

**NEW CAR ASSESSMENT PROGRAM
DYNAMIC BRAKE SUPPORT SYSTEM CONFIRMATION TEST
NCAP-DRI-DBS-20-15**

2020 Volvo S60 T6 AWD Momentum

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7 August 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.

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Date: 7 August 2020

1. Report No. NCAP-DRI-DBS-20-15	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Final Report of Dynamic Brake Support System Confirmation Test of a 2020 Volvo S60 T6 AWD Momentum.		5. Report Date 7 August 2020	
		6. Performing Organization Code DRI	
7. Author(s) J. Lenkeit, Technical Director S. Rhim, Test Engineer		8. Performing Organization Report No. DRI-TM-19-168	
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 February - August 2020	
		14. Sponsoring Agency Code NRM-110	
15. Supplementary Notes			
16. Abstract These tests were conducted on the subject 2020 Volvo S60 T6 AWD Momentum in accordance with the specifications of the New Car Assessment Program's (NCAP) most current Test Procedure in docket NHTSA-2015-0006-0026; DYNAMIC BRAKE SUPPORT PERFORMANCE EVALUATION CONFIRMATION TEST FOR THE NEW CAR ASSESSMENT PROGRAM, October 2015. The vehicle passed the requirements of the test for the stopped Principal Other Vehicle (POV) and for the slower moving POV but failed the requirements when the POV decelerated in front of the subject vehicle. Therefore, it failed the overall test.			
17. Key Words Dynamic Brake Support, DBS, 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 166	22. Price

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Section I

INTRODUCTION

Dynamic Brake Support (DBS) systems are a subset of Automatic Emergency Braking (AEB) systems. DBS systems are designed to avoid or mitigate consequences of rear-end crashes by automatically applying supplemental braking on the subject vehicle when the system determines that the braking applied by the driver is insufficient to avoid a collision.

DBS systems intervene in driving situations where a rear-end collision is expected to be unavoidable unless additional braking is realized. Since DBS interventions are designed to occur late in the pre-crash timeline, and the driver has already initiated crash-avoidance braking, DBS systems are not required to alert the driver that a DBS intervention has occurred. In addition to sensors monitoring vehicle operating conditions, such as speed, brake application, etc., DBS systems employ RADAR, LIDAR, and/or vision-based sensors capable of detecting surrounding vehicles in traffic. Algorithms in the system's Central Processing Unit (CPU) use this information to continuously monitor the likelihood of a rear-end crash, and command additional braking as needed to avoid or mitigate such a crash.

The method prescribed by the National Highway Traffic Safety Administration (NHTSA) to evaluate DBS performance on the test track involves three longitudinal, 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 fourth scenario is used to evaluate the propensity of a DBS system to inappropriately activate in a non-critical driving scenario that does not present a safety risk to the SV occupant(s).

The purpose of the testing reported herein was to objectively quantify the performance of a Dynamic Brake Support system installed on a 2020 Volvo S60 T6 AWD Momentum. This test to assess Dynamic Brake Support systems is sponsored by the National Highway Traffic Safety Administration under Contract No. DTNH22-14-D-00333 with the New Car Assessment Program (NCAP).

Section II
DATA SHEETS

DYNAMIC BRAKE SUPPORT
DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2020 Volvo S60 T6 AWD Momentum

VIN: 7JRA22TKXLG03xxxx

Test Date: 2/3/2020

Dynamic Brake Support System setting: Early

**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: Fail

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

SV 25 mph: Pass

SV 45 mph: Pass

Overall: Fail

Notes:

DYNAMIC BRAKE SUPPORT
DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2020 Volvo S60 T6 AWD Momentum

TEST VEHICLE INFORMATION

VIN: 7JRA22TKXLG03xxxx

Body Style: Sedan

Color: Osmium Grey Metallic

Date Received: 1/27/2020

Odometer Reading: 10 mi

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: VOLVO CAR CORPORATION

Date of manufacture: 08/19

Vehicle Type: PC (Passenger Car)

DATA FROM TIRE PLACARD

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

Rear: 235/45 R18

Recommended cold tire pressure: Front: 250 kPa (36 psi)

Rear: 250 kPa (36 psi)

TIRES

Tire manufacturer and model: Continental ProContact TX

Front tire specification: 235/45 R18 98H

Rear tire specification: 235/45 R18 98H

Front tire DOT prefix: VYFUWCCO

Rear tire DOT prefix: VYFUWCCO

DYNAMIC BRAKE SUPPORT
DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Volvo S60 T6 AWD Momentum

GENERAL INFORMATION

Test date: 2/3/2020

AMBIENT CONDITIONS

Air temperature: 7.2 C (45 F)

Wind speed: 2.3 m/s (5.2 mph)

X Wind speed \leq 10 m/s (22 mph).

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

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

VEHICLE PREPARATION

Verify the following:

All non-consumable fluids at 100% capacity: X

Fuel tank is full: X

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

Front: 250 kPa (36 psi)

Rear: 250 kPa (36 psi)

DYNAMIC BRAKE SUPPORT
DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2020 Volvo S60 T6 AWD Momentum

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front: 548.4 kg (1209 lb)

Right Front: 523.9 kg (1155 lb)

Left Rear: 436.8 kg (963 lb)

Right Rear: 421.8 kg (930 lb)

Total: 1930.9 kg (4257 lb)

DYNAMIC BRAKE SUPPORT
DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 1 of 3)

2020 Volvo S60 T6 AWD Momentum

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

City Safety (standard equipment)

Type and location of sensor(s) the system uses:

Radar and mono camera (fusion). Both located in the mid-upper part of the windshield.

System setting used for test (if applicable): Early

Brake application mode used for test: Hybrid control

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

Minimum vehicle speed is 4 km/h (2.5 mph). (Per manufacturer supplied information)

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

There is no maximum speed. (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

____ Yes
X ____ No

If yes, please provide a full description.

No initialization process required for the function to be active. It's recommended though that in addition to the procedure in CIB & DBS test protocols, the vehicle has been pre-conditioned with normal driving on public roads. Preferably multiple driving cycles with a total of 60 miles.

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 2 of 3)

2020 Volvo S60 T6 AWD Momentum

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

If yes, please provide a full description.

No deactivation occurs. There is a three seconds time-out after each intervention but after that the system is activated automatically again.

How is the Forward Collision Warning presented to the driver? X Warning light
(Check all that apply) X Buzzer or audible alarm
 X Vibration
 Other

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

- Visual alert – The first visual alert will be a collision warning in the instrument panel. If City Safety applies the brakes, a text message will appear in the instrument panel to notify the driver that the function is/was activated. See Figure A16 in Appendix A.
- Auditory alert – Repeated beeps.
- Haptic alert – Short brake pulses (the pulsation varies according to the vehicle’s speed). The seat belt pretensioner may be activated when the AEB function is triggered.

Is there a way to deactivate the system? Yes
 X No

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 DBS system to detect and respond to a stopped lead vehicle in the immediate forward path of the SV, as depicted in Figure 1.

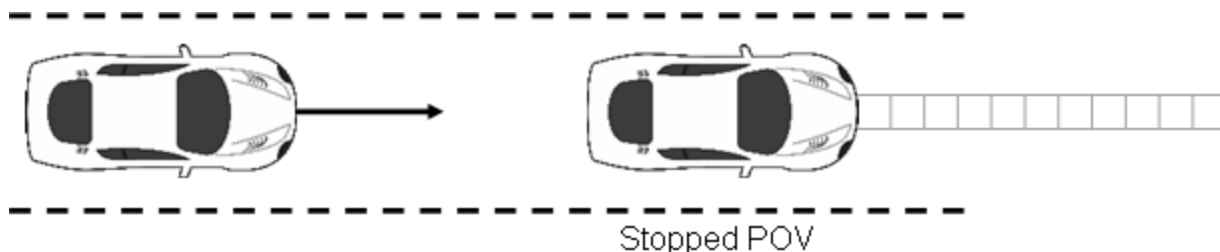


Figure 1. Depiction of Test 1

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 approaches 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 SV brakes were applied at $TTC = 1.1$ seconds (SV-to-POV distance of 40 ft (12 m)). 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).

Table 1. Nominal Stopped POV DBS Test Choreography

Test Speeds		SV Speed Held Constant		SV Throttle Fully Released By		SV Brake Application Onset (for each application magnitude)	
SV	POV	TTC (seconds)	SV-to-POV Headway	TTC (seconds)	SV-to-POV Headway	TTC (seconds)	SV-to-POV Headway
25 mph (40.2 km/h)	0	5.1 → t_{FCW}	187 ft (57 m) → t_{FCW}	Within 500 ms of FCW1 onset	Varies	1.1	40 ft (12 m)

b. Criteria

The performance requirement for this series of tests is that there be no SV-POV impact for at least five of the seven valid test trials.

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

This test evaluates the ability of the DBS 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.

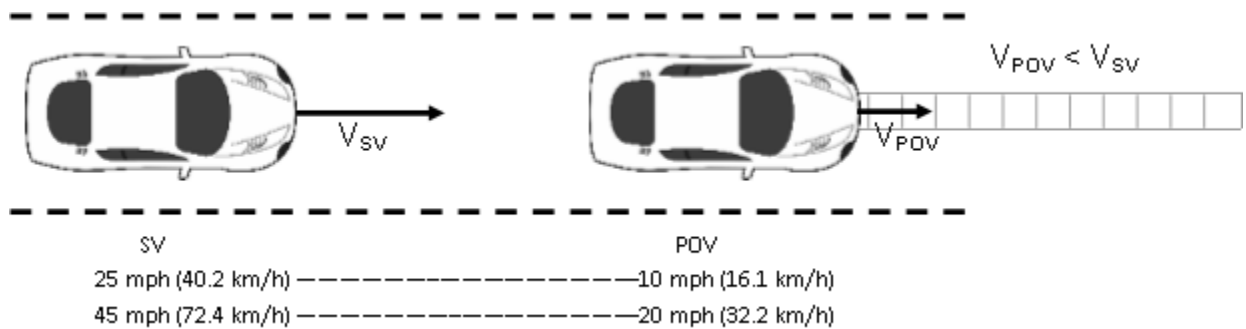


Figure 2. Depiction of Test 2

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 SV brakes were applied at $TTC = 1.0$ seconds, assumed to be SV-to-POV distance of 22 ft (7 m) for an SV speed of 25 mph and 37 ft (11 m) for an SV speed of 45 mph.

The test concluded when either:

- The SV came into contact with the POV or
- 1 second after the speed 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 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.

Table 2. Nominal Slower-Moving POV DBS Test Choreography

Test Speeds		SV Speed Held Constant		SV Throttle Fully Released By		SV Brake Application Onset (for each application magnitude)	
SV	POV	TTC (seconds)	SV-to-POV Headway	TTC (seconds)	SV-to-POV Headway	TTC (seconds)	SV-to-POV Headway
25 mph (40 km/h)	10 mph (16 km/h)	5.0 \rightarrow t_{FCW}	110 ft (34 m) \rightarrow t_{FCW}	Within 500 ms of FCW1 onset	Varies	1.0	22 ft (7 m)
45 mph (72 km/h)	20 mph (32 km/h)	5.0 \rightarrow t_{FCW}	183 ft (56 m) \rightarrow t_{FCW}	Within 500 ms of FCW1 onset	Varies	1.0	37 ft (11 m)

b. Criteria

The performance requirement for this series of tests is that there be no SV-POV impact for at least five of the seven valid test trials.

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

This test evaluates the ability of the DBS 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. Should the SV foundation brake system be unable to prevent an SV-to-POV impact for a given test condition, the DBS system should automatically provide supplementary braking capable of preventing an SV-to-POV collision.

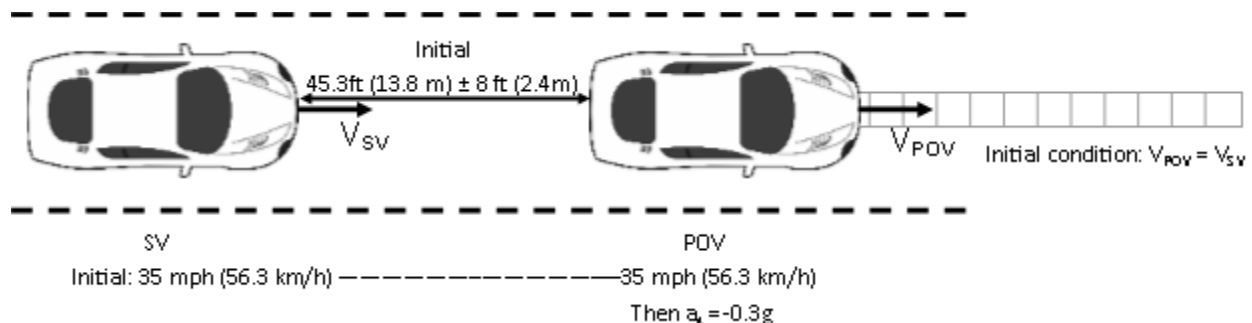


Figure 3. Depiction of Test 3

a. Procedure

The SV ignition was cycled prior to each test run. For this 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 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 $0.3 \pm 0.03 g$. The SV throttle pedal was released within 500 ms of t_{FCW} , and the SV brakes were applied when TTC was 1.4 seconds (31.5 ft (9.6 m)).

The test concluded when either:

- 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.

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 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 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.

Table 3. Nominal Decelerating POV DBS Test Choreography

Test Speeds		SV Speed Held Constant		SV Throttle Fully Released By		SV Brake Application Onset (for each application magnitude)	
SV	POV	TTC (seconds)	SV-to-POV Headway	TTC (seconds)	SV-to-POV Headway	TTC (seconds)	SV-to-POV Headway
35 mph (56 km/h)	35 mph (56 km/h)	3.0 seconds prior to POV braking → t_{FCW}	45 ft (14 m) → t_{FCW}	Within 500 ms of FCW1 onset	Varies	1.4	32 ft (10 m)

b. Criteria

The performance requirement for this series of tests is that no SV-POV contact occurs for at least five of the seven valid test trials.

4. TEST 4 – FALSE POSITIVE SUPPRESSION

The false positive suppression test series evaluates the ability of a DBS 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 DBS 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. The SV was driven at constant speed in the center of the lane toward the STP. If the SV did not present an FCW alert during the approach to the STP by $TTC = 2.1$ s, the SV driver initiated release of the throttle pedal at $TTC = 2.1$ s and the throttle pedal was fully released within 500 ms

of TTC = 2.1 s. The SV brakes were applied at TTC of 1.1 seconds, assumed to be 40 ft (12.3 m) from the edge of the STP at 25 mph or 73 ft (22.1 m) at 45 mph. The test concluded when the front most part of the SV reached a vertical plane defined by the edge of the STP first encountered by the SV.

b. Criteria

In order to pass the False Positive test series, the magnitude of the SV deceleration reduction attributable to DBS intervention must have been less than or equal to 1.25 times the average of the deceleration experienced by the baseline command from the braking actuator 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 haptic, visual, or audible, and the onset of the alert is determined by post-processing the test data.

For systems that implement audible or haptic alerts, part of the pre-test instrumentation verification process is 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 is accomplished in order to identify the center frequency around which a band-pass filter is applied to subsequent audible or tactile warning data so that the beginning of such warnings can be programmatically determined. The band-pass filter used for these warning signal types is a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 4.

Table 4. Audible and Tactile Warning Filter Parameters

Warning Type	Filter Order	Peak-to-Peak Ripple	Minimum Stop Band Attenuation	Passband Frequency Range
Audible	5 th	3 dB	60 dB	Identified Center Frequency \pm 5%
Tactile	5 th	3 dB	60 dB	Identified Center Frequency \pm 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. All braking shall be performed by the programmable brake controller.
- 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: 2 seconds prior to the SV throttle pedal being released

The valid test interval ended:

- Test 1: When either of the following occurred:
 - The SV came in 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.
- Test 2: 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.
- Test 3: When either of the following occurred:
 - The SV came in contact with the POV; or
 - 1 second after minimum SV-to-POV range occurred.
- Test 4: When the SV stopped.

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 defining 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, conduct 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

DBS 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 allow 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 rearward direction. In operation, the shell and roller assembly engages the rail assembly through detents to prevent relative motion during run-up to test speeds and minor 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 and 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 soft 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. Foundation Brake System Characterization

Data collected and analyzed from a series of pre-test braking runs were used to objectively quantify the response of the vehicle's foundation brake system without the contribution of DBS. The results of these analyses were used to determine the brake pedal input magnitudes needed for the main tests.

This characterization was accomplished by recording longitudinal acceleration and brake pedal force and travel data for a variety of braking runs. For three initial brake characterization runs, the vehicle was driven at 45 mph, and the brakes were applied at a rate of 1 inch/sec up to the brake input level needed for at least 0.7 g. Linear regressions were performed on the data from each run to determine the linear vehicle deceleration

response as a function of both applied brake pedal force and brake pedal travel. The brake input force or displacement level needed to achieve a vehicle deceleration of 0.4 g was determined from the average of the three runs. Using the 0.4 g brake input force or displacement level found from the three initial runs, subsequent runs were performed at 25 mph, 35 mph, and 45 mph, with the brakes applied at a rate of 10 inch/sec to the determined 0.4 g brake input force or displacement level. For each of the three test speeds, if the average calculated deceleration level was found to be within 0.4 ± 0.025 g, the resulting force or displacement was recorded and used. If the average calculated deceleration level exceeded this tolerance, the brake input force or displacement levels were adjusted and retested until the desired magnitude was realized. Prior to each braking event, the brake pad temperatures were required to be in the range of 149° - 212°F.

E. Brake Control

1. SUBJECT VEHICLE PROGRAMMABLE BRAKE CONTROLLER

To achieve accurate, repeatable, and reproducible SV brake pedal inputs, a programmable brake controller was used for all brake applications. The controller has the capability to operate in one of two user-selectable, closed-loop, control modes:

- Constant pedal displacement. By maintaining constant actuator stroke, the position of the vehicle's brake pedal remains fixed for the duration of the input. To achieve this, the brake controller modulates application force.
- Hybrid control. Hybrid control uses position-based control to command the initial brake application rate and actuator position, then changes to force-based control to command a reduction of applied force to a predetermined force. This force is maintained until the end of the braking maneuver by allowing the brake controller to modulate actuator displacement.

2. SUBJECT VEHICLE BRAKE PARAMETERS

- Each test run began with the brake pedal in its natural resting position, with no preload or position offset.
- The onset of the brake application was considered to occur when the brake actuator had applied 2.5 lbf (11 N) of force to the brake pedal.
- The magnitude of the brake application was that needed to produce 0.4 g deceleration, as determined in the foundation brake characterization.
- The SV brake application rate was between 9 to 11 in/s (229 to 279 mm/s), where the application rate is defined as the slope of a linear regression line applied to brake pedal position data over a range from 25% to 75% of the commanded input magnitude.

3. POV AUTOMATIC BRAKING SYSTEM

The POV was equipped with an automatic braking system, which was used in Test Type

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.

F. Instrumentation

Table 5 lists the sensors, signal conditioning, and data acquisition equipment used for these tests.

Table 5. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	< 1% error between 20 and	Omega DPG8001	17042707002	By: DRI Date: 7/3/2019 Due: 7/3/2020
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform 5338 N/	0.5% of applied load	Intercomp SWI	1110M206352	By: DRI Date: 1/6/2020 Due: 1/6/2021
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
Load Cell	Force applied to brake pedal					By: DRI
		0 - 250 lb 0 -1112 N	0.1% FS	Honeywell 41A	1464391	Date: 8/30/2019 Due: 8/30/2020
		0-250 lb 1112 N	0.05% FS	Stellar Technology PNC700	1607338	Date: 8/30/2019 Due: 8/30/2020
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

Table 5. Test Instrumentation and Equipment (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels;	Accels $\pm 10g$, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +		By: Oxford Technical Solutions
	Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates;				2176	Date: 4/11/2018 Due: 4/11/2020
	Roll, Pitch, Yaw Angles				2258	Date: 5/3/2019 Due: 5/3/2021
Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW)	Distance and Velocity to lane markings (LDW) and POV (FCW)	Lateral Lane Dist: ± 30 m Lateral Lane Velocity: ± 20 m/sec Longitudinal Range to POV: ± 200 m Longitudinal Range Rate: ± 50 m/sec	Lateral Distance to Lane Marking: ± 2 cm Lateral Velocity to Lane Marking: ± 0.02 m/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)	$\pm 5g$	$\leq 3\%$ of full range	Silicon Designs, 2210-005	NA	NA

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Coordinate Measurement Machine	Inertial Sensing System Coordinates	0-8 ft 0-2.4 m	±.0020 in. ±.051 mm (Single point articulation accuracy)	Faro Arm, Fusion	UO8-05-08-06636	By: DRI Date: 1/6/2020 Due: 1/6/2021
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

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Figure A1. Front View of Subject Vehicle



Figure A2. Rear View of Subject Vehicle

2020VOLVO

S60 T6 AWD MOMENTUM



Volvo Car USA LLC
www.volvocars.com/us

PERFORMANCE

2.0L Super & Turbo-Charged, Direct Inject Engine
316 HP @ 5700 RPM and 295 lb-ft Torque @ 2200 RPM
8-Speed Geartronic Automatic Trans w/ Start-Stop
All-Wheel Drive with Instant Traction
Adjustable Drive-Mode settings
Double Wishbone Front & Integral Link Rear Susp
Anti-Lock Braking Sys (ABS) w/ Hill Start Assist
Advanced Electronic Stability Control (ESC)
Electronic Power Steering Personalization
18" Alloy Wheels with All-Season Tires

AUDIO & TECHNOLOGY

12.3" Digital Driver Display
9" Integrated Sensus Connect Touchscreen feat. Smartphone Inleg (Apple CarPlay/Android Auto)
Volvo On Call with 4-Yr Complimentary Subscription
Incl Mobile App w/ Remote Start
WiFi Hotspot and Complimentary Trial Subscription
Bluetooth Connectivity w/ Audio Streaming
SIRIUSXM Radio w/ 3 Month Trial Subscription
AM / FM / HD Radio
USB Ports, 2 Front
Standard Apps: Spotify, Pandora, TuneIn
220W High Performance Audio System w/ 10 Speakers

SAFETY & SECURITY

LED Headlights w/ Thor's Hammer DRL, Auto Highbeam
Collision Avoidance by City Safety
Low & High Speed Collision Mitigation
Detects Vehicle/Pedestrian/Cyclist/Large Animal
Road Sign Information
Run-off Road Protection & Run-off Road Mitigation
Lane Departure Warning / Lane Keeping Aid
Oncoming Mitigation by Braking
Front, Side & Curtain Airbags
with Driver Side Knee Airbag
Whiplash Protection System (WHIPS) in Front Seats
Side Impact Protection System (SIPS)
Power Child Lock, Rear Doors
Automatic Braking After Collision
Driver Alert Control
Lower Anchors and Tethers for Child Seats (LATCH)
Roll Stability Control
Five, 3-Point Safety Belts with Pretensioners
Rear Park Assist Camera

LUXURY & CONVENIENCE

Laminated Panoramic Moonroof w/Power Sunshade
Leatherette Upholstery Seating Surfaces
Leather Wrapped Tilt & Telescopic Steering Wheel
10-Way, Power Front Seats w/ Driver Seat Memory
2-Way Power Lumbar Support, Front Seats
Power Foldable Rear Seat Headrests
Heated Front Seats
Keyless Engine Start/Turnoff
Cargo Scuff Plate
Cargo Grille, High-Gloss Black
Auto Dimming Interior Rearview Mirror
2-Zone Automatic Climate Control + CleanZone
Volvo Aluminum Tread Plates
Iron Ore Aluminum Deco Inlays
Dual Visible Tailpipes w/ Chrome Sleeves

AUTHORIZED RETAILER

CULVER CITY VOLVO 5162
11201 WASHINGTON BLVD
CULVER CITY, CA 90230

WARRANTY

48 Month/50,000 Mile Limited Warranty Coverage
144 Month Corrosion Protection "Unlimited Mileage"
Refer to Warranty Info Book for Specific Limitations.

VOLVO On-Call Roadside Assistance

Volvo Increased Protection: Ask Your Volvo Retailer
About an Extended Service Contract

MAINTENANCE

Complimentary Factory Scheduled Maintenance for the
First 3 Years or 36,000 Miles

ACCESSORIES

Enhance the driving pleasure with Volvo accessories.
Enrich the styling, integrate technology, boost
performance, or simply carry more cargo - from
function to fun, there's something for everyone.

To view full accessory product line -
Scan this Smartphone QR code
or visit <https://accessories.volvocars.com/en-us>

JOIN THE CONVERSATION

See what our fans are saying about Volvo and join in!

Have a question?
Feel free to ask us on Twitter! @VolvoCarUSA
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Instagram: @VolvoCarUSA
Facebook: Volvo Car USA
YouTube: Volvo Car USA

The price shown does not include Gasoline, License and Title Fees, State and
Local Taxes and Dealer Installed Options and Accessories. The factory reserves
the right to modify price, designs and equipment without previous notice.

PRICING

IMPORTER'S SUGGESTED LIST PRICE P.O.E.: \$40,550.00

Premium Package 2,050.00

Power Retractable Rearview Mirrors
Automatically Dimmed Inner & Exterior Mirrors
HomeLink Garage Door Transmitter
Compass in Rearview Mirror
Blind Spot Information System with Steer Assist (BLIS)
& Cross Traffic Alert with Autobrake
Park Assist Front & Rear
Keyless Entry with Illuminated Door Handles &
Power-Release Trunklid

Heated Rear Seats & Heated Steering Wheel 750.00

Metallic Paint 645.00

Destination Charge 995.00

Total Suggested Retail Price: \$44,990.00

Fuel Economy and Environment

Fuel Economy

25 MPG
Combined city/hwy

Compact Car range from 14 to 119 MPG.
The best vehicle rates 136 MPG.

You spend \$2,250
more in fuel costs
over 5 years
compared to the
average new vehicle.

4.0 gallons per 100 miles

Annual Fuel Cost \$1,950

Fuel Economy & Greenhouse Gas Rating (tailpipe only) Smog Rating (tailpipe only)

1 5 10 Best

This vehicle emits 352 grams CO2 per mile. The best emits 6 grams per mile (tailpipe only). Producing and distributing fuel also create emissions; learn more at fuelconomy.gov.

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 27 MPG and costs \$ 7,500 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at \$3.25 per gallon. MPG is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fuelconomy.gov

Calculate personalized estimates and compare vehicles

PARTS CONTENT INFORMATION

FOR VEHICLES IN THIS
CARLINE: VOLVO SERIES

U.S./CANADIAN PARTS
CONTENT: 20%

MAJOR SOURCES OF
FOREIGN PARTS CONTENT:
SWEDEN: 20%
BELGIUM: 20%

FOR THIS VEHICLE:
FINAL ASSEMBLY POINT:
RIDGEVILLE, SC

COUNTRY OF ORIGIN:
ENGINE PARTS:
SWEDEN

TRANSMISSION PARTS:
JAPAN

Note: Parts contents does not include
final assembly, distribution, or other
non-parts costs.

GOVERNMENT 5-STAR SAFETY RATINGS

This vehicle has not been rated by the government for overall
vehicle score, frontal crash or rollover risk.

Star ratings range from 1 to 5 stars (*****), with 5 being the highest.
Source: National Highway Traffic Safety Administration (NHTSA)
www.safercar.gov or 1-888-327-4236

VEHICLE IDENTIFICATION
Type & Chassis: 224 03
Model Year: 2020
Color: Osmium Grey Metall
VIN: 7JRAZ2TKXLG03

Port of Importation: Charleston VFC,
Delivered by: Truck
DELIVERY ADDRESS





MFD BY VOLVO CAR CORPORATION DATE: 08/19

VIN: 7JRA22TKXLG03	MARKET CODE: 31	GVWR: 5030 LB
TYPE: PC	COLOUR: 714	GAWR FRONT: 2535 LB
		GAWR REAR: 2555 LB

THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR VEHICLE SAFETY, BUMPER AND THEFT PREVENTION STANDARDS IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE.


VOLVO  31689476

Figure A4. Vehicle Certification Label



TIRE AND LOADING INFORMATION

SEATING CAPACITY | TOTAL 5 | FRONT 2 | REAR 3

The combined weight of occupants and cargo should never exceed : 405kg or 890lbs.

TIRE	SIZE	COLD TIRE PRESSURE	SEE OWNERS MANUAL FOR ADDITIONAL INFORMATION
FRONT	235/45R18	250kPa, 36psi	
REAR	235/45R18	250kPa, 36psi	
SPARE	T125/70R18	420kPa, 60psi	

VOLVO 31416488

Figure A5. Tire Placard



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



Figure A7. Load Frame/Slider of SSV

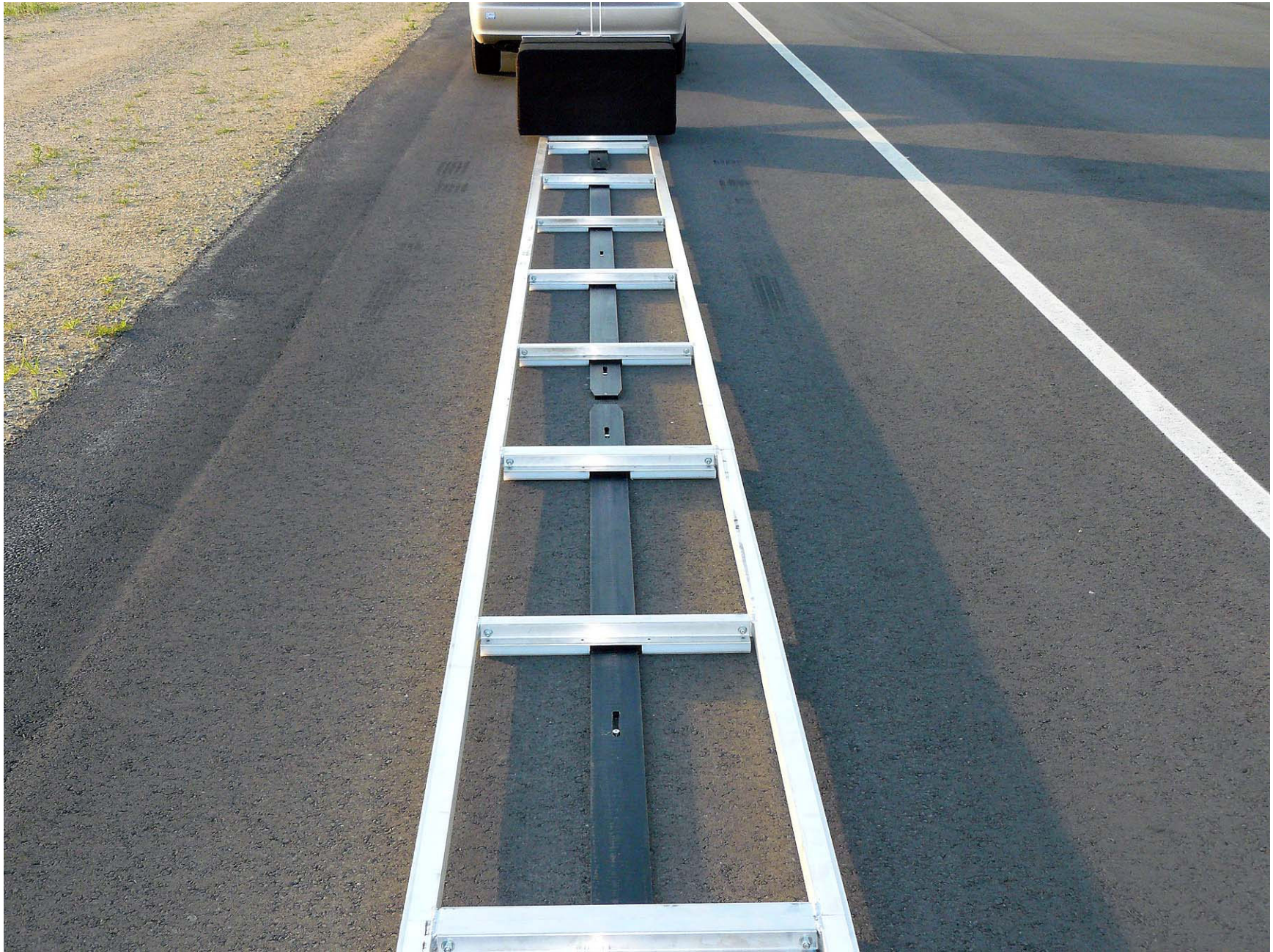


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track



Figure A9. Steel Trench Plate
A-11



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



Figure A11. Sensor for Detecting Visual Alerts
A-13



Figure A12. Sensor for Detecting Auditory Alerts



Figure A13. Computer and Brake Actuator Installed in Subject Vehicle



Figure A14. Brake Actuator Installed in POV System

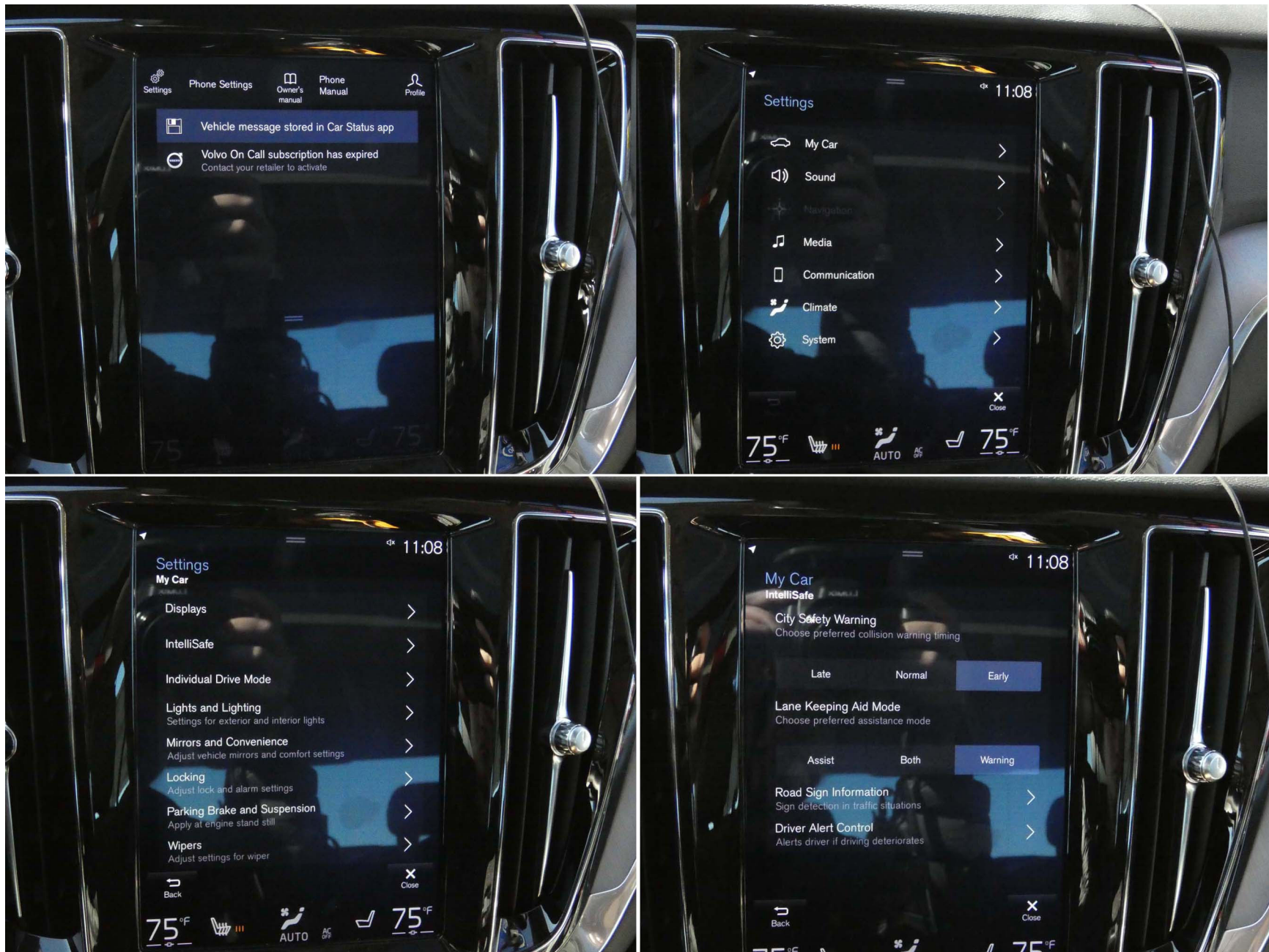


Figure A15. Menu Page for AEB Settings



Figure A16. AEB Visual Alert
A-18

APPENDIX B

Excerpts from Owner's Manual

⚠ WARNING

The driver should be aware that if conditions suddenly change when using Passing Assistance, the function may implement an undesired acceleration in certain conditions.

Some situations should be avoided, e.g. if:

- the vehicle is approaching an exit in the same direction as passing would normally occur
- the vehicle ahead slows before your vehicle has had time to switch to the passing lane
- traffic in the passing lane slows down

Situations of this type can be avoided by temporarily putting Adaptive Cruise Control or Pilot Assist in standby mode.

Related information

- Passing assistance (p. 296)
- Adaptive Cruise Control* (p. 270)
- Pilot Assist* (p. 279)
- Adaptive Cruise Control* standby mode (p. 274)
- Pilot Assist* standby mode (p. 284)

Radar sensor

The radar sensor is used by several driver support systems to detect other vehicles.



Location of radar sensor.

The radar sensor is used by the following functions:

- Distance Alert*
- Adaptive Cruise Control*
- Pilot Assist*
- Lane Keeping Aid
- City Safety

Any modifications to the radar sensor may make its use illegal.

Related information

- Driver support systems (p. 260)
- Camera/radar sensor limitations (p. 301)

- Recommended camera and radar sensor maintenance (p. 305)
- Radar sensor type approval (p. 298)

* Option/accessory. 297

DRIVER SUPPORT

Camera

The camera is used by several driver support systems to e.g. detect lane marker lines or road signs.



Location of the camera.

The camera is used by the following functions:

- Adaptive Cruise Control*
- Pilot Assist*
- Lane Keeping Aid*
- Steering assistance at risk of collision
- City Safety
- Driver Alert Control*
- Road Sign Information*
- Active high beams*
- Park Assist*

Related information

- Driver support systems (p. 260)
- Camera/radar sensor limitations (p. 301)
- Recommended camera and radar sensor maintenance (p. 305)

Camera/radar sensor limitations

The camera and radar sensor used by several of the driver support functions has certain limitations, which also affect the functions using the camera and radar sensor. The driver should be aware of the following limitations:

Camera and radar

Obstructed camera



The area marked in the illustration must be cleaned regularly and kept free of decals, objects, solar film, etc.

The camera is located on the upper interior section of the windshield along with the radar sensor.

Do not place, affix or mount anything on the inside or outside of the windshield, or in front of or around the camera and radar sensor – this could disrupt camera and radar-based functions. It could cause functions to be reduced, deactivated completely or to produce an incorrect function response.



If this symbol and the message “**Windscreen sensor blocked, see Owner's manual**” is displayed in the instrument panel, it means that the camera and radar sensor are unable to detect other vehicles, cyclists, pedestrians and large animals in front of the vehicle and that the vehicle's camera and radar-based functions may be obstructed.

The following table shows some of the situations that can cause the message to be displayed, and suggested actions:

Cause	Action
The area of the windshield in front of the camera/radar sensor is dirty or covered by ice or snow.	Clean the windshield in front of the camera/radar sensor and remove dirt, ice and snow.
Thick fog, heavy rain or snow is blocking the radar signals or the camera's range of visibility.	No action. Heavy precipitation may sometimes prevent the camera/radar sensor from functioning.

▶▶



Cause	Action
Water or snow is spraying/swirling up and blocking the radar signals or the camera's range of visibility.	No action. Very wet or snow-covered roads may sometimes prevent the camera/radar sensor from functioning.
There is dirt between the inside of the windshield and the camera/radar sensor.	Consult a workshop to have the area of the windshield on the inside of the camera's casing cleaned. An authorized Volvo workshop is recommended.
Bright sunlight.	No action. The camera/radar sensor will reset automatically when lighting conditions improve.

High temperatures

If the temperature in the passenger compartment is very high, the camera/radar sensor will switch off temporarily for approx. 15 minutes after the engine is started to protect its electronic components. When the temperature has cooled sufficiently, the camera/radar sensor will automatically restart.

Damaged windshield

<p>i NOTE</p> <p>Failure to take action could result in reduced performance for the driver support systems that use the camera and radar unit. It could cause functions to be reduced, deactivated completely or to produce an incorrect function response.</p>
--

To avoid the risk of malfunction of the driver support systems that use the radar sensor, the following also apply:

- If there are cracks, scratches or stone chips on the windshield in front of any of the camera and radar sensor "windows" and this covers an area of about 0.5 × 3.0 mm (0.02 × 0.12 in.) or more, contact a workshop to have the windshield replaced⁵³.
- Volvo advises **against** repairing cracks, scratches or stone chips in the area in front of the camera and radar sensor – the entire windshield should instead be replaced.
- Before replacing the windshield, contact a workshop⁵³ to verify that the right windshield has been ordered and installed.

- The same type of windshield wipers or wipers approved by Volvo should be used for replacement.
- If the windshield is replaced, the camera and radar sensor must be recalibrated by a workshop⁵³ to help ensure proper functioning of all of the vehicle's camera and radar-based systems.

Radar

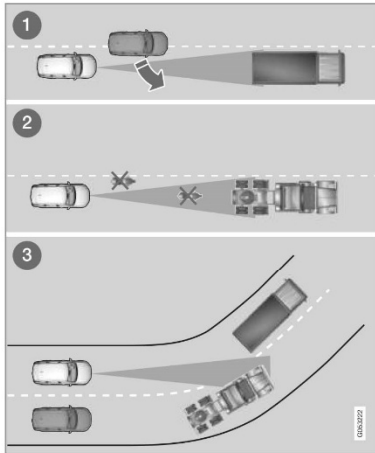
Vehicle speed

The radar sensor's ability to detect a vehicle ahead is significantly reduced if the speed of the vehicle ahead differs greatly from your vehicle's speed.

⁵³ An authorized Volvo workshop is recommended.

Limited field of vision

The radar sensor has a limited field of vision. In some situations, it may detect a vehicle later than expected or not at all.



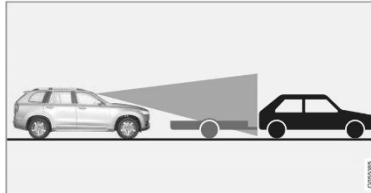
The radar sensor's field of vision.

- 1 The radar sensor's detection of vehicles very close to your vehicle may be delayed in certain situations, e.g. if a vehicle pulls

in between your vehicle and the vehicle directly ahead.

- 2 Small vehicles, such as motorcycles, or vehicles that are not driving in the center of the lane may remain undetected.
- 3 In curves, the radar may detect the wrong vehicle or lose sight of a target vehicle.

Low trailers



Low trailer in the radar shadow.

Low trailers may also be difficult or even impossible for the radar to detect. The driver should be extra alert when driving behind vehicles towing low trailers when Adaptive Cruise Control* or Pilot Assist* is activated.

Camera

Reduced visibility

Cameras have the same limitations as the human eye. In other words, their "vision" is impaired by adverse weather conditions such as heavy snowfall/rain, dense fog, swirling dust/snow, etc. These conditions may reduce

the function of systems that depend on the camera or cause these systems to temporarily stop functioning.

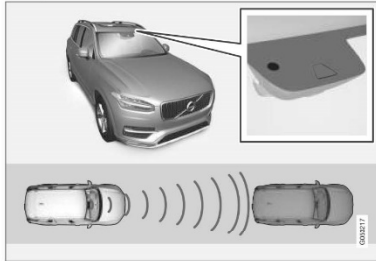
Strong sunlight, reflections from the road surface, ice or snow covering the road, a dirty road surface, or unclear lane marker lines may drastically reduce the camera's ability to detect the side of a lane, a pedestrian, a cyclist, a large animal or another vehicle.



* Option/accessory. 303

City Safety™

City Safety⁵⁴ can alert the driver with light, sound and pulsations in the brake pedal to help the driver detect pedestrians, cyclists, large animals and vehicles that appear suddenly.



Location of the camera and radar sensor.

City Safety can help prevent a collision or lower the vehicle's speed at the point of impact.

City Safety is an aid intended to assist the driver if a collision with a pedestrian, large animal, cyclist or vehicle is imminent.

City Safety can help the driver avoid a collision when e.g. driving in stop-and-go traffic, when changes in the traffic ahead and driver distraction could lead to an incident.

⁵⁴ This function is not available on all markets.

The function assists the driver by automatically applying the brakes if there is an imminent risk of a collision and the driver does not react in time by braking and/or steering away.

City Safety activates a brief, forceful braking in an attempt to stop your vehicle immediately behind the vehicle or object ahead.

City Safety is activated in situations in which the driver should have applied the brakes much earlier, which means that the system will not be able to assist the driver in all situations.

City Safety is designed to be activated as late as possible to help avoid unnecessary intervention. Automatic braking will only be applied after or during a collision warning.

Normally, the occupants of the vehicle will not be aware of City Safety except when the system intervenes when a collision is imminent.

WARNING

- The function is supplementary driver support intended to facilitate driving and help make it safer – it cannot handle all situations in all traffic, weather and road conditions.
- The driver is advised to read all sections in the Owner's Manual about this function to learn of its limitations, which the driver must be aware of before using the function.
- Driver support functions are not a substitute for the driver's attention and judgment. The driver is always responsible for ensuring the vehicle is driven in a safe manner, at the appropriate speed, with an appropriate distance to other vehicles, and in accordance with current traffic rules and regulations.

Related information

- Driver support systems (p. 260)
- City Safety sub-functions (p. 307)
- Setting a warning distance for City Safety (p. 309)
- Detecting obstacles with City Safety (p. 310)

- City Safety braking for oncoming vehicles (p. 315)
- Automatic braking during delayed evasive maneuvers with City Safety (p. 315)
- City Safety in crossing traffic (p. 312)
- City Safety steering assistance for evasive maneuver (p. 314)
- City Safety limitations (p. 316)
- City Safety messages (p. 319)

City Safety sub-functions

City Safety⁵⁵ can help the driver avoid a collision with a vehicle, cyclist or large animal ahead by reducing the vehicle's speed using its automatic braking function.

If the difference in speed is greater than the speeds specified below, the City Safety auto-brake function cannot prevent a collision, but it can help mitigate its effects.

Vehicles

City Safety can help prevent a collision with a vehicle ahead by reducing your vehicle's speed by up to 60 km/h (37 mph).

Cyclists

City Safety can help prevent a collision with a cyclist ahead by reducing your vehicle's speed by up to 50 km/h (30 mph).

Pedestrians

City Safety can help prevent a collision with a pedestrian ahead by reducing your vehicle's speed by up to 45 km/h (28 mph).

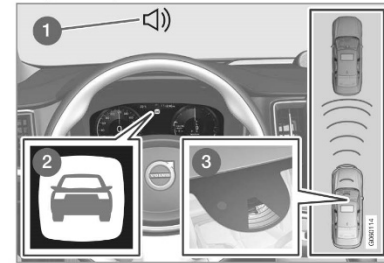
Large animals

If there is a risk of colliding with a large animal, City Safety can help reduce your vehicle's speed by up to 15 km/h (9 mph).

The braking function for large animals is primarily intended to mitigate the force of a collision at higher speeds. Braking is most effective

at speeds above 70 km/h (43 mph) and less effective at lower speeds.

City Safety sub-functions



Function overview.

- 1 Acoustic collision warning signal
- 2 Collision warning symbol
- 3 Camera/radar sensor distance monitoring

City Safety carries out three steps in the following order:

1. Collision warning
2. Brake assistance
3. Auto-brake

Descriptions of what happens in these three steps are provided below.

⁵⁵ This function is not available on all markets.

▶▶

◀ **1 - Collision warning**

The driver is first alerted to the risk of an imminent collision.

