NEW CAR ASSESSMENT PROGRAM
CRASH IMMINENT BRAKING SYSTEM CONFIRMATION TEST
NCAP-DRI-CIB-21-06

2021 Ford Bronco Sport Badlands 4x4

DYNAMIC RESEARCH, INC.
355 Van Ness Avenue, STE 200
Torrance, California 90501

19 April 2021

Final Report

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

U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
New Car Assessment Program
1200 New Jersey Avenue, SE
West Building, 4th Floor (NRM-110)
Washington, DC 20590

Prepared for the Department of Transportation, National Highway Traffic Safety Administration, under Contract No. DTNH22-14-D-00333.

This publication is distributed by the U.S. Department of Transportation, National Highway Traffic Safety Administration, in the interest of information exchange. The opinions, findings, and conclusions expressed in this publication are those of the author(s) and not necessarily those of the Department of Transportation or the National Highway Traffic Safety Administration. The United States Government assumes no liability for its contents or use thereof. If trade or manufacturer's names or products are mentioned, it is only because they are considered essential to the object of the publication and should not be construed as an endorsement. The United States Government does not endorse products of manufacturers.

Prepared By: J. Lenkeit — Program Manager
J. Partridge — Test Engineer

Date: 19 April 2021

1. Report No. NCAP-DRI-CIB-21-06	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Final Report of Crash Imminent Braking System Confirmation Test of a 2021 Ford Bronco Sport Badlands 4x4.		5. Report Date 19 April 2021	
		6. Performing Organization Code DRI	
7. Author(s) J. Lenkeit, Program Manager J. Partridge, Test Engineer		8. Performing Organization Report No. DRI-TM-20-192	
9. Performing Organization Name and Address Dynamic Research, Inc. 355 Van Ness Ave, STE 200 Torrance, CA 90501		10. Work Unit No.	
		11. Contract or Grant No. DTNH22-14-D-00333	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration New Car Assessment Program 1200 New Jersey Avenue, SE, West Building, 4th Floor (NRM-110) Washington, DC 20590		13. Type of Report and Period Covered Final Test Report March - April 2021	
		14. Sponsoring Agency Code NRM-110	
15. Supplementary Notes			
16. Abstract These tests were conducted on the subject 2021 Ford Bronco Sport Badlands 4x4 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. The vehicle passed the requirements of the test for all four CIB test scenarios and all speeds.			
17. Key Words Crash Imminent Braking, CIB, AEB, New Car Assessment Program, NCAP		18. Distribution Statement Copies of this report are available from the following: NHTSA Technical Reference Division National Highway Traffic Safety Administration 1200 New Jersey Avenue, SE Washington, DC 20590	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 114	22. Price

TABLE OF CONTENTS

SECTION		PAGE
I.	INTRODUCTION	1
II.	DATA SHEETS	2
	Data Sheet 1: Test Results Summary	3
	Data Sheet 2: Vehicle Data	4
	Data Sheet 3: Test Conditions	5
	Data Sheet 4: Crash Imminent Braking System Operation	7
III.	TEST PROCEDURES	11
A.	Test Procedure Overview	11
B.	General Information	16
C.	Principal Other Vehicle	19
D.	Automatic Braking System	20
E.	Instrumentation	21
APPENDIX A	Photographs	A-1
APPENDIX B	Excerpts from Owner's Manual	B-1
APPENDIX C	Run Log	C-1
APPENDIX D	Time Histories	D-1

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) to evaluate CIB performance on the test track[1] involves three rear-end type crash configurations and a "false positive" test. In the rear-end scenarios, a subject vehicle (SV) approaches a stopped, slower-moving, or decelerating principal other vehicle (POV) in the same lane of travel. For these tests, the POV is a strikeable object with the characteristics of a compact passenger car. The false positive scenarios are used to evaluate the propensity of a CIB system to inappropriately activate in a non-critical driving scenario that does not involve a forward vehicle or present a safety risk to the SV occupant(s).

The purpose of the testing reported herein was to objectively quantify the performance of a Crash Imminent Braking system installed on a 2021 Ford Bronco Sport Badlands 4x4. This test is part of the New Car Assessment Program to assess Crash Imminent Braking Systems sponsored by the National Highway Traffic Safety Administration under Contract No. DTNH22-14-D-00333.

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

Section II

DATA SHEETS

CRASH IMMINENT BRAKING

DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2021 Ford Bronco Sport Badlands 4x4

VIN: *3FMCR9D95MRA0xxxx*

Test Date: *3/24/2021*

Crash Imminent Braking System settings: *Pre-Collision Assist: Active Braking*

Alert Sensitivity: High

Test 1 – **Subject Vehicle Encounters Stopped Principal Other Vehicle**

SV 25 mph: *Pass*

Test 2 – **Subject Vehicle Encounters Slower Principal Other Vehicle**

SV 25 mph POV 10 mph: *Pass*

SV 45 mph POV 20 mph: *Pass*

Test 3 – **Subject Vehicle Encounters Decelerating Principal Other Vehicle**

SV 35 mph POV 35 mph: *Pass*

Test 4 – **Subject Vehicle Encounters Steel Trench Plate**

SV 25 mph: *Pass*

SV 45 mph: *Pass*

Overall: *Pass*

Notes:

CRASH IMMINENT BRAKING

DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2021 Ford Bronco Sport Badlands 4x4

TEST VEHICLE INFORMATION

VIN: *3FMCR9D95MRA0xxxx*

Body Style: *SUV* Color: *Area 51*

Date Received: *3/16/2021* Odometer Reading: *4 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *FORD MOTOR CO.*

Date of manufacture: *02/21*

Vehicle Type: *MPV*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *235/65R17 104H*

Rear: *235/65R17 104H*

Recommended cold tire pressure: Front: *230 kPa (33 psi)*

Rear: *230 kPa (33 psi)*

TIRES

Tire manufacturer and model: *Falken Wildpeak A/T AT3W*

Front tire designation: *235/65R17 104H*

Rear tire designation: *235/65R17 104H*

Front tire DOT prefix: *1R8L8 3MDR*

Rear tire DOT prefix: *1R8L8 3MDR*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2021 Ford Bronco Sport Badlands 4x4

GENERAL INFORMATION

Test date: *3/24/2021*

AMBIENT CONDITIONS

Air temperature: *18.9 C (66 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: *230 kPa (33 psi)*

Rear: *230 kPa (33 psi)*

CRASH IMMINENT BRAKING

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2021 Ford Bronco Sport Badlands 4x4

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*539.3 kg (1189 lb)*	Right Front:	*504.8 kg (1113 lb)*
Left Rear:	*399.6 kg (881 lb)*	Right Rear:	*384.6 kg (848 lb)*
		Total:	*1828.3 kg (4031 lb)*

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

(Page 1 of 4)

2021 Ford Bronco Sport Badlands 4x4

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

Pre-Collision Assist with Automatic Emergency Braking, which is part of Ford Co-Pilot360.

Type and location of sensors the system uses:

Camera-only sensing: Top center of windshield (camera) (system tested)

OR

Radar-camera (fusion) sensing: Top center of windshield (camera), left side of front bumper & right side of front bumper (radars)

System setting used for test (if applicable):

Pre-Collision Assist: Active Braking

Alert Sensitivity: High

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

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

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

360 km/h (225 mph) (Per manufacturer supplied information)

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

____ No

If yes, please provide a full description.

A 40 to 50 mile drive above 35 mph on a roadway with moving and stationary targets will confirm the sensors are fully aligned.

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

If yes, please provide a full description.

The system will deactivate due to three consecutive AEB activations within a short (approximately 1 minute) timeframe. This is indicated to the driver via a visual message that reads "Pre-Collision Assist Not Available" (in yellow text) displayed within the instrument panel cluster. If the system is deactivated due to consecutive activations within the short timeframe, it can be reactivated via an ignition cycle.

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

X Warning light

X Buzzer or auditory 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, auditory, vibration, or combination), etc.

The visual warning is displayed in the center of the instrument panel. The words "Pre-Collision Assist" are displayed above a crashing vehicle icon with a red background that flashes on and off.

See Appendix A, Figure A15.

An auditory warning comprising of repeated four pulse bursts of an 1800 Hz tone is also provided.

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.

A center mounted touchscreen is used to interact with system menus. The hierarchy is:

Settings

Driver Assistance

Pre-Collision Assist

Select or deselect "Active Braking"

See Appendix A, Figure A14

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.

A center mounted touchscreen is used to interact with system menus. The hierarchy is:

Settings

Driver Assistance

Pre-Collision Assist

Alert Sensitivity

Choose from "High", "Normal", or "Low"

See Appendix A, Figure A14

CRASH IMMINENT BRAKING

DATA SHEET 4: CRASH IMMINENT BRAKING SYSTEM OPERATION

(Page 4 of 4)

2021 Ford Bronco Sport Badlands 4x4

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.

System limitations are described on page 217-218 of the Owner's Manual, shown in Appendix B, pages B-3 and B-4.

Notes:

The 2021 Ford Bronco Sport Badlands 4x4 is available with two types of AEB system. One of these uses a camera-only system and the other uses a fusion of camera and forward-facing radar system. The vehicle covered in this report was equipped with the camera-only system.

Section III

TEST PROCEDURES

A. Test Procedure Overview

Four test scenarios were used, as follows:

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

Test 2. Subject Vehicle Encounters Slower Principal Other Vehicle

Test 3. Subject Vehicle Encounters Decelerating Principal Other Vehicle

Test 4. Subject Vehicle Encounters Steel Trench Plate

An overview of each of the test procedures follows.

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

This test evaluates the ability of the CIB system to detect and respond to a stopped lead vehicle in the immediate forward path of the SV, as depicted in Figure 1.

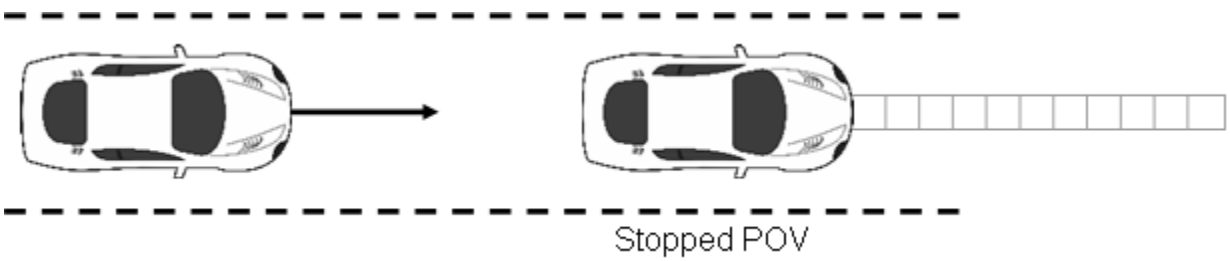


Figure 1. Depiction of Test 1

a. Procedure

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

The SV ignition was cycled prior to each test run. The SV was driven at a nominal speed of 25 mph (40.2 km/h) 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}. For this test, TTC = 5.1 seconds is taken to occur at an SV-to-POV distance of 187 ft (57 m).

b. Criteria

In order to pass the test, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 9.8 mph (15.8 km/h) for at least five of seven valid test trials.

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

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

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

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

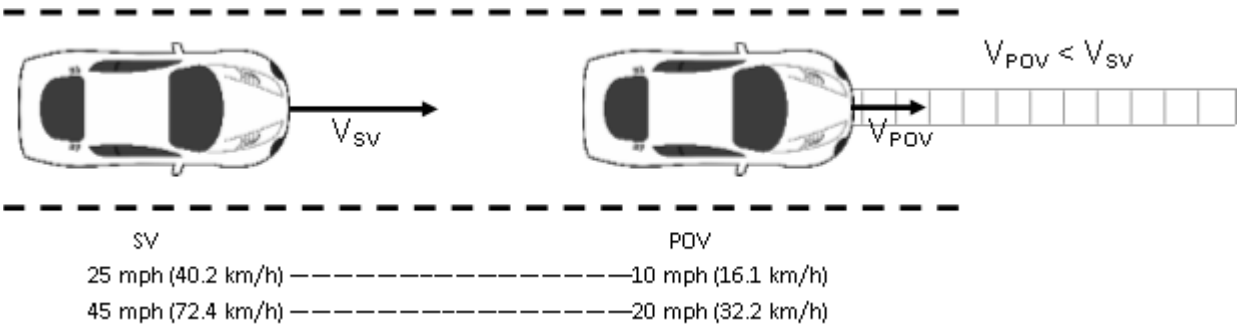


Figure 2. Depiction of Test 2

a. Procedure

The SV ignition was cycled prior to each test run. The tests were conducted two ways. In the first, the POV was driven at a constant 10.0 mph (16.1 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 passing was that there be no SV-to-POV impact for at least five of the seven valid test trials.

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

- 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 in Figure 3.

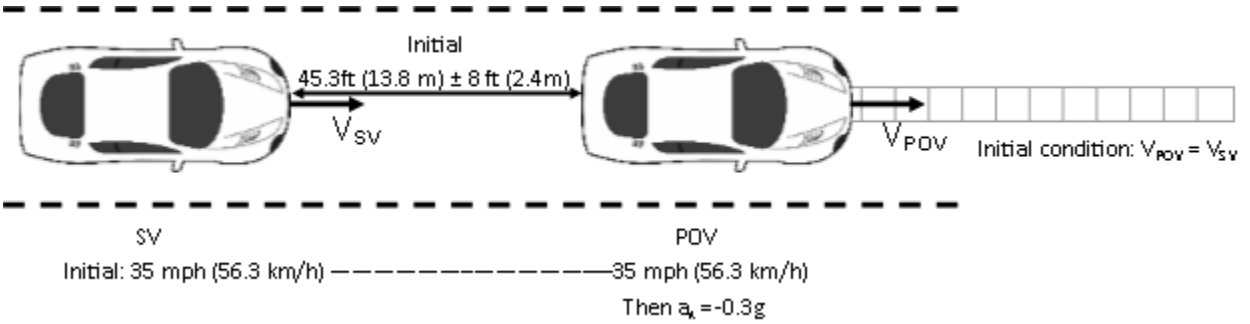


Figure 3. Depiction of Test 3

a. Procedure

The SV ignition was cycled prior to each test run. For this test scenario, both the POV and SV were driven at a constant 35.0 mph (56.3 km/h) in the center of the lane, with a headway of 45.3 ft (13.8 m) ± 8 ft (2.4 m). Once these conditions were met, the POV tow vehicle brakes were applied to achieve 0.3 ± 0.03 g of deceleration. The test concluded when either:

- The SV came into contact with the POV or
- For the decelerating POV, 1 second after minimal longitudinal SV-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 during the interval beginning at 1.5 seconds after the onset of POV braking and ending either 250 ms prior to the POV coming to a stop or the SV coming into contact with the POV.

b. Criteria

In order to pass the decelerating POV test series, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 10.5 mph (16.9 km/h) for at least five of seven valid test trials. The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

- If SV-to-POV contact occurred during a test trial, the CIB speed reduction was calculated by subtracting the SV speed at the time of SV-to-POV contact (i.e., when longitudinal range 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}.

4. TEST 4 – FALSE POSITIVE SUPPRESSION

The false positive suppression test series evaluates the ability of a CIB system to differentiate a steel trench plate (STP) from an object presenting a genuine safety risk to the SV. Although the STP is large and metallic, it is designed to be driven over without risk of injury to the driver or damage to the SV. Therefore, in this scenario, the automatic braking available from CIB is not necessary and should be suppressed. The test condition is nearly equivalent to that previously defined for Test 1, the stopped POV condition, but with an STP in the SV forward path in lieu of a POV.

a. Procedure

This test was conducted at two speeds, 25 mph (40.2 km/h) and 45 mph (72.4 km/h). The SV was driven directly towards, and over, the STP, which was positioned in the center of a travel lane, with its longest sides parallel to the road edge.

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

- The SV speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during an interval defined by a Time to Collision (TTC) = 5.1 seconds to t_{FCW} where:
    - For SV test speed of 25 mph, TTC = 5.1 seconds is taken to occur at an SV-to-STP distance of 187 ft (57 m).
    - For SV test speed of 45 mph, TTC = 5.1 seconds is taken to occur at an SV-to-STP distance of 337 ft (106 m).
- If the SV did not present an FCW alert before the end of the validity period, SV speed could not deviate more than ±1.0 mph (±1.6 km/h) from TTC = 5.1 s to the end of the validity period.

If an FCW alert was presented, the driver released the throttle pedal within 500 ms of the alert. If no alert was presented, the driver did not release the throttle pedal until the end of the validity period. The SV driver then braked to a stop.

b. Criteria

In order to pass the False Positive test series, the magnitude of the SV deceleration reduction attributable to CIB intervention must have been ≤ 0.50 g for at least five of seven valid test trials.

B. General Information

1. T_{FCW}

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

For systems that implement auditory or haptic alerts, part of the pre-test instrumentation verification process was to determine the tonal frequency of the auditory 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 auditory 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 1.

Table 1. Auditory and Tactile Warning Filter Parameters

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

2. GENERAL VALIDITY CRITERIA

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

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

3. VALIDITY PERIOD

The valid test interval began:

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

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

Test 3: 3 seconds before the onset of POV braking

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

The valid test interval ended:

Test 1: When either of the following occurred:

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

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

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

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

4. STATIC INSTRUMENTATION CALIBRATION

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

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

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

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

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

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

5. NUMBER OF TRIALS

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

6. TRANSMISSION

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

C. Principal Other Vehicle

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

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

- A POV shell which is a visually and dimensionally accurate representation of a passenger car.
- A slider and load frame assembly to which the shell is attached.
- A two-rail track on which the slider operates.
- A road-based lateral restraint track.
- A tow vehicle.

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 35 mph (56 km/h).
- Accurately control the lateral position of the POV within the travel lane.
- Allow the POV to move away from the SV after an impact occurs.

Operationally, the POV shell is attached to the slider and load frame which includes rollers that allows the entire assembly to move longitudinally along the guide rail. The guide rail is coupled to a tow vehicle and guided by the lateral restraint track secured to the test track surface. The rail includes a provision for restraining the shell and roller assembly in the ward direction. In operation, the shell and roller assembly engage the rail assembly through detents to prevent relative motion during run-up to test speeds and deceleration of the tow vehicle. The combination of rearward stops and forward motion detents allows the test conditions, such as relative SV-to-POV headway distance, speed, etc., to be achieved and adjusted as needed in the preliminary part of a test. If during the test, the SV strikes the rear of the POV shell, the detents are overcome and the entire shell/roller assembly moves forward in a two-stage manner along the rail and away from the SV. The forward end of the rail has a cushioned stop to restrain forward motion of the shell/roller assembly. After impacting the SSV, the SV driver uses the steering wheel to maintain SV position in the center of the travel lane, thereby straddling the two-rail track. The SV driver must manually apply the SV brakes after impact. The SSV system is shown in Figures A6 through A8 and a detailed description can be found in the NHTSA report: NHTSA'S STRIKEABLE SURROGATE VEHICLE PRELIMINARY DESIGN+OVERVIEW, May 2013.

D. Automatic Braking System

The POV was equipped with an automatic braking system, which was used in Test 3. The braking system consisted of the following components:

- Electronically controlled linear actuator, mounted on the seat rail and attached to the brake pedal. The actuator can be programmed for control of stroke and rate.
- PC module programmed for control of the stroke and rate of the linear actuator.
- Switch to activate actuator.

In some cases, the 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 SV is

likely to fail a test. The system fires when TTC is below 0.7 sec. It is typically enabled when an SV has already impacted the SSV one or two times.

E. Instrumentation

Table 2 lists the sensors, signal conditioning, and data acquisition equipment used for these tests.

Table 2. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	< 1% error between 20 and 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: 2/10/2021 Due: 2/10/2022
Linear (string) encoder	Throttle pedal travel	10 in	0.1 in	UniMeasure LX-EP	50060726	By: DRI Date: 6/19/2020 Due: 6/19/2021
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	N/A
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 +		By: Oxford Technical Solutions
					2258	Date: 5/3/2019 Due: 5/3/2021
					2258	Date: 5/3/2019 Due: 5/3/2021

Table 2. Test Instrumentation and Equipment (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW)	Distance and Velocity to lane markings (LDW) and POV (FCW)	Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	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
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: 1/6/2021 Due: 1/6/2022

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

		Page
Figure A1.	Front View of Subject Vehicle	A-3
Figure A2.	Rear View of Subject Vehicle	A-4
Figure A3.	Window Sticker (Monroney Label)	A-5
Figure A4.	Vehicle Certification Label	A-6
Figure A5.	Tire Placard	A-7
Figure A6.	Rear View of Principal Other Vehicle (SSV)	A-8
Figure A7.	Load Frame/Slider of SSV	A-9
Figure A8.	Two-Rail Track and Road-Based Lateral Restraint Track	A-10
Figure A9.	Steel Trench Plate	A-11
Figure A10.	DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle	A-12
Figure A11.	Sensors for Detecting Auditory and Visual Alerts	A-13
Figure A12.	Computer Installed in Subject Vehicle	A-14
Figure A13.	Brake Actuator Installed in POV System	A-15
Figure A14.	AEB Setup Menus	A-16
Figure A15.	Visual Alert	A-17

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

Figure A3. Window Sticker (Monroney Label)

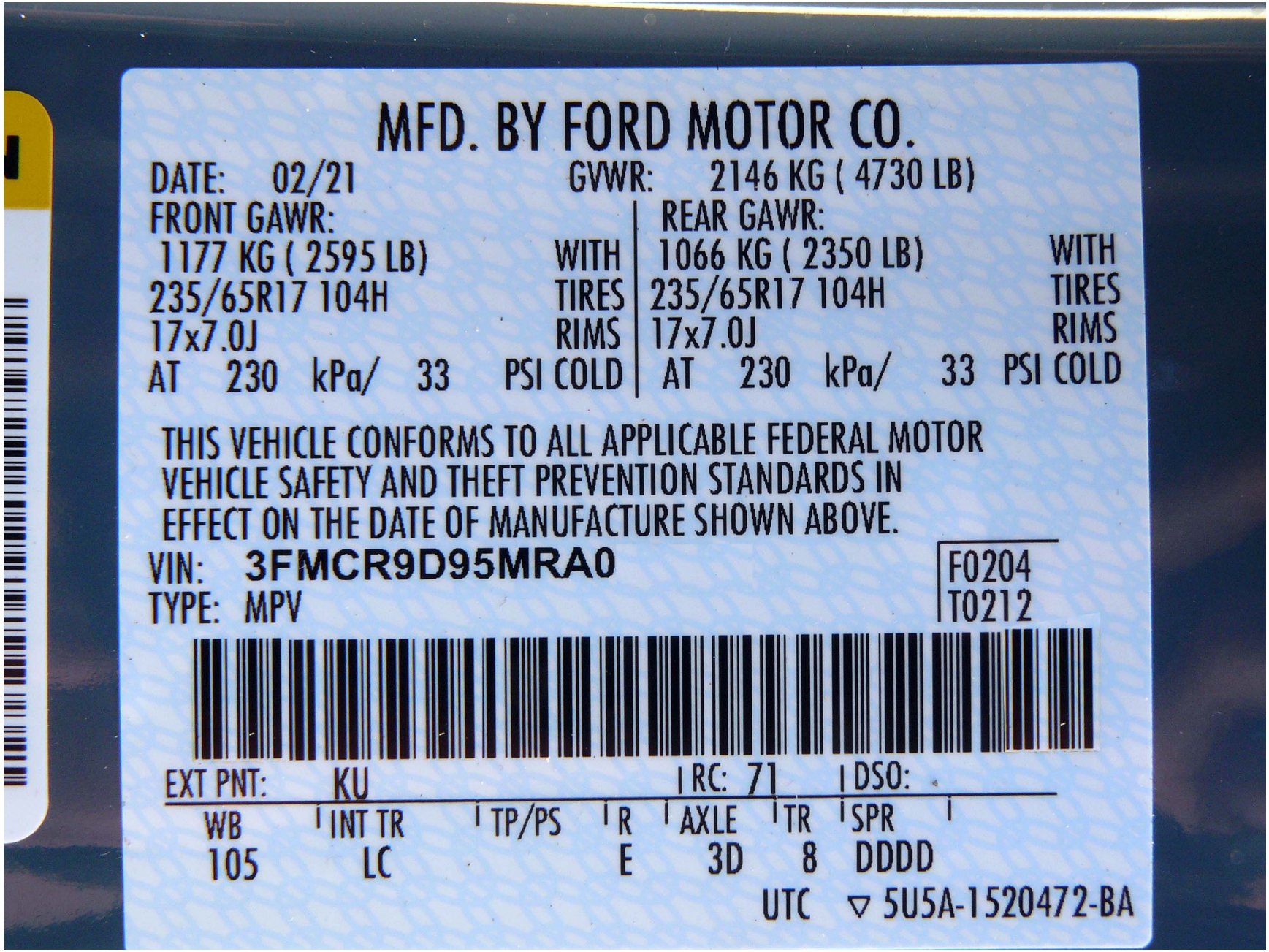


Figure A4. Vehicle Certification Label

Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

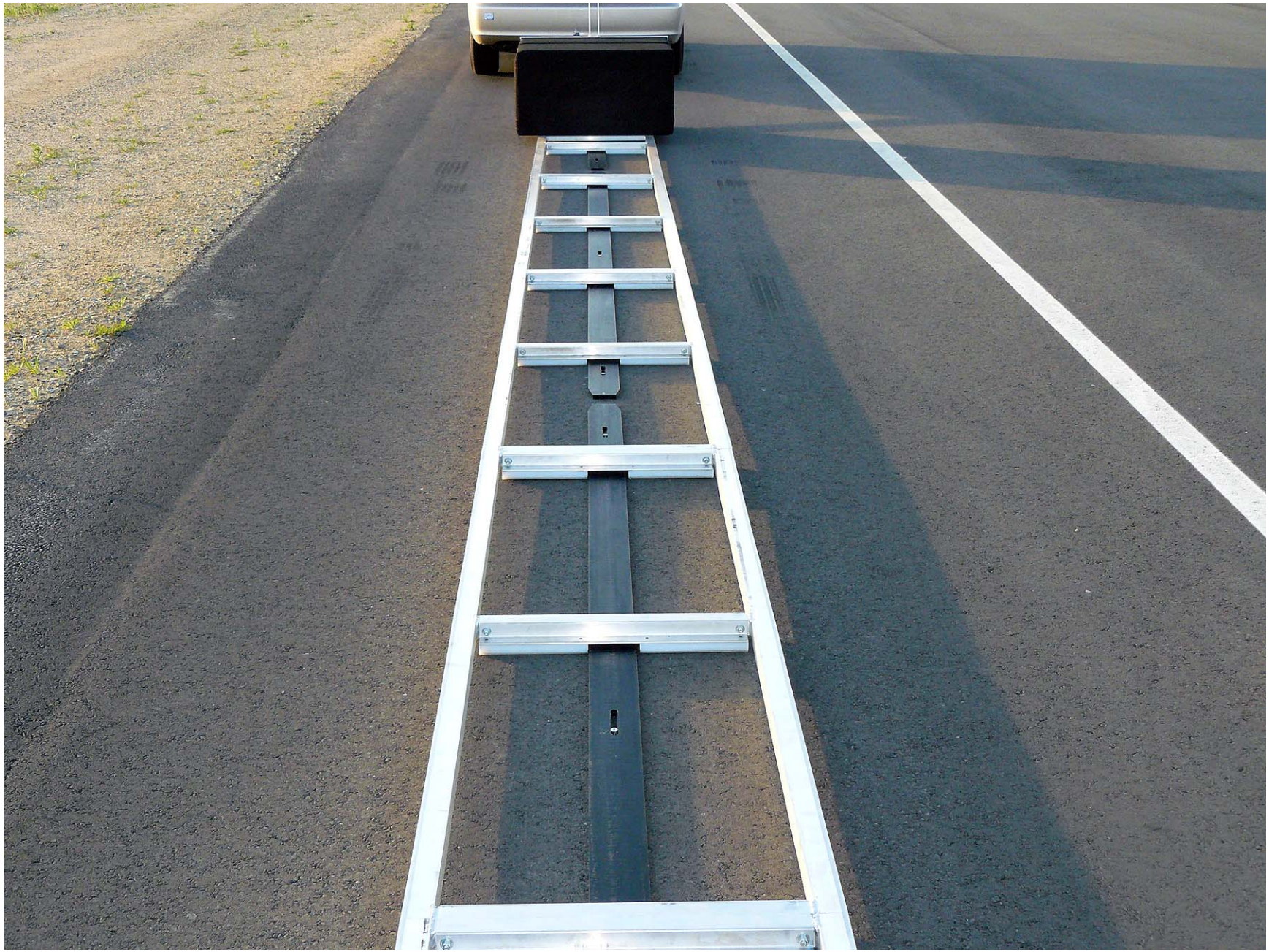


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

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

Figure A11. Sensors for Detecting Auditory and Visual Alerts

Figure A12. Computer Installed in Subject Vehicle

Figure A13. Brake Actuator Installed in POV System

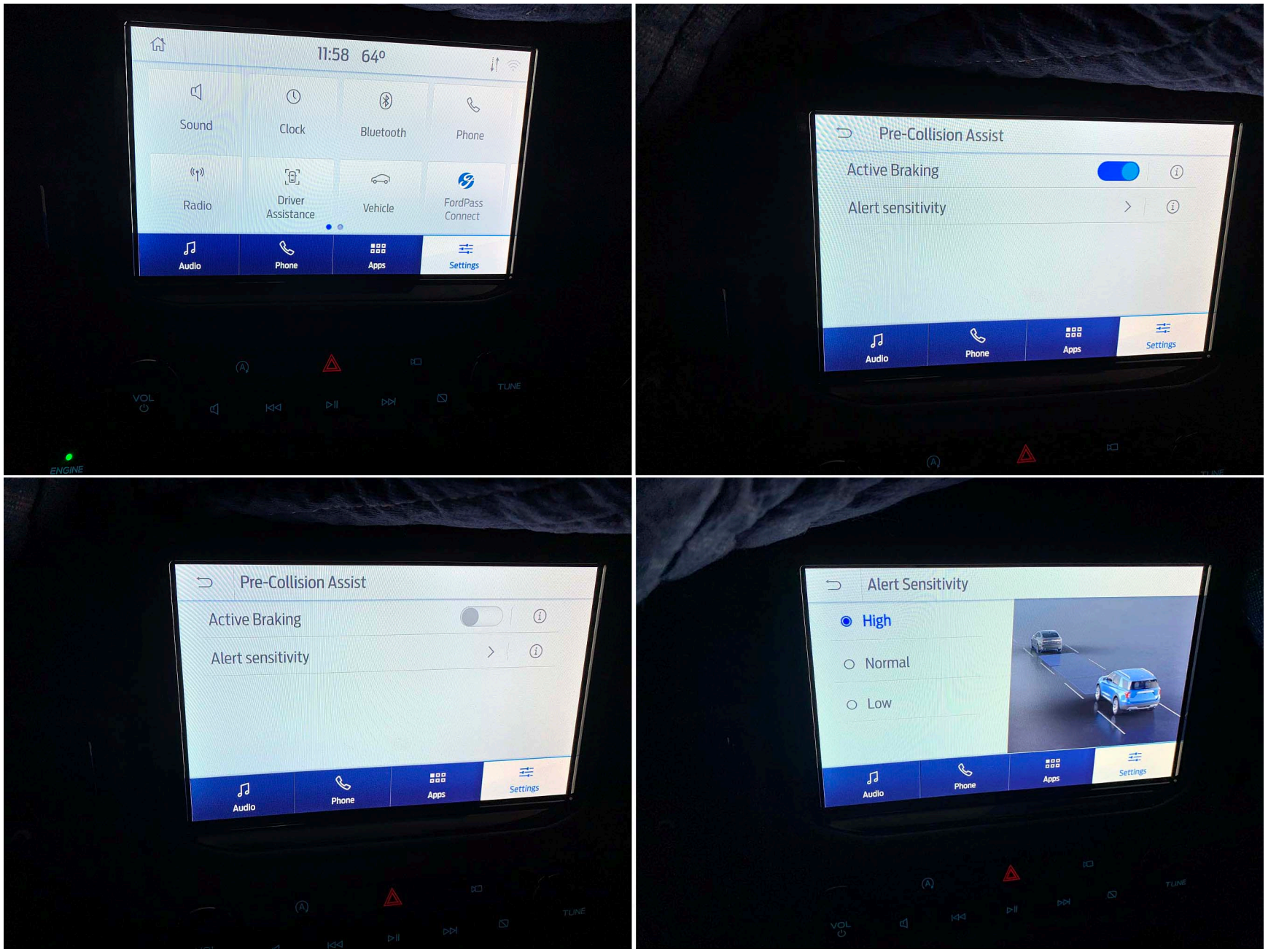


Figure A14. AEB Setup Menus

Figure A15. Visual Alert

APPENDIX B

Excerpts from Owner's Manual

Message	Action
Park Brake Limited Function Service Required	The electric park brake system has detected a condition that requires service. Some functionality may still be available. Contact your authorized dealer.
Park Brake Malfunction Service Now	The electric parking brake system has detected a condition that requires service. Contact your authorized dealer.
Park Brake System Overheated	Numerous park brake applies have overheated the system. Wait 2 minutes before attempting to apply again.

