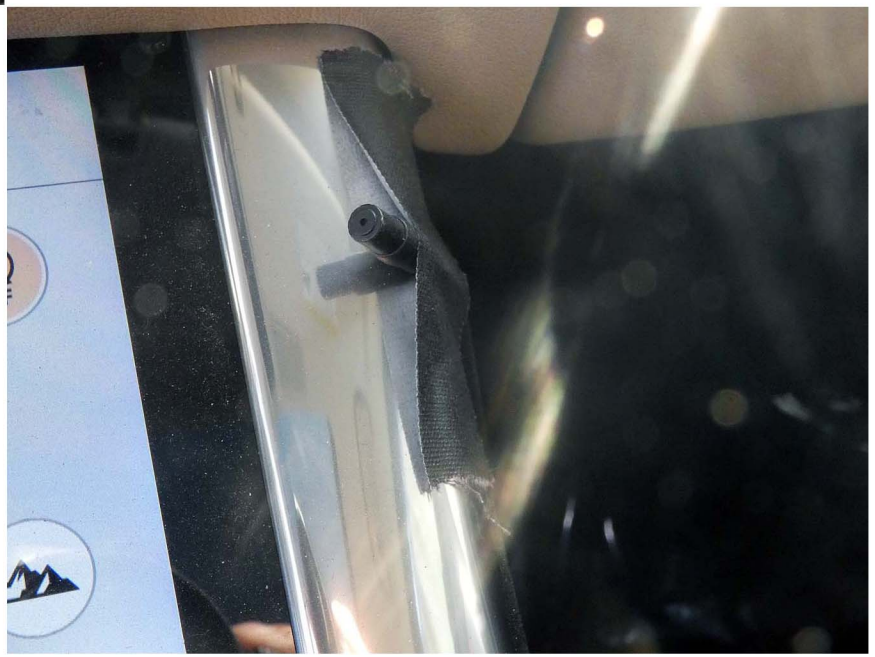


Figure A9. Sensors for Detecting Auditory and Visual Alerts

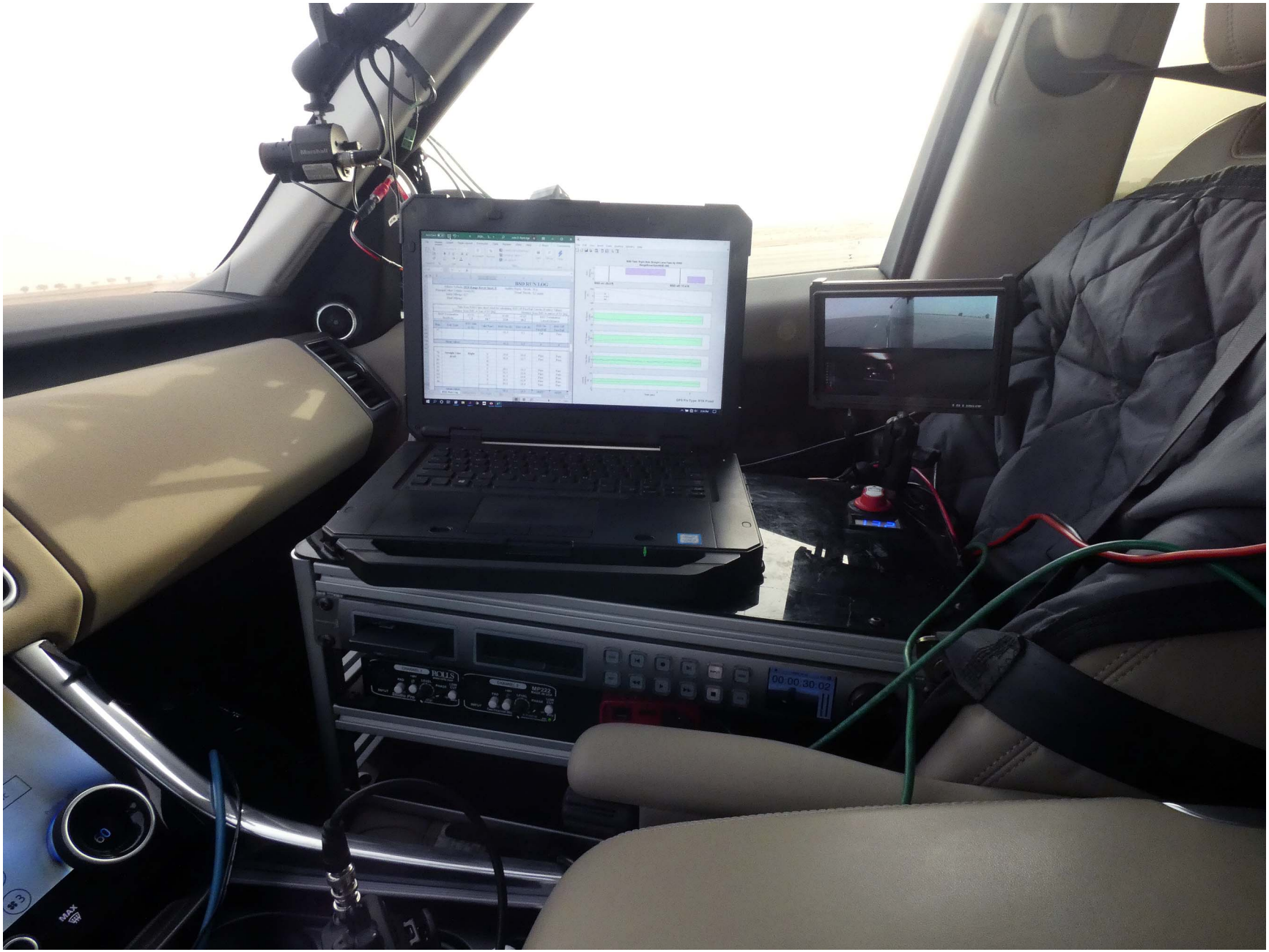


Figure A10. Computer Installed in Subject Vehicle

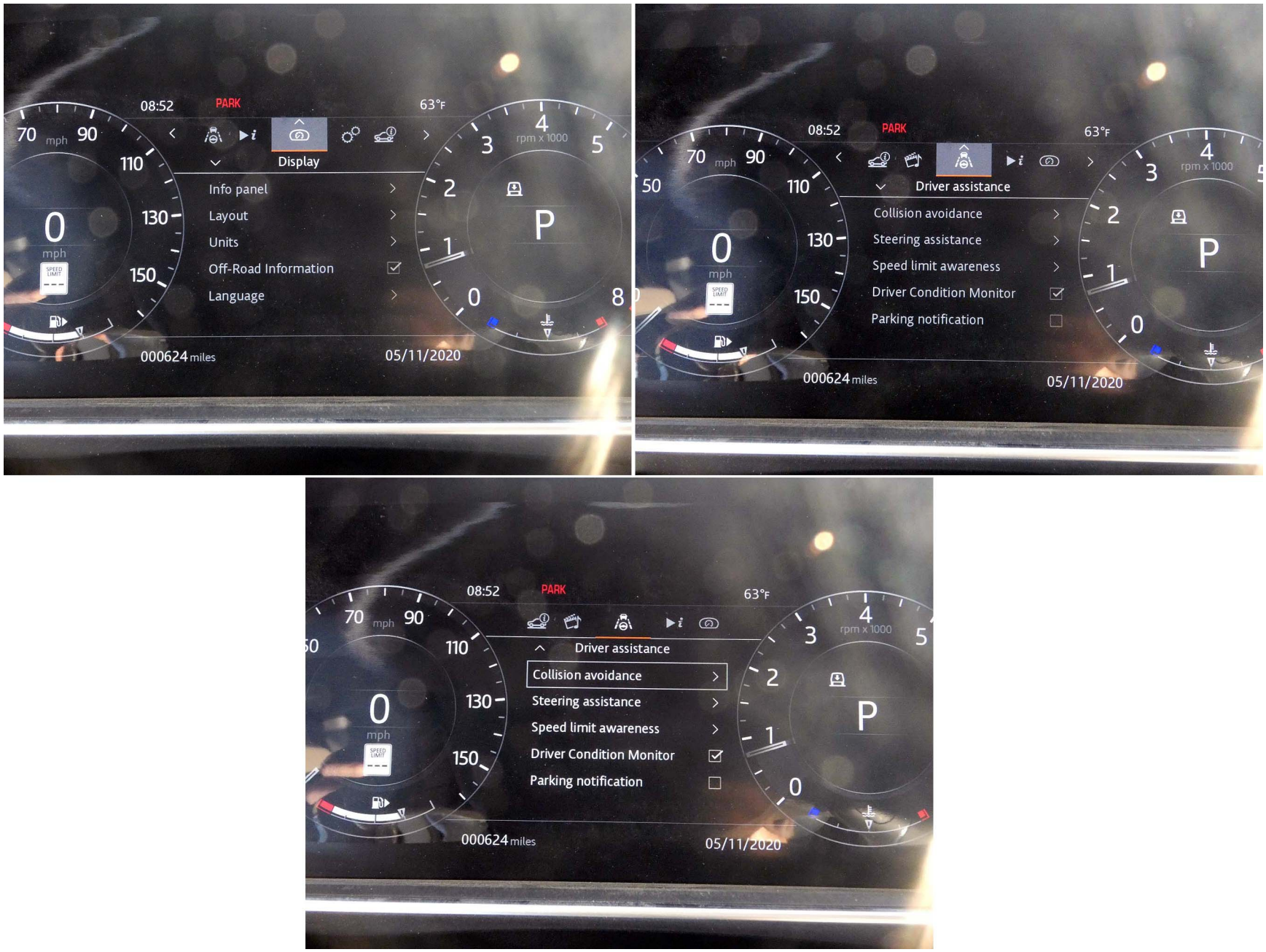


Figure A11. AEB Setup Menus (page 1 of 2)

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

Figure A13. Controls for Driver Assistance Settings Menus

Figure A14. Visual Alert

APPENDIX B

Excerpts from Owner’s Manual

Warning and information lamps

OVERVIEW

The following warning and information lamps may illuminate in the instrument panel:

See **72, BATTERY CHARGE (RED)**.

USA: See **72, BRAKE (RED)**.

Canada: See **72, BRAKE (RED)**.

See **73, CHARGING STATUS (RED)**.

See **73, CRITICAL WARNING MESSAGE (RED)**.

See **73, DIESEL EXHAUST FLUID (DEF) (RED)**.

USA: **73, ELECTRIC PARKING BRAKE (EPB) (RED)**.

Canada: See **73, ELECTRIC PARKING BRAKE (EPB) (RED)**.

See **73, ENGINE TEMPERATURE (RED)**.

See **74, LANE DEPARTURE WARNING (RED)**.

See **74, HYBRID SYSTEM BATTERY FAULT (RED)**.

See **74, LOW OIL PRESSURE (RED)**.

See **74, SEAT BELT (RED)**.

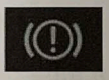
See **74, ADAPTIVE SPEED LIMITER (AMBER)**.

See **74, AIR BAG (AMBER)**.

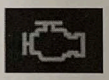
See **74, ALL TERRAIN PROGRESS CONTROL (ATPC) (AMBER)**.

See **75, ANTI-LOCK BRAKING SYSTEM (ABS) (AMBER)**.

USA: See **75, BRAKE (AMBER)**.

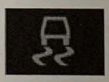


Canada: See **75, BRAKE (AMBER)**.



See **75, CHECK ENGINE (AMBER)**.

See **75, DIESEL EXHAUST FLUID (DEF) (AMBER)**.



See **76, DYNAMIC STABILITY CONTROL (DSC) (AMBER)**.

See **76, DYNAMIC STABILITY CONTROL (DSC) OFF (AMBER)**.

See **76, EXTERNAL TEMPERATURE (AMBER)**.

See **76, FOLLOW MODE (AMBER)**.

See **76, GENERAL WARNING AND INFORMATION MESSAGE (AMBER)**.

COLLISION AVOIDANCE SAFETY

Make sure the following warnings have been read and fully understood before driving the vehicle. Failure to use the collision avoidance systems safely could result in an accident, leading to serious injury or death.

⚠WARNING

Collision avoidance systems are not a substitute for driving safely, with due care and attention. Staying alert, driving safely, and being in control of the vehicle at all times is the responsibility of the driver.

⚠WARNING

Blind spot driving aids are a supplement to, not a replacement for, a safe driving style.

⚠WARNING

The driver is responsible for driving with due care and attention, and in a safe manner for the vehicle, the occupants, and other road users. The driver is responsible for detecting obstacles, and estimating the vehicle's distance from them, when maneuvering the vehicle. The driver should observe all road signs, road markings and any potential braking situations, and act appropriately.

⚠WARNING

Always use the door and rear-view mirrors. Drive safely at all times, and use the door and rear-view mirrors to help avoid accidents.

⚠WARNING

Blind spot driving aids may not function at all speeds, or in all weather conditions.

⚠WARNING

Blind spot driving aids do not correct errors of judgement when driving.

⚠WARNING

The radar and camera sensors used by the blind spot driving aids may become impaired by mud, rain, frost, ice, snow, road spray, etc. The blind spot driving aids ability to detect a vehicle in the driver's blind spot may subsequently be affected and may give false indications.

⚠WARNING

Do not attach stickers or objects to the rear bumper or to the windshield. Operation of the blind spot sensors and camera may subsequently become impaired. The blind spot driving aids ability to detect a vehicle in the driver's blind spot may subsequently be affected and may give false indications.

⚠WARNING

Do not attach stickers or other objects to the door mirrors, as the blind spot icons and indicators may become obscured. Obscuring the icons and indicators could increase the risk of a collision during a vehicle maneuver.

⚠WARNING

The blind spot monitor system may not be able to give adequate warning of vehicles approaching very quickly from behind.

⚠WARNING

The blind spot monitor system may not be able to detect all vehicles and may also detect objects such as roadside barriers, etc.

⚠WARNING

Do not use blind spot assist when a trailer is connected. The trailer may provide miscalculations or false indications. False indications could increase the risk of a collision during a vehicle maneuver.

⚠WARNING

The radar sensor must be calibrated if it is replaced, its mounting is replaced, or it becomes misaligned, e.g., as a result of impact damage. Contact a retailer/authorized repairer.

FORWARD ALERT

⚠WARNING

Make sure the relevant safety warnings have been read and understood before driving the vehicle. See 193, COLLISION AVOIDANCE SAFETY.

⚠WARNING

Forward alert may not react to slow-moving vehicles. Always drive with due care and attention. Driving without due care and attention greatly increases the risk of an accident.

Forward alert monitors an area in front of the vehicle. The driver is warned if forward alert detects an object within the detection area. The instrument panel also displays a warning message if the vehicle is traveling between 18 mph (30 km/h) and 50 mph (80 km/h). The driver is responsible for taking appropriate action.

Three forward alert sensitivity settings are available:

- Normal.
- Medium.
- High.

Warnings sound and the instrument panel displays a warning message if forward alert detects an object in front of the vehicle.

Forward alert can be switched on and off via the **Driver assistance** instrument panel menu. See **65, INSTRUMENT PANEL MENU**.

Forward alert sensitivity can be adjusted. See **194, CHANGING THE FORWARD ALERT SENSITIVITY**.

CHANGING THE FORWARD ALERT SENSITIVITY

Forward alert has three different sensitivity settings. The default setting is **Normal**.

The sensitivity of the forward alert feature can be changed as follows:

1. Switch the vehicle's ignition on.
2. Select **Collision avoidance** from the **Driver assistance** instrument panel menu. See **65, INSTRUMENT PANEL MENU**.
3. Use the steering wheel controls to highlight the required setting: **Normal**, **Medium**, or **High**.

4. Press and release the **OK** button on the steering wheel.

The forward alert sensitivity setting is retained in the vehicle's memory after the vehicle is switched off.

AUTONOMOUS EMERGENCY BRAKING (AEB) SAFETY

Make sure the following warnings have been read and fully understood before driving the vehicle. Failure to understand the Autonomous Emergency Braking (AEB) system could result in an accident, leading to serious injury or death.

⚠WARNING

The AEB system is a driving aid only. The driver is responsible for driving with due care and attention, and in a safe manner for the vehicle, the occupants, and other road users. The driver should observe all road signs, road markings and any potential emergency braking situations, and act appropriately.

⚠WARNING

The AEB system uses forward-facing cameras to detect real vehicles and pedestrians, plus other certified target objects. AEB is not designed to detect any other objects, including non-industry approved targets.

⚠WARNING

In order for AEB to operate, it must be able to detect a clear image of the object and be able to determine its movement. If neither of these occur, the AEB system may not operate.

⚠WARNING

Seat belts should be worn by all vehicle occupants, for every trip, no matter how short. Failure to do so greatly increases the risk of death or serious injury in the event of an accident.

⚠WARNING

Make sure that the windshield is kept clean and that the camera's line of sight is not obstructed by labels, stickers, etc. Failure to do so can cause incorrect AEB operation.

Note: *AEB efficiency is dependent on the condition of the current driving surface and the vehicle's speed, tires, and braking system.*

Note: *When a vehicle is parked outside, in full sunlight and in high ambient temperatures, the forward-facing camera may reach an internal temperature of 210°F (99°C). In this state, the instrument panel displays the warning message* ***AEB not available****. When the forward-facing camera cools to less than 190°F (88°C), normal operation is resumed, and the warning message extinguishes.*

Note: *When driving off-road, it is recommended to switch off the AEB system.*

Note: *When the vehicle's ignition is first switched on, AEB may require an initialisation period before it is fully functional. AEB efficiency is limited during this period.*

AUTONOMOUS EMERGENCY BRAKING (AEB)

⚠WARNING

Make sure the relevant safety warnings have been read and understood before driving the vehicle. See 195, AUTONOMOUS EMERGENCY BRAKING (AEB) SAFETY.

Note: *Not all vehicles are fitted with Autonomous Emergency Braking (AEB). Consult a retailer/authorized repairer for confirmation.*

AEB uses forward-facing cameras, located above the rear-view mirror, to help identify an imminent risk of collision with:

- Another vehicle traveling in front.
- A crossing pedestrian.

In most instances, AEB helps reduce the severity of an impact. In some cases, AEB helps to stop the vehicle before an impact takes place.

AEB automatically switches on, every time the vehicle's ignition is switched on.

If required, AEB can be switched off via the **Driver assistance** instrument panel menu. See **65, INSTRUMENT PANEL MENU**.

AEB operates at speeds above 3 mph (5 km/h). The vehicle detection AEB system is able to operate at speeds of up to 50 mph (80 km/h). The pedestrian detection AEB systems is able to operate at speeds of up to 37 mph (60 km/h).

If an imminent risk of a collision is detected, the system automatically applies the brakes. The instrument panel also displays the message **AEB active** while AEB is operating.

⚠WARNING

If AEB brings the vehicle to a stop, the brakes continue to hold the vehicle stationary for a few seconds. After this period, the driver must resume full control of the vehicle. Failure to take back full control of the vehicle could result in an accident, leading to serious injury or death.

Note: *The brake lights are automatically operated in heavy braking situations.*

The driver can override AEB operation by turning the steering wheel, or pressing the accelerator pedal. When overridden, AEB cancels its request for braking to make sure that the driver remains in full control of the vehicle.

After AEB has been activated, a warning sounds and the instrument panel displays the message **AEB was activated**.

AUTONOMOUS EMERGENCY BRAKING (AEB) LIMITATIONS

Vehicle detection Autonomous Emergency Braking (AEB) does not operate if:

- The vehicle is negotiating a tight corner.
- The forward-facing cameras are dirty or obscured.
- The vehicle's speed is below 3 mph (5 km/h), or above 50 mph (80 km/h).
- Visibility is impaired due to severe weather conditions, e.g., heavy rain, fog, or snow.

In addition to the items listed for the vehicle detection AEB system, the pedestrian detection AEB system does not operate if:

- The vehicles speed is above 37 mph (60 km/h).
- The detected object is not identified as a pedestrian.
- The height of the object is less than 39 in (1 m).
- The pedestrian detection AEB system cannot determine that the target object is a pedestrian. For example, if the pedestrian is carrying a large object.

ADVANCED EMERGENCY BRAKE ASSIST (AEBA)

⚠WARNING

Make sure the relevant safety warnings have been read and understood before driving the vehicle. See 193, COLLISION AVOIDANCE SAFETY.

Advanced Emergency Brake Assist (AEBA) prepares the braking system if it detects a collision is imminent. If the driver subsequently presses the brake pedal, full braking force is applied immediately.

If forward alert is switched on, AEBA activates after the instrument panel displays the warning message **Forward alert**. AEBA automatically applies a light braking force. Full braking force is applied immediately when the driver presses the brake pedal.

AEBA still operates if forward alert is switched off.

ADVANCED EMERGENCY BRAKE ASSIST (AEBA) LIMITATIONS

Make sure the following warnings have been read and fully understood before driving the vehicle. The Advanced Emergency Brake Assist (AEBA) feature does not take away the requirement to always drive with due care and attention. Driving without due care and attention could result in an accident, leading to serious injury or death.

⚠WARNING

The AEBA feature may not react to slow-moving vehicles.

⚠WARNING

The AEBA feature does not react to stationary vehicles or vehicles traveling in the opposite direction.

⚠WARNING

In some circumstances, warnings may not display in the instrument panel. For example, if the distance to the vehicle ahead is very small. Another example includes when carrying out a collision avoidance maneuver by making large steering wheel and pedal movements.

AEBA operates at speeds above approximately 5 mph (8 km/h).

HIGH-SPEED EMERGENCY BRAKING

⚠WARNING

Make sure the relevant safety warnings have been read and understood before driving the vehicle. See 193, COLLISION AVOIDANCE SAFETY.

APPENDIX C

Run Log

Subject Vehicle: **2020 Land Rover Range Rover Sport HSE** Test Date: **9/8/2020**

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								
2	**Stopped POV, 25 mph**	Y	2.04	5.65	25.3	1.07	0.91	Yes	
3		Y	2.02	5.64	25.4	1.06	0.91	Yes	
4		Y	2.05	7.42	25.2	1.02	0.95	Yes	
5		Y	1.97	4.90	25.2	1.02	0.86	Yes	
6		Y	2.05	8.06	25.3	1.01	0.96	Yes	
7		Y	1.89	6.21	24.6	1.09	0.89	Yes	
8		Y	2.00	8.02	25.0	1.03	0.97	Yes	
9	Static Run								
10	**Stopped POV, 30 mph**	Y	2.02	7.65	30.2	1.04	1.03	Yes	
11		Y	2.42	7.76	30.3	1.07	1.03	Yes	
12		Y	1.97	3.46	30.1	1.02	0.95	Yes	
13		Y	2.31	9.93	29.4	1.04	1.07	Yes	
14		Y	2.36	7.03	29.8	1.03	1.00	Yes	
15		Y	2.43	9.10	30.5	1.02	1.07	Yes	
16		Y	2.46	9.64	30.0	1.03	1.06	Yes	
17	Static Run								
18	**Stopped POV, 35 mph**	Y	1.97	0.00	30.5	1.02	0.97	Yes	
19		Y	2.38	0.00	31.0	1.03	1.12	Yes	
20		N							Brake application by driver
21		Y	2.36	0.00	30.7	1.02	1.11	Yes	
22		N							Communication dropout

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

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Acceptability Criteria met [5]	Notes
23	**Stopped POV, 35 mph**	Y	2.23	0.00	29.9	1.02	1.08	Yes	
24	Static Run								
25		N							Brake application by driver
26		N							Communication dropout
27		Y	2.25	0.00	30.4	1.06	1.12	Yes	
28		Y	2.27	0.00	31.1	1.04	1.09	Yes	
29		Y	2.32	0.00	29.6	1.06	1.13	Yes	
30	Static Run								
31	**Stopped POV, 40 mph**	Y	1.97	0.00	32.0	1.04	1.11	Yes	
32		N							GPS error
33		Y	2.00	0.00	31.8	1.05	1.09	Yes	
34		Y	1.97	0.00	31.1	1.05	1.03	Yes	
35		N							Throttle release
36		Y	2.01	0.00	29.1	1.02	1.00	Yes	
37		Y	1.91	0.00	28.2	1.04	0.99	Yes	
38		Y	1.92	0.00	30.5	1.06	1.07	Yes	
39	Static Run								
40	**Stopped POV, 45 mph**	Y	1.69	0.00	27.4	1.04	1.02	Yes	
41		Y	1.74	0.00	28.1	1.03	1.06	Yes	
42		Y	1.65	0.00	27.0	1.01	1.04	Yes	
43		Y	1.80	0.00	29.8	1.03	1.07	Yes	
44		Y	1.75	0.00	29.7	1.03	1.09	Yes	
45	Static Run								
46	Static Run								
47	**Slower POV, 25/10 mph**	N							POV speed
48		Y	2.32	5.74	15.4	1.12	0.81	Yes	
49		Y	2.21	5.47	14.6	1.11	0.81	Yes	
50		N							POV speed

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
51	**Slower POV, 25/10 mph**	N							POV speed
52		N							POV speed
53		Y	2.34	5.41	15.2	1.11	0.79	Yes	
54		Y	2.33	5.37	15.5	1.11	0.87	Yes	
55		Y	2.24	5.37	15.1	1.12	0.83	Yes	
56		N							POV speed
57		Y	2.25	4.45	15.3	1.10	0.82	Yes	
58		N							Check CIB TTC
59		Y	2.27	5.69	15.7	1.10	0.78	Yes	
60	Static Run								
61	**Slower POV, 45/20 mph**	Y	2.24	12.05	25.7	1.05	1.45	Yes	
62		N							POV speed
63		Y	2.39	10.02	24.8	1.06	1.39	Yes	
64		Y	2.34	12.54	24.9	1.07	1.38	Yes	
65		N							Driver application of brakes
66		Y	2.40	10.44	25.6	1.07	1.42	Yes	
67		Y	2.50	11.85	25.3	1.08	1.41	Yes	
68		N							Driver application of brakes
69		Y	2.43	13.43	25.6	1.05	1.44	Yes	
70		Y	2.47	12.53	25.3	1.09	1.43	Yes	
71	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
72	**Decelerating POV, 0.3g 35 mph**	N							Headway, POV yaw, POV lateral
73		Static Run							Resume testing 11/9/20
74		N							SV speed, lateral offset, throttle
75		Y	1.44	5.02	22.3	1.14	0.85	Yes	
76		Y	1.49	6.27	22.1	1.16	0.88	Yes	
77		Y	1.74	6.91	22.1	1.13	0.94	Yes	
78		N							POV Ax
79		Y	1.62	5.57	22.8	1.10	0.86	Yes	
80		Y	1.62	5.30	22.5	1.08	0.87	Yes	
81		N							POV speed
82		N							POV speed
83		Y	1.60	3.45	22.9	1.11	0.76	Yes	
84	Static Run								
85	**Decelerating POV, 0.5g 35 mph**	N							Brake
86		N							POV speed
87		N							Headway, POV speed, brake
88		N							POV speed
89		Y	1.51	0.00	30.3	1.12	1.07	Yes	
90		Y	1.42	0.00	30.4	1.11	1.05	Yes	
91		Y	1.45	0.00	30.4	1.14	0.96	Yes	
92		N							Brake applied
93		N							GPS
94		Y	1.43	0.00	30.0	1.12	0.97	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
95		Y	1.54	0.00	30.8	1.13	0.97	Yes	
96	Static Run								
97	**Decelerating POV, 0.3g 45 mph**	N							GPS fix type
98		Y	1.66	8.67	21.3	1.12	1.00	Yes	
99		N							POV brake
100		Y	1.82	5.61	22.9	1.13	0.89	Yes	
101		N							GPS fix type
102		N							POV brake
103		Y	1.72	5.43	23.5	1.13	0.86	Yes	
104		Y	1.57	4.30	23.9	1.11	0.81	Yes	
105	Static Run								

APPENDIX D

Time History Plots

LIST OF FIGURES

Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from both the Subject Vehicle (SV) and the Principal Other Vehicle (POV), as well as pass/fail envelopes and thresholds. The following is a description of data types shown in the time history plots, as well as a description of the color codes indicating to which vehicle the data pertain.

Time History Plot Description

Each time history plot consists of data relevant to the test type under consideration, and therefore the data channels plotted vary according to test type. The test types (shown in the plot titles) include:

Stopped POV (SV at 25 mph)
Stopped POV (SV at 30 mph)
Stopped POV (SV at 35 mph)
Stopped POV (SV at 40 mph)
Stopped POV (SV at 45 mph)
Slower POV, 25/10 (SV at 25 mph, POV at 10 mph)
Slower POV, 45/20 (SV at 45 mph, POV at 20 mph)
Decelerating POV 35 mph (Both vehicles at 35 mph with 13.8 m gap, POV brakes at 0.3 g)
Decelerating POV 35 mph (Both vehicles at 35 mph with 13.8 m gap, POV brakes at 0.5 g)
Decelerating POV 45 mph (Both vehicles at 45 mph with 13.8 m gap, POV brakes at 0.3 g)

Time history figures include the following sub-plots:

- FCW Warning – Displays the Forward Collision Warning alert (which can be audible, visual, or haptic). Depending on the type of FCW alert or instrumentation used to measure the alert, this can be any combination of the following:
    - Filtered, rectified, and normalized sound signal. The vertical scale is 0 to 1.
    - Filtered, rectified, and normalized acceleration (i.e., haptic alert, such as steering wheel vibration). The vertical scale is 0 to 1.
    - Normalized light sensor signal. The vertical scale is 0 to 1.

  As only the audible or haptic alert is perceptible by the driver during a test run, the earliest of either of these alerts is used to define the onset of the FCW alert. A vertical black bar on the plot indicates the TTC (sec) at

the first moment of the warning issued by the FCW system. The FCW TTC is displayed to the right of the subplot in green.

- Headway (ft) – Longitudinal separation (gap) between the front-most point of the Subject Vehicle and the rearmost point of the Global Vehicle Target (GVT). The minimum headway during the run is displayed to the right of the subplot.

- SV/POV Speed (mph) – Speed of the Subject Vehicle and Principal Other Vehicle (if any). For CIB tests, the speed reduction experienced by the Subject Vehicle is displayed to the right of the subplot.

- Yaw Rate (deg/sec) – Yaw rate of the Subject Vehicle and Principal Other Vehicle (if any).

- Lateral Offset (ft) – Lateral offset within the lane of the Subject Vehicle to the center of the lane of travel. The lateral offset is defined to be the lateral distance between the centerline of the SV and the centerline of the POV.

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

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

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

Envelopes and Thresholds

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

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

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

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

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

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

Color Codes

Color codes have been adopted to easily identify which data correspond to which vehicle, as well as to indicate the types of envelopes and thresholds used in the plots.

Color codes can be broken into four categories:

1. Time-varying data
2. Validation envelopes and thresholds
3. Individual data points
4. Text

1. Time-varying data color codes:
   - Blue = Subject Vehicle data
   - Magenta = Principal Other Vehicle data
   - Brown = Relative data between SV and POV (i.e., TTC, lateral offset and headway distance)

2. Validation envelope and threshold color codes:
   - Green envelope = time varying data must be within the envelope at all times in order to be valid
   - Yellow envelope = time varying data must be within limits at left and/or right ends
   - Black threshold (Solid) = time varying data must cross this threshold in the time period shown in order to be valid
   - Black threshold (Dashed) = for reference only – this can include warning level thresholds, TTC thresholds, and acceleration thresholds

3. Individual data point color codes:
   - Green circle = passing or valid value at a given moment in time
   - Red asterisk = failing or invalid value at a given moment in time

4. Text color codes:
   - Green = passing or valid value
   - Red = failing or invalid value

Other Notations

- NG – Indicates that the value for that variable was outside of bounds and therefore “No Good”.
- No Wng – No warning was detected.
- POV – Indicates that the value for the Principal Other Vehicle was out of bounds.
- SV – Indicates that the value for the Subject Vehicle was out of bounds.
- SR – Shows the speed reduction value.
- Thr – Indicates that the requirements for the throttle were not met.

