

**NEW CAR ASSESSMENT PROGRAM
DYNAMIC BRAKE SUPPORT SYSTEM CONFIRMATION TEST
NCAP-DRI-DBS-22-07**

2022 Hyundai Kona Electric

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13 September 2022

Final Report

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Section I

INTRODUCTION

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

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

The method prescribed by the National Highway Traffic Safety Administration (NHTSA) to evaluate DBS performance on the test track involves three longitudinal, rear-end type crash configurations and a false positive test. In the rear-end scenarios, an 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 2022 Hyundai Kona Electric. This test to assess Dynamic Brake Support systems is sponsored by the National Highway Traffic Safety Administration under Contract No. DTNH22-14-D-00333 with the New Car Assessment Program (NCAP).

Section II

DATA SHEETS

DYNAMIC BRAKE SUPPORT
DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2022 Hyundai Kona Electric

VIN: KM8K53AG1NU15xxxx

Test start date: 9/8/2022

Test end date: 9/8/2022

Dynamic Brake Support System settings: Late

**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)

2022 Hyundai Kona Electric

TEST VEHICLE INFORMATION

VIN: KM8K53AG1NU15xxxx

Body Style: SUV

Color: Pulse Red

Date Received: 8/23/2022

Odometer Reading: 54 mi

DATA FROM VEHICLE'S CERTIFICATION LABEL

Vehicle manufactured by: Hyundai Motor Company

Date of manufacture: Jun/2022

Vehicle Type: MPV

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: 215/55R17

Rear: 215/55R17

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

Rear: 250 kPa (36 psi)

TIRES

Tire manufacturer and model: Nexen Npriz AH8

Front tire specification: 215/55R17 94V

Rear tire specification: 215/55R17 94V

Front tire DOT prefix: UA8V CALR

Rear tire DOT prefix: UA8V CALR

DYNAMIC BRAKE SUPPORT
DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2022 Hyundai Kona Electric

GENERAL INFORMATION

Test start date: 9/8/2022

Test start date: 9/8/2022

AMBIENT CONDITIONS

Air temperature: 40.6 C (105 F)

Wind speed: 1.5 m/s (3.5 mph)

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

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

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

VEHICLE PREPARATION

Verify the following:

All non-consumable fluids at 100% capacity: X

Fuel tank is full: X

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

Front: 250 kPa (36 psi)

Rear: 250 kPa (36 psi)

DYNAMIC BRAKE SUPPORT
DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2022 Hyundai Kona Electric

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front: 519.8 kg (1146 lb)

Right Front: 494.4 kg (1090 lb)

Left Rear: 415.5 kg (916 lb)

Right Rear: 408.7 kg (901 lb)

Total: 1838.4 kg (4053 lb)

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

(Page 1 of 3)

2022 Hyundai Kona Electric

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

Forward Collision-Avoidance Assist (FCA) comes standard on this vehicle.

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

Front radar located in the lower grille and front view camera located in the upper center windshield.

System settings used for test (if applicable):

Late

Brake application mode used for test: Hybrid control

Over what speed range is the system operational?

The AEB system is operational between 10-75 km/h (6-47 mph) for CIB and 10-180 km/h (6-112 mph) for DBS (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? _____ Yes

 X No

If yes, please provide a full description.

In general, FCA does not deactivate due to repeated FCA activations or impacts. However, if the brake actuator or radar/camera sensors are damaged or have problems due to repeated FCA activations or impacts, FCA can deactivate.

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 2 of 3)

2022 Hyundai Kona Electric

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

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

The AEB system alerts the driver with a visual and auditory alert. The visual alert is a sequence of images shown in the center of the instrument panel and consists of an image of two vehicles between lane lines. The first stage of the sequence is the FCW alert and displays the words "Collision Warning". When the AEB system activates, the words change to "Emergency Braking". After the vehicle has come to a stop, the words "Drive Carefully" are displayed. The auditory alert consists of repeated beeps with a primary frequency at approximately 1515 Hz.

Is there a way to deactivate the system? ☒ Yes
☐ No

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

The AEB system can be turned on/off using the touch screen display on the center dash. The procedure is as follows:

1. Select "Setup" to bring up the setup menu.
2. Select "Vehicle" -> "Driver Assistance" -> "Forward Safety".
3. Select between "Active Assist", "Warning Only", and "Off" to turn the AEB system on/off.

When the AEB system is turned off, the FCA off warning light illuminates. The system is automatically enabled each time the engine switch is turned on.

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 3 of 3)

2022 Hyundai Kona Electric

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

If yes, please provide a full description.

The vehicle offers two warning timing settings for the FCW alert (Standard and Late) using the touch screen display on the center dash. However, this does not affect the performance of the AEB system (per manufacturer supplied information).

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

If yes, please provide a full description.

Refer to the owner's manual pages 7-21 to 7-28 shown in Appendix B pages B-8 to B-15.

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.

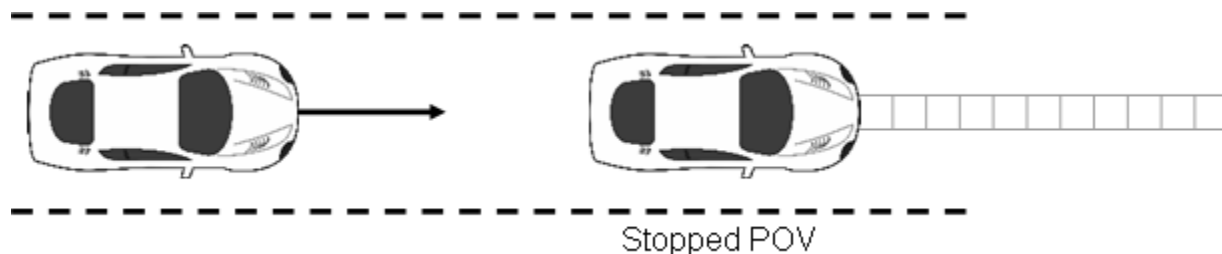


Figure 1. Depiction of Test 1

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 or SV brake application if no FCW alert was given. 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 lateral distance between the centerline of the SV to the center of the travel lane could not deviate more than ± 1 ft (0.3 m) during the validity period.
- The yaw rate of the SV could not deviate more than ± 1 deg/sec during the validity period.
- 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} or impact if no FCW alert was given.

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 \rightarrow t_{FCW} | 187 ft (57 m) \rightarrow t_{FCW} | Within 500 ms of FCW1 onset | Varies | 1.1 | 40 ft (12 m) |

b. Criteria

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

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

This test evaluates the ability of the DBS system to detect and respond to a slower-moving lead vehicle traveling at a constant speed in the immediate forward path of the SV, as depicted in Figure 2.

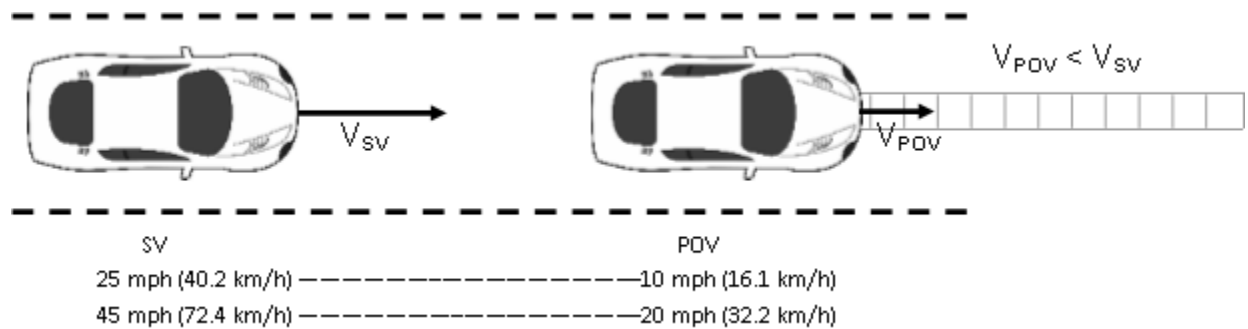


Figure 2. Depiction of Test 2

a. Procedure

The SV ignition was cycled prior to each test run. The tests were conducted two ways. In the first, the POV was driven at a constant 10.0 mph (16.1 km/h) in the center of the lane of travel while the SV was driven at 25.0 mph (40.2 km/h), in the center lane of travel, toward the slower-moving POV. In the second, the POV was driven at a constant 20.0 mph (32.2 km/h) in the center of the lane of travel while the SV was driven at 45.0 mph (72.4 km/h), in the center lane of travel, toward the slower-moving POV. In both cases, the SV throttle pedal was released within 500 ms after t_{FCW} , i.e., within 500 ms of the FCW alert or SV brake application if no FCW alert was given. 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 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 SV and POV to the center of the travel lane could not deviate more than ± 1 ft (0.3 m) during the validity period.
- The yaw rate of the SV and POV could not deviate more than ± 1 deg/sec 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} or impact if no FCW alert was given.
- 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.

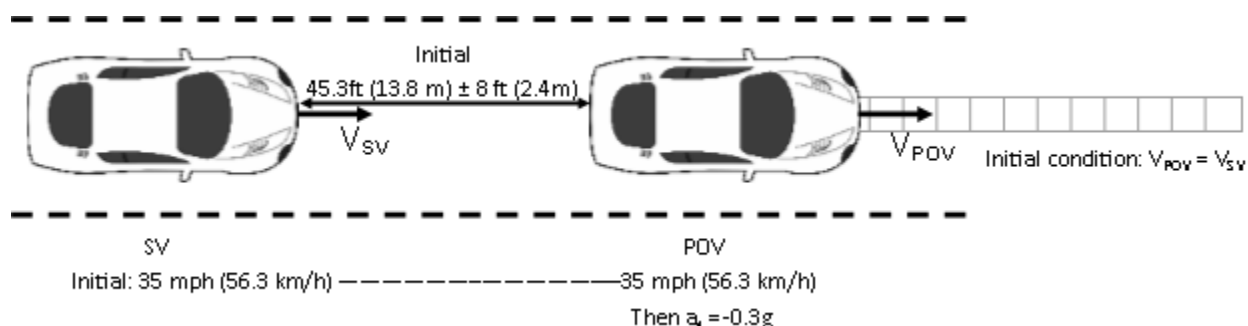


Figure 3. Depiction of Test 3

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 of deceleration within 1.5 ± 0.1 sec. The SV throttle pedal was released within 500 ms of t_{FCW} or SV brake application if no FCW alert was given. 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 SV and POV to the center of the travel lane could not deviate more than ± 1 ft (0.3 m) during the validity period.
- The yaw rate of the SV and POV could not deviate more than ± 1 deg/sec during the validity period.
- The SV speed could not deviate more than ± 1.0 mph (1.6 km/h) during an interval defined by 3.0 seconds before the onset of POV braking to t_{FCW} or impact if no FCW alert was given.
- The POV speed could not deviate more than ± 1.0 mph (1.6 km/h) during an interval of 3.0 seconds before the onset of POV braking.
- The SV- POV headway distance could not deviate more than ± 8 ft (2.4 m) during an interval defined by the onset of the validity period to the onset of POV braking.
- The average POV deceleration could not deviate by more than ± 0.03 g from the nominal 0.3 g deceleration during the interval beginning at 1.5 seconds after the onset of POV braking and ending either 250 ms prior to the POV coming to a stop or the SV coming into contact with the POV.

Table 3. Nominal Decelerating POV DBS Test Choreography

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

b. Criteria

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

4. TEST 4 – FALSE POSITIVE SUPPRESSION

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

a. Procedure

This test was conducted at two speeds, 25 mph (40.2 km/h) and 45 mph (72.4 km/h). The SV was driven directly towards, and over, the STP, which was positioned in the center of a travel lane, with its longest sides parallel to the road edge. The test concluded when the front of the SV reached the leading edge of the STP.

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 SV to the center of the travel lane could not deviate more than ± 1 ft (0.3 m) during the validity period.
- The yaw rate of the SV could not deviate more than ± 1 deg/sec during the validity period.
- The SV speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during an interval from $TTC = 5.1$ s to the earlier of t_{FCW} or $TTC = 2.1$ s.
- The throttle pedal was modulated using smooth inputs until an FCW alert was presented or a $TTC = 2.1$ s, at which point the SV driver released the throttle pedal within 500 ms.
- The SV brakes were then applied at $TTC = 1.1$ seconds.
 - For SV test speed of 25 mph, $TTC = 1.1$ seconds is taken to occur at an SV-to-STP distance of 40 ft (12.3 m).
 - For SV test speed of 45 mph, $TTC = 1.1$ seconds is taken to occur at an SV-to-STP distance of 73 ft (22.1 m).

b. Criteria

In order to pass the False Positive test series, the magnitude of the SV deceleration reduction attributable to DBS intervention must have been less than or equal to 1.5 times

the average of the deceleration experienced by the baseline command from the braking actuator for at least five of seven valid test trials.

B. General Information

1. T_{FCW}

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

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

Table 4. Auditory and Tactile Warning Filter Parameters

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

2. GENERAL VALIDITY CRITERIA

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

- The SV driver seatbelt was latched.
- If any load had been placed on the SV front passenger seat (e.g., for instrumentation), the vehicle's front passenger seatbelt was latched.
- The SV was driven at the nominal speed in the center of the travel lane, toward the POV or STP.
- The driver used the least amount of steering input necessary to maintain SV position in the center of the travel lane during the validity period; use of abrupt

steering inputs or corrections was avoided.

- The yaw rate of the SV did not exceed ± 1.0 deg/s from the onset of the validity period to the instant SV deceleration exceeded 0.25 g.
- The SV driver did not apply any force to the brake pedal during the applicable validity period. All braking shall be performed by the programmable brake controller.
- The lateral distance between the centerline of the SV and the centerline of the POV or STP did not deviate more than ± 1 ft (0.3 m) during the applicable validity period.

3. VALIDITY PERIOD

The valid test interval began:

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

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

Test 3: 3 seconds before the onset of POV braking

Test 4: When the SV-to-STP TTC = 5.1 seconds

The valid test interval ended:

Test 1: When either of the following occurred:

- The SV came into contact with the POV (assessed by using GPS-based range data); or
- The SV came to a stop before making contact with the POV.

Tests 2 and 3: When either of the following occurred:

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

Test 4: The front of the SV reached the leading edge of the STP.

4. STATIC INSTRUMENTATION CALIBRATION

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

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

For Tests 1, 2, and 3, the SV was positioned such that it just contacted a vertical plane defining the rearmost location of the POV. For Test 4, the front-most location of the SV was positioned such that it just reached a vertical plane defined by the leading edge of the STP first encountered by the SV (i.e., just before it is driven onto the STP). This is the “zero position.”

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 offset was adjusted to output zero, another pre-test static calibration data file was collected, and the test series was repeated.

5. NUMBER OF TRIALS

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

6. TRANSMISSION

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

C. Principal Other Vehicle

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

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

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

The key requirements of the POV element are to:

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

repeated SV-to-POV impacts.

The key requirements of the POV delivery system are to:

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

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

D. Foundation Brake System Characterization

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

This characterization was accomplished by recording longitudinal acceleration and brake pedal force and travel data for a variety of braking runs. For three initial brake characterization runs, the vehicle was driven at 45 mph, and the brakes were applied at a rate of 1 inch/sec up to the brake input level needed for at least 0.7 g. Linear regressions were performed on the data from each run to determine the linear vehicle deceleration response as a function of both applied brake pedal force and brake pedal travel. The brake input force or displacement level needed to achieve a vehicle deceleration of 0.4 g was determined from the average of the three runs. Using the 0.4 g brake input force or displacement level found from the three initial runs, subsequent runs were performed at 25 mph, 35 mph, and 45 mph, with the brakes applied at a rate of 10 inch/sec to the determined 0.4 g brake input force or displacement level. For each of the three test speeds, if the average calculated deceleration level was found to be within 0.4 ± 0.025 g, the resulting force or displacement was recorded and used. If the average calculated

deceleration level exceeded this tolerance, the brake input force or displacement levels were adjusted and retested until the desired magnitude was realized. Prior to each braking event, the brake pad temperatures were required to be in the range of 149° - 212°F.

E. Brake Control

1. SUBJECT VEHICLE PROGRAMMABLE BRAKE CONTROLLER

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

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

2. SUBJECT VEHICLE BRAKE PARAMETERS

- Each test run began with the brake pedal in its natural resting position, with no preload or position offset.
- The onset of the brake application was considered to occur when the brake actuator had applied 2.5 lbf (11 N) of force to the brake pedal.
- The magnitude of the brake application was that needed to produce 0.4 g deceleration, as determined in the foundation brake characterization.
- The SV brake application rate was between 9 to 11 in/s (229 to 279 mm/s), where the application rate is defined as the slope of a linear regression line applied to brake pedal position data over a range from 25% to 75% of the commanded input magnitude.
- If the brake application rate could not be achieved due to brake pedal movement during AEB activation, the application rate requirement was removed. Instead, the brakes were applied 1 second after the onset of FCW and the target brake pedal displacement was achieved within 250 ms.

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 100 psi | Omega DPG8001 | 17042707002 | By: DRI Date: 10/5/2021 Due: 10/5/2022 |
| Platform Scales | Vehicle Total, Wheel, and Axle Load | 2200 lb/platform | 0.1% of reading | Intercomp SW wireless | 0410MN20001 | By: DRI Date: 2/11/2022 Due: 2/11/2023 |
| Linear (string) encoder | Throttle pedal travel | 10 in | 0.01 in | UniMeasure JX-EP | 52041382 | By: DRI Date: 4/29/2022 Due: 4/29/2023 |
| Load Cell | Force applied to brake pedal | | | | | By: DRI |
| | | 0-250 lb 1112 N | 0.05% FS | Stellar Technology PNC700 | 1607338 | Date: 3/30/2022 Due: 3/30/2023 |
| | | 0-250 lb | 0.05% FS | Stellar Technology PNC700 | 2002506 | Date: 2/25/2022 Due: 2/25/2023 |
| Differential Global Positioning System | Position, Velocity | Latitude: ± 90 deg Longitude: ± 180 deg Altitude: 0-18 km Velocity: 0-1000 knots | Horizontal Position: ± 1 cm Vertical Position: ± 2 cm Velocity: 0.05 km/h | Trimble GPS Receiver, 5700 (base station and in-vehicle) | 00440100989 | N/A |

Table 5. Test Instrumentation and Equipment (continued)

| Type | Output | Range | Accuracy, Other Primary Specs | Mfr, Model | Serial Number | Calibration Dates Last Due |
|--|--|---|---|---|---------------|-------------------------------------|
| Multi-Axis Inertial Sensing System | Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles | Accels $\pm 10g$, 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 |
| | | | | | 2182 | Date: 11/19/2021 Due: 11/19/2023 |
| | | | | | 2258 | Date: 4/28/2021 Due: 4/28/2023 |
| Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW) | Distance and Velocity to lane markings (LDW) and POV (FCW) | Lateral Lane Dist: ± 30 m Lateral Lane Velocity: ± 20 m/sec Longitudinal Range to POV: ± 200 m Longitudinal Range Rate: ± 50 m/sec | Lateral Distance to Lane Marking: ± 2 cm Lateral Velocity to Lane Marking: ± 0.02 m/sec Longitudinal Range: ± 3 cm Longitudinal Range Rate: ± 0.02 m/sec | Oxford Technical Solutions (OXTS), RT-Range | 97 | N/A |
| Microphone | Sound (to measure time at alert) | Frequency Response: 80 Hz – 20 kHz | Signal-to-noise: 64 dB, 1 kHz at 1 Pa | Audio-Technica AT899 | N/A | N/A |
| Light Sensor | Light intensity (to measure time at alert) | Spectral Bandwidth: 440-800 nm | Rise time < 10 msec | DRI designed and developed Light Sensor | N/A | N/A |
| Accelerometer | Acceleration (to measure time at alert) | $\pm 5g$ | $\leq 3\%$ of full range | Silicon Designs, 2210-005 | N/A | N/A |

| Type | Output | Range | Accuracy, Other Primary Specs | Mfr, Model | Serial Number | Calibration Dates Last Due |
|--------------------------------|---|-------------------|--|-----------------------------------|-----------------|--|
| Coordinate Measurement Machine | Inertial Sensing System Coordinates | 0-8 ft 0-2.4 m | ± 0.0020 in. ± 0.051 mm (Single point articulation accuracy) | Faro Arm, Fusion | UO8-05-08-06636 | By: DRI Date: 1/6/2022 Due: 1/6/2023 |
| 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

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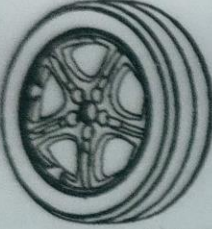
Figure A1. Front View of Subject Vehicle



Figure A2. Rear View of Subject Vehicle



Figure A4. Vehicle Certification Label



TIRE AND LOADING INFORMATION

RENSEIGNEMENTS SUR LES PNEUS ET LE CHARGEMENT

| | | | |
|--------------------------------------|---------|------------------|-------------------|
| SEATING CAPACITY NOMBRE DE PLACES | TOTAL 5 | FRONT 2 AVANT | REAR 3 ARRIÈRE |
|--------------------------------------|---------|------------------|-------------------|

The combined weight of occupants and cargo should never exceed 390 kg or 860 lbs.
 Le poids total des occupants et du chargement ne doit jamais dépasser 390 kg ou 860 lb.

| TIRE PNEU | SIZE DIMENSIONS | COLD TIRE PRESSURE PRESSION DES PNEUS À FROID |
|---------------------|--------------------|---|
| FRONT AVANT | 215/55R17 | 250kPa, 36psi |
| REAR ARRIÈRE | 215/55R17 | 250kPa, 36psi |
| SPARE DE SECOURS | NONE AUCUN | |

**SEE OWNER'S
MANUAL FOR
ADDITIONAL
INFORMATION**

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

EV3

Figure A5. Tire Placard



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



Figure A7. Load Frame/Slider of SSV

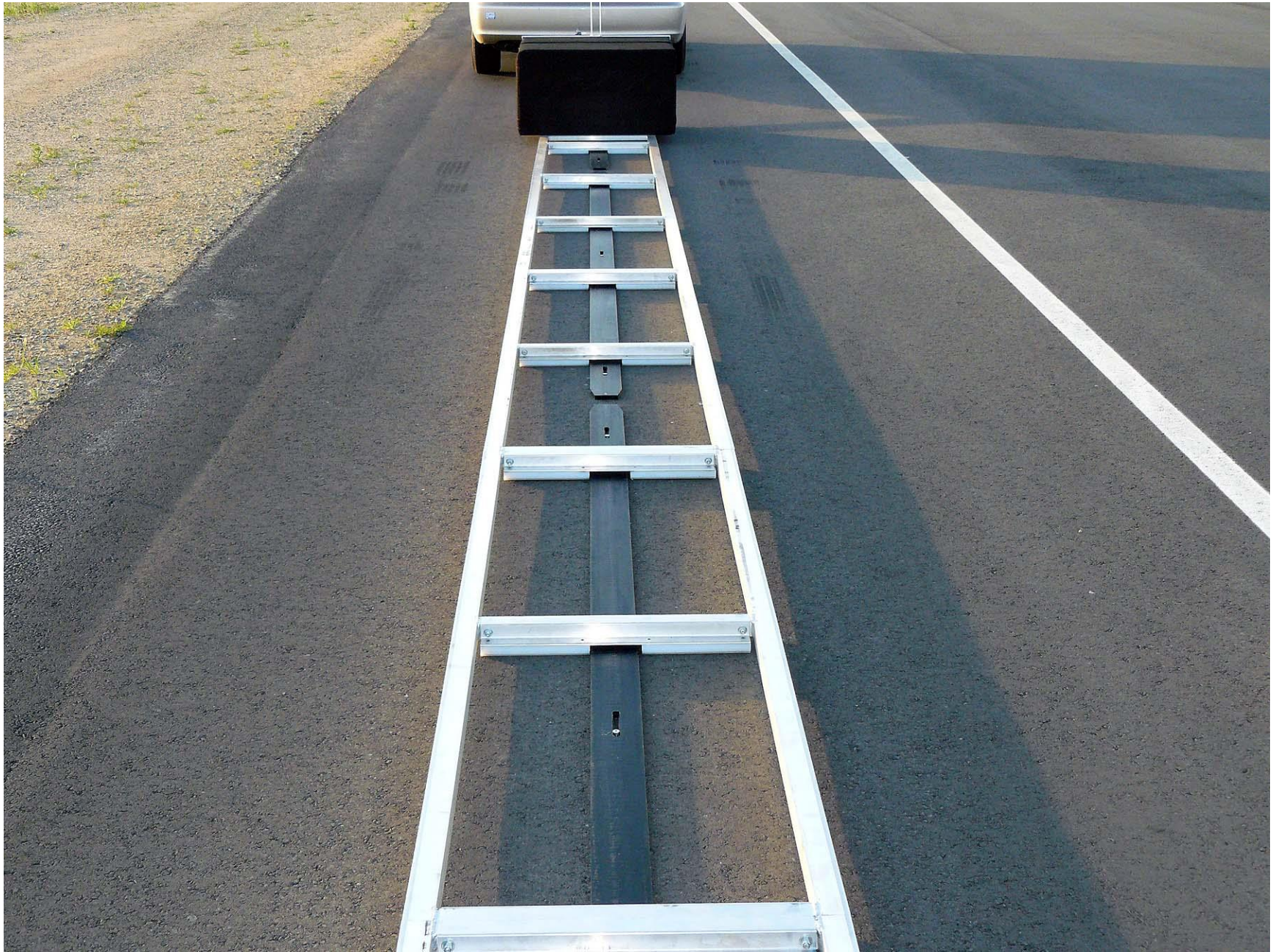


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track



Figure A9. Steel Trench Plate
A-11



Figure A10. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle
A-12



Figure A11. Sensors for Detecting Visual and Auditory Alerts



Figure A12. Computer Installed in Subject Vehicle
A-14

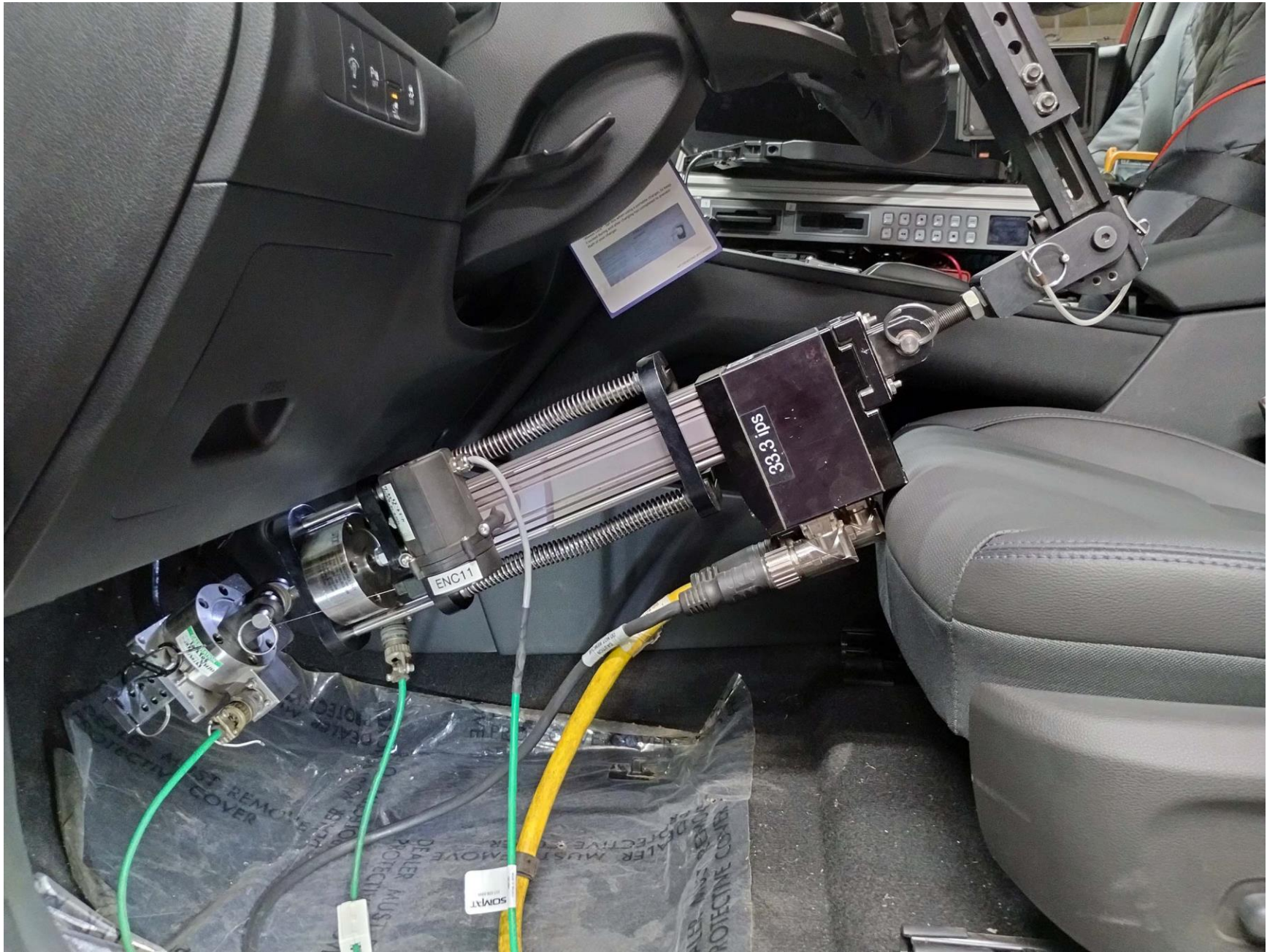


Figure A13. Brake Actuator Installed in Subject Vehicle
A-15



Figure A14. Brake Actuator Installed in POV System

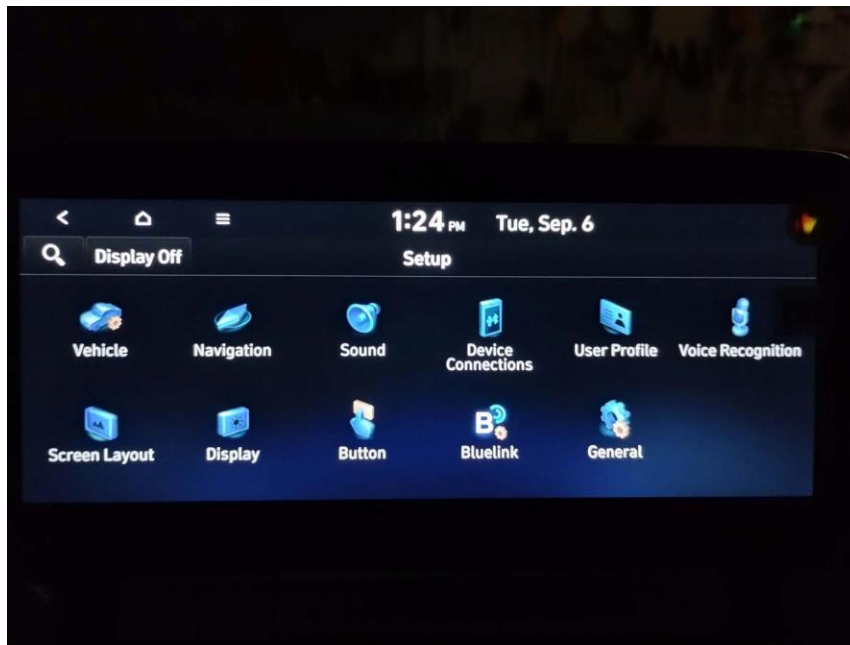


Figure A15. Menus for Turning AEB System On/Off

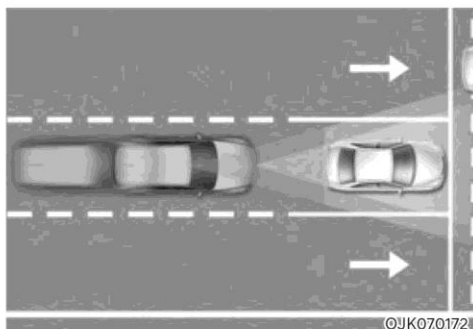


Figure A16. Visual Alert
A-18

APPENDIX B

Excerpts from Owner's Manual

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



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

Detecting sensor



[1]: Front view camera, [2]: Front radar
Refer to the picture above for the detailed location of the detecting sensors.



CAUTION

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

- Never disassemble the detecting sensor or sensor assembly, or apply any impact on it.
- If the detecting sensors have been replaced or repaired, have your vehicle inspected by an authorized HYUNDAI dealer.
- Never install any accessories or stickers on the front windshield, or tint the front windshield.

- Pay extreme caution to keep the front view camera dry.
- Never place any reflective objects (i.e. white paper, mirror) over the dashboard.
- Do not apply license plate frame or objects, such as a bumper sticker, film or a bumper guard, near the front radar cover.
- Always keep the front radar and cover clean and free of dirt and debris.
Use only a soft cloth to wash the vehicle. Do not spray pressurized water directly on the sensor or sensor cover.
- If unnecessary force has been applied to the radar or around the radar, Forward Collision-Avoidance Assist may not properly operate even though a warning message does not appear on the cluster. Have the vehicle inspected by an authorized HYUNDAI dealer.
- Use only genuine parts to repair or replace a damaged front radar cover. Do not apply paint to the front radar cover.

Forward Collision-Avoidance Assist settings


Setting features



Forward Safety

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

- If 'Active Assist' is selected, Forward Collision-Avoidance Assist will warn the driver with a warning message, an audible warning depending on the collision risk levels. Braking assist or steering assist (if equipped) will be applied depending on the collision risk.
- If 'Warning Only' is selected, Forward Collision-Avoidance Assist will warn the driver with a warning message, an audible warning depending on the collision risk levels. Braking and steering (if equipped) will not be assisted. The driver must apply the brake pedal or steer the vehicle if necessary.

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



WARNING

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




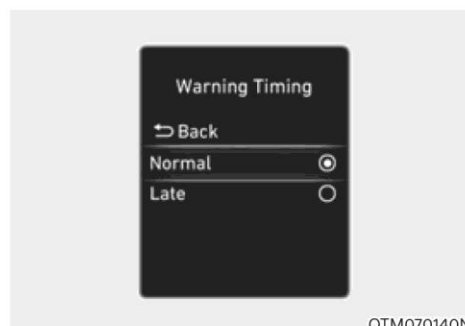
CAUTION

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



Information

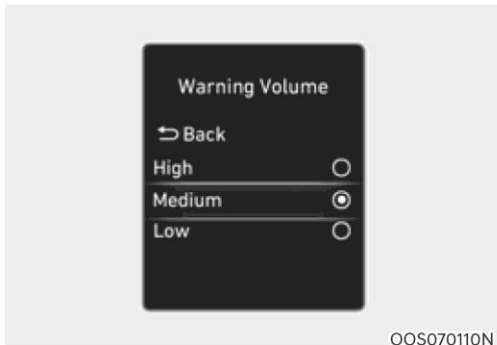
Forward Collision-Avoidance Assist will turn off when ESC is turned off by pressing and holding the ESC OFF button. The  warning light will illuminate on the cluster.



Warning Timing

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

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



Warning Volume

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

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



CAUTION

- The setting of the Warning Timing and Warning Volume applies to all functions of Forward Collision-Avoidance Assist.
- Even though, 'Normal' is selected for Warning Timing, if the front vehicle suddenly stops, the initial warning activation time may seem late.
- Select 'Late' for Warning Timing when traffic is light and when driving speed is slow.



Information

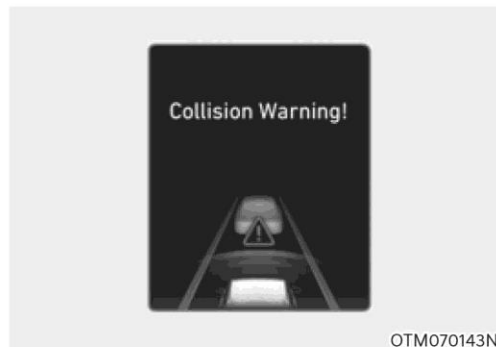
If the engine is restarted, Warning Timing and Warning Volume will maintain the last setting.

Forward Collision-Avoidance Assist operation

Basic function

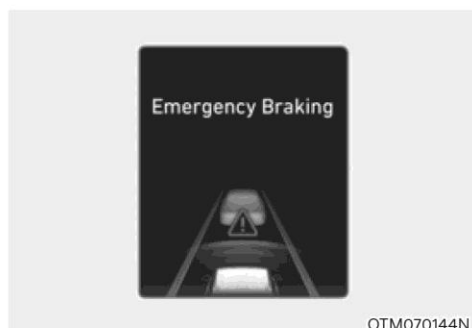
Warning and control

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



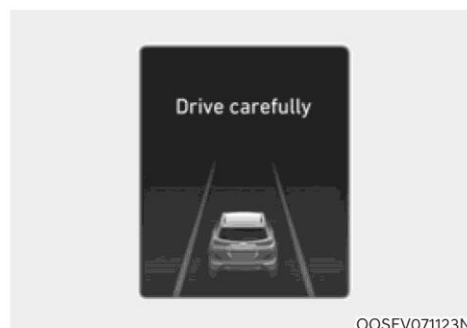
Collision Warning

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



Emergency Braking

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




Stopping vehicle and ending brake control

- When the vehicle is stopped due to emergency braking, the 'Drive carefully' warning message will appear on the cluster.
For your safety, the driver should depress the brake pedal immediately and check the surroundings.
- Brake control will end after the vehicle is stopped by emergency braking for approximately 2 seconds.



WARNING

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



WARNING

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

**CAUTION**

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



**Information**

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

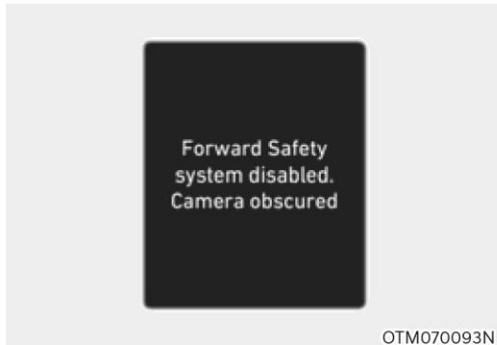
Forward Collision-Avoidance Assist malfunction and limitations

Forward Collision-Avoidance Assist malfunction



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

Forward Collision-Avoidance Assist disabled



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

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

Forward Collision-Avoidance Assist will operate normally when snow, rain or foreign material is removed.

If Forward Collision-Avoidance Assist does not operate normally after obstruction (snow, rain, or foreign material) is removed, have the function inspected by an authorized HYUNDAI dealer.



WARNING

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

Limitations of Forward Collision-Avoidance Assist

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

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

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



The illustration above shows the image the front view camera and front radar is capable of detecting as a vehicle, pedestrian and cyclist.

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

**WARNING**

- Driving on a curve



OADAS014



OADAS016



OADAS018

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

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



OADAS015



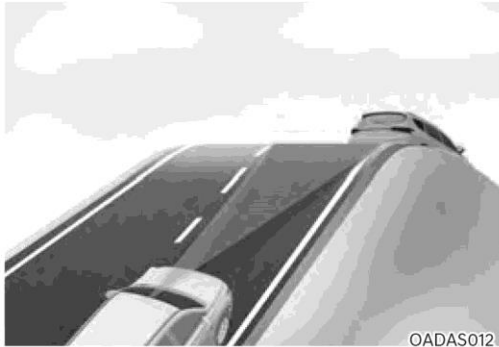
OADAS017



OADAS019

Forward Collision-Avoidance Assist may detect a vehicle, pedestrian or cyclist in the next lane or outside the lane when driving on a curved road. If this occurs, Forward Collision-Avoidance Assist may unnecessarily warn the driver and control the brake or steering wheel (if equipped). Always check the traffic conditions around the vehicle.

- Driving on a slope



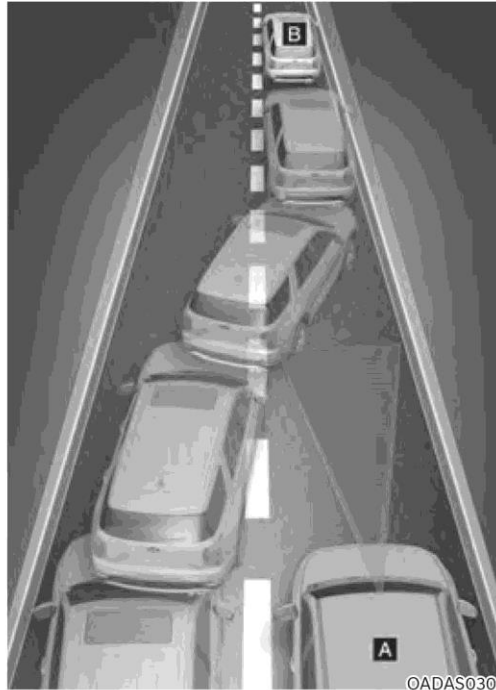
Forward Collision-Avoidance Assist may not detect other vehicles, pedestrians or cyclists in front of you while driving uphill or downhill, adversely affecting the performance of the sensors.

This may result in unnecessary warning, braking assist or steering assist (if equipped) or no warning, braking assist or steering assist (if equipped) when necessary.

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

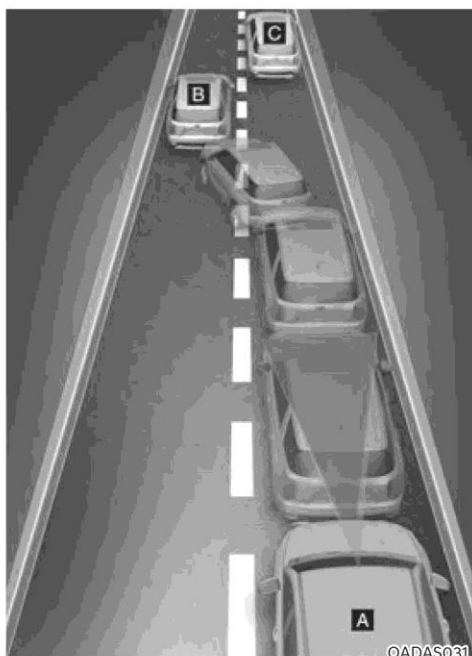
Always have your eyes on the road while driving uphill or downhill and if necessary, steer your vehicle and depress the brake pedal to reduce your driving speed in order to maintain a safe distance.

- Changing lanes



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

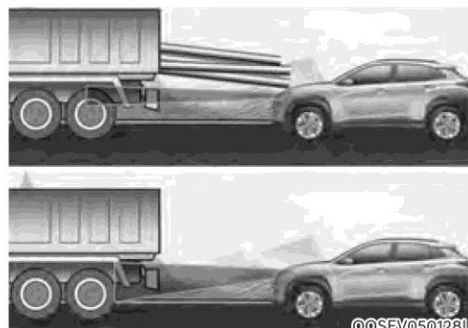
When a vehicle moves into your lane from an adjacent lane, it cannot be detected by the sensor until it is in the sensor's detection range. **Forward Collision-Avoidance Assist** may not immediately detect the vehicle when the vehicle changes lanes abruptly. In this case, you must maintain a safe braking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



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

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

- **Detecting vehicle**



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



WARNING

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



Information

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



Information

This device complies with Part 15 of the FCC rules.

