NEW CAR ASSESSMENT PROGRAM
DYNAMIC BRAKE SUPPORT SYSTEM CONFIRMATION TEST
NCAP-DRI-DBS-21-08

2021 Hyundai Elantra SEL

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

7 April 2021

Final Report

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

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

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

Prepared By: J. Lenkeit and K. Nagao

Technical Director Test Engineer

Date: 7 April 2021

1. Report No. NCAP-DRI-DBS-21-08	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Final Report of Dynamic Brake Support System Confirmation Test of a 2021 Hyundai Elantra SEL.		5. Report Date 7 April 2021	
		6. Performing Organization Code DRI	
7. Author(s) J. Lenkeit, Technical Director K. Nagao, Test Engineer		8. Performing Organization Report No. DRI-TM-20-212	
9. Performing Organization Name and Address Dynamic Research, Inc. 355 Van Ness Ave, STE 200 Torrance, CA 90501		10. Work Unit No.	
		11. Contract or Grant No. DTNH22-14-D-00333	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration New Car Assessment Program 1200 New Jersey Avenue, SE, West Building, 4th Floor (NRM-110) Washington, DC 20590		13. Type of Report and Period Covered Final Test Report March – April 2021	
		14. Sponsoring Agency Code NRM-110	
15. Supplementary Notes			
16. Abstract These tests were conducted on the subject 2021 Hyundai Elantra SEL in accordance with the specifications of the New Car Assessment Program's (NCAP) most current Test Procedure in docket NHTSA-2015-0006-0026; DYNAMIC BRAKE SUPPORT PERFORMANCE EVALUATION CONFIRMATION TEST FOR THE NEW CAR ASSESSMENT PROGRAM**,** October 2015. The vehicle passed the requirements of the test for all four DBS test scenarios.			
17. Key Words Dynamic Brake Support, DBS, AEB, New Car Assessment Program, NCAP		18. Distribution Statement Copies of this report are available from the following: NHTSA Technical Reference Division National Highway Traffic Safety Administration 1200 New Jersey Avenue, SE Washington, DC 20590	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 186	22. Price

TABLE OF CONTENTS

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 Hyundai Elantra SEL. 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).

The 2021 Hyundai Elantra is available with two types of AEB systems. One of these uses a camera-only system and the other system uses a fusion of a camera and forward-facing radar. The vehicle covered in this report was equipped with the fusion system.

Section II

DATA SHEETS

DYNAMIC BRAKE SUPPORT

DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2021 Hyundai Elantra SEL

VIN: *5NPLN4AG0MH01xxxx*

Test Date: *3/8/2021*

Dynamic Brake Support System settings: *Forward Safety: Active Assist*
Warning Timing: Normal
Warning Volume: High

Test 1 - Subject Vehicle Encounters Stopped Principal Other Vehicle

SV 25 mph: *Pass*

Test 2 - Subject Vehicle Encounters Slower Principal Other Vehicle

SV 25 mph POV 10 mph: *Pass*

SV 45 mph POV 20 mph: *Pass*

Test 3 - Subject Vehicle Encounters Decelerating Principal Other Vehicle

SV 35 mph POV 35 mph: *Pass*

Test 4 - Subject Vehicle Encounters Steel Trench Plate

SV 25 mph: *Pass*

SV 45 mph: *Pass*

Overall: *Pass*

Notes:

DYNAMIC BRAKE SUPPORT

DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2021 Hyundai Elantra SEL

TEST VEHICLE INFORMATION

VIN: *5NPLN4AG0MH01xxxx*

Body Style: *Sedan* Color: *Phantom Black*

Date Received: *3/1/2021* Odometer Reading: *24 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Hyundai Motor Manufacturing Alabama, LLC*

Date of manufacture: *Dec/03/20*

Vehicle Type: *Passenger Car*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *225/45R17*

Rear: *225/45R17*

Recommended cold tire pressure: Front: *235 kPa (34 psi)*

Rear: *215 kPa (31 psi)*

TIRES

Tire manufacturer and model: *Kuhmo Majesty Solus*

Front tire specification: *225/45R17 91W*

Rear tire specification: *225/45R17 91W*

Front tire DOT prefix: *000 U1YAVP*

Rear tire DOT prefix: *000 U1YAVP*

DYNAMIC BRAKE SUPPORT

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2021 Hyundai Elantra SEL

GENERAL INFORMATION

Test date: *3/8/2021*

AMBIENT CONDITIONS

Air temperature: *10.0 C (50 F)*

Wind speed: *0.0 m/s (0.0 mph)*

X Wind speed ≤ 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: *235 kPa (34 psi)*

Rear: *215 kPa (31 psi)*

DYNAMIC BRAKE SUPPORT

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2021 Hyundai Elantra SEL

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*448.6 kg (989 lb)*	Right Front:	*420.0 kg (926 lb)*
Left Rear:	*301.2 kg (664 lb)*	Right Rear:	*279.9 kg (617 lb)*
		Total:	*1449.7 kg (3196 lb)*

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 1 of 4)

2021 Hyundai Elantra SEL

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

Forward Collision-Avoidance Assist (FCA) w/ Pedestrian. This is standard equipment. In order to have the sensor fusion, the vehicle must also be equipped with Smart Cruise Control w/ Stop & Go, which is part of the optional package 'Convenience Package'.

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

Sensor fusion (radar and mono camera)

Front view camera: top of windshield, behind the inside mirror

Front radar: on bottom center of the radiator grille

System settings used for test (if applicable): *Forward Safety: Active Assist*

Warning Timing: Normal

Warning Volume: High

Brake application mode used for test: *Hybrid control*

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

10 km/h (6 mph) (Per manufacturer supplied information)

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

75 km/h (47 mph) (Per manufacturer supplied information)

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

X No

If yes, please provide a full description.

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 2 of 4)

2021 Hyundai Elantra SEL

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

____ Yes

X No

If yes, please provide a full description.

In general, FCA does not deactivate due to repeated FCA activations or impacts. However, if the brake actuator or radar/camera sensors have damage or problems due to repeated FCA activations or impacts, FCA can deactivate. In this case, the system provides a diagnostic lamp to the driver.

How is the Forward Collision Warning presented to the driver?

(Check all that apply)

X Warning light

X Buzzer or auditory alarm

____ Vibration

____ Other _____

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

See Appendix A, Figure A16. The visual warning is presented in the center of the instrument cluster. It depicts the upper rear view of a passenger car following a lead passenger car. The initial alert (FCW) shows the words "Collision Warning" and a triangle with an exclamation point. When braking is initiated, the words change to "Emergency Braking". The auditory alert is a 1008 Hz tone pulsed at approximately 8 Hz.

Is there a way to deactivate the system?

X Yes

____ No

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

See Appendix A, Figures A14 and A17.

A menu button on the steering wheel is used to access the system menus displayed on the center touchscreen. The hierarchy is:

User Settings

Driver Assistance

Forward Safety

Select either "Active Assist", "Warning Only", or "Off"

FCA is reactivated on each ignition cycle.

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

X Yes

____ No

If yes, please provide a full description.

See Appendix A, Figures A15 and A17.

A menu button on the steering wheel is used to access the system menus displayed on the center touchscreen. The hierarchy is:

User Settings

Driver Assistance

Warning Timing

Select either "Normal" or "Late"

The warning volume can be adjusted in a similar manner.

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 4 of 4)

2021 Hyundai Elantra SEL

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

If yes, please provide a full description.

Limitations of the system are described on pages 7-23 through 7-28 of the Owner's manual, shown in Appendix B, pages B-29 through B-34.

Notes:

The 2021 Hyundai Elantra is available with two types of AEB systems. One uses a camera-only system and the other system uses a fusion of a camera and forward-facing radar system. The vehicle covered in this report was equipped with the fusion system.

Section III

TEST PROCEDURES

A. Test Procedure Overview

Four test scenarios were used, as follows:

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

Test 2. Subject Vehicle Encounters Slower Principal Other Vehicle

Test 3. Subject Vehicle Encounters Decelerating Principal Other Vehicle

Test 4. Subject Vehicle Encounters Steel Trench Plate

An overview of each of the test procedures follows.

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

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

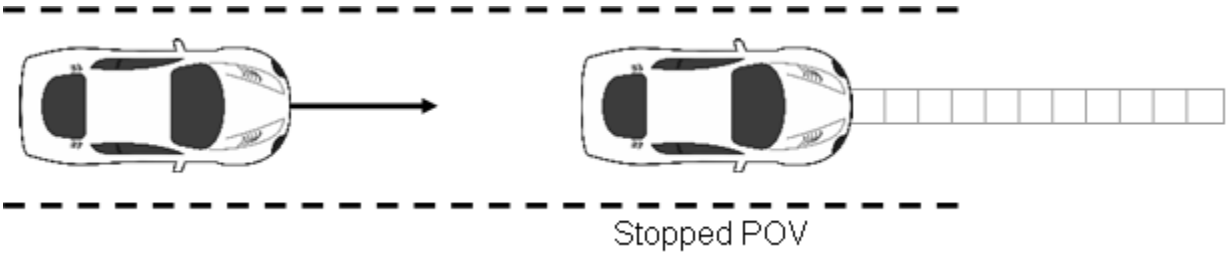


Figure 1. Depiction of Test 1

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.

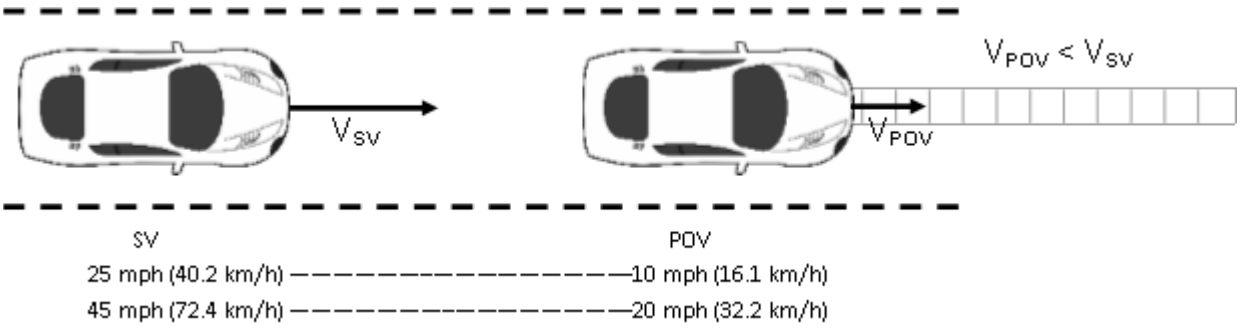


Figure 2. Depiction of Test 2

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

Table 2. Nominal Slower-Moving POV DBS Test Choreography

Test Speeds		SV Speed Held Constant		SV Throttle Fully Released By		SV Brake Application Onset (for each application magnitude)	
SV	POV	TTC (seconds)	SV-to-POV Headway	TTC (seconds)	SV-to-POV Headway	TTC (seconds)	SV-to-POV Headway
25 mph (40 km/h)	10 mph (16 km/h)	5.0 → t_{FCW}	110 ft (34 m) → 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 → t_{FCW}	183 ft (56 m) → 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.

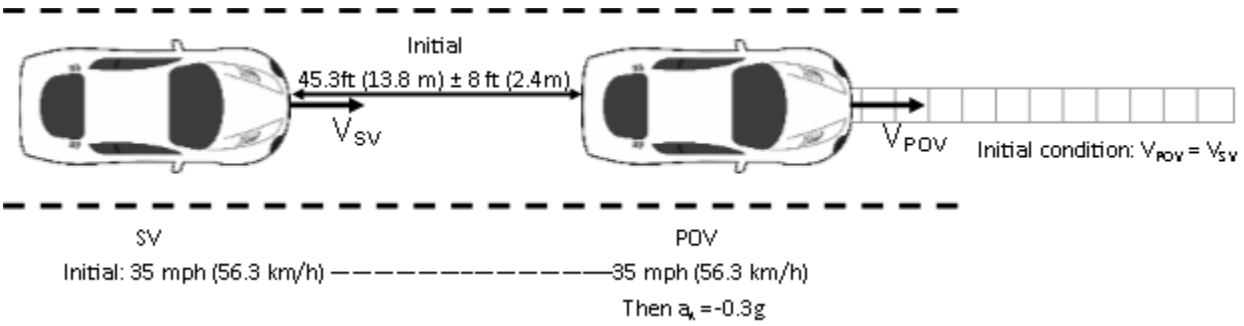


Figure 3. Depiction of Test 3

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 ± 0.03 g. The SV throttle pedal was released within 500 ms of $t_{FCW,}$ and the SV brakes were applied when TTC was 1.4 seconds (31.5 ft (9.6 m)).

The test concluded when either:

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

The SV driver then braked to a stop.

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

- The lateral distance between the centerline of the POV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.
- The headway between the SV and POV must have been constant from the onset

of the applicable validity period to the onset of POV braking.

- The SV and POV speed could not deviate more than ±1.0 mph (1.6 km/h) during an interval defined by the onset of the validity period to the onset of POV braking.
- The average POV deceleration could not deviate by more than ±0.03 g from the nominal 0.3 g deceleration during the interval beginning at 1.5 seconds after the onset of POV braking and ending either 250 ms prior to the POV coming to a stop or the SV coming into contact with the POV.

Table 3. Nominal Decelerating POV DBS Test Choreography

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

b. Criteria

The performance requirement for this series of tests is that no SV-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_{FCW}

The time at which the Forward Collision Warning (FCW) activation flag indicates that the system has issued an alert to the SV driver is designated as t_{FCW}. FCW alerts are typically haptic, visual, or 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

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

2. GENERAL VALIDITY CRITERIA

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

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

3. VALIDITY PERIOD

The valid test interval began:

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

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

Test 3: 3 seconds before the onset of POV braking

Test 4: 2 seconds prior to the SV throttle pedal being released

The valid test interval ended:

Test 1: When either of the following occurred:

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

Test 2: When either of the following occurred:

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

Test 3: When either of the following occurred:

- The SV came in contact with the POV; or
- 1 second after minimum SV-to-POV range occurred.

Test 4: When the SV stopped.

4. STATIC INSTRUMENTATION CALIBRATION

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

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

For Tests 1, 2, and 3, the SV was positioned such that it just contacted a vertical plane defining the rearmost location of the POV. For Test 4, the front-most location of the SV was positioned such that it just reached a vertical plane defined by the leading edge of

the STP first encountered by the SV (i.e., just before it is driven onto the STP). This is the "zero position."

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

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

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

5. NUMBER OF TRIALS

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

6. TRANSMISSION

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

C. Principal Other Vehicle

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

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

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

- A road-based lateral restraint track.
- A tow vehicle.

The key requirements of the POV element are to:

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

The key requirements of the POV delivery system are to:

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

Operationally, the POV shell is attached to the slider and load frame, which includes rollers that allow the entire assembly to move longitudinally along the guide rail. The guide rail is coupled to a tow vehicle and guided by the lateral restraint track secured to the test track surface. The rail includes a provision for restraining the shell and roller assembly in the rearward direction. In operation, the shell and roller assembly engages the rail assembly through detents to prevent relative motion during run-up to test speeds and minor deceleration of the tow vehicle. The combination of rearward stops and forward motion detents allows the test conditions, such as relative 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 ± 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: 4/20/2020 Due: 4/20/2021
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; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +		By: Oxford Technical Solutions
					2258	Date: 5/3/2019 Due: 5/3/2021
					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: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	N/A
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	N/A	N/A
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	N/A	N/A
Accelerometer	Acceleration (to measure time at alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	N/A	N/A

Type	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

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

VIN: 5NPLN4AG0MH01 Affix FULL Label to driver side Left-Rear. VIN: 5NPLN4AG0MH01

2021 ELANTRA SEL

All-new 2021 Elantra North American Car Of The Year

SOLD TO:

VIN:	5NPLN4AG0MH01
MODEL:	49422F4S
ENGINE:	G4NSLK017417
PORT OF ENTRY:	MA
EXTERIOR COLOR:	PHANTOM BLACK
INTERIOR/SEAT COLOR:	GRAY/GRAY
TRANSPORT:	TRUCK
ACCESSORY WEIGHT:	8 lbs./ 3 kgs.
EMISSIONS:	This vehicle meets California Emissions regulations and is Certified as a Super Ultra Low Emission Vehicle (SULEV)

GOVERNMENT 5-STAR SAFETY RATINGS

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

Source: National Highway Traffic Safety Administration (NHTSA). www.safercar.gov or 1-888-327-4236

Fuel Economy

35 MPG combined city/hwy — 31 city, 41 highway

Midsize Cars range from 14 to 142 MPG. The best vehicle rates 141 MPGe.

2.9 gallons per 100 miles

You save **$1,750** in fuel costs over 5 years compared to the average new vehicle.

Annual fuel cost **$1,150**

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

This vehicle emits 257 grams CO_2 per mile. The best emits 0 grams per mile (tailpipe only). Producing and distributing fuel also create emissions; learn more at fueleconomy.gov.

STANDARD FEATURES:

AMERICA'S BEST WARRANTY
5-year/60,000-mile New Vehicle Warranty*
10-year/100,000-mile Powertrain Warranty*
7-year/Unlimited-mile Anti-perforation Warranty*
3-year/36,000-mile Complimentary Maintenance*
5-year/Unlimited-mile Roadside Assistance
*Limited warranties, see dealer for details

ADVANCED SAFETY TECHNOLOGY
Forward Collision-Avoidance Assist w/ Pedestrian Detection
Blind-Spot Collision-Avoidance Assist
Rear Cross-Traffic Collision-Avoidance Assist
Lane Keeping Assist & Lane Following Assist
Safe Exit Waring & Driver Attention Warning
High Beam Assist

POWERTRAIN TECHNOLOGY
Smartstream 2.0L, 147 HP, 132 lbs-ft Torque, DOHC 4-Cylinder
Dual Continuous Variable Valve Timing
Smartstream Intelligent Variable Transmission
4-wheel Disc Brakes

EXTERIOR
16-Inch Alloy Wheels with 205/55 R16 Tires
Projector Headlights w/ LED Daytime Running Lights
Bodycolor Door Handles & Power Side Mirrors

COMFORT & CONVENIENCE
Wireless Apple CarPlay (TM) & Android Auto (TM) Integration
8-inch High Resolution Touchscreen
Proximity Key w/ Push Button Start
Hands-Free Smart Trunk Release
Dual Automatic Temperature Control
Driver's Auto-up Window
Illuminated Vanity Mirrors and Sliding Sun Visors
Rearview Camera w/ Dynamic Guidelines
Single 12V Outlet & Dual USB Ports
Map Lights w/ Dome Lamp & Trunk Lamp
Bluetooth Hands-free Phone System
Steering Wheel Mounted Audio & Cruise Controls
Automatic Headlamp Control
Driver Seat Height Adjustment
Bench Folding Rear Seatback
Center Armrest w/ Flip-up Storage Compartment
4.2-inch Color TFT Cluster Display
AM/FM/HD® Radio w/ 6 Speakers
SiriusXM® Radio w/ 90-Day Trial; Not Available in AK & HI
Hyundai Blue Link® Connected Car System

COMFORT & CONVENIENCE(cont.)
Hyundai Blue Link® Connected Care & Remote Package
Complimentary 3-Year Trial (enrollment required)
Temporary Compact Spare Tire
Full Tank of Gas

Manufacturer's Suggested Retail Price: $20,900.00

ADDED FEATURES:

***Convenience Package:**	$950.00
·Forward Collision-Avoidance Assist w/ Pedestrian, Cyclist and Junction-Turning Detection	
·Full 10.25-inch LCD TFT cluster	
·Smart Cruise Control w/ Stop & Go	
·Electronic Parking Brake w/ Automatic Vehicle Hold	
·Leather-Wrapped Steering Wheel & Shifter	
·Wireless Charging Pad (Qi format)	
·Heated Front Seats	
·Heated Outside Mirror	
***Premium Package:**	$2,100.00
·17-Inch Alloy Wheels & 225/45 R17 Tires	
·Power Sunroof	
·Dark Chrome Exterior Accents	
·LED + Bulb Taillights	
·Bose Premium Audio w/8 Speakers	
·Side Mirror Turn Signal Indicators	
·60/40 Split Folding Rear Seatback w/ Armrest & Cup Holders	
·Power Driver's Seat w/ Lumbar	
·Hyundai Digital Key	
·Passenger seat back pocket	
*Carpeted Floor Mats	$155.00
Inland Freight & Handling :	$995.00
Total Price :	**$25,100.00**

Manufacturer's suggested retail price includes manufacturer's recommended pre-delivery service. Gasoline license and title fees state and local taxes and dealer installed options and accessories are not included in the manufacturer's suggested retail price. This label has been affixed to this vehicle by Hyundai Motor America, pursuant to the requirements of 15 U.S.C. 1231 et seq. which prohibits its removal or alteration prior to delivery to the ultimate purchaser.

PARTS CONTENT INFORMATION
FOR VEHICLE IN THIS CARLINE:
U.S./CANADIAN PARTS CONTENT: 54 %
MAJOR SOURCES OF FOREIGN PARTS CONTENT: KOREA: 27 %
MEXICO: 15 %
Note: Parts content does not include final assembly, distribution, or other non-parts costs.
FOR THIS VEHICLE:
FINAL ASSEMBLY POINT: MONTGOMERY, ALABAMA U.S.A.
COUNTRY OF ORIGIN:
ENGINE: U.S.A.
TRANSMISSION: MEXICO

342 A

VIN: 5NPLN4AG0MH01

Figure A3. Window Sticker (Monroney Label)

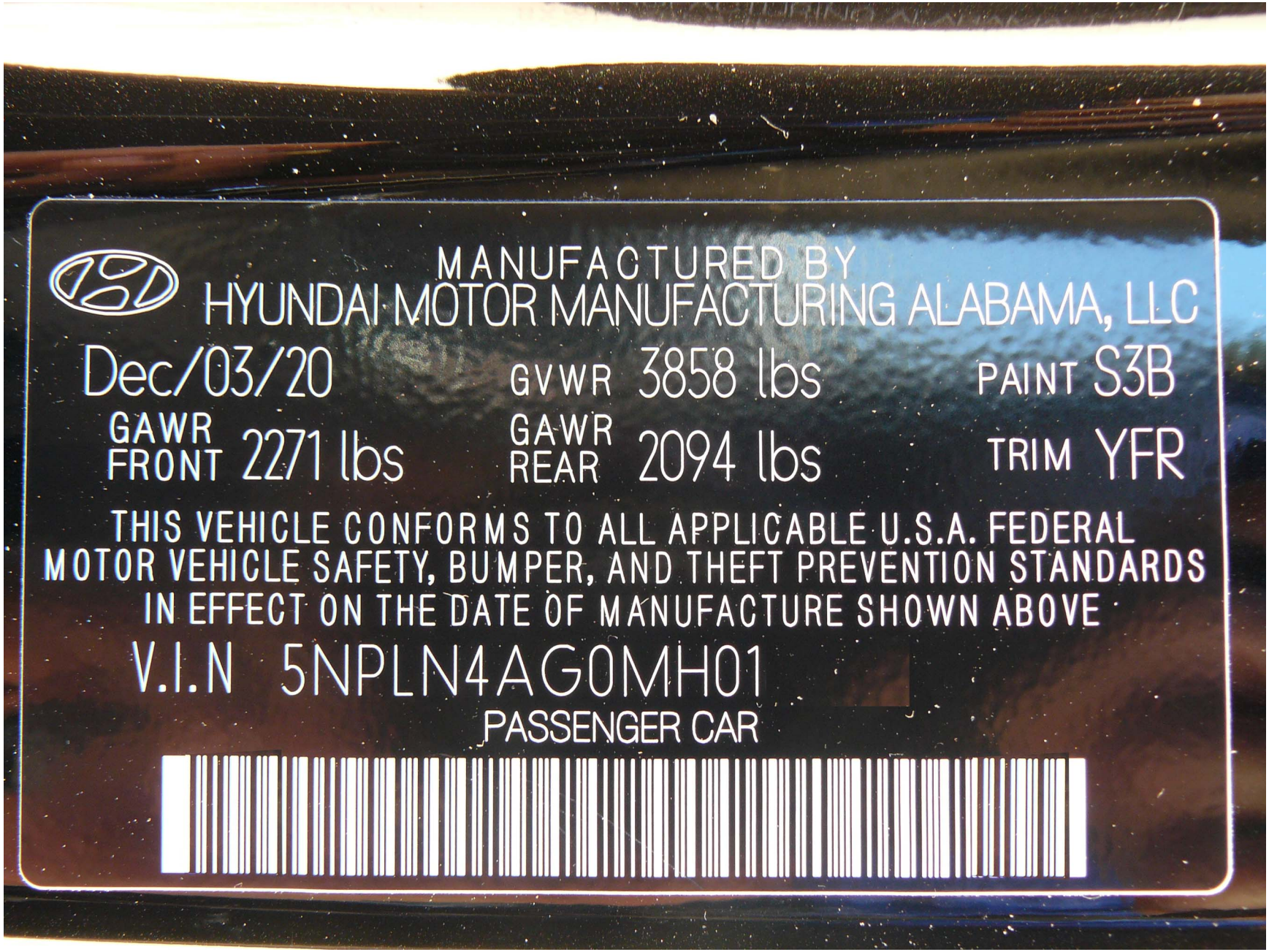


Figure A4. Vehicle Certification Label

Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

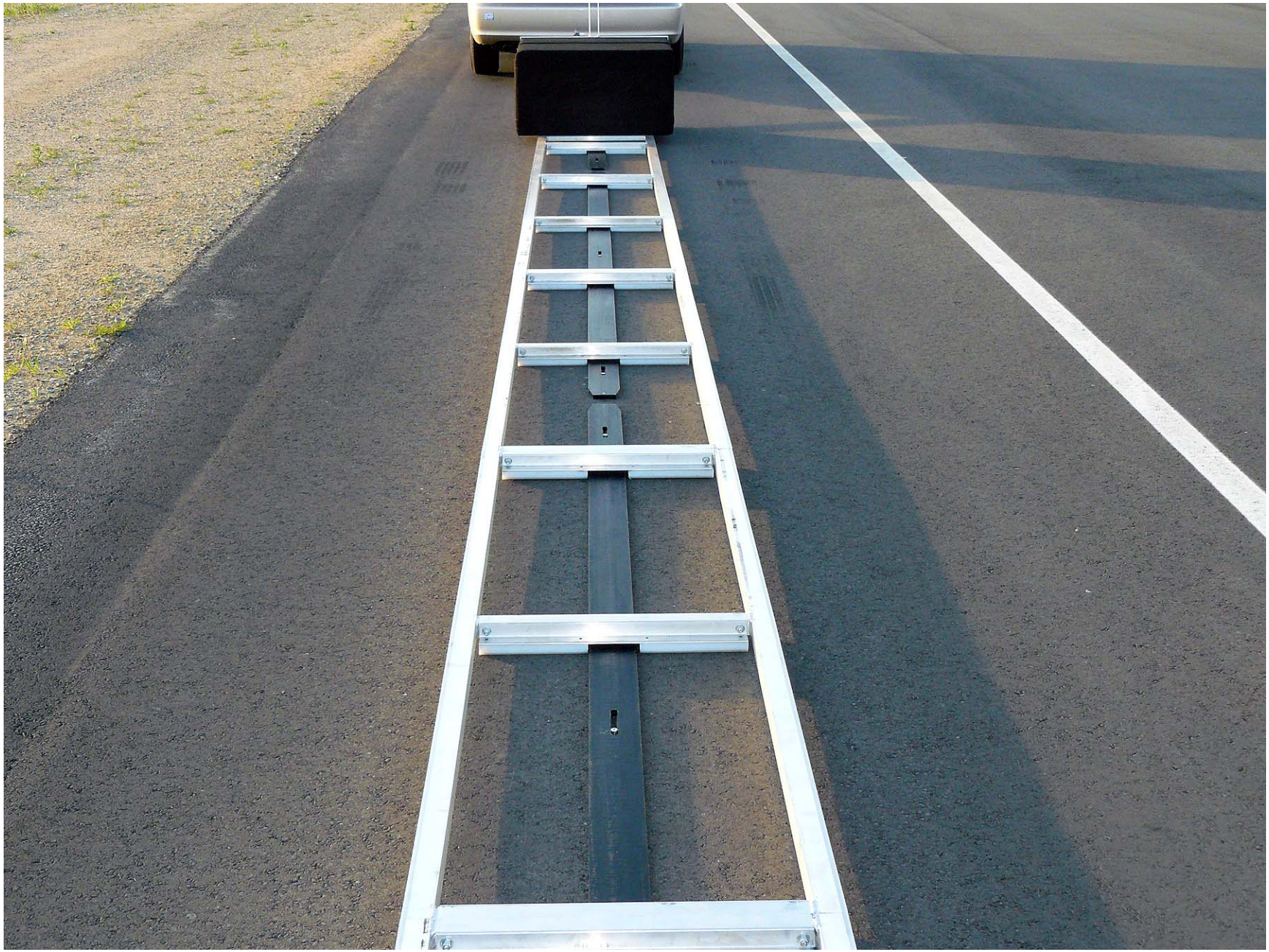


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

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

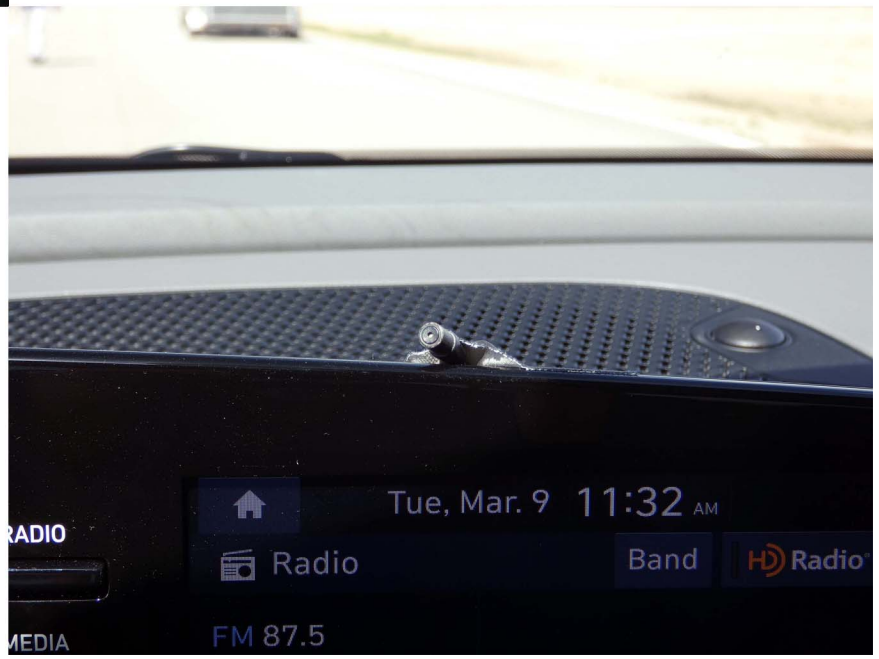


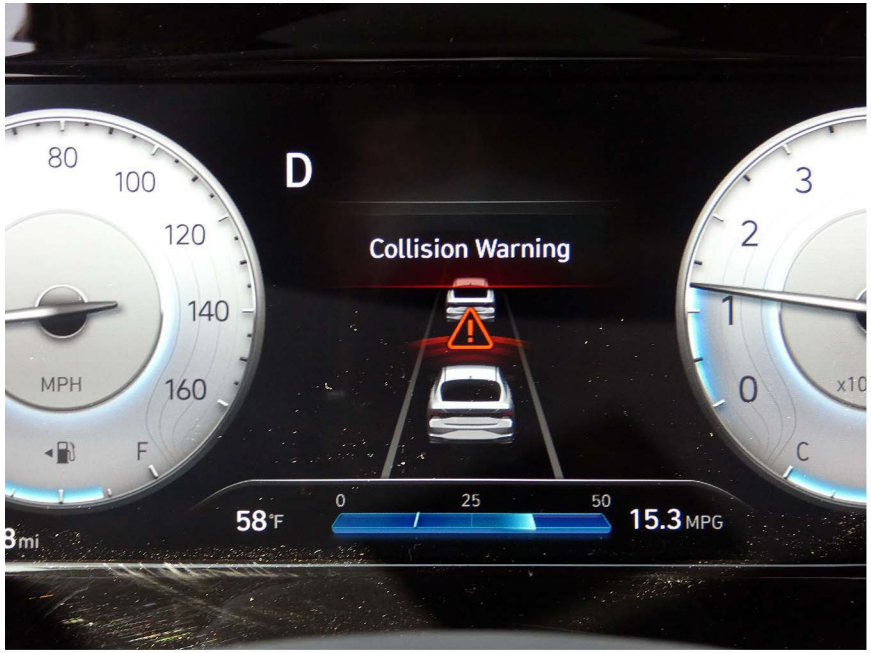
Figure A11. Sensors for Detecting Visual and Auditory Alerts

Figure A12. Computer and Brake Actuator Installed in Subject Vehicle

Figure A13. Brake Actuator Installed in POV System

Figure A14. AEB Setup Menus (page 1 of 2)

Figure A15. AEB Setup Menus (page 2 of 2)



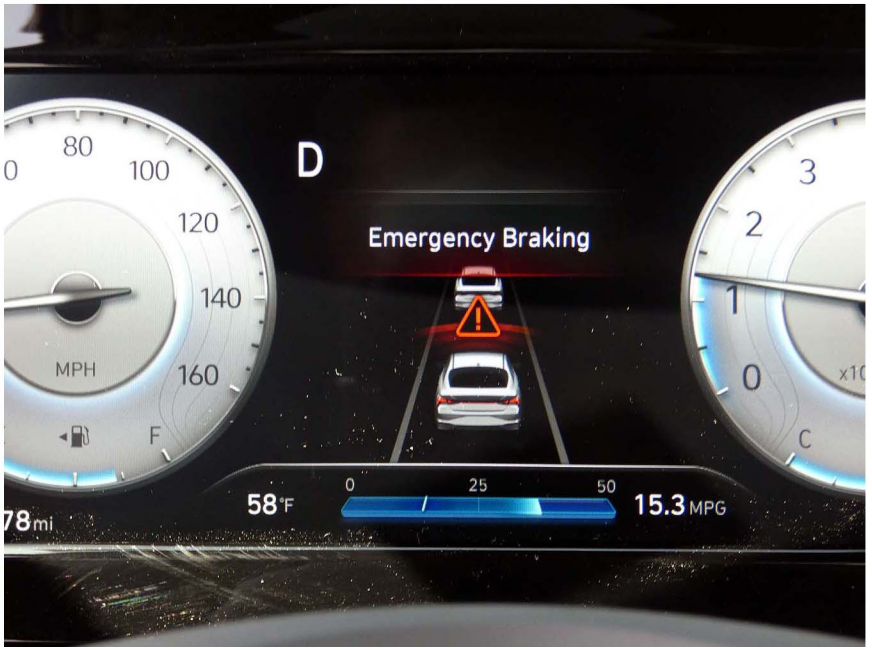


Figure A16. Visual Alert

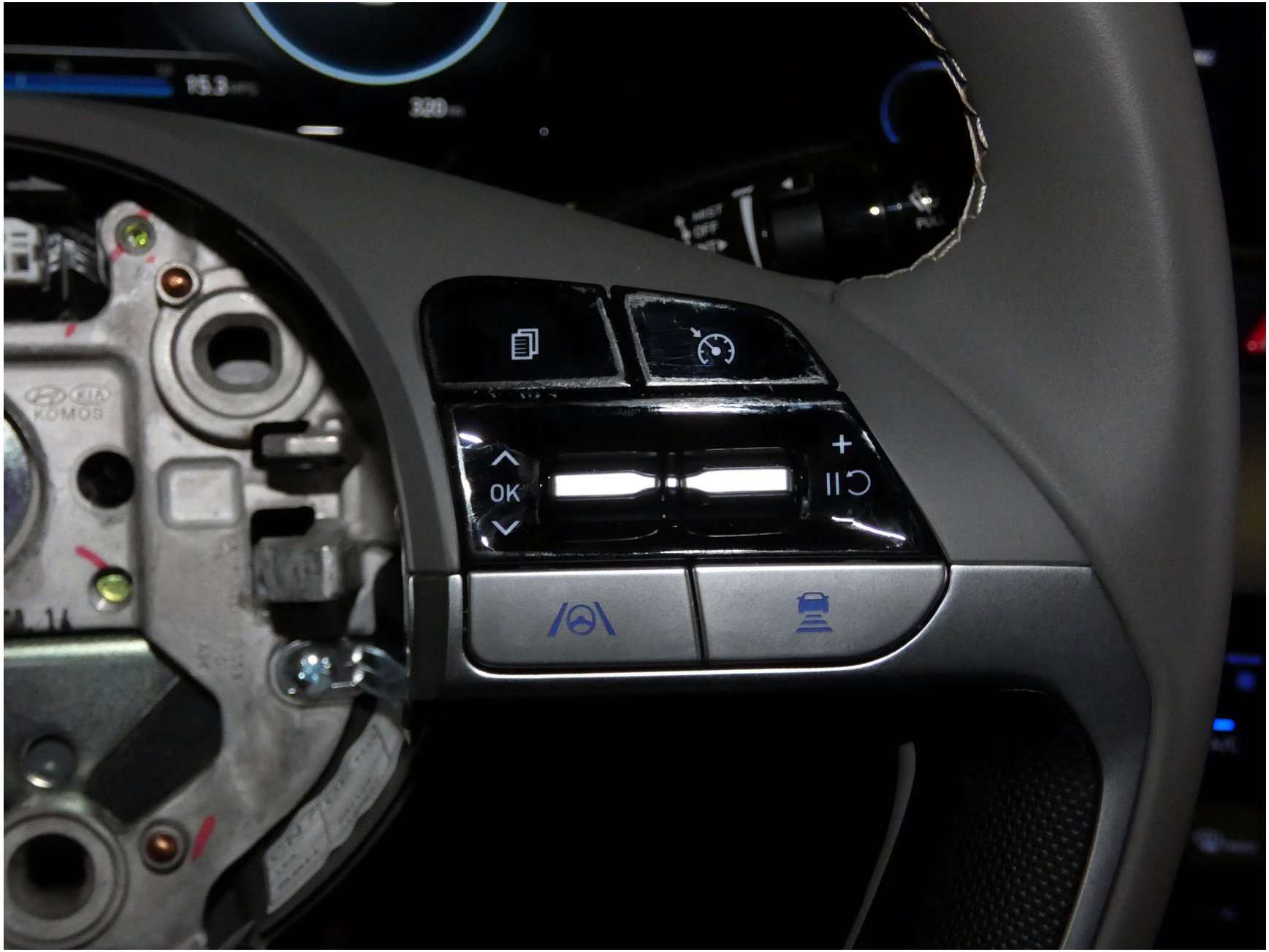


Figure A17. Button for Accessing System Setup Menus

APPENDIX B

Excerpts from Owner’s Manual

Master Warning Light

This indicator light illuminates:

When there is a malfunction in operation in any of the following systems:

- Forward Collision-Avoidance Assist system malfunction (if equipped)
- Forward Collision-Avoidance Assist radar blocked (if equipped)
- Blind-Spot Collision Warning system malfunction (if equipped)
- Blind-Spot Collision Warning radar blocked (if equipped)
- High Beam Assist malfunction (if equipped)
- Lamp malfunction (if equipped)
- Smart Cruise Control malfunction (if equipped)
- Tire Pressure Monitoring System (TPMS) malfunction (if equipped)

To identify the details of the warning, look at the LCD display.

Low Tire Pressure Warning Light (if equipped)

This warning light illuminates:

- When you place the ignition in the ON position.
  - It illuminates for approximately 3 seconds and then goes off.
- When one or more of your tires are significantly underinflated. (The location of the underinflated tires is displayed on the LCD display.)

For more information, refer to "Tire Pressure Monitoring System (TPMS)" in chapter 7.

This warning light remains ON after blinking for approximately 60 seconds, or repeatedly blinks ON and OFF in 3 second intervals:

When there is a malfunction with the TPMS.

In this case, have the vehicle inspected by an authorized HYUNDAI dealer as soon as possible.

For more information, refer to "Tire Pressure Monitoring System (TPMS)" in chapter 7.

WARNING

Safe Stopping

- **The TPMS cannot alert you to severe and sudden tire damage caused by external factors.**
- **If you notice any vehicle instability, immediately take your foot off the accelerator pedal, apply the brakes gradually with light force, and slowly move to a safe position off the road.**

Electronic Stability Control (ESC) Indicator Light

This indicator light illuminates:

- When you place the ignition switch to the ON position.
  - The Electronic Stability Control indicator light illuminates for about 3 seconds and then goes off.
- Whenever there is a malfunction with the ESC system.

  If this occurs, have the vehicle inspected by an authorized HYUNDAI dealer.

This indicator light blinks:

While the ESC is operating.

For more information, refer to "Electronic Stability Control (ESC)" in chapter 6.

Forward Collision-Avoidance Assist Warning Light (if equipped)

This warning light illuminates:

- When you set the ignition switch or Engine Start/Stop button to the ON position.
  - It illuminates for approximately 3 seconds and then goes off.
- When there is a malfunction with FCA. In this case, have your vehicle inspected by an authorized dealer of HYUNDAI.

For more information, refer to "Forward Collision-Avoidance Assist (FCA)" in chapter 6.

Lane Keep Assist Indicator Light (if equipped)

This indicator light illuminates:

- [Green] When you activate the lane departure warning system by pressing the Lane Safety button and all of the system operating conditions are satisfied.
- [White] When function operating conditions are not satisfied or when the sensor does not detect the lane line.
- [Yellow] When there is a malfunction with Lane Keeping Assist system.

In this case, have your vehicle inspected by an authorized HYUNDAI dealer.

For more information, refer to "Lane Keeping Assist (LKA)" in chapter 6.

Cruise Indicator Light

CRUISE

This indicator light illuminates:

- When the cruise control system is enabled.

For more details, refer to "Cruise Control System" in chapter 6.

SPORT Mode Indicator Light (if equipped)

SPORT

This indicator light illuminates:

- When you select "SPORT" mode as drive mode.

For more details, refer to "Drive Mode Integrated Control System" in chapter 6.

SMART Mode Indicator Light (if equipped)

SMART

This indicator light illuminates:

- When you select ''SMART" mode as drive mode.

For more details, refer to "Drive Mode Integrated Control System" in chapter 6.

Check Forward Collision-Avoidance Assist system (if equipped)

This warning message is displayed if there is a problem with Forward Collision-Avoidance Assist. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to “Forward Collision-Avoidance Assist (FCA)” in chapter 6.

Check Lane Keeping Assist system (if equipped)

This warning message is displayed if there is a problem with Lane Keeping Assist. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to “Lane Keeping Assist (LKA)” in chapter 6.

Check Blind-Spot Collision Warning system (if equipped)

This warning message is displayed if there is a problem with the Blind-Spot Collision Warning. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to “Blind-Spot Collision Warning (BCW)” in chapter 6.

Check Driver Attention Warning system (if equipped)

This warning message is displayed if there is a problem with Driver Attention Warning. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to “Driver Attention Warning (DAW)” in chapter 6.

Check High Beam Assist system (if equipped)

This warning message is displayed if there is a problem with the High Beam Assist. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to “High Beam Assist (HBA)” in chapter 5.

Check Smart Cruise Control system (if equipped)

This warning message is displayed if there is a problem with Smart Cruise Control. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to “Smart Cruise Control (SCC)” in chapter 6.

Master warning mode

OIG059097L

This warning light informs the driver the following situations.

- Forward Collision-Avoidance Assist system malfunction (if equipped)
- Forward Collision-Avoidance Assist radar blocked (if equipped)
- Blind-Spot Collision Warning system malfunction (if equipped)
- Blind-Spot Collision Warning radar blocked (if equipped)
- High Beam Assist malfunction (if equipped)
- Lamp malfunction (if equipped)
- Smart Cruise Control malfunction (if equipped)
- Tire Pressure Monitoring System (TPMS) malfunction (if equipped)

The Master Warning Light illuminates if one or more of the above warning situations occur. At this time, a Master Warning icon (⚠) will appear beside the User Settings icon (⚙), on the LCD display.

If the warning situation is solved, the master warning light will be turned off and the Master Warning icon will disappear.

ODN8049019L

Tire Pressure

This mode displays information related to Tire Pressure.

For more information, refer to "Tire Pressure Monitoring System (TPMS)" in chapter 8.

1. Driver Assistance

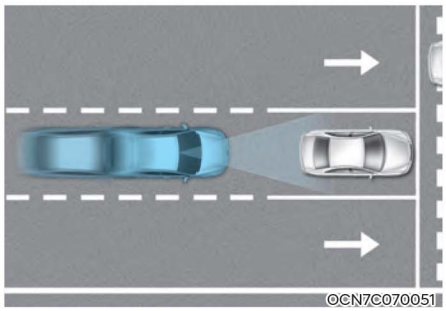
Items	Explanation
Driving Assist	• Highway Driving Assist: The function assists the driver to maintain the set speed, keep a safe distance with a vehicle ahead and keep the vehicle inside of the lane while driving on the highway. **For more details, refer to the "Highway Driving Assist (HDA)" in chapter 7.**
Speed limit	To adjust the Speed Limit function. • Speed Limit Offset • Auto Speed Change • Speed Limit Assist/Speed Limit Warning/Off **For more details, refer to the "Intelligent Speed Limit Assist (ISLA)" in chapter 7.**
Warning Timing	To adjust the warning timing of the driver assistance system. • Normal / Late
Warning Volume	To adjust the warning timing of the driver assistance system. • High / Medium / Low / Off
Driver Attention Warning	• Leading Vehicle Departure Alert To activate or deactivate the Leading vehicle departure alert. • Inattentive Driving Warning To activate or deactivate the Driver Attention Warning. **For more details, refer to the "Driver Attention Warning (DAW)" in chapter 7.**
Forward Safety	To adjust the Lane Keeping Assist function. • Active Assist/Warning Only/Off **For more details, refer to the "Forward Collision-Avoidance Assist (FCA)" in chapter 7.**
Lane Safety	To adjust the Lane Keeping Assist function. • Lane Keeping Assist/Lane Departure Warning/Off **For more details, refer to "Lane Keeping Assist (LKA)" in chapter 7.**
Blind-Spot Safety	• Safe Exit Warning (SEW) To activate or deactivate the Safe Exit Warning. **For more details, refer to the "Safe Exit Warning (SEW)" in chapter 7.** • Active Assist/Warning Only/Off **For more details, refer to "Blind-Spot Collision Warning (BCW)" or "Blind-Spot Collision-Avoidance Assist (BCA)" in chapter 7.**

1. Driver Assistance

Items	Explanation
Driving Assist	• Highway Driving Assist: The function assists the driver to maintain the set speed, keep a safe distance with a vehicle ahead and help keep the vehicle inside of the lane while driving on the highway. **For more details, refer to the "Highway Driving Assist (HDA)" in chapter 7.**
Speed limit	To adjust the Speed Limit function. • Speed Limit Offset • Auto Speed Change • Speed Limit Assist/Speed Limit Warning/Off **For more details, refer to the "Intelligent Speed Limit Assist (ISLA)" in chapter 7.**
Warning Timing	To adjust the warning timing of the driver assistance system. • Normal / Late
Warning Volume	To adjust the warning volume of the driver assistance system. • High / Medium / Low / Off
Driver Attention Warning	• Leading Vehicle Departure Alert To activate or deactivate the Leading vehicle departure alert. • Inattentive Driving Warning To activate or deactivate the Driver Attention Warning. **For more details, refer to the "Driver Attention Warning (DAW)" in chapter 7.**
Forward Safety	To adjust Forward Collision-Avoidance Assist function. • Active Assist/Warning only/Off **For more details, refer to the "Forward Collision-Avoidance Assist (FCA)" in chapter 7.**
Lane Safety	To adjust the Lane Keeping Assist function. • Lane Keeping Assist/Lane Departure Warning/Off **For more details, refer to "Lane Keeping Assist (LKA)" in chapter 7.**
Blind-Spot Safety	• Safe Exit Warning (SEW) To activate or deactivate the Safe Exit Warning. **For more details, refer to the "Safe Exit Warning (SEW)" in chapter 7.** • Active Assist/Warning only/Off **For more details, refer to "Blind-Spot Collision Warning (BCW)" or "Blind-Spot Collision-Avoidance Assist (BCA)" in chapter 7.**

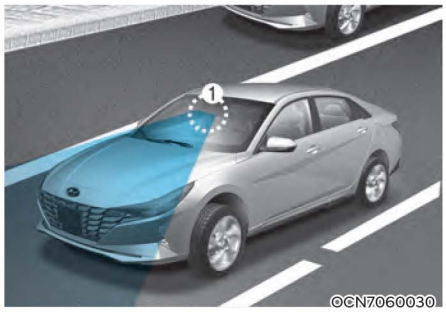
FORWARD COLLISION-AVOIDANCE ASSIST (FCA) (FRONT VIEW CAMERA ONLY) (IF EQUIPPED)

Basic function



Forward Collision-Avoidance Assist is designed to help detect and monitor the vehicle ahead or detect a pedestrian in the roadway and warn the driver that a collision is imminent with a warning message and audible warning, and if necessary, apply emergency braking.

Detecting sensor



[1] : Front view camera

Refer to the picture above for the detailed location of the detecting sensor.

CAUTION

Take the following precautions to maintain optimal performance of the detecting sensor:

- **NEVER disassemble the detecting sensor or sensor assembly, or apply any impact on it.**
- **If the detecting sensor have been replaced or repaired, we recommend that you have your vehicle inspected by an authorized HYUNDAI dealer.**
- **NEVER install any accessories or stickers on the front windshield, or tint the front windshield.**
- **Pay extreme caution to keep the front view camera dry.**
- **NEVER place any reflective objects (i.e. white paper, mirror) over the dashboard. Any light reflection may prevent the system from functioning properly.**

Function settings

Setting

OTM070090N

Forward Safety

With the engine on, select or deselect 'Driver Assistance → Forward Safety' from the Settings menu to set whether or not to use each function.

- If 'Active Assist' is selected, the function will warn the driver with a warning message and an audible warning depending on the collision risk levels. Braking assist will be applied depending on the collision risk.
- If 'Warning Only' is selected, the function will warn the driver with a warning message and an audible warning depending on the collision risk levels. Braking will not be assisted.
- If 'Off' is selected, the system will turn off. The warning light will illuminate on the cluster.

The driver can monitor Forward Collision-Avoidance Assist ON/OFF status from the Settings menu. If the warning light remains ON when the system is ON, we recommend that you have the function inspected by an HYUNDAI dealer.

WARNING

When the engine is restarted, Forward Collision-Avoidance Assist will always turn on. However, if 'Off' is selected after the engine is restarted, the driver should always be aware of the surroundings and drive safely.

CAUTION

'If 'Warning Only' is selected, braking and is not assisted.

Information

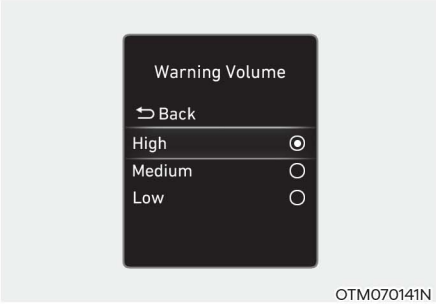
Forward Collision-Avoidance Assist will turn off when ESC is turned off by pressing and holding the ESC OFF button for more than 3 seconds. The warning light will illuminate on the cluster.

OTM070140N

Warning Timing

With the engine on, select 'Driver Assistance → Warning Timing' from the Settings menu to change the initial warning activation time for Forward Collision-Avoidance Assist.

When the vehicle is first delivered, Warning Timing is set to 'Normal'. If you change the Warning Timing, the warning time of other Driver Assistance systems may change.



OTM070141N

Warning Volume

With the engine on, select 'Driver Assistance → Warning Volume' from the Settings menu to change the Warning Volume to 'High', 'Medium' or 'Low' for Forward Collision-Avoidance Assist.

If you change the warning volume, the Warning Volume of other Driver Assistance systems may change.