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

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

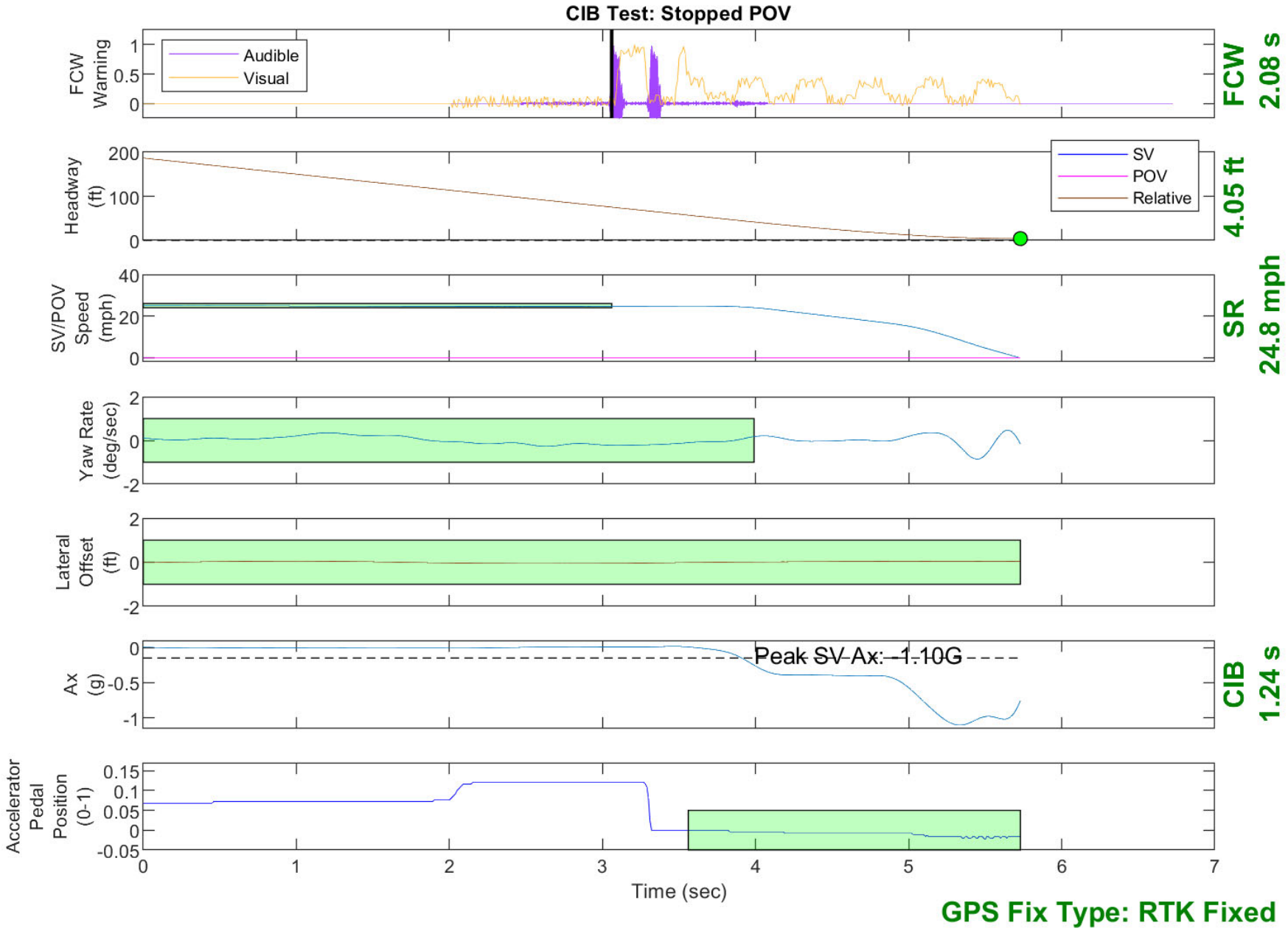


Figure D1. Example Time History for Stopped POV, Passing

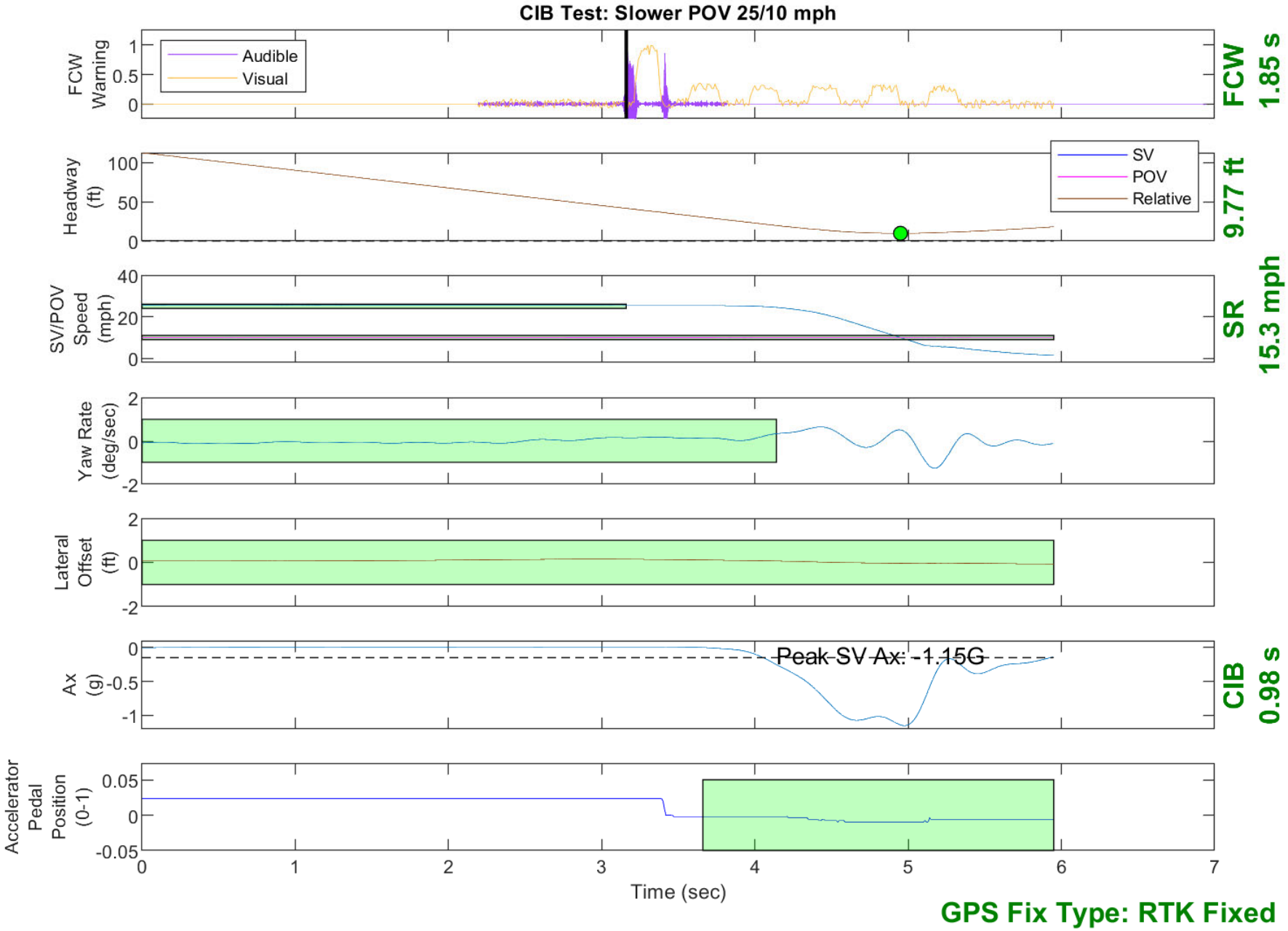


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

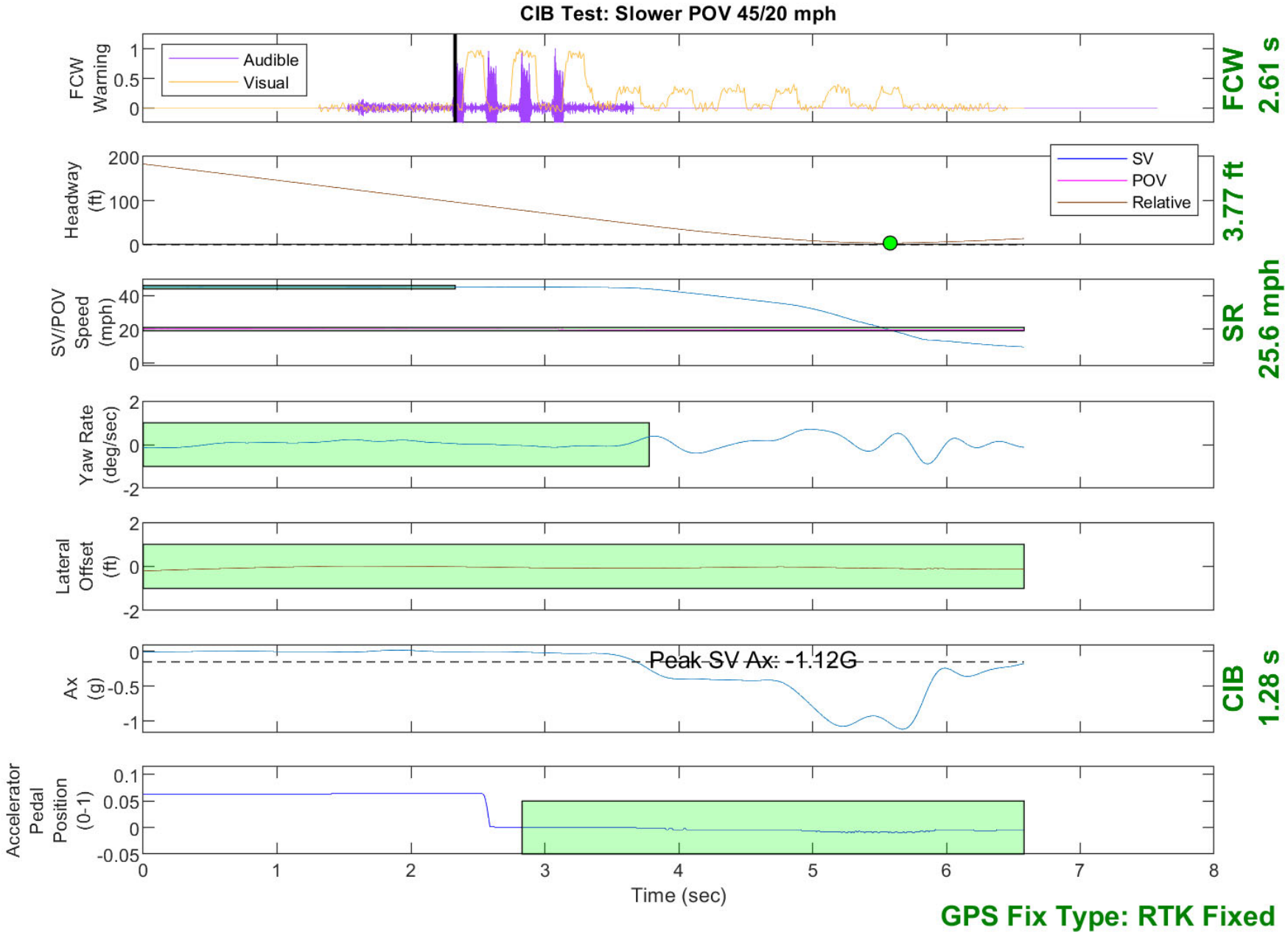


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

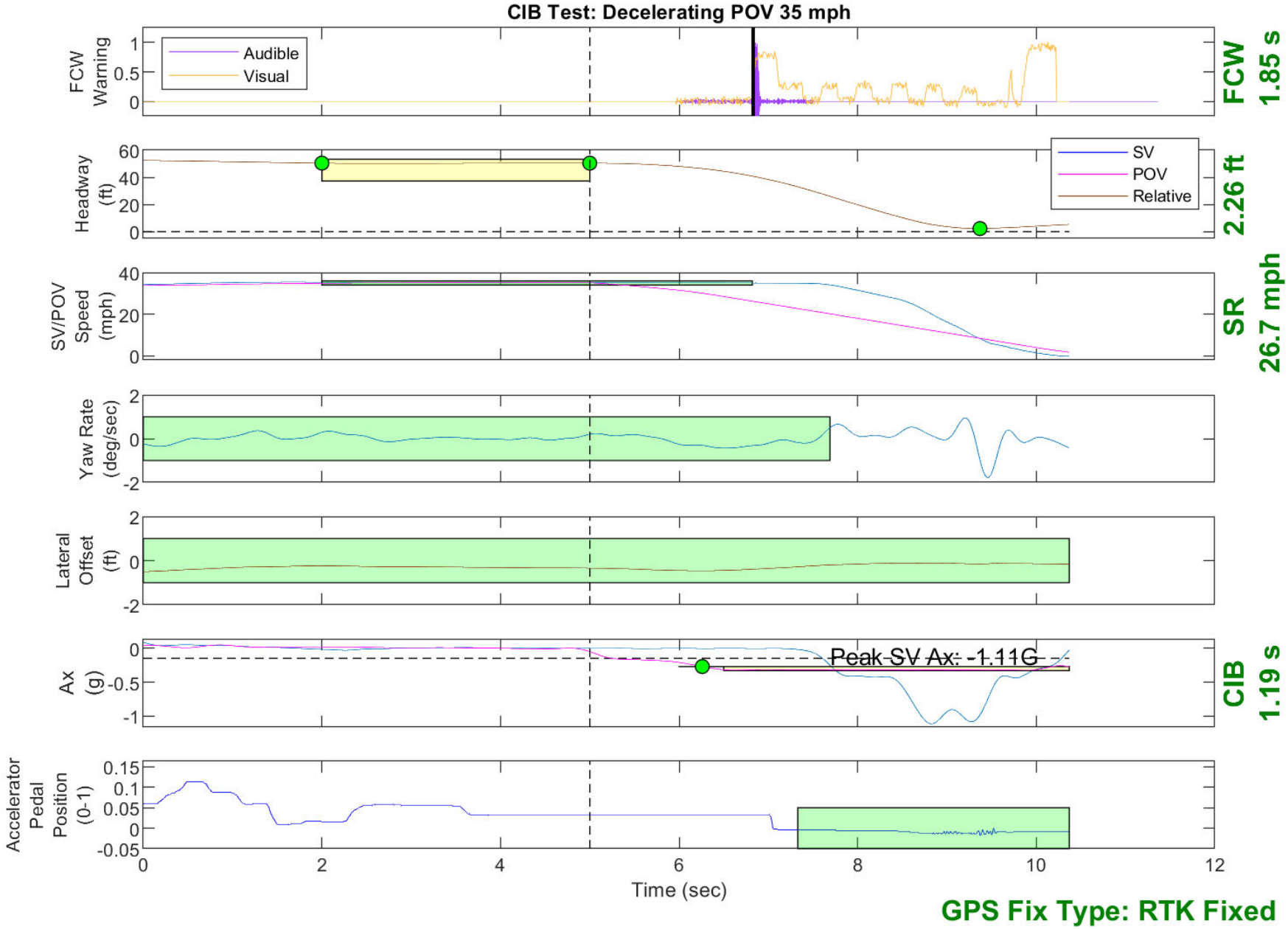


Figure D4. Example Time History for Decelerating POV 35, Passing

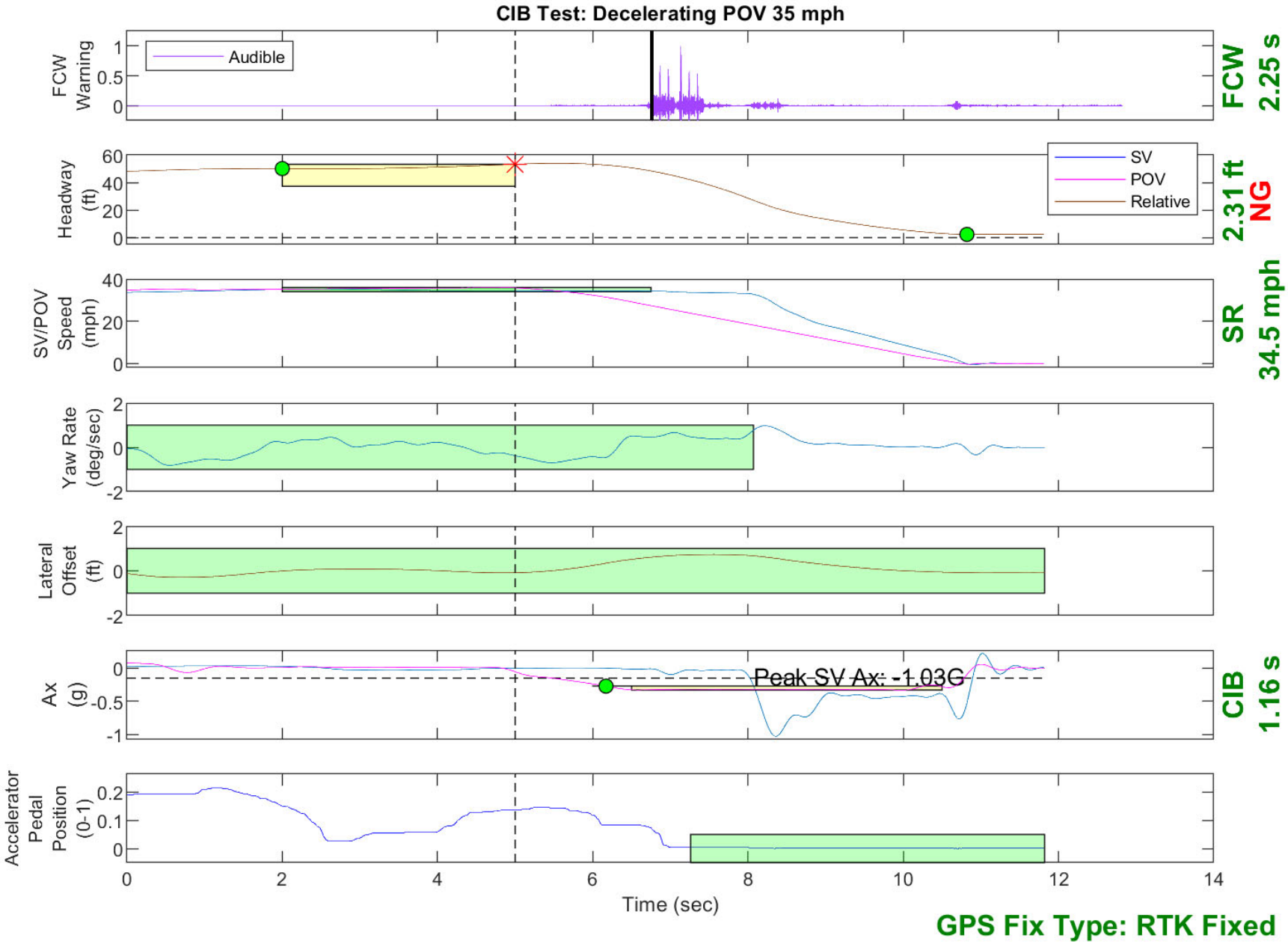


Figure D5. Example Time History Displaying Invalid Headway Criteria

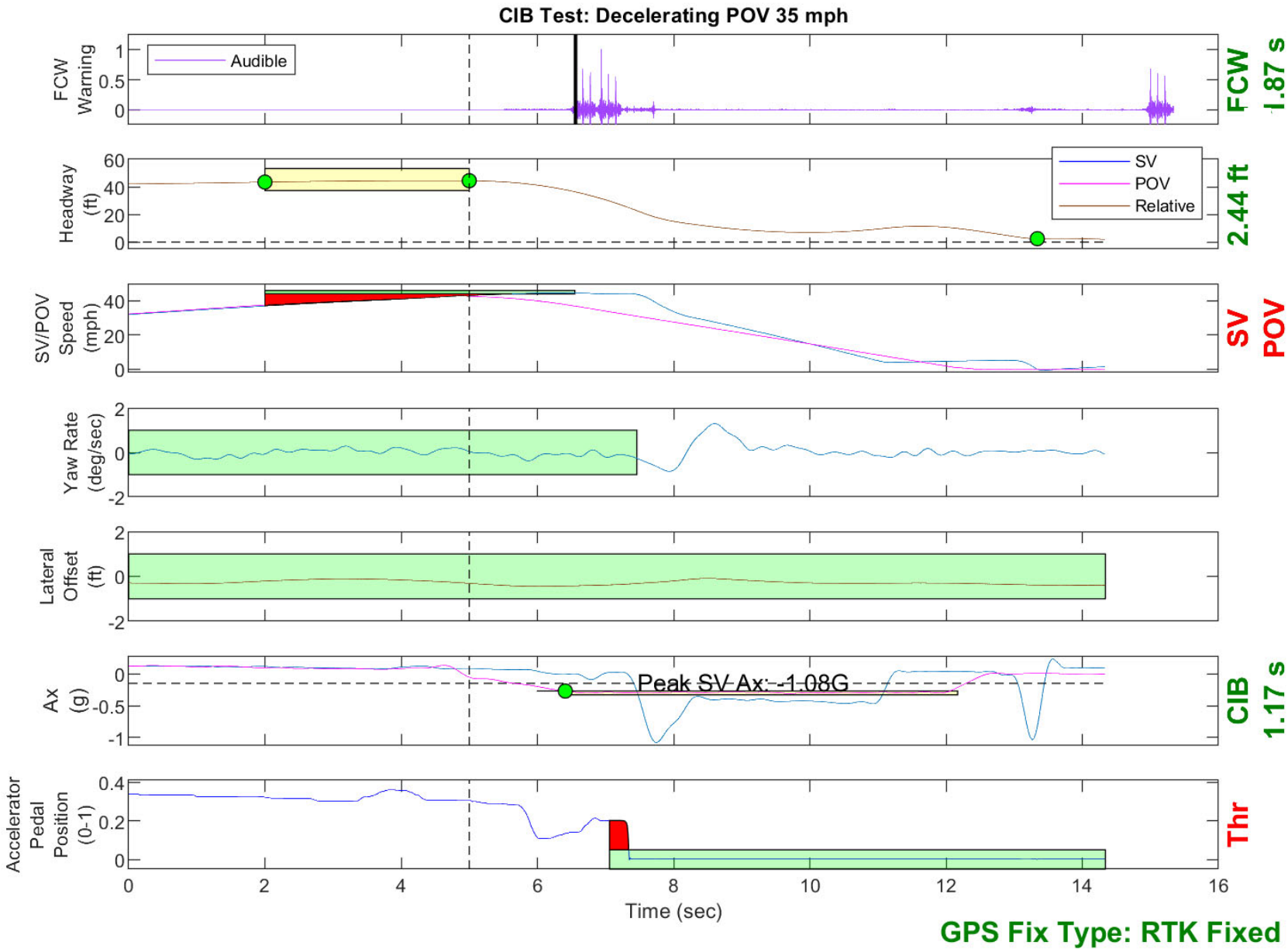


Figure D6. Example Time History Displaying Various Other Invalid Criteria

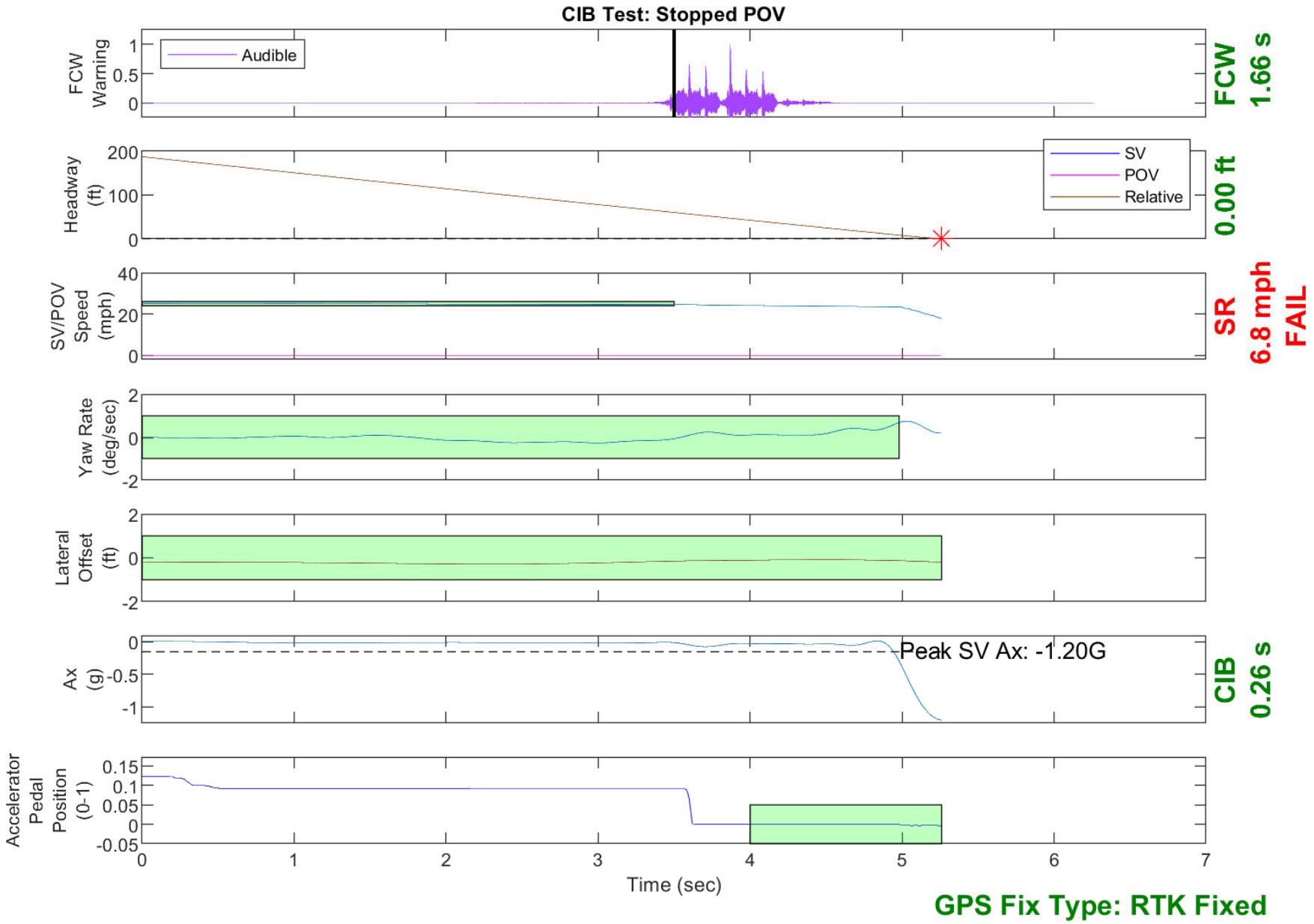


Figure D7. Example Time History for a Failed Run

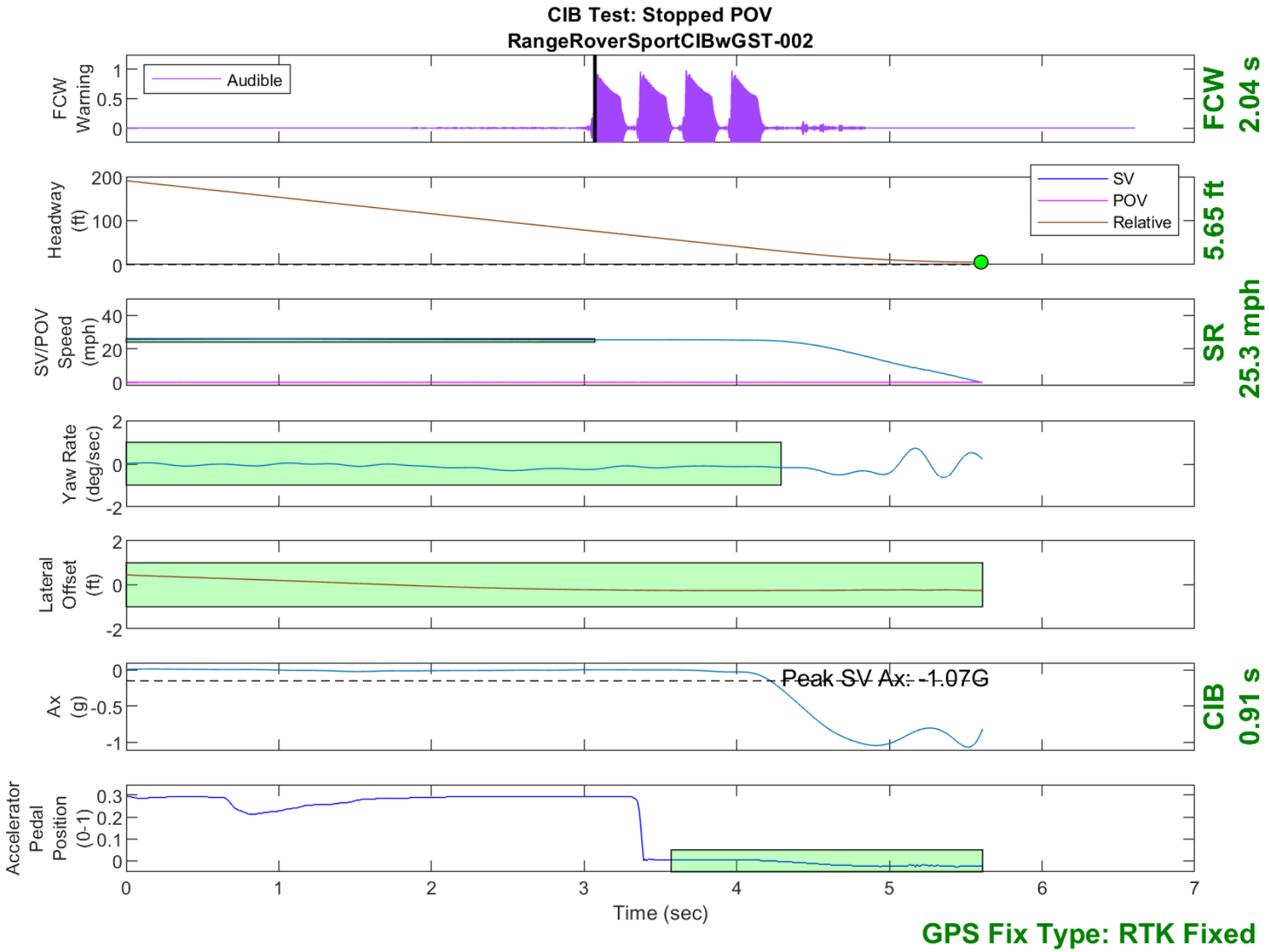


Figure D8. Time History for CIB Run 2, Stopped POV, 25 mph

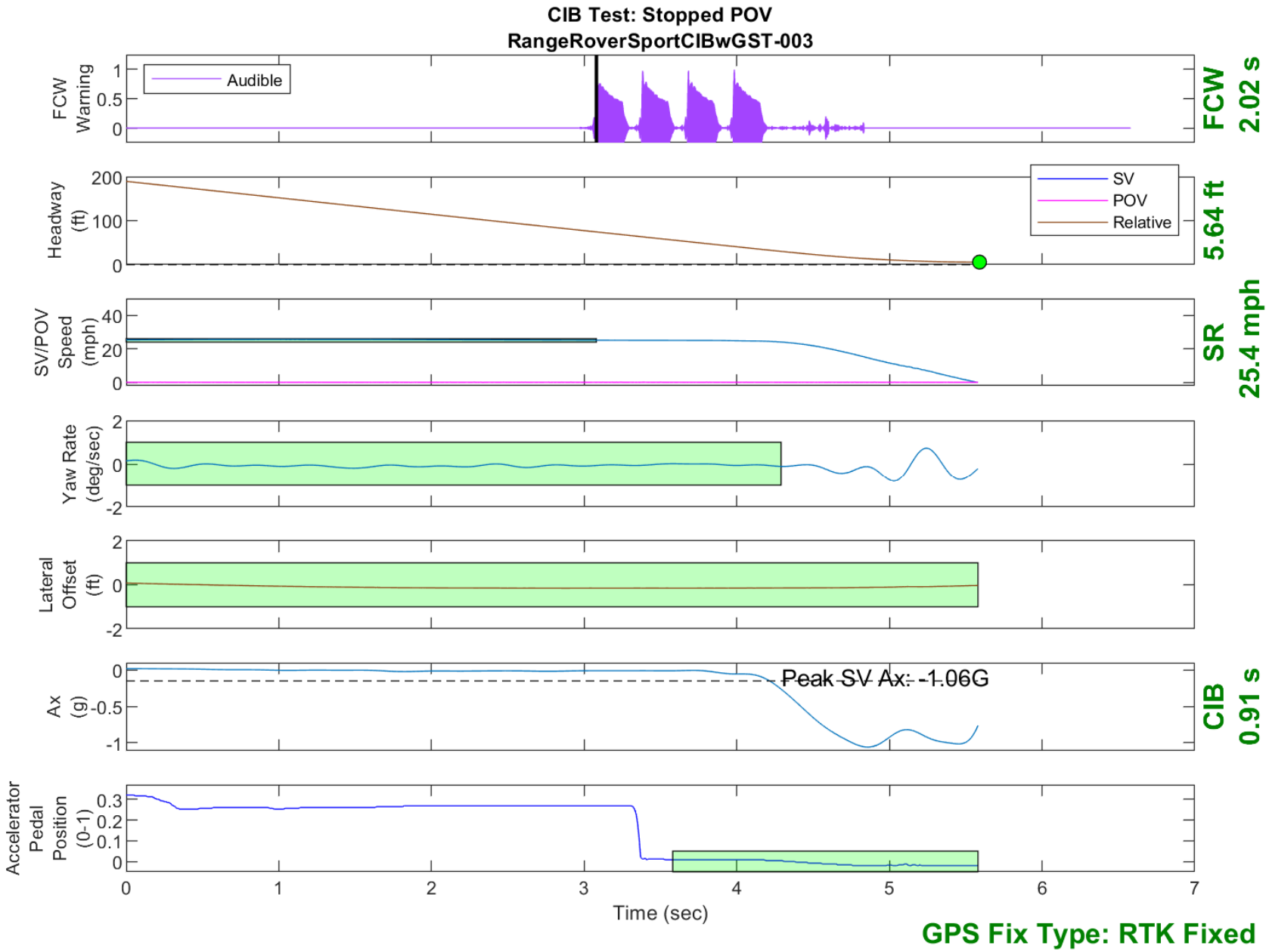


Figure D9. Time History for CIB Run 3, Stopped POV, 25 mph

