

**NEW CAR ASSESSMENT PROGRAM  
DYNAMIC BRAKE SUPPORT SYSTEM CONFIRMATION TEST  
NCAP-DRI-DBS-21-17**

**2021 Toyota Prius LE Hybrid**

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**20 April 2021**

**Final Report**

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16. Abstract These tests were conducted on the subject 2021 Toyota Prius LE Hybrid 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 for the stopped POV and slower moving POV scenarios but failed the requirements for the decelerating POV scenario, resulting in an overall failure for the DBS test.			
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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 (SV) 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 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 2021 Toyota Prius LE Hybrid. 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)

**2021 Toyota Prius LE Hybrid**

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VIN: JTDKAMFU3M313xxxx

Test Date: 3/31/2021

Dynamic Brake Support System settings:

Pre-Collision System: On

Pre-Collision Sensitivity: Early (Far)

**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)

**2021 Toyota Prius LE Hybrid**

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**TEST VEHICLE INFORMATION**

VIN: JTDKAMFU3M313xxxx

Body Style: Sedan

Color: Supersonic Red/FD20

Date Received: 3/29/2021

Odometer Reading: 27 mi

**DATA FROM VEHICLE'S CERTIFICATON LABEL**

Vehicle manufactured by: Toyota Motor Corporation

Date of manufacture: 10/20

Vehicle Type: Pass. Car

**DATA FROM TIRE PLACARD**

Tires size as stated on Tire Placard: Front: 195/65R15

Rear: 195/65R15

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

Rear: 240 kPa (35 psi)

**TIRES**

Tire manufacturer and model: Toyo NanoEnergy A41

Front tire specification: 195/65R15 91S

Rear tire specification: 195/65R15 91S

Front tire DOT prefix: N39N 6H3

Rear tire DOT prefix: N39N 6H3



**DYNAMIC BRAKE SUPPORT**  
**DATA SHEET 3: TEST CONDITIONS**

(Page 1 of 2)

2021 Toyota Prius LE Hybrid

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**GENERAL INFORMATION**

Test date: 3/31/2021

**AMBIENT CONDITIONS**

Air temperature: 31.1 C (88 F)

Wind speed: 1.5 m/s (3.5 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: 240 kPa (35 psi)

**DYNAMIC BRAKE SUPPORT**  
**DATA SHEET 3: TEST CONDITIONS**

(Page 2 of 2)

**2021 Toyota Prius LE Hybrid**

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**WEIGHT**

Weight of vehicle as tested including driver and instrumentation

Left Front: 470.8 kg (1038 lb)

Right Front: 433.6 kg (956 lb)

Left Rear: 320.7 kg (707 lb)

Right Rear: 300.3 kg (662 lb)

Total: 1525.4 kg (3363 lb)

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

(Page 1 of 3)

**2021 Toyota Prius LE Hybrid**

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

Pre-Collision System (PCS) w/ Pedestrian Detection is part of Toyota Safety Sense 2.0. It is standard equipment.

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

Mono Camera: Top center of windshield

Millimeter Wave Radar: Central part of front bumper grille

System settings used for test (if applicable):

Pre-Collision System: On

Pre-Collision Sensitivity: Early (Far)

Brake application mode used for test: Hybrid control

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

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

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

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

Does the vehicle system require an initialization sequence/procedure?

  X   Yes

       No

If yes, please provide a full description.

Sensor calibration is necessary which can be done by following procedure.

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

**DYNAMIC BRAKE SUPPORT**

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

(Page 2 of 3)

**2021 Toyota Prius LE Hybrid**

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

If yes, please provide a full description.

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

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

Warning light illuminates red with white text reading "Brake!" for visual warning. Repeated beep at a high pitch as an auditory warning.

See Appendix A, Figure A17 and page 297 of the Owner's Manual, shown in Appendix B, page B-8.

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

(Page 3 of 3)

**2021 Toyota Prius LE Hybrid**

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Is there a way to deactivate the system?  Yes  
 No

If yes, please provide a full description including the switch location and method of operation, any associated instrument panel indicator, etc.

Controls on the right side of the steering wheel are used to interact with system menus.

Press right arrow until settings menu (gear picture) is highlighted.

Use down arrow to get to (AEB) settings, press center button to select "On" or "Off".

See Appendix A, Figure A14 and Figure A16 and pages 151-152 of the Owner's Manual, shown in Appendix B, pages B-4 and B-5.

Is the vehicle equipped with a control whose purpose is to adjust the range setting or otherwise influence the operation of DBS?  Yes  
 No

If yes, please provide a full description.

Controls on the right side of the steering wheel are used to interact with system menus.

Press right arrow until settings menu (gear picture) is highlighted.

Use down arrow to get to PCS warning timing, press center button to scroll through the three sensitivity setting options—Early, Middle, Late.

See Appendix A, Figure A15 and Figure A16 and pages 151-152 of the Owner's Manual, shown in Appendix B, pages B-4 and B-5.

Are there other driving modes or conditions that render DBS inoperable or reduce its effectiveness?  Yes  
 No

If yes, please provide a full description.

Limitations of the system are described in the Owner's Manual on pages 298 - 299, and pages 302-306. These are shown in Appendix B, pages B-9 through B-10, and B-13 through B-17.

Notes:

## Section III

### TEST PROCEDURES

#### A. Test Procedure Overview

Four test scenarios were used, as follows:

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

Test 2. Subject Vehicle Encounters Slower Principal Other Vehicle

Test 3. Subject Vehicle Encounters Decelerating Principal Other Vehicle

Test 4. Subject Vehicle Encounters Steel Trench Plate

An overview of each of the test procedures follows.

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

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

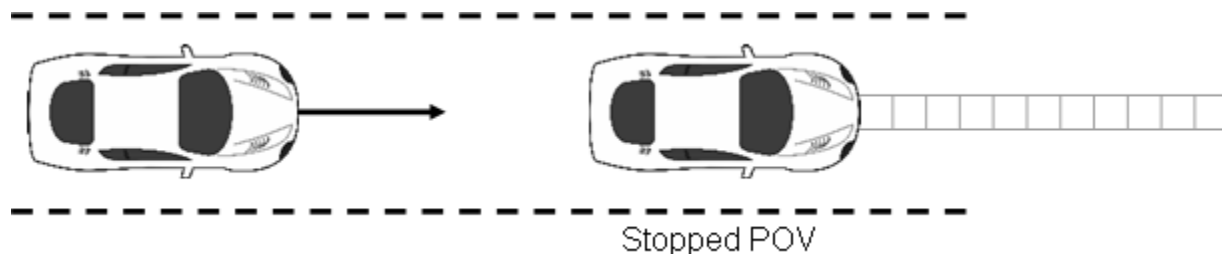


Figure 1. Depiction of Test 1

##### 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-to-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.

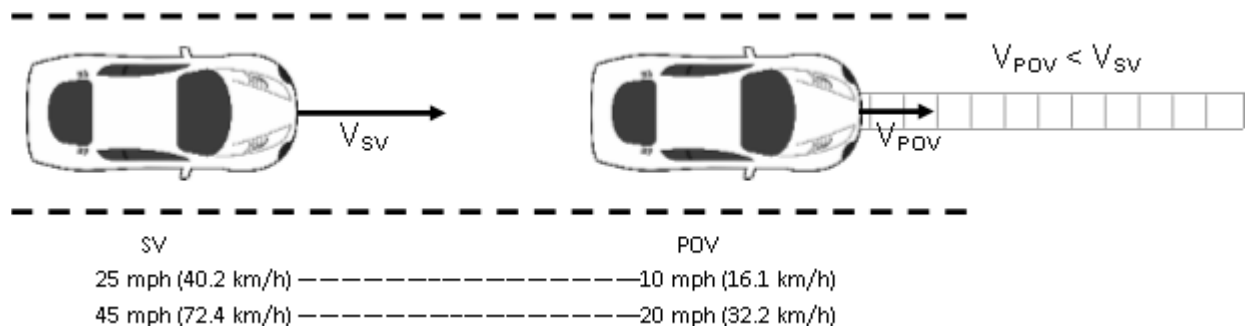


Figure 2. Depiction of Test 2

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  $\pm 1$  ft (0.3 m) during the validity period.
- The SV speed could not deviate more than  $\pm 1.0$  mph ( $\pm 1.6$  km/h) during an interval defined by  $TTC = 5.0$  seconds to  $t_{FCW}$ .
- The POV speed could not deviate more than  $\pm 1.0$  mph ( $\pm 1.6$  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-to-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.

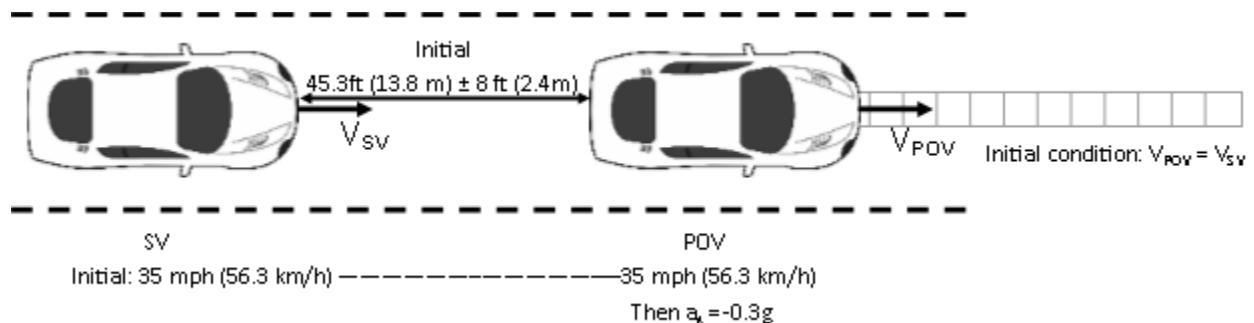


Figure 3. Depiction of Test 3

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  $\pm 1$  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  $\pm 1.0$  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  $\pm 0.03$  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 $\rightarrow t_{FCW}$	45 ft (14 m) $\rightarrow t_{FCW}$	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-to-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 1.5 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<sub>FCW</sub>

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 auditory, and the onset of the alert is determined by post-processing the test data.

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

**Table 4. Auditory and Tactile Warning Filter Parameters**

<b>Warning Type</b>	<b>Filter Order</b>	<b>Peak-to-Peak Ripple</b>	<b>Minimum Stop Band Attenuation</b>	<b>Passband Frequency Range</b>
Auditory	5 <sup>th</sup>	3 dB	60 dB	Identified Center Frequency $\pm$ 5%
Tactile	5 <sup>th</sup>	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  $\pm 1.0$  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  $\pm 1$  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  $\pm 2$  in ( $\pm 5$  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  $\pm 2$  in ( $\pm 5$  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 SV-to-POV 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  $0.4 \pm 0.025$  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	< 1% error between 20 and 100 psi	Omega DPG8001	18111410000	By: DRI Date: 5/4/2020 Due: 5/4/2021
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform	0.1% of reading	Intercomp SW wireless	0410MN20001	By: DRI Date: 2/10/2021 Due: 2/10/2022
Linear (string) encoder	Throttle pedal travel	10 in	0.1 in	UniMeasure LX-EP	50060726	By: DRI Date: 6/19/2020 Due: 6/19/2021
Load Cell	Force applied to brake pedal					By: DRI
		0 - 250 lb 0 -1112 N	0.1% FS	Honeywell 41A	1464391	Date: 2/4/2021 Due: 2/4/2022
		0-250 lb 1112 N	0.05% FS	Stellar Technology PNC700	1607338	Date: 7/2/2020 Due: 7/2/2021
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	N/A

**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 Rate $\pm 100$ deg/s, Angle $>45$ deg, Velocity $>200$ km/h	Accels $.01g$ , Angular Rate $0.05$ deg/s, Angle $0.05$ deg, Velocity $0.1$ km/h	Oxford Inertial +		By: Oxford Technical Solutions
	Lateral, Longitudinal and Vertical Velocities;				2258	Date: 5/3/2019 Due: 5/3/2021
	Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles				2182	Date: 9/16/2019 Due: 9/16/2021
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: $\pm 30$ m Lateral Lane Velocity: $\pm 20$ m/sec Longitudinal Range to POV: $\pm 200$ m Longitudinal Range Rate: $\pm 50$ m/sec	Lateral Distance to Lane Marking: $\pm 2$ cm Lateral Velocity to Lane Marking: $\pm 0.02$ m/sec Longitudinal Range: $\pm 3$ cm Longitudinal Range Rate: $\pm 0.02$ m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	N/A
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	N/A	N/A
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time $< 10$ msec	DRI designed and developed Light Sensor	N/A	N/A
Accelerometer	Acceleration (to measure time at alert)	$\pm 5g$	$\leq 3\%$ of full range	Silicon Designs, 2210-005	N/A	N/A

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: 1/6/2021 Due: 1/6/2022
Type	Description			Mfr, Model	Serial Number	
Data Acquisition System	Data acquisition is achieved using a dSPACE MicroAutoBox II. Data from the Oxford IMU, including Longitudinal, Lateral, and Vertical Acceleration, Roll, Yaw, and Pitch Rate, Forward and Lateral Velocity, Roll and Pitch Angle are sent over Ethernet to the MicroAutoBox. The Oxford IMUs are calibrated per the manufacturer's recommended schedule (listed above).			dSPACE Micro-Autobox II 1401/1513		
				Base Board	549068	
				I/O Board	588523	

## APPENDIX A

### Photographs

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Figure A1. Front View of Subject Vehicle

A-3



Figure A2. Rear View of Subject Vehicle

A-4





DESC.: **PRIUS LE HYBRID**  
**JTDKAMFU3M313**  
 VIN: **JTDKAMFU3M313**  
 YR/MDL: 2021/1223A  
 CLR: SUPERSONIC RED/FD20 (03U5/20)  
 FINAL ASSEMBLY POINT: TOYOTA, AICHI, JAPAN

**GOVERNMENT 5-STAR SAFETY RATINGS**

**Overall Vehicle Score** Not Rated  
 Based on the combined ratings of frontal, side and rollover. Should ONLY be compared to other vehicles of similar size and weight.

**Frontal Crash** Driver Passenger Not Rated Not Rated  
 Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.

**Side Crash** Front seat Rear seat Not Rated Not Rated  
 Based on the risk of injury in a side impact.

**Rollover** ★★★★★  
 Based on the risk of rollover in a single-vehicle crash.

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

**STANDARD EQUIPMENT**

- MECHANICAL & PERFORMANCE**  
 - Hybrid Synergy Drive System, AT-PZEV  
 - 1.8L DOHC 16V VVT-i 4-Cylinder Engine  
 - E/ECO POWER Modes  
**SAFETY & CONVENIENCE**  
 - 10 Airbags; Star Safety System  
 - Toyota Safety Sense 2.0: Pre-Collision Sys w/Pedestrian Detection, Dynamic Radar Cruise Control, Lane Departure Alert w/Steering Assist, Automatic High Beams, Road Sign Assist  
 - BlindSpot Monitor w/Rear Cross Traffic Alert  
 - Intelligent Clearance Sonar w/Intelligent Park Assist  
 - Smart Key System w/ Push Button Start  
 - Safety Connect w/ 1-Year Trial  
**EXTERIOR**  
 - Bi-LED Headlights w/Auto-Off, LED DRLs  
 - Heated Power Outside Mirrors  
**INTERIOR**  
 - Audio - 7-in Touchscreen, 6 Speakers, HandsFree Bluetooth Phone/Music, USB Media Port, 2 USB Charge-Ports, SiriusXM w/3-Month All Access Trial  
 - Android Auto & Apple CarPlay Compatible  
 - Fabric-Trimmed Seats  
 - 60/40 Split Folding Rear Seat  
 - 12V Outlet  
 - Temporary Spare Tire  
 \*\*\*Full Tank of Gas\*\*\*

**MANUFACTURER'S SUGGESTED RETAIL PRICE \$25,735.00**

OPTIONAL EQUIPMENT		
FE	50 State Emissions Special Color	425.00
63	All Weather Floor Liners	169.00
EF	Rear Bumper Applique	69.00
D5	Door Edge Guards	125.00
DK	Preferred Owner's Portfolio	

**EPA DOT Fuel Economy and Environment**

**Fuel Economy**  
**52 MPG** Midsize Cars range from 14 to 141 MPG. The best vehicle rates 141 MPG.  
 54 50  
 combined city/hwy city highway  
 1.9 gallons per 100 miles

**You save \$3,500**  
 in fuel costs over 5 years compared to the average new vehicle.

**Annual fuel cost \$800**



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 \$7,600 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at \$2.70 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



DELIVERY PROCESSING AND HANDLING FEE 995.00

**TOTAL \$27,518.00**

The New Vehicle Limited Warranty provides 3-year/36,000 mile basic coverage, 5-year/60,000 mile powertrain coverage, 5-year/unlimited mile corrosion perforation coverage, 3-year/100,000 mile coverage for specific hybrid components and 10-year/100,000 mile coverage for the Hybrid Battery. Some components and less longer coverage components are not included in the manufacturer's suggested retail price. See participating dealer for details. See Warranty and Maintenance Guide for details. An extended service contract may be available for the vehicle. Ask dealer for details. Manufacturer's suggested retail includes manufacturer's recommended pre-delivery service, gasoline, license and title fees, applicable federal, state and local taxes and dealer and distributor fees. Installed options and accessories are not included in the manufacturer's suggested retail price. ToyotaCare, which covers normal factory scheduled maintenance for two years or 25,000 miles, whichever occurs first, is included as part of the sales price of the vehicle for qualifying buyers. See participating dealer for eligibility and coverage details.

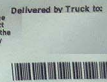


Figure A3. Window Sticker (Monroney Label)

MFD. BY: TOYOTA MOTOR CORPORATION 10/20  
GVWR 3945LB GAWR FR 2250LB RR 2150LB  
THIS VEHICLE CONFORMS TO ALL APPLICABLE  
FEDERAL MOTOR VEHICLE SAFETY, BUMPER, AND  
THEFT PREVENTION STANDARDS IN EFFECT ON  
THE DATE OF MANUFACTURE SHOWN ABOVE.  
JTDKAMFU3M313 PASS. CAR



C/TR: 3U5/FD20 ZVW51L-AHXEBA  
A/TM: -01A/P610 MADE IN JAPAN

329 C

Figure A4. Vehicle Certification Label



**TIRE AND LOADING INFORMATION**

**RENSEIGNEMENTS SUR LES PNEUS ET LE CHARGEMENT**

SEATING CAPACITY : TOTAL 5  
FRONT 2 : REAR 3

NOMBRE DE PLACES : TOTAL 5  
AVANT 2 : ARRIÈRE 3

The combined weight of occupants and cargo should never exceed 375 kg or 825 lbs.

Le poids total des occupants et du chargement ne doit jamais dépasser 375 kg ou 825 lb.

SEE OWNER'S  
MANUAL FOR  
ADDITIONAL  
INFORMATION.

TIRE	SIZE	COLD TIRE PRESSURE
FRONT	195/65R15	250kPa, 36PSI
REAR	195/65R15	240kPa, 35PSI
SPARE	T125/70D17	420kPa, 60PSI

PNEU	DIMENSIONS	PRESSION DES PNEUS À FROID
AVANT	195/65R15	250kPa, 36PSI
ARRIÈRE	195/65R15	240kPa, 35PSI
DE SECOURS	T125/70D17	420kPa, 60PSI

VOIR LE MANUEL  
DE L'USAGER  
POUR PLUS DE  
RENSEIGNEMENTS.

TH 47880

Figure A5. Tire Placard



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



Figure A7. Load Frame/Slider of SSV

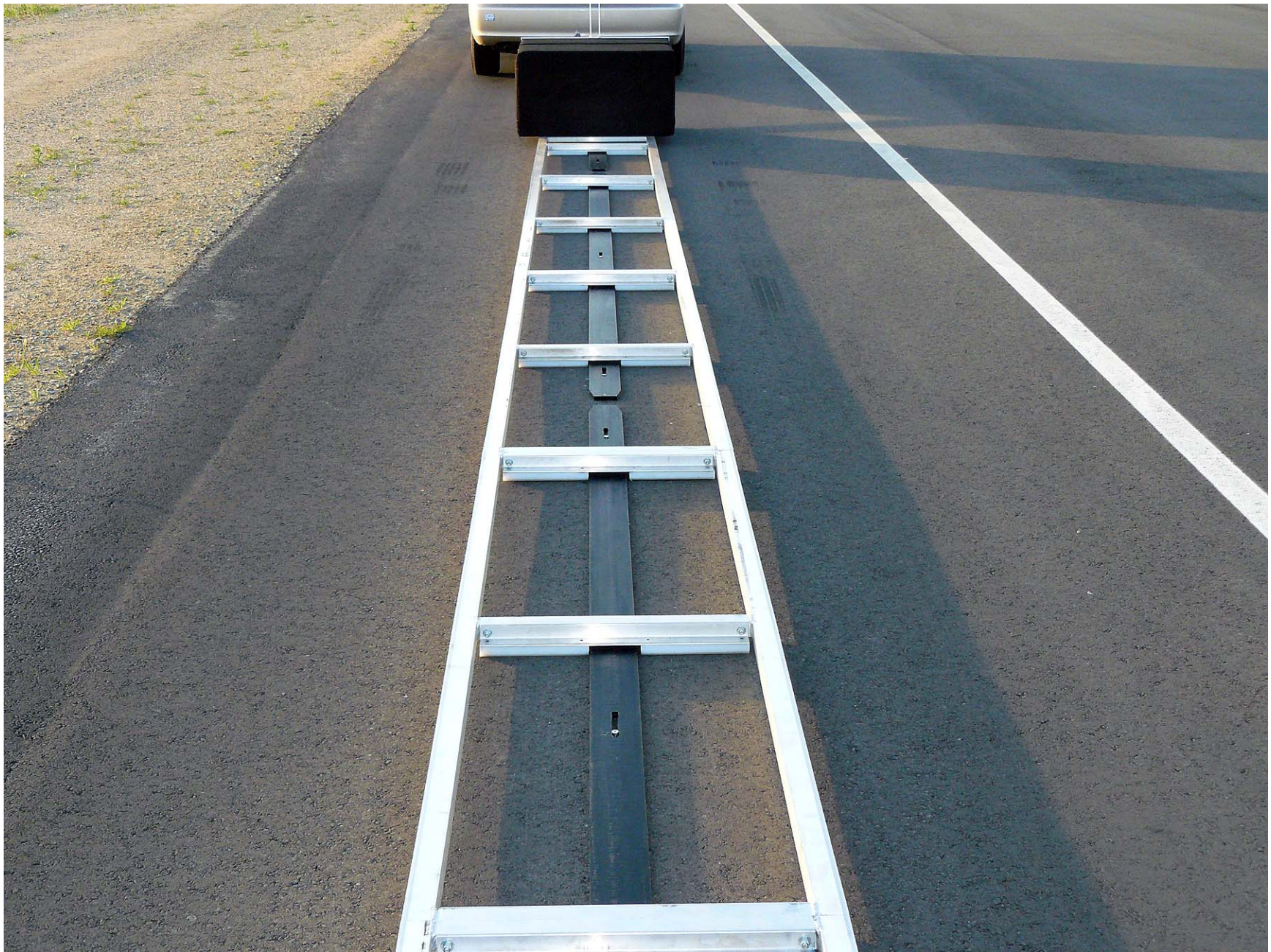


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track



Figure A9. Steel Trench Plate  
A-11

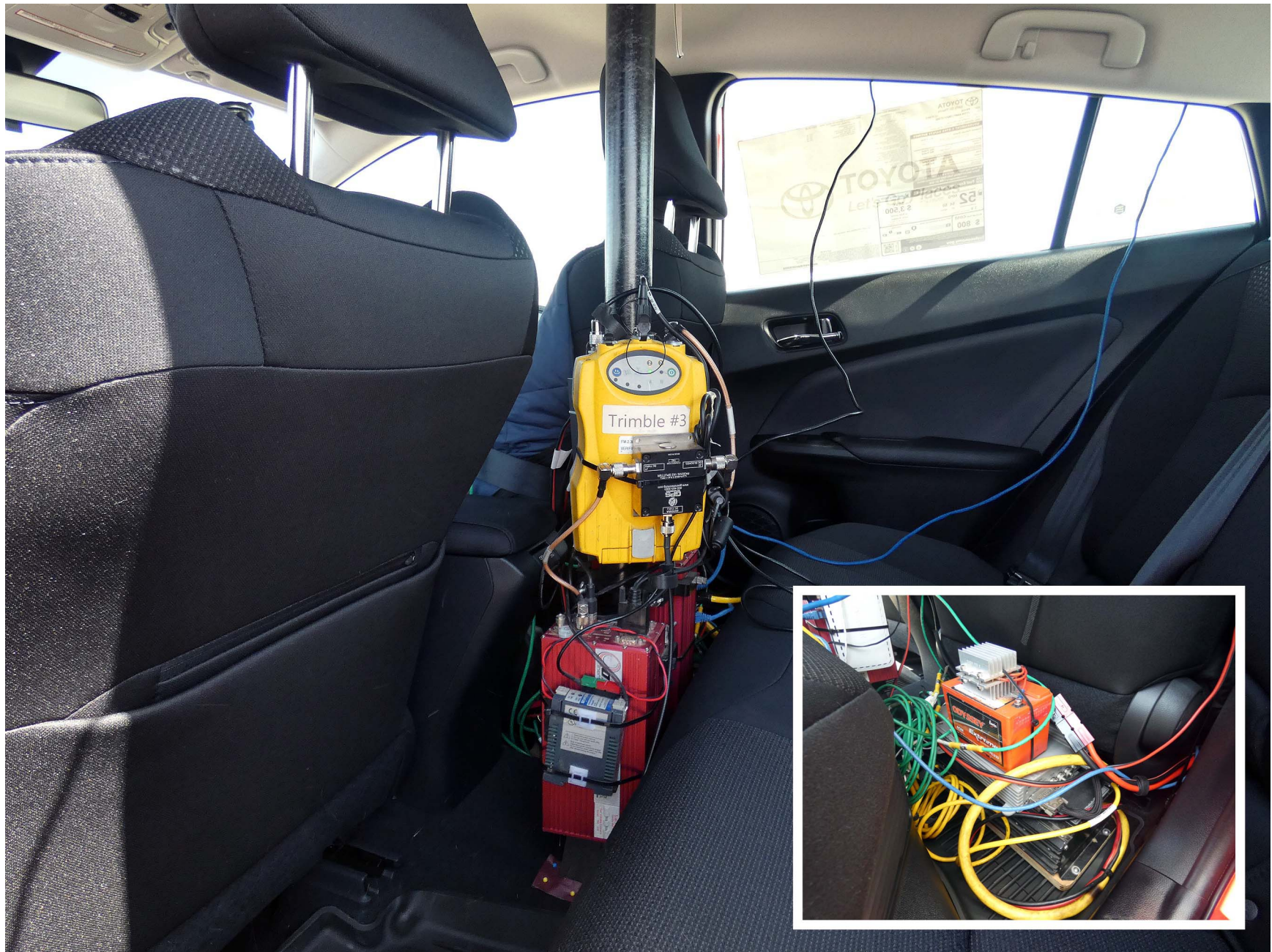


Figure A10. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle





Figure A11. Sensors for Detecting Visual and Auditory Alerts



Figure A12. Computer and Brake Actuator Installed in Subject Vehicle



Figure A13. Brake Actuator Installed in POV System



Figure A14. AEB Setup Menus  
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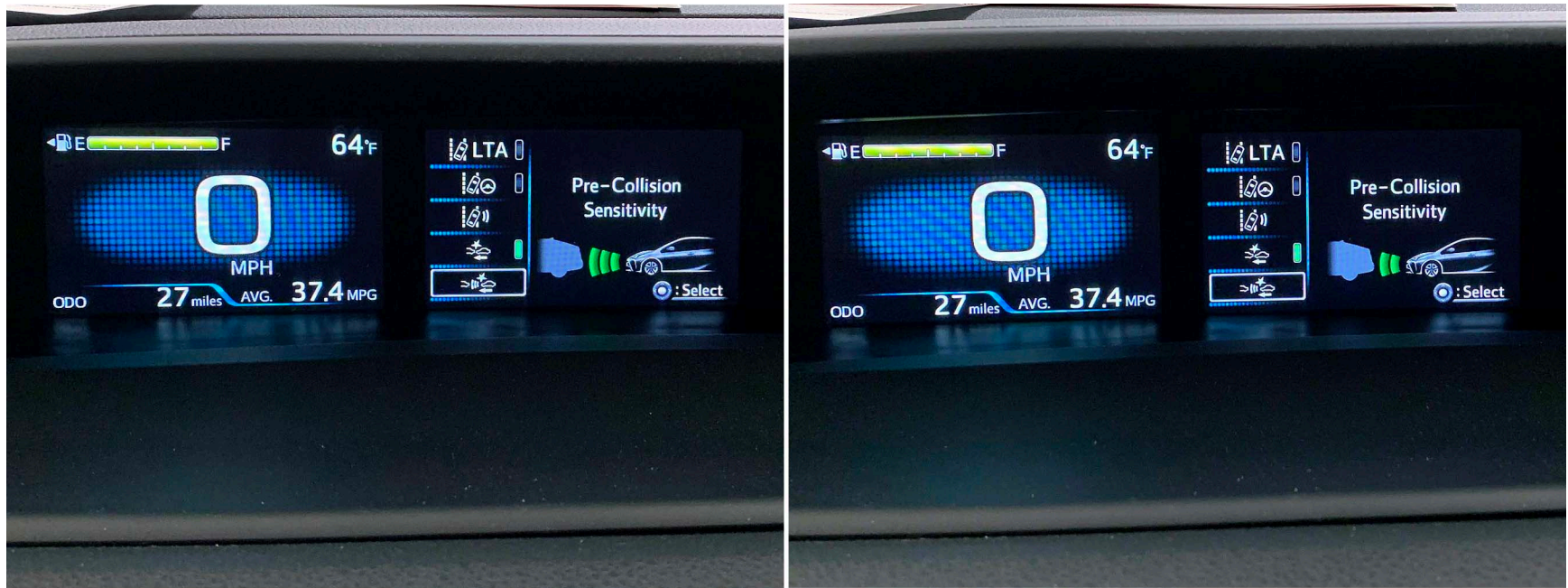


Figure A15. Menus for Pre-Collision Sensitivity  
A-17



Figure A16. Button for Accessing System Setup Menus



Figure A17. Visual Alert  
A-19













## APPENDIX B












Excerpts from Owner's Manual



**Warning lights**

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

Warning lights			Pages
*1	<b>BRAKE</b>	Brake system warning light (U.S.A.)	P. 592
*1		Brake system warning light (Canada) (Red)	P. 592
*1		Brake system warning light (Yellow)	P. 592
*1		Charging system warning light	P. 592
*1		Low engine oil pressure warning light	P. 592
*1		Malfunction indicator lamp (U.S.A.)	P. 592
*1		Malfunction indicator lamp (Canada)	P. 592
*1		SRS warning light	P. 593
*1	<b>ABS</b>	ABS warning light (U.S.A.)	P. 593
*1		ABS warning light (Canada)	P. 593
*1		Electric power steering system warning light (Red/yellow)	P. 593
*1,2	 OFF	PCS warning light (if equipped)	P. 593
		LTA indicator (Orange) (if equipped)	P. 593
*1		Slip indicator light	P. 594

Indicators			Pages
		Dynamic radar cruise control indicator (if equipped)	P. 326
	<b>SET</b>	Cruise control "SET" indicator	P. 326, 342
	<b>AFS OFF</b>	AFS OFF indicator (if equipped)	P. 265, 595
*1, 3	 OFF	PCS warning light (if equipped)	P. 300
*4		LTA indicator (if equipped)	P. 316
		Steering control indicator (if equipped)	P. 316
		Automatic High Beam indicator (if equipped)	P. 268
		Heated steering wheel indicator (if equipped)	P. 457
	<b>BSM</b>	"BSM" indicator (if equipped)	P. 349
		Intuitive parking assist indicator (if equipped)	P. 362
*1, 3	 OFF	PKSB OFF indicator (if equipped)	P. 375
*1		S-APGS indicator (if equipped)	P. 390
*1		"AIR BAG ON/OFF" indicator (U.S.A.)	P. 49
*1		"AIR BAG ON/OFF" indicator (Canada)	P. 49



## Settings display

The operation contents of the driving support systems and settings related to the combination meter display can be changed.

Driving support systems such as the PCS (Pre-Collision System) (if equipped) and Blind Spot Monitor (if equipped) is turned on and off by simply pressing . Make sure not to cancel the systems accidentally.

### Setting procedure

- 1 Press or of the meter control switches on the steering wheel and select .
- 2 Press or of the meter control switches and select the item to change, and then press .

If the function is turned on and off or the sensitivity, etc. is changed on the setting screen, the setting is changed each time the is pressed.

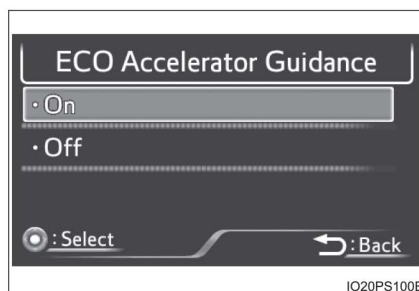
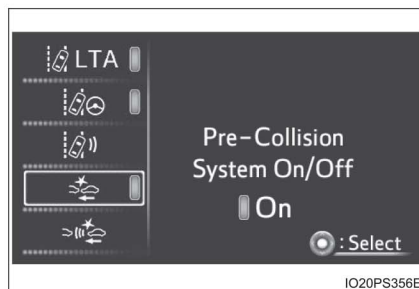
For functions that allow operation contents, display contents, etc., of a function to be selected, the setting screen is displayed.

- 3 When the setting screen is displayed, select the setting or desired value (time, etc.) with the meter control switches.\*1, 2

For selectable operation contents and setting values, select the desired setting or value, and then press .

To stop the selection, press .














When the setting check screen is displayed, select proceed or cancel and press .



\*1: Depending on the items, a subsequent setting screen may be displayed after selecting an item.

\*2: For items which set the adjustment level or time, after the item is set, the setting screen remains displayed until is pressed.

■ Settings table

Item	Settings	Setting result
 LTA *	“On”	Turns the LTA (Lane Tracing Assist) lane centering function on and off. (→P. 307)
	“Off”	
 *	“On”	Turns the LTA (Lane Tracing Assist) steering assist function on and off. (→P. 307)
	“Off”	
 *	“High”	Switches the LTA (Lane Tracing Assist) alert sensitivity. (→P. 307)
	“Standard”	
 *	“On”	Turns the PCS (Pre-Collision System) on and off. (→P. 300)
	“Off”	
 *	Early	Switches the PCS (Pre-Collision System) warning timing. (→P. 300)
	Middle	
	Late	
 *	“On”	Turns the Intuitive parking assist on and off. (→P. 362)
	“Off”	
 *	“On”	Turns the Parking Support Brake function on and off. (→P. 375)
	“Off”	
 *	“On”	Turns the Blind Spot Monitor on and off. (→P. 350)
	“Off”	
 *	“On”	Turns the LTA (Lane Tracing Assist) vehicle sway warning on and off. (→P. 307)
	“Off”	
 *	“High”	Switches the LTA (Lane Tracing Assist) vehicle sway warning sensitivity. (→P. 307)
	“Standard”	
	“Low”	
 *	Height	Changes the display position and brightness of the head-up display. (→P. 160)
	Brightness	
 *	“On”	Turns the RSA (Road Sign Assist) on and off. (→P. 322)
	“Off”	
 km/h MPH	“km/h”	Switches the speed unit used by the screen display.
	“MPH”	

## Insert display

### ■ Insert displays of the driving support systems

Insert displays are linked with the operation of the following systems and used to show some of the information shown on the multi-information display on the head-up display.

System	Displayed information
PCS (Pre-Collision System)* (→P. 296)	Pre-collision warning
LTA (Lane Tracing Assist)* (→P. 307)	Lane departure alert function display
	Hands off steering wheel warning
	Vehicle sway warning function display
Dynamic radar cruise control with full-speed range* (→P. 326)	Approach warning display
RSA (Road Sign Assist) (→P. 322)	Road signs
Parking Support Brake function* (→P. 373)	Operation display (symbol display)

\*: If equipped

### ■ Master warning light insert display

When the master warning light (→P. 595) is illuminated or flashing, an insert display is shown on the head-up display to inform the driver.

When the master warning light is illuminated or flashing, check the message displayed on the multi-information display and perform the corresponding troubleshooting procedure. (→P. 603)



## **PCS (Pre-Collision System)\***

The pre-collision system uses a radar sensor and front camera to detect objects (→P. 296) in front of the vehicle. When the system determines that the possibility of a frontal collision with an object is high, a warning operates to urge the driver to take evasive action and the potential brake pressure is increased to help the driver avoid the collision. If the system determines that the possibility of a frontal collision with an object is extremely high, the brakes are automatically applied to help avoid the collision or help reduce the impact of the collision.

The pre-collision system can be disabled/enabled and the warning timing can be changed. (→P. 300)

### **Detectable objects**

The system can detect the following:

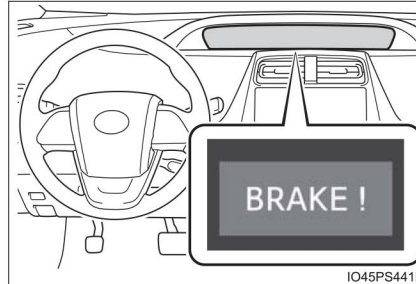
- Vehicles
- Bicyclists
- Pedestrians

\*: If equipped

## System functions

### ■ Pre-collision warning

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




### ■ Pre-collision brake assist

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

### ■ Pre-collision braking

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

 **WARNING****■ Limitations of the pre-collision system**

- The driver is solely responsible for safe driving. Always drive safely, taking care to observe your surroundings.  
Do not use the pre-collision system instead of normal braking operations under any circumstances. This system will not prevent collisions or lessen collision damage or injury in every situation. Do not overly rely on this system. Failure to do so may lead to an accident, resulting in death or serious injury.
- Although this system is designed to help avoid a collision or help reduce the impact of the collision, its effectiveness may change according to various conditions, therefore the system may not always be able to achieve the same level of performance.  
Read the following conditions carefully. Do not overly rely on this system and always drive carefully.
  - Conditions under which the system may operate even if there is no possibility of a collision: →P. 302
  - Conditions under which the system may not operate properly: →P. 304
- Do not attempt to test the operation of the pre-collision system yourself. Depending on the objects used for testing (dummies, cardboard objects imitating detectable objects, etc.), the system may not operate properly, possibly leading to an accident.

**■ Pre-collision braking**

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




 **WARNING****■ When to disable the pre-collision system**

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

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

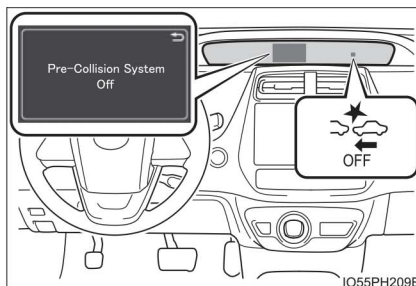
### Changing settings of the pre-collision system

#### ■ Enabling/disabling the pre-collision system


The pre-collision system can be enabled/disabled on  (→P. 151) of the multi-information display.

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

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



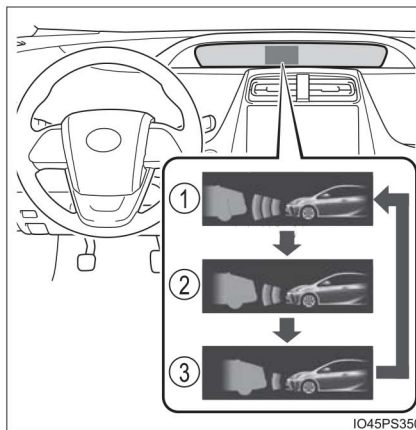
#### ■ Changing the pre-collision warning timing

The pre-collision warning timing can be changed on  (→P. 151) of the multi-information display.

The warning timing setting is retained when the power switch is turned off.

However, if the pre-collision system is disabled and re-enabled, the operation timing will return to the default setting (middle).

- ① Early
- ② Middle  
This is the default setting.
- ③ Late



### ■ Operational conditions

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

Each function is operational at the following speed

#### ● Pre-collision warning

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

#### ● Pre-collision brake assist

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

#### ● Pre-collision braking

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

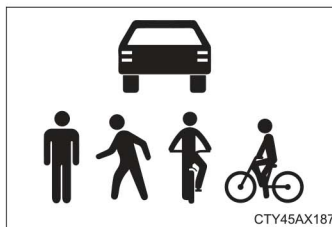
The system may not operate in the following situations:

- If a 12-volt battery terminal has been disconnected and reconnected and then the vehicle has not been driven for a certain amount of time
- If the shift position is in R
- When the VSC OFF indicator is illuminated (only the pre-collision warning function will be operational)

■ **Object detection function**

The system detects objects based on their size, profile, motion, etc. However, an object may not be detected depending on the surrounding brightness and the motion, posture, and angle of the detected object, preventing the system from operating properly. (→P. 304)

The illustration shows an image of detectable objects.



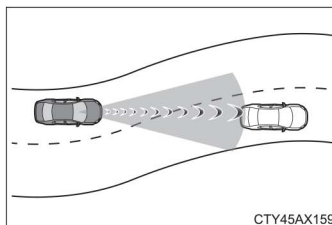
■ **Cancelation of the pre-collision braking**

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

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

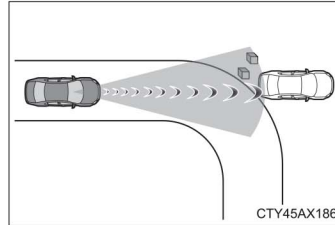
■ **Conditions under which the system may operate even if there is no possibility of a collision**

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

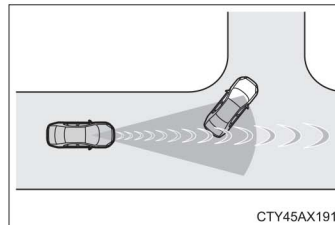


- When rapidly closing on a detectable object, etc.
- When approaching objects on the roadside, such as detectable objects, guardrails, utility poles, trees, or walls

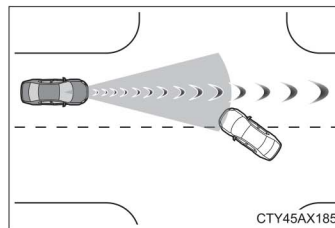
- When there is a detectable object or other object by the roadside at the entrance of a curve



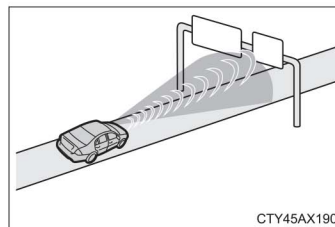
- When there are patterns or paint in front of your vehicle that may be mistaken for a detectable object
- When the front of your vehicle is hit by water, snow, dust, etc.
- When overtaking a detectable object that is changing lanes or making a right/left turn



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

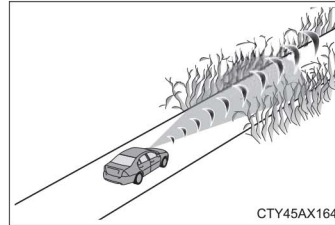


- When a detectable object approaches very close and then stops before entering the path of your vehicle
- If the front of your vehicle is raised or lowered, such as when on an uneven or undulating road surface
- When driving on a road surrounded by a structure, such as in a tunnel or on an iron bridge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



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

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

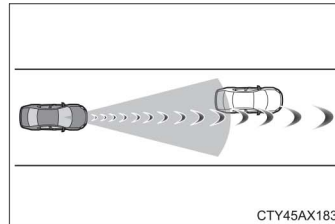


- When driving through steam or smoke
- When driving near an object that reflects radio waves, such as a large truck or guardrail
- When driving near a TV tower, broadcasting station, electric power plant, or other location where strong radio waves or electrical noise may be present

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

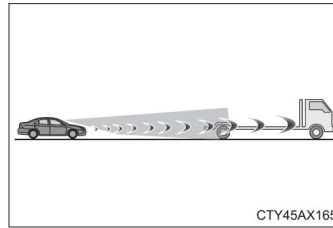
- In some situations such as the following, an object may not be detected by the radar sensor and front camera, preventing the system from operating properly:

- When a detectable object is approaching your vehicle
- When your vehicle or a detectable object is wobbling
- If a detectable object makes an abrupt maneuver (such as sudden swerving, acceleration or deceleration)
- When your vehicle approaches a detectable object rapidly
- When a detectable object is not directly in front of your vehicle

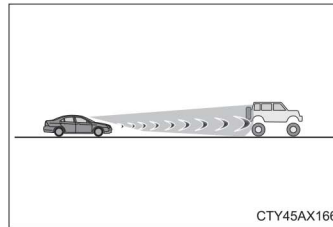


- When a detectable object is near a wall, fence, guardrail, manhole cover, vehicle, steel plate on the road, etc.
- When a detectable object is under a structure
- When part of a detectable object is hidden by an object, such as large baggage, an umbrella, or guardrail
- When multiple detectable objects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

- If a vehicle ahead is narrow, such as a personal mobility vehicle
- If a preceding vehicle has a small rear end, such as an unloaded truck
- If a preceding vehicle has a low rear end, such as a low bed trailer

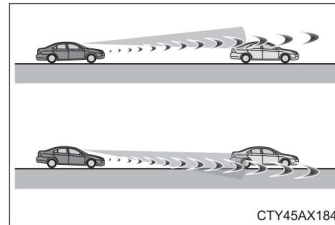


- If a vehicle ahead has extremely high ground clearance








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

- If the front of the vehicle is raised or lowered



- If the wheels are misaligned
- If a wiper blade is blocking the front camera
- The vehicle is being driven at extremely high speeds
- When driving on a hill
- If the radar sensor or front camera is misaligned
- In some situations such as the following, sufficient braking force may not be obtained, preventing the system from performing properly:
  - If the braking functions cannot operate to their full extent, such as when the brake parts are extremely cold, extremely hot, or wet
  - If the vehicle is not properly maintained (brakes or tires are excessively worn, improper tire inflation pressure, etc.)
  - When the vehicle is being driven on a gravel road or other slippery surface
- **If VSC is disabled**
  - If VSC is disabled (→P. 422), the pre-collision brake assist and pre-collision braking functions are also disabled.
  - The PCS warning light will turn on and “VSC Turned Off Pre-Collision Brake System Unavailable” will be displayed on the multi-information display.