Power Steering

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

Pre-Collision Assist

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

Remote Start

Message	Action
To Drive: Press Brake and Gear Shift Button	Displays as a reminder to apply the brake and push the gear shift button to drive the vehicle after a remote start.

Bronco Sport (CHD) Canada/United States of America, enUSA, Edition date: 202007, First-Printing

STEERING

Electric Power Steering

WARNING: The electric power steering system has diagnostic checks that continuously monitor the system. If a fault is detected, a message displays in the information display. Stop your vehicle as soon as it is safe to do so. Switch the ignition off. After at least 10 seconds, switch the ignition on and watch the information display for a steering system warning message. If a steering system warning message returns, have the system checked as soon as possible.

WARNING: If the system detects an error, you may not feel a difference in the steering, however a serious condition may exist. Have your vehicle checked as soon as possible. Failure to do so may result in loss of steering control.

Your vehicle is equipped with an electric power-assisted steering system. There is no fluid reservoir to check or fill.

If your vehicle loses electrical power while you are driving (or if the ignition is turned off), you can steer the vehicle manually, but it takes more effort. You must adapt your speed and driving behavior to reduced steering assist. Extreme continuous steering may increase the effort it takes for you to steer. This occurs to prevent internal overheating and permanent damage to your steering system. If this should occur, you will neither lose the ability to steer the vehicle manually nor will it cause permanent damage. Typical steering and driving maneuvers will allow the system to cool down and steering assist will return to normal.

Steering Tips

If the steering wanders or pulls, check for:

- An improperly inflated tire.
- Uneven tire wear.
- Loose or worn suspension components.
- Loose or worn steering components.
- Improper vehicle alignment.

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

PRE-COLLISION ASSIST

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

WARNING: The system does not detect vehicles that are driving in a different direction, cyclists or animals. Apply the brakes when necessary. Failure to follow this instruction could result in the loss of control of your vehicle, personal injury or death.

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

Bronco Sport (CHD) Canada/United States of America, enUSA, Edition date: 202007, First-Printing

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

WARNING: Some situations and objects prevent hazard detection. For example low or direct sunlight, inclement weather, unconventional vehicle types, and pedestrians. Apply the brakes when necessary. Failure to follow this instruction could result in the loss of control of your vehicle, personal injury or death.

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

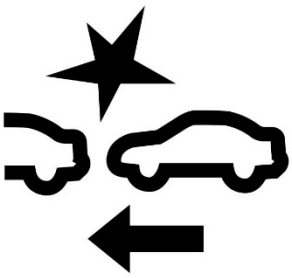
Using the Pre-Collision Assist System

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

E156130

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

1. Alert.
2. Brake support.
3. Active braking.



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

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

Active braking: It activates if the system determines that a collision is about to occur. The system may help the driver reduce impact damage or completely avoid the crash.

Note: *Brake support and active braking are active at speeds up to 75 mph (120 km/h). If your vehicle is equipped with a radar sensor, included with adaptive cruise control, then brake support and active braking are active up to the maximum speed of your vehicle.*

Note: *If you perceive pre-collision assist alerts as being too frequent or disturbing, you can reduce the alert sensitivity, though we recommend using the highest sensitivity setting where possible. Setting lower sensitivity would lead to fewer and later system warnings.*

Bronco Sport (CHD) Canada/United States of America, enUSA, Edition date: 202007, First-Printing

Note: *The system turns off when you manually disable AdvanceTrac™.*

Distance Indication and Alert (If Equipped)

This feature provides the driver with a graphical indication of the time gap to other preceding vehicles traveling in the same direction. The information display screen shows one of the images that follow.

Note: *Distance indication and alert deactivates and the images do not display when adaptive cruise control is active.*

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

Evasive Steering Assist (If Equipped)

If your vehicle is rapidly approaching a stationary vehicle or a vehicle traveling in the same direction as your vehicle, the system helps you steer around the vehicle.

The system only activates when all of the following occur:

- The pre-collision assist system detects a vehicle ahead and starts to apply active braking.
- You turn the steering wheel in an attempt to steer around the vehicle.

Bronco Sport (CHD) Canada/United States of America, enUSA, Edition date: 202007, First-Printing

After you turn the steering wheel, the system applies additional steering torque to help you steer around the vehicle. After you pass the vehicle, the system applies steering torque in the opposite direction to encourage you to steer back into the lane. The system deactivates after you fully pass the vehicle.

Note: *The system does not automatically steer around a vehicle. If you do not turn the steering wheel, the system does not activate.*

Note: *The system does not activate if the distance to the vehicle ahead is too small and a crash cannot be avoided.*

Adjusting the Pre-Collision Assist Settings

Depending on your vehicle options, the pre-collision assist settings may be in the following:

- Information display. See **General Information** (page 98).
- Touchscreen. See **Settings** (page 376).

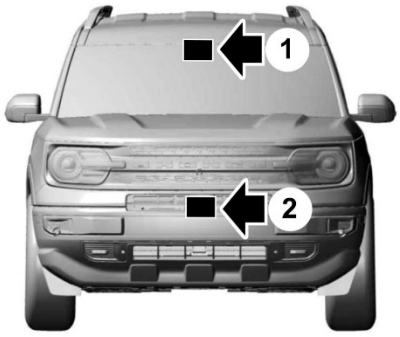
You can adjust the following settings:

- Change alert and distance alert sensitivity to one of three possible settings.
- Switch distance indication and alert on or off.
- If required, switch active braking on or off.
- If required, switch evasive steering assist on or off.

Note: *Active braking and evasive steering assist turn on every time you switch the ignition on.*

Note: *If you switch active braking off, evasive steering assist turns off.*

Blocked Sensors



1 Camera.
2 Radar sensor (if equipped).

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

Bronco Sport (CHD) Canada/United States of America, enUSA, Edition date: 202007, First-Printing

Camera Troubleshooting

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

Radar Troubleshooting (If Equipped)

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

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

Note: *If something hits the front end of your vehicle or damage occurs and your vehicle is equipped with a radar sensor, the radar sensing zone may change. This could cause missed or false detections. Have the radar checked for proper coverage and operation.*

Bronco Sport (CHD) Canada/United States of America, enUSA, Edition date: 202007, First-Printing

APPENDIX C

Run Log

Subject Vehicle: **2021 Ford Bronco Sport Badlands 4x4** Test Date: **3/24/2021**

Principal Other Vehicle: **SSV**

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
1	Static Run								Zero SV front bumper to SSV rear bumper and collect data
2	**Stopped POV**	Y	2.16	7.09	24.9	1.17	0.95	Pass	
3		Y	2.22	5.54	25.2	1.11	0.92	Pass	
4		Y	2.21	4.91	24.9	1.12	0.90	Pass	
5		Y	2.27	6.02	25.6	1.05	0.95	Pass	
6		Y	2.28	8.56	24.9	1.15	1.01	Pass	
7		Y	2.20	6.88	25.2	1.16	0.94	Pass	
8		Y	2.22	7.01	25.3	1.04	0.94	Pass	
9	Static Run								
10	**Slower POV, 25 vs 10**	Y	1.85	3.00	14.5	1.12	0.64	Pass	
11		Y	1.79	2.75	14.3	1.06	0.63	Pass	
12		Y	1.94	2.36	15.4	1.05	0.61	Pass	
13		Y	1.86	3.79	15.2	1.08	0.68	Pass	
14		Y	1.85	3.18	15.3	1.14	0.64	Pass	
15		Y	1.91	2.61	15.2	1.03	0.61	Pass	
16		Y	1.86	3.68	14.9	1.10	0.66	Pass	
17	Static Run								Check zero data is within ± 0.167 ft (±0.05m)
18	**Slower POV, 45 vs 20**	Y	2.57	8.08	25.3	1.06	1.00	Pass	
19		N							Throttle drop
20		Y	2.62	6.92	24.5	1.05	0.95	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
21	**Slower POV, 45 vs 20**	Y	2.44	8.08	24.2	1.07	1.01	Pass	
22		Y	2.62	6.79	25.3	1.08	0.97	Pass	
23		Y	2.62	9.56	25.0	1.07	1.02	Pass	
24		Y	2.60	8.94	25.6	1.05	1.01	Pass	
25		Y	2.67	7.80	25.4	1.07	1.02	Pass	
26	Static run								Check zero data is within ± 0.167 ft (±0.05m)
27	**Decelerating POV**	N							POV brakes
28		Y	1.72	1.89	22.5	1.06	0.74	Pass	
29		Y	1.87	0.60	25.5	1.04	0.76	Pass	
30		N							POV brakes
31		Y	1.61	2.04	21.9	1.07	0.72	Pass	
32		Y	1.82	0.00	18.6	1.01	0.69	Pass	
33		Y	1.63	2.27	22.3	1.02	0.76	Pass	
34		Y	1.64	2.90	21.9	1.03	0.77	Pass	
35		Y	1.74	1.84	22.8	1.06	0.74	Pass	
36	Static Run								Check zero data is within ± 0.167 ft (±0.05m)
37	STP - Static Run								Zero SV front bumper to rear edge of steel plate and collect data
38	**STP False Positive, 25**	Y				0.00		Pass	
39		Y				0.01		Pass	
40		Y				0.01		Pass	
41		Y				0.00		Pass	
42		Y				0.00		Pass	
43		Y				0.00		Pass	
44		Y				0.01		Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
45	STP - Static Run								Check zero data is within ± 0.167 ft (±0.05m)
46	STP - Static Run								Check zero data is within ± 0.167 ft (±0.05m)
47	**STP False Positive, 45**	Y				0.01		Pass	
48		Y				0.00		Pass	
49		Y				0.02		Pass	
50		Y				0.02		Pass	
51		Y				0.01		Pass	
52		Y				0.01		Pass	
53		Y				0.01		Pass	
54	STP - Static Run								Check zero data is within ± 0.167 ft (±0.05m)

APPENDIX D

Time History Plots

LIST OF FIGURES

Page
Figure D1. Example Time History for Stopped POV, Passing D-9
Figure D2. Example Time History for Slower POV 25 vs. 10, Passing D-10
Figure D3. Example Time History for Slower POV 45 vs. 20, Passing D-11
Figure D4. Example Time History for Decelerating POV 35, Passing D-12
Figure D5. Example Time History for False Positive STP 25, Passing D-13
Figure D6. Example Time History for False Positive STP 45, Passing D-14
Figure D7. Example Time History Displaying Invalid Headway Criteria D-15
Figure D8. Example Time History Displaying Various Invalid Criteria D-16
Figure D9. Example Time History for a Failed Run D-17
Figure D10. Time History for CIB Run 2, SV Encounters Stopped POV D-18
Figure D11. Time History for CIB Run 3, SV Encounters Stopped POV D-19
Figure D12. Time History for CIB Run 4, SV Encounters Stopped POV D-20
Figure D13. Time History for CIB Run 5, SV Encounters Stopped POV D-21
Figure D14. Time History for CIB Run 6, SV Encounters Stopped POV D-22
Figure D15. Time History for CIB Run 7, SV Encounters Stopped POV D-23
Figure D16. Time History for CIB Run 8, SV Encounters Stopped POV D-24
Figure D17. Time History for CIB Run 10, SV Encounters Slower POV, SV 25 mph, POV 10 mph D-25
Figure D18. Time History for CIB Run 11, SV Encounters Slower POV, SV 25 mph, POV 10 mph D-26
Figure D19. Time History for CIB Run 12, SV Encounters Slower POV, SV 25 mph, POV 10 mph D-27
Figure D20. Time History for CIB Run 13, SV Encounters Slower POV, SV 25 mph, POV 10 mph D-28
Figure D21. Time History for CIB Run 14, SV Encounters Slower POV, SV 25 mph, POV 10 mph D-29
Figure D22. Time History for CIB Run 15, SV Encounters Slower POV, SV 25 mph, POV 10 mph D-30
Figure D23. Time History for CIB Run 16, SV Encounters Slower POV, SV 25 mph, POV 10 mph D-31
Figure D24. Time History for CIB Run 18, SV Encounters Slower POV, SV 45 mph, POV 20 mph D-32
Figure D25. Time History for CIB Run 20, SV Encounters Slower POV, SV 45 mph, POV 20 mph D-33
Figure D26. Time History for CIB Run 21, SV Encounters Slower POV, SV 45 mph, POV 20 mph D-34
Figure D27. Time History for CIB Run 22, SV Encounters Slower POV, SV 45 mph, POV 20 mph D-35
Figure D28. Time History for CIB Run 23, SV Encounters Slower POV, SV 45 mph, POV 20 mph D-36
Figure D29. Time History for CIB Run 24, SV Encounters Slower POV, SV 45 mph, POV 20 mph D-37
Figure D30. Time History for CIB Run 25, SV Encounters Slower POV, SV 45 mph, POV 20 mph D-38
Figure D31. Time History for CIB Run 28, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph D-39
Figure D32. Time History for CIB Run 29, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph D-40

Figure D33. Time History for CIB Run 31, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph D-41
Figure D34. Time History for CIB Run 32, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph D-42
Figure D35. Time History for CIB Run 33, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph D-43
Figure D36. Time History for CIB Run 34, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph D-44
Figure D37. Time History for CIB Run 35, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph D-45
Figure D38. Time History for CIB Run 38, SV Encounters Steel Trench Plate, SV 25 mph D-46
Figure D39. Time History for CIB Run 39, SV Encounters Steel Trench Plate, SV 25 mph D-47
Figure D40. Time History for CIB Run 40, SV Encounters Steel Trench Plate, SV 25 mph D-48
Figure D41. Time History for CIB Run 41, SV Encounters Steel Trench Plate, SV 25 mph D-49
Figure D42. Time History for CIB Run 42, SV Encounters Steel Trench Plate, SV 25 mph D-50
Figure D43. Time History for CIB Run 43, SV Encounters Steel Trench Plate, SV 25 mph D-51
Figure D44. Time History for CIB Run 44, SV Encounters Steel Trench Plate, SV 25 mph D-52
Figure D45. Time History for CIB Run 47, SV Encounters Steel Trench Plate, SV 45 mph D-53
Figure D46. Time History for CIB Run 48, SV Encounters Steel Trench Plate, SV 45 mph D-54
Figure D47. Time History for CIB Run 49, SV Encounters Steel Trench Plate, SV 45 mph D-55
Figure D48. Time History for CIB Run 50, SV Encounters Steel Trench Plate, SV 45 mph D-56
Figure D49. Time History for CIB Run 51, SV Encounters Steel Trench Plate, SV 45 mph D-57
Figure D50. Time History for CIB Run 52, SV Encounters Steel Trench Plate, SV 45 mph D-58
Figure D51. Time History for CIB Run 53, SV Encounters Steel Trench Plate, SV 45 mph D-59

Description of Time History Plots

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

Time History Plot Description

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

- Stopped POV (SV at 25 mph)
- Slower POV, 25/10 (SV at 25 mph, POV at 10 mph)
- Slower POV, 45/20 (SV at 45 mph, POV at 20 mph)
- Decelerating POV 35 mph (Both vehicles at 35 mph with 13.8 m gap, POV brakes at 0.3 g)
- False Positive STP 25 mph (Steel trench plate run over at 25 mph)
- False Positive STP 45 mph (Steel trench plate run over at 45 mph)

Time history figures include the following sub-plots:

- FCW Warning – Displays the Forward Collision Warning alert (which can be auditory, 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 auditory 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. For False Positive tests, when the FCW presents a warning “FCW” is shown in red at the right edge of the FCW plot.

- Headway (ft) – Longitudinal separation (gap) between the frontmost point of the Subject Vehicle and the rearmost point of the Strikeable Surrogate Vehicle (SSV) towed by the Principal Other Vehicle. The minimum headway during the run is displayed to the right of the subplot.

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

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

- Lateral Offset (ft) – Lateral offset within the lane of the Subject Vehicle to the center of the lane of travel. Note that for tests involving the Strikeable Surrogate Vehicle (SSV), the associated lateral restraint track is defined to be the center of the lane of travel. If testing is done with a different POV which does not have a lateral restraint track, lateral offset is defined to be the lateral offset between the SV and POV.

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

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

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. For false positive runs a green dot, rather than a green envelope is displayed. The green dot indicates that at the end of the run the accelerator pedal had not been released. If the accelerator had been released a red asterisk would appear.

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 Figure D1 through Figure D9. Figures D1 through D6 show passing runs for each of the 6 test types. Figures D7 and D8 show examples of invalid runs. Figure D9 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 D10.