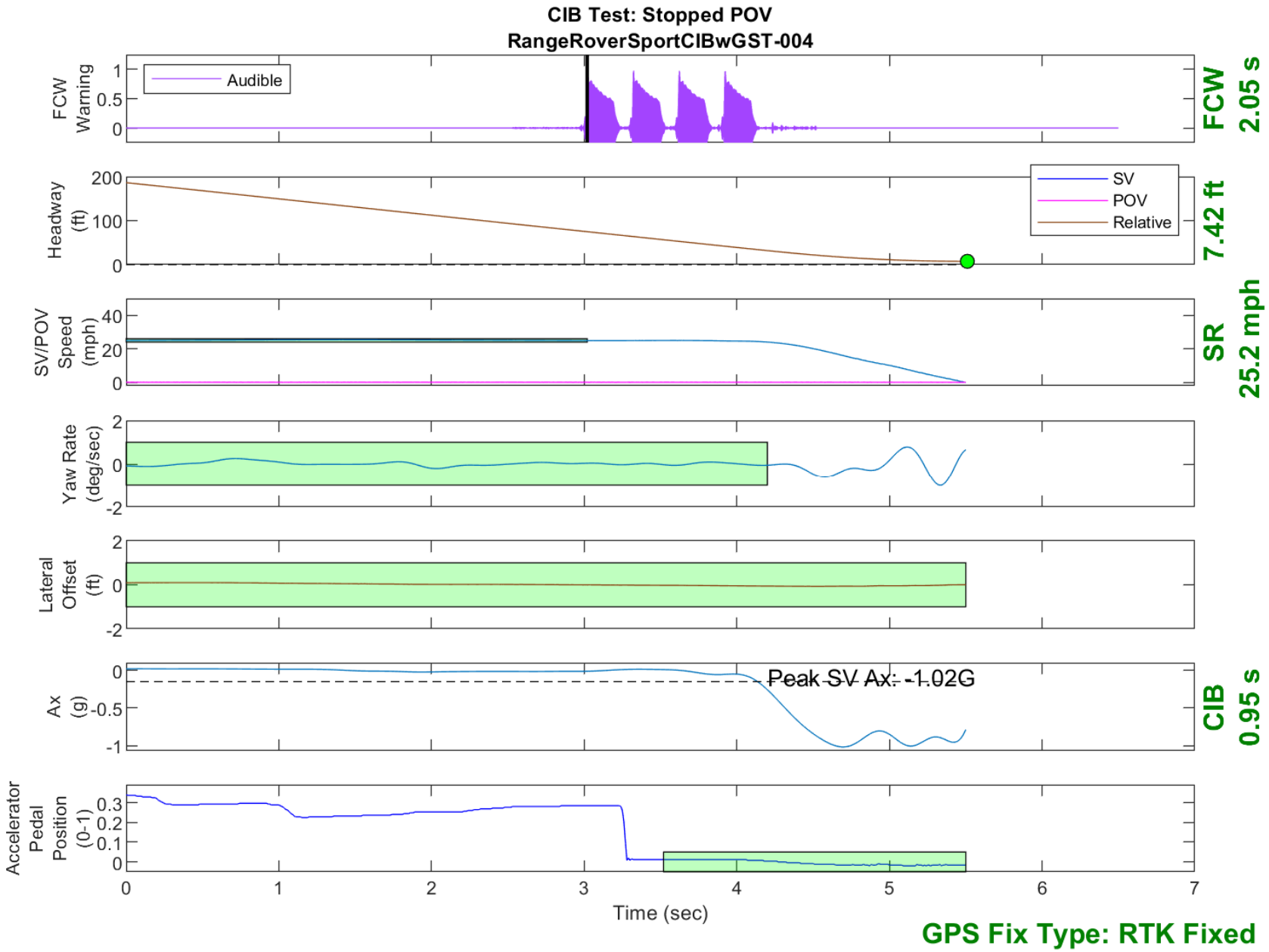


Figure D10. Time History for CIB Run 4, Stopped POV, 25 mph

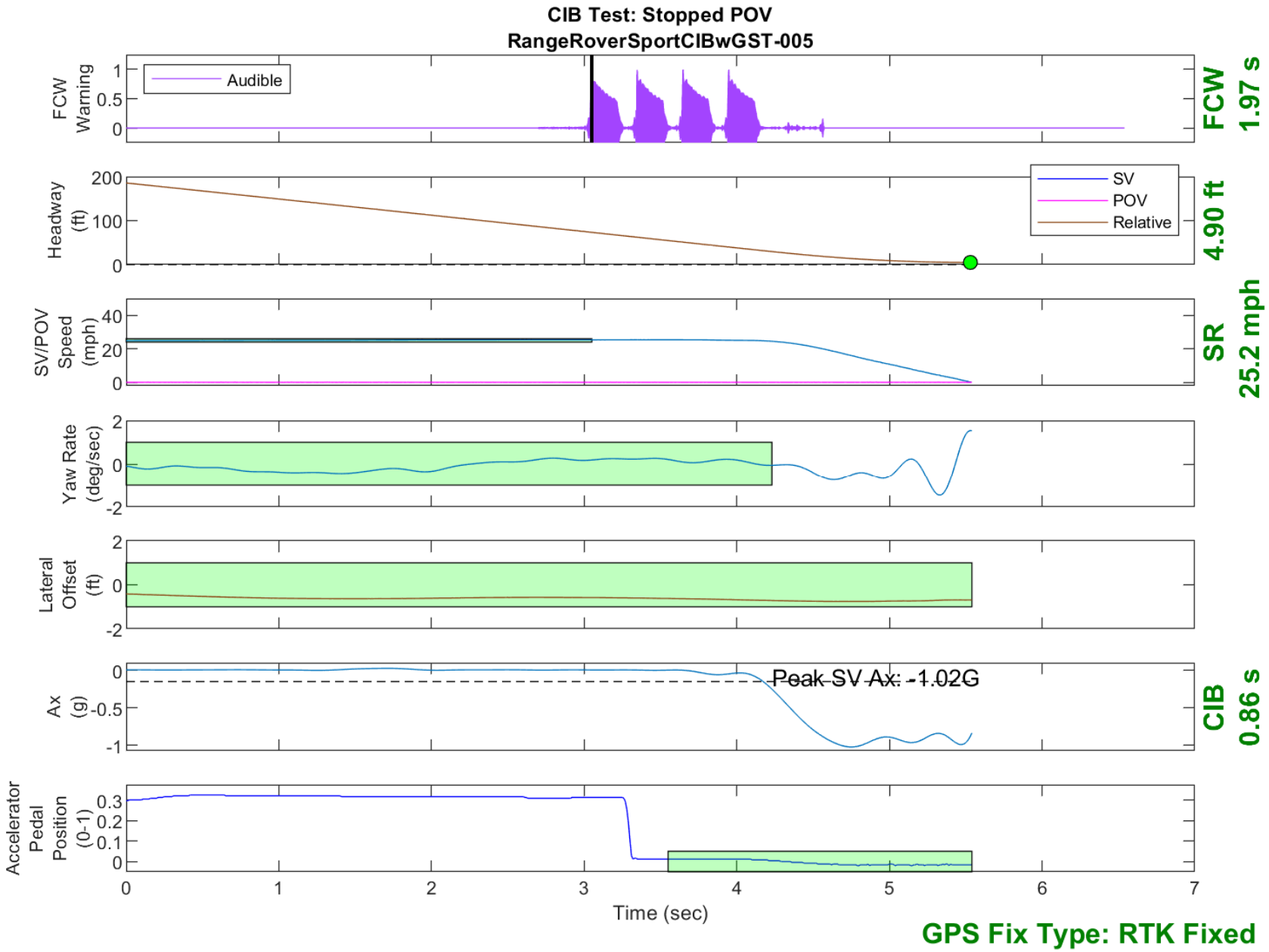


Figure D11. Time History for CIB Run 5, Stopped POV, 25 mph

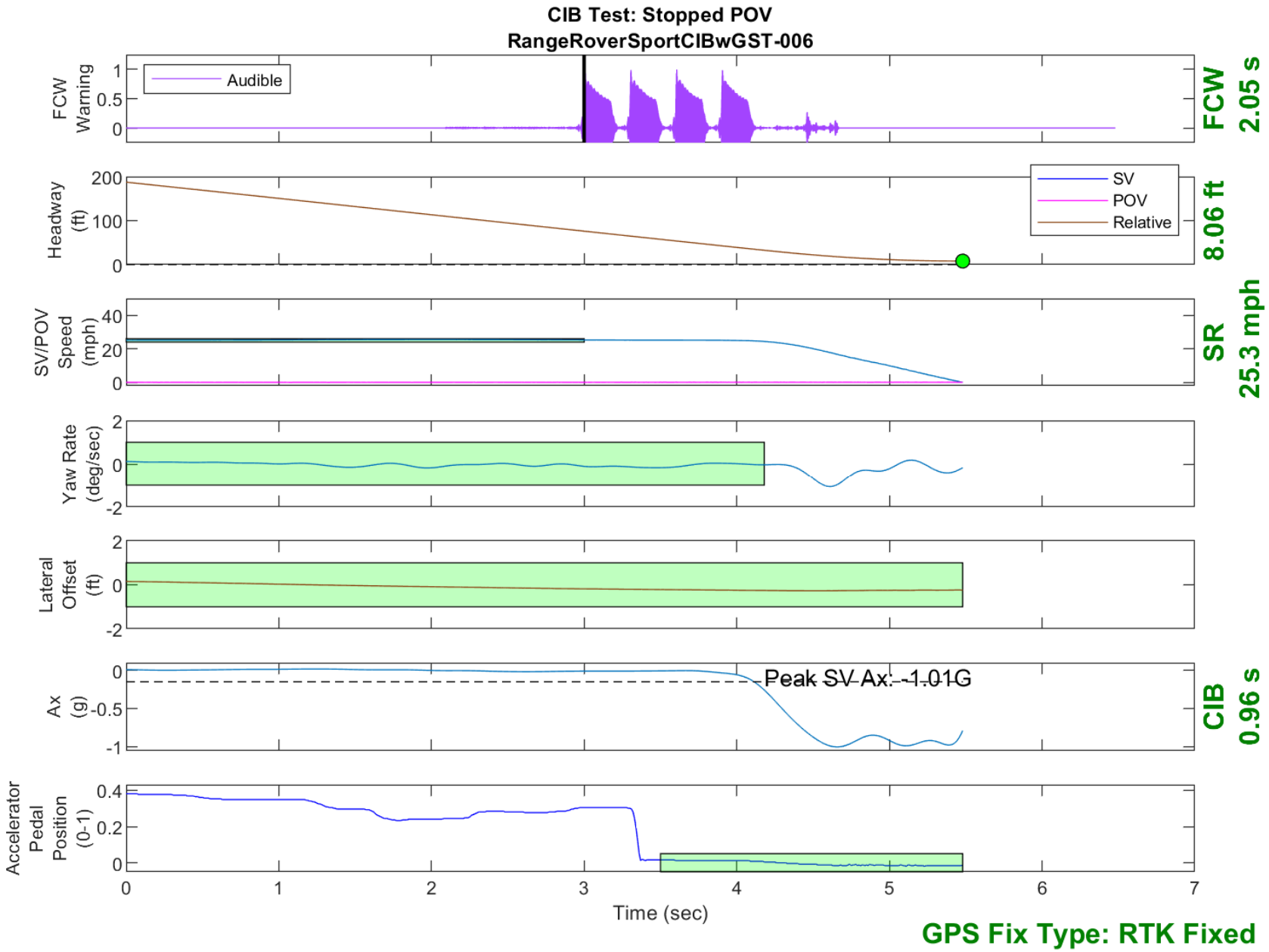


Figure D12. Time History for CIB Run 6, Stopped POV, 25 mph

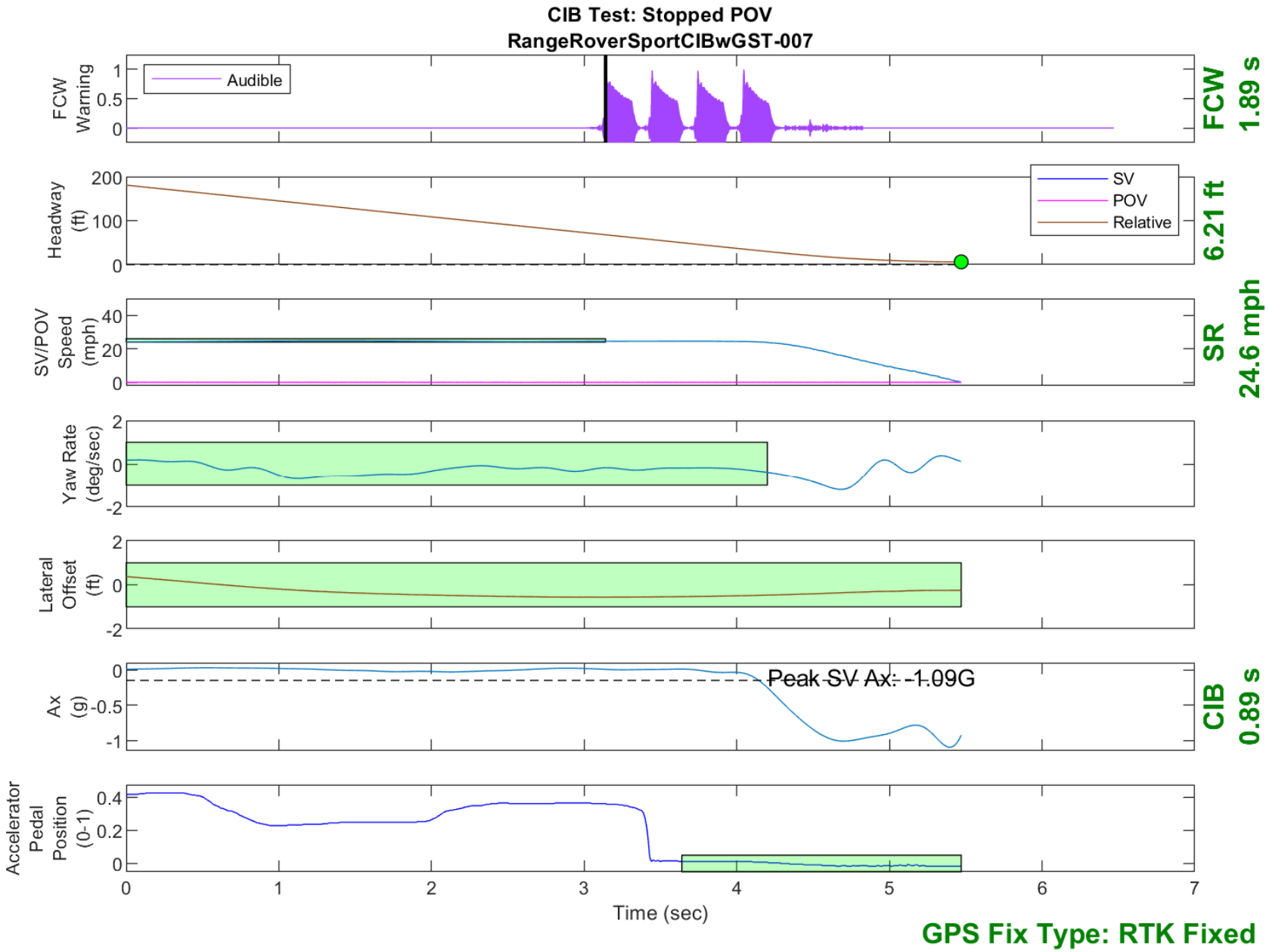


Figure D13. Time History for CIB Run 7, Stopped POV, 25 mph

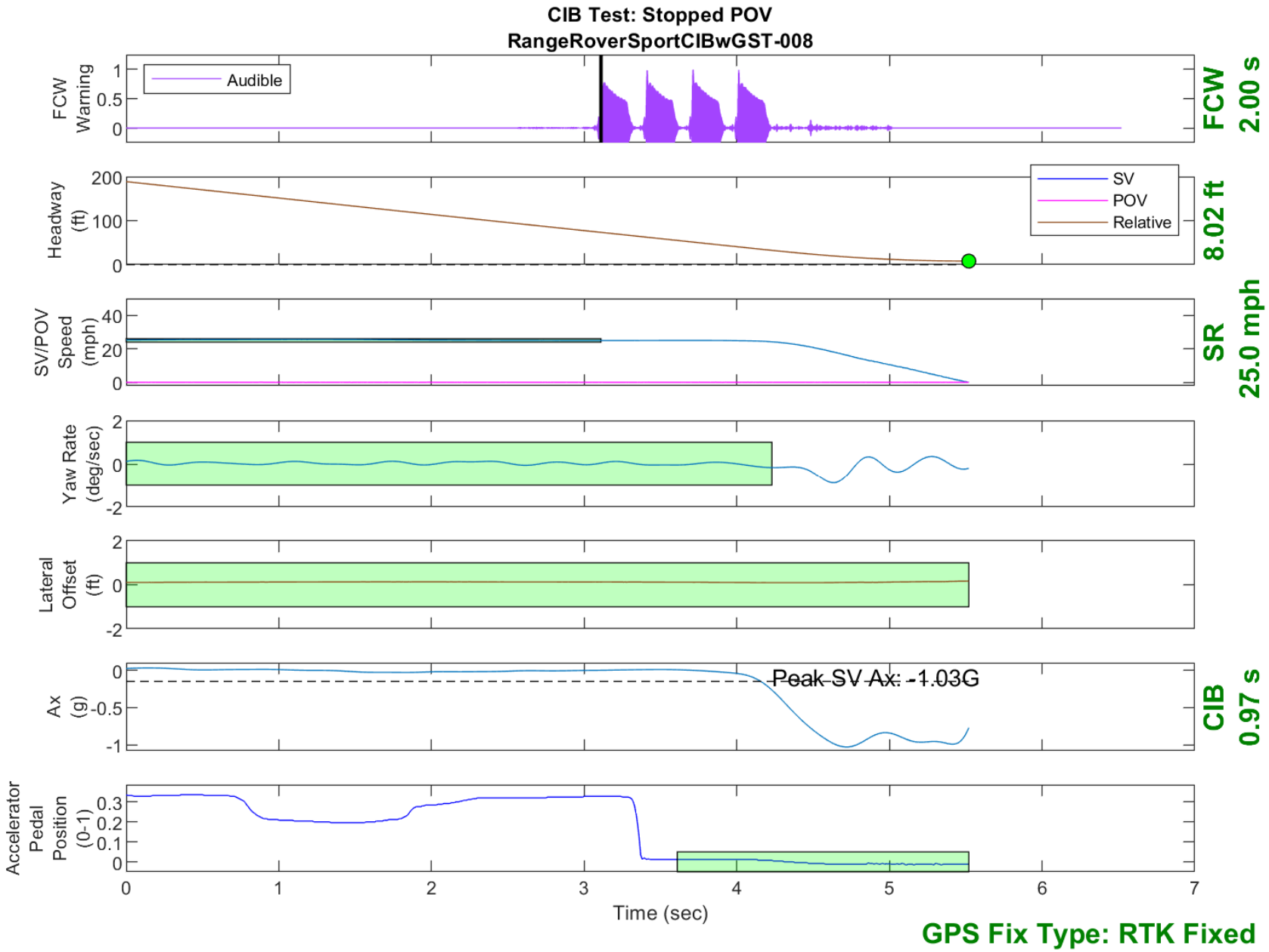


Figure D14. Time History for CIB Run 8, Stopped POV, 25 mph

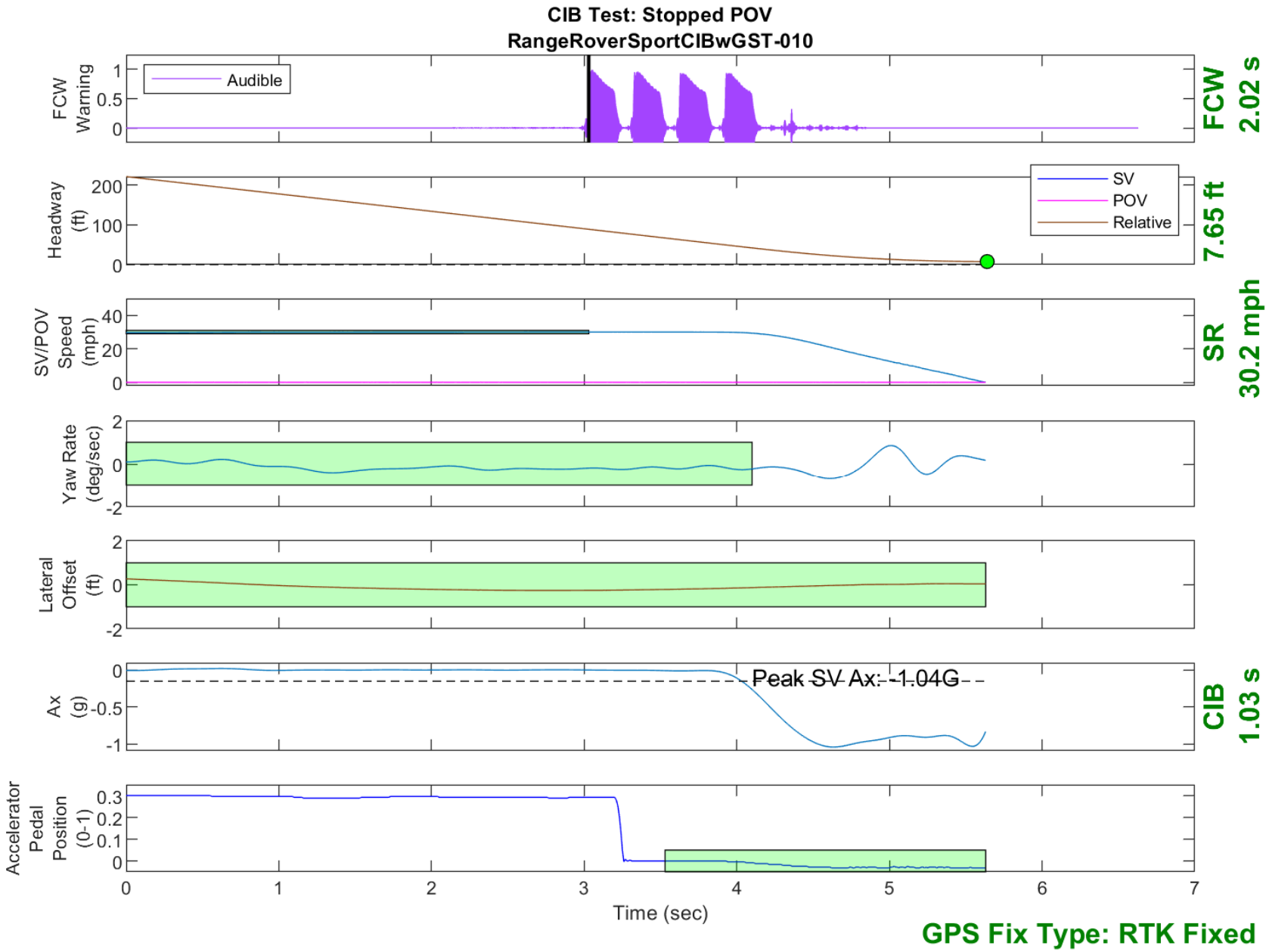


Figure D15. Time History for CIB Run 10, Stopped POV, 30 mph

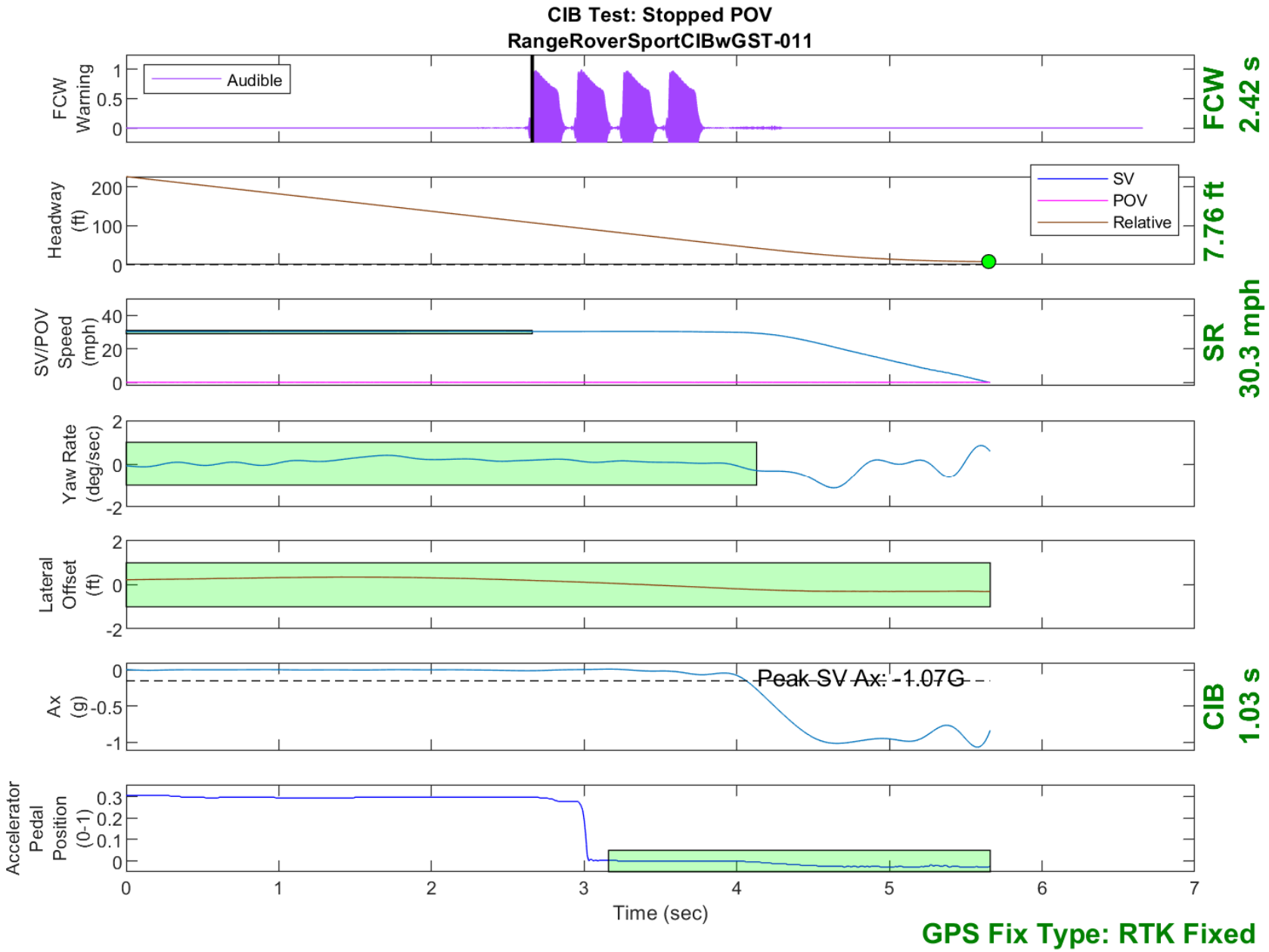


Figure D16. Time History for CIB Run 11, Stopped POV, 30 mph

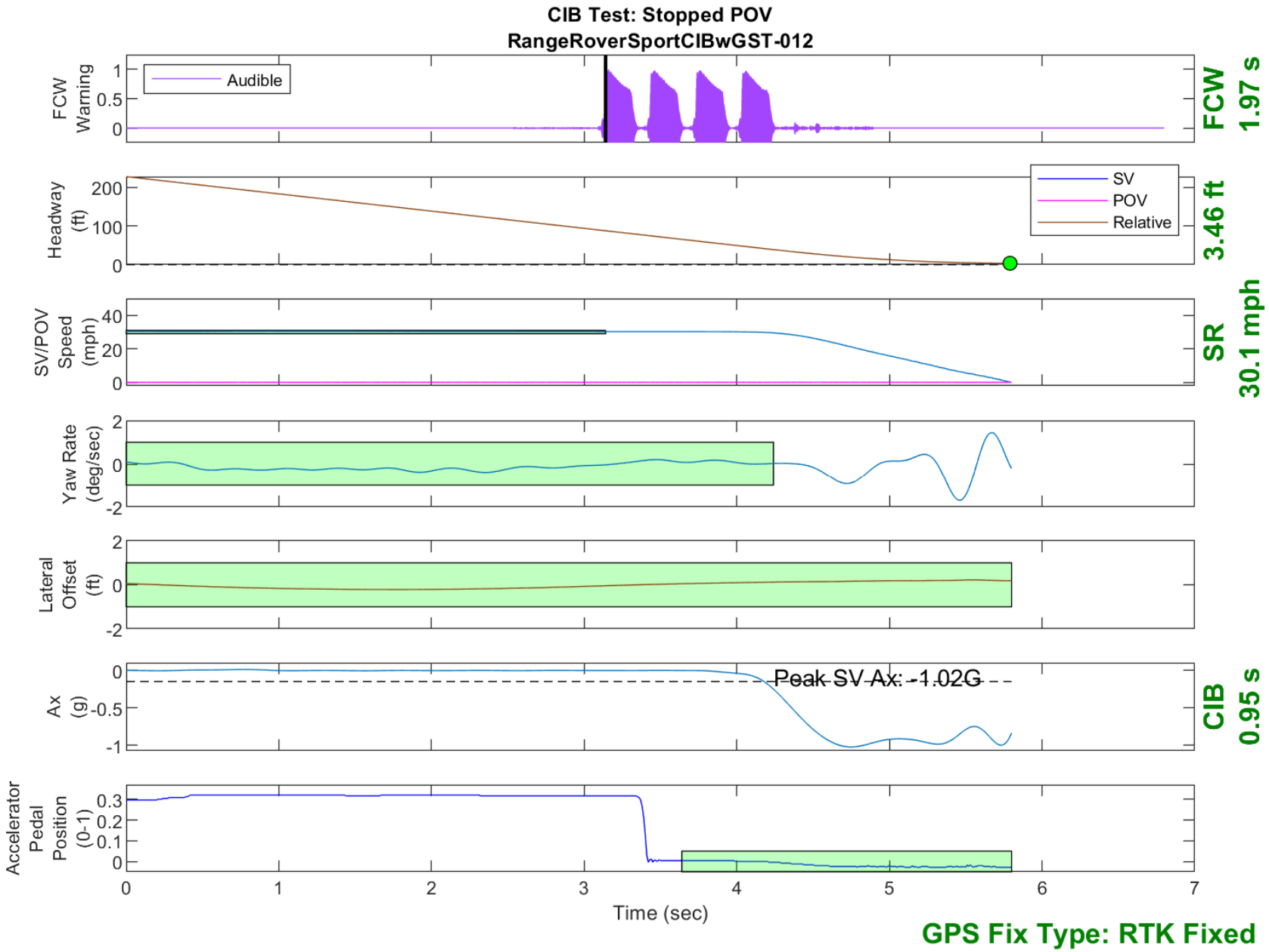


Figure D17. Time History for CIB Run 12, Stopped POV, 30 mph

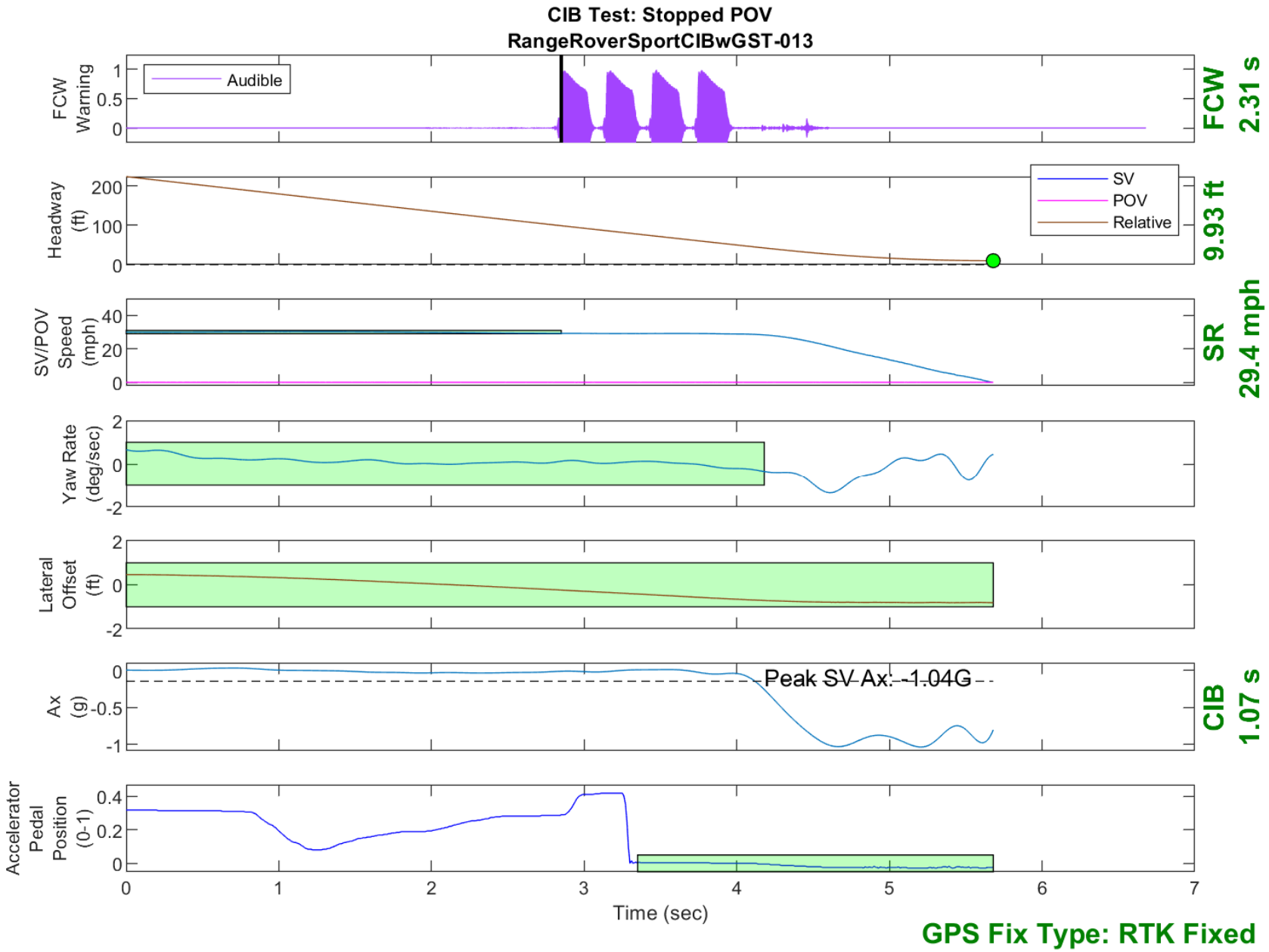


Figure D18. Time History for CIB Run 13, Stopped POV, 30 mph

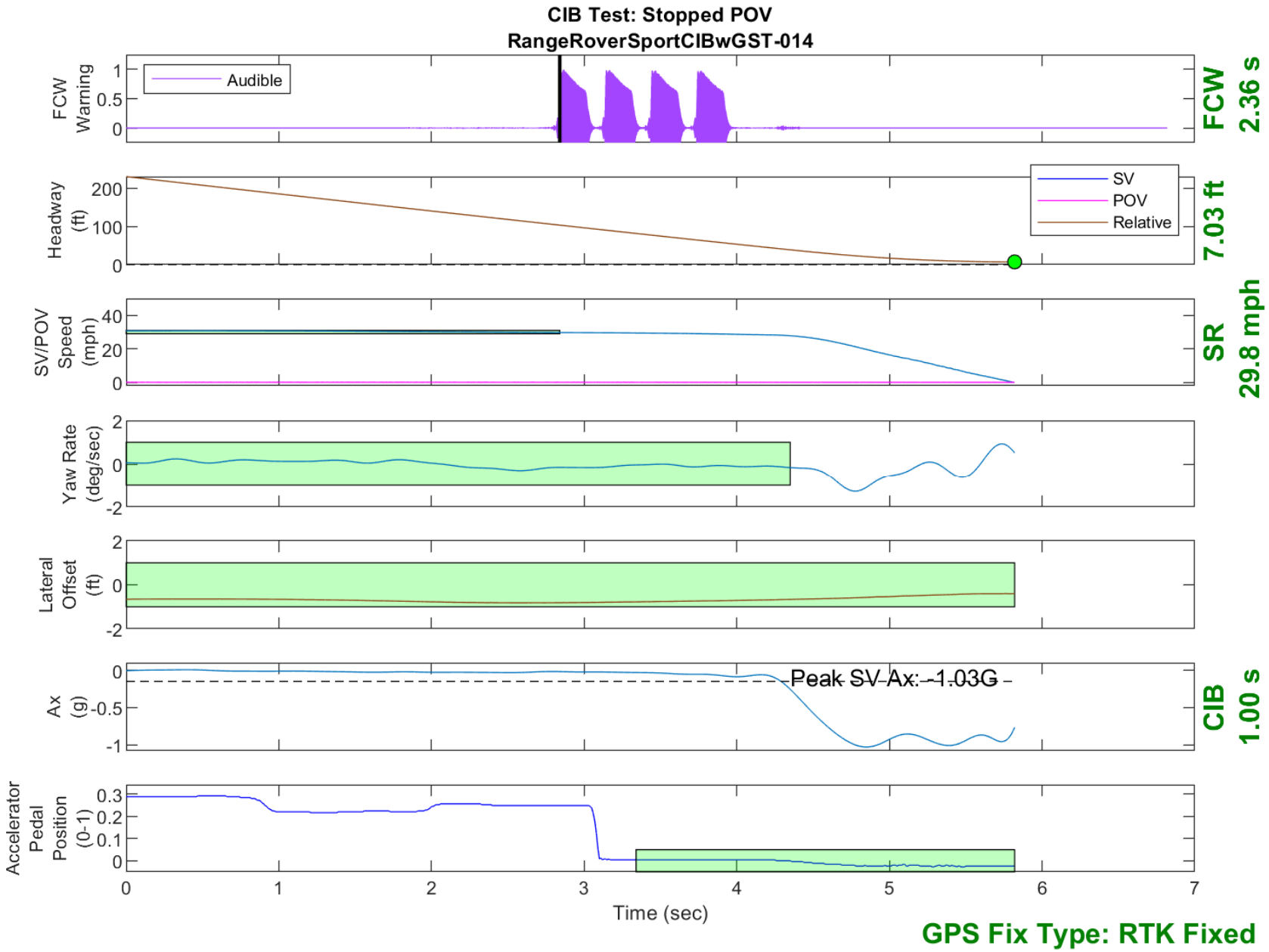


Figure D19. Time History for CIB Run 14, Stopped POV, 30 mph

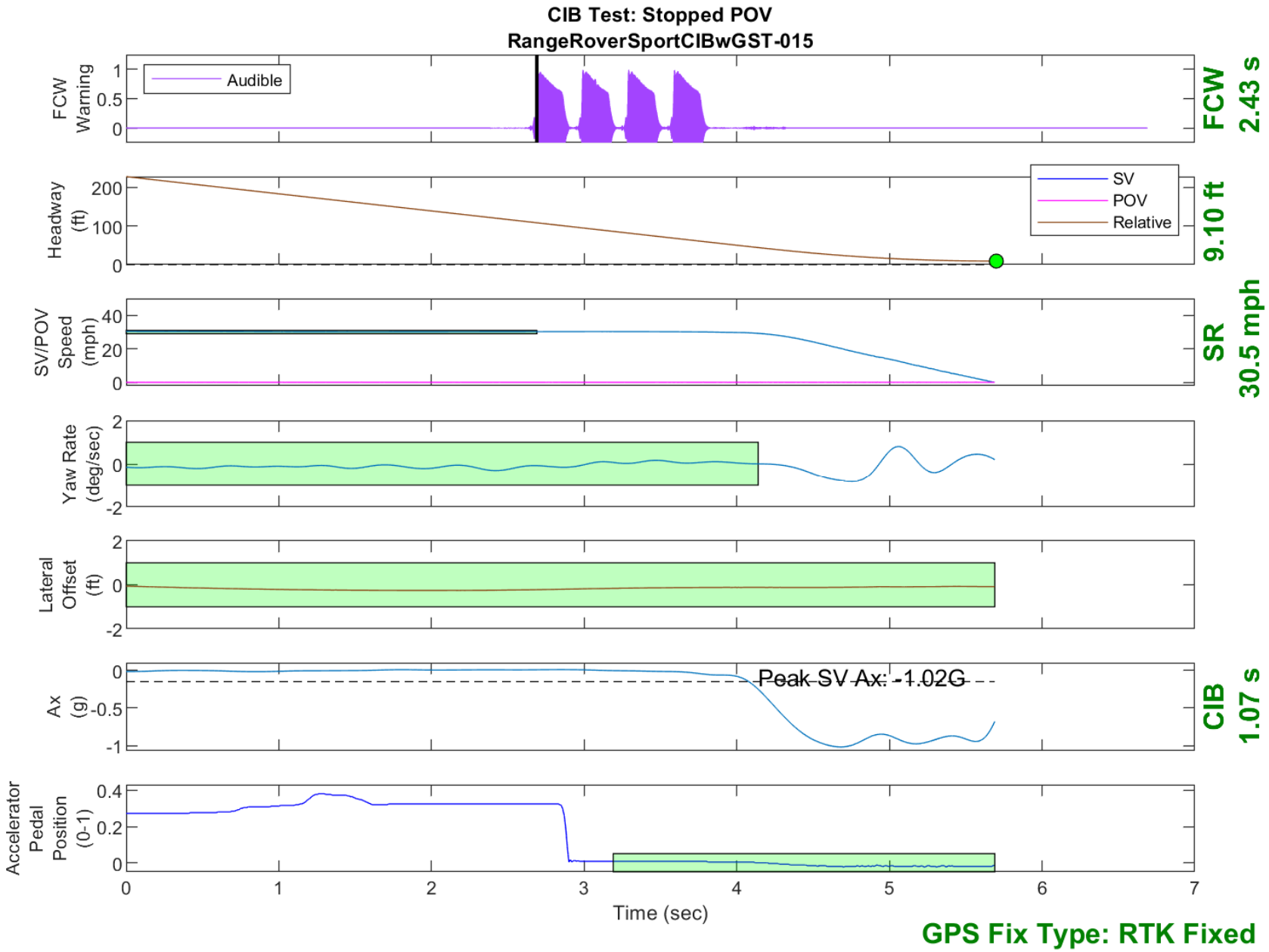


