NEW CAR ASSESSMENT PROGRAM
CRASH IMMINENT BRAKE SYSTEM CONFIRMATION TEST
NCAP-DRI-CIB-20-09

2020 Lexus ES 350

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

28 February 2020

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.

Prepared By: J. Lenkeit — Program Manager

J. Partridge — Test Engineer

Date: 28 February 2020

<table>
<tr><td>1. Report No.

NCAP-DRI-CIB-20-09</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Final Report of Crash Imminent Brake System Confirmation Test of a 2020 Lexus ES 350.</td><td colspan="2">5. Report Date

28 February 2020</td></tr>
<tr><td colspan="2">6. Performing Organization Code

DRI</td></tr>
<tr><td colspan="2">7. Author(s)
J. Lenkeit, Program Manager
J. Partridge, Test Engineer</td><td colspan="2">8. Performing Organization Report No.

DRI-TM-19-147</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address

Dynamic Research, Inc.
355 Van Ness Ave, STE 200
Torrance, CA 90501</td><td colspan="2">10. Work Unit No.</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
DTNH22-14-D-00333</td></tr>
<tr><td colspan="2" rowspan="2">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, D.C. 20590</td><td colspan="2">13. Type of Report and Period Covered

Final Test Report
January - February 2020</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code

NRM-110</td></tr>
<tr><td colspan="4">15. Supplementary Notes</td></tr>
<tr><td colspan="4">16. Abstract
These tests were conducted on the subject 2020 Lexus ES 350 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 for the slower moving Principal Other Vehicle (POV), but failed the decelerating POV scenario, resulting in an overall Fail. The decelerating lead vehicle case was not completed, and the stopped POV and Steel Trench Plate scenarios were not tested due to damage to the vehicle sustained during the decelerating POV scenario.</td></tr>
<tr><td colspan="2">17. Key Words

Crash Imminent Brake,
CIB,
AEB,
New Car Assessment Program,
NCAP</td><td colspan="2">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, D.C. 20590</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
96</td><td>22. Price</td></tr>
</table>

TABLE OF CONTENTS

Section I

INTRODUCTION

Crash Imminent Brake (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 Brake system installed on a 2020 Lexus ES 350. This test is part of the New Car Assessment Program to assess Crash Imminent Brake 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 BRAKE SYSTEM

DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2020 Lexus ES 350

SUMMARY RESULTS

VIN: *58ADZ1B17LU0xxxx*

Test Date: *1/15/2020*

Crash Imminent Brake System setting: *Early*

Test 1 - Subject Vehicle Encounters Stopped Principal Other Vehicle

SV 25 mph: *Not tested**

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: *Fail, Testing not completed**

Test 4 - Subject Vehicle Encounters Steel Trench Plate

SV 25 mph: *Not tested**

SV 45 mph: *Not tested**

Overall: ***Fail***

Notes:
**Testing ended after damage to the vehicle was sustained during the decelerating lead vehicle case, Test 3.*

CRASH IMMINENT BRAKE SYSTEM

DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2020 Lexus ES 350

TEST VEHICLE INFORMATION

VIN: *58ADZ1B17LU0xxxx*

Body Style: *4-door Sedan* Color: *Eminent White*

Date Received: *1/6/2020* Odometer Reading: *6 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Toyota Motor Manufacturing. Kentucky, Inc.*

Date of manufacture: *11/19*

Vehicle Type: *PASS. CAR*

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: *235/45R18*

Rear: *235/45R18*

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

Rear: *240 kPa (35 psi)*

TIRES

Tire manufacturer and model: *Michelin Energy Saver A/S*

Front tire designation: *235/45R18 94V*

Rear tire designation: *235/45R18 94V*

Front tire DOT prefix: *B9EL 02NX*

Rear tire DOT prefix: *B9EL 02NX*

CRASH IMMINENT BRAKE SYSTEM

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Lexus ES 350

GENERAL INFORMATION

Test date: *1/15/2020*

AMBIENT CONDITIONS

Air temperature: *12.8 C (55 F)*

Wind speed: *1.0 m/s (2.3 mph)*

X Windspeed ≤ 10 m/s (22 mph)

X Tests were not performed during periods of inclement weather. This includes, but is not limited to, rain, snow, hail, fog, smoke, or ash.

X Tests were conducted during daylight hours with good atmospheric visibility (defined as an absence of fog and the ability to see clearly for more than 5000 meters). The tests were not conducted with the vehicle oriented into the sun during very low sun angle conditions, where the sun is oriented 15 degrees or less from horizontal, and camera "washout" or system inoperability results.

VEHICLE PREPARATION

Verify the following:

All non-consumable fluids at 100 % capacity: **X**

Fuel tank is full: **X**

Tire pressures are set to manufacturer's recommended cold tire pressure: **X**

Front: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

CRASH IMMINENT BRAKE SYSTEM
DATA SHEET 3: TEST CONDITIONS
(Page 2 of 2)

2020 Lexus ES 350

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*551.6 kg (1216 lb)*	Right Front	*545.2 kg (1202 lb)*
Left Rear:	*381.5 kg (841 lb)*	Right Rear:	*359.2 kg (792 lb)*
		Total:	*1837.5 kg (4051 lb)*

CRASH IMMINENT BRAKE

DATA SHEET 4: CRASH IMMINENT BRAKE SYSTEM OPERATION

2020 Lexus ES 350

Name of the CIB option, option package, etc.

Pre-collision warning as part of the Lexus Safety System+ 2.0 (LSS+ 2.0) option

Type of sensors the system uses:

LSS+ 2.0: Millimeter wave Radar and Mono camera

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

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

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

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

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

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

____ No

If yes, please provide a full description.

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

- *Driving along the lane marker for more than 1 km at greater than 35mph driving speed.*
- *1 km distance driving is not necessarily continuous driving, but split driving in total of 1 km distance is OK.*
- *Lane marker should exist both on sides (left and right) and it does not matter whether it is a solid line or dotted line.*
- *It is ideal to put several vehicles (2-3 vehicles) beside the driving lane to be detected by camera.*
- *No sensor calibration completed indication will be displayed to the driver.*

Please make sure no IG OFF (engine is not shut off) after sensor calibration is completed. If an ignition cycle occurs again, sensor calibration needs to be done again.

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

____ Yes

X No

If yes, please provide a full description.

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

How is the Crash Imminent Brake System alert presented to the driver?

(Check all that apply)

X Warning light

X Buzzer or audible alarm

____ Vibration

____ Other ____________

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

When the system determines that the possibility of a frontal collision is high, a buzzer will sound and a warning message will be displayed on the multi-information display located to the left of the center gauge in the instrument cluster. The display shows "BRAKE!" in white letters on a red background as shown in Appendix A Figure XX. The auditory alert is presented tone bursts of 2400 HZ at a rate of approximately 4 bursts/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.

The settings menus (displayed as a gear) are accessed by controls on the left side of the steering wheel. The pre-collision warning system can be turned on/off by scrolling up or down to the PCS On/Off image and toggling the system on or off using the "OK" button.

The system resets to "on" at each ignition cycle.

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

X Yes

___ No

If yes, please provide a full description.

The settings menus (displayed as a gear) are accessed by controls on the left side of the steering wheel. The pre-collision warning timing can be changed on the settings menu of the multi-information display by scrolling up/down to the "Sensitivity" image and toggling through the available options using the "OK" button. For FCW/AEB the available options are Early, Middle (default) and Late. See Figures A15 and A16 in Appendix A.
The warning timing setting is retained when the engine switch is turned off. However, if the pre-collision system is disabled and re-enabled, the operation timing will return to the default setting (middle).

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.

A detailed description of the limitations of the system is given in the Owner's Manual on pages 176 through 181 shown in Appendix B, pages B-4 through B-9.

Notes:

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.

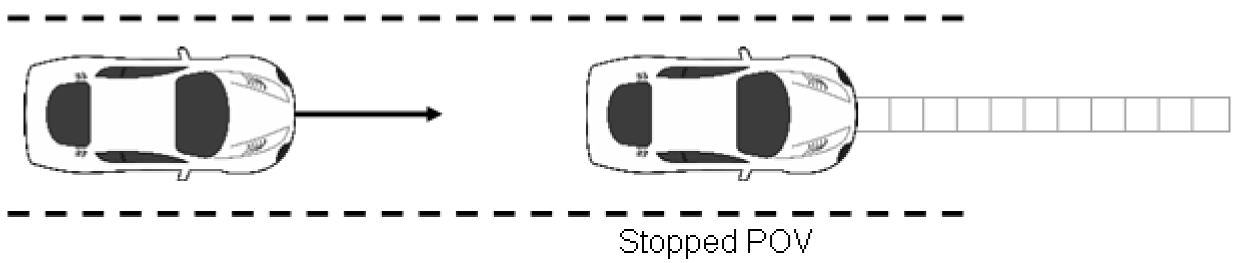


Figure 1. Depiction of Test 1

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.

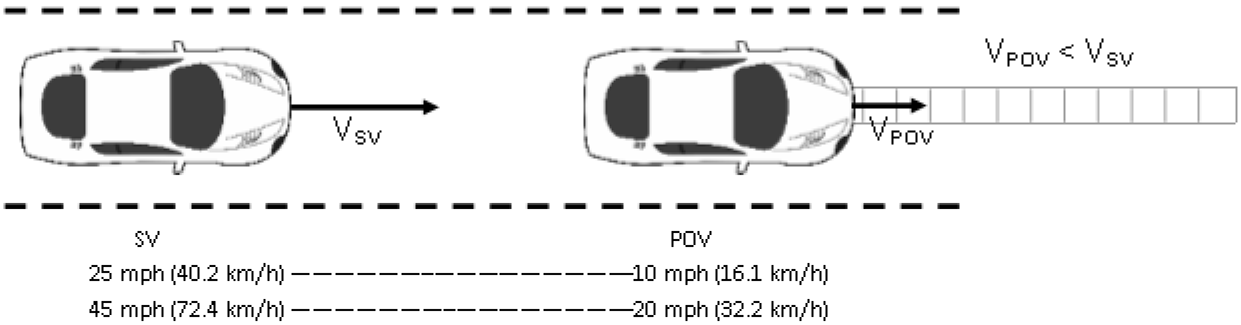


Figure 2. Depiction of Test 2

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-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-POV range during the validity period from the SV speed at t_{FCW}.

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

This test evaluates the ability of the CIB system to detect and respond to a lead vehicle slowing with a constant deceleration in the immediate forward path of the SV, as depicted in Figure 3.

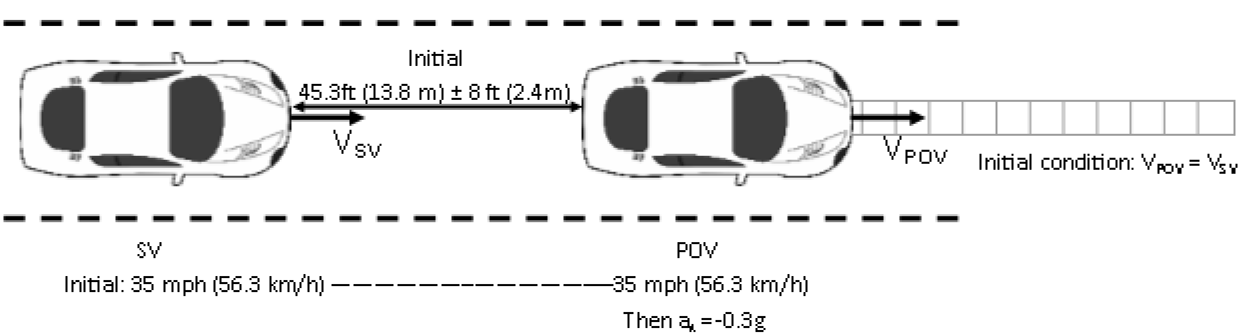


Figure 3. Depiction of Test 3 with POV Decelerating

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-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 haptic or audible, 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 bandpass 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. Audible and Tactile Warning Filter Parameters

Warning Type	Filter Order	Peak-to-Peak Ripple	Minimum Stop Band Attenuation	Pass-Band 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 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 0.25g.
- 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-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, and 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 DBS 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 POV-SV 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 subject vehicle is also equipped with an automatic braking system (E-brake) for the purpose of slowing the subject vehicle 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.

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	Omega DPG8001	17042707002	By: DRI Date: 6/21/2018 Due: 6/21/2019
Platform Scales	Vehicle Total, Wheel, and Axle Load	1200 lb/platform 5338 N/	0.5% of applied load	Intercomp SWI	1110M206352	By: DRI Date: 1/3/2019 Due: 1/3/2020
Linear (string) encoder	Throttle pedal travel	10 in 254 mm	0.1 in 2.54 mm	UniMeasure LX-EP	45040532	By: DRI Date: 5/10/2019 Due: 5/10/2020
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	NA
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +		By: Oxford Technical Solutions
					2258	Date: 5/3/2019 Due: 5/3/2021
					2176	Date: 4/11/2018 Due: 4/11/2020

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	NA
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	NA	NA
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	NA	NA
Accelerometer	Acceleration (to measure time at alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	NA	NA
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: 1/2/2019 Due: 1/2/2020

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

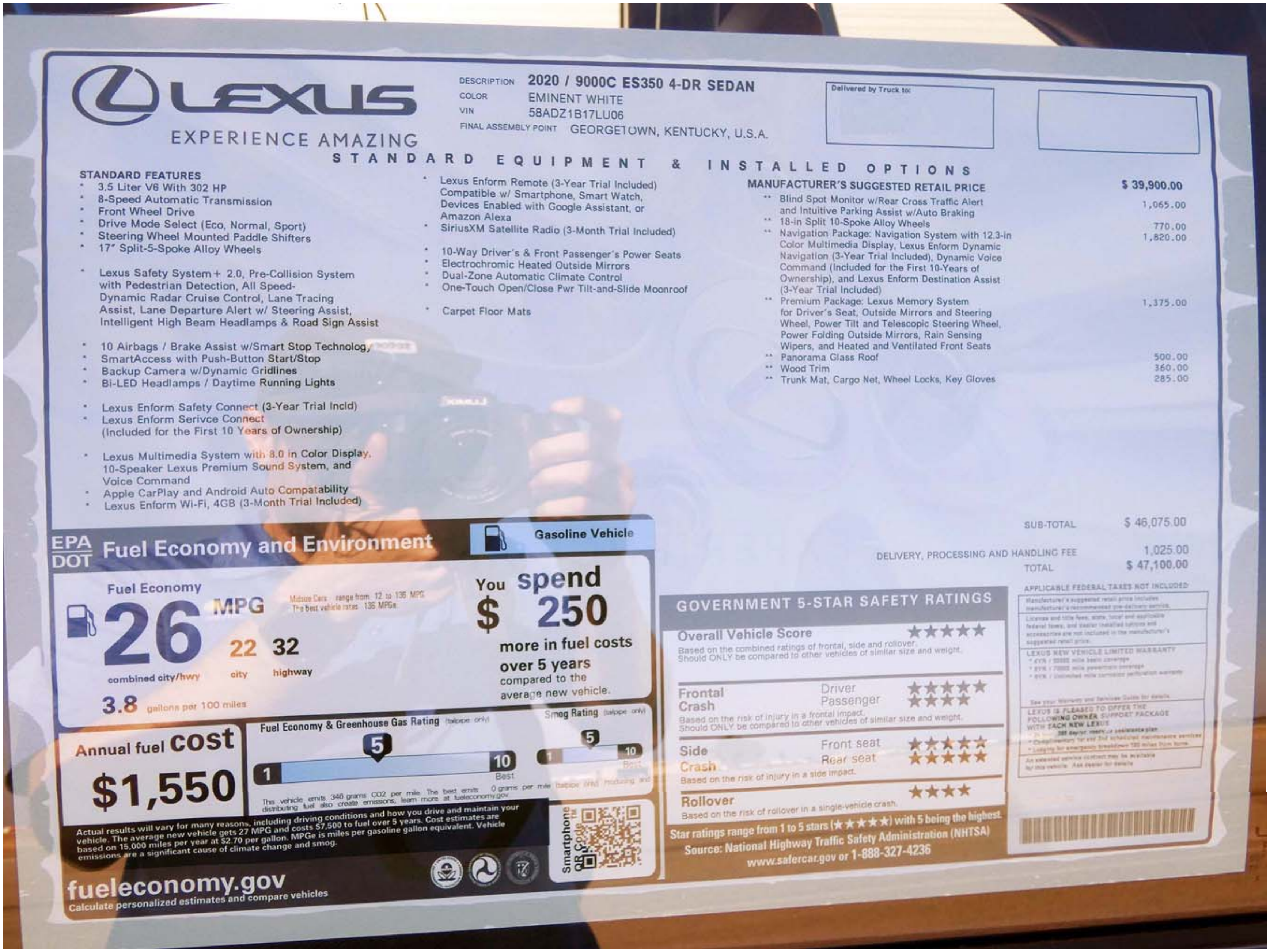


Figure A3. Window Sticker (Monroney Label)