CAUTION

- **Even though, 'Normal' is selected for Warning Timing if the front vehicle suddenly stops the initial warning activation time may not seem late.**
- **Select 'Late' for Warning Timing when traffic is light and when driving speed is slow.**

Information

If the engine is restarted, Warning Timing and Warning Volume will maintain the last setting.

Function operation

Basic function

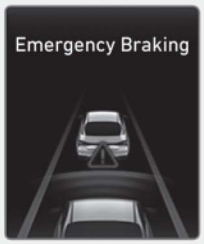
Function warning and control

The basic feature of Forward Collision-Avoidance Assist is to help warn and control the vehicle depending on collision level: ‘Collision Warning’, ‘Emergency Braking’ and ‘Stopping vehicle and ending brake control ’.

OCN7070028L

Collision warning

- To warn the driver of a collision, the ‘Collision Warning’ warning message will appear on the cluster and an audible warning will sound.
- If a vehicle is detected in front, the function will operate when your vehicle speed is between approximately 6~112 mph (10~180 km/h).
- If a pedestrian is detected in front, the function will operate when your vehicle speed is between approximately 6~53 mph (10~85 km/h).
- If ‘Active Assist’ is selected, braking may be assisted.



OCN7070029L

Emergency braking

- To warn the driver that emergency braking will occur, the ‘Emergency Braking’ warning message will appear on the cluster and an audible warning will sound.
- If a vehicle is detected in front, the function will operate when your vehicle speed is between approximately 6~47 mph (10~75 km/h).
- If a pedestrian is detected in front, the function will operate when your vehicle speed is between approximately 6~47 mph (10~75 km/h).
- In emergency braking situation, braking is assisted with strong braking power by the function to help prevent collision with the vehicle ahead or pedestrian.

OCN7070030L

Stopping vehicle and ending brake control

- When the vehicle is stopped due to emergency braking, 'Drive carefully' warning message will appear on the cluster.

  For your safety, the driver should depress the brake pedal immediately and check the surroundings.
- Brake control will end after the vehicle is stopped by emergency braking for approximately 2 seconds.

WARNING

Take the following precautions when using Forward Collision-Avoidance Assist:

- **For your safety, change the Settings after parking the vehicle at a safe location.**
- **With 'Active Assist' or 'Warning Only' selected, when ESC is turned off by pressing and holding the ESC OFF button for more than 3 seconds, Forward Collision-Avoidance Assist will turn off automatically. In this case, the function cannot be set from the Settings menu and the warning light will illuminate on the cluster which is normal. If ESC is turned on by pressing the ESC OFF button, Forward Collision-Avoidance Assist will maintain the last setting.**
- **Forward Collision-Avoidance Assist does not operate in all situations or cannot avoid all collisions.**
- **The driver should hold the responsibility to control the vehicle. Do not solely depend on Forward Collision-Avoidance Assist function. Rather, maintain a safe braking distance, and, if necessary, depress the brake pedal to reduce driving speed or to stop the vehicle.**
- **Never deliberately operate Forward Collision-Avoidance Assist on people, animal, objects, etc. It may cause serious injury or death.**
- **Forward Collision-Avoidance Assist may not operate if the driver depresses the brake pedal to avoid collision.**
- **Depending on the road and driving conditions, Forward Collision-Avoidance Assist may warn the driver late or may not warn the driver.**
- **During Forward Collision-Avoidance Assist operation the vehicle may stop suddenly injuring passengers and shifting loose objects. Always have the seat belt on and keep loose objects secured.**
- **If any other system's warning message is displayed or audible warning is generated, Forward Collision-Avoidance Assist warning message may not be displayed and audible warning may not be generated.**
- **You may not hear the warning sound of Forward Collision-Avoidance Assist if the surrounding is noisy.**
- **Forward Collision-Avoidance Assist may turn off or may not operate properly or may operate unnecessarily depending on the road conditions and the surroundings.**

WARNING

- **Even if there is a problem with Forward Collision-Avoidance Assist, the vehicle's basic braking performance will operate normally.**
- **During emergency braking, braking control by the function will automatically cancel when the driver excessively depresses the accelerator pedal or sharply steers the vehicle.**

CAUTION

Forward Collision-Avoidance Assist operating speed range may reduce due to the conditions of the vehicle or pedestrian in front or surroundings. Depending on the speed, the function may only warn the driver, or the function may not operate.

Information

In a situation where collision is imminent, braking may be assisted by Forward Collision-Avoidance Assist when braking is insufficient by the driver.

Function malfunction and limitations

Function malfunction

OCN7070031L

When Forward Collision-Avoidance Assist system is not working properly, the 'Check Forward Safety system(s)' warning message will appear, and the and warning lights will illuminate on the cluster. We recommend that the function be inspected by an authorized HYUNDAI dealer.

Function disabled

OCN7070032L

When the front windshield where the front view camera is located or the sensor is covered with foreign material, such as snow or rain, it can reduce the detecting performance and temporarily limit or disable Forward Collision-Avoidance Assist.

If this occurs the 'Forward Safety system disabled. Camera obscured' warning message, and the ⚠ and warning lights will illuminate on the cluster.

The system will operate normally when such snow, rain or foreign material is removed.

If the system does not operate normally after obstruction (snow, rain, or foreign material) is removed, we recommend that the system be inspected by an authorized HYUNDAI dealer.

⚠ WARNING

- **Even though the warning message or warning light does not appear on the cluster, Forward Collision-Avoidance Assist may not properly operate.**
- **Forward Collision-Avoidance Assist may not properly operate in an area (e.g. open terrain), where any substance are not detected after turning ON the engine.**

Limitations of the function

Forward Collision-Avoidance Assist may not operate normally, OR the function may operate unexpectedly under the following circumstances:

- The detecting sensor or the surroundings are contaminated or damaged
- The temperature around the front view camera is high or low
- The camera lens is contaminated due to tinted, filmed or coated windshield, damaged glass, or stuck of foreign material (sticker, bug, etc.) on the glass
- Moisture is not removed or frozen on the windshield
- Washer fluid is continuously sprayed, or the wiper is on
- Driving in heavy rain or snow, or thick fog
- The field of view of the front view camera is obstructed by sun glare
- Street light or light from an oncoming vehicle is reflected on the wet road surface, such as a puddle on the road
- An object is placed on the dashboard
- Your vehicle is being towed
- The surrounding is very bright
- The surrounding is very dark, such as in a tunnel, etc.
- The brightness changes suddenly, for example when entering or exiting a tunnel
- The brightness outside is low, and the headlamps are not on or are not bright

- Driving through steam, smoke or shadow
- Only part of the vehicle, pedestrian or cyclist is detected
- The vehicle in front is a bus, heavy truck, truck with a unusually shaped luggage, trailer, etc.
- The vehicle in front has no tail lights, tail lights are located unusually, etc.
- The brightness outside is low, and the tail lamps are not on or are not bright
- The rear of the front vehicle is small or the vehicle does not look normal, such as when the vehicle is tilted, overturned, or the side of the vehicle is visible, etc.
- The front vehicle's ground clearance is low or high
- A vehicle or pedestrian suddenly cuts in front
- The vehicle in front is detected late
- The vehicle in front is suddenly blocked by a obstacle
- The vehicle in front suddenly changes lane or suddenly reduces speed
- The vehicle in front is bent out of shape
- The front vehicle's speed is fast or slow
- The vehicle in front steers in the opposite direction of your vehicle to avoid a collision
- With a vehicle in front, your vehicle changes lane at low speed
- The vehicle in front is covered with snow
- You are departing or returning to the lane
- Unstable driving
- You are on a roundabout and the vehicle in front is not detected
- You are continuously driving in a circle
- The vehicle in front has an unusual shape
- The vehicle in front is driving uphill or downhill
- The pedestrian is not fully detected, for example, if the pedestrian is leaning over or is not fully walking upright
- The pedestrian is wearing clothing or equipment that makes it difficult to detect as a pedestrian

OADAS051

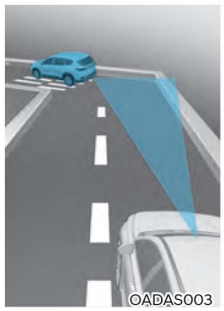
The illustration above shows the image the front view camera will detect as a vehicle and pedestrian.

- The pedestrian in front is moving very quickly
- The pedestrian in front is short or is posing a low posture
- The pedestrian in front has impaired mobility
- The pedestrian in front is moving intersected with the driving direction

- There is a group of pedestrians or a large crowd in front
- The pedestrian is wearing clothing that easily blends into the background, making it difficult to detect
- The pedestrian is difficult to distinguish from the similar shaped structure in the surroundings
- You are driving by a pedestrian, traffic sign, structure, etc. near the intersection
- Driving in a parking lot
- Driving through a tollgate, construction area, unpaved road, partial paved road, uneven road, speed bumps, etc.
- Driving on an incline road, curved road, etc.
- Driving through a roadside with trees or streetlights
- The adverse road conditions cause excessive vehicle vibrations while driving
- Your vehicle height is low or high due to heavy loads, abnormal tire pressure, etc.
- Driving through a narrow road where trees or grass or overgrown
- There is interference by electromagnetic waves such as driving in an area with strong radio waves or electrical noise

WARNING

- **Driving on a curve**



Forward Collision-Avoidance Assist may not detect other vehicles or pedestrians in front of you on curved roads adversely affecting the performance of the sensors. This may result in no warning or braking assist when necessary.

When driving on a curve, you must maintain a safe braking distance, and if necessary, steer the vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

Forward Collision-Avoidance Assist may detect a vehicle or pedestrian in the next lane or outside the lane when driving on a curved road.

If this occurs, the system may unnecessarily warn the driver and control the brake. Always check the traffic conditions around the vehicle.

- **Driving on a slope**

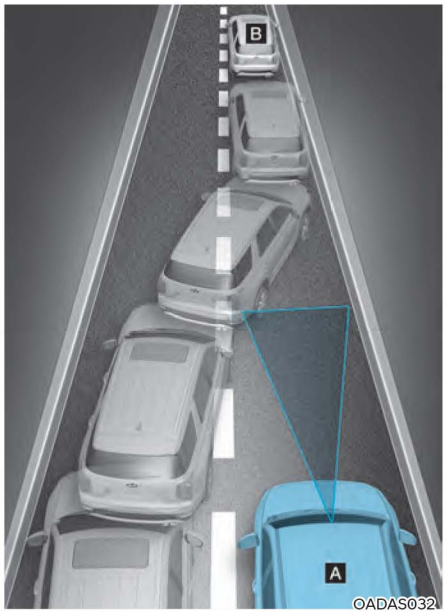
Forward Collision-Avoidance Assist may not detect other vehicles or pedestrians in front of you while driving uphill or downhill adversely affecting the performance of the sensors.

This may result in unnecessary warning or braking assist, or no warning or braking assist when necessary.

Also, vehicle speed may rapidly decrease when a vehicle or pedestrian ahead is suddenly detected.

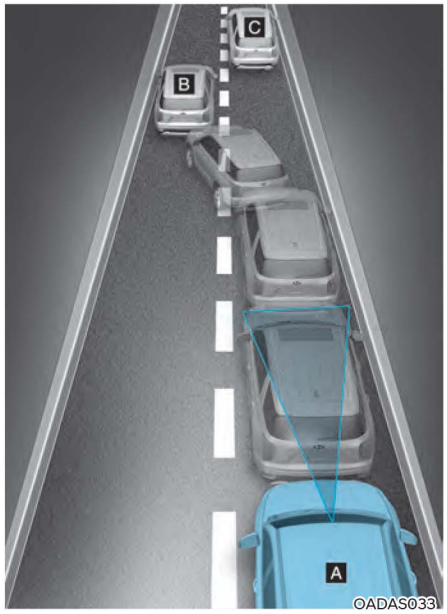
Always have your eyes on the road while driving uphill or downhill and if necessary, steer the vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

- **Changing lanes**



[A] : Your vehicle,
[B] : Lane changing vehicle

When a vehicle moves into your lane from an adjacent lane, it cannot be detected by the sensor until it is in the sensor's detection range. Forward Collision-Avoidance Assist may not immediately detect the vehicle when the vehicle changes lanes abruptly. In this case, you must maintain a safe braking distance, and if necessary, steer the vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

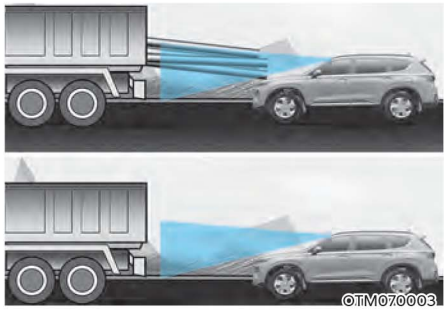


[A] : Your vehicle,
[B] : Lane changing vehicle,
[C] : Same lane vehicle

When a vehicle in front of you merges out of the lane, Forward Collision-Avoidance Assist may not immediately detect the vehicle that is now in front of you.

In this case, you must maintain a safe braking distance, and if necessary, steer the vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

- **Detecting vehicle**



If the vehicle in front of you has cargo that extends rearward from the cab, or when the vehicle in front of you has higher ground clearance, additional special attention is required. Forward Collision-Avoidance Assist may not be able to detect the cargo extending from the vehicle. In these instances, you must maintain a safe braking distance from the rearmost object, and if necessary, steer the vehicle and depress the brake pedal to reduce your driving speed in order to maintain distance.

WARNING

- **When you are towing a trailer or another vehicle, we recommend that Forward Collision-Avoidance Assist is turned off due to safety reasons.**
- **Forward Collision-Avoidance Assist may operate if objects that are similar in shape or characteristics to vehicles and pedestrians are detected.**
- **Forward Collision-Avoidance Assist does not operate on bicycles, motorcycles, or smaller wheeled objects, such as luggage bags, shopping carts, or strollers.**
- **Forward Collision-Avoidance Assist may not operate normally if interfered by strong electromagnetic waves.**
- **Forward Collision-Avoidance Assist may not operate for 15 seconds after the vehicle is started, or the front view camera is initialized.**

Information

This device complies with Part 15 of the FCC rules.

Operation is subject to the following three conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.
3. Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the device.

Information

Radio frequency radiation exposure information:

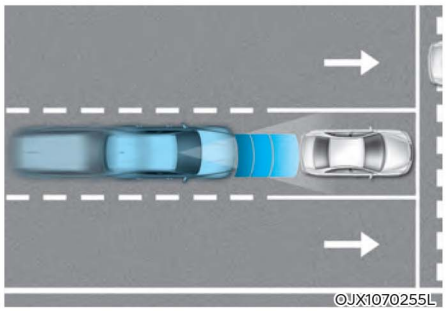
This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment.

This equipment should be installed and operated with minimum distance of 8 in. (20 cm) between the radiator (antenna) and your body.

This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

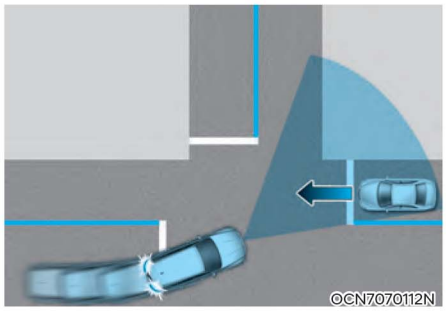
FORWARD COLLISION-AVOIDANCE ASSIST (FCA) (SENSOR FUSION) (IF EQUIPPED)

Basic function



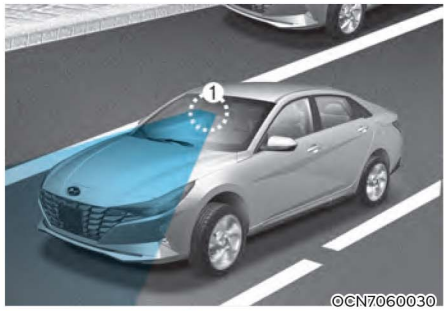
Forward Collision-Avoidance Assist is designed to help detect and monitor the vehicle ahead or help detect a pedestrian or cyclist in the roadway and warn the driver that a collision is imminent with a warning message and an audible warning, and if necessary, apply emergency braking.

Junction Turning function (if equipped)



Junction Turning function will help avoid a collision with an oncoming vehicle in an adjacent lane when turning left at a crossroad with the turn signal on by applying emergency braking.

Detecting sensor



[1] : Front view camera,
[2] : Front radar

Refer to the picture above for the detailed location of the detecting sensors.

CAUTION

Take the following precautions to maintain optimal performance of the detecting sensor:

- **Never disassemble the detecting sensor or sensor assembly, or apply any impact on it.**
- **If the detecting sensors have been replaced or repaired, we recommend that you have your vehicle inspected by an authorized HYUNDAI dealer.**
- **Never install any accessories or stickers on the front windshield, or tint the front windshield.**
- **Pay extreme caution to keep the front view camera dry.**
- **Never place any reflective objects (i.e. white paper, mirror) over the dashboard. Any light reflection may prevent the system from functioning properly.**
- **Do not apply license plate frame or objects, such as a bumper sticker, film or a bumper guard, near the front radar cover.**
- **Always keep the front radar and cover clean and free of dirt and debris.**

  Use only a soft cloth to wash the vehicle. Do not spray pressurized water directly on the sensor or sensor cover.
- **If unnecessary force has been applied to the radar or around the radar, Forward Collision-Avoidance Assist may not properly operate even though a warning message does not appear on the cluster. We recommend that the vehicle be inspected by an authorized HYUNDAI dealer.**
- **Use only genuine parts to repair or replace a damaged front radar cover. Do not apply paint to the front radar cover.**

Function settings

Setting

Forward Safety

With the engine on, select or deselect 'Driver Assistance → Forward Safety' from the Settings menu to set whether or not to use each function.

- If 'Active Assist' is selected, the function will warn the driver with a warning message and an audible warning depending on the collision risk levels. Braking assist will be applied depending on the collision risk.
- If 'Warning Only' is selected, the function will warn the driver with a warning message and an audible warning depending on the collision risk levels. Braking will not be assisted.
- If 'Off' is selected, the function will turn off. The warning light will illuminate on the cluster.

The driver can monitor Forward Collision-Avoidance Assist ON/OFF status from the Settings menu. If the warning light remains ON when the system is ON, we recommend that the system be inspected by an authorized HYUNDAI dealer.

WARNING

When the engine is restarted, Forward Collision-Avoidance Assist will always turn on. However, if 'Off' is selected after the engine is restarted, the driver should always be aware of the surroundings and drive safely.

CAUTION

- **If 'Warning Only' is selected, braking is not assisted.**
- **The settings for Forward Safety include 'Basic function' and 'Junction Turning' (if equipped).**

Information

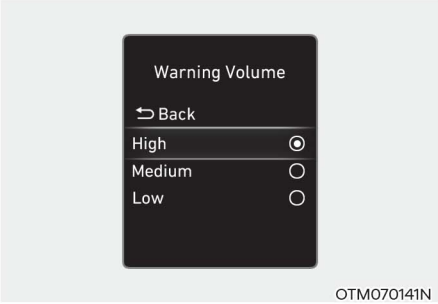
Forward Collision-Avoidance Assist will turn off when ESC is turned off by pressing and holding the ESC OFF button for more than 3 seconds. The warning light will illuminate on the cluster.

OTM070140N

Warning Timing

With the engine on, select 'Driver Assistance → Warning Timing' from the Settings menu to change the initial warning activation time for Forward Collision-Avoidance Assist.

When the vehicle is first delivered, Warning Timing is set to 'Normal'. If you change the Warning Timing, the warning time of other Driver Assistance systems may change.



OTM070141N

Warning Volume

With the engine on, select 'Driver Assistance → Warning Volume' from the Settings menu to change the Warning Volume to 'High', 'Medium' or 'Low' for Forward Collision-Avoidance Assist.

If you change the warning volume, the Warning Volume of other Driver Assistance systems may change.

CAUTION

- **The setting of the Warning Timing and Warning Volume applies to all functions of Forward Collision-Avoidance Assist.**
- **Even though 'Normal' is selected for Warning Timing, if the front vehicle suddenly stops, the initial warning activation time may not seem late.**
- **Select 'Late' for Warning Timing when traffic is light and when driving speed is slow.**

Information

If the engine is restarted, Warning Timing and Warning Volume will maintain the last setting.

Function operation

Basic function

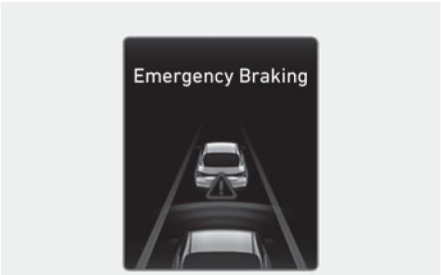
Function warning and control

The basic function for Forward Collision-Avoidance Assist is to help warn and control the vehicle depending on the collision level: 'Collision Warning', 'Emergency Braking' and 'Stopping vehicle and ending brake control'.

OCN7070028L

Collision Warning

- To warn the driver of a collision, the 'Collision Warning' warning message will appear on the cluster and an audible warning will sound.
- If a vehicle is detected in front, the system will operate when your vehicle speed is between approximately 6~112 mph (10~180 km/h).
- If a pedestrian or cyclist is detected in front, the system will operate when your vehicle speed is between approximately 6~53 mph (10~85 km/h).
- If 'Active Assist' is selected, braking may be assisted.



OCN7070029L

Emergency Braking

- To warn the driver that emergency braking will be assisted, the 'Emergency Braking' warning message will appear on the cluster and an audible warning will sound.
- If a vehicle is detected in front, the system will operate when your vehicle speed is between approximately 6~47 mph (10~75 km/h).
- If a pedestrian or cyclist is detected in front, the system will operate when your vehicle speed is between approximately 6~40 mph (10~65 km/h).
- In emergency braking situation, braking is assisted with strong braking power by the system to help prevent collision with the vehicle, pedestrian or cyclist ahead.

OCN7070030L

Stopping vehicle and ending brake control

- When the vehicle is stopped due to emergency braking, the 'Drive carefully' warning message will appear on the cluster.

  For your safety, the driver should depress the brake pedal immediately and check the surroundings.
- Brake control will end after the vehicle is stopped by emergency braking for approximately 2 seconds.

Junction Turning function (if equipped)

Function warning and control

Junction Turning function will help warn and control the vehicle depending on the collision level: 'Collision Warning', 'Emergency Braking' and 'Stopping vehicle and ending brake control'

OCN7070099L

Collision Warning

- To warn the driver of a collision, the 'Collision Warning' warning message will appear on the cluster and an audible warning will sound.
- The function will operate when your vehicle speed is between approximately 6~19 mph (10~30 km/h) and the oncoming vehicle speed is between approximately 19~44 mph (30~70 km/h).
- If 'Active Assist' is selected, braking may be assisted.

OCN7070098L

Emergency Braking

- To warn the driver that emergency braking will be assisted, the 'Emergency Braking' warning message will appear on the cluster and an audible warning will sound.
- The system will operate when your vehicle speed is between approximately 6~19 mph (10~30 km/h) and the oncoming vehicle speed is between approximately 19~44 mph (30~70 km/h).
- In emergency braking situation, braking is assisted with strong braking power by the system to help prevent collision with the oncoming vehicle.

Information

If the driver's seat is on the left side, Junction Turning function will operate only when the driver turns left. If the driver's seat position is on right side, the function will operate only when you turn right.

OCN7070030L

Stopping vehicle and ending brake control

- When the vehicle is stopped due to emergency braking, the 'Drive carefully' warning message will appear on the cluster.

  For your safety, the driver should depress the brake pedal immediately and check the surroundings.
- Brake control will end after the vehicle is stopped by emergency braking for approximately 2 seconds.

WARNING

Take the following precautions when using Forward Collision-Avoidance Assist:

- **For your safety, change the Settings after parking the vehicle at a safe location.**
- **With 'Active Assist' or 'Warning Only' selected, when ESC is turned off by pressing and holding the ESC OFF button for more than 3 seconds, Forward Collision-Avoidance Assist will turn off automatically. In this case, the function cannot be set from the Settings menu and the warning light will illuminate on the cluster which is normal. If ESC is turned on by pressing the ESC OFF button, Forward Collision-Avoidance Assist will maintain the last setting.**
- **Forward Collision-Avoidance Assist does not operate in all situations or cannot avoid all collisions.**
- **The driver should hold the responsibility to control the vehicle. Do not solely depend on Forward Collision-Avoidance Assist. Rather, maintain a safe braking distance, and if necessary, depress the brake pedal to reduce driving speed or to stop the vehicle.**
- **Never deliberately operate Forward Collision-Avoidance Assist on people, animal, objects, etc. It may cause serious injury or death.**
- **Forward Collision-Avoidance Assist may not operate if the driver depresses the brake pedal to avoid collision.**
- **Depending on the road and driving conditions, Forward Collision-Avoidance Assist may warn the driver late or may not warn the driver.**
- **During Forward Collision-Avoidance Assist operation, the vehicle may stop suddenly injuring passengers and shifting loose objects. Always have the seat belt on and keep loose objects secured.**
- **If any other function's warning message is displayed or audible warning is generated, Forward Collision-Avoidance Assist warning message may not be displayed and audible warning may not be generated.**
- **You may not hear the warning sound of Forward Collision-Avoidance Assist if the surrounding is noisy.**
- **Forward Collision-Avoidance Assist may turn off or may not operate properly or may operate unnecessarily depending on the road conditions and the surroundings.**

WARNING

- **Even if there is a problem with Forward Collision-Avoidance Assist, the vehicle's basic braking performance will operate normally.**
- **During emergency braking, braking control by the function will automatically cancel when the driver excessively depresses the accelerator pedal or sharply steers the vehicle.**

CAUTION

- **Forward Collision-Avoidance Assist operating speed range may reduce due to the conditions of the vehicle or pedestrian in front or surroundings. Depending on the speed, the system may only warn the driver, or the system may not operate.**
- **Forward Collision-Avoidance Assist will operate under certain conditions by judging the risk level based on the condition of the oncoming vehicle, driving direction, speed and surroundings.**

Information

In a situation where collision is imminent, braking may be assisted by Forward Collision-Avoidance Assist when braking is insufficient by the driver.

Function malfunction and limitations

Function malfunction

When Forward Collision-Avoidance Assist is not working properly, the 'Check Forward Safety system(s)' warning message will appear, and the and warning lights will illuminate on the cluster. We recommend that the function be inspected by an authorized HYUNDAI dealer.

System disabled

OCN7070032L

OCN7070033L

When the front windshield where the front view camera is located, front radar cover, bumper or sensor is covered with foreign material, such as snow or rain, it can reduce the detecting performance and temporarily limit or disable Forward Collision-Avoidance Assist.

If this occurs the 'Forward Safety system(s) disabled. Camera obscured' or the 'Forward Safety system(s) disabled. Radar blocked' warning message, and the ⚠ and warning lights will illuminate on the cluster.

The function will operate normally when when such snow, rain or foreign material is removed.

If the function does not operate normally after obstruction (snow, rain, or foreign material) is removed, we recommend that the function be inspected by an authorized HYUNDAI dealer.

WARNING

- **Even though the warning message or warning light does not appear on the cluster, Forward Collision-Avoidance Assist may not properly operate.**
- **Forward Collision-Avoidance Assist may not properly operate in an area (e.g. open terrain), where any substance are not detected after turning ON the engine.**

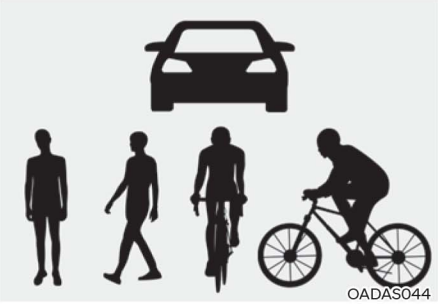
Limitations of the function

Forward Collision-Avoidance Assist may not operate normally, or the function may operate unexpectedly under the following circumstances:

- The detecting sensor or the surroundings are contaminated or damaged
- The temperature around the front view camera is high or low
- The camera lens is contaminated due to tinted, filmed or coated windshield, damaged glass, or stuck of foreign material (sticker, bug, etc.) on the glass
- Moisture is not removed or frozen on the windshield
- Washer fluid is continuously sprayed, or the wiper is on
- Driving in heavy rain or snow, or thick fog
- The field of view of the front view camera is obstructed by sun glare
- Street light or light from an oncoming vehicle is reflected on the wet road surface, such as a puddle on the road
- An object is placed on the dashboard

- Your vehicle is being towed
- The surrounding is very bright
- The surrounding is very dark, such as in a tunnel, etc.
- The brightness changes suddenly, for example when entering or exiting a tunnel
- The brightness outside is low, and the headlamps are not on or are not bright
- Driving through steam, smoke or shadow
- Only part of the vehicle, pedestrian or cyclist is detected
- The vehicle in front is a bus, heavy truck, truck with a unusually shaped luggage, trailer, etc.
- The vehicle in front has no tail lights, tail lights are located unusually, etc.
- The brightness outside is low, and the tail lamps are not on or are not bright
- The rear of the front vehicle is small or the vehicle does not look normal, such as when the vehicle is tilted, overturned, or the side of the vehicle is visible, etc.
- The front vehicle's ground clearance is low or high
- A vehicle, pedestrian or cyclist suddenly cuts in front
- The bumper around the front radar is impacted, damaged or the front radar is out of position
- The temperature around the front radar is high or low
- Driving through a tunnel or iron bridge
- Driving in large areas where there are few vehicles or structures (i.e. desert, meadow, suburb, etc.)
- Driving near areas containing metal substances, such as a construction zone, railroad, etc.
- A material is near that reflects very well on the front radar, such as a guardrail, nearby vehicle, etc.
- The cyclist in front is on a bicycle made of material that does not reflect on the front radar
- The vehicle in front is detected late
- The vehicle in front is suddenly blocked by a obstacle
- The vehicle in front suddenly changes lane or suddenly reduces speed
- The vehicle in front is bent out of shape
- The front vehicle's speed is fast or slow
- The vehicle in front steers in the opposite direction of your vehicle to avoid a collision
- With a vehicle in front, your vehicle changes lane at low speed
- The vehicle in front is covered with snow
- You are departing or returning to the lane
- Unstable driving
- You are on a roundabout and the vehicle in front is not detected
- You are continuously driving in a circle
- The vehicle in front has an unusual shape
- The vehicle in front is driving uphill or downhill

- The pedestrian or cyclist is not fully detected, for example, if the pedestrian is leaning over or is not fully walking upright
- The pedestrian or cyclist is wearing clothing or equipment that makes it difficult to detect as a pedestrian or cyclist

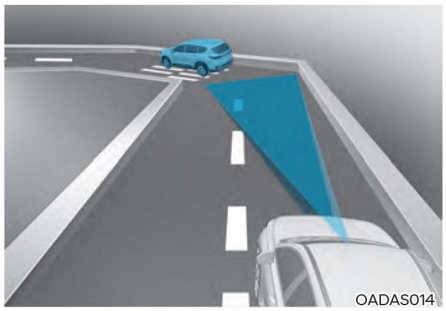


The illustration above shows the image the front view camera will detect as a vehicle, pedestrian and cyclist.

- The pedestrian or cyclist in front is moving very quickly
- The pedestrian or cyclist in front is short or is posing a low posture
- The pedestrian or cyclist in front has impaired mobility
- The pedestrian or cyclist in front is moving intersected with the driving direction
- There is a group of pedestrians, cyclists or a large crowd in front
- The pedestrian or cyclist is wearing clothing that easily blends into the background, making it difficult to detect
- The pedestrian or cyclist is difficult to distinguish from the similar shaped structure in the surroundings
- You are driving by a pedestrian, cyclist, traffic sign, structure, etc. near the intersection
- Driving in a parking lot
- Driving through a tollgate, construction area, unpaved road, partial paved road, uneven road, speed bumps, etc.
- Driving on an incline road, curved road, etc.
- Driving through a roadside with trees or streetlights
- The adverse road conditions cause excessive vehicle vibrations while driving
- Your vehicle height is low or high due to heavy loads, abnormal tire pressure, etc.
- Driving through a narrow road where trees or grass are overgrown
- There is interference by electromagnetic waves, such as driving in an area with strong radio waves or electrical noise

WARNING

- **Driving on a curve**

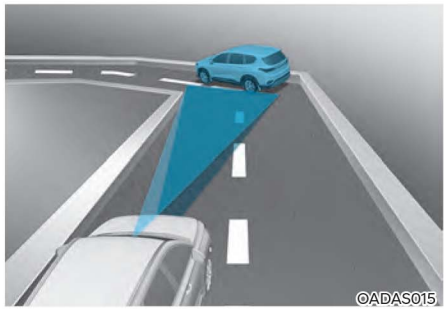

OADAS014


OADAS016


OADAS018

Forward Collision-Avoidance Assist may not detect other vehicles, pedestrians or cyclists in front of you on curved roads adversely affecting the performance of the sensors. This may result in no warning or braking assist when necessary.

When driving on a curve, you must maintain a safe braking distance, and if necessary, steer the vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.


OADAS015


OADAS017


OADAS019

Forward Collision-Avoidance Assist may detect a vehicle, pedestrian or cyclist in the next lane or outside the lane when driving on a curved road.

If this occurs, the system may unnecessarily warn the driver and control the brake. Always check the traffic conditions around the vehicle.

- **Driving on a slope**

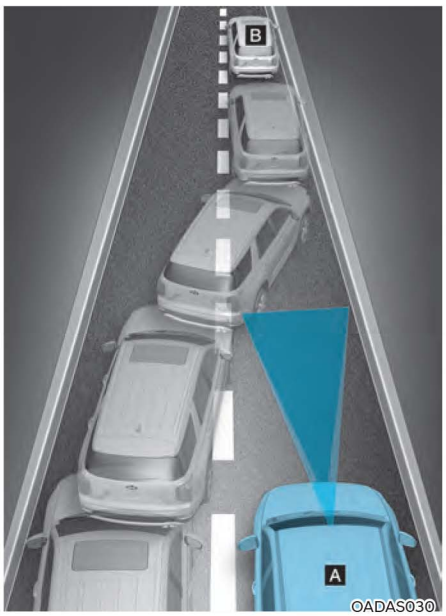
Forward Collision-Avoidance Assist may not detect other vehicles, pedestrians or cyclists in front of you while driving uphill or downhill adversely affecting the performance of the sensors.

This may result in unnecessary warning or braking assist, or no warning or braking assist when necessary.

Also, vehicle speed may rapidly decrease when a vehicle, pedestrian or cyclist ahead is suddenly detected.

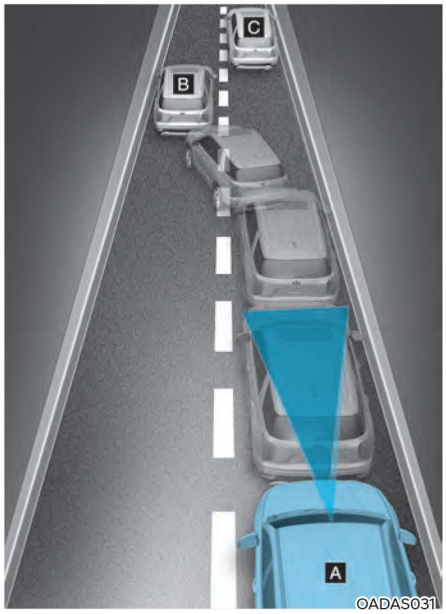
Always have your eyes on the road while driving uphill or downhill and if necessary, steer your vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

- **Changing lanes**



[A] : Your vehicle,
[B] : Lane changing vehicle

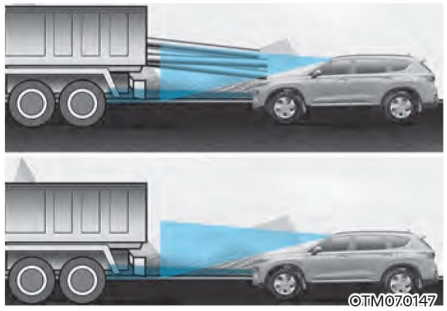
When a vehicle moves into your lane from an adjacent lane, it cannot be detected by the sensor until it is in the sensor's detection range. Forward Collision-Avoidance Assist may not immediately detect the vehicle when the vehicle changes lanes abruptly. In this case, you must maintain a safe braking distance, and if necessary, steer your vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.



[A] : Your vehicle, [B] : Lane changing vehicle,
[C] : Same lane vehicle

When a vehicle in front of you merges out of the lane, Forward Collision-Avoidance Assist may not immediately detect the vehicle that is now in front of you. In this case, you must maintain a safe braking distance, and if necessary, steer your vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

- **Detecting vehicle**



If the vehicle in front of you has cargo that extends rearward from the cab, or when the vehicle in front of you has higher ground clearance, additional special attention is required. Forward Collision-Avoidance Assist may not be able to detect the cargo extending from the vehicle. In these instances, you must maintain a safe braking distance from the rearmost object, and if necessary, steer your vehicle and depress the brake pedal to reduce your driving speed in order to maintain distance.

APPENDIX C

Run Log

Subject Vehicle: **2021 Hyundai Elantra SEL** Test Date: **3/8/2021**

Principal Other Vehicle: **SSV**

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
1-12	Brake characterization and determination						See Appendix D
21	Static Run						Zero SV front bumper to SSV rear bumper and collect data
22	**Stopped POV**	Y	2.13	15.82	1.09	Pass	
23		Y	2.15	16.10	1.05	Pass	
24		Y	2.15	15.32	1.08	Pass	
25		Y	2.18	15.30	1.05	Pass	
26		Y	2.15	15.49	1.05	Pass	
27		Y	2.14	15.32	1.05	Pass	
28		Y	2.16	15.14	1.05	Pass	
29	Static Run						
30	**Slower POV, 25 vs 10**	Y	1.98	10.59	1.06	Pass	
31		Y	1.90	11.12	1.10	Pass	
32		Y	1.89	11.09	1.11	Pass	
33		Y	1.93	12.00	1.10	Pass	
34		Y	1.94	10.18	1.06	Pass	
35		Y	1.94	10.00	1.06	Pass	
36		Y	1.97	12.21	1.12	Pass	
37	Static run						Check zero data is within ± 0.167 ft (±0.05m)

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
38	**Slower POV, 45 vs 20**	Y	2.37	13.76	1.10	Pass	
39		Y	2.42	14.03	1.06	Pass	
40		Y	2.44	14.60	1.09	Pass	
41		Y	2.42	13.85	1.10	Pass	
42		Y	2.35	13.32	1.06	Pass	
43		Y	2.41	13.79	1.09	Pass	
44		Y	2.44	13.85	1.10	Pass	
45	Static run						Check zero data is within ± 0.167 ft (±0.05m)
46	**Decelerating POV**	N					SV speed
47		N					SV throttle
48		Y	1.65	8.81	0.61	Pass	
49		Y	1.66	8.39	0.62	Pass	
50		Y	1.60	11.62	0.61	Pass	
51		Y	1.61	10.19	0.63	Pass	
52		Y	1.84	6.72	0.68	Pass	
53		Y	1.79	6.27	0.64	Pass	
54		Y	1.68	9.92	0.62	Pass	
55	Static run						Check zero data is within ± 0.167 ft (±0.05m)
56	STP - Static run						Zero SV front bumper to rear edge of steel plate and collect data

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
57	**Baseline, 25**	N					GPS fix type
58		Y			0.47		
59		Y			0.47		
60		Y			0.43		
61		Y			0.42		
62		Y			0.42		
63		Y			0.42		
64		Y			0.42		
65	STP - Static run						Check zero data is within ± 0.167 ft (±0.05m)
66	**Baseline, 45**	Y			0.44		
67		Y			0.45		
68		Y			0.45		
69		Y			0.46		
70		Y			0.45		
71		Y			0.46		
72		Y			0.44		
73	STP - Static run						Check zero data is within ± 0.167 ft (±0.05m)
74	STP - Static Run						
75	**STP False Positive, 25**	Y			0.46	Pass	
76		Y			0.43	Pass	
77		Y			0.43	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
78	**STP False Positive, 25**	Y			0.41	Pass	
79		Y			0.43	Pass	
80		Y			0.41	Pass	
81		Y			0.41	Pass	
82	STP - Static run						Check zero data is within ± 0.167 ft (±0.05m)
83	**STP False Positive, 45**	Y			0.39	Pass	
84		Y			0.42	Pass	
85		Y			0.40	Pass	
86		Y			0.40	Pass	
87		Y			0.42	Pass	
88		Y			0.40	Pass	
89		Y			0.40	Pass	
90	STP - Static run						Check zero data is within ± 0.167 ft (±0.05m)

APPENDIX D

Brake Characterization

Subject Vehicle: **2021 Hyundai Elantra SEL** Test Date: **3/8/2021**

DBS Initial Brake Characterization				
Run Number	**Stroke at 0.4 g (in)**	**Force at 0.4 g (lb)**	**Slope**	**Intercept**
1	2.897	16.780	0.407	-0.194
2	2.790	16.411	0.404	-0.196
3	2.855	15.957	0.406	-0.186

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	0.479	2.85		2.38	
5		35	Y	0.221	2.38		4.31	
6		35	N					SV speed
7		35	Y	0.385	2.65		2.75	
8		35	Y	0.405	2.67		2.64	
9		25	Y	0.402	2.67		2.66	
10		45	N					SV speed
11		45	Y	0.379	2.67		2.82	
12	**Hybrid**	35	N					SV speed
13		35	Y	0.474		15.20	12.83	

DBS Brake Characterization Determination								
Run	**DBS Mode**	**Speed**	**Valid Run**	**Average Decel. (g)**	**0.4 g Stroke Value (in)**	**0.4 g Force Value (lb)**	**Stroke/Force Calculator (in)**	**Notes**
14	**Hybrid**	35	Y	0.438		14.00	12.79	
15		35	Y	0.452		13.00	11.50	
16		35	Y	0.430		12.30	11.44	
17		35	Y	0.413		11.80	11.43	
18		25	Y	0.407		11.80	11.60	
19		45	Y	0.406		11.80	11.63	
20		45	Y	0.411		11.80	11.48	

Appendix E

TIME HISTORY PLOTS

LIST OF FIGURES

Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from both the Subject Vehicle (SV) and the Principal Other Vehicle (POV), as well as pass/fail envelopes and thresholds. 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 g ± 0.03 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 fore necessary to be valid
- If the tests are done in Displacement mode, there are no relevant brake force level thresholds or average brake force calculations.

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

Color Codes

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

Color codes can be broken into four categories:

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

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

2. Validation envelope and threshold color codes:
   - Green envelope = time varying data must be within the envelope at all times in order to be valid
   - Yellow envelope = time varying data must be within limits at left and/or right ends
   - Blue envelope = visualized target range for the time varying data averaged over a period equal to the length of the envelope
   - Black threshold (Solid) = time varying data must cross this threshold in the time period shown in order to be valid
   - Black threshold (Dashed) = for reference only – this can include warning level thresholds, TTC thresholds, and acceleration thresholds.
   - Red threshold (Solid) = for reference only – indicates the activation of last-minute braking by the brake robot. Data after the solid red line is not used to determine test validity.

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

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

Other Notations

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

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

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

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.