Figure D20. Time History for CIB Run 15, Stopped POV, 30 mph

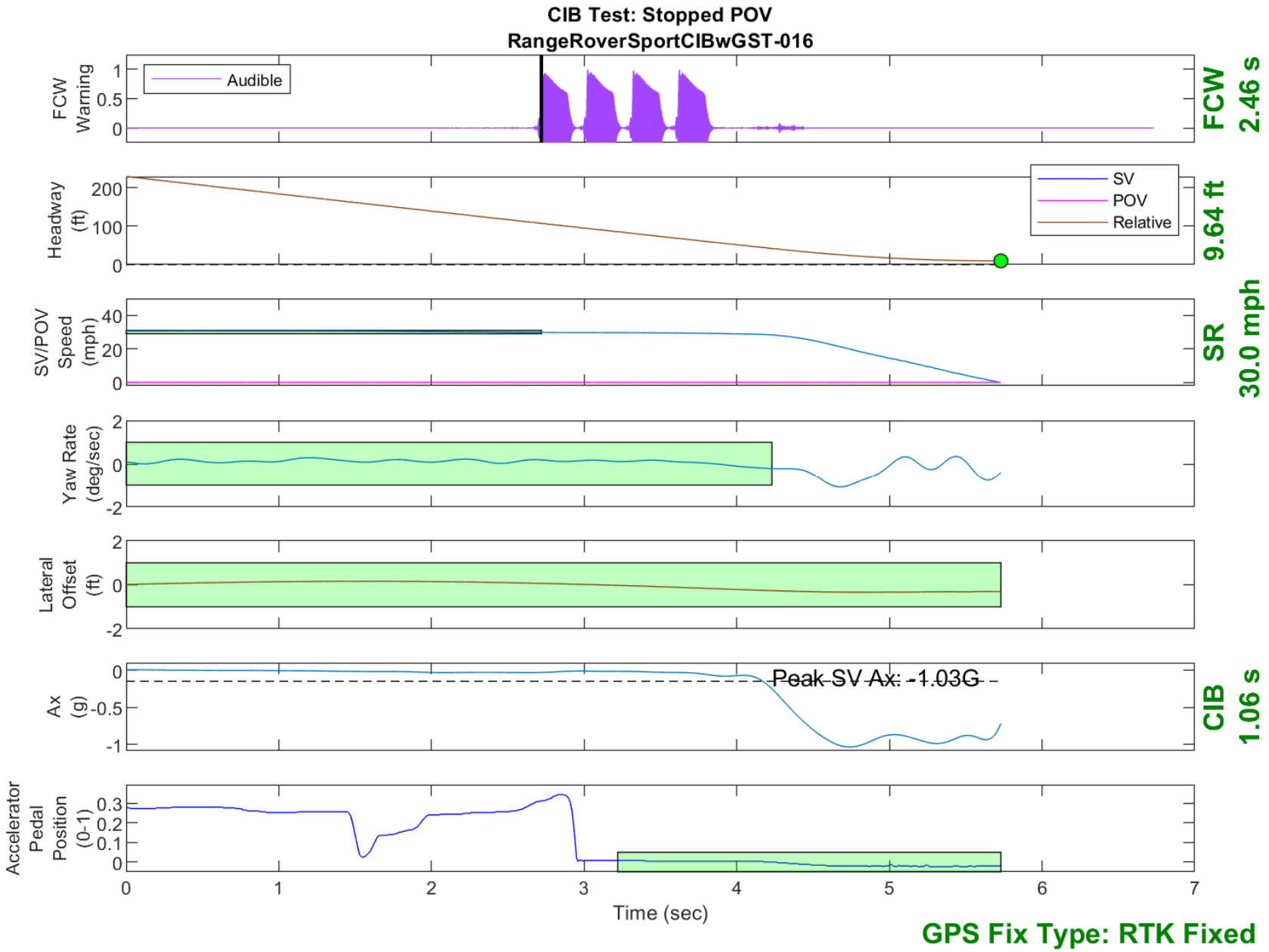


Figure D21. Time History for CIB Run 16, Stopped POV, 30 mph

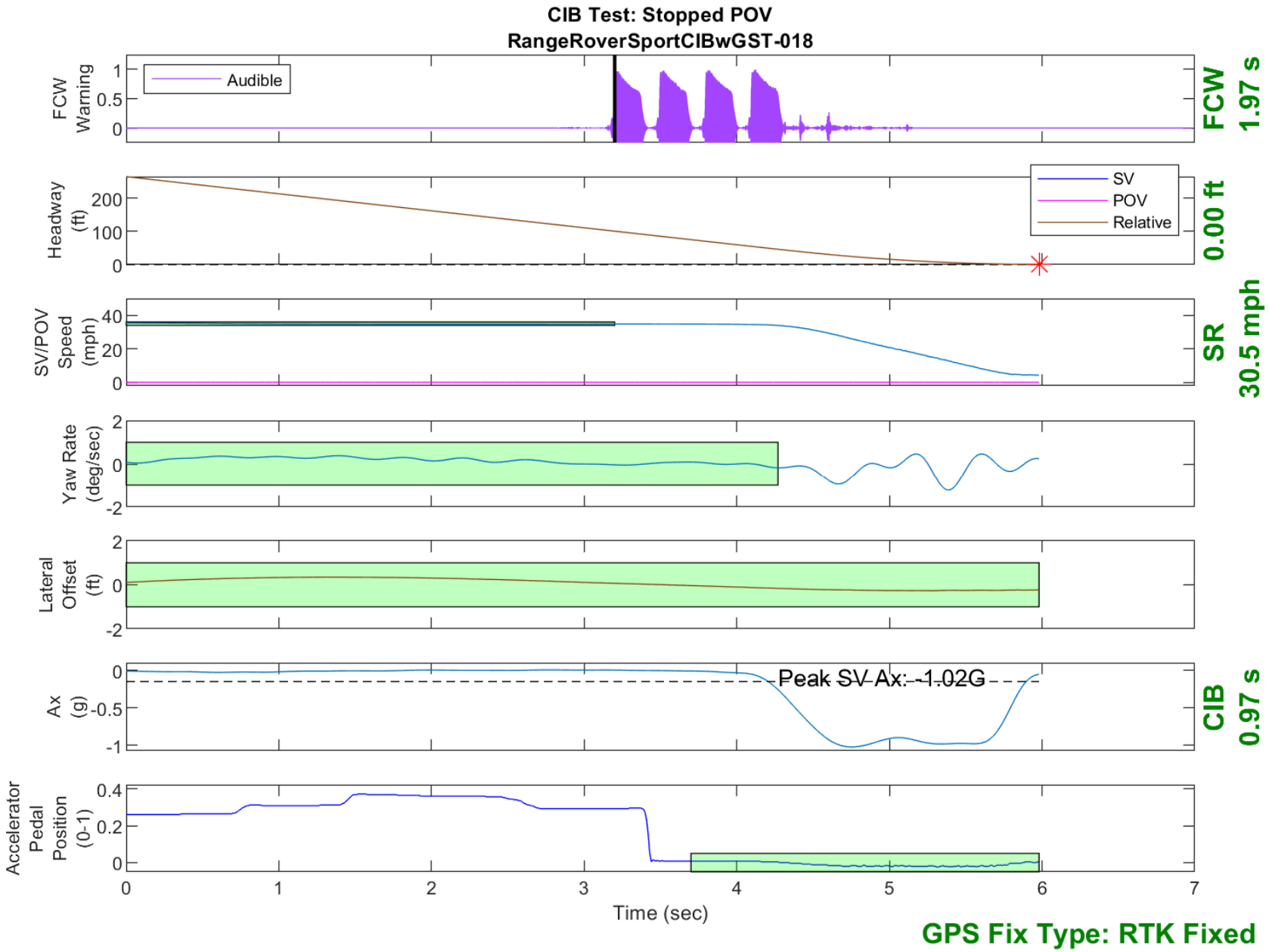


Figure D22. Time History for CIB Run 18, Stopped POV, 35 mph

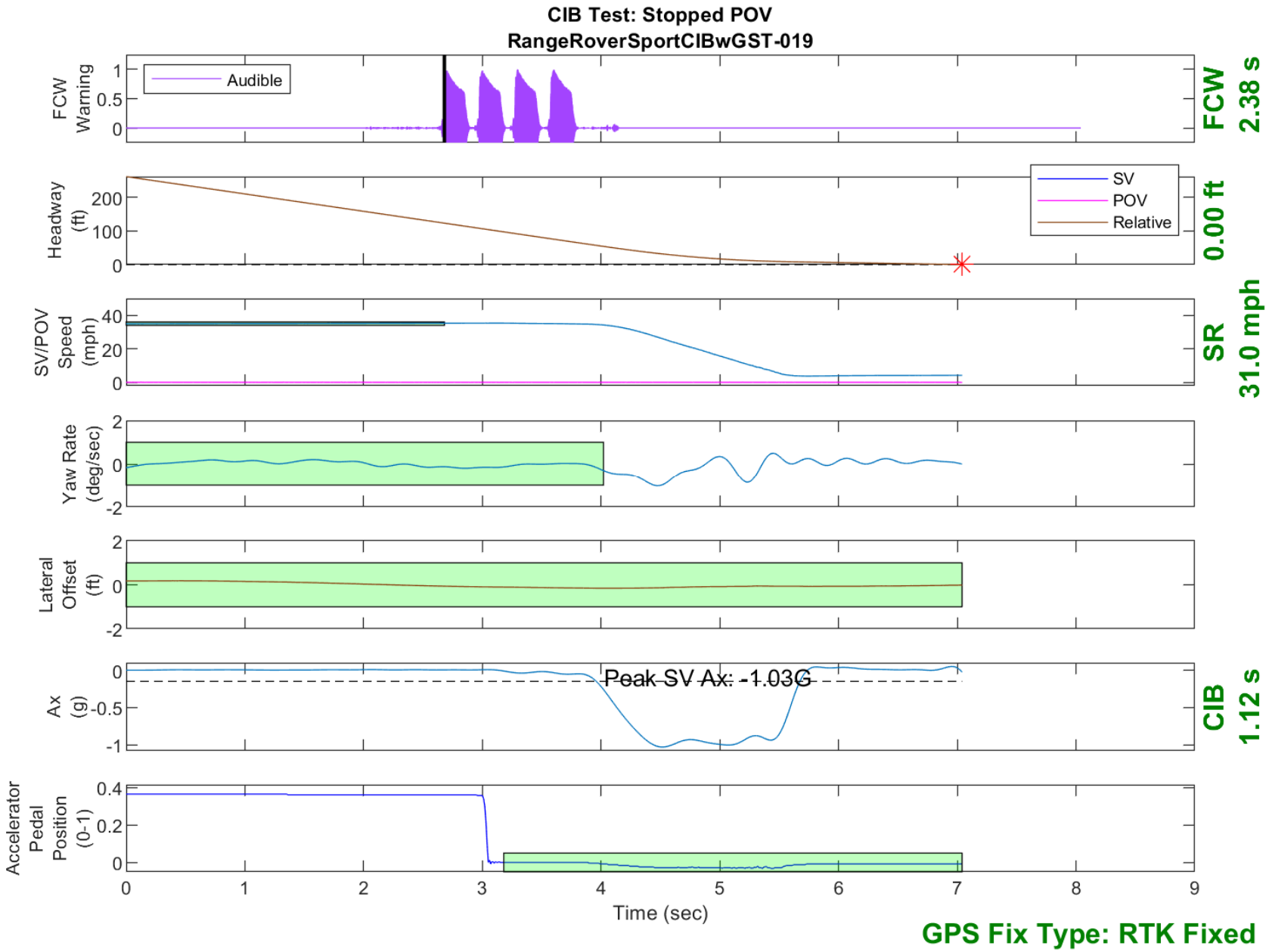


Figure D23. Time History for CIB Run 19, Stopped POV, 35 mph

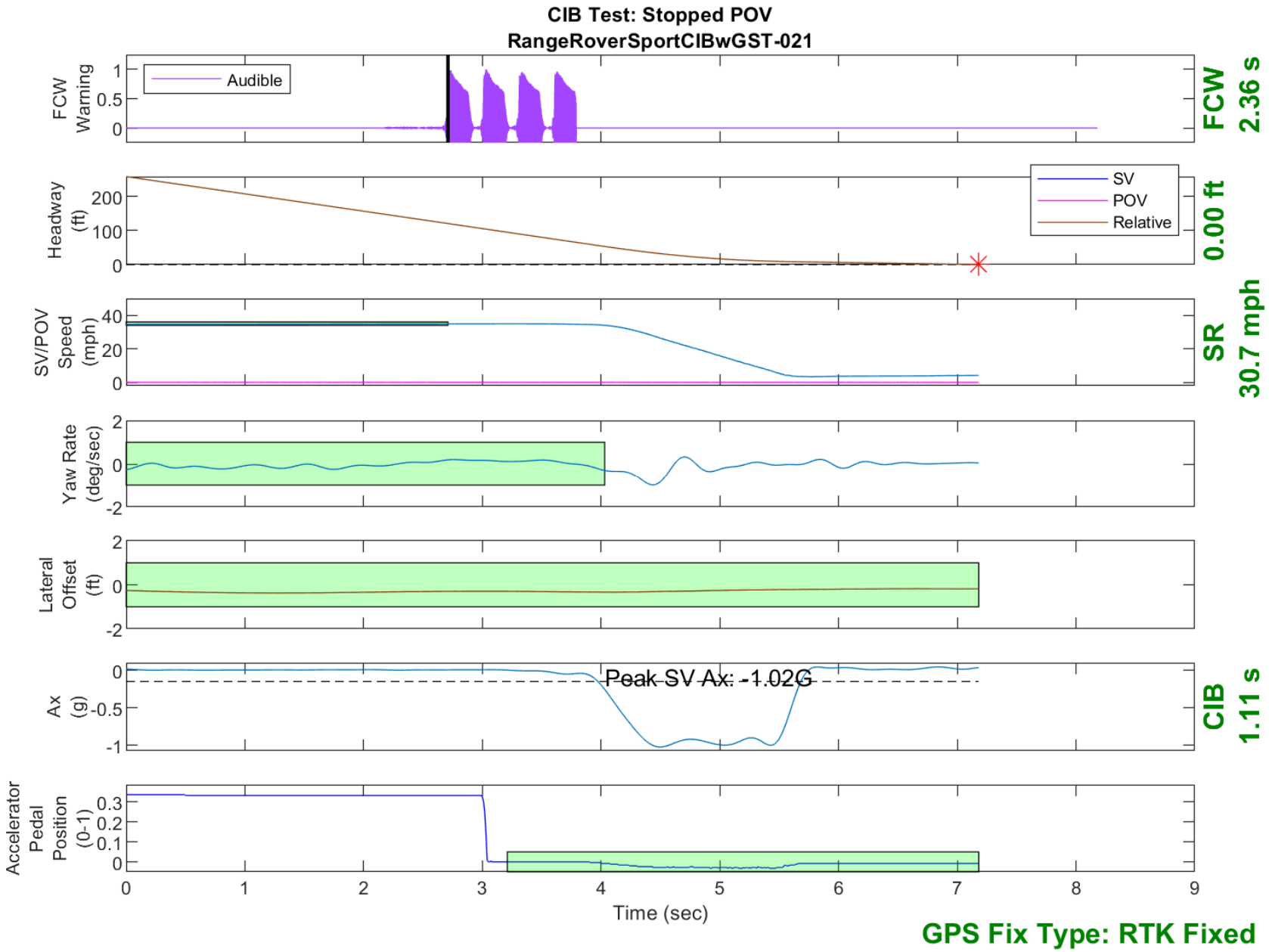


Figure D24. Time History for CIB Run 21, Stopped POV, 35 mph

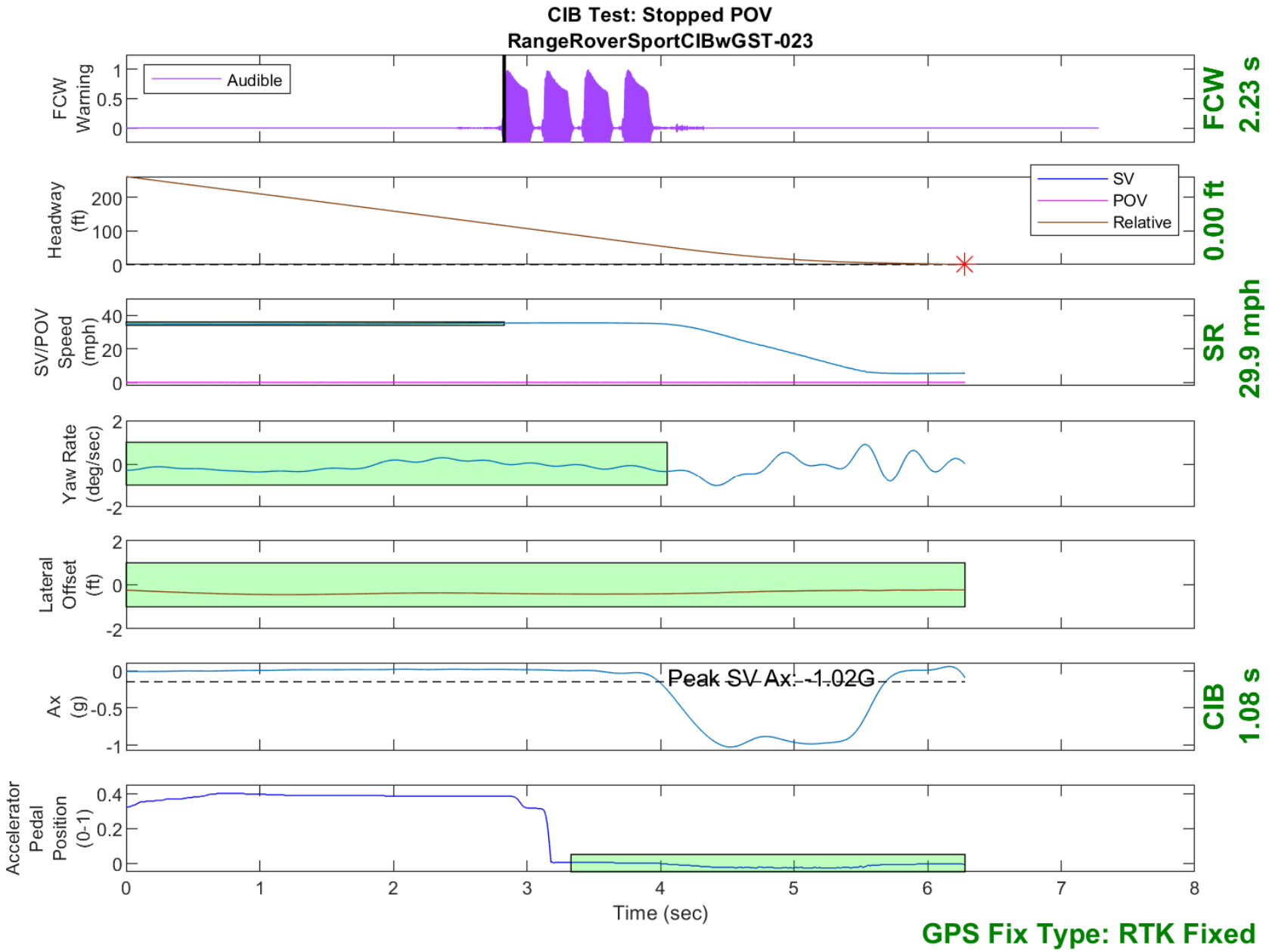


Figure D25. Time History for CIB Run 23, Stopped POV, 35 mph

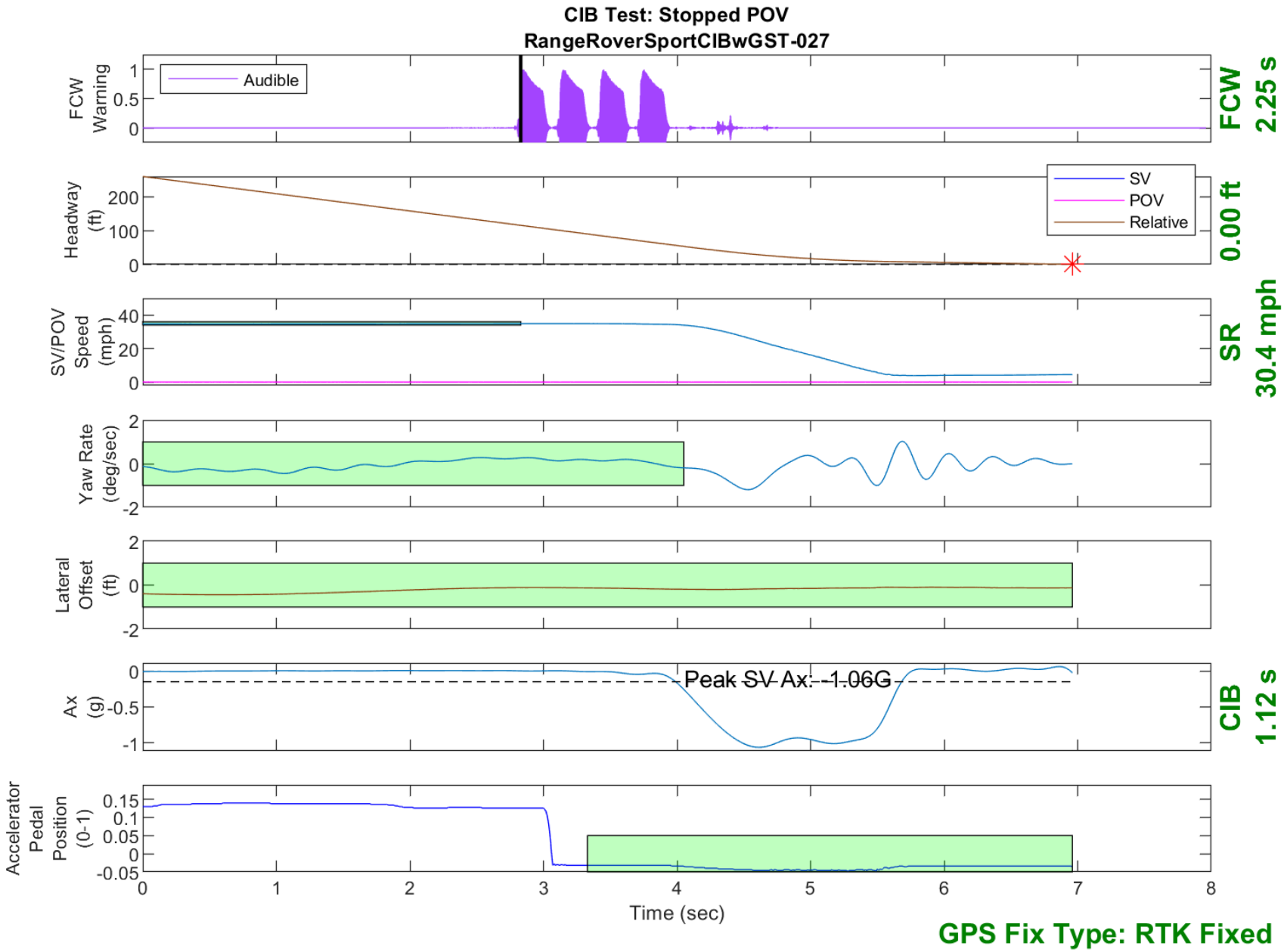


Figure D26. Time History for CIB Run 27, Stopped POV, 35 mph

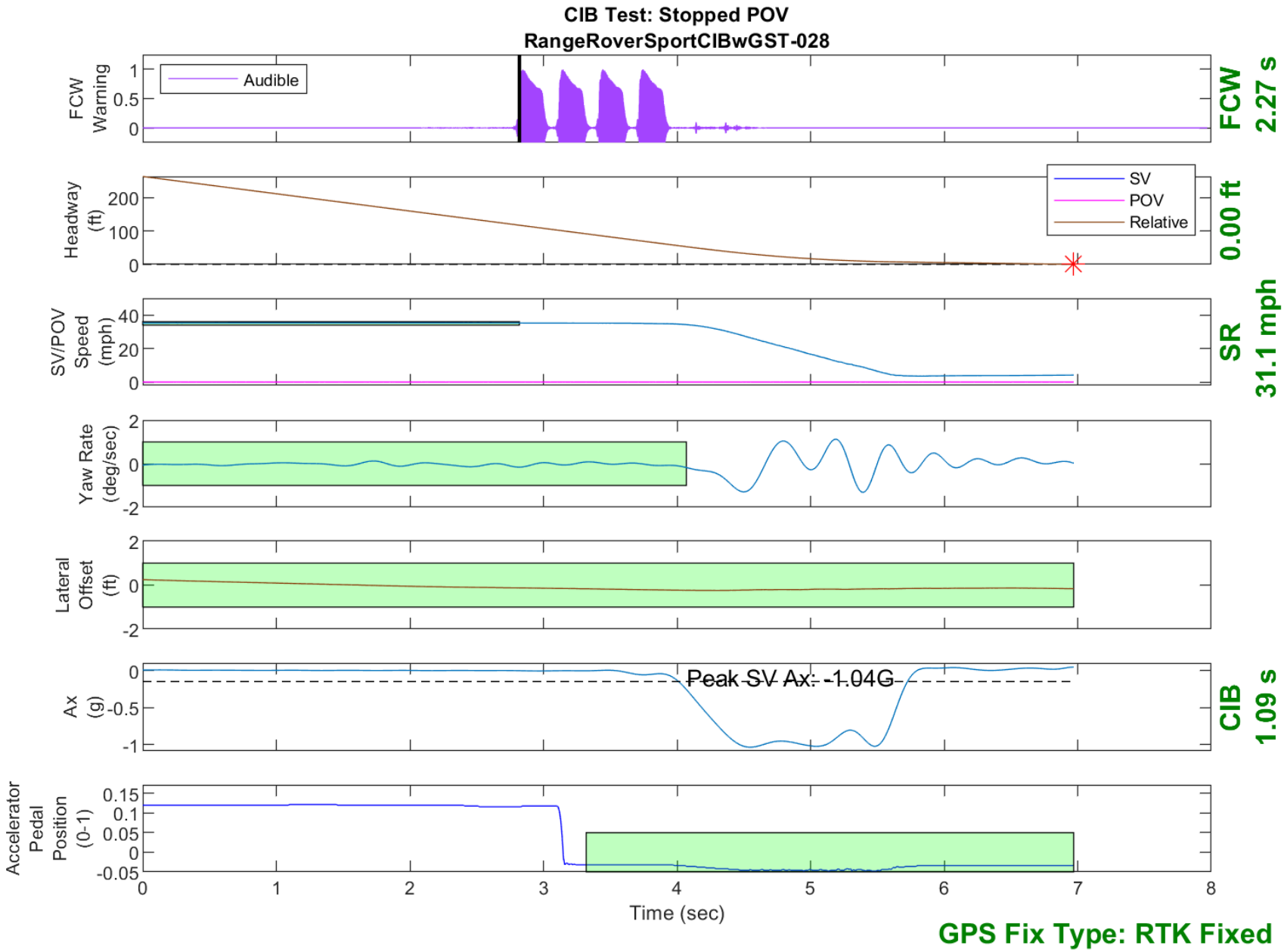


Figure D27. Time History for CIB Run 28, Stopped POV, 35 mph

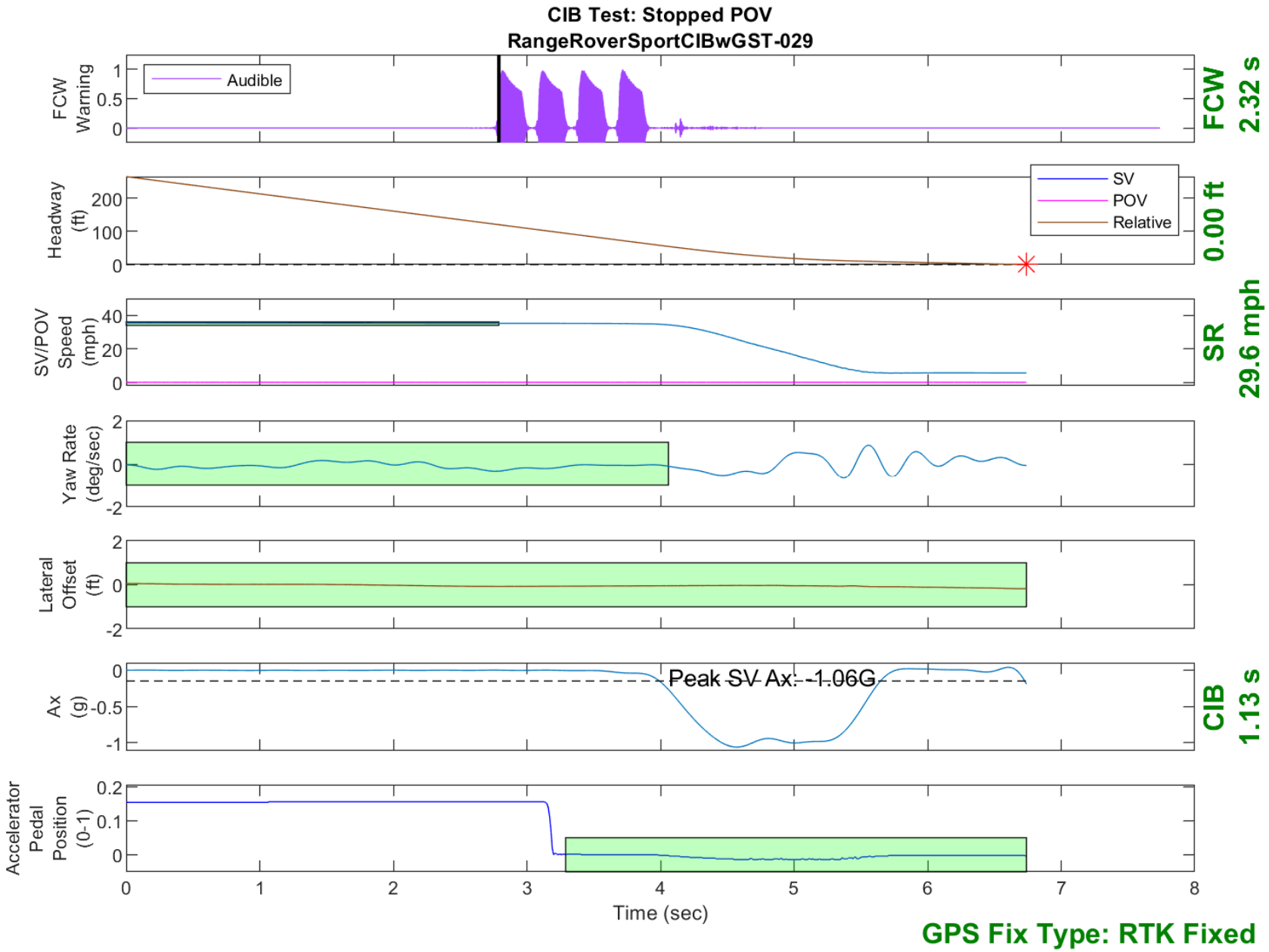


Figure D28. Time History for CIB Run 29, Stopped POV, 35 mph

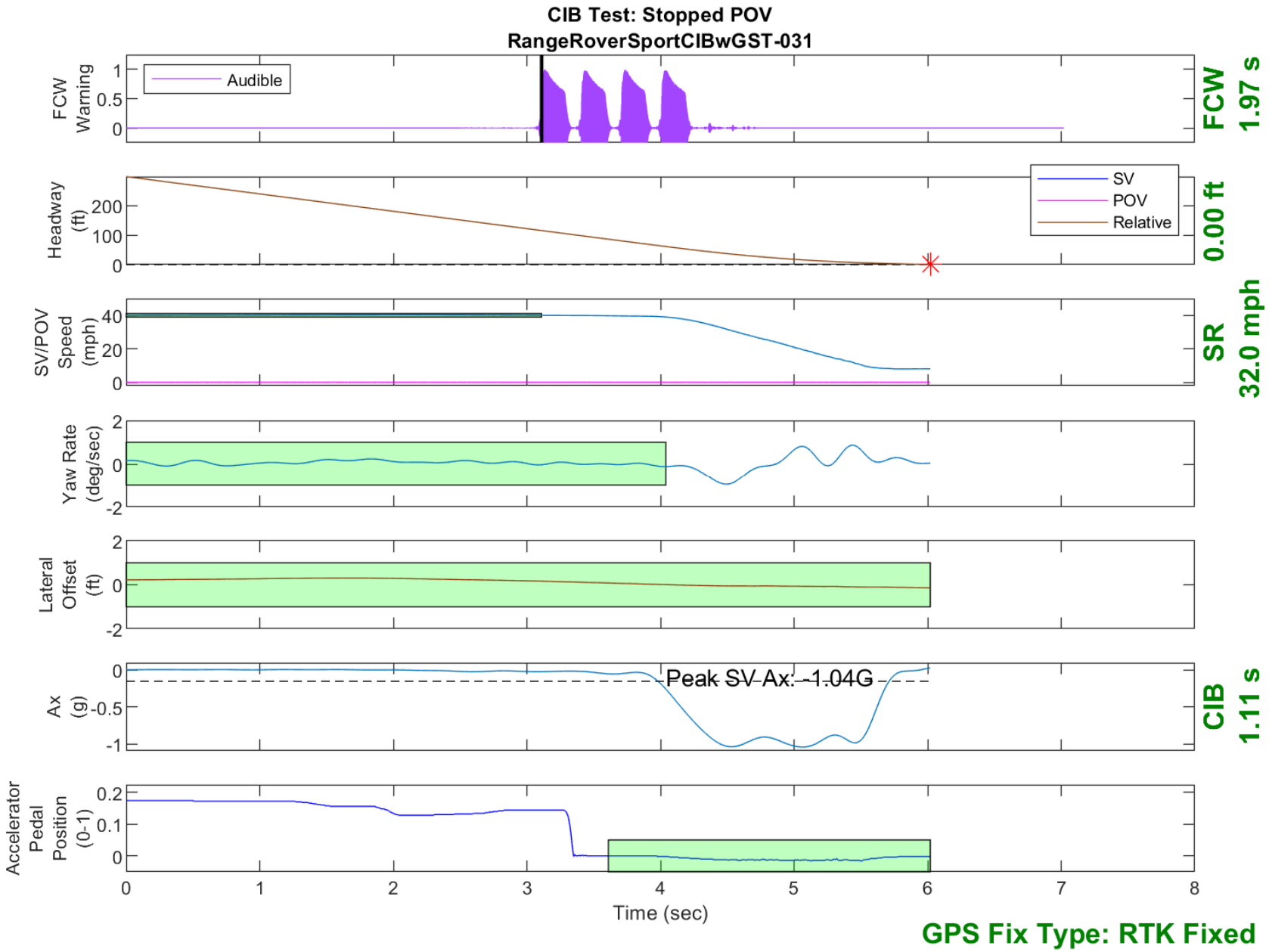


Figure D29. Time History for CIB Run 31, Stopped POV, 40 mph

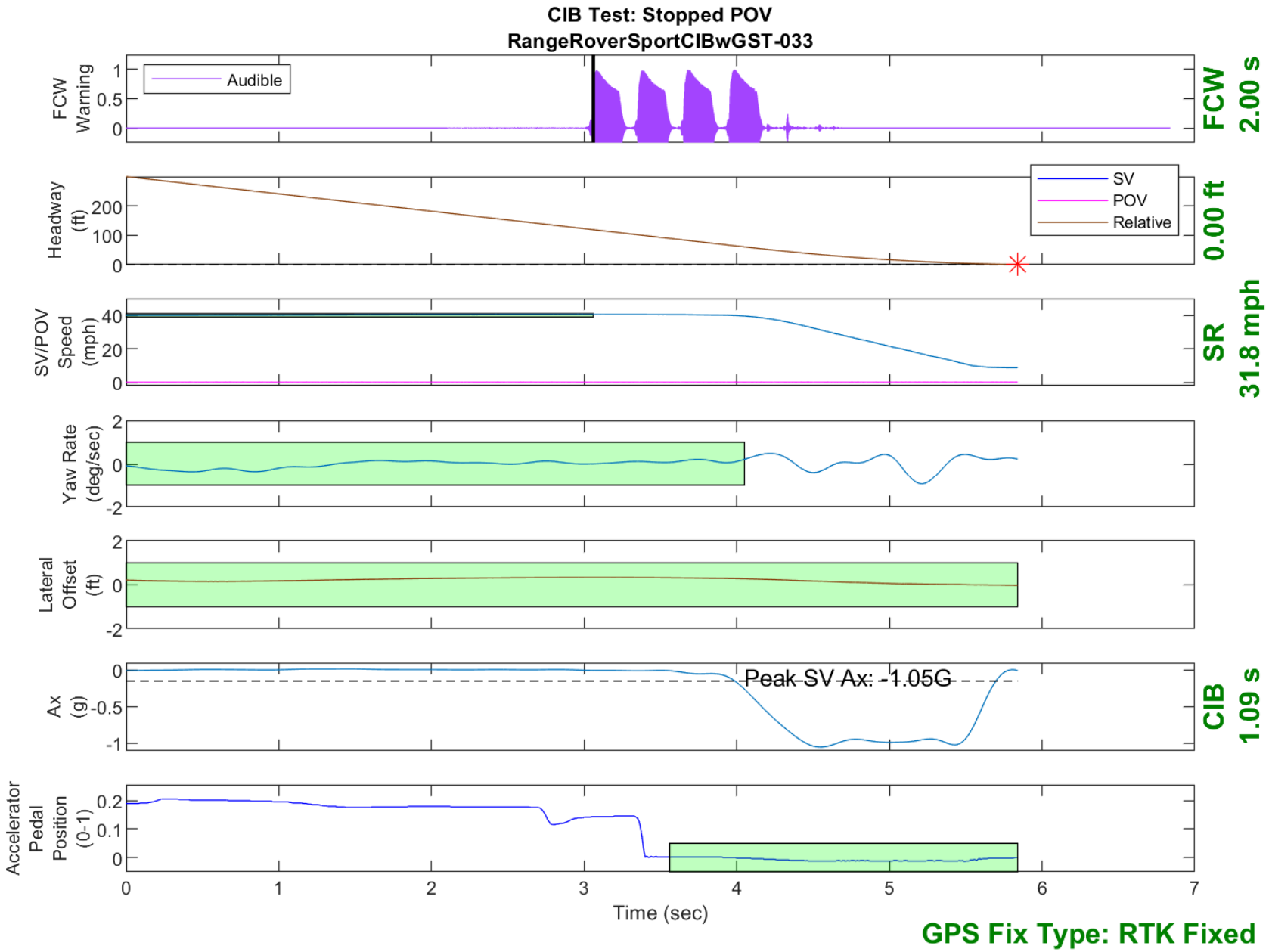