Operation is subject to the following three conditions:

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



Information

Radio frequency radiation exposure information:

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

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

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

APPENDIX C

Run Log

Subject Vehicle: **2022 Hyundai Kona Electric**

Test start date: **9/8/2022**

Principal Other Vehicle: **SSV**

Test end date: **9/8/2022**

| Run | Test Type | Valid Run? | FCW TTC (s) | Minimum Distance (ft) | Peak Deceleration (g) | Pass/Fail | Notes |
|-----|--|------------|-------------|-----------------------|-----------------------|-----------|----------------|
| | Brake characterization and determination | | | | | | See Appendix D |
| 45 | Stopped POV | Y | 1.65 | 6.86 | 0.92 | Pass | |
| 46 | | Y | 1.69 | 6.85 | 0.93 | Pass | |
| 47 | | Y | 1.70 | 6.82 | 0.88 | Pass | |
| 48 | | Y | 1.71 | 6.98 | 0.91 | Pass | |
| 49 | | Y | 1.66 | 6.08 | 0.88 | Pass | |
| 50 | | Y | 1.63 | 7.83 | 0.92 | Pass | |
| 51 | | Y | 1.71 | 6.77 | 0.90 | Pass | |
| 52 | Static Run | | | | | | |
| | | | | | | | |
| 53 | Slower POV, 25 vs 10 | Y | 1.55 | 6.93 | 1.02 | Pass | |
| 54 | | Y | 1.60 | 6.46 | 1.06 | Pass | |
| 55 | | Y | 1.48 | 5.62 | 1.05 | Pass | |
| 56 | | Y | 1.54 | 7.15 | 1.04 | Pass | |
| 57 | | Y | 1.57 | 7.31 | 1.04 | Pass | |
| 58 | | Y | 1.54 | 7.74 | 1.00 | Pass | |
| 59 | | Y | 1.55 | 7.36 | 1.04 | Pass | |

| Run | Test Type | Valid Run? | FCW TTC (s) | Minimum Distance (ft) | Peak Deceleration (g) | Pass/Fail | Notes |
|-----|----------------------|------------|-------------|-----------------------|-----------------------|-----------|------------------------|
| 60 | Static run | | | | | | |
| | | | | | | | |
| 61 | Slower POV, 45 vs 20 | Y | 2.64 | 9.68 | 0.87 | Pass | |
| 62 | | Y | 2.56 | 8.71 | 0.86 | Pass | |
| 63 | | Y | 2.53 | 9.91 | 0.88 | Pass | |
| 64 | | Y | 2.52 | 8.96 | 0.86 | Pass | |
| 65 | | Y | 2.58 | 9.12 | 0.87 | Pass | |
| 66 | | Y | 2.64 | 9.88 | 0.84 | Pass | |
| 67 | | Y | 2.58 | 9.42 | 0.86 | Pass | |
| 68 | Static run | | | | | | |
| | | | | | | | |
| 69 | Decelerating POV, 35 | N | | | | | Brake TTC |
| 70 | | Y | 1.81 | 4.33 | 0.85 | Pass | |
| 71 | | N | | | | | POV Braking, Brake TTC |
| 72 | | Y | 1.52 | 6.14 | 0.58 | Pass | |
| 73 | | Y | 1.82 | 4.37 | 0.59 | Pass | |
| 74 | | Y | 1.82 | 5.12 | 1.12 | Pass | |
| 75 | | N | | | | | Brake TTC |
| 76 | | Y | 1.68 | 1.93 | 0.58 | Pass | |
| 77 | | Y | 1.73 | 2.87 | 0.58 | Pass | |

| Run | Test Type | Valid Run? | FCW TTC (s) | Minimum Distance (ft) | Peak Deceleration (g) | Pass/Fail | Notes |
|-----|---------------------|------------|-------------|-----------------------|-----------------------|-----------|-------|
| 78 | | Y | 1.69 | 4.99 | 0.60 | Pass | |
| 79 | Static run | | | | | | |
| | | | | | | | |
| 12 | STP - Static run | | | | | | |
| 13 | Baseline, 25 | Y | | | 0.45 | | |
| 14 | | Y | | | 0.44 | | |
| 15 | | Y | | | 0.44 | | |
| 16 | | Y | | | 0.45 | | |
| 17 | | Y | | | 0.46 | | |
| 18 | | Y | | | 0.45 | | |
| 19 | | Y | | | 0.44 | | |
| 20 | STP - Static run | | | | | | |
| | | | | | | | |
| 21 | Baseline, 45 | Y | | | 0.45 | | |
| 22 | | Y | | | 0.45 | | |
| 23 | | Y | | | 0.45 | | |
| 24 | | Y | | | 0.45 | | |
| 25 | | Y | | | 0.45 | | |
| 26 | | Y | | | 0.45 | | |
| 27 | | Y | | | 0.45 | | |

| Run | Test Type | Valid Run? | FCW TTC (s) | Minimum Distance (ft) | Peak Deceleration (g) | Pass/Fail | Notes |
|-----|-------------------------------|------------|-------------|-----------------------|-----------------------|-----------|-------|
| 28 | STP - Static run | | | | | | |
| | | | | | | | |
| 29 | STP False Positive, 25 | Y | | | 0.44 | Pass | |
| 30 | | Y | | | 0.44 | Pass | |
| 31 | | Y | | | 0.44 | Pass | |
| 32 | | Y | | | 0.44 | Pass | |
| 33 | | Y | | | 0.44 | Pass | |
| 34 | | Y | | | 0.44 | Pass | |
| 35 | | Y | | | 0.44 | Pass | |
| 36 | STP - Static run | | | | | | |
| | | | | | | | |
| 37 | STP False Positive, 45 | Y | | | 0.44 | Pass | |
| 38 | | Y | | | 0.45 | Pass | |
| 39 | | Y | | | 0.43 | Pass | |
| 40 | | Y | | | 0.44 | Pass | |
| 41 | | Y | | | 0.44 | Pass | |
| 42 | | Y | | | 0.45 | Pass | |
| 43 | | Y | | | 0.44 | Pass | |
| 44 | STP - Static run | | | | | | |

APPENDIX D

Brake Characterization

Subject Vehicle: **2022 Hyundai Kona Electric**

Test start date: **9/8/2022**

Test end date: **9/8/2022**

| DBS Initial Brake Characterization | | | | |
|------------------------------------|----------------------|---------------------|-------|-----------|
| Run Number | Stroke at 0.4 g (in) | Force at 0.4 g (lb) | Slope | Intercept |
| 1 | 1.22 | 10.47 | 1.10 | -0.49 |
| 2 | 1.22 | 10.63 | 1.06 | -0.35 |
| 3 | 1.23 | 10.68 | 0.95 | -0.25 |

| 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 | 0.457 | 1.22 | | 1.07 | |
| 5 | | 35 | Y | 0.404 | 1.15 | | 1.14 | |
| 6 | | 25 | Y | 0.405 | 1.15 | | 1.14 | |
| 7 | | 45 | Y | 0.410 | 1.15 | | 1.12 | |
| | | | | | | | | |
| 8 | Hybrid | 35 | Y | 0.546 | 1.15 | 10.50 | 7.69 | |
| 9 | | 35 | Y | 0.405 | 1.15 | 8.50 | 8.40 | |

| 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 |
| 10 | | 25 | Y | 0.388 | 1.15 | 8.50 | 8.76 | |
| 11 | | 45 | Y | 0.401 | 1.15 | 8.50 | 8.48 | |

Appendix E

TIME HISTORY PLOTS

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Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from both the Subject Vehicle (SV) and the Principal Other Vehicle (POV), as well as pass/fail envelopes and thresholds. Plots shown herein are grouped by test type and are presented sequentially within a given test type. The following is a description of data types shown in the time history plots, as well as a description of the color code indicating to which vehicle the data pertain.

Time History Plot Description

Each time history plot consists of data relevant to the test type under consideration, and therefore the data channels plotted vary according to test type. The test types (shown in the plot titles) include:

- Stopped POV (SV at 25 mph)
- Slower POV, 25/10 (SV at 25 mph, POV at 10 mph)
- Slower POV, 45/20 (SV at 45 mph, POV at 20 mph)
- Decelerating POV 35 mph (Both vehicles at 35 mph with 13.8 m gap, POV brakes at 0.3 g)
- False Positive Baseline 25 mph (Baseline run at 25 mph)
- False Positive Baseline 45 mph (Baseline run at 45 mph)
- False Positive STP 25 mph (Steel trench plate run over at 25 mph)
- False Positive STP 45 mph (Steel trench plate run over at 45 mph)
- DBS Brake Characterization Initial
- DBS Brake Characterization Determination

Time history figures include the following sub-plots:

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

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

- Headway (ft) – Longitudinal separation between the front-most point of the Subject Vehicle and the rearmost point of the Strikeable Surrogate Vehicle (SSV) towed by the Principal Other Vehicle. The minimum headway during the run is displayed to the right of the subplot.
- SV/POV Speed (mph) – Speed of the Subject Vehicle and the Principal Other Vehicle (if any). For DBS tests, in the case of an impact, the speed reduction experienced by the Subject Vehicle up until the moment of impact is displayed to the right of the subplot.
- Yaw Rate (deg/sec) – Yaw rate of the Subject Vehicle and Principal Other Vehicle (if any).
- Lateral Offset (ft) – Lateral offset within the lane of the Subject Vehicle to the center of the lane of travel. Note that for tests involving the Strikeable Surrogate Vehicle (SSV), the associated lateral restraint track is defined to be the center of the lane of travel. If testing is done with a different POV which does not have a lateral restraint track, lateral offset is defined to be the lateral offset between the SV and POV.
- Ax (g) – Longitudinal acceleration of the Subject Vehicle and Principal Other Vehicle (if any). The peak value of Ax for the SV is shown on the subplot.
- Pedal Position – Position of the accelerator pedal and brake pedal. The units for the brake pedal are inches and the units for the accelerator pedal are percent of full scale divided by 10.
- Brake Force (lb) – Force on the brake pedal as applied by the DBS controller. The TTC at the onset of the brake by the DBS controller is shown on the subplot. Additionally, the average force at the brake pedal while the DBS controller is active is displayed.

Envelopes and Thresholds

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

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

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

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

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

For the pedal position plot:

- A thick black bar, green circle, or red asterisk appears on the brake pedal position data over the DBS controller brake onset period. The black bar signifies the time over which the brake application rate is determined, and the calculated brake application rate is displayed on the figure. If instead, a green dot or red asterisk is displayed,

the brake application rate is being assessed under a newly developed requirement. For vehicles that exhibit brake pedal movement during the activation of the brake actuator, the target brake pedal displacement that results in 0.4 g of vehicle deceleration must be achieved within 250 ms of activation. If the target brake pedal displacement was achieved, a green circle is displayed. If not, a red asterisk is displayed.

- If the tests are performed in Displacement mode, the plot shows a short dashed black line above the brake onset period representing the maximum allowable 20% overshoot and 100 ms time period beyond the commanded pedal position.

Additionally, a green envelope representing $\pm 10\%$ of the target brake pedal position is shown. If the brake pedal position exceeds the boundaries of the envelope, the run is invalid.

- If the tests are performed in Hybrid mode, no other brake pedal position requirements are shown.

For the brake force plots:

- A short, solid black line at 2.5 lbs is displayed representing the required nominal TTC or distance in which the brakes must be applied. If the brakes are applied based on a real-time calculation of TTC (which is standard practice), the tolerance is ± 0.05 sec and the TTC of the brake onset is displayed. If the brakes cannot be applied based on a real-time TTC due to regenerative braking or other factors, the brakes are applied based on a distance calculation. The tolerance is ± 2 ft and no other values are displayed. If the brakes are applied at the correct TTC or distance, a green dot is displayed. If not, a red asterisk is displayed.
- If the tests are performed in Displacement mode, no other brake force requirements are shown.
- If the tests are performed in Hybrid mode, a long, dashed black line is displayed at 2.5 lbs representing the minimum brake force required while the brake actuator is active. Exceedances of this brake force threshold are indicated by red shading in the area between the measured time-varying data and the dashed threshold line.

additionally, a blue envelope representing $\pm 10\%$ of the target average brake force is shown along with the calculated average during that time period. Note that the brake force may exceed the boundaries of the envelope as long as the overall average is within tolerance.

In the instance of “last second” braking applied by the brake actuator, a thick vertical red line will appear on the plots at the moment the brake actuator 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
 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.
- Brk – Indicates that the requirements for the brake application rate were not met