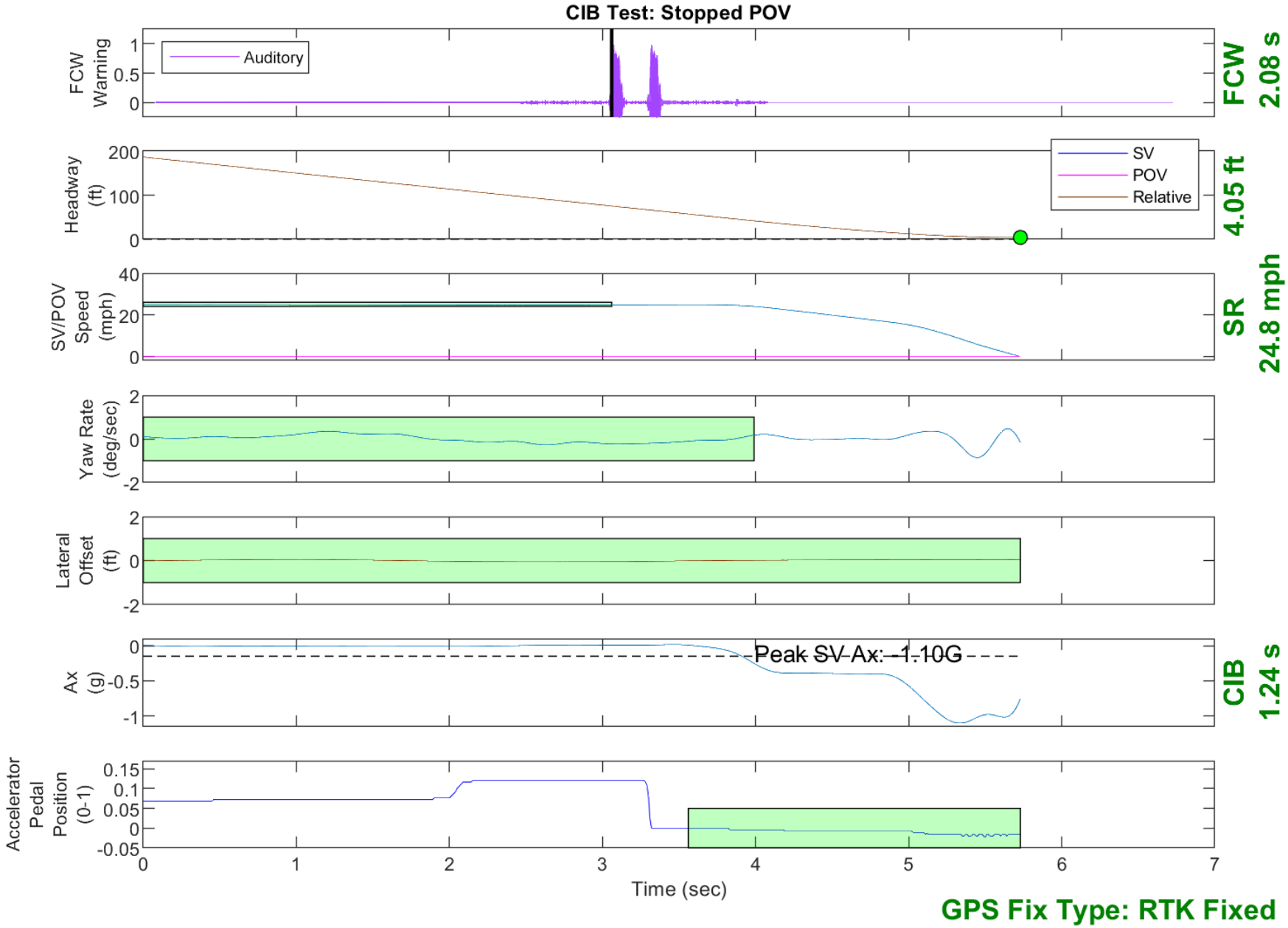


Figure D1. Example Time History for Stopped POV, Passing

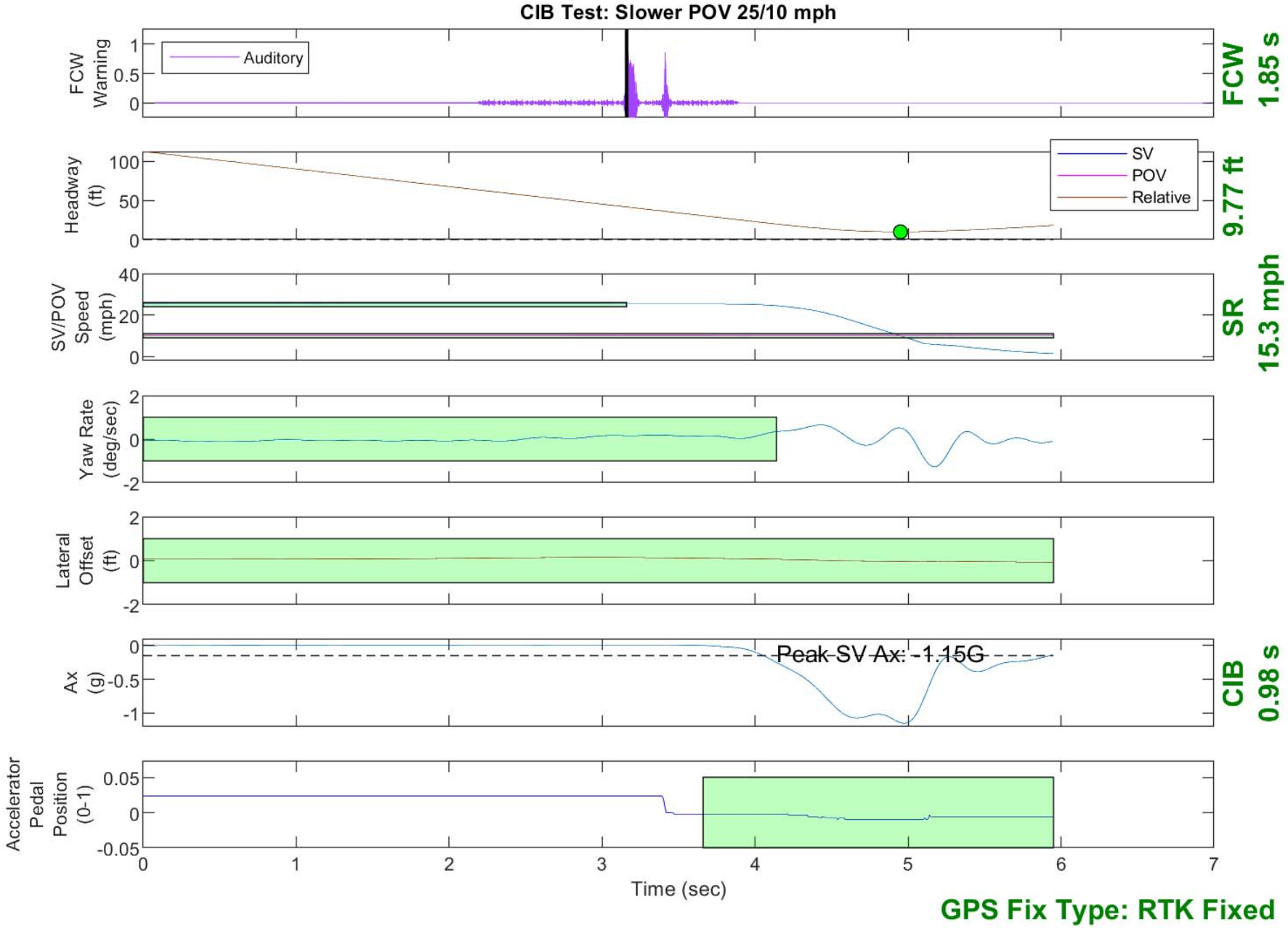


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

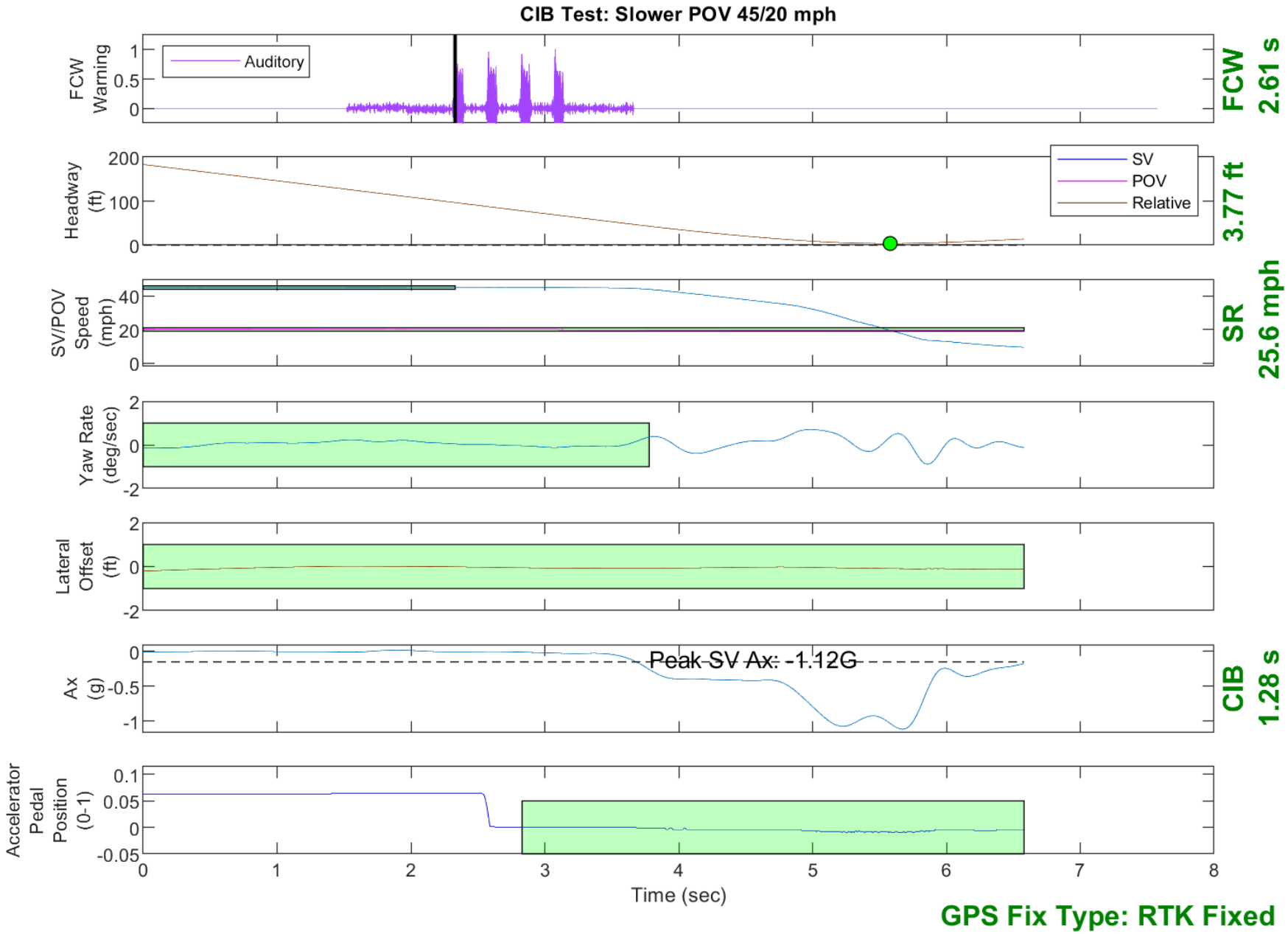


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

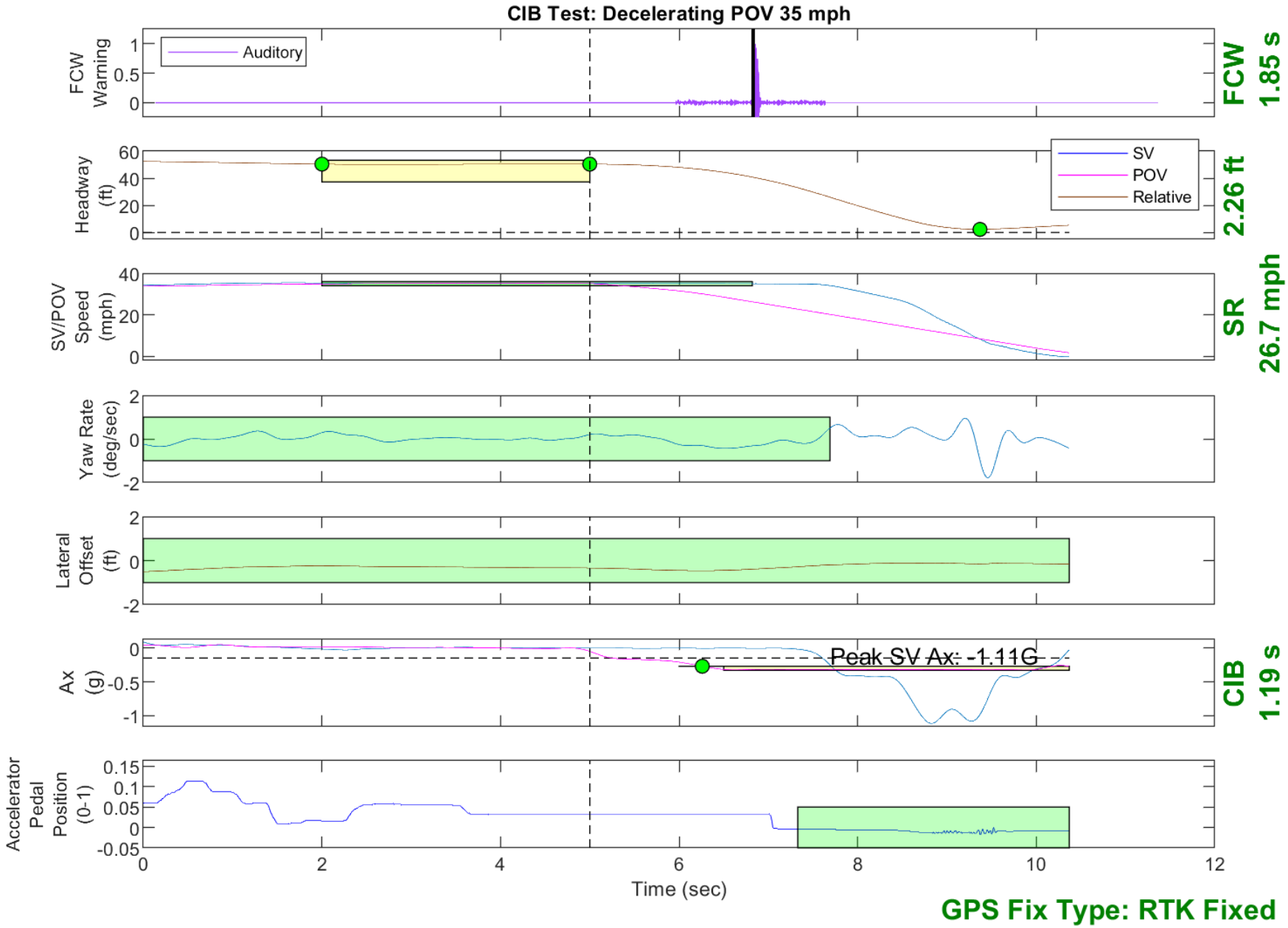


Figure D4. Example Time History for Decelerating POV 35, Passing

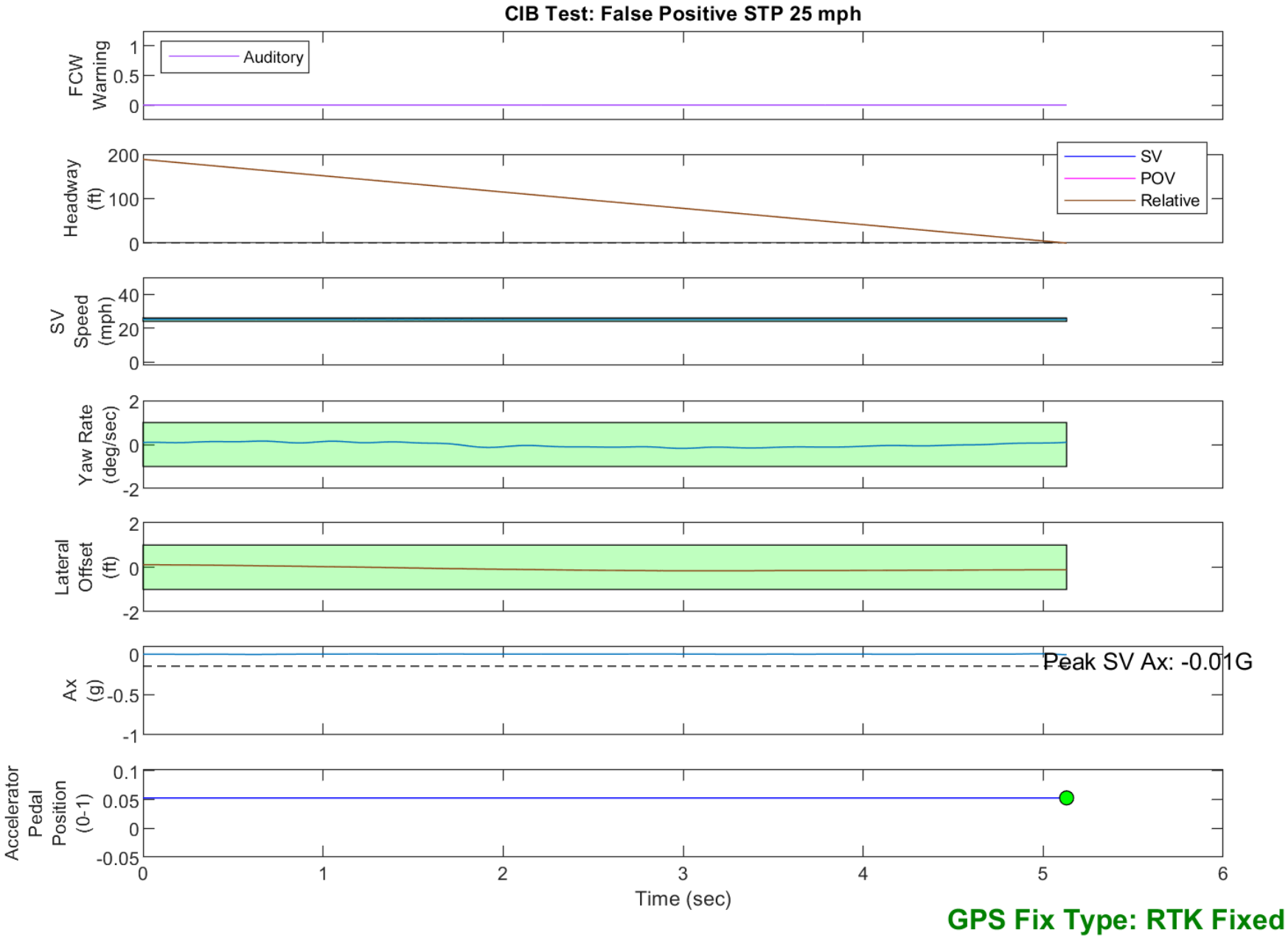


Figure D5. Example Time History for False Positive STP 25, Passing

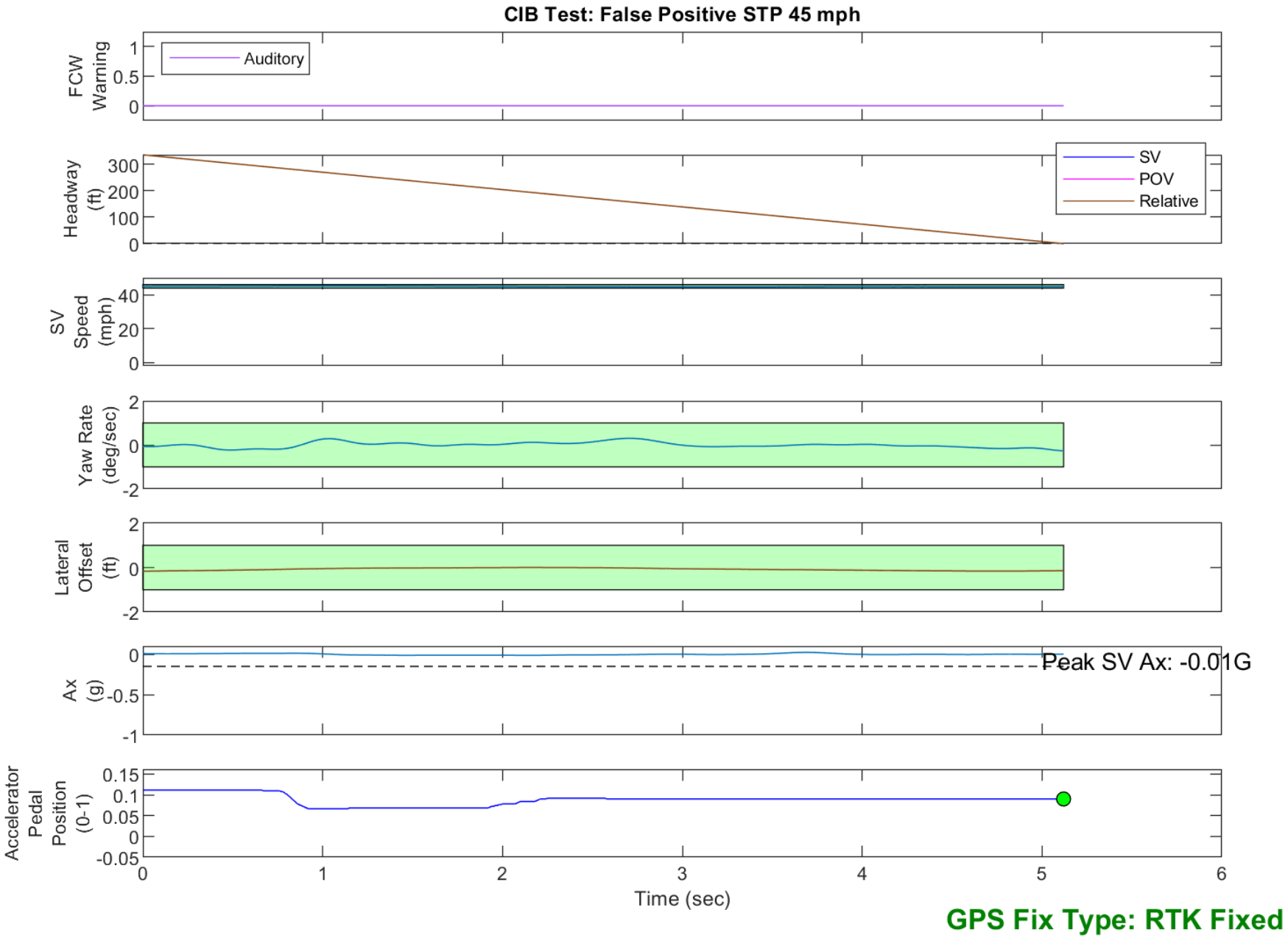


Figure D6. Example Time History for False Positive STP 45, Passing

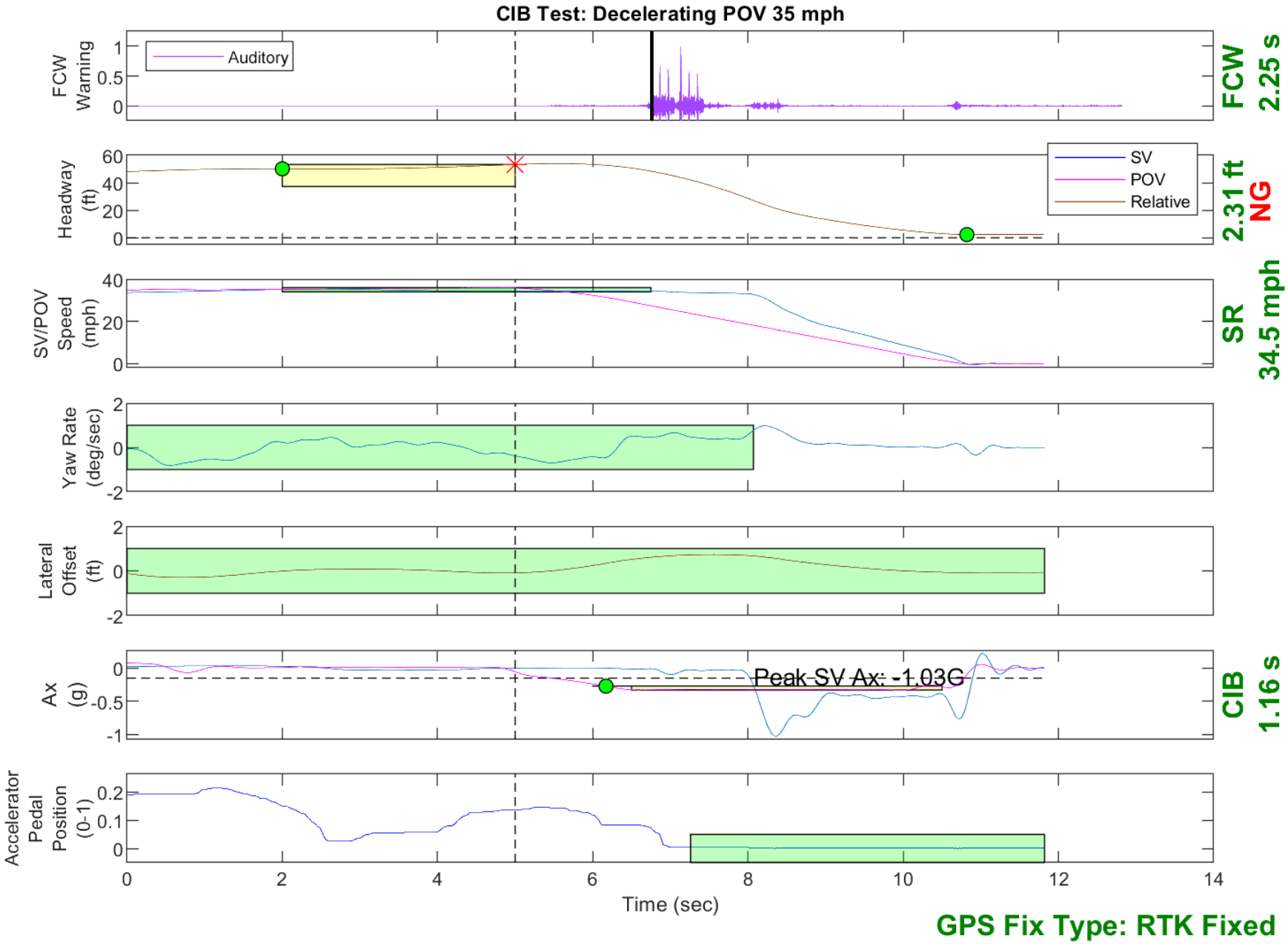


Figure D7. Example Time History Displaying Invalid Headway Criteria

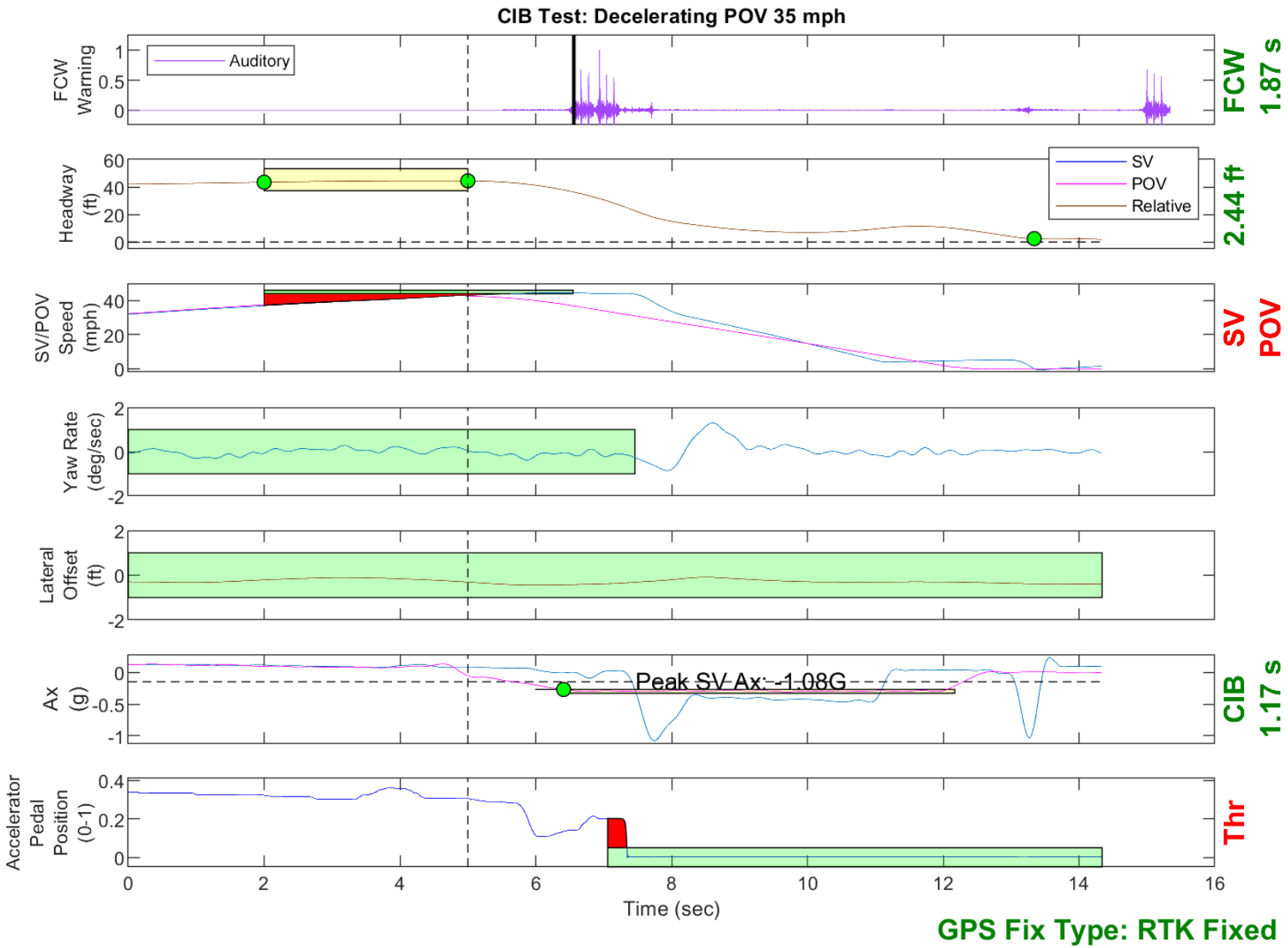


Figure D8. Example Time History Displaying Various Invalid Criteria

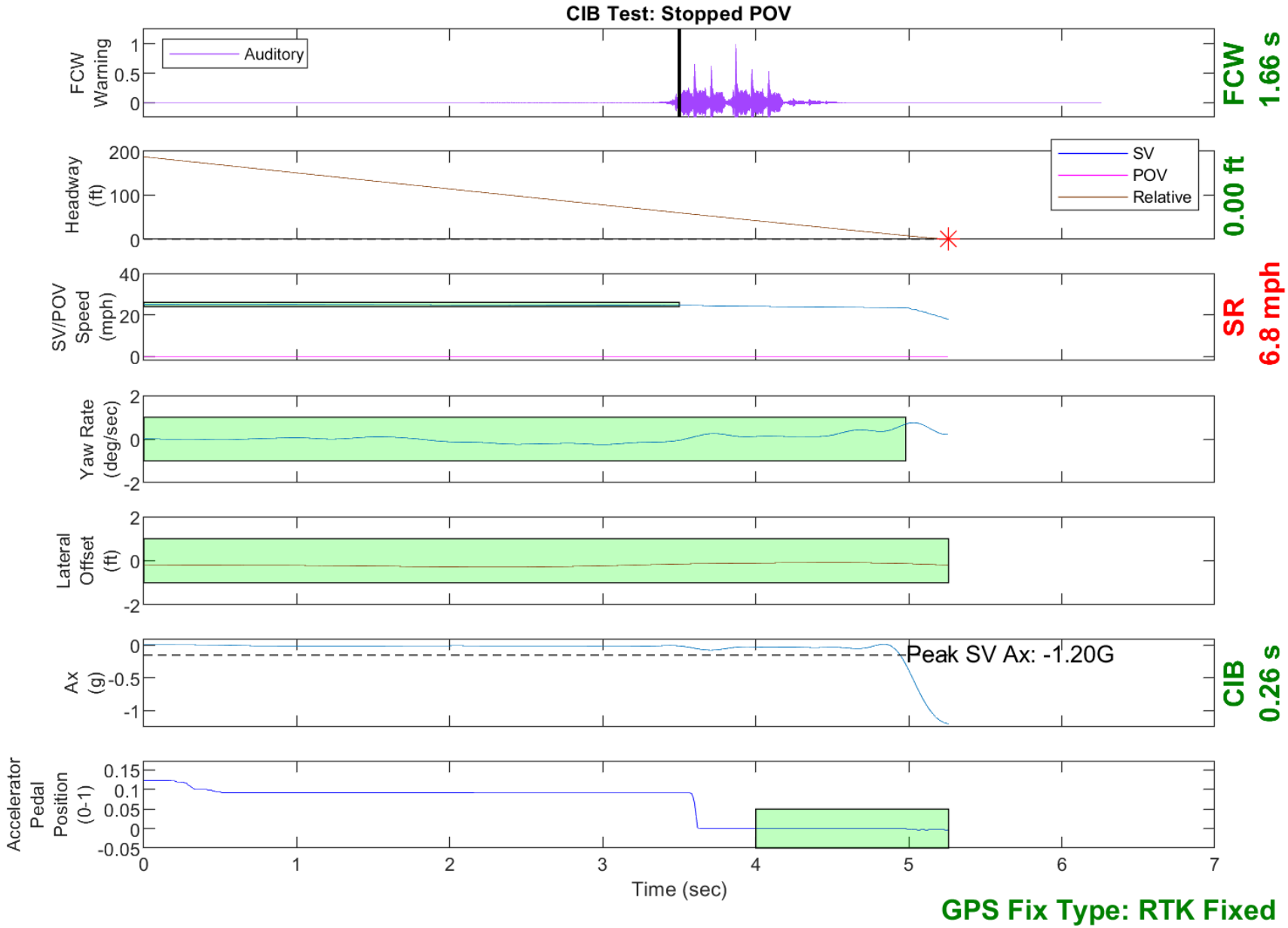


Figure D9. Example Time History for a Failed Run

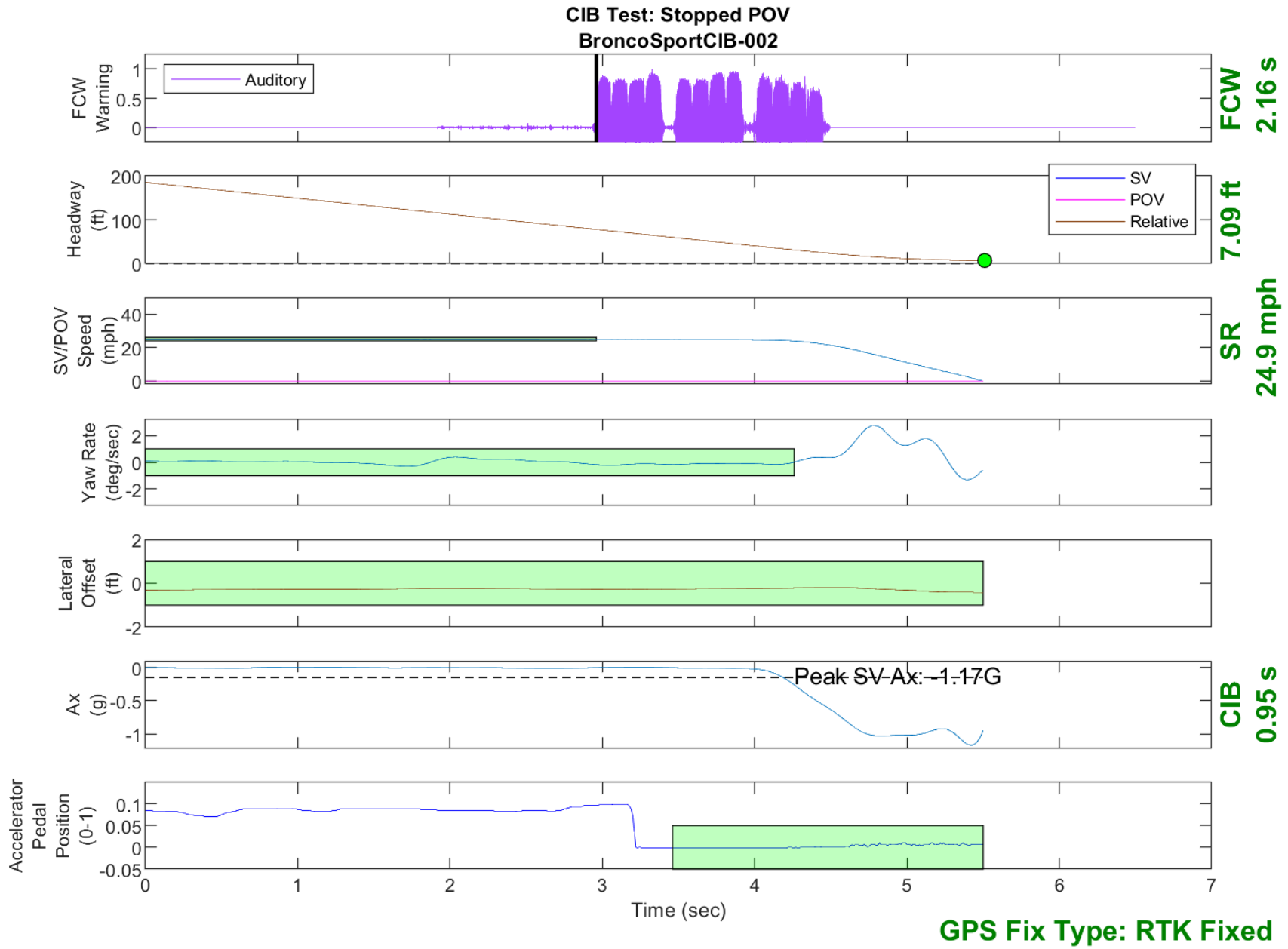


Figure D10. Time History for CIB Run 2, SV Encounters Stopped POV

