

**OCAS-DRI-DBS-19-23
NEW CAR ASSESSMENT PROGRAM
DYNAMIC BRAKE SUPPORT CONFIRMATION TEST**

2019 Toyota Highlander

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12 July 2019

Final Report

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16. Abstract These tests were conducted on the subject 2019 Toyota Highlander 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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TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
I. OVERVIEW AND TEST SUMMARY	1
II. DATA SHEETS	2
A. Data Sheet 1: Test Summary.....	3
B. Data Sheet 2: Vehicle Data.....	4
C. Data Sheet 3: Test Conditions	6
D. Data Sheet 4: Dynamic Brake Support System Operation.....	8
III. TEST PROCEDURES.....	13
A. Test Procedure Overview.....	13
B. General Information.....	18
C. Principal Other Vehicle.....	21
D. Foundation Brake System Characterization.....	22
E. Brake Control.....	23
F. Instrumentation.....	24
Appendix A Photographs	A-1
Appendix B Excerpts from Owner's Manual.....	B-1
Appendix C Run Logs	C-1
Appendix D Brake Characterization.....	D-1
Appendix E Time Histories.....	E-1

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 Toyota Highlander. 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

(Page 1 of 1)

2019 Toyota Highlander

SUMMARY RESULTS

VIN: 5TDZARFH7KS0xxxx

Test Date: 1/16/2019

**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 Toyota Highlander

TEST VEHICLE INFORMATION

VIN: 5TDZARFH7KS0xxxx

Body Style: SUV

Color: Blizzard Pearl

Date Received: 1/2/2019

Odometer Reading: 4 mi

Engine: 2.7 L Inline 4

Transmission: Automatic

Final Drive: FWD

Is the vehicle equipped with:

ABS	<u>X</u>	Yes	<u> </u>	No
Adaptive Cruise Control	<u>X</u>	Yes	<u> </u>	No
Collision Mitigating Brake System	<u>X</u>	Yes	<u> </u>	No

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: Toyota Motor Manufacturing, Indiana, Inc.

Date of manufacture: 10/18

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: 245/60R18

Rear: 245/60R18

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 Toyota Highlander

TIRES

Tire manufacturer and model: Michelin Latitude Tour

Front tire size: 245/60R18

Rear tire size: 245/60R18

VEHICLE ACCEPTANCE

Verify the following before accepting the vehicle:

- ☒ All options listed on the “window sticker” are present on the test vehicle
- ☒ Tires and wheel rims are the same as listed.
- ☒ There are no dents or other interior or exterior flaws.
- ☒ The vehicle has been properly prepared and is in running condition.
- ☒ 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 Toyota Highlander

GENERAL INFORMATION

Test date: 1/16/2019

AMBIENT CONDITIONS

Air temperature: 20.0 C (68 F)

Wind speed: 5.1 m/s (11.5 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: 250 kPa (36 psi)

Rear: 250 kPa (36 psi)

DYNAMIC BRAKE SUPPORT
DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2019 Toyota Highlander

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front: 568.4 kg (1253 lb)

Right Front 532.1 kg (1173 lb)

Left Rear 481.3 kg (1061 lb)

Right Rear 450.9 kg (994 lb)

Total: 2032.7 kg (4481 lb)

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 1 of 5)

2019 Toyota Highlander

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

Toyota Safety Sense P (TSS-P), standard

System setting used for test (if applicable):

Far

Brake application mode used for test:

Hybrid control

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

10 km/h (7 mph) (Per manufacturer supplied information)

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

180 km/h (110) mph) (Per manufacturer supplied information)

Does the vehicle system require an initialization sequence/procedure?

_____ Yes

 X No

If yes, please provide a full description.

Sensor calibration is necessary which can be done by the following procedure:

- Driving along the lane marker for more than 1 km with greater than 35 mph driving speed.
- 1 km distance driving is not necessarily continuous driving, but split driving with a total of 1 km distance is OK.
- Lane marker should exist both on sides (left and right) and it does not matter whether it is solid line or dotted line.
- It is ideal to put several vehicles (2-3 vehicles) beside the driving lane to be detected by camera.
- No sensor calibration completed indication will be displayed to driver.
- Please make sure no "IG OFF" after sensor calibration is completed. If an ignition cycle occurs, sensor calibration needs to be done again.

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 2 of 5)

2019 Toyota Highlander

Will the system deactivate due to repeated DBS activations, impacts or near-misses? ☐ Yes
☒ No

If yes, please provide a full description.

No

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

<input checked="" type="checkbox"/>	Warning light
<input checked="" type="checkbox"/>	Buzzer or audible alarm
<input type="checkbox"/>	Vibration
<input type="checkbox"/>	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.

Light:

Location: In the driver control IP meter (TFT display) and heads-up display (if equipped)

Color: Red and white

Word: "BRAKE"

Sound: Repeated beeping sound

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

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

Default setting at the production plant is "ON" and it can be turned off by the switches on the steering pad. Once it is turned off, "OFF" status will be kept until customer turns ignition on again.

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 3 of 5)

2019 Toyota Highlander

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

If yes, please provide a full description.

In the settings menu on the multi-information display using the steering wheel controls. The settings are Far, Middle, and Near

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

If yes, please provide a full description.

In some situations such as the following, the system may determine that there is a possibility of a frontal collision and operate.

- When passing a vehicle or pedestrian
- When changing lanes while overtaking a preceding vehicle
- When overtaking a preceding vehicle that is changing lanes
- When overtaking a preceding vehicle that is making a left/right turn
- When passing a vehicle in an oncoming lane that is stopped to make a right/left turn
- When driving on a road where relative location to vehicle ahead in an adjacent lane may change, such as on a winding road
- When rapidly closing on a vehicle ahead
- If the front of the vehicle is raised or lowered, such as when the road surface is uneven or undulating
- When approaching objects on the roadside, such as guardrails, utility poles, trees, or walls
- When there is a vehicle, pedestrian, or object by the roadside at the entrance of a curve
- When driving on a narrow path surrounded by a structure, such as in a tunnel or on an iron bridge
- When there is a metal object (manhole cover, steel plate, etc.), steps, or a protrusion on the road surface or roadside

(Continued next page)

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 4 of 5)

2019 Toyota Highlander

- When a crossing pedestrian approaches very close to the vehicle
- When passing through a place with a low structure above the road (low ceiling, traffic sign, etc.)
- When passing under an object (billboard, etc.) at the top of an uphill road
- When rapidly closing on an electric toll gate barrier, parking area barrier, or other barrier that opens and closes
- When using an automatic car wash
- When driving through or under objects that may contact the vehicle, such as thick grass, tree branches, or a banner
- When the vehicle is hit by water, snow, dust, etc. from a vehicle ahead
- When driving through steam or smoke
- When there are patterns or paint on the road or a wall that may be mistaken for a vehicle or pedestrian
- When driving near an object that reflects radio waves, such as a large truck or guardrail
- When driving near a TV tower, broadcasting station, electric power plant, or other location where strong radio waves or electrical noise may be present

In some situations such as the following, a vehicle may not be detected by the radar sensor and camera sensor, preventing the system from operating properly:

- If an oncoming vehicle is approaching your vehicle
- If a vehicle ahead is a motorcycle or bicycle
- When approaching the side or front of a vehicle
- If a preceding vehicle has a small rear end, such as an unloaded truck
- If a preceding vehicle has a low rear end, such as a low bed trailer
- If a vehicle ahead is carrying a load which protrudes past its rear bumper
- If a vehicle ahead has extremely high ground clearance
- If a vehicle ahead is irregularly shaped, such as a tractor or side car

(Continued next page)

DYNAMIC BRAKE SUPPORT

DATA SHEET 4: DYNAMIC BRAKE SUPPORT SYSTEM OPERATION

(Page 5 of 5)

2019 Toyota Highlander

- If the sun or other light is shining directly on a vehicle ahead
- If a vehicle cuts in front of your vehicle or emerges from beside a vehicle
- If a vehicle ahead makes an abrupt maneuver (such as sudden swerving, acceleration or deceleration)
- When suddenly cutting behind a preceding vehicle
- When a vehicle ahead is not directly in front of your vehicle
- When driving in inclement weather such as heavy rain, fog, snow or a sandstorm
- When the vehicle is hit by water, snow, dust, etc. from a vehicle ahead
- When driving through steam or smoke
- When driving in a place where the surrounding brightness changes suddenly, such as at the entrance or exit of a tunnel
- When a very bright light, such as the sun or the headlights of oncoming traffic, shines directly into the camera sensor
- When the surrounding area is dim, such as at dawn or dusk, or while at night or in a tunnel
- After the engine has started the vehicle has not been driven for a certain amount of time
- While making a left/right turn and for a few seconds after making a left/right turn
- While driving on a curve and for a few seconds after driving on a curve
- If your vehicle is skidding
- If the front of the vehicle is raised or lowered
- If the wheels are misaligned
- If a wiper blade is blocking the camera sensor
- The vehicle is wobbling.
- The vehicle is being driven at extremely high speeds.
- When driving on a hill
- If the radar sensor or camera sensor is misaligned

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.

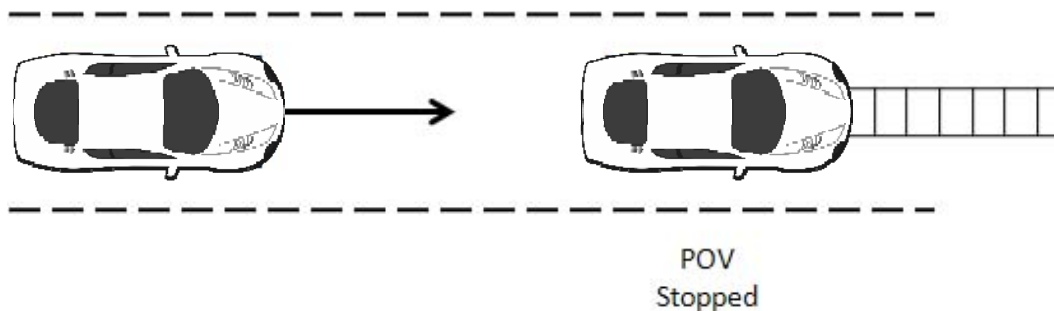


Figure 1. Depiction of Test 1

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.

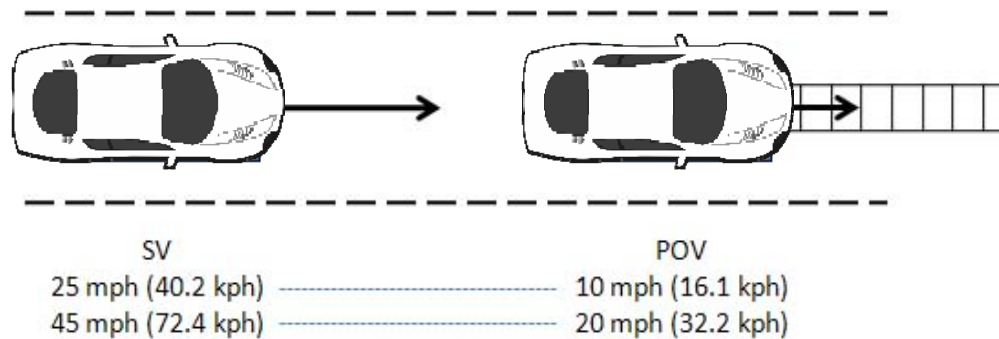


Figure 2. Depiction of Test 2

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 \rightarrow t_{FCW}	110 ft (34 m) \rightarrow 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 \rightarrow t_{FCW}	183 ft (56 m) \rightarrow 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.

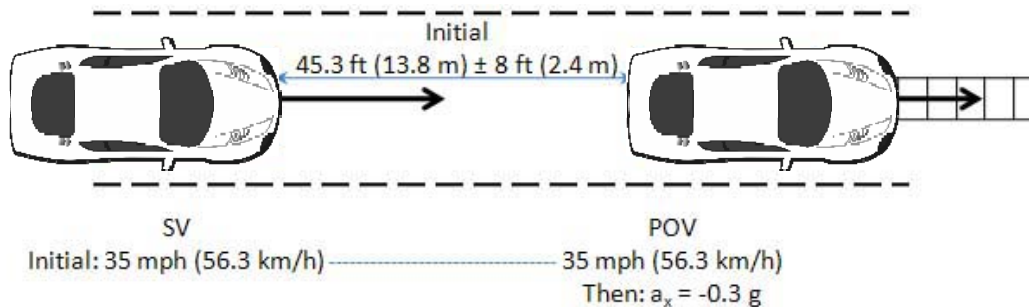


Figure 3. Depiction of Test 3 with POV Decelerating

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) \pm 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 $\rightarrow t_{FCW}$	45 ft (14 m) $\rightarrow t_{FCW}$	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 \pm 5%
Tactile	5 th	3 dB	60 dB	Identified Center Frequency \pm 20%

2. General Validity Criteria

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

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

3. Validity Period

The valid test interval began:

- Test 1: When the SV-to-POV TTC = 5.1 seconds
- Test 2: When the SV-to-POV TTC = 5.0 seconds
- Test 3: 3 seconds before the onset of POV braking
- Test 4: 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;	Accels $\pm 10g$, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +		By: Oxford Technical Solutions
	Lateral, Longitudinal and Vertical Velocities;				2182	Date: 10/16/2017 Due: 10/16/2019
	Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles				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: ± 0.02 m/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)	$\pm 5g$	$\leq 3\%$ 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	± 0.0020 in. ± 0.051 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

	Page
Figure A1. Front View of Subject Vehicle.....	A-3
Figure A2. Rear View of Subject Vehicle.....	A-4
Figure A3. Window Sticker (Monroney Label)	A-5
Figure A4. Vehicle Certification Label.....	A-6
Figure A5. Tire Placard.....	A-7
Figure A6. Rear View of Principal Other Vehicle (SSV).....	A-8
Figure A7. Load Frame/Slider of SSV.....	A-9
Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track.....	A-10
Figure A9. Steel Trench Plate.....	A-11
Figure A10. DGPS, Inertial Measurement Unit and MicroAutoBox Installed in Subject Vehicle.....	A-12
Figure A11. Sensor for Detecting Auditory Alerts.....	A-13
Figure A12. Sensor for Detecting Visual Alerts.....	A-14
Figure A13. Computer Installed in Subject Vehicle.....	A-15
Figure A14. Brake Actuator Installed in Subject System.....	A-16
Figure A15. Brake Actuator Installed in POV System.....	A-17
Figure A16. AEB Visual Alert.....	A-18
Figure A17. AEB Setup Menus.....	A-19
Figure A18. Steering Wheel Mounted Control Buttons for Changing Parameters....	A-20
Figure A19. Steering Wheel Mounted Control Buttons for Setting Range.....	A-21



Figure A1. Front View of Subject Vehicle



Figure A2. Rear View of Subject Vehicle



TOYOTA
Let's Go Places

DESC: **HIGHLANDER** LE - L4 FWD
VIN: **5TDZARFH7KS04**
YR/MDL: 2019/6942A
CLR: BLIZZARD PEARL/20 (0070/20)
FINAL ASSEMBLY POINT: PRINCETON, INDIANA, U.S.A.

GOVERNMENT 5-STAR SAFETY RATINGS

Overall Vehicle Score ★★★★★
Based on the combined ratings of frontal, side and rollover.
Should ONLY be compared to other vehicles of similar size and weight.

Frontal Crash ★★★★★
Driver Passenger
Based on the risk of injury in a frontal impact.
Should ONLY be compared to other vehicles of similar size and weight.

