OCAS-DRI-DBS-19-15
NEW CAR ASSESSMENT PROGRAM
DYNAMIC BRAKE SUPPORT CONFIRMATION TEST

2019 Kia Sportage

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

23 July 2019

Final Report

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

U. S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Office of Crash Avoidance Standards
1200 New Jersey Avenue, SE
West Building, 4th Floor (NRM-200)
Washington, DC 20590

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

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These tests were conducted on the subject 2019 Kia Sportage in accordance with the specifications of the Office of Crash Avoidance Standards most current Test Procedure in docket NHTSA-2015-0006-0026; DYNAMIC BRAKE SUPPORT PERFORMANCE EVALUATION CONFIRMATION TEST FOR THE NEW CAR ASSESSMENT PROGRAM, October 2015. The vehicle passed the requirements of the test for all four DBS test scenarios.</td></tr>
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Section I
OVERVIEW AND TEST SUMMARY

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

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

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

The purpose of the testing reported herein was to objectively quantify the performance of a Dynamic Brake Support system installed on a 2019 Kia Sportage. 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

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2019 Kia Sportage

SUMMARY RESULTS

VIN: *KNDPR3A65K75xxxx*

Test Date: *12/3/2018*

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 2)

2019 Kia Sportage

TEST VEHICLE INFORMATION

VIN: *KNDPR3A65K75xxxx*

Body Style: *SUV* Color: *Black Cherry*

Date Received: *11/9/2018* Odometer Reading: *166 mi*

Engine: *2 L Inline 4*

Transmission: *Automatic*

Final Drive: *FWD*

Is the vehicle equipped with:

ABS	**X**	Yes		No
Adaptive Cruise Control		Yes	**X**	No
Collision Mitigating Brake System	**X**	Yes		No

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Kia Motors Corporation*

Date of manufacture: *09/18*

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: *245/45 R19*

Rear: *245/45 R19*

Recommended cold tire pressure: Front: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

DYNAMIC BRAKE SUPPORT

DATA SHEET 2: VEHICLE DATA

(Page 2 of 2)

2019 Kia Sportage

TIRES

Tire manufacturer and model: *Kumho Krugen*

Front tire size: *245/45 R19*

Rear tire size: *245/45 R19*

VEHICLE ACCEPTANCE

Verify the following before accepting the vehicle:

__X__ All options listed on the "window sticker" are present on the test vehicle

__X__ Tires and wheel rims are the same as listed.

__X__ There are no dents or other interior or exterior flaws.

__X__ The vehicle has been properly prepared and is in running condition.

__X__ Verify that spare tire, jack, lug wrench, and tool kit (if applicable) is located in the vehicle cargo area.

DYNAMIC BRAKE SUPPORT

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2019 Kia Sportage

GENERAL INFORMATION

Test date: *12/3/2018*

AMBIENT CONDITIONS

Air temperature: *13.9 C (57 F)*

Wind speed: *1.5 m/s (3.5 mph)*

X Windspeed ≤ 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: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*533.0 kg (1175 lb)*	Right Front	*508.5 kg (1121 lb)*
Left Rear	*371.9 kg (820 lb)*	Right Rear	*360.6 kg (795 lb)*
		Total:	*1774.0 kg (3911 lb)*

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

2019 Kia Sportage

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

Autonomous Emergency Braking (AEB)

System setting used for test (if applicable):

Early

Brake application mode used for test:

Hybrid control

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

5 mph (Per manufacturer supplied information)

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

50 mph (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

____ Yes

X No

If yes, please provide a full description.

The vehicle system does not require an initialization sequence/procedure.

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

X Yes

No

If yes, please provide a full description.

(1) Deactivation by driver (User Settings Mode)

To activate, enable AEB again or restart engine after turning ignition off. AEB reactivates upon each ignition cycle.

(2) Deactivation by temporarily disabling event (radar blindness):

1) Indicator - Pop-up display (displayed for a few seconds)

2) To activate, the event which caused temporary disabling must be remedied (e.g. clean radar cover).

(3) Deactivation by event requiring service (e.g. brake system fail, vehicle communication fail, etc.)

1) Indicator - Pop-up display (displayed for a few seconds)

2) To activate, check and fix malfunction. In some cases, it may require a dealer shop visit.- MIL

2) To activate, check and fix malfunction. In some cases, it may require a dealer shop visit.

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

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

(1) There are 3 different warnings displayed in the cluster as follows:
a) 1st alert: “Forward Warning”
b) 2nd alert: “Collision Warning”
c) 3rd warning: “Emergency Braking”
(2) The system also provides an audio warning via repeated beep.

The first and second warning sounds are the same while the third warning sound is different.

Is there a way to deactivate the system? __X__ Yes

_____ No

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

The method to deactivate the AEB system is to uncheck AEB within the USM (User Settings Menu). The AEB system reactivates upon each ignition cycle.

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

_____ No

If yes, please provide a full description.

While switched on, the driver may select various FCW warning times (Early / Normal / Late).

Are there other driving modes or conditions that render DBS inoperable or reduce its effectiveness? __X__ Yes

_____ No

If yes, please provide a full description.

The driver should exercise caution in the following situations, as the AEB operation may be limited:

Recognizing vehicles

- *The radar or the camera is contaminated with foreign substances.*
- *It heavily rains or snows.*
- *There is electromagnetic interference.*
- *Something in the path of travel deflects the radar waves.*
- *The vehicle is in a construction area or near a rail road and certain metal objects are on the road.*

(continued next page)

- *The vehicle passes a bumpy, unpaved, or steep incline road.*
- *The vehicle drives into an under-ground or indoor parking lot.*
- *The vehicle in front has a narrow body. (i.e. motorcycles and bicycles).*
- *The driver's view is degraded by driving towards sunlight, reflected light, or darkness.*
- *The camera cannot see the full profile of the vehicle in front.*
- *The vehicle in front is a special vehicle, such as a heavily-loaded truck or a trailer.*
- *The vehicle in front does not turn ON the rear lights, does not have rear lights, has asymmetric rear lights, or has rear lights out of angle.*
- *The outside brightness is greatly changed, such as entering/exiting the tunnel.*
- *The vehicle driving is unstable.*
- *The radar/camera sensor recognition is limited.*

Driving on a curve

- *The AEB performance decreases while driving on a curve. The AEB may not recognize the vehicle in front even in the same lane. It may unnecessarily produce the warning message and the warning alarm, or it may not produce the warning message and the warning alarm at all.*
- *While driving on a curve, the AEB may recognize the vehicle in front in the next lane and it produces the warning message and activates as a result.*

Driving on a slope

- *The AEB performance decreases while driving upward or downward on a slope, not recognizing the vehicle in front in the same lane. It may unnecessarily produce the warning message and the warning alarm, or it may not produce the warning message and the warning alarm at all.*
- *When the AEB suddenly recognizes the vehicle in front while passing over a slope, you may experience sharp deceleration.*

(continued next page)

Changing lanes

- *Even though the vehicle in the next lane enters into your lane, it may not be recognized by the AEB, until it enters the AEB sensing range.*
- *Especially when the vehicle in the next lane abruptly enters into your lane, it is more likely not be recognized.*
- *When the stopped vehicle in front gets out of the lane, it may not be recognized by your AEB.*

Recognizing the vehicle

- *When the vehicle in front has heavy loading extended rearward, or when the vehicle in front has higher ground clearance, it may induce a hazardous situation.*

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.

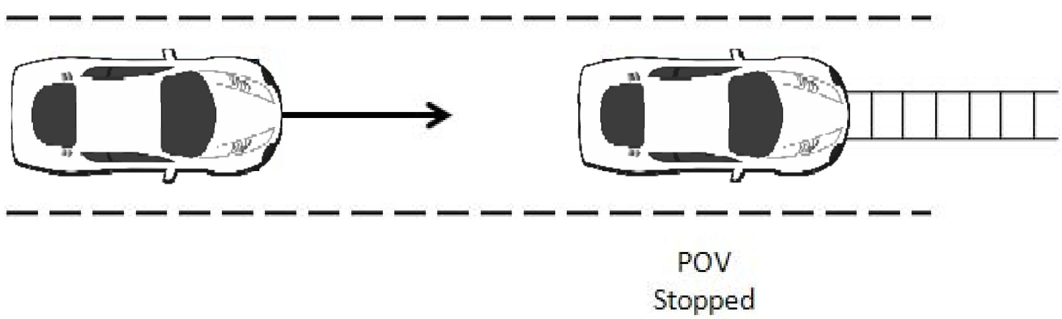


Figure 1. Depiction of Test 1

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 kph) in the center of the lane of travel, toward the parked POV. The SV throttle pedal was released within 500 ms after t_{FCW}, i.e., within 500 ms of the

FCW alert. The SV brakes were applied at TTC = 1.1 seconds (SV-to-POV distance of 40 ft (12 m)). The test concluded when either:

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

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

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

Table 1. Nominal Stopped POV DBS Test Choreography

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

b. Criteria

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

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

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

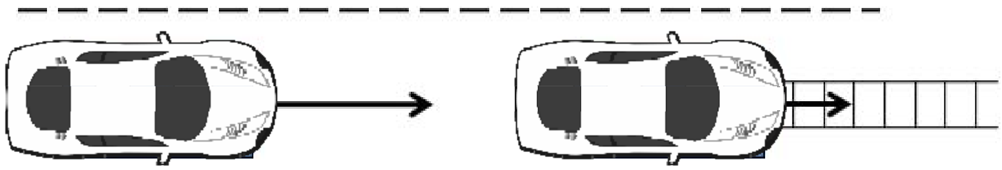


Figure 2. Depiction of Test 2

a. Procedure

The SV ignition was cycled prior to each test run. The tests were conducted two ways. In the first, the POV was driven at a constant 10.0 mph (16.1 kph) in the center of the lane of travel while the SV was driven at 25.0 mph (40.2 kph), 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 kph) in the center of the lane of travel while the SV was driven at 45.0 mph (74.4 kph), in the center lane of travel, toward the slower-moving POV. In both cases, the SV throttle pedal was released within 500 ms after $t_{FCW,}$ i.e., within 500 ms of the FCW alert. The SV brakes were applied at TTC = 1.0 seconds, assumed to be SV-to-POV distance of 22 ft (7 m) for an SV speed of 25 mph and 37 ft (11 m) for an SV speed of 45 mph.

The test concluded when either:

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

The SV driver then braked to a stop.

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

- The lateral distance between the centerline of the POV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.
- The SV speed could not deviate more than ±1.0 mph (±1.6 kph) during an interval defined by TTC = 5.0 seconds to t_{FCW}.
- The POV speed could not deviate more than ±1.0 mph (±1.6 kph) 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 kph)	10 mph (16 kph)	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 kph)	20 mph (32 kph)	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-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.

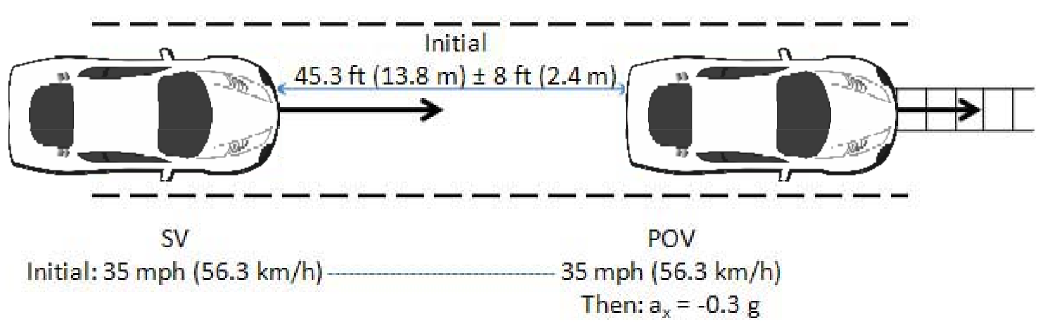


Figure 3. Depiction of Test 3 with POV Decelerating

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 kph) in the center of the lane, with headway of 45 ft (14 m) ± 8 ft (2.4 m). Once these conditions were met, the POV tow vehicle brakes were applied to achieve 0.3 ± 0.03 g. The SV throttle pedal was released within 500 ms of $t_{FCW,}$ and the SV brakes were applied when TTC was 1.4 seconds (31.5 ft (9.6 m)).

The test concluded when either:

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

The SV driver then braked to a stop.

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

- The lateral distance between the centerline of the POV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.
- The headway between the SV and POV must have been constant from the onset of the applicable validity period to the onset of POV braking.
- The SV and POV speed could not deviate more than ±1.0 mph (1.6 kph) 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 kph)	35 mph (56 kph)	3.0 seconds prior to POV braking → t_{FCW}	45 ft (14 m) → t_{FCW}	Within 500 ms of FCW1 onset	Varies	1.4	32 ft (10 m)

b. Criteria

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

4. TEST 4 – FALSE POSITIVE SUPPRESSION

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

a. Procedure

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

b. Criteria

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

B. GENERAL INFORMATION

1. t_{FCW}

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

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

Table 4. Audible and Tactile Warning Filter Parameters

Warning Type	Filter Order	Peak-to-Peak Ripple	Minimum Stop Band Attenuation	Pass-Band Frequency Range
Audible	5^{th}	3 dB	60 dB	Identified Center Frequency ± 5%
Tactile	5^{th}	3 dB	60 dB	Identified Center Frequency ± 20%

2. General Validity Criteria

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

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

3. Validity Period

The valid test interval began:

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

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

Test 3: 3 seconds before the onset of POV braking

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

The valid test interval ended:

Test 1: When either of the following occurred:

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

Test 2: When either of the following occurred:

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

Test 3: When either of the following occurred:

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

Test 4: When the SV stopped.

4. Static Instrumentation Calibration

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

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

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

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

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

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

5. Number of Trials

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

6. Transmission

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

C. PRINCIPAL OTHER VEHICLE

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

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

- POV element, whose requirements 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.

- POV delivery system, whose requirements are to:

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

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.

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

D. FOUNDATION BRAKE SYSTEM CHARACTERIZATION

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

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

E. BRAKE CONTROL

1. Subject Vehicle programmable brake controller

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

- Constant pedal displacement. By maintaining constant actuator stroke, the position of the vehicle's brake pedal remains fixed for the duration of the input. To achieve this, the brake controller modulates application force.

- Hybrid control. Hybrid control uses position-based control to command the initial brake application rate and actuator position, then changes to force-based control to command a reduction of applied force to a predetermined force. This force is maintained until the end of the braking maneuver by allowing the brake controller to modulate actuator displacement.

2. Subject Vehicle brake parameters

- Each test run began with the brake pedal in its natural resting position, with no preload or position offset.

- The onset of the brake application was considered to occur when the brake actuator had applied 2.5 lbf (11 N) of force to the brake pedal.

- The magnitude of the brake application was that needed to produce 0.4 g deceleration, as determined in the foundation brake characterization.

- The SV brake application rate was between 9 to 11 in/s (229 to 279 mm/s), where the application rate is defined as the slope of a linear regression line applied to brake pedal position data over a range from 25% to 75% of the commanded input magnitude.

3. POV Automatic Braking System

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

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

- PC module programmed for control of the stroke and rate of the linear actuator.

- Switch to activate actuator.

F. INSTRUMENTATION

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

TABLE 5. TEST INSTRUMENTATION AND EQUIPMENT

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi 0-690 kPa	< 1% error between 20 and	Omega DPG8001	17042707002	By: DRI Date: 6/21/2018 Due: 6/21/2019
Platform Scales	Vehicle Total, Wheel, and Axle Load	1200 lb/platform 5338 N/	0.5% of applied load	Intercomp SWI	1110M206352	By: DRI Date: 2/1/2018 Due: 2/1/2019
Linear (string) encoder	Throttle pedal travel	10 in 254 mm	0.1 in 2.54 mm	UniMeasure LX-EP	45040532	By: DRI Date: 5/1/2018 Due: 5/1/2019
Load Cell	Force applied to brake pedal					By: DRI
		0-250 lb 1112 N	0.05% FS	Stellar Technology PNC700	1607338	Date: 8/28/2018 Due: 8/28/2019
		0 - 250 lb 0 -1112 N	0.1% FS	Honeywell 41A	1464391	Date: 8/28/2018 Due: 8/28/2019
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 kph	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	NA

TABLE 5. TEST INSTRUMENTATION AND EQUIPMENT (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +		By: Oxford Technical Solutions
					2182	Date: 10/16/2017 Due: 10/16/2019
					2258	Date: 3/8/2017 Due: 3/8/2019
Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW)	Distance and Velocity to lane markings (LDW) and POV (FCW)	Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	NA
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	NA	NA
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	NA	NA
Accelerometer	Acceleration (to measure time at alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	NA	NA

<table>
<tr><th>Type</th><th>Output</th><th>Range</th><th>Accuracy, Other Primary Specs</th><th>Mfr, Model</th><th>Serial Number</th><th>Calibration Dates
Last
Due</th></tr>
<tr><td>Coordinate Measurement Machine</td><td>Inertial Sensing System Coordinates</td><td>0-8 ft
0-2.4 m</td><td>±.0020 in.
±.051 mm
(Single point articulation accuracy)</td><td>Faro Arm,
Fusion</td><td>UO8-05-08-06636</td><td>By: DRI
Date: 1/4/2018
Due: 1/4/2019</td></tr>
</table>

<table>
<tr><th>Type</th><th>Description</th><th>Mfr, Model</th><th>Serial Number</th></tr>
<tr><td rowspan="3">Data Acquisition System</td><td rowspan="3">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).</td><td>D-Space Micro-Autobox II 1401/1513</td><td></td></tr>
<tr><td>Base Board</td><td>549068</td></tr>
<tr><td>I/O Board</td><td>588523</td></tr>
</table>

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

Figure A3. Window Sticker (Monroney Label)

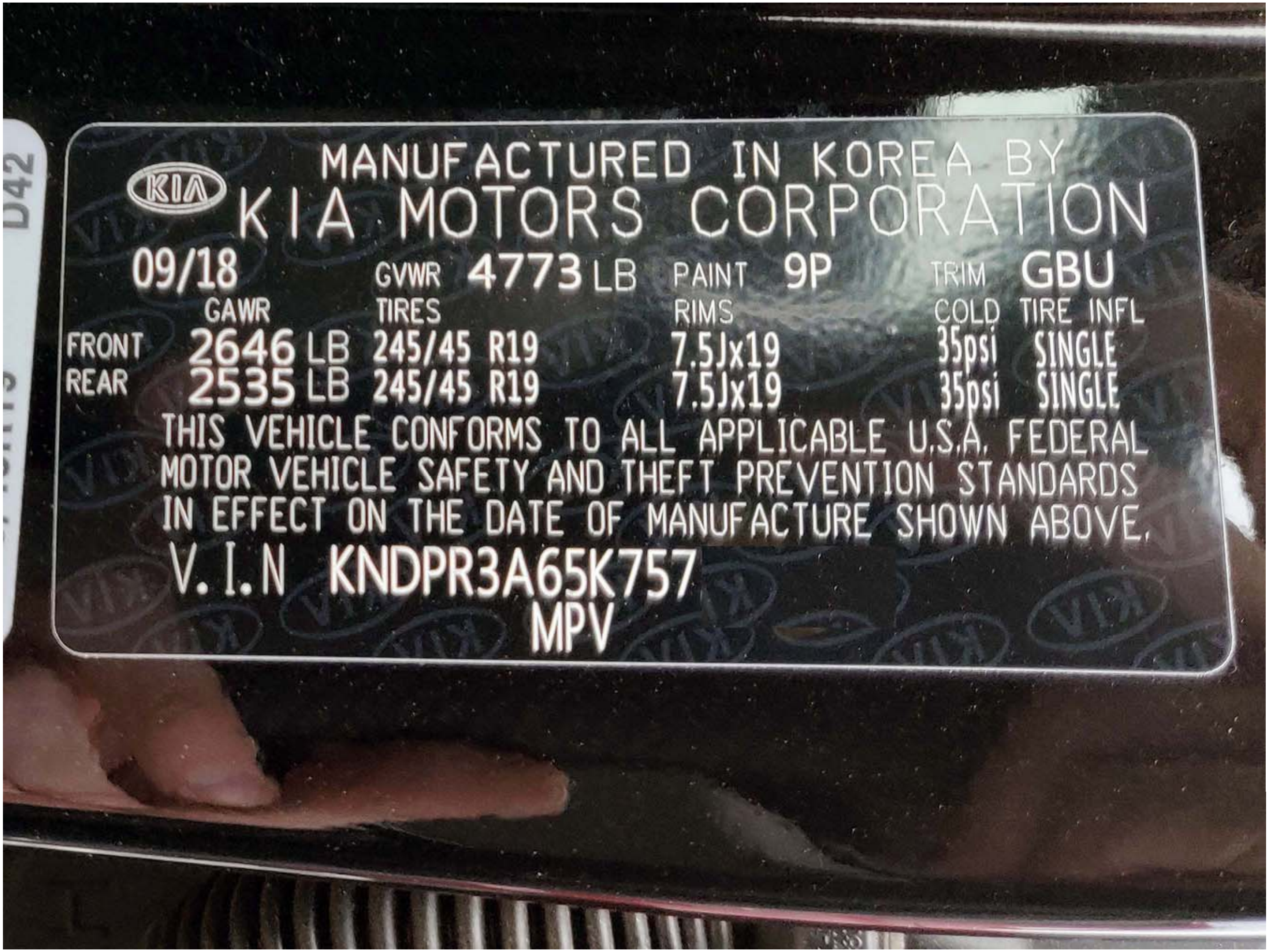


Figure A4. Vehicle Certification Label

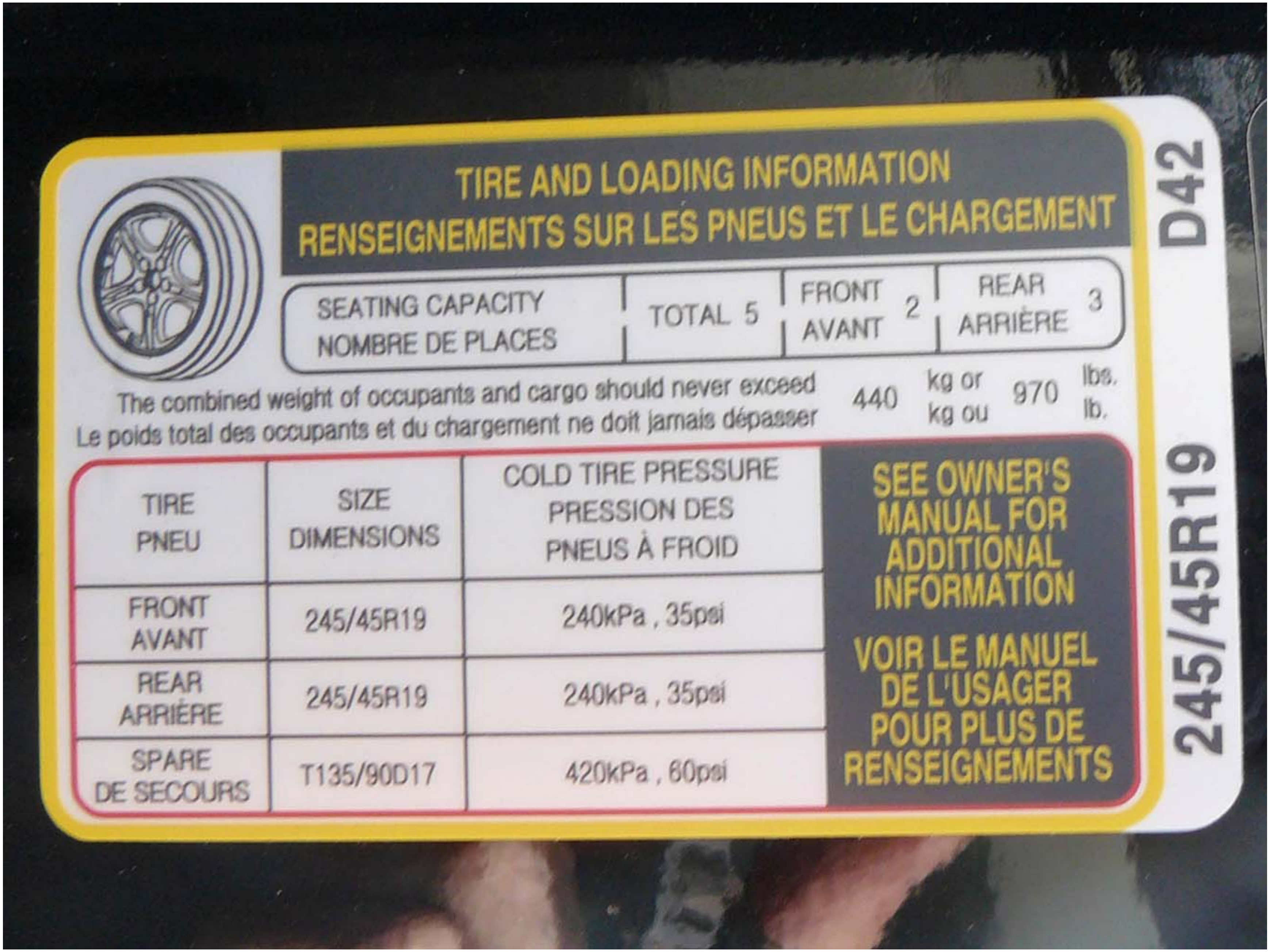


Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

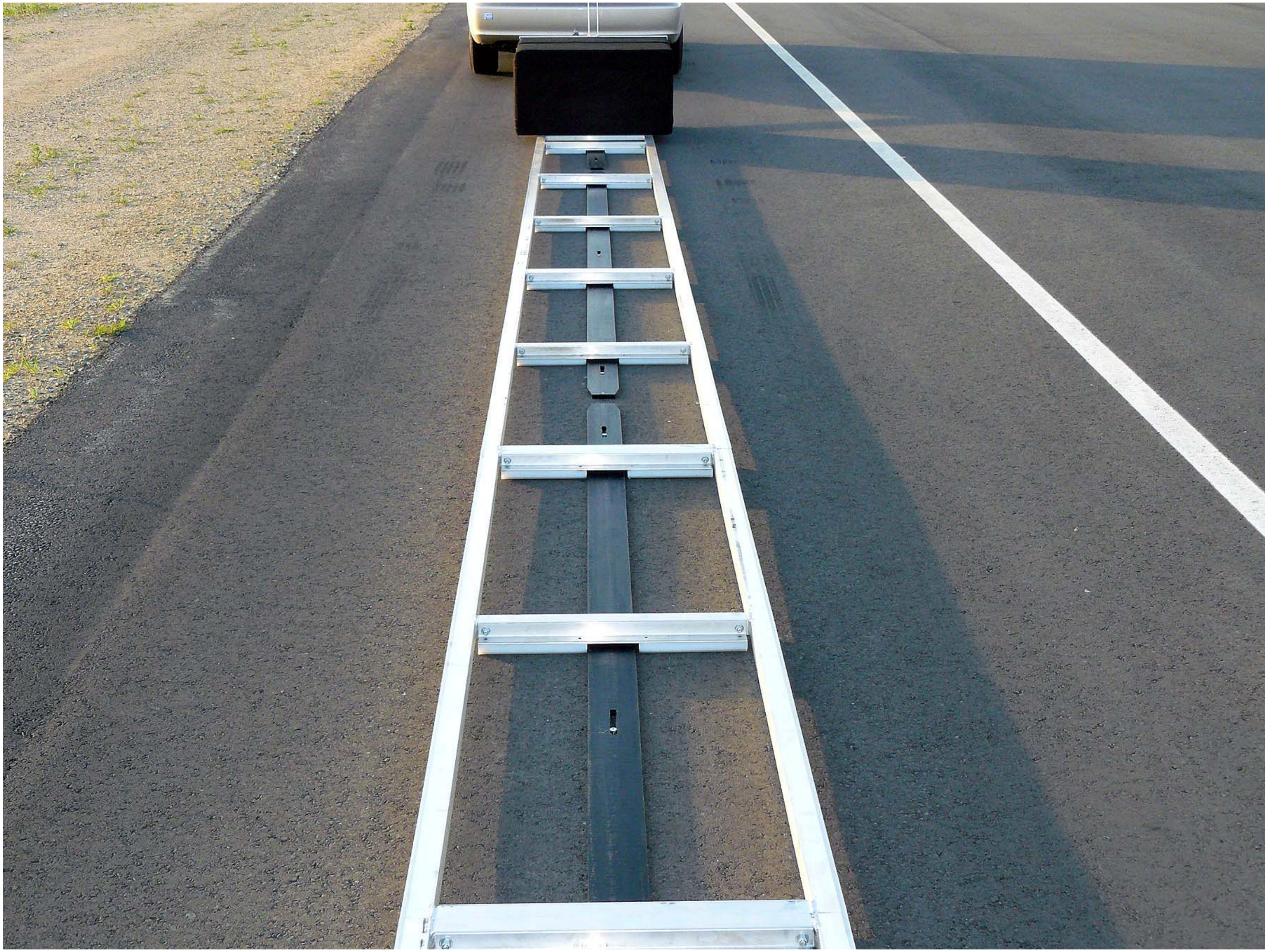


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

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

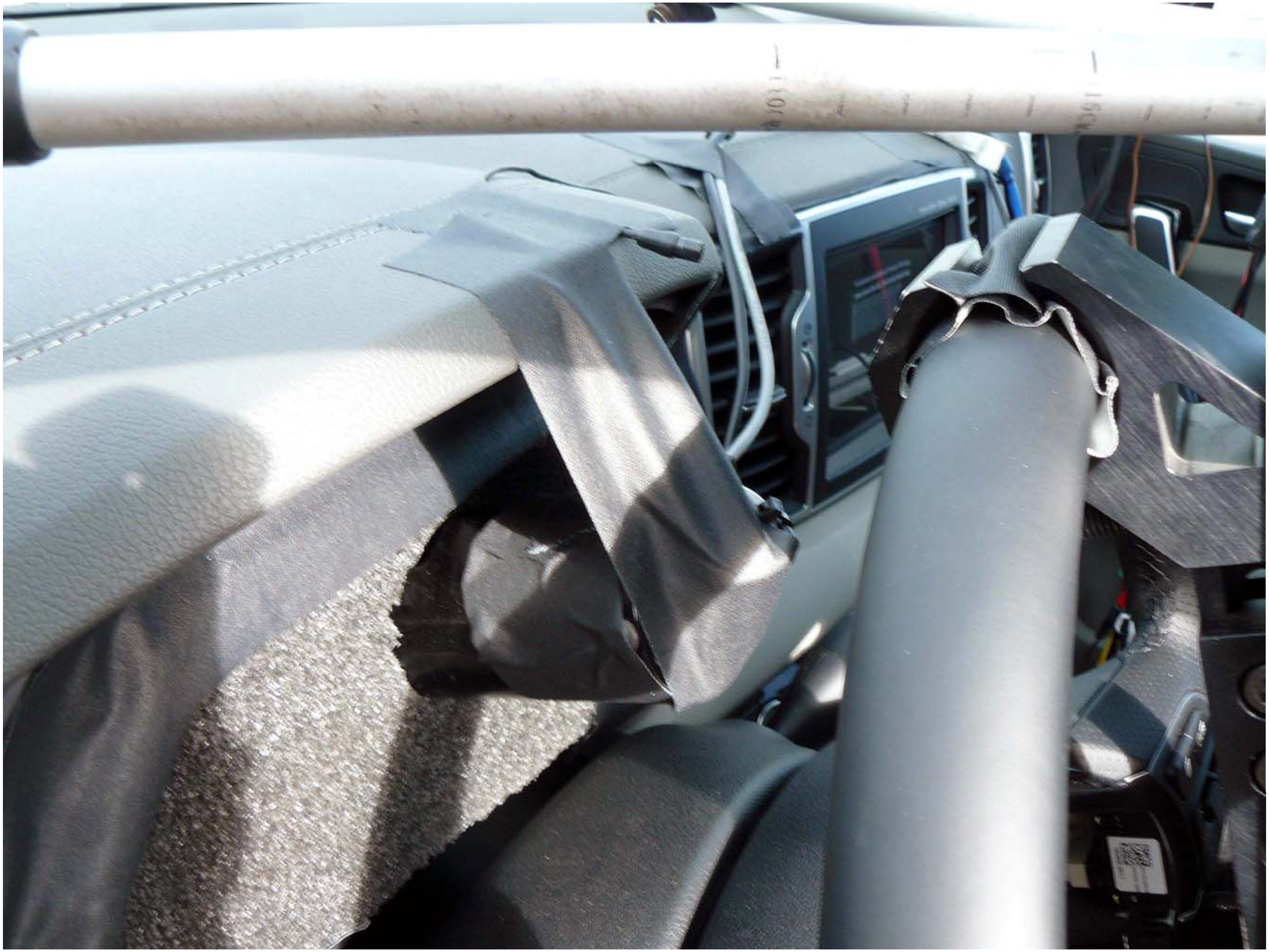


Figure A11. Sensors for Detecting Auditory and Visual Alerts

Figure A12. Computer and Brake Actuator Installed in Subject Vehicle

Figure A13. Brake Actuator Installed in POV System

Figure A14. AEB Visual Alert

Figure A15. AEB Setup Menus

Figure A16. Steering Wheel Mounted Control Buttons for Changing Parameters

APPENDIX B

Excerpts from Owner's Manual

Master Warning Mode

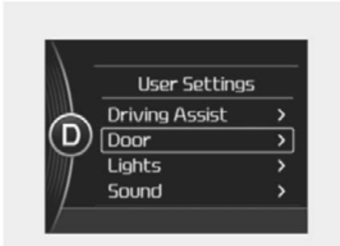
- This warning light informs the driver the following situations
  - Blind Spot Detection (BSD) malfunction (if equipped)
  - Tire Pressure Monitoring System (TPMS) malfunction (if equipped)
  - Autonomous Emergency Braking (AEB) malfunction (if equipped)
  - Lamp malfunction and so on.

The Master Warning Light illuminates when more than one of the above warning situations occur. At this time, the LCD Modes Icon will change from (⚙) to (▲).

If the warning situation is solved, the master warning light will be turned off and the LCD Modes Icon will be changed back to its previous icon (⚙).

User Settings Mode

Description



OQLE045118

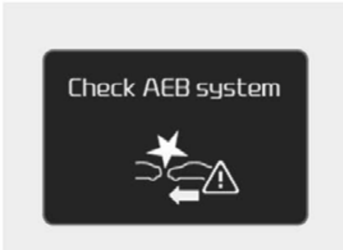
In this mode, you can change setting of the doors, lights, etc.

> **⚠ WARNING**
>
> **Do not adjust the User Setting while driving. You may lose your steering control and cause severe personal injury or accidents.**

Driving Assist (if equipped)

Items	Explanation
Rear Cross Traffic Alert (if equipped)	If this item is checked, the rear cross traffic alert function will be activated. ❈ For more details, refer to “Blind Spot Detection System” in chapter 6.
AEB (Autonomous Emergency Braking) (if equipped)	To activate or deactivate the AEB system. ❈ For more details, refer to “Autonomous Emergency Braking (AEB)” in chapter 6.
FCW (Forward Collision Warning) (if equipped)	Choose the sensitivity of the FCW. ❈ For more details, refer to “Autonomous Emergency Braking(AEB)” in chapter 6.

Check AEB system (if equipped)



OQLE045212

- This warning message illuminates if there is a malfunction with the Autonomous Emergency Braking (AEB) system. In this case, have your vehicle be inspected by an authorized Kia dealer.

❈For more details, refer to "Autonomous Emergency Braking (AEB) system" in chapter 6.

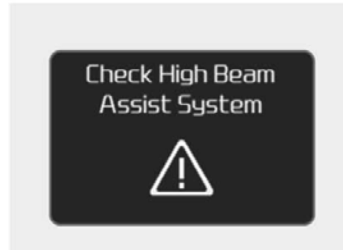
Check Smart Phone Wireless Charger (if equipped)

OQLE045135

If a smart phone is still left on the wireless charging pad unattended, even when the ignition is in ACC OFF and the instrument panel's one time driving information mode has finished, a warning message will light up on the instrument panel.

❈For more details, refer to "Smart Phone Wireless Charger" in this chapter.

Check high beam assist system (if equipped)



OQLE045210

This warning message illuminates if there is a malfunction (burned-out bulb or circuit malfunction) with the headlamp. In this case, have your vehicle inspected by an authorized Kia dealer.

Electronic Parking Brake (EPB) Warning Light

EPB

This warning light illuminates:

- Once you set the ignition switch or Engine Start/Stop Button to the ON position.
  - It illuminates for approximately 3 seconds and then goes off.
- When there is a malfunction with the EPB.

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

✽ NOTICE - Electronic Parking Brake (EPB) Warning Light

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

Master Warning light (if equipped)

- This warning light informs the driver of the following situations
  - Blind Spot Detection (BSD) malfunction (if equipped)
  - Tire Pressure Monitoring System (TPMS) malfunction (if equipped)
  - Autonomous Emergency Braking (AEB) malfunction (if equipped)
  - Lamp malfunction and so on.

The Master Warning Light illuminates when more than one of the above warning situations occur. At this time, the LCD Modes Icon will change from (⚙) to (▲).

If the warning situation is solved, the master warning light will be turned off and the LCD Modes Icon will be changed back to its previous icon (⚙).

Autonomous Emergency Braking (AEB) Warning light (if equipped)

This indicator light illuminates:

- When there is a malfunction with the AEB.

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

All Wheel Drive (AWD) Warning Light (if equipped)

This warning light illuminates:

- Once you set the ignition switch or Engine Start/Stop Button to the ON position.
  - It illuminates for approximately 3 seconds and then goes off.
- When there is a malfunction with the AWD system.

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

AUTONOMOUS EMERGENCY BRAKING (AEB) (IF EQUIPPED)

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

⚠ WARNING
- Autonomous Emergency Braking (AEB) Limitations

The AEB system is a supplemental system and is not a substitute for safe driving practices. It is the responsibility of the driver to always check the speed and distance to the vehicle ahead to ensure it is safety to use the AEB system.

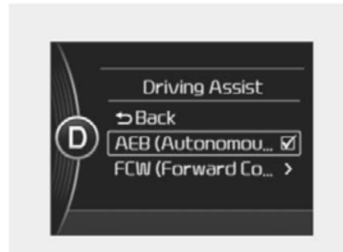
✻ NOTICE

Take the following precautions when using the Autonomous Emergency Braking (AEB):

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

System setting and activation

System setting

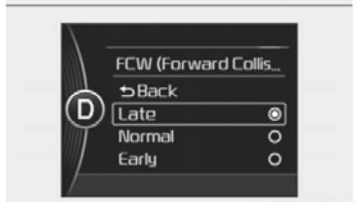


OQLA055135

The driver can activate the AEB by placing the ignition switch to the ON position and by selecting 'User Settings', 'Driving Assist', and 'Autonomous Braking System'. The AEB deactivates, when the driver cancels the system setting.

The warning light illuminates on the LCD display, when you cancel the AEB system. The driver can monitor the AEB ON/OFF status on the LCD display. When the warning light remains ON with the AEB activated, we recommend you to have the system checked by an authorized Kia dealer.

OQLA055136



OQLE045236

The driver can select the initial warning activation time in the User Settings in the instrument cluster LCD display. The options for the initial Forward Collision Warning include the following:

- EARLY - When this condition is selected, the initial Forward Collision Warning is activated earlier than normal. This setting maximizes the amount of distance between the vehicle or pedestrian ahead before the initial warning occurs. Even though FCW is set in early mode, if the vehicle in front stops abruptly, the FCW warning may be displayed later than anticipated.
- NORMAL - When this condition is selected, the initial Forward Collision Warning is activated normally. This setting allows for a nominal amount of distance between the vehicle or pedestrian ahead before the initial warning occurs.

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

Prerequisite for activation

The AEB will activate activated when the AEB is selected on the LCD display, and when the following prerequisites are satisfied:

- The ESC (Electronic Stability Control) is activated.
- The driving speed is over 6 mph. (The AEB only works within a certain range of vehicle speeds)
- When the AEB recognizes a vehicle or the pedestrian in front. (The AEB may not recognize every obstacle or provide warnings and braking in every situation, so do not rely on the AEB to stop the vehicle in instances where the driver sees an obstacle and has the ability to apply the brakes)

⚠ WARNING

To avoid driver distractions, do not attempt to set or cancel the AEB while operating the vehicle.

• The AEB automatically activates when you turn the vehicle on.

The driver can deactivate the AEB by canceling the in the system setting on the LCD display.

• The AEB automatically deactivates when canceling the ESC. When the ESC is canceled, the AEB cannot be activated on the LCD display.

AEB warning message and system control

The AEB produces warning messages, warning alarms, and emergency braking based on the level of risk of a frontal collision, such as when a vehicle ahead suddenly brakes, when there is no following distance from the vehicle in front, or when it detects a collision with a pedestrian is imminent.

Forward Warning (1st warning)

OQLE055132

The warning message appears on the LCD display with the warning alarms.

Collision Warning (2nd warning)

OQLE055133

- The warning message appears on the LCD display with the warning alarms.
- The AEB applies the brakes within certain limit to reduce the impact from a collision.

Emergency braking (3rd warning)

OQLE055134

- The warning message appears on the LCD display with the warning alarms.
- The AEB controls the brakes within certain limit to release shock from the collision.

  The AEB controls the maximum brakes just before the collision.

Brake operation

- In an urgent situation, the braking system enters into the ready status for prompt reaction against the driver's depressing the brake pedal.
- The AEB provides additional braking power for optimum braking performance, when the driver depresses the brake pedal.
- The braking control is automatically deactivated, when the driver sharply depresses the brake pedal, or when the driver abruptly turns the steering wheel.
- The braking control is automatically canceled, when risk factors disappear.

The driver should always exercise caution when operating the vehicle, even though there is no warning message or warning alarm.

⚠ WARNING

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

✽ NOTICE

The AEB operates in accordance with the risk levels, such as the distance from the vehicle/passer-by in front, the speed of the vehicle/passer-by in front, and the driver's vehicle operation.
Do not drive the vehicle dangerously to activate the AEB system on purpose.

Sensor to detect the distance from the vehicle in front (front radar)

AWD

OQLA055021

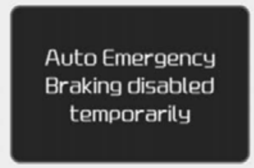
2WD

OQL055021

The sensor is to maintain a certain distance from the vehicle in front. However, the smudged sensor or sensor cover with foreign substances, such as snow and rain, adversely affects the sensing performance. It may even temporarily cancel the AEB. Always keep the sensor clean.

Warning message and warning light

■ Type A



OQLE045237

■ Type B

OQLE055147

When the sensor is covered or the sensor is dirty with foreign substances, such as snow or rain, the AEB operation may temporarily stop. In this case, a warning message will appear to notify the driver.