Figure D30. Time History for CIB Run 33, Stopped POV, 40 mph

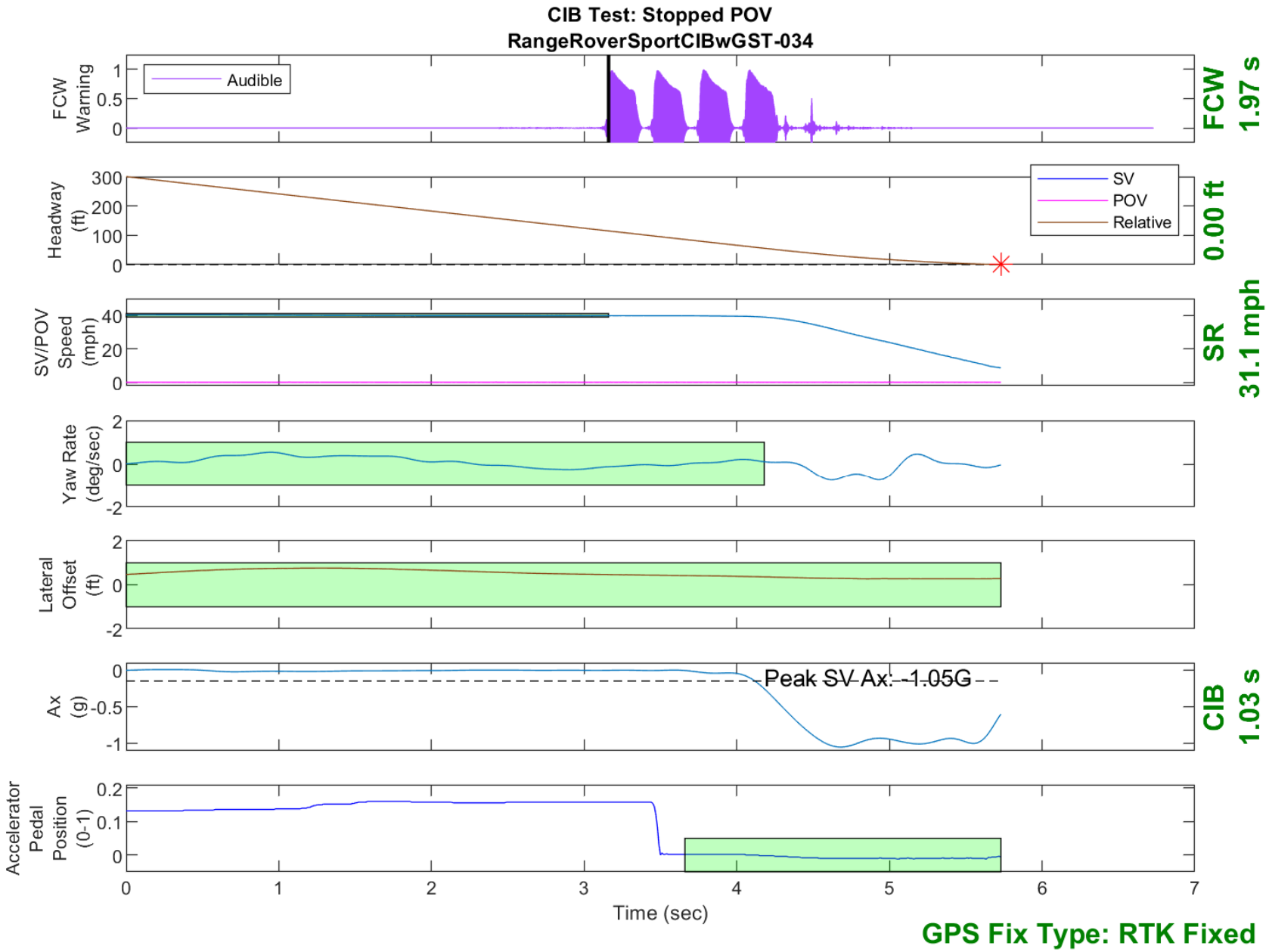


Figure D31. Time History for CIB Run 34, Stopped POV, 40 mph

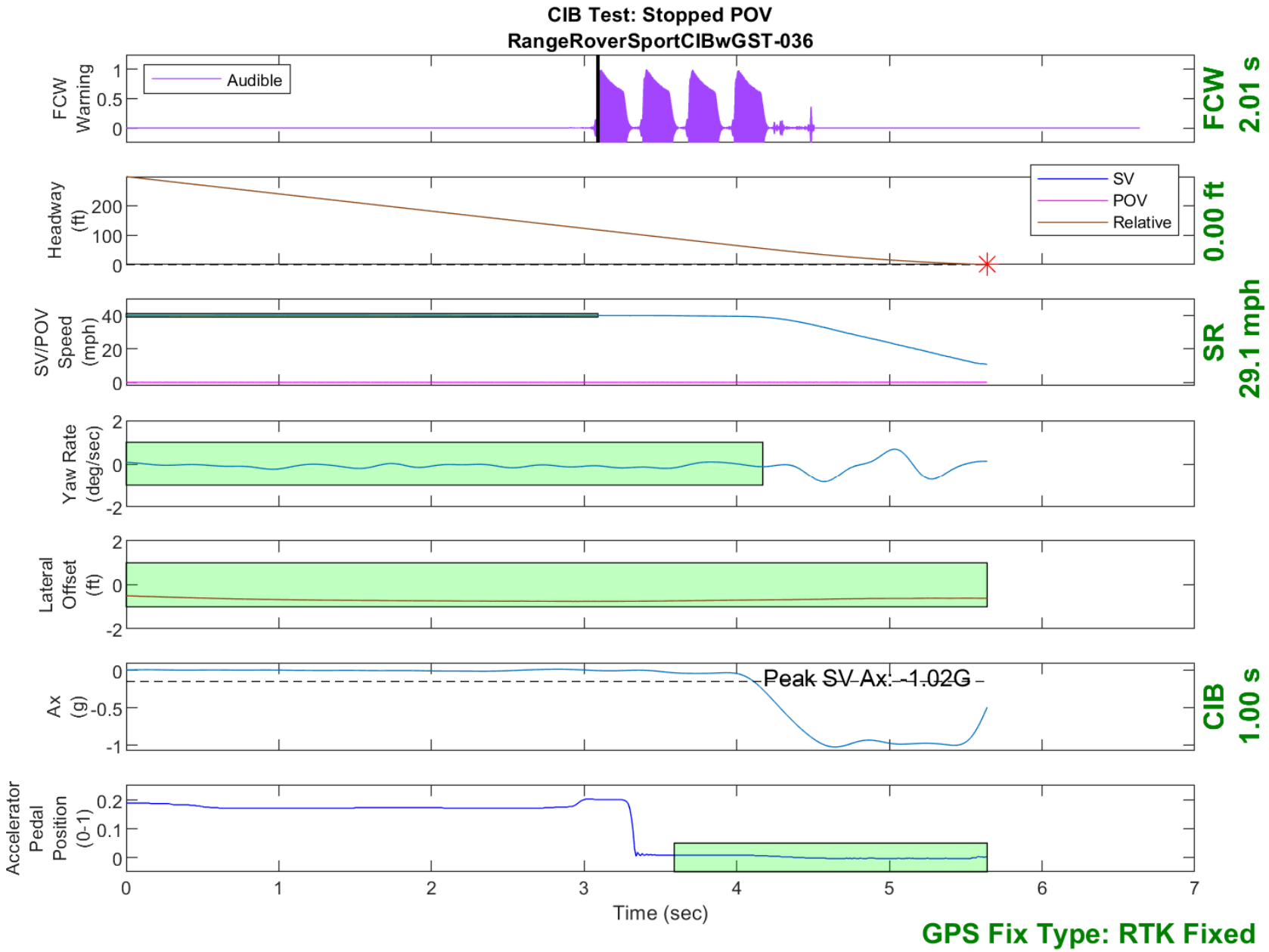


Figure D32. Time History for CIB Run 36, Stopped POV, 40 mph

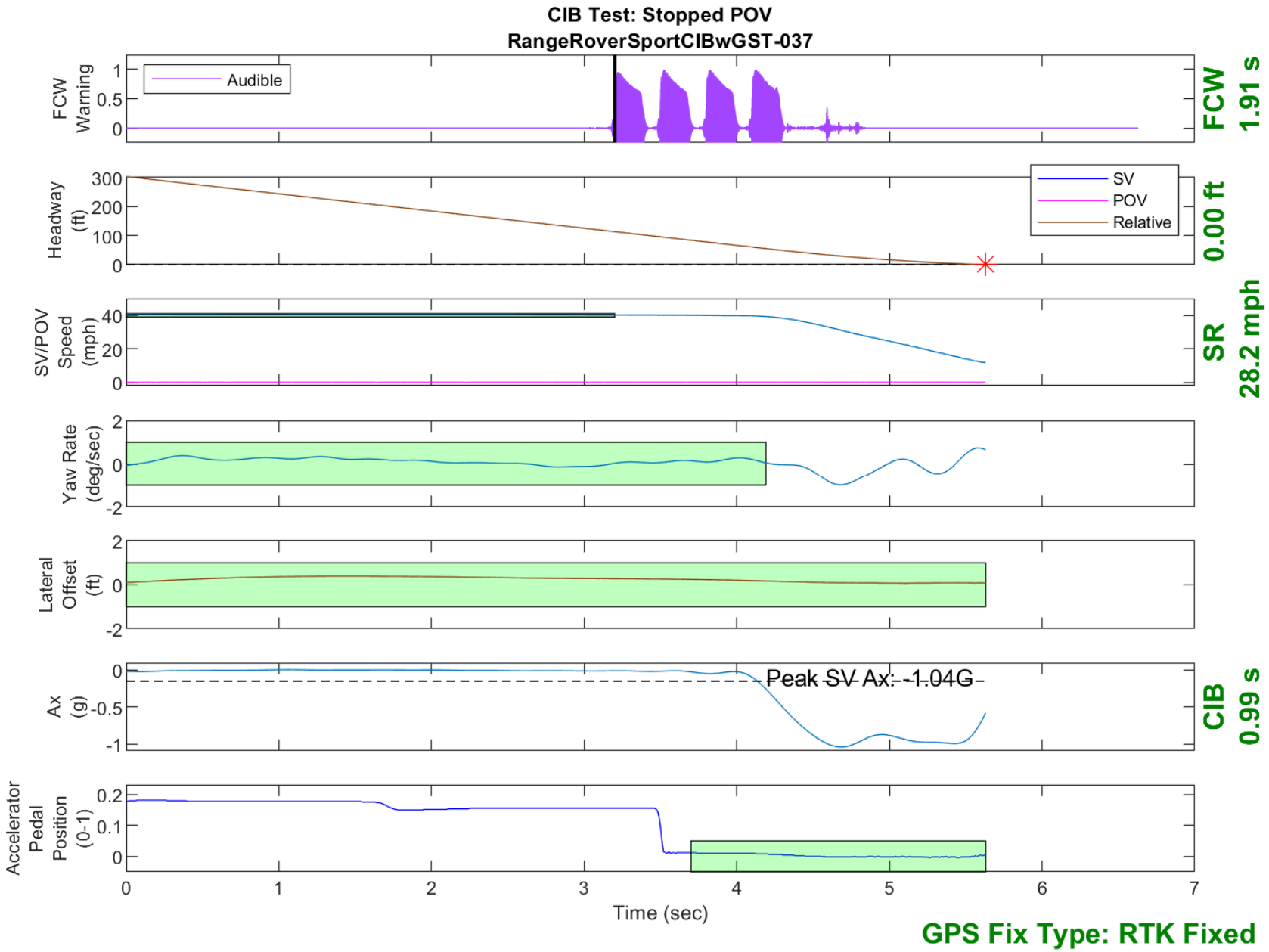


Figure D33. Time History for CIB Run 37, Stopped POV, 40 mph

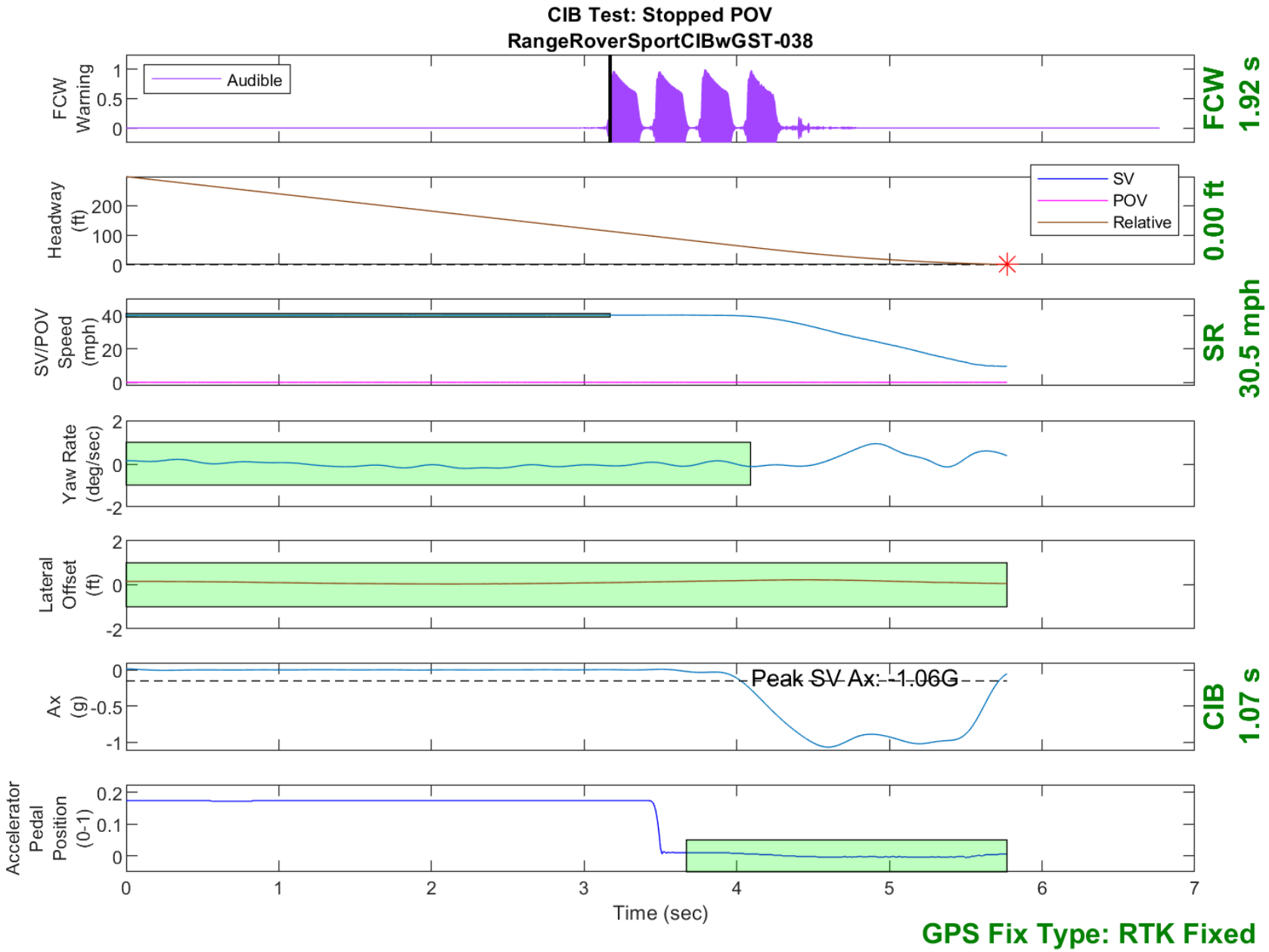


Figure D34. Time History for CIB Run 38, Stopped POV, 40 mph

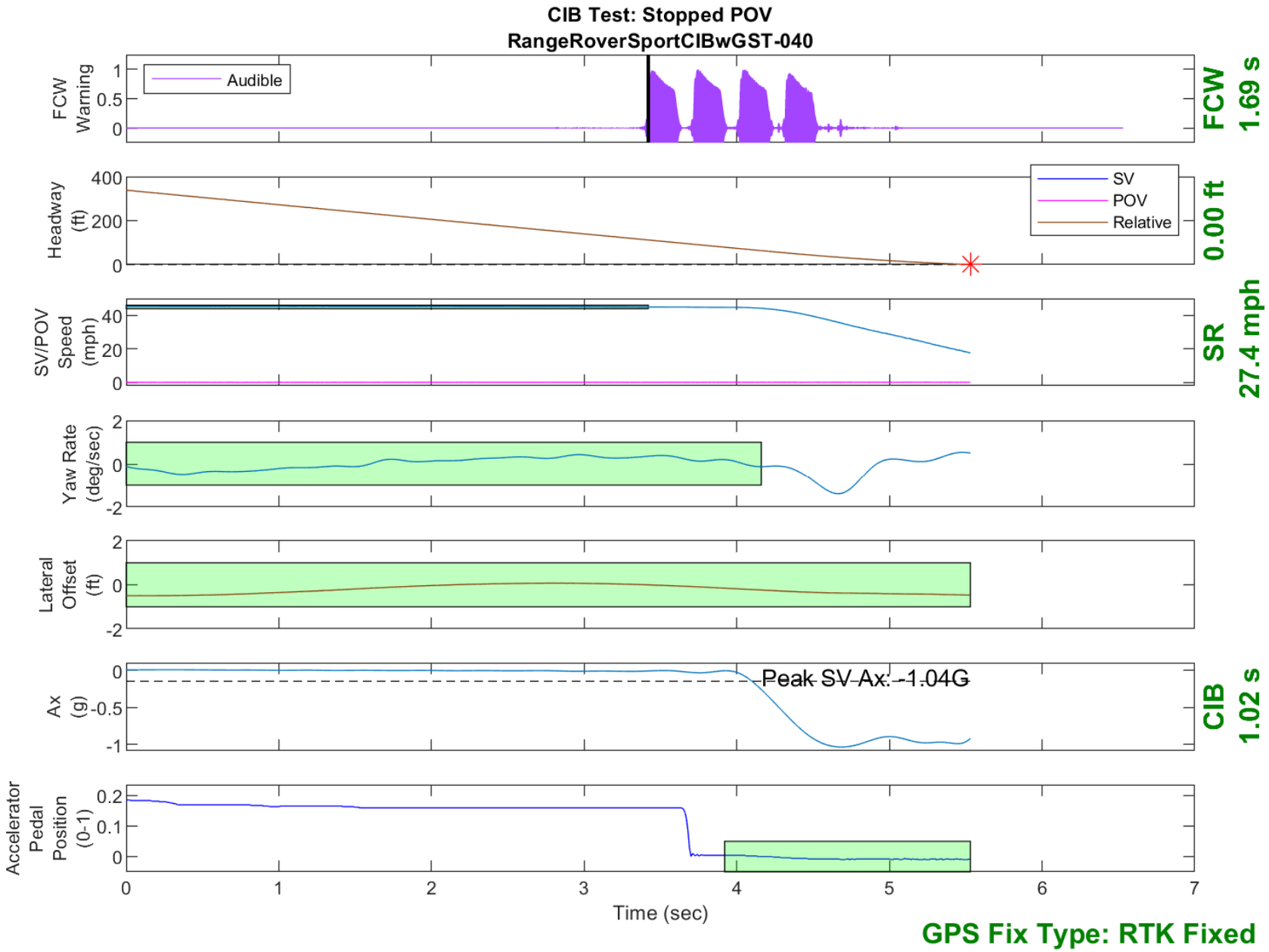


Figure D35. Time History for CIB Run 40, Stopped POV, 45 mph

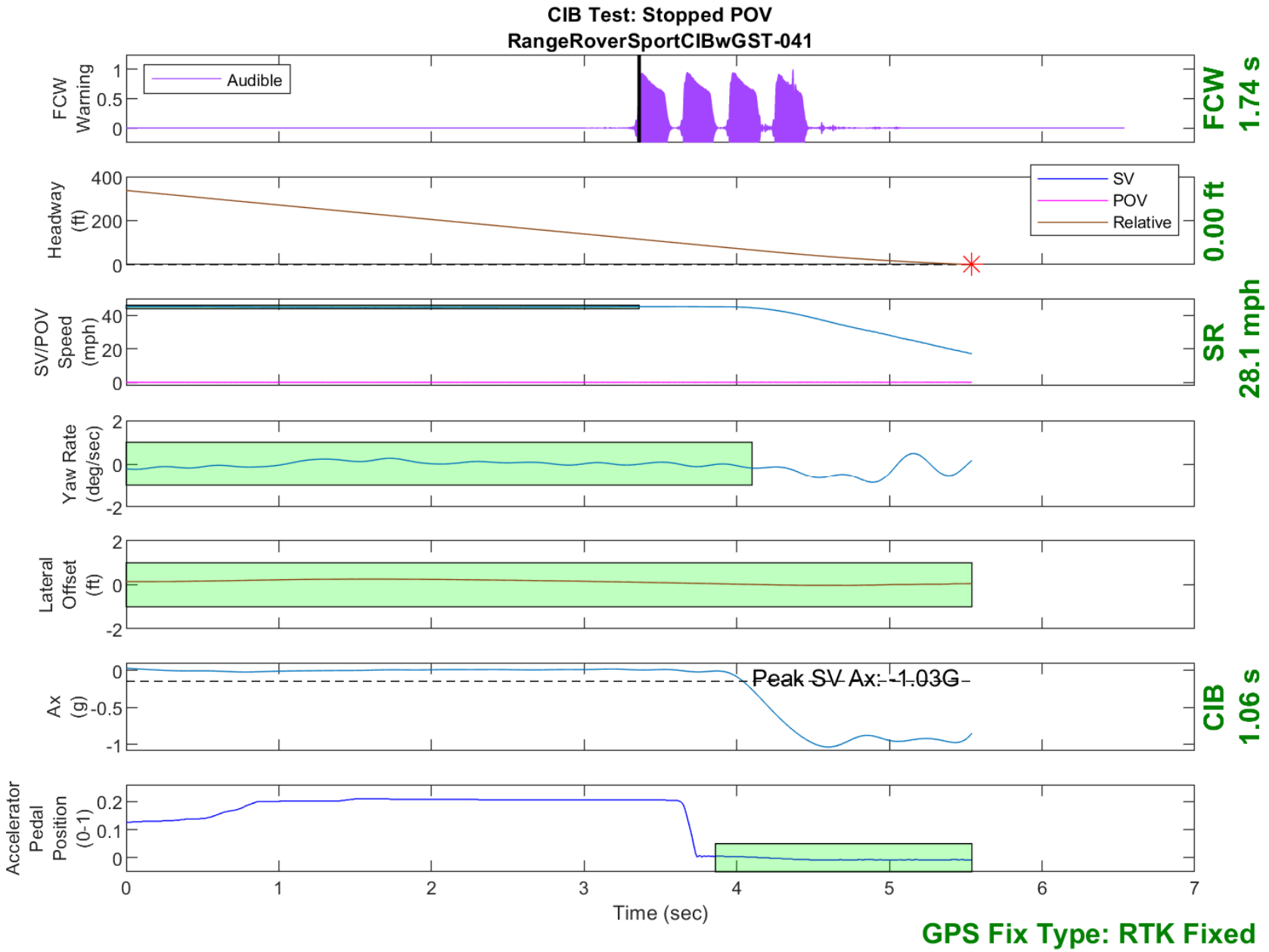


Figure D36. Time History for CIB Run 41, Stopped POV, 45 mph

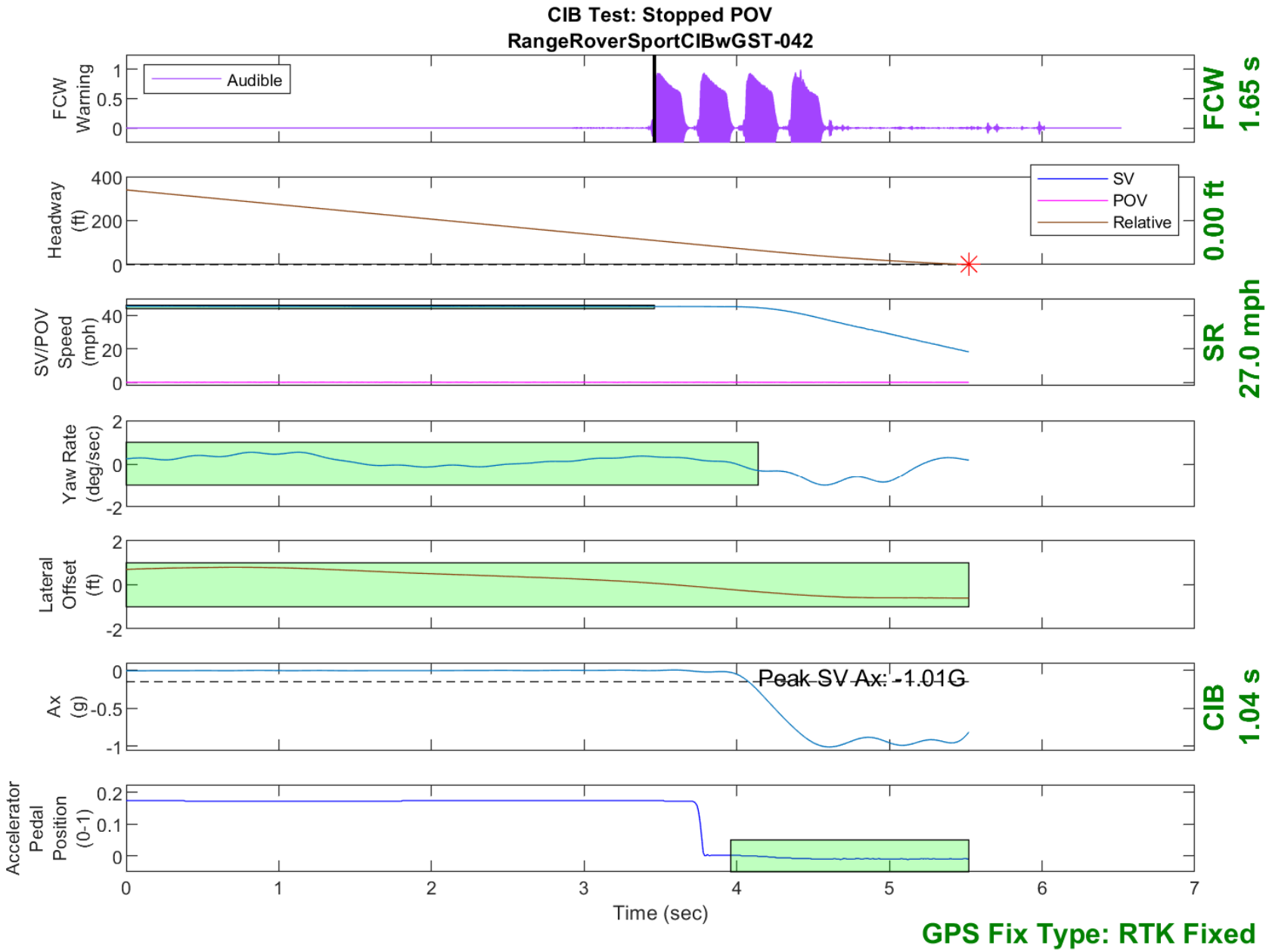


Figure D37. Time History for CIB Run 42, Stopped POV, 45 mph

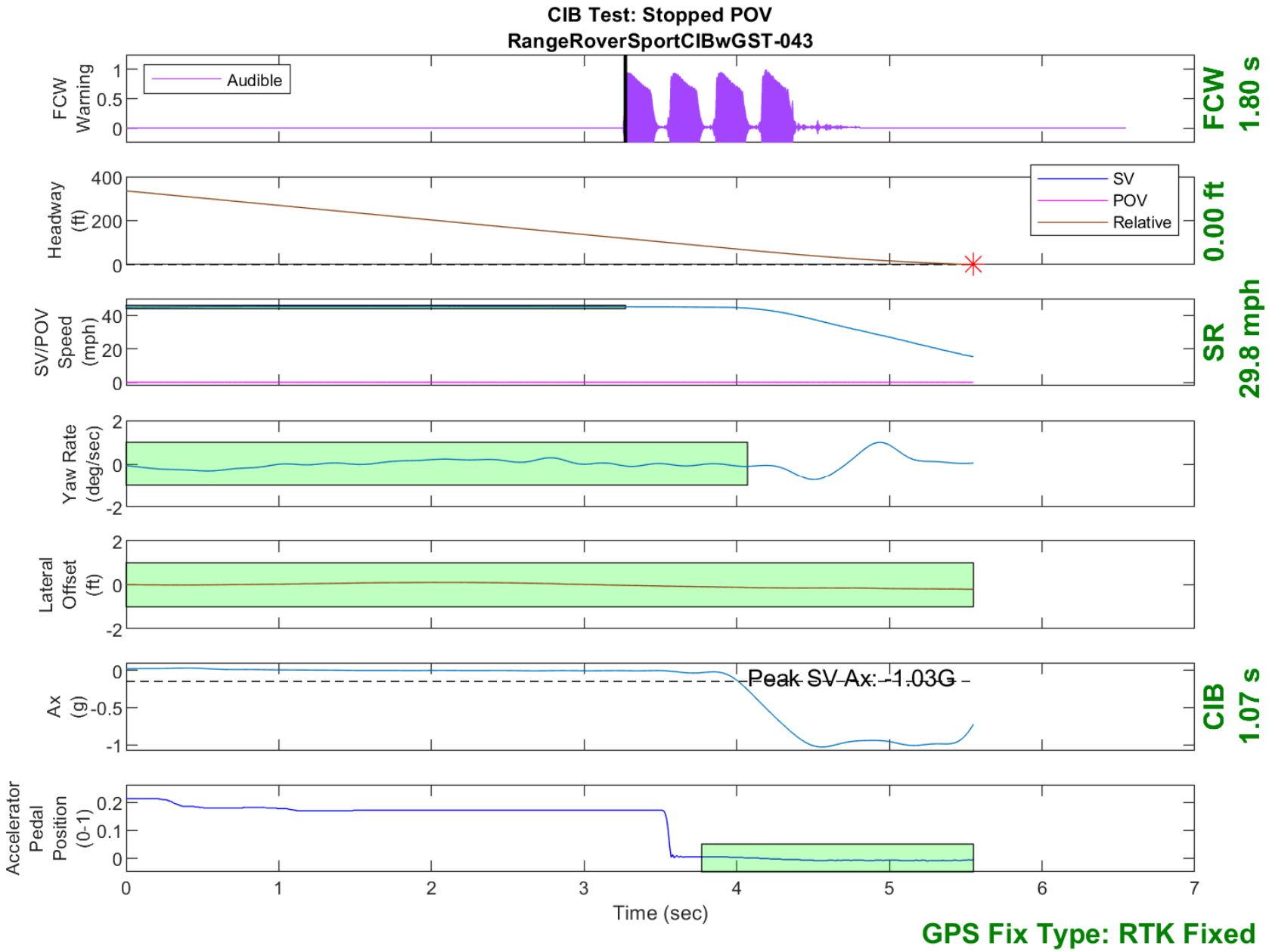


Figure D38. Time History for CIB Run 43, Stopped POV, 45 mph

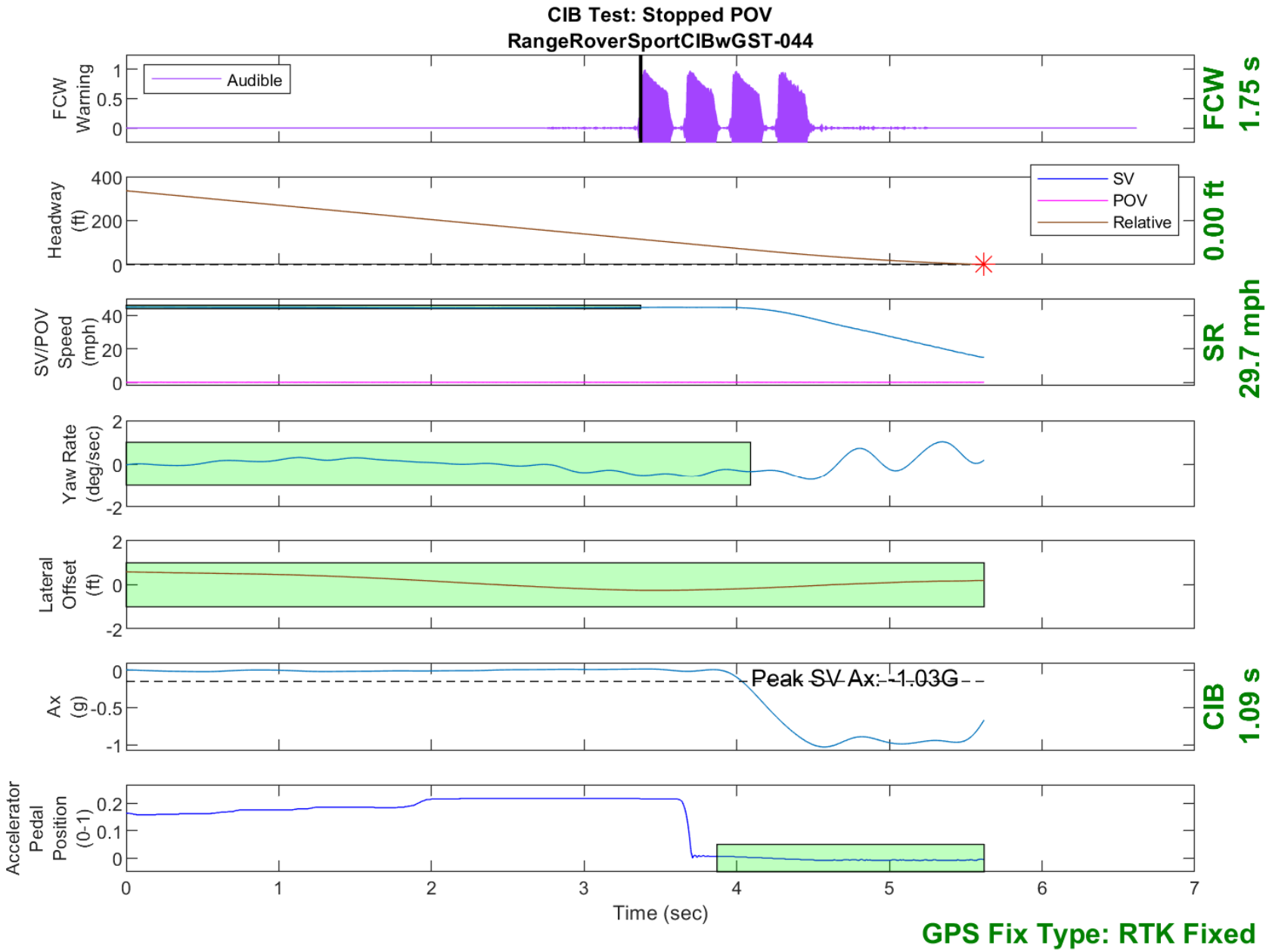


Figure D39. Time History for CIB Run 44, Stopped POV, 45 mph

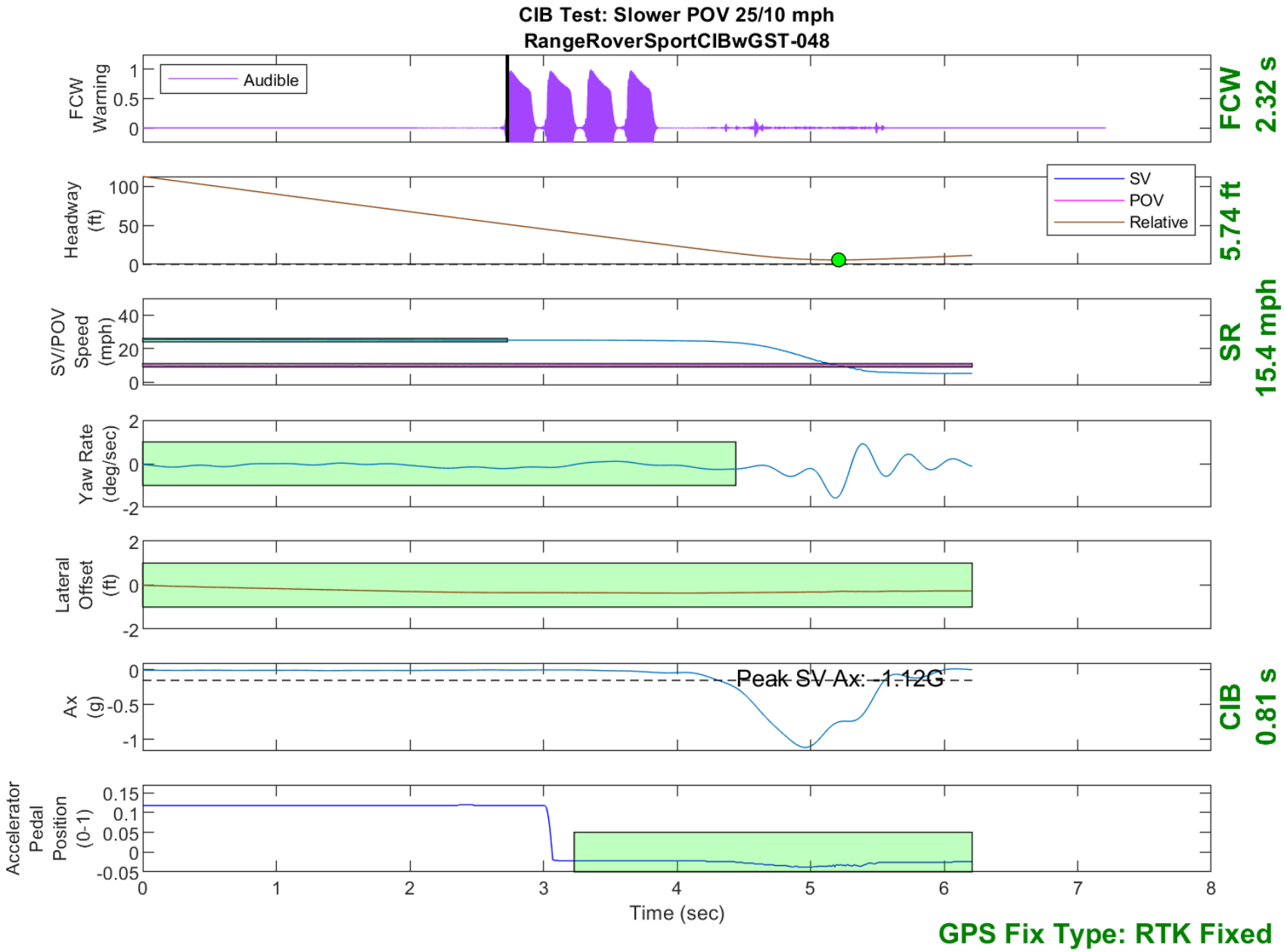