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

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

Notes

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

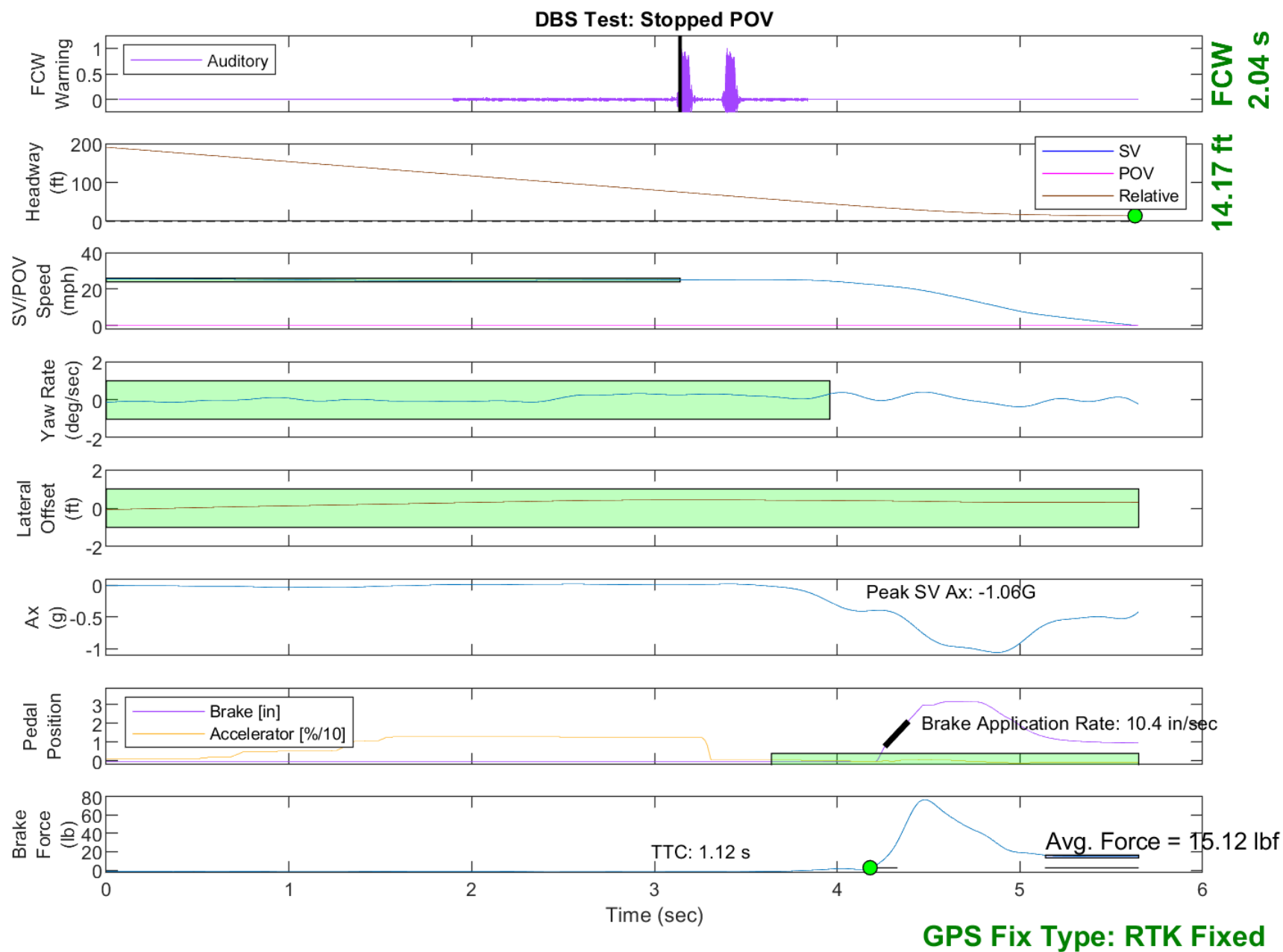


Figure E1. Example Time History for Stopped POV, Passing

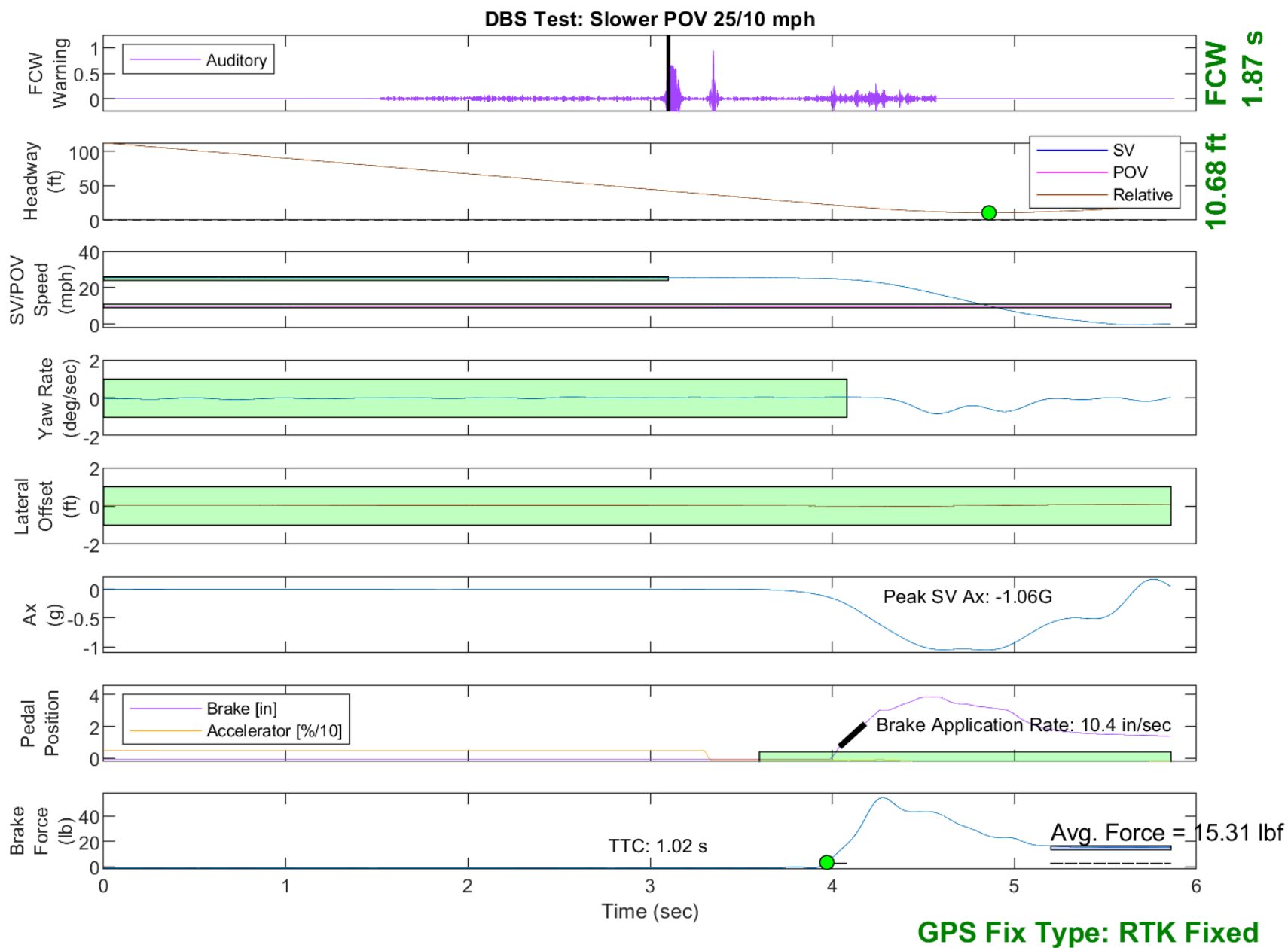


Figure E2. Example Time History for Slower POV 25 vs. 10, Passing

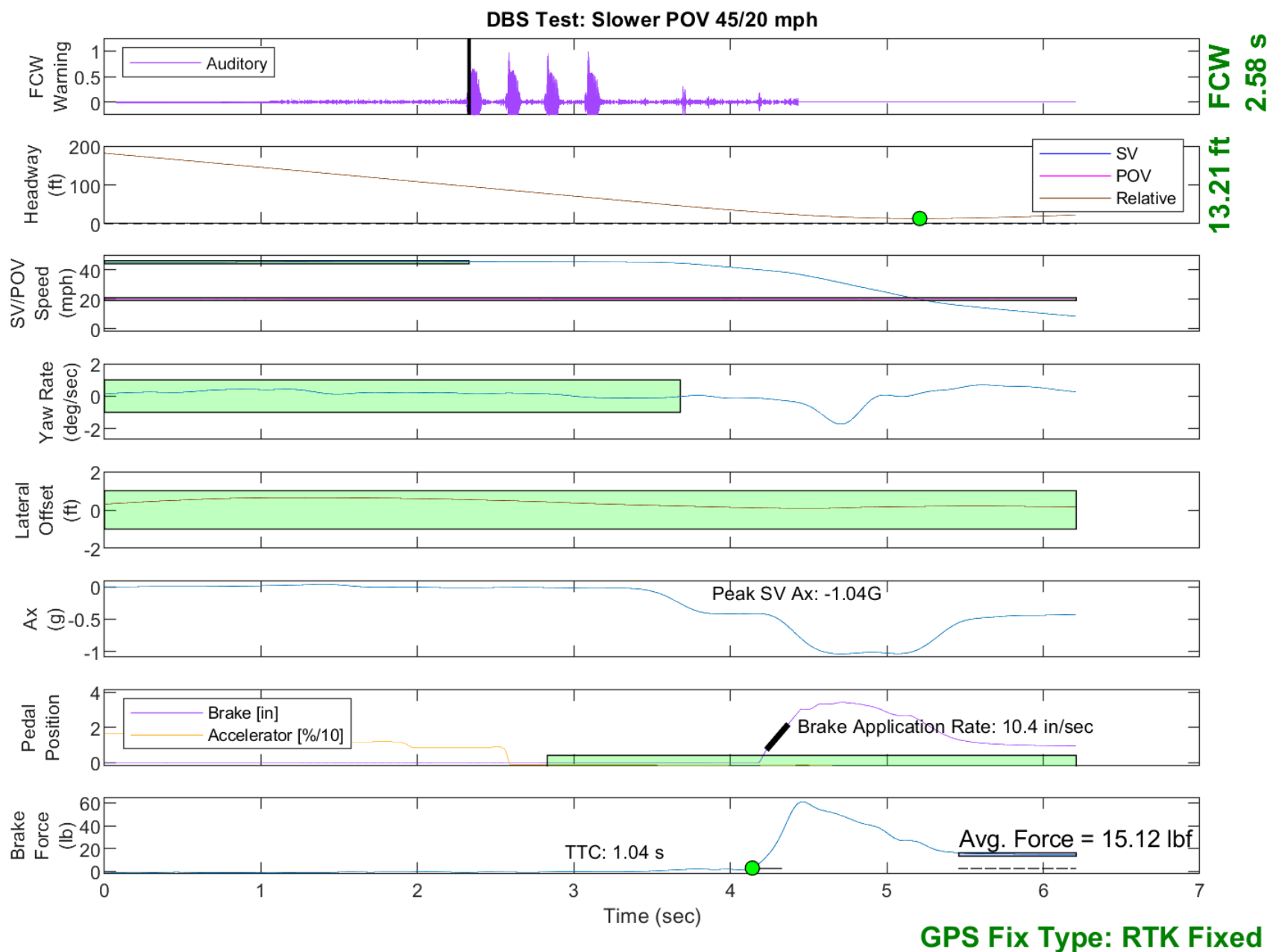


Figure E3. Example Time History for Slower POV 45 vs. 20, Passing

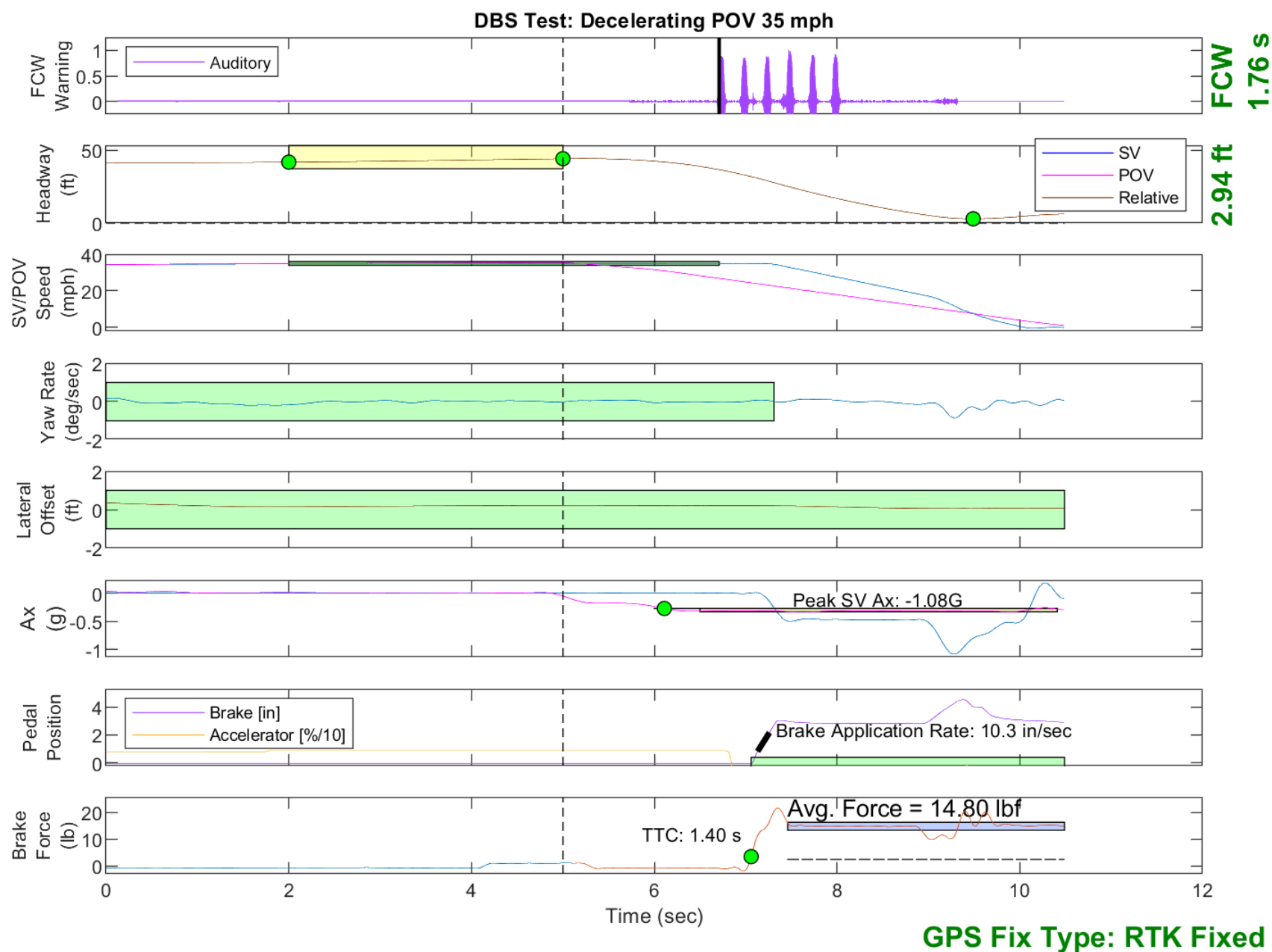


Figure E4. Example Time History for Decelerating POV 35, Passing

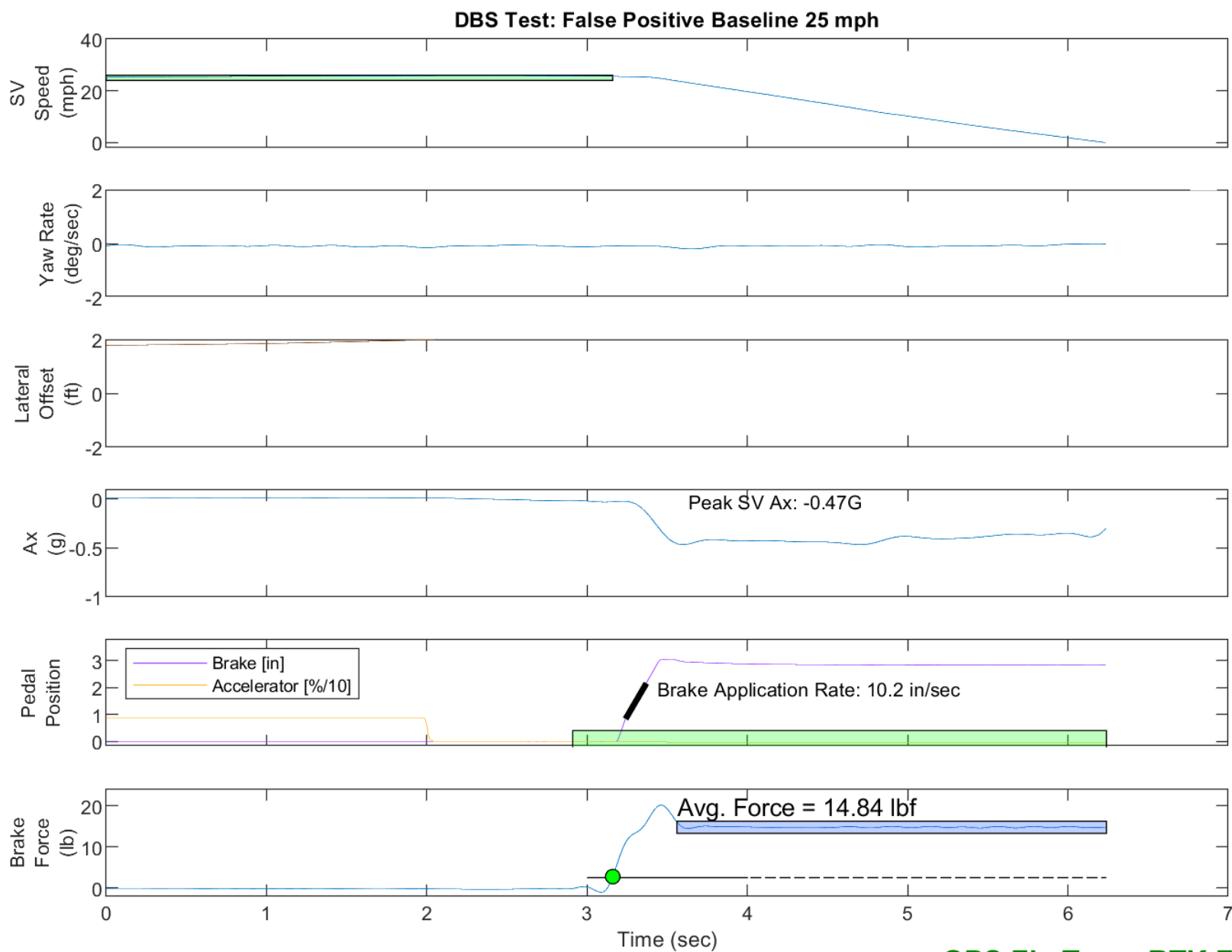


Figure E5. Example Time History for False Positive Baseline 25

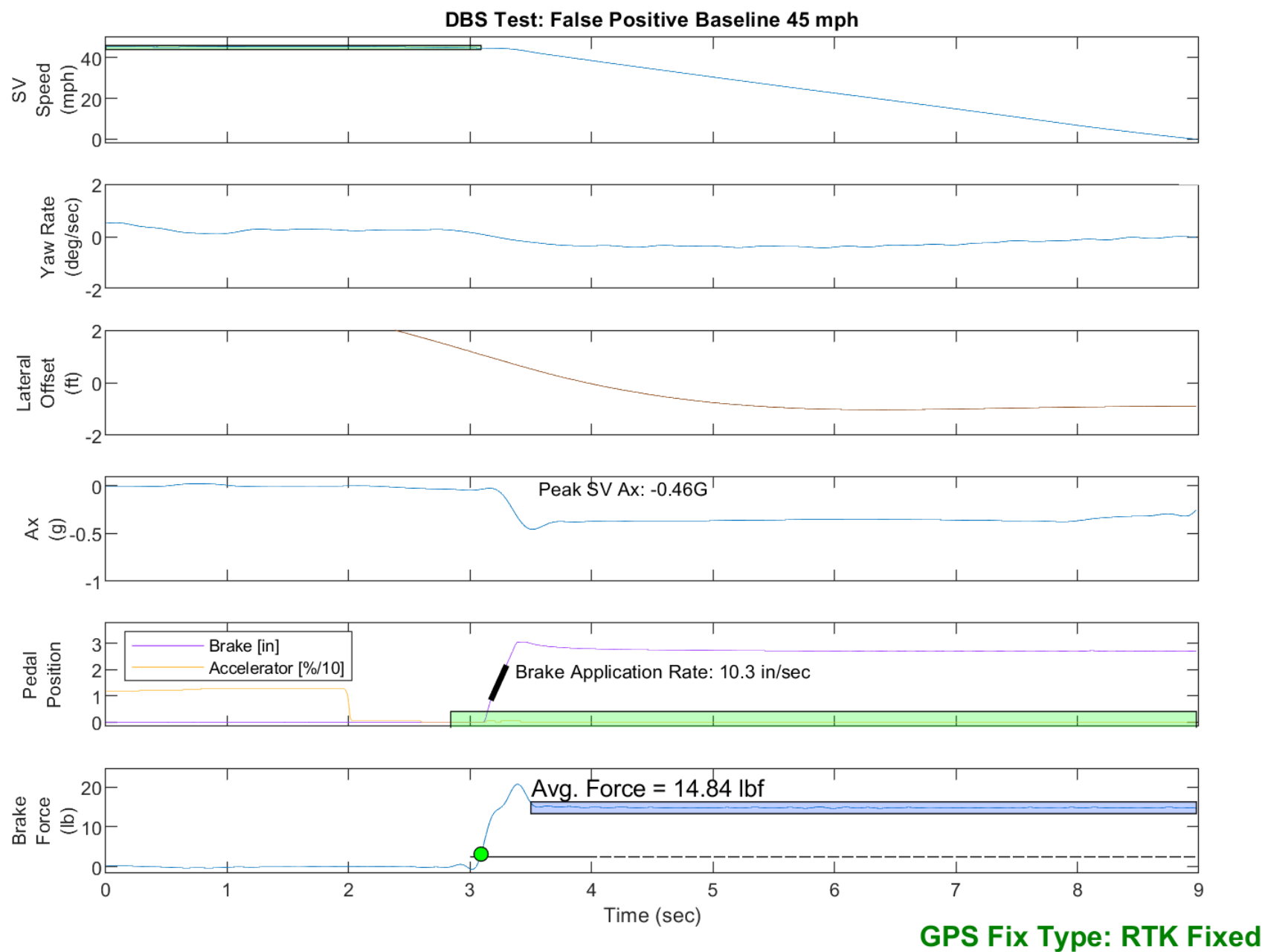


Figure E6. Example Time History for False Positive Baseline 45

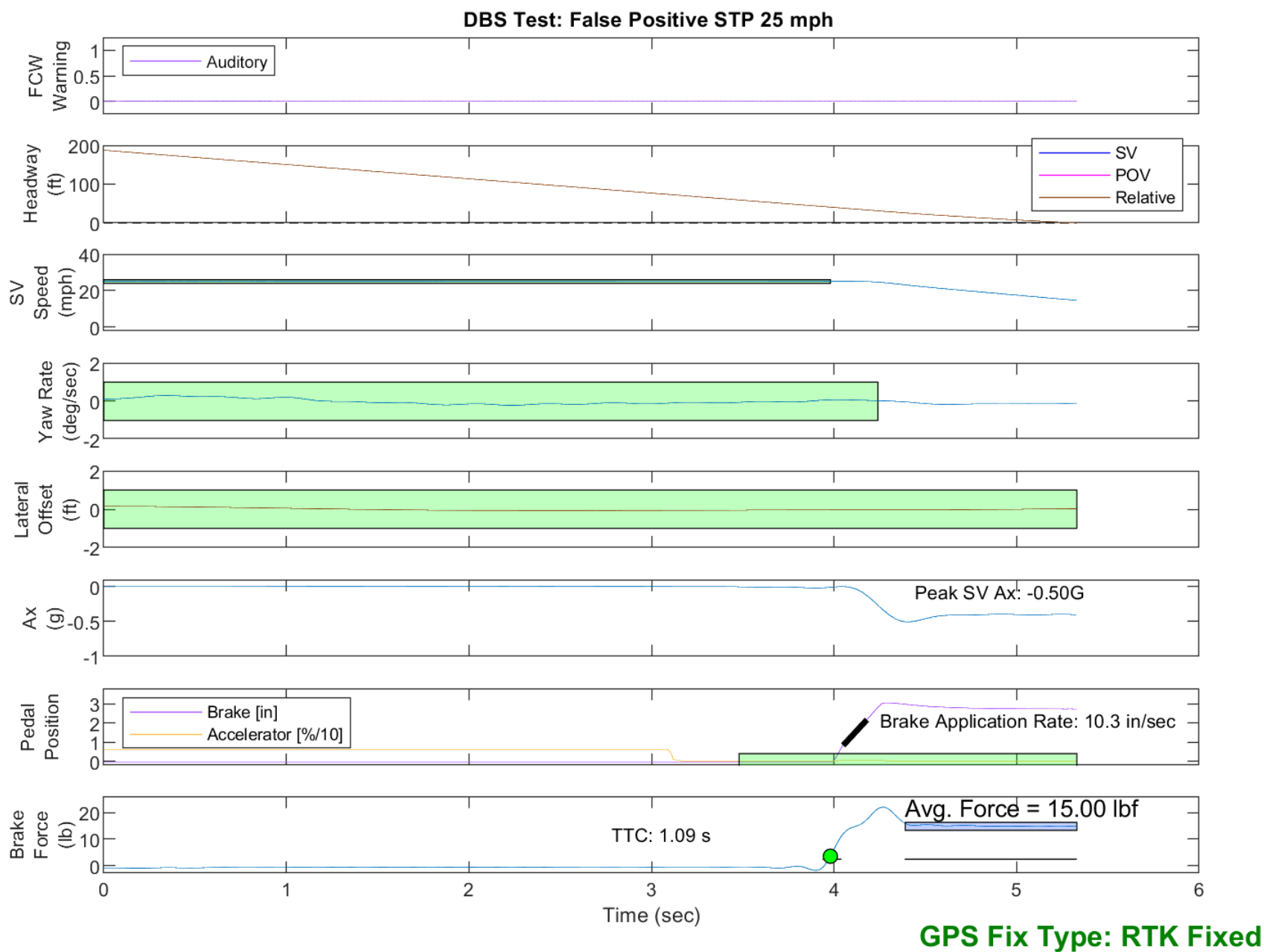


Figure E7. Example Time History for False Positive Steel Plate 25, Passing

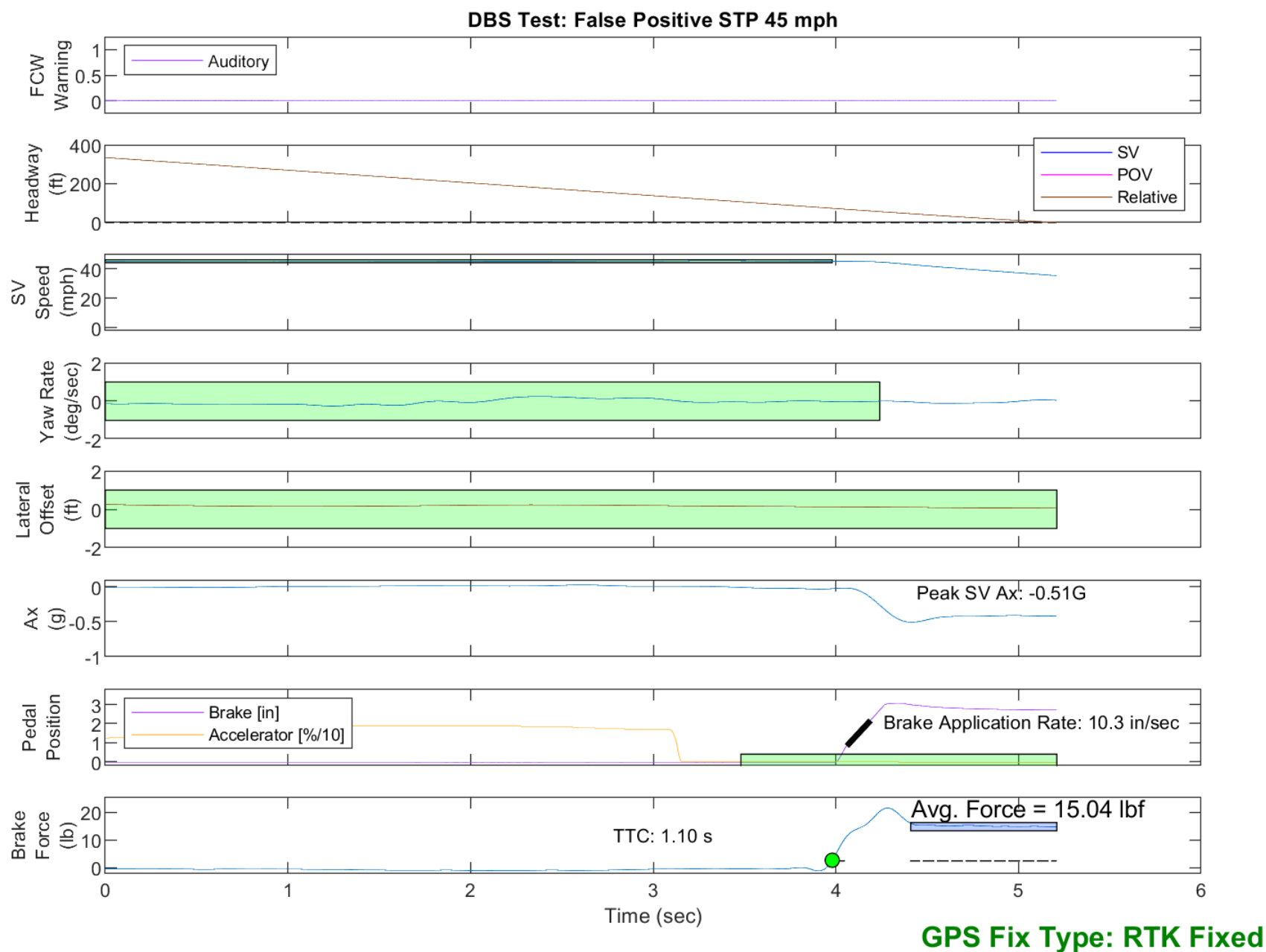


Figure E8. Example Time History for False Positive Steel Plate 45, Passing

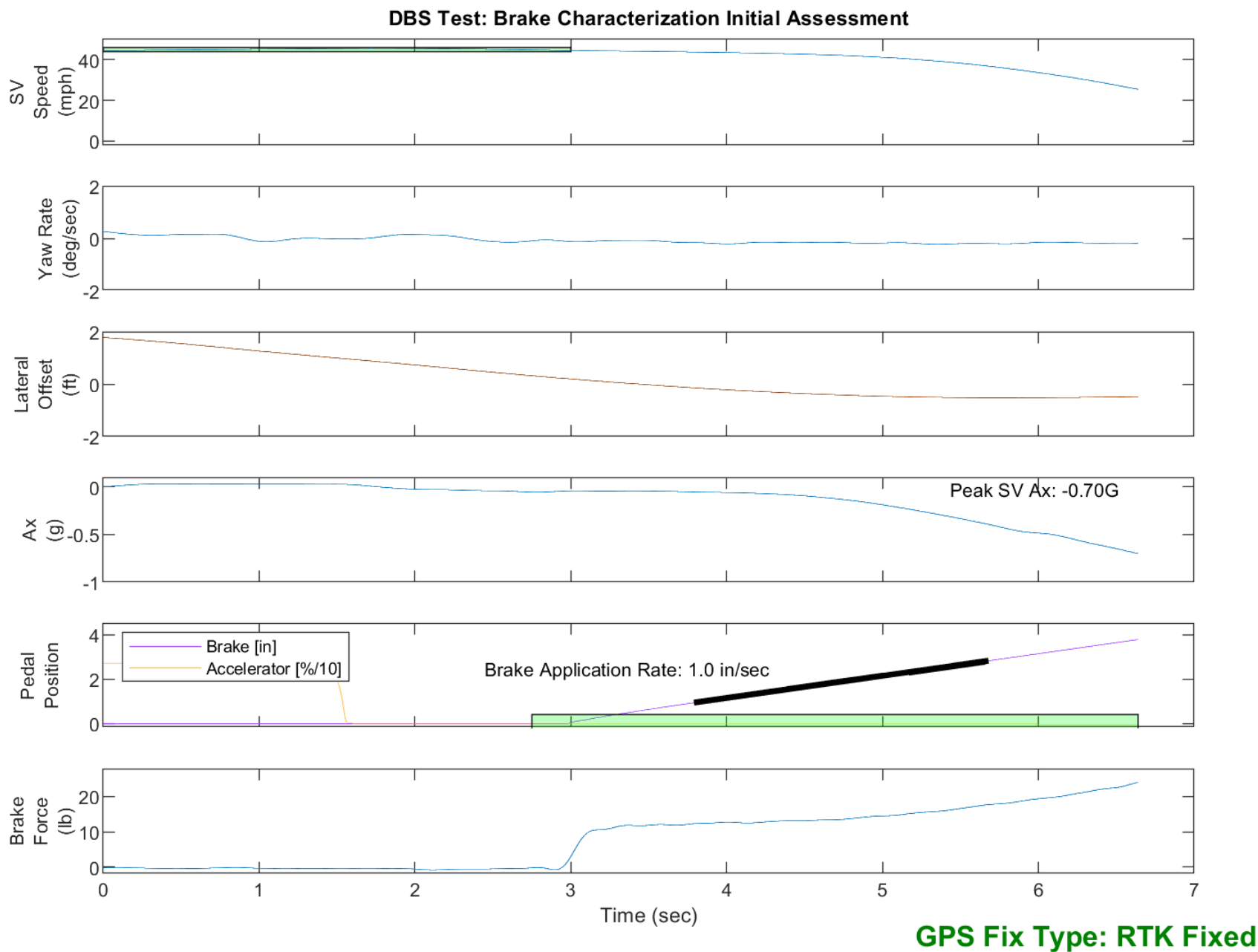


Figure E9. Example Time History for DBS Brake Characterization, Passing

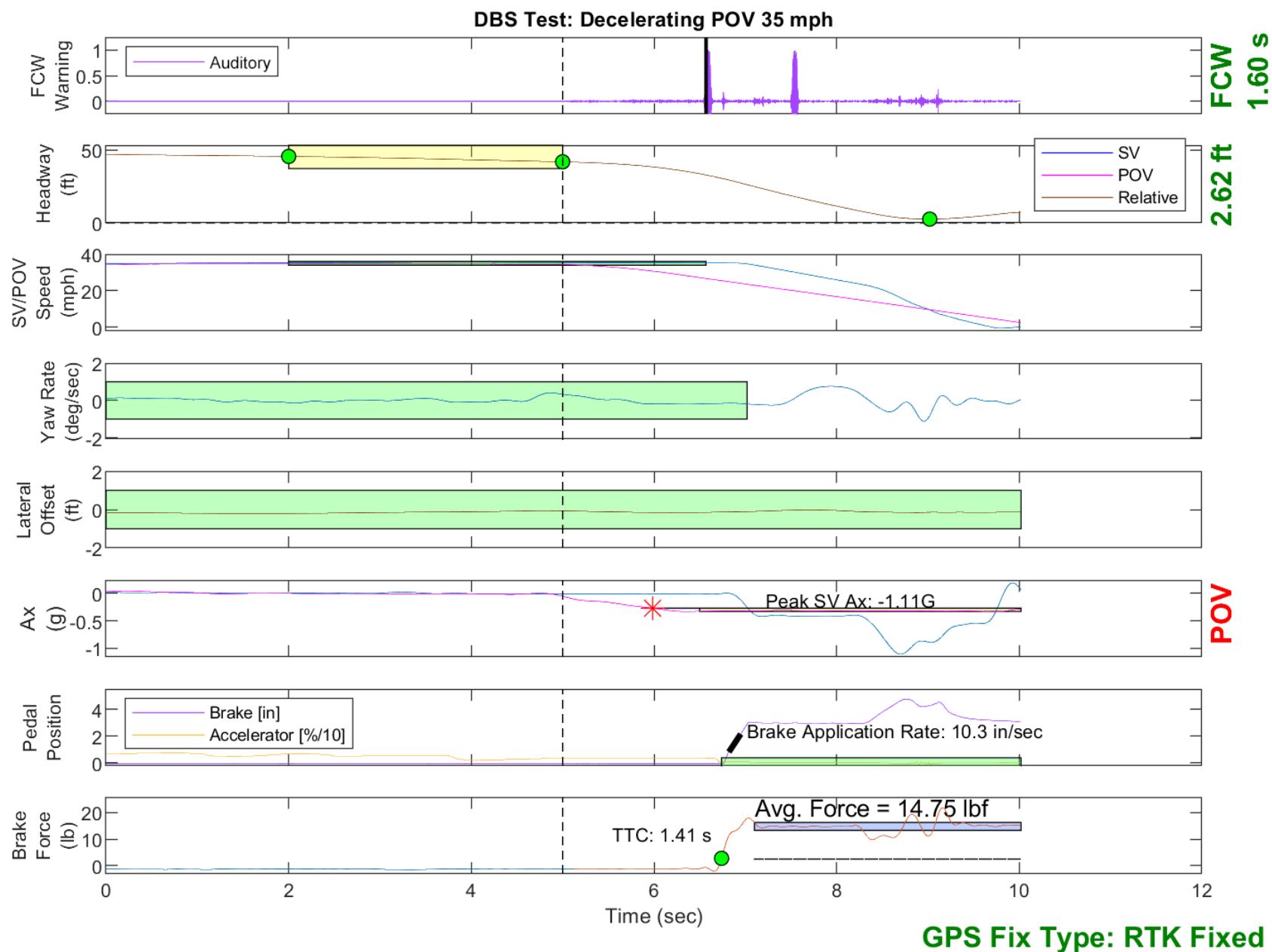


Figure E10. Example Time History Displaying Invalid POV Acceleration Criteria

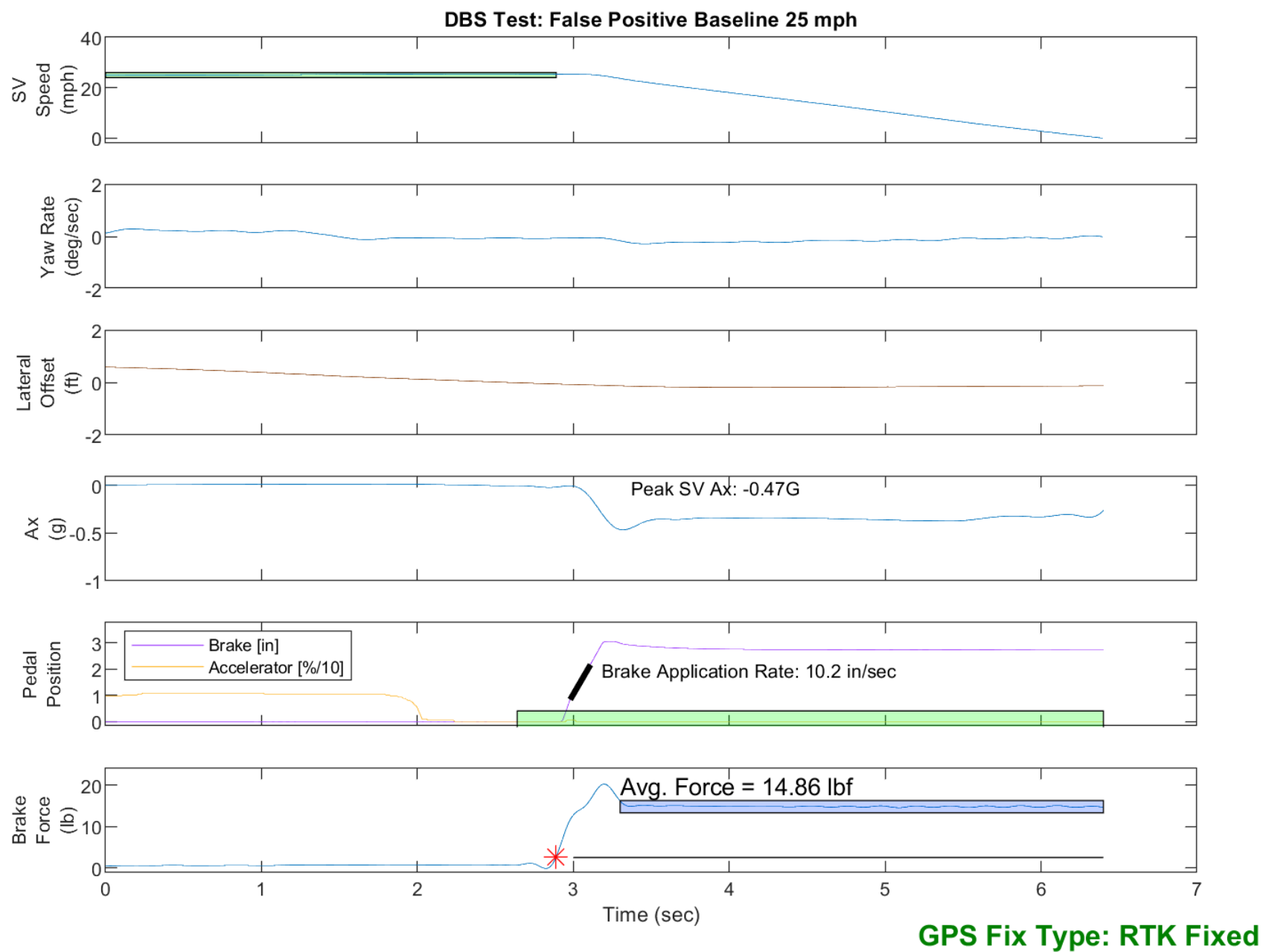


Figure E11. Example Time History Displaying Invalid Brake Force Criteria

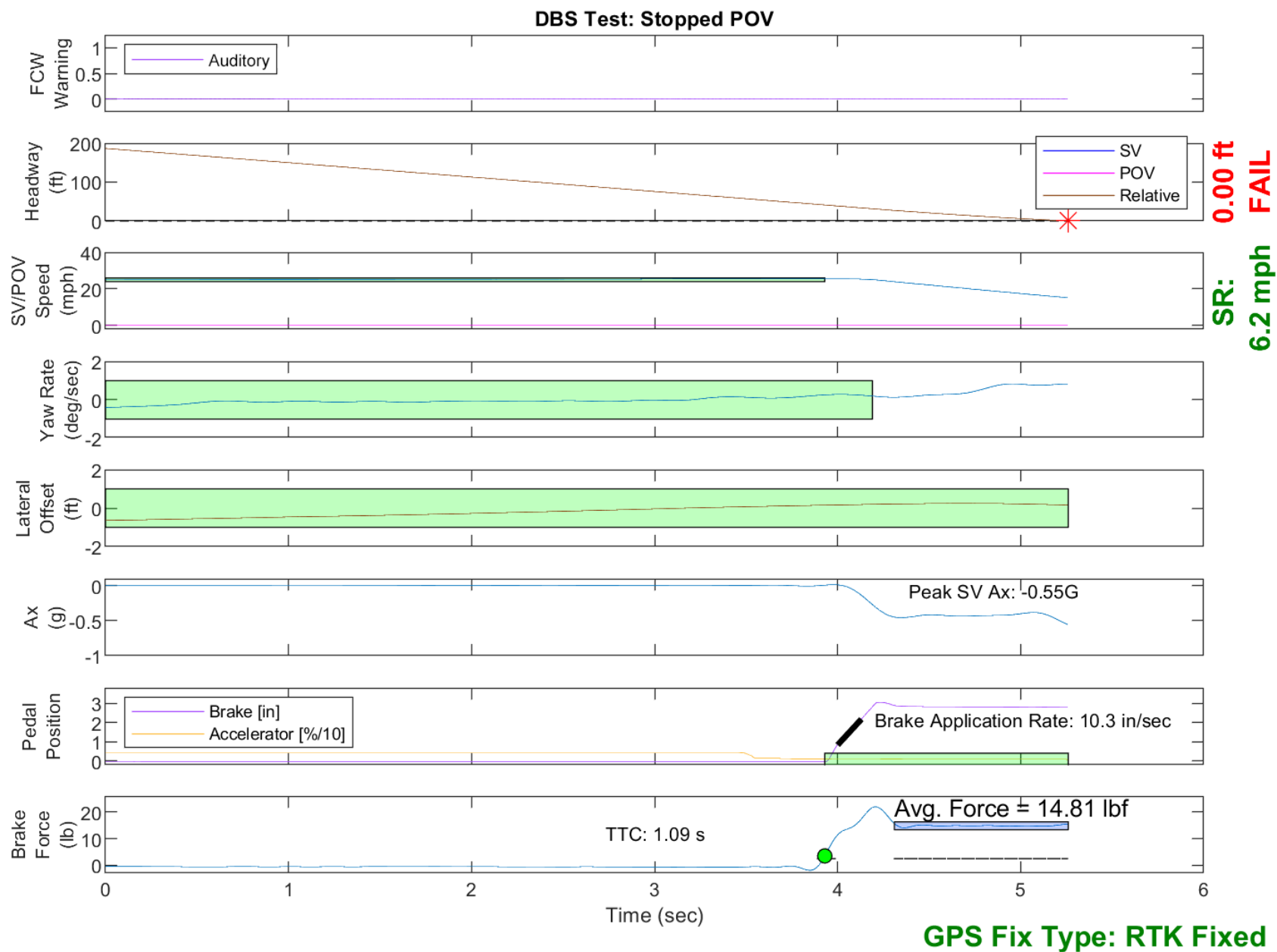