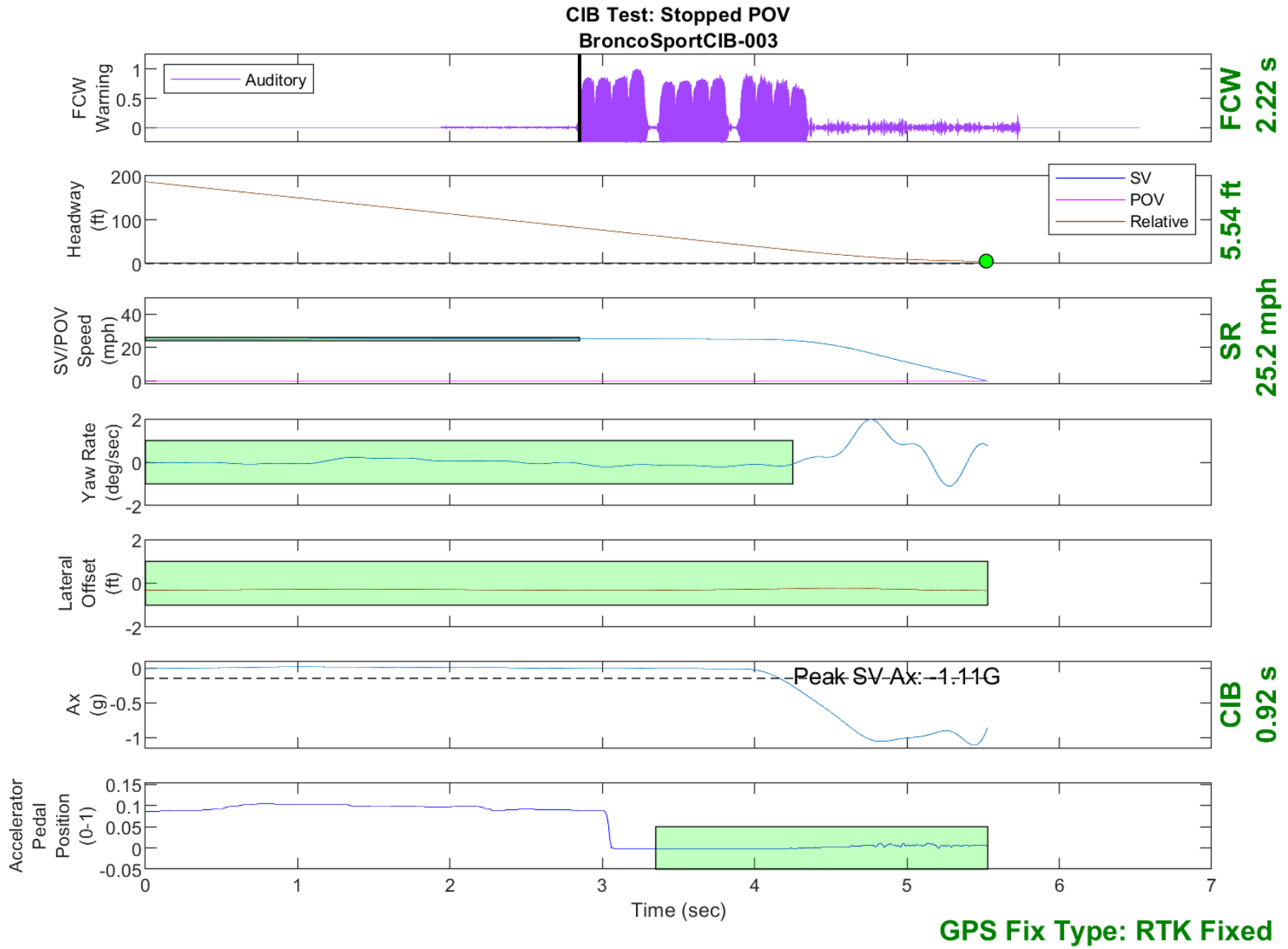


Figure D11. Time History for CIB Run 3, SV Encounters Stopped POV

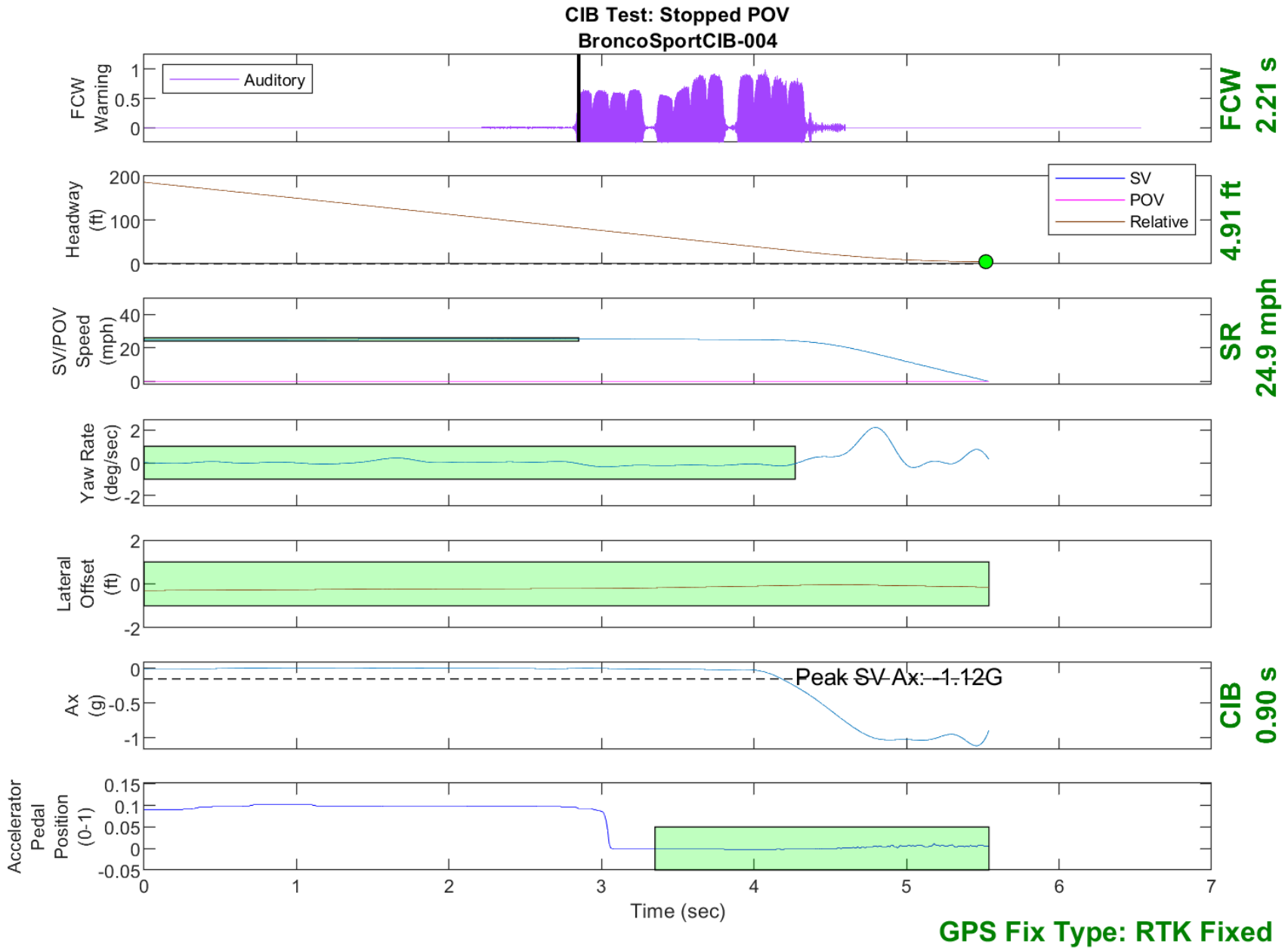


Figure D12. Time History for CIB Run 4, SV Encounters Stopped POV

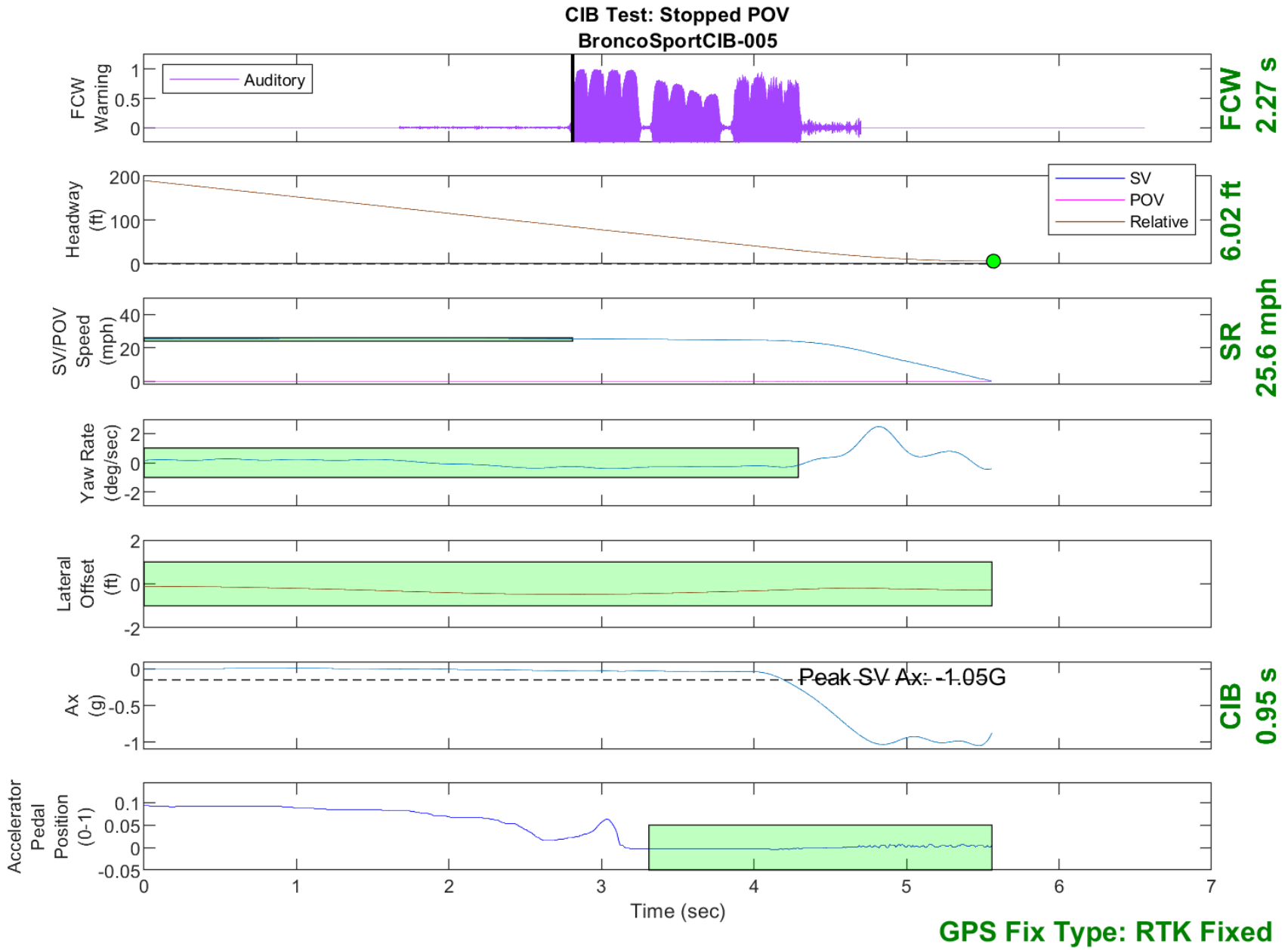


Figure D13. Time History for CIB Run 5, SV Encounters Stopped POV

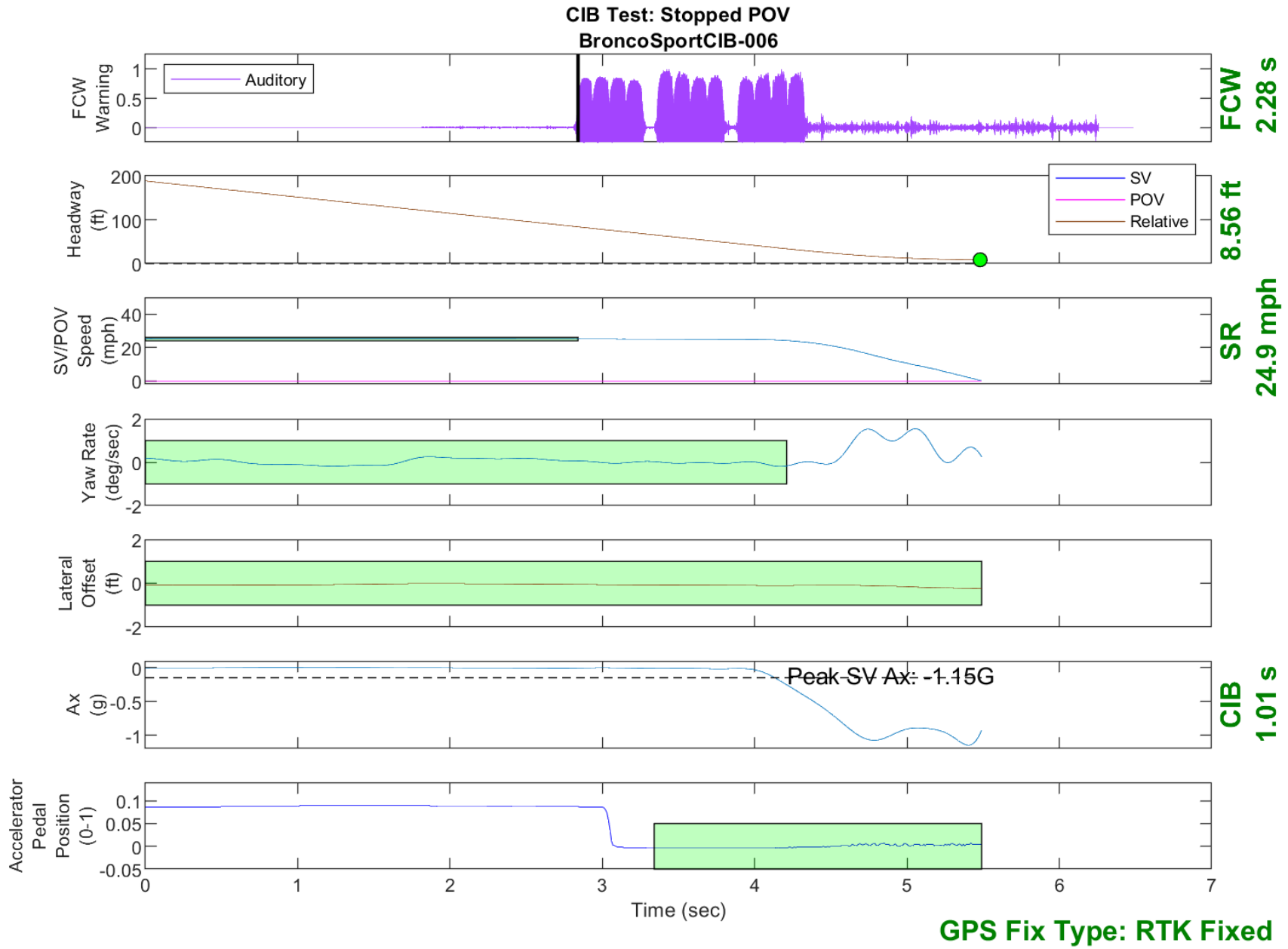


Figure D14. Time History for CIB Run 6, SV Encounters Stopped POV

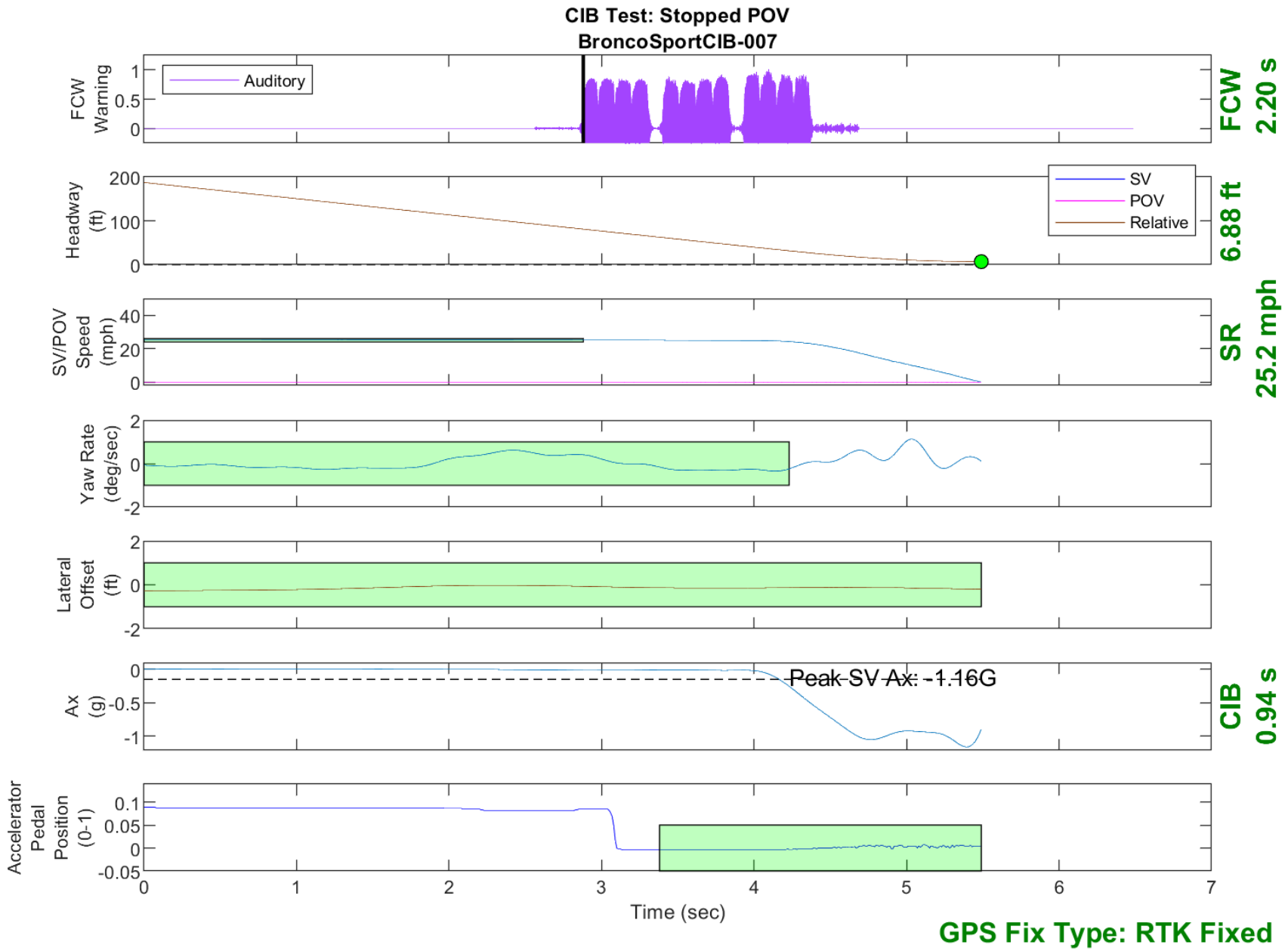


Figure D15. Time History for CIB Run 7, SV Encounters Stopped POV

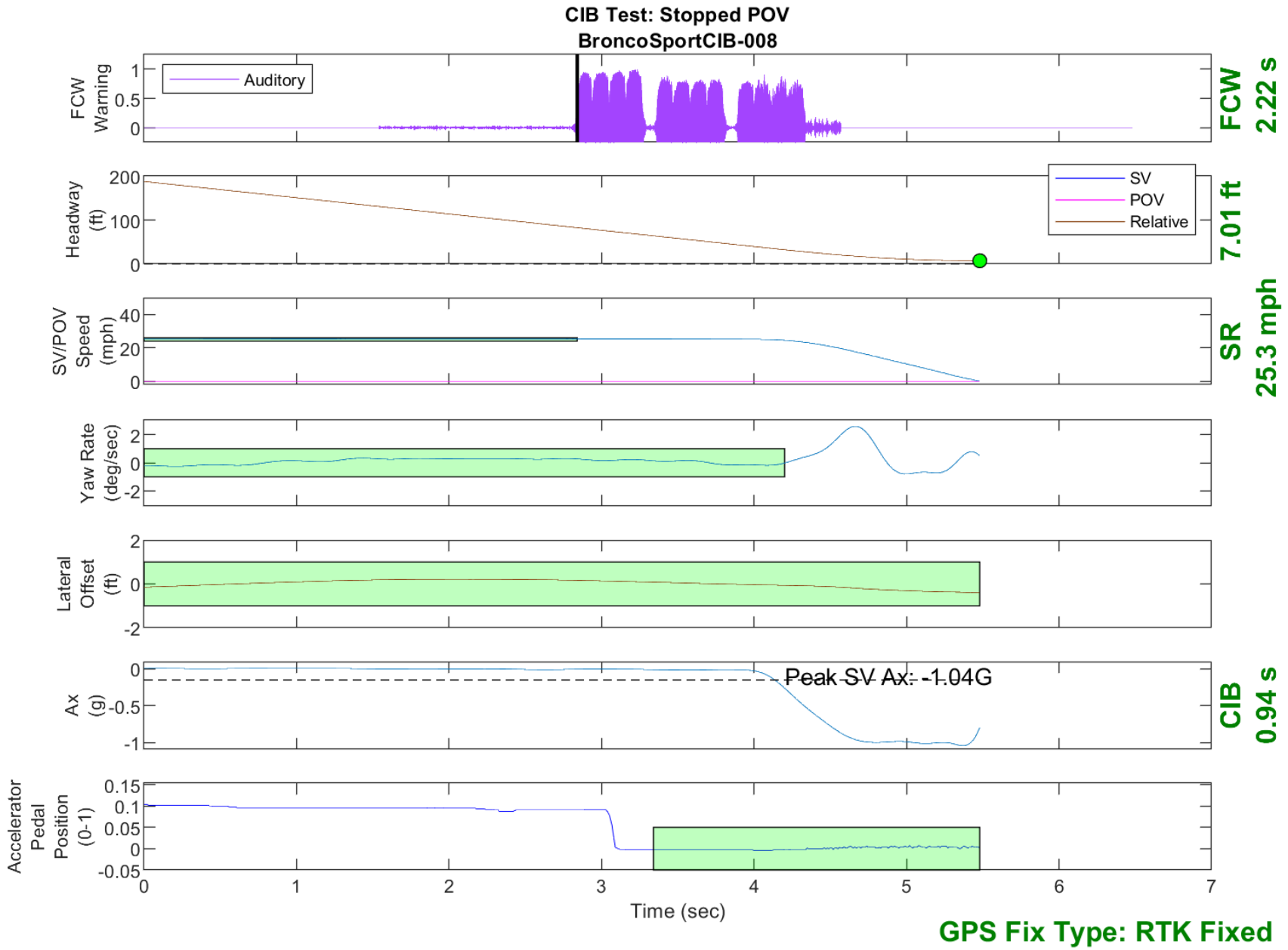


Figure D16. Time History for CIB Run 8, SV Encounters Stopped POV

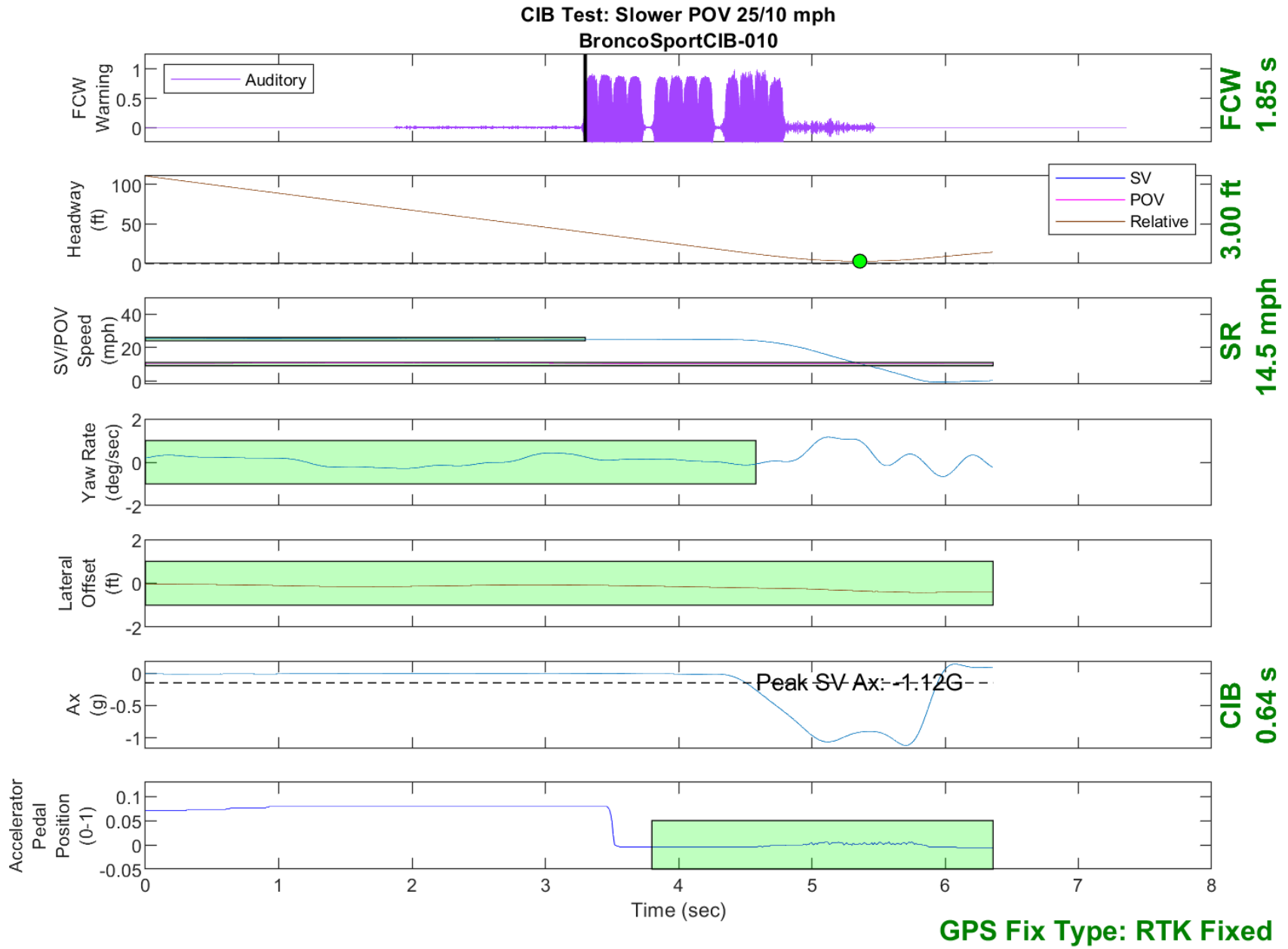


Figure D17. Time History for CIB Run 10, SV Encounters Slower POV, SV 25 mph, POV 10 mph

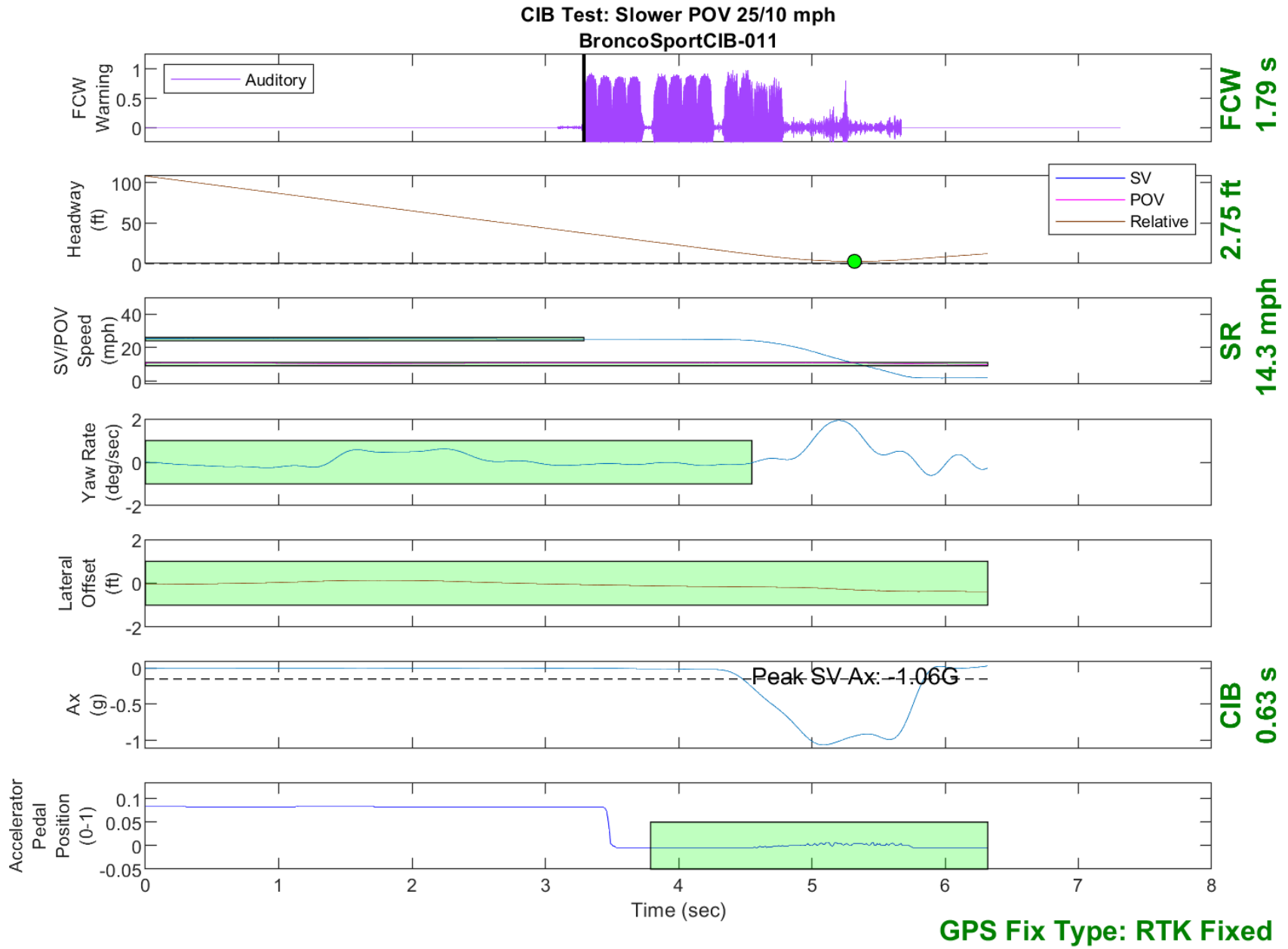


Figure D18. Time History for CIB Run 11, SV Encounters Slower POV, SV 25 mph, POV 10 mph

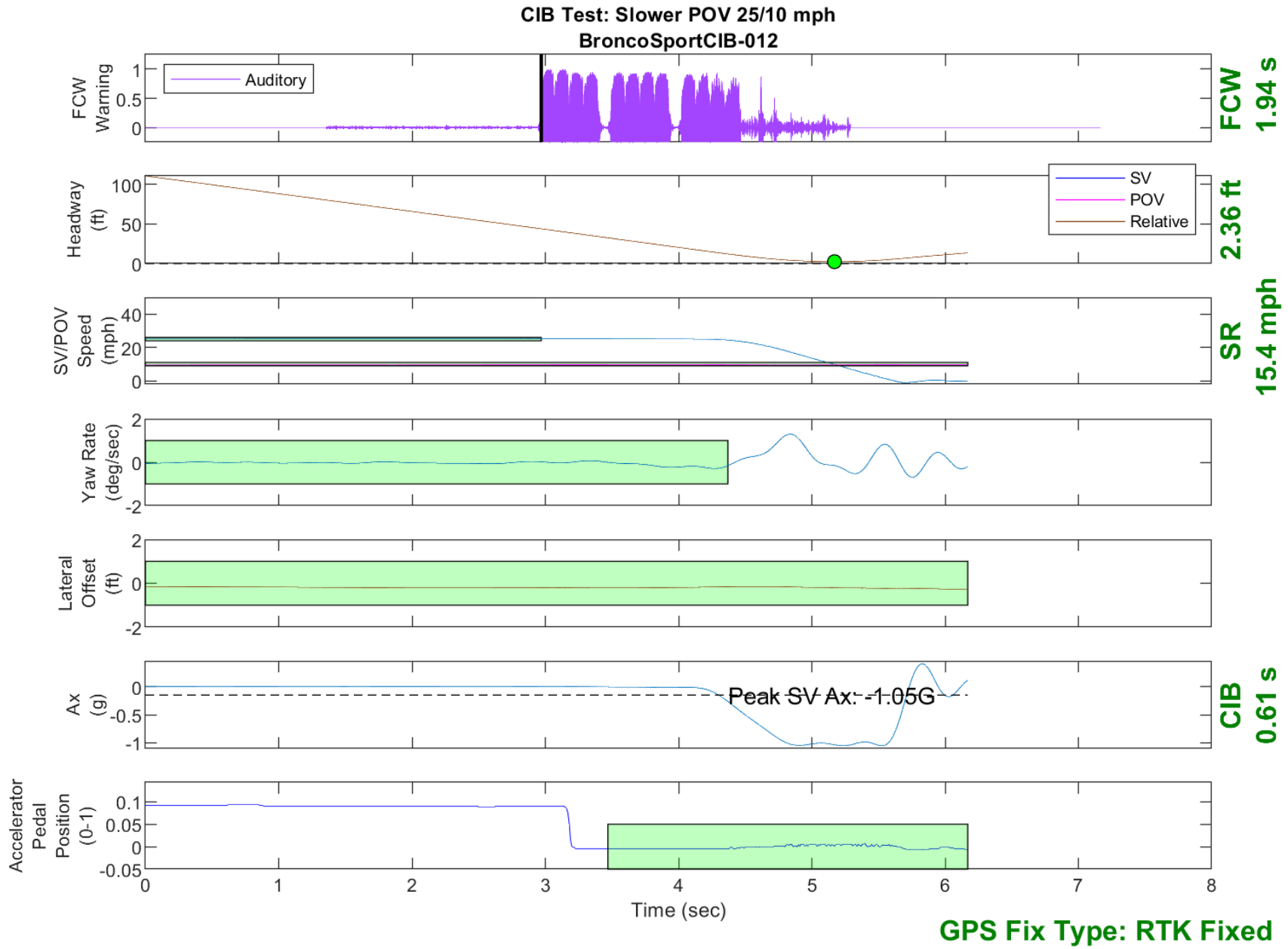


Figure D19. Time History for CIB Run 12, SV Encounters Slower POV, SV 25 mph, POV 10 mph

