OCAS-DRI-DBS-19-02
NEW CAR ASSESSMENT PROGRAM
DYNAMIC BRAKE SUPPORT CONFIRMATION TEST

2019 Ford Fusion

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Final Report

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16. Abstract These tests were conducted on the subject 2019 Ford Fusion 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.			
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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 Ford Fusion. This test to assess Dynamic Brake Support systems is sponsored by the National Highway Traffic Safety Administration under Contract No. DTNH22-14-D-00333 with the New Car Assessment Program (NCAP).

Section II
DATA SHEETS

DYNAMIC BRAKE SUPPORT

DATA SHEET 1: TEST RESULTS SUMMARY

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2019 Ford Fusion

SUMMARY RESULTS

VIN: *3FA6P0HD3KR2xxxx*

Test Date: *3/27/2019*

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 Ford Fusion

TEST VEHICLE INFORMATION

VIN: *3FA6P0HD3KR2xxxx*

Body Style: *Sedan* Color: *White Platinum Met Tri-Coat*

Date Received: *3/21/2019* Odometer Reading: *38 mi*

Engine: *1.5 L Inline 4*

Transmission: *Automatic*

Final Drive: *FWD*

Is the vehicle equipped with:

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

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Ford Motor Co*

Date of manufacture: *02/19*

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: *235/50 R17*

Rear: *235/50 R17*

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

Rear: *250 kPa (36 psi)*

DYNAMIC BRAKE SUPPORT

DATA SHEET 2: VEHICLE DATA

(Page 2 of 2)

2019 Ford Fusion

TIRES

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

Front tire size: *235/50 R17*

Rear tire size: *235/50 R17*

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 Ford Fusion

GENERAL INFORMATION

Test date: *3/27/2019*

AMBIENT CONDITIONS

Air temperature: *13.9 C (57 F)*

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

Rear: *250 kPa (36 psi)*

DYNAMIC BRAKE SUPPORT

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2019 Ford Fusion

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*517.5 kg (1141 lb)*	Right Front	*488.5 kg (1077 lb)*
Left Rear	*366.0 kg (807 lb)*	Right Rear	*343.8 kg (758 lb)*
		Total:	*1715.8 kg (3783 lb)*

DYNAMIC BRAKE SUPPORT SYSTEM

DATA SHEET 4:

DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 1 of 3)

2019 Ford Fusion

Name of the DBS option, option package etc.

Pre-collision Assist

System setting used for test (if applicable)

High Sensitivity

Brake application mode used for test:

Constant pedal displacement

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

The system is available from 5 kph for detected vehicles. (Per manufacturer supplied information)

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

The system is available up to the maximum speed of the vehicle for detected vehicles.

Does the vehicle system require an initialization sequence/procedure?

Yes; a 40 to 50 mile drive above 35 mph on a roadway with moving and stationary targets will confirm the sensors are fully aligned. If Active Braking is enabled, the vehicle should require no other initialization. (Per manufacturer supplied information)

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

The system effectiveness may reduce if too many AEB activations occur in quick succession.

If there has been a sufficiently hard impact to the target, the radar mounting may become damaged.

How is the Forward Collision Warning presented to the driver? (Check all that apply)

- X Warning light
- X Buzzer or audible alarm
- ___ Vibration
- ___ Other

DYNAMIC BRAKE SUPPORT SYSTEM

DATA SHEET 4:

DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 2 of 3)

2019 Ford Fusion

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

The driver is provided with audible and visual alerts. The audible sound is a four-tone chime repeated three times. The visual alert is through a red flashing LED light bar that is reflected in the lower part of the windshield in front of the driver. A visual alert is also provided in the center of the instrument panel.

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.

A set of buttons is provided on the left side of the steering wheel for interacting with the vehicle system menus. The CIB and DBS functionality can be turned off through a single checkbox in the instrument panel menu:

Driver Assist

Pre-Collision

Active Braking checkbox

CIB and DBS are on by default after every ignition cycle

The entire Pre-Collision Assist system can also be disabled through the instrument panel:

Driver Assist

Pre-Collision

Pre-Collision Assist On/Off

If this has occurred, the driver will be prompted to re-enable the feature after each ignition cycle.

DYNAMIC BRAKE SUPPORT SYSTEM

DATA SHEET 4:

DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 3 of 3)

2019 Ford Fusion

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.

A set of buttons is provided on the left side of the steering wheel for interacting with the vehicle system menus. The Alert Sensitivity has three settings (High, Normal, Low) and they can be accessed by means of the steering wheel buttons interaction with the vehicle system menu:

Driver Assist

Pre-Collision

Alert Sensitivity: High, Normal or Low.

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 system does not operate during hard acceleration or steering.*
- *The system may fail or operate with reduced function during cold and severe weather conditions.*
- *Snow, ice, rain, spray and fog can adversely affect the system.*
- *In situations where the vehicle camera has limited detection capability, this may reduce system performance. These situations include but are not limited to:*
  - *direct or low sunlight,*
  - *vehicles at night without tail lights,*
  - *unconventional vehicle types,*
  - *pedestrians with complex backgrounds,*
  - *partly obscured pedestrians, or*
  - *pedestrians that the system cannot distinguish from a group.*

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.

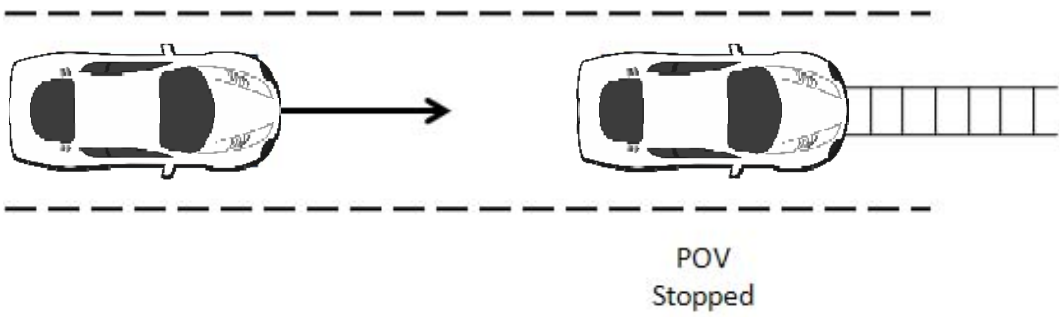

Figure 1. Depiction of Test 1

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.

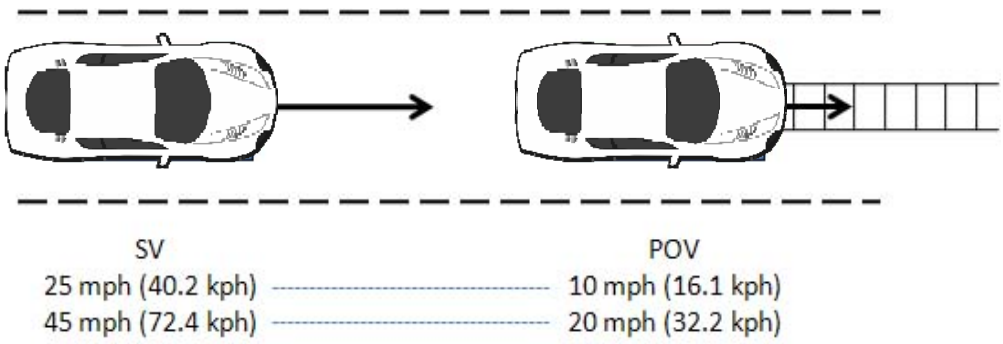

Figure 2. Depiction of Test 2

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 (72.4 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.

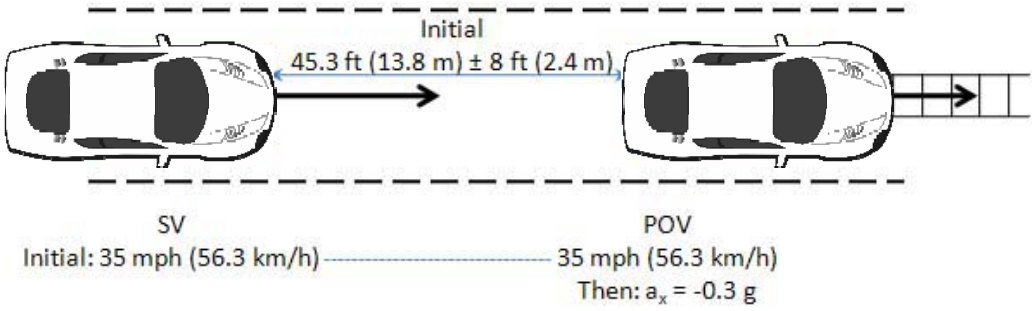

Figure 3. Depiction of Test 3 with POV Decelerating

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	5th	3 dB	60 dB	Identified Center Frequency ± 5%
Tactile	5th	3 dB	60 dB	Identified Center Frequency ± 20%

2. General Validity Criteria

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

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

3. Validity Period

The valid test interval began:

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

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

Test 3: 3 seconds before the onset of POV braking

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

The valid test interval ended:

Test 1: When either of the following occurred:

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

Test 2: When either of the following occurred:

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

Test 3: When either of the following occurred:

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

Test 4: When the SV stopped.

4. Static Instrumentation Calibration

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

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

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

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

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

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

5. Number of Trials

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

6. Transmission

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

C. PRINCIPAL OTHER VEHICLE

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

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

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

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: 1/3/2019 Due: 1/3/2020
Linear (string) encoder	Throttle pedal travel	10 in 254 mm	0.1 in 2.54 mm	UniMeasure LX-EP	43020490	By: DRI Date: 5/1/2018 Due: 5/1/2019
Load Cell	Force applied to brake pedal					By: DRI
		0 - 250 lb 0 -1112 N	0.1% FS	Honeywell 41A	1464391	Date: 8/28/2018 Due: 8/28/2019
		0-250 lb 1112 N	0.05% FS	Stellar Technology PNC700	1607338	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
					2176	Date: 4/11/2018 Due: 4/11/2020
Real-Time Calculation of Position and Velocity Relative to Lane Markings (LDW) and POV (FCW)	Distance and Velocity to lane markings (LDW) and POV (FCW)	Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec	Oxford Technical Solutions (OXTS), RT-Range	97	NA
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899	NA	NA
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	NA	NA
Accelerometer	Acceleration (to measure time at alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	NA	NA

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Coordinate Measurement Machine	Inertial Sensing System Coordinates	0-8 ft 0-2.4 m	±.0020 in. ±.051 mm (Single point articulation accuracy)	Faro Arm, Fusion	UO8-05-08-06636	By: DRI Date: 1/2/2019 Due: 1/2/2020

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

APPENDIX A

Photographs

LIST OF FIGURES

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Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

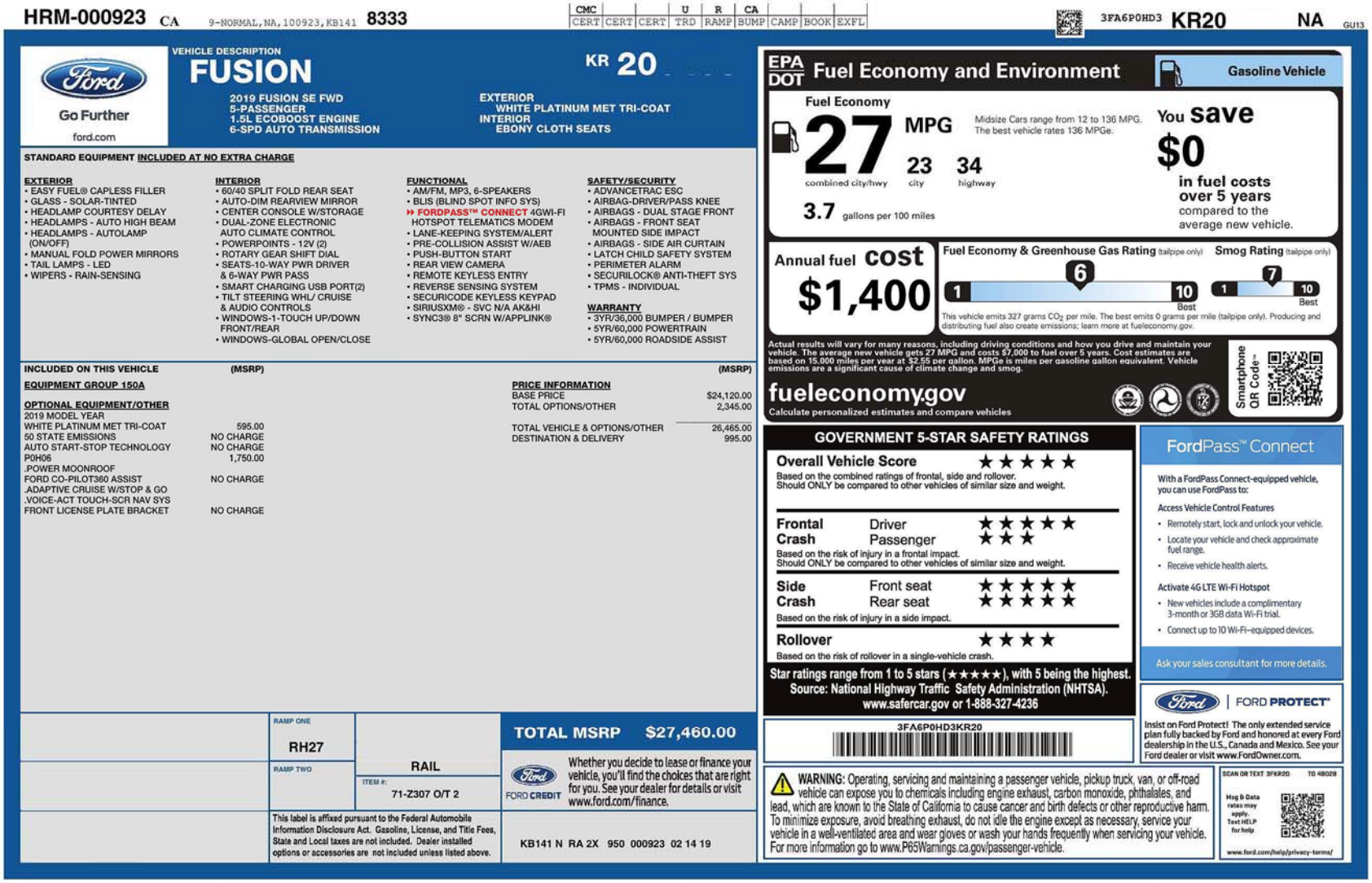

Figure A3. Window Sticker (Monroney Label)

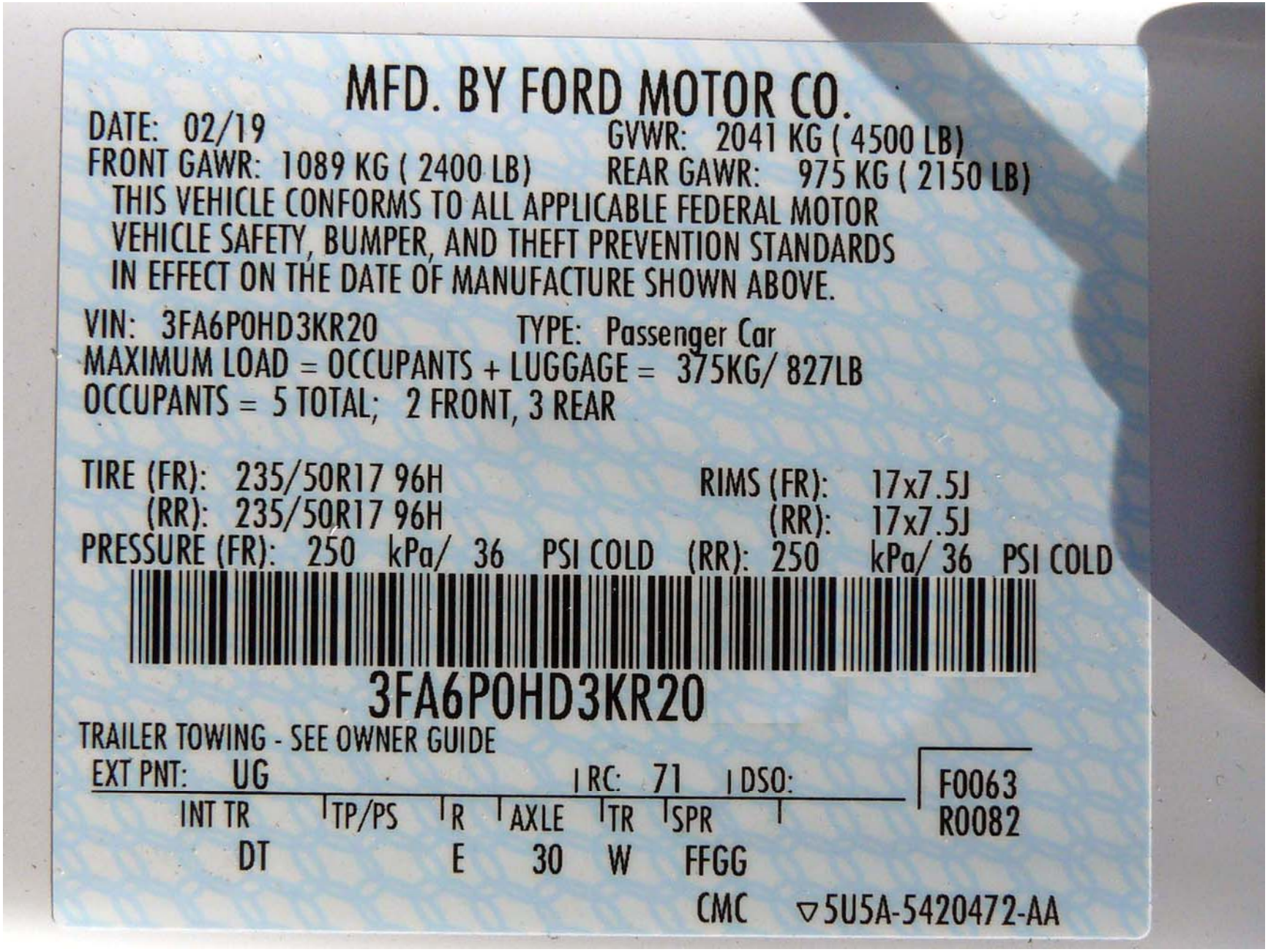

Figure A4. Vehicle Certification Label

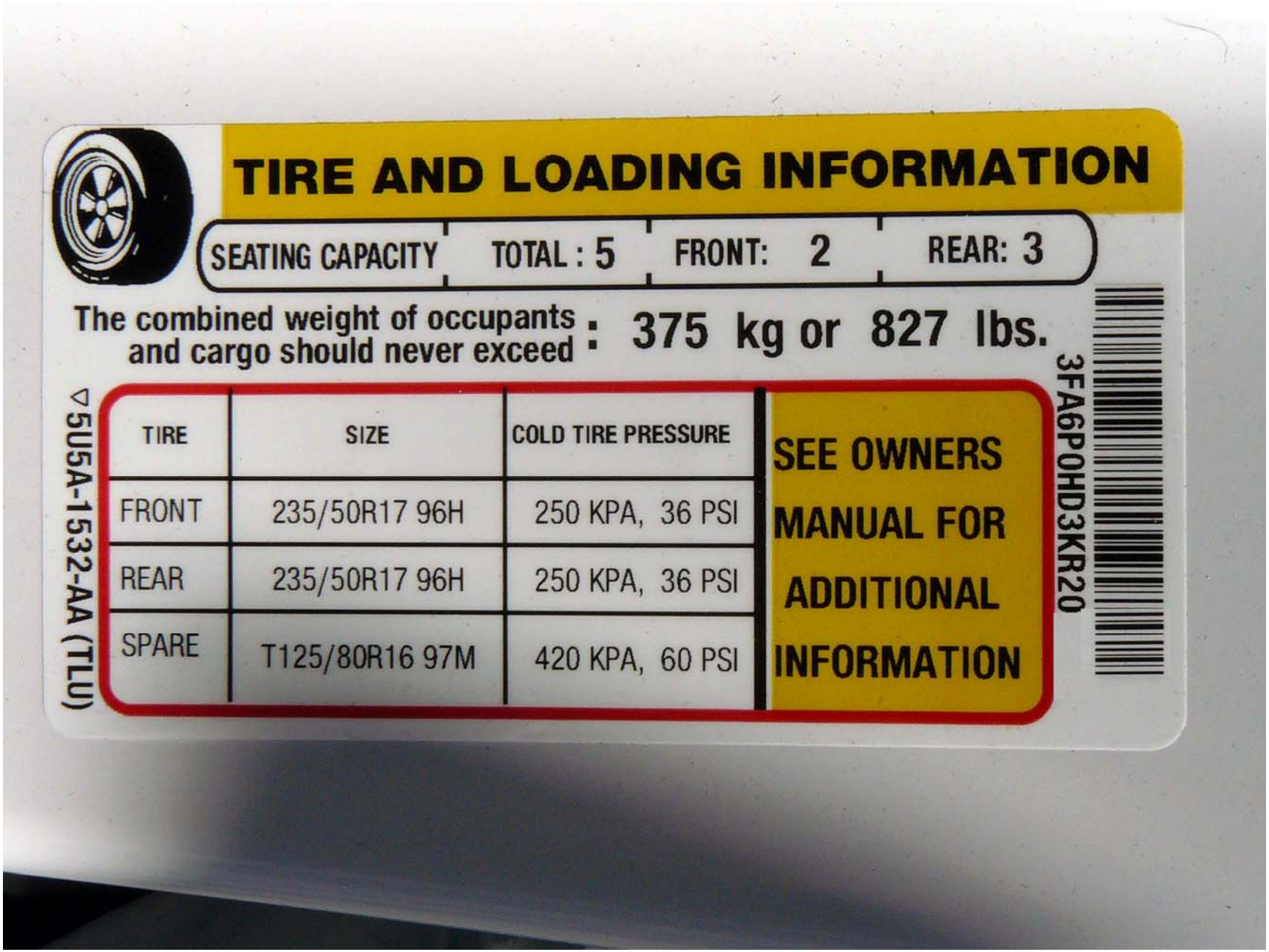

Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

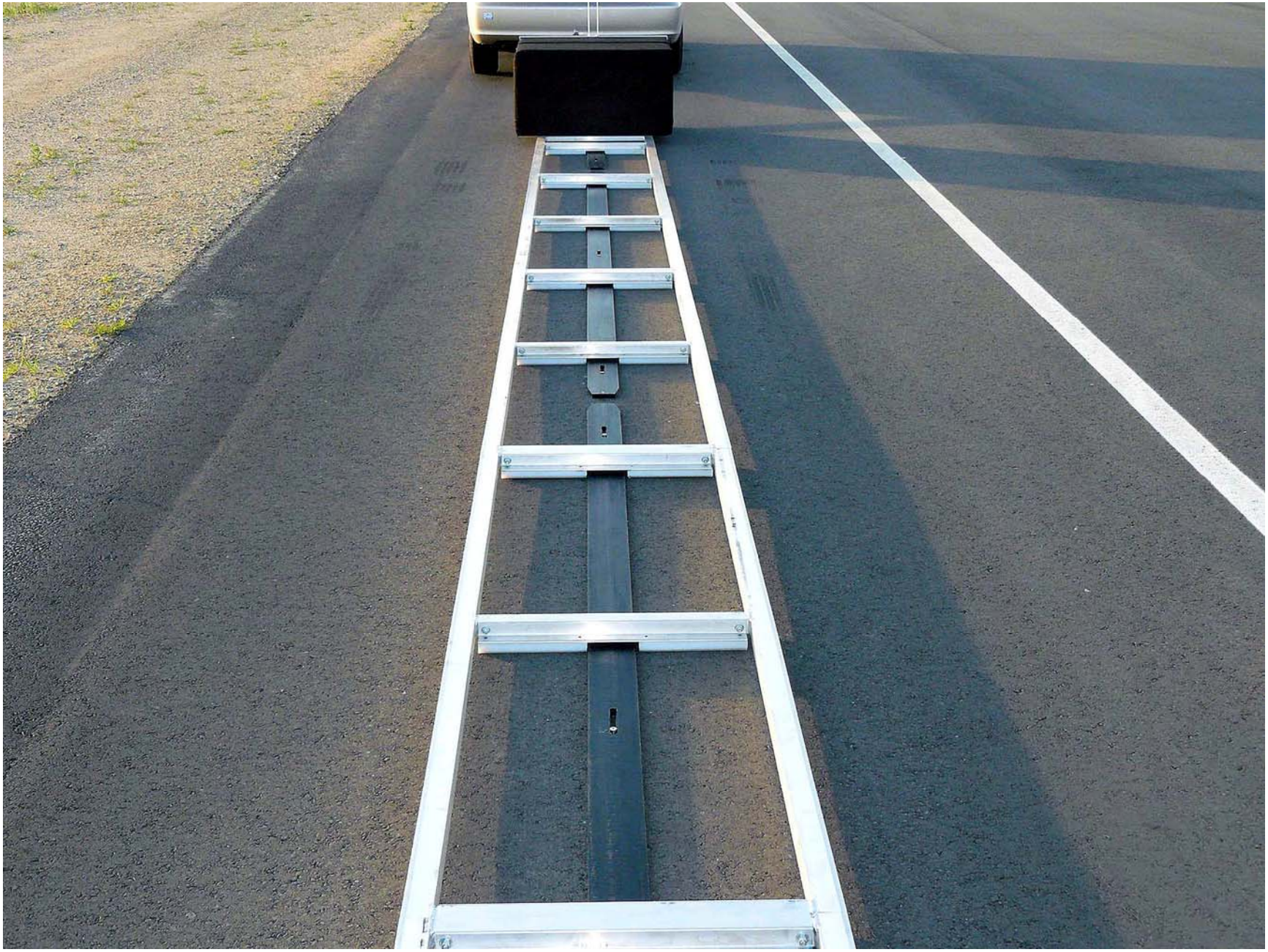

Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

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

Figure A11. Sensor for Detecting Heads Up Visual Alerts

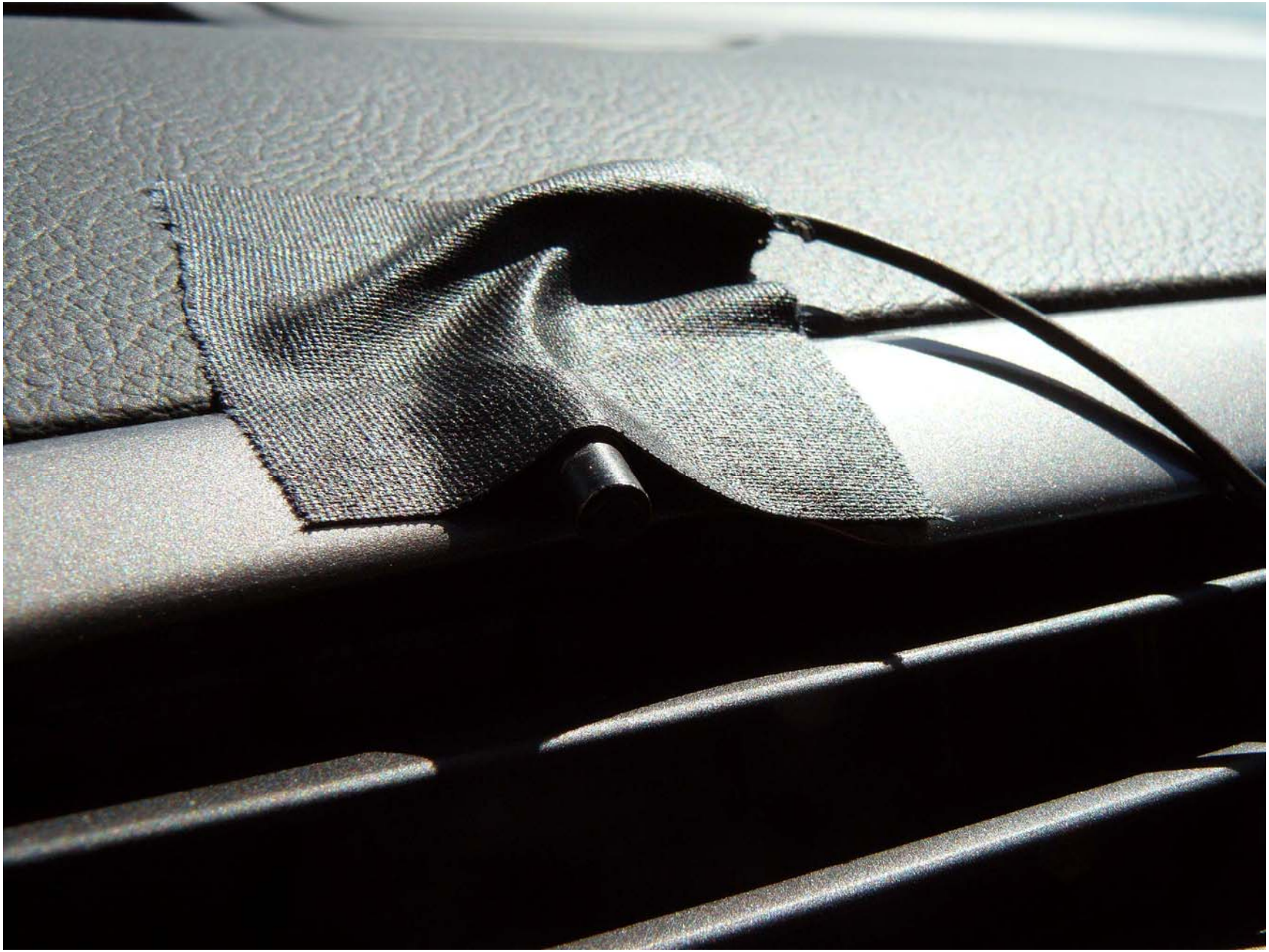

Figure A12. Sensor for Detecting Auditory Alerts

Figure A13. Computer Installed in Subject Vehicle

Figure A14. Brake Actuator Installed in Subject Vehicle

Figure A15. Brake Actuator Installed in POV System

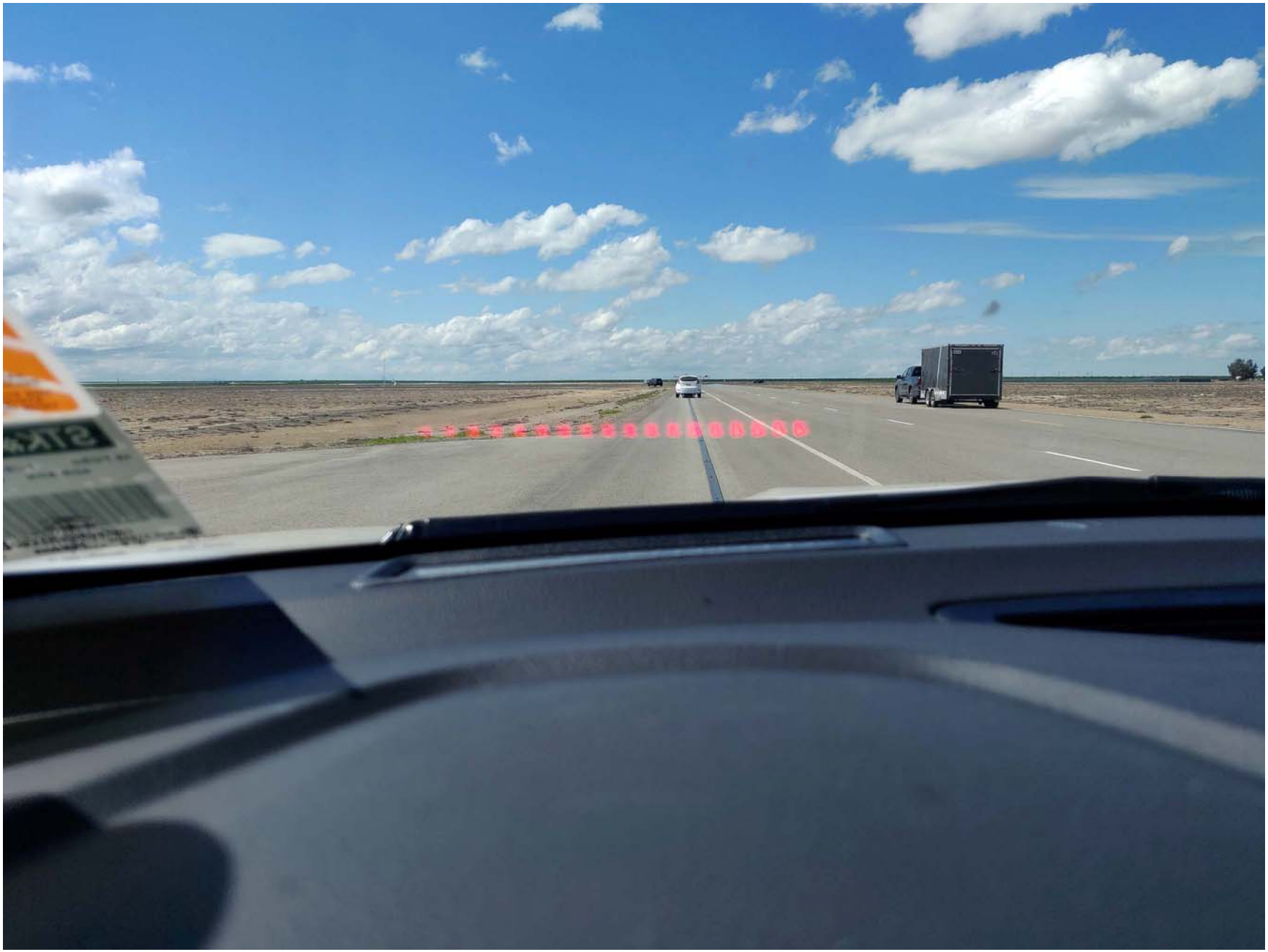

Figure A16. Heads Up Collision Warning Visual Alert

Figure A17. Instrument Panel Collision Warning Visual Alert

Figure A18. Menu Page for AEB Settings

Figure A19. Steering Wheel Mounted Control Buttons for Changing Parameters

APPENDIX B

Excerpts from Owner's Manual

Fuel Economy
All Values [1]
Auto StartStop

[1] Type 2

- Distance to Empty - Shows the approximate distance your vehicle can travel before running out of fuel.
- Inst Fuel Economy - Shows a visual graph of your instantaneous fuel economy along with your Avg MPG since the function was last reset.
- Long Term Fuel Economy - Shows your long term fuel economy.
- Fuel History - Shows a bar chart of your fuel history.
- Average Fuel — Shows the average fuel economy for a given trip.
- All Values — Shows all fuel economy values (DTE, Inst Fuel Econ, Avg Fuel).
- Auto StartStop - Available Auto Start-Stop messaging will provide details about what is happening with your system. See **Information Messages** (page 106).

Note: *You can reset your average fuel economy by pressing and holding the **OK** button on the left hand steering wheel controls.*

Driver Assist		
Traction Ctrl - check enabled or uncheck disabled		
Blind Spot - check enabled or uncheck disabled [1]		
Cross Traffic - check enabled or uncheck disabled [1]		
Cruise Control [1]	Adaptive or Normal	
Driver Alert [1]	Driver Alert or Driver Alert Display	
Hill Start Assist - check enabled or uncheck disabled		
Intelligent AWD [1]		
Lane Keeping System [1]	Mode	Alert, Aid or Both
	Intensity	High, Normal or Low
Pre-Collision	Alert Sensitivity	High, Normal or Low
	Active Braking - check enabled or uncheck disabled	

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Driver Assist		
Traction Control - check enabled or uncheck disabled		
Blind Spot - check enabled or uncheck disabled		
Cross Traffic Alert - check enabled or uncheck disabled		
Cruise Control	Adaptive or Normal	
Driver Alert	Driver Alert or Driver Alert Display	
Hill Start Assist - check enabled or uncheck disabled		
Lane Keeping System	Mode	Alert, Aid or Both
	Intensity	High, Normal or Low
Pre-Collision	Alert Sensitivity	High, Normal or Low
	Active Braking - check enabled or uncheck disabled	
Rear Park Aid - check enabled or uncheck disabled		
Tire Monitor	Tire Monitor - Hold ***OK*** to Reset	

Note: *Some items are optional and may not appear.*

Settings

In this mode, you can configure different driver setting choices.

Settings			
Vehicle	Auto Engine Off - check enabled or uncheck disabled		
	Easy Entry/Exit - check enabled or uncheck disabled		
	Lighting	Auto Highbeam - check enabled or uncheck disabled	
		Autolamp Delay	Off or XX Seconds
		Daytime Lights - check enabled or uncheck disabled	
	Locks	Autolock - check enabled or uncheck disabled	
		Autounlock - check enabled or uncheck disabled	
		Mislock - check enabled or uncheck disabled	
		Remote Unlock	All Doors or Driver First

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Power Steering

Message	Action
Steering Fault Service Now	The power steering system detects a condition that requires service. Contact an authorized dealer.
Steering Loss Stop Safely	The power steering system is not working. Stop your vehicle in a safe place. Contact an authorized dealer.
Steering Assist Fault Service Required	The power steering system detects a condition that requires service. Contact an authorized dealer.

Pre-Collision Assist

Message	Action
Pre-Collision Assist Malfunction	There is a system malfunction with the pre-collision assist system. The system will be disabled. Contact an authorized dealer as soon as possible.
Pre-Collision Assist Not Available Sensor Blocked	The pre-collision assist system radar is blocked because of poor radar visibility due to bad weather or ice, mud, water in front of the radar. Driver can typically clean the sensor to resolve. Contact an authorized dealer as soon as possible.
Pre-Collision Assist Not Available	There is a system malfunction with the pre-collision assist system. The system will be disabled. Contact an authorized dealer as soon as possible.

Remote Start

Message	Action
To Drive: Turn Key to On	A reminder to turn the key on to drive your vehicle after a remote start.
To Drive: Press Brake and Start Button	A reminder to apply the brake and push the gearshift button to drive your vehicle after a remote start.

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PRE-COLLISION ASSIST (IF EQUIPPED)

WARNING: You are responsible for controlling your vehicle at all times. The system is designed to be an aid and does not relieve you of your responsibility to drive with due care and attention. Failure to follow this instruction could result in the loss of control of your vehicle, personal injury or death.

WARNING: The system does not detect vehicles that are driving in a different direction, pedestrians at night, cyclists or animals. Failure to take care may result in the loss of control of your vehicle, serious personal injury or death.

WARNING: The system does not operate during hard acceleration or steering. Failure to take care may lead to a crash or personal injury.

WARNING: The system may fail or operate with reduced function during cold and severe weather conditions. Snow, ice, rain, spray and fog can adversely affect the system. Keep the front camera and radar free of snow and ice. Failure to take care may result in the loss of control of your vehicle, serious personal injury or death.

WARNING: In situations where the vehicle camera has limited detection capability, this may reduce system performance. These situations include but are not limited to direct or low sunlight, vehicles at night without tail lights, unconventional vehicle types, pedestrians with complex backgrounds, running pedestrians, partly obscured pedestrians, or pedestrians that the system cannot distinguish from a group. Failure to take care may result in the loss of control of your vehicle, serious personal injury or death.

WARNING: The system cannot help prevent all crashes. Do not rely on this system to replace driver judgment and the need to maintain a safe distance and speed.

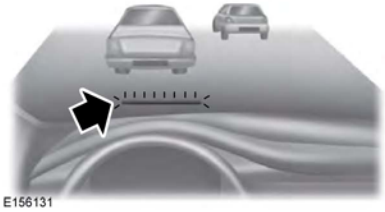
Using the Pre-Collision Assist System

The Pre-Collision Assist system is active at speeds above approximately 3 mph (5 km/h) and pedestrian detection is active at speeds up to 50 mph (80 km/h).

E156130

If your vehicle is rapidly approaching another stationary vehicle, a vehicle traveling in the same direction as yours, or a pedestrian within your driving path, the system design is to provide three levels of functionality:

1. Alert
2. Brake Support
3. Active Braking



E156131

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Alert: When active, the system provides a flashing visual warning and an audible warning sound.

Brake Support: The system design is to help reduce the impact speed by preparing the brakes for rapid braking. The system does not automatically apply the brakes. If you press the brake pedal, the system could apply additional braking up to maximum braking force, even if you lightly press the brake pedal.

Active Braking: Active braking may activate if the system determines that a collision is imminent. The system may help the driver reduce impact damage or avoid the crash completely.

Note: *If you perceive Pre-Collision Assist alerts as being too frequent or disturbing, then you can reduce the alert sensitivity, though the manufacturer recommends using the highest sensitivity setting where possible. Setting lower sensitivity would lead to fewer and later system warnings.*

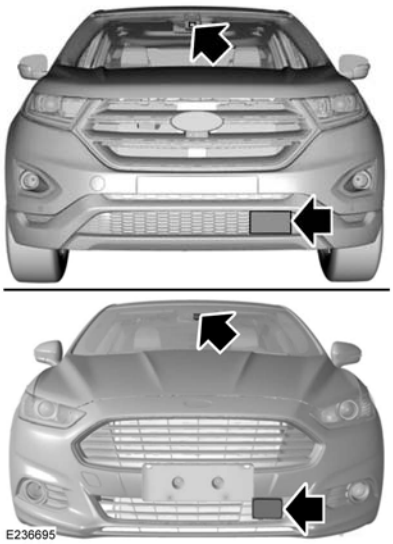
Adjusting Pre-Collision Assist Settings

You can adjust the Alert sensitivity to one of three possible settings by using the information display control. See **General Information** (page 97).