In vehicles equipped with a head-up display*, a flashing warning symbol will be displayed on the windshield.



Collision warning symbol on the windshield.

NOTE

Visual warnings on the windshield may be difficult to notice in cases of strong sunlight, reflections, extreme light contrasts, or if the driver is wearing sunglasses or is not looking straight ahead.

City Safety can detect pedestrians, cyclists or vehicles that are stationary, are moving in the same direction as your vehicle and are ahead of your vehicle. City Safety can also detect

pedestrians, cyclists or large animals that are crossing the road in front of your vehicle.

If there is a risk of a collision with a pedestrian, large animal, cyclist or another vehicle, the driver will be alerted with light, sound and pulsations in the brake pedal. At lower speeds, during hard braking or if the accelerator pedal is pressed, the brake pedal pulsation warning will not be given. The intensity of the brake pedal pulsations varies according to the vehicle's speed.

2 - Brake assistance

If the risk of a collision increases after the collision warning, brake support will be activated.

If the system determines that the pressure the driver is exerting on the brake pedal is insufficient to prevent the collision, brake support will increase pressure.

3 - Auto-brake

The automatic braking function is activated at the last moment.

If the driver has not taken evasive action by this stage and a collision is imminent, the automatic braking function will be triggered. This occurs whether or not the driver is pressing the brake pedal. Full braking force will be applied to reduce the speed at impact or reduced braking effect will be applied if this is sufficient to avoid the collision.

The seat belt tensioner may be activated when the automatic braking function is triggered.

In certain situations, auto-braking may begin with a limited braking force before applying full braking force.

If City Safety has prevented a collision, the vehicle will be kept at a standstill until the driver takes action. If the vehicle has slowed to avoid colliding with a slower-moving vehicle ahead, your speed will be reduced to that vehicle's speed.

Auto-braking can always be cancelled if the driver presses hard on the accelerator pedal.

NOTE

When City Safety activates the brakes, the brake lights come on.

When City Safety applies the brakes, a text message will appear in the instrument panel to notify the driver that the function is/was activated.

WARNING

City Safety may not be used to change how the driver operates the vehicle. The driver must not only rely on City Safety to brake the vehicle.

Related information

- City Safety™ (p. 306)
- City Safety in crossing traffic (p. 312)
- City Safety braking for oncoming vehicles (p. 315)
- City Safety limitations (p. 316)
- Head-up display* (p. 139)
- Seat belt tensioners (p. 50)

Setting a warning distance for City Safety

City Safety⁵⁶ is always active, but the function's warning distance can be adjusted.

NOTE

The City Safety function cannot be deactivated. It is activated automatically each time the engine/electric motor is started.

The alert distance determines the sensitivity of the system and regulates the distance at which the light, sound and brake pulsations will be activated.

To select warning distance:

1. Select **Settings** → **My Car** → **IntelliSafe** in the center display's Top view.
2. Under **City Safety Warning**, tap **Late**, **Normal** or **Early** to set the desired warning distance.

If the driver feels that the **Early** setting is giving too many warnings or finds them irritating, the **Normal** or **Late** warning distance settings can be selected instead.

If the driver feels that the warnings are too frequent and distracting, the warning distance can be reduced. This will reduce the total

number of warnings, but it will also result in City Safety providing warnings at a later stage.

The **Late** warning distance setting should therefore only be used in exceptional cases, such as when a more dynamic driving style is preferred.

⁵⁶ This function is not available on all markets.



* Option/accessory. 309



⚠ WARNING

- No automatic system can guarantee 100% correct function in all situations. You should therefore never test use of City Safety in the direction of people, animals or vehicles – this could lead to severe damage, serious personal injury or even death.
- City Safety warns the driver if there is a risk of collision, but the function cannot reduce the driver's reaction time.
- Even if the warning distance has been set to **Early**, warnings may be perceived as late in certain situations – e.g. when there are large speed differences or if the vehicle ahead suddenly brakes heavily.
- With the warning distance set to **Early**, warnings come further in advance. This may cause the warnings to come more frequently than with warning distance **Normal**, but is recommended since it can make City Safety more effective.

i NOTE

The warning with direction indicators for Rear Collision Warning* is deactivated if the collision warning distance in the City Safety function is set to the lowest level "Late".

The seat belt tensing and braking functions remain active.

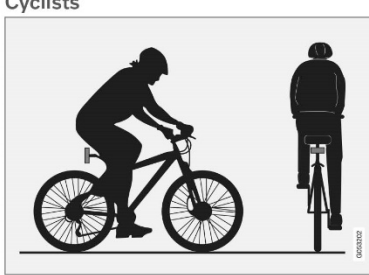
- Related information**
- City Safety™ (p. 306)
 - City Safety limitations (p. 316)
 - Rear Collision Warning* (p. 320)

Detecting obstacles with City Safety

City Safety⁵⁷ can help the driver detect other vehicles, cyclists, large animals and pedestrians.

Vehicles
 City Safety can detect most vehicles that are stationary or are moving in the same direction as your vehicle. In some cases, it can also detect oncoming vehicles and crossing traffic.

For City Safety to be able to detect a vehicle in the dark, its headlights and taillights must be on and clearly visible.



Examples of what City Safety would interpret to be a cyclist: clear body and bicycle shapes.

⁵⁷ This function is not available on all markets.

For good performance, the system's function for cyclist detection needs the clearest possible information about the contours of the bicycle and of the cyclist's head, arm, shoulders, legs, torso and lower body in combination with normal human movements.

If large portions of the cyclist's body or the bicycle itself are not visible to the function's camera, it will not be able to detect a cyclist.

The system can only detect adult cyclists riding on bicycles intended for adults.

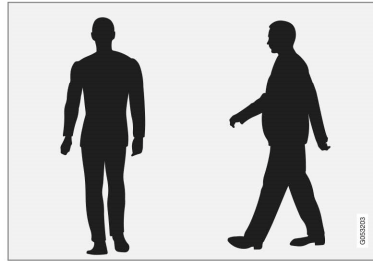
WARNING

City Safety is supplementary driver support, but it cannot detect all cyclists in all situations and, for example, cannot see:

- partially obscured cyclists.
- cyclists if the background contrast of the cyclist is poor - warning and brake interventions may then be late or not occur at all.
- cyclists in clothing that hides their body contour.
- bikes loaded with large objects.

The driver is always responsible for ensuring that the vehicle is driven correctly and with a safety distance suitable for the speed.

Pedestrians



Examples of what the system considers to be a pedestrian: clear body contours.

For good performance, the system's function for pedestrian detection needs the clearest possible information about the contours of the pedestrian's head, arm, shoulders, legs, torso and lower body in combination with normal human movements.

In order to detect a pedestrian, there must be a contrast to the background, which could depend on clothing, weather conditions, etc. If there is little contrast, the person may be detected late or not at all, which may result in a delayed reaction from the system or no reaction at all.

City Safety can detect pedestrians even in dark conditions if they are illuminated by the vehicle's headlights.

WARNING

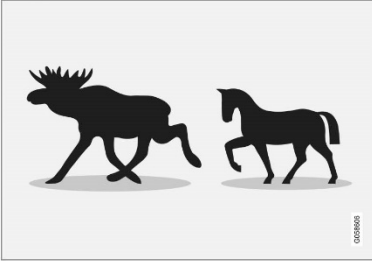
City Safety is supplementary driver support, but it cannot detect all pedestrians in all situations and, for example, cannot see:

- partially obscured pedestrians, people in clothing that hides their body contour or pedestrians shorter than 80 cm (32 in.).
- pedestrians if the background contrast of the pedestrians is poor - warning and brake interventions may then be late or not occur at all.
- pedestrians who are carrying large objects.

The driver is always responsible for ensuring that the vehicle is driven correctly and with a safety distance suitable for the speed.

▶▶

◀ Large animals



Examples of what City Safety would interpret as a large animal: stationary or moving slowly and with clear body contours.

For good performance, the system's function for detecting large animals (e.g. moose, horses, etc.) needs the clearest possible information about body contours. This entails being able to detect the animal straight from the side in combination with normal movements for that animal.

If parts of the animal's body are not visible to the function's camera, the system will not be able to detect the animal.

City Safety can detect large animals even in dark conditions if they are illuminated by the vehicle's headlights.

⁵⁸ This function is not available on all markets.

⚠ WARNING

City Safety is supplementary driver support, but it cannot detect all large animals in all situations and, for example, cannot see:

- partially obscured larger animals.
- larger animals seen from the front or from behind.
- running or fast moving larger animals.
- larger animals if the contrast of the animal's background is poor - warning and brake interventions may then occur late or not at all.
- smaller animals such as cats and dogs.

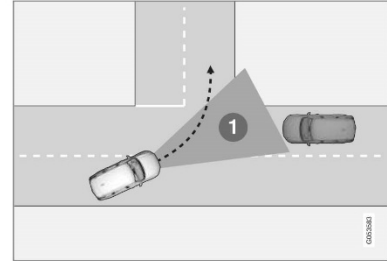
The driver is always responsible for ensuring that the vehicle is driven correctly and with a safety distance suitable for the speed.

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

City Safety in crossing traffic

City Safety⁵⁸ can assist the driver when turning into the path of an oncoming vehicle in an intersection.



1 Sector in which City Safety can detect an oncoming vehicle in crossing traffic.

In order for City Safety to detect an oncoming vehicle in situations where there is a risk of a collision, that vehicle must be within the sector in which City Safety can analyze the situation.

The following criteria must also be met:

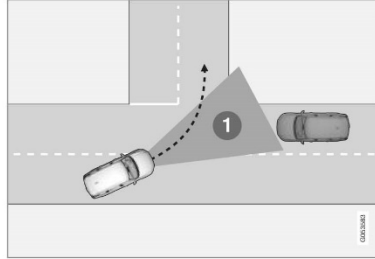
- your vehicle's speed must be at least 4 km/h (3 mph)
- your vehicle must be making a left turn
- the oncoming vehicle's headlights must be on

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

Limitations of City Safety in crossing traffic

In certain situations, it may be difficult for City Safety to help the driver avoid a collision with crossing traffic.



For example:

- on slippery roads when Electronic Stability Control (ESC) is actively operating
- if an approaching vehicle is detected at a late stage
- if the oncoming vehicle is partially obstructed by another vehicle or object
- if the oncoming vehicle's headlights are off
- if the oncoming vehicle is moving erratically and e.g. suddenly changes lanes at a late stage.

NOTE

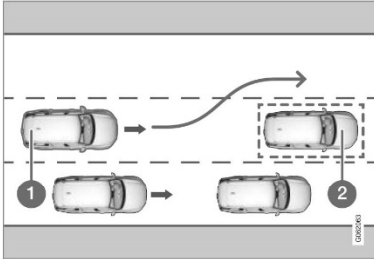
The function uses the vehicle's camera and radar sensor, which has certain general limitations.

Related information

- City Safety in crossing traffic (p. 312)
- City Safety limitations (p. 316)
- Camera/radar sensor limitations (p. 301)

City Safety steering assistance for evasive maneuver

City Safety steering assistance can help the driver steer away from a vehicle/obstacle when it is not possible to avoid a collision by braking alone. City Safety steering assistance is always activated and cannot be switched off.



- 1 Your vehicle swerves away
- 2 Slow-moving/stationary vehicle or obstacle.

City Safety helps provide assistance by strengthening the driver's steering movements, but only if the driver has begun evasive action and the system detects that the driver's steering movements are not sufficient to avoid a collision.

The brake system is used simultaneously to further strengthen steering movements. The

function also helps stabilize the vehicle after it has passed the obstacle.

City Safety steering assistance can detect:

- vehicles
- cyclists
- pedestrians
- large animals

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

City Safety steering assistance limitations during evasive maneuvers

City Safety steering assistance may have limited functionality in certain situations and not intervene, e.g.:

- at speeds outside the range of 50-100 km/h (30-62 mph)
- if the driver does not take evasive action
- if speed-dependent power steering wheel resistance is working at reduced power – e.g. during cooling due to overheating.

NOTE

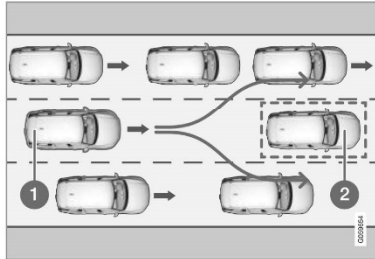
The function uses the vehicle's camera and radar sensor, which has certain general limitations.

Related information

- City Safety steering assistance for evasive maneuver (p. 314)
- City Safety limitations (p. 316)
- Speed-dependent steering wheel resistance (p. 260)
- Camera/radar sensor limitations (p. 301)

Automatic braking during delayed evasive maneuvers with City Safety

City Safety⁵⁹ can assist the driver by automatically braking the vehicle when it is not possible to avoid a collision by steering alone. City Safety assists the driver by periodically attempting to predict possible "escape routes" to the sides of the vehicle in the event a slow-moving or stationary vehicle were to be detected at a late stage.



Your vehicle (1) cannot detect any potential escape routes for veering away from the vehicle ahead (2) and may therefore apply the brakes at an earlier stage.

- 1 Own vehicle
- 2 Slow-moving/stationary vehicles

⁵⁹ This function is not available on all markets.

City Safety will not intervene to automatically apply the brakes if it is possible for the driver to avoid a collision by steering the vehicle.

However, if City Safety determines that an evasive maneuver would not be possible due to traffic in the adjacent lane(s), the function can assist the driver by automatically starting to apply the brakes at an earlier stage.

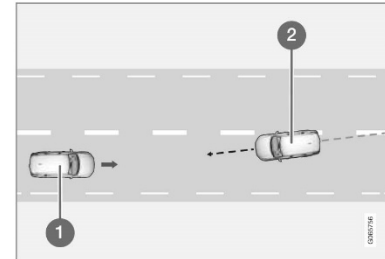
Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

City Safety braking for oncoming vehicles

City Safety can help you apply the brakes for an oncoming vehicle in your lane.

If an oncoming vehicle veers into your lane and a collision is unavoidable, City Safety can help reduce your vehicle's speed to attempt to mitigate the force of the collision.



- 1 Own vehicle
- 2 Oncoming vehicles

The following criteria must be met for the function to work:

- your vehicle's speed must be above 4 km/h (3 mph)
- the road must be straight



- ◀• your lane must have clear side lane markings
- your vehicle must be positioned straight in your lane
- the oncoming vehicle must be positioned within your vehicle's lane markings
- the oncoming vehicle's headlights must be on
- the function can only handle "front-to-front" collisions
- the function can only detect vehicles with four wheels.

⚠ WARNING

Warnings and brake interventions due to an imminent collision with an oncoming vehicle always come very late.

Related information

- City Safety™ (p. 306)
- City Safety limitations (p. 316)

City Safety limitations

City Safety⁶⁰ functionality may be reduced in certain situations.

Surroundings

Low objects

Hanging objects, such as flags for overhanging loads or accessories such as auxiliary lights or front protective grids that extend beyond the height of the hood, may limit City Safety functionality.

Slippery road conditions

The extended braking distance on slippery roads may reduce City Safety's capacity to help avoid a collision. In these types of situations, the Anti-lock Braking System and Electronic Stability Control (ESC⁶¹) are designed for optimal braking power with maintained stability.

Backlighting

The visual warning signal in the windshield may be difficult to detect in bright sunlight, if there are reflections, or if the driver is wearing sunglasses or not looking straight ahead.

Heat

If the temperature in the passenger compartment is high due to e.g. bright sunlight, the visual warning signal in the windshield may be temporarily disabled.

Camera and radar sensor's field of vision

The camera's field of vision is limited and in certain situations, it may be unable to detect pedestrians, large animals, cyclists or vehicles, or it may detect them later than expected.

Vehicles that are dirty may be detected later than clean vehicles, and in dark conditions, motorcycles may be detected late or not at all.

If a text message displayed in the instrument panel indicates that the camera/radar sensor is obstructed, it may be difficult for City Safety to detect pedestrians, large animals, cyclists, vehicles or lane markings in front of the vehicle. City Safety functionality may therefore be reduced.

Text messages may not be displayed for all situations in which the windshield sensors are blocked. The driver must therefore always keep the windshield in front of the camera/radar sensor clean.

⚠ CAUTION

Only a workshop may perform maintenance on driver support components – an authorized Volvo workshop is recommended.

⁶⁰ This function is not available on all markets.
⁶¹ Electronic Stability Control

Driver intervention

Backing up

City Safety is temporarily deactivated when the vehicle is backing up.

Low speed

City Safety is not activated at very low speeds under 4 km/h (3 mph). The system will therefore not intervene in situations in which your vehicle is approaching another vehicle very slowly, such as when parking.

Active driver

Action by the driver always has priority. City Safety will therefore not react or will react at a later stage with a warning or intervention in situations in which the driver is clearly steering and operating the accelerator pedal, even if a collision is unavoidable.

An active and aware driving style may therefore delay collision warnings and intervention in order to minimize unnecessary warnings.

Other limitations

WARNING

The driver support system only issues a warning for obstacles detected by its radar sensor – thus, a warning may come after a delay or not at all.

- Never wait for a warning or assistance. Apply the brakes when necessary.

WARNING

- Warnings and brake interventions can be triggered late or not at all if the traffic situation or external influences prevent the camera and radar unit from properly detecting pedestrians, cyclists, large animals or vehicles ahead of the vehicle.
- To be able to detect vehicles at night, its front and rear lights must work and illuminate clearly.
- The camera and radar unit have a limited range for pedestrians and cyclists – the system can provide effective warnings and brake interventions if the relative speed is lower than 50 km/h (30 mph). For stationary or slow-moving vehicles, warnings and brake interventions are effective at vehicle speeds of up to 70 km/h (43 mph). Speed reduction for large animals is less than 15 km/h (9 mph) and can be achieved at vehicle speeds over 70 km/h (43 mph). At lower speeds, the warning and brake intervention for large animals is less effective.
- Warnings for stationary or slow-moving vehicles and large animals can be disengaged due to darkness or poor visibility.

- Warnings and brake interventions for pedestrians and cyclists are disengaged at vehicle speeds over 80 km/h (50 mph).
- Do not place, affix or mount anything on the inside or outside of the windshield, or in front of or around the camera and radar unit – this could disrupt camera-based functions.
- Objects, snow, ice or dirt in the area of the camera sensor can reduce the function, disengage it completely or give an improper function response.

▶▶



WARNING

- The City Safety auto-brake function can prevent a collision or reduce collision speed, but to ensure full brake performance the driver should always depress the brake pedal – even when the car auto-brakes.
- The warning and steering assistance are only activated if there is a high risk of collision – you must therefore never wait for the collision warning or City Safety to intervene.
- Warnings and brake interventions for pedestrians and cyclists are disengaged at vehicle speeds over 80 km/h (50 mph).
- City Safety does not activate auto-braking intervention during heavy acceleration.



NOTE

The function uses the vehicle's camera and radar sensor, which has certain general limitations.

Market limitations

City Safety is not available in all countries. If City Safety is not shown in the center display's

Settings menu, your vehicle is not equipped with this function.

In the center display's Top view, tap:

- **Settings** → **My Car** → **IntelliSafe**

Related information


- City Safety™ (p. 306)
- Camera/radar sensor limitations (p. 301)

City Safety messages

A number of messages related to City Safety may be displayed in the instrument panel. Several examples are provided below.

Message	Meaning
City Safety Automatic intervention	When City Safety is braking or has activated the automatic braking function, one or more symbols may illuminate in the instrument panel and a text message may be displayed.
City Safety Reduced functionality Service required	The system is not functioning as intended. Contact a workshop ^A .

^A An authorized Volvo workshop is recommended.

A text message can be erased by briefly pressing the  button in the center of the right-side steering wheel keypad.

If a message cannot be erased, contact a workshop^A.

Related information

- City Safety™ (p. 306)

⚠ WARNING

If the warning symbols for both brake fault and ABS fault are lit simultaneously, there may be a fault in the brake system.

- If the brake fluid reservoir level is normal when this occurs, drive carefully to the nearest workshop to have the brake system checked - an authorized Volvo workshop is recommended.
- If the brake fluid has fallen below the **MIN** level in the brake fluid reservoir, the vehicle should not be driven until the brake fluid has been filled. The reason for the brake fluid loss must be checked.

Related information

- Brake Assist System (p. 380)
- Auto-hold brakes (p. 385)
- Hill Start Assist (p. 386)
- Braking on wet roads (p. 380)
- Braking on salted roads (p. 381)
- Maintenance of the brake system (p. 381)
- Brake lights (p. 157)

³ Brake Assist System

Brake Assist System

The brake enhancing system, (BAS³), helps increase braking force and can thereby reduce braking distance.

The system monitors the driver's braking habits and increases braking force when necessary. Braking force can be increased up to the point at which the ABS intervenes. The function is deactivated when pressure on the brake pedal is decreased.

ⓘ NOTE

When BAS is activated, the brake pedal will go down slightly more than usual. Press (hold) down the brake pedal as long as necessary.

When the brake pedal is released, all braking ceases.

Related information

- Brakes (p. 379)

Braking on wet roads

Prolonged driving in heavy rain without braking may cause braking effect to be slightly delayed the first time the brakes are applied. This may also occur after washing the vehicle. It will then be necessary to apply greater pressure to the brake pedal. You should therefore maintain a greater distance to the vehicle ahead.

Firmly apply the brakes after washing the vehicle or driving on wet roads. This helps warm up the brake discs, enabling them to dry more quickly and protecting them against corrosion. Consider the current traffic situation when braking.

Related information

- Brakes (p. 379)
- Braking on salted roads (p. 381)

APPENDIX C

Run Log

Subject Vehicle: **2020 Volvo S60 T6 AWD Momentum**

Test Date: **2/3/2020**

Principal Other Vehicle: **SSV**

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
1-16	Brake characterization and determination						See Appendix D
17	Static Run						
18	Stopped POV	N					CIB activated before brake actuator
19		N					Brake Rate, CIB activated before brake actuator, brake calc method changed to Distance mode
20		N					RT Range Issue during run
21		N					SV headway problem
22		N					IMU, RT Range low voltage problem
23		Y	1.21	4.56	1.03	Pass	
24		Y	1.17	6.26	1.09	Pass	
25		Y	0.89	4.87	1.03	Pass	
26		N					Throttle Release
27		N					Throttle Release
28		Y	0.92	5.81	1.09	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
29		N					SV speed, Thr
30		N					Throttle Release
31		Y	0.91	2.24	1.02	Pass	
32		Y	0.84	2.10	0.86	Pass	
33		Y	2.56	3.58	0.82	Pass	
34	Static Run						
35	Slower POV, 25 vs 10 mph	Y	1.89	6.71	0.93	Pass	
36		Y	2.00	4.90	0.71	Pass	
37		Y	1.87	4.55	0.74	Pass	
38		Y	1.98	4.61	0.72	Pass	
39		Y	1.73	4.59	0.77	Pass	
40		Y	1.88	6.16	0.86	Pass	
41		Y	1.90	4.99	0.76	Pass	
42	Static run						
43	Slower POV, 45 vs 20 mph	N					brake force
44		Y	2.65	5.20	1.07	Pass	
45		Y	2.69	4.00	1.08	Pass	
46		Y	2.72	4.75	1.07	Pass	
47		Y	2.62	4.61	1.03	Pass	
48		Y	2.65	5.47	1.00	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
49		N					lateral offset
50		Y	2.67	6.15	1.04	Pass	
51		Y	2.70	8.14	1.04	Pass	
52	Static run						
92	Static run						
93	Braking POV, 35 mph	Y	1.86	0.00	0.85	Fail	
94		N					lateral offset
95		Y	1.90	0.00	0.83	Fail	
96		Y	1.82	0.00	0.79	Fail	
97		Y	1.94	0.00	0.80	Fail	
98	Static run						
53	Baseline, 25 mph	N			(0.56)		The brake force for these runs was applied early, thus making the runs technically invalid. However, the deceleration values in parenthesis are presented for reference to serve as an indicant of performance had the brake force timing been correct.
54		N			(0.49)		
55		N			(0.49)		
56		N			(0.49)		
57		N			(0.48)		
58		N			(0.48)		
59		N			(0.52)		
60	STP - Static run						

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes	
61	Baseline, 45 mph	N			(0.49)		The brake force for these runs was applied early, thus making the runs technically invalid. However, the deceleration values in parenthesis are presented for reference to serve as an indicant of performance had the brake force timing been correct.	
62		N			(0.49)			
63		N			(0.49)			
64		N			(0.49)			
65		N			(0.50)			
66		N					speed	
67		N			(0.49)		See above, e.g. runs 61-64	
68		Y			0.47			
69		STP - Static run						
70	STP - Static run							
71	STP False Positive, 25 mph	N					analog channels not zeroed	
72		N					throttle	
73		N					throttle	
74		N					throttle	
75		Y				0.61	Pass	
76		Y				0.59	Pass	
77		Y				0.61	Pass	
78		Y				0.61	Pass	
79		Y				0.57	Pass	
80		Y				0.60	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
81		Y			0.60	Pass	
82	STP - Static run						
83	STP False Positive, 45 mph	N					lateral offset
84		Y			0.55	Pass	
85		Y			0.56	Pass	
86		Y			0.57	Pass	
87		Y			0.57	Pass	
88		Y			0.56	Pass	
89		Y			0.56	Pass	
90		Y			0.57	Pass	
91	STP - Static run						

APPENDIX D

Brake Characterization

Subject Vehicle: 2020 Volvo S60 T6 AWD Momentum

Test Date: 2/3/2020

DBS Initial Brake Characterization				
Run Number	Stroke at 0.4 g (in)	Force at 0.4 g (lb)	Slope	Intercept
2	2.408083	15.79136	0.497676	0.13444
3	2.418785	15.73003	0.46637	0.171988
4	2.402419	15.35913	0.4444	0.218401

DBS Brake Characterization Determination								
Run	DBS Mode	Speed	Valid Run	Average Decel. (g)	0.4 g Stroke Value (in)	0.4 g Force Value (lb)	Stroke/Force Calculator (in)	Notes
5	Displacement	35	Y	0.375	2.41		2.57	
6		25	Y	0.360	2.41		2.68	
7		25	Y	0.425	2.55		2.40	
8		45	Y	0.388	2.55		2.63	
9		35	Y	0.443	2.55		2.30	
10	Hybrid	35	Y	0.480	2.41	15.63	13.03	
11		35	Y	0.478	2.41	14.00	11.72	
12		35	Y	0.397	2.41	12.00	12.09	
13		25	Y	0.427	2.55	12.00	11.24	

DBS Brake Characterization Determination								
Run	DBS Mode	Speed	Valid Run	Average Decel. (g)	0.4 g Stroke Value (in)	0.4 g Force Value (lb)	Stroke/Force Calculator (in)	Notes
14		25	Y	0.409	2.55	11.70	11.44	
15		45	Y	0.386	2.55	11.70	12.12	
16		35	Y	0.352	2.41	11.70	13.30	

Appendix E

TIME HISTORY PLOTS

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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. Plots shown herein are grouped by test type and are presented sequentially within a given test type. The following is a description of data types shown in the time history plots, as well as a description of the color code 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 Baseline 25 mph (Baseline run at 25 mph)
- False Positive Baseline 45 mph (Baseline run at 45 mph)
- 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)
- DBS Brake Characterization Initial
- DBS Brake Characterization Determination

Time history figures include the following sub-plots:

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

As only the audible or haptic alert is perceptible by the driver during a test run, the earliest of either of these alerts is used to define the onset of the FCW alert. A vertical black bar on the plot indicates the TTC (sec) at the first moment of the warning issued by the FCW system. The FCW TTC is displayed to the right of the subplot in green.

- Headway (ft) – Longitudinal separation 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 the Principal Other Vehicle (if any). For DBS tests, in the case of an impact, the speed reduction experienced by the Subject Vehicle up until the moment of impact 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). The peak value of Ax for the SV is shown on the subplot.
- Pedal Position – Position of the accelerator pedal and brake pedal. The units for the brake pedal are inches and the units for the accelerator pedal are percent of full scale divided by 10.
- Brake Force (lb) – Force on the brake pedal as applied by the DBS controller. The TTC at the onset of the brake by the DBS controller is shown on the subplot. Additionally, the average force at the brake pedal while the DBS controller is active is displayed.

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 or red 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 within the envelope. Exceedances of a green envelope are indicated by red shading in the area between the measured time-varying data and the envelope boundaries.

With the exception of the brake force plots (see description below), 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 given. 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 0.27g (the upper edge of the envelope, i.e., $0.30 \text{ g} \pm 0.03 \text{ g}$). A green circle or red asterisk is displayed at the moment the POV brake level achieves 0.27g. 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 out of the appropriate interval).

For the pedal position plot, a thick black bar appears on the brake pedal position data over the DBS controller brake onset period to signify the time over which the brake application rate is determined. The calculated brake application rate is also displayed on the figure.

For the brake force plots:

- If the tests are done in Hybrid mode, the brake force plot shows a dashed black threshold line indicating a brake force of 2.5 lbs. For the time period where the DBS controller is active, the brake force at the pedal must not fall below this 2.5 lb threshold. Exceedances of this threshold are indicated by red shading in the area between the measured time-varying data and the dashed threshold line. A blue envelope represents the target average brake force necessary to be valid
- If the tests are done in Displacement mode, there are no relevant brake force level thresholds or average brake force calculations.

In the instance of the “last second” braking applied by the brake robot, a thick vertical red line will appear on the plots at the moment the brake robot activates. Note that last second braking is only done when it has been determined by the onboard computer that test failure cannot be avoided. It is done simply to reduce the collision speed in order to minimize the likelihood of damage to the SSV and to the Subject Vehicle. Therefore, data validity checks are not performed after the red line, and certain values, such as minimum distance or peak deceleration, may not be accurate.

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
- Blue envelope = visualized target range for the time varying data averaged over a period equal to the length of the envelope
- 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.
- Red threshold (Solid) = for reference only – indicates the activation of last-minute braking by the brake robot. Data after the solid red line is not used to determine test validity.

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 valid or passing time history plots for each test type (including passing, failing, and invalid runs) are shown in Figure E1 through E12. Figures E1 through E8 show passing runs for each of the 8 test types. Figure E9 shows an example of a passing brake characterization run. Figures E10 and E11 show examples of invalid runs. Figure E12 shows an example of a valid test that failed the DBS requirements. Time history data plots for the tests of the vehicle under consideration herein are provided beginning with Figure E13.

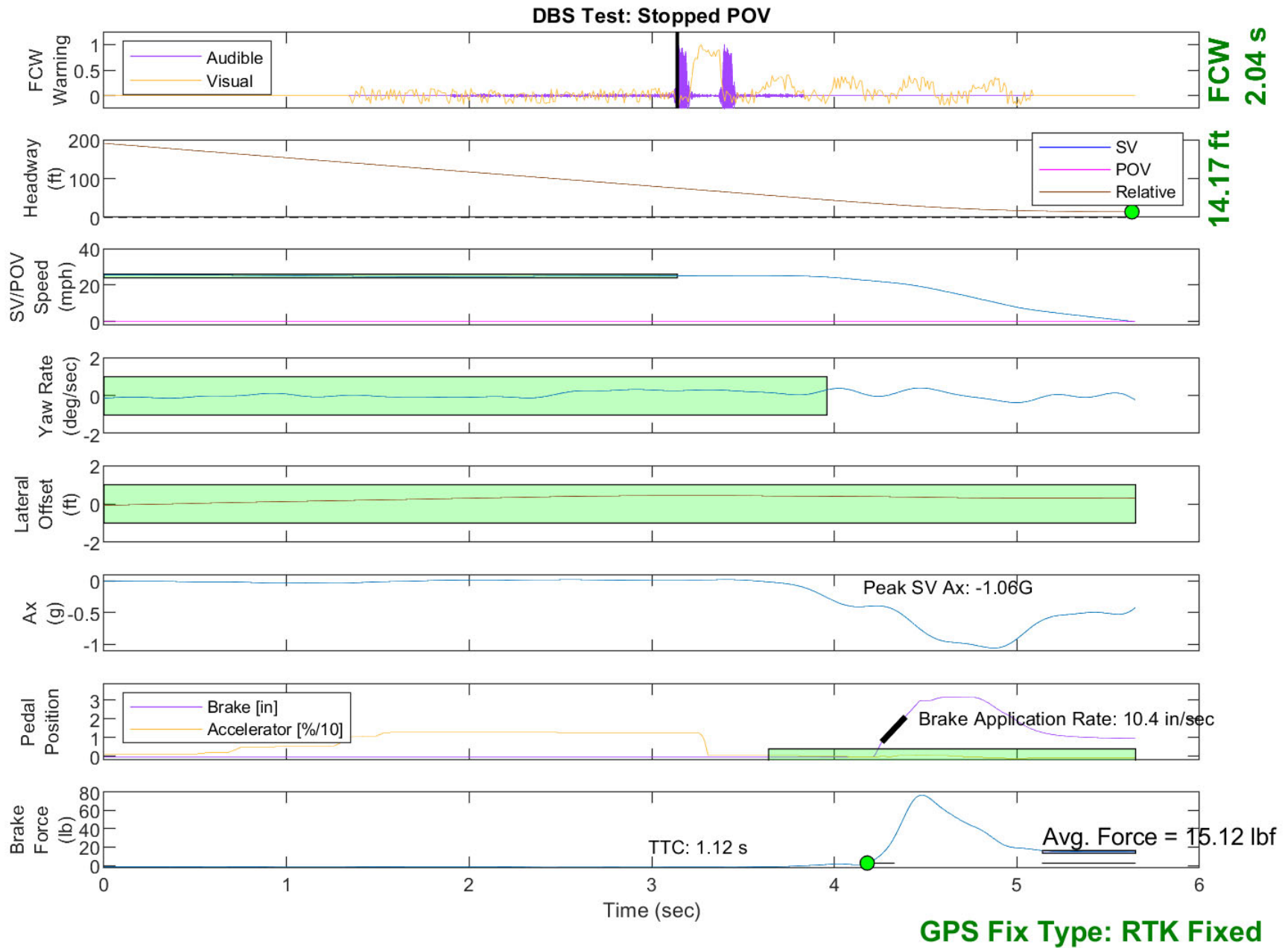


Figure E1. Example Time History for Stopped POV, Passing

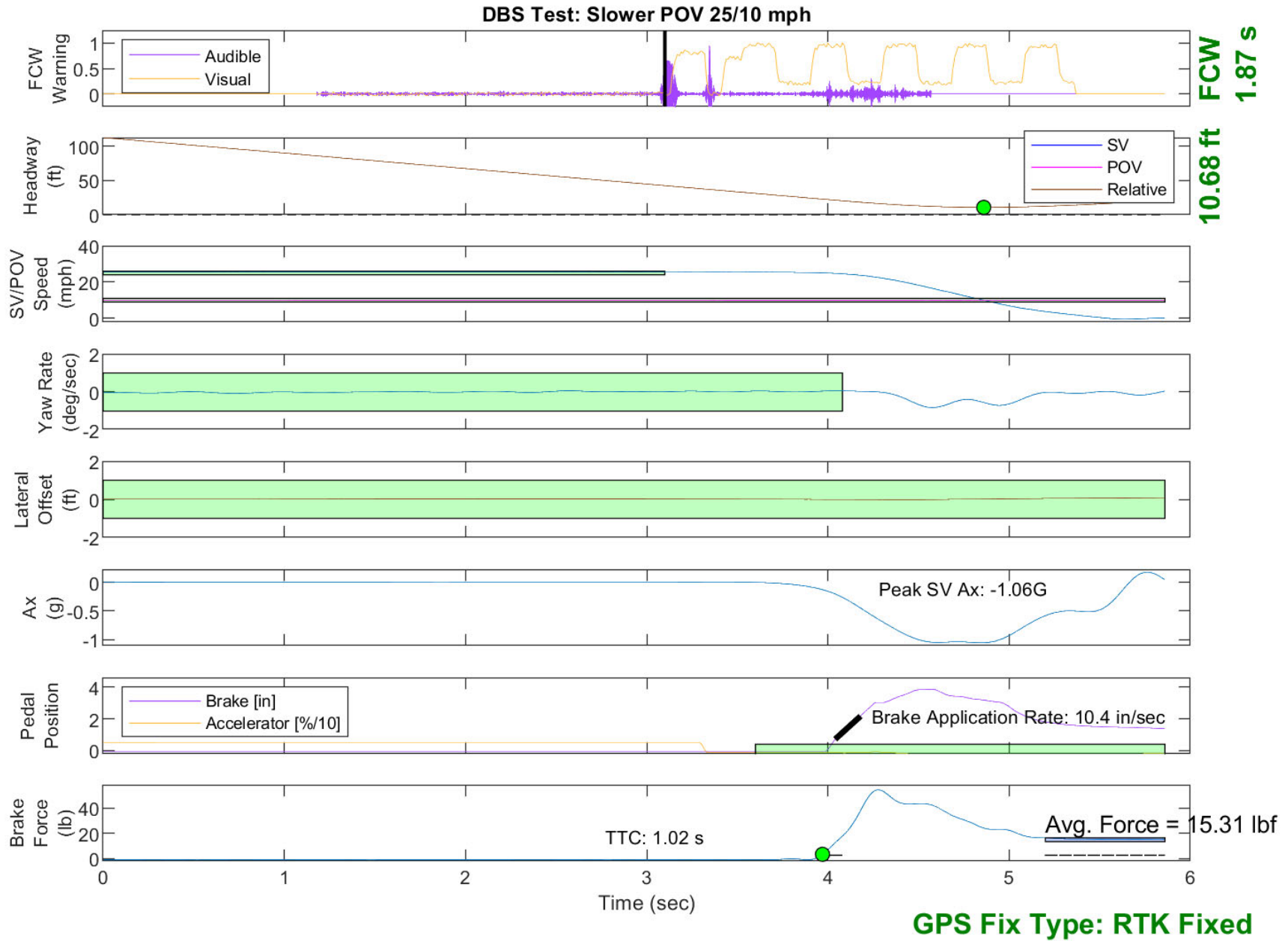


Figure E2. Example Time History for Slower POV 25 vs. 10, Passing

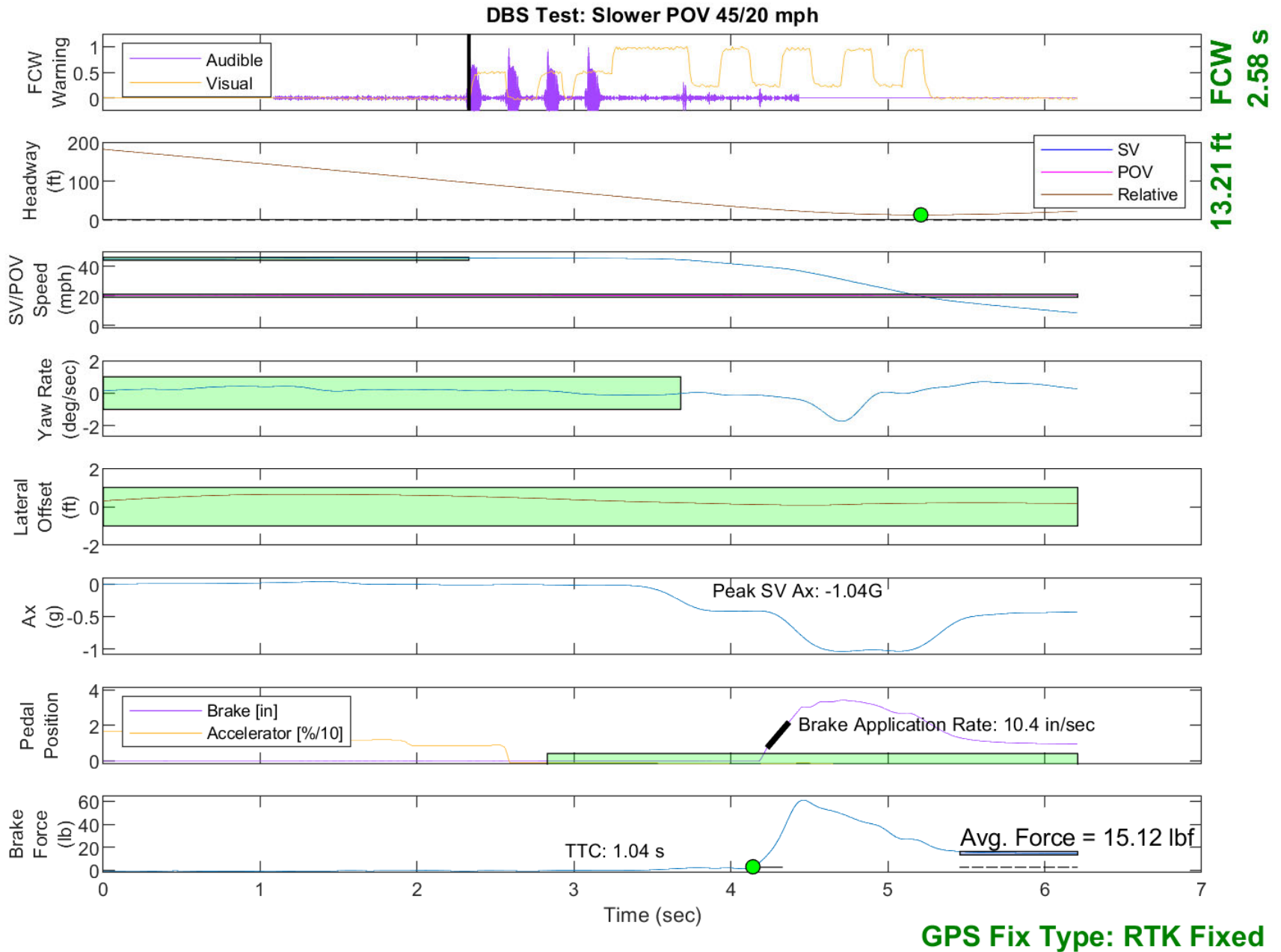


Figure E3. Example Time History for Slower POV 45 vs. 20, Passing

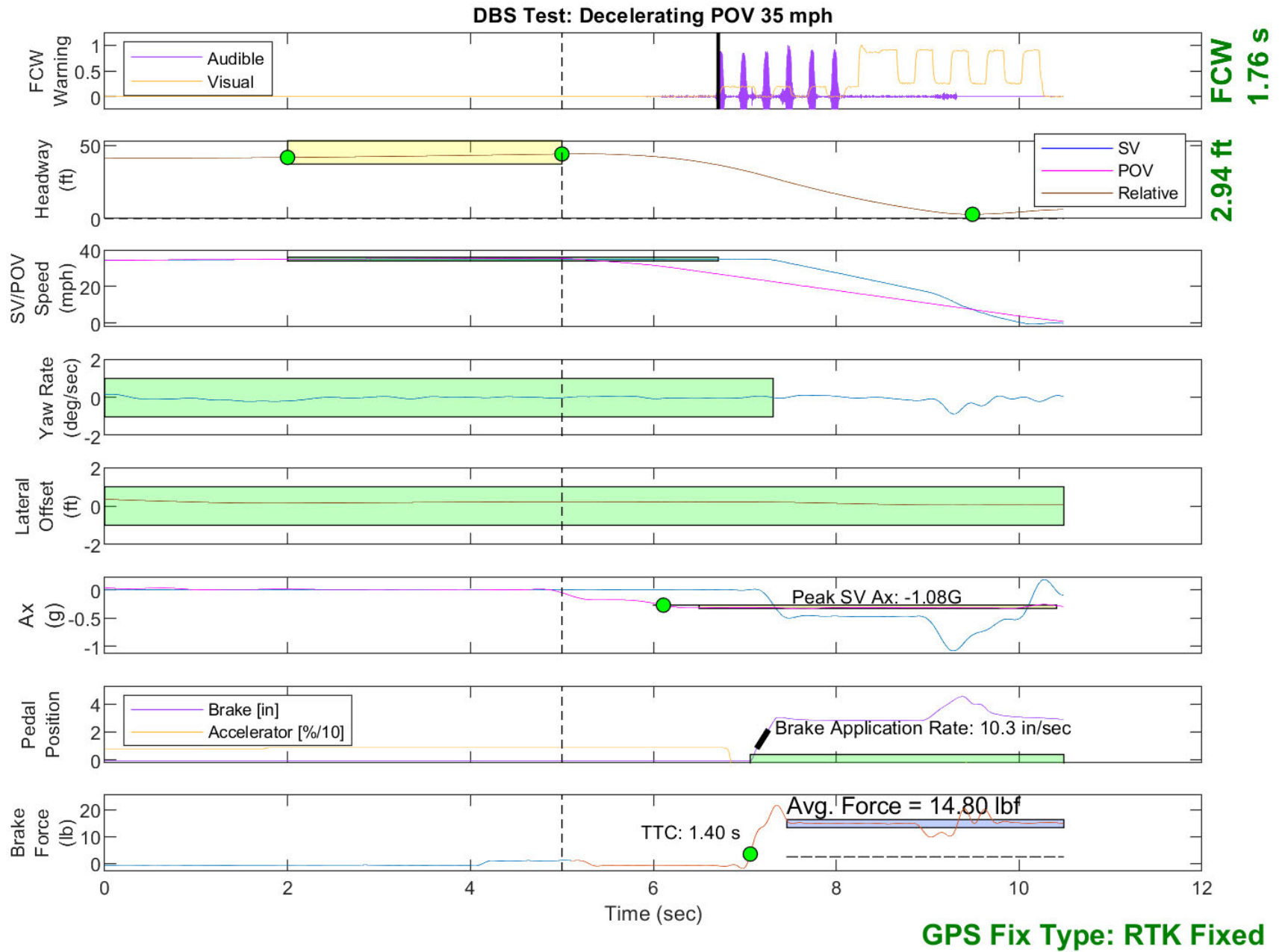
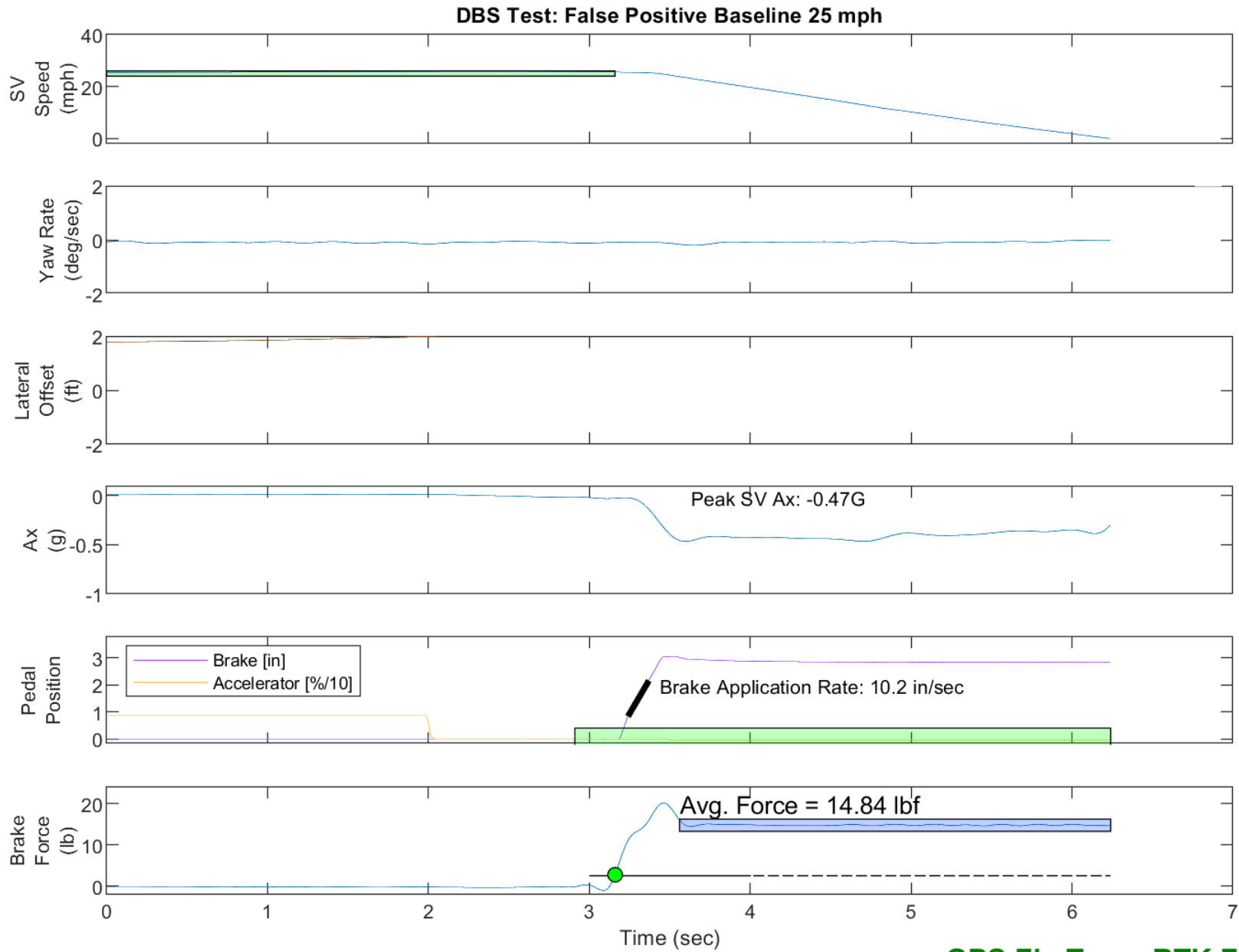
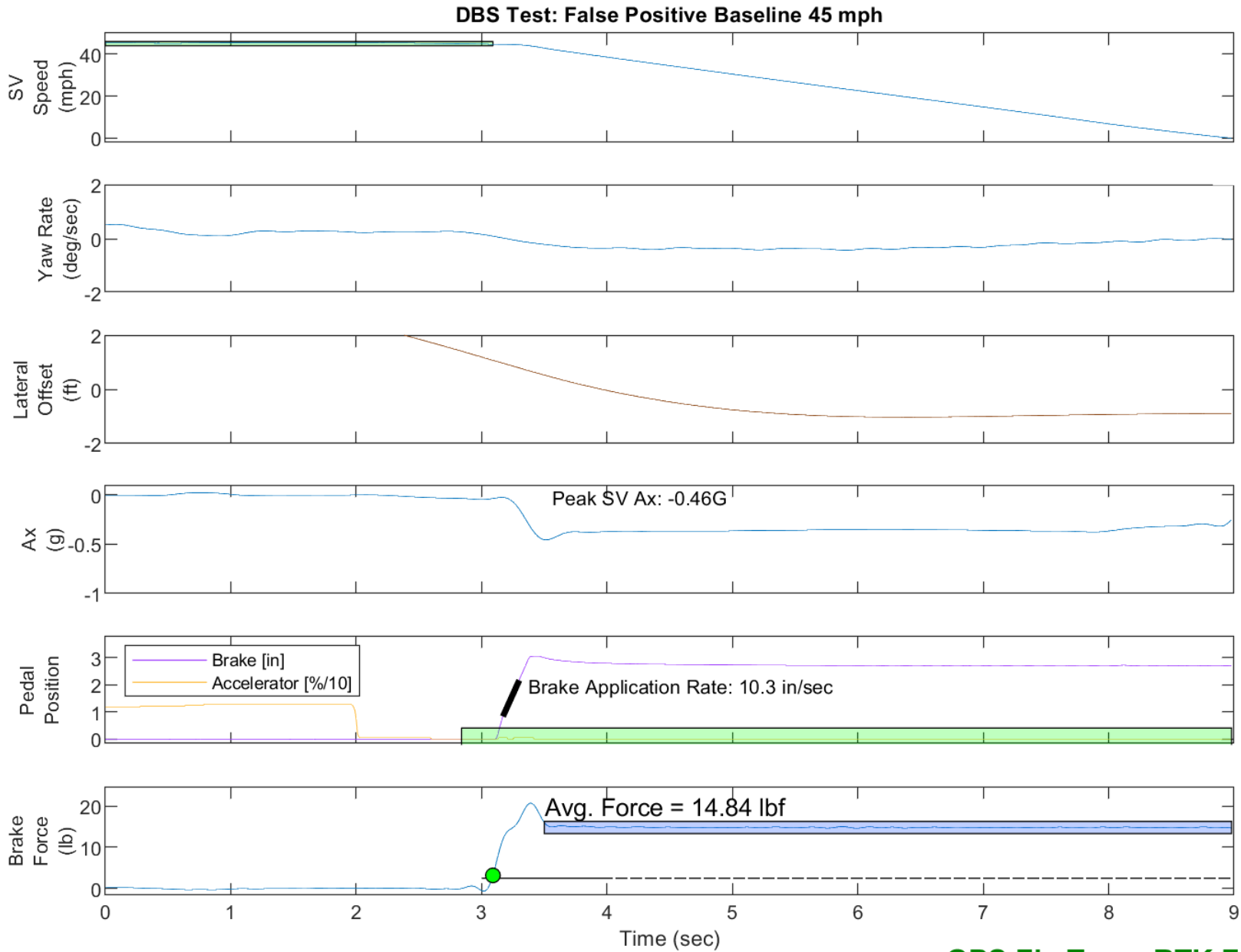