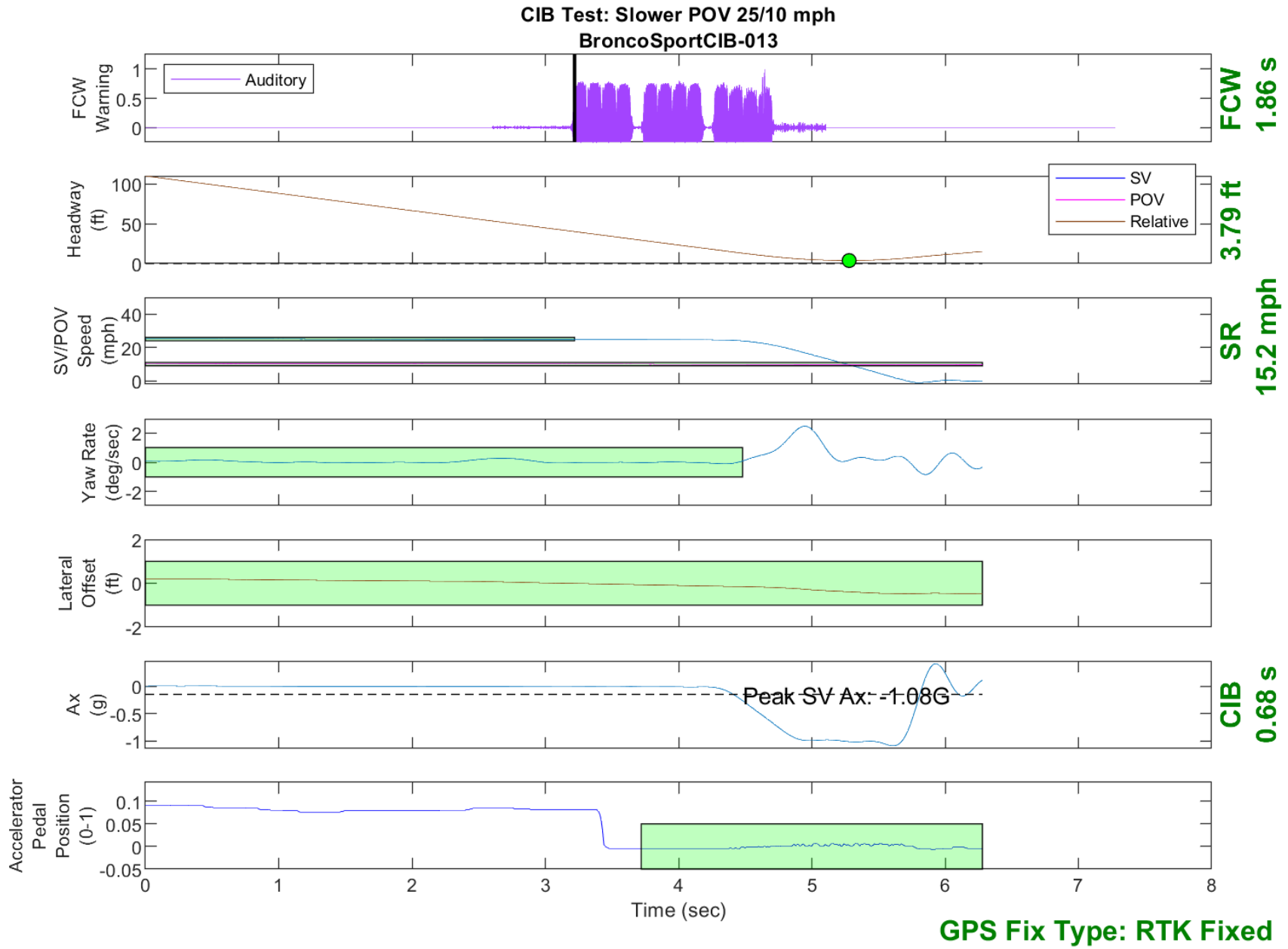


Figure D20. Time History for CIB Run 13, SV Encounters Slower POV, SV 25 mph, POV 10 mph

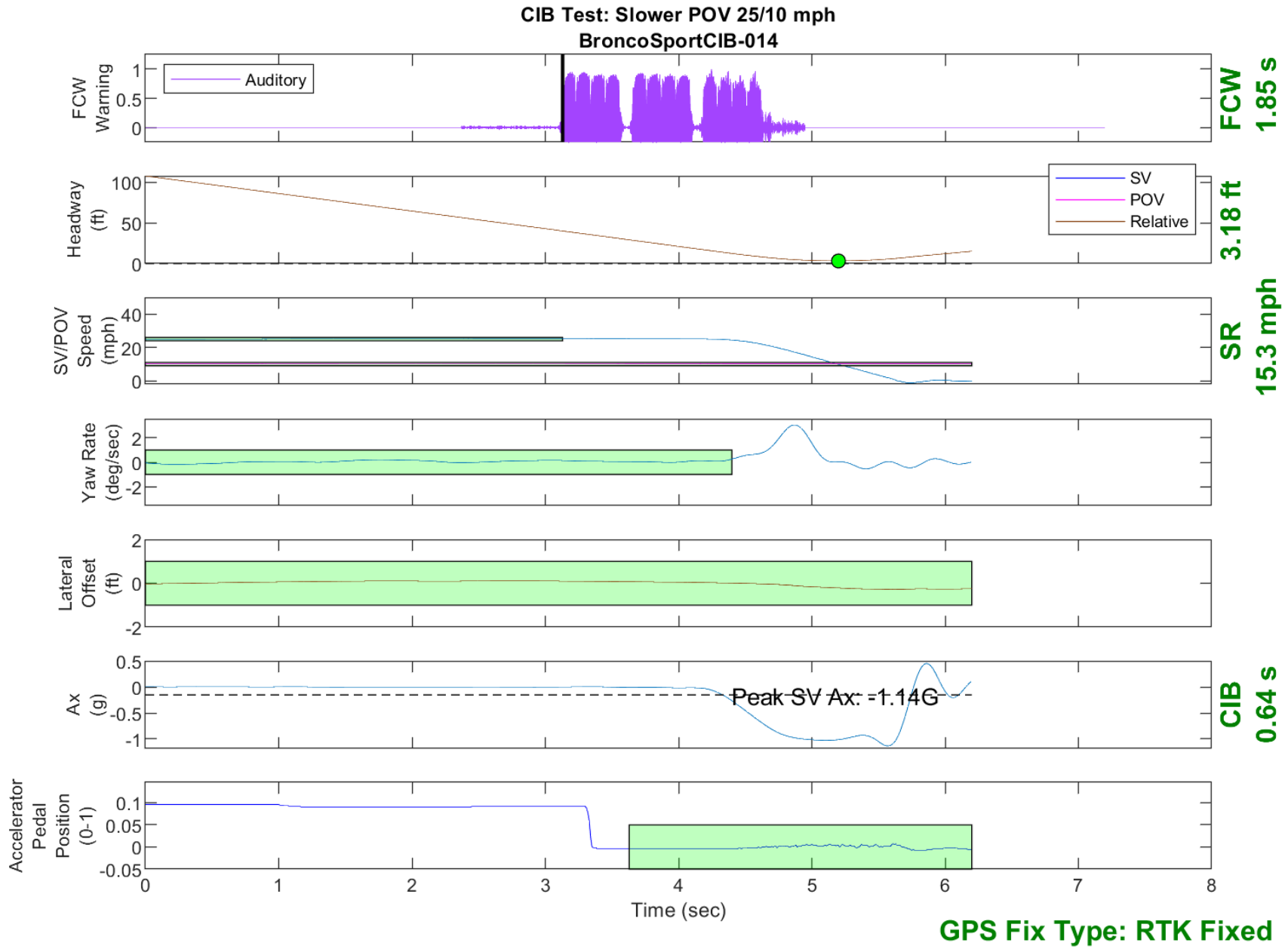


Figure D21. Time History for CIB Run 14, SV Encounters Slower POV, SV 25 mph, POV 10 mph

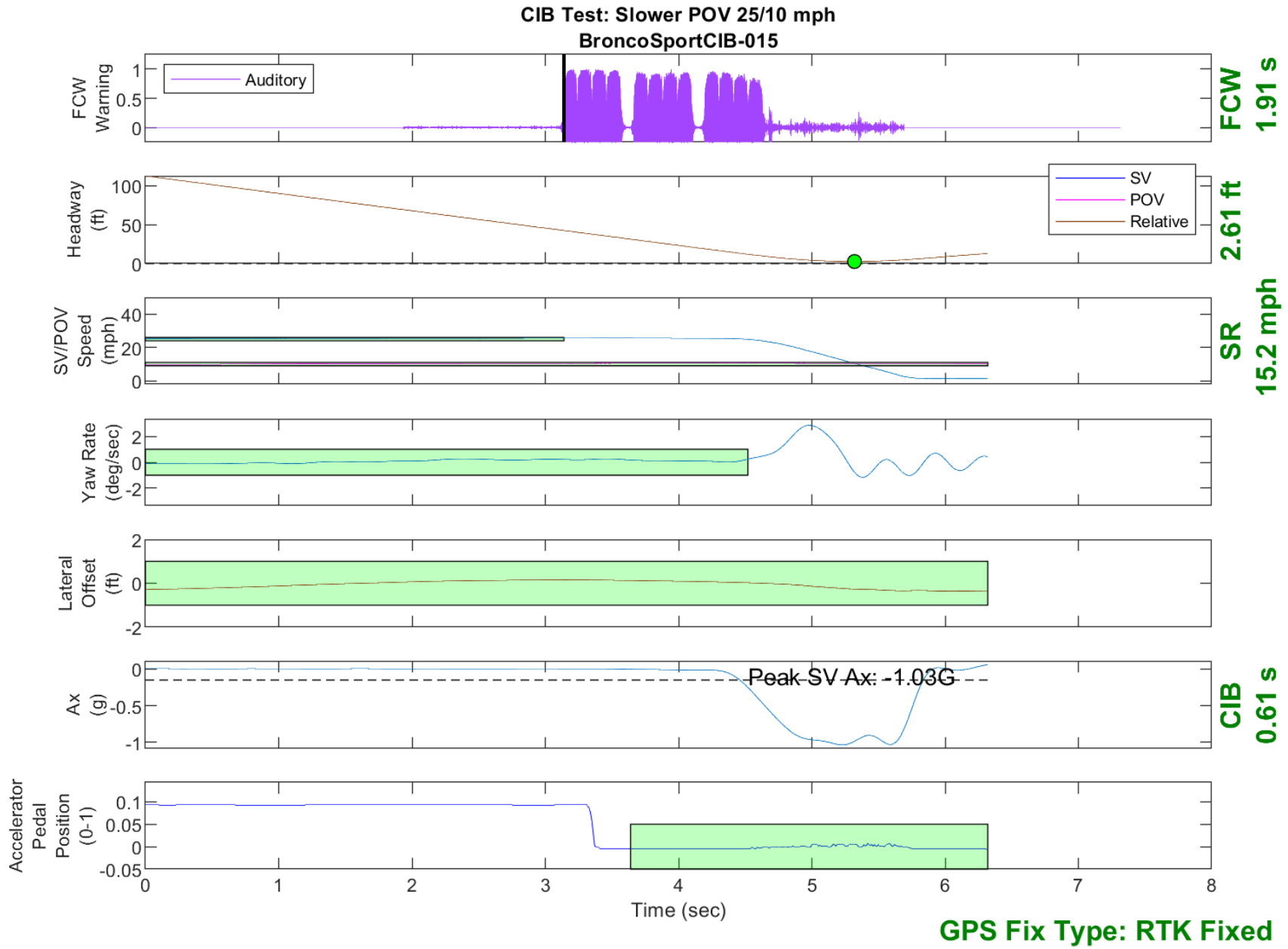


Figure D22. Time History for CIB Run 15, SV Encounters Slower POV, SV 25 mph, POV 10 mph

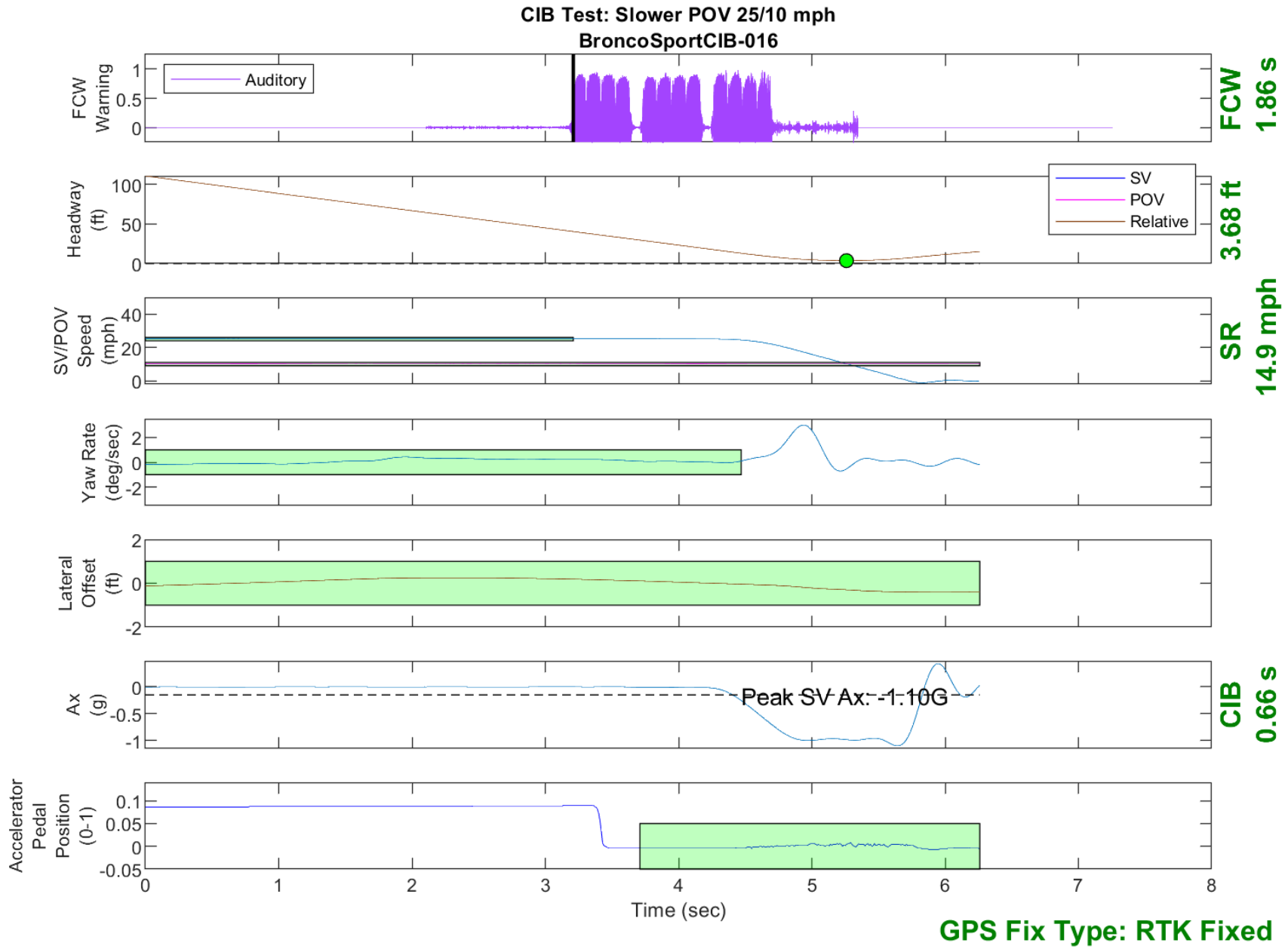


Figure D23. Time History for CIB Run 16, SV Encounters Slower POV, SV 25 mph, POV 10 mph

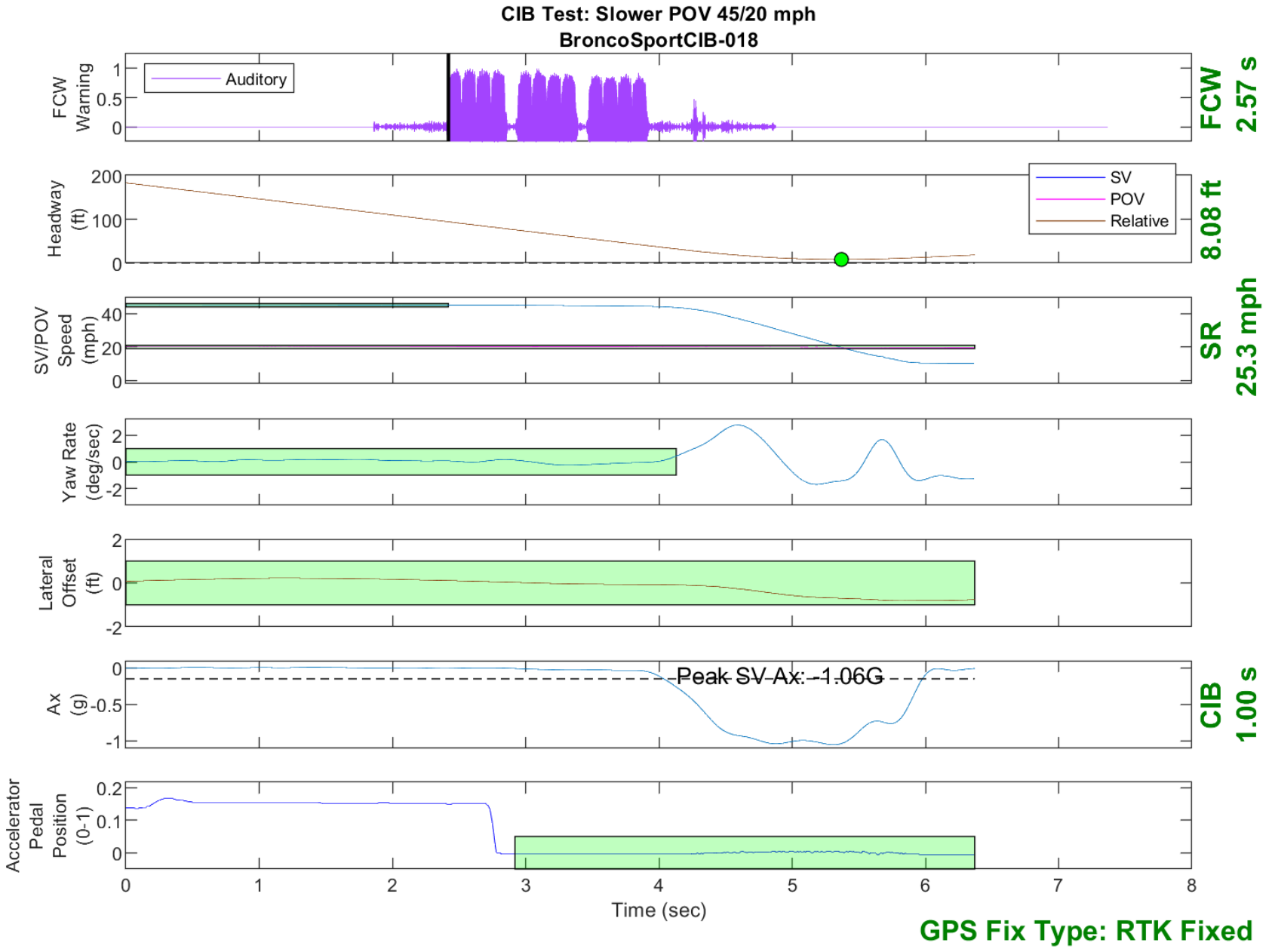


Figure D24. Time History for CIB Run 18, SV Encounters Slower POV, SV 45 mph, POV 20 mph

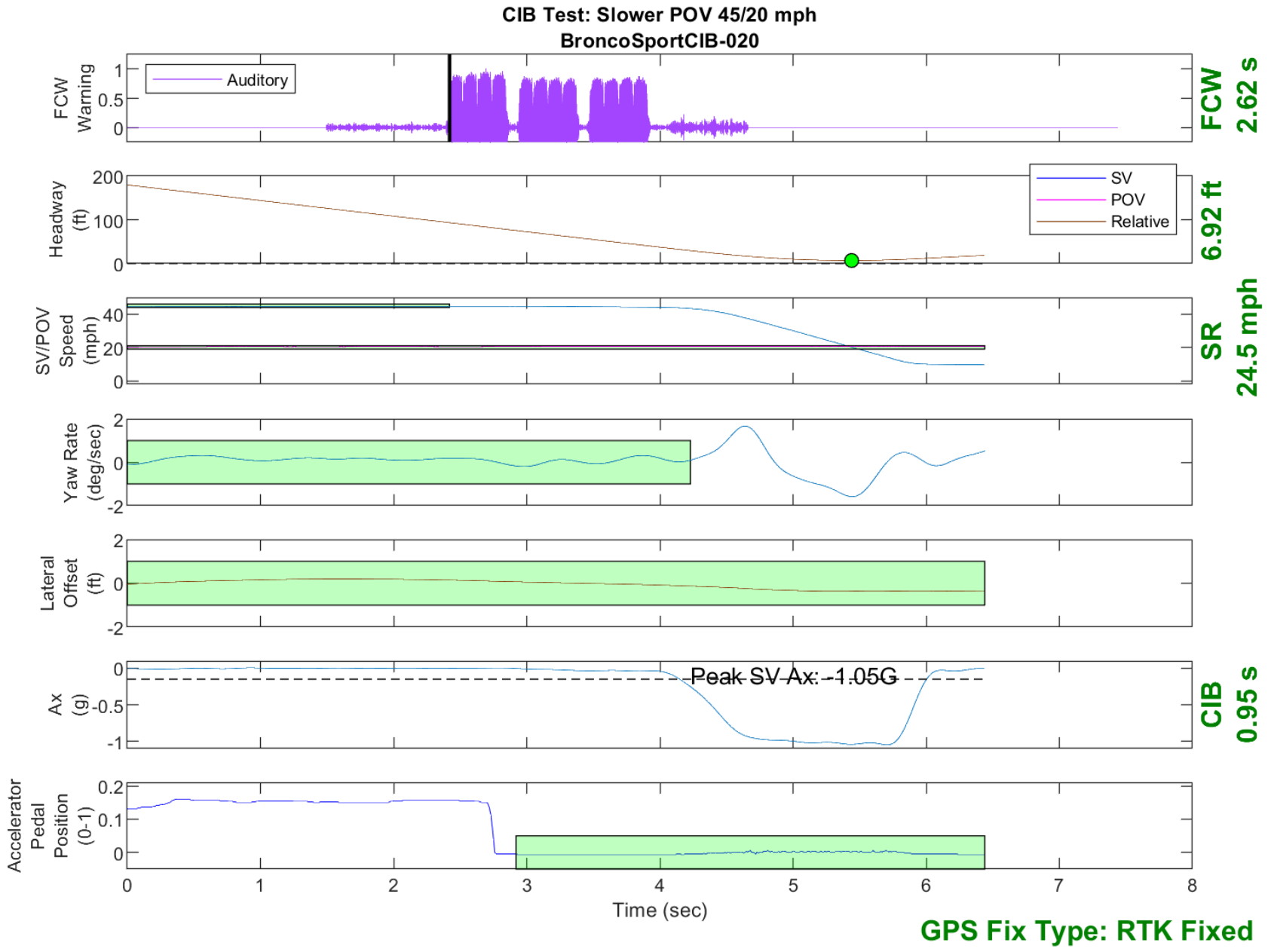


Figure D25. Time History for CIB Run 20, SV Encounters Slower POV, SV 45 mph, POV 20 mph

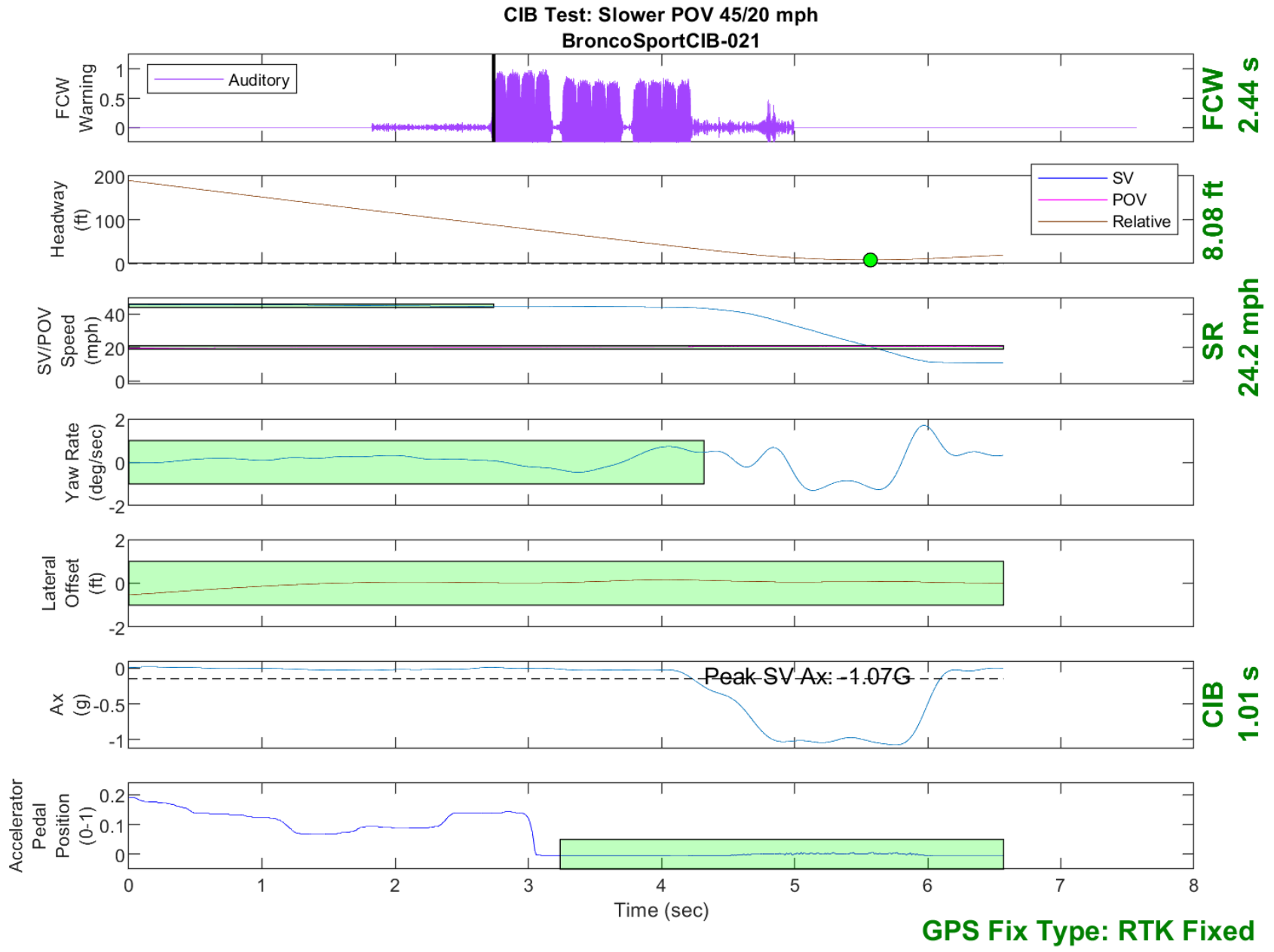


Figure D26. Time History for CIB Run 21, SV Encounters Slower POV, SV 45 mph, POV 20 mph

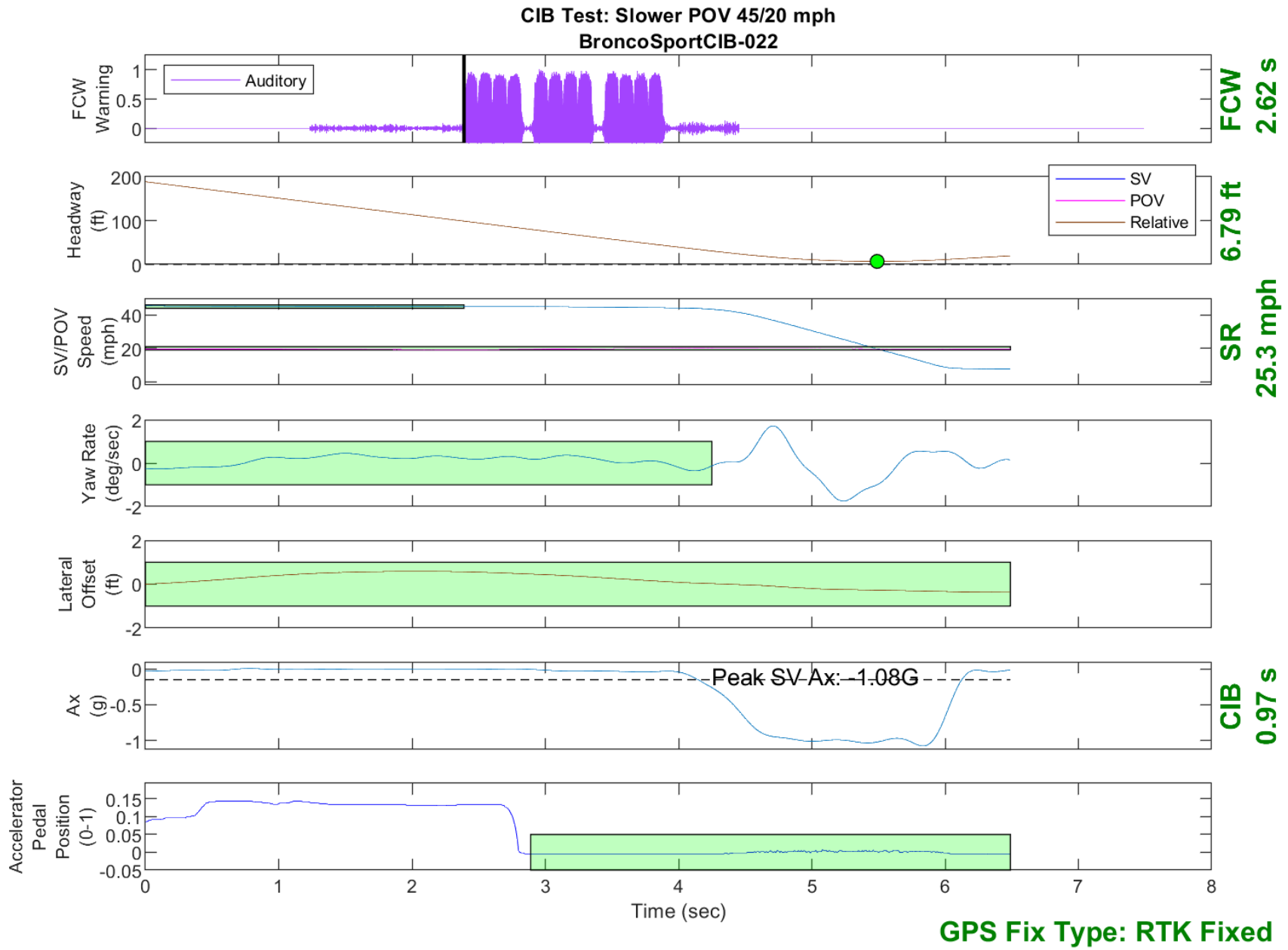


Figure D27. Time History for CIB Run 22, SV Encounters Slower POV, SV 45 mph, POV 20 mph