Figure D40. Time History for CIB Run 48, Slower POV, 25/10 mph

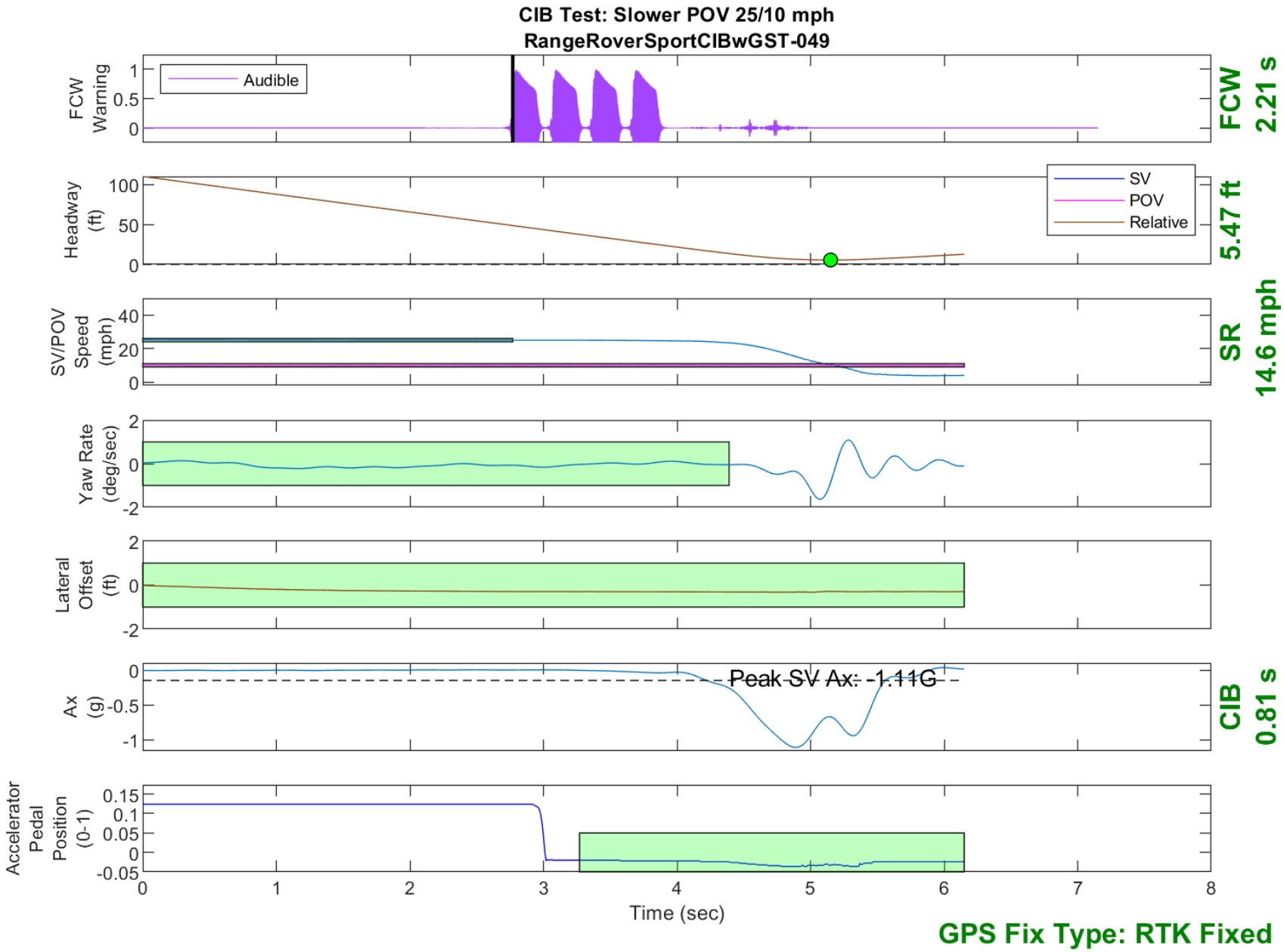


Figure D41. Time History for CIB Run 49, Slower POV, 25/10 mph

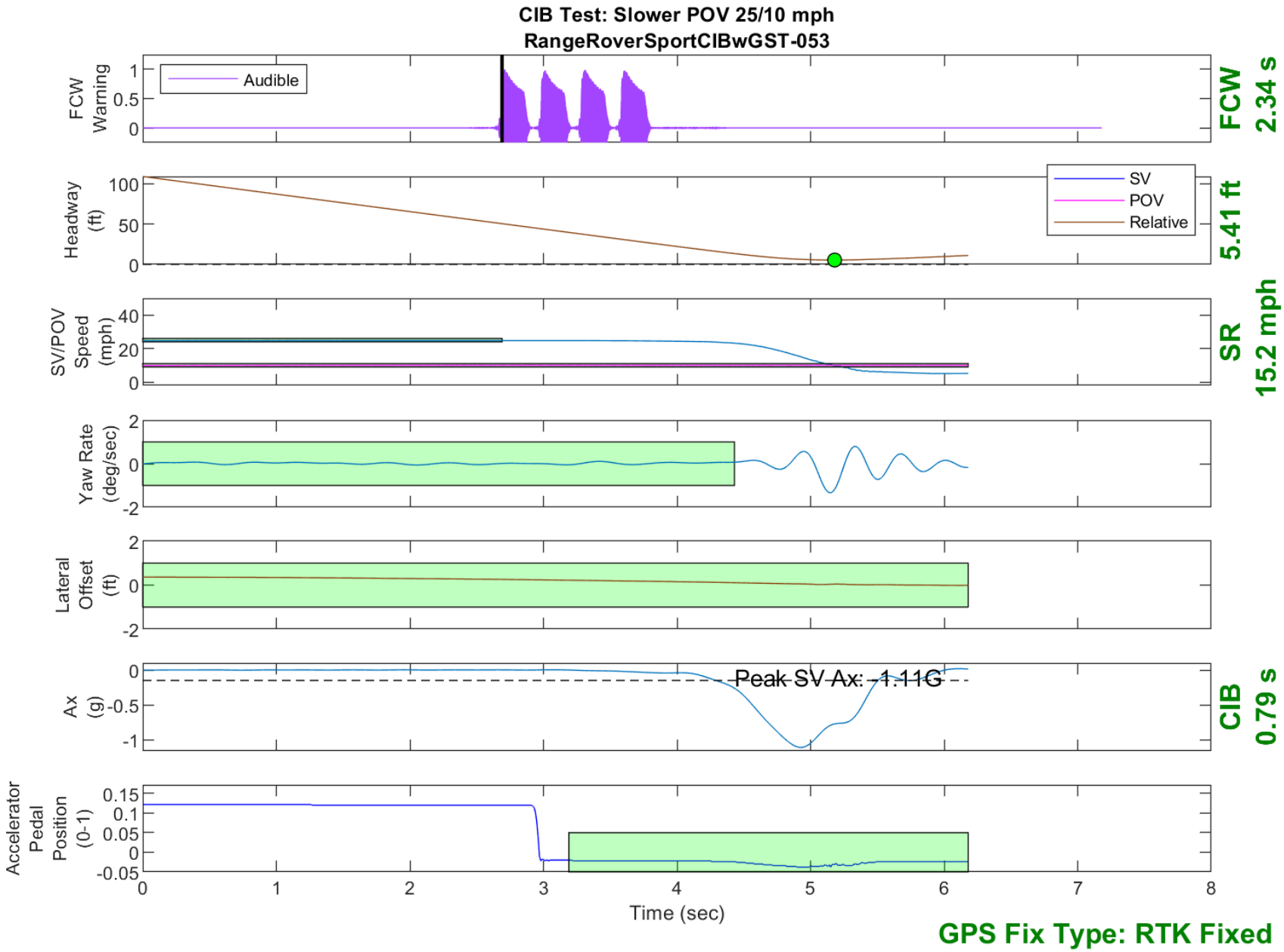


Figure D42. Time History for CIB Run 53, Slower POV, 25/10 mph

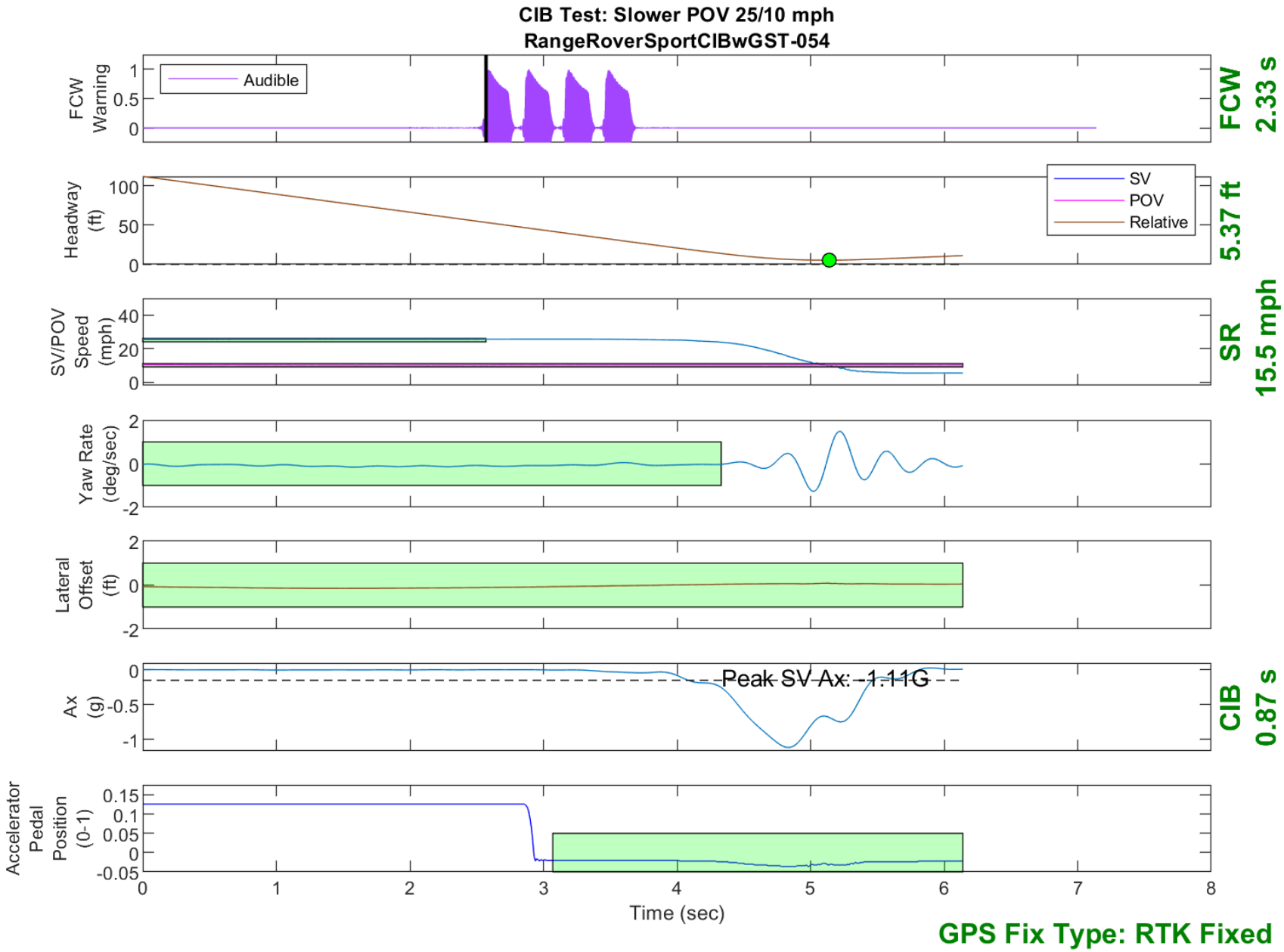


Figure D43. Time History for CIB Run 54, Slower POV, 25/10 mph

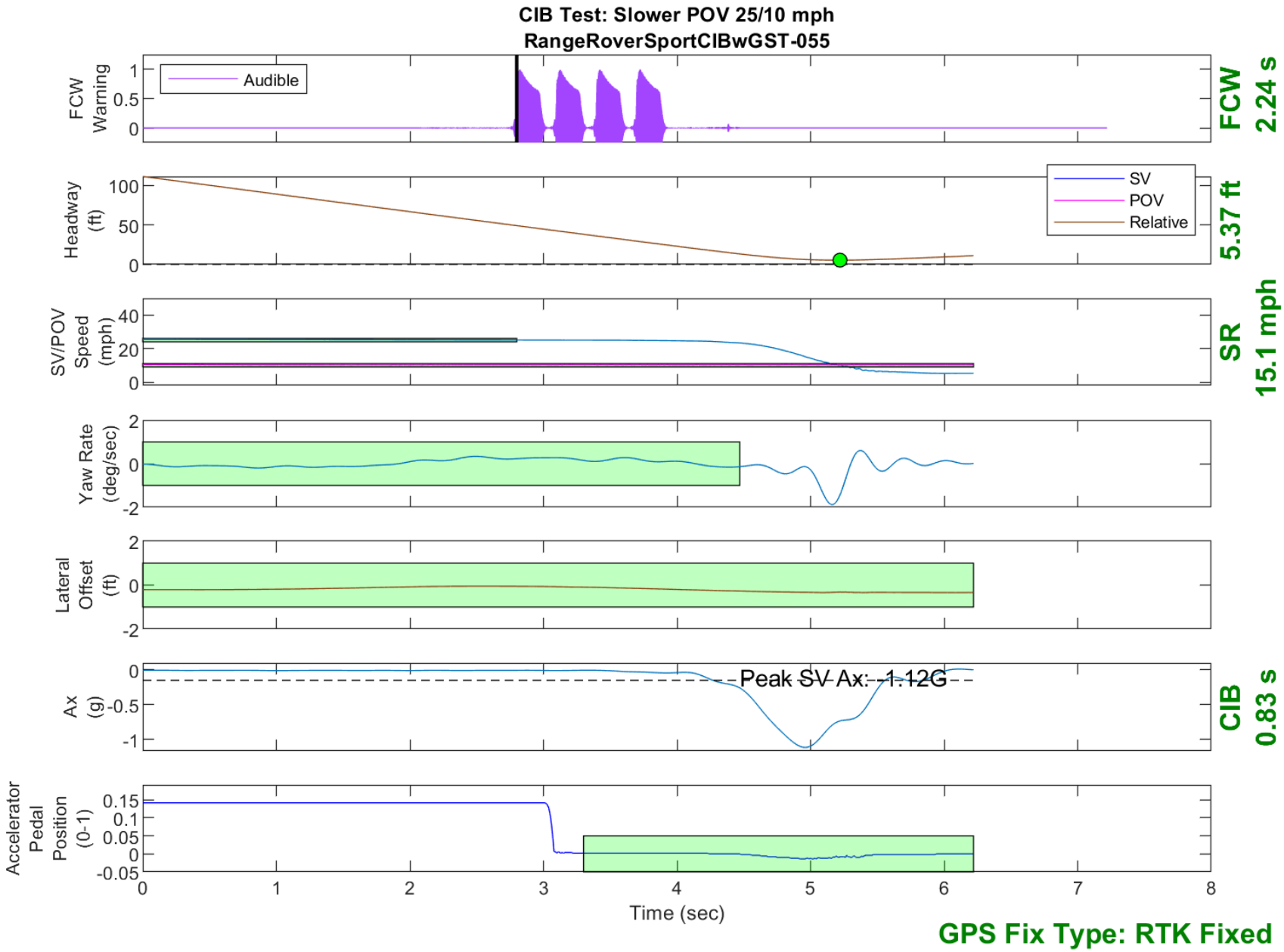


Figure D44. Time History for CIB Run 55, Slower POV, 25/10 mph

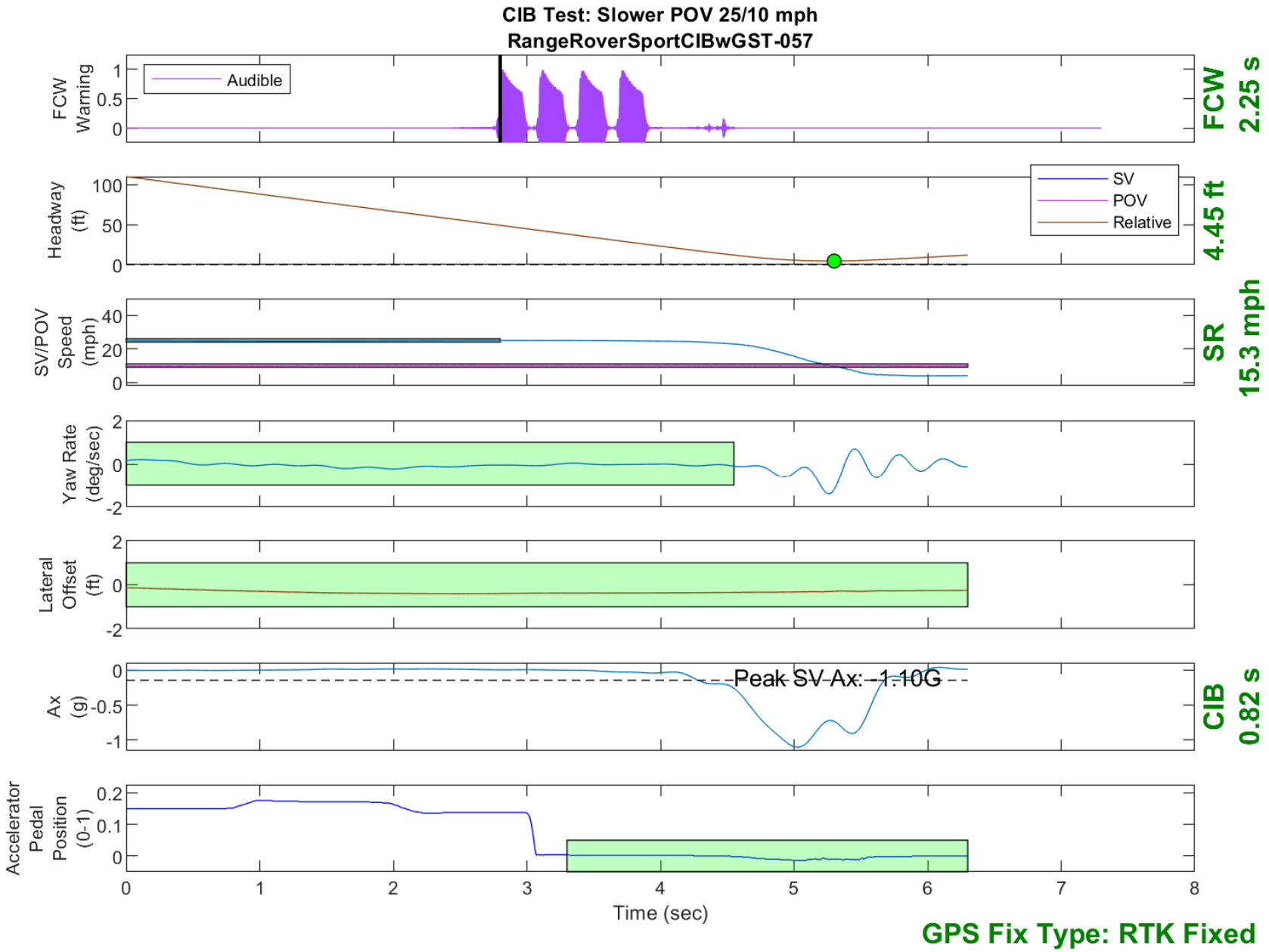


Figure D45. Time History for CIB Run 57, Slower POV, 25/10 mph

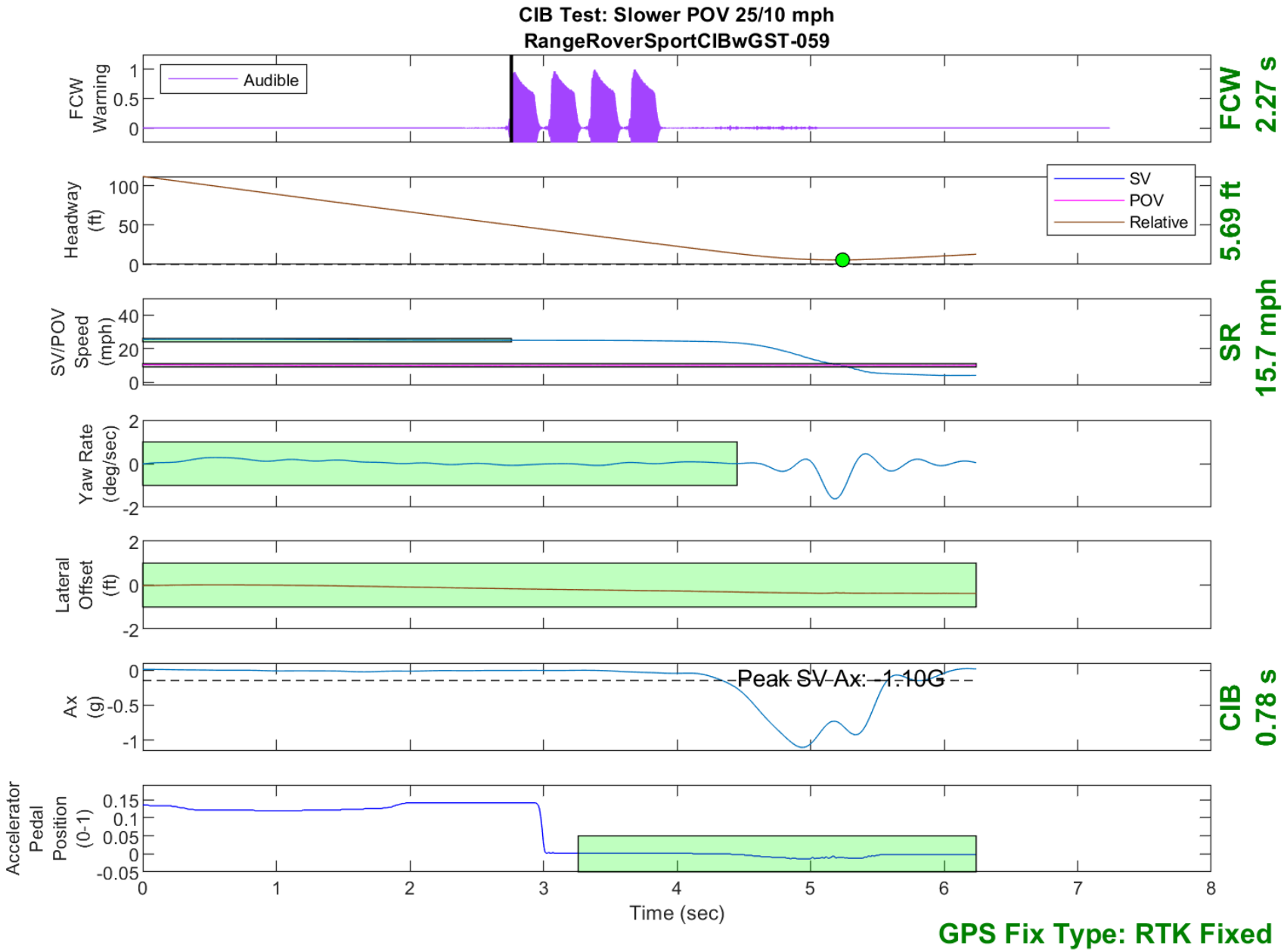


Figure D46. Time History for CIB Run 59, Slower POV, 25/10 mph

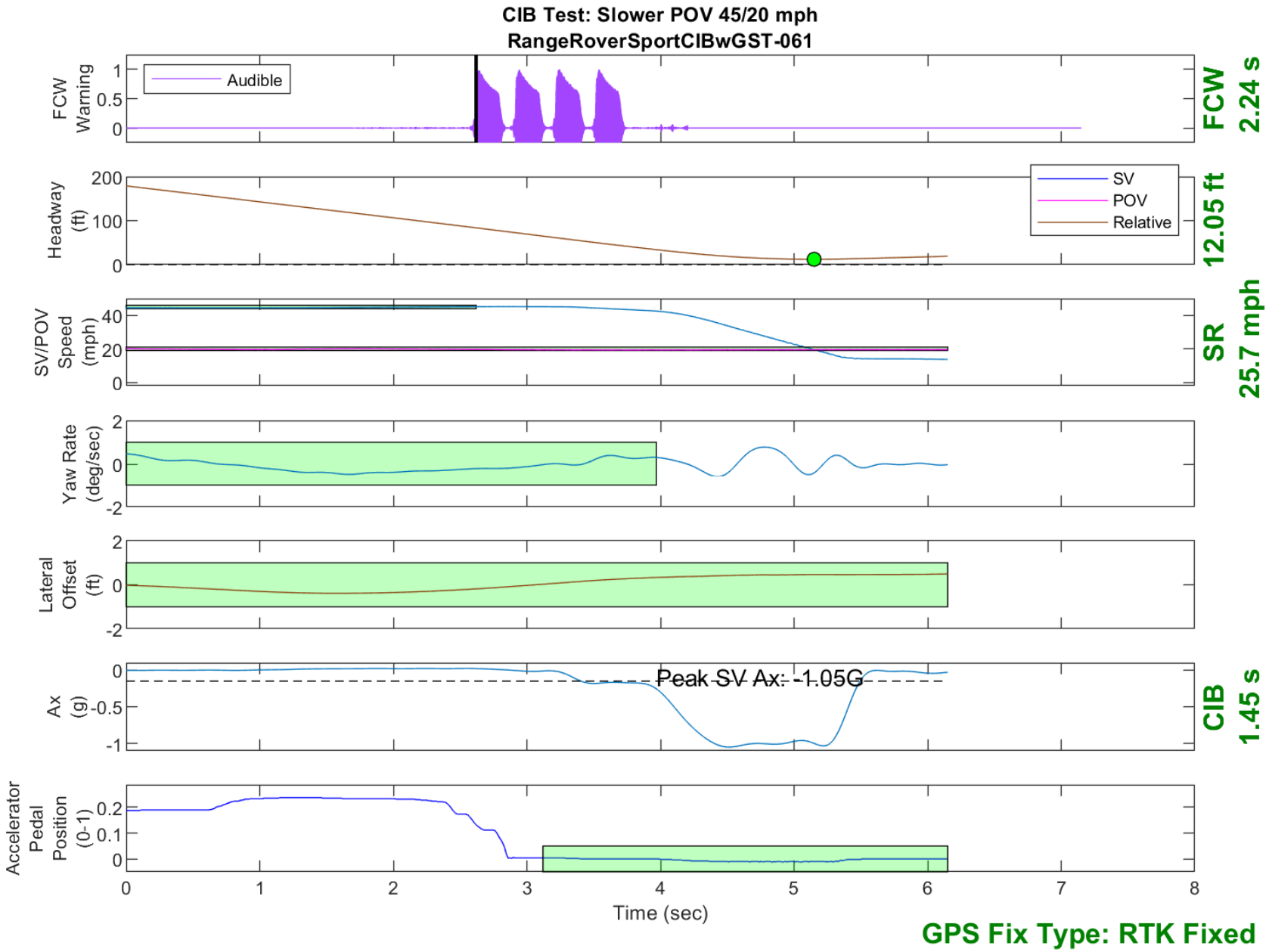


Figure D47. Time History for CIB Run 61, Slower POV, 45/20 mph

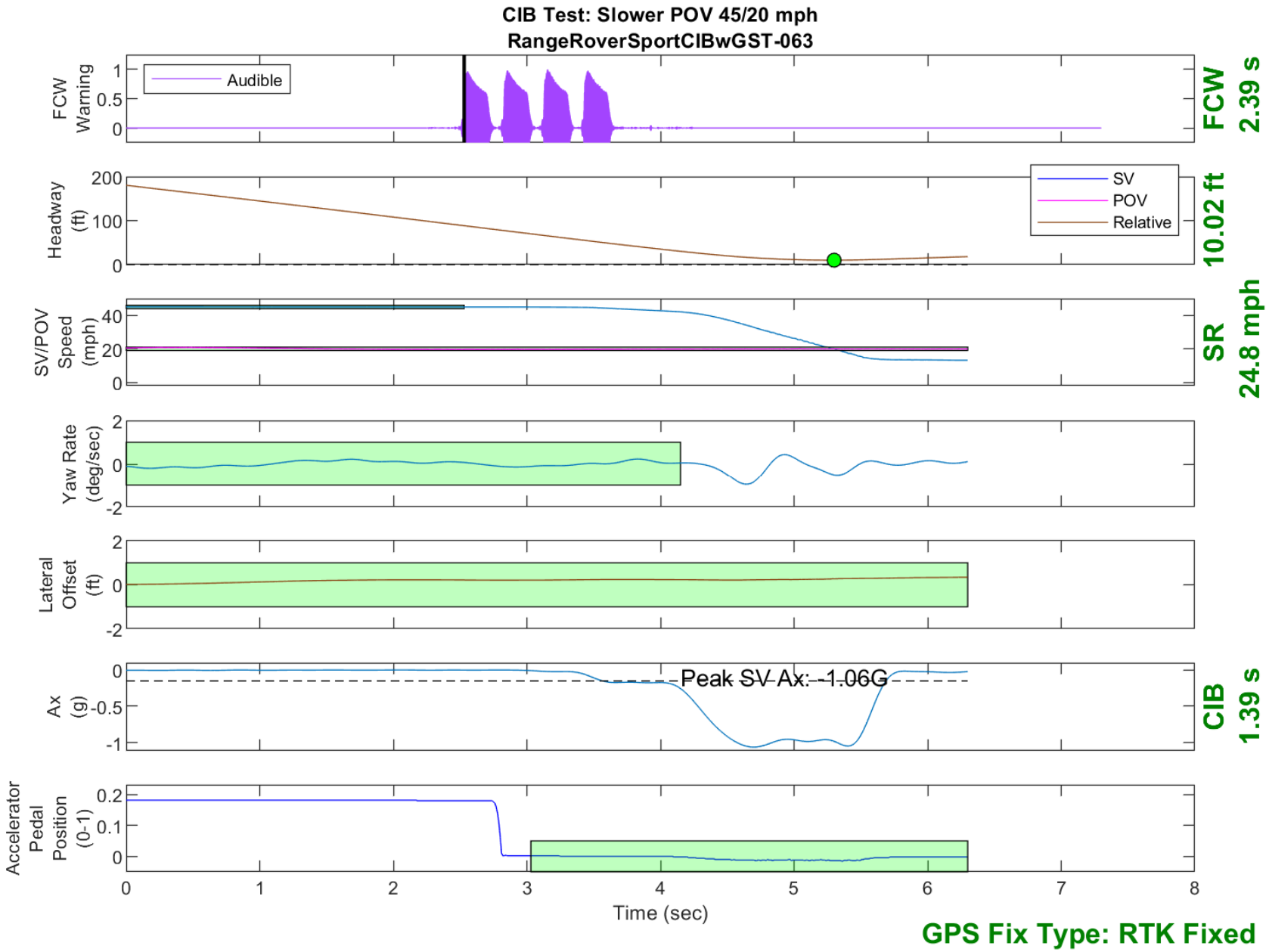


Figure D48. Time History for CIB Run 63, Slower POV, 45/20 mph

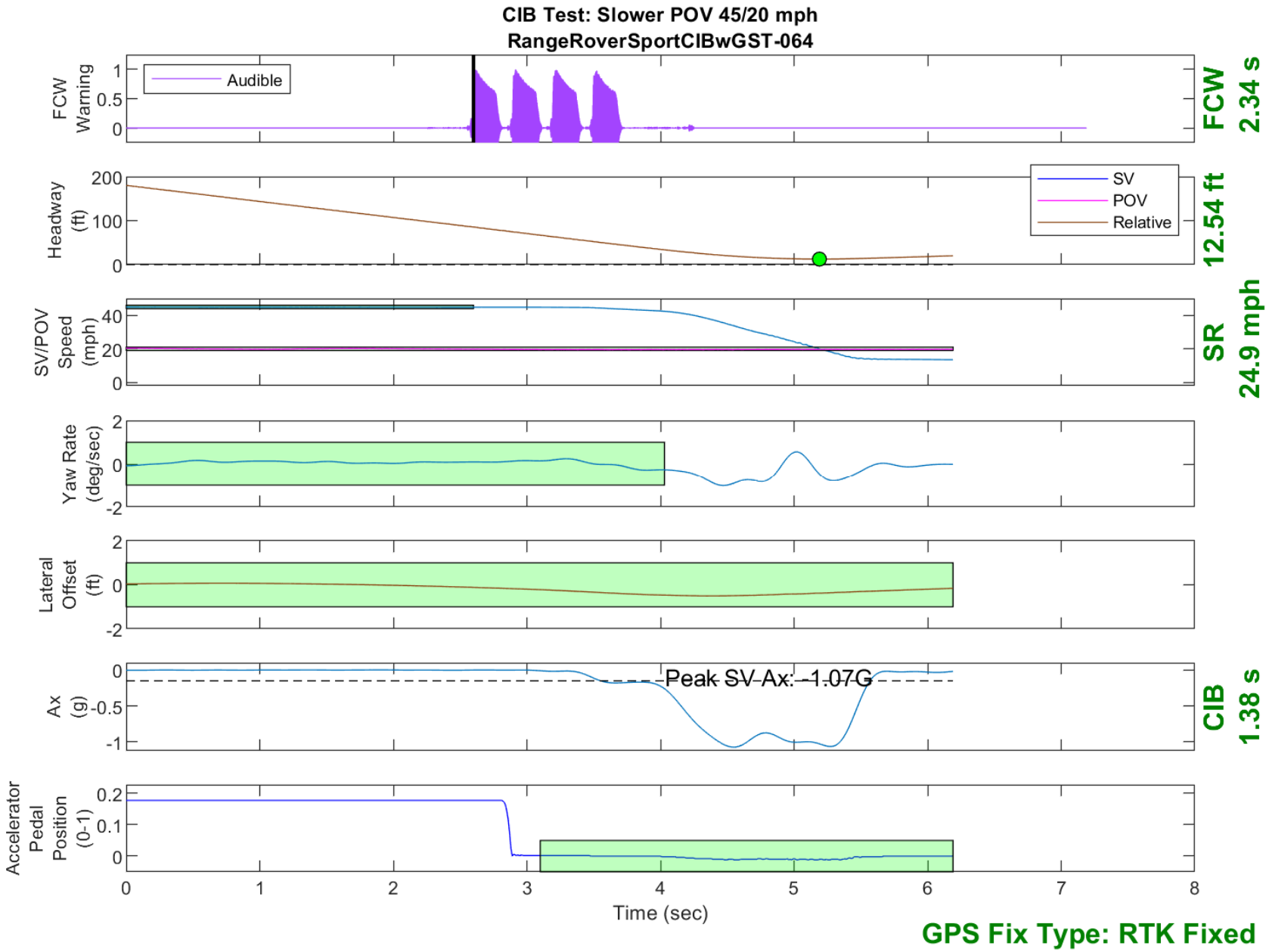


Figure D49. Time History for CIB Run 64, Slower POV, 45/20 mph

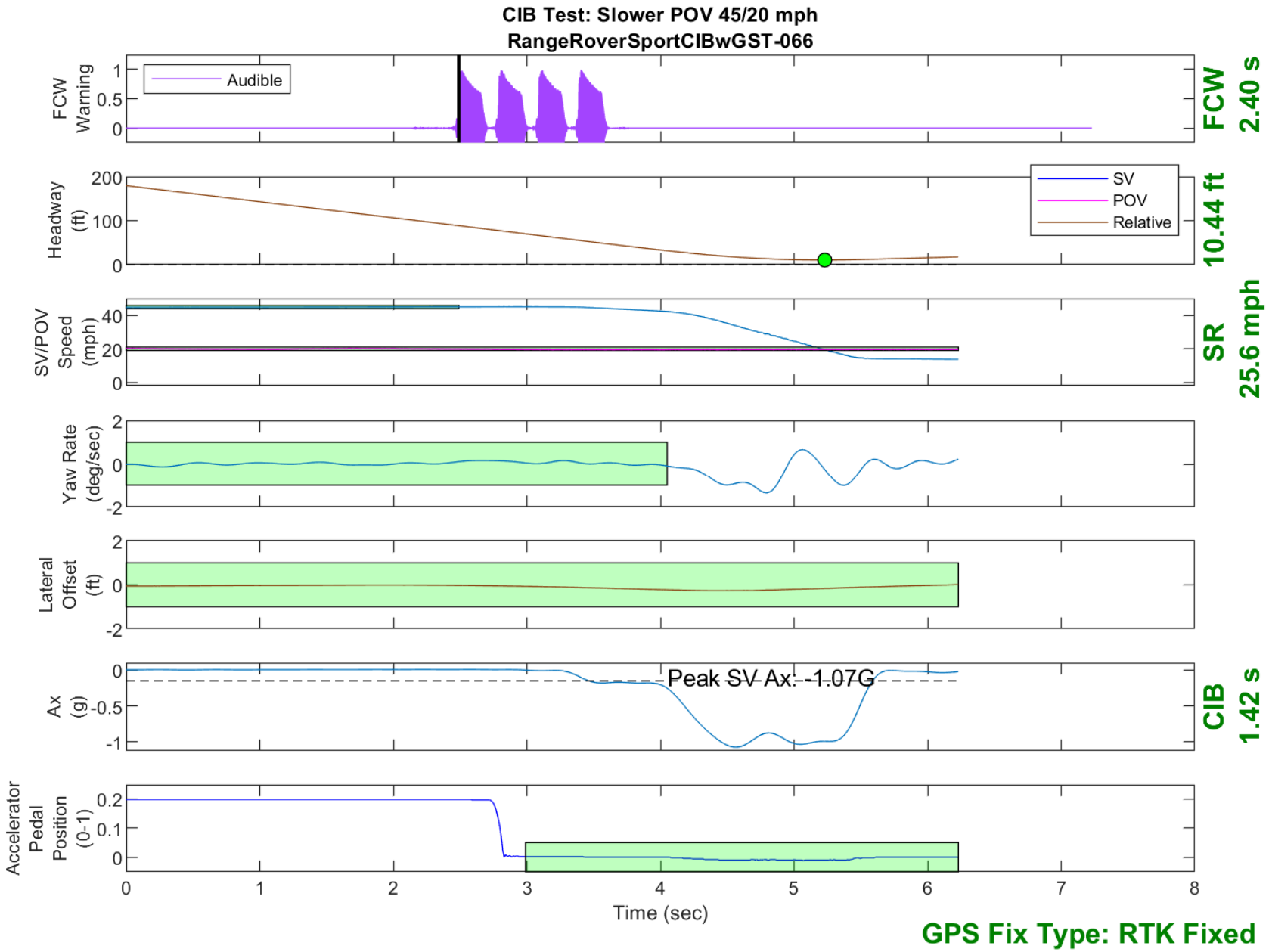