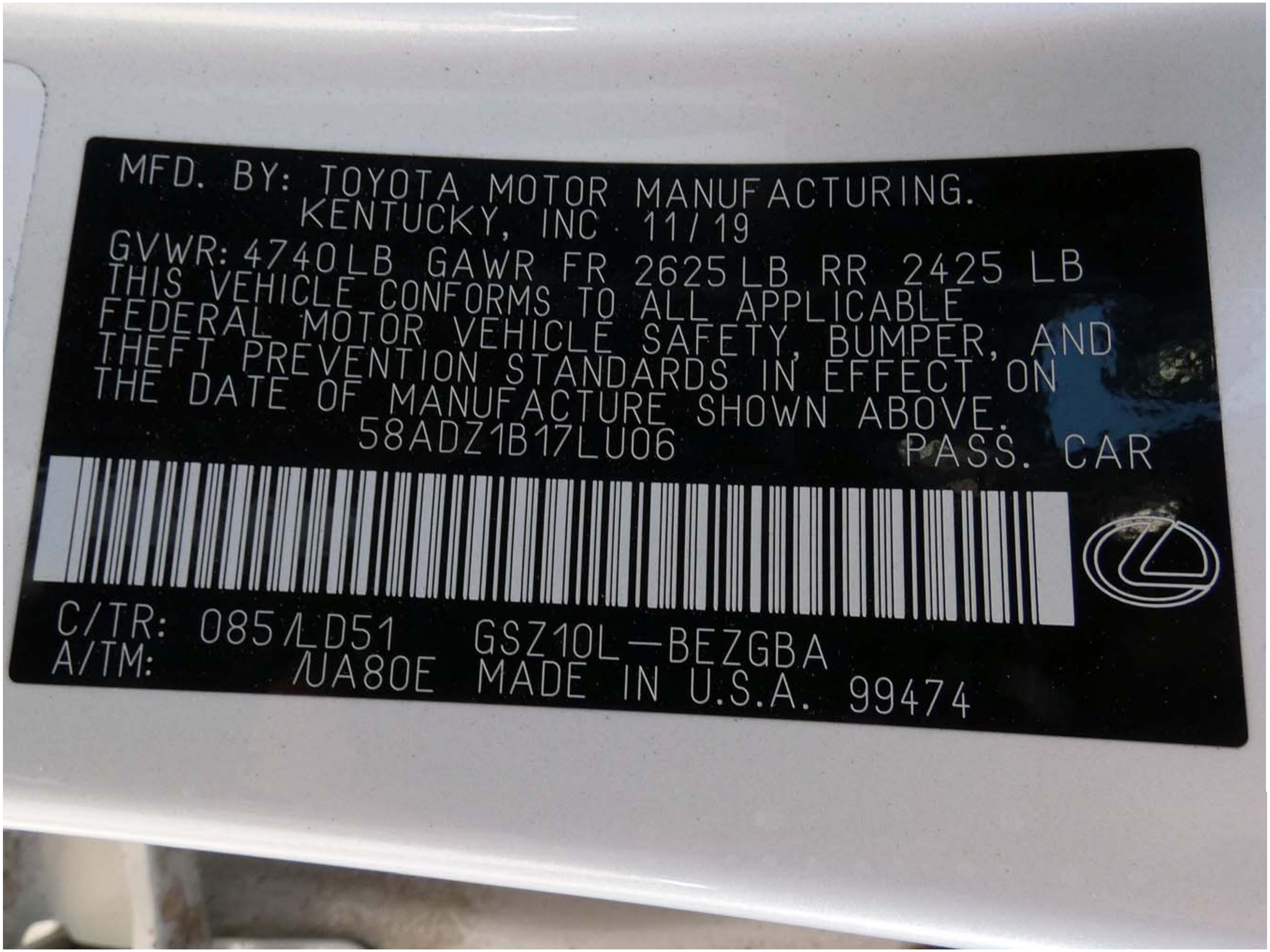


Figure A4. Vehicle Certification Label

Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

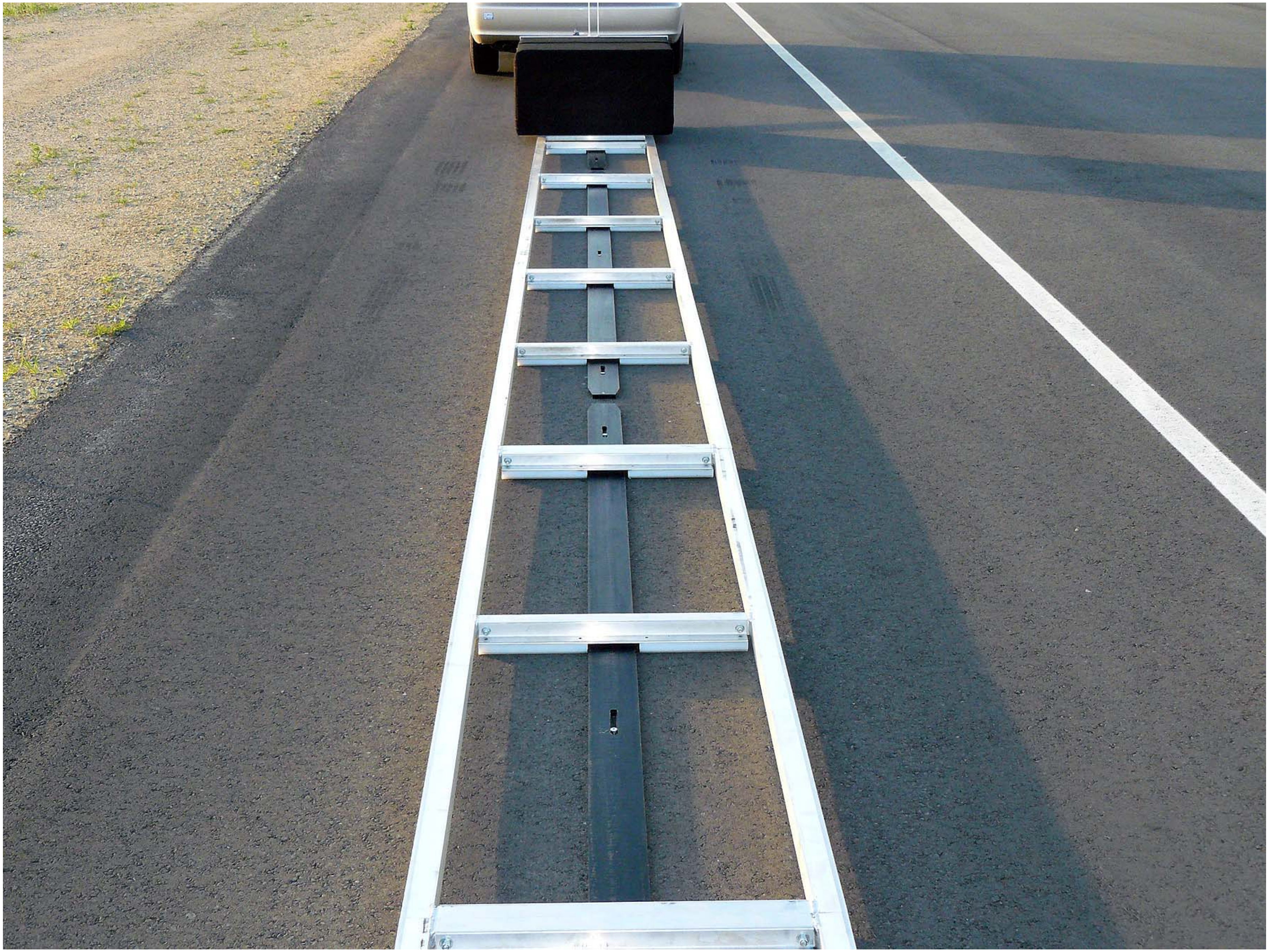


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

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

Figure A11. Sensor for Detecting Visual Alerts

Figure A12. Computer Installed in Subject Vehicle

Figure A13. Brake Actuator Installed in POV System

Figure A14. Brake Actuator Installed in Subject Vehicle

Figure A15. AEB Setup Menus

Figure A16. Control for Changing Vehicle Parameters

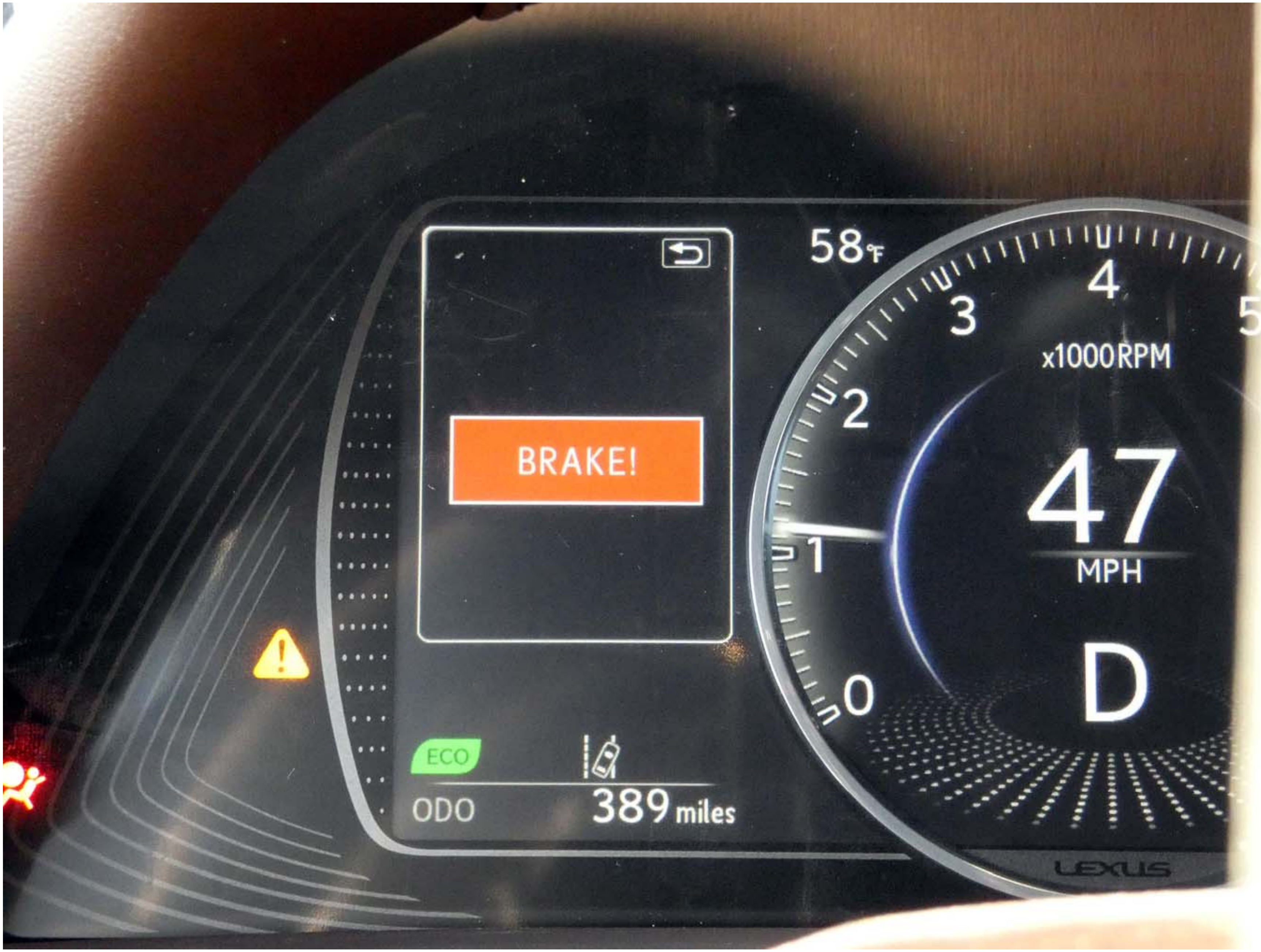


Figure A17. AEB Visual Alert

APPENDIX B

Excerpts from Owner's Manual

Lexus Safety System + 2.0

The Lexus Safety System + 2.0 consists of the following drive assist systems and contributes to a safe and comfortable driving experience:

Driving assist system

■ **PCS (Pre-Collision System)**

→P.175

■ **LTA (Lane Tracing Assist)**

→P.182

■ **Automatic High Beam**

→P.159

■ **RSA (Road Sign Assist) (if equipped)**

→P.191

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

→P.193

WARNING

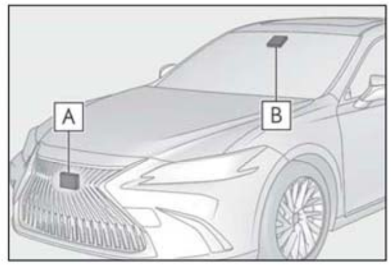
■ **Lexus Safety System + 2.0**

The Lexus Safety System + 2.0 is designed to operate under the assumption that the driver will drive safely, and is designed to help reduce the impact to the occupants and the vehicle in the case of a collision or assist the driver in normal driving conditions.

As there is a limit to the degree of recognition accuracy and control performance that this system can provide, do not overly rely on this system. The driver is always responsible for paying attention to the vehicle's surroundings and driving safely.

Sensors

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



A Radar sensor

B Front camera

WARNING

■ **To avoid malfunction of the radar sensor**

Observe the following precautions.

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

PCS (Pre-Collision System)

The pre-collision system uses a radar sensor and front camera to detect objects (→P.175) in front of the vehicle. When the system determines that the possibility of a frontal collision with an object is high, a warning operates to urge the driver to take evasive action and the potential brake pressure is increased to help the driver avoid the collision. If the system determines that the possibility of a frontal collision with an object is extremely high, the brakes are automatically applied to help avoid the collision or help reduce the impact of the collision.

The pre-collision system can be disabled/enabled and the warning timing can be changed. (→P.177)

Detectable objects

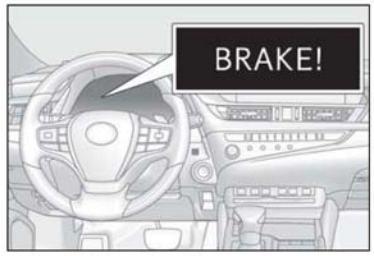
The system can detect the following:

- Vehicles
- Bicyclists
- Pedestrians

System functions

■ Pre-collision warning

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



■ Pre-collision brake assist

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

■ Pre-collision braking

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

■ Suspension control (if equipped)

When the system determines that the possibility of a frontal collision is high, the Adaptive Variable Suspension System (→P.244) will control the damping force of the shock absorbers to help maintain an appropriate vehicle posture.

WARNING

■ Limitations of the pre-collision system

● The driver is solely responsible for safe driving. Always drive safely, taking care to observe your surroundings. Do not use the pre-collision system instead of normal braking operations under any circumstances. This system will not prevent collisions or lessen collision damage or injury in every situation. Do not overly rely on this system. Failure to do so may lead to an accident, resulting in death or serious injury.

● Although this system is designed to help avoid a collision or help reduce the impact of the collision, its effectiveness may change according to various conditions, therefore the system may not always be able to achieve the same level of performance.
Read the following conditions carefully. Do not overly rely on this system and always drive carefully.

- Conditions under which the system may operate even if there is no possibility of a collision: →P.179
- Conditions under which the system may not operate properly: →P.180

● Do not attempt to test the operation of the pre-collision system yourself. Depending on the objects used for testing (dummies, cardboard objects imitating detectable objects, etc.), the system may not operate properly, possibly leading to an accident.

■ Pre-collision braking

● When the pre-collision braking function is operating, a large amount of braking force will be applied.

● If the vehicle is stopped by the operation of the pre-collision braking function, the pre-collision braking function operation will be canceled after approximately 2 seconds.
Depress the brake pedal as necessary.

● The pre-collision braking function may not operate if certain operations are performed by the driver. If the accelerator pedal is being depressed strongly or the steering wheel is being turned, the system may determine that the driver is taking evasive action and possibly prevent the pre-collision braking function from operating.

● In some situations, while the pre-collision braking function is operating, operation of the function may be canceled if the accelerator pedal is depressed strongly or the steering wheel is turned and the system determines that the driver is taking evasive action.

● If the brake pedal is being depressed, the system may determine that the driver is taking evasive action and possibly delay the operation timing of the pre-collision braking function.

■ When to disable the pre-collision system

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

● When the vehicle is being towed

● When your vehicle is towing another vehicle

● When transporting the vehicle via truck, boat, train or similar means of transportation

● When the vehicle is raised on a lift with the engine running and the tires are allowed to rotate freely

● When inspecting the vehicle using a drum tester such as a chassis dynamometer or speedometer tester, or when using an on vehicle wheel balancer

● When a strong impact is applied to the front bumper or front grille, due to an accident or other reasons

⚠ WARNING

- If the vehicle cannot be driven in a stable manner, such as when the vehicle has been in an accident or is malfunctioning
- When the vehicle is driven in a sporty manner or off-road
- When the tires are not properly inflated
- When the tires are very worn
- When tires of a size other than specified are installed
- When tire chains are installed
- When a compact spare tire or an emergency tire puncture repair kit is used
- If equipment (snow plow, etc.) that may obstruct the radar sensor or front camera is temporarily installed to the vehicle

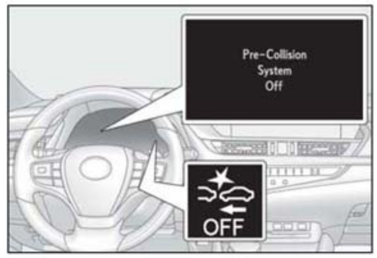
Changing settings of the pre-collision system

■ Enabling/disabling the pre-collision system

The pre-collision system can be enabled/disabled on ⚙ (→P.78) of the multi-information display.

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

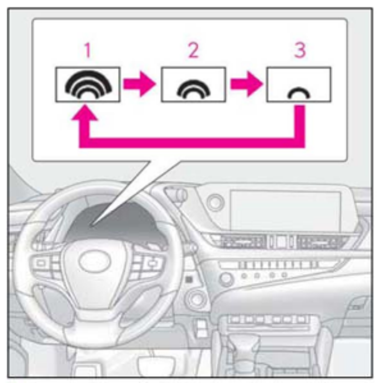
If the system is disabled, the PCS warning light will turn on and a message will be displayed on the multi-information display.



■ Changing the pre-collision warning timing

The pre-collision warning timing can be changed on ⚙ (→P.78) of the multi-information display.

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



1 Early

2 Middle

This is the default setting.

3 Late

■ Operational conditions

The pre-collision system is enabled and the system determines that the possibility of a frontal collision with a detected object is high.

Each function is operational at the following speed

● Pre-collision warning

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

● Pre-collision brake assist

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

● Pre-collision braking

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

The system may not operate in the following situations:

● If a battery terminal has been disconnected and reconnected and then the vehicle has not been driven for a certain amount of time

● If the shift lever is in R

● When the VSC OFF indicator is illuminated (only the pre-collision warning function will be operational)

■ **Object detection function**

The system detects objects based on their size, profile, motion, etc. However, an object may not be detected depending on the surrounding brightness and the motion, posture, and angle of the detected object, preventing the system from operating properly. (→P.180) The illustration shows an image of detectable objects.

■ Cancelation of the pre-collision braking

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

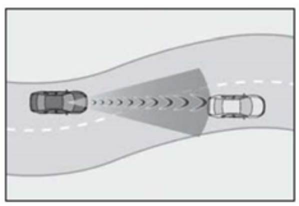
● The accelerator pedal is depressed strongly.

● The steering wheel is turned sharply or abruptly.

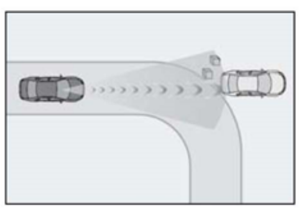
■ Conditions under which the system may operate even if there is no possibility of a collision

● In some situations such as the following, the system may determine that there is a possibility of a frontal collision and operate.