Figure E12. Example Time History for a Failed Run

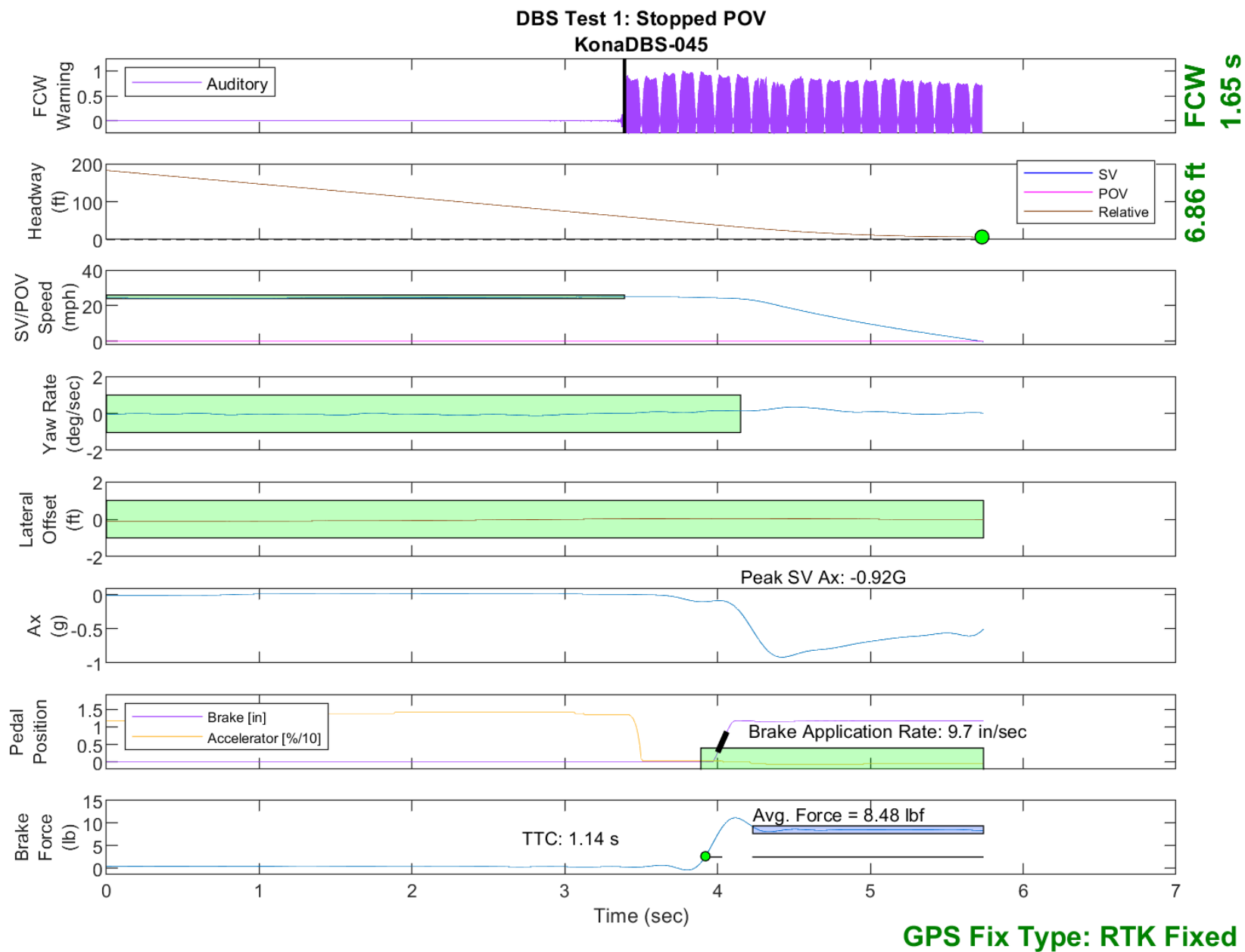


Figure E13. Time History for DBS Run 45, Test 1 - Stopped POV

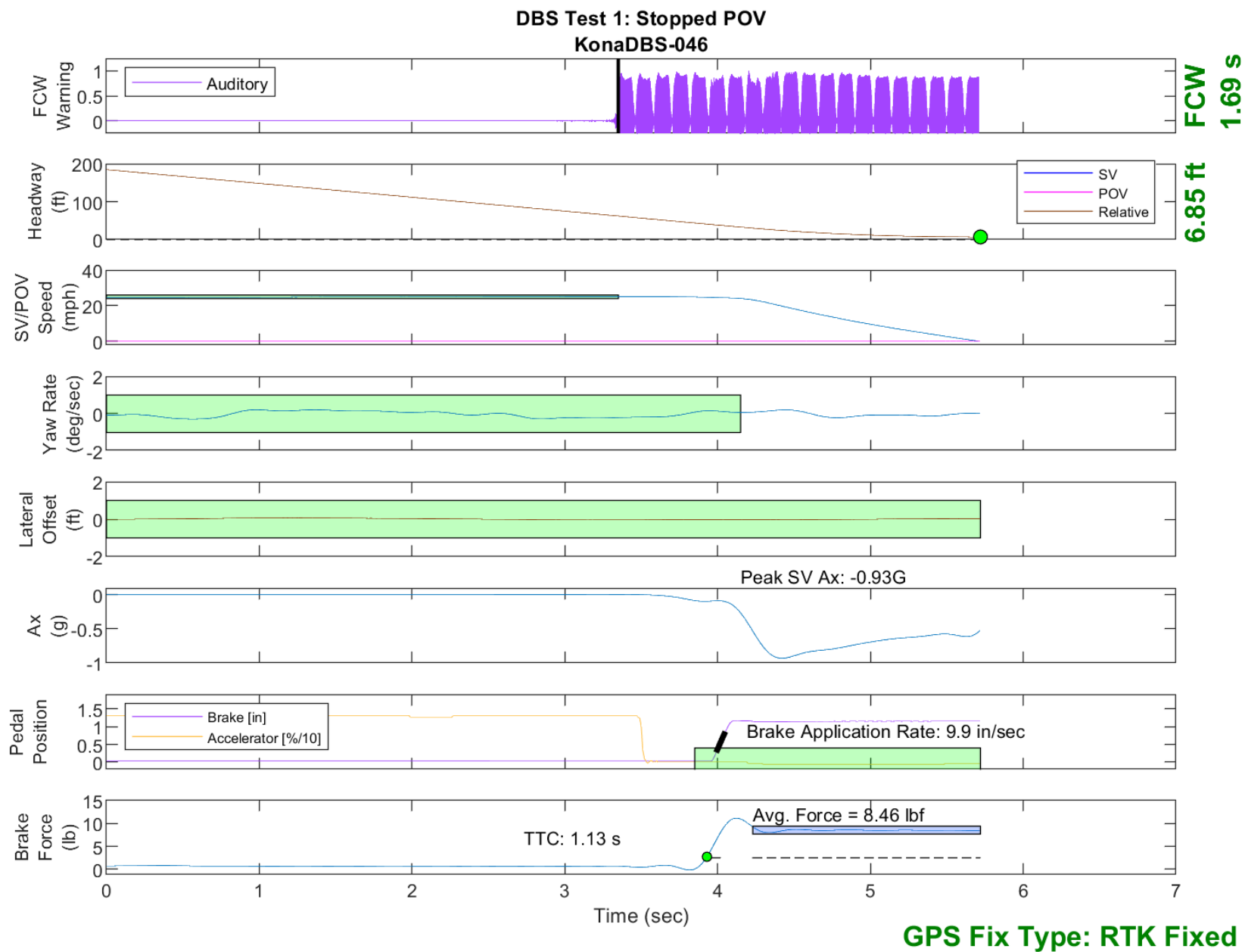


Figure E14. Time History for DBS Run 46, Test 1 - Stopped POV

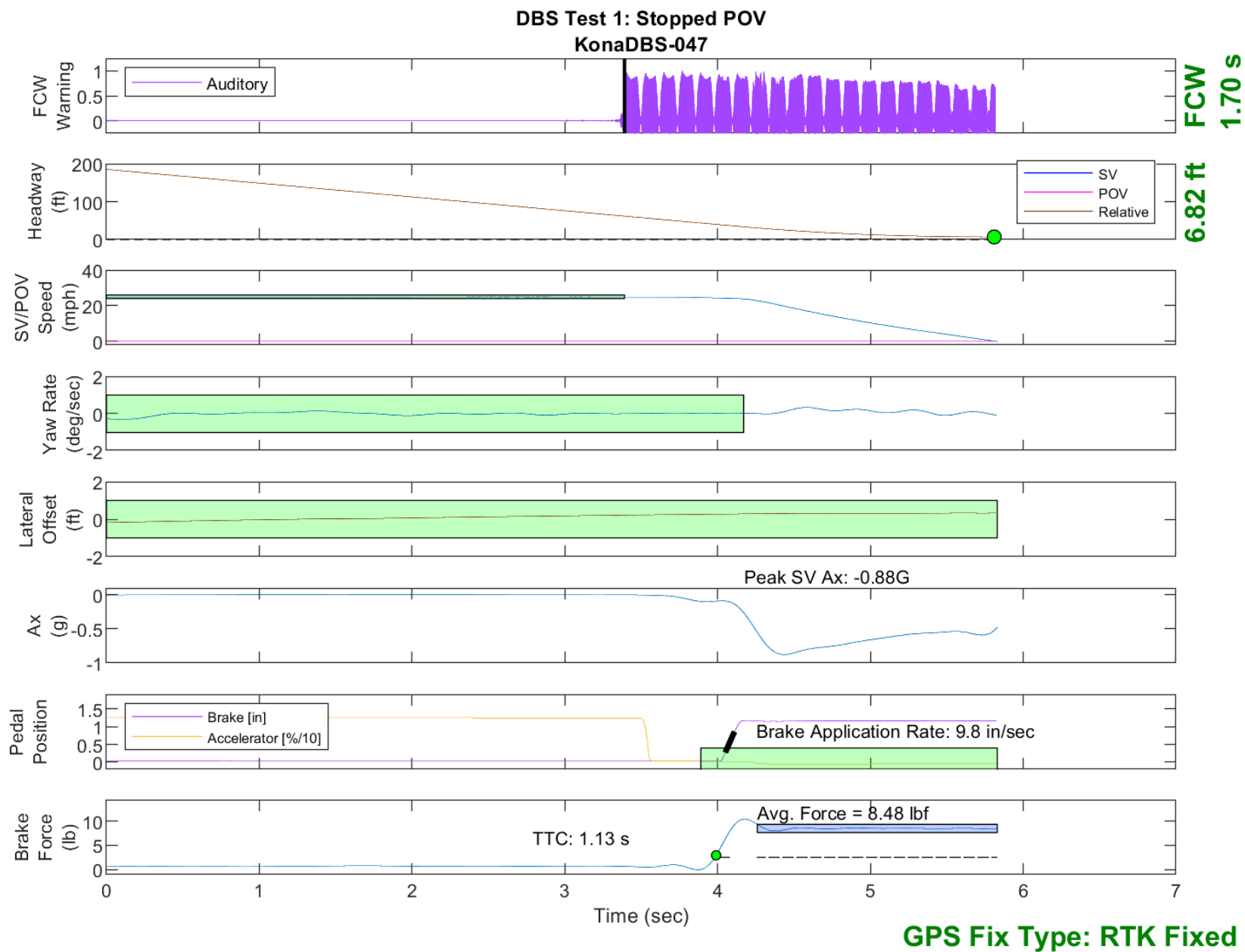


Figure E15. Time History for DBS Run 47, Test 1 - Stopped POV

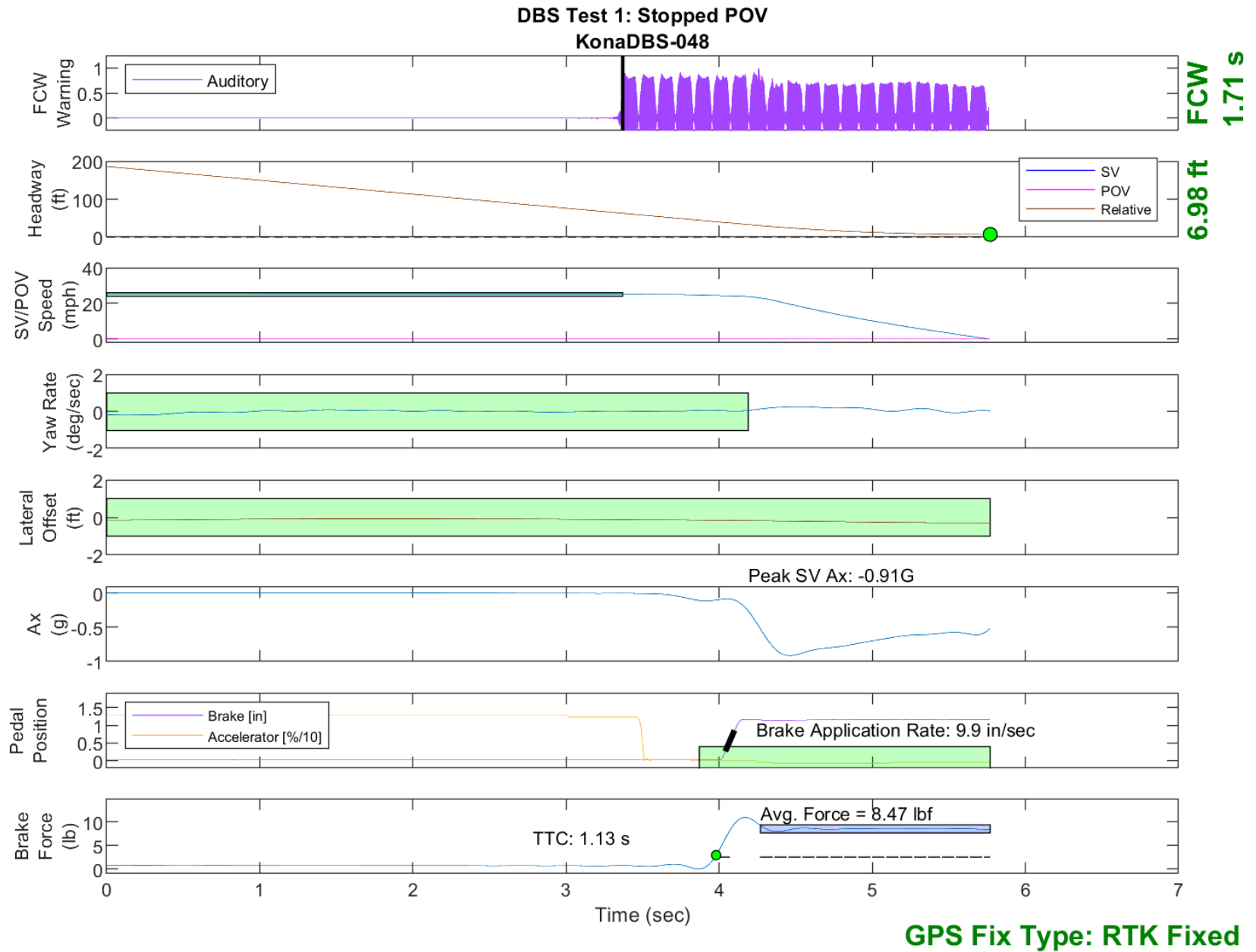


Figure E16. Time History for DBS Run 48, Test 1 - Stopped POV

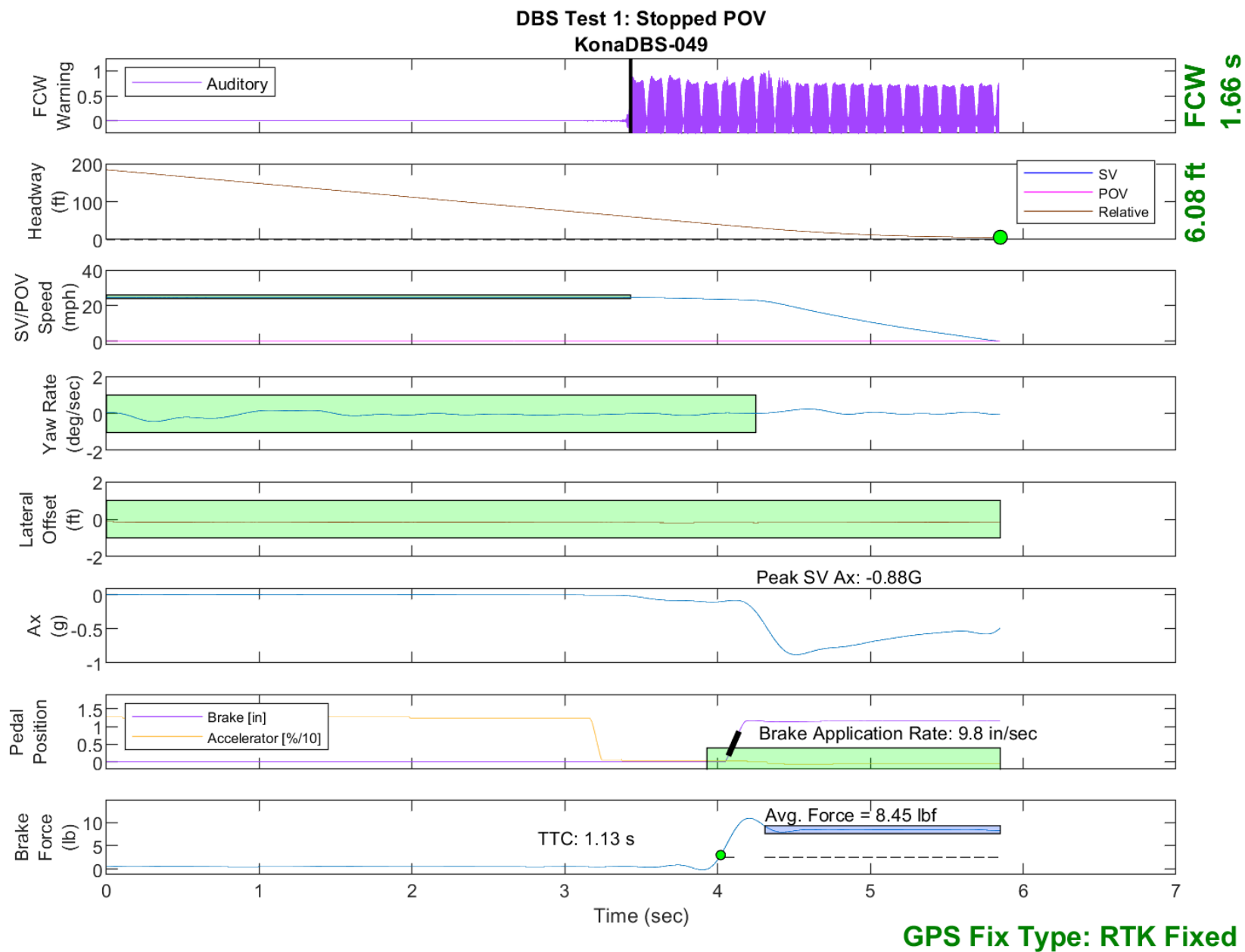


Figure E17. Time History for DBS Run 49, Test 1 - Stopped POV

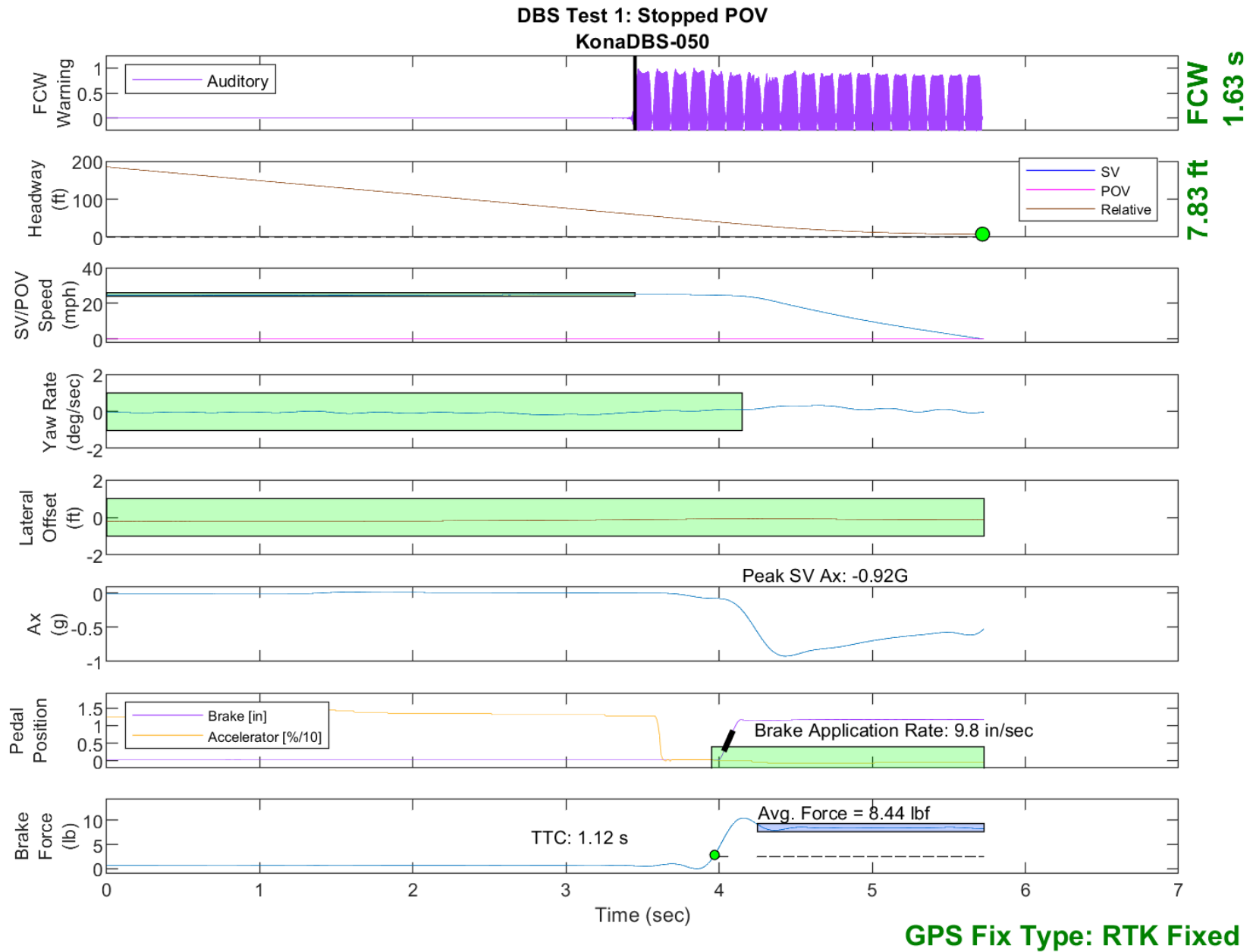


Figure E18. Time History for DBS Run 50, Test 1 - Stopped POV

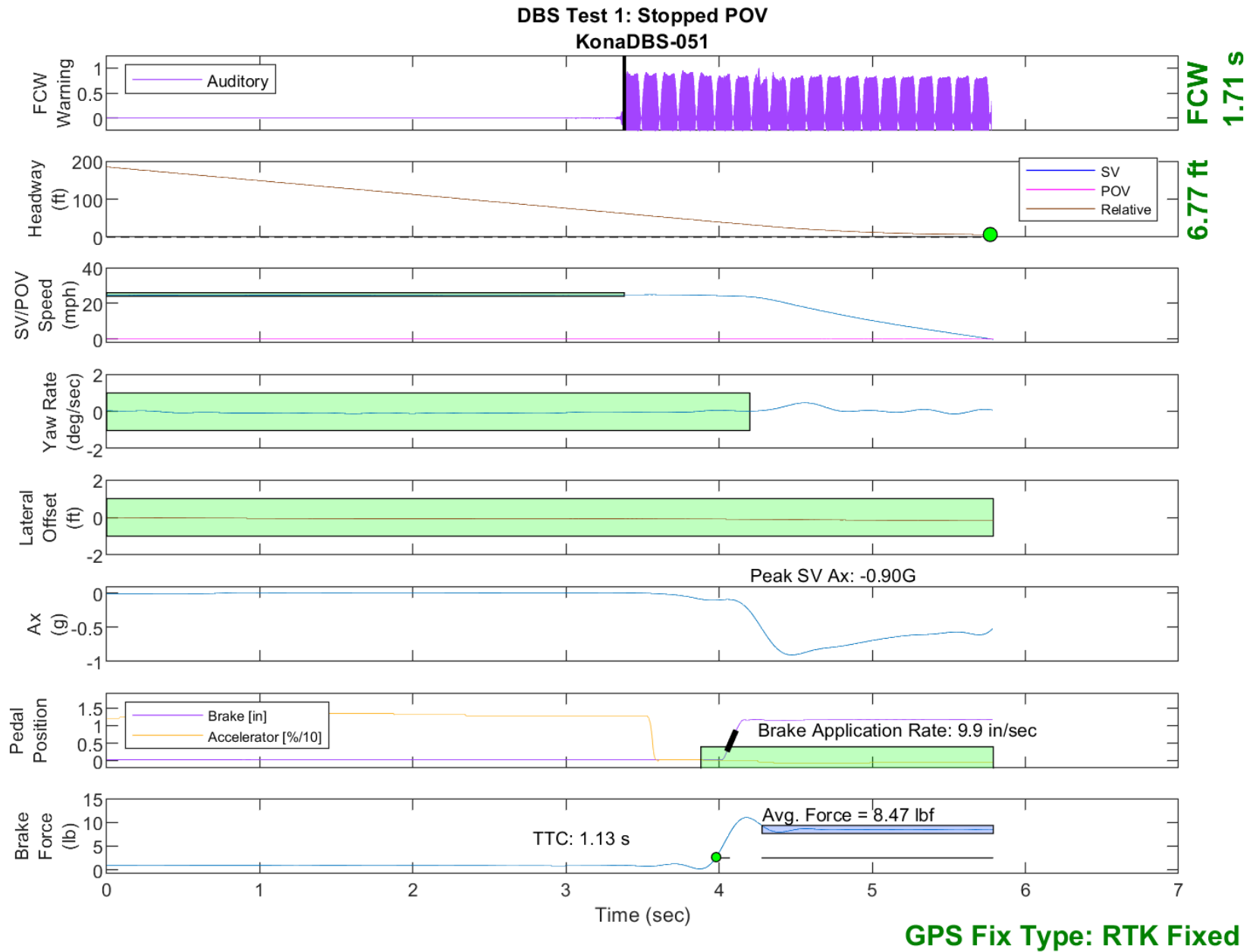


Figure E19. Time History for DBS Run 51, Test 1 - Stopped POV

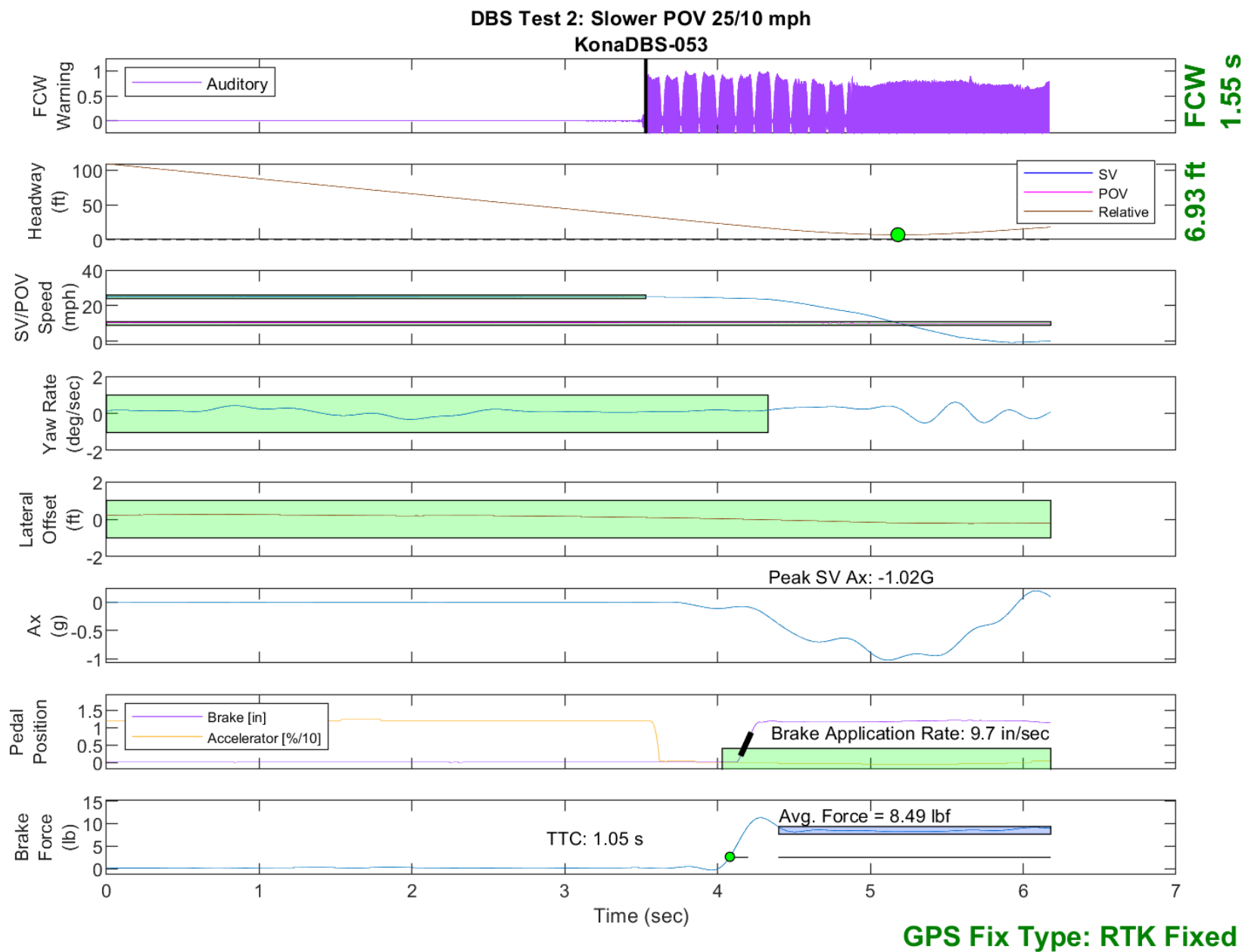


Figure E20. Time History for DBS Run 53, Test 2 - Slower Moving POV 25/10 mph

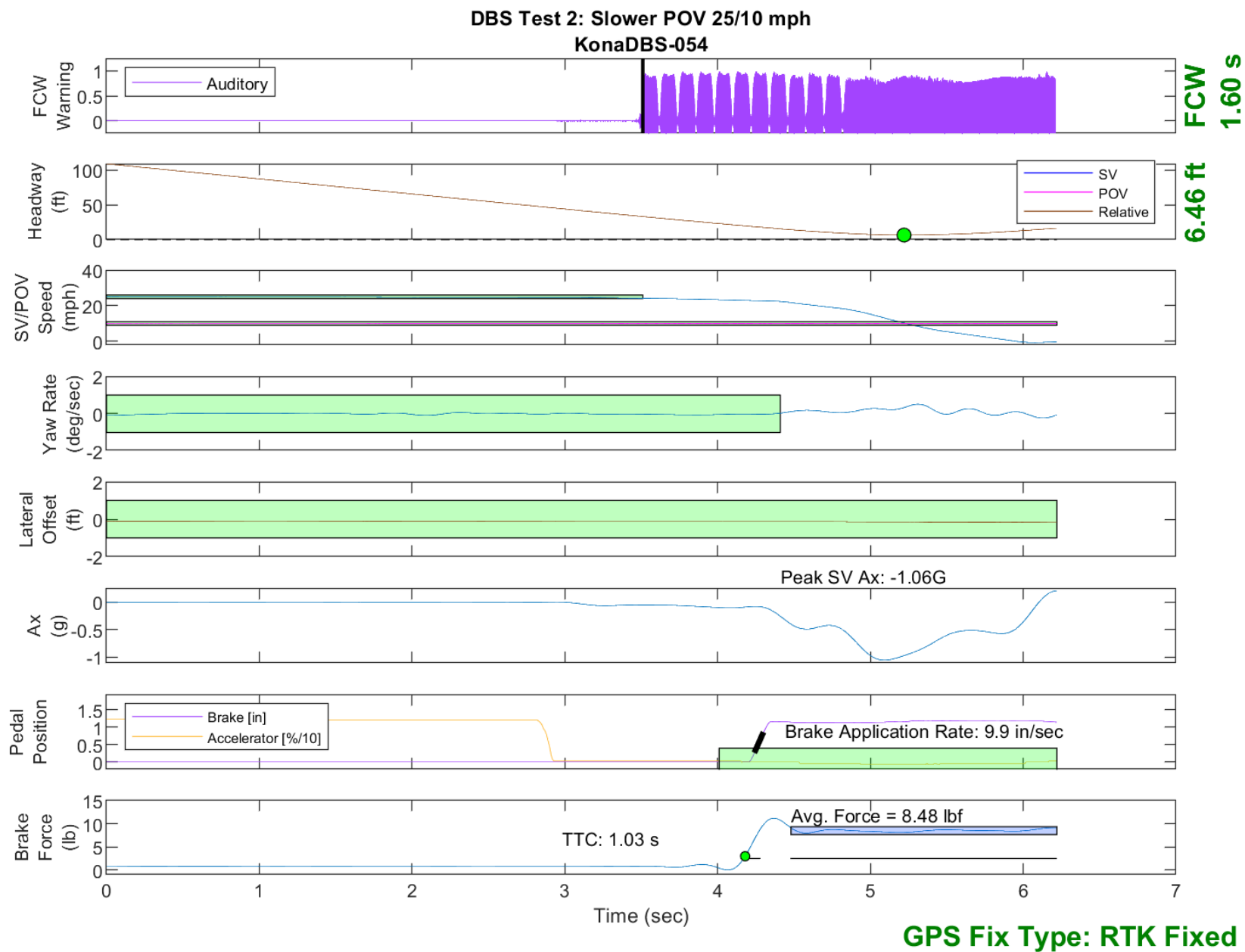


Figure E21. Time History for DBS Run 54, Test 2 - Slower Moving POV 25/10 mph

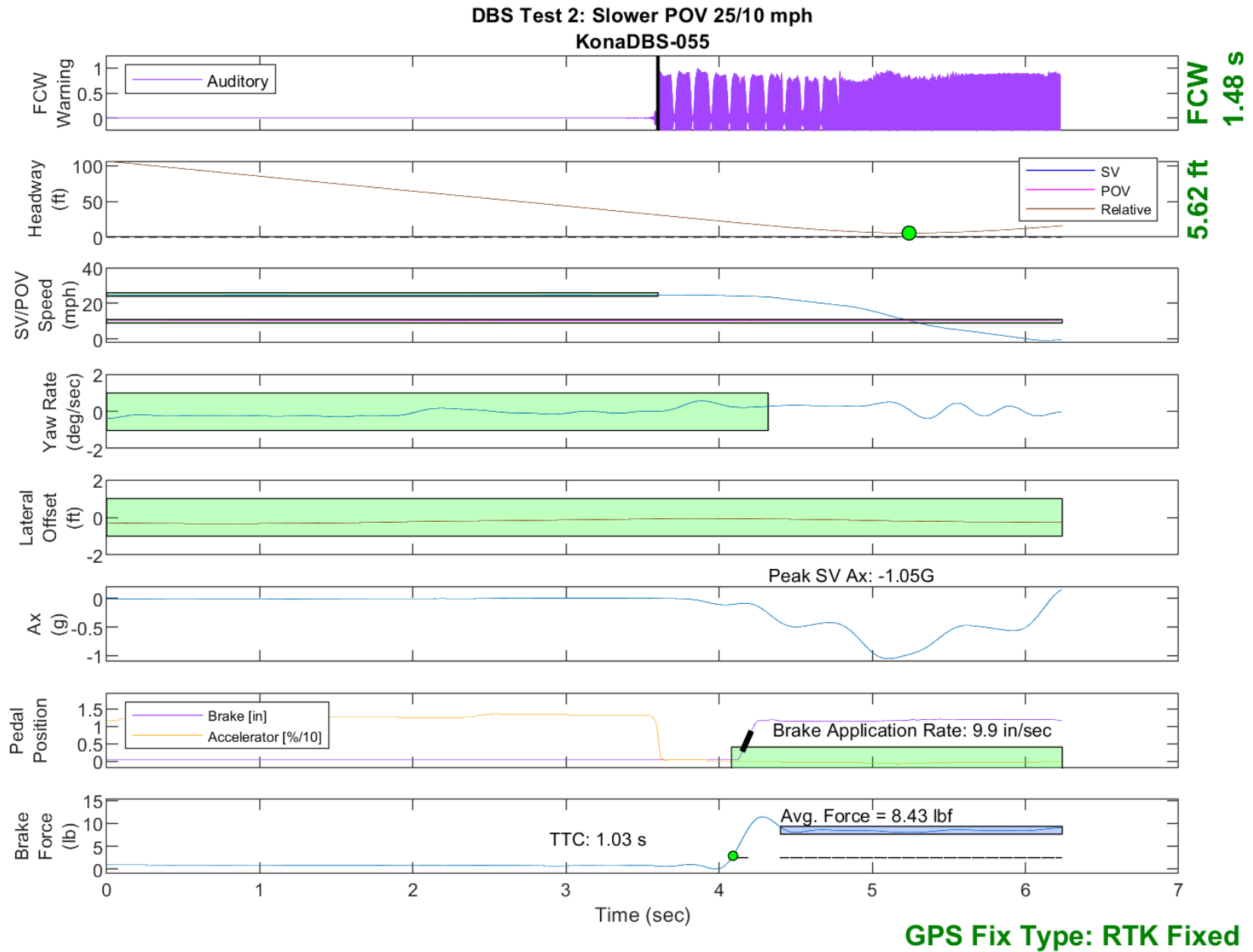


Figure E22. Time History for DBS Run 55, Test 2 - Slower Moving POV 25/10 mph

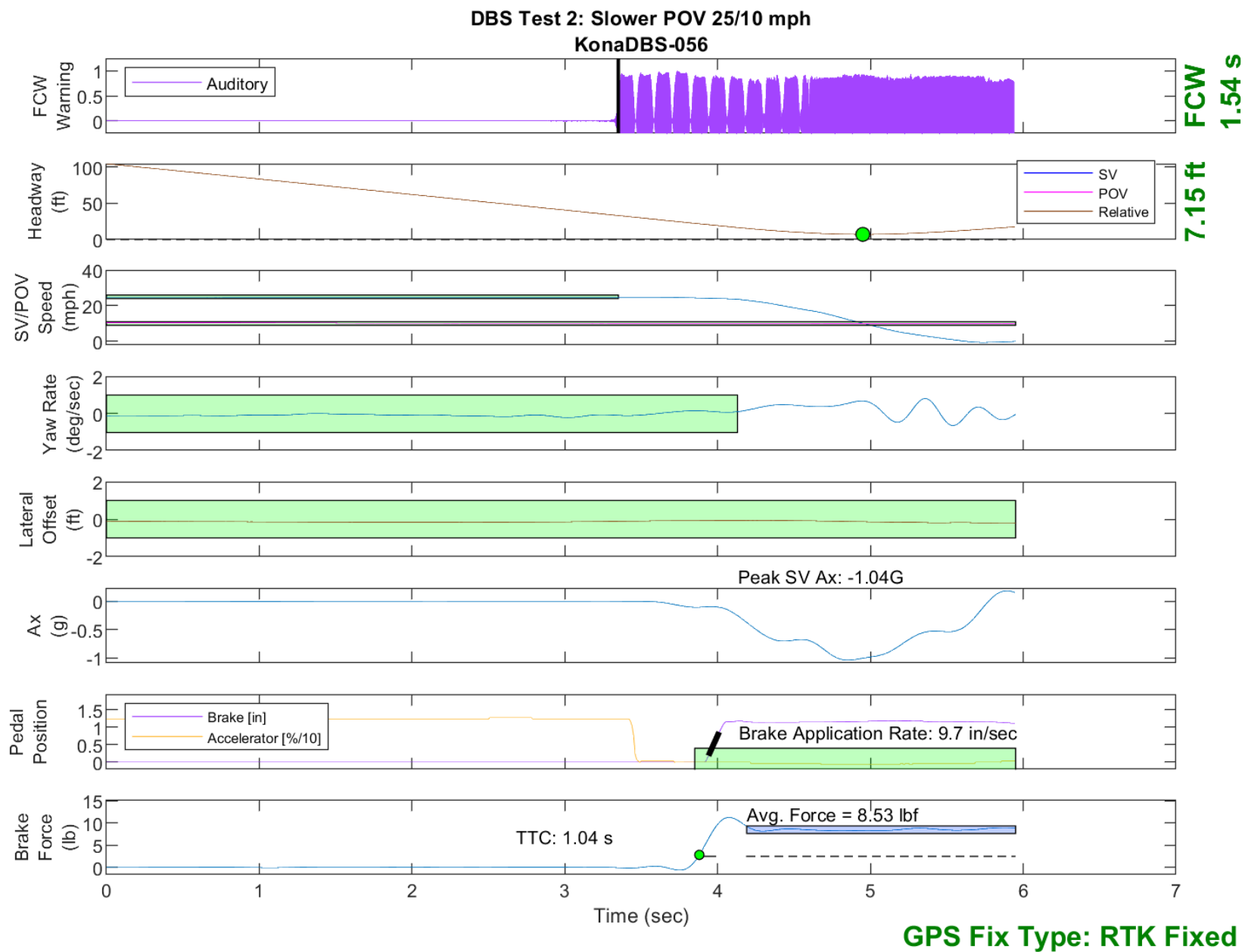


Figure E23. Time History for DBS Run 56, Test 2 - Slower Moving POV 25/10 mph

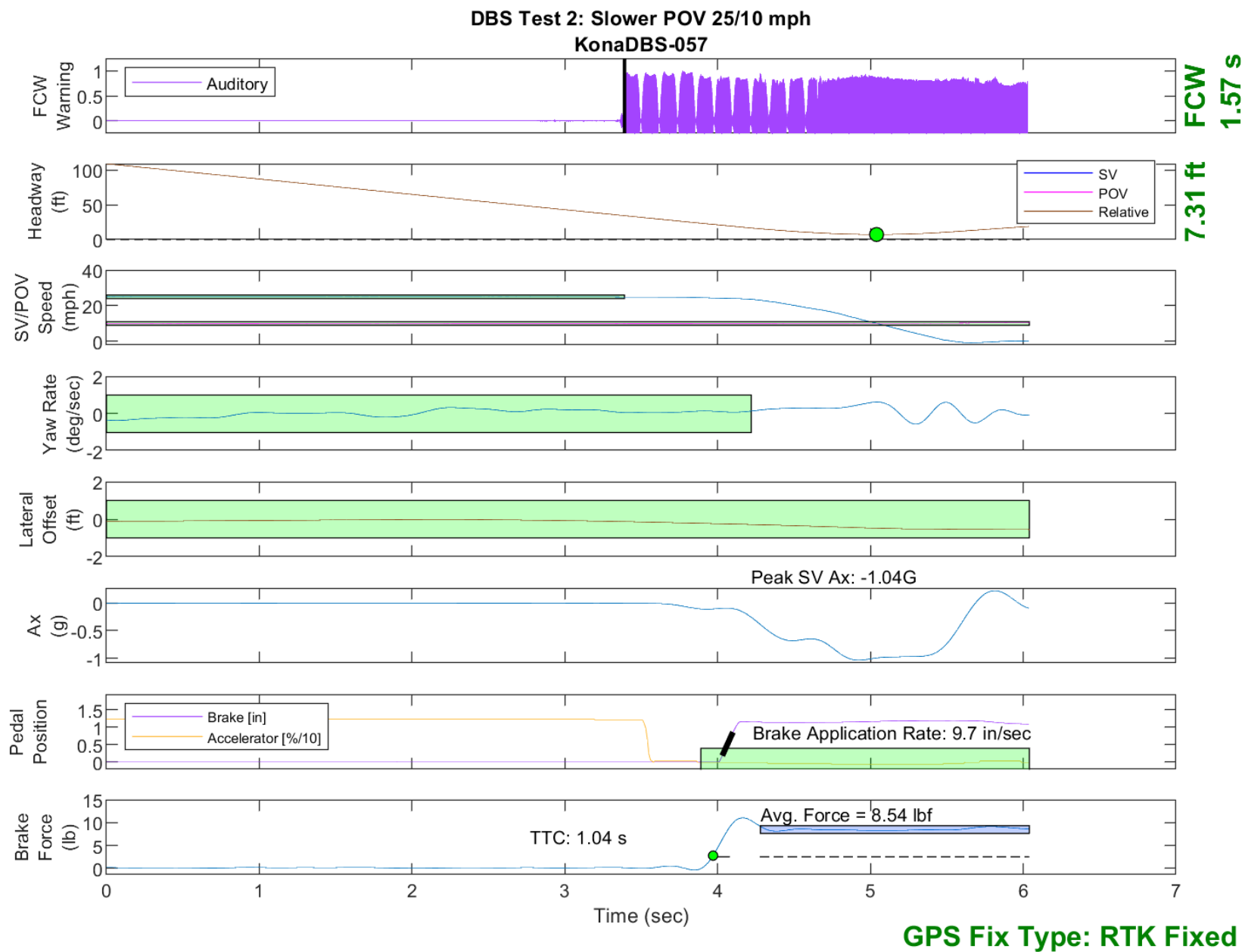


Figure E24. Time History for DBS Run 57, Test 2 - Slower Moving POV 25/10 mph

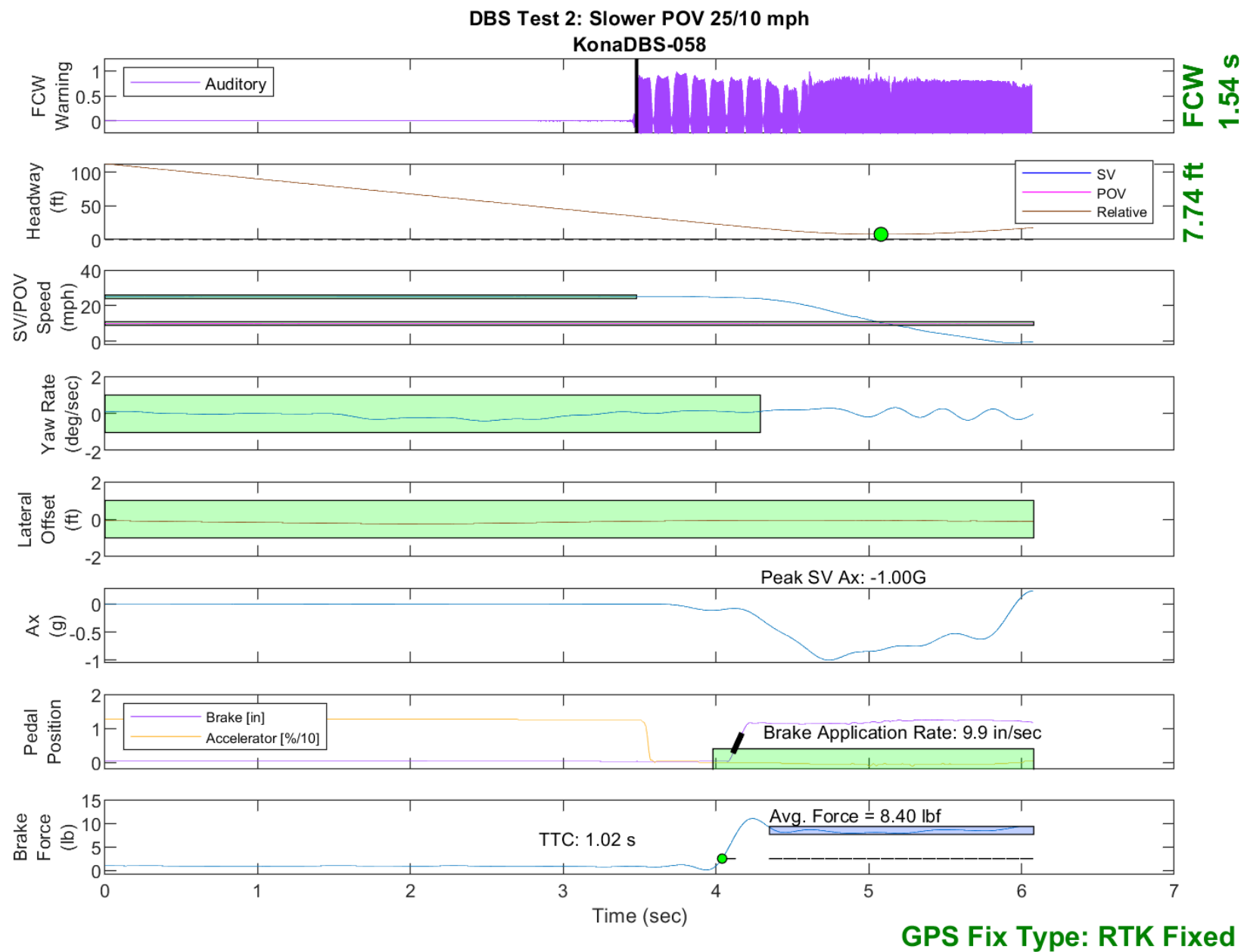