Figure D50. Time History for CIB Run 66, Slower POV, 45/20 mph

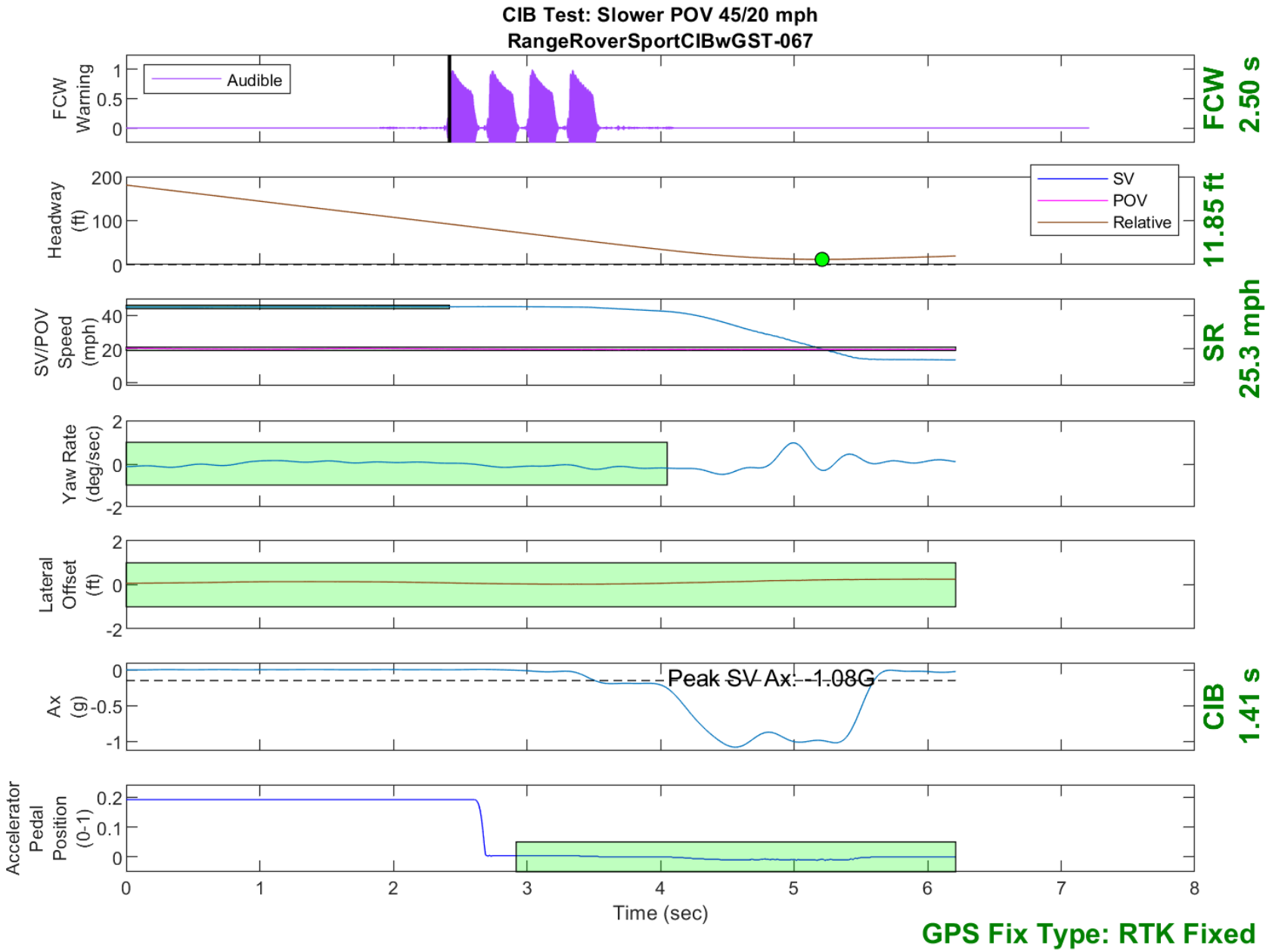


Figure D51. Time History for CIB Run 67, Slower POV, 45/20 mph

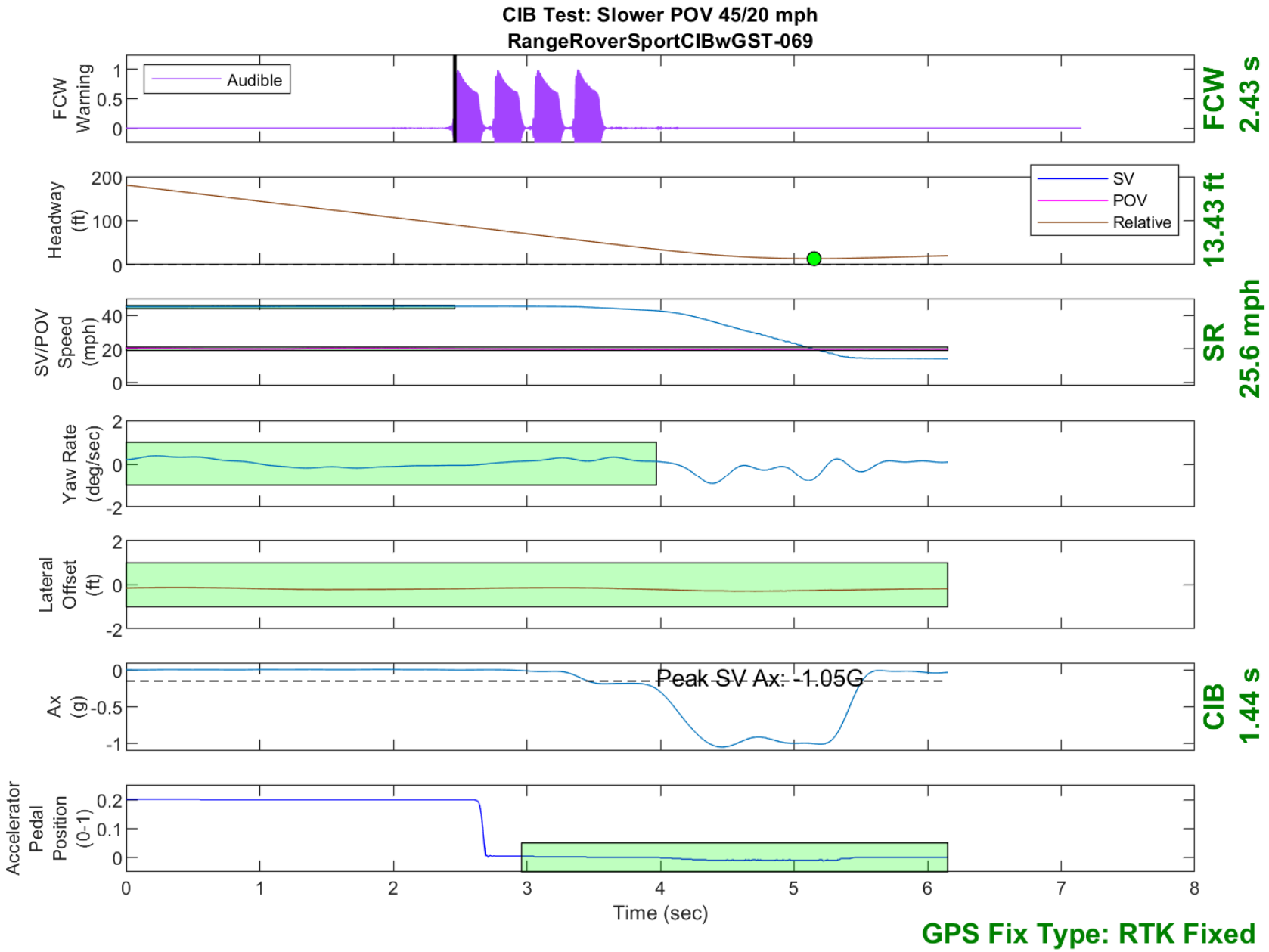


Figure D52. Time History for CIB Run 69, Slower POV, 45/20 mph

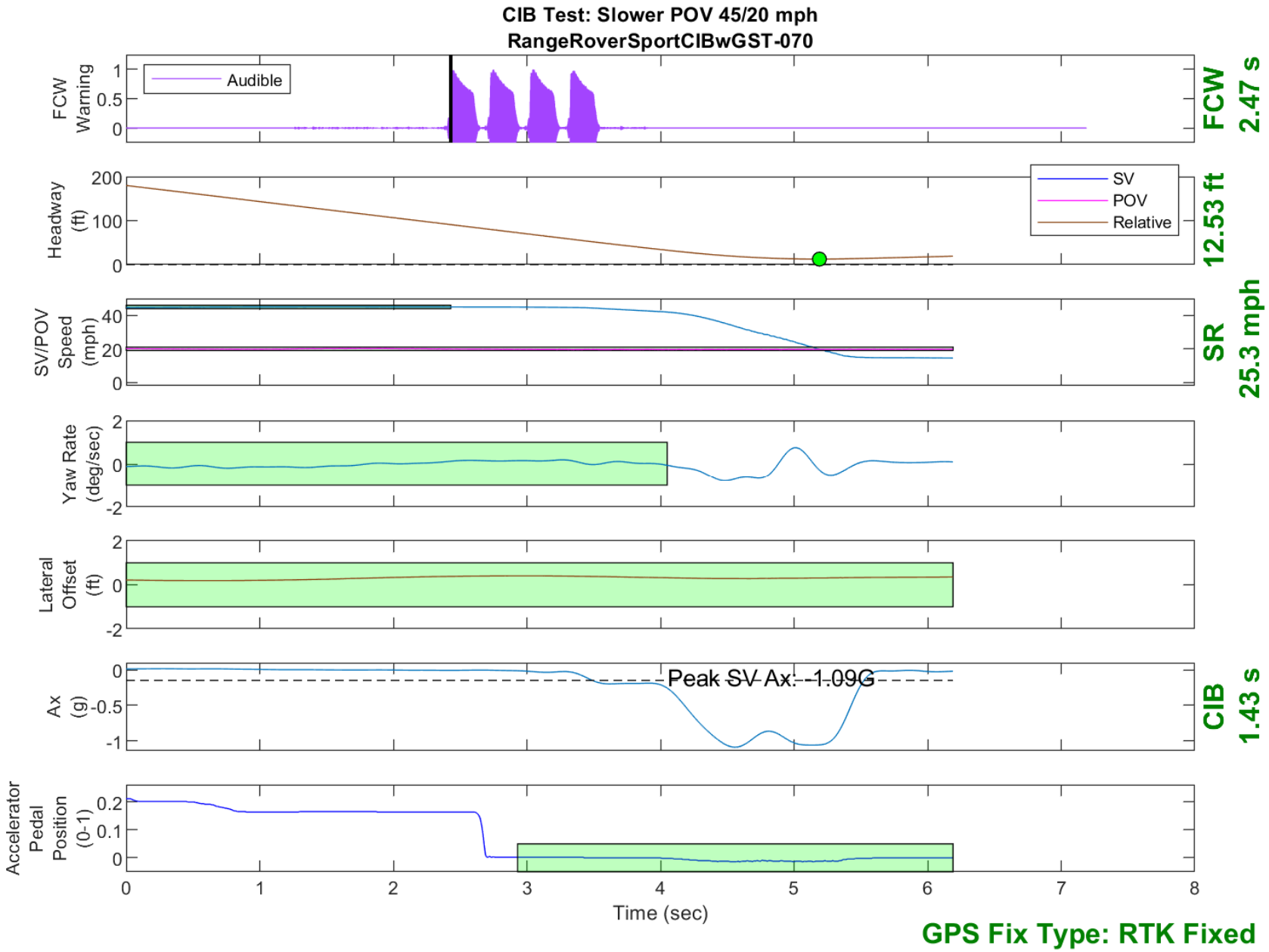


Figure D53. Time History for CIB Run 70, Slower POV, 45/20 mph

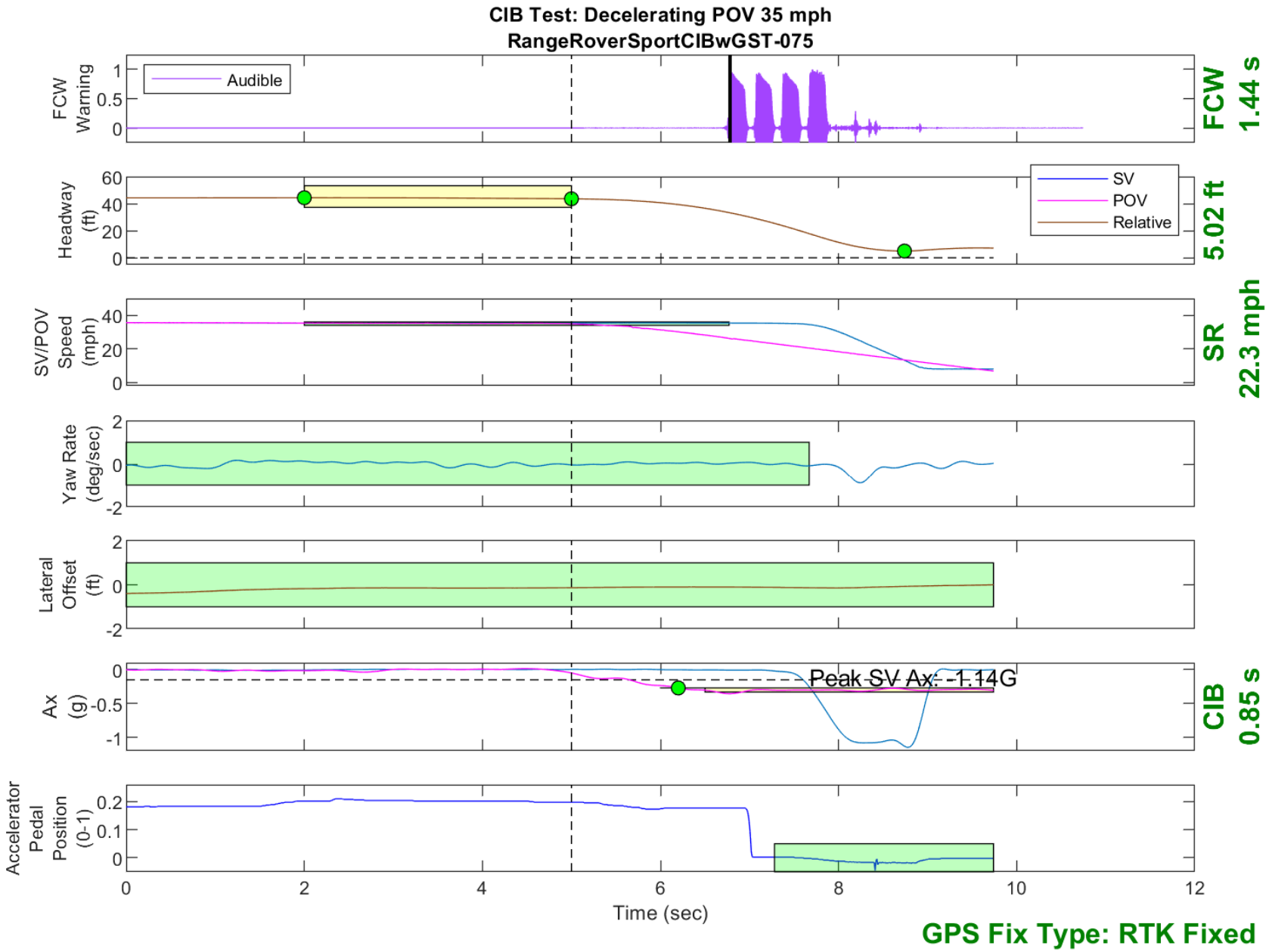


Figure D54. Time History for CIB Run 75, Decelerating POV, 35 mph 0.3g

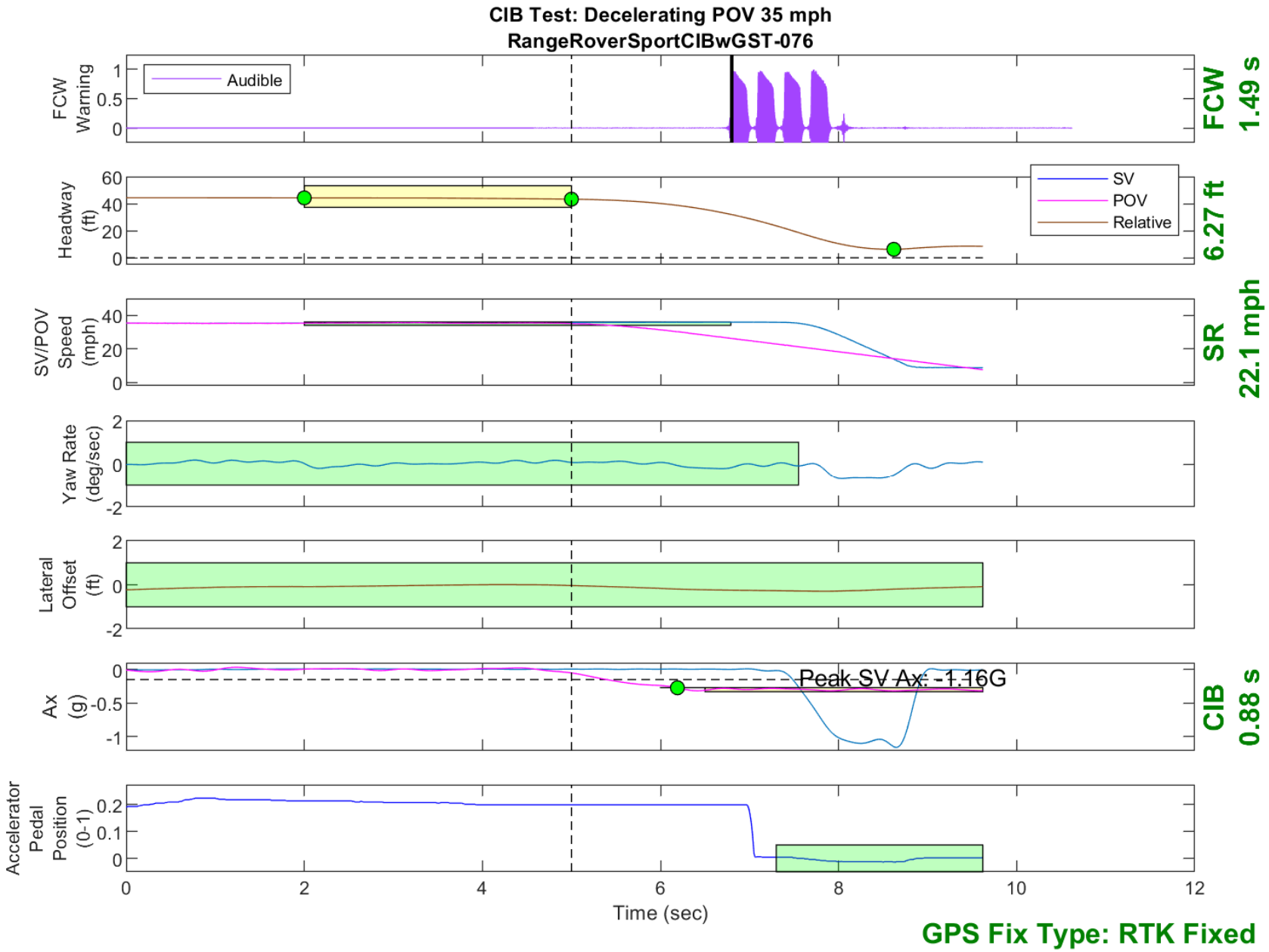


Figure D55. Time History for CIB Run 76, Decelerating POV, 35 mph 0.3g

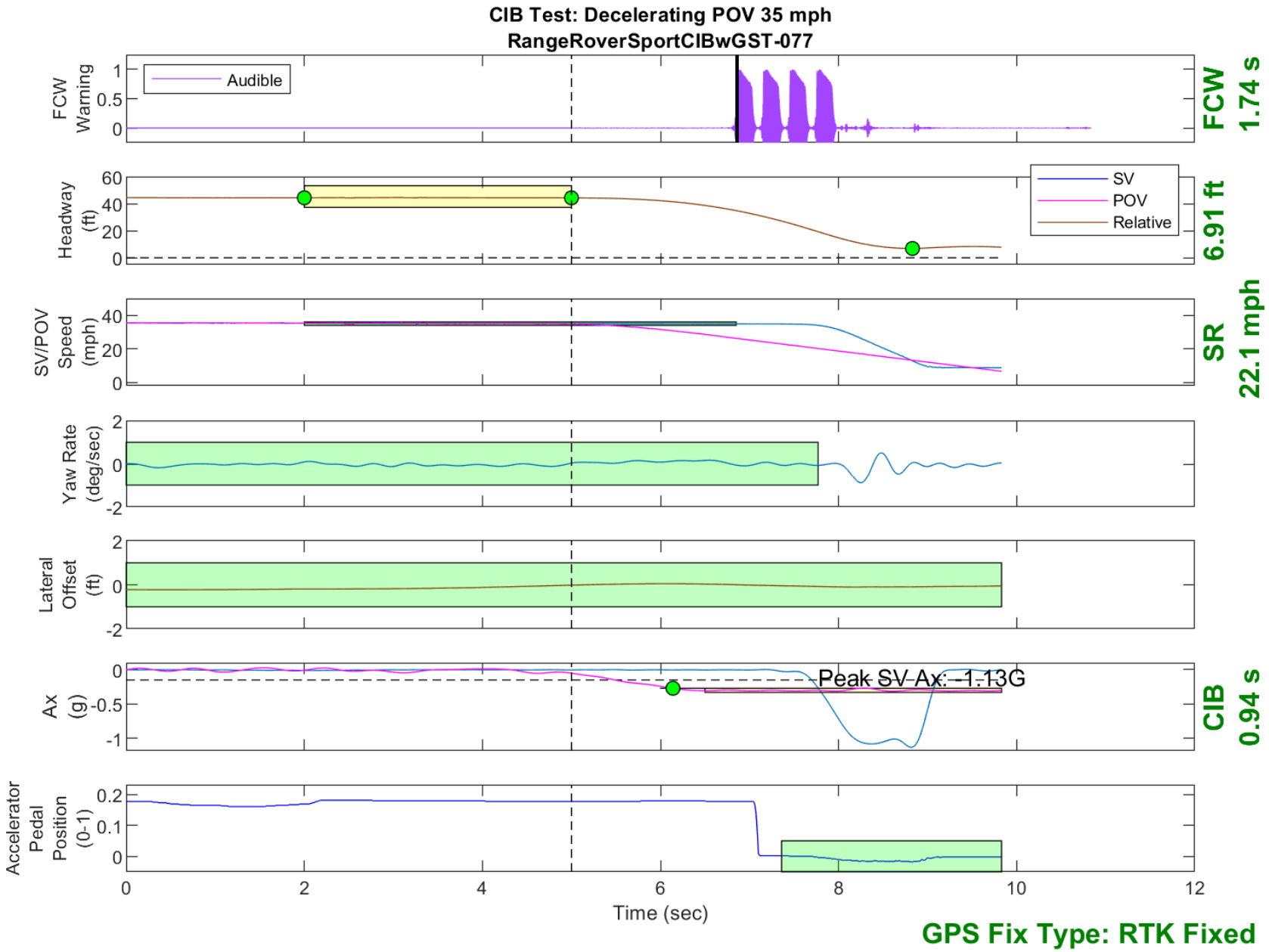


Figure D56. Time History for CIB Run 77, Decelerating POV, 35 mph 0.3g

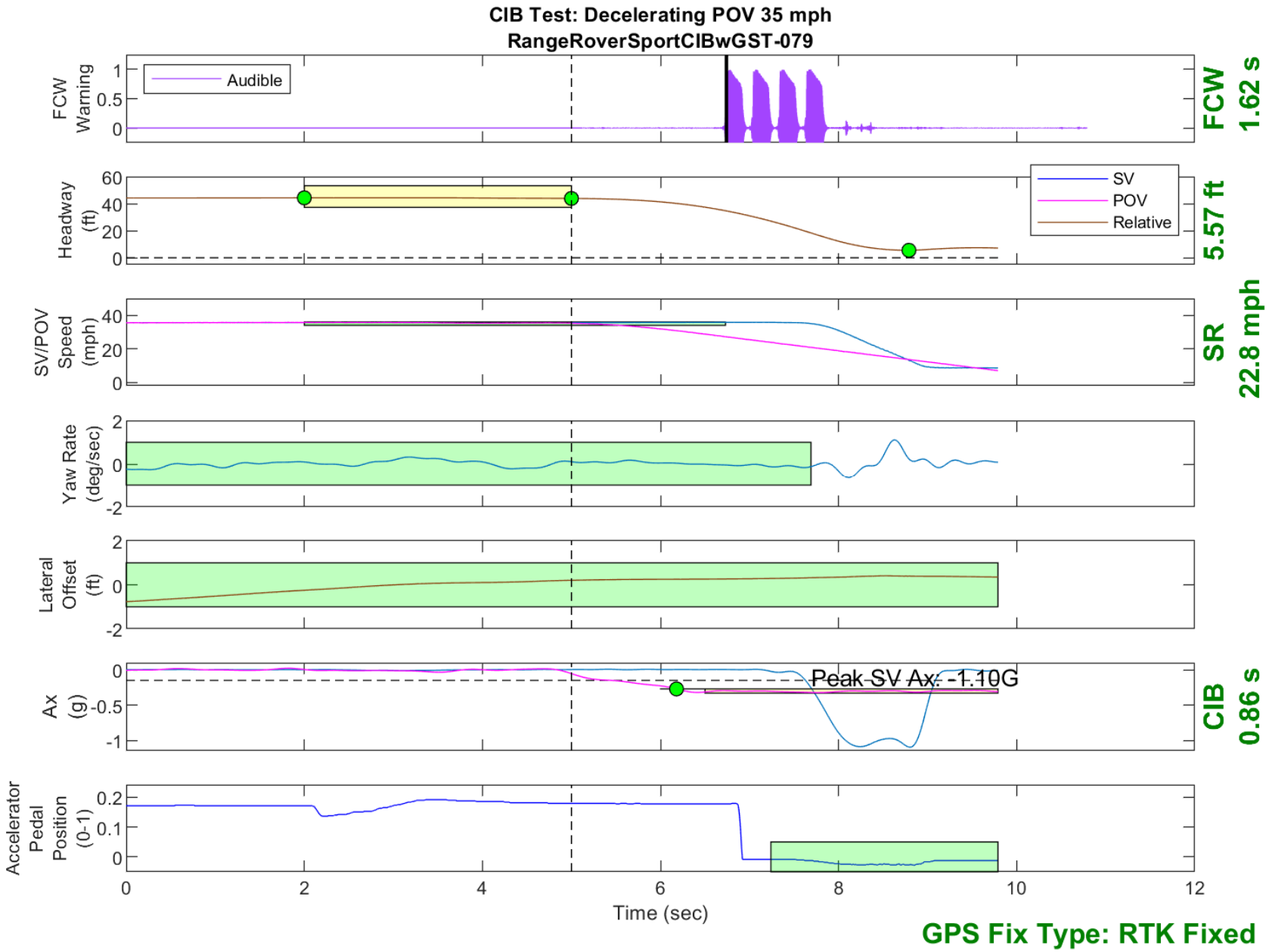


Figure D57. Time History for CIB Run 79, Decelerating POV, 35 mph 0.3g

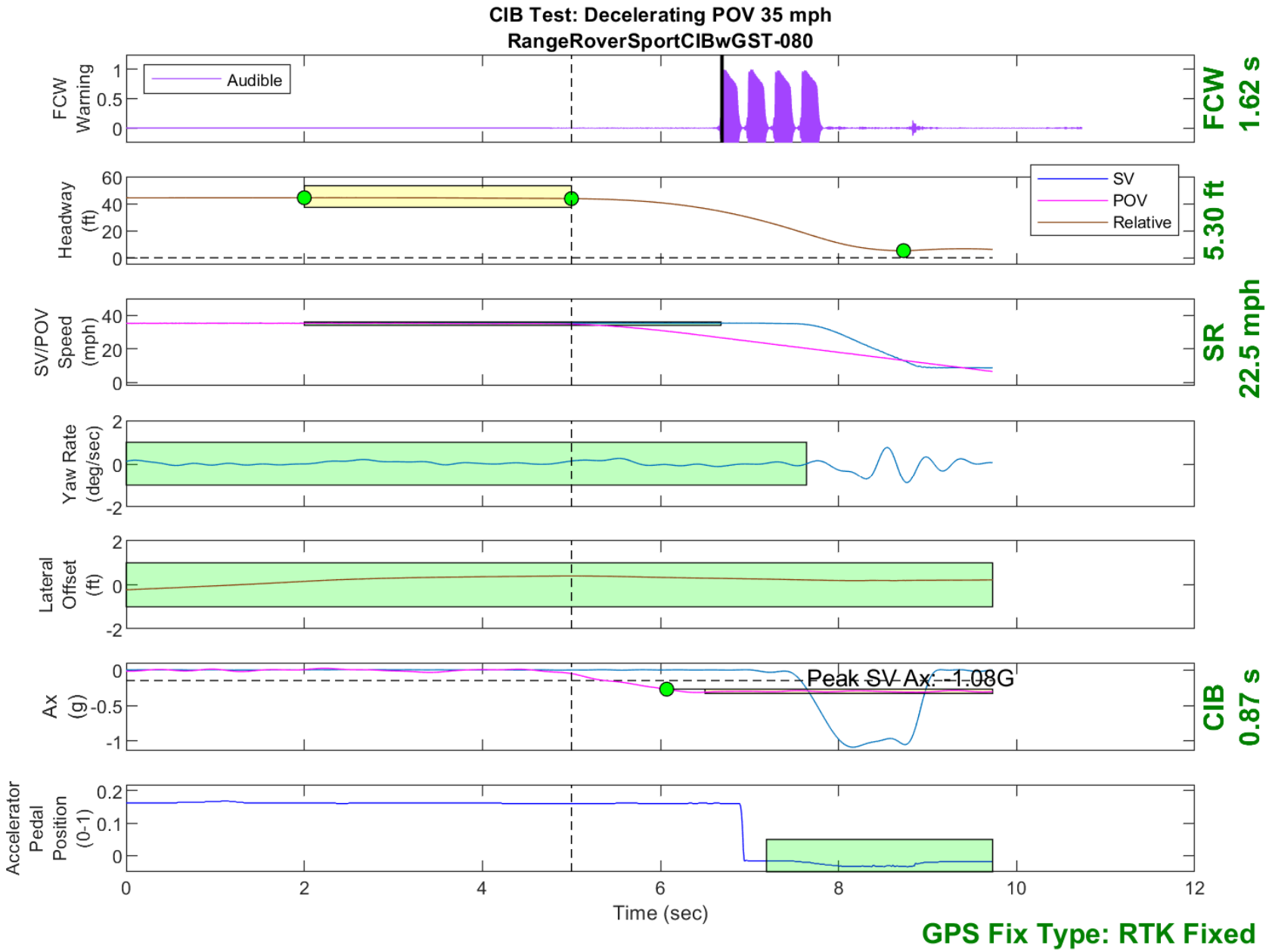


Figure D58. Time History for CIB Run 80, Decelerating POV, 35 mph 0.3g

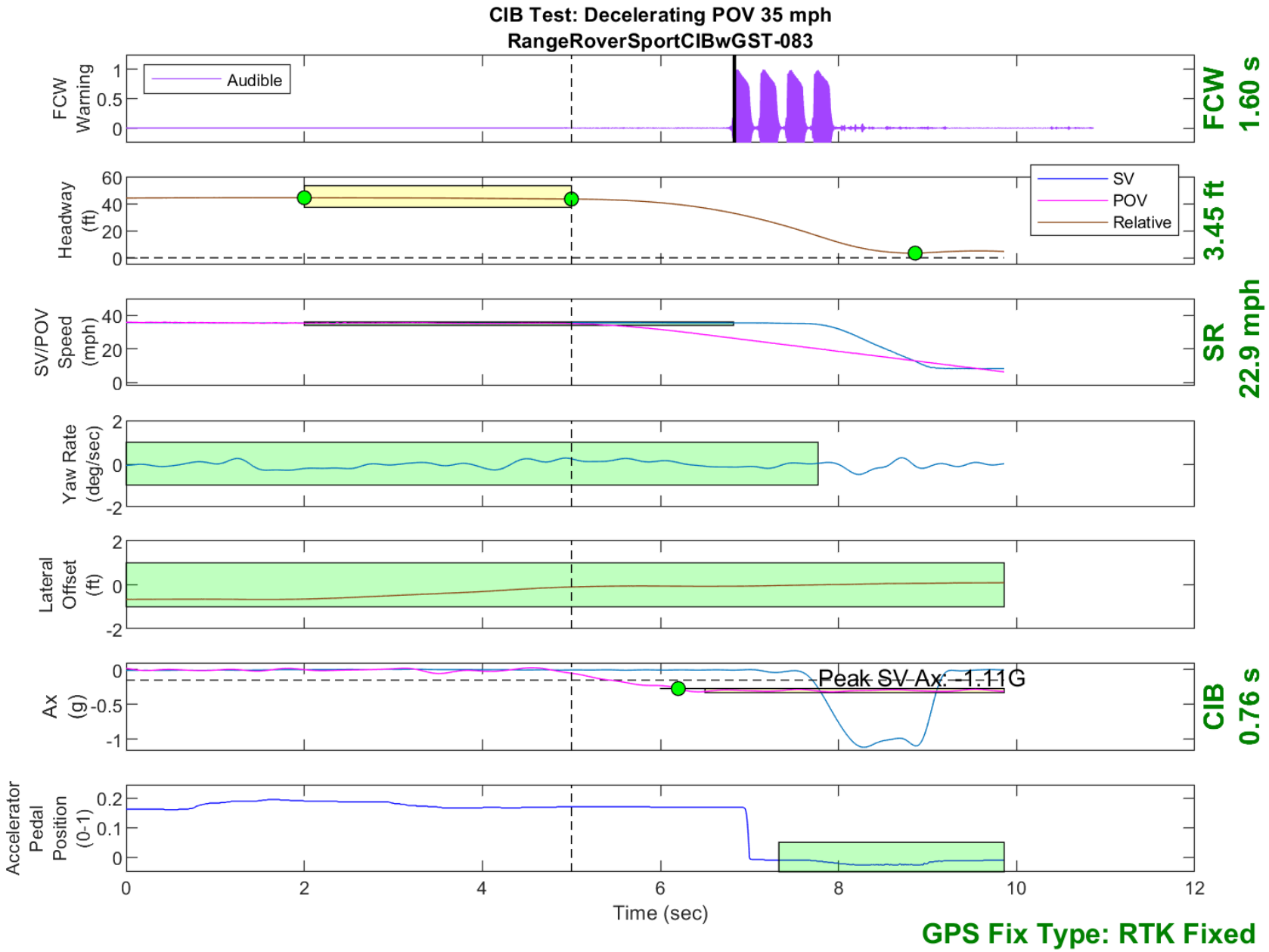


Figure D59. Time History for CIB Run 83, Decelerating POV, 35 mph 0.3g