Warning light	Warning light/Details/Actions
	<p><b>SRS warning light</b> Indicates a malfunction in:</p> <ul style="list-style-type: none"> <li>• The SRS airbag system;</li> <li>• The front passenger occupant classification system; or</li> <li>• The seat belt pretensioner system</li> </ul> <p>→ <b>Have the vehicle inspected by your Toyota dealer immediately.</b></p>
	<p><b>ABS warning light</b> Indicates a malfunction in:</p> <ul style="list-style-type: none"> <li>• The ABS; or</li> <li>• The brake assist system</li> </ul> <p>→ <b>Have the vehicle inspected by your Toyota dealer immediately.</b></p>
 <p>(Red/yellow)</p>	<p><b>Electric power steering system warning light (warning buzzer)</b> Indicates a malfunction in the EPS (Electric Power Steering) system</p> <p>→ <b>Have the vehicle inspected by your Toyota dealer immediately.</b></p>
 <p>(Flashes or illuminates) (if equipped)</p>	<p><b>PCS warning light</b></p> <ul style="list-style-type: none"> <li>• When a buzzer sounds simultaneously: Indicates a malfunction has occurred in the PCS (Pre-Collision System).</li> </ul> <p>→ <b>Have the vehicle inspected by your Toyota dealer immediately.</b></p> <ul style="list-style-type: none"> <li>• When a buzzer does not sound: The PCS (Pre-Collision System) has become temporarily unavailable, corrective action may be necessary.</li> </ul> <p>→ <b>Follow the instructions displayed on the multi-information display. (→P. 294, 608)</b></p> <p>If the PCS (Pre-Collision System) or VSC (Vehicle Stability Control) system is disabled, the PCS warning light will illuminate.</p> <p>→ <b>P. 306</b></p>
 <p>(Orange) (if equipped)</p>	<p><b>LTA indicator (warning buzzer)</b> Indicates a malfunction in the LTA (Lane Tracing Assist)</p> <p>→ <b>Follow the instructions displayed on the multi-information display. (→P. 321)</b></p>

 **WARNING**

■ **When using the compact spare tire (if equipped)**

- Remember that the spare tire provided is specifically designed for use with your vehicle. Do not use your spare tire on another vehicle.
- Do not use more than one compact spare tire simultaneously.
- Replace the spare tire with a standard tire as soon as possible.
- Avoid sudden acceleration, abrupt steering, sudden braking and shifting operations that cause sudden engine braking.

■ **When the compact spare tire is attached (if equipped)**

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

- |   |   |
|---|---|
| • ABS & Brake assist                                  | • Cruise control*                                   |
| • VSC   | • BSM (Blind Spot Monitor)*                         |
| • TRAC  | • Intuitive parking assist*                         |
| • EPS   | • Parking Support Brake function*                   |
| • AHB (Automatic High Beam)*                          | • S-APGS (Simple Advanced Parking Guidance System)* |
| • PCS (Pre-Collision System)*                         | • Rear view monitor system                          |
| • LTA (Lane Tracing Assist)*                          | • Navigation system*                                |
| • Dynamic radar cruise control with full-speed range* |   |

Also, not only can the following system not be utilized fully, but it may even negatively affect the drive-train components:

- E-Four (Electric Four wheel drive system)\*

\*: If equipped

■ **Speed limit when using the compact spare tire (if equipped)**

Do not drive at speeds in excess of 50 mph (80 km/h) when a compact spare tire is installed on the vehicle.

The compact spare tire is not designed for driving at high speeds. Failure to observe this precaution may lead to an accident causing death or serious injury.

■ **After using the tools and jack**

Before driving, make sure all the tools and jack are securely in place in their storage location to reduce the possibility of personal injury during a collision or sudden braking.

## APPENDIX C

### Run Log

Subject Vehicle: **2021 Toyota Prius LE Hybrid**

Test Date: **3/31/2021**

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						Zero SV front bumper to SSV rear bumper and collect data
18	<b>Stopped POV</b>	N					Incorrect brake parameters used
19		N					Incorrect brake parameters used
20		N					Incorrect brake parameters used
21		N					Incorrect brake parameters used
22		N					Incorrect brake parameters used
23		N					Incorrect brake parameters used
24		N					Incorrect brake parameters used
25		N					Incorrect brake parameters used
26	Static Run						
109	Brake Check Run						Brake Stroke = 2.24 in, Brake Force = 10.4 lb
110	Brake Check Run						Brake Stroke = 2.2 in, Brake Force = 10 lb
111	Static						
112	<b>Stopped POV</b>	Y	2.44	13.19	1.13	Pass	
113		Y	2.43	12.77	1.14	Pass	
114		Y	2.43	12.41	1.09	Pass	
115		Y	2.43	12.49	1.16	Pass	
116		Y	2.44	12.33	1.10	Pass	
117		Y	2.38	11.55	1.04	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
118	<b>Stopped POV</b>	Y	2.45	13.34	1.14	Pass	
119	Static Run						
27	<b>Slower POV, 25 vs 10</b>	N					Incorrect brake parameters used
28		N					Incorrect brake parameters used
29		N					Incorrect brake parameters used
30		N					Incorrect brake parameters used
31		N					Incorrect brake parameters used
32		N					Incorrect brake parameters used
33		N					Incorrect brake parameters used
34	Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)
120	<b>Slower POV, 25 vs 10</b>	N					POV GPS
121		Y	2.15	7.27	1.10	Pass	
122		Y	2.31	0.00	0.44	Fail	
123		Y	2.16	1.53	1.06	Pass	
124		Y	2.32	0.92	0.47	Pass	
125		Y	2.49	6.92	1.09	Pass	
126		Y	2.20	6.68	1.04	Pass	
127		Y	2.21	7.54	1.14	Pass	
128	Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)
35	<b>Slower POV, 45 vs 20</b>	Y	2.79	11.92	1.04	Pass	
36		Y	2.86	12.39	1.05	Pass	
37		Y	2.85	11.73	0.98	Pass	
38		Y	2.80	11.22	0.97	Pass	
39		Y	2.89	12.18	1.00	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
40	<b>Slower POV, 45 vs 20</b>	Y	2.77	10.77	1.01	Pass	
41		Y	2.90	11.56	1.04	Pass	
42	Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)
43	<b>Decelerating POV</b>	N					Incorrect brake parameters used
44		N					Incorrect brake parameters used
45		N					Incorrect brake parameters used
46		N					Incorrect brake parameters used
47		N					Incorrect brake parameters used
48		N					Incorrect brake parameters used
49		N					Incorrect brake parameters used
50		N					Incorrect brake parameters used
51	Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)
97	Brake Check Run						Retest 4/6/21
98	Static						
99	<b>Decelerating POV</b>	Y	1.78	0.00	1.01	Fail	
100		Y	1.72	0.00	0.47	Fail	
101		Y	1.74	0.00	0.47	Fail	
102		N					TTC timing
103		Y	1.77	2.87	1.05	Pass	
104		N					Throttle
105		N					TTC timing
106		N					Throttle
107		Y	1.82	0.00	0.51	Fail	

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
108	Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)
129	<b>Decelerating POV, 35</b>	N					Check run
130		N					Brakes too high
131-146	Check Runs	N					Check runs
147	Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)
52	STP - Static run						Zero SV front bumper to rear edge of steel plate and collect data
53	<b>Baseline, 25</b>	N					Brake
54		Y			0.46		
55		Y			0.44		
56		Y			0.45		
57		Y			0.44		
58		Y			0.42		
59		Y			0.43		
60		Y			0.45		
61	STP - Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)
62	<b>Baseline, 45</b>	N					Speed
63		N					Light brake
64		Y			0.42		
65		Y			0.42		
66		Y			0.38		

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes	
67	<b>Baseline, 45</b>	N					Brake high	
68		Y			0.47			
69		Y			0.45			
70		Y			0.42			
71		Y			0.41			
72	STP - Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)	
73	<b>STP False Positive, 25</b>	Y			0.37	Pass		
74		N					Brake zero issue	
75		N					Brake zero issue	
76		N					Brake zero issue	
77		N					Brake zero issue	
78		Y				0.44	Pass	
79		Y				0.41	Pass	
80		Y				0.44	Pass	
81		Y				0.41	Pass	
82		N						Speed
83		Y				0.42	Pass	
84		Y				0.41	Pass	
85	STP - Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)	
86	<b>STP False Positive, 45</b>	N					Light brake	
87		Y			0.45	Pass		
88		Y			0.43	Pass		
89		N					Throttle	
90		Y				0.40	Pass	



Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
91	<b>STP False Positive, 45</b>	Y			0.41	Pass	
92		N					Throttle
93		Y			0.40	Pass	
94		Y			0.43	Pass	
95		Y			0.45	Pass	
96	STP - Static run						Check zero data is within $\pm 0.167$ ft ( $\pm 0.05$ m)

## APPENDIX D

### Brake Characterization

Subject Vehicle: 2021 Toyota Prius LE Hybrid

Test Date: 3/31/2021

DBS Initial Brake Characterization				
Run Number	Stroke at 0.4 g (in)	Force at 0.4 g (lb)	Slope	Intercept
1	2.34	10.13	0.45	0.01
2	2.38	10.30	0.46	0.13
3	2.40	10.23	0.46	-0.05

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
4	Displacement	35	Y	0.451	2.38		2.11	
5		35	Y	0.391	2.20		2.25	
6		25	Y	0.381	2.20		2.31	
7		25	Y	0.386	2.24		2.32	
8		45	Y	0.394	2.24		2.27	
9	Hybrid	35	Y	0.388		10.22	10.54	
10		35	Y	0.393		10.40	10.59	
11		25	Y	0.407		10.40	10.22	
12		25	Y	0.392		10.40	10.61	
13		45	Y	0.441		10.40	9.43	
14		45	Y	0.472		10.18	8.63	

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
15	Hybrid	45	Y	0.420		9.40	8.95	
16		45	Y	0.389		9.05	9.31	

Appendix E

TIME HISTORY PLOTS

## LIST OF FIGURES

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

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

- Headway (ft) – Longitudinal separation between the front-most 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.

## 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 0.27 g (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 0.27 g. A green circle indicates that the test was valid (the threshold was crossed during the appropriate interval) and a red asterisk indicates that the test was invalid (the threshold was crossed 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 Figures 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.

### **Notes**

For valid runs, plots are shown for all warning types. In some cases, one of the plots may indicate that a run was invalid, but if the run was valid for either warning type it is considered valid. The companion plots are shown for the sake of completeness.

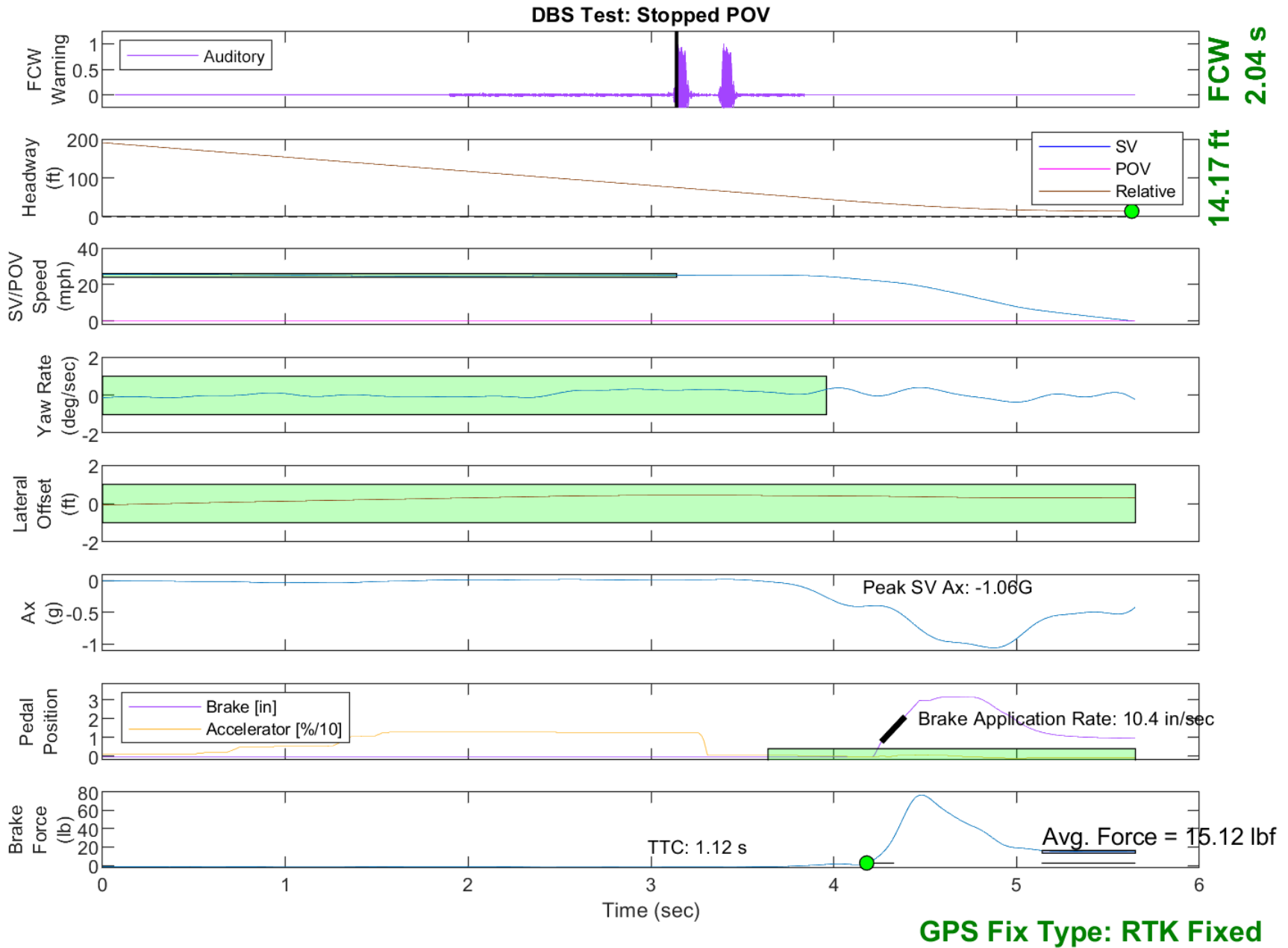


Figure E1. Example Time History for Stopped POV, Passing

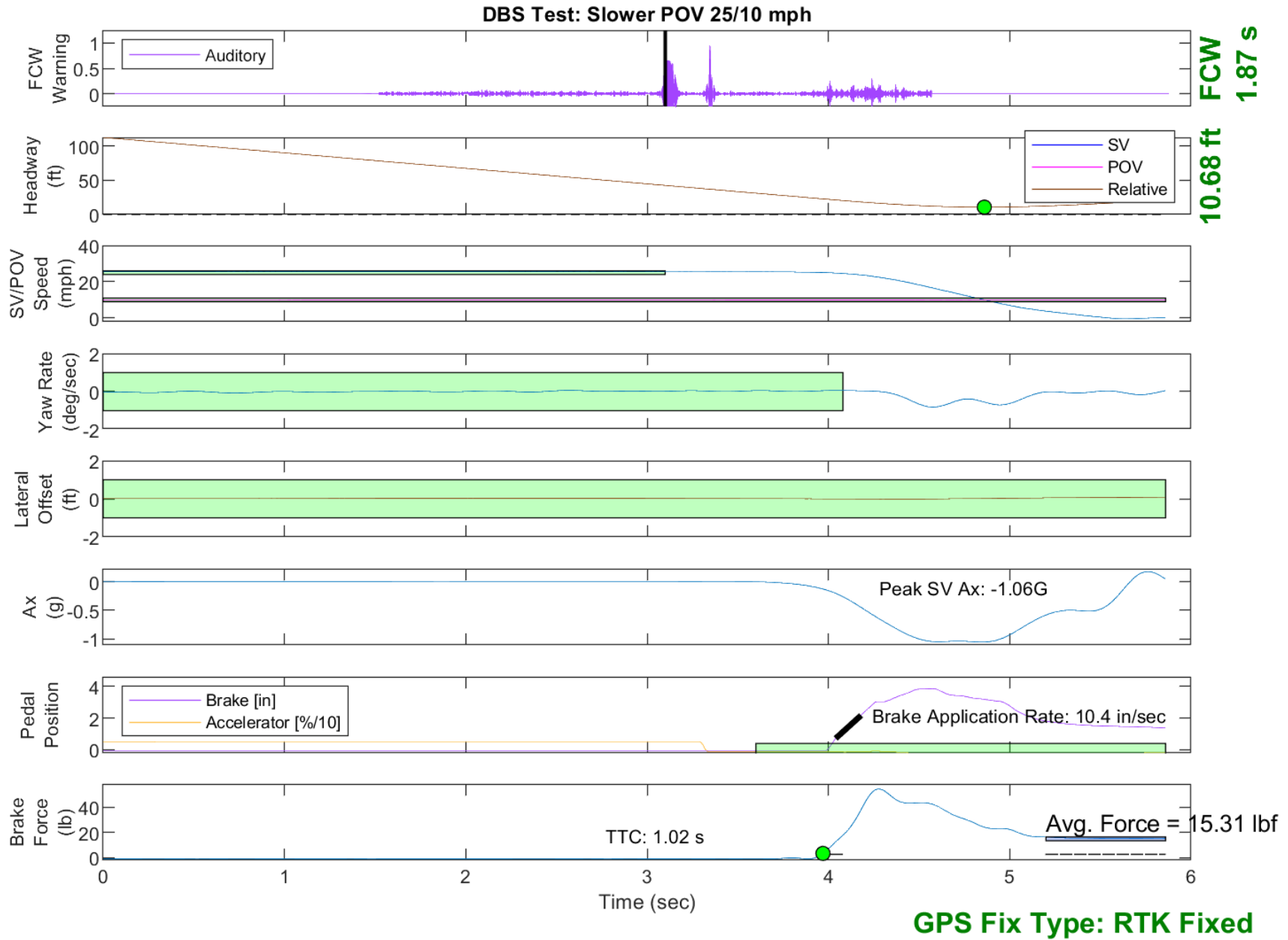


Figure E2. Example Time History for Slower POV 25 vs. 10, Passing



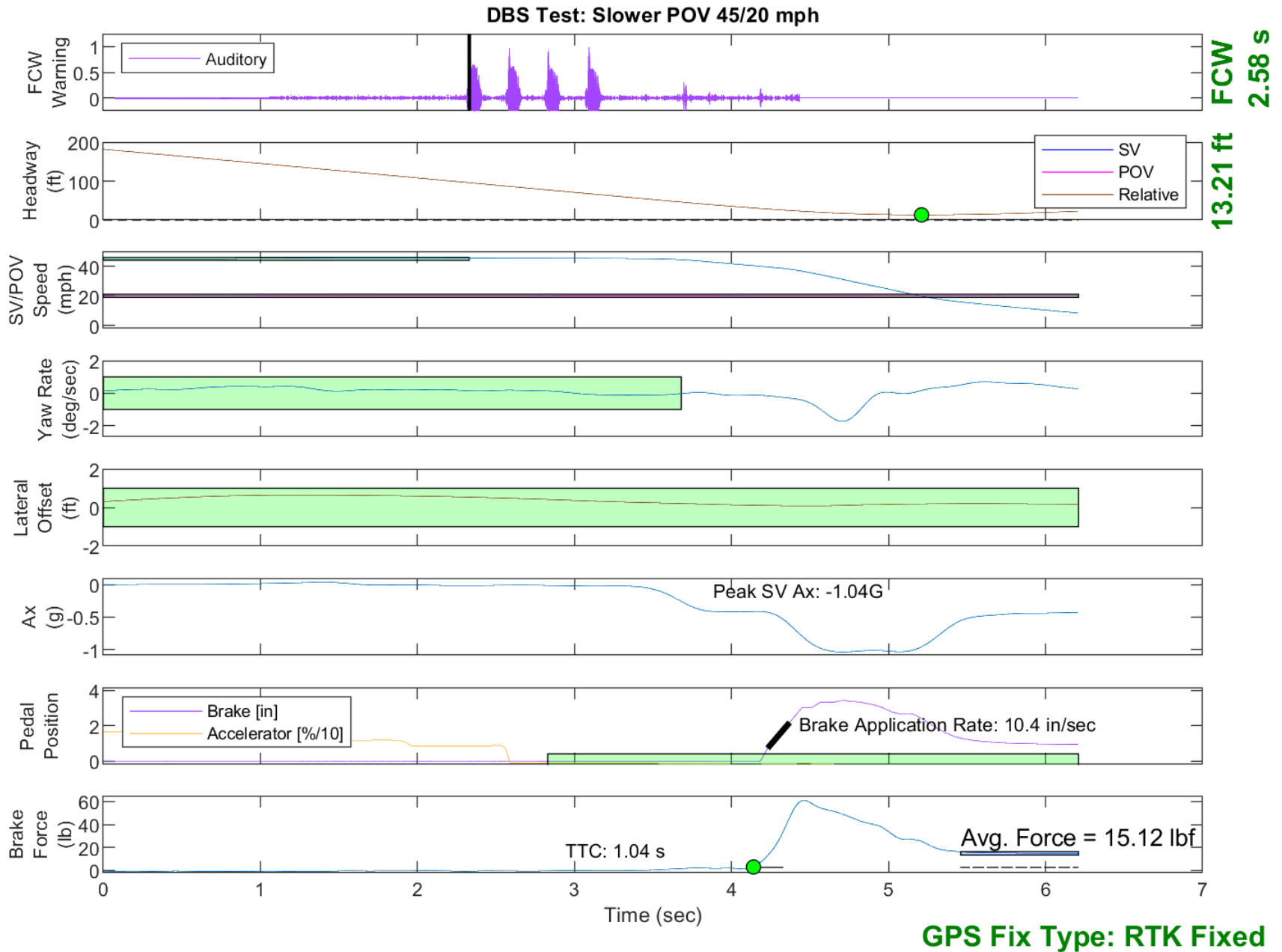


Figure E3. Example Time History for Slower POV 45 vs. 20, Passing

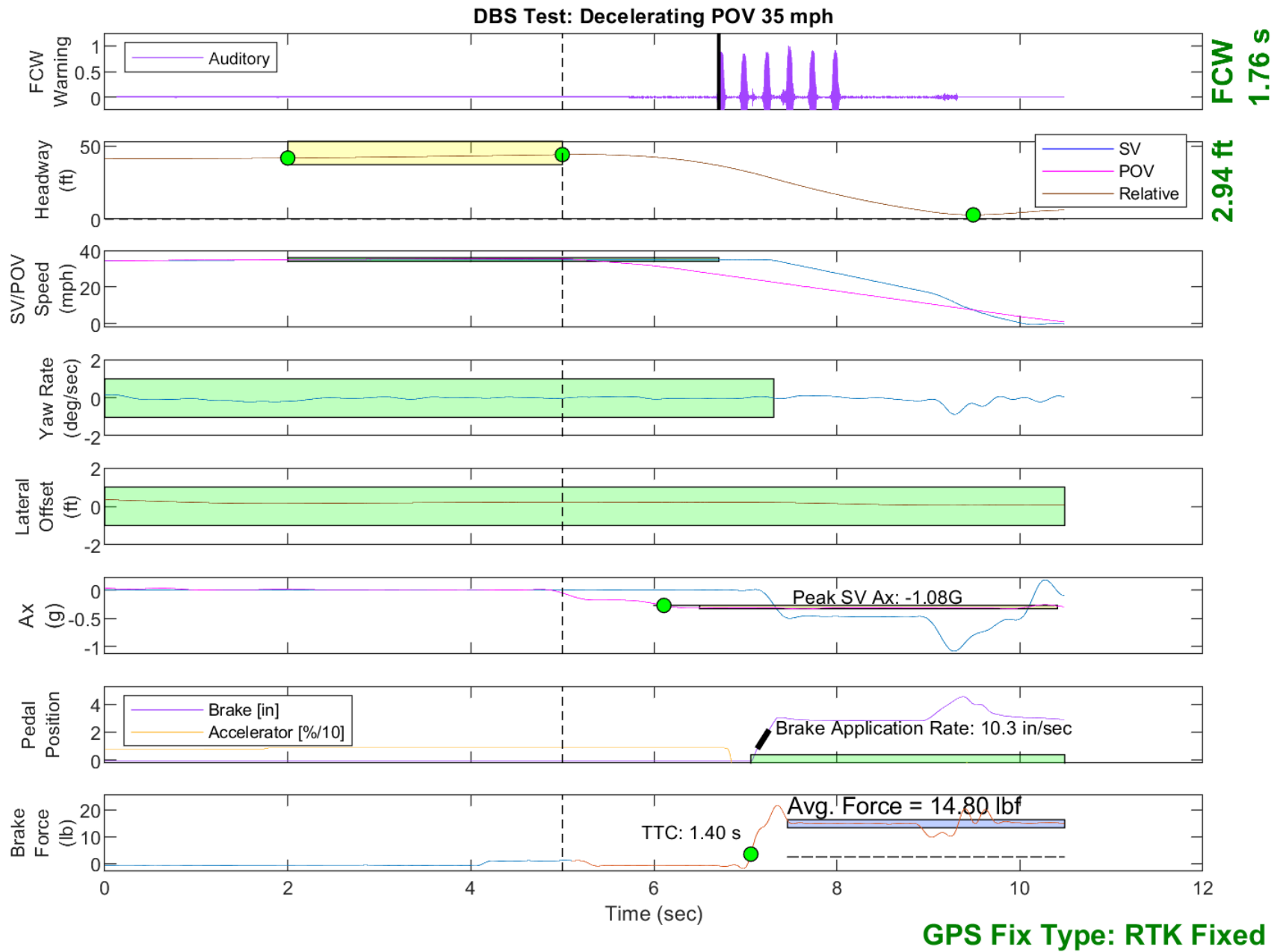
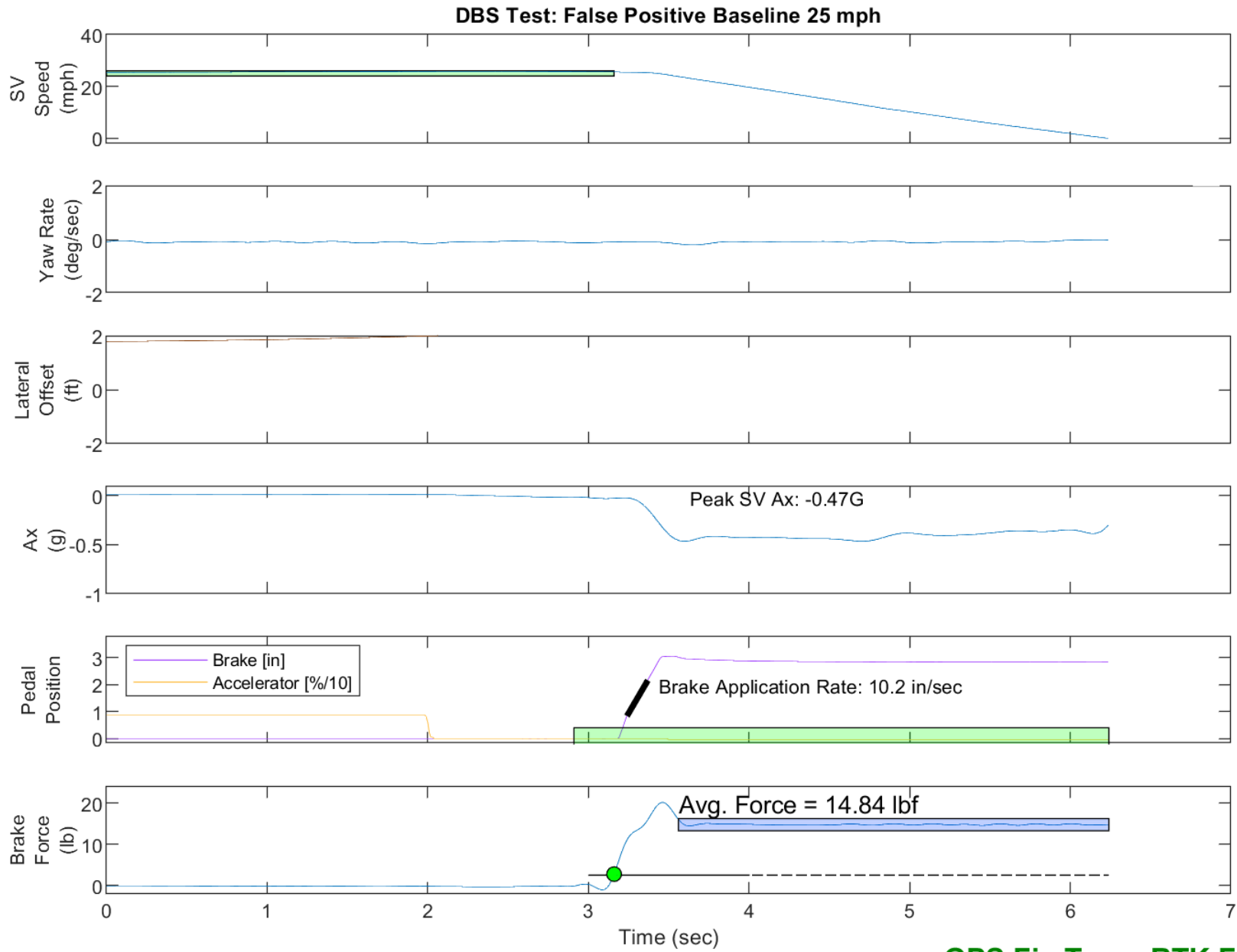
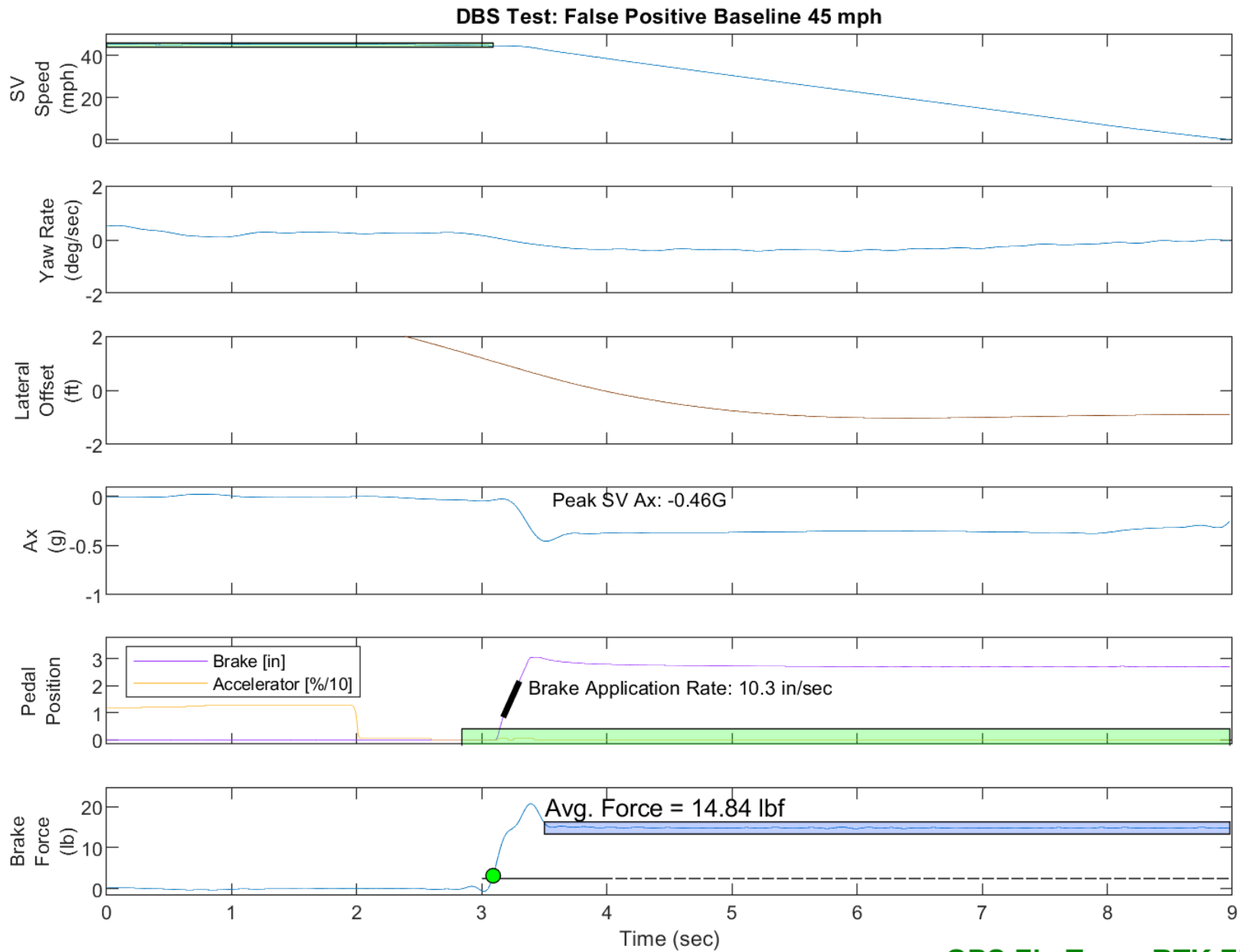


Figure E4. Example Time History for Decelerating POV 35, Passing



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

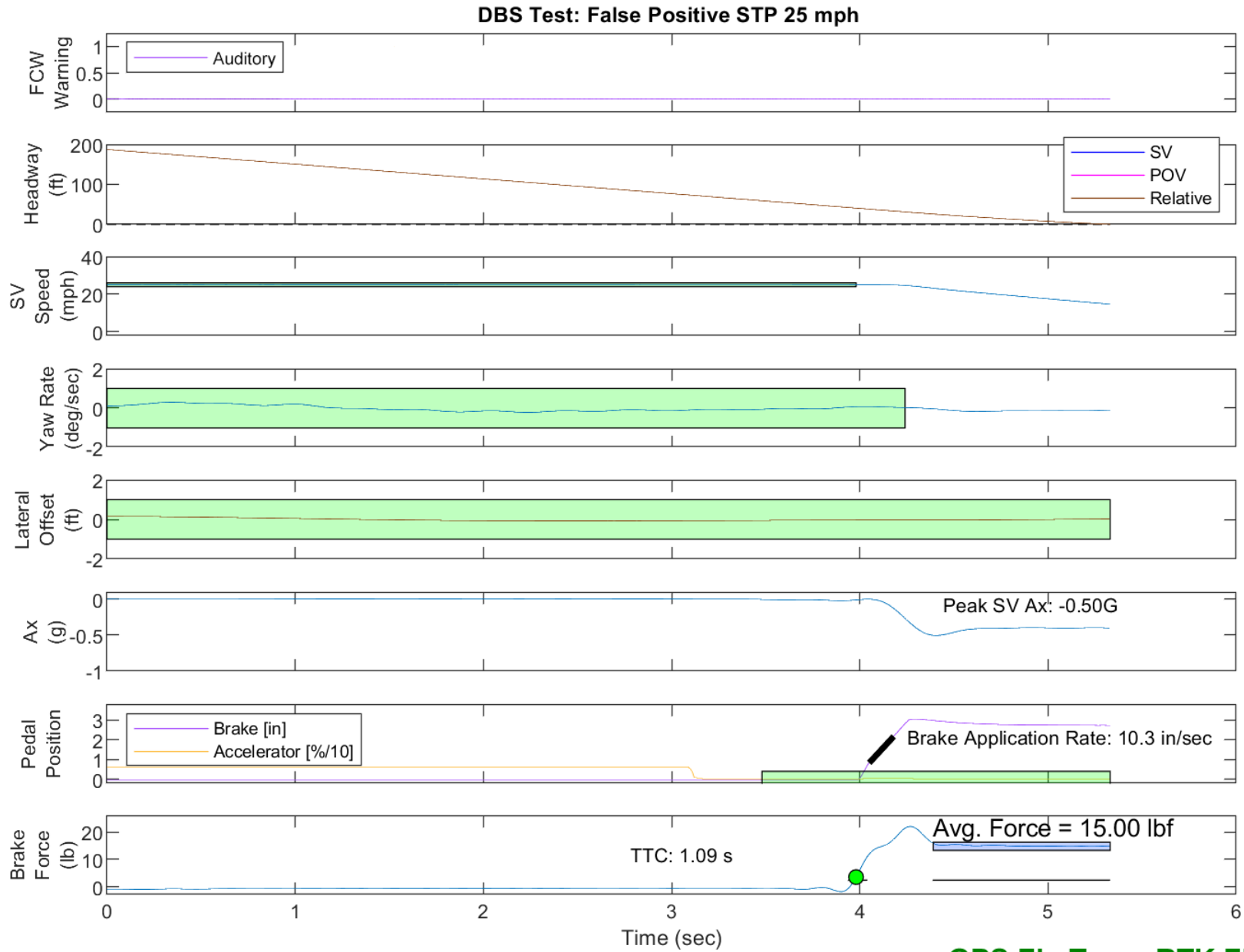
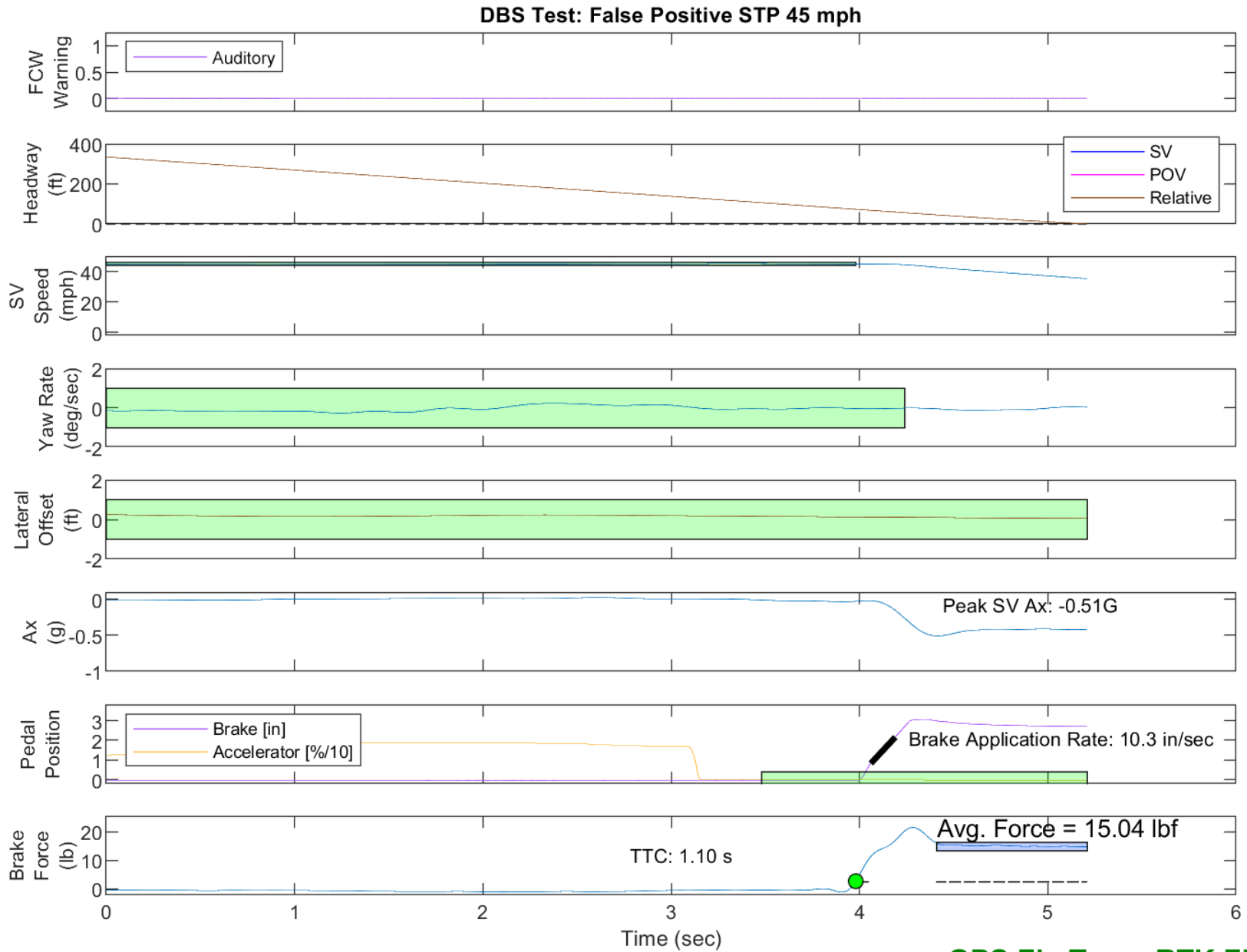


Figure E7. Example Time History for False Positive Steel Plate 25, Passing



**GPS Fix Type: RTK Fixed**

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

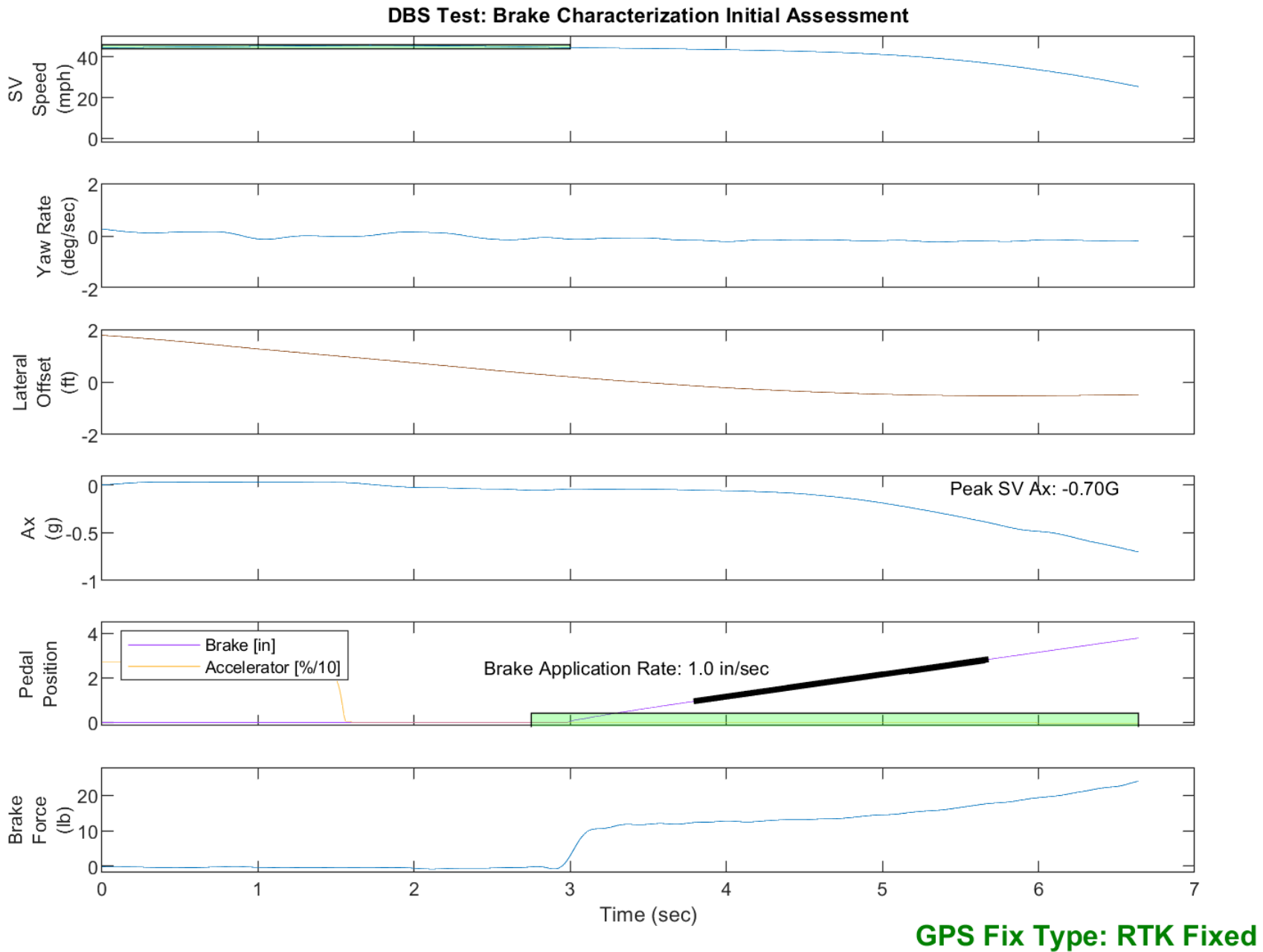


Figure E9. Example Time History for DBS Brake Characterization, Passing

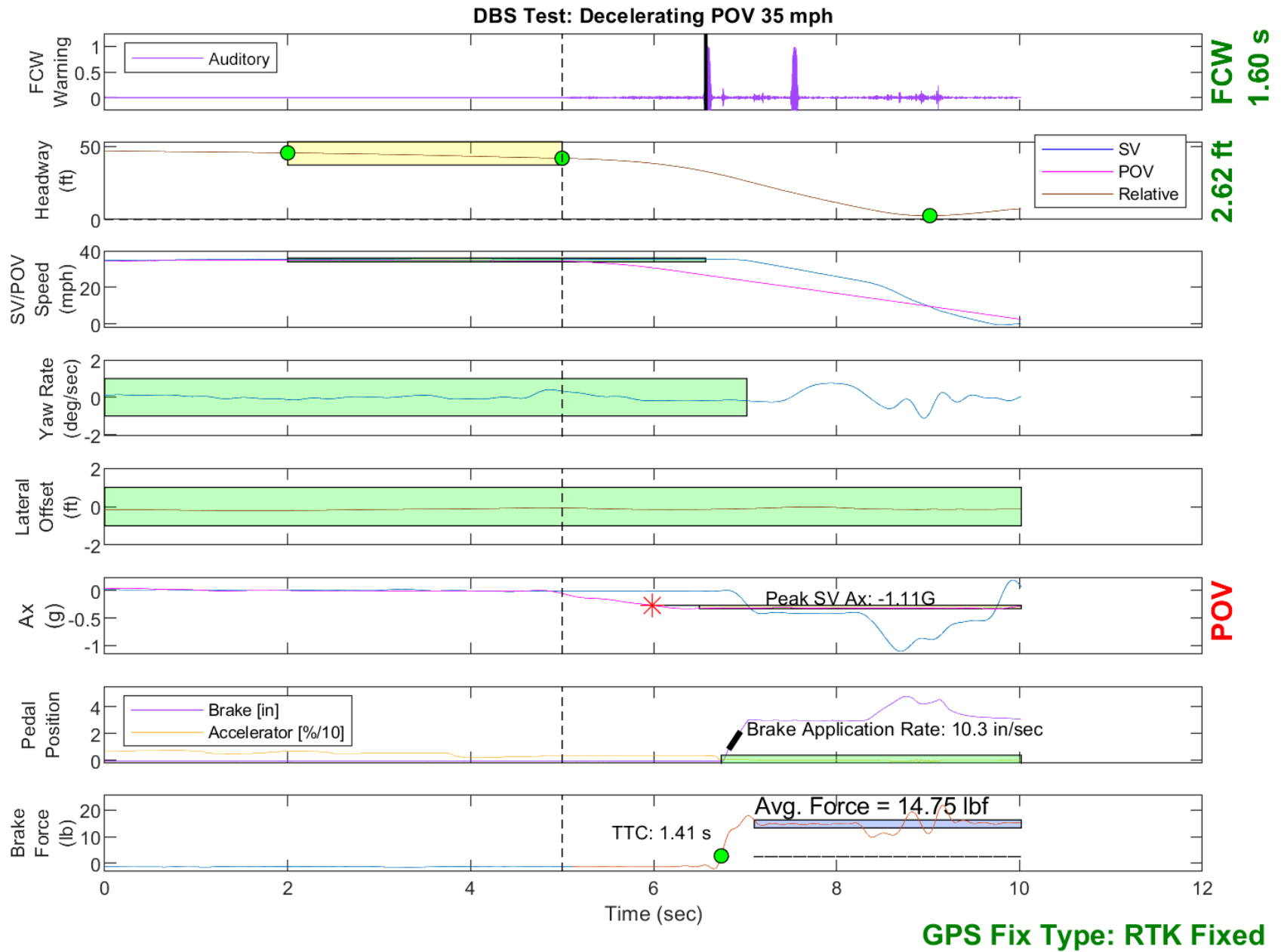
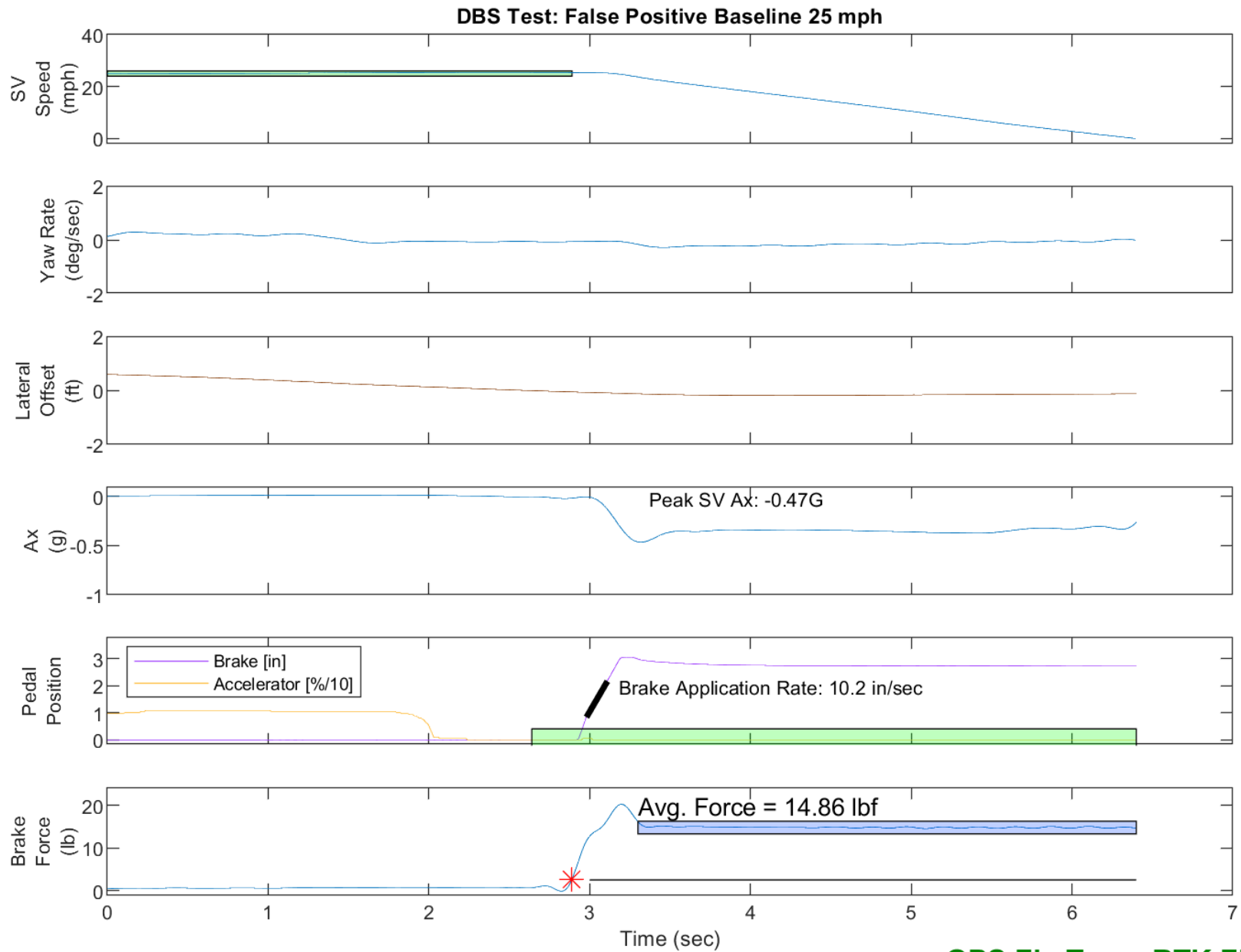


Figure E10. Example Time History Displaying Invalid POV Acceleration Criteria





**GPS Fix Type: RTK Fixed**

Figure E11. Example Time History Displaying Invalid Brake Force Criteria

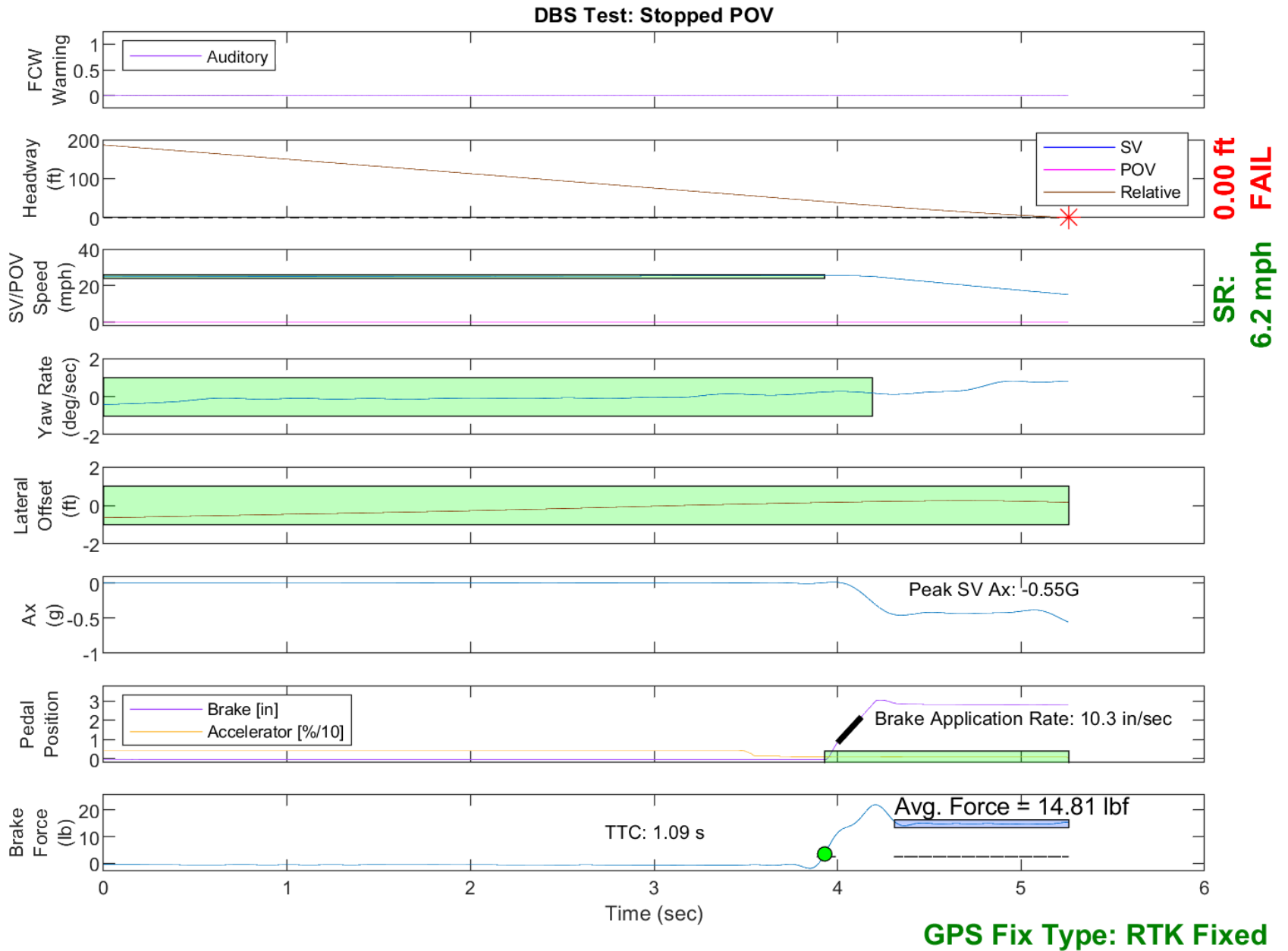


Figure E12. Example Time History for a Failed Run

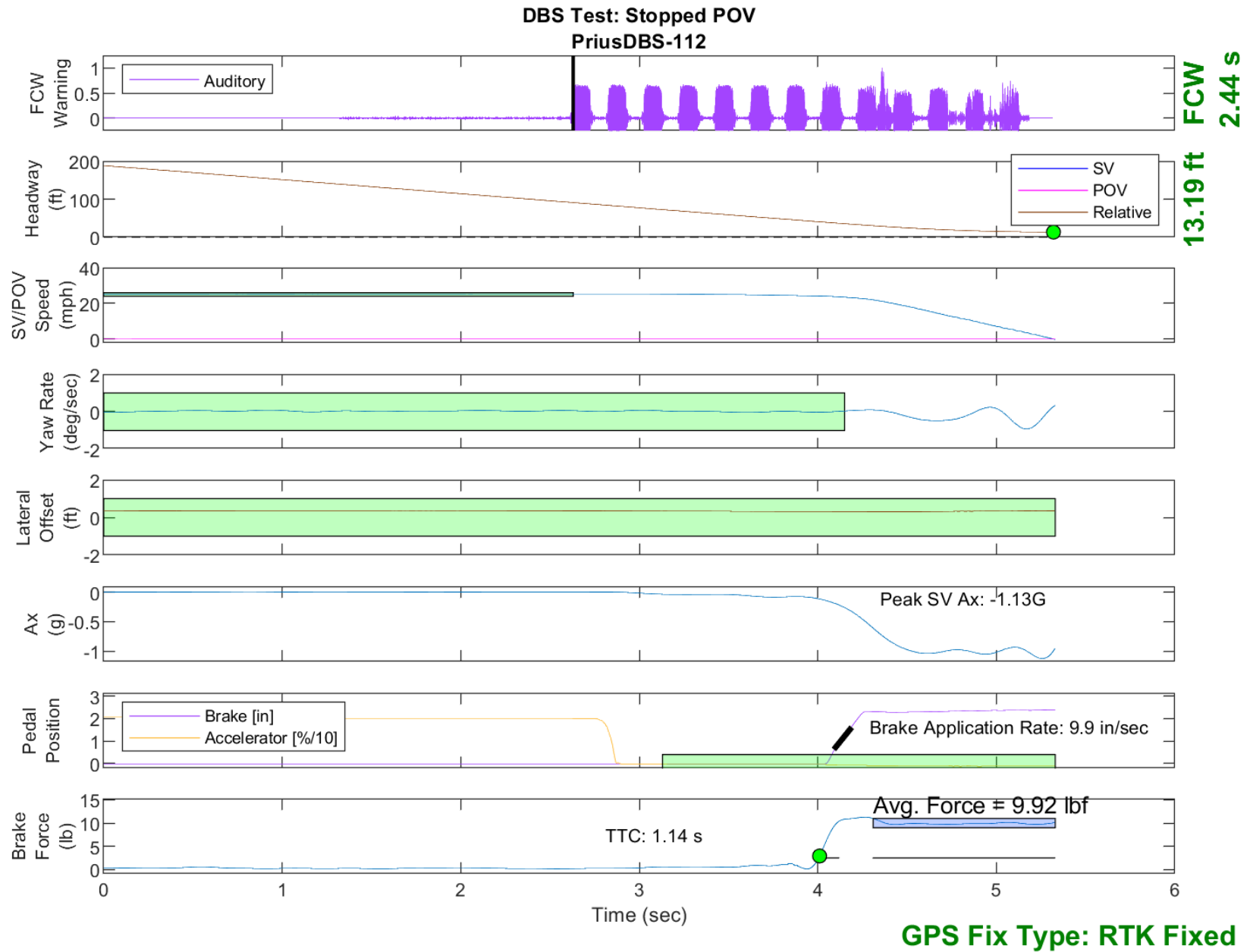


Figure E13. Time History for DBS Run 112, SV Encounters Stopped POV

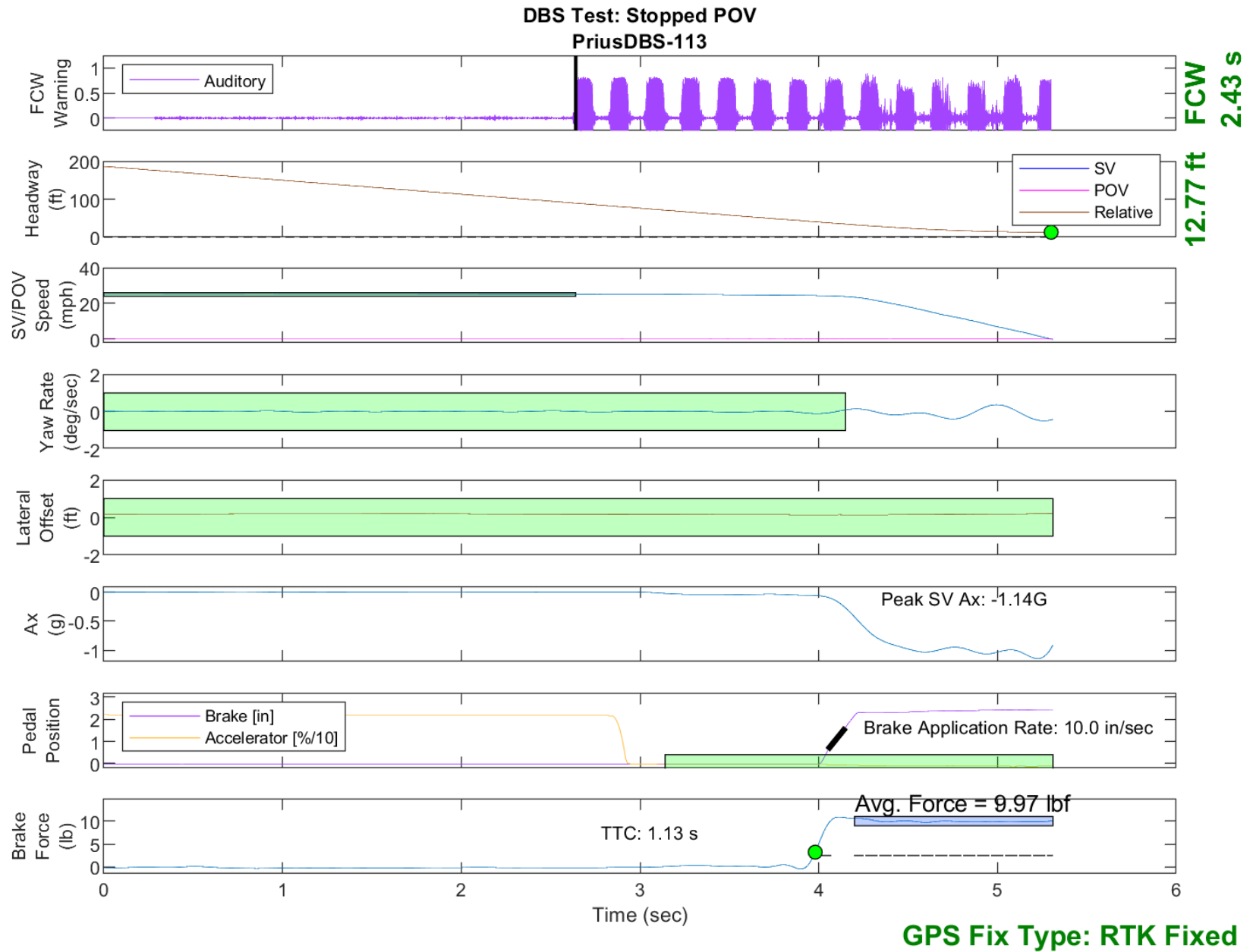


Figure E14. Time History for DBS Run 113, SV Encounters Stopped POV

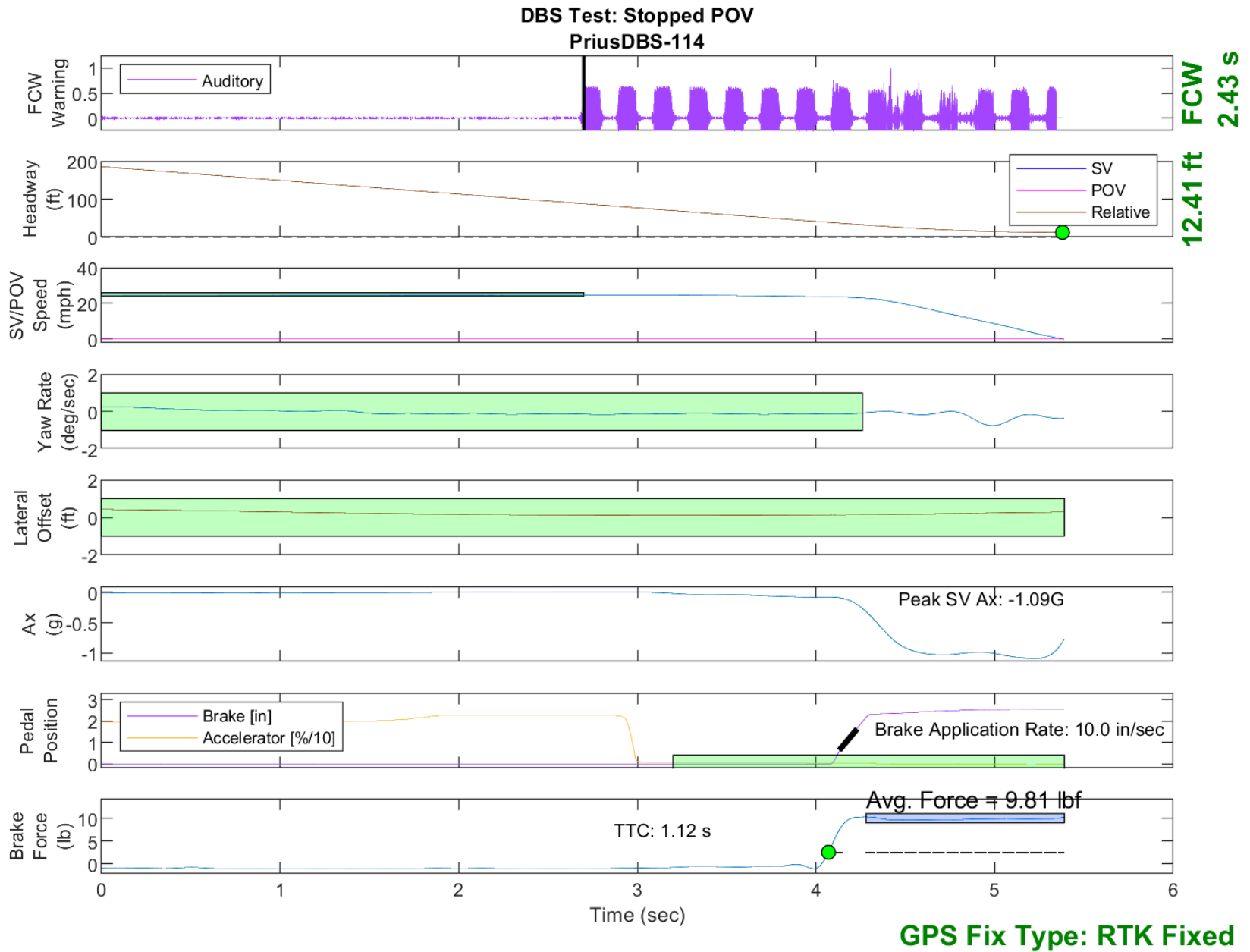


Figure E15. Time History for DBS Run 114, SV Encounters Stopped POV

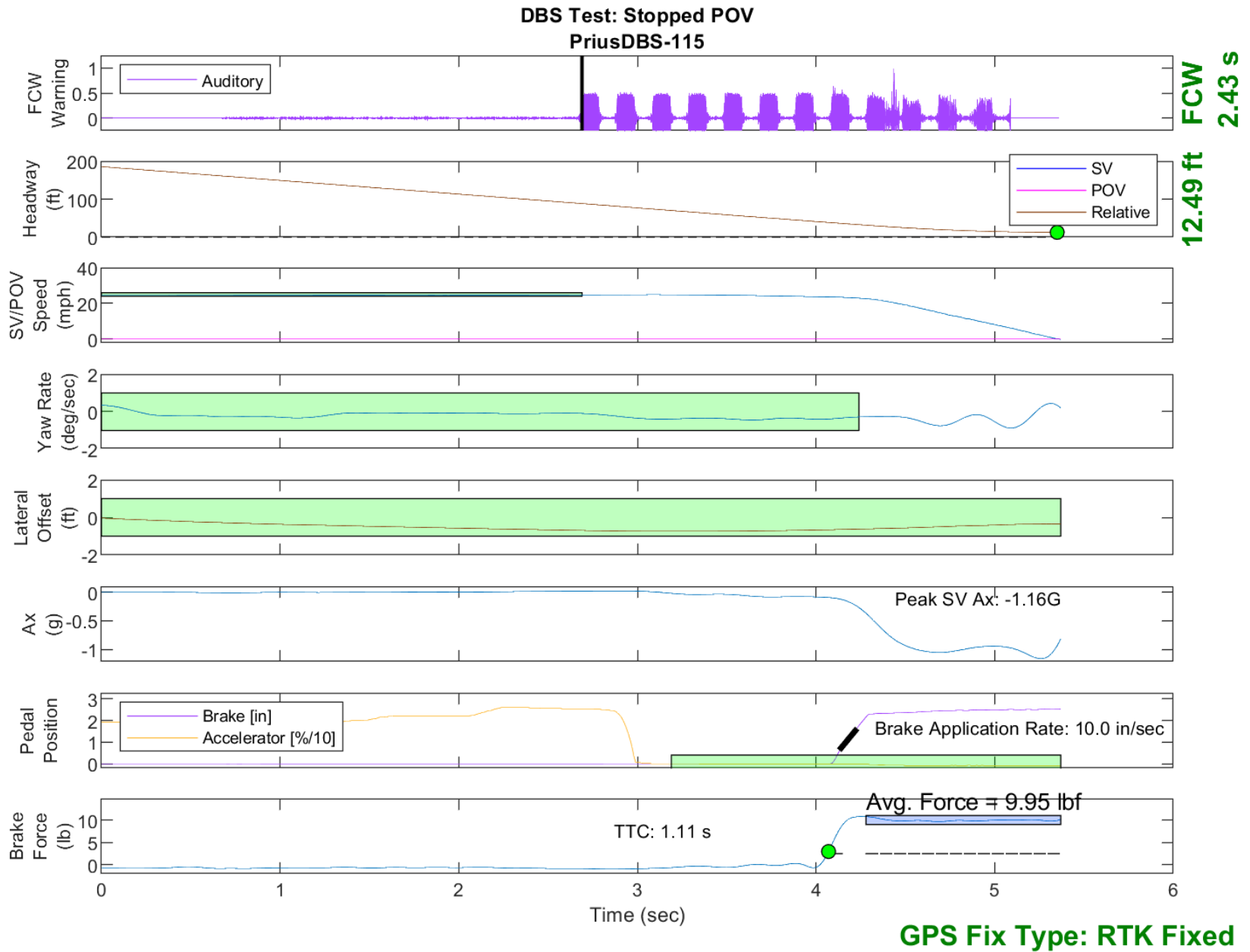


Figure E16. Time History for DBS Run 115, SV Encounters Stopped POV

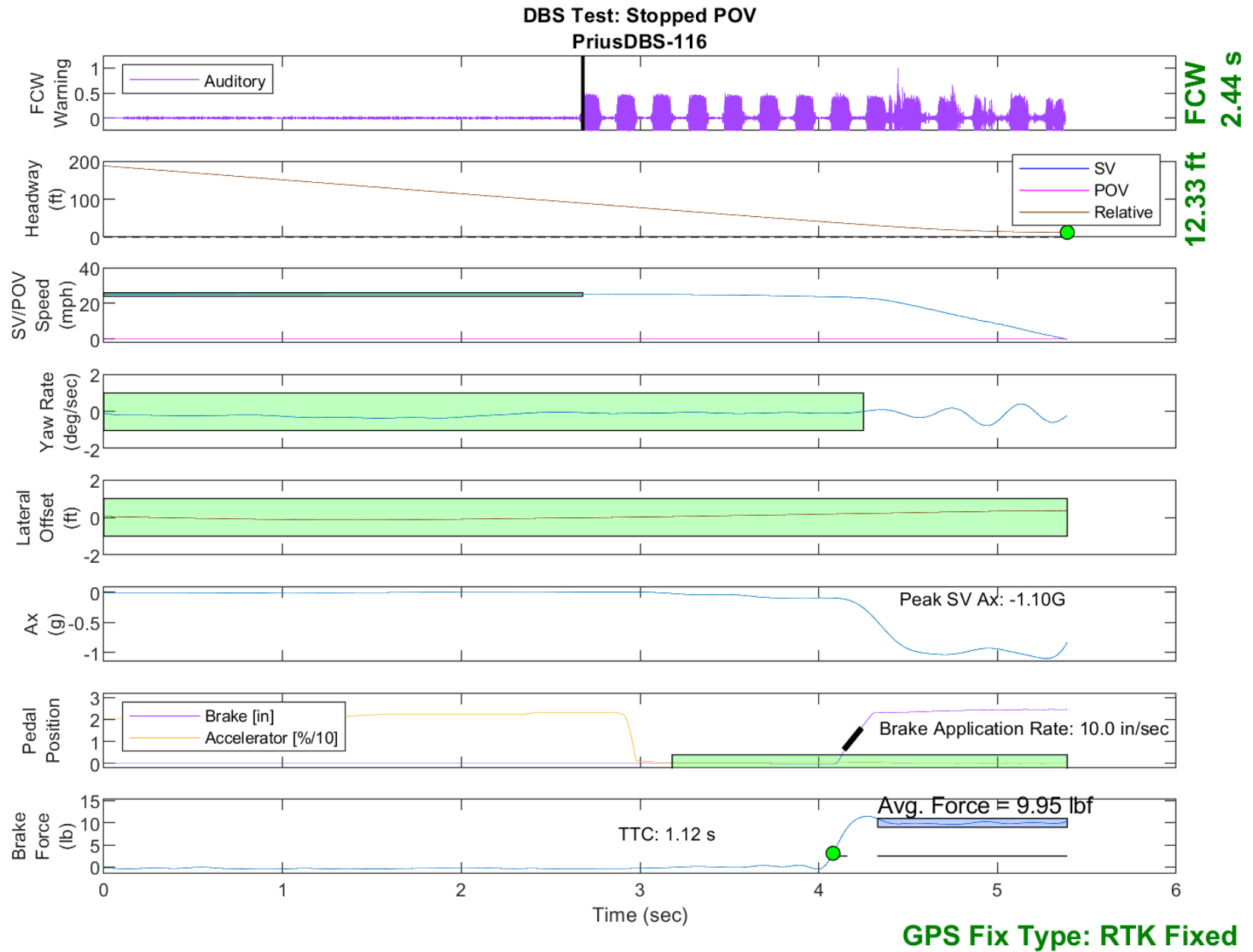


Figure E17. Time History for DBS Run 116, SV Encounters Stopped POV

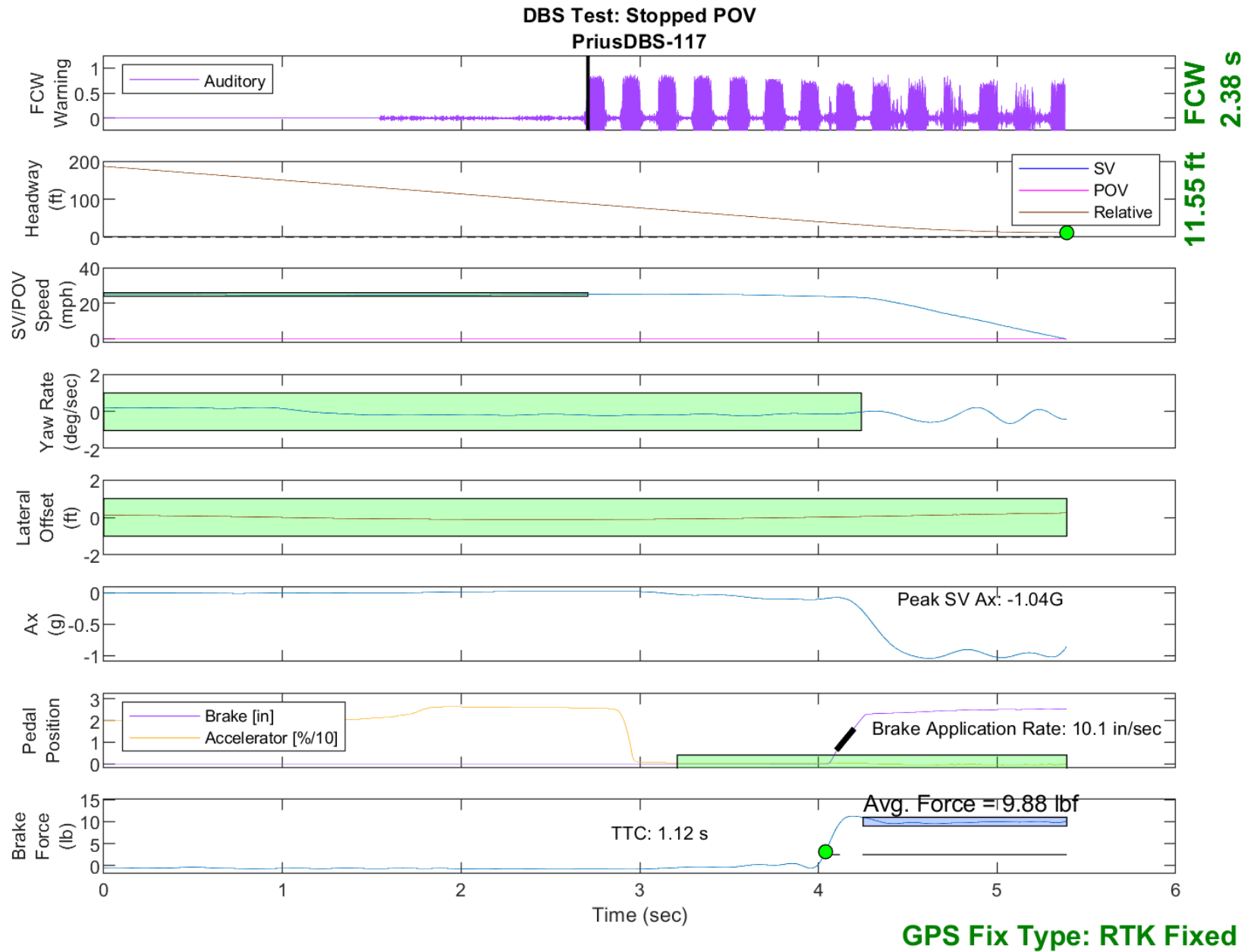


Figure E18. Time History for DBS Run 117, SV Encounters Stopped POV



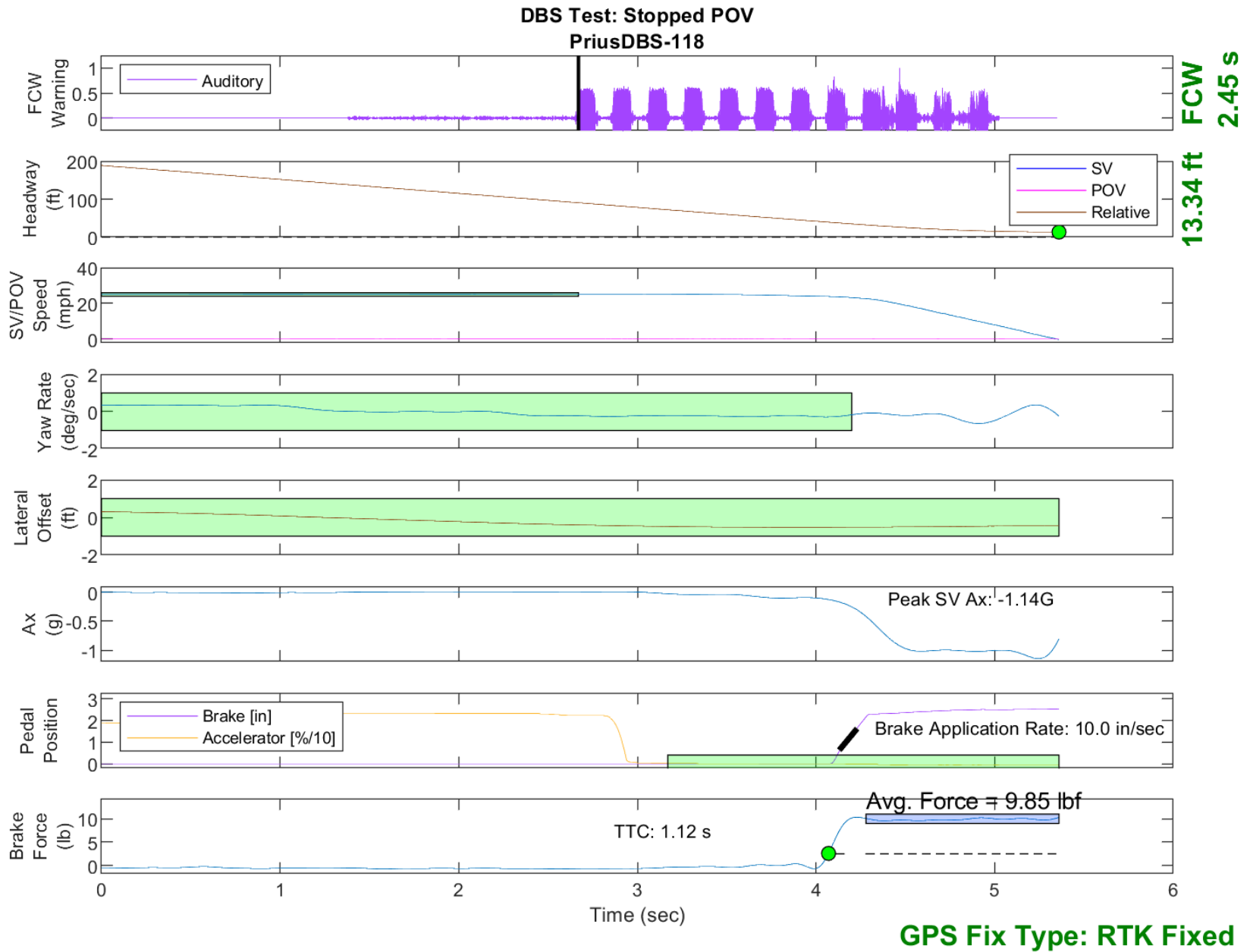


Figure E19. Time History for DBS Run 118, SV Encounters Stopped POV

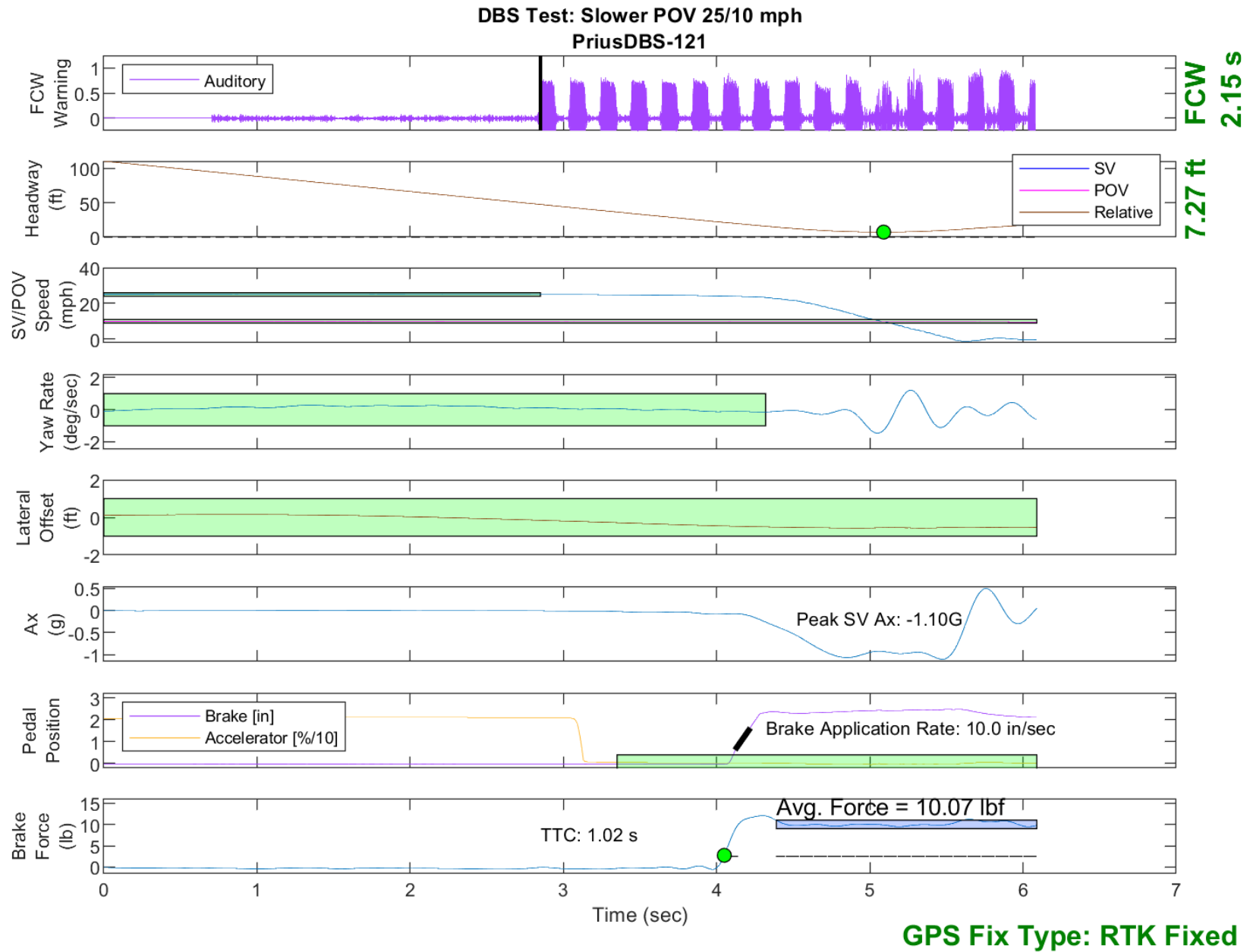


Figure E20. Time History for DBS Run 121, SV Encounters Slower POV, SV 25 mph, POV 10 mph

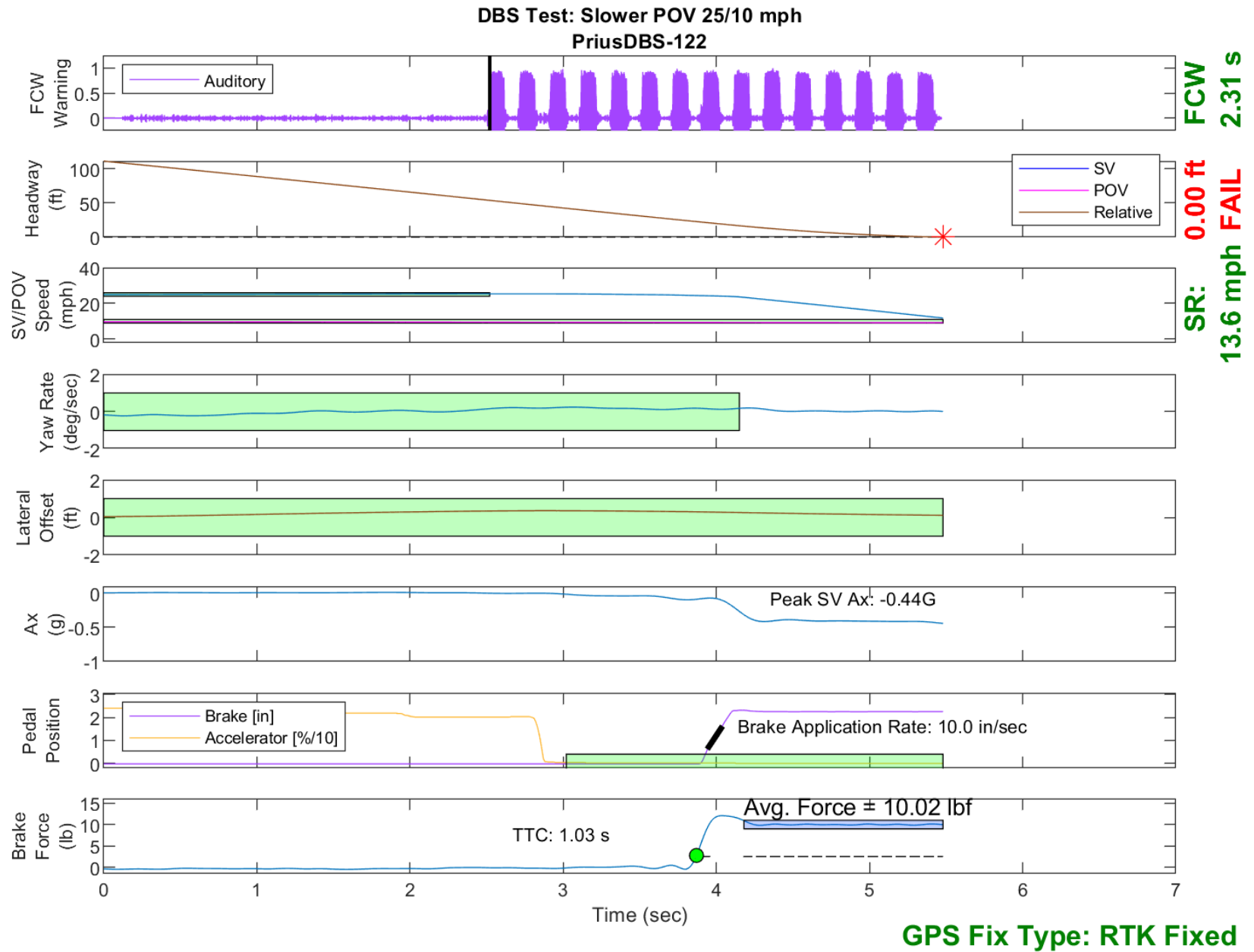


Figure E21. Time History for DBS Run 122, SV Encounters Slower POV, SV 25 mph, POV 10 mph

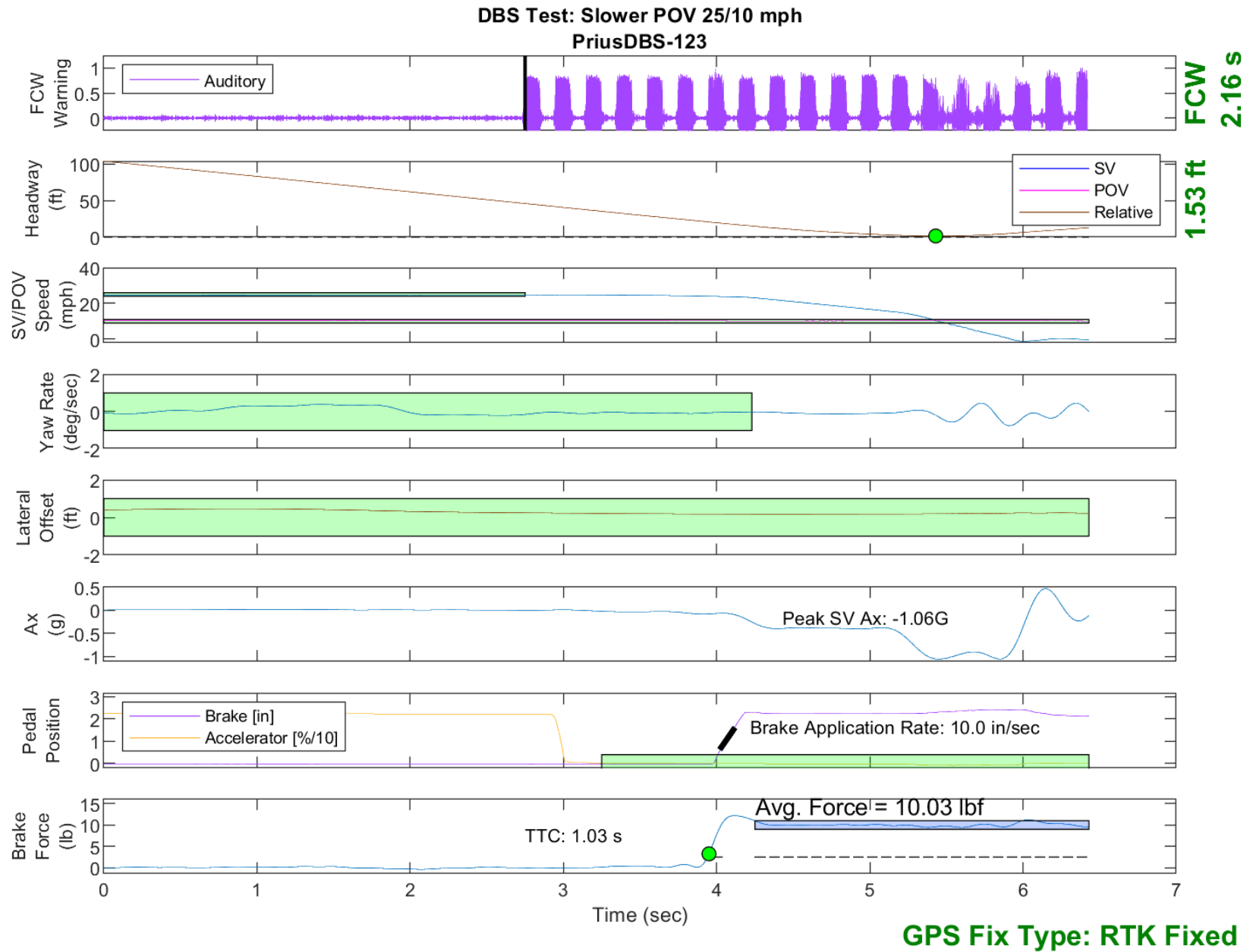


Figure E22. Time History for DBS Run 123, SV Encounters Slower POV, SV 25 mph, POV 10 mph

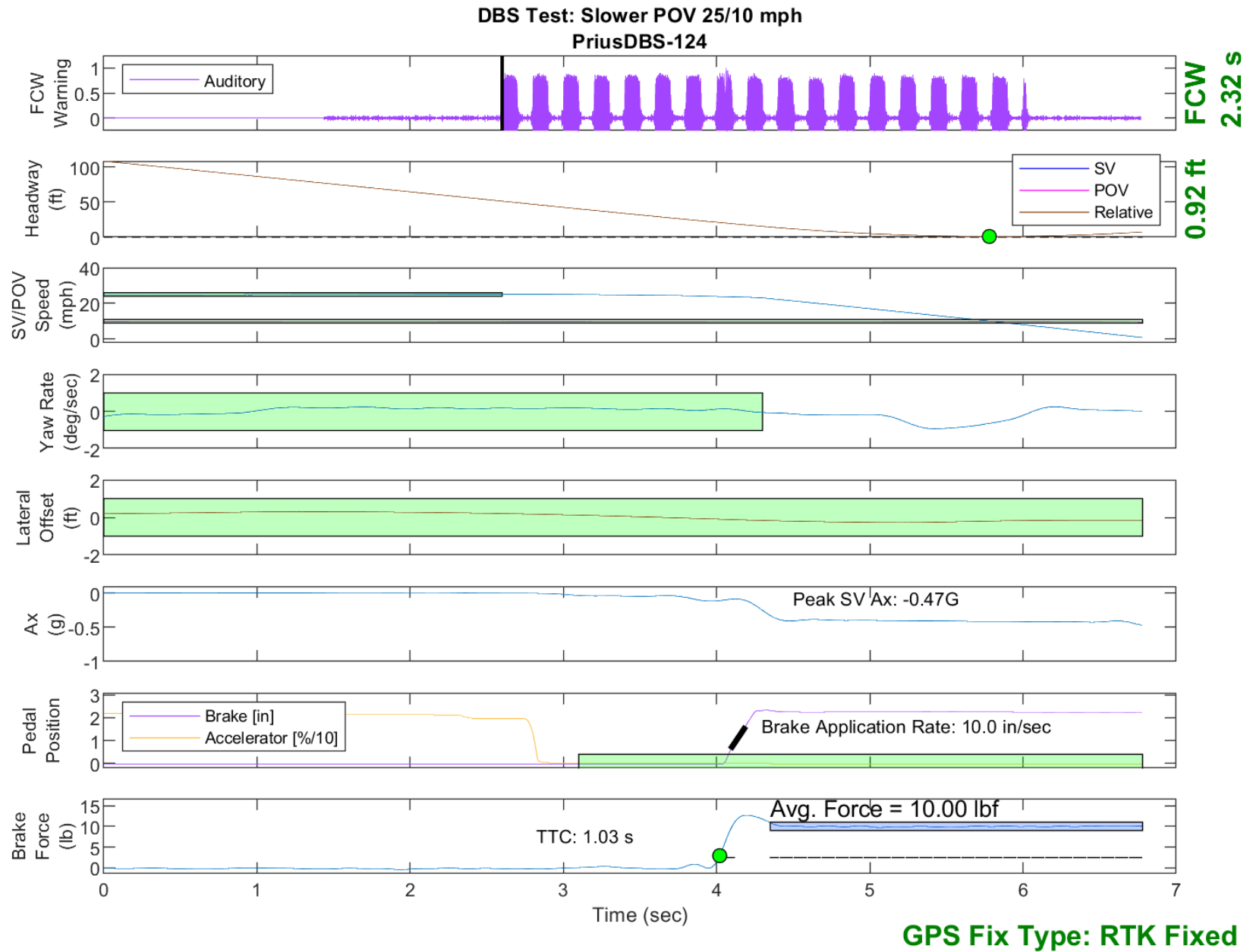


Figure E23. Time History for DBS Run 124, SV Encounters Slower POV, SV 25 mph, POV 10 mph

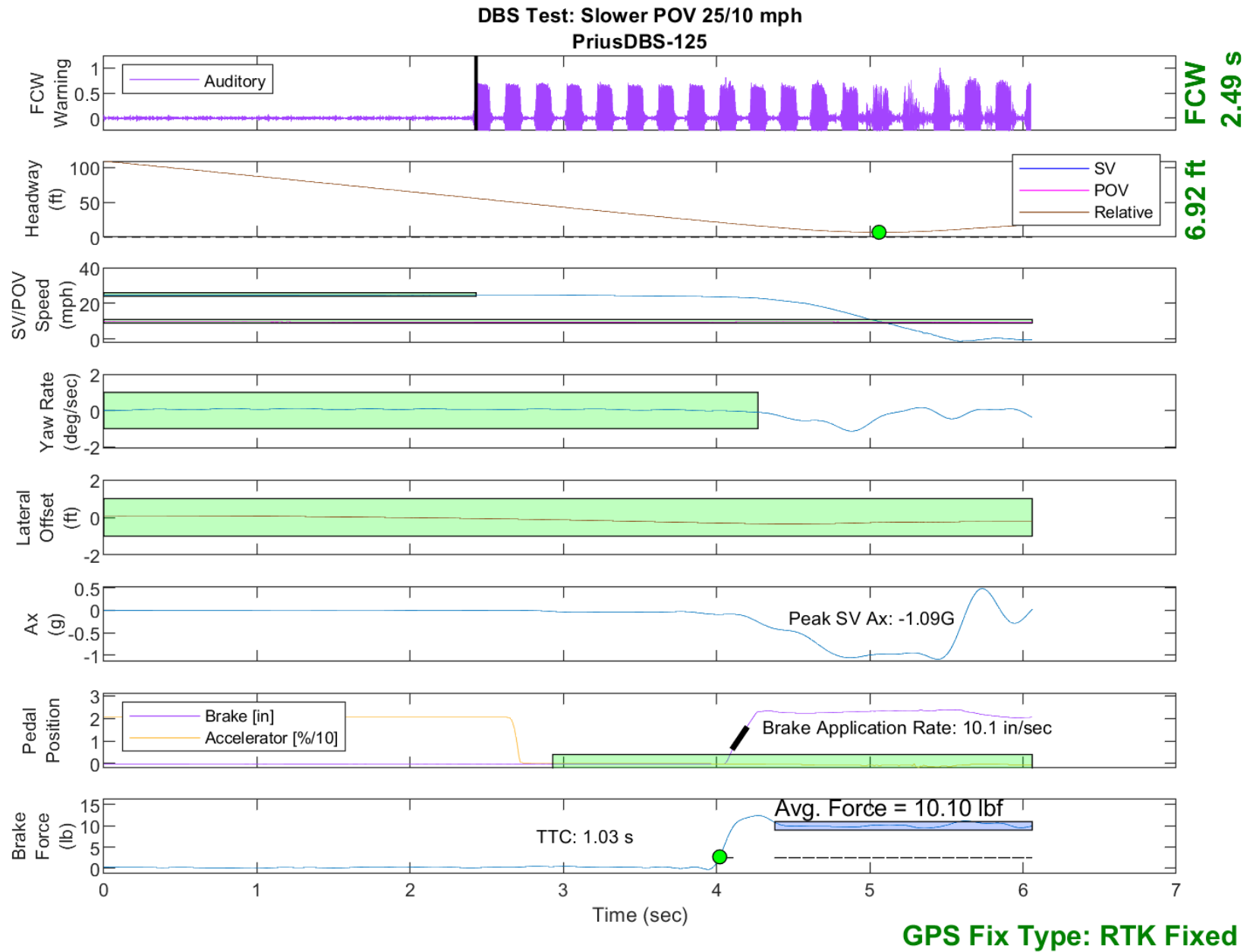


Figure E24. Time History for DBS Run 125, SV Encounters Slower POV, SV 25 mph, POV 10 mph

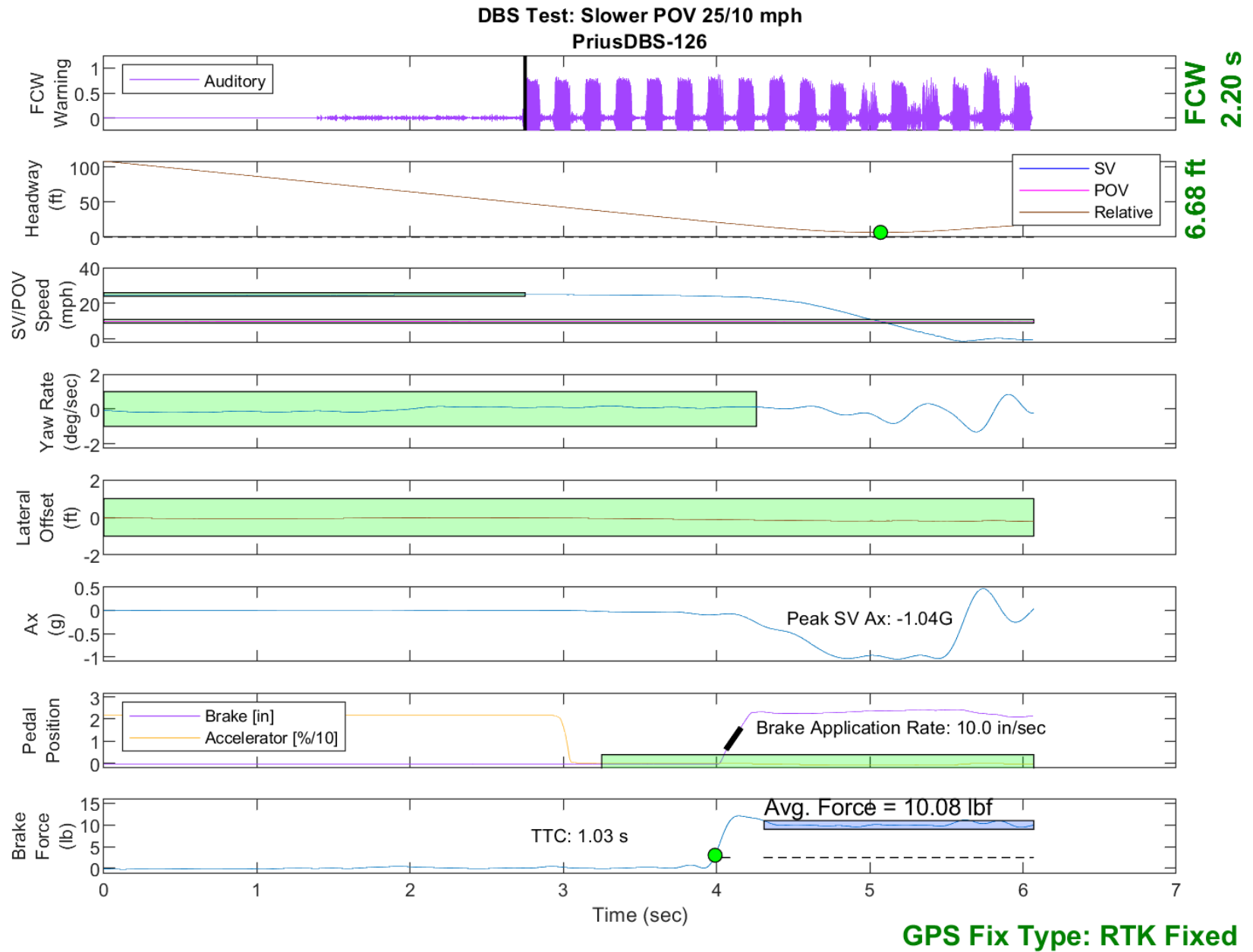


Figure E25. Time History for DBS Run 126, SV Encounters Slower POV, SV 25 mph, POV 10 mph

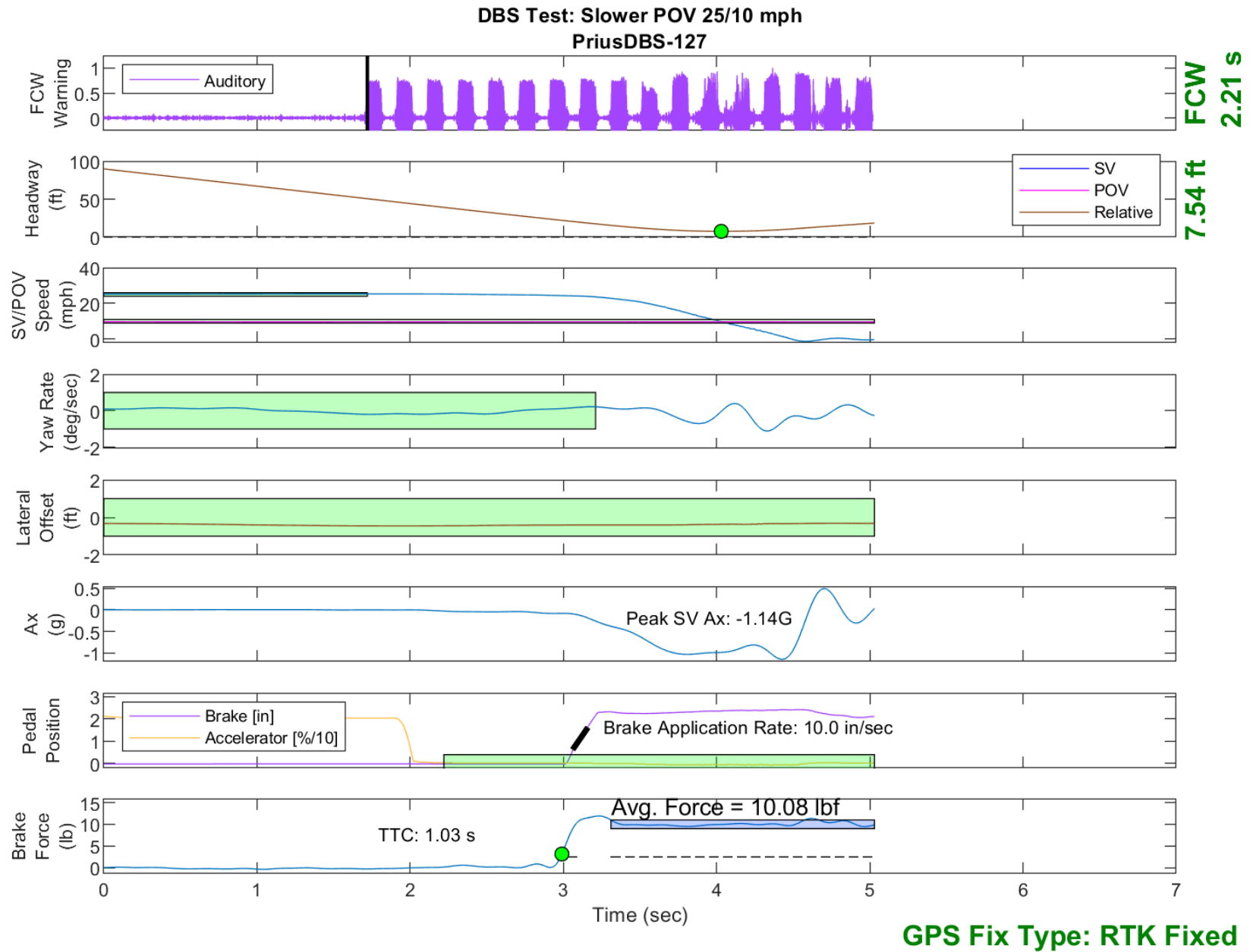


Figure E26. Time History for DBS Run 127, SV Encounters Slower POV, SV 25 mph, POV 10 mph



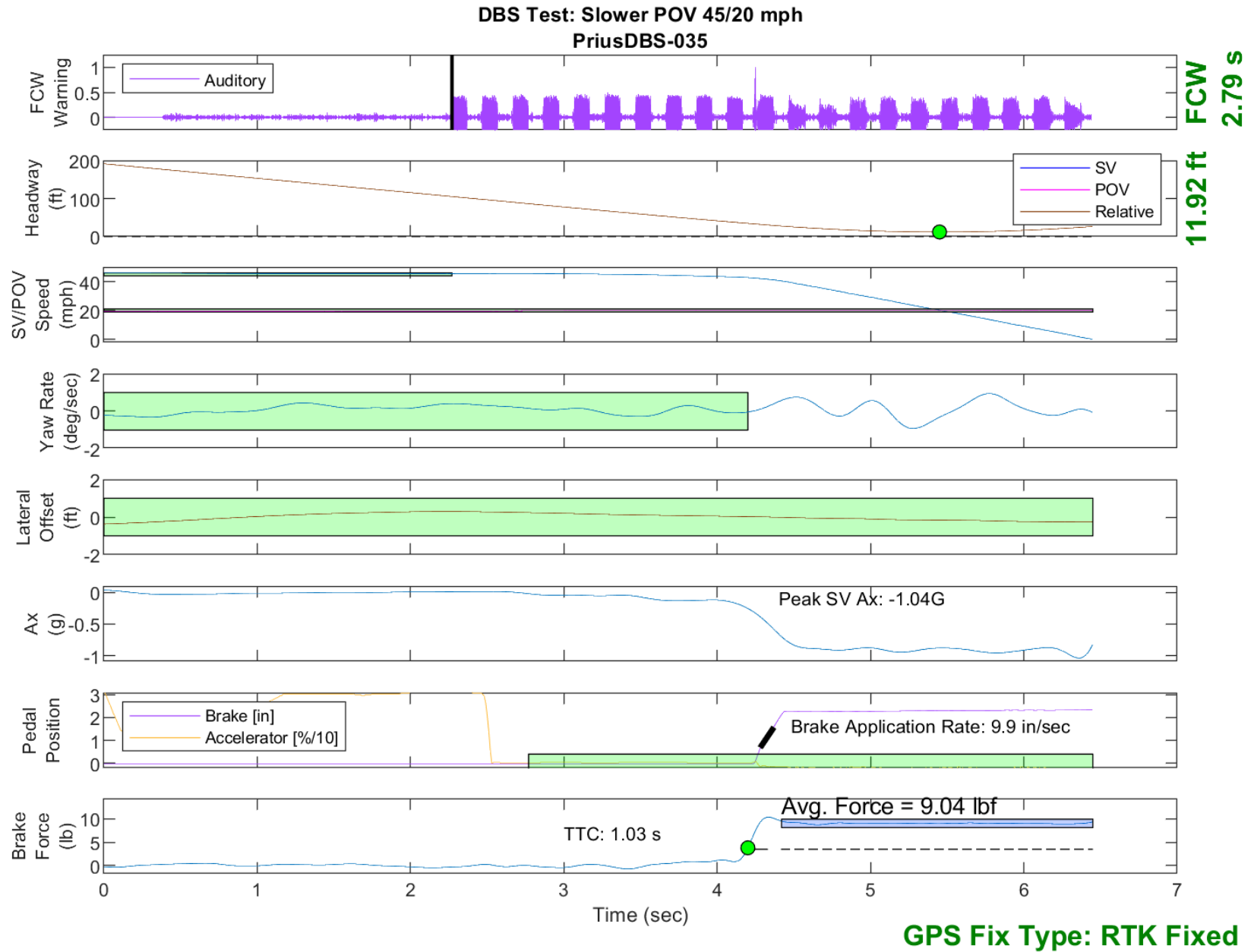


Figure E27. Time History for DBS Run 35, SV Encounters Slower POV, SV 45 mph, POV 20 mph

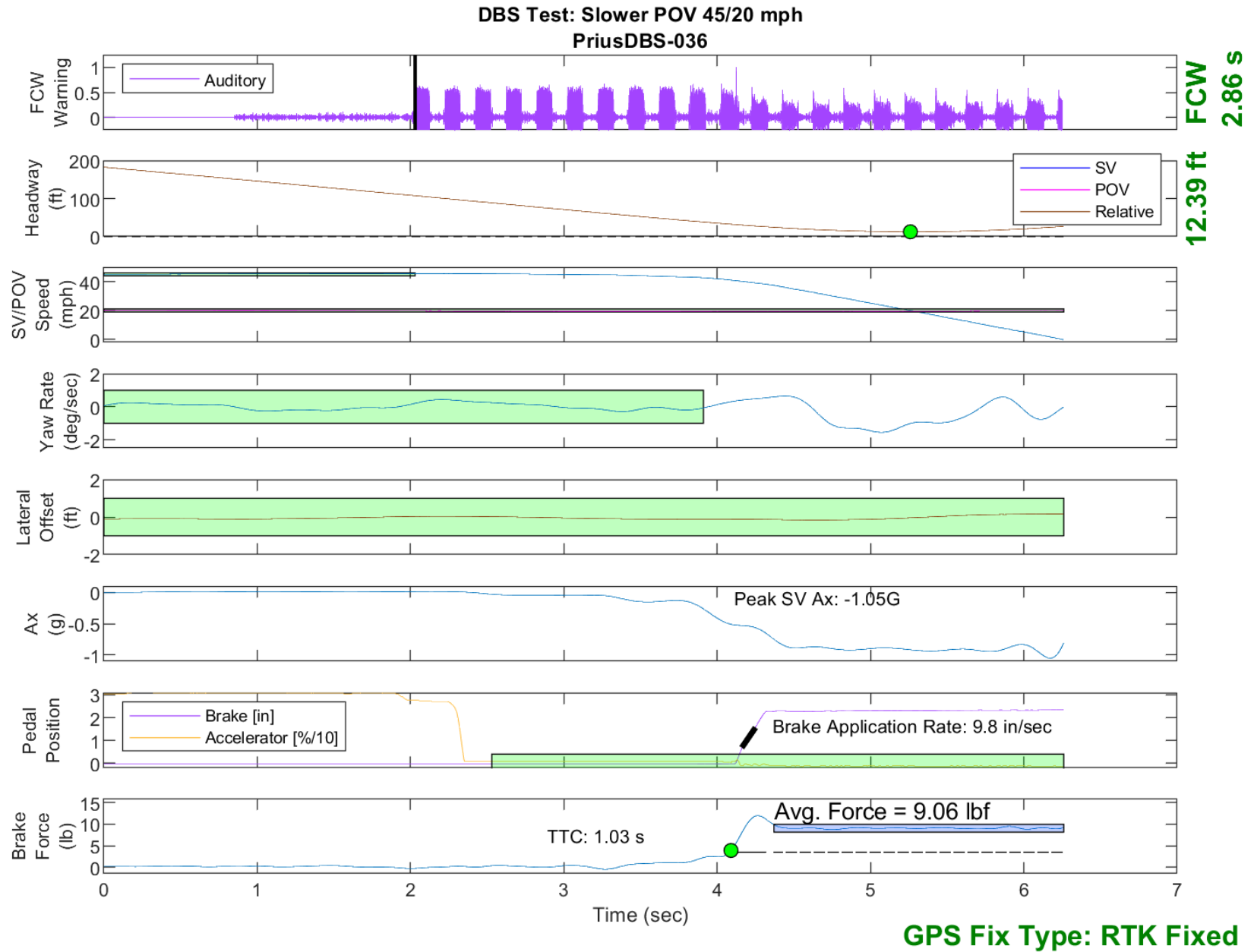


Figure E28. Time History for DBS Run 36, SV Encounters Slower POV, SV 45 mph, POV 20 mph

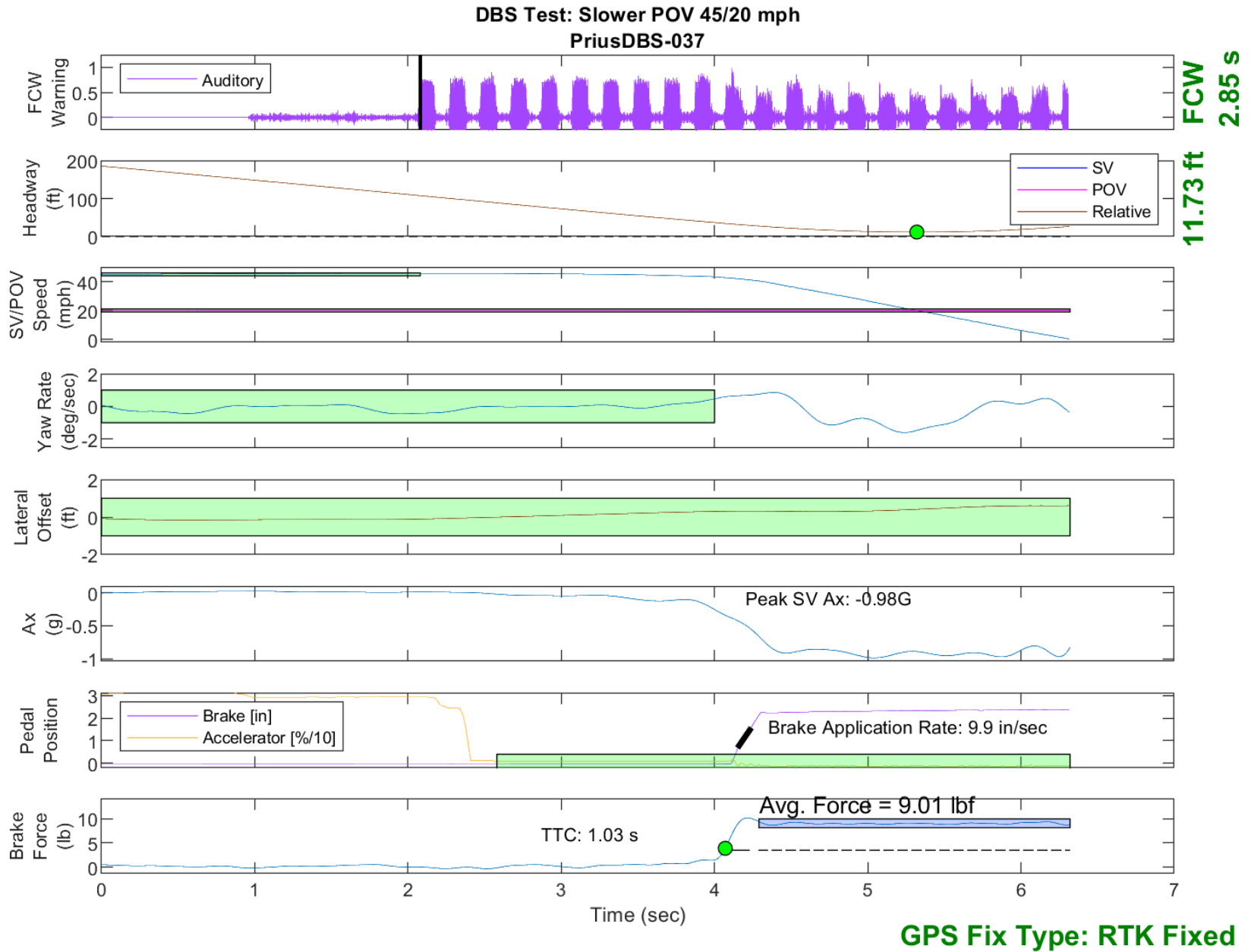


Figure E29. Time History for DBS Run 37, SV Encounters Slower POV, SV 45 mph, POV 20 mph

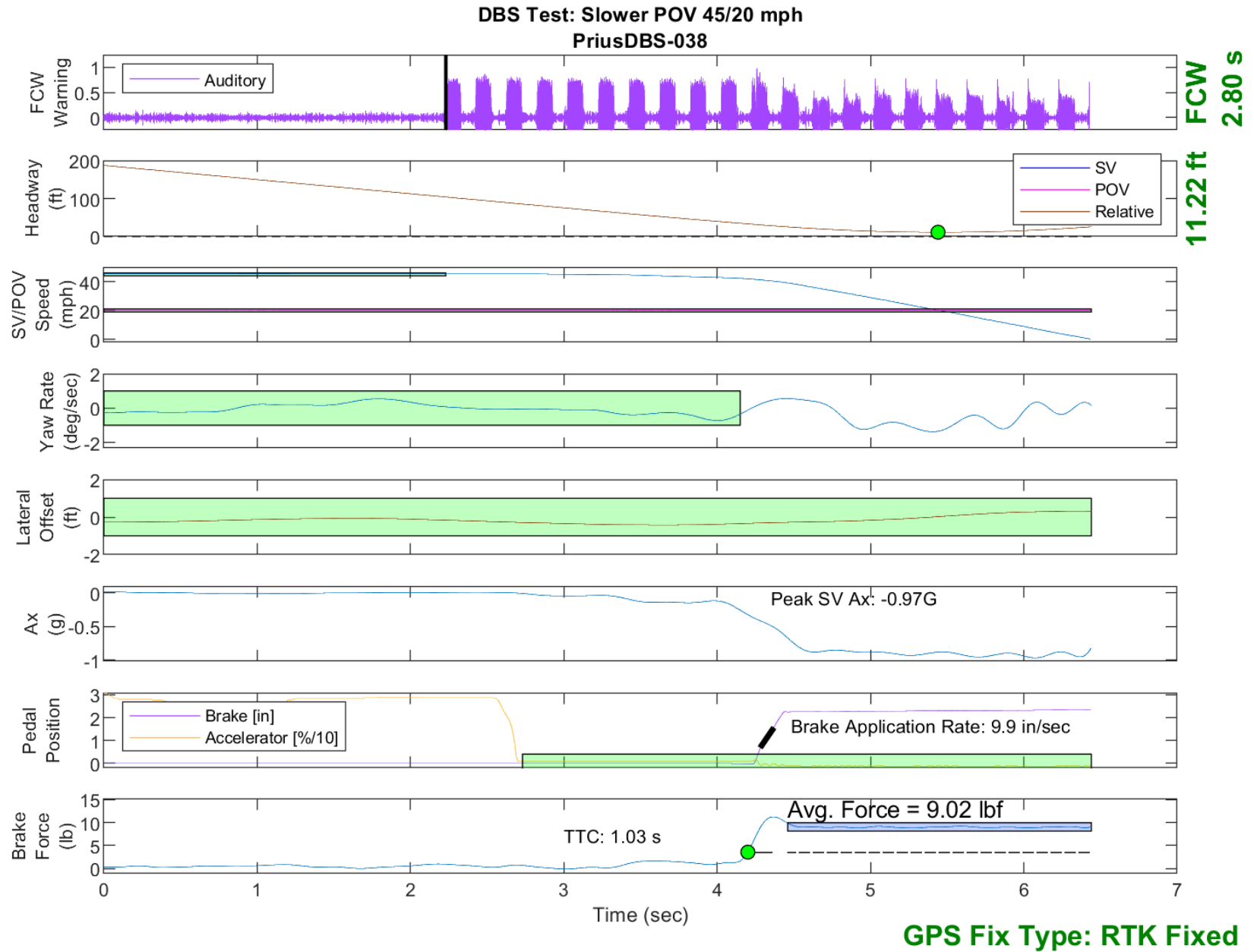


Figure E30. Time History for DBS Run 38, SV Encounters Slower POV, SV 45 mph, POV 20 mph

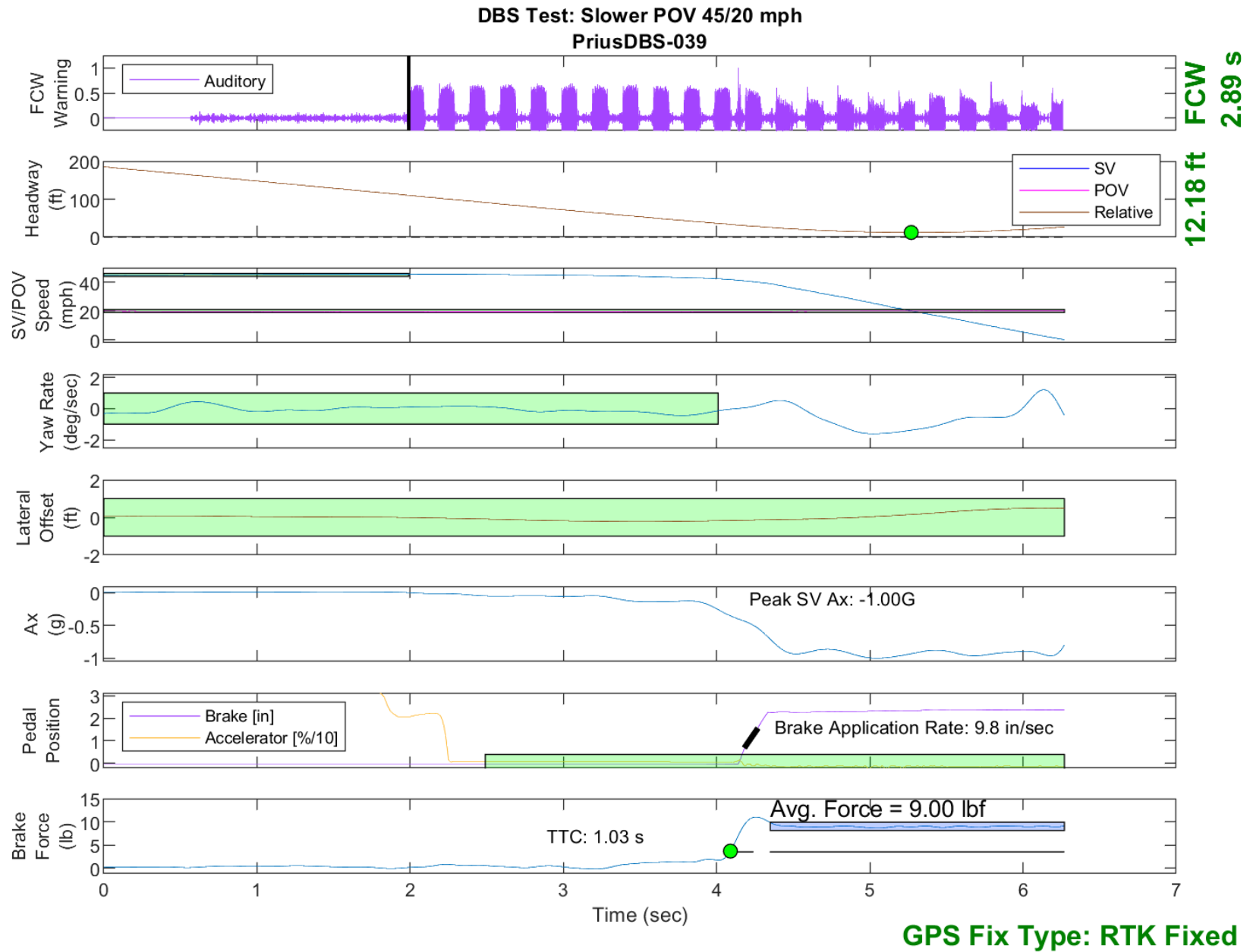


Figure E31. Time History for DBS Run 39, SV Encounters Slower POV, SV 45 mph, POV 20 mph

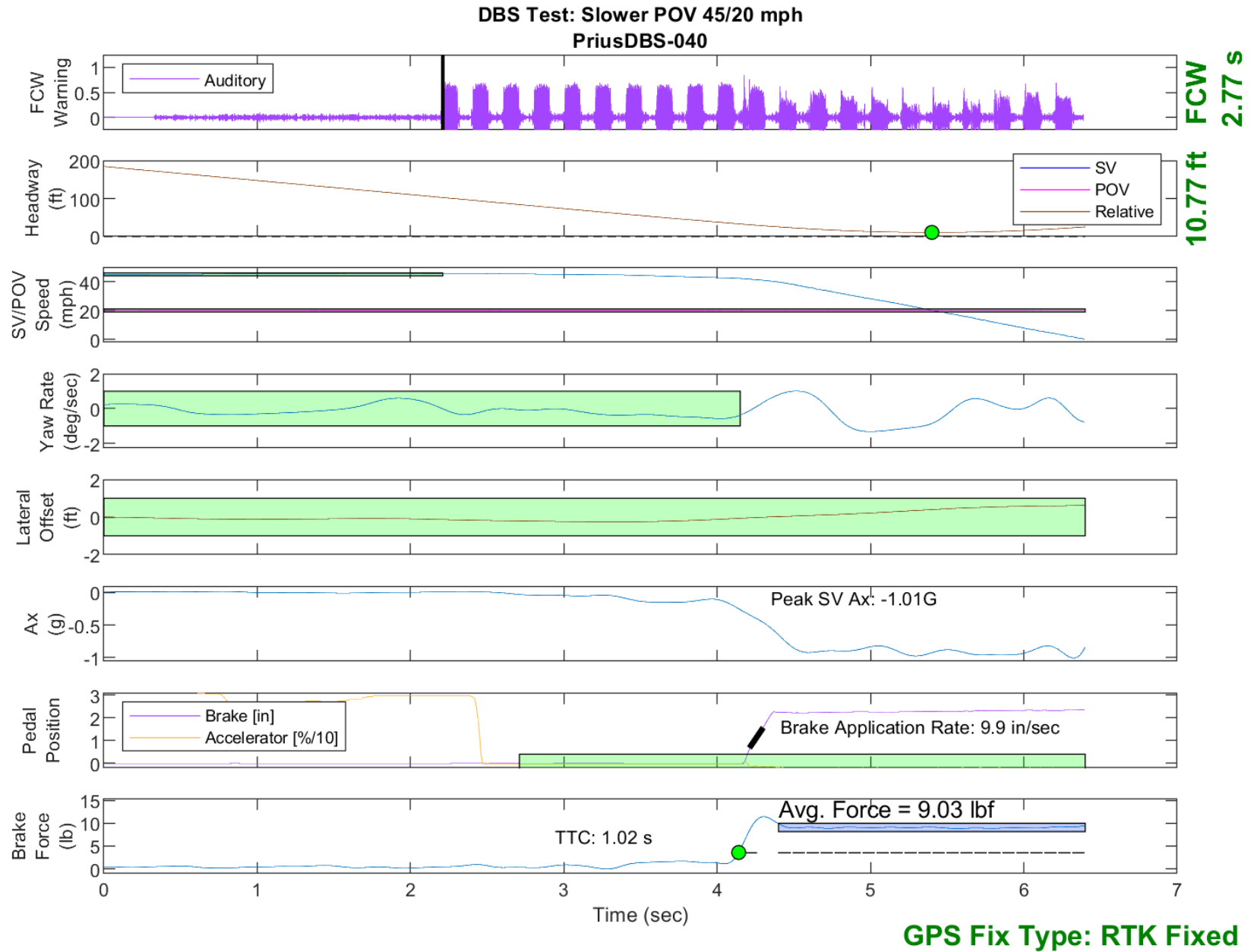


Figure E32. Time History for DBS Run 40, SV Encounters Slower POV, SV 45 mph, POV 20 mph

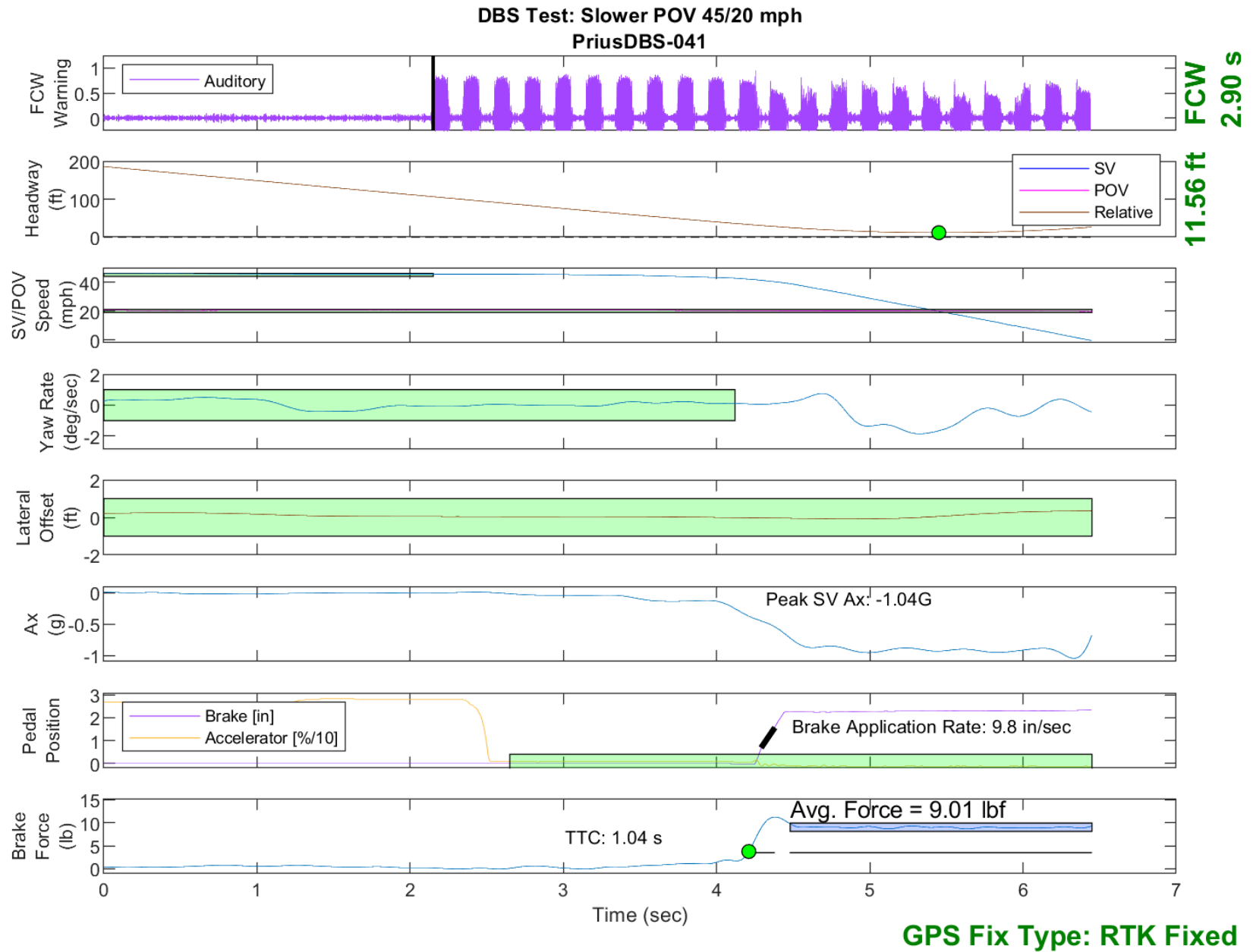


Figure E33. Time History for DBS Run 41, SV Encounters Slower POV, SV 45 mph, POV 20 mph

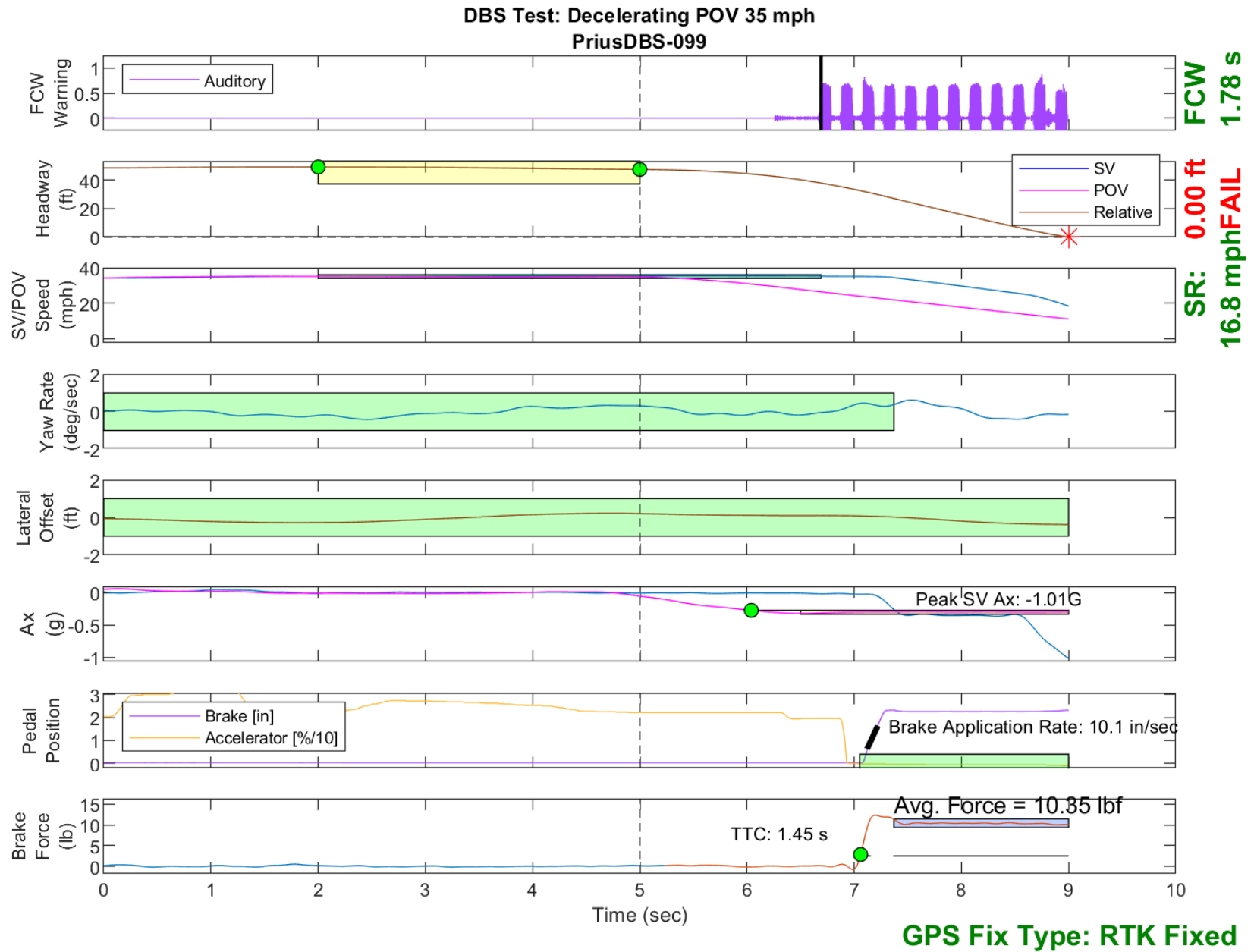


Figure E34. Time History for DBS Run 99, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph



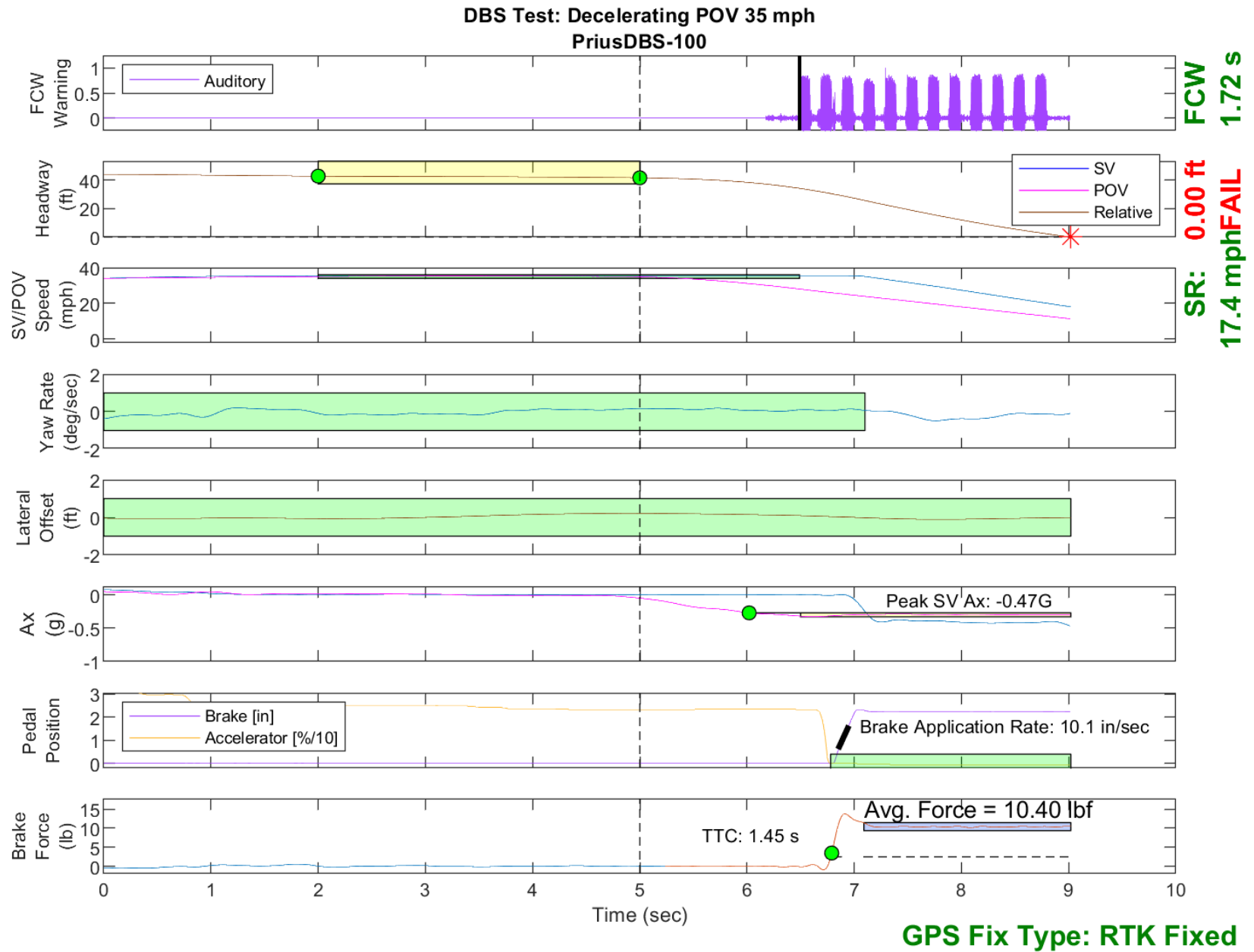


Figure E35. Time History for DBS Run 100, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

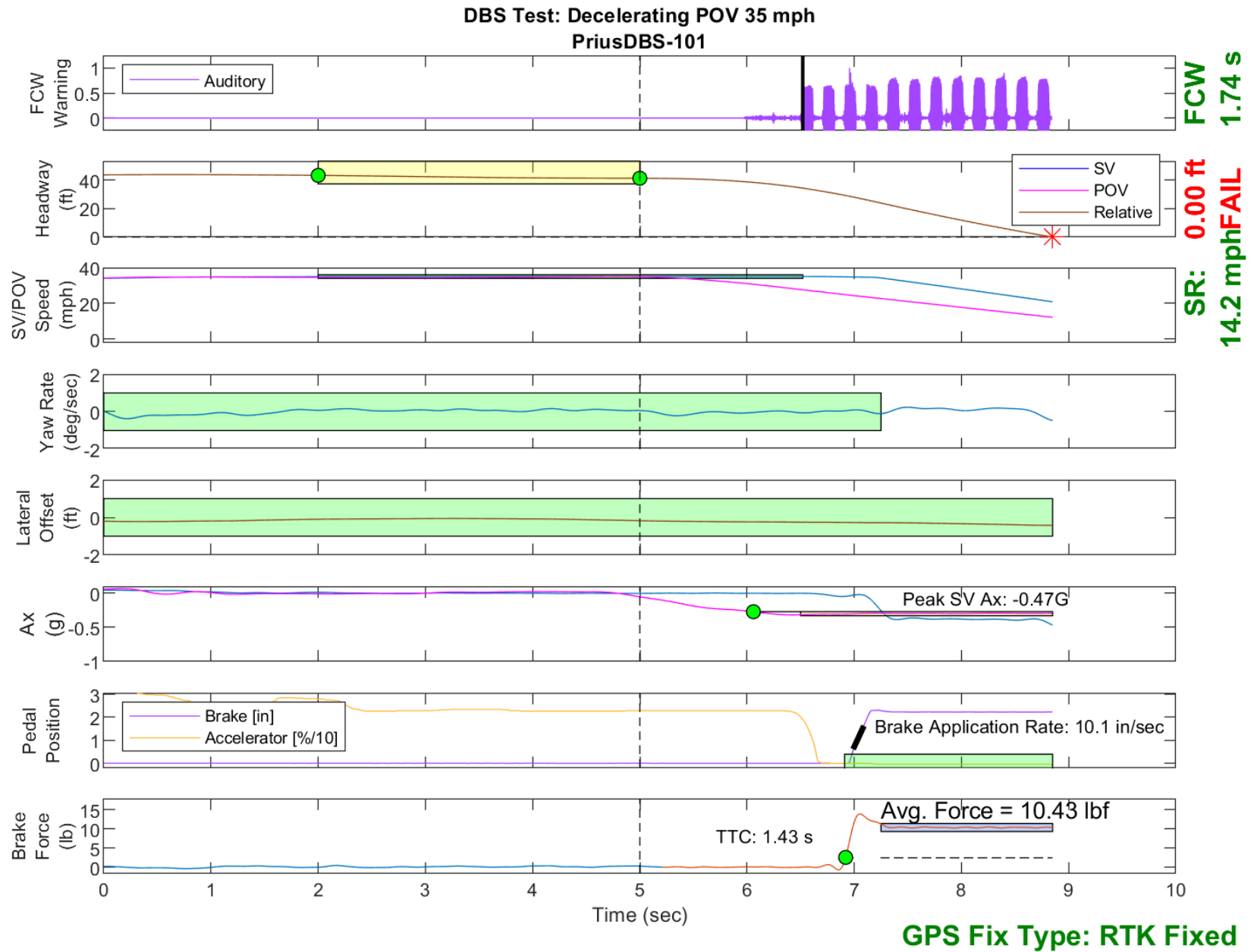


Figure E36. Time History for DBS Run 101, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

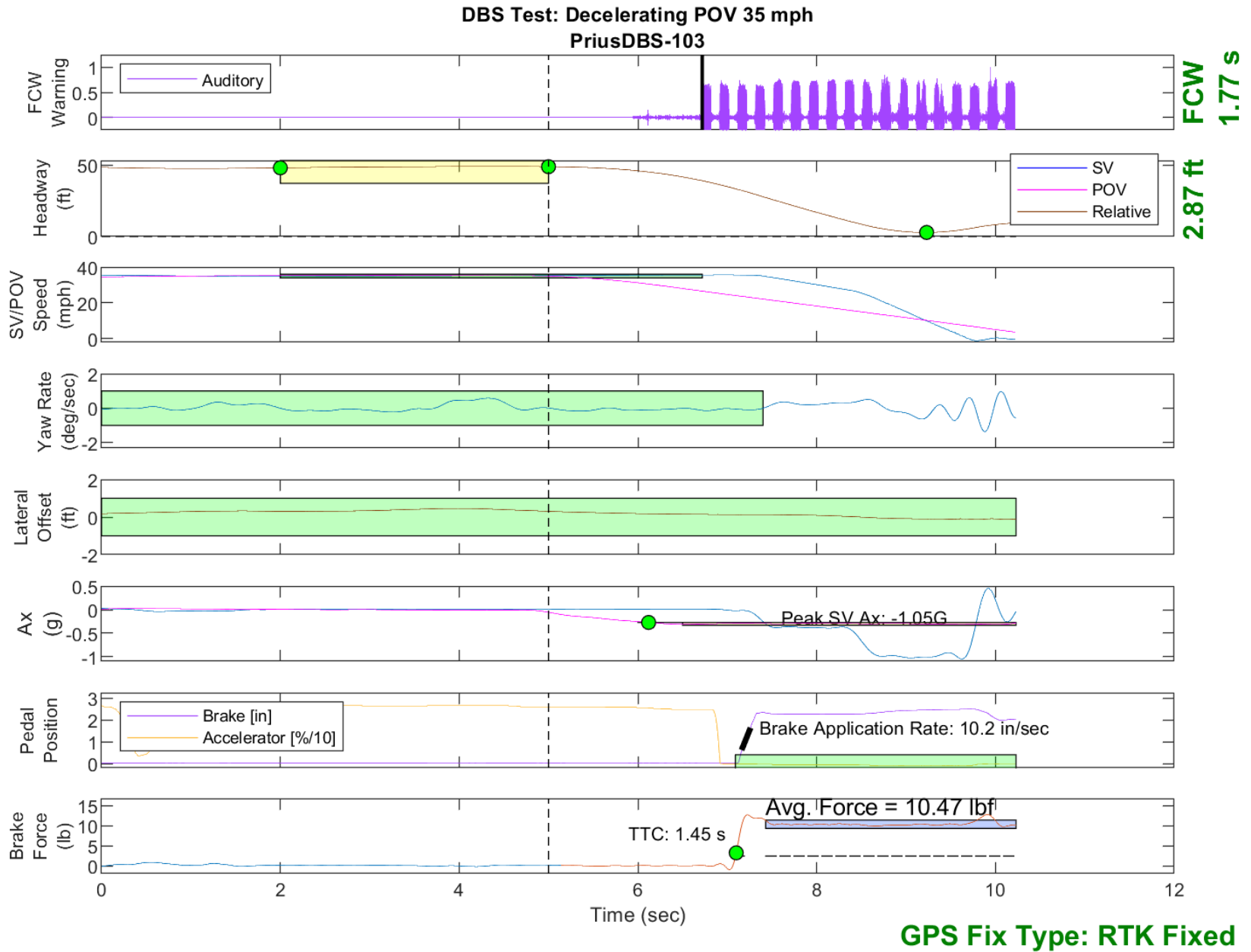


Figure E37. Time History for DBS Run 103, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

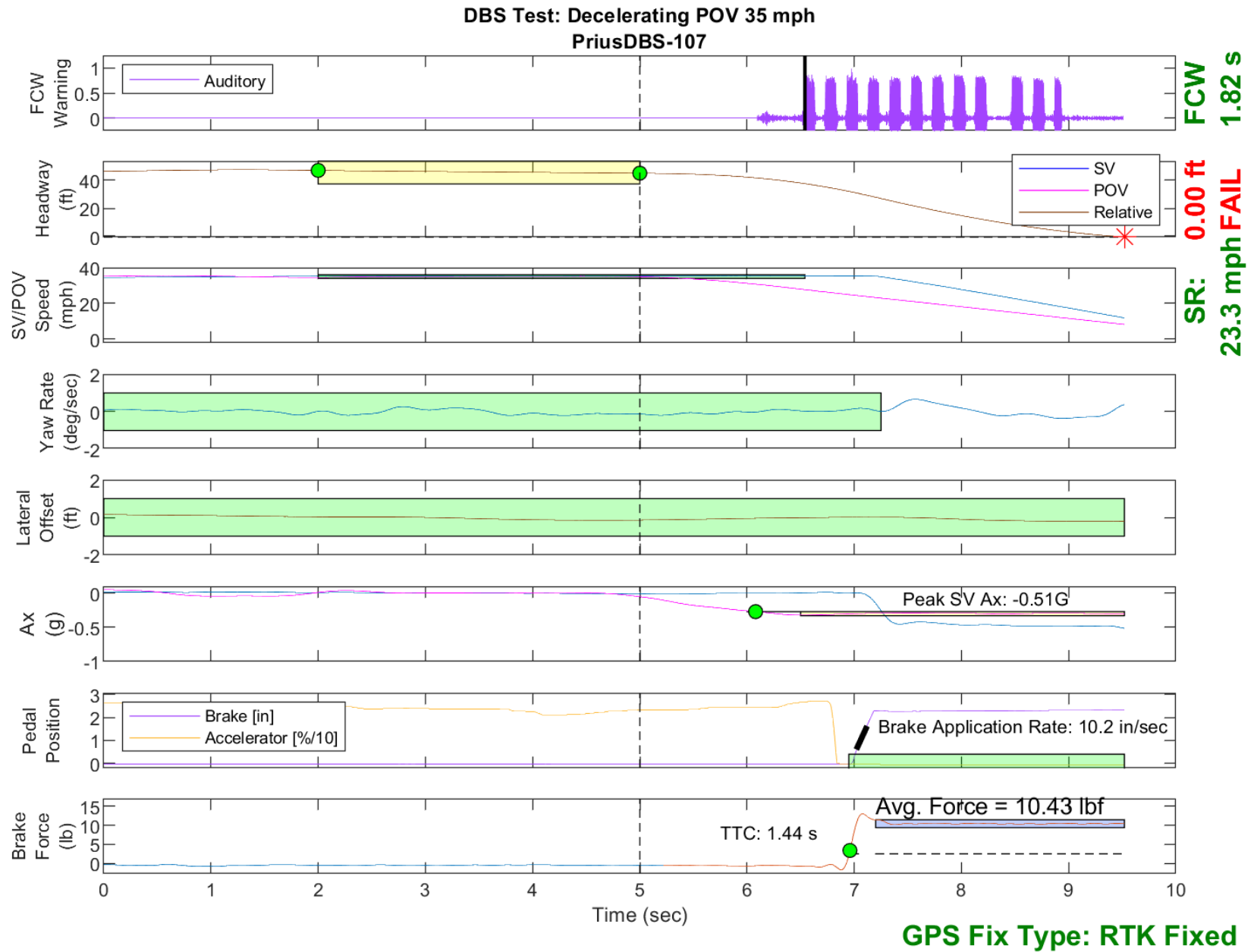
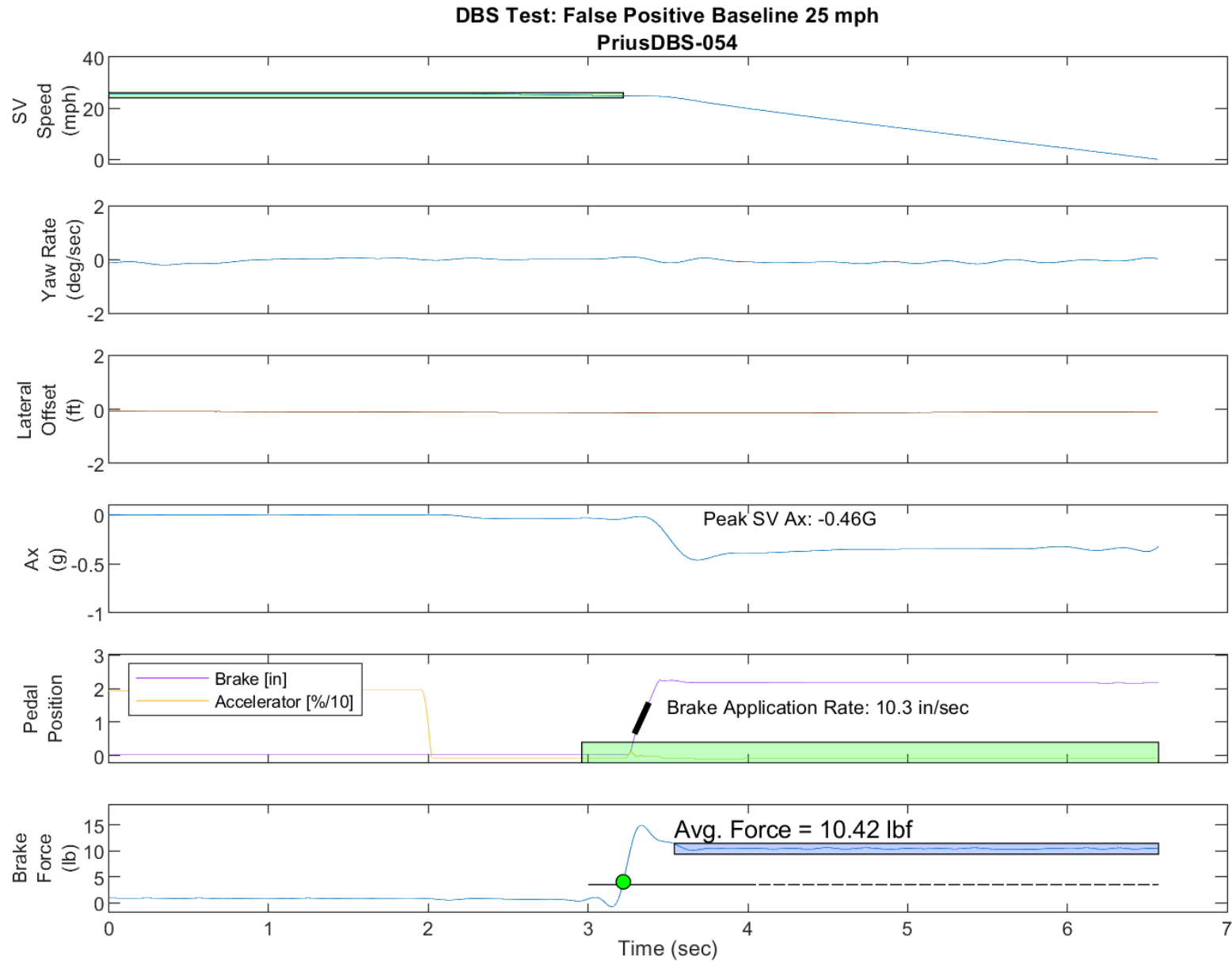


Figure E38. Time History for DBS Run 107, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph



**GPS Fix Type: RTK Fixed**

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

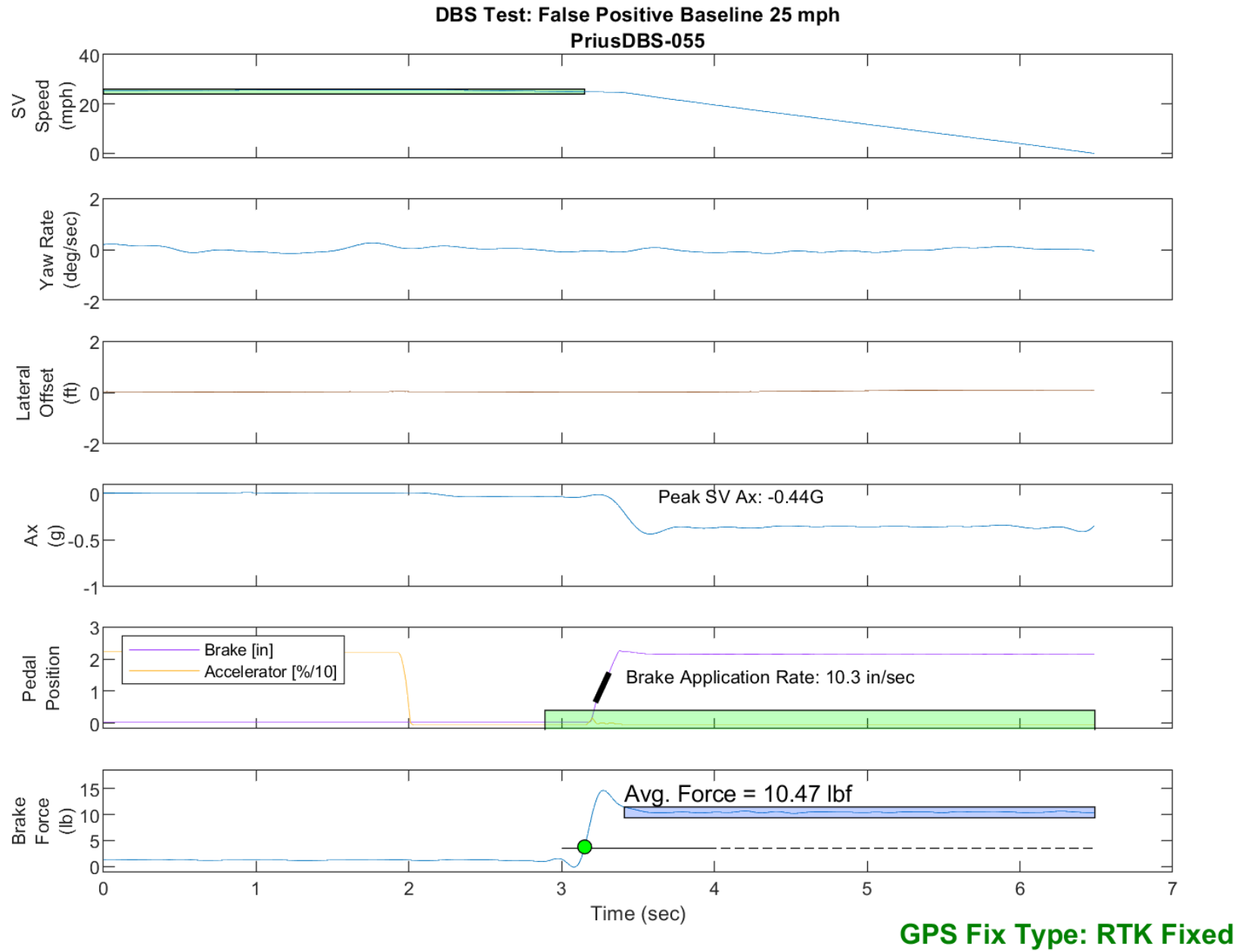


Figure E40. Time History for DBS Run 55, False Positive Baseline, SV 25 mph

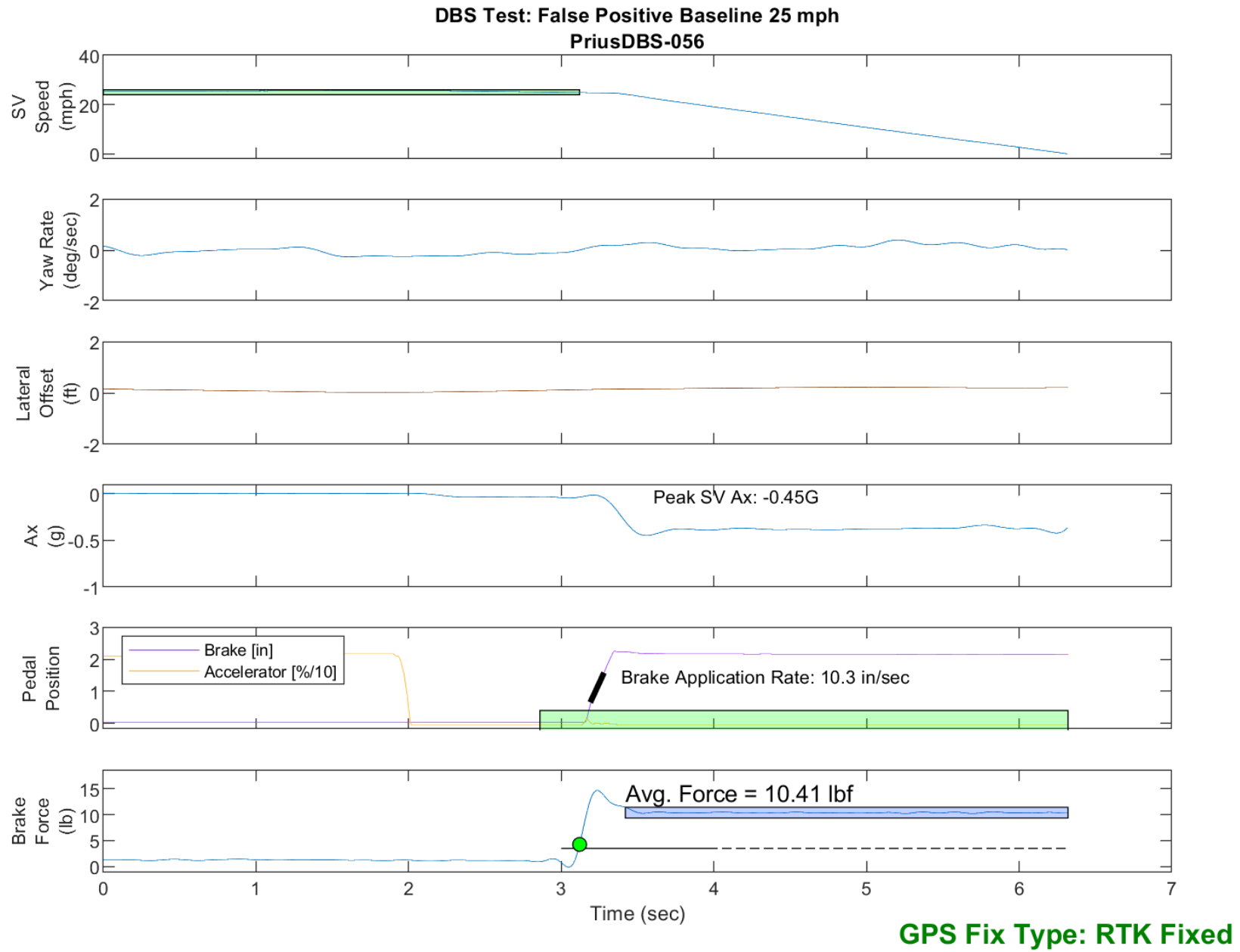


Figure E41. Time History for DBS Run 56, False Positive Baseline, SV 25 mph

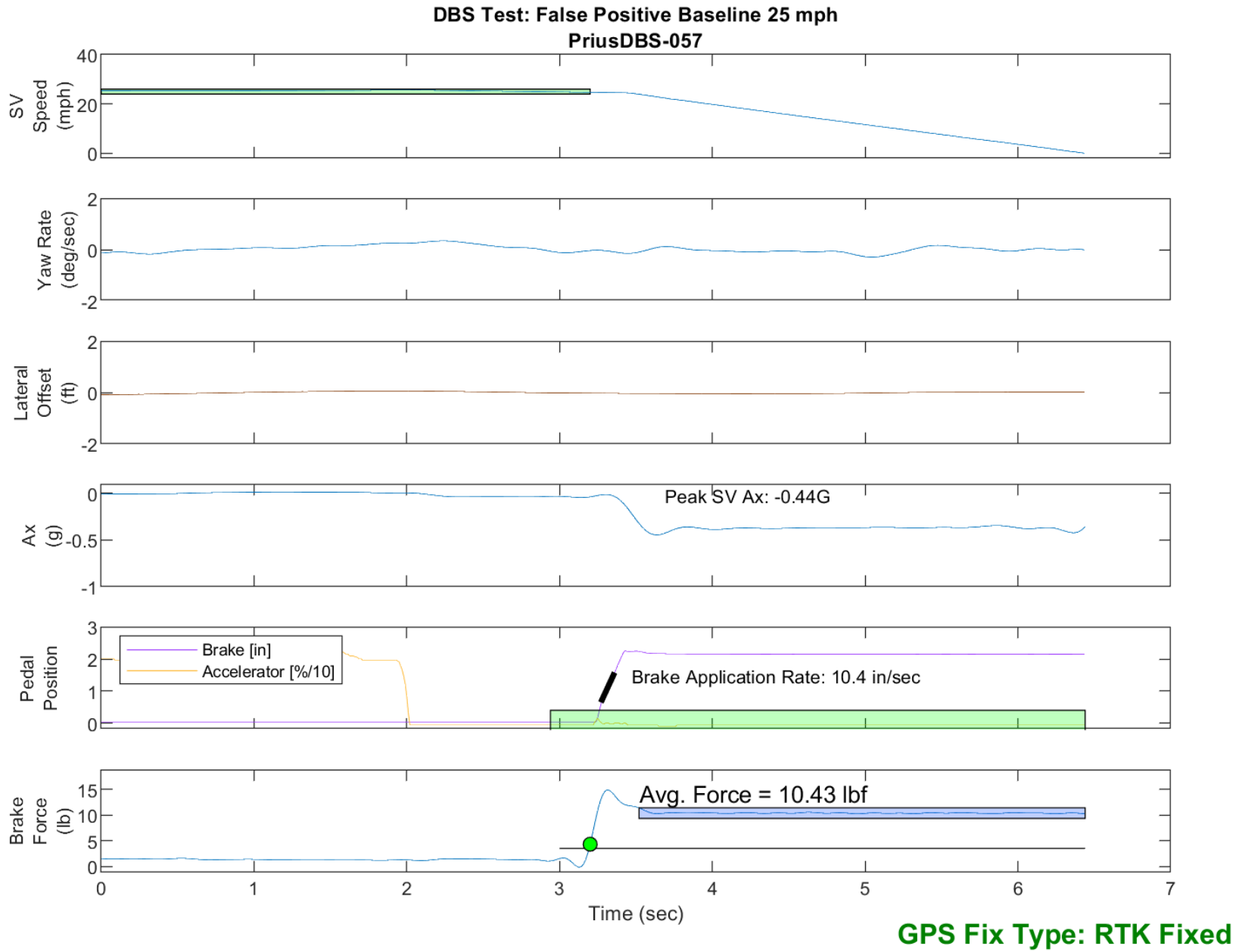


Figure E42. Time History for DBS Run 57, False Positive Baseline, SV 25 mph



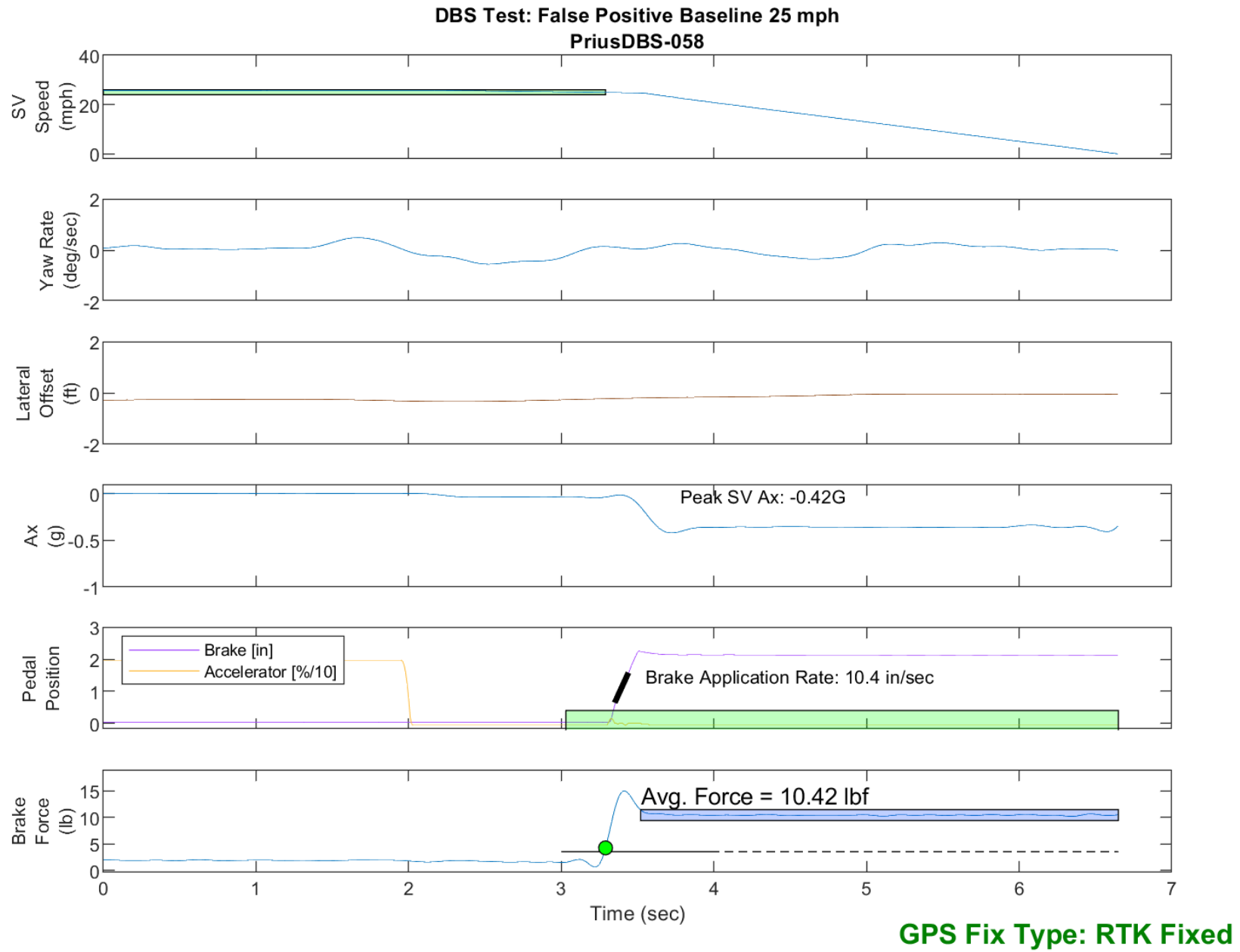


Figure E43. Time History for DBS Run 58, False Positive Baseline, SV 25 mph

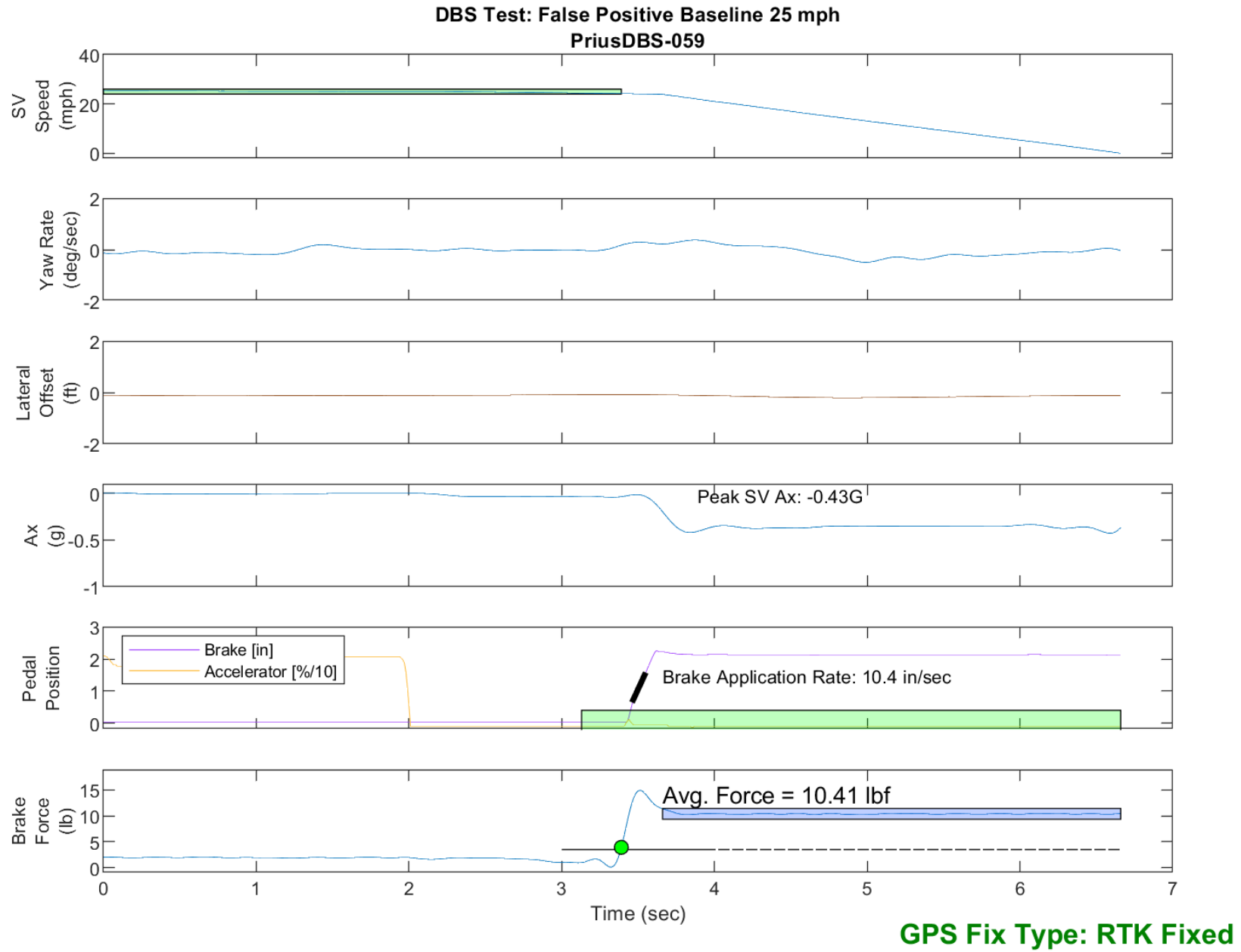


Figure E44. Time History for DBS Run 59, False Positive Baseline, SV 25 mph

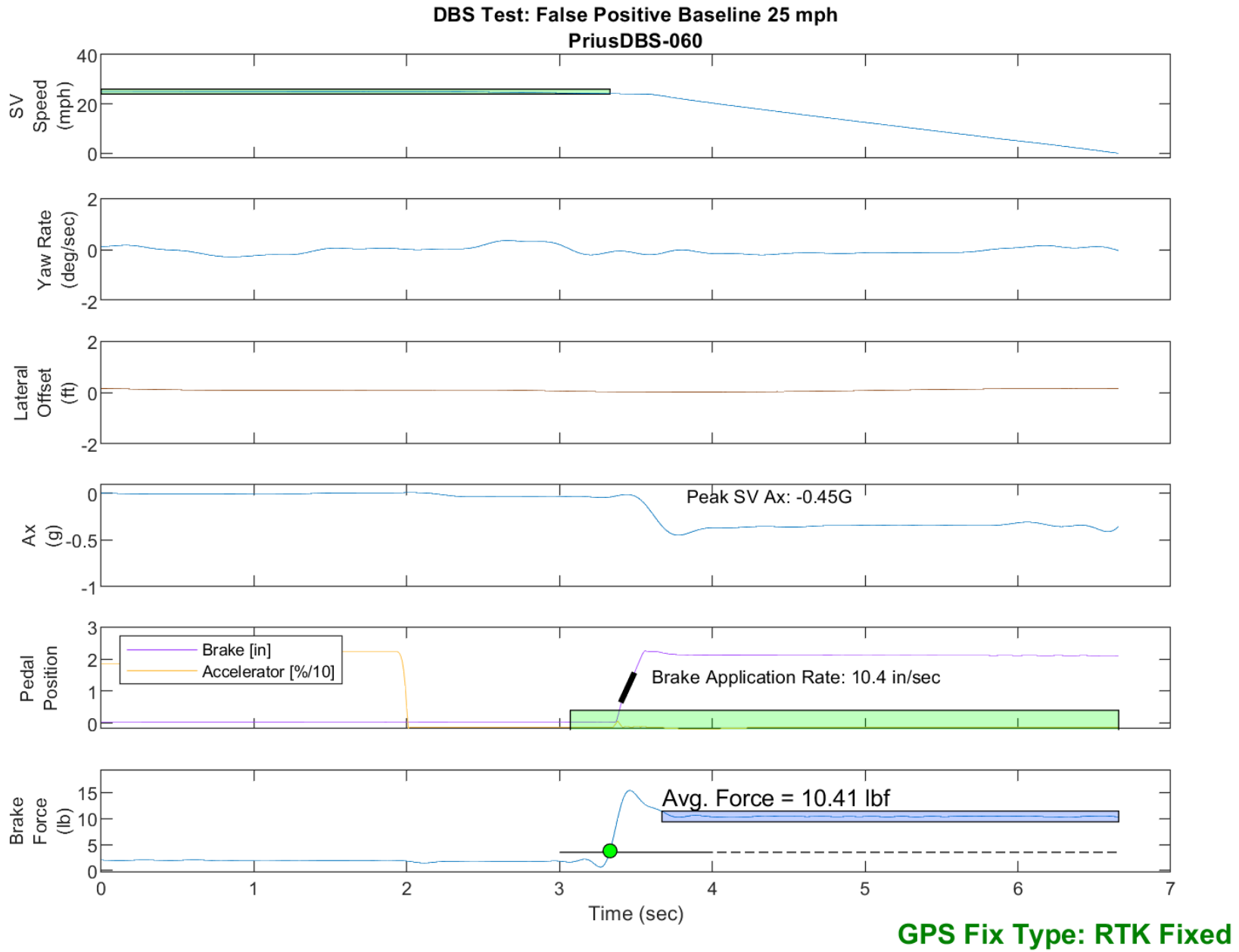
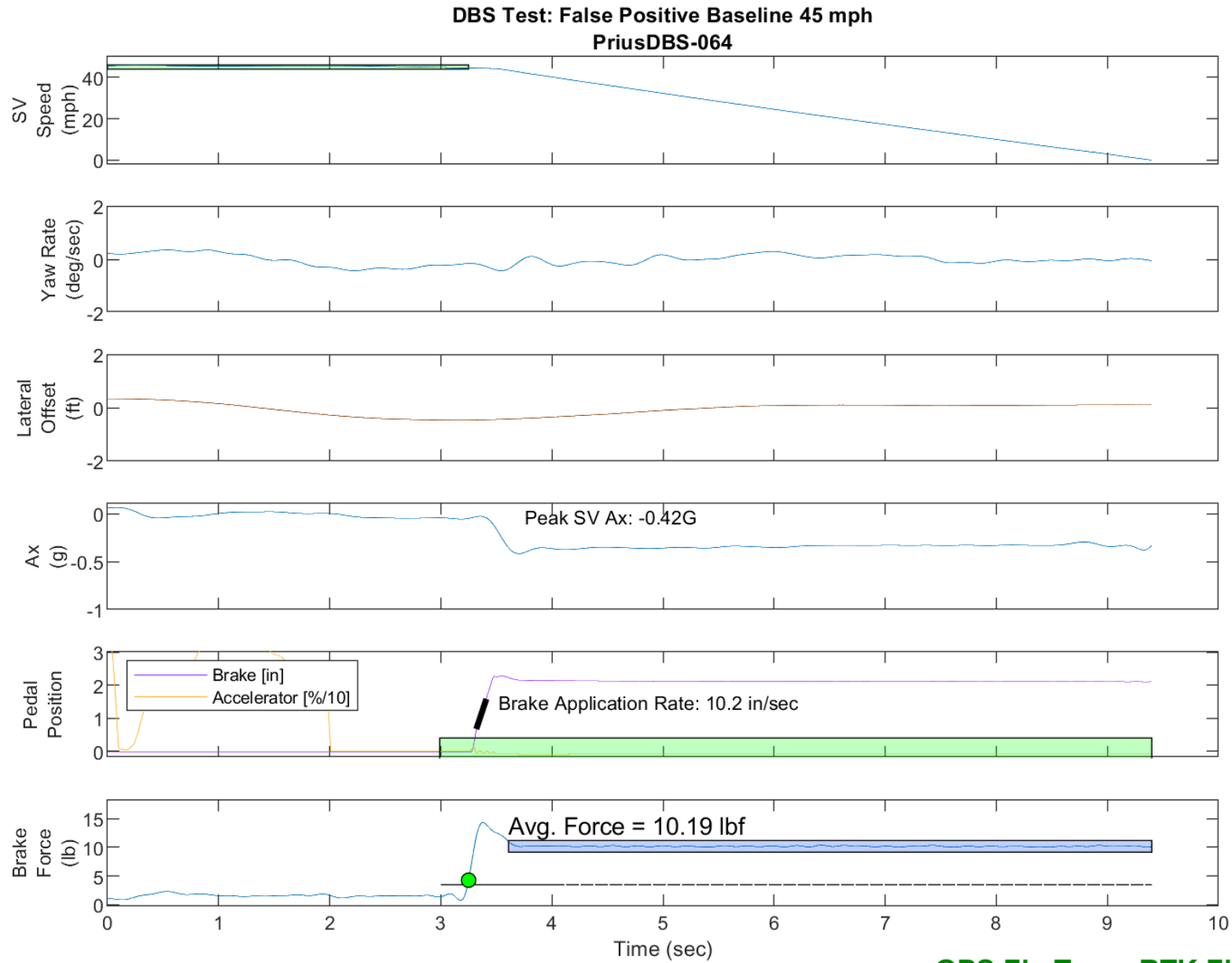
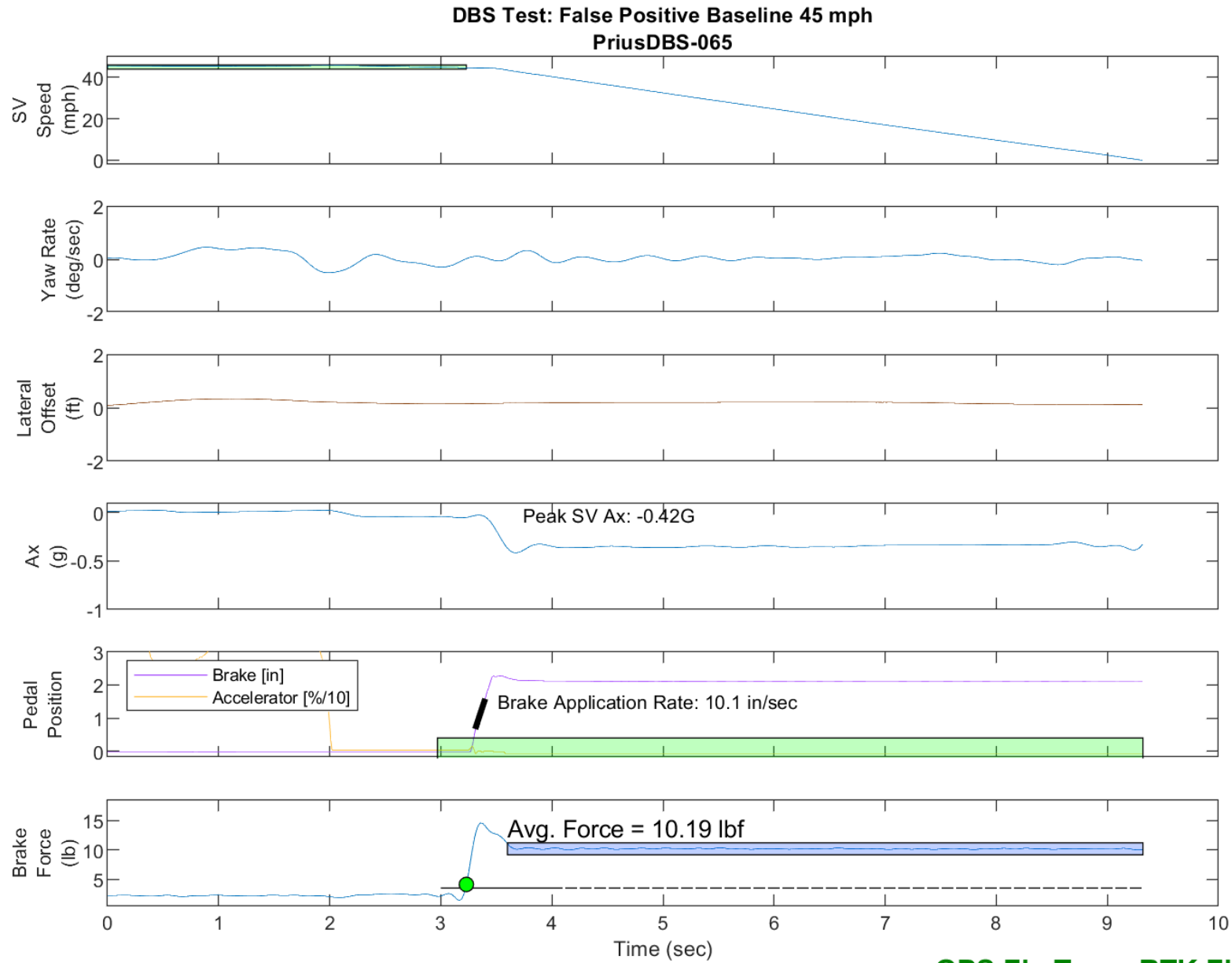


Figure E45. Time History for DBS Run 60, False Positive Baseline, SV 25 mph



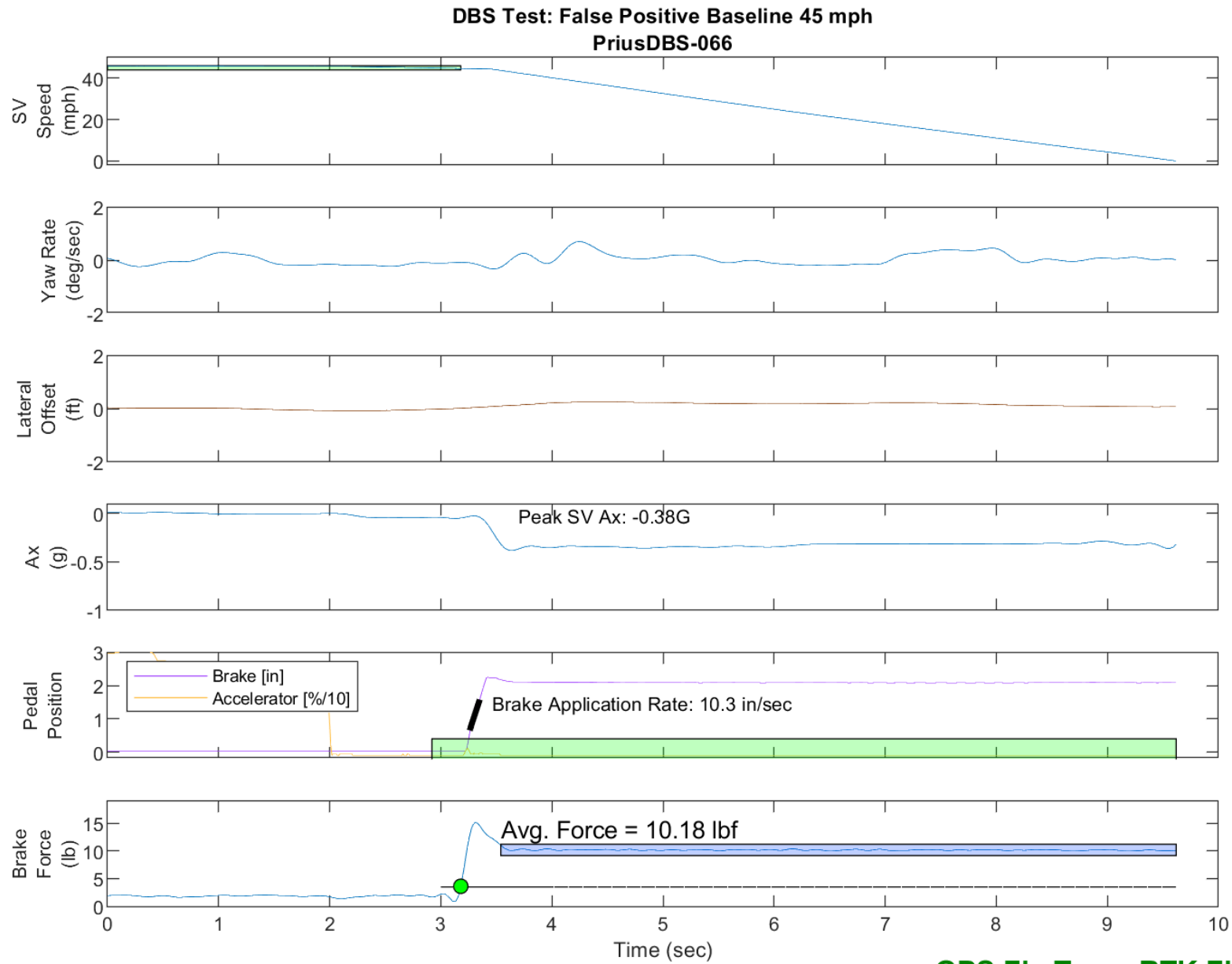
**GPS Fix Type: RTK Fixed**

Figure E46. Time History for DBS Run 64, False Positive Baseline, SV 45 mph



**GPS Fix Type: RTK Fixed**

Figure E47. Time History for DBS Run 65, False Positive Baseline, SV 45 mph



**GPS Fix Type: RTK Fixed**

Figure E48. Time History for DBS Run 66, False Positive Baseline, SV 45 mph

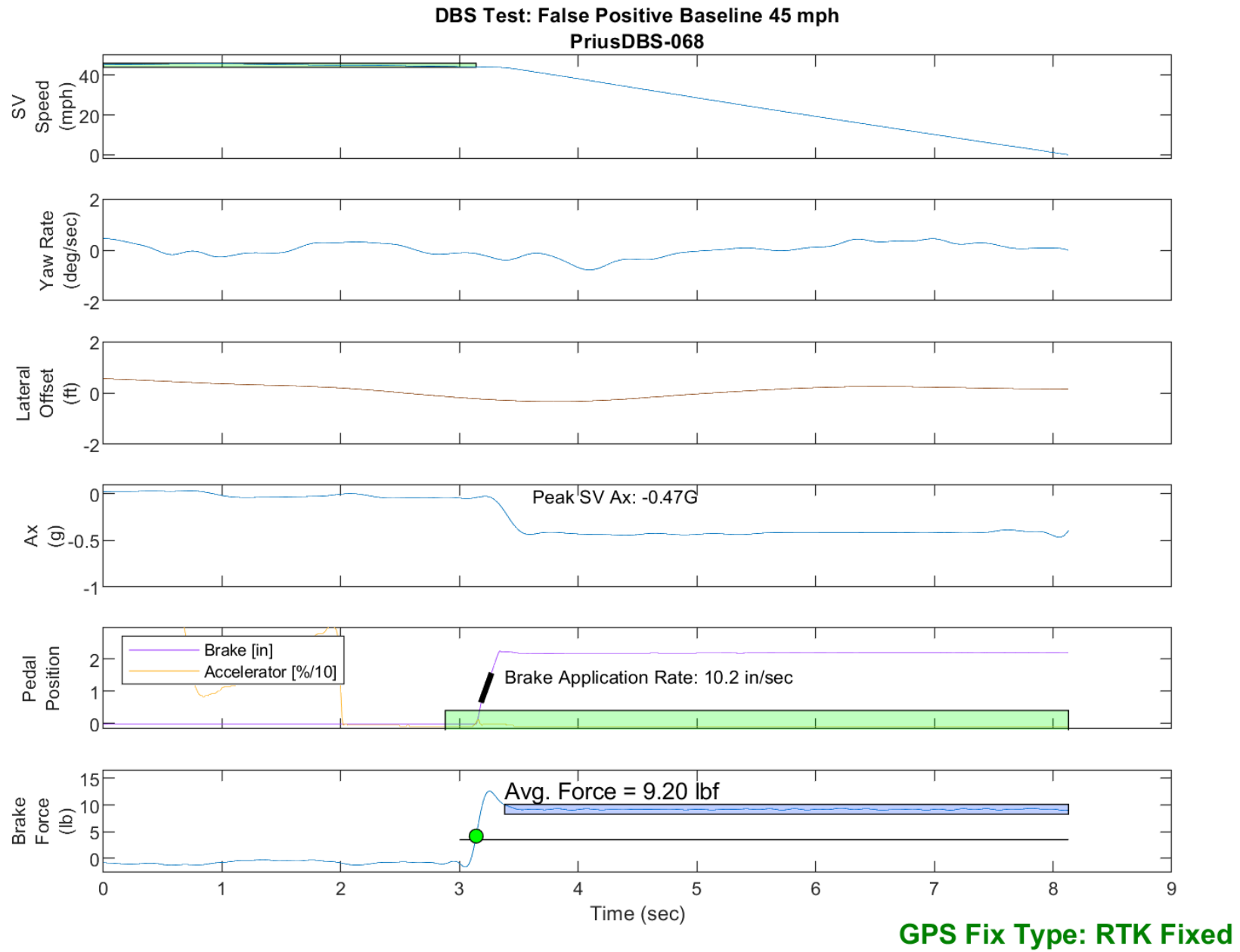
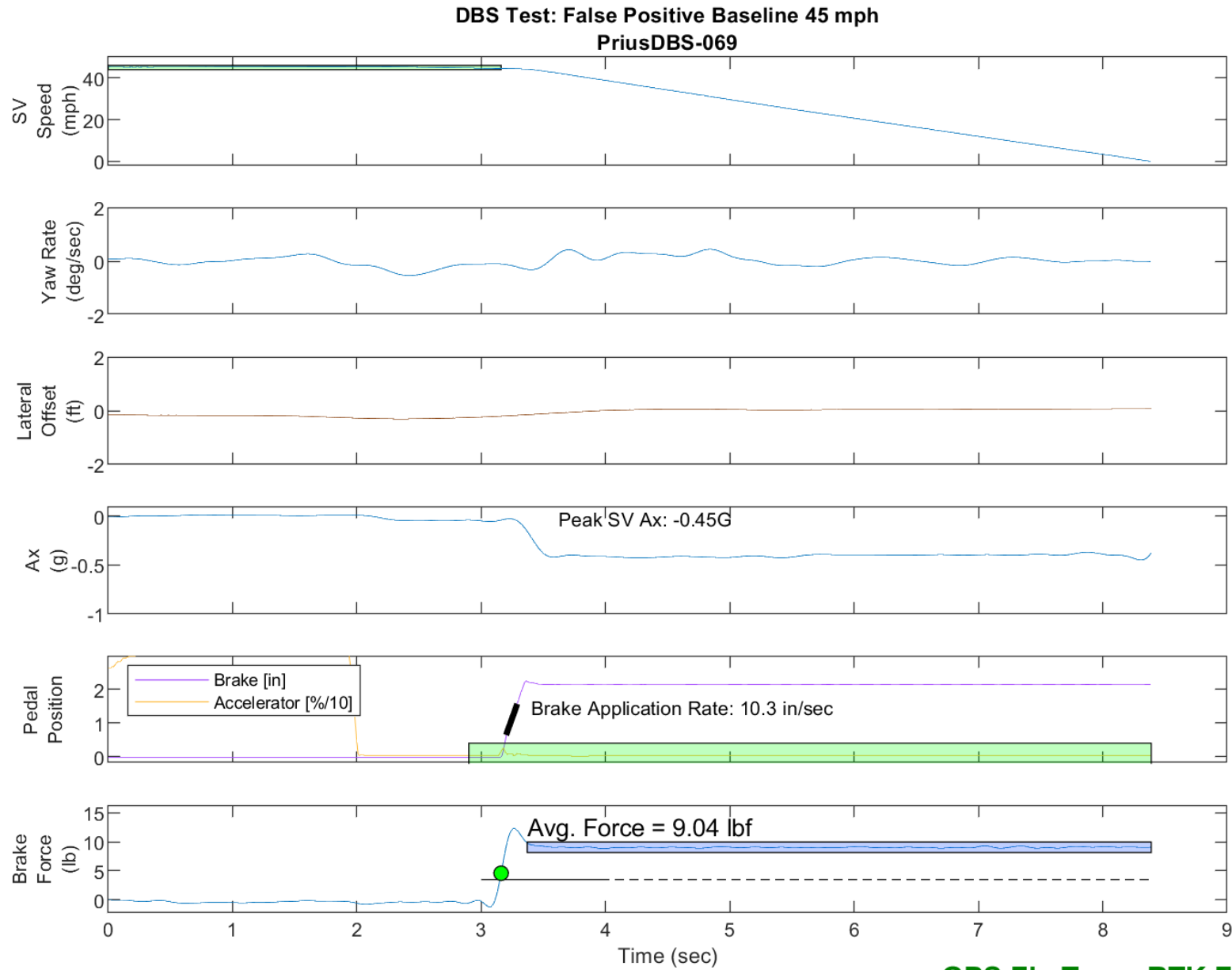


Figure E49. Time History for DBS Run 68, False Positive Baseline, SV 45 mph



**GPS Fix Type: RTK Fixed**

Figure E50. Time History for DBS Run 69, False Positive Baseline, SV 45 mph



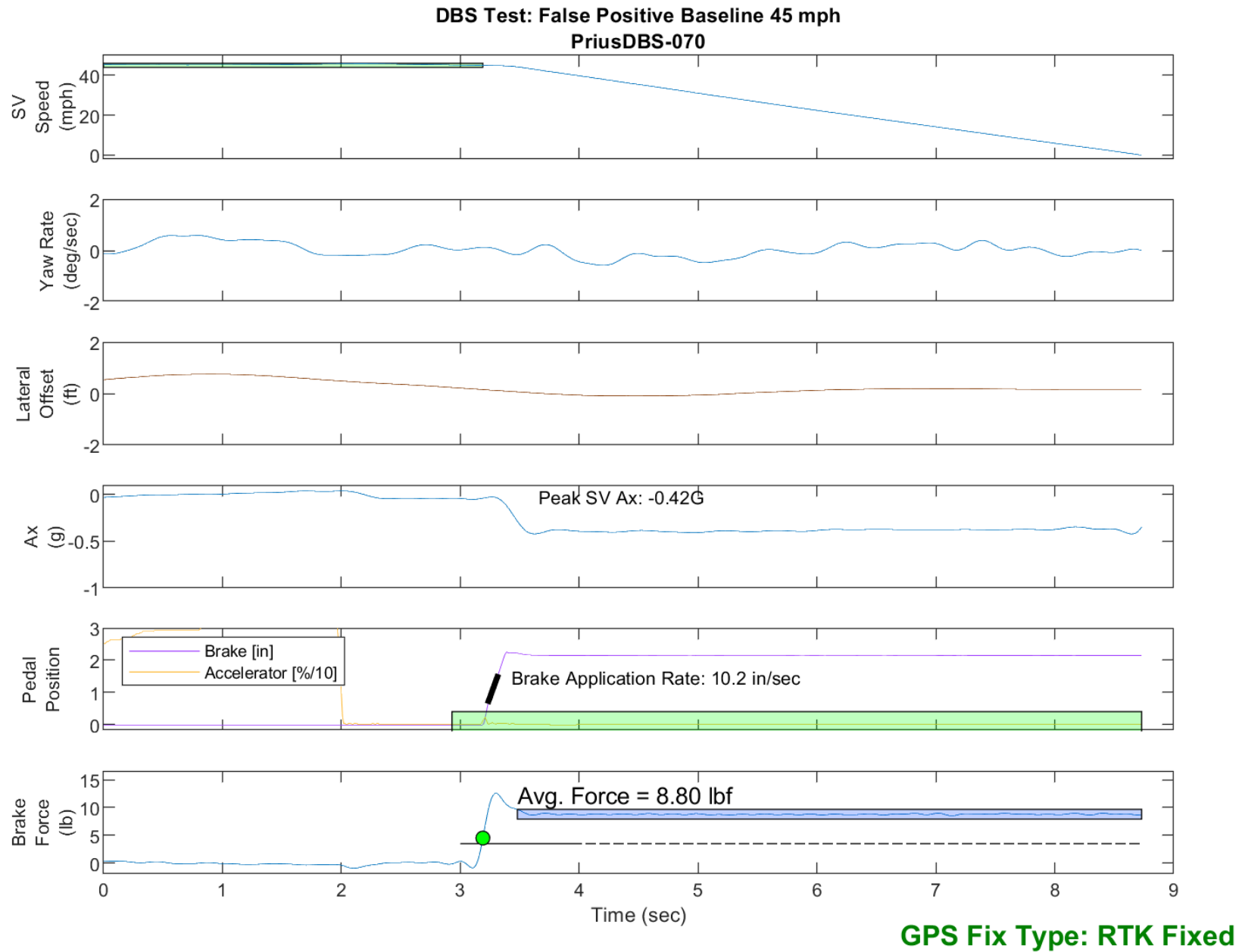


Figure E51. Time History for DBS Run 70, False Positive Baseline, SV 45 mph

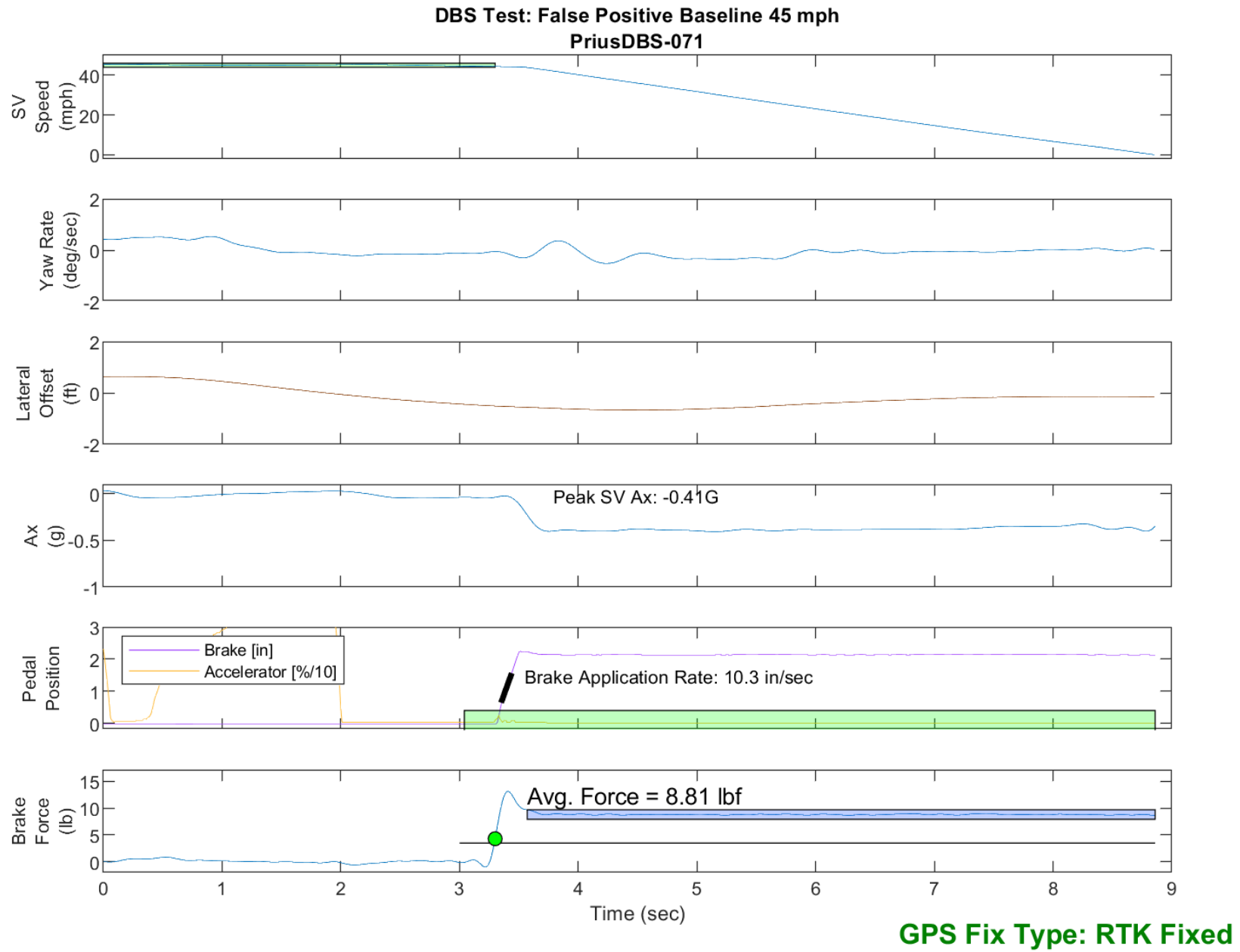


Figure E52. Time History for DBS Run 71, False Positive Baseline, SV 45 mph

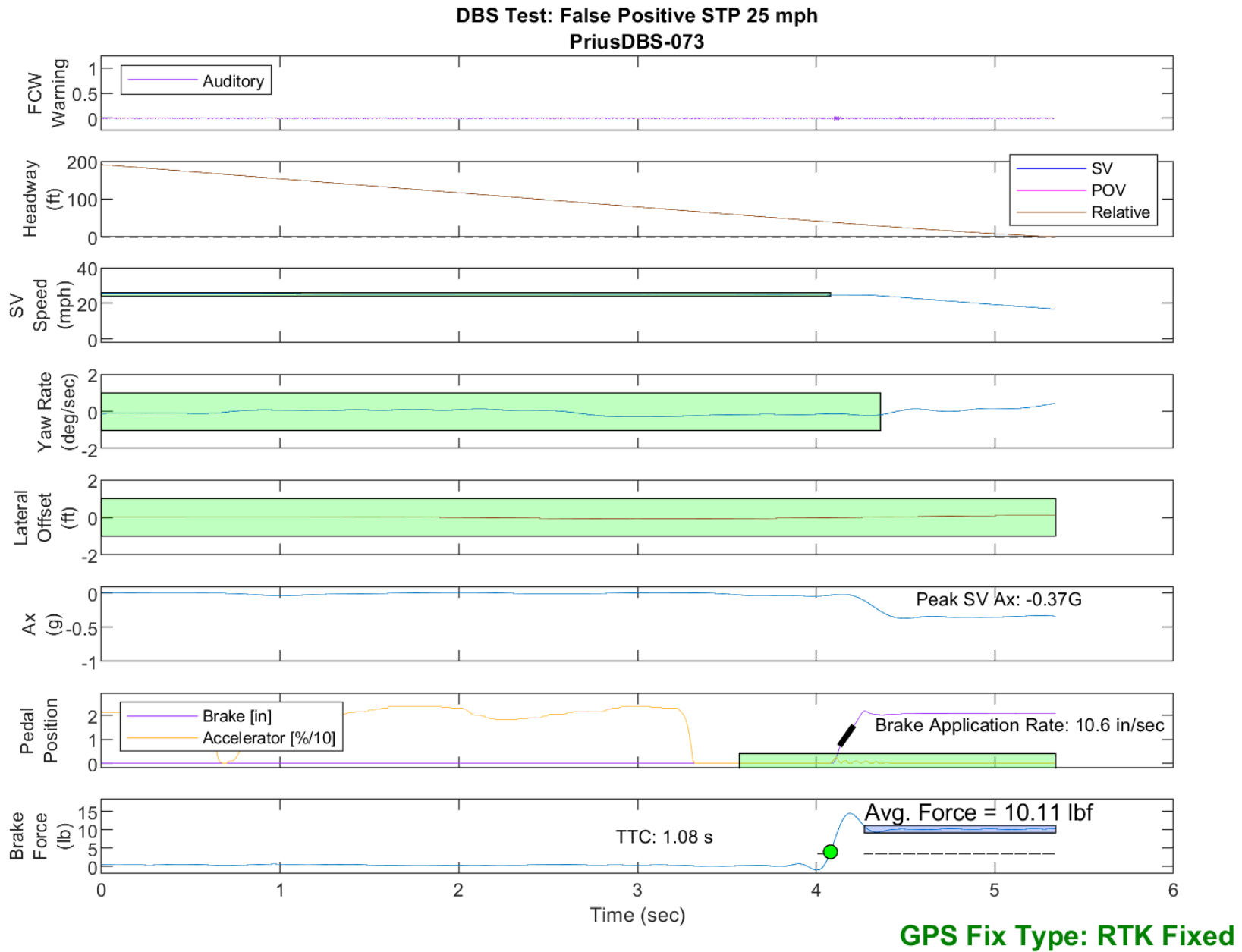


Figure E53. Time History for DBS Run 73, SV Encounters Steel Trench Plate, SV 25 mph

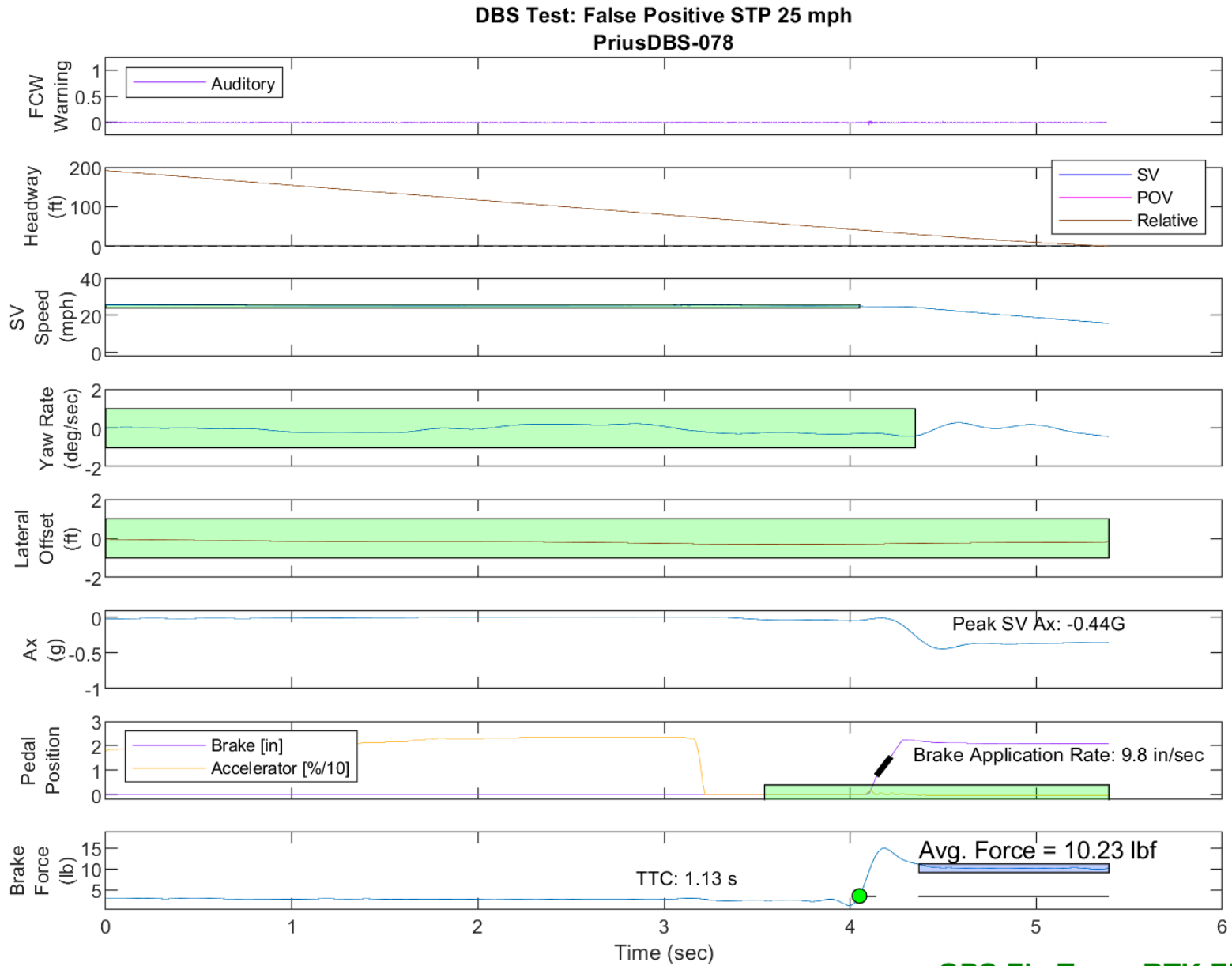


Figure E54. Time History for DBS Run 78, SV Encounters Steel Trench Plate, SV 25 mph

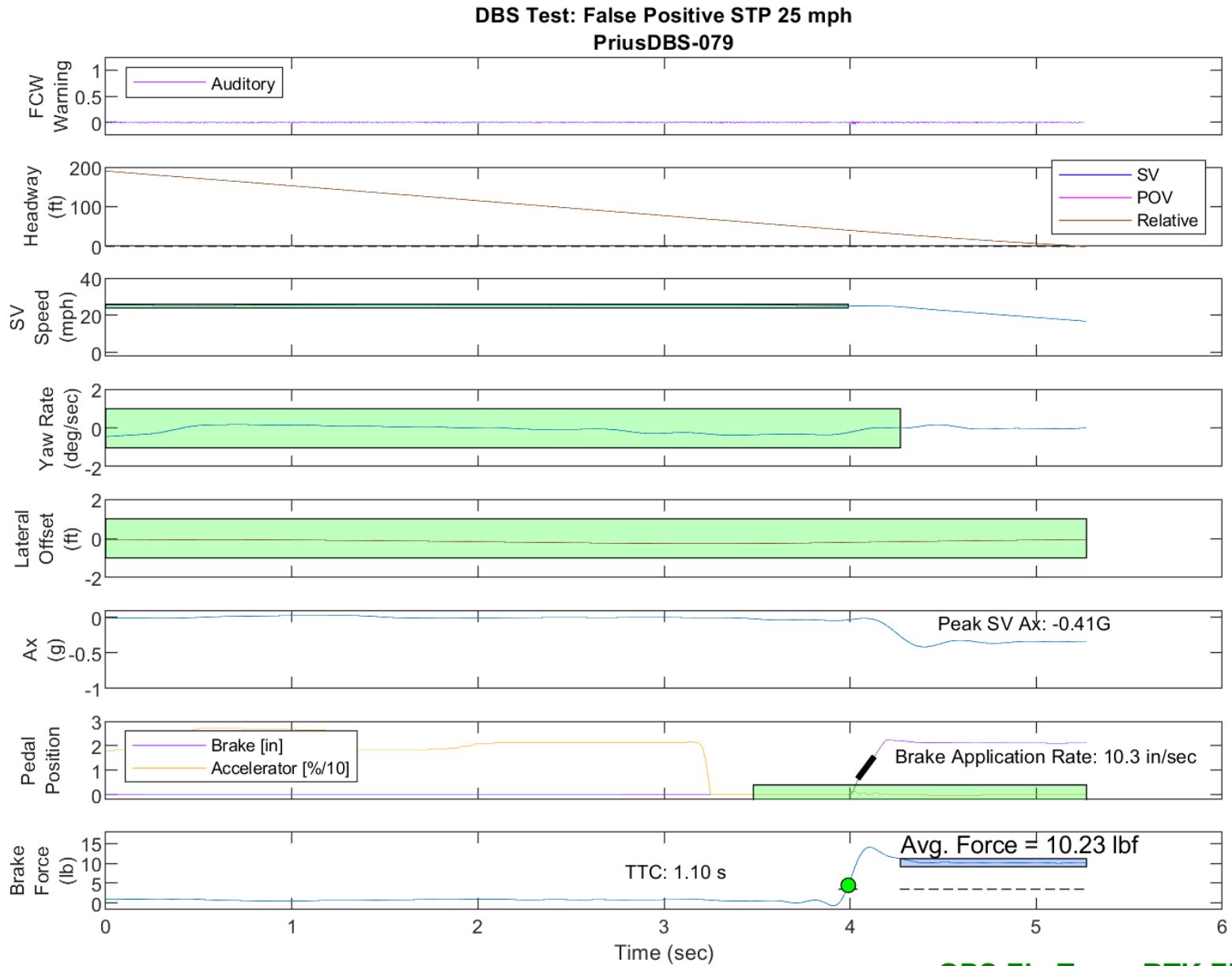


Figure E55. Time History for DBS Run 79, SV Encounters Steel Trench Plate, SV 25 mph

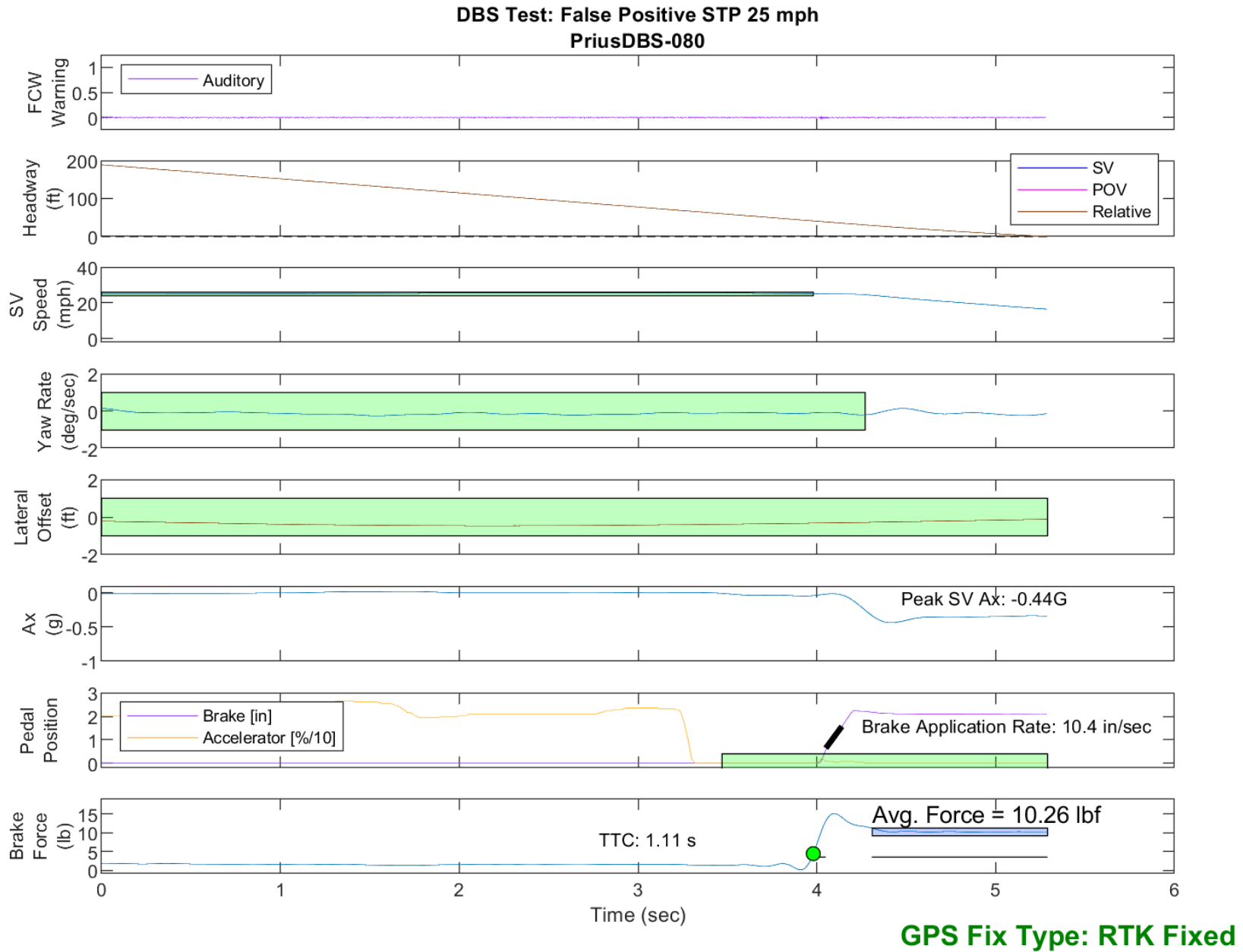


Figure E56. Time History for DBS Run 80, SV Encounters Steel Trench Plate, SV 25 mph

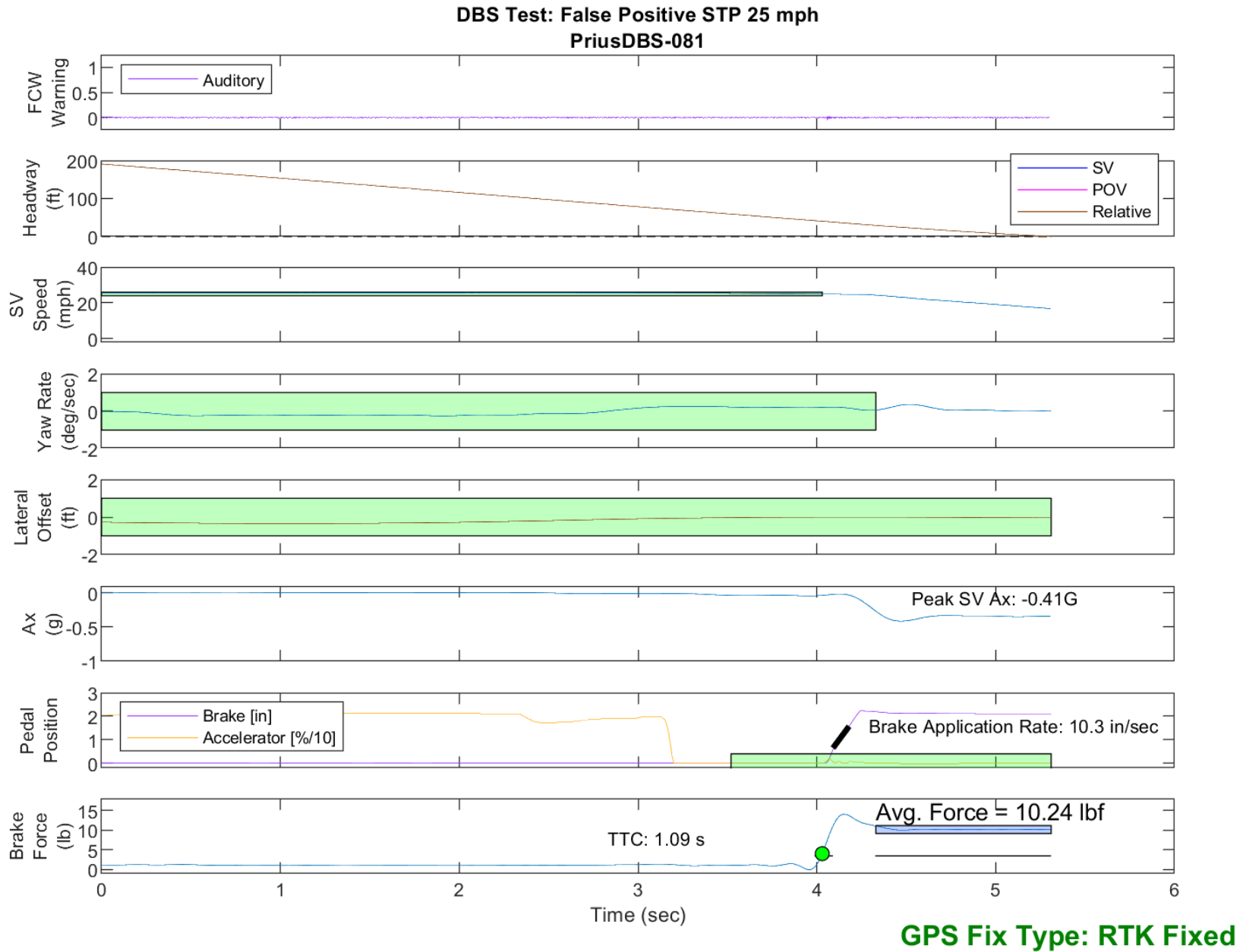


Figure E57. Time History for DBS Run 81, SV Encounters Steel Trench Plate, SV 25 mph

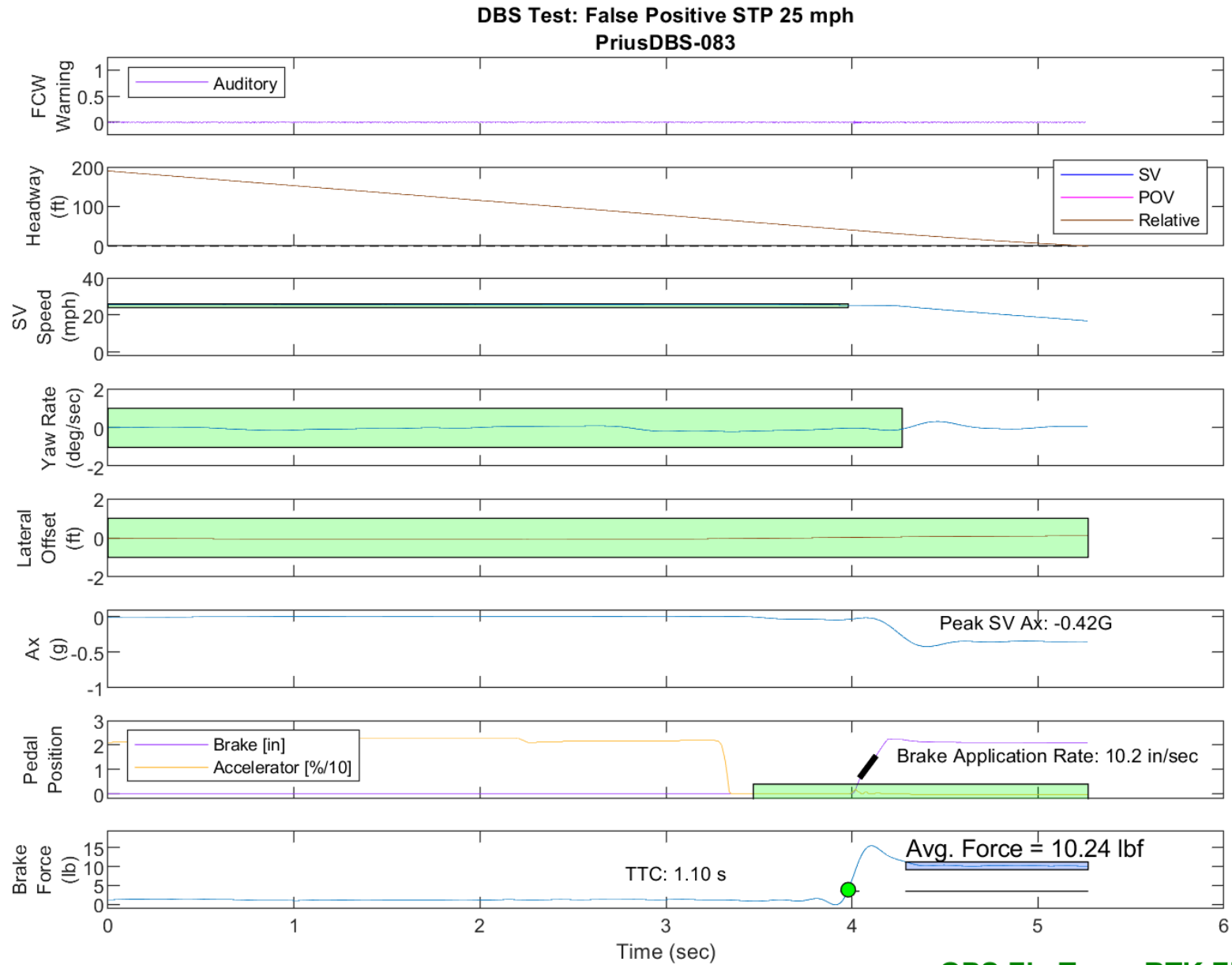


Figure E58. Time History for DBS Run 83, SV Encounters Steel Trench Plate, SV 25 mph



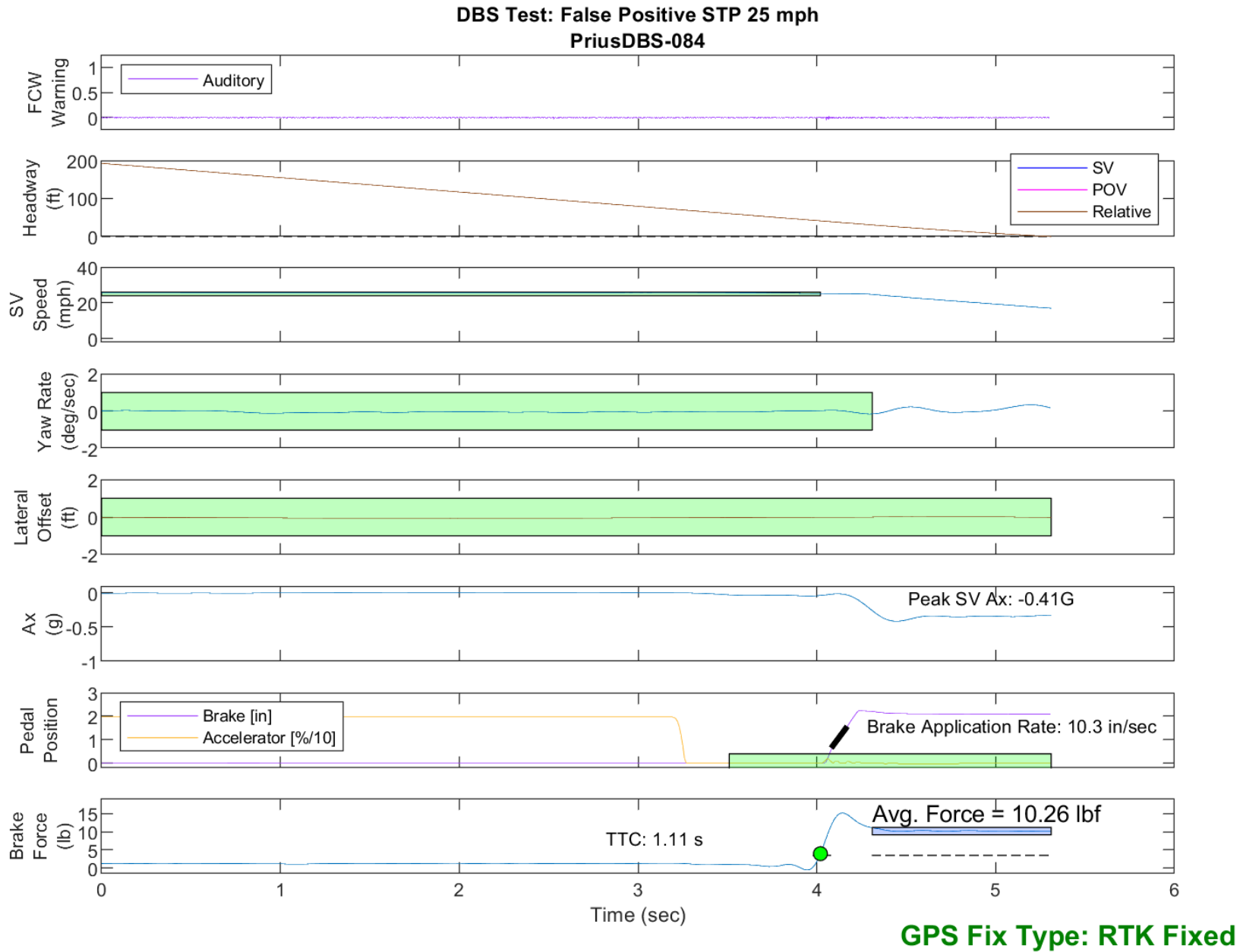
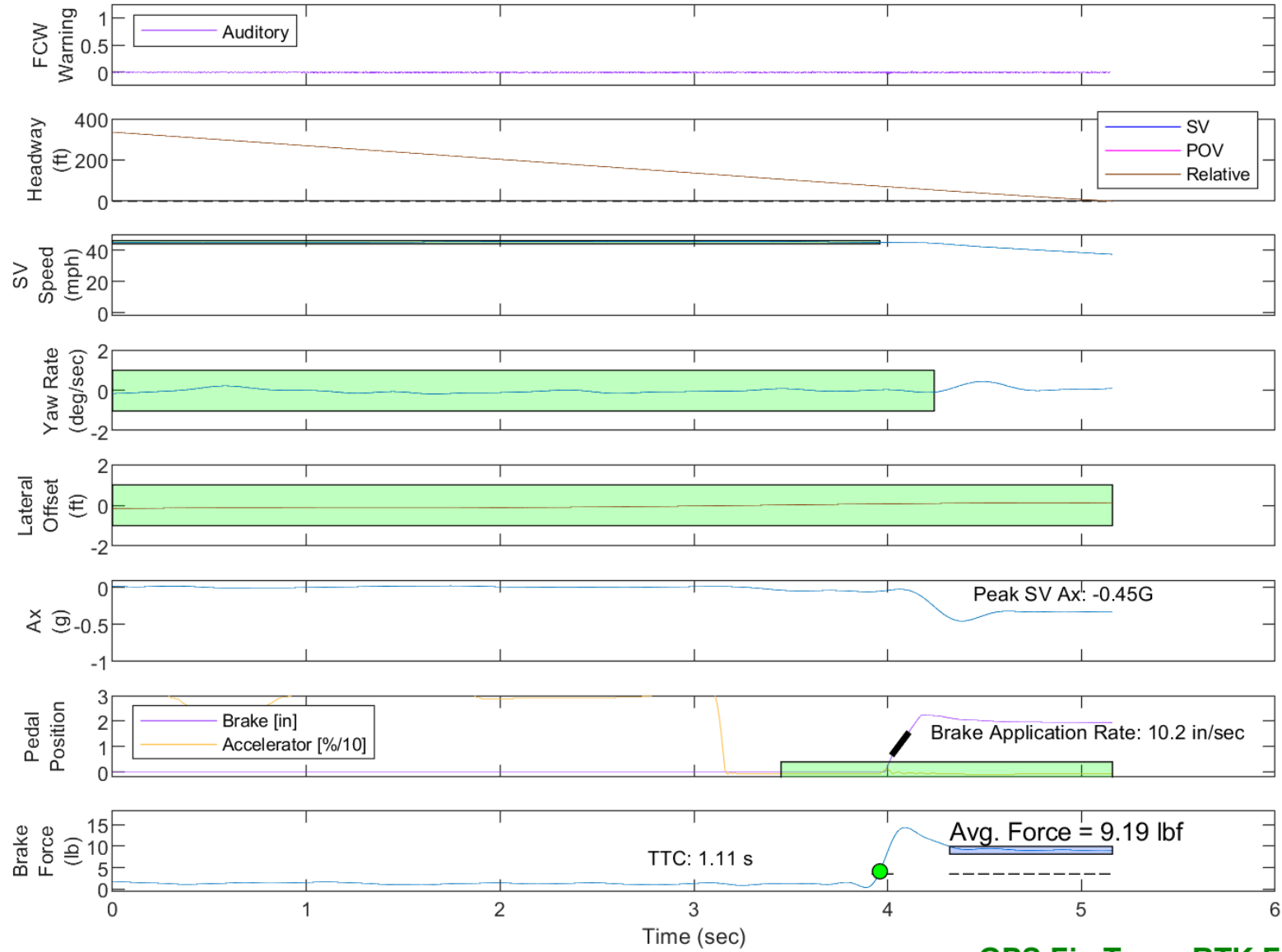


Figure E59. Time History for DBS Run 84, SV Encounters Steel Trench Plate, SV 25 mph

DBS Test: False Positive STP 45 mph  
PriusDBS-087



GPS Fix Type: RTK Fixed

Figure E60. Time History for DBS Run 87, SV Encounters Steel Trench Plate, SV 45 mph

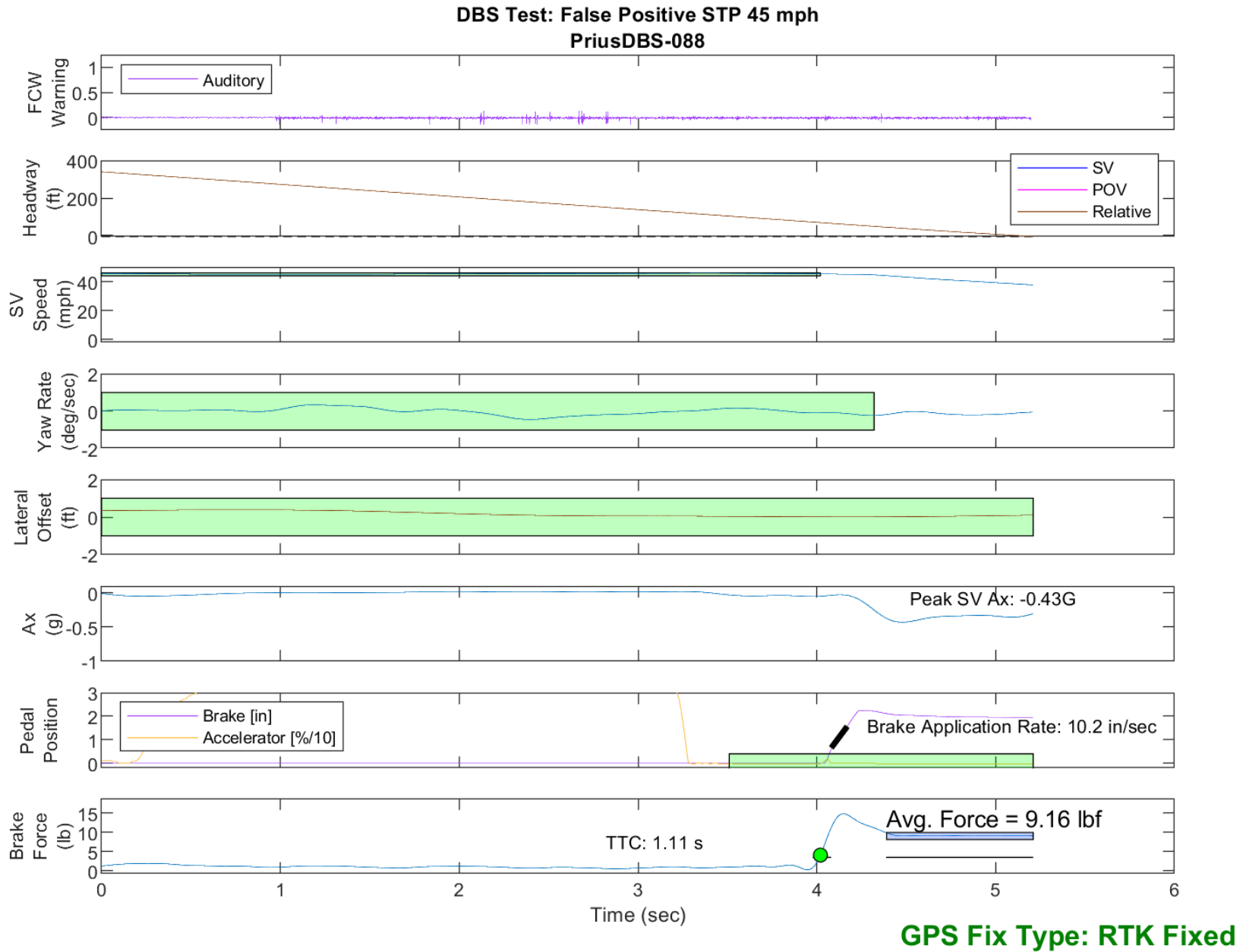


Figure E61. Time History for DBS Run 88, SV Encounters Steel Trench Plate, SV 45 mph

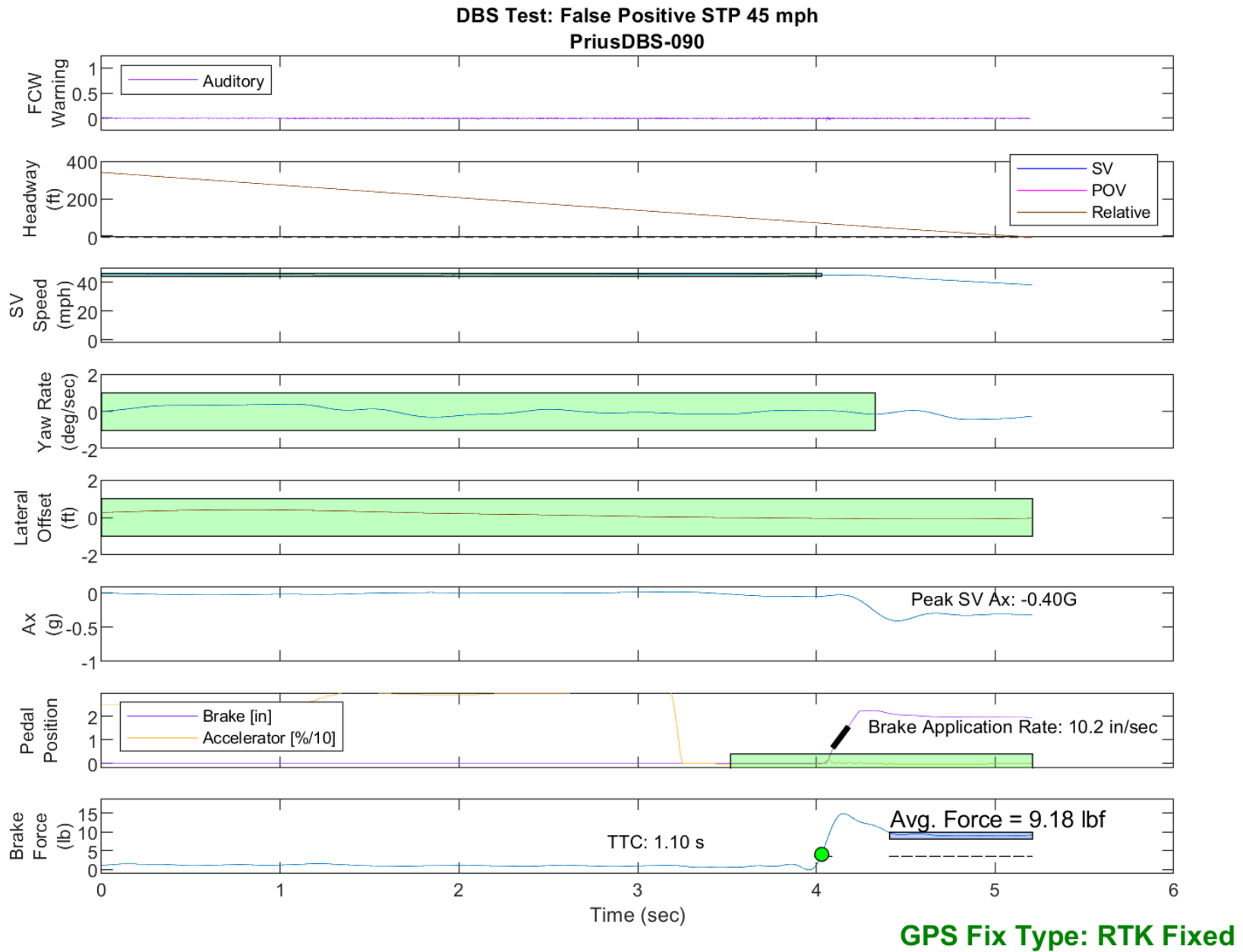
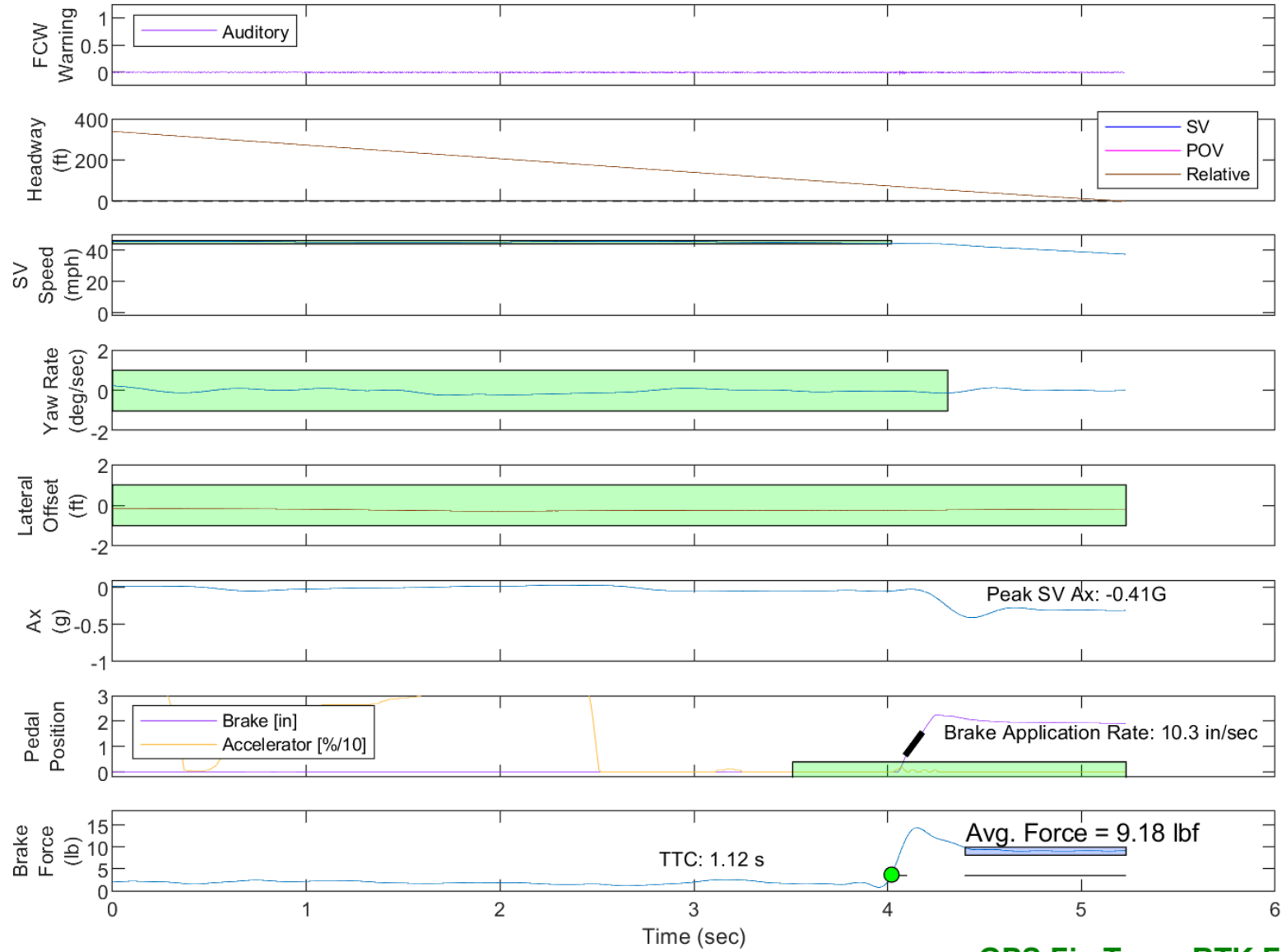


Figure E62. Time History for DBS Run 90, SV Encounters Steel Trench Plate, SV 45 mph

DBS Test: False Positive STP 45 mph  
PriusDBS-091



GPS Fix Type: RTK Fixed

Figure E63. Time History for DBS Run 91, SV Encounters Steel Trench Plate, SV 45 mph

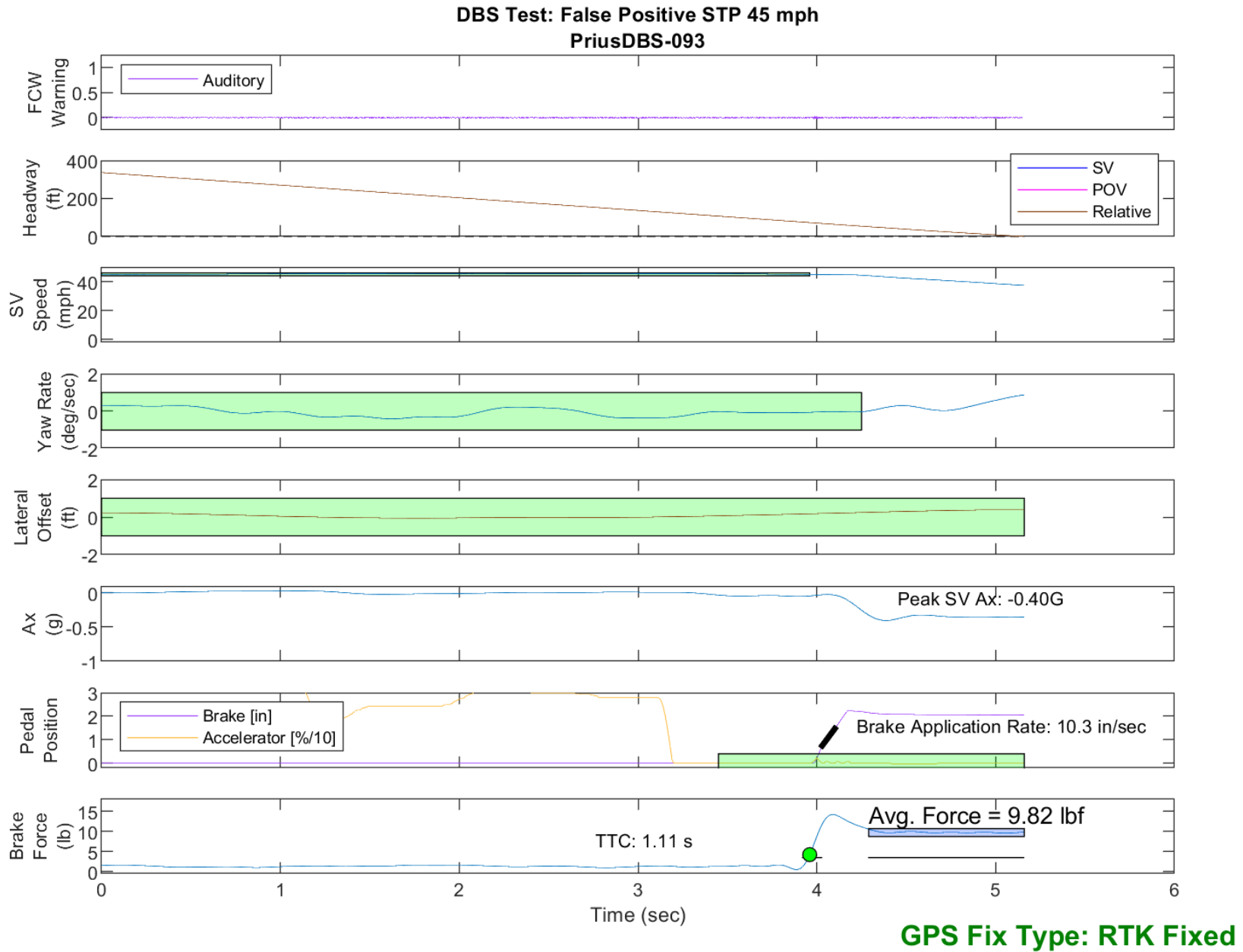
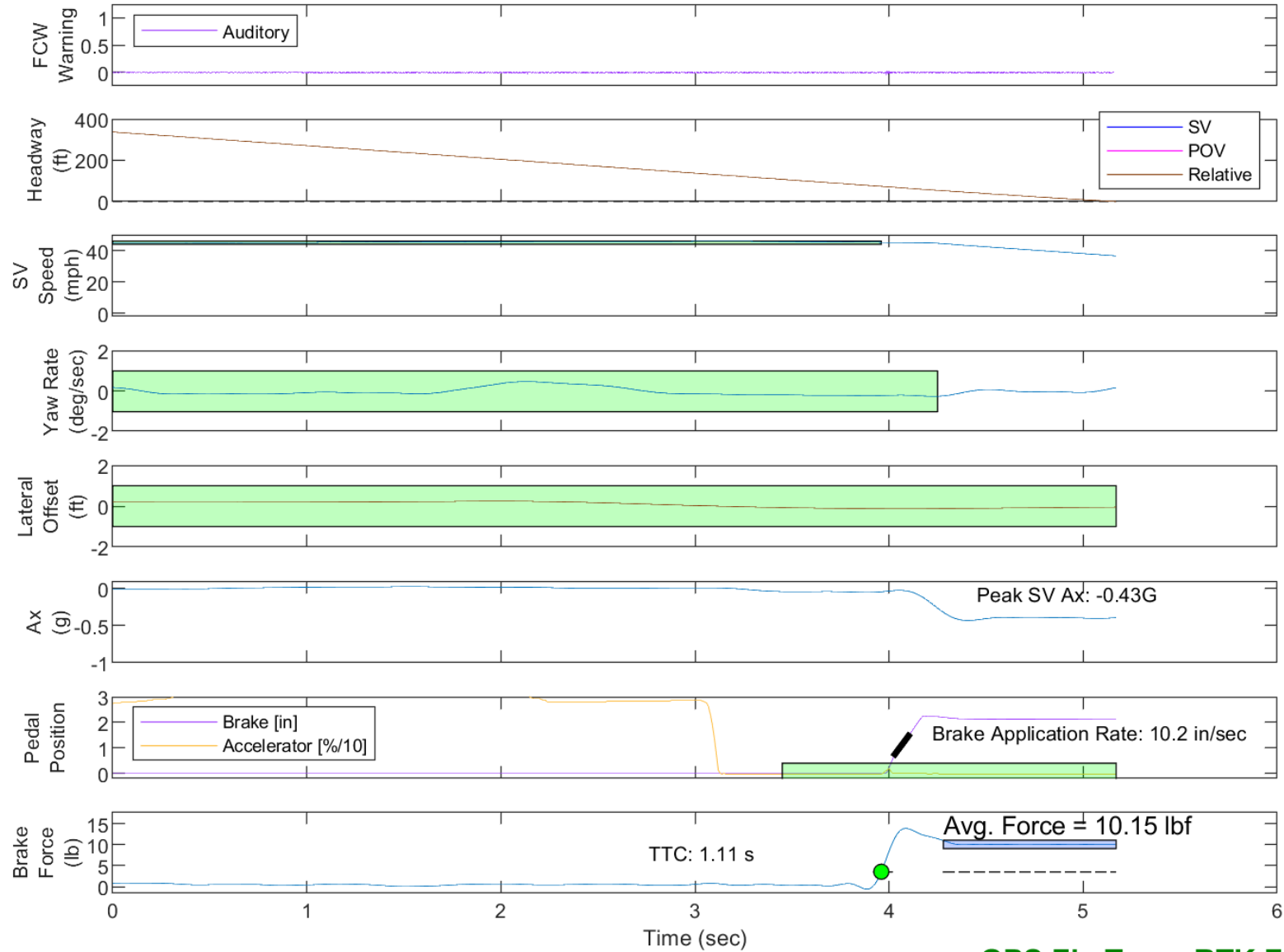


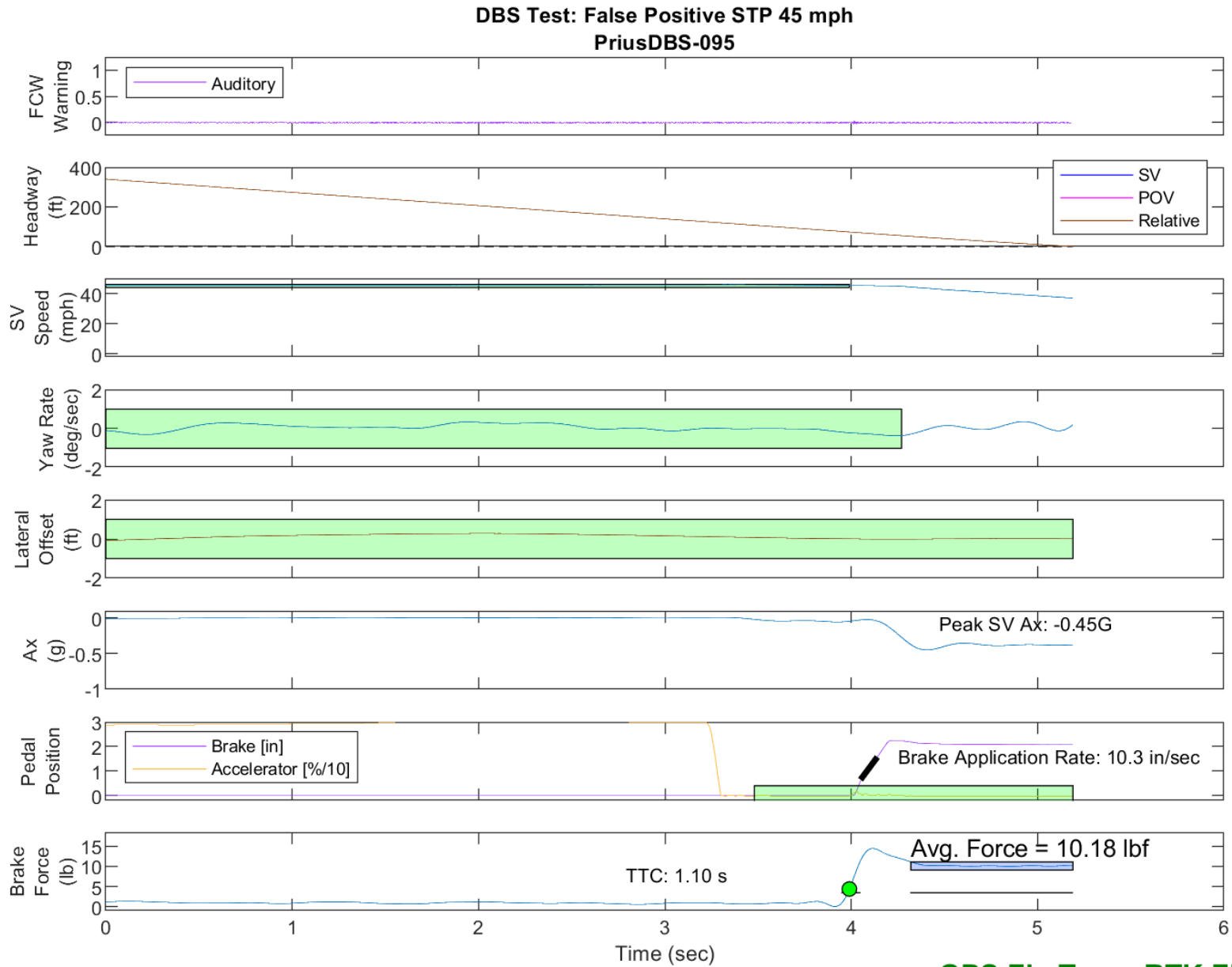
Figure E64. Time History for DBS Run 93, SV Encounters Steel Trench Plate, SV 45 mph

DBS Test: False Positive STP 45 mph  
PriusDBS-094



GPS Fix Type: RTK Fixed

Figure E65. Time History for DBS Run 94, SV Encounters Steel Trench Plate, SV 45 mph



**GPS Fix Type: RTK Fixed**

Figure E66. Time History for DBS Run 95, SV Encounters Steel Trench Plate, SV 45 mph



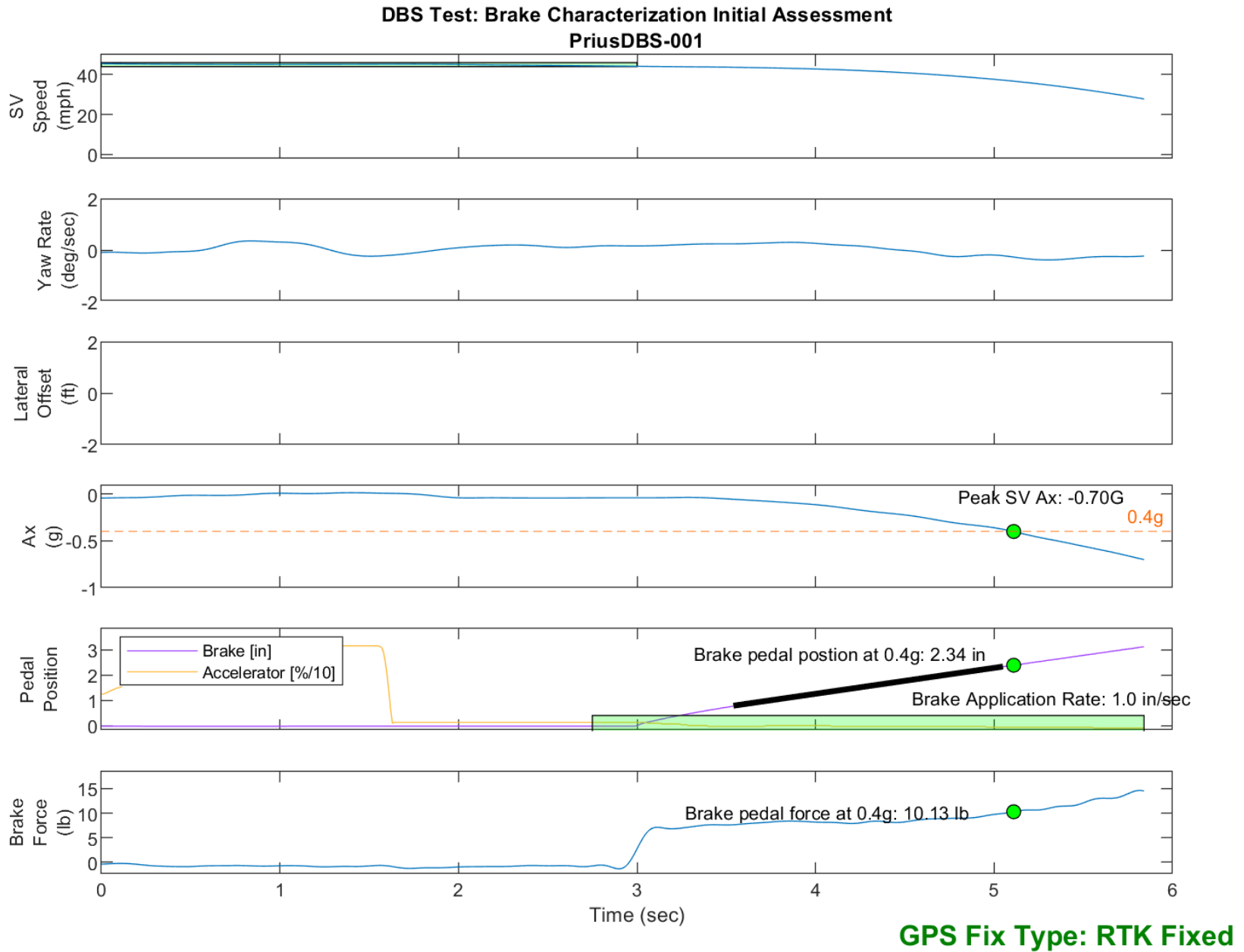
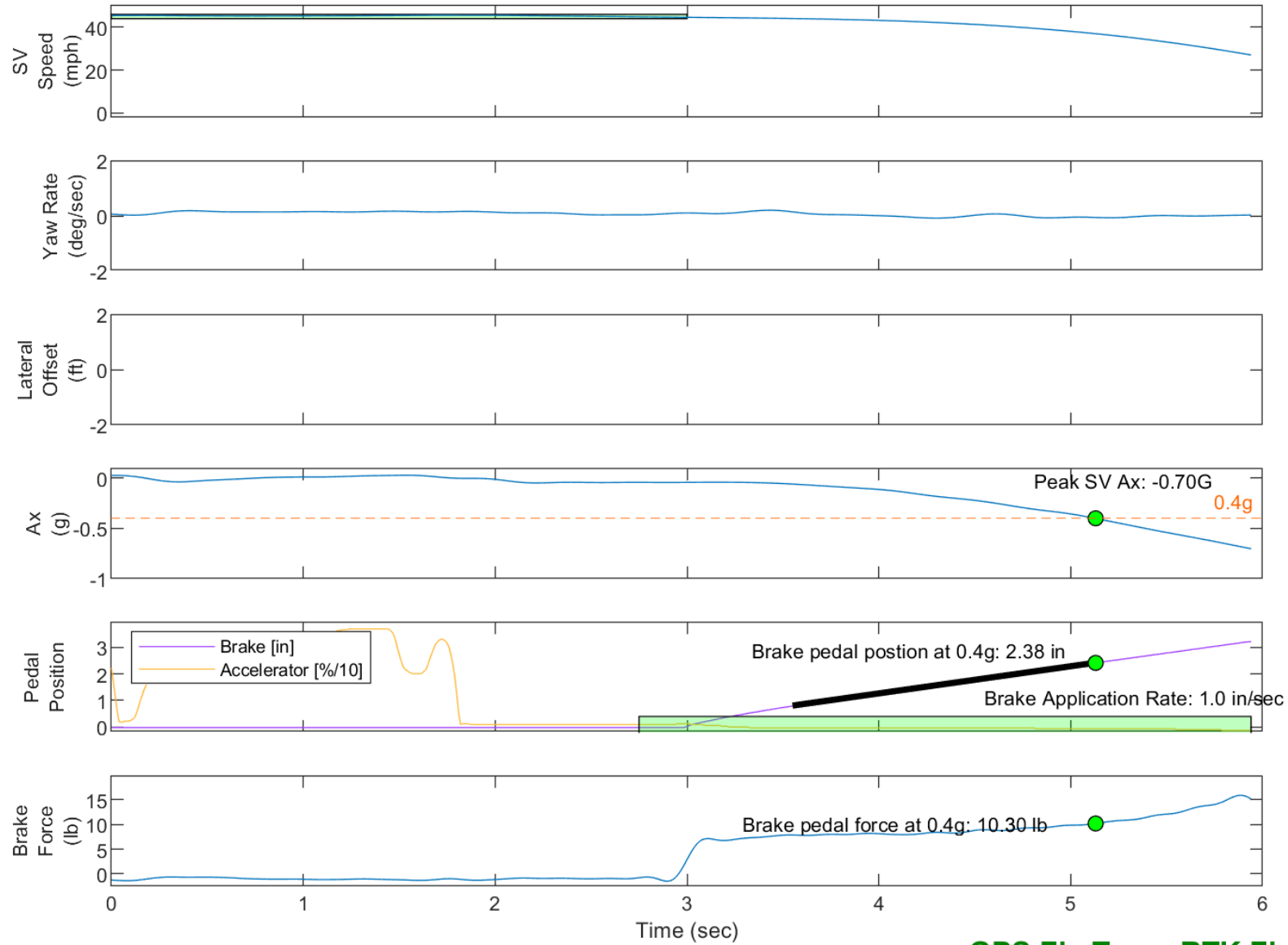


Figure E67. Time History for DBS Run 1, Brake Characterization Initial

### DBS Test: Brake Characterization Initial Assessment PriusDBS-002



GPS Fix Type: RTK Fixed

Figure E68. Time History for DBS Run 2, Brake Characterization Initial

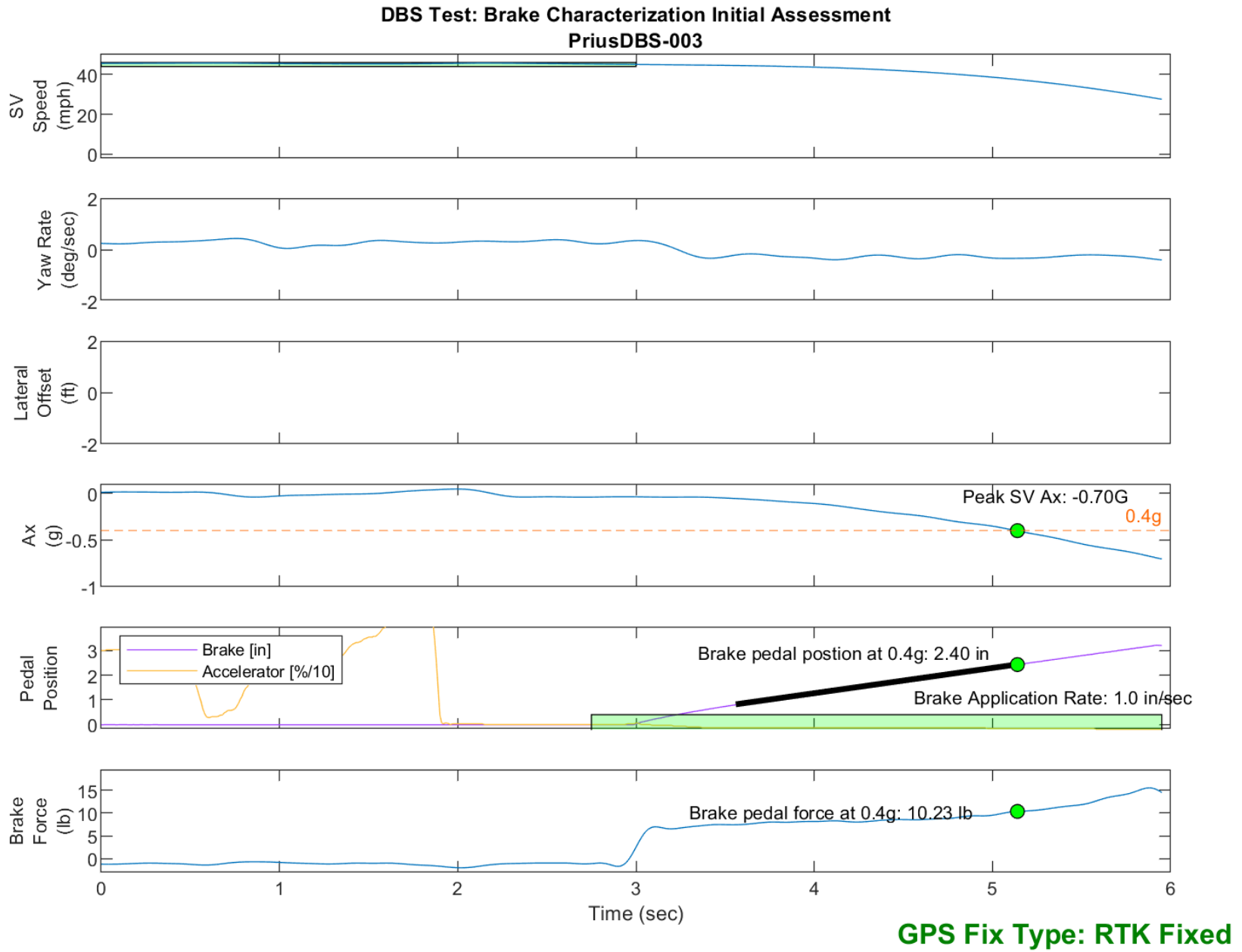


Figure E69. Time History for DBS Run 3, Brake Characterization Initial

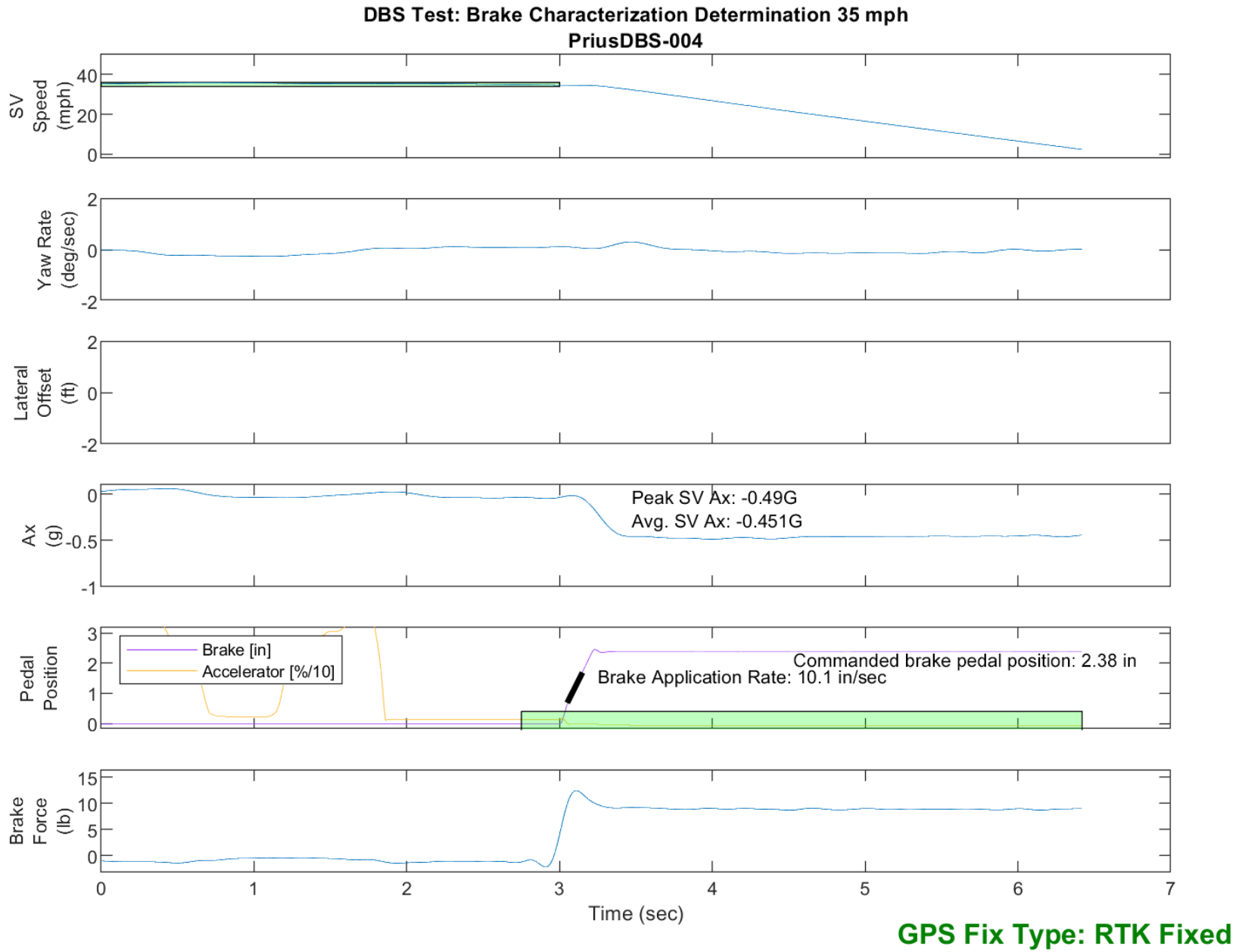


Figure E70. Time History for DBS Run 4, Brake Characterization Determination, Displacement Mode, 35 mph

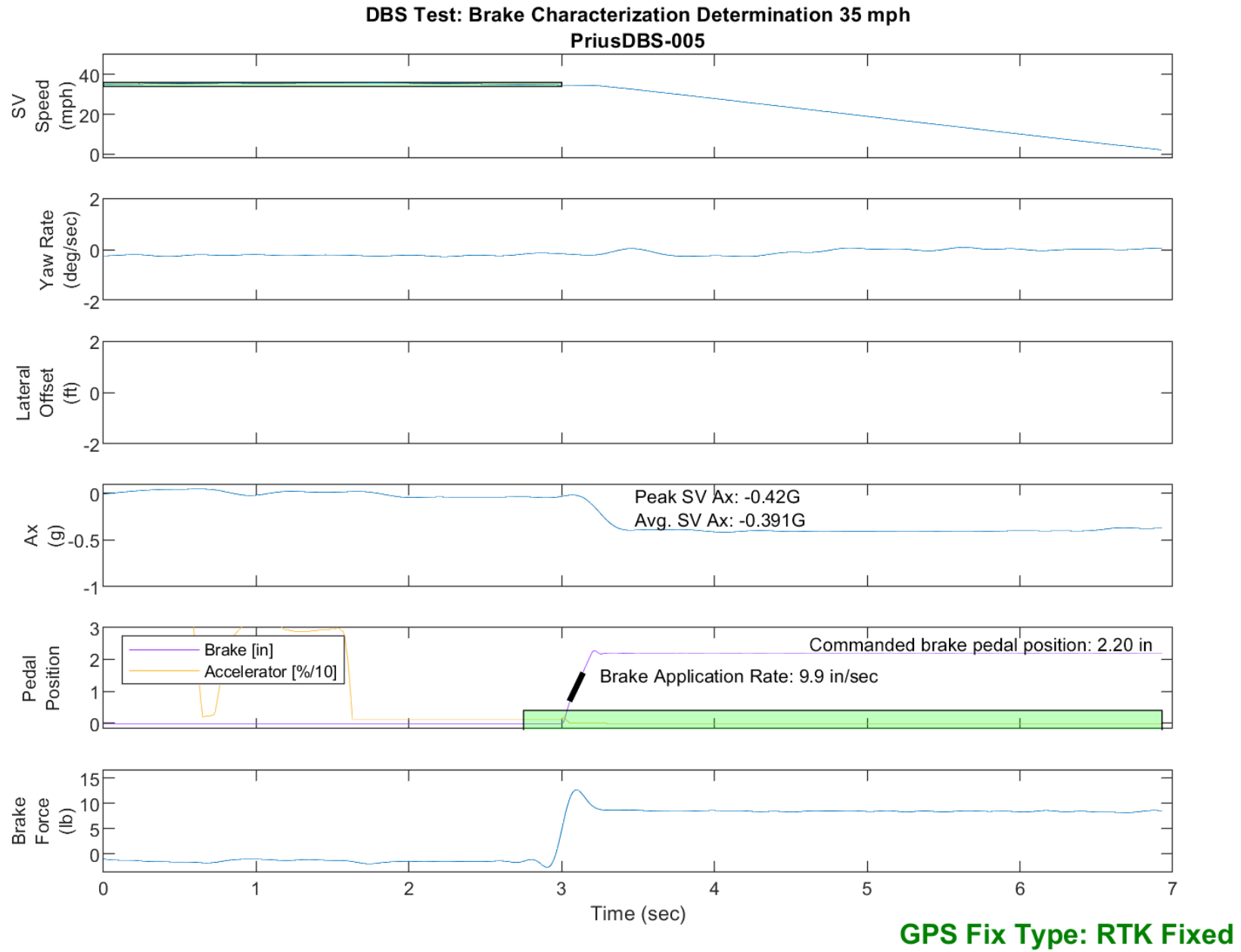
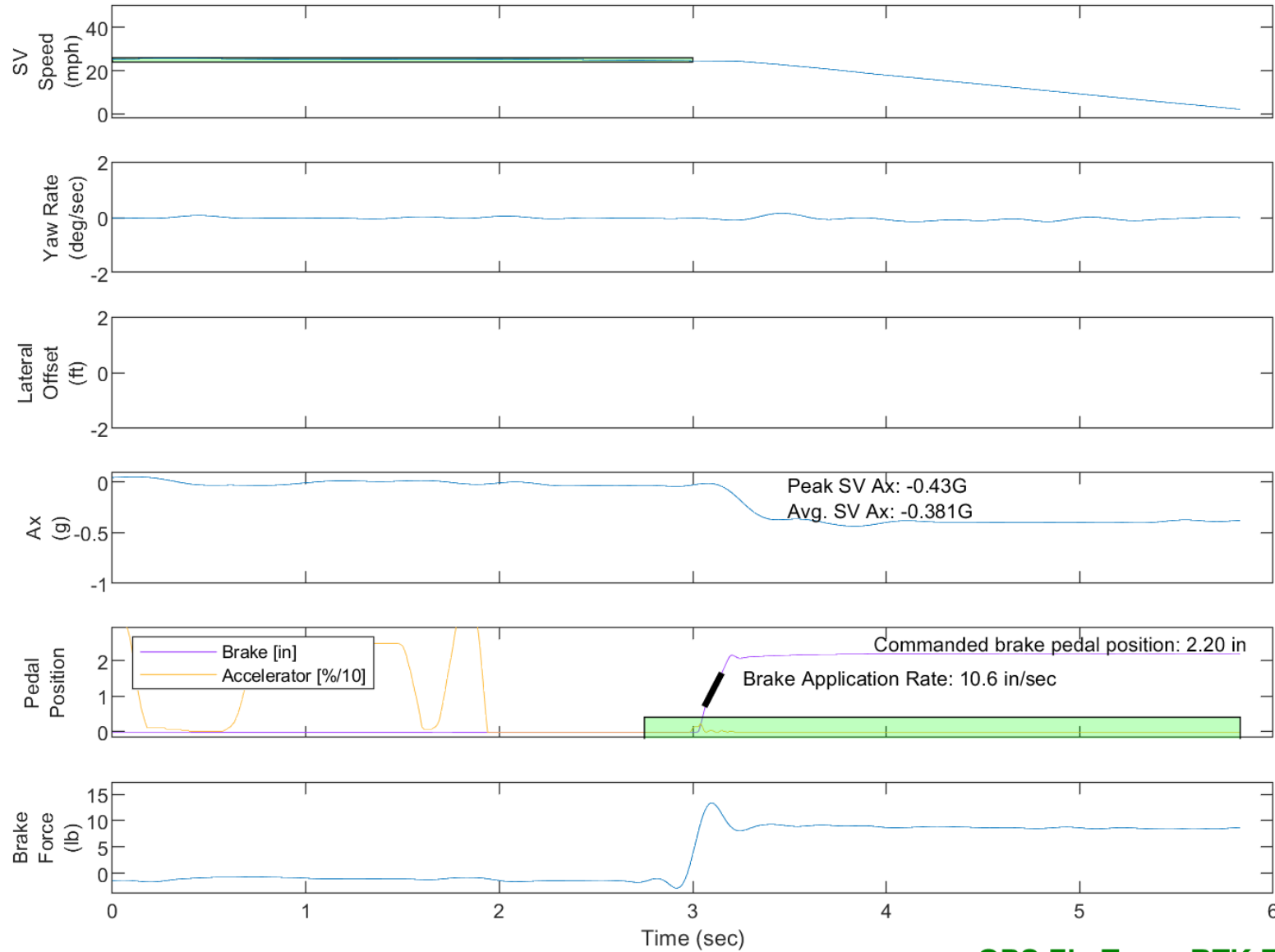


Figure E71. Time History for DBS Run 5, Brake Characterization Determination, Displacement Mode, 35 mph

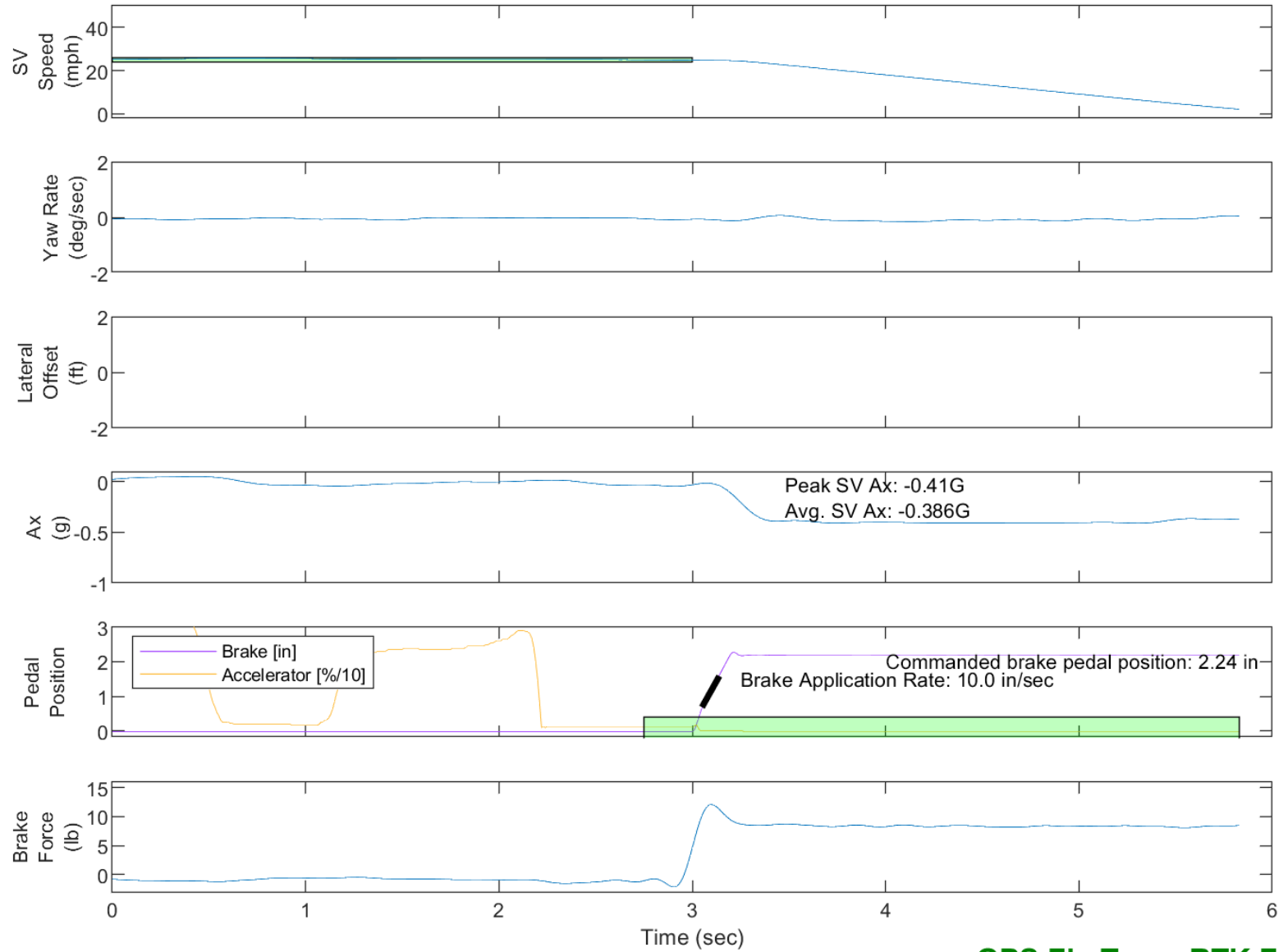
DBS Test: Brake Characterization Determination 25 mph  
PriusDBS-006



GPS Fix Type: RTK Fixed

Figure E72. Time History for DBS Run 6, Brake Characterization Determination, Displacement Mode, 25 mph

DBS Test: Brake Characterization Determination 25 mph  
PriusDBS-007



GPS Fix Type: RTK Fixed

Figure E73. Time History for DBS Run 7, Brake Characterization Determination, Displacement Mode, 25 mph

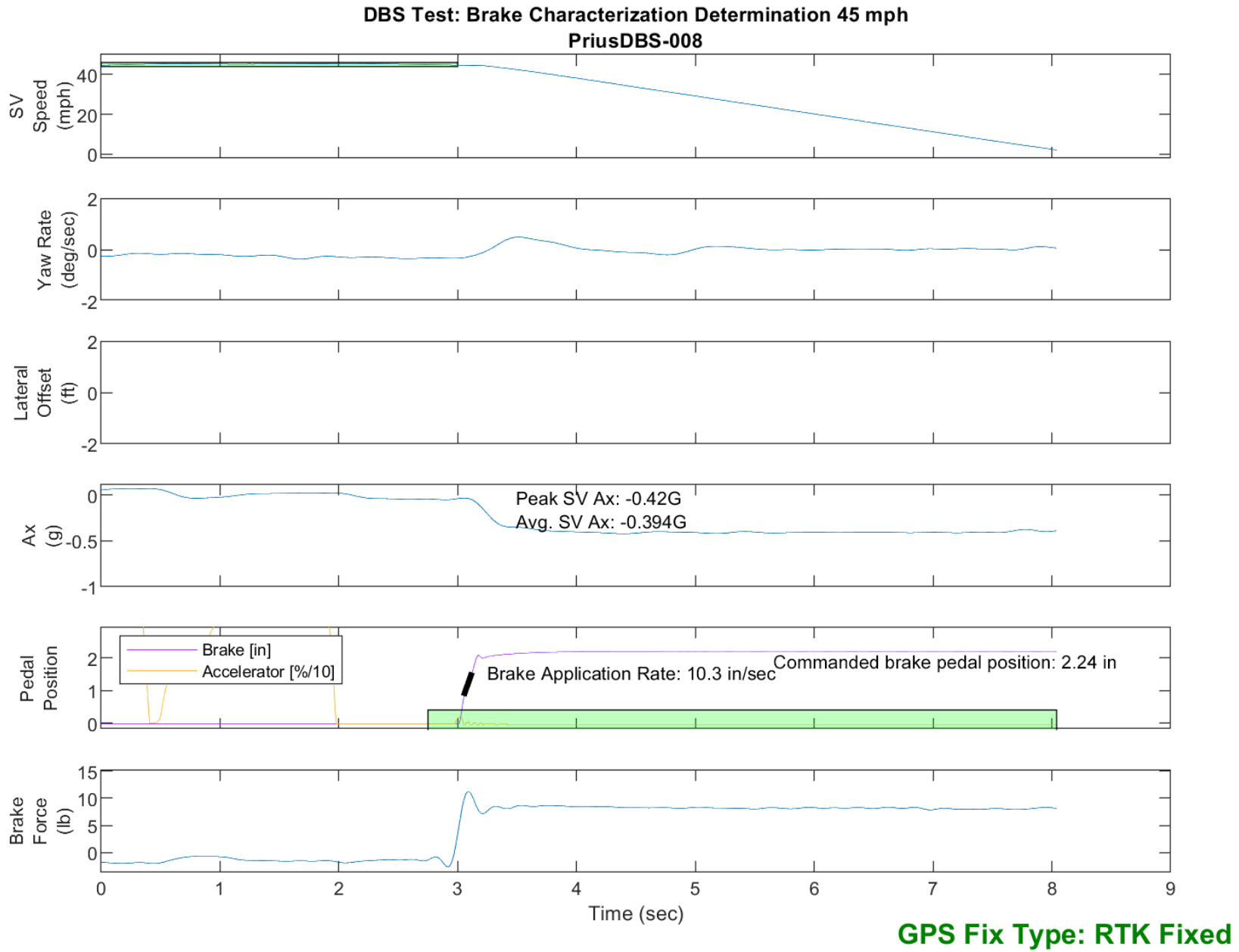


Figure E74. Time History for DBS Run 8, Brake Characterization Determination, Displacement Mode, 45 mph



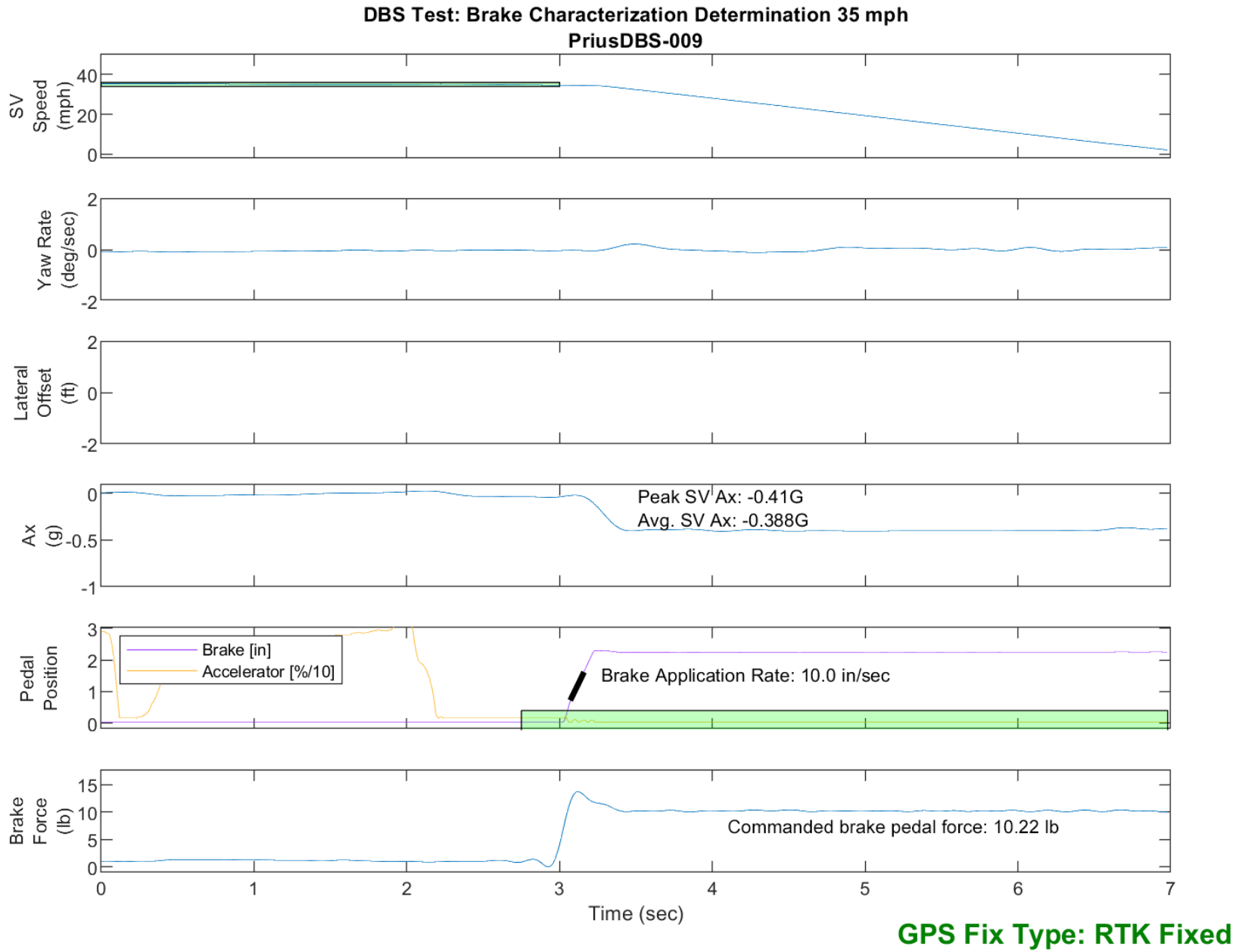


Figure E75. Time History for DBS Run 9, Brake Characterization Determination, Hybrid Mode, 35 mph

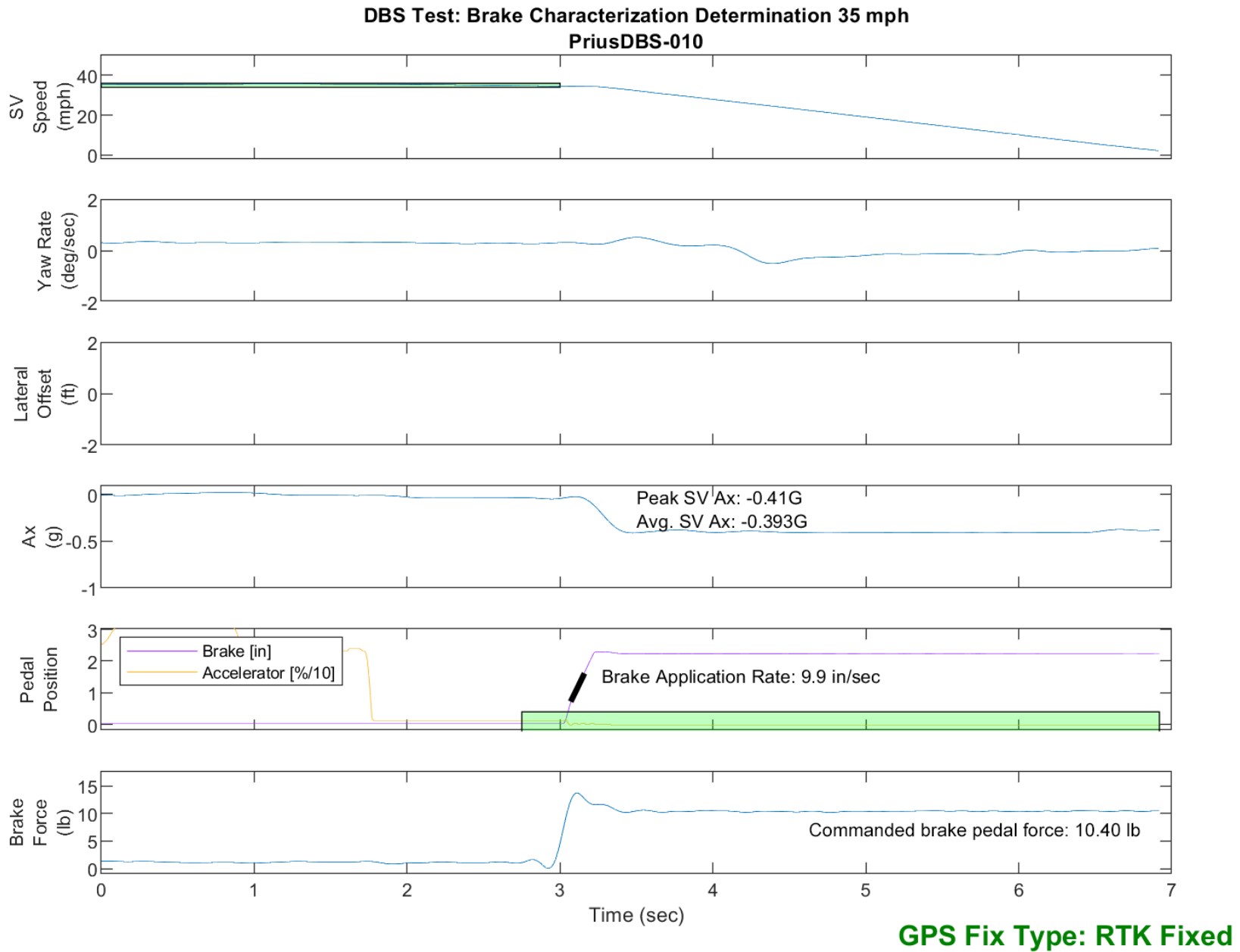


Figure E76. Time History for DBS Run 10, Brake Characterization Determination, Hybrid Mode, 35 mph

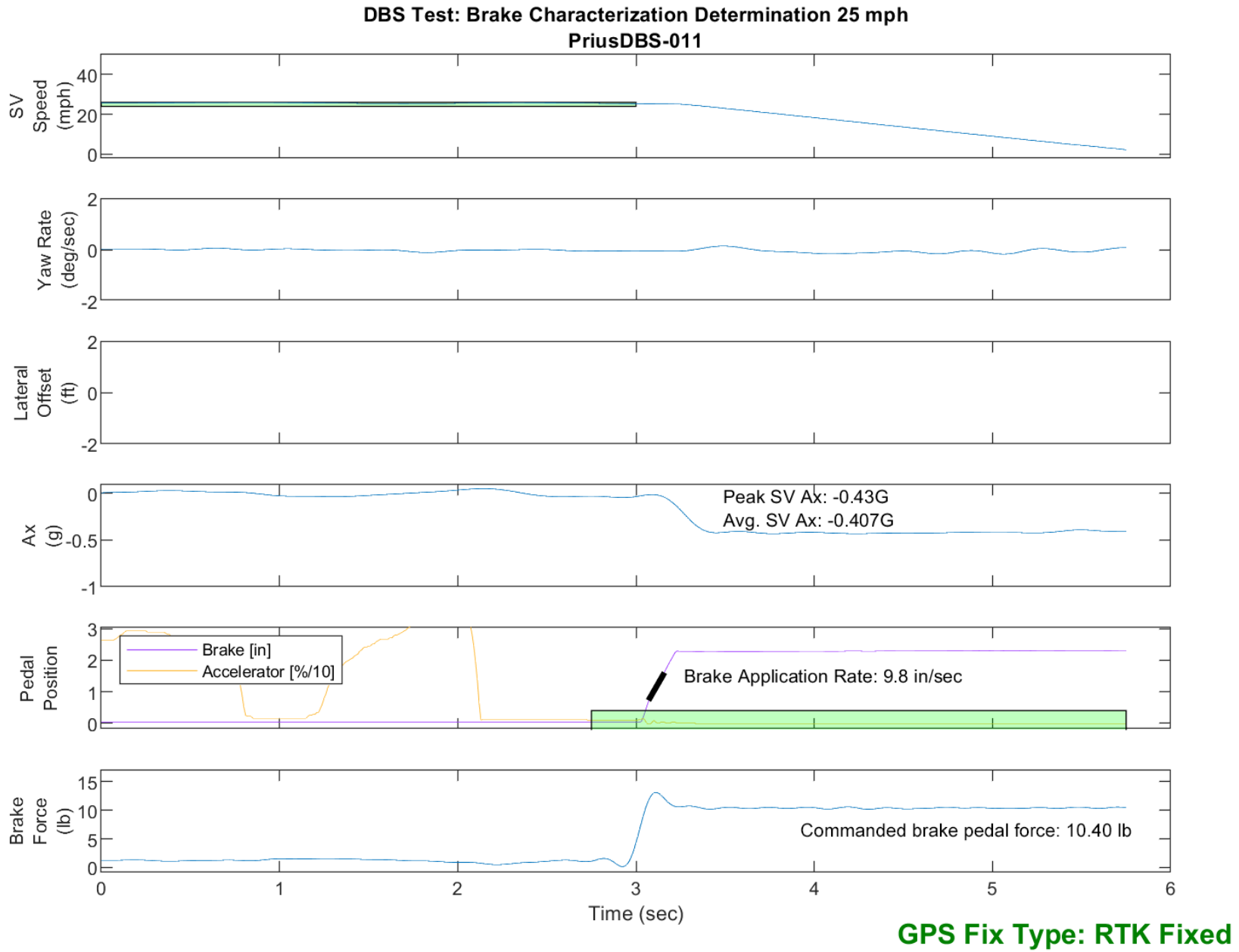
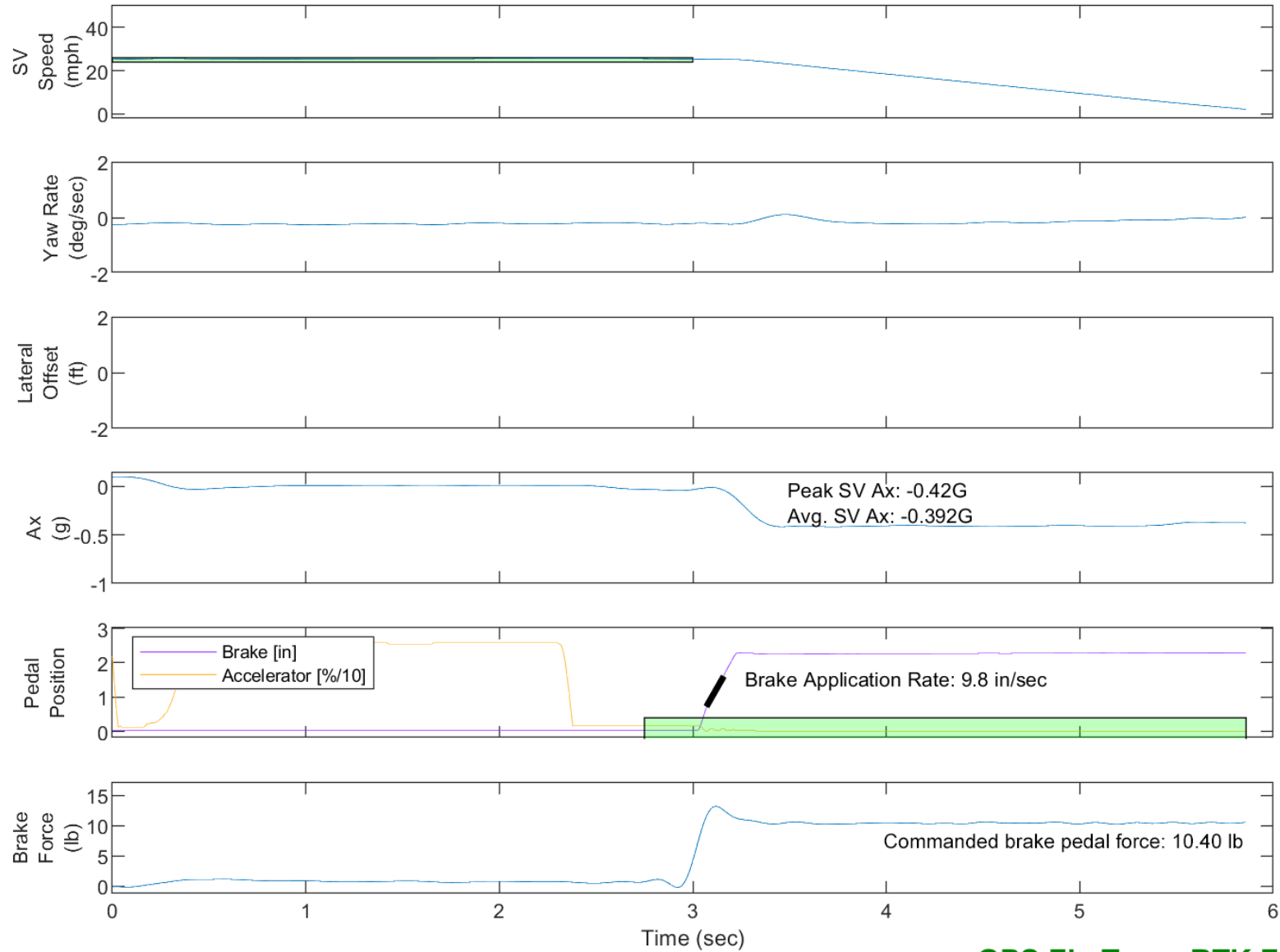


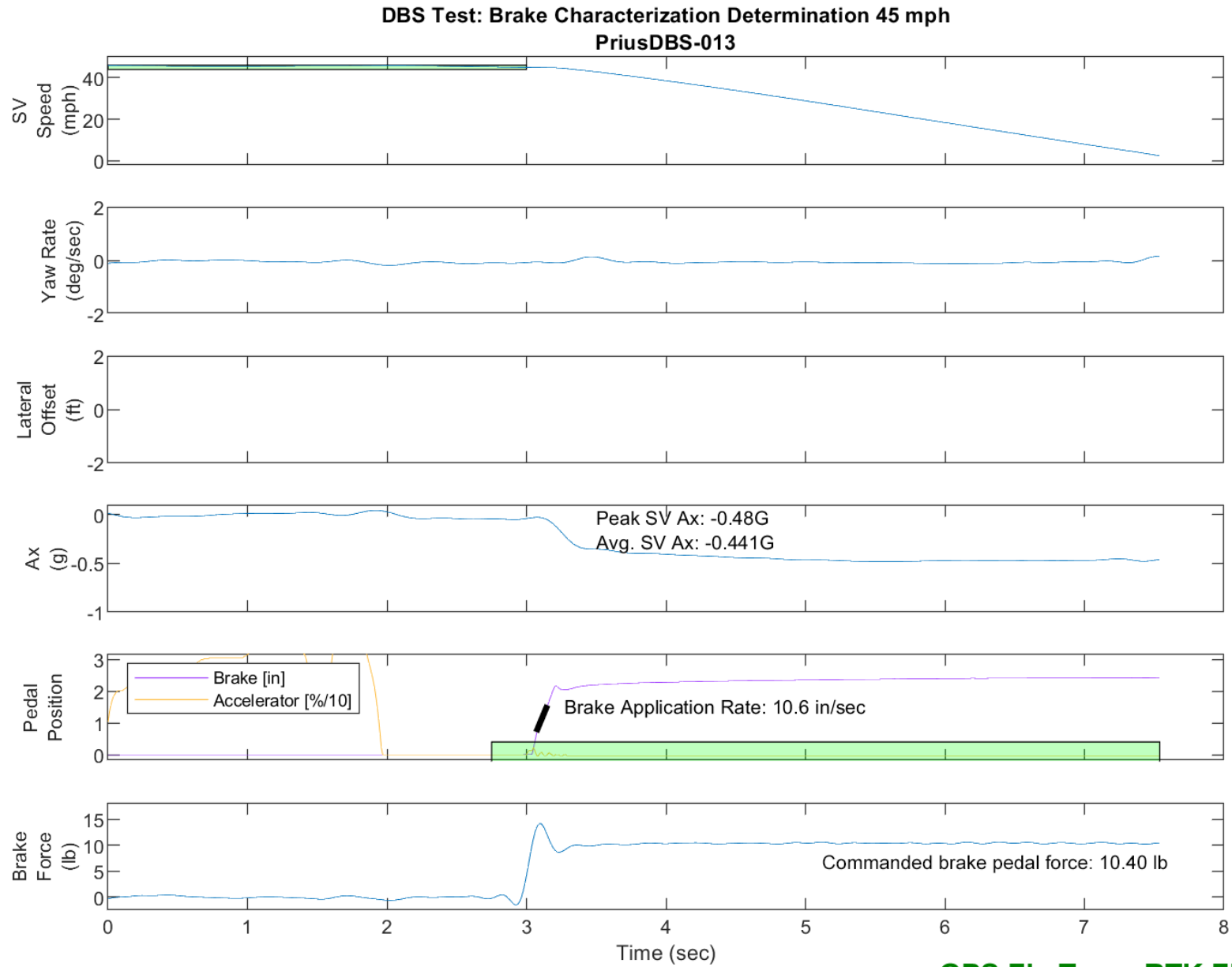
Figure E77. Time History for DBS Run 11, Brake Characterization Determination, Hybrid Mode, 25 mph

DBS Test: Brake Characterization Determination 25 mph  
PriusDBS-012



GPS Fix Type: RTK Fixed

Figure E78. Time History for DBS Run 12, Brake Characterization Determination, Hybrid Mode, 25 mph



**GPS Fix Type: RTK Fixed**

Figure E79. Time History for DBS Run 13, Brake Characterization Determination, Hybrid Mode, 45 mph

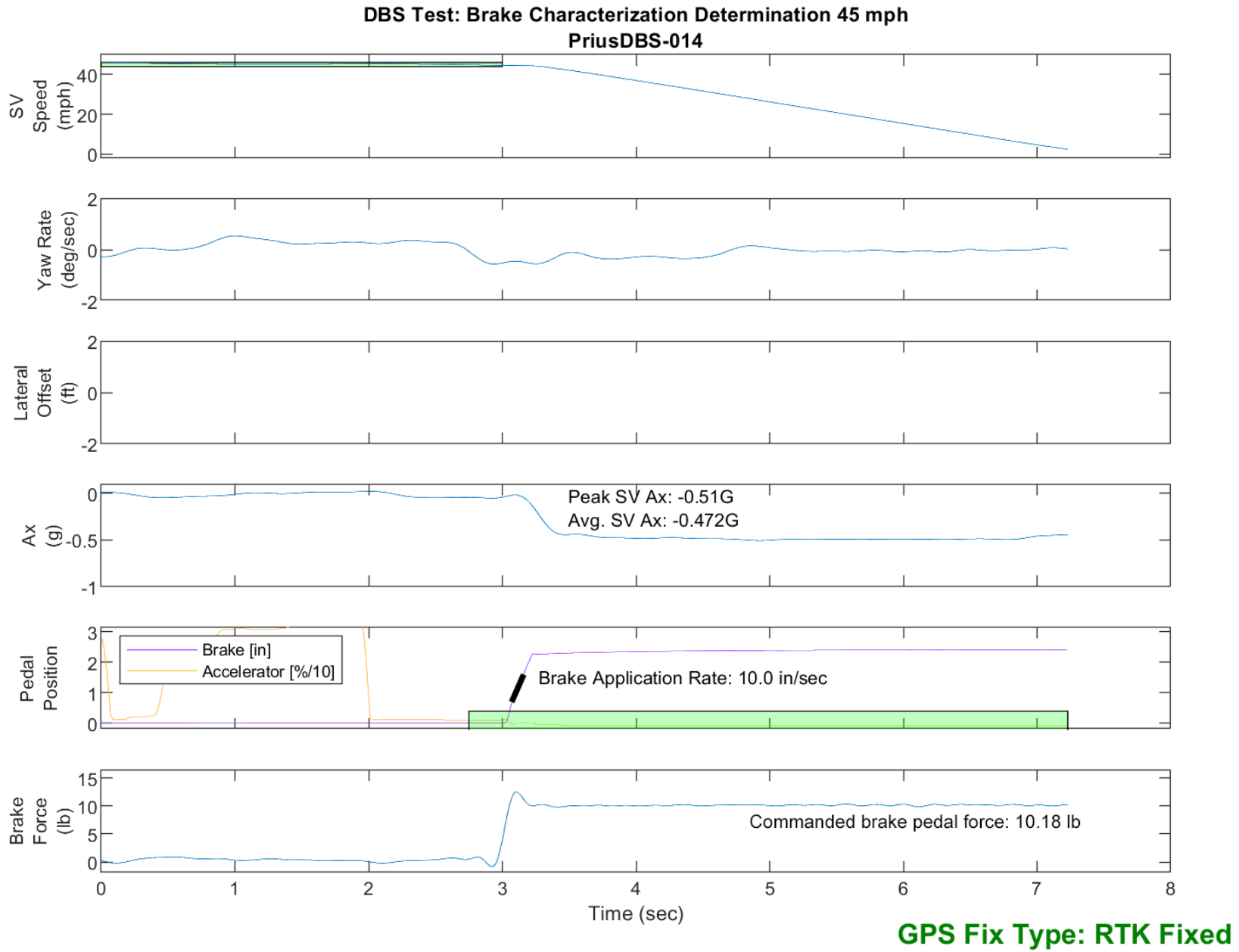
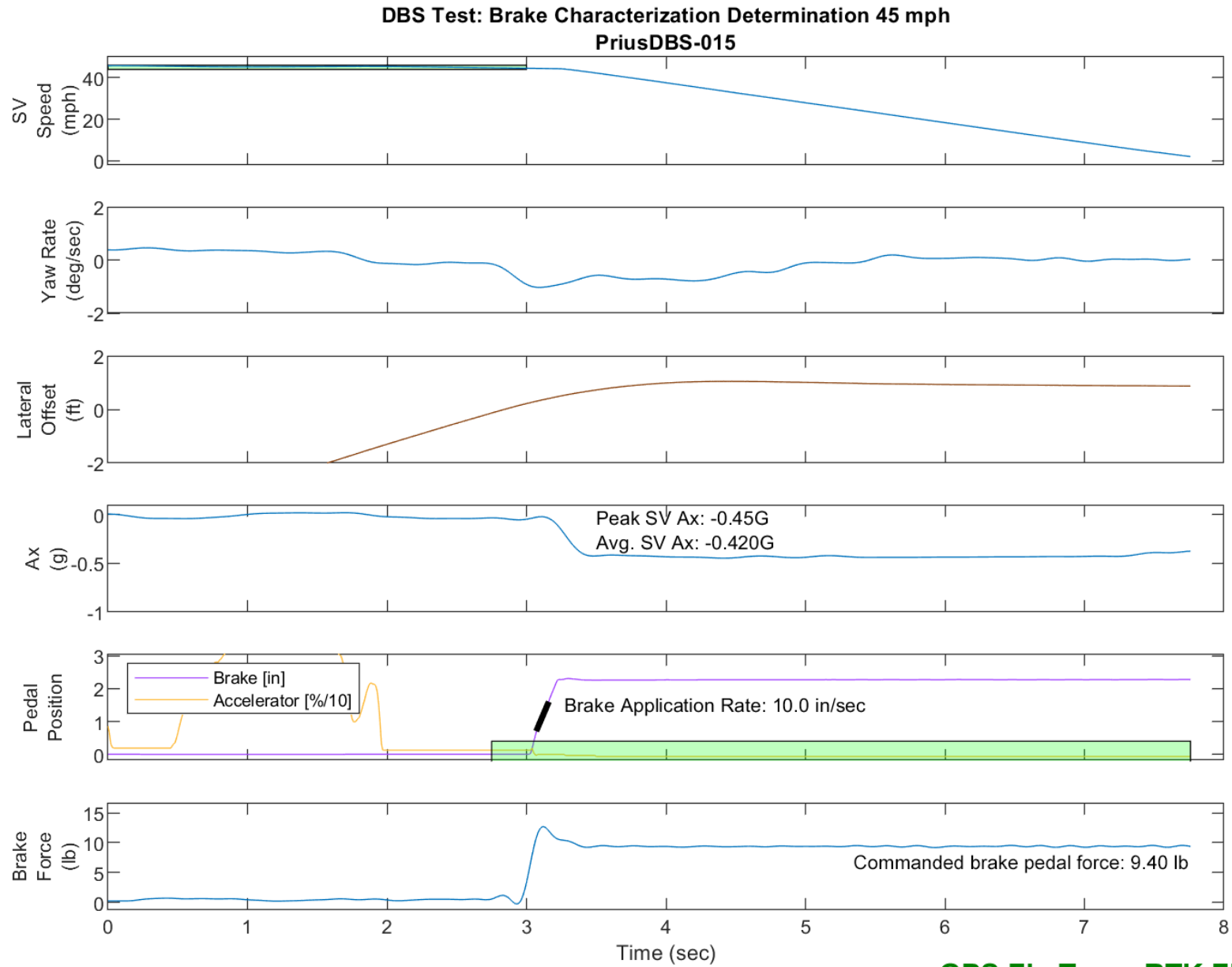


Figure E80. Time History for DBS Run 14, Brake Characterization Determination, Hybrid Mode, 45 mph



**GPS Fix Type: RTK Fixed**

Figure E81. Time History for DBS Run 15, Brake Characterization Determination, Hybrid Mode, 45 mph

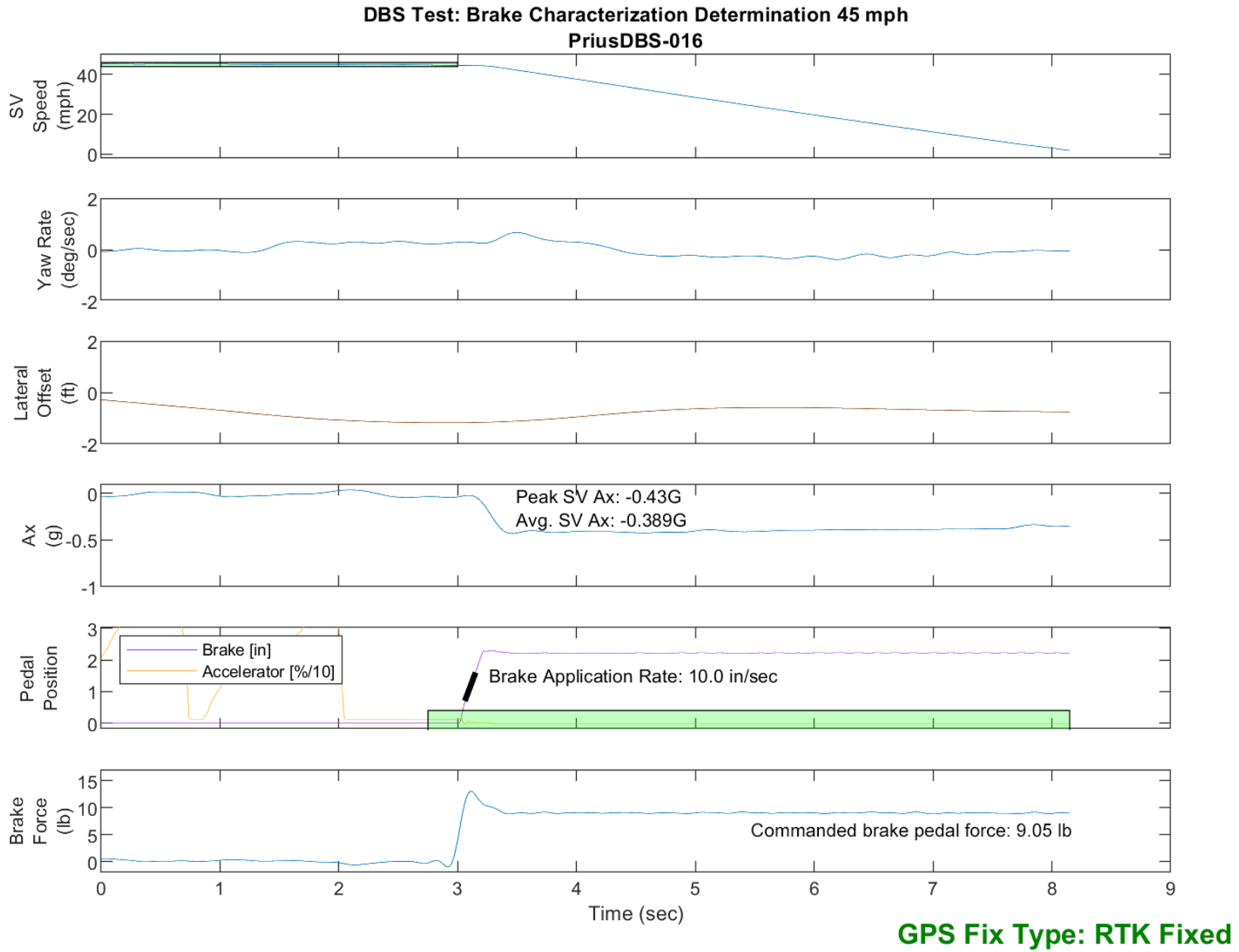


Figure E82. Time History for DBS Run 16, Brake Characterization Determination, Hybrid Mode, 45 mph