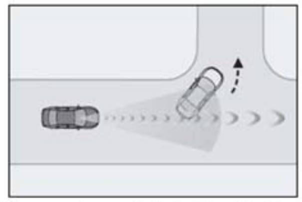
- When passing a detectable object, etc.
- When changing lanes while overtaking a detectable object, etc.
- When approaching a detectable object in an adjacent lane or on the roadside, such as when changing the course of travel or driving on a winding road



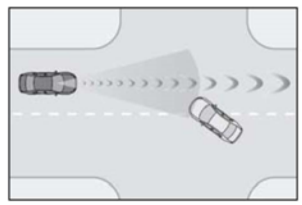
- When rapidly closing on a detectable object, etc.
- When approaching objects on the roadside, such as detectable objects, guardrails, utility poles, trees, or walls
- When there is a detectable object or other object by the roadside at the entrance of a curve



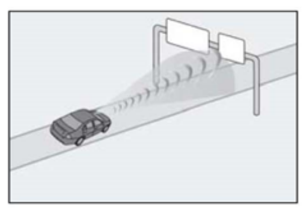
- When there are patterns or paint in front of your vehicle that may be mistaken for a detectable object
- When the front of your vehicle is hit by water, snow, dust, etc.
- When overtaking a detectable object that is changing lanes or making a right/left turn



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

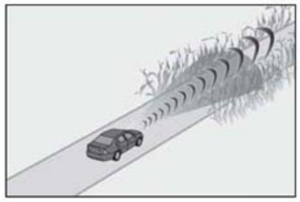


- When a detectable object approaches very close and then stops before entering the path of your vehicle
- If the front of your vehicle is raised or lowered, such as when on an uneven or undulating road surface
- When driving on a road surrounded by a structure, such as in a tunnel or on an iron bridge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



- When approaching an electric toll gate barrier, parking area barrier, or other barrier that opens and closes

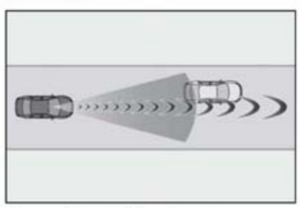
- When using an automatic car wash
- When driving through or under objects that may contact your vehicle, such as thick grass, tree branches, or a banner



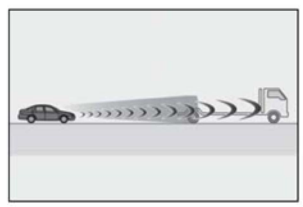
- When driving through steam or smoke
- When driving near an object that reflects radio waves, such as a large truck or guardrail
- When driving near a TV tower, broadcasting station, electric power plant, or other location where strong radio waves or electrical noise may be present

■ **Situations in which the system may not operate properly**

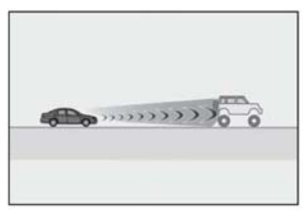
● In some situations such as the following, an object may not be detected by the radar sensor and front camera, preventing the system from operating properly:
- When a detectable object is approaching your vehicle
- When your vehicle or a detectable object is wobbling
- If a detectable object makes an abrupt maneuver (such as sudden swerving, acceleration or deceleration)
- When your vehicle approaches a detectable object rapidly
- When a detectable object is not directly in front of your vehicle



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

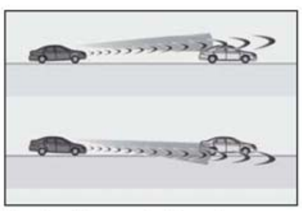


- If a vehicle ahead has extremely high ground clearance



- If a vehicle ahead is carrying a load which protrudes past its rear bumper
- If a vehicle ahead is irregularly shaped, such as a tractor or side car

- If a vehicle ahead is a child sized bicycle, a bicycle that is carrying a large load, a bicycle ridden by more than one person, or a uniquely shaped bicycle (bicycle with a child seat, tandem bicycle, etc.)
- If a pedestrian/or the riding height of a bicyclist ahead is shorter than approximately 3.2 ft. (1 m) or taller than approximately 6.5 ft. (2 m)
- If a pedestrian/bicyclist is wearing oversized clothing (a rain coat, long skirt, etc.), making their silhouette obscure
- If a pedestrian is bending forward or squatting or bicyclist is bending forward
- If a pedestrian/bicyclist is moving fast
- If a pedestrian is pushing a stroller, wheelchair, bicycle or other vehicle
- When driving in inclement weather such as heavy rain, fog, snow or a sandstorm
- When driving through steam or smoke
- When the surrounding area is dim, such as at dawn or dusk, or while at night or in a tunnel, making a detectable object appear to be nearly the same color as its surroundings
- When driving in a place where the surrounding brightness changes suddenly, such as at the entrance or exit of a tunnel
- After the engine has started the vehicle has not been driven for a certain amount of time
- While making a left/right turn and for a few seconds after making a left/right turn
- While driving on a curve and for a few seconds after driving on a curve
- If your vehicle is skidding
- If the front of the vehicle is raised or lowered



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

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

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

■ **If VSC is disabled**

● If VSC is disabled (→P.245), the pre-collision brake assist and pre-collision braking functions are also disabled.

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

mode. (→P.208)

■ **When the TRAC/VSC systems are operating**

The slip indicator light will flash while the TRAC/VSC systems are operating.

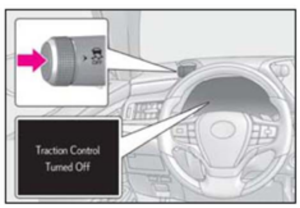
■ **Disabling the TRAC system**

If the vehicle gets stuck in mud, dirt or snow, the TRAC system may reduce power from the engine to the wheels. Pressing the switch to turn the system off may make it easier for you to rock the vehicle in order to free it.

To turn the TRAC system off, quickly press and release the switch.

"Traction Control Turned Off" will be shown on the multi-information display.

Press the switch again to turn the system back on.



■ **Turning off both TRAC and VSC systems**

To turn the TRAC and VSC systems off, press and hold the switch for more than 3 seconds while the vehicle is stopped.

The VSC OFF indicator light will come on and the "Traction Control Turned Off" will be shown on the multi-information display.*

Press the switch again to turn the system back on.

*: PCS (Pre-Collision System) will also be disabled (only Pre-Collision warning is available). The PCS warning light will come on and a message will be displayed on the multi-information display. (→P.181)

■ **When the message is displayed on the multi-information display showing that TRAC has been disabled even if the switch has not been pressed**

TRAC is temporary deactivated. If the information continues to show, contact your Lexus dealer.

■ **Operating conditions of hill-start assist control**

When the following four conditions are met, the hill-start assist control will operate:

- The shift lever is in a position other than P or N (when starting off forward/backward on an upward incline).
- The vehicle is stopped.
- The accelerator pedal is not depressed.
- The parking brake is not engaged.

■ **Automatic system cancelation of hill-start assist control**

The hill-start assist control will turn off in any of the following situations:

- The shift lever is shifted to P or N.
- The accelerator pedal is depressed.
- The parking brake is engaged.
- 2 seconds at maximum elapsed after the brake pedal is released.

■ **Sounds and vibrations caused by the ABS, brake assist, VSC, TRAC and hill-start assist control systems**

- A sound may be heard from the engine compartment when the brake pedal is depressed repeatedly, when the engine is started or just after the vehicle begins to move. This sound does not indicate that a malfunction has occurred in any of these systems.

■ PCS warning light (warning buzzer)

Warning light	Details/Actions
 (flashes or illuminates)	When a buzzer sounds simultaneously: Indicates a malfunction has occurred in the PCS (Pre-Collision System) → **Have the vehicle inspected by your Lexus dealer immediately.** When a buzzer does not sound: The PCS (Pre-Collision System) has become temporarily unavailable, corrective action may be necessary. → **Follow the instructions displayed on the multi-information display. (→P.173, 362)** If the PCS (Pre-Collision System) or VSC (Vehicle Stability Control) system is disabled, the PCS warning light will illuminate. → **P.181**

■ Slip indicator

Warning light	Details/Actions
	Indicates a malfunction in: ● The VSC system; ● The TRAC system; or ● The hill-start assist control system → **Have the vehicle inspected by your Lexus dealer immediately.**

■ Parking brake indicator

Warning light	Details/Actions
 (flashes) (U.S.A.) or  (flashes) (Canada)	Indicates a malfunction in the parking brake system → **Have the vehicle inspected by your Lexus dealer immediately.**

speed range system is suspended temporarily or until the problem shown in the message is resolved. (causes and coping methods: →P.173)

■ If "Radar Cruise Control Unavailable" is shown

The dynamic radar cruise control with full-speed range system cannot be used temporarily. Use the system when it becomes available again.

■ If "Front Camera Unavailable" or "Front Camera Unavailable See Owner's Manual" is displayed

The following systems may be suspended until the problem shown in the message is resolved. (→P.173, 358)

- PCS (Pre-Collision System)
- LTA (Lane Tracing Assist)
- Automatic High Beam
- RSA (Road Sign Assist) (if equipped)
- Dynamic radar cruise control with full-speed range

■ If "Maintenance Required Soon" is displayed

Indicates that all maintenance according to the driven distance on the maintenance schedule* should be performed soon.

Comes on approximately 4500 miles (7200 km) after the message has been reset. If necessary, perform maintenance. Please reset the message after the maintenance is performed. (→P.305)

*: Refer to the separate "Scheduled Maintenance" or "Owner's Manual Supplement" for the maintenance interval applicable to your vehicle.

■ If "Maintenance Required Visit Your Dealer" is displayed

Indicates that all maintenance is required to correspond to the driven distance on the maintenance schedule*.

Comes on approximately 5000 miles (8000 km) after the message has been reset. (The indicator will not work properly unless the message has been reset.) Perform the necessary maintenance. Please reset the message after the maintenance is performed. (→P.305)

*: Refer to the separate "Scheduled Maintenance" or "Owner's Manual Supplement" for the maintenance interval applicable to your vehicle.

■ If "Oil Maintenance Required Soon" is displayed

Indicates that the engine oil should be scheduled to be changed.

Check the engine oil and change it if necessary. After changing the engine oil, make sure to reset the message. (→P.316)

■ If "Oil Maintenance Required" is displayed

Indicates that the engine oil should be changed.

Check and change the engine oil, and oil filter by your Lexus dealer. After changing the engine oil, make sure to reset the message. (→P.316)

■ If a message that indicates the need for visiting your Lexus dealer is displayed

The system or part shown on the multi-information display is malfunctioning. Have the vehicle inspected by your Lexus dealer immediately.

■ If a message that indicates the need for referring to Owner's Manual is displayed

- If any of the following messages are shown on the multi-information display, follow the instructions.
  - "Engine Coolant Temp High" (→P.381)
- If any of the following messages are shown on the multi-information display, it may indicate a malfunction. Have the vehicle inspected by your Lexus dealer immediately.
  - "Access System with Elec. Key Malfunction"
- If any of the following messages are shown on the multi-information display, it may indicate a malfunction. Immediately stop the vehicle and contact your Lexus dealer.
  - "Braking Power Low"
  - "Charging System Malfunction"

76 ft•lbf (103 N•m, 10.5 kgf•m)

5 Stow the flat tire, tire jack and all tools.

■ **The compact spare tire**

● The compact spare tire is identified by the label "TEMPORARY USE ONLY" on the tire sidewall.
Use the compact spare tire temporarily, and only in an emergency.

● Make sure to check the tire inflation pressure of the compact spare tire. (→P.391)

■ **After completing the tire change**

The tire pressure warning system must be reset. (→P.326)

■ **When using the compact spare tire**

As the compact spare tire is not equipped with a tire pressure warning valve and transmitter, low inflation pressure of the spare tire will not be indicated by the tire pressure warning system. Also, if you replace the compact spare tire after the tire pressure warning light comes on, the light remains on.

■ **When the compact spare tire is attached**

The vehicle becomes lower when driving with the compact spare tire compared to when driving with standard tires.

■ **If you have a flat front tire on a road covered with snow or ice**

Install the compact spare tire on one of the rear wheels of the vehicle. Perform the following steps and fit tire chains to the front tires:

1 Replace a rear tire with the compact spare tire.

2 Replace the flat front tire with the tire removed from the rear of the vehicle.

3 Fit tire chains to the front tires.

WARNING

■ **When using the compact spare tire**

● Remember that the compact spare tire provided is specifically designed for use with your vehicle. Do not use your compact spare tire on another vehicle.

● Do not use more than one compact spare tire simultaneously.

● Replace the compact spare tire with a standard tire as soon as possible.

● Avoid sudden acceleration, abrupt steering, sudden braking and shifting operations that cause sudden engine braking.

■ **When the compact spare tire is attached**

The vehicle speed may not be correctly detected, and the following systems may not operate correctly:

- ABS & Brake assist
- VSC
- TRAC
- Dynamic radar cruise control with full-speed range
- PCS (Pre-Collision System)
- EPS
- LTA (Lane Tracing Assist)
- Panoramic view monitor (if equipped)
- Lexus parking assist monitor (if equipped)
- Intuitive parking assist (if equipped)
- Navigation system (if equipped)
- BSM (Blind spot monitor) (if equipped)
- Automatic high Beam

*: If equipped

■ Power windows, and moon roof* or panoramic moon roof* (→P.124, 126, 129)

Function	Default setting	Customized setting	A	B	C
Mechanical key linked operation	Off	On	—	—	O
Wireless remote control linked operation	Off	On (open only)	—	—	O
Wireless remote control linked operation signal (buzzer)	On	Off	—	—	O

*: If equipped

■ Automatic light control system (→P.156)

Function	Default setting	Customized setting	A	B	C
Light sensor sensitivity	Standard	-2 to 2	O	—	O
Time elapsed before headlights automatically turn off after doors are closed	30 seconds	Off	O	—	O
		60 seconds			
		90 seconds			
Windshield wiper linked headlight illumination	On	Off	—	—	O

■ Lights (→P.156)

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

*1: Except for Canada

*2: If equipped

■ PCS (Pre-Collision System) (→P.175)

Function	Default setting	Customized setting	A	B	C
PCS (Pre-Collision System)	On	Off	—	O	—

Function	Default setting	Customized setting	A	B	C
Adjust alert timing	Middle	Early	—	O	—
		Late			

■ LTA (Lane Tracing Assist) (→P.182)

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

■ RSA (Road Sign Assist)* (→P.191)

Function	Default setting	Customized setting	A	B	C
RSA (Road Sign Assist)	On	Off	—	O	—
Excess speed notification method	Display only	No notification	—	O	—
		Display and buzzer			
Excess speed notification level	1 mph (2 km/h)	3 mph (5 km/h)	—	O	—
		5 mph (10 km/h)			
Other notifications method (No-entry notification)	Display only	No notification	—	O	—
		Display and buzzer			

*: If equipped

■ BSM (Blind Spot Monitor)* (→P.203)

Function	Default setting	Customized setting	A	B	C
BSM (Blind Spot Monitor)	On	Off	—	O	—
Outside rear view mirror indicator brightness	Bright	Dim	—	O	—

APPENDIX C

Run Log

Subject Vehicle: **2020 Lexus ES 350** Test Date: **1/15/2020**

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								
2	**Slower POV, 25 vs 10**	N							Lateral Offset
3		Y	2.20	5.39	15.0	1.01	0.78	Pass	
4		Y	2.19	4.17	14.5	1.10	0.85	Pass	
5		Y	2.33	2.64	14.7	1.07	0.74	Pass	
6		Y	2.18	3.94	14.5	1.01	0.69	Pass	
7		Y	2.27	2.44	15.1	1.00	0.79	Pass	
8		Y	2.28	3.53	15.1	1.08	0.78	Pass	
9		Y	2.23	3.04	14.9	1.06	0.75	Pass	
10	Static Run								
11	**Slower POV, 45 vs 20**	Y	2.78	0.00	23.1	0.93	1.04	Pass	
12		Y	1.98	0.00	21.8	0.87	1.04	Pass	
13		Y	2.53	0.50	25.9	1.02	1.05	Pass	
14		Y	2.87	0.04	25.2	1.05	1.11	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
15		Y	2.70	0.76	25.0	1.10	1.09	Pass	
16		Y	2.78	2.84	24.3	0.99	1.00	Pass	
17		Y	2.81	0.00	19.6	0.73	1.03	Pass	
18	Static run								
19	Static Run								
20	**Decelerating POV, 35**	Y	1.82	0.00	4.7	0.64	0.86	Fail	Inspected grill and radar, no apparent damage
21		Y	1.89	0.00	5.0	0.67	1.05	Fail	Inspected grill and radar, no apparent damage
22		Y	1.92	0.00	6.2	0.74	0.88	Fail	Inspected grill and radar, DAMAGE to grill
TESTING ENDED DUE TO FAILURE AND DAMAGE TO VEHICLE									

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)
- 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 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. 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. A green dot is displayed if the accelerator pedal was released within 0.5 seconds of the onset of the FCW warning.

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.

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

Examples of time history plots for each test type (including passing, failing and invalid runs) are shown in Figure 1 through Figure 9. Figures 1 through 6 show passing runs for each of the 6 test types. Figures 7 and 8 show examples of invalid runs. Figure 9 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 10.