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

✻ NOTICE

- **Do not install any accessories, such as a license plate bracket or bumper sticker near the sensor area. Do not replace the bumper by yourself. Doing so may adversely affect the sensing performance.**
- **Always keep the sensor/bumper area clean.**
- **Use only a soft cloth to wash the vehicle. Also, do not spray highly pressurized water on the sensor installed on the bumper.**
- **Be careful not to apply unnecessary force on the frontal sensor area. When the sensor moves out of the correct position due to external force, the system may not operate correctly even without the warning light or message. In this case, we recommend you to have the vehicle inspected by an authorized Kia dealer.**
- **Use only the genuine Kia sensor cover. Do not arbitrarily apply paint on the sensor cover.**

System malfunction

■ Type A

OQLE045228

■ Type B

OQLE055158

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

⚠ WARNING

The AEB is only a supplemental system for the driver's convenience.

The driver still maintains responsibility to control the vehicle. Do not solely depend on the AEB system. Rather, maintain a safe braking distance, and, if necessary, depress the brake pedal to lower the driving speed.

- The AEB may unnecessarily produce warning messages and warning alarms. Due to the sensing limitation, the AEB may not produce warning messages or warning alarm at all.
- When there is a malfunction with the AEB, the braking control does not operate upon detecting a collision risk even with other braking systems normally operating.
- The AEB operates only for the vehicle / pedestrian in front, while driving forward. It does not operate for any animals or vehicles in the opposite direction.
- The AEB can not recognize cross-traffic or parked vehicles presenting a side-profile.

Limitation of the system

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

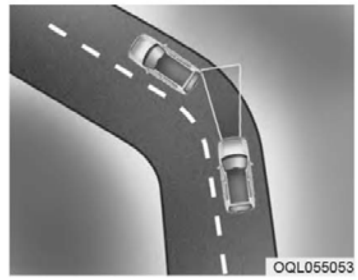
The AEB monitors the driving situations through the radar and the camera sensor. For any vehicle activity occurring outside the sensor range, the AEB may not function. The driver should exercise caution in the following situations, as the AEB operation may be limited:

Recognizing vehicles

- The radar or the camera is contaminated with foreign substances.
- It heavily rains or snows.
- There is electromagnetic interference.
- Something in the path of travel deflects the radar waves.
- The vehicle is in a construction area or near a rail road and certain metal objects are on the road.
- The vehicle passes a bumpy, unpaved, or steep incline road.
- The vehicle drives into an underground or indoor parking lot.
- The vehicle in front has a narrow body. (i.e. motorcycles and bicycles)
- The driver's view is degraded by driving towards sunlight, reflected light, or darkness.
- The camera cannot see the full profile of the vehicle in front.
- The vehicle in front is a special vehicle, such as a heavily-loaded truck or a trailer.

The vehicle in front does not turn ON the rear lights, does not have rear lights, has asymmetric rear lights, or has rear lights out of angle.

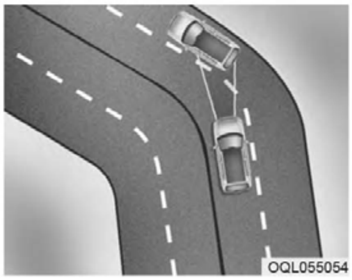
- The outside brightness is greatly changed, such as entering/exiting the tunnel.
- The vehicle driving is unstable.
- The radar/camera sensor recognition is limited.



- Driving on a curve

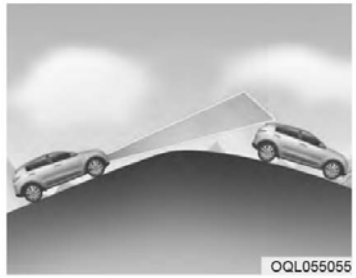
The AEB performance decreases while driving on a curve. The AEB may not recognize the vehicle in front even in the same lane. It may unnecessarily produce the warning message and the warning alarm, or it may not produce the warning message and the warning alarm at all.

While driving on a curve, exercise caution, and, if necessary, depress the brake pedal.


OQL055054

While driving on a curve, the AEB may recognize the vehicle in front in the next lane and it produces the warning message and activates as a result. Exercise caution, and, if necessary, depress the brake pedal.

Or, depress the accelerator pedal to maintain the driving speed. Always take a look around the vehicle for your safety.

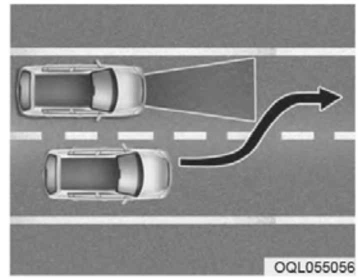

OQL055055

- Driving on a slope

The AEB performance decreases while driving upward or downward on a slope, not recognizing the vehicle in front in the same lane. It may unnecessarily produce the warning message and the warning alarm, or it may not produce the warning message and the warning alarm at all.

When the AEB suddenly recognizes the vehicle in front while passing over a slope, you may experience sharp deceleration.

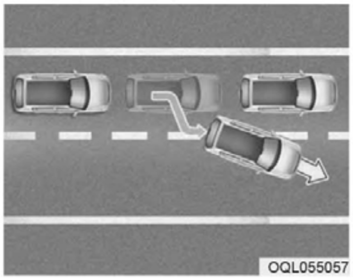
Always keep your eyes forward while driving upward or downward on a slope, and, if necessary, depress the brake pedal.


OQL055056

- Changing lanes

Even though the vehicle in the next lane enters into your lane, it may not be recognized by the AEB, until it enters the AEB sensing range.

Especially when the vehicle in the next lane abruptly enters into your lane, it is more likely not be recognized. Always be attentive to driving conditions.


OQL055057

When the stopped vehicle in front gets out of the lane, it may not be recognized by your AEB. Always be attentive to driving conditions.


OQL055058

- Recognizing the vehicle

When the vehicle in front has heavy loading extended rearward, or when the vehicle in front has higher ground clearance, it may induce a hazardous situation.

Recognizing pedestrians

- The pedestrian is not fully captured by the camera sensor, or the pedestrian does not walk in the upright position.
- The pedestrian moves very fast.
- The pedestrian abruptly appears in front.
- The pedestrian wears clothes similar in color to the background.
- Conditions outside are too bright or too dark.
- The vehicle drives at night or in the darkness.
- There is an item similar in shape a person's body structure.
- The pedestrian is small.
- The pedestrian has impaired mobility.
- The pedestrian blends in with their surroundings.
- Sensor recognition is limited by rain, snow, fog, etc.
- There is a group of pedestrians.

⚠ WARNING - Testing the AEB

The AEB does not operate in certain situations. Thus, never test-operate the AEB against a person or an object. It may cause a severe injury or even death.

⚠ WARNING - AEB and Towing

Cancel the AEB in the User Settings on the LCD display, before towing another vehicle. While towing, the brake application may adversely affect your vehicle safety.

✻ NOTICE

The system may temporarily cancel due to the strong electric waves.

- Pay great caution to the vehicle in front, when it has heavy loading extended rearward, or when it has higher ground clearance.
- The sensor only detects pedestrian, not carts, bicycles, motorcycles, luggage bags, or strollers.

Downhill Brake Control (DBC)

OQL055117

OQL055116

The Downhill Brake Control (DBC) supports the driver come down a steep hill without depressing the brake pedal.

APPENDIX C

Run Log

Subject Vehicle: **2019 Kia Sportage** Test Date: 12/3/2018

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
1-13	Brake characterization and confirmation						See Appendix D
14	STP - Static run						
15	**Baseline, 25**	Y			0.52	Pass	
16		N					Throttle Drop
17		Y			0.53	Pass	
18		Y			0.52	Pass	
19		Y			0.51	Pass	
20		Y			0.51	Pass	
21		Y			0.50	Pass	
22		Y			0.52	Pass	
23	STP - Static run						

Subject Vehicle: **2019 Kia Sportage** Test Date: 12/3/2018

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
24	**Baseline, 45**	Y			0.47	Pass	
25		Y			0.46	Pass	
26		Y			0.48	Pass	
27		Y			0.52	Pass	
28		N					SV Speed, Throttle Drop
29		Y			0.53	Pass	
30		Y			0.53	Pass	
31		Y			0.51	Pass	
32	STP - Static run						
33	**STP False Positive, 25**	Y			0.48	Pass	
34		Y			0.45	Pass	
35		Y			0.46	Pass	
36		Y			0.44	Pass	
37		Y			0.44	Pass	

Subject Vehicle: **2019 Kia Sportage** Test Date: 12/3/2018

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
38		Y			0.44	Pass	
39		Y			0.43	Pass	
40	STP - Static run						
41	**STP False Positive, 45**	Y			0.41	Pass	
42		Y			0.44	Pass	
43		Y			0.47	Pass	
44		Y			0.47	Pass	
45		Y			0.48	Pass	
46		Y			0.48	Pass	
47		Y			0.50	Pass	
48	STP - Static run						
49	Static Run						Brake Parameters changed after check runs to Stroke: 1.65 Force: 10.00

Subject Vehicle: **2019 Kia Sportage** Test Date: 12/3/2018

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
50	**Stopped POV**	Y	1.64	0.72	1.19	Pass	
51		Y	1.66	0.92	1.20	Pass	
52		Y	1.62	0.34	1.20	Pass	
53		Y	1.69	0.22	1.07	Pass	
54		Y	1.64	0.00	1.12	Fail	
55		Y	1.68	0.16	1.17	Pass	
56		Y	1.63	0.41	1.12	Pass	
57	Static Run						
58	Static Run						
59	**Slower POV, 25 vs 10**	Y	1.30	3.61	0.57	Pass	
60		Y	1.25	3.85	0.56	Pass	
61		Y	1.32	3.89	0.57	Pass	
62		Y	1.32	3.98	0.58	Pass	
63		Y	1.29	3.29	0.52	Pass	
64		N					Throttle Drop

Subject Vehicle: **2019 Kia Sportage** Test Date: 12/3/2018

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
65		N					Throttle Drop
66	Static run						
67	**Slower POV, 45 vs 20**	N					POV Speed
68		1.82	8.66	1.08	Pass	1.82	
69		1.85	7.18	1.02	Pass	1.85	
70		1.84	9.85	1.07	Pass	1.84	
71							POV Speed
72							SV Yaw Rate
73		1.84	10.77	1.13	Pass	1.84	
74							POV Speed
75		1.90	11.27	1.10	Pass	1.90	
76		1.88	10.42	1.14	Pass	1.88	
77		1.86	9.51	1.07	Pass	1.86	
78	Static run						

Subject Vehicle: **2019 Kia Sportage** Test Date: 12/3/2018

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
79	**Braking POV, 35**	Y	1.44	1.29	1.00	Pass	
80		Y	1.59	0.00	1.03	Fail	
81		N					POV Speed
82	Static run						Brake Changed to Stroke: 1.55 Force: 9.5 after check runs
83		N					SV Speed
84		Y	1.65	0.89	1.12	Pass	
85		Y	1.64	0.25	1.09	Pass	
86		N					Headway
87		Y	1.54	1.27	0.59	Pass	
88		Y	1.58	1.85	0.57	Pass	
89		Y	1.50	0.70	1.11	Pass	
90	Static run						

APPENDIX D

Brake Characterization

Subject Vehicle: **2019 Kia Sportage** Test Date: 12/3/2018

DBS Initial Brake Characterization				
Run Number	**Stroke at 0.4 g (in)**	**Force at 0.4 g (lb)**	**Slope**	**Intercept**
1	1.710872	13.84651	0.962363	-0.4174
2	1.776042	13.8336	0.940546	-0.4178
3	1.777433	13.48045	0.907309	-0.36233

DBS Brake Characterization Confirmation								
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	N	0.446	1.75		1.57	
5			Y	0.383	1.65		1.72	
6		25	Y	0.384	1.65		1.72	
7		45	N	0.361	1.65		1.83	Brake App Rate
8			Y	0.379	1.72		1.82	
9	**Hybrid**	35	N	0.442	1.65	11.00	9.95	
10			Y	0.417	1.65	10.50	10.07	
11		25	Y	0.410	1.65	10.50	10.24	
12		45	N	0.428	1.72	10.50	9.81	
13			Y	0.405	1.72	10.00	9.88	

Appendix E

TIME HISTORY PLOTS

LIST OF FIGURES

Description of Time History Plots

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

Time History Plot Description

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

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

Time history figures include the following sub-plots:

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

- Normalized light sensor signal. The vertical scale is 0 to 1.

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

- Headway (ft) – longitudinal separation between the frontmost point of the Subject Vehicle and the rearmost point of the Strikeable Surrogate Vehicle (SSV) towed by the Principal Other Vehicle. The minimum headway during the run is displayed to the right of the subplot.

SV/POV Speed (mph) – speed of the Subject Vehicle and the Principal Other Vehicle (if any). For DBS tests, in the case of an impact, the speed reduction experienced by the Subject Vehicle up until the moment of impact is displayed to the right of the subplot.

- Yaw Rate (deg/sec) – yaw rate of the Subject Vehicle and Principal Other Vehicle (if any).

- Lateral Offset (ft) – lateral offset within the lane of the Subject Vehicle to the center of the lane of travel. Note that for tests involving the Strikeable Surrogate Vehicle (SSV), the associated lateral restraint track is defined to be the center of the lane of travel. If testing is done with a different POV which does not have a lateral restraint track, lateral offset is defined to be the lateral offset between the SV and POV.

- Ax (g) – longitudinal acceleration of the Subject Vehicle and Principal Other Vehicle (if any). The peak value of Ax for the SV is shown on the subplot.

- Pedal Position – position of the accelerator pedal and brake pedal. The units for the brake pedal are inches and the units for the accelerator pedal are percent of full scale divided by 10.

- Brake Force (lb) – force on the brake pedal as applied by the DBS controller. The TTC at the onset of the brake by the DBS controller is shown on the subplot. Additionally, the average force at the brake pedal while the DBS controller is active is displayed.

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

Envelopes and Thresholds

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

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

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

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

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

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

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

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

Color Codes

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

Color codes can be broken into four categories:

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

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

2. Validation envelope and threshold color codes:
   - Green envelope = time varying data must be within the envelope at all times in order to be valid
   - Yellow envelope = time varying data must be within limits at left and/or right ends
   - 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

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

Time history data plots for the tests of the vehicle under consideration herein are provided beginning with Figure E13.