Figure E4. Example Time History for Decelerating POV 35, Passing



GPS Fix Type: RTK Fixed

Figure E5. Example Time History for False Positive Baseline 25



GPS Fix Type: RTK Fixed

Figure E6. Example Time History for False Positive Baseline 45

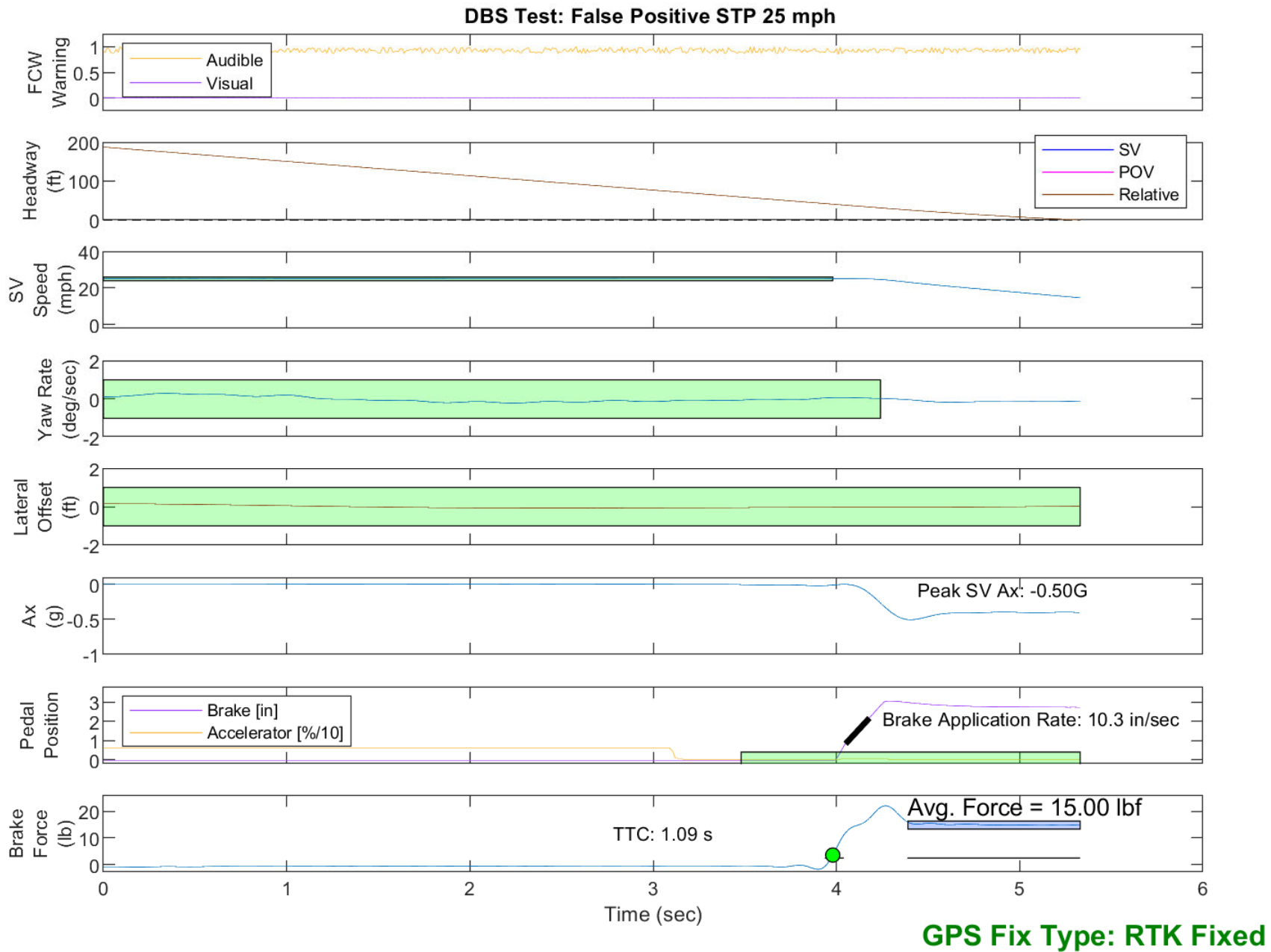
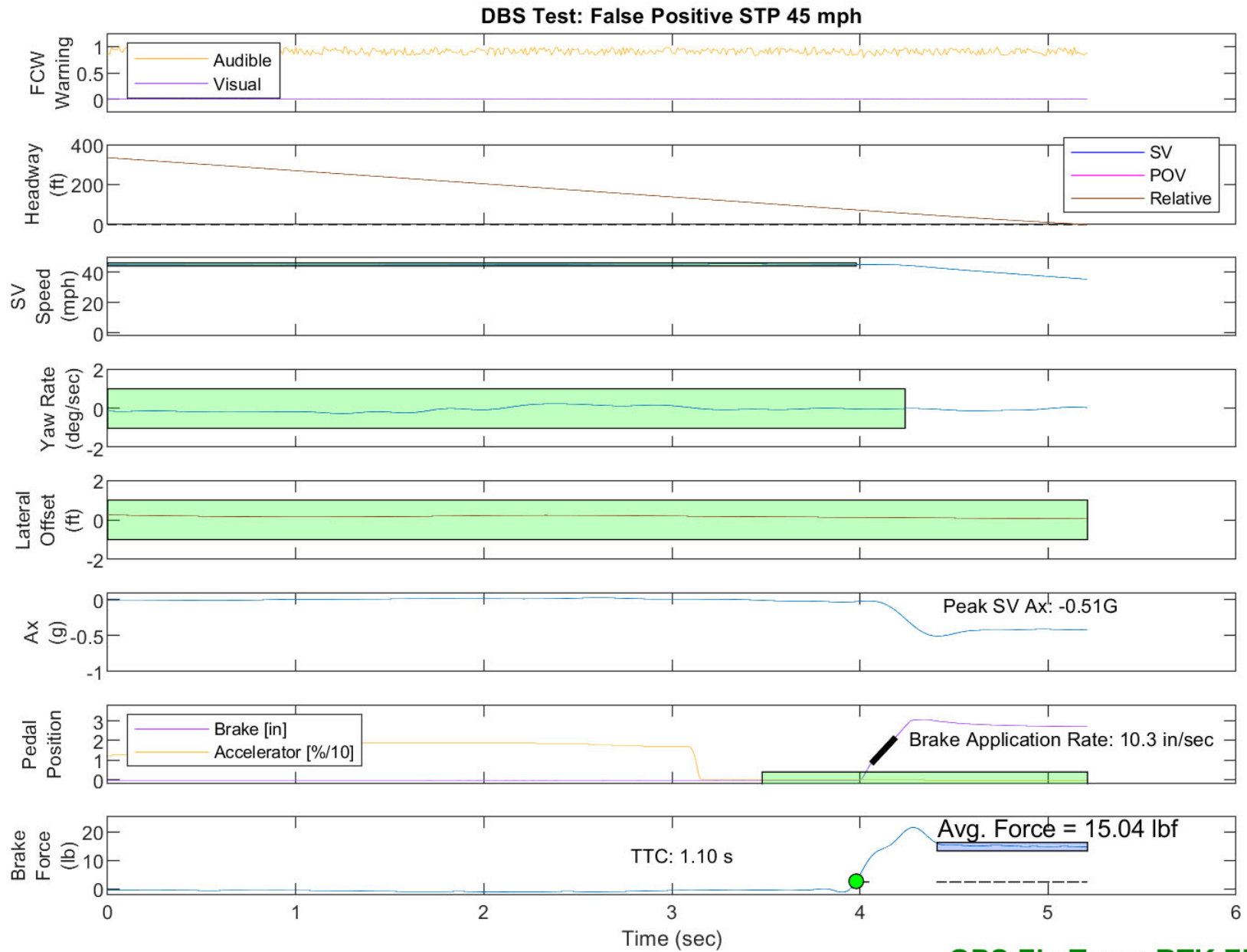


Figure E7. Example Time History for False Positive Steel Plate 25, Passing



GPS Fix Type: RTK Fixed

Figure E8. Example Time History for False Positive Steel Plate 45, Passing

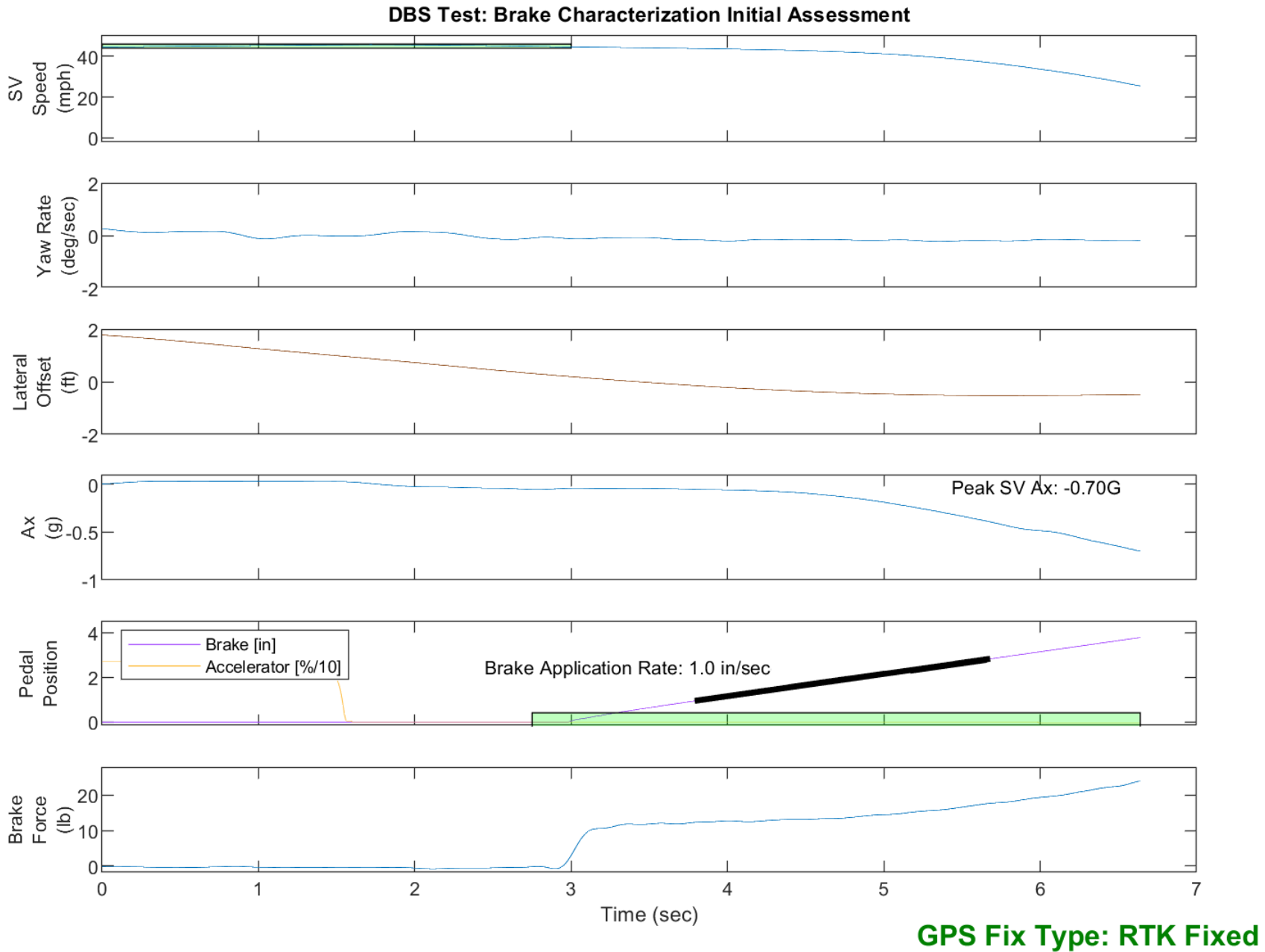


Figure E9. Example Time History for DBS Brake Characterization, Passing

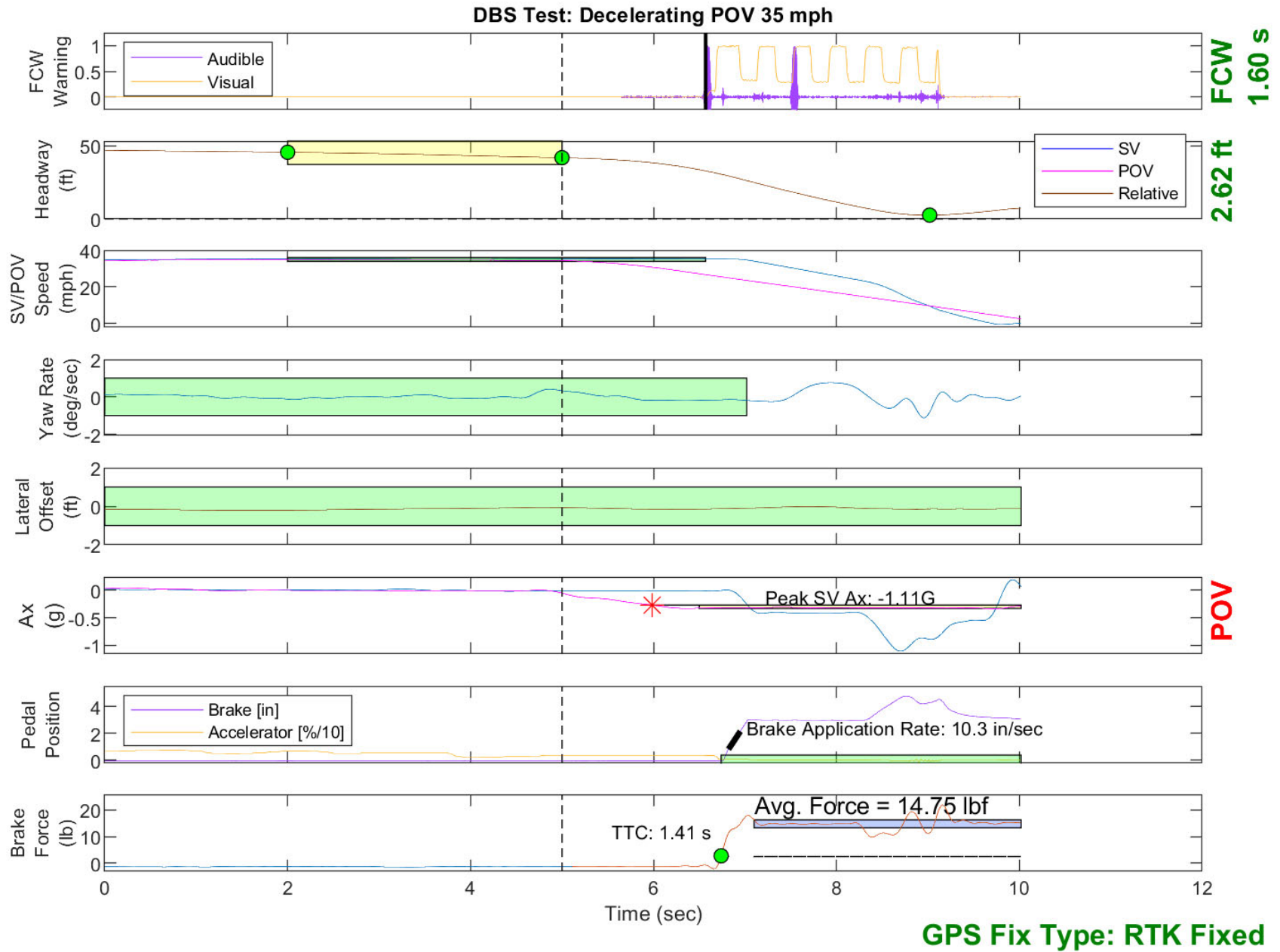
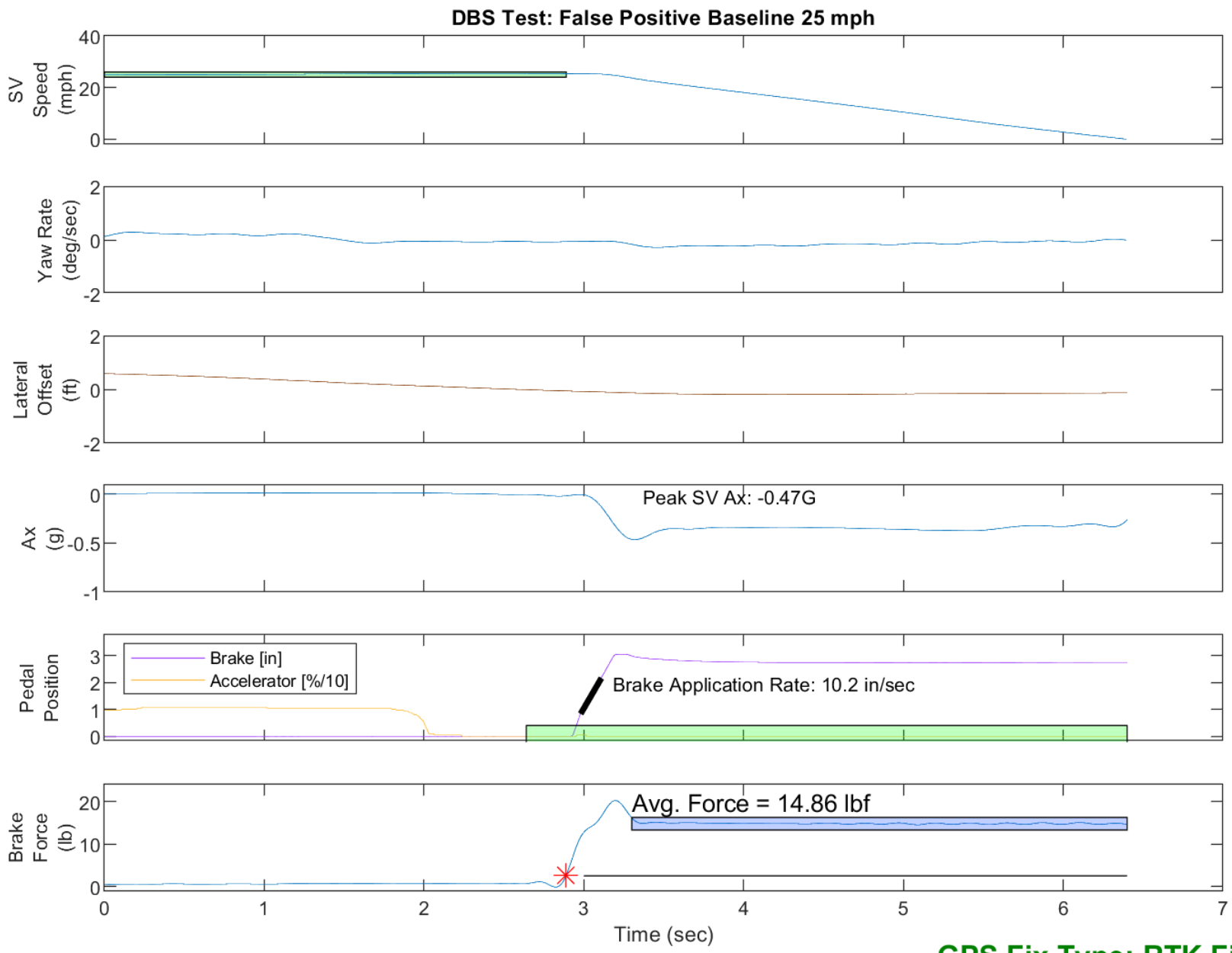