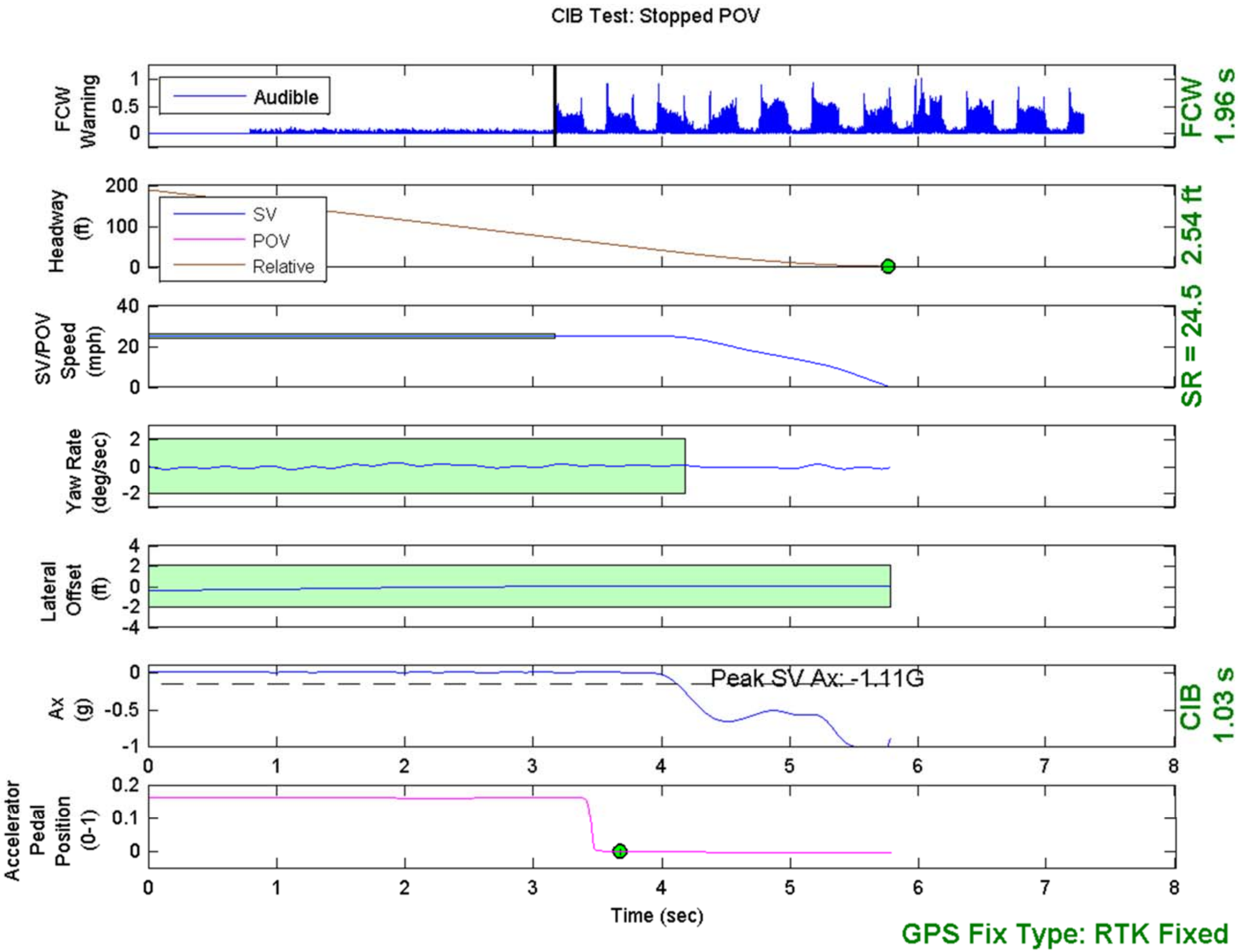


Figure D1. Example Time History for Stopped POV, Passing

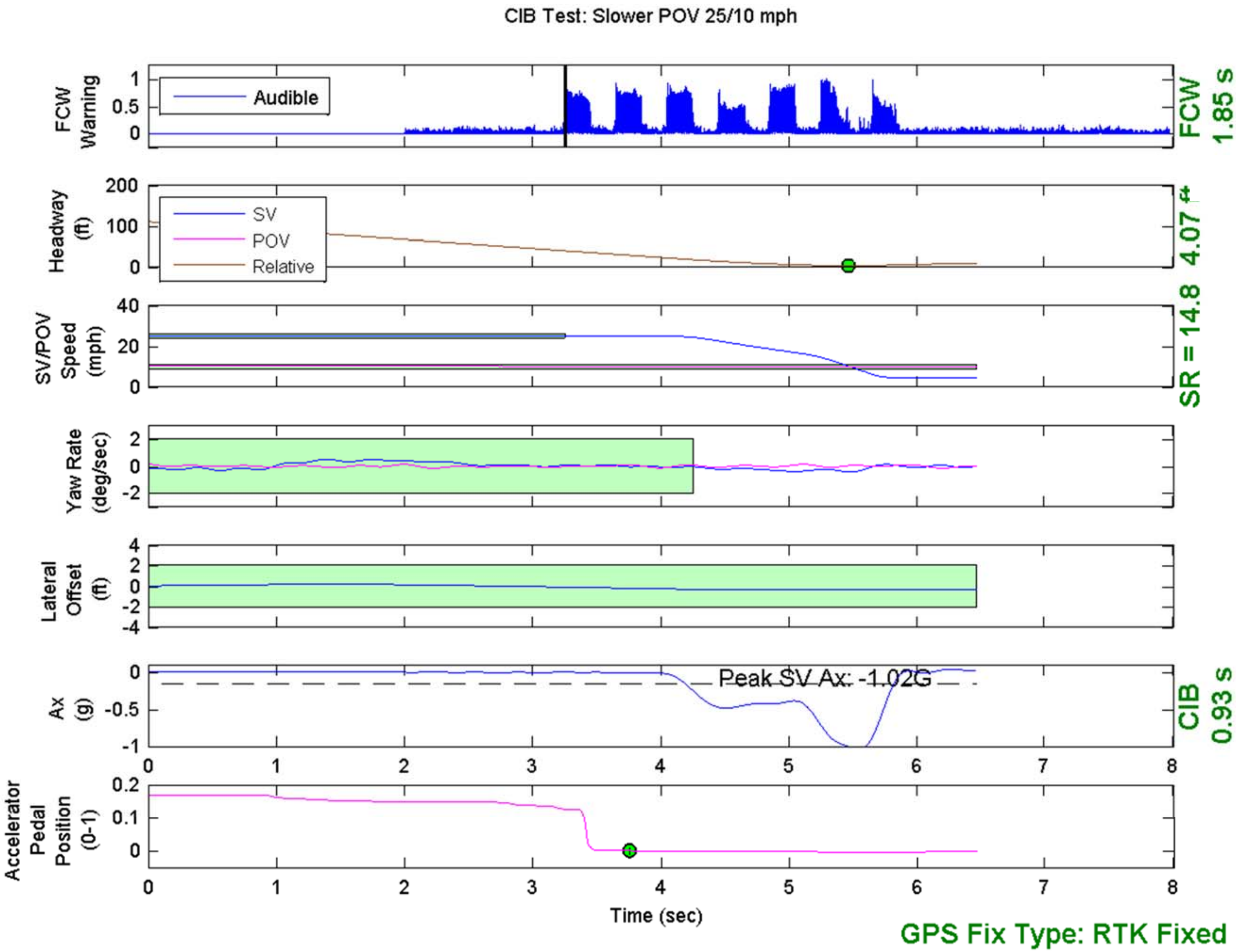


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

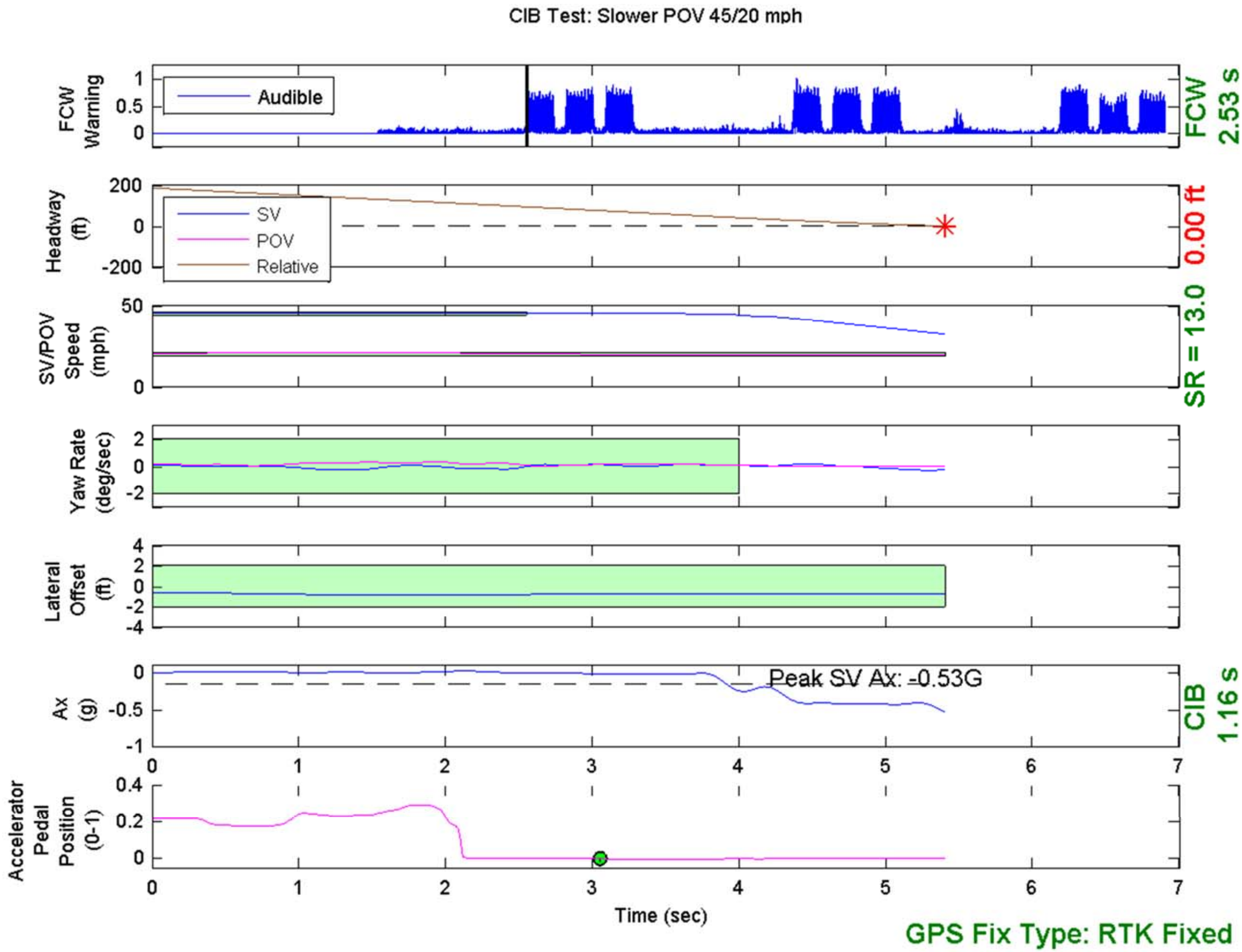


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

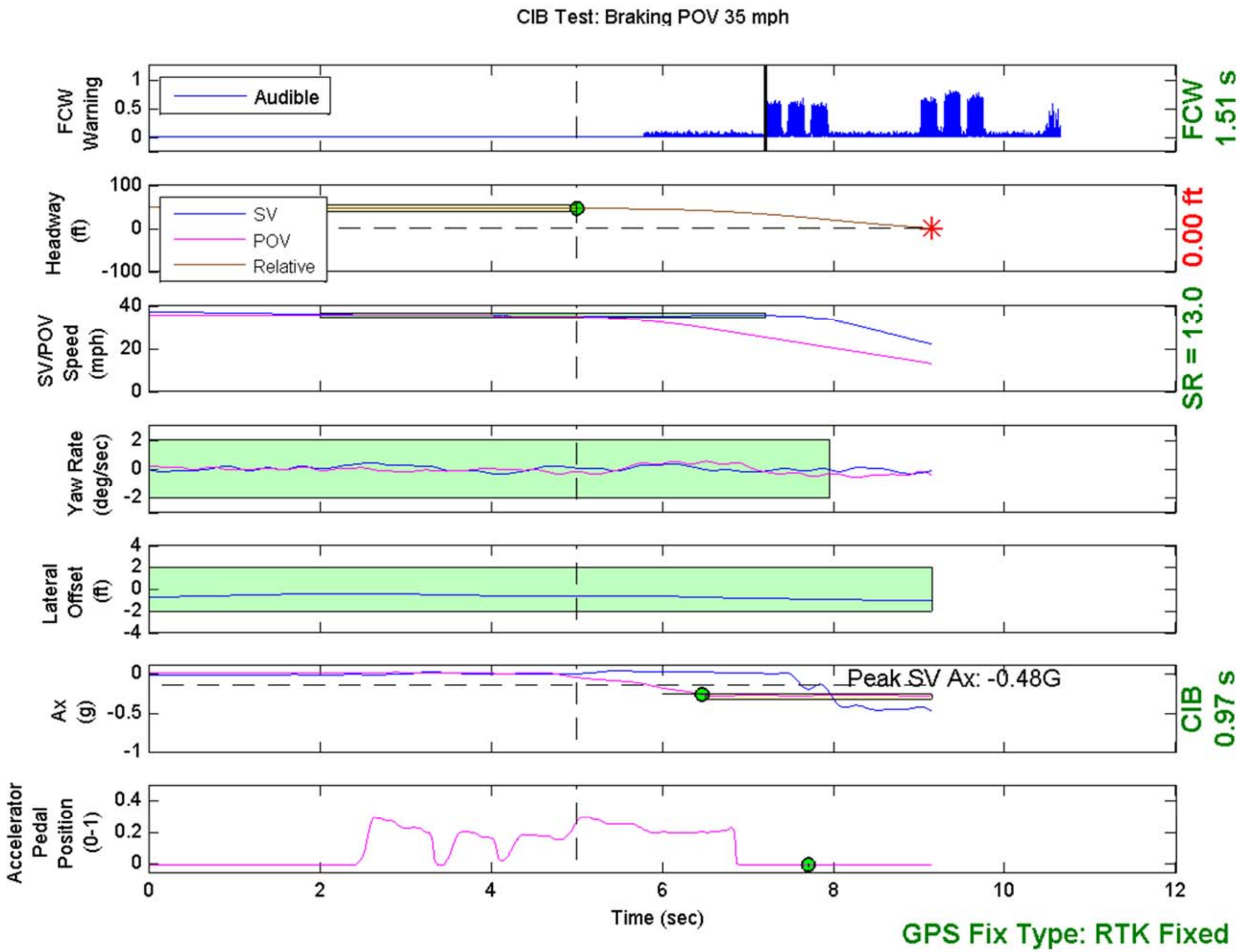


Figure D4. Example Time History for Decelerating POV 35, Passing

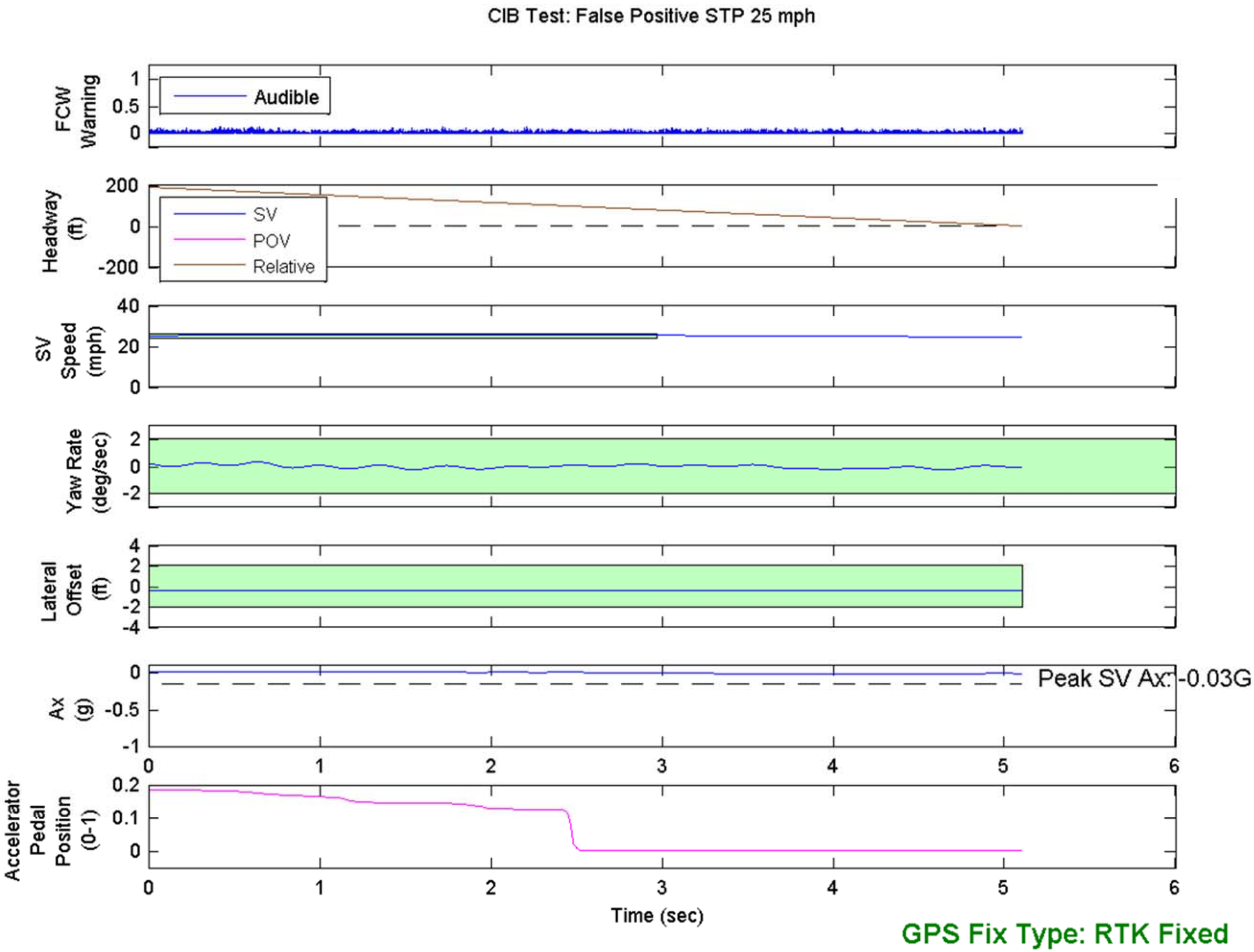


Figure D5. Example Time History for False Positive STP 25, Passing

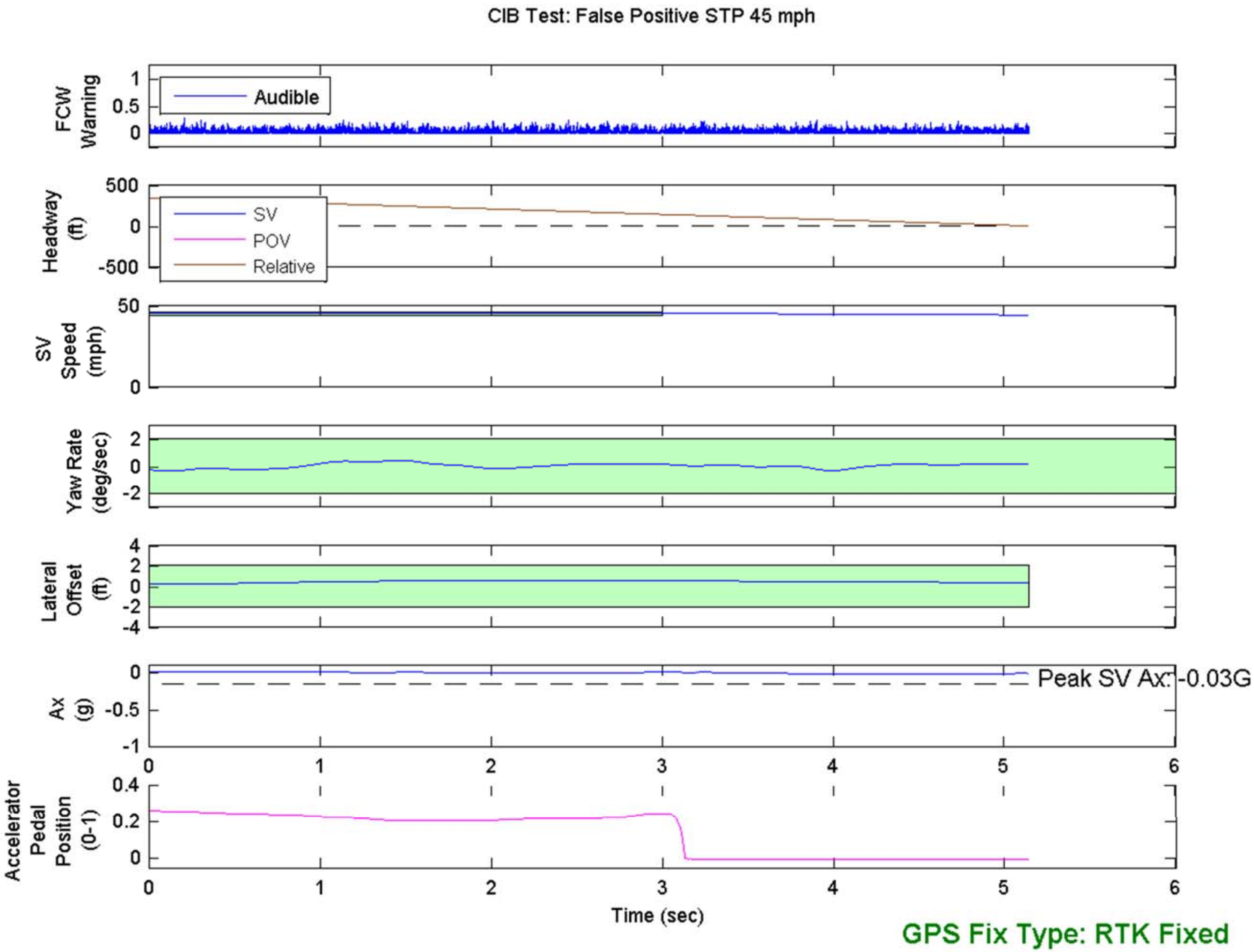


Figure D6. Example Time History for False Positive STP 45, Passing