Side Crash ★★★★★
Front seat Rear seat
Based on the risk of injury in a side impact.

Rollover ★★★★★
Based on the risk of rollover in a single-vehicle crash.

Star ratings range from 1 to 5 stars (★★★★★) with 5 being the highest.
Source: National Highway Traffic Safety Administration (NHTSA)
www.safercar.gov or 1-888-327-4236

EPA DOT Fuel Economy and Environment

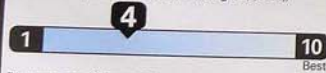
Fuel Economy
22 MPG
20 24
combined city/hwy city highway
4.5 gallons per 100 miles

Small SUVs range from 18 to 37 MPG.
The best vehicle rates 135 MPG.

You spend
\$1,750
more in fuel costs
over 5 years
compared to the
average new vehicle.

Annual fuel cost
\$1,750

Fuel Economy & Greenhouse Gas Rating (tailpipe only)



Smog Rating (tailpipe only)
1 3 10
Best Worst

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 27 MPG and costs \$7,000 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at \$2.55 per gallon. MPGe is miles per gasoline gallon equivalent. Vehicle emissions are a significant cause of climate change and smog.

fuel economy.gov

Calculate personalized estimates and compare vehicles

STANDARD EQUIPMENT

MECHANICAL & PERFORMANCE
- 2.7L D-4Di 4-Cylinder Eng w/Dual VVT-iw
- 6-Speed Auto Transmission
- 1,500-lb Tow Capacity; 185 Horsepower
- Power-Assisted 4-Wheel Disc Brakes
- 18" Alloys w/P245/60R18 Tires
- Temporary Spare

SAFETY & CONVENIENCE
- Toyota Safety Sense P (TSS-P): Includes Pre-Collision System with Pedestrian Detection (PCS w/PD), Lane Departure Alert with Steering Assist (LDA w/SA), Automatic High Beams (AHB) and Dynamic Radar Cruise Control (DRCC)
- 8 Airbags, + Star Safety System
- Remote Keyless Entry System
- LATCH-Lower Anchor & Tether for Children
- Hill-Start Assist Control (HAC)

EXTERIOR
- Chrome Auto On/Off Headlights
- LED Tail and Foglights
- Heated PWR Adjustable Outside Mirrors
- Windshield Wiper w/De-Icer; Rear Wiper

INTERIOR
- Seating for 8; Fabric 6-way Driver Seat, 4-way Passenger Seat, 2nd & 3rd Row 60/40 Split Fold-Flat Seats w/Recline
- Front and Rear Air Conditioning
- Entune Audio 6.1" Touch Screen w/Backup Camera, AM/FM/CD, 6 Speakers, USB Media Port, 4 USB Charge Ports, Bluetooth Phone/Music, Siri Eyes Free
- 4.2-in Multi-Info Display w/Vehicle Info
- Steering Wheel w/Multimedia Controls
- Roll-Over Protection System (ROPS)
- 12 Cup/Bottle Holders; Two 12V Outlets
- **Full Tank of Gas**

MANUFACTURER'S SUGGESTED RETAIL PRICE **\$31,330.00**

OPTIONAL EQUIPMENT

FE	50 State Emissions	
PC	Special Color	395.00
2T	All-Weather Floor Liner/Cargo Liner	269.00
DS	Door Edge Guard	125.00
EF	Rear Bumper Applique	69.00

DELIVERY PROCESSING AND HANDLING FEE 1,045.00

TOTAL \$33,233.00

The New Vehicle Limited Warranty provides 3-year/36,000-mile basic coverage, 5-year/60,000-mile powertrain coverage, plus 8-year/unlimited-mile corrosion perforation coverage. See Warranty and Maintenance Guide for details. An extended service contract may be available for the vehicle.
Manufacturer's suggested retail price includes manufacturer's recommended pre-delivery service. Gasoline, license and title fees, applicable federal, state and local taxes and dealer and distributor installed options and accessories are not included in the manufacturer's suggested retail price.
ToyotaCare, which covers normal factory scheduled maintenance for two years or 25,000 miles, whichever occurs first, is included as part of the sales price of the vehicle for qualifying buyers. See participating dealer for eligibility and coverage details.



Figure A3. Window Sticker (Monroney Label)




MFD. BY: TOYOTA MOTOR MANUFACTURING, INDIANA, INC. 10/18
GVWR: 2570KG (5665LB)
GAWR: FRT. 1345KG (2955LB) WITH 245/60R18 TIRES,
18X7.5J RIMS.
RR. 1490KG (3275LB) WITH 245/60R18 TIRES,
18X7.5J RIMS.
THIS VEHICLE CONFORMS TO ALL APPLICABLE FEDERAL MOTOR
VEHICLE SAFETY AND THEFT PREVENTION STANDARDS IN EFFECT ON
THE DATE OF MANUFACTURE SHOWN ABOVE.
5TDZARFH7KS04 MPV

C/TR: 070/FB20 ASU50L-ARTNKA
A/TM: -03A/U760E MADE IN U.S.A. 813 T

Figure A4. Vehicle Certification Label



TIRE AND LOADING INFORMATION **RENSEIGNEMENTS SUR LES PNEUS ET LE CHARGEMENT**

SEATING CAPACITY	TOTAL	8	FRONT	2	REAR	6
NOMBRE DE PLACES	TOTAL :	8	AVANT :	2	ARRIÈRE :	6

The combined weight of occupants and cargo should never exceed 660 kg or 1460 lbs.
Le poids total des occupants et du chargement ne doit jamais dépasser 660 kg ou 1460 lb.

TIRE PNEU	SIZE DIMENSIONS	COLD TIRE PRESSURE PRESSION DES PNEUS À FROID	SEE OWNER'S MANUAL FOR ADDITIONAL INFORMATION VOIR LE MANUEL DE L'USAGER POUR PLUS DE RENSEIGNEMENTS
FRONT AVANT	245/60R18	250 kPa, 36 PSI	
REAR ARRIÈRE	245/60R18	250 kPa, 36 PSI	
SPARE DE SECOURS	T165/90D18	420 kPa, 60 PSI	

8M

0E510



Figure A5. Tire Placard



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



Figure A7. Load Frame/Slider of SSV

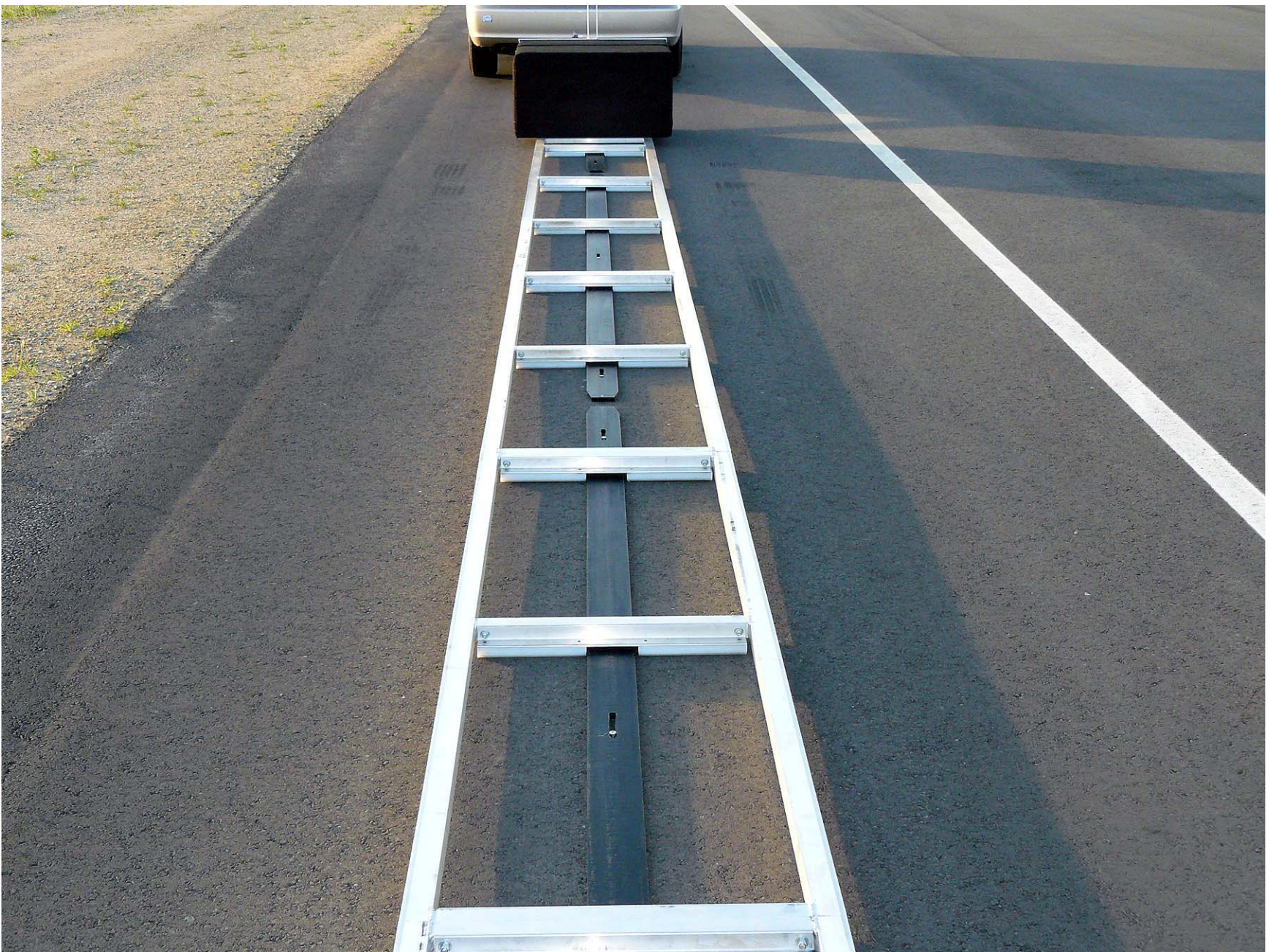


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track



Figure A9. Steel Trench Plate



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



Figure A11. Sensor for Detecting Auditory Alerts



Figure A12. Sensor for Detecting Visual Alerts



Figure A13. Computer Installed in Subject Vehicle

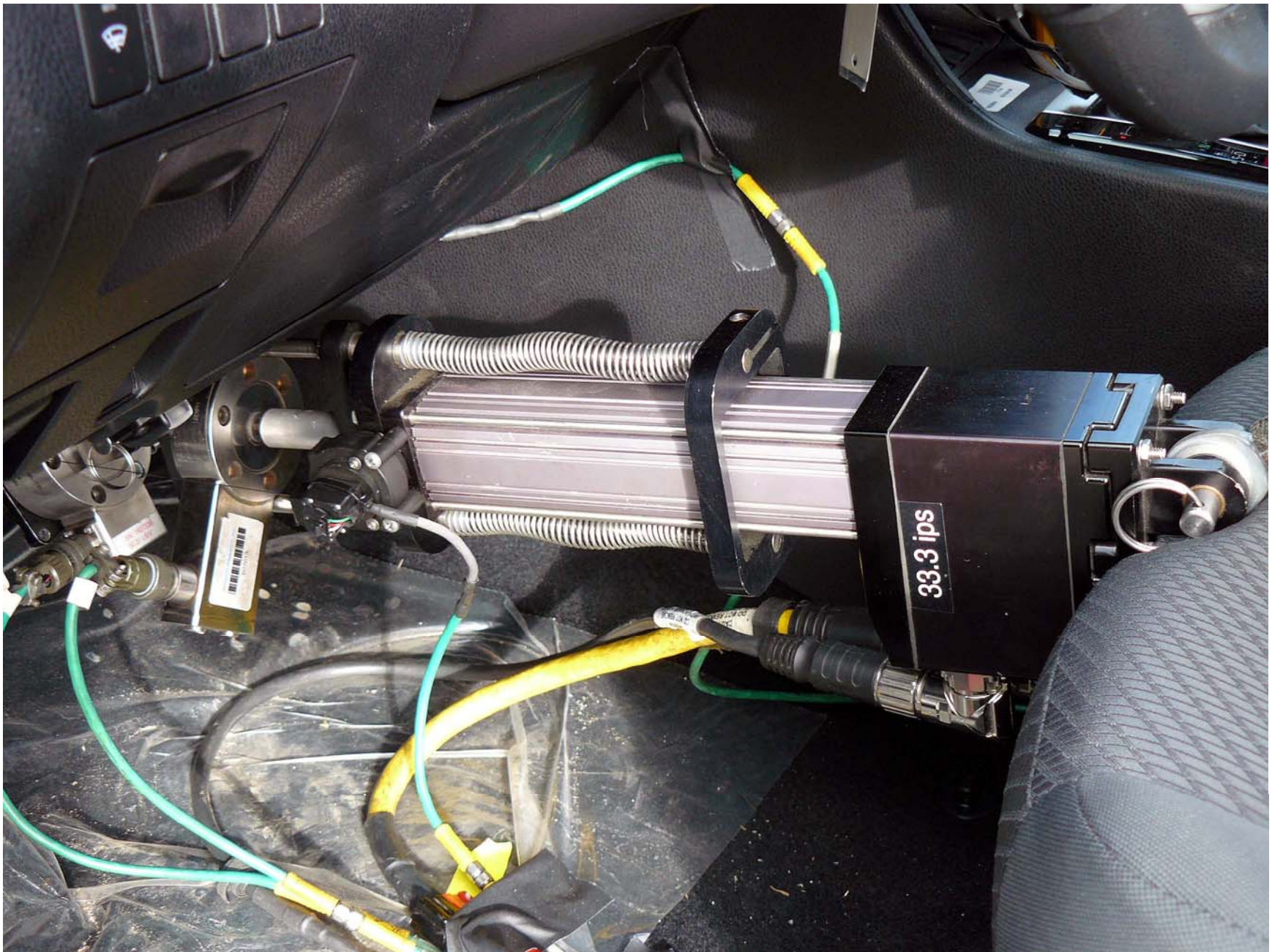


Figure A14. Brake Actuator Installed in Subject System



Figure A15. Brake Actuator Installed in POV System



Figure A16. AEB Visual Alert



Figure A17. AEB Setup Menus



Figure A18. Steering Wheel Mounted Control Buttons for Changing Parameters





















Figure A19. Steering Wheel Mounted Control Buttons for Setting Range

APPENDIX B

Excerpts from Owner's Manual

Warning lights

Warning lights inform the driver of malfunctions in the indicated vehicle's systems.

*1  (U.S.A.)	Brake system warning light (→P. 583)	 (Amber)	LDA (Lane Departure Alert with steering control) indicator (→P. 585)
*1  (Canada)	Brake system warning light (→P. 583)	*1 	Slip indicator (→P. 584)
*1  (U.S.A.)	Malfunction indicator lamp (→P. 583)		Low fuel level warning light (→P. 584)
*1  (Canada)	Malfunction indicator lamp (→P. 583)		Driver's and front passenger's seat belt reminder light (→P. 584)
*1 	SRS warning light (→P. 583)	*4 	Rear seat seat belt reminder lights (→P. 584)
*1  (U.S.A.)	ABS warning light (→P. 583)	*2, 5 	Stop & Start cancel indicator (→P. 585)
*1  (Canada)	ABS warning light (→P. 583)	*1 	Master warning light (→P. 586)
*1 	Electric power steering system warning light (→P. 584)	*1 	Tire pressure warning light (→P. 586)
*1, 3  OFF	PCS (Pre-Collision System) warning light (→P. 585)	*1  PARK (U.S.A.)	Parking brake warning light (→P. 584)





















2

Instrument cluster

HIGHLANDER_U

Indicators

The indicators inform the driver of the operating state of the vehicle's various systems.

	Turn signal indicator (→P. 239)		LDA (Lane Departure Alert with steering control) indicator (→P. 281)
	Headlight indicator (→P. 241)		*2, 3 Intuitive parking assist indicator
	Tail light indicator (→P. 241)		*2 BSM (Blind Spot Monitor) indicator(→P. 323)
	Headlight high beam indicator (→P. 242)		*2, 6, 7 BSM (Blind Spot Monitor) outside rear view mirror indicators (→P. 323)
	Automatic High Beam indicator (→P. 245)		*1, 4 Slip indicator (→P. 340)
	*2 Front fog light indicator (→P. 249)		*1 VSC OFF indicator (→P. 340)
	Dynamic radar cruise control (constant speed control mode) indicator (→P. 300)		*1, 2 All-wheel drive lock indicator (→P. 337)
	Dynamic radar cruise control (vehicle-to-vehicle distance control mode) indicator (→P. 296)		*2 Downhill assist control system indicator (→P. 344)
	Dynamic radar cruise control "SET" indicator (→P. 296, 300)		*8 Security indicator (→P. 86, 88)
	*1, 5 PCS (Pre-Collision System) warning light (→P. 267)		*1, 9 Eco Driving Indicator Light (→P. 108)

2

Instrument cluster

HIGHLANDER_U

PCS (Pre-Collision System)

The pre-collision system uses a radar sensor and camera sensor to detect vehicles and pedestrians*¹ in front of your vehicle. When the system determines that the possibility of a frontal collision with a vehicle or pedestrian is high, a warning operates to urge the driver to take evasive action and the potential brake pressure is increased to help the driver avoid the collision. If the system determines that the possibility of a frontal collision with a vehicle or pedestrian is extremely high, the brakes are automatically applied to help avoid the collision or help reduce the impact of the collision.

The pre-collision system can be disabled/enabled and the warning timing can be changed. (→P. 271)

*¹: Depending on the region in which the vehicle was sold, the pedestrian detection function may not be available. See the following table for details.

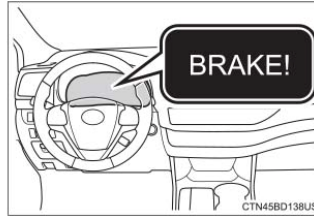
Countries/areas	Function availability	Regions
U.S. mainland, Canada, Hawaii	The pedestrian detection function is available	Region A
Guam, Saipan, Puerto Rico	The pedestrian detection function is not available	Region B

4

Driving

◆ Pre-collision warning

When the system determines that the possibility of a frontal collision is high, a buzzer will sound and a warning message will be displayed on the multi-information display to urge the driver to take evasive action.

**◆ Pre-collision brake assist**

When the system determines that the possibility of a frontal collision is high, the system applies greater braking force in relation to how strongly the brake pedal is depressed.

◆ Pre-collision braking

When the system determines that the possibility of a frontal collision is high, the system warns the driver. If the system determines that the possibility of a frontal collision is extremely high, the brakes are automatically applied to help avoid the collision or reduce the collision speed.

⚠ WARNING**■ Limitations of the pre-collision system**

- The driver is solely responsible for safe driving. Always drive safely, taking care to observe your surroundings.
Do not use the pre-collision system instead of normal braking operations under any circumstances. This system will not prevent collisions or lessen collision damage or injury in every situation. Do not overly rely on this system. Failure to do so may lead to an accident, resulting in death or serious injury.
- Although this system is designed to help avoid a collision or help reduce the impact of the collision, its effectiveness may change according to various conditions, therefore the system may not always be able to achieve the same level of performance.
Read the following conditions carefully. Do not overly rely on this system and always drive carefully.
 - Conditions under which the system may operate even if there is no possibility of a collision: →P. 274
 - Conditions under which the system may not operate properly: →P. 277
- Do not attempt to test the operation of the pre-collision system yourself, as the system may not operate properly, possibly leading to an accident.

■ Pre-collision braking

- When the pre-collision braking function is operating, a large amount of braking force will be applied.
- If the vehicle is stopped by the operation of the pre-collision braking function, the pre-collision braking function operation will be canceled after approximately 2 seconds. Depress the brake pedal as necessary.
- The pre-collision braking function may not operate if certain operations are performed by the driver. If the accelerator pedal is being depressed strongly or the steering wheel is being turned, the system may determine that the driver is taking evasive action and possibly prevent the pre-collision braking function from operating.
- In some situations, while the pre-collision braking function is operating, operation of the function may be canceled if the accelerator pedal is depressed strongly or the steering wheel is turned and the system determines that the driver is taking evasive action.
- If the brake pedal is being depressed, the system may determine that the driver is taking evasive action and possibly delay the operation timing of the pre-collision braking function.

⚠ WARNING**■ When to disable the pre-collision system**


In the following situations, disable the system, as it may not operate properly, possibly leading to an accident resulting in death or serious injury:

- When the vehicle is being towed
- When your vehicle is towing another vehicle
- When transporting the vehicle via truck, boat, train or similar means of transportation
- When the vehicle is raised on a lift with the engine running and the tires are allowed to rotate freely
- When inspecting the vehicle using a drum tester such as a chassis dynamometer or speedometer tester, or when using an on vehicle wheel balancer
- When a strong impact is applied to the front bumper or front grille, due to an accident or other reasons
- If the vehicle cannot be driven in a stable manner, such as when the vehicle has been in an accident or is malfunctioning
- When the vehicle is driven in a sporty manner or off-road
- When the tires are not properly inflated
- When the tires are very worn
- When tires of a size other than specified are installed
- When tire chains are installed
- When a compact spare tire or an emergency tire puncture repair kit is used
- If equipment (snow plow, etc.) that may obstruct the radar sensor or camera sensor is temporarily installed to the vehicle

HIGHLANDER_U

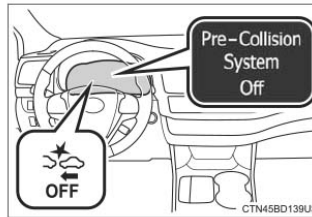
Changing settings of the pre-collision system

■ Enabling/disabling the pre-collision system


The pre-collision system can be enabled/disabled on  (→P. 105) of the multi-information display.

The system is automatically enabled each time the engine switch is turned to the "ON" position (vehicles without a smart key system) or IGNITION ON mode (vehicles with a smart key system).

If the system is disabled, the PCS warning light will turn on and a message will be displayed on the multi-information display.



■ Changing the pre-collision warning timing

The pre-collision warning timing can be changed on  (→P. 105) of the multi-information display.

The operation timing setting is retained when the engine switch is turned off.

① Far

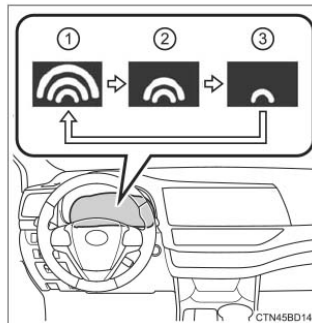
The warning will begin to operate earlier than with the default timing.

② Middle

This is the default setting.

③ Near

The warning will begin to operate later than with the default timing.



■ Operational conditions

Availability of the pedestrian detection function depends on the region in which the vehicle was sold. (For specific countries/areas: →P. 267)

Read the following for details:

► Region A

(The pedestrian detection function is available)

The pre-collision system is enabled and the system determines that the possibility of a frontal collision with a vehicle or pedestrian is high.

Each function is operational at the following speeds:

● Pre-collision warning:

- Vehicle speed is between approximately 7 and 110 mph (10 and 180 km/h). (For detecting a pedestrian, vehicle speed is between approximately 7 and 50 mph [10 and 80 km/h].)
- The relative speed between your vehicle and the vehicle or pedestrian ahead is approximately 7 mph (10 km/h) or more.

● Pre-collision brake assist:

- Vehicle speed is between approximately 20 and 110 mph (30 and 180 km/h). (For detecting a pedestrian, vehicle speed is between approximately 19 and 50 mph [30 and 80 km/h].)
- The relative speed between your vehicle and the vehicle or pedestrian ahead is approximately 20 mph (30 km/h) or more.

● Pre-collision braking:

- Vehicle speed is between approximately 7 and 110 mph (10 and 180 km/h). (For detecting a pedestrian, vehicle speed is between approximately 7 and 50 mph [10 and 80 km/h].)
- The relative speed between your vehicle and the vehicle or pedestrian ahead is approximately 7 mph (10 km/h) or more.

The system may not operate in the following situations:

- If a battery terminal has been disconnected and reconnected and then the vehicle has not been driven for a certain amount of time
- If the shift lever is in R
- If VSC is disabled (only the pre-collision warning function will be operational)

HIGHLANDER_U

► Region B

(The pedestrian detection function is not available)

The pre-collision system is enabled and the system determines that the possibility of a frontal collision with a vehicle is high.

Each function is operational at the following speeds:

● Pre-collision warning:

- Vehicle speed is between approximately 10 and 110 mph (15 and 180 km/h).
- The relative speed between your vehicle and the vehicle ahead is approximately 7 mph (10 km/h) or more.

● Pre-collision brake assist:

- Vehicle speed is between approximately 20 and 110 mph (30 and 180 km/h).
- The relative speed between your vehicle and the vehicle ahead is approximately 20 mph (30 km/h) or more.

● Pre-collision braking:

- Vehicle speed is between approximately 10 and 110 mph (15 and 180 km/h).
- The relative speed between your vehicle and the vehicle ahead is approximately 7 mph (10 km/h) or more.

The system may not operate in the following situations:

- If a battery terminal has been disconnected and reconnected and then the vehicle has not been driven for a certain amount of time
- If the shift lever is in R
- If VSC is disabled (only the pre-collision warning function will be operational)

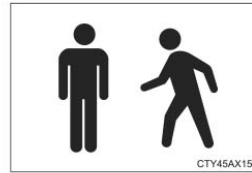
4

Driving

HIGHLANDER_U

Pedestrian detection function*2

The pre-collision system detects pedestrians based on the size, profile, and motion of a detected object. However, a pedestrian may not be detected depending on the surrounding brightness and the motion, posture, and angle of the detected object, preventing the system from operating properly. (→P. 277)



*2: For countries/areas specified as Region B (→P. 267), the pedestrian detection function may not be available.

Cancellation of the pre-collision braking

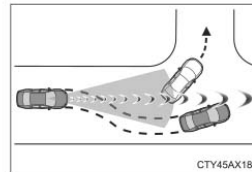
If either of the following occurs while the pre-collision braking function is operating, it will be canceled:

- The accelerator pedal is depressed strongly.
- The steering wheel is turned sharply or abruptly.

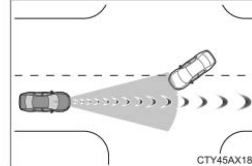
Conditions under which the system may operate even if there is no possibility of a collision

● In some situations such as the following, the system may determine that there is a possibility of a frontal collision and operate.

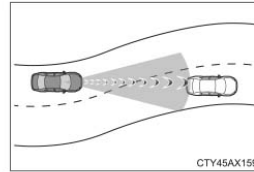
- When passing a vehicle or pedestrian*2
- When changing lanes while overtaking a preceding vehicle
- When overtaking a preceding vehicle that is changing lanes
- When overtaking a preceding vehicle that is making a left/right turn



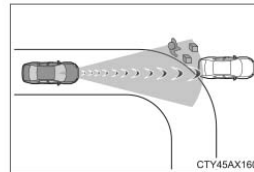
- When passing a vehicle in an oncoming lane that is stopped to make a right/left turn



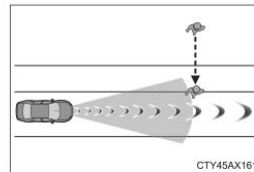
- When driving on a road where relative location to vehicle ahead in an adjacent lane may change, such as on a winding road



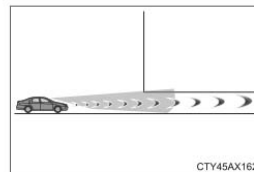
- When rapidly closing on a vehicle ahead
- If the front of the vehicle is raised or lowered, such as when the road surface is uneven or undulating
- When approaching objects on the roadside, such as guardrails, utility poles, trees, or walls
- When there is a vehicle, pedestrian^{*2}, or object by the roadside at the entrance of a curve



- When driving on a narrow path surrounded by a structure, such as in a tunnel or on an iron bridge
- When there is a metal object (manhole cover, steel plate, etc.), steps, or a protrusion on the road surface or roadside
- When a crossing pedestrian approaches very close to the vehicle^{*2}



- When passing through a place with a low structure above the road (low ceiling, traffic sign, etc.)

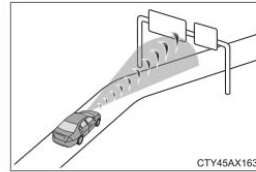


4

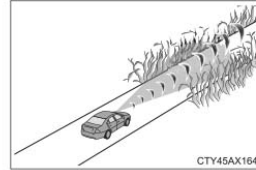
Driving

HIGHLANDER_U

- When passing under an object (billboard, etc.) at the top of an uphill road



- When rapidly closing on an electric toll gate barrier, parking area barrier, or other barrier that opens and closes
- When using an automatic car wash
- When driving through or under objects that may contact the vehicle, such as thick grass, tree branches, or a banner



- When the vehicle is hit by water, snow, dust, etc. from a vehicle ahead
- When driving through steam or smoke
- When there are patterns or paint on the road or a wall that may be mistaken for a vehicle or pedestrian^{*2}
- When driving near an object that reflects radio waves, such as a large truck or guardrail
- When driving near a TV tower, broadcasting station, electric power plant, or other location where strong radio waves or electrical noise may be present

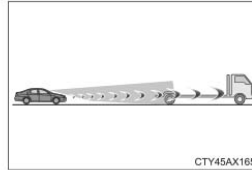
^{*2}: For countries/areas specified as Region B (→P. 267), the pedestrian detection function may not be available.

HIGHLANDER_U

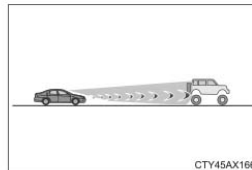
■ Situations in which the system may not operate properly

- In some situations such as the following, a vehicle may not be detected by the radar sensor and camera sensor, preventing the system from operating properly:

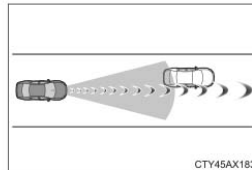
- If an oncoming vehicle is approaching your vehicle
- If a vehicle ahead is a motorcycle or bicycle
- When approaching the side or front of a vehicle
- If a preceding vehicle has a small rear end, such as an unloaded truck
- If a preceding vehicle has a low rear end, such as a low bed trailer



- If a vehicle ahead is carrying a load which protrudes past its rear bumper
- If a vehicle ahead has extremely high ground clearance



- If a vehicle ahead is irregularly shaped, such as a tractor or side car
- If the sun or other light is shining directly on a vehicle ahead
- If a vehicle cuts in front of your vehicle or emerges from beside a vehicle
- If a vehicle ahead makes an abrupt maneuver (such as sudden swerving, acceleration or deceleration)
- When suddenly cutting behind a preceding vehicle
- When a vehicle ahead is not directly in front of your vehicle

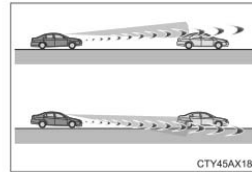


4

Driving

HIGHLANDER_U

- When driving in inclement weather such as heavy rain, fog, snow or a sandstorm
- When the vehicle is hit by water, snow, dust, etc. from a vehicle ahead
- When driving through steam or smoke
- When driving in a place where the surrounding brightness changes suddenly, such as at the entrance or exit of a tunnel
- When a very bright light, such as the sun or the headlights of oncoming traffic, shines directly into the camera sensor
- When the surrounding area is dim, such as at dawn or dusk, or while at night or in a tunnel
- After the engine has started the vehicle has not been driven for a certain amount of time
- While making a left/right turn and for a few seconds after making a left/right turn
- While driving on a curve and for a few seconds after driving on a curve
- If your vehicle is skidding
- If the front of the vehicle is raised or lowered



- If the wheels are misaligned
- If a wiper blade is blocking the camera sensor
- The vehicle is wobbling.
- The vehicle is being driven at extremely high speeds.
- When driving on a hill
- If the radar sensor or camera sensor is misaligned
- In some situations such as the following, sufficient braking force may not be obtained, preventing the system from performing properly:
 - If the braking functions cannot operate to their full extent, such as when the brake parts are extremely cold, extremely hot, or wet
 - If the vehicle is not properly maintained (brakes or tires are excessively worn, improper tire inflation pressure, etc.)
 - When the vehicle is being driven on a gravel road or other slippery surface

HIGHLANDER_U

- Some pedestrians such as the following may not be detected by the radar sensor and camera sensor, preventing the system from operating properly*2:
 - Pedestrians shorter than approximately 3.2 ft. (1 m) or taller than approximately 6.5 ft. (2 m)
 - Pedestrians wearing oversized clothing (a rain coat, long skirt, etc.), making their silhouette obscure
 - Pedestrians who are carrying large baggage, holding an umbrella, etc., hiding part of their body
 - Pedestrians who are bending forward or squatting
 - Pedestrians who are pushing a stroller, wheelchair, bicycle or other vehicle
 - Groups of pedestrians which are close together
 - Pedestrians who are wearing white and look extremely bright
 - Pedestrians in the dark, such as at night or while in a tunnel
 - Pedestrians whose clothing appears to be nearly the same color or brightness as their surroundings
 - Pedestrians near walls, fences, guardrails, or large objects
 - Pedestrians who are on a metal object (manhole cover, steel plate, etc.) on the road
 - Pedestrians who are walking fast
 - Pedestrians who are changing speed abruptly
 - Pedestrians running out from behind a vehicle or a large object
 - Pedestrians who are extremely close to the side of the vehicle (outside rear view mirror, etc.)

*2: For countries/areas specified as Region B (→P. 267), the pedestrian detection function may not be available.

■ **If the PCS warning light flashes or illuminates and a warning message is displayed on the multi-information display**




The pre-collision system may be temporarily unavailable or there may be a malfunction in the system.





- In the following situations, the warning light will turn off, the message will disappear and the system will become operational when normal operating conditions return:
 - When the radar sensor or camera sensor or the area around either sensor is hot, such as in the sun
 - When the radar sensor or camera sensor or the area around either sensor is cold, such as in an extremely cold environment
 - When a front sensor is dirty or covered with snow, etc.
 - When the part of the windshield in front of the camera sensor is fogged up or covered with condensation or ice
(Defogging the windshield: →P. 443, 450)
 - If the camera sensor is obstructed, such as when the hood is open or a sticker is attached to the windshield near the camera sensor

HIGHLANDER_U

- If the PCS warning light continues to flash or remains illuminated or the warning message does not disappear even though the vehicle has returned to normal, the system may be malfunctioning.
Have the vehicle inspected by your Toyota dealer immediately.
- **If VSC is disabled**
 - If VSC is disabled (→P. 341), the pre-collision brake assist and pre-collision braking functions are also disabled.
 - The PCS warning light will turn on and "VSC Turned Off Pre-Collision Brake System Unavailable" will be displayed on the multi-information display.

HIGHLANDER_U




Warning light	Warning light/Details/Actions
 (Flashes or illuminates)	<p>PCS (Pre-Collision System) warning light Indicates a malfunction in the PCS (Pre-Collision System) or that the system is temporarily unavailable due to the vehicle being extremely hot/cold, or dirt around a front sensor, etc. (→P. 279, 593) → Follow the instructions displayed on the multi-information display. (→P. 279, 593) If the PCS (Pre-Collision System) or VSC (Vehicle Stability Control) system is disabled, the PCS warning light will illuminate. → P. 280</p>
 (Amber)	<p>LDA (Lane Departure Alert with steering control) indicator The indicator comes on and a warning message is displayed to indicate that the LDA (Lane Departure Alert with steering control) system is not available temporarily or has detected a malfunction. → P. 594</p>
 (Flashes)	<p>Stop & Start cancel indicator*3 Indicates a malfunction in the Stop & Start system (The Stop & Start cancel indicator will come on when the system is canceled.: →P. 305) → Have the vehicle inspected by your Toyota dealer immediately.</p>

Warning message	Details/Actions
<p>Front Camera Unavailable</p> 	<p>The operation conditions of the camera sensor (temperature, etc.) are not met.</p> <p>→ When the operation conditions of the camera sensor (temperature, etc.) are met, the following systems will become available.</p> <ul style="list-style-type: none"> • PCS (Pre-Collision System) • LDA (Lane Departure Alert with steering control) system • Dynamic radar cruise control • Automatic High Beam
<p>Front Camera Unavailable Remove Debris On Windshield</p> 	<p>Dirt, rain, condensation, ice, snow, etc., are present on the windshield in front of the camera sensor.</p> <p>The following systems will be temporarily unusable.</p> <ul style="list-style-type: none"> • PCS (Pre-Collision System) • LDA (Lane Departure Alert with steering control) system • Dynamic radar cruise control • Automatic High Beam <p>→ Turn the system off, remove any dirt, rain, condensation, ice, snow, etc., from the windshield, and then turn the system back on.</p>
<p>Pre-Collision System Malfunction</p> <p>Visit Your Dealer</p> 	<p>Indicates a malfunction in the pre-collision system.</p> <p>A buzzer also sounds.</p> <p>→ Have the vehicle inspected by your Toyota dealer.</p>
<p>Check BSM System</p>  <p>(If equipped)</p>	<p>Indicates a malfunction in the BSM (Blind Spot Monitor) system.</p> <p>A buzzer also sounds.</p> <p>→ Have the vehicle inspected by your Toyota dealer.</p>

■ **LDA (Lane Departure Alert with steering control) (→P. 281)**

Function	Default setting	Customized setting	①	②	③
Steering Assist	On	Off	—	O	—
Alert sensitivity	Standard	High	—	O	—
Vehicle sway warning	On	Off	—	O	—
Vehicle sway warning sensitivity	Standard	Low	—	O	—
		High			

■ **PCS (Pre-Collision System) (→P. 267)**

Function	Default setting	Customized setting	①	②	③
PCS (Pre-Collision System)	On	Off	—	O	—
Alert timing	 (Middle)	 (Far)	—	O	—
		 (Near)			

APPENDIX C

Run Log

Subject Vehicle: **2019 Toyota Highlander**

Test Date: 1/16/2019

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
1-20	Brake characterization and confirmation						See Appendix D
21	Static Run						
22	Stopped POV	Y	2.44	13.03	1.01	Pass	
23		Y	2.57	12.21	1.01	Pass	
24		Y	2.48	12.70	1.03	Pass	
25		Y	2.56	12.39	1.01	Pass	
26		Y	2.50	12.08	1.04	Pass	
27		Y	2.52	12.63	1.02	Pass	
28		Y	2.51	12.06	1.00	Pass	
29	Static Run						
30	Slower POV, 25 vs 10	Y	2.38	10.71	1.06	Pass	Brake Force
31		Y	2.37	10.39	1.04	Pass	
32		Y	2.35	10.54	1.00	Pass	
33		Y	2.29	10.13	1.01	Pass	
34		Y	2.11	10.62	1.02	Pass	
35		Y	2.35	10.62	1.02	Pass	
36		Y	2.27	10.81	1.00	Pass	

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
37	Static run						
38	Slower POV, 45 vs 20	Y	2.86	13.34	1.00	Pass	
39		Y	2.91	12.79	1.06	Pass	
40		Y	2.85	11.42	1.00	Pass	
41		Y	2.95	12.53	0.99	Pass	
42		Y	2.86	11.75	1.02	Pass	
43		Y	2.85	9.90	1.06	Pass	
44		Y	2.87	8.96	0.99	Pass	
45	Static run						
46	Braking POV, 35	Y	1.90	0.00	0.58	Fail	
47		Y	2.06	6.33	0.56	Pass	
48		Y	1.98	8.50	0.57	Pass	
49		Y	1.97	7.31	0.58	Pass	
50		Y	1.86	8.85	0.57	Pass	
51		Y	2.00	8.28	0.58	Pass	
52		N					SV Speed
53		Y	1.88	10.52	0.58	Pass	

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
54		Y	1.84	11.12	0.58	Pass	
55	Static run						
56	STP - Static run						
57	Baseline, 25	Y			0.47		
58		N					Throttle and brake force
59		Y			0.46		
60		Y			0.46		
61		Y			0.47		
62		Y			0.46		
63		Y			0.45		
64		Y			0.47		
65	STP - Static run						
66	Baseline, 45	Y			0.44		
67		Y			0.44		
68		Y			0.46		
69		Y			0.48		
70		Y			0.48		

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
71		Y			0.46		
72		Y			0.47		
73	STP - Static run						
74	Static						
75	STP False Positive, 25	N					brake rate
76		Y			0.57	Pass	
77		Y			0.59	Pass	
78		Y			0.64	Pass	
79		Y			0.58	Pass	
80		Y			0.59	Pass	
81		Y			0.59	Pass	
82		Y			0.58	Pass	
83	STP - Static run						
84	STP False Positive, 45	Y			0.55	Pass	
85		Y			0.55	Pass	

Principal Other Vehicle: SSV

Run	Test Type	Valid Run?	FCW TTC (s)	Minimum Distance (ft)	Peak Deceleration (g)	Pass/Fail	Notes
86		Y			0.57	Pass	
87		Y			0.57	Pass	
88		Y			0.58	Pass	
89	STP - Static run						
90		Y			0.48	Pass	
91		Y			0.51	Pass	
92		N					throttle
93		Y			0.58	Pass	
94	STP - Static run						

APPENDIX D

Brake Characterization

DBS Initial Brake Characterization				
Run Number	Stroke at 0.4 g (in)	Force at 0.4 g (lb)	Slope	Intercept
1	1.721114	21.33438	0.733184	0.059129
2	1.679158	21.05842	0.629007	0.193766
3	1.74907	21.37499	0.596044	0.214169

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		1.72			Brake rate
5			N		1.72			Brake rate
6			N		1.65			Brake rate
7			Y	0.395	1.65		1.67	
8		25	Y	0.436	1.65		1.51	
9			Y	0.423	1.65		1.56	
10		45	Y	0.394	1.65		1.68	
11	Hybrid	35	Y	0.468	1.65	21.26	18.17	
12			Y	0.450	1.65	18.50	16.44	
13			Y	0.421	1.65	16.50	15.68	
14		25	Y	0.444	1.65	16.50	14.86	

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
15			Y	0.400	1.65	15.00	15.00	
16		45	Y	0.355	1.65	15.00	16.90	
17			Y	0.324	1.65	15.00	18.52	
18			Y	0.382	1.65	15.00	15.71	
19		35	Y	0.428	1.65	15.00	14.02	
20			Y	0.415	1.65	15.00	14.46	

Appendix E

TIME HISTORY PLOTS

LIST OF FIGURES

	Page
Figure E1. Example Time History for Stopped POV, Passing	11
Figure E2. Example Time History for Slower POV 25 vs. 10, Passing	12
Figure E3. Example Time History for Slower POV 45 vs. 20, Passing	13
Figure E4. Example Time History for Braking POV 35, Passing	14
Figure E5. Example Time History for False Positive Baseline 25, Passing.....	15
Figure E6. Example Time History for False Positive Baseline 45, Passing.....	16
Figure E7. Example Time History for False Positive Steel Plate 25, Passing	17
Figure E8. Example Time History for False Positive Steel Plate 45, Passing	18
Figure E9. Example Time History for DBS Brake Characterization, Passing	19
Figure E10. Example Time History Displaying Various Invalid Criteria.....	20
Figure E11. Example Time History Displaying Various Invalid Criteria.....	21
Figure E12. Example Time History for a Failed Run.....	22
Figure E13. Time History for DBS Run 22, SV Encounters Stopped POV	23
Figure E14. Time History for DBS Run 23, SV Encounters Stopped POV	24
Figure E15. Time History for DBS Run 24, SV Encounters Stopped POV	25
Figure E16. Time History for DBS Run 25, SV Encounters Stopped POV	26
Figure E17. Time History for DBS Run 26, SV Encounters Stopped POV	27
Figure E18. Time History for DBS Run 27, SV Encounters Stopped POV	28
Figure E19. Time History for DBS Run 28, SV Encounters Stopped POV	29
Figure E20. Time History for DBS Run 30, SV Encounters Slower POV, SV 25 mph, POV 10 mph.....	30
Figure E21. Time History for DBS Run 31, SV Encounters Slower POV, SV 25 mph, POV 10 mph.....	31
Figure E22. Time History for DBS Run 32, SV Encounters Slower POV, SV 25 mph, POV 10 mph.....	32
Figure E23. Time History for DBS Run 33, SV Encounters Slower POV, SV 25 mph, POV 10 mph.....	33
Figure E24. Time History for DBS Run 34, SV Encounters Slower POV, SV 25 mph, POV 10 mph.....	34
Figure E25. Time History for DBS Run 35, SV Encounters Slower POV, SV 25 mph, POV 10 mph.....	35
Figure E26. Time History for DBS Run 36, SV Encounters Slower POV, SV 25 mph, POV 10 mph.....	36
Figure E27. Time History for DBS Run 38, SV Encounters Slower POV, SV 45 mph, POV 20 mph.....	37

Figure E28. Time History for DBS Run 39, SV Encounters Slower POV, SV 45 mph, POV 20 mph.....	38
Figure E29. Time History for DBS Run 40, SV Encounters Slower POV, SV 45 mph, POV 20 mph.....	39
Figure E30. Time History for DBS Run 41, SV Encounters Slower POV, SV 45 mph, POV 20 mph.....	40
Figure E31. Time History for DBS Run 42, SV Encounters Slower POV, SV 45 mph, POV 20 mph.....	41
Figure E32. Time History for DBS Run 43, SV Encounters Slower POV, SV 45 mph, POV 20 mph.....	42
Figure E33. Time History for DBS Run 44, SV Encounters Slower POV, SV 45 mph, POV 20 mph.....	43
Figure E34. Time History for DBS Run 46, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph.....	44
Figure E35. Time History for DBS Run 47, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph.....	45
Figure E36. Time History for DBS Run 48, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph.....	46
Figure E37. Time History for DBS Run 49, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph.....	47
Figure E38. Time History for DBS Run 50, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph.....	48
Figure E39. Time History for DBS Run 51, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph.....	49
Figure E40. Time History for DBS Run 53, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph.....	50
Figure E41. Time History for DBS Run 54, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph.....	51
Figure E42. Time History for DBS Run 57, False Positive Baseline, SV 25 mph.....	52
Figure E43. Time History for DBS Run 59, False Positive Baseline, SV 25 mph.....	53
Figure E44. Time History for DBS Run 60, False Positive Baseline, SV 25 mph.....	54
Figure E45. Time History for DBS Run 61, False Positive Baseline, SV 25 mph.....	55
Figure E46. Time History for DBS Run 62, False Positive Baseline, SV 25 mph.....	56
Figure E47. Time History for DBS Run 63, False Positive Baseline, SV 25 mph.....	57
Figure E48. Time History for DBS Run 64, False Positive Baseline, SV 25 mph.....	58
Figure E49. Time History for DBS Run 66, False Positive Baseline, SV 45 mph.....	59
Figure E50. Time History for DBS Run 67, False Positive Baseline, SV 45 mph.....	60
Figure E51. Time History for DBS Run 68, False Positive Baseline, SV 45 mph.....	61
Figure E52. Time History for DBS Run 69, False Positive Baseline, SV 45 mph.....	62
Figure E53. Time History for DBS Run 70, False Positive Baseline, SV 45 mph.....	63

Figure E54. Time History for DBS Run 71, False Positive Baseline, SV 45 mph.....	64
Figure E55. Time History for DBS Run 72, False Positive Baseline, SV 45 mph.....	65
Figure E56. Time History for DBS Run 76, SV Encounters Steel Trench Plate, SV 25 mph	66
Figure E57. Time History for DBS Run 77, SV Encounters Steel Trench Plate, SV 25 mph	67
Figure E58. Time History for DBS Run 78, SV Encounters Steel Trench Plate, SV 25 mph	68
Figure E59. Time History for DBS Run 79, SV Encounters Steel Trench Plate, SV 25 mph	69
Figure E60. Time History for DBS Run 80, SV Encounters Steel Trench Plate, SV 25 mph	70
Figure E61. Time History for DBS Run 81, SV Encounters Steel Trench Plate, SV 25 mph	71
Figure E62. Time History for DBS Run 82, SV Encounters Steel Trench Plate, SV 25 mph	72
Figure E63. Time History for DBS Run 84, SV Encounters Steel Trench Plate, SV 45 mph	73
Figure E64. Time History for DBS Run 85, SV Encounters Steel Trench Plate, SV 45 mph	74
Figure E65. Time History for DBS Run 86, SV Encounters Steel Trench Plate, SV 45 mph	75
Figure E66. Time History for DBS Run 87, SV Encounters Steel Trench Plate, SV 45 mph	76
Figure E67. Time History for DBS Run 88, SV Encounters Steel Trench Plate, SV 45 mph	77
Figure E68. Time History for DBS Run 90, SV Encounters Steel Trench Plate, SV 45 mph	78
Figure E69. Time History for DBS Run 91, SV Encounters Steel Trench Plate, SV 45 mph	79
Figure E70. Time History for DBS Run 92, SV Encounters Steel Trench Plate, SV 45 mph	80
Figure E71. Time History for DBS Run 93, SV Encounters Steel Trench Plate, SV 45 mph	81
Figure E72. Time History for DBS Run 1, Brake Characterization Initial	82
Figure E73. Time History for DBS Run 2, Brake Characterization Initial	83
Figure E74. Time History for DBS Run 3, Brake Characterization Initial	84
Figure E75. Time History for DBS Run 7, Brake Characterization Determination 35 mph.....	85
Figure E76. Time History for DBS Run 11, Brake Characterization Determination 35 mph	86

Figure E77. Time History for DBS Run 12, Brake Characterization Determination 35 mph	87
Figure E78. Time History for DBS Run 13, Brake Characterization Determination 35 mph	88
Figure E79. Time History for DBS Run 19, Brake Characterization Determination 35 mph	89
Figure E80. Time History for DBS Run 20, Brake Characterization Determination 35 mph	90
Figure E81. Time History for DBS Run 8, Brake Characterization Determination 25 mph	91
Figure E82. Time History for DBS Run 9, Brake Characterization Determination 25 mph	92
Figure E83. Time History for DBS Run 14, Brake Characterization Determination 25 mph	93
Figure E84. Time History for DBS Run 15, Brake Characterization Determination 25 mph	94
Figure E85. Time History for DBS Run 10, Brake Characterization Determination 45 mph	95
Figure E86. Time History for DBS Run 16, Brake Characterization Determination 45 mph	96
Figure E87. Time History for DBS Run 17, Brake Characterization Determination 45 mph	97
Figure E88. Time History for DBS Run 18, Brake Characterization Determination 45 mph	98

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., $0.30\text{ g} \pm 0.03\text{ g}$). 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.

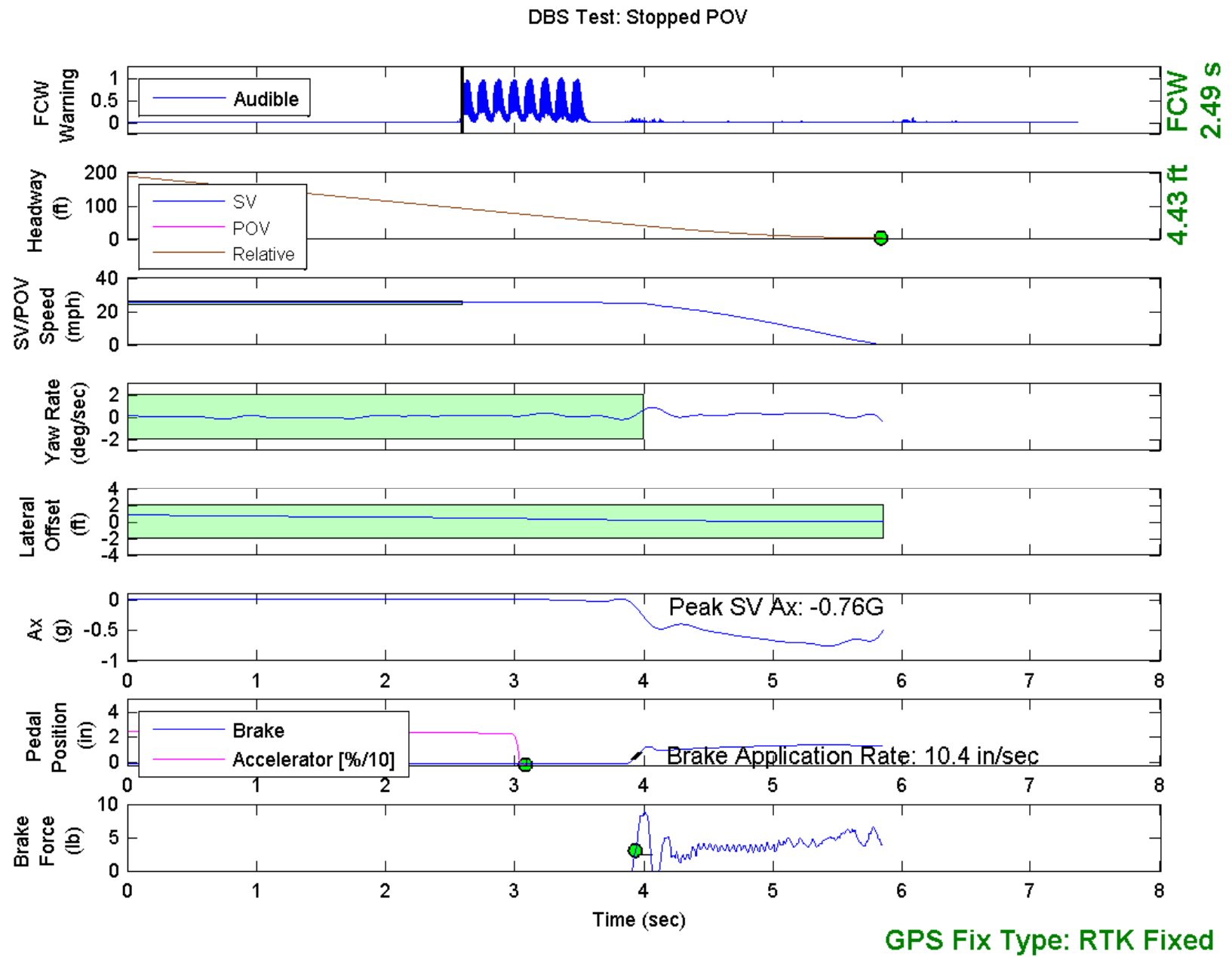


Figure E1. Example Time History for Stopped POV, Passing

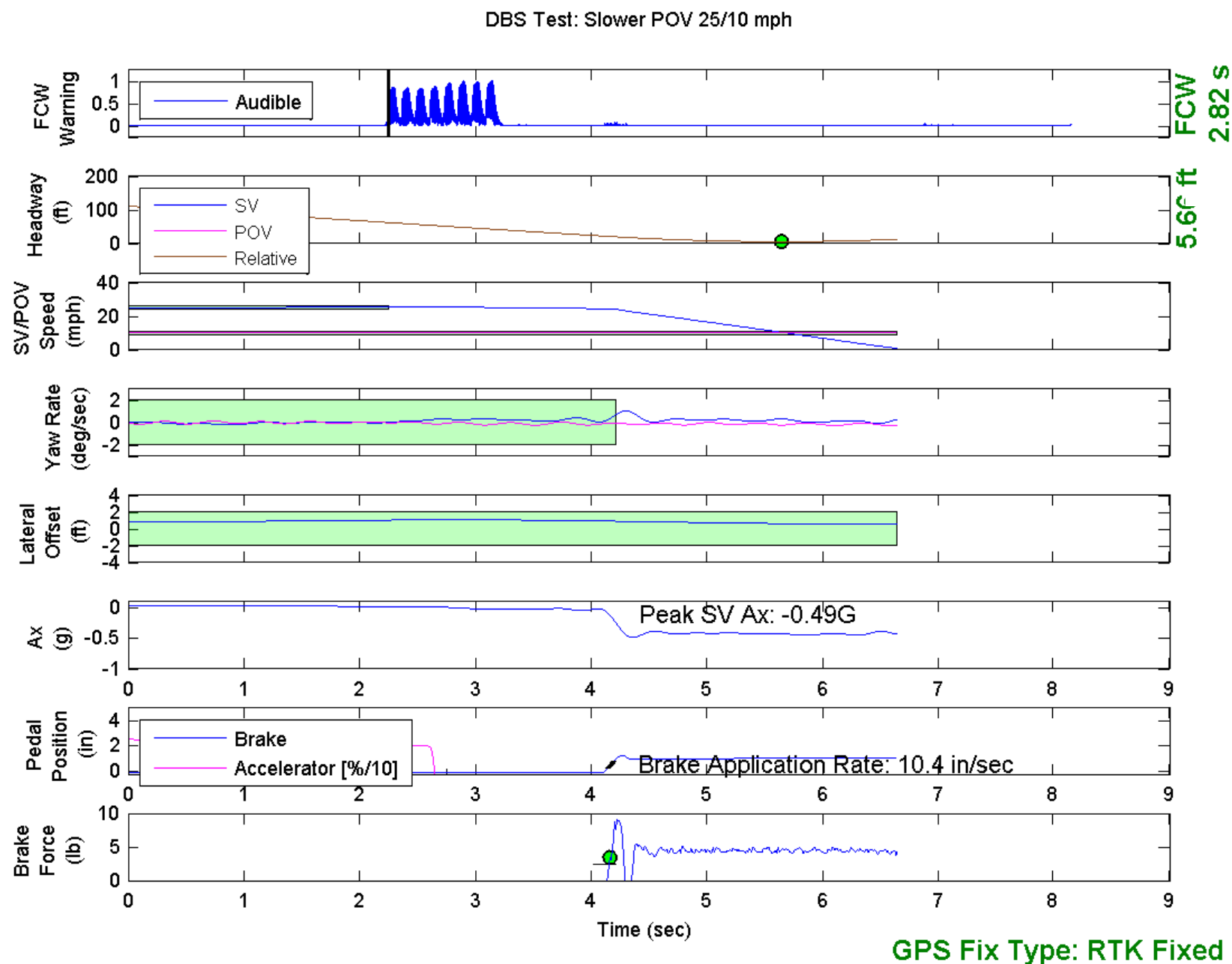


Figure E2. Example Time History for Slower POV 25 vs. 10, Passing

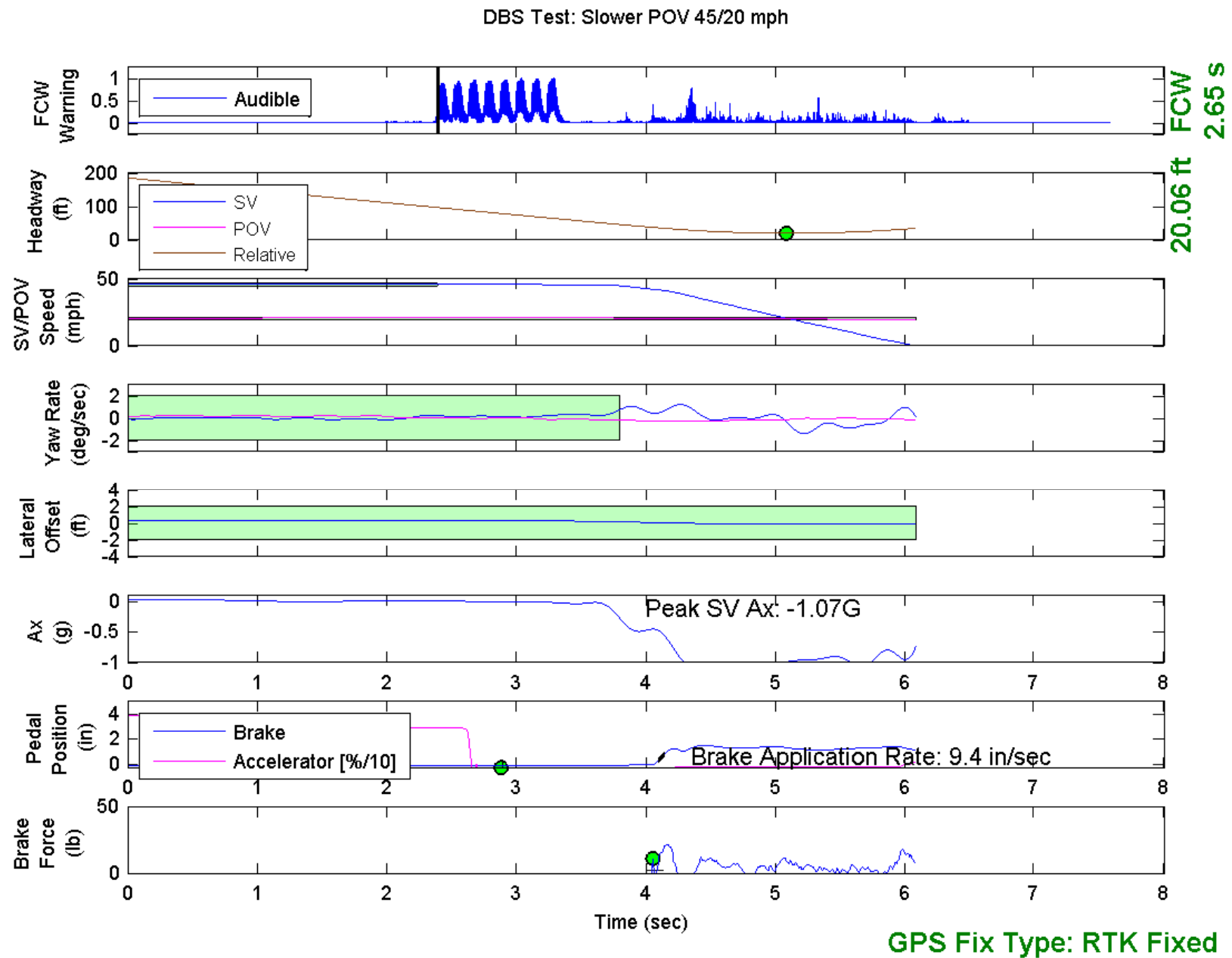


Figure E3. Example Time History for Slower POV 45 vs. 20, Passing

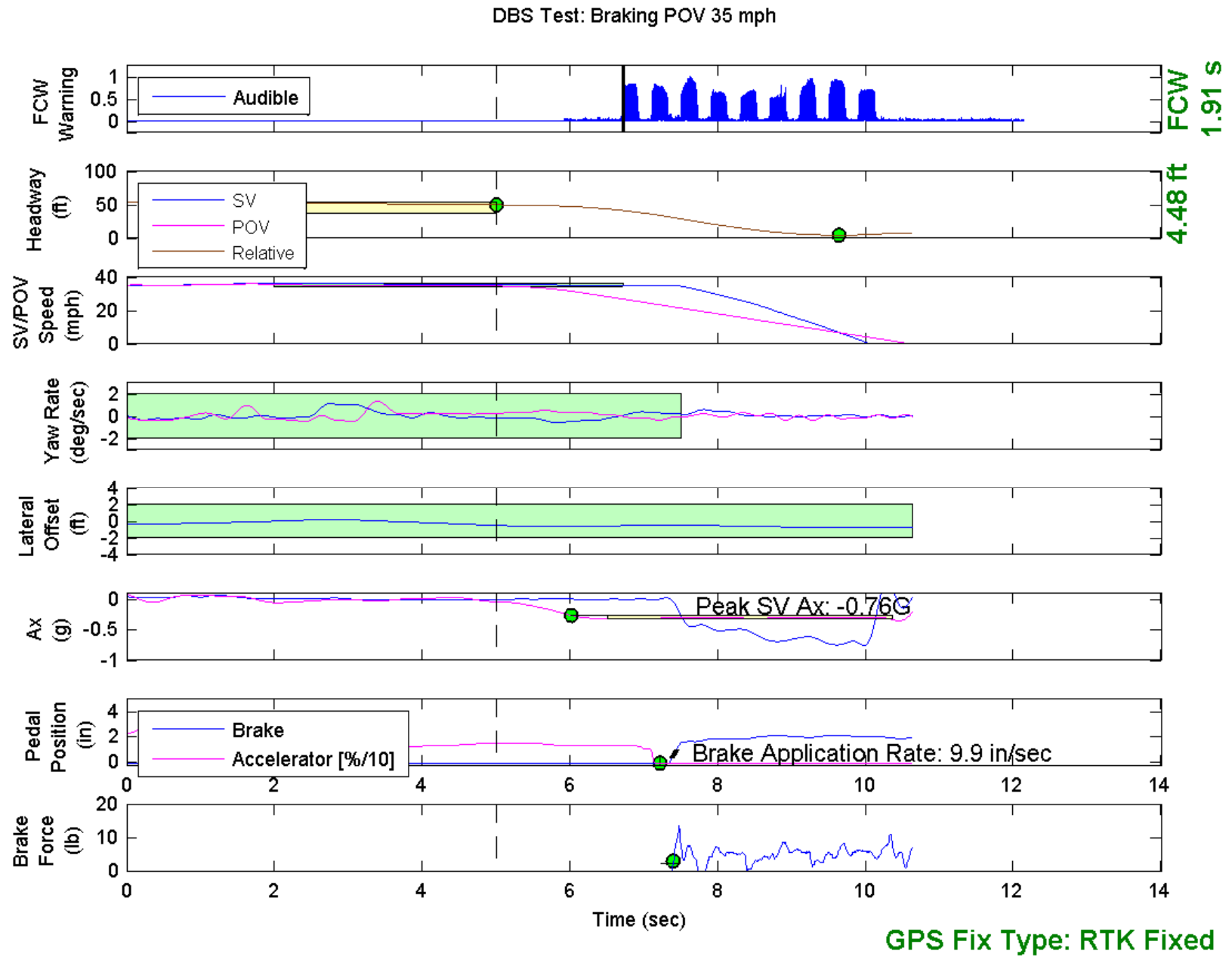


Figure E4. Example Time History for Braking POV 35, Passing

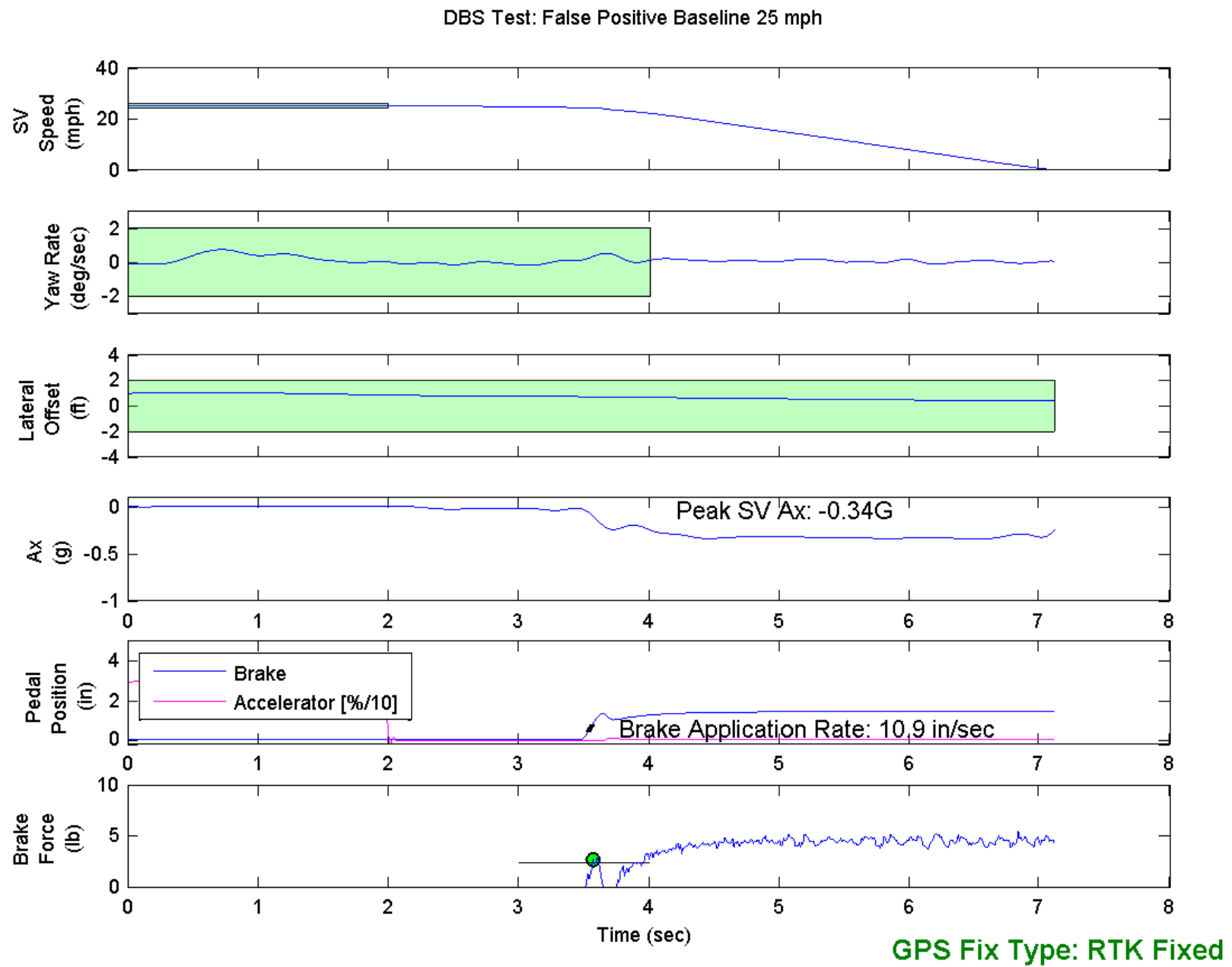


Figure E5. Example Time History for False Positive Baseline 25, Passing

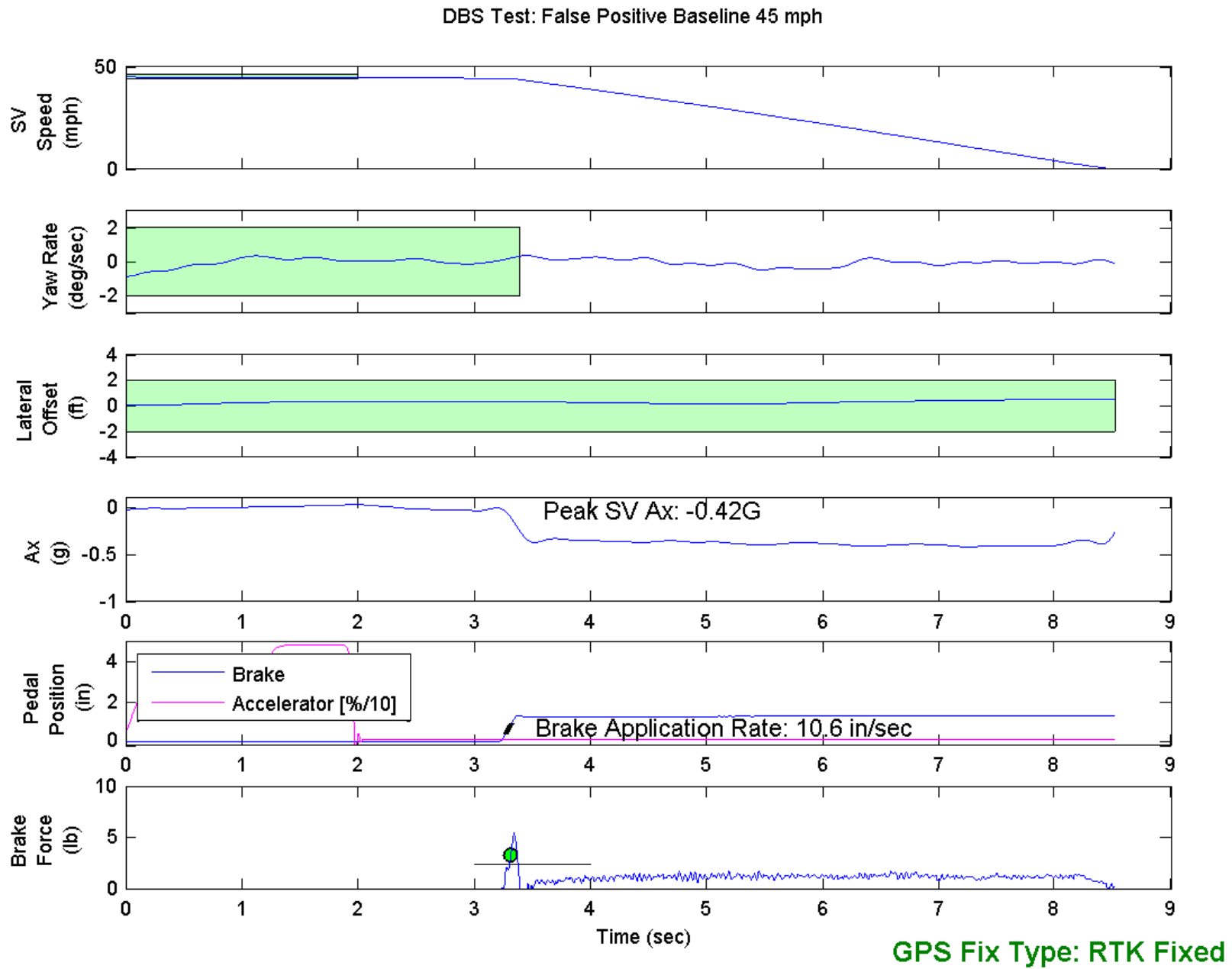


Figure E6. Example Time History for False Positive Baseline 45, Passing

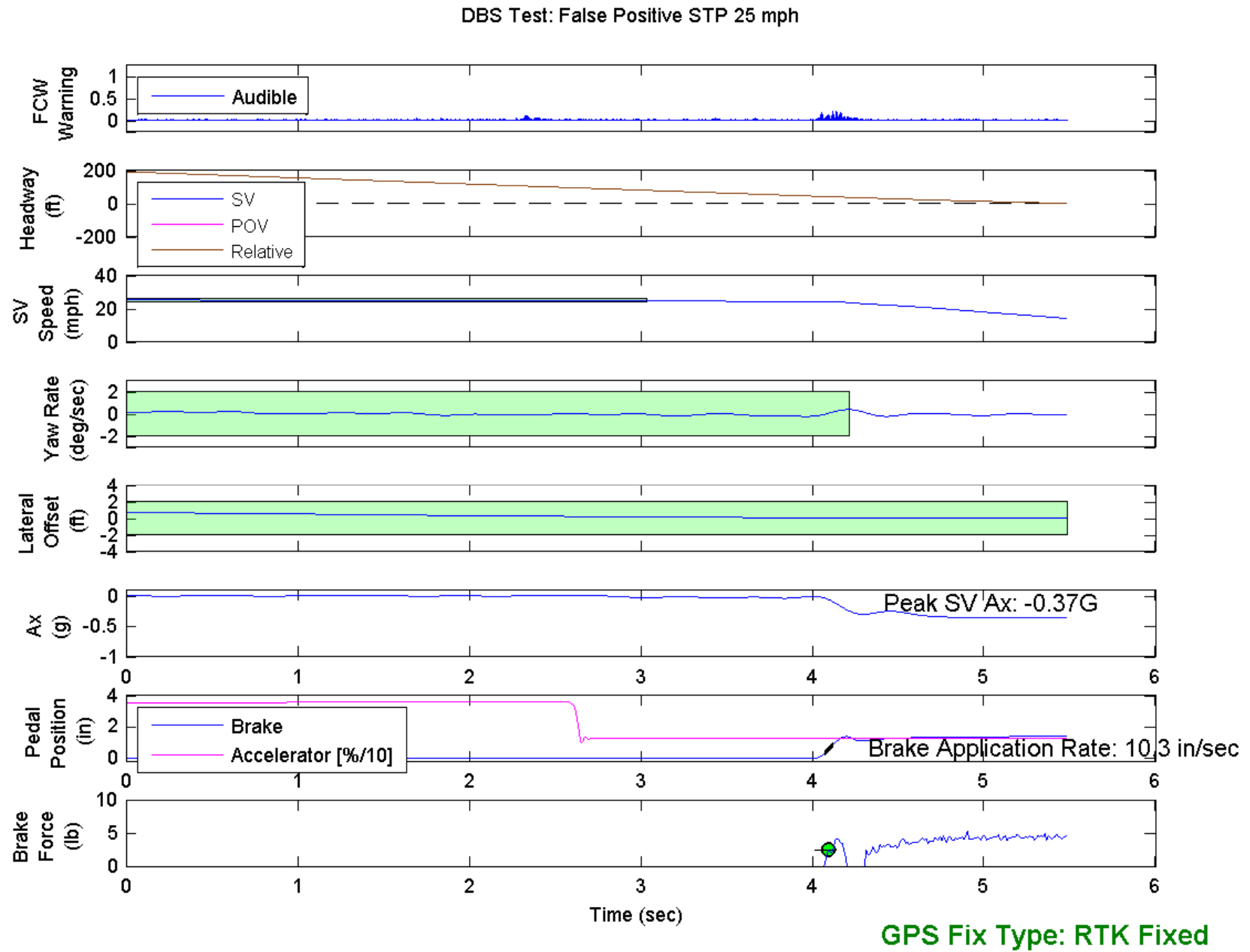


Figure E7. Example Time History for False Positive Steel Plate 25, Passing

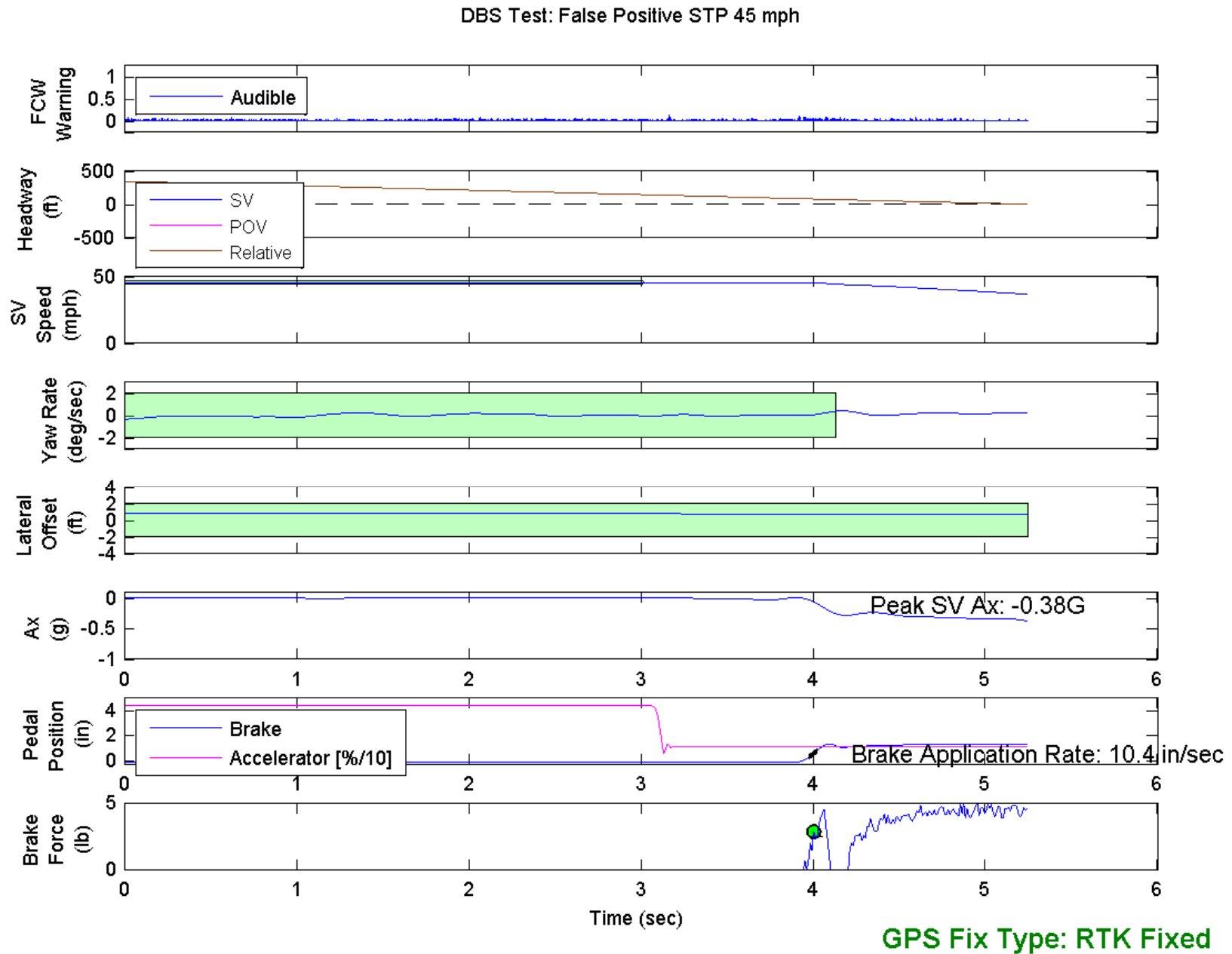


Figure E8. Example Time History for False Positive Steel Plate 45, Passing

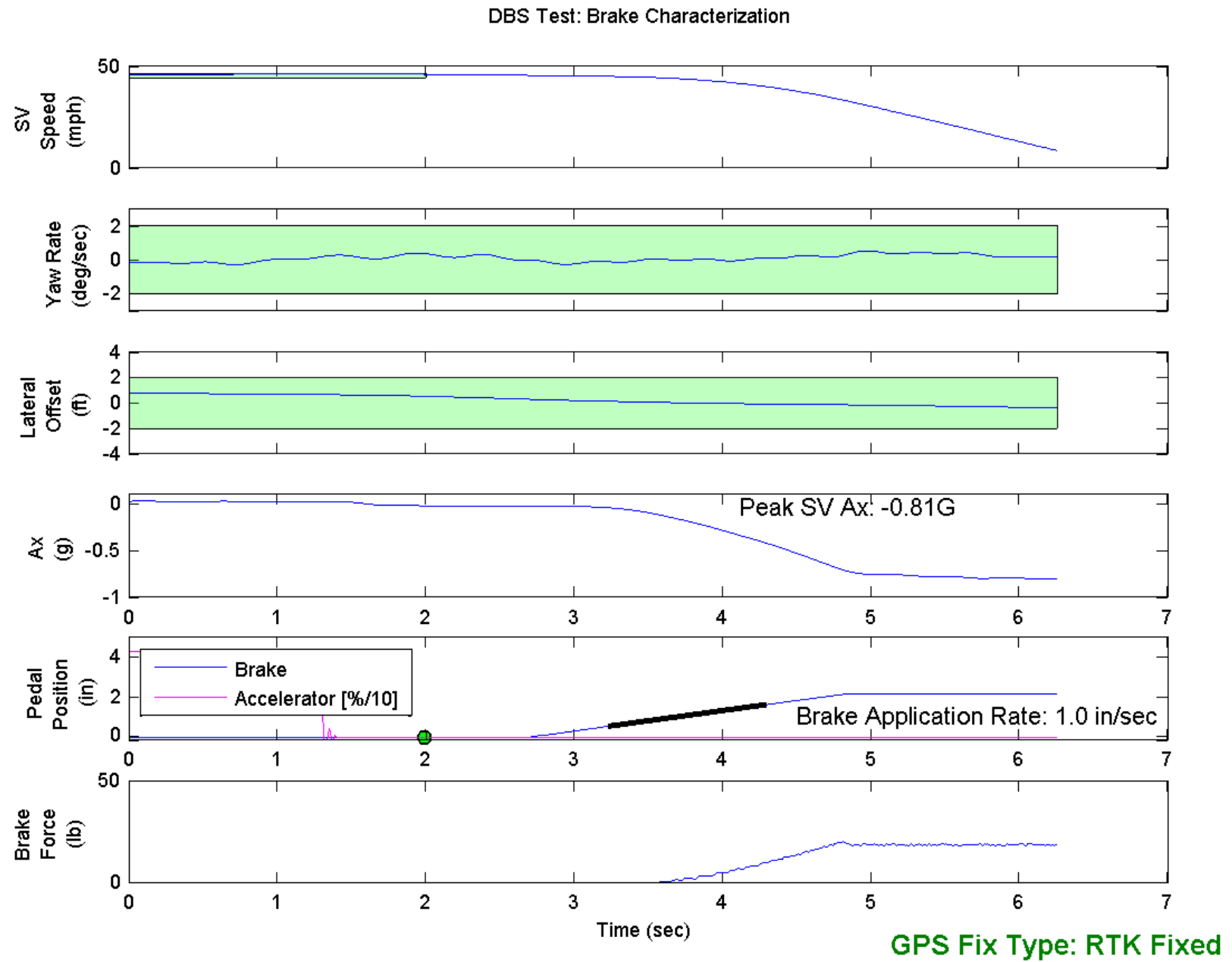


Figure E9. Example Time History for DBS Brake Characterization, Passing

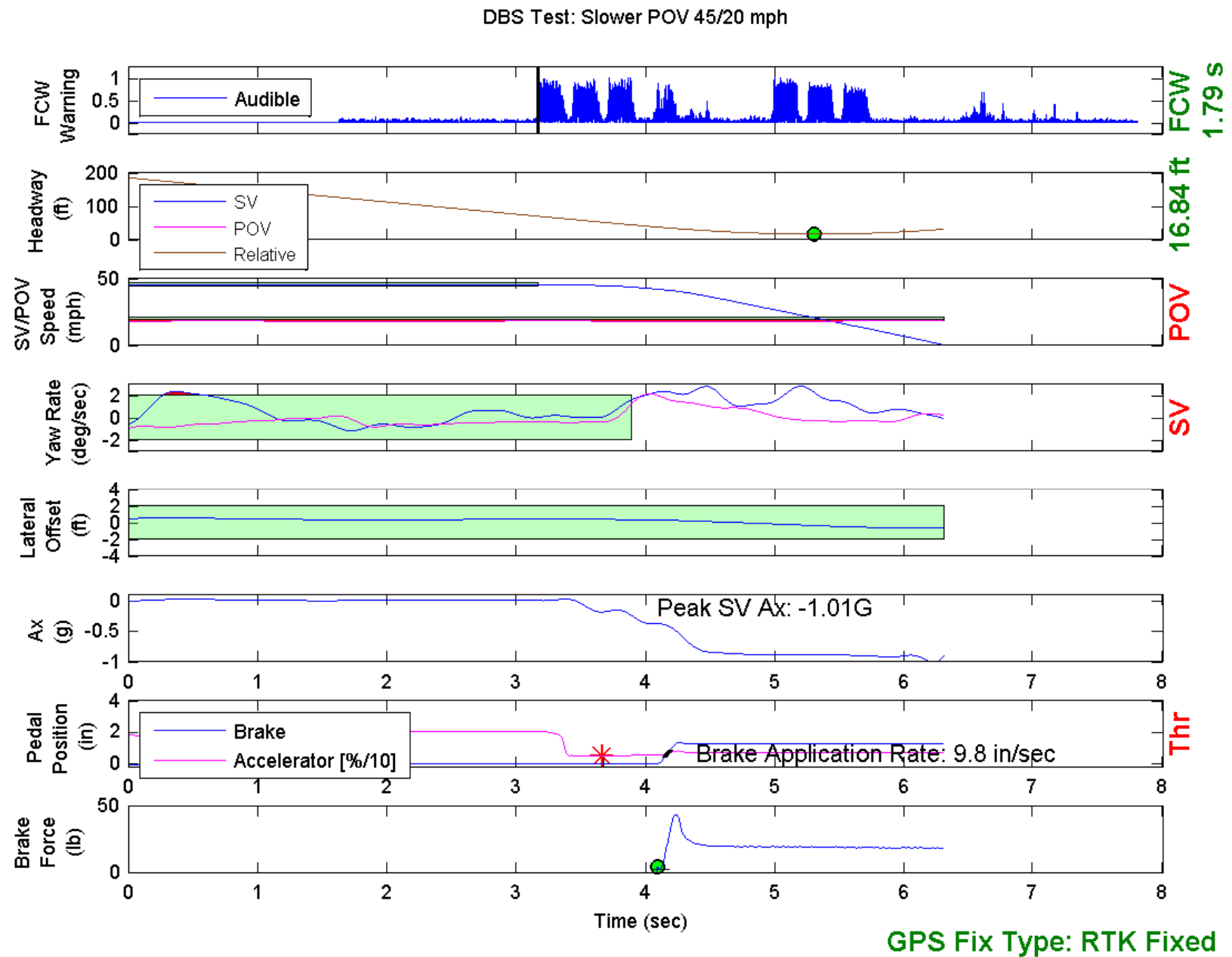


Figure E10. Example Time History Displaying Various Invalid Criteria

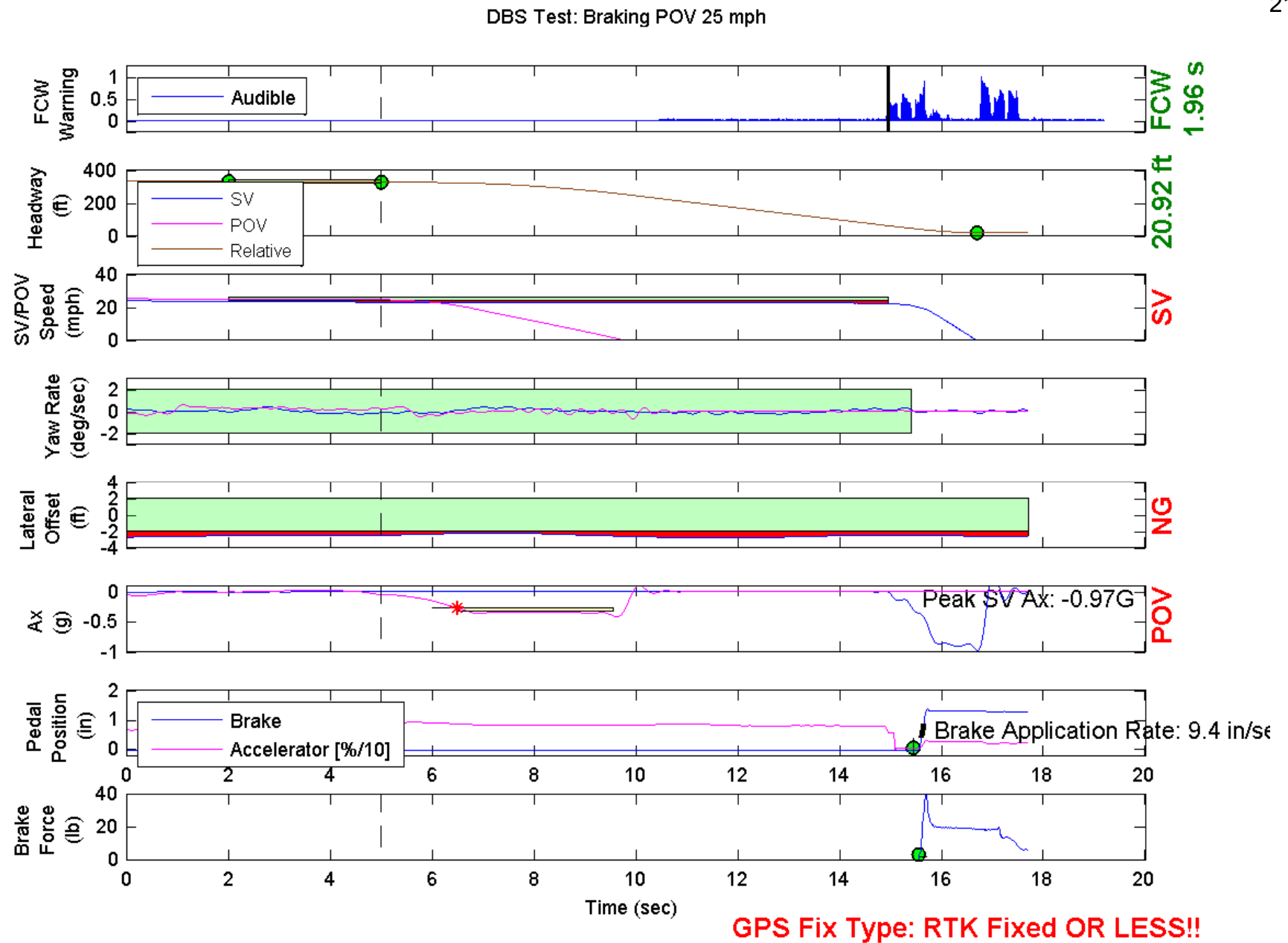


Figure E11. Example Time History Displaying Various Invalid Criteria

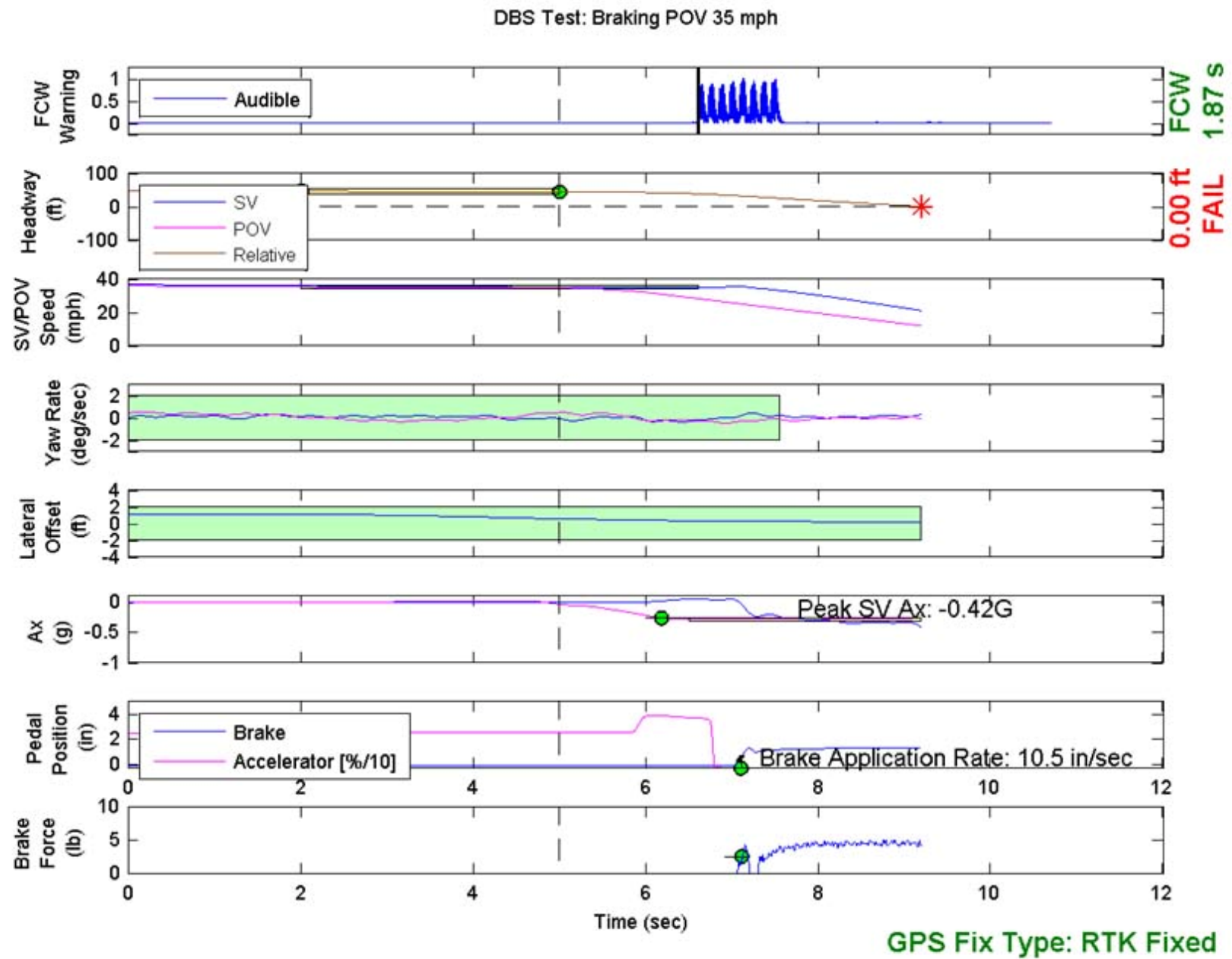


Figure E12. Example Time History for a Failed Run

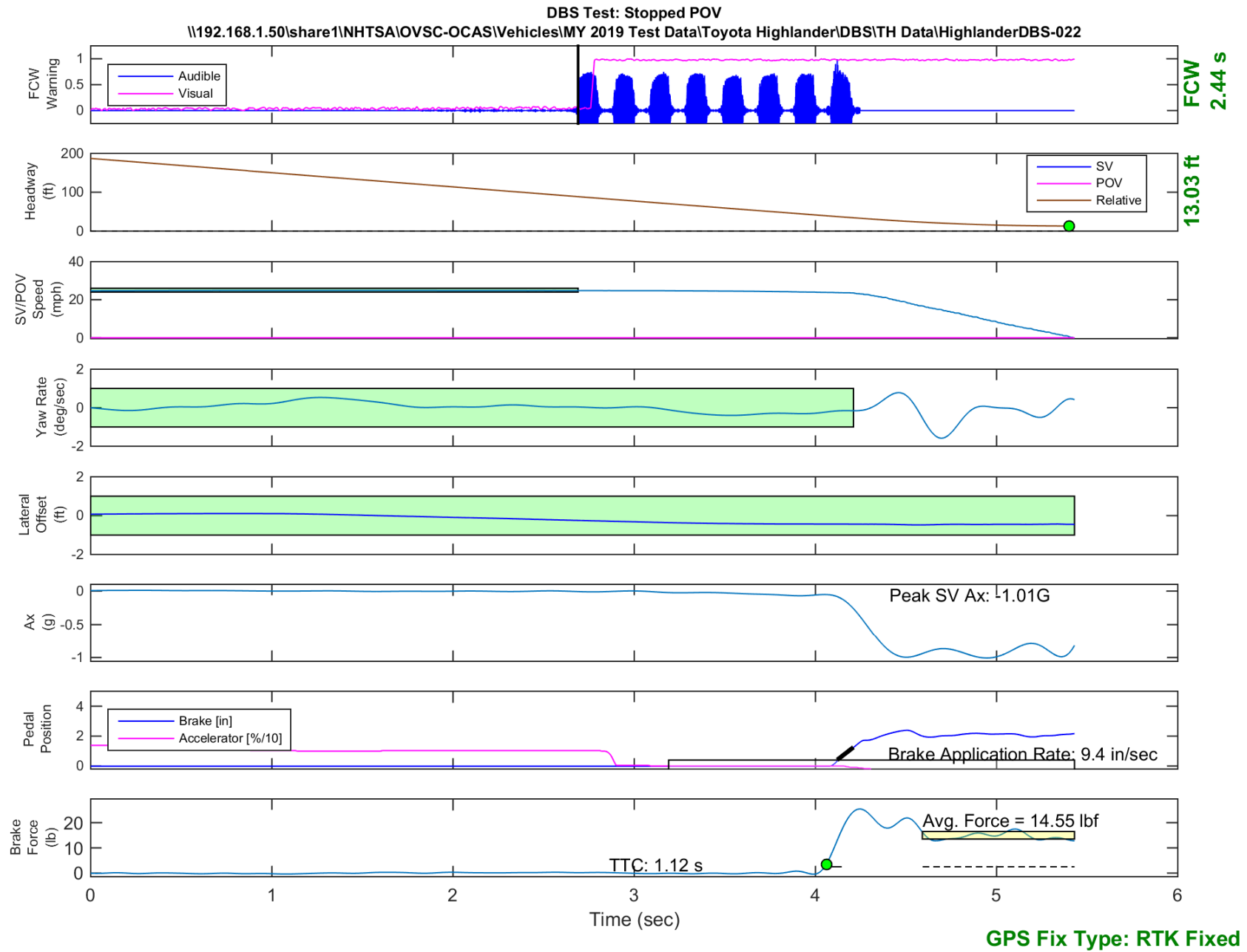


Figure E13. Time History for DBS Run 22, SV Encounters Stopped POV

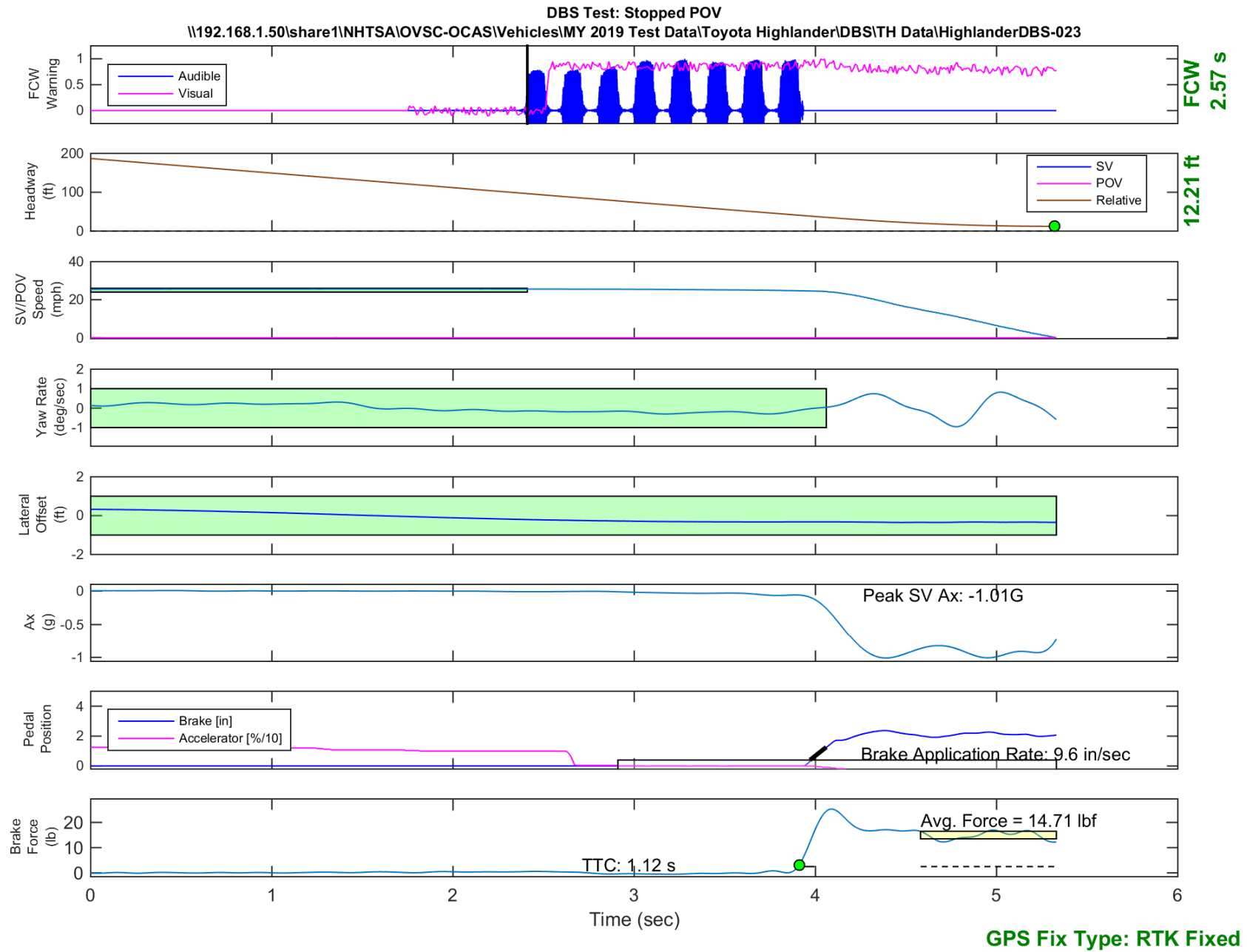


Figure E14. Time History for DBS Run 23, SV Encounters Stopped POV

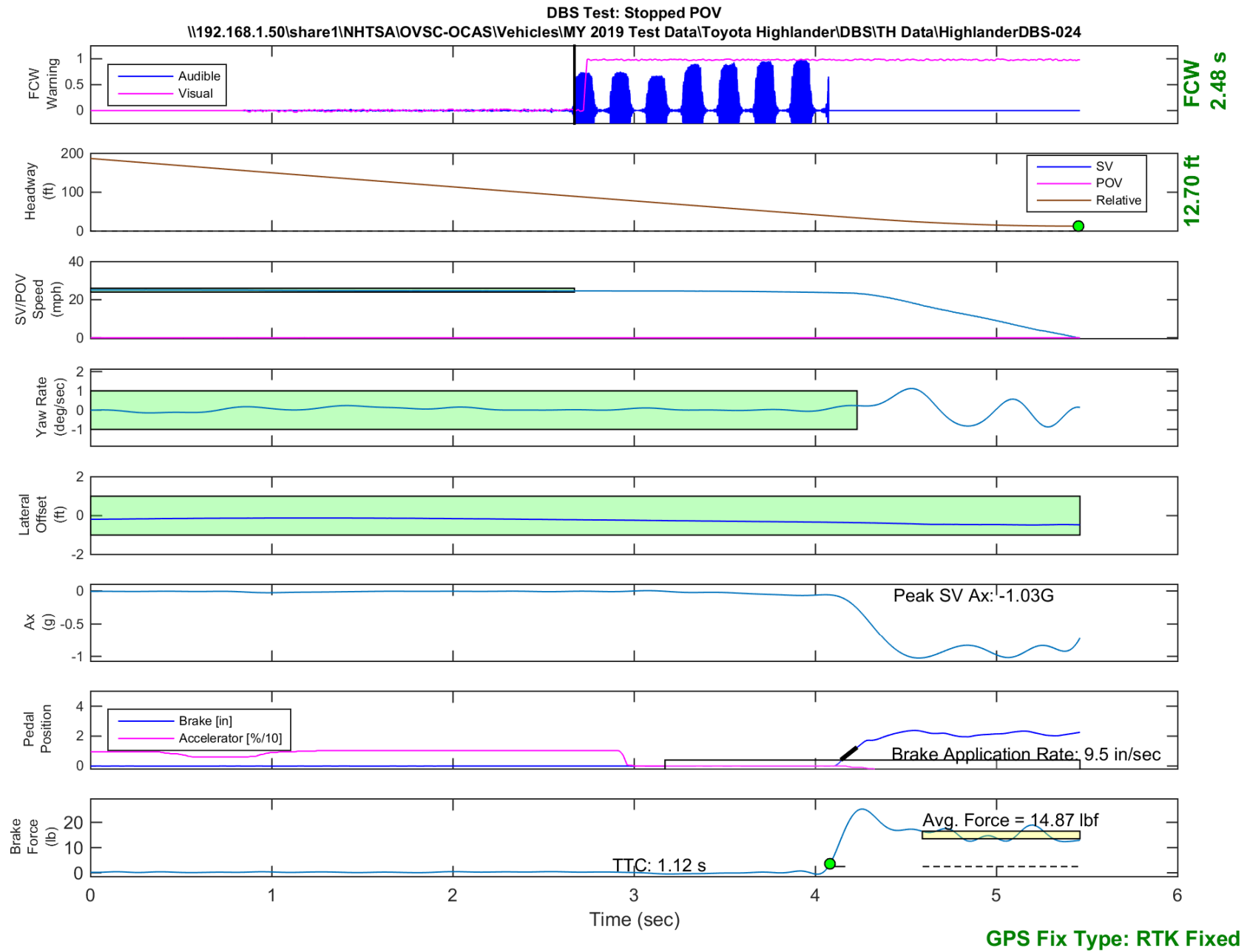


Figure E15. Time History for DBS Run 24, SV Encounters Stopped POV