Figure E10. Example Time History Displaying Invalid POV Acceleration Criteria



GPS Fix Type: RTK Fixed

Figure E11. Example Time History Displaying Invalid Brake Force Criteria

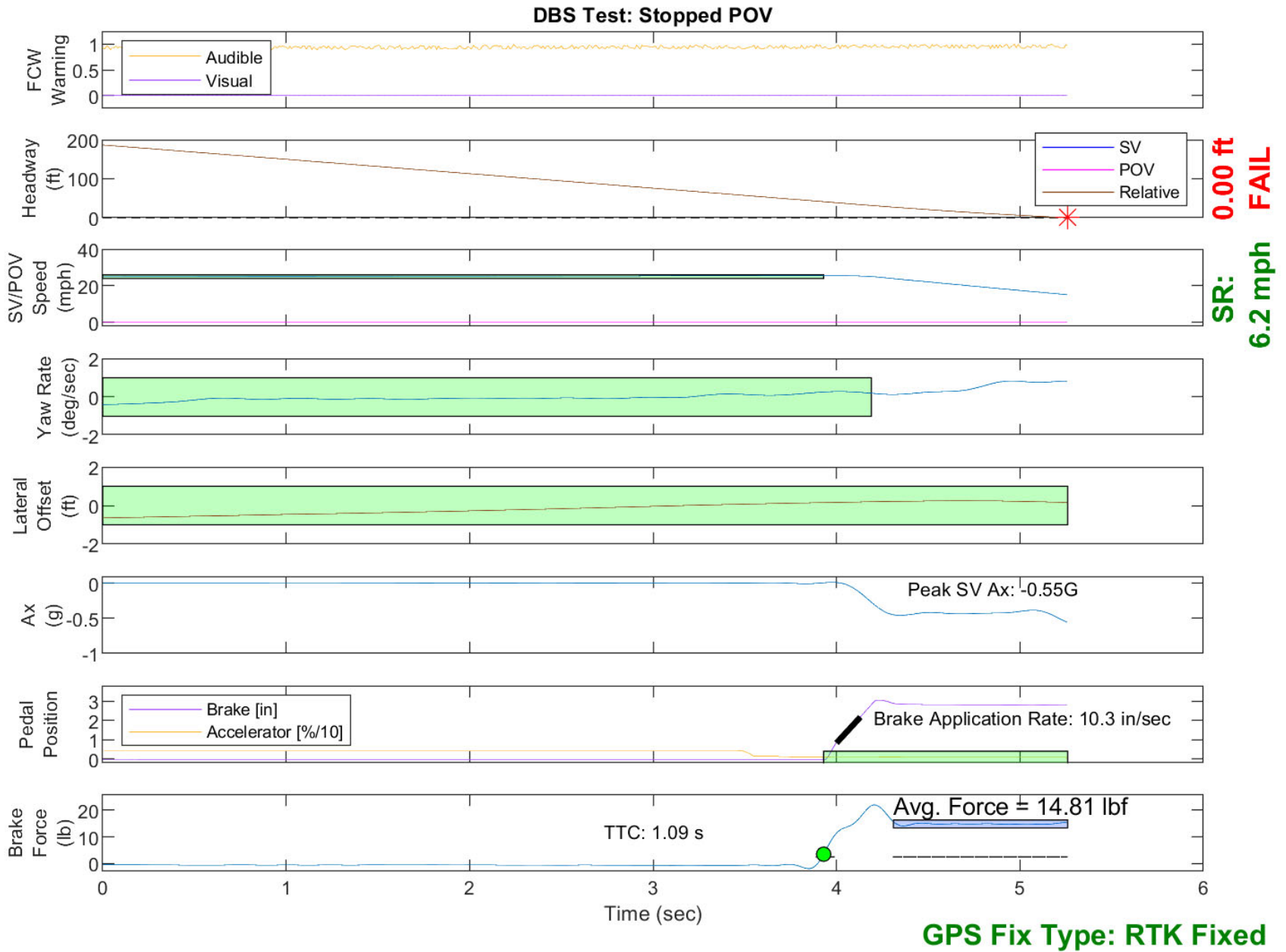


Figure E12. Example Time History for a Failed Run

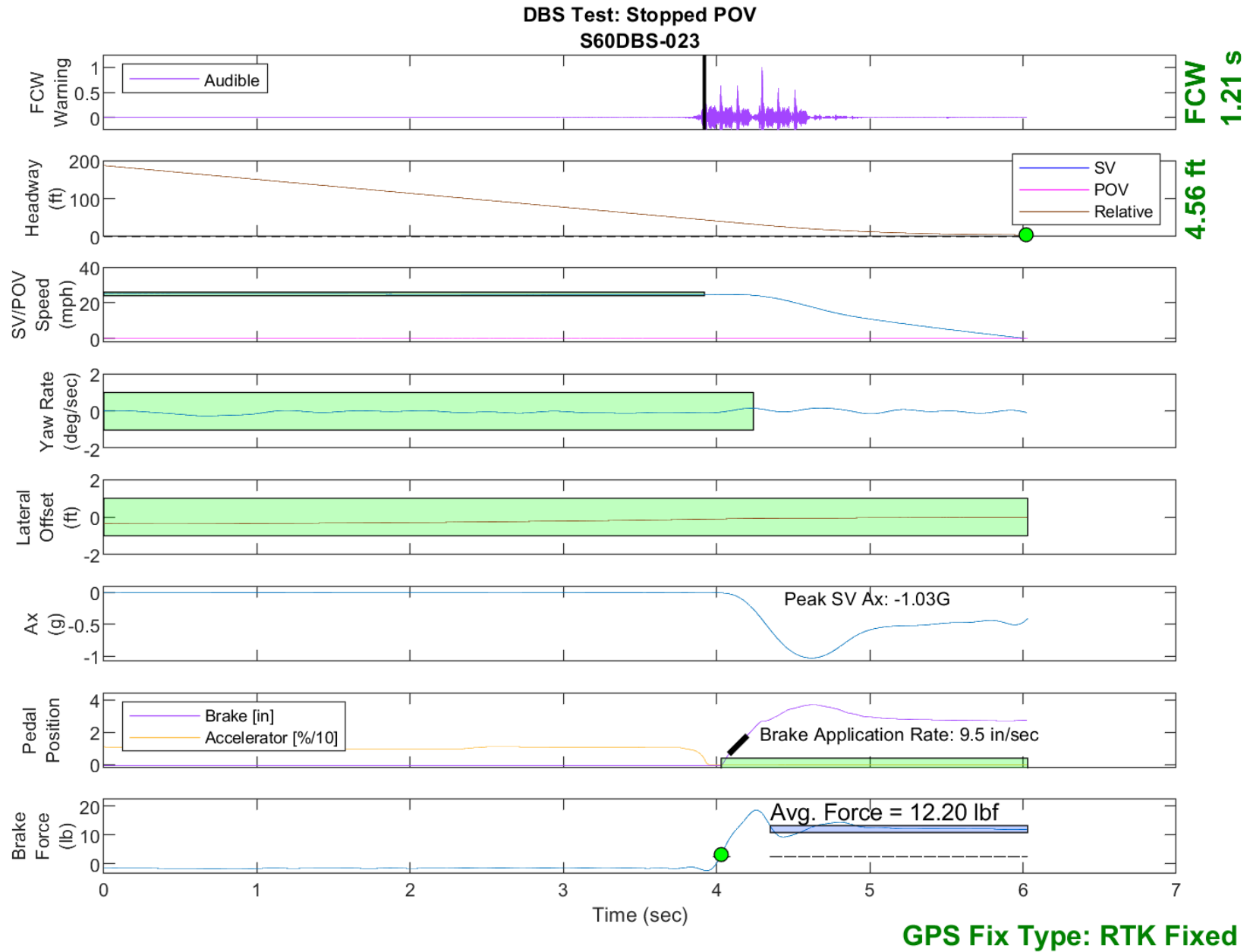


Figure E13. Time History for DBS Run 23, SV Encounters Stopped POV

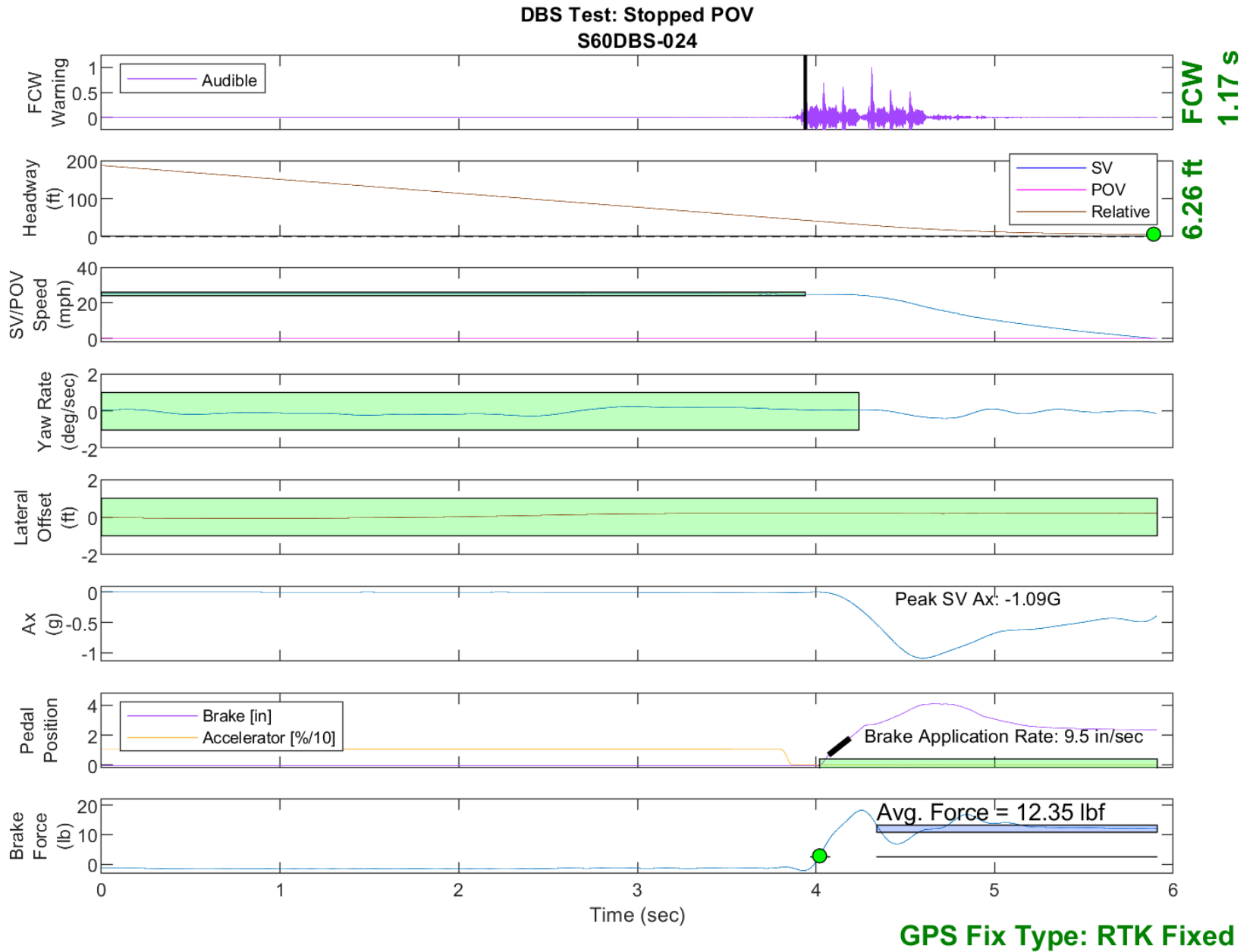


Figure E14. Time History for DBS Run 24, SV Encounters Stopped POV

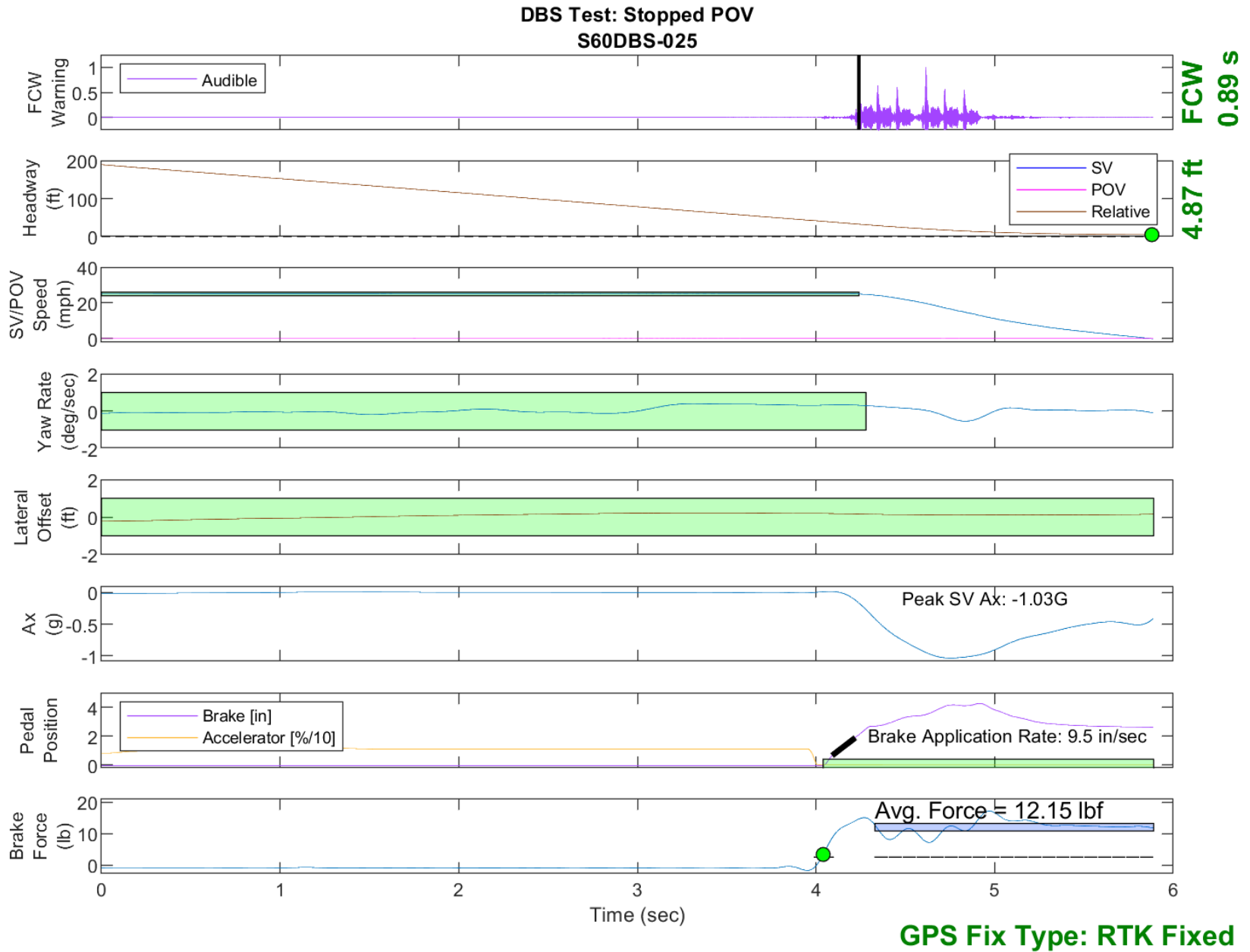


Figure E15. Time History for DBS Run 25, SV Encounters Stopped POV

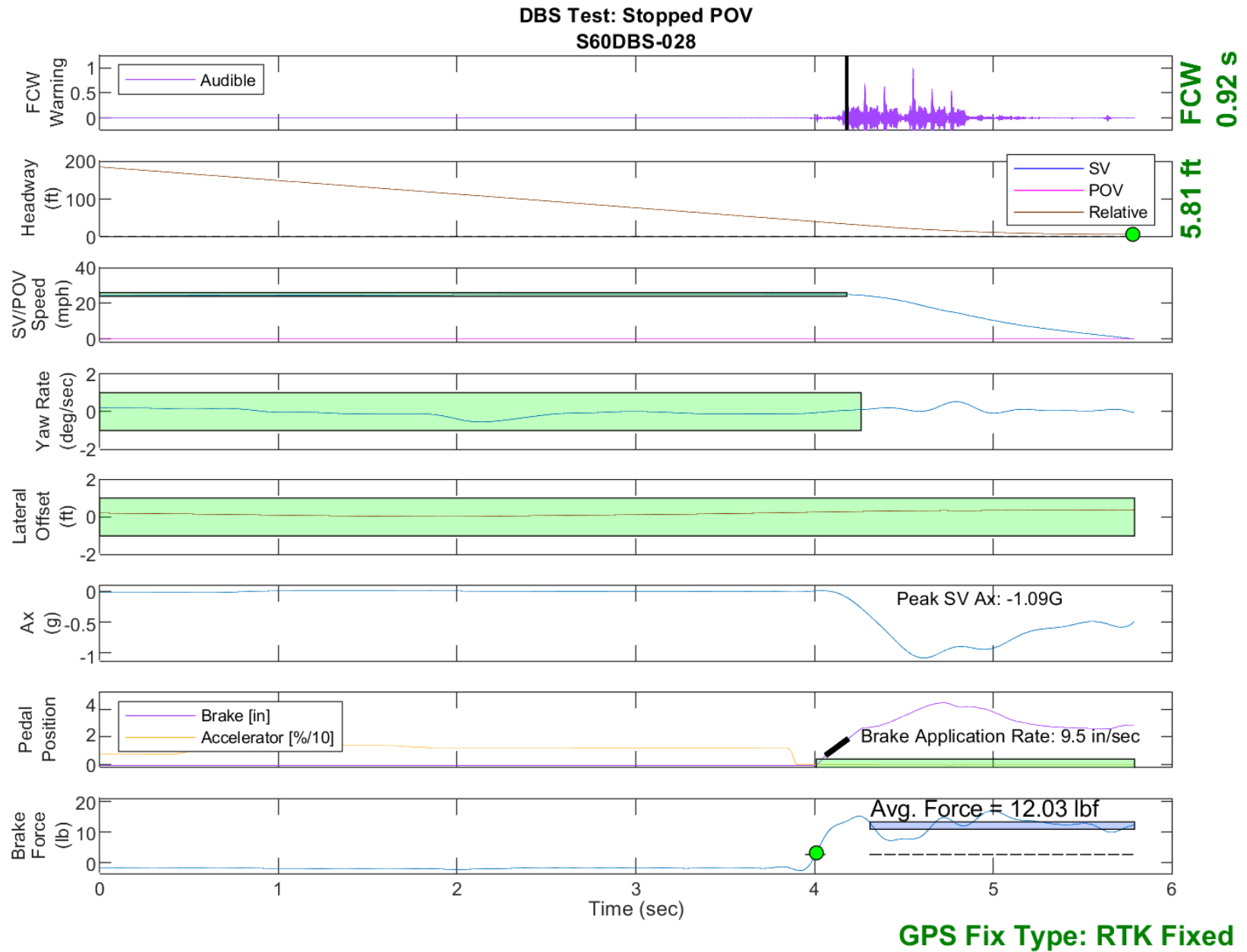


Figure E16. Time History for DBS Run 28, SV Encounters Stopped POV

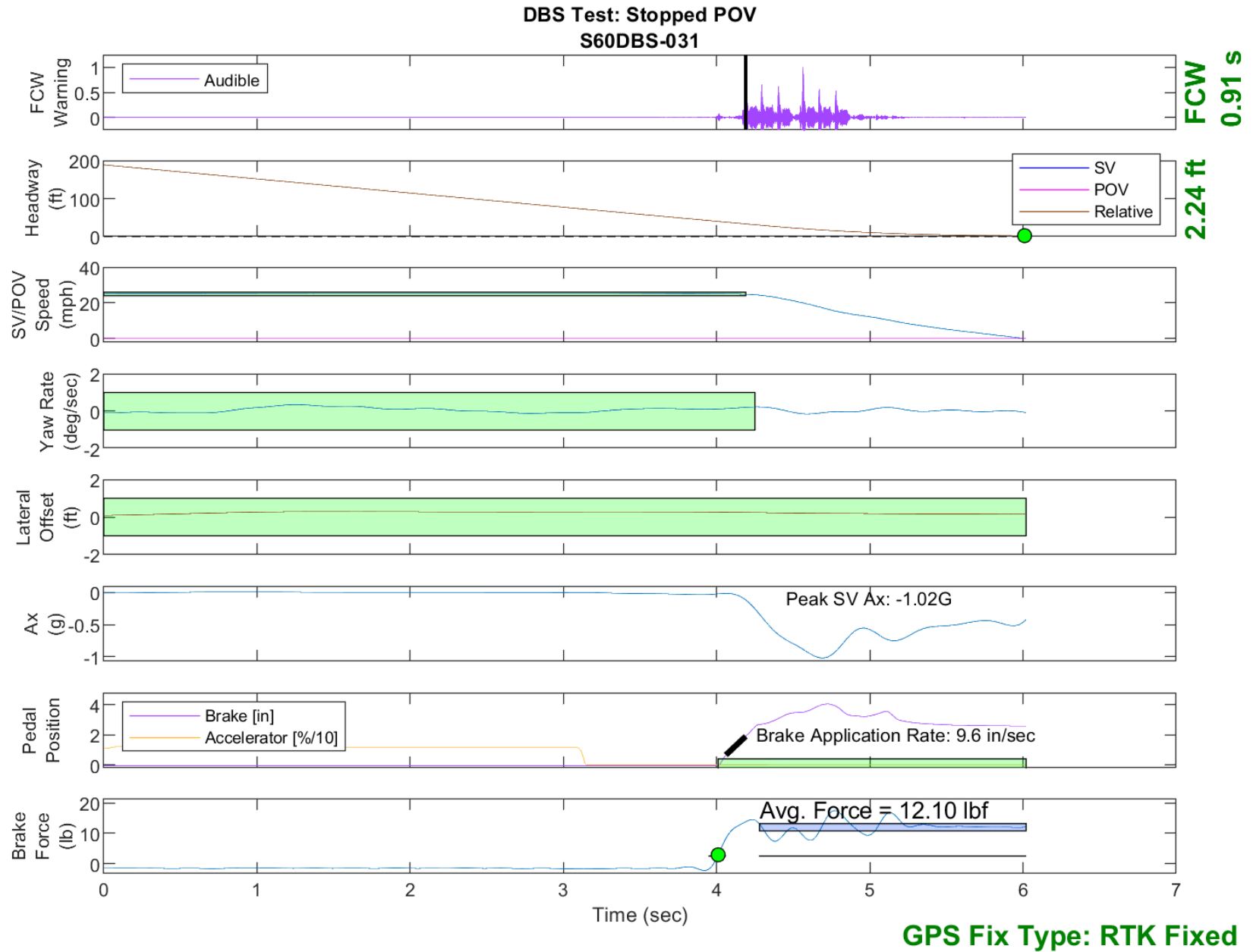


Figure E17. Time History for DBS Run 31, SV Encounters Stopped POV

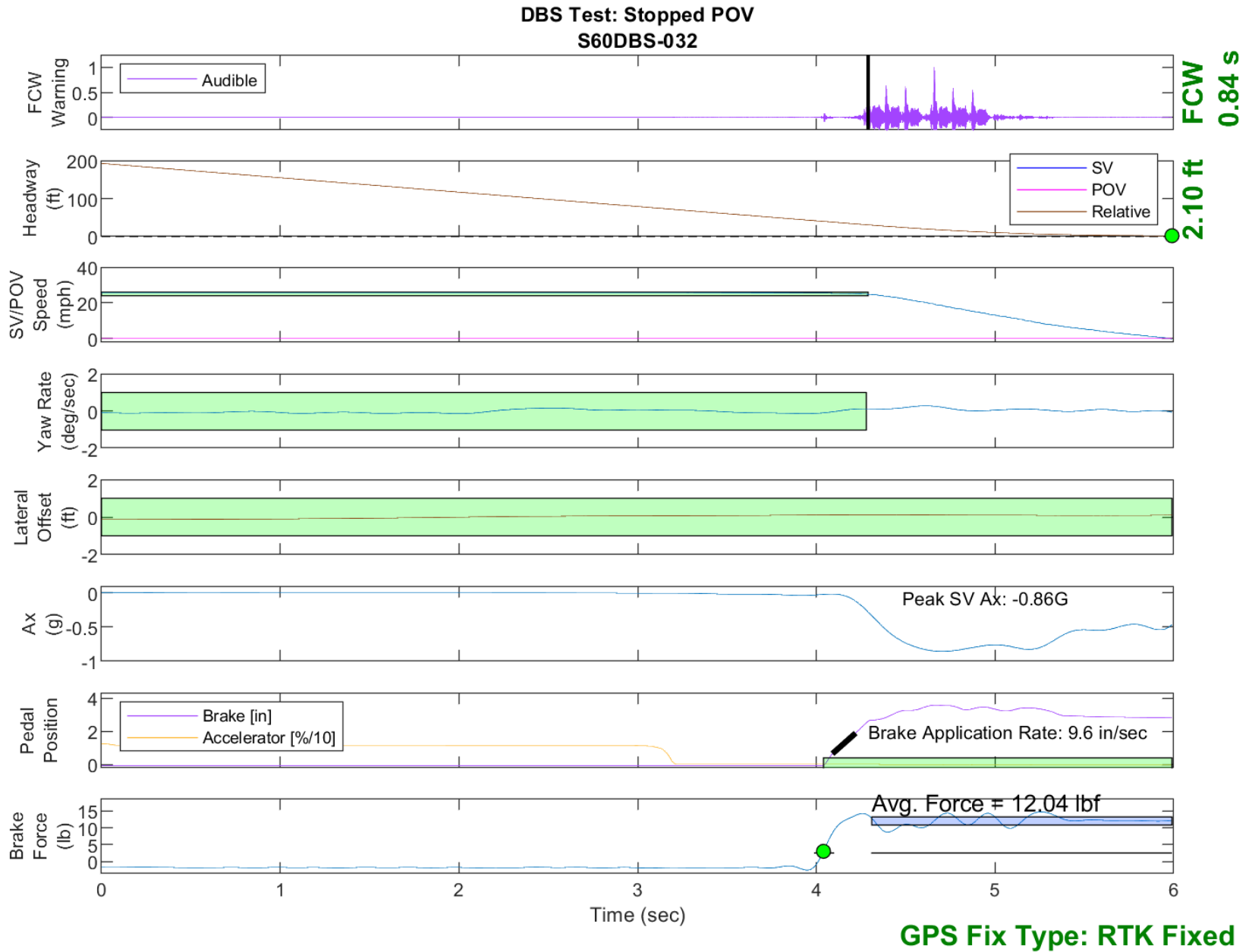


Figure E18. Time History for DBS Run 32, SV Encounters Stopped POV

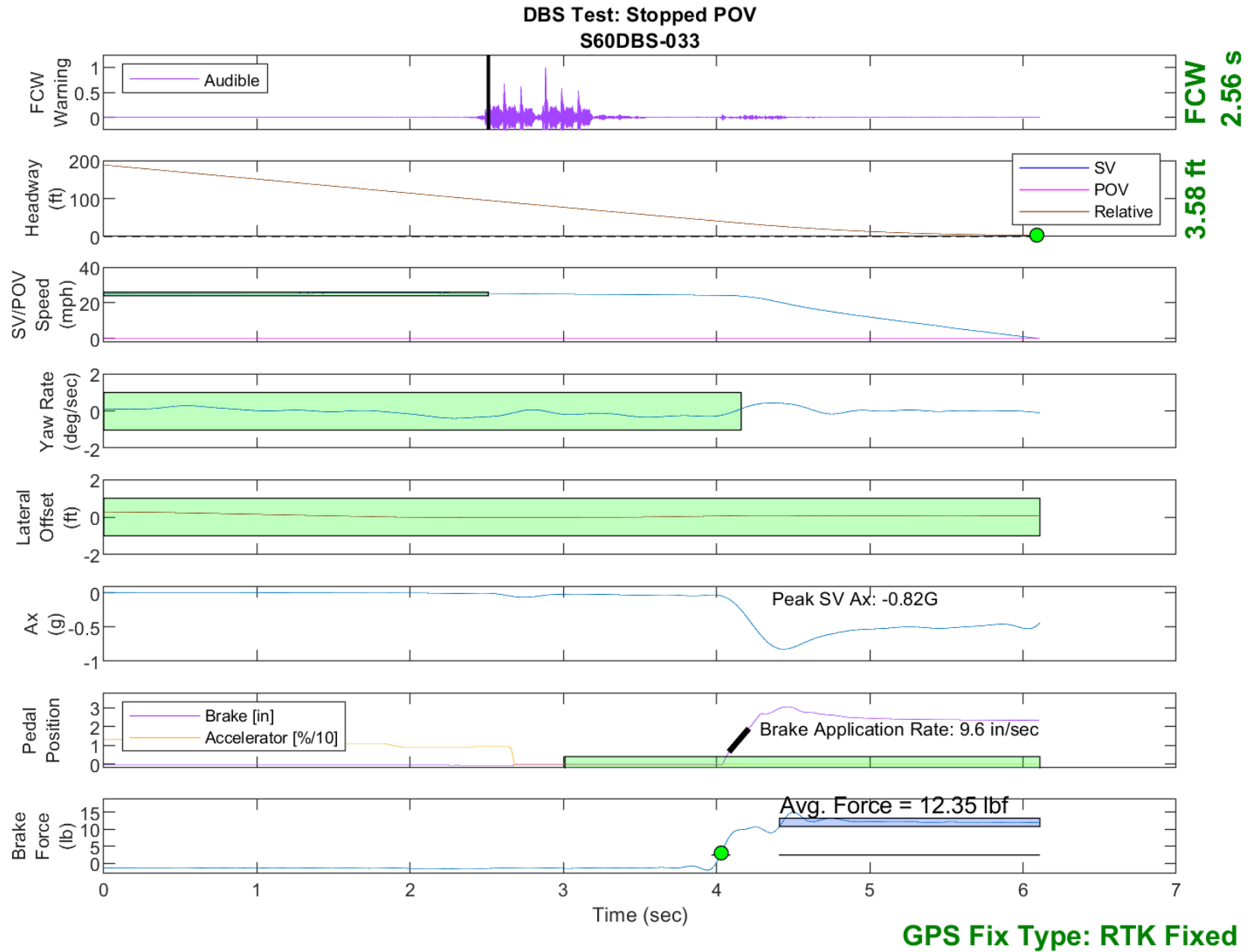


Figure E19. Time History for DBS Run 33, SV Encounters Stopped POV

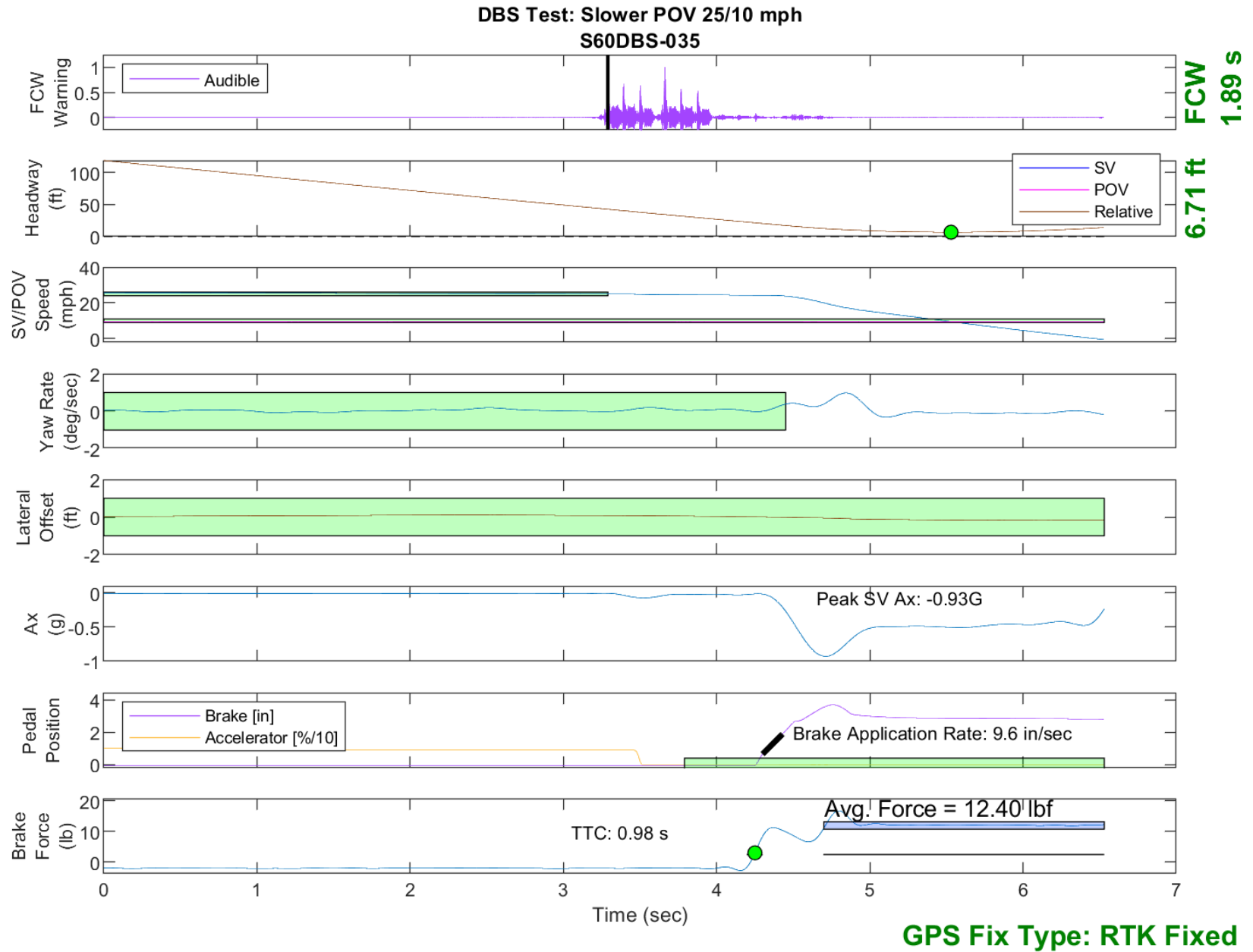


Figure E20. Time History for DBS Run 35, SV Encounters Slower POV, SV 25 mph, POV 10 mph

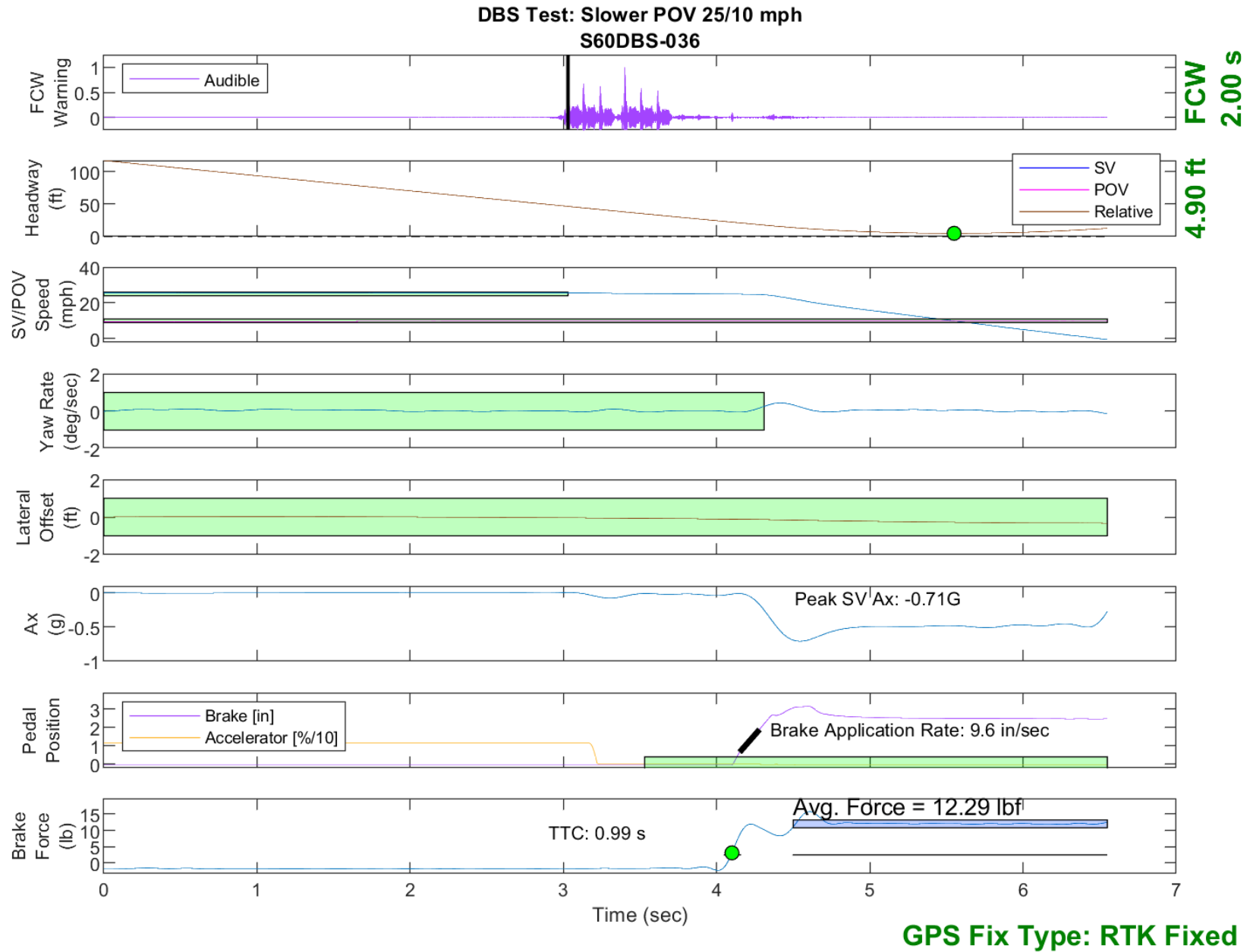


Figure E21. Time History for DBS Run 36, SV Encounters Slower POV, SV 25 mph, POV 10 mph

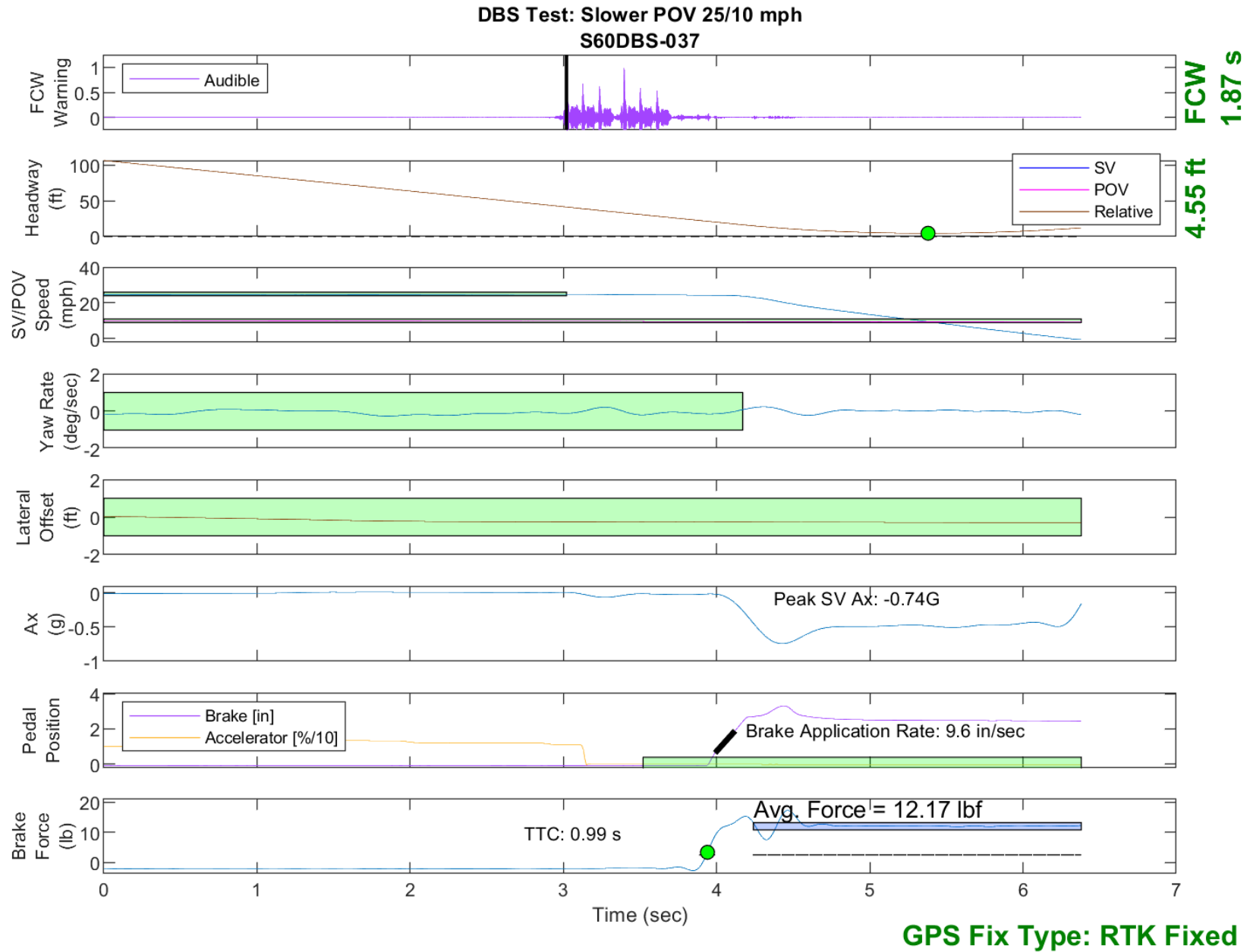


Figure E22. Time History for DBS Run 37, SV Encounters Slower POV, SV 25 mph, POV 10 mph

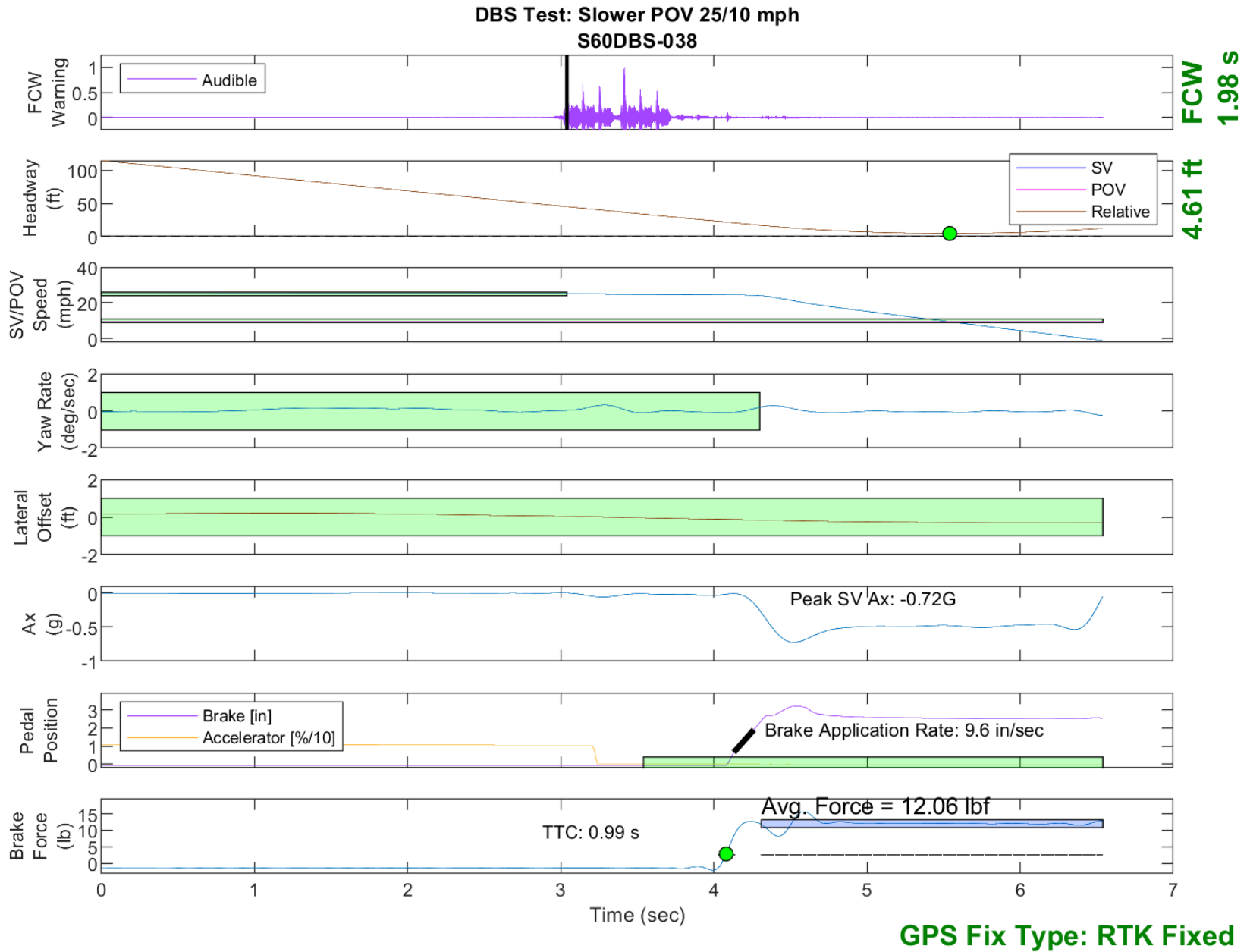


Figure E23. Time History for DBS Run 38, SV Encounters Slower POV, SV 25 mph, POV 10 mph

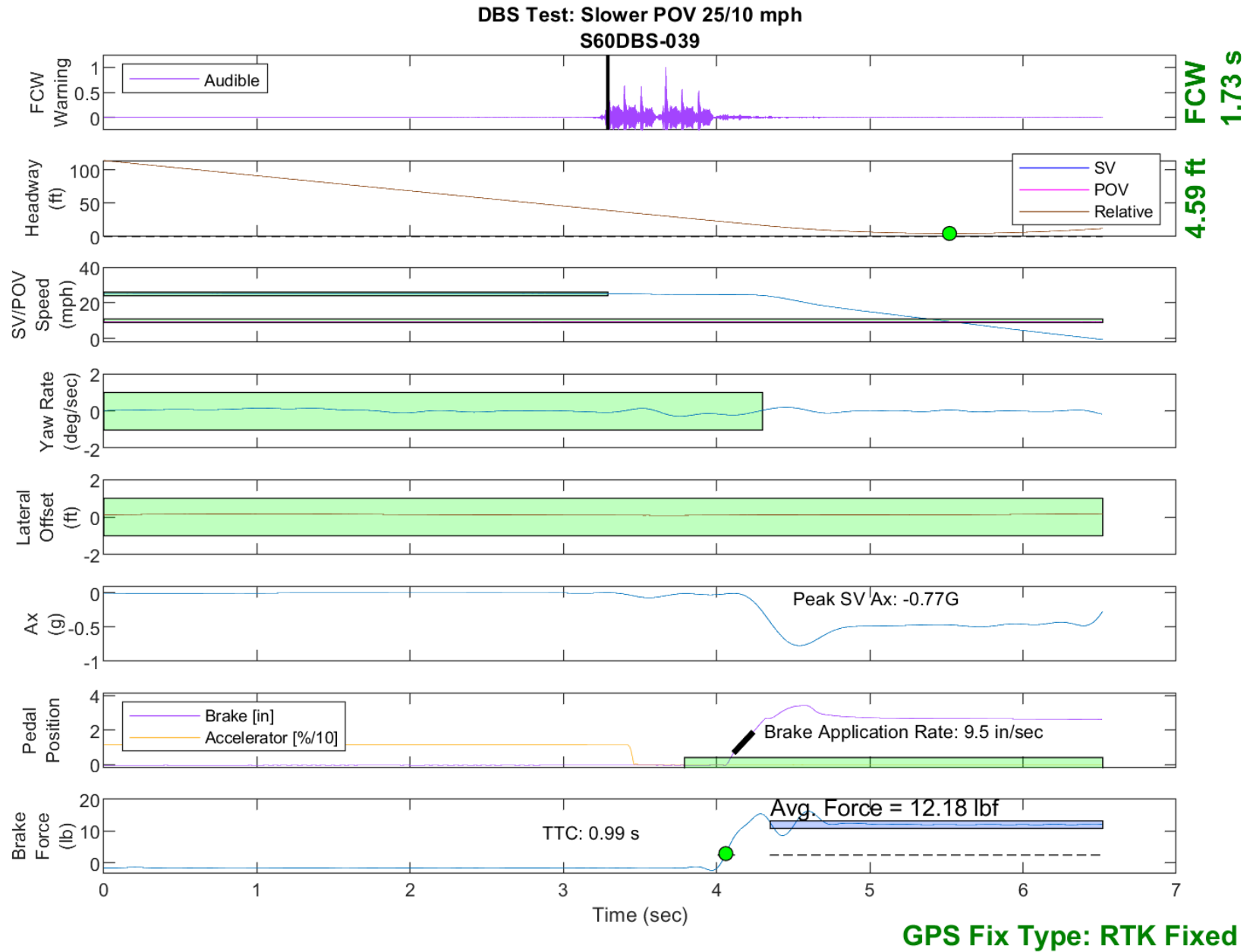


Figure E24. Time History for DBS Run 39, SV Encounters Slower POV, SV 25 mph, POV 10 mph

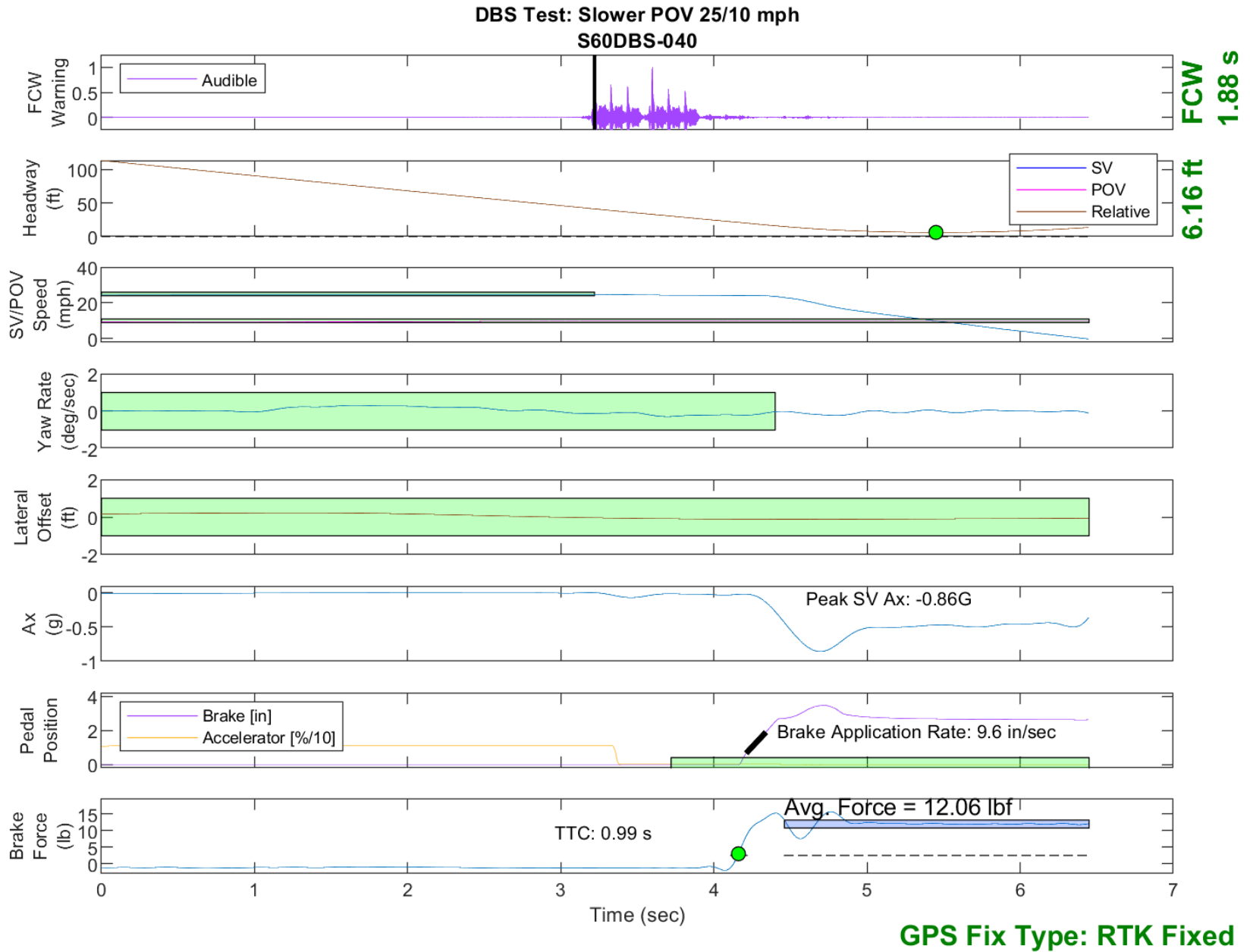


Figure E25. Time History for DBS Run 40, SV Encounters Slower POV, SV 25 mph, POV 10 mph

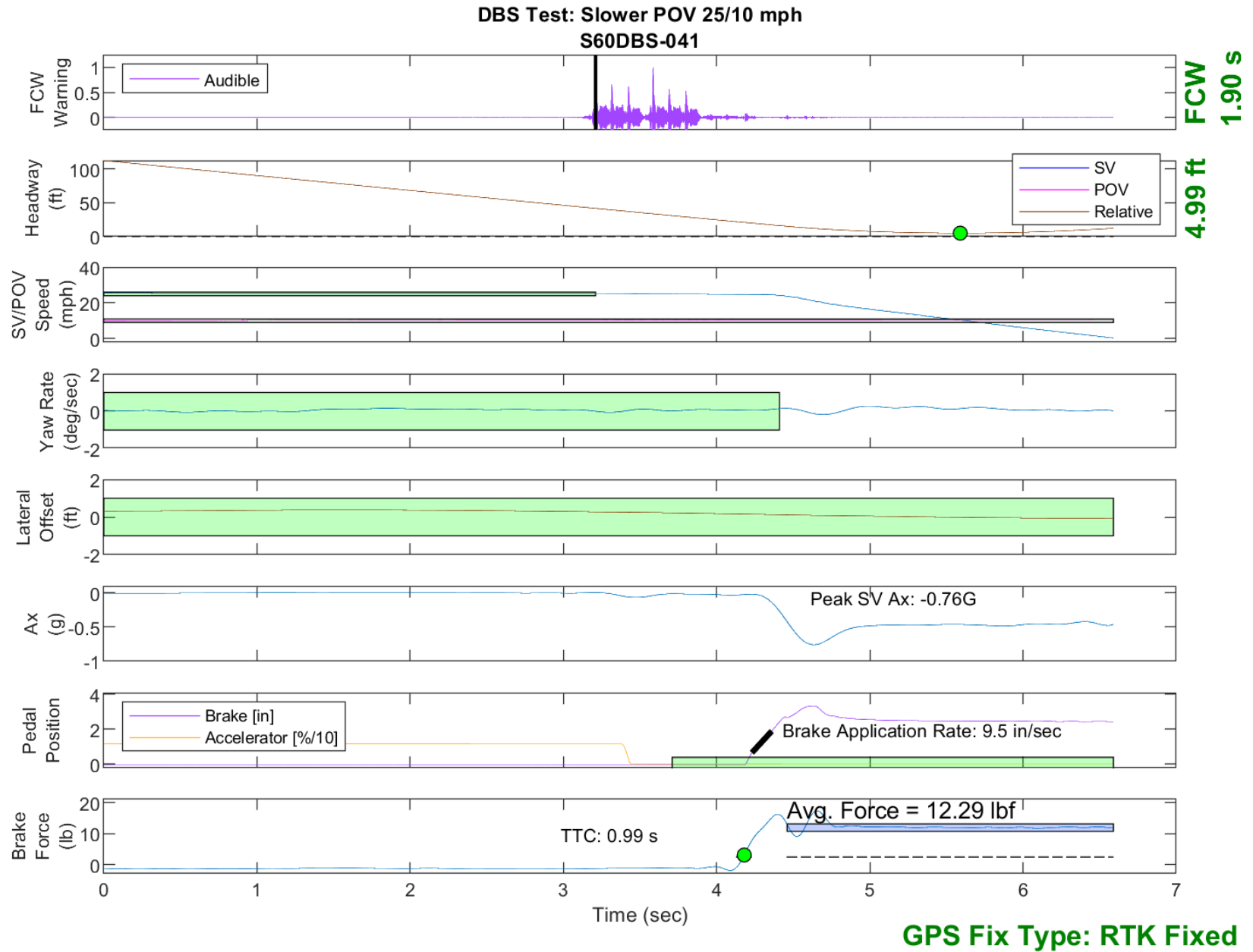


Figure E26. Time History for DBS Run 41, SV Encounters Slower POV, SV 25 mph, POV 10 mph

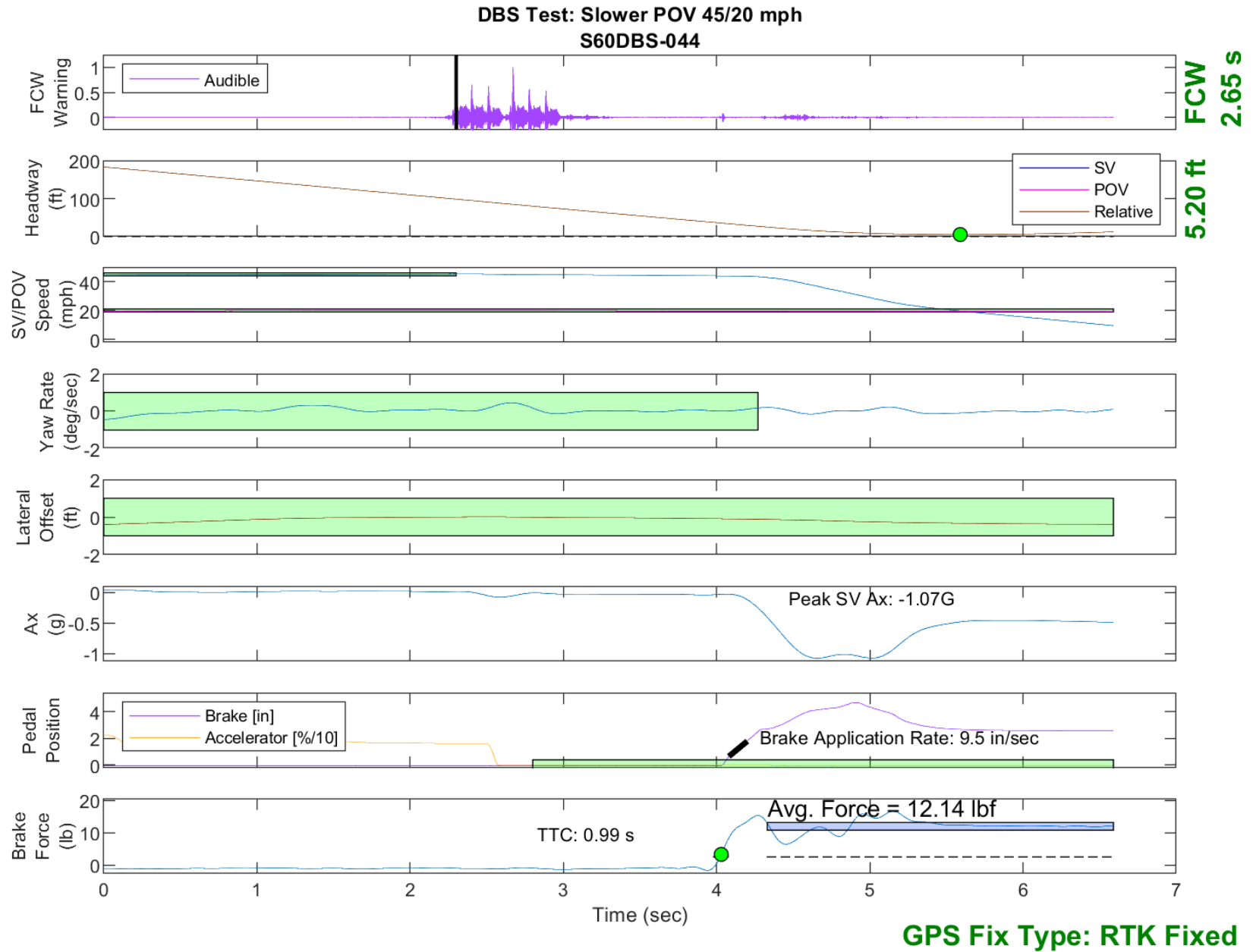


Figure E27. Time History for DBS Run 44, SV Encounters Slower POV, SV 45 mph, POV 20 mph

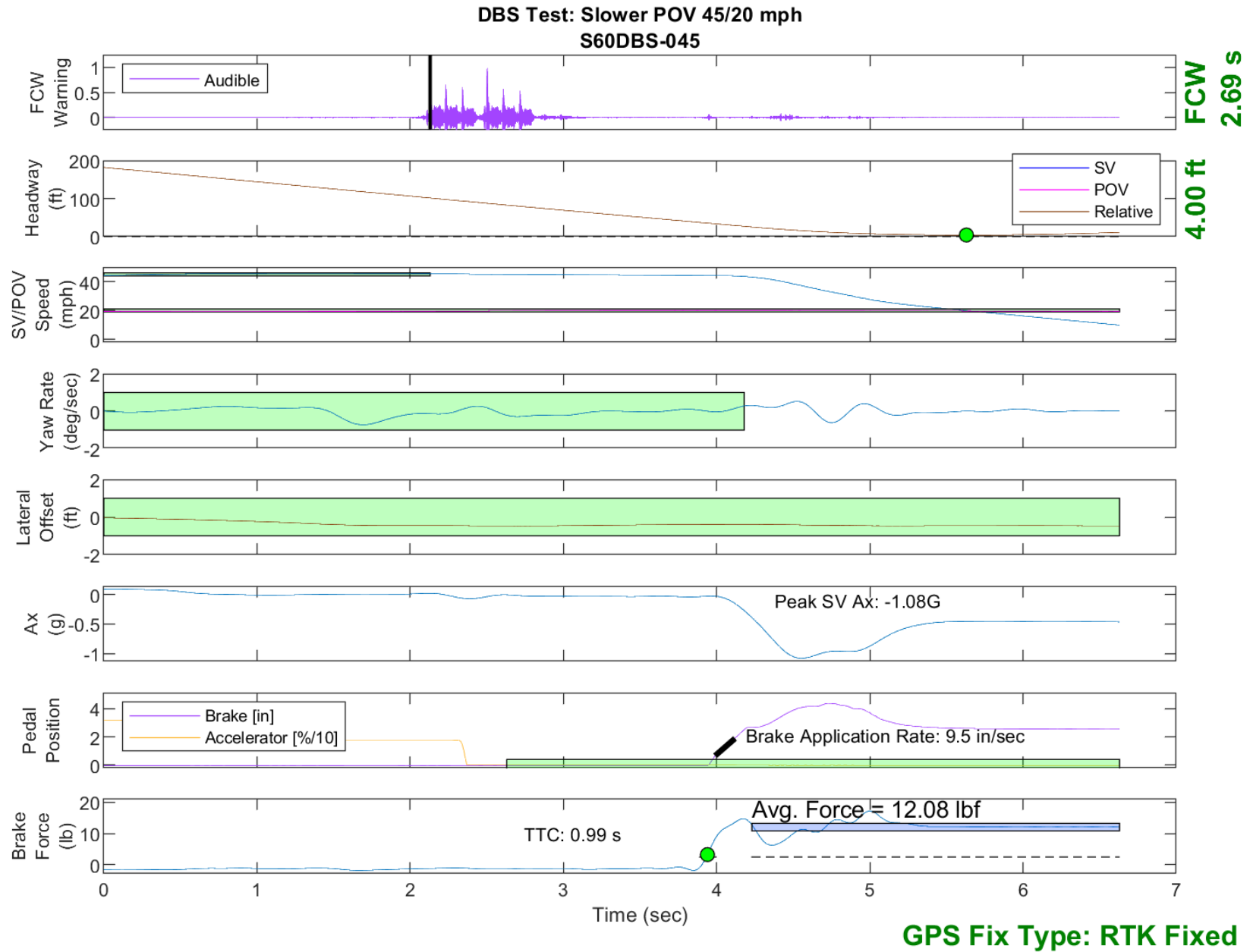


Figure E28. Time History for DBS Run 45, SV Encounters Slower POV, SV 45 mph, POV 20 mph

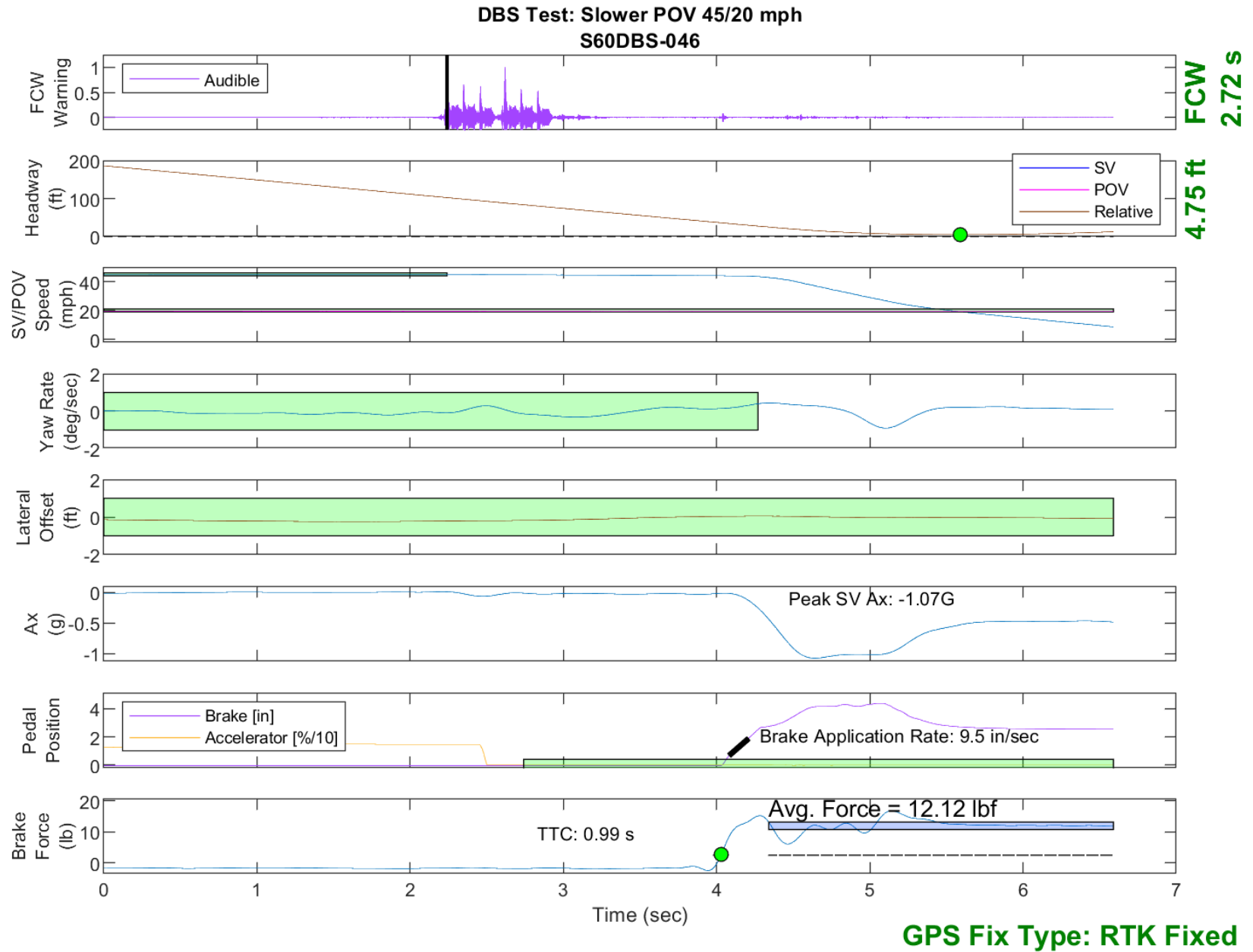


Figure E29. Time History for DBS Run 46, SV Encounters Slower POV, SV 45 mph, POV 20 mph

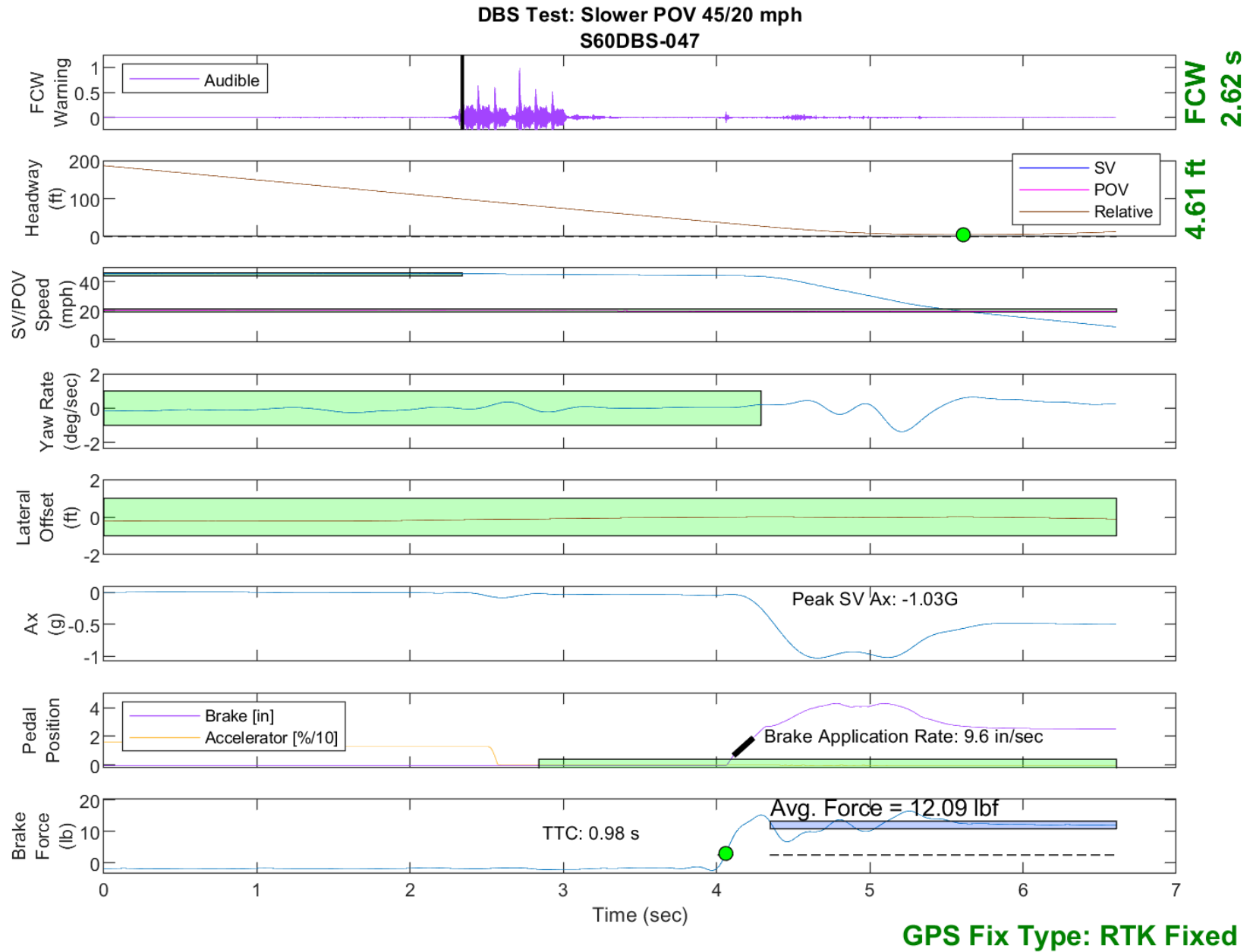


Figure E30. Time History for DBS Run 47, SV Encounters Slower POV, SV 45 mph, POV 20 mph