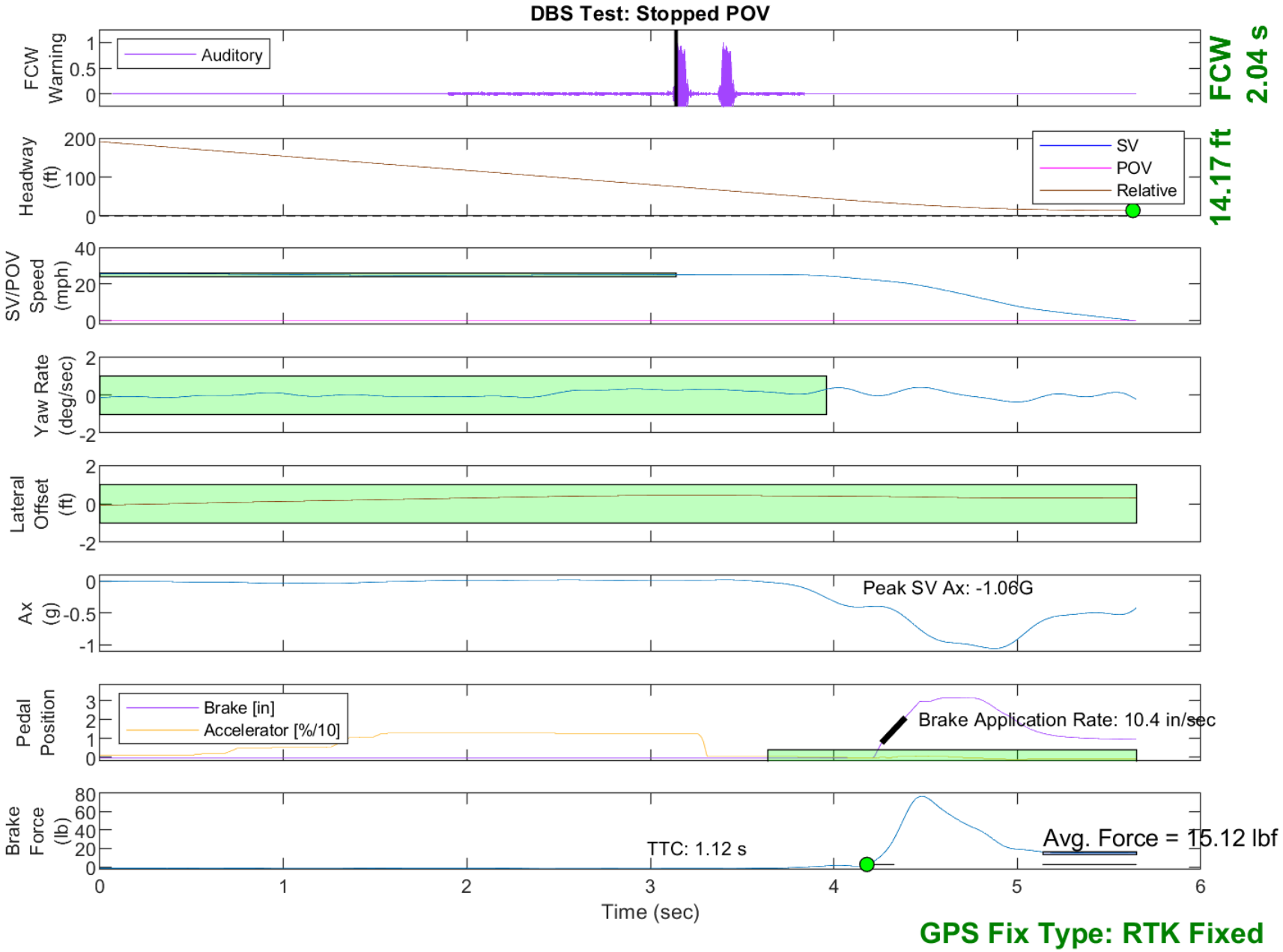


Figure E1. Example Time History for Stopped POV, Passing

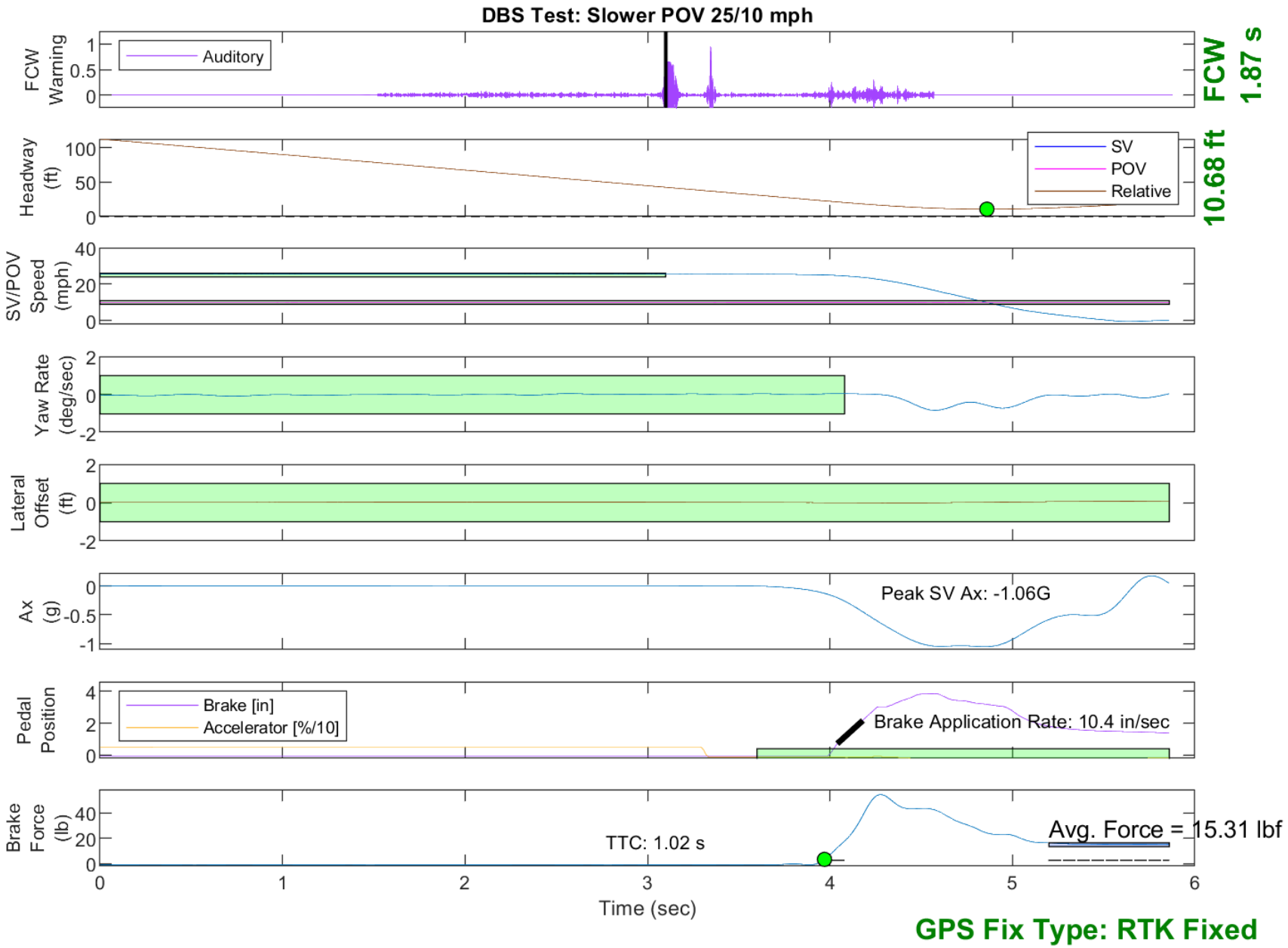


Figure E2. Example Time History for Slower POV 25 vs. 10, Passing

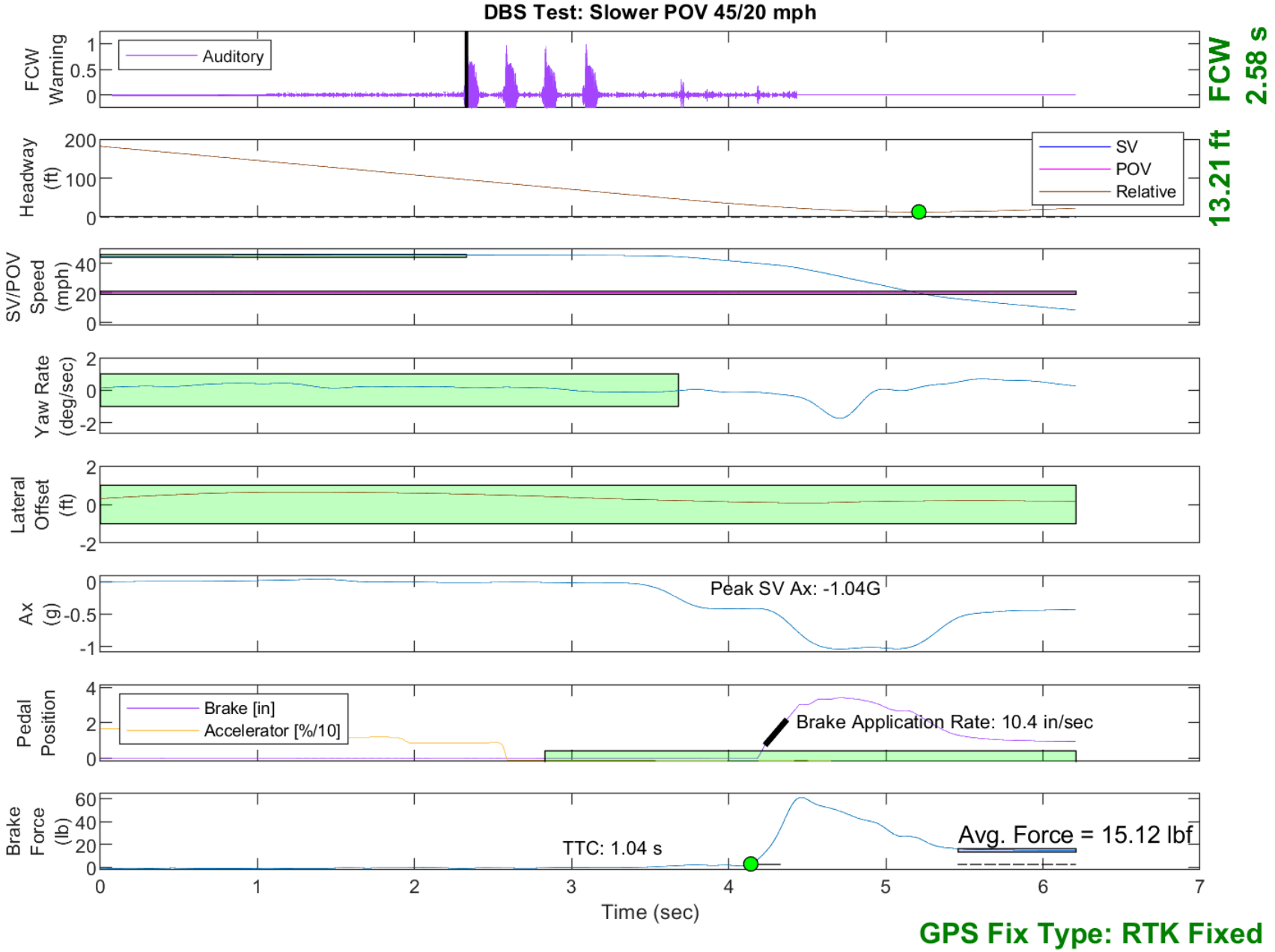


Figure E3. Example Time History for Slower POV 45 vs. 20, Passing

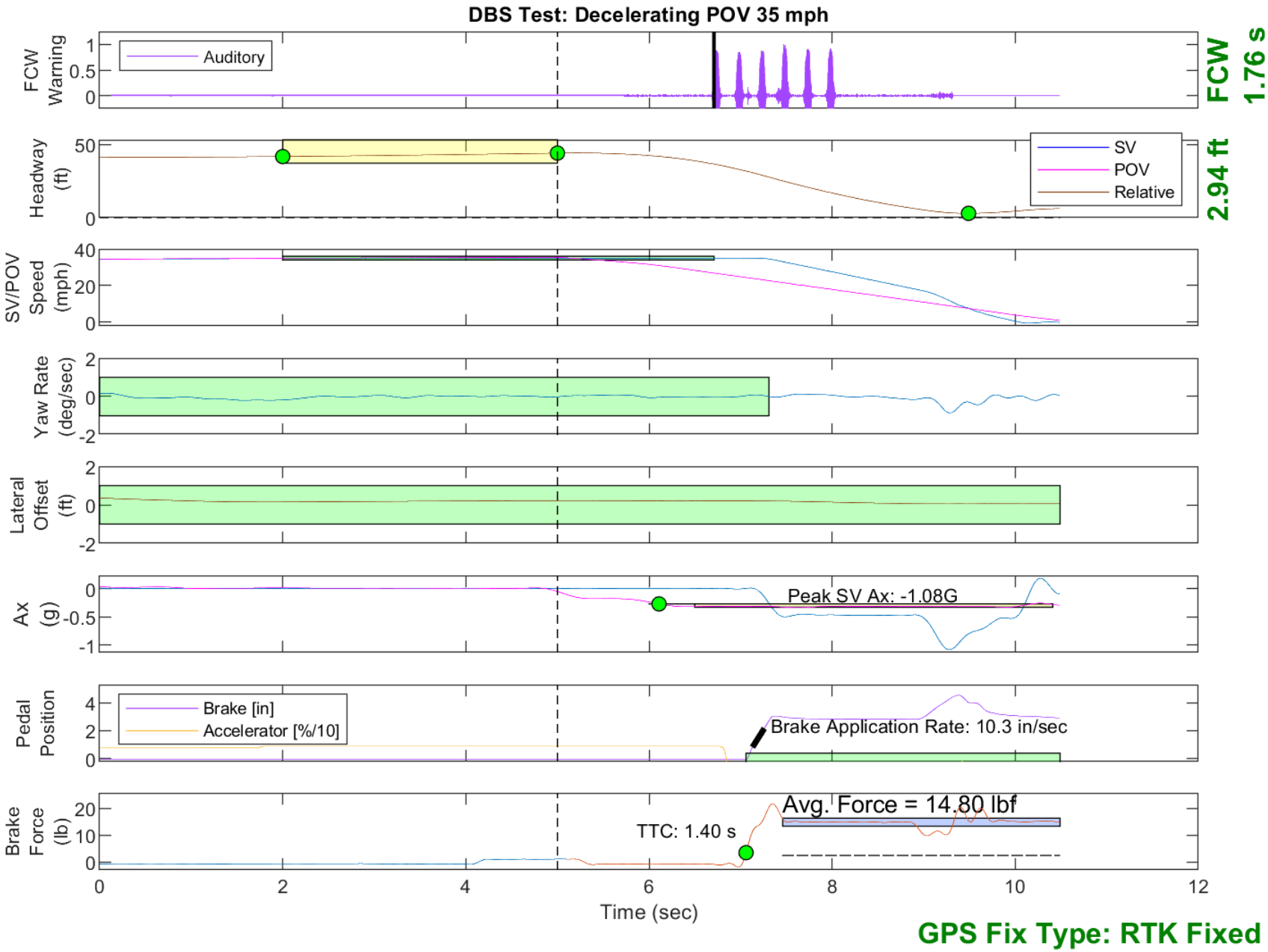


Figure E4. Example Time History for Decelerating POV 35, Passing

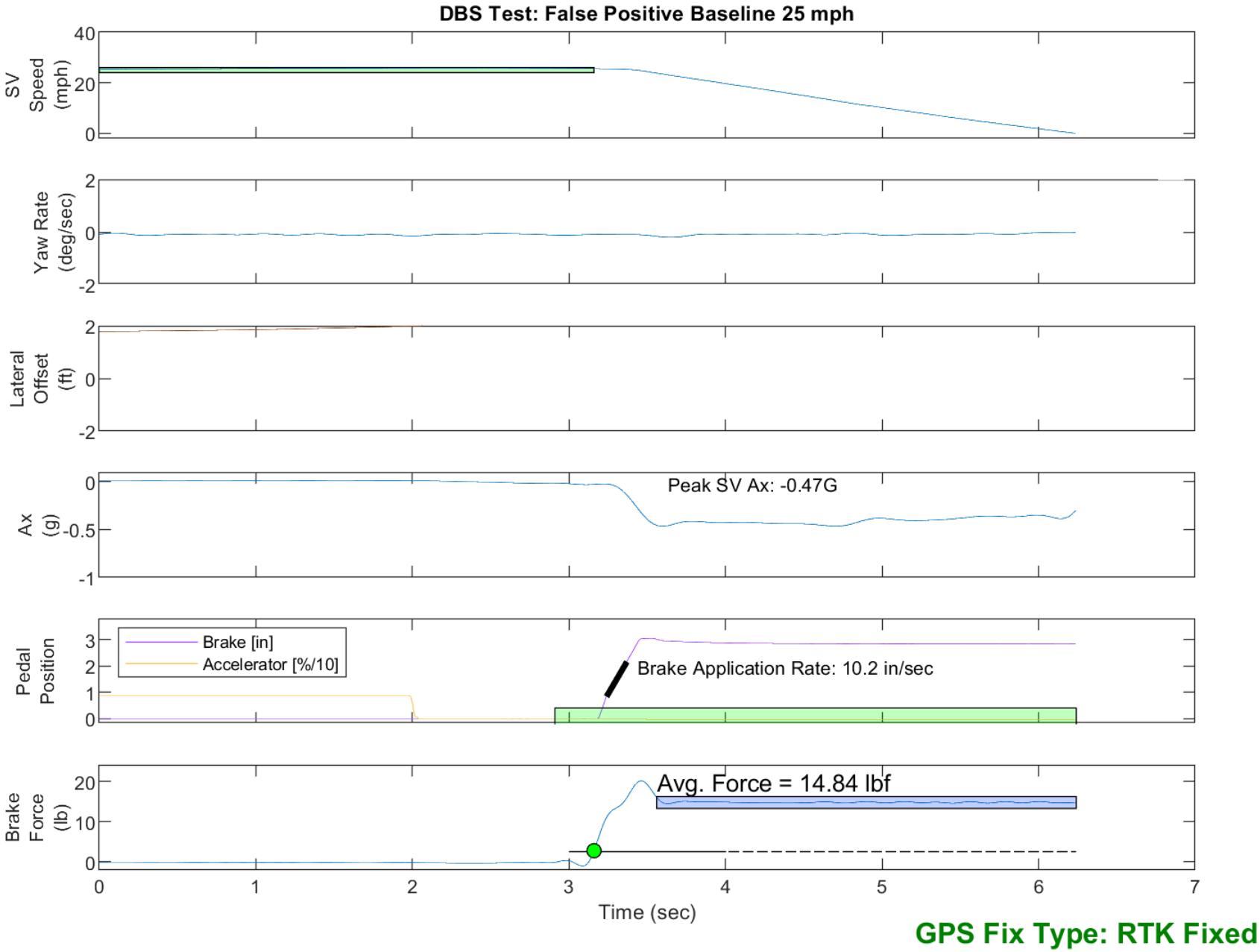


Figure E5. Example Time History for False Positive Baseline 25

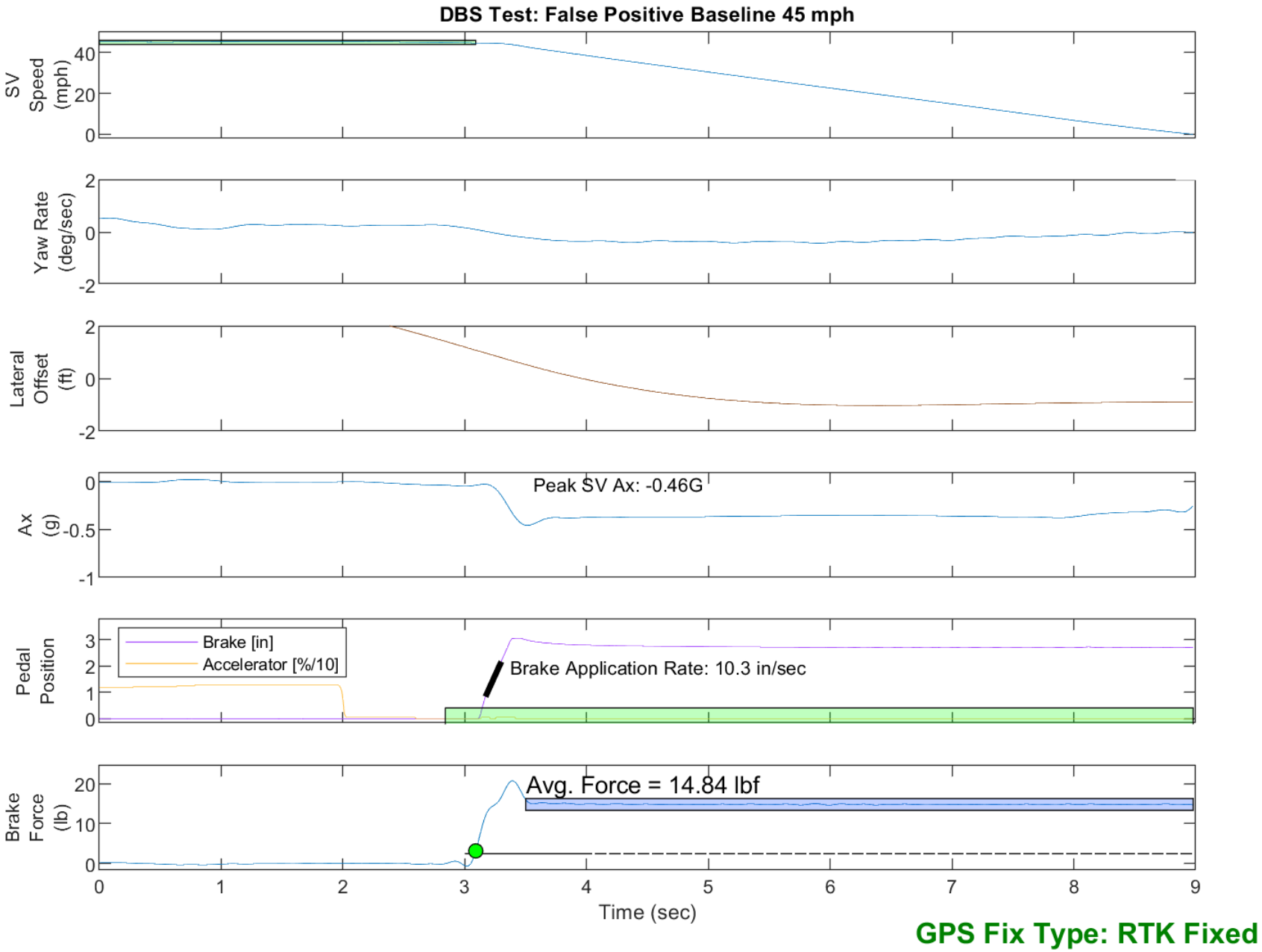


Figure E6. Example Time History for False Positive Baseline 45

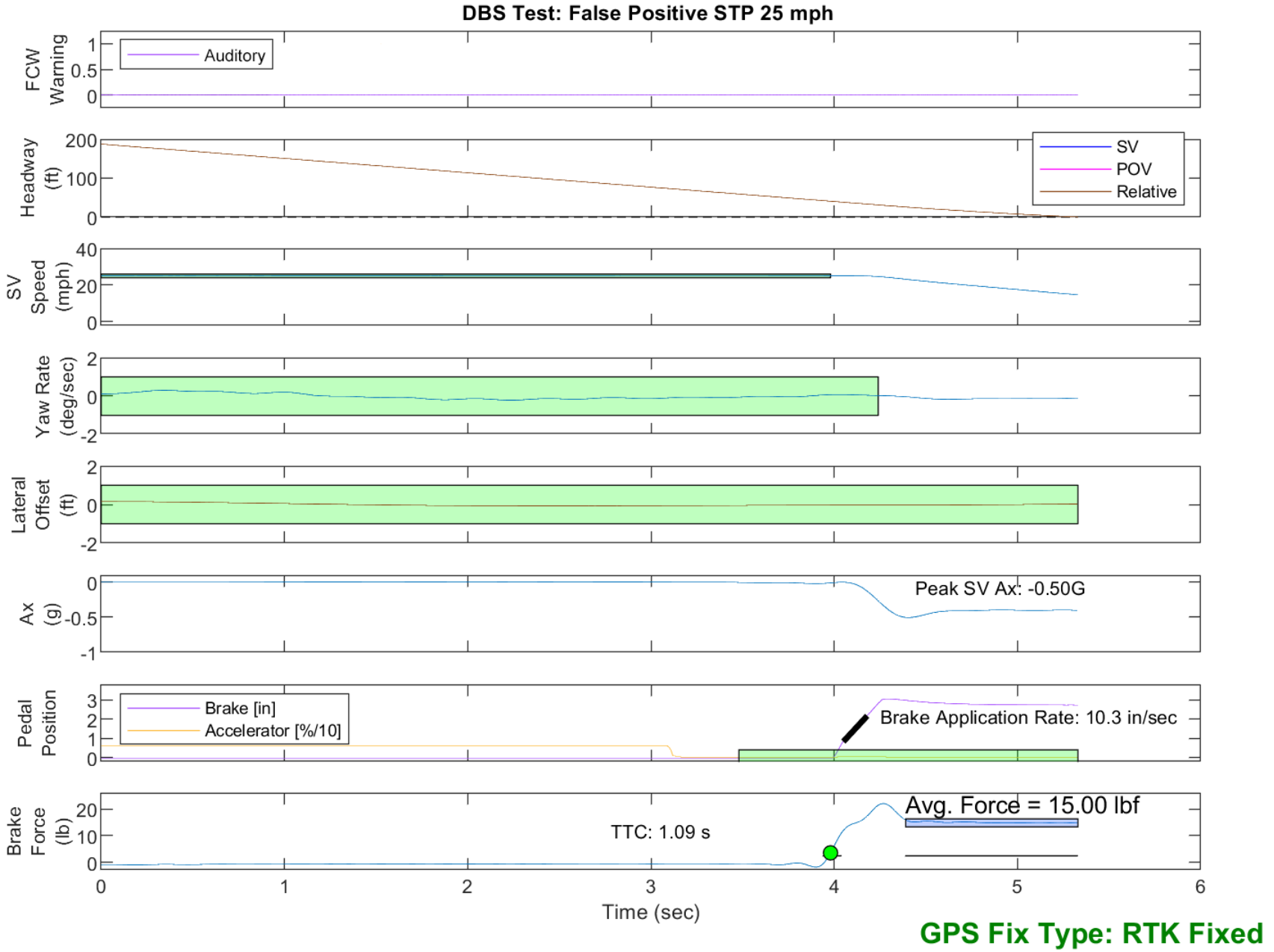


Figure E7. Example Time History for False Positive Steel Plate 25, Passing

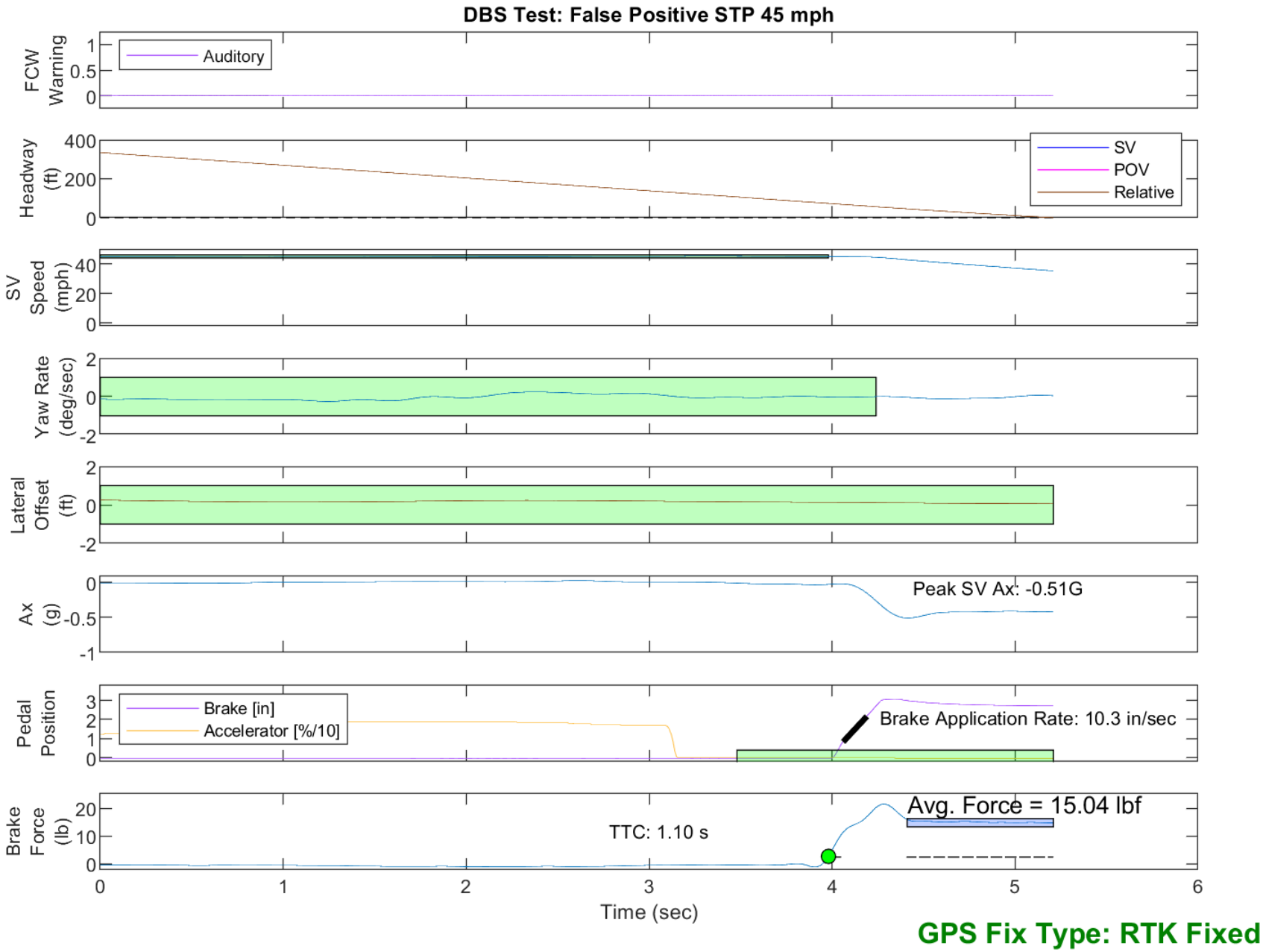


Figure E8. Example Time History for False Positive Steel Plate 45, Passing

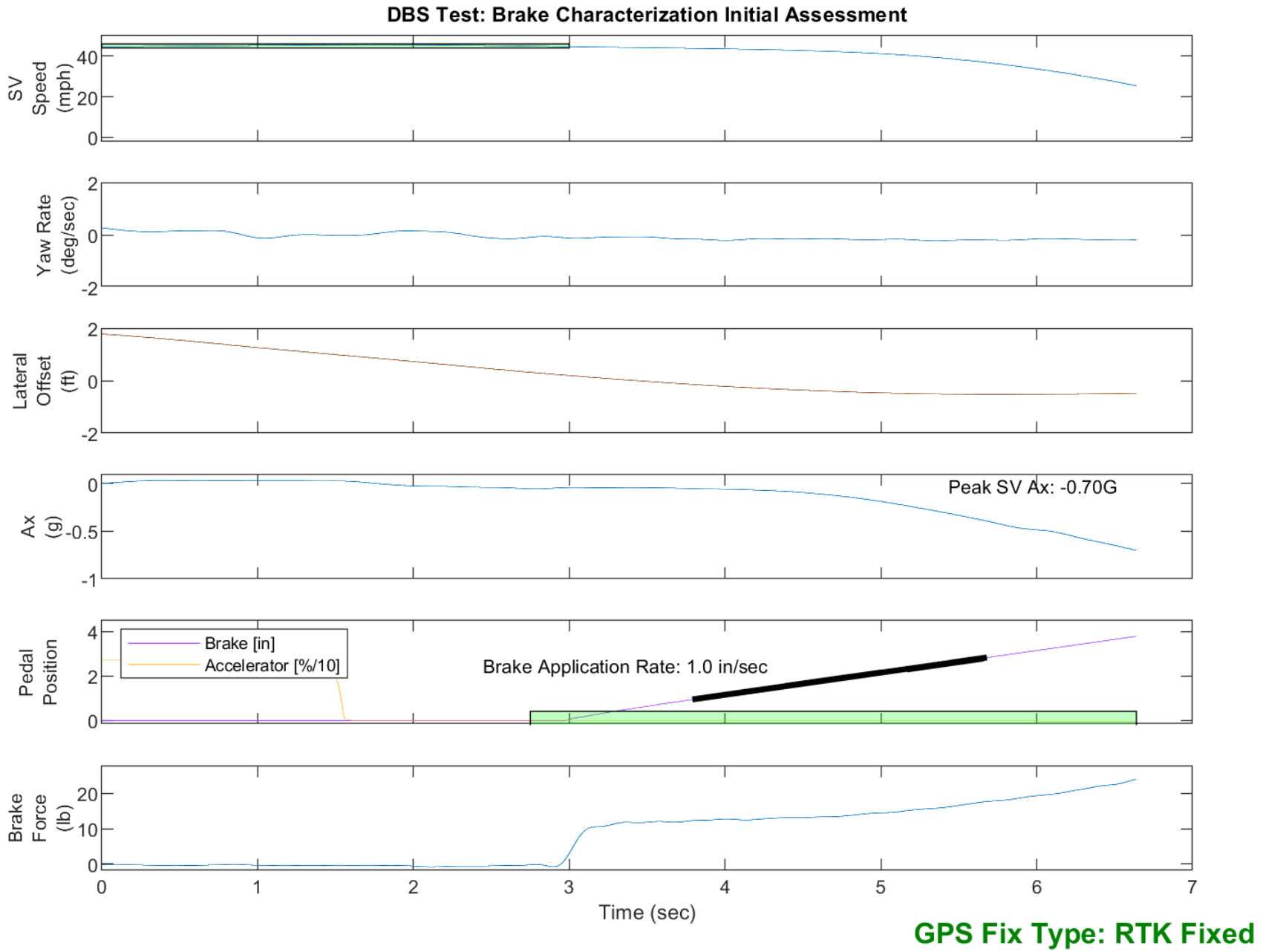


Figure E9. Example Time History for DBS Brake Characterization, Passing

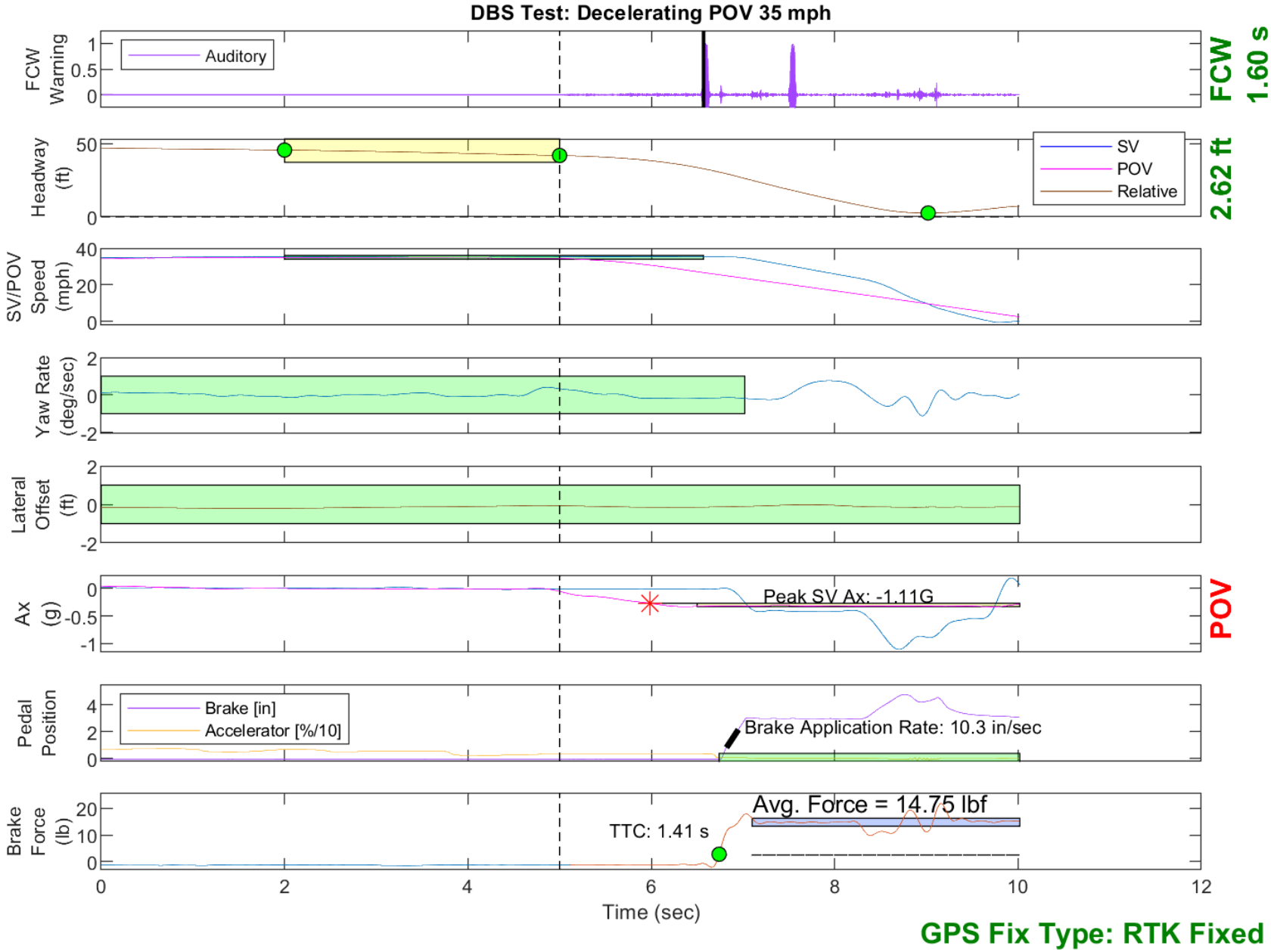


Figure E10. Example Time History Displaying Invalid POV Acceleration Criteria

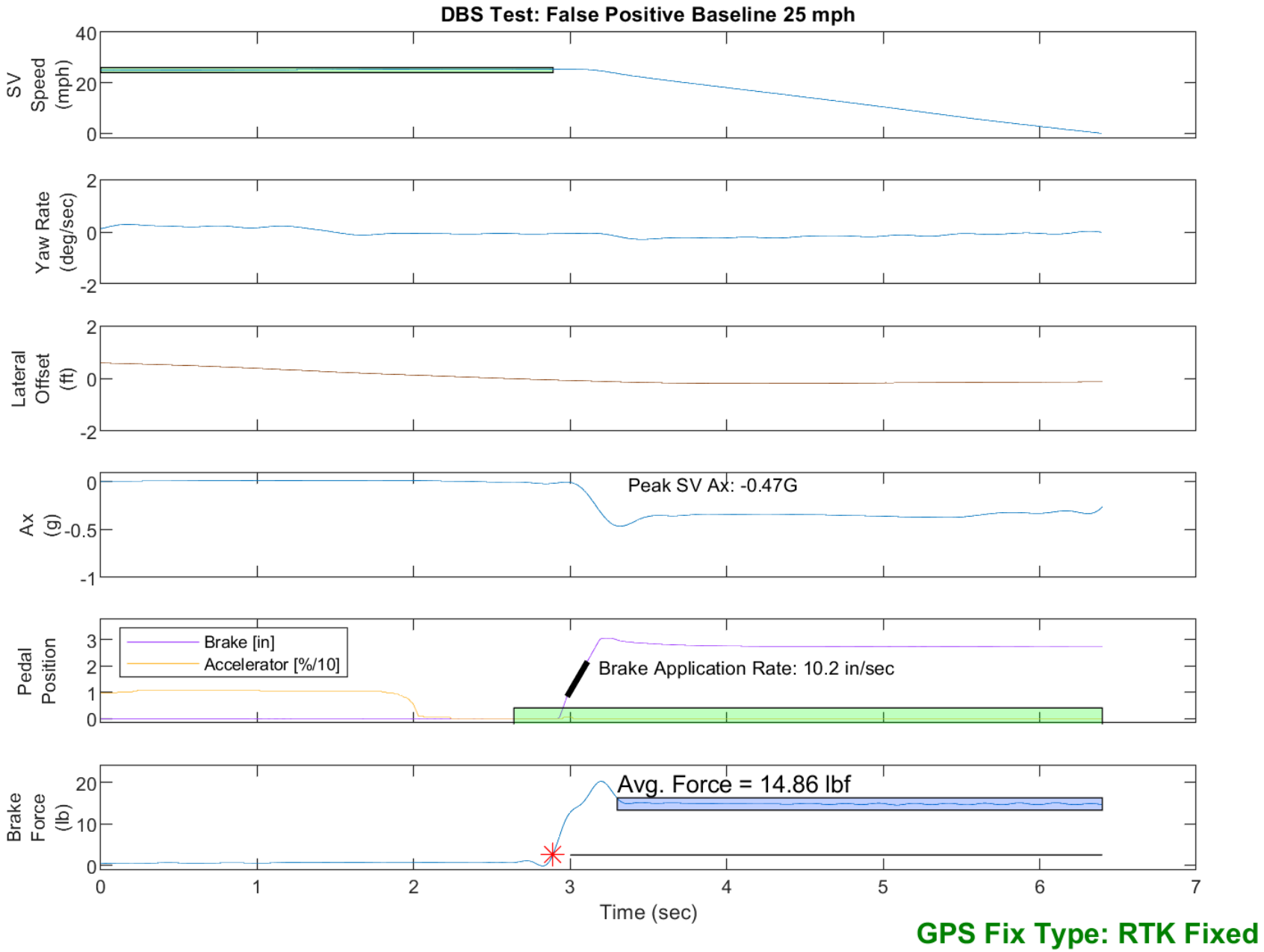


Figure E11. Example Time History Displaying Invalid Brake Force Criteria

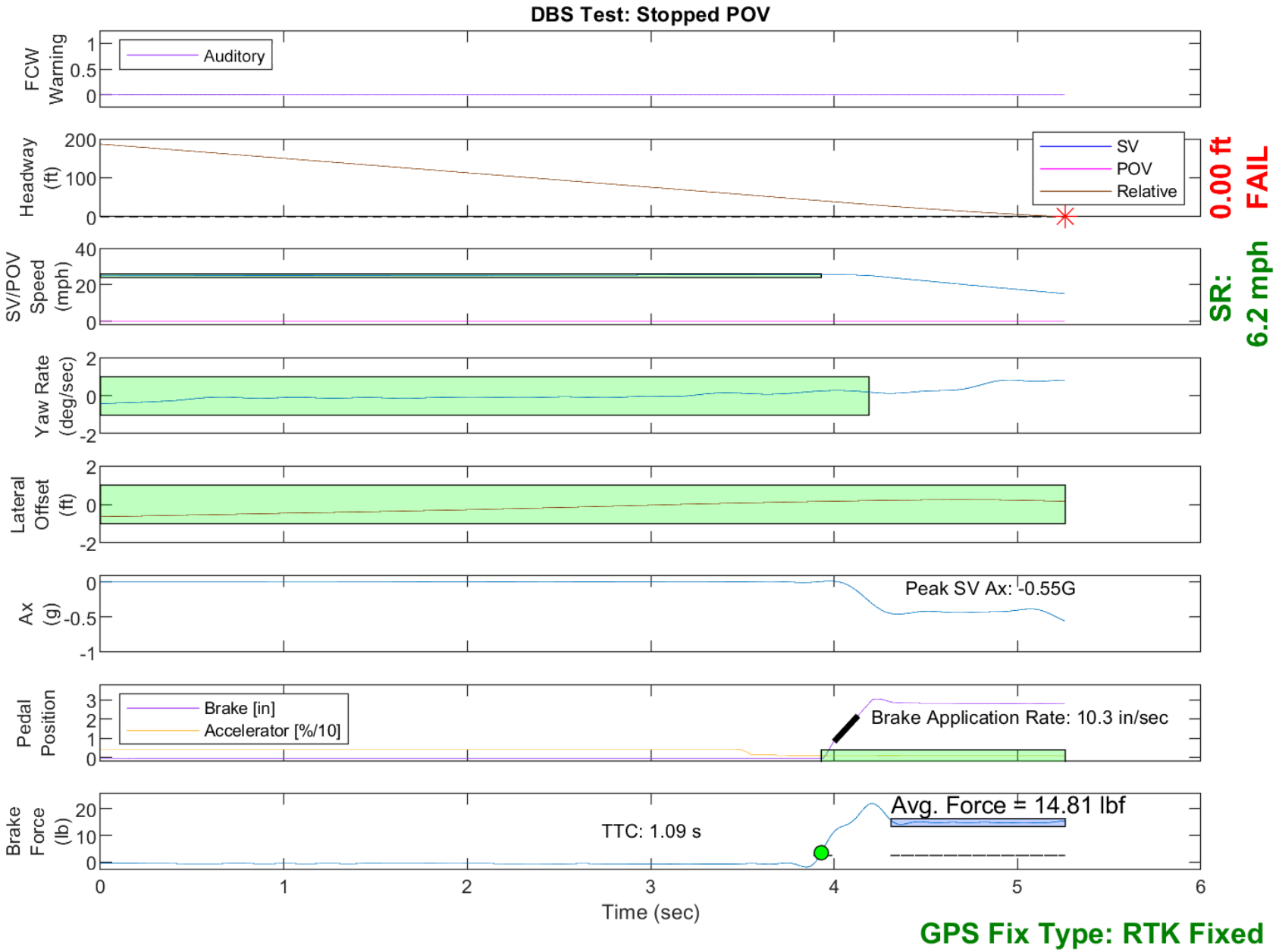


Figure E12. Example Time History for a Failed Run

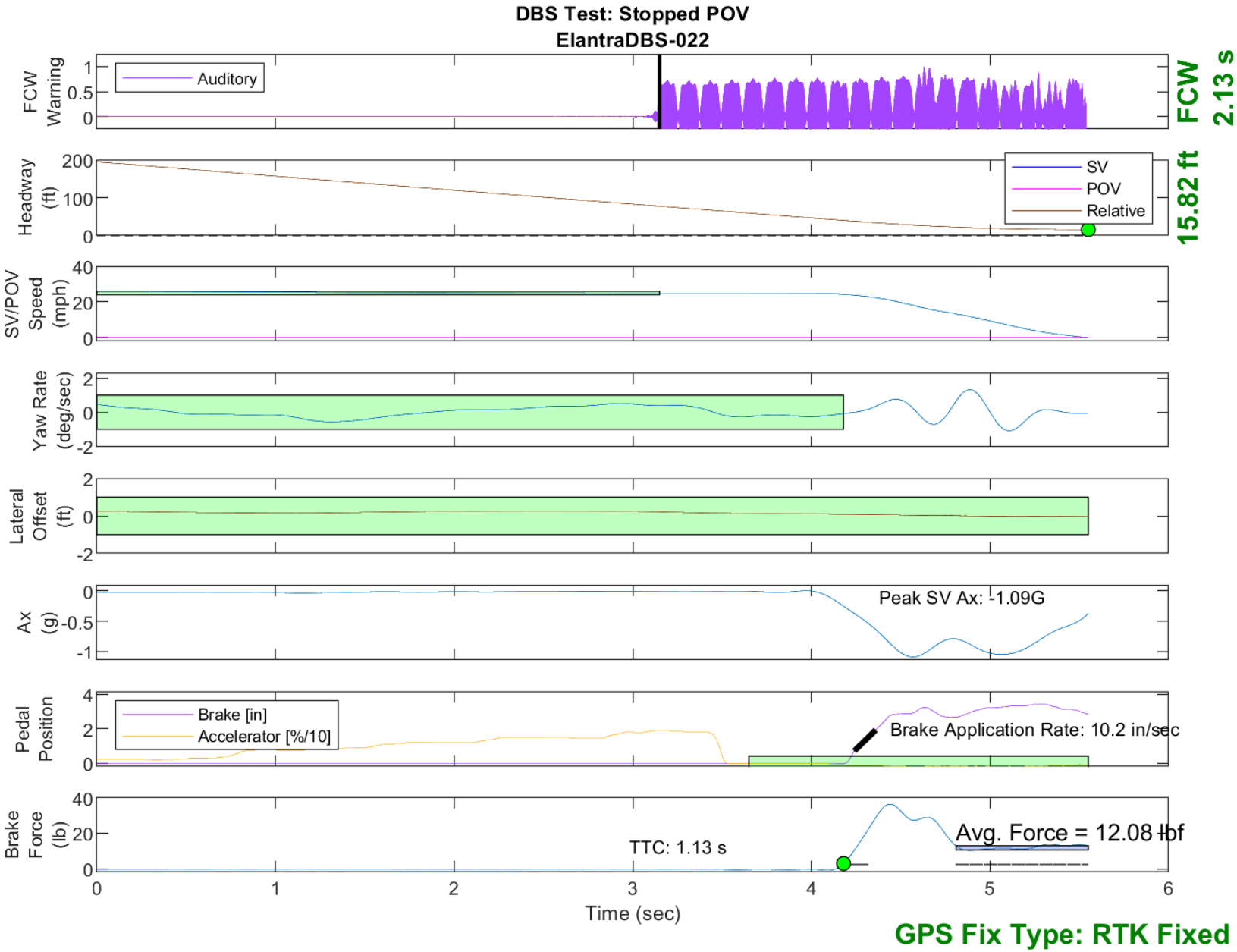


Figure E13. Time History for DBS Run 22, SV Encounters Stopped POV

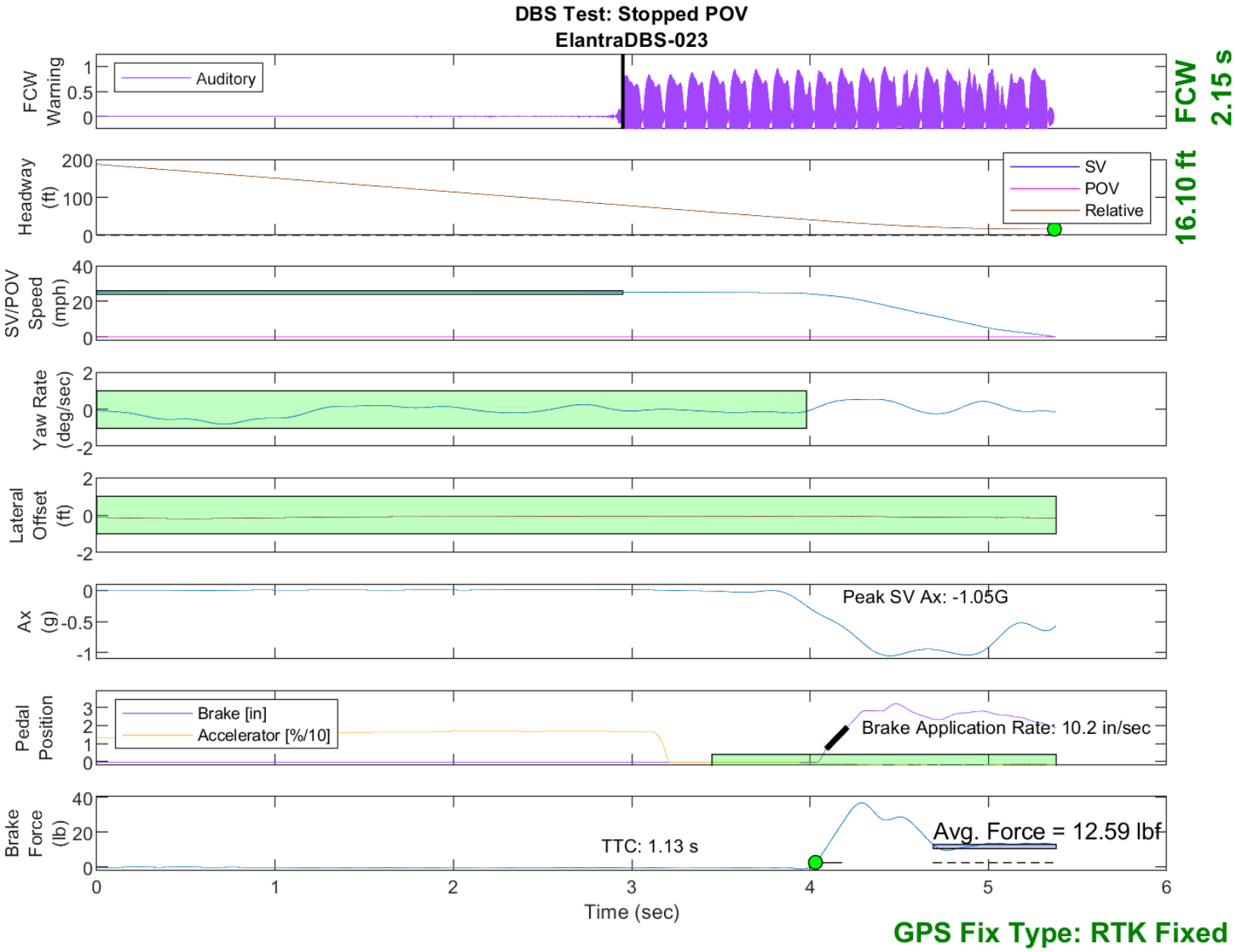


Figure E14. Time History for DBS Run 23, SV Encounters Stopped POV

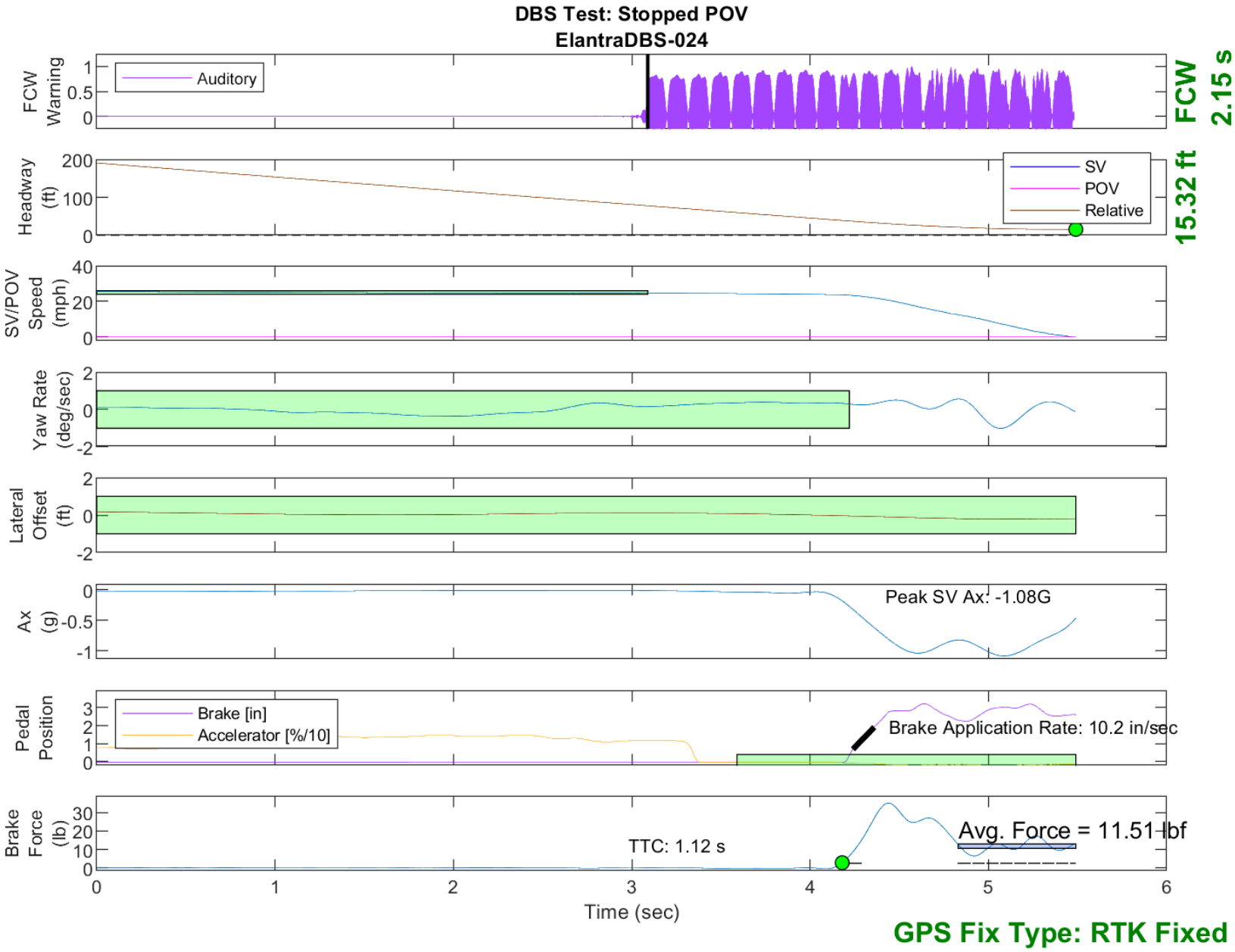


Figure E15. Time History for DBS Run 24, SV Encounters Stopped POV

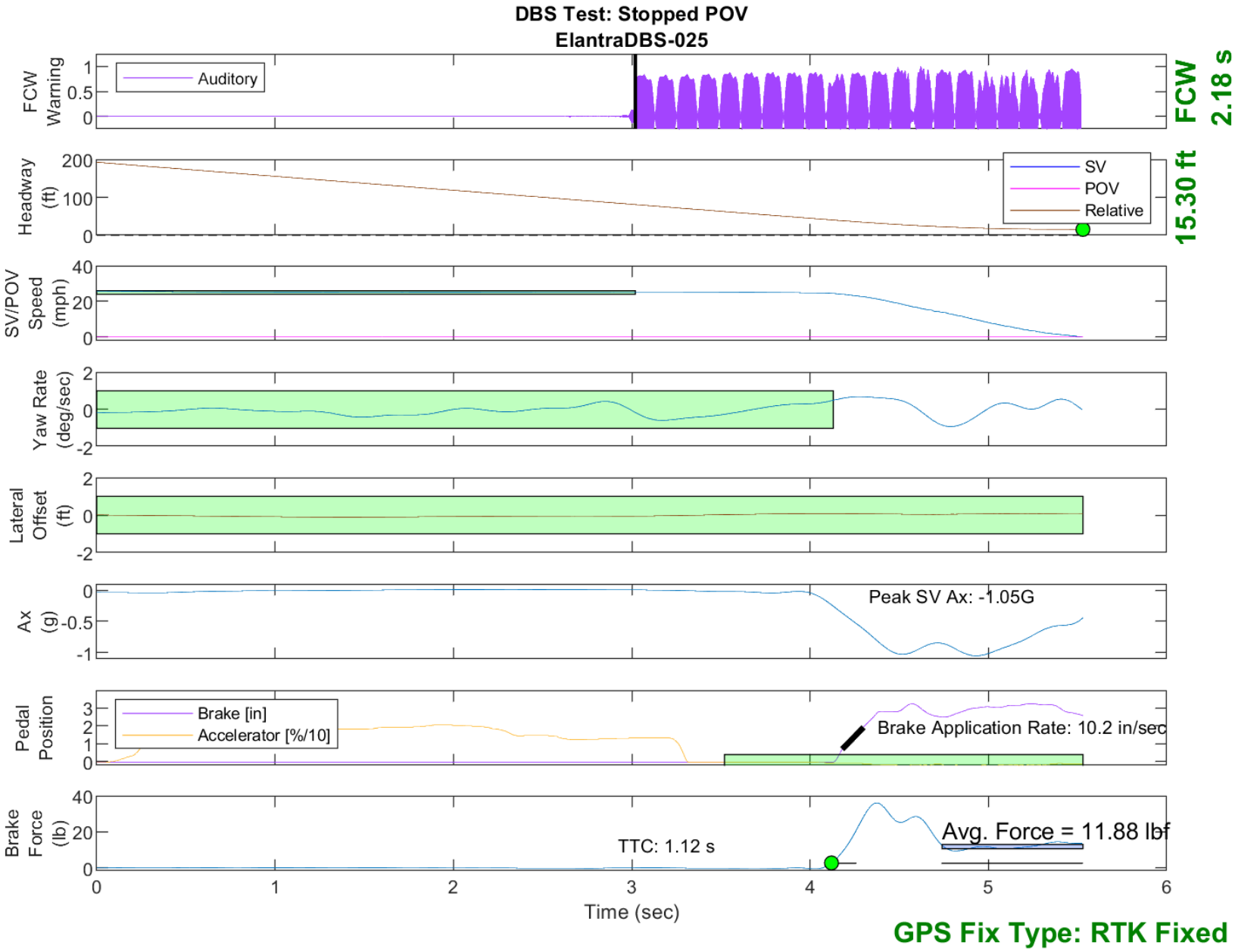


Figure E16. Time History for DBS Run 25, SV Encounters Stopped POV

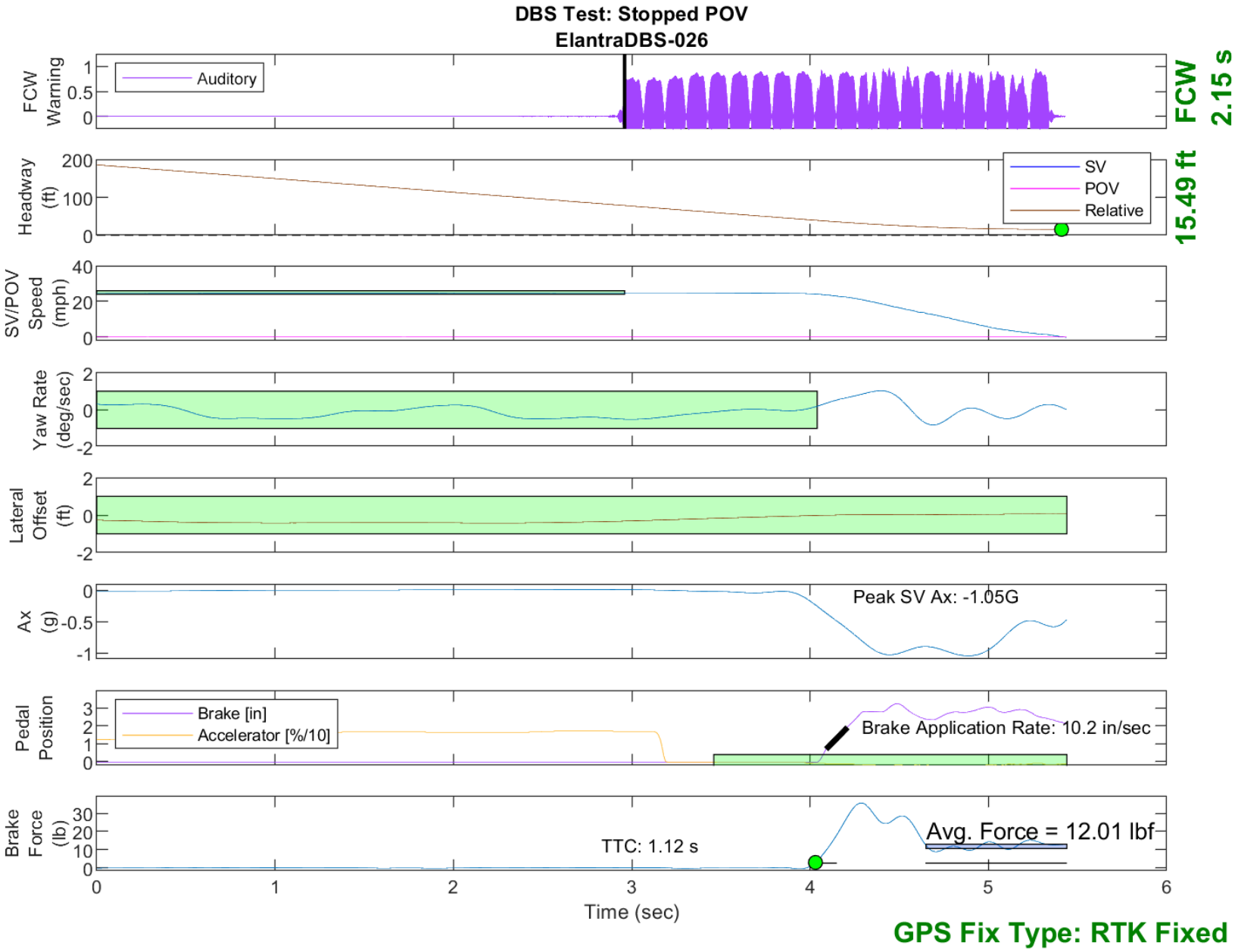


Figure E17. Time History for DBS Run 26, SV Encounters Stopped POV

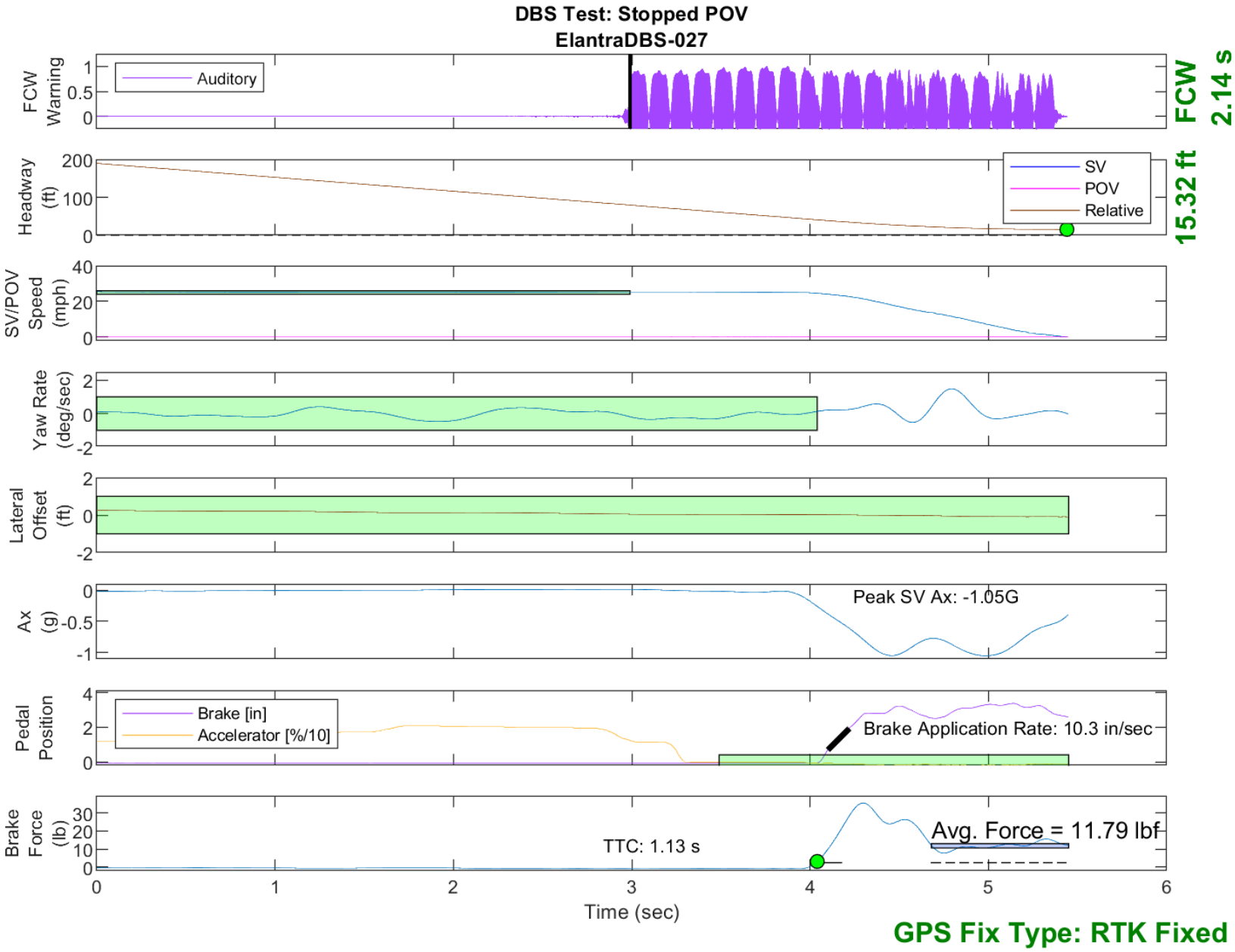


Figure E18. Time History for DBS Run 27, SV Encounters Stopped POV

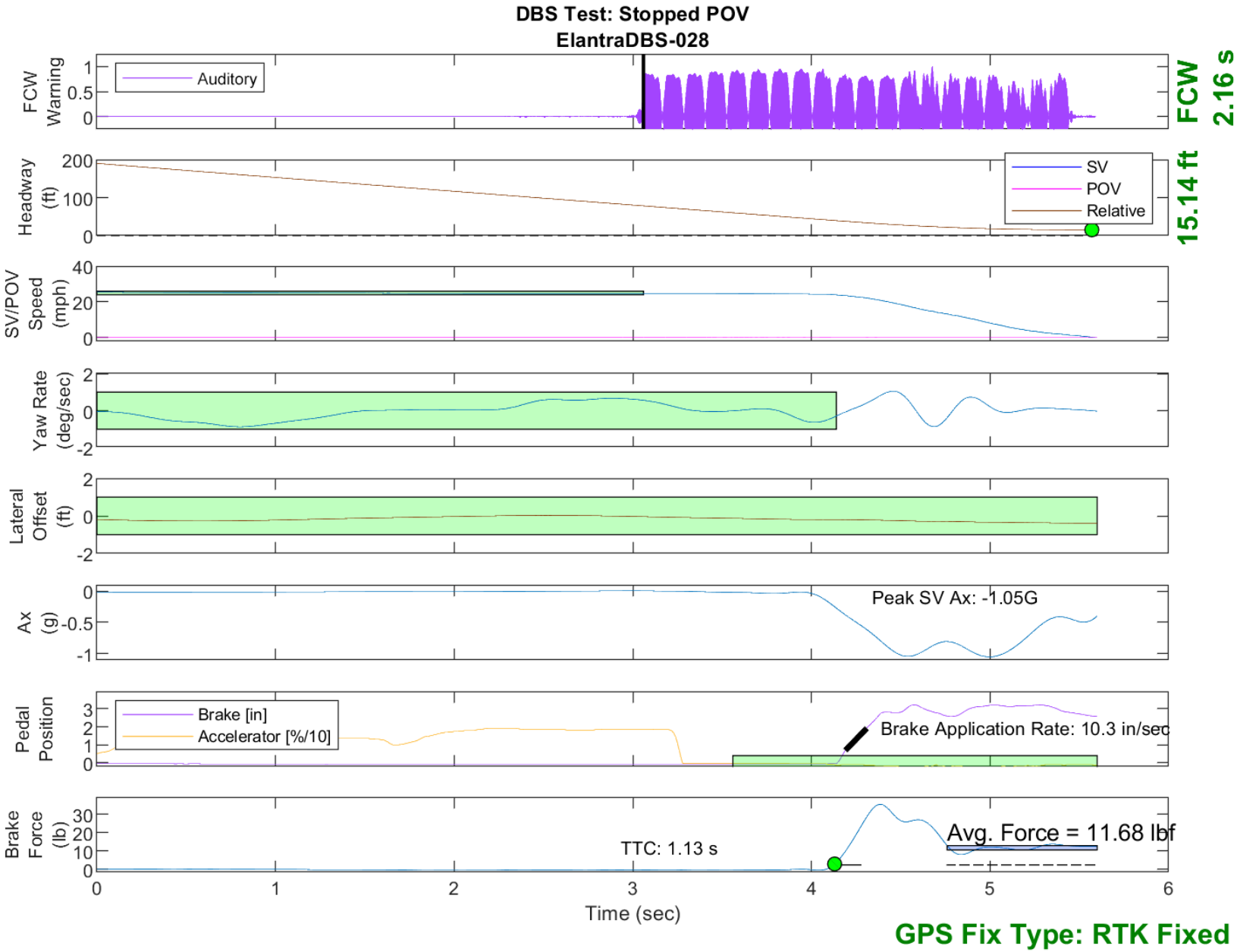


Figure E19. Time History for DBS Run 28, SV Encounters Stopped POV

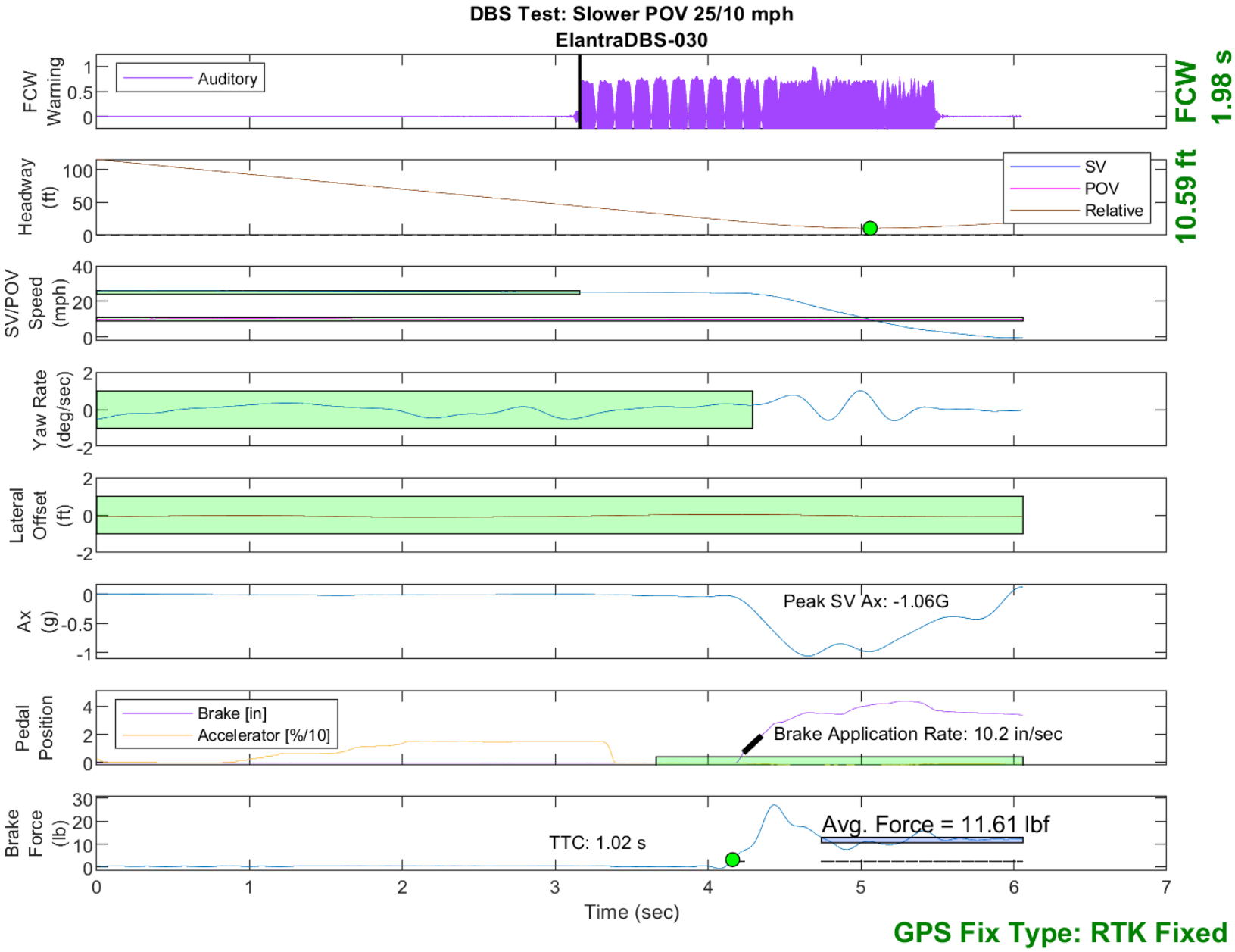


Figure E20. Time History for DBS Run 30, SV Encounters Slower POV, SV 25 mph, POV 10 mph

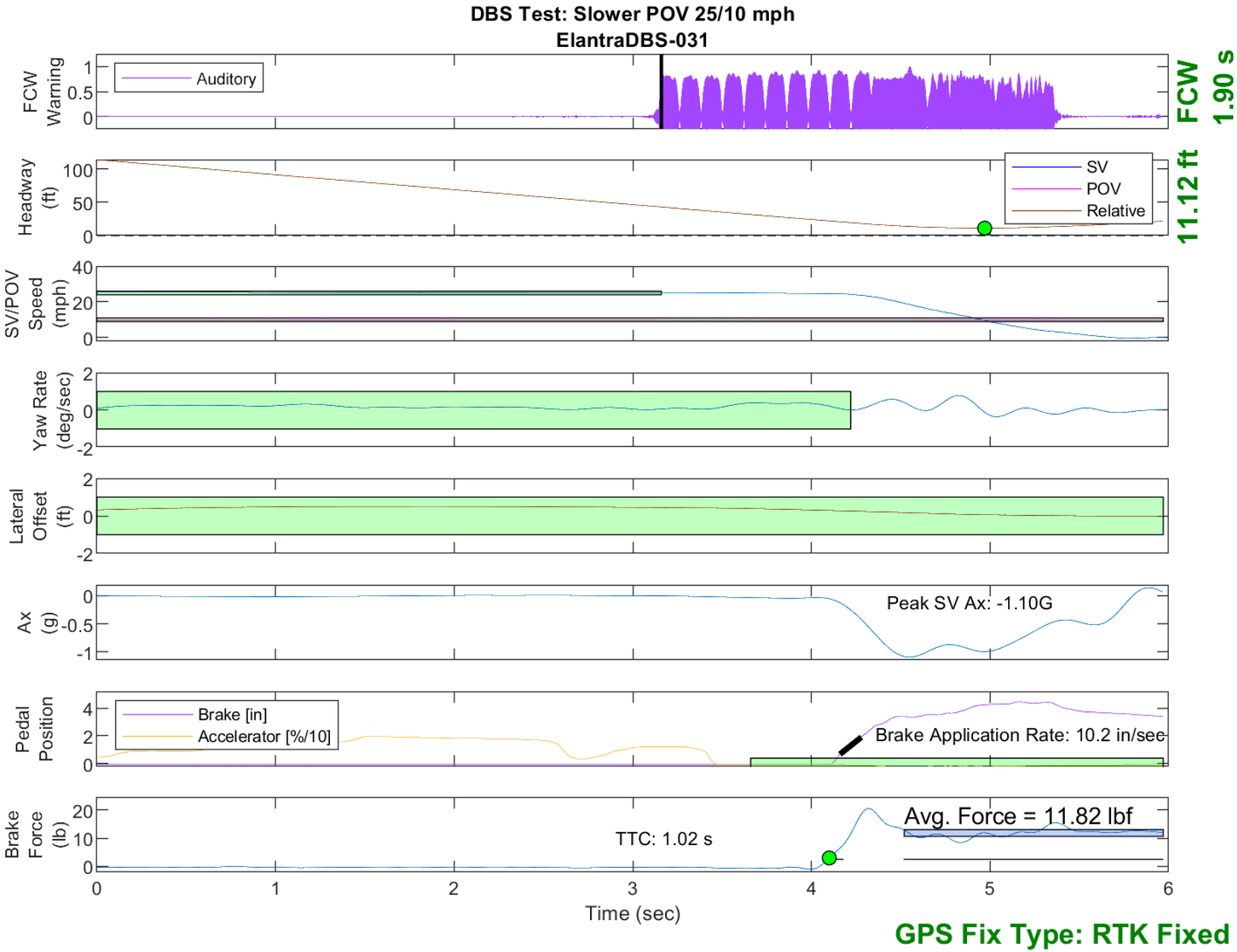


Figure E21. Time History for DBS Run 31, SV Encounters Slower POV, SV 25 mph, POV 10 mph

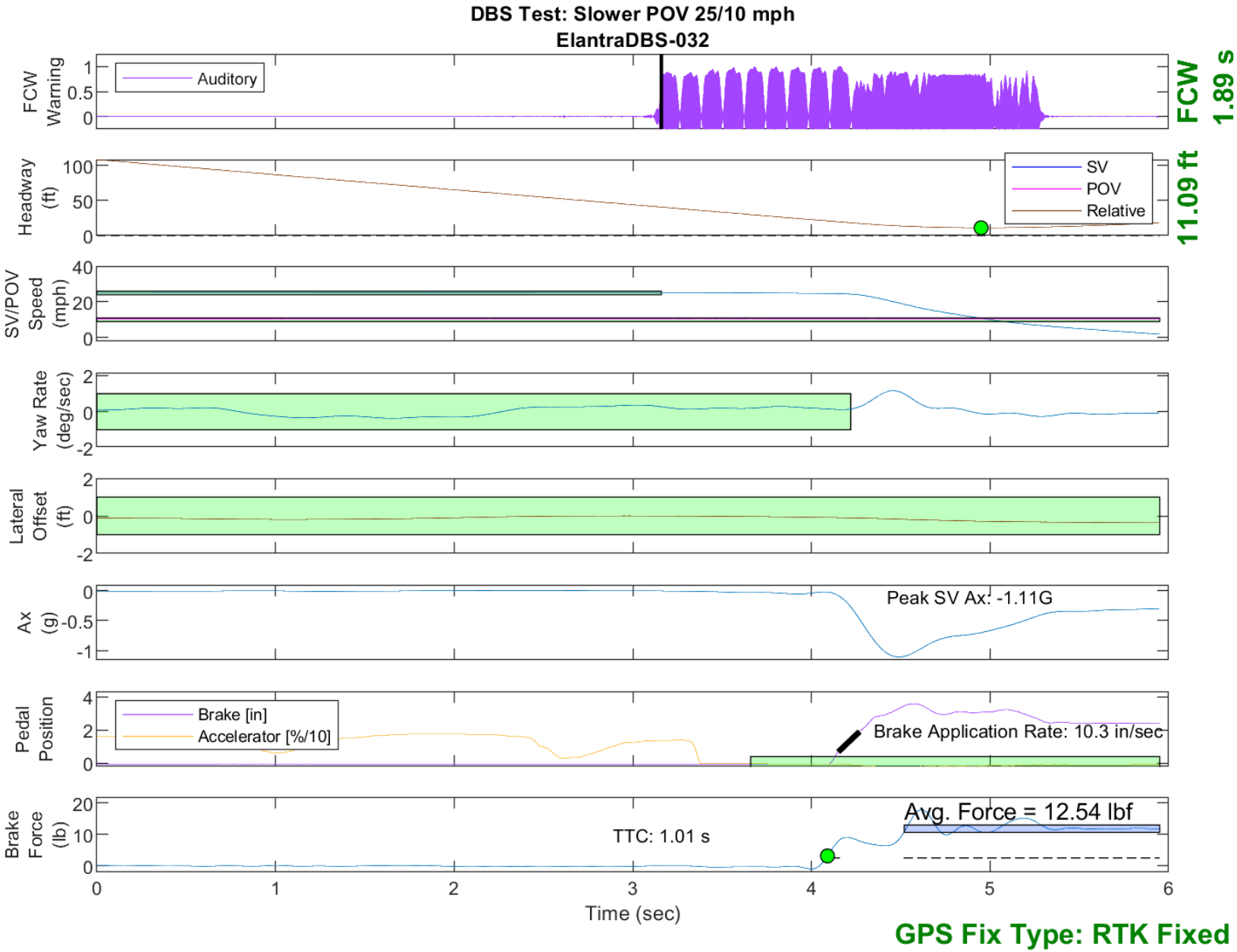


Figure E22. Time History for DBS Run 32, SV Encounters Slower POV, SV 25 mph, POV 10 mph

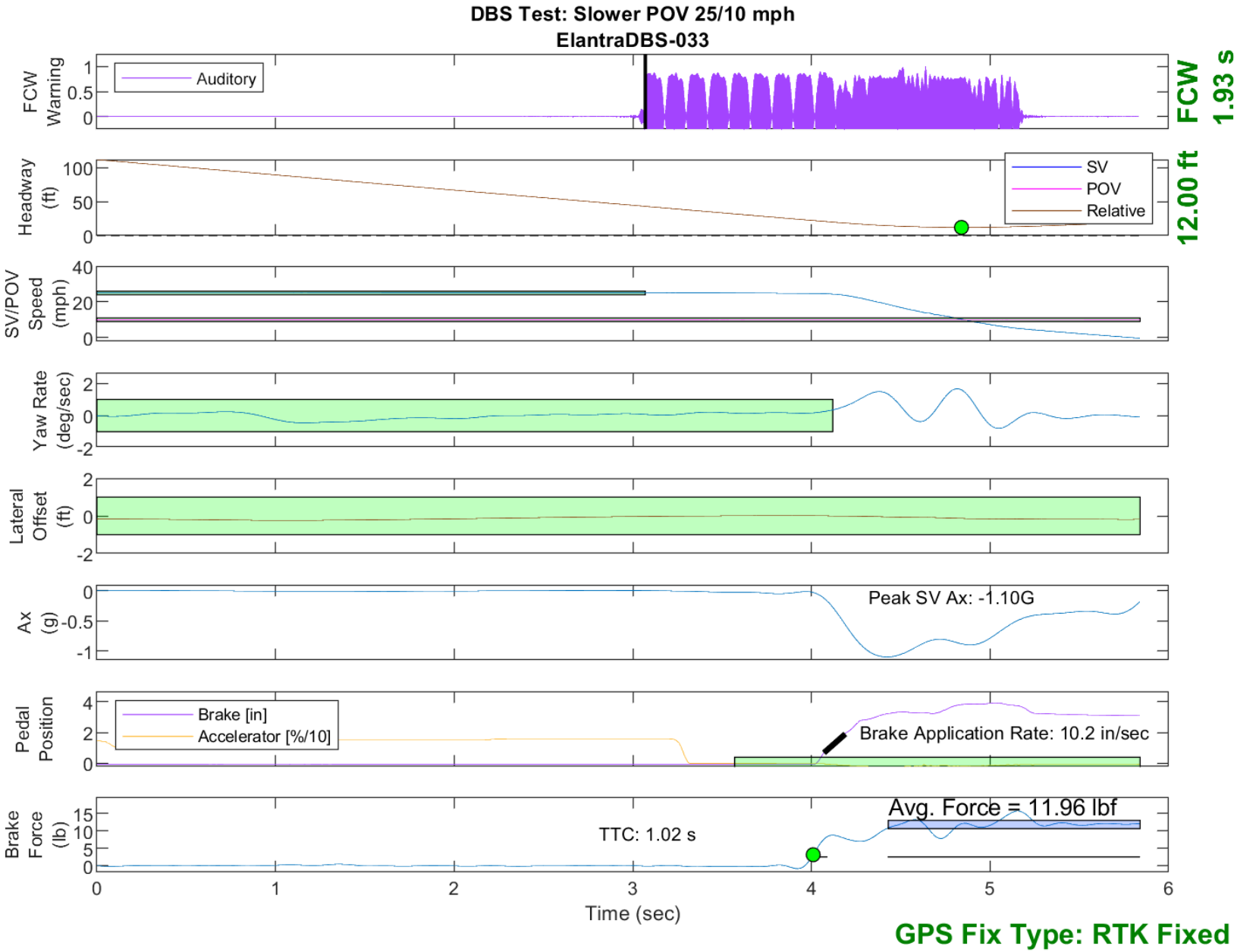


Figure E23. Time History for DBS Run 33, SV Encounters Slower POV, SV 25 mph, POV 10 mph

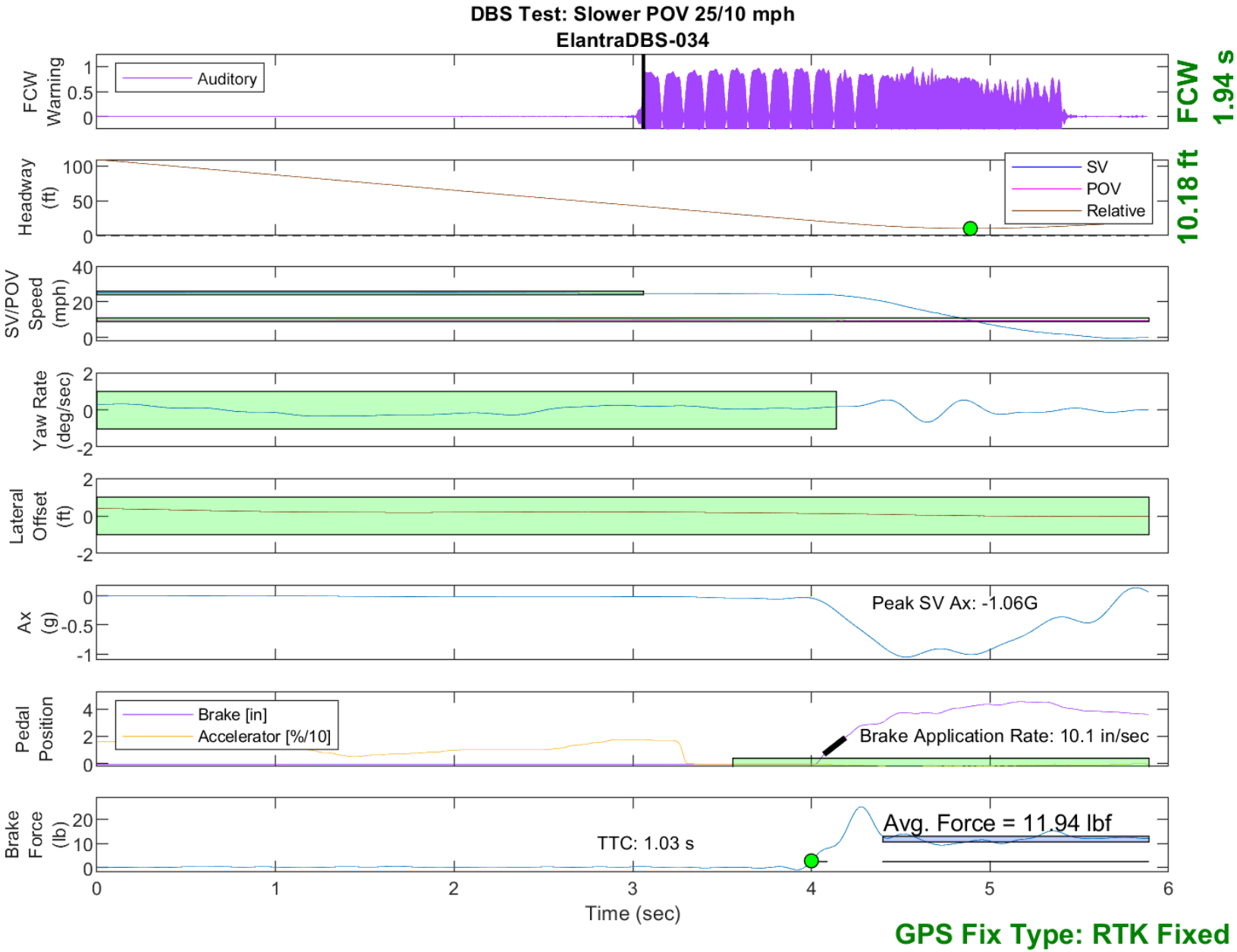


Figure E24. Time History for DBS Run 34, SV Encounters Slower POV, SV 25 mph, POV 10 mph

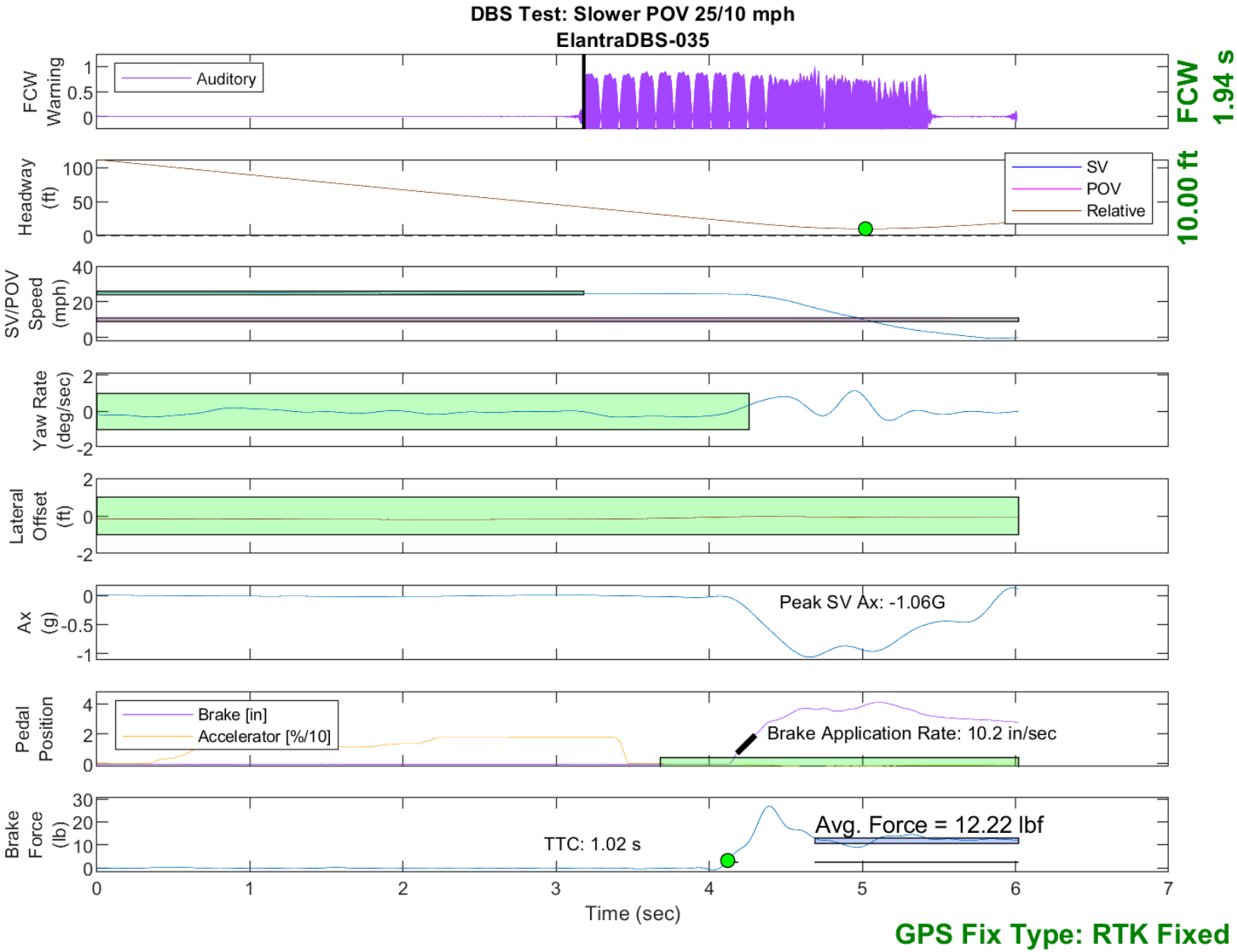


Figure E25. Time History for DBS Run 35, SV Encounters Slower POV, SV 25 mph, POV 10 mph

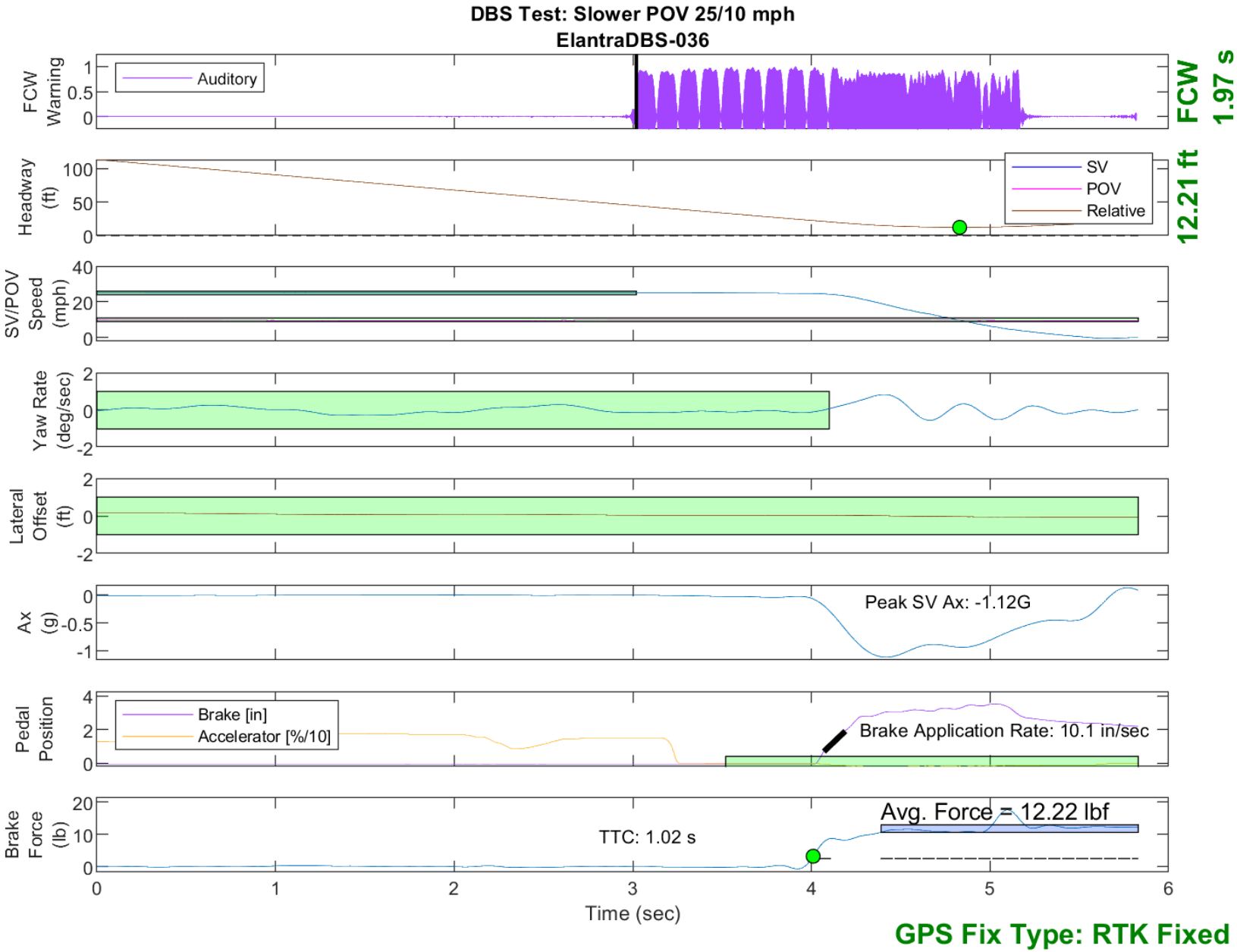


Figure E26. Time History for DBS Run 36, SV Encounters Slower POV, SV 25 mph, POV 10 mph

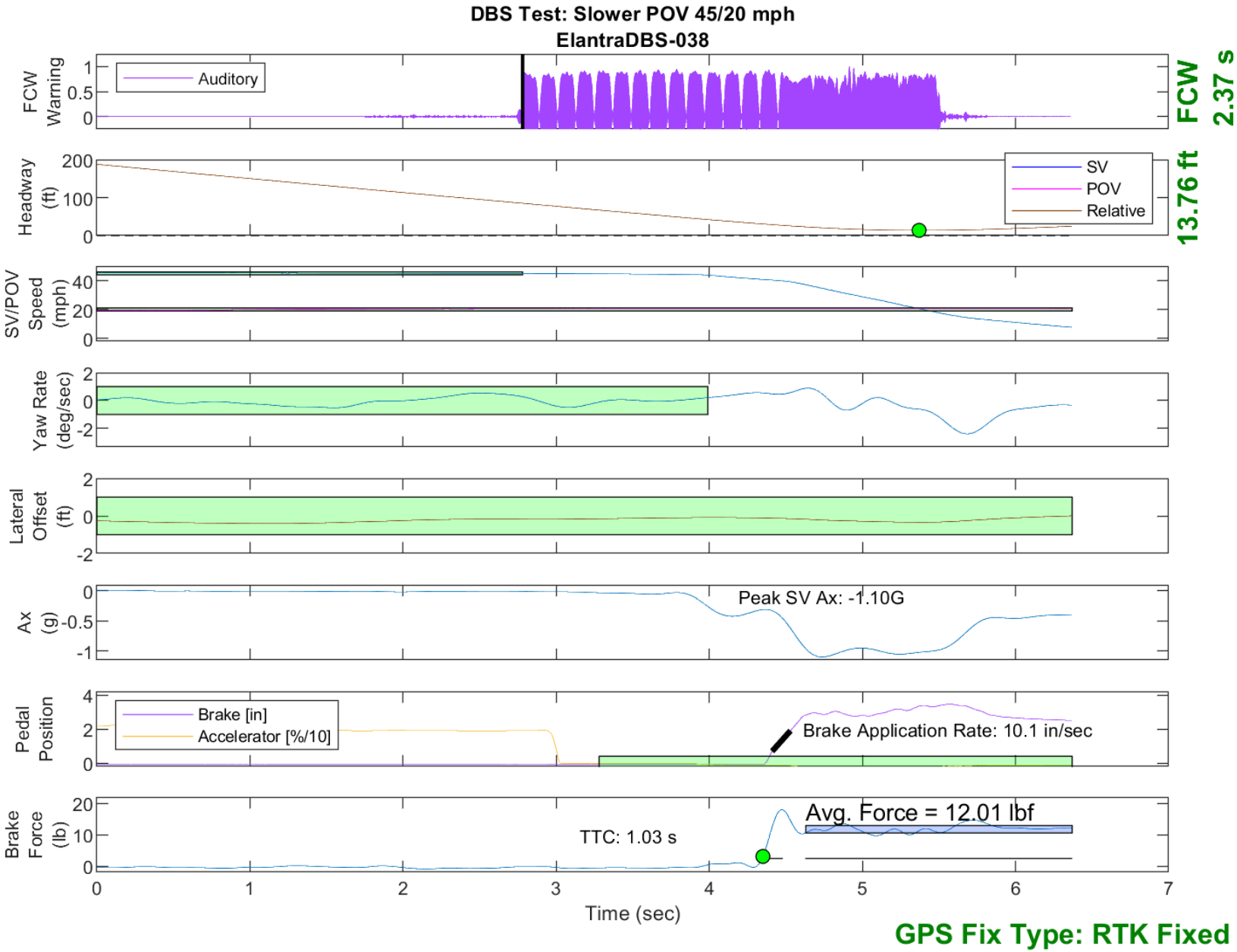


Figure E27. Time History for DBS Run 38, SV Encounters Slower POV, SV 45 mph, POV 20 mph

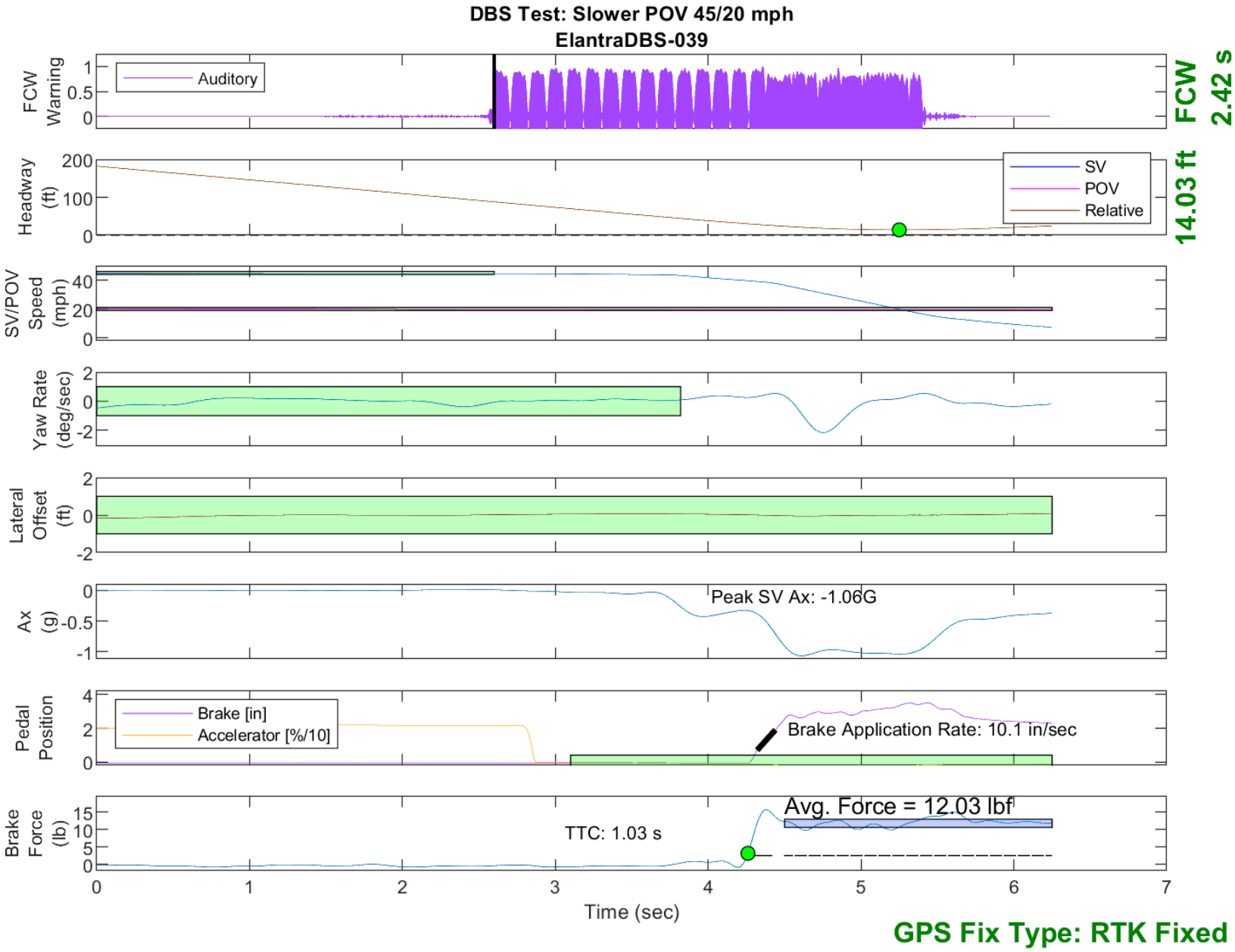


Figure E28. Time History for DBS Run 39, SV Encounters Slower POV, SV 45 mph, POV 20 mph

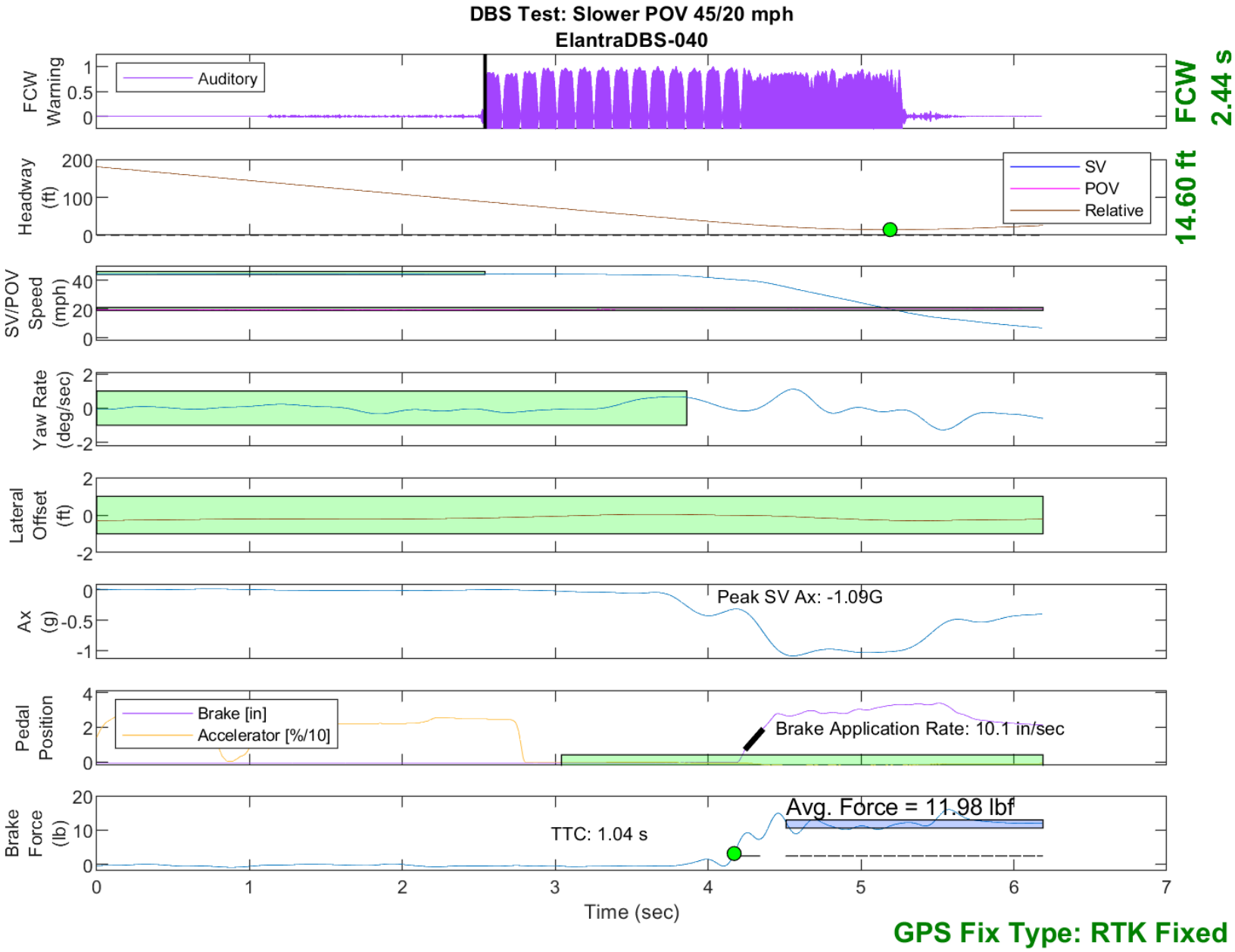


Figure E29. Time History for DBS Run 40, SV Encounters Slower POV, SV 45 mph, POV 20 mph

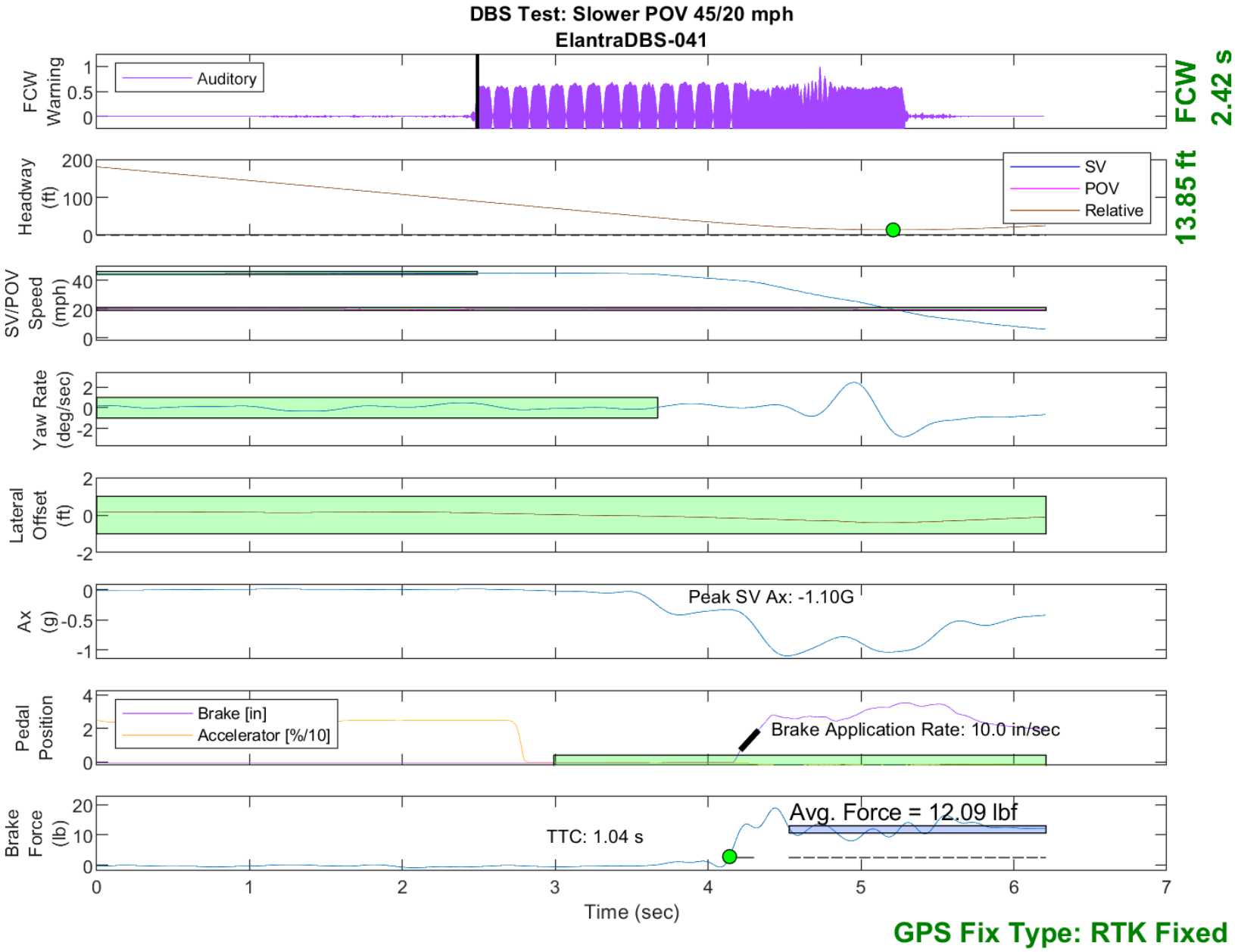


Figure E30. Time History for DBS Run 41, SV Encounters Slower POV, SV 45 mph, POV 20 mph

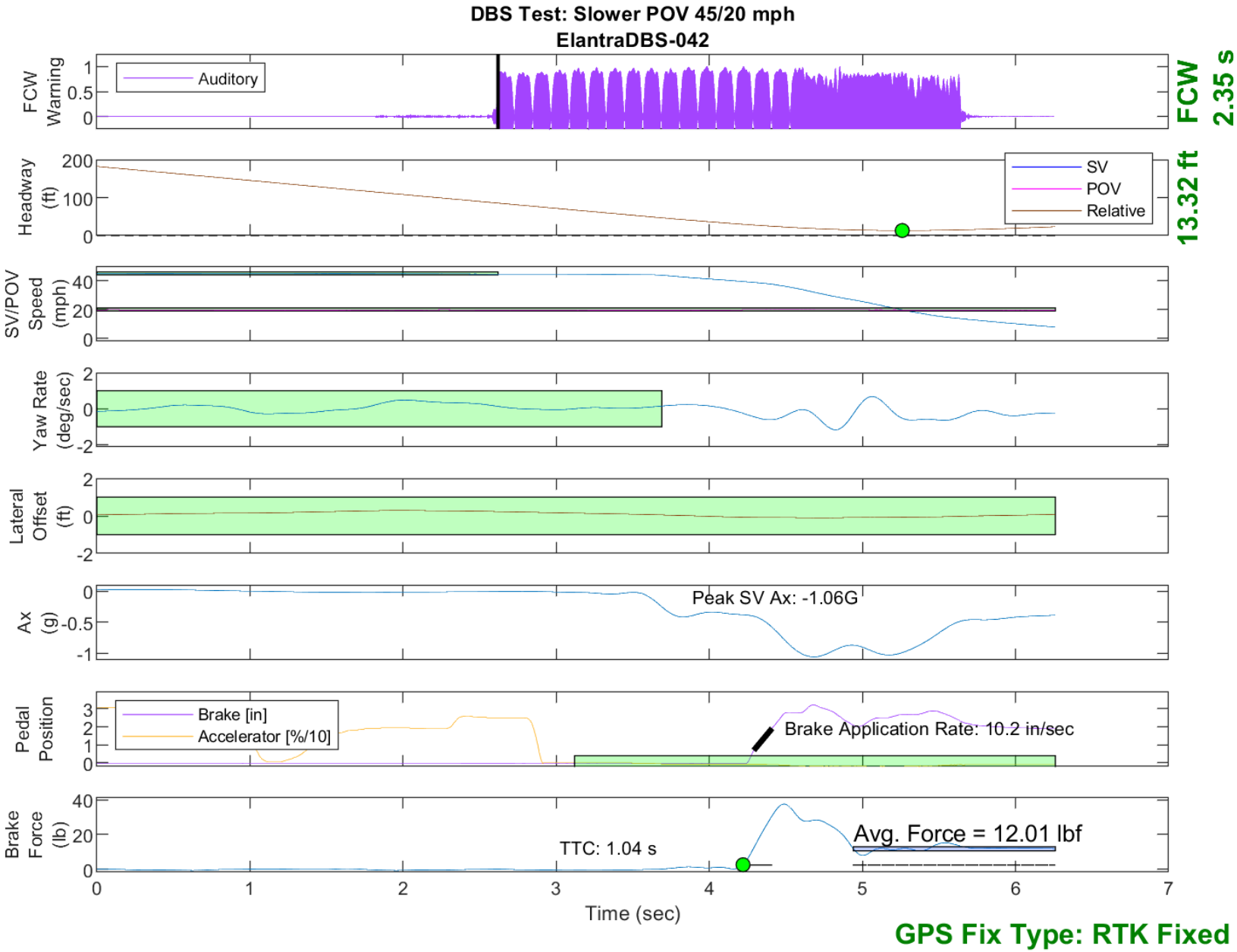


Figure E31. Time History for DBS Run 42, SV Encounters Slower POV, SV 45 mph, POV 20 mph

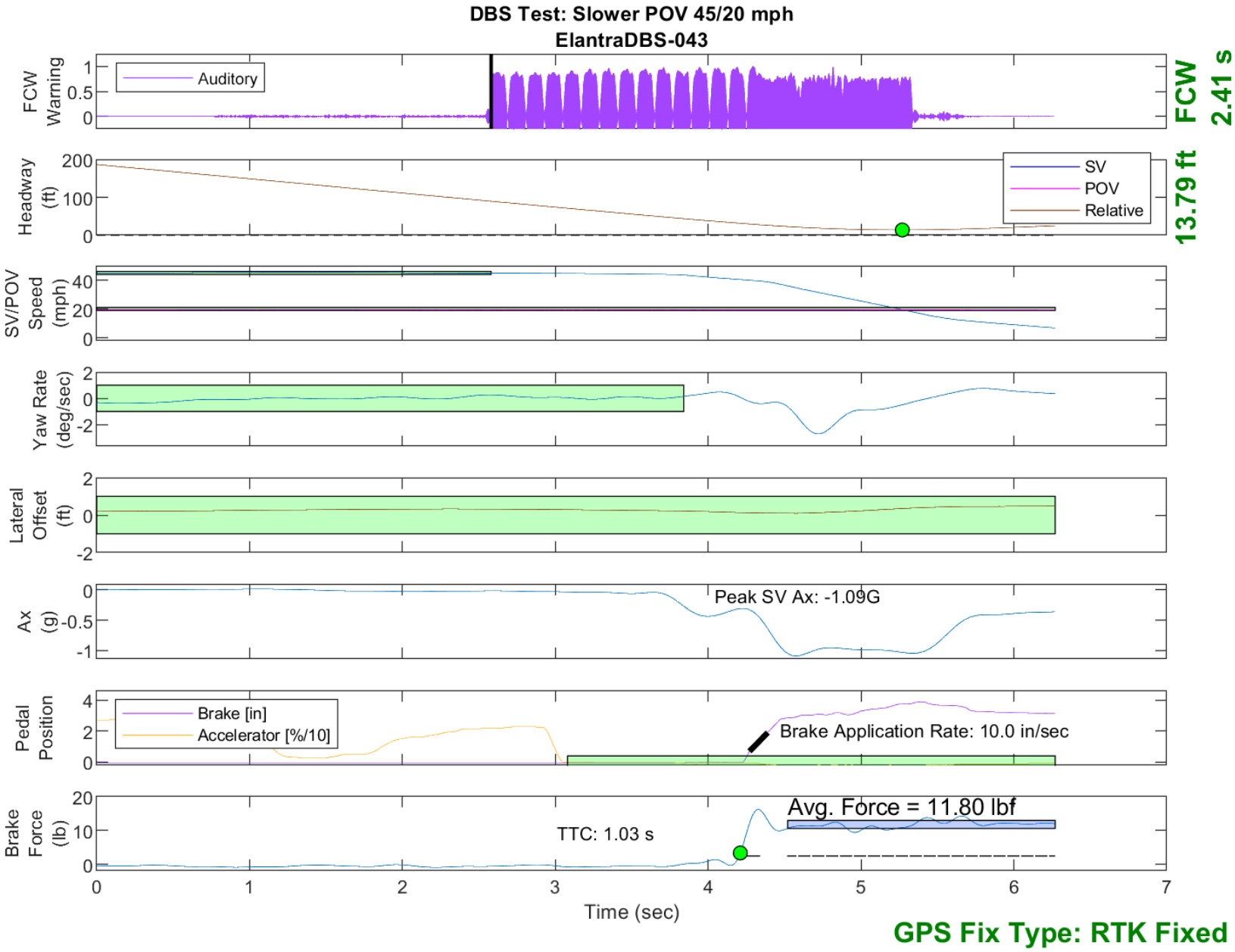


Figure E32. Time History for DBS Run 43, SV Encounters Slower POV, SV 45 mph, POV 20 mph

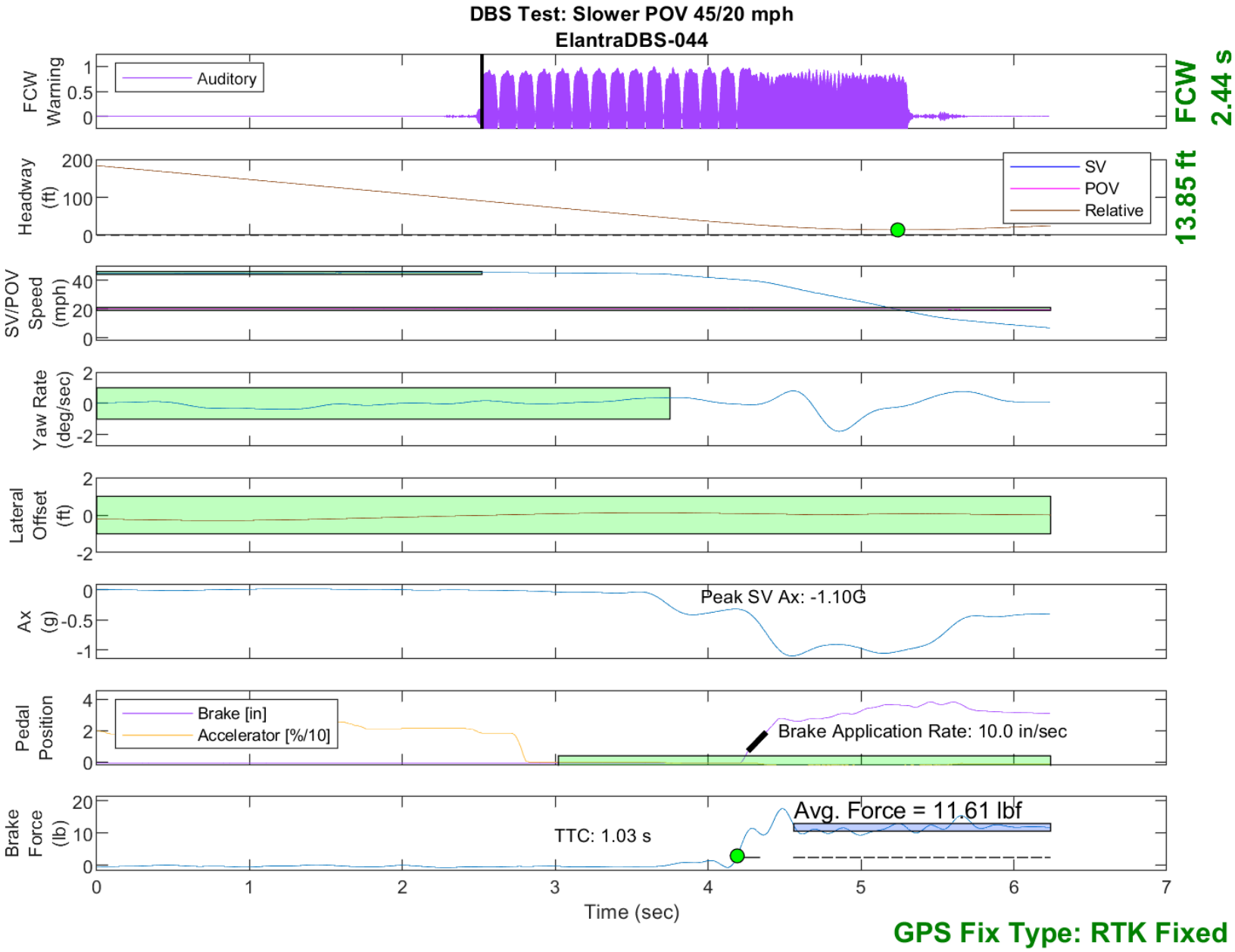


Figure E33. Time History for DBS Run 44, SV Encounters Slower POV, SV 45 mph, POV 20 mph

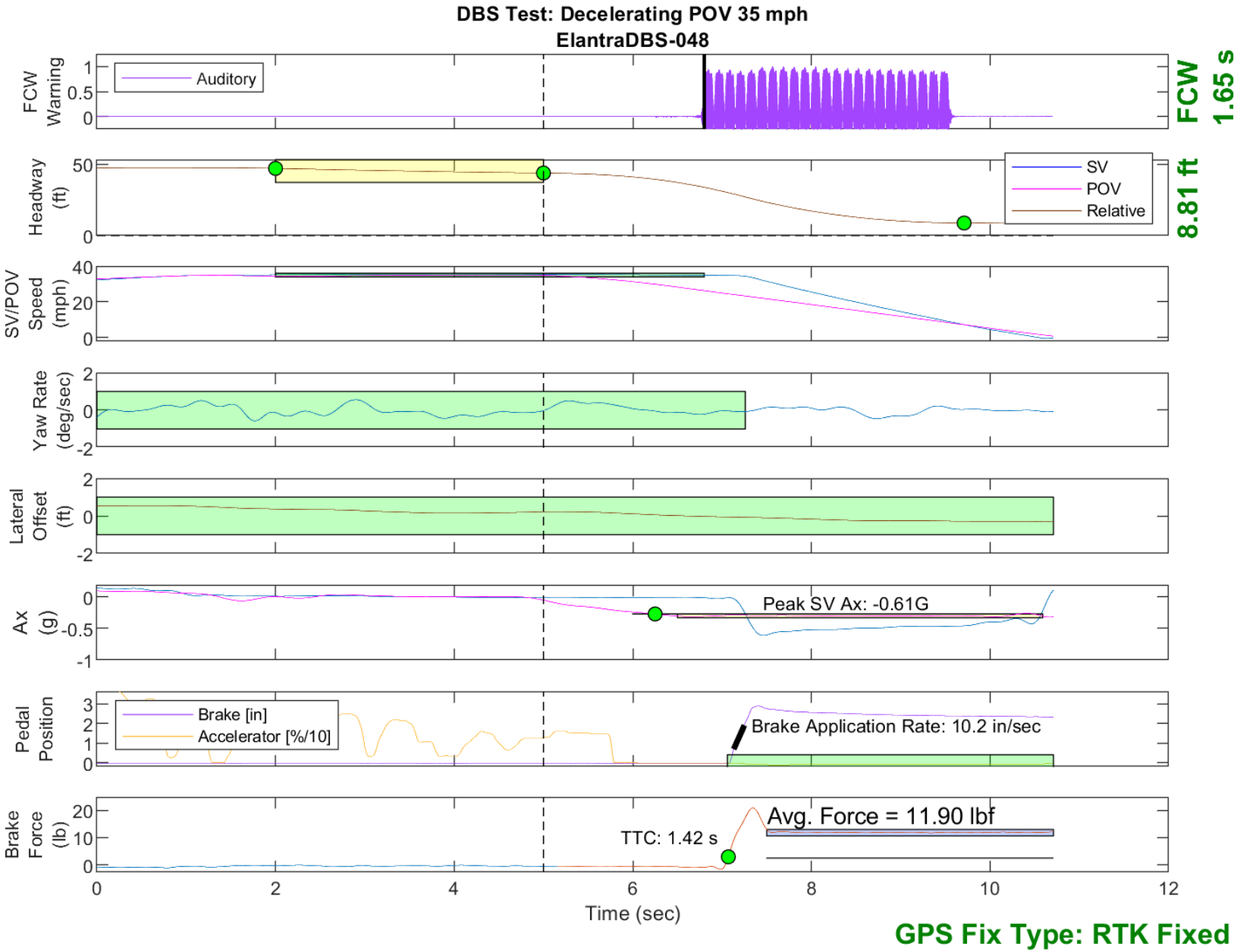


Figure E34. Time History for DBS Run 48, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

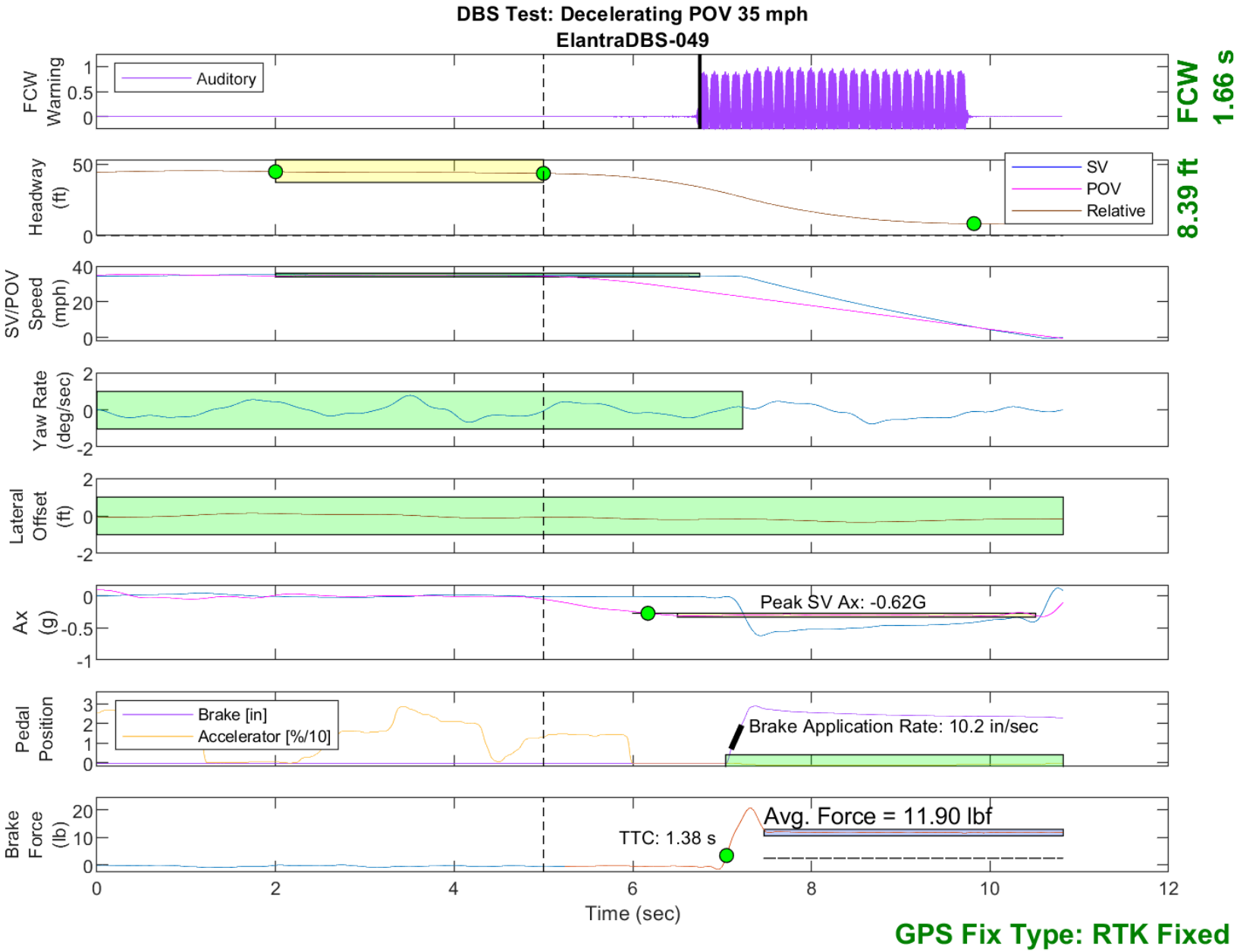


Figure E35. Time History for DBS Run 49, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

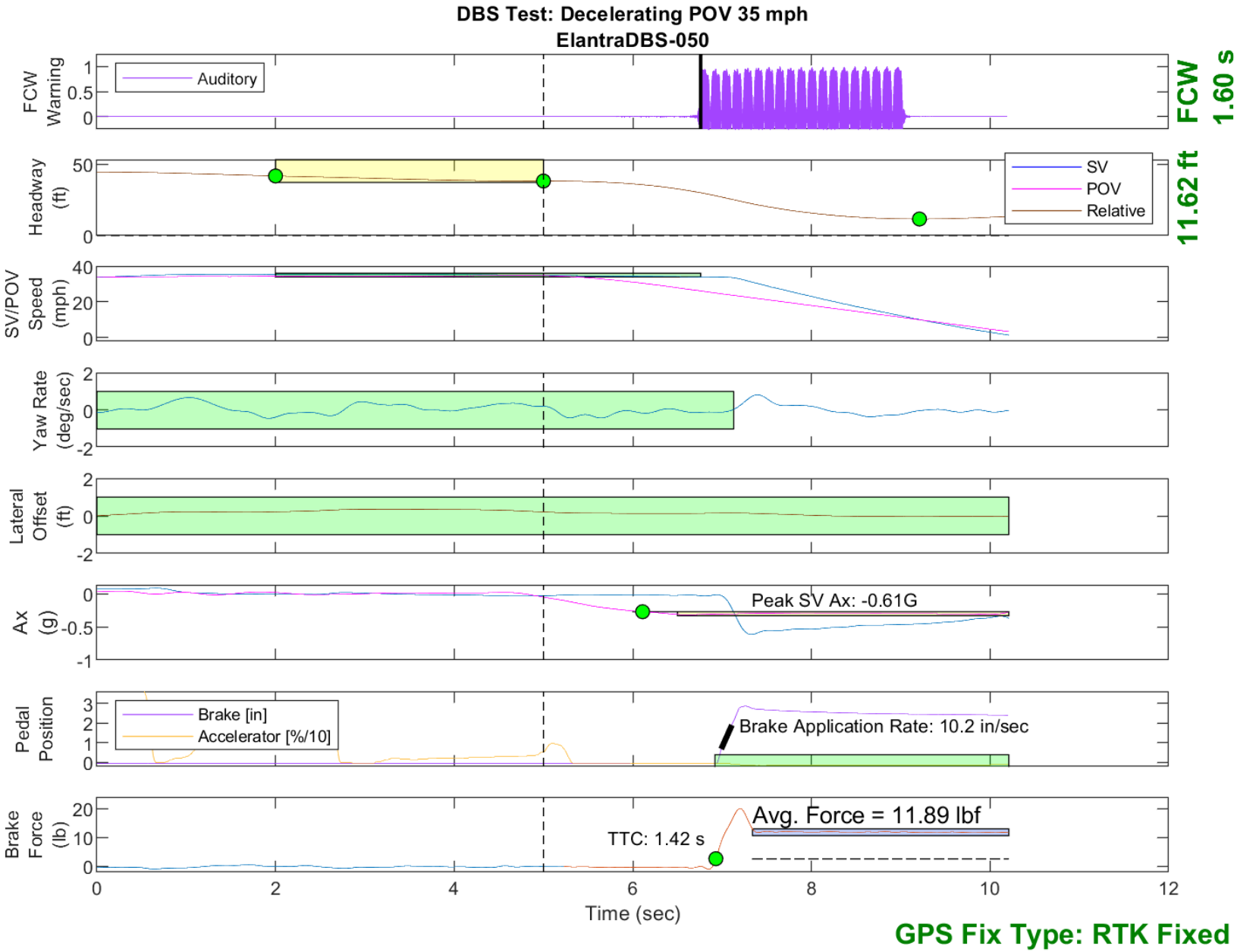


Figure E36. Time History for DBS Run 50, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

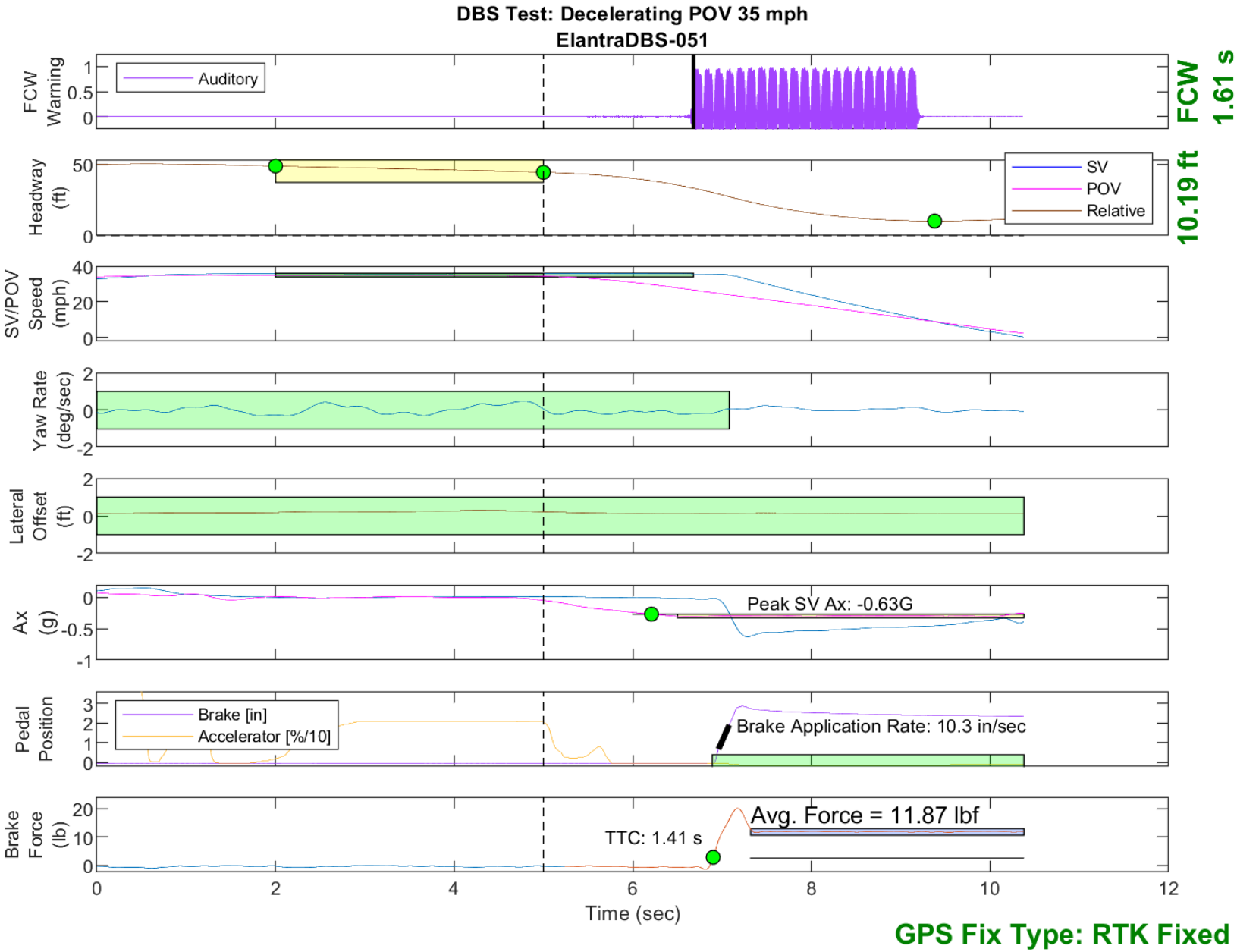


Figure E37. Time History for DBS Run 51, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

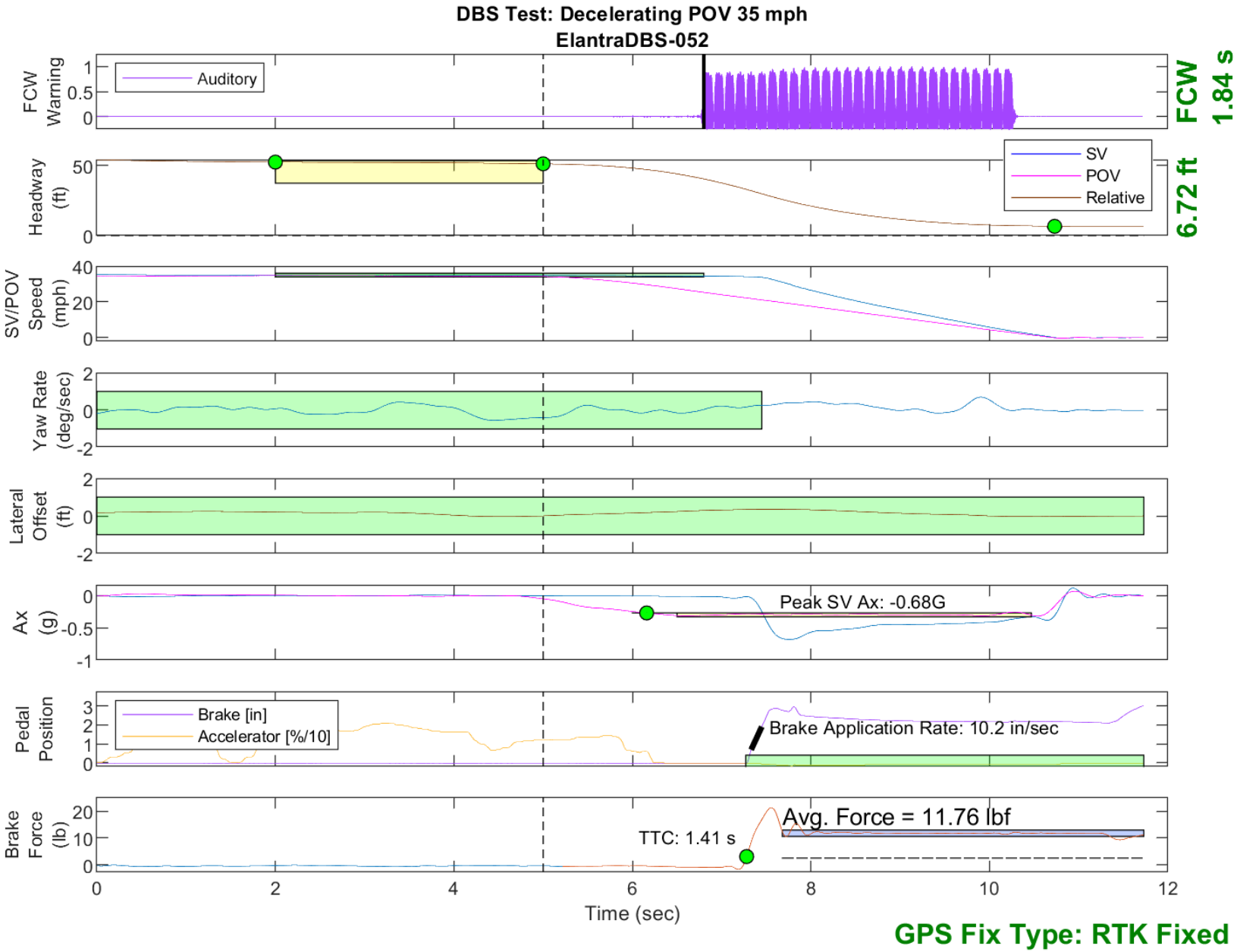


Figure E38. Time History for DBS Run 52, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

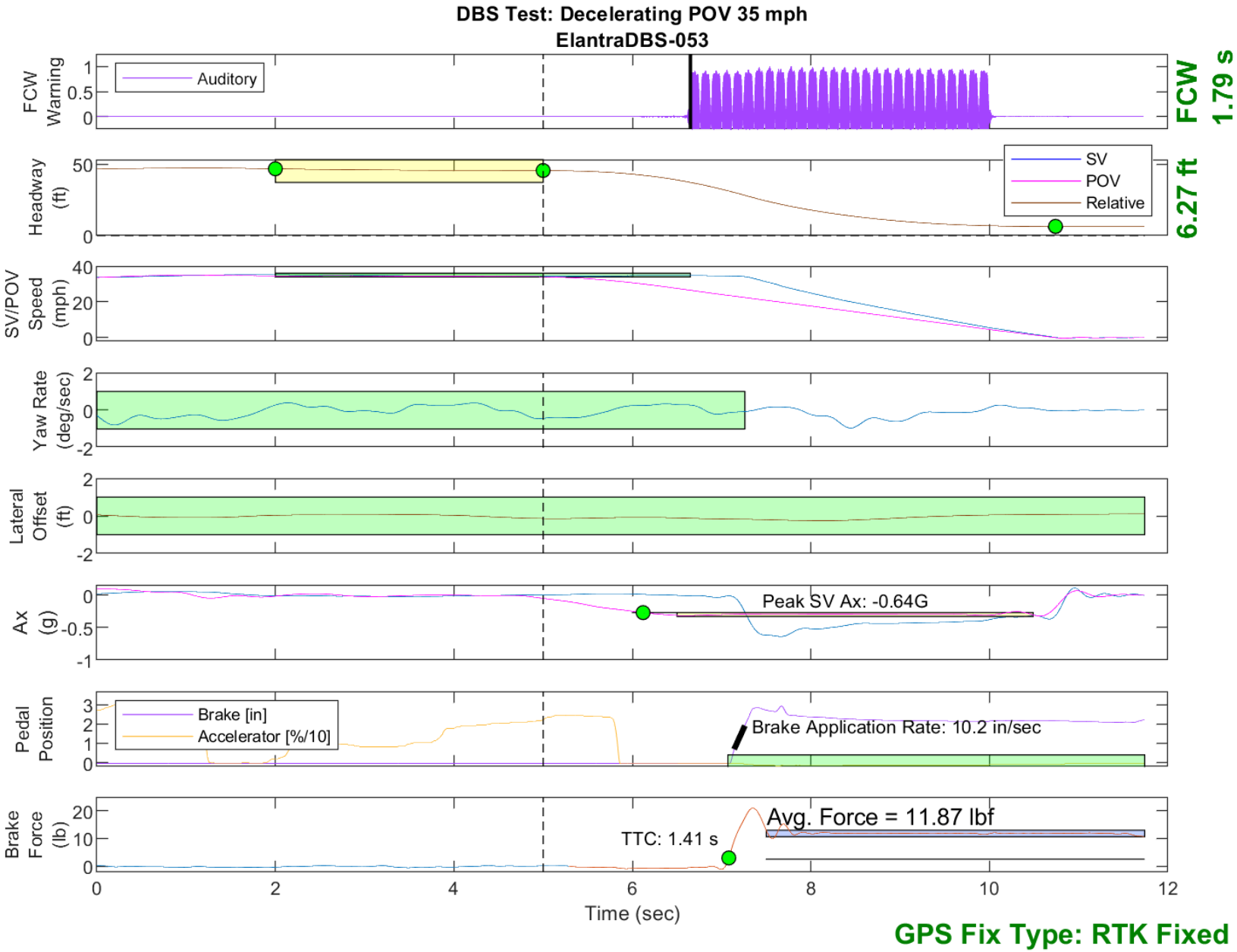


Figure E39. Time History for DBS Run 53, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

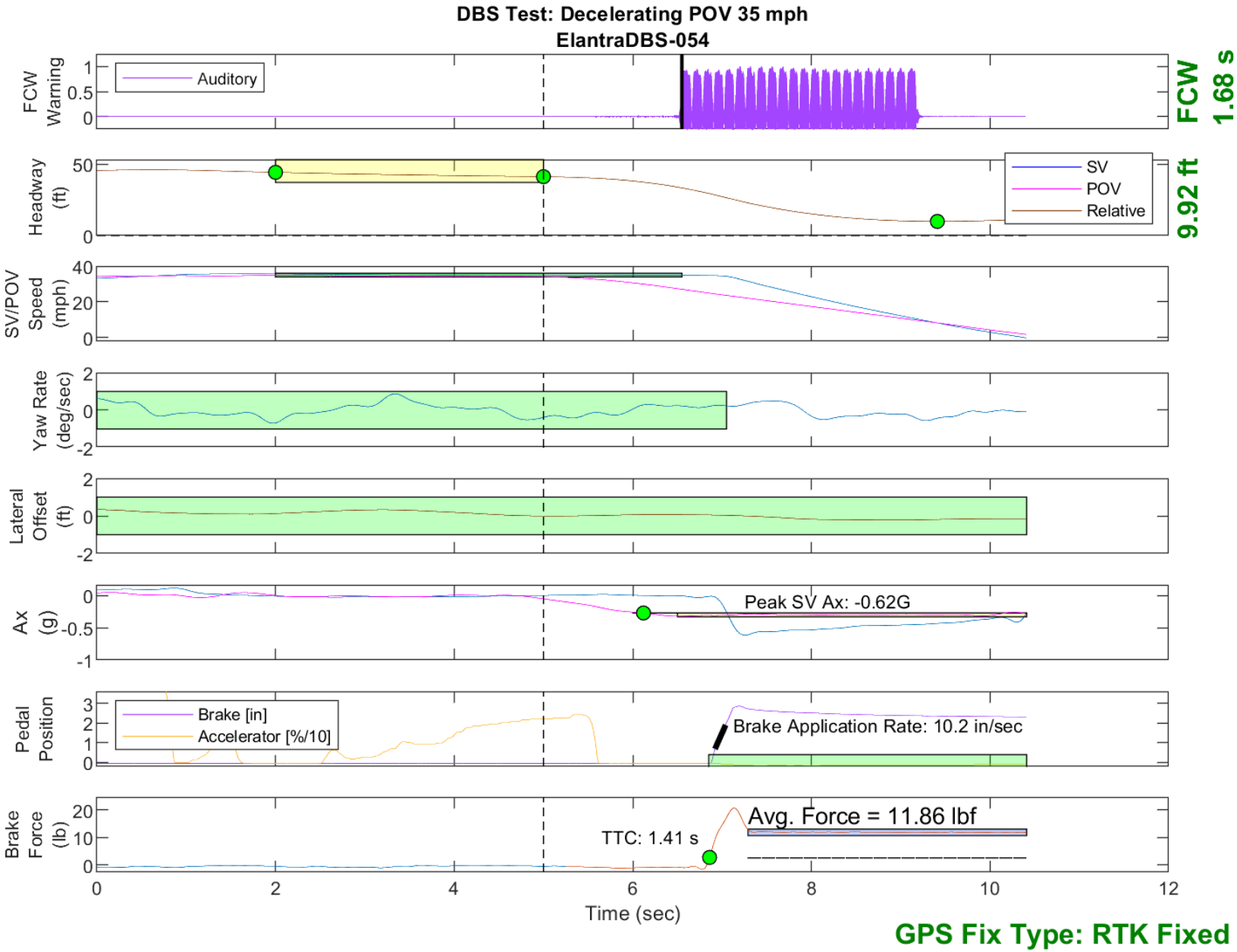


Figure E40. Time History for DBS Run 54, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

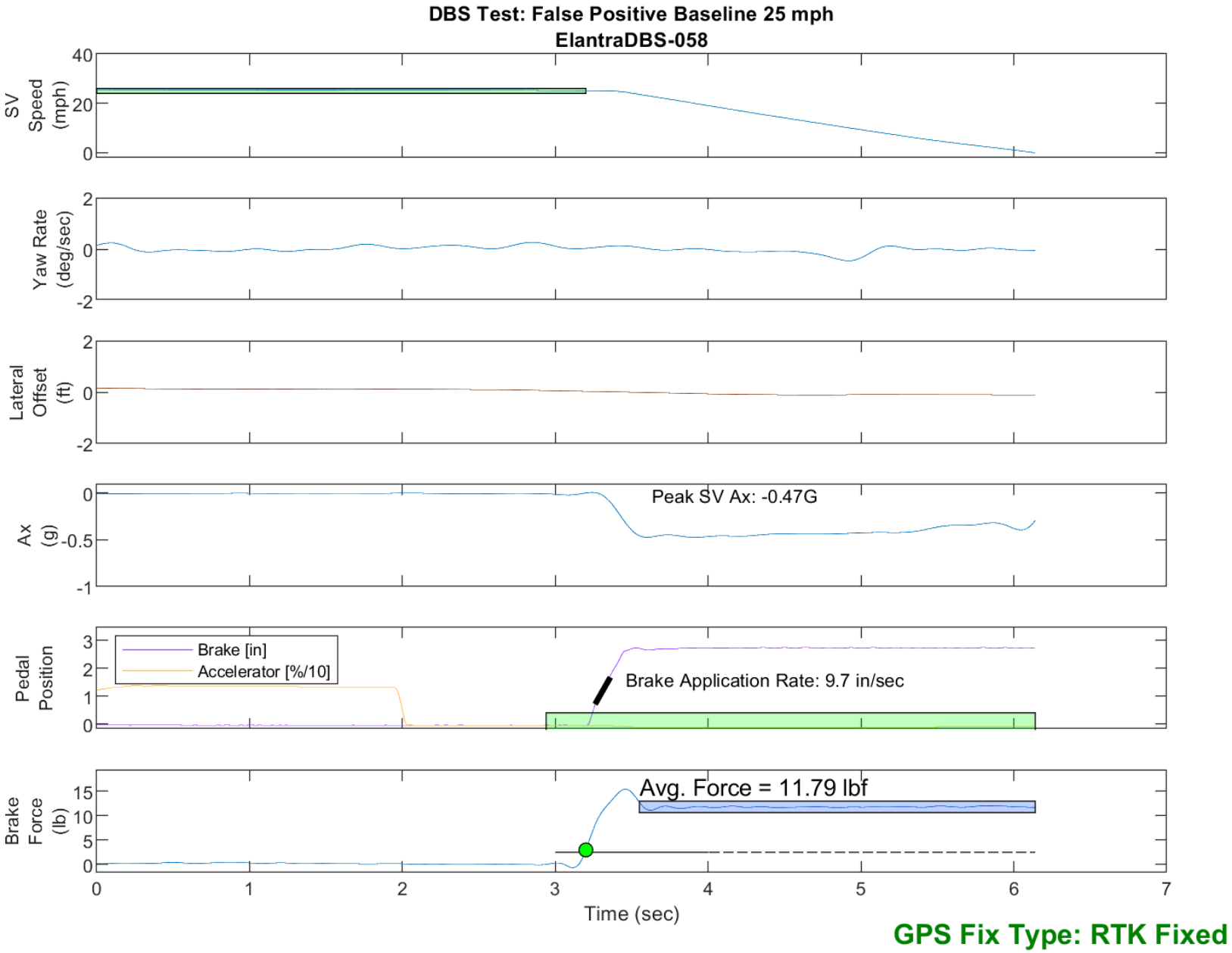


Figure E41. Time History for DBS Run 58, False Positive Baseline, SV 25 mph

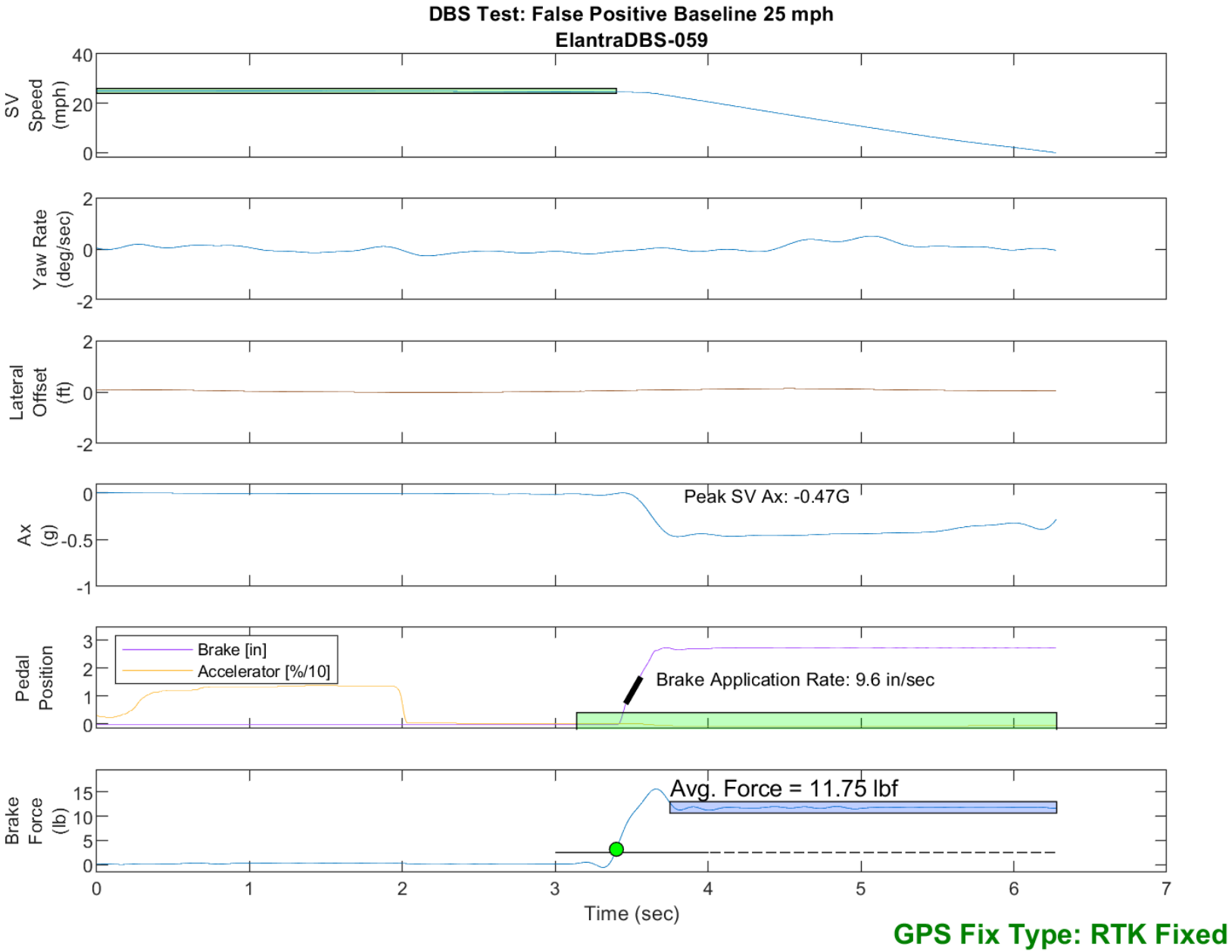


Figure E42. Time History for DBS Run 59, False Positive Baseline, SV 25 mph

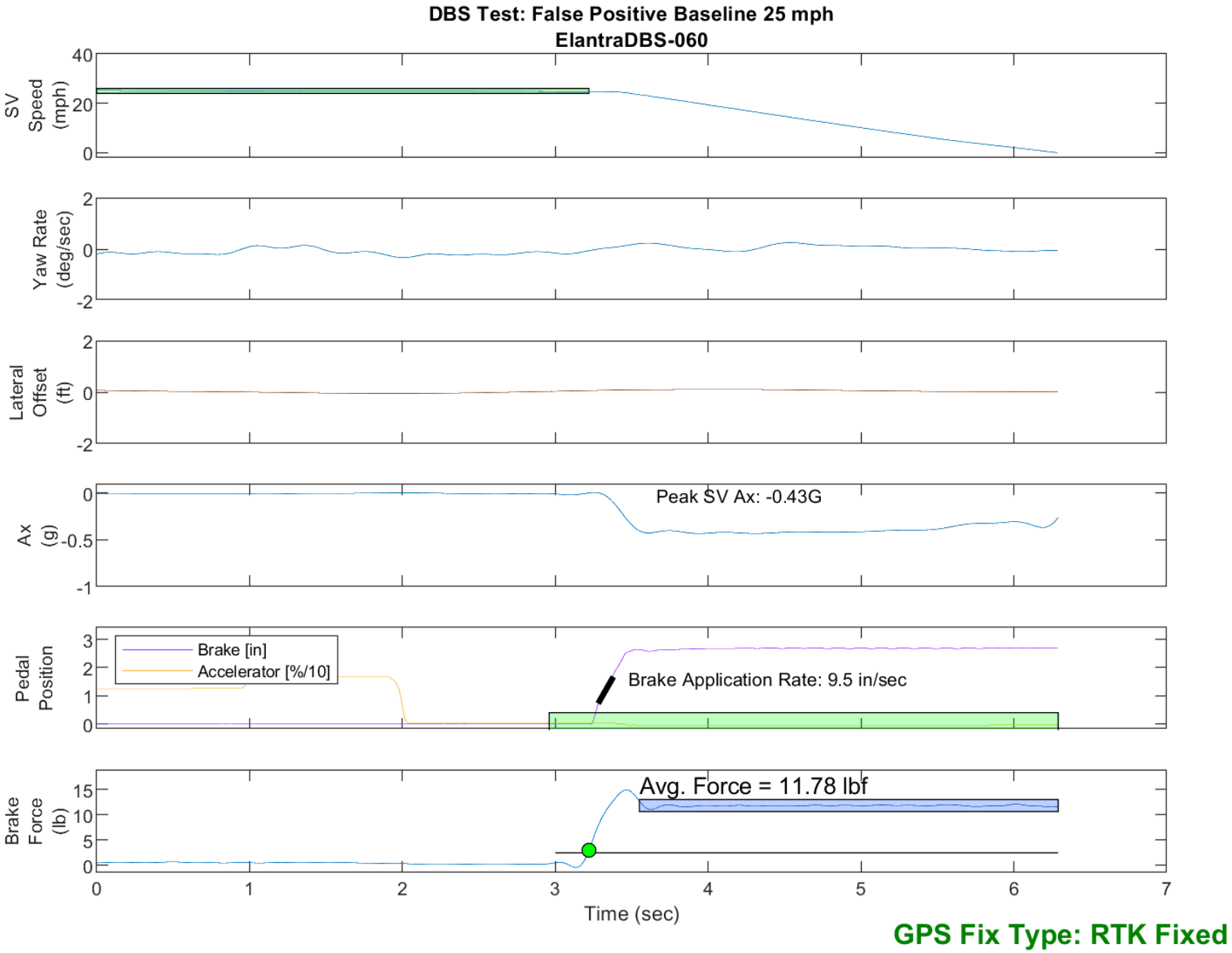


Figure E43. Time History for DBS Run 60, False Positive Baseline, SV 25 mph

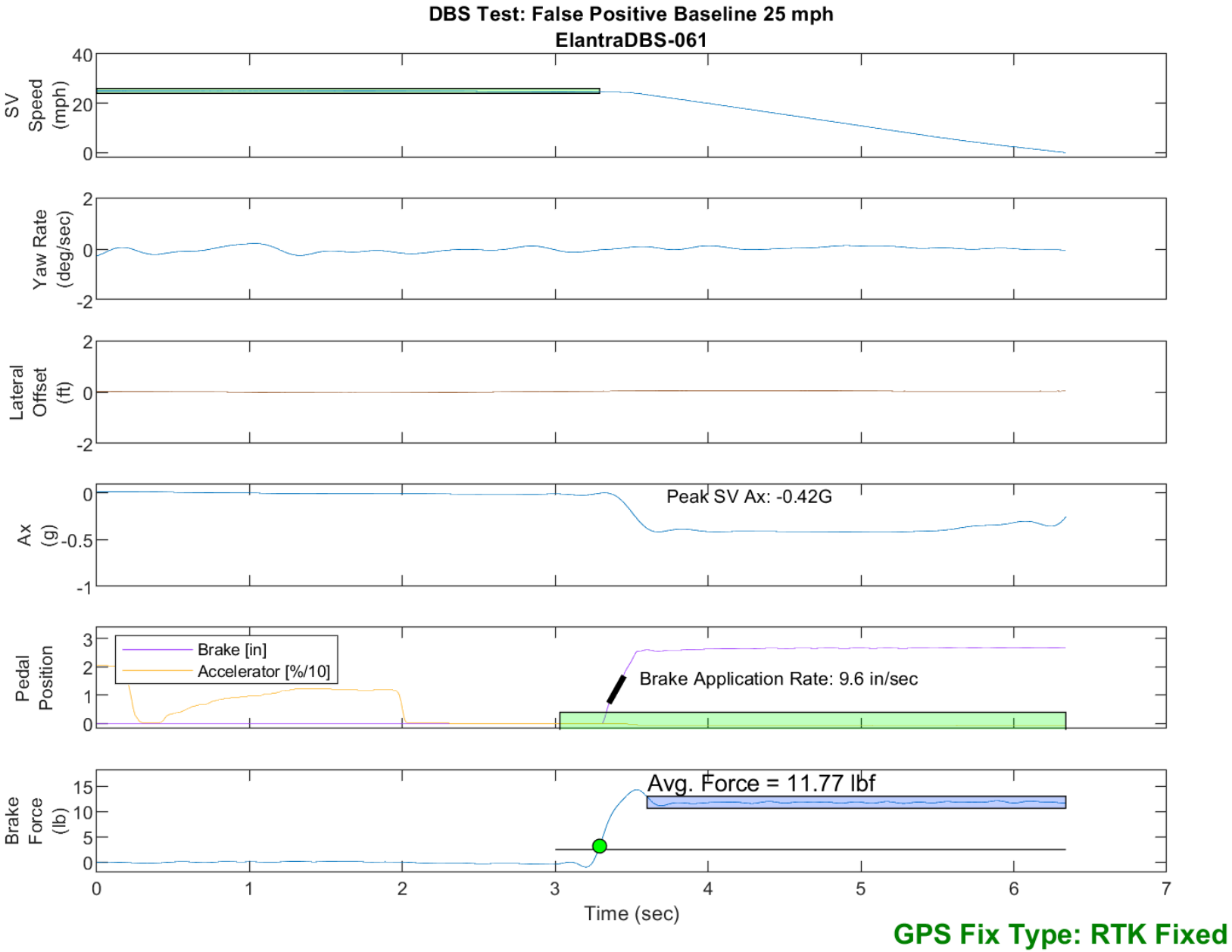


Figure E44. Time History for DBS Run 61, False Positive Baseline, SV 25 mph

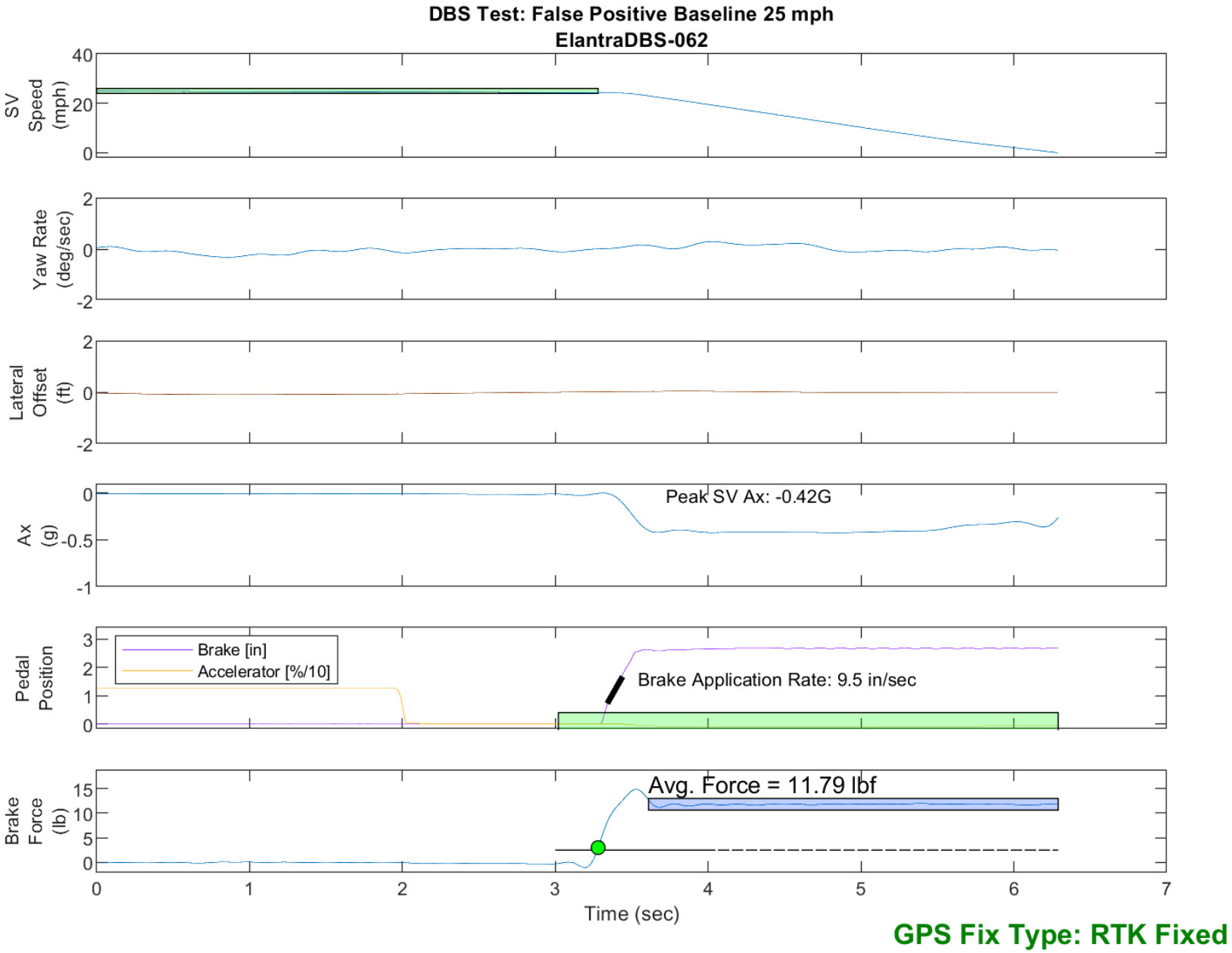


Figure E45. Time History for DBS Run 62, False Positive Baseline, SV 25 mph

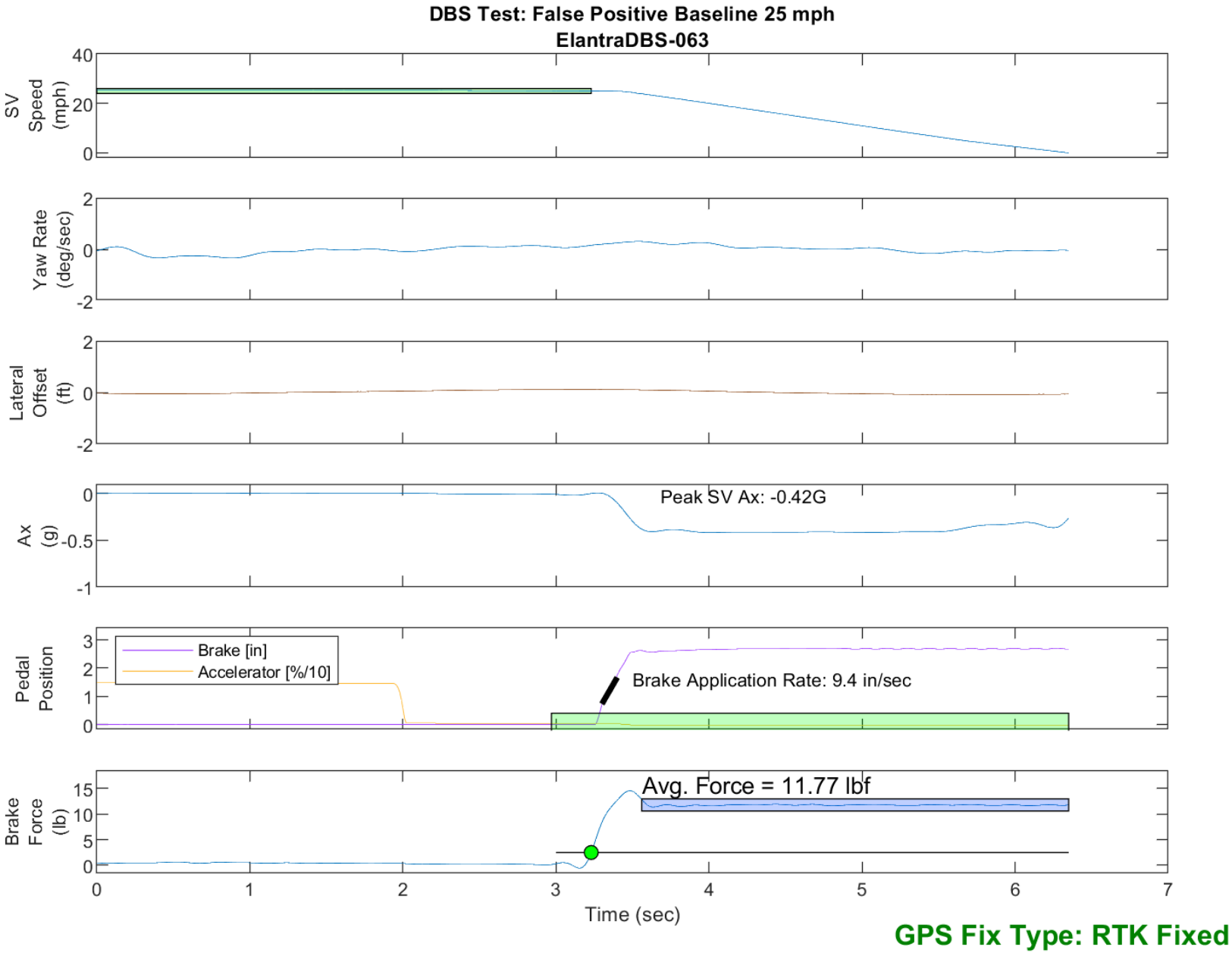


Figure E46. Time History for DBS Run 63, False Positive Baseline, SV 25 mph

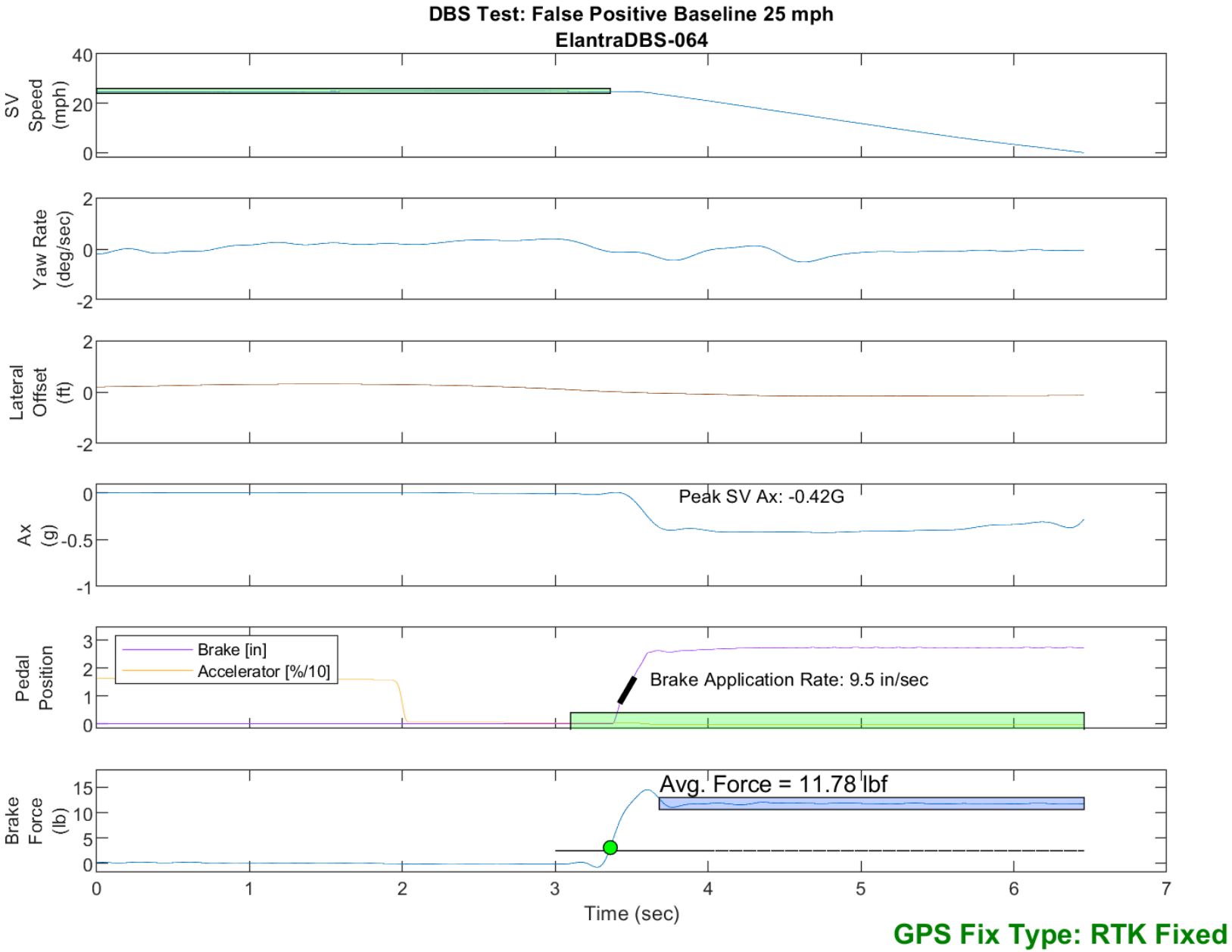


Figure E47. Time History for DBS Run 64, False Positive Baseline, SV 25 mph

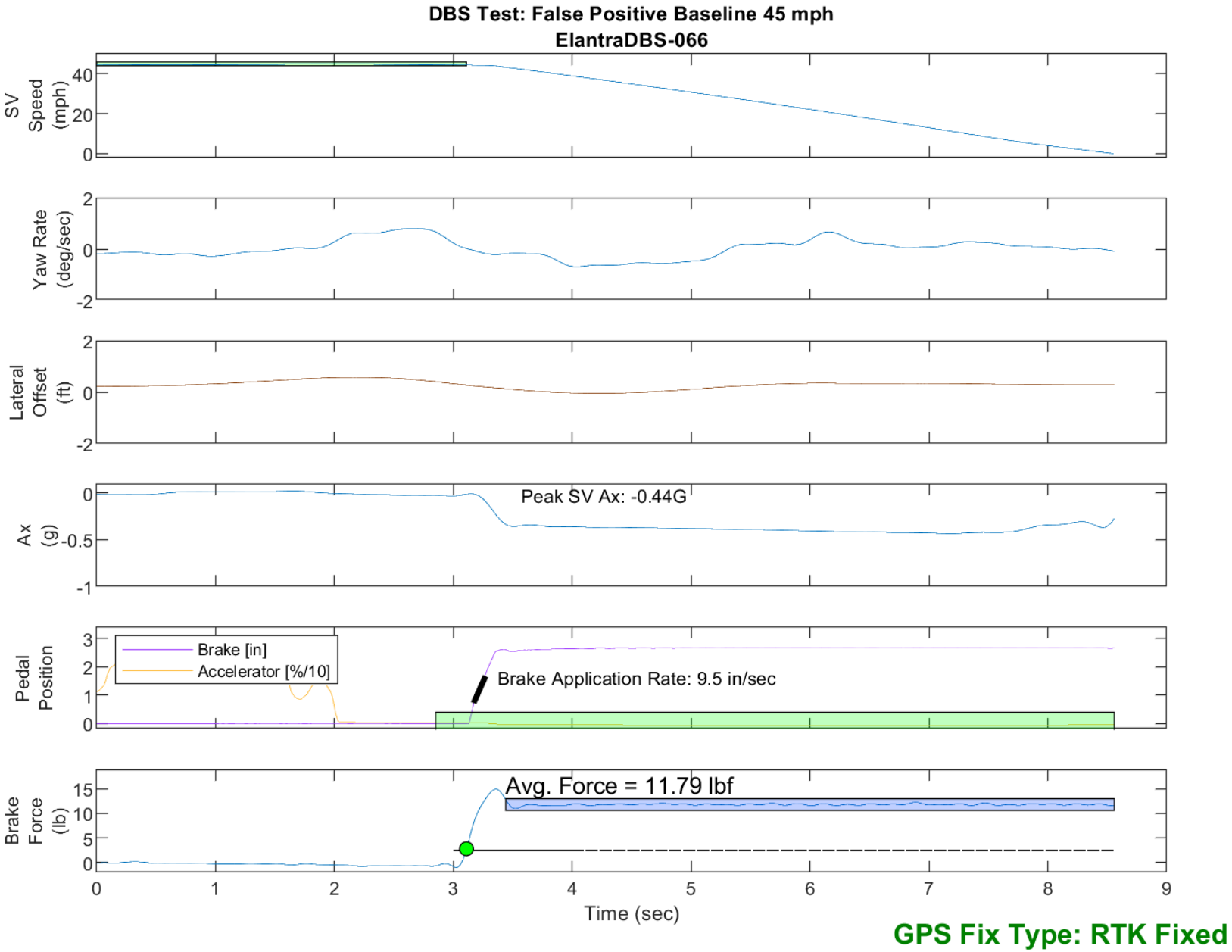


Figure E48. Time History for DBS Run 66, False Positive Baseline, SV 45 mph

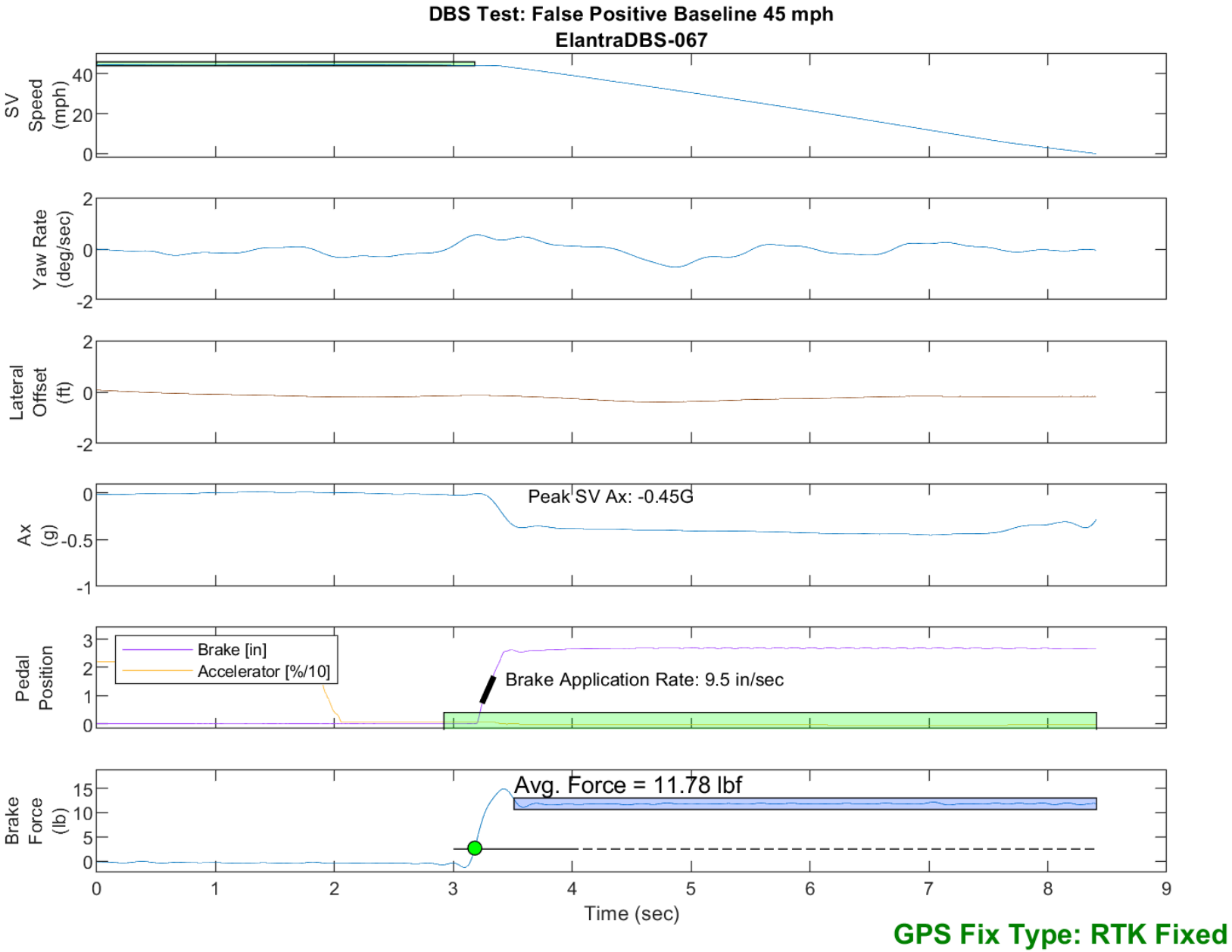


Figure E49. Time History for DBS Run 67, False Positive Baseline, SV 45 mph

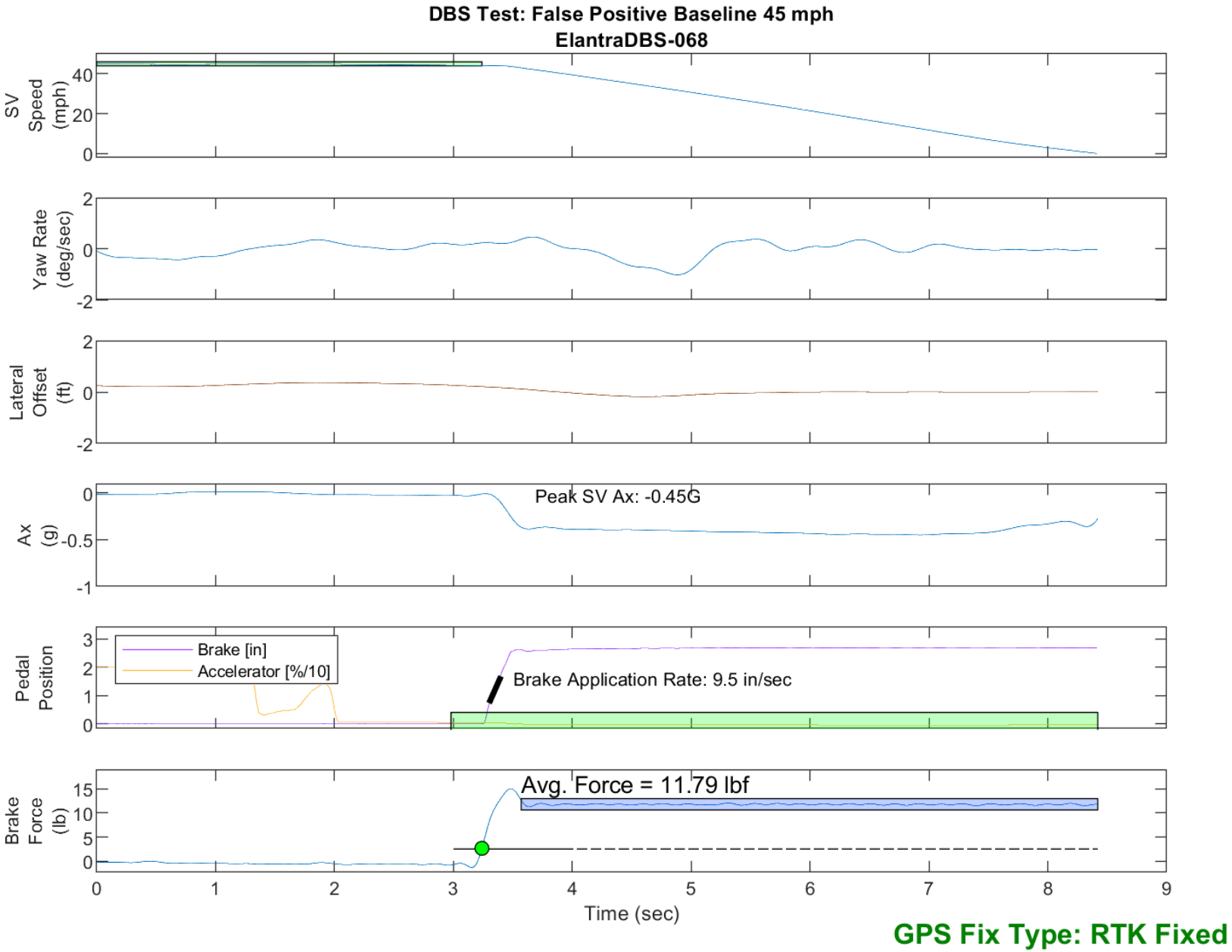


Figure E50. Time History for DBS Run 68, False Positive Baseline, SV 45 mph

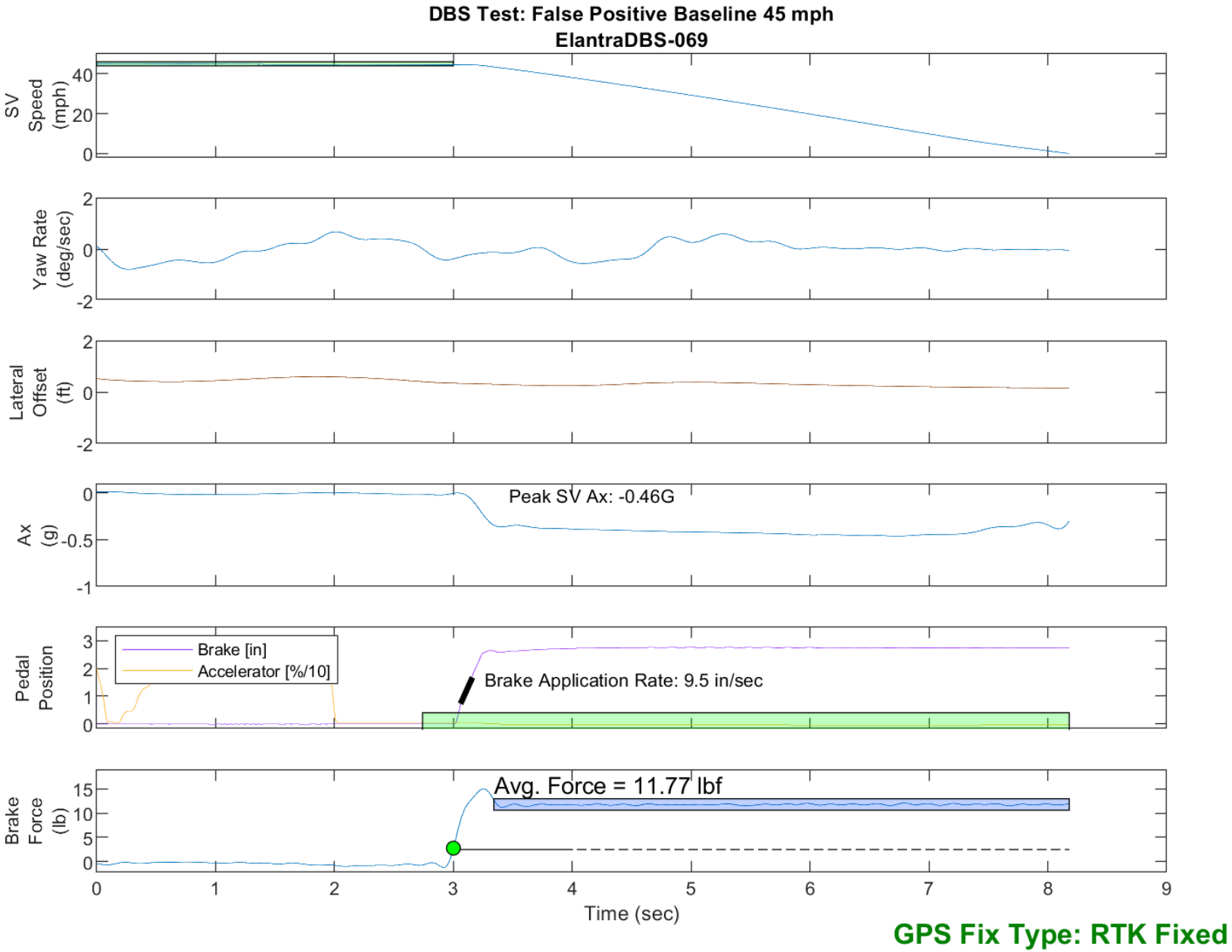


Figure E51. Time History for DBS Run 69, False Positive Baseline, SV 45 mph

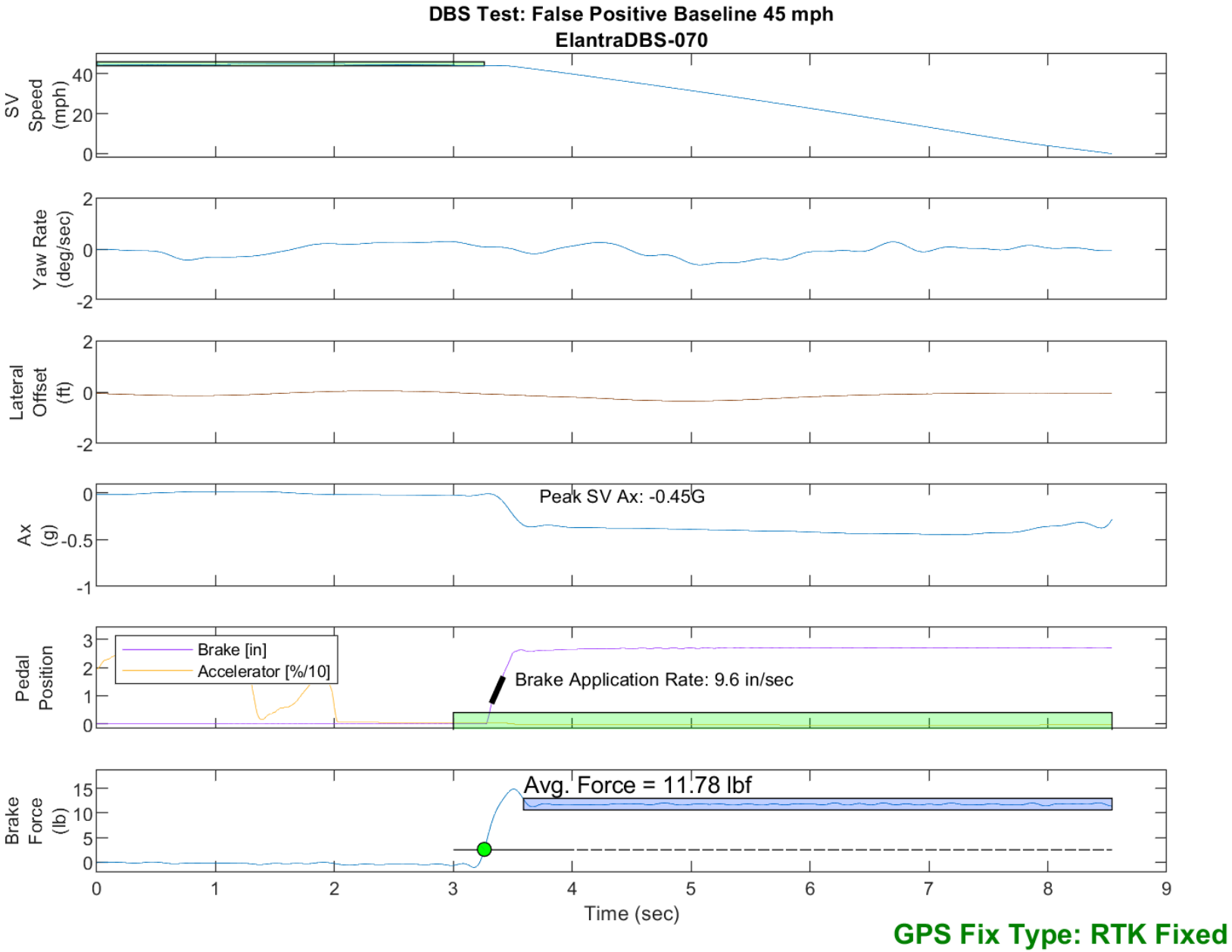


Figure E52. Time History for DBS Run 70, False Positive Baseline, SV 45 mph

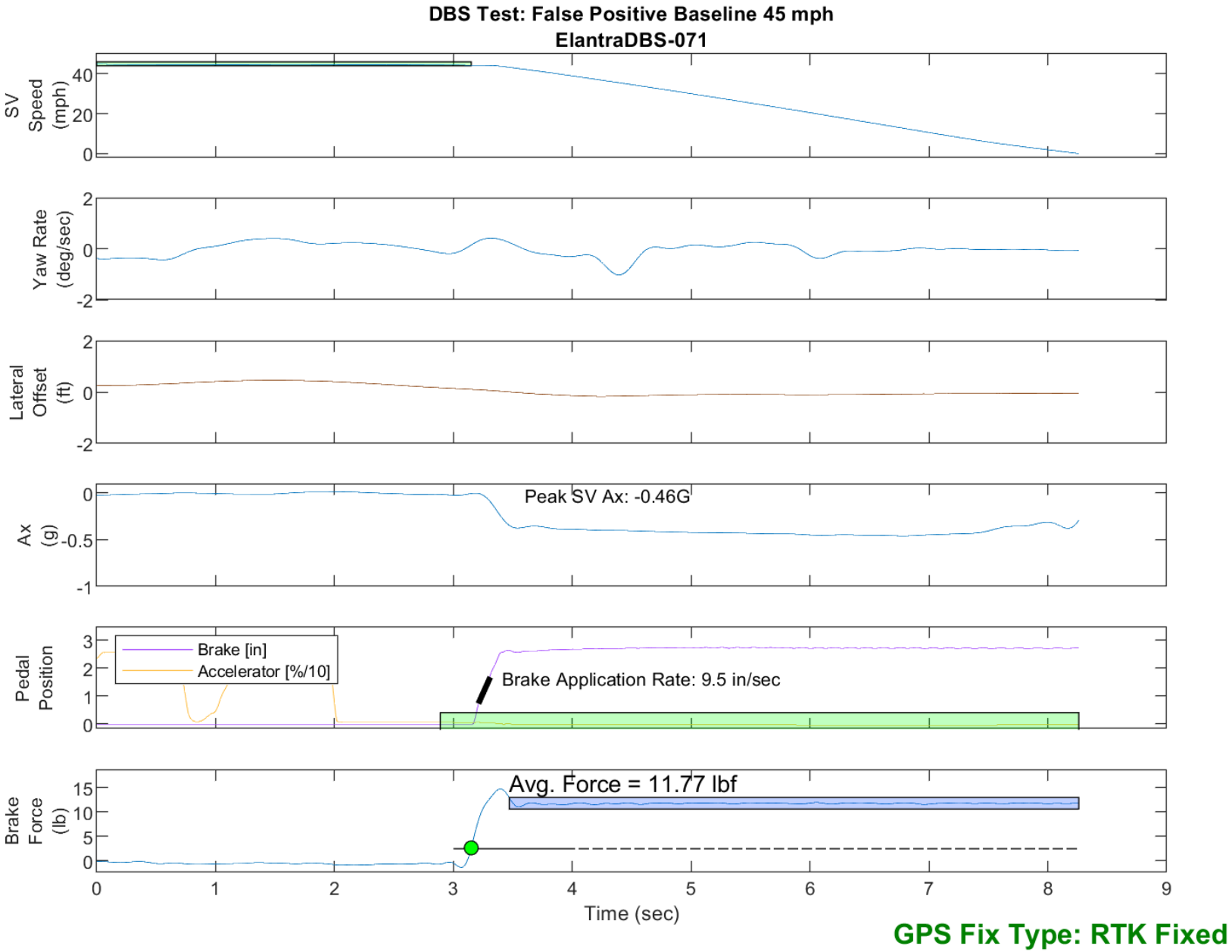


Figure E53. Time History for DBS Run 71, False Positive Baseline, SV 45 mph

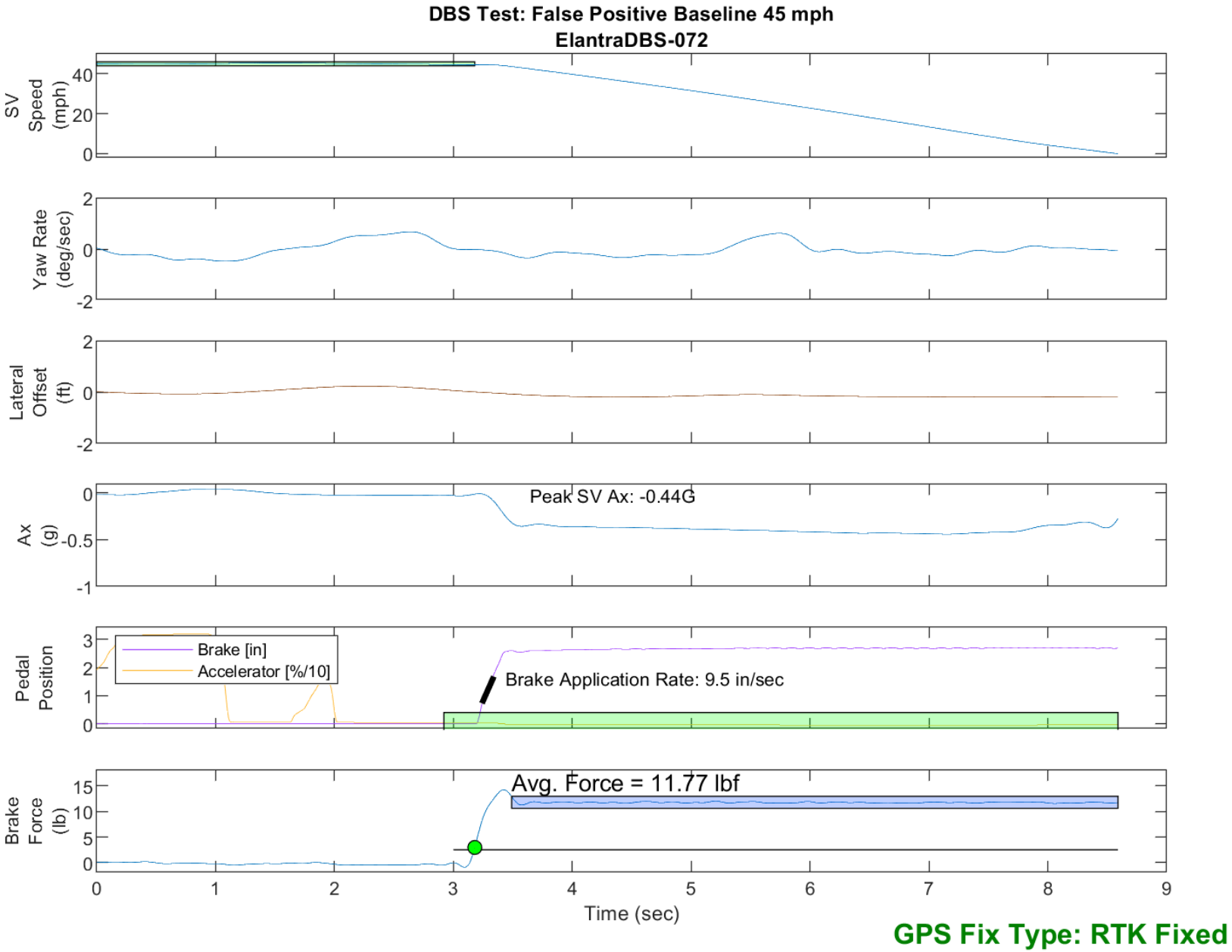


Figure E54. Time History for DBS Run 72, False Positive Baseline, SV 45 mph

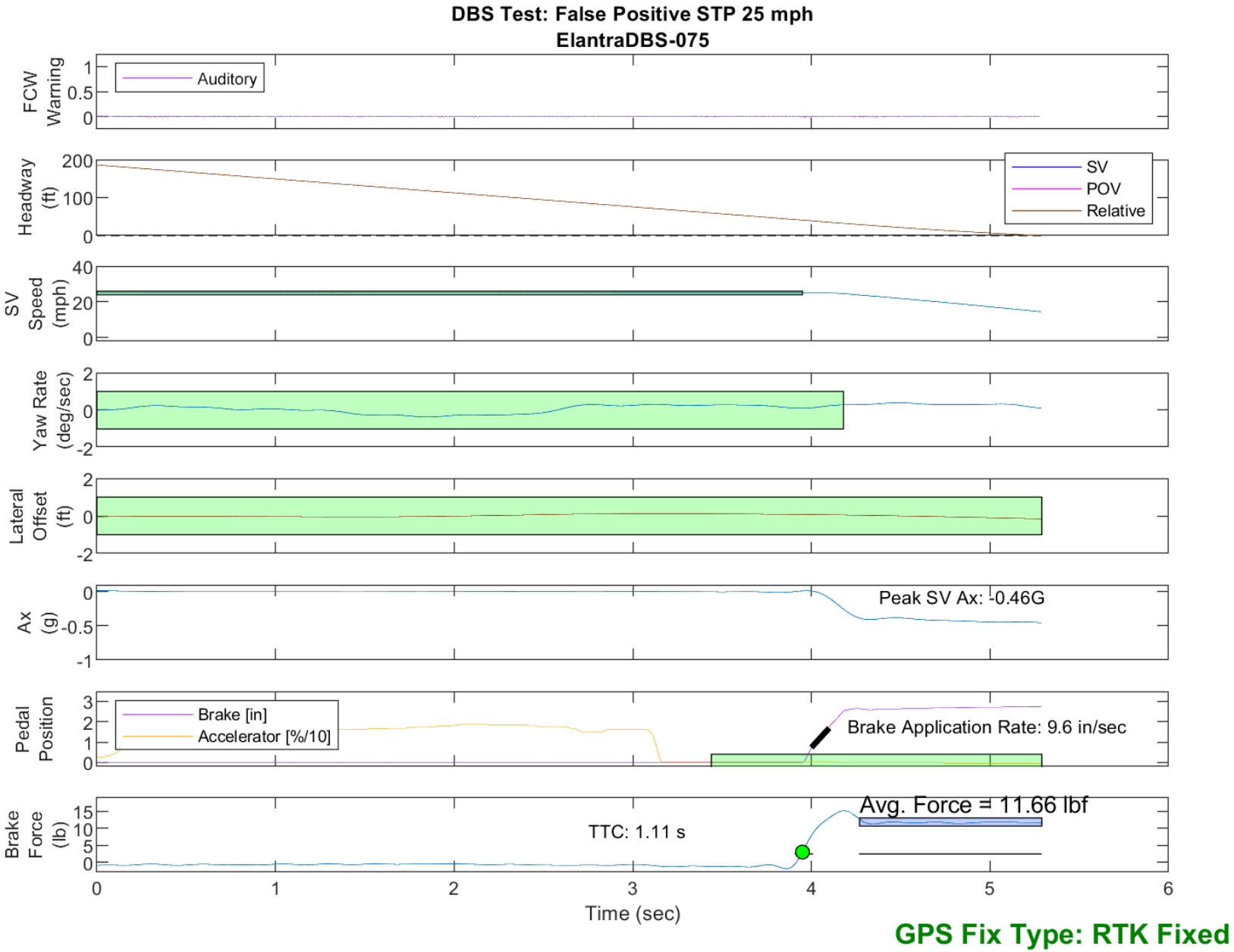


Figure E55. Time History for DBS Run 75, SV Encounters Steel Trench Plate, SV 25 mph

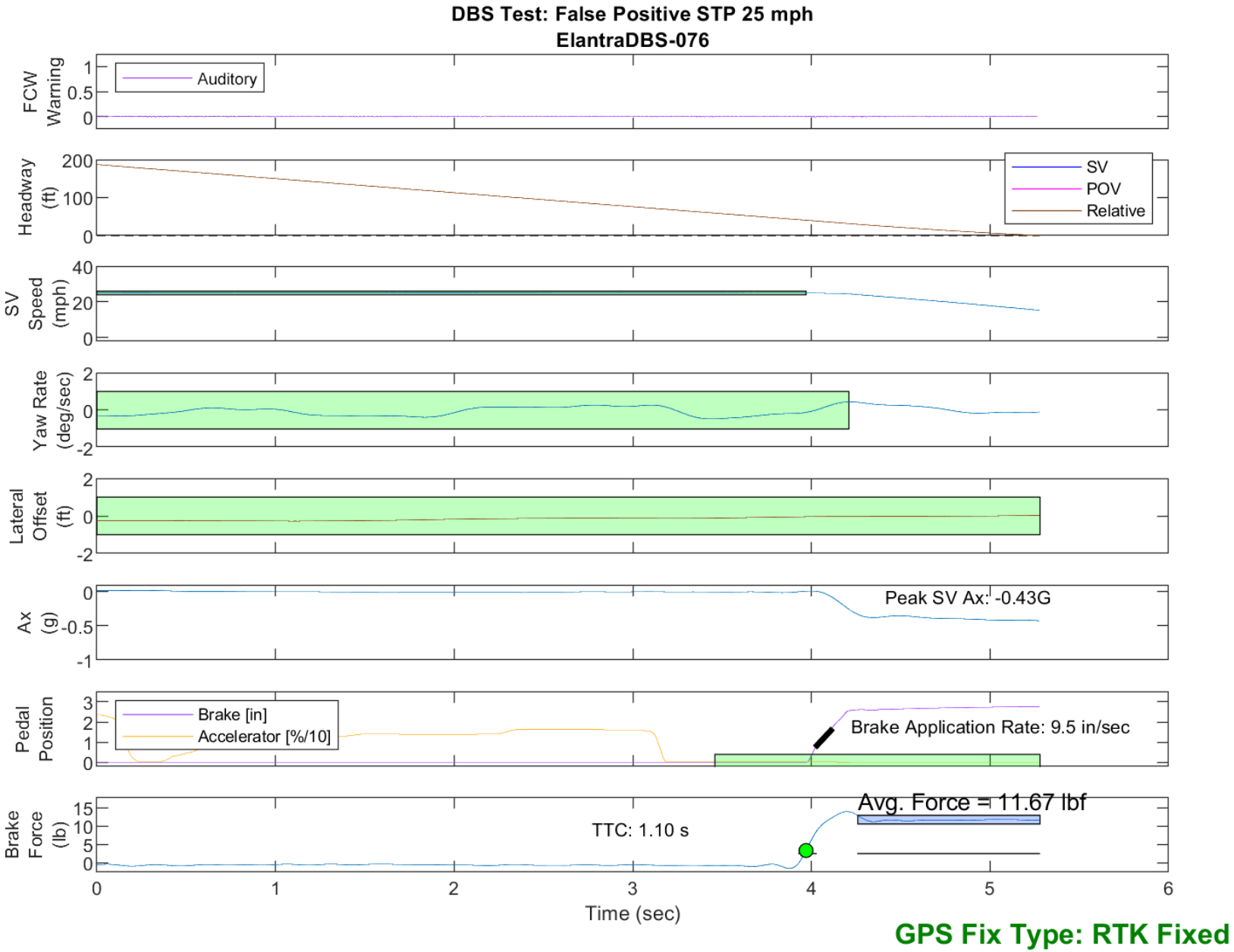


Figure E56. Time History for DBS Run 76, SV Encounters Steel Trench Plate, SV 25 mph

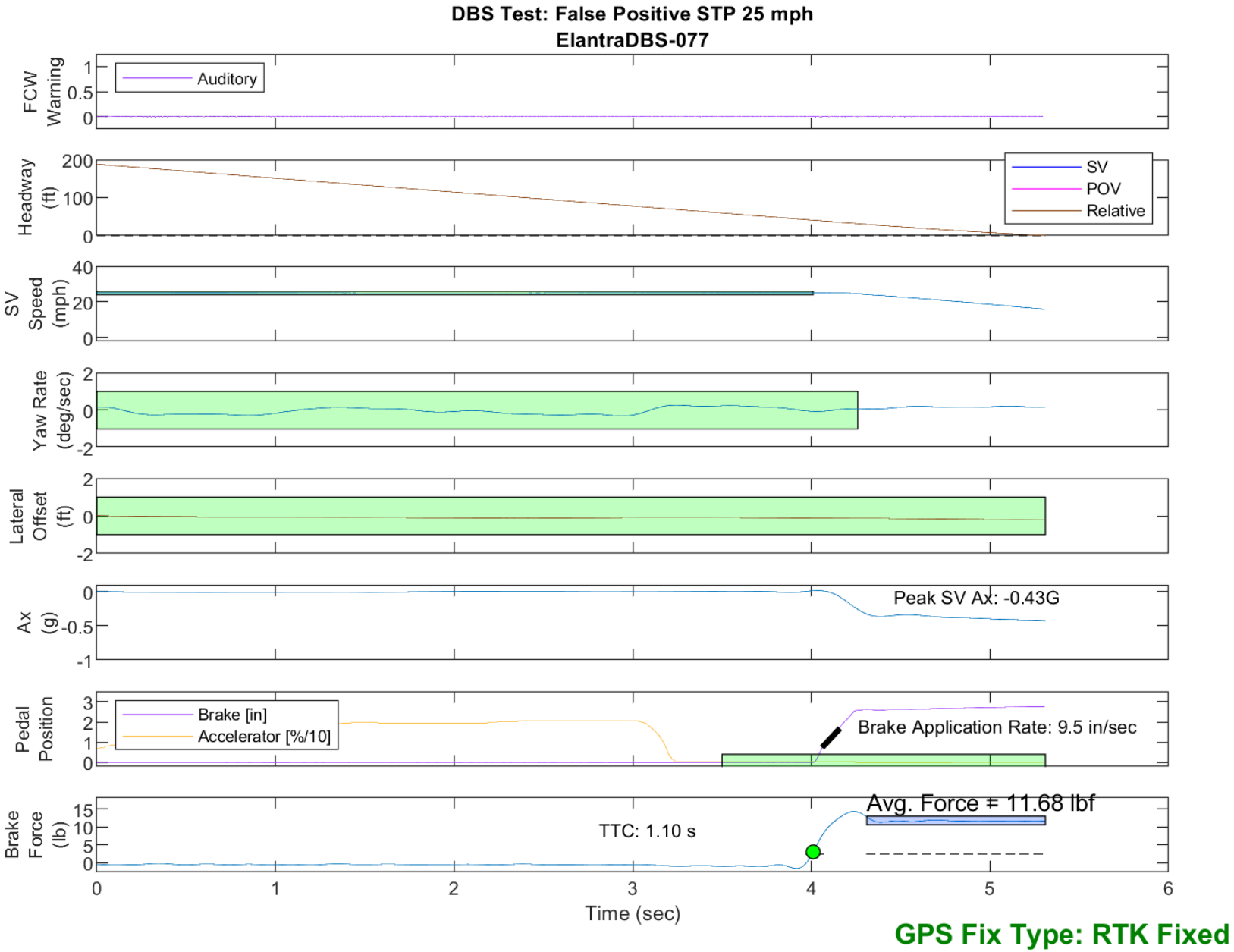


Figure E57. Time History for DBS Run 77, SV Encounters Steel Trench Plate, SV 25 mph

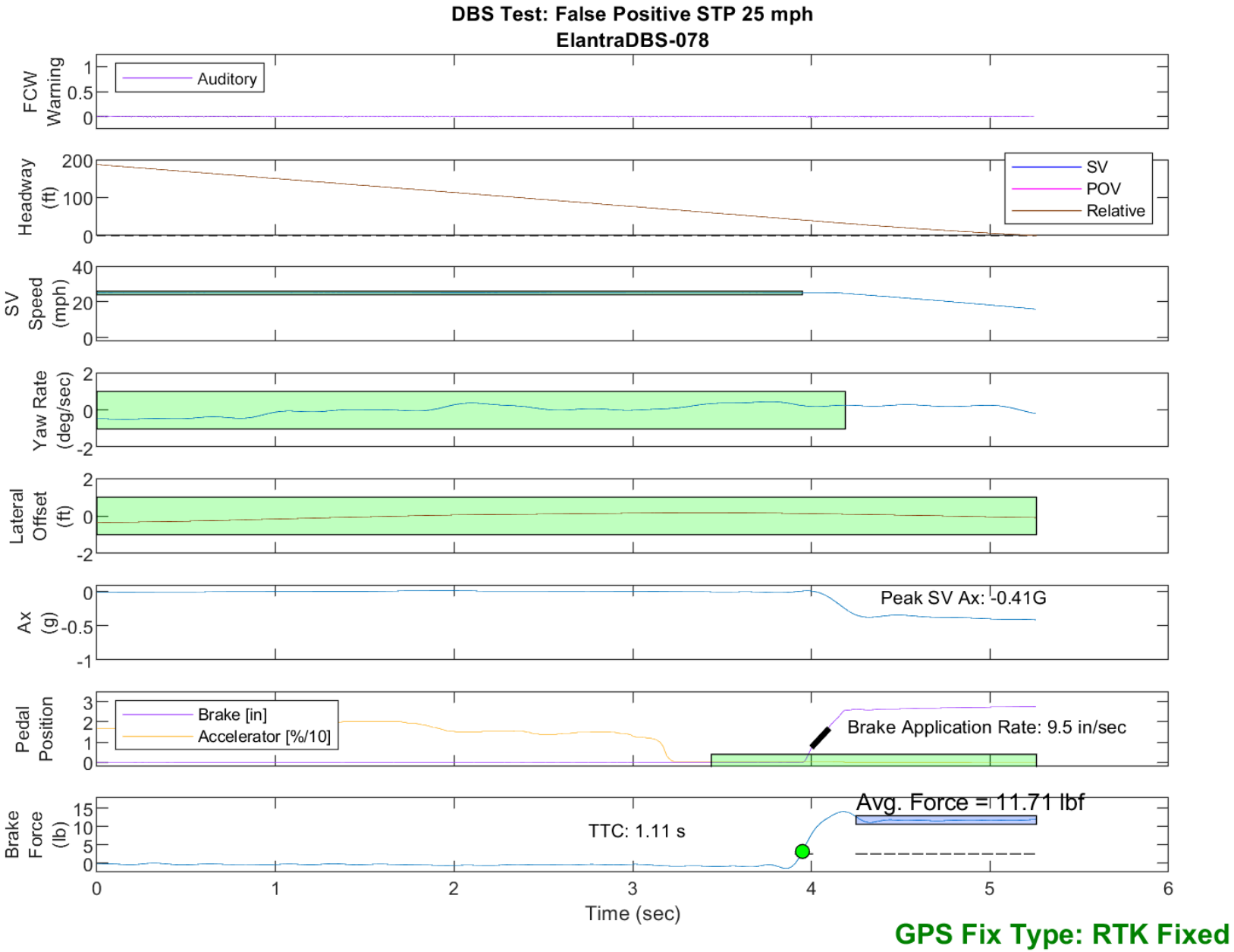


Figure E58. Time History for DBS Run 78, SV Encounters Steel Trench Plate, SV 25 mph

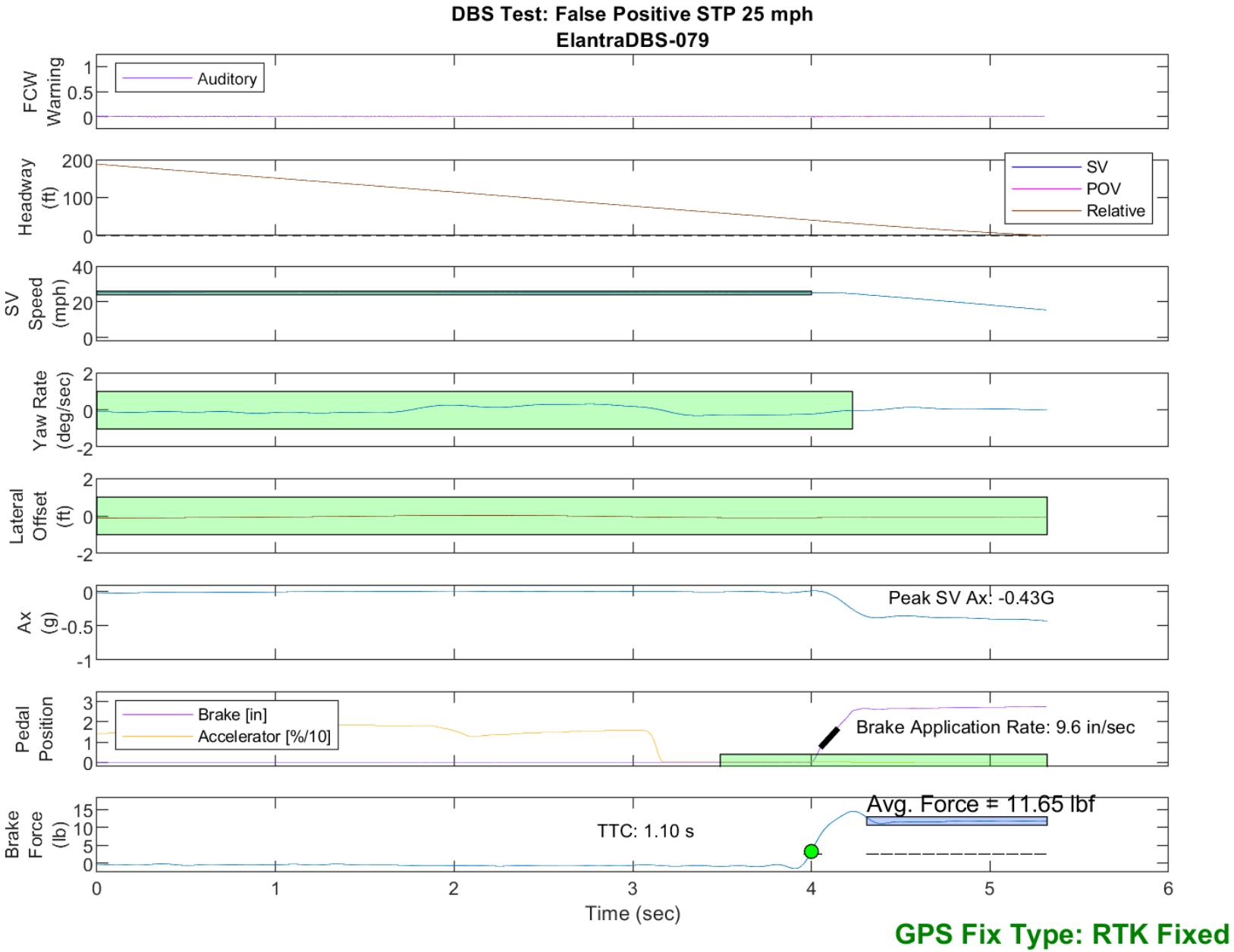


Figure E59. Time History for DBS Run 79, SV Encounters Steel Trench Plate, SV 25 mph

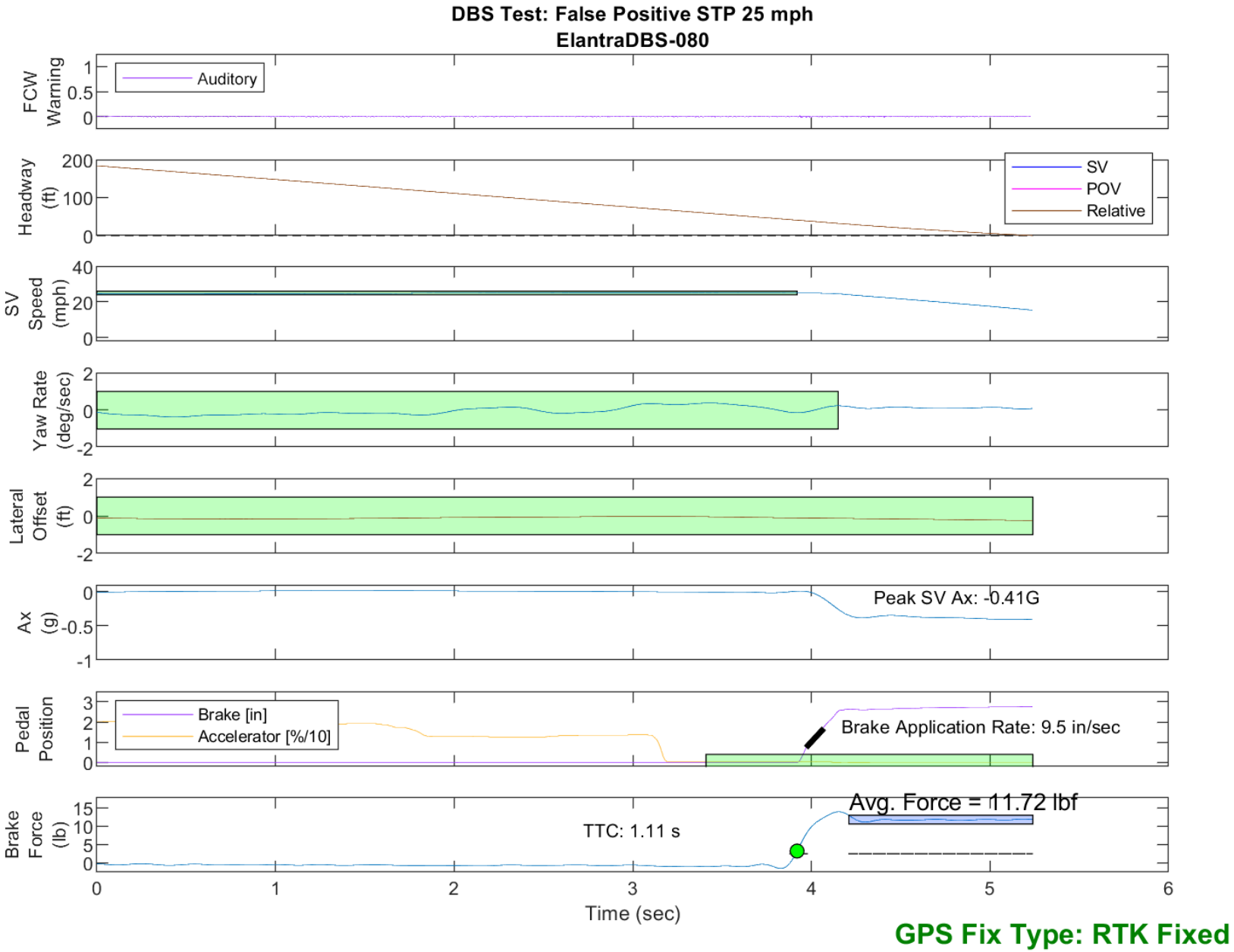


Figure E60. Time History for DBS Run 80, SV Encounters Steel Trench Plate, SV 25 mph

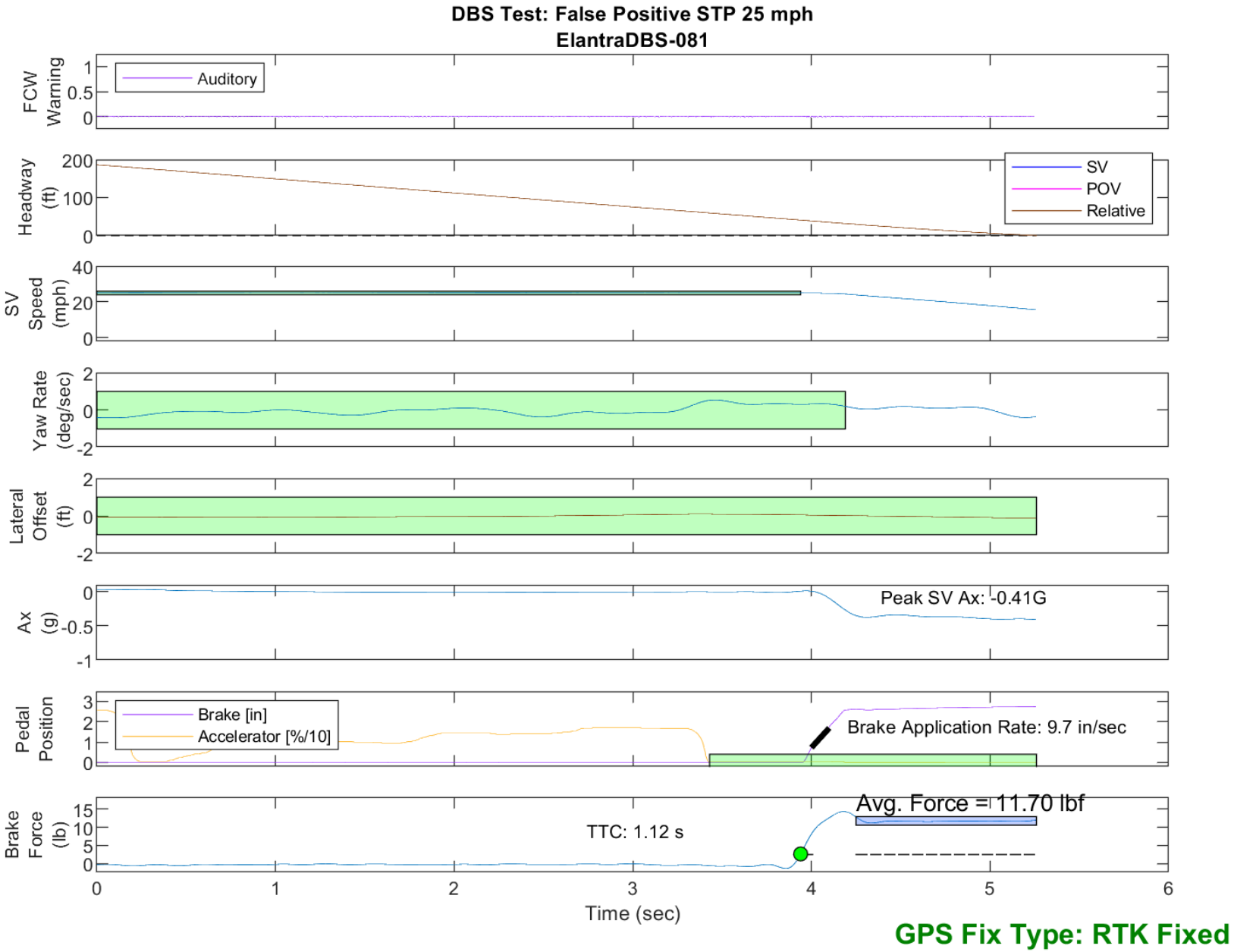


Figure E61. Time History for DBS Run 81, SV Encounters Steel Trench Plate, SV 25 mph

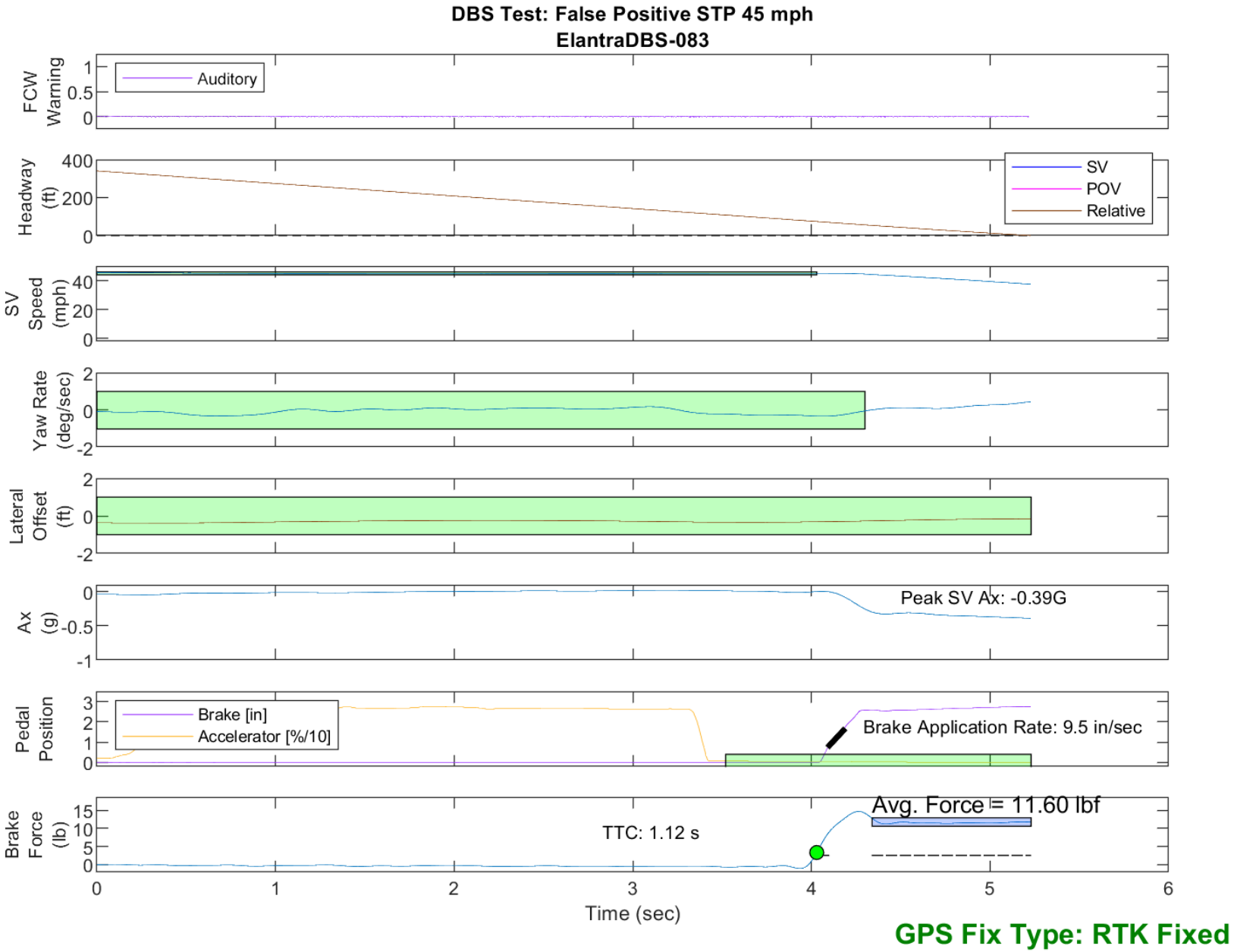


Figure E62. Time History for DBS Run 83, SV Encounters Steel Trench Plate, SV 45 mph

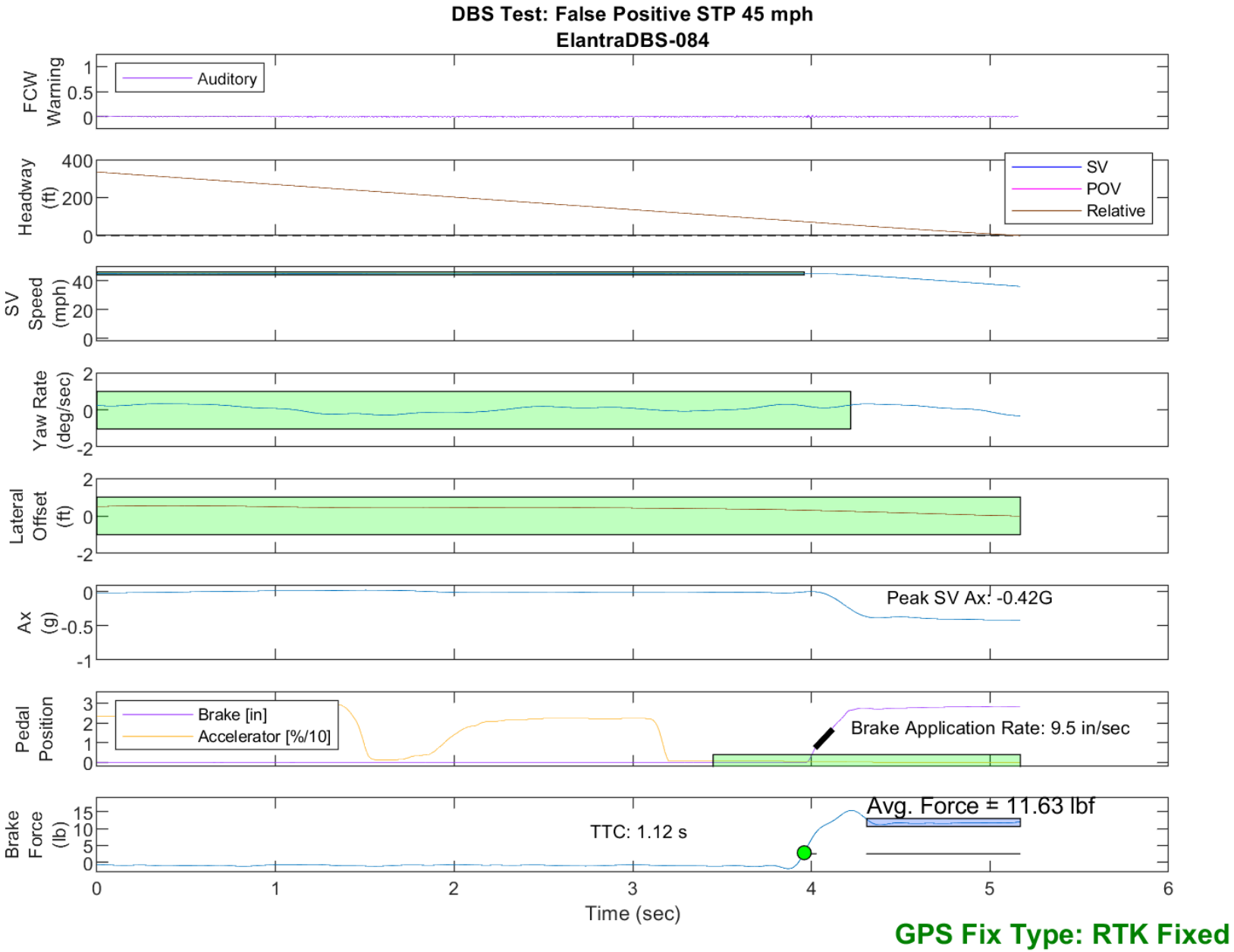


Figure E63. Time History for DBS Run 84, SV Encounters Steel Trench Plate, SV 45 mph

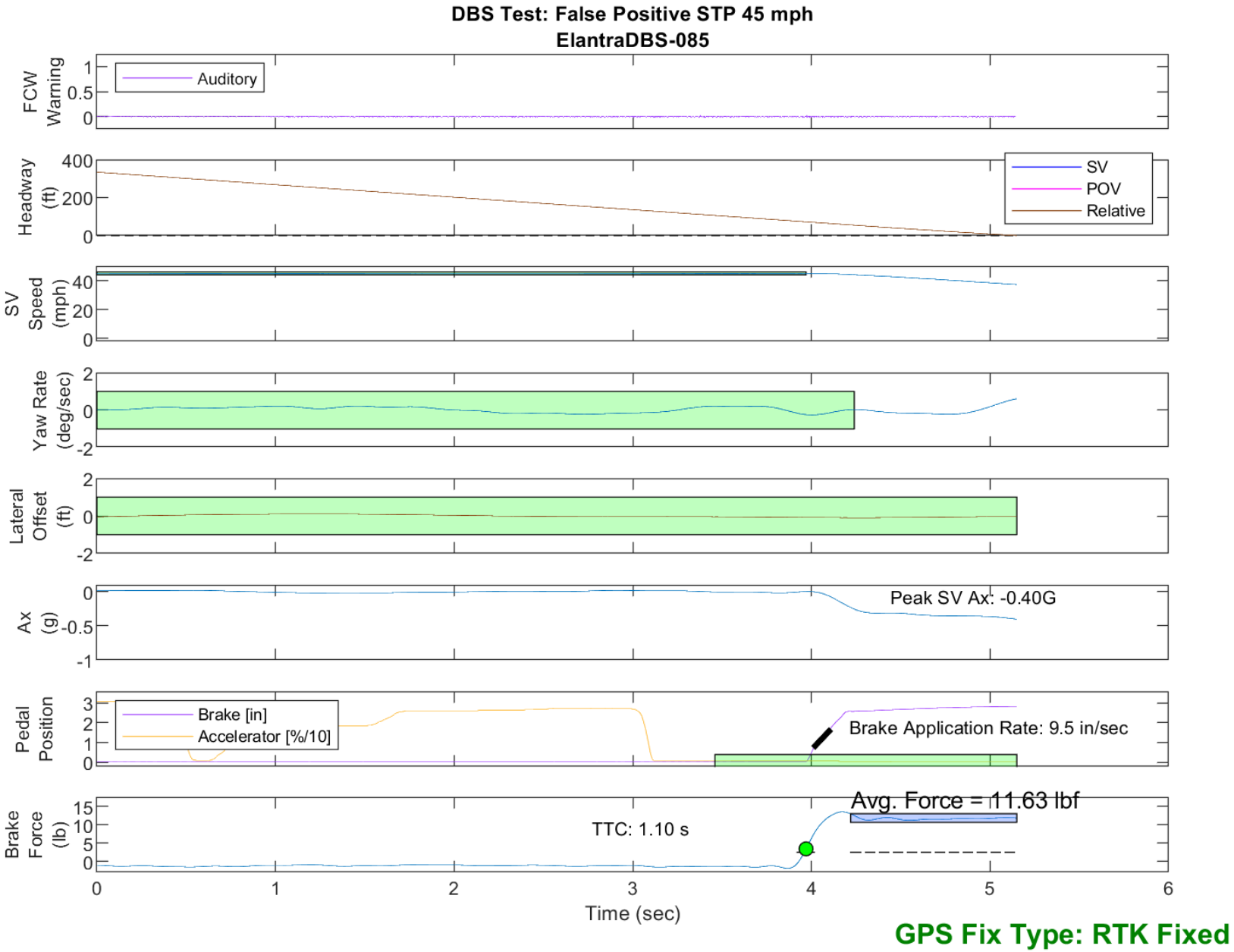


Figure E64. Time History for DBS Run 85, SV Encounters Steel Trench Plate, SV 45 mph

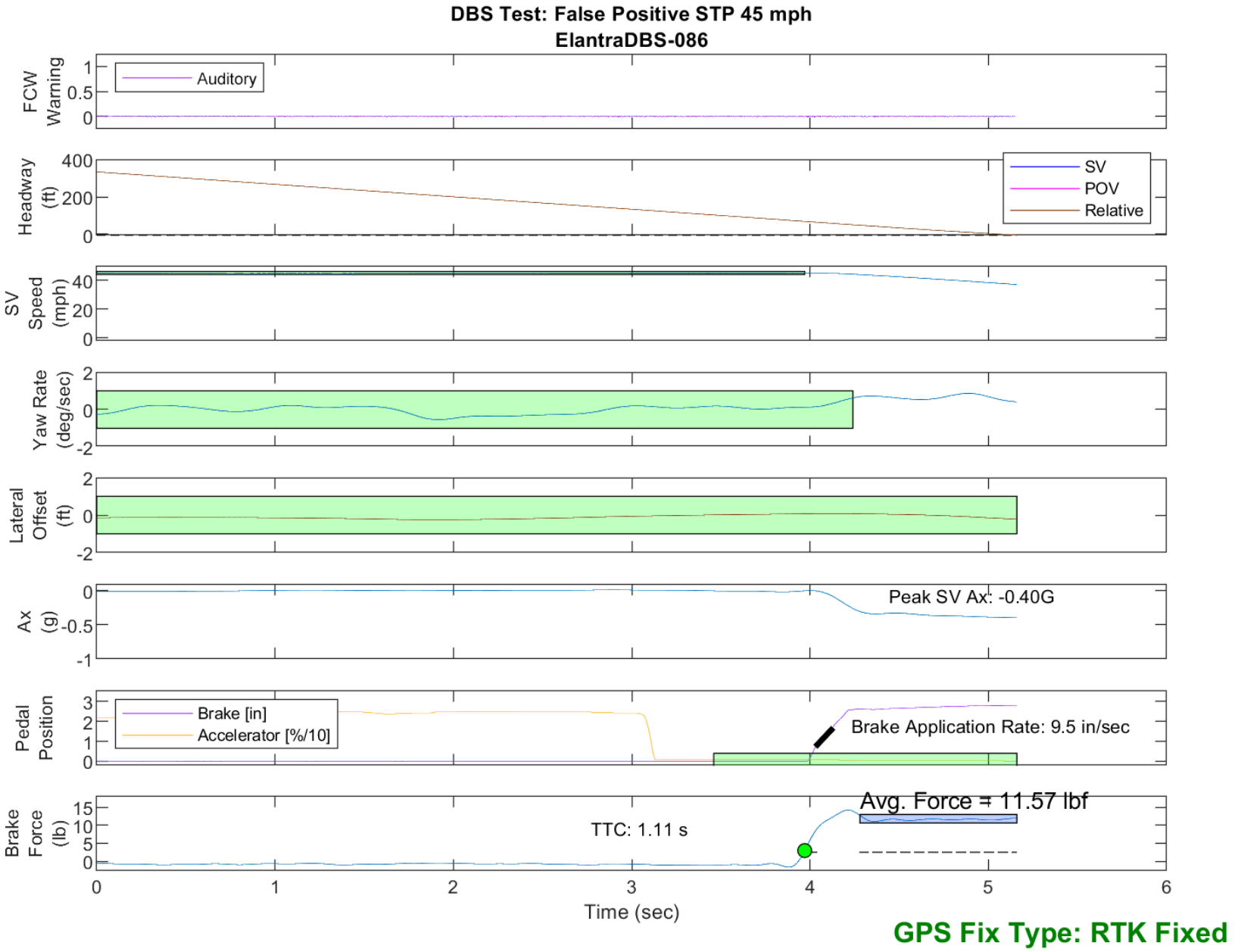


Figure E65. Time History for DBS Run 86, SV Encounters Steel Trench Plate, SV 45 mph

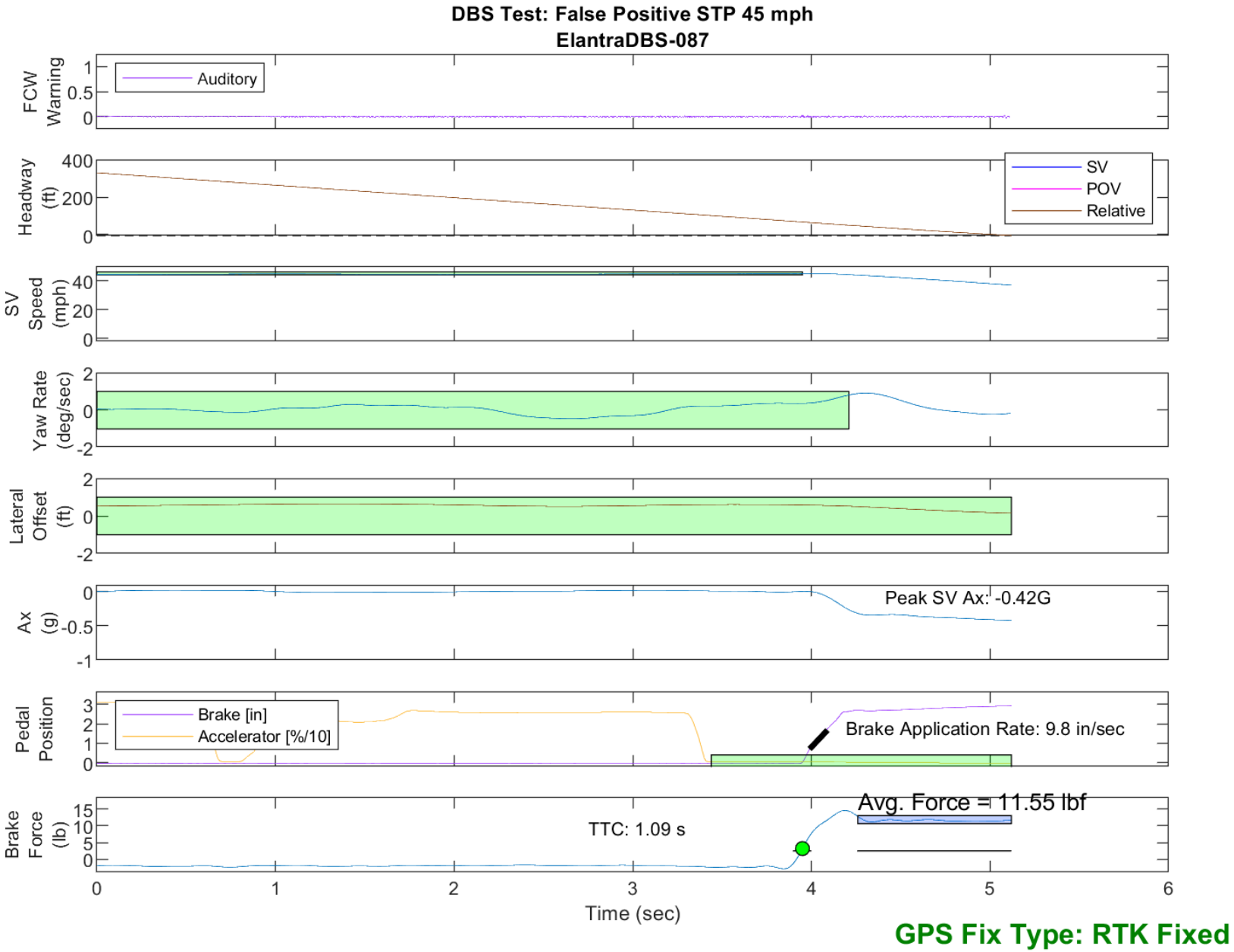


Figure E66. Time History for DBS Run 87, SV Encounters Steel Trench Plate, SV 45 mph

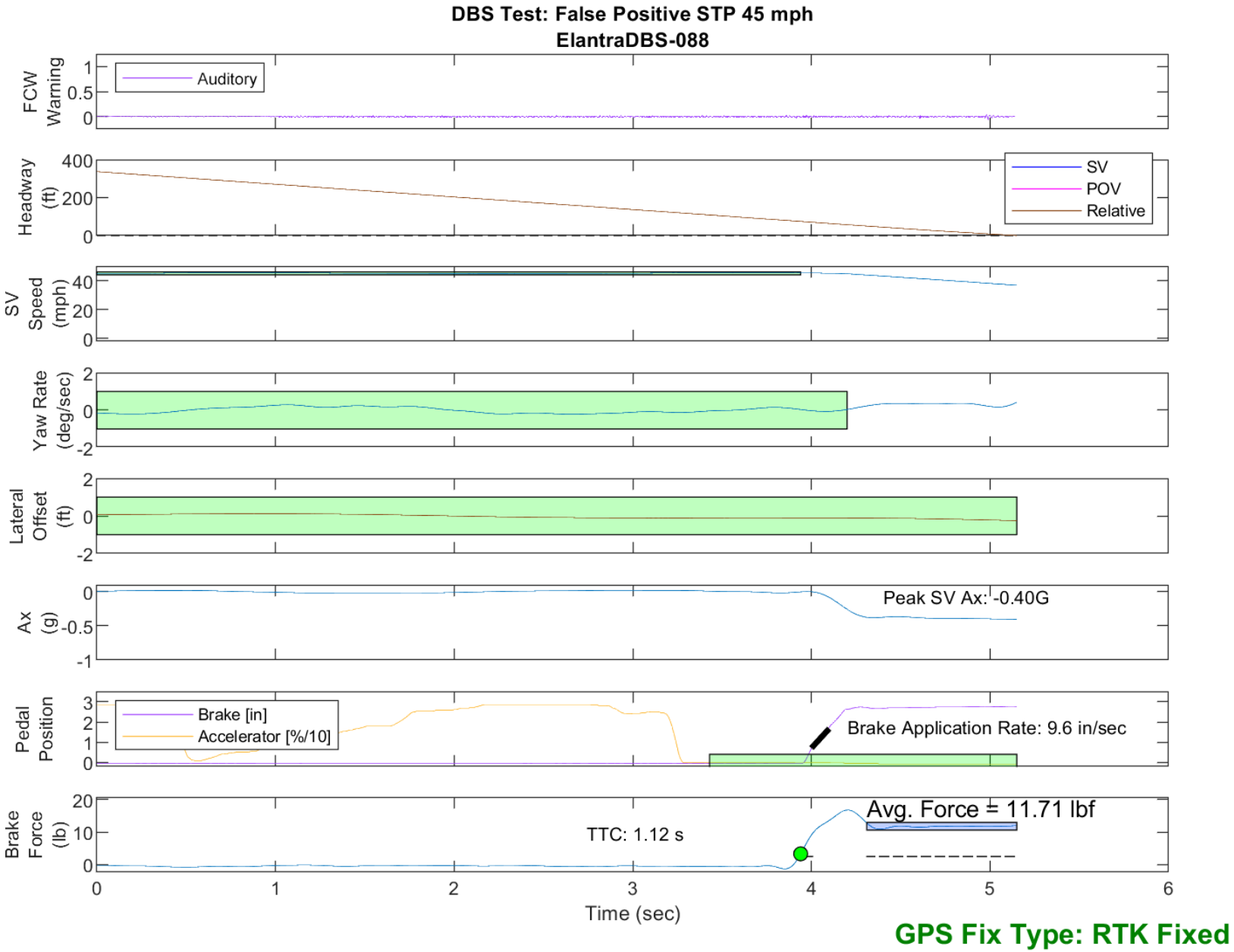


Figure E67. Time History for DBS Run 88, SV Encounters Steel Trench Plate, SV 45 mph

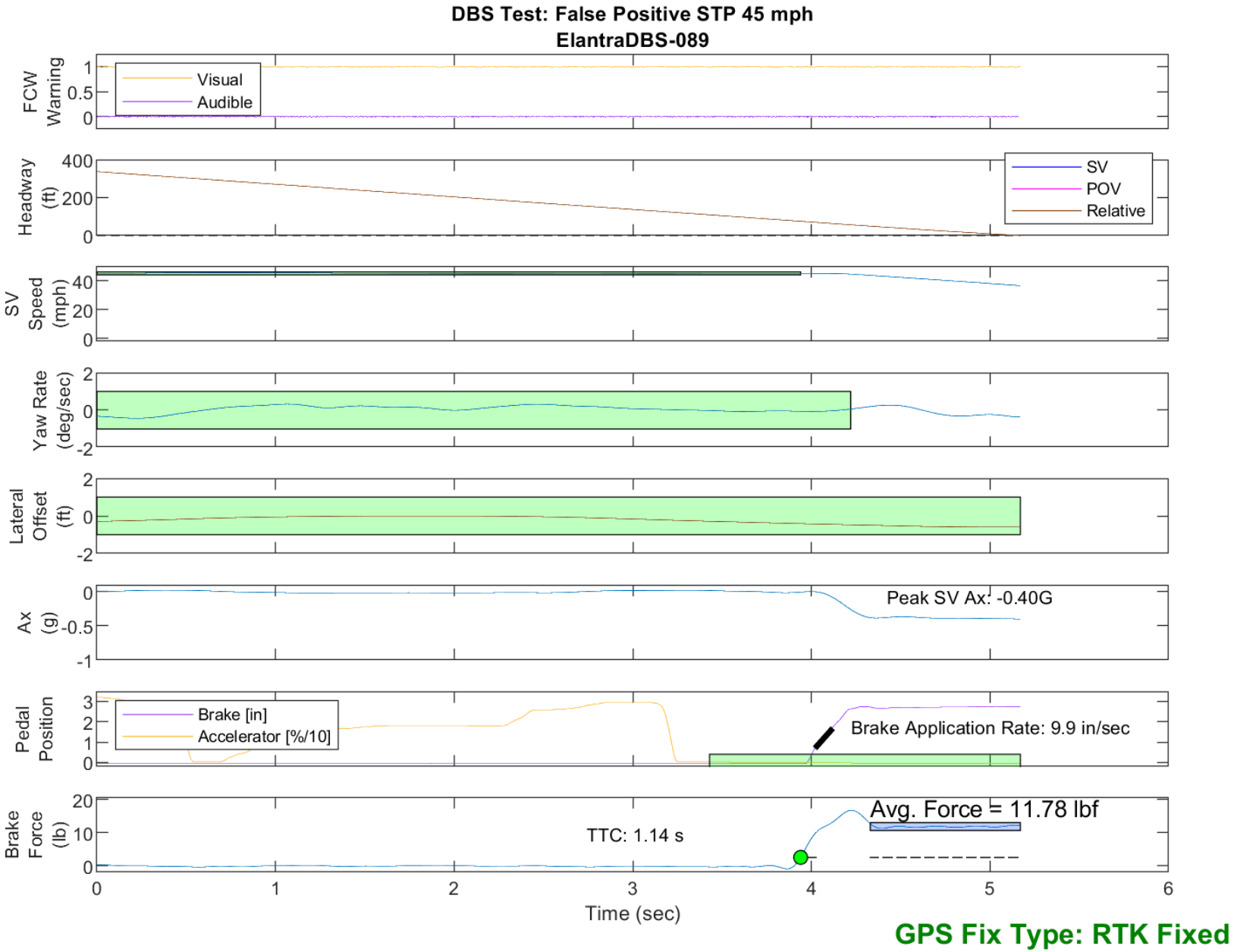


Figure E68. Time History for DBS Run 89, SV Encounters Steel Trench Plate, SV 45 mph

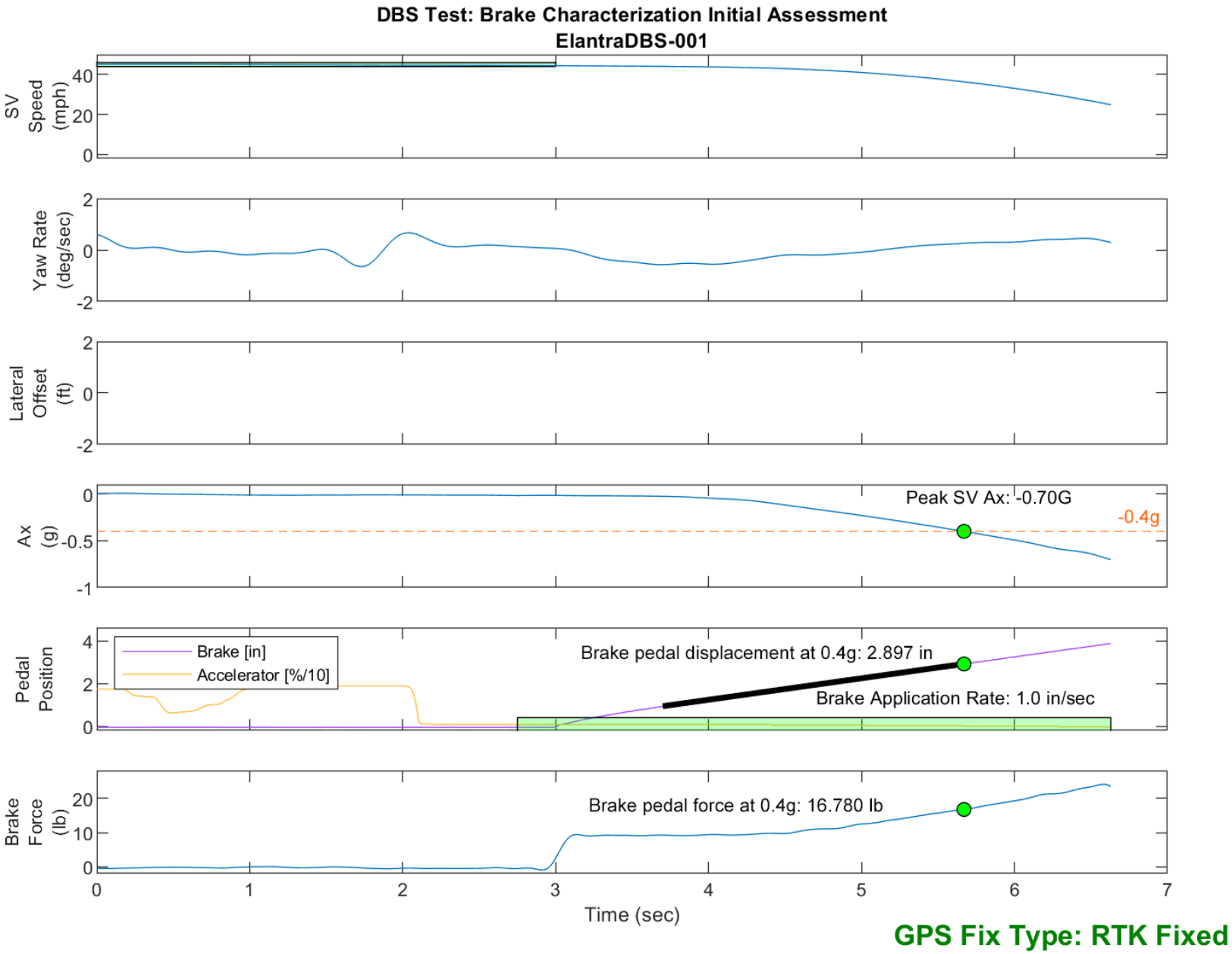


Figure E69. Time History for DBS Run 1, Brake Characterization Initial

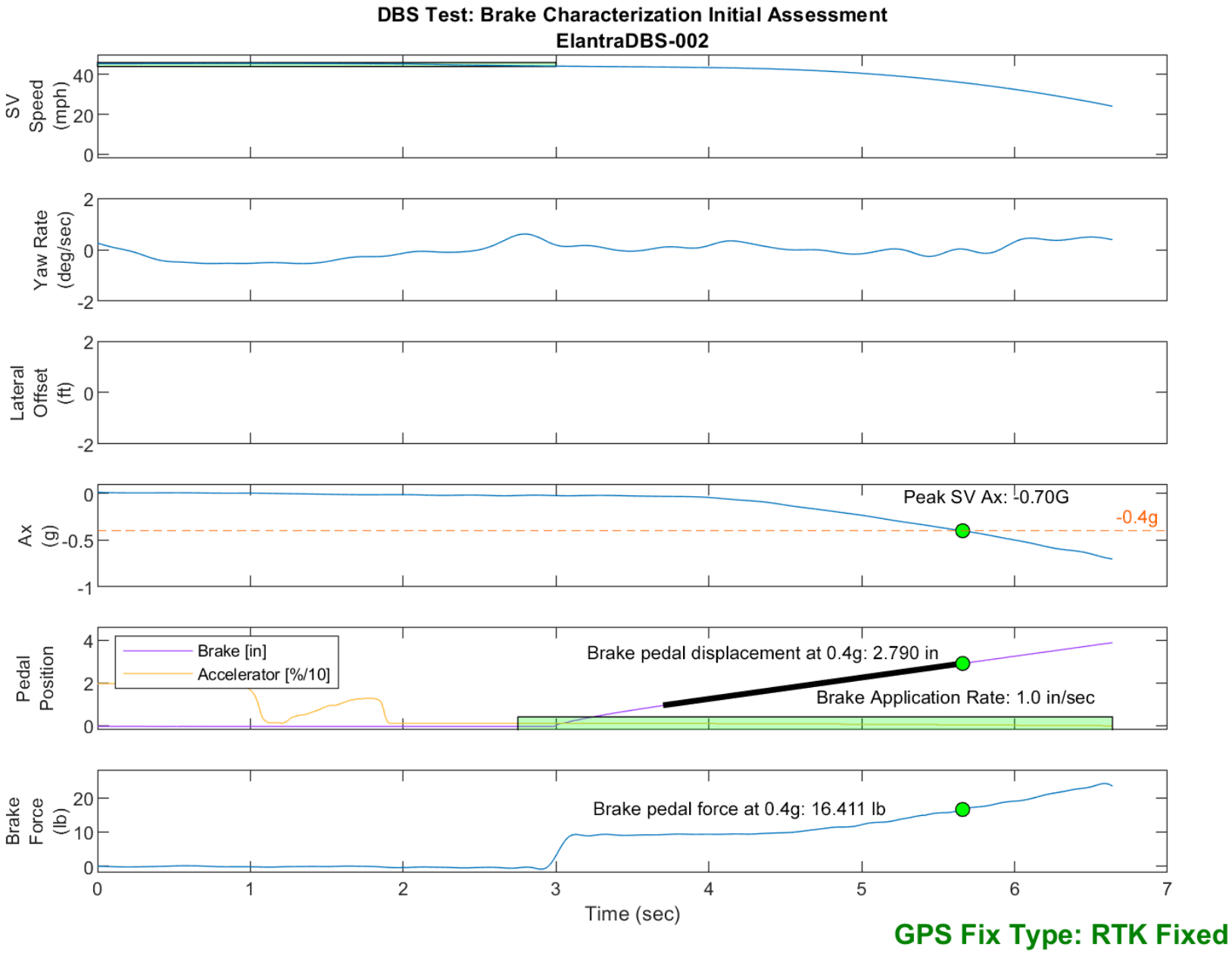


Figure E70. Time History for DBS Run 2, Brake Characterization Initial

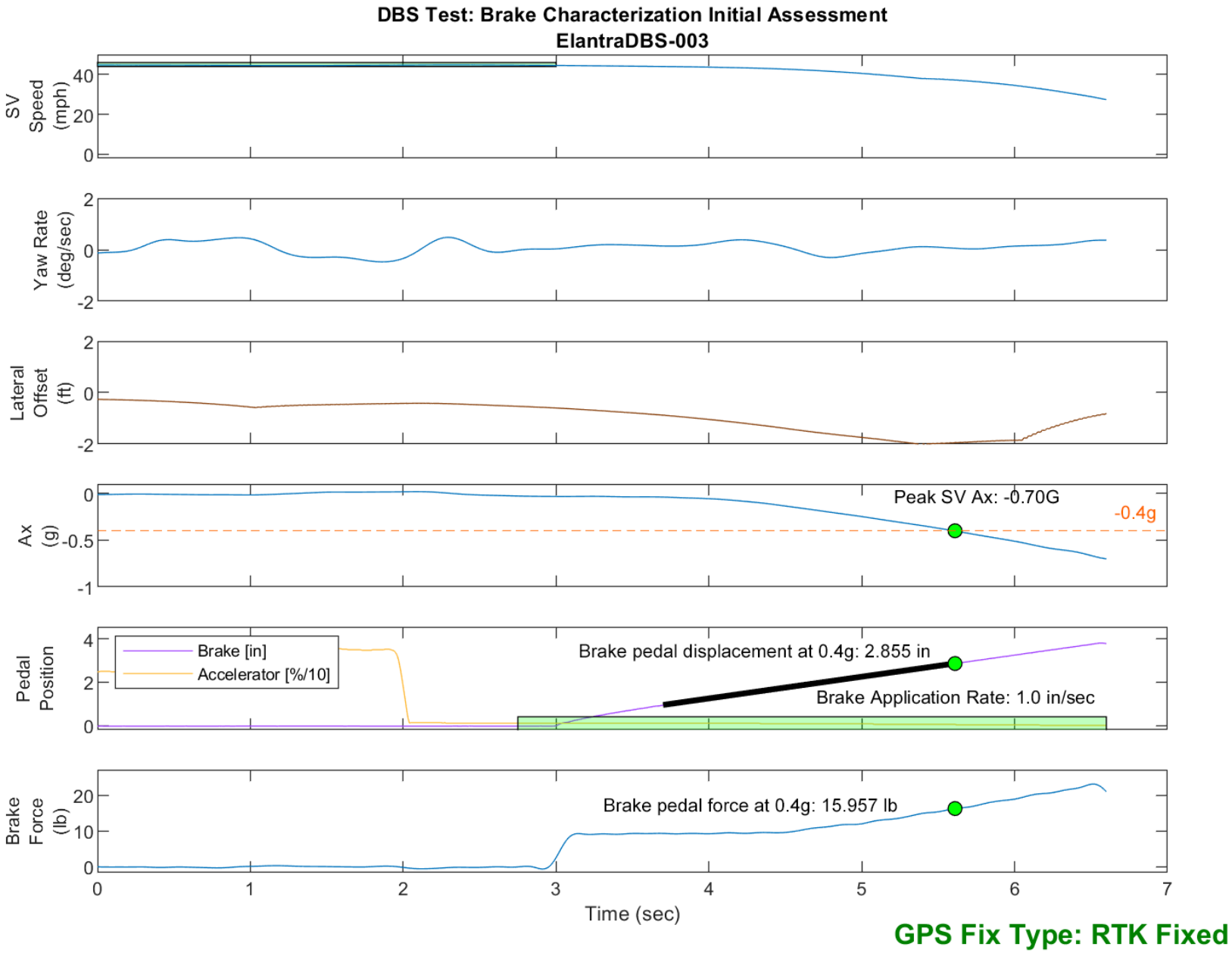


Figure E71. Time History for DBS Run 3, Brake Characterization Initial

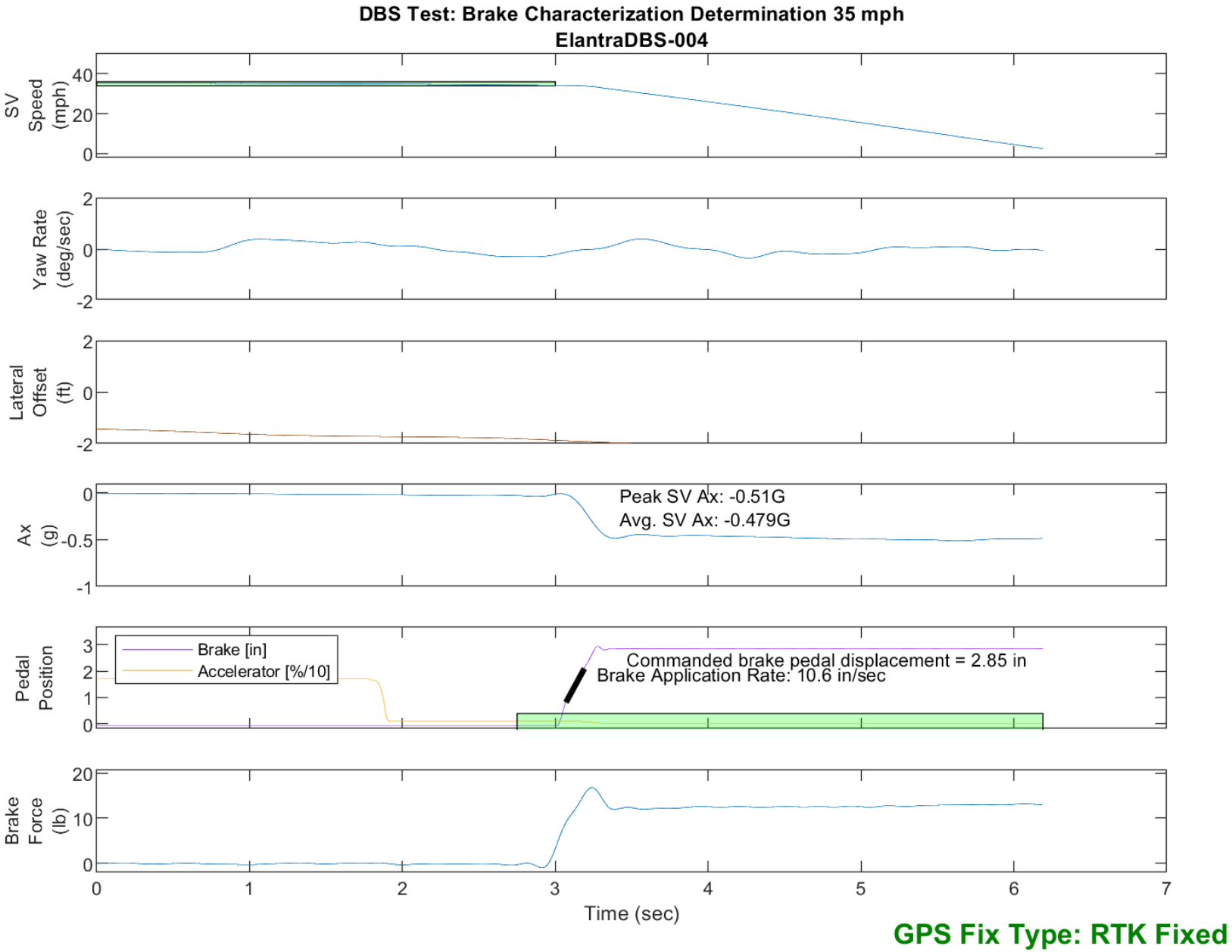


Figure E72. Time History for DBS Run 4, Brake Characterization Determination, Displacement Mode, 35 mph

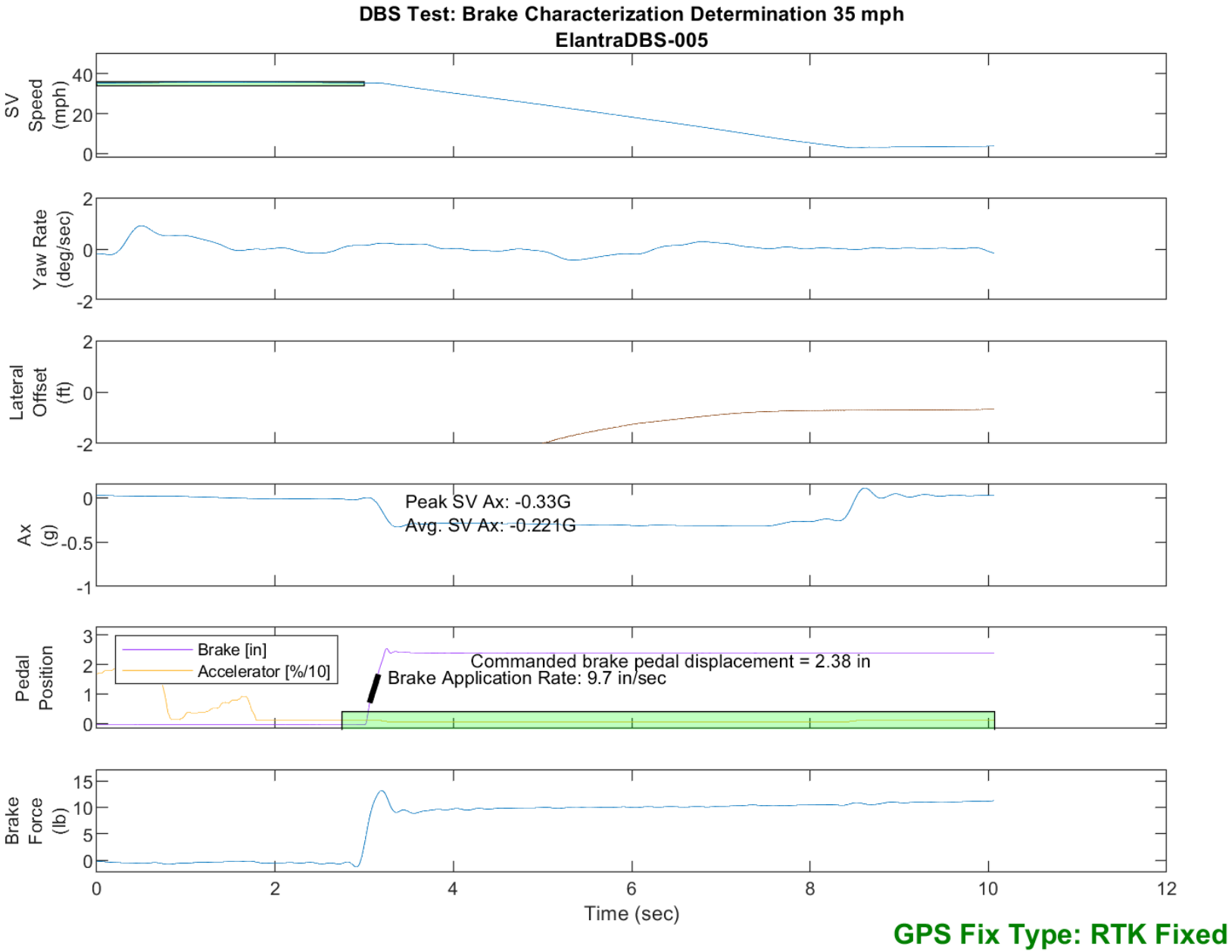


Figure E73. Time History for DBS Run 5, Brake Characterization Determination, Displacement Mode, 35 mph

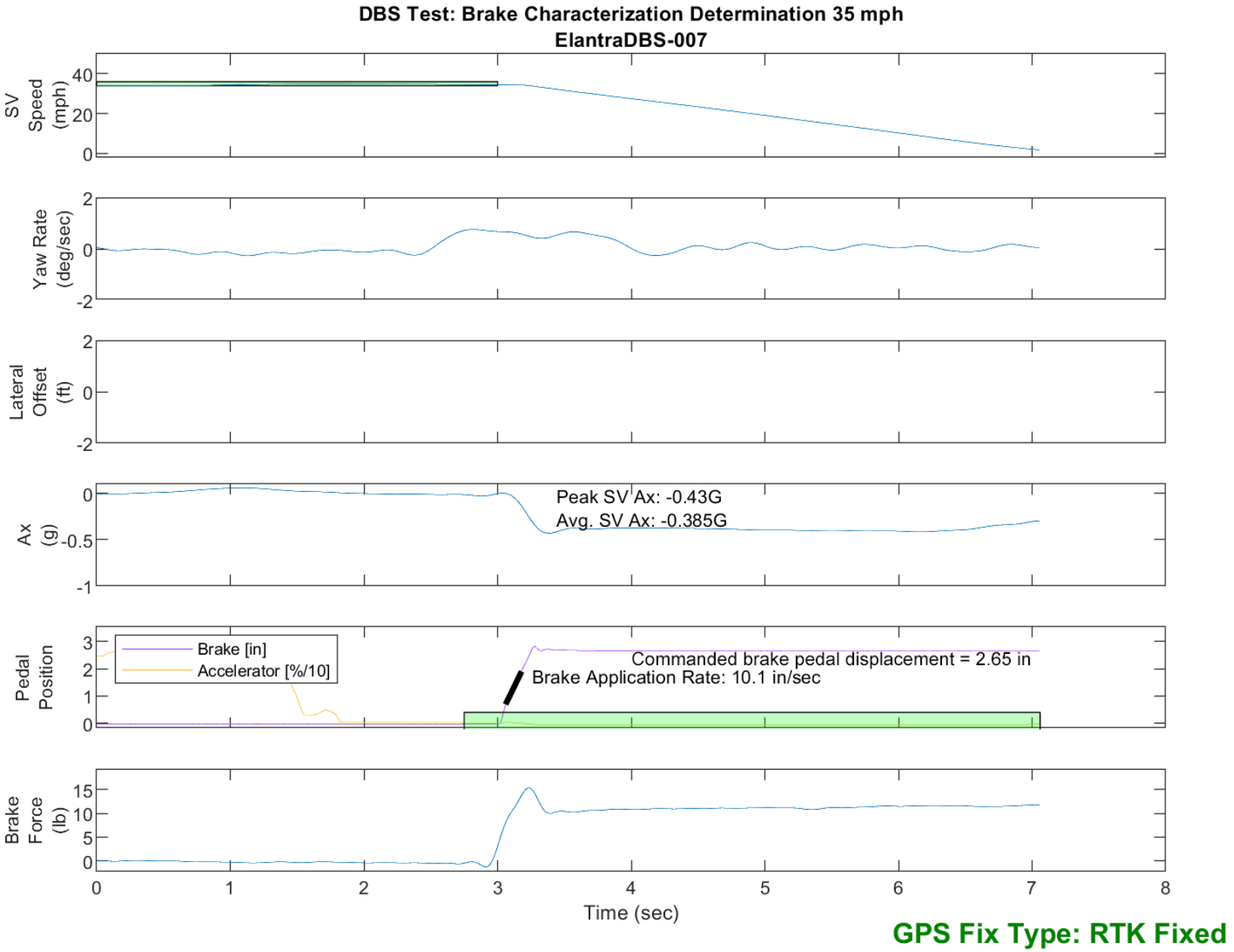


Figure E74. Time History for DBS Run 7, Brake Characterization Determination, Displacement Mode, 35 mph

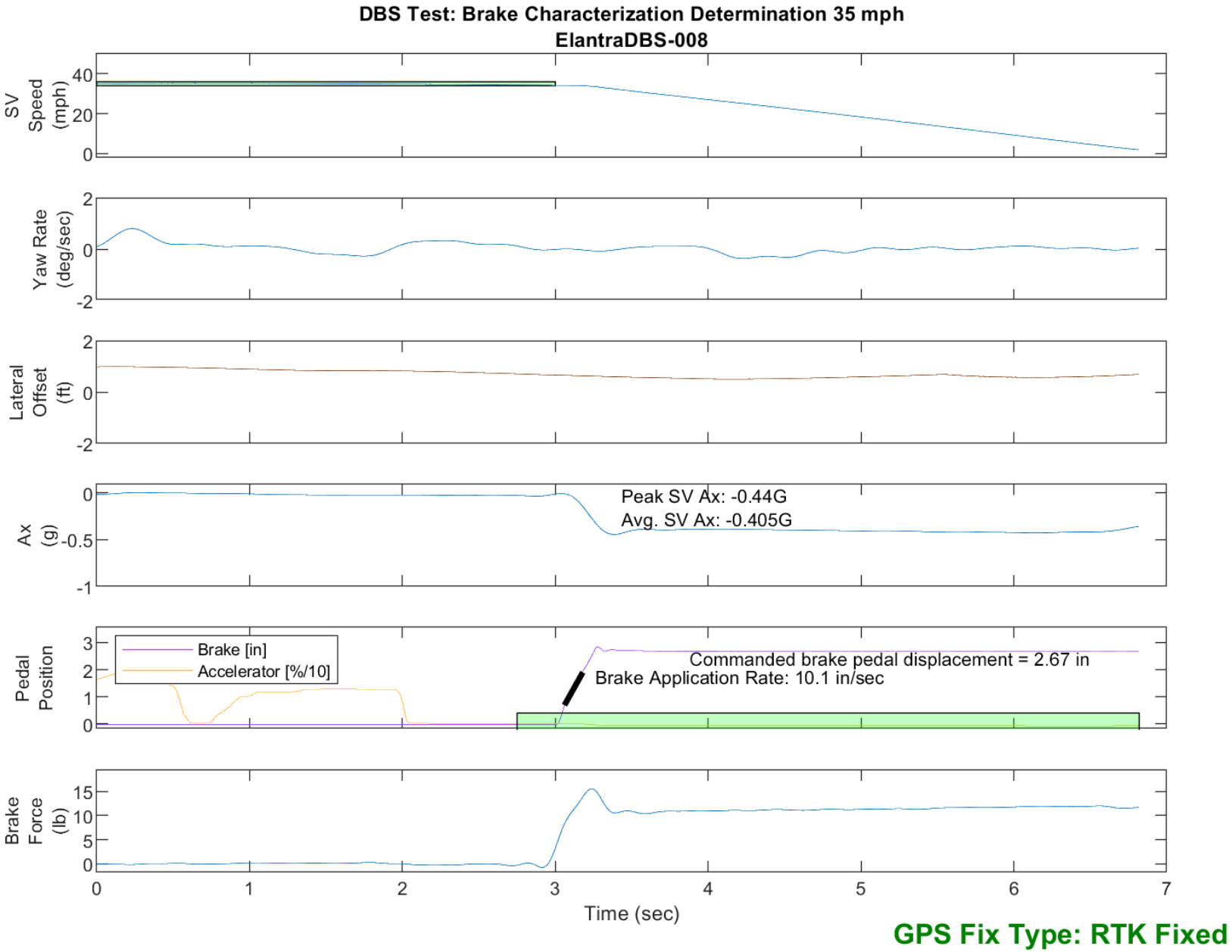


Figure E75. Time History for DBS Run 8, Brake Characterization Determination, Displacement Mode, 35 mph

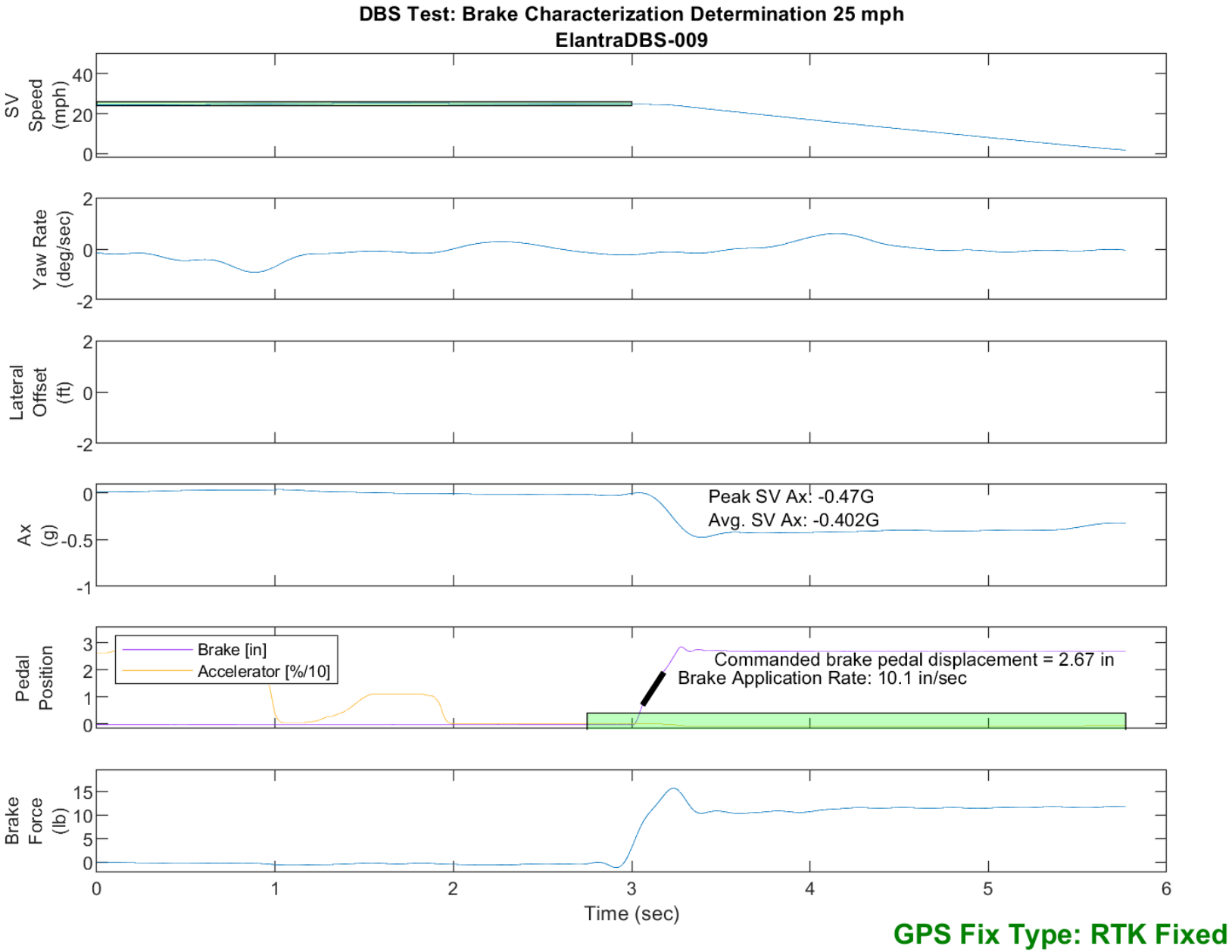


Figure E76. Time History for DBS Run 9, Brake Characterization Determination, Displacement Mode, 25 mph

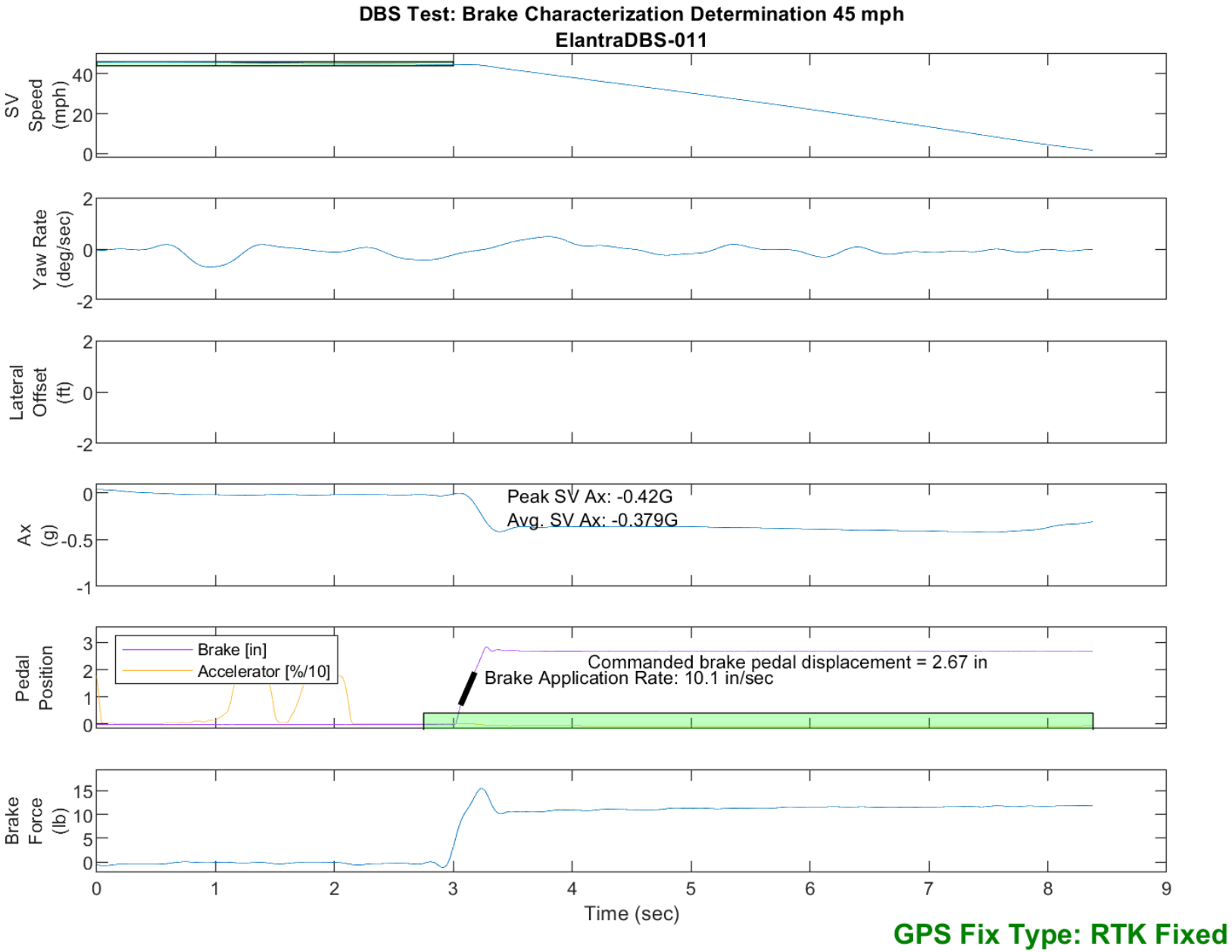


Figure E77. Time History for DBS Run 11, Brake Characterization Determination, Displacement Mode, 45 mph

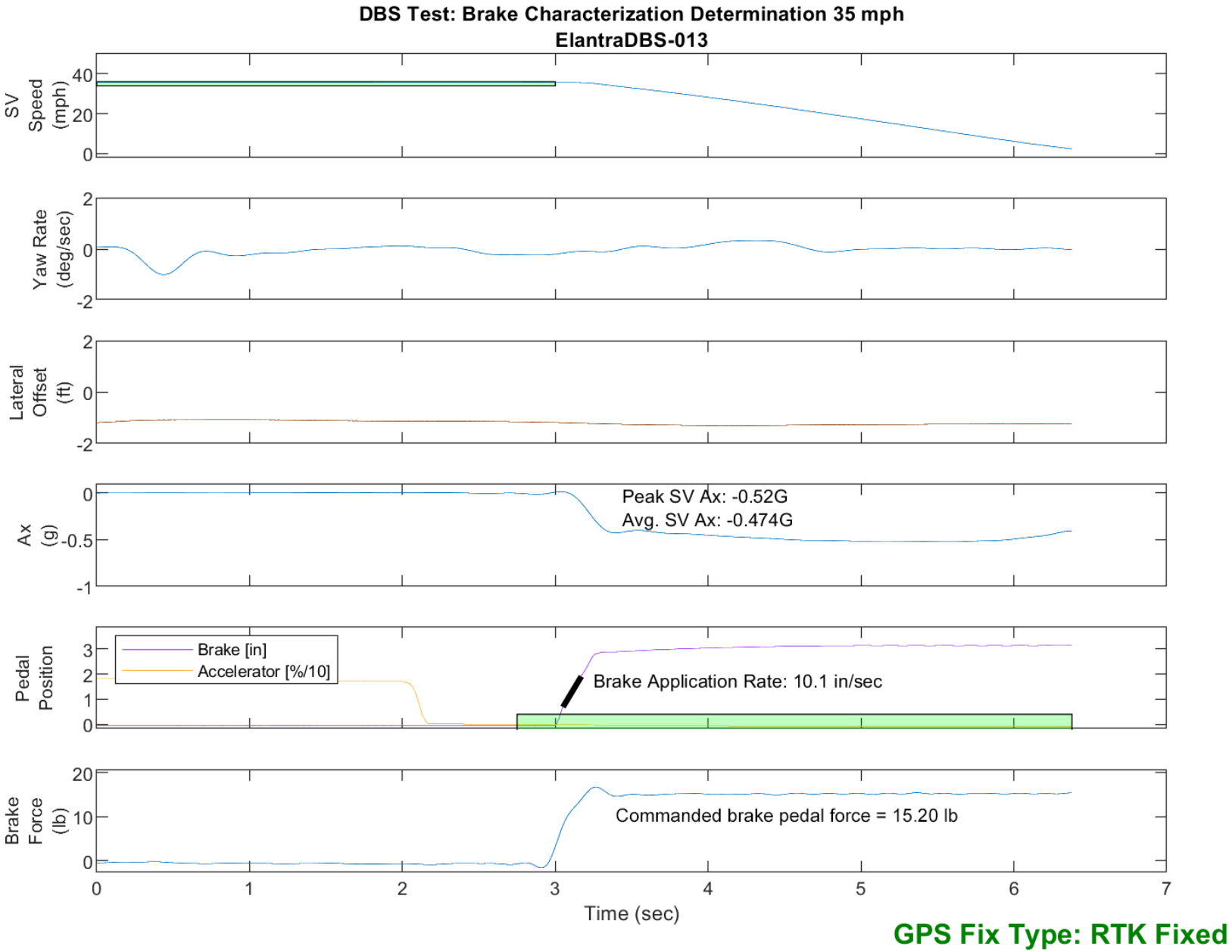


Figure E78. Time History for DBS Run 13, Brake Characterization Determination, Hybrid Mode, 35 mph

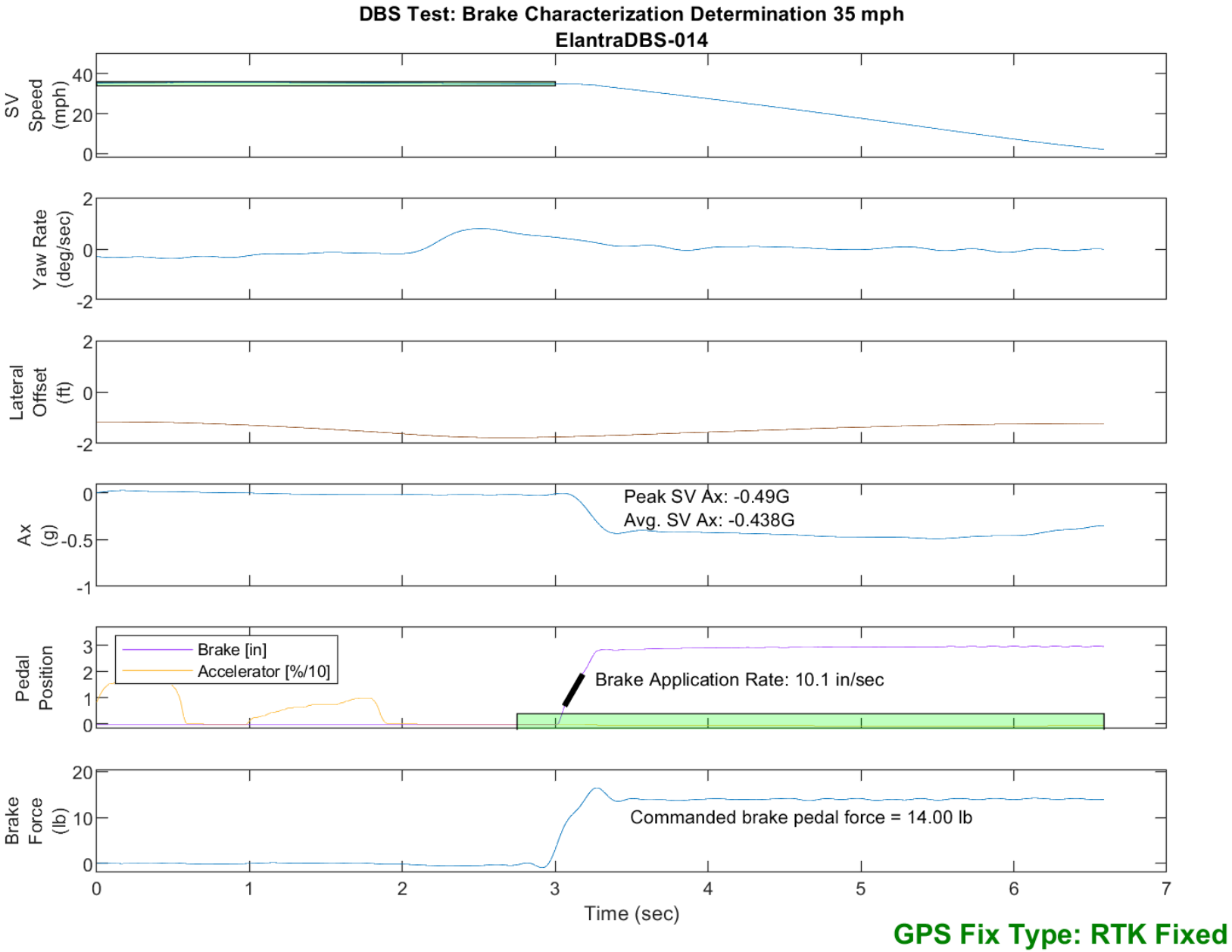


Figure E79. Time History for DBS Run 14, Brake Characterization Determination, Hybrid Mode, 35 mph

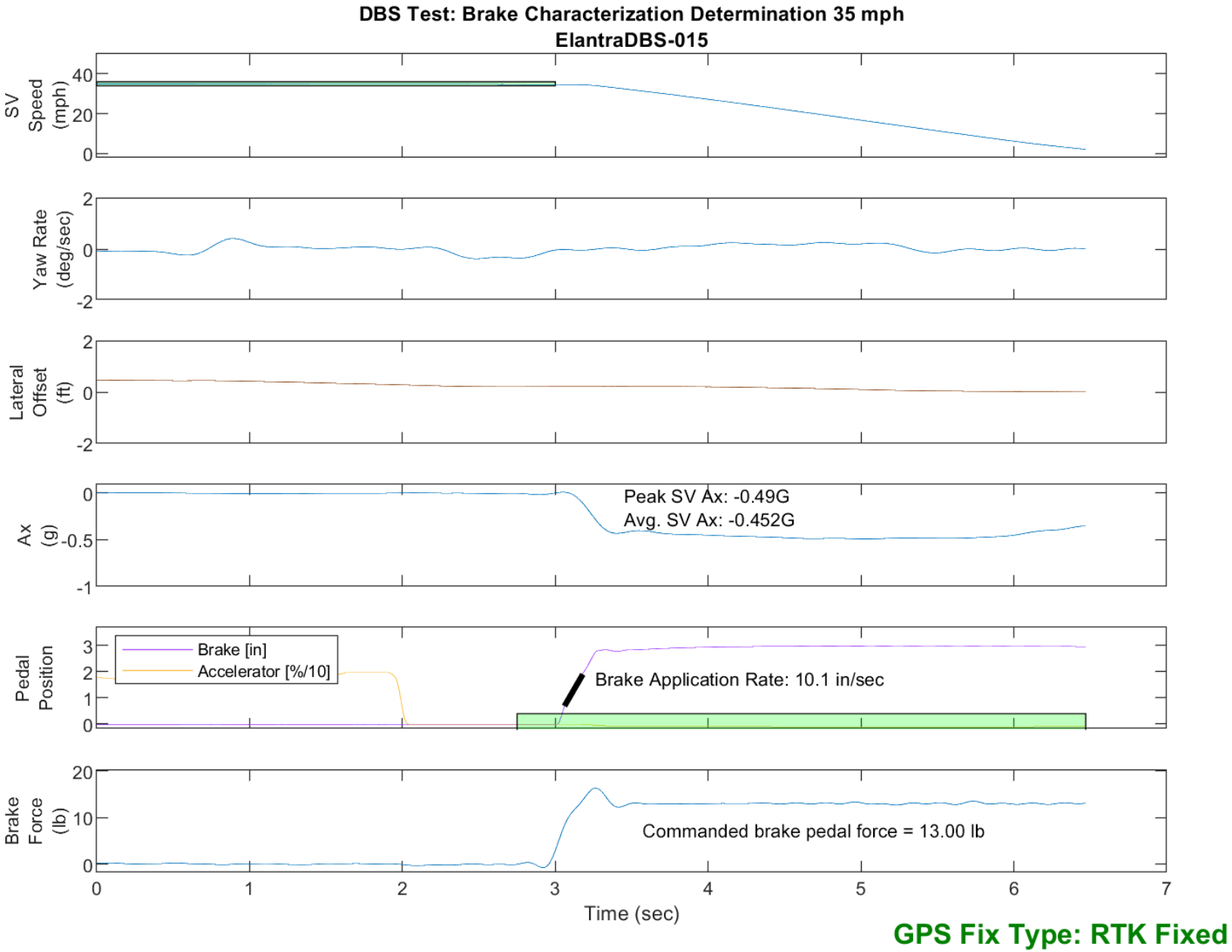


Figure E80. Time History for DBS Run 15, Brake Characterization Determination, Hybrid Mode, 35 mph

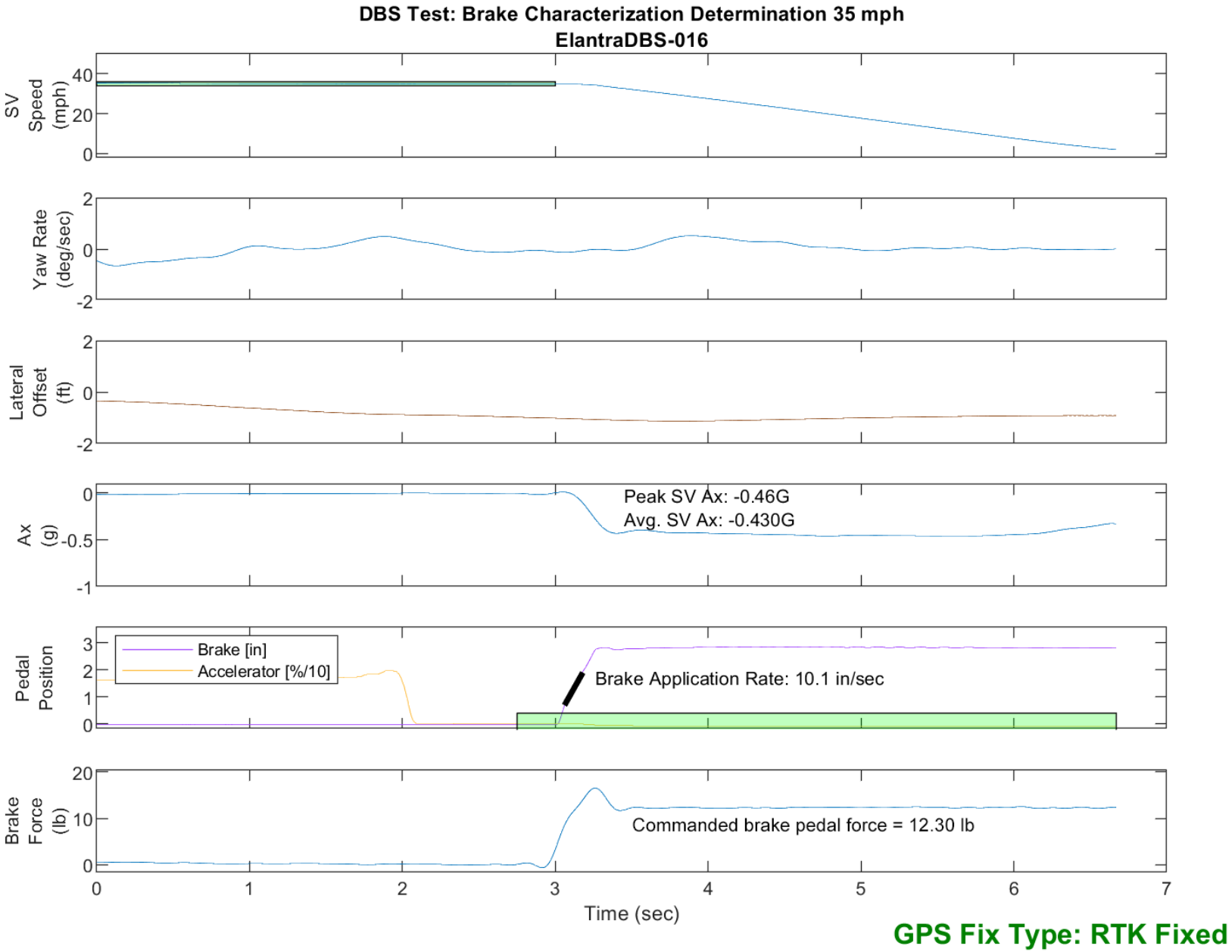


Figure E81. Time History for DBS Run 16, Brake Characterization Determination, Hybrid Mode, 35 mph

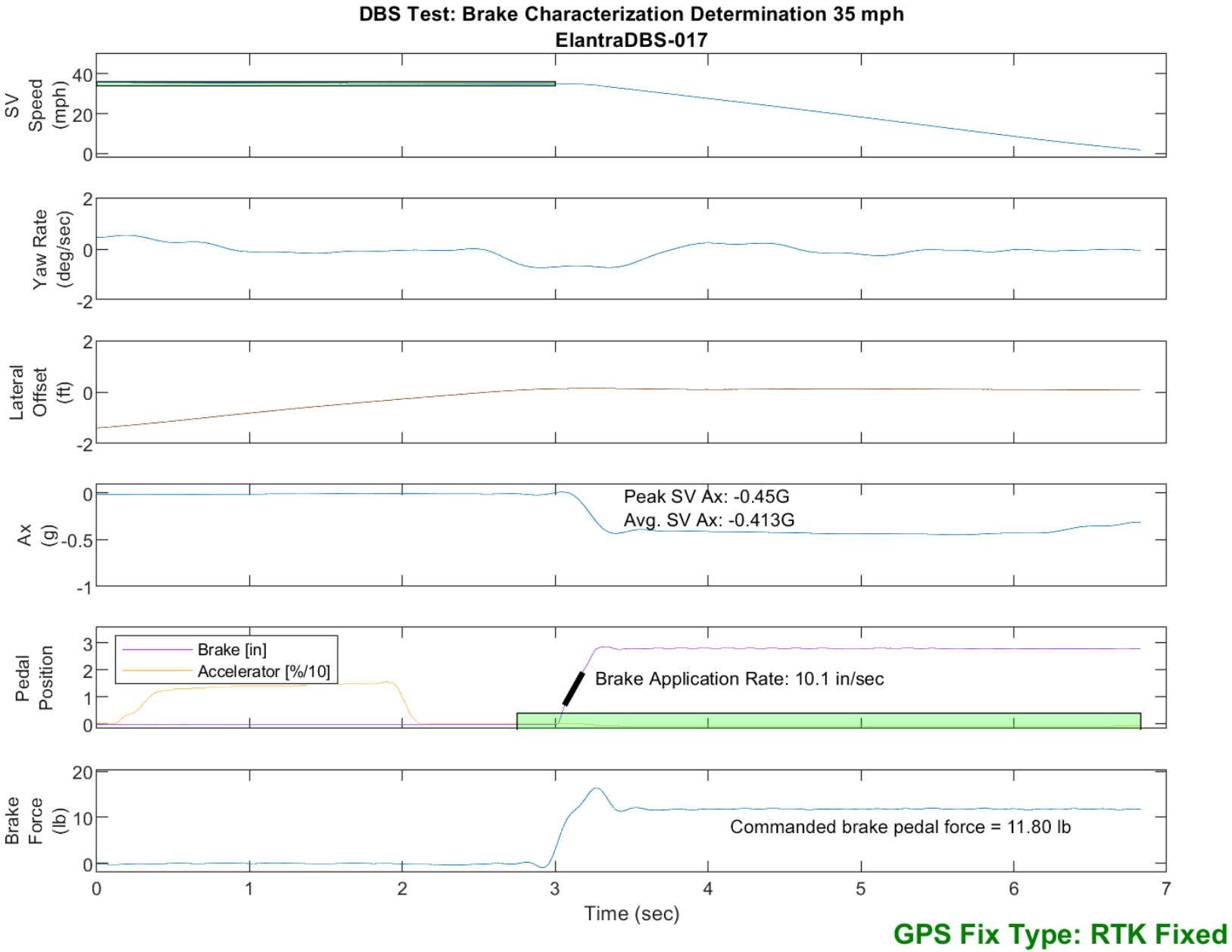


Figure E82. Time History for DBS Run 17, Brake Characterization Determination, Hybrid Mode, 35 mph

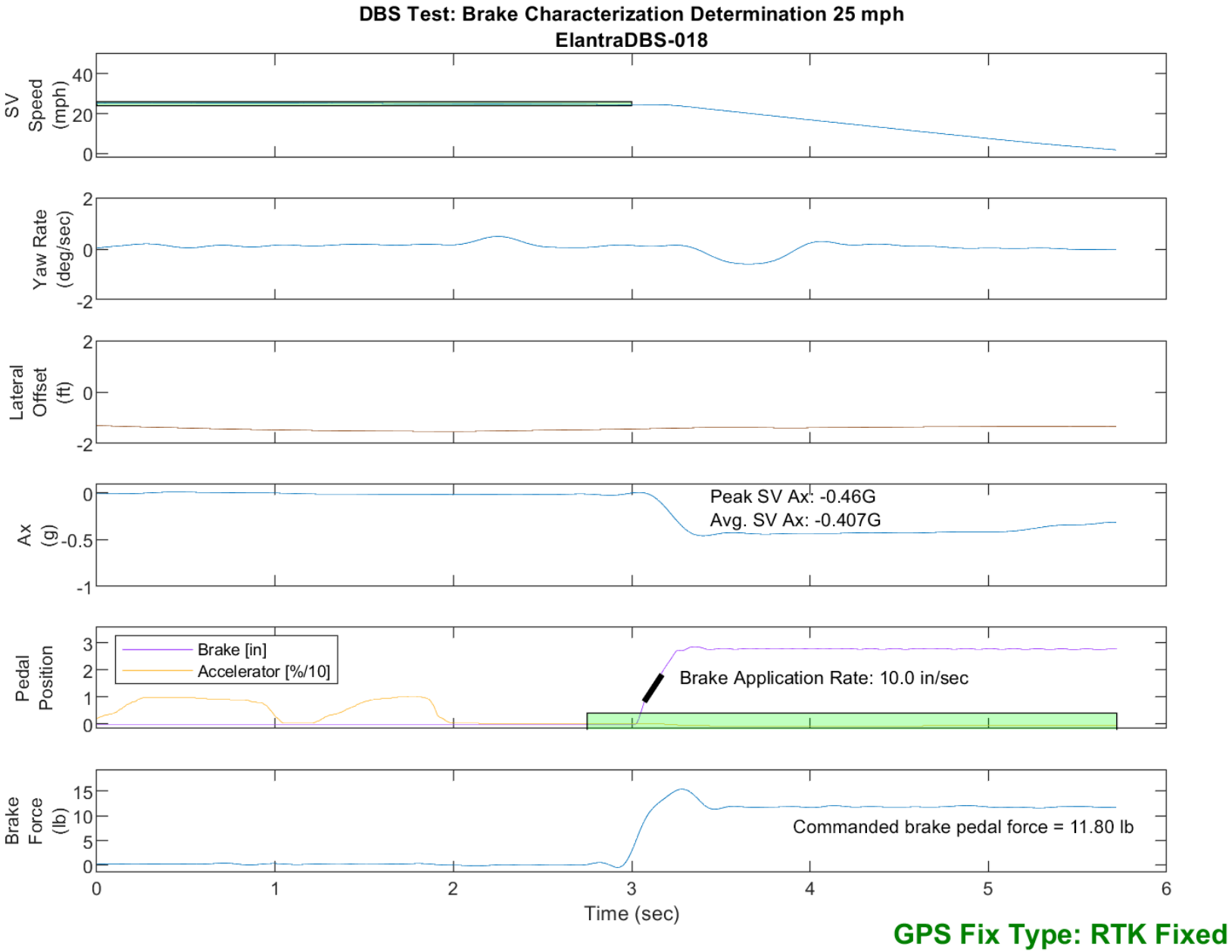


Figure E83. Time History for DBS Run 18, Brake Characterization Determination, Hybrid Mode, 25 mph

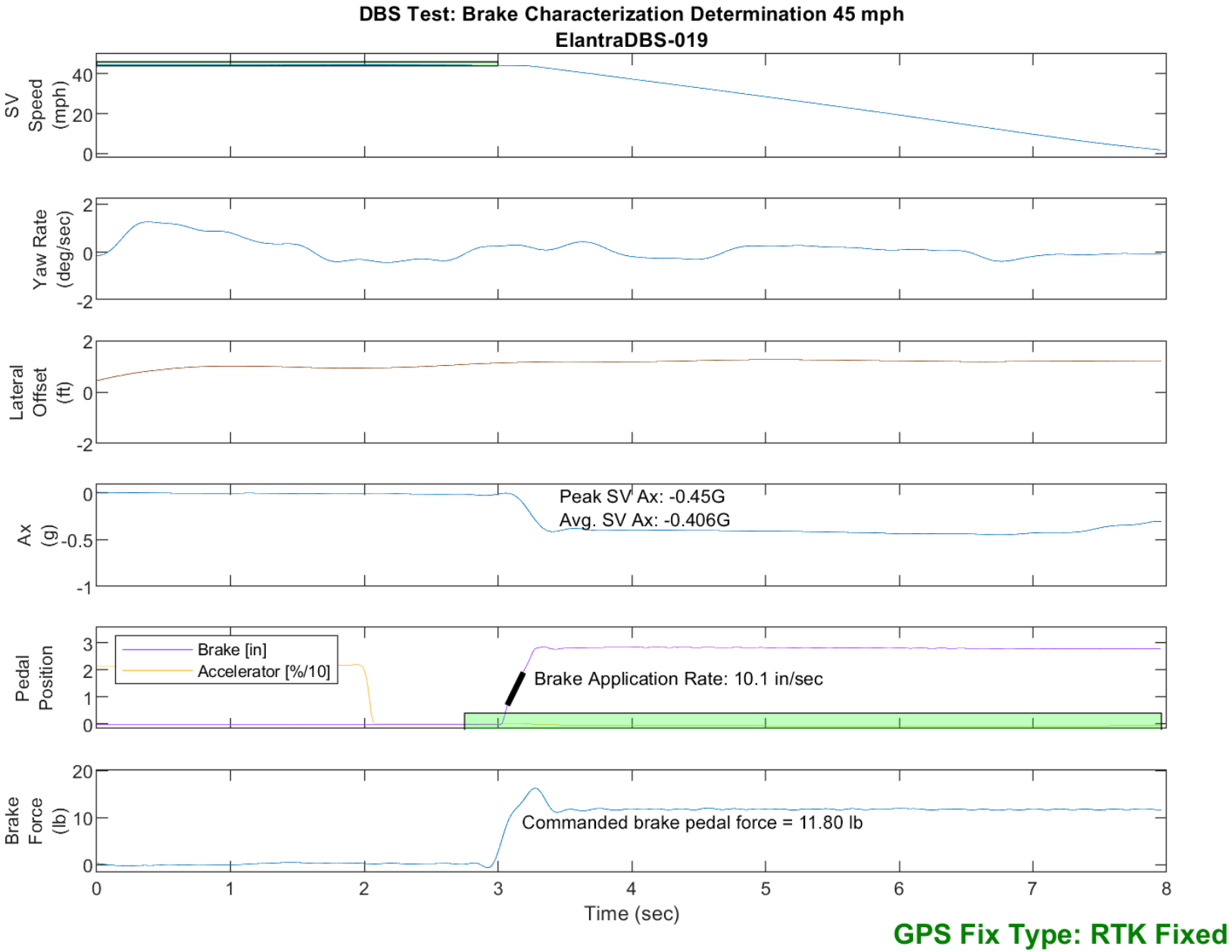


Figure E84. Time History for DBS Run 19, Brake Characterization Determination, Hybrid Mode, 45 mph

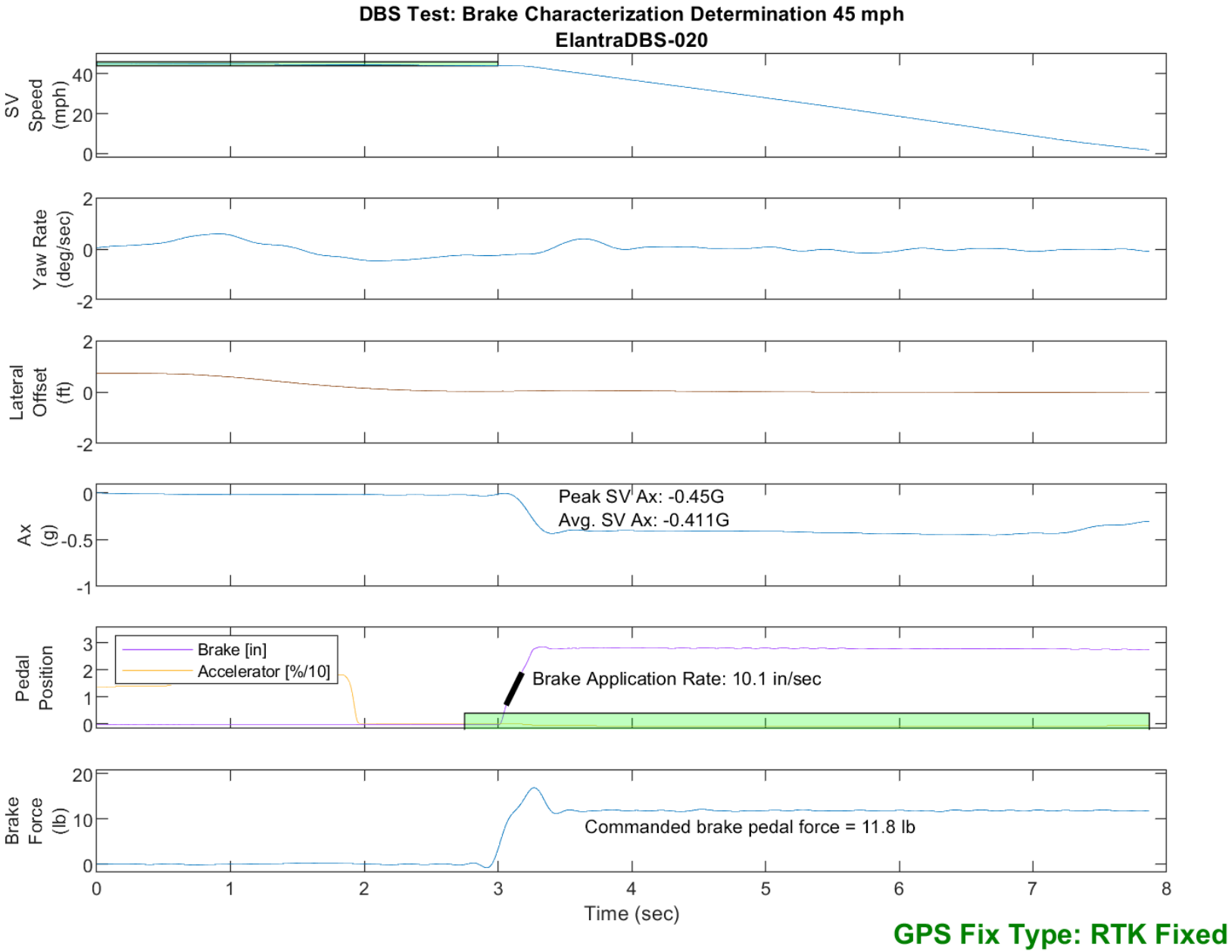


Figure E85. Time History for DBS Run 20, Brake Characterization Determination, Hybrid Mode, 45 mph