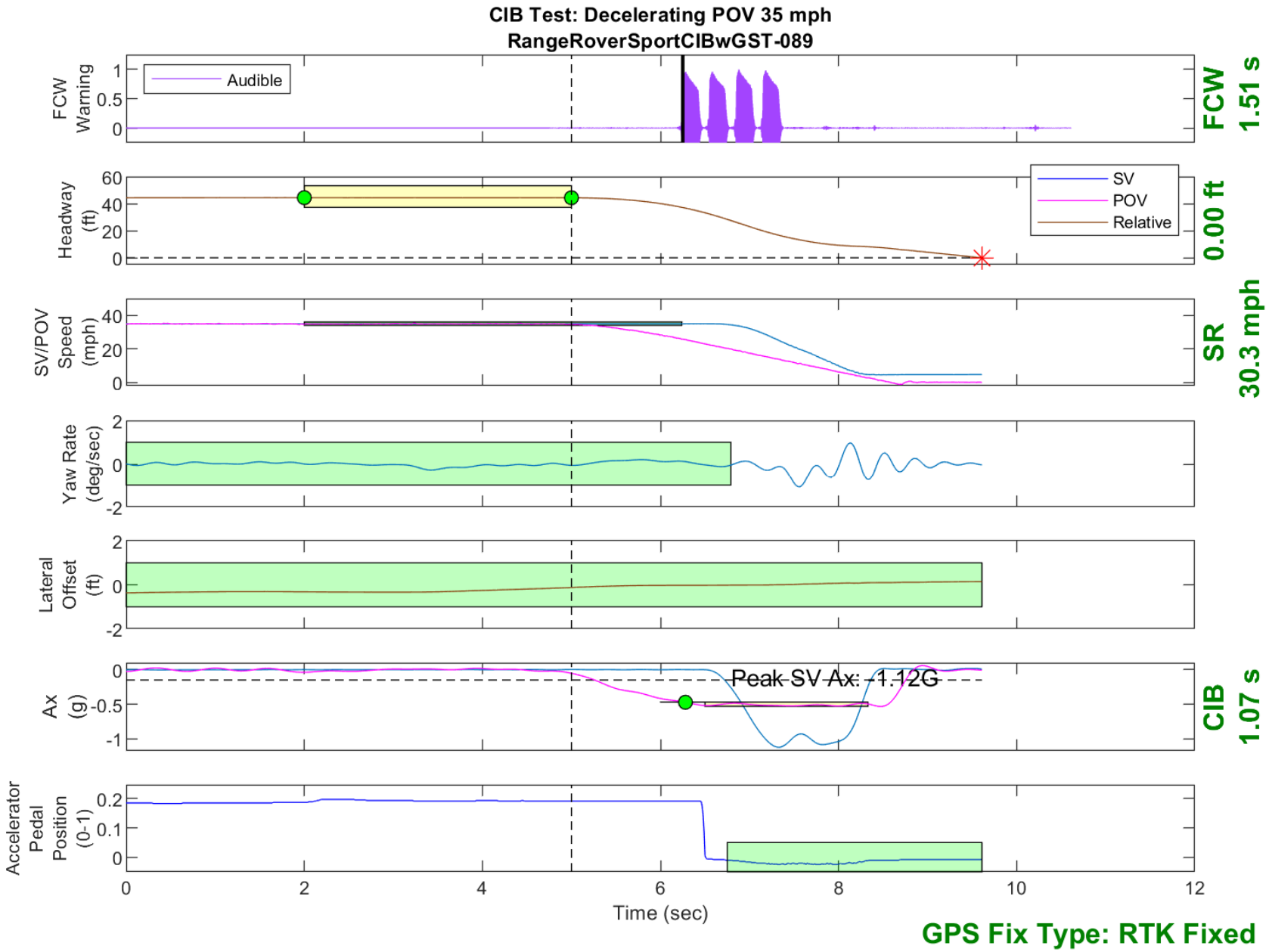


Figure D60. Time History for CIB Run 89, Decelerating POV, 35 mph 0.5g

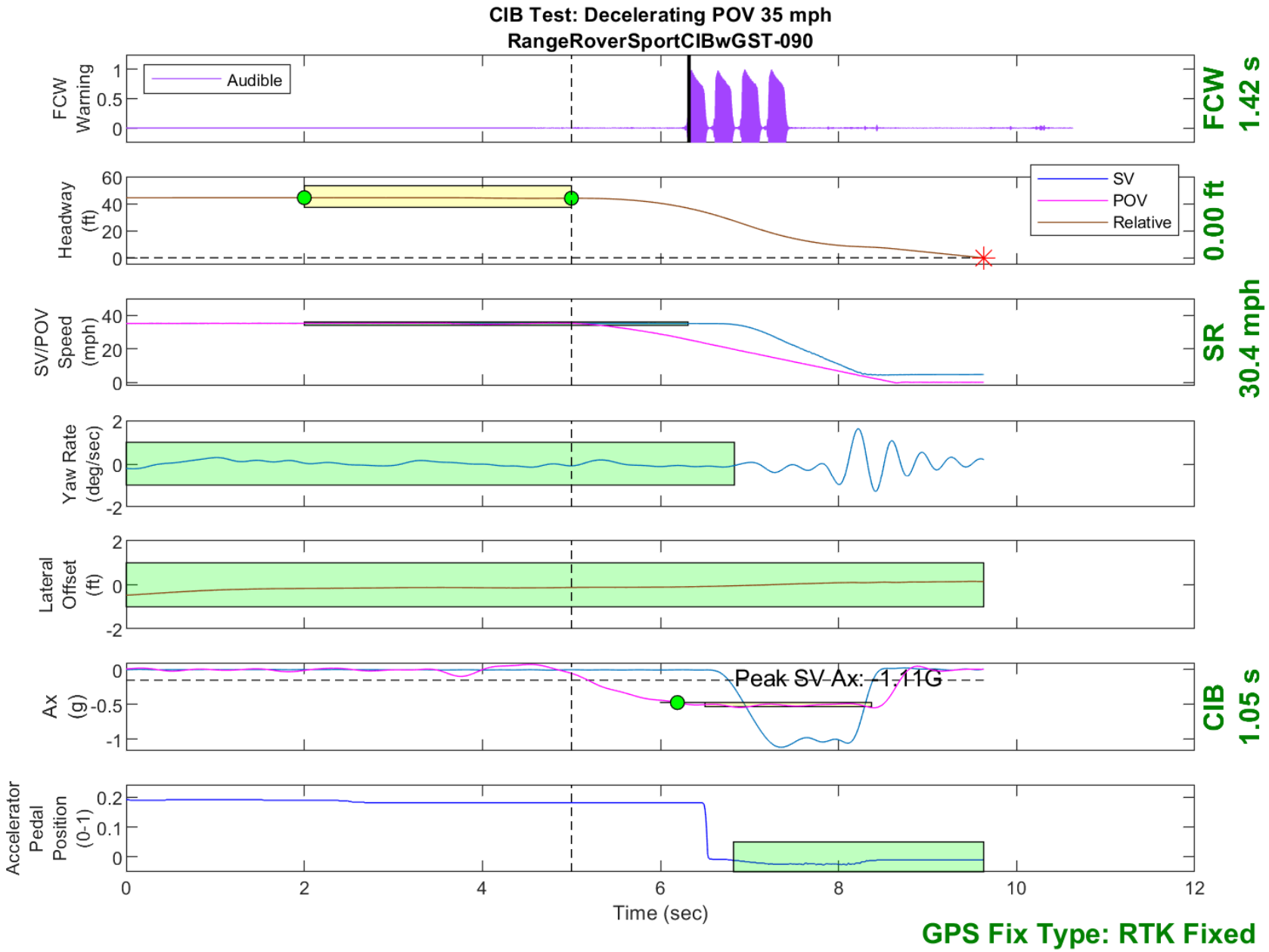


Figure D61. Time History for CIB Run 90, Decelerating POV, 35 mph 0.5g

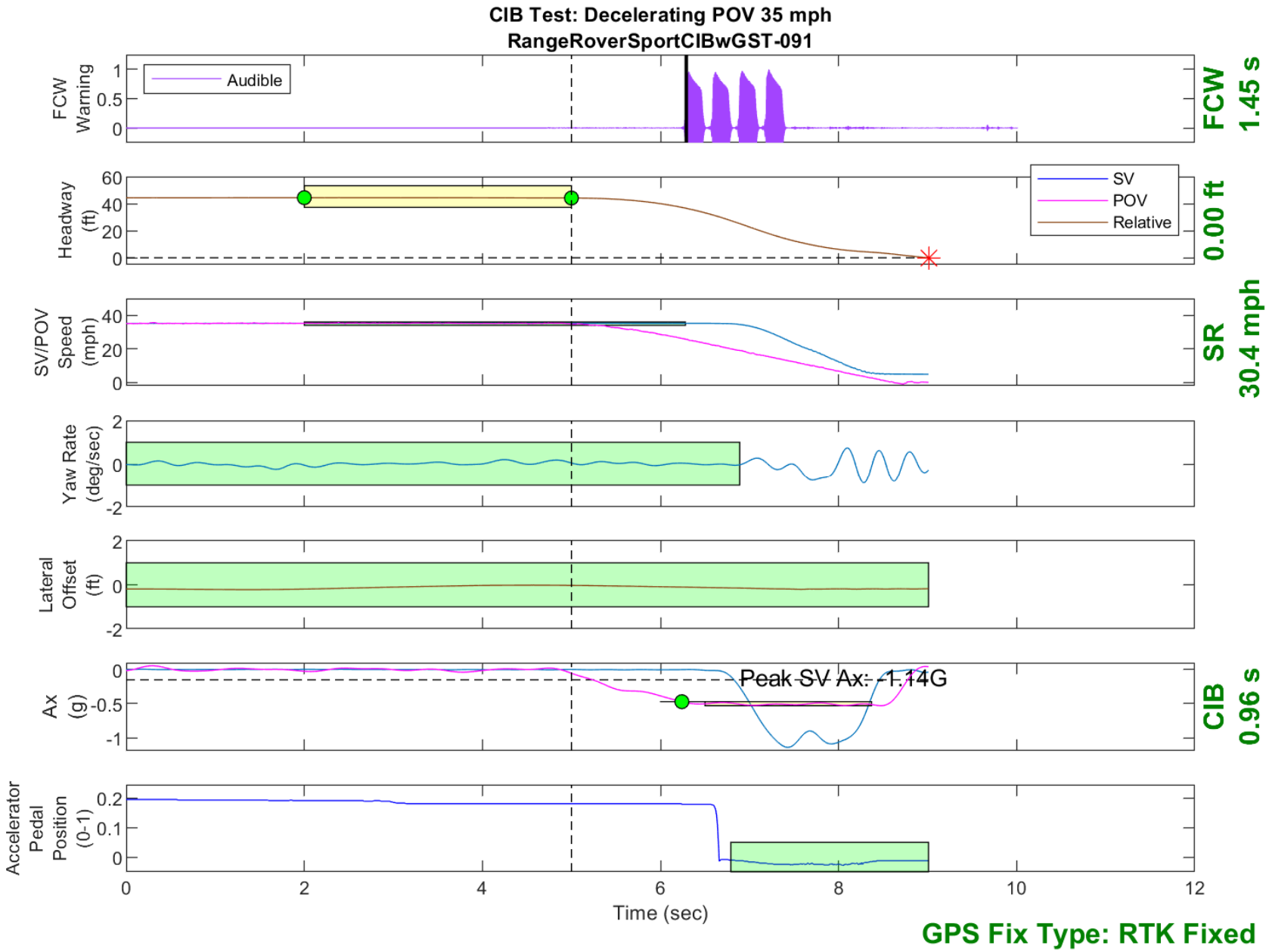


Figure D62. Time History for CIB Run 91, Decelerating POV, 35 mph 0.5g

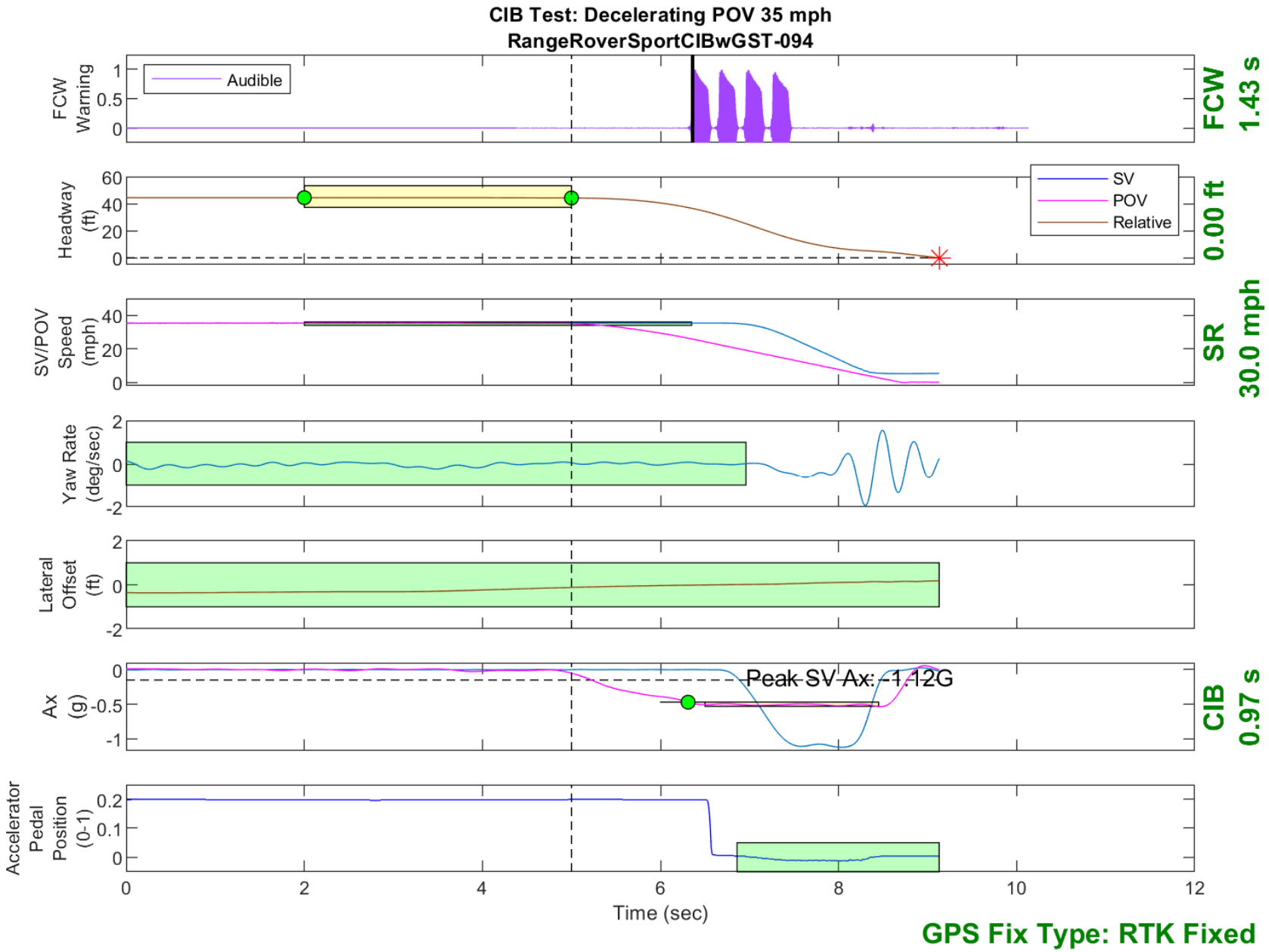


Figure D63. Time History for CIB Run 94, Decelerating POV, 35 mph 0.5g

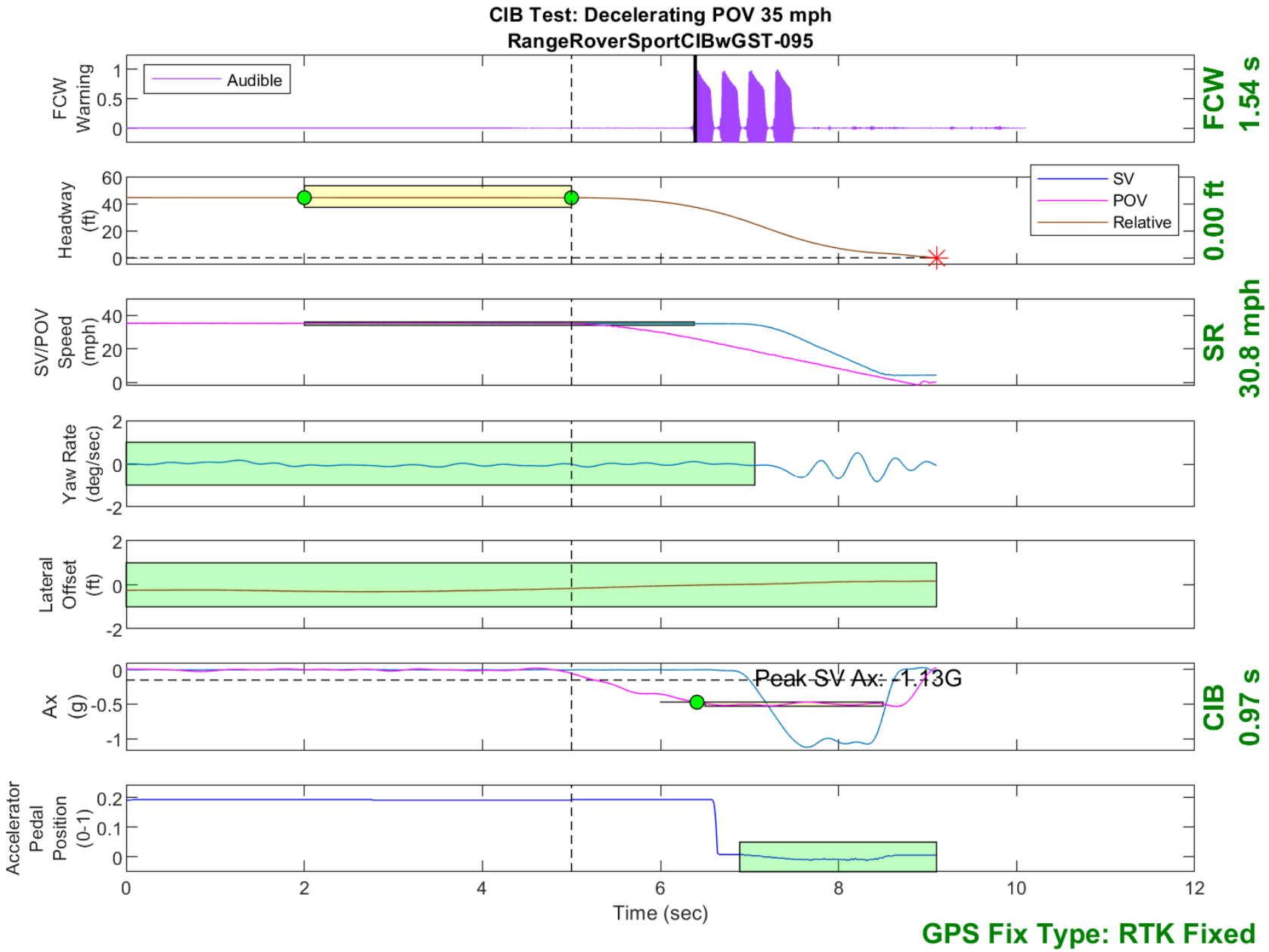


Figure D64. Time History for CIB Run 95, Decelerating POV, 35 mph 0.5g

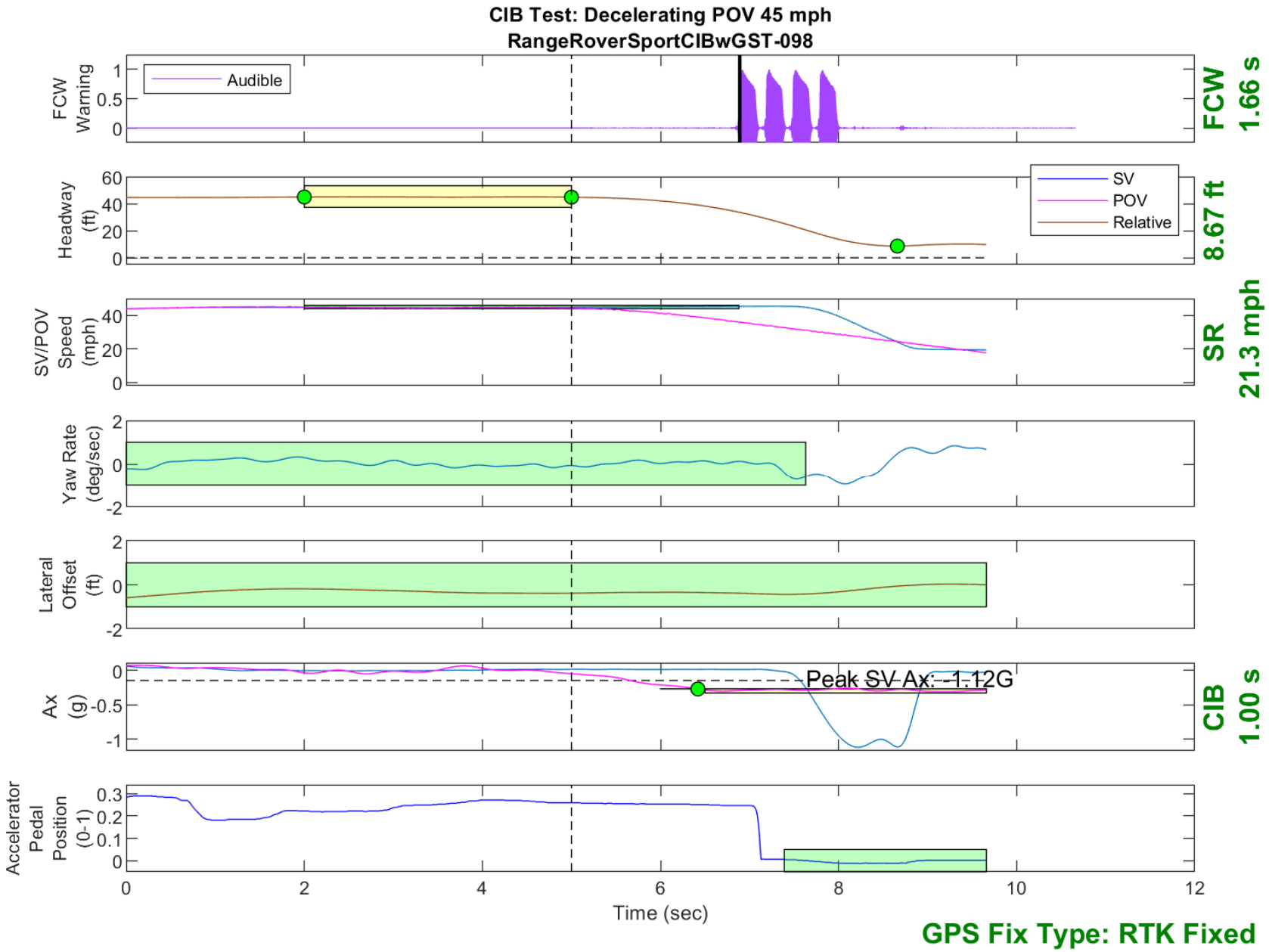


Figure D65. Time History for CIB Run 98, Decelerating POV, 45 mph 0.3g

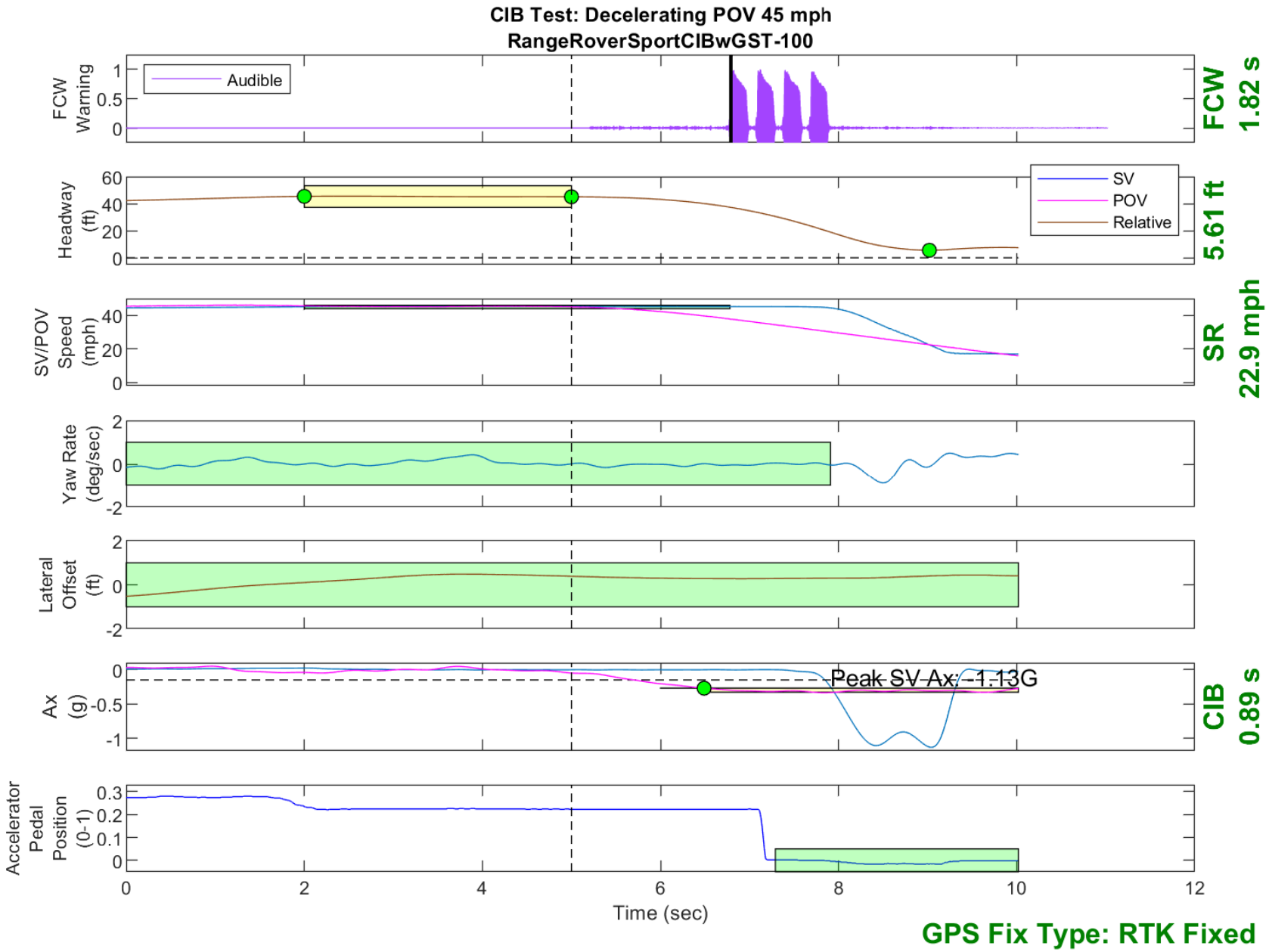


Figure D66. Time History for CIB Run 100, Decelerating POV, 45 mph 0.3g

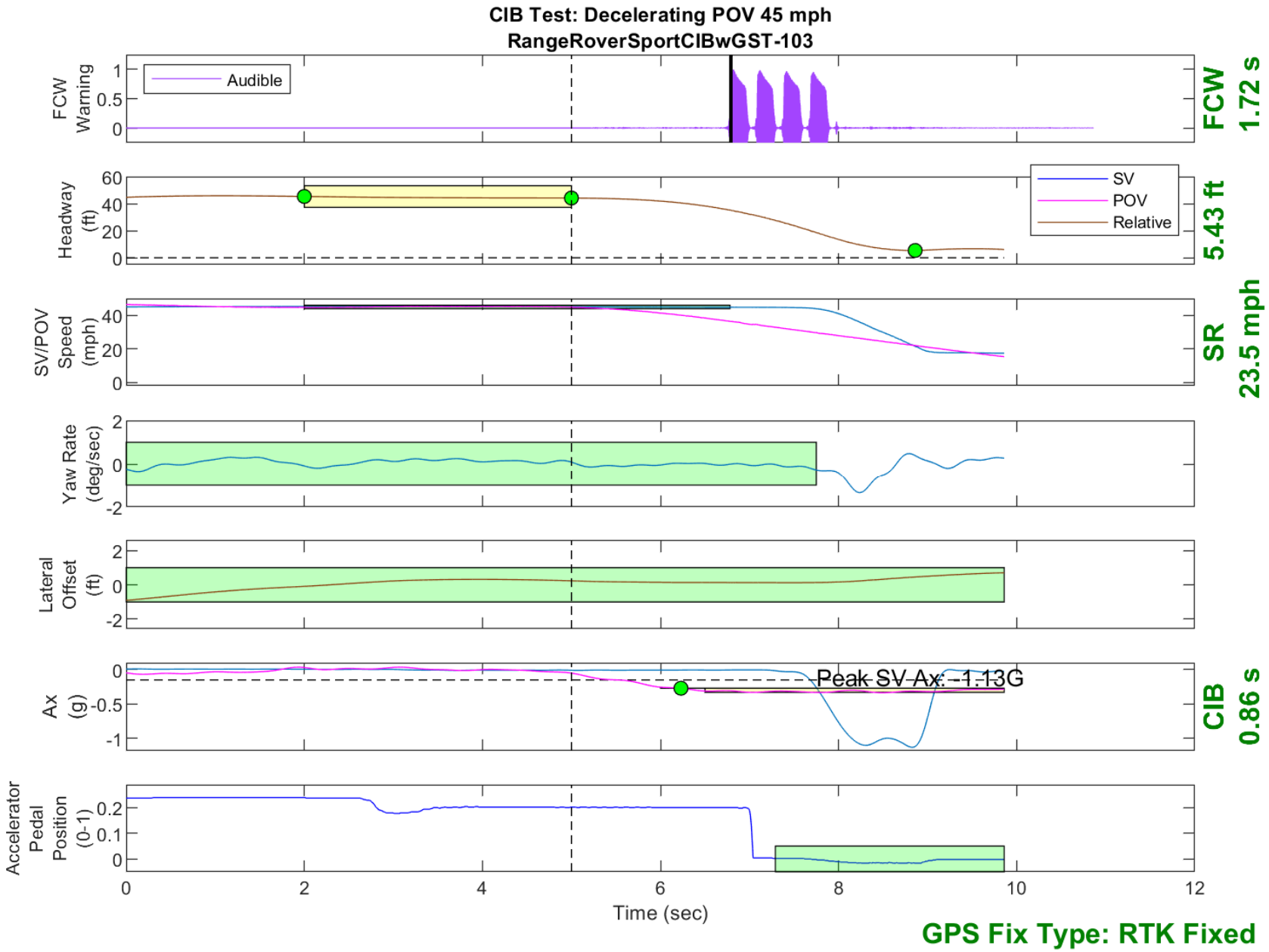


Figure D67. Time History for CIB Run 103, Decelerating POV, 45 mph 0.3g

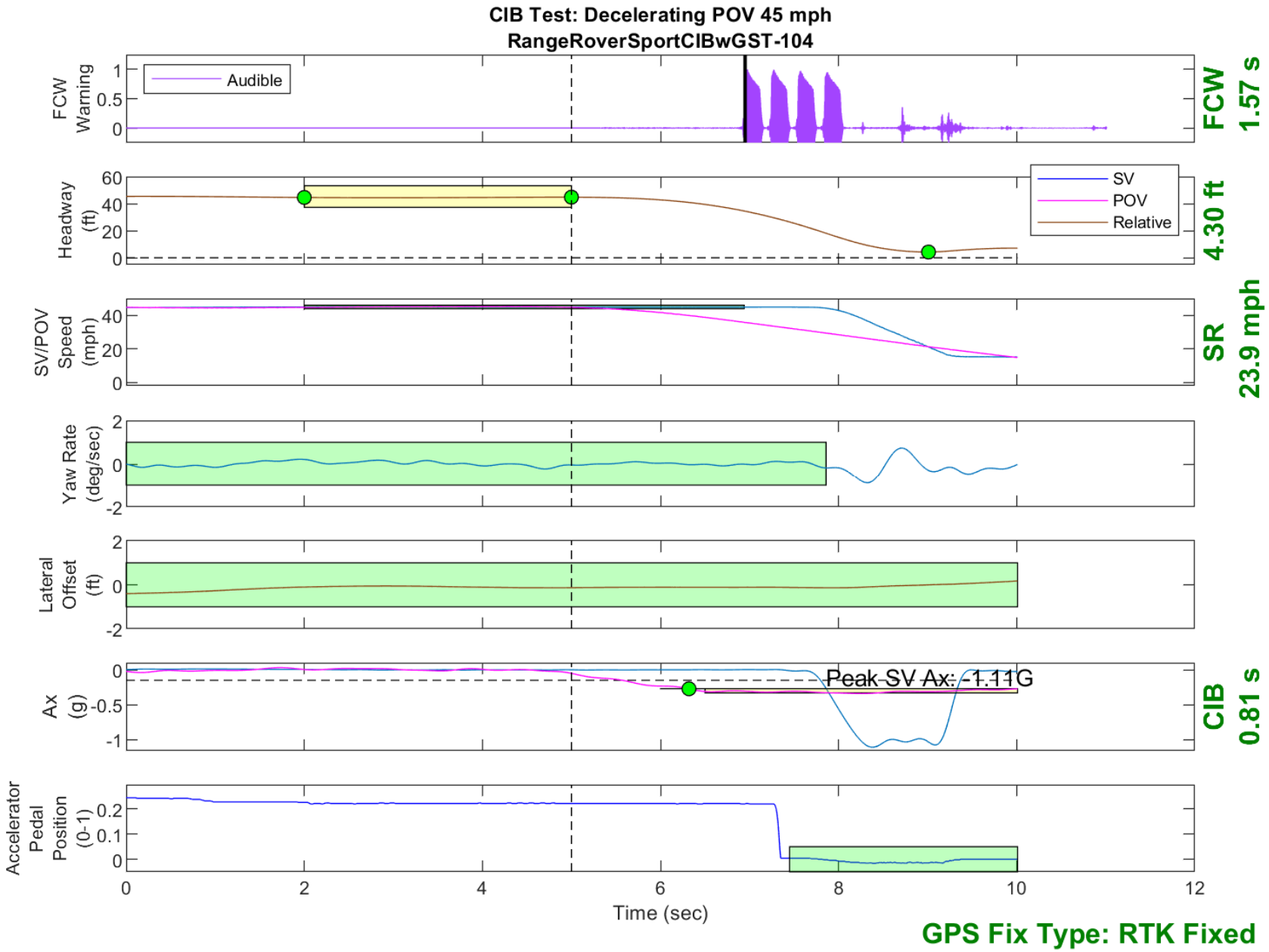


Figure D68. Time History for CIB Run 104, Decelerating POV, 45 mph 0.3g