Figure E25. Time History for DBS Run 58, Test 2 - Slower Moving POV 25/10 mph

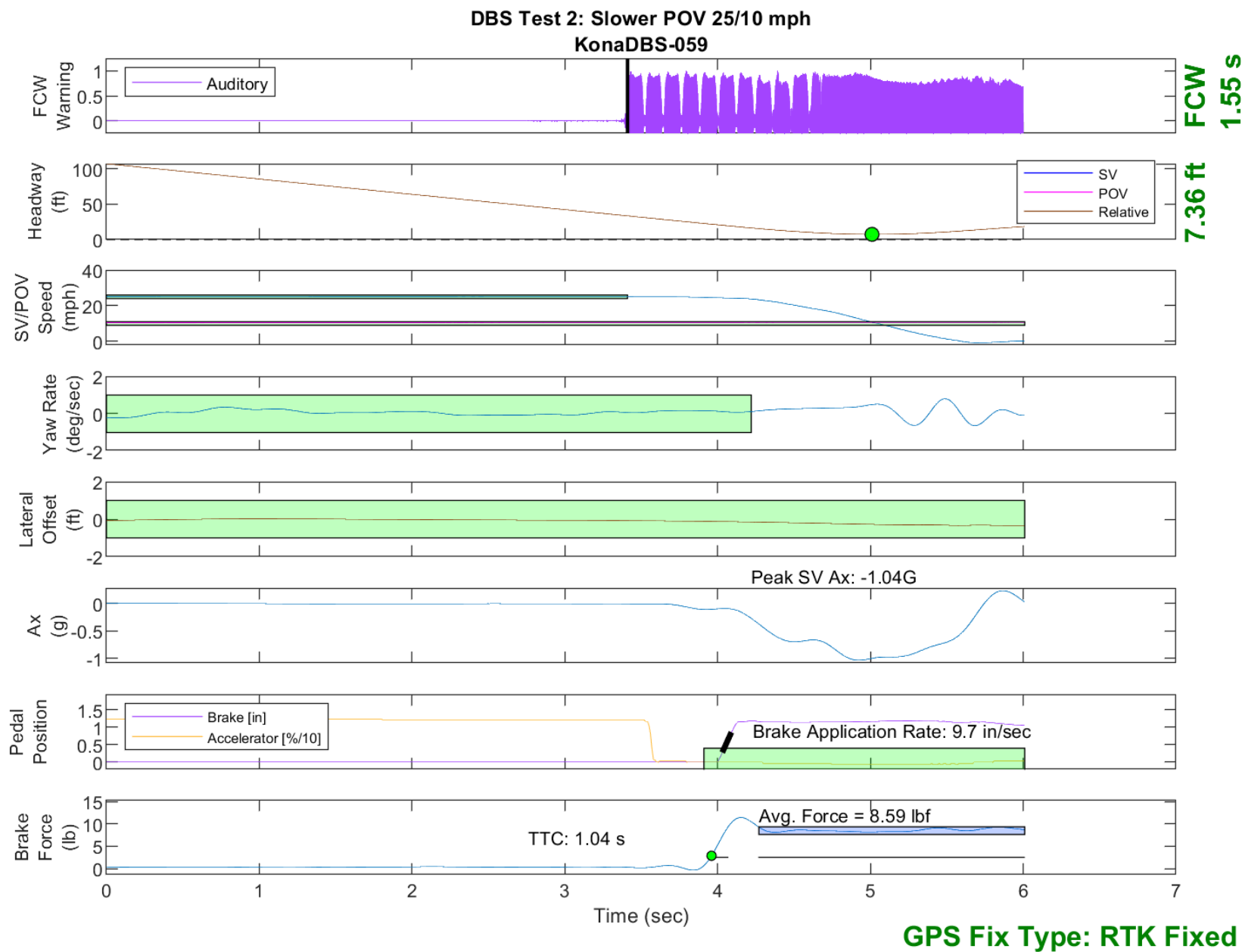


Figure E26. Time History for DBS Run 59, Test 2 - Slower Moving POV 25/10 mph

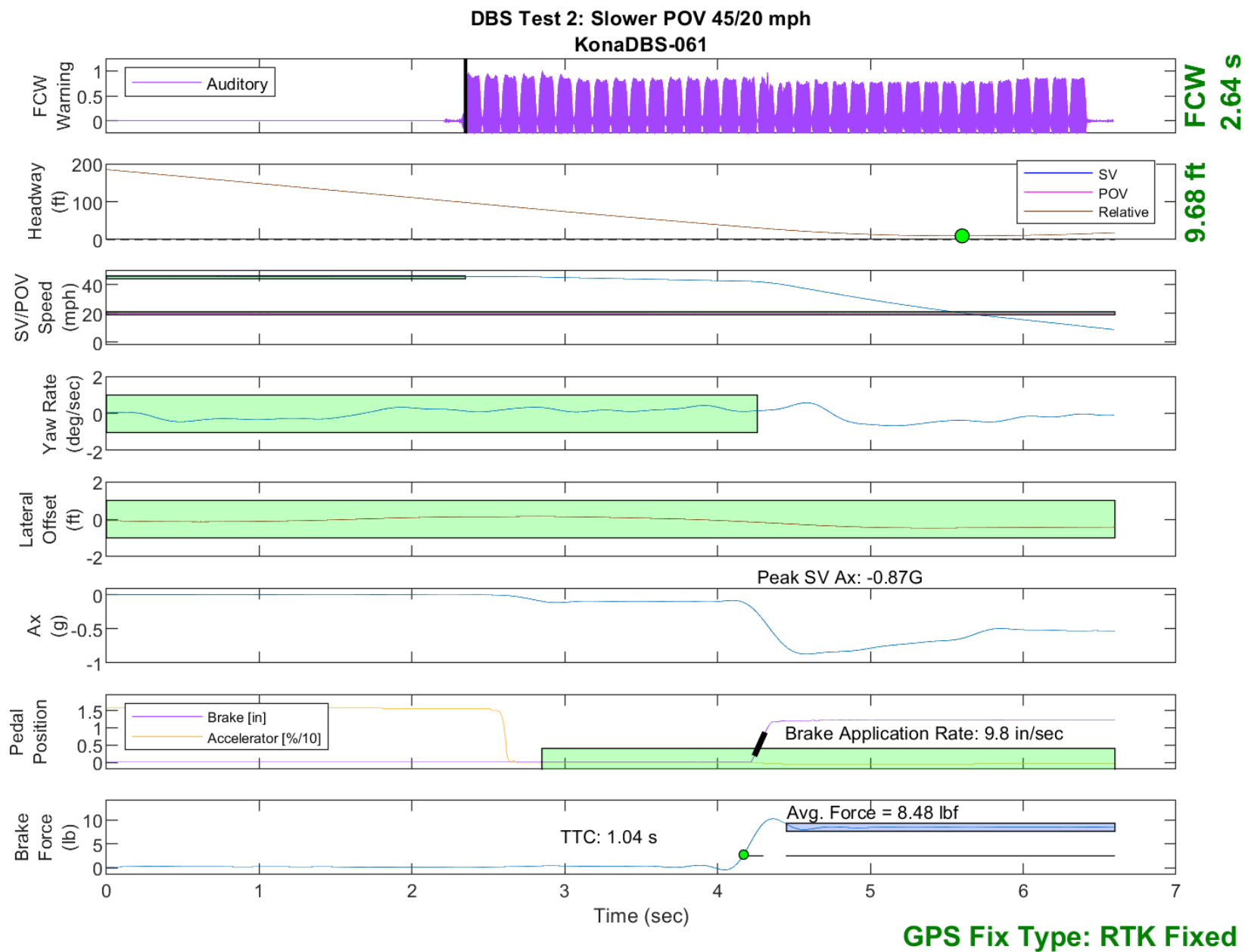


Figure E27. Time History for DBS Run 61, Test 2 - Slower Moving POV 45/20 mph

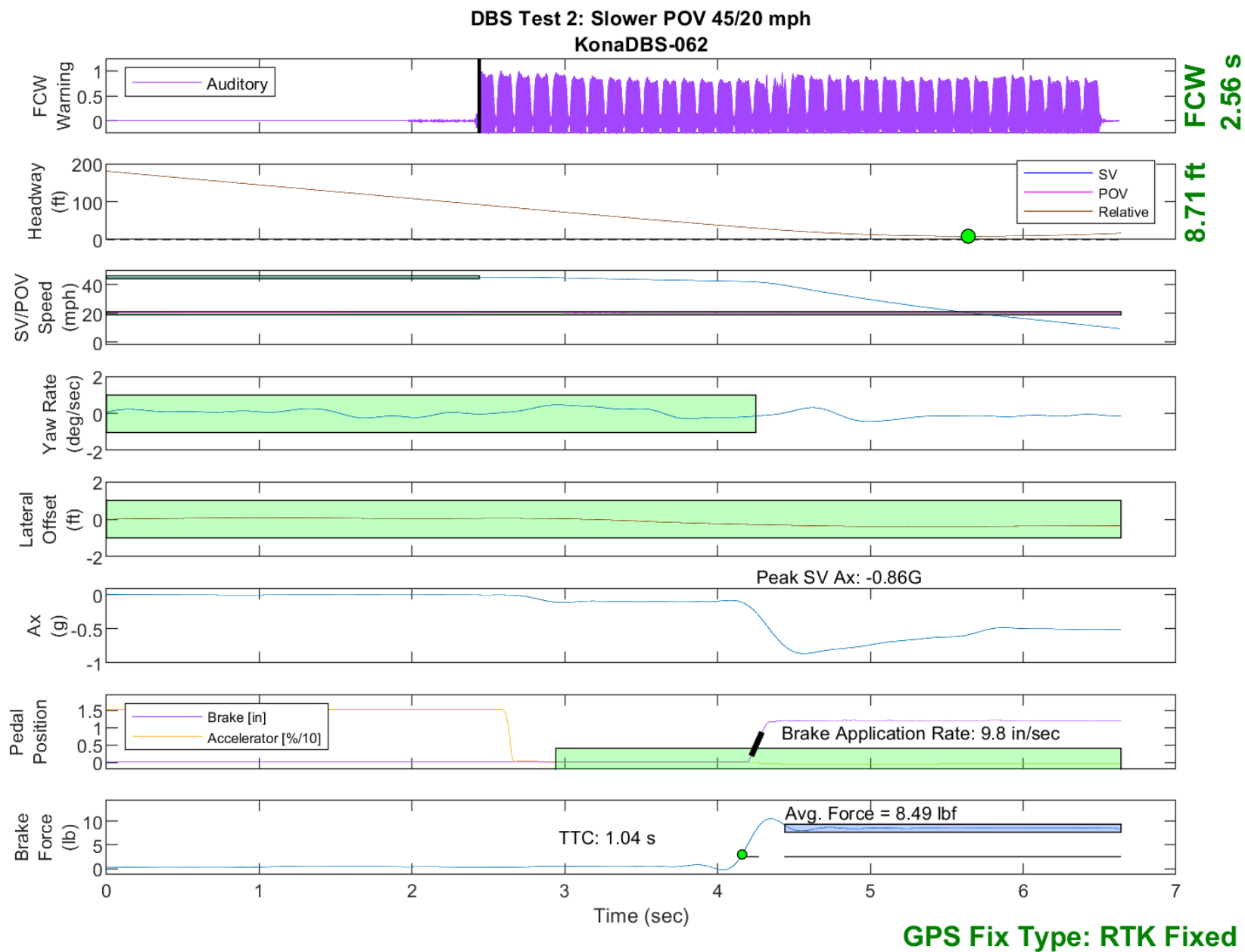


Figure E28. Time History for DBS Run 62, Test 2 - Slower Moving POV 45/20 mph

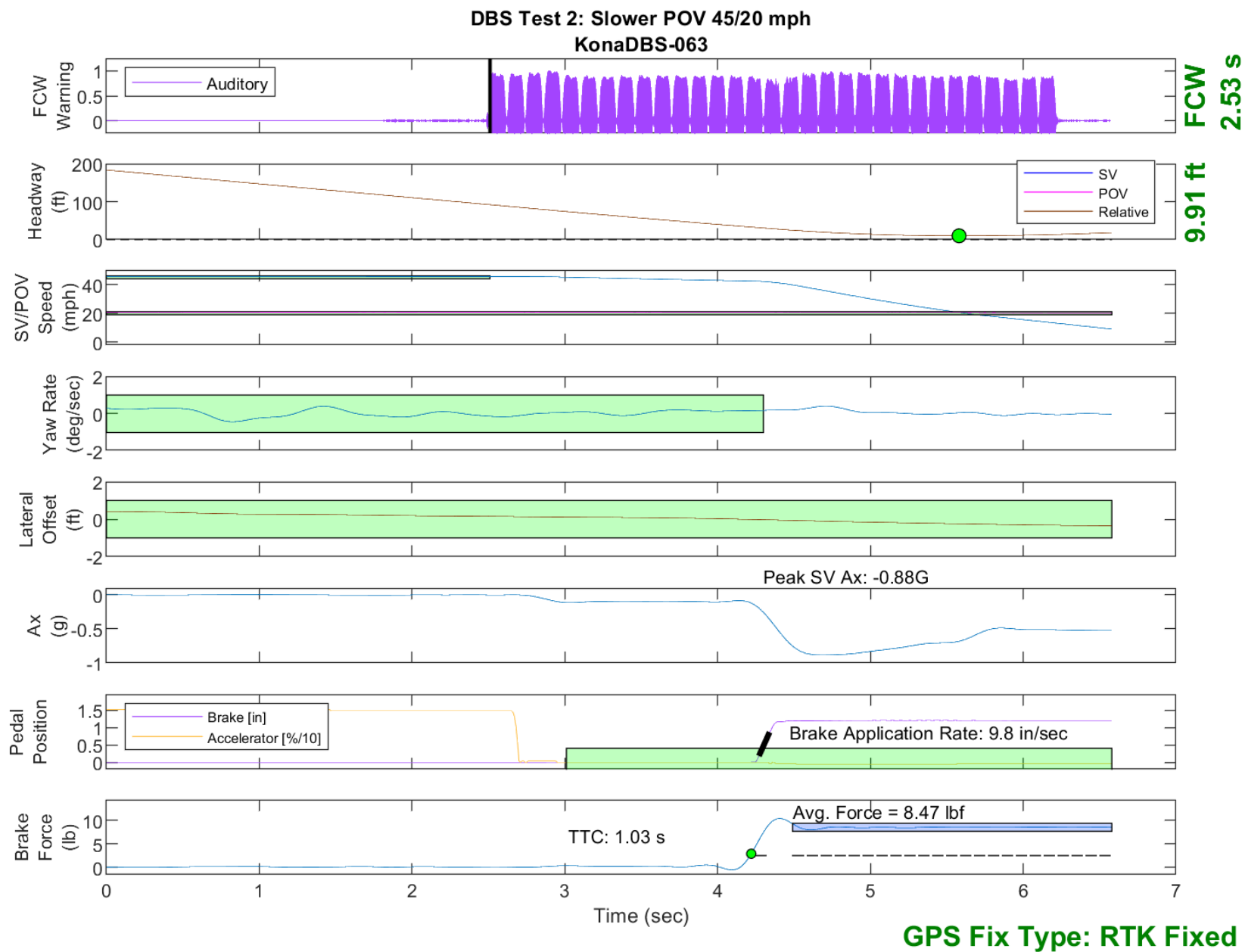


Figure E29. Time History for DBS Run 63, Test 2 - Slower Moving POV 45/20 mph

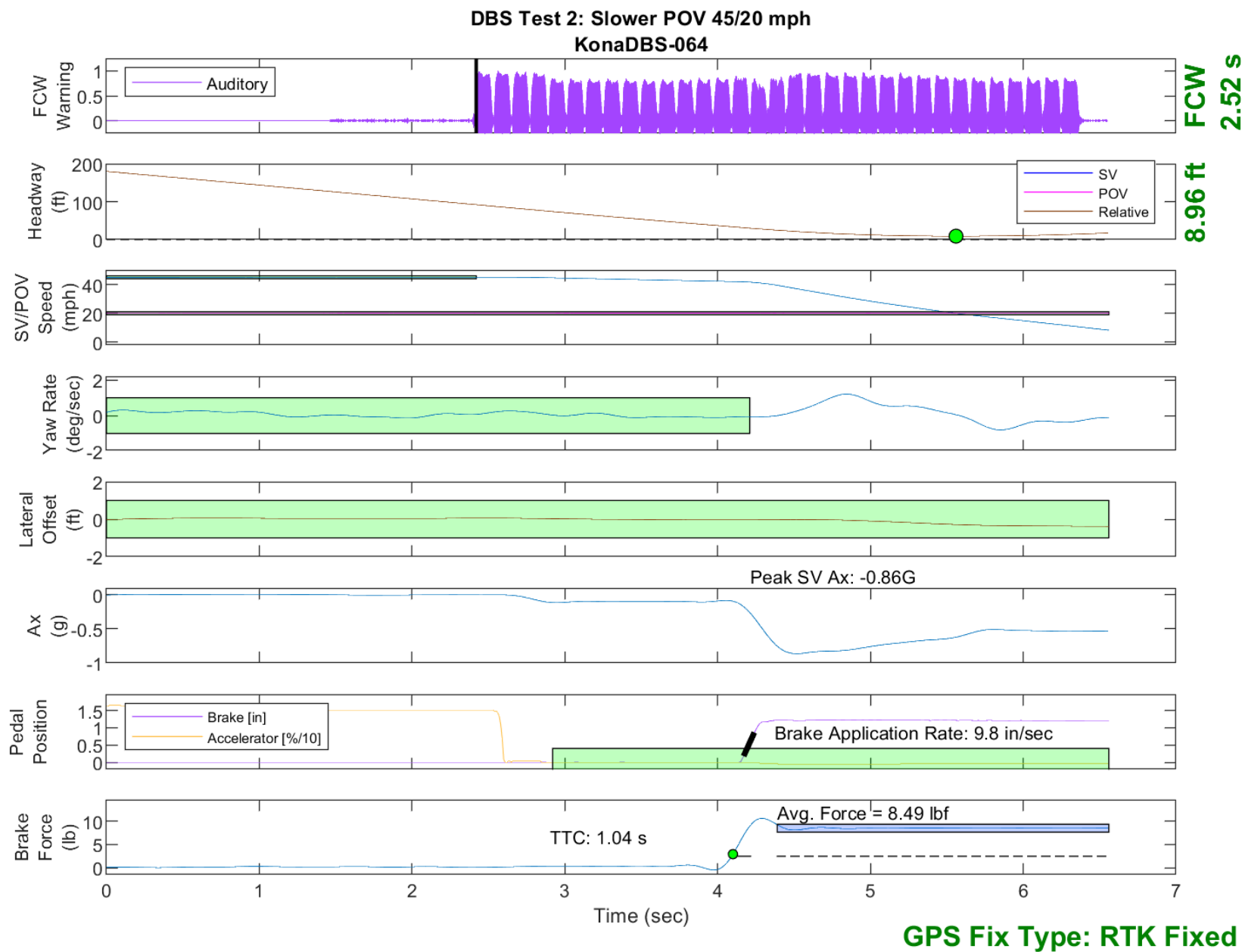


Figure E30. Time History for DBS Run 64, Test 2 - Slower Moving POV 45/20 mph

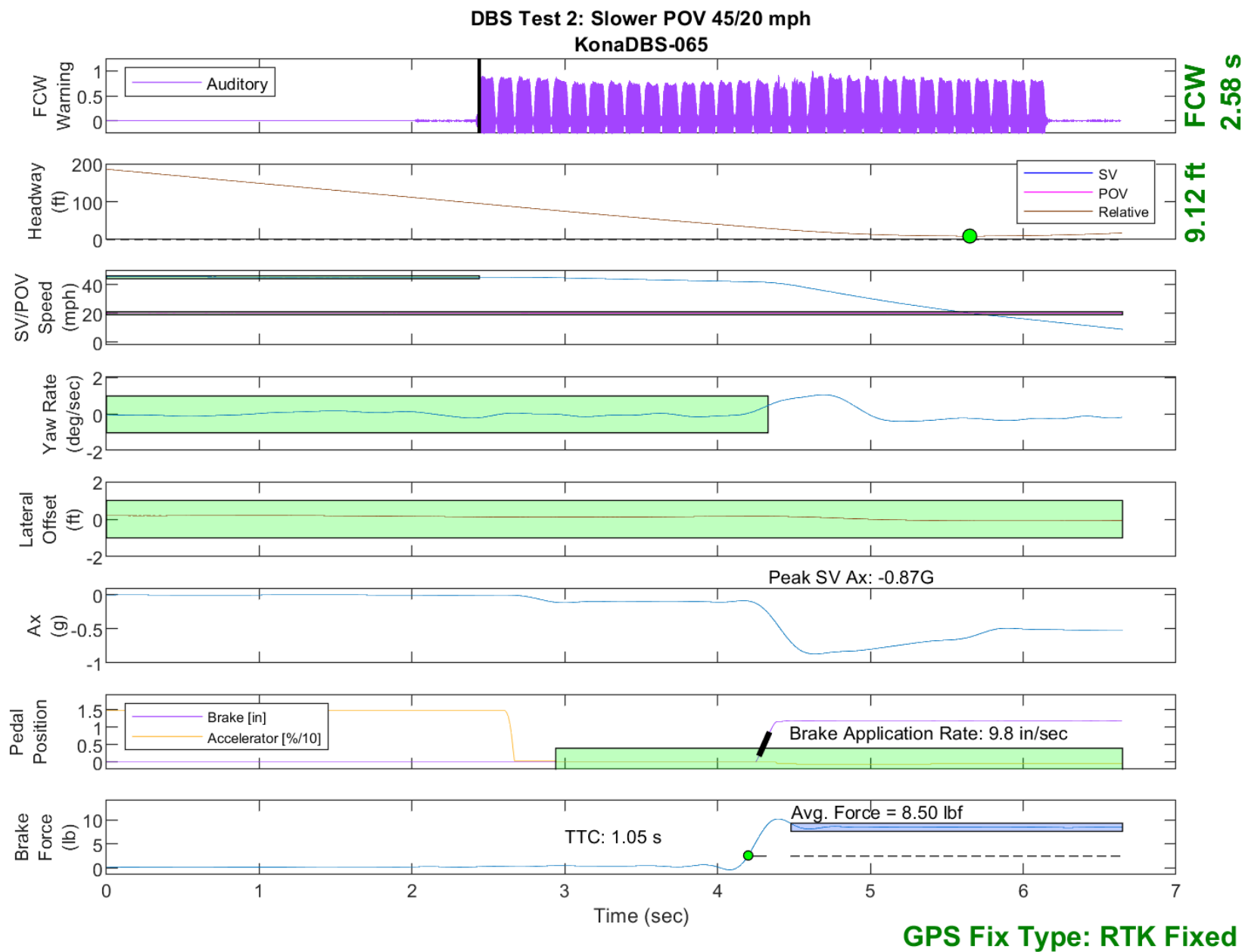


Figure E31. Time History for DBS Run 65, Test 2 - Slower Moving POV 45/20 mph

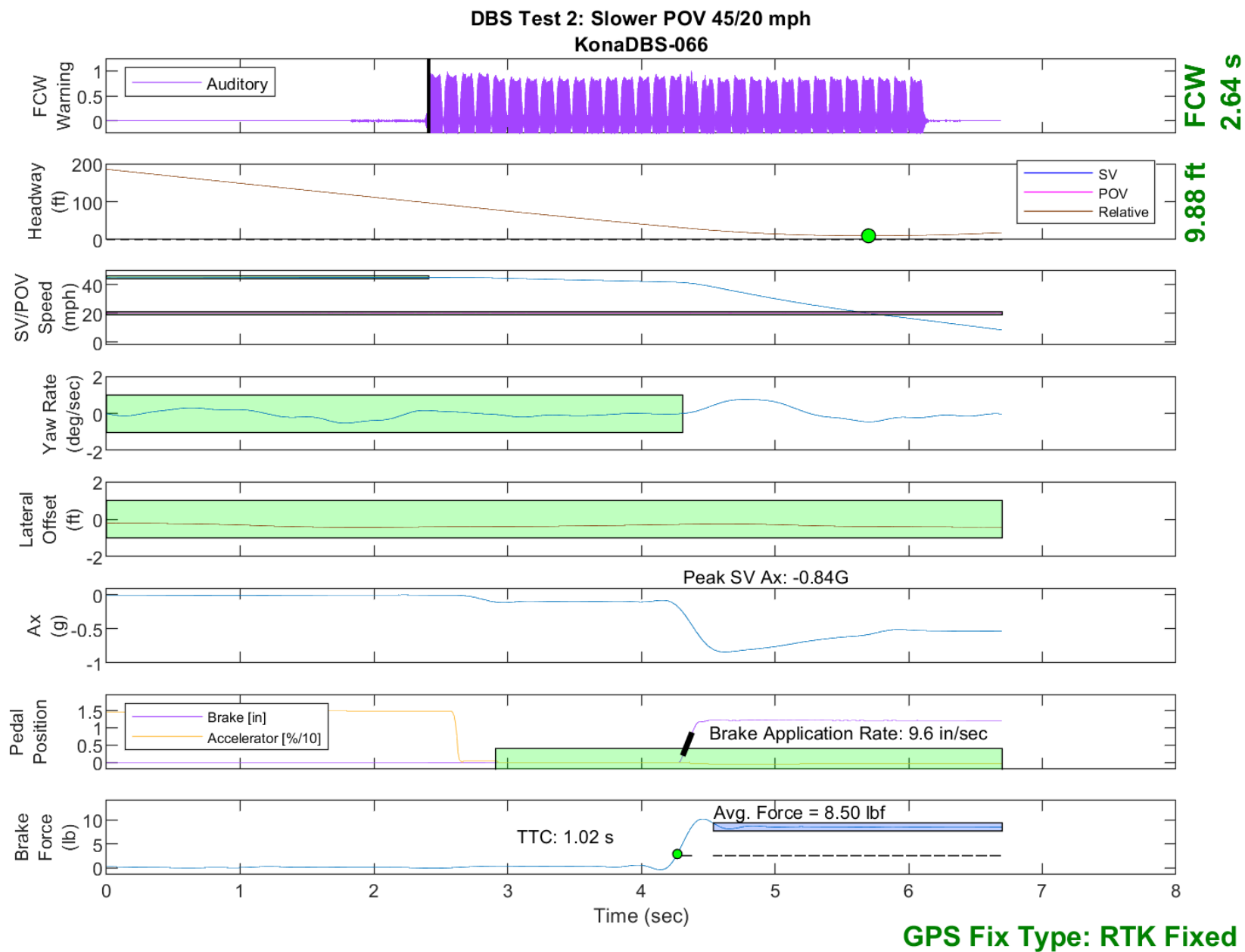


Figure E32. Time History for DBS Run 66, Test 2 - Slower Moving POV 45/20 mph

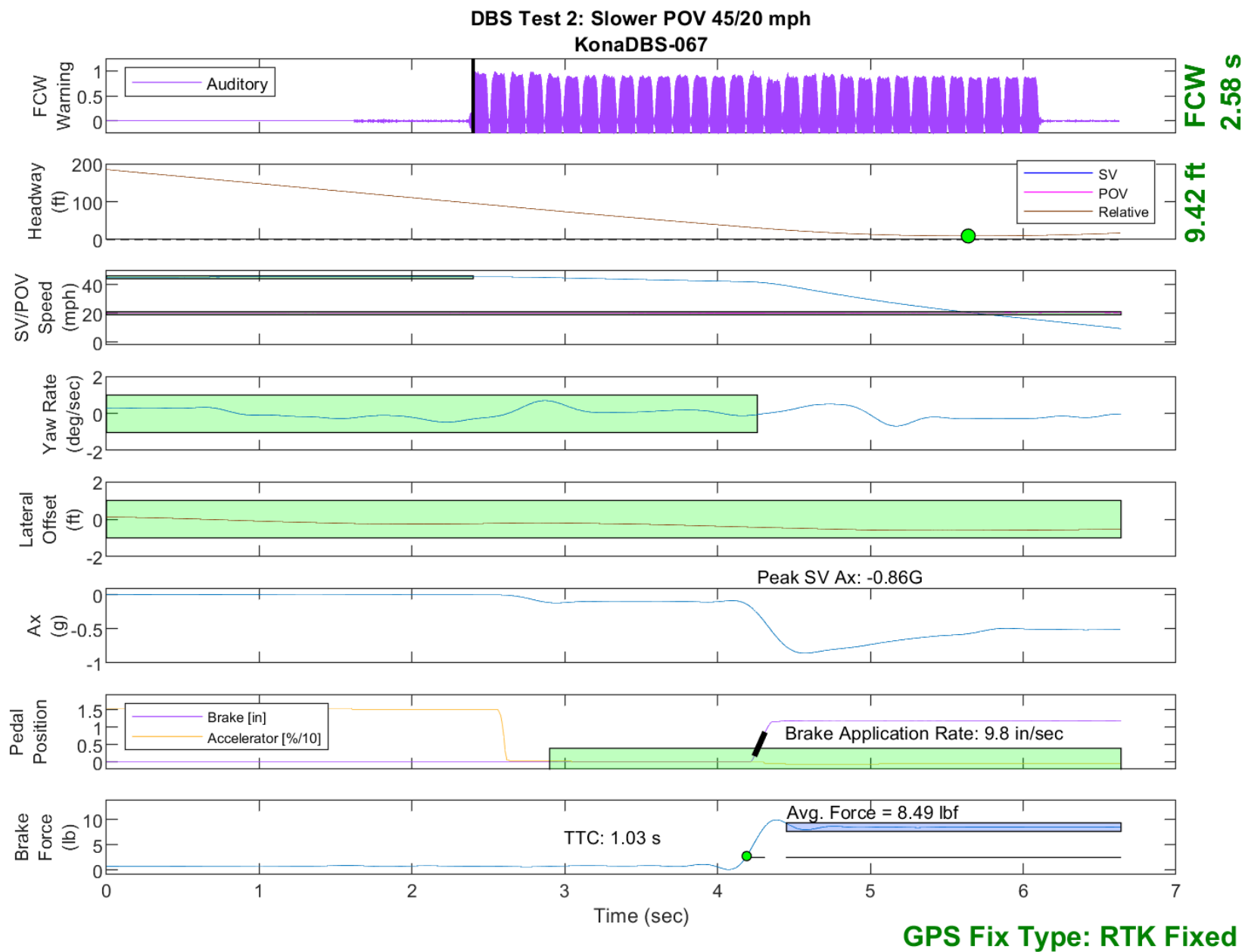


Figure E33. Time History for DBS Run 67, Test 2 - Slower Moving POV 45/20 mph

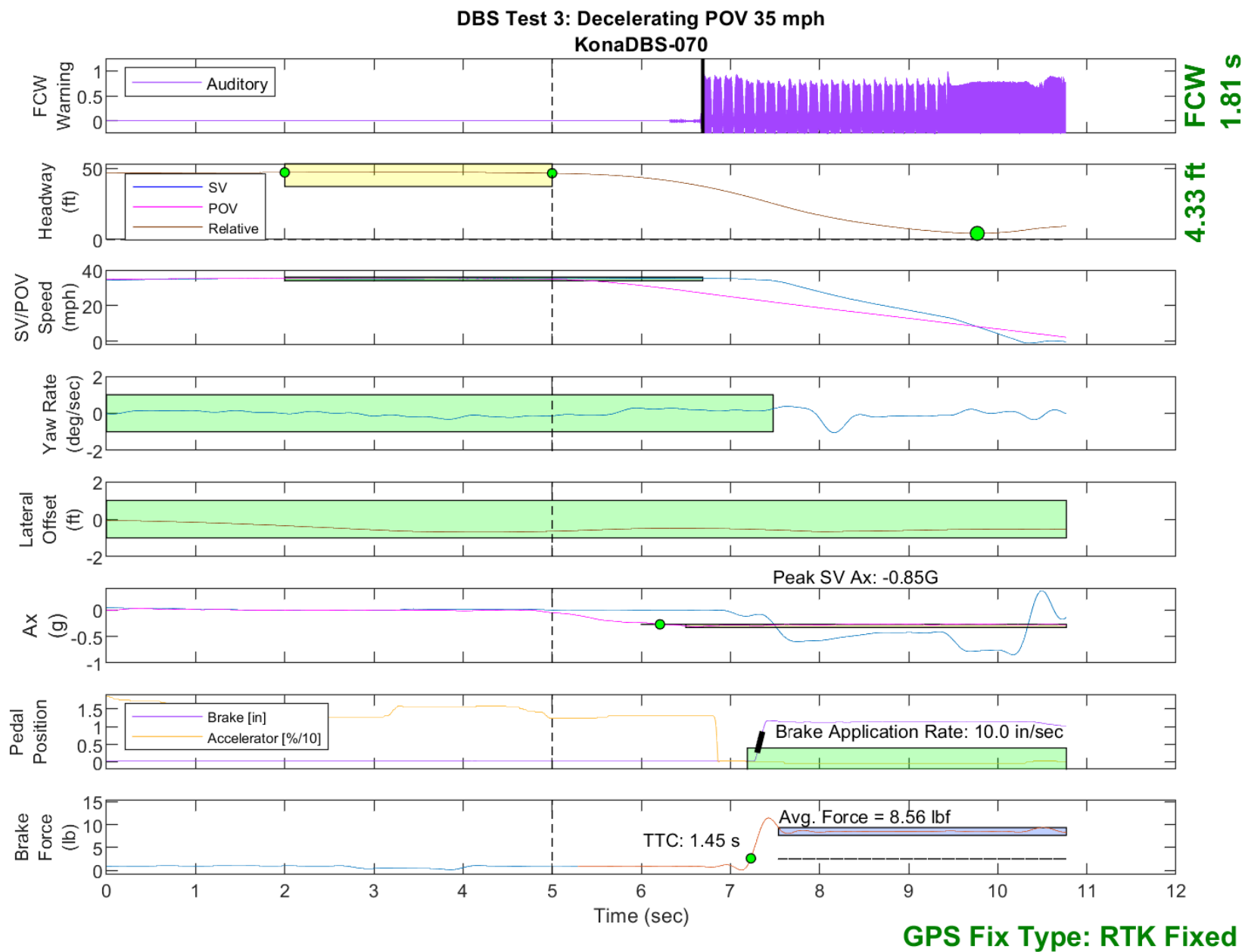


Figure E34. Time History for DBS Run 70, Test 3 - Decelerating POV 35 mph

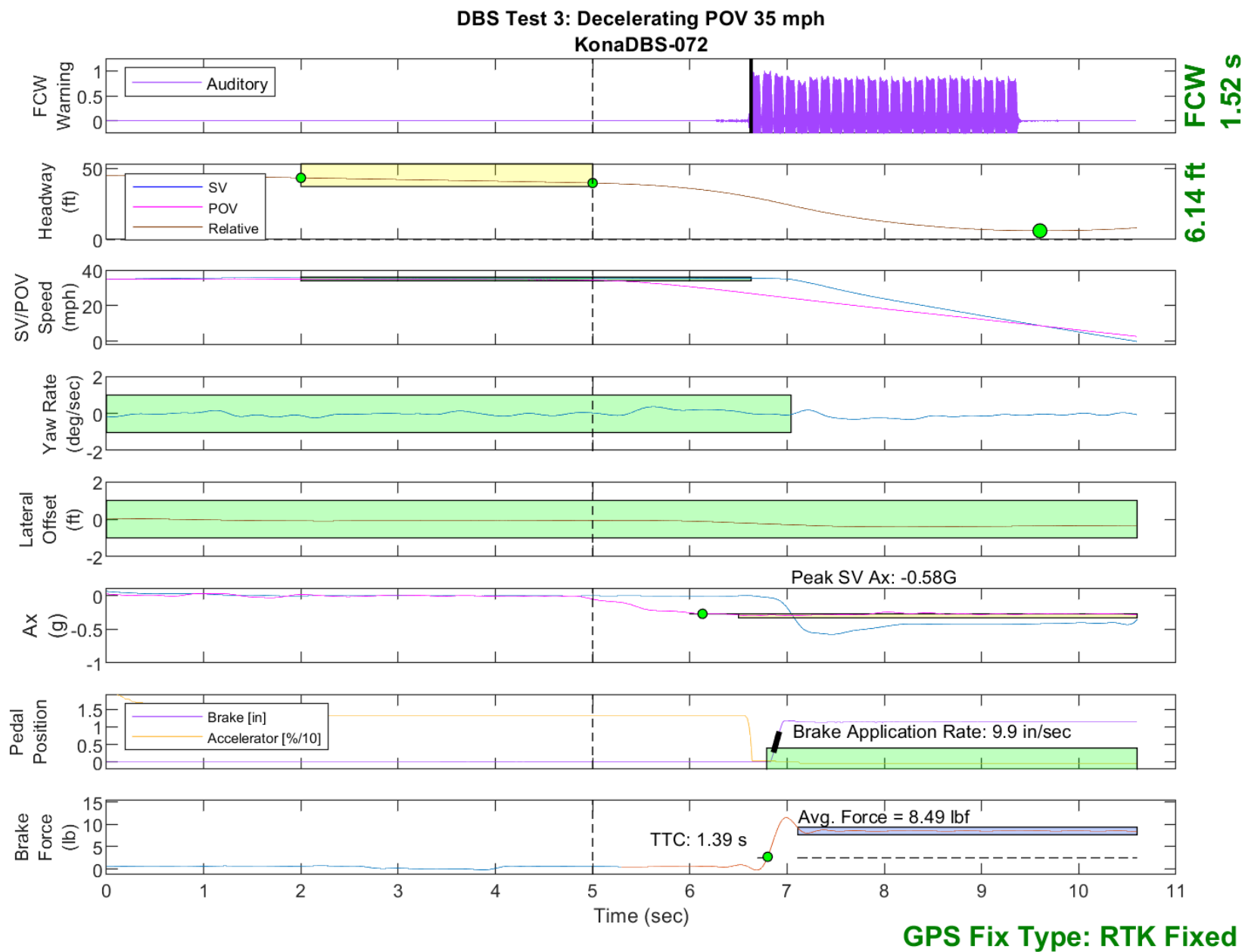


Figure E35. Time History for DBS Run 72, Test 3 - Decelerating POV 35 mph

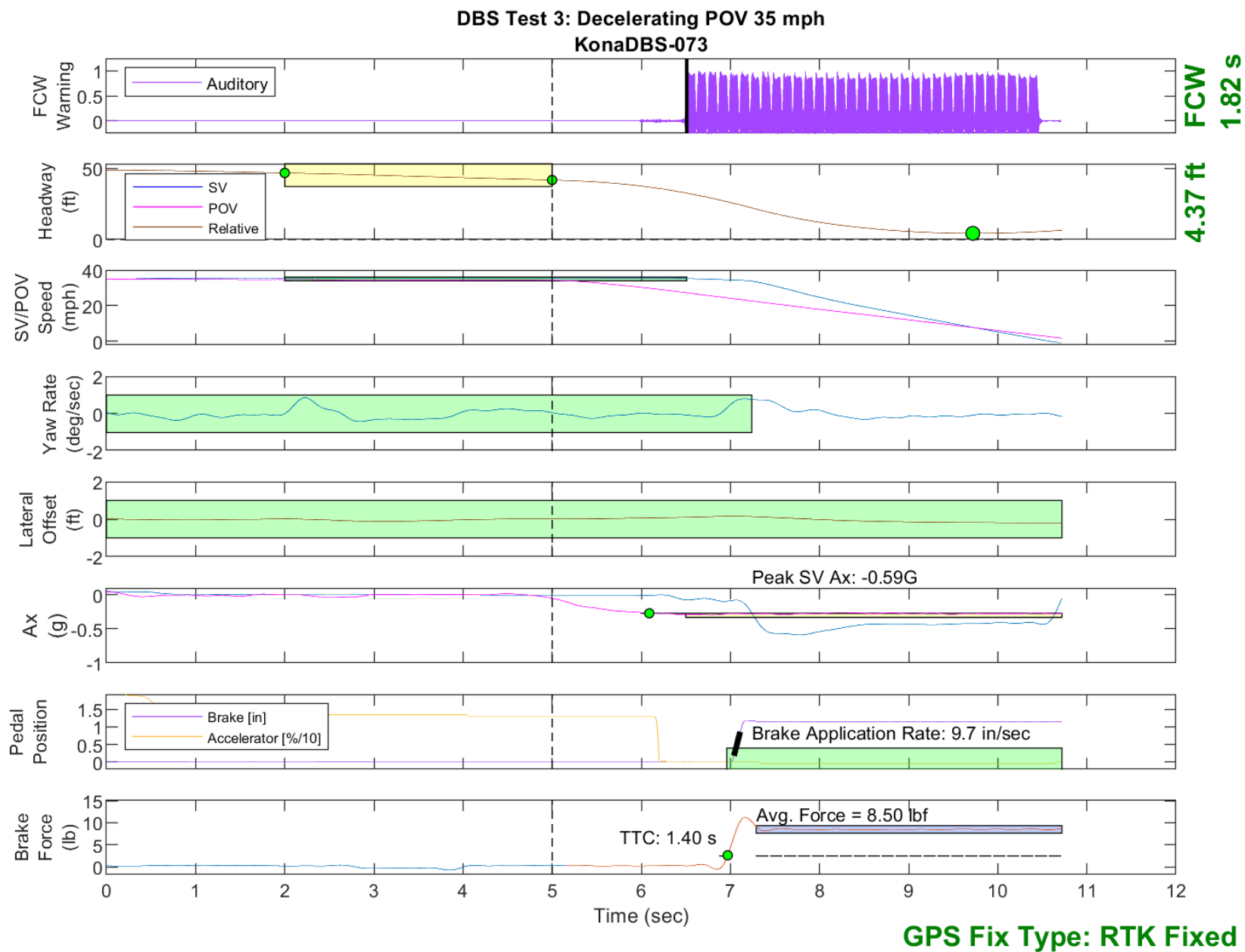


Figure E36. Time History for DBS Run 73, Test 3 - Decelerating POV 35 mph

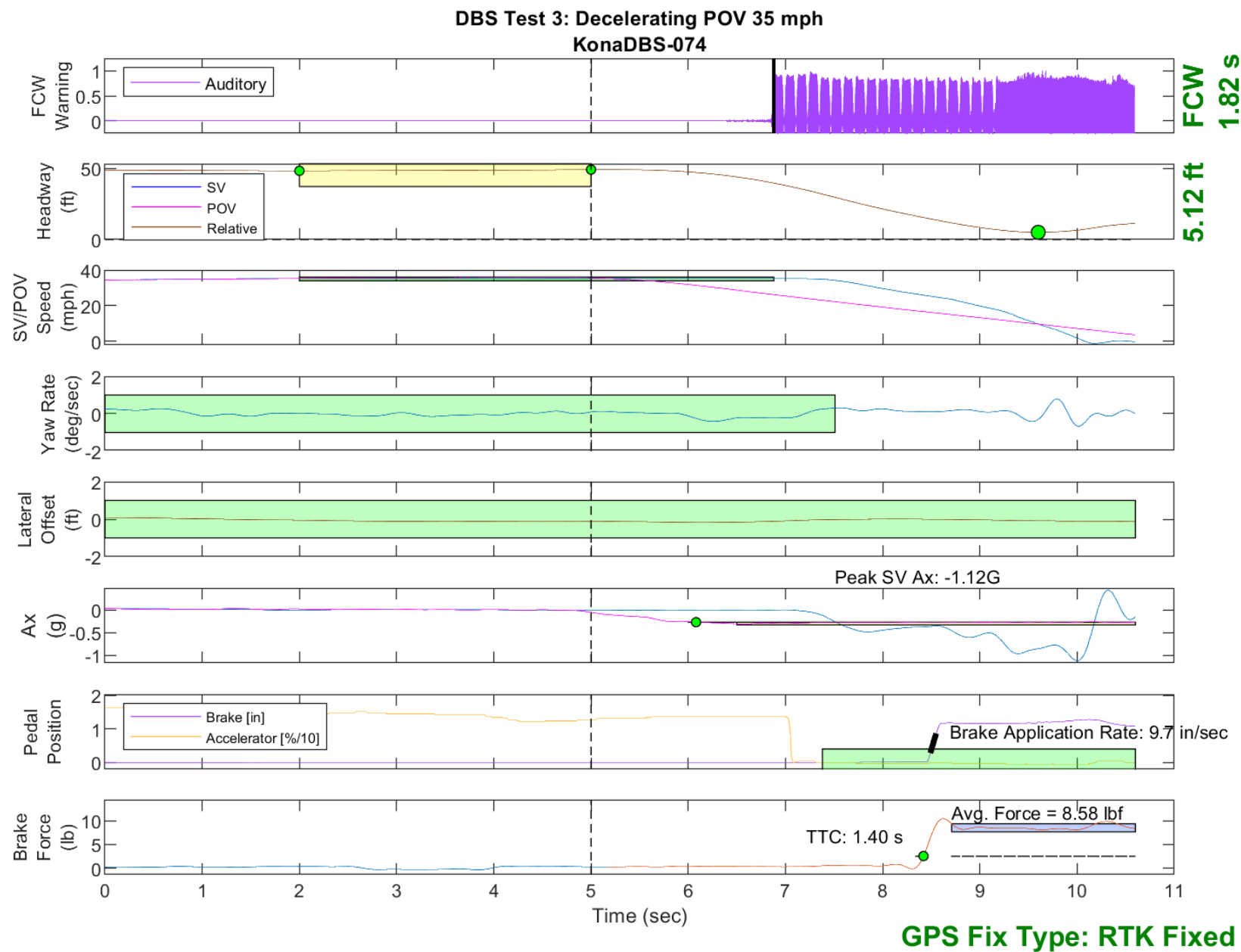