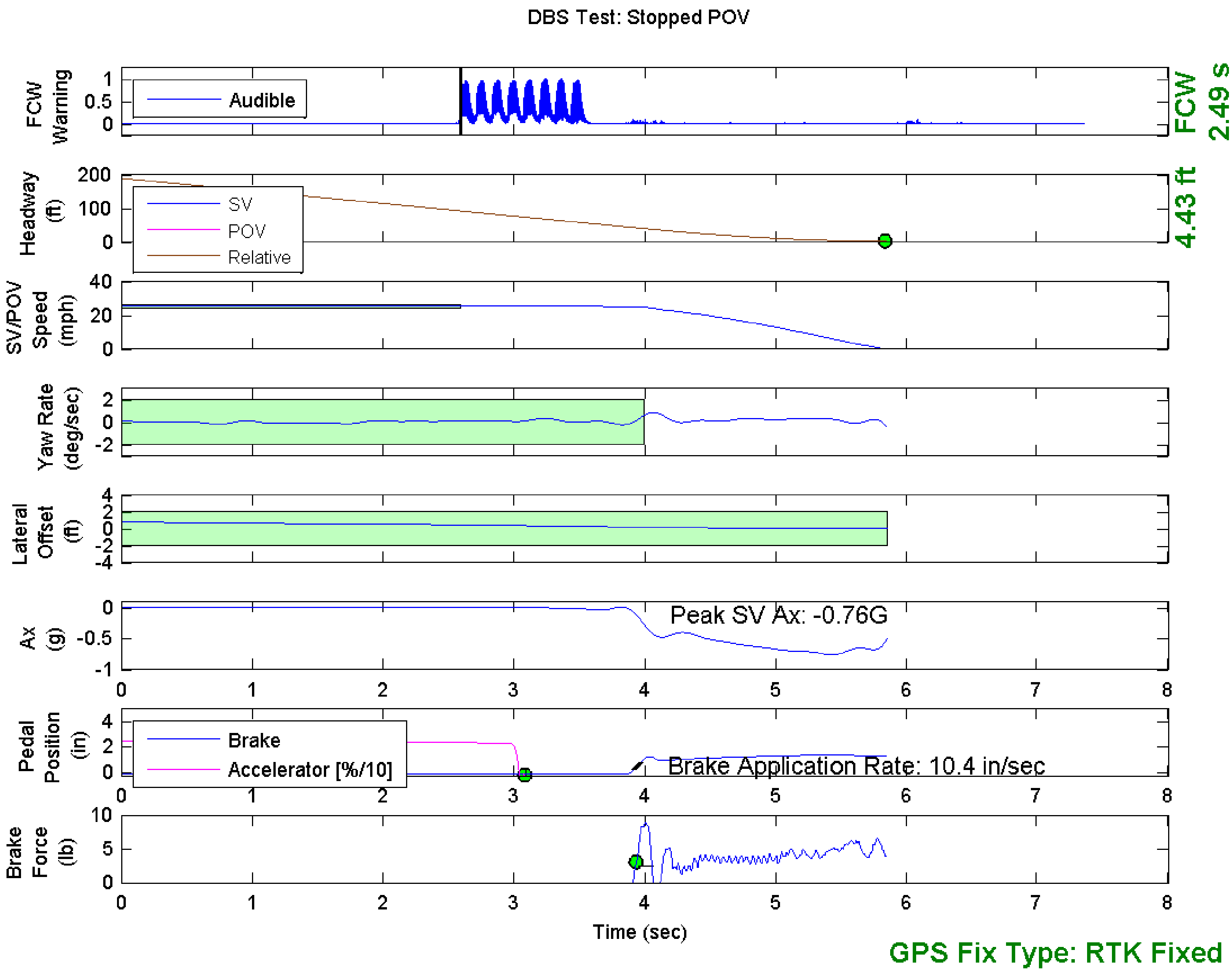


Figure E1. Example Time History for Stopped POV, Passing

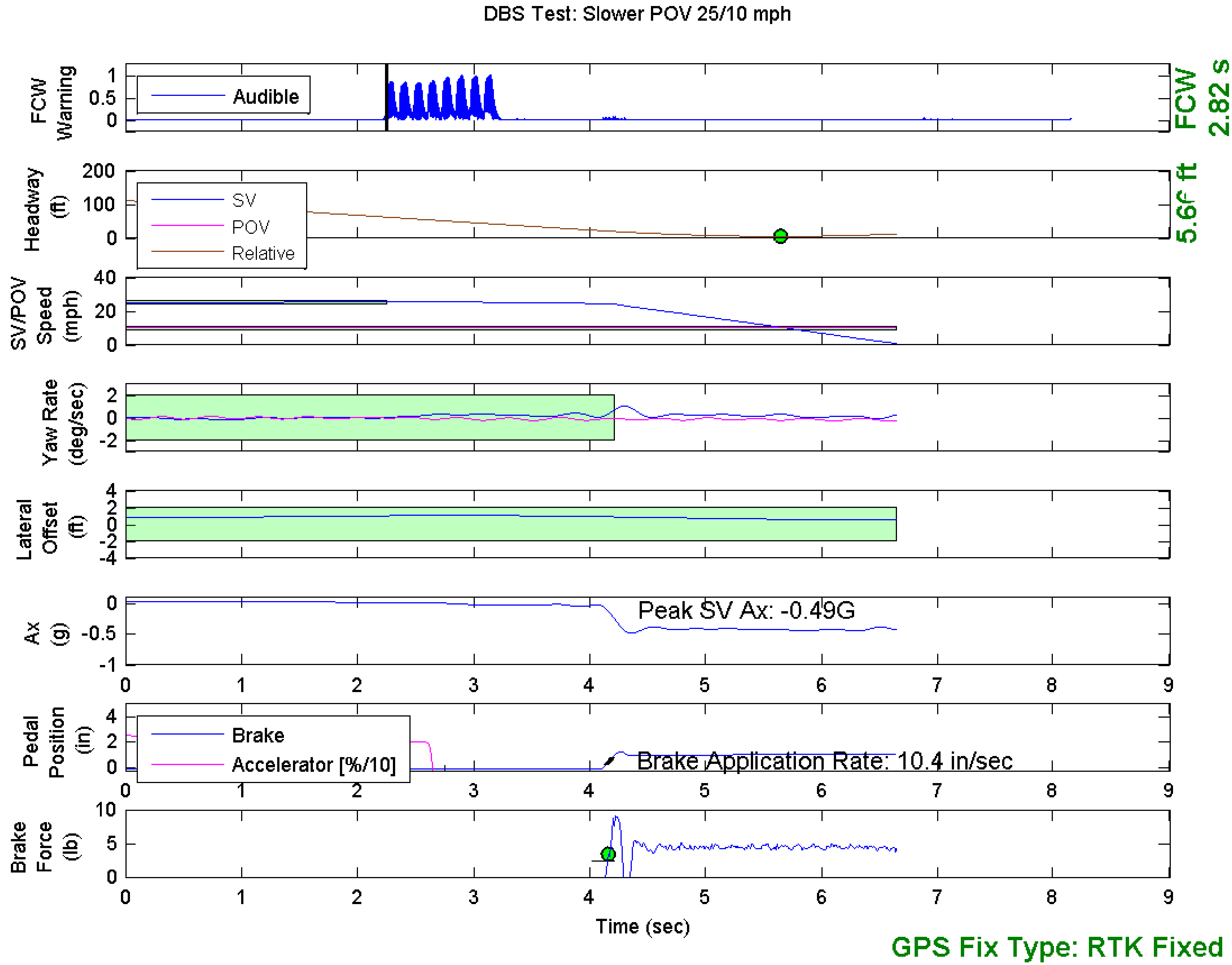


Figure E2. Example Time History for Slower POV 25 vs. 10, Passing

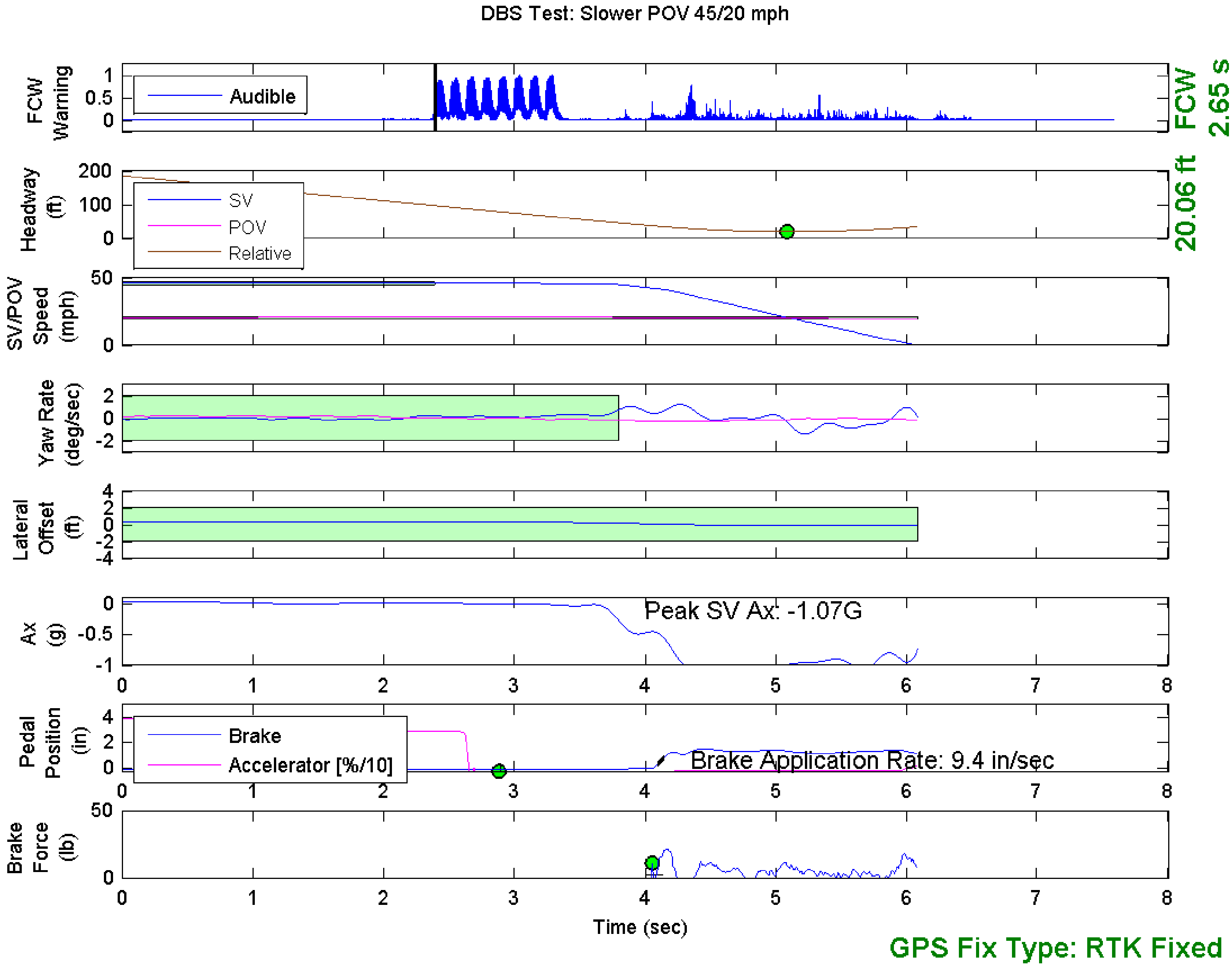


Figure E3. Example Time History for Slower POV 45 vs. 20, Passing

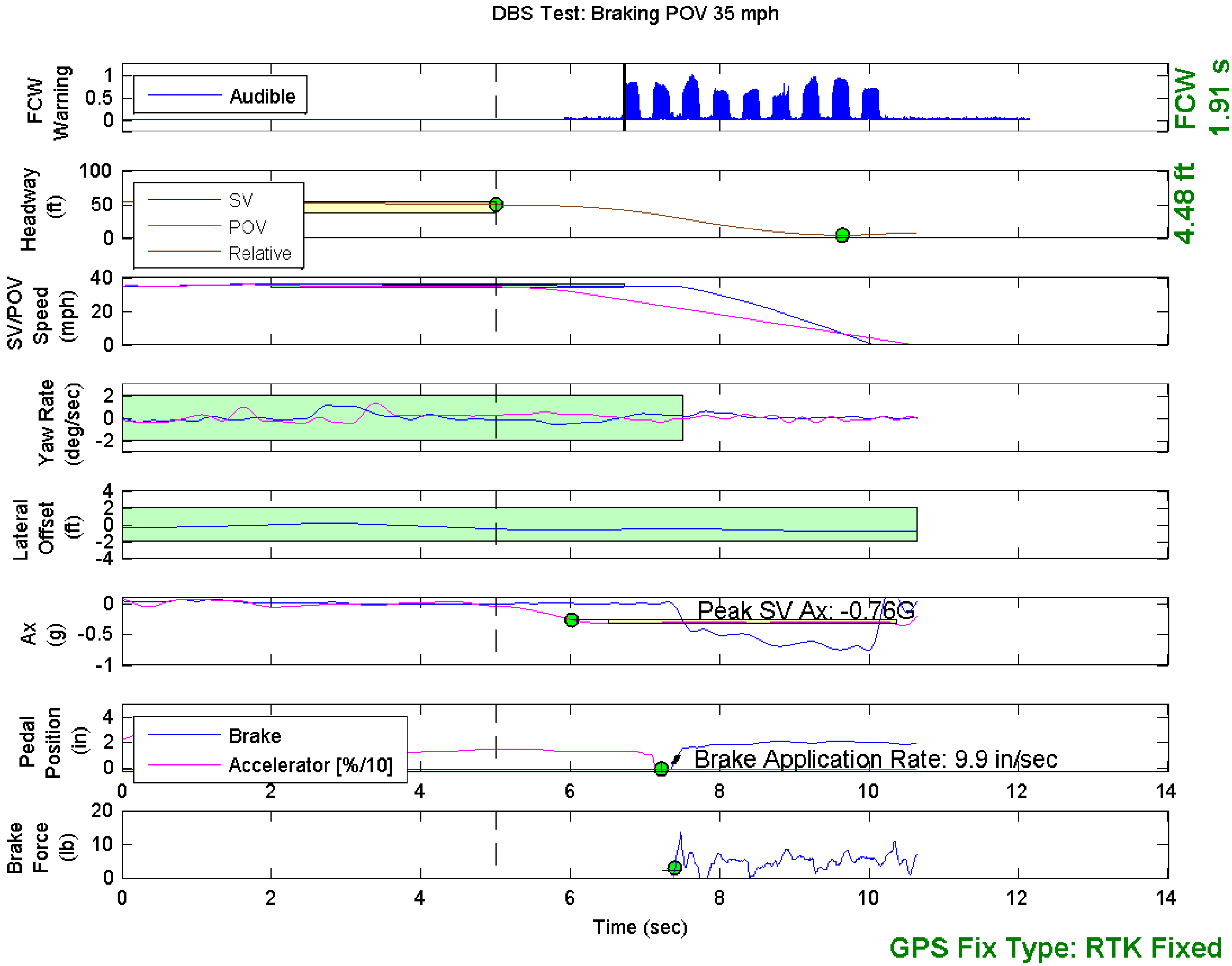


Figure E4. Example Time History for Braking POV 35, Passing

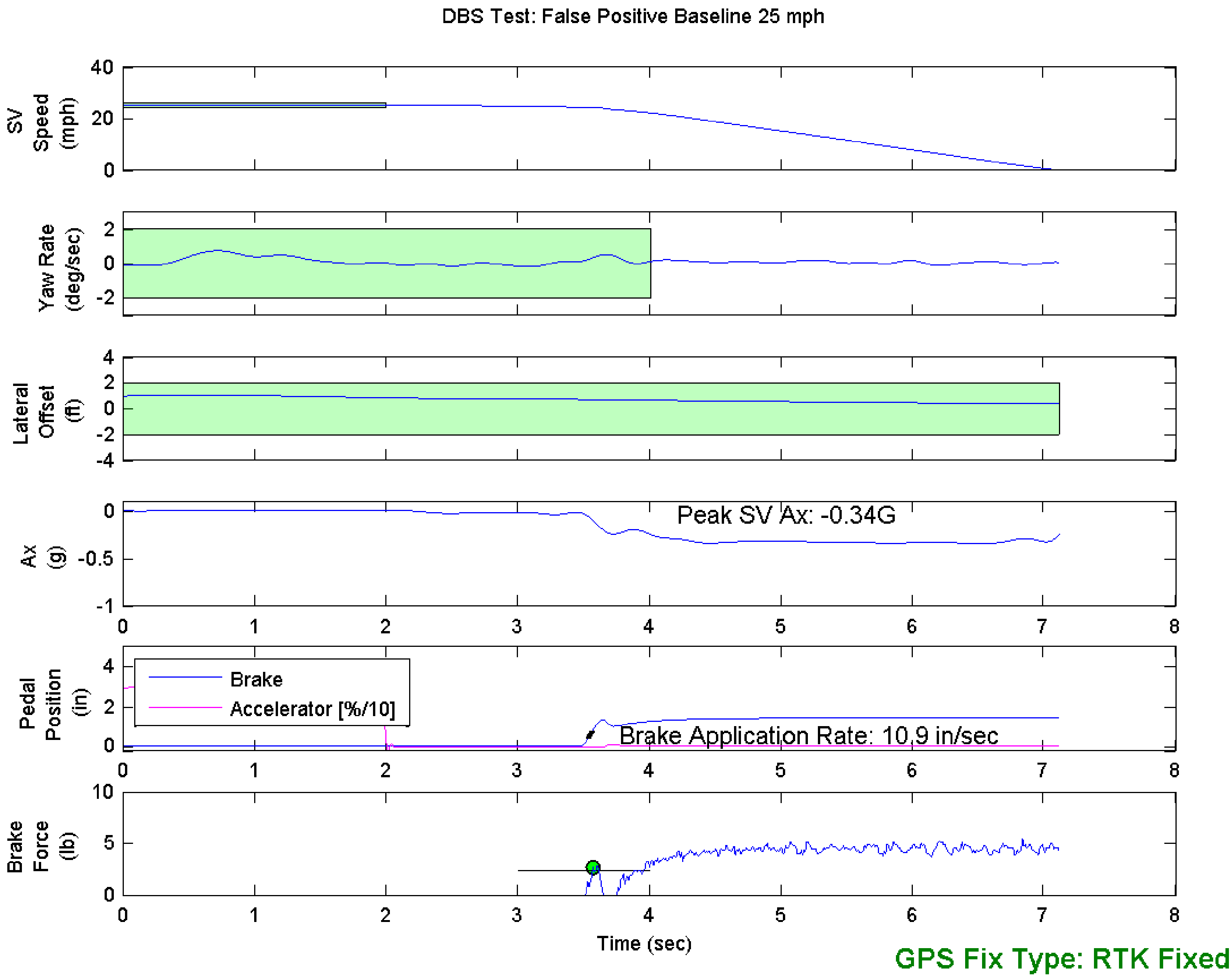


Figure E5. Example Time History for False Positive Baseline 25, Passing

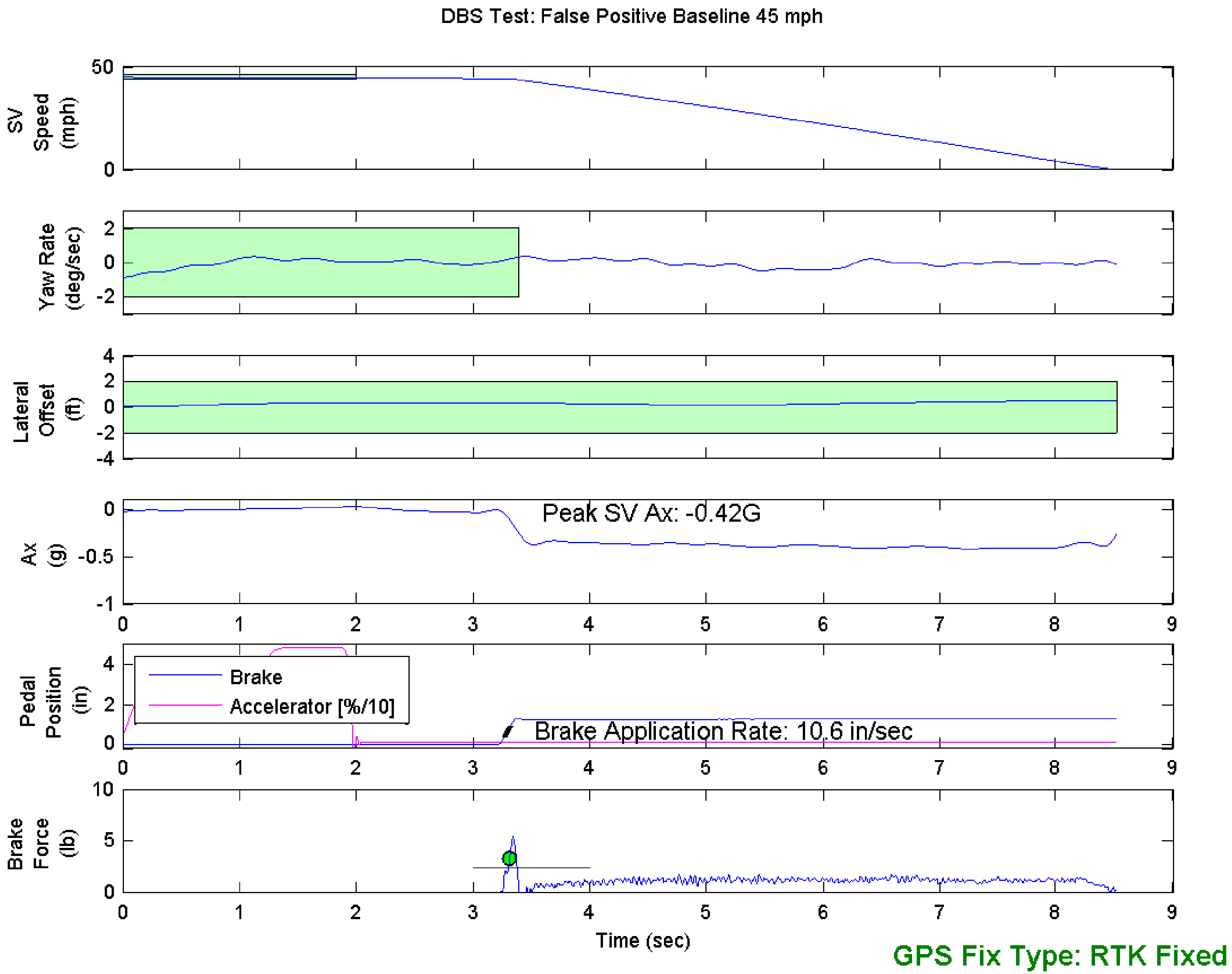


Figure E6. Example Time History for False Positive Baseline 45, Passing

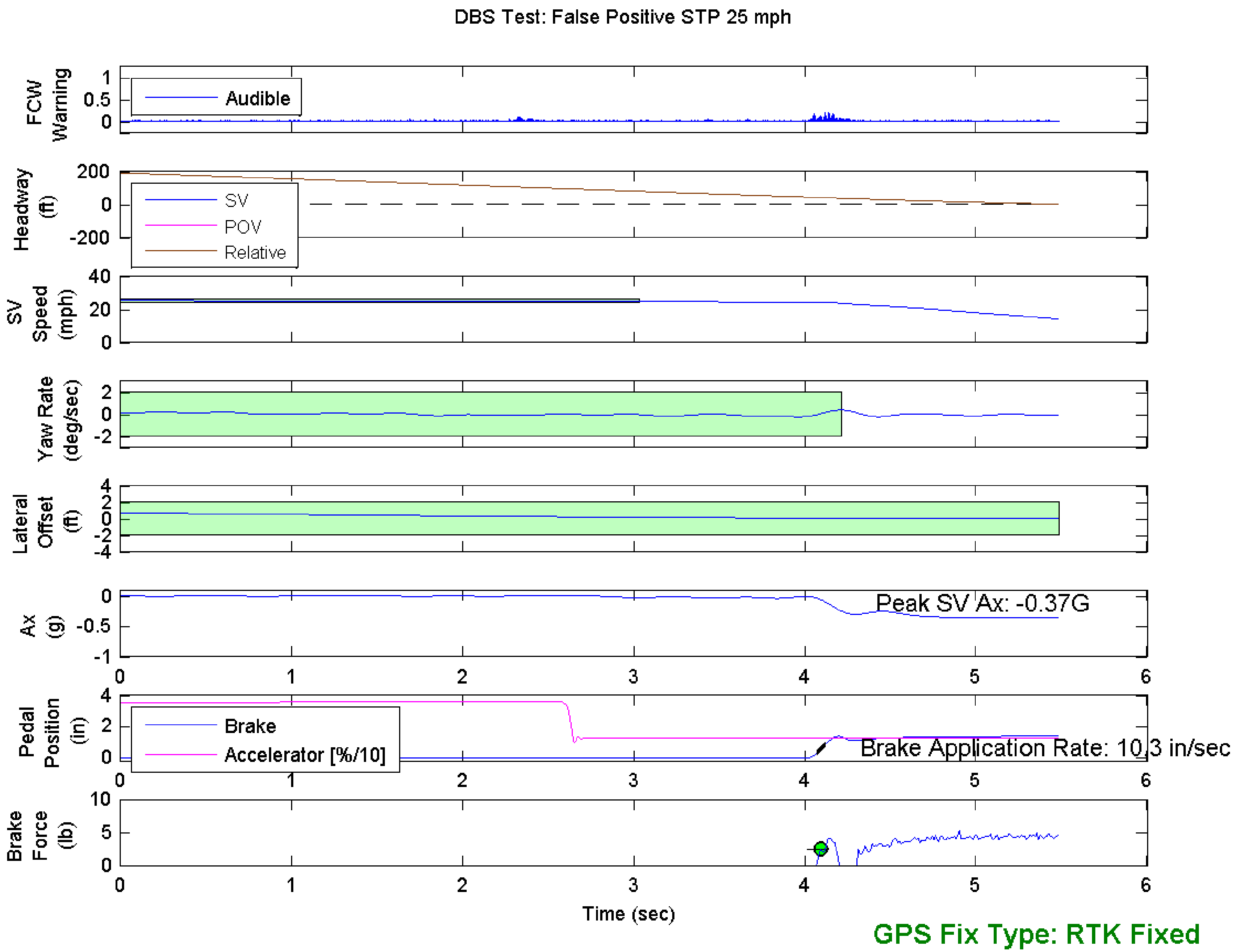


Figure E7. Example Time History for False Positive Steel Plate 25, Passing

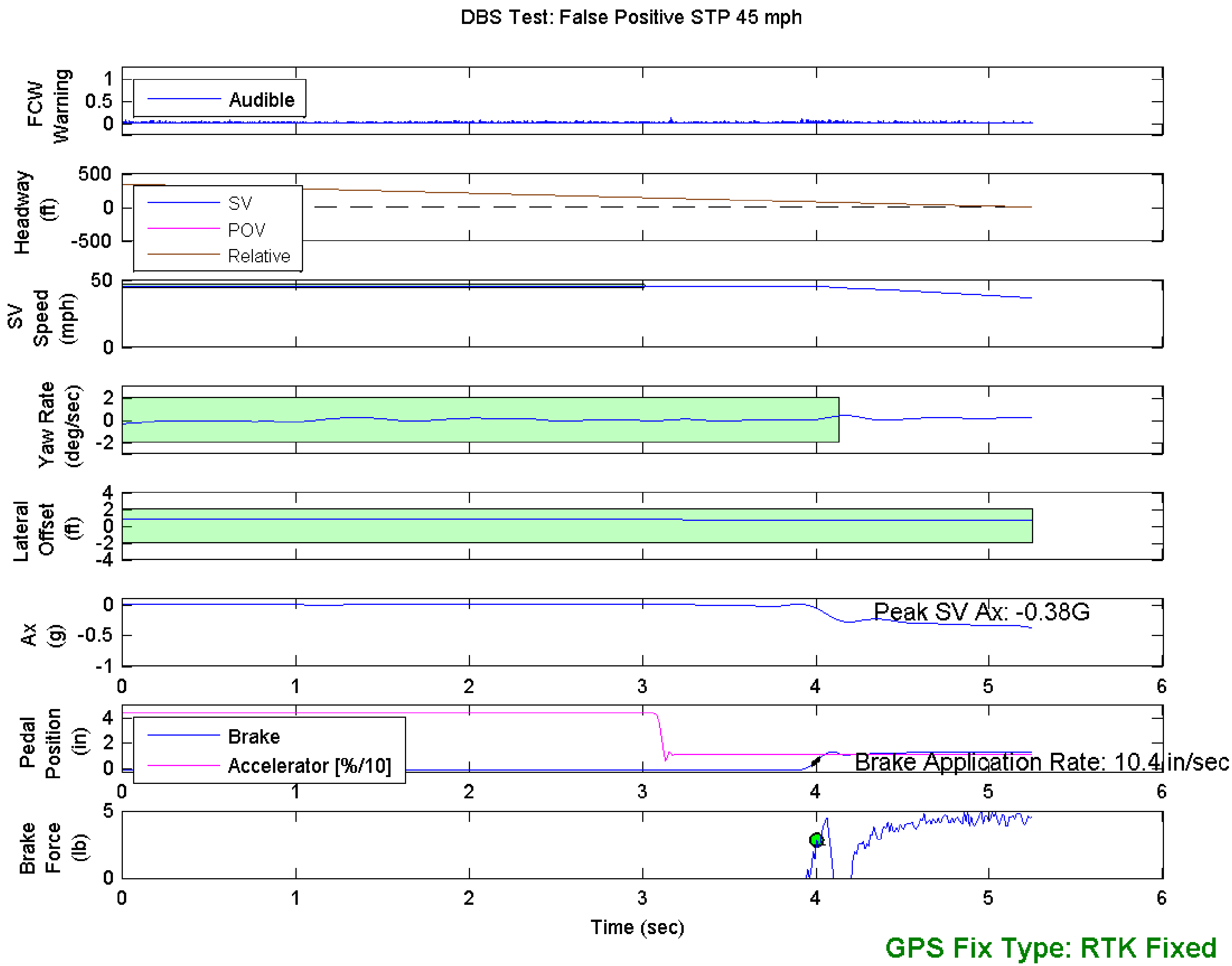


Figure E8. Example Time History for False Positive Steel Plate 45, Passing

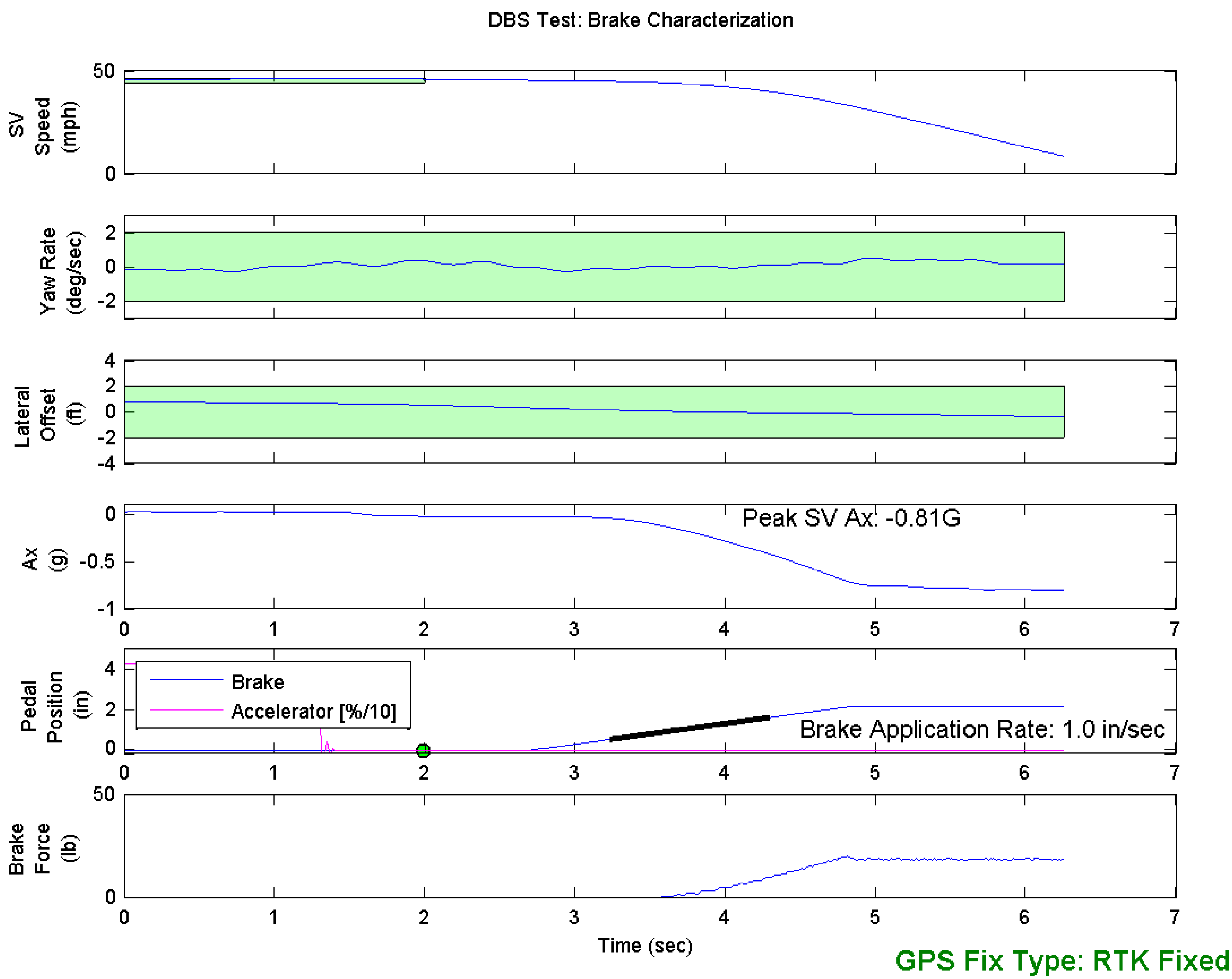


Figure E9. Example Time History for DBS Brake Characterization, Passing

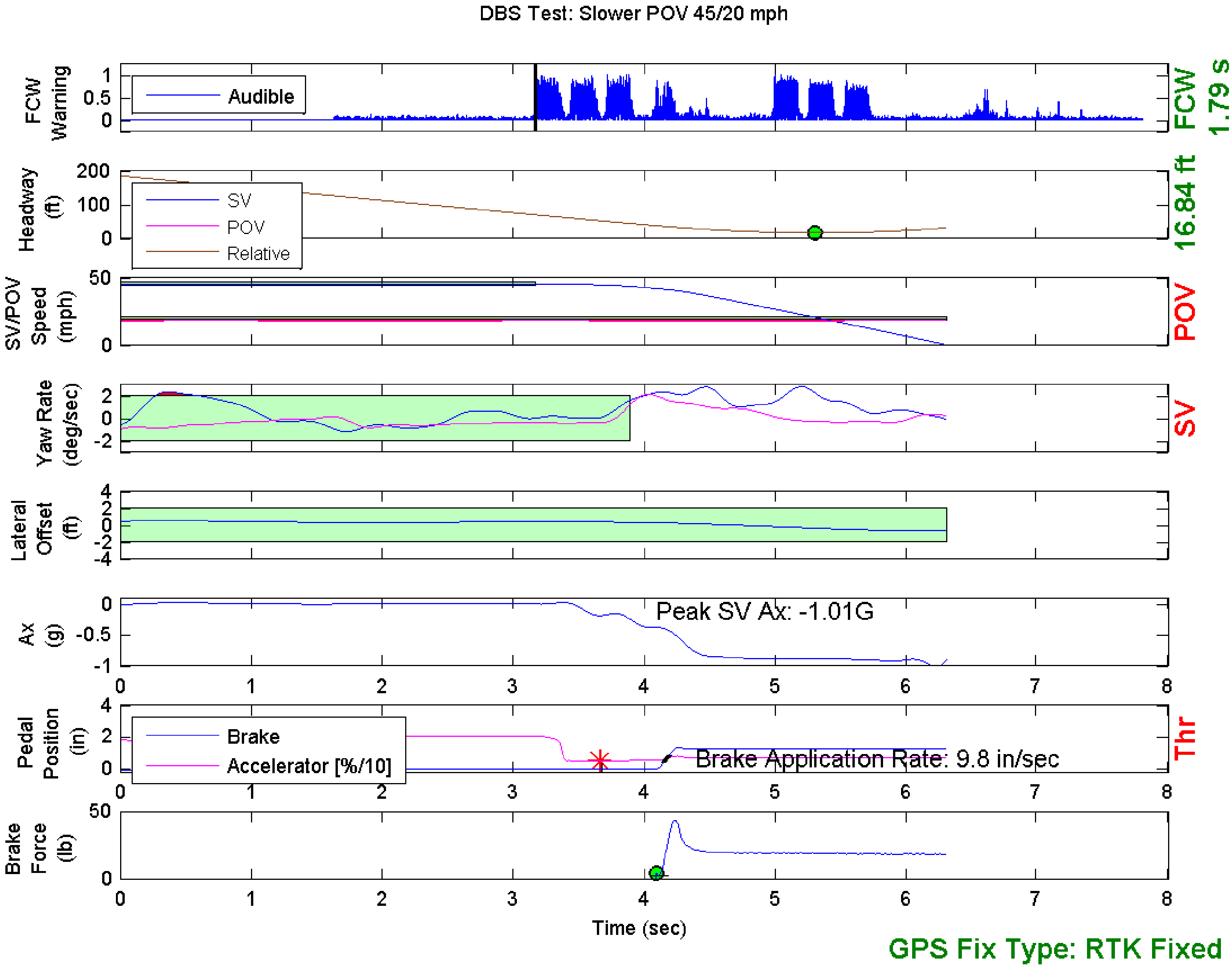


Figure E10. Example Time History Displaying Various Invalid Criteria

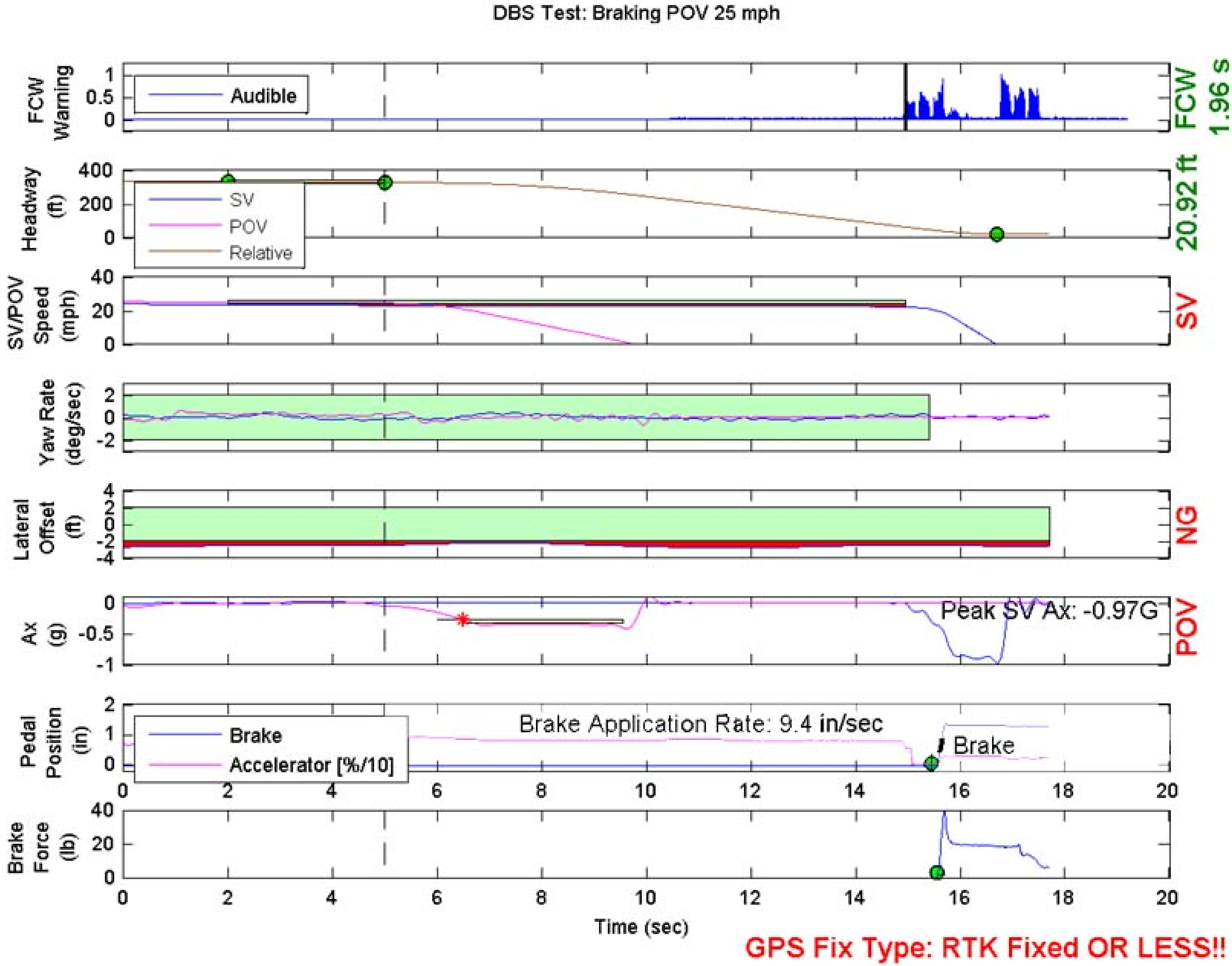


Figure E11. Example Time History Displaying Various Invalid Criteria

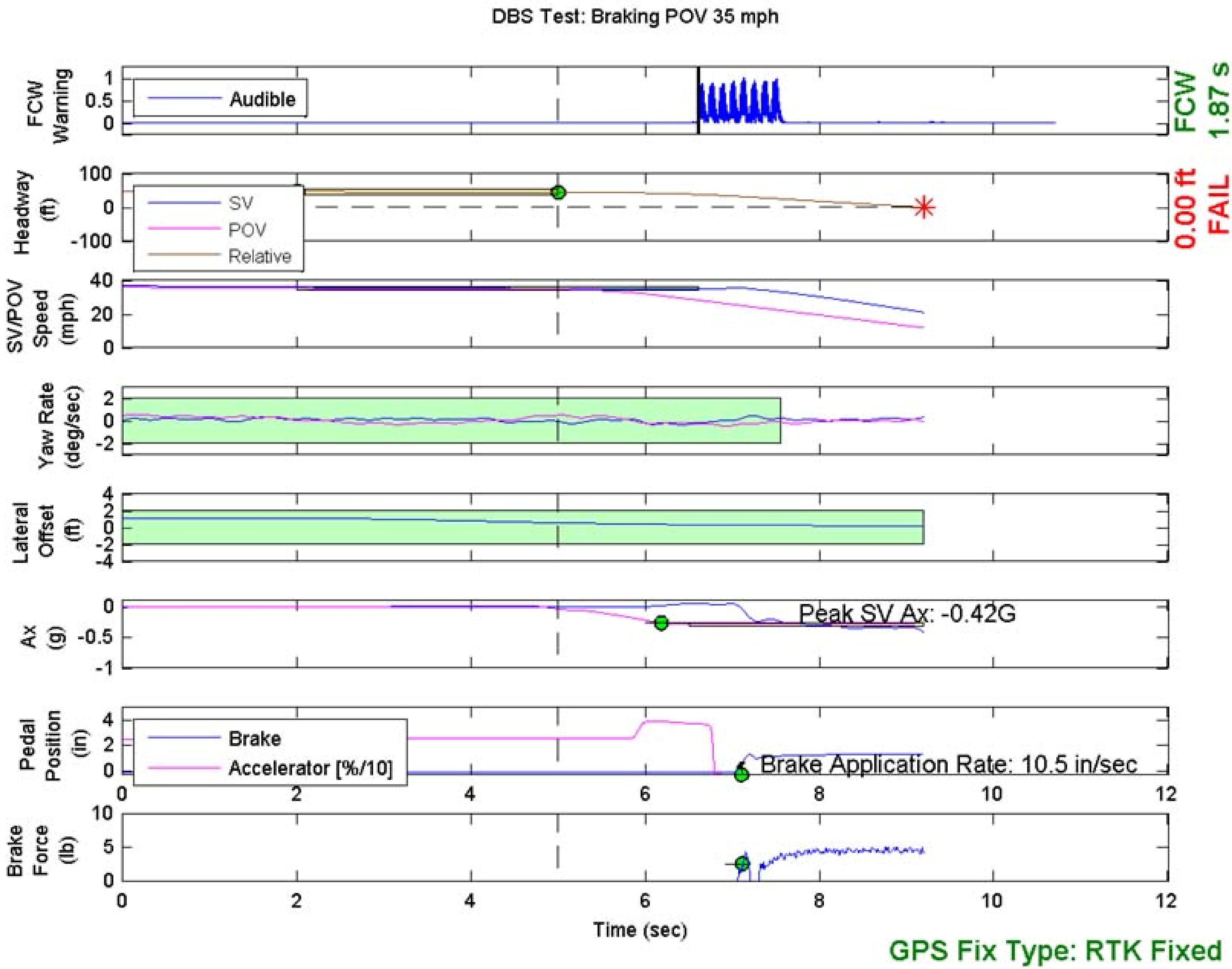


Figure E12. Example Time History for a Failed Run

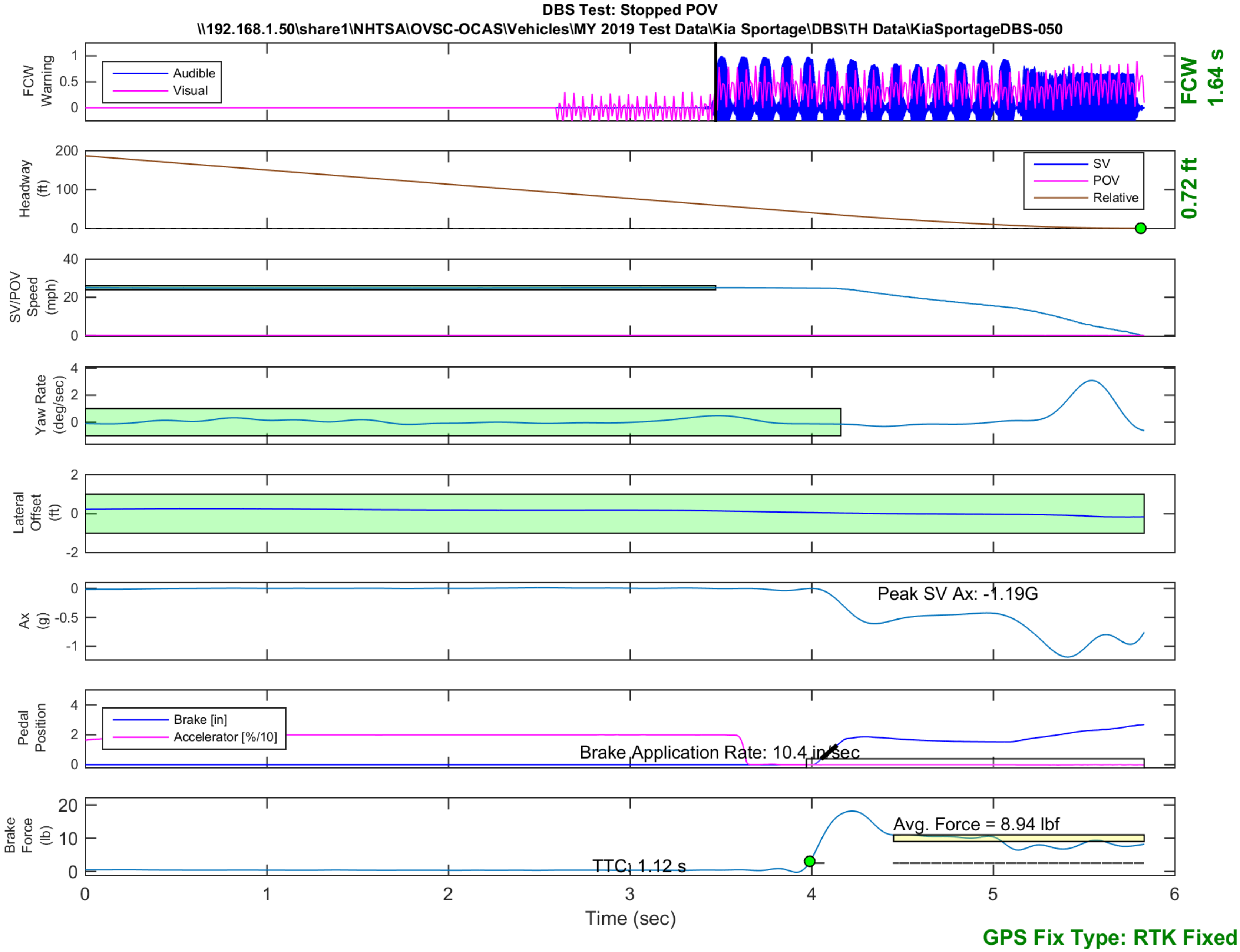


Figure E13. Time History for DBS Run 50, SV Encounters Stopped POV

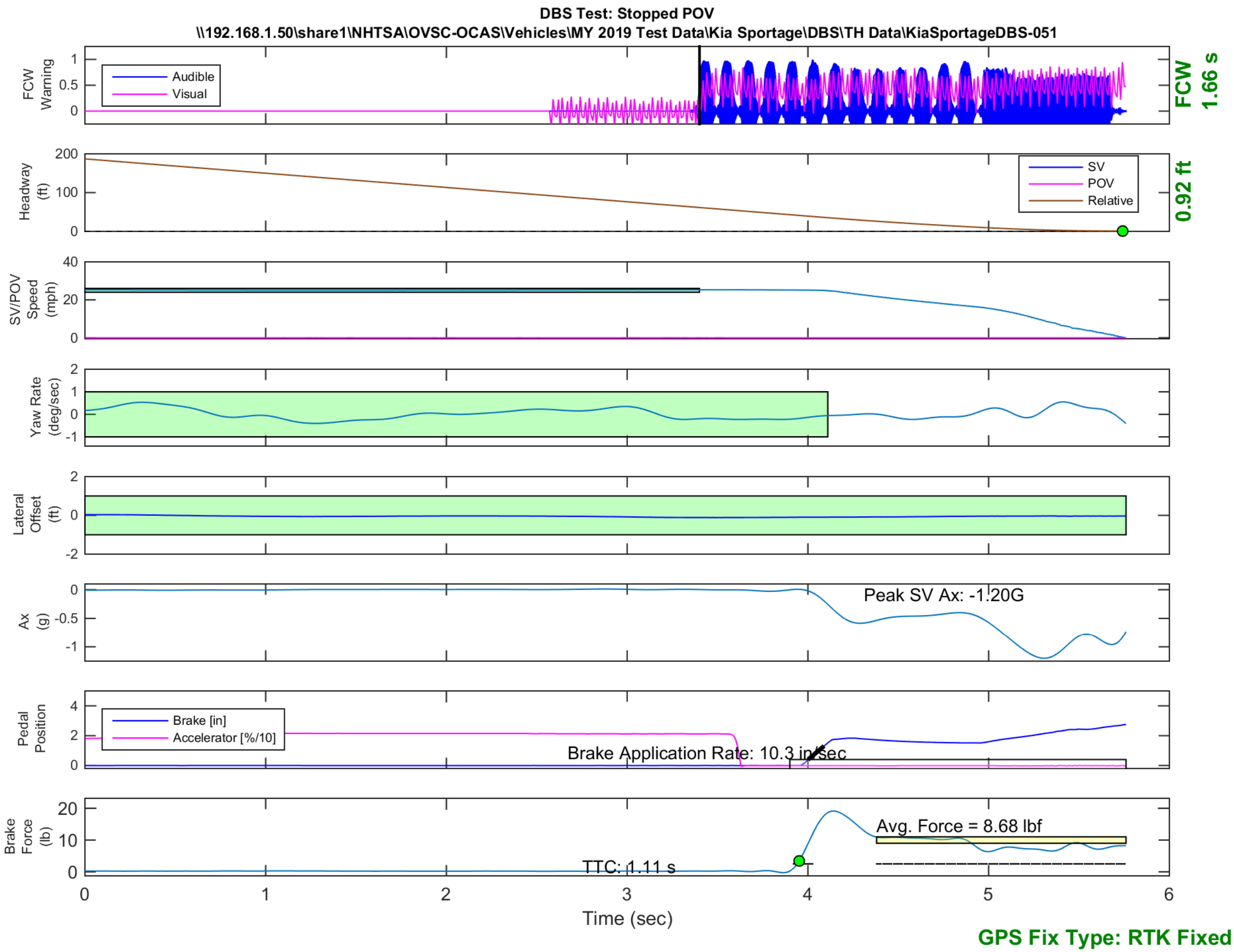


Figure E14. Time History for DBS Run 51, SV Encounters Stopped POV

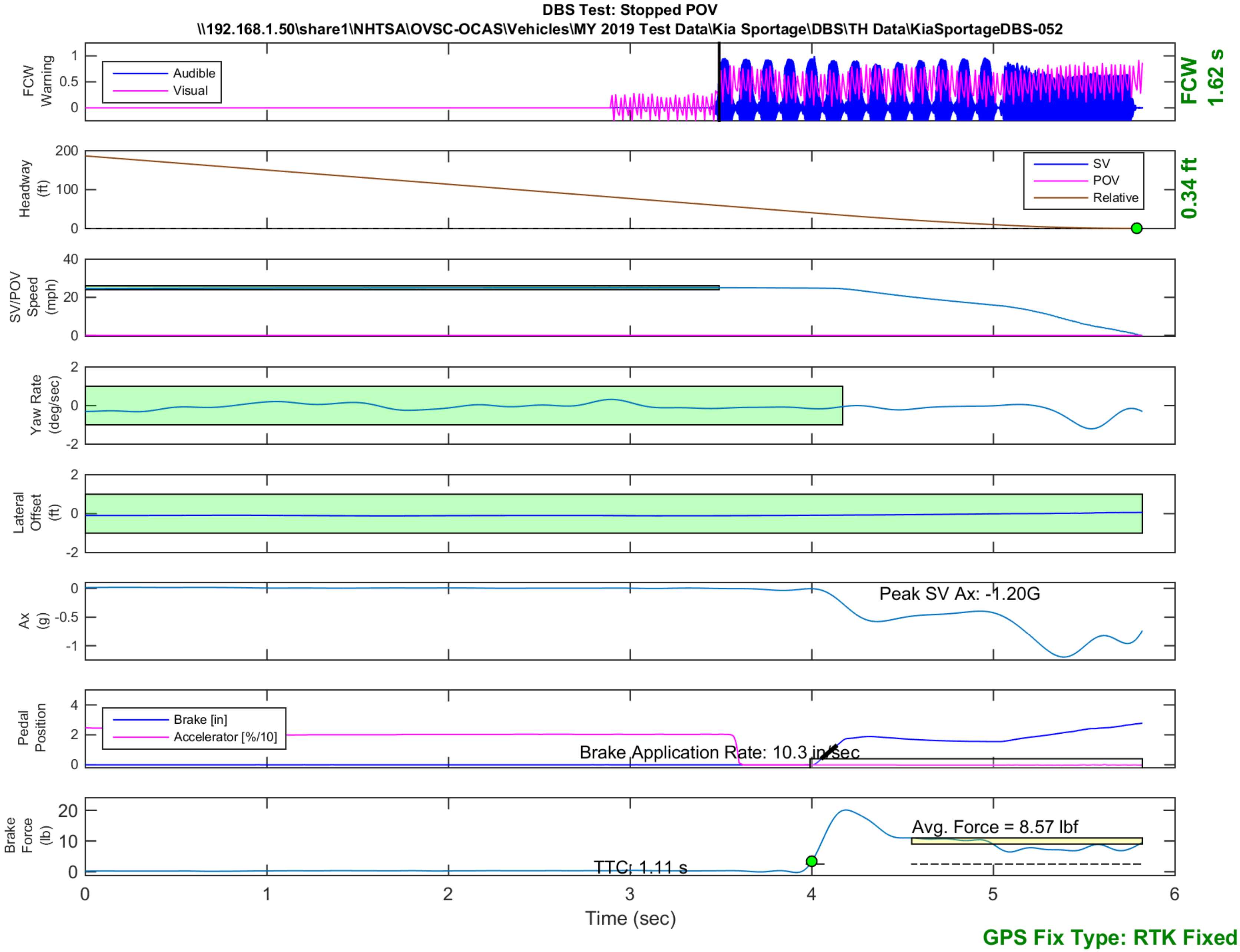


Figure E15. Time History for DBS Run 52, SV Encounters Stopped POV

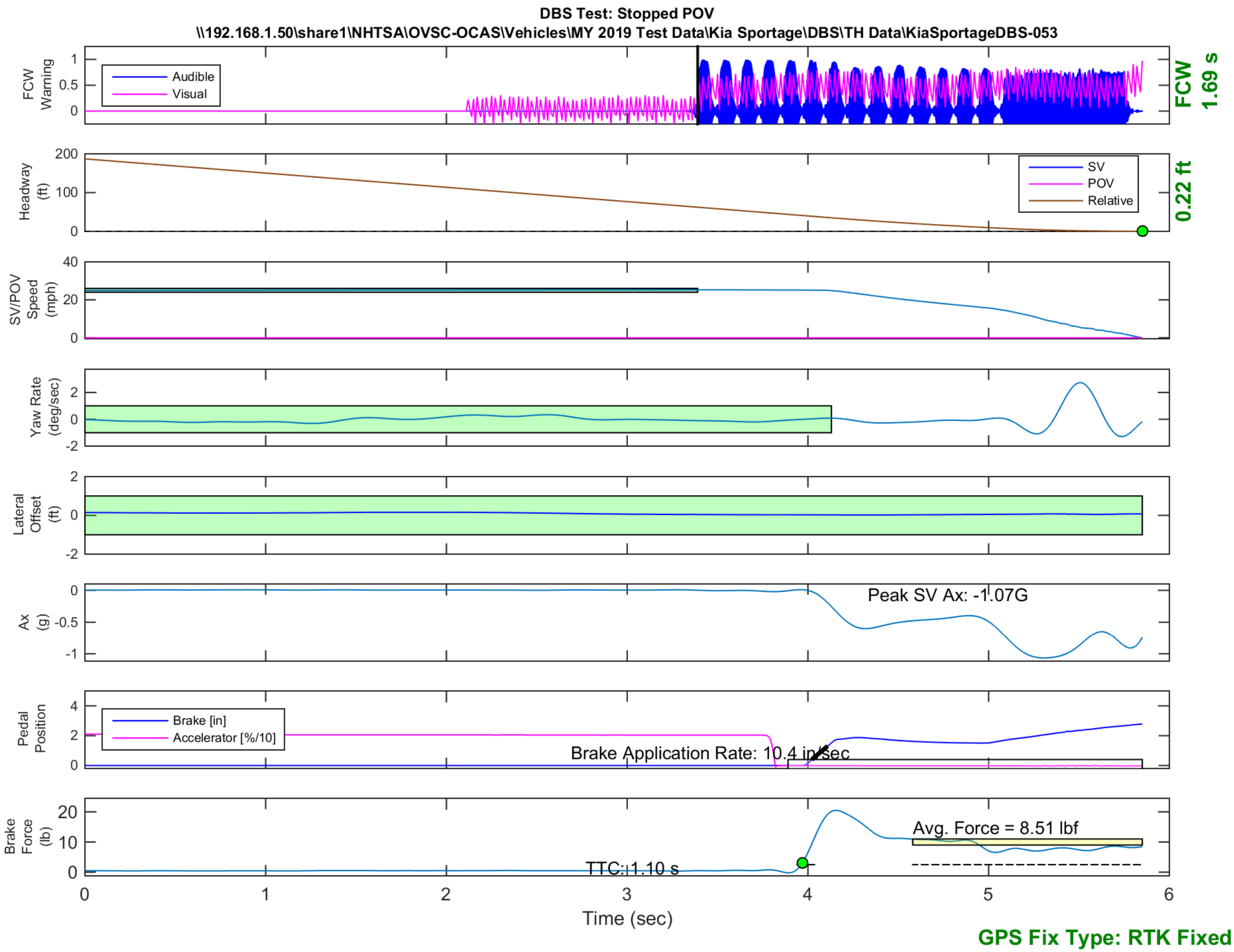


Figure E16. Time History for DBS Run 53, SV Encounters Stopped POV

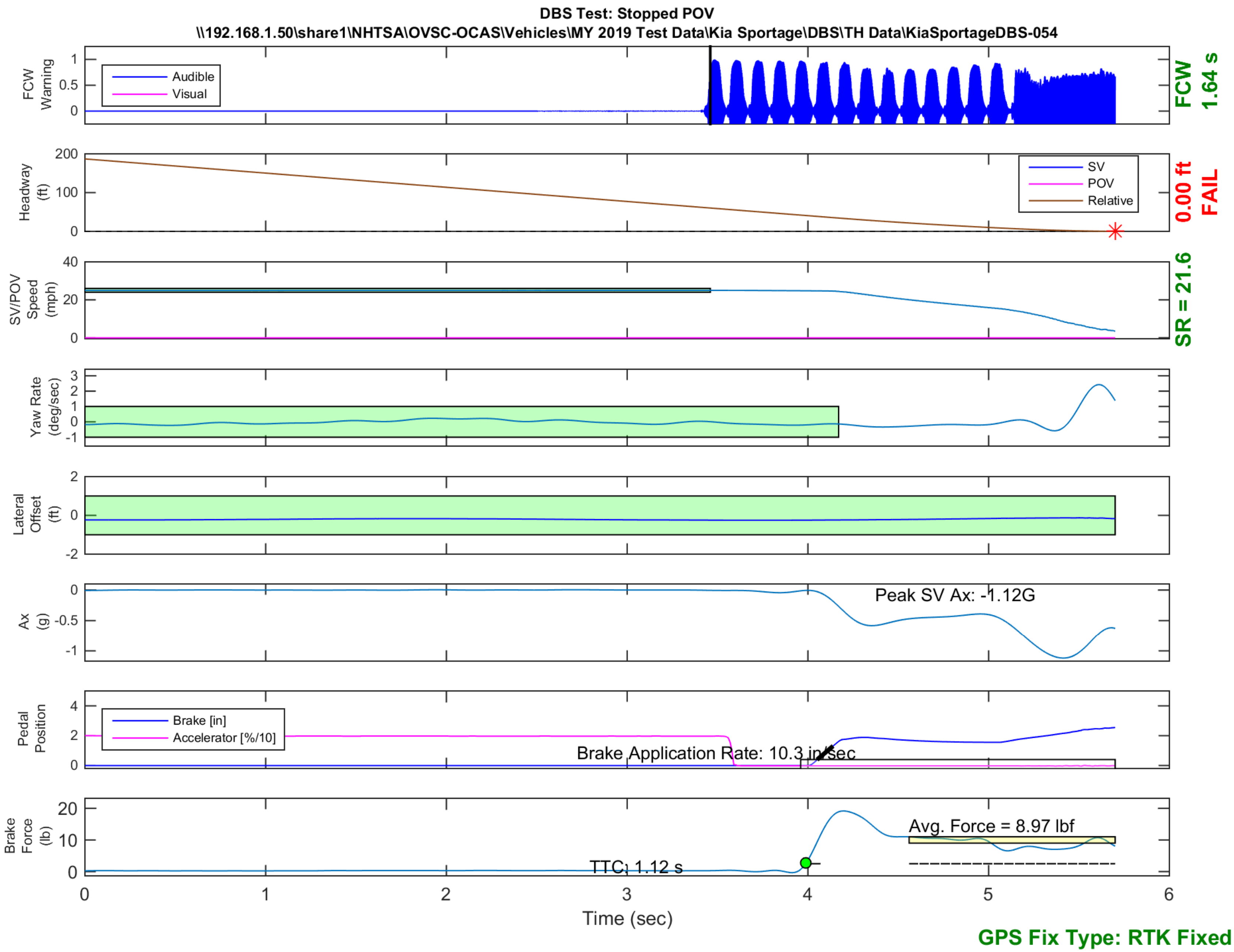


Figure E17. Time History for DBS Run 54, SV Encounters Stopped POV

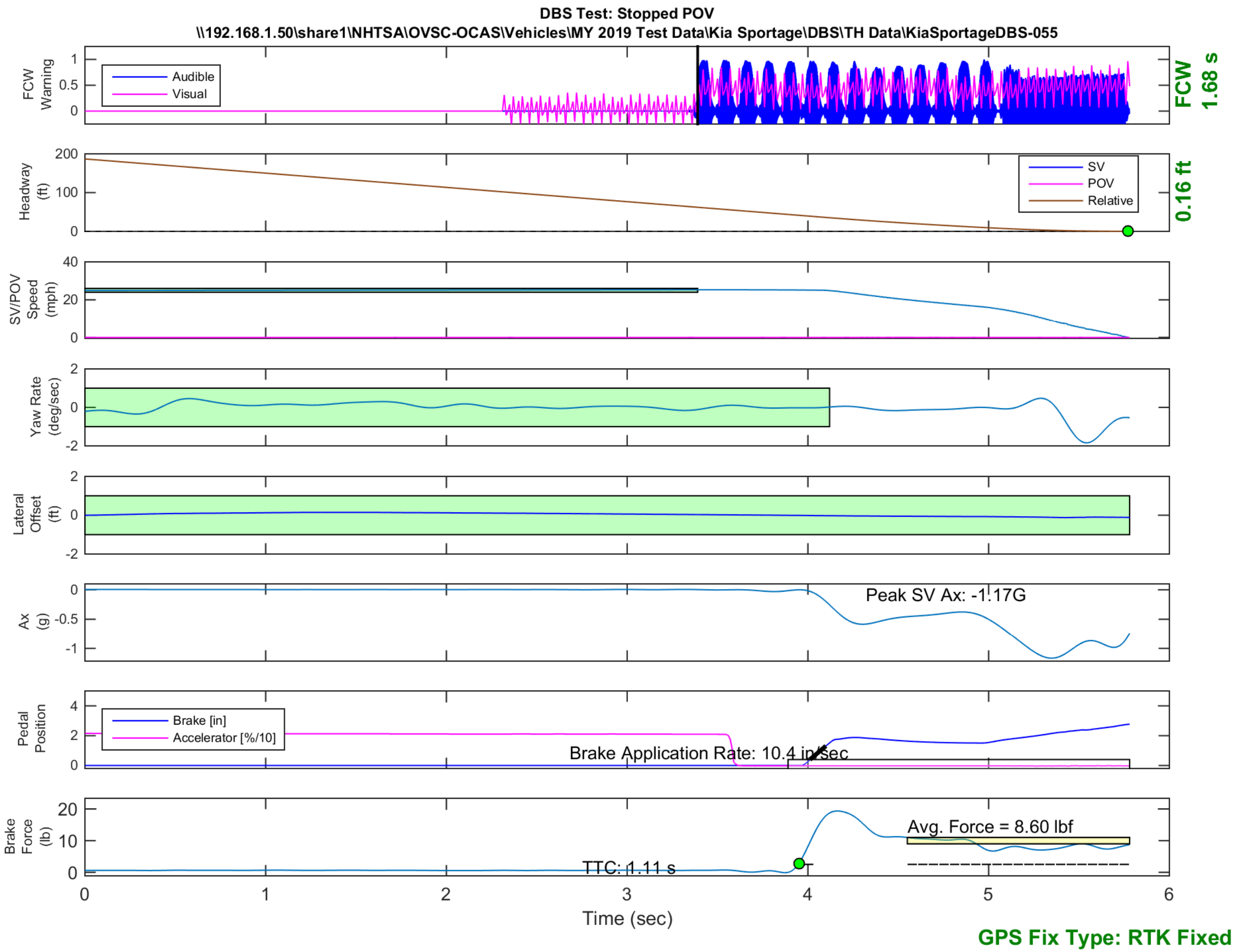


Figure E18. Time History for DBS Run 55, SV Encounters Stopped POV

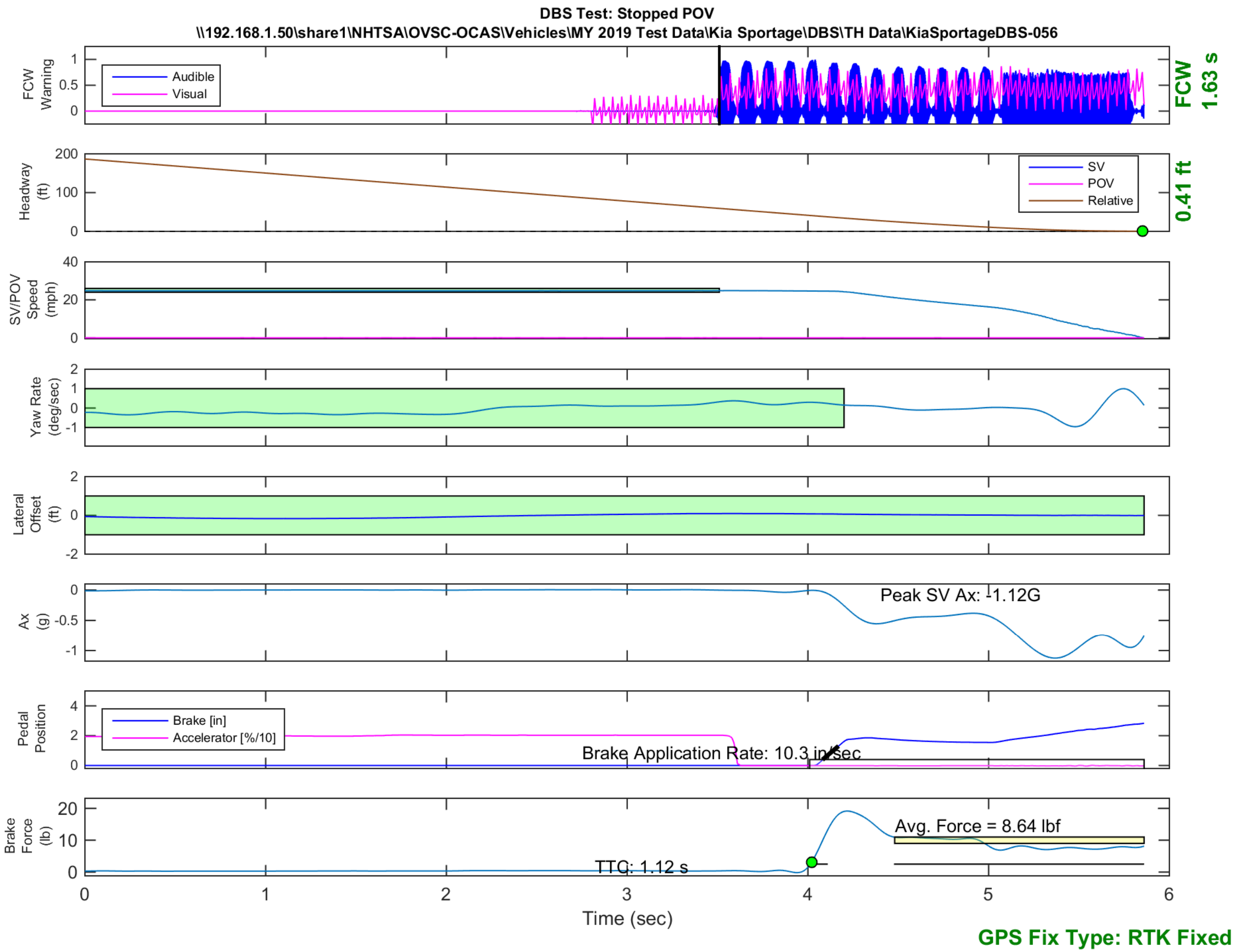


Figure E19. Time History for DBS Run 56, SV Encounters Stopped POV

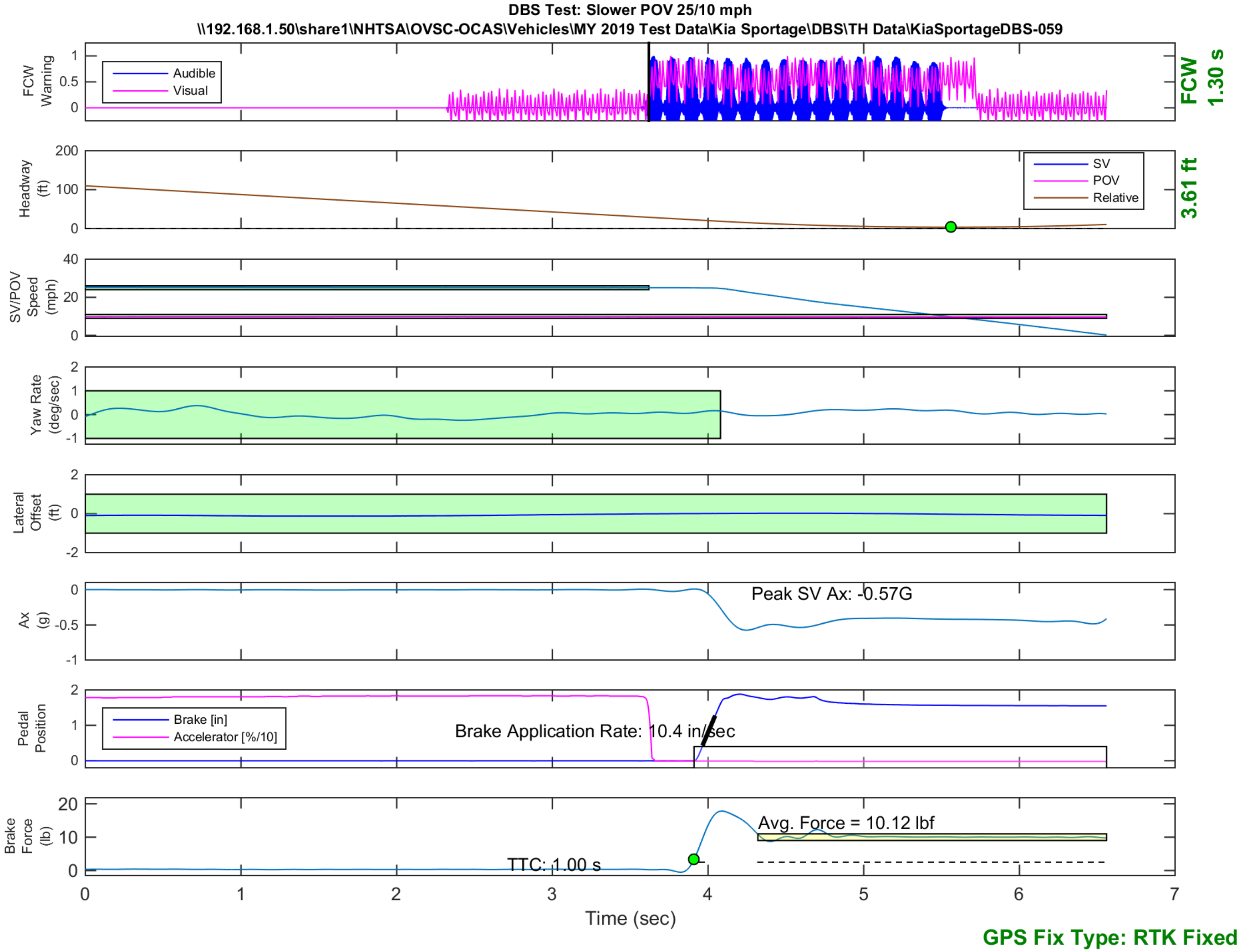


Figure E20. Time History for DBS Run 59, SV Encounters Slower POV, SV 25 mph, POV 10 mph

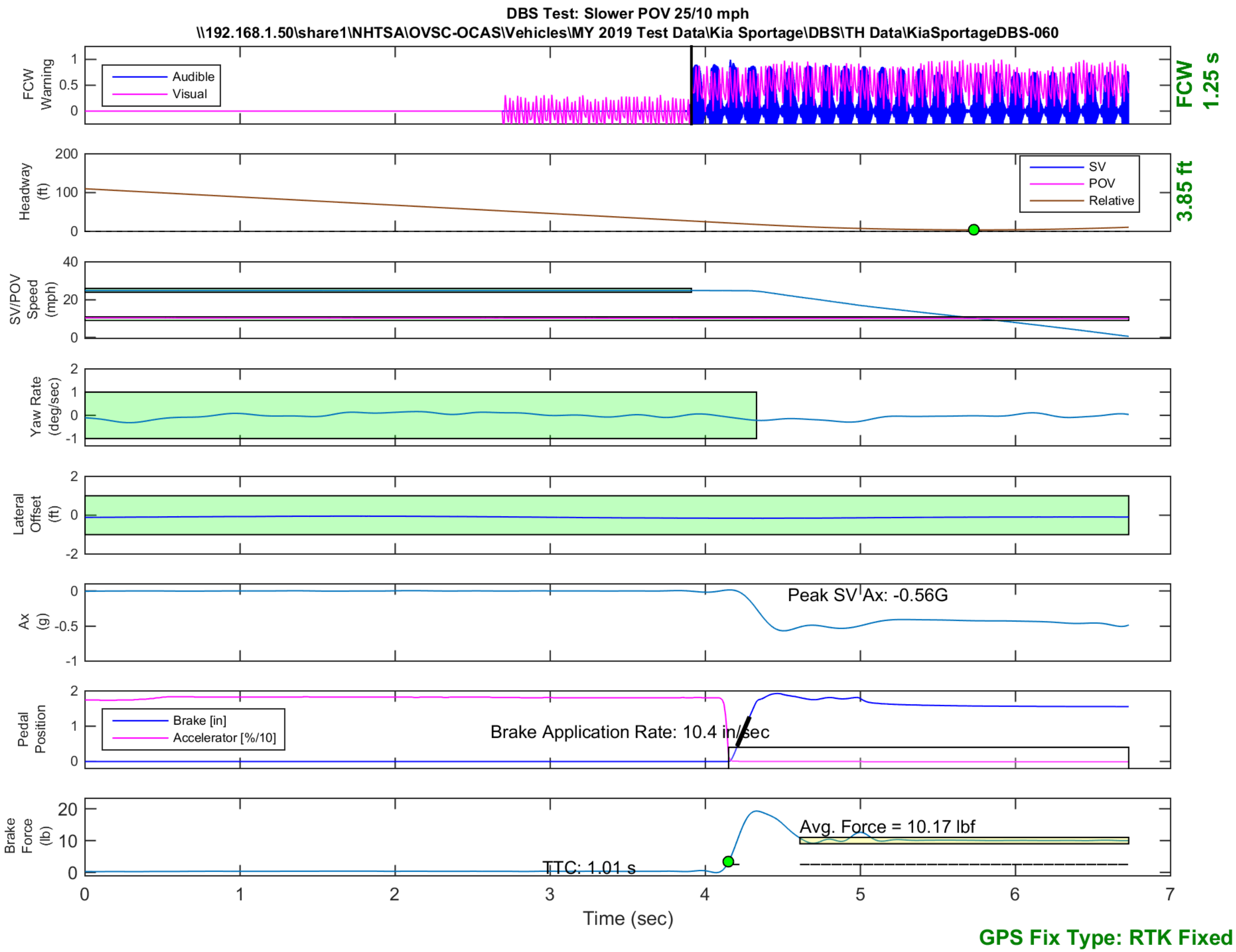


Figure E21. Time History for DBS Run 60, SV Encounters Slower POV, SV 25 mph, POV 10 mph

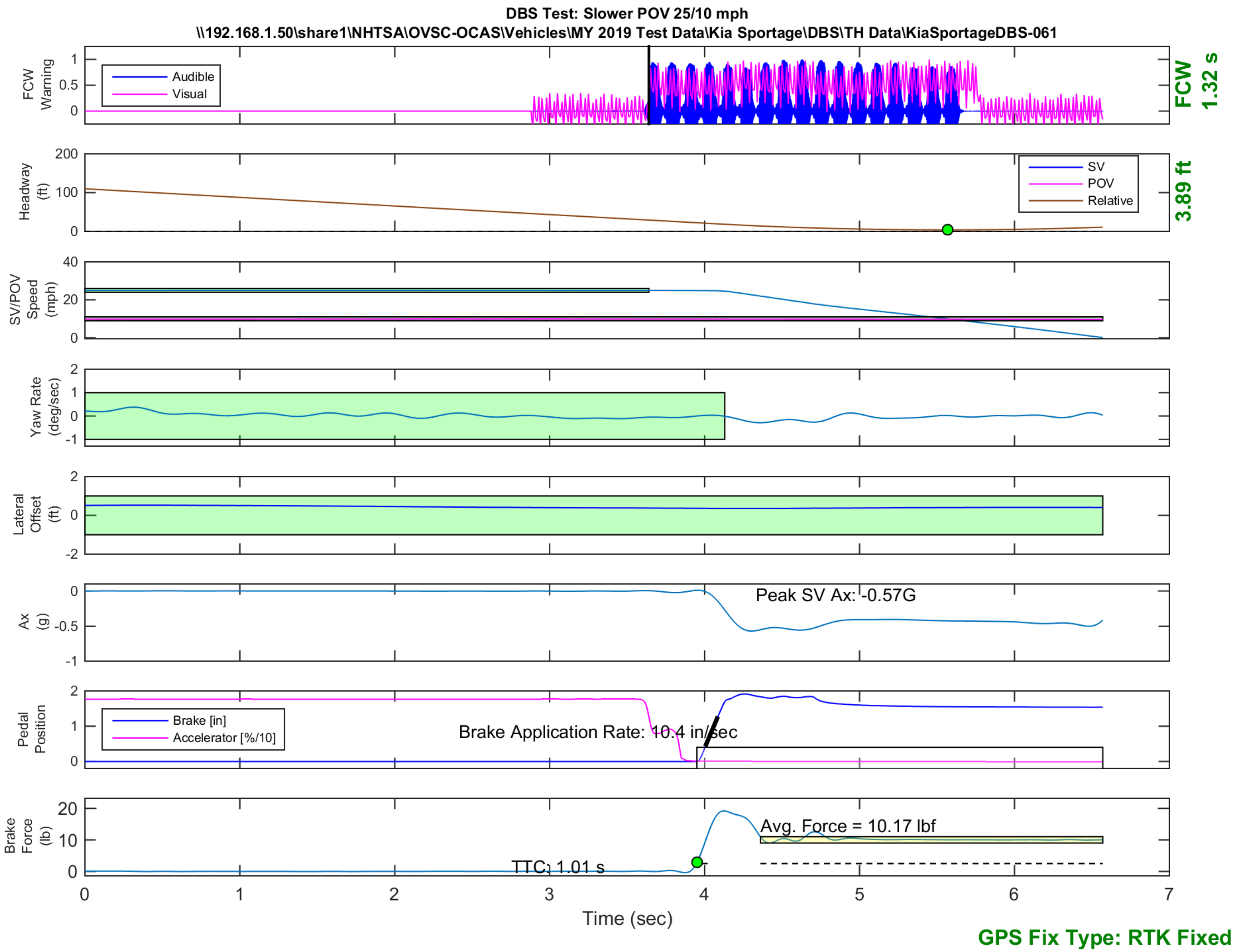


Figure E22. Time History for DBS Run 61, SV Encounters Slower POV, SV 25 mph, POV 10 mph

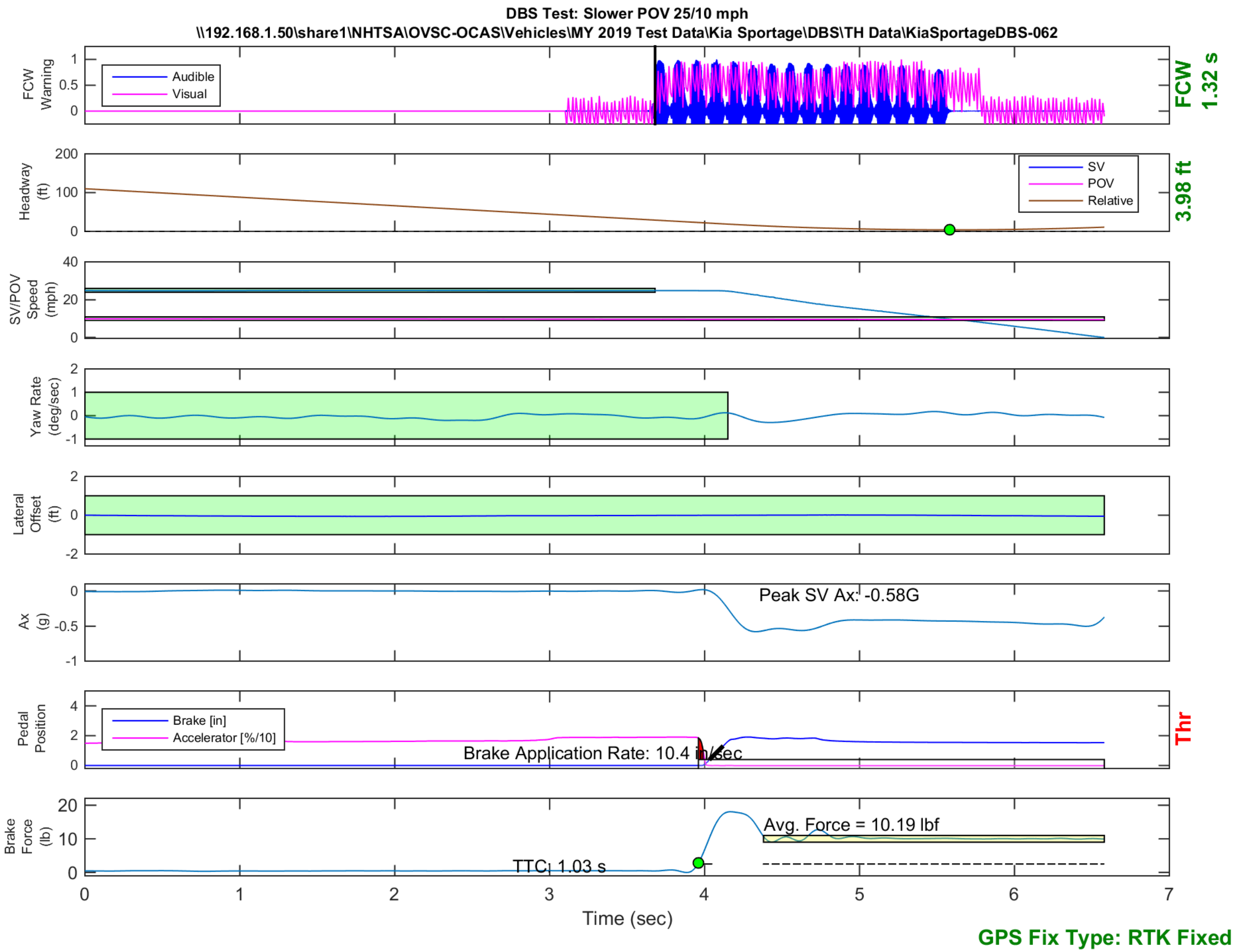


Figure E23. Time History for DBS Run 62, SV Encounters Slower POV, SV 25 mph, POV 10 mph

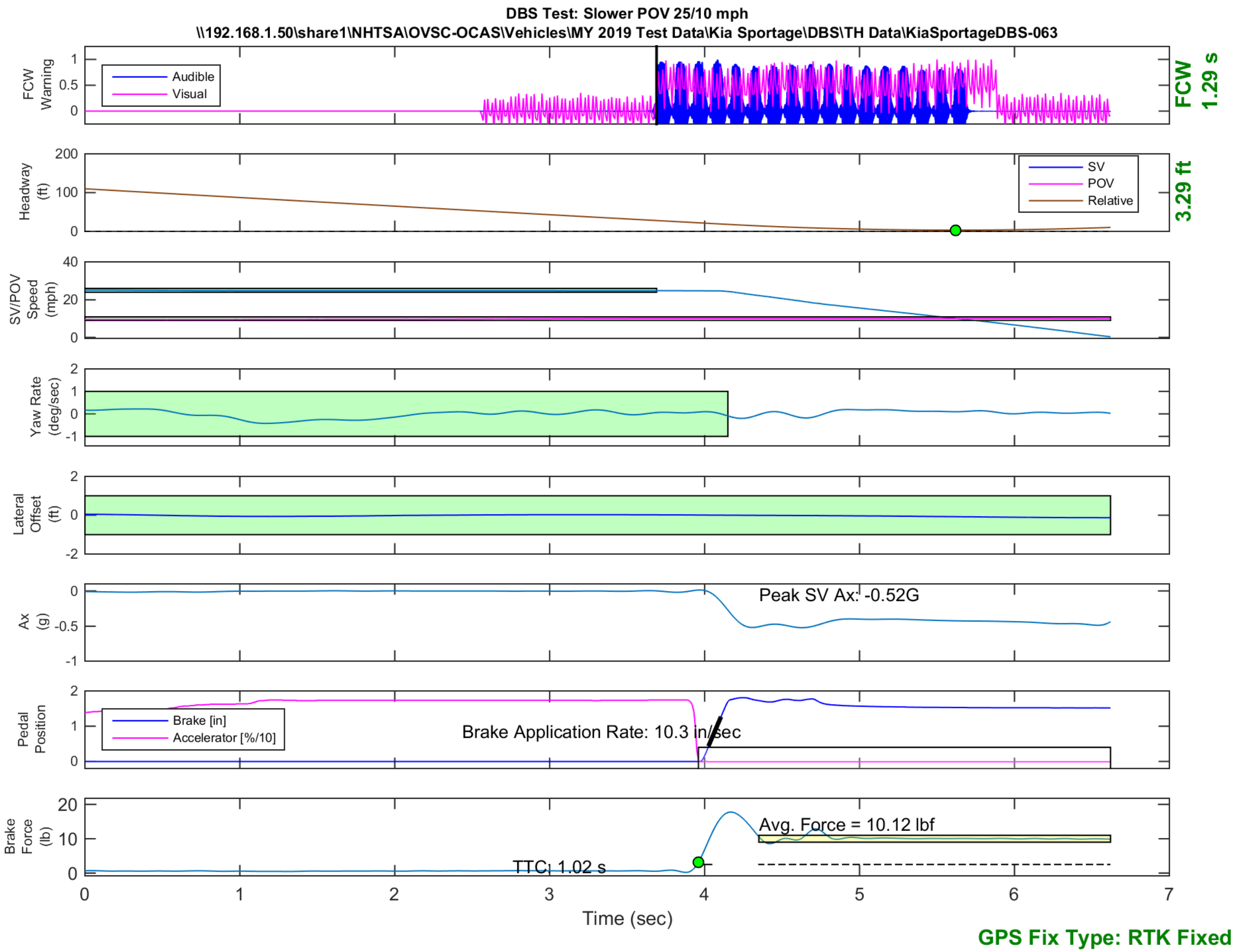


Figure E24. Time History for DBS Run 63, SV Encounters Slower POV, SV 25 mph, POV 10 mph

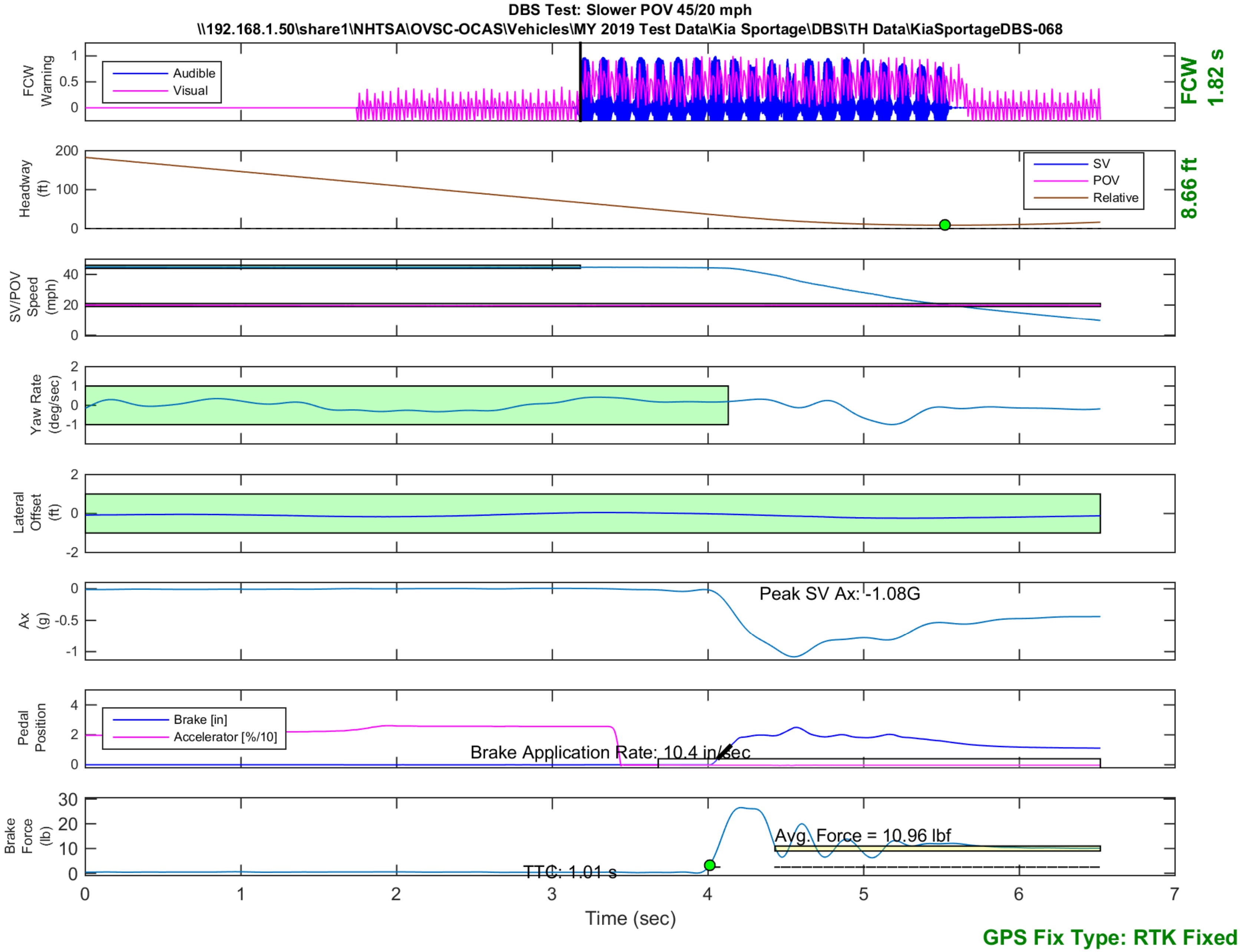


Figure E25. Time History for DBS Run 68, SV Encounters Slower POV, SV 45 mph, POV 20 mph

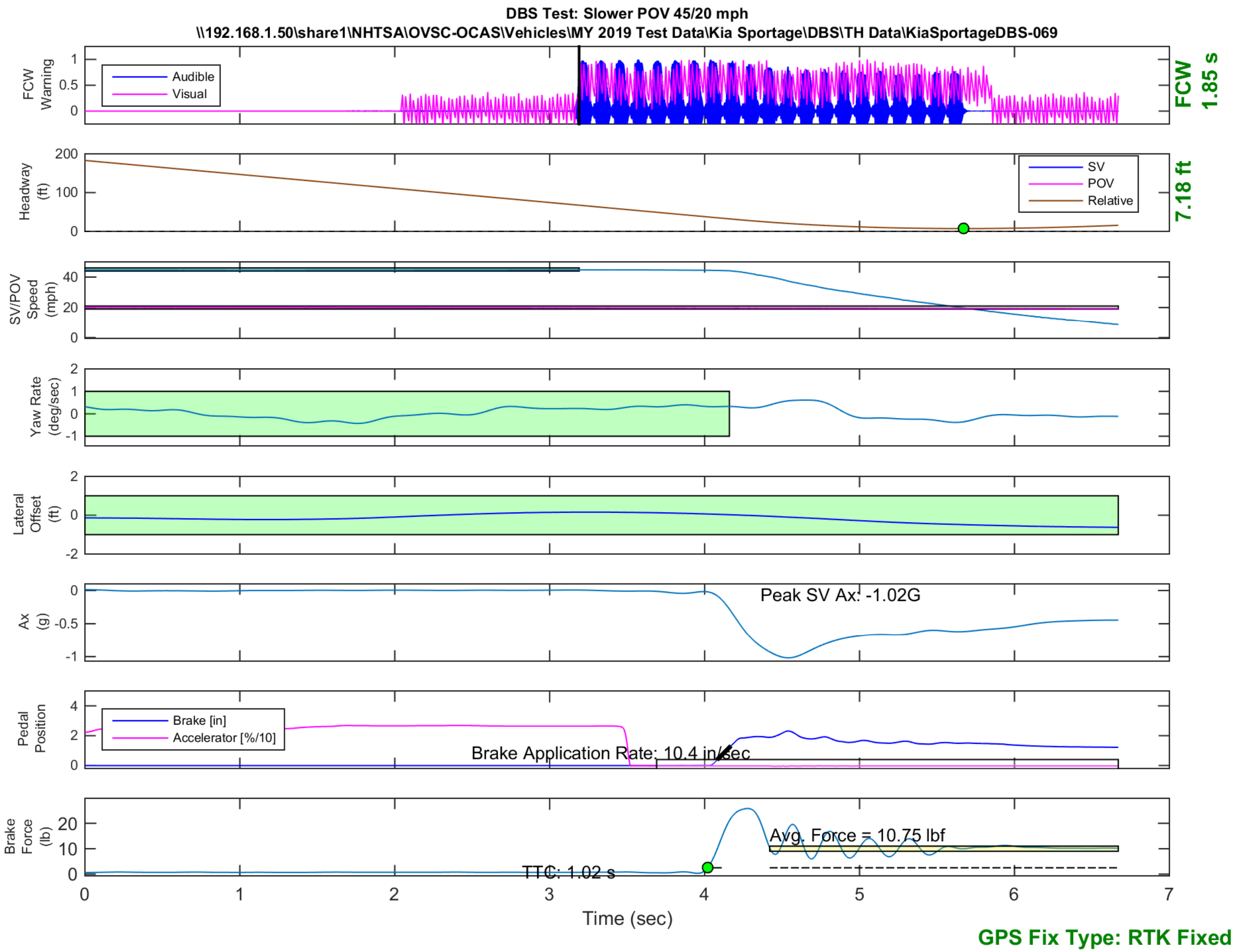


Figure E26. Time History for DBS Run 69, SV Encounters Slower POV, SV 45 mph, POV 20 mph

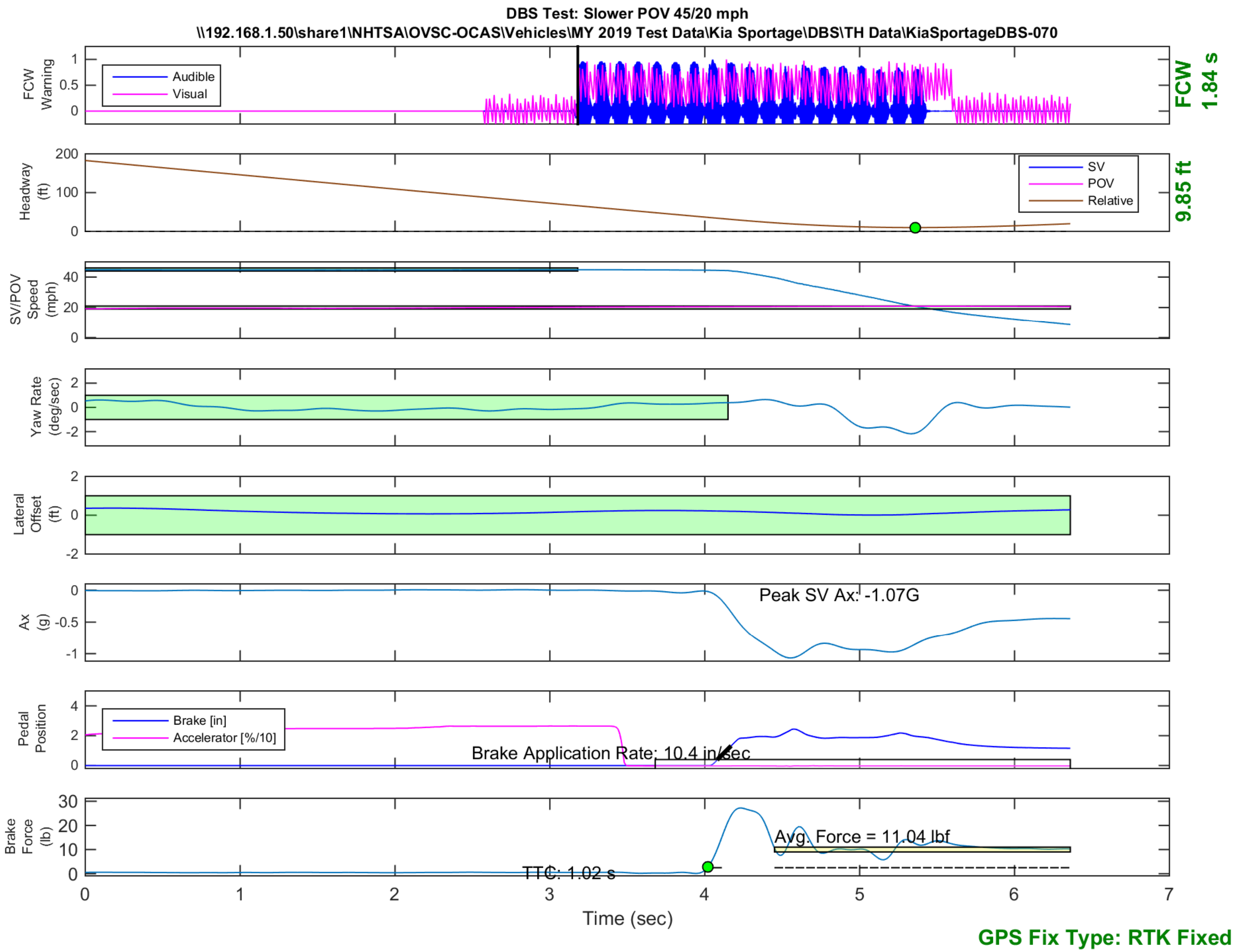


Figure E27. Time History for DBS Run 70, SV Encounters Slower POV, SV 45 mph, POV 20 mph

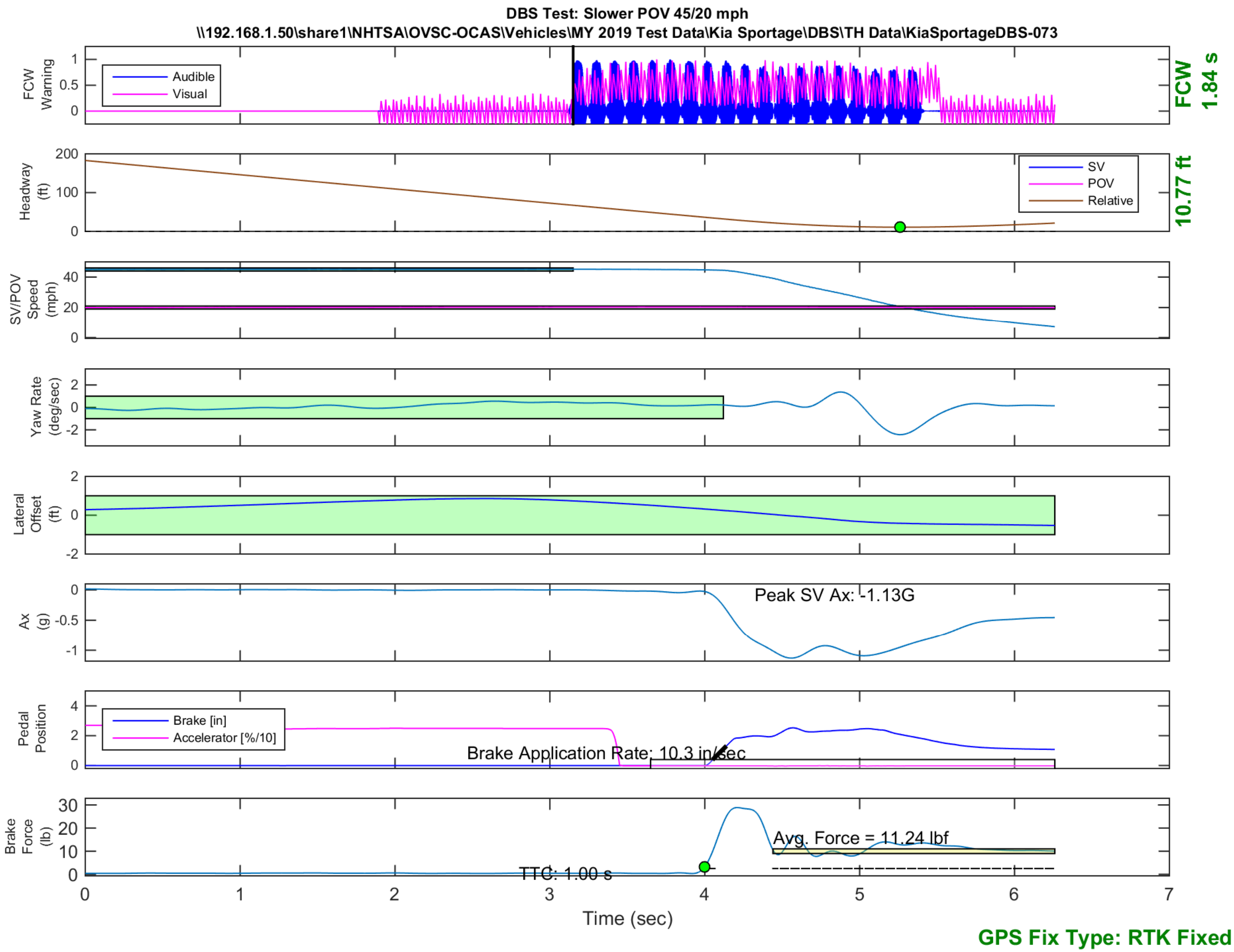


Figure E28. Time History for DBS Run 73, SV Encounters Slower POV, SV 45 mph, POV 20 mph

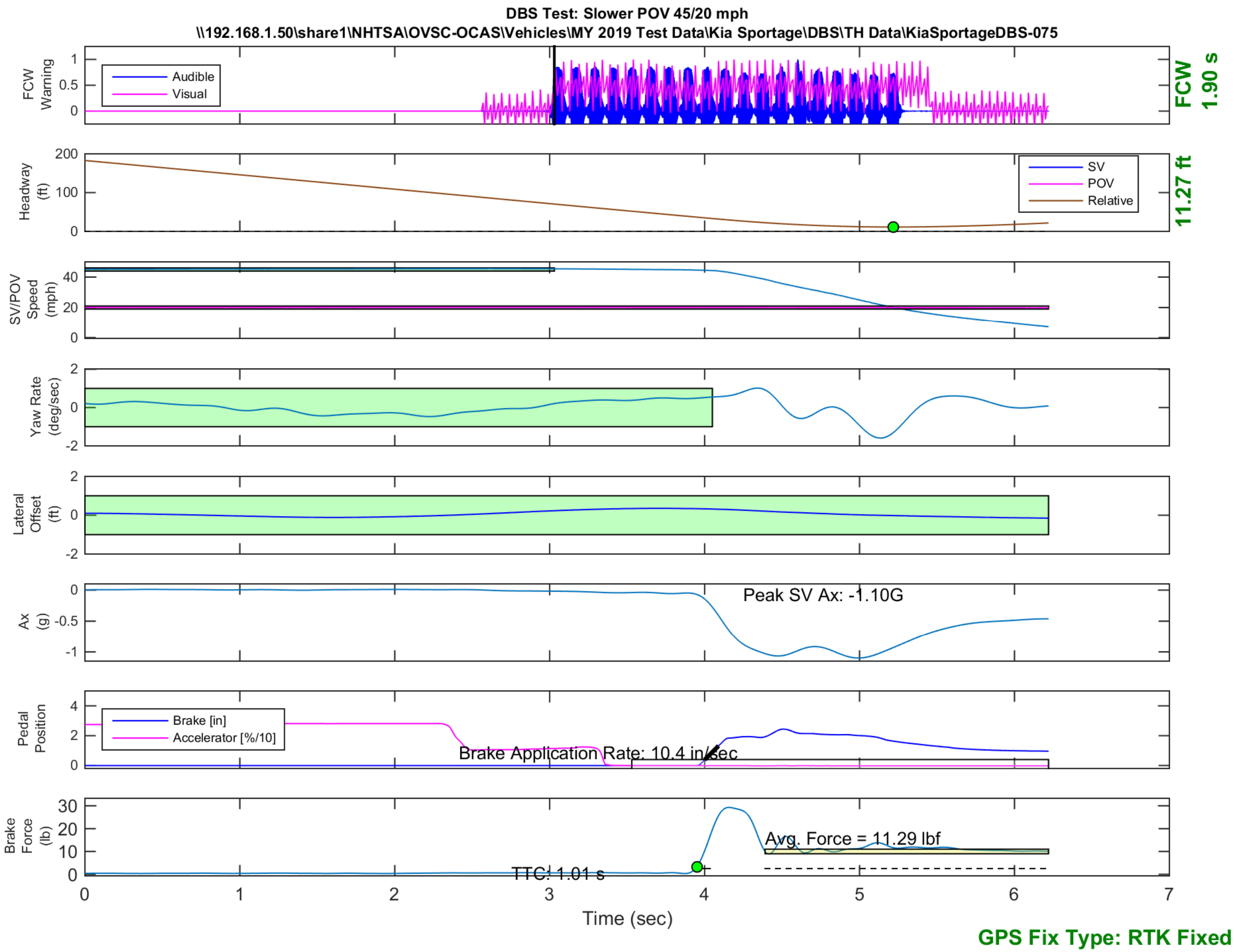


Figure E29. Time History for DBS Run 75, SV Encounters Slower POV, SV 45 mph, POV 20 mph

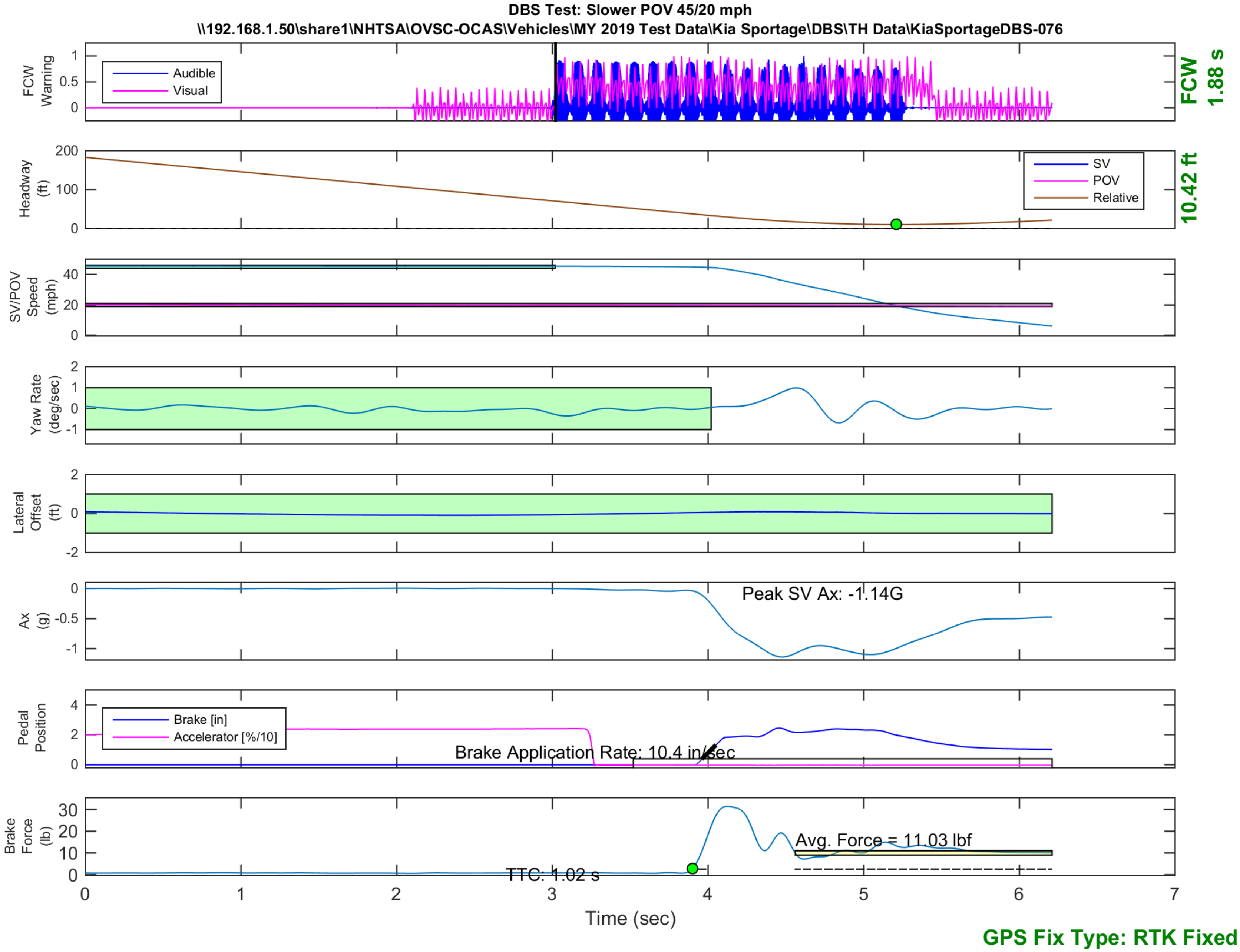


Figure E30. Time History for DBS Run 76, SV Encounters Slower POV, SV 45 mph, POV 20 mph

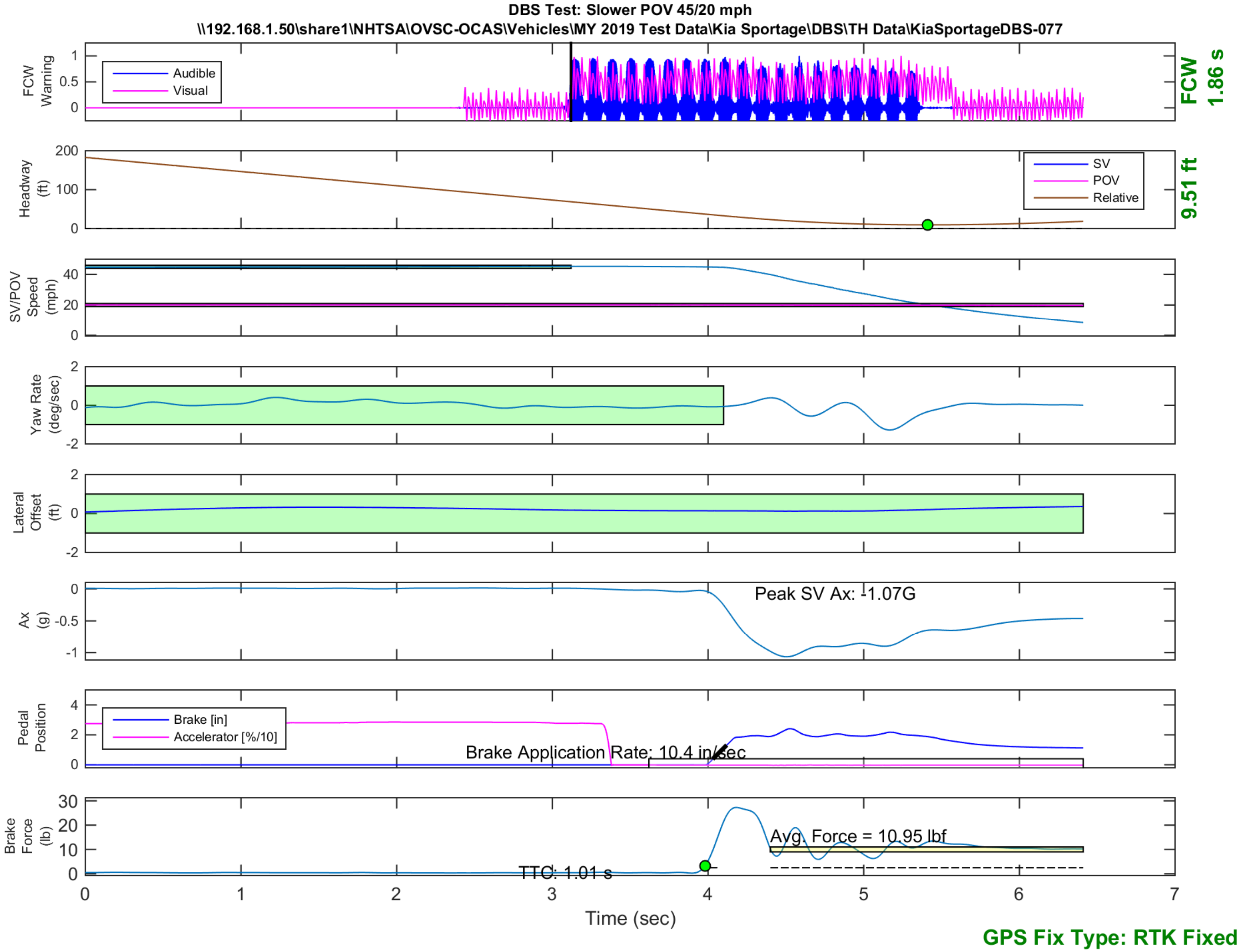


Figure E31. Time History for DBS Run 77, SV Encounters Slower POV, SV 45 mph, POV 20 mph

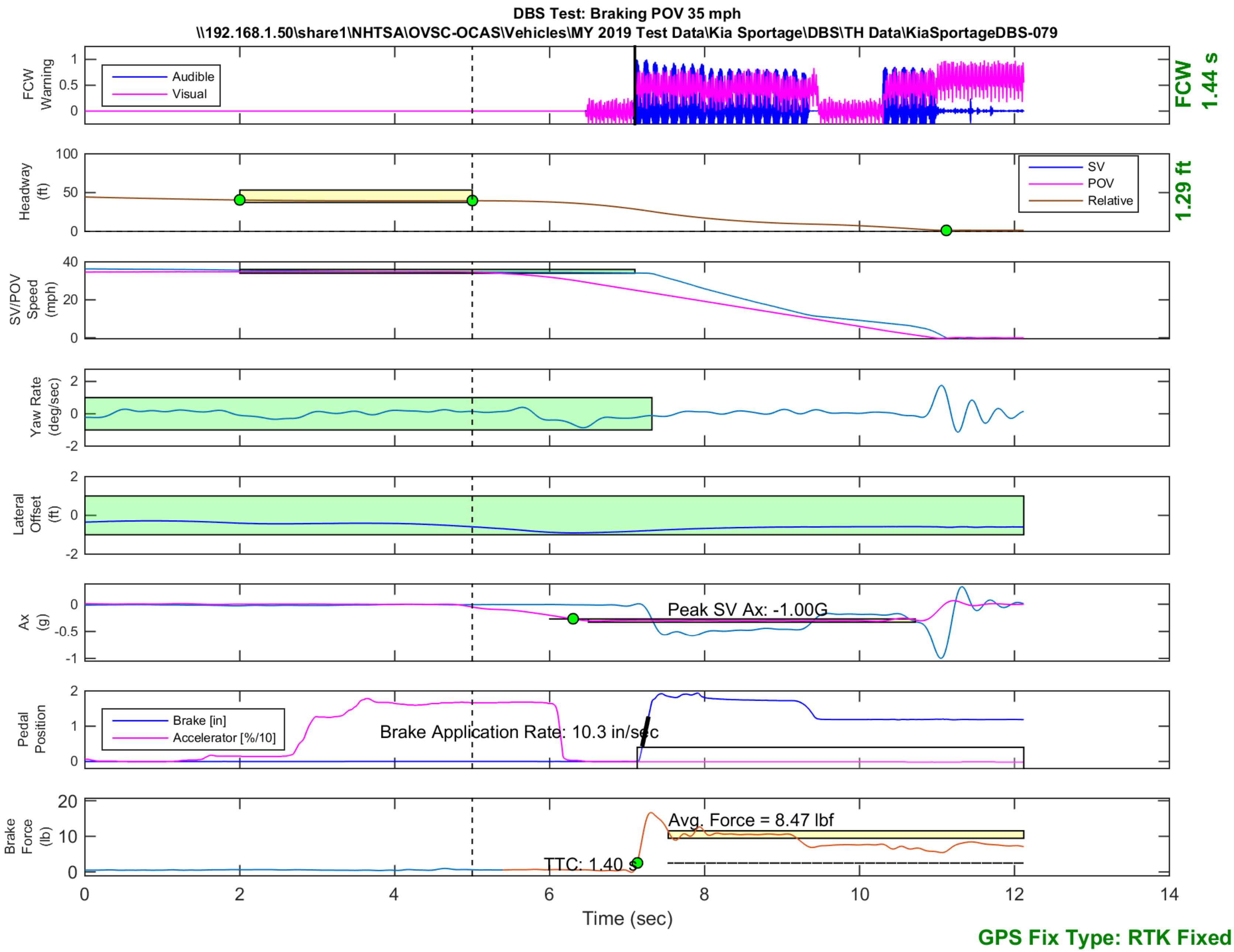


Figure E32. Time History for DBS Run 79, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

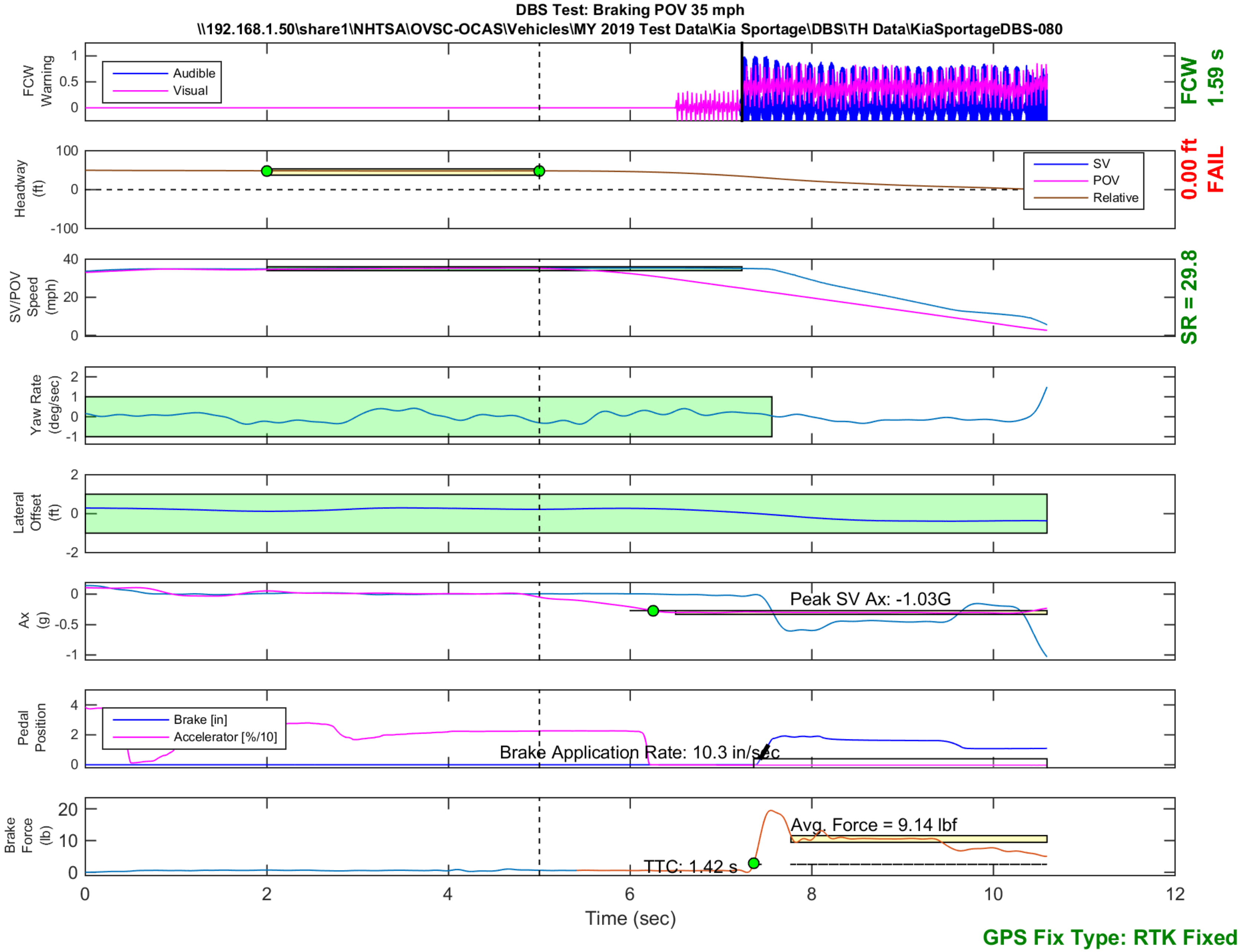


Figure E33. Time History for DBS Run 80, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

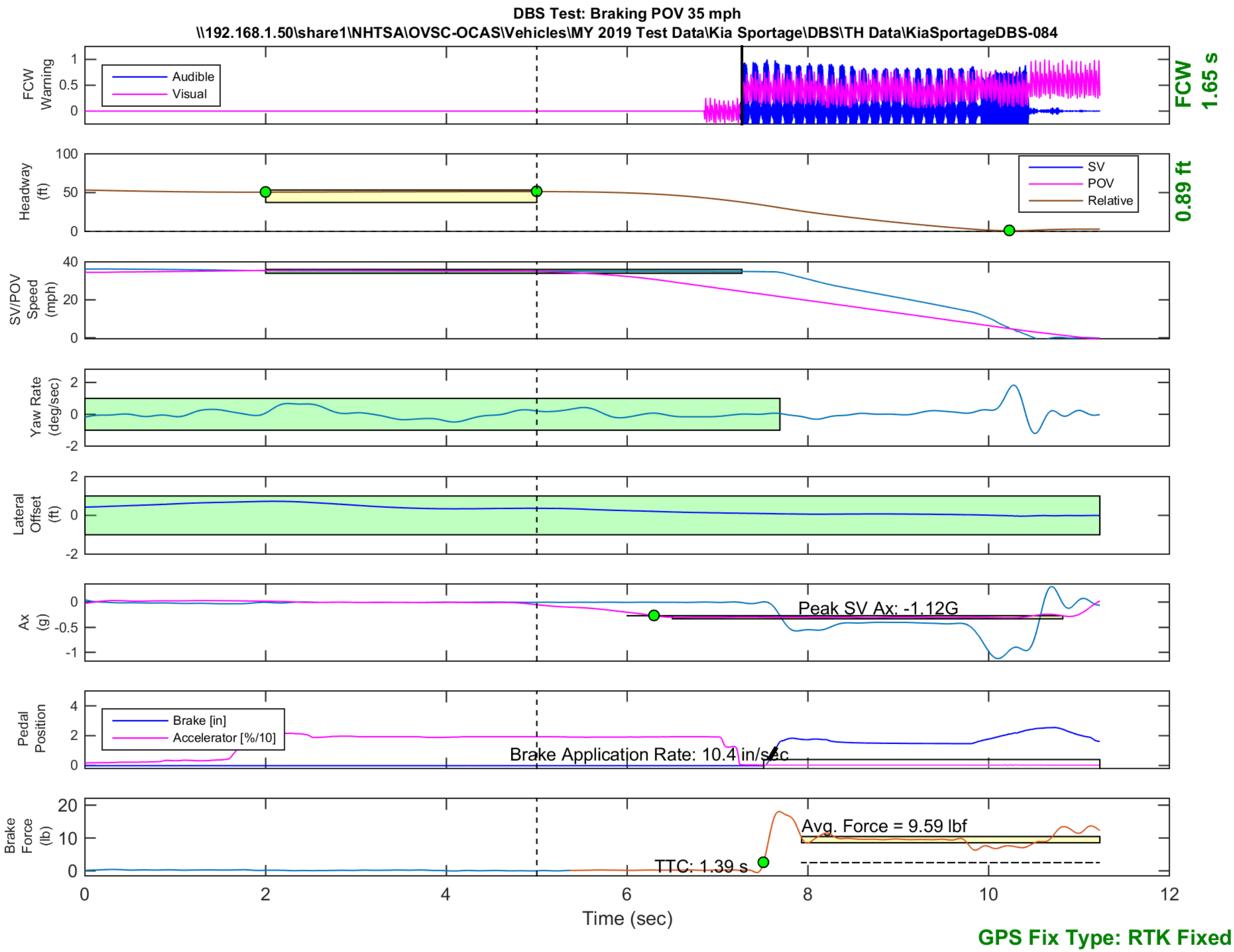


Figure E34. Time History for DBS Run 84, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

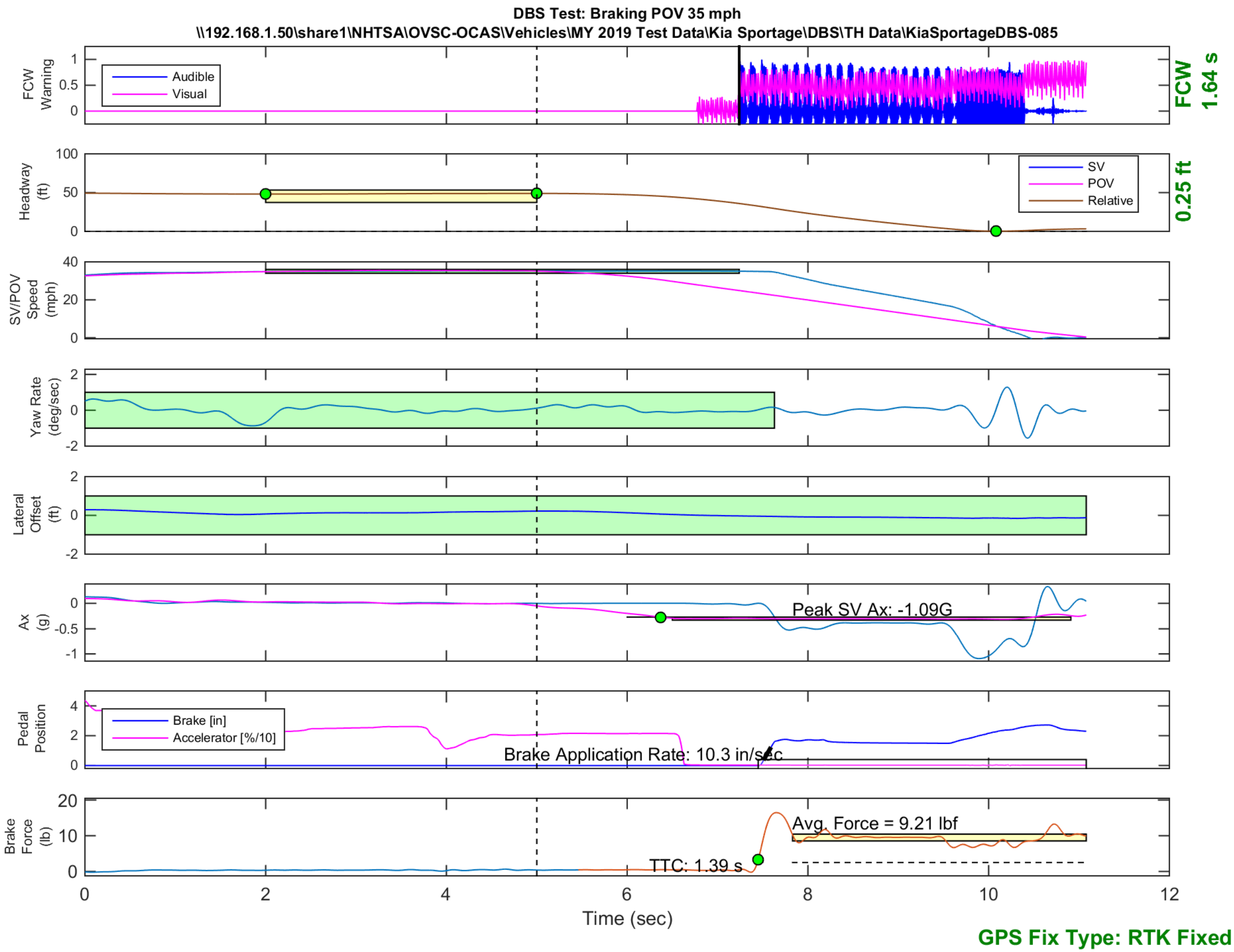


Figure E35. Time History for DBS Run 85, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

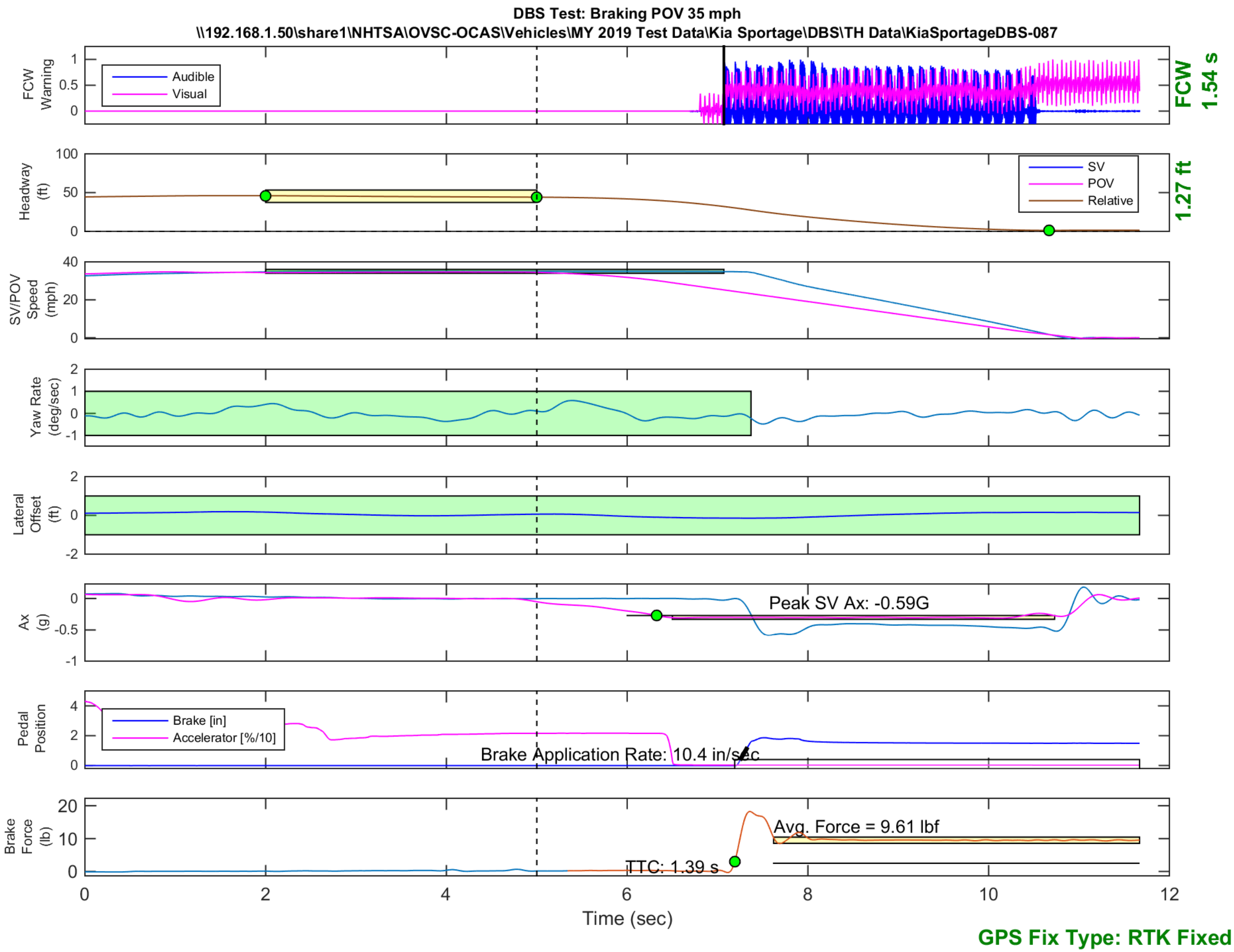


Figure E36. Time History for DBS Run 87, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

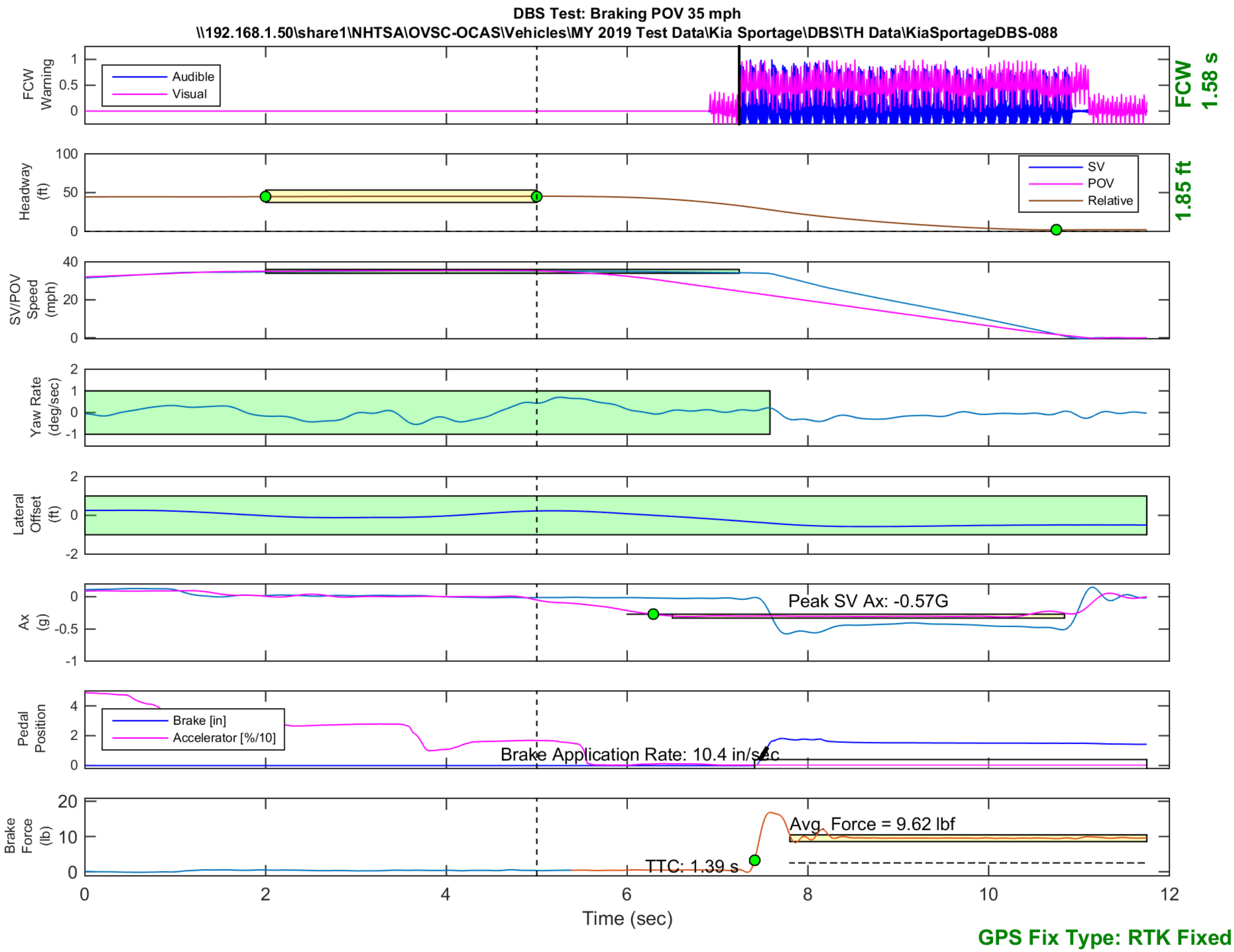


Figure E37. Time History for DBS Run 88, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

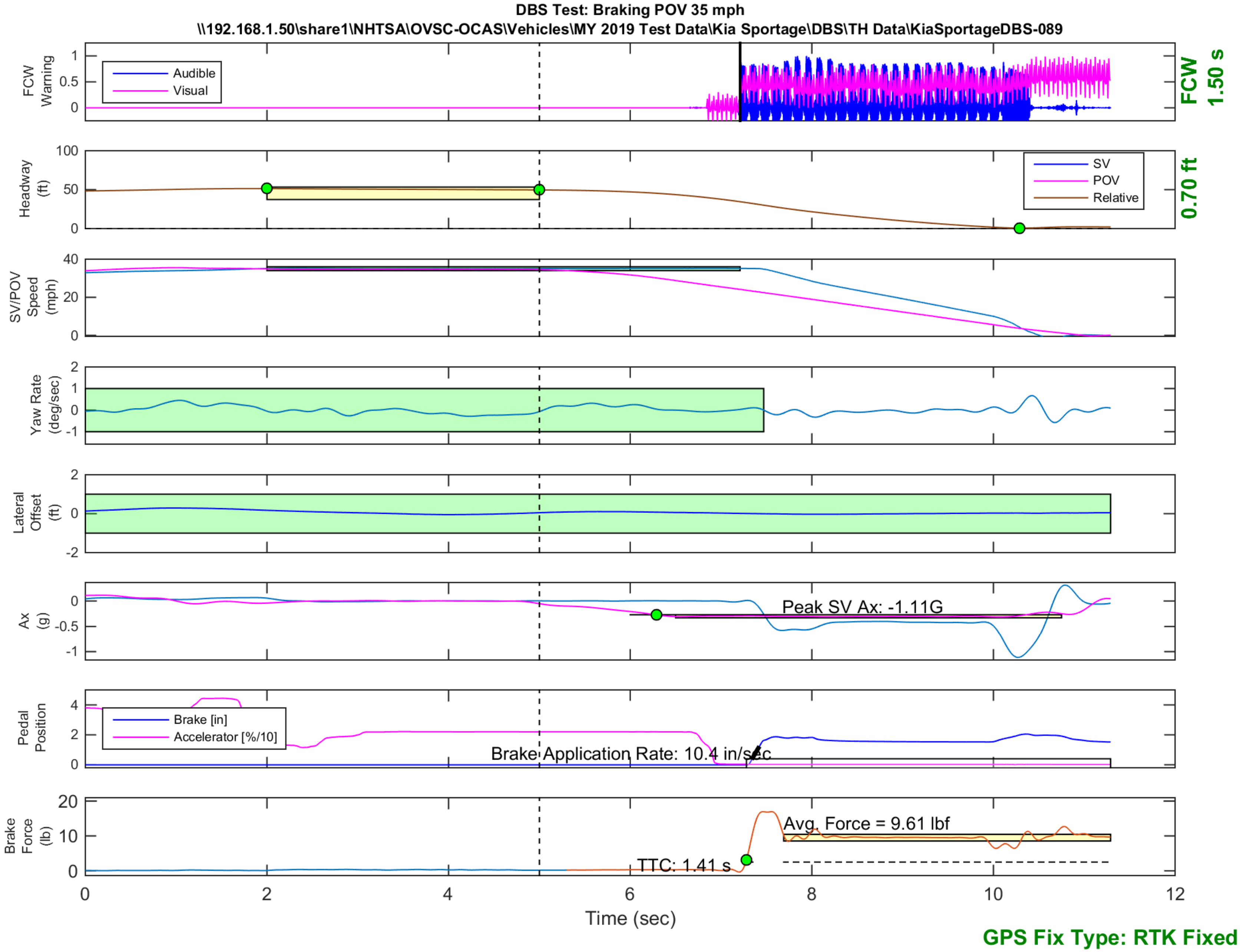


Figure E38. Time History for DBS Run 89, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

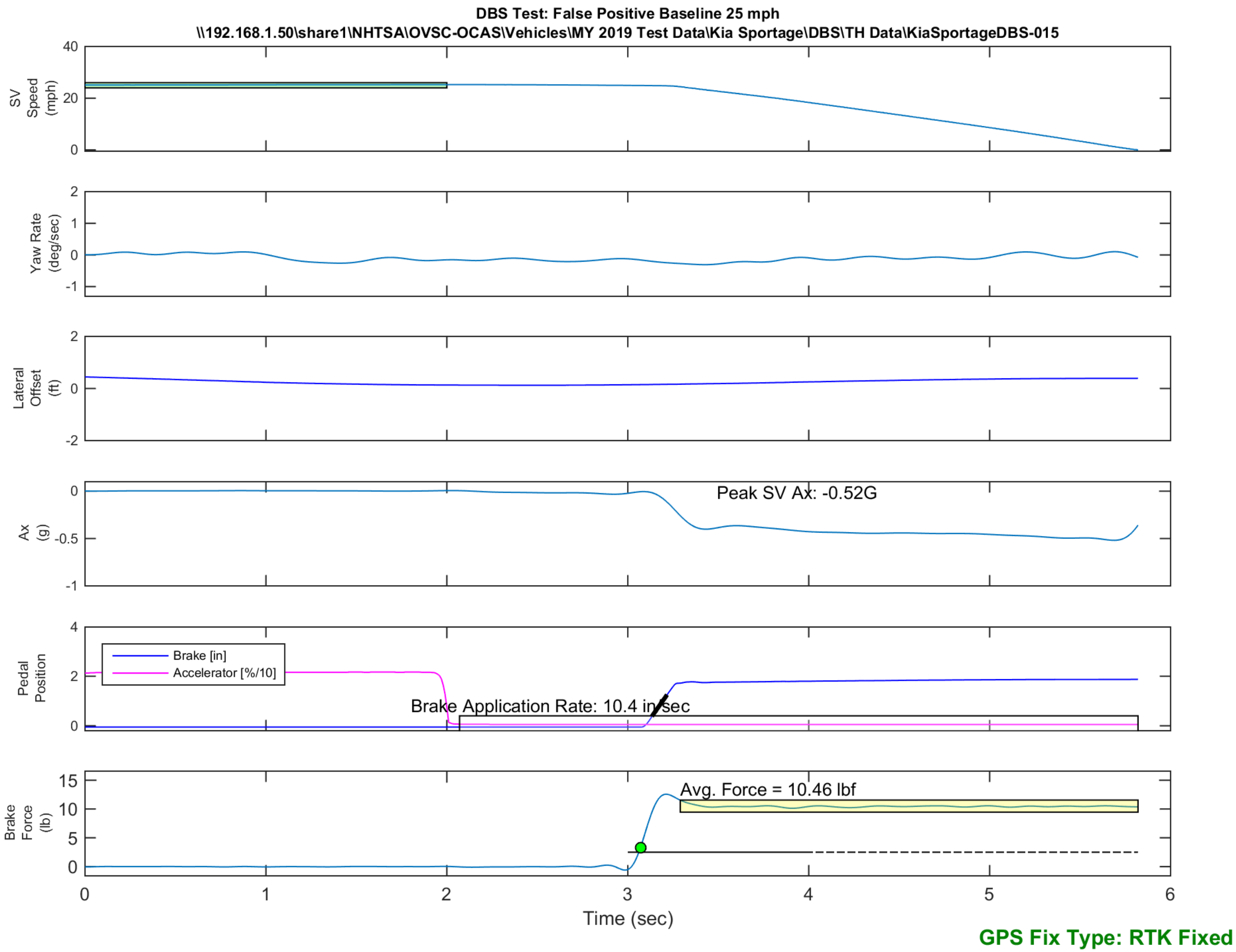


Figure E39. Time History for DBS Run 15, False Positive Baseline, SV 25 mph

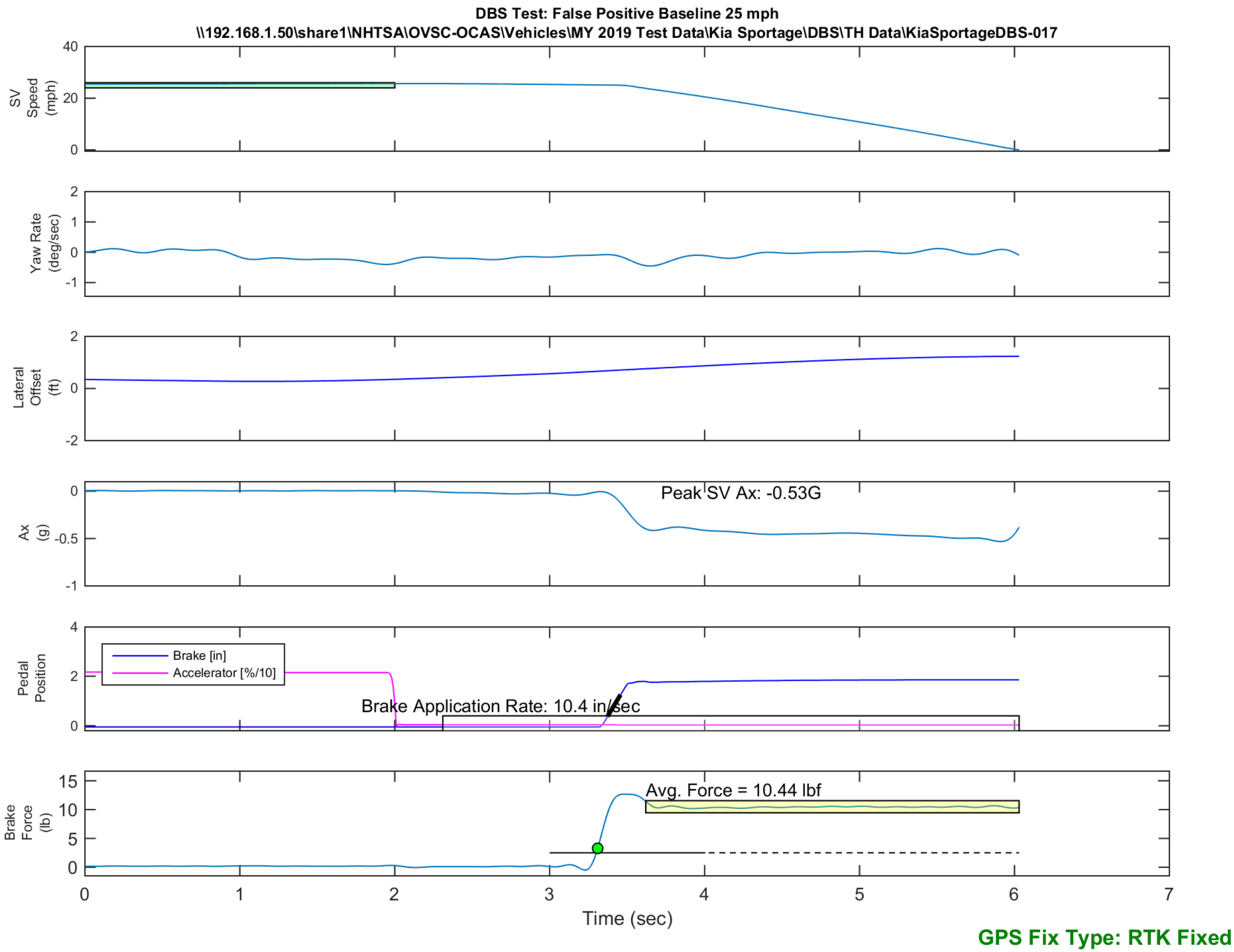


Figure E40. Time History for DBS Run 17, False Positive Baseline, SV 25 mph

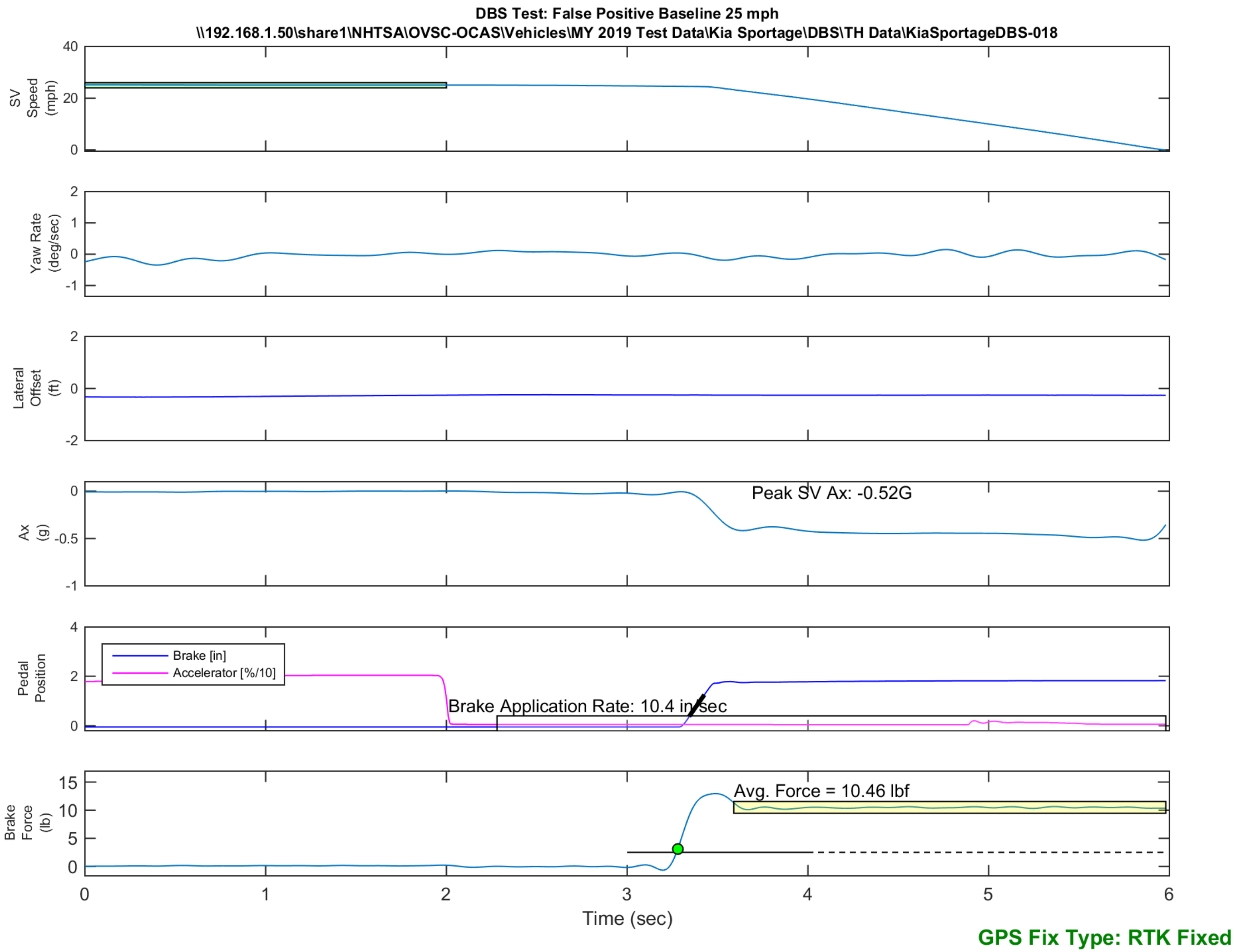


Figure E41. Time History for DBS Run 18, False Positive Baseline, SV 25 mph

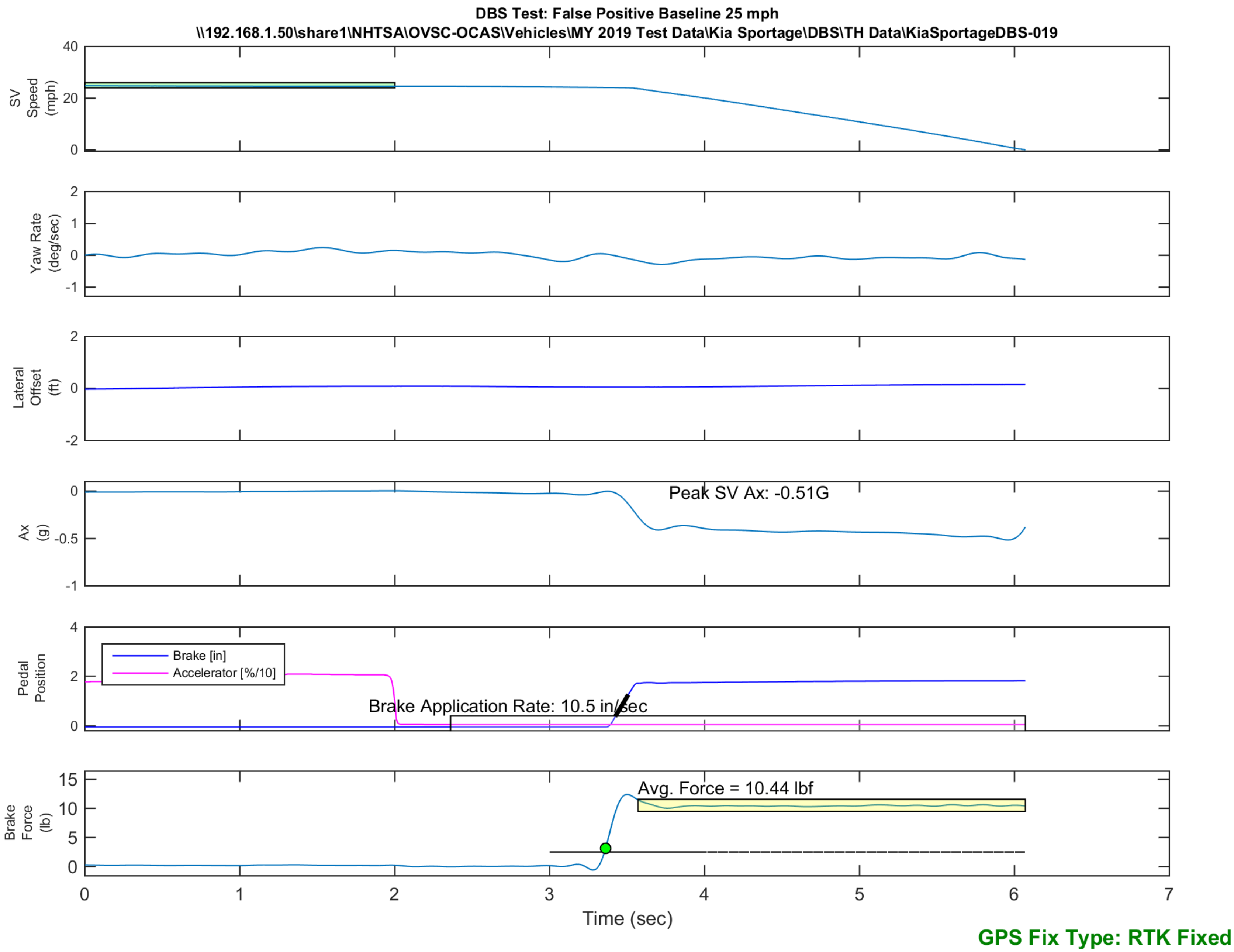


Figure E42. Time History for DBS Run 19, False Positive Baseline, SV 25 mph

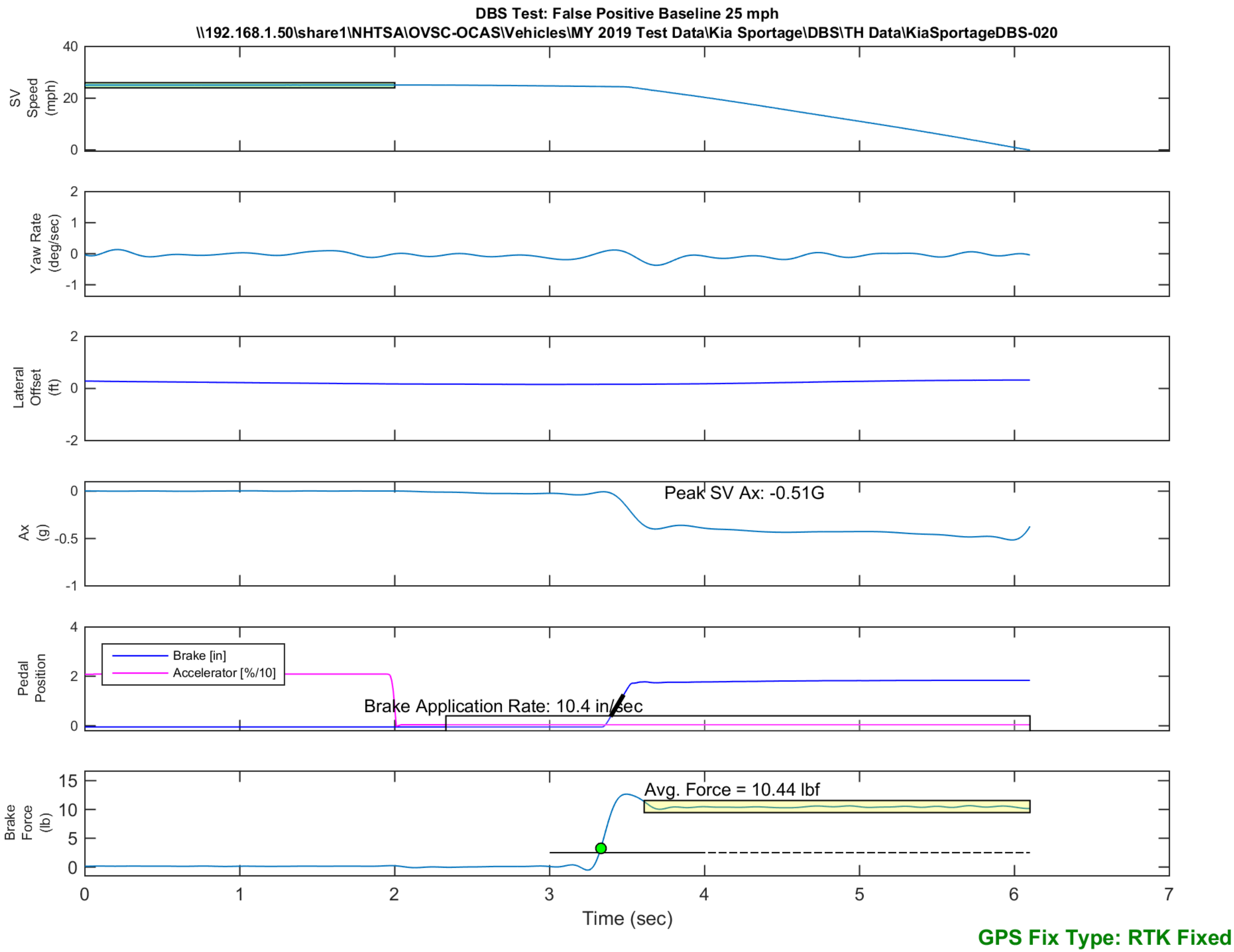


Figure E43. Time History for DBS Run 20, False Positive Baseline, SV 25 mph

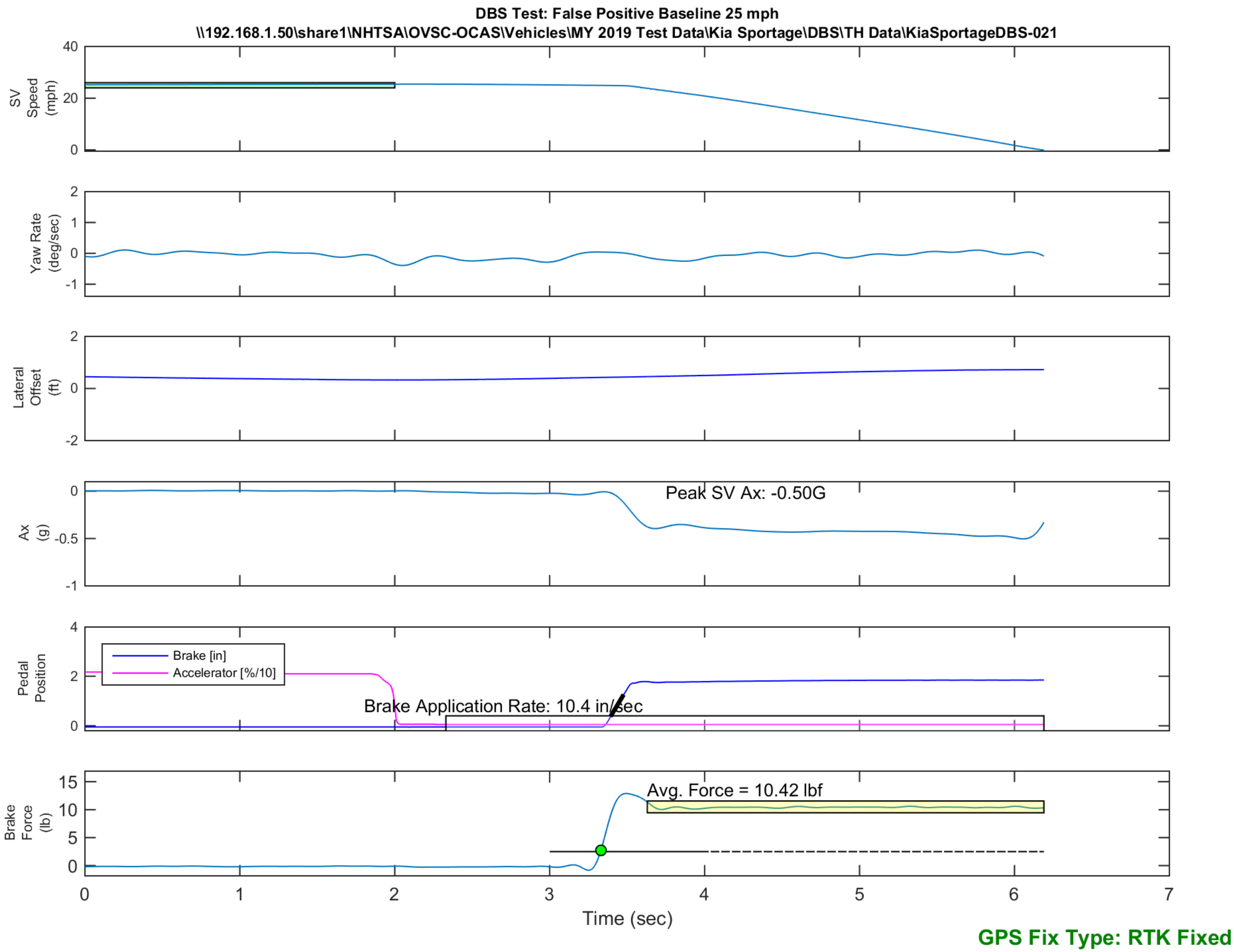


Figure E44. Time History for DBS Run 21, False Positive Baseline, SV 25 mph

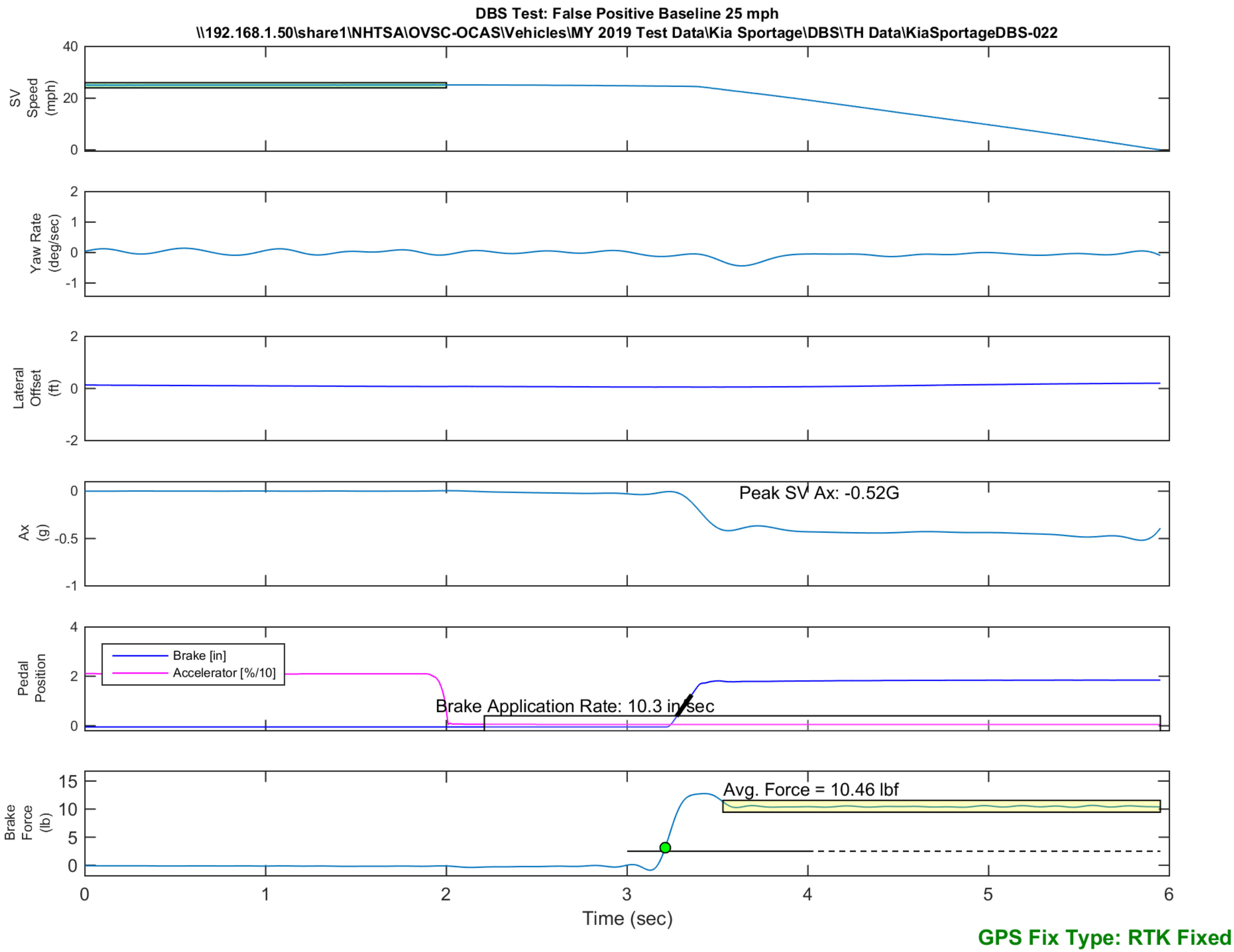


Figure E45. Time History for DBS Run 22, False Positive Baseline, SV 25 mph

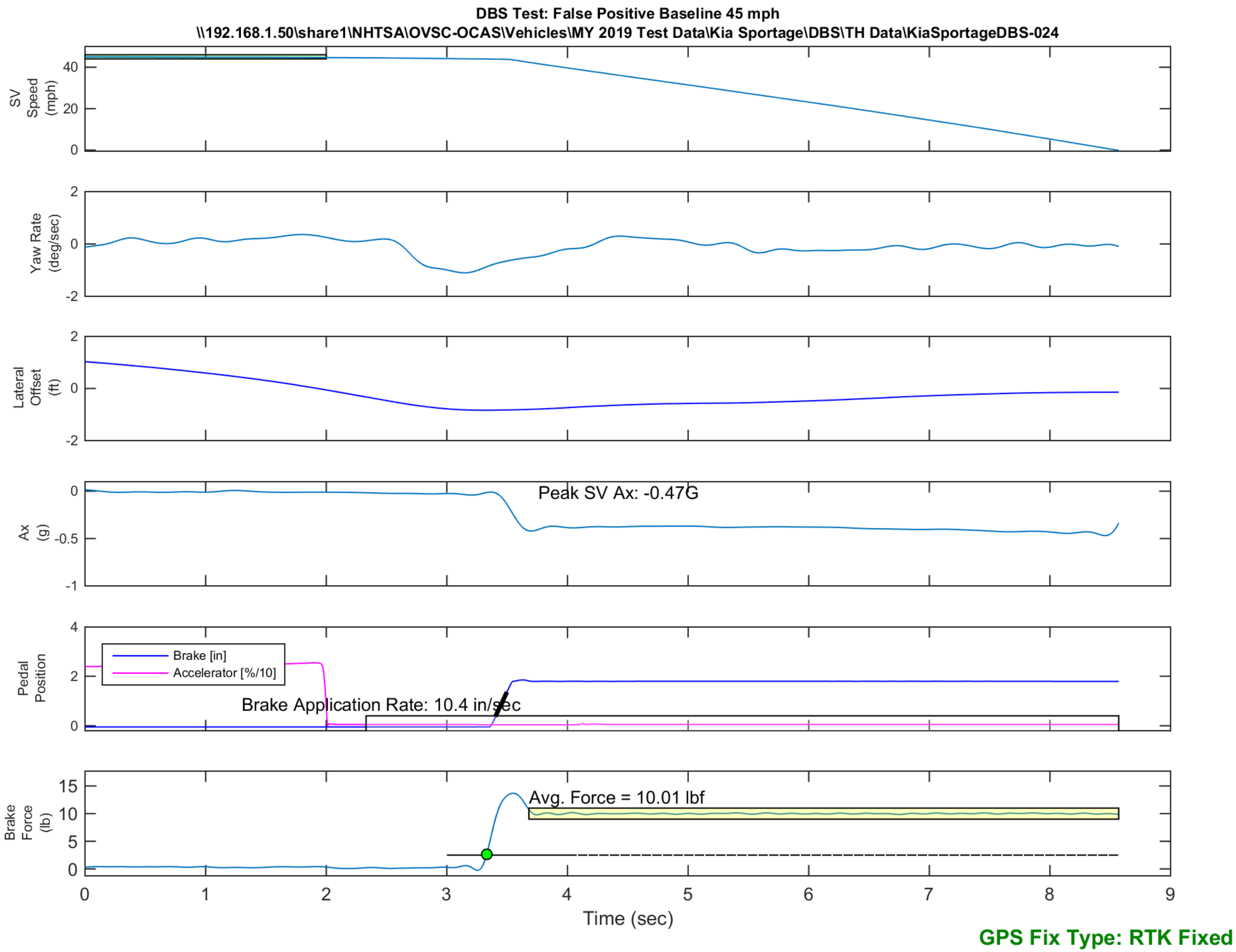


Figure E46. Time History for DBS Run 24, False Positive Baseline, SV 45 mph

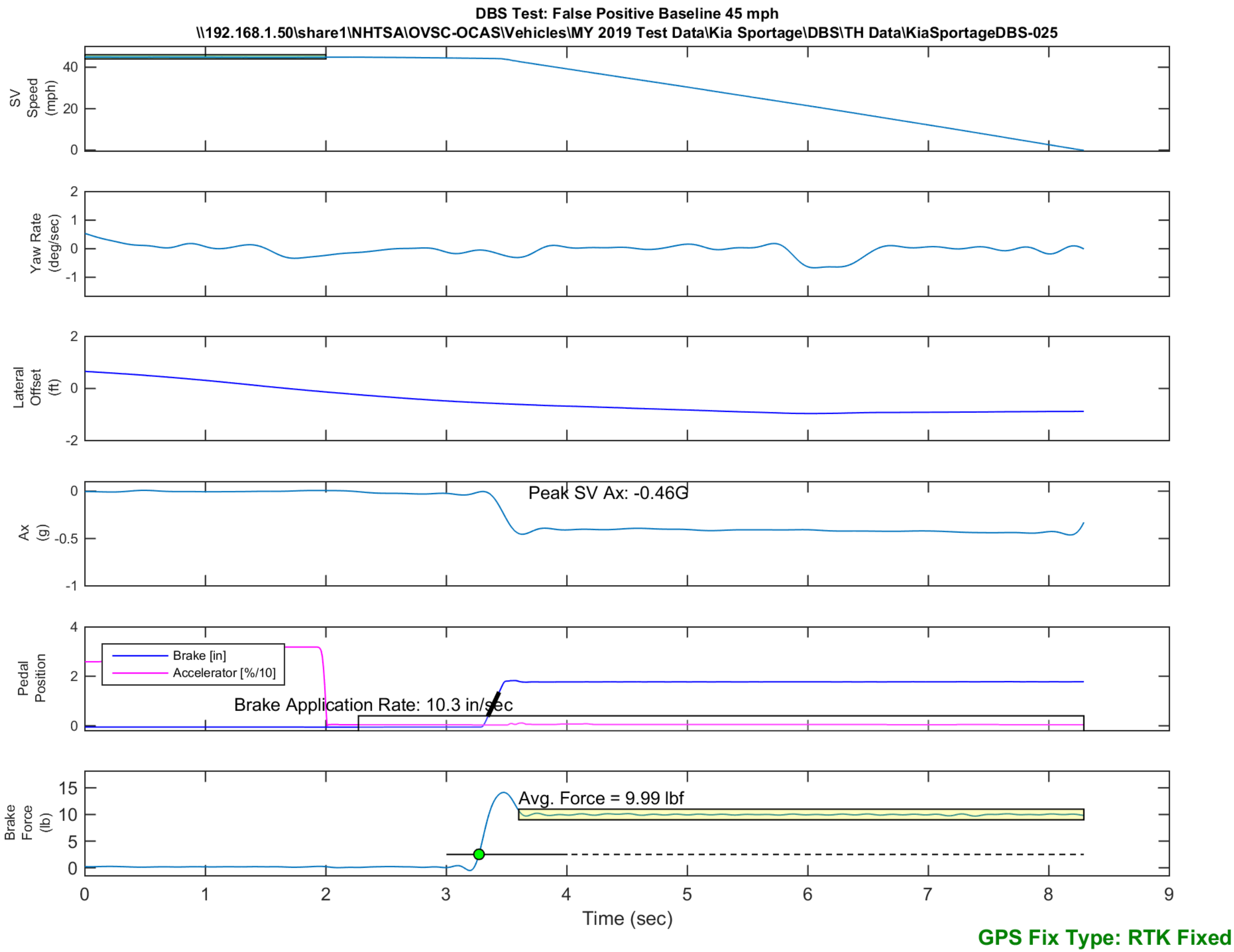


Figure E47. Time History for DBS Run 25, False Positive Baseline, SV 45 mph

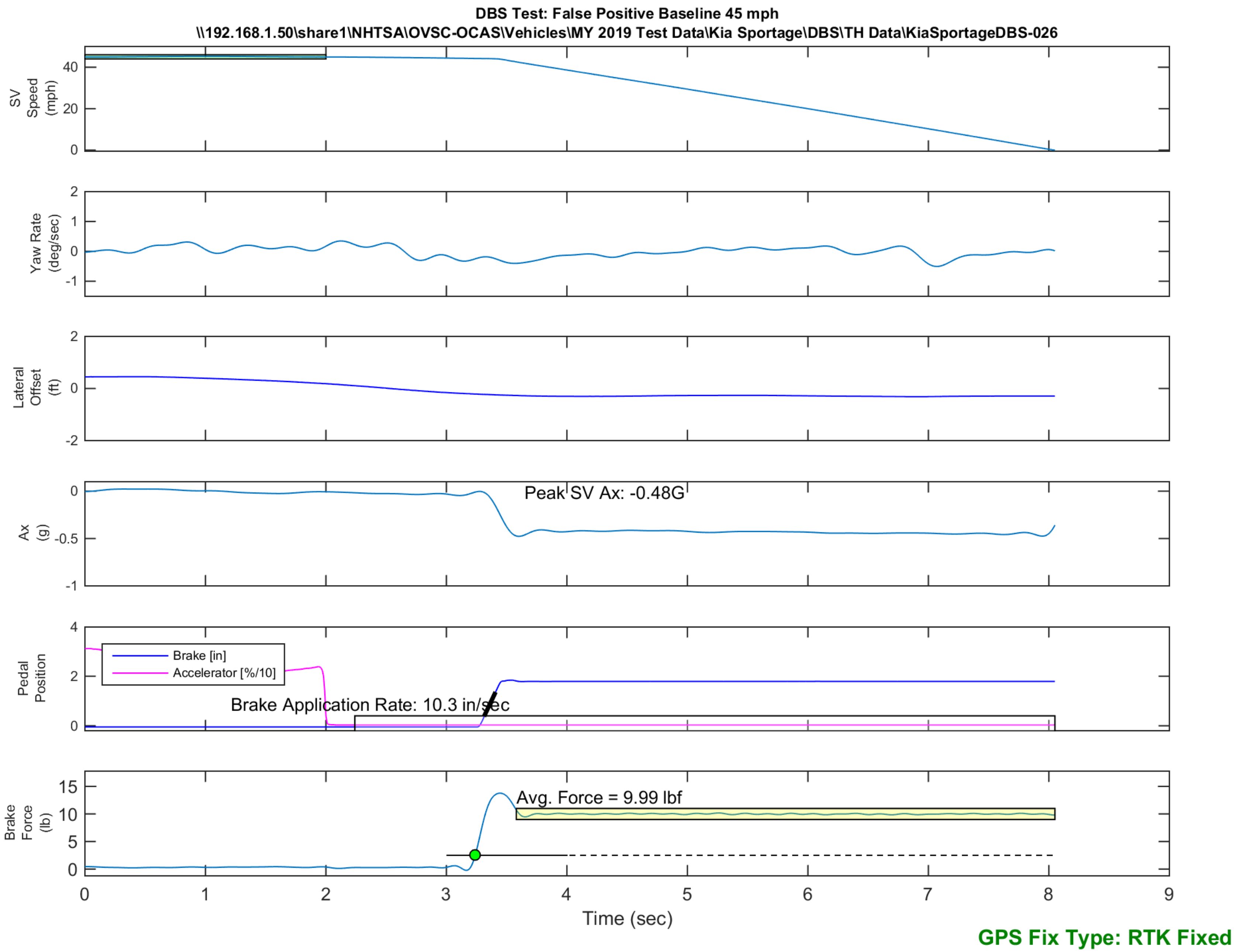


Figure E48. Time History for DBS Run 26, False Positive Baseline, SV 45 mph

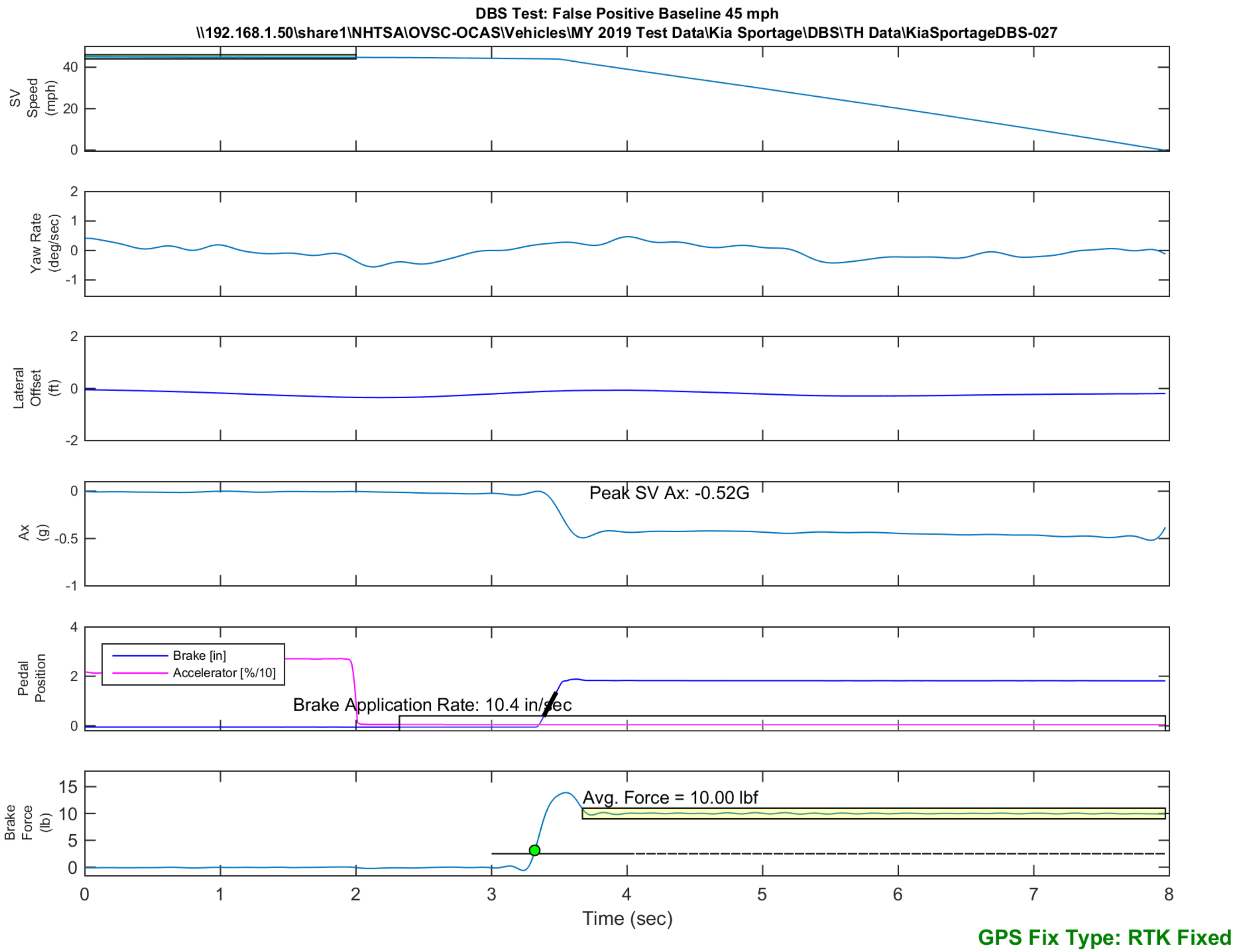


Figure E49. Time History for DBS Run 27, False Positive Baseline, SV 45 mph

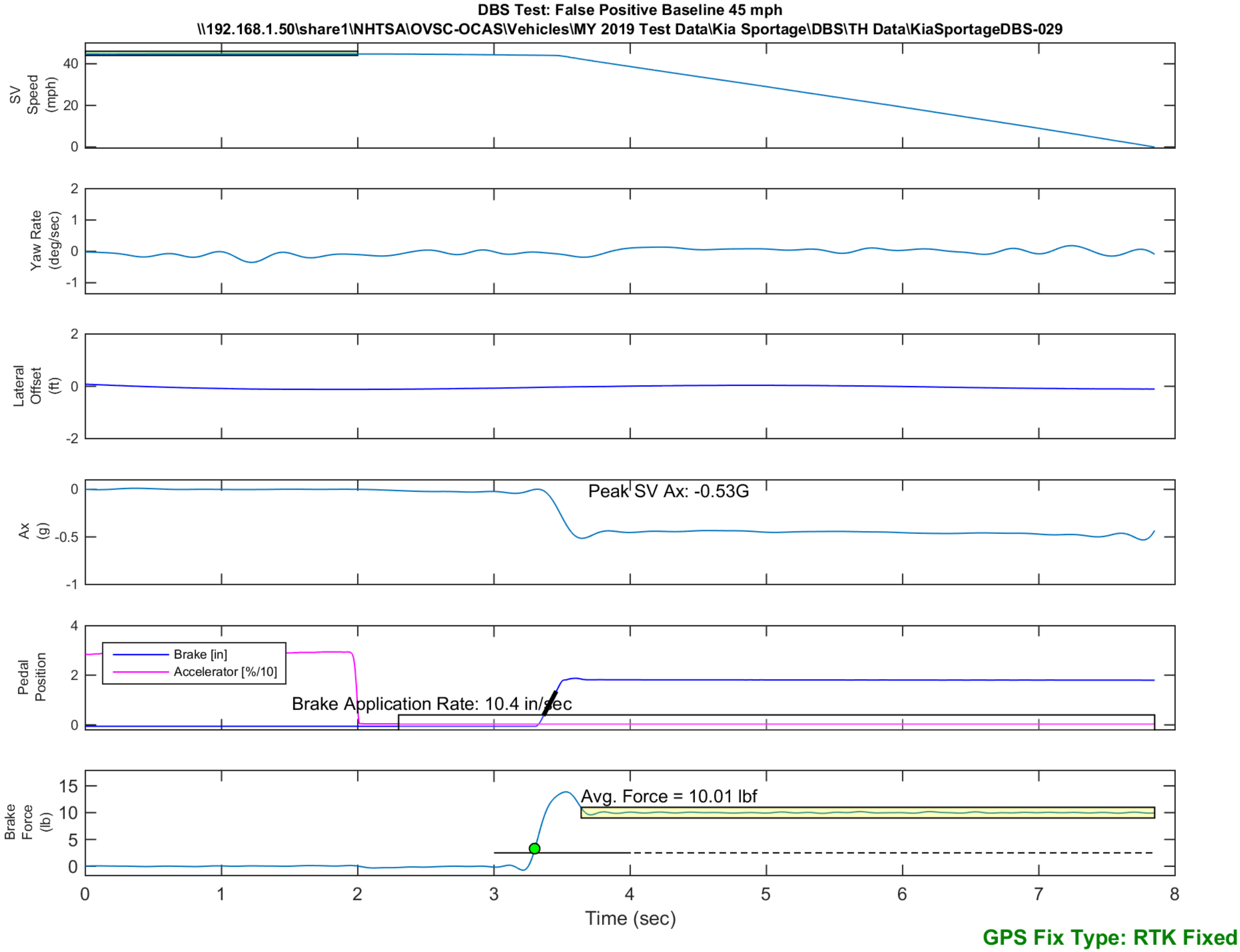


Figure E50. Time History for DBS Run 29, False Positive Baseline, SV 45 mph

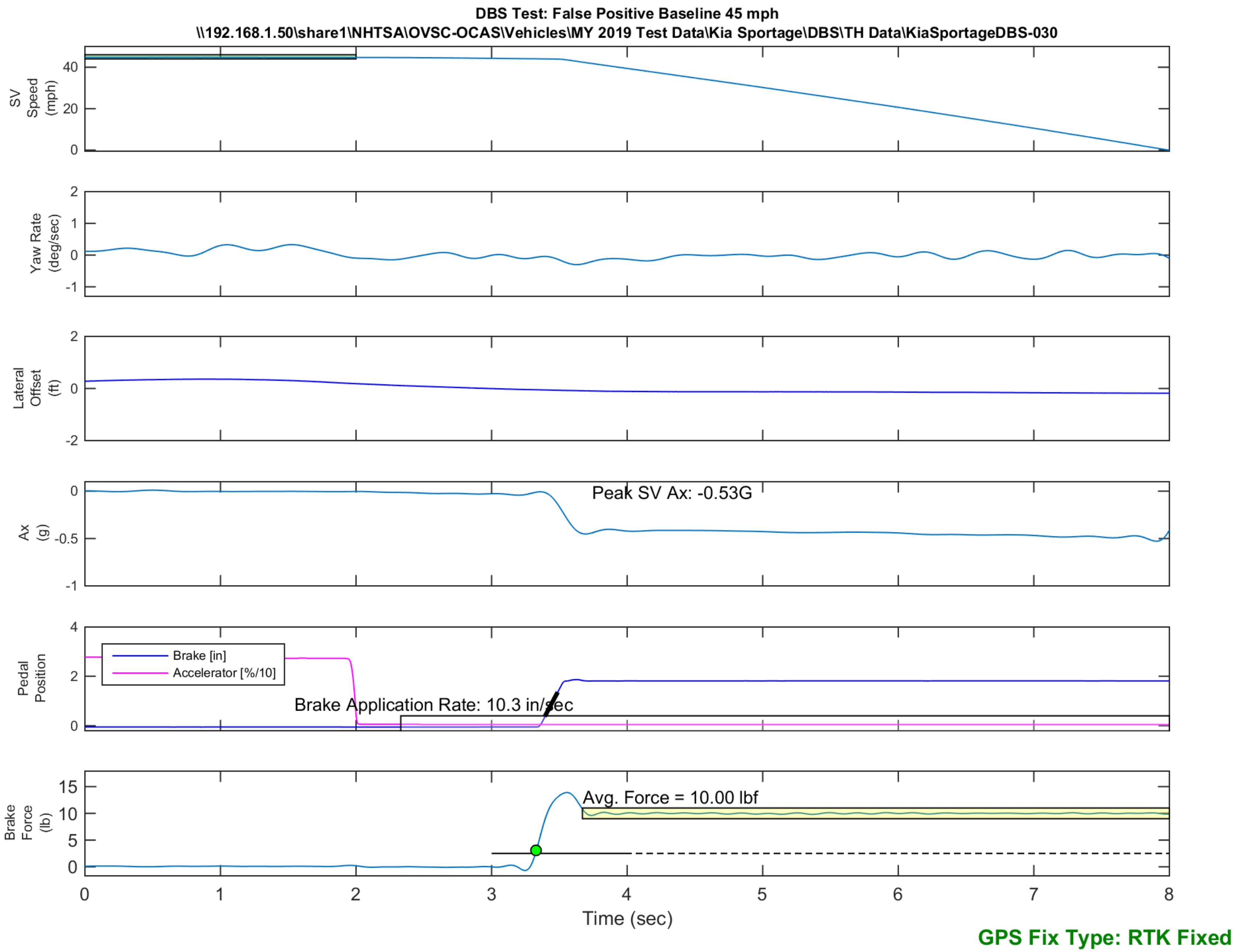


Figure E51. Time History for DBS Run 30, False Positive Baseline, SV 45 mph

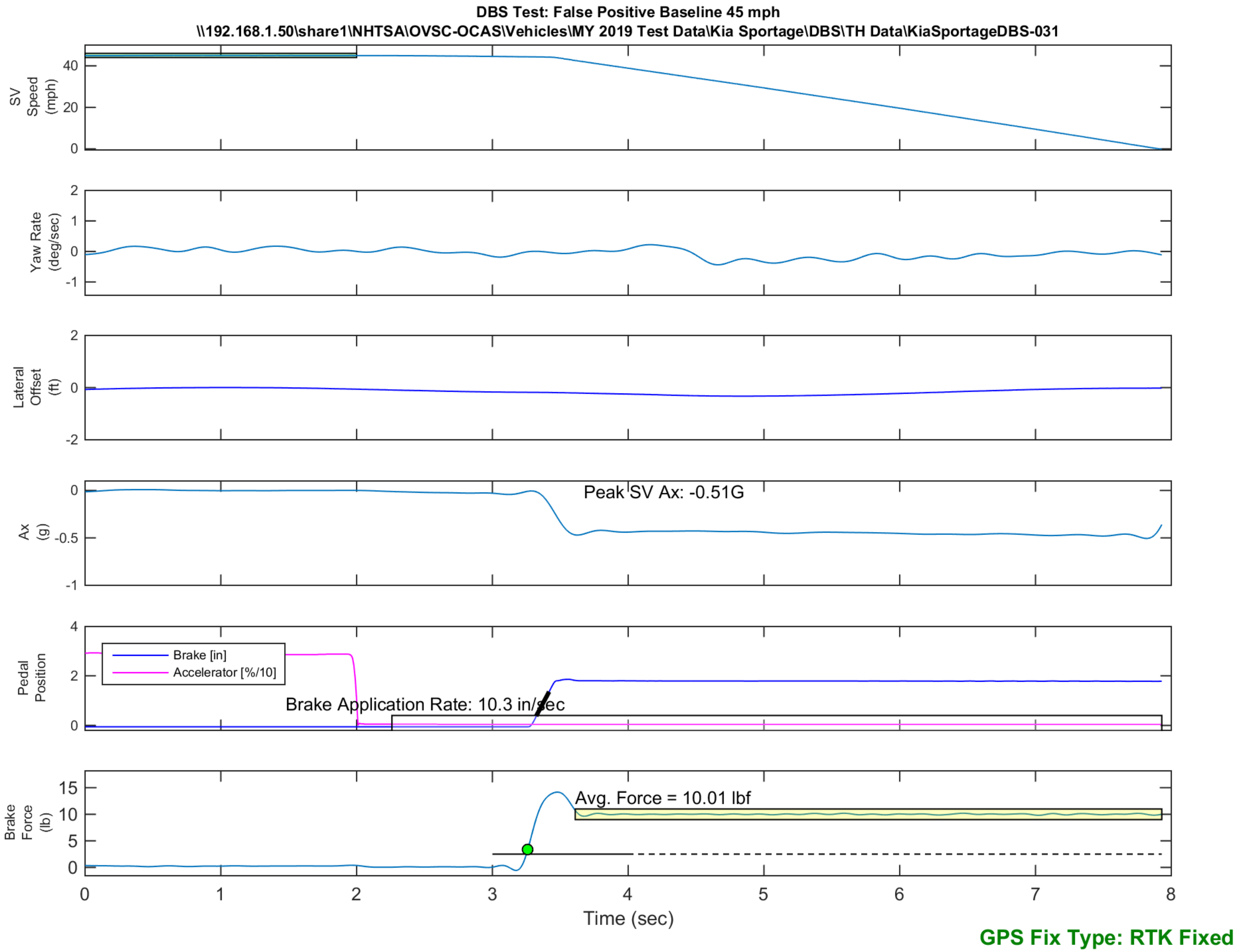


Figure E52. Time History for DBS Run 31, False Positive Baseline, SV 45 mph

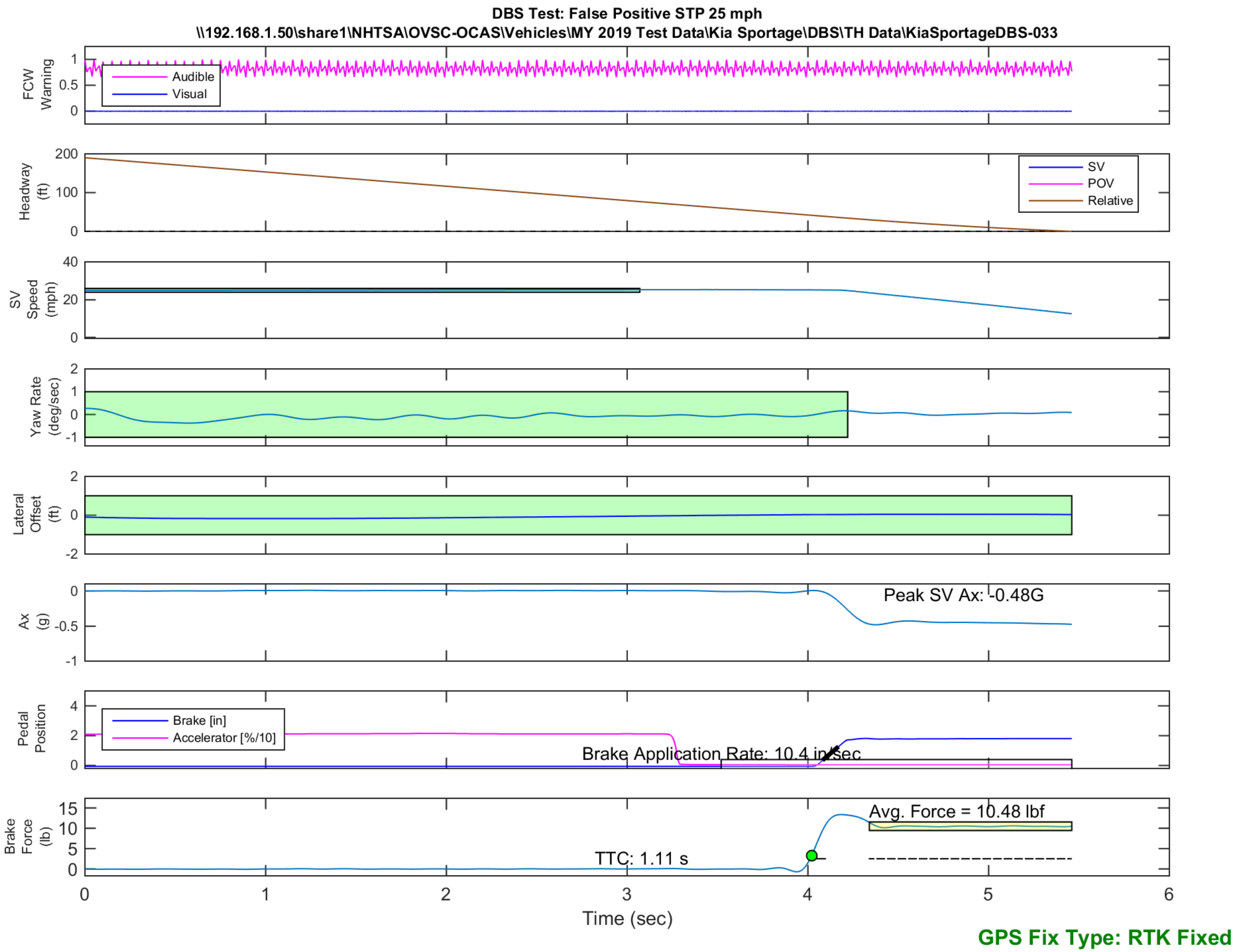


Figure E53. Time History for DBS Run 33, SV Encounters Steel Trench Plate, SV 25 mph