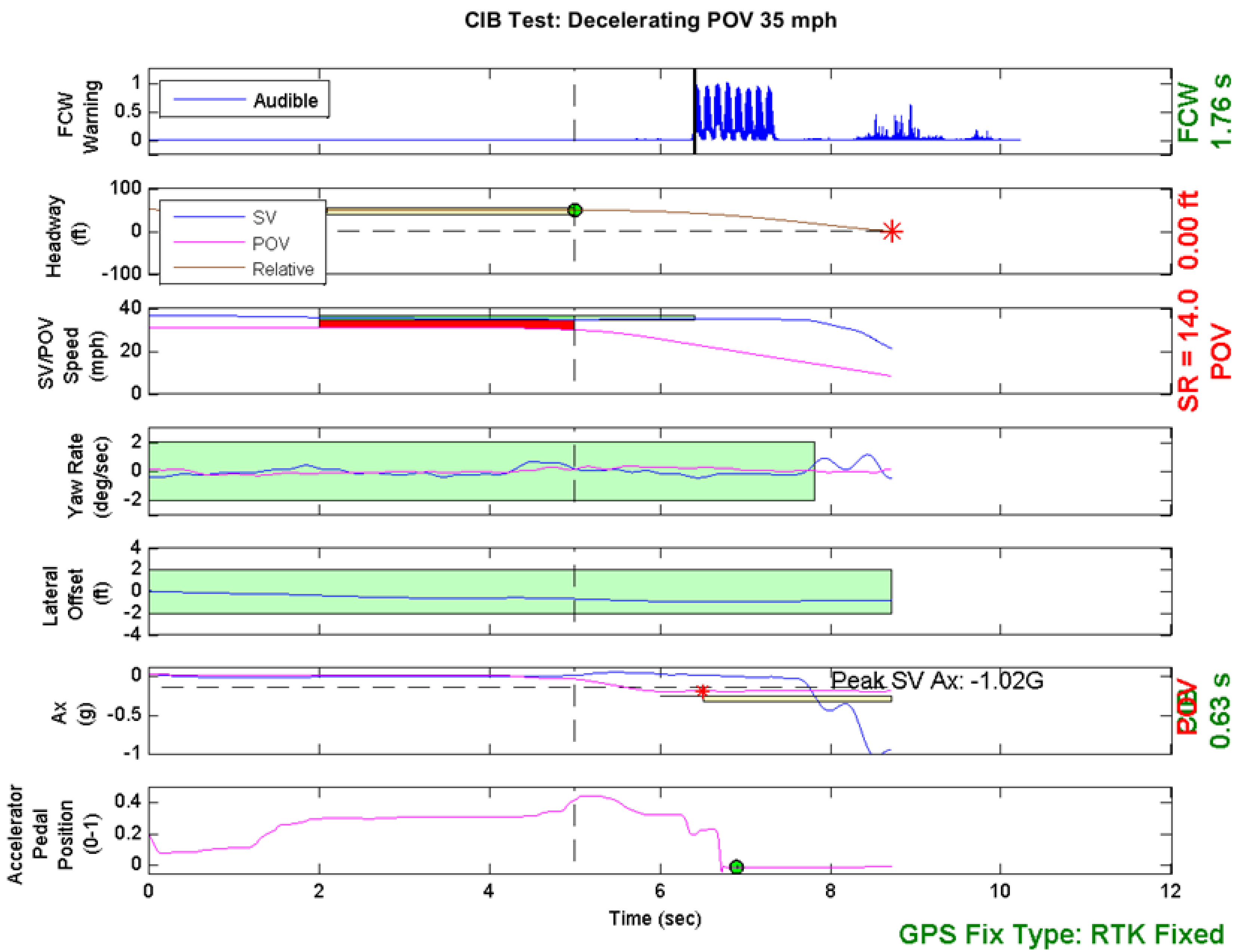


Figure D7. Example Time History Displaying Various Invalid Criteria

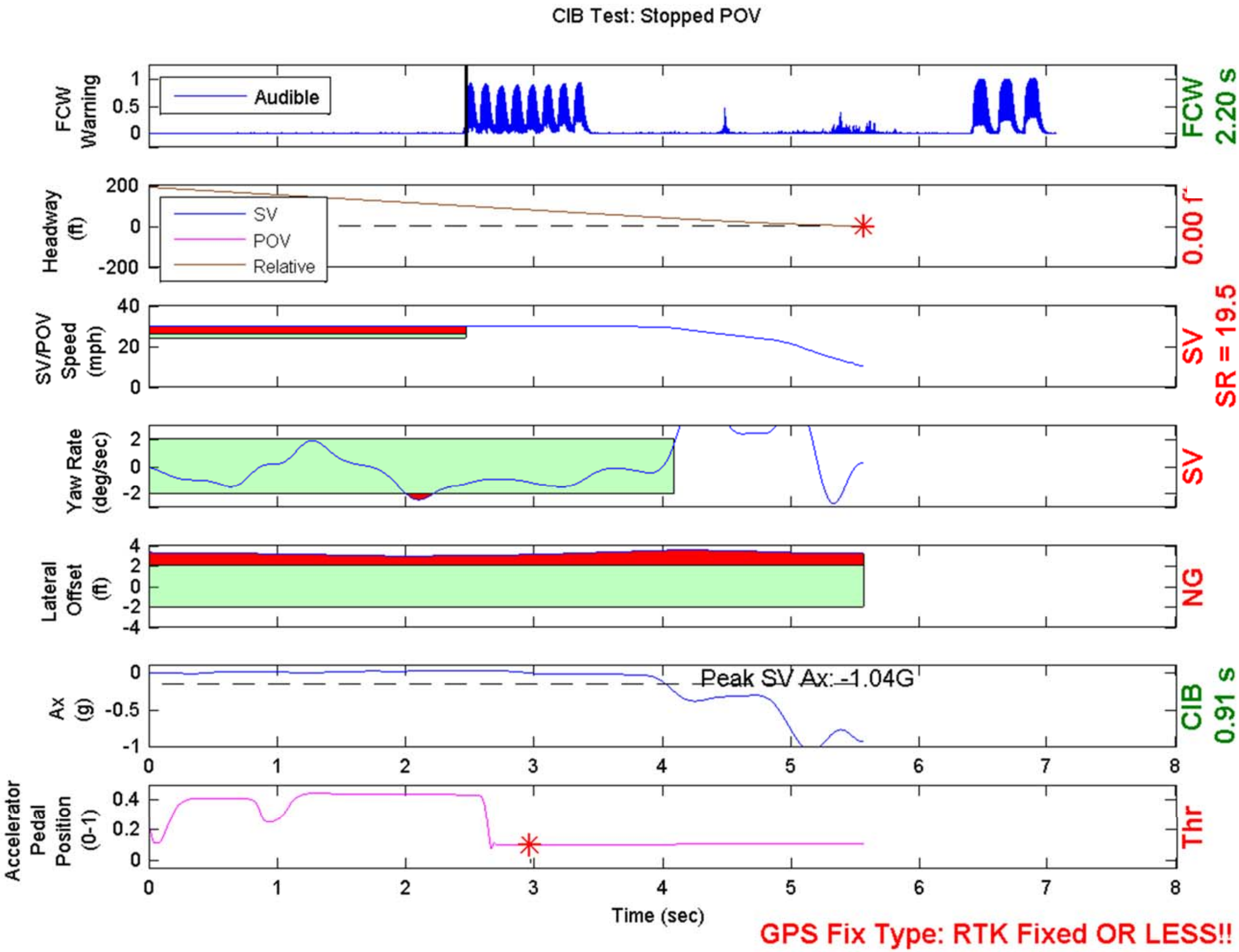


Figure D8. Example Time History Displaying Various Invalid Criteria

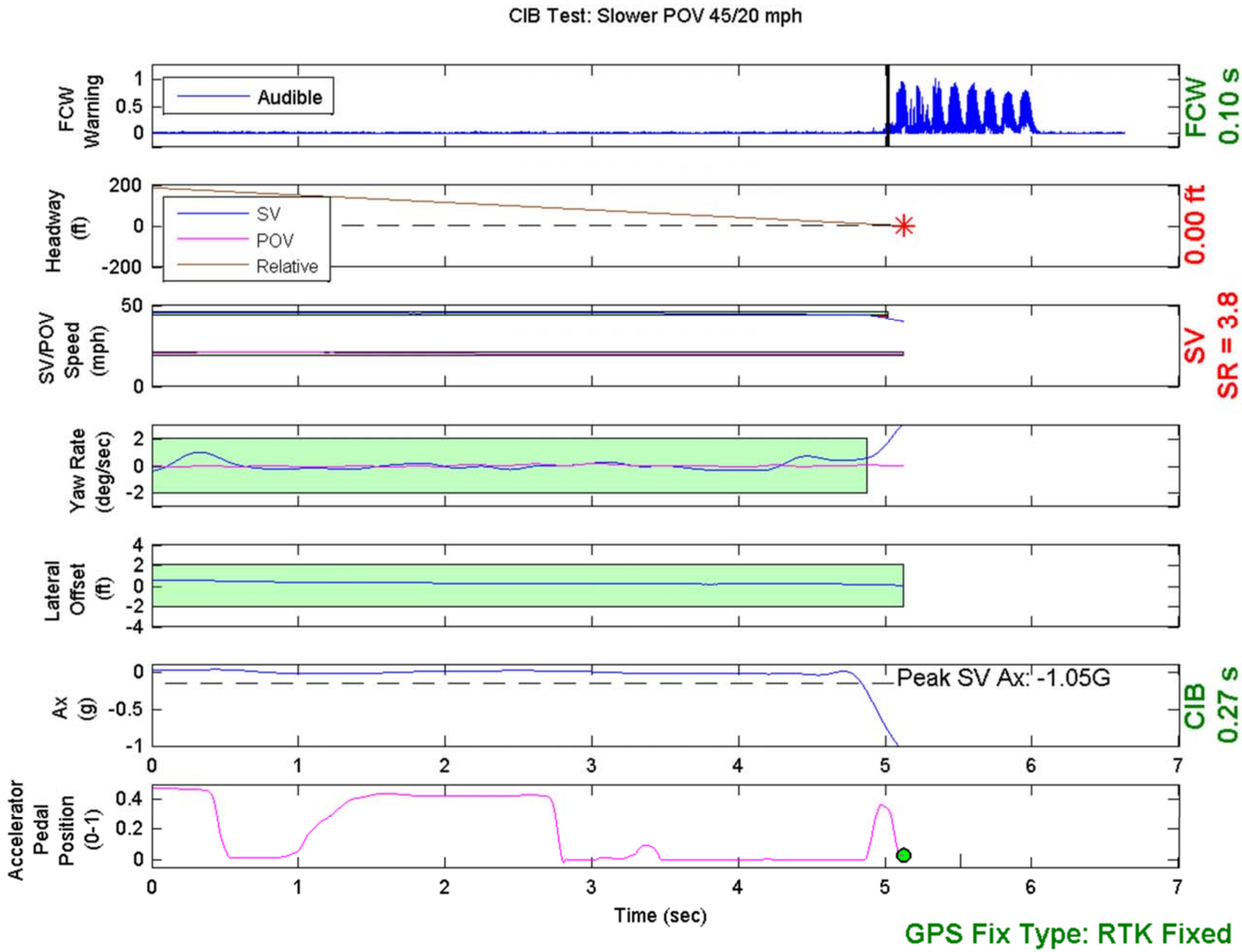


Figure D9. Example Time History for a Failed Run

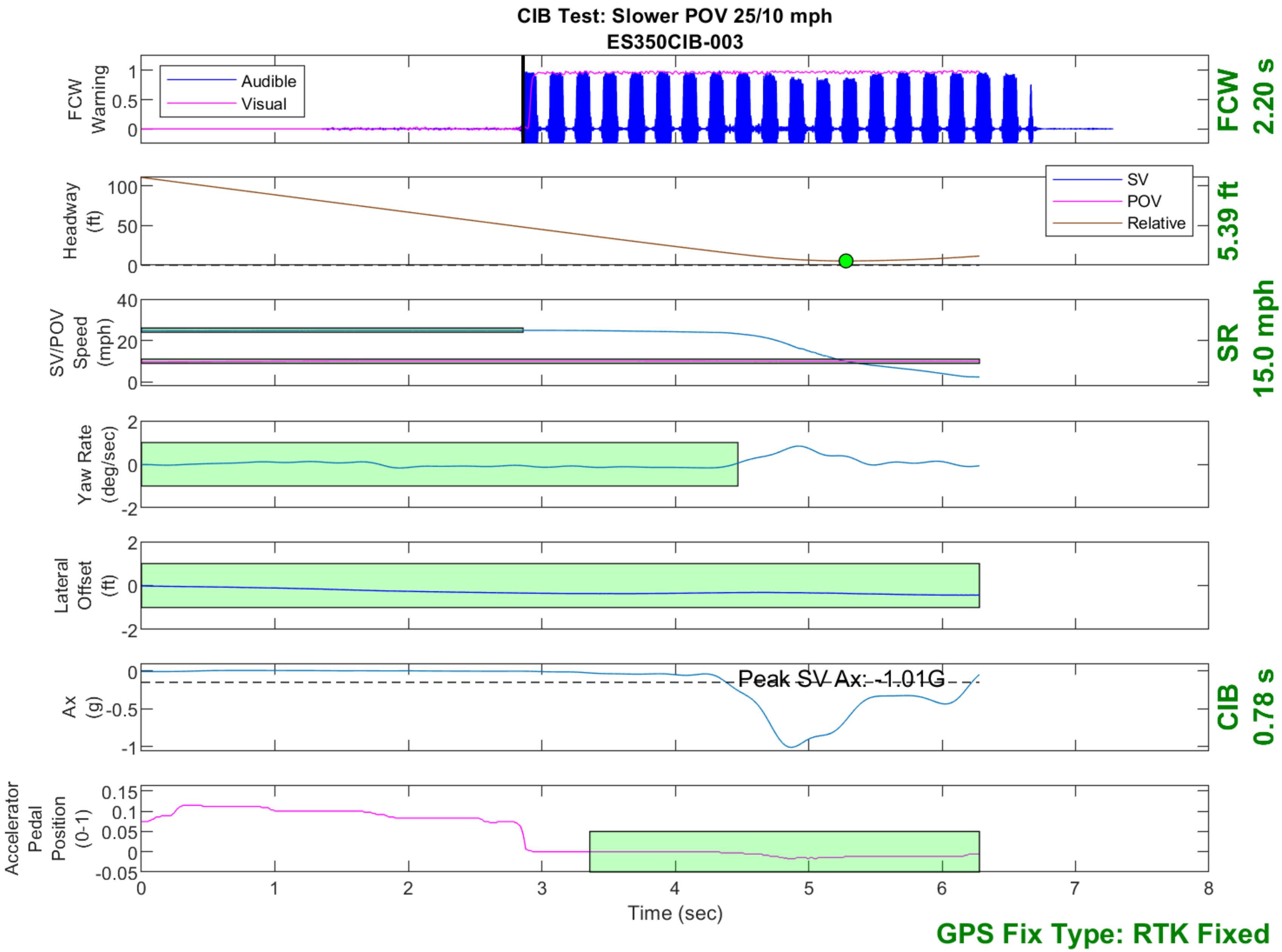


Figure D10. Time History for CIB Run 3, SV Encounters Slower POV, SV 25 mph, POV 10 mph

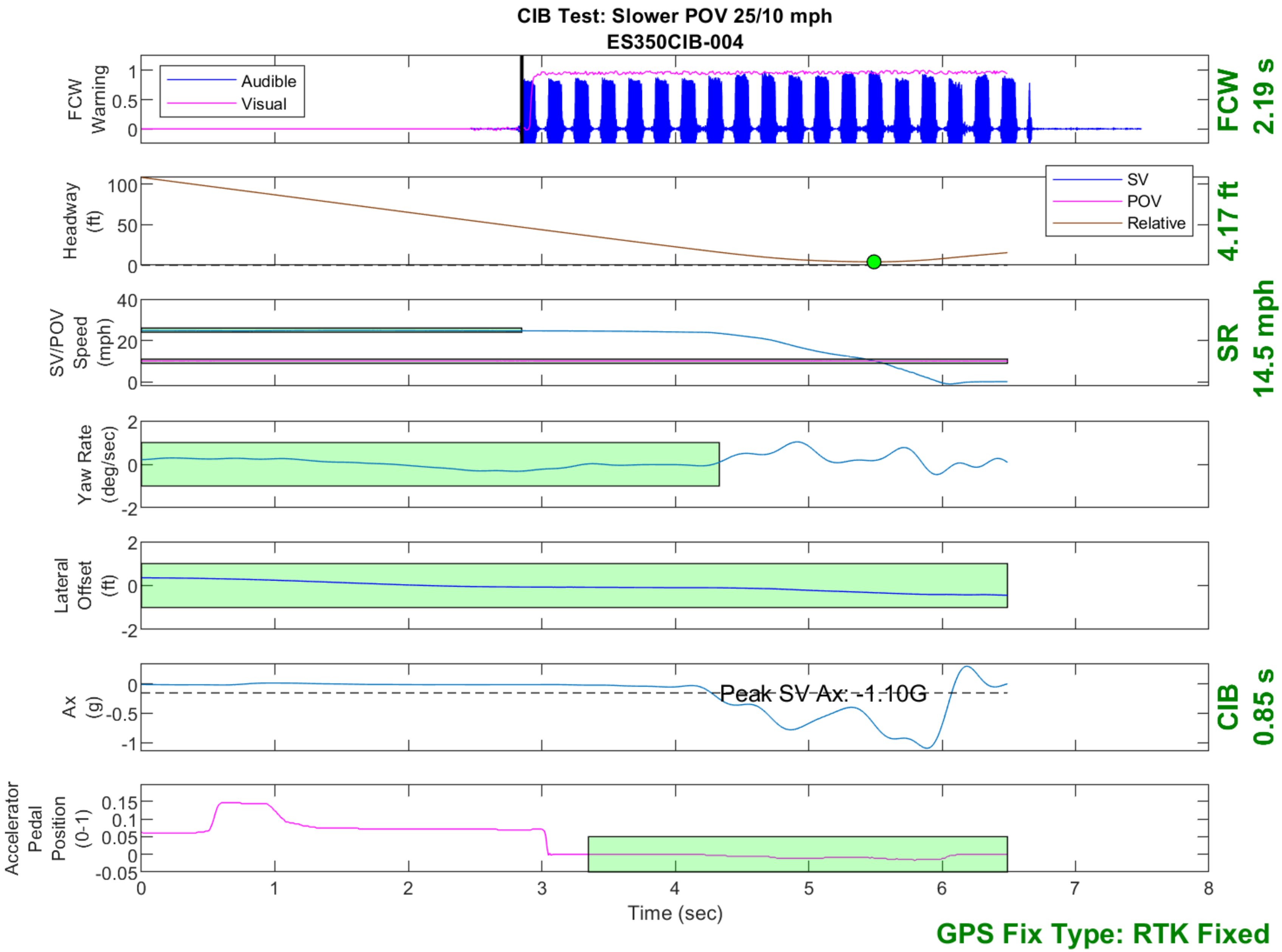


Figure D11. Time History for CIB Run 4, SV Encounters Slower POV, SV 25 mph, POV 10 mph