Figure E37. Time History for DBS Run 74, Test 3 - Decelerating POV 35 mph

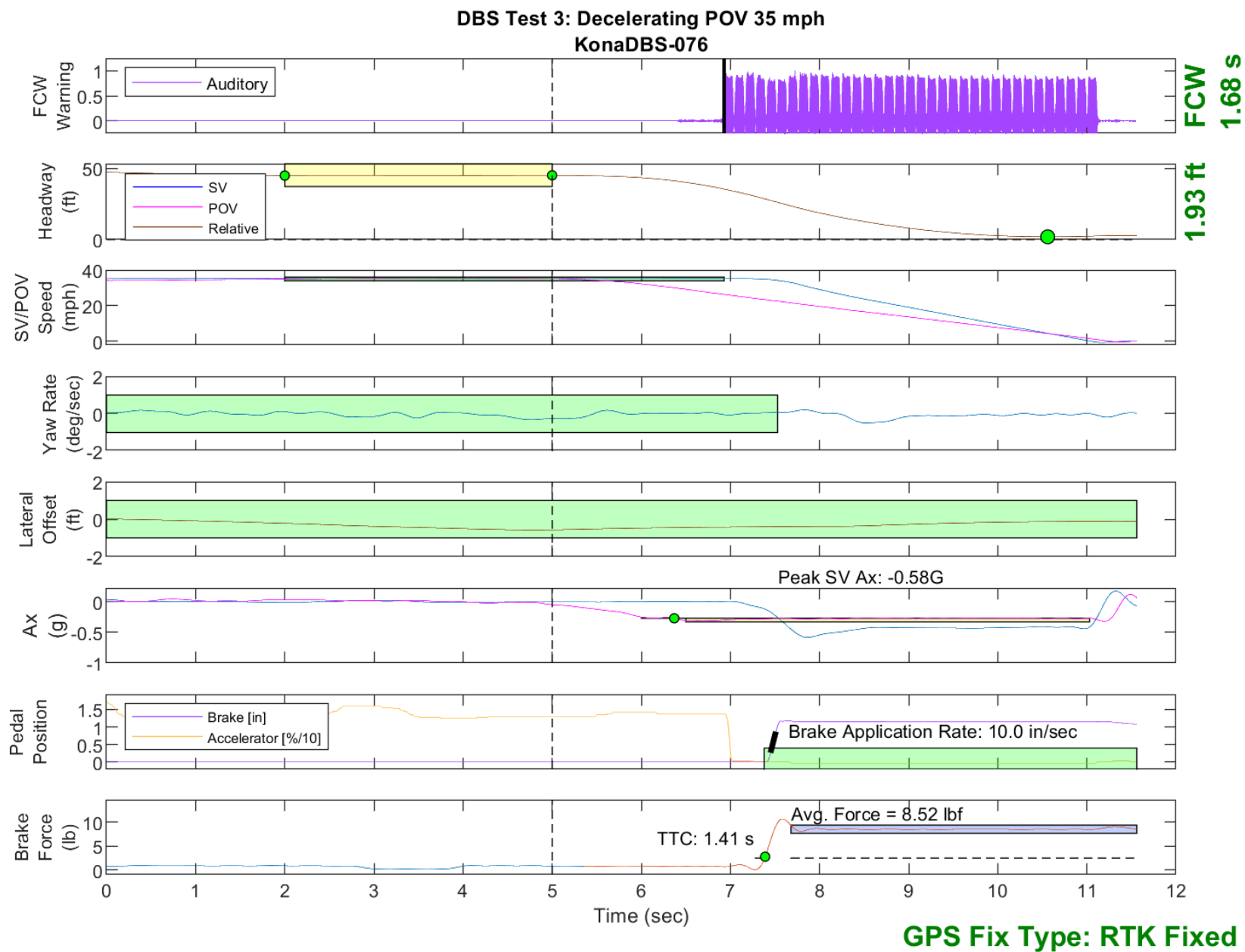


Figure E38. Time History for DBS Run 76, Test 3 - Decelerating POV 35 mph

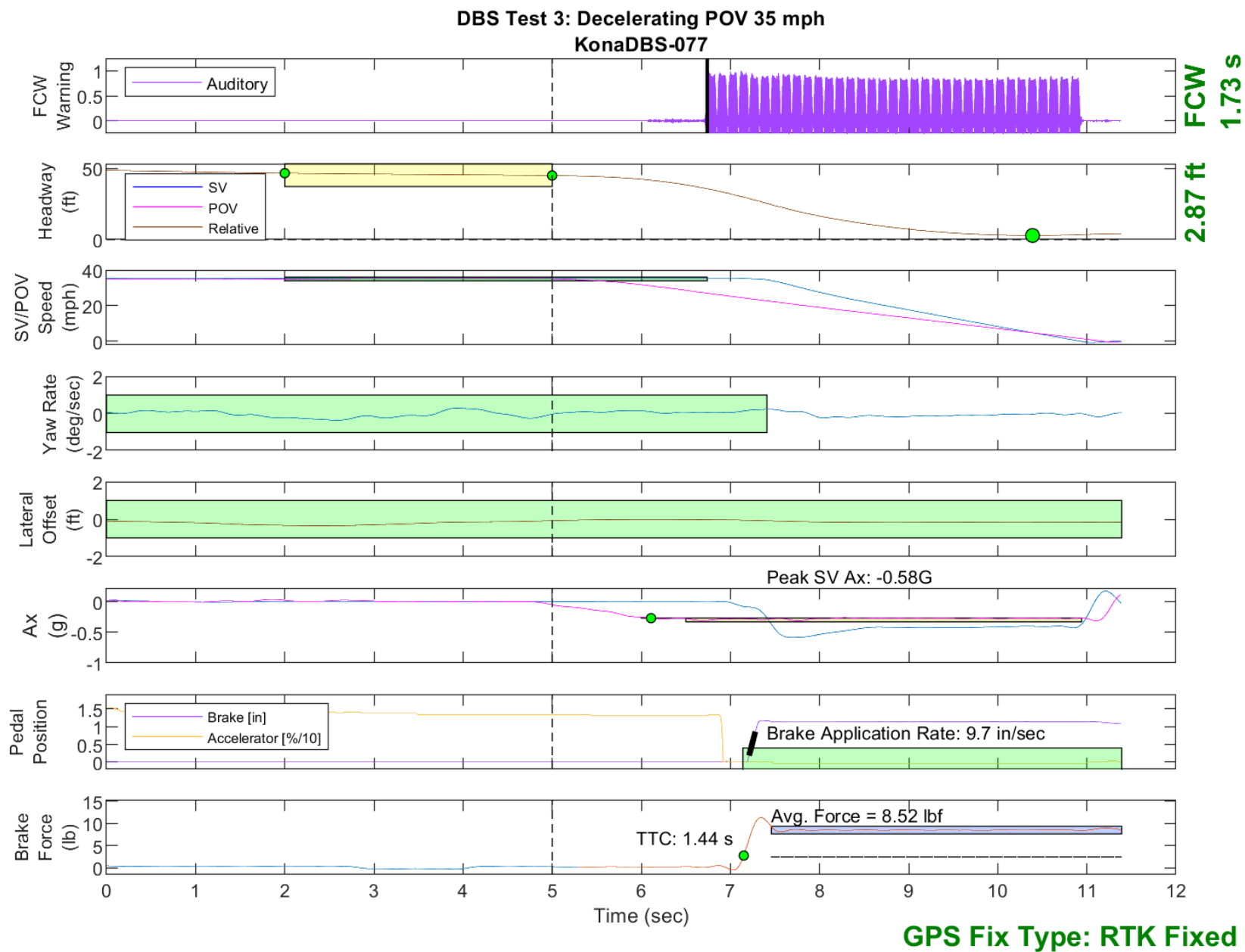


Figure E39. Time History for DBS Run 77, Test 3 - Decelerating POV 35 mph

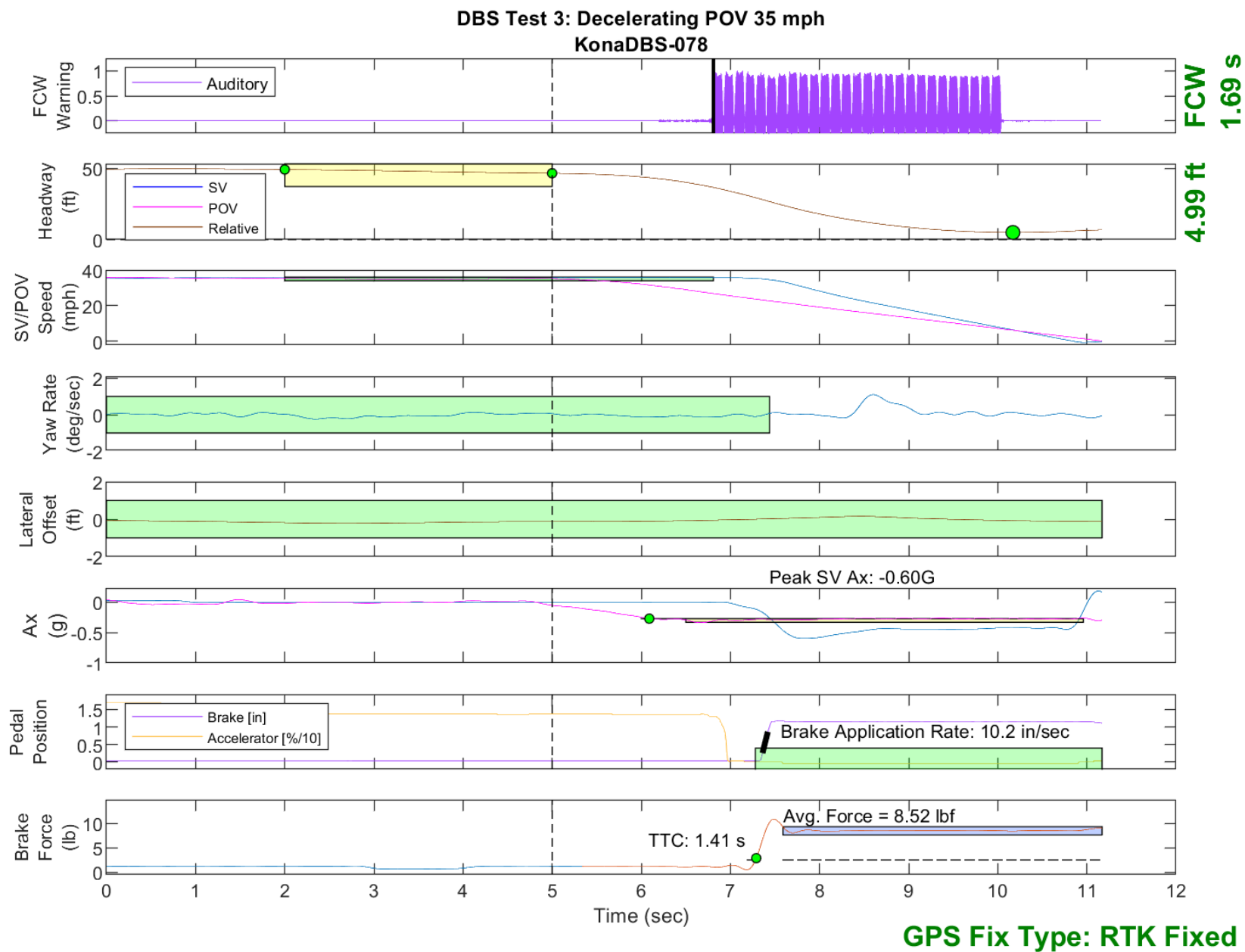


Figure E40. Time History for DBS Run 78, Test 3 - Decelerating POV 35 mph

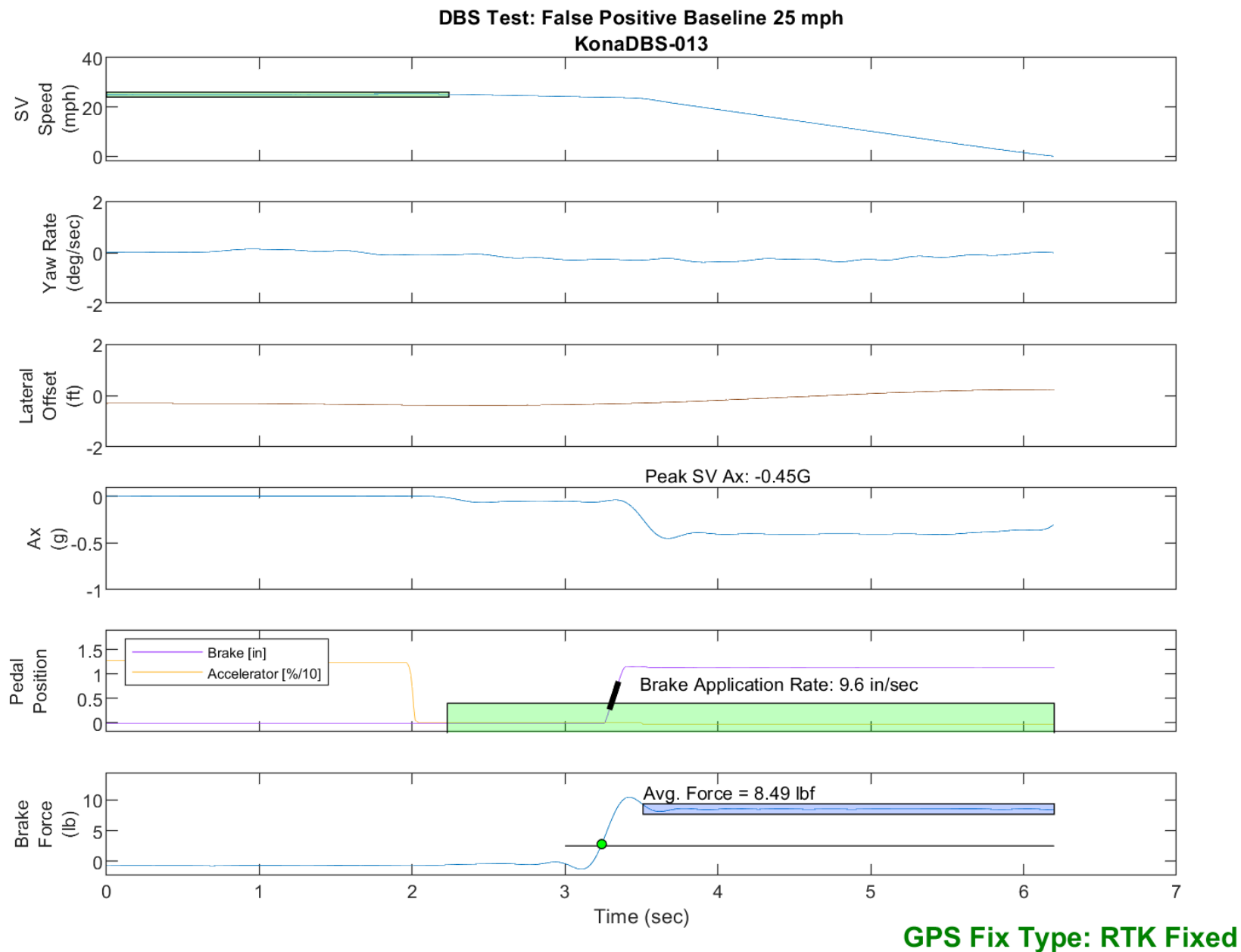


Figure E41. Time History for DBS Run 13, False Positive Baseline, SV 25 mph

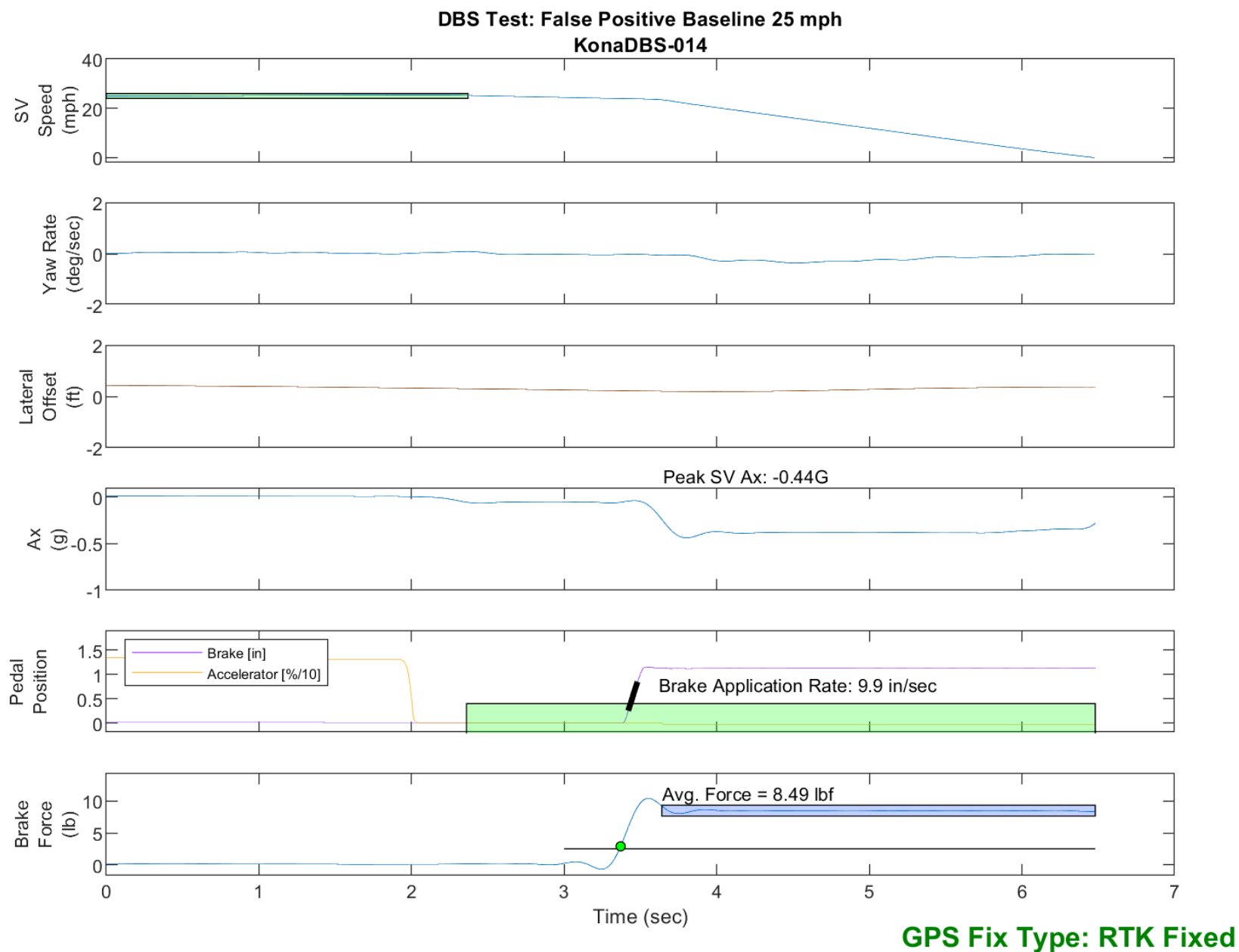


Figure E42. Time History for DBS Run 14, False Positive Baseline, SV 25 mph

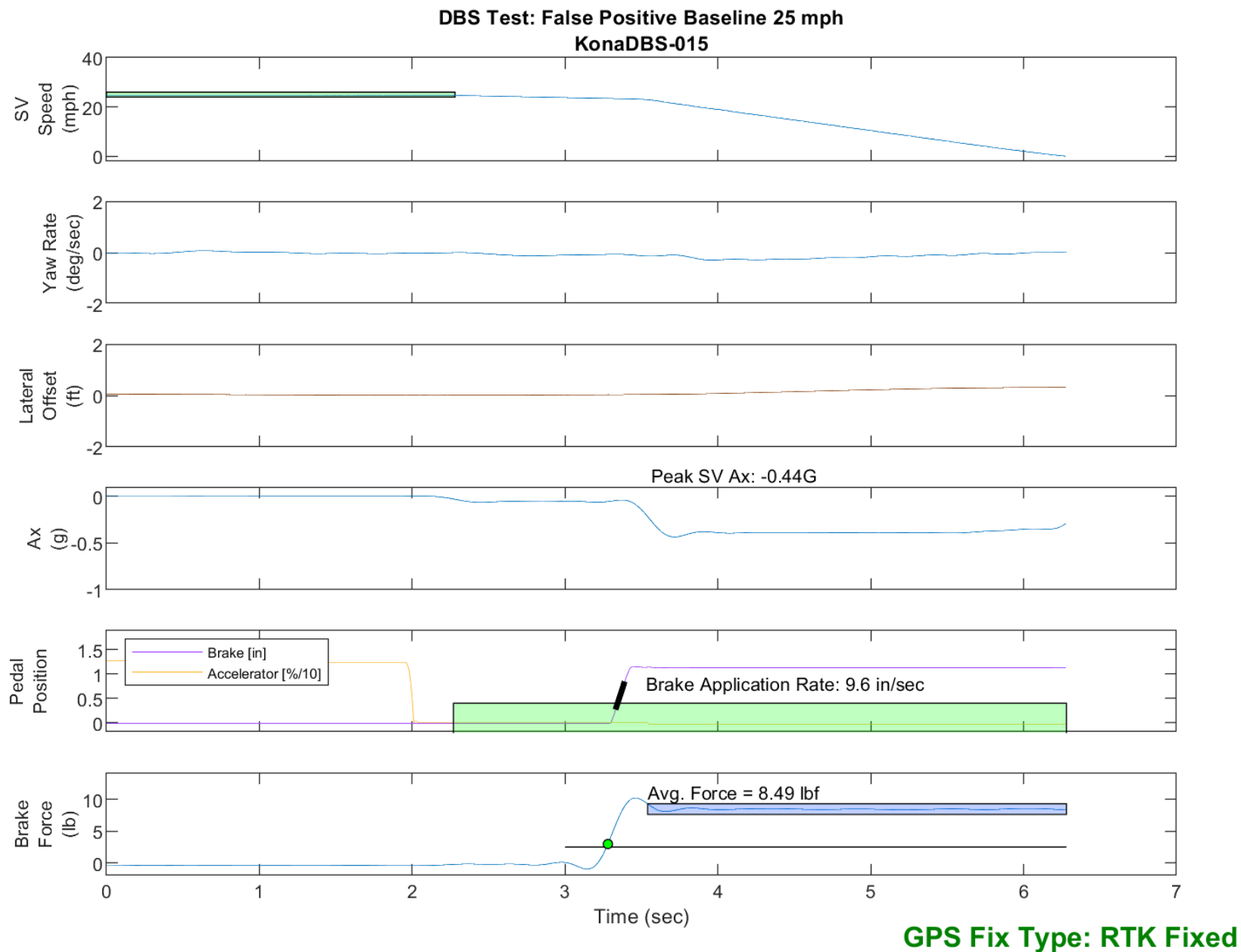


Figure E43. Time History for DBS Run 15, False Positive Baseline, SV 25 mph

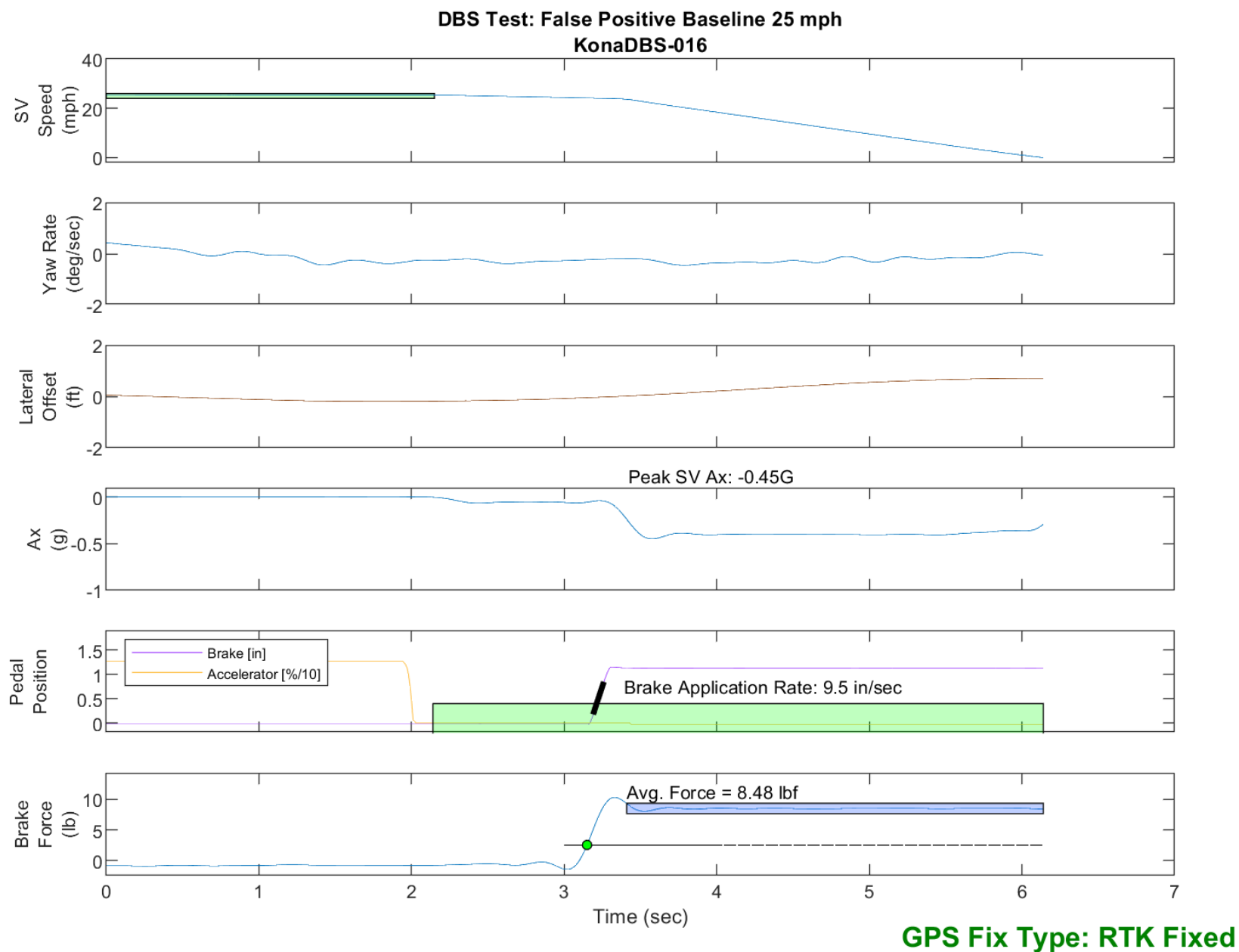


Figure E44. Time History for DBS Run 16, False Positive Baseline, SV 25 mph

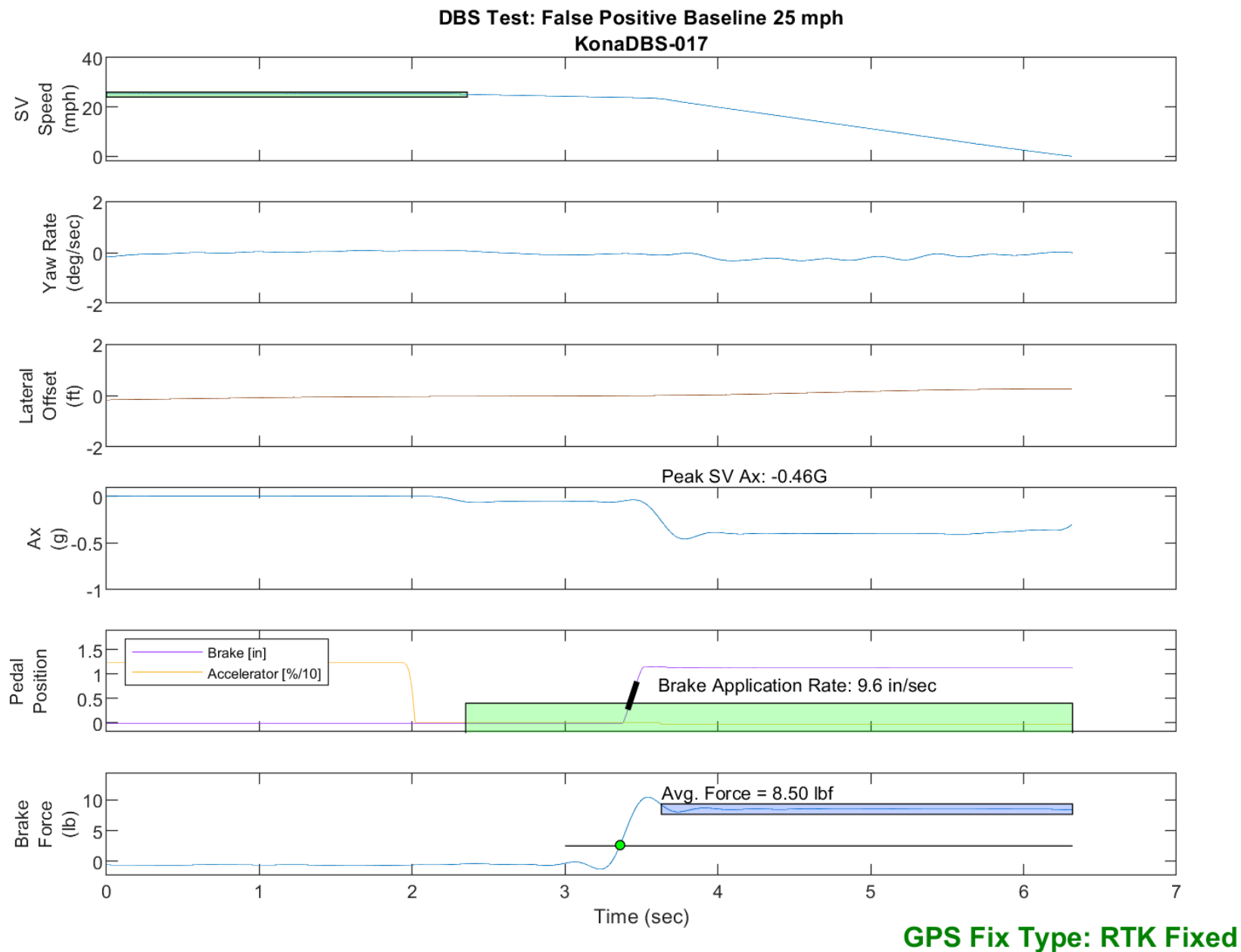


Figure E45. Time History for DBS Run 17, False Positive Baseline, SV 25 mph

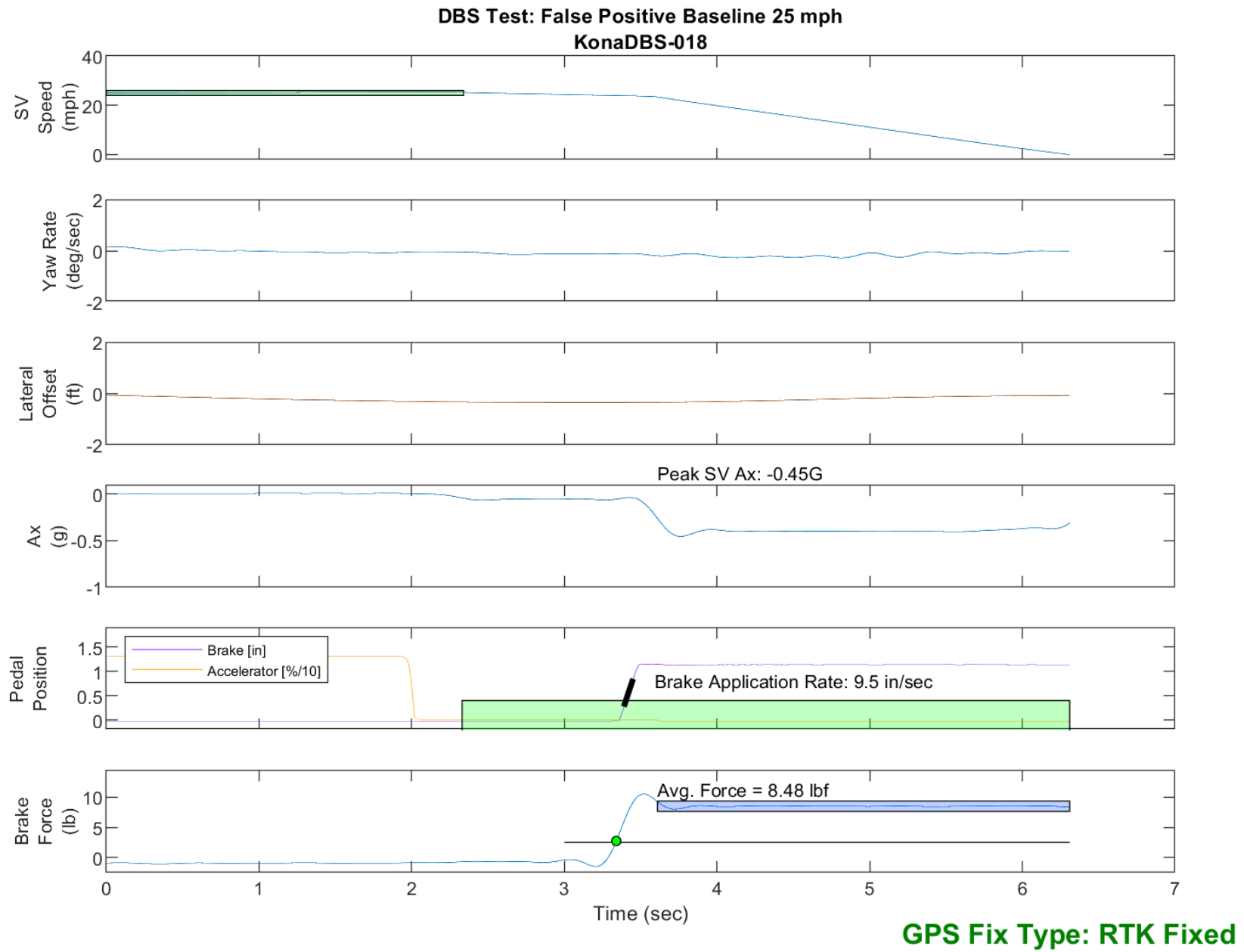


Figure E46. Time History for DBS Run 18, False Positive Baseline, SV 25 mph

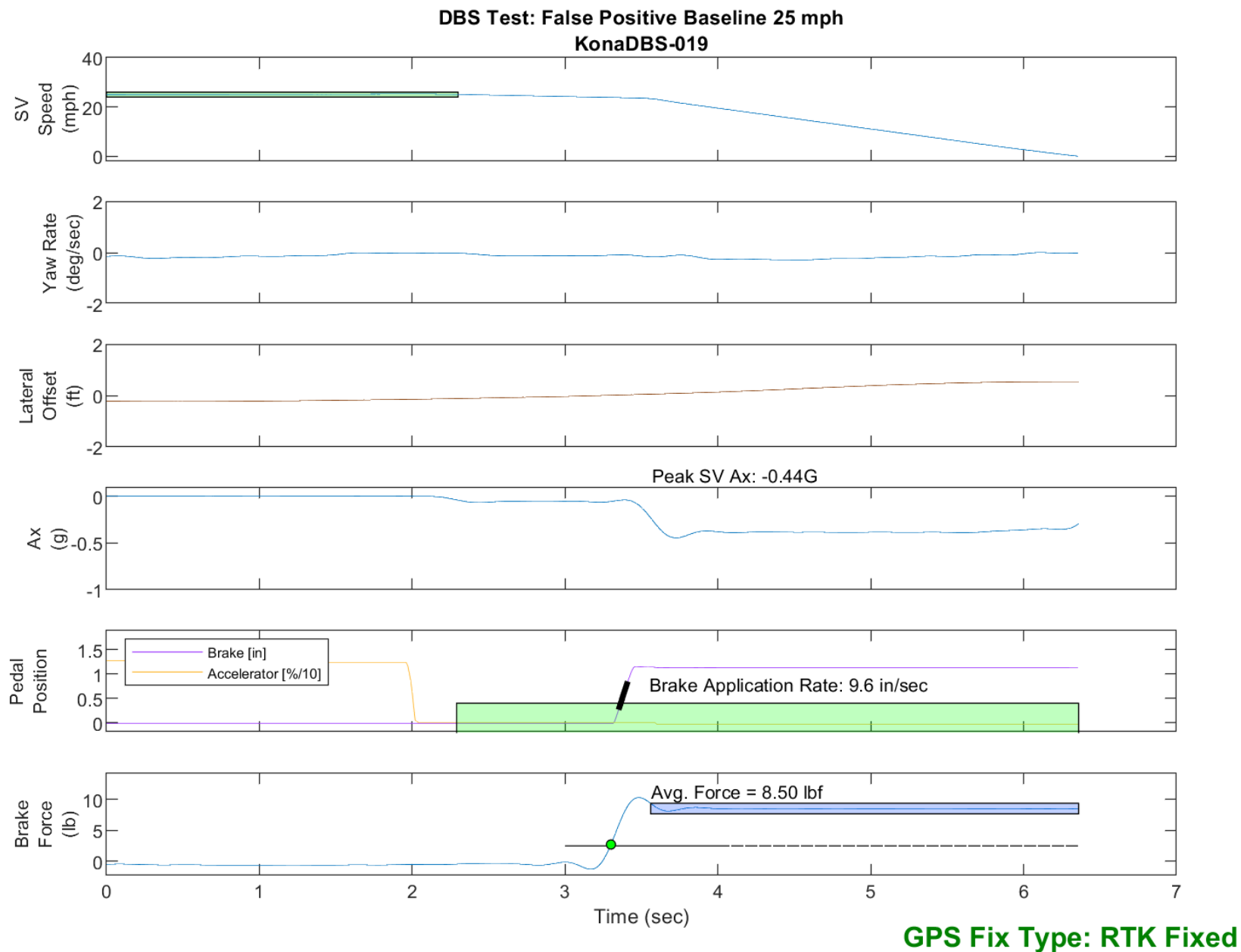


Figure E47. Time History for DBS Run 19, False Positive Baseline, SV 25 mph

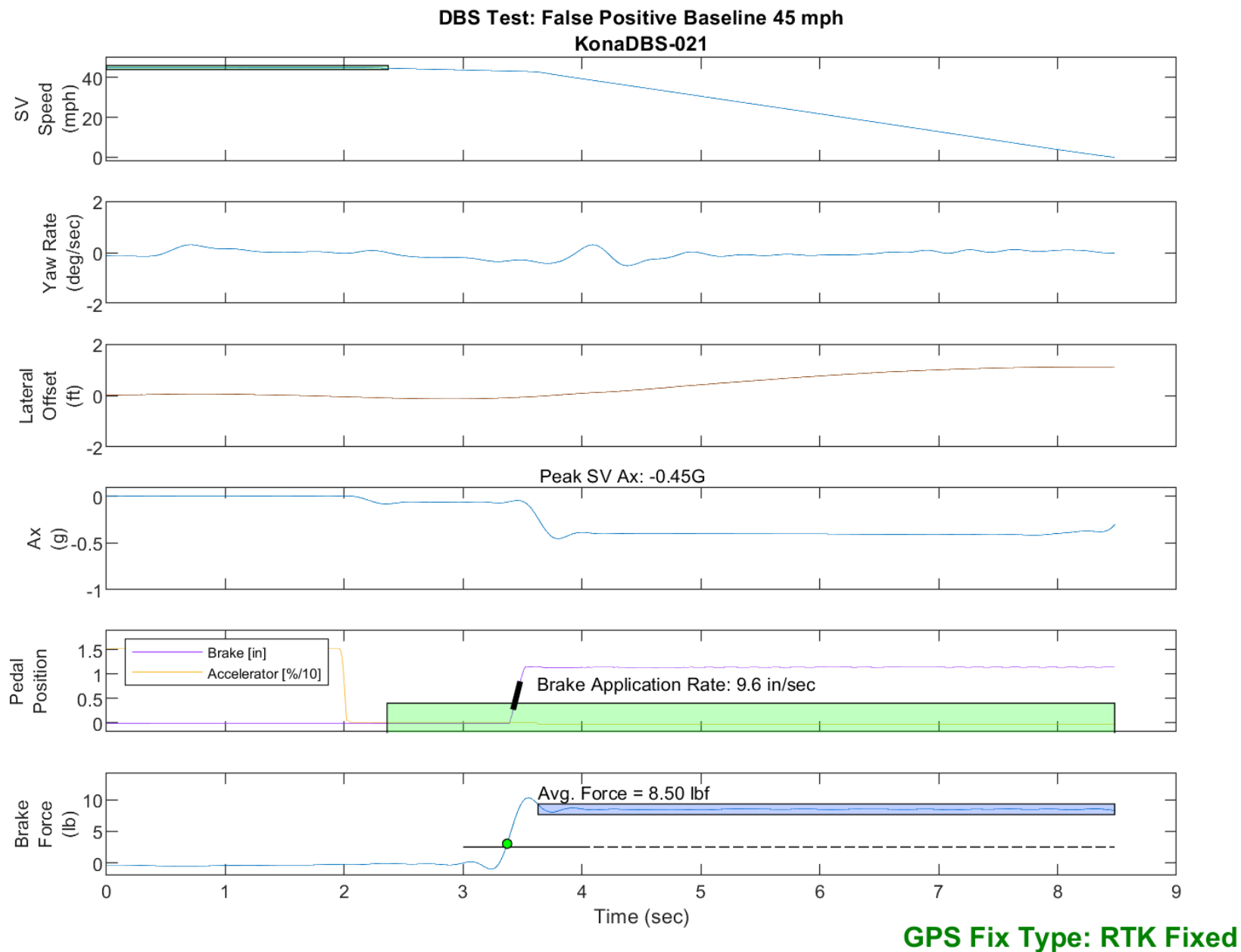


Figure E48. Time History for DBS Run 21, False Positive Baseline, SV 45 mph

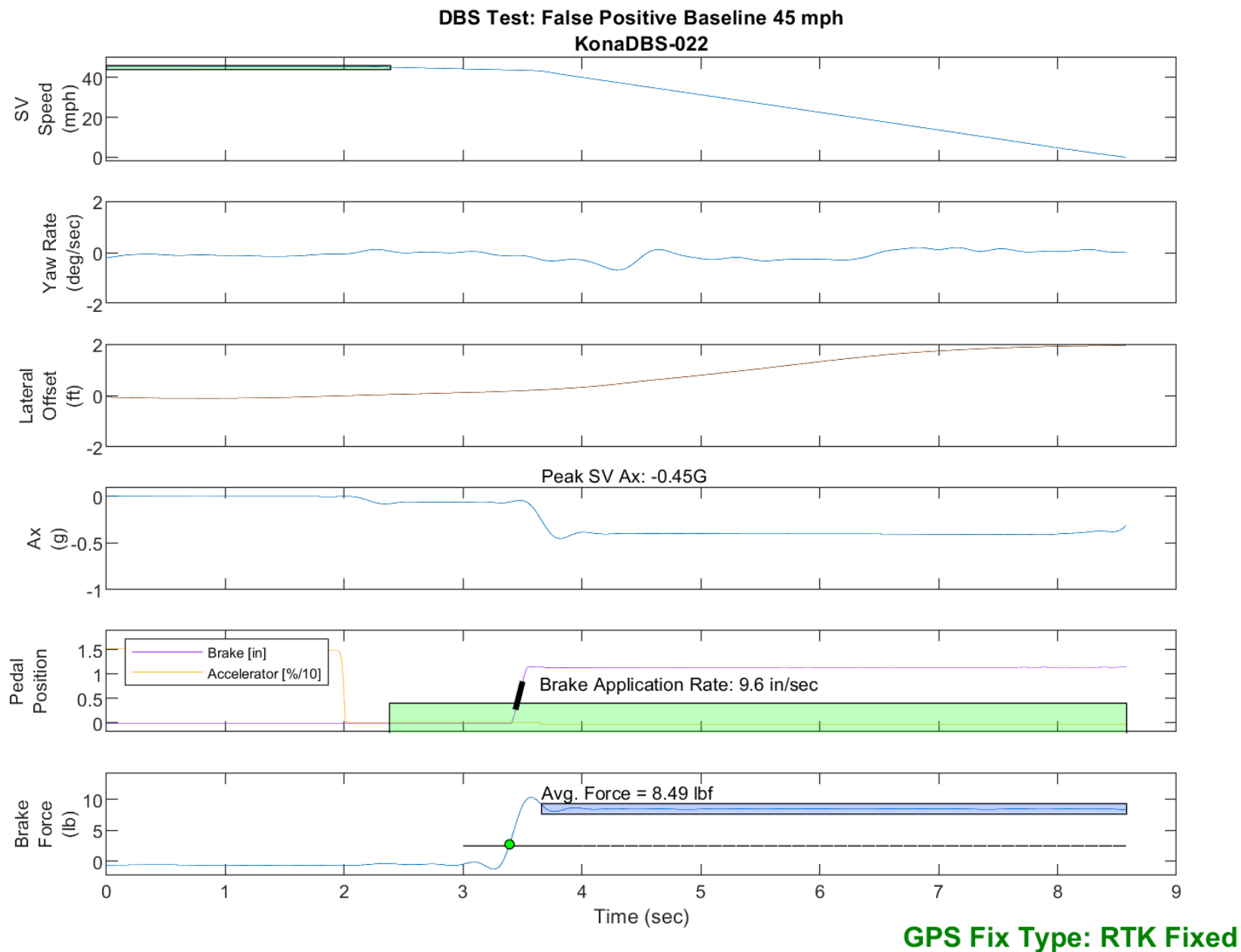