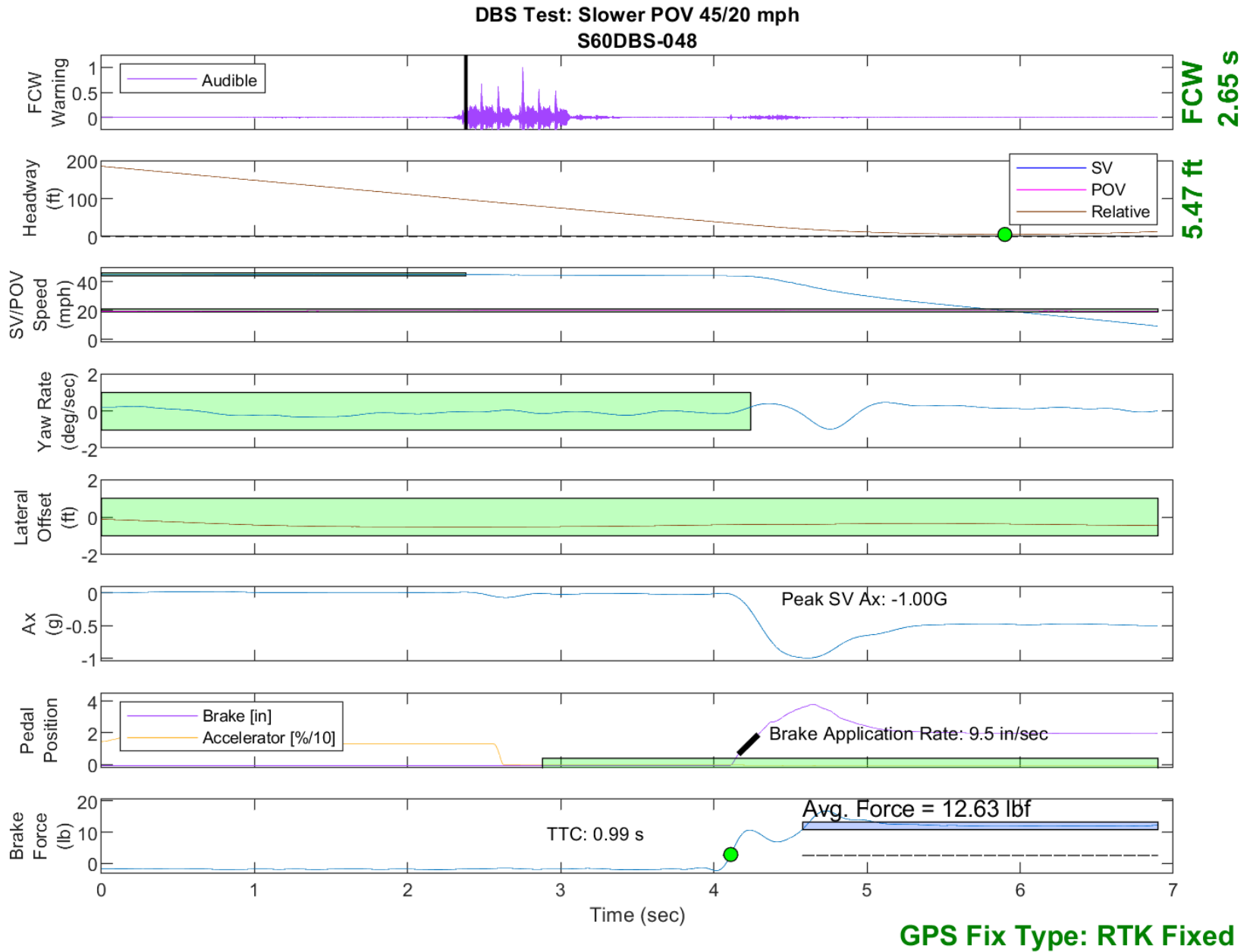


Figure E31. Time History for DBS Run 48, SV Encounters Slower POV, SV 45 mph, POV 20 mph

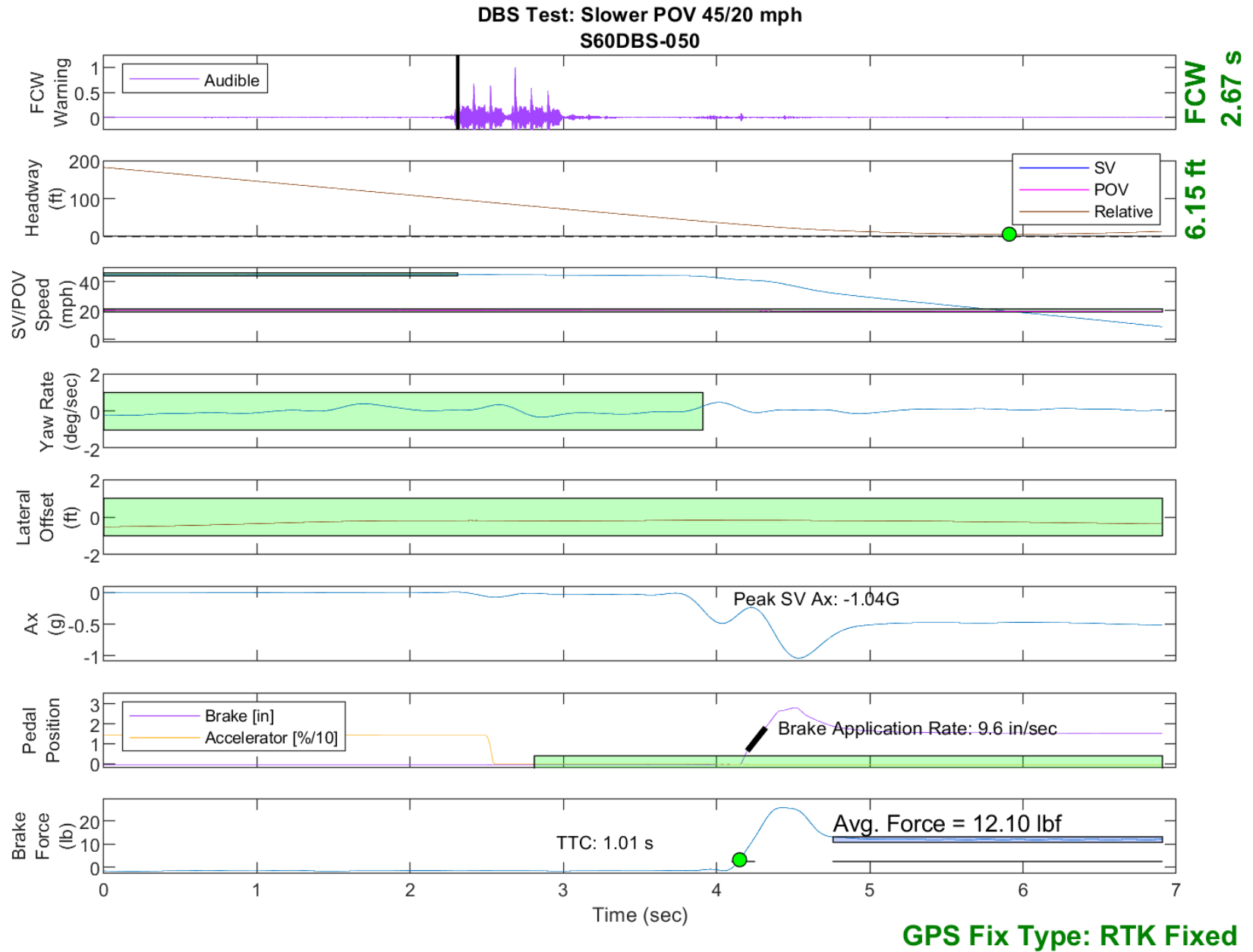


Figure E32. Time History for DBS Run 50, SV Encounters Slower POV, SV 45 mph, POV 20 mph

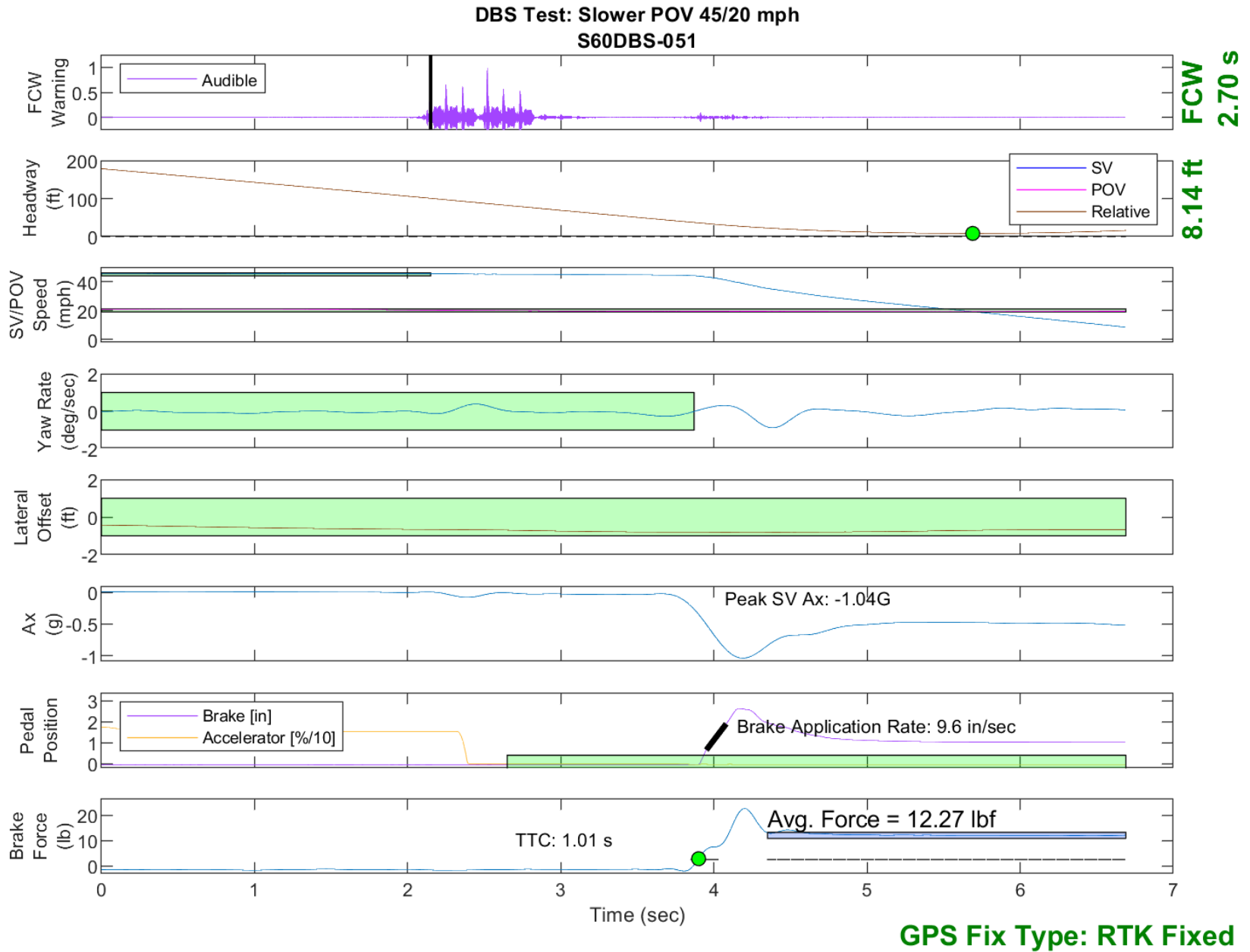


Figure E33. Time History for DBS Run 51, SV Encounters Slower POV, SV 45 mph, POV 20 mph

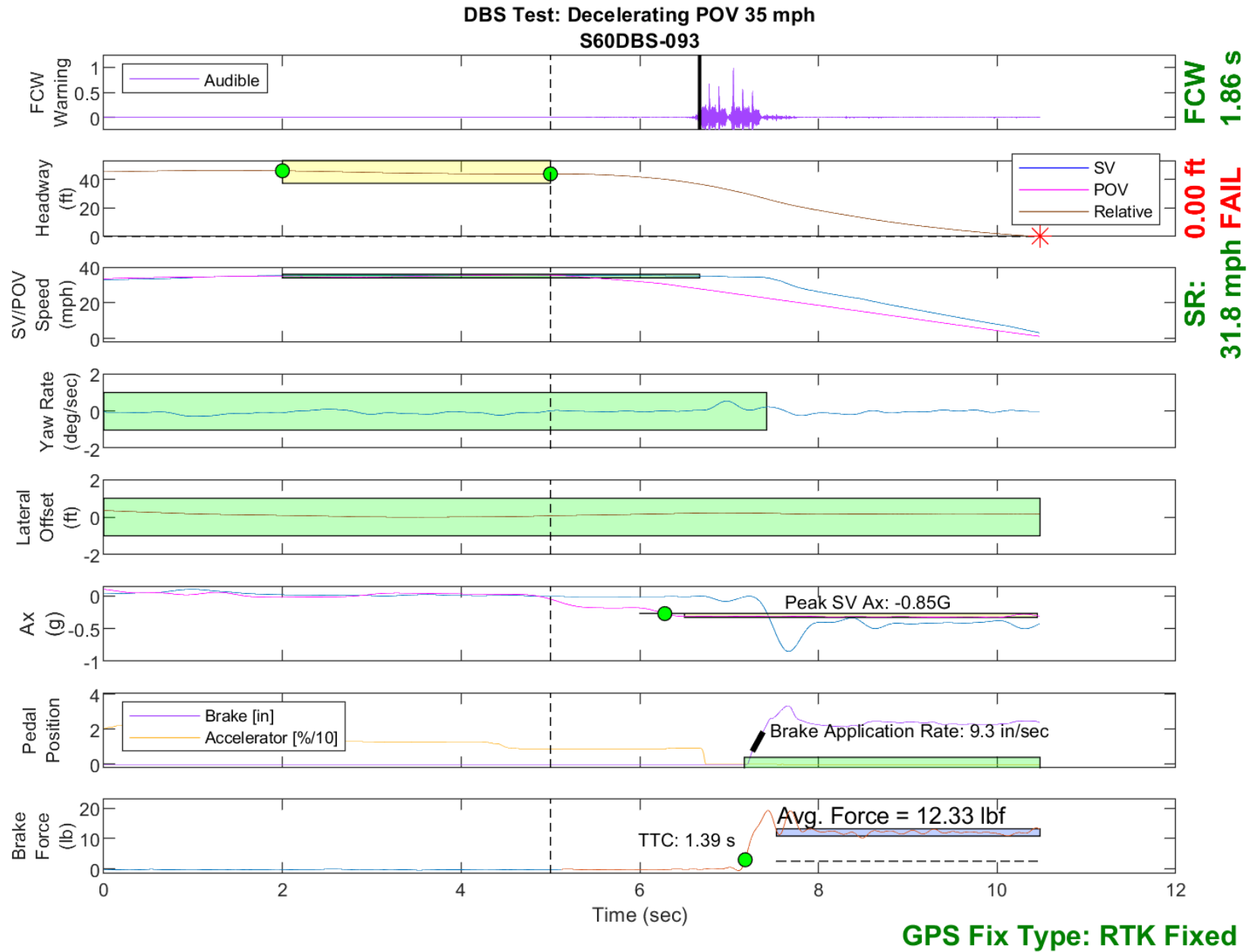


Figure E34. Time History for DBS Run 93, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

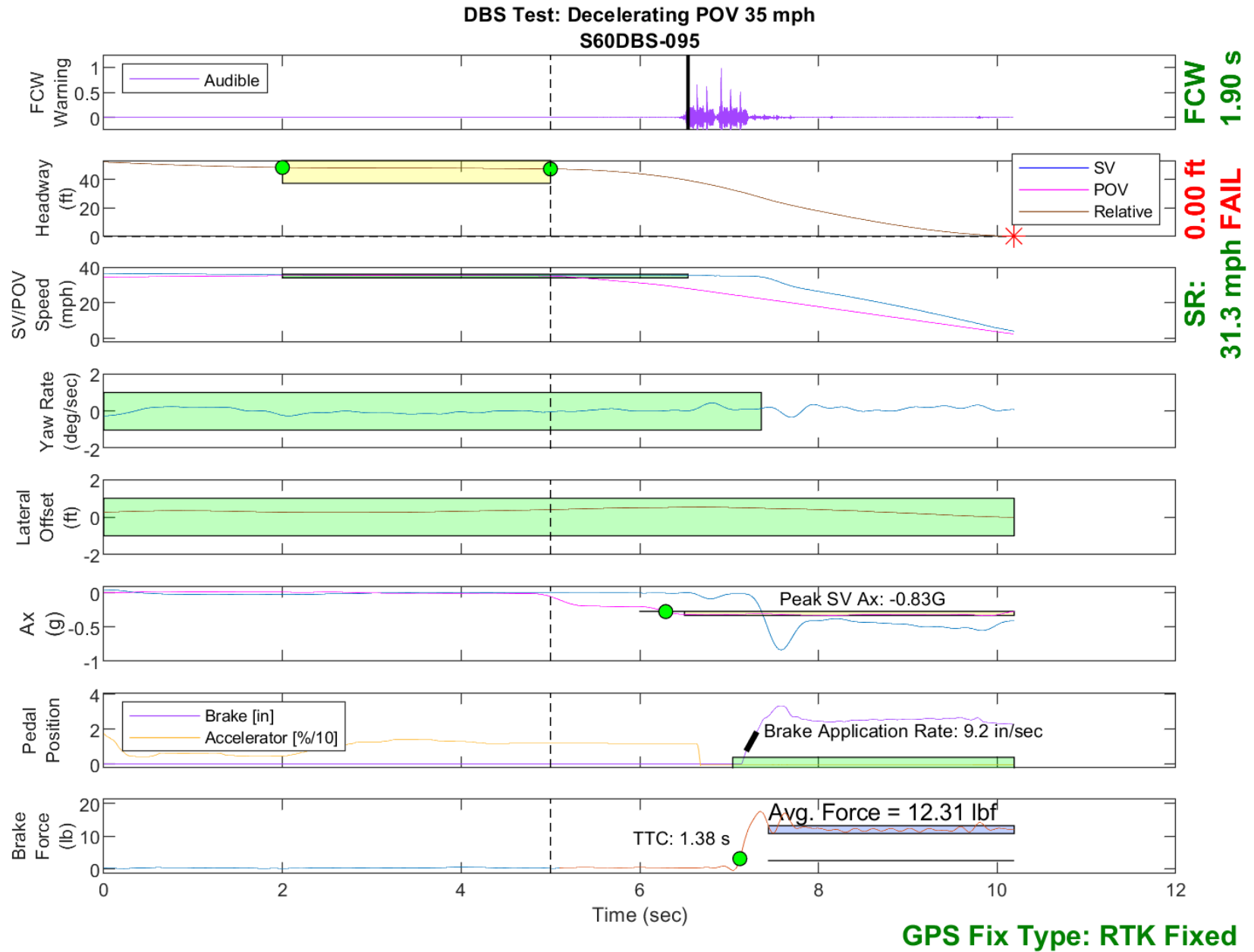


Figure E35. Time History for DBS Run 95, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

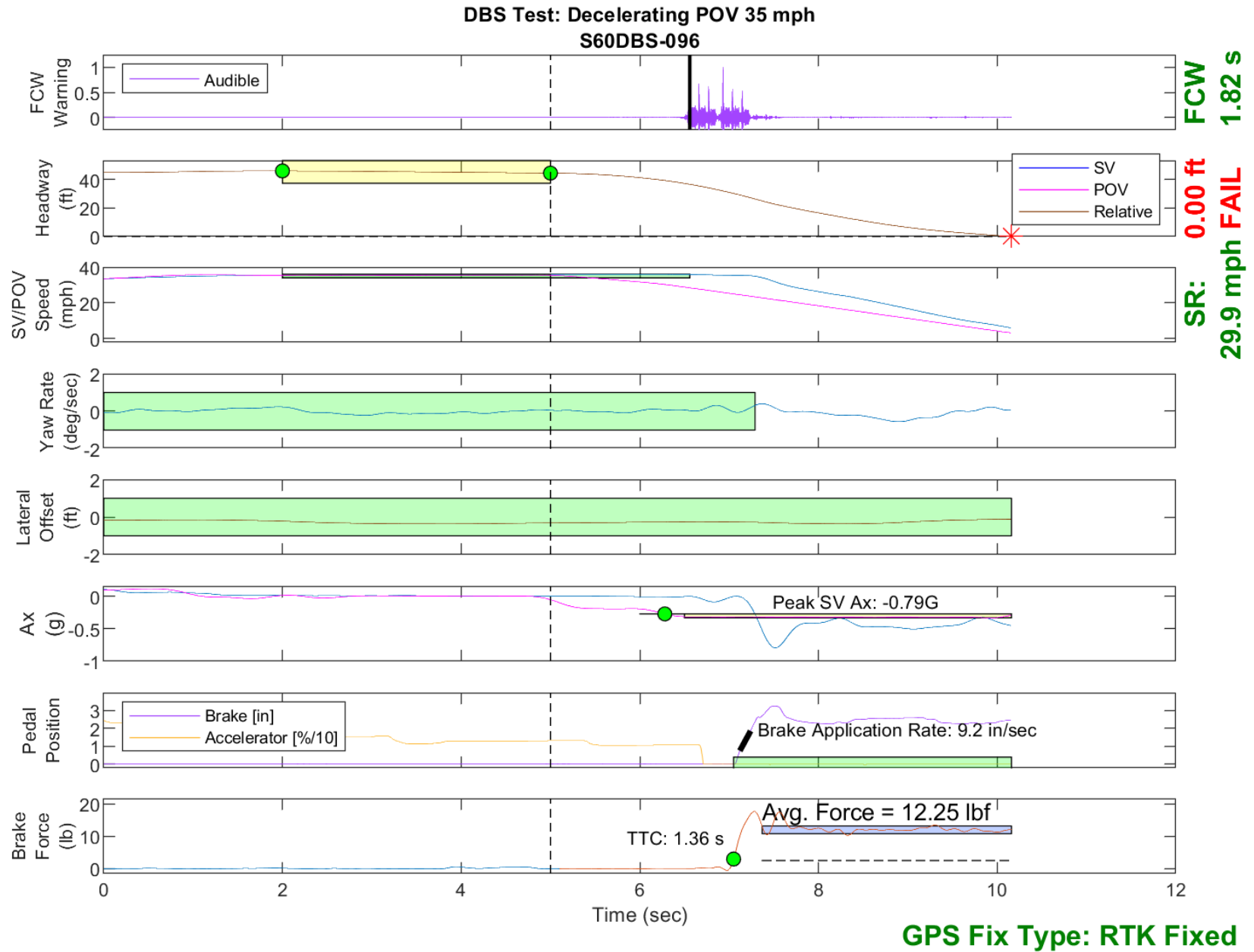


Figure E36. Time History for DBS Run 96, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

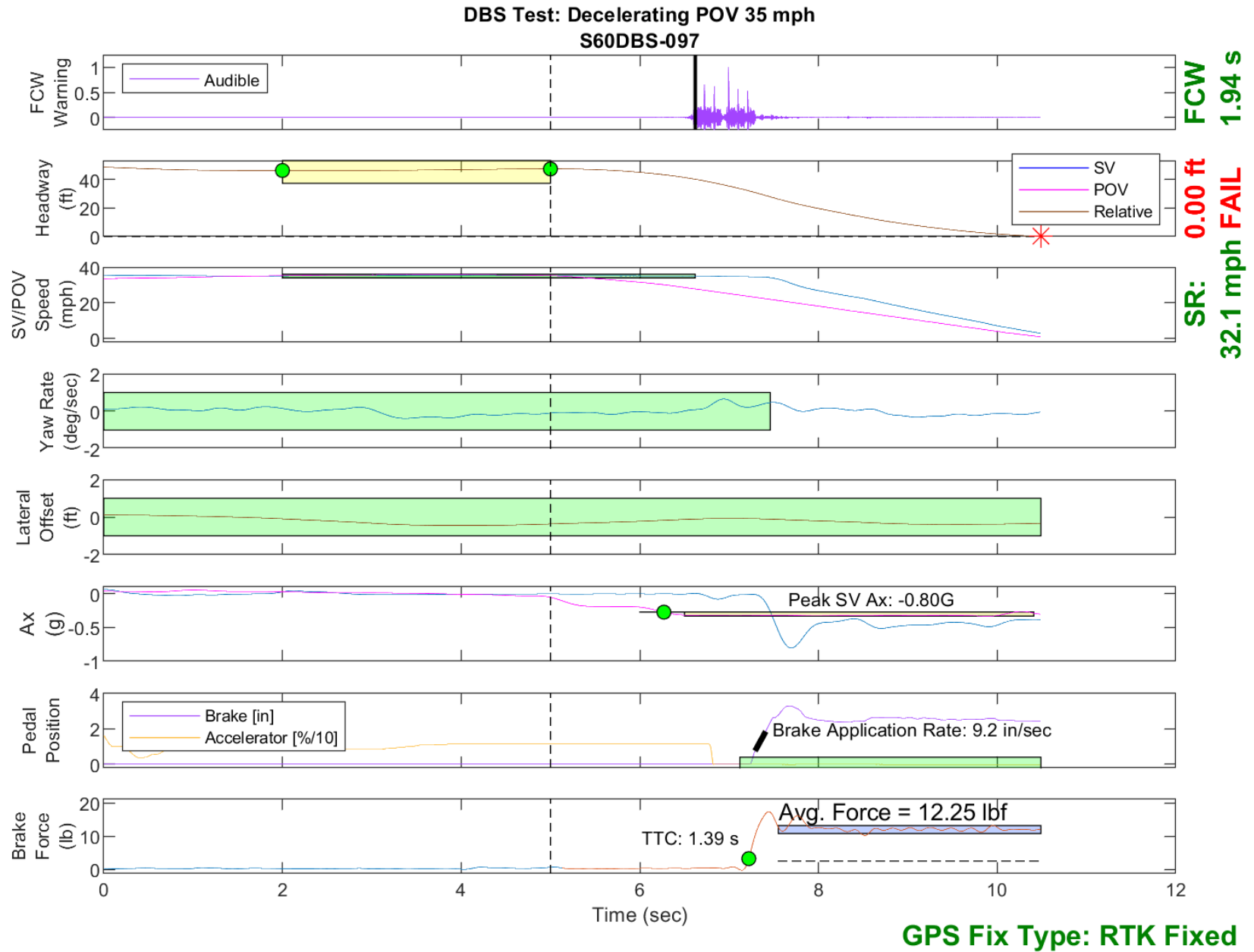


Figure E37. Time History for DBS Run 97, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

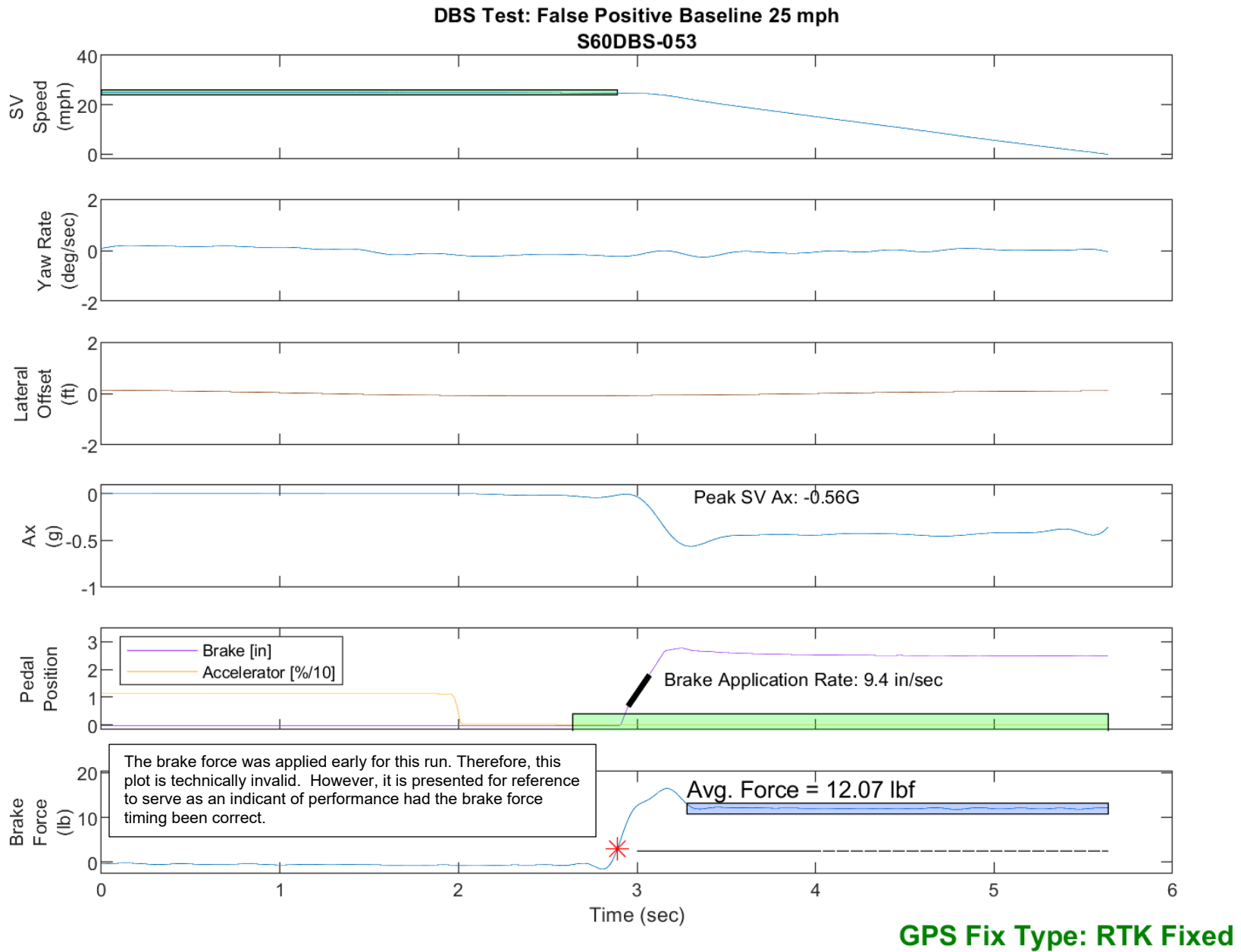


Figure E38. Time History for DBS Run 53, False Positive Baseline, SV 25 mph

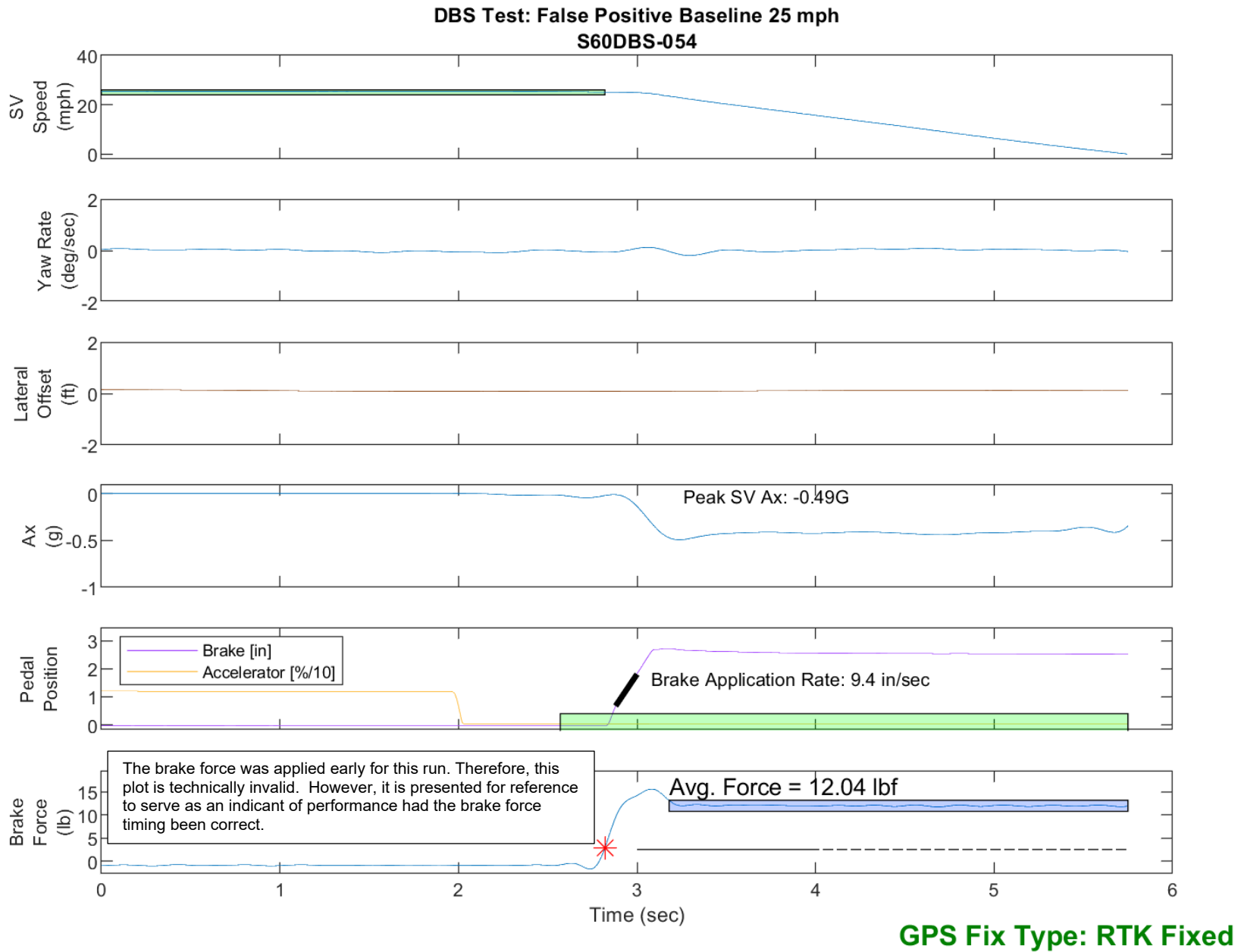


Figure E39. Time History for DBS Run 54, False Positive Baseline, SV 25 mph

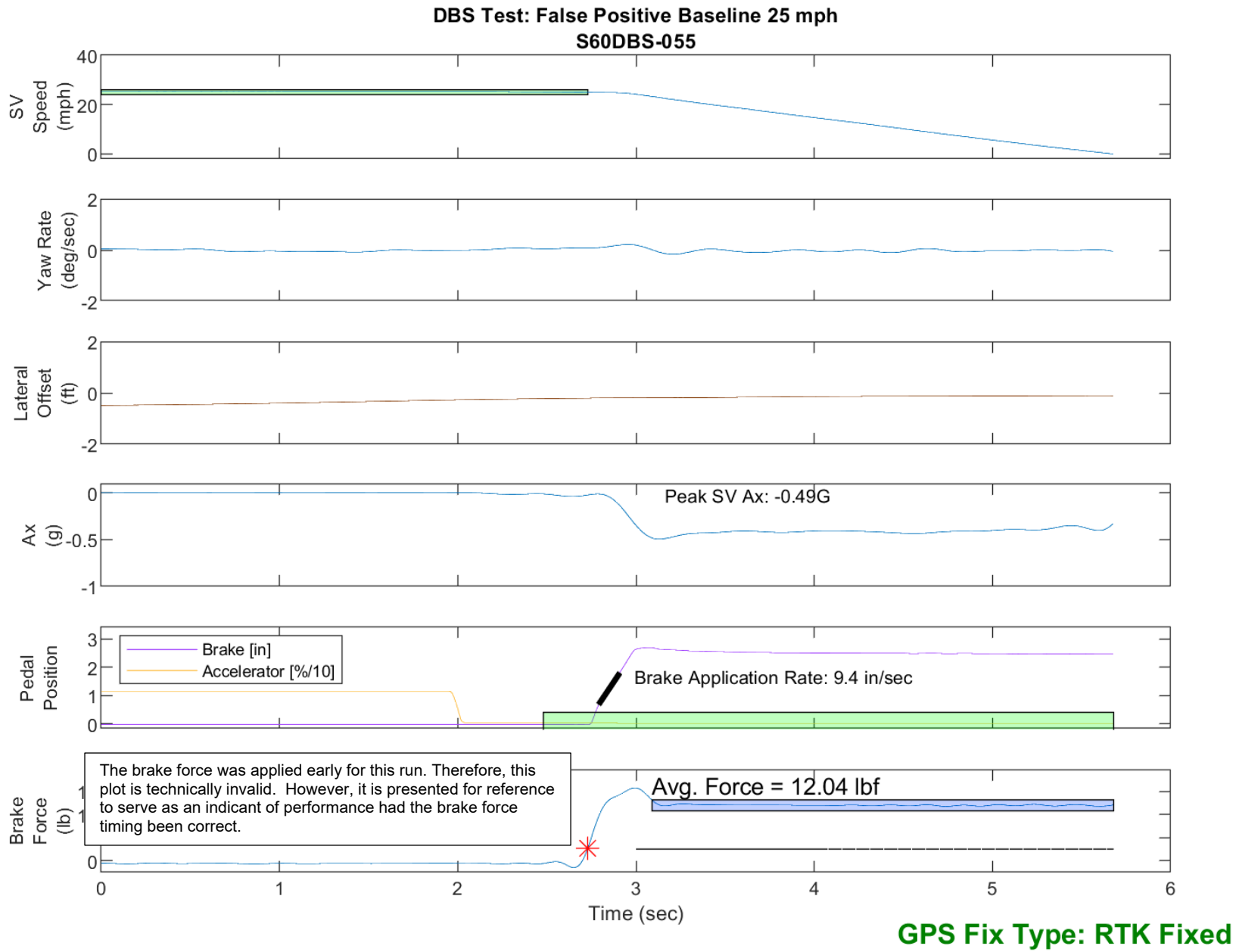


Figure E40. Time History for DBS Run 55, False Positive Baseline, SV 25 mph

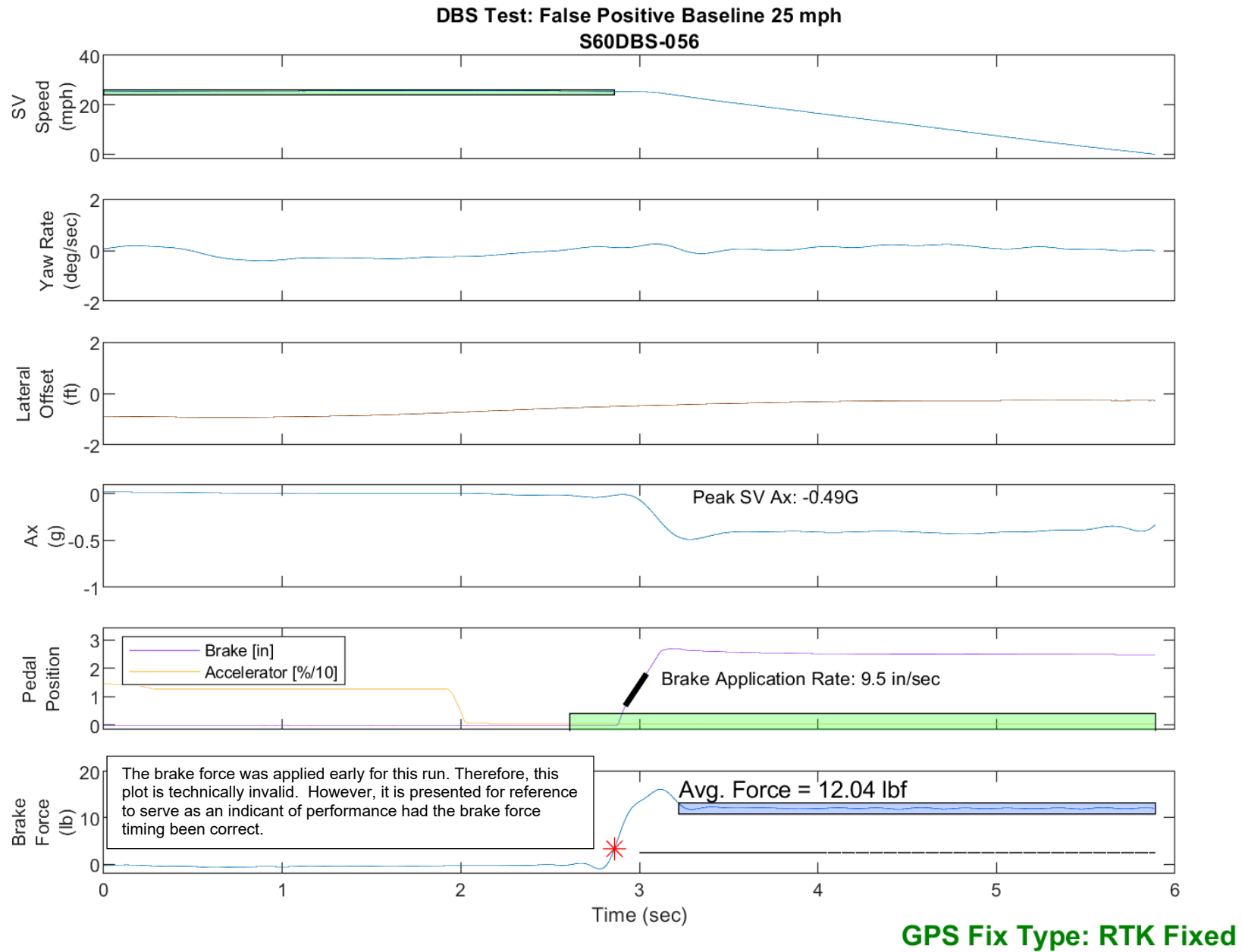


Figure E41. Time History for DBS Run 56, False Positive Baseline, SV 25 mph

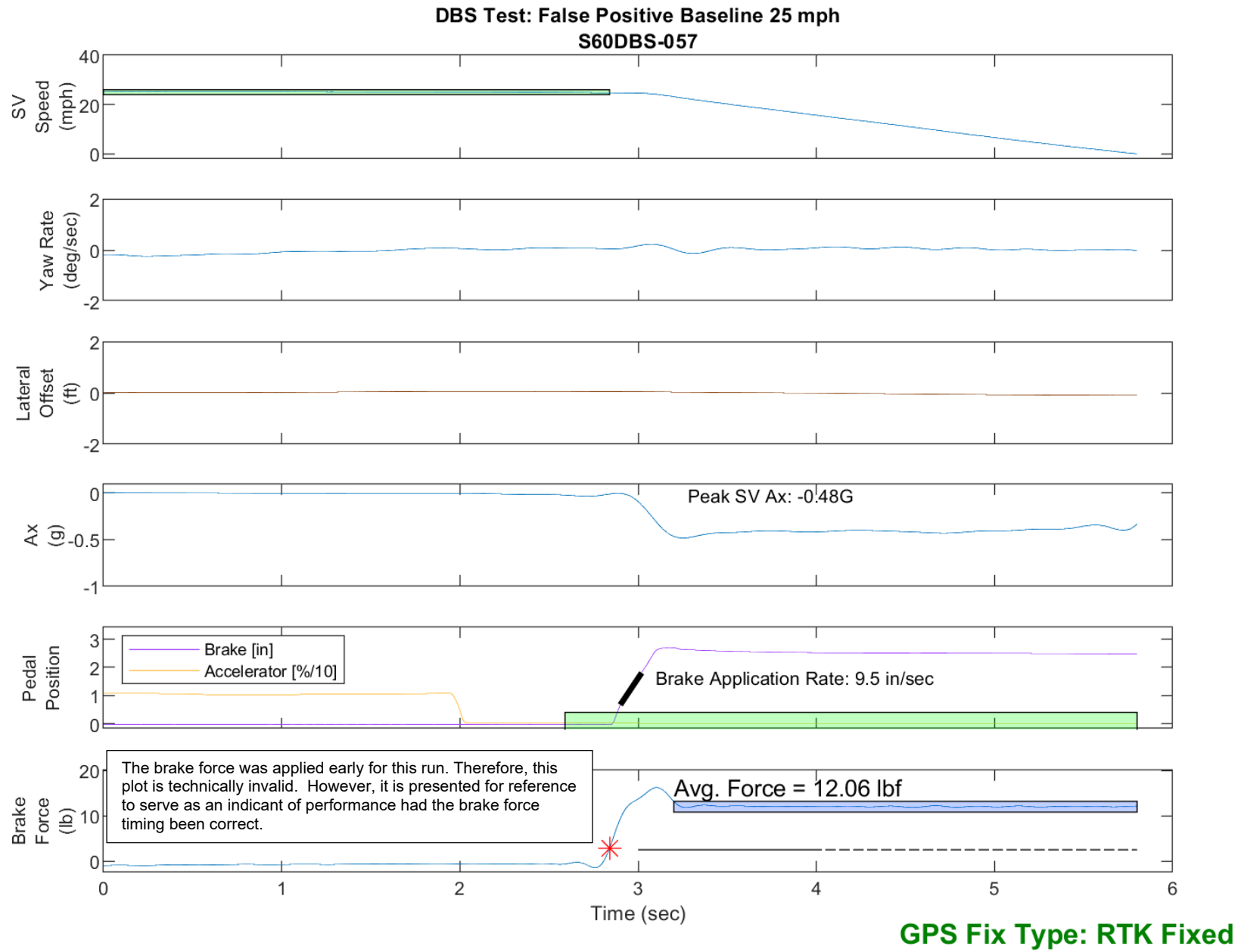


Figure E42. Time History for DBS Run 57, False Positive Baseline, SV 25 mph

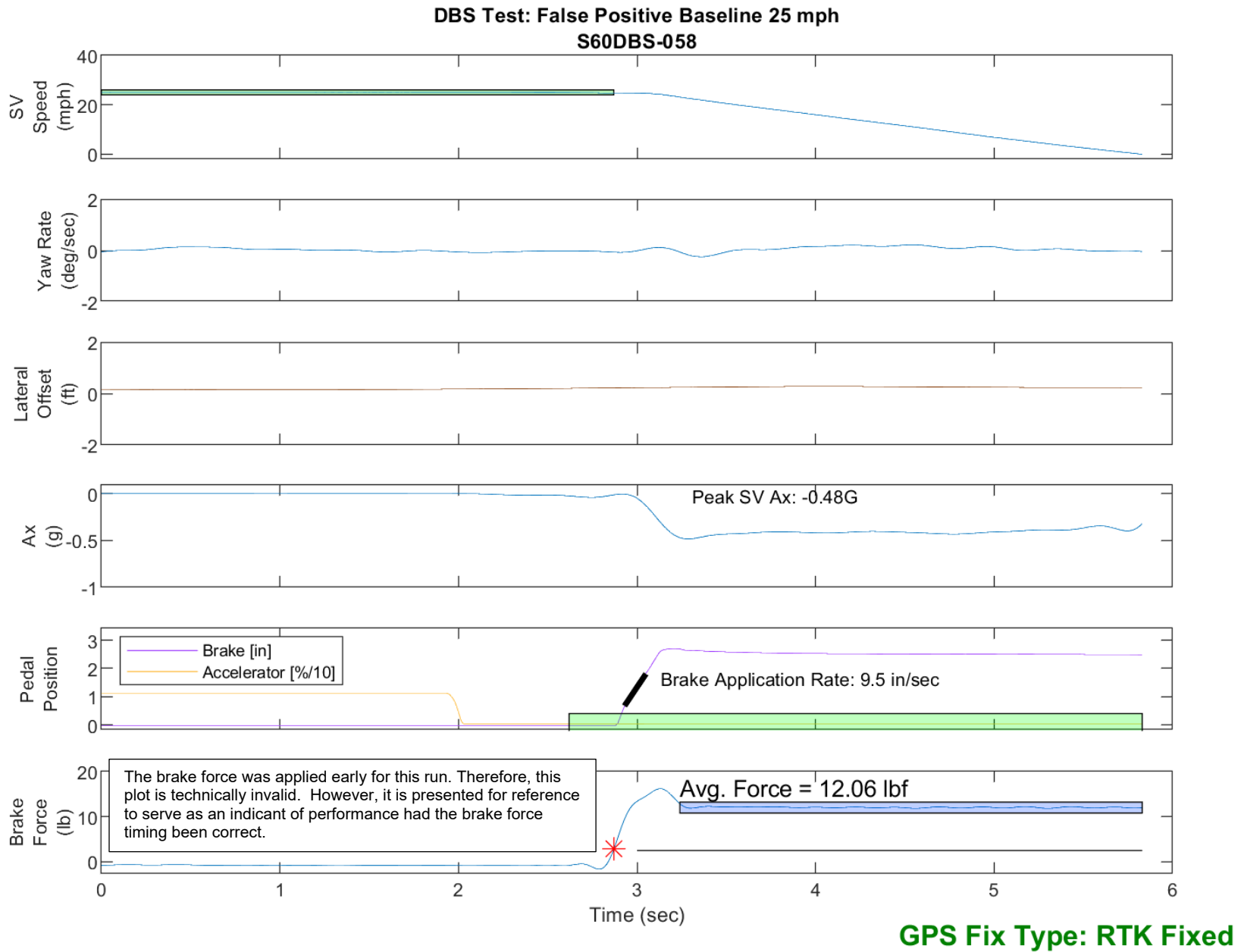


Figure E43. Time History for DBS Run 58, False Positive Baseline, SV 25 mph

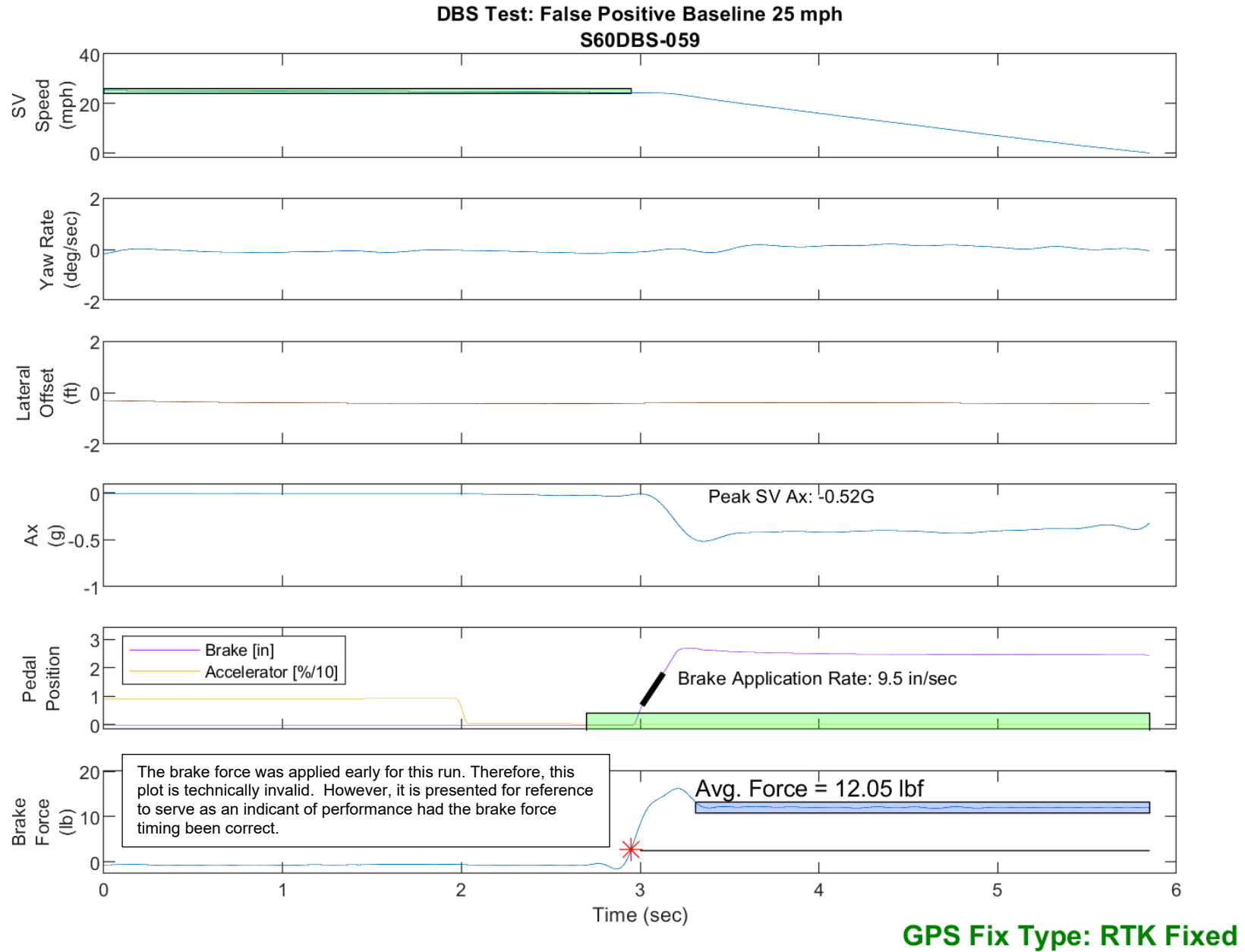


Figure E44. Time History for DBS Run 59, False Positive Baseline, SV 25 mph

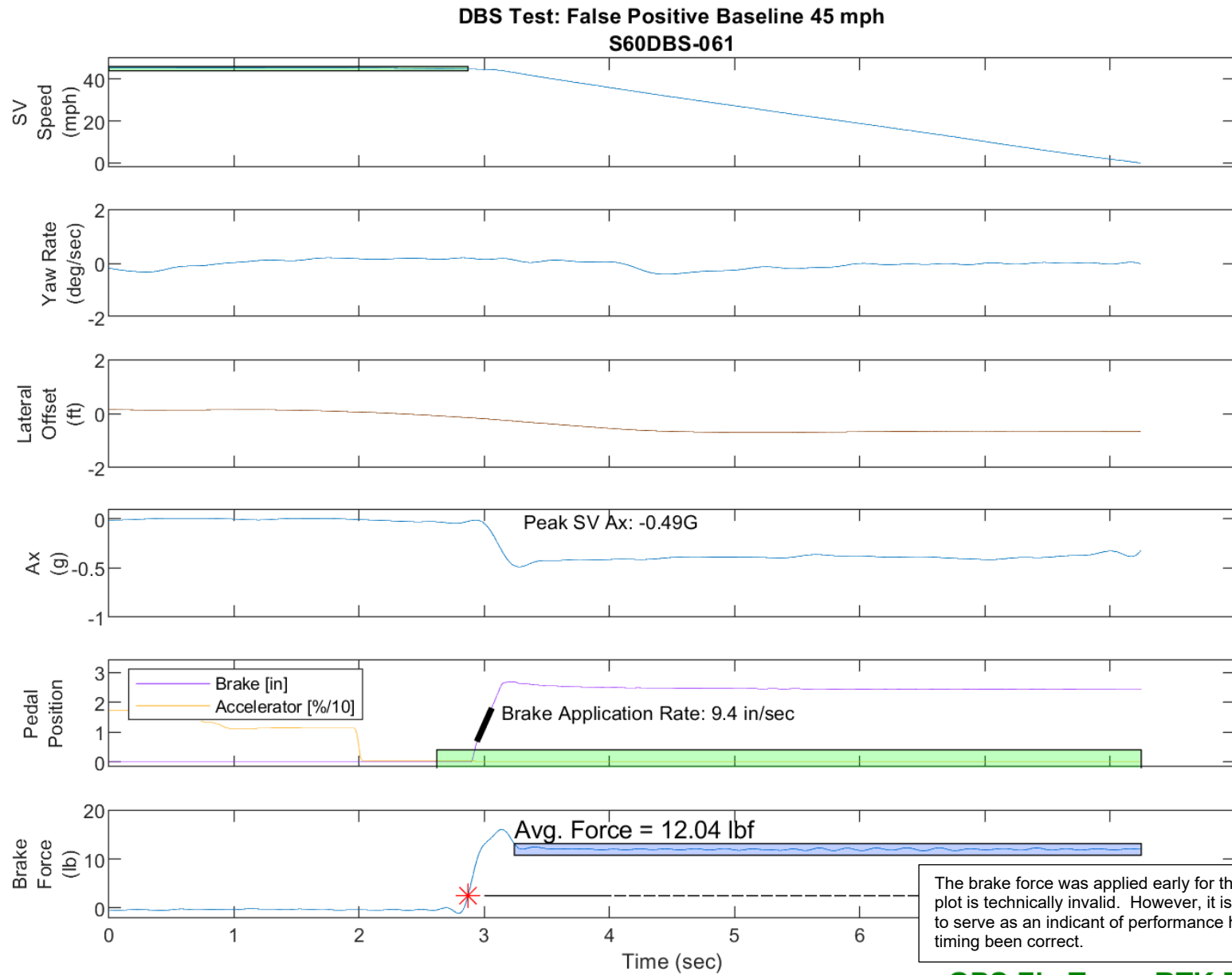


Figure E45. Time History for DBS Run 61, False Positive Baseline, SV 45 mph

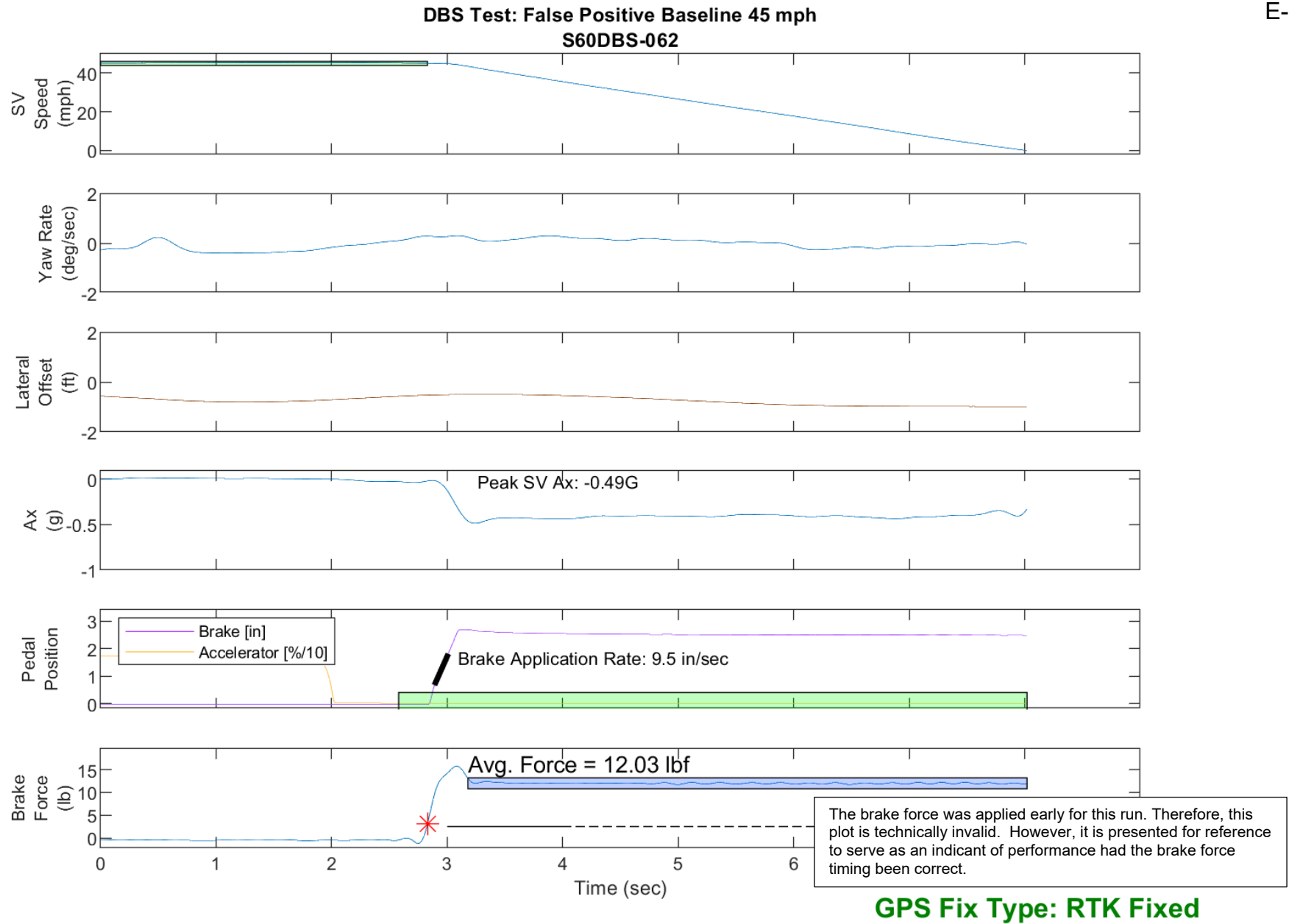
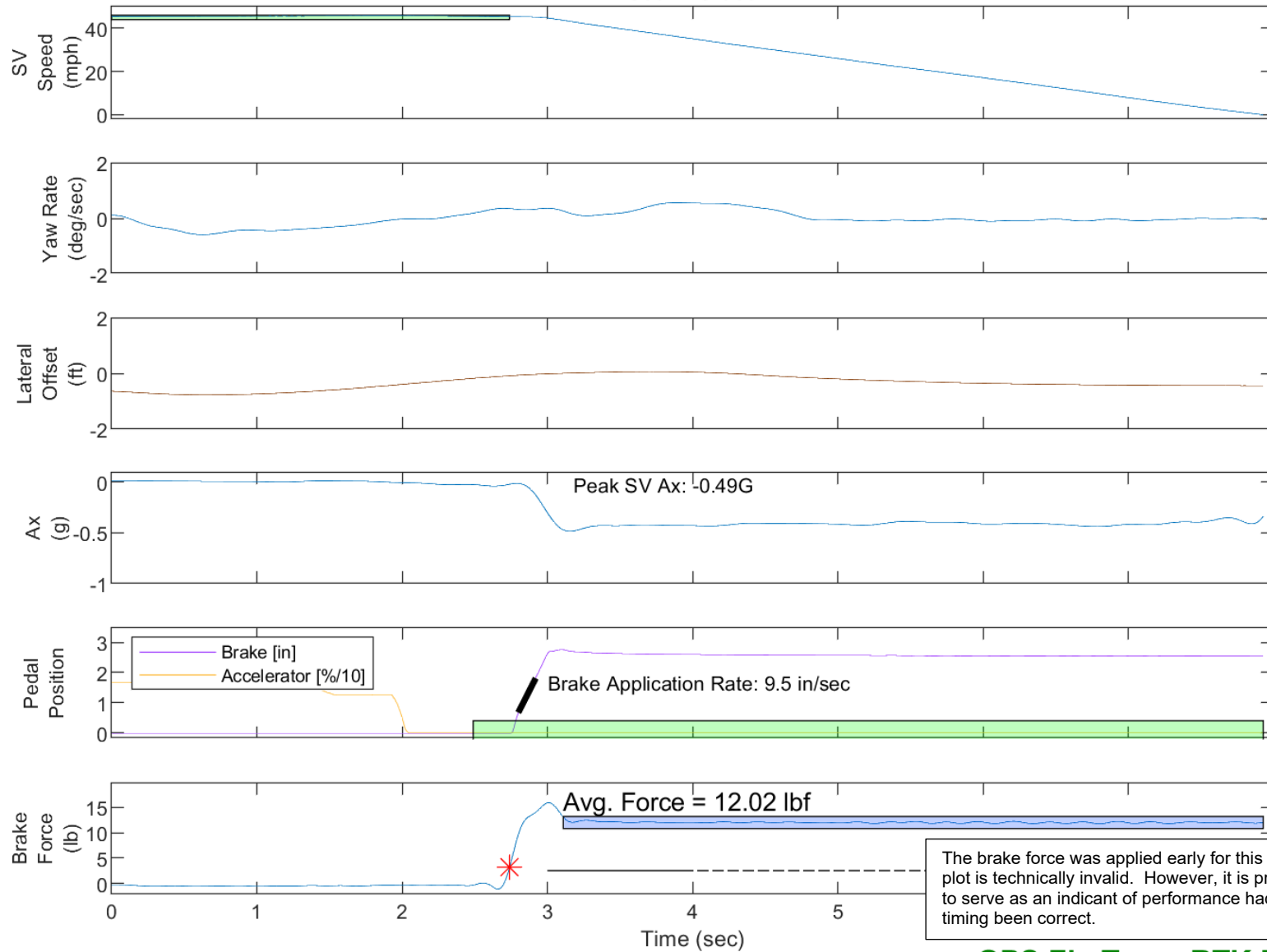


Figure E46. Time History for DBS Run 62, False Positive Baseline, SV 45 mph

DBS Test: False Positive Baseline 45 mph
S60DBS-063



GPS Fix Type: RTK Fixed

Figure E47. Time History for DBS Run 63, False Positive Baseline, SV 45 mph

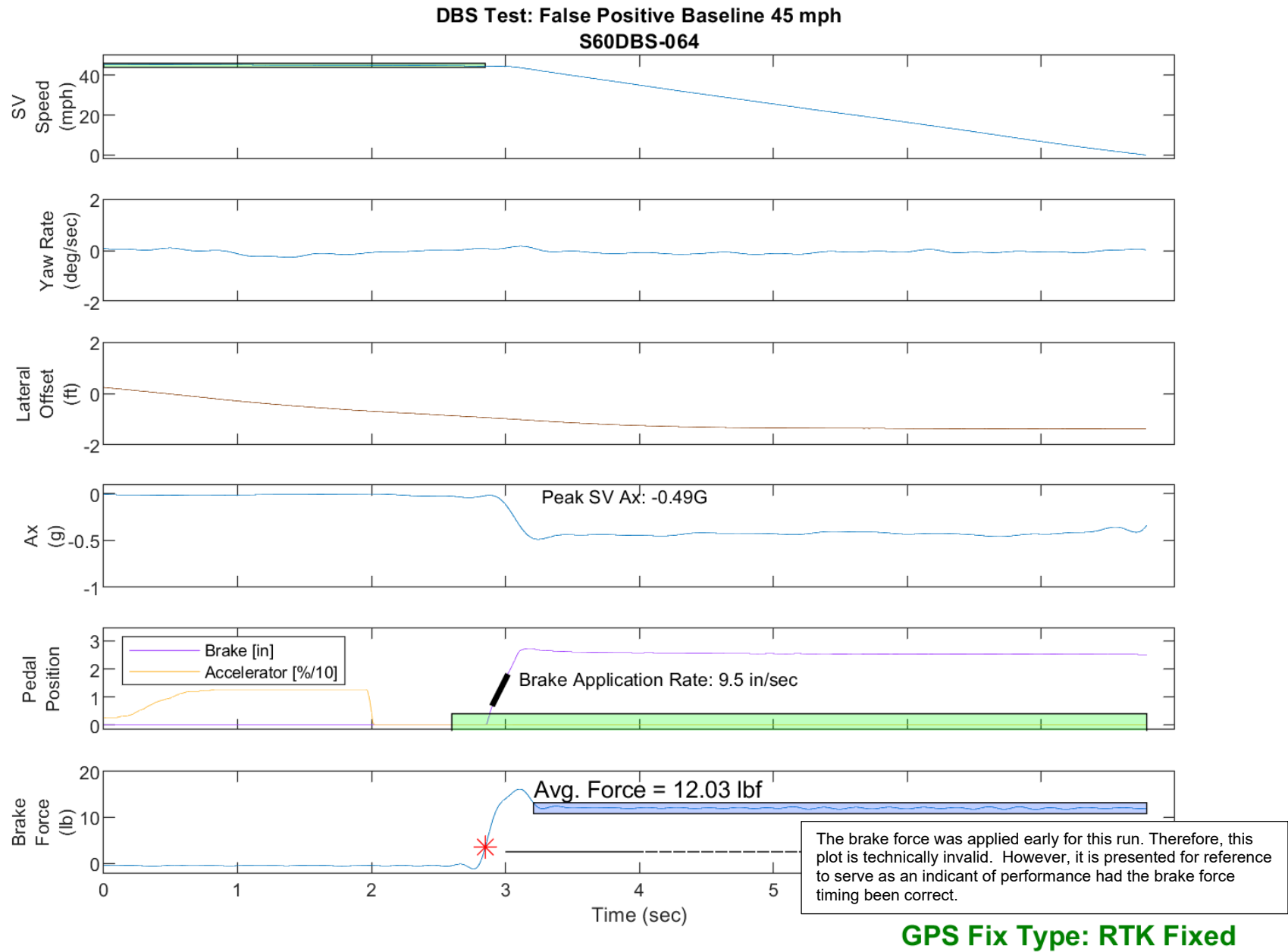


Figure E48. Time History for DBS Run 64, False Positive Baseline, SV 45 mph

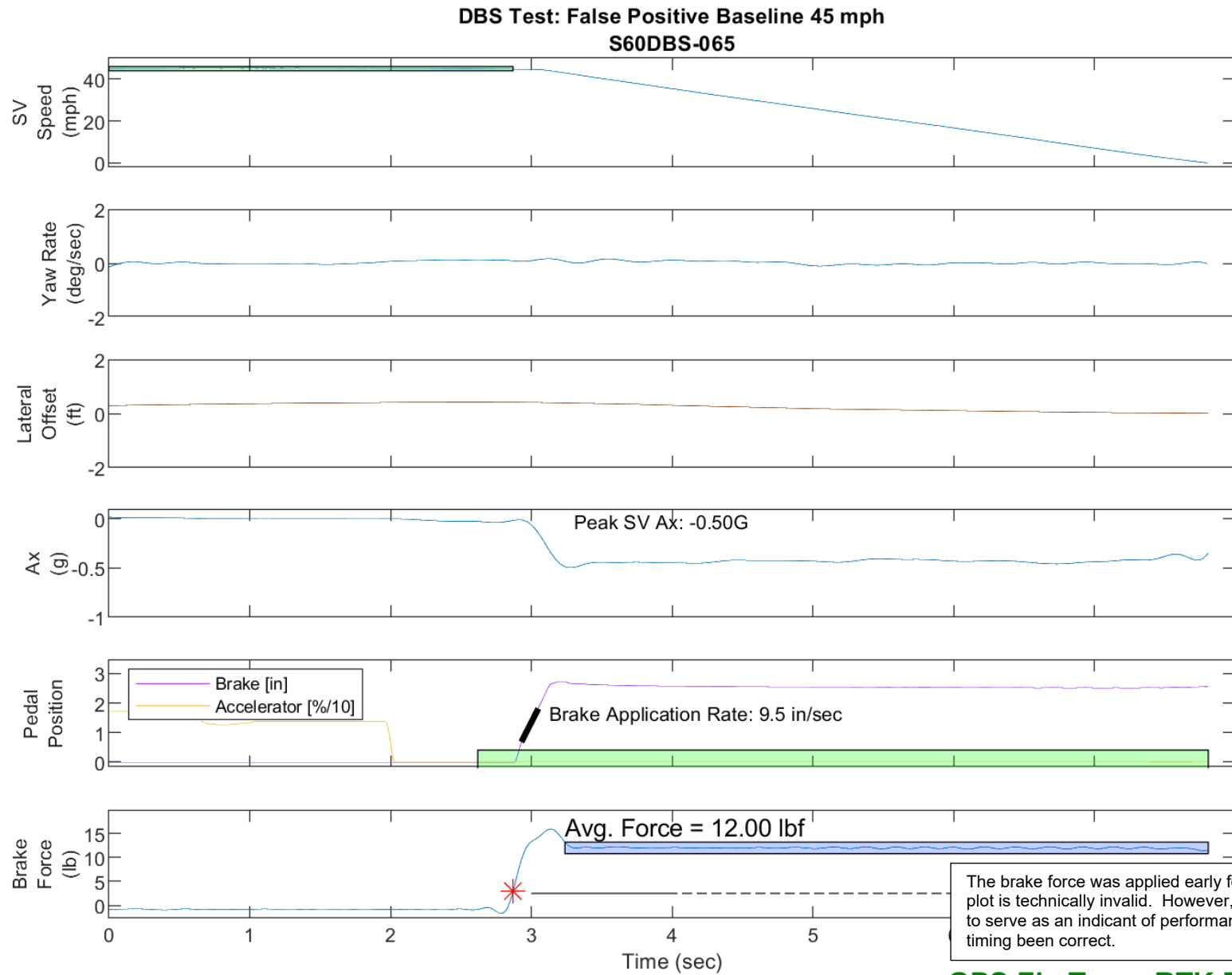


Figure E49. Time History for DBS Run 65, False Positive Baseline, SV 45 mph

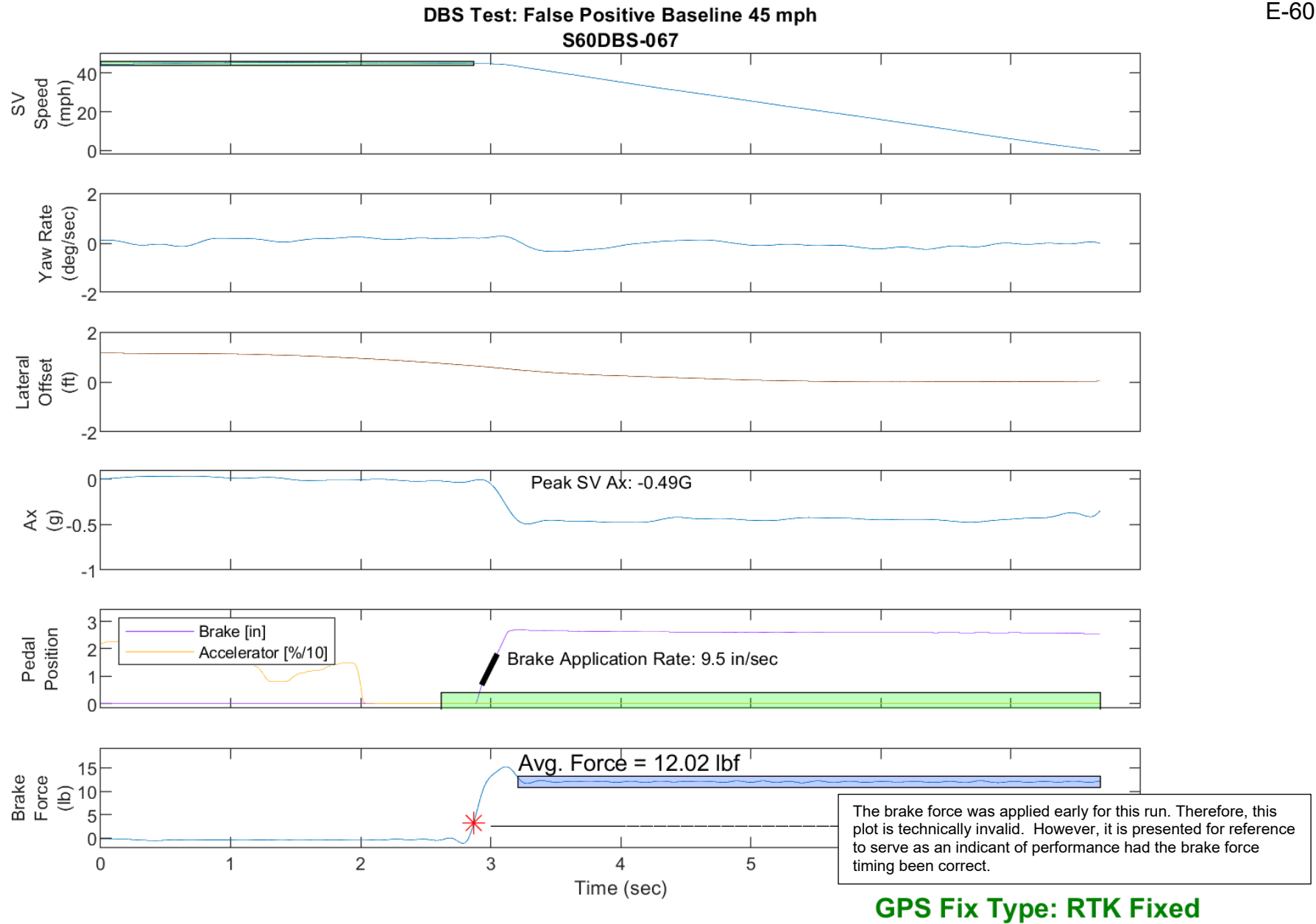


Figure E50. Time History for DBS Run 67, False Positive Baseline, SV 45 mph

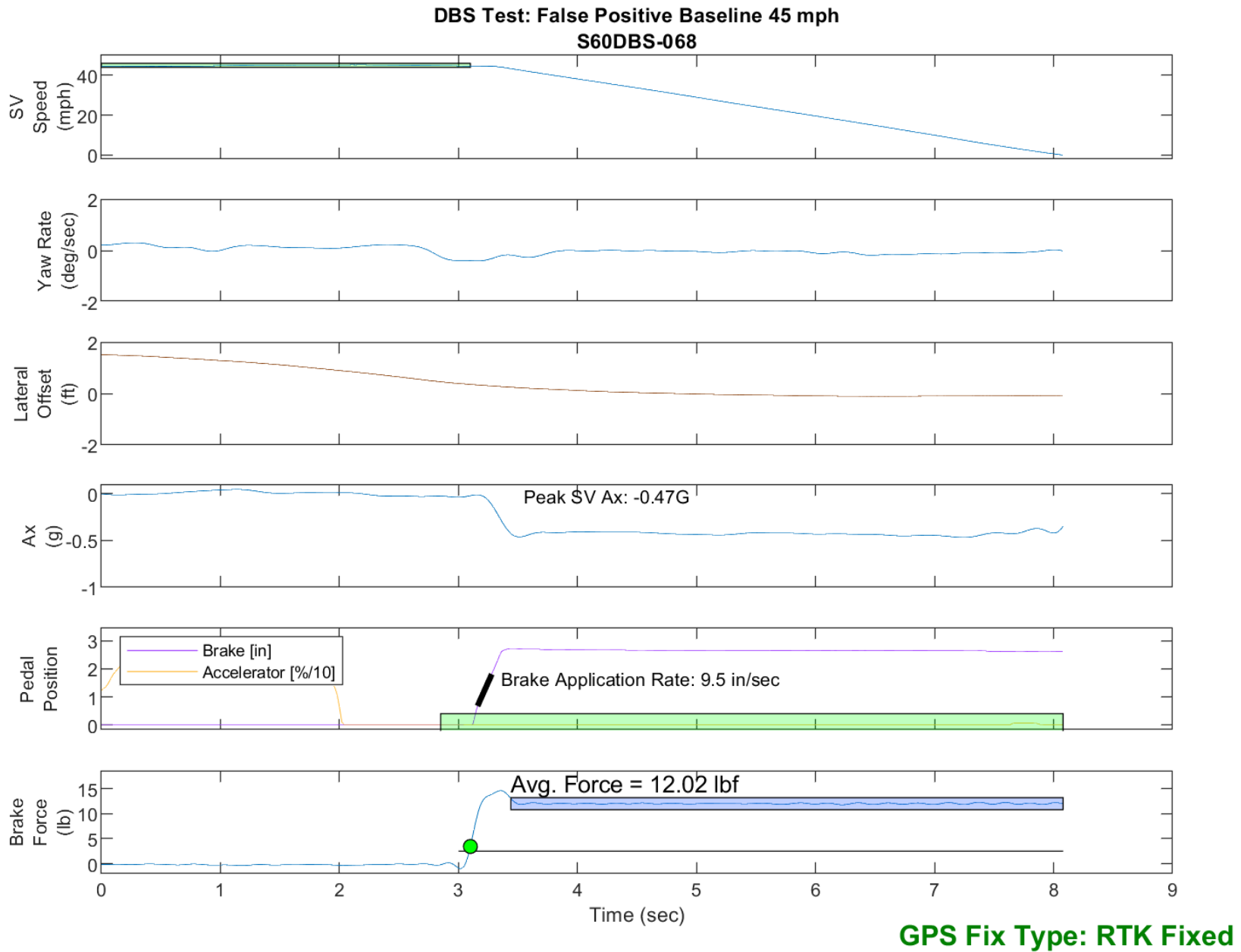


Figure E51. Time History for DBS Run 68, False Positive Baseline, SV 45 mph

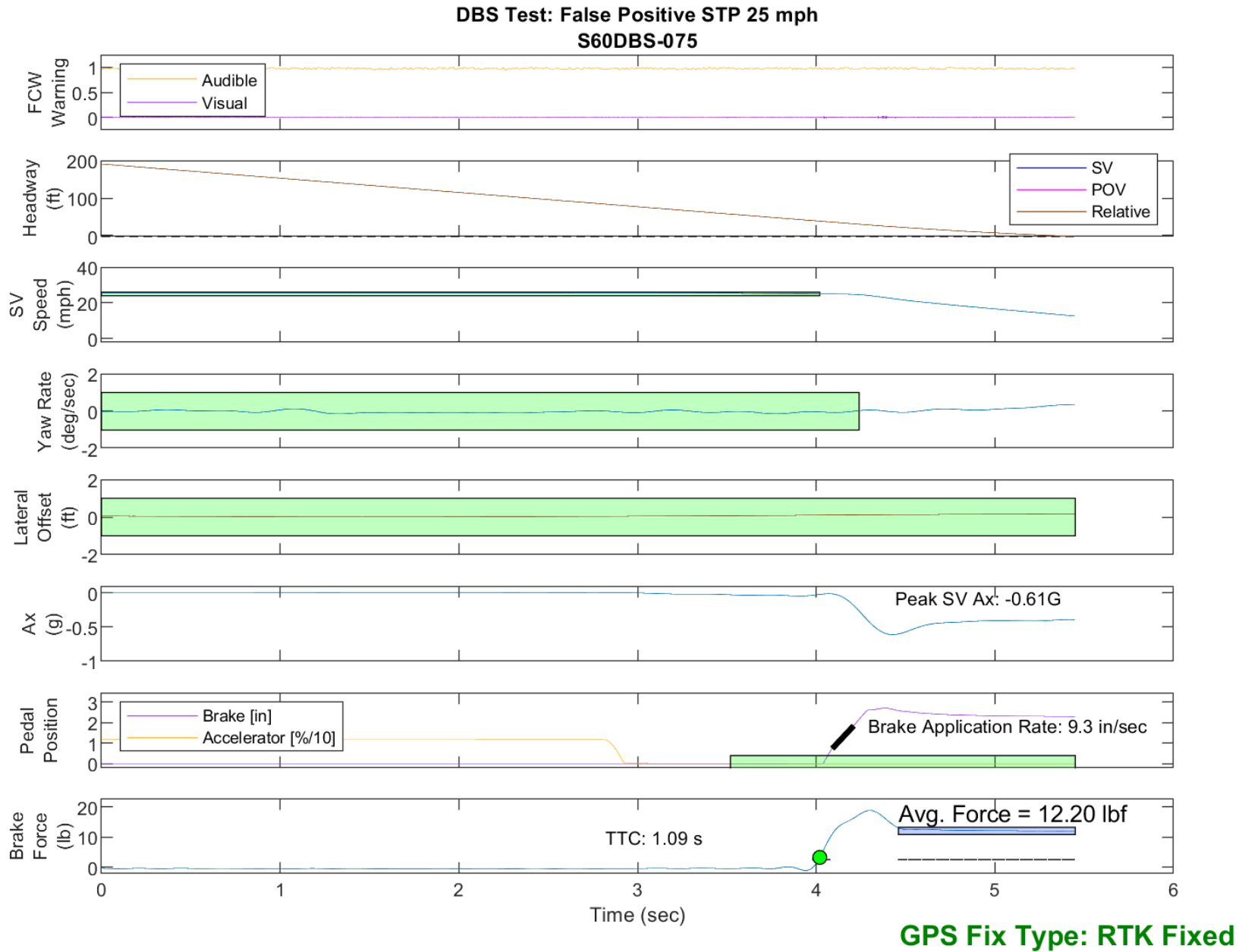


Figure E52. Time History for DBS Run 75, SV Encounters Steel Trench Plate, SV 25 mph

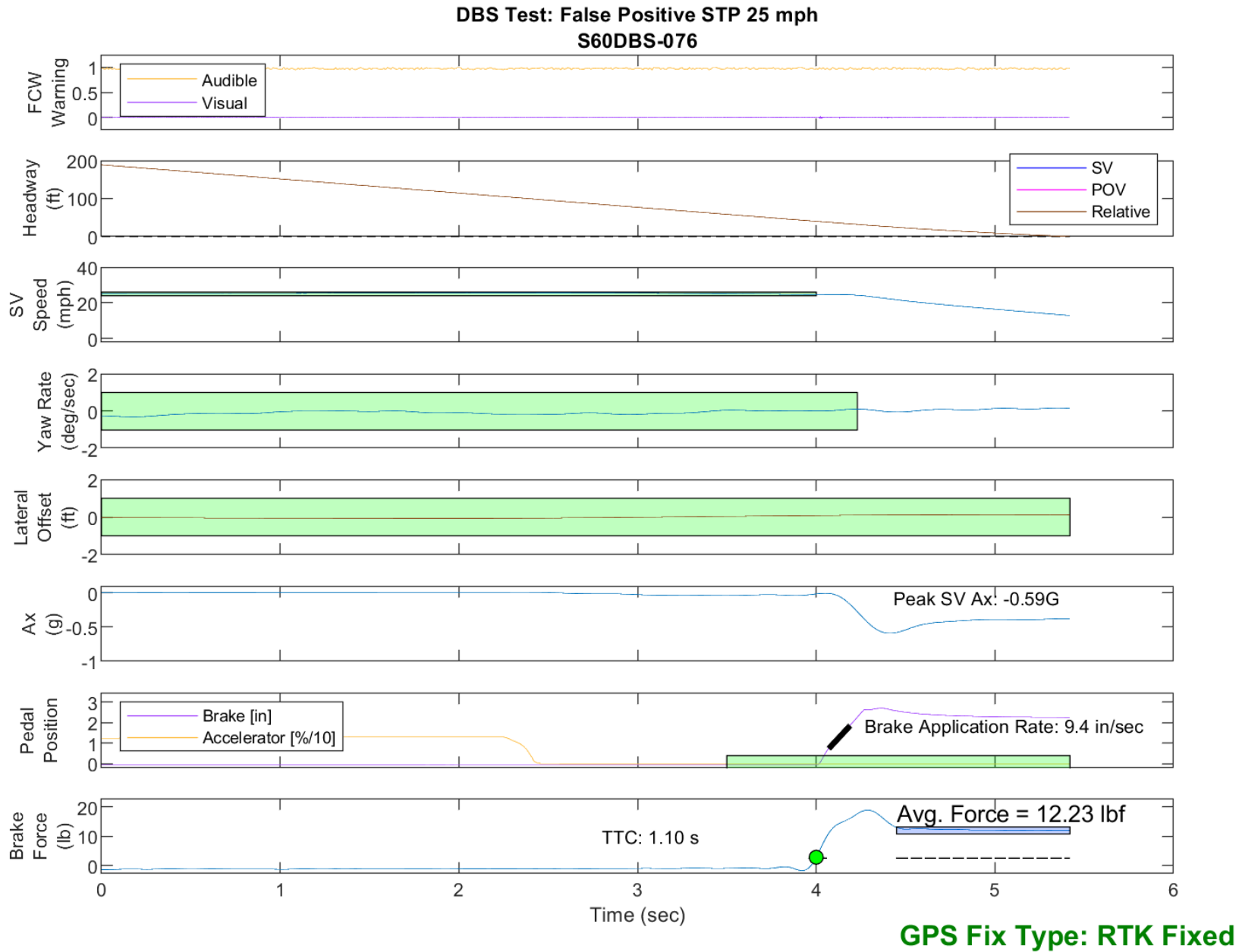


Figure E53. Time History for DBS Run 76, SV Encounters Steel Trench Plate, SV 25 mph

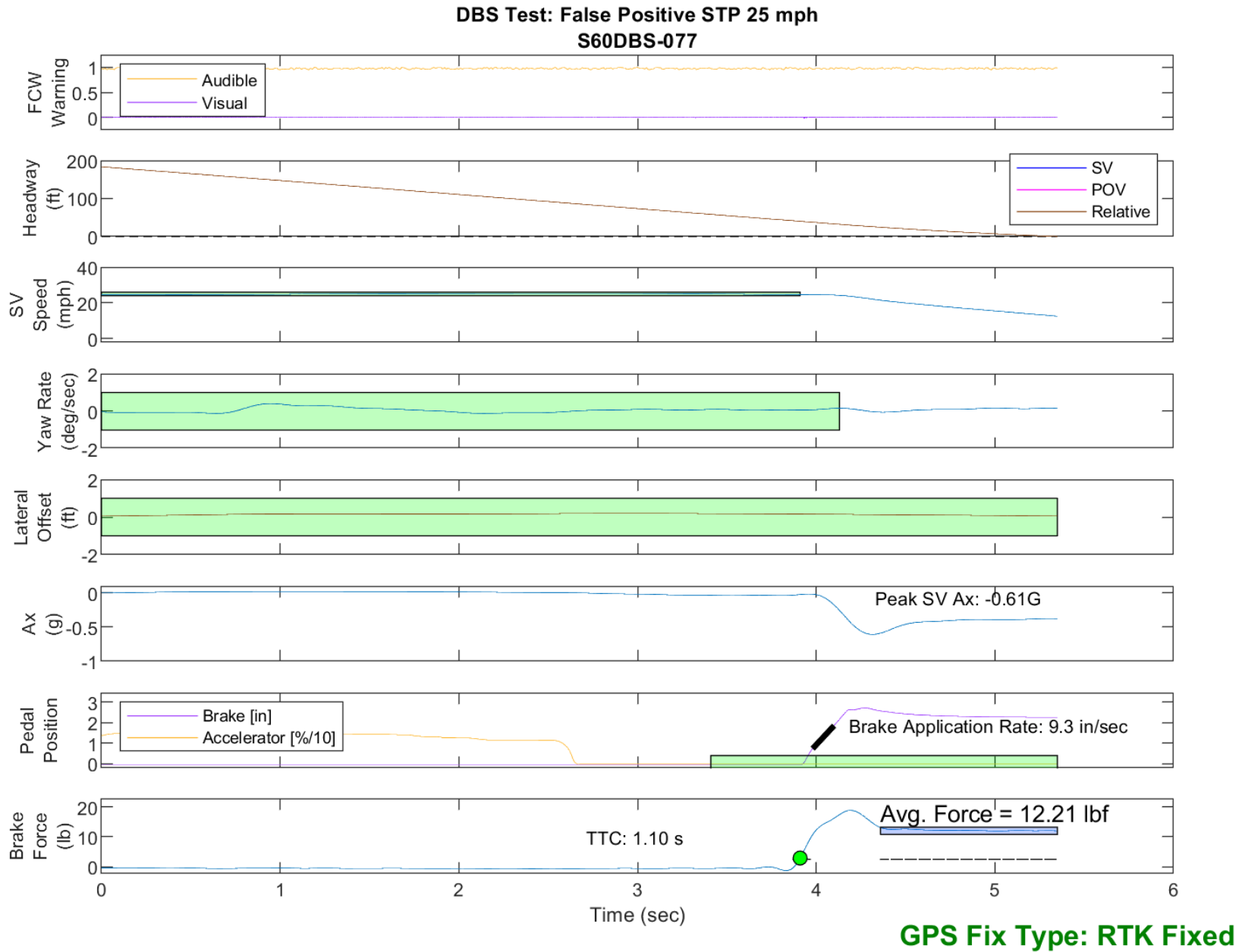


Figure E54. Time History for DBS Run 77, SV Encounters Steel Trench Plate, SV 25 mph

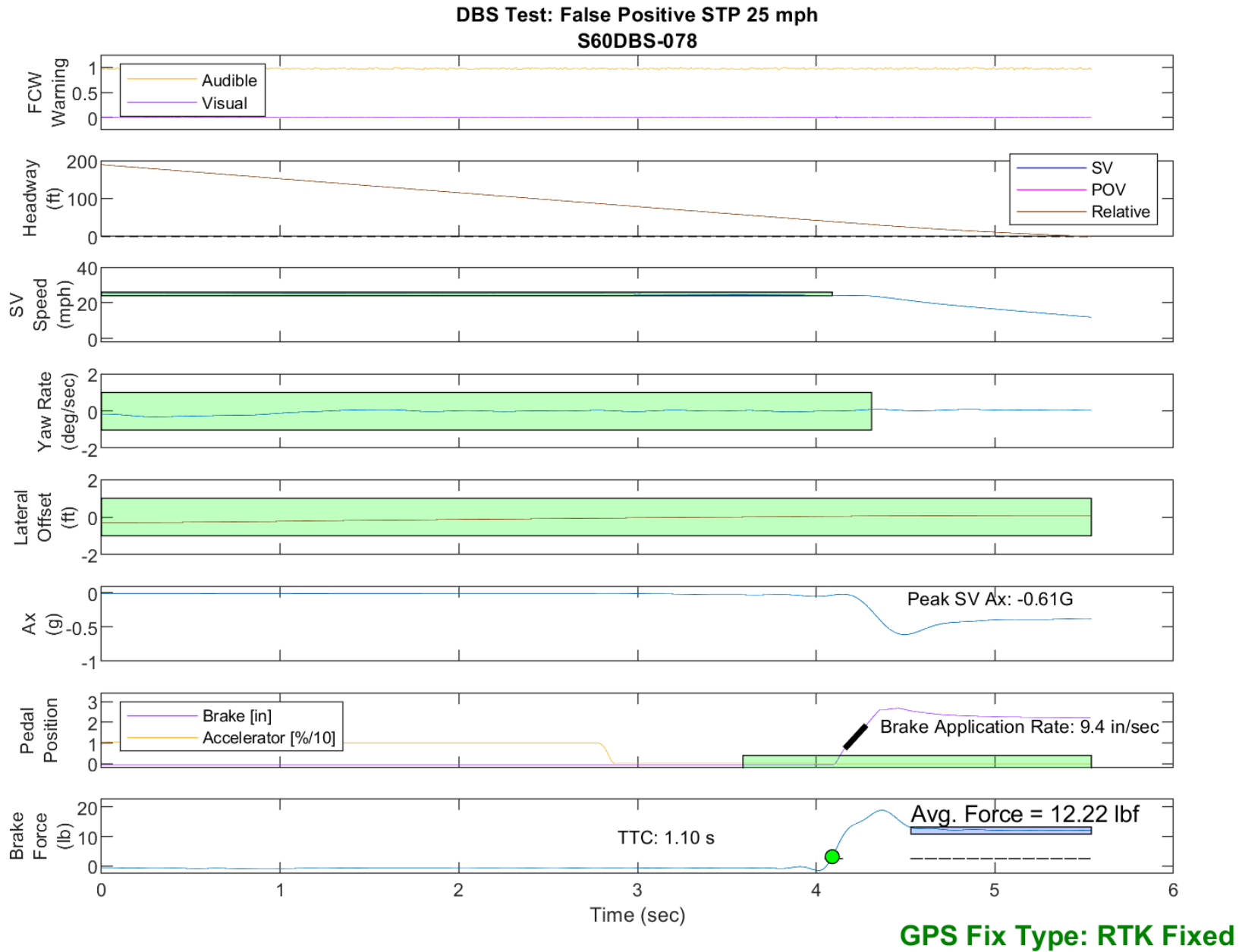


Figure E55. Time History for DBS Run 78, SV Encounters Steel Trench Plate, SV 25 mph

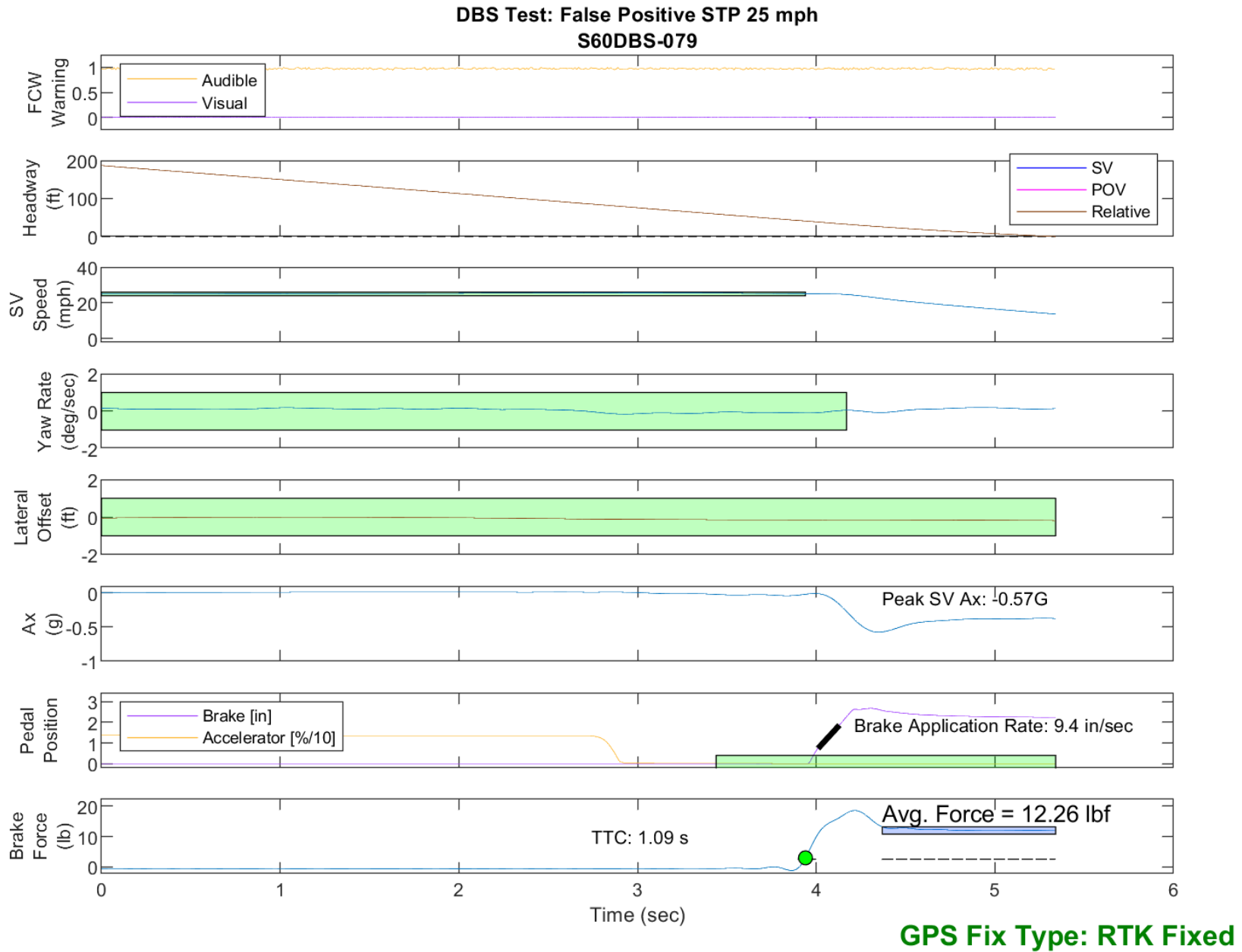


Figure E56. Time History for DBS Run 79, SV Encounters Steel Trench Plate, SV 25 mph

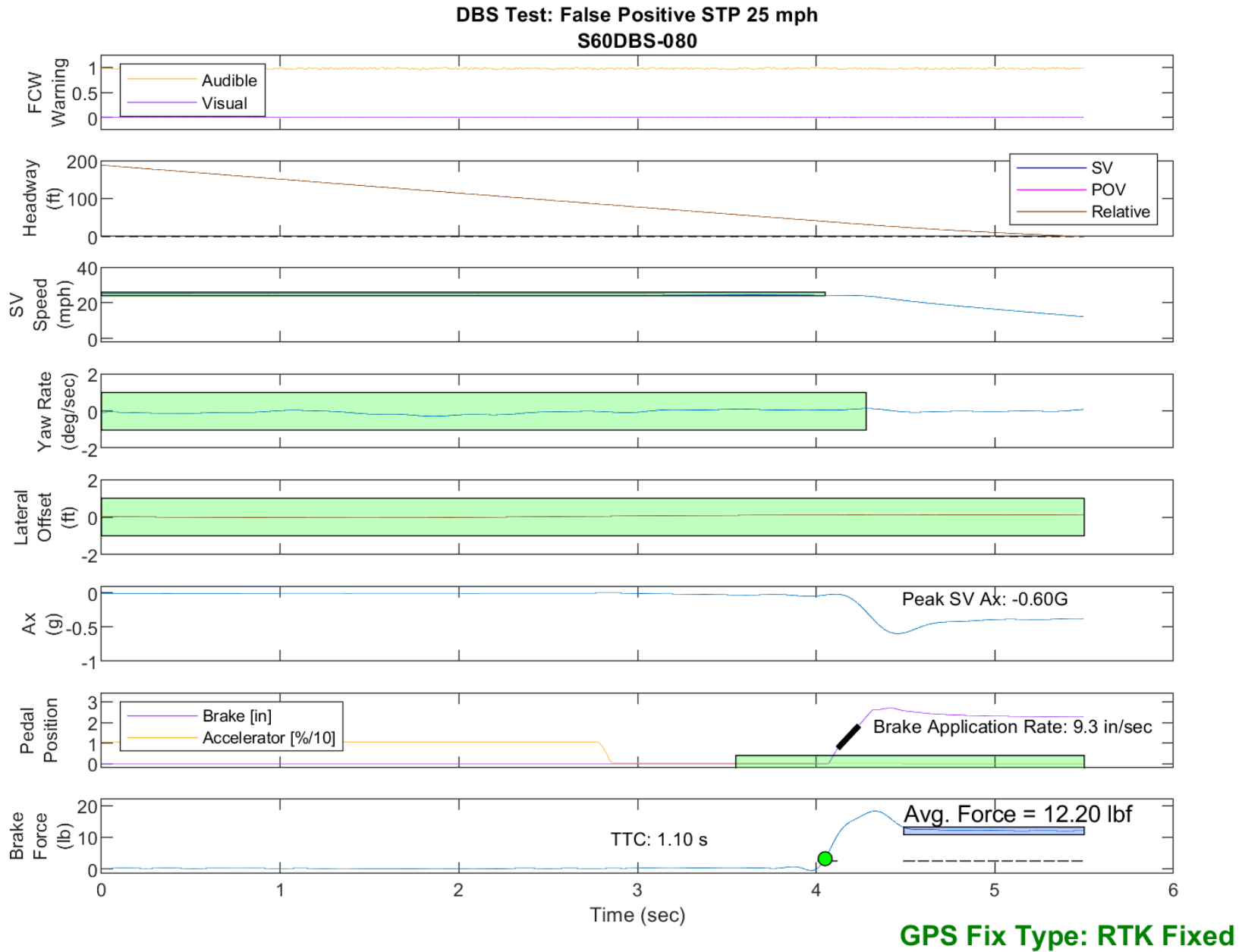


Figure E57. Time History for DBS Run 80, SV Encounters Steel Trench Plate, SV 25 mph

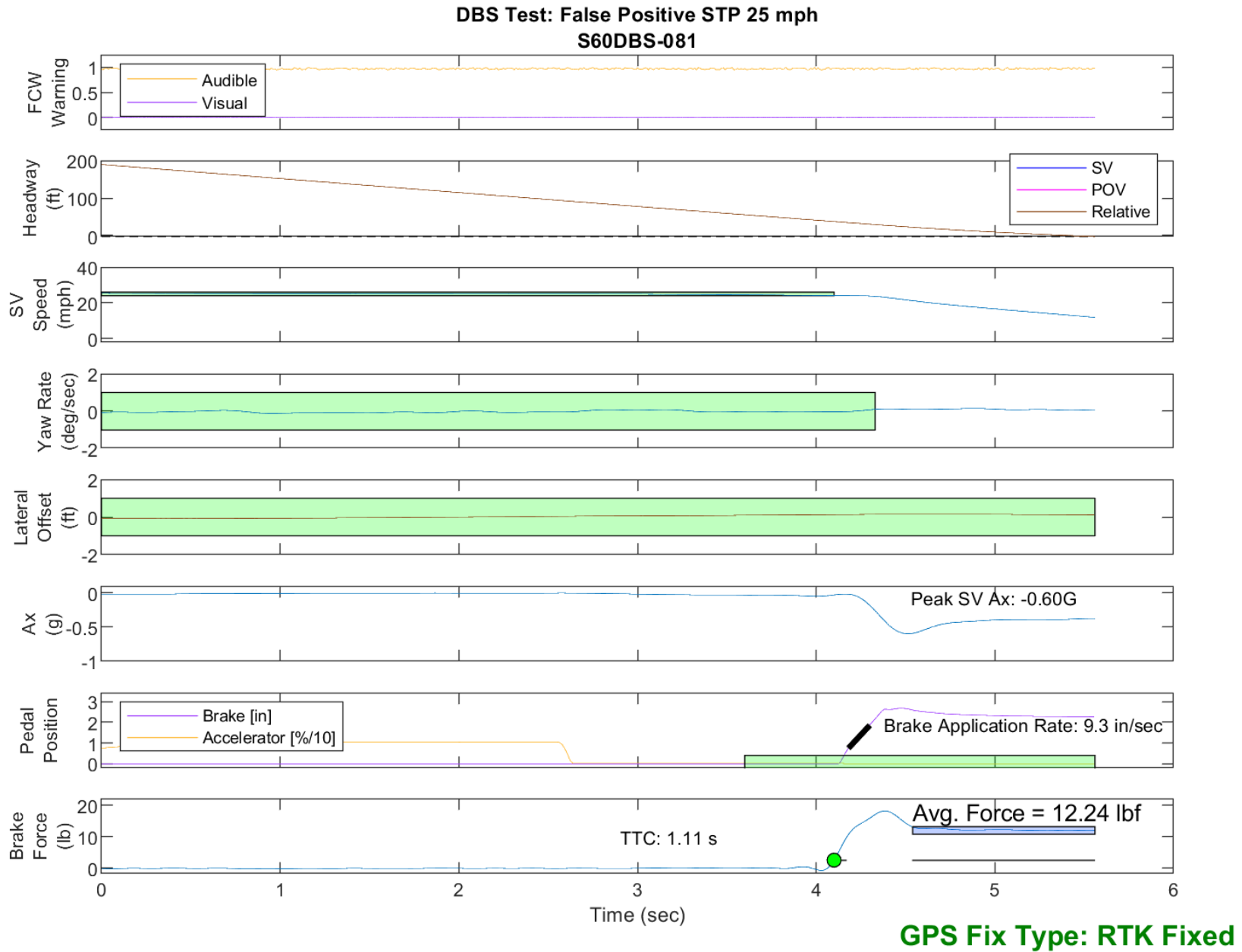


Figure E58. Time History for DBS Run 81, SV Encounters Steel Trench Plate, SV 25 mph

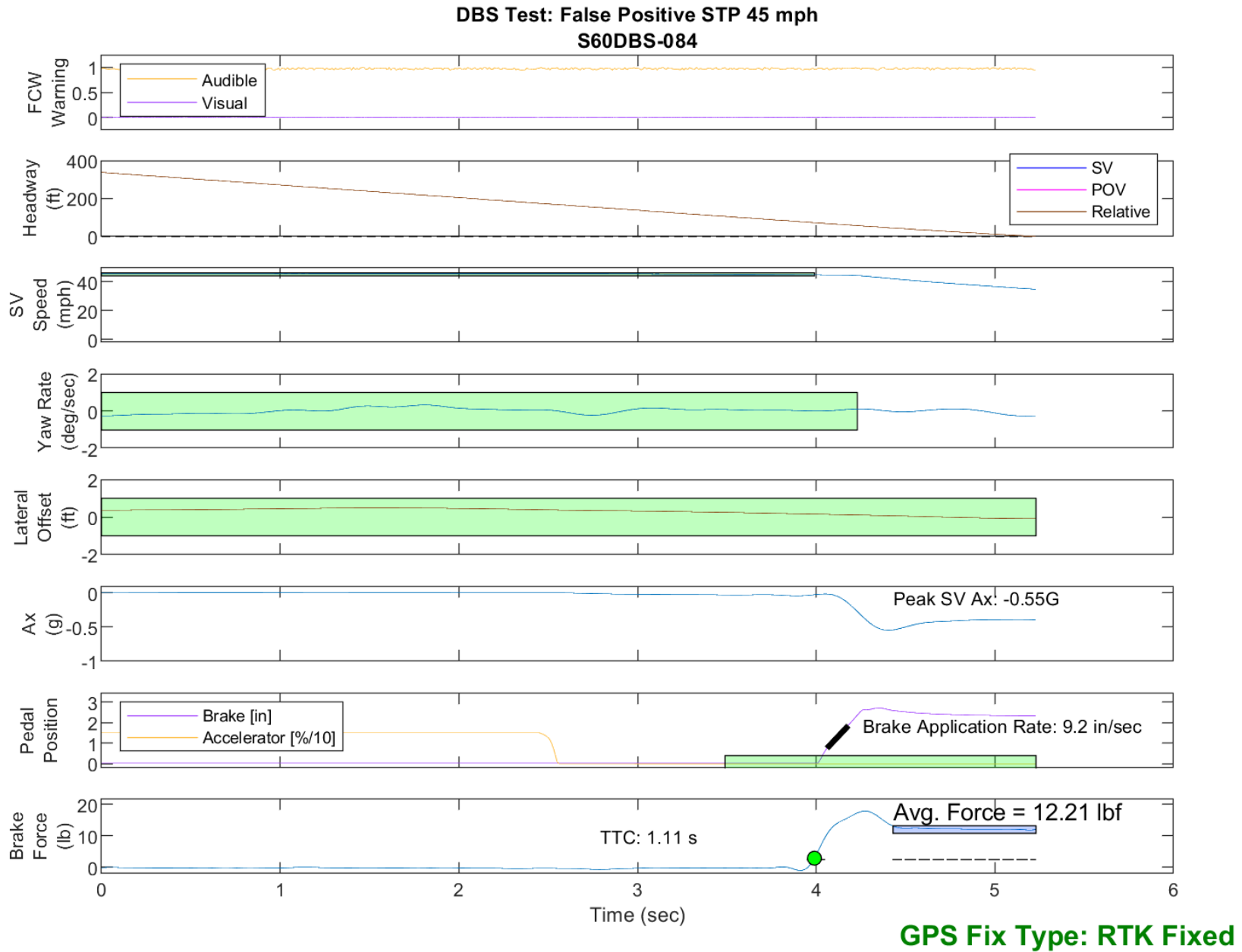


Figure E59. Time History for DBS Run 84, SV Encounters Steel Trench Plate, SV 45 mph

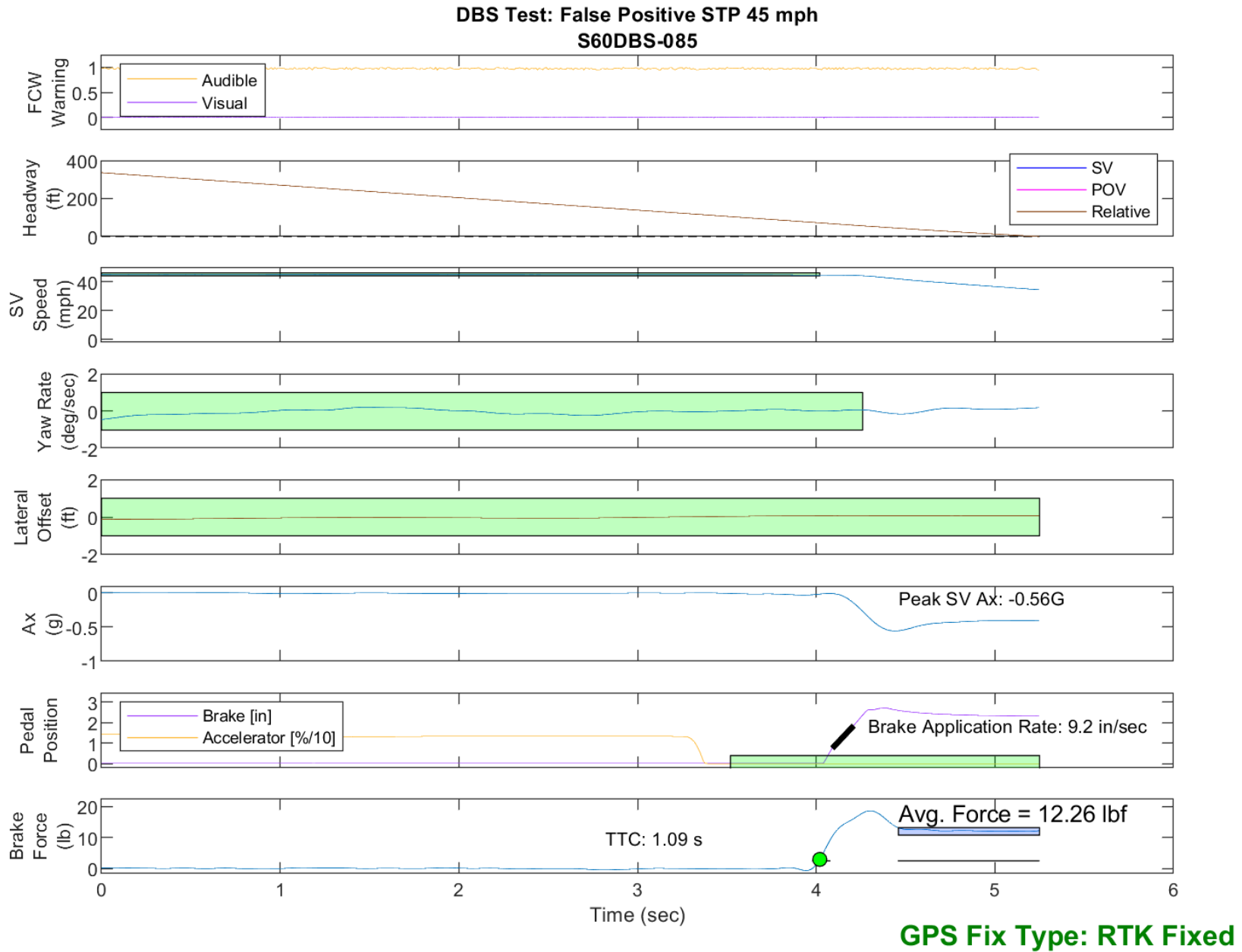


Figure E60. Time History for DBS Run 85, SV Encounters Steel Trench Plate, SV 45 mph

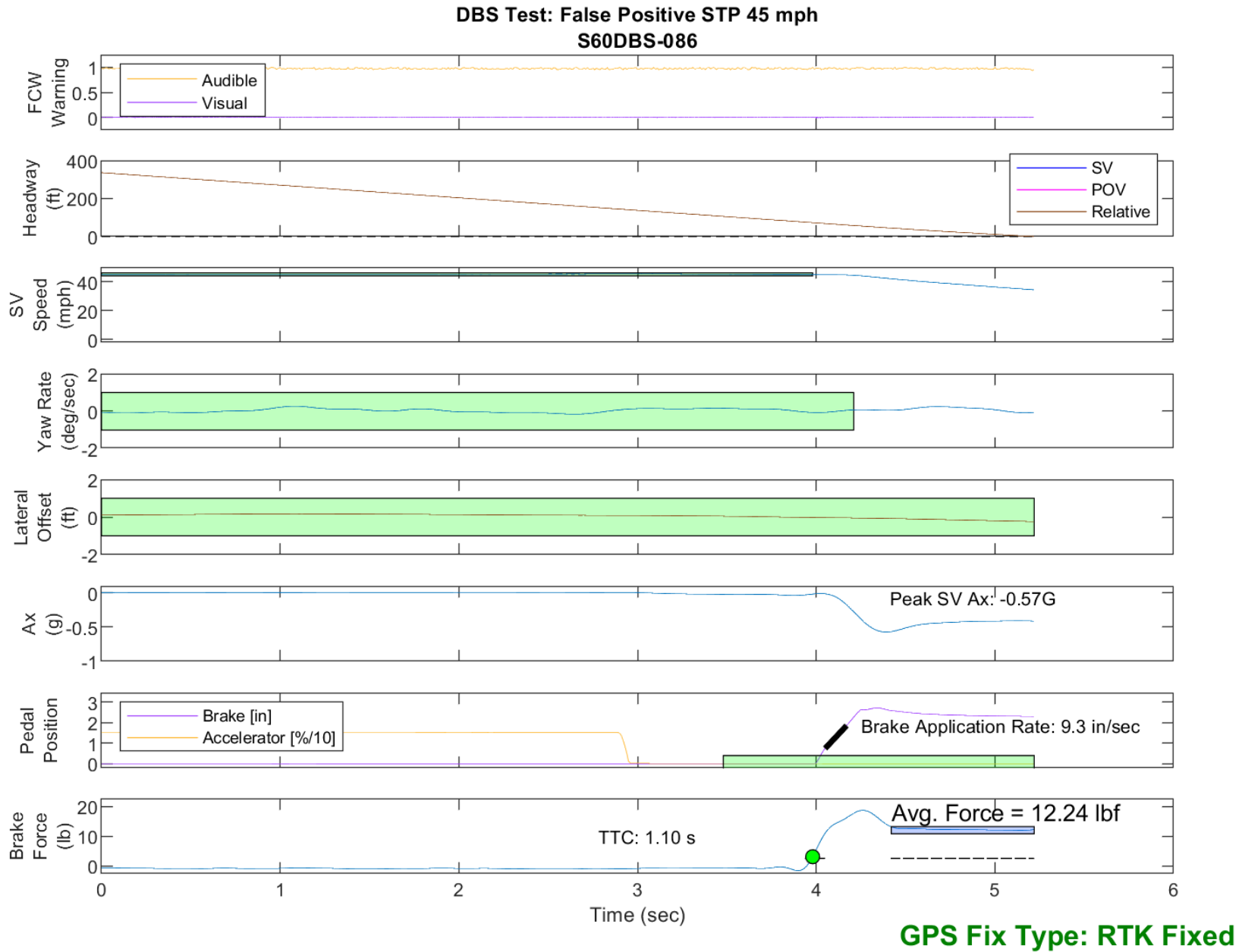


Figure E61. Time History for DBS Run 86, SV Encounters Steel Trench Plate, SV 45 mph

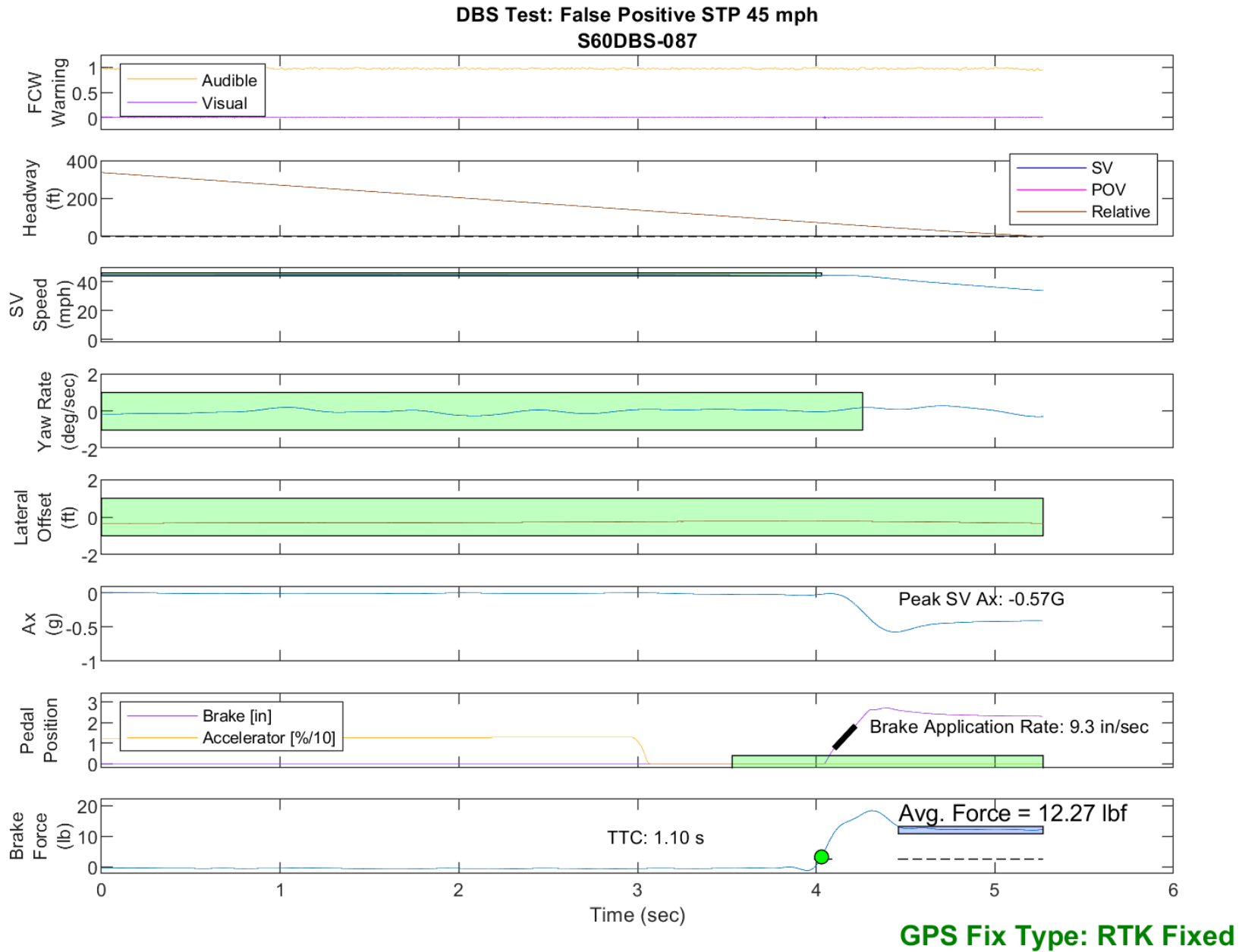


Figure E62. Time History for DBS Run 87, SV Encounters Steel Trench Plate, SV 45 mph

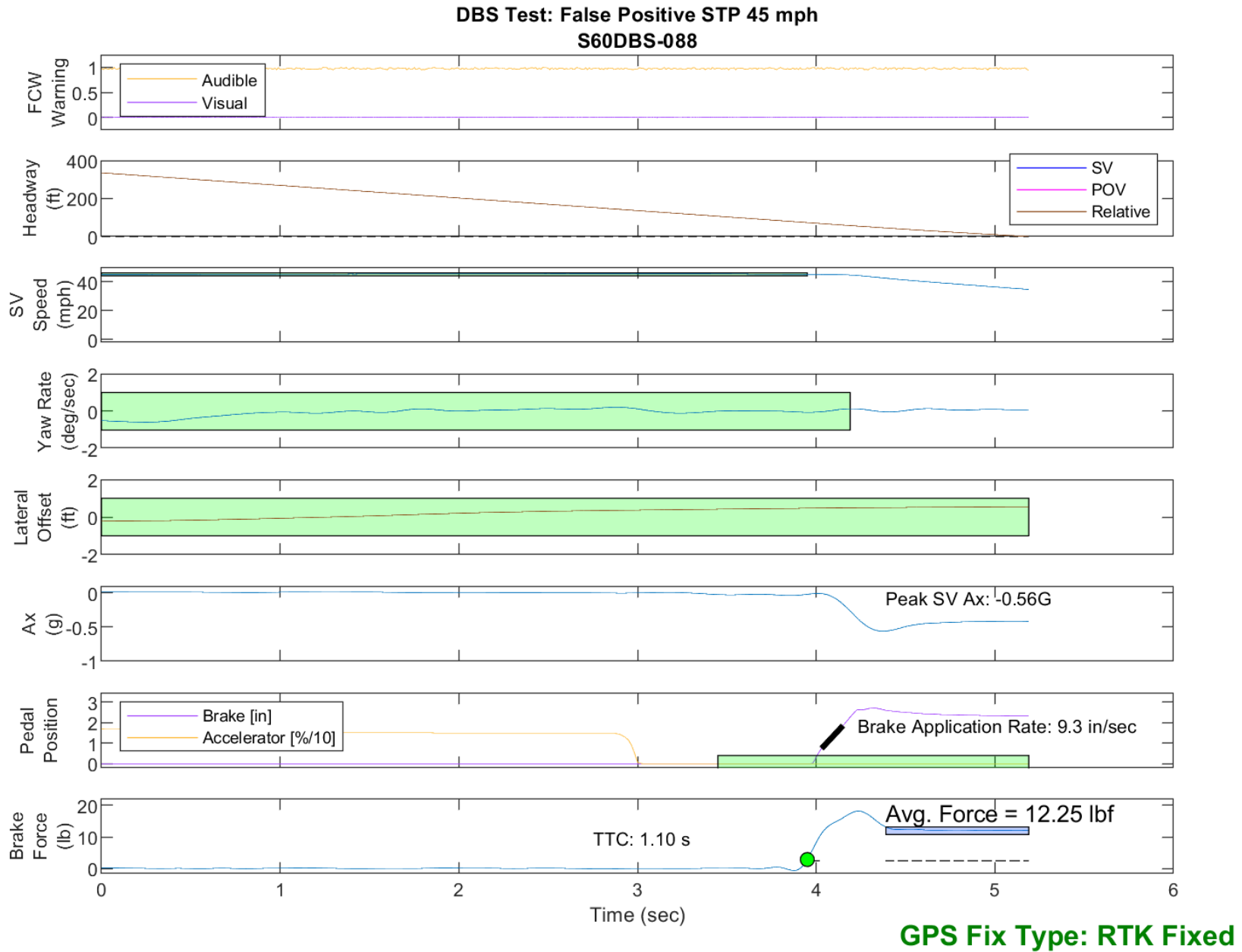


Figure E63. Time History for DBS Run 88, SV Encounters Steel Trench Plate, SV 45 mph

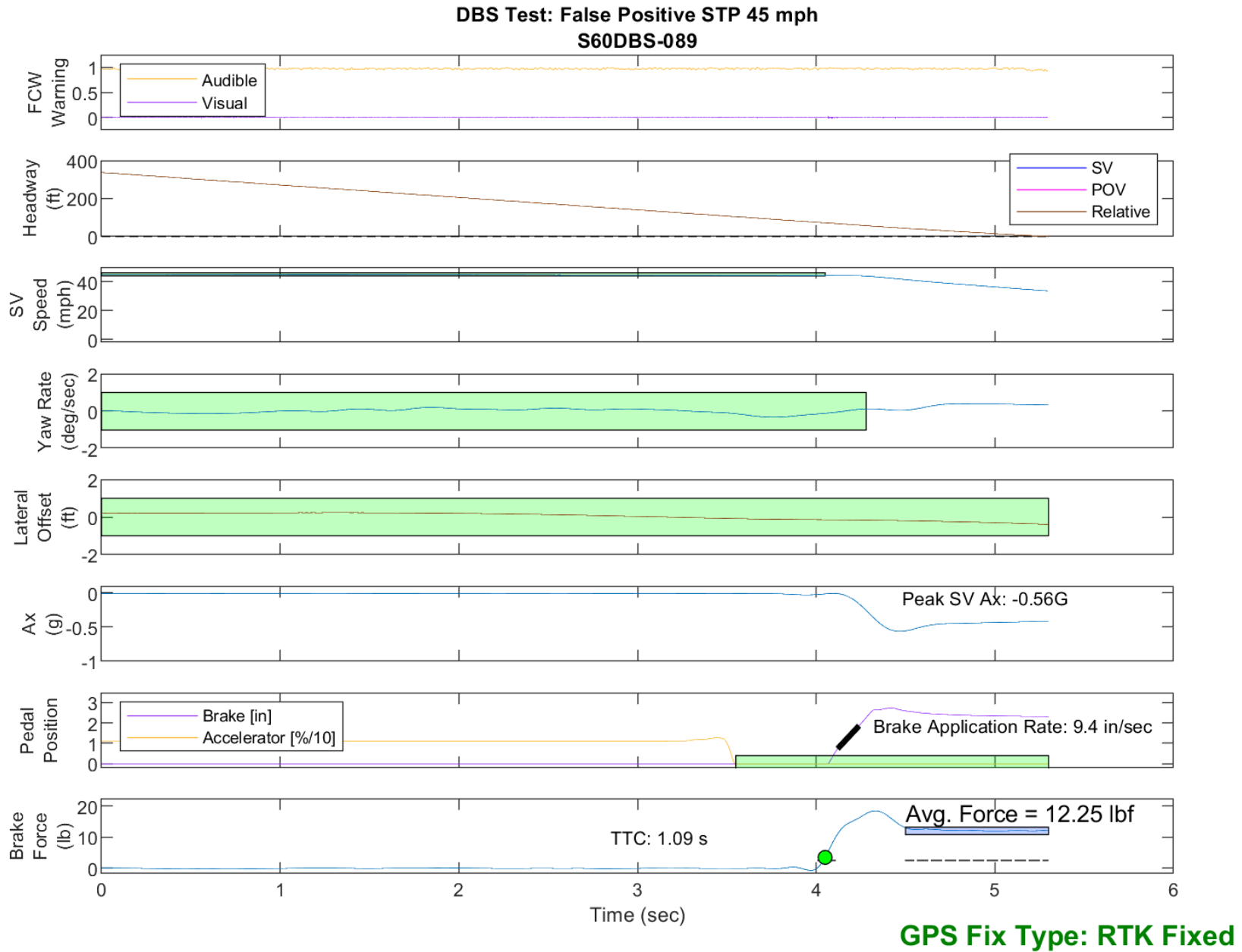


Figure E64. Time History for DBS Run 89, SV Encounters Steel Trench Plate, SV 45 mph

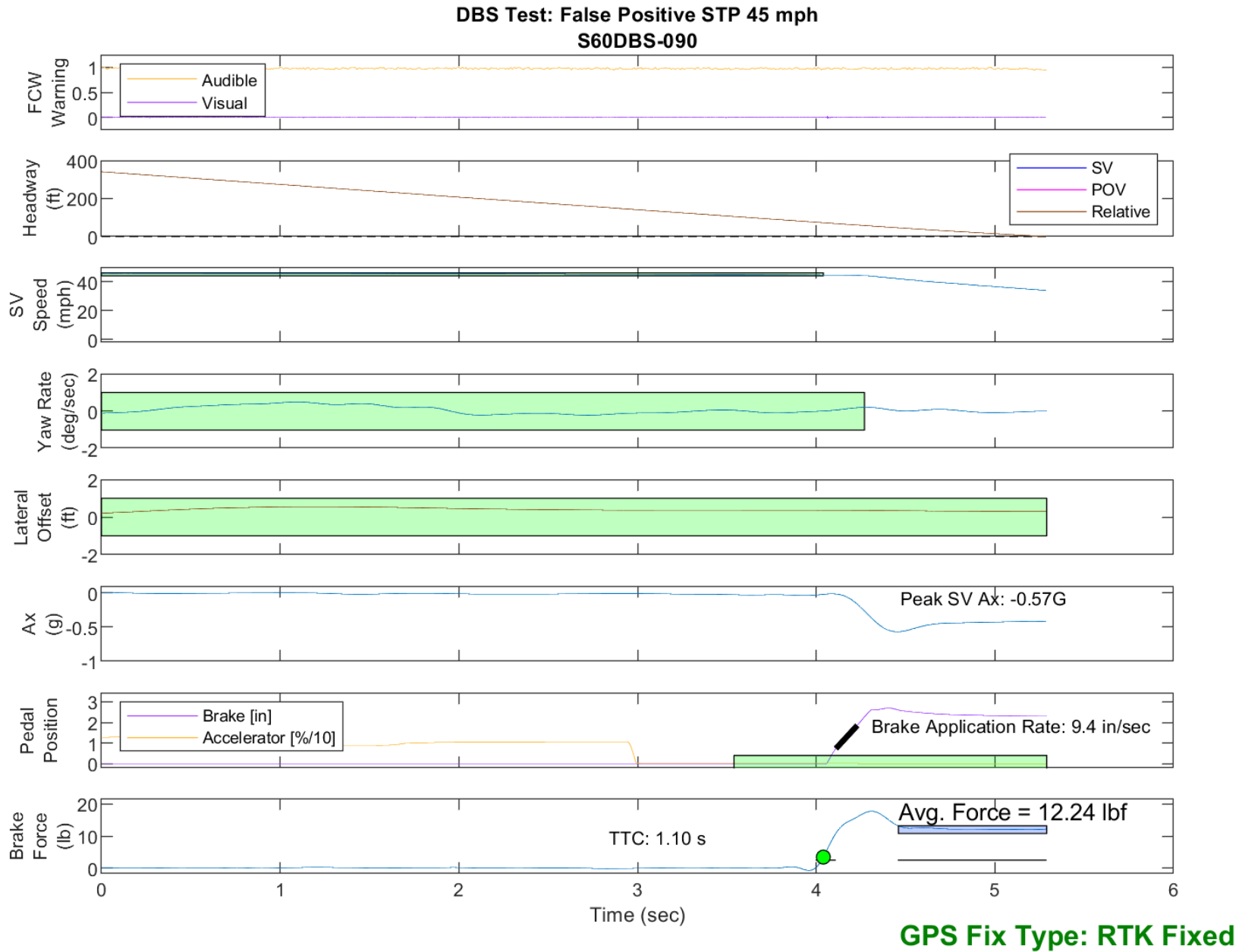


Figure E65. Time History for DBS Run 90, SV Encounters Steel Trench Plate, SV 45 mph

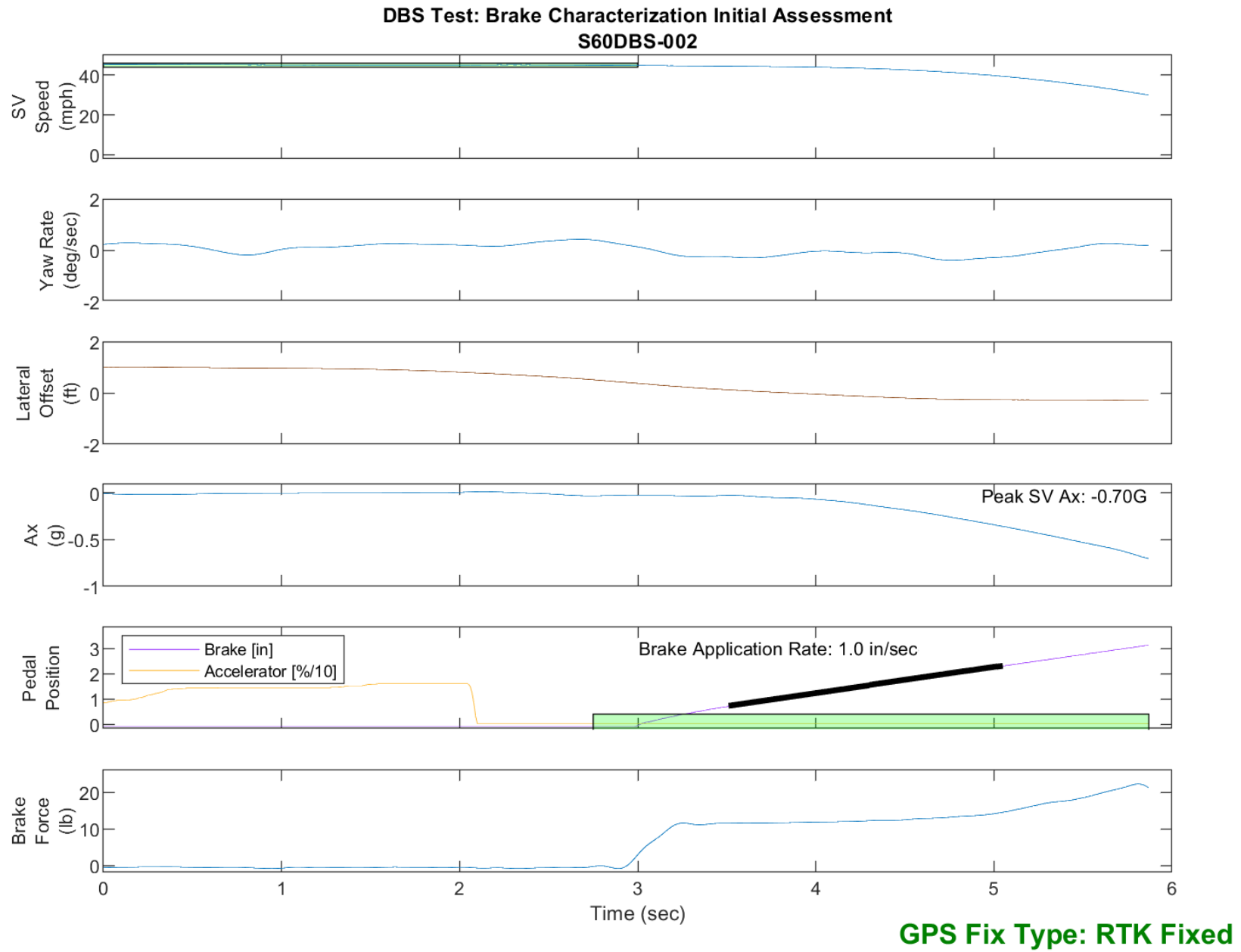
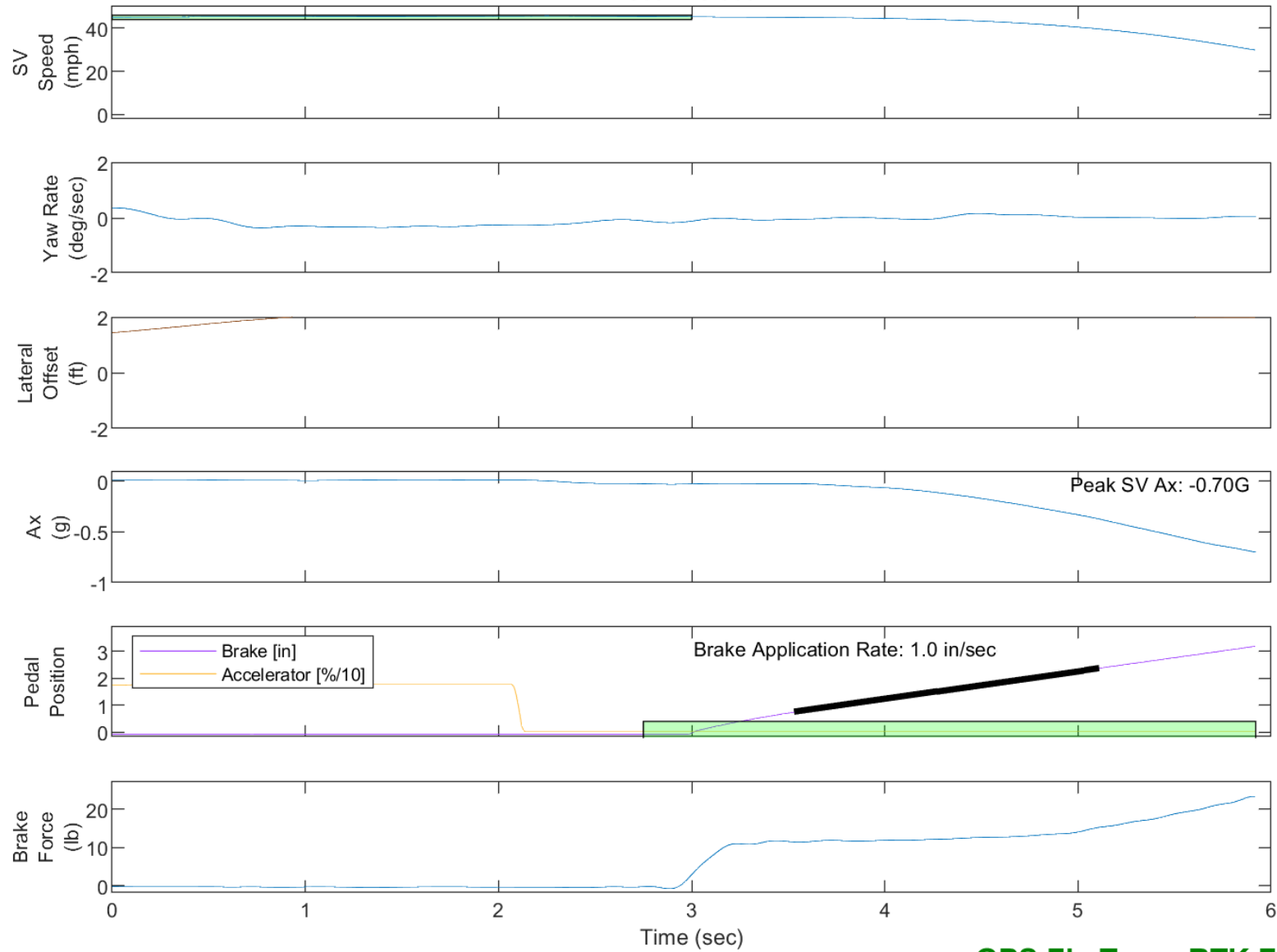


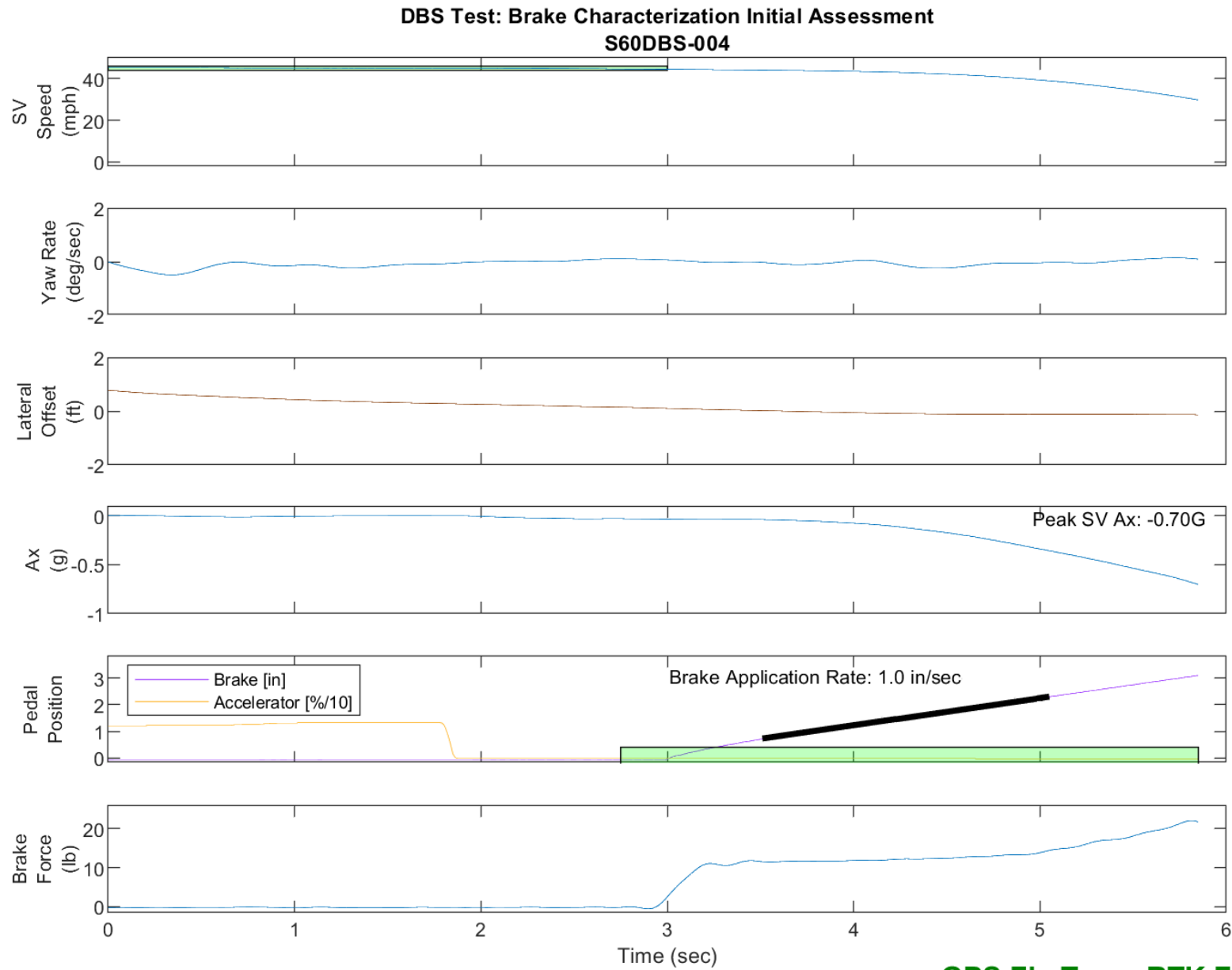
Figure E66. Time History for DBS Run 2, Brake Characterization Initial