If required, you can switch active braking off using the information display controls. See **General Information** (page 97).

Note: *Active braking automatically turns on every time you switch your vehicle on.*

Blocked Sensors



If a message regarding a blocked sensor or camera appears in the information display, the radar signals or camera images are obstructed. The radar sensor is located behind a fascia cover near the driver side of the lower grille. With an obstructed radar, the Pre-Collision Assist system does not function and cannot detect a vehicle ahead. With the front camera obstructed, the Pre-Collision Assist system does not respond to pedestrians or stationary vehicles and the system performance on moving vehicles reduces. The following table lists possible causes and actions for when this message displays.

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Cause	Action
The surface of the radar in the grille is dirty or obstructed in some way.	Clean the grille surface in front of the radar or remove the object causing the obstruction.
The surface of the radar in the grille is clean but the message remains in the display.	Wait a short time. It may take several minutes for the radar to detect that there is no obstruction.
Heavy rain, spray, snow, or fog is interfering with the radar signals.	The Pre-Collision Assist system is temporarily disabled. Pre-Collision Assist should automatically reactivate a short time after the weather conditions improve.
Swirling water, or snow or ice on the surface of the road may interfere with the radar signals.	The Pre-Collision Assist system is temporarily disabled. Pre-Collision Assist should automatically reactivate a short time after the weather conditions improve.
Radar is out of alignment due to a front end impact.	Contact an authorized dealer to have the radar checked for proper coverage and operation.
The windshield in front of the camera is dirty or obstructed in some way.	Clean the outside of the windshield in front of the camera.
The windshield in front of the camera is clean but the message remains in the display.	Wait a short time. It may take several minutes for the camera to detect that there is no obstruction.

Note: *Proper system operation requires a clear view of the road by the camera. Have any windshield damage in the area of the camera's field of view repaired.*

Note: *If something hits the front end of your vehicle or damage occurs, the radar sensing zone may change. This could cause missed or false vehicle detections. Contact an authorized dealer to have the radar checked for proper coverage and operation.*

Note: *If your vehicle detects excessive heat at the camera or a potential misalignment condition, a message may display in the information display indicating temporary sensor unavailability. This message deactivates automatically when operational conditions are correct. For example, when the ambient temperature around the sensor decreases or the sensor automatically recalibrates successfully.*

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APPENDIX C

Run Log

Subject Vehicle: **2019 Ford Fusion** Test Date: 3/27/2019

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
1-9	**Brake characterization and confirmation**						See Appendix D
10	Static Run						
11	**Stopped POV**	Y	1.97	17.26	1.09	Pass	
12		Y	1.96	16.29	1.03	Pass	
13		Y	1.91	16.64	1.01	Pass	
14		N					Brake Force
15		Y	1.92	16.92	1.04	Pass	
16		Y	1.98	15.29	1.06	Pass	
17		Y	1.92	16.41	0.99	Pass	
18		Y	1.93	15.31	1.02	Pass	
19	Static Run						
20	**Slower POV, 25 vs 10**	Y	1.80	8.74	0.95	Pass	
21		Y	1.75	8.57	0.91	Pass	

Subject Vehicle: **2019 Ford Fusion** Test Date: 3/27/2019

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
22		Y	1.72	9.30	0.90	Pass	
23		Y	1.79	9.01	0.90	Pass	
24		Y	1.78	8.24	0.91	Pass	
25		Y	1.69	8.86	0.93	Pass	
26		Y	1.80	9.29	0.94	Pass	
27	Static run						
28	**Slower POV, 45 vs 20**	Y	2.14	13.30	1.10	Pass	
29		Y	2.12	13.83	1.04	Pass	
30		Y	2.13	13.12	1.02	Pass	
31		Y	2.14	12.76	1.03	Pass	
32		Y	2.08	13.43	1.05	Pass	
33		Y	2.20	12.89	1.04	Pass	
34		N					Driver Braking
35		Y	2.12	12.89	1.08	Pass	

Subject Vehicle: **2019 Ford Fusion** Test Date: 3/27/2019

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
36	Static run						
37	**Braking POV, 35**	Y	1.69	1.39	0.83	Pass	
38		N					POV Braking
39		Y	1.93	0.79	0.78	Pass	
40		Y	1.79	1.45	0.83	Pass	
41		N					POV Braking
42		Y	1.83	1.21	0.81	Pass	
43		N					POV Braking
44		Y	1.84	1.44	0.83	Pass	
45		Y	2.10	6.87	0.63	Pass	
46		Y	1.75	1.10	0.83	Pass	
47	Static run						
48	STP - Static run						

Subject Vehicle: **2019 Ford Fusion** Test Date: 3/27/2019

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
49	**Baseline, 25**	Y			0.40		
50		Y			0.41		
51		Y			0.45		
52		Y			0.43		
53		Y			0.45		
54		Y			0.44		
55		Y			0.43		
56	STP - Static run						
57	**Baseline, 45**	Y			0.41		
58		Y			0.42		
59		Y			0.42		
60		Y			0.42		
61		Y			0.46		
62		Y			0.42		
63		Y			0.43		

Subject Vehicle: **2019 Ford Fusion** Test Date: 3/27/2019

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
64	STP - Static run						
65	**STP False Positive, 25**	Y			0.41	Pass	
66		Y			0.41	Pass	
67		Y			0.40	Pass	
68		N					Low Braking
69		Y			0.45	Pass	
70		Y			0.46	Pass	
71		Y			0.46	Pass	
72		Y			0.43	Pass	
73	STP - Static run						
74	**STP False Positive, 45**	N					Low Braking
75		Y			0.40	Pass	
76		Y			0.44	Pass	

Subject Vehicle: **2019 Ford Fusion** Test Date: 3/27/2019

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
77		Y			0.42	Pass	
78		Y			0.42	Pass	
79		Y			0.43	Pass	
80		Y			0.41	Pass	
81		Y			0.43	Pass	
82	STP - Static run						

APPENDIX D

Brake Characterization

Subject Vehicle: **2019 Ford Fusion** Test Date: 3/27/2019

DBS Initial Brake Characterization				
Run Number	**Stroke at 0.4 g (in)**	**Force at 0.4 g (lb)**	**Slope**	**Intercept**
1	1.595405	19.75373	1.123374	0.078733
2	1.528812	18.78187	0.977713	0.246171
3	1.541197	19.15685	1.006499	0.152299

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	0.475	1.56		1.31	Brake Rate
5			N	0.368	1.40		1.52	Brake Rate
6			N	0.425	1.47		1.38	Brake Rate
7			Y	0.394	1.43		1.45	
8		25	Y	0.411	1.43		1.39	
9		45	Y	0.407	1.43		1.41	

Appendix E

TIME HISTORY PLOTS

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Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from both the Subject Vehicle (SV) and the Principal Other Vehicle (POV), as well as pass/fail envelopes and thresholds. 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 (in) – Position of the accelerator pedal and brake pedal.

- 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 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 plot indicating the Ax, 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). A green circle or red asterisk is displayed at the moment the POV brake level achieves 0.27g. A green circle indicates that the test was valid (the threshold was crossed during the appropriate interval) and a red asterisk indicates that the test was invalid (the threshold was crossed out of the appropriate interval).

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

For the brake force plot, a dashed black threshold line indicating a brake force of 2.5 lbs is given. 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.

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

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 E13 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.

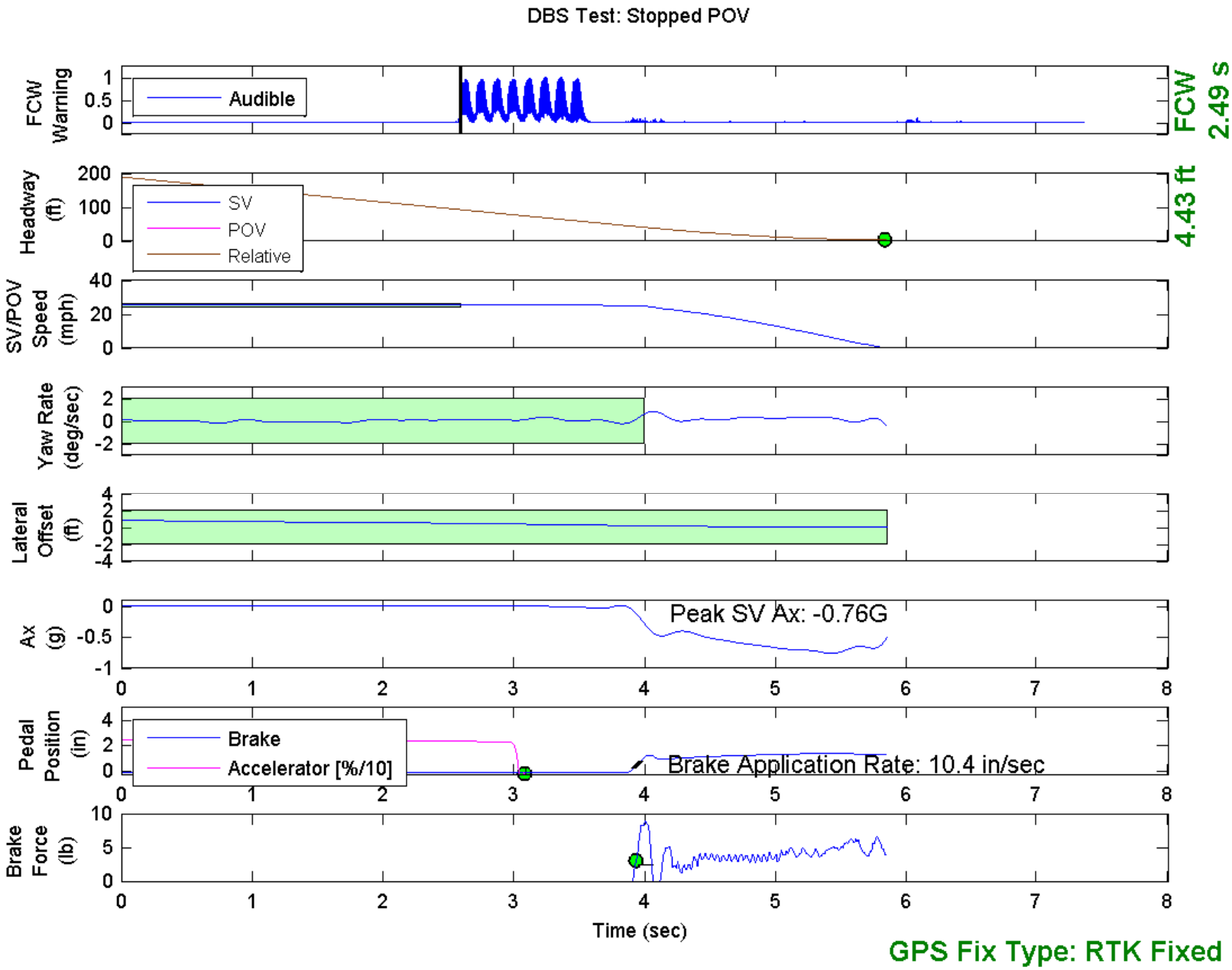

Figure E1. Example Time History for Stopped POV, Passing

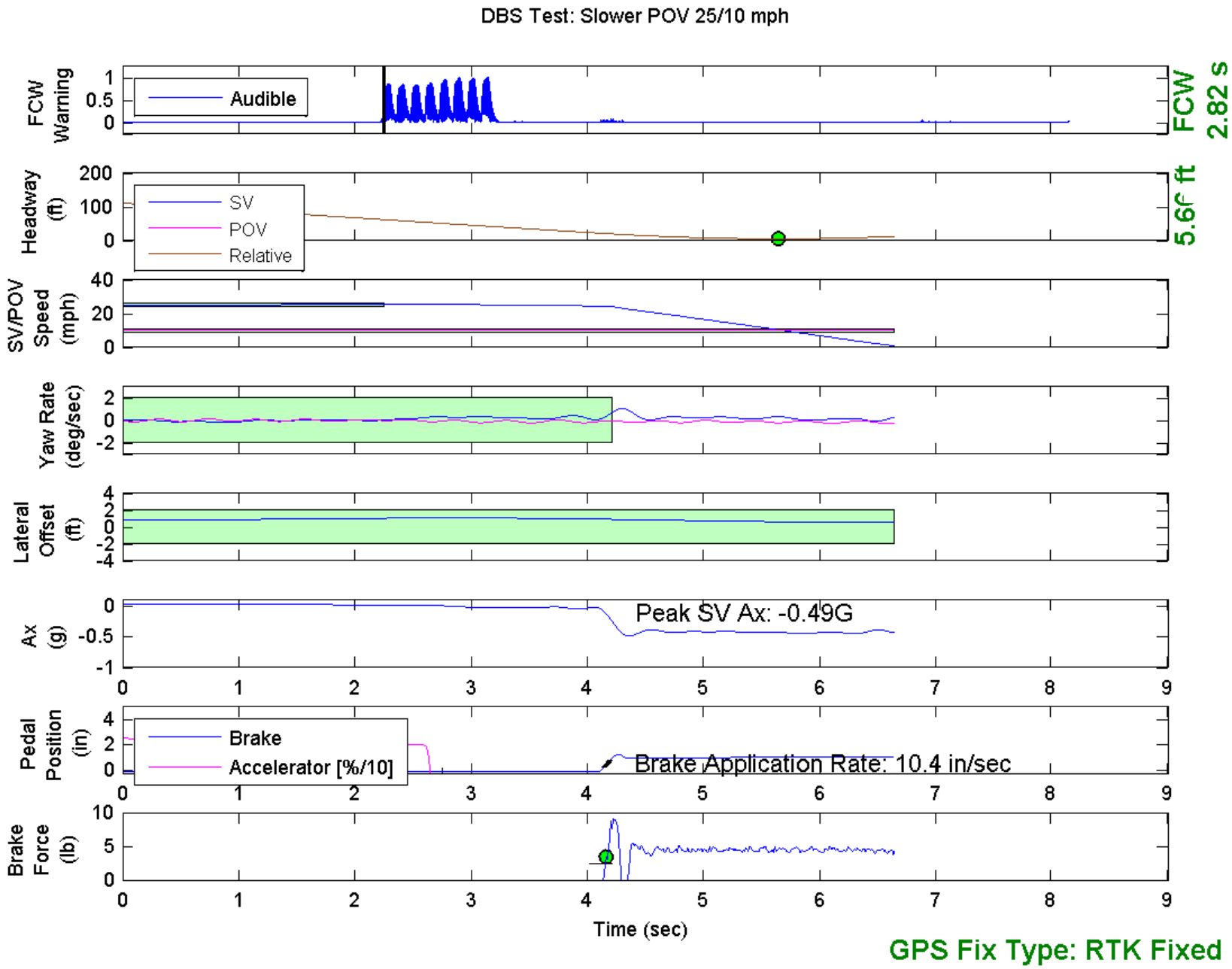

Figure E2. Example Time History for Slower POV 25 vs. 10, Passing

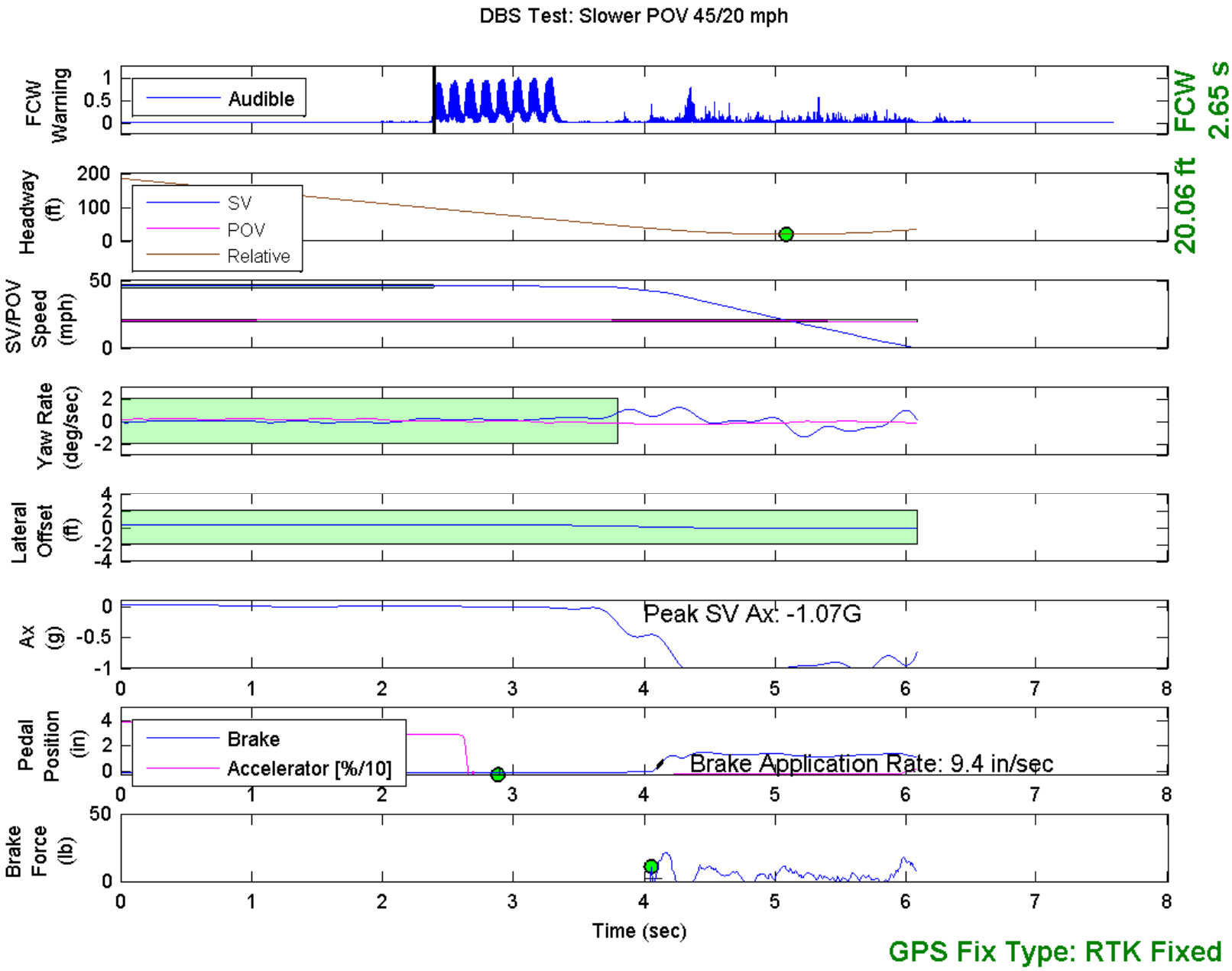

Figure E3. Example Time History for Slower POV 45 vs. 20, Passing

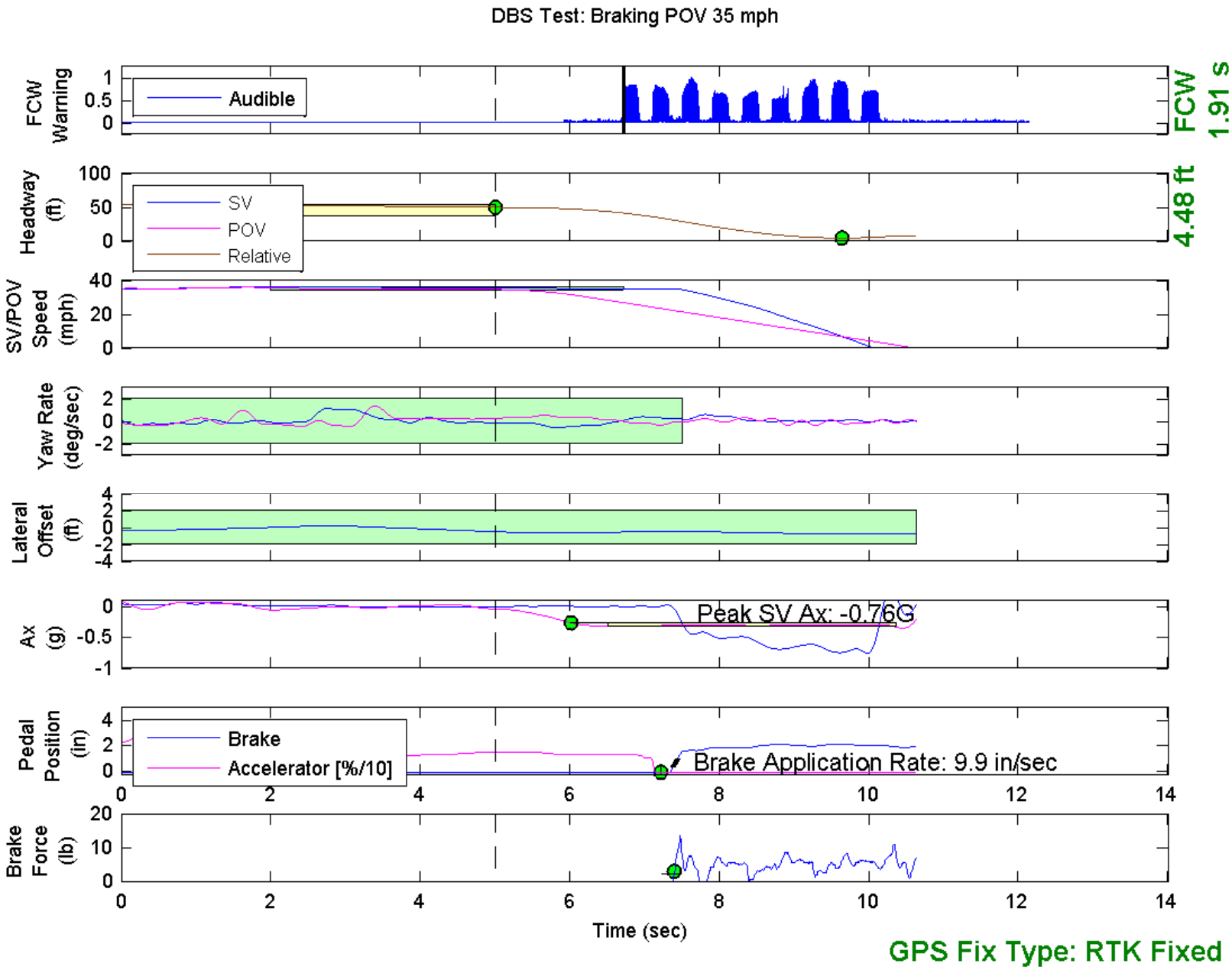

Figure E4. Example Time History for Braking POV 35, Passing

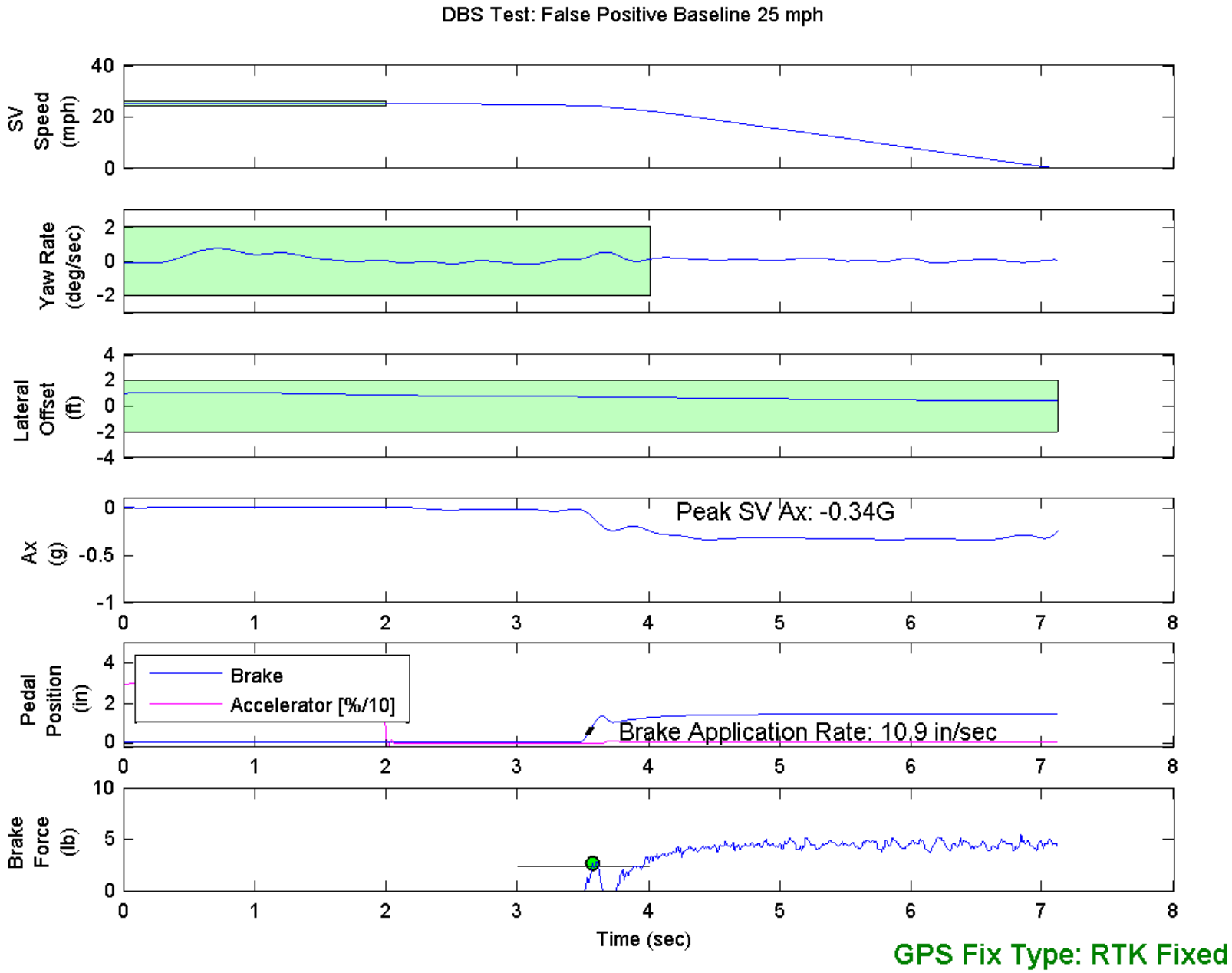

Figure E5. Example Time History for False Positive Baseline 25, Passing

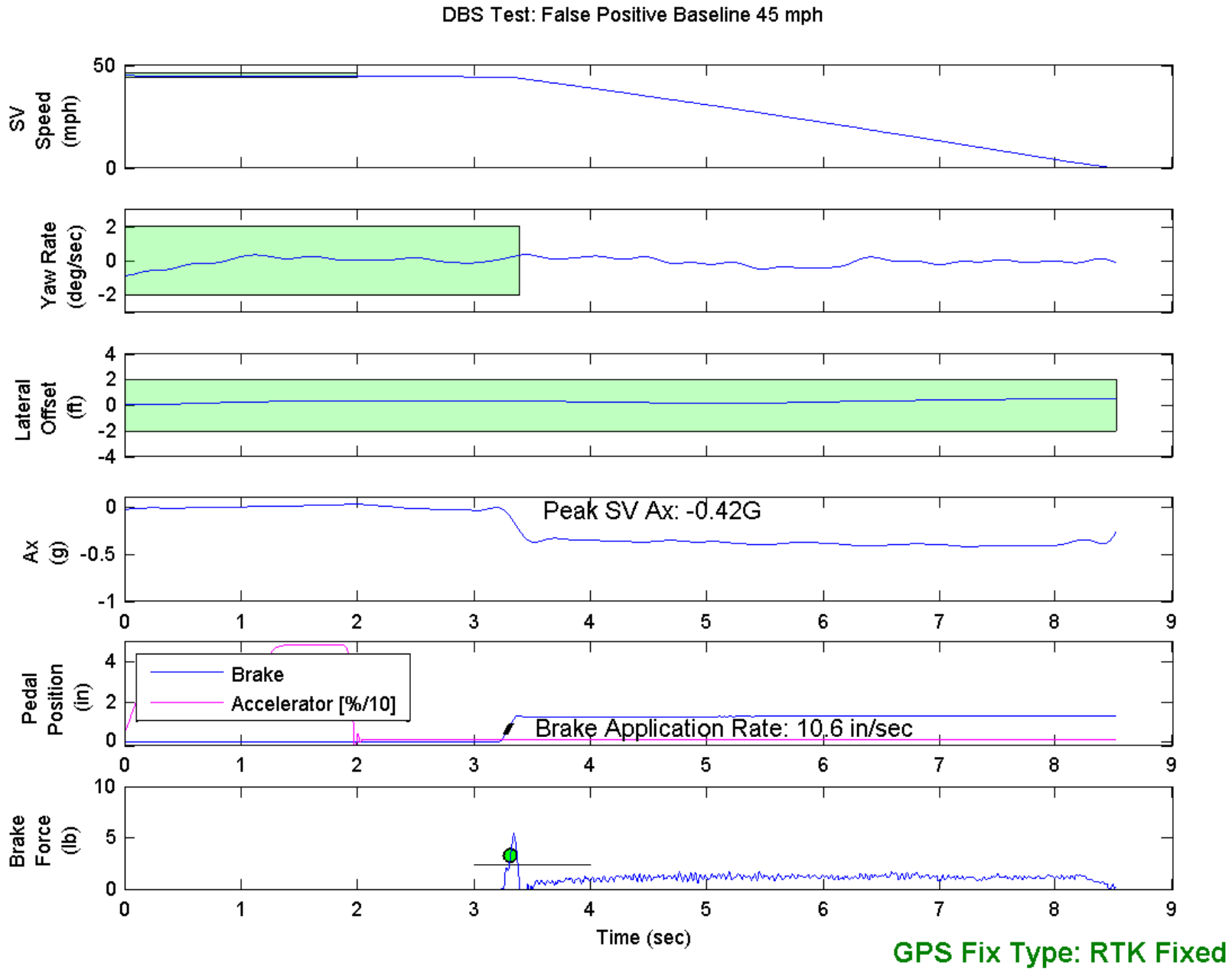

Figure E6. Example Time History for False Positive Baseline 45, Passing

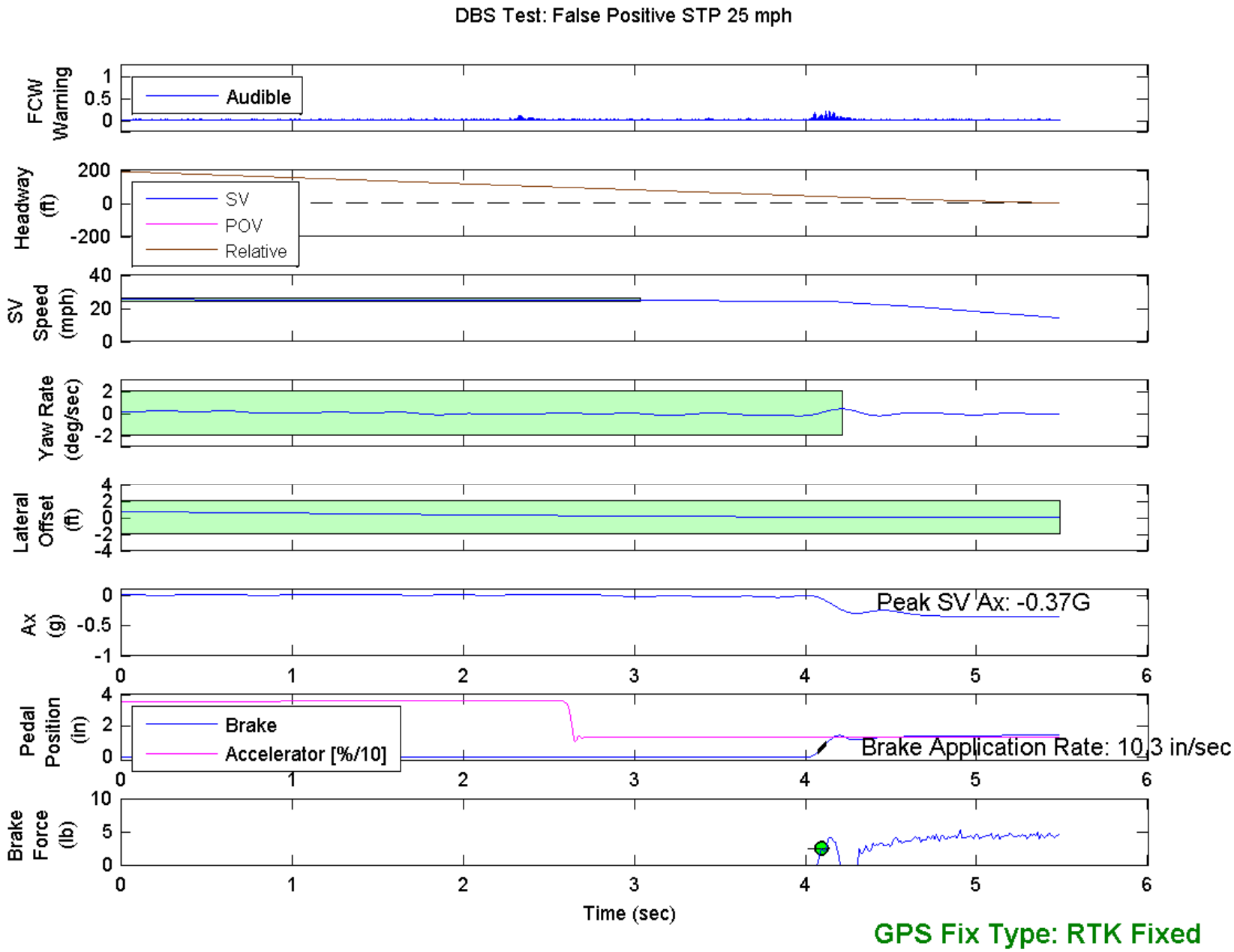

Figure E7. Example Time History for False Positive Steel Plate 25, Passing

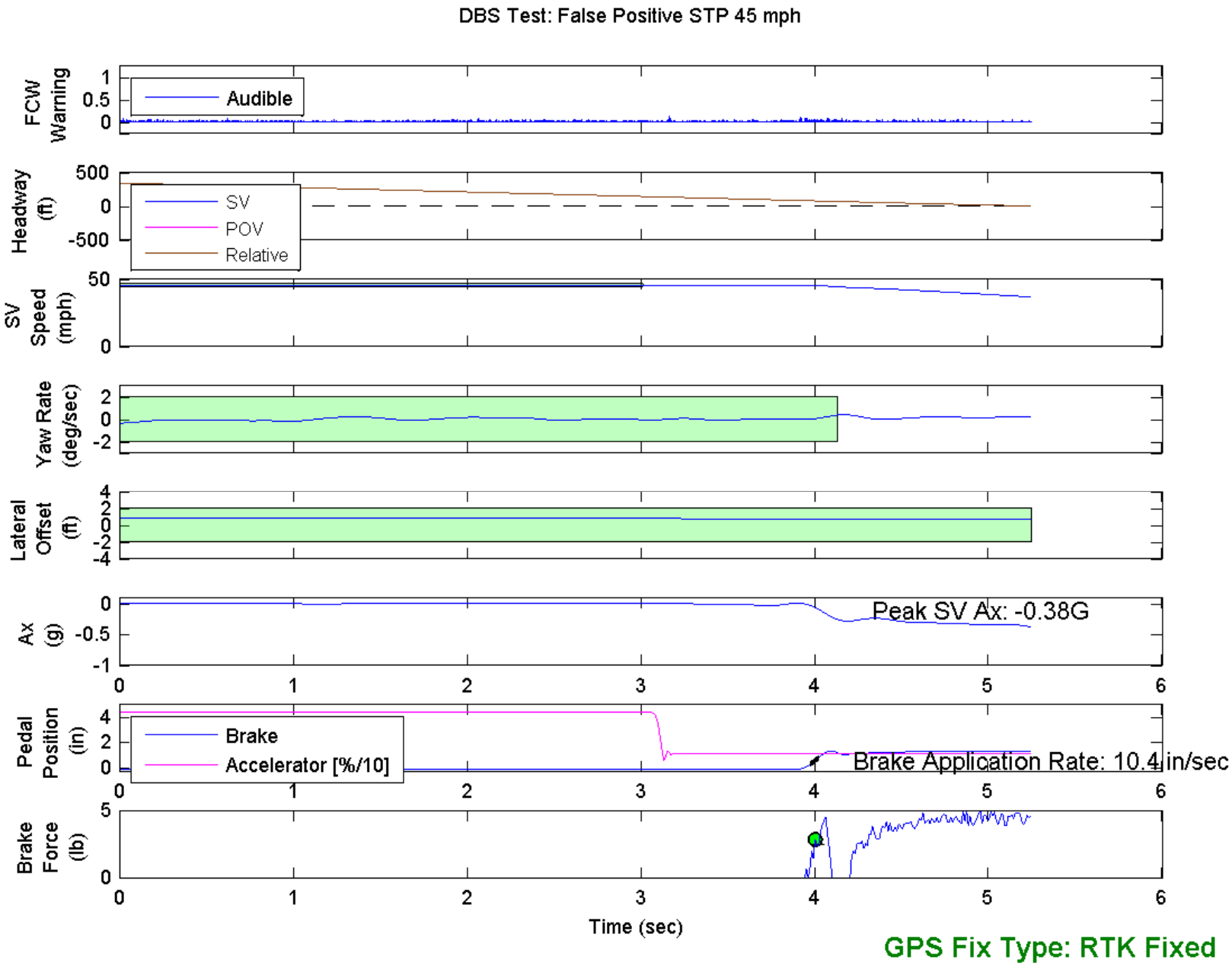

Figure E8. Example Time History for False Positive Steel Plate 45, Passing

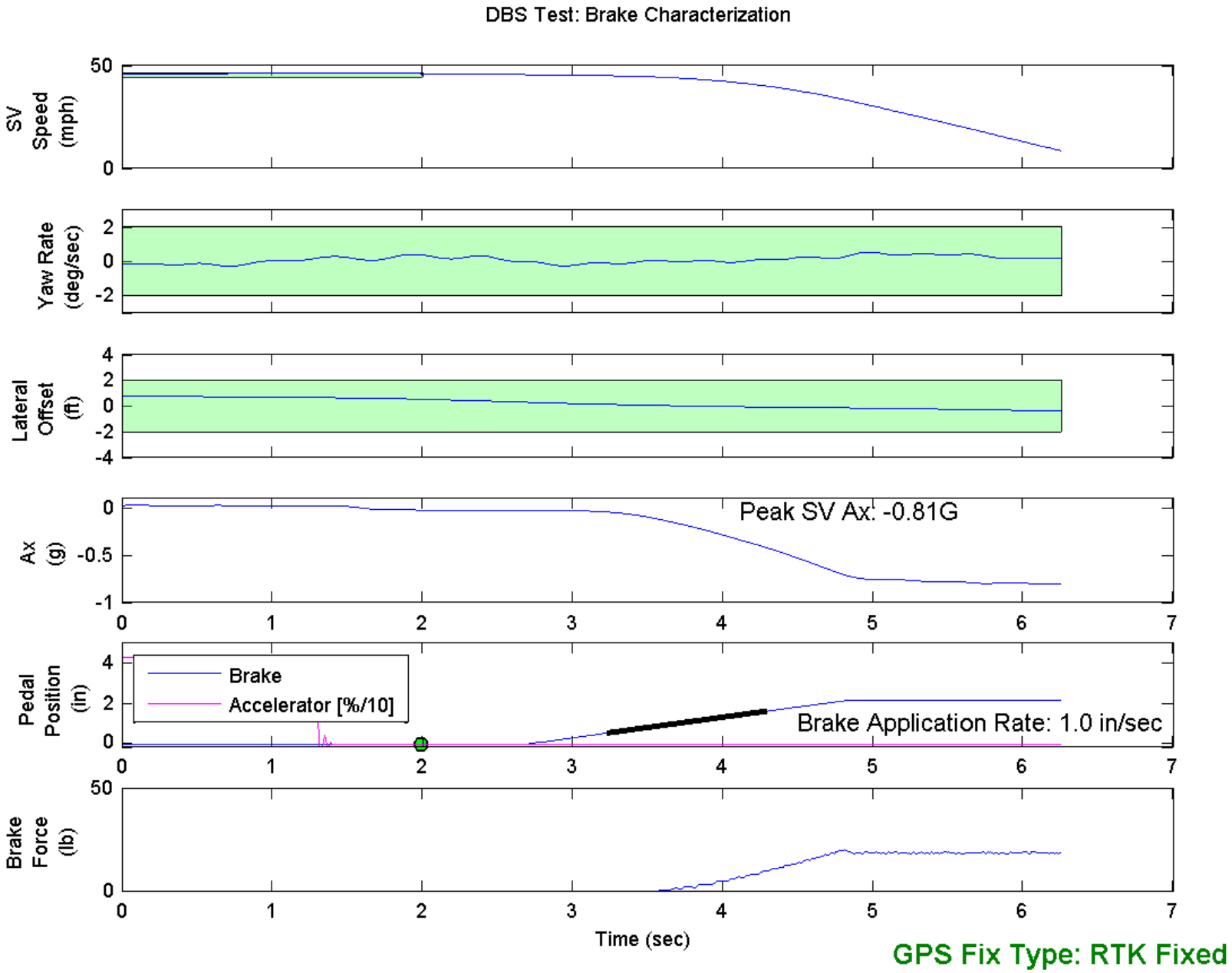

Figure E9. Example Time History for DBS Brake Characterization, Passing

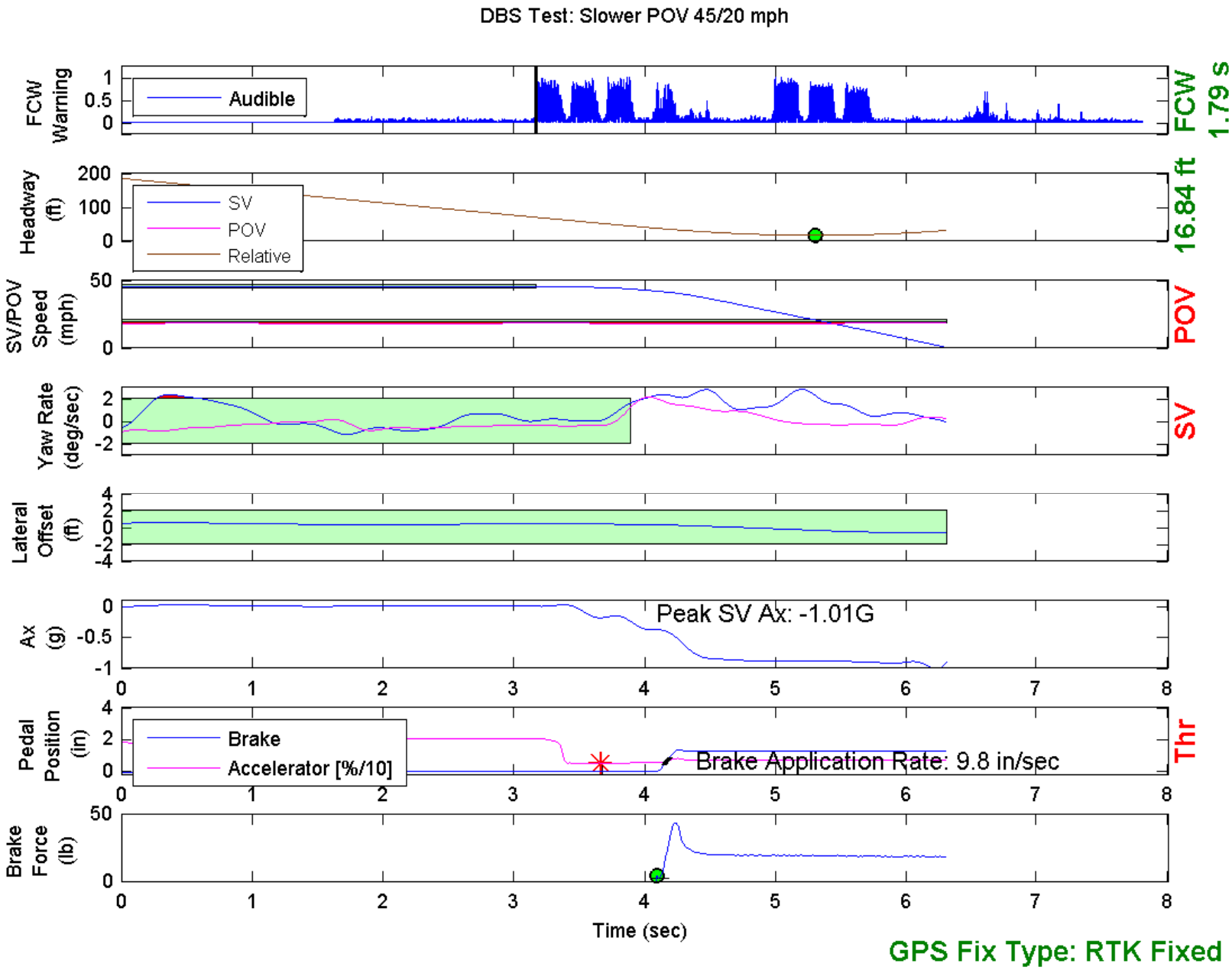

Figure E10. Example Time History Displaying Various Invalid Criteria

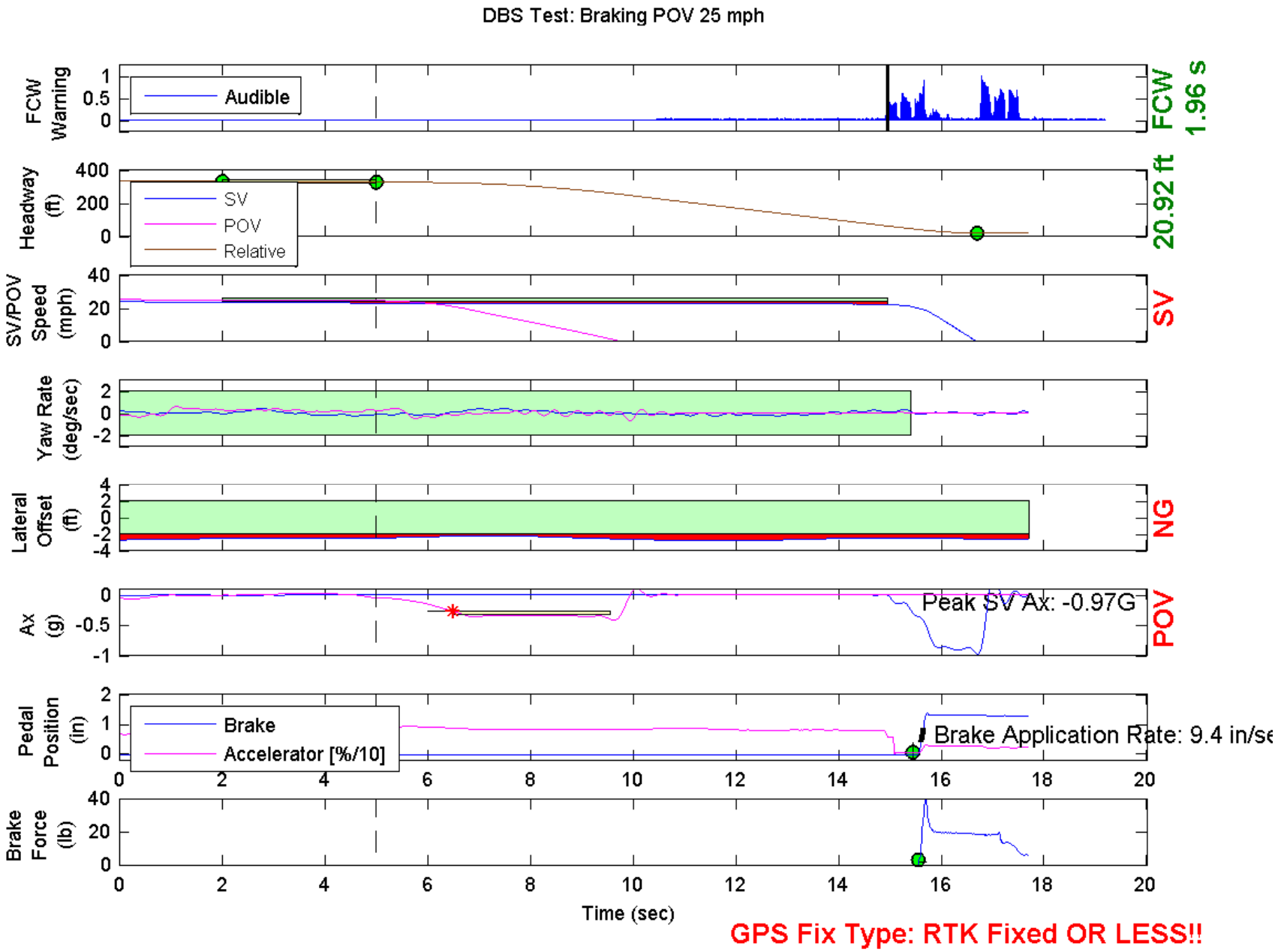

Figure E11. Example Time History Displaying Various Invalid Criteria

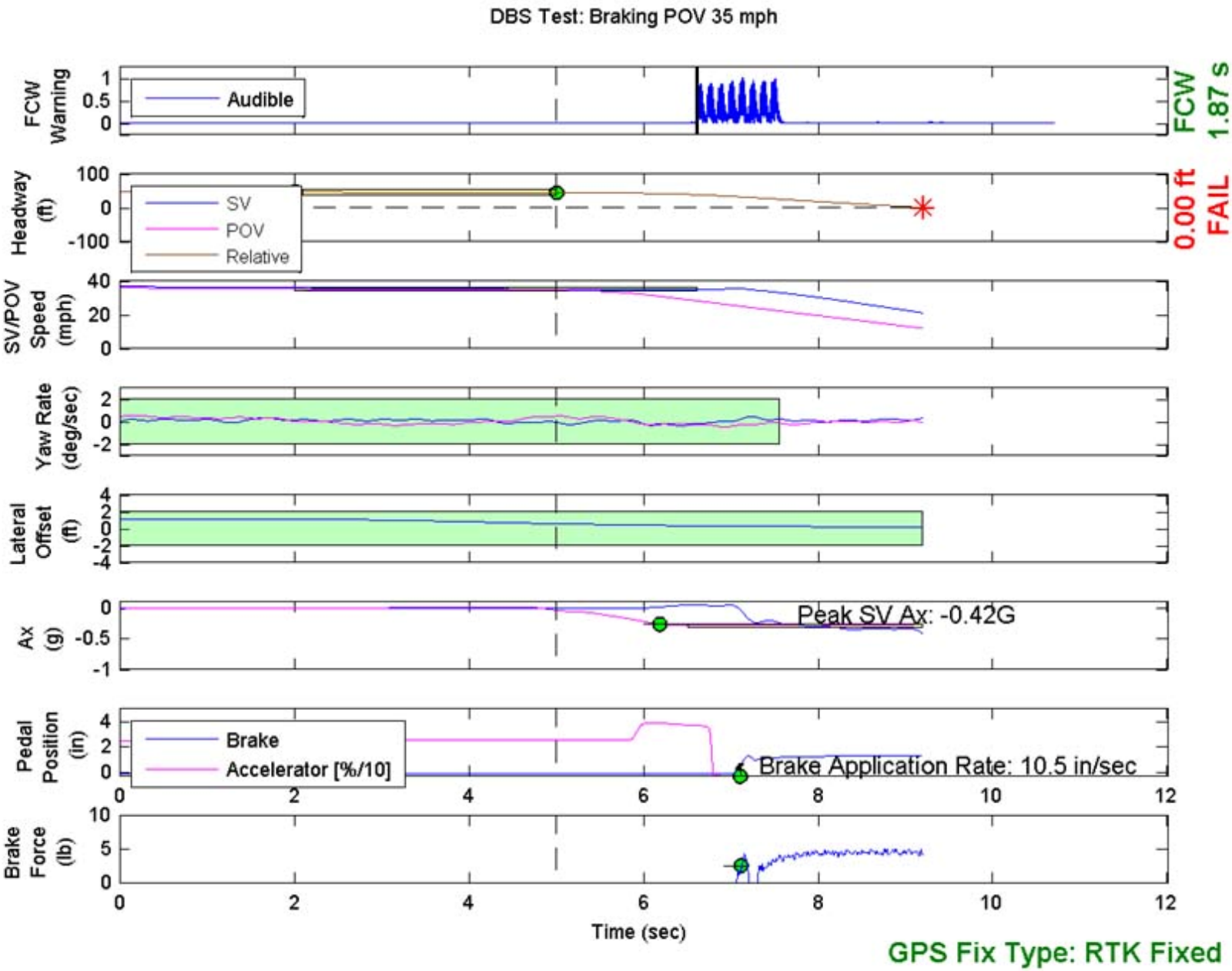

Figure E12. Example Time History for a Failed Run

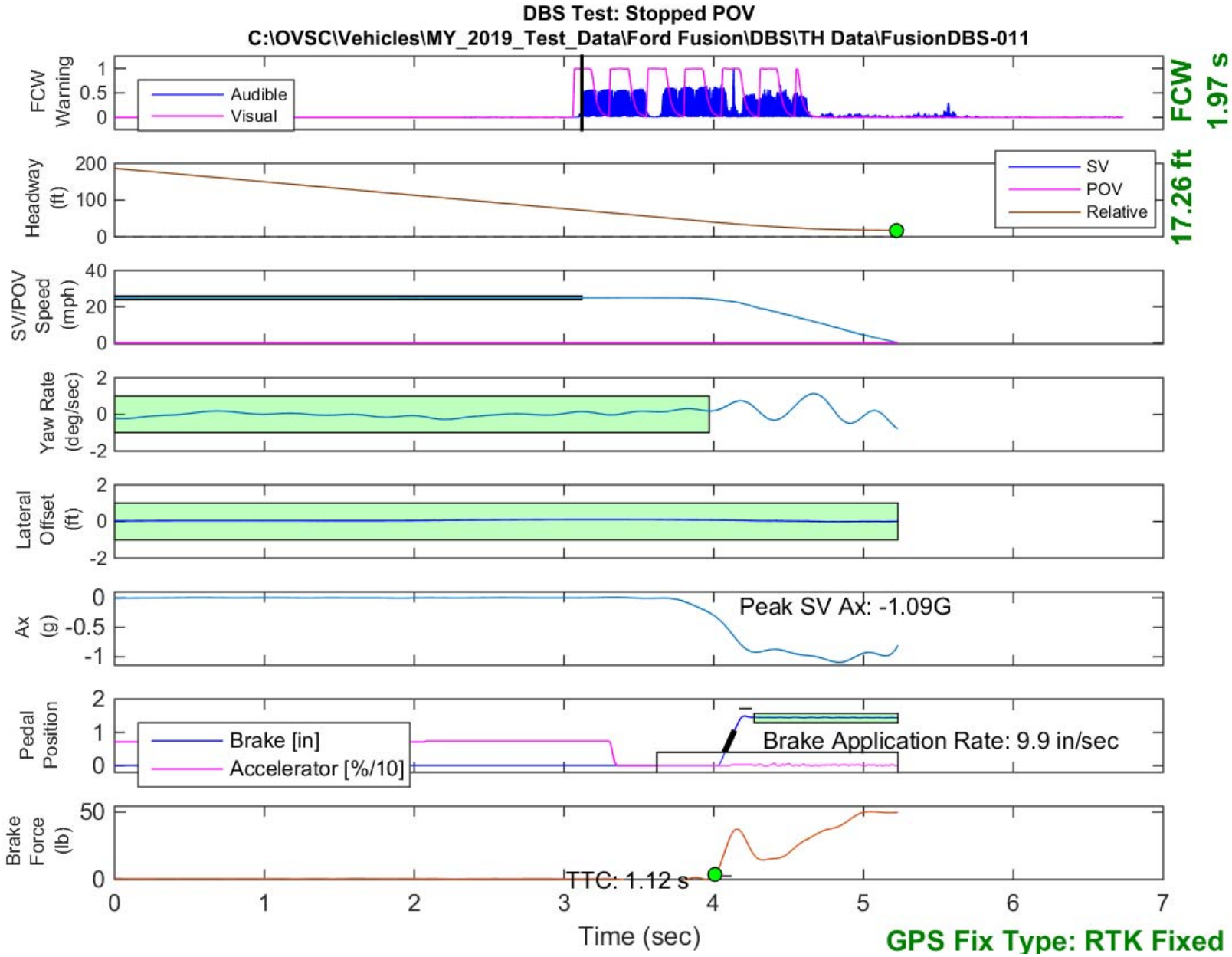

Figure E13. Time History for DBS Run 11, SV Encounters Stopped POV

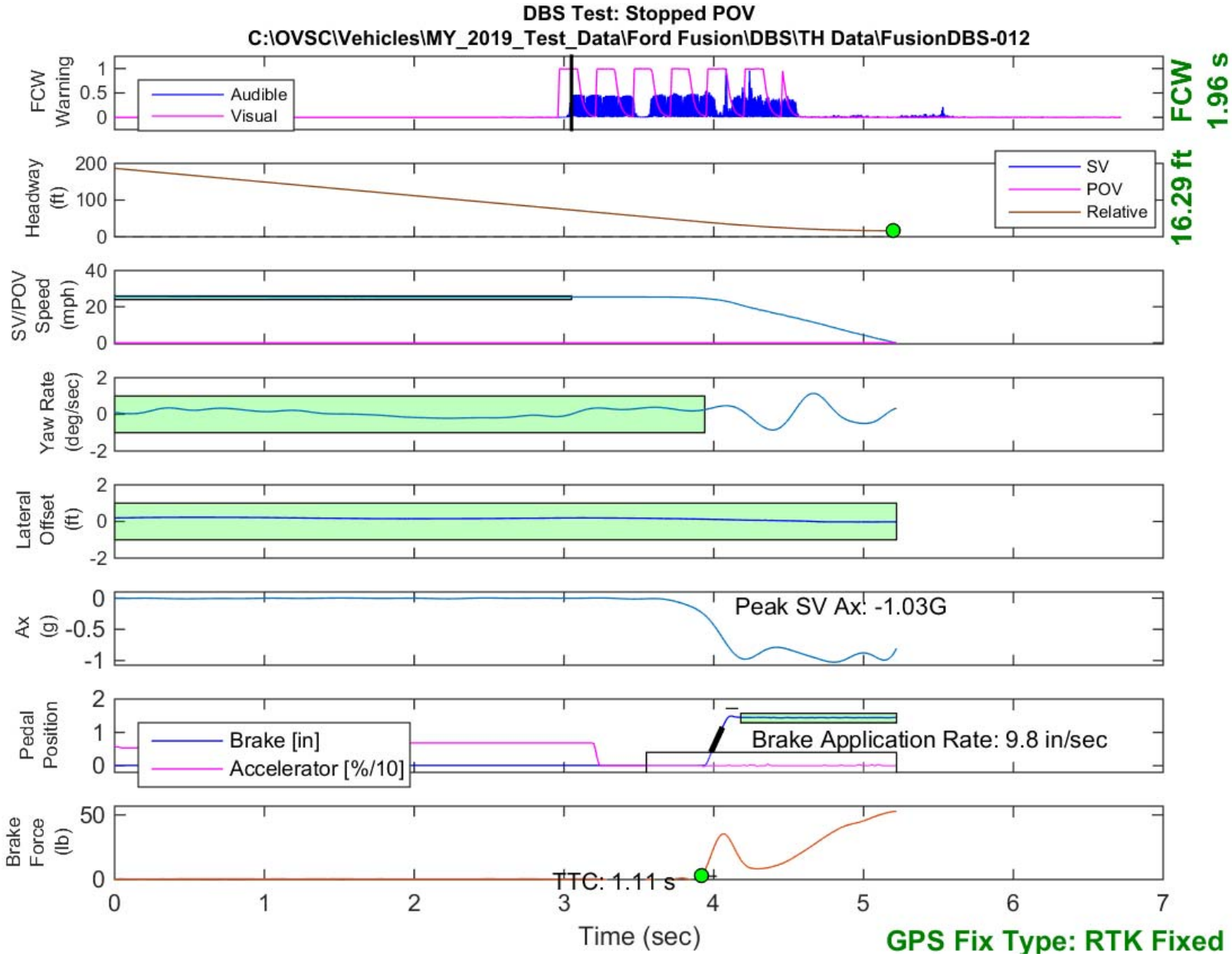

Figure E14. Time History for DBS Run 12, SV Encounters Stopped POV

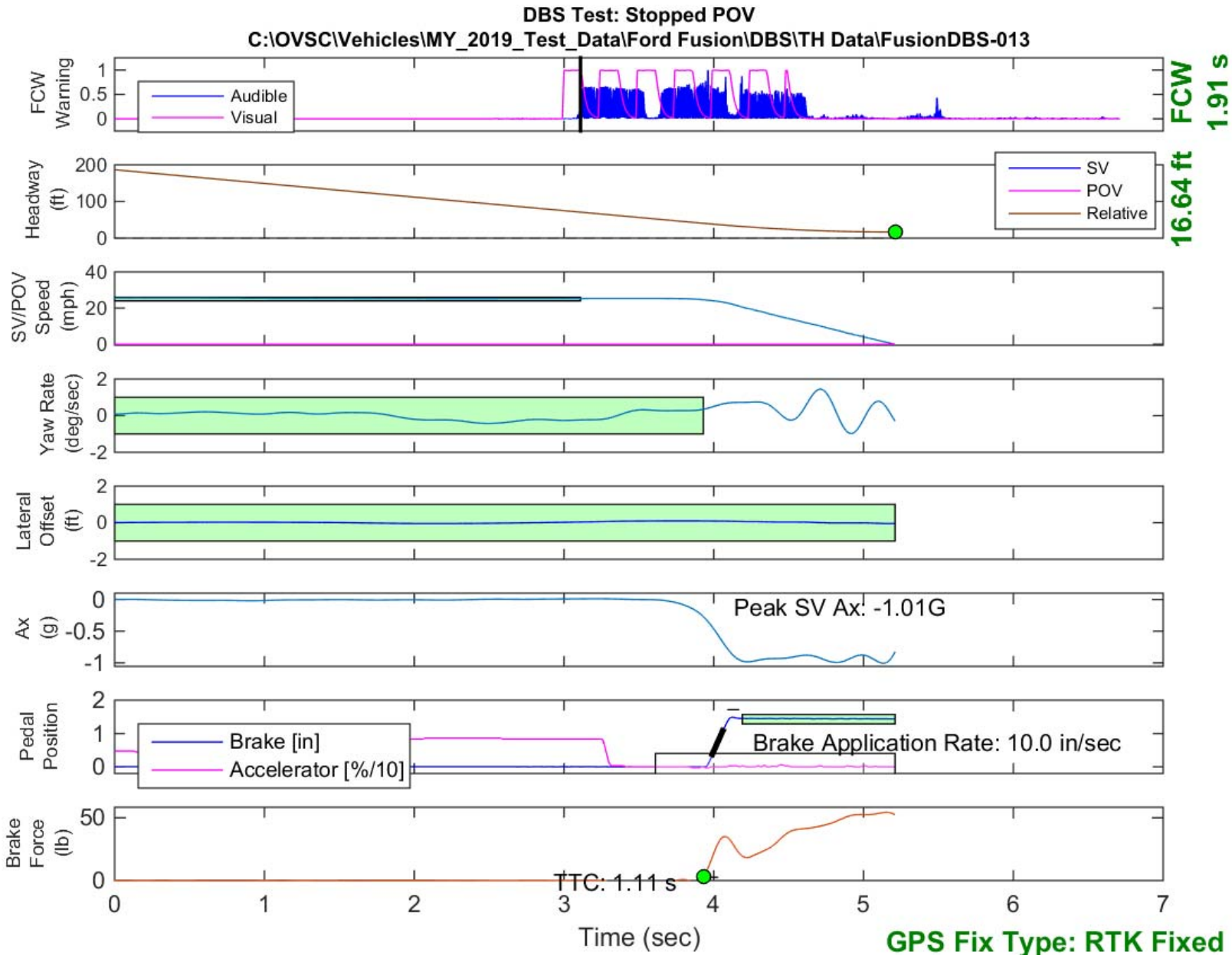

Figure E15. Time History for DBS Run 13, SV Encounters Stopped POV

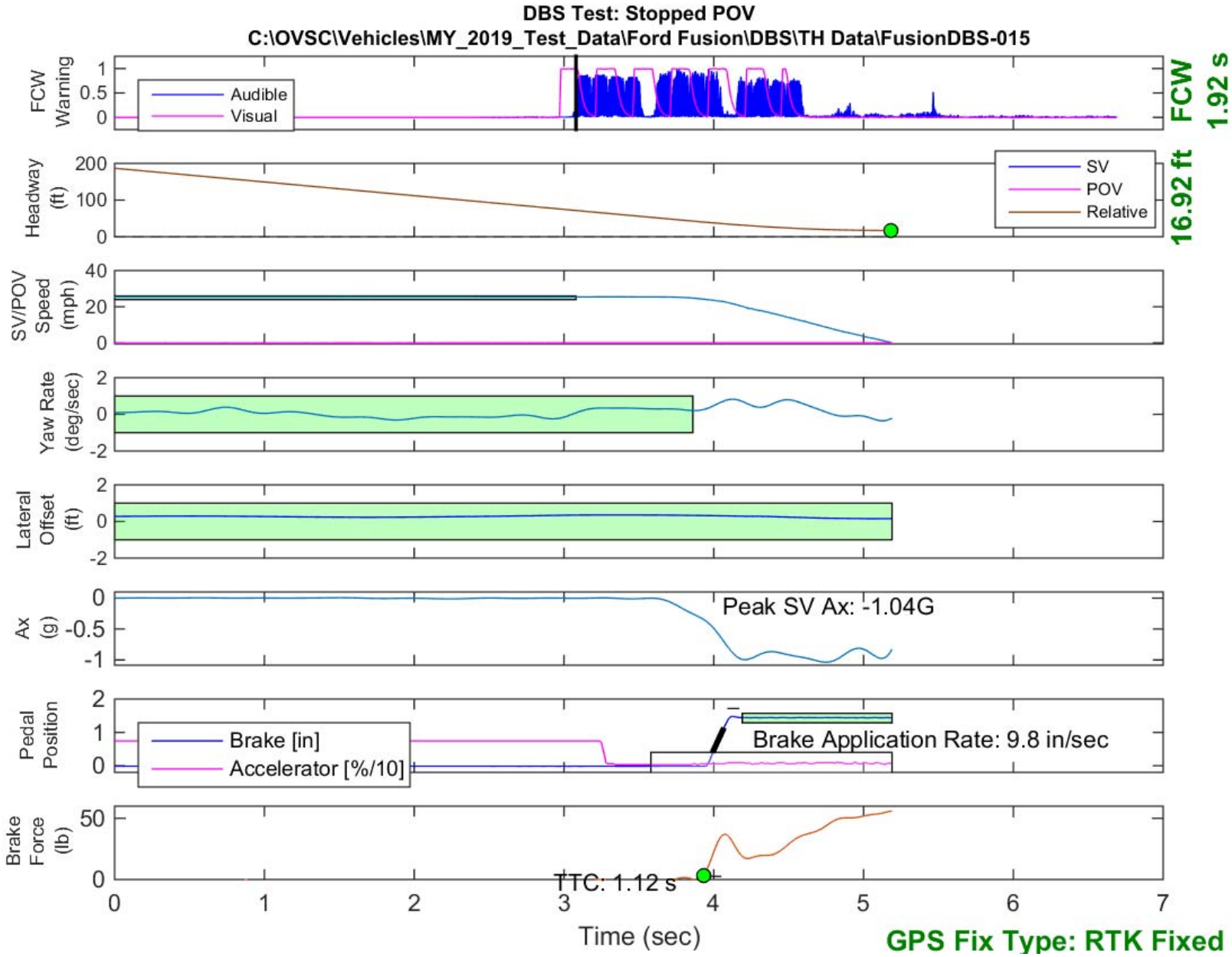

Figure E16. Time History for DBS Run 15, SV Encounters Stopped POV

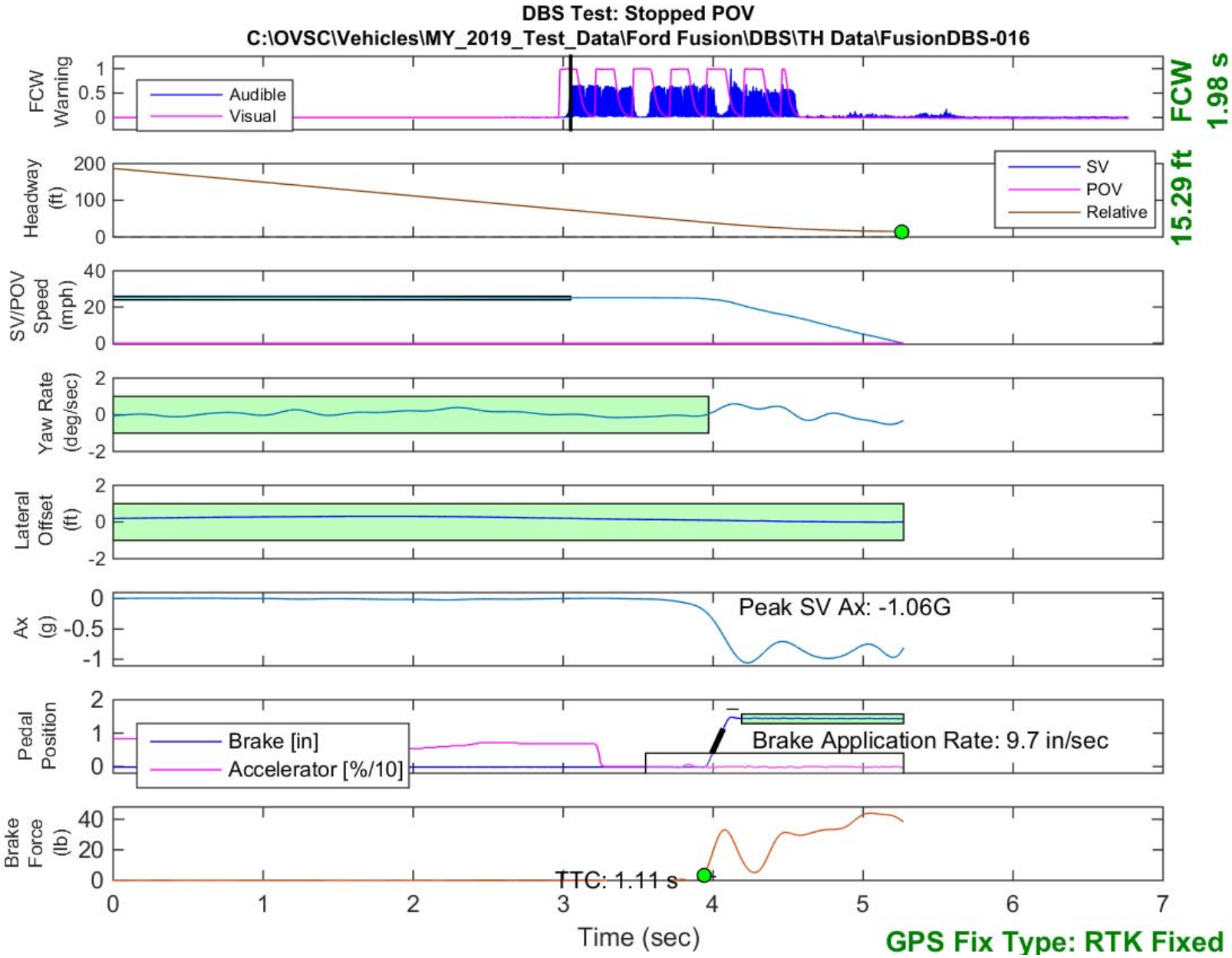

Figure E17. Time History for DBS Run 16, SV Encounters Stopped POV

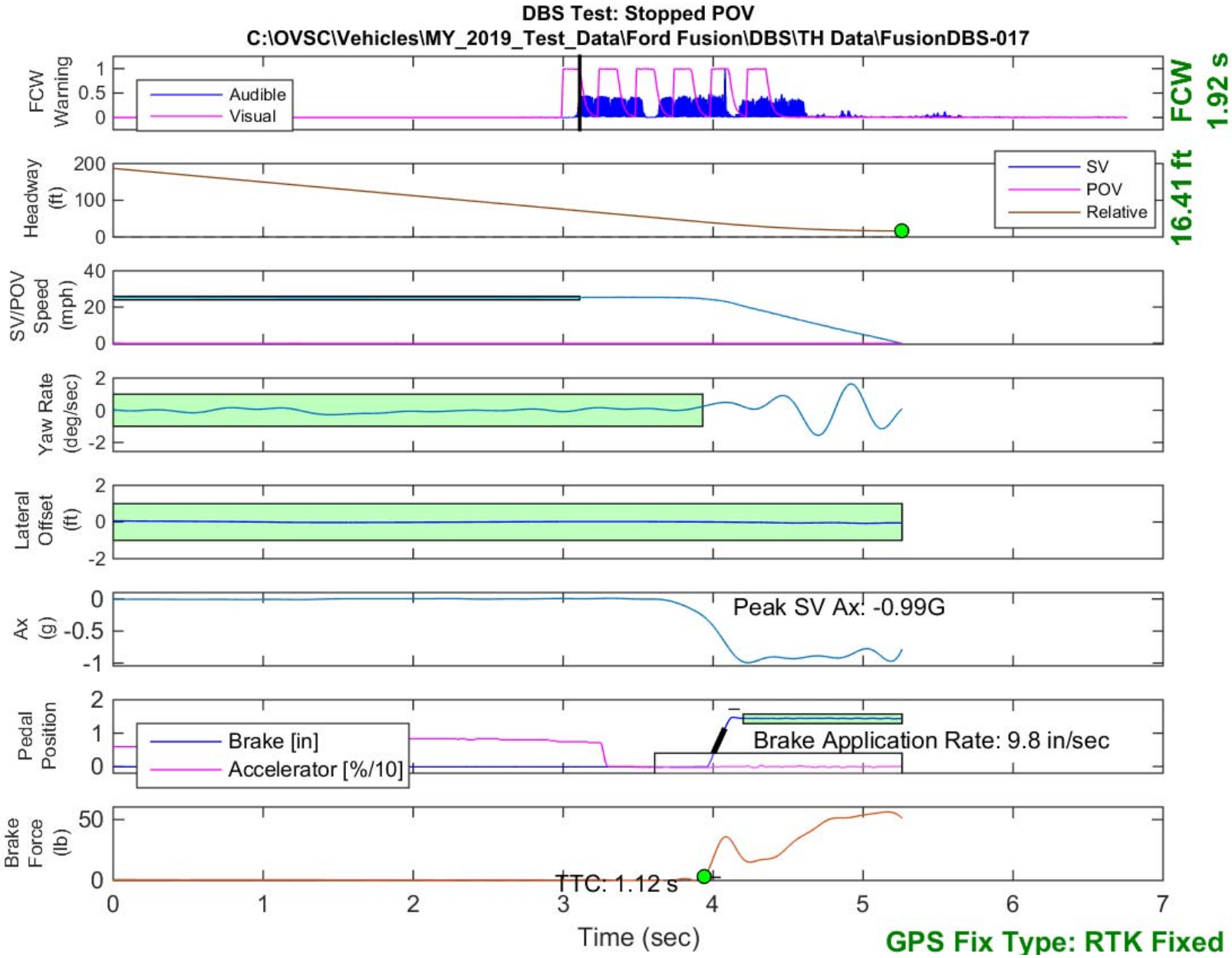

Figure E18. Time History for DBS Run 17, SV Encounters Stopped POV

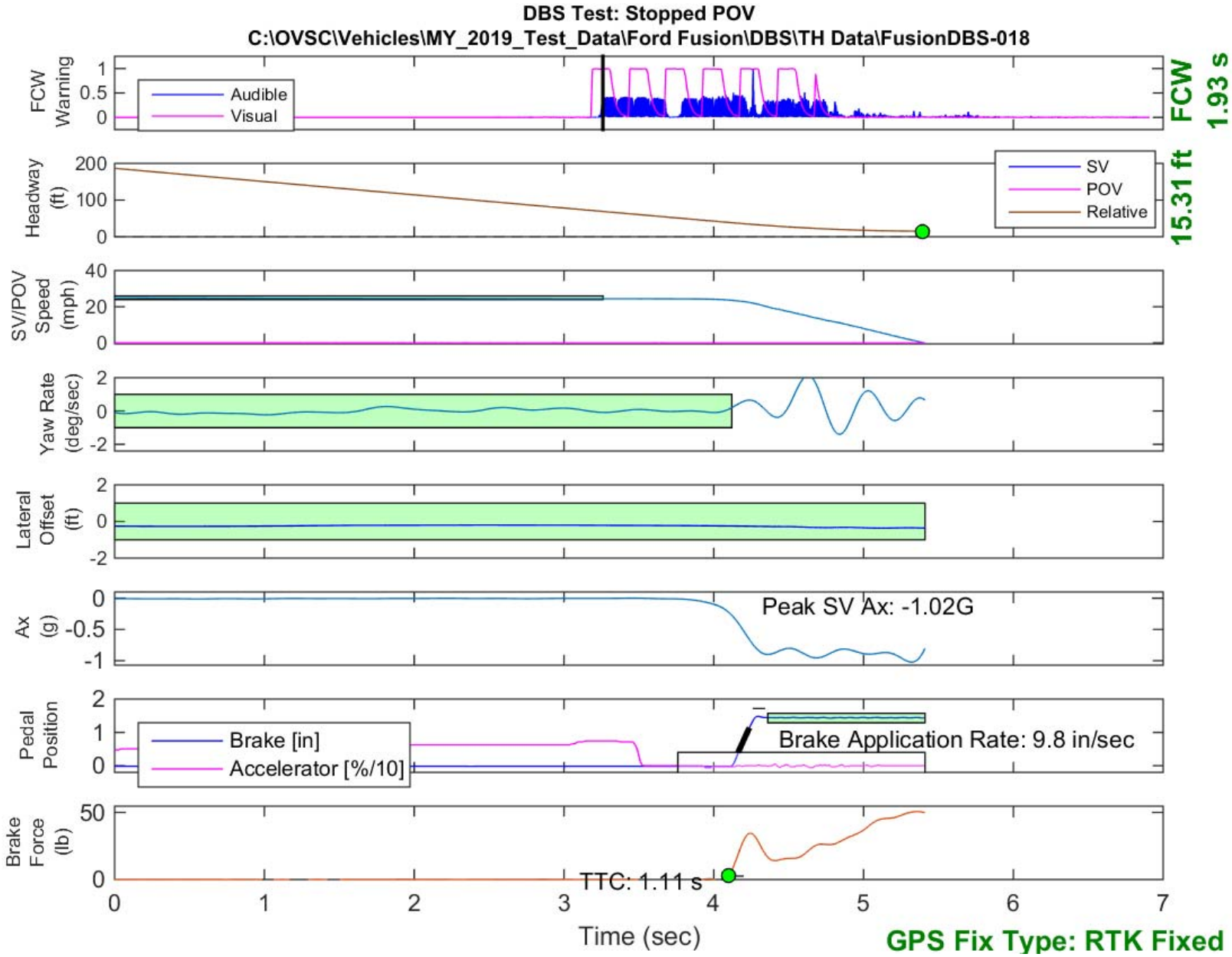

Figure E19. Time History for DBS Run 18, SV Encounters Stopped POV

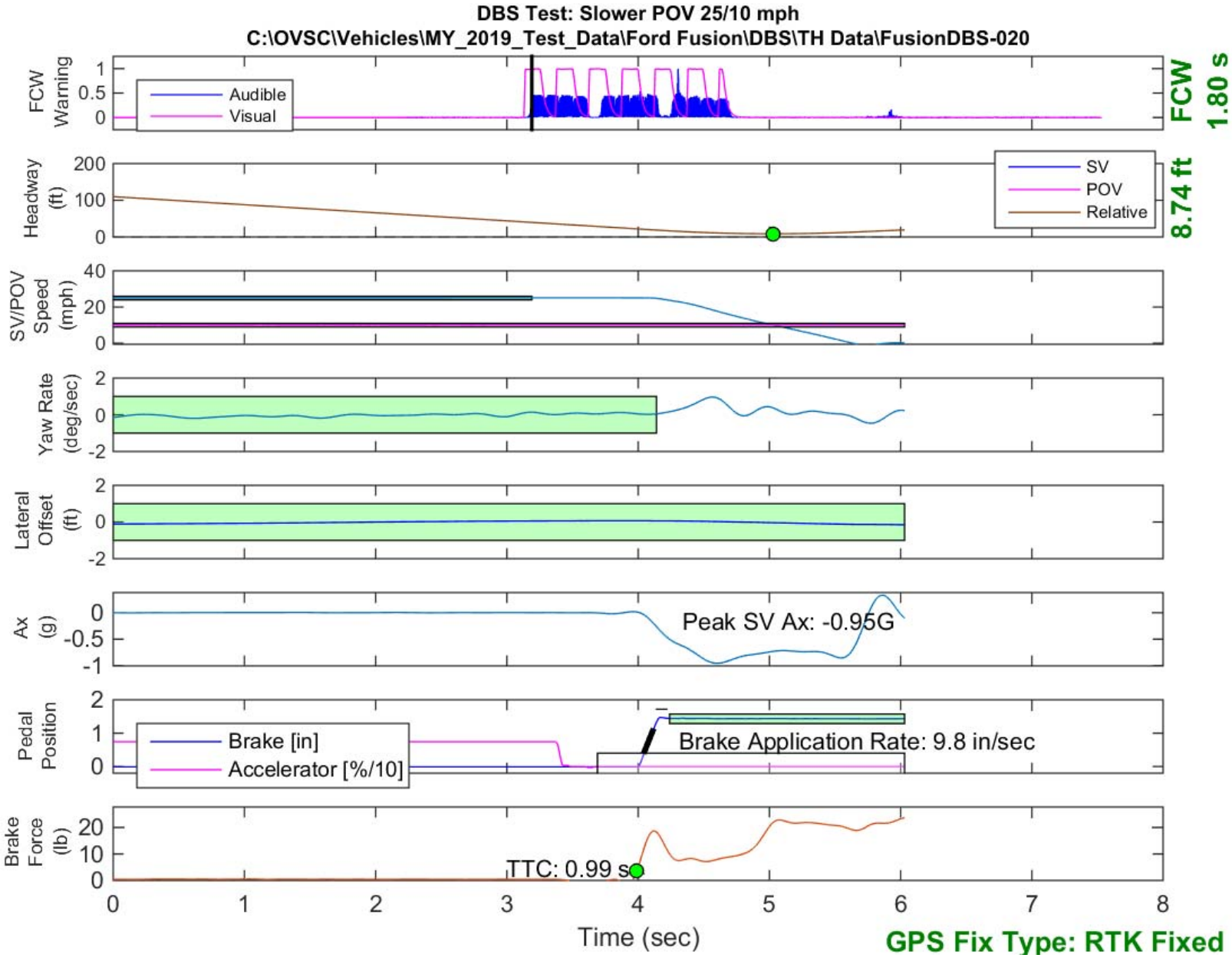

Figure E20. Time History for DBS Run 20, SV Encounters Slower POV, SV 25 mph, POV 10 mph

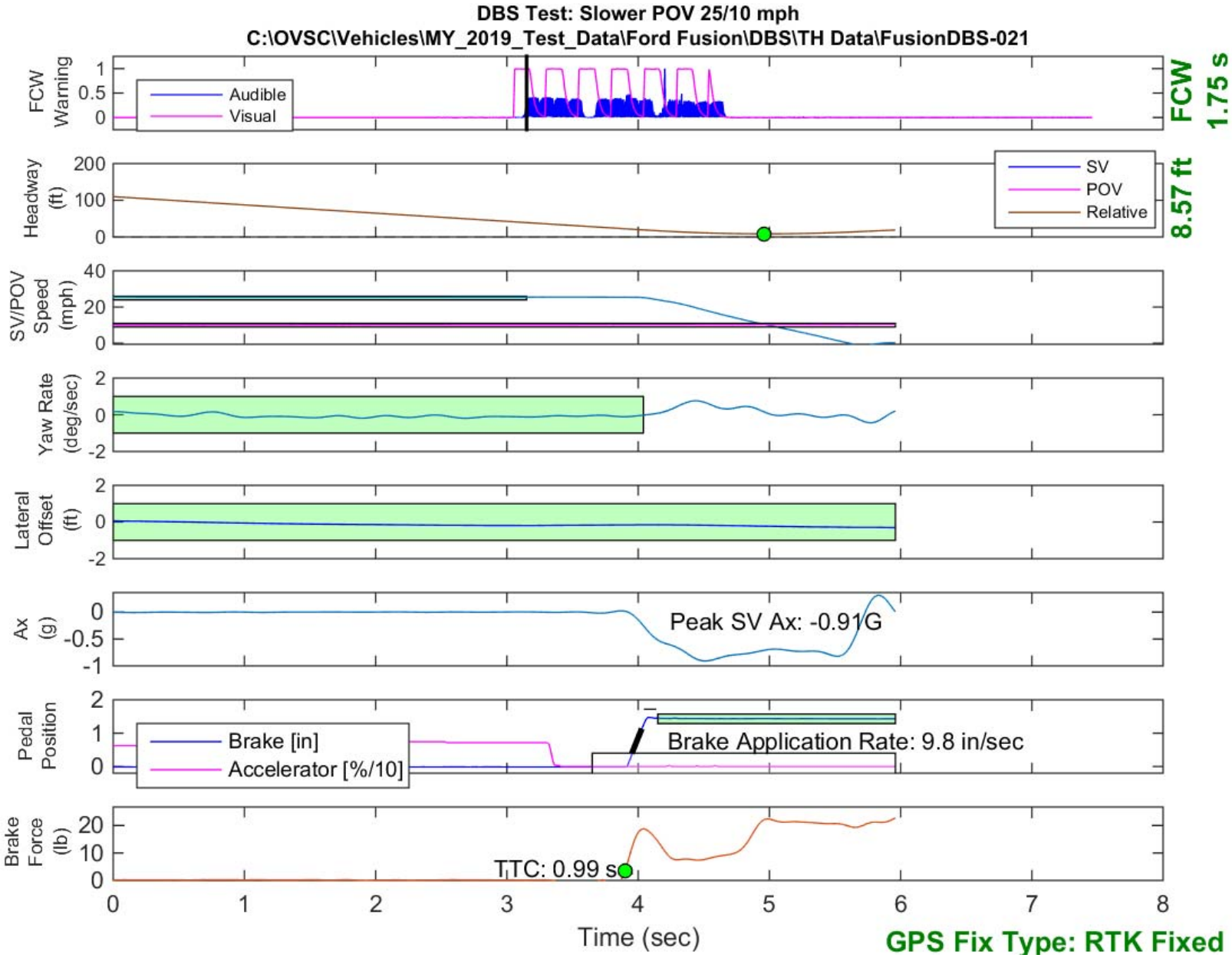

Figure E21. Time History for DBS Run 21, SV Encounters Slower POV, SV 25 mph, POV 10 mph

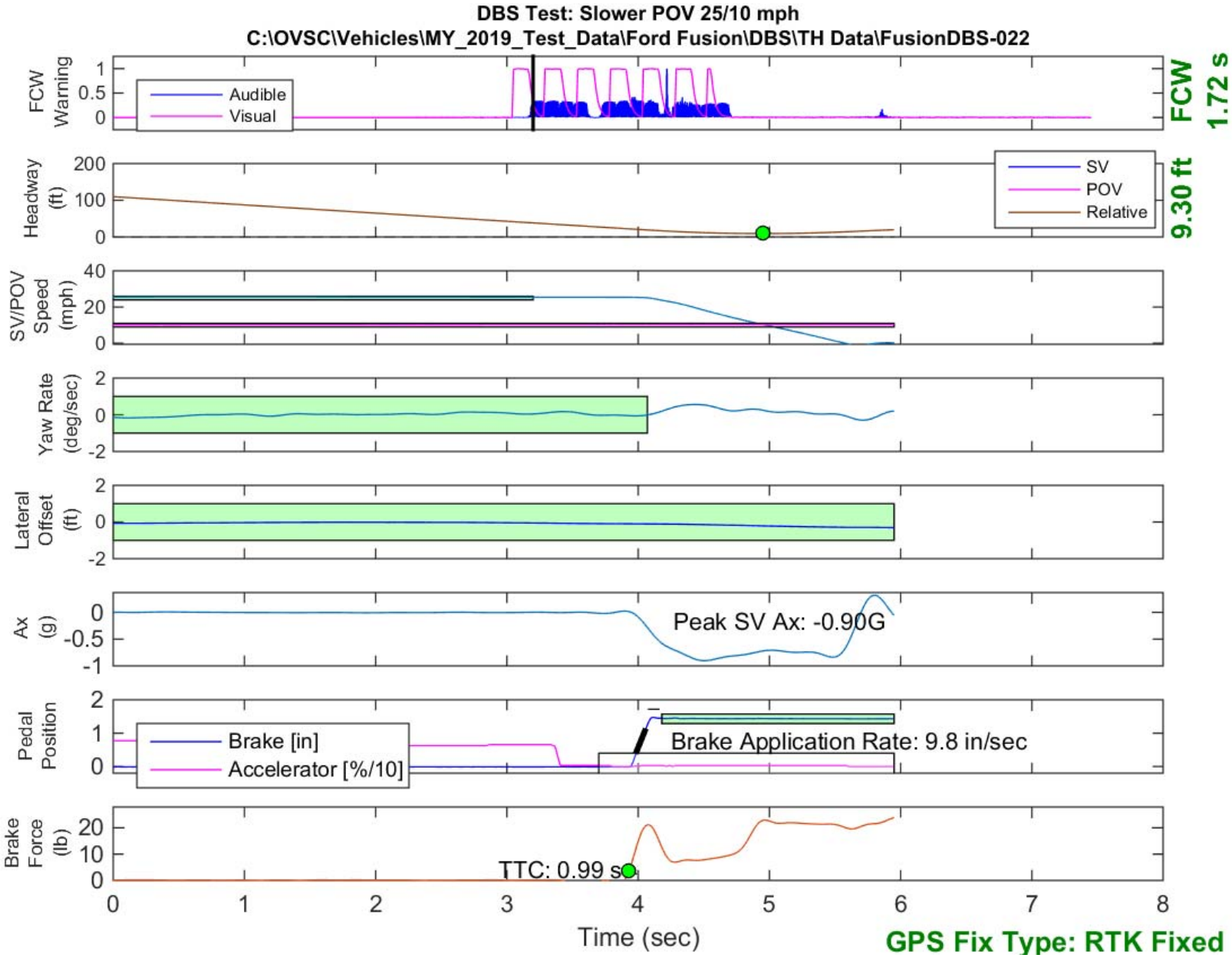

Figure E22. Time History for DBS Run 22, SV Encounters Slower POV, SV 25 mph, POV 10 mph

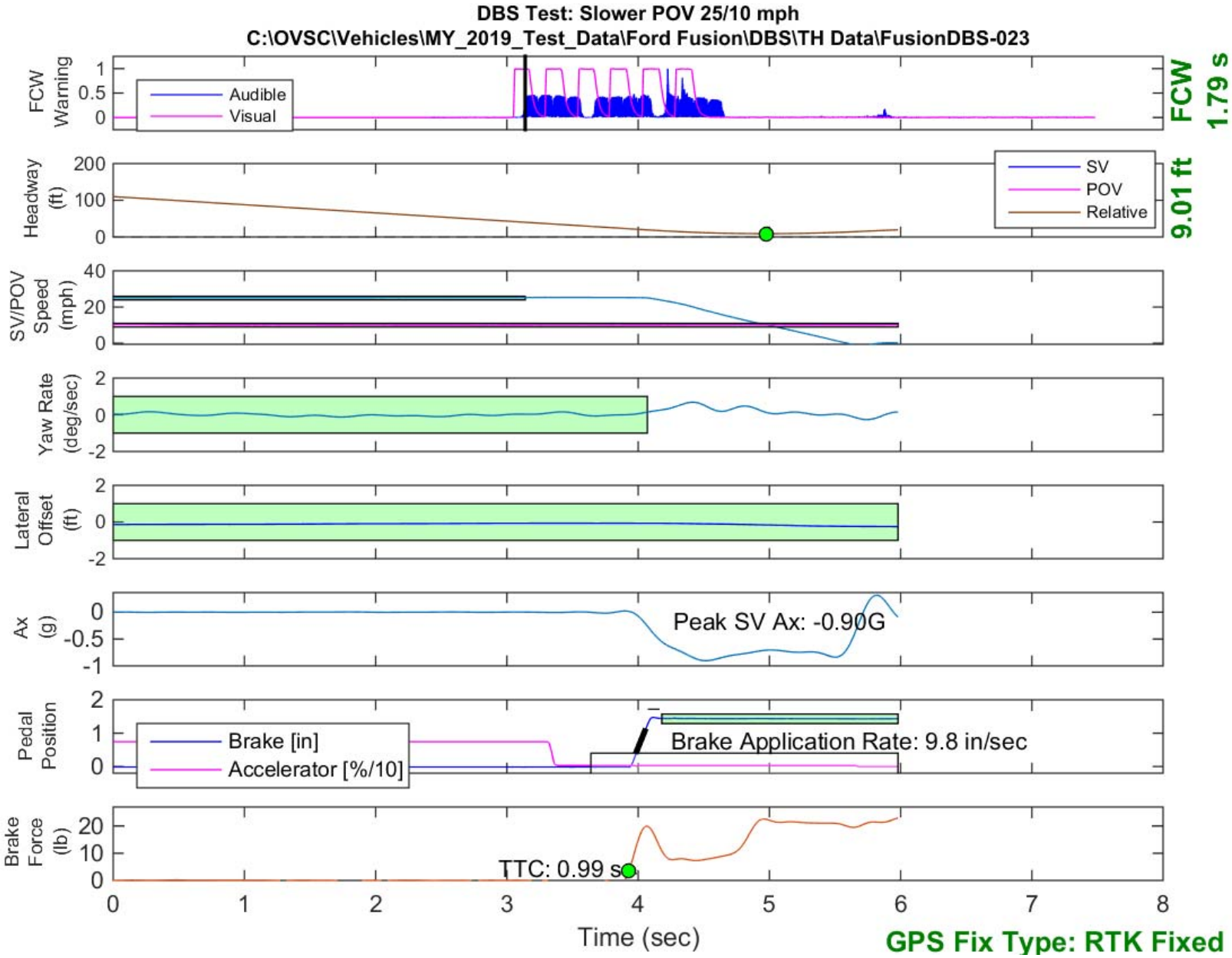

Figure E23. Time History for DBS Run 23, SV Encounters Slower POV, SV 25 mph, POV 10 mph

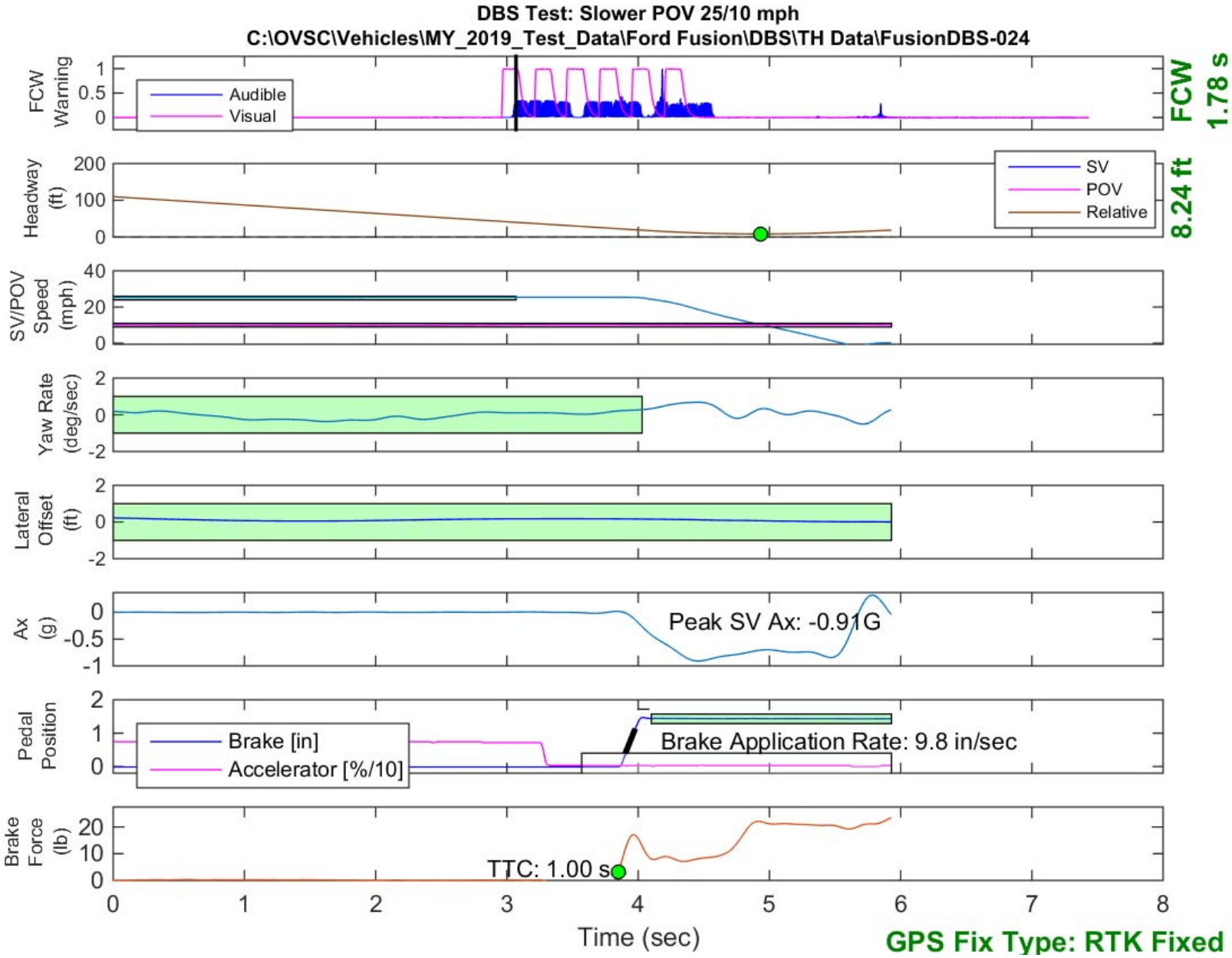

Figure E24. Time History for DBS Run 24, SV Encounters Slower POV, SV 25 mph, POV 10 mph

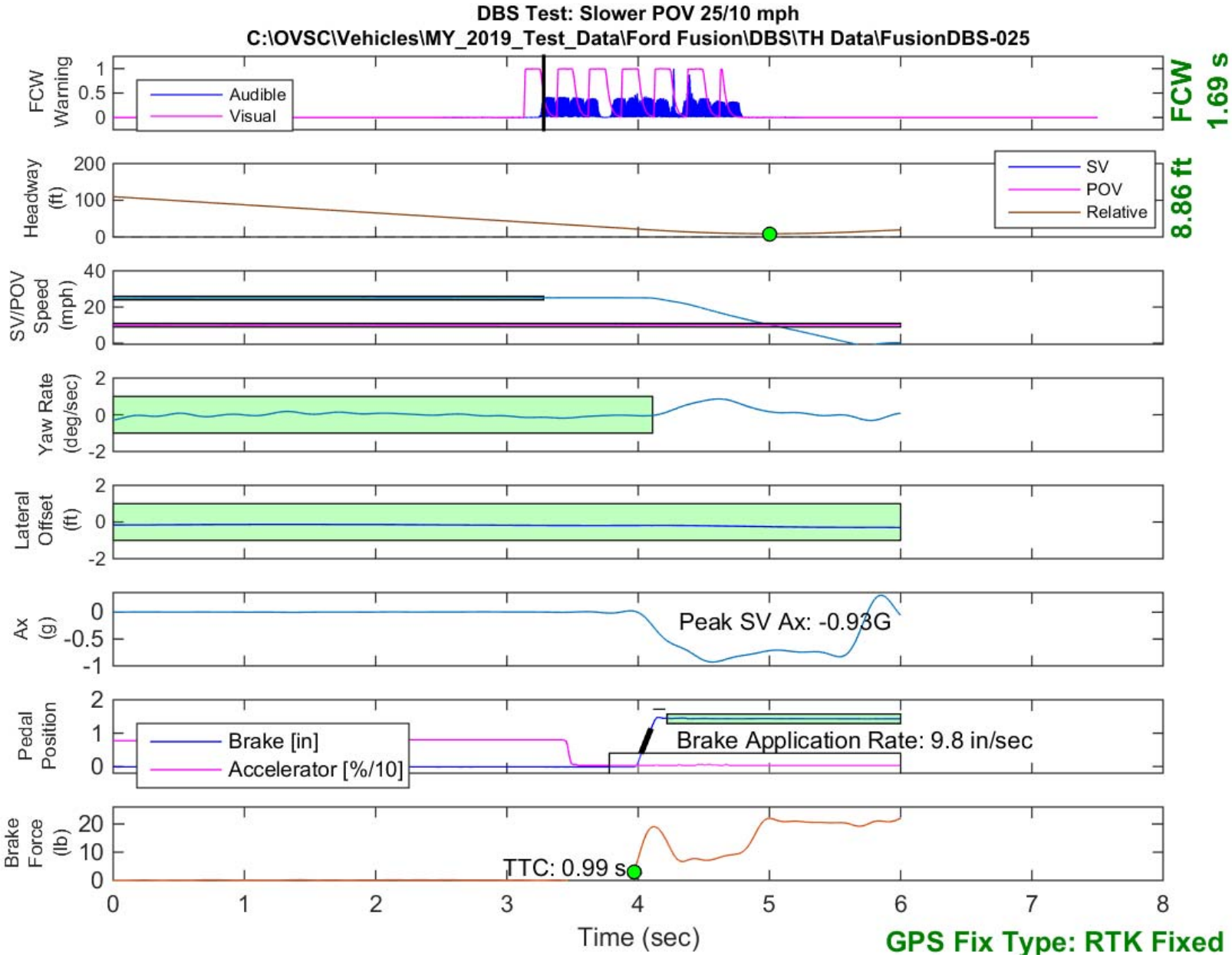

Figure E25. Time History for DBS Run 25, SV Encounters Slower POV, SV 25 mph, POV 10 mph

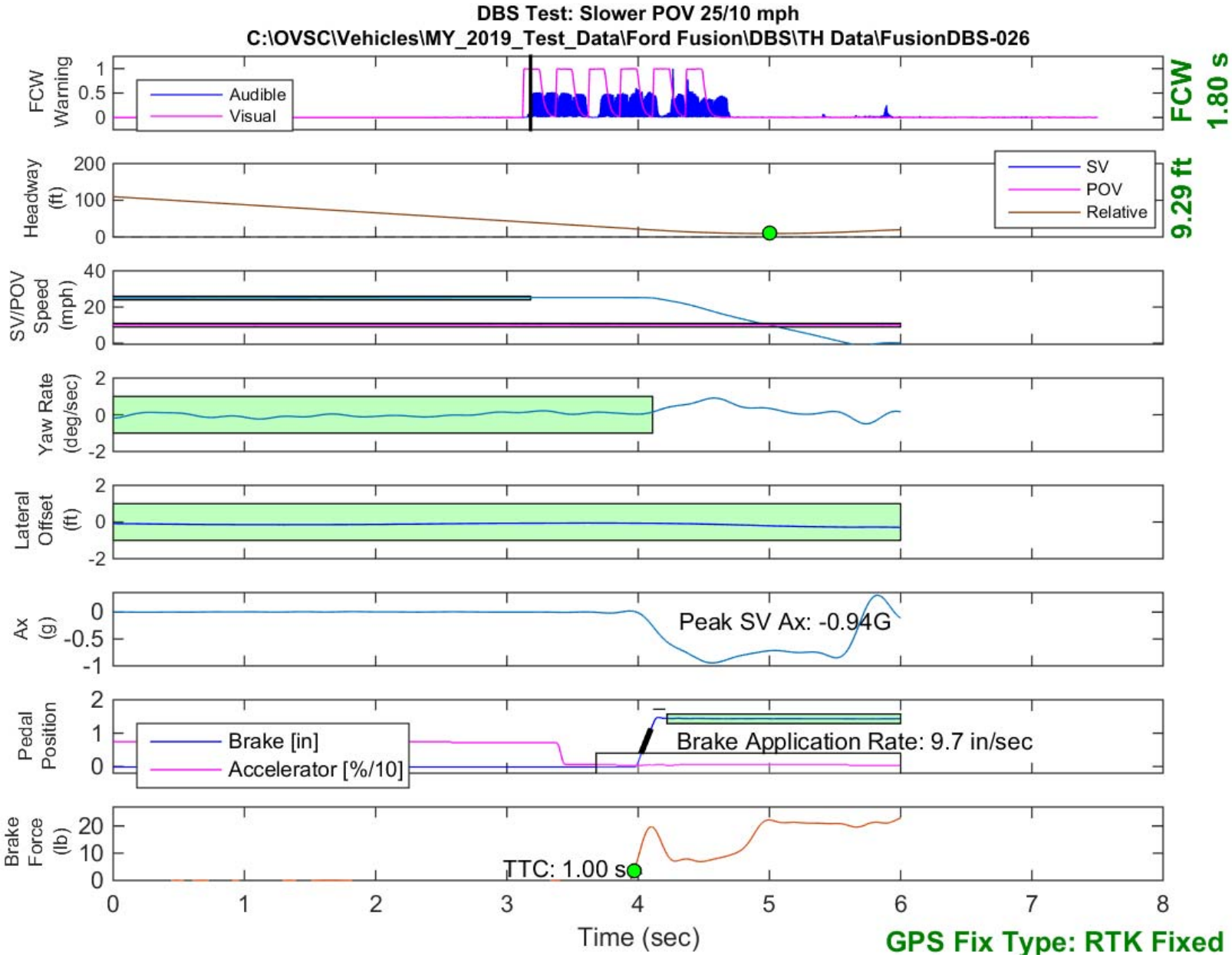

Figure E26. Time History for DBS Run 26, SV Encounters Slower POV, SV 25 mph, POV 10 mph

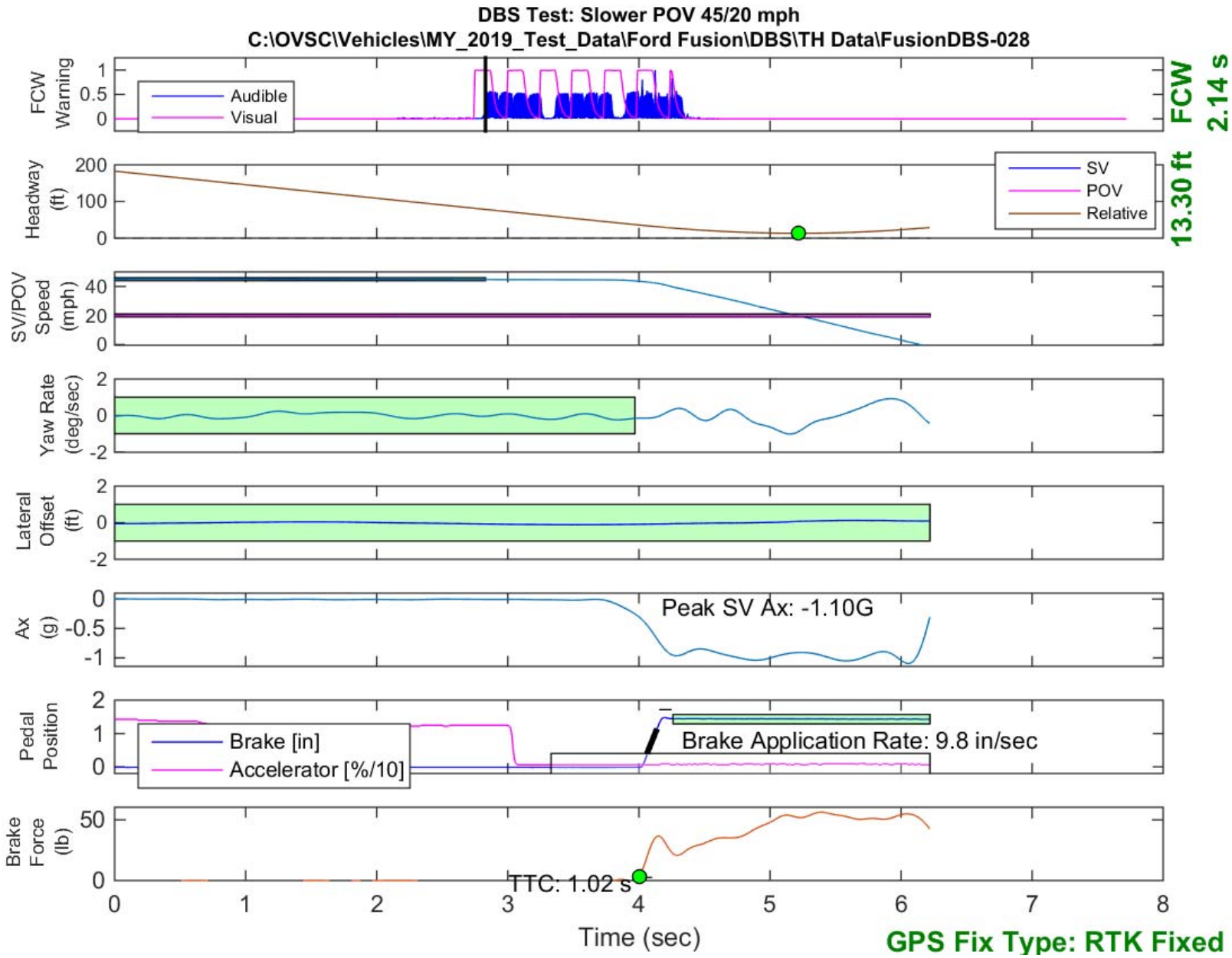

Figure E27. Time History for DBS Run 28, SV Encounters Slower POV, SV 45 mph, POV 20 mph

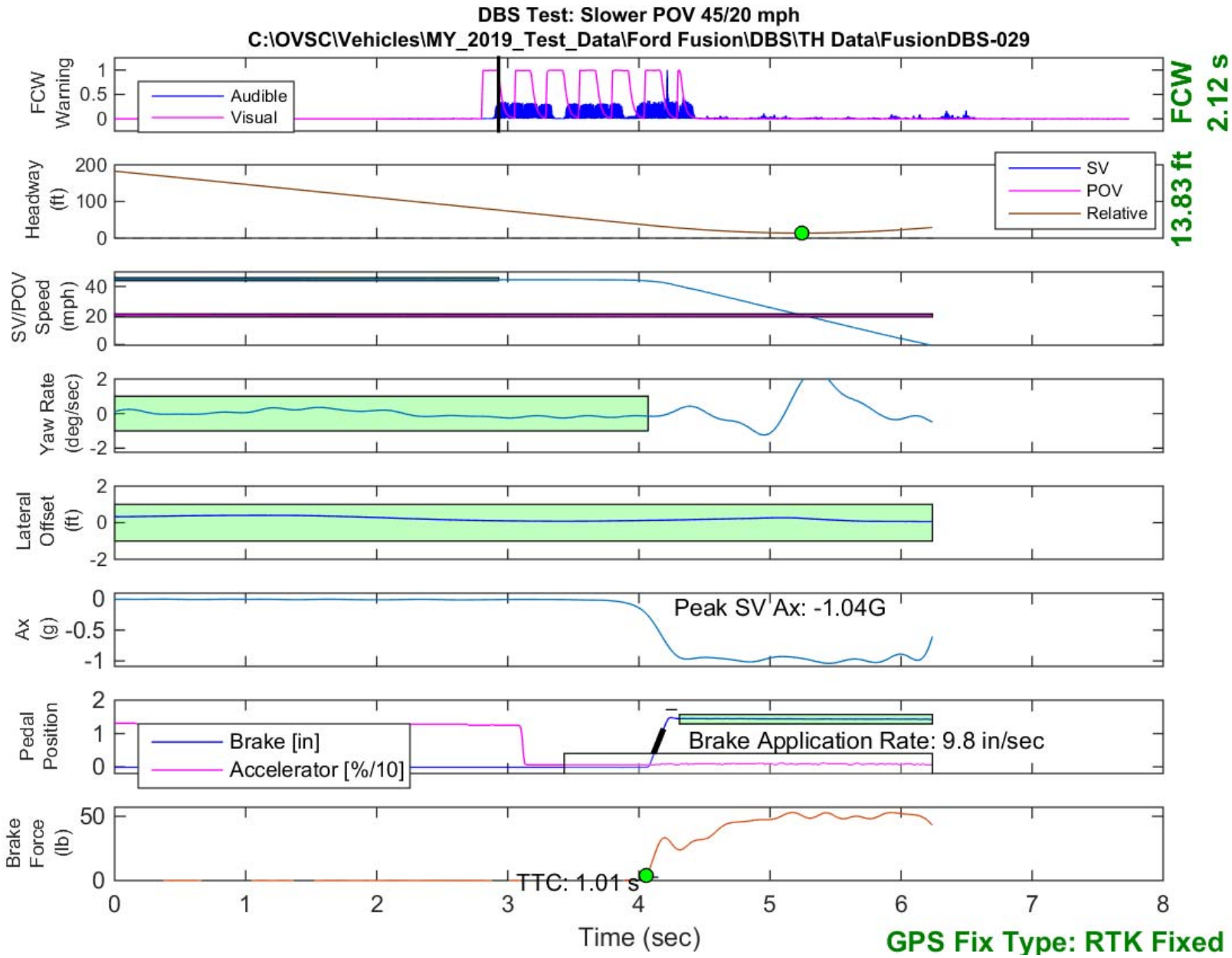

Figure E28. Time History for DBS Run 29, SV Encounters Slower POV, SV 45 mph, POV 20 mph

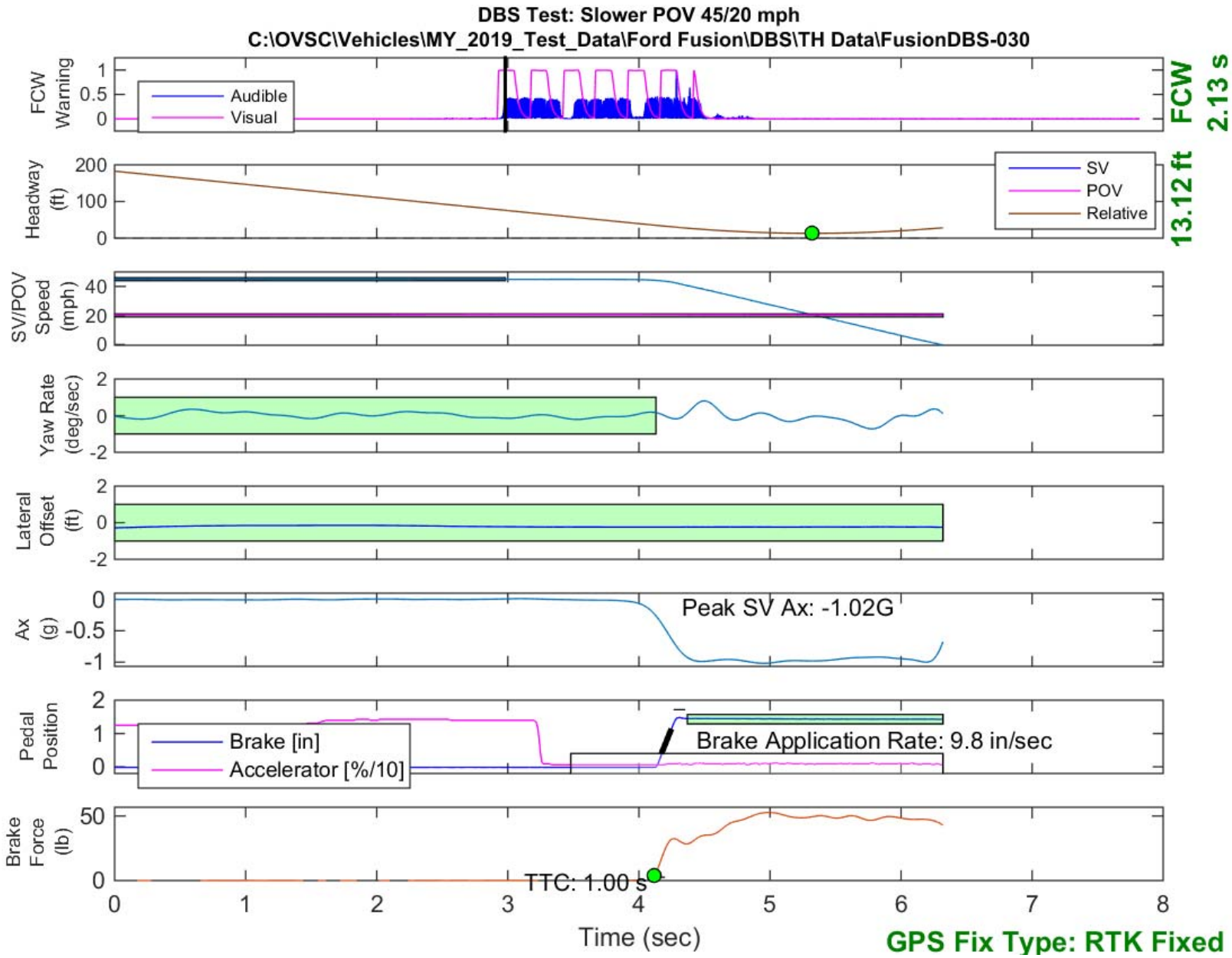

Figure E29. Time History for DBS Run 30, SV Encounters Slower POV, SV 45 mph, POV 20 mph

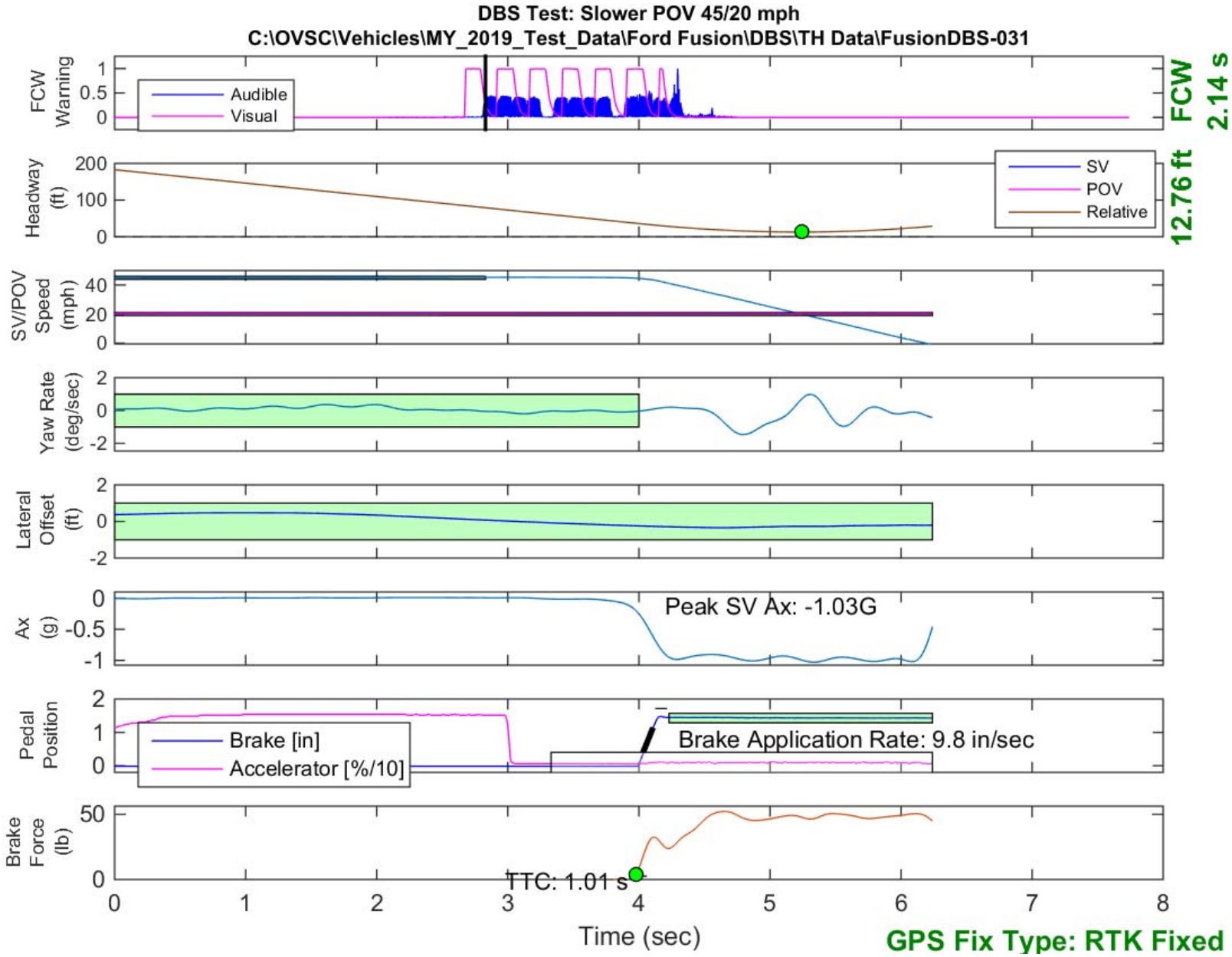

Figure E30. Time History for DBS Run 31, SV Encounters Slower POV, SV 45 mph, POV 20 mph

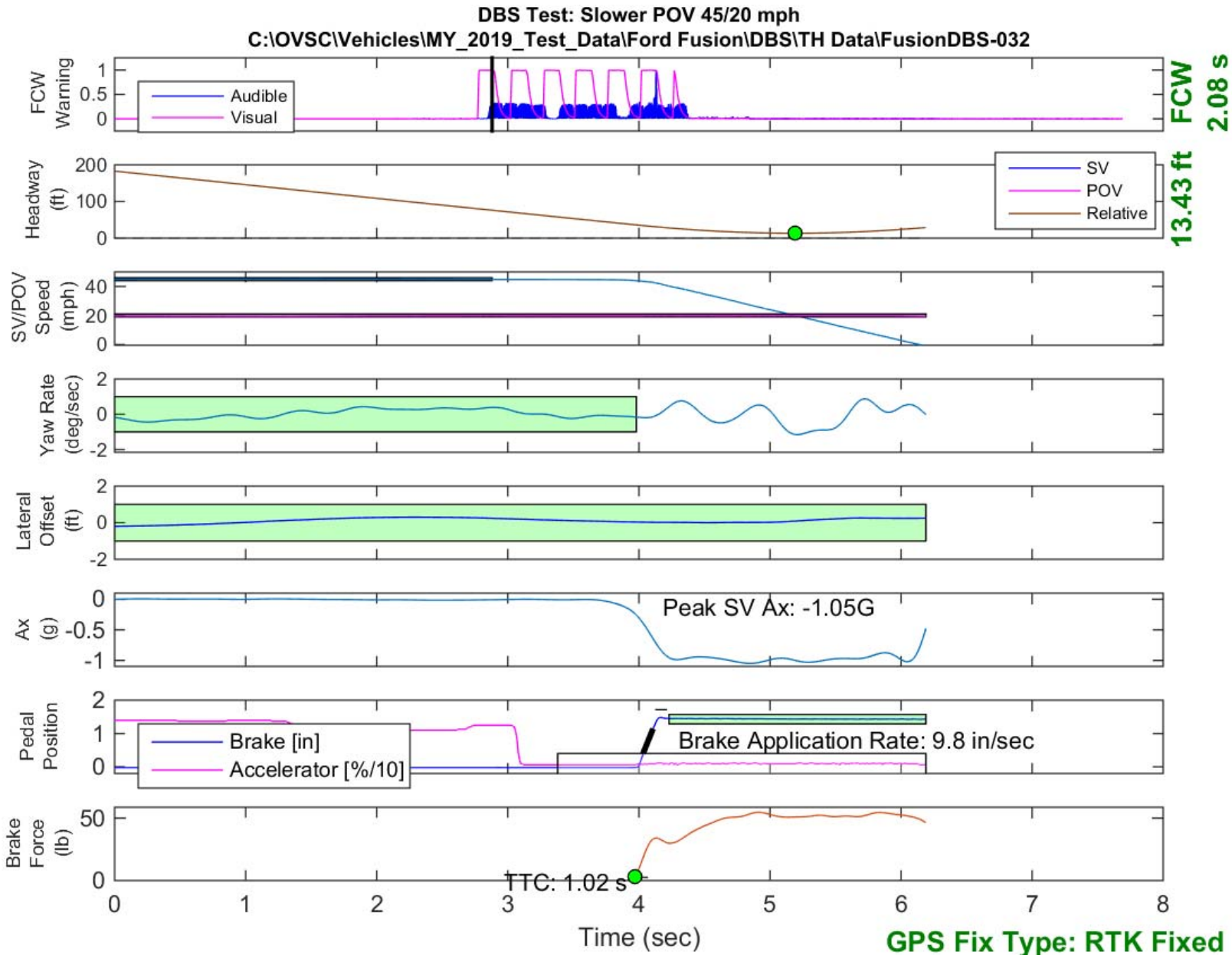

Figure E31. Time History for DBS Run 32, SV Encounters Slower POV, SV 45 mph, POV 20 mph

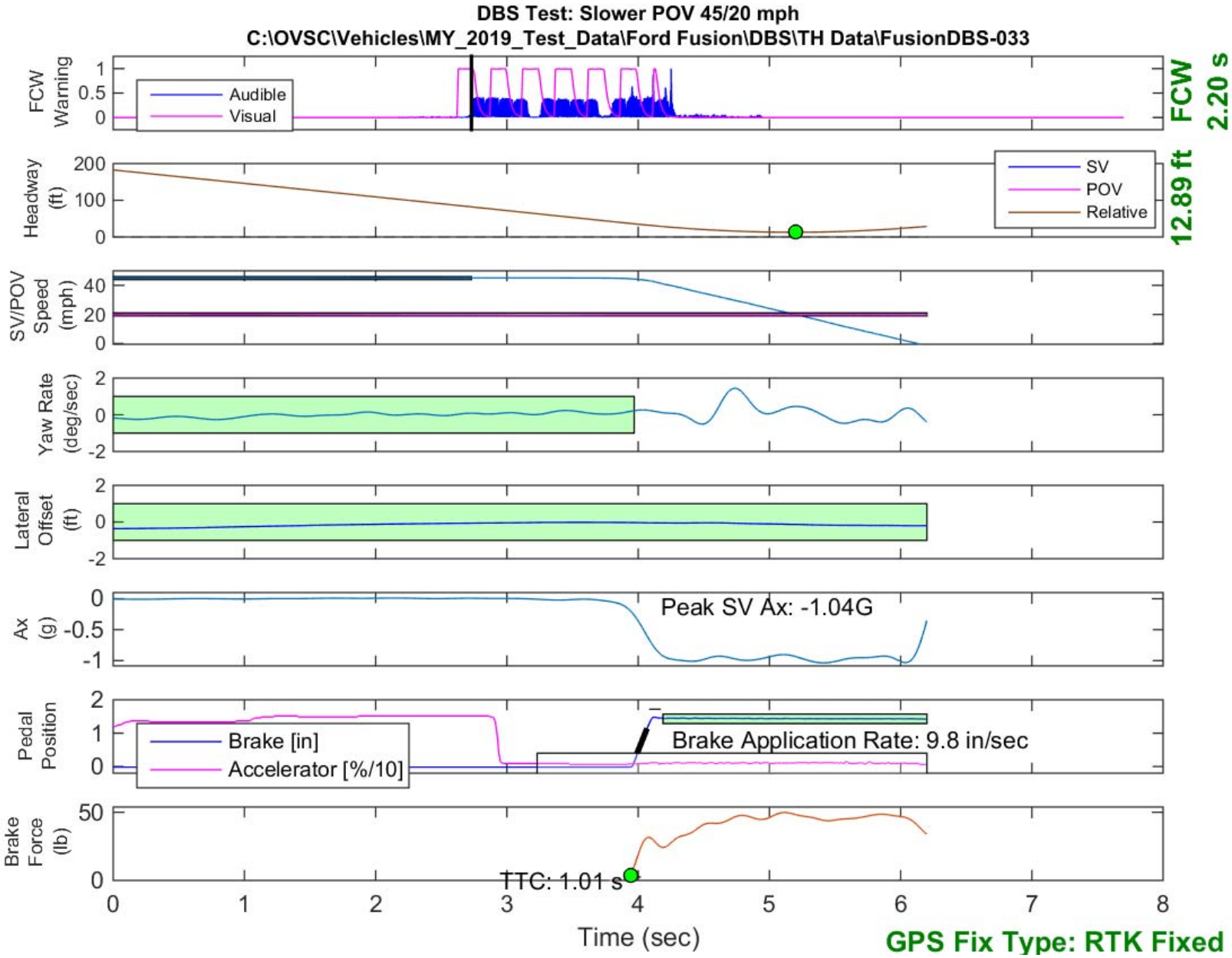

Figure E32. Time History for DBS Run 33, SV Encounters Slower POV, SV 45 mph, POV 20 mph

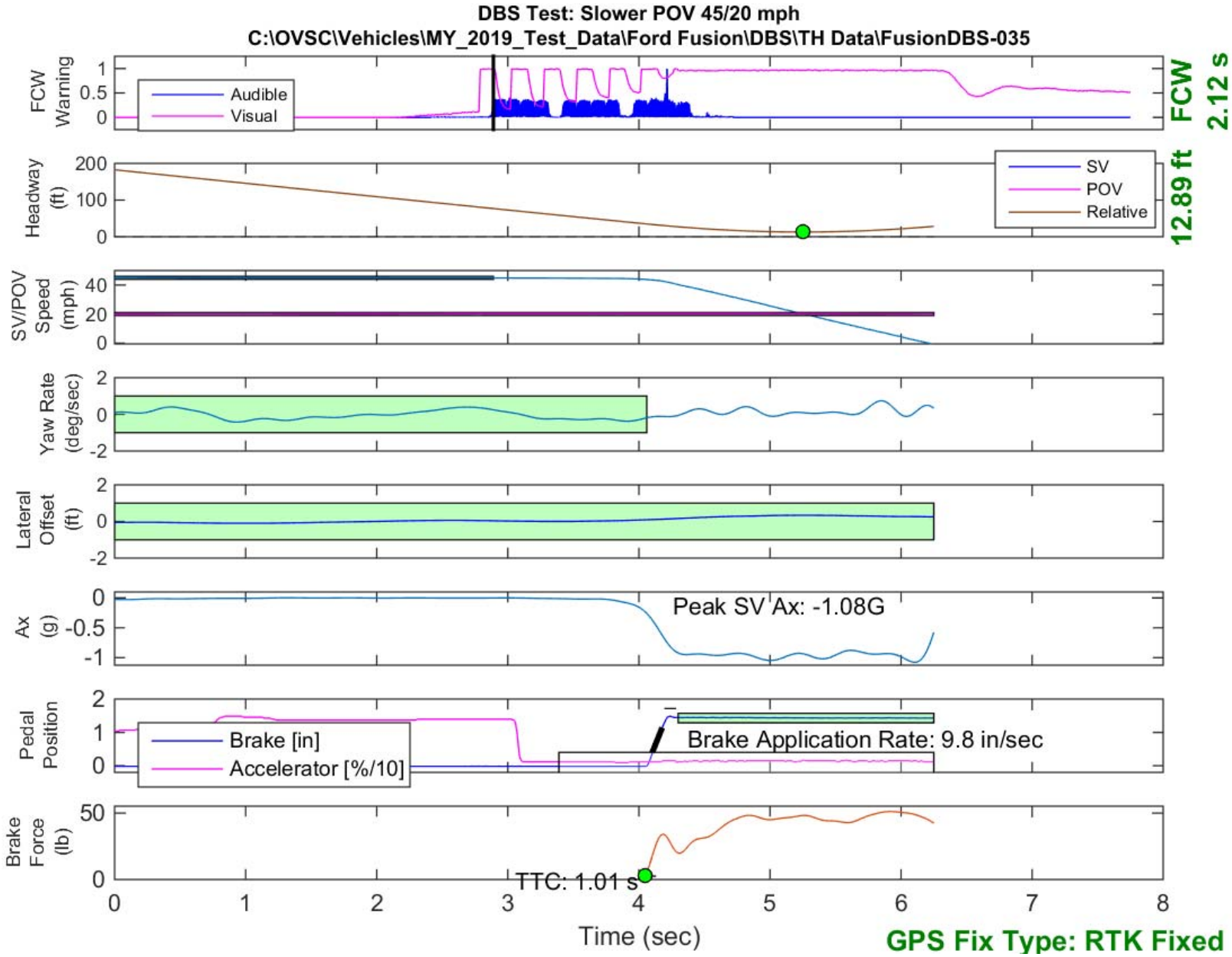

Figure E33. Time History for DBS Run 35, SV Encounters Slower POV, SV 45 mph, POV 20 mph

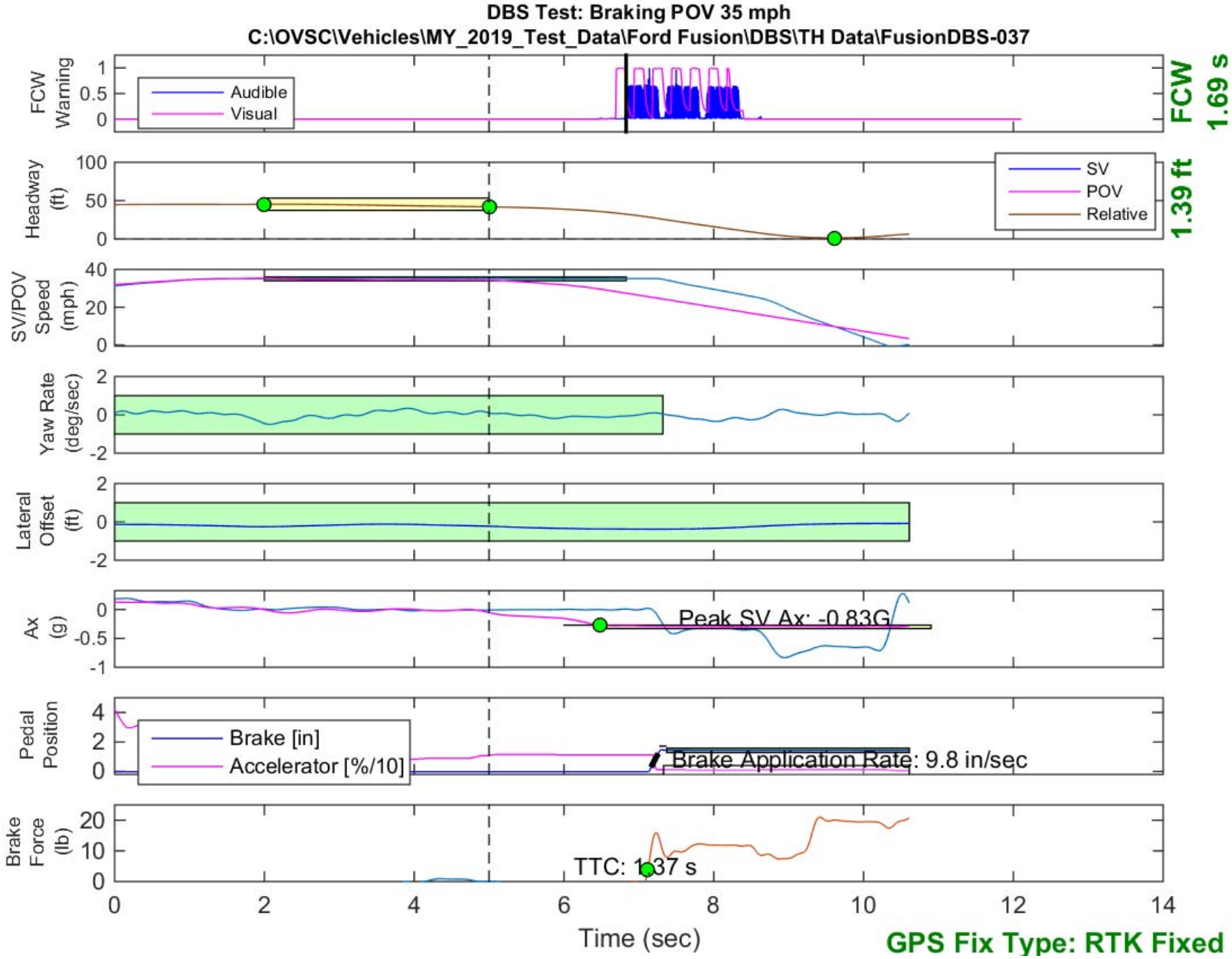

Figure E34. Time History for DBS Run 37, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

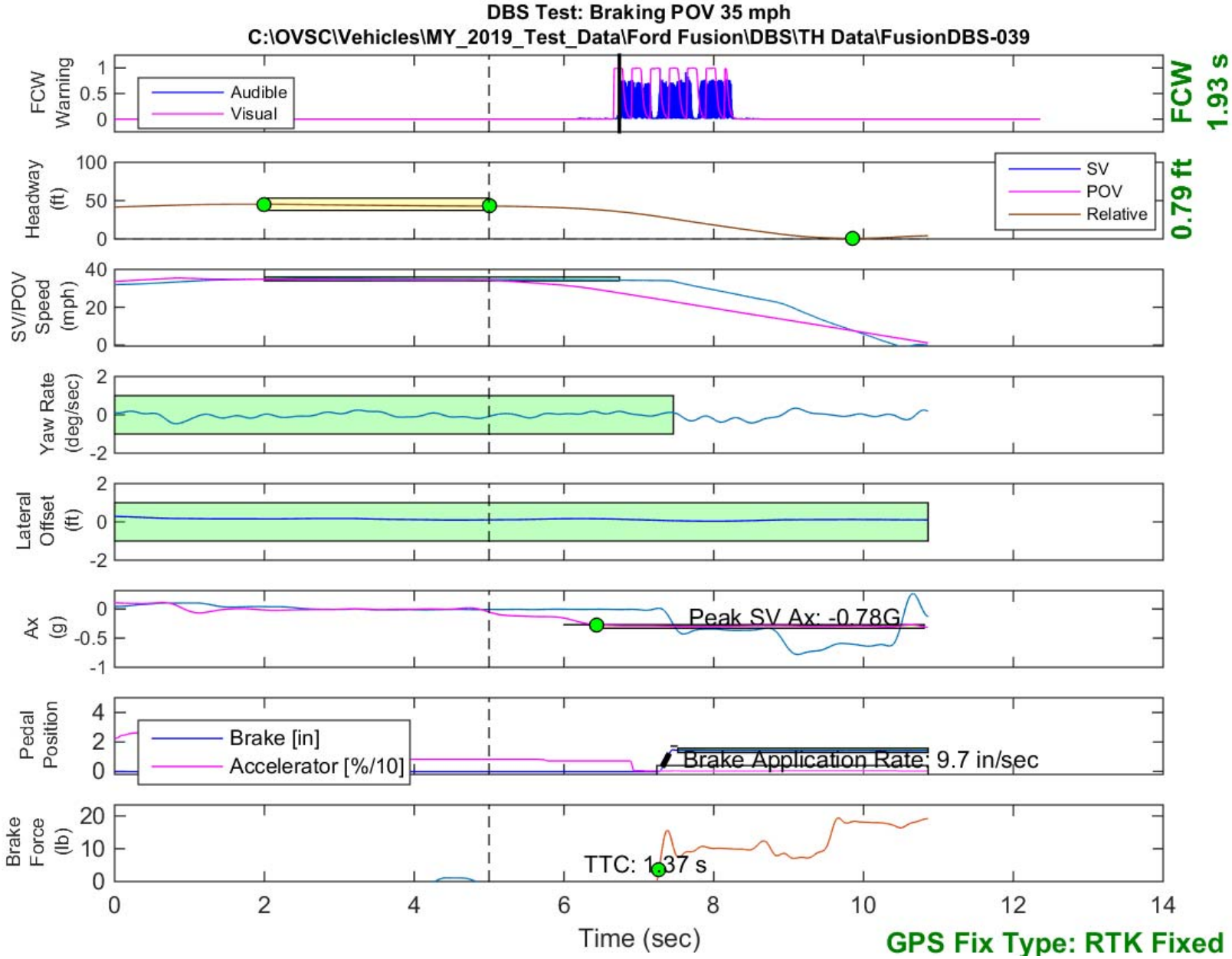

Figure E35. Time History for DBS Run 39, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

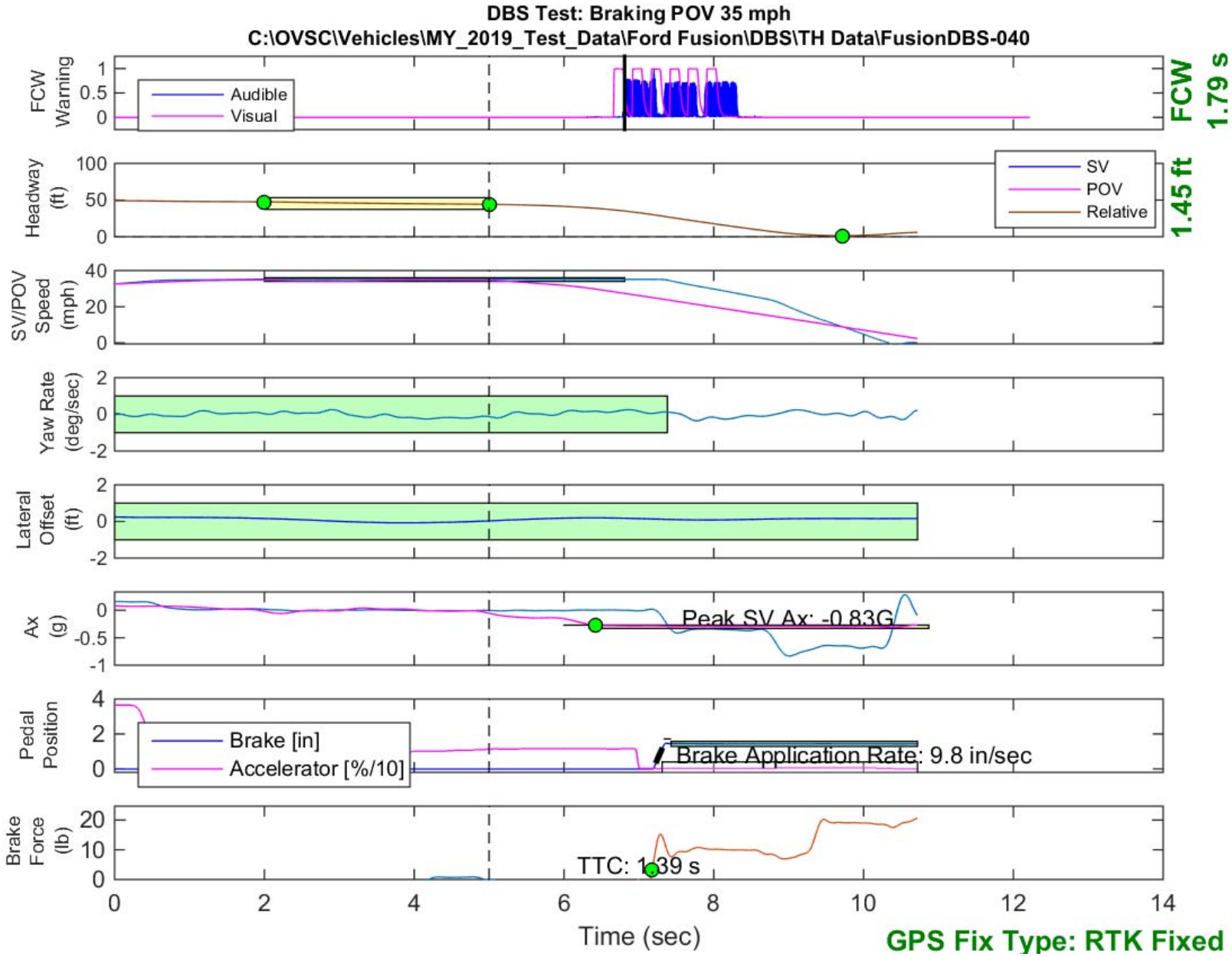

Figure E36. Time History for DBS Run 40, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

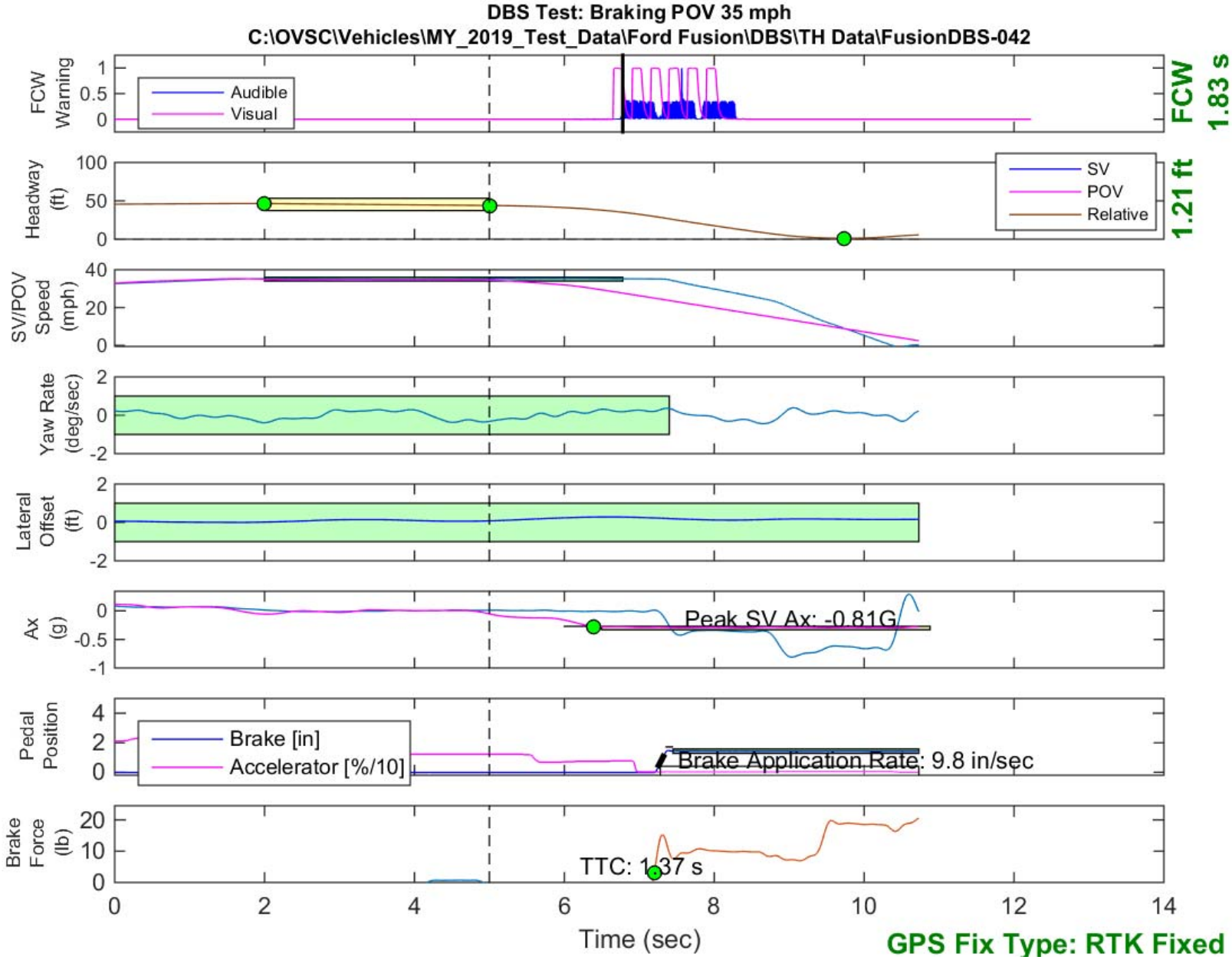

Figure E37. Time History for DBS Run 42, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

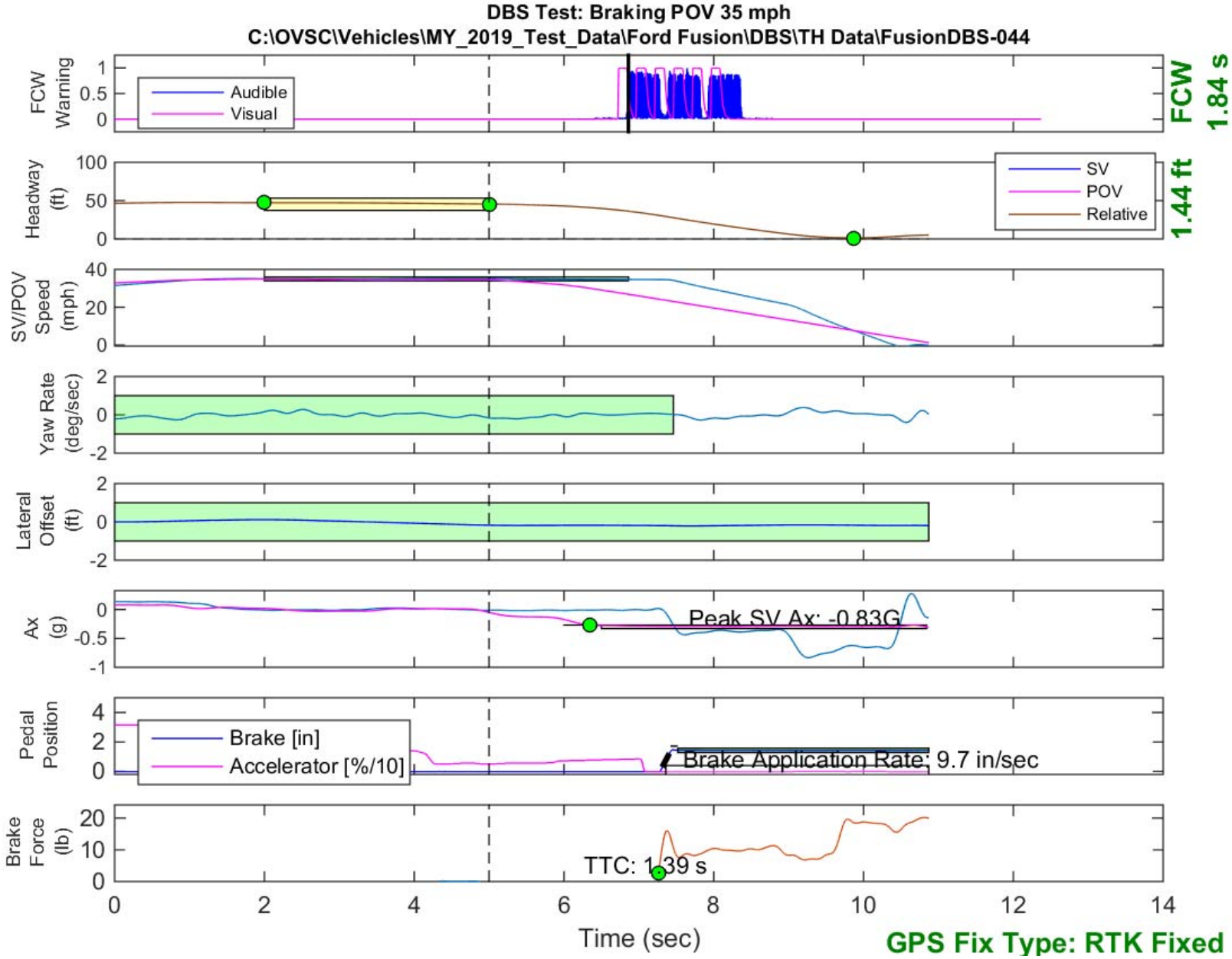

Figure E38. Time History for DBS Run 44, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

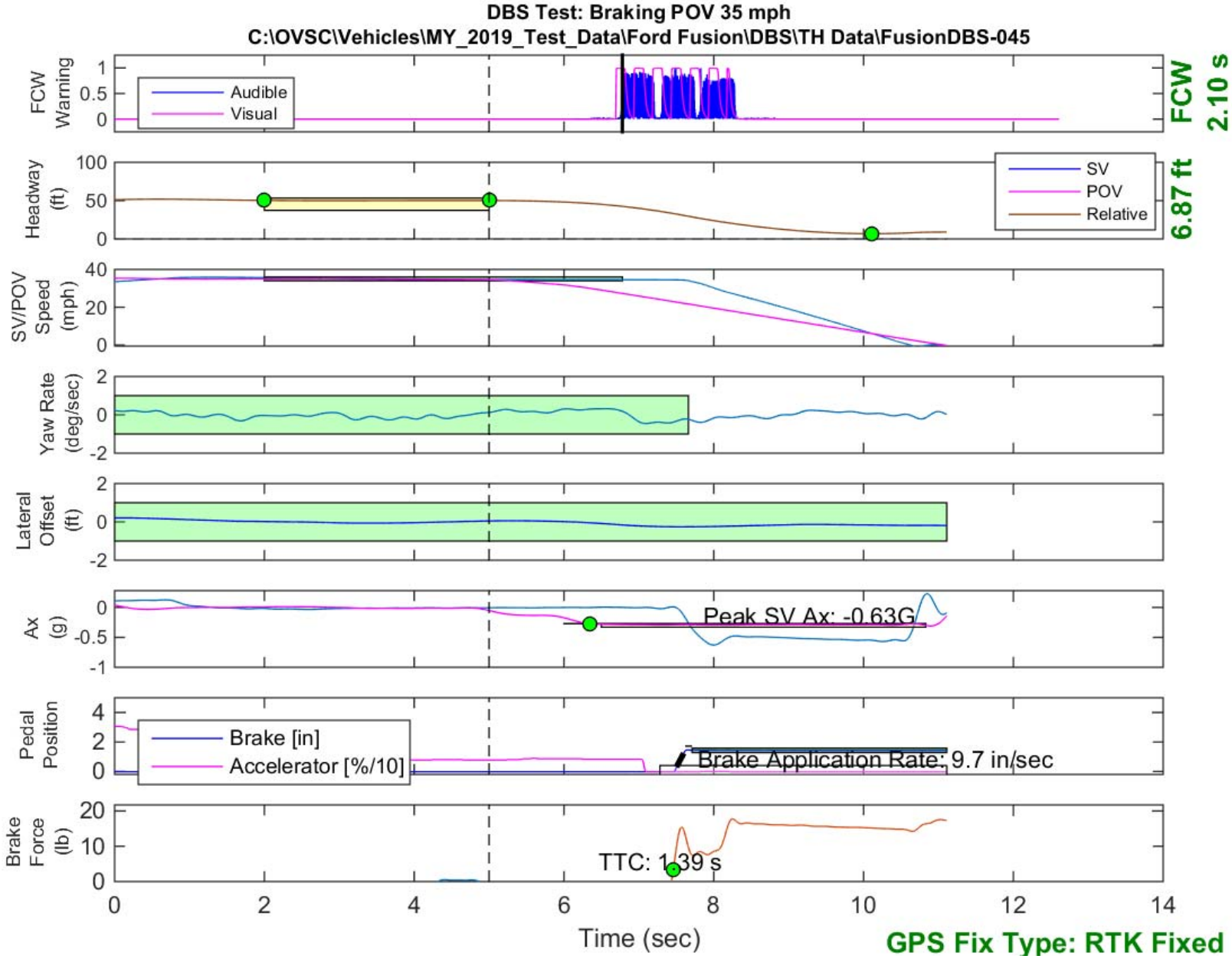

Figure E39. Time History for DBS Run 45, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

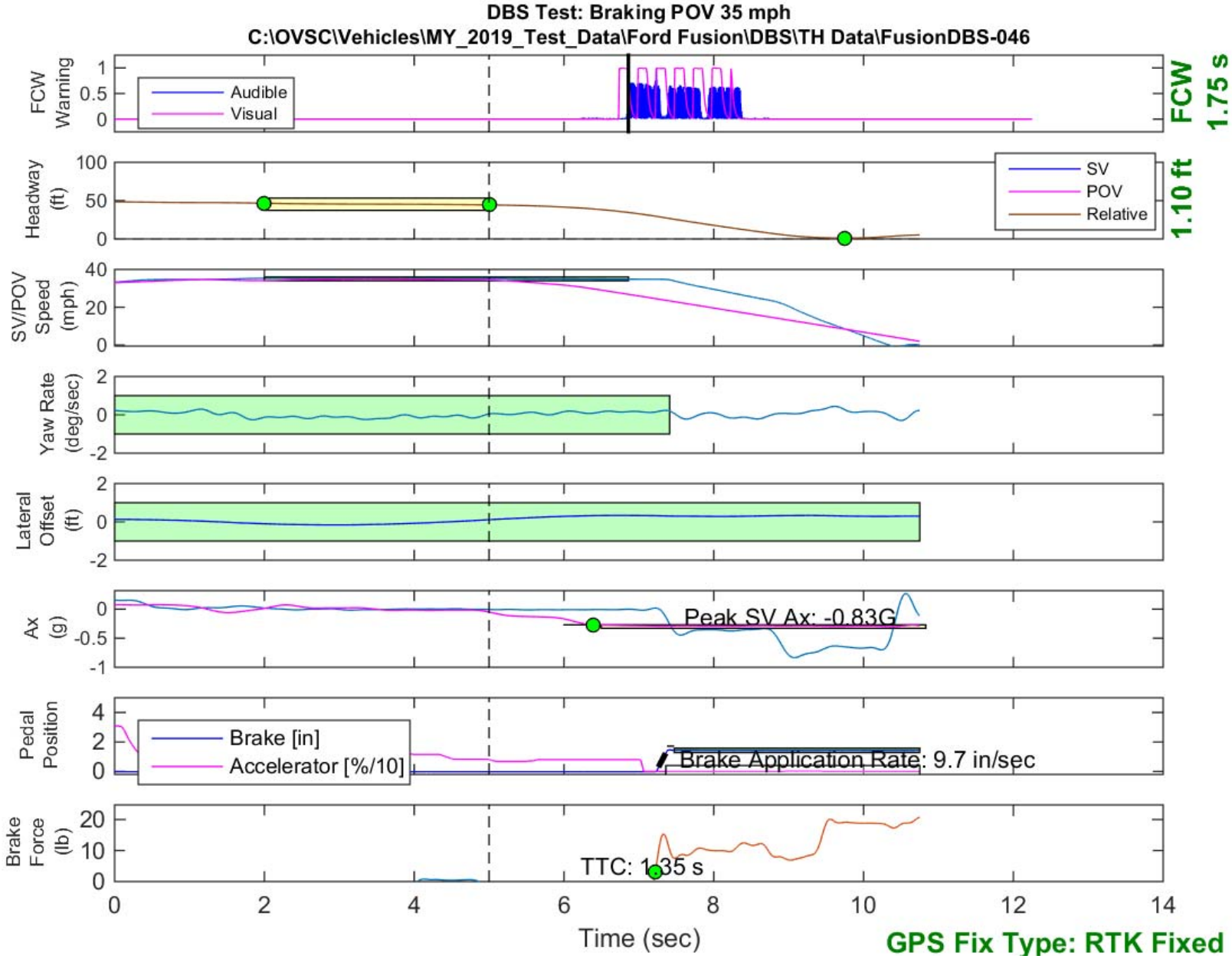

Figure E40. Time History for DBS Run 46, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

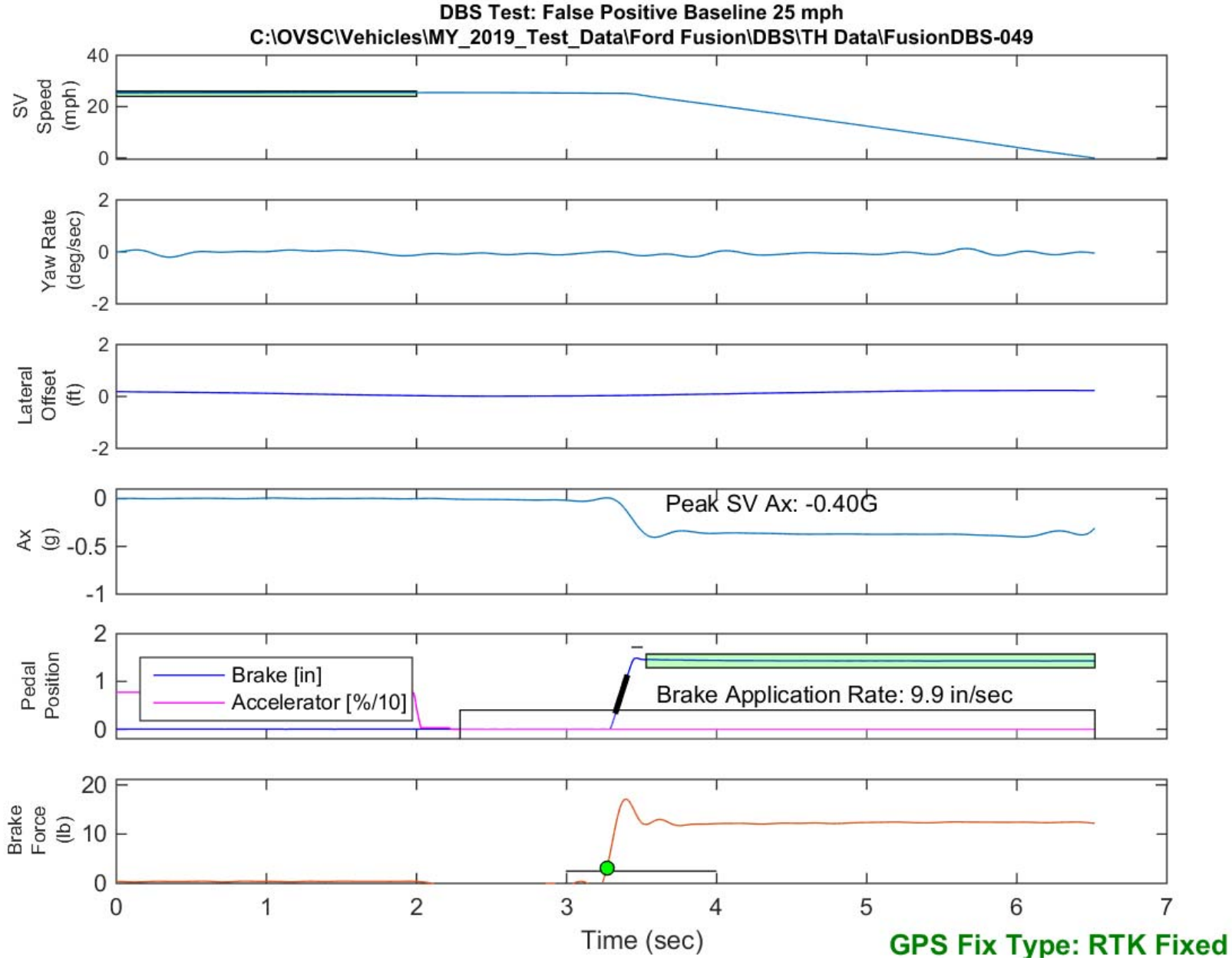

Figure E41. Time History for DBS Run 49, False Positive Baseline, SV 25 mph

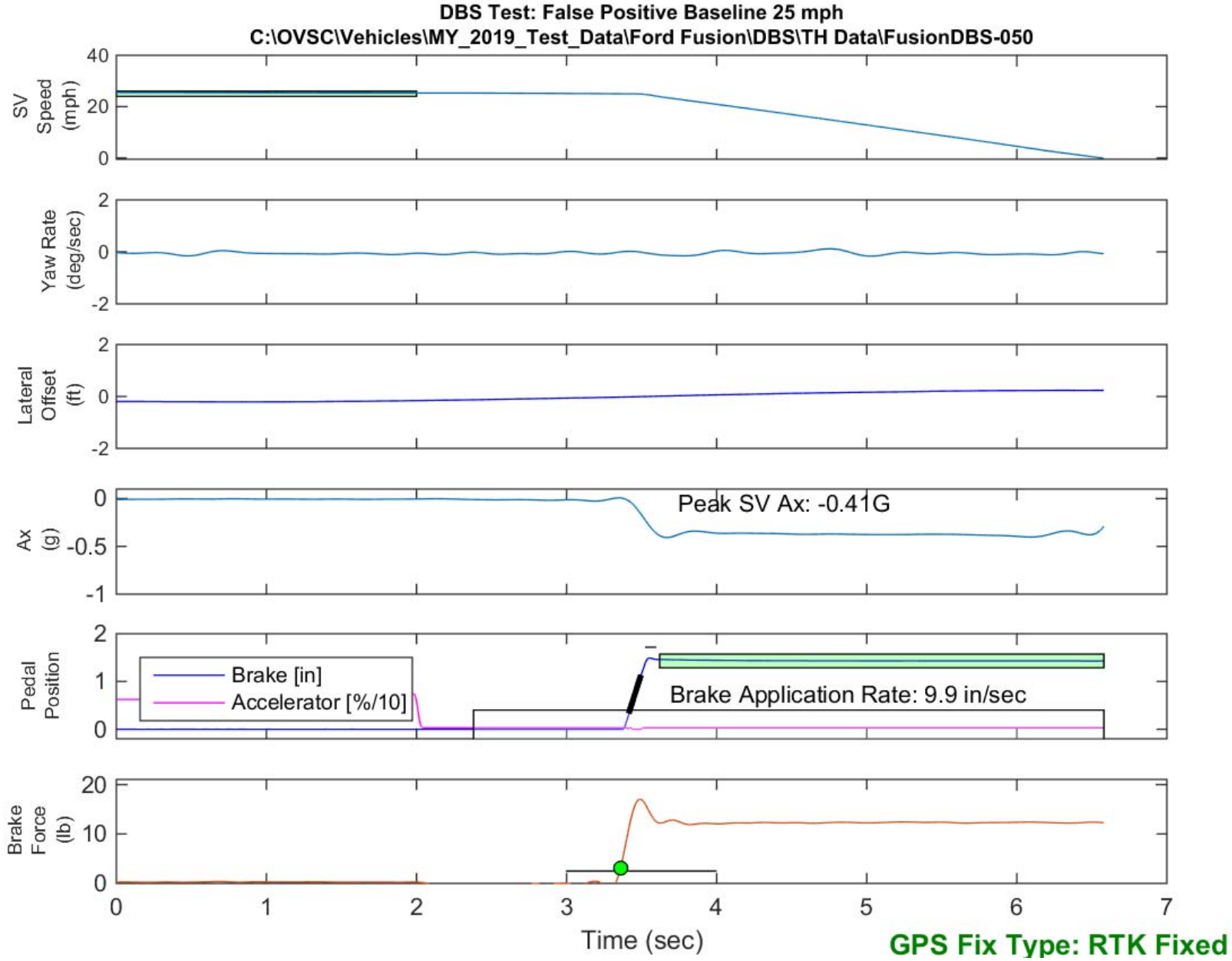

Figure E42. Time History for DBS Run 50, False Positive Baseline, SV 25 mph

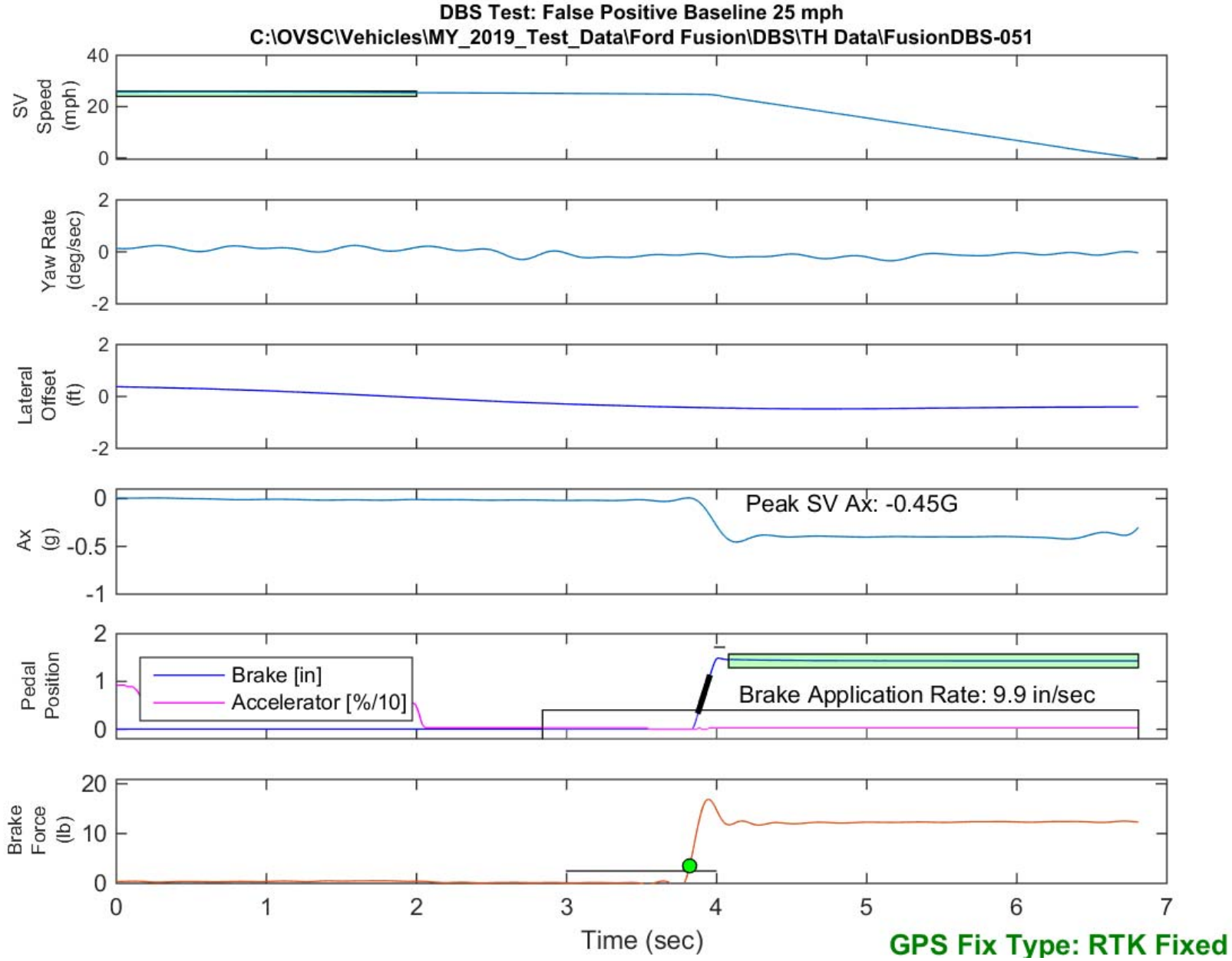

Figure E43. Time History for DBS Run 51, False Positive Baseline, SV 25 mph

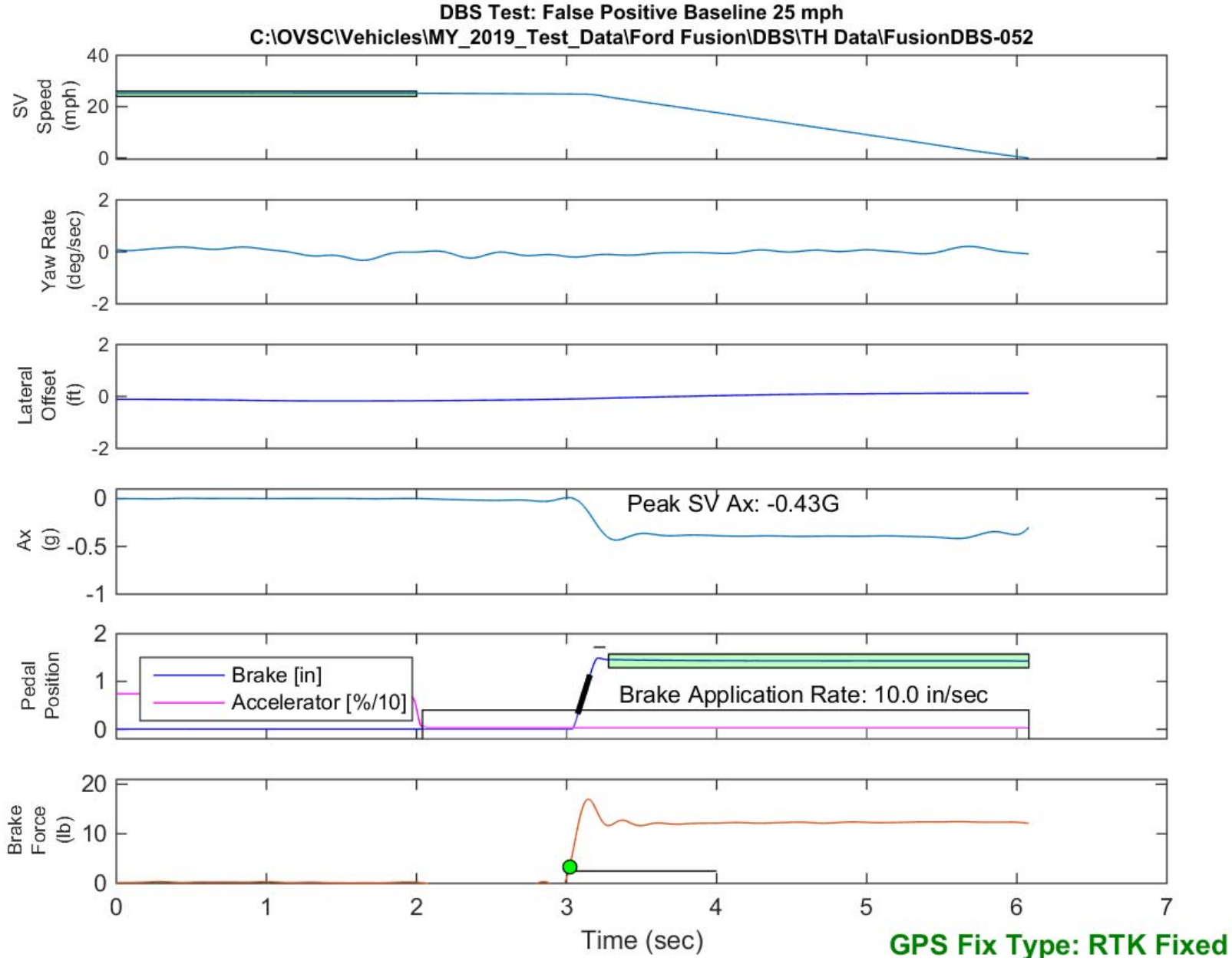

Figure E44. Time History for DBS Run 52, False Positive Baseline, SV 25 mph

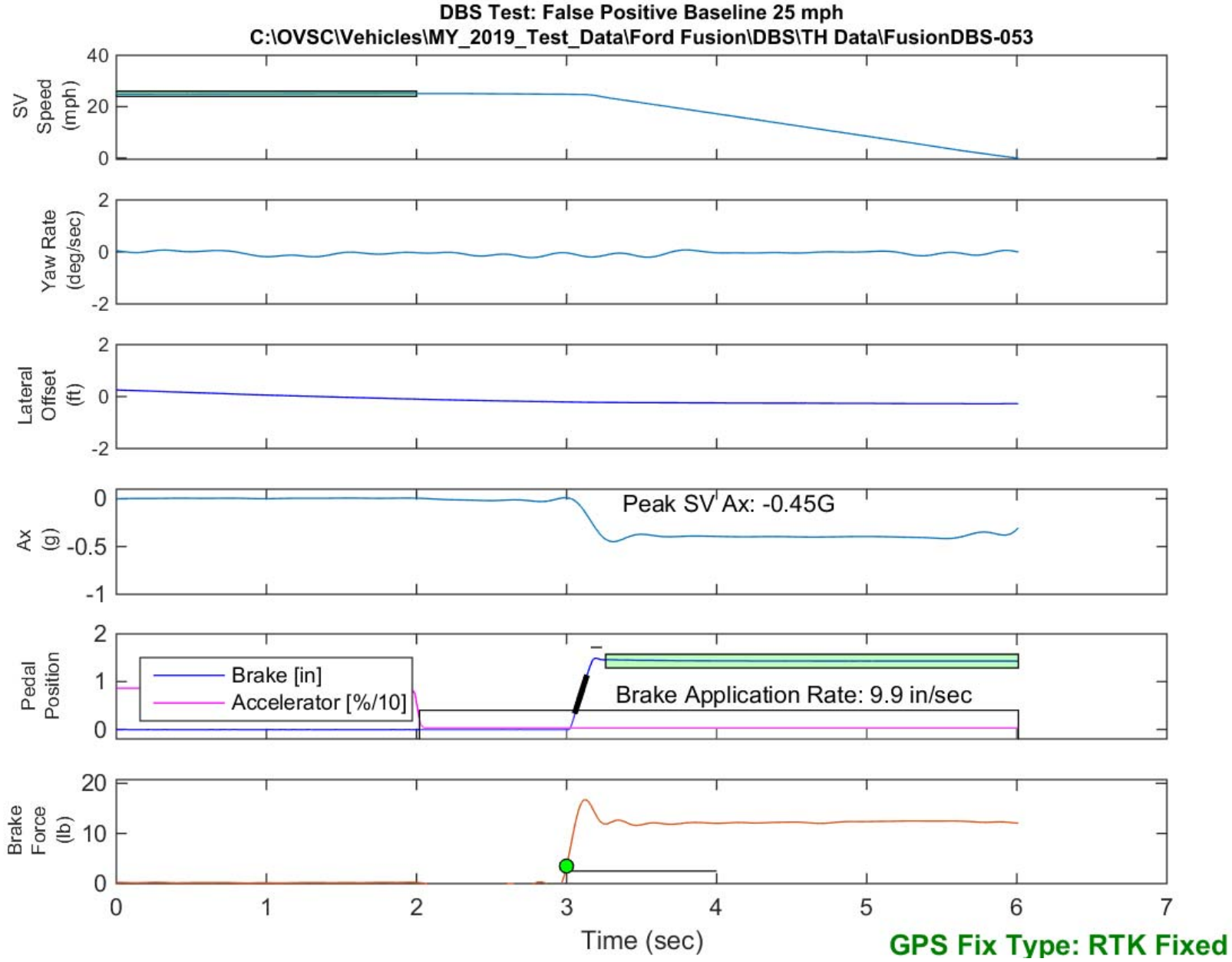

Figure E45. Time History for DBS Run 53, False Positive Baseline, SV 25 mph

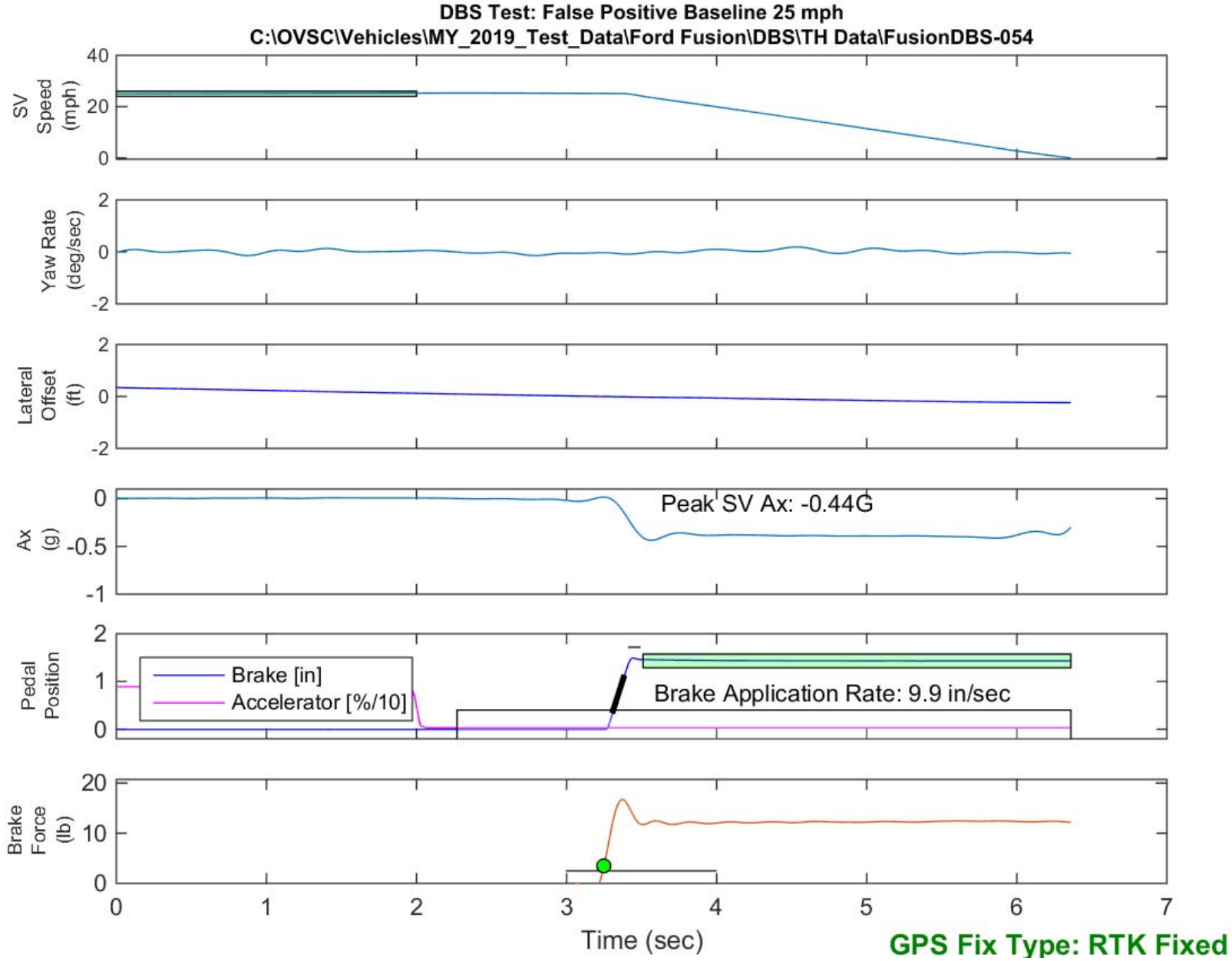

Figure E46. Time History for DBS Run 54, False Positive Baseline, SV 25 mph

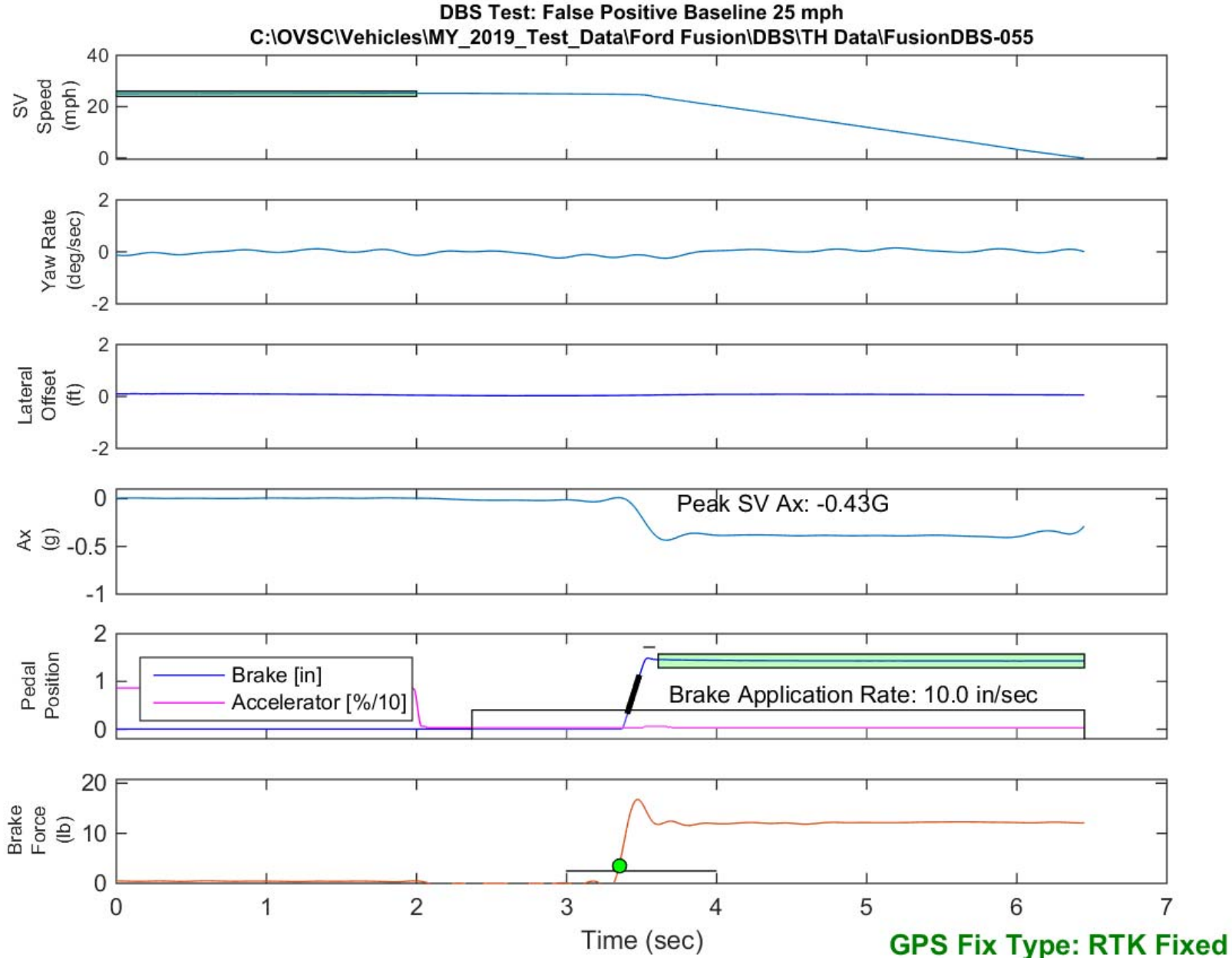

Figure E47. Time History for DBS Run 55, False Positive Baseline, SV 25 mph

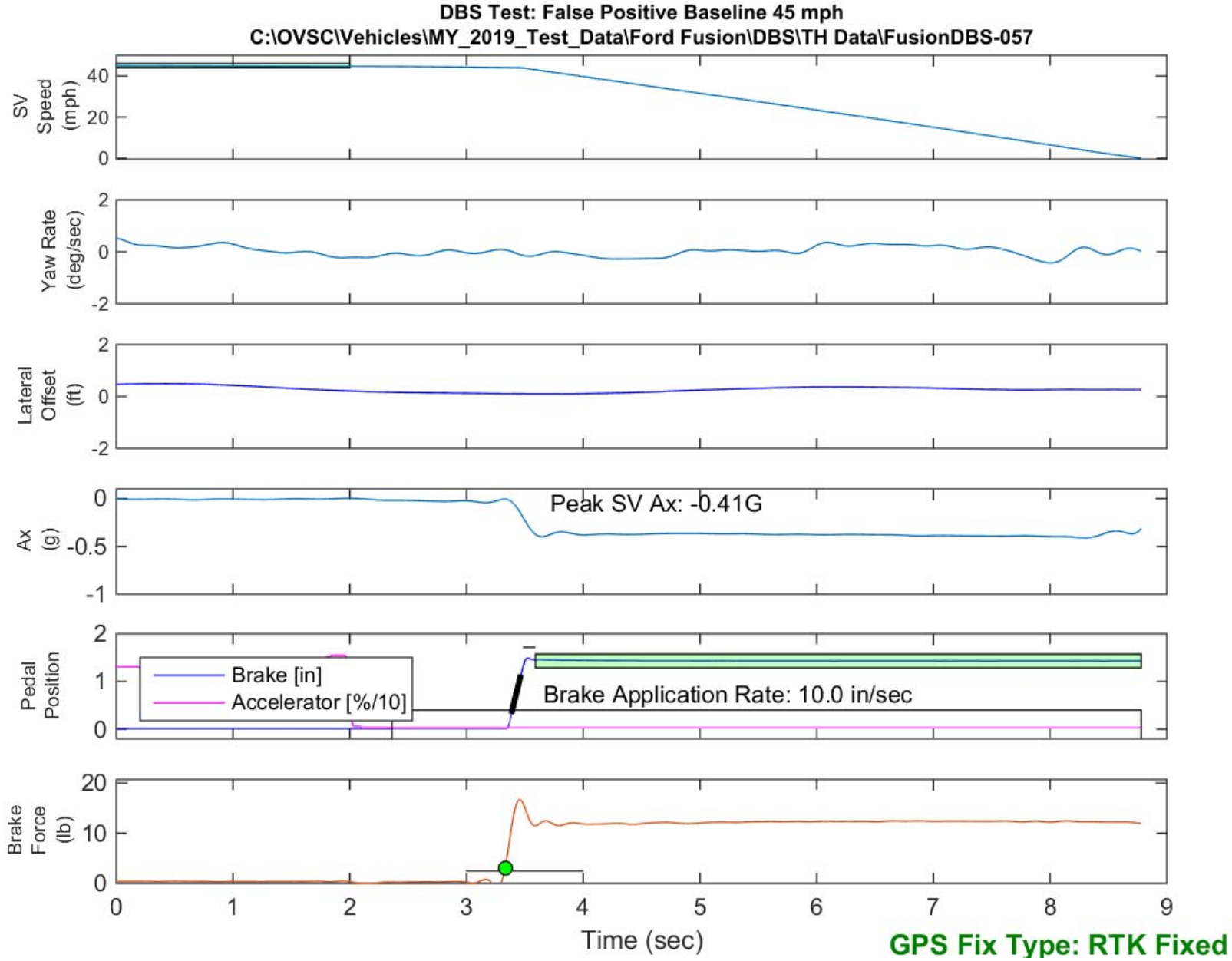

Figure E48. Time History for DBS Run 57, False Positive Baseline, SV 45 mph

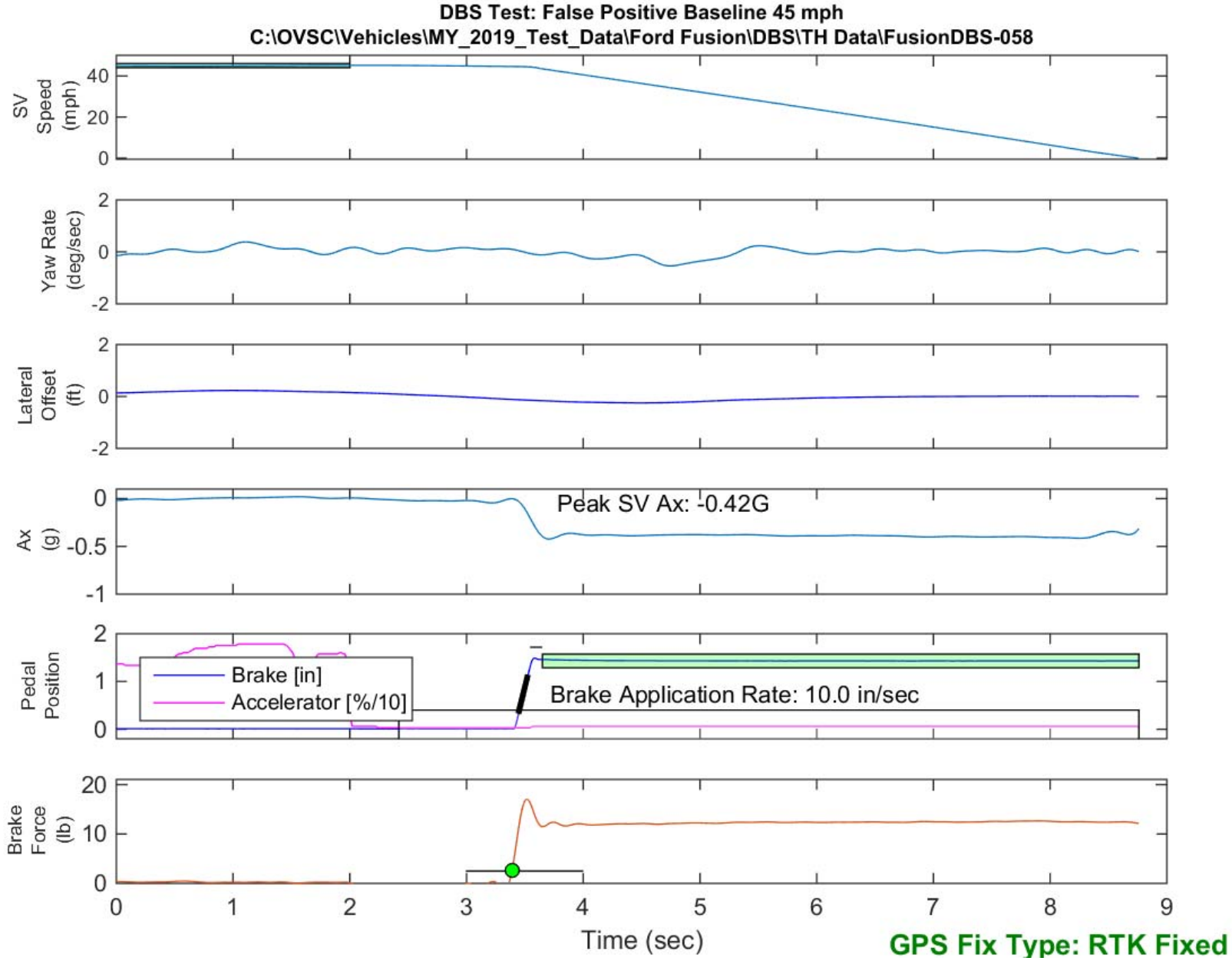

Figure E49. Time History for DBS Run 58, False Positive Baseline, SV 45 mph

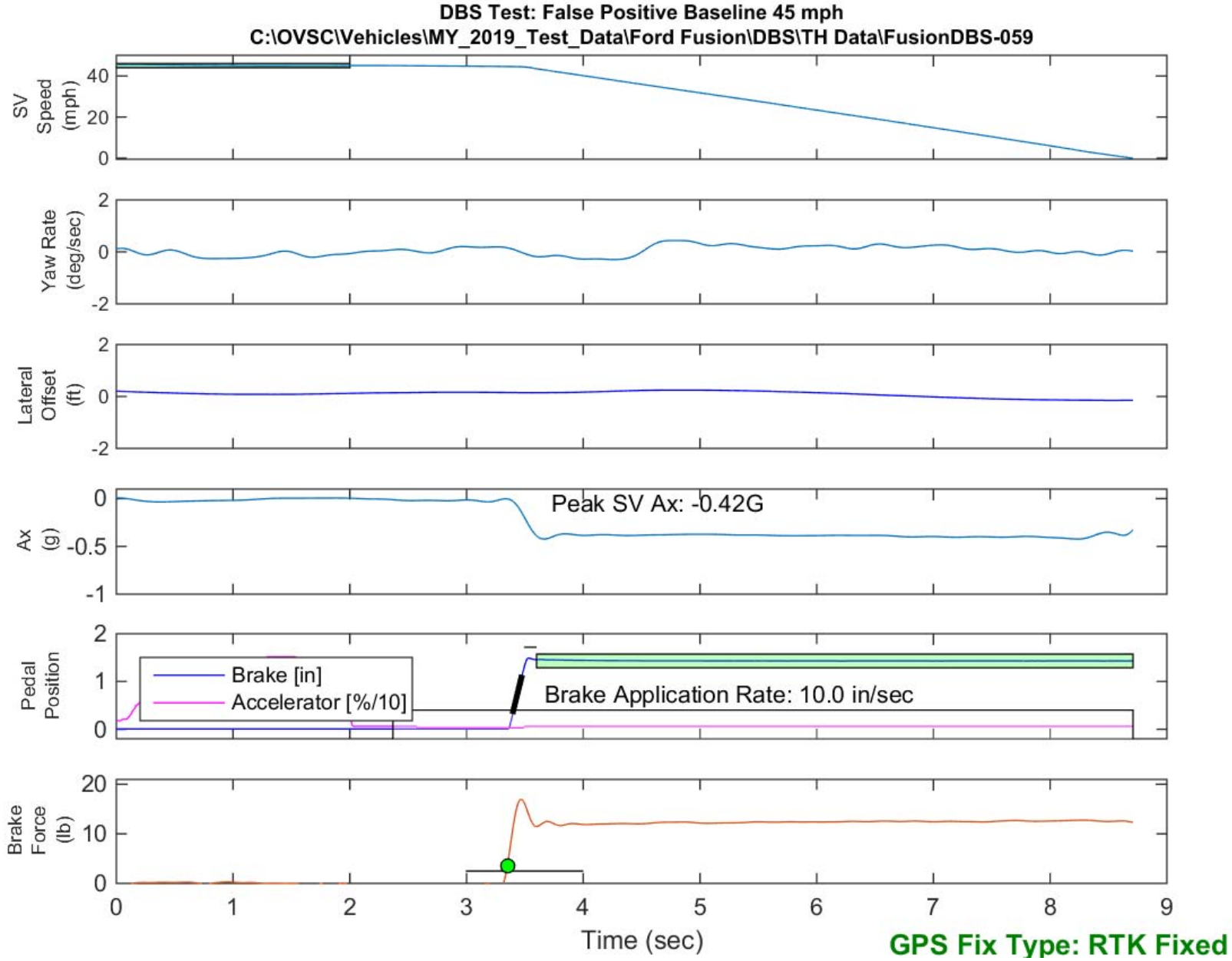

Figure E50. Time History for DBS Run 59, False Positive Baseline, SV 45 mph

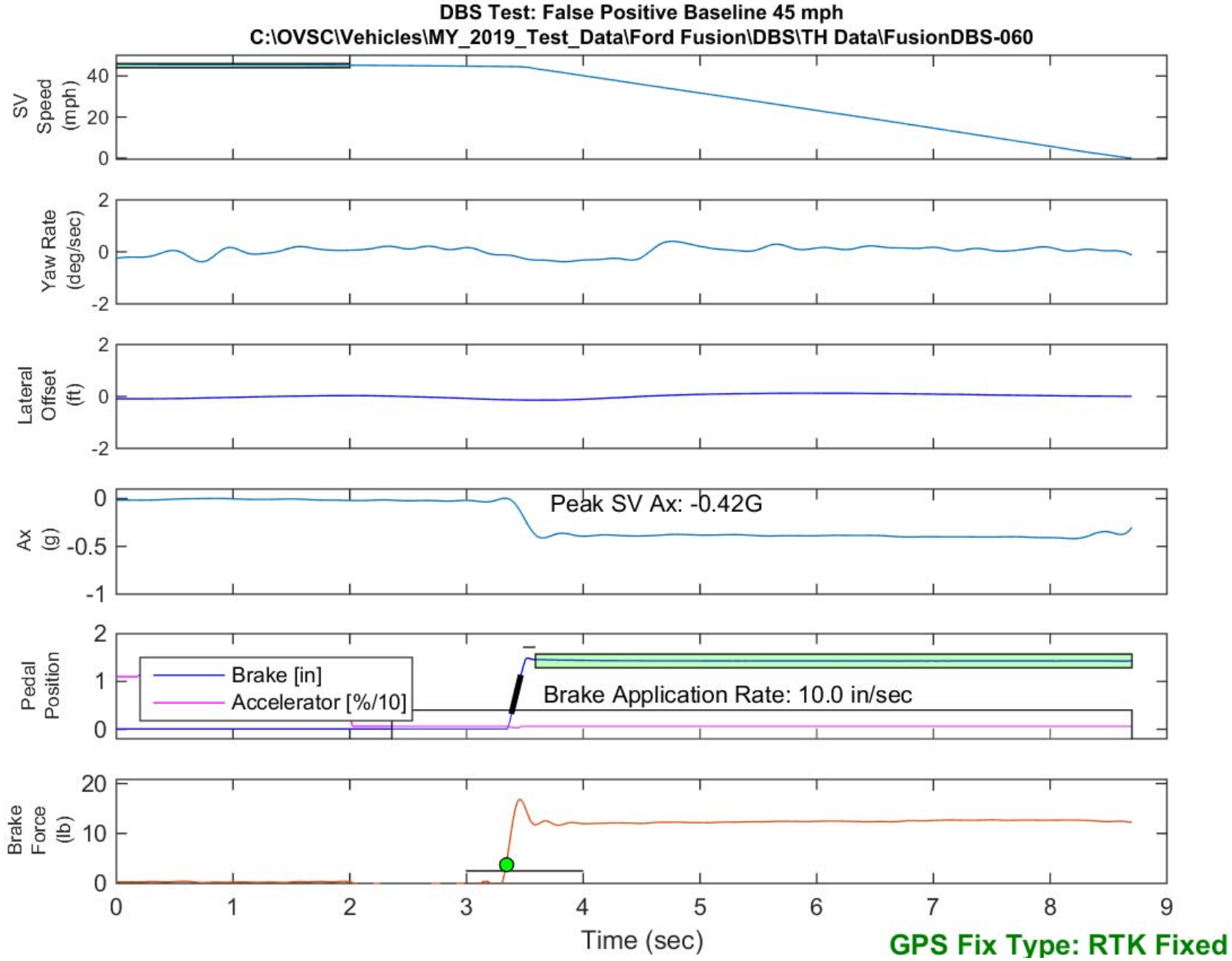

Figure E51. Time History for DBS Run 60, False Positive Baseline, SV 45 mph

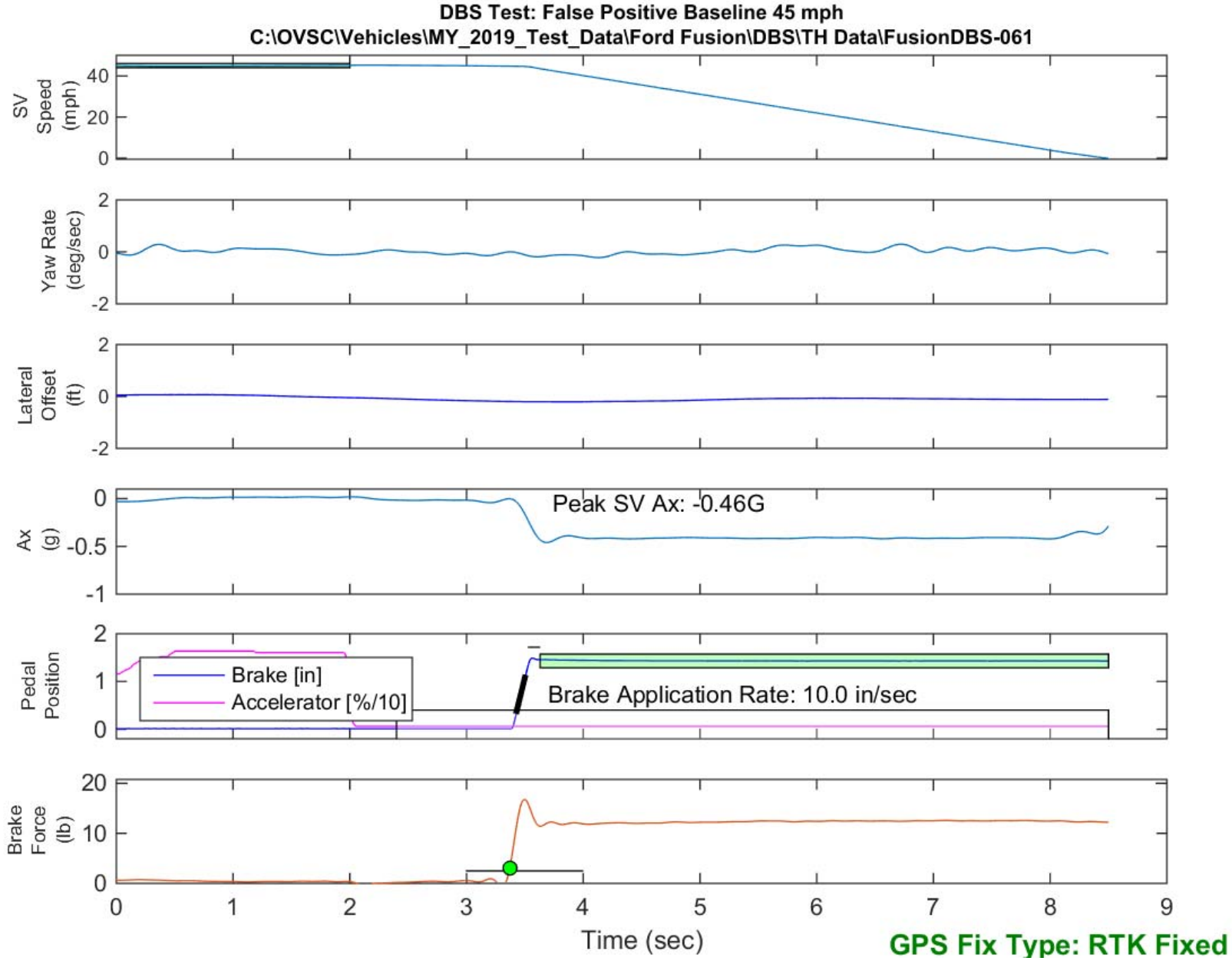

Figure E52. Time History for DBS Run 61, False Positive Baseline, SV 45 mph

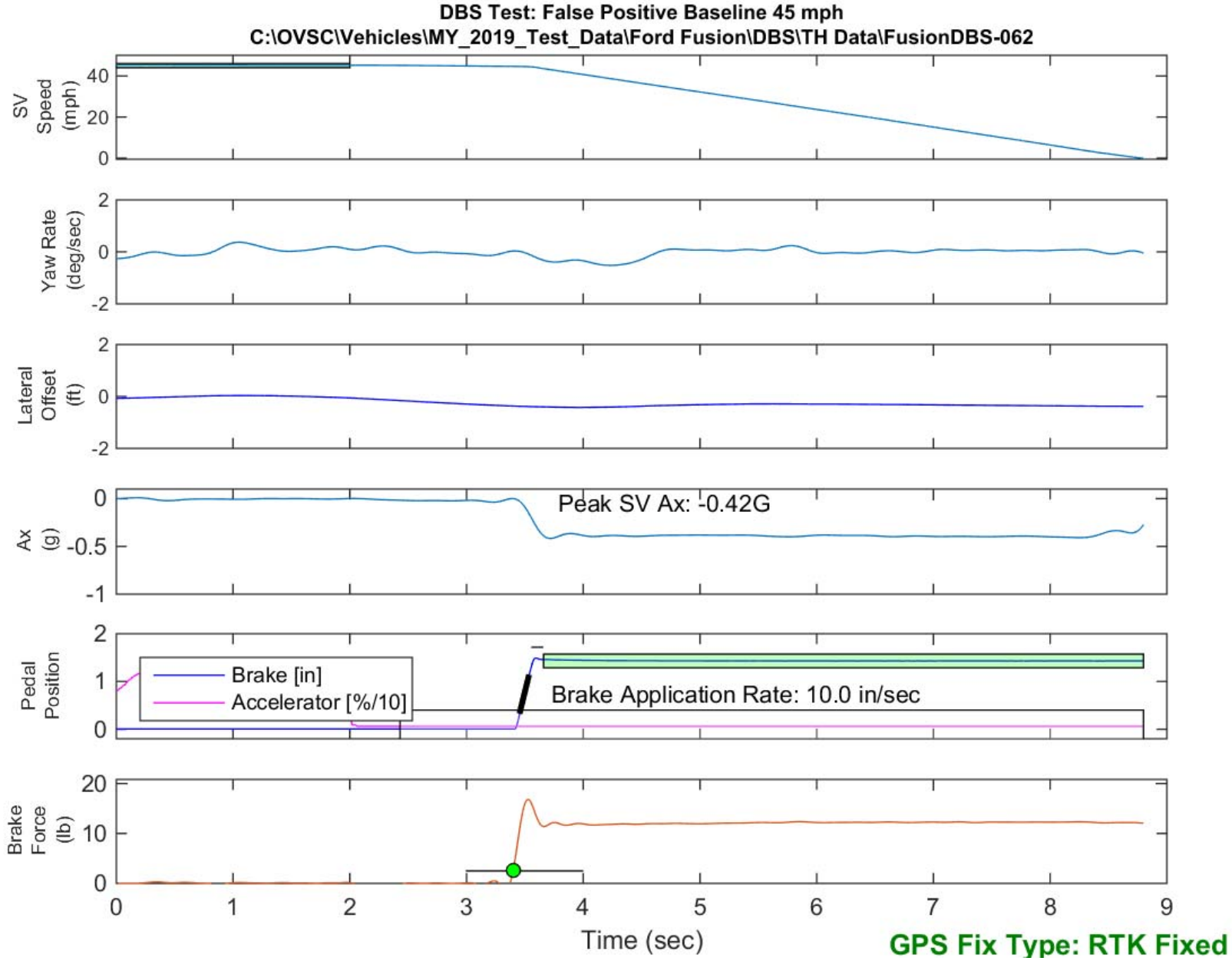

Figure E53. Time History for DBS Run 62, False Positive Baseline, SV 45 mph

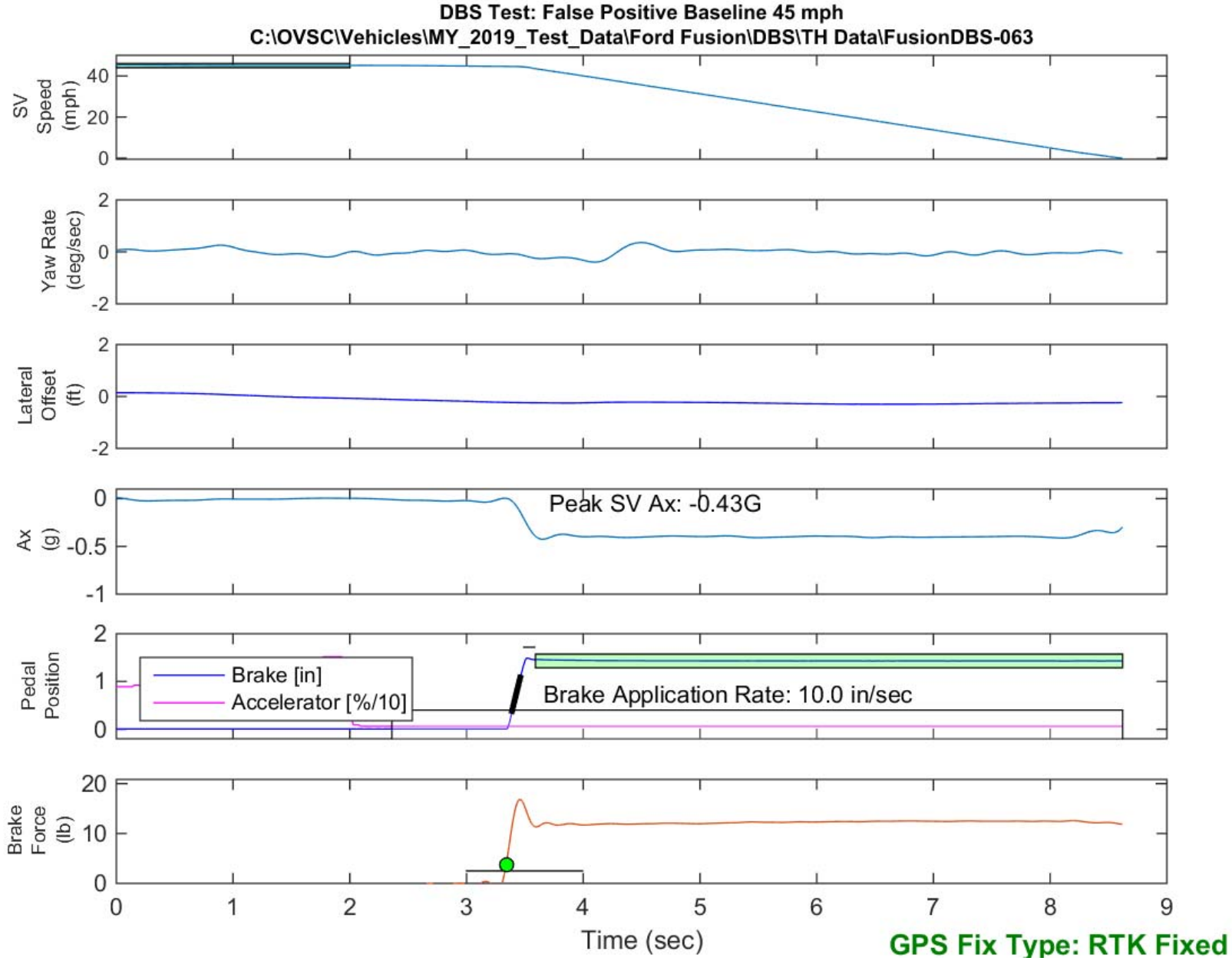

Figure E54. Time History for DBS Run 63, False Positive Baseline, SV 45 mph

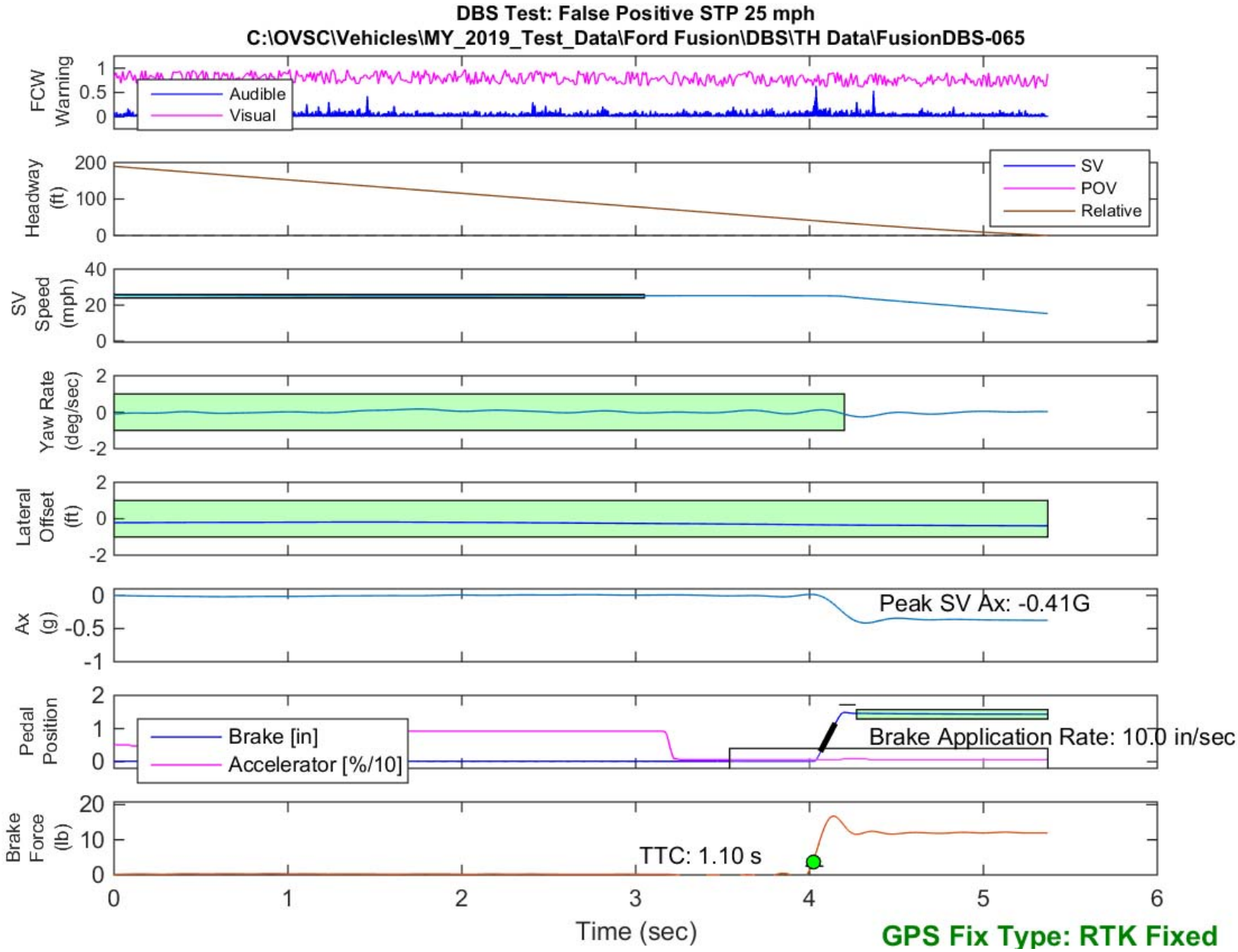

Figure E55. Time History for DBS Run 65, SV Encounters Steel Trench Plate, SV 25 mph

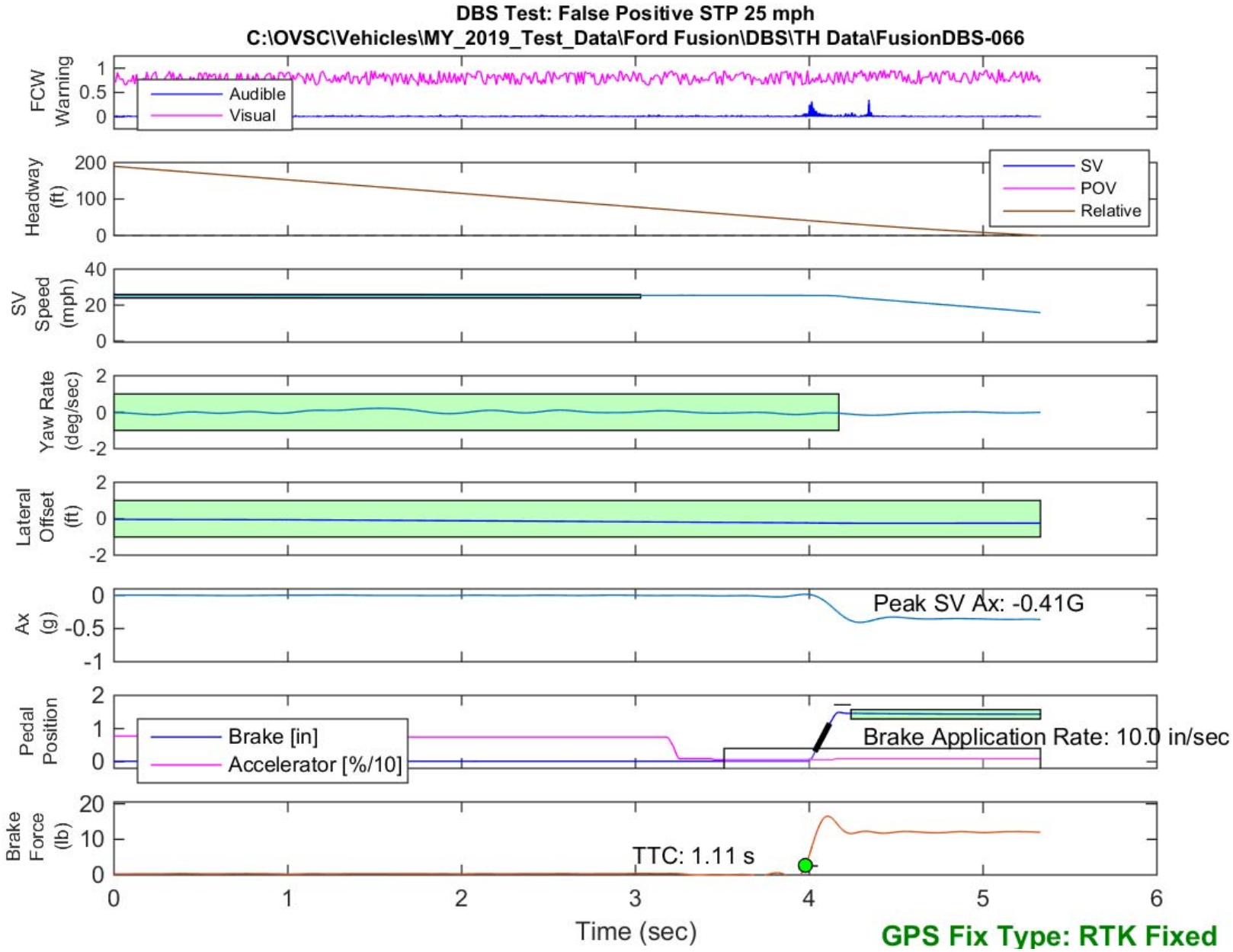

Figure E56. Time History for DBS Run 66, SV Encounters Steel Trench Plate, SV 25 mph

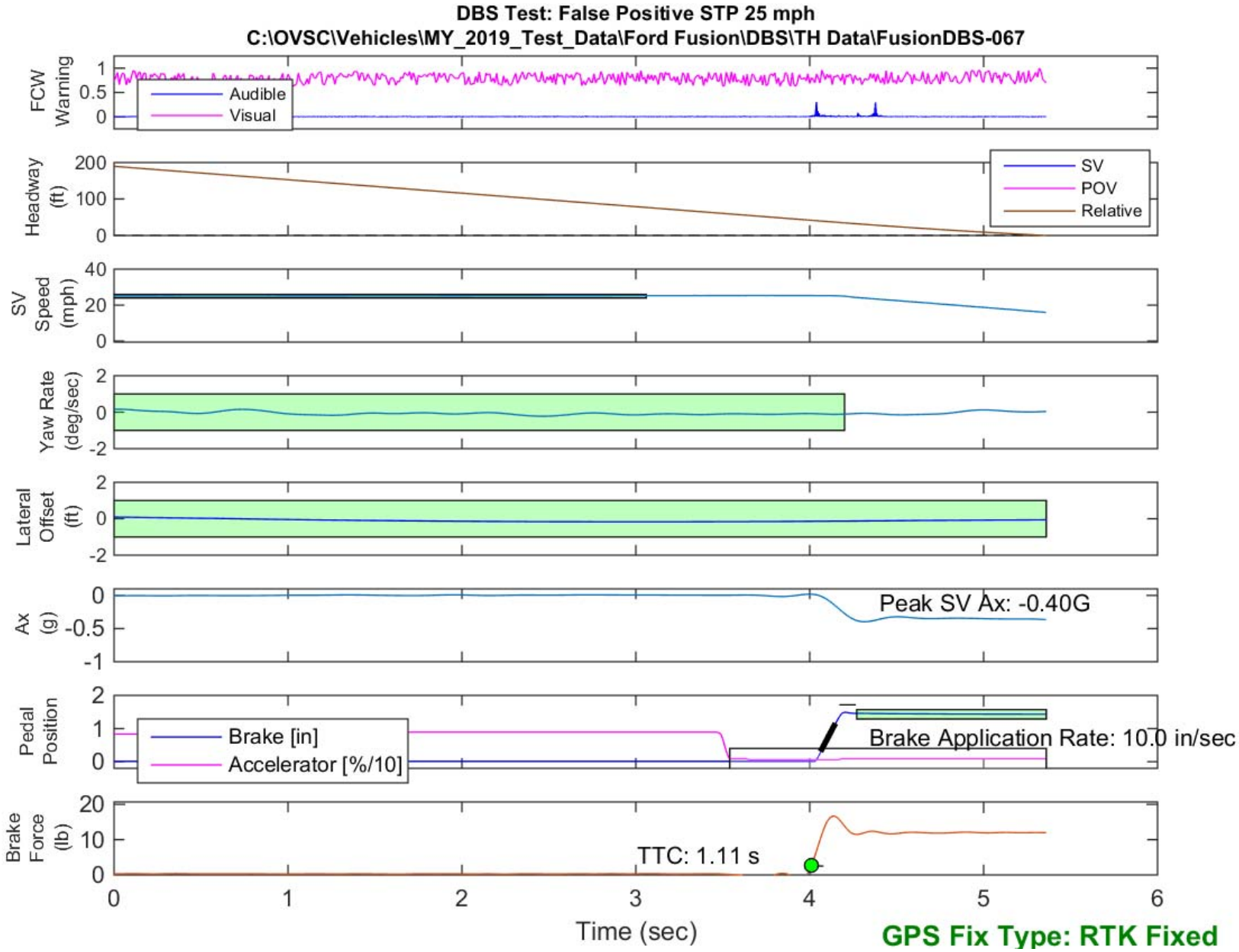

Figure E57. Time History for DBS Run 67, SV Encounters Steel Trench Plate, SV 25 mph

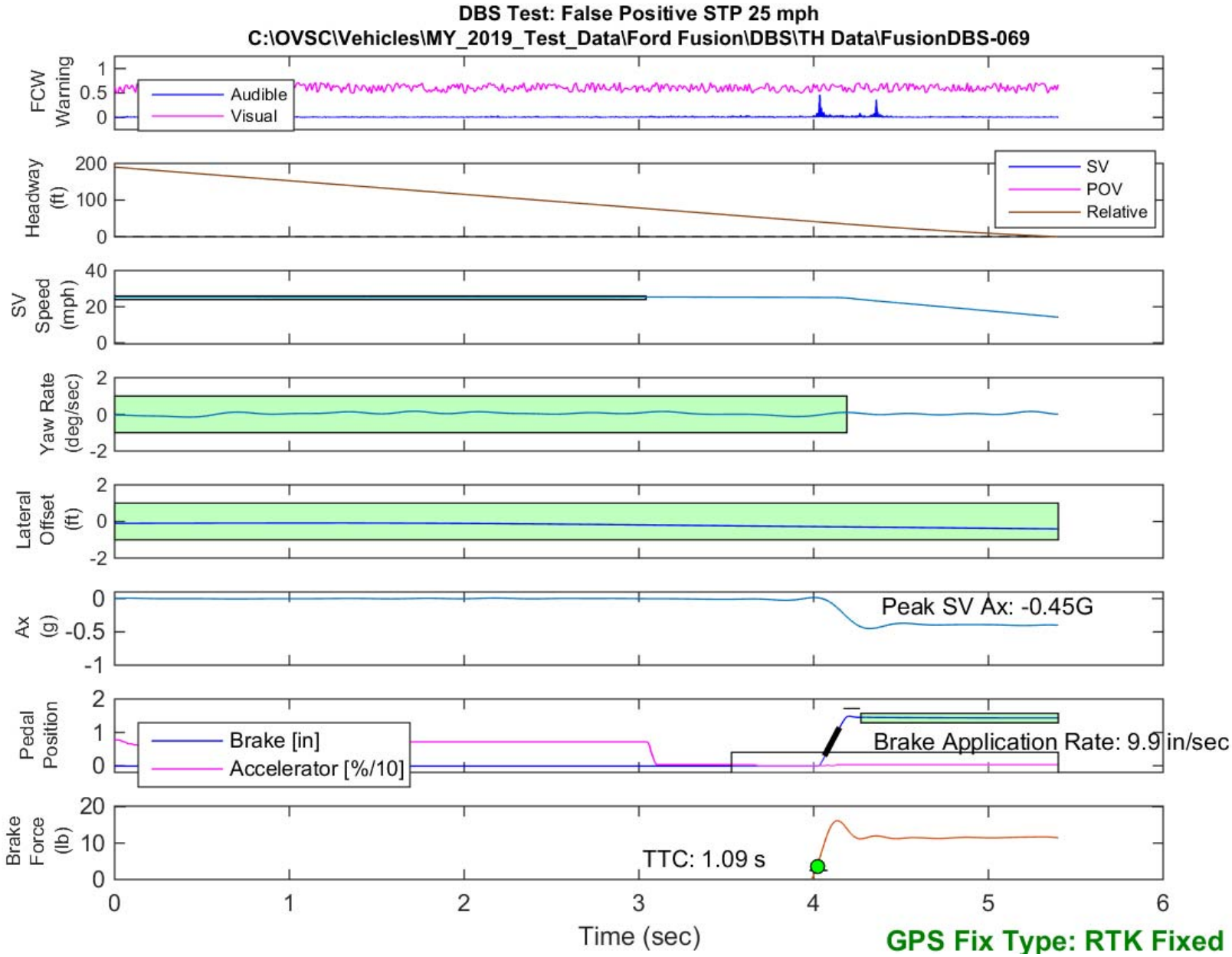

Figure E58. Time History for DBS Run 69, SV Encounters Steel Trench Plate, SV 25 mph

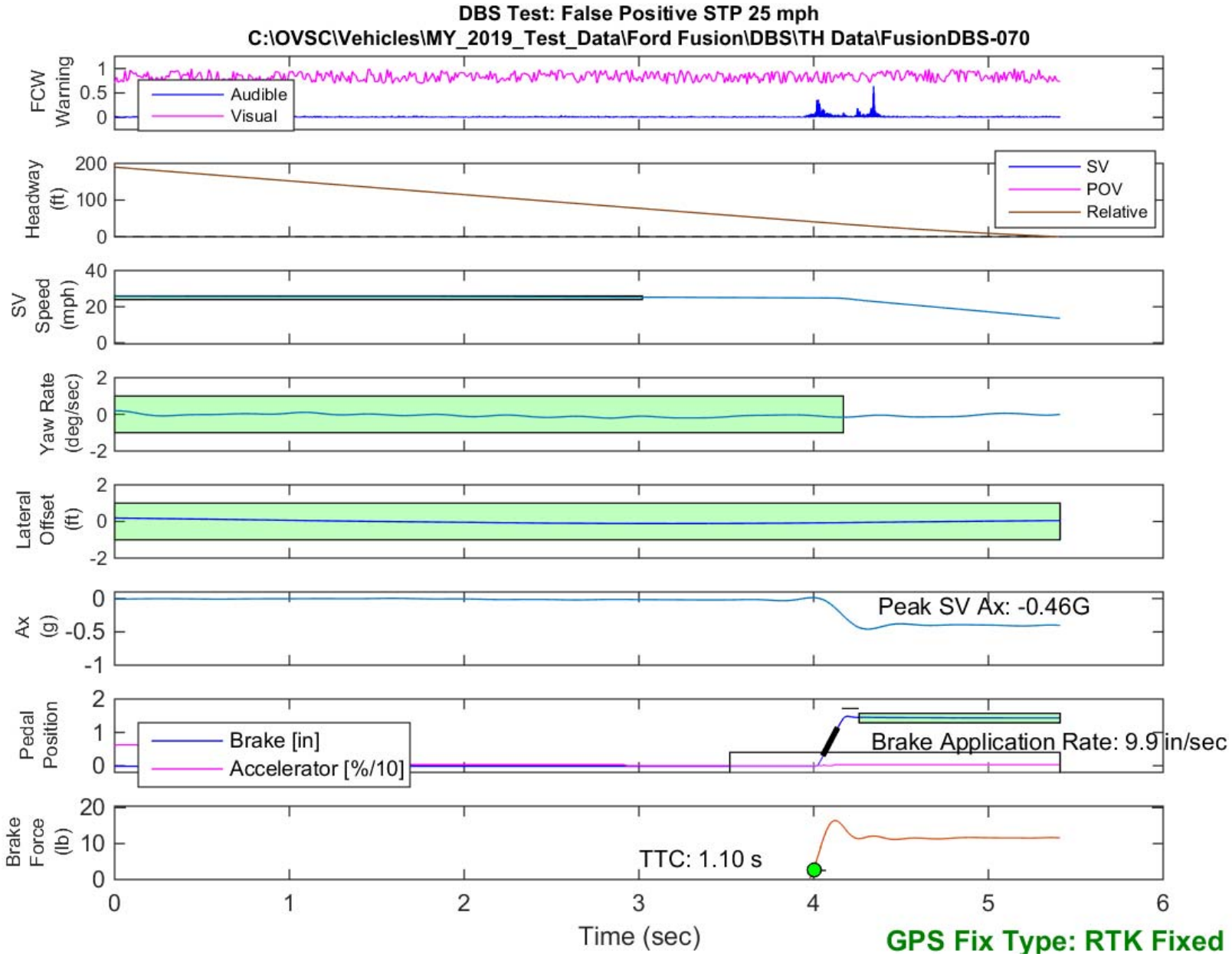

Figure E59. Time History for DBS Run 70, SV Encounters Steel Trench Plate, SV 25 mph

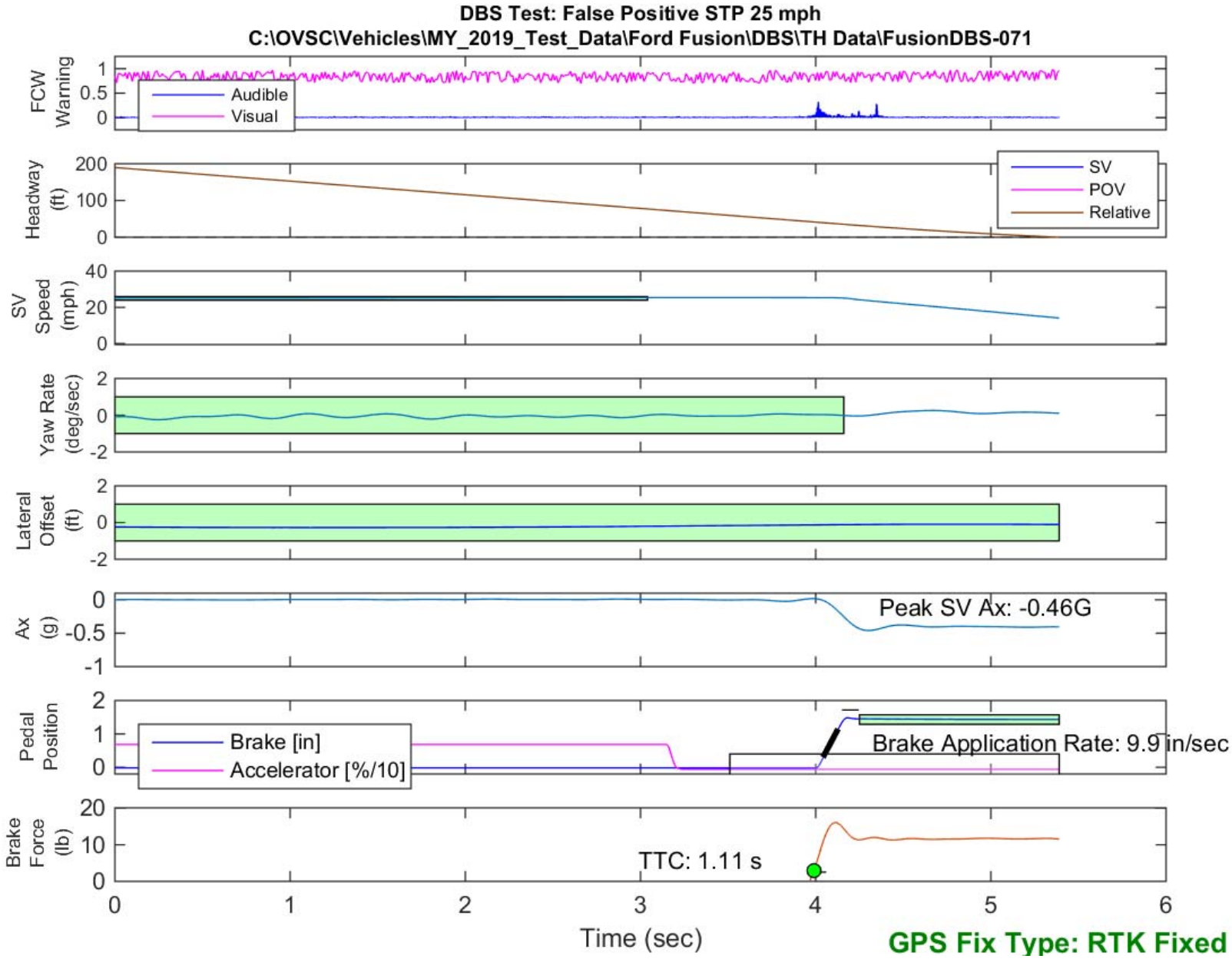

Figure E60. Time History for DBS Run 71, SV Encounters Steel Trench Plate, SV 25 mph

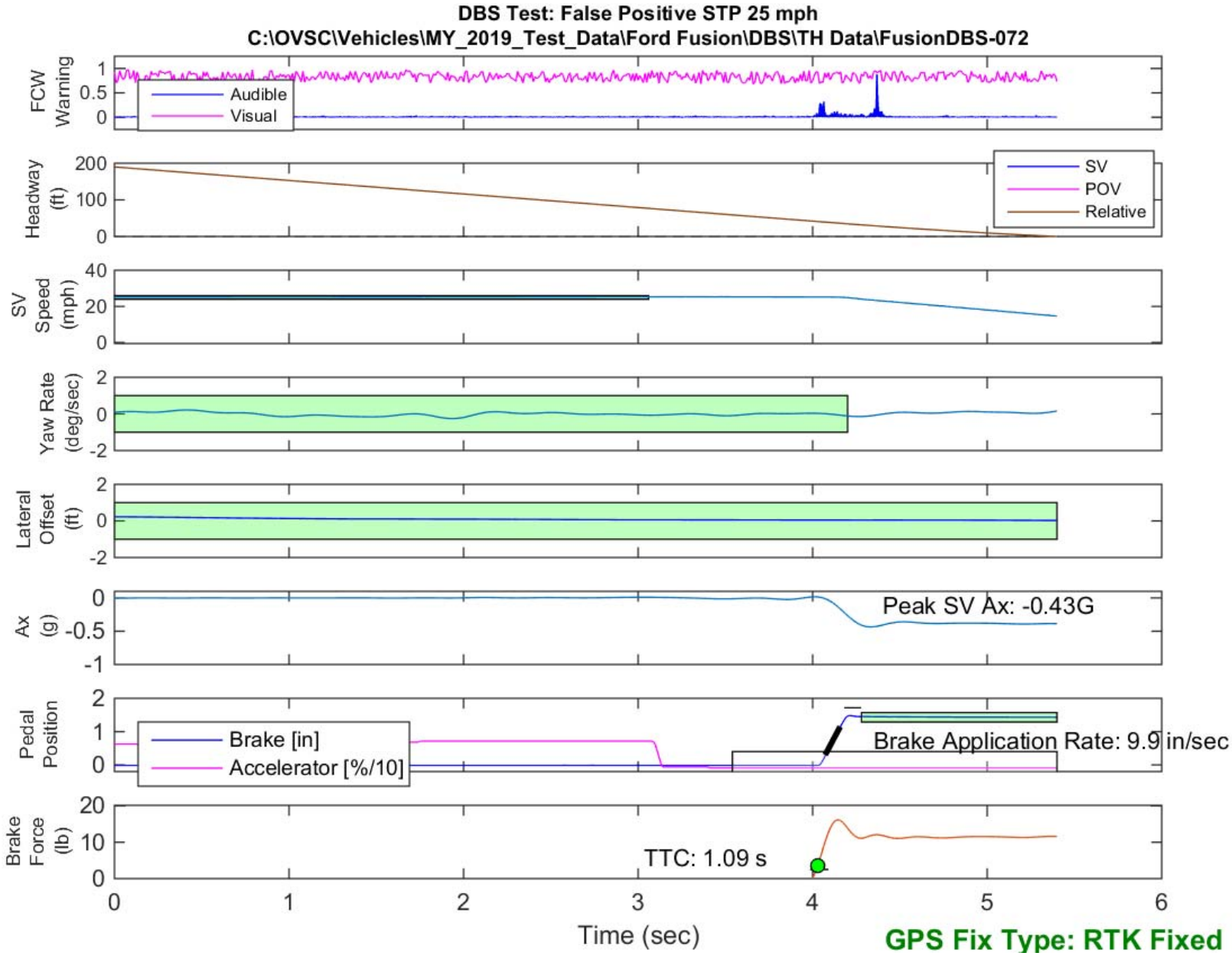

Figure E61. Time History for DBS Run 72, SV Encounters Steel Trench Plate, SV 25 mph

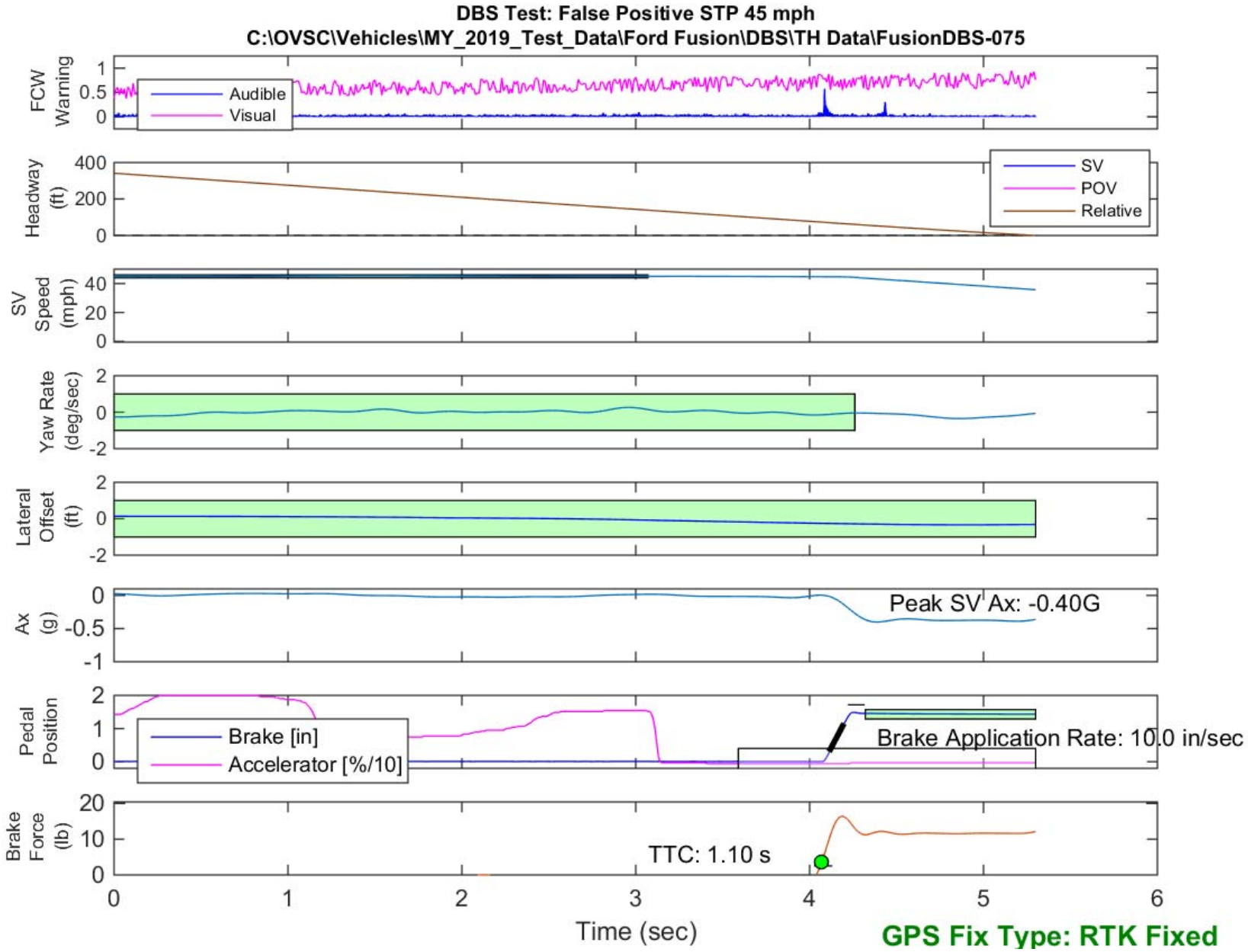

Figure E62. Time History for DBS Run 75, SV Encounters Steel Trench Plate, SV 45 mph

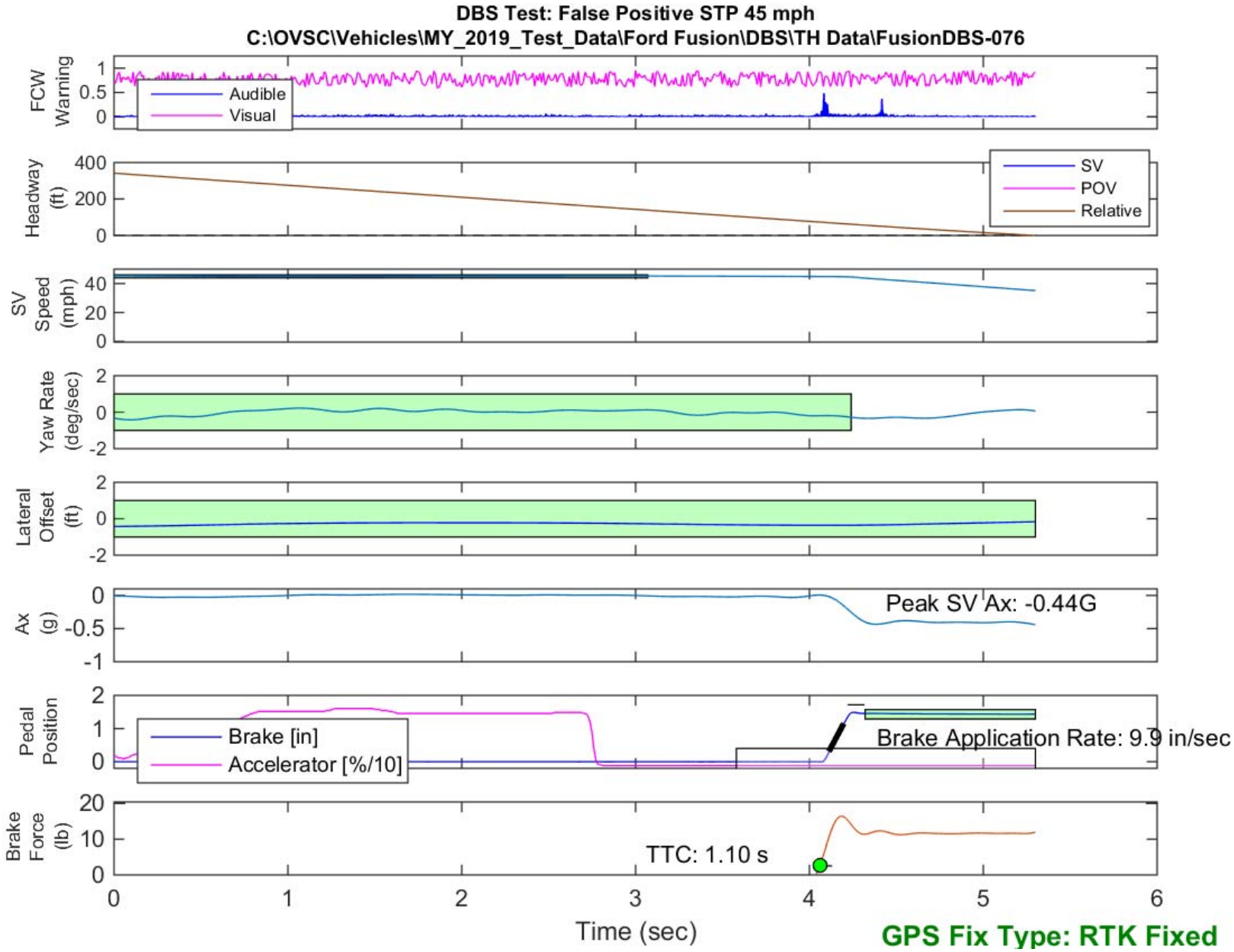

Figure E63. Time History for DBS Run 76, SV Encounters Steel Trench Plate, SV 45 mph

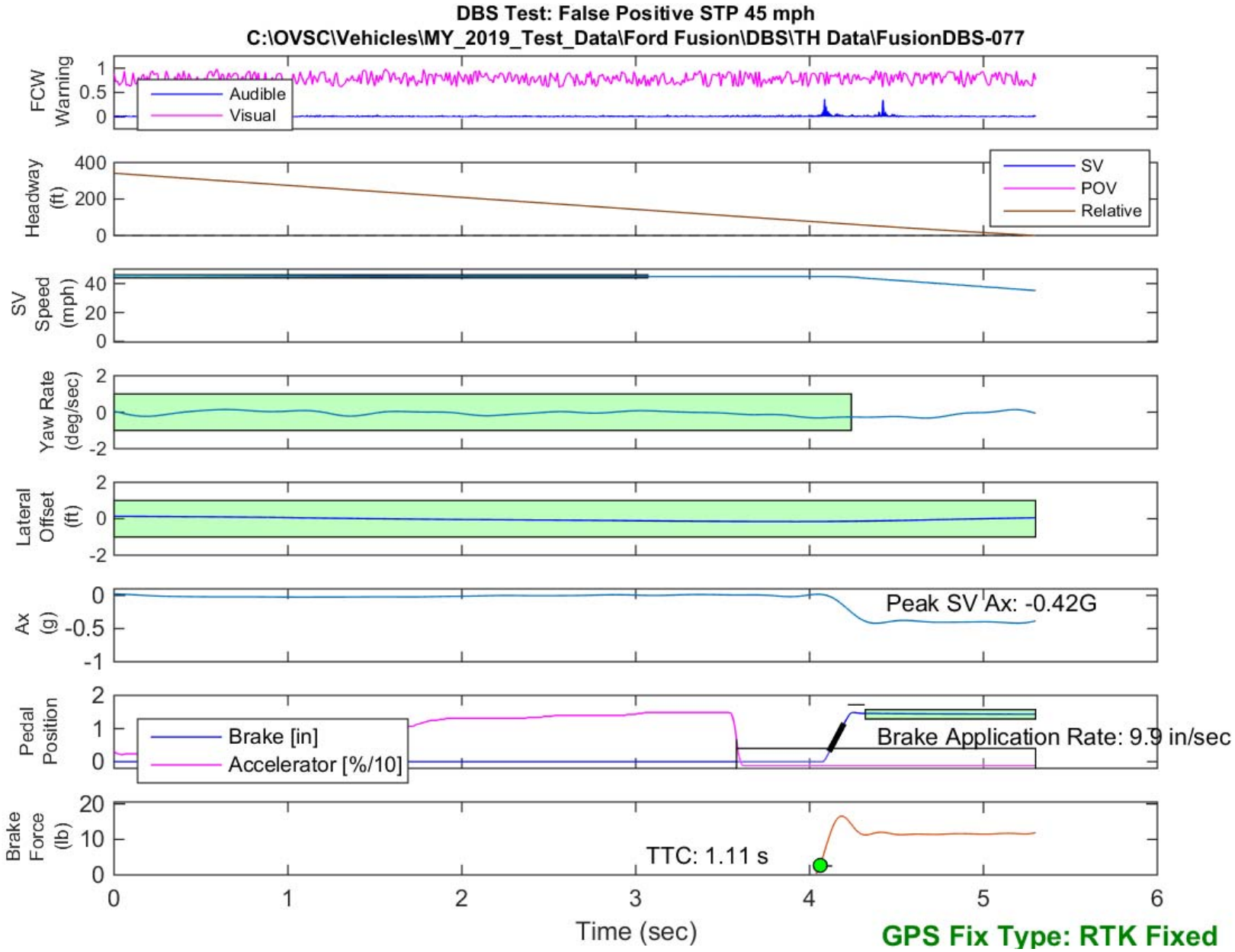

Figure E64. Time History for DBS Run 77, SV Encounters Steel Trench Plate, SV 45 mph

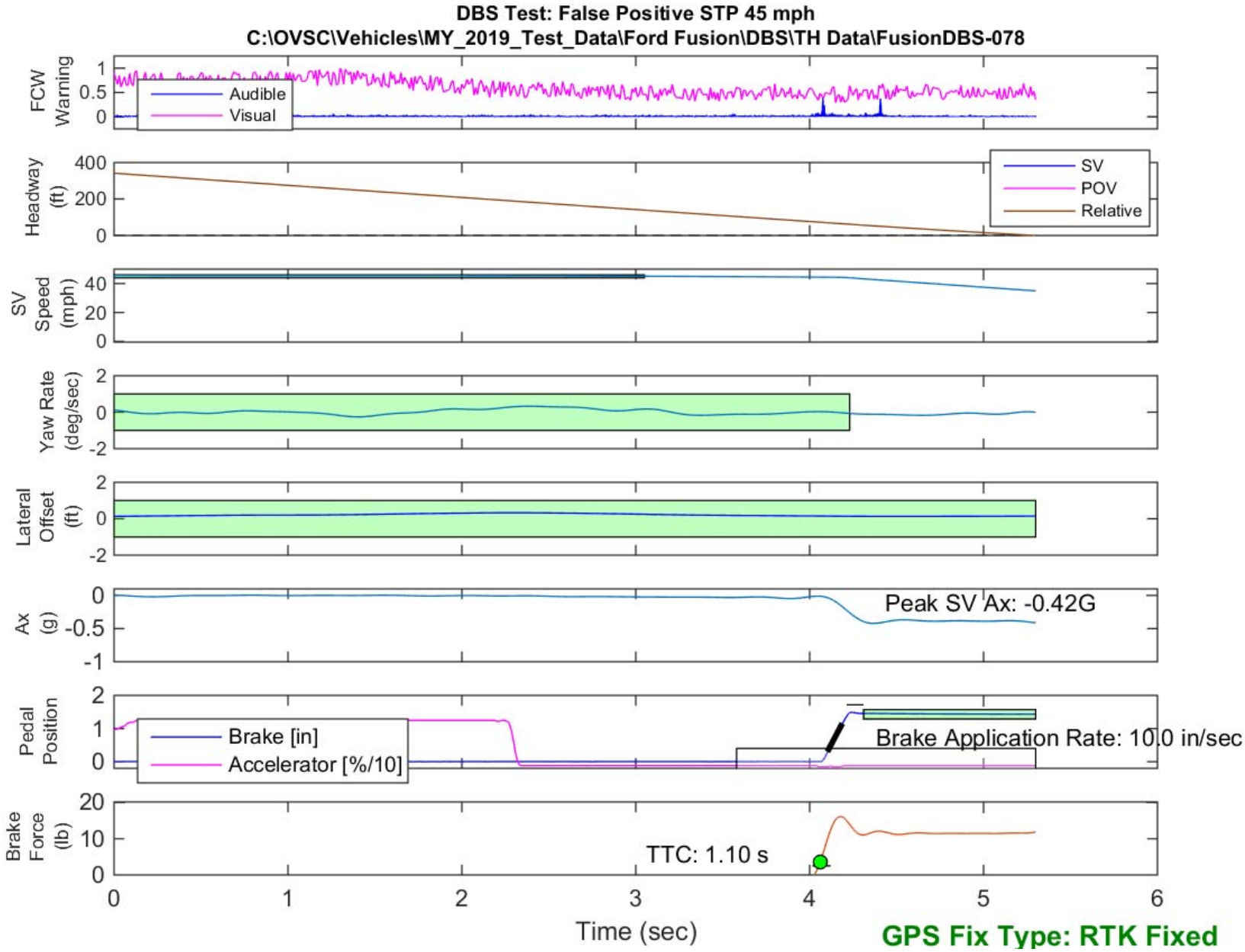

Figure E65. Time History for DBS Run 78, SV Encounters Steel Trench Plate, SV 45 mph

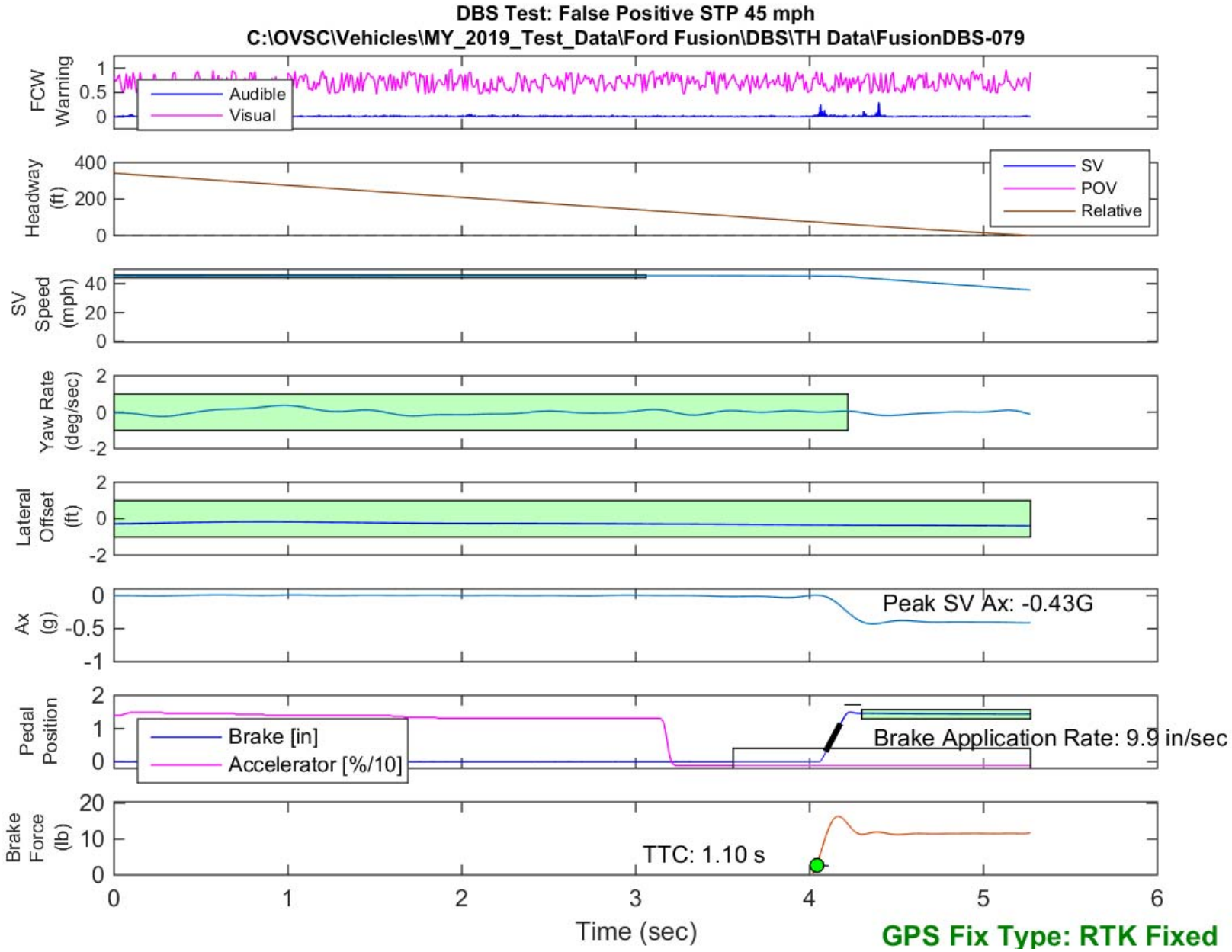

Figure E66. Time History for DBS Run 79, SV Encounters Steel Trench Plate, SV 45 mph

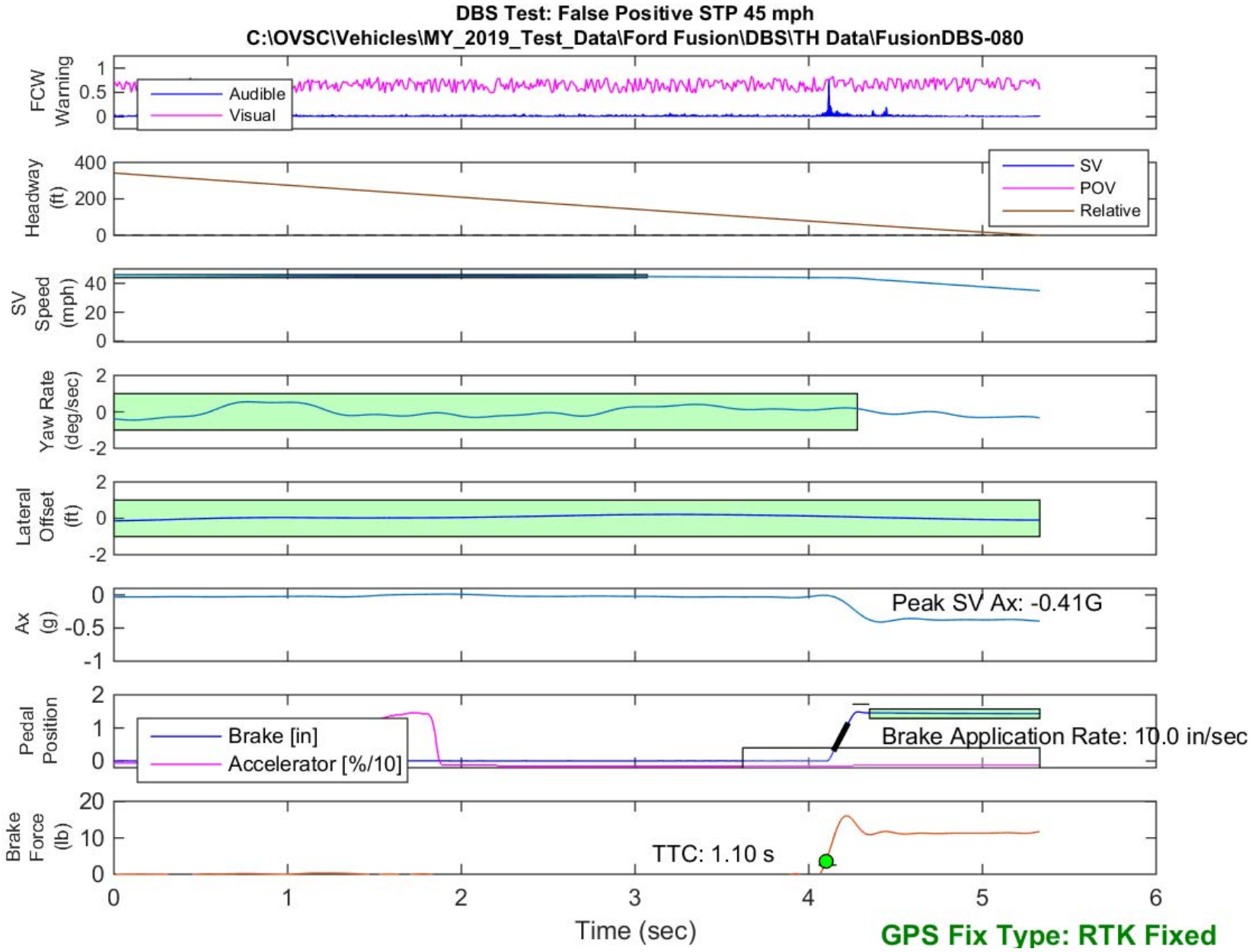

Figure E67. Time History for DBS Run 80, SV Encounters Steel Trench Plate, SV 45 mph

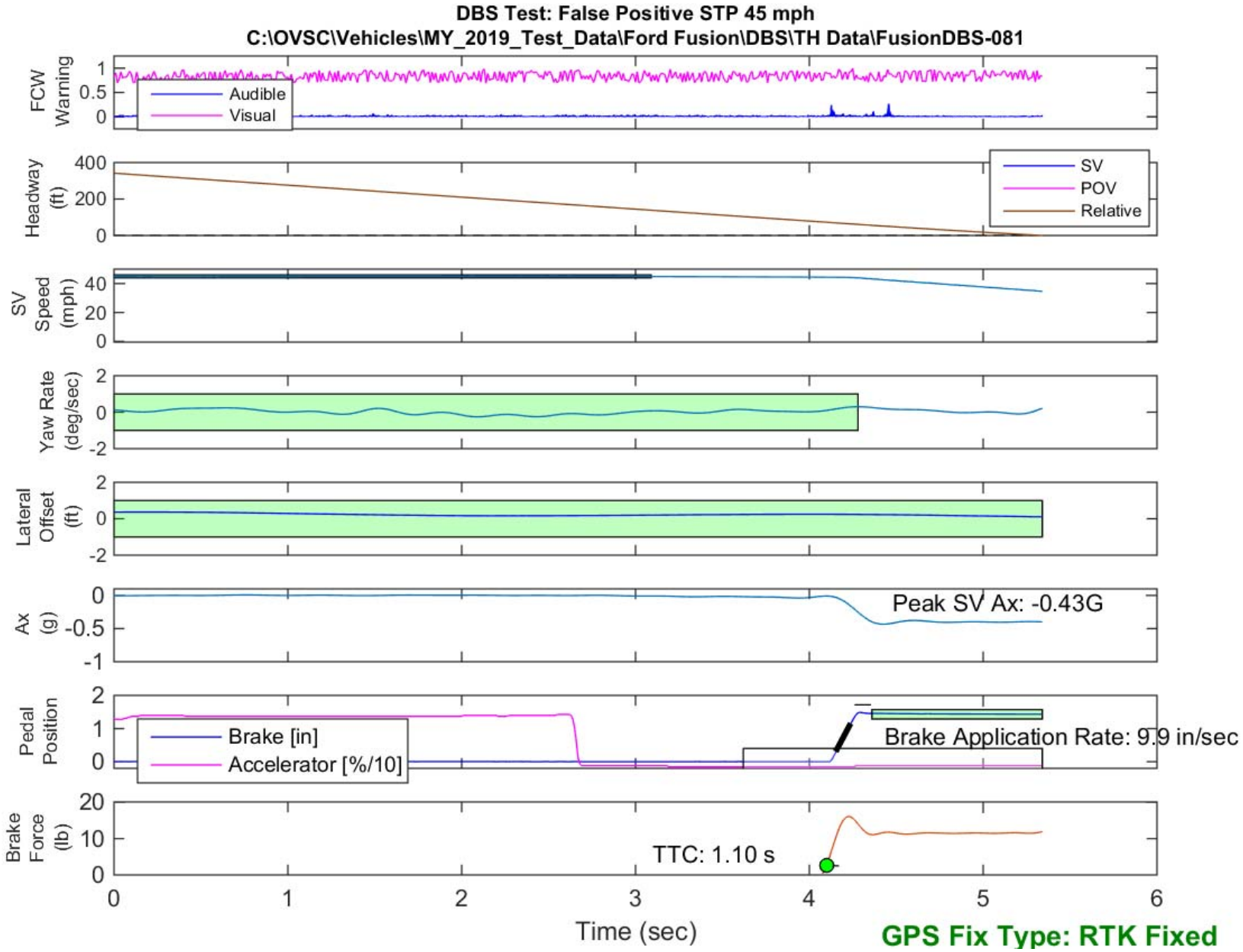

Figure E68. Time History for DBS Run 81, SV Encounters Steel Trench Plate, SV 45 mph

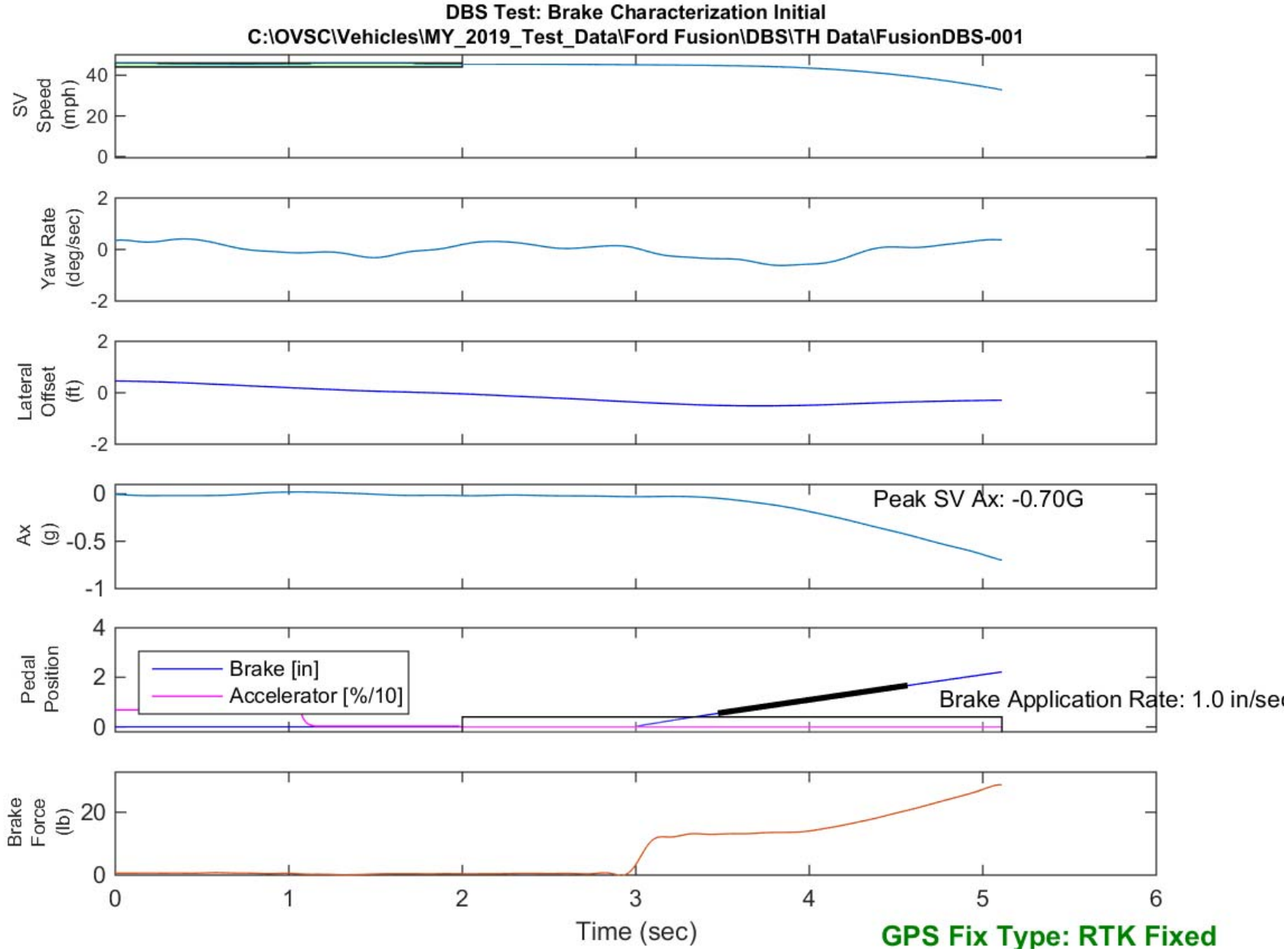

Figure E69. Time History for DBS Run 1, Brake Characterization Initial

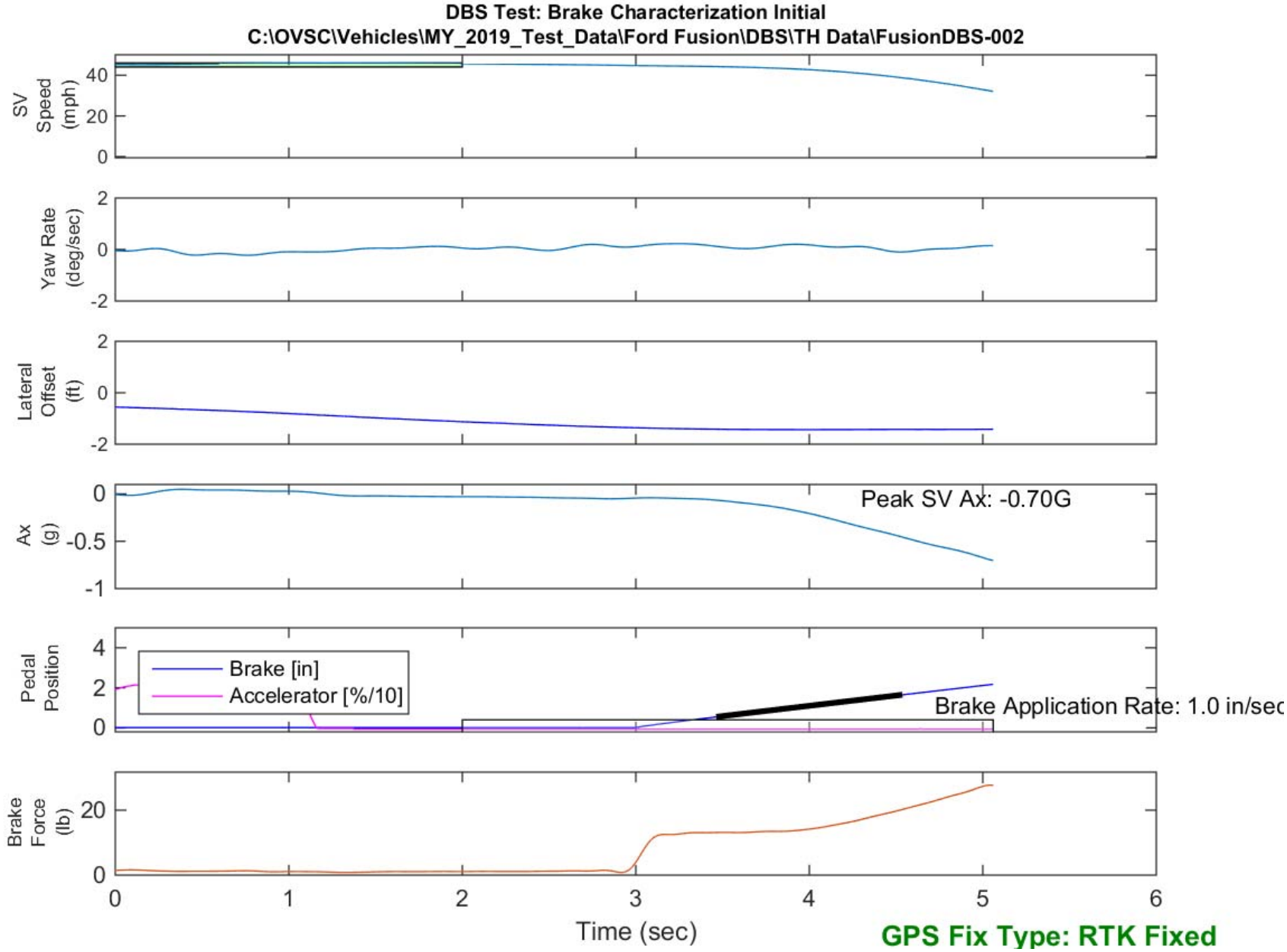

Figure E70. Time History for DBS Run 2, Brake Characterization Initial

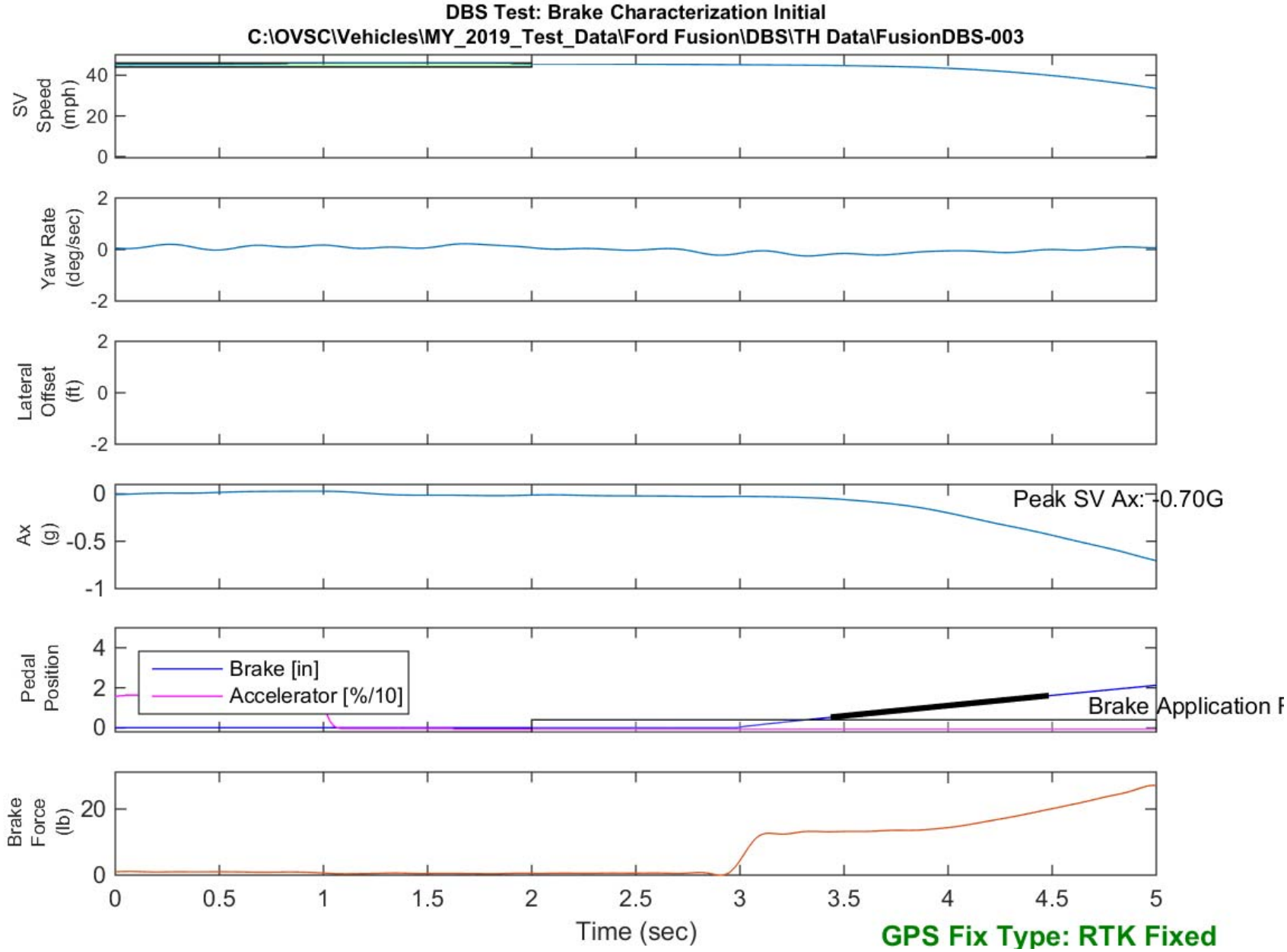

Figure E71. Time History for DBS Run 3, Brake Characterization Initial

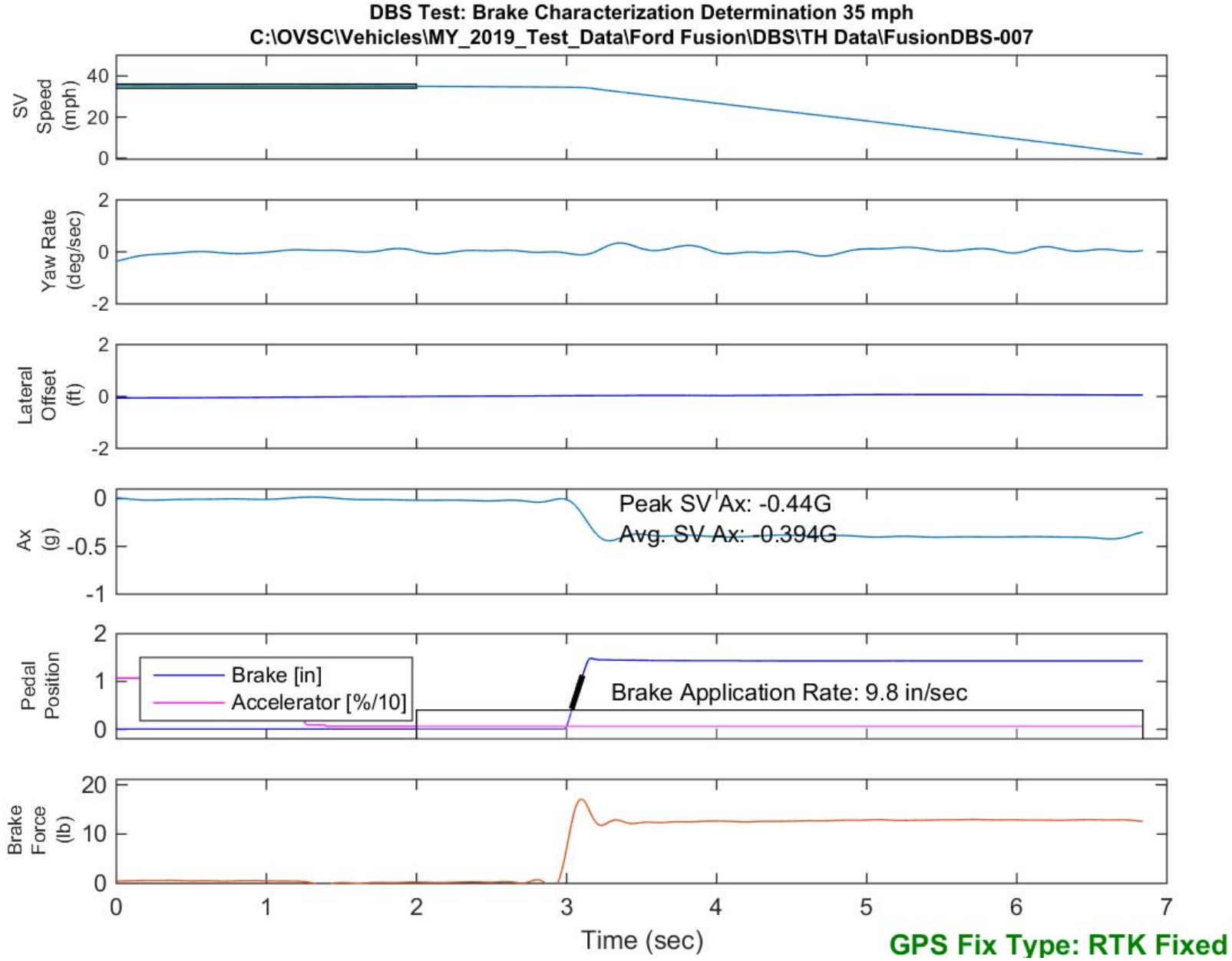

Figure E72. Time History for DBS Run 7, Brake Characterization Determination 35 mph

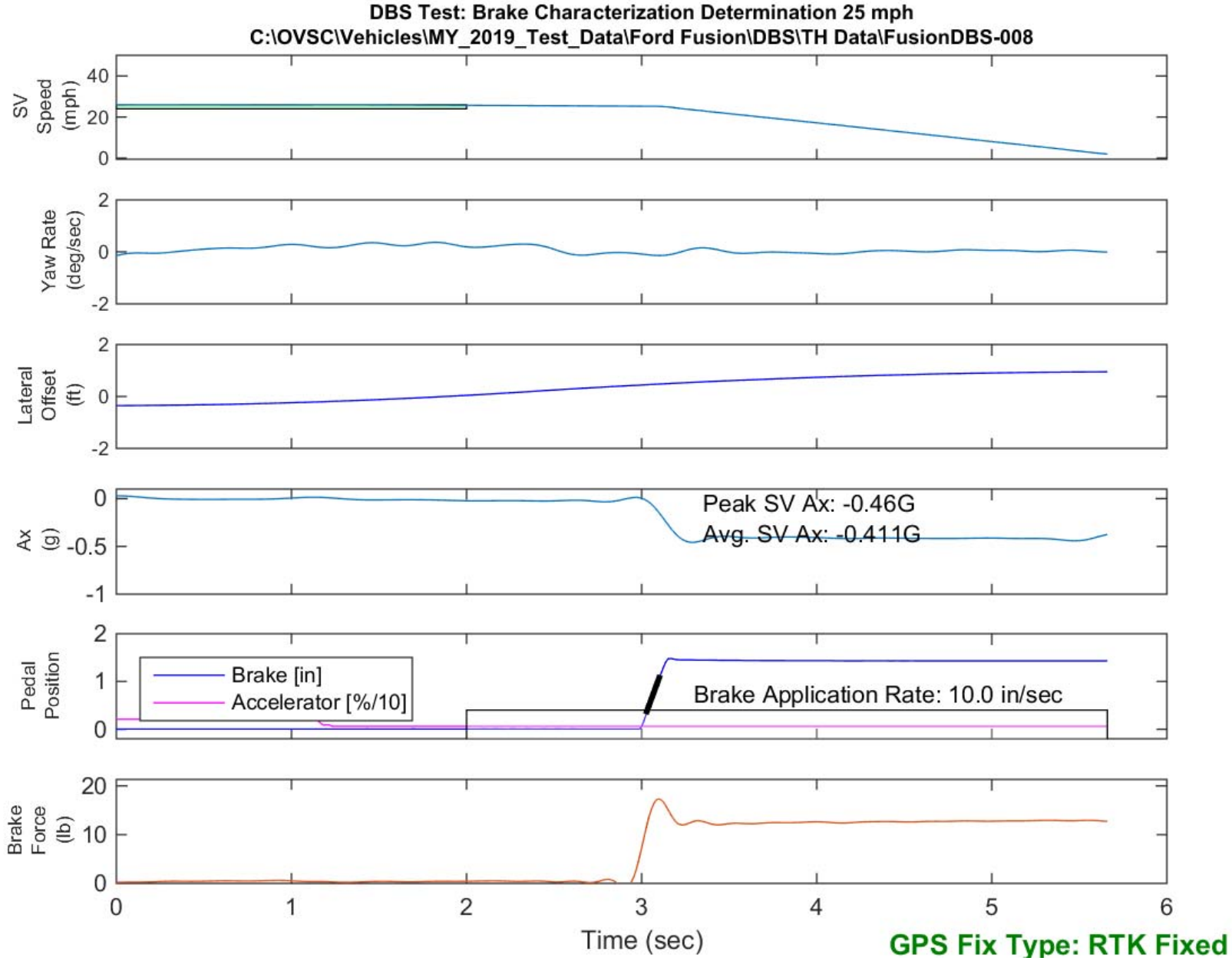

Figure E73. Time History for DBS Run 8, Brake Characterization Determination 25 mph

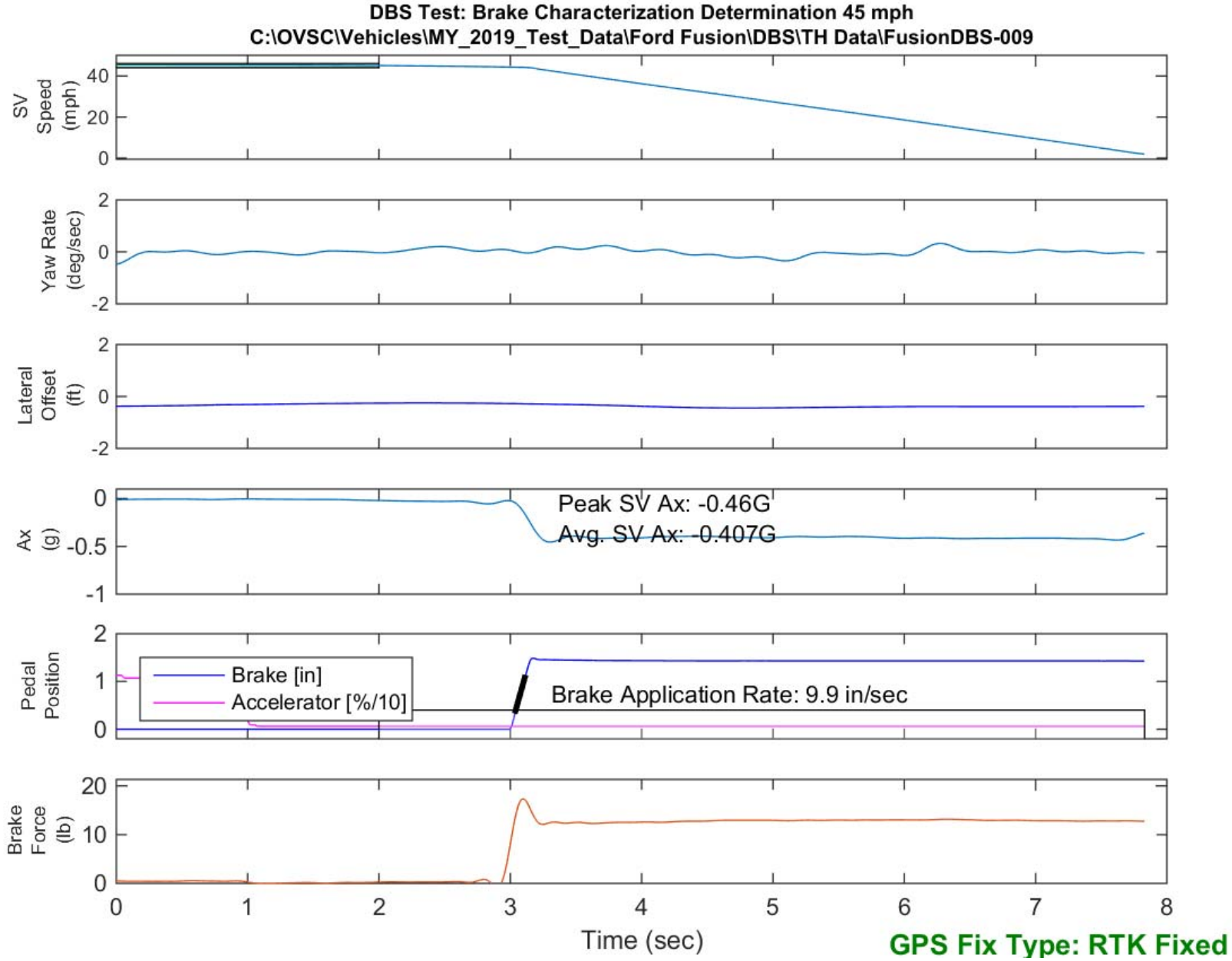

Figure E74. Time History for DBS Run 9, Brake Characterization Determination 45 mph