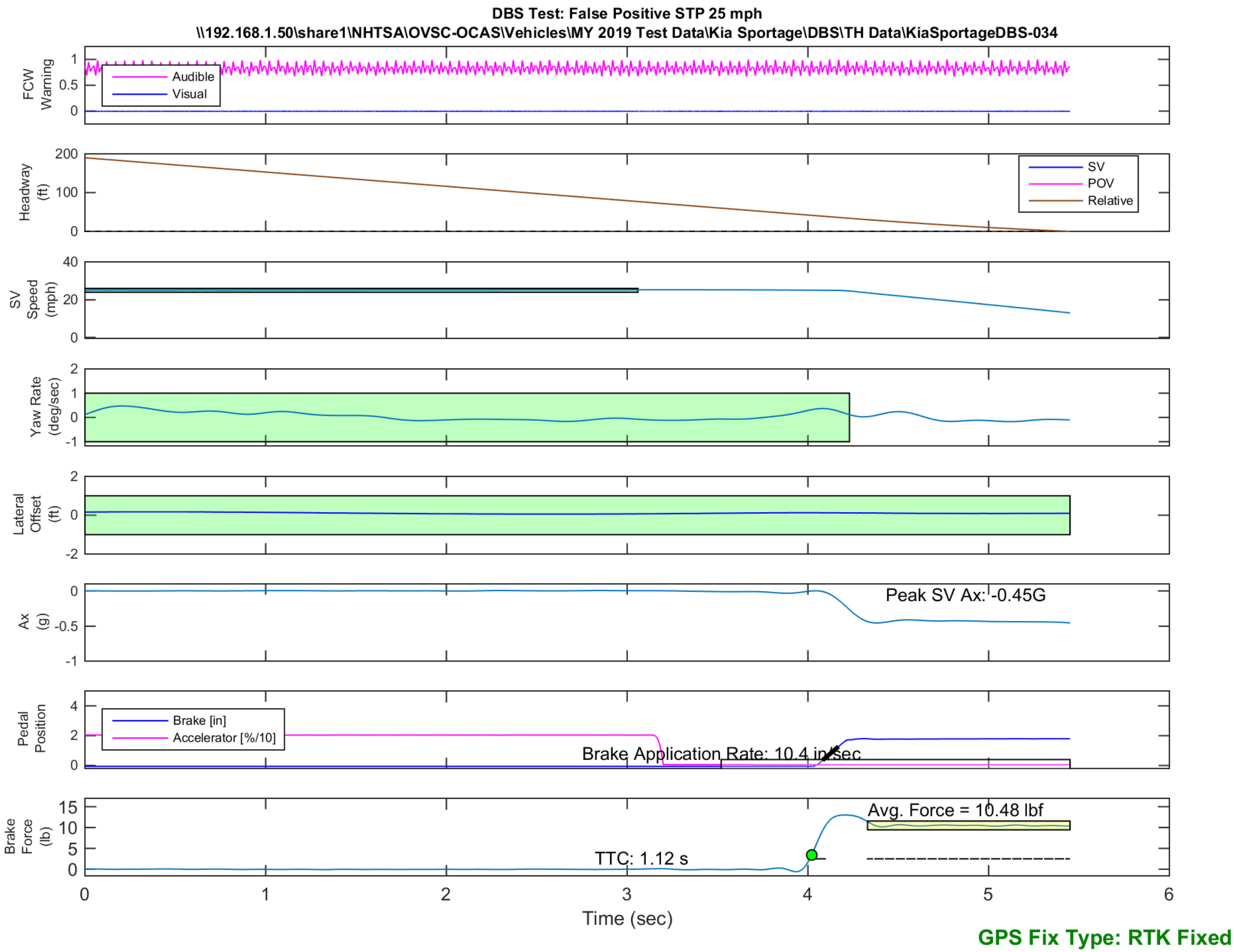


Figure E54. Time History for DBS Run 34, SV Encounters Steel Trench Plate, SV 25 mph

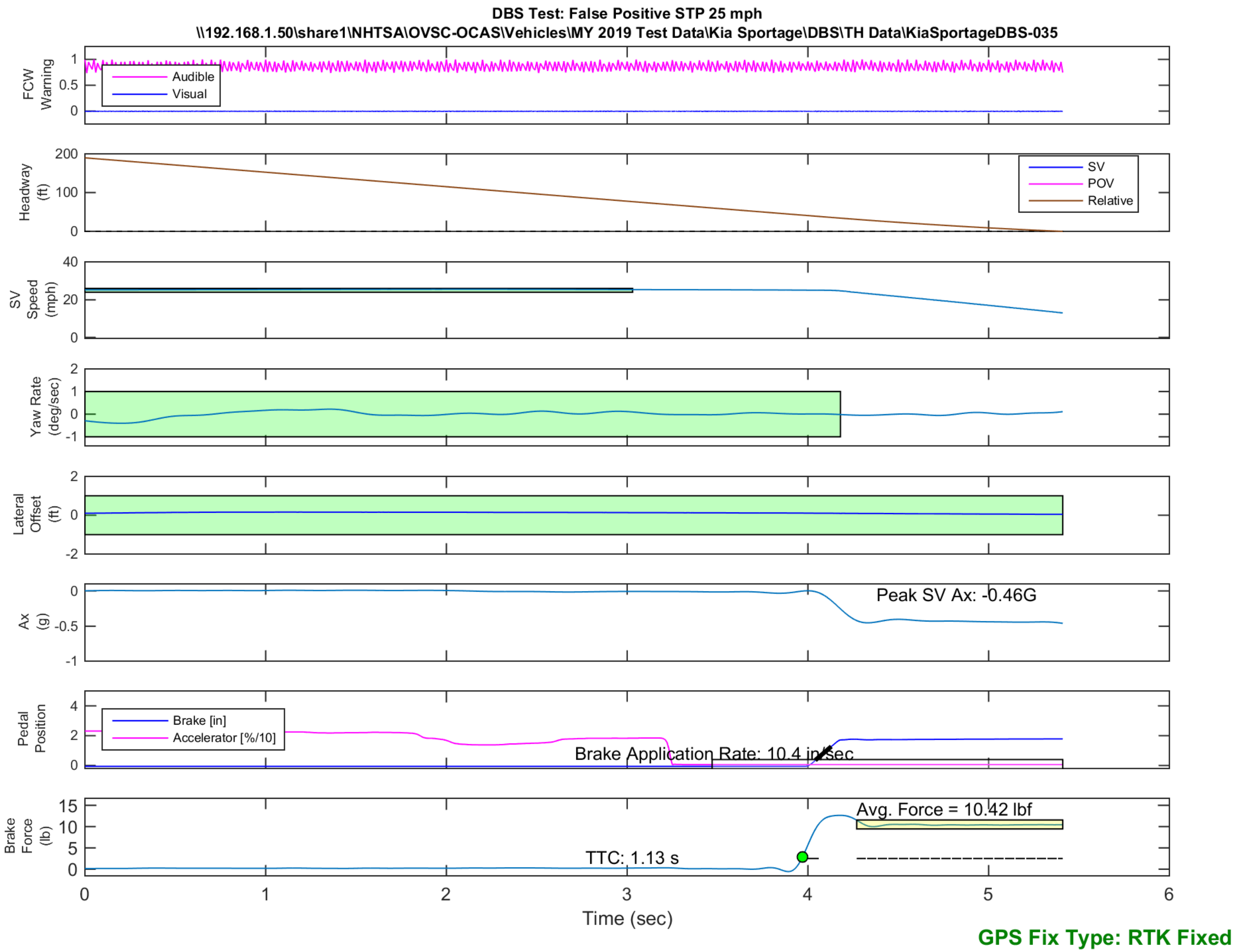


Figure E55. Time History for DBS Run 35, SV Encounters Steel Trench Plate, SV 25 mph

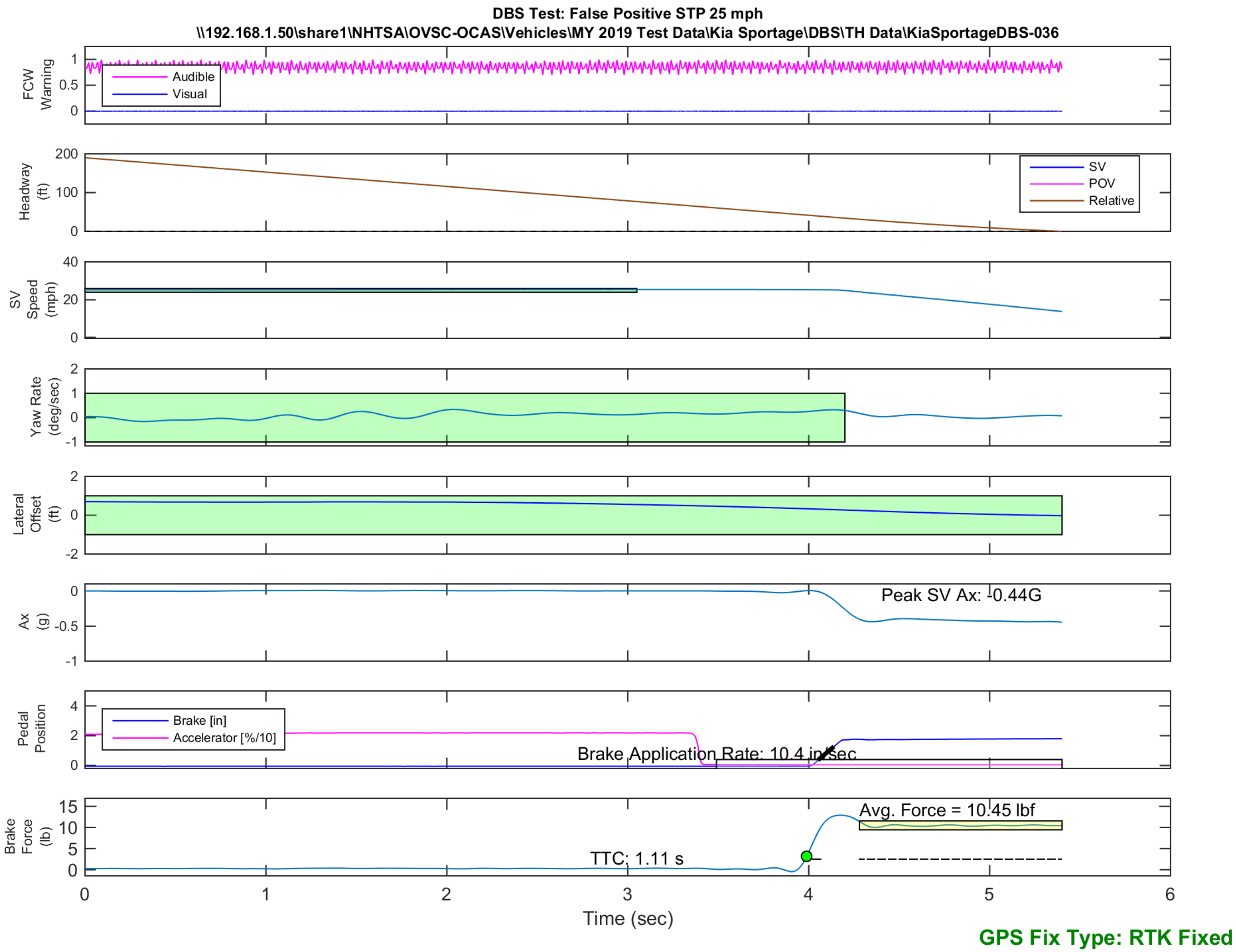


Figure E56. Time History for DBS Run 36, SV Encounters Steel Trench Plate, SV 25 mph

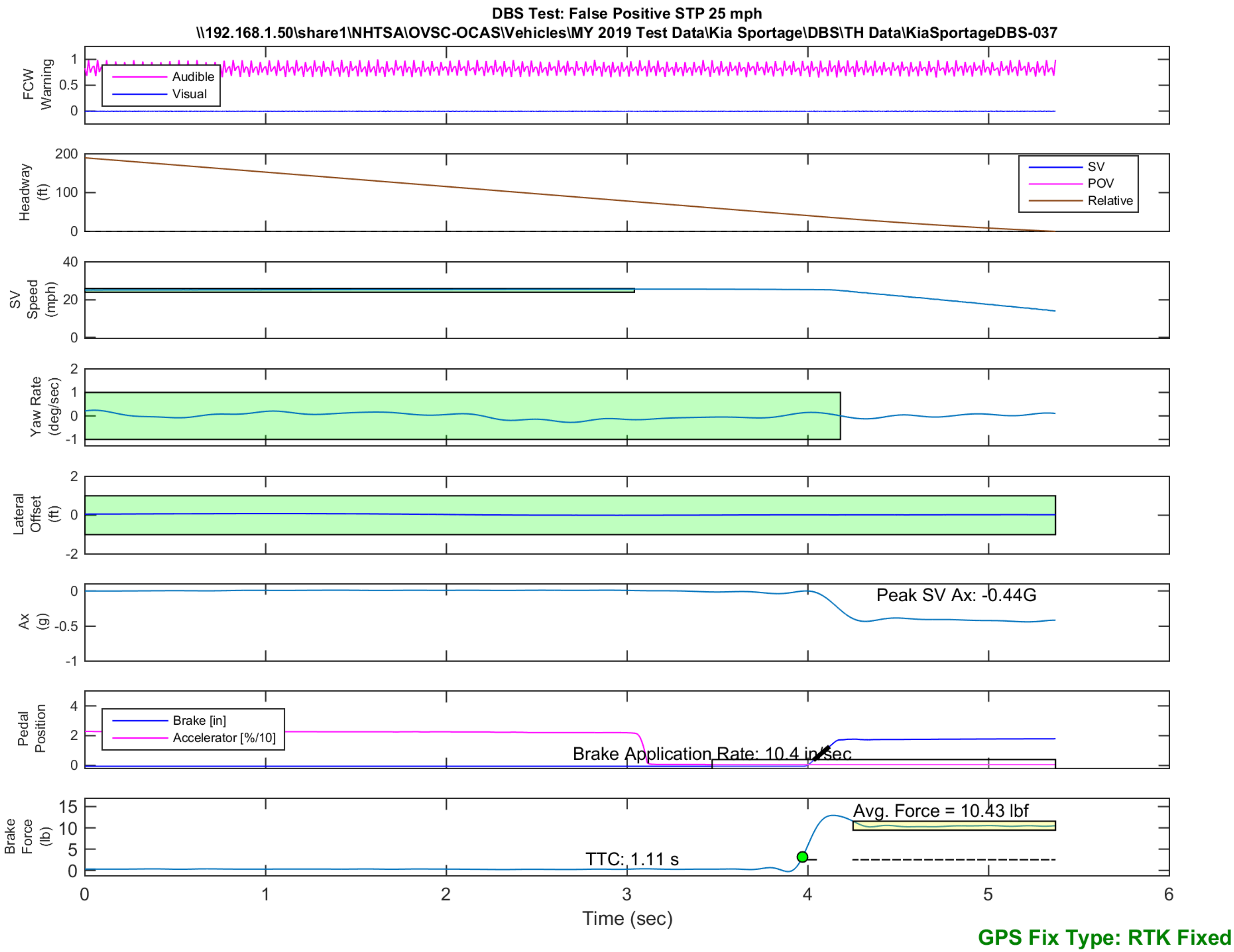


Figure E57. Time History for DBS Run 37, SV Encounters Steel Trench Plate, SV 25 mph

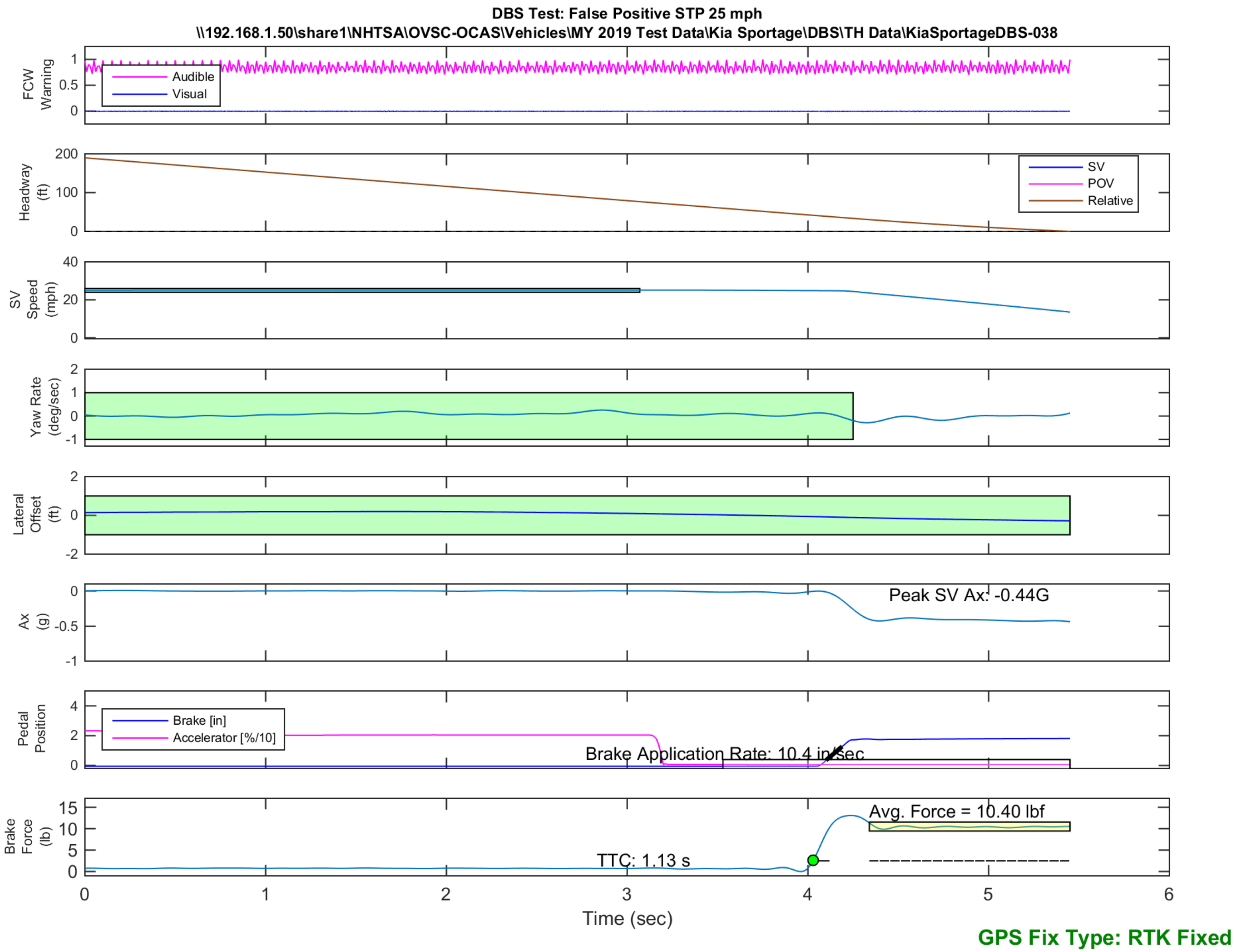


Figure E58. Time History for DBS Run 38, SV Encounters Steel Trench Plate, SV 25 mph

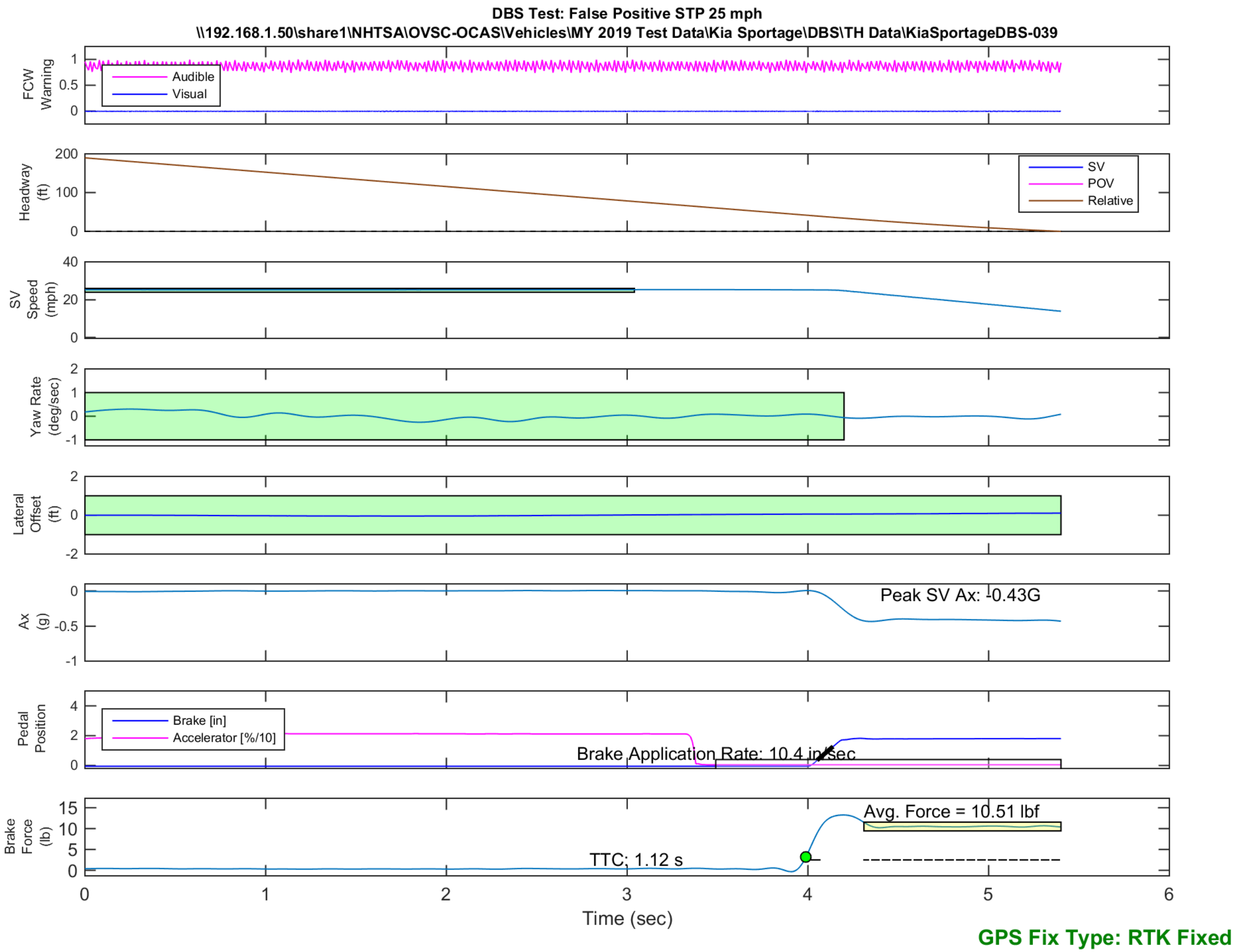


Figure E59. Time History for DBS Run 39, SV Encounters Steel Trench Plate, SV 25 mph

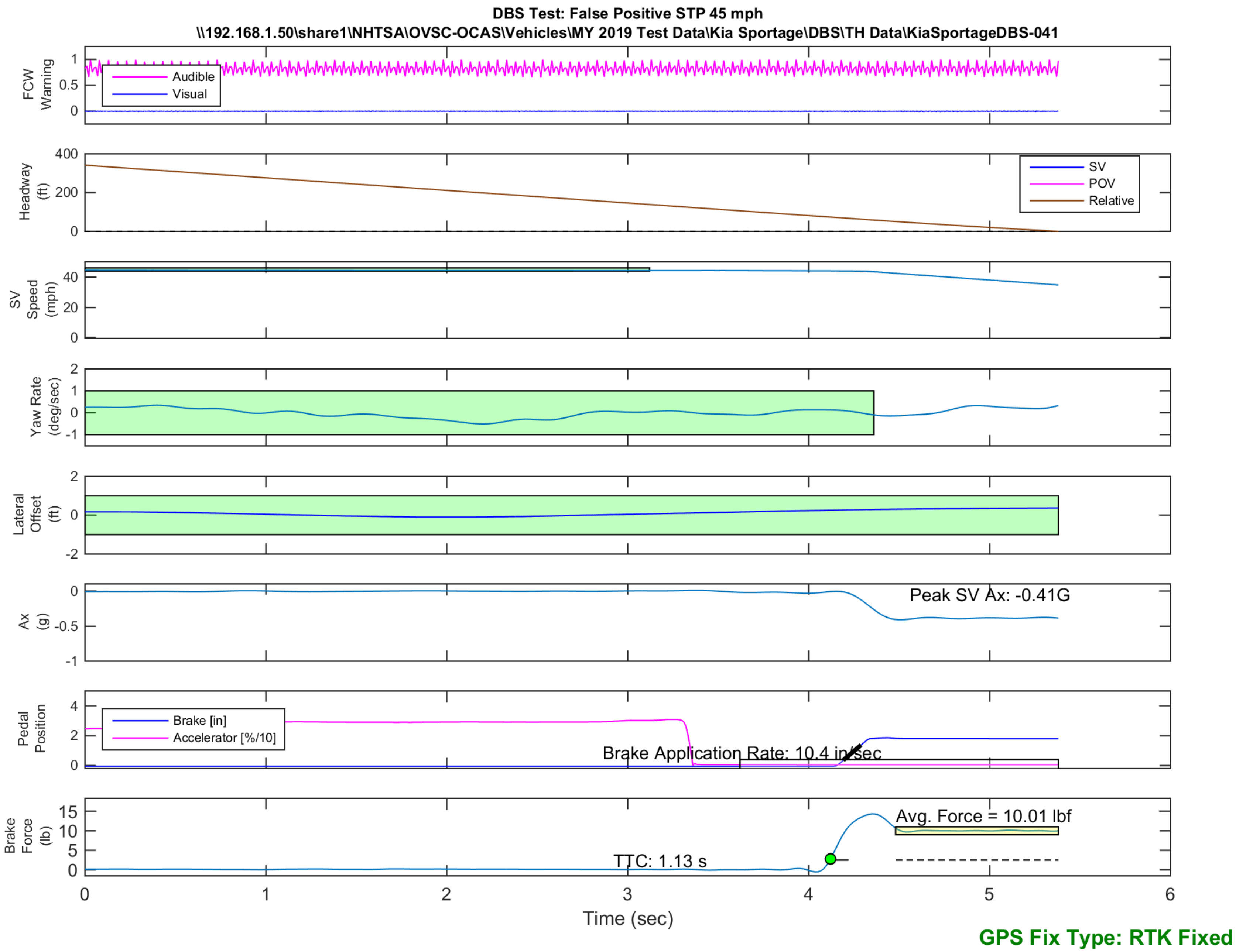


Figure E60. Time History for DBS Run 41, SV Encounters Steel Trench Plate, SV 45 mph

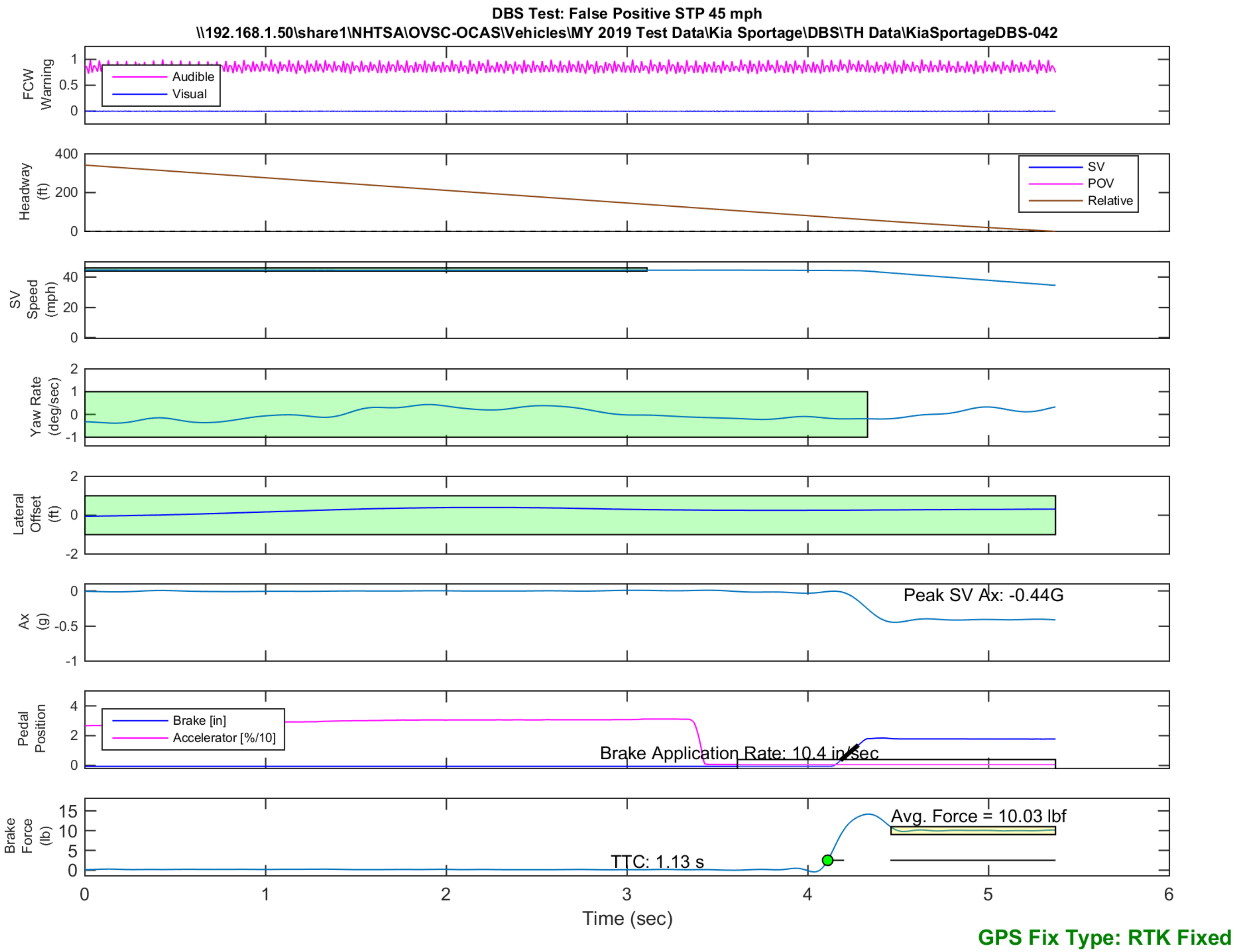


Figure E61. Time History for DBS Run 42, SV Encounters Steel Trench Plate, SV 45 mph

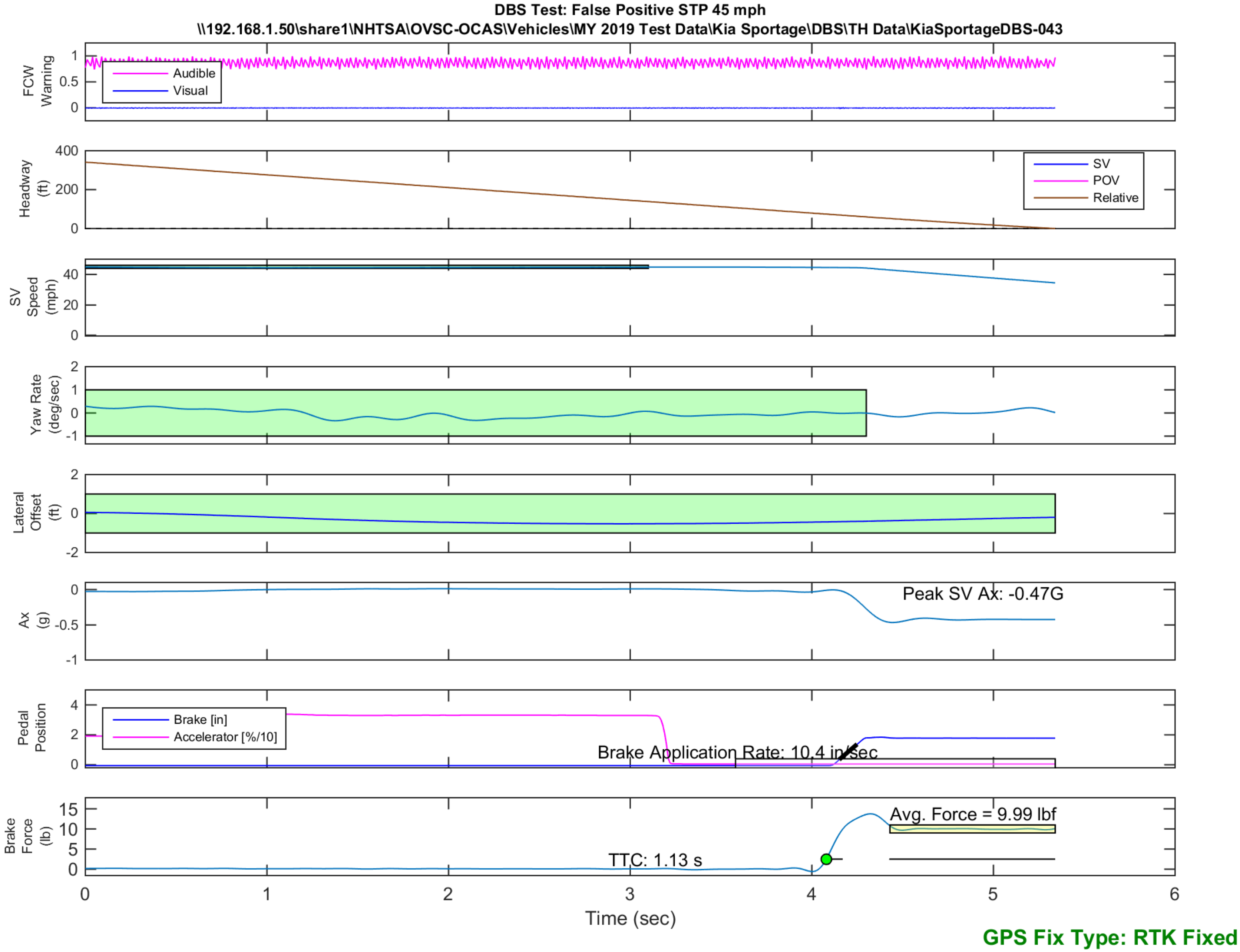


Figure E62. Time History for DBS Run 43, SV Encounters Steel Trench Plate, SV 45 mph

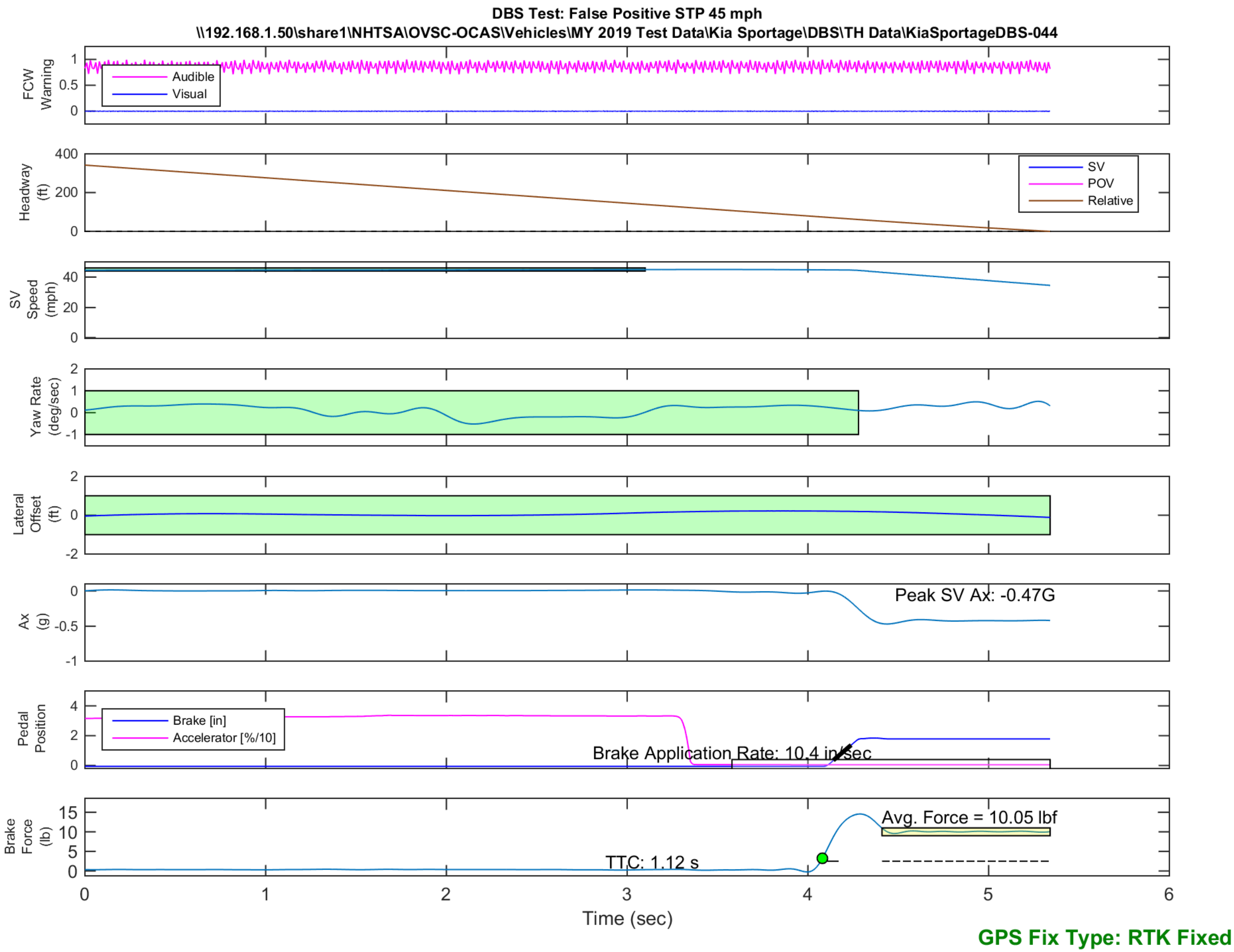


Figure E63. Time History for DBS Run 44, SV Encounters Steel Trench Plate, SV 45 mph

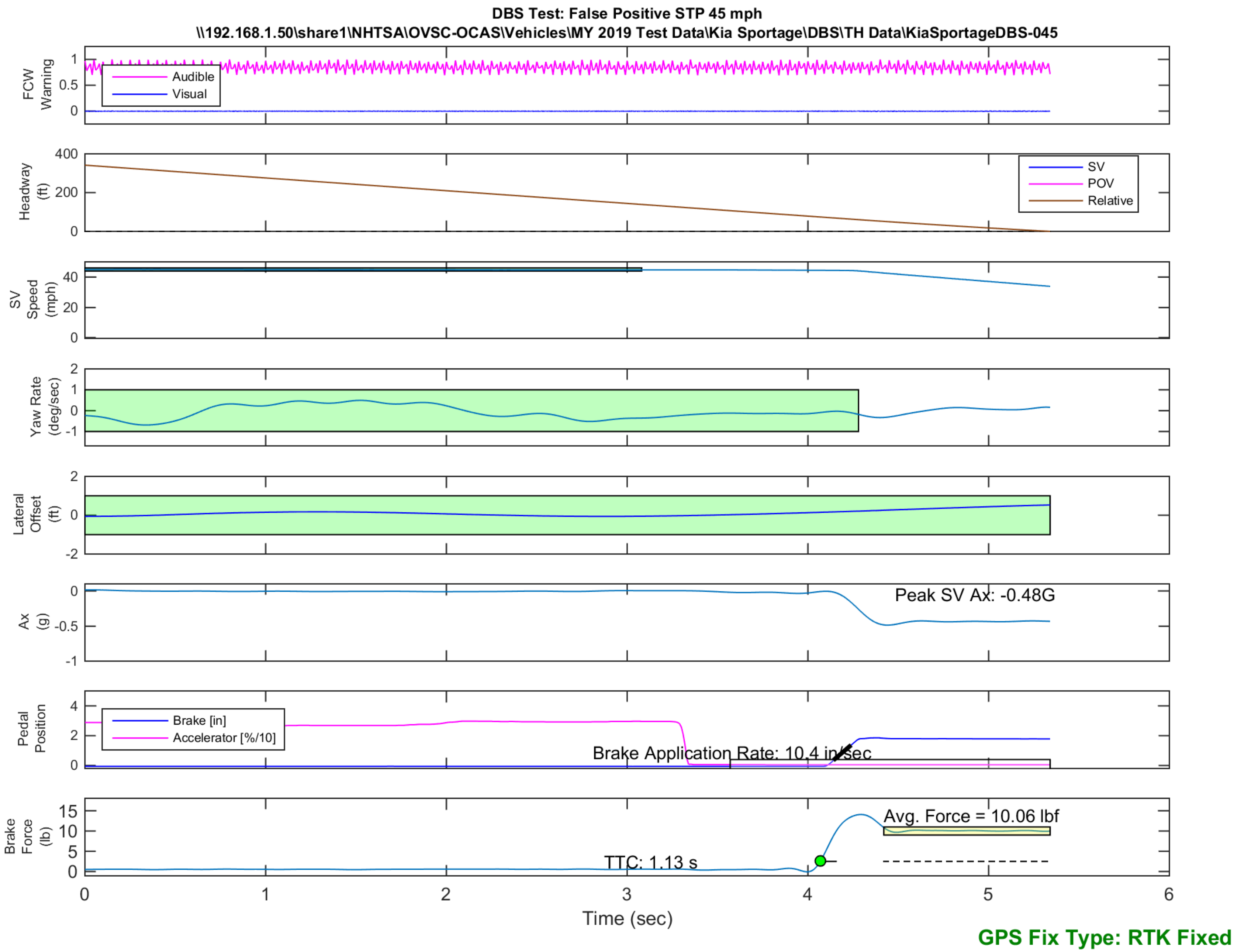


Figure E64. Time History for DBS Run 45, SV Encounters Steel Trench Plate, SV 45 mph

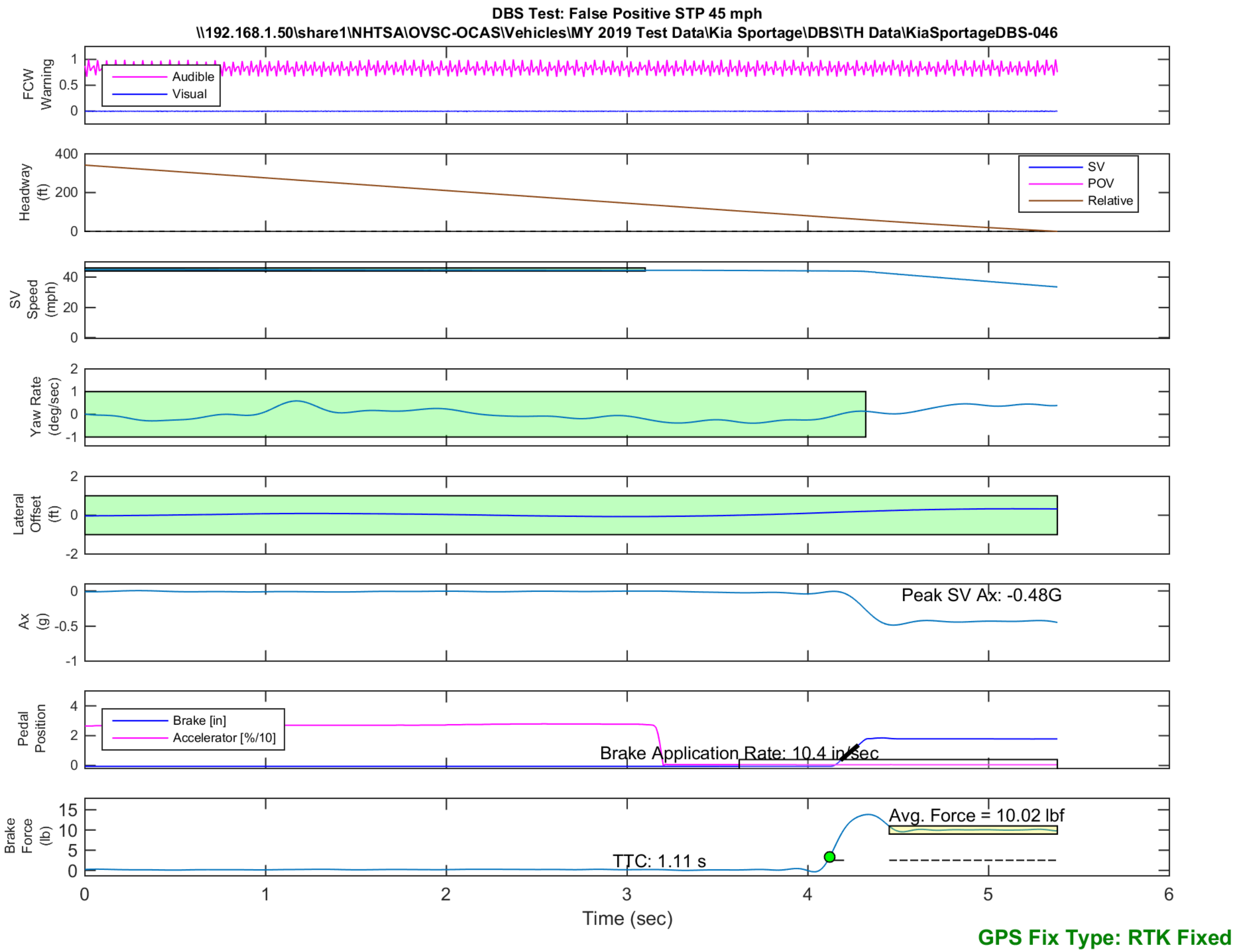


Figure E65. Time History for DBS Run 46, SV Encounters Steel Trench Plate, SV 45 mph

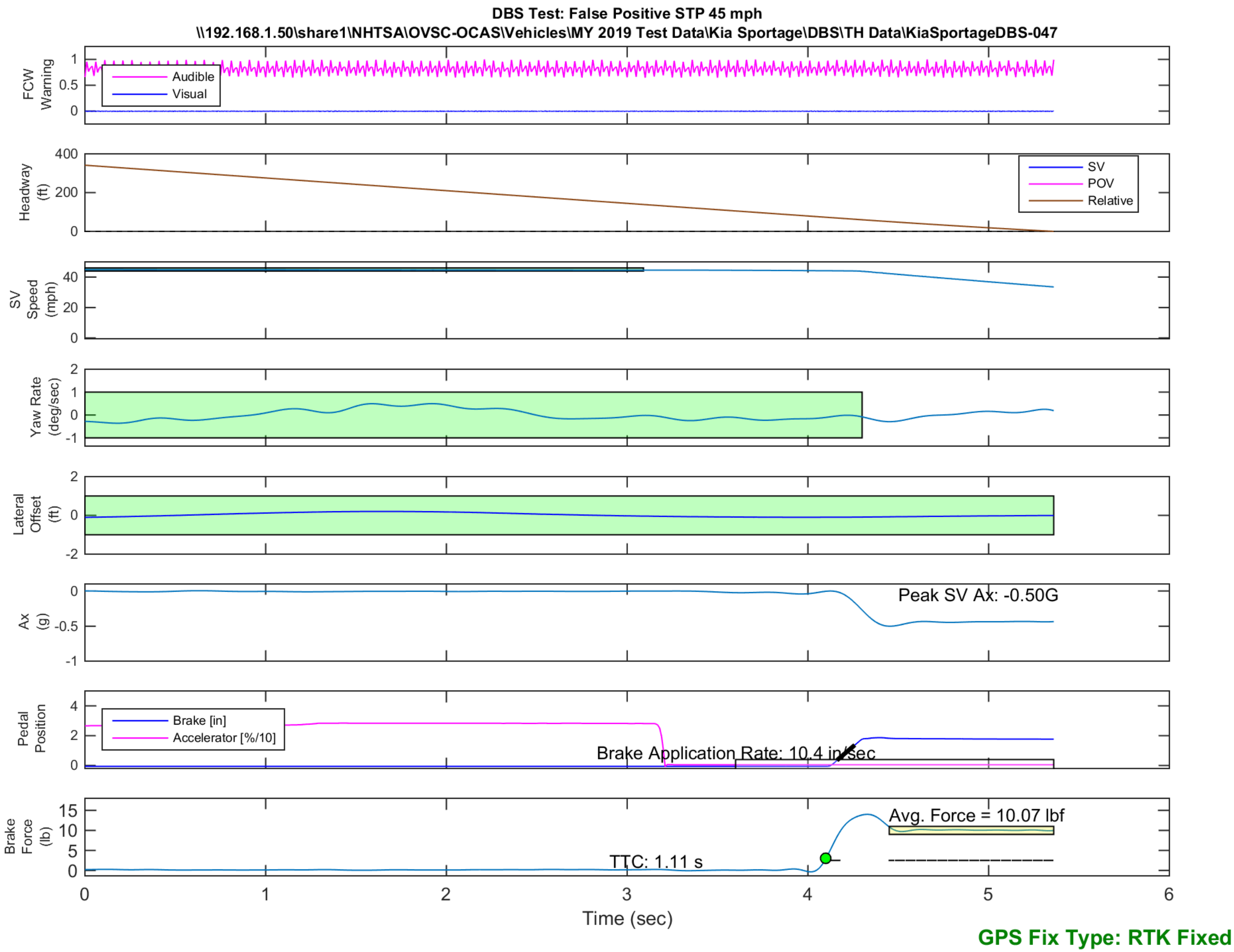


Figure E66. Time History for DBS Run 47, SV Encounters Steel Trench Plate, SV 45 mph

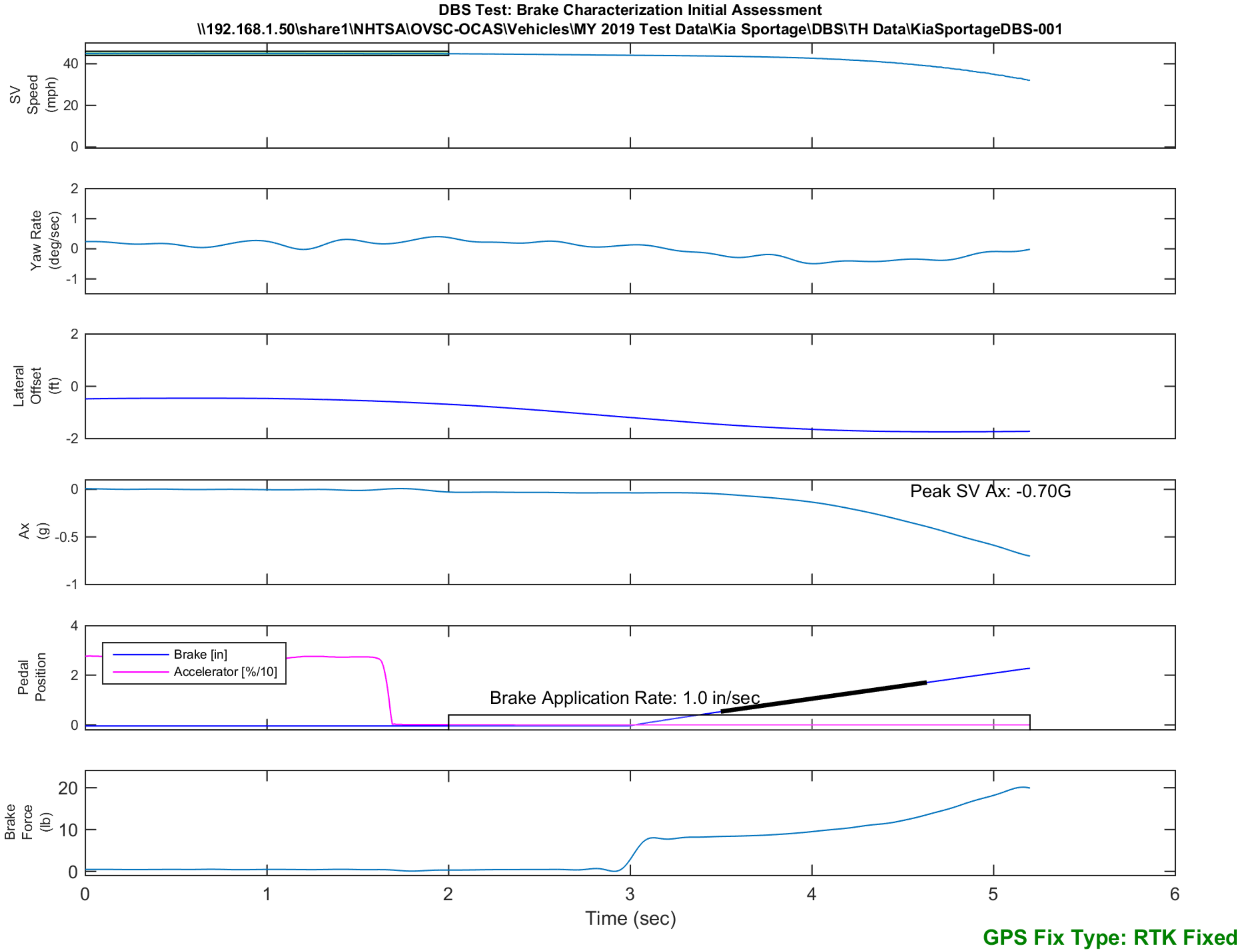


Figure E67. Time History for DBS Run 1, Brake Characterization Initial

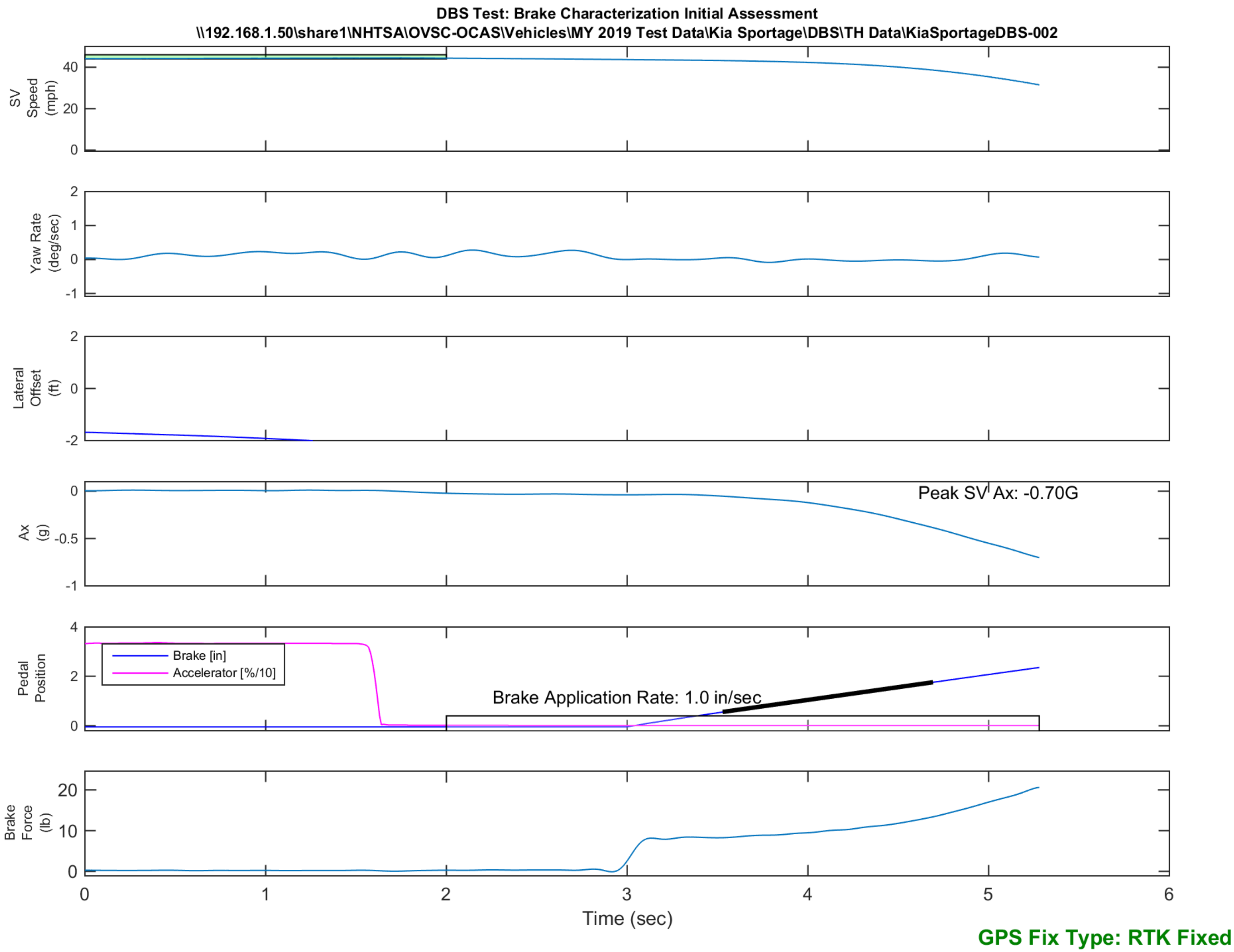


Figure E68. Time History for DBS Run 2, Brake Characterization Initial

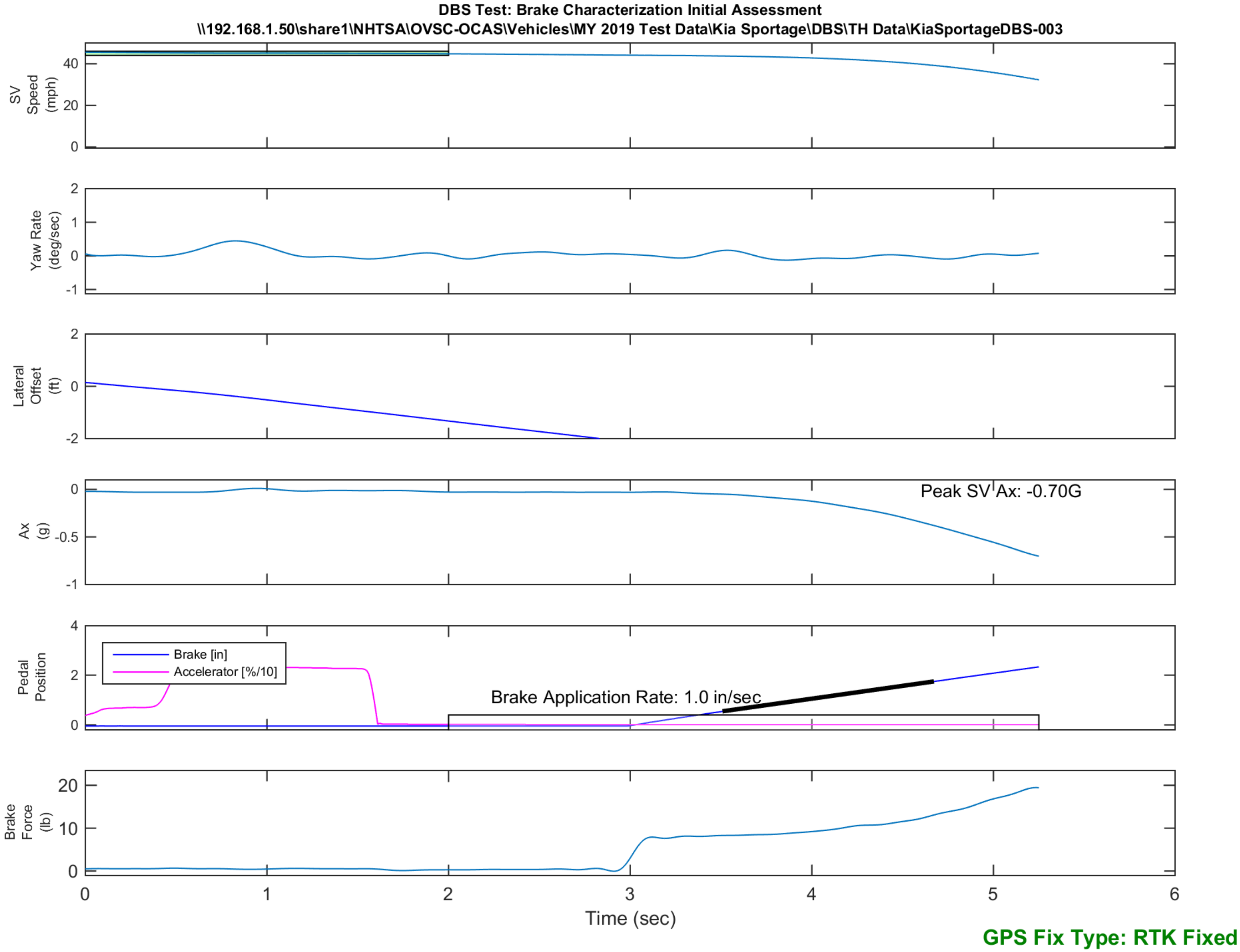


Figure E69. Time History for DBS Run 3, Brake Characterization Initial

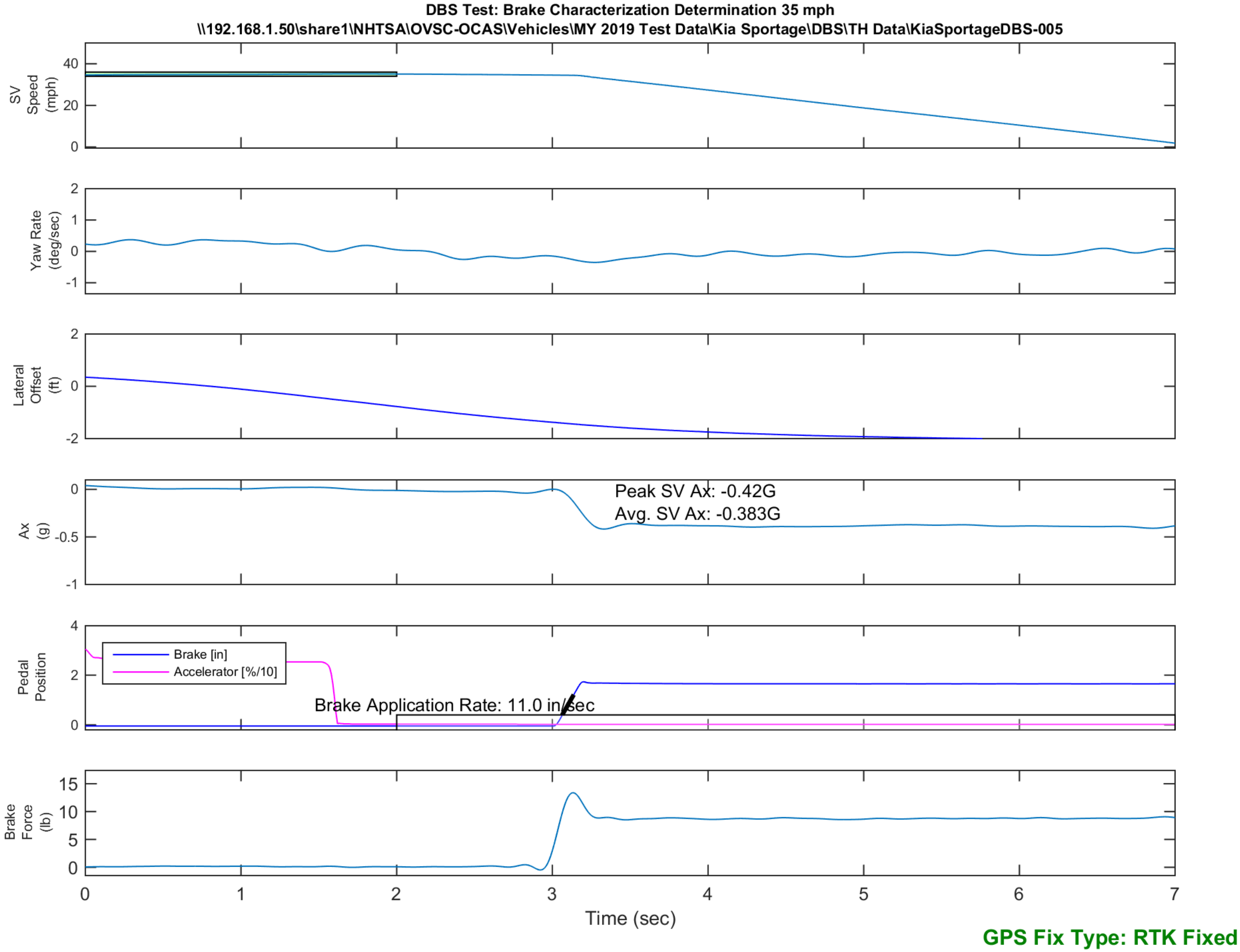


Figure E70. Time History for DBS Run 5, Brake Characterization Determination 35 mph

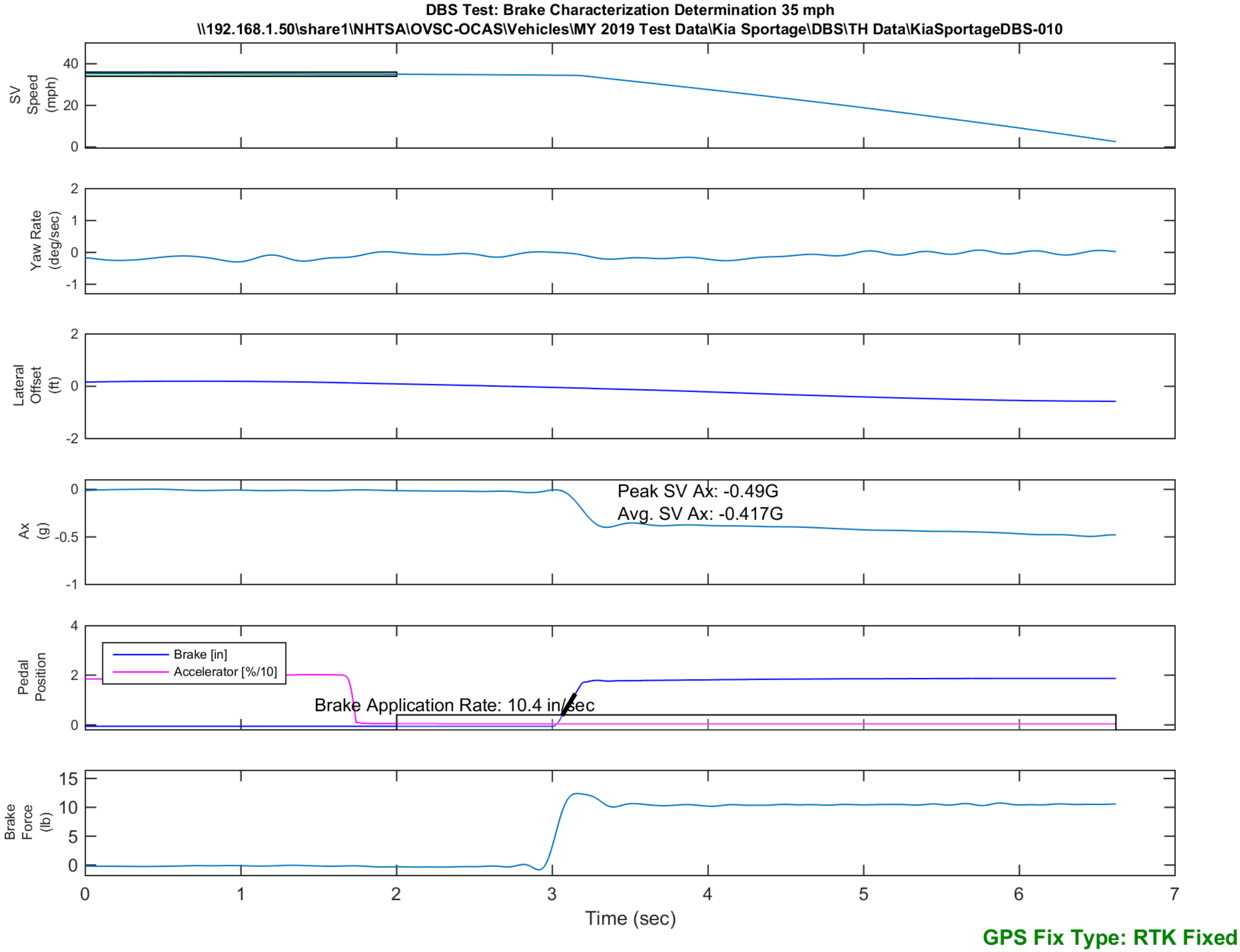


Figure E71. Time History for DBS Run 10, Brake Characterization Determination 35 mph

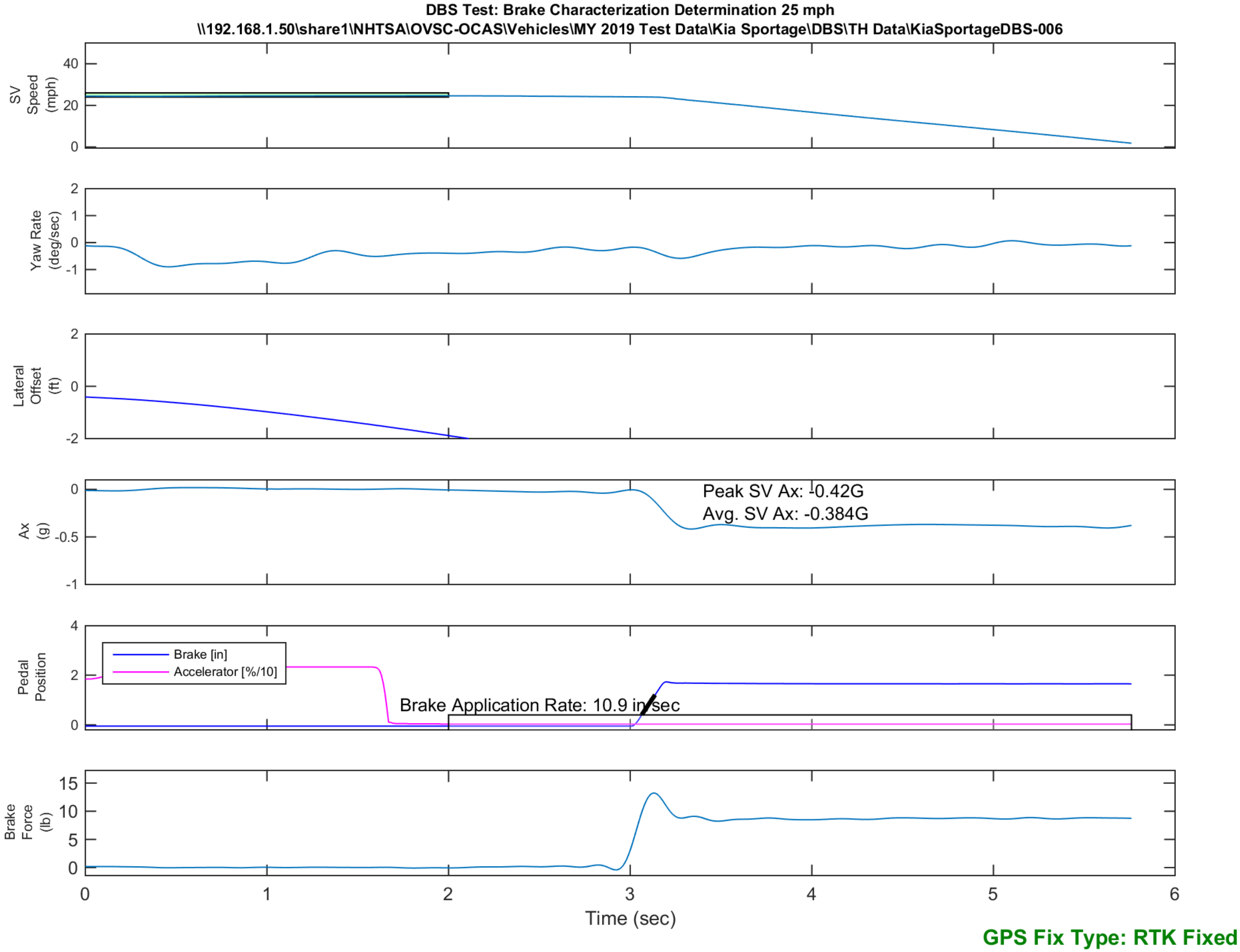


Figure E72. Time History for DBS Run 6, Brake Characterization Determination 25 mph

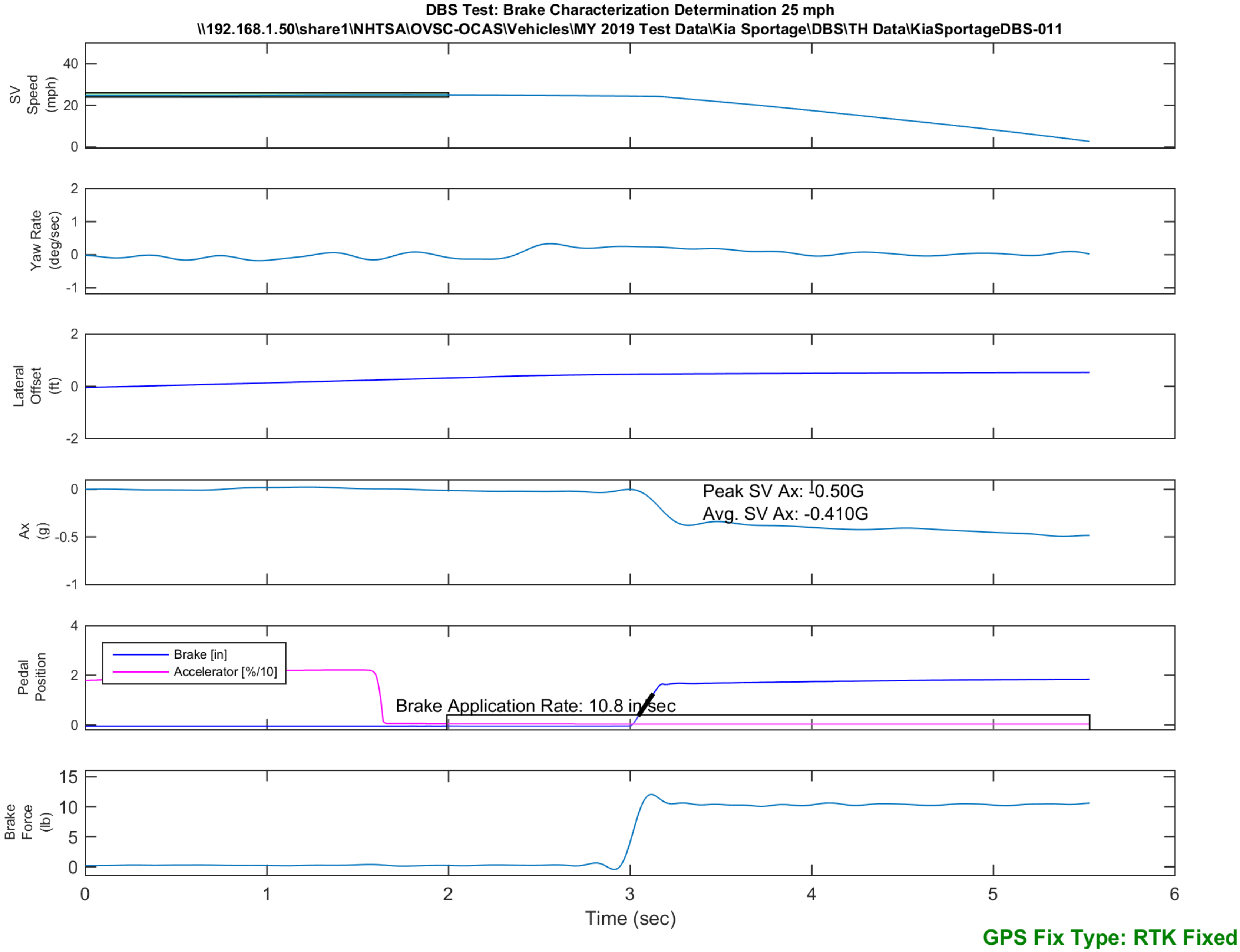


Figure E73. Time History for DBS Run 11, Brake Characterization Determination 25 mph

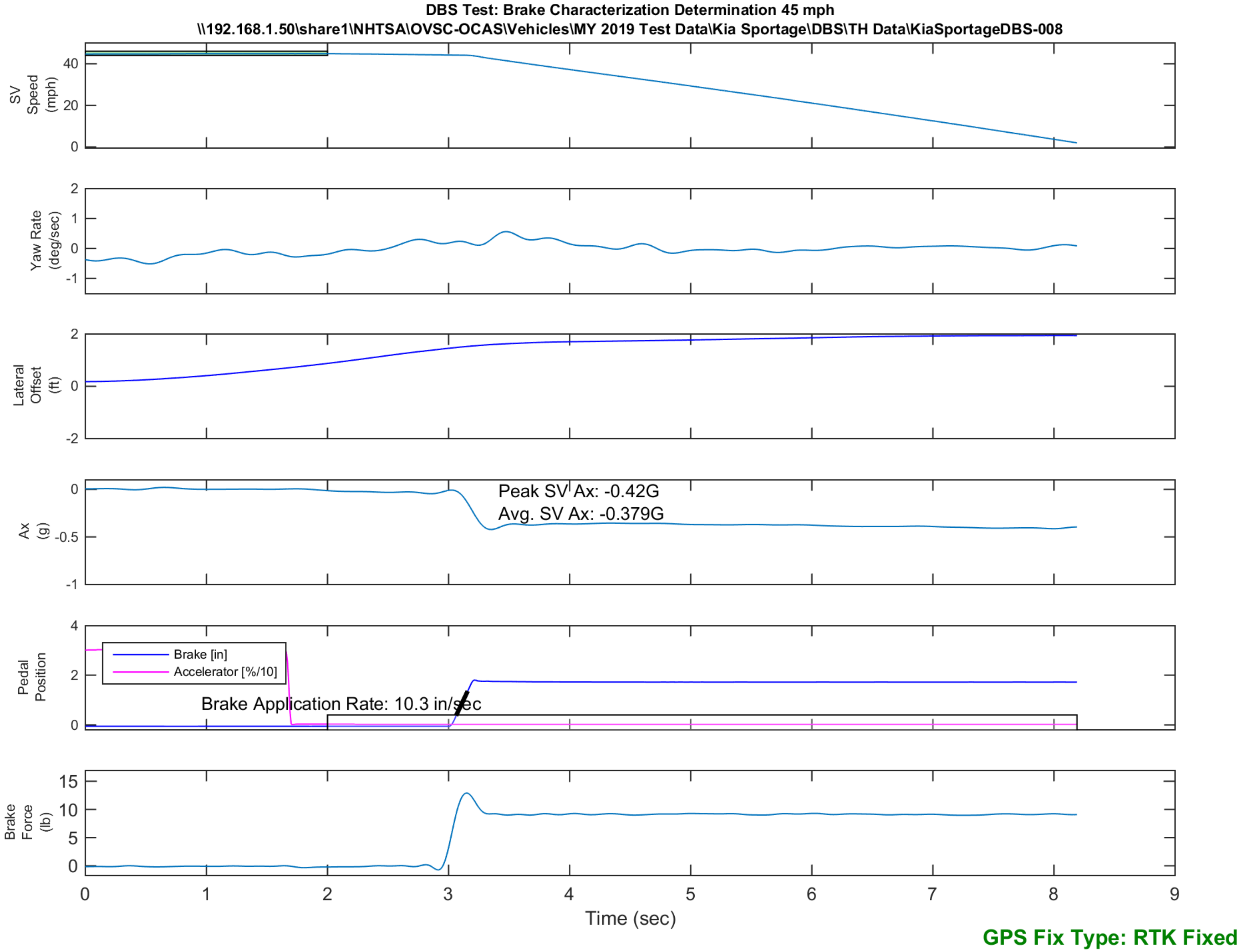


Figure E74. Time History for DBS Run 8, Brake Characterization Determination 45 mph

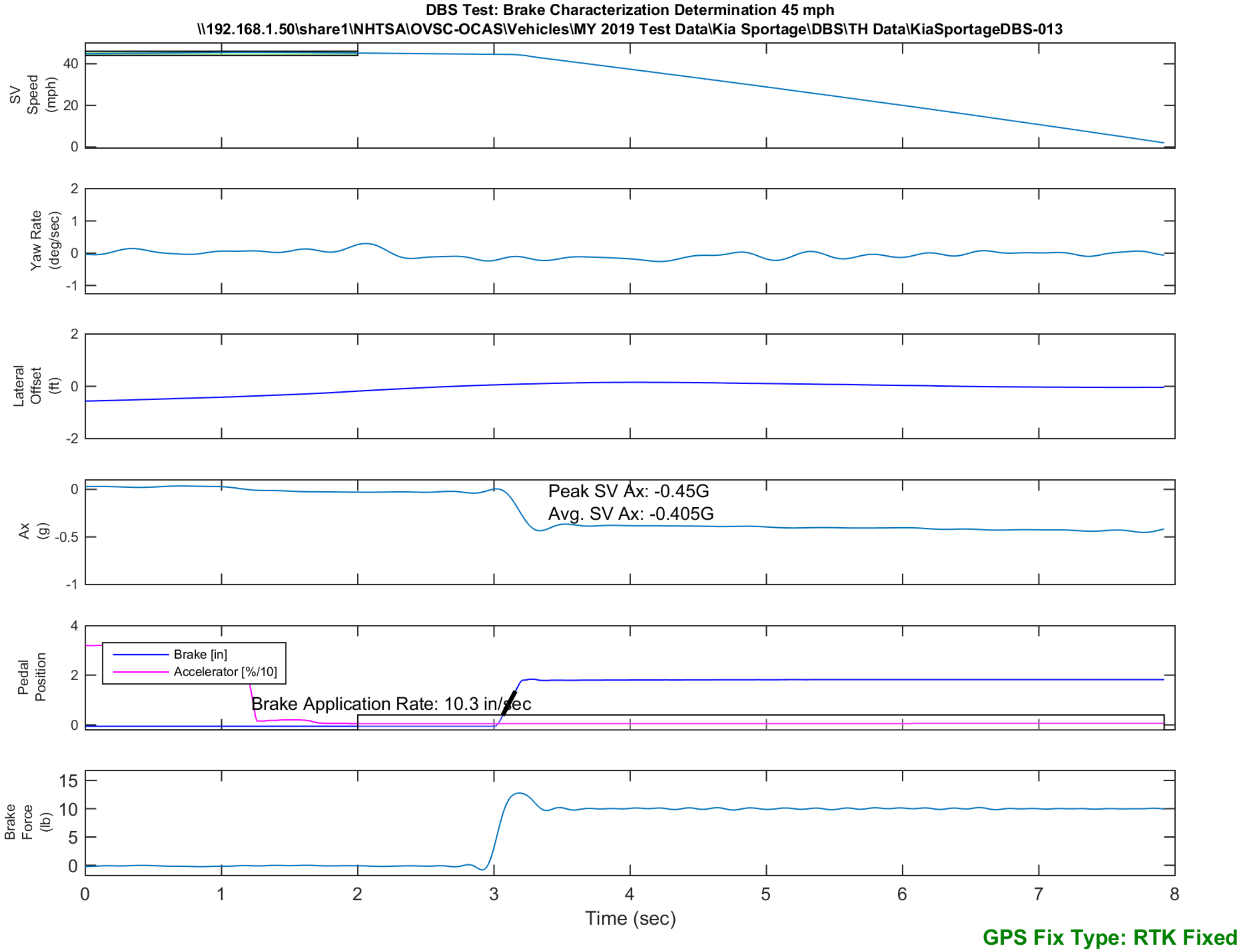


Figure E75. Time History for DBS Run 13, Brake Characterization Determination 45 mph