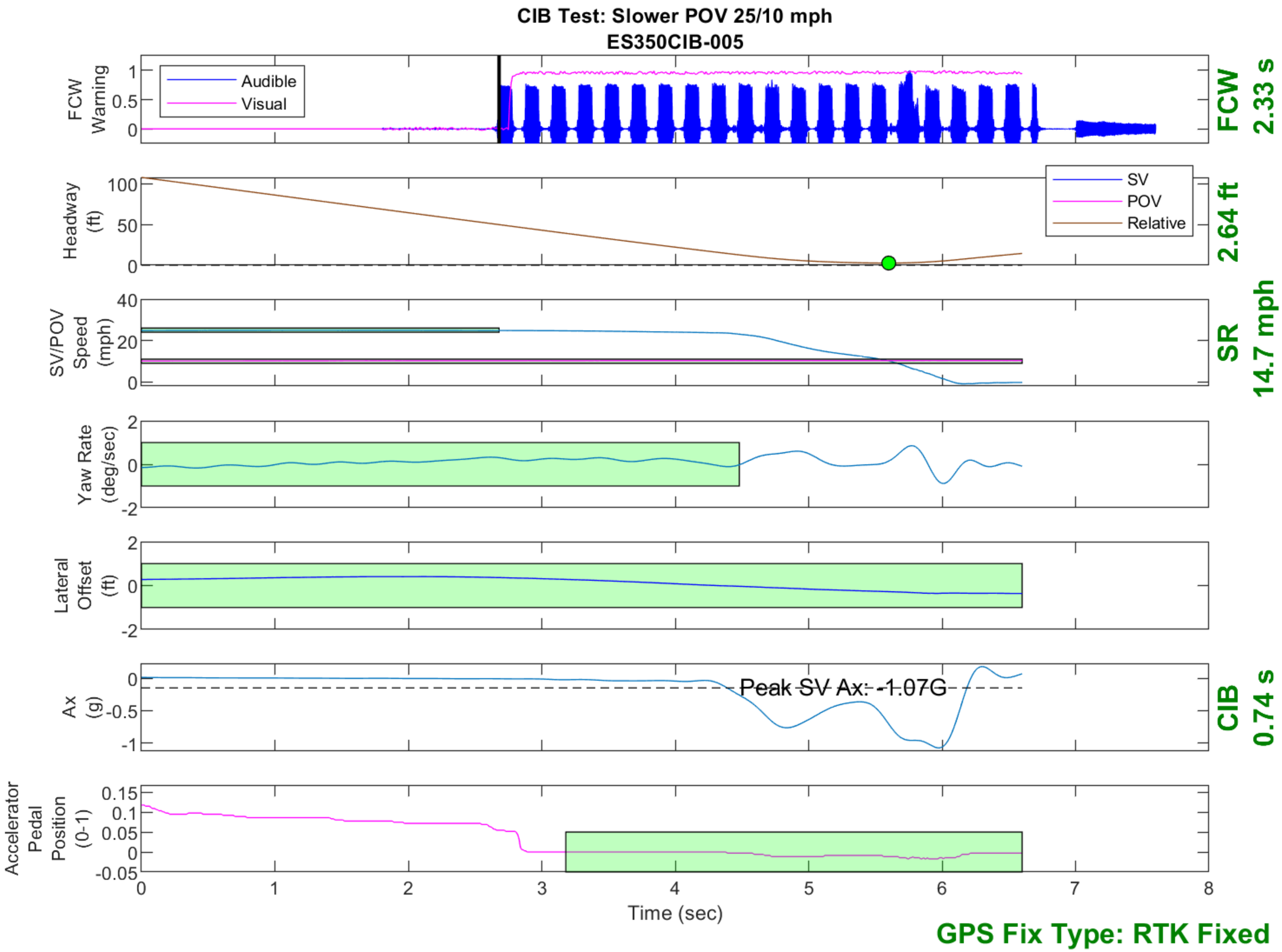


Figure D12. Time History for CIB Run 5, SV Encounters Slower POV, SV 25 mph, POV 10 mph

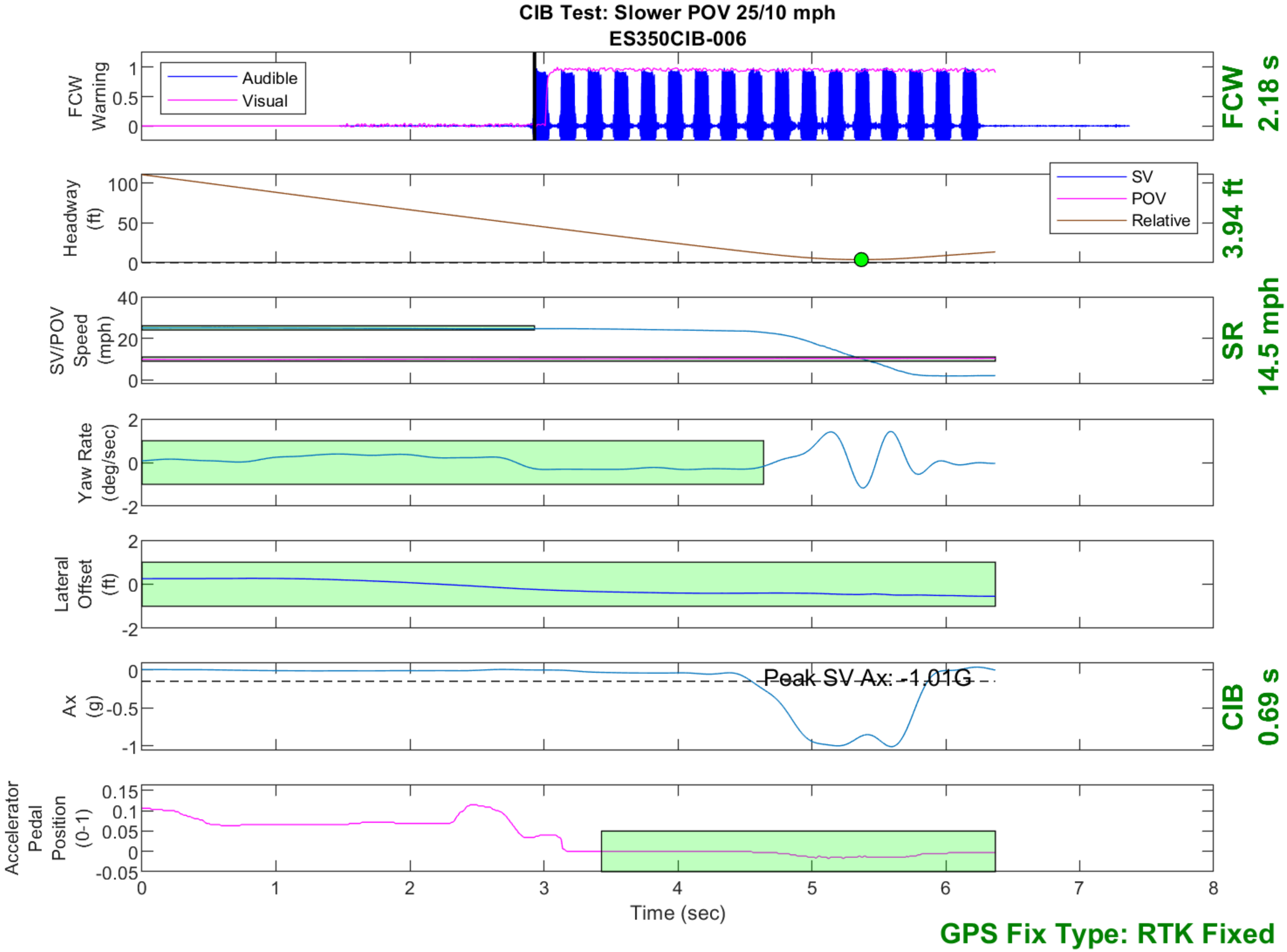


Figure D13. Time History for CIB Run 6, SV Encounters Slower POV, SV 25 mph, POV 10 mph

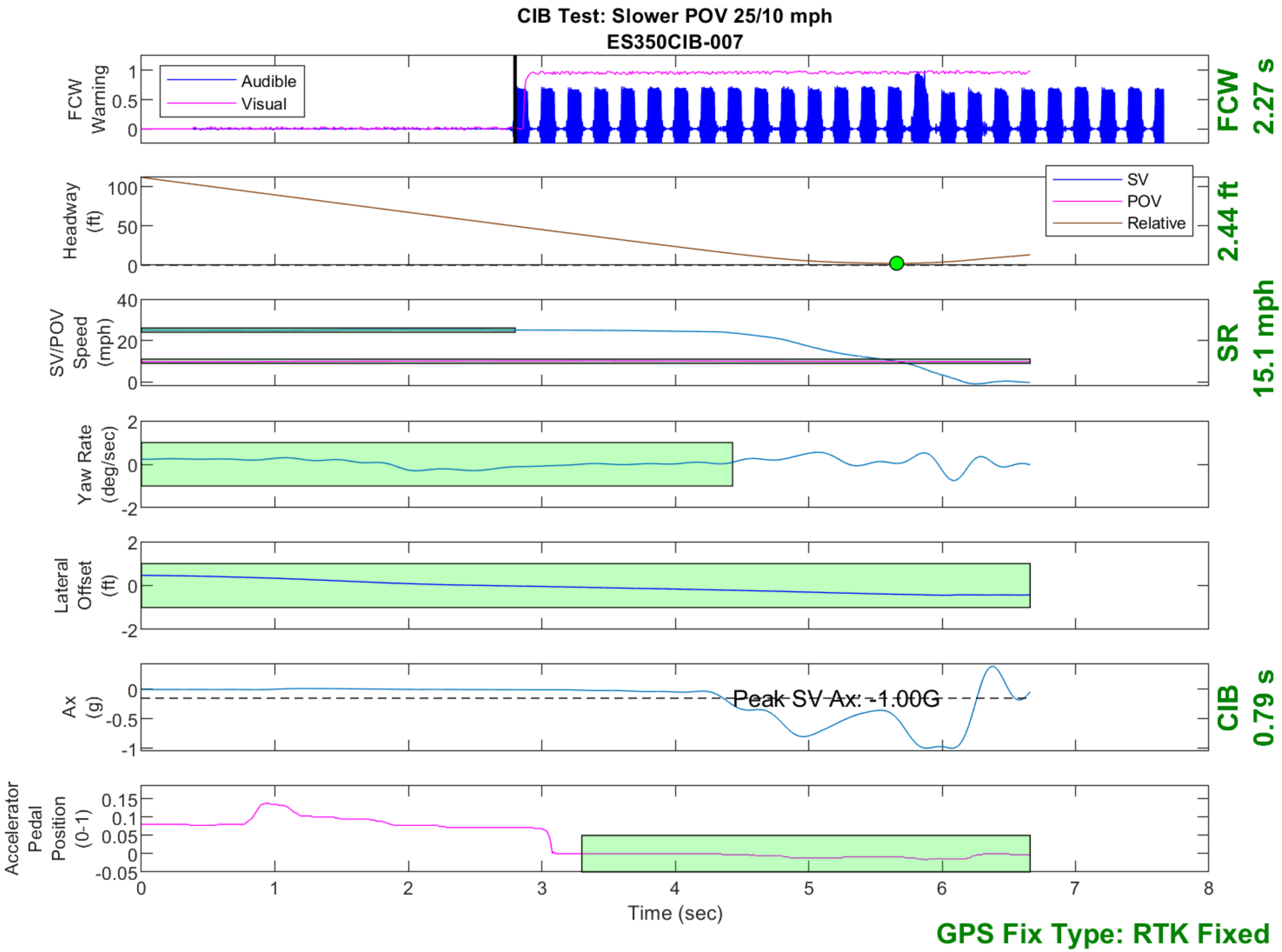


Figure D14. Time History for CIB Run 7, SV Encounters Slower POV, SV 25 mph, POV 10 mph

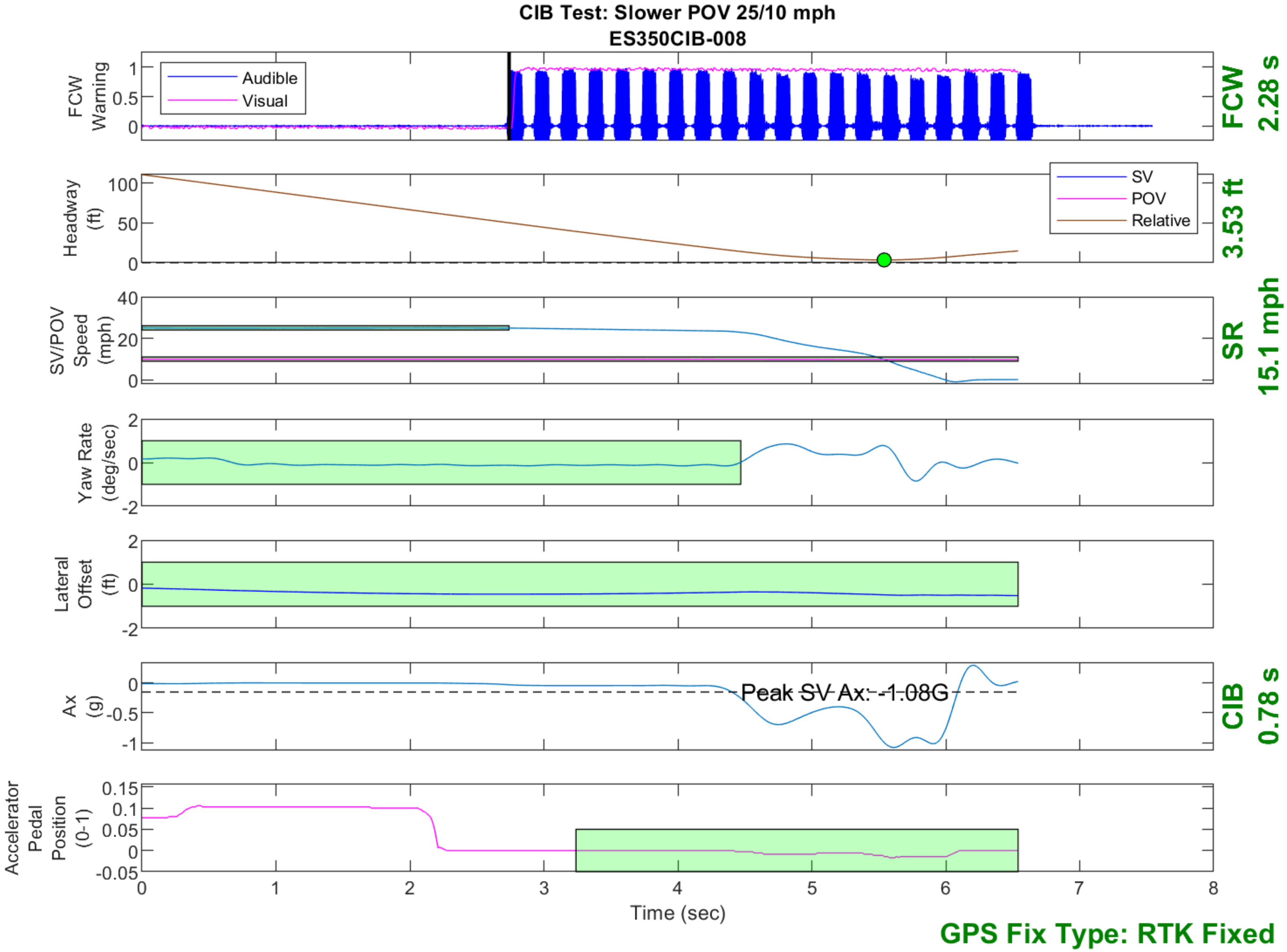


Figure D15. Time History for CIB Run 8, SV Encounters Slower POV, SV 25 mph, POV 10 mph

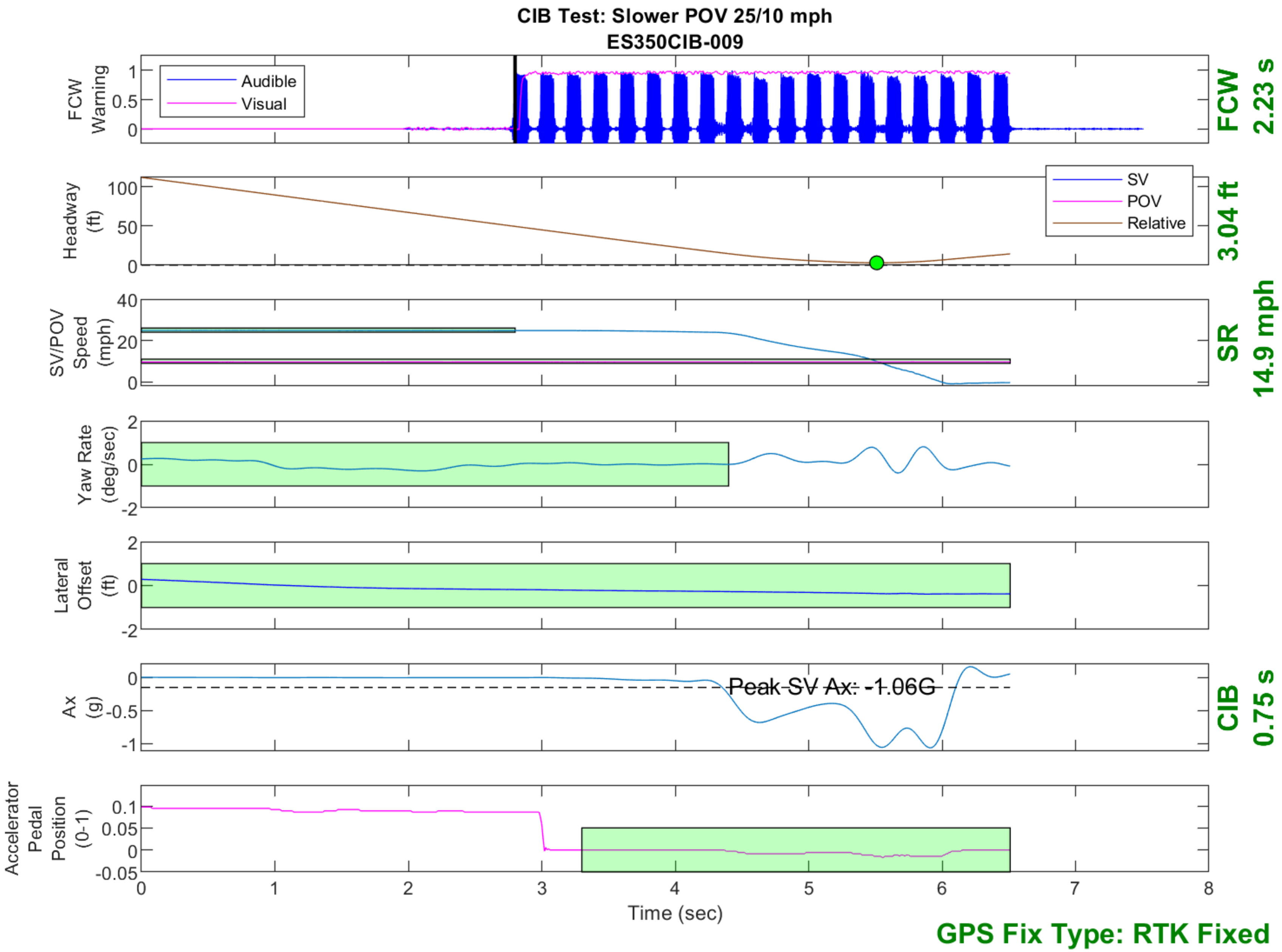


Figure D16. Time History for CIB Run 9, SV Encounters Slower POV, SV 25 mph, POV 10 mph

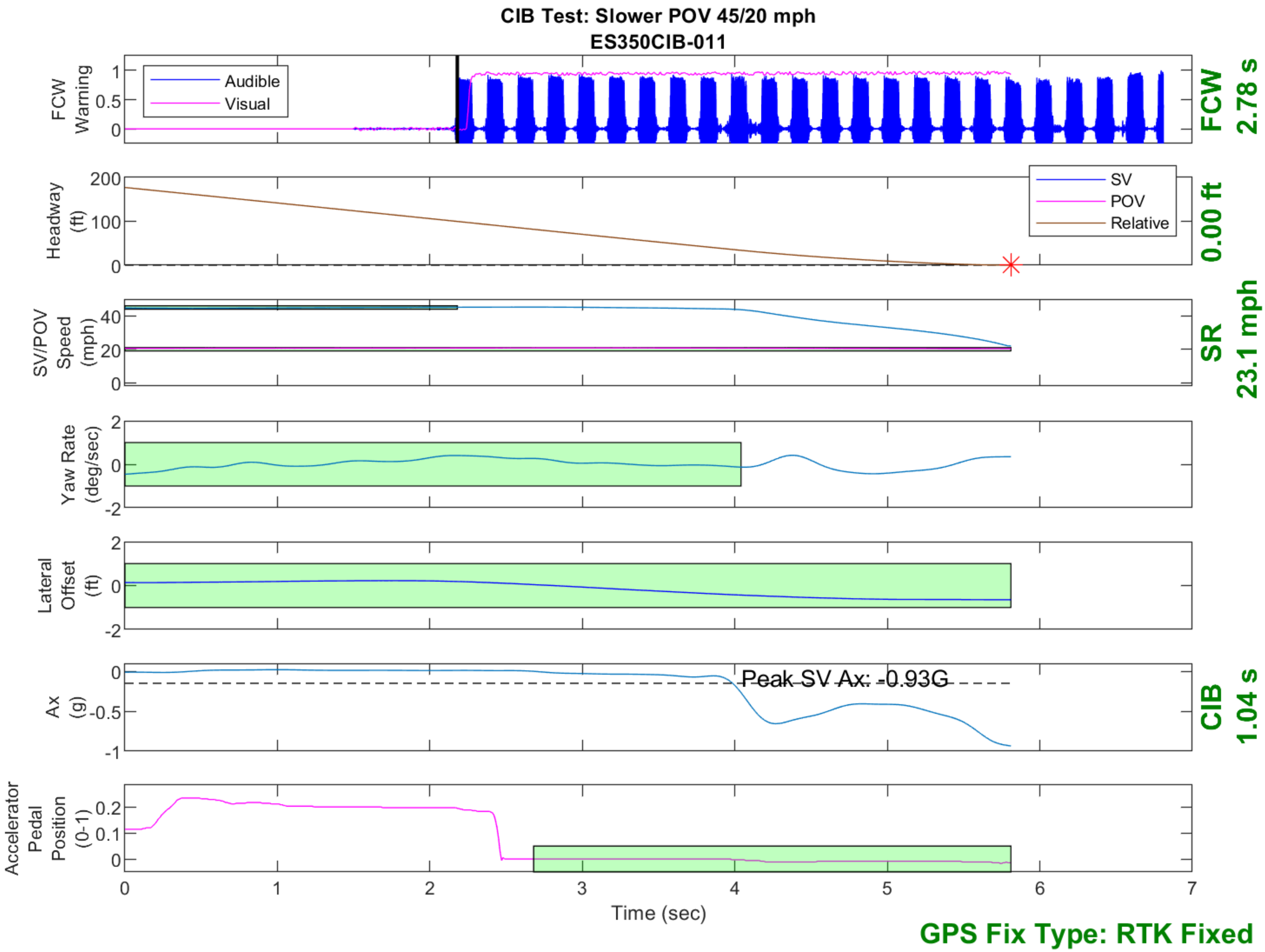


Figure D17. Time History for CIB Run 11, SV Encounters Slower POV, SV 45 mph, POV 20 mph

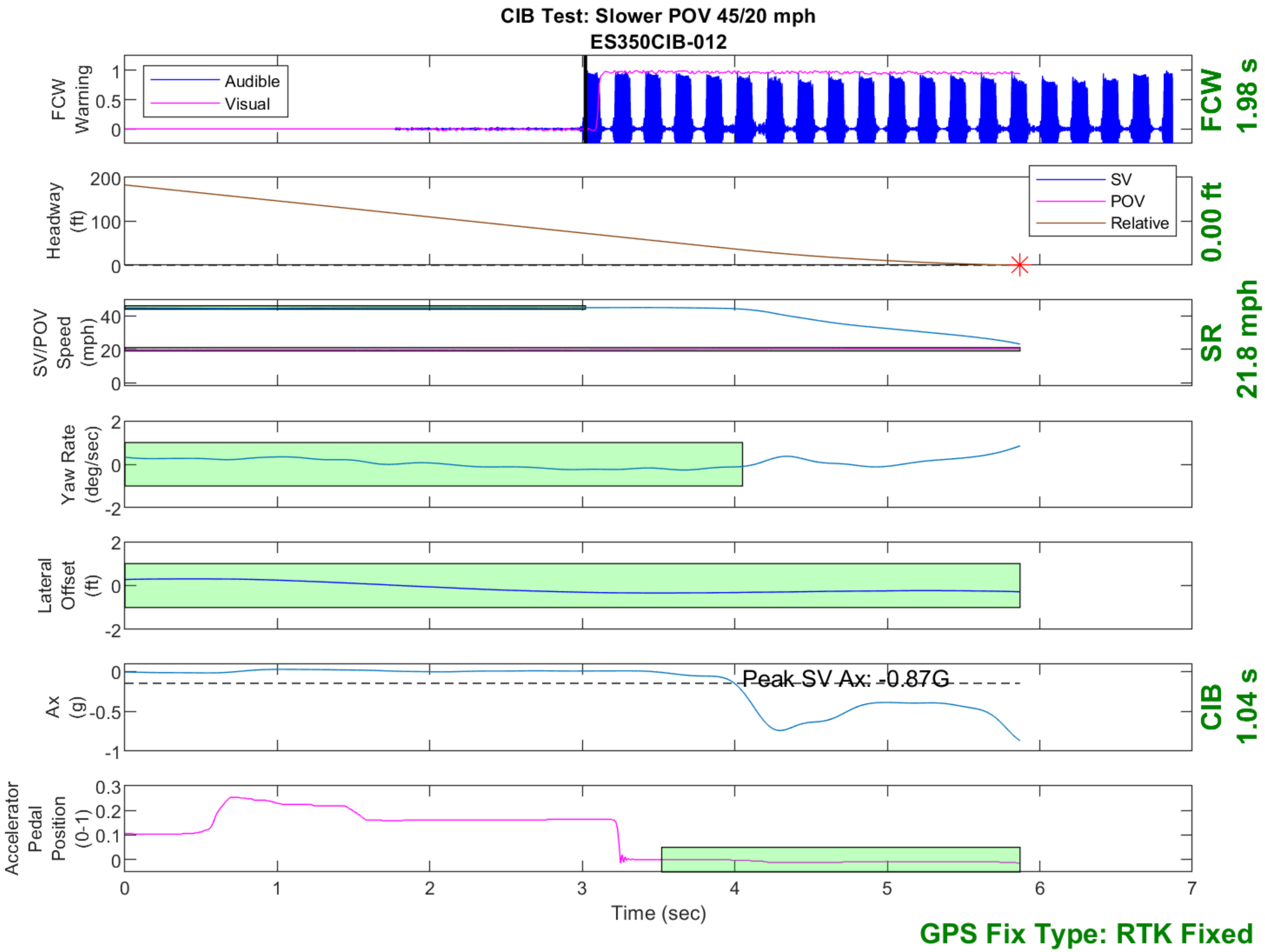


Figure D18. Time History for CIB Run 12, SV Encounters Slower POV, SV 45 mph, POV 20 mph

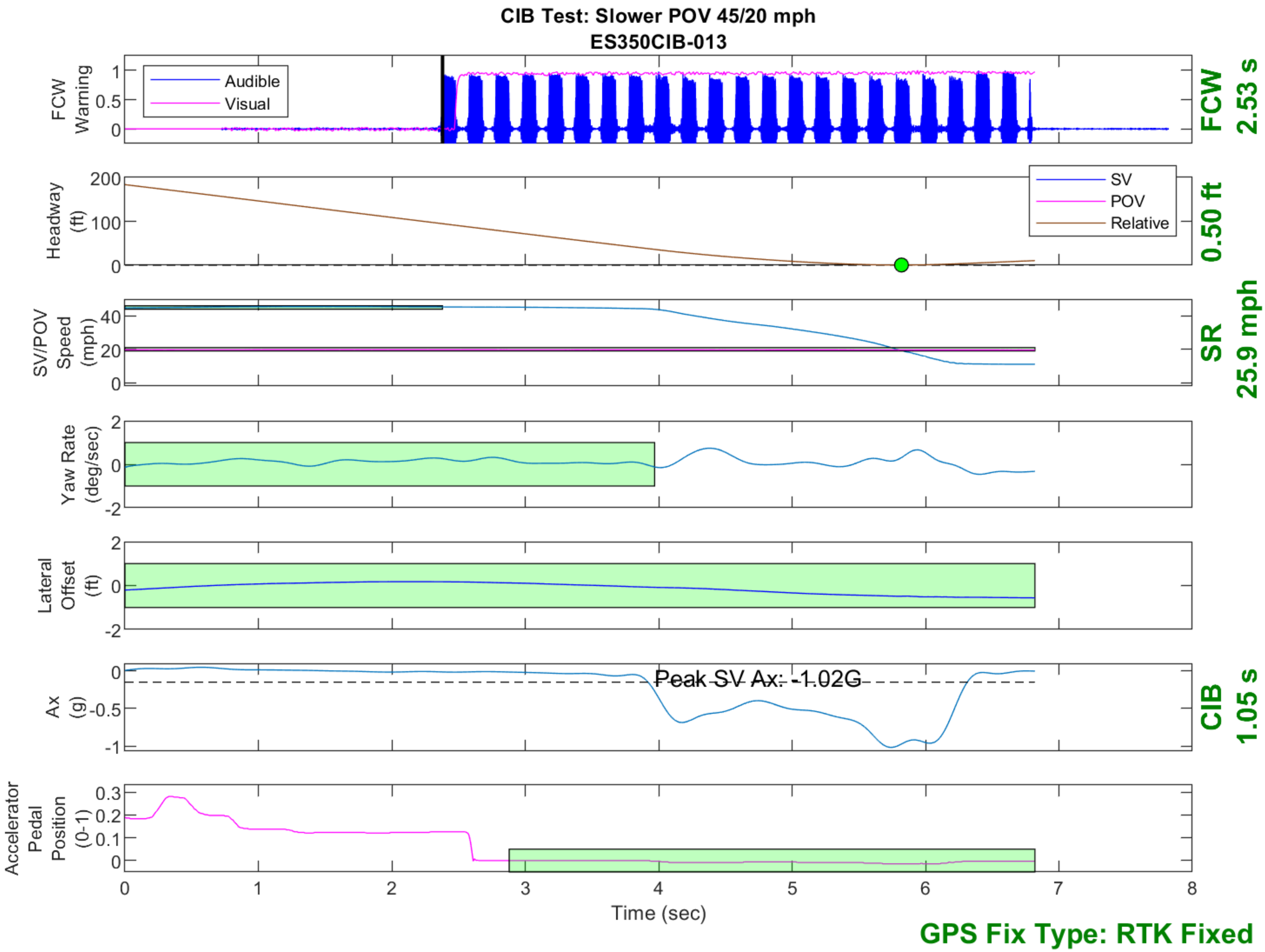


Figure D19. Time History for CIB Run 13, SV Encounters Slower POV, SV 45 mph, POV 20 mph

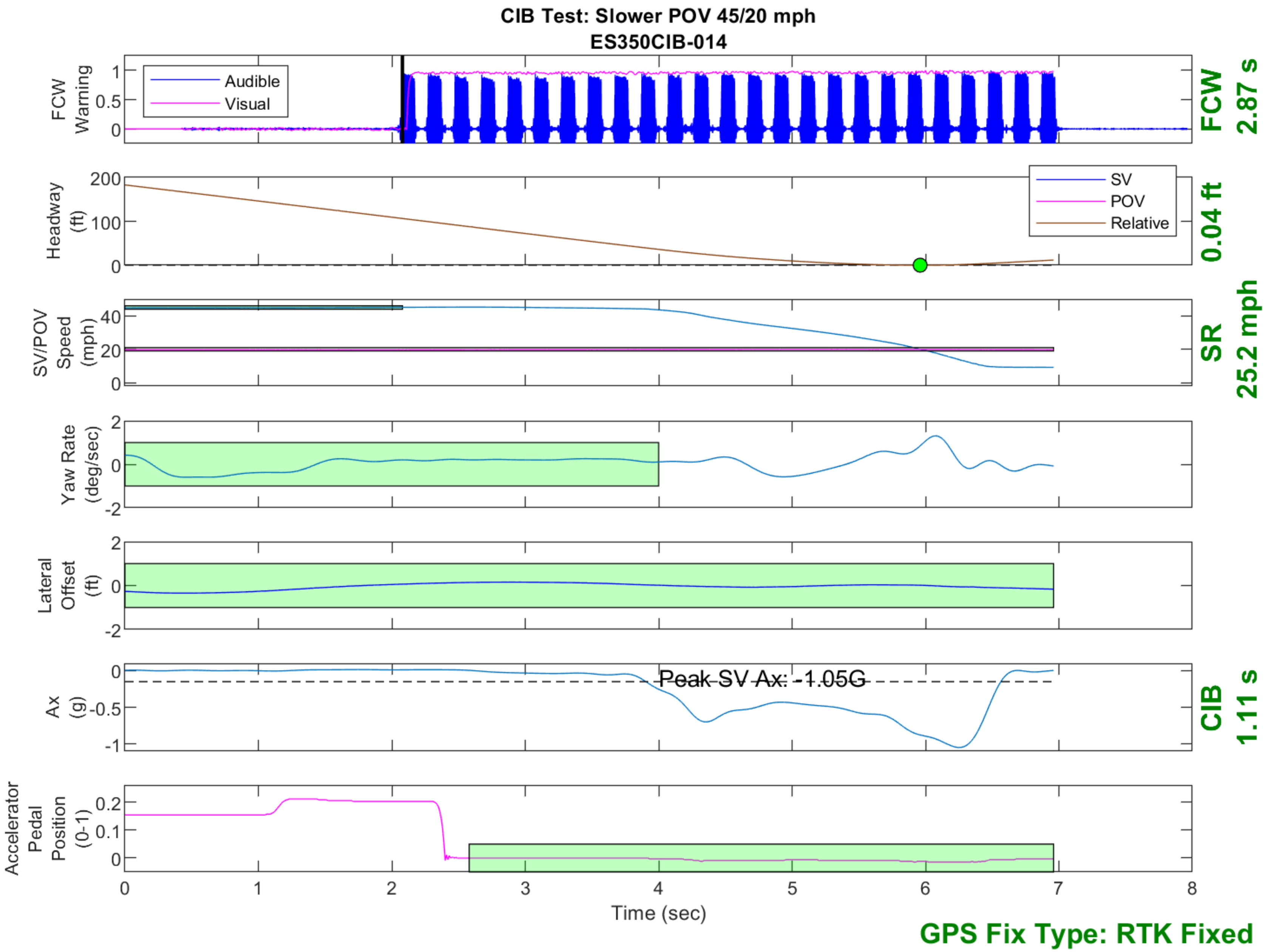


Figure D20. Time History for CIB Run 14, SV Encounters Slower POV, SV 45 mph, POV 20 mph

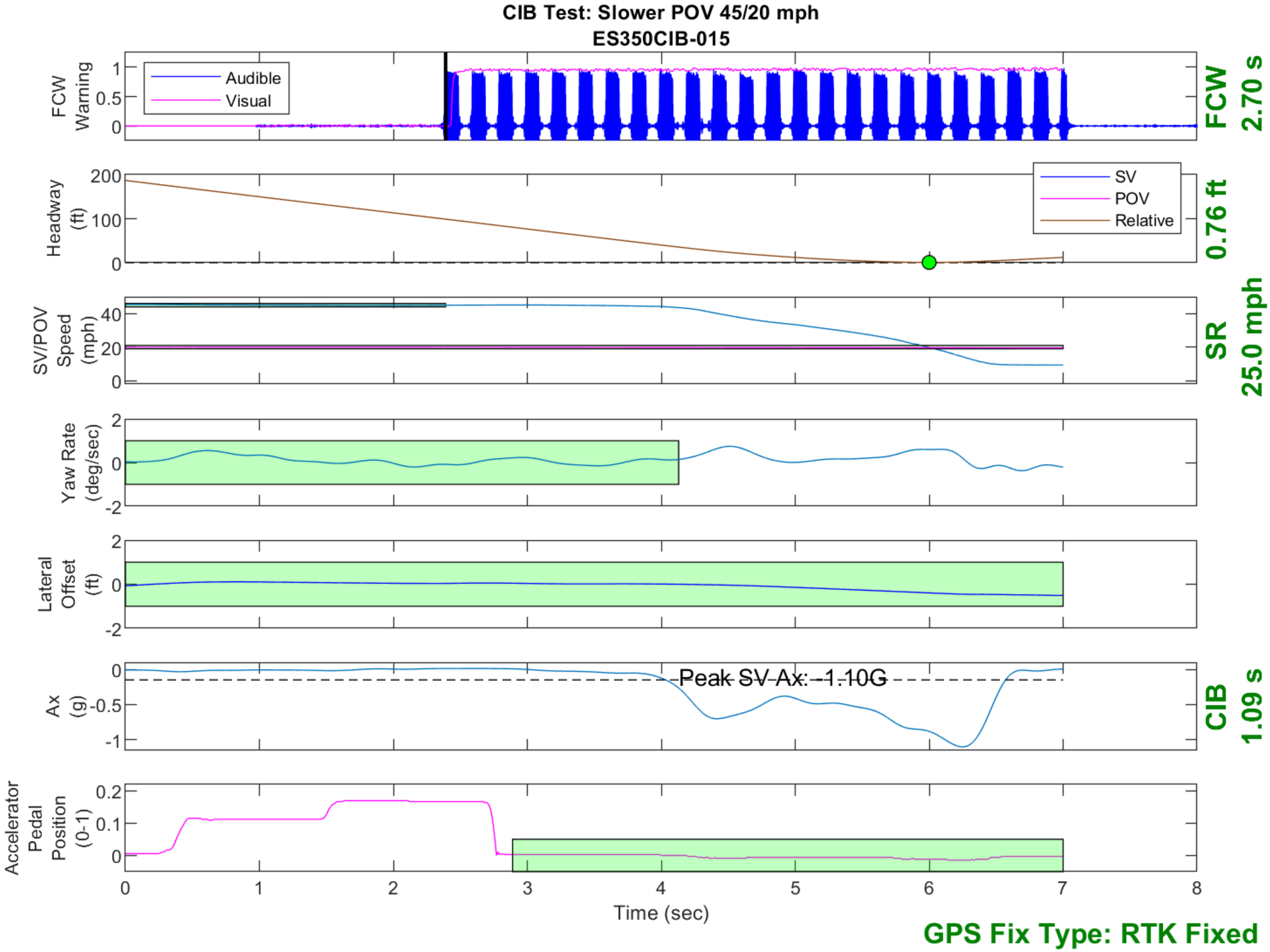


Figure D21. Time History for CIB Run 15, SV Encounters Slower POV, SV 45 mph, POV 20 mph

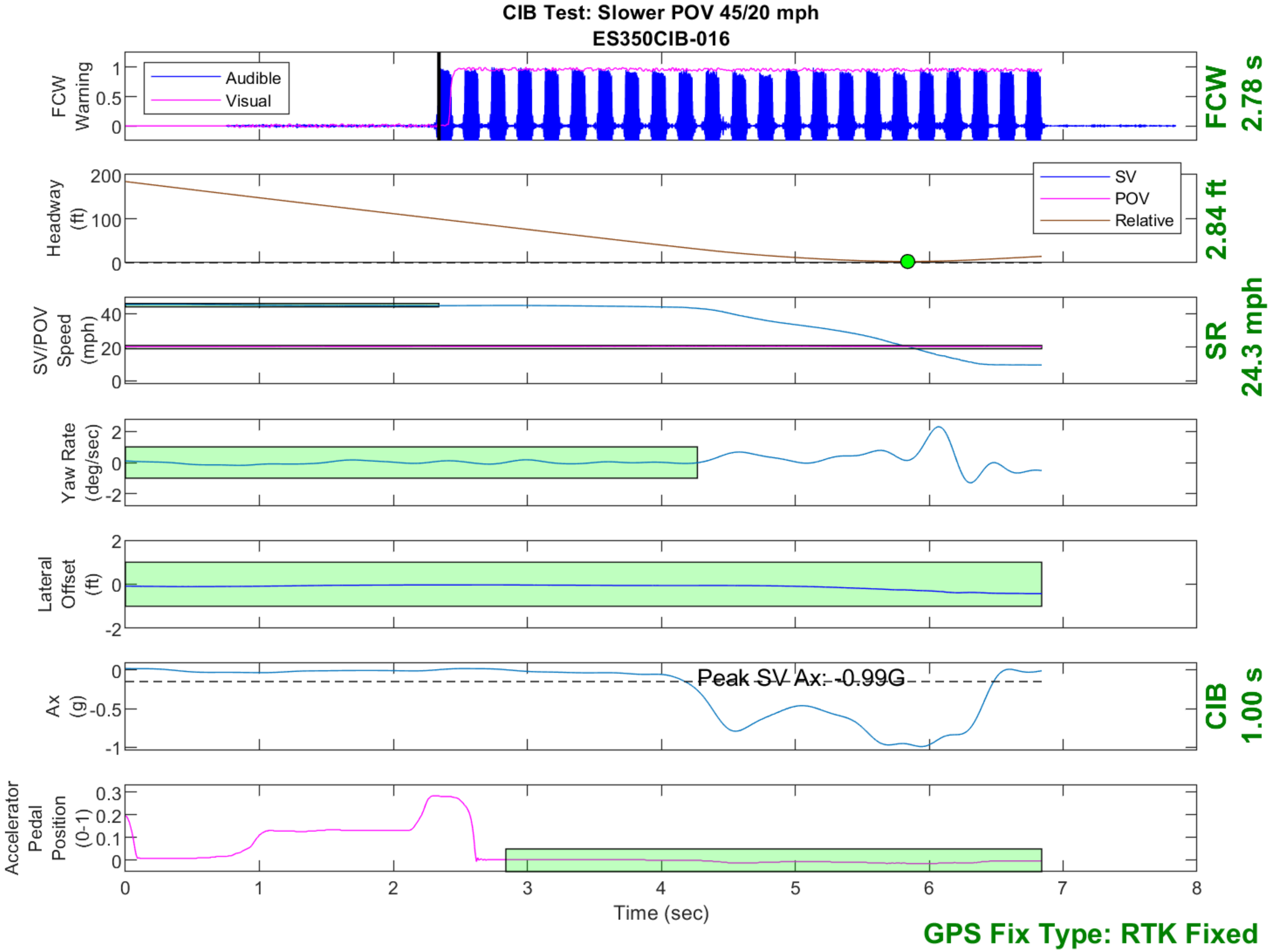


Figure D22. Time History for CIB Run 16, SV Encounters Slower POV, SV 45 mph, POV 20 mph

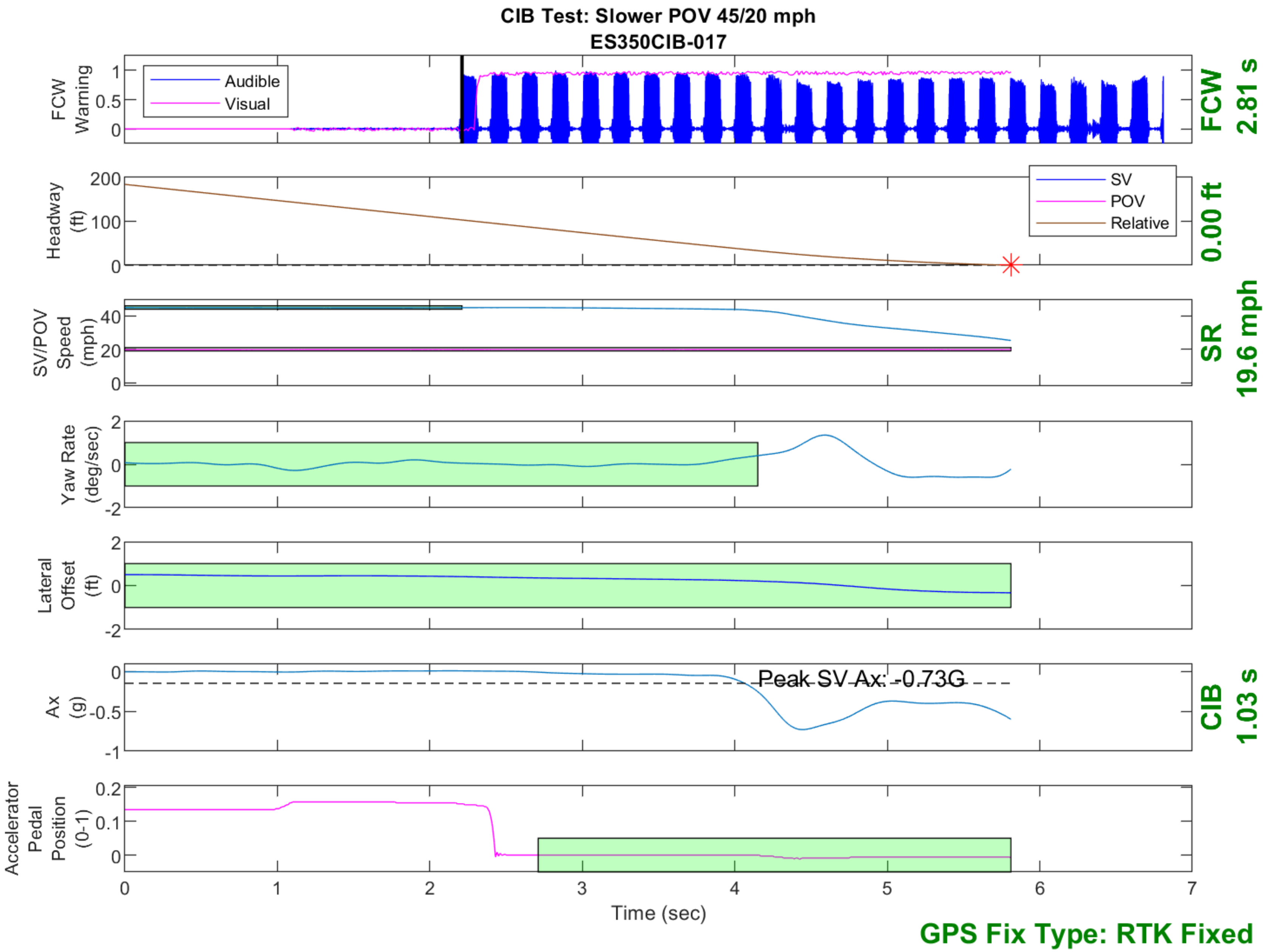


Figure D23. Time History for CIB Run 17, SV Encounters Slower POV, SV 45 mph, POV 20 mph

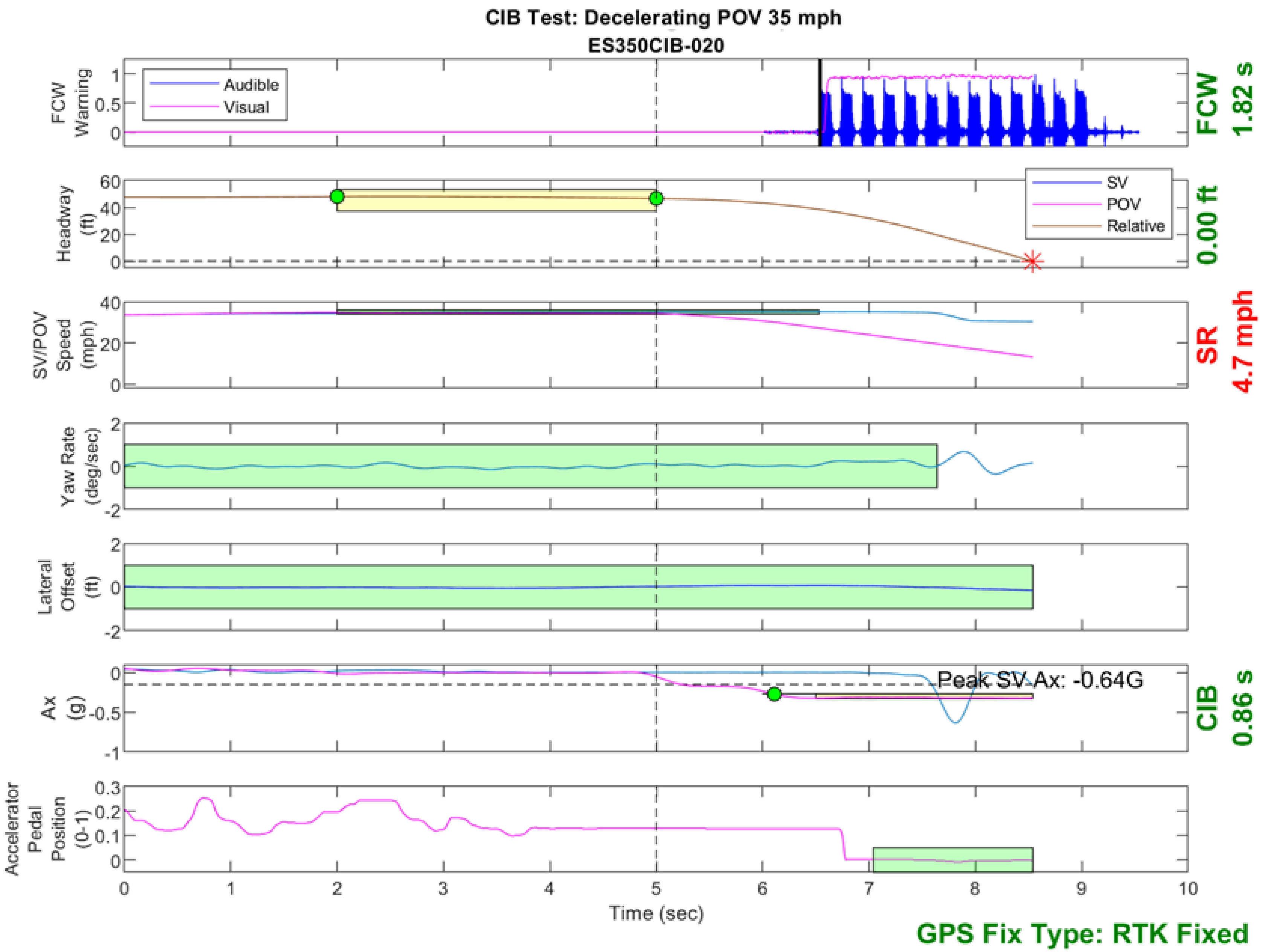


Figure D24. Time History for CIB Run 20, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

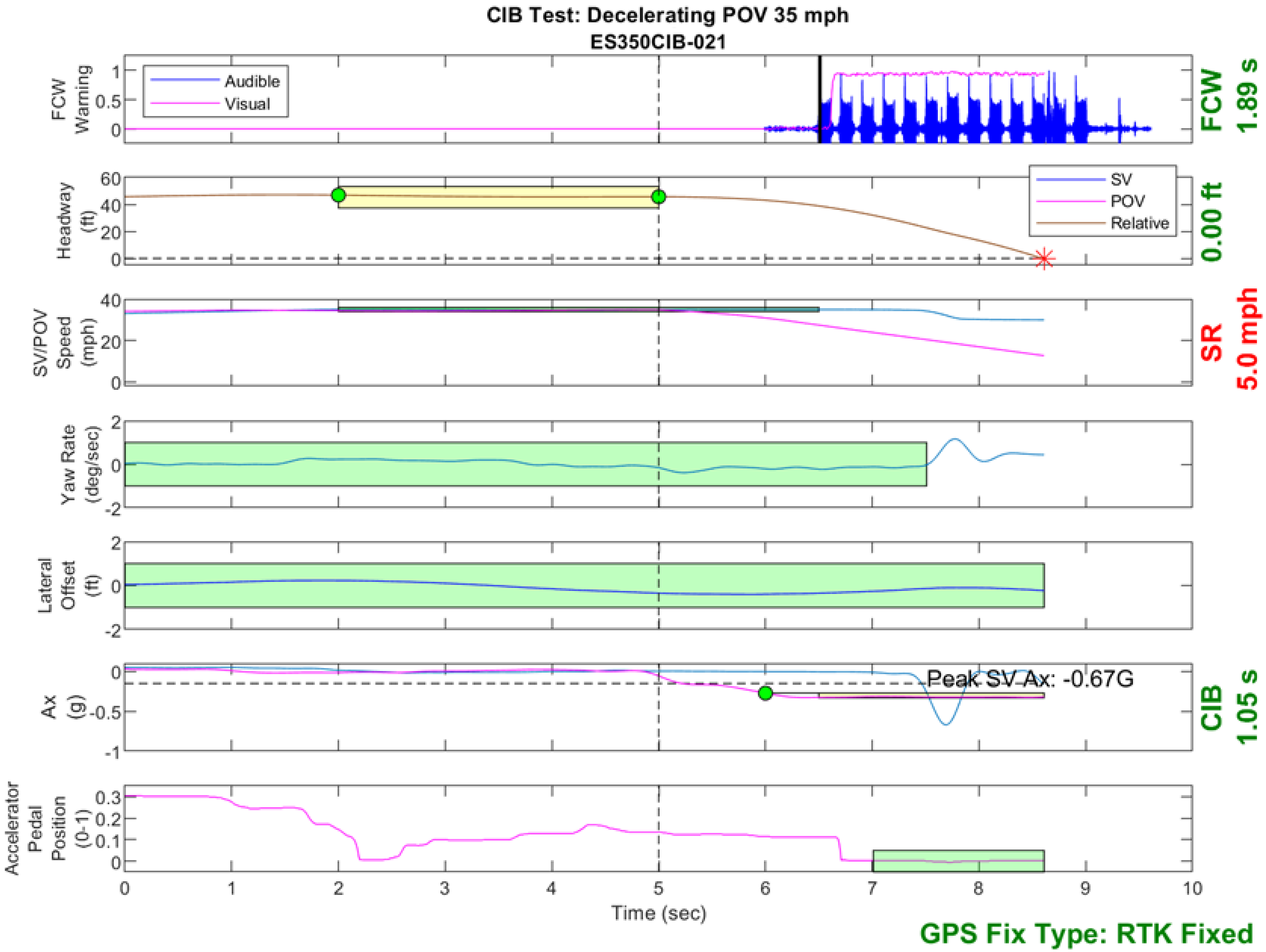


Figure D25. Time History for CIB Run 21, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

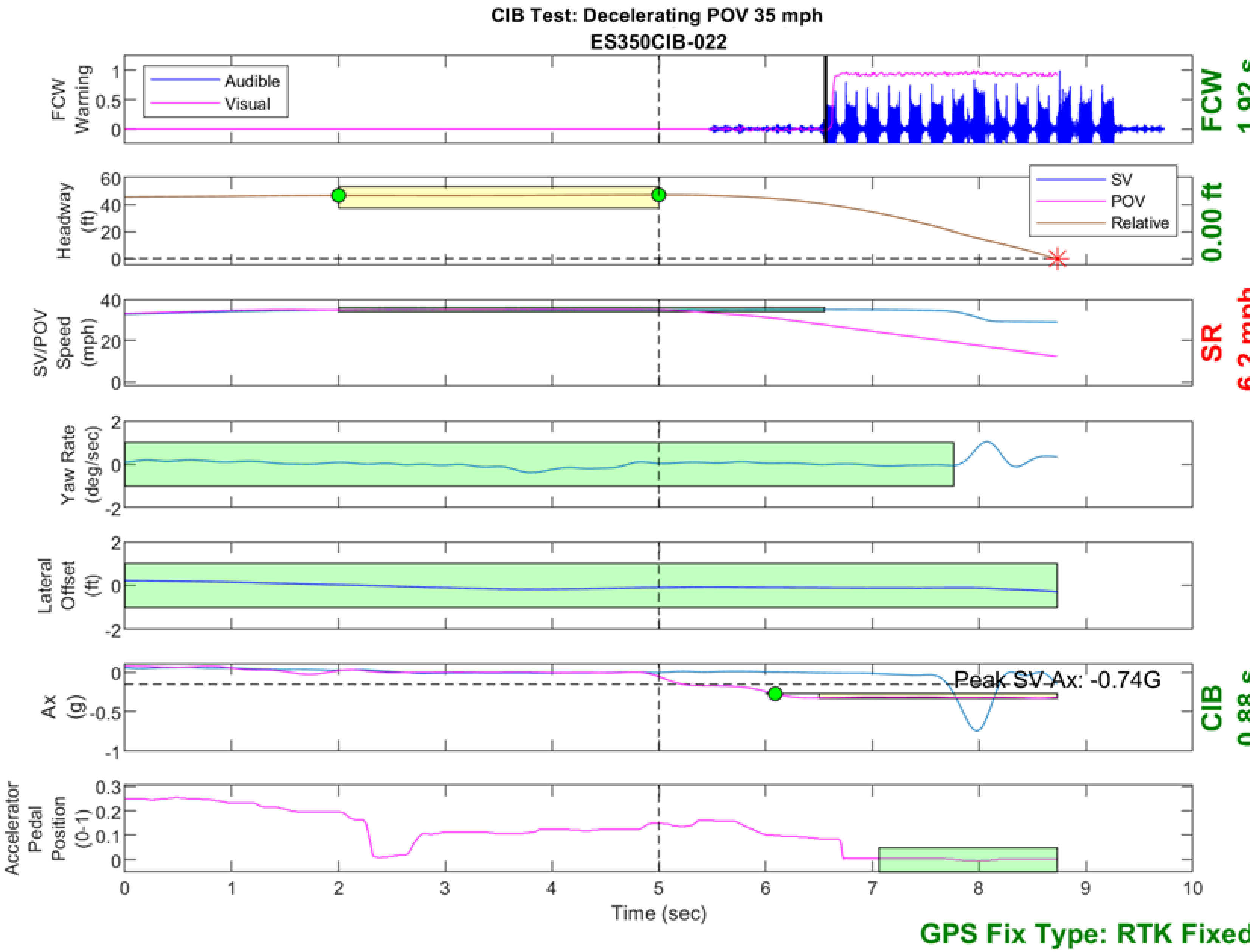


Figure D26. Time History for CIB Run 22, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph