NEW CAR ASSESSMENT PROGRAM
DYNAMIC BRAKE SUPPORT SYSTEM CONFIRMATION TEST
NCAP-DRI-DBS-20-07

2020 Kia Niro Hybrid EX Premium

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1 July 2020

Final Report

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

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

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16. Abstract

These tests were conducted on the subject 2020 Kia Niro Hybrid EX Premium 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.

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Section I

INTRODUCTION

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

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

The method prescribed by the National Highway Traffic Safety Administration (NHTSA) to evaluate DBS performance on the test track involves three longitudinal, rear-end type crash configurations and a false positive test. In the rear-end scenarios, a subject vehicle (SV) approaches a stopped, slower-moving, or decelerating principal other vehicle (POV) in the same lane of travel. For these tests, the POV is a strikeable object with the characteristics of a compact passenger car. The fourth scenario is used to evaluate the propensity of a DBS system to inappropriately activate in a non-critical driving scenario that does not present a safety risk to the SV occupant(s).

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

Section II

DATA SHEETS

DYNAMIC BRAKE SUPPORT

DATA SHEET 1: TEST RESULTS SUMMARY

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2020 Kia Niro Hybrid EX Premium

VIN: *KNDCE3LC3L537xxxx*

Test Date: *6/3/2020*

Dynamic Brake Support System setting: *Forward Safety: Active Assist on*
Warning Timing: Normal

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)

2020 Kia Niro Hybrid EX Premium

TEST VEHICLE INFORMATION

VIN: *KNDCE3LC3L537xxxx*

Body Style: *SUV* Color: *Silky Silver*

Date Received: *5/26/2020* Odometer Reading: *25 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *KIA MOTORS CORPORATION*

Date of manufacture: *12/19*

Vehicle Type: *MPV*

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: *205/60R16*

Rear: *205/60R16*

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

Rear: *250 kPa (36 psi)*

TIRES

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

Front tire specification: *205/60R16 92H*

Rear tire specification: *205/60R16 92H*

Front tire DOT prefix: *B3 7R 04MX*

Rear tire DOT prefix: *B3 7R 04MX*

DYNAMIC BRAKE SUPPORT

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Kia Niro Hybrid EX Premium

GENERAL INFORMATION

Test date: *6/3/2020*

AMBIENT CONDITIONS

Air temperature: *28.3 C (83 F)*

Wind speed: *2.6 m/s (5.8 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: *250 kPa (36 psi)*

Rear: *250 kPa (36 psi)*

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*482.6 kg (1064 lb)*	Right Front:	*453.6 kg (1000 lb)*
Left Rear:	*330.7 kg (729 lb)*	Right Rear:	*311.6 kg (687 lb)*
		Total:	*1578.5 kg (3480 lb)*

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 1 of 3)

2020 Kia Niro Hybrid EX Premium

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

Forward Collision Avoidance Assist-Ped (FCA-Ped)

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

The system uses a fusion type which includes radar and mono camera. The camera is located behind the windshield near the rearview mirror and the radar is located behind the front grille.

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

Warning Timing: Normal

Brake application mode used for test: *Hybrid control*

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

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

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

80 km/h (50 mph) (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

___ Yes

X No

If yes, please provide a full description.

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

X Yes

___ No

If yes, please provide a full description.

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

How is the Forward Collision Warning presented to the driver?

(Check all that apply)

X Warning light

X Buzzer or audible alarm

X Vibration

____ Other ____________

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

The driver is alerted by images in the instrument cluster, an auditory alert and a steering wheel vibration.

The image initially shown in the instrument cluster is shown in Appendix A, Figure A19. When the system determines that braking is needed, the words "Emergency Braking" replace "Collision Warning". See the Owner's Manual pages 5-72 and 5-73 shown in Appendix B, Pages B-9 and B-10.

The auditory alert is a 1500 Hz tone that is initially pulsed approximately 8 times per second and then becomes continuous.

Is there a way to deactivate the system?

X Yes

____ No

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

2020 Kia Niro Hybrid EX Premium

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

The driver can deactivate the FCA using controls located on the right side of the steering wheel to interact with menus on the LCD. The sequence is:

User Settings

Driver Assistance

Forward Safety

Select "Off" or deselect "Active Assist"

See Appendix A, Figure A16.

The 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.

The driver can adjust the warning timing using controls located on the right side of the steering wheel to interact with menus on the LCD. The sequence is:

User Settings

Driver Assistance

Warning Timing

Select: Normal or Later

See Appendix A, Figure A17.

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.

System limitations are described in the Owner's Manual, Pages 5-78 through 5-85 shown in Appendix B, Pages B-15 through B-22.

Notes:

Section III

TEST PROCEDURES

A. Test Procedure Overview

Four test scenarios were used, as follows:

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

Test 2. Subject Vehicle Encounters Slower Principal Other Vehicle

Test 3. Subject Vehicle Encounters Decelerating Principal Other Vehicle

Test 4. Subject Vehicle Encounters Steel Trench Plate

An overview of each of the test procedures follows.

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

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

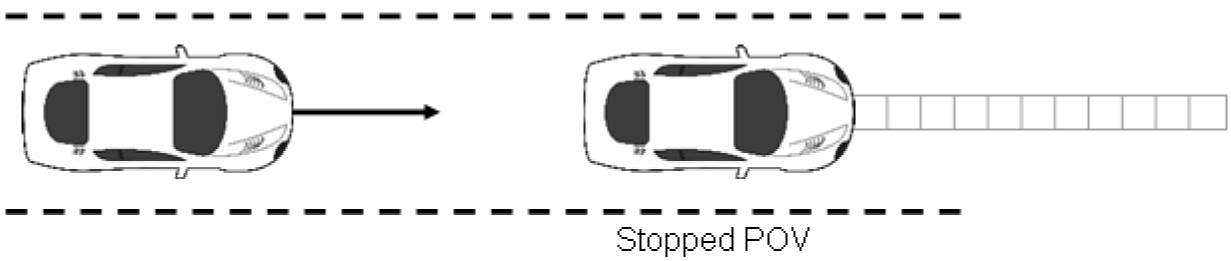


Figure 1. Depiction of Test 1

a. Procedure

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

The SV ignition was cycled prior to each test run. The SV was driven at a nominal speed of 25 mph (40.2 km/h) in the center of the lane of travel, toward the parked POV. The SV throttle pedal was released within 500 ms after t_{FCW}, i.e., within 500 ms of the FCW alert. The SV brakes were applied at TTC = 1.1 seconds (SV-to-POV distance of 40 ft (12 m)). The test concluded when either:

- The SV came into contact with the POV or

- The SV came to a stop before making contact with the POV.

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

- The SV speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during an interval defined by a Time to Collision (TTC) = 5.1 seconds to t_{FCW}. For this test, TTC = 5.1 seconds is taken to occur at an SV-to-POV distance of 187 ft (57 m).

Table 1. Nominal Stopped POV DBS Test Choreography

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

b. Criteria

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

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

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.

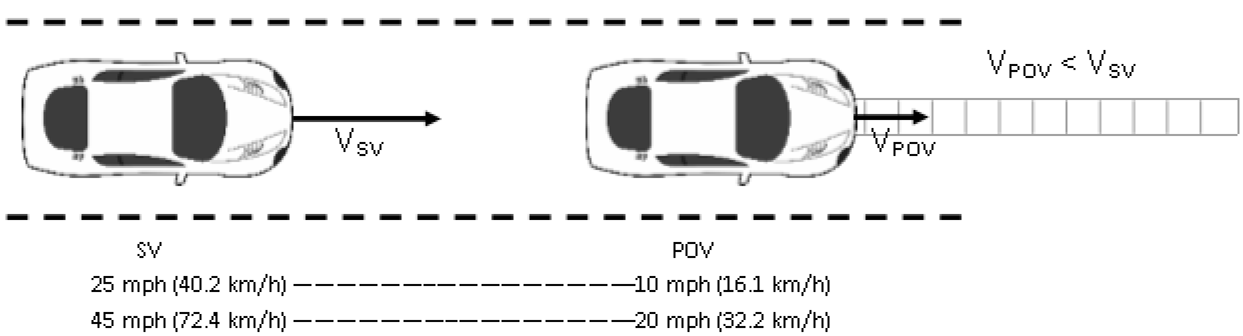


Figure 2. Depiction of Test 2

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.

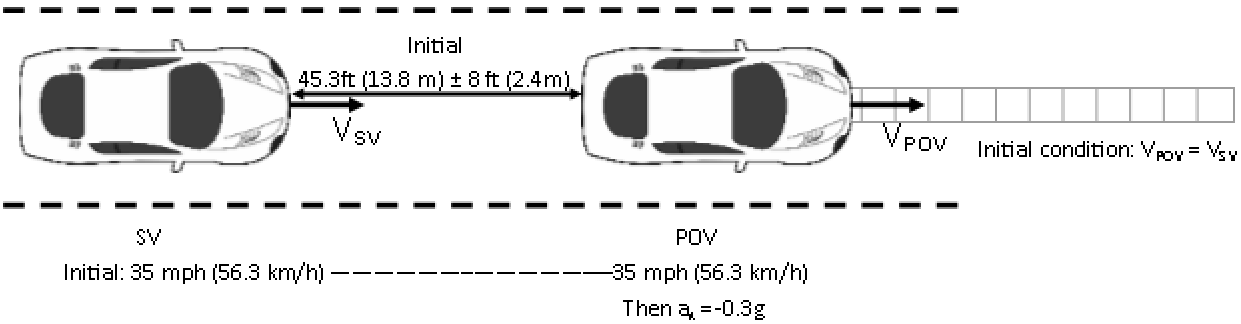


Figure 3. Depiction of Test 3

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. <u>TEST 4 – FALSE POSITIVE SUPPRESSION</u>

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

a. Procedure

This test was conducted at two speeds, 25 mph (40.2 km/h) and 45 mph (72.4 km/h). The SV was driven directly towards, and over, the STP, which was positioned in the center of a travel lane, with its longest sides parallel to the road edge. The SV was driven at constant speed in the center of the lane toward the STP. If the SV did not present an FCW alert during the approach to the STP by TTC = 2.1 s, the SV driver initiated release of the throttle pedal at TTC = 2.1 s and the throttle pedal was fully released within 500 ms of TTC = 2.1 s. The SV brakes were applied at TTC of 1.1 seconds, assumed to be 40 ft (12.3 m) from the edge of the STP at 25 mph or 73 ft (22.1 m) at 45 mph. The test concluded when the front most part of the SV reached a vertical plane defined by the edge of the STP first encountered by the SV.

b. Criteria

In order to pass the False Positive test series, the magnitude of the SV deceleration reduction attributable to DBS intervention must have been less than or equal to 1.25 times the average of the deceleration experienced by the baseline command from the braking actuator for at least five of seven valid test trials.

B. General Information

1. T_{FCW}

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

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

Table 4. Audible and Tactile Warning Filter Parameters

Warning Type	Filter Order	Peak-to-Peak Ripple	Minimum Stop Band Attenuation	Passband Frequency Range
Audible	5^{th}	3 dB	60 dB	Identified Center Frequency ± 5%
Tactile	5^{th}	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, 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. <u>NUMBER OF TRIALS</u>

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. <u>TRANSMISSION</u>

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

C. Principal Other Vehicle

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

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

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

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

The key requirements of the POV element are to:

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

The key requirements of the POV delivery system are to:

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

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

D. Foundation Brake System Characterization

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

This characterization was accomplished by recording longitudinal acceleration and brake pedal force and travel data for a variety of braking runs. For three initial brake characterization runs, the vehicle was driven at 45 mph, and the brakes were applied at a rate of 1 inch/sec up to the brake input level needed for at least 0.7 g. Linear regressions were performed on the data from each run to determine the linear vehicle deceleration response as a function of both applied brake pedal force and brake pedal travel. The brake input force or displacement level needed to achieve a vehicle deceleration of 0.4 g was determined from the average of the three runs. Using the 0.4 g brake input force or displacement level found from the three initial runs, subsequent runs were performed at 25 mph, 35 mph, and 45 mph, with the brakes applied at a rate of 10 inch/sec to the determined 0.4 g brake input force or displacement level. For each of the three test speeds, if the average calculated deceleration level was found to be within 0.4 ± 0.025 g, the resulting force or displacement was recorded and used. If the average calculated deceleration level exceeded this tolerance, the brake input force or displacement levels were adjusted and retested until the desired magnitude was realized. Prior to each braking event, the brake pad temperatures were required to be in the range of 149° - 212°F.

E. Brake Control

1. SUBJECT VEHICLE PROGRAMMABLE BRAKE CONTROLLER

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

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

2. SUBJECT VEHICLE BRAKE PARAMETERS

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

3. POV AUTOMATIC BRAKING SYSTEM

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

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

F. Instrumentation

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

Table 5. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	< 1% error between 20 and	Omega DPG8001	17042707002	By: DRI Date: 7/3/2019 Due: 7/3/2020
Platform Scales	Vehicle Total, Wheel, and Axle Load	1500 lb/platform 6672 N	0.5% of applied load	Intercomp SW II	NT2888	By: DRI Date: 1/16/2020 Due: 1/16/2021
Linear (string) encoder	Throttle pedal travel	10 in 254 mm	0.1 in 2.54 mm	UniMeasure LX-EP	49041189	By: DRI Date: 5/22/20 Due: 5/22/2021
Load Cell	Force applied to brake pedal					By: DRI
		0 - 250 lb 0 -1112 N	0.1% FS	Honeywell 41A	1464391	Date: 8/30/2019 Due: 8/30/2020
		0-250 lb 1112 N	0.05% FS	Stellar Technology PNC700	1607338	Date: 8/30/2019 Due: 8/30/2020
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	NA

Table 5. Test Instrumentation and Equipment (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; 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	NA
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	NA	NA
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	NA	NA
Accelerometer	Acceleration (to measure time at alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	NA	NA

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

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

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

Figure A3. Window Sticker (Monroney Label)

Figure A4. Vehicle Certification Label

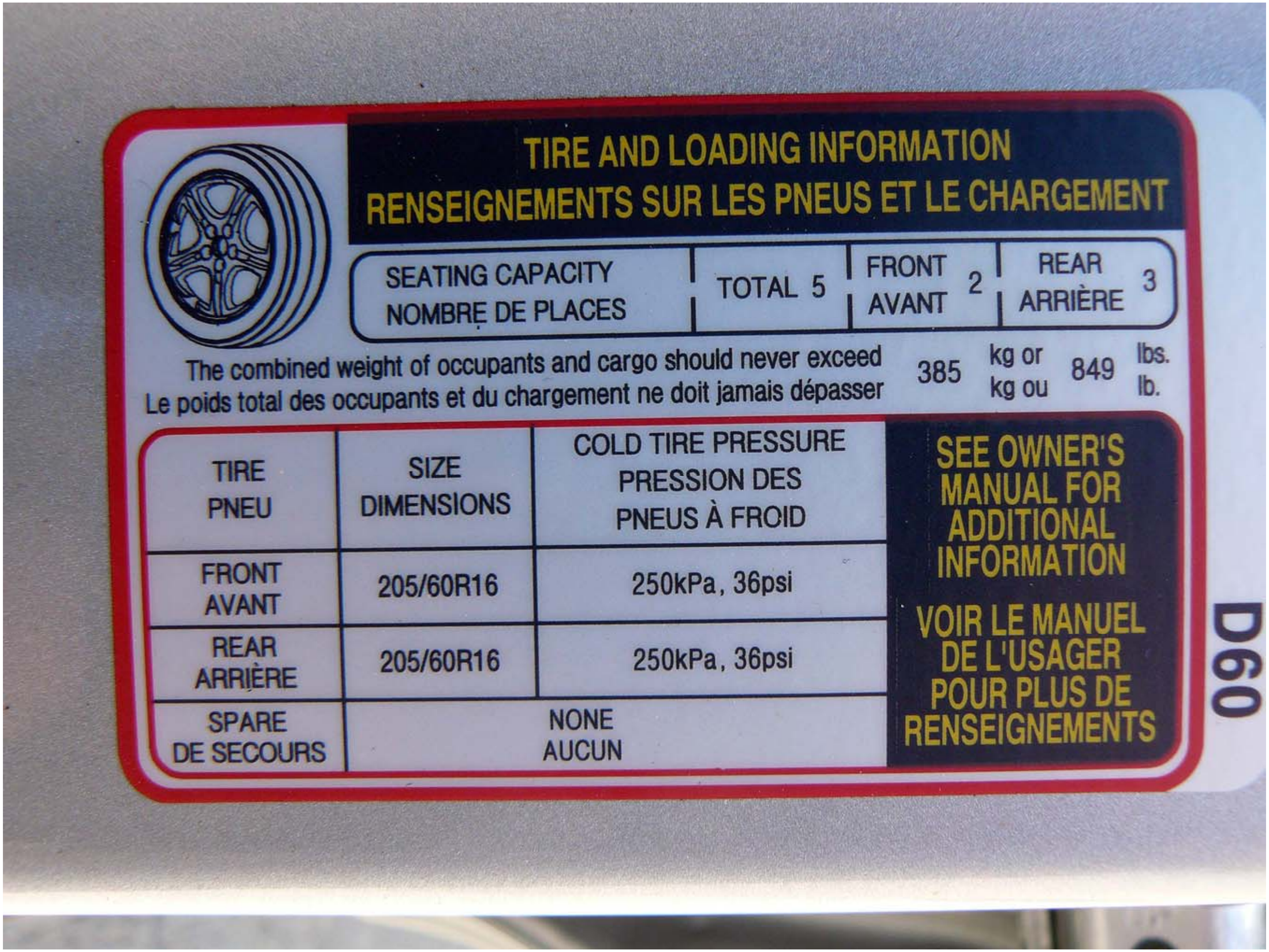


Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

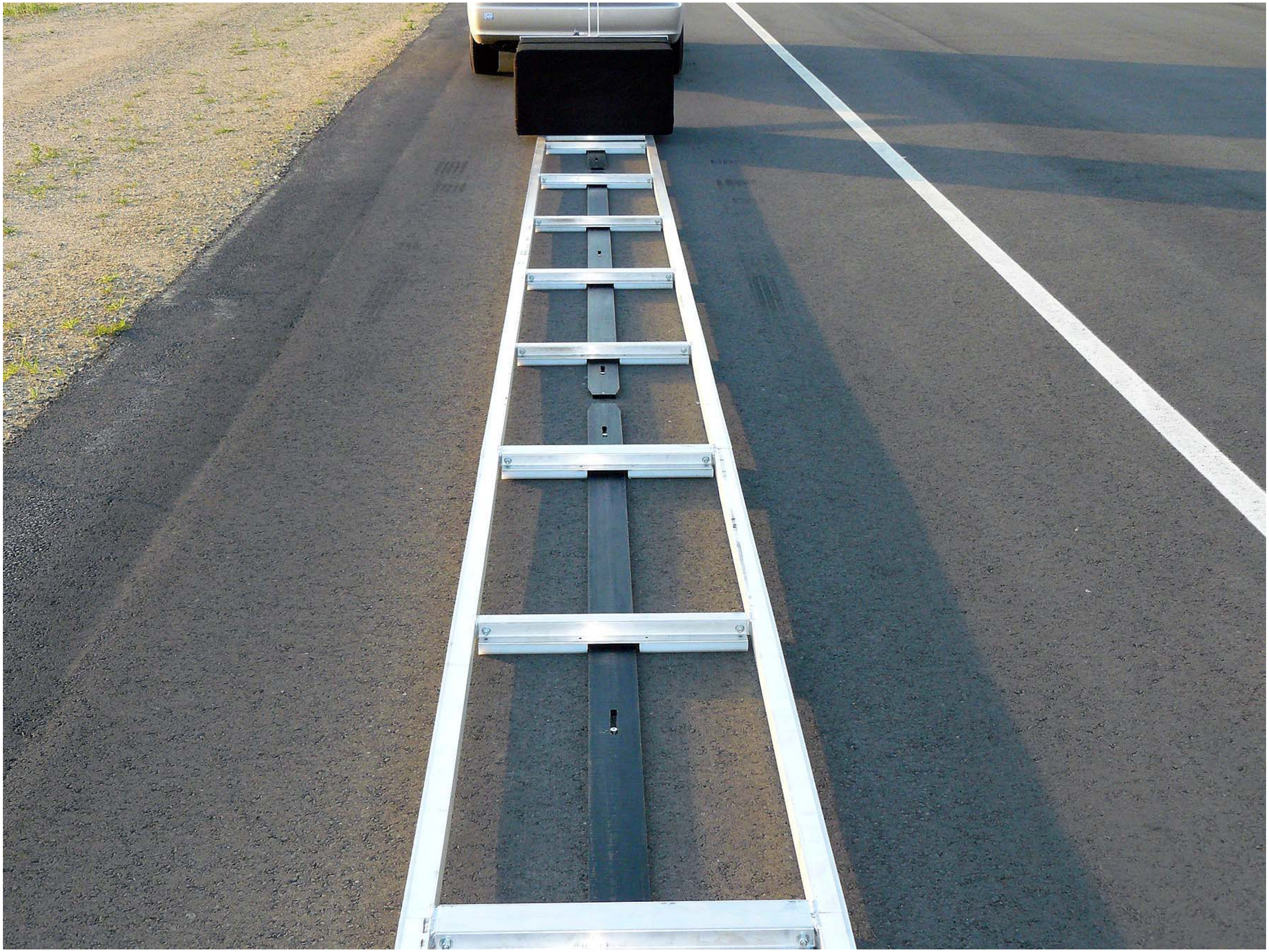


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

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

Figure A11. Sensor for Detecting Auditory Alerts

Figure A12. Sensor for Detecting Visual Alerts

Figure A13. Computer Installed in Subject Vehicle

Figure A14. Brake Actuator Installed in Subject System

Figure A15. Brake Actuator Installed in POV System

Figure A16. Menu Page for AEB Settings (page 1 of 2)

Figure A17. Menu Page for AEB Settings (page 2 of 2)

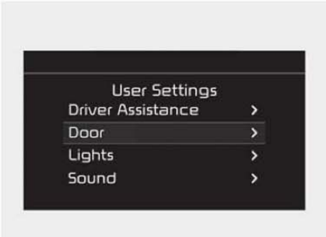
Figure A18. Controls for Changing System Setup Parameters

Figure A19. AEB Visual Alert

APPENDIX B

Excerpts from Owner's Manual

User settings mode (if equipped)



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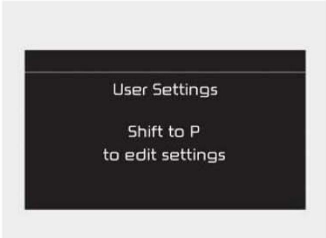
In this mode, you can change the settings of the instrument cluster, doors, lamps, etc.

1. Driver Assistance
2. Door
3. Lights
4. Sound
5. Convenience
6. Service Interval
7. Other
8. Language
9. Reset

The information provided may differ depending on which functions are applicable to your vehicle.



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Shift to P to edit settings

This warning message appears if you try to adjust the User Settings while driving.

For your safety, change the User Settings after parking the vehicle, applying the parking brake and moving the shift lever to P (Park).

1. Driver Assistance (if equipped)

Items	Explanation
SCC Reaction	• Fast/Normal/Slow To adjust the sensitivity of Smart Cruise Control system. ❇ For more details, refer to “Smart Cruise Control (SCC)” in chapter 5.
Driving Assist	• Lane Following Assist To select the function. ❇ For more details, refer to “Lane Following Assist (LFA)” in chapter 5. • Highway Driving Assist To select the function. ❇ For more details, refer to “Highway Driving Assist (HDA)” in chapter 5.
Driver Attention Warning	• Leading Vehicle Departure Alert To select the function. ❇ For more details, refer to “Leading vehicle departure alert” in chapter 5. • Low Activity Warning To select the function. ❇ For more details, refer to “Driver Attention Warning (DAW)” in chapter 5.
Warning Timing	• Normal/Later To select when to provide a warning for all driver assistance system.

❇ The information provided may differ depending on which functions are applicable to your vehicle.

Items	Explanation
Forward Safety	• Active Assist/Warning Only/Off To select the function. ❇ For more details, refer to "Forward Collision-Avoidance Assist (FCA)" in chapter 5.
Lane Safety	• Lane Keeping Assist / Lane Departure Warning / Off To select the function. ❇ For more details, refer to "Lane Keeping Assist (LKA)" in chapter 5.
Blind-Spot Safety	• Warning Only/Off To select the function. ❇ For more details, refer to "Blind-spot Collision Warning (BCW)" in chapter 5.
Parking Safety	• Rear Cross-Traffic Safety To select the function. ❇ For more details, refer to "Rear Cross-traffic Collision Warning (RCCW)" in chapter 5.

❇ The information provided may differ depending on which functions are applicable to your vehicle.

Electronic Parking Brake (EPB) Warning Light (if equipped)

EPB

This warning light illuminates:

- Once 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 the EPB.

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

✽ NOTICE - Electronic Parking Brake (EPB) Warning Light

The Electronic Parking Brake (EPB) Warning Light may illuminate when the Electronic Stability control (ESC) Indicator Light comes on to indicate that the ESC is not working properly (This does not indicate malfunction of the EPB).

LED Headlamp Warning Light (if equipped)

This warning light illuminates:

- Once 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 the LED headlamp.

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

⚠ CAUTION - LED Headlamp Warning Light

Continuous driving with the LED Headlamp Warning Light on can reduce LED headlamp (low beam) life.

Forward Collision-Avoidance Assist System Warning Light (if equipped)

This warning light illuminates:

- Once you set the ignition switch or ENGINE START/STOP button to the ON position.
  - The FCA warning light illuminates for approximately 3 seconds and then turns off.
- When there is a malfunction with FCA.

  If this occurs, have your vehicle inspected by an authorized Kia dealer.

❈ For more details, refer to “Forward Collision-Avoidance Assist (FCA)” in chapter 5.

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

FCA system is to reduce or to avoid accident risk. It recognizes the distance from the vehicle ahead, the pedestrian or the cyclist through the sensors (i.e. front view camera and front radar), and, if necessary, warns the driver of accident risk with the warning message or the warning alarms and apply emergency braking.

❈ FCA stands for Forward Collision-Avoidance Assist.

❈ Sensor fusion (front view camera + front radar) FCA system operates for the vehicle ahead, the pedestrian or the cyclist in front.

⚠ WARNING

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

- **This system is only a supplemental system and it is not intended to, nor does it replace the need for the extreme care and attention of the driver. The sensing range and objects detectable by the sensors are limited. Pay attention to the road conditions at all times.**
- **NEVER drive too fast in accordance with the road conditions or while cornering.**
- **Always drive cautiously to prevent unexpected and sudden situations from occurring. FCA system does not stop the vehicle completely and is only intended to help mitigate an imminent collision.**

System setting and activation

Forward safety

The driver can activate FCA system by placing the ignition switch or ENGINE START/STOP button to the ON position and by selecting:

“User Settings → Driver Assistance → Forward Safety”

- If you select “Active Assist”, FCA system activates. FCA produces warning messages and warning alarms in accordance with the collision risk levels. Also, it controls the brakes in accordance with the collision risk levels.
- If you select “Warning Only”, FCA system activates and produces only warning alarms in accordance with the collision risk levels. You should control the brake directly because FCA system do not control the brake.
- If you select “Off”, FCA system deactivates,

The warning light illuminates on the LCD display, when you cancel FCA system. The driver can monitor the FCA ON/OFF status on the LCD display. Also, the warning light illuminates when the ESC (Electronic Stability Control) is turned off. When the warning light remains ON with FCA activated, have your vehicle inspected by an authorized Kia dealer.

Warning Timing

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The driver can select the initial warning activation time on the LCD display.

Go to the "User Settings → Driver Assistance → Warning Timing → Normal/Later"

The options for the initial Forward Collision Warning includes the following:

- Normal:

When this condition is selected, the initial Forward Collision Warning system is activated normally. This setting allows for a nominal amount of distance between the vehicle ahead before the initial warning occurs.

- Later:

When this condition is selected, the initial Forward Collision Warning system is activated later than normal. This setting reduces the amount of distance between the vehicle ahead, the pedestrian or the cyclist before the initial warning occurs.

Select 'Later' when traffic is light and when driving speed is slow.

If the vehicle in front puts on a burst of speed, the driver can notice the warning alarm is early even though the later option is selected.

✽ NOTICE

If you change the warning timing, the warning timing of other systems may change. Always be aware of warning timing before changing the warning timing.

Prerequisite for activation

FCA system gets ready to be activated, when the “Active assist” or “Warning only” under the Forward Safety is selected on the LCD display, and when the following prerequisites are satisfied.

- The ESC is activated.
- The driving speed is over 5 mph (8 km/h). (However, FCA is activated within certain driving speed.)
- When recognizing the vehicle or the pedestrian or the cyclist in front. (However, FCA does not activate according to conditions in front and vehicle systems, but it notices only certain warnings.)
- FCA does not operate properly or it only produces a warning alarms in accordance with the driving or vehicle condition.
- If the warning only under the Forward Safety is selected, FCA produces only warning alarms in accordance with the collision risk levels.

✽ NOTICE

FCA may not operate properly according to the frontal situation, the direction of pedestrian or cyclist and speed.

⚠ WARNING

- **Completely stop the vehicle in a safe location before operating the switch on the steering wheel to activate/deactivate FCA system.**
- **FCA system automatically activates upon placing the ignition switch to the ON position. The driver can deactivate FCA system by canceling the system setting on the LCD display or Infotainment System screen.**
- **FCA system automatically deactivates upon canceling the ESC. When the ESC is canceled, FCA system cannot be activated on the LCD display or Infotainment System screen.**

  FCA system warning light will illuminate, which is normal.

FCA warning message and system control

FCA system produces warning messages and warning alarms in accordance with the collision risk levels of followings like vehicle's sudden braking in front or lack of vehicle to vehicle distance or collision to pedestrians or cyclist. Also, it controls the brakes in accordance with the collision risk levels.

The driver can select the initial warning activation time in the User settings in the LCD display. The options for the initial Forward Collision Warning include Normal or Late initial warning time.

Collision Warning (1st warning)

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- The warning message appears on the LCD display with the warning alarms.
- The Vehicle may slow down slightly
  - It will operate if the vehicle speed is greater than 5 mph (8 km/h) and less than or equal to 110 mph (180 km/h) on a forward vehicle. (Depending on the condition of the vehicle ahead and the environment surrounding it, the possible maximum operating speed may be reduced.)

- For pedestrians and cyclists, the vehicle speed is greater than or equal to 5 mph (8 km/h) and less than 45 mph (70 km/h). (Depending on the condition of pedestrians and bike riders and the surrounding environment the possible maximum operating speed may be reduced.)

- FCA system controls the brakes within certain limit to release shock from the collision.
  - If you select “Warning Only”, FCA system activates and produces only warning alarms in accordance with the collision risk levels. You should control the brake directly because FCA system do not control the brake.

Emergency braking (2nd warning)

OJF058390L

- The warning message appears on the LCD display with the warning alarms.
- The brake control is maximized just before a collision, reducing impact when it strikes a forward vehicle.
  - It will operate if the vehicle speed is greater than 5 mph (8 km/h) and less than or equal to 50 mph (80 km/h) on a forward vehicle. (Depending on the condition of the vehicle ahead and the environment surrounding it, the possible maximum operating speed may be reduced.)
  - For pedestrians and cyclists, the vehicle speed is greater than or equal to 5 mph (8 km/h) and less than 45 mph (70 km/h). (Depending on the condition of pedestrians and bike riders and the surrounding environment the possible maximum operating speed may be reduced.)
- FCA system controls the brakes within certain limit to release shock from the collision.

  FCA system controls the maximum brakes just before the collision.
  - If you select “Warning Only”, FCA system activates and produces only warning alarms in accordance with the collision risk levels. You should control the brake directly because FCA system do not control the brake.

Brake operation

- In an urgent situation, the braking system enters into the ready status for prompt reaction to assist the driver in depressing the brake pedal.
- FCA system provides additional braking power for optimum braking performance, when the driver depresses the brake pedal.
- The braking control is automatically deactivated, when the driver sharply depresses the accelerator pedal, or when the driver abruptly operates the steering wheel.
- The braking control is automatically canceled, when risk factors disappear.

⚠ CAUTION

The driver should always pay great caution to vehicle operation, even though there is no warning message or warning alarm.

⚠ WARNING

FCA system cannot avoid all collisions. FCA system might not completely stop the vehicle before a collision, due to ambient, weather and road conditions. The driver has the responsibility to drive safely and control the vehicle.

⚠ WARNING

FCA system operates in accordance with certain risk factors, such as the distance from the vehicle/passer-by in front, the speed of the vehicle/passer-by in front, and the driver's vehicle operation.

Detecting sensors (front view camera/front radar)

ODEP059029

ODEP059017

The sensors are that detecting the distance to vehicles ahead, pedestrian or cyclist.

In bad weather conditions such as heavy rain, heavy snow, and fog, or when sensor is covered by foreign material, dust, tec., the sensors will be degraded and the system will be temporarily disabled.

Always keep the sensor clean.

✻ NOTICE

- **Do not install any accessories, such as license plate molding or sticker, on the sensor area. Nor arbitrarily replace the bumper. Those may adversely affect the sensing performance.**
- **Always keep the sensor/bumper area clean.**
- **Use only soft cloths to wash the vehicle. Also, do not spray highly-pressurized water on the sensor installed on the bumper.**
- **Be careful not to apply unnecessary force on the frontal sensor area. When the sensor moves out of the correct position due to external force, the system may not normally operate even without the warning light or message. In this case, have your vehicle inspected by an authorized Kia dealer.**
- **Use only the genuine Kia sensor cover. Do not arbitrarily apply paint on the sensor cover.**

(Continued)

(Continued)

- **Do not tint the window or install stickers, accessories around the inside mirror where the camera is installed.**
- **Make sure the frontal camera installation point does not get wet.**
- **Do not impact or arbitrarily remove any radar/camera components.**
- **Do not place reflective objects(white paper or mirror etc.) on the crash pad.**
  The system may activate unnecessarily due to reflect of the sunlight.
- **Excessive audio volume may disturb the sound of the system warning alarm.**
- **For more cautions for the camera sensor, refer to the “Lane Keeping Assist (LKA)” in this chapter.**

Warning message and warning light

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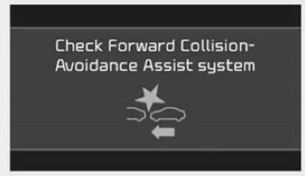
If the sensor or sensor cover is covered by bad weather or foreign objects, dust, etc., FCA system operation may temporarily stop. In this case, the warning message appears to warn the driver.

This is not a malfunction with FCA system. To operate FCA system again, remove the foreign substances.

FCA system may not properly operate when the front radar is contaminated or an object such as an open area is not existed after engine start.

> **⚠ WARNING**
>
> **FCA system may not activate without any warning messages according to driving condition, traffic on the road, weather, road condition, etc.**

System malfunction



OJF058394L

- When FCA system is not working properly, the FCA warning light ( ) will illuminate and the warning message will appear for a few seconds. After the message disappears, the master warning light ( ) will illuminate. In this case, have your vehicle inspected by an authorized Kia dealer.
- The FCA warning message may appear along with the illumination of the ESC warning light.

⚠ WARNING

- FCA system is only a supplemental system for the driver's convenience. The driver has the ultimate responsibility to control and operate the vehicle safely. Do not solely depend on FCA system. Rather, maintain a safe braking distance, and, if necessary, depress the brake pedal to lower the driving speed.
- In certain instances and under certain driving conditions, FCA system may activate unintentionally. This initial warning message appears on the LCD display with a warning chime.

(Continued)

(Continued)

Also, in certain instances the front radar sensor or camera recognition system may not detect the vehicle, pedestrian or cyclist (if equipped) ahead. FCA system may not activate and the warning message will not be displayed.

- FCA system may unnecessarily produce the warning message and the warning alarms. Also, due to the sensing limitation, FCA system may not produce the warning message and the warning alarm at all.
- When there is a malfunction with FCA system, the braking control does not operate upon detecting a collision risk even with other braking systems normally operating.

(Continued)

(Continued)

- FCA system operates only for the vehicle/pedestrian in front, while driving forward. It does not operate for any animals or vehicles in the opposite direction.
- FCA system does not recognize the vehicle, which transversally drives across the crossroad, or the vehicle, which is parked in the transversal direction.
- If the vehicle in front stops suddenly, you may have less control of the brake system. Therefore, always keep safe distance between your vehicle and the vehicle in front of you.
- FCA system may activate during braking and the vehicle may stop suddenly. And the load in the vehicle may endanger passengers. Therefore, always be mindful of the load volume in the vehicle.

(Continued)

(Continued)
- **FCA system may not activate if the driver applies the brake pedal to avoid risk of collision.**
- **FCA system does not operate when the vehicle is in reverse. In these circumstances, you must maintain a safe braking distance, and if necessary, depress the brake pedal to reduce the driving speed in order to maintain a safe dis tance.**
- **The regular braking function will operate normally even if There is a problem with the FCA brake control system or other functions. In this case, the braking control will not operate in an imminent collision.**

(Continued)

(Continued)
- **FCA system may not activate according to driving condition, traffic on the road, weather, road condition, etc.**
- **FCA system may not activate in response to all types of vehicles.**

Limitation of the system

FCA system is an assistant system for a driver in a certain risky driving condition and it does not take every responsibility for all risks from driving condition.

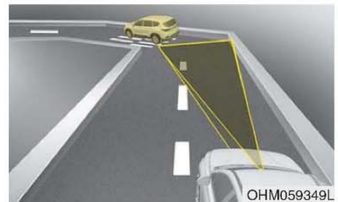
FCA system monitors the driving situations through the radar and the camera sensor. Thus, for a situation out of the sensing range, FCA system may not normally operate. The driver should pay great caution in the following situations. FCA system operation may be limited.

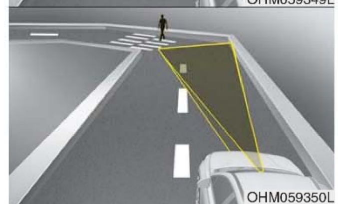
Recognizing vehicles

The sensor may be limited when:

- The front view camera or front radar sensor is blocked with a foreign object or debris
- The camera lens is contaminated due to tinted, filmed or coated windshield, damaged glass, or stuck of foreign matter (sticker, bug, etc.) on the glass
- Inclement weather such as heavy rain or snow obscures the field of view of the radar sensor or camera
- There is interference by electromagnetic waves
- There is severe irregular reflection from the radar sensor
- The front view camera/front radar sensor recognition is limited
- The vehicle in front is too small to be detected (for example a motorcycle etc.)
- The vehicle in front is an oversize vehicle or trailer that is too big to be detected by the camera recognition system (for example a tractor trailer, etc.)
- The camera's field of view is not well illuminated (either too dark or too much reflection or too much backlight that obscures the field of view)
- The vehicle in front does not have their rear lights or their rear lights does not turned ON or their rear lights are located unusually.
- The outside brightness changes suddenly, for example when entering or exiting a tunnel
- When light coming from a street light or an oncoming vehicle is reflected on a wet road surface such as a puddle in the road
- The field of view in front is obstructed by sun glare
- The vehicle in front is driving erratically
- The vehicle is on unpaved or uneven rough surfaces, or road with sudden gradient changes.
- The vehicle is driven near areas containing metal substances as a construction zone, railroad, etc.
- The vehicle drives inside a building, such as a basement parking lot
- The front view camera does not recognize the entire vehicle in front.
- The front view camera is damaged.
- The brightness outside is too low such as when the headlamps are not on at night or the vehicle is going through a tunnel.
- The shadow is on the road by a median strip, trees, etc.
- The vehicle drives through a tollgate.
- The windshield glass is fogged up; a clear view of the road is obstructed.
- The rear part of the vehicle in front is not normally visible. (the vehicle turns in other direction or the vehicle is overturned.)
- The adverse road conditions cause excessive vehicle vibrations while driving
- The sensor recognition changes suddenly when passing over a speed bump

- The vehicle in front is moving longitudinally to the driving direction
- The vehicle in front is stopped longitudinally
- The vehicle in front is driving towards your vehicle or reversing
- You are on a roundabout and the vehicle in front circles
- It is difficult to secure the field of view of the front view camera such as backlight, reflected light, and darkness.
- When the front camera is blocked by continuous washer spray and wiper operation.
- The vehicle in front is a special purpose vehicle, a trailer, or a truck loading with unusual shape of luggage.
- The ambient light is too high or low.
- The front view camera is contaminated by front glass tinting, attaching film, water proof coating, damaged, foreign material such as a sticker, worm, etc.
- When the front view camera (including lens) or front radar is damaged.
- If not using headlamp or using weak light in the night or in a tunnel.
- Backlight is shining in the driving direction of the vehicle. (Including oncoming vehicle headlights.)
- When the rear part of the front vehicle is small or low.
- When a trailer or other vehicle is towing the front vehicle.
- When the ground clearance of the front vehicle is high.
- When a front vehicle makes sudden lane changes unexpectedly.


OHM059349L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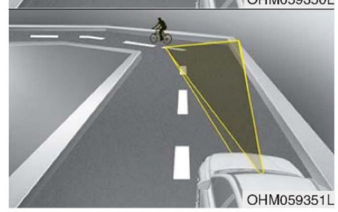

OHM059351L

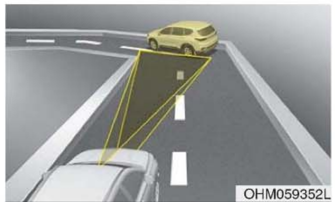
- Driving on a curve

The performance of Forward Collision-Avoidance Assist system may be limited when driving on a curved road.

The front view camera or front radar sensor recognition system may not detect the vehicle, pedestrian or cyclist traveling in front on a curved road.

This may result in no alarm and braking when necessary.

Always pay attention to road and driving conditions, and if necessary, depress the brake pedal to reduce your driving speed in order to maintain a safe distance.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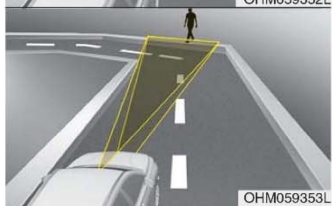
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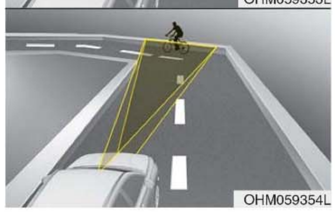
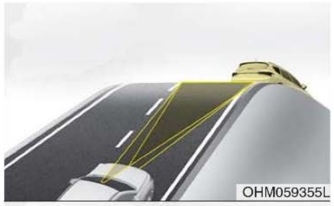

OHM059354L

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

If this occurs, the system may unnecessarily alarm the driver and apply the brake. Always pay attention to road and driving conditions, while driving.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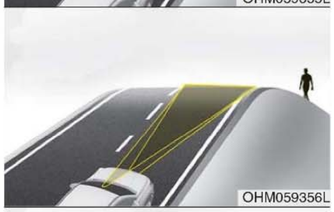
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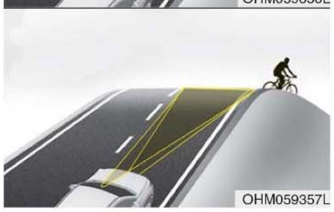

OHM059357L

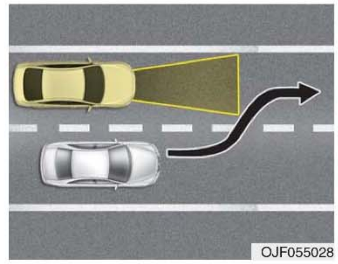
- Driving on a slope

The performance of Forward Collision-Avoidance Assist system may be decreased while driving upward or downward on a slope. The front view camera or front radar sensor recognition may not detect the vehicle, pedestrian or cyclist in front.

This may result in unnecessary alarm and braking or no alarm and braking when necessary.

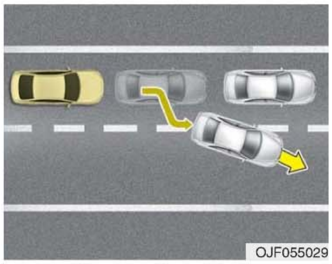
When the system suddenly recognizes the vehicle, pedestrian or cyclist in front while passing over a slope, you may experience sharp deceleration.

Always keep your eyes forward while driving upward or downward on a slope, and, if necessary, depress the brake pedal to reduce your driving speed in order to maintain distance.


OJF055028

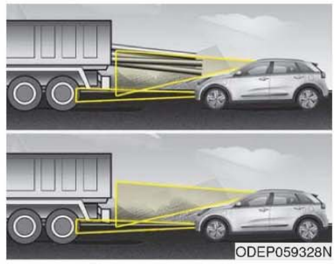
- Changing lanes

When a vehicle changes lanes in front of you, Forward Collision-Avoidance Assist system may not immediately detect the vehicle, especially if the vehicle changes lanes abruptly. In this case, you must maintain a safe braking distance, and if necessary, depress the brake pedal to reduce your driving speed in order to maintain a safe distance.



OJF055029

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



ODEP059328N

- Recognizing the vehicle

When the vehicle in front has heavy loading extended rearward, or when the vehicle in front has higher ground clearance, it may induce a hazardous situation. Always pay attention to road and driving conditions, while driving and, if necessary, depress the brake pedal to reduce your driving speed in order to maintain distance.

Detecting pedestrian or cyclist

The sensor may be limited when:

- The pedestrian or cyclist is not fully detected by the camera recognition system, for example, if the pedestrian is leaning over or is not fully walking upright
- The pedestrian or cyclist is moving very quickly or appears abruptly in the front view camera detection area
- The pedestrian or cyclist is wearing clothing that easily blends into the background, making it difficult to be detected by the front view camera recognition system
- The outside lighting is too bright (e.g. when driving in bright sunlight or in sun glare) or too dark (e.g. when driving on a dark rural road at night)

- It is difficult to detect and distinguish the pedestrian or cyclist from other objects in the surroundings, for example, when there is a group of pedestrians, cyclists or a large crowd
- There is an item similar in shape or appearance to a person
- The pedestrian or cyclist is below the sensor's viewing range
- The sensor can not identify the pedestrian's outline because of other items changing their profile, such as mobility assistance devices
- The front view camera or front radar is obstructed by a foreign object or debris
- Inclement weather such as heavy rain or snow obscures the field of view of the radar sensor or camera
- When light coming from a street light or an oncoming vehicle is reflected on a wet road surface such as a puddle in the road
- The field of view in front is obstructed by sun glare
- The windshield glass is fogged up; a clear view of the road is obstructed
- The adverse road conditions cause excessive vehicle vibrations while driving
- When the pedestrian or cyclist suddenly enters the path of travel of the vehicle
- When the cyclist in front is riding perpendicular to the direction of travel
- When there is any electromagnetic interference
- When the cyclist is near areas containing metal objects such as a construction zone, railroad, etc.
- If the bicycle material is not reflected well on the radar
- When a pedestrian or cyclist's height is small.
- When a pedestrian or cyclist's behavior is unstable.
- When a pedestrian or cyclist suddenly interrupts in front of the vehicle.
- When there are many pedestrians or cyclists.
- When there is an object that reflects radar well. (such as a guardrail or a nearby vehicle)

⚠ WARNING

- **Do not use Forward Collision avoidance Assist system when towing a vehicle. Application of FCA system while towing may adversely affect the safety of your vehicle or the towing vehicle.**
- **Use extreme caution when 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.**
- **FCA system is designed to detect and monitor the vehicle ahead or detect a pedestrian or cyclist in the roadway through front view camera recognition and front radar signals. It may not always detect bicycles, motorcycles, or smaller wheeled objects such as luggage bags, shopping carts, or strollers.**

(Continued)

(Continued)

- **Never try to test the operation of FCA system. Doing so may cause severe injury or death.**
- **If the front bumper, front glass, front view camera or front radar have been replaced or repaired, have your vehicle inspected by an authorized Kia dealer.**
- **If the system detects an object that has a similar shape or characteristics of a vehicle or a pedestrian, FCA system may operate.**

✼ NOTICE

In some instances, FCA system may be cancelled when subjected to electromagnetic interference.

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.
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.

APPENDIX C

Run Log

Subject Vehicle: **2020 Kia Niro Hybrid EX Premium** Test Date: **6/3/2020**

Principal Other Vehicle: **SSV**

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
1-21	Brake characterization and determination						See Appendix D
22	Static Run						
23	**Stopped POV**	N					Throttle release late
24		Y	2.00	7.14	0.99	Pass	
25		N					Throttle release late
26		Y	1.96	2.34	0.99	Pass	
27		Y	1.93	2.46	0.98	Pass	
28		N					No brake actuator action
29		Y	2.04	2.11	0.96	Pass	
30		Y	1.98	0.43	0.93	Pass	
31		Y	2.00	6.30	0.95	Pass	
32		Y	2.00	2.48	0.96	Pass	
33	Static Run						
34	**Slower POV, 25 vs 10**	Y	1.74	1.79	1.00	Pass	
35		Y	1.72	2.35	1.02	Pass	
36		Y	1.68	3.60	1.04	Pass	
37		Y	1.71	1.70	0.97	Pass	
38		Y	1.71	2.10	1.01	Pass	
39		Y	1.62	5.68	0.97	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
40		Y	1.74	2.28	1.07	Pass	
41	Static run						
42	Brake Force Check Run						SV speed
43	Brake Force Check Run						Check run to verify force @ 0.4g
44	Brake Force Check Run						SV speed
45	Brake Force Check Run						SV speed
46	**Slower POV, 45 vs 20**	N					SV speed
47		N					SV speed
48		Y	2.31	10.74	0.98	Pass	
49		N					POV speed
50		Y	2.28	10.66	0.97	Pass	
51		Y	2.32	10.58	0.98	Pass	
52		N					Lateral offset
53		Y	2.37	10.78	0.96	Pass	
54		Y	2.25	11.36	0.99	Pass	
55		Y	2.33	10.37	0.96	Pass	
56		Y	2.29	10.82	0.99	Pass	
57	Static run						

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
58	**Decelerating POV, 35**	N					POV braking
59		N					Throttle release late
60		Y	1.60	3.50	0.56	Pass	
61		Y	1.45	1.79	0.98	Pass	
62		N					SV speed
63		N					Lateral offset
64		N					SV speed
65		N					Headway
66		N					Lateral offset
67		Y	1.65	1.75	1.01	Pass	
68		Y	1.55	3.19	0.54	Pass	
69		Y	1.68	1.71	0.85	Pass	
70		Y	1.57	4.08	0.54	Pass	
71		N					Brake force not zeroed
72		N					Lateral offset
73		N					Throttle release late
74		N					SV speed
75		Y	1.61	5.38	0.60	Pass	
76	Static run						
77	STP - Static run						
78	**Baseline, 25**	Y			0.60		
79		N					Throttle release late
80		N					SV speed
81		Y			0.57		

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
82		N					Throttle release late
83		N					SV speed
84		Y			0.49		
85		Y			0.52		
86		Y			0.50		
87		Y			0.57		
88		Y			0.49		
89	STP - Static run						
90	**Baseline, 45**	N					Speed
91		Y			0.59		
92		N					SV speed
93		N					SV speed
94		N					Throttle release late
95		N					SV speed
96		Y			0.55		
97		N					Throttle release late
98		N					SV speed
99		Y			0.56		
100		N					SV speed
101		Y			0.52		
102		Y			0.55		
103		Y			0.53		
104		Y			0.54		
105	STP - Static run						

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
106	**STP False Positive, 25**	Y			0.54	Pass	
107		Y			0.52	Pass	
108		Y			0.48	Pass	
109		N					SV speed
110		Y			0.48	Pass	
111		Y			0.49	Pass	
112		Y			0.47	Pass	
113		Y			0.47	Pass	
114	STP - Static run						
115	**STP False Positive, 45**	Y			0.49	Pass	
116		Y			0.48	Pass	
117		Y			0.54	Pass	
118		Y			0.53	Pass	
119		Y			0.52	Pass	
120		Y			0.55	Pass	
121		Y			0.59	Pass	
122	STP - Static run						

APPENDIX D

Brake Characterization

Subject Vehicle: **2020 Kia Niro Hybrid EX Premium** Test Date: **6/3/2020**

DBS Initial Brake Characterization				
Run Number	**Stroke at 0.4 g (in)**	**Force at 0.4 g (lb)**	**Slope**	**Intercept**
1	2.048894	12.51607	0.620217	0.198116
2	2.017290	12.10103	0.619150	0.199445
3	2.001643	12.05400	0.620767	0.199995

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	0.491	2.02		1.65	
5			N					Brake rate
6			Y	0.386	1.85		1.92	
7		25	Y	0.407	1.85		1.82	
8		45	Y	0.403	1.85		1.84	

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**
9	**Hybrid**	35	N					Speed
10			N					Throttle
11			Y	0.539		12.22	9.07	
12			N					Speed
13			Y	0.458		10.00	8.73	
14			N					Speed
15			Y	0.366		9.20	10.05	
16			Y	0.431		9.80	9.10	
17			N					Speed
18			Y	0.407		9.55	9.39	
19			N					Brake rate
20			Y	0.394		9.00	9.14	
21		45	Y	0.413		9.00	8.72	

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

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

- Headway (ft) – Longitudinal separation between the 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.

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

Envelopes and Thresholds

Some of the time history plot figures contain either green or yellow envelopes and/or black or red threshold lines. These envelopes and thresholds are used to programmatically and visually determine the validity of a given test run. Envelope and threshold exceedances are indicated with either red shading or red asterisks, and red text is placed to the right side of the plot indicating the type of exceedance. Such exceedances indicate either that the test was invalid or that the requirements of the test were not met (i.e., failure of the AEB system).

For plots with green envelopes, in order for the test to be valid, the time-varying data must not exceed the envelope boundaries at any time within the envelope. Exceedances of a green envelope are indicated by red shading in the area between the measured time-varying data and the envelope boundaries.

With the exception of the brake force plots (see description below), for plots with yellow envelopes, in order for the test to be valid, the time-varying data must not exceed the envelope at the beginning (left edge of the boundary) and/or end (right edge), but may exceed the boundary during the time between the left and right edges. Exceedances at the left or right extent of a yellow envelope are indicated by red asterisks.

For the headway plot, a dashed black threshold line indicating a relative headway of zero is given. If no impact occurs, a green circle is displayed at the moment of minimum distance. If impact occurs, a red asterisk is displayed at the moment of impact.

For the Ax plot, if the scenario is an AEB brake to stop scenario, a vertical dashed black line is displayed for all plots indicating the moment of first POV braking. The yellow envelope in this case is relevant to the POV braking only. The left edge of the envelope is at 1.5 seconds after the first POV braking. A solid black threshold line extends horizontally 0.5 seconds to the left of the envelope. This threshold line represents the time during which the Ax of the Principal Other Vehicle must first achieve 0.27g (the upper edge of the envelope, i.e., 0.30 g ± 0.03 g). A green circle or red asterisk is displayed at the moment the POV brake level achieves 0.27g. A green circle indicates that the test was valid (the threshold was crossed during the appropriate interval) and a red asterisk indicates that the test was invalid (the threshold was crossed out of the appropriate interval).

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

For the brake force plots:

- If the tests are done in Hybrid mode, the brake force plot shows a dashed black threshold line indicating a brake force of 2.5 lbs. For the time period where the DBS controller is active, the brake force at the pedal must not fall below this 2.5 lb threshold. Exceedances of this threshold are indicated by red shading in the area between the measured time-varying data and the dashed threshold line. A blue envelope represents the target average brake 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.

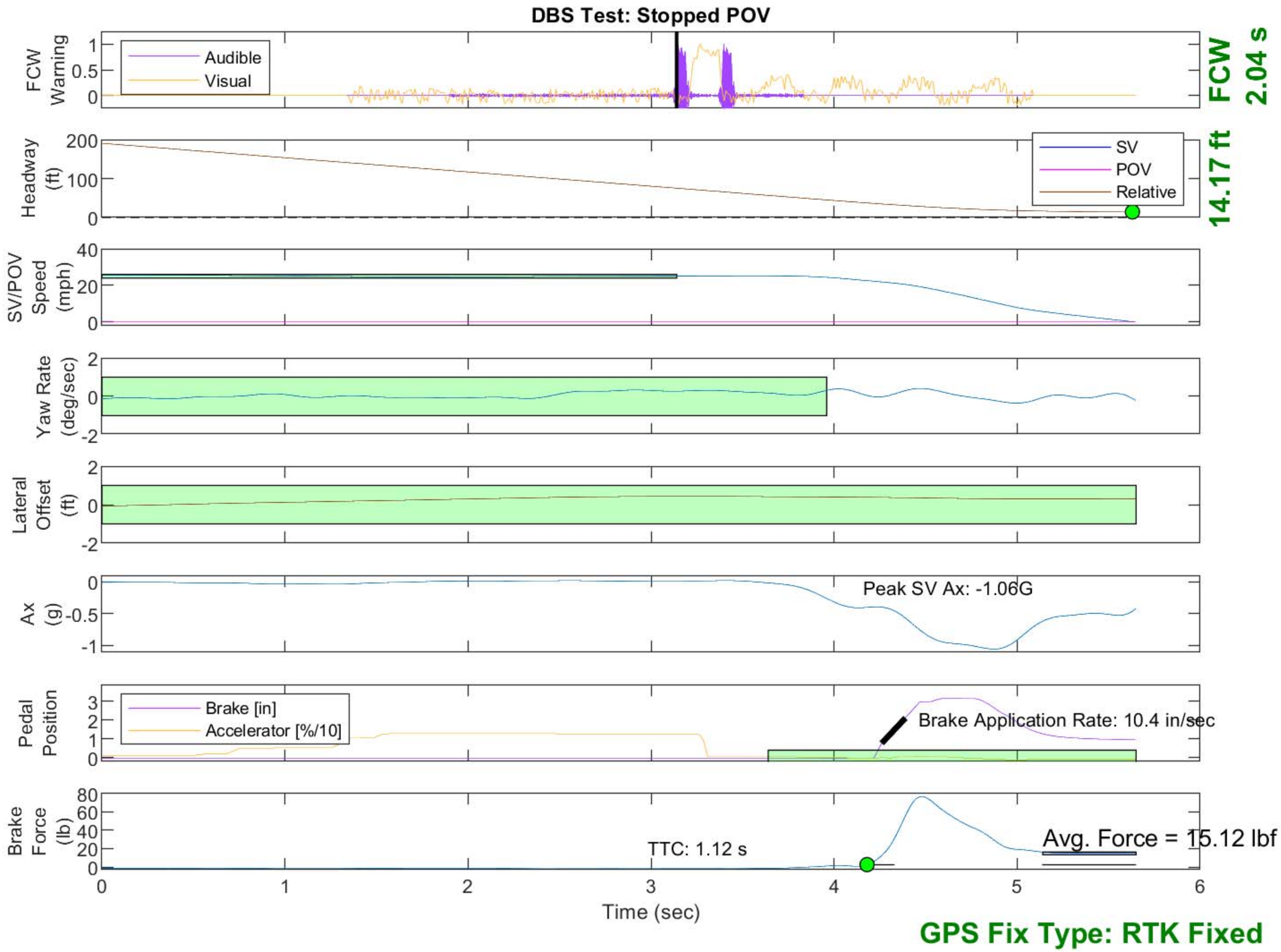


Figure E1. Example Time History for Stopped POV, Passing

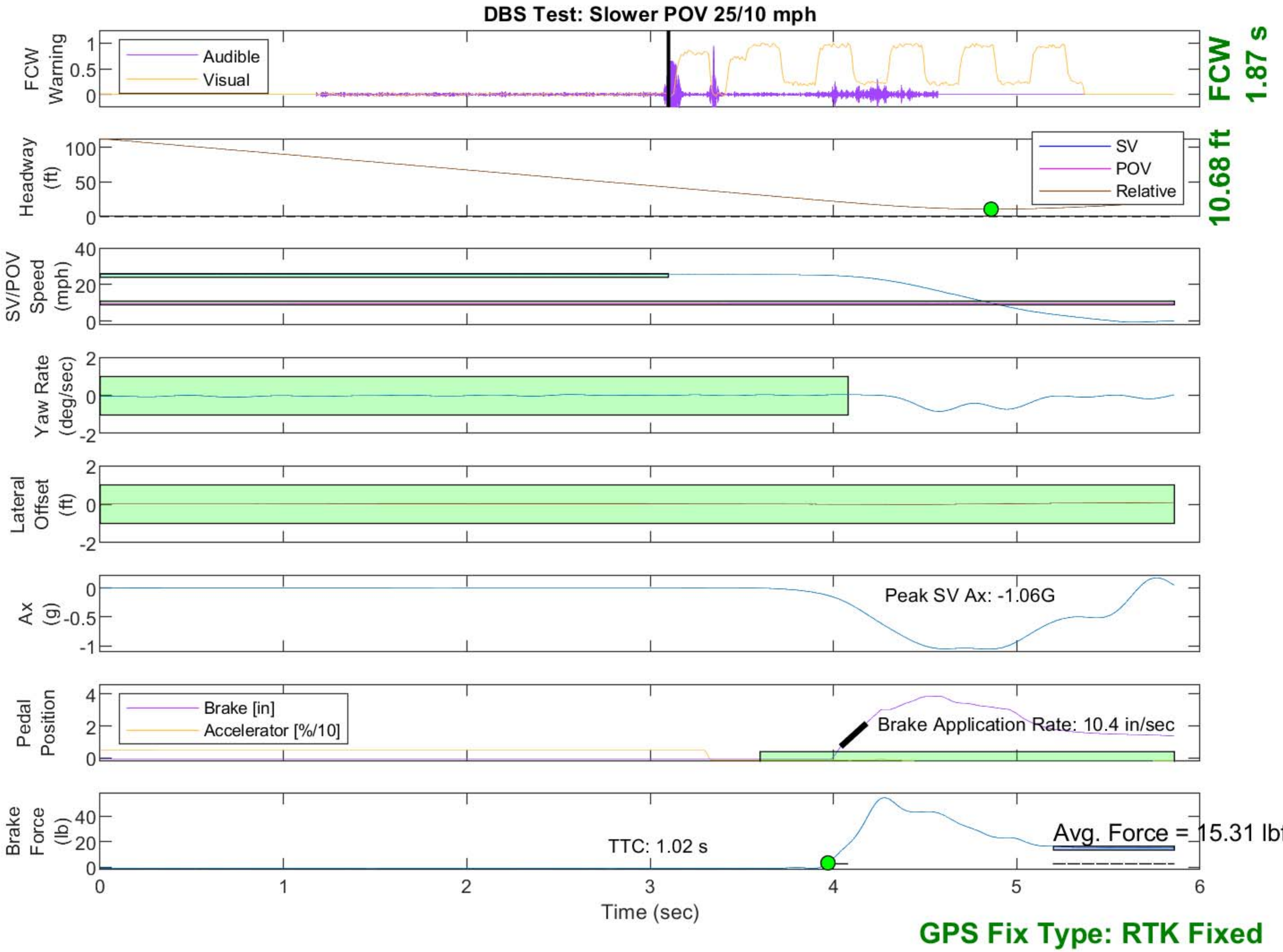


Figure E2. Example Time History for Slower POV 25 vs. 10, Passing

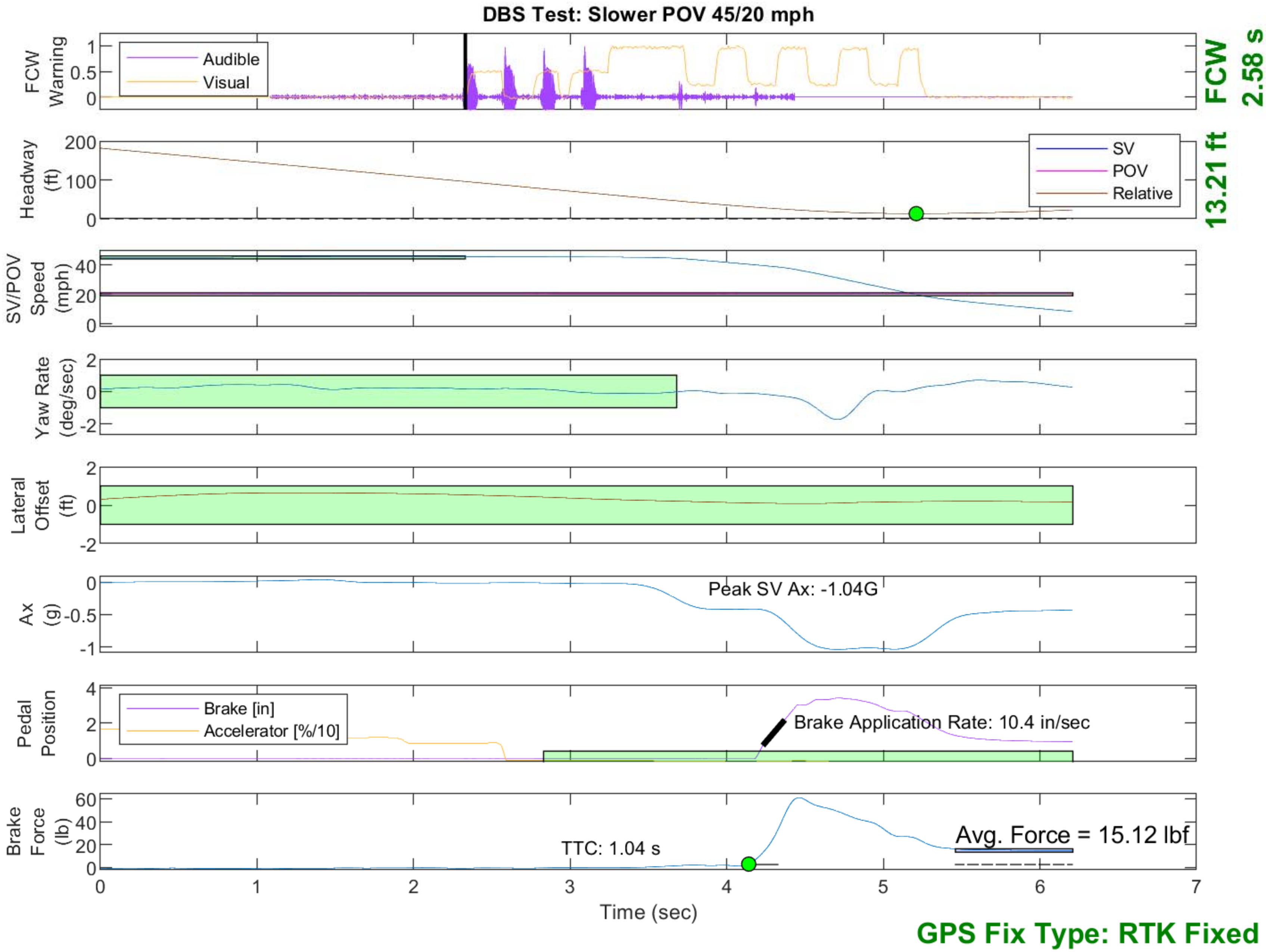


Figure E3. Example Time History for Slower POV 45 vs. 20, Passing

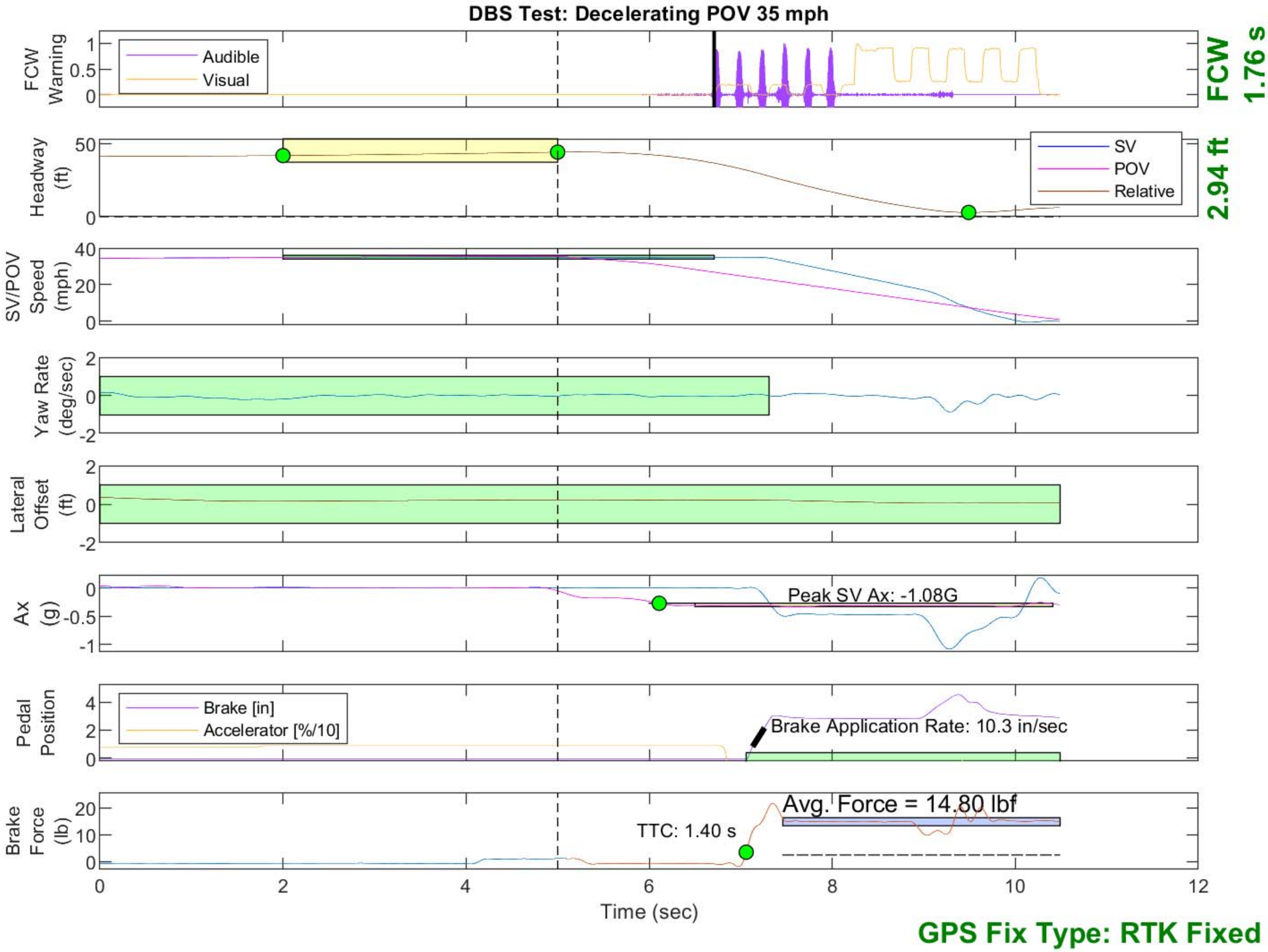


Figure E4. Example Time History for Decelerating POV 35, Passing

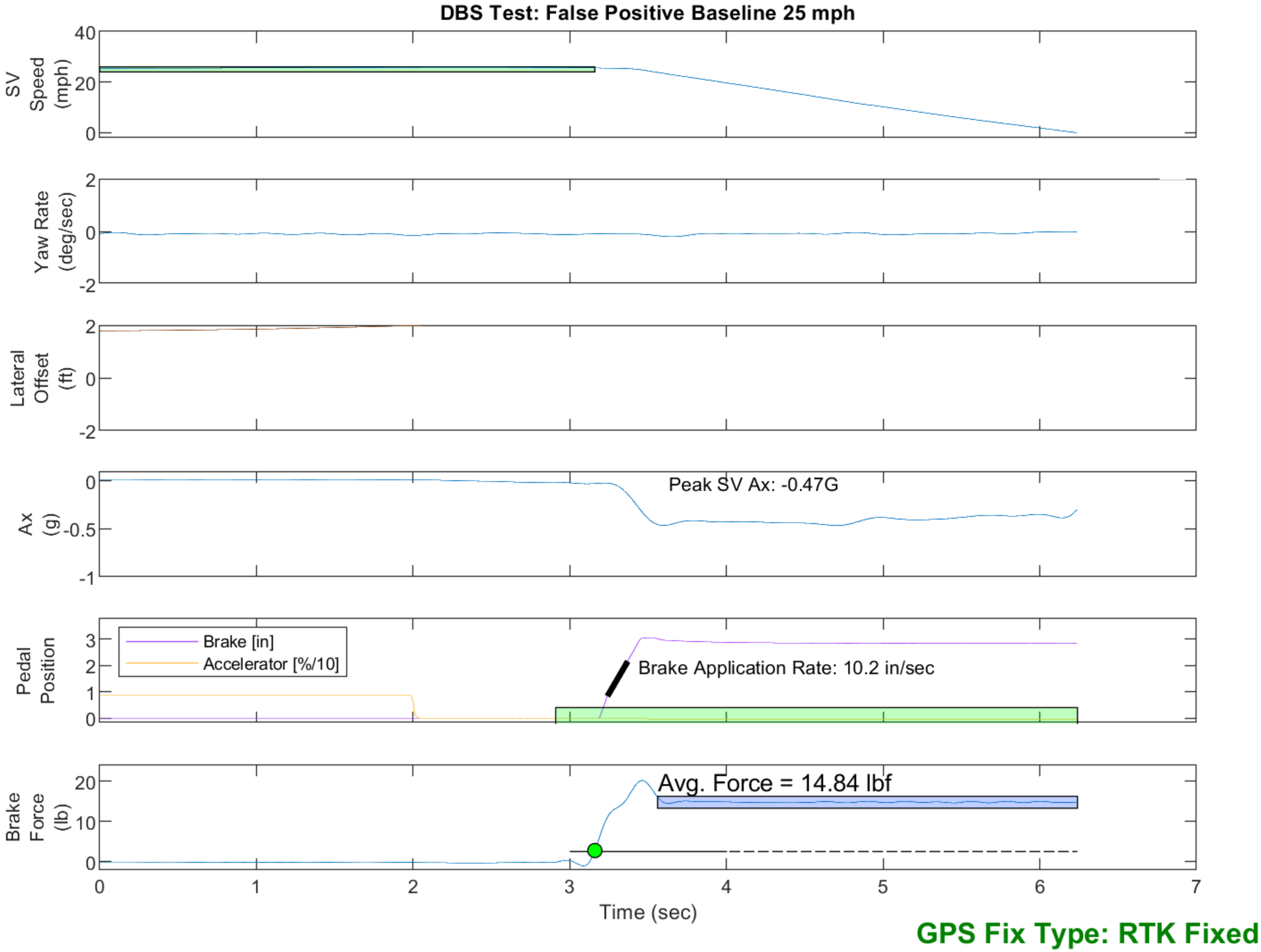


Figure E5. Example Time History for False Positive Baseline 25

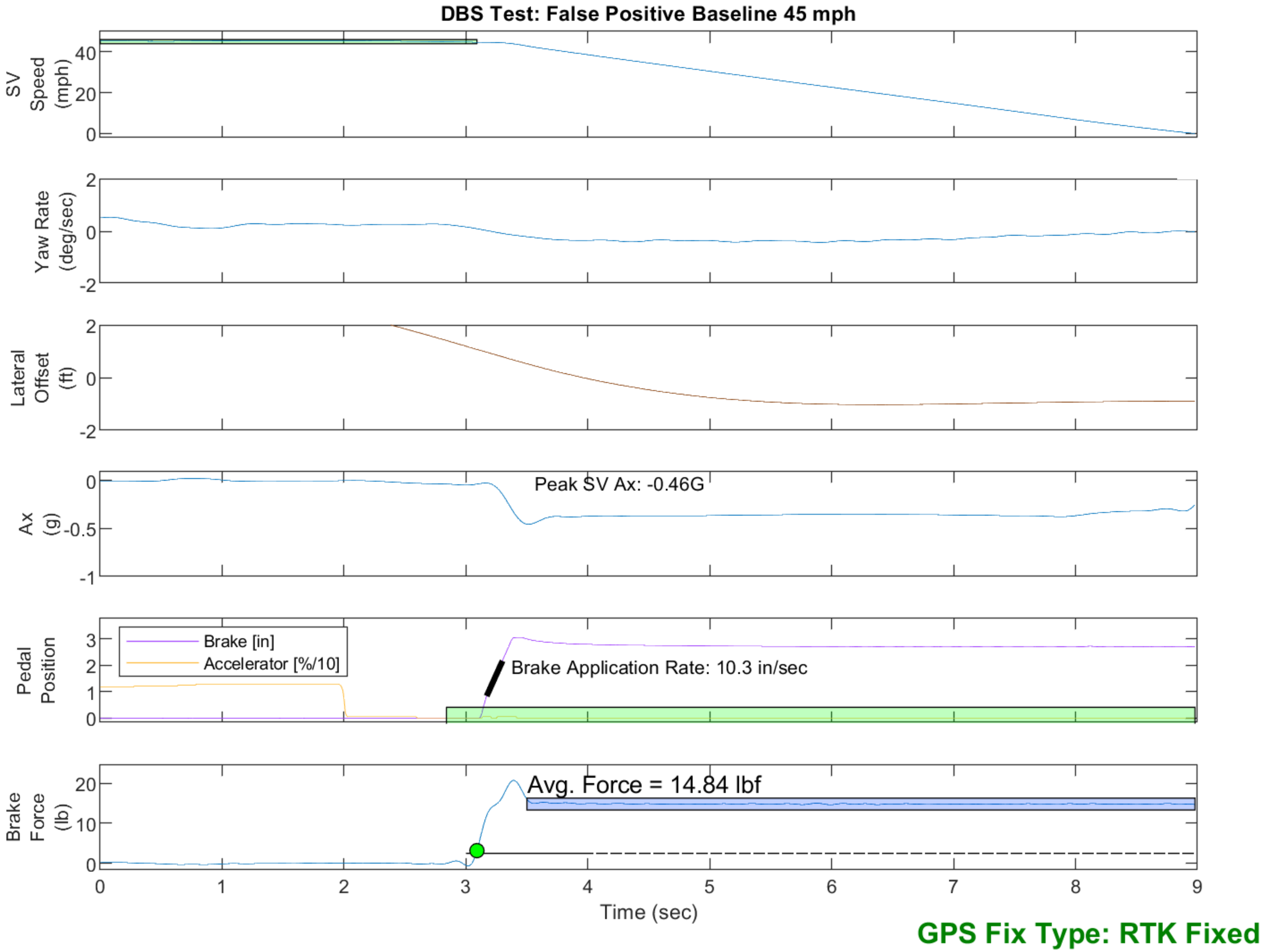


Figure E6. Example Time History for False Positive Baseline 45

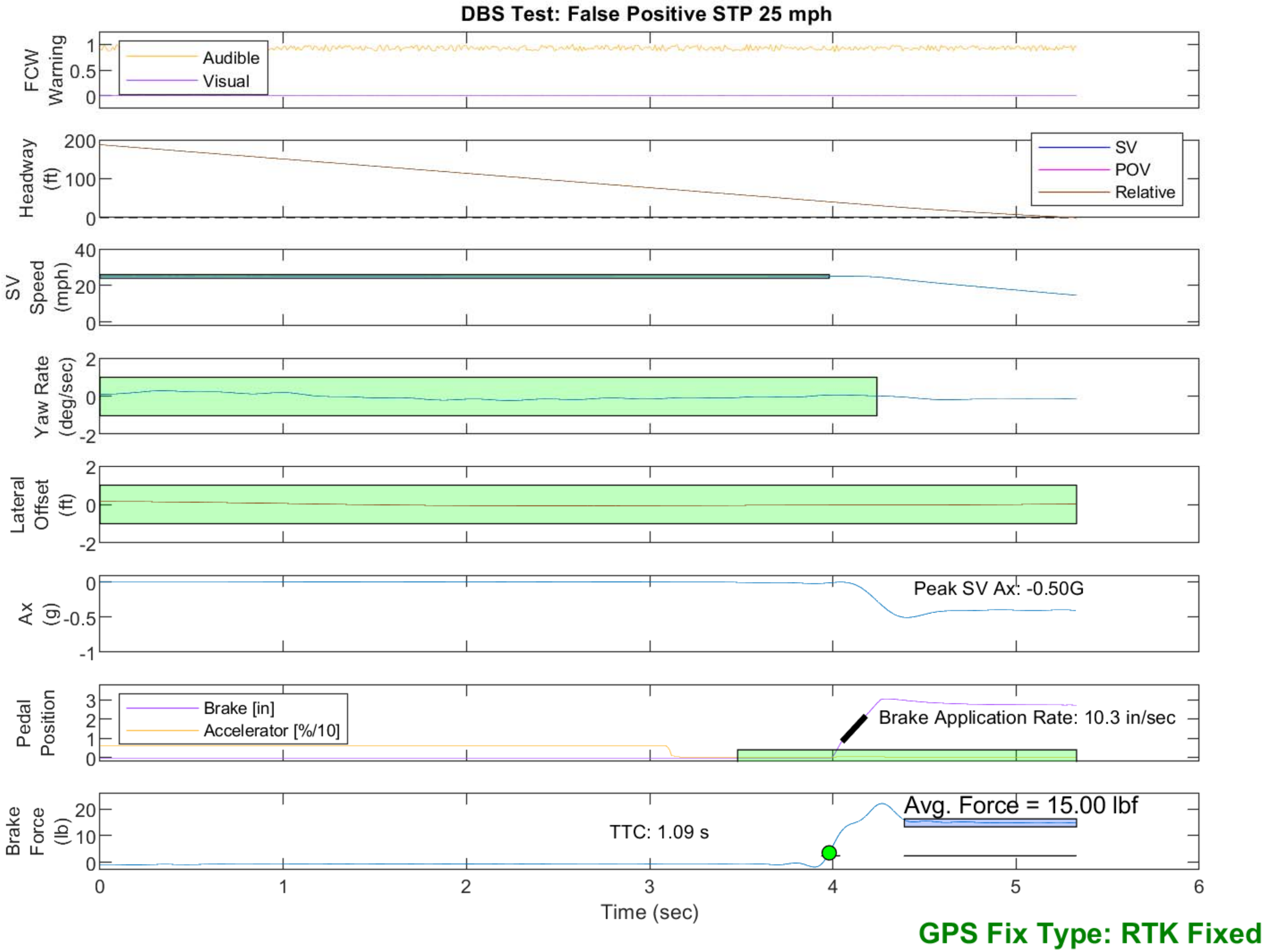


Figure E7. Example Time History for False Positive Steel Plate 25, Passing

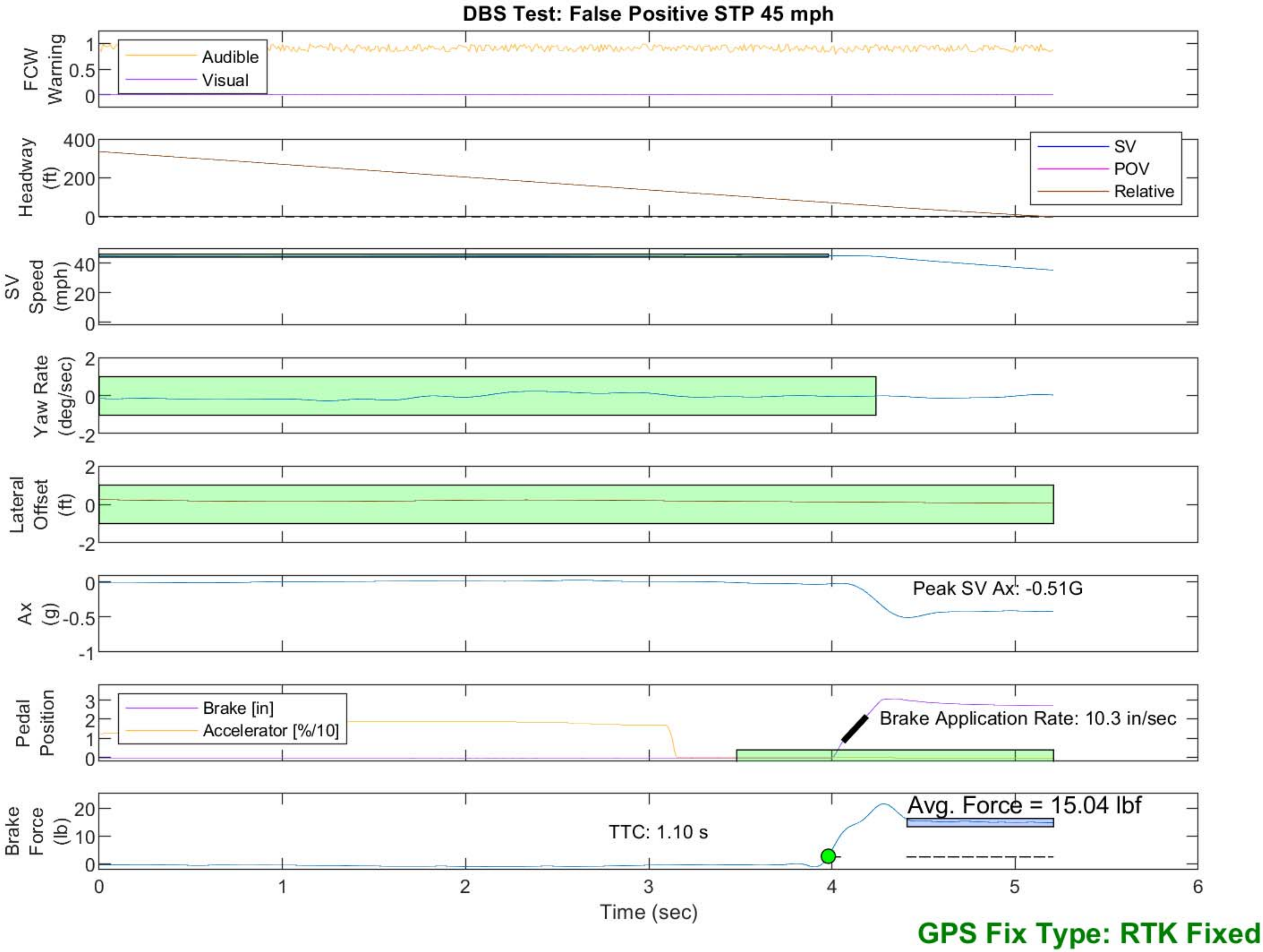


Figure E8. Example Time History for False Positive Steel Plate 45, Passing

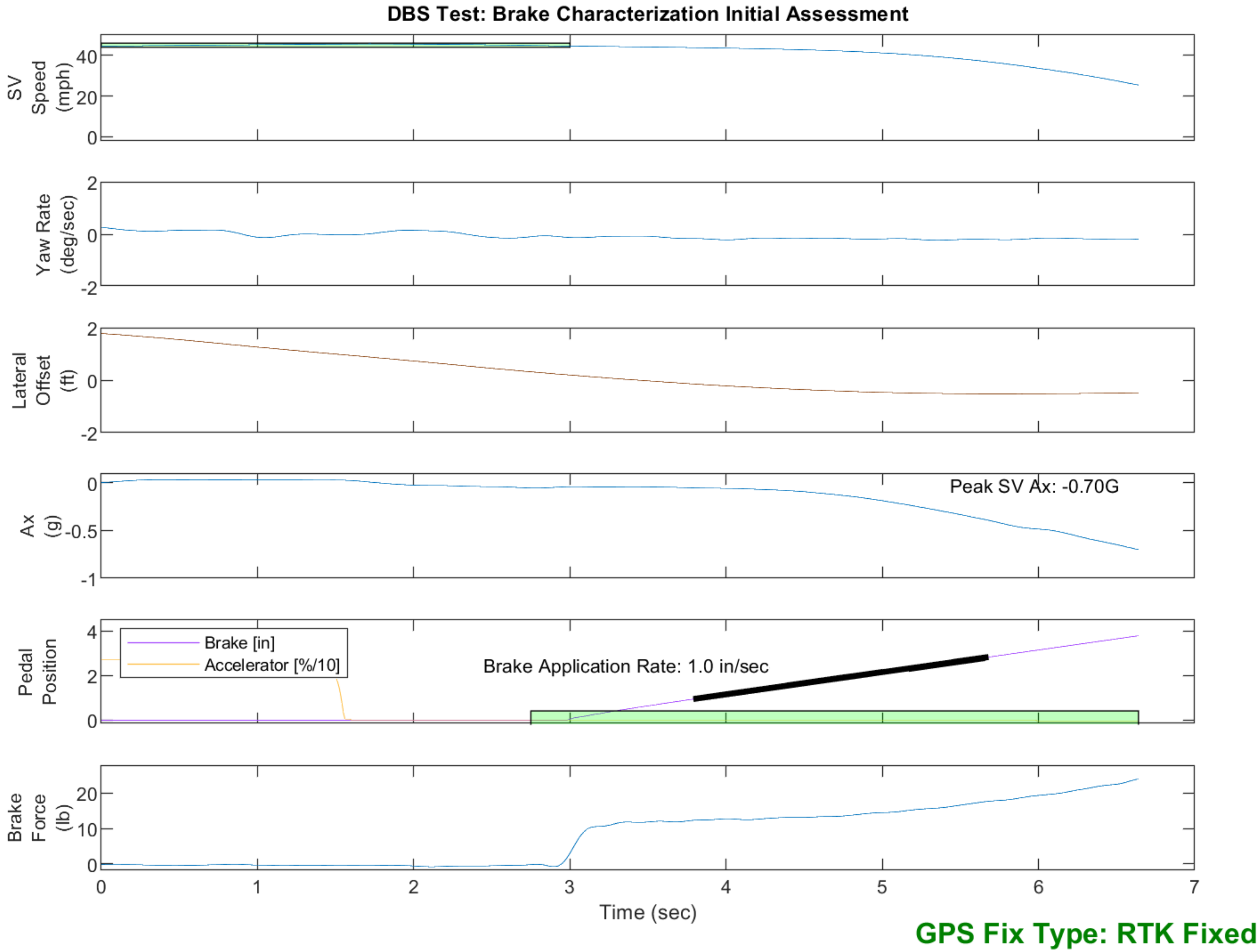


Figure E9. Example Time History for DBS Brake Characterization, Passing

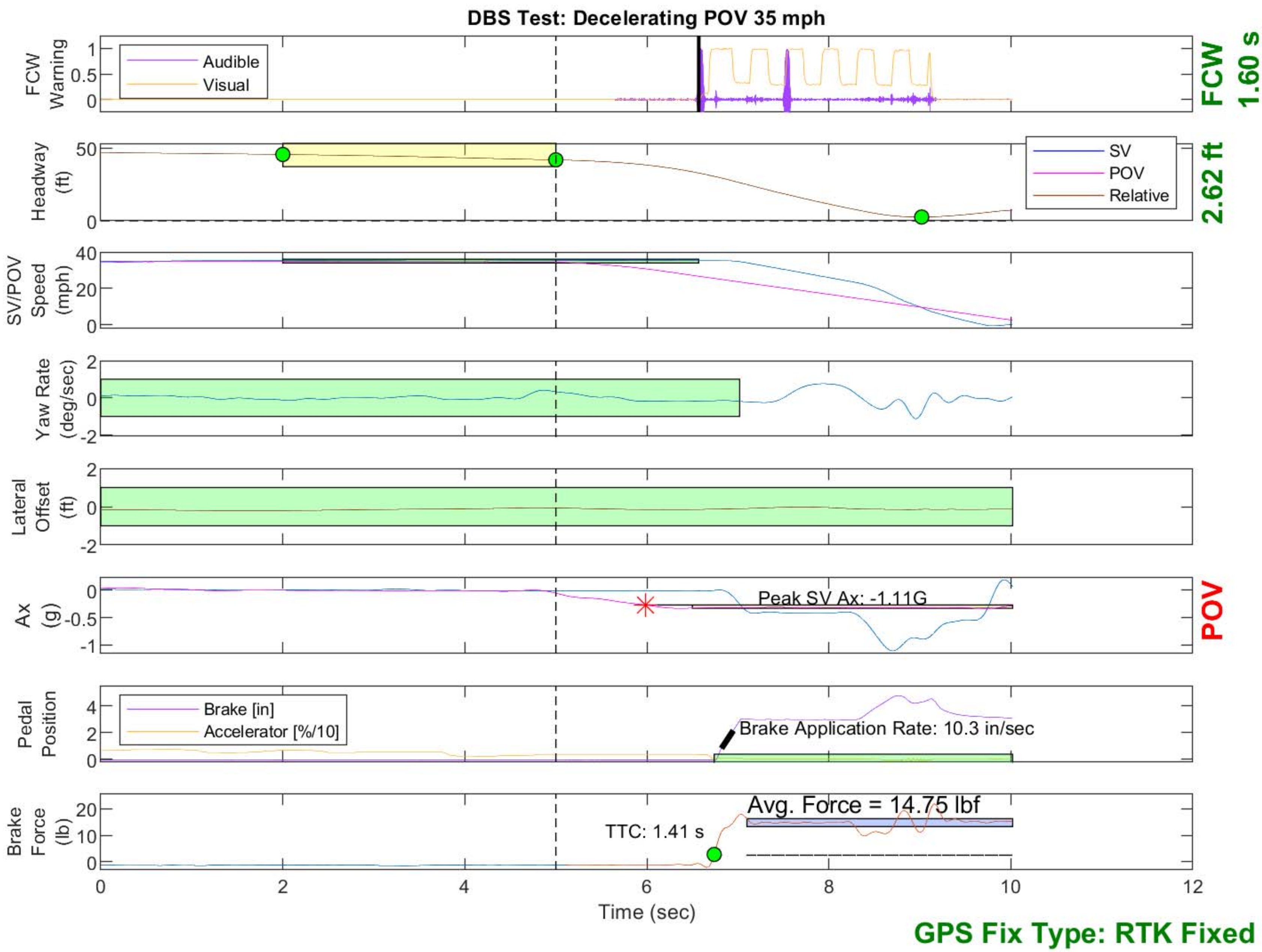


Figure E10. Example Time History Displaying Invalid POV Acceleration Criteria

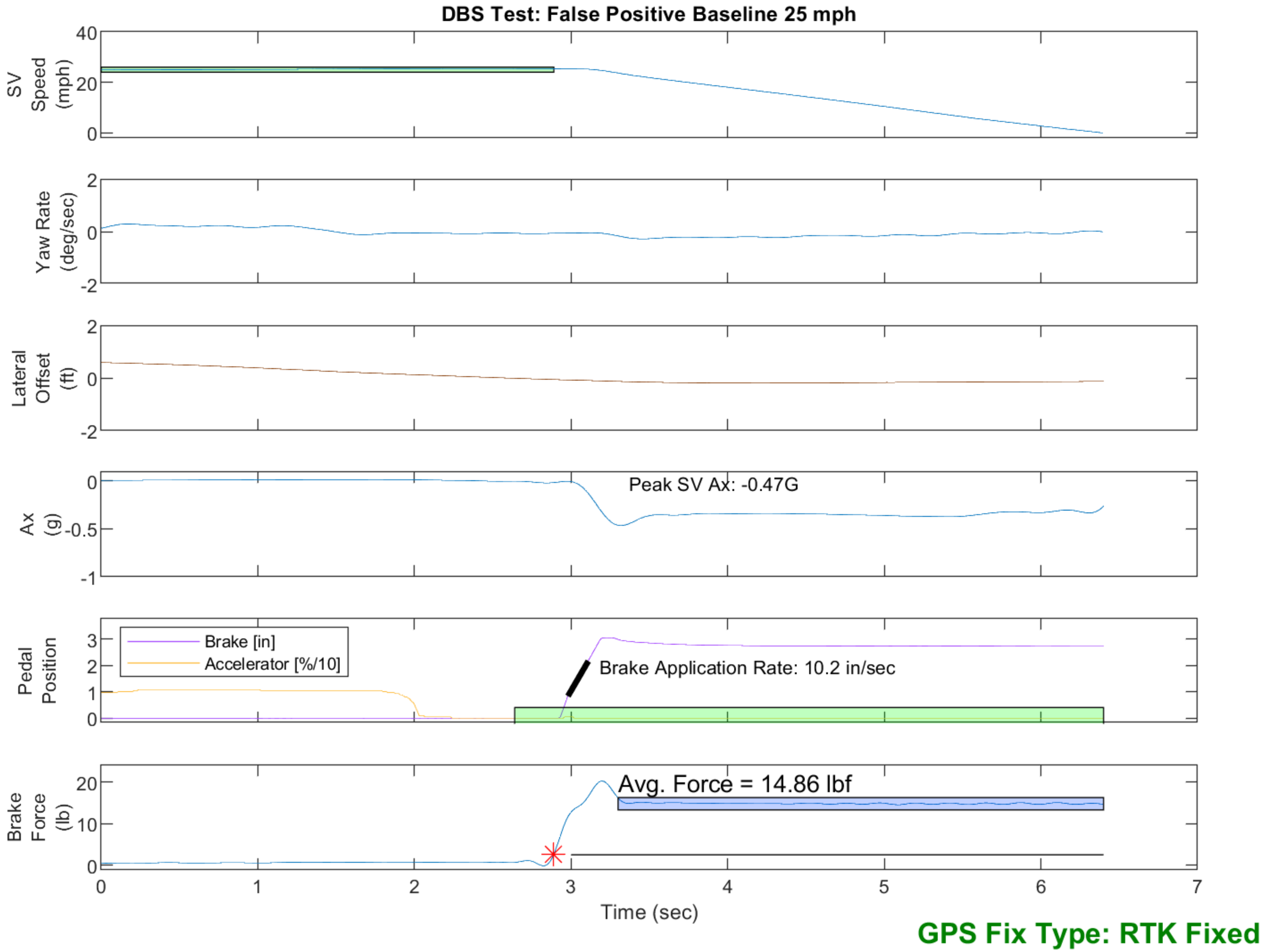


Figure E11. Example Time History Displaying Invalid Brake Force Criteria

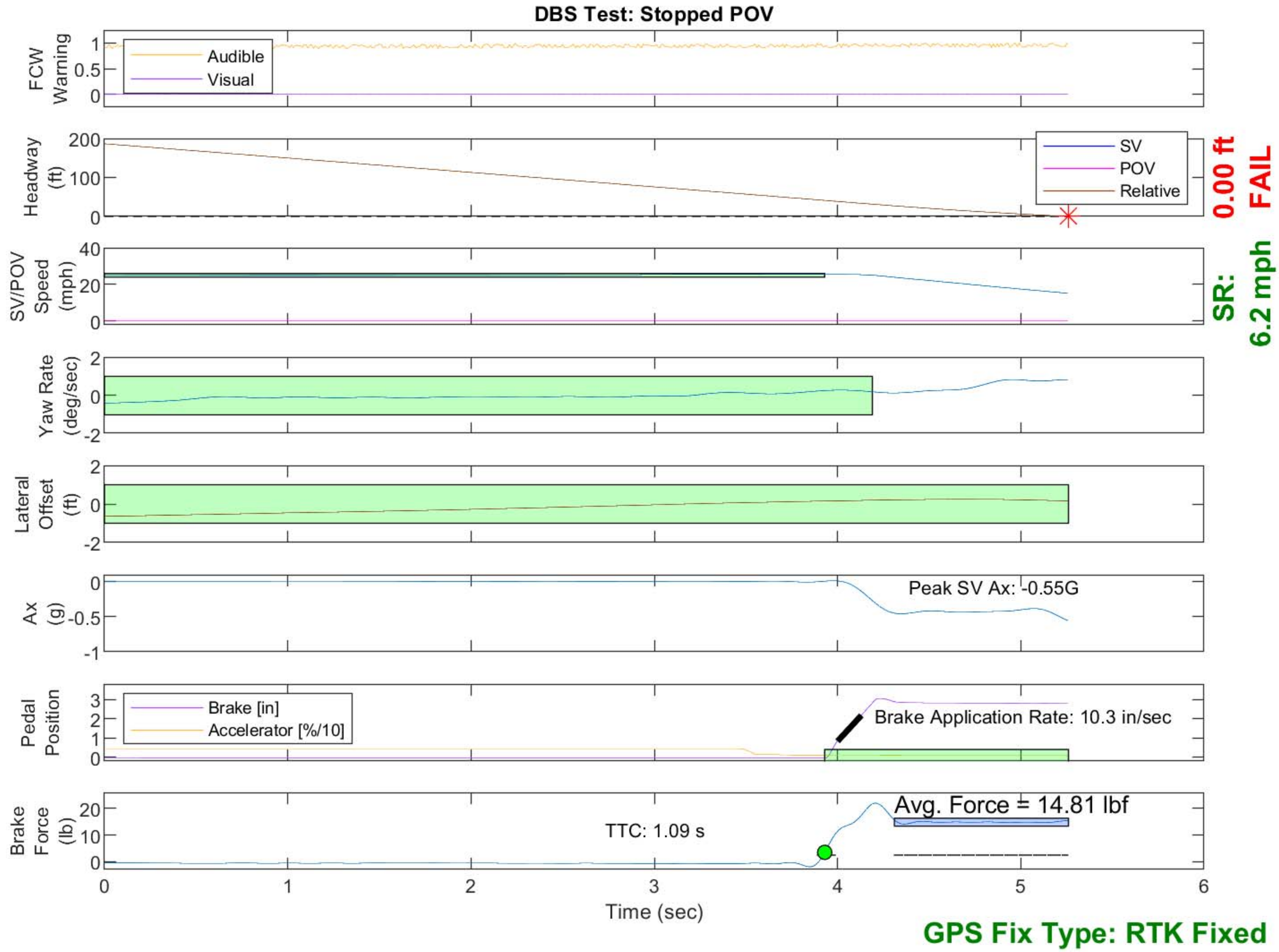


Figure E12. Example Time History for a Failed Run

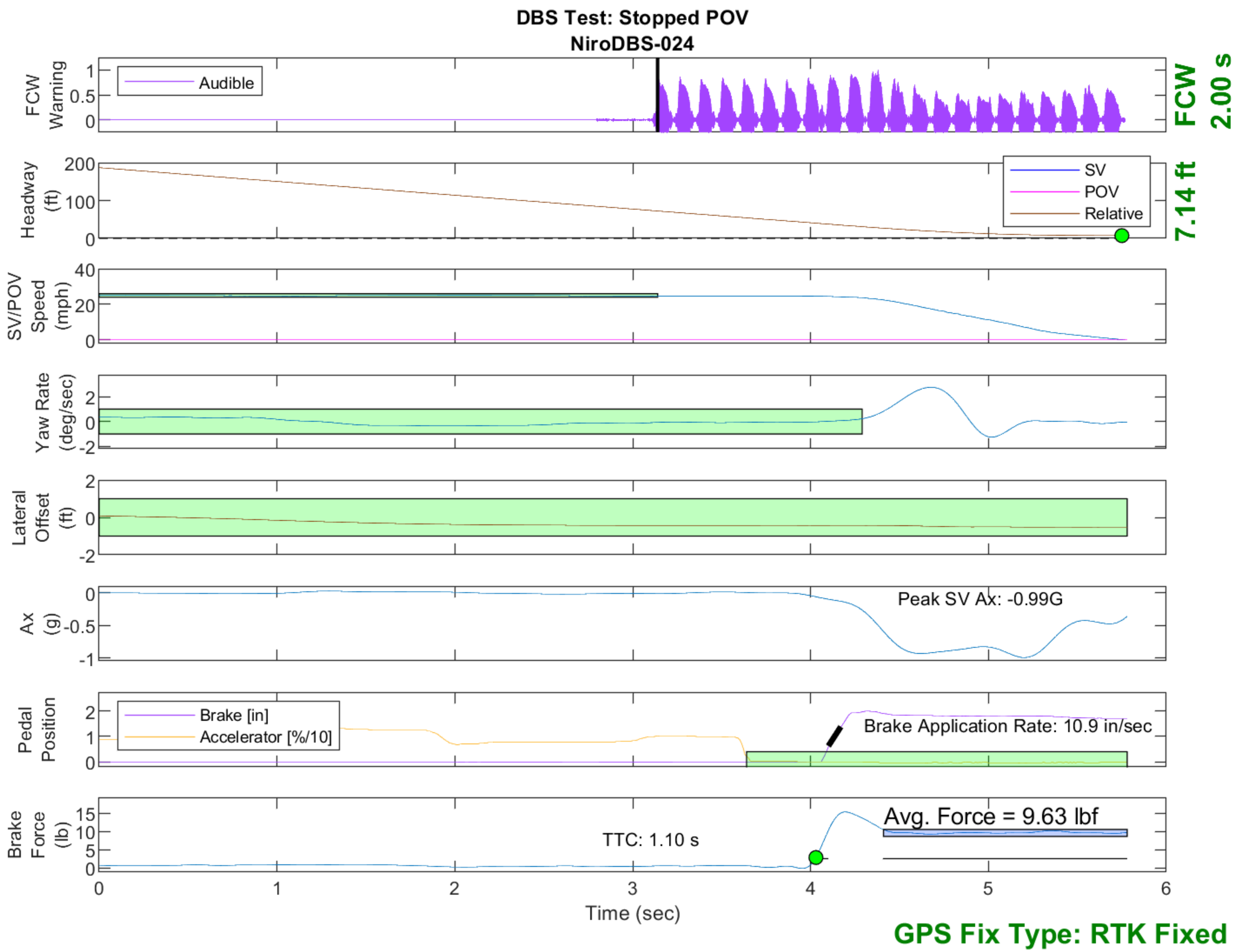


Figure E13. Time History for DBS Run 24, SV Encounters Stopped POV

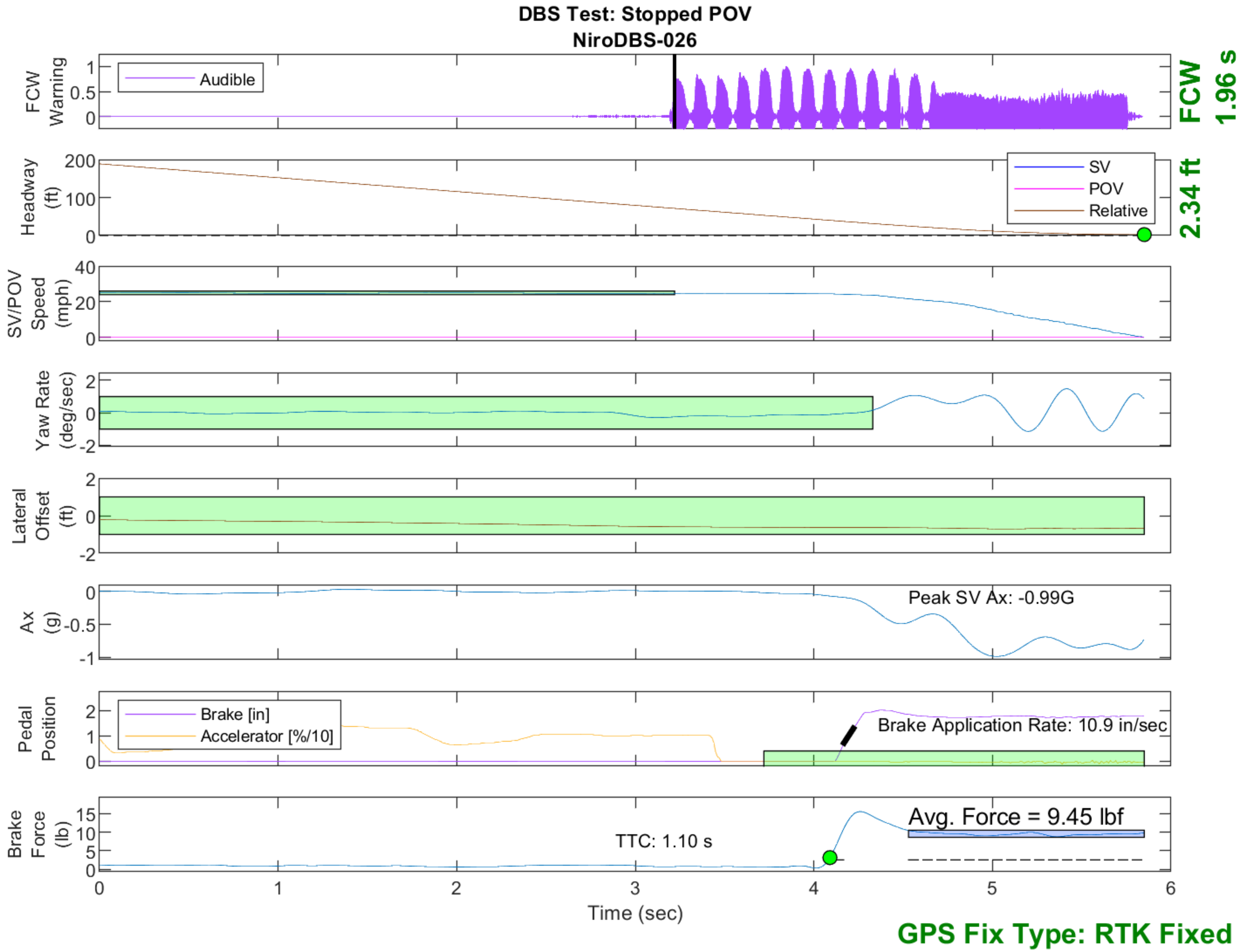


Figure E14. Time History for DBS Run 26, SV Encounters Stopped POV

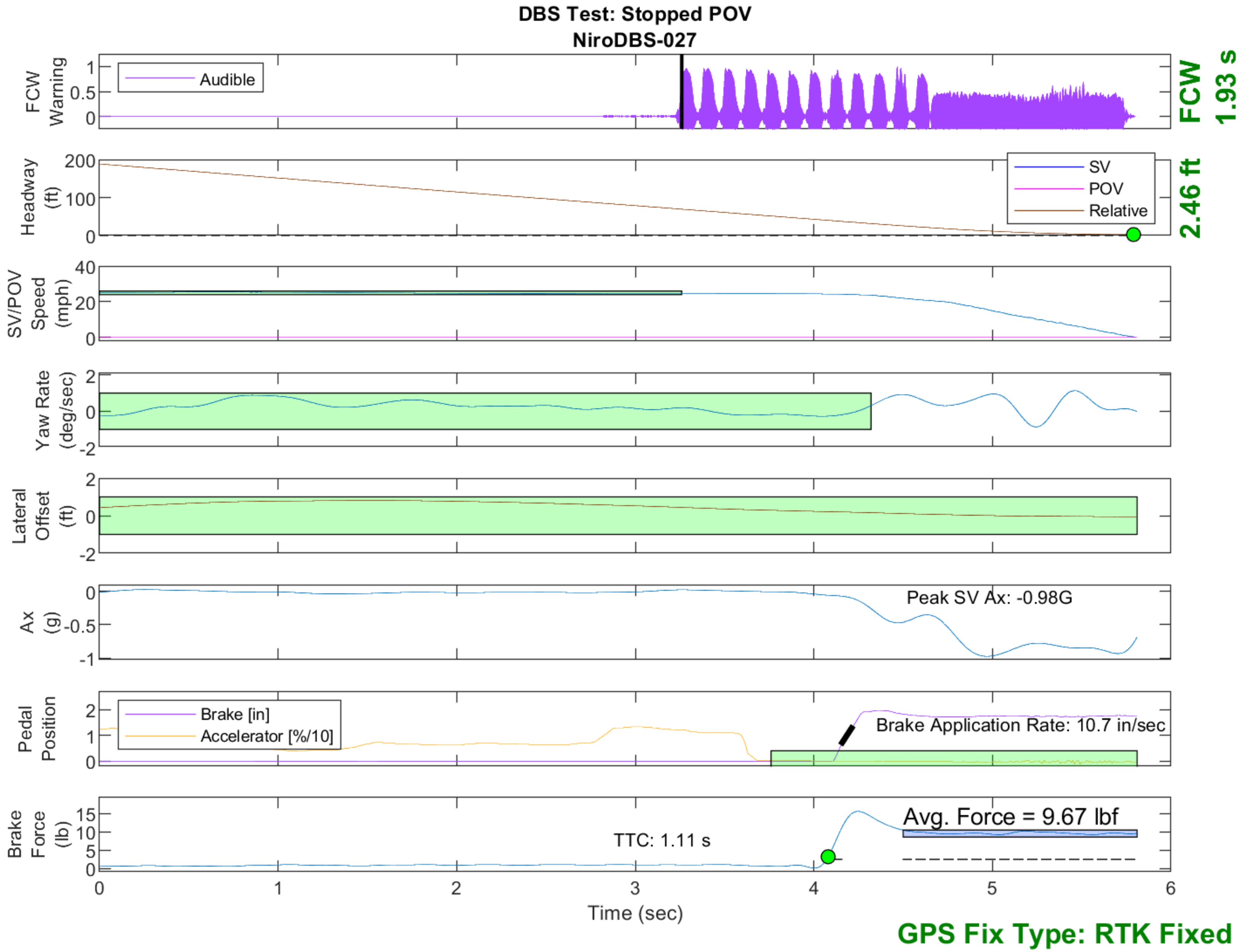


Figure E15. Time History for DBS Run 27, SV Encounters Stopped POV

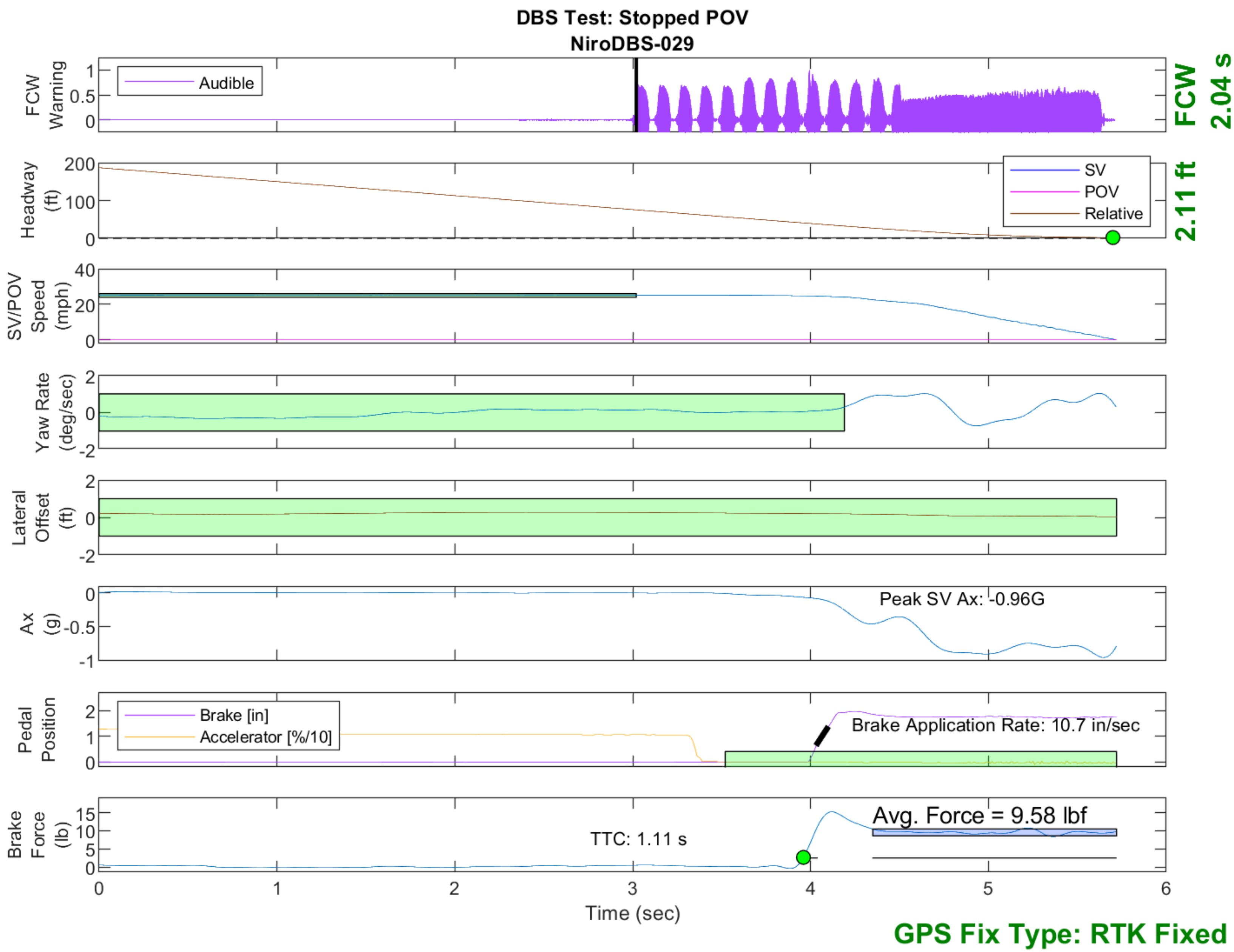


Figure E16. Time History for DBS Run 29, SV Encounters Stopped POV

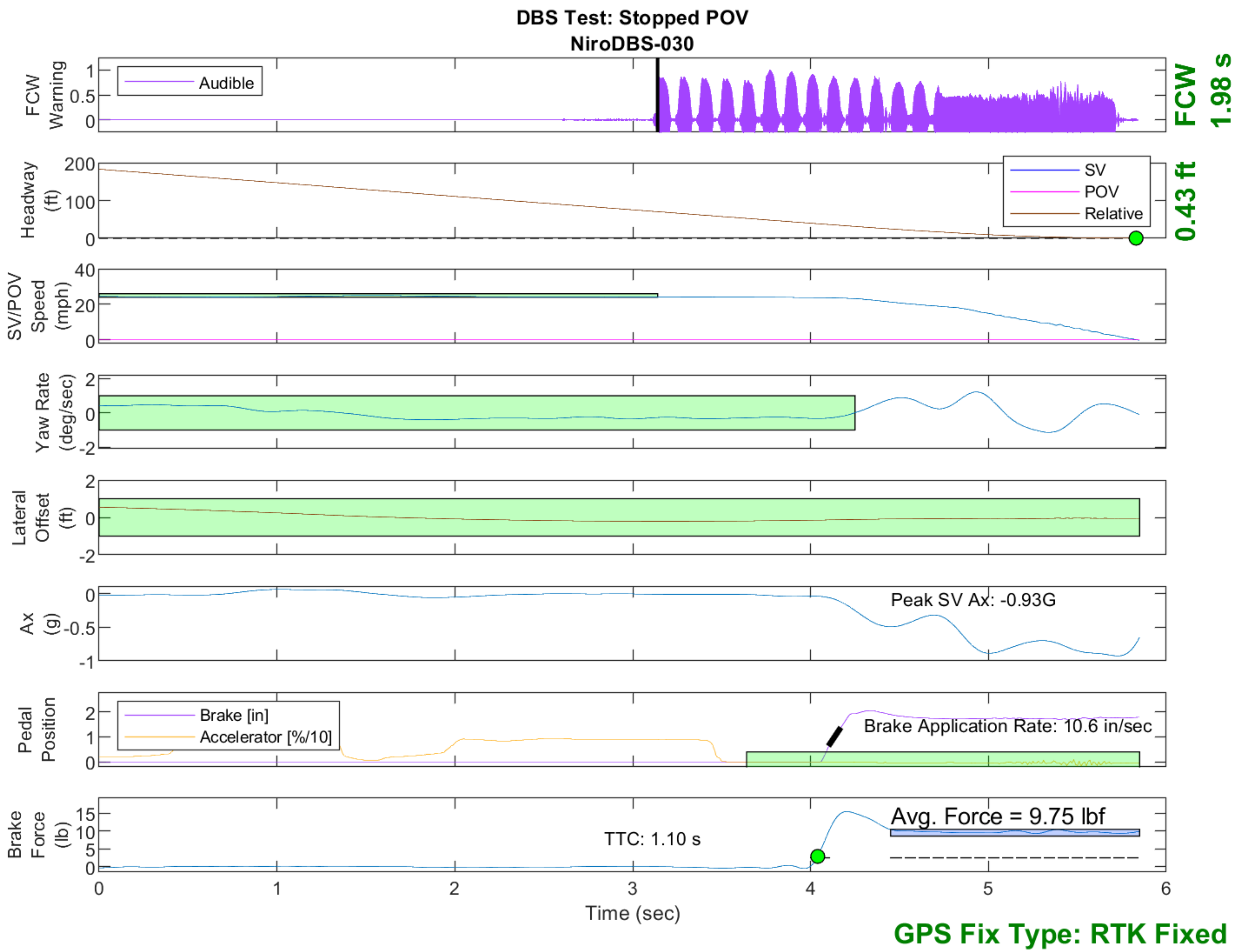


Figure E17. Time History for DBS Run 30, SV Encounters Stopped POV

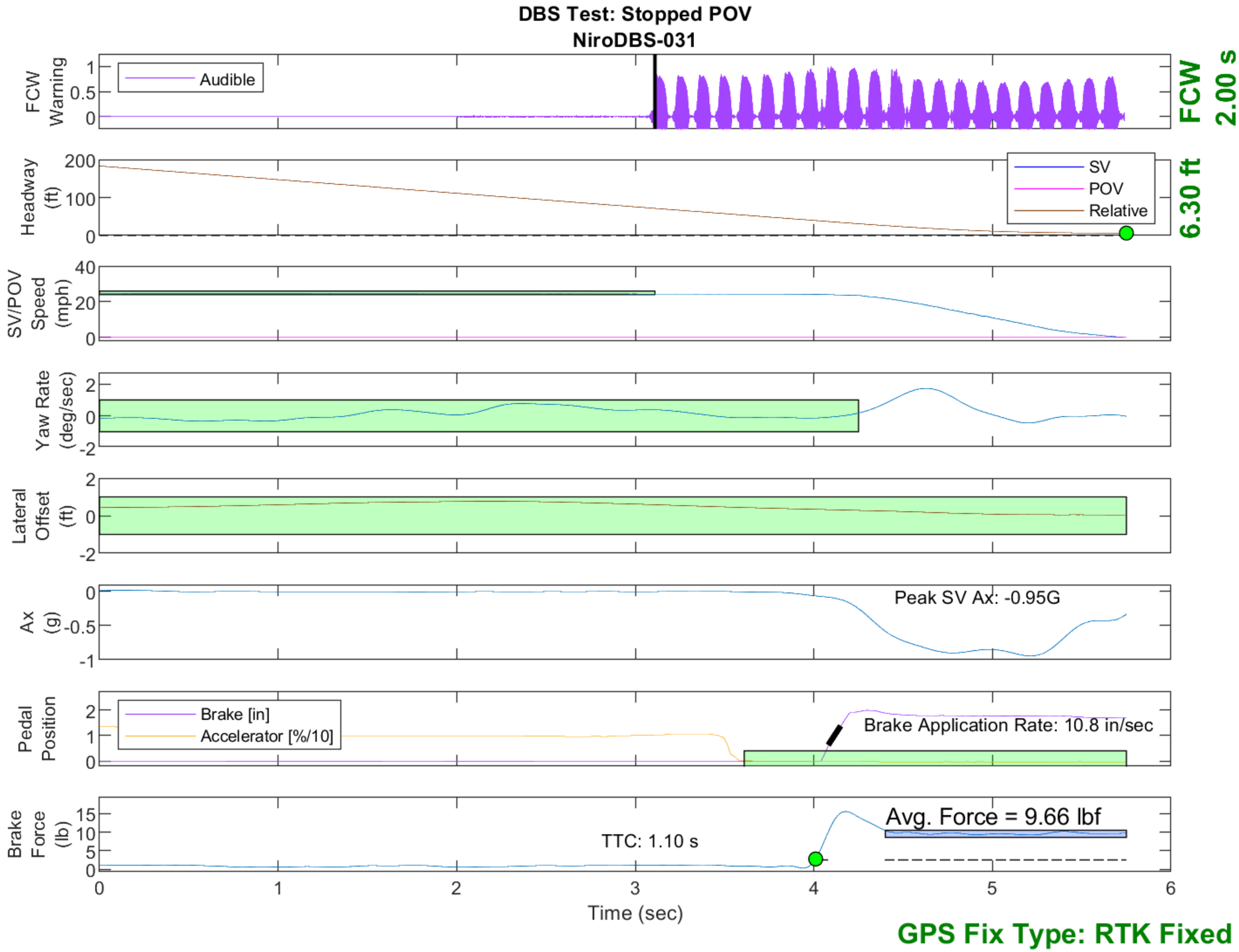


Figure E18. Time History for DBS Run 31, SV Encounters Stopped POV

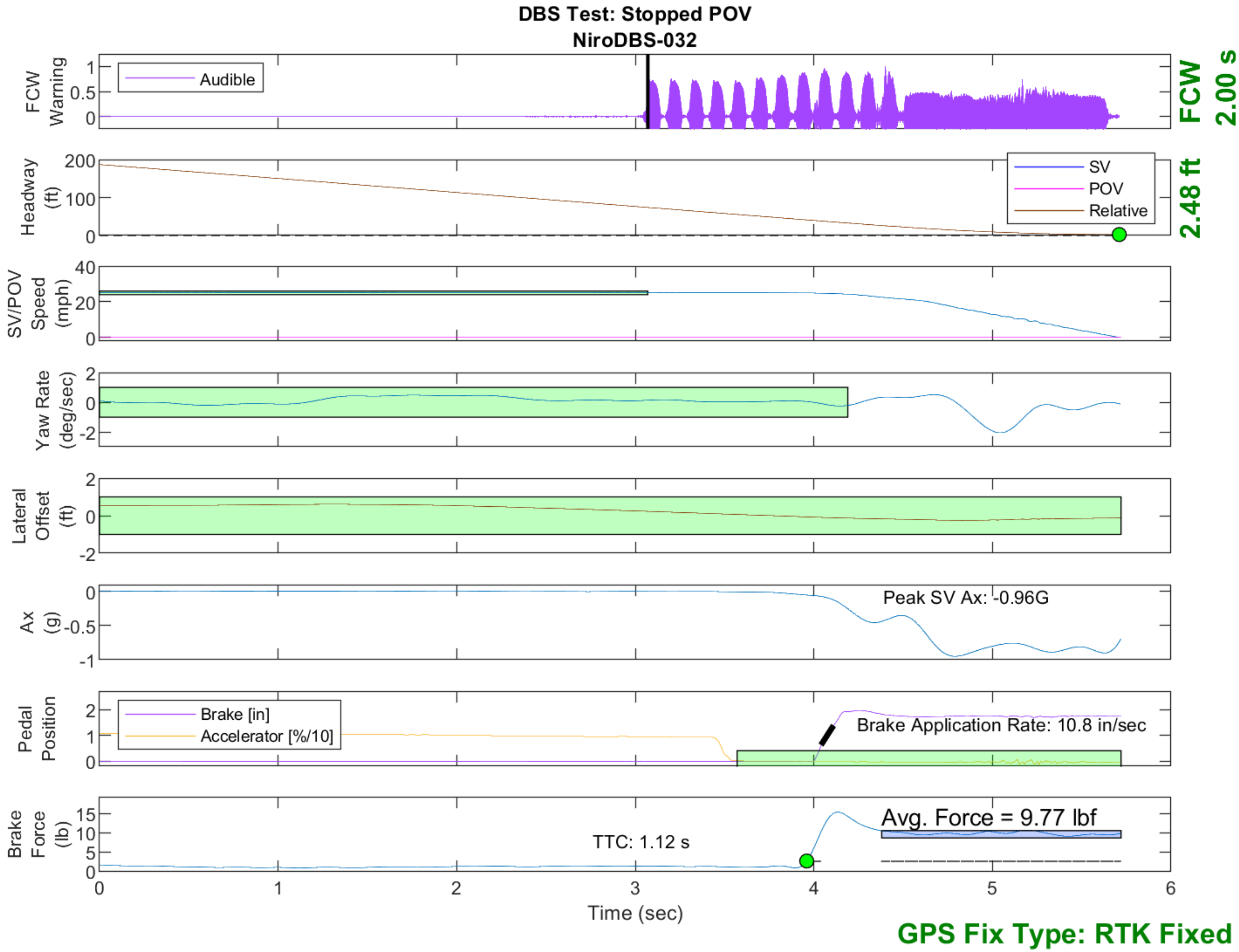


Figure E19. Time History for DBS Run 32, SV Encounters Stopped POV

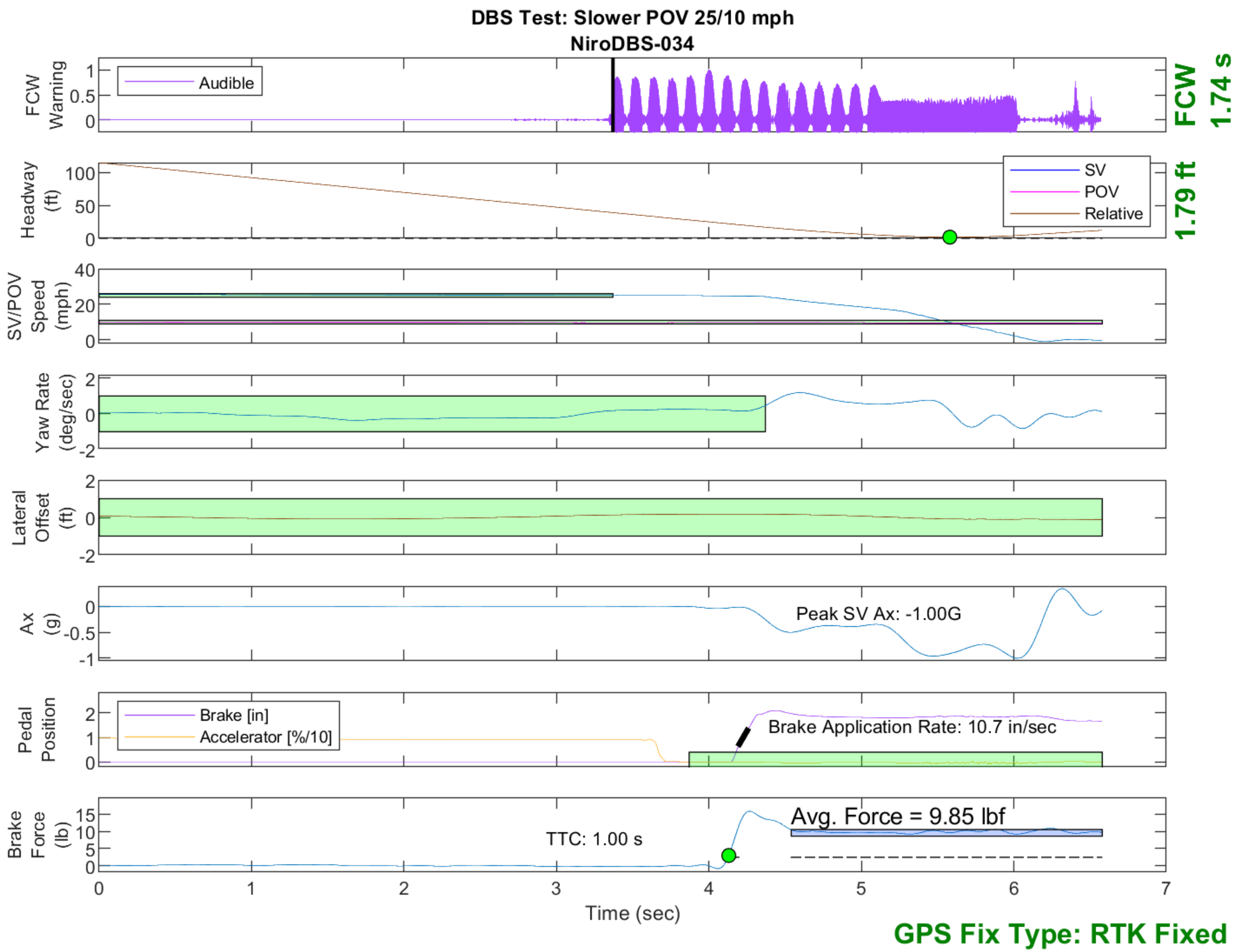


Figure E20. Time History for DBS Run 34, SV Encounters Slower POV, SV 25 mph, POV 10 mph

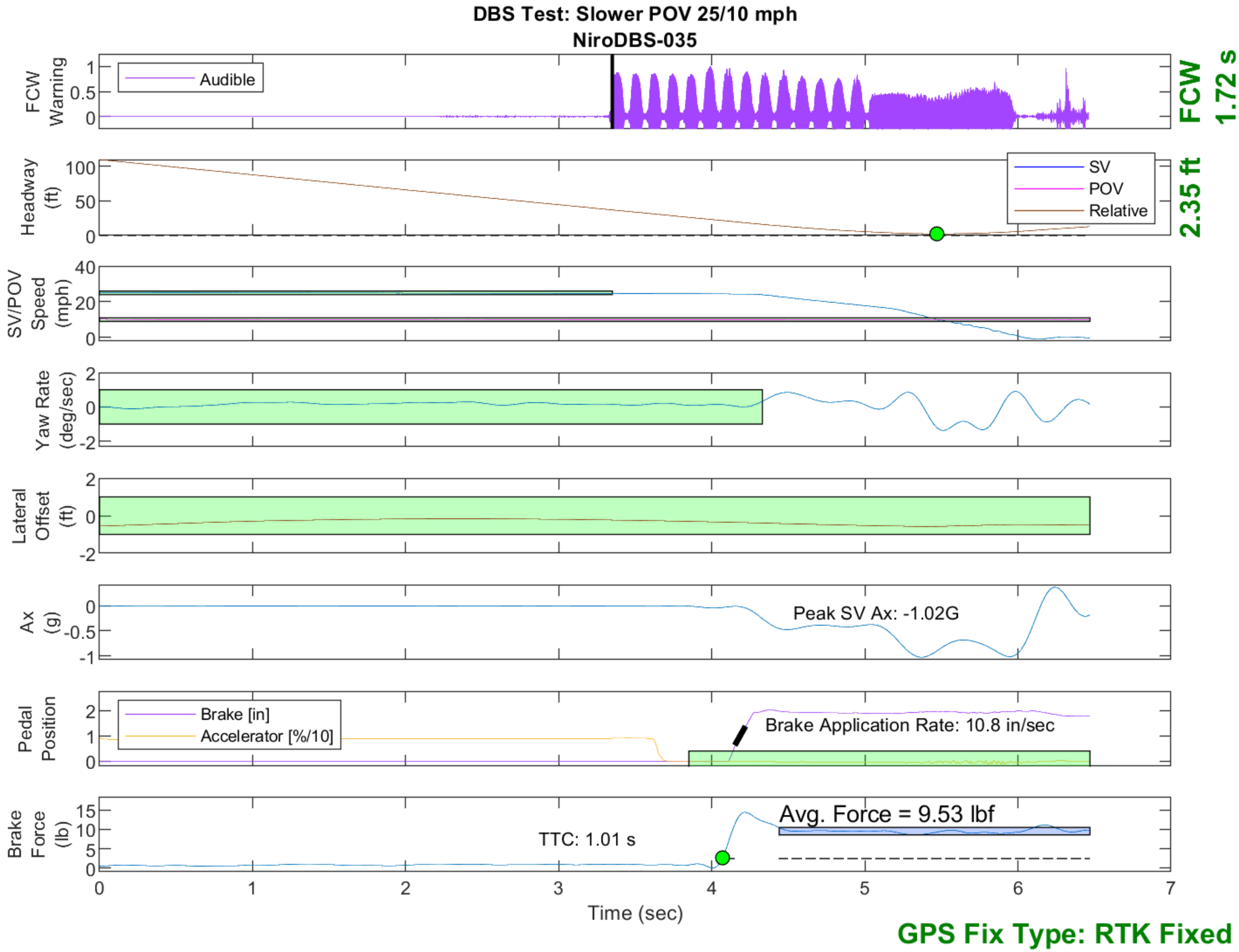


Figure E21. Time History for DBS Run 35, SV Encounters Slower POV, SV 25 mph, POV 10 mph

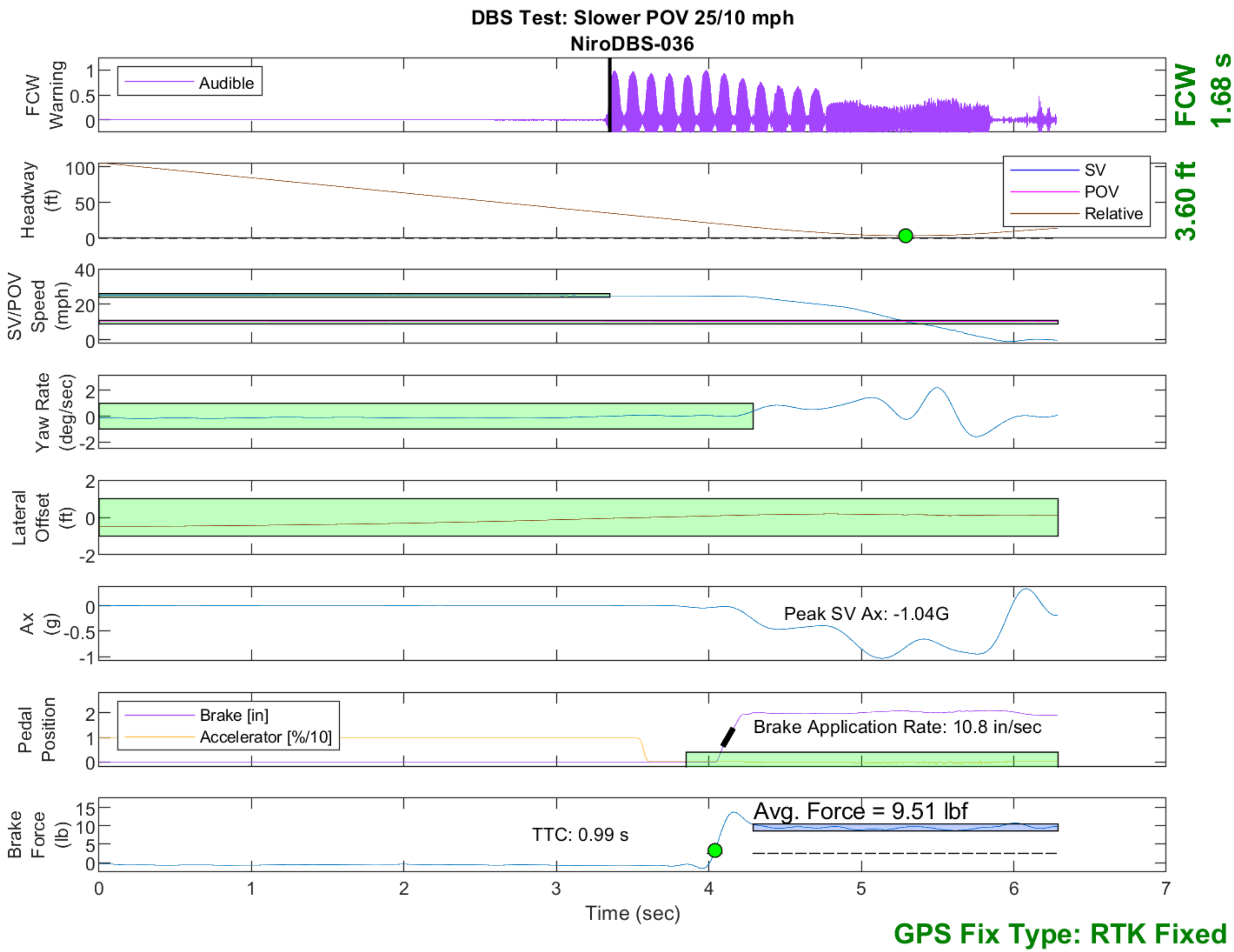


Figure E22. Time History for DBS Run 36, SV Encounters Slower POV, SV 25 mph, POV 10 mph

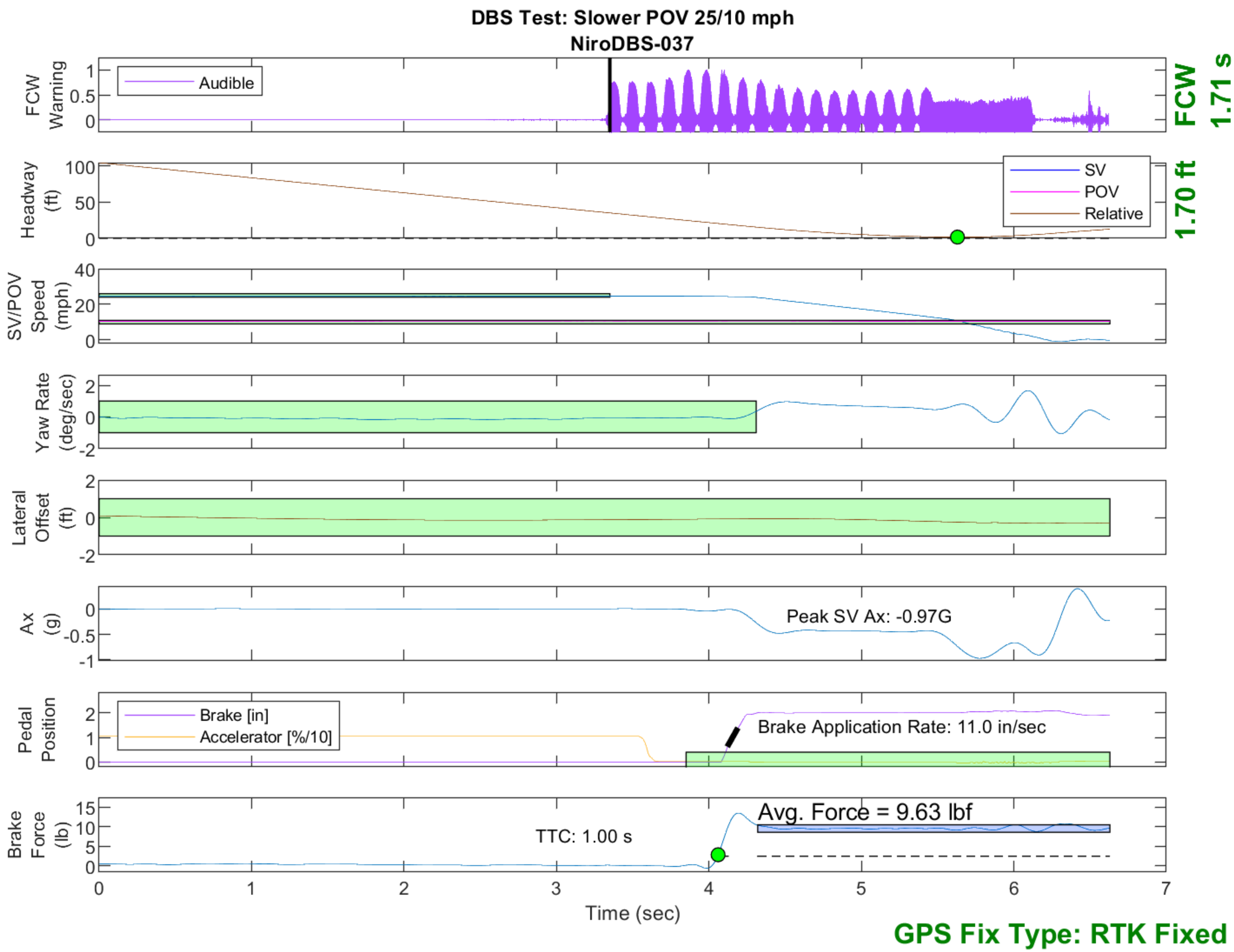


Figure E23. Time History for DBS Run 37, SV Encounters Slower POV, SV 25 mph, POV 10 mph

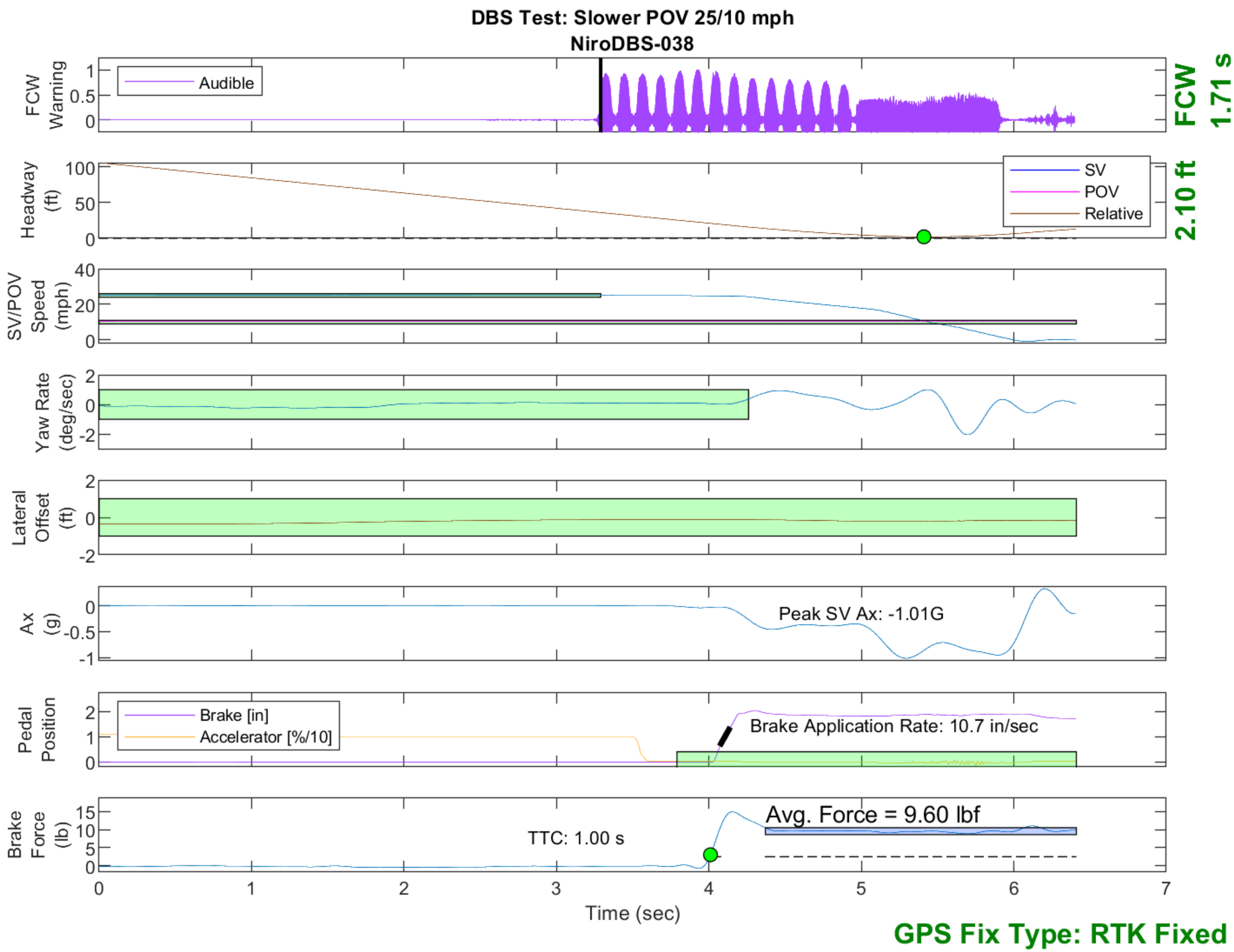


Figure E24. Time History for DBS Run 38, SV Encounters Slower POV, SV 25 mph, POV 10 mph

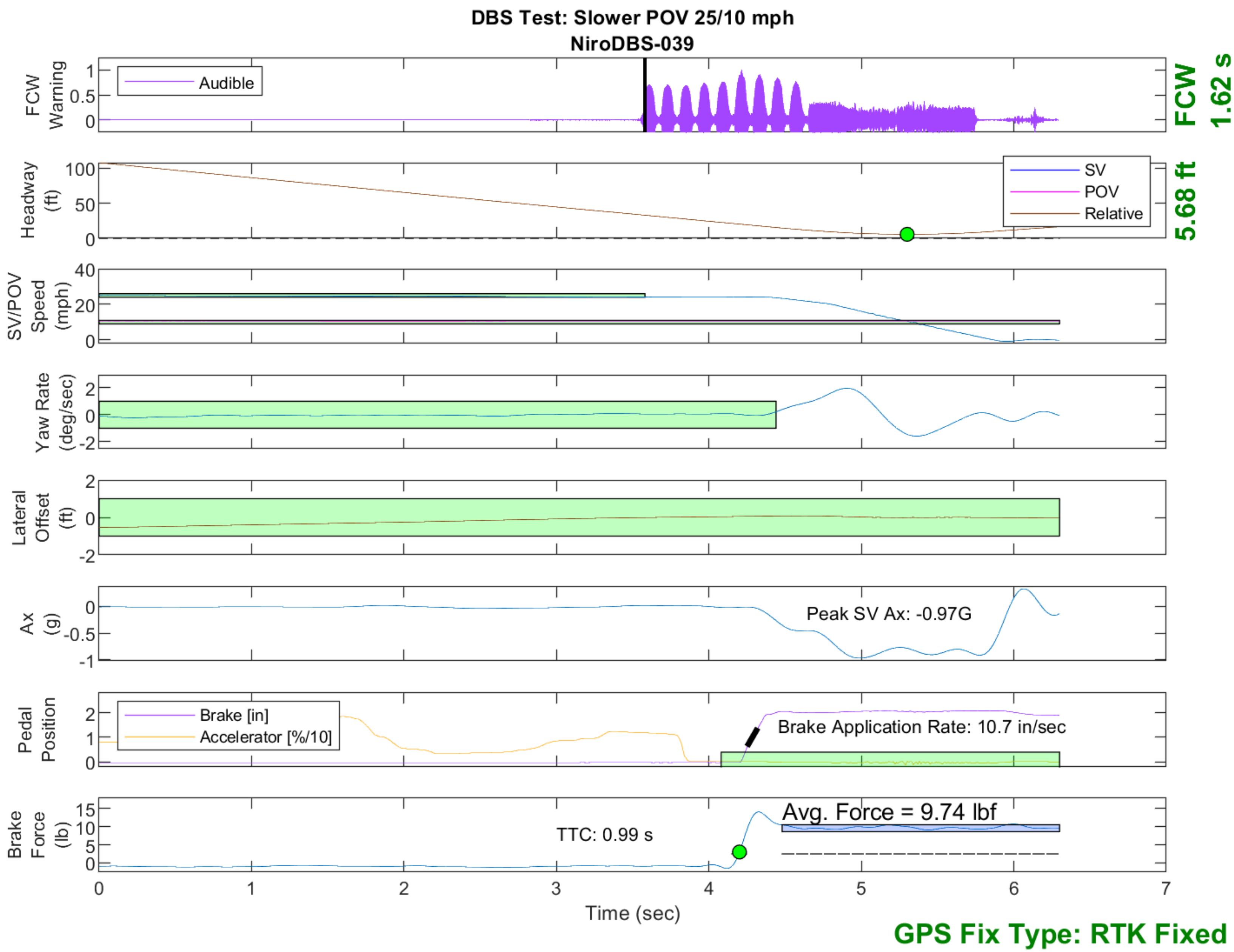


Figure E25. Time History for DBS Run 39, SV Encounters Slower POV, SV 25 mph, POV 10 mph

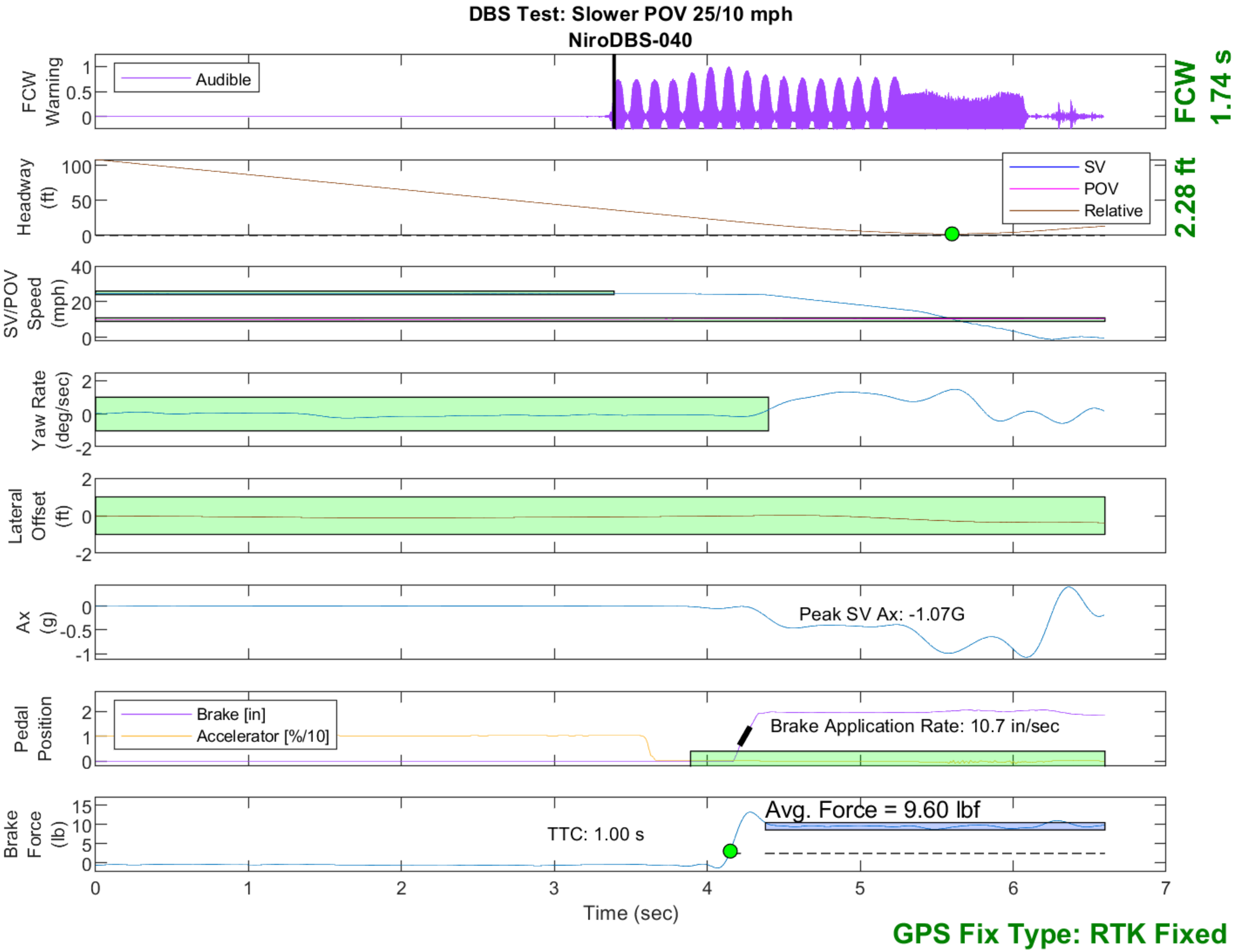


Figure E26. Time History for DBS Run 40, SV Encounters Slower POV, SV 25 mph, POV 10 mph

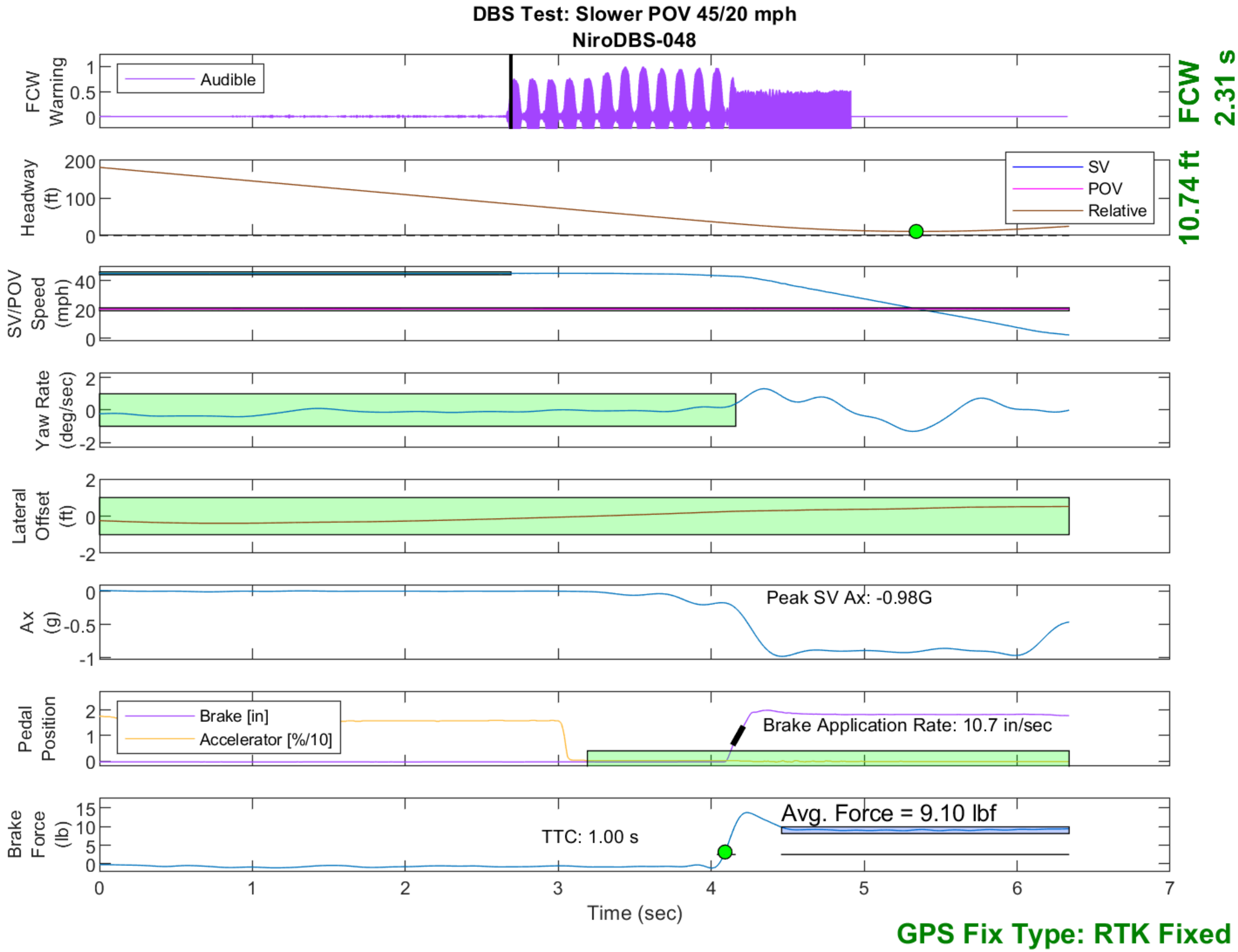


Figure E27. Time History for DBS Run 48, SV Encounters Slower POV, SV 45 mph, POV 20 mph

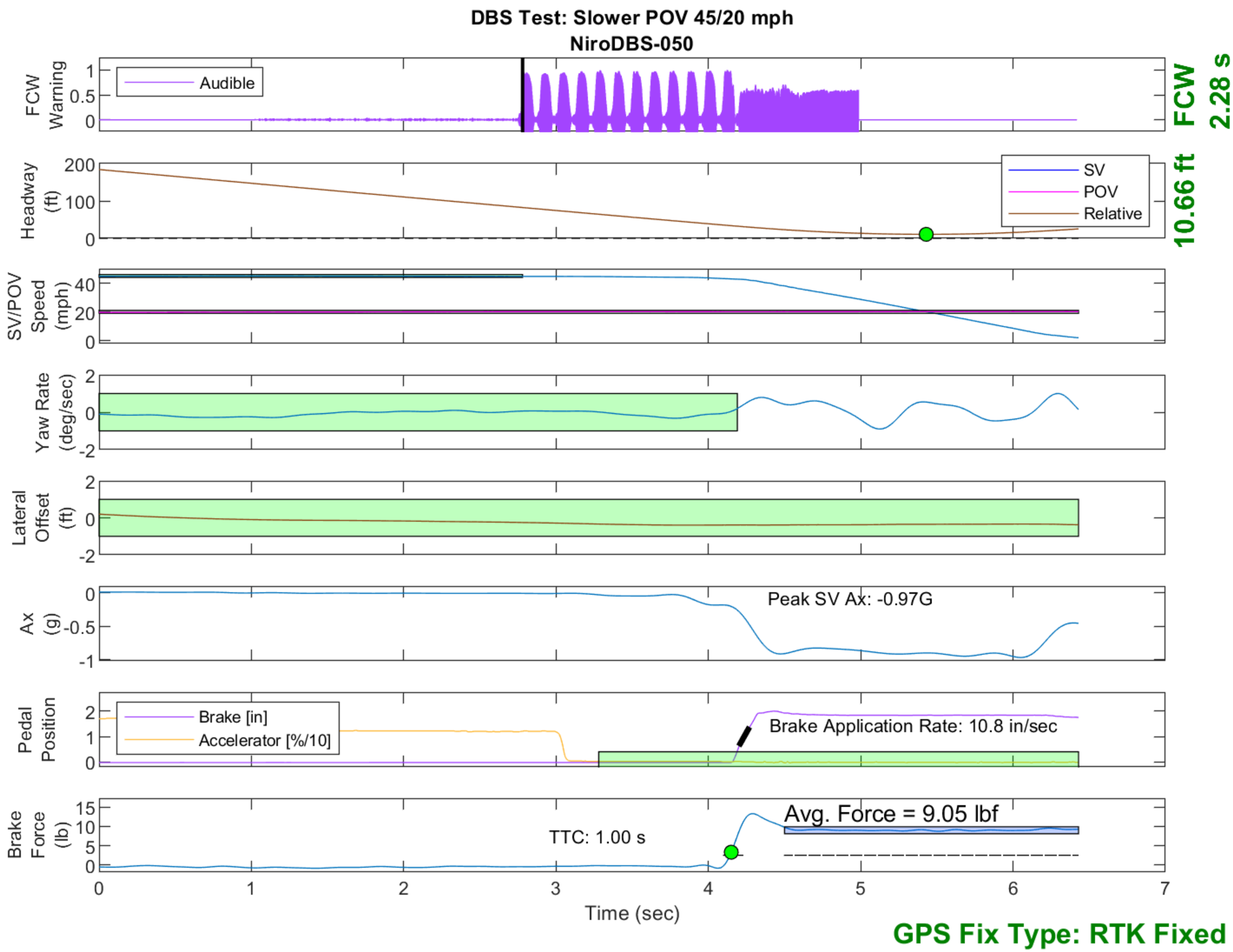


Figure E28. Time History for DBS Run 50, SV Encounters Slower POV, SV 45 mph, POV 20 mph

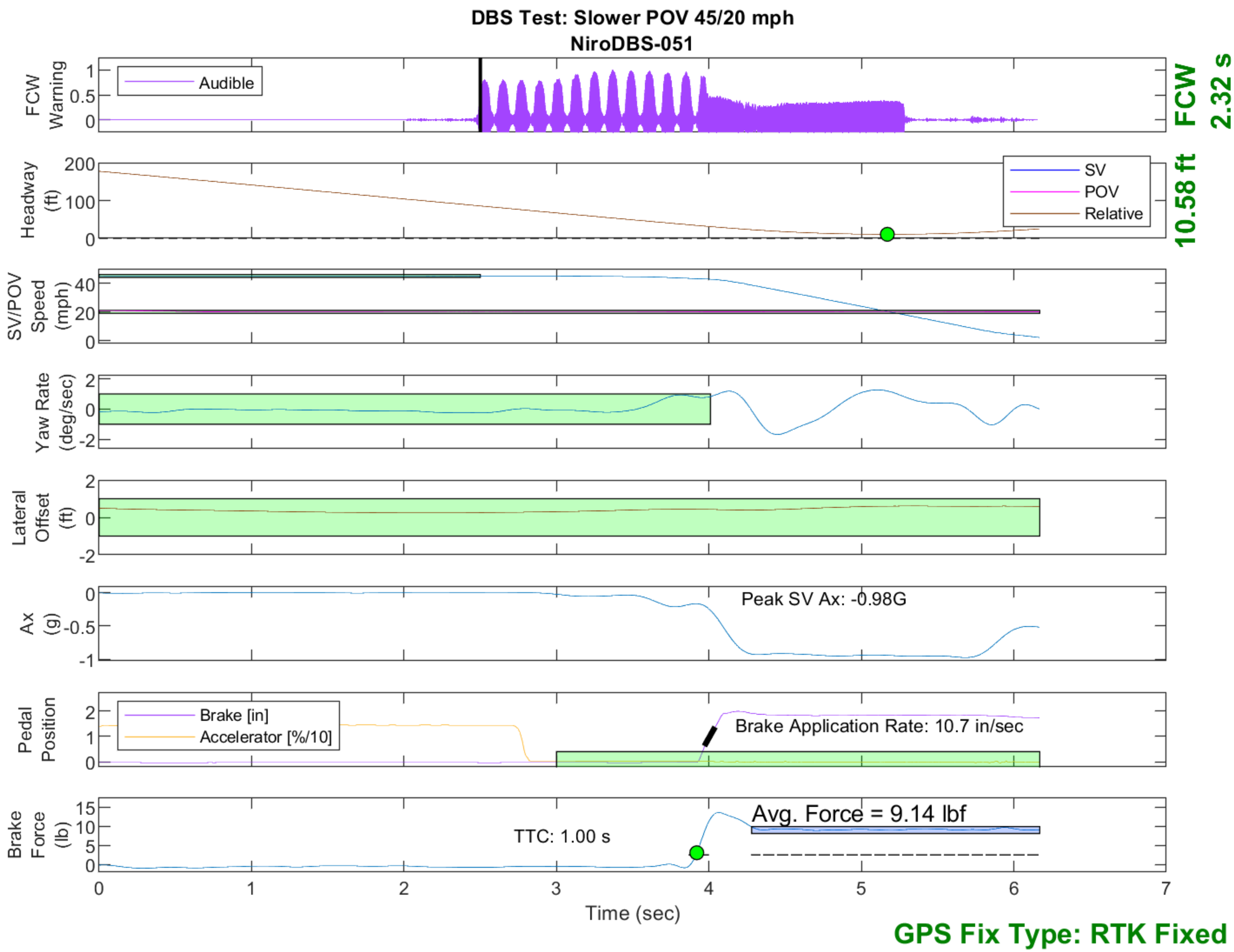


Figure E29. Time History for DBS Run 51, SV Encounters Slower POV, SV 45 mph, POV 20 mph

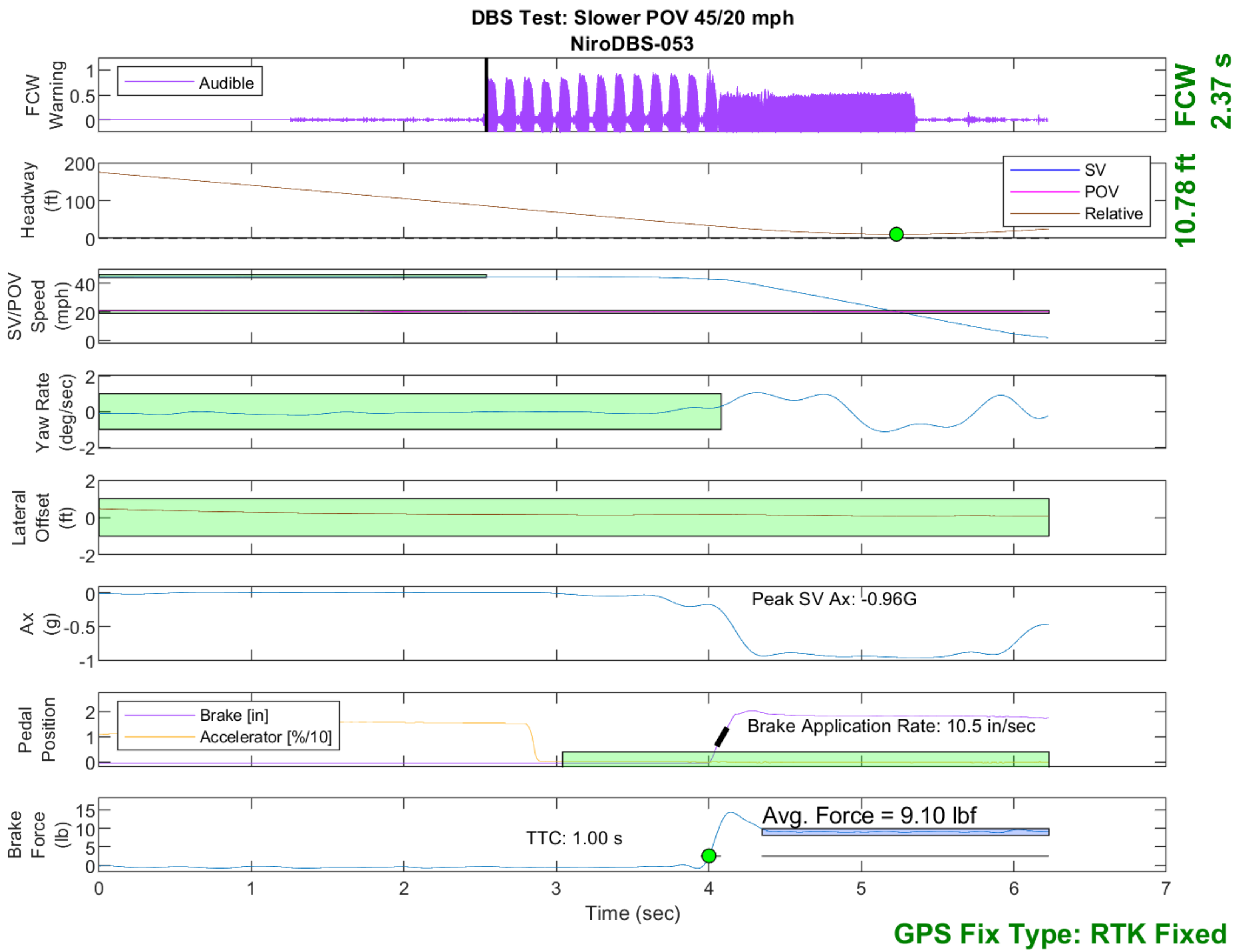


Figure E30. Time History for DBS Run 53, SV Encounters Slower POV, SV 45 mph, POV 20 mph

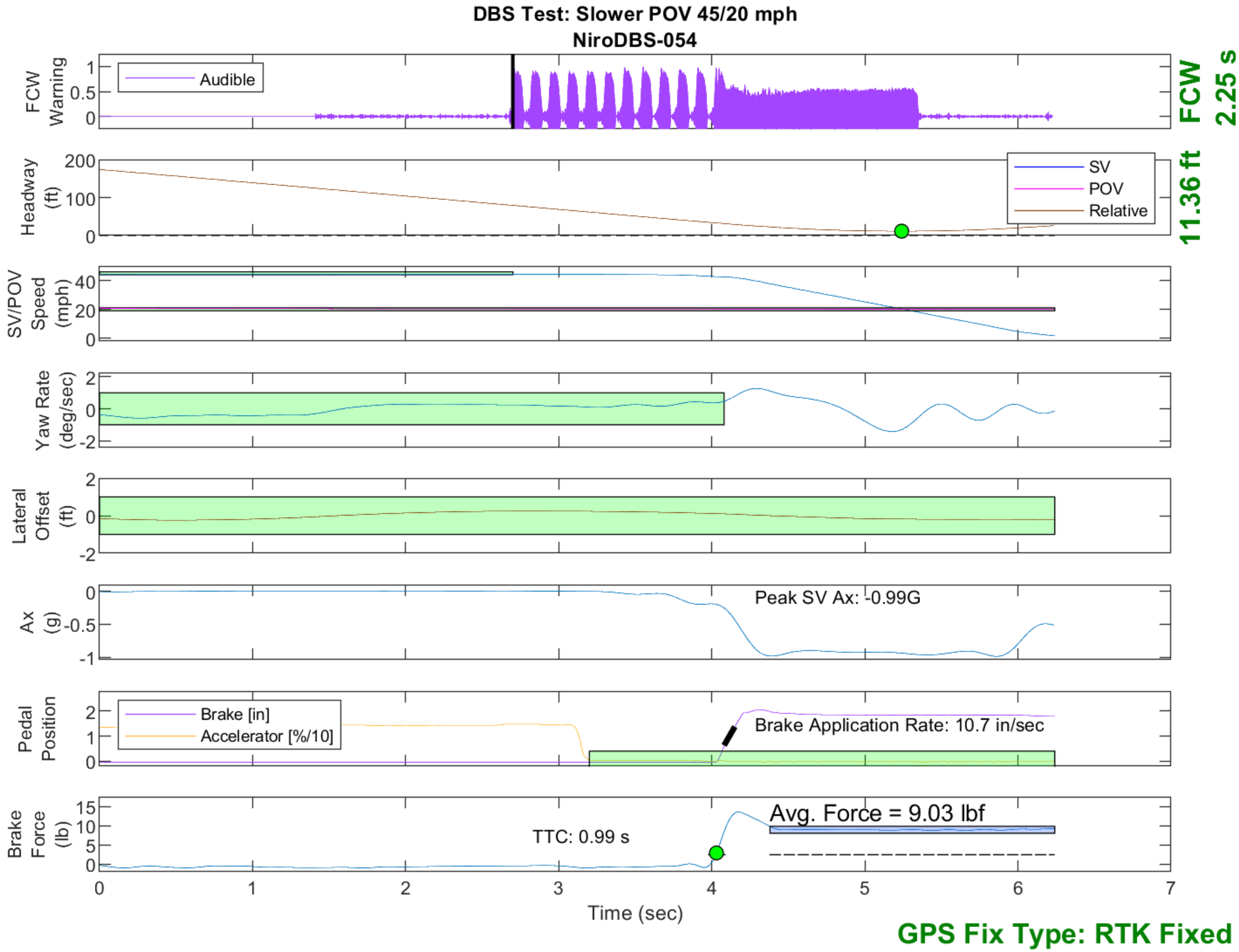


Figure E31. Time History for DBS Run 54, SV Encounters Slower POV, SV 45 mph, POV 20 mph

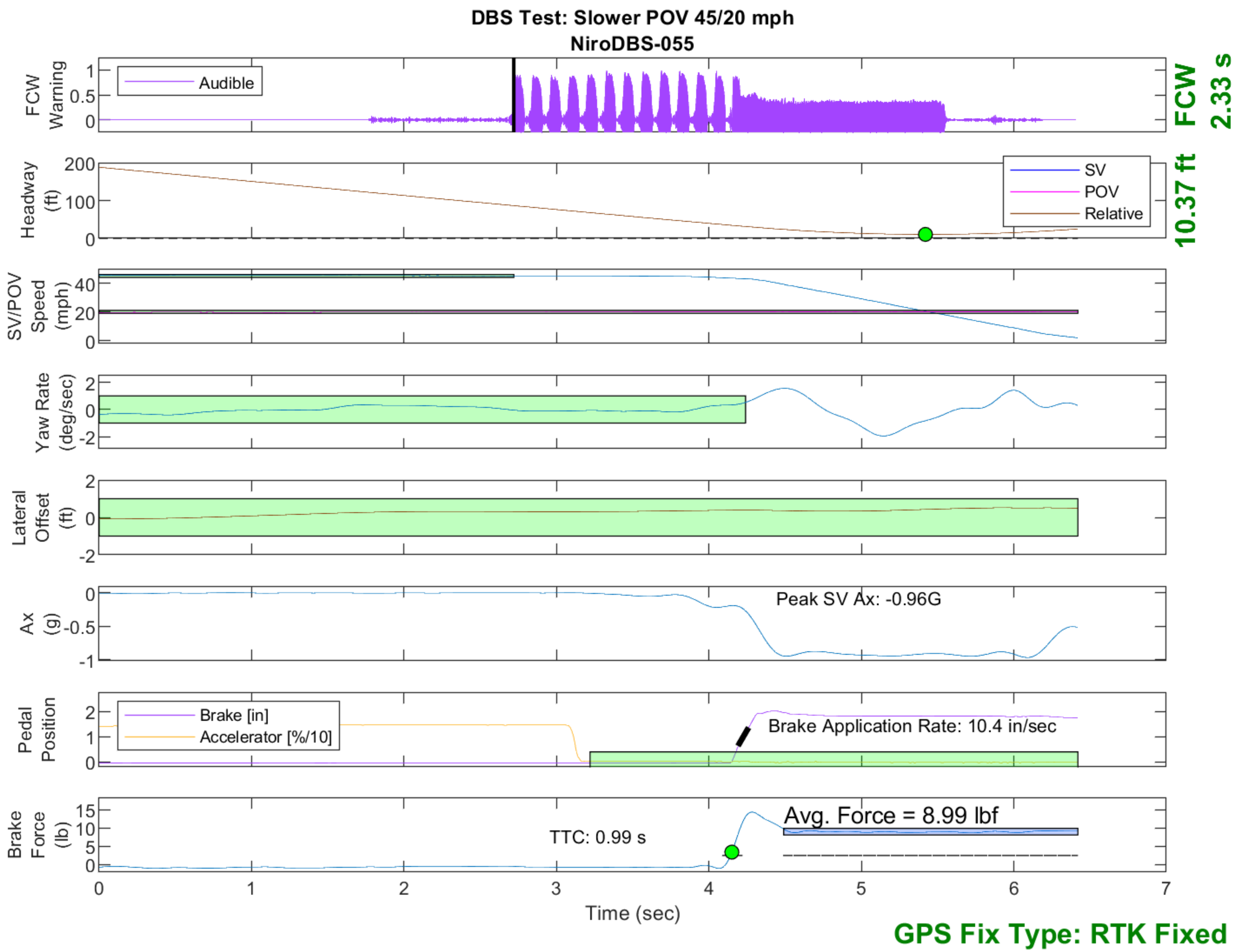


Figure E32. Time History for DBS Run 55, SV Encounters Slower POV, SV 45 mph, POV 20 mph

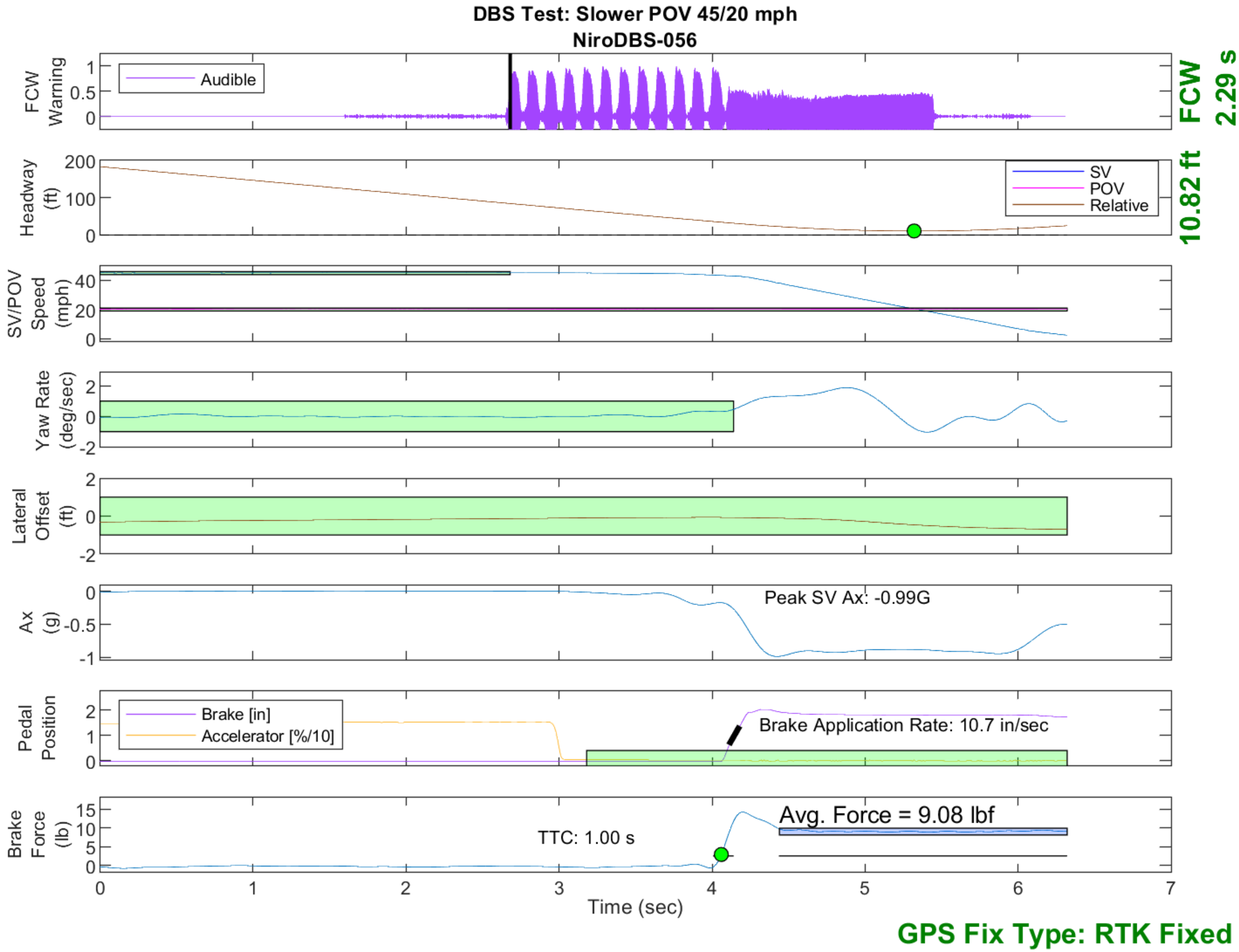


Figure E33. Time History for DBS Run 56, SV Encounters Slower POV, SV 45 mph, POV 20 mph

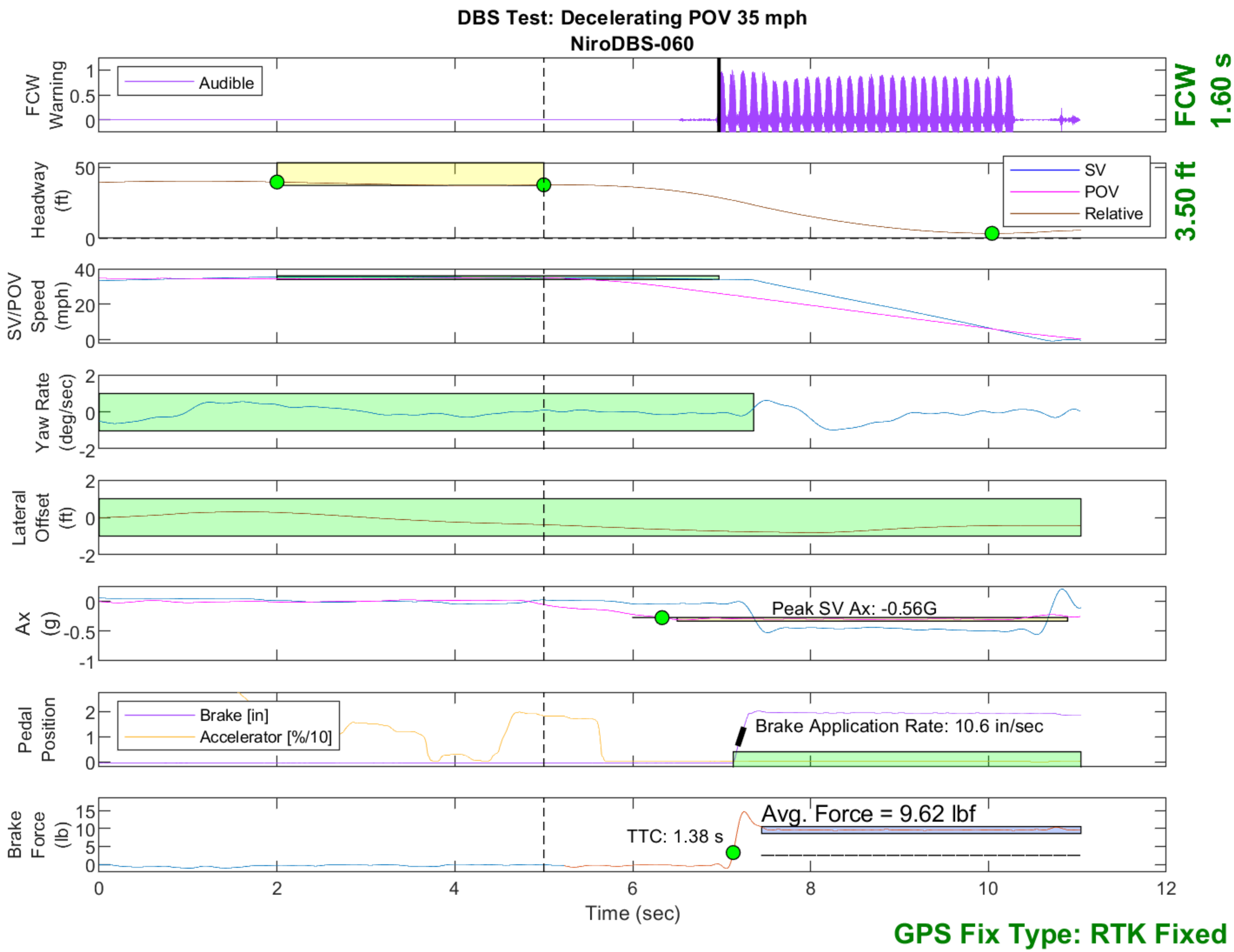


Figure E34. Time History for DBS Run 60, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

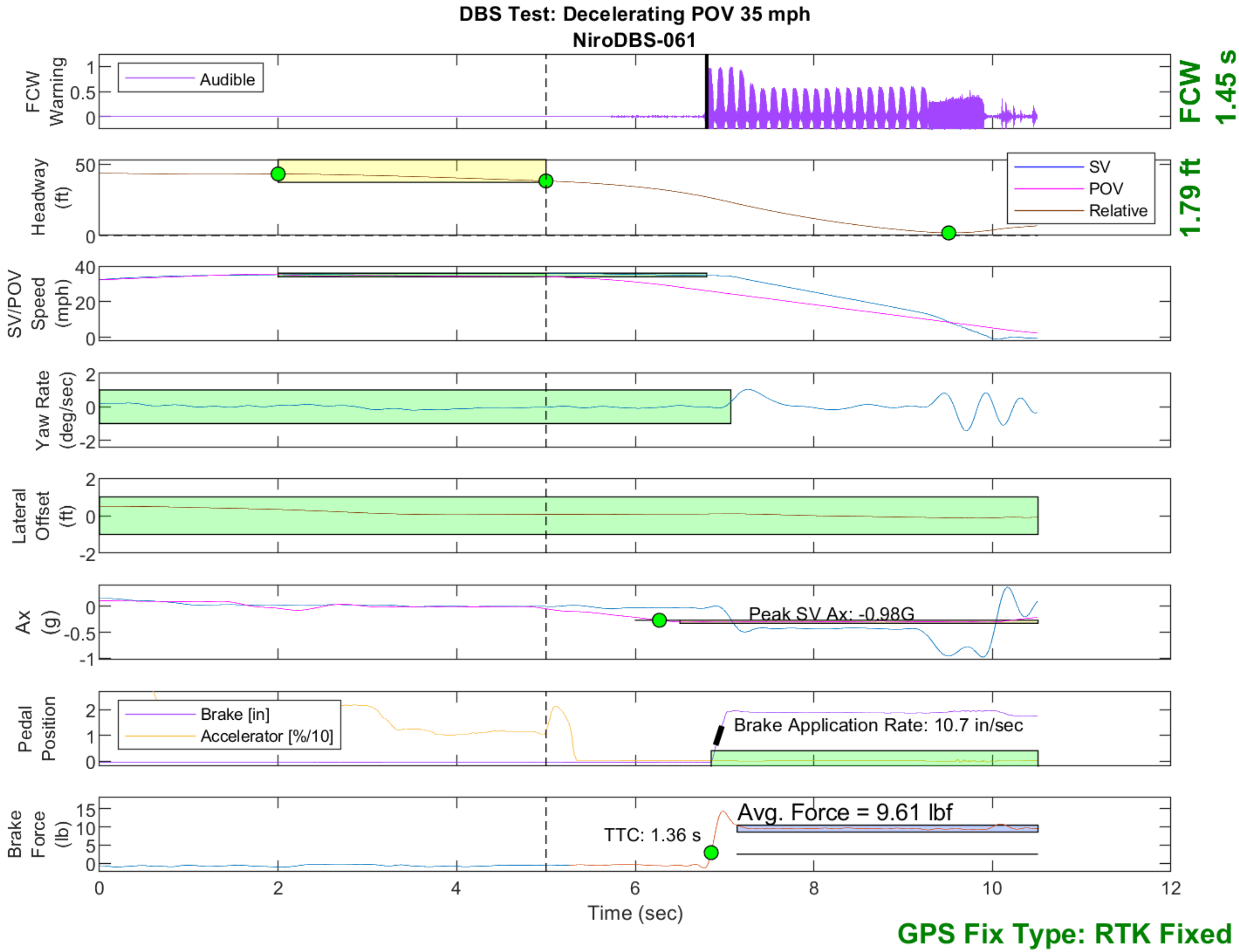


Figure E35. Time History for DBS Run 61, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

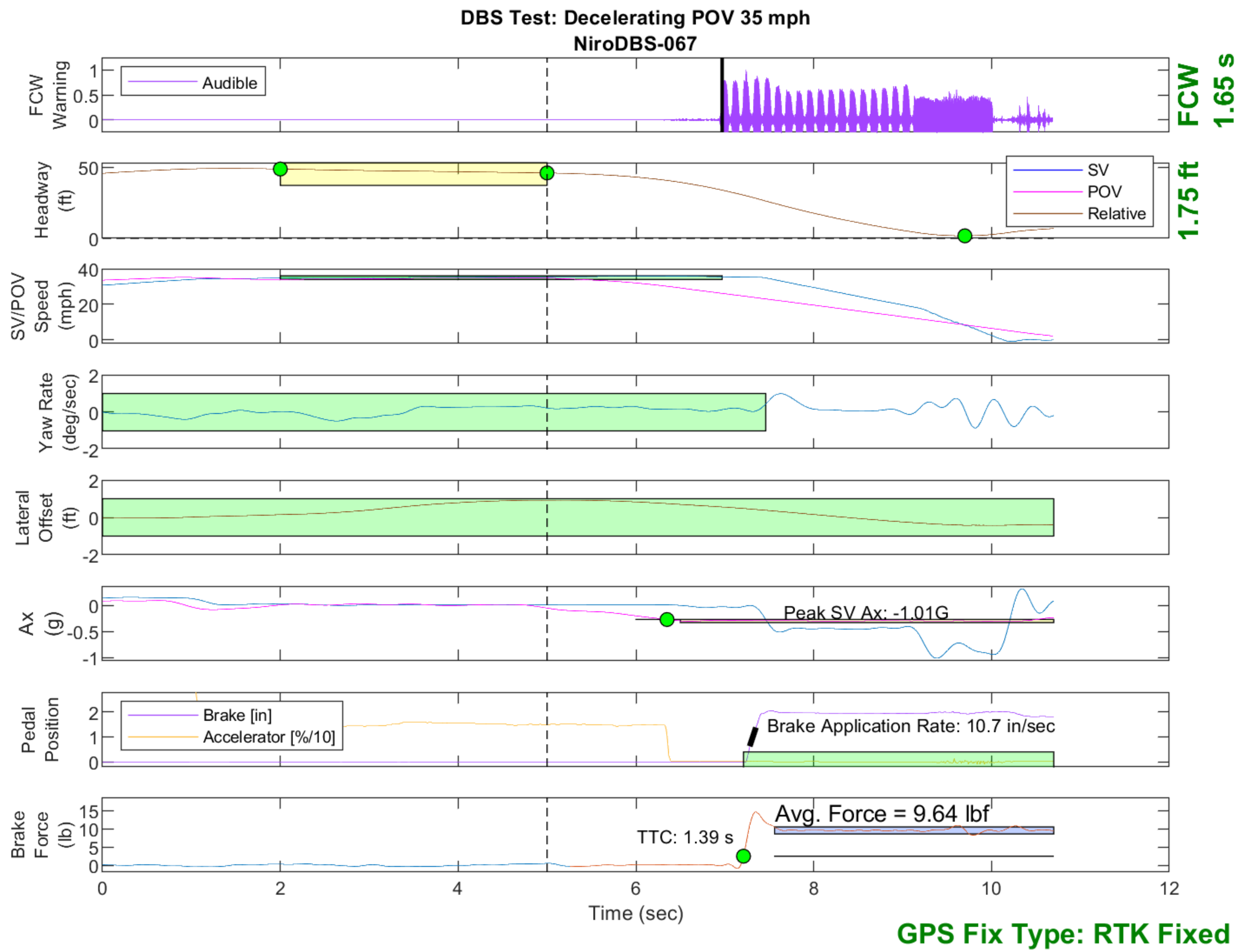


Figure E36. Time History for DBS Run 67, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

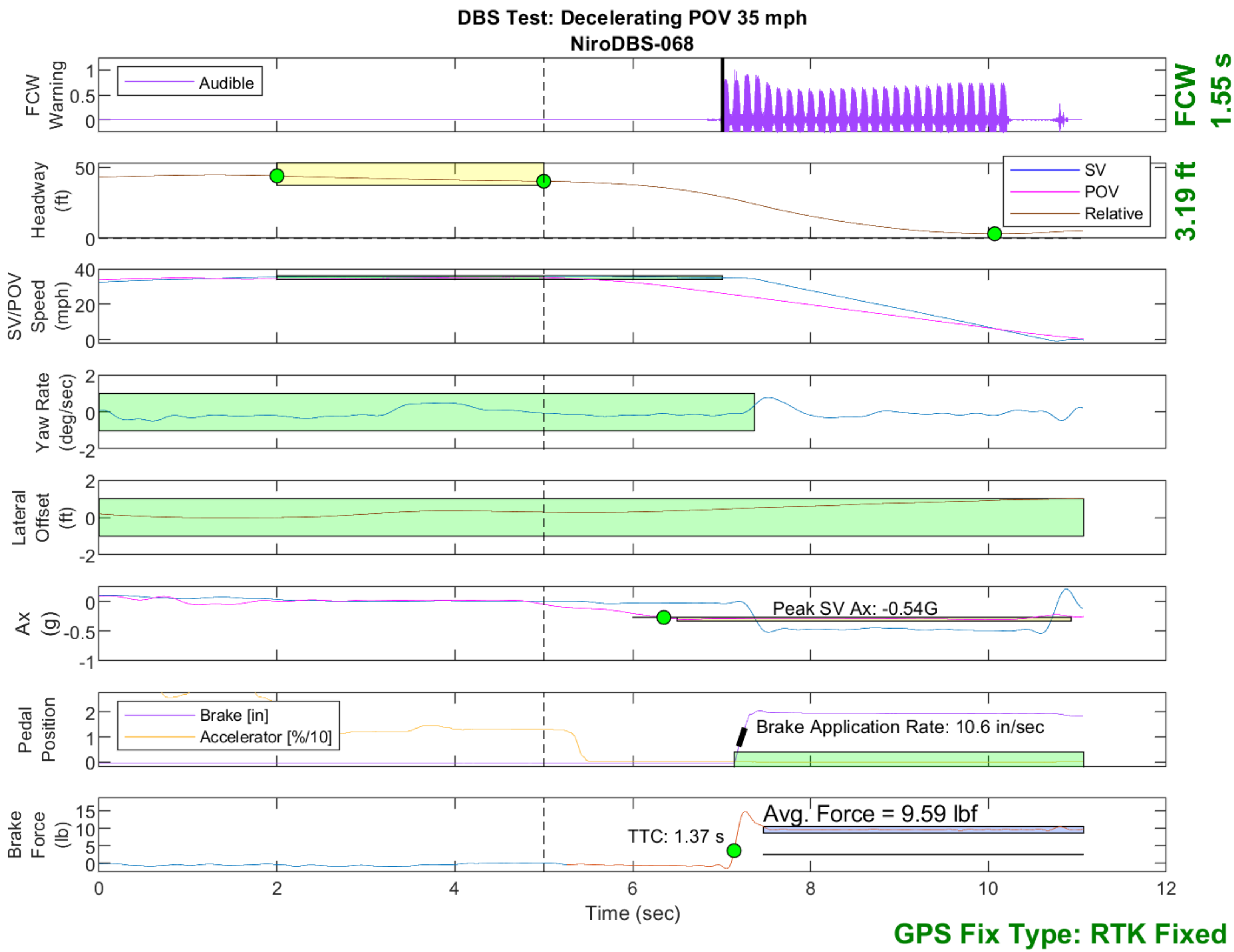


Figure E37. Time History for DBS Run 68, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

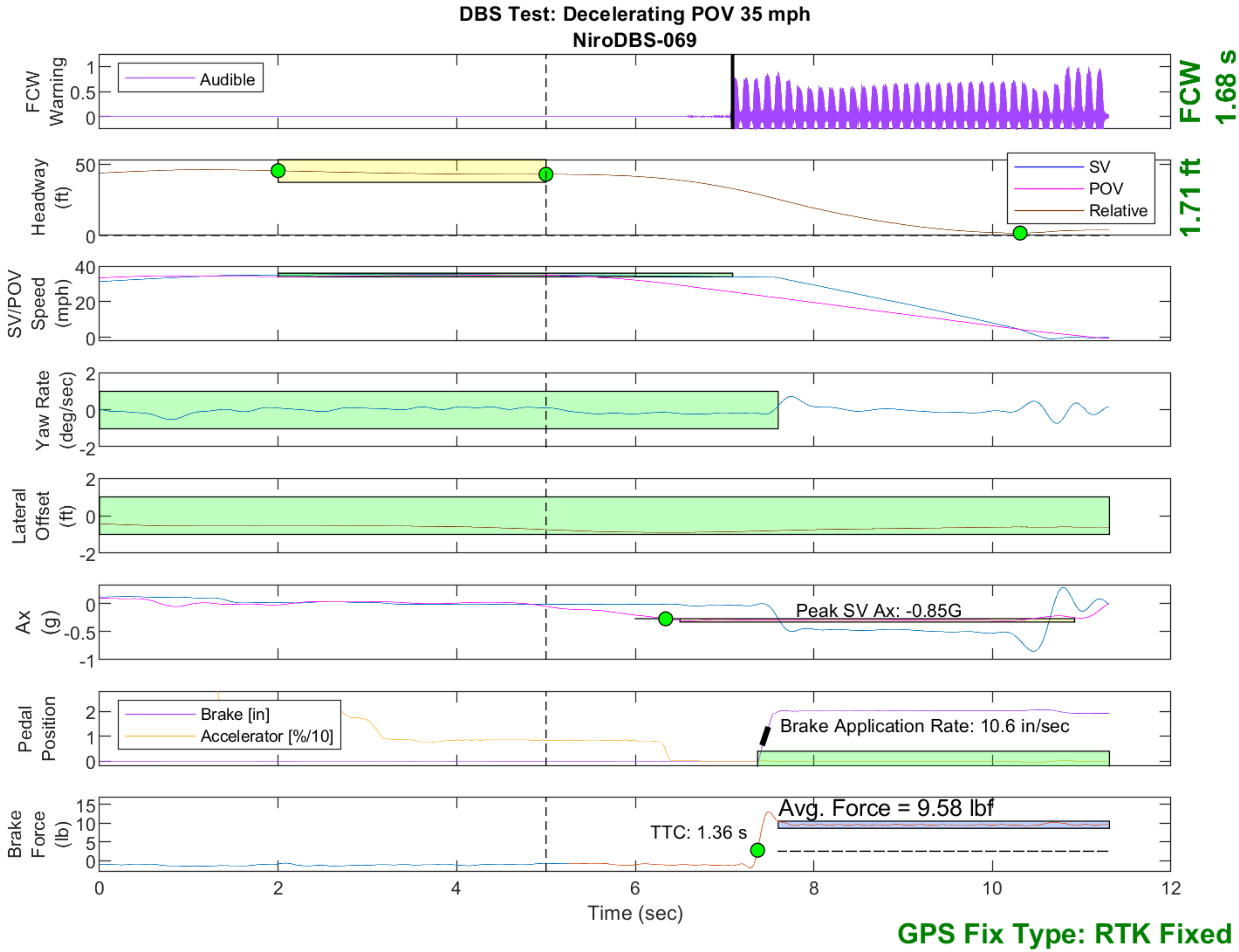


Figure E38. Time History for DBS Run 69, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

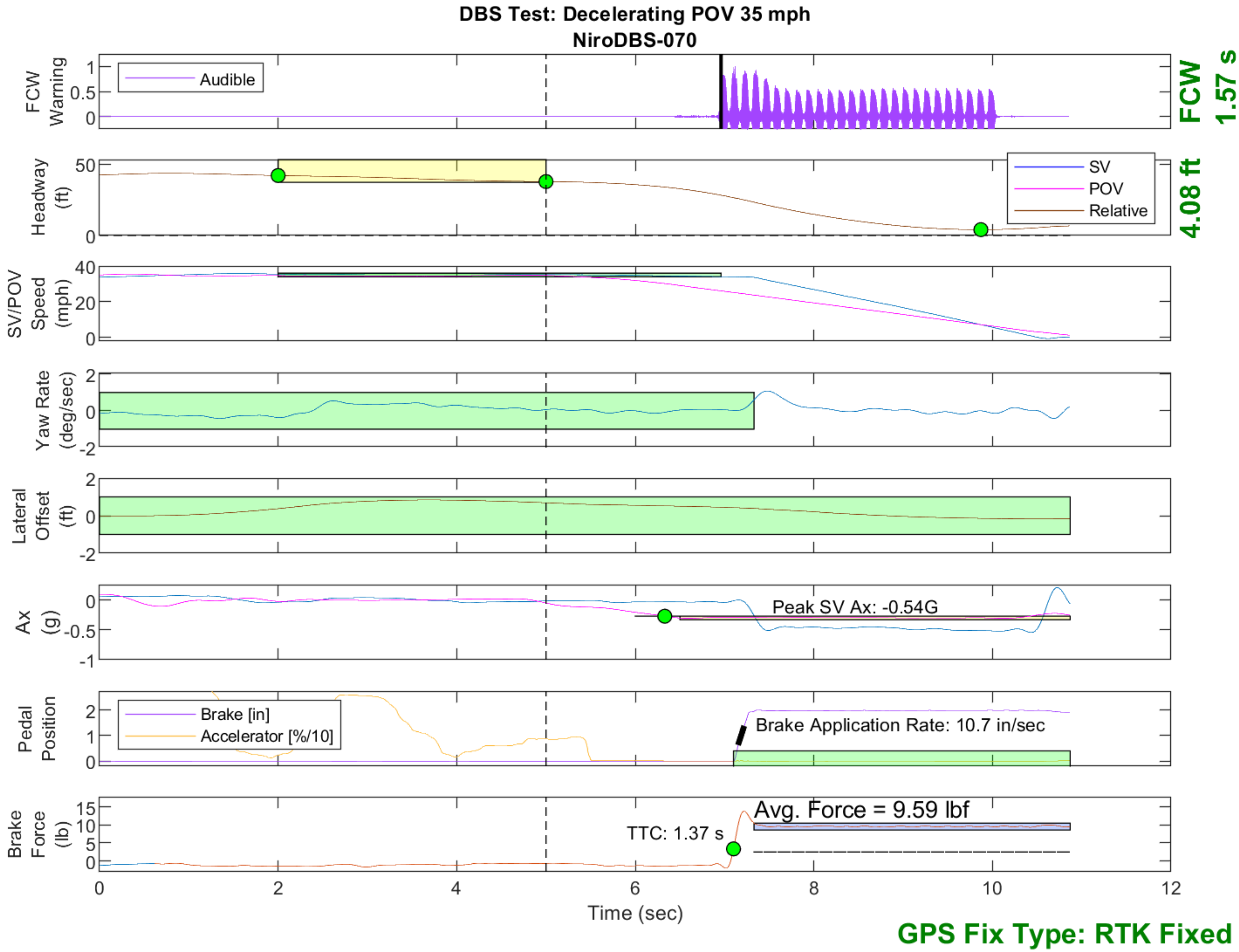


Figure E39. Time History for DBS Run 70, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

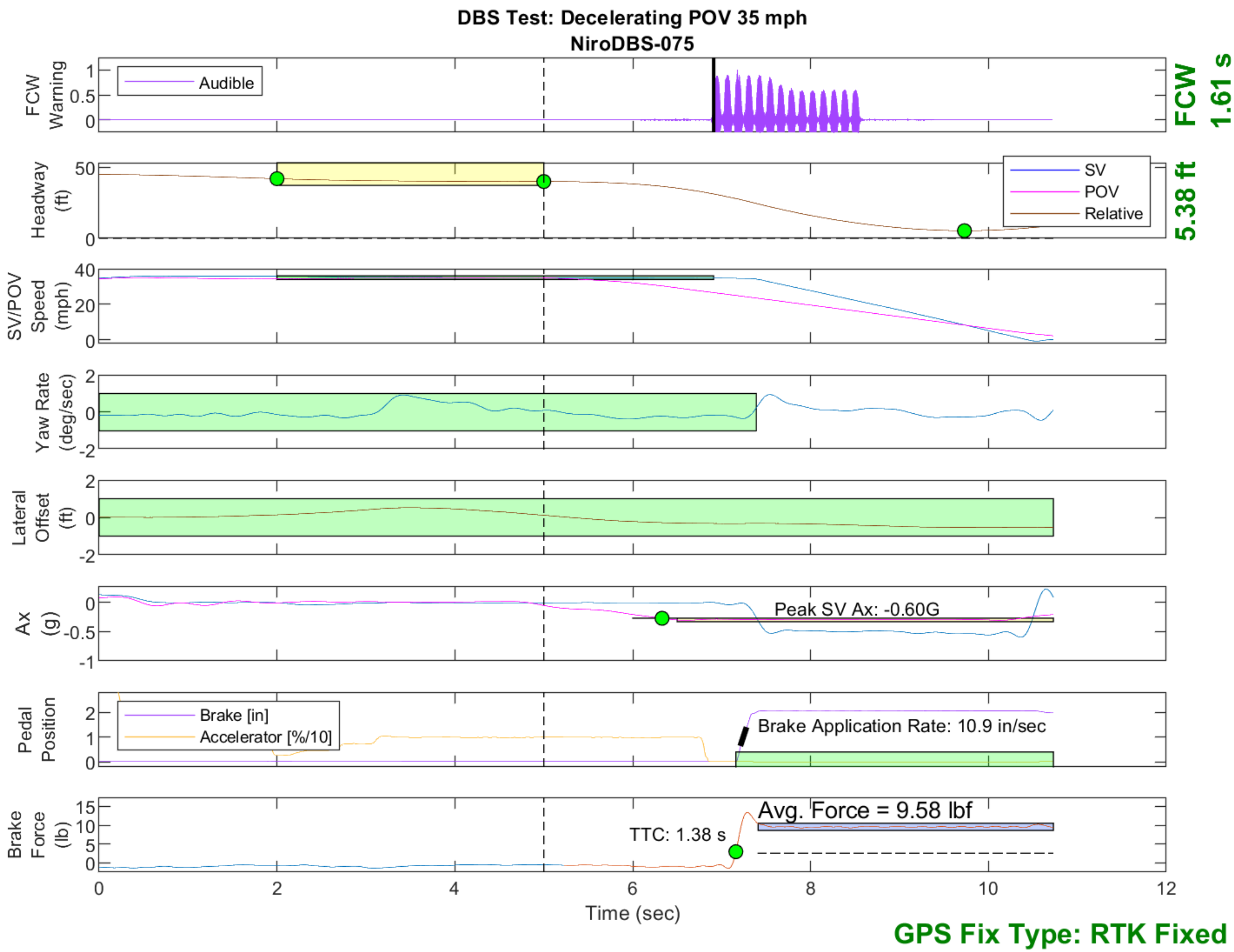


Figure E40. Time History for DBS Run 75, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

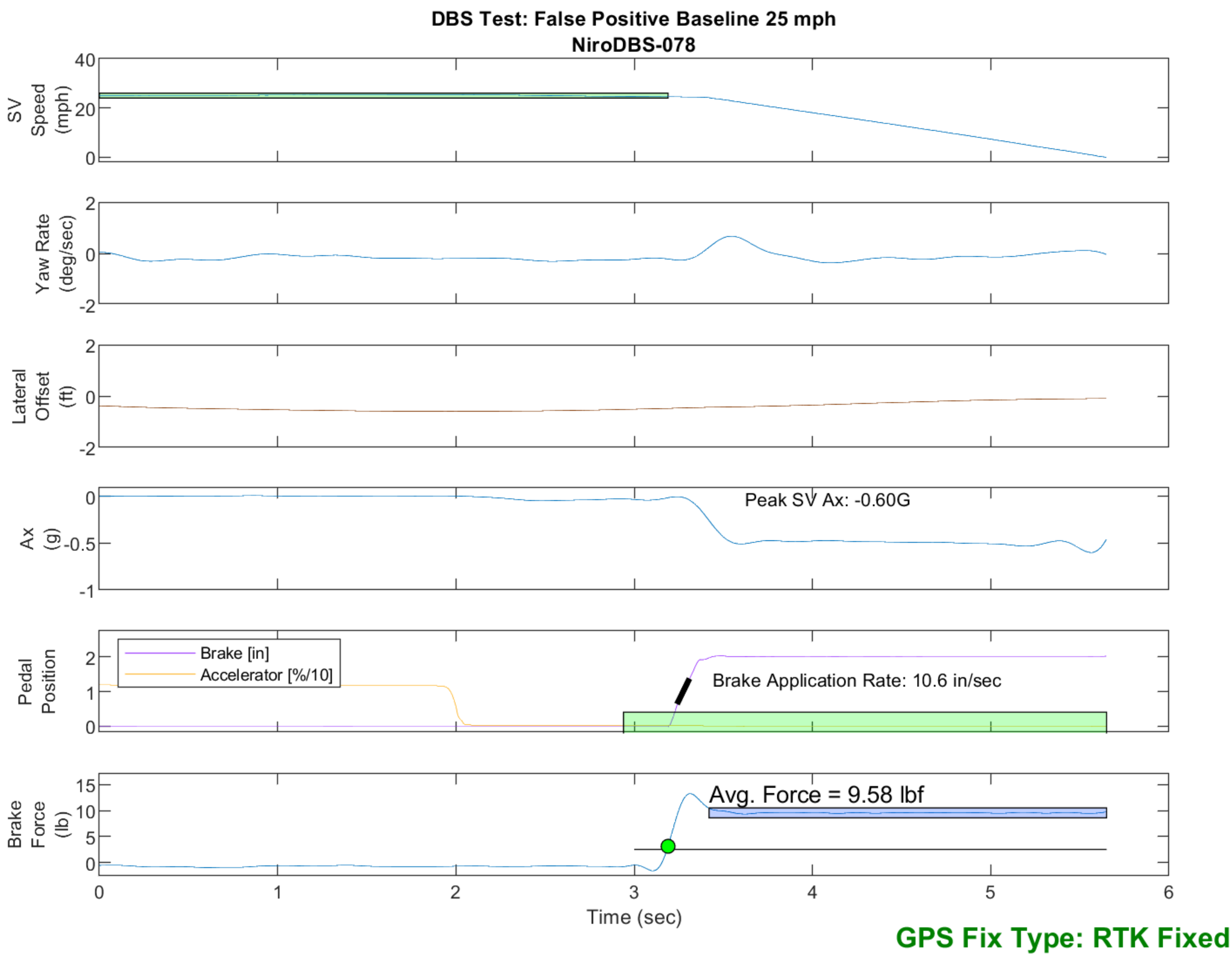


Figure E41. Time History for DBS Run 78, False Positive Baseline, SV 25 mph

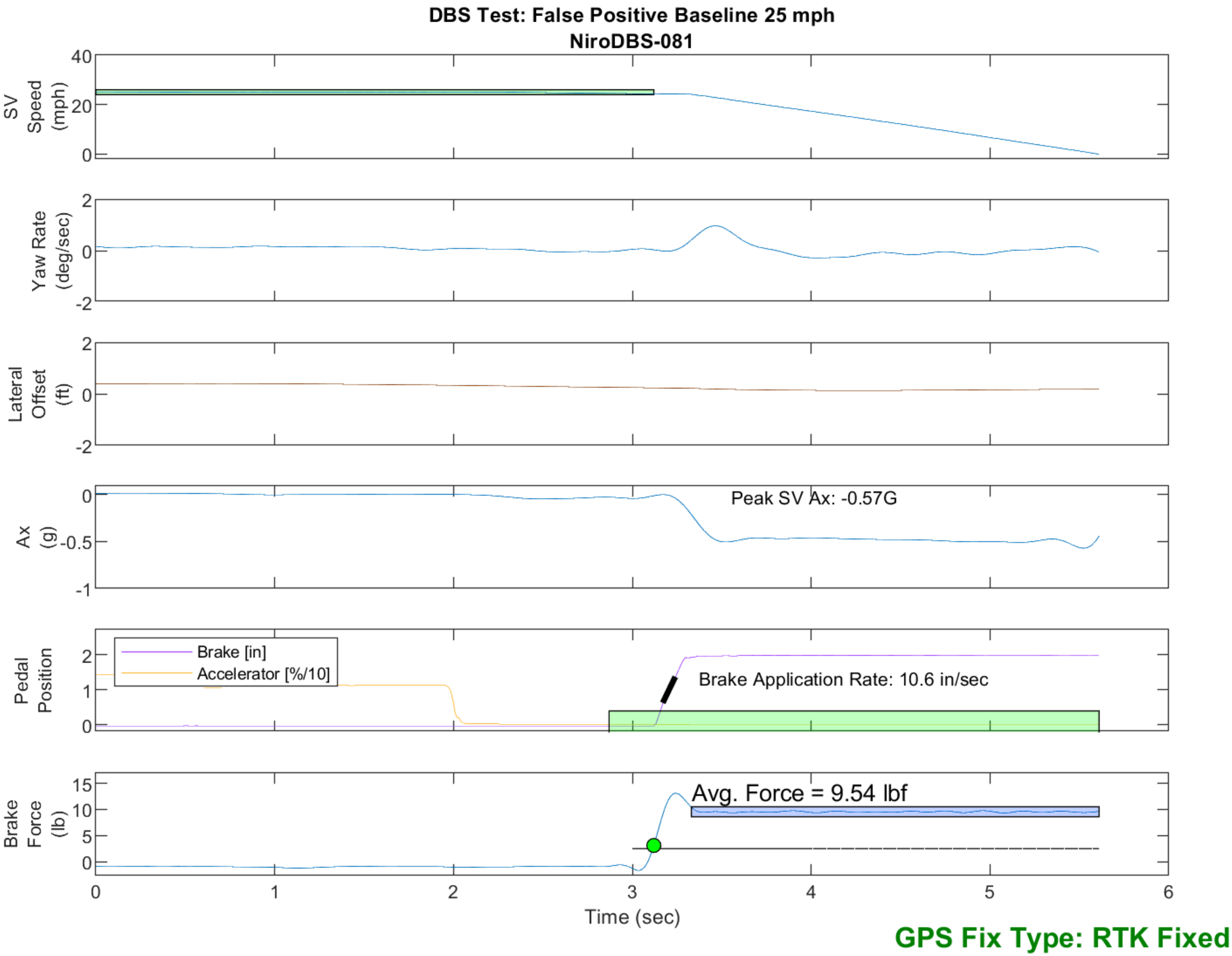


Figure E42. Time History for DBS Run 81, False Positive Baseline, SV 25 mph

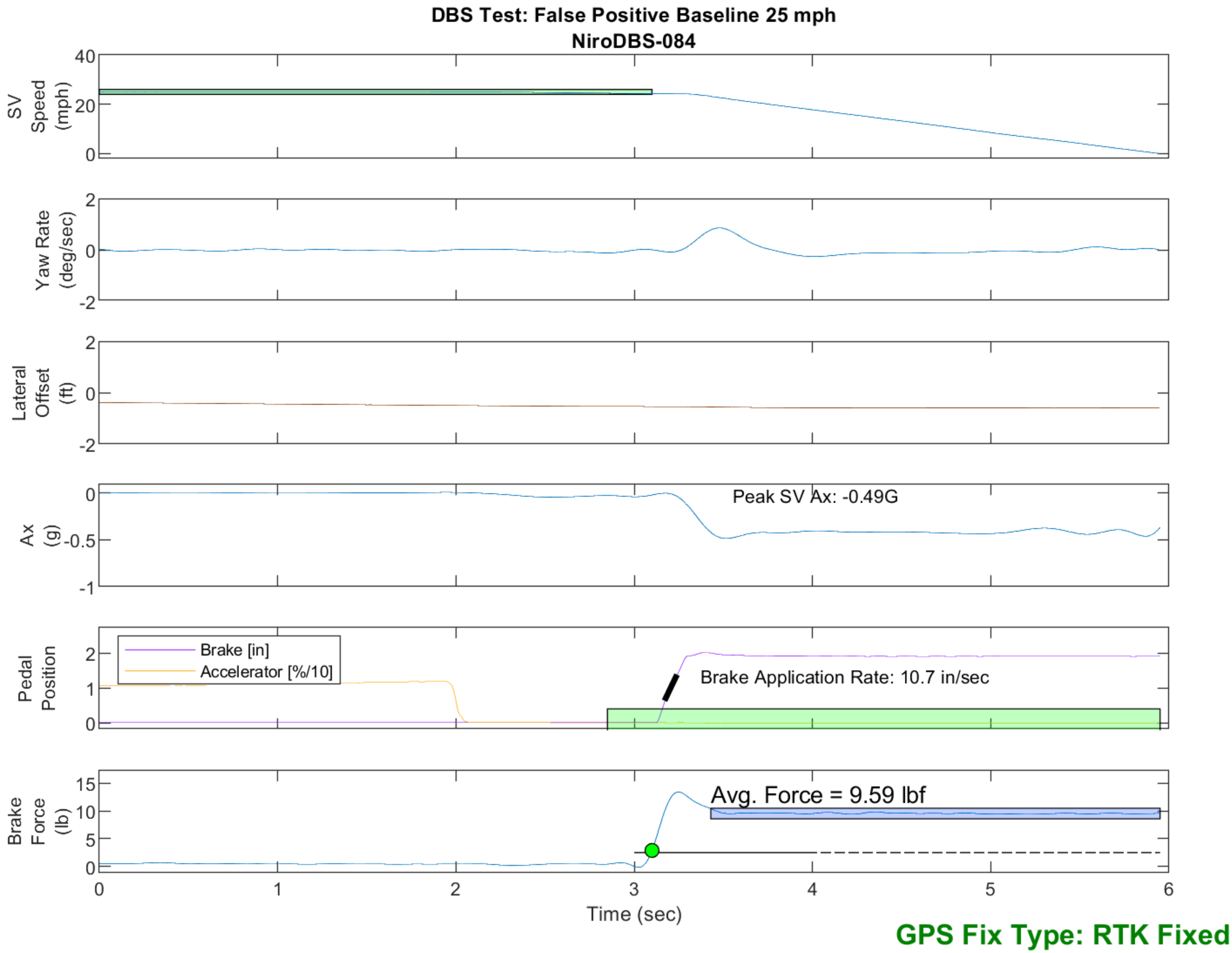


Figure E43. Time History for DBS Run 84, False Positive Baseline, SV 25 mph

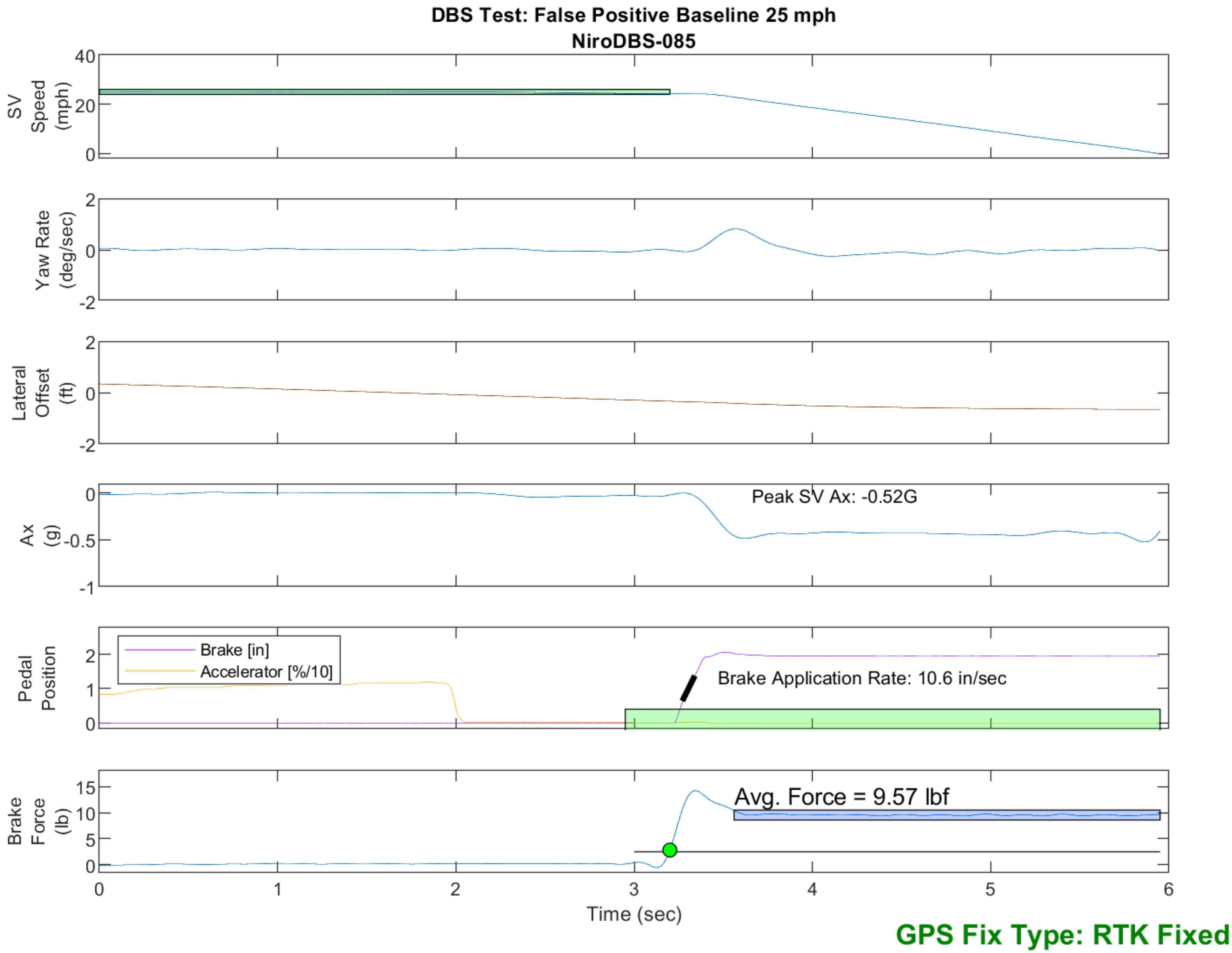


Figure E44. Time History for DBS Run 85, False Positive Baseline, SV 25 mph

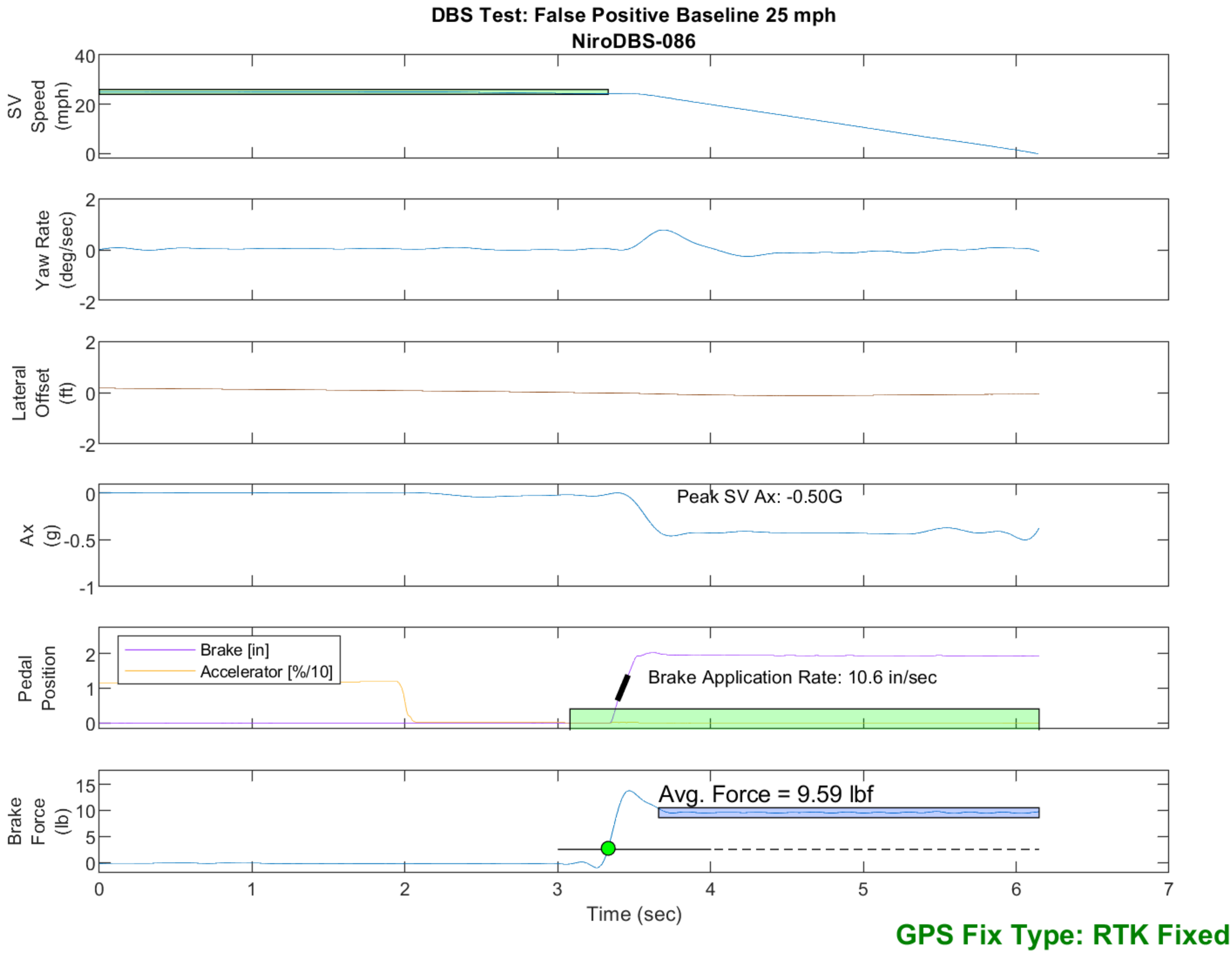


Figure E45. Time History for DBS Run 86, False Positive Baseline, SV 25 mph

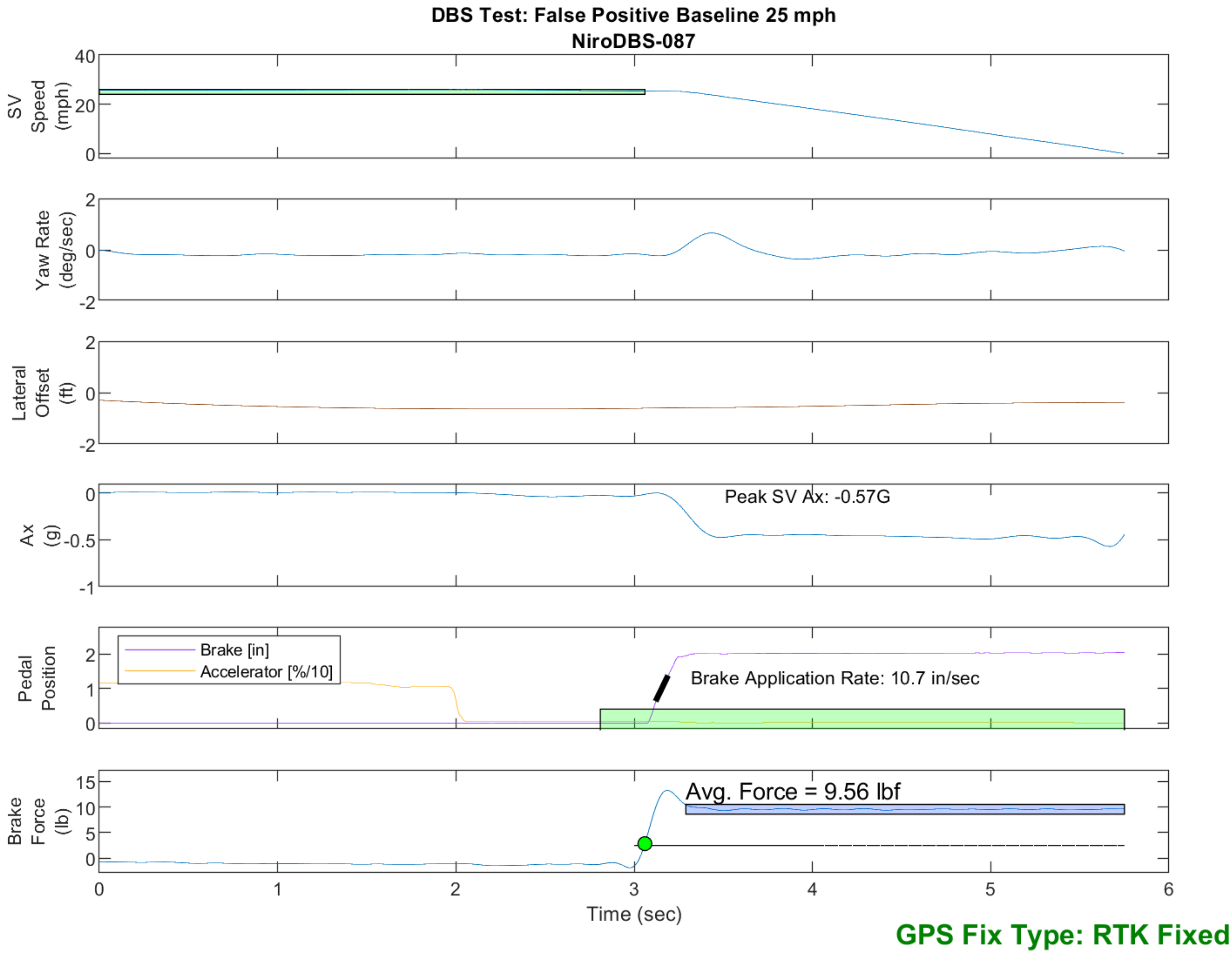


Figure E46. Time History for DBS Run 87, False Positive Baseline, SV 25 mph

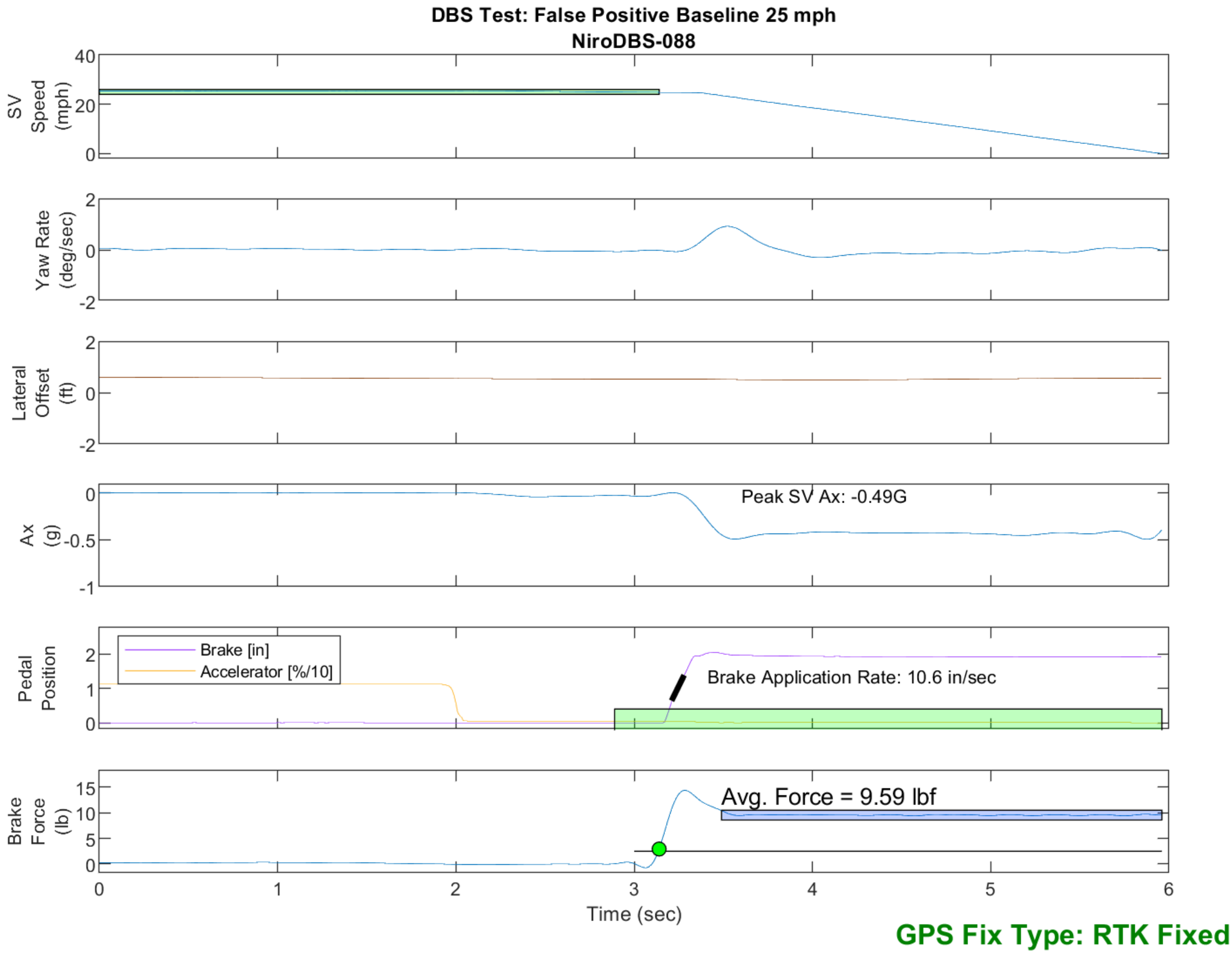


Figure E47. Time History for DBS Run 88, False Positive Baseline, SV 25 mph

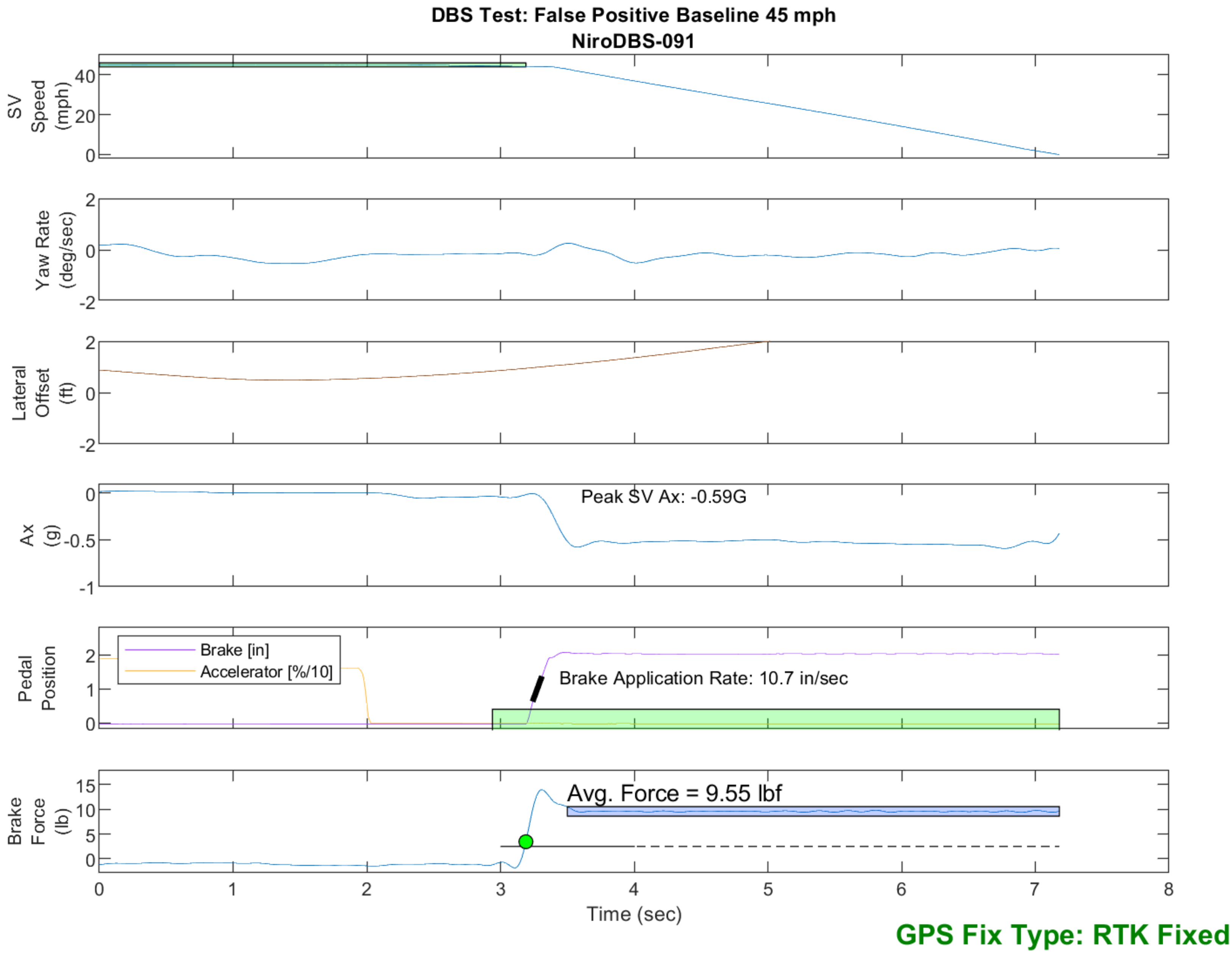


Figure E48. Time History for DBS Run 91, False Positive Baseline, SV 45 mph

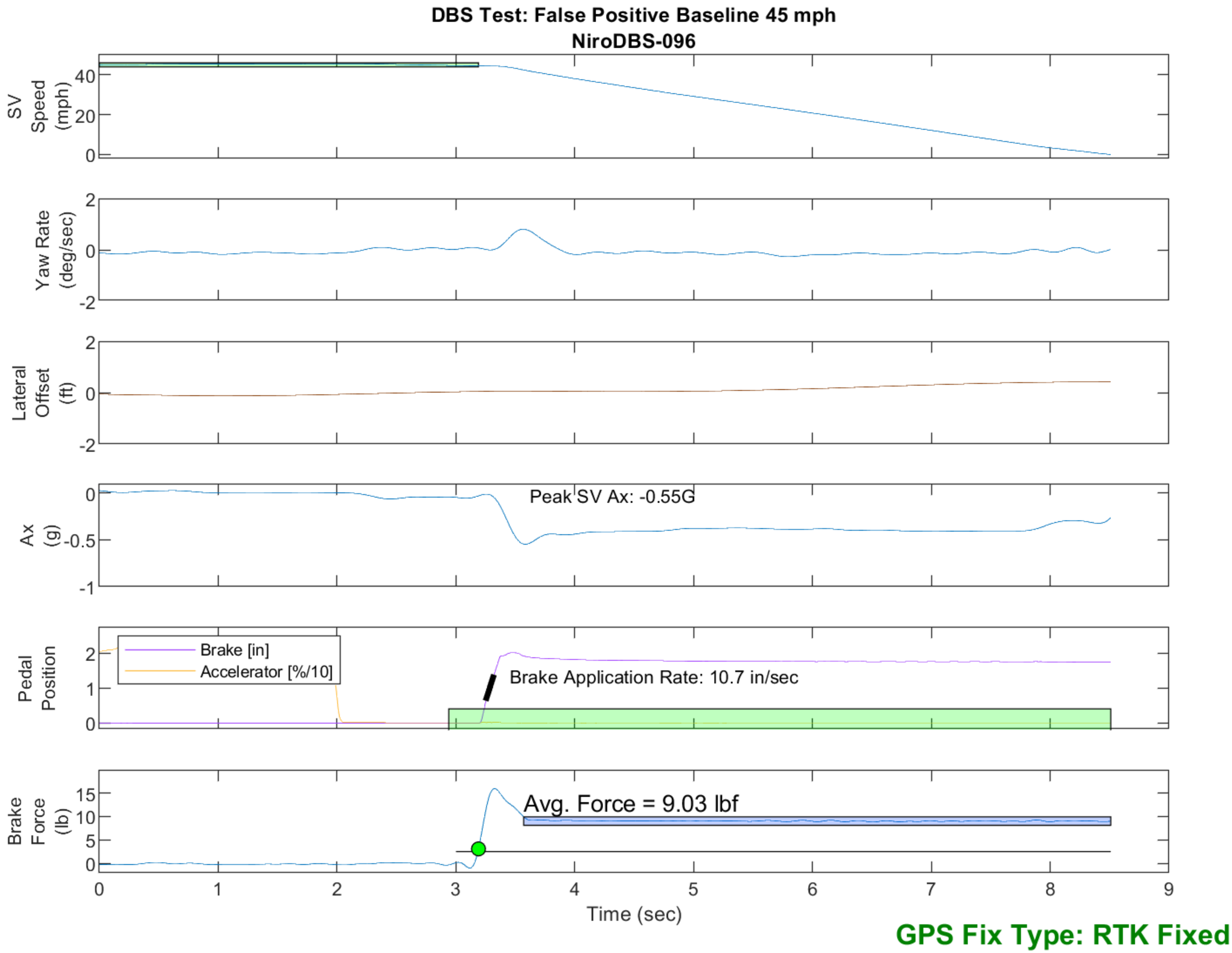


Figure E49. Time History for DBS Run 96, False Positive Baseline, SV 45 mph

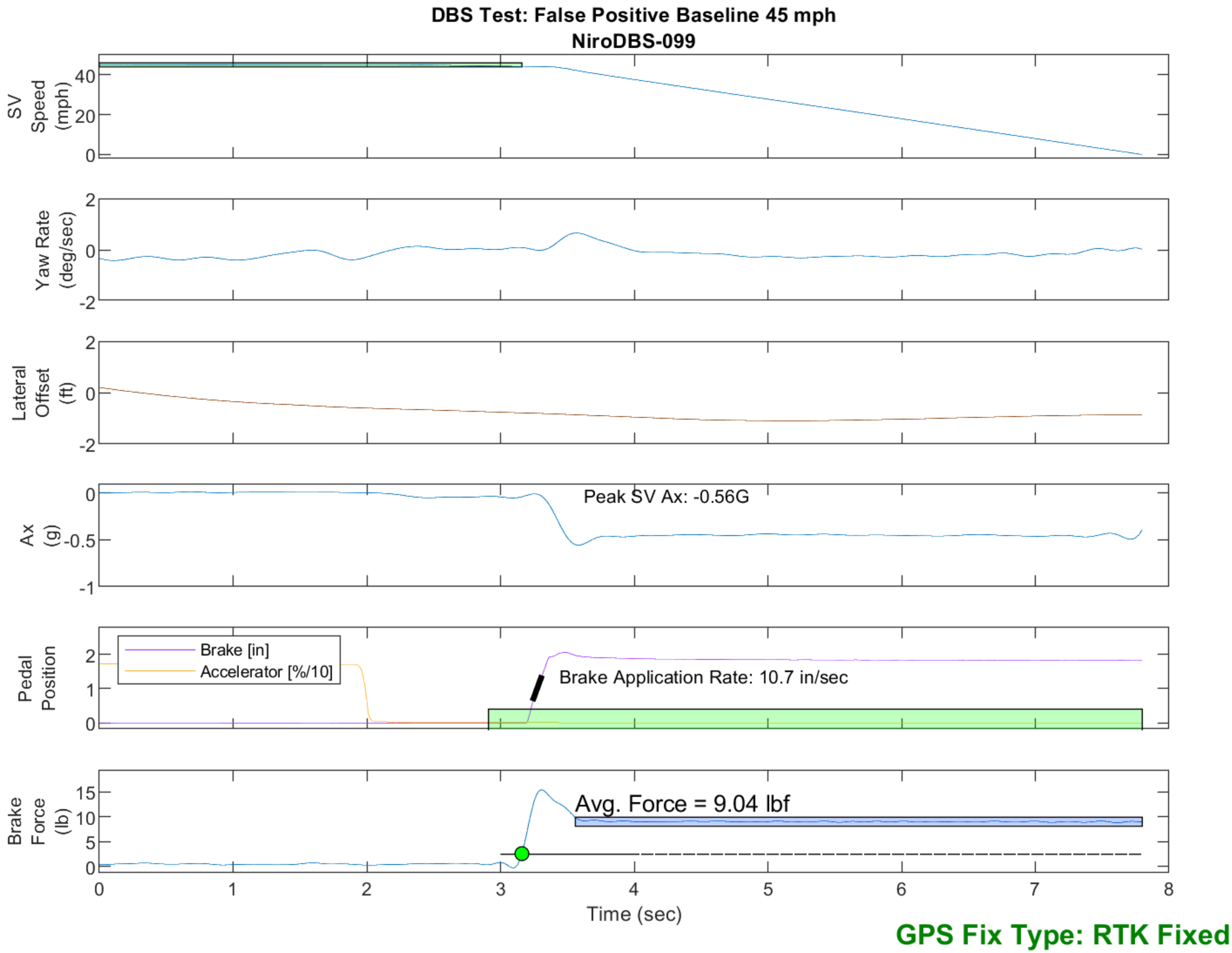


Figure E50. Time History for DBS Run 99, False Positive Baseline, SV 45 mph

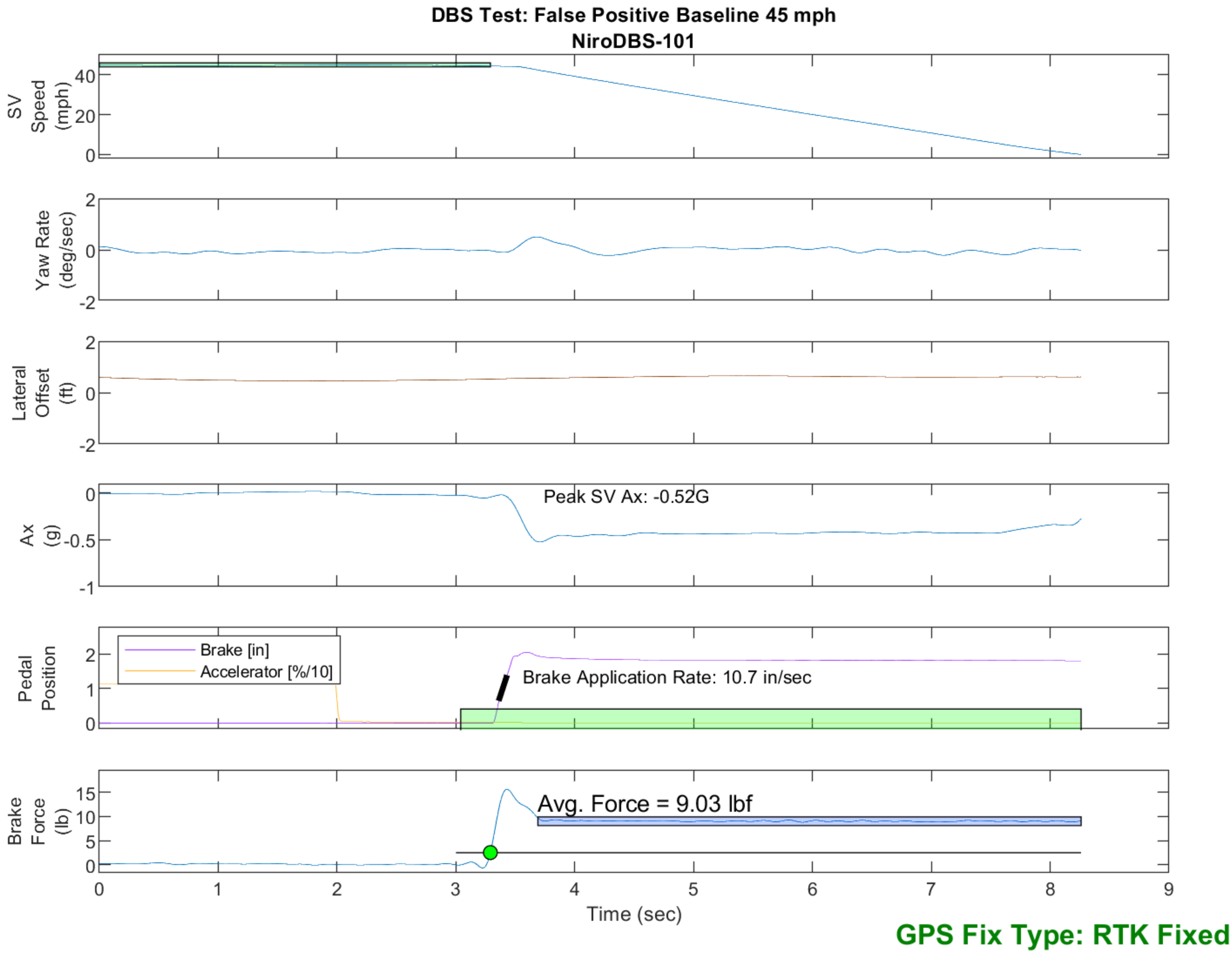


Figure E51. Time History for DBS Run 101, False Positive Baseline, SV 45 mph

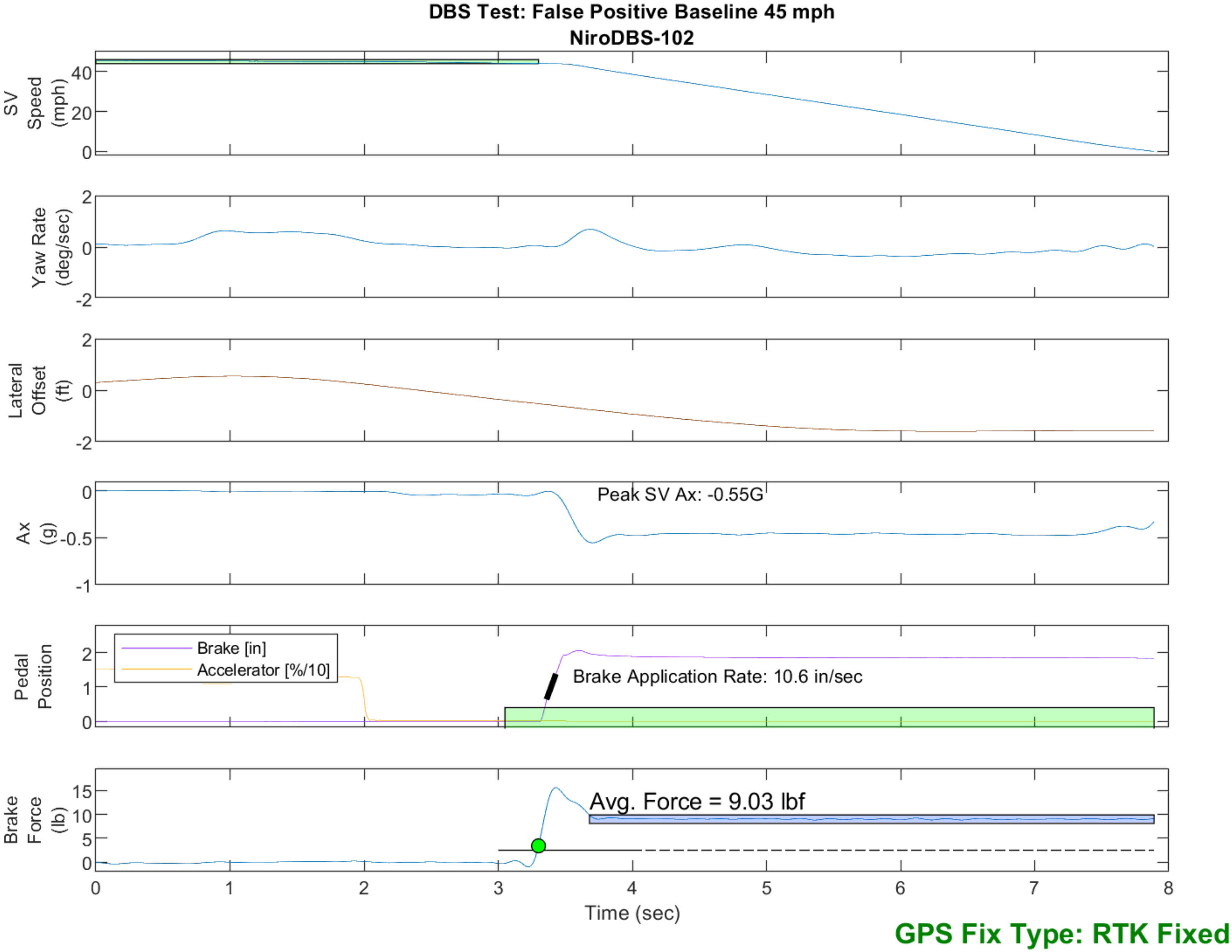


Figure E52. Time History for DBS Run 102, False Positive Baseline, SV 45 mph

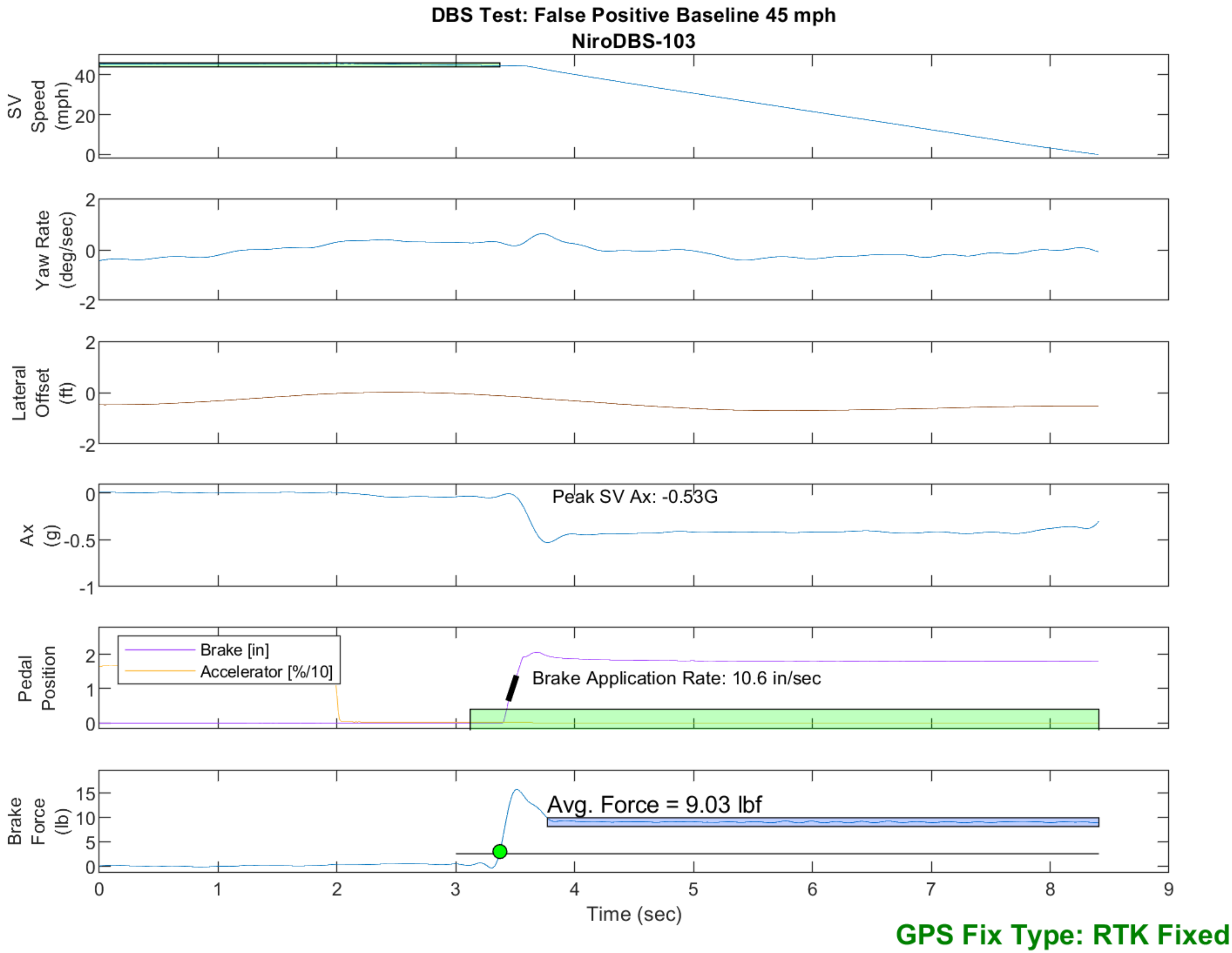


Figure E53. Time History for DBS Run 103, False Positive Baseline, SV 45 mph

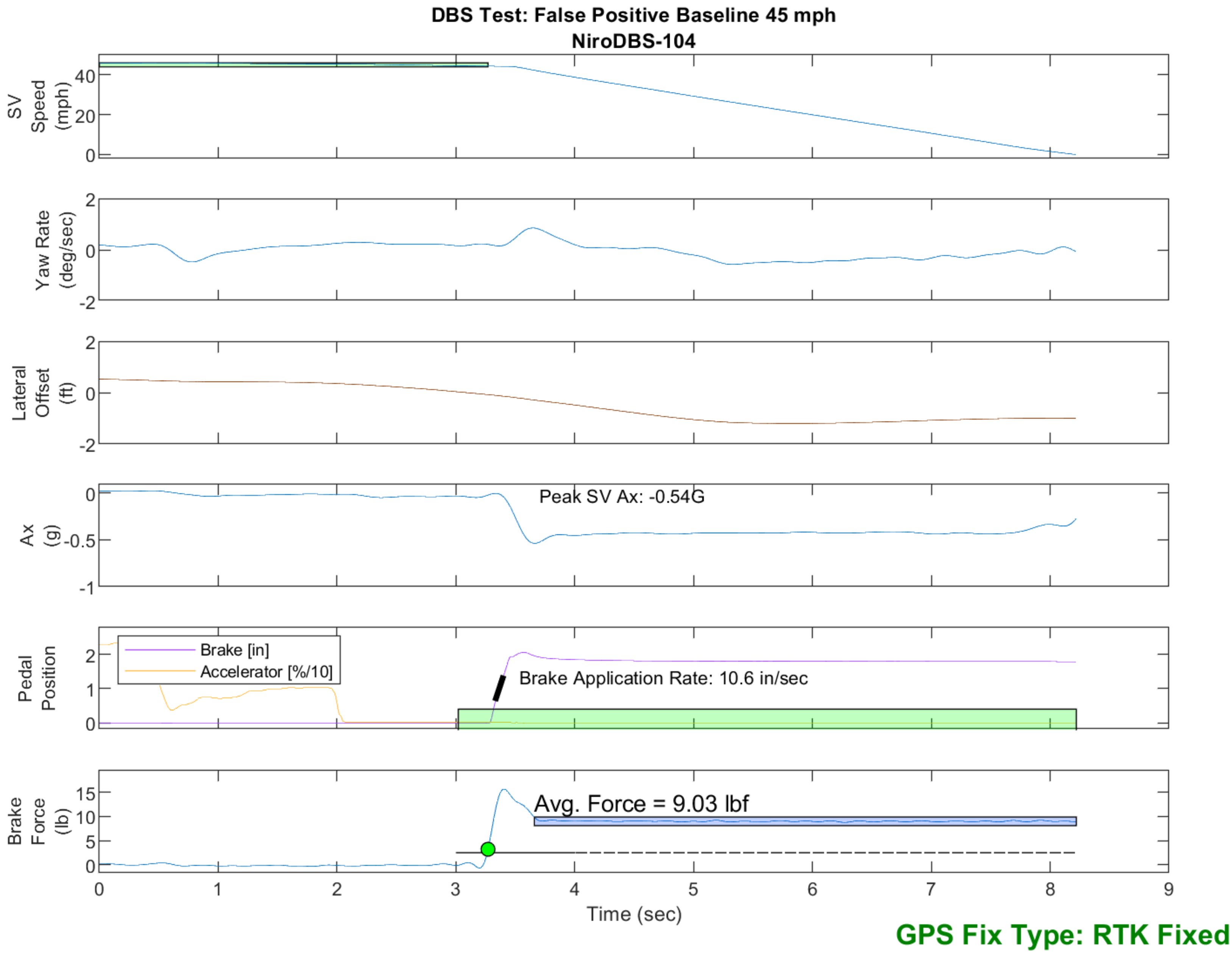


Figure E54. Time History for DBS Run 104, False Positive Baseline, SV 45 mph

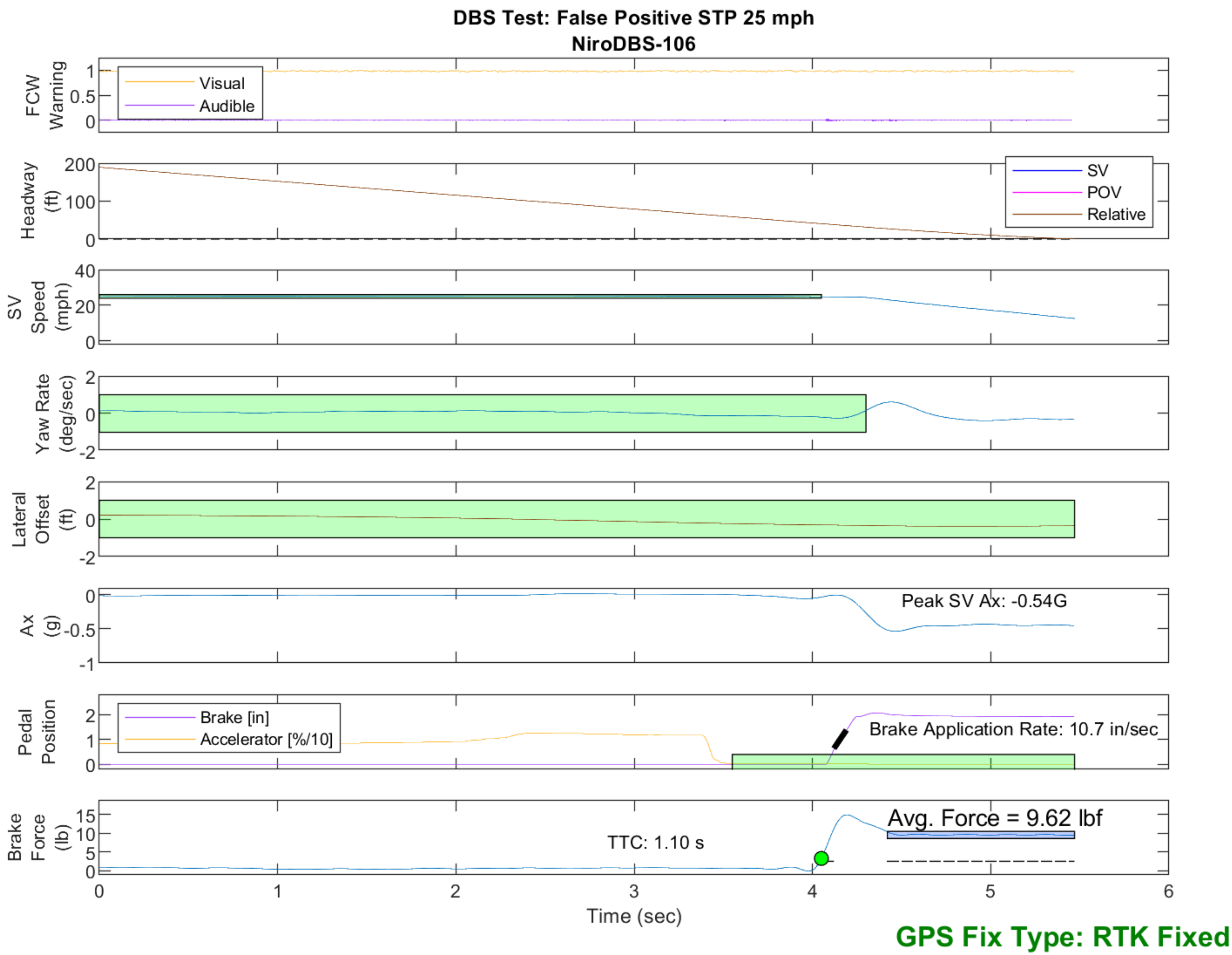


Figure E55. Time History for DBS Run 106, SV Encounters Steel Trench Plate, SV 25 mph

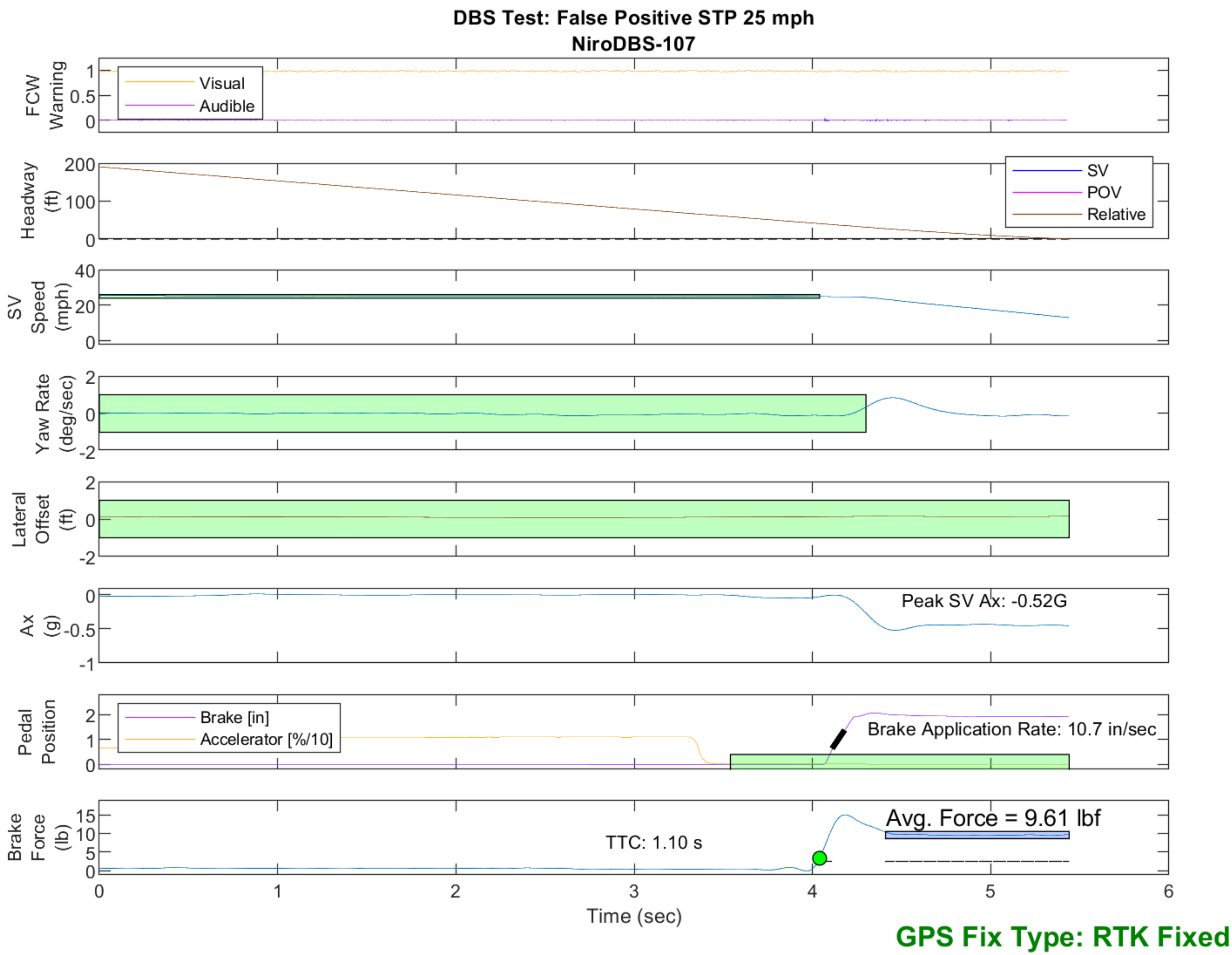


Figure E56. Time History for DBS Run 107, SV Encounters Steel Trench Plate, SV 25 mph

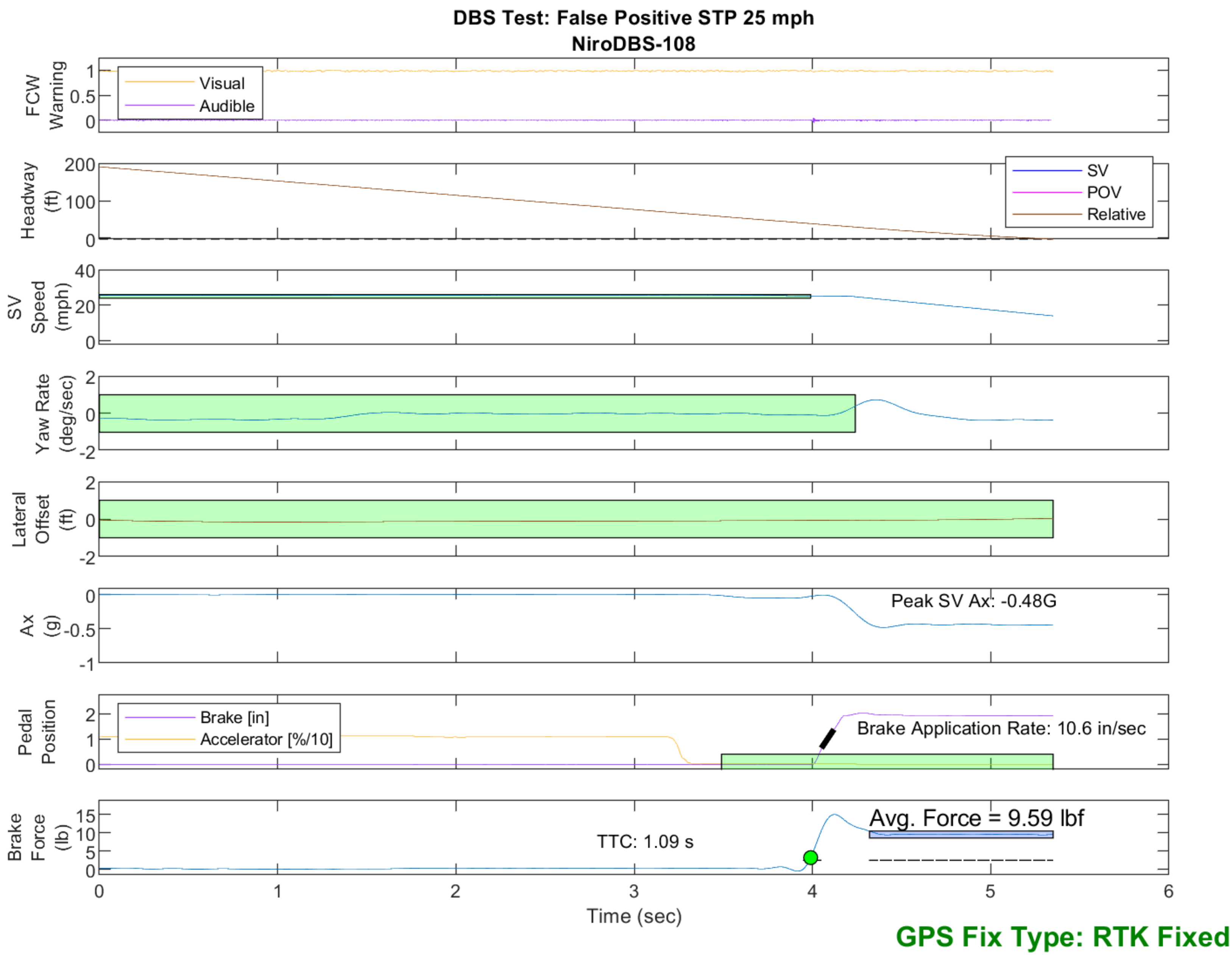


Figure E57. Time History for DBS Run 108, SV Encounters Steel Trench Plate, SV 25 mph

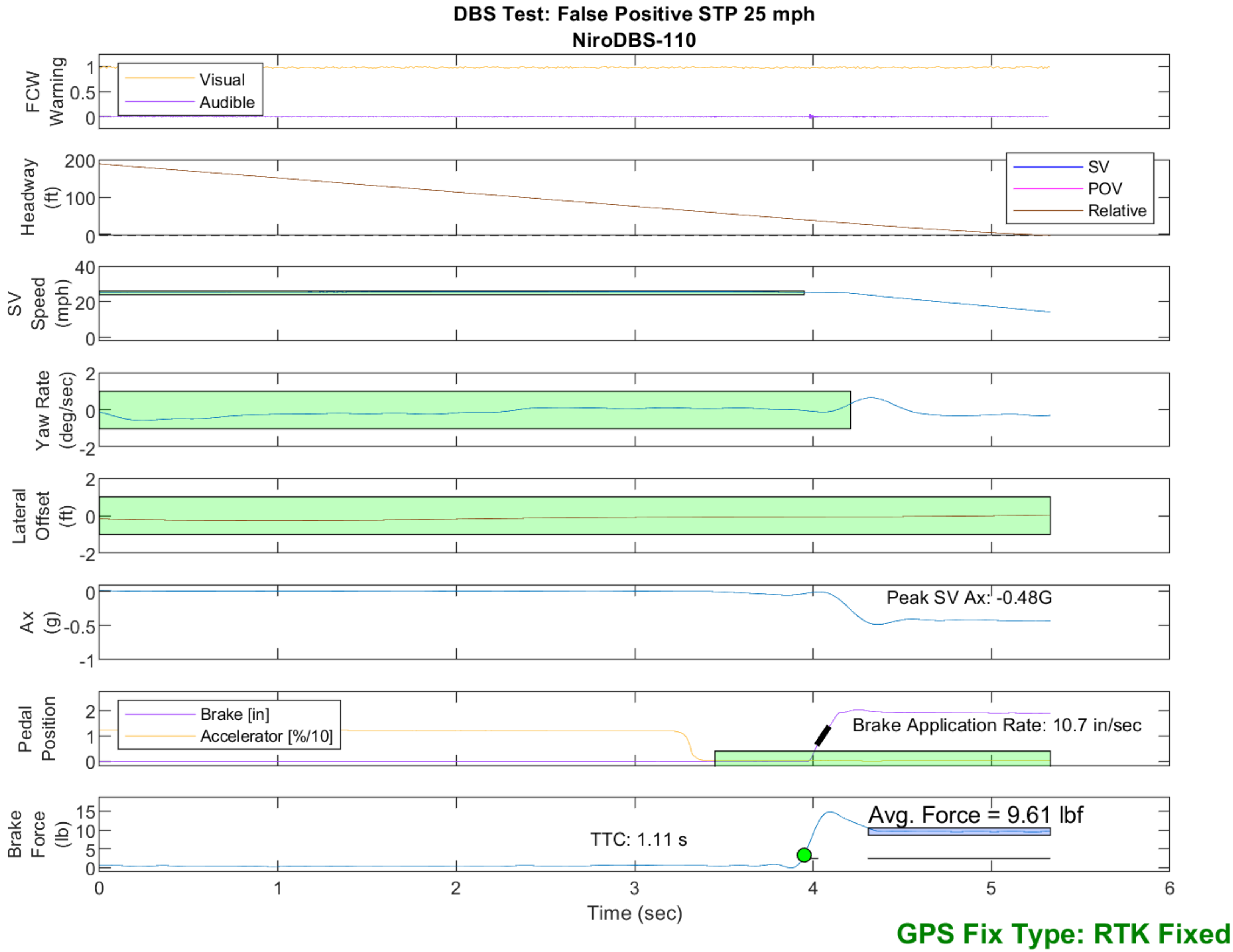


Figure E58. Time History for DBS Run 110, SV Encounters Steel Trench Plate, SV 25 mph

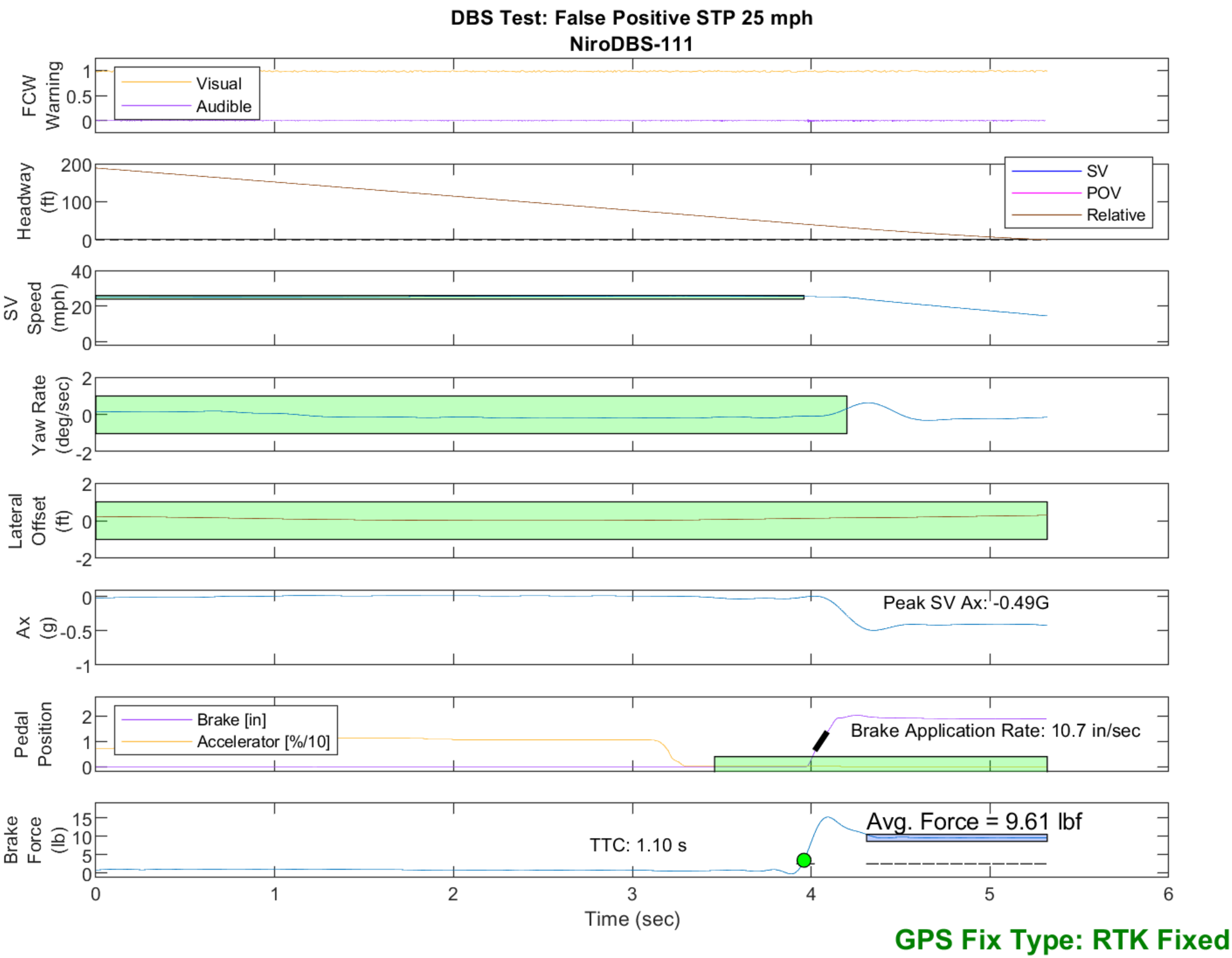


Figure E59. Time History for DBS Run 111, SV Encounters Steel Trench Plate, SV 25 mph

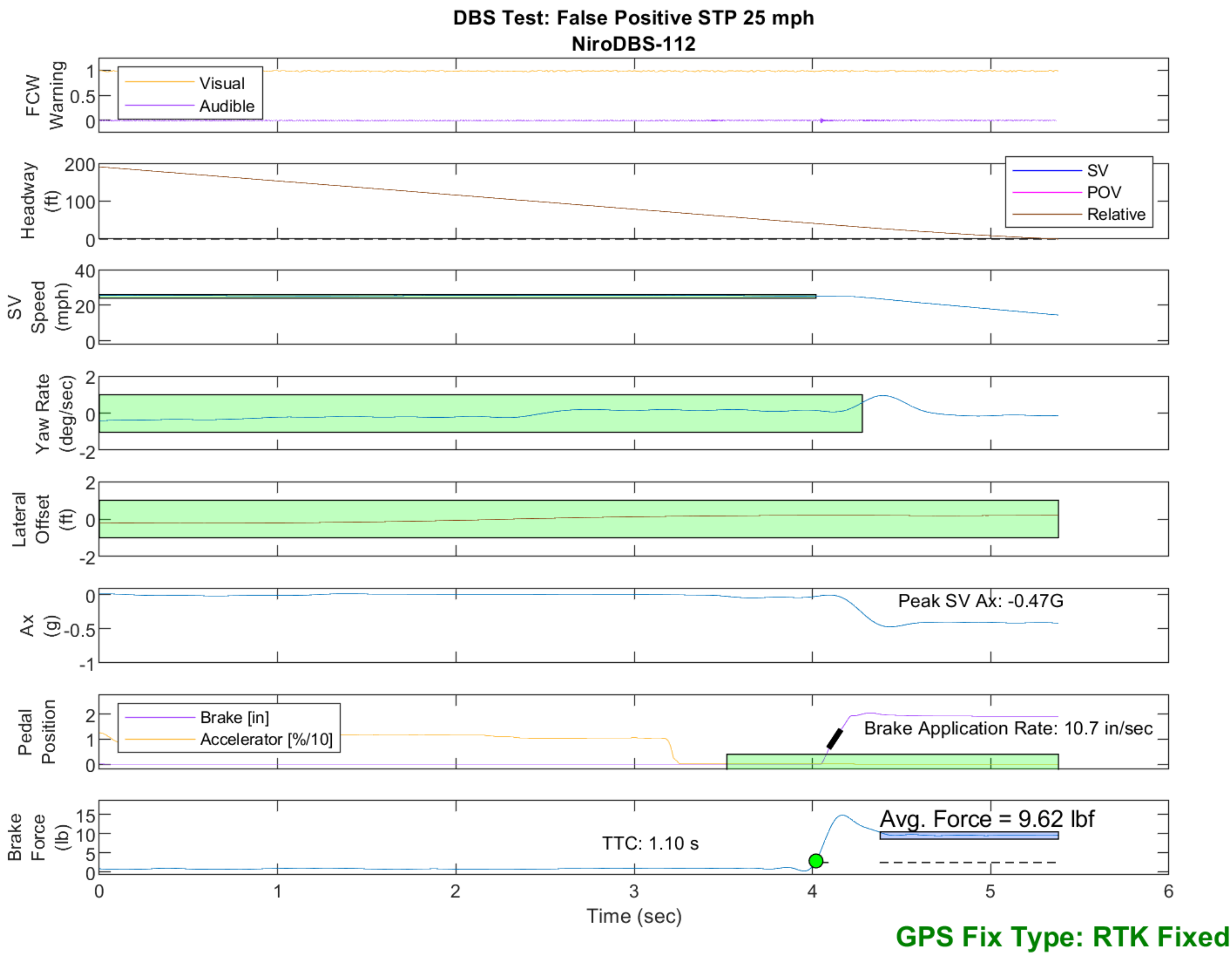


Figure E60. Time History for DBS Run 112, SV Encounters Steel Trench Plate, SV 25 mph

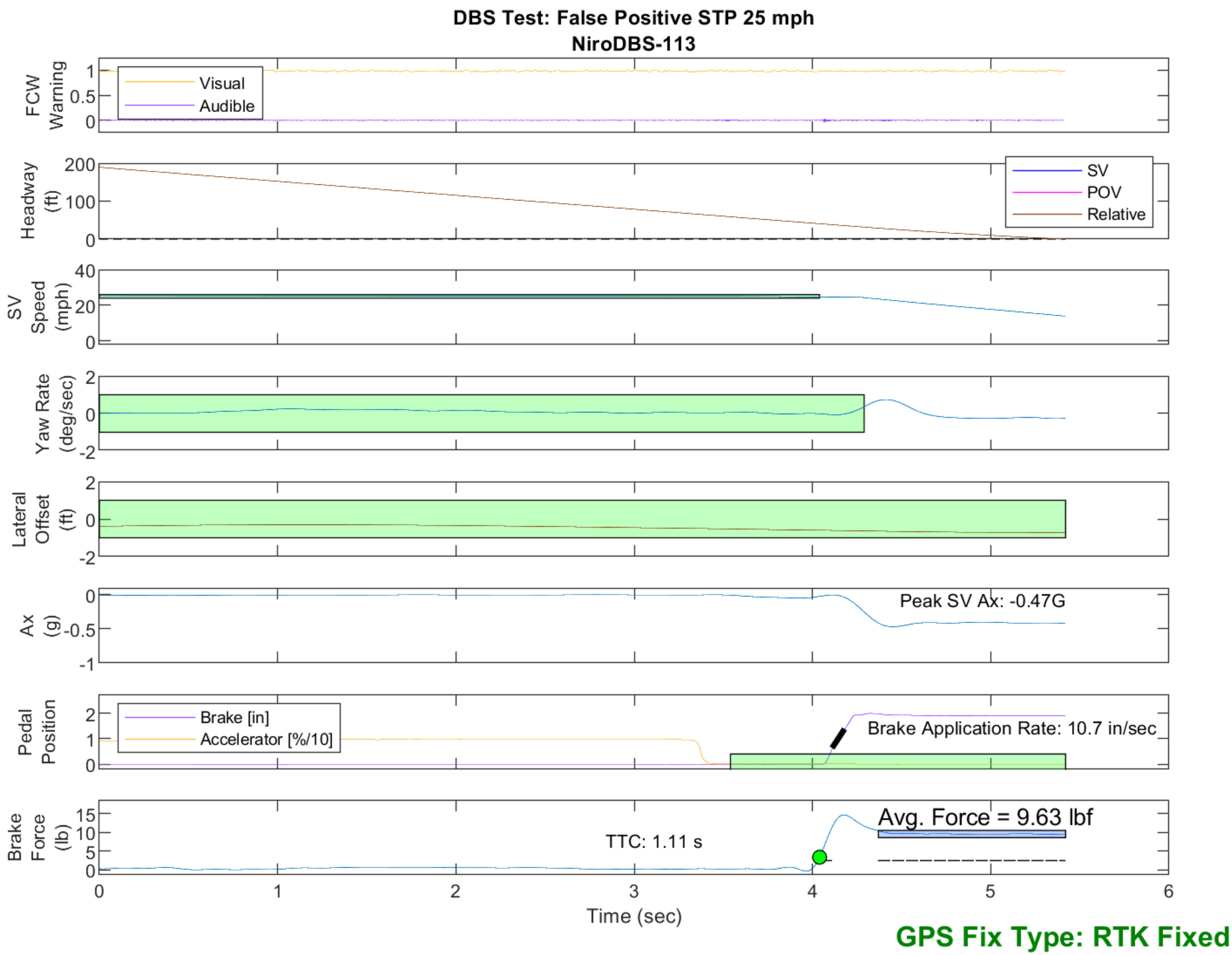


Figure E61. Time History for DBS Run 113, SV Encounters Steel Trench Plate, SV 25 mph

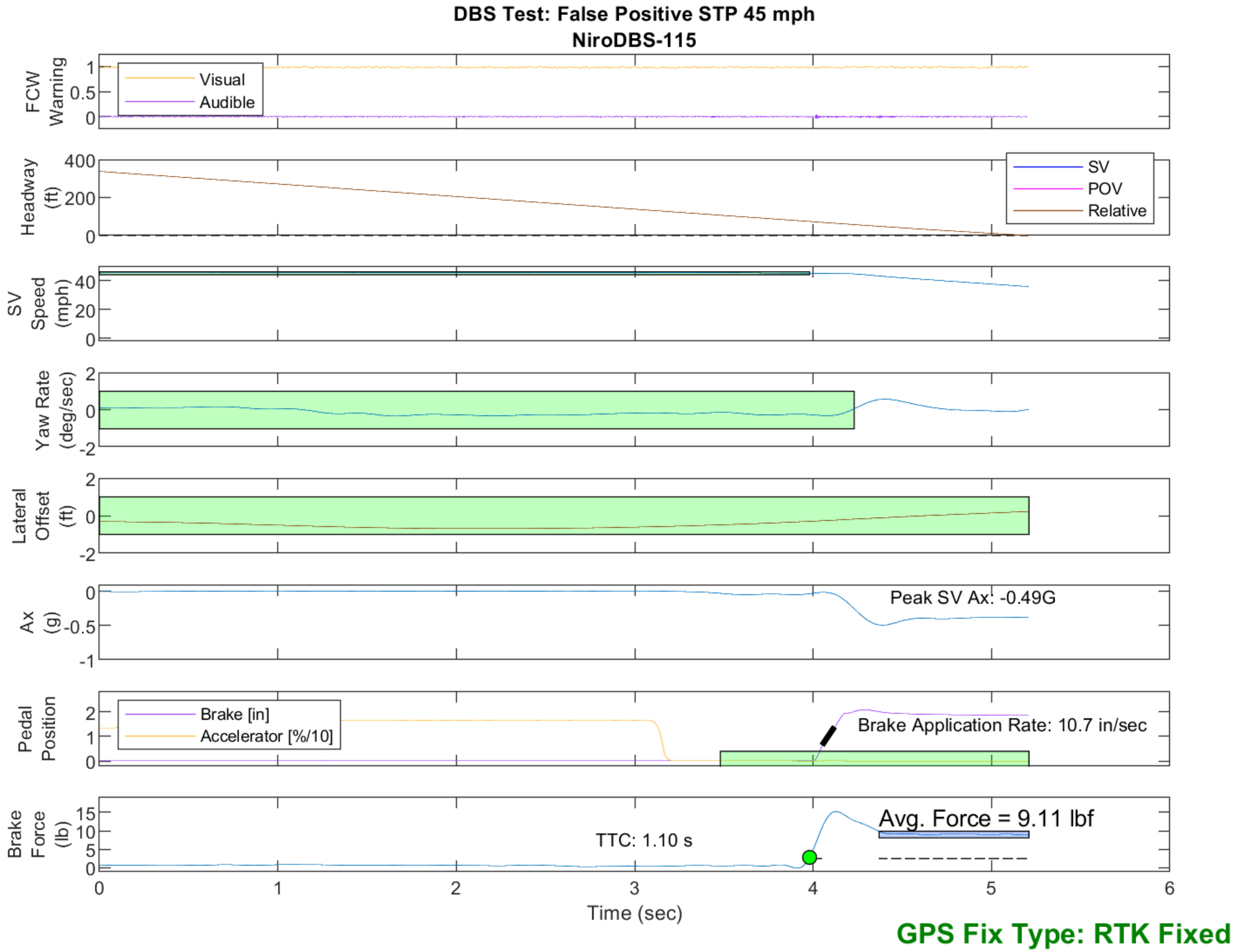


Figure E62. Time History for DBS Run 115, SV Encounters Steel Trench Plate, SV 45 mph

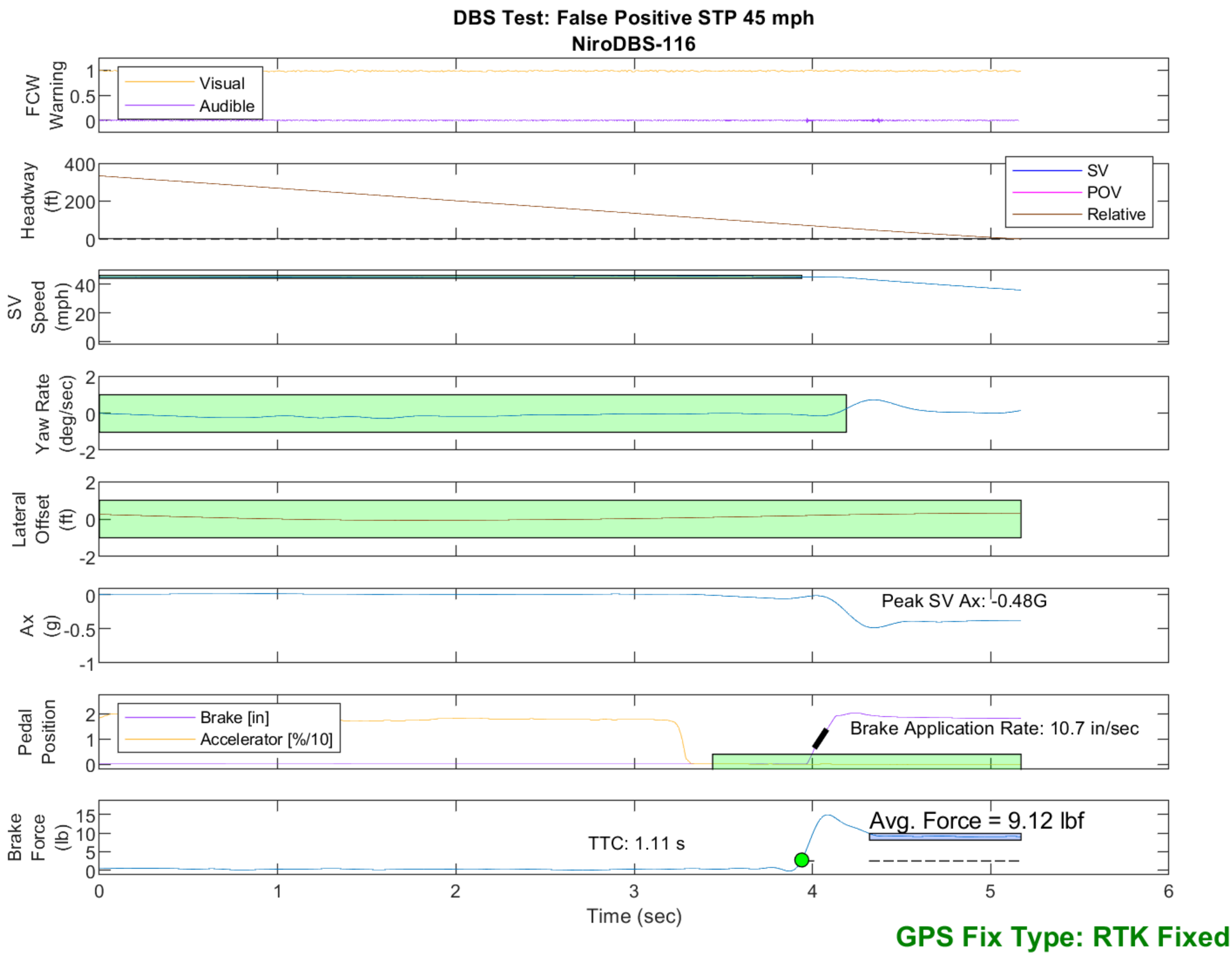


Figure E63. Time History for DBS Run 116, SV Encounters Steel Trench Plate, SV 45 mph

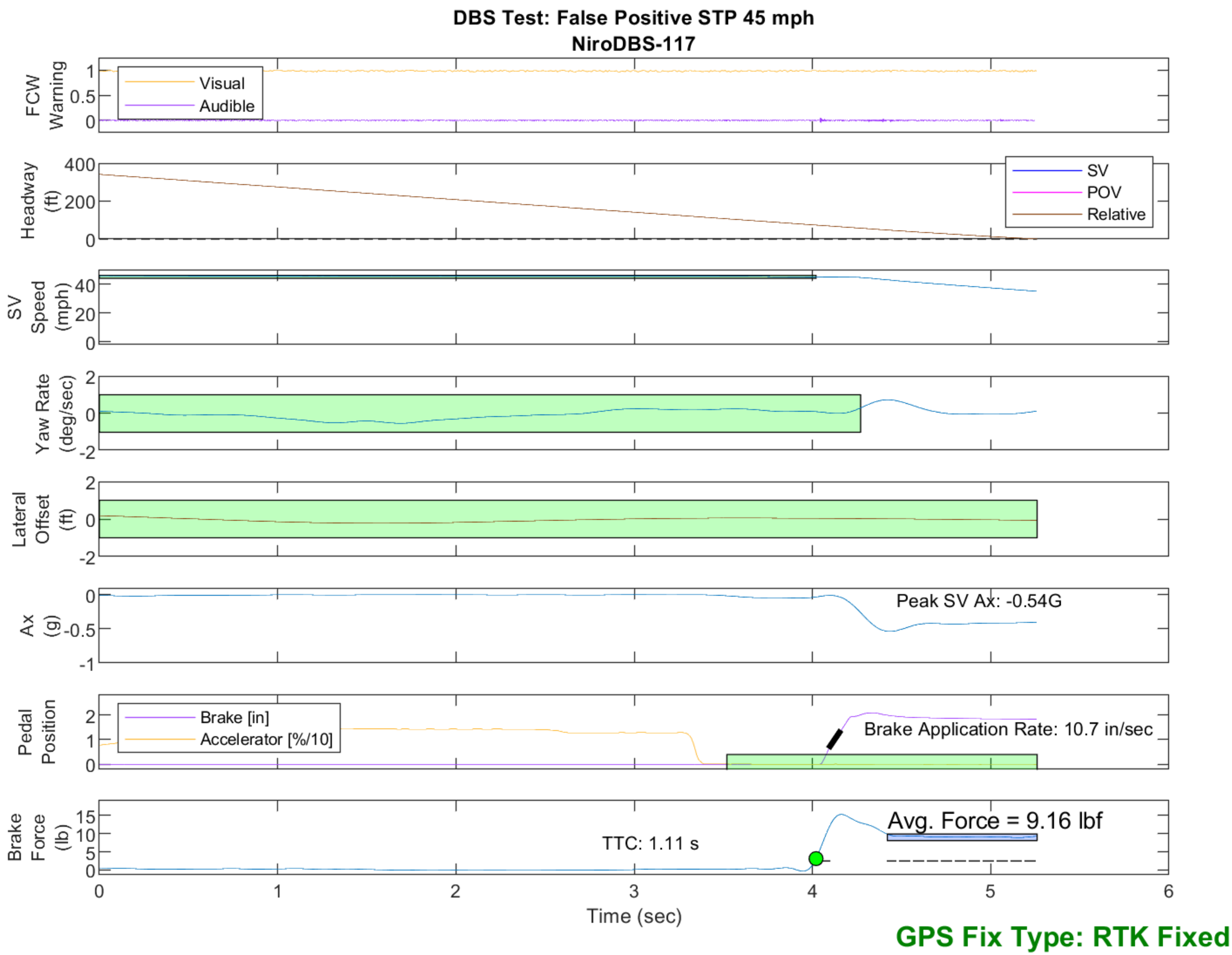


Figure E64. Time History for DBS Run 117, SV Encounters Steel Trench Plate, SV 45 mph

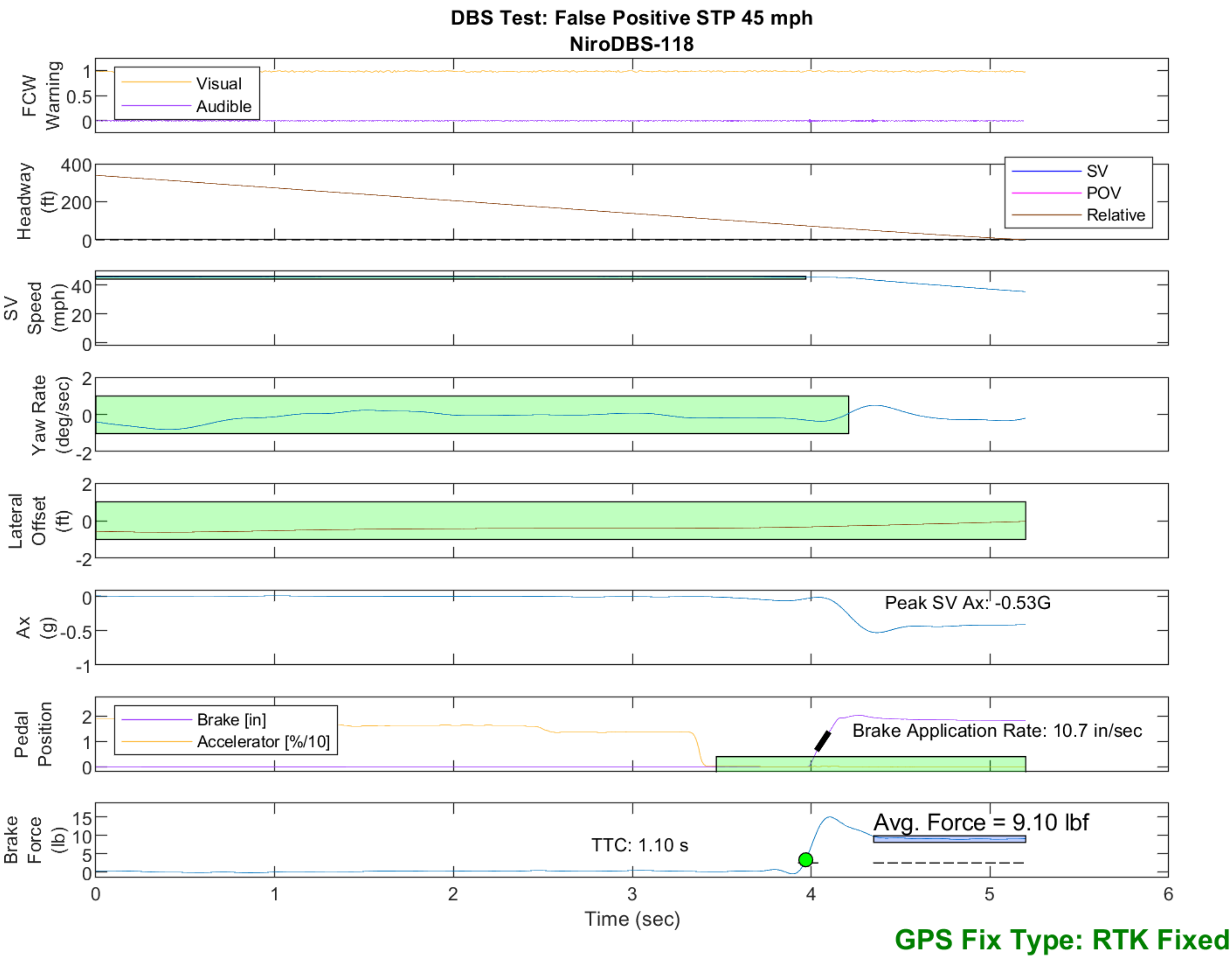


Figure E65. Time History for DBS Run 118, SV Encounters Steel Trench Plate, SV 45 mph

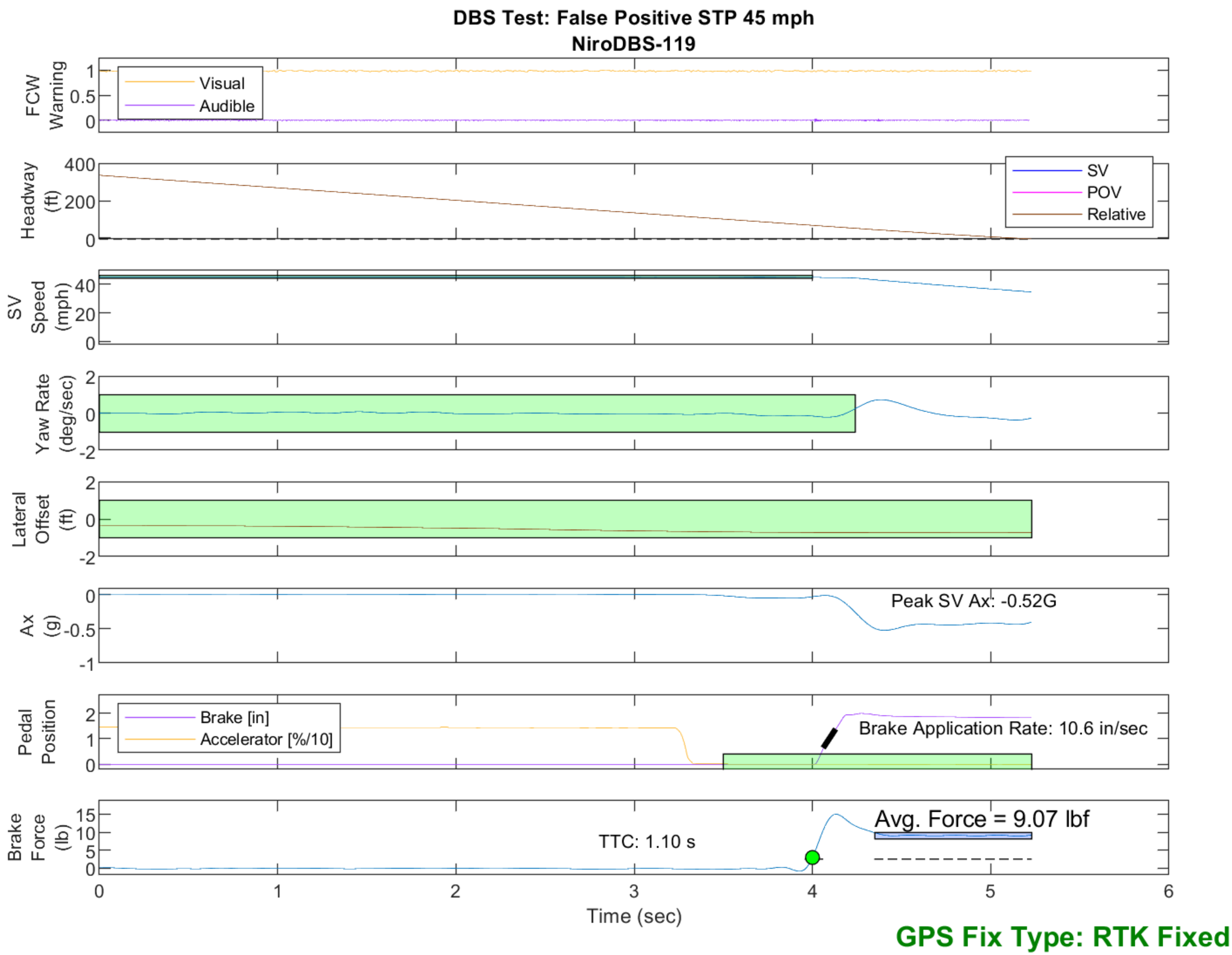


Figure E66. Time History for DBS Run 119, SV Encounters Steel Trench Plate, SV 45 mph

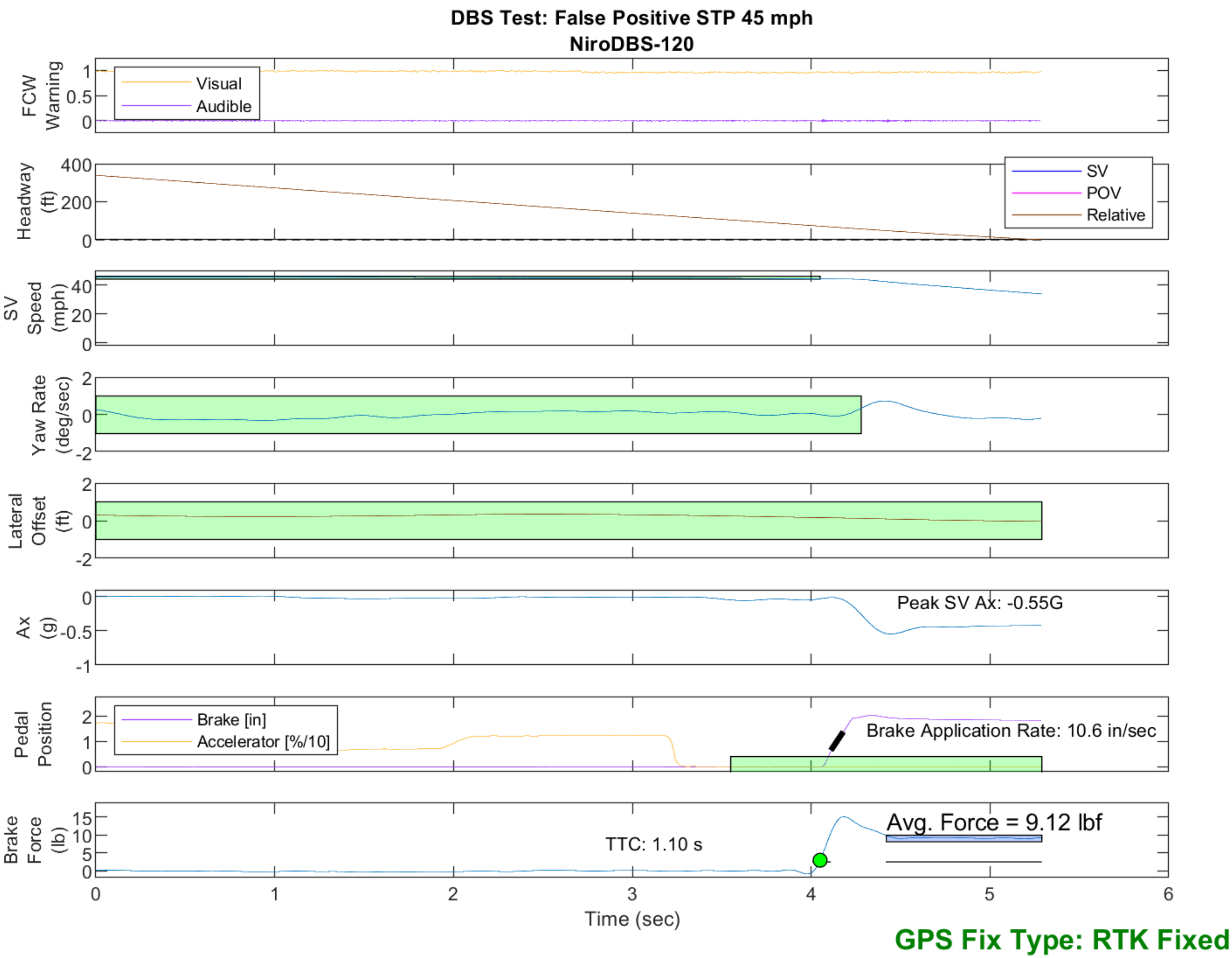


Figure E67. Time History for DBS Run 120, SV Encounters Steel Trench Plate, SV 45 mph

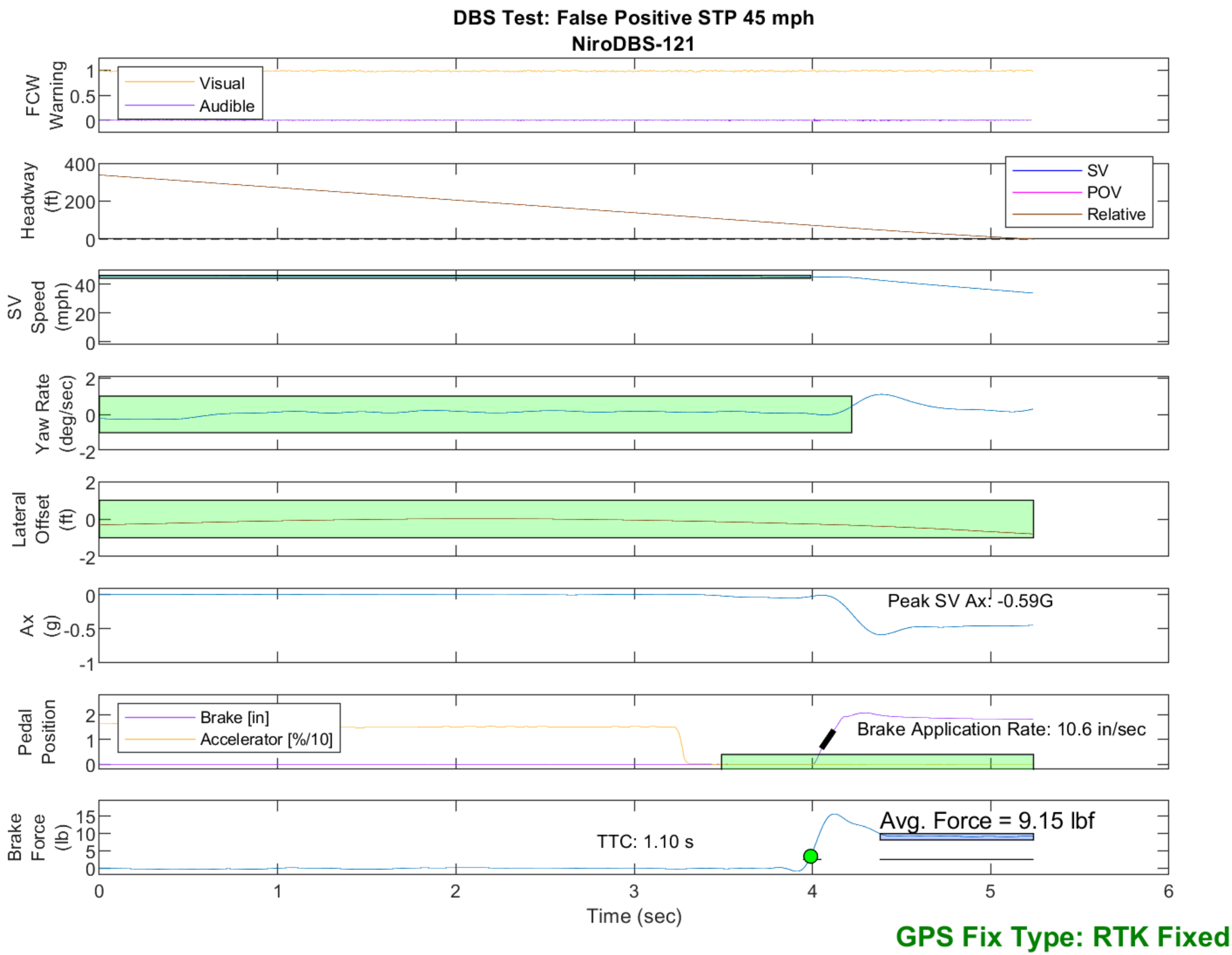


Figure E68. Time History for DBS Run 121, SV Encounters Steel Trench Plate, SV 45 mph

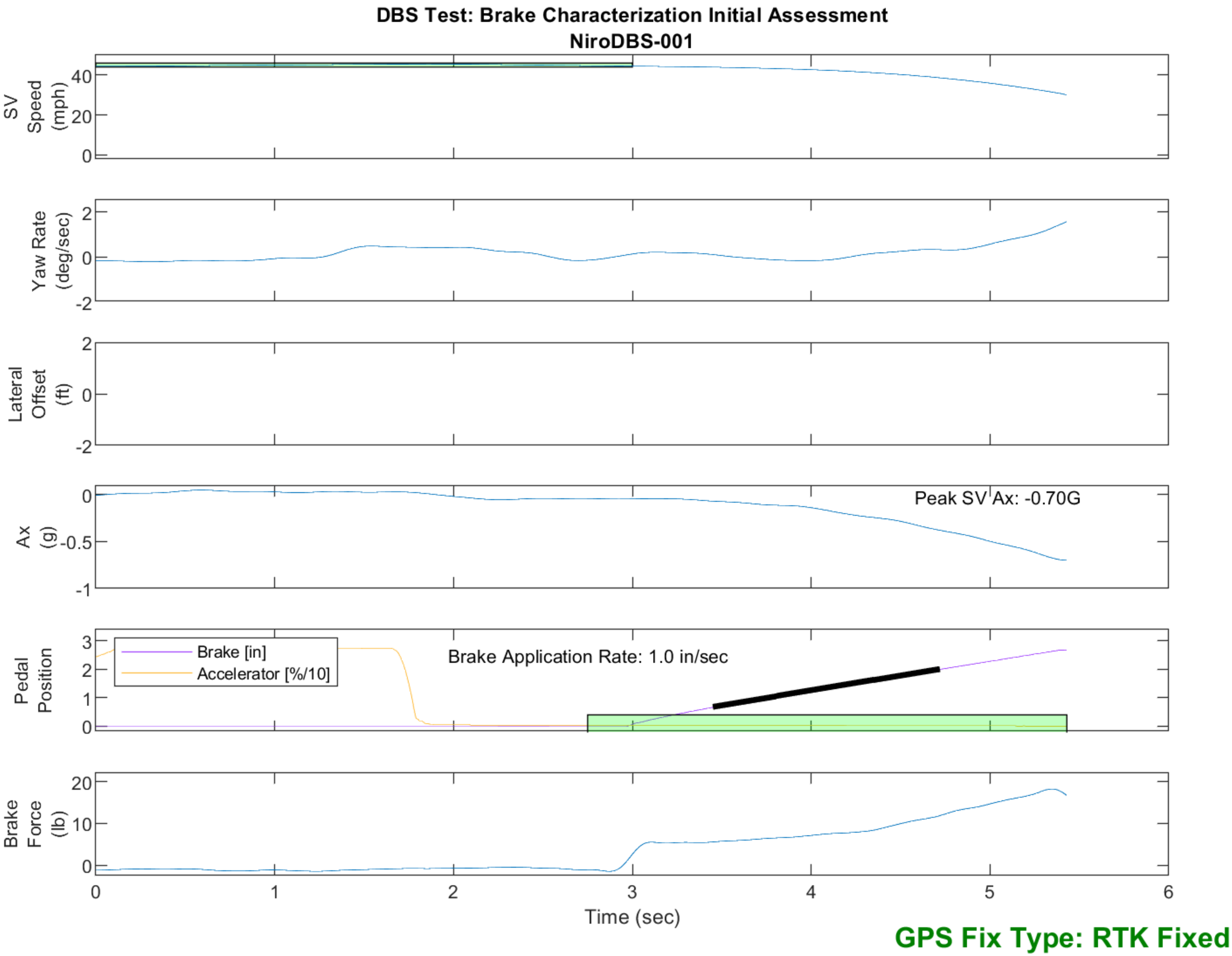


Figure E69. Time History for DBS Run 1, Brake Characterization Initial

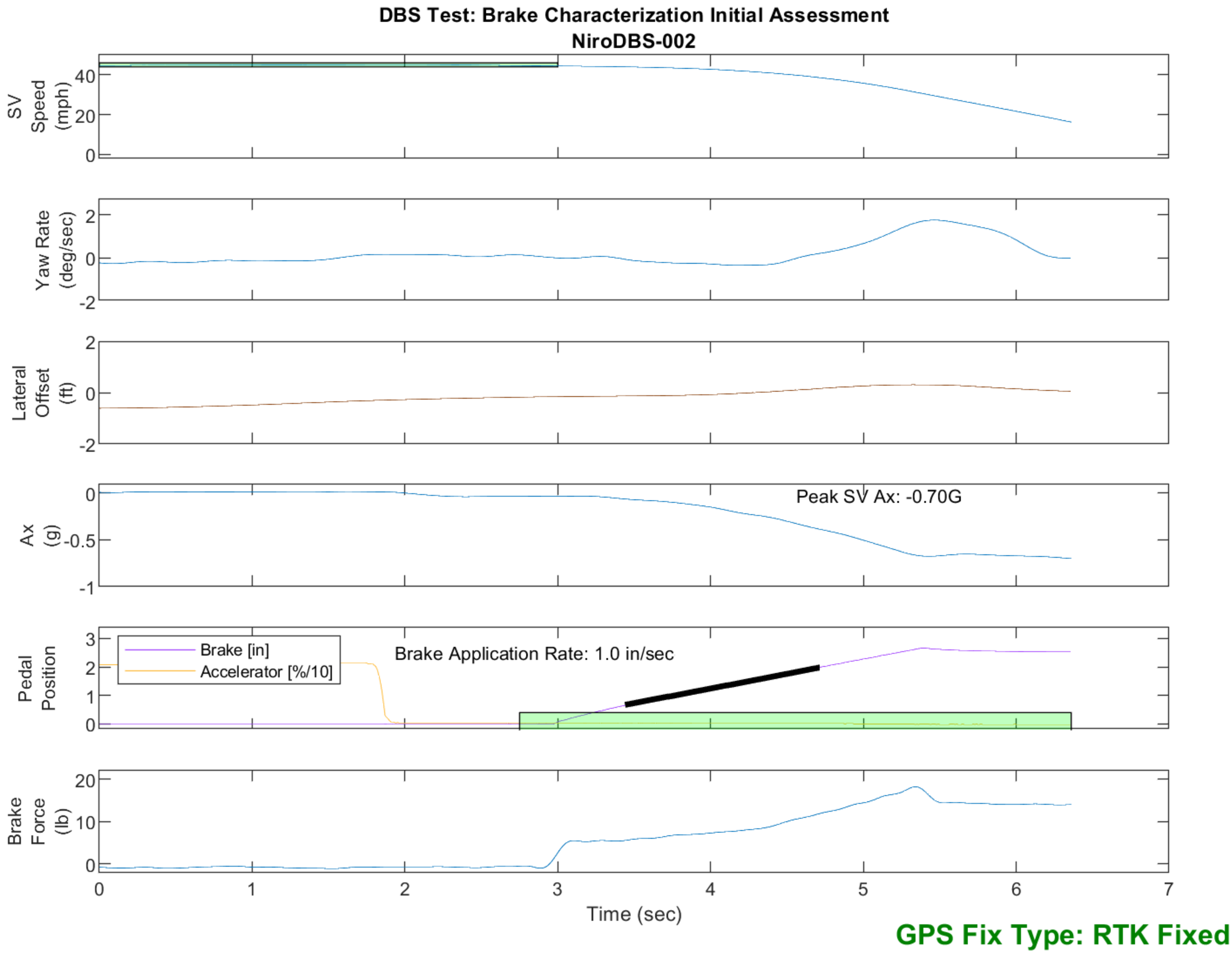


Figure E70. Time History for DBS Run 2, Brake Characterization Initial

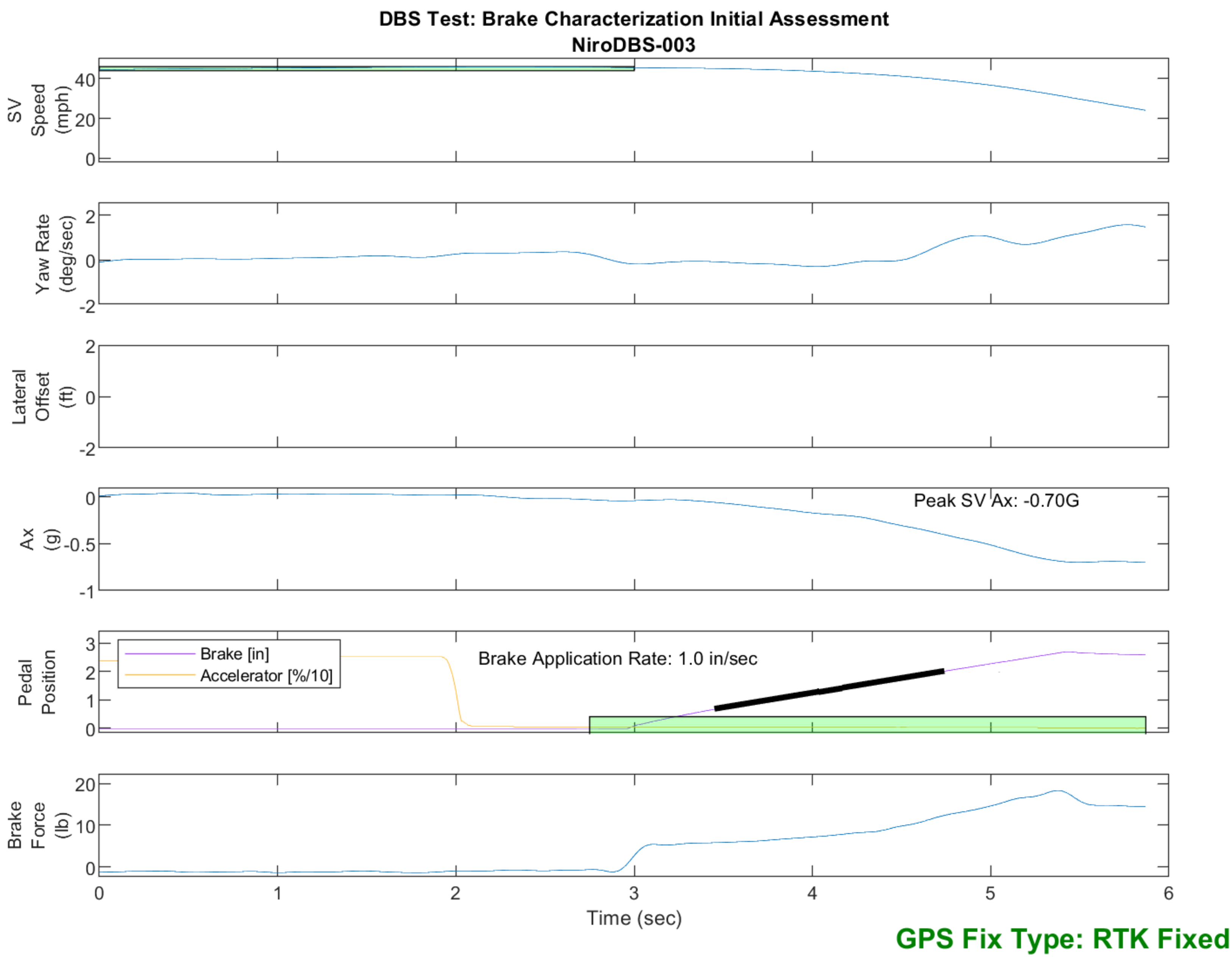


Figure E71. Time History for DBS Run 3, Brake Characterization Initial

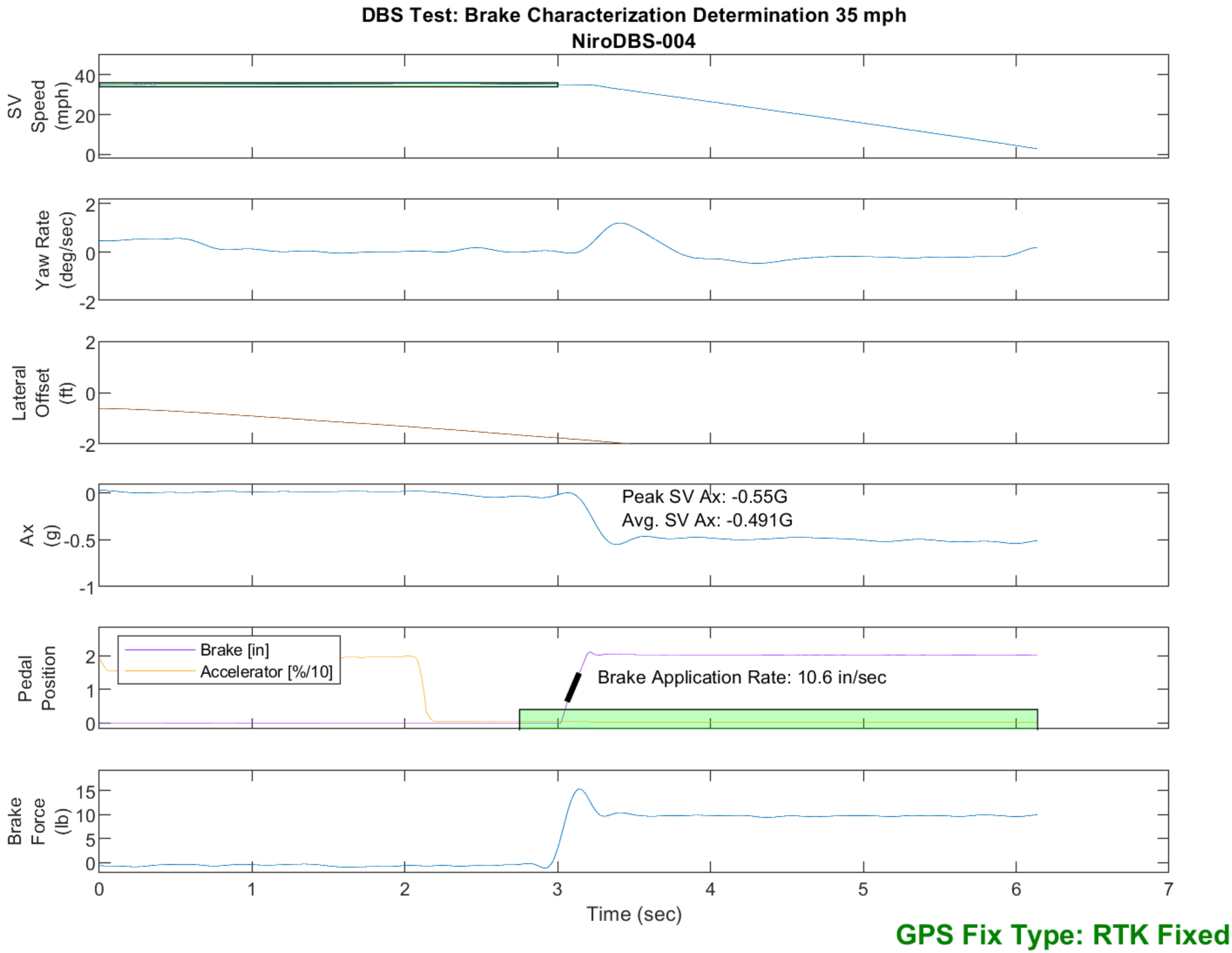


Figure E72. Time History for DBS Run 4, Brake Characterization Determination 35 mph

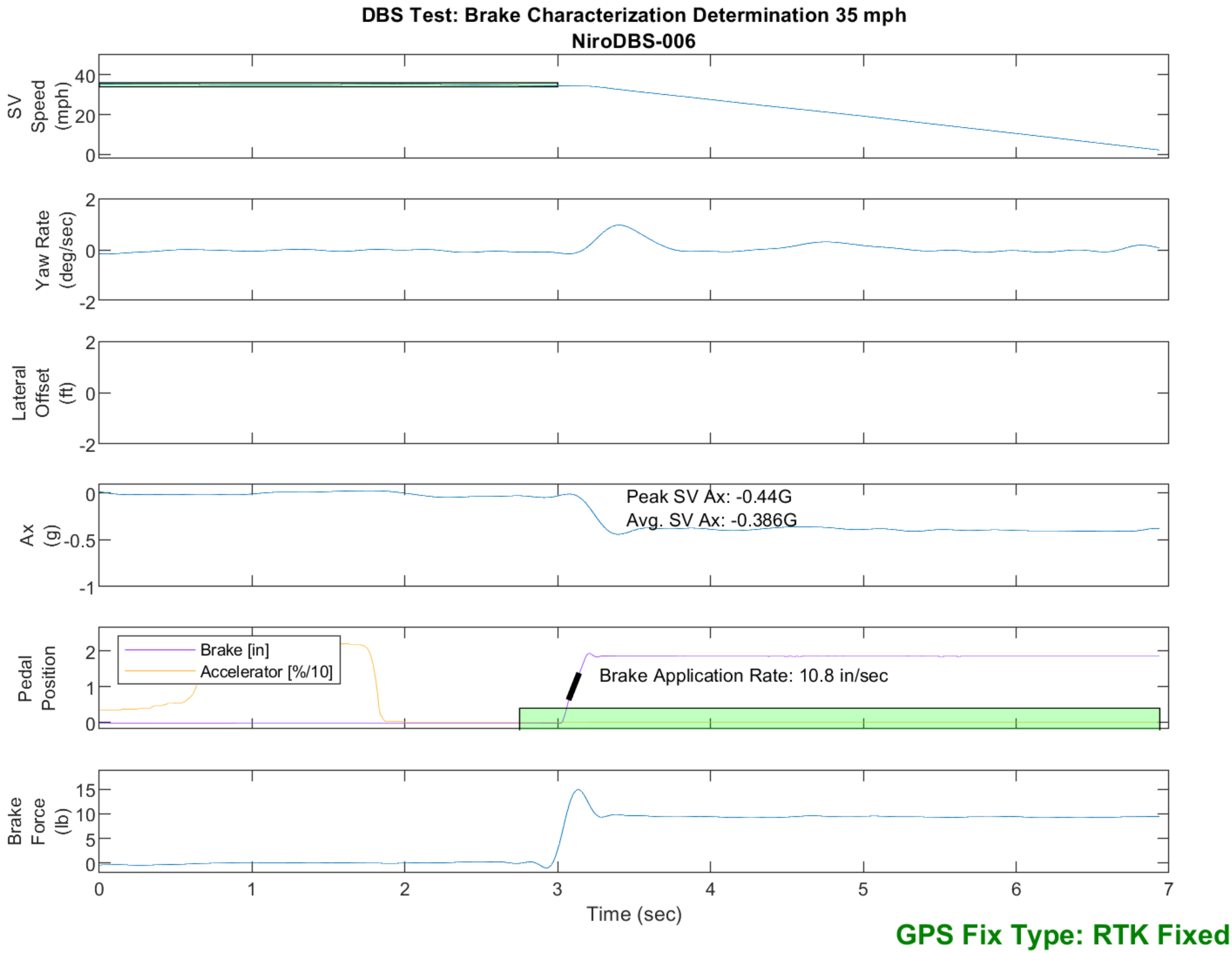


Figure E73. Time History for DBS Run 6, Brake Characterization Determination 35 mph

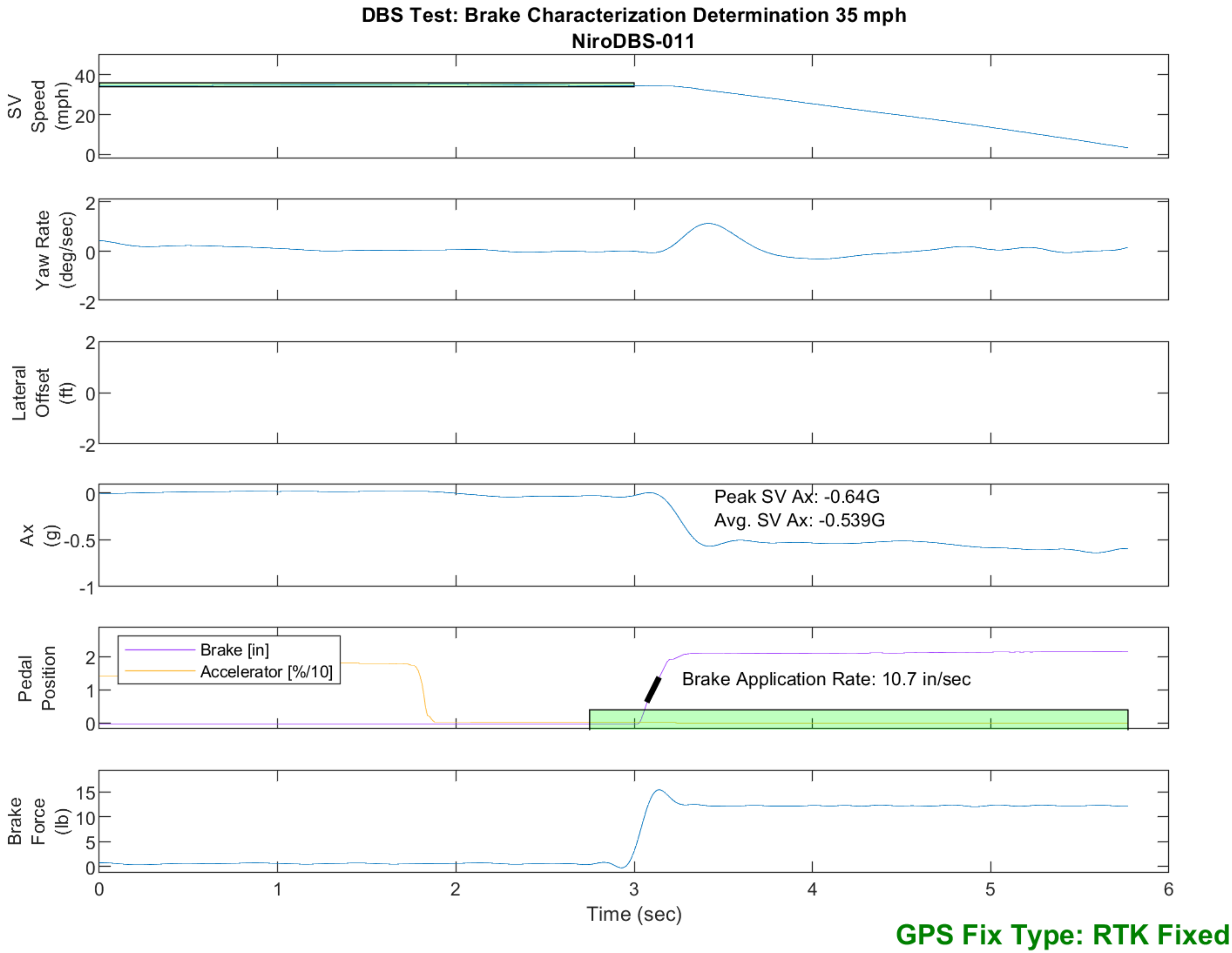


Figure E74. Time History for DBS Run 11, Brake Characterization Determination 35 mph

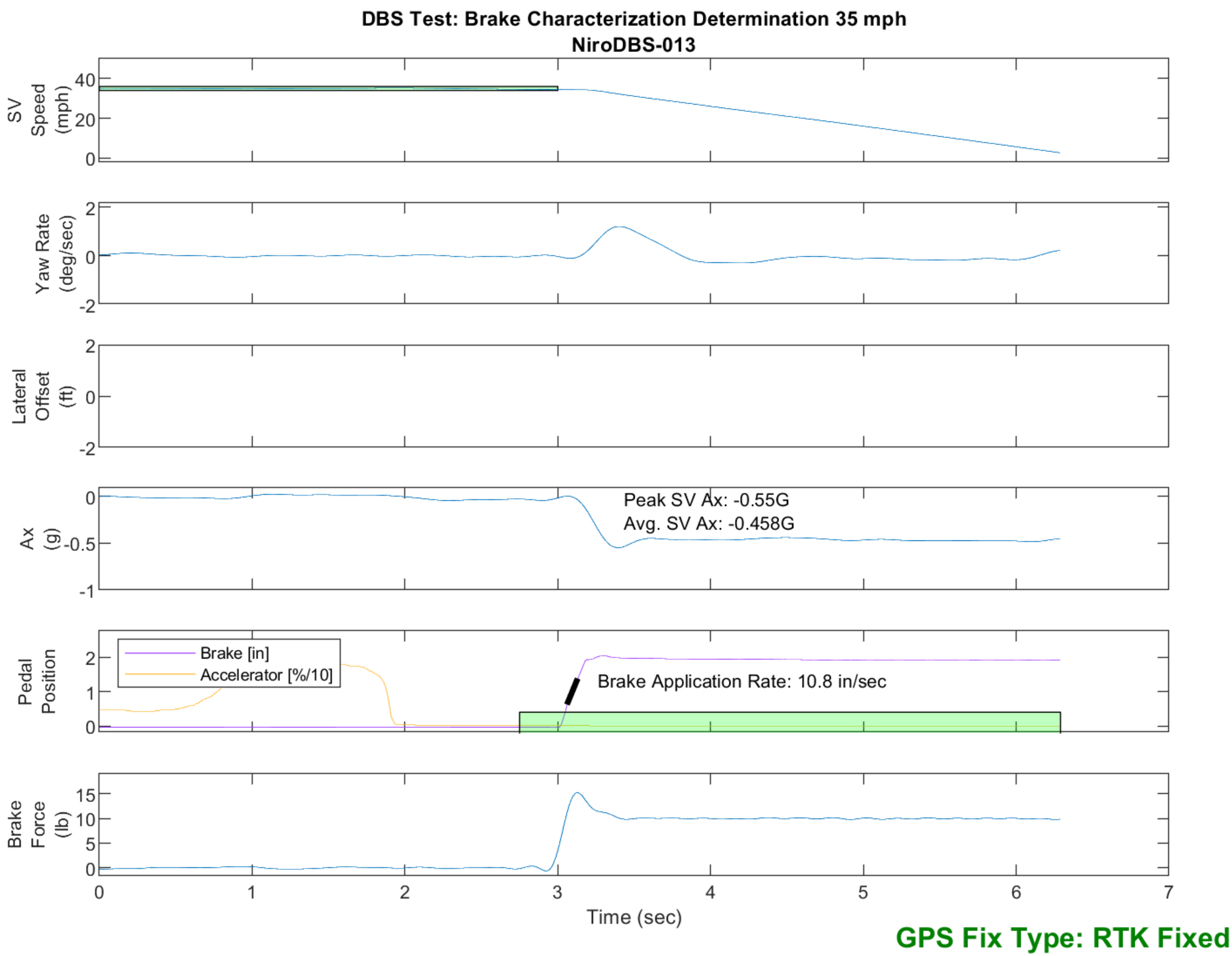


Figure E75. Time History for DBS Run 13, Brake Characterization Determination 35 mph

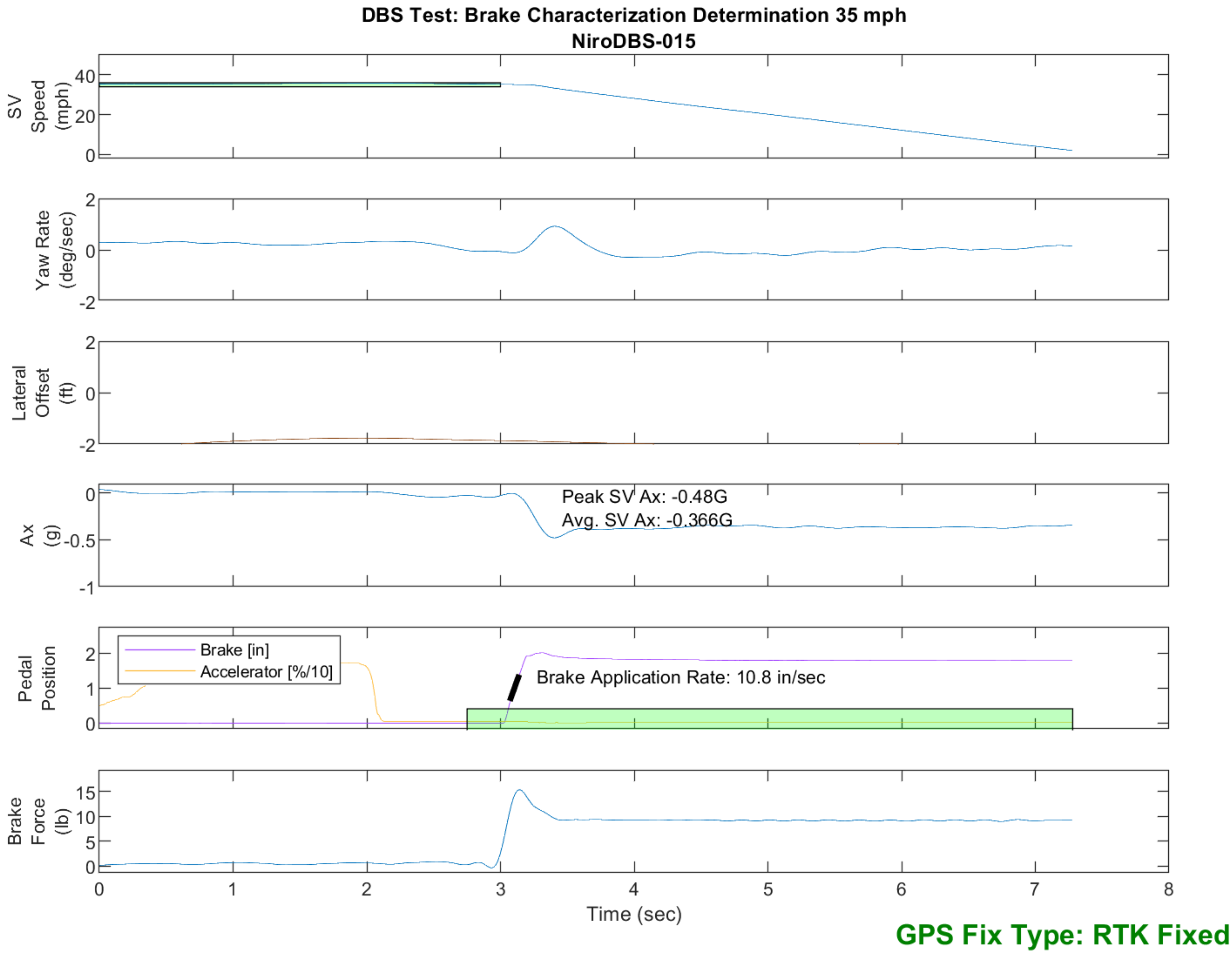


Figure E76. Time History for DBS Run 15, Brake Characterization Determination 35 mph

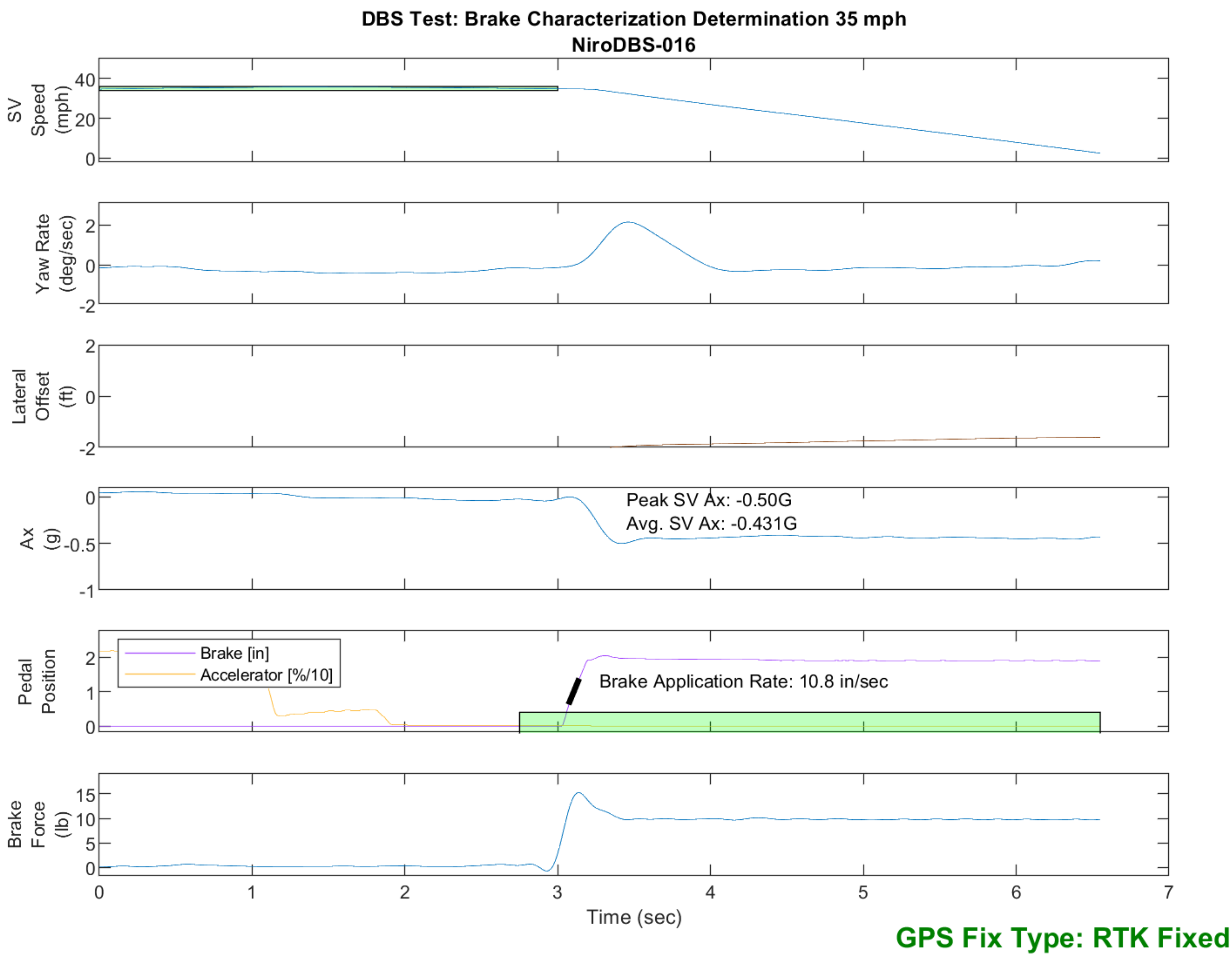


Figure E77. Time History for DBS Run 16, Brake Characterization Determination 35 mph

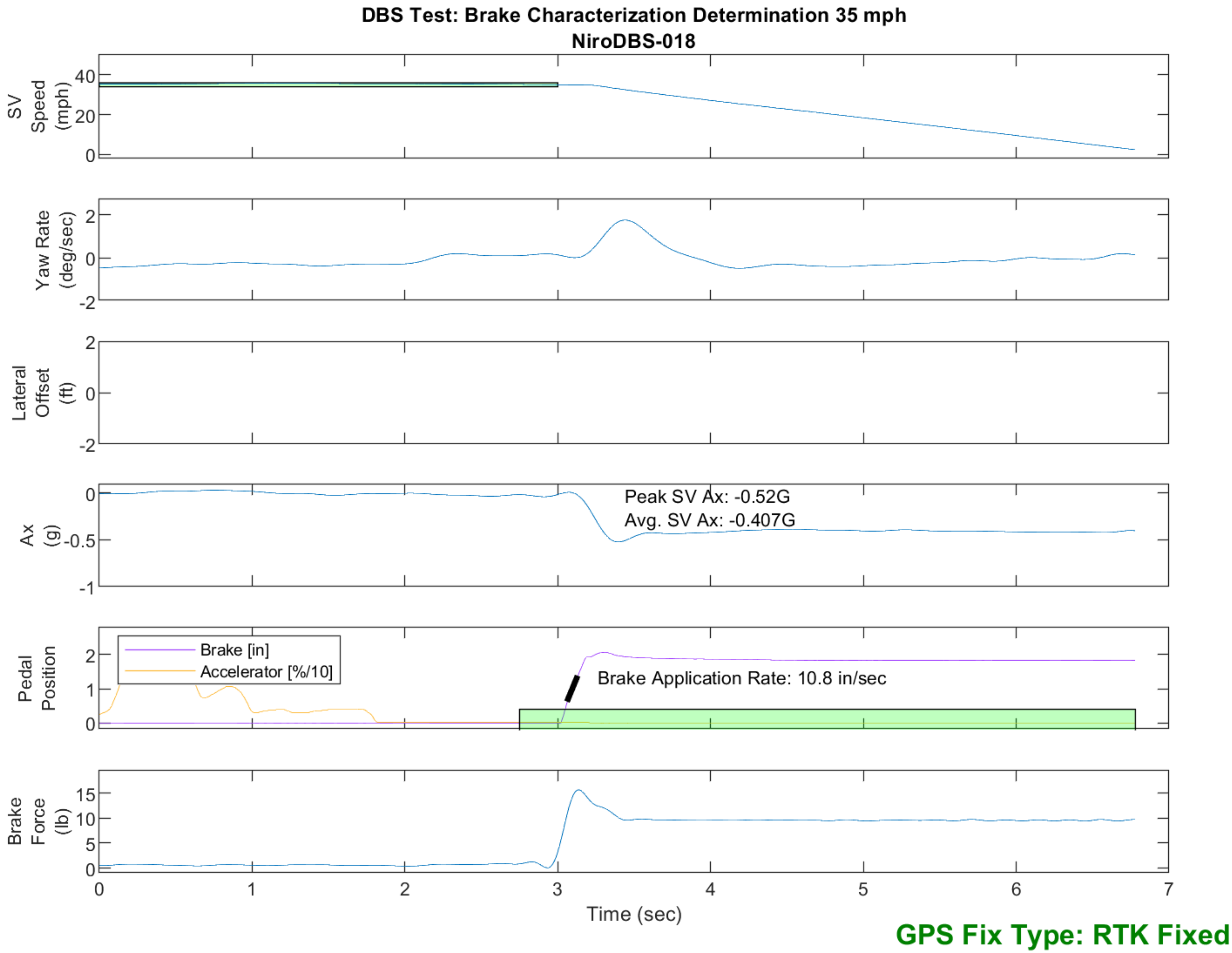


Figure E78. Time History for DBS Run 18, Brake Characterization Determination 35 mph

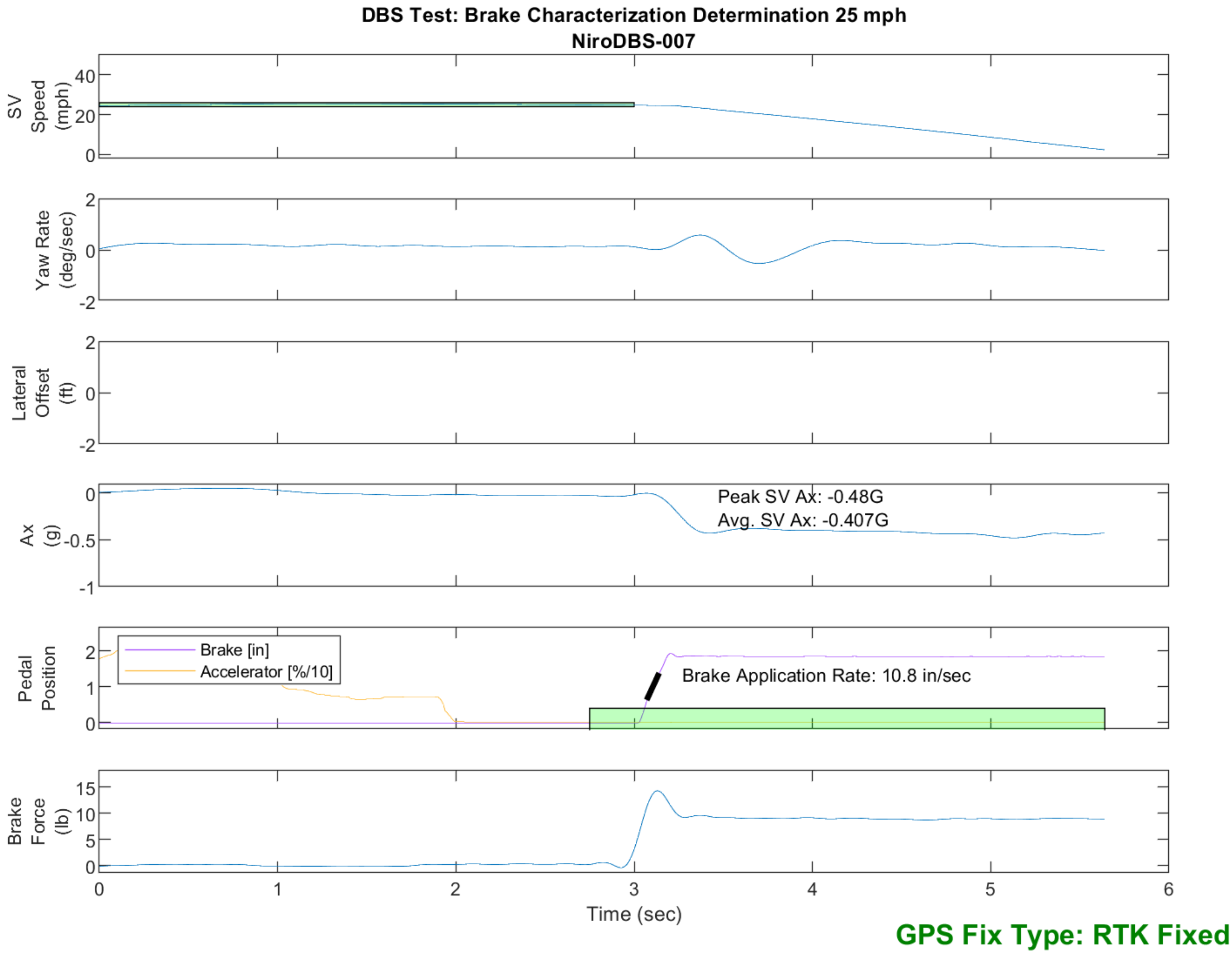


Figure E79. Time History for DBS Run 7, Brake Characterization Determination 25 mph

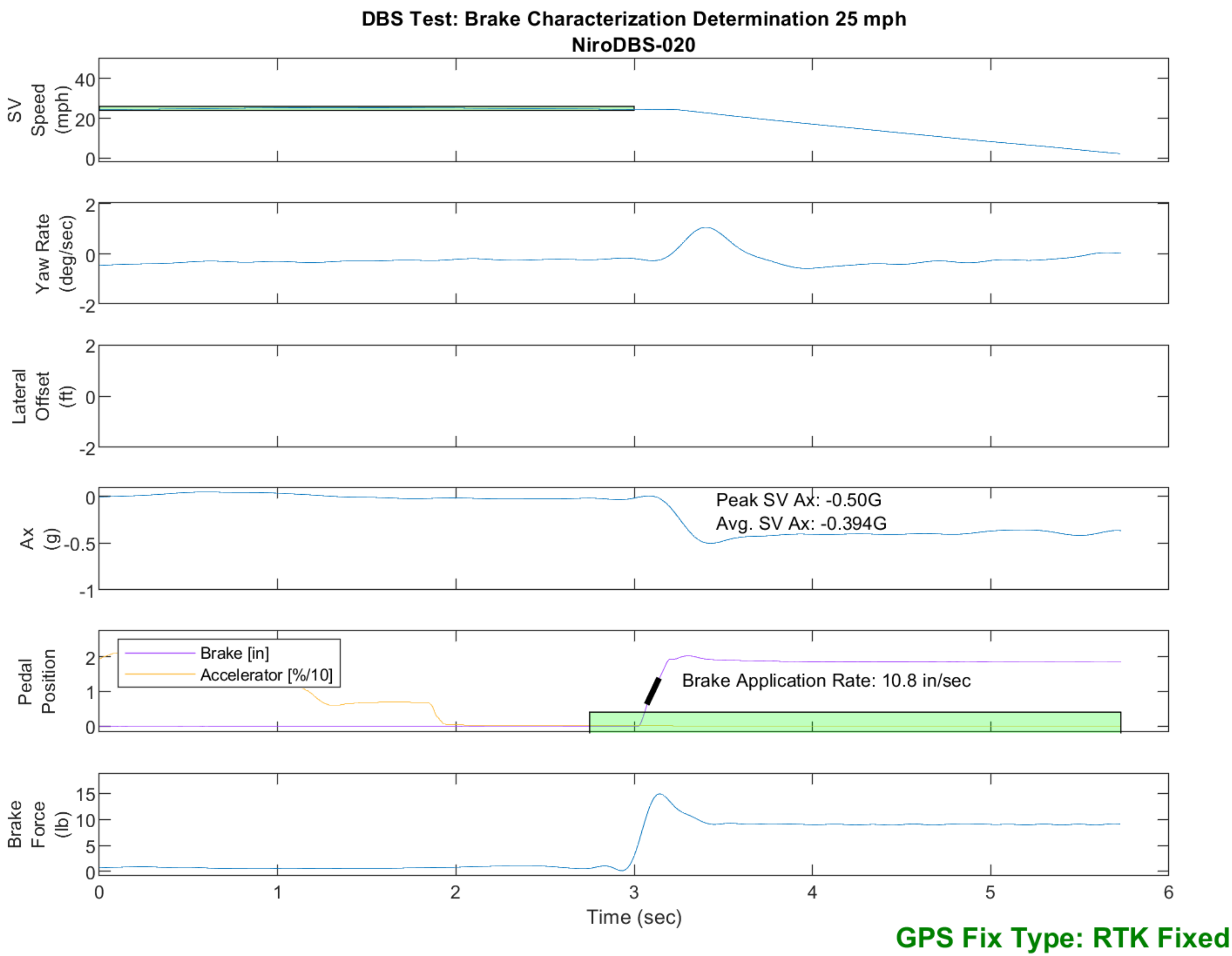


Figure E80. Time History for DBS Run 20, Brake Characterization Determination 25 mph

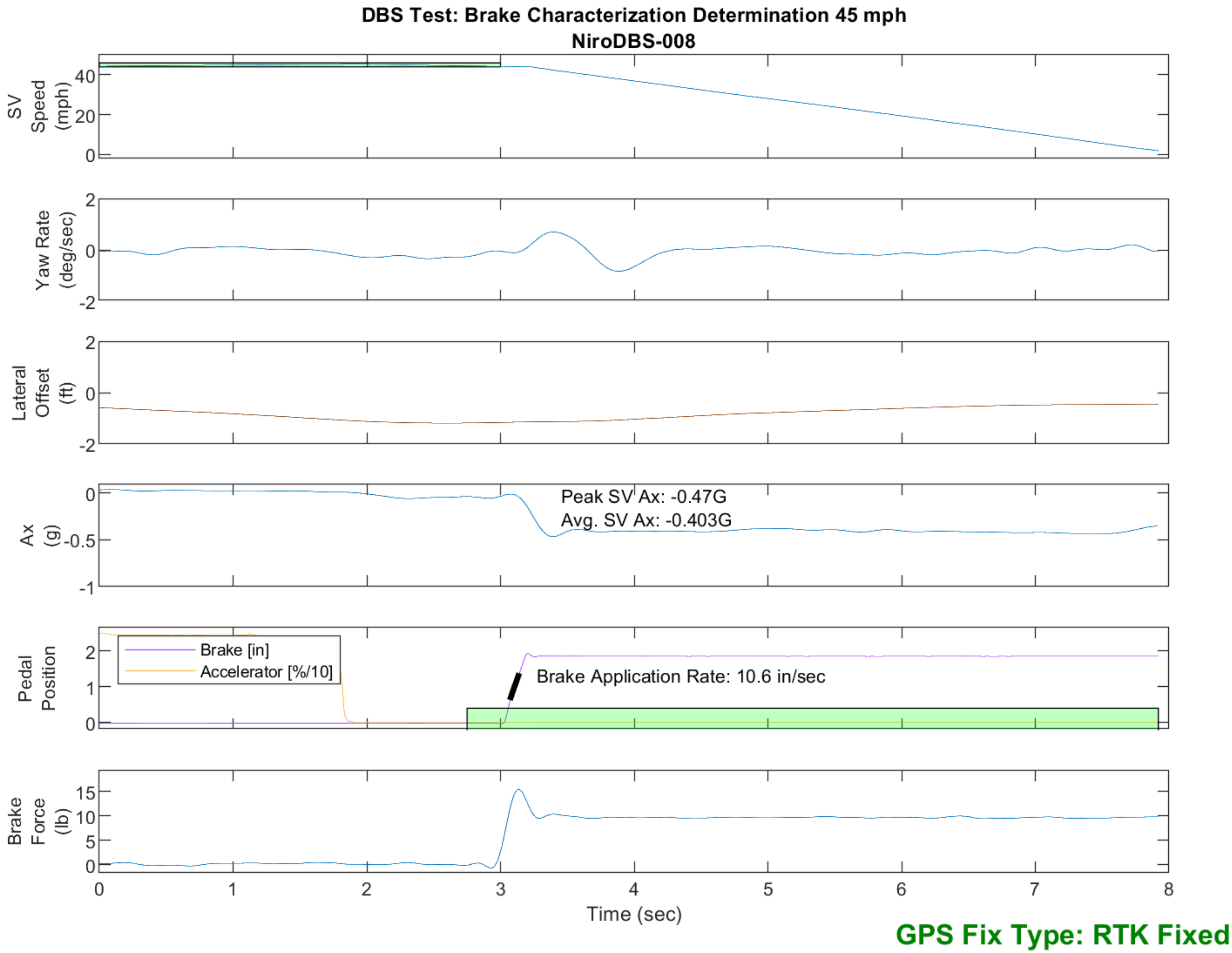


Figure E81. Time History for DBS Run 8, Brake Characterization Determination 45 mph

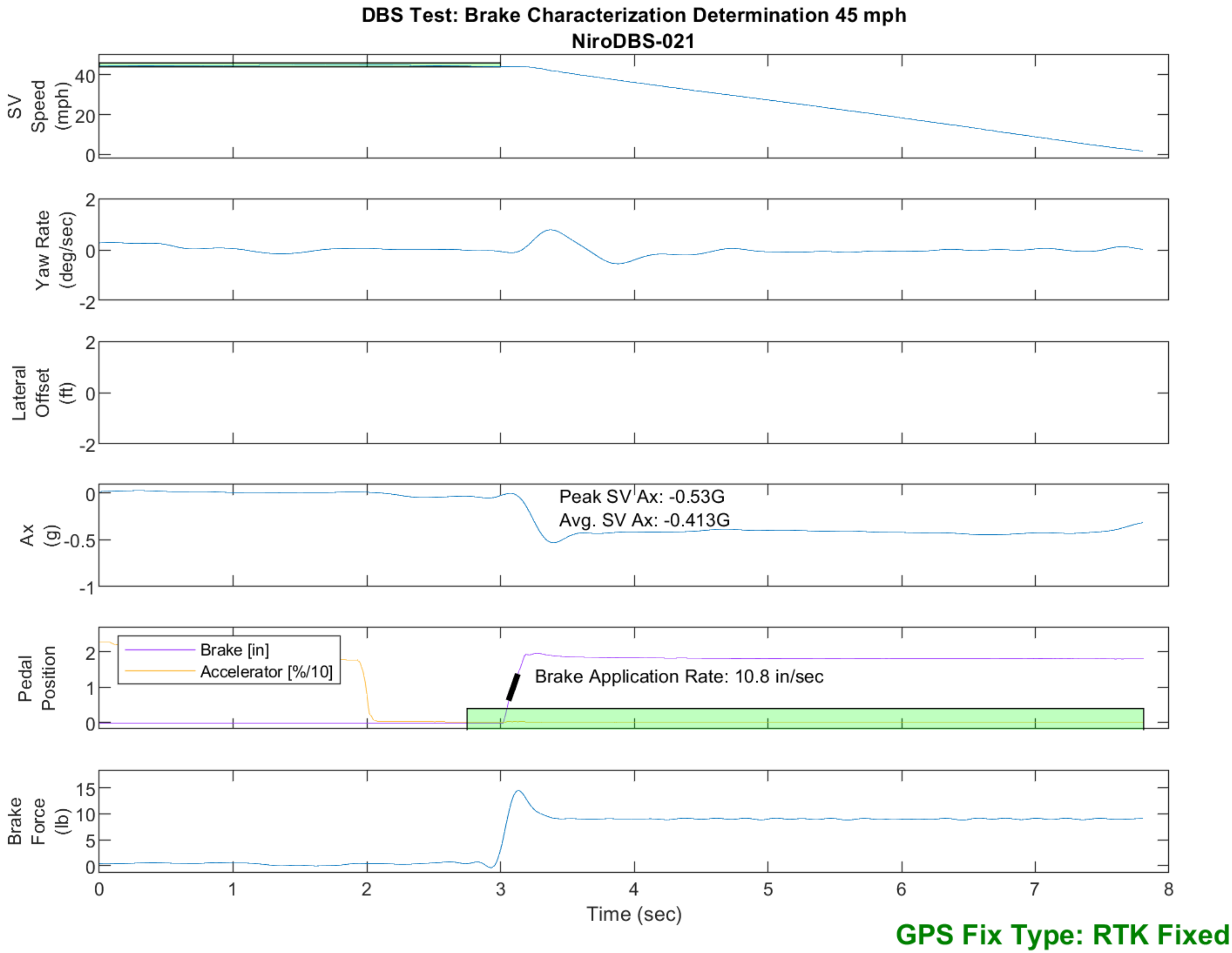


Figure E82. Time History for DBS Run 21, Brake Characterization Determination 45 mph