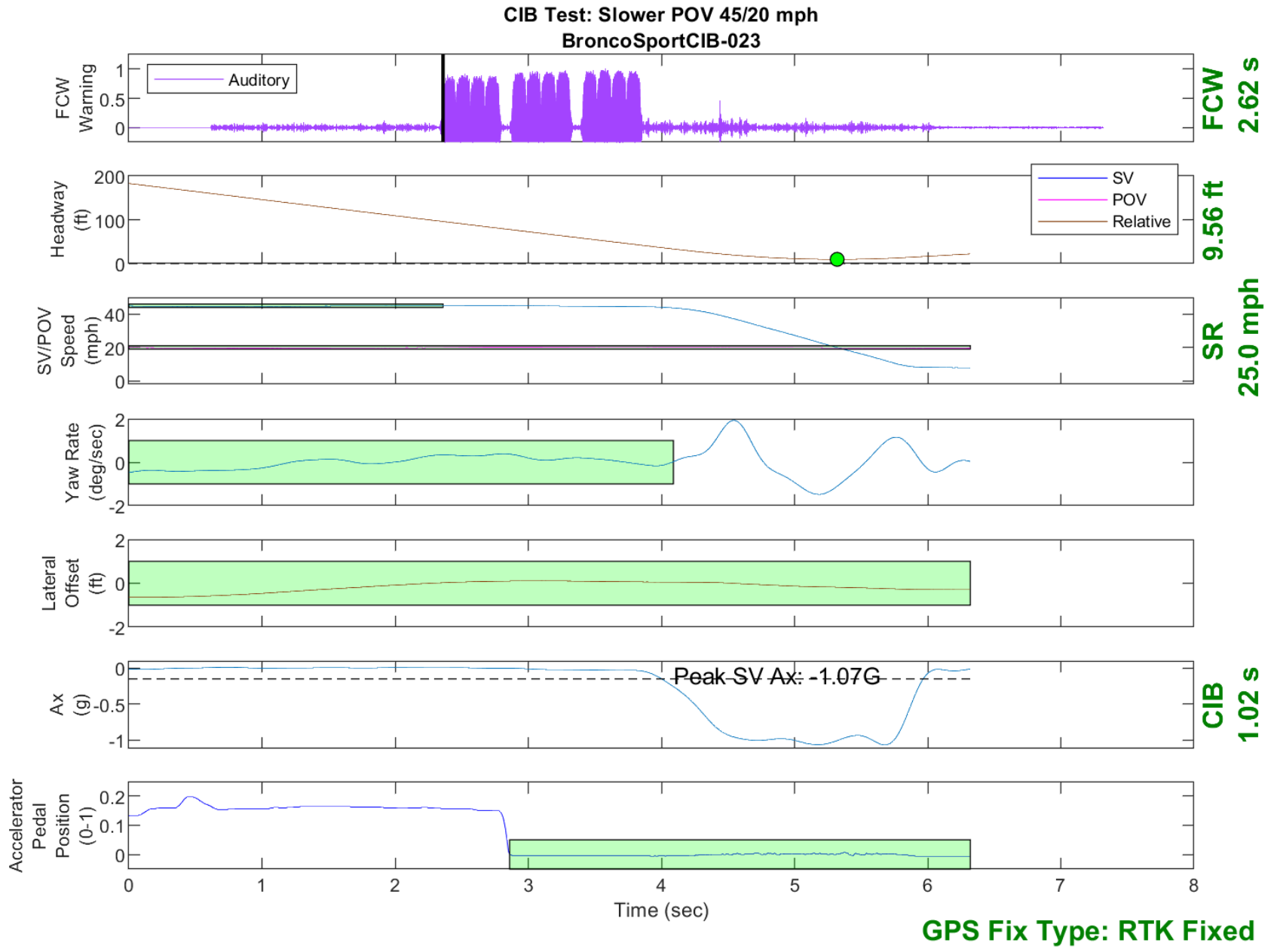


Figure D28. Time History for CIB Run 23, SV Encounters Slower POV, SV 45 mph, POV 20 mph

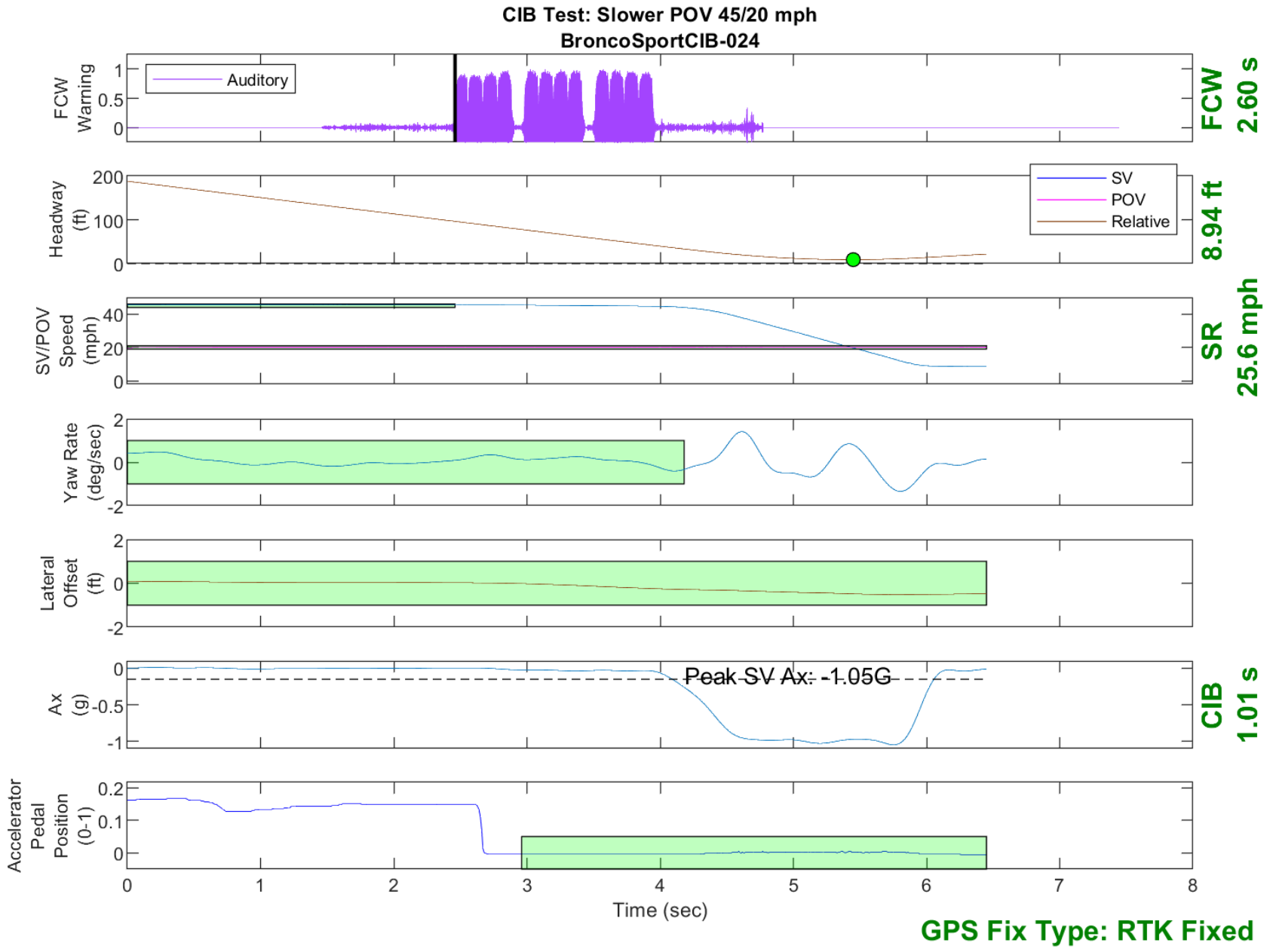


Figure D29. Time History for CIB Run 24, SV Encounters Slower POV, SV 45 mph, POV 20 mph

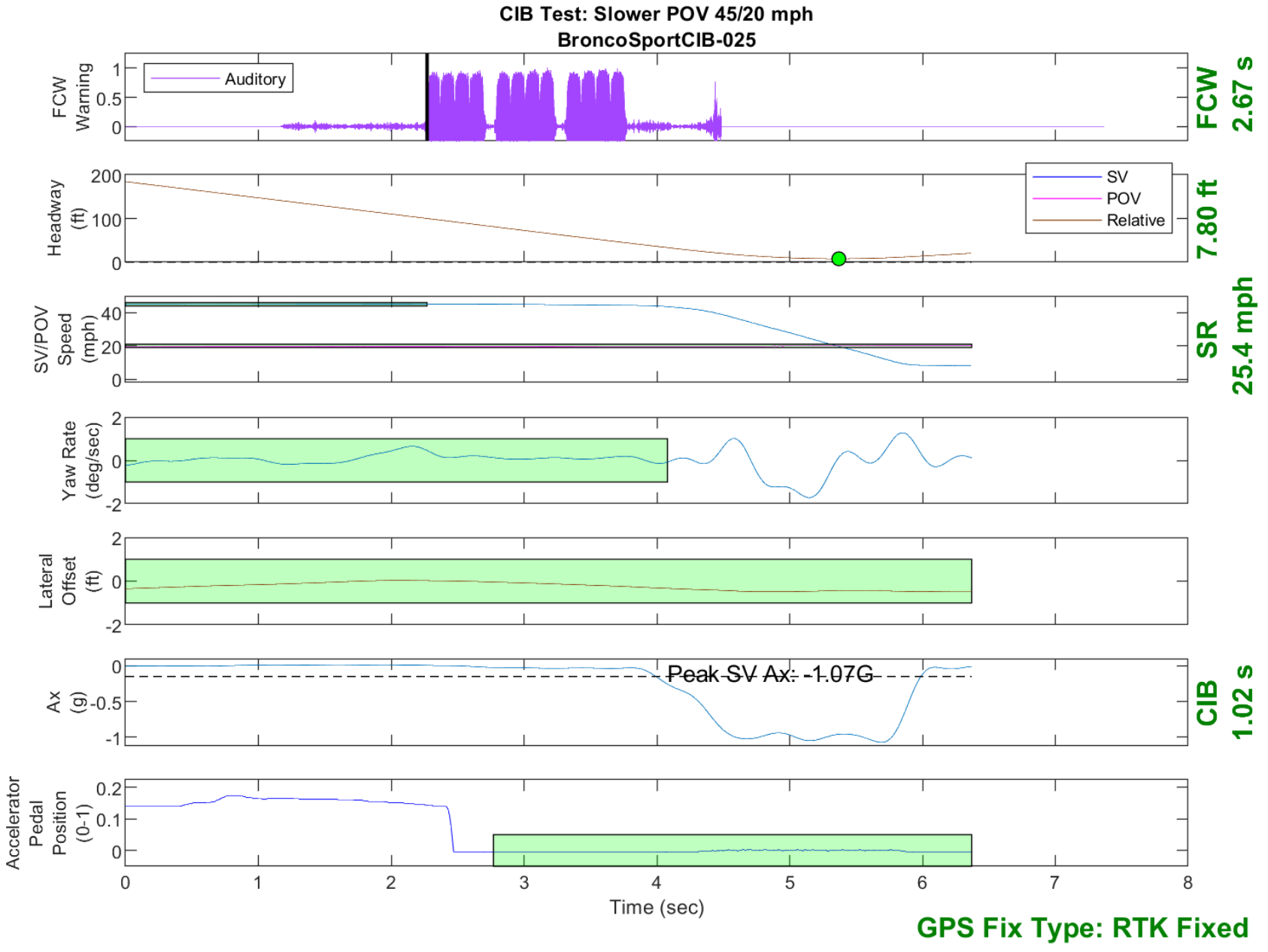


Figure D30. Time History for CIB Run 25, SV Encounters Slower POV, SV 45 mph, POV 20 mph

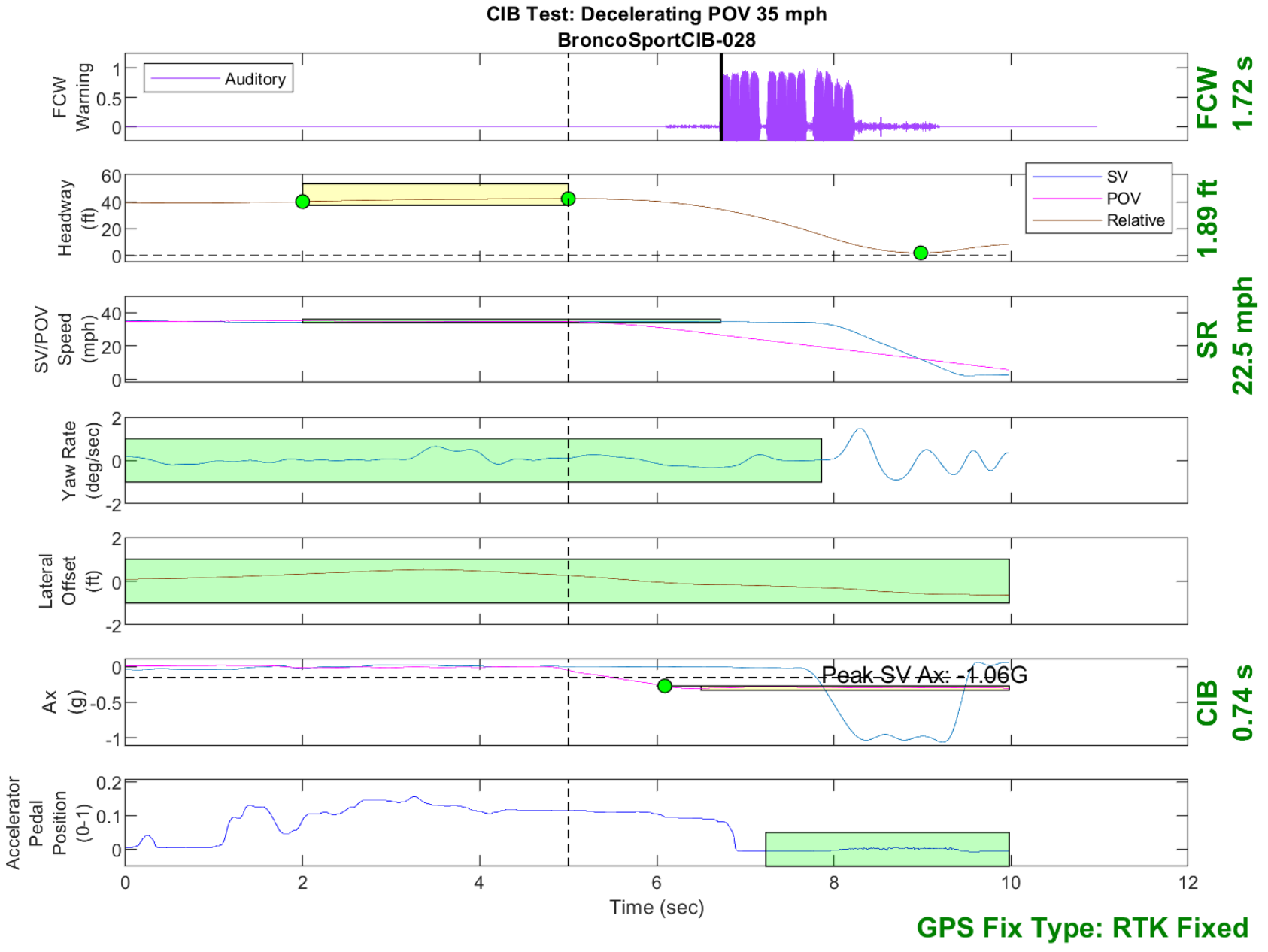


Figure D31. Time History for CIB Run 28, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

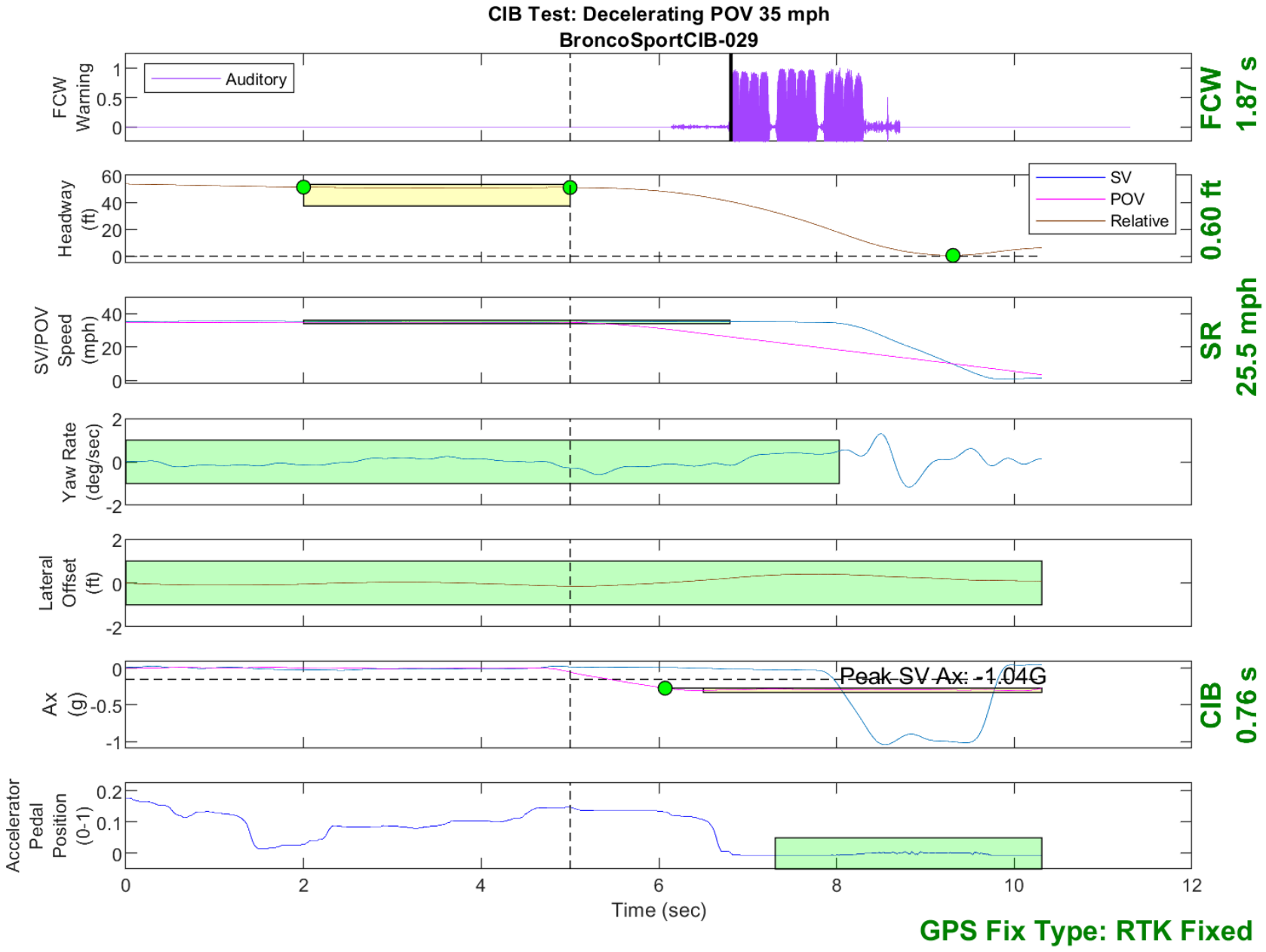


Figure D32. Time History for CIB Run 29, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

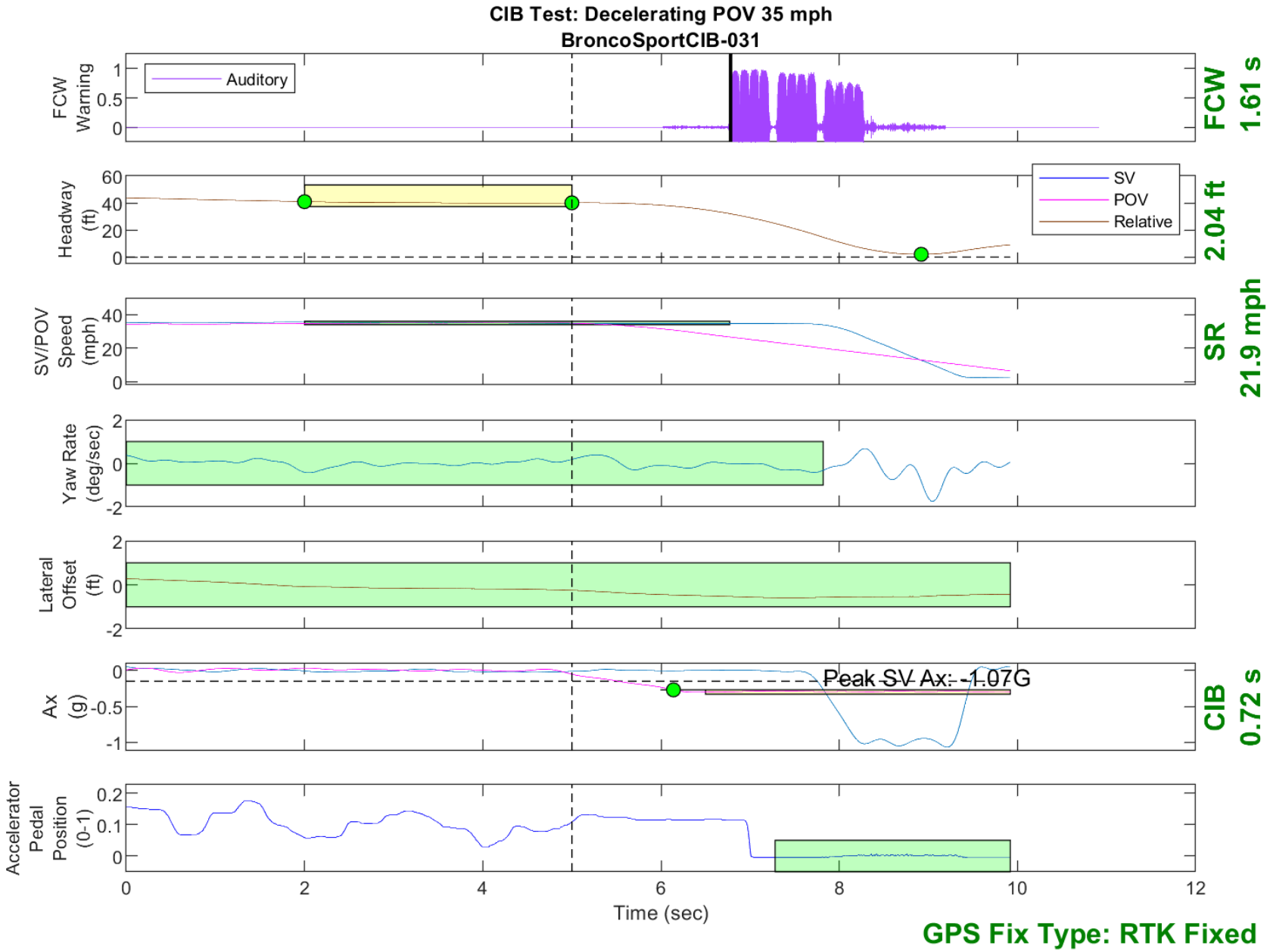


Figure D33. Time History for CIB Run 31, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

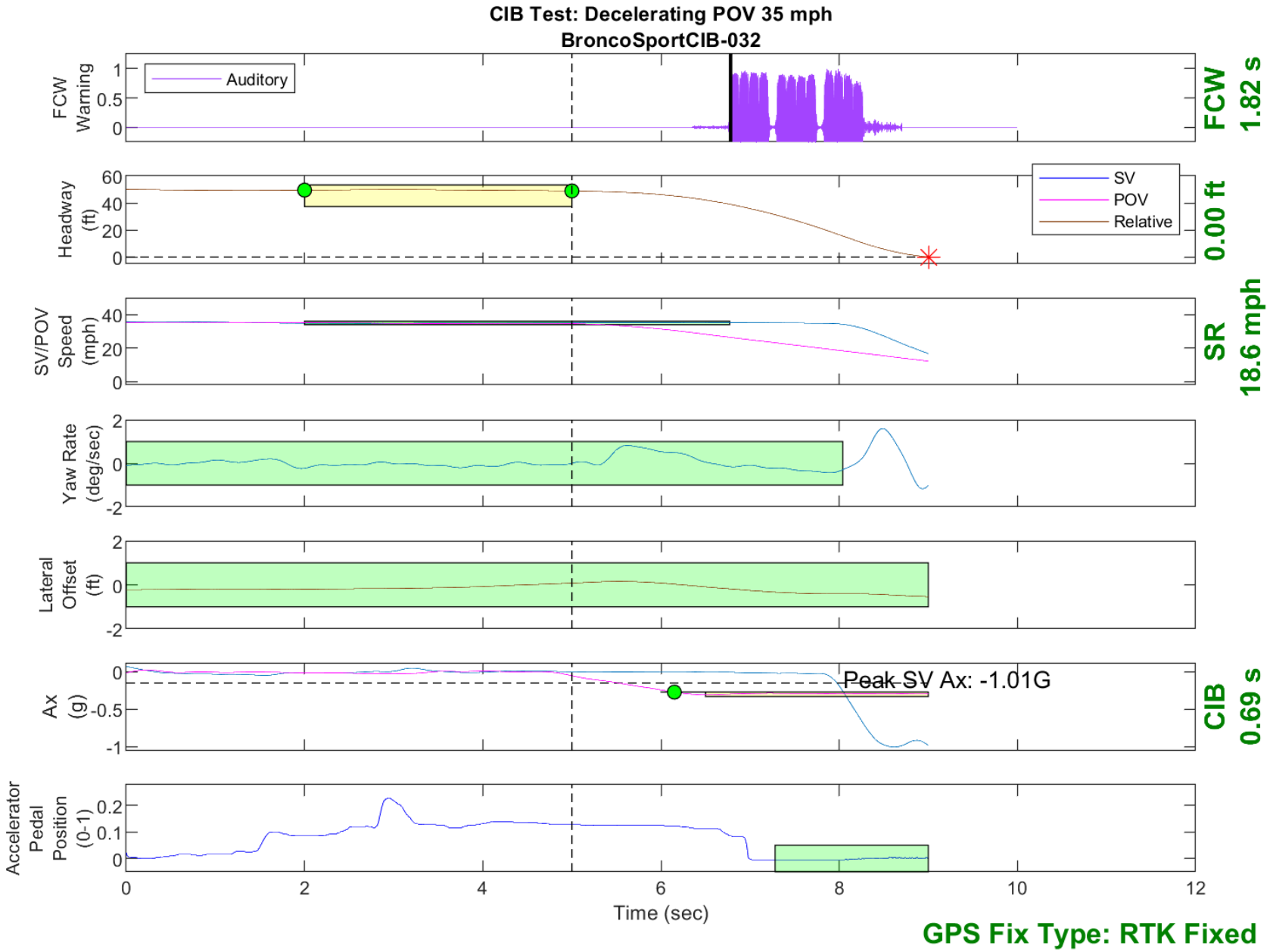


Figure D34. Time History for CIB Run 32, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

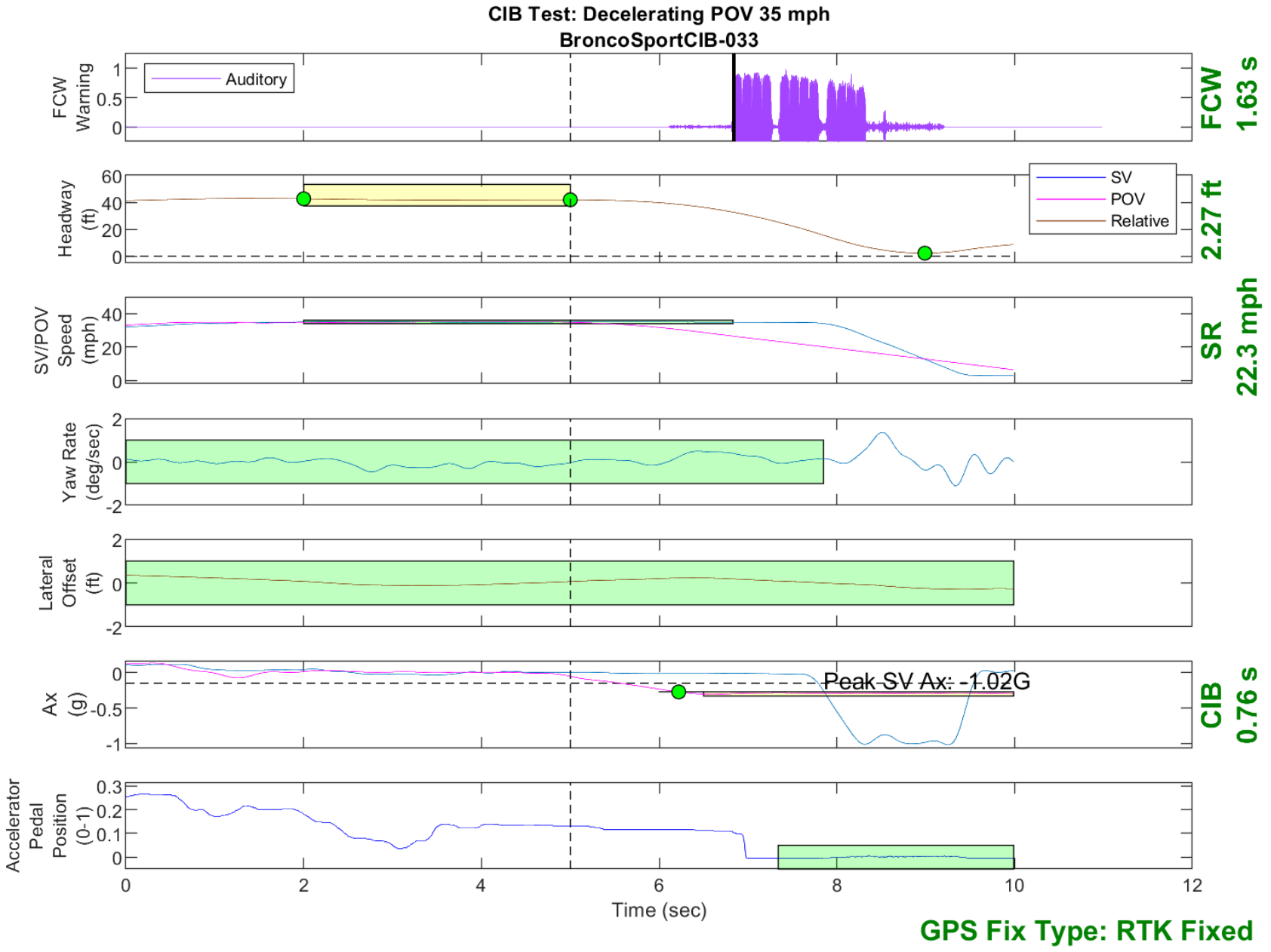


Figure D35. Time History for CIB Run 33, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