Figure E49. Time History for DBS Run 22, False Positive Baseline, SV 45 mph

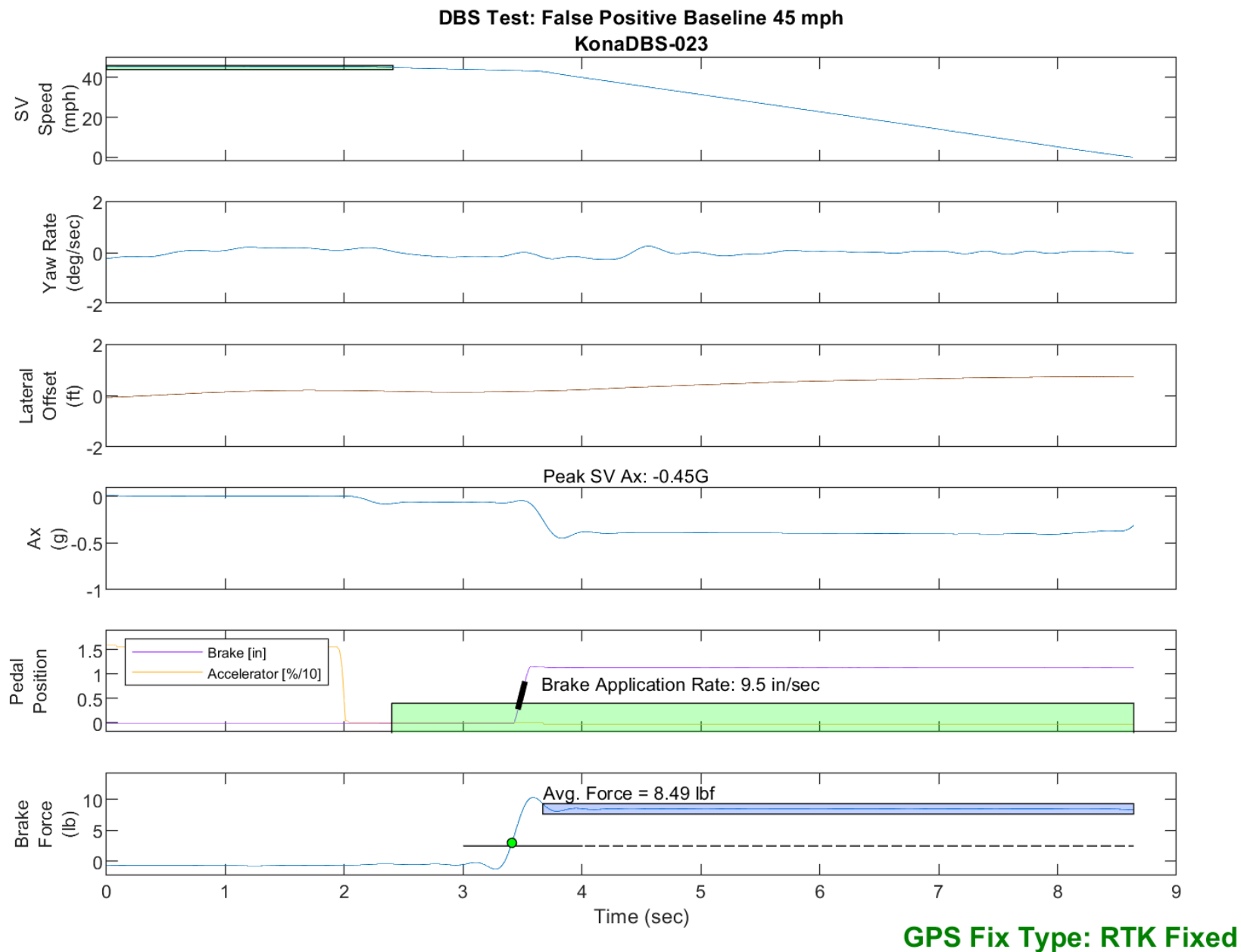


Figure E50. Time History for DBS Run 23, False Positive Baseline, SV 45 mph

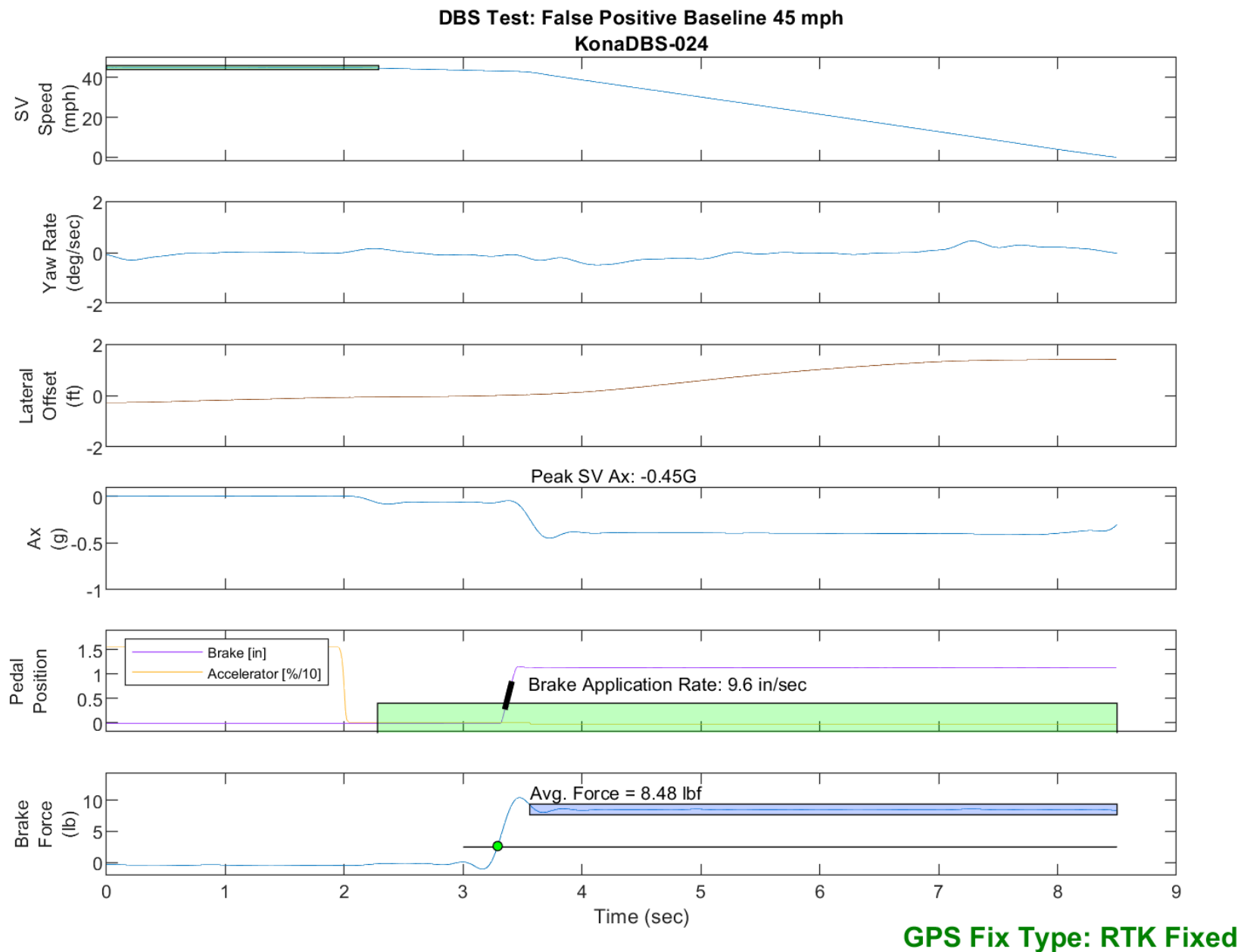


Figure E51. Time History for DBS Run 24, False Positive Baseline, SV 45 mph

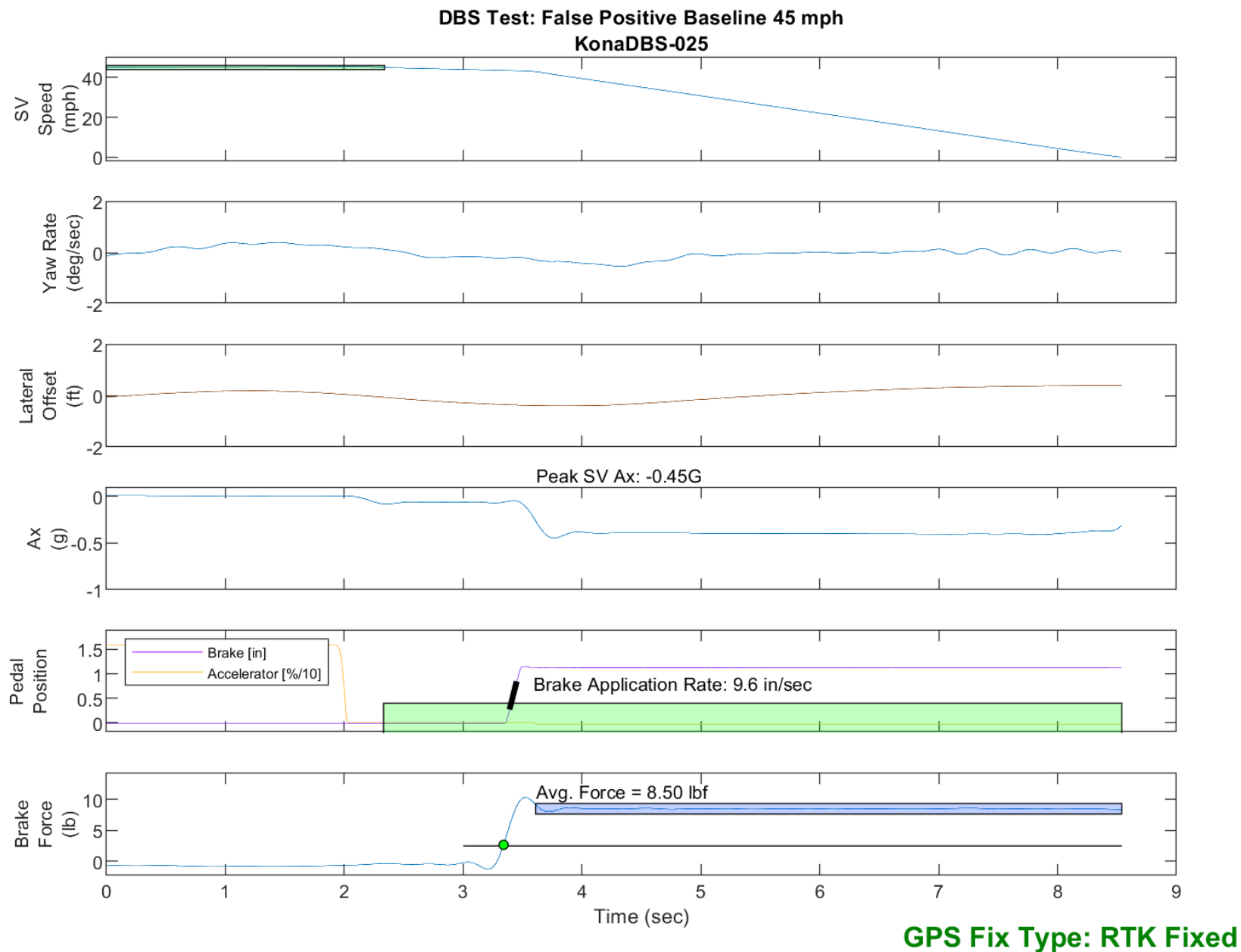


Figure E52. Time History for DBS Run 25, False Positive Baseline, SV 45 mph

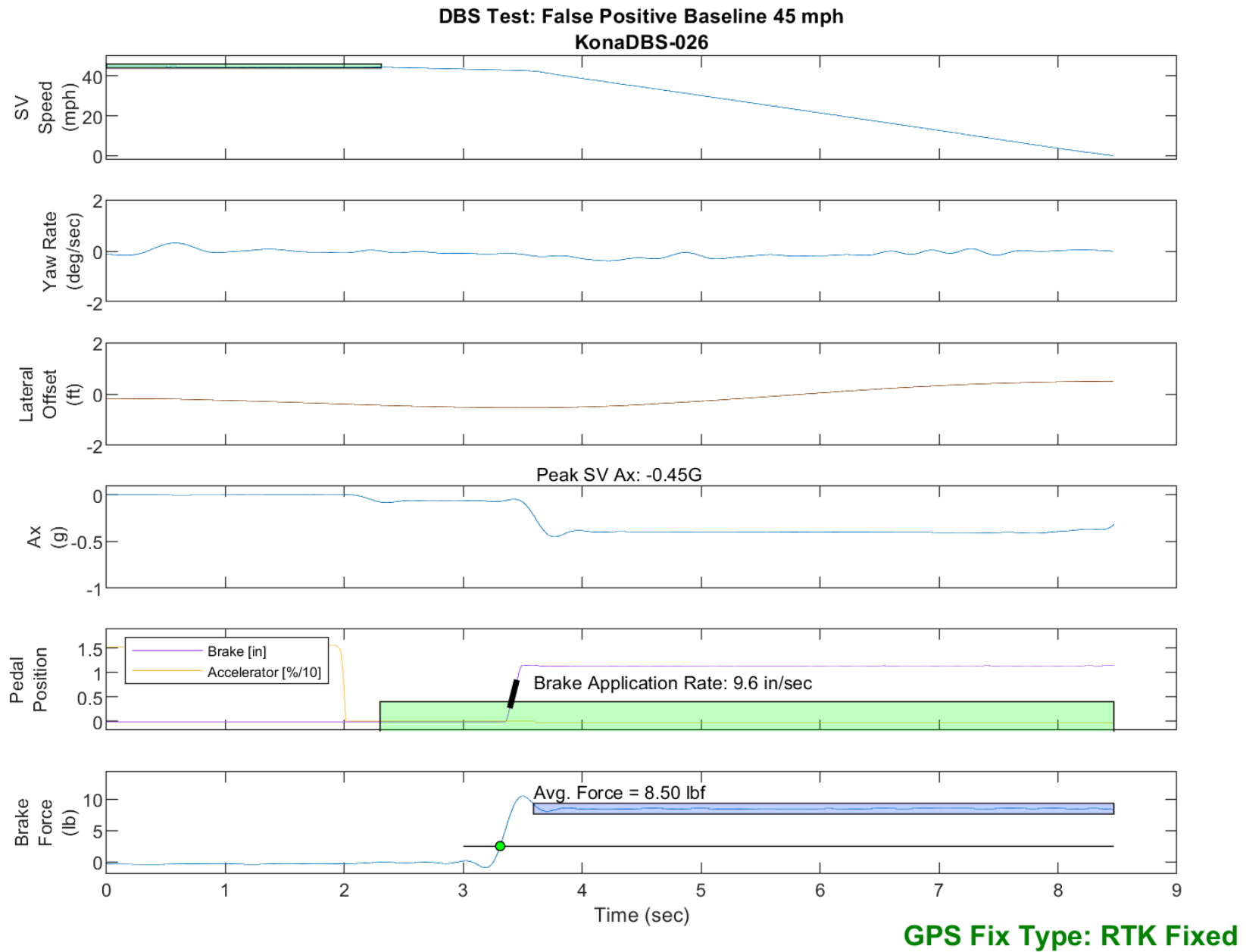


Figure E53. Time History for DBS Run 26, False Positive Baseline, SV 45 mph

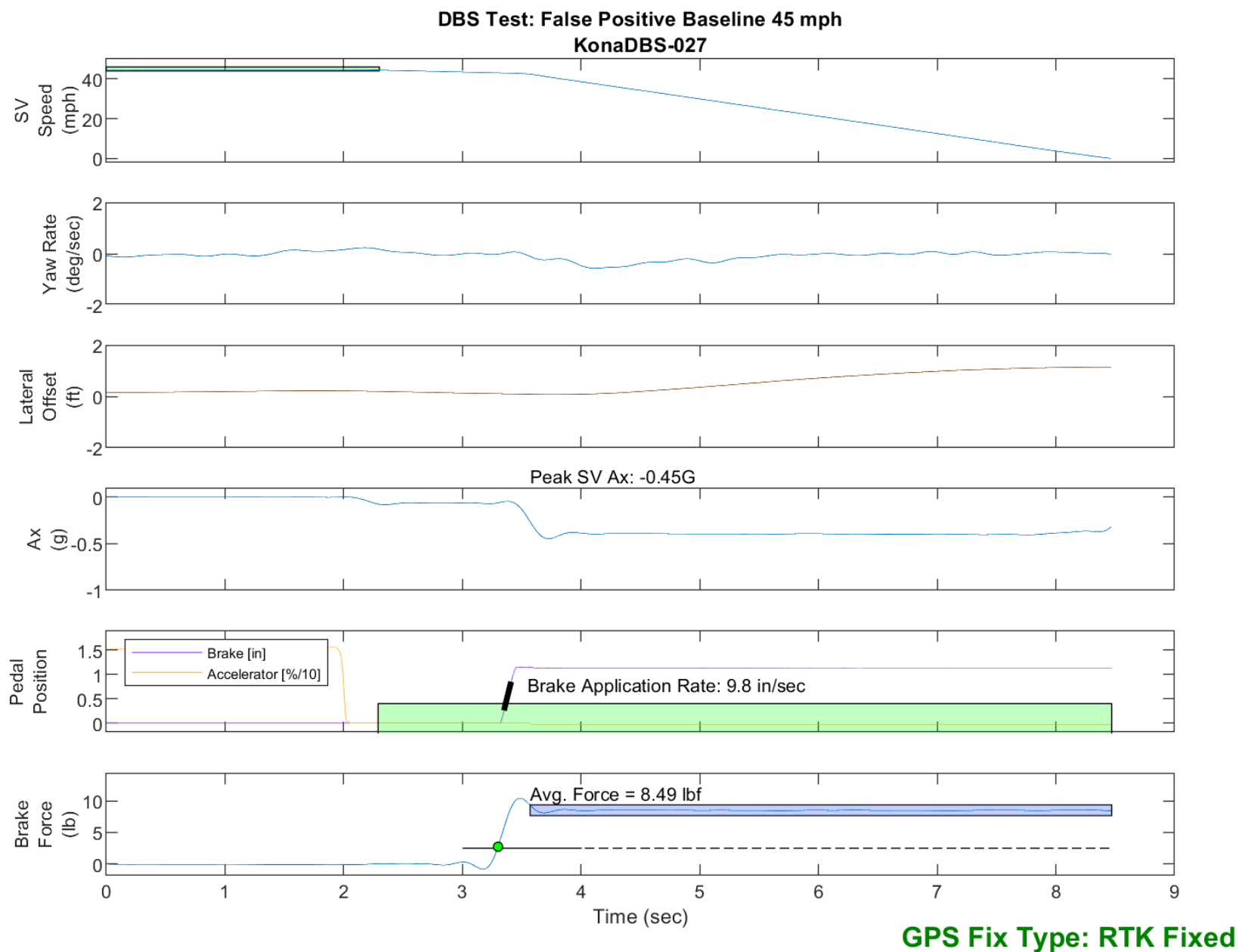


Figure E54. Time History for DBS Run 27, False Positive Baseline, SV 45 mph

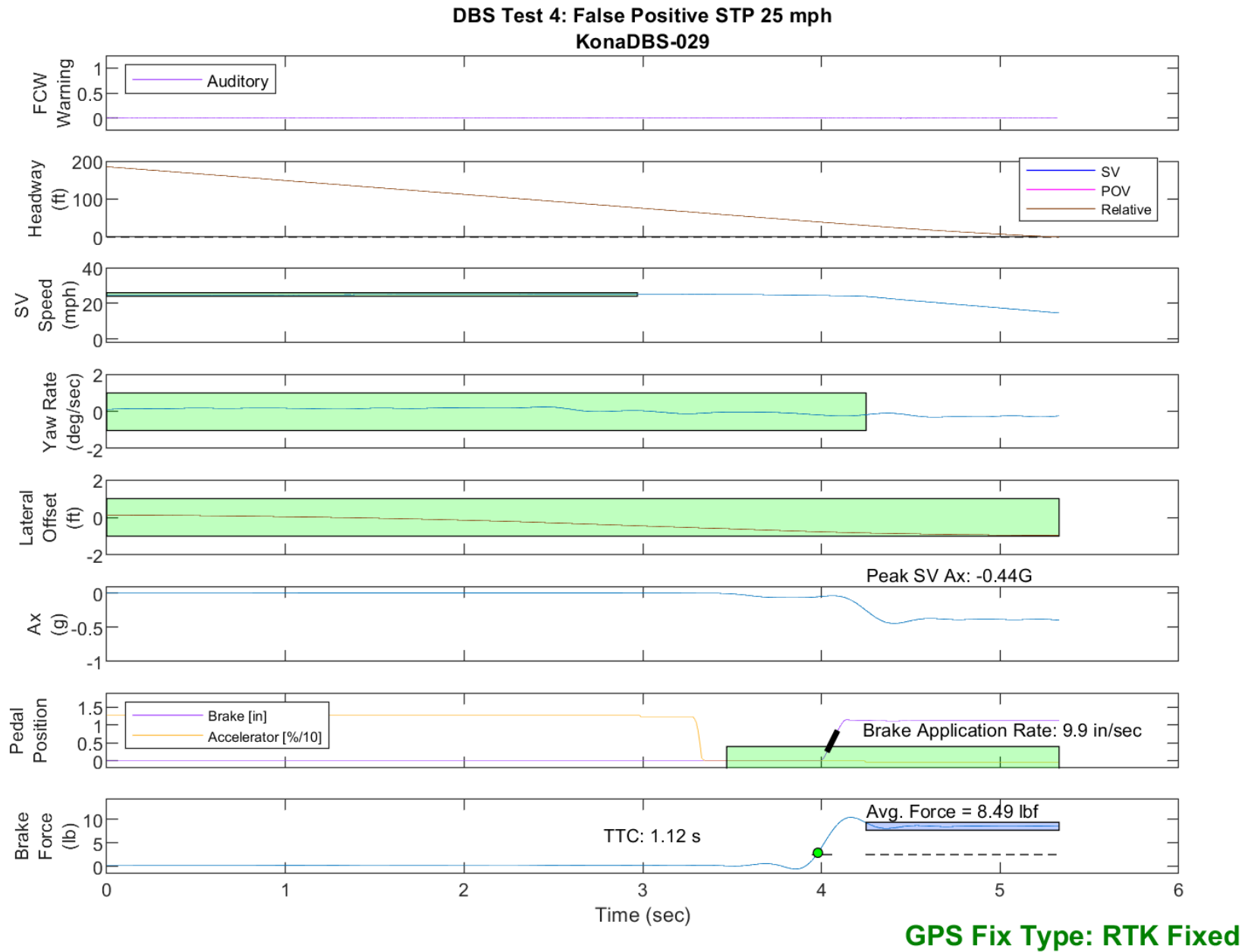


Figure E55. Time History for DBS Run 29, Test 4 - False Positive STP 25 mph

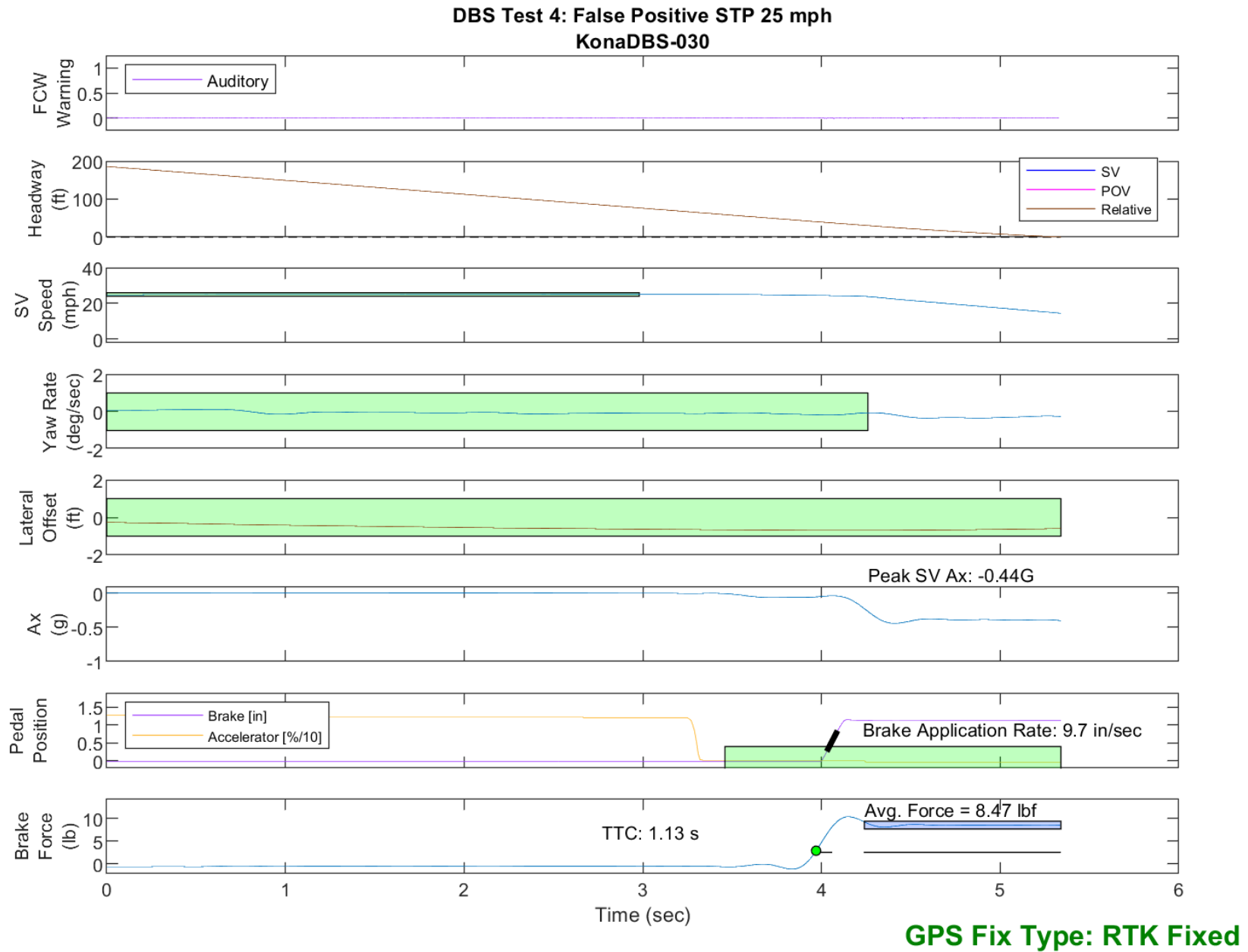


Figure E56. Time History for DBS Run 30, Test 4 - False Positive STP 25 mph

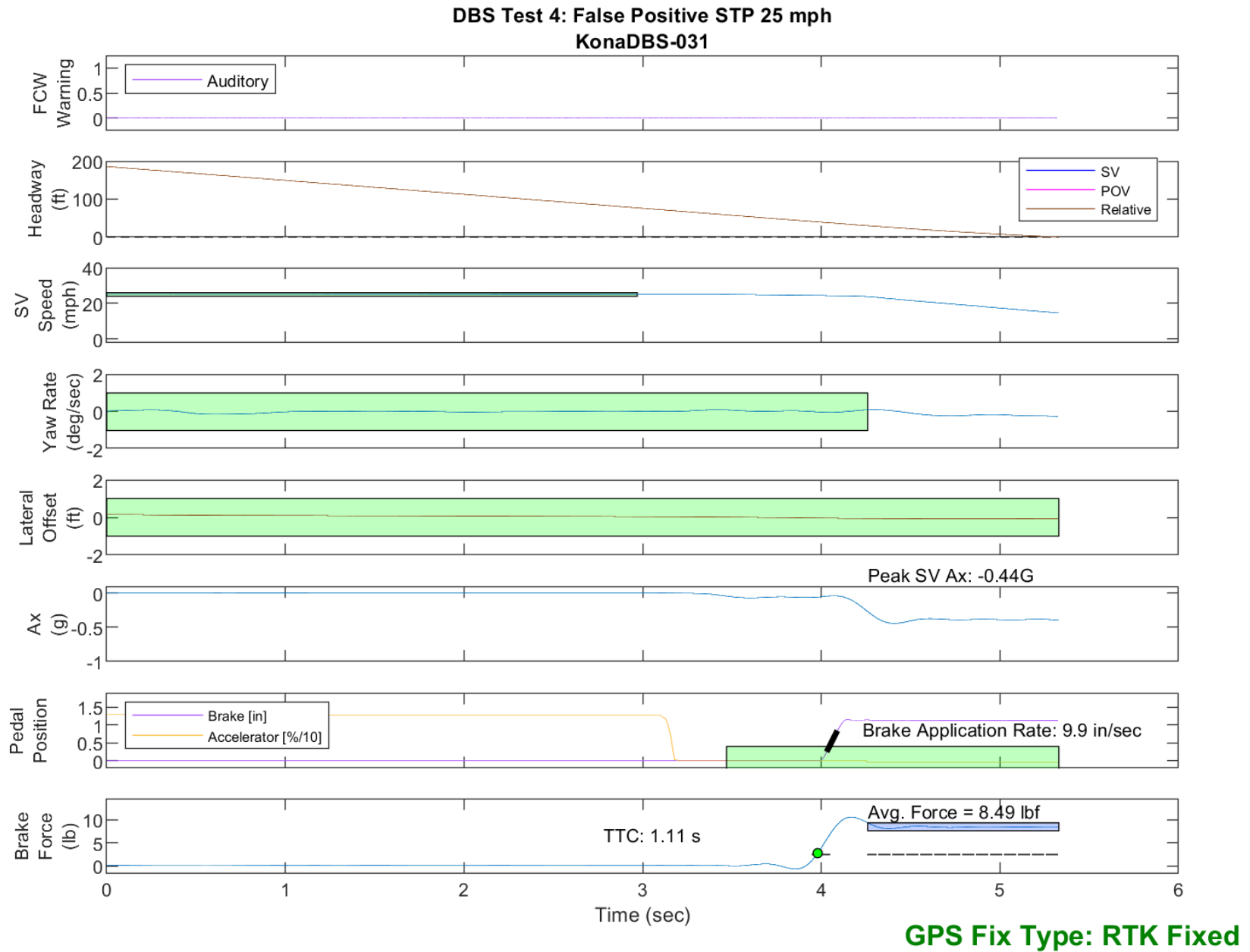


Figure E57. Time History for DBS Run 31, Test 4 - False Positive STP 25 mph

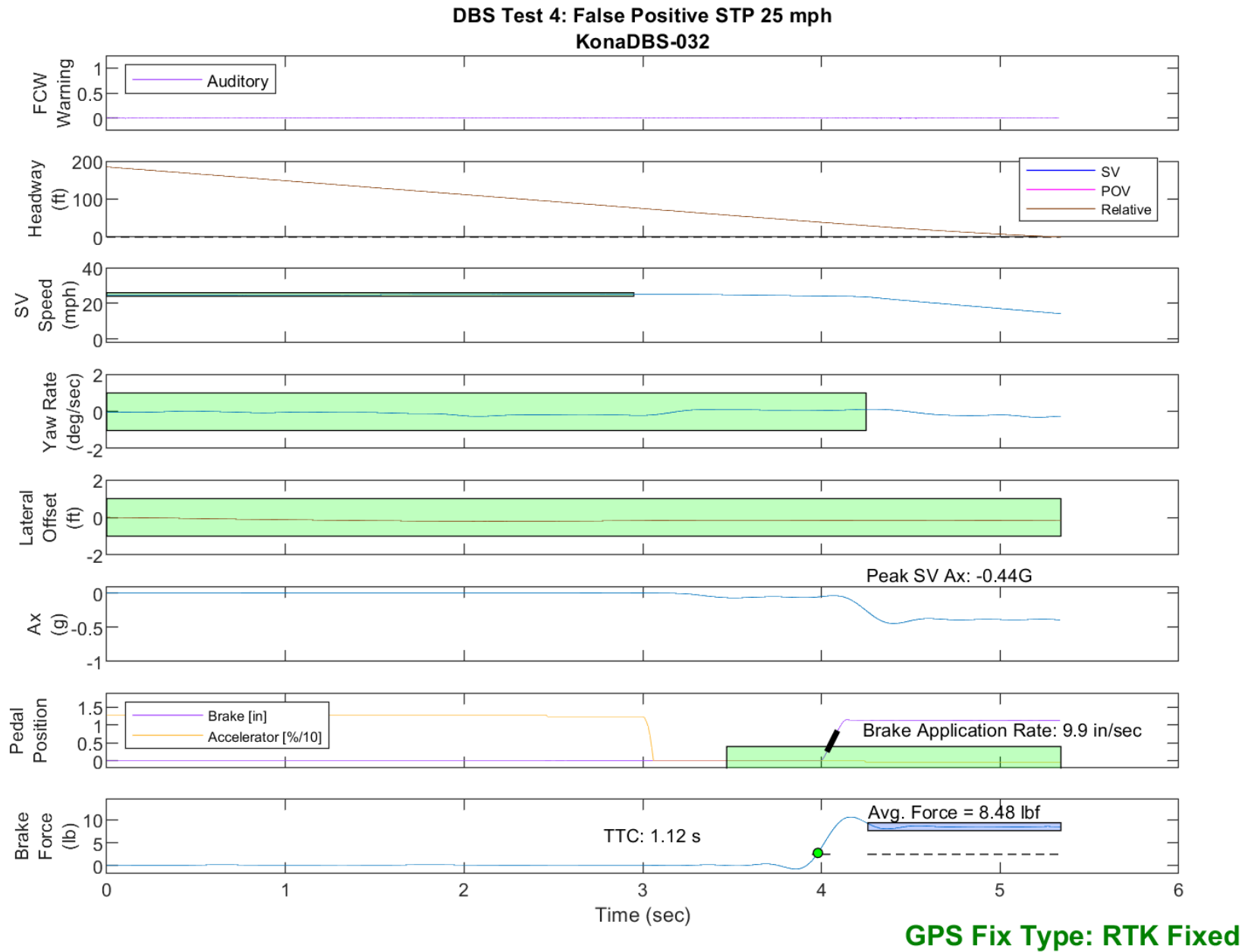


Figure E58. Time History for DBS Run 32, Test 4 - False Positive STP 25 mph

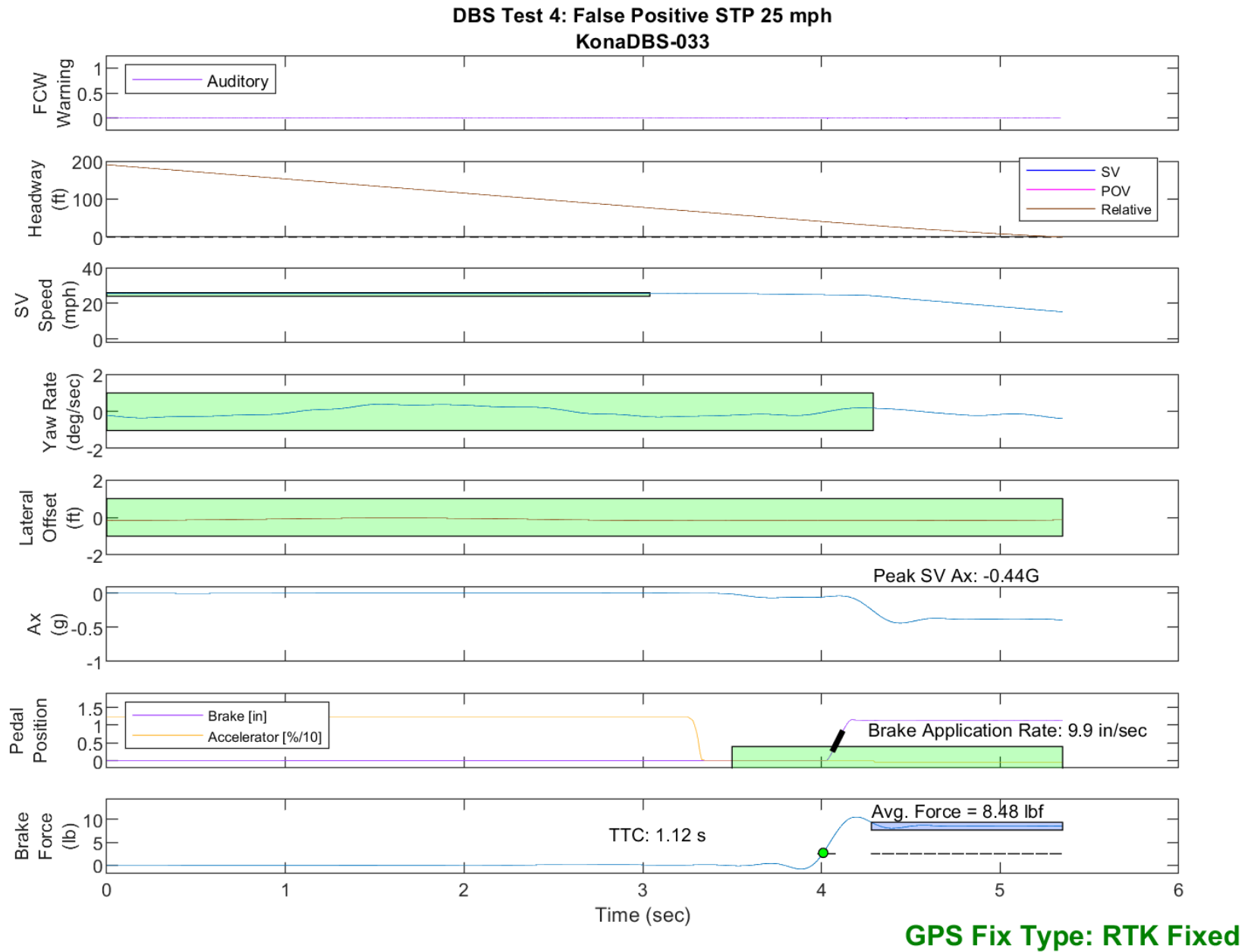


Figure E59. Time History for DBS Run 33, Test 4 - False Positive STP 25 mph

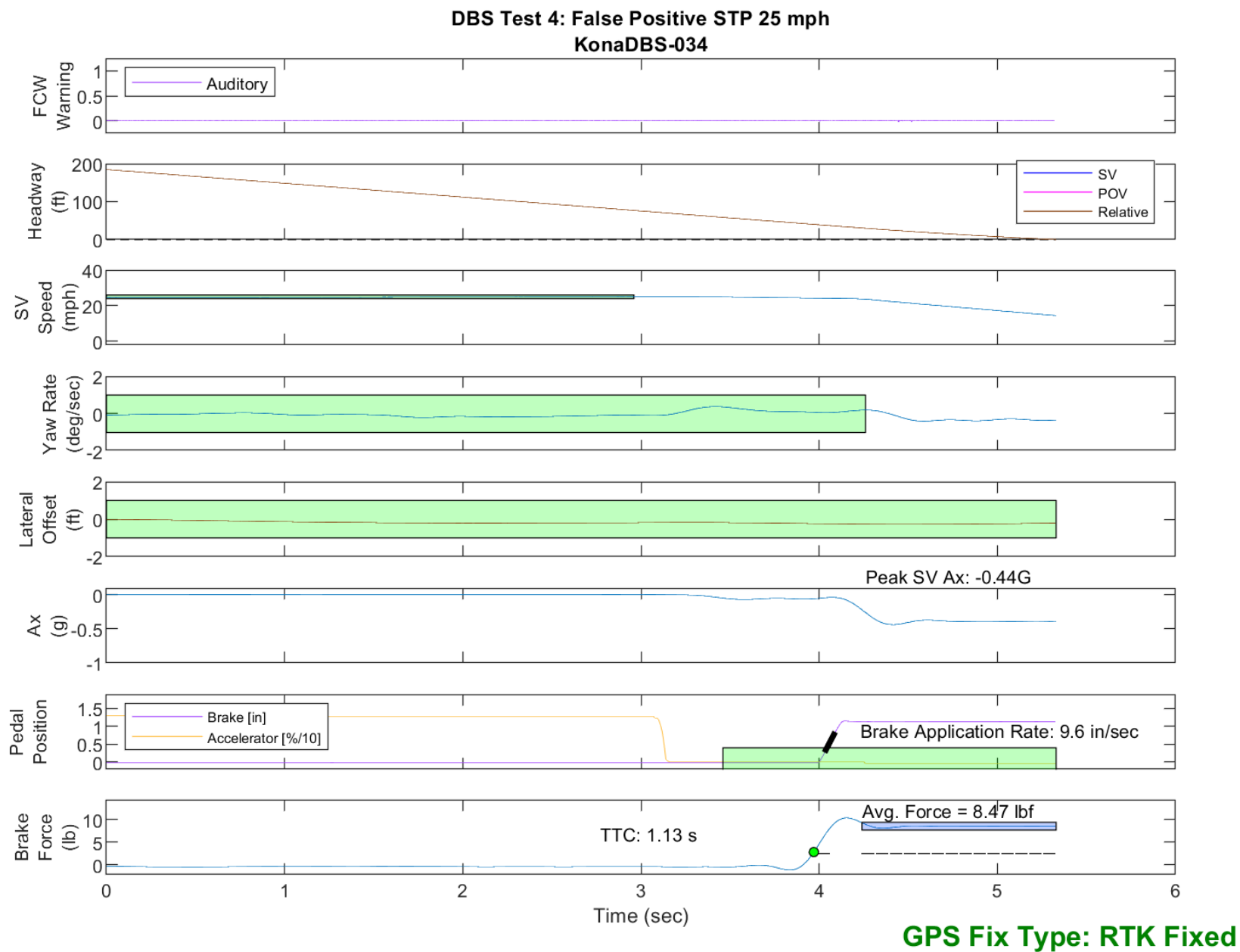


Figure E60. Time History for DBS Run 34, Test 4 - False Positive STP 25 mph

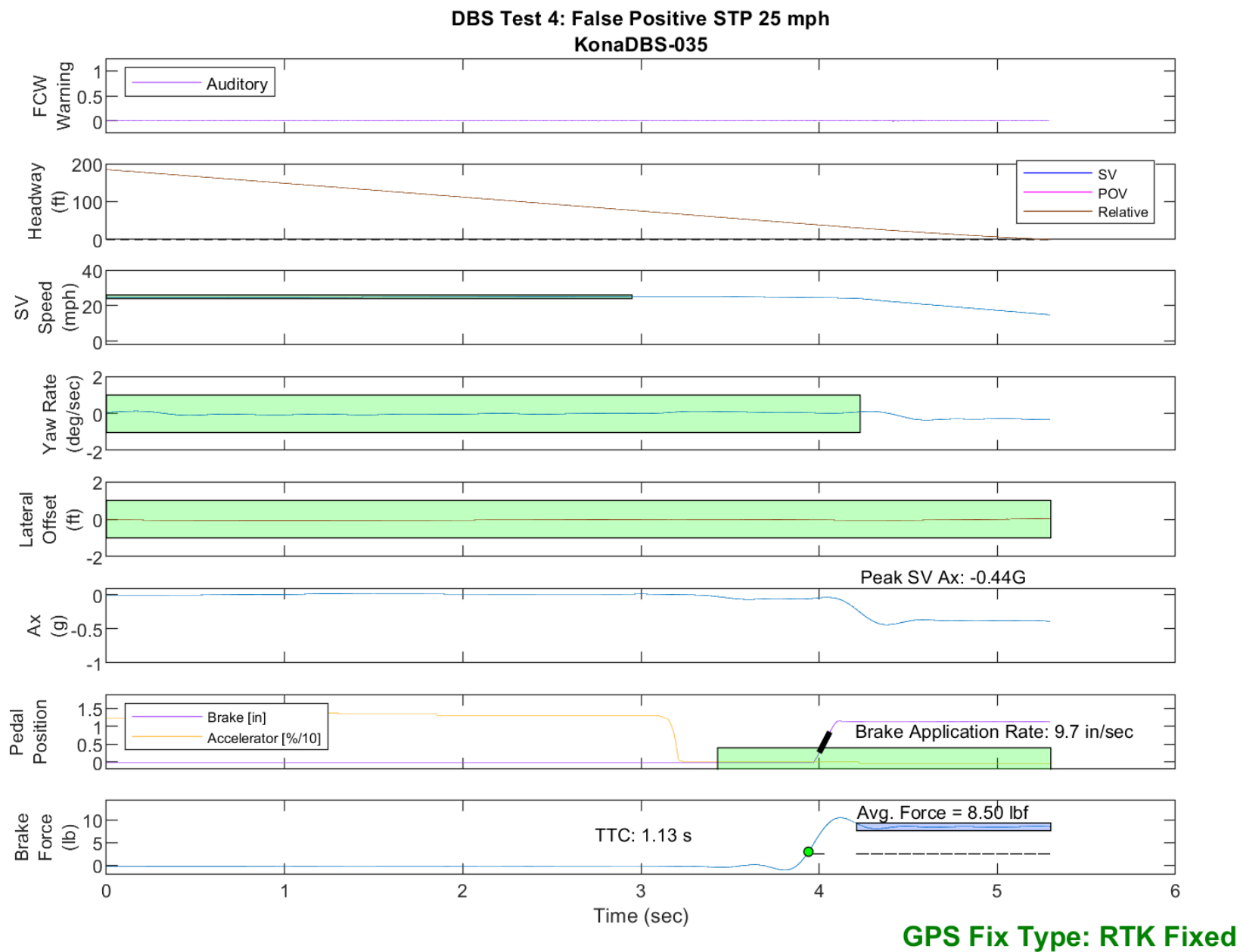
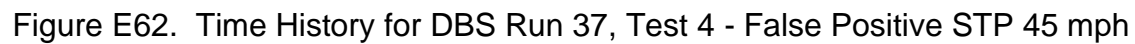