DBS Test: Brake Characterization Initial Assessment S60DBS-003



GPS Fix Type: RTK Fixed

Figure E67. Time History for DBS Run 3, Brake Characterization Initial



GPS Fix Type: RTK Fixed

Figure E68. Time History for DBS Run 4, Brake Characterization Initial

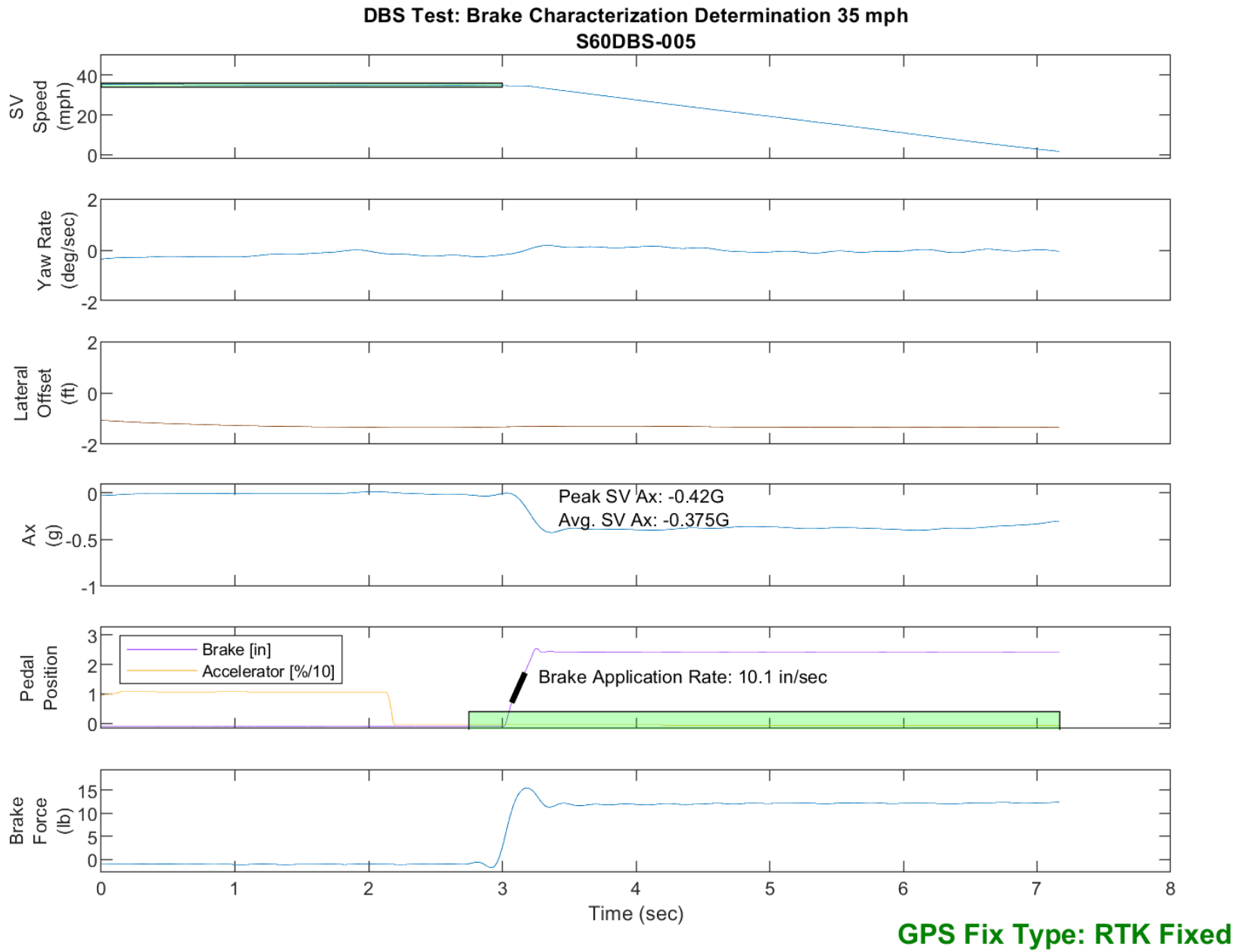


Figure E69. Time History for DBS Run 5, Brake Characterization Determination 35 mph

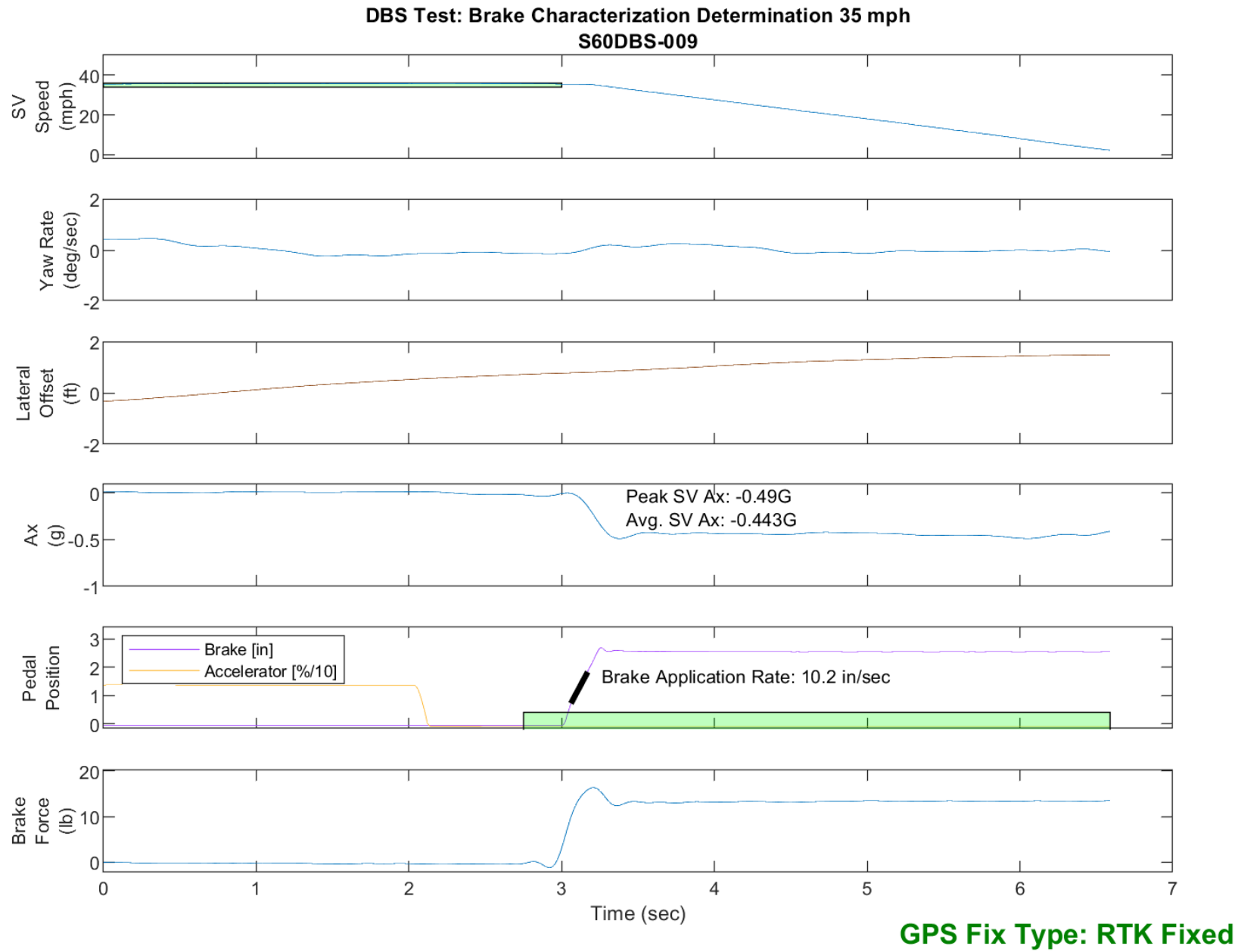


Figure E70. Time History for DBS Run 9, Brake Characterization Determination 35 mph

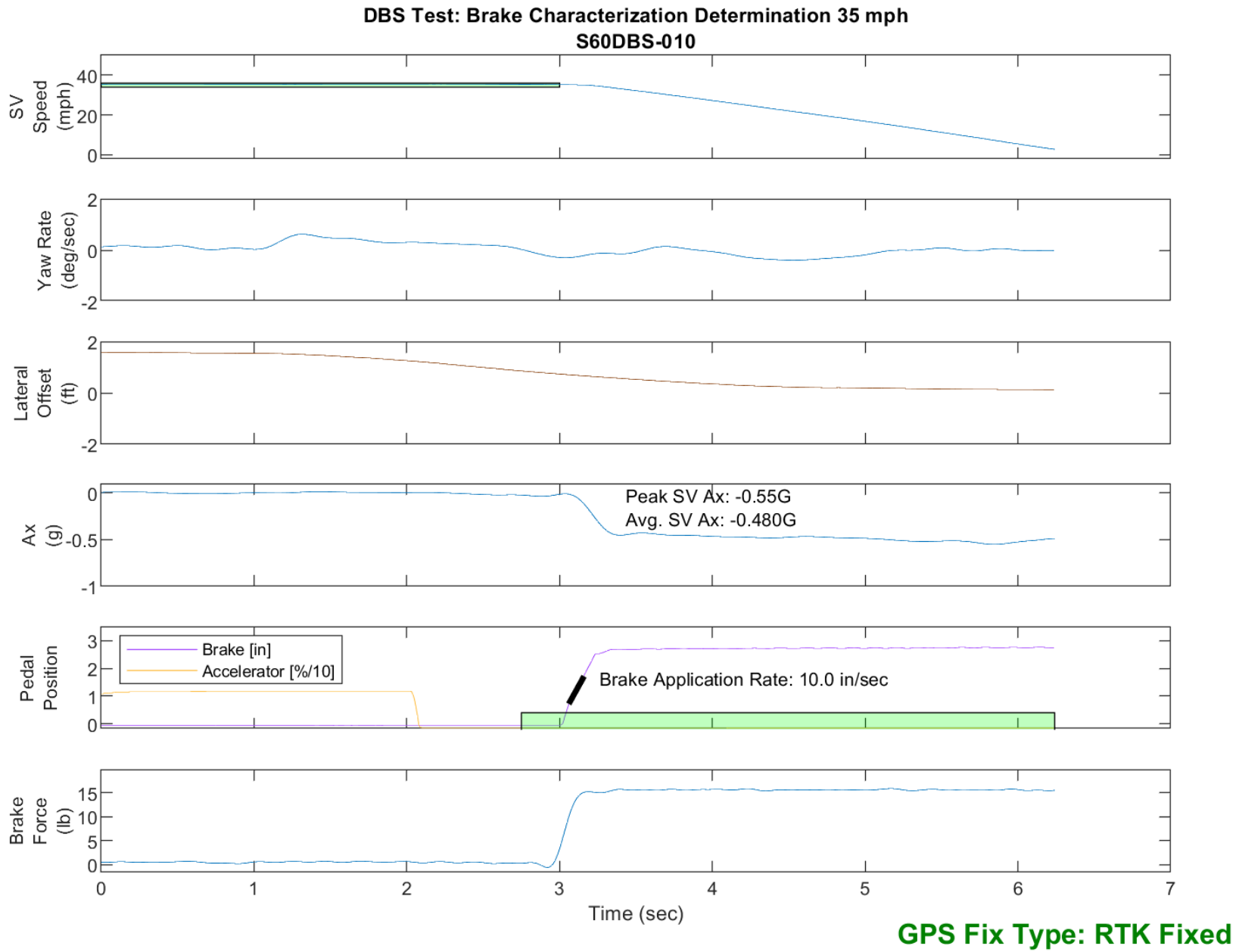


Figure E71. Time History for DBS Run 10, Brake Characterization Determination 35 mph

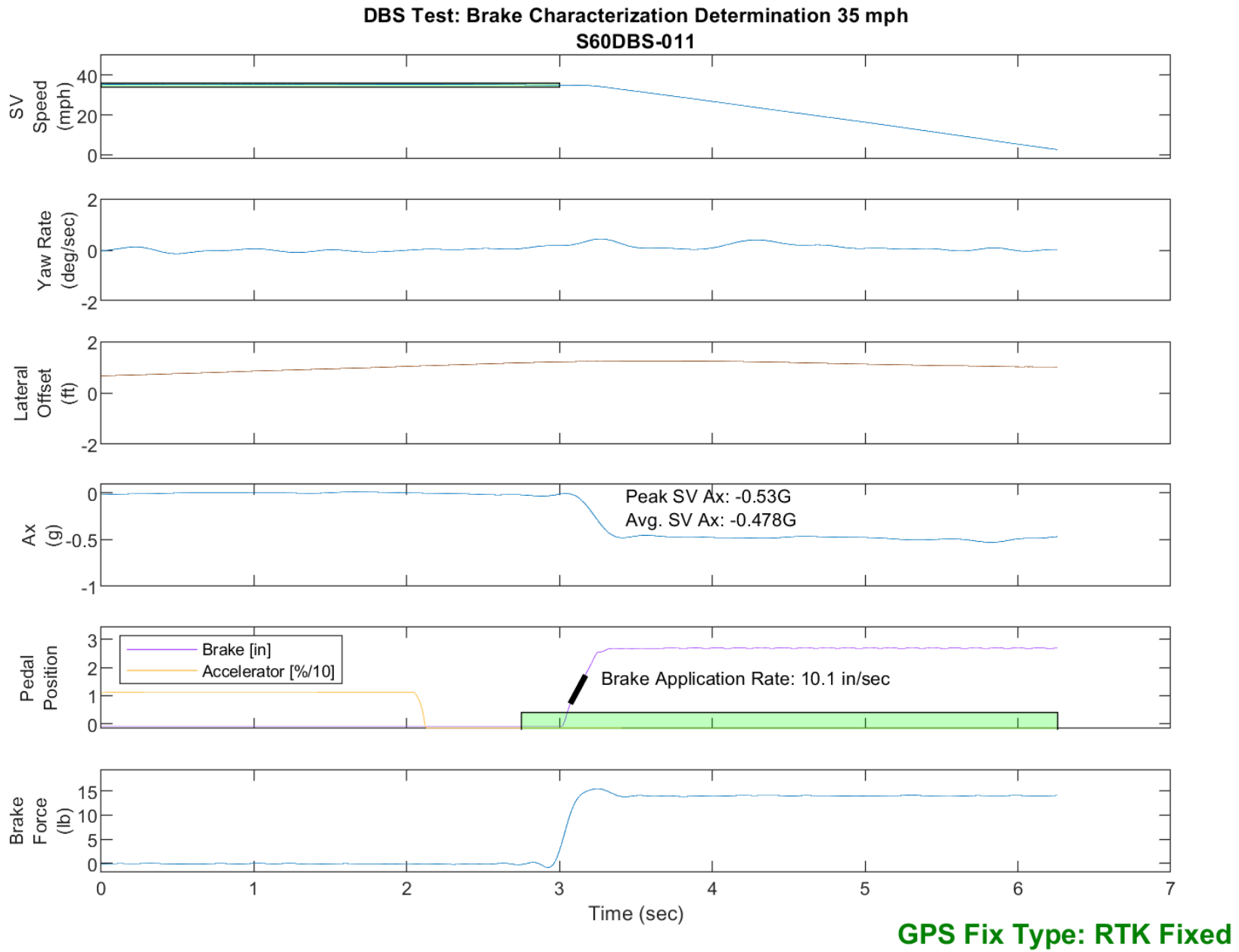
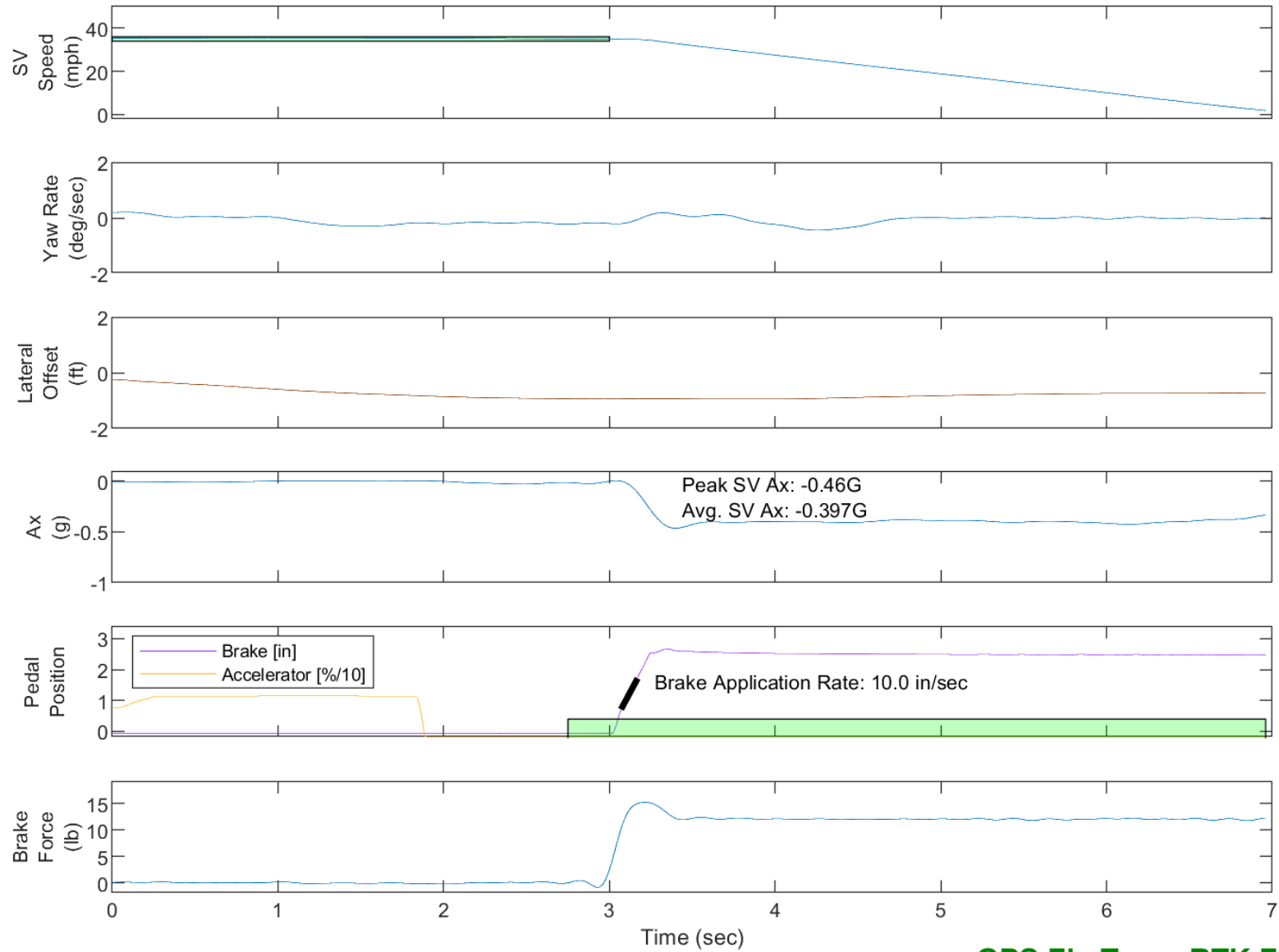


Figure E72. Time History for DBS Run 11, Brake Characterization Determination 35 mph

DBS Test: Brake Characterization Determination 35 mph
S60DBS-012



GPS Fix Type: RTK Fixed

Figure E73. Time History for DBS Run 12, Brake Characterization Determination 35 mph

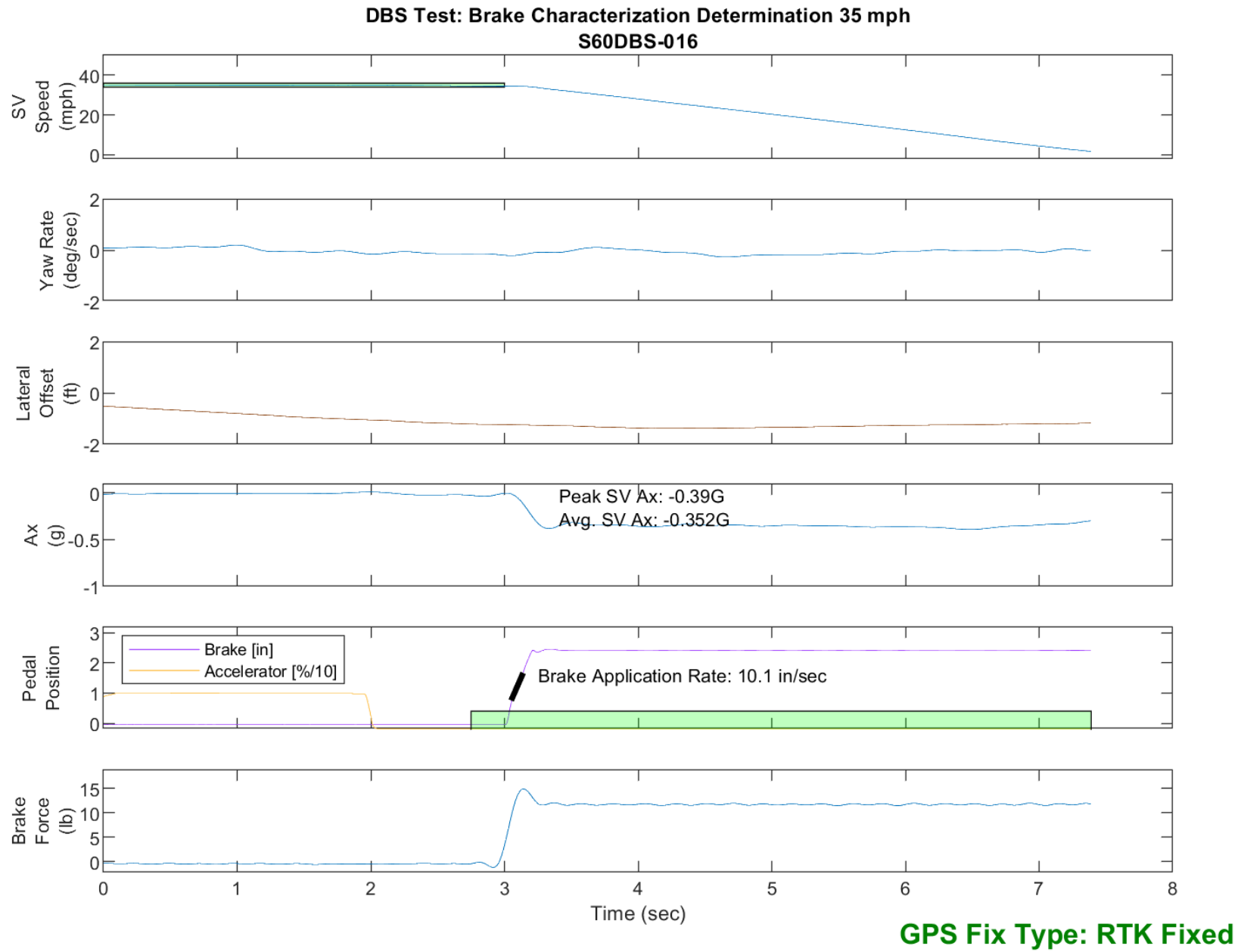
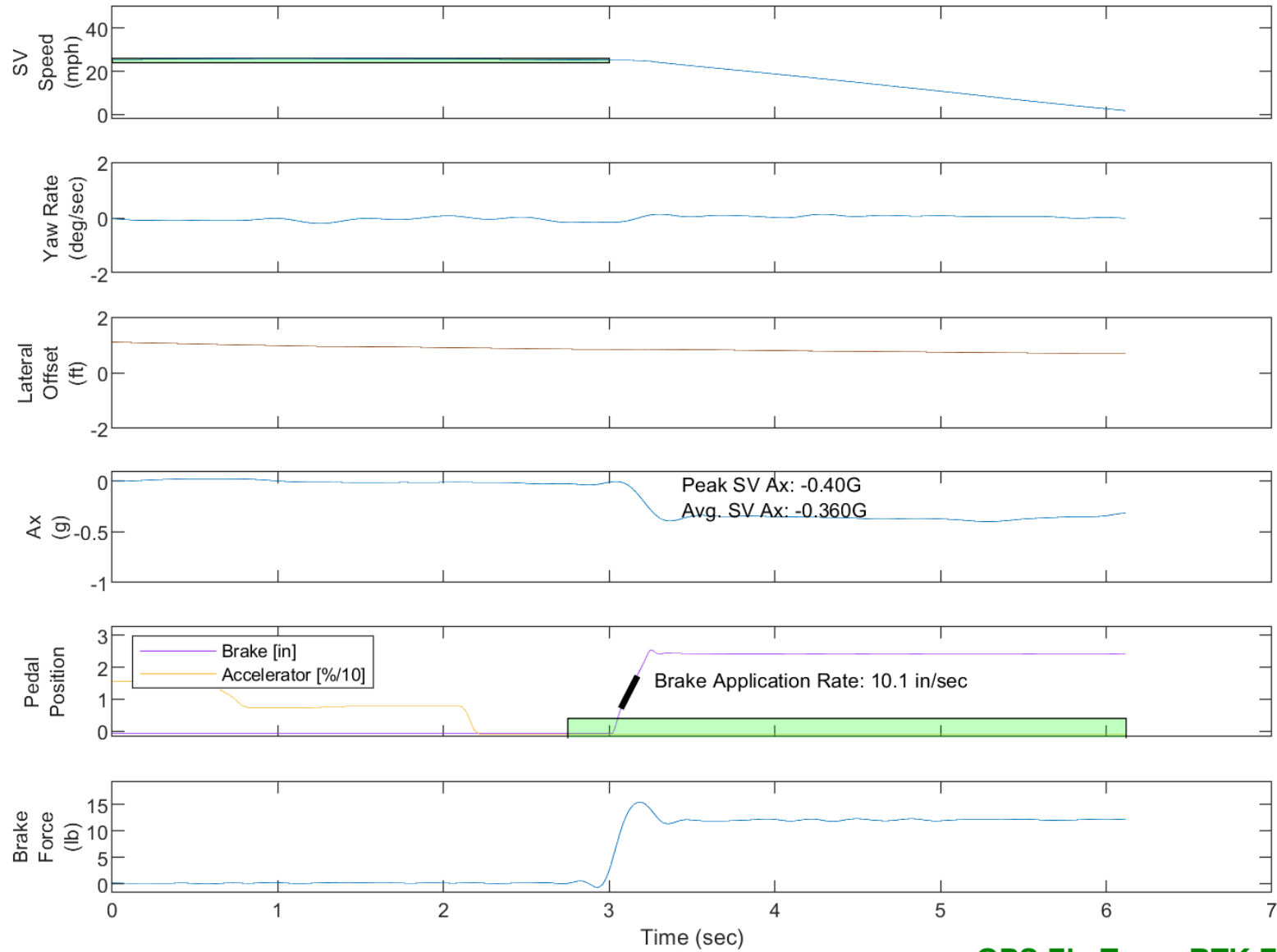


Figure E74. Time History for DBS Run 16, Brake Characterization Determination 35 mph

DBS Test: Brake Characterization Determination 25 mph
S60DBS-006



GPS Fix Type: RTK Fixed

Figure E75. Time History for DBS Run 6, Brake Characterization Determination 25 mph

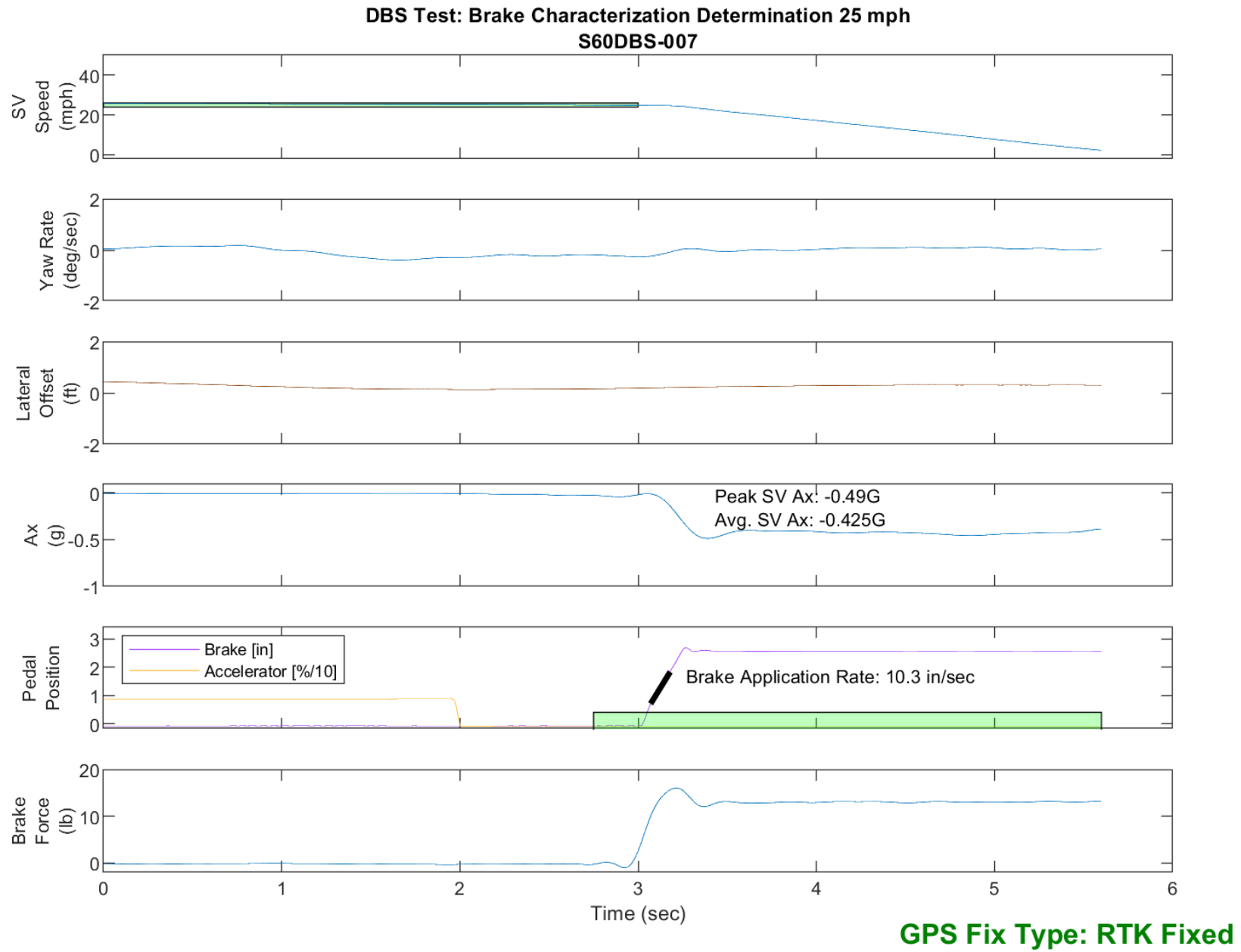
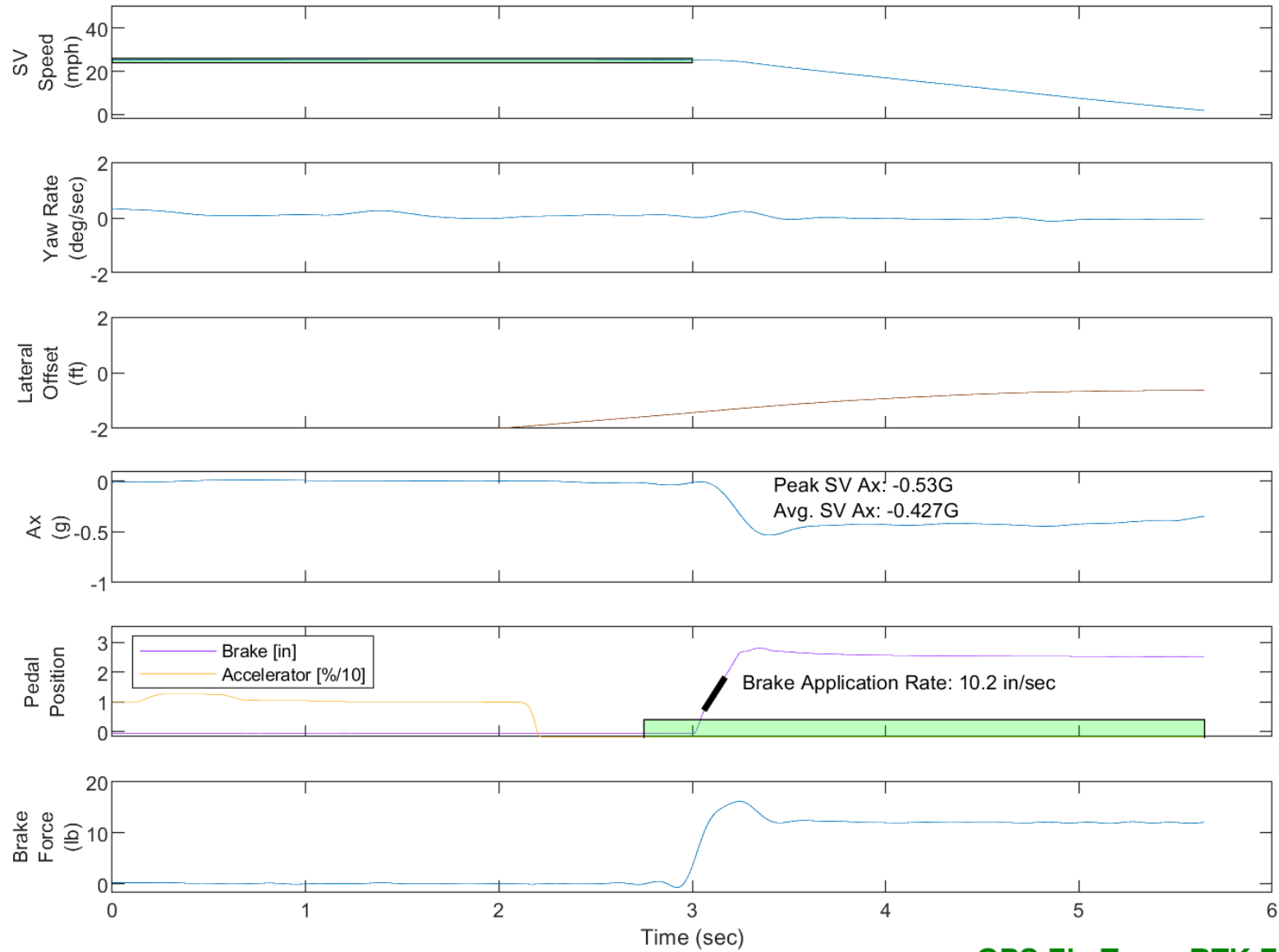


Figure E76. Time History for DBS Run 7, Brake Characterization Determination 25 mph

DBS Test: Brake Characterization Determination 25 mph
S60DBS-013



GPS Fix Type: RTK Fixed

Figure E77. Time History for DBS Run 13, Brake Characterization Determination 25 mph

DBS Test: Brake Characterization Determination 25 mph
S60DBS-014

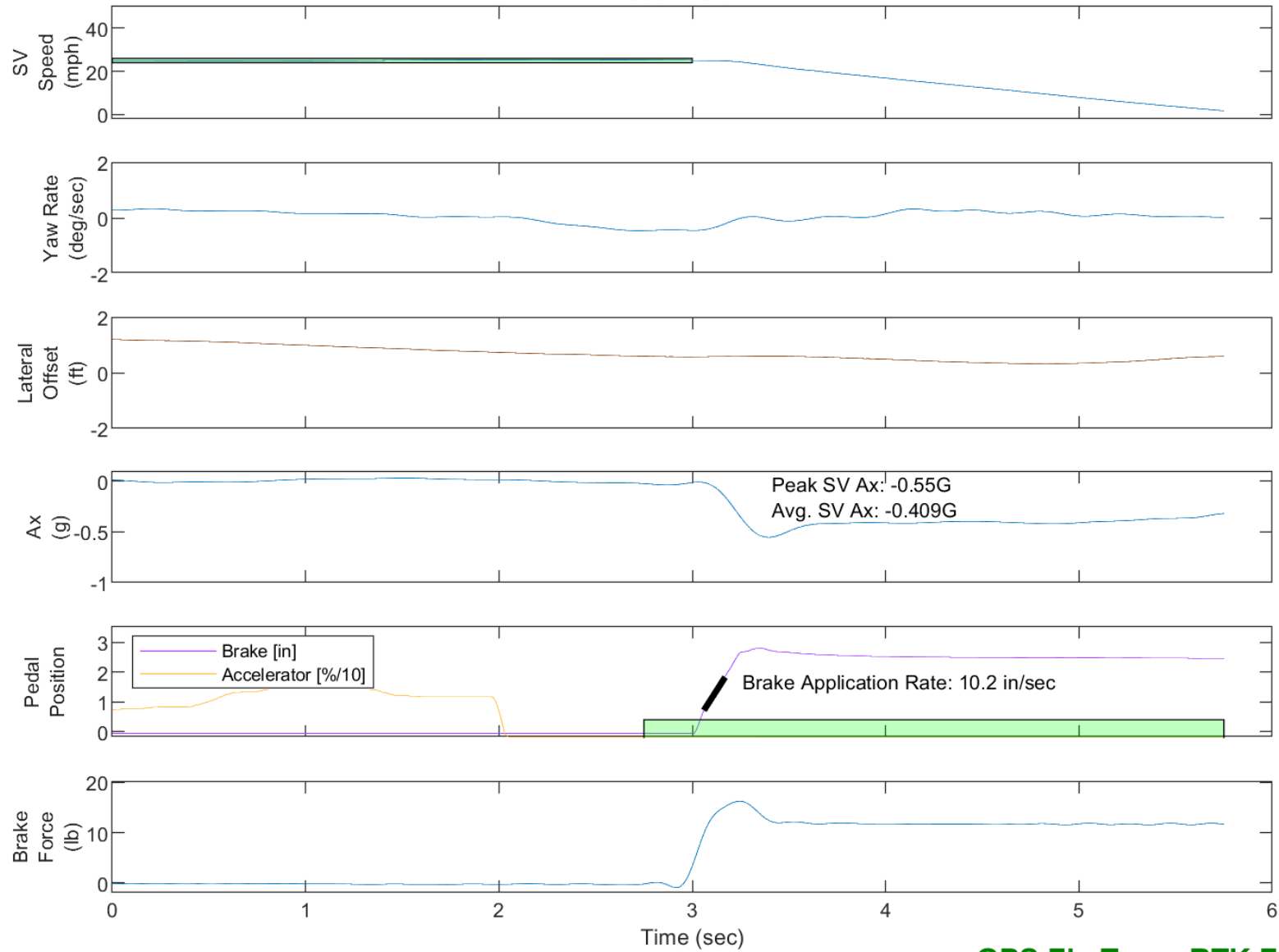


Figure E78. Time History for DBS Run 14, Brake Characterization Determination 25 mph

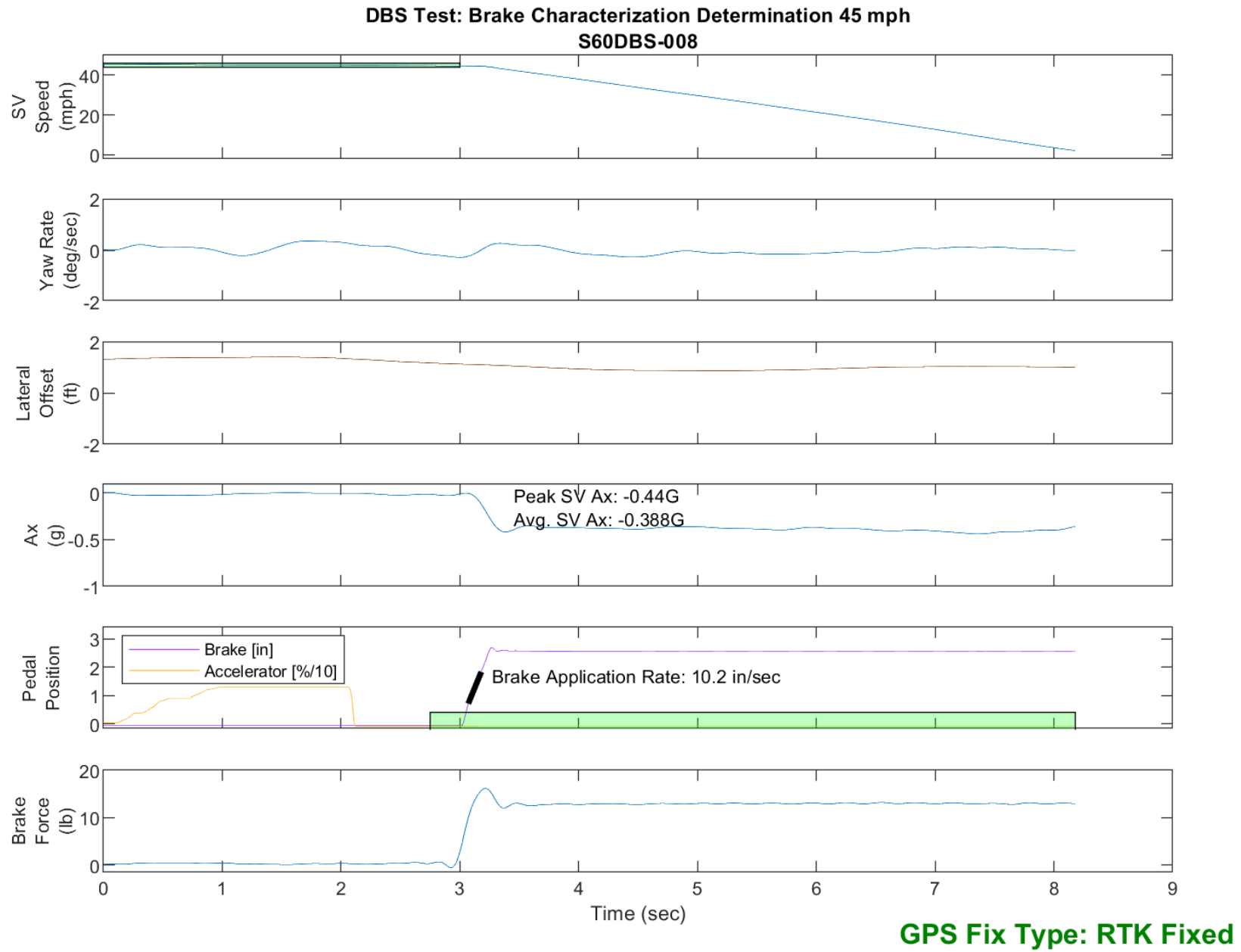


Figure E79. Time History for DBS Run 8, Brake Characterization Determination 45 mph

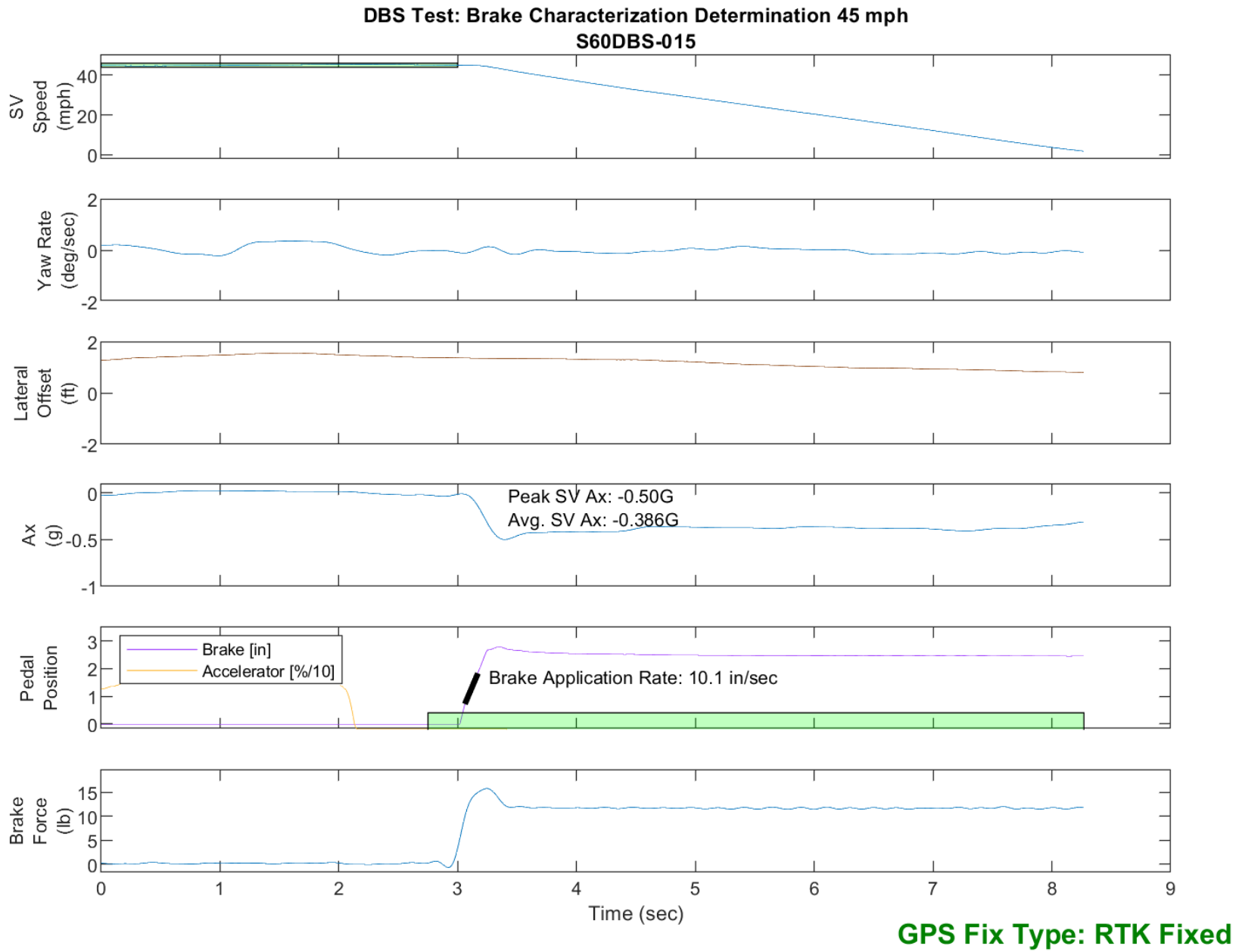


Figure E80. Time History for DBS Run 15, Brake Characterization Determination 45 mph