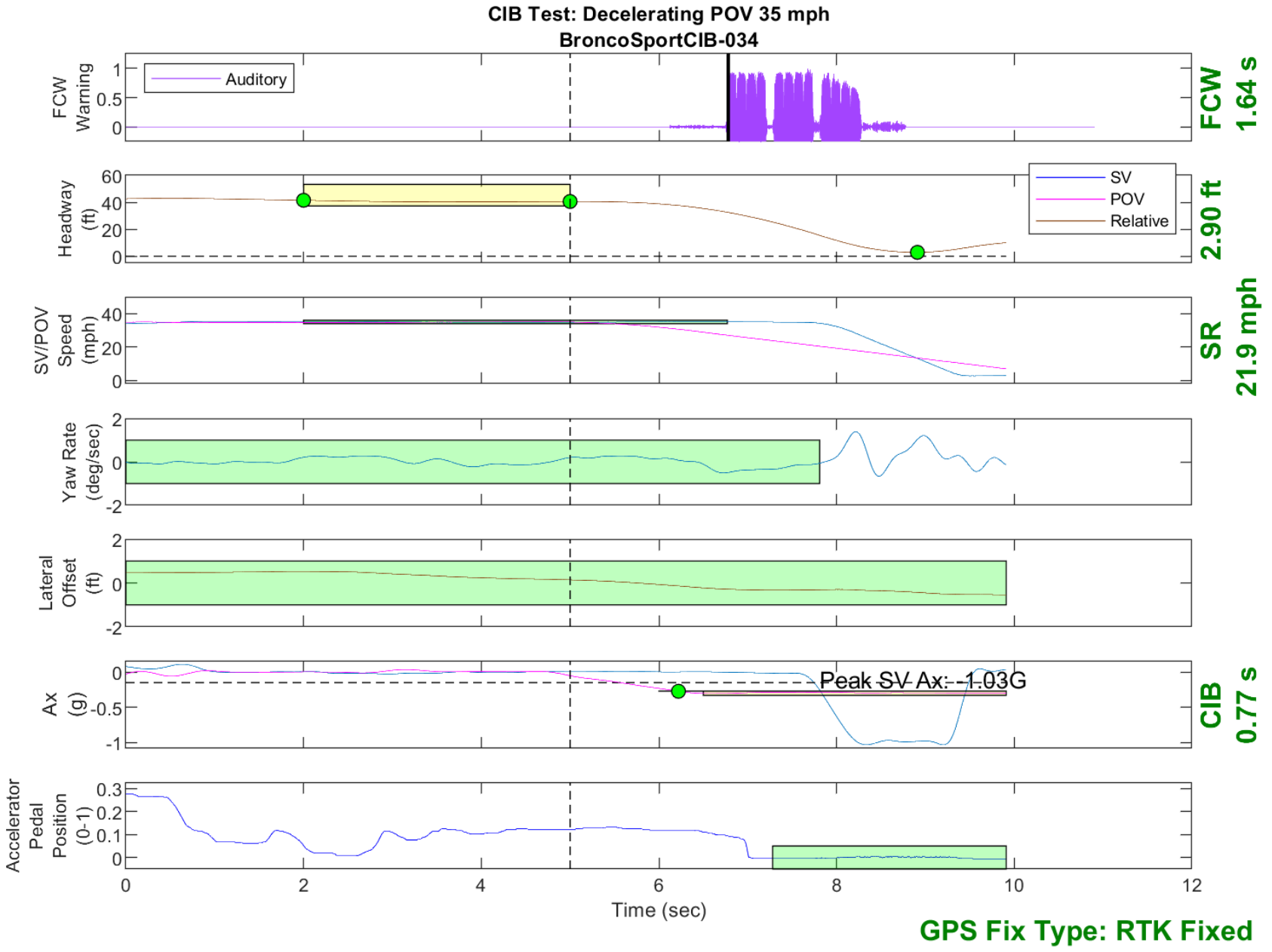


Figure D36. Time History for CIB Run 34, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

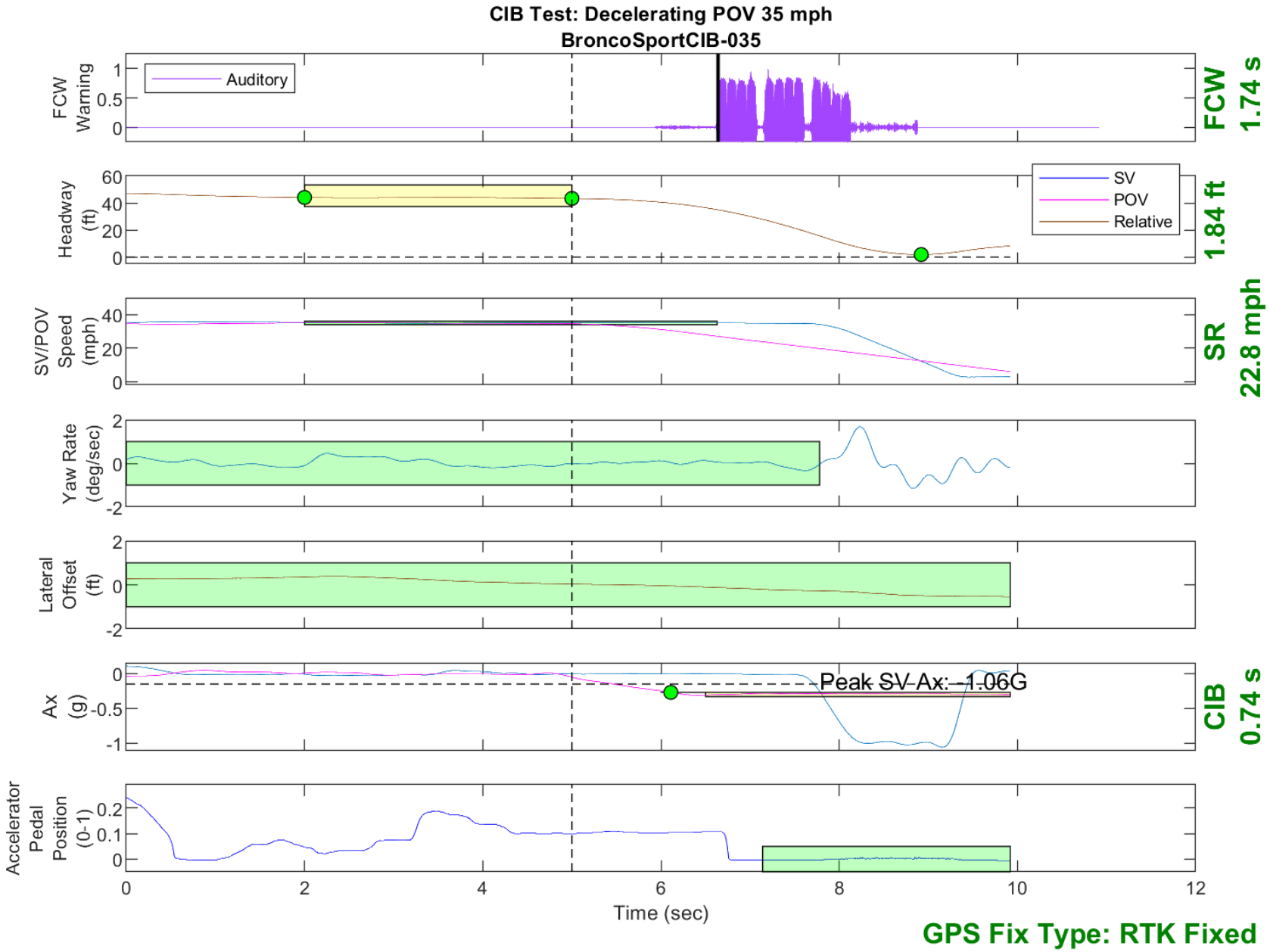


Figure D37. Time History for CIB Run 35, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

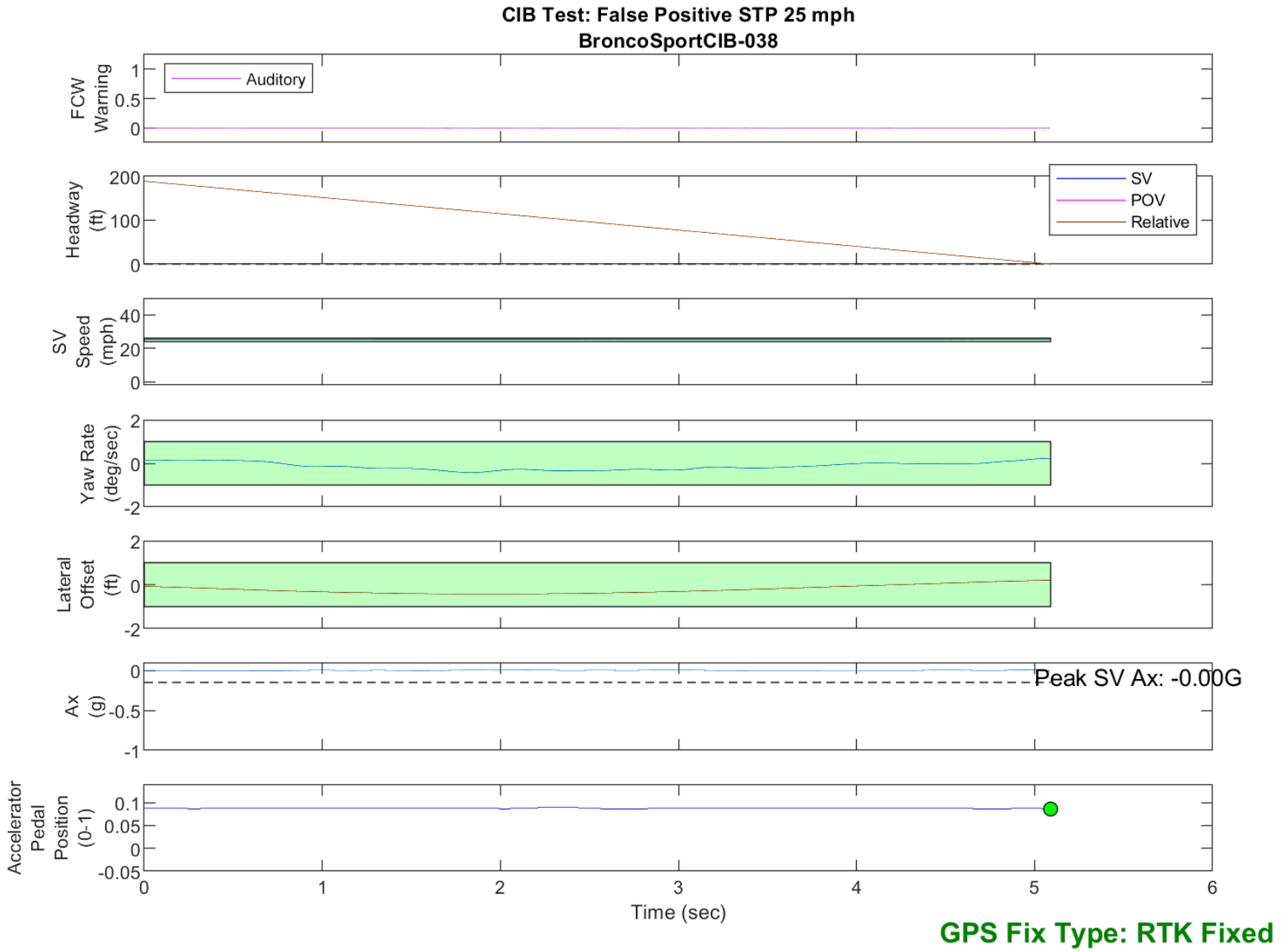


Figure D38. Time History for CIB Run 38, SV Encounters Steel Trench Plate, SV 25 mph

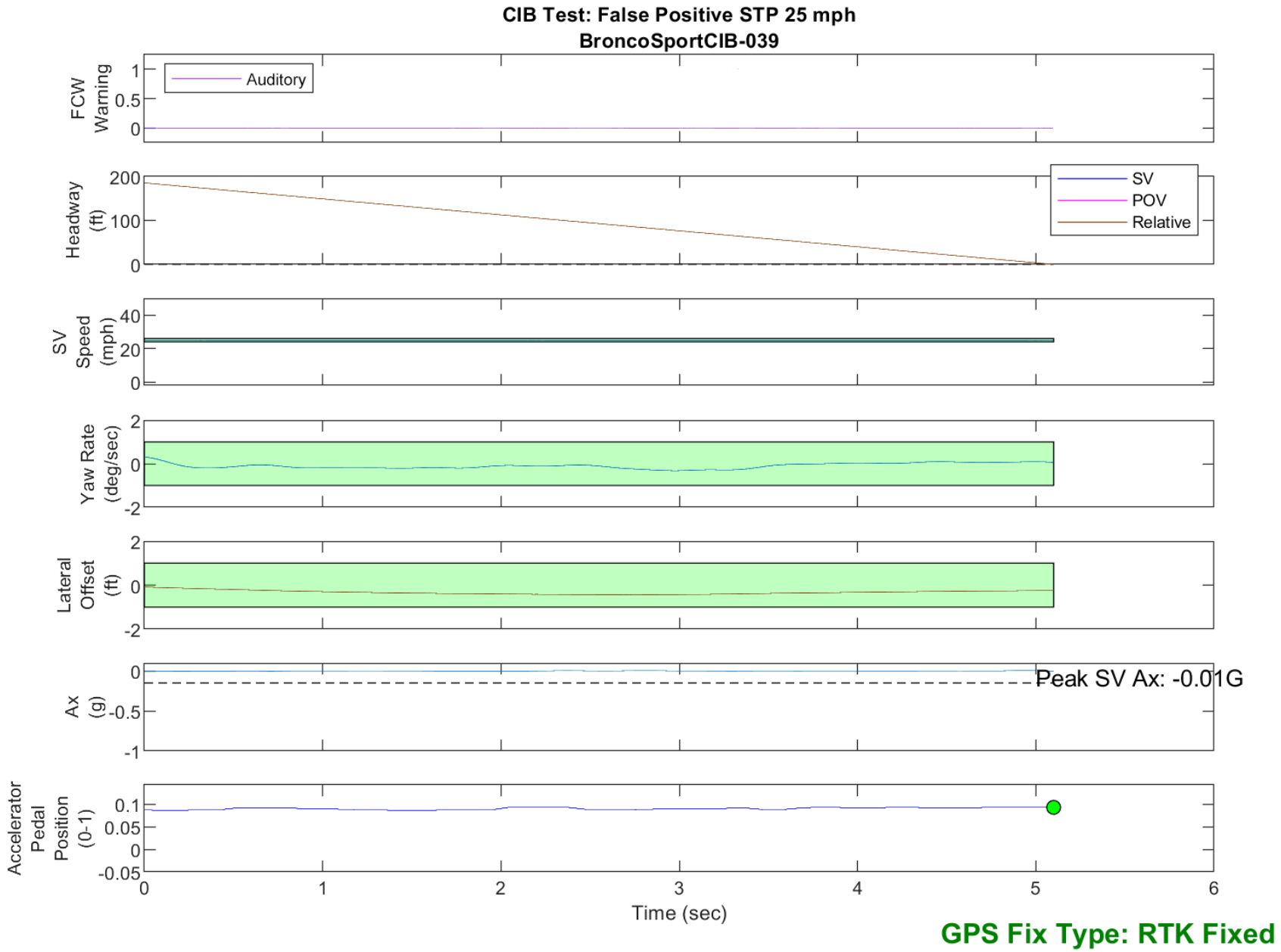


Figure D39. Time History for CIB Run 39, SV Encounters Steel Trench Plate, SV 25 mph

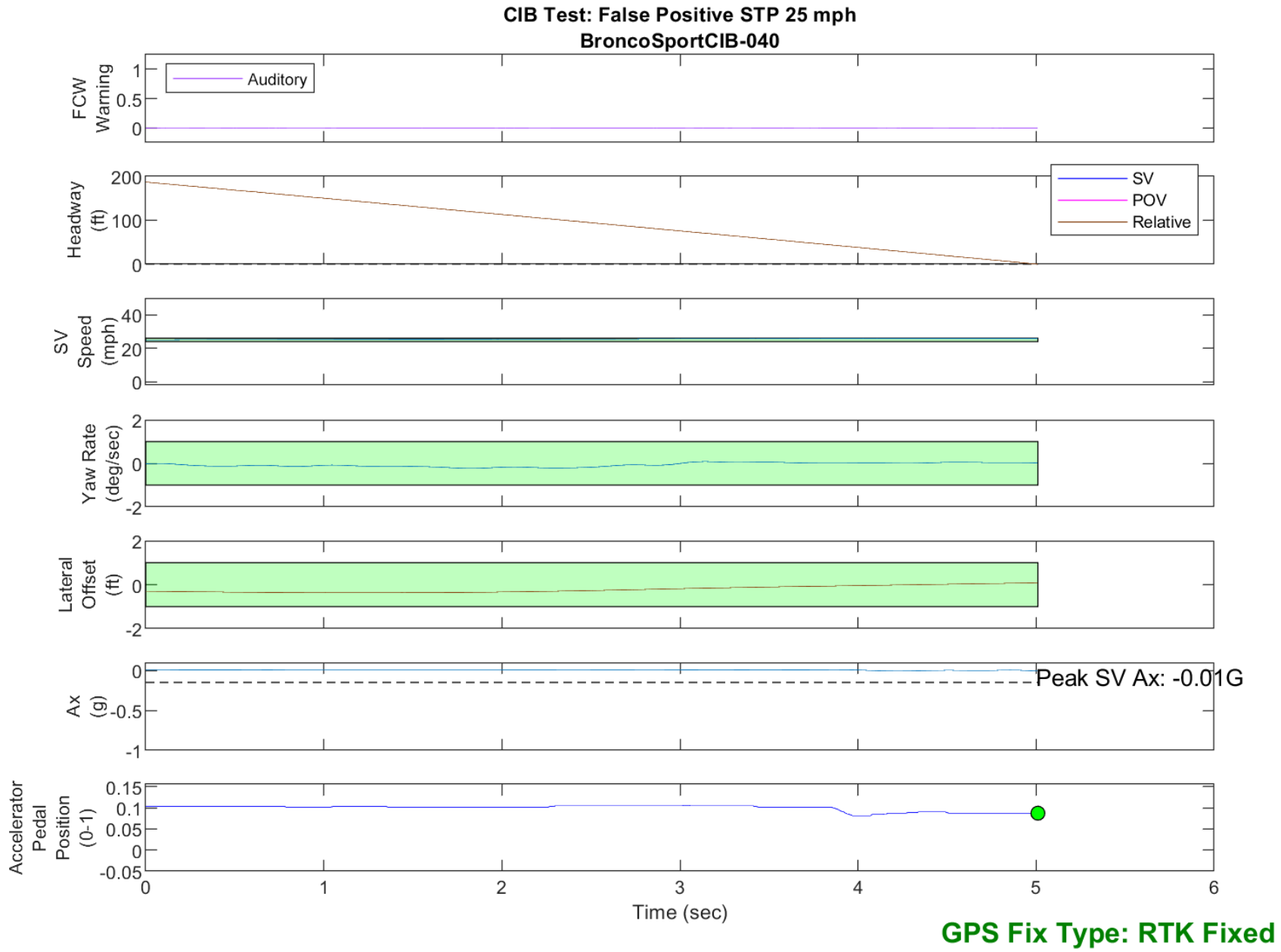


Figure D40. Time History for CIB Run 40, SV Encounters Steel Trench Plate, SV 25 mph

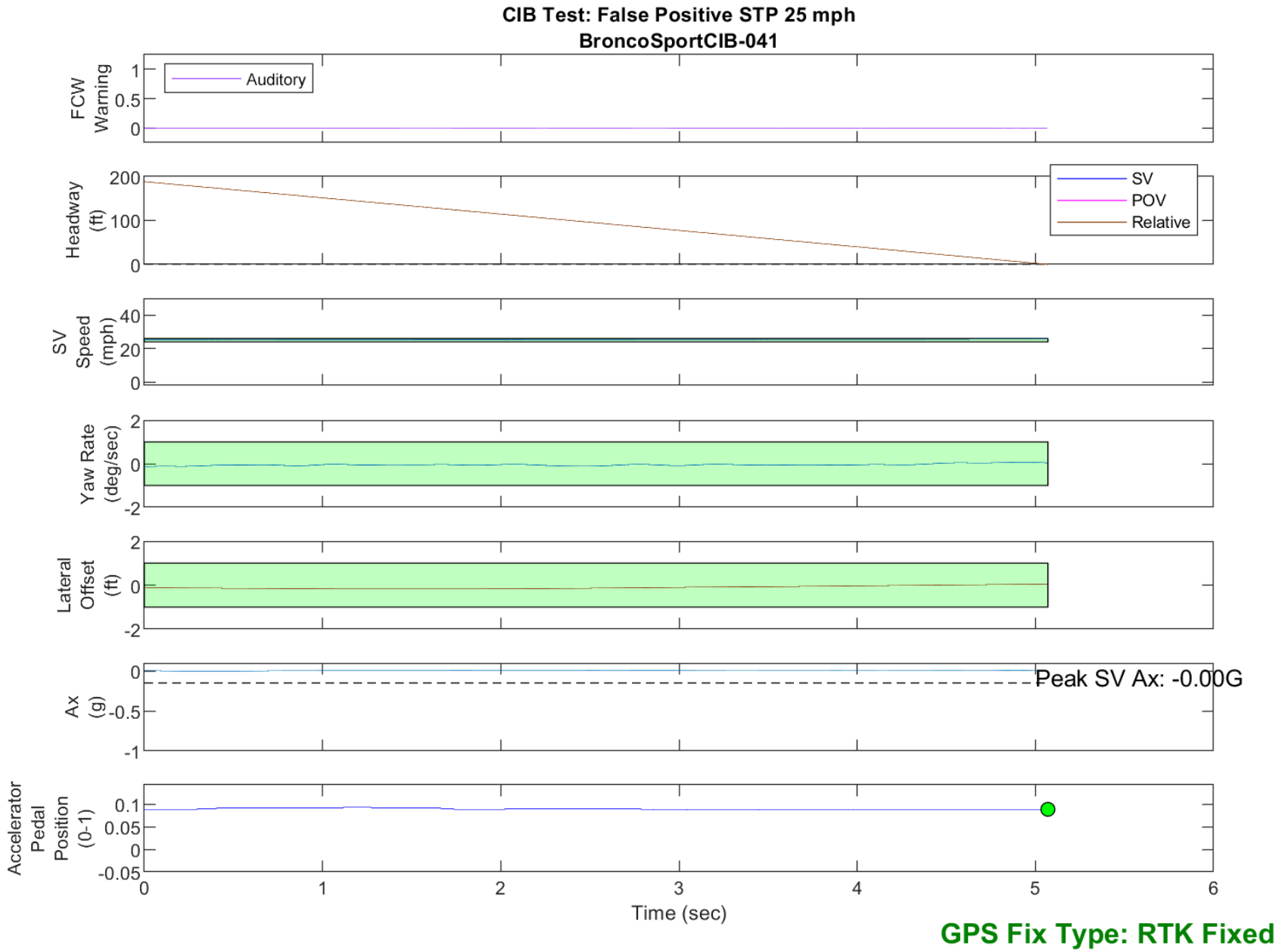


Figure D41. Time History for CIB Run 41, SV Encounters Steel Trench Plate, SV 25 mph

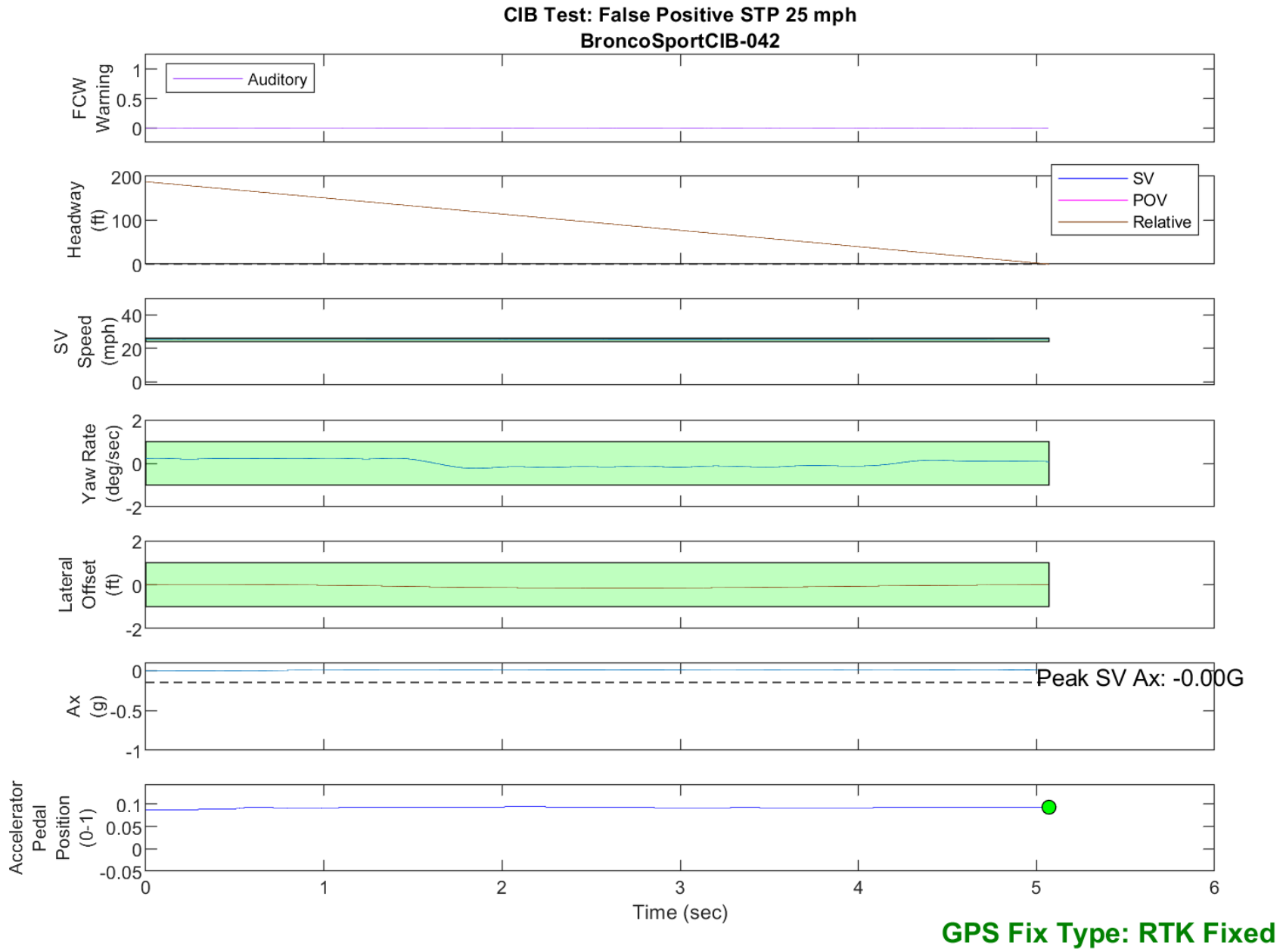


Figure D42. Time History for CIB Run 42, SV Encounters Steel Trench Plate, SV 25 mph

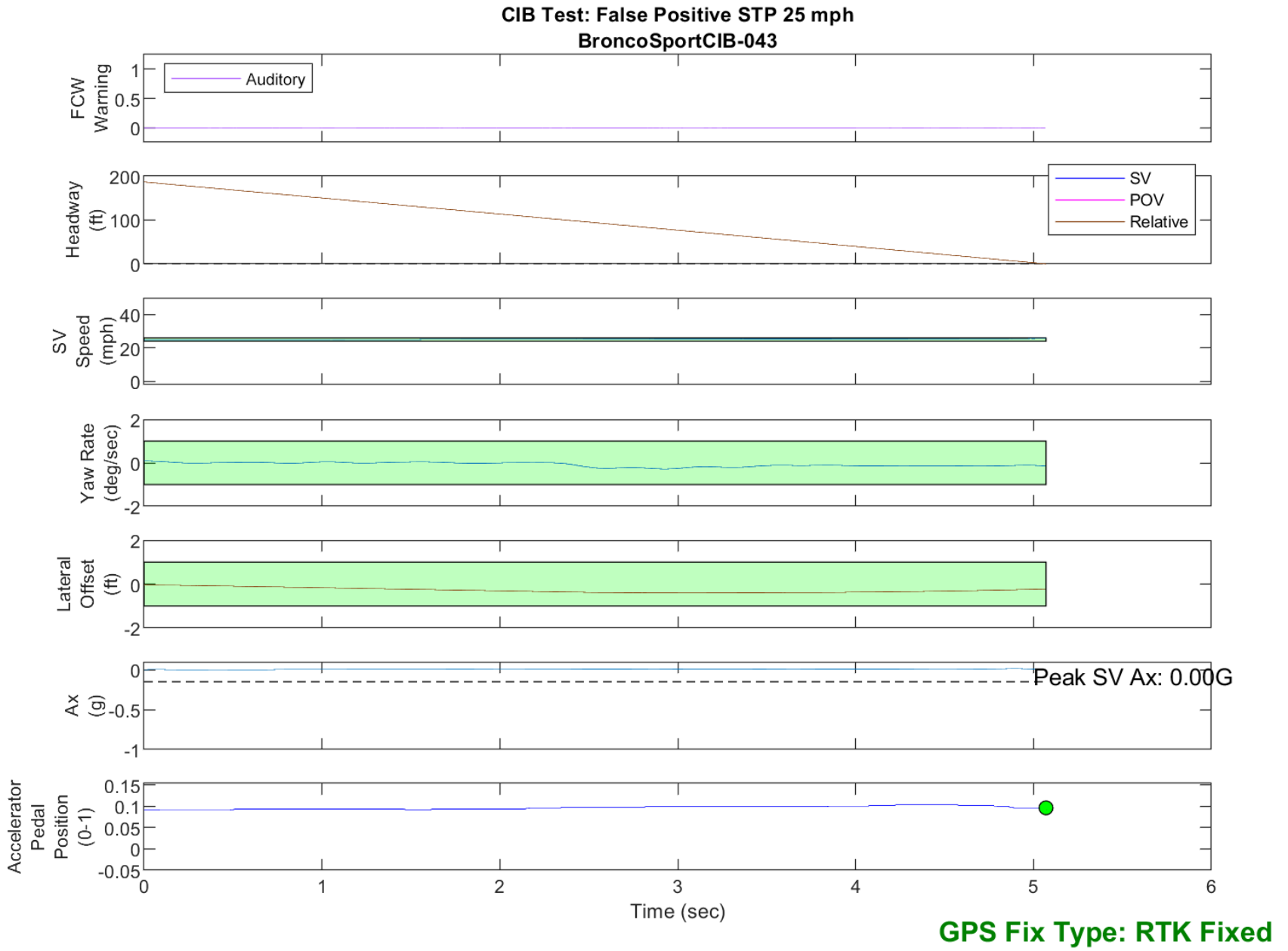


Figure D43. Time History for CIB Run 43, SV Encounters Steel Trench Plate, SV 25 mph