Figure E61. Time History for DBS Run 35, Test 4 - False Positive STP 25 mph



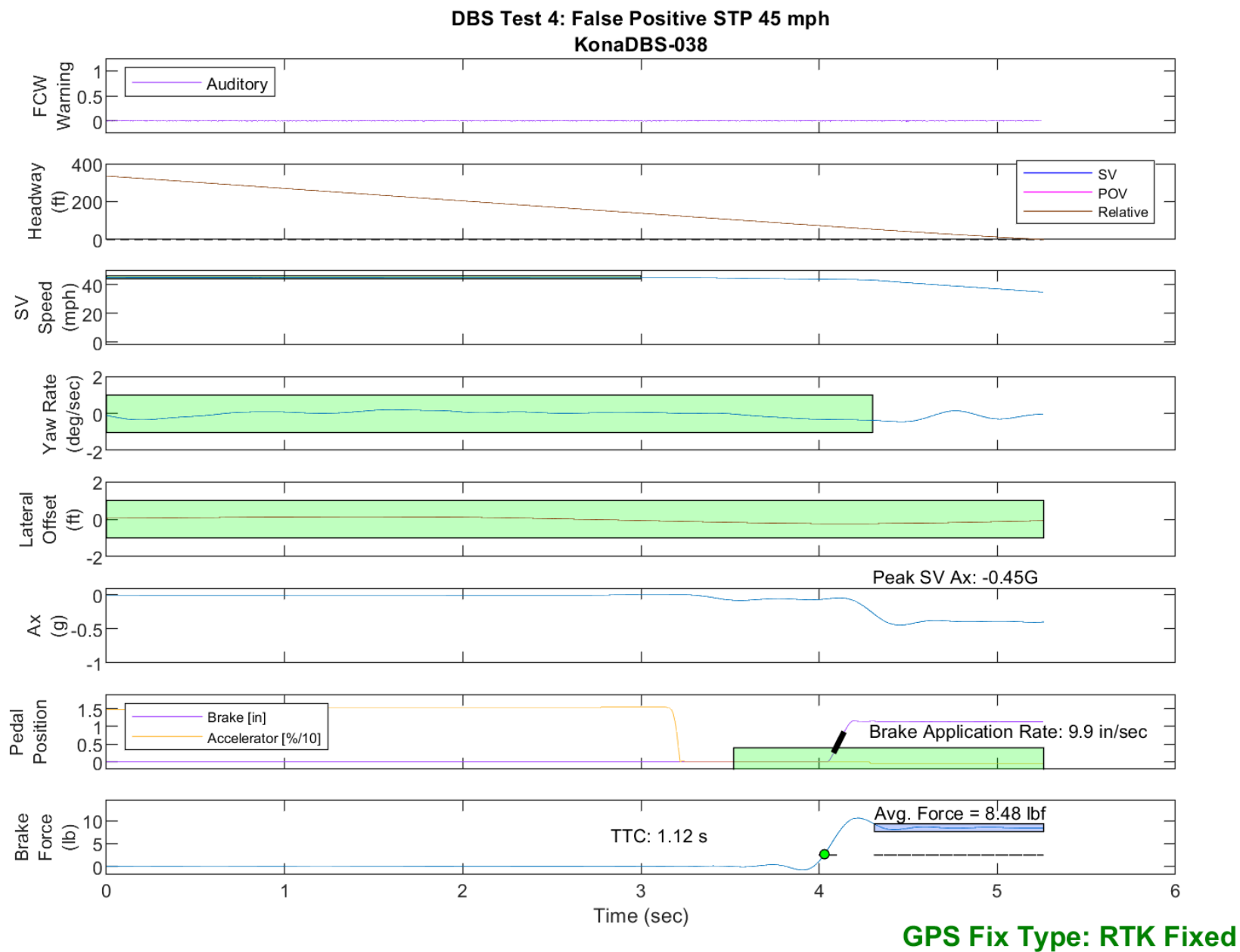


Figure E63. Time History for DBS Run 38, Test 4 - False Positive STP 45 mph

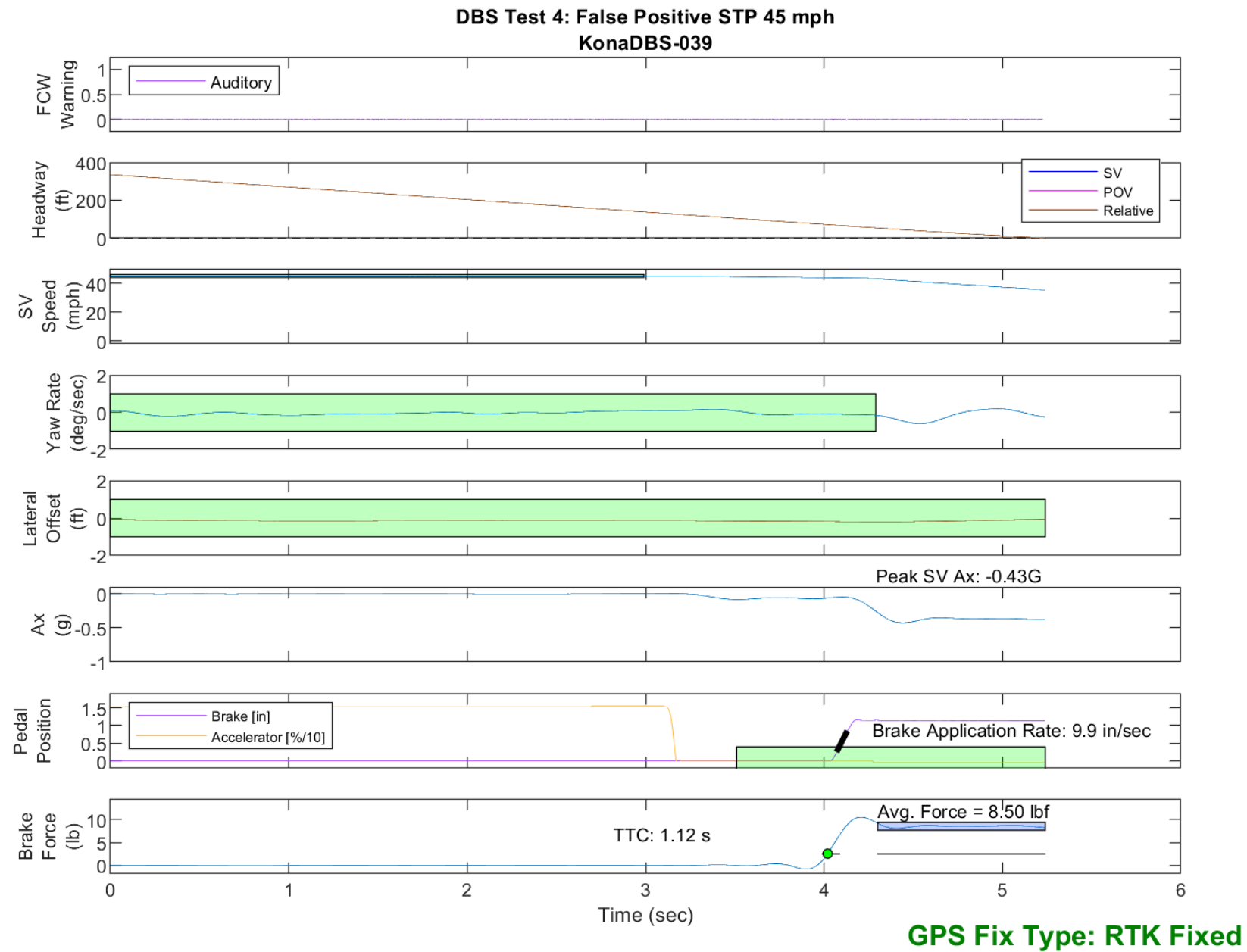


Figure E64. Time History for DBS Run 39, Test 4 - False Positive STP 45 mph

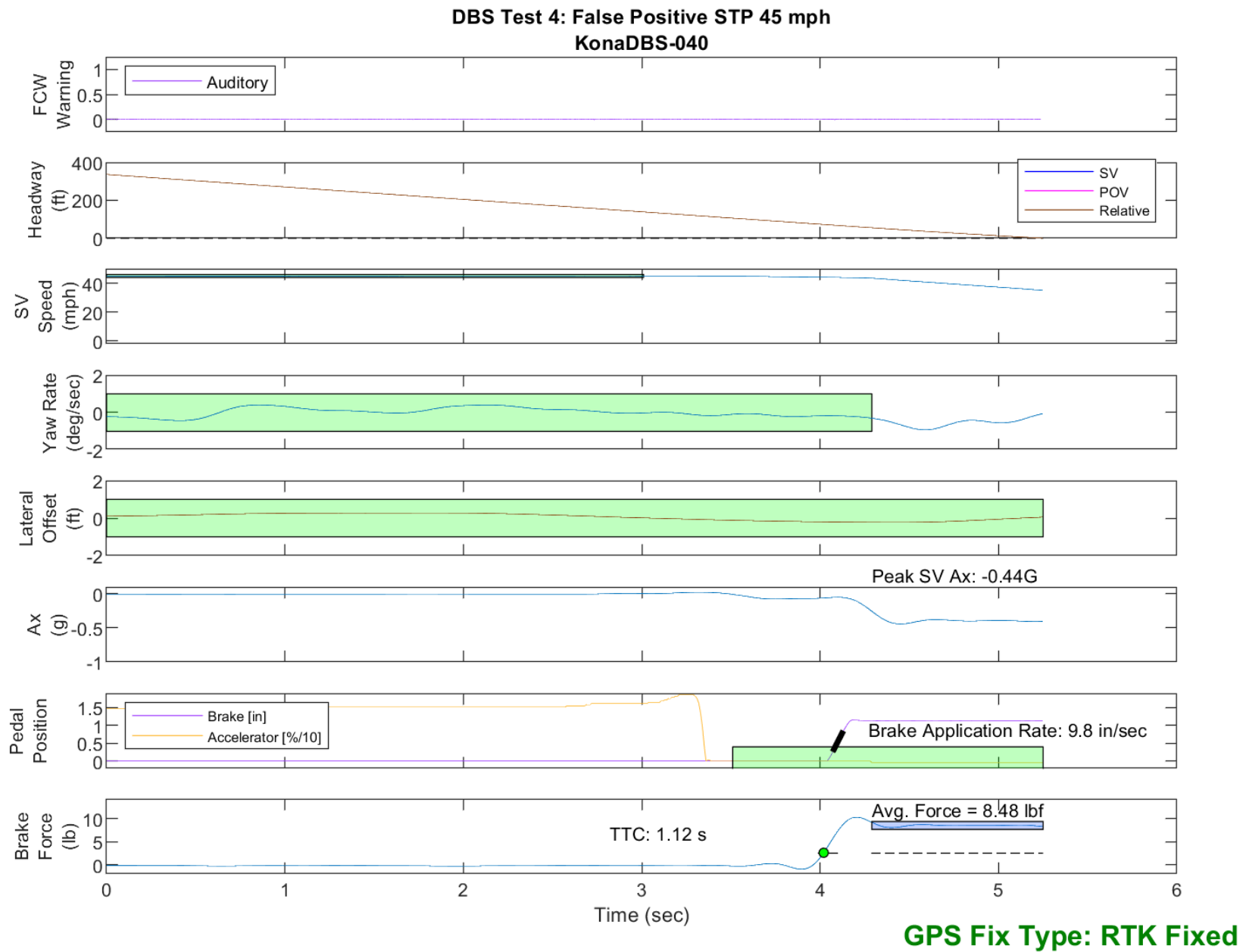


Figure E65. Time History for DBS Run 40, Test 4 - False Positive STP 45 mph

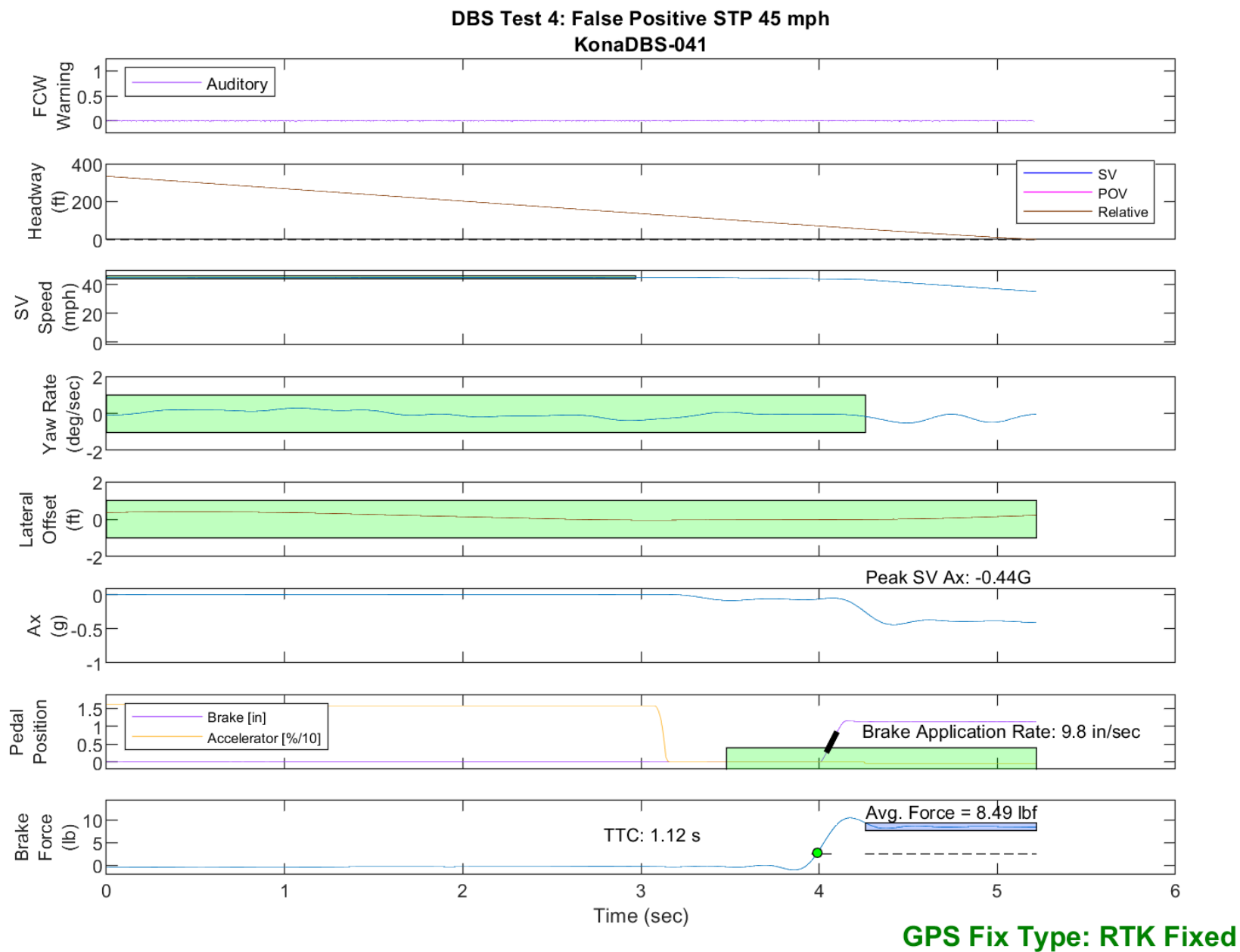


Figure E66. Time History for DBS Run 41, Test 4 - False Positive STP 45 mph

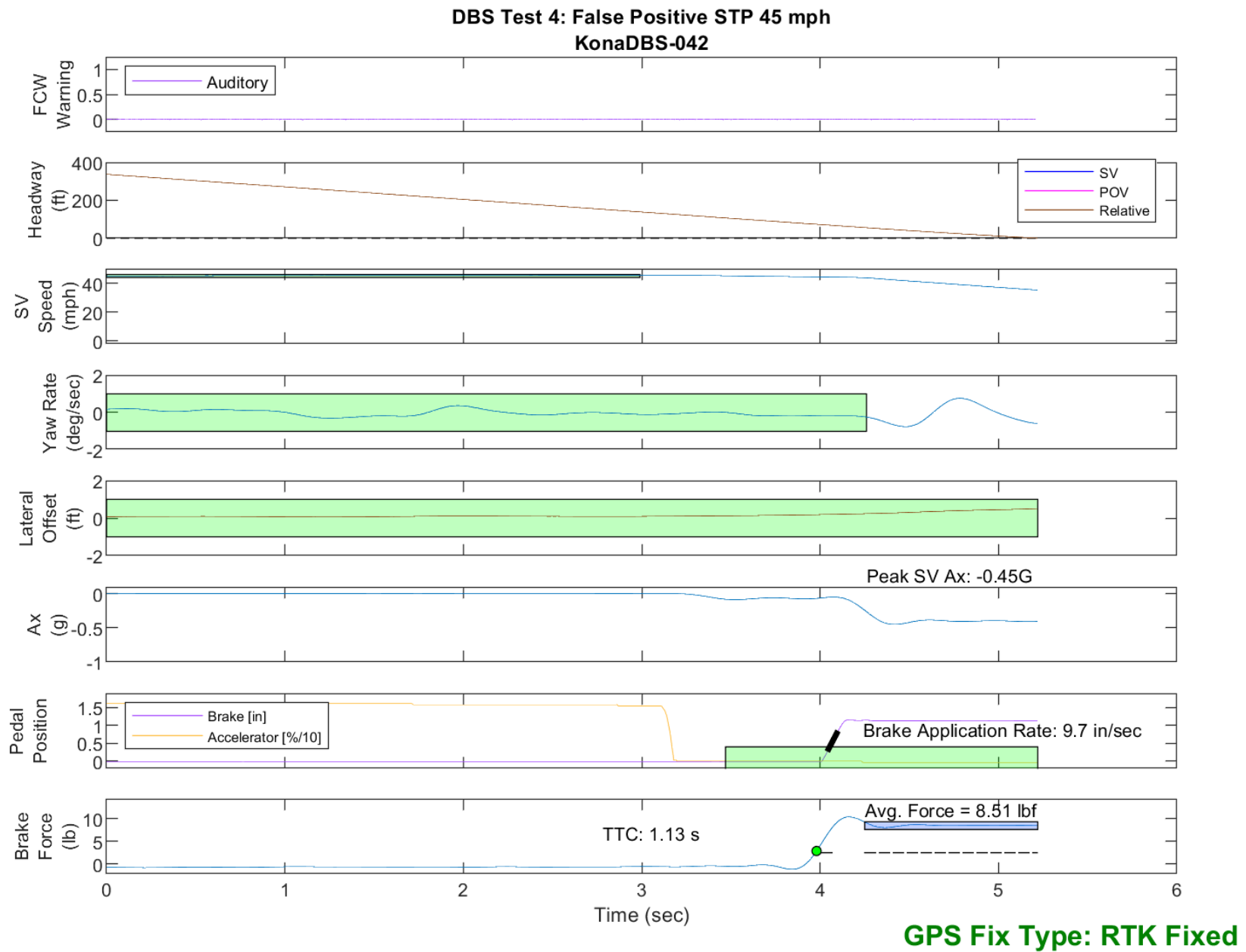


Figure E67. Time History for DBS Run 42, Test 4 - False Positive STP 45 mph

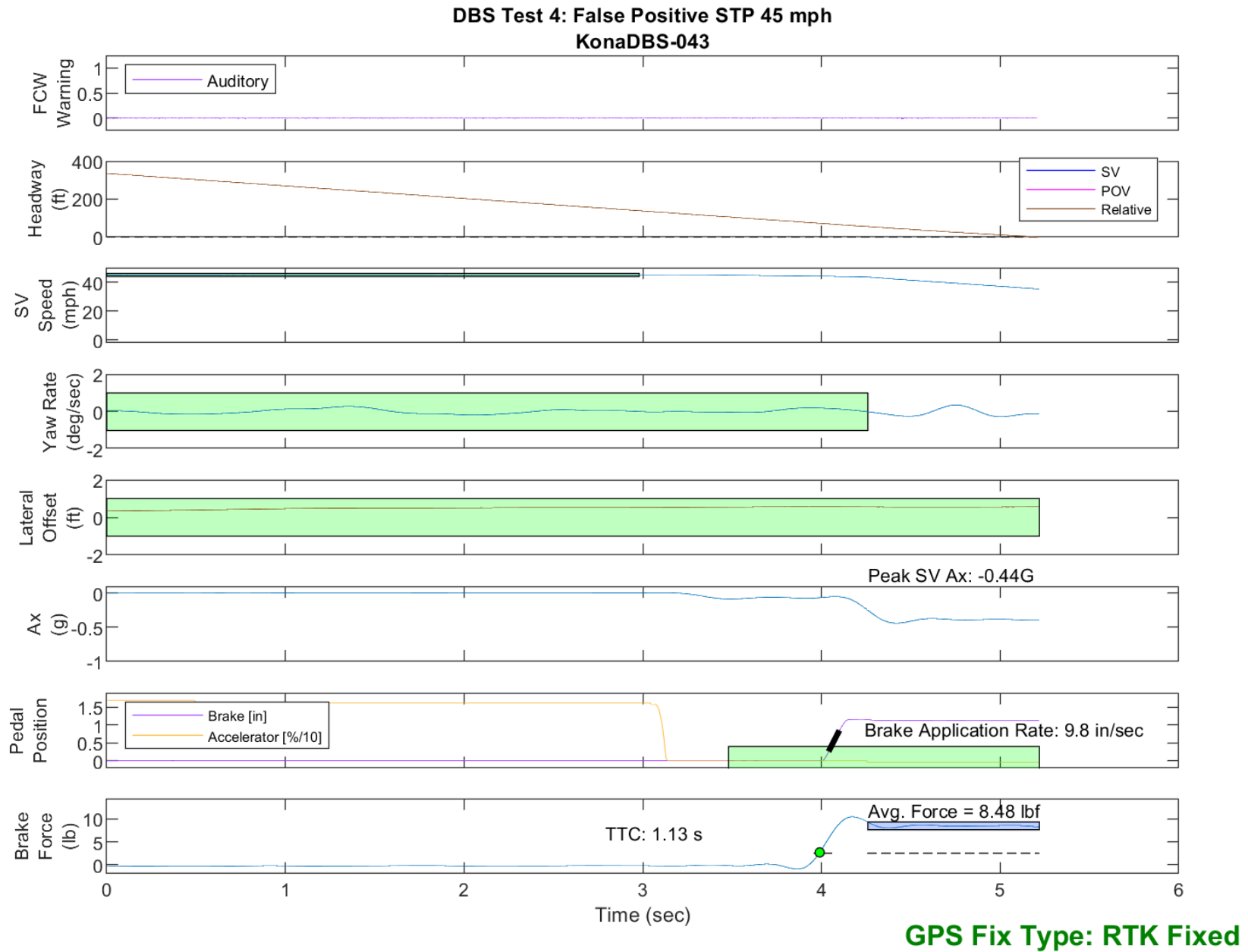


Figure E68. Time History for DBS Run 43, Test 4 - False Positive STP 45 mph

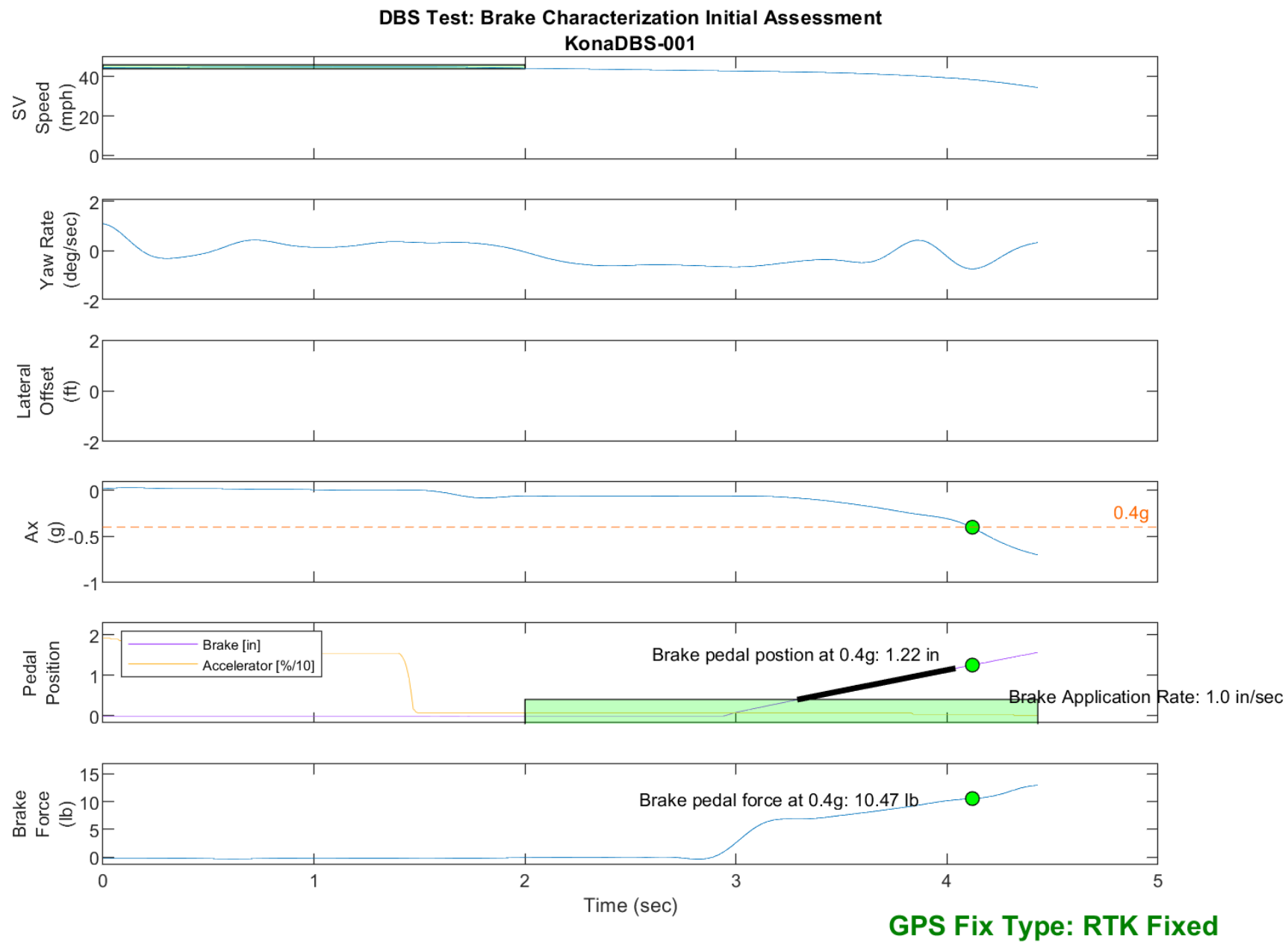


Figure E69. Time History for DBS Run 1, Brake Characterization Initial

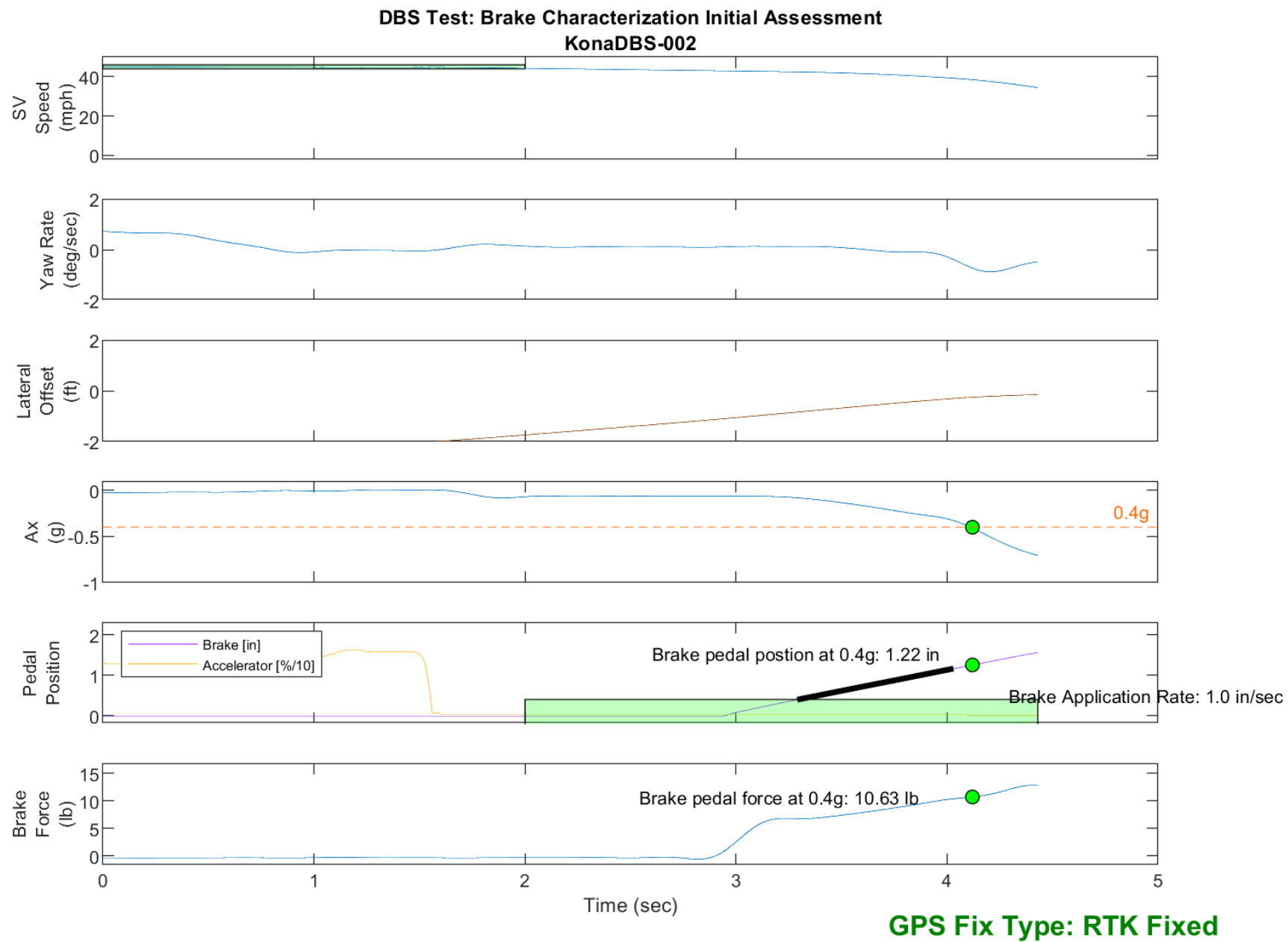


Figure E70. Time History for DBS Run 2, Brake Characterization Initial

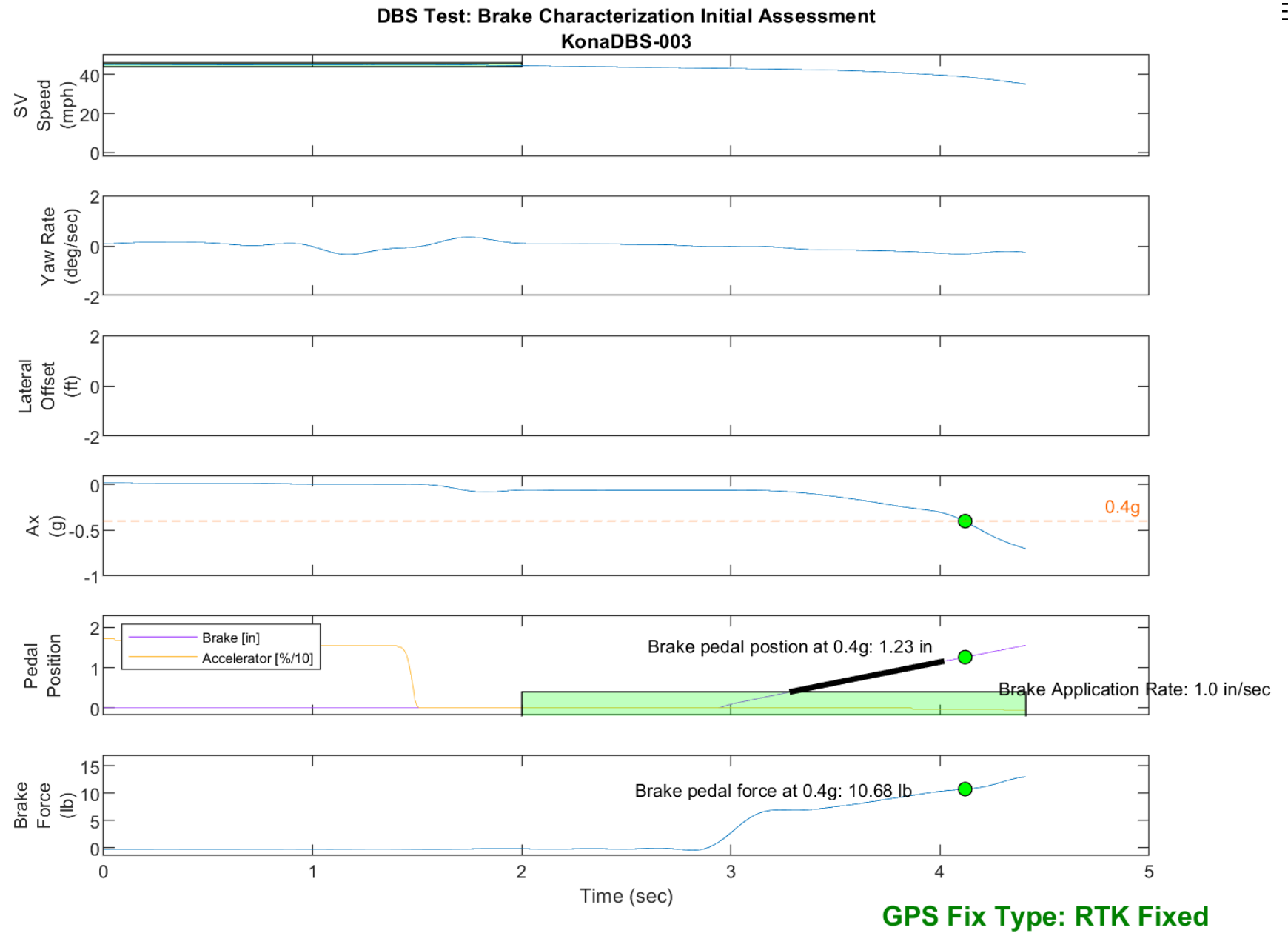


Figure E71. Time History for DBS Run 3, Brake Characterization Initial

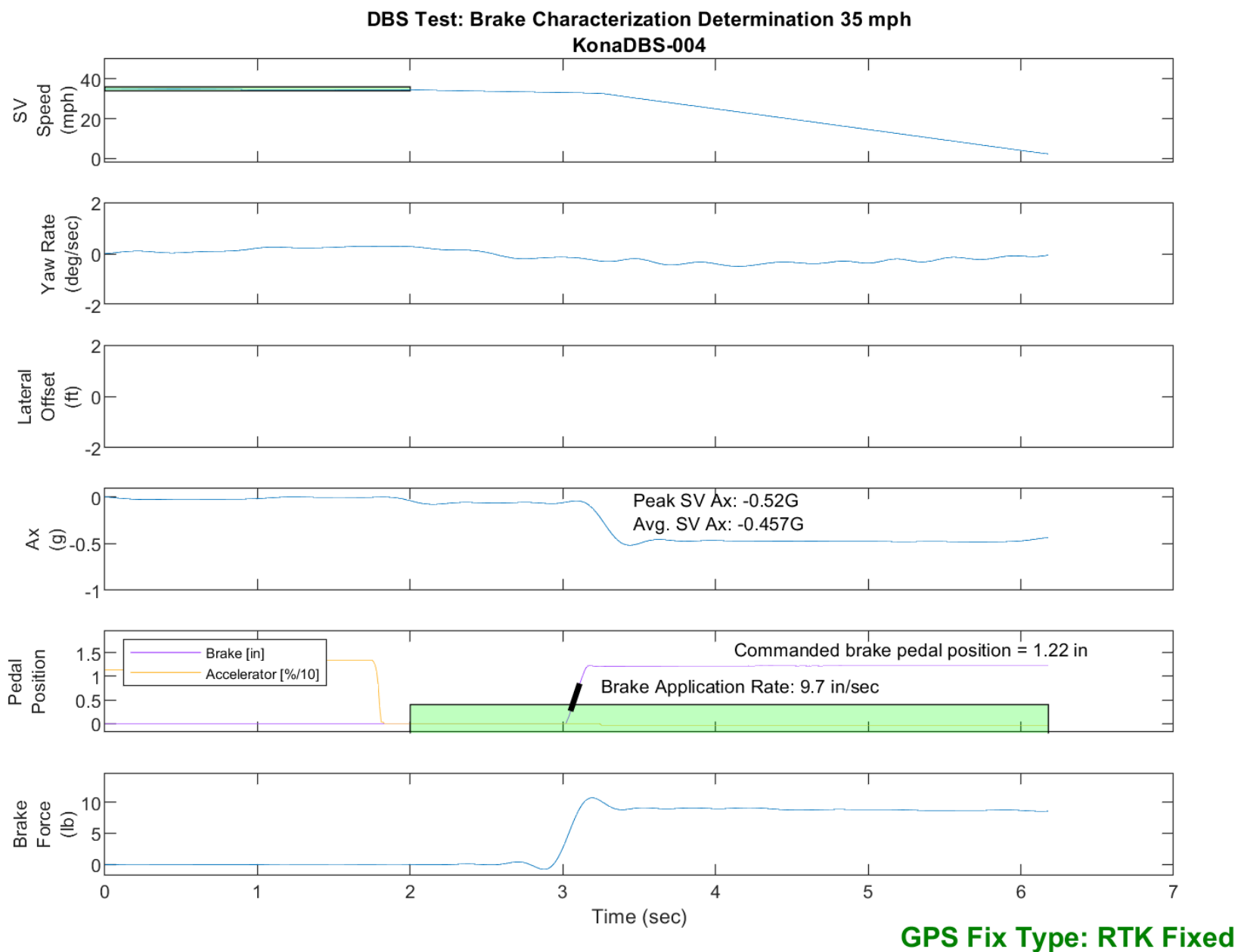


Figure E72. Time History for DBS Run 4, Brake Characterization Determination, Displacement Mode, 35 mph

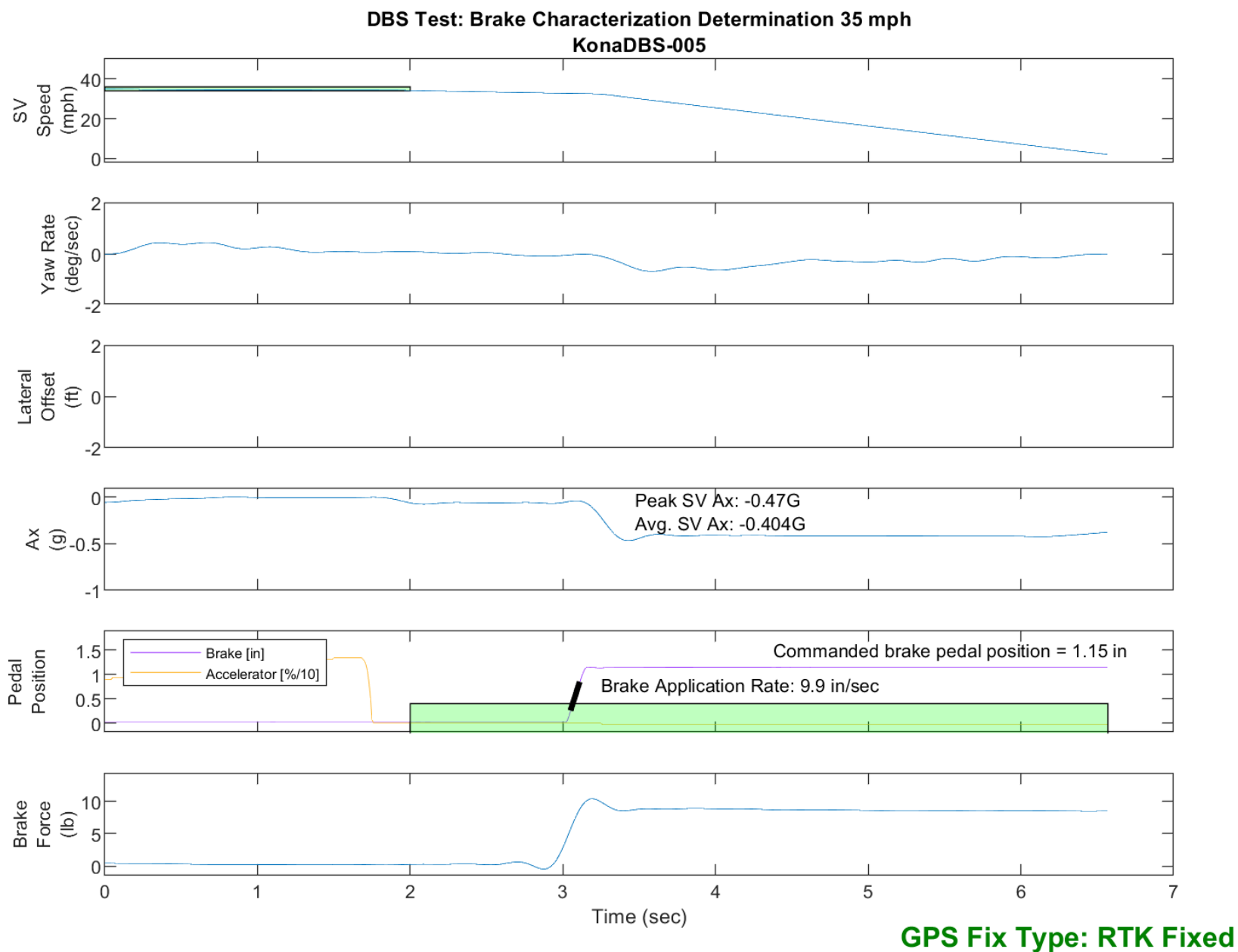


Figure E73. Time History for DBS Run 5, Brake Characterization Determination, Displacement Mode, 35 mph

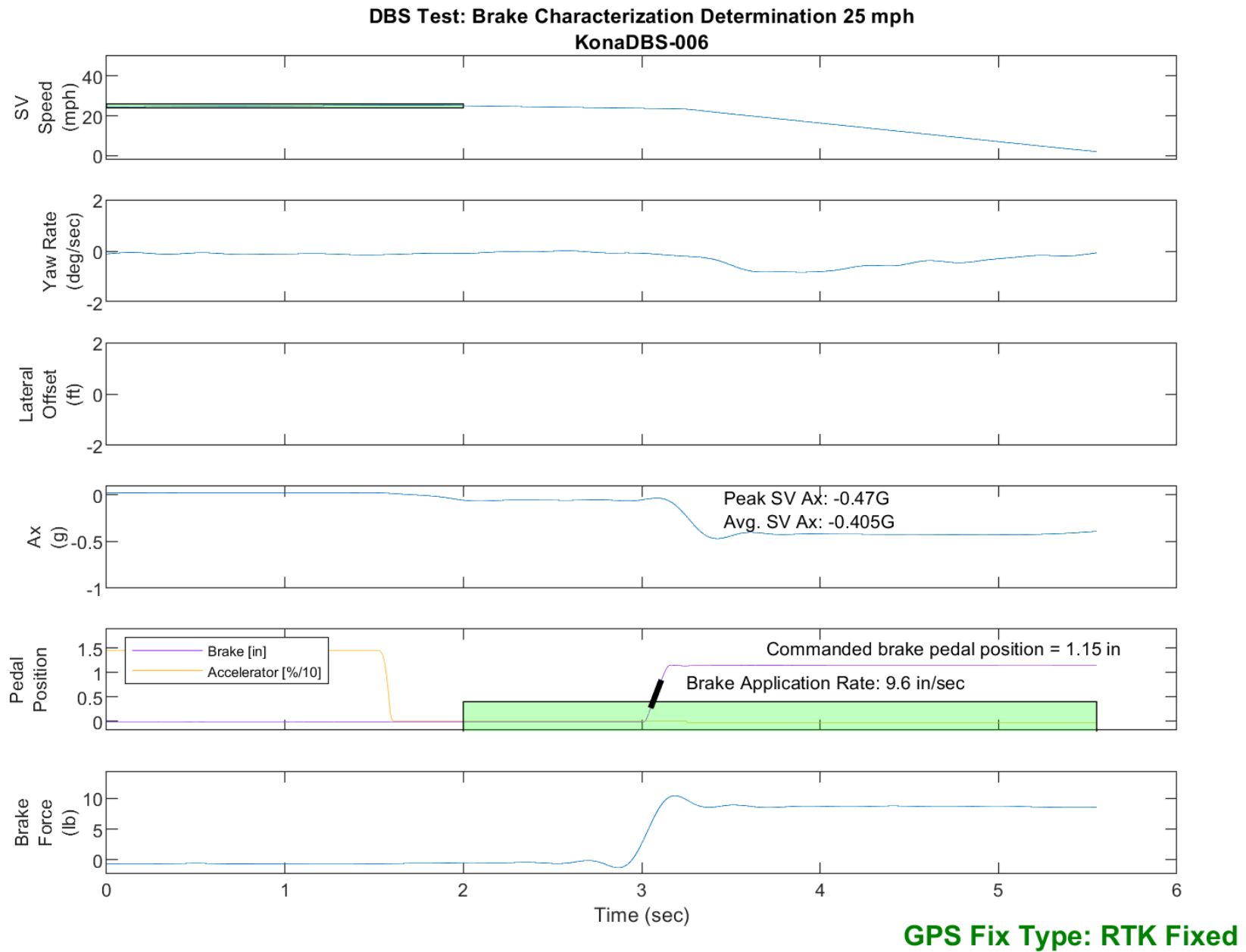


Figure E74. Time History for DBS Run 6, Brake Characterization Determination, Displacement Mode, 25 mph

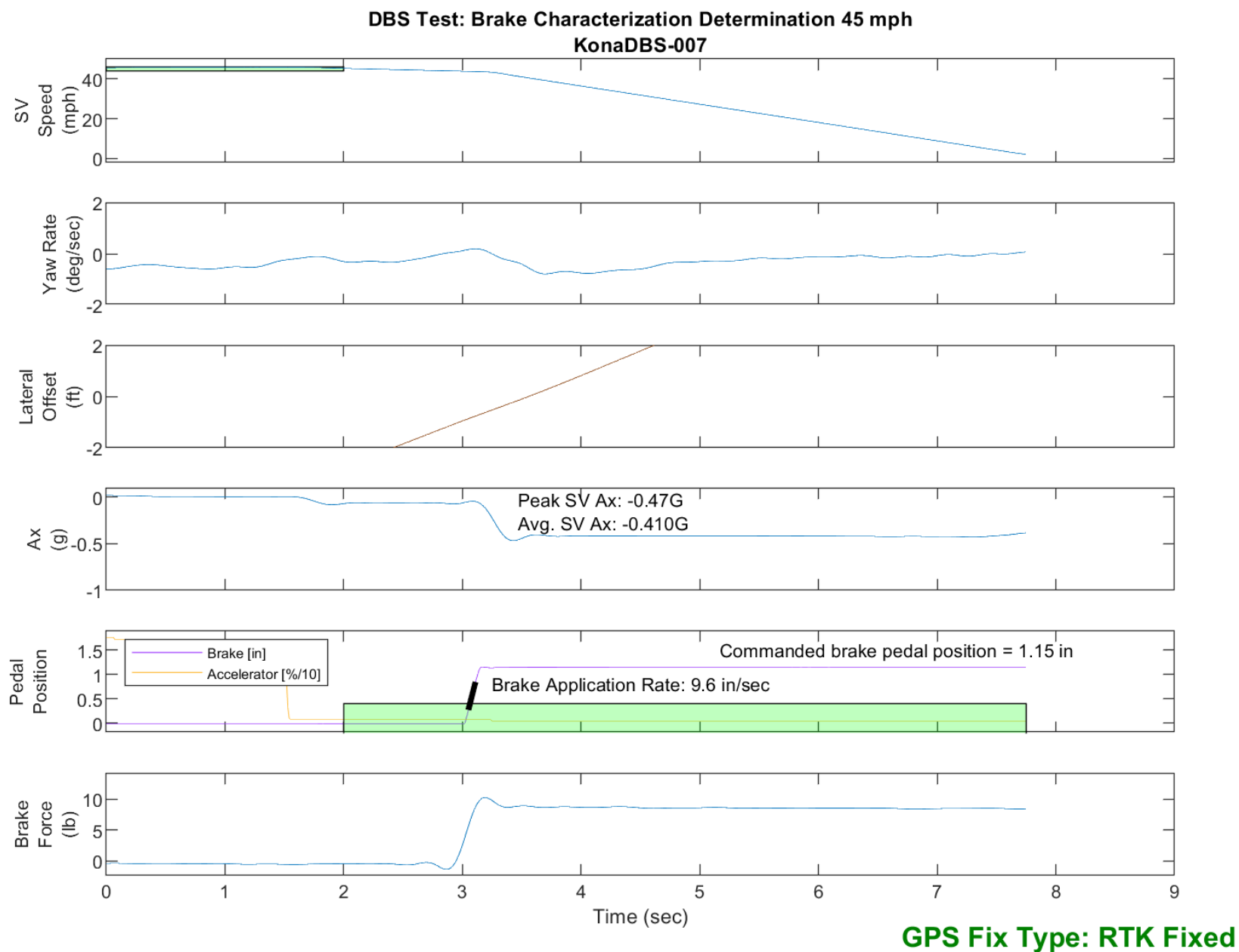


Figure E75. Time History for DBS Run 7, Brake Characterization Determination, Displacement Mode, 45 mph

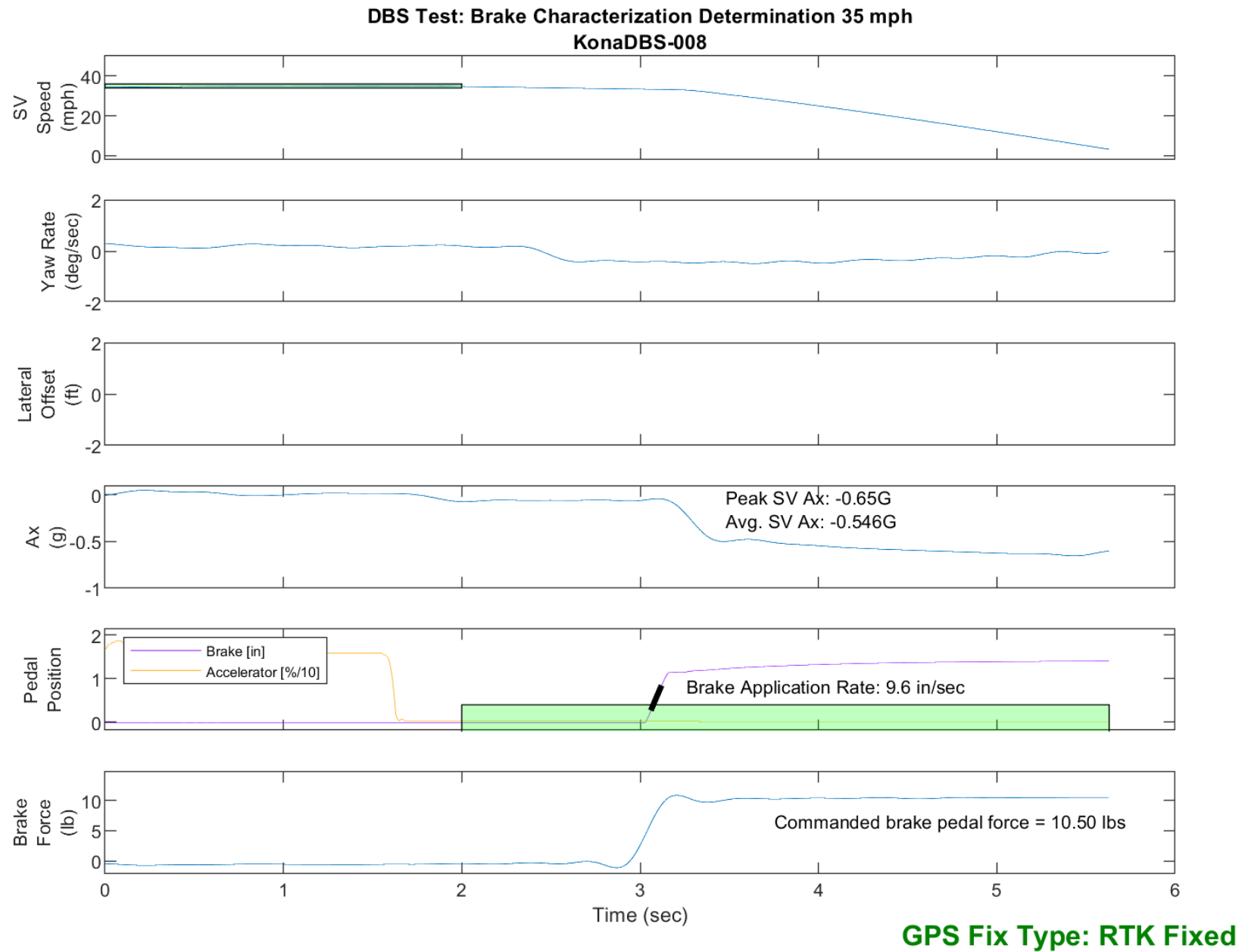


Figure E76. Time History for DBS Run 8, Brake Characterization Determination, Hybrid Mode, 35 mph

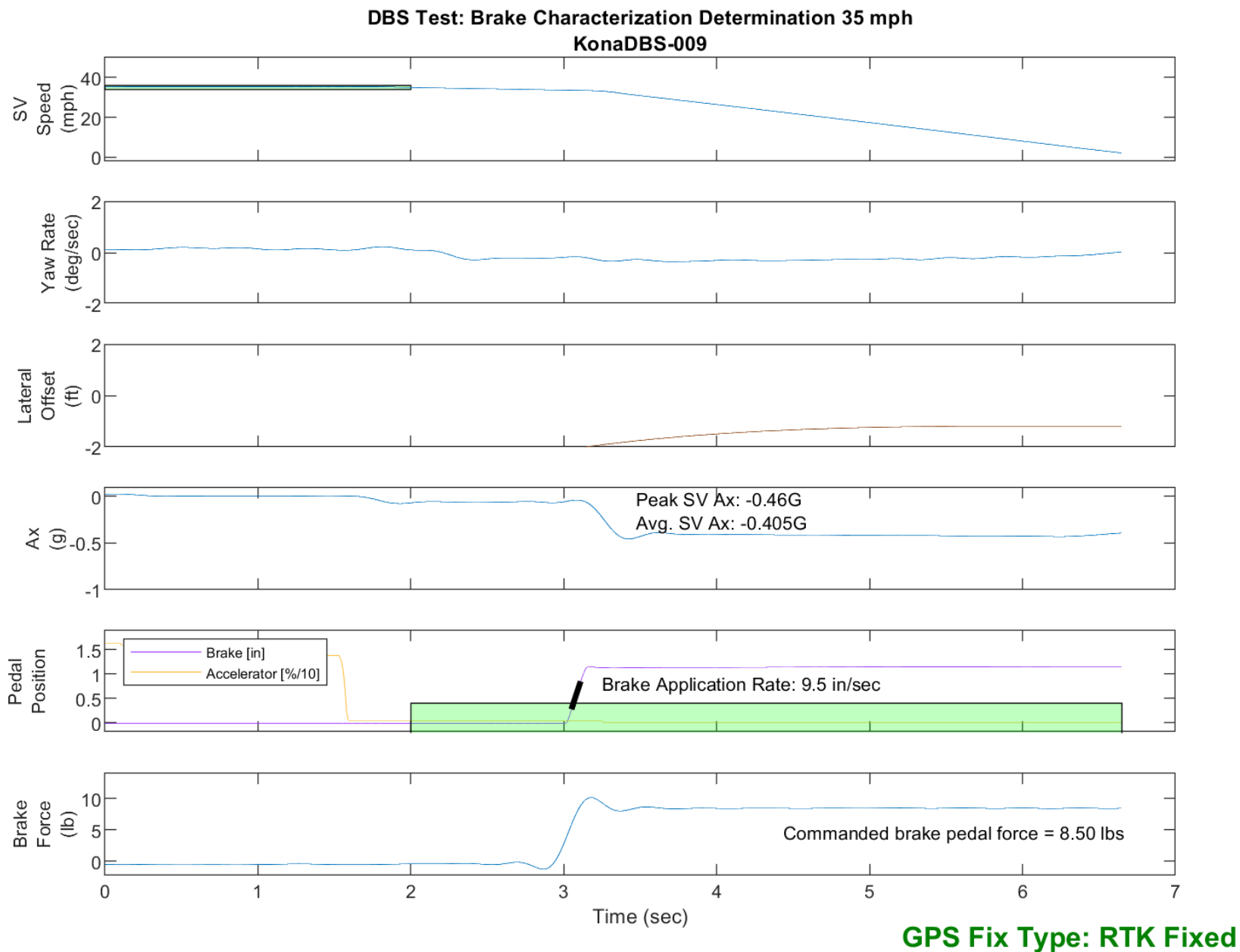


Figure E77. Time History for DBS Run 9, Brake Characterization Determination, Hybrid Mode, 35 mph

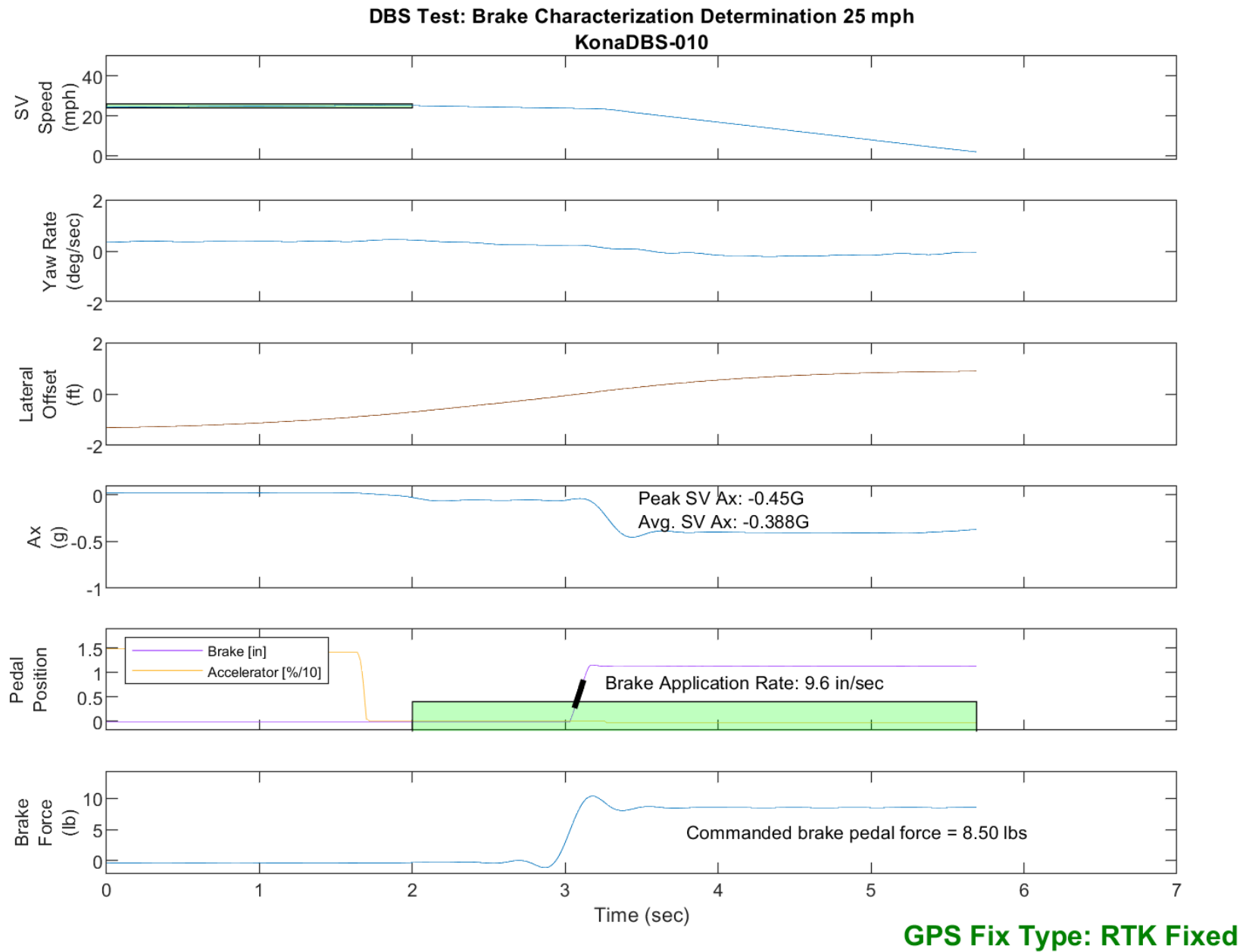


Figure E78. Time History for DBS Run 10, Brake Characterization Determination, Hybrid Mode, 25 mph

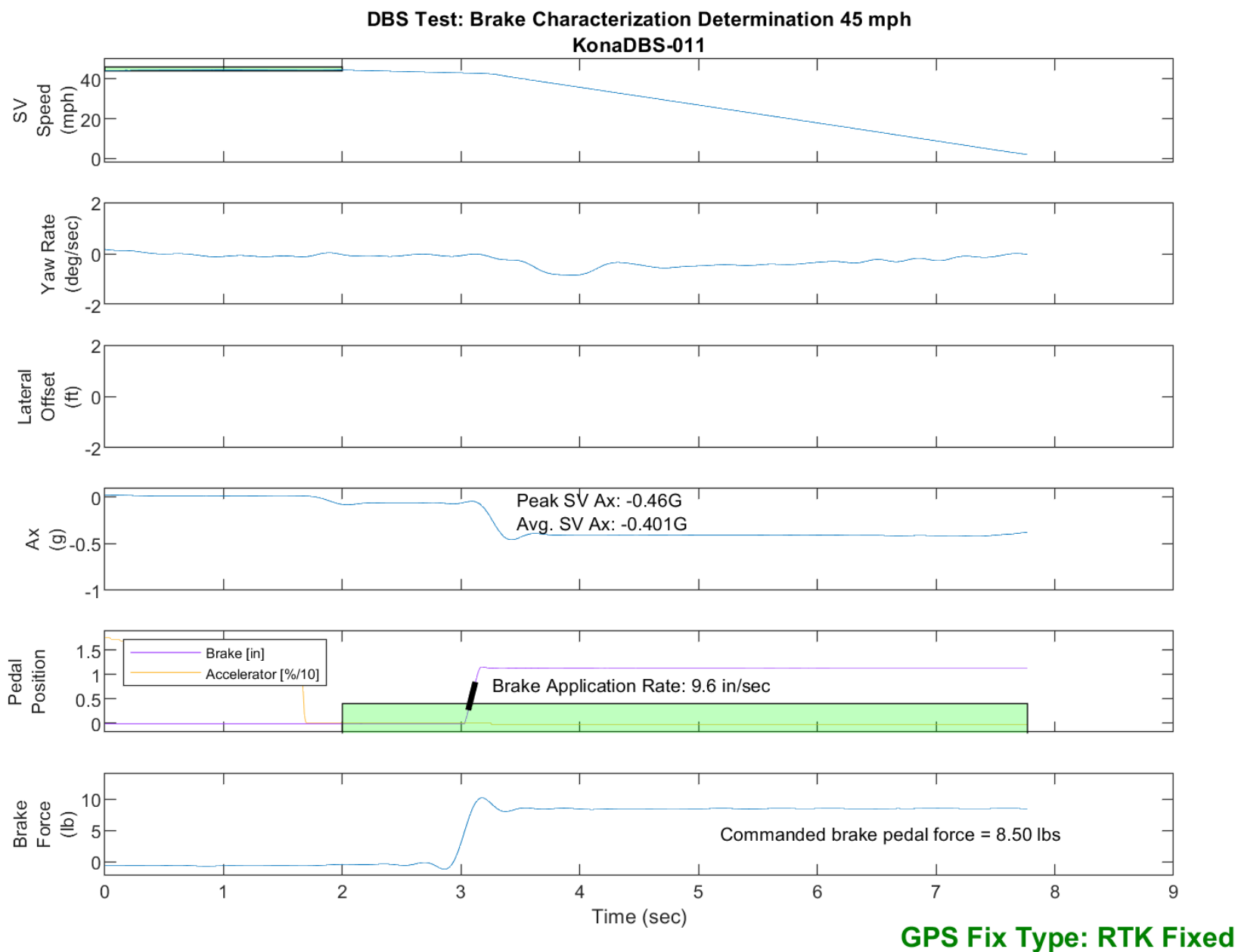


Figure E79. Time History for DBS Run 11, Brake Characterization Determination, Hybrid Mode, 45 mph