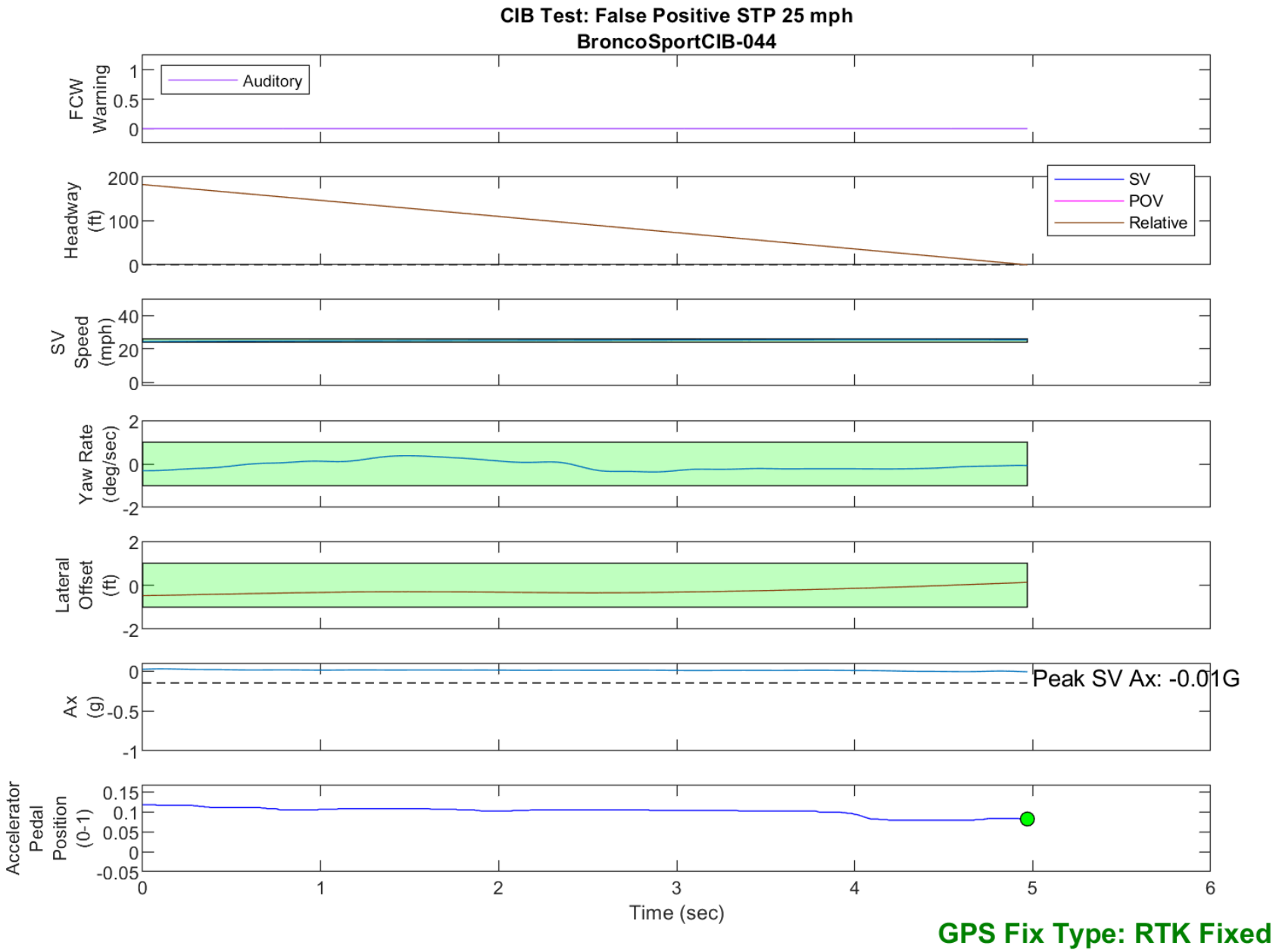


Figure D44. Time History for CIB Run 44, SV Encounters Steel Trench Plate, SV 25 mph

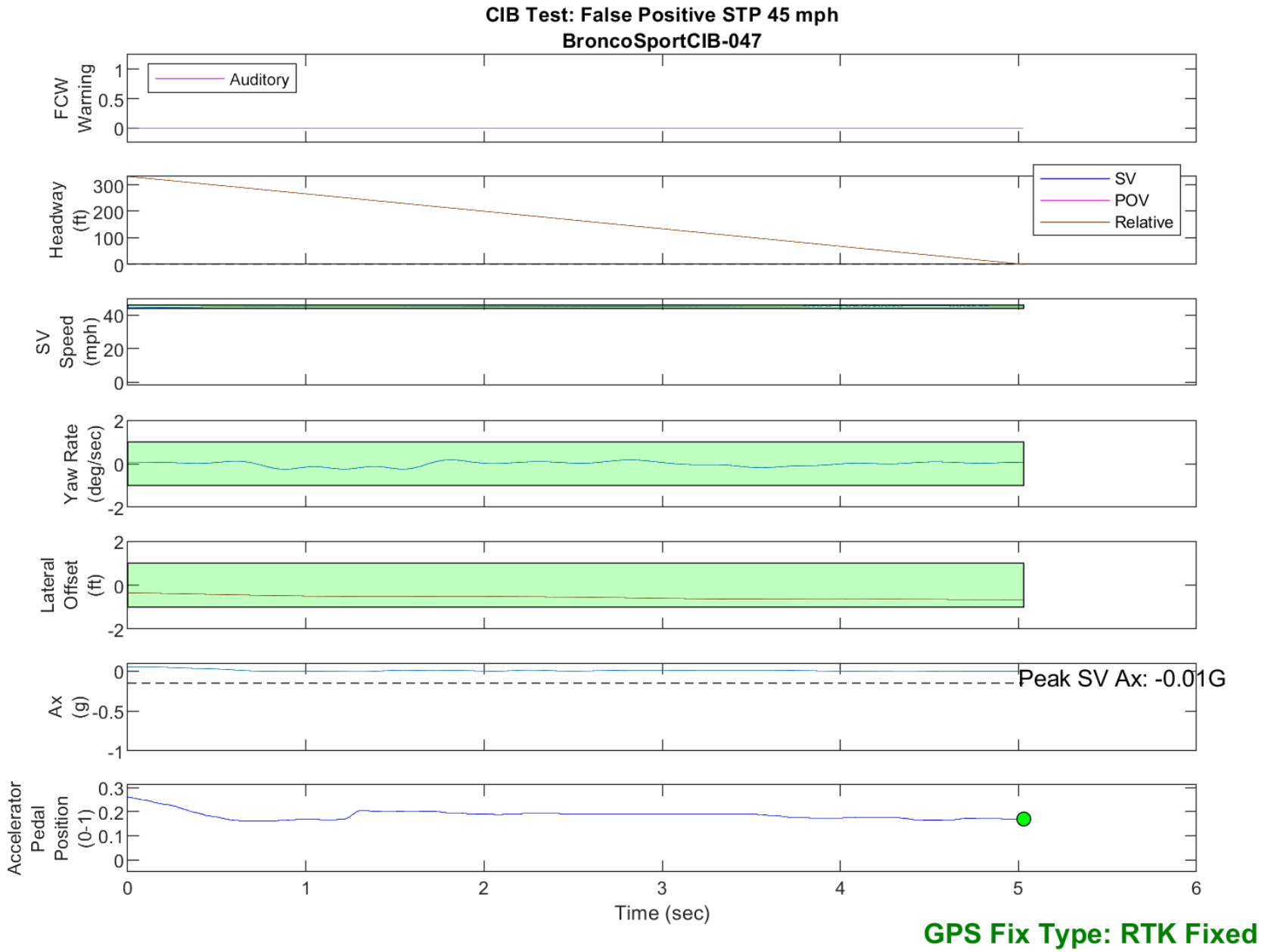


Figure D45. Time History for CIB Run 47, SV Encounters Steel Trench Plate, SV 45 mph

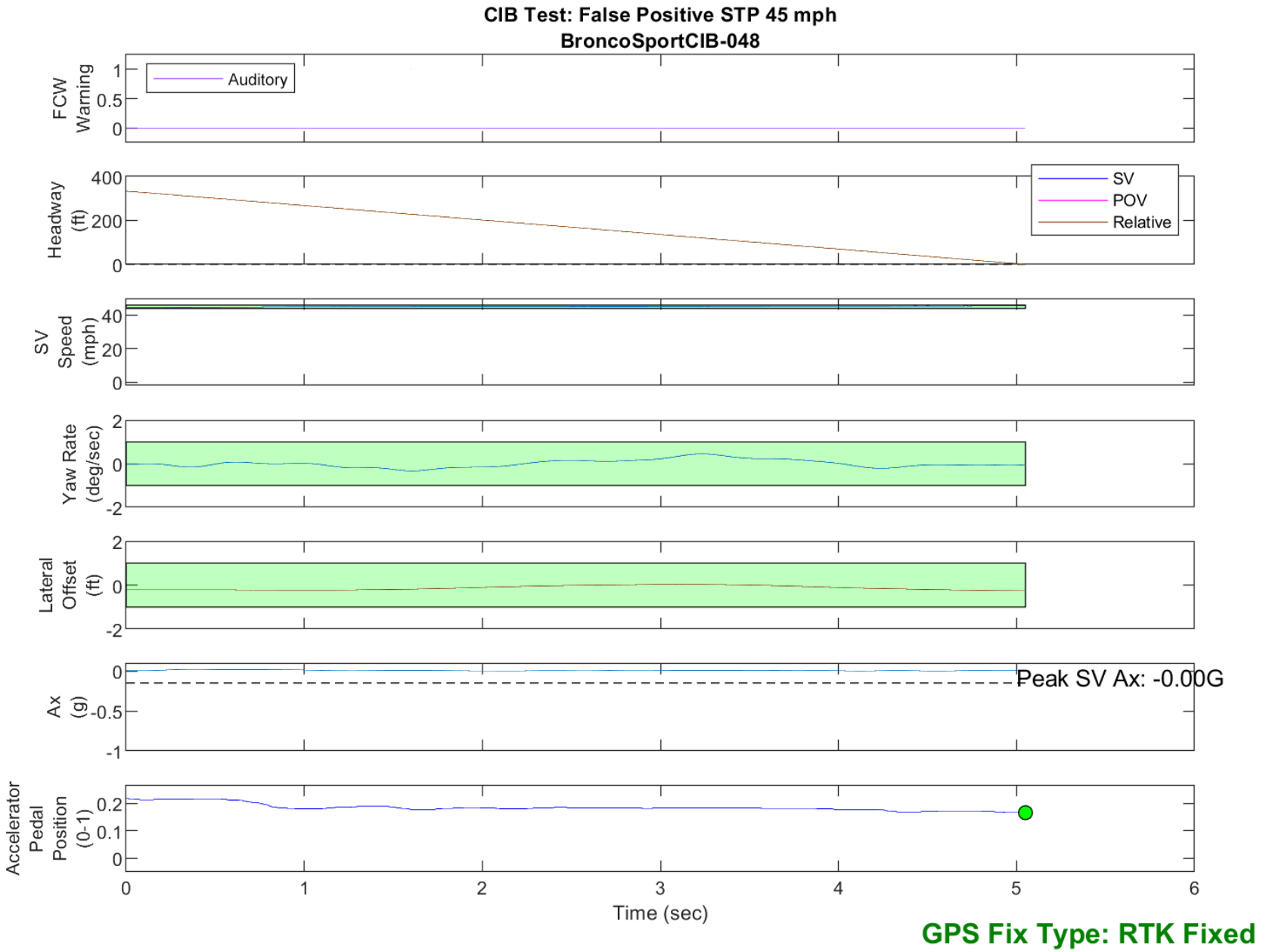


Figure D46. Time History for CIB Run 48, SV Encounters Steel Trench Plate, SV 45 mph

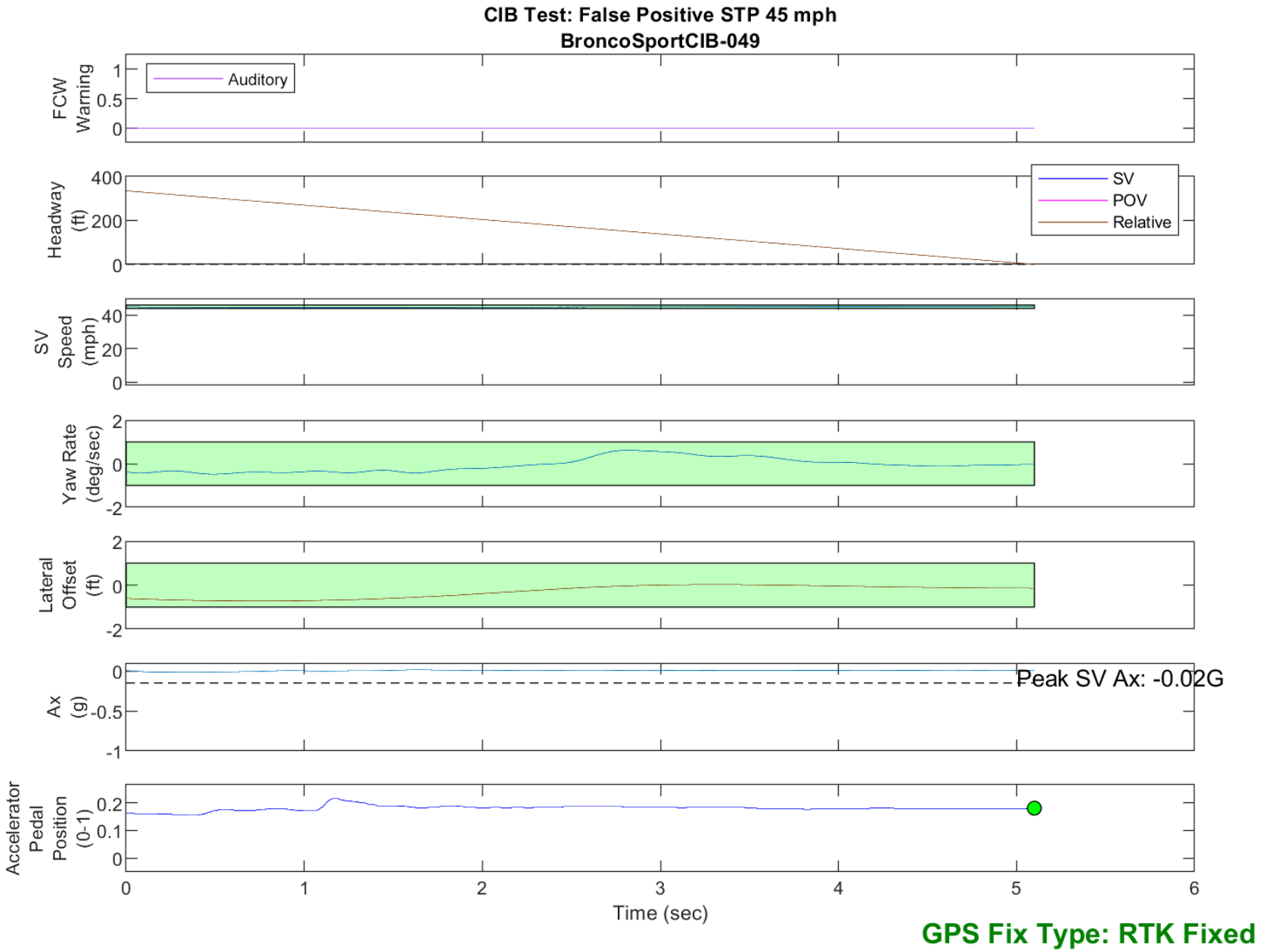


Figure D47. Time History for CIB Run 49, SV Encounters Steel Trench Plate, SV 45 mph

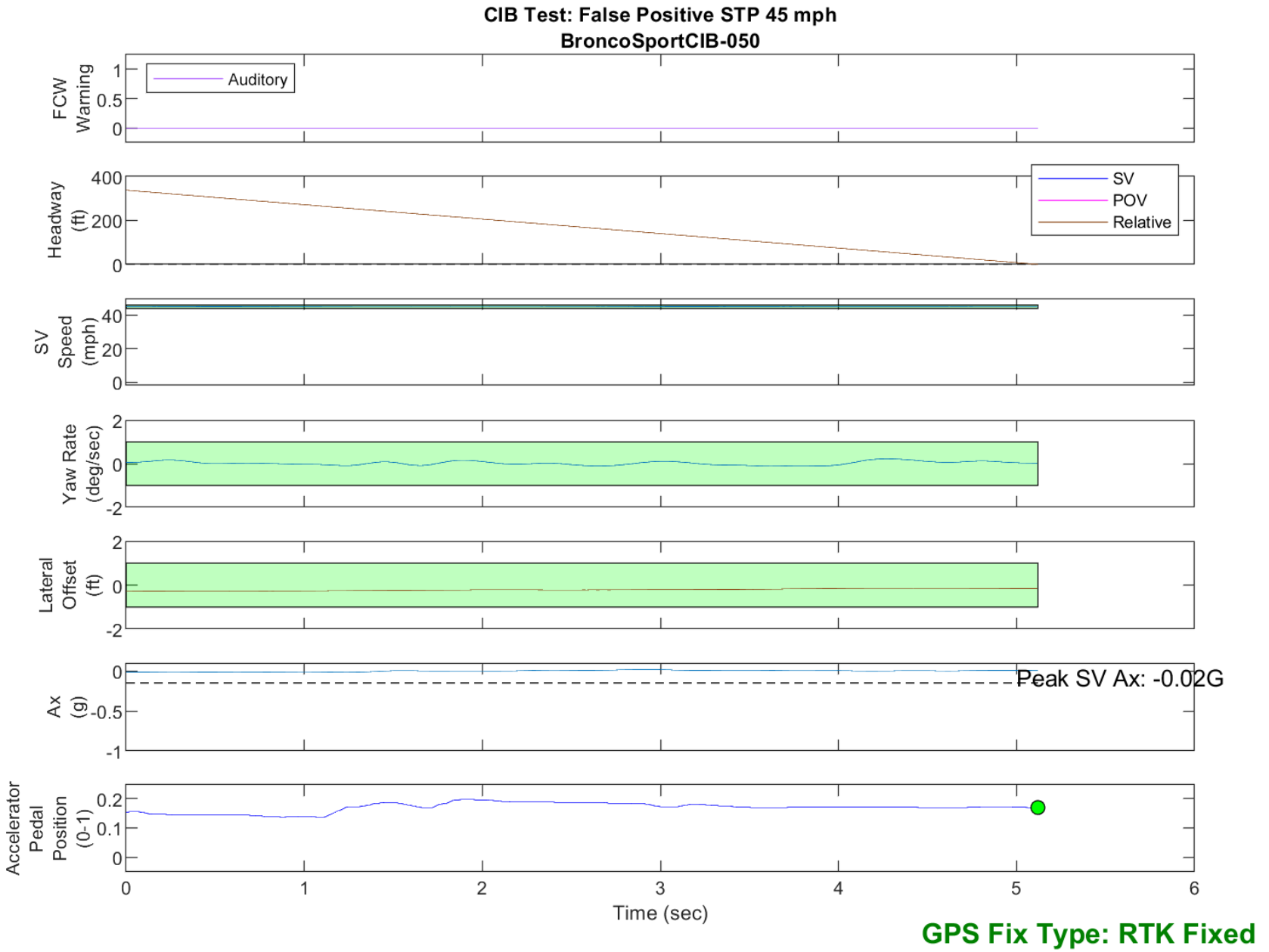


Figure D48. Time History for CIB Run 50, SV Encounters Steel Trench Plate, SV 45 mph

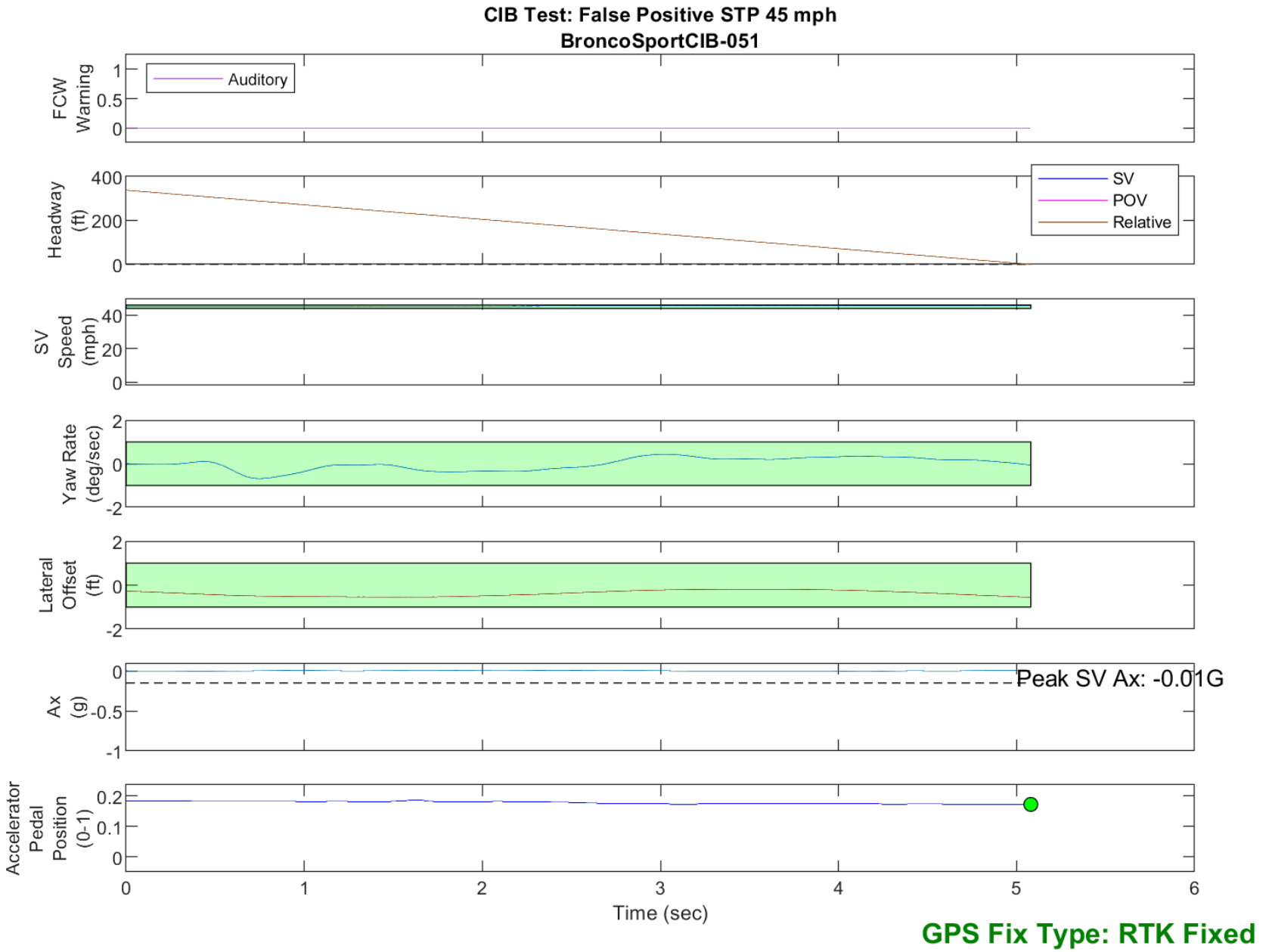


Figure D49. Time History for CIB Run 51, SV Encounters Steel Trench Plate, SV 45 mph

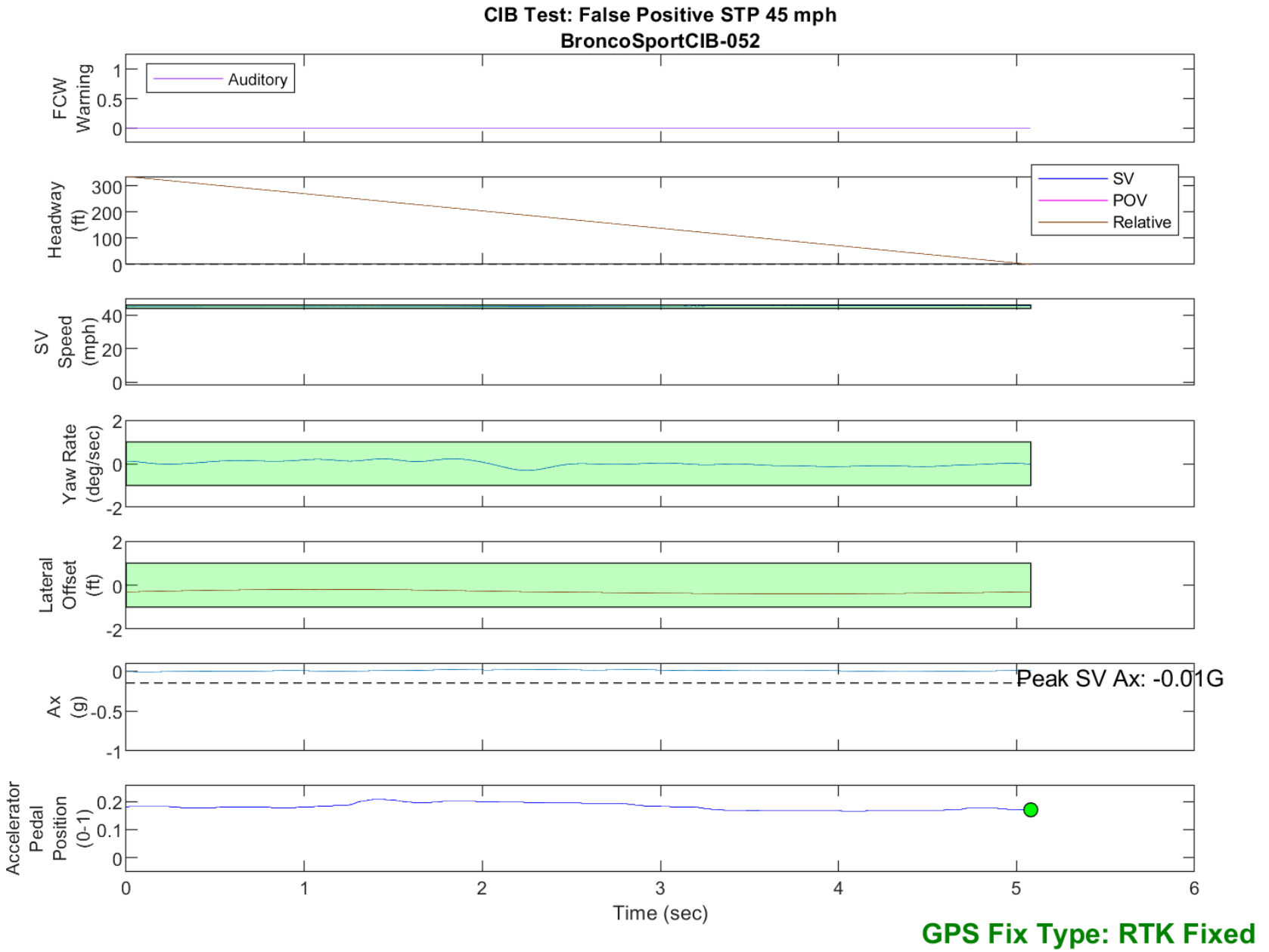


Figure D50. Time History for CIB Run 52, SV Encounters Steel Trench Plate, SV 45 mph

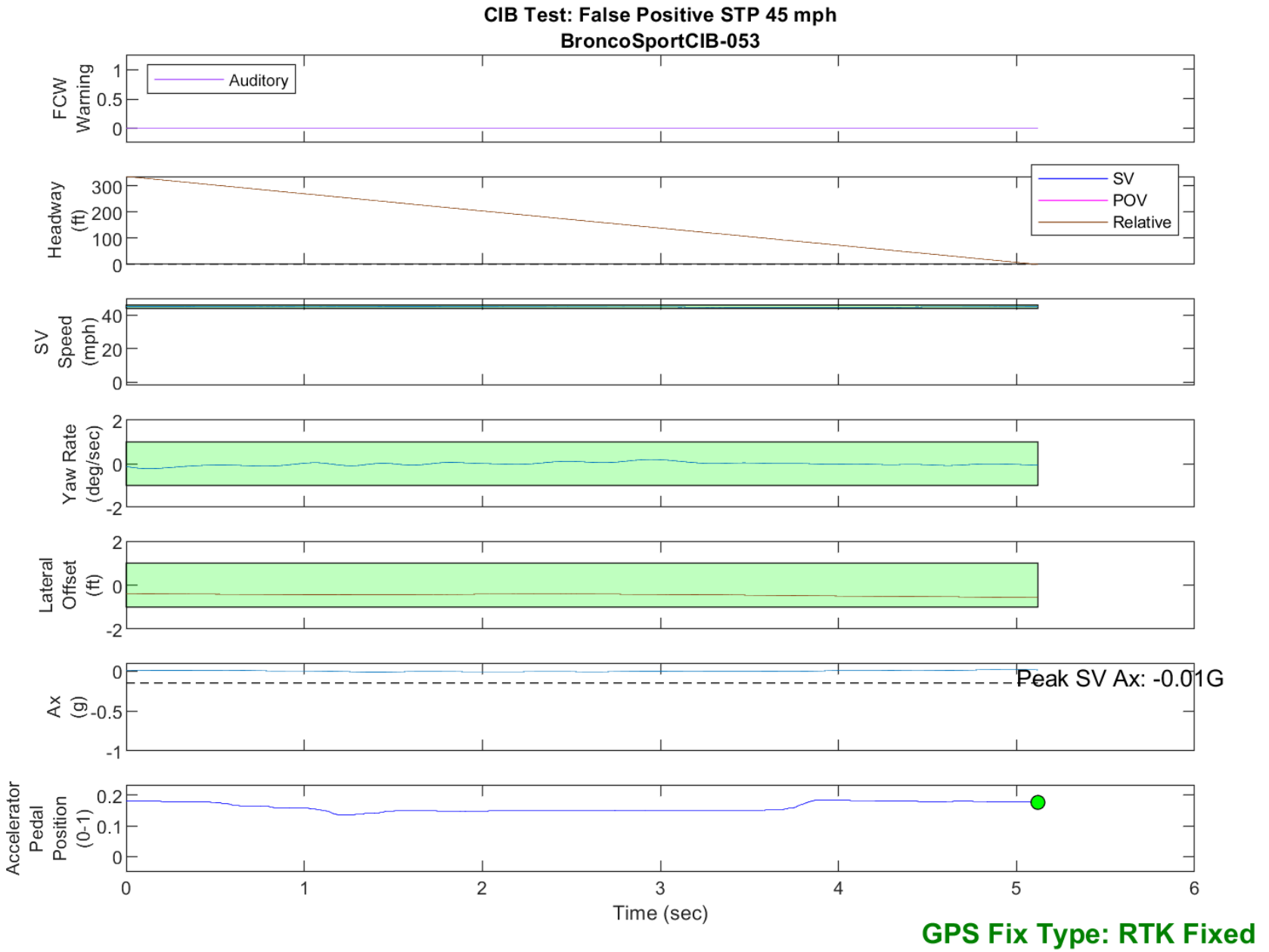


Figure D51. Time History for CIB Run 53, SV Encounters Steel Trench Plate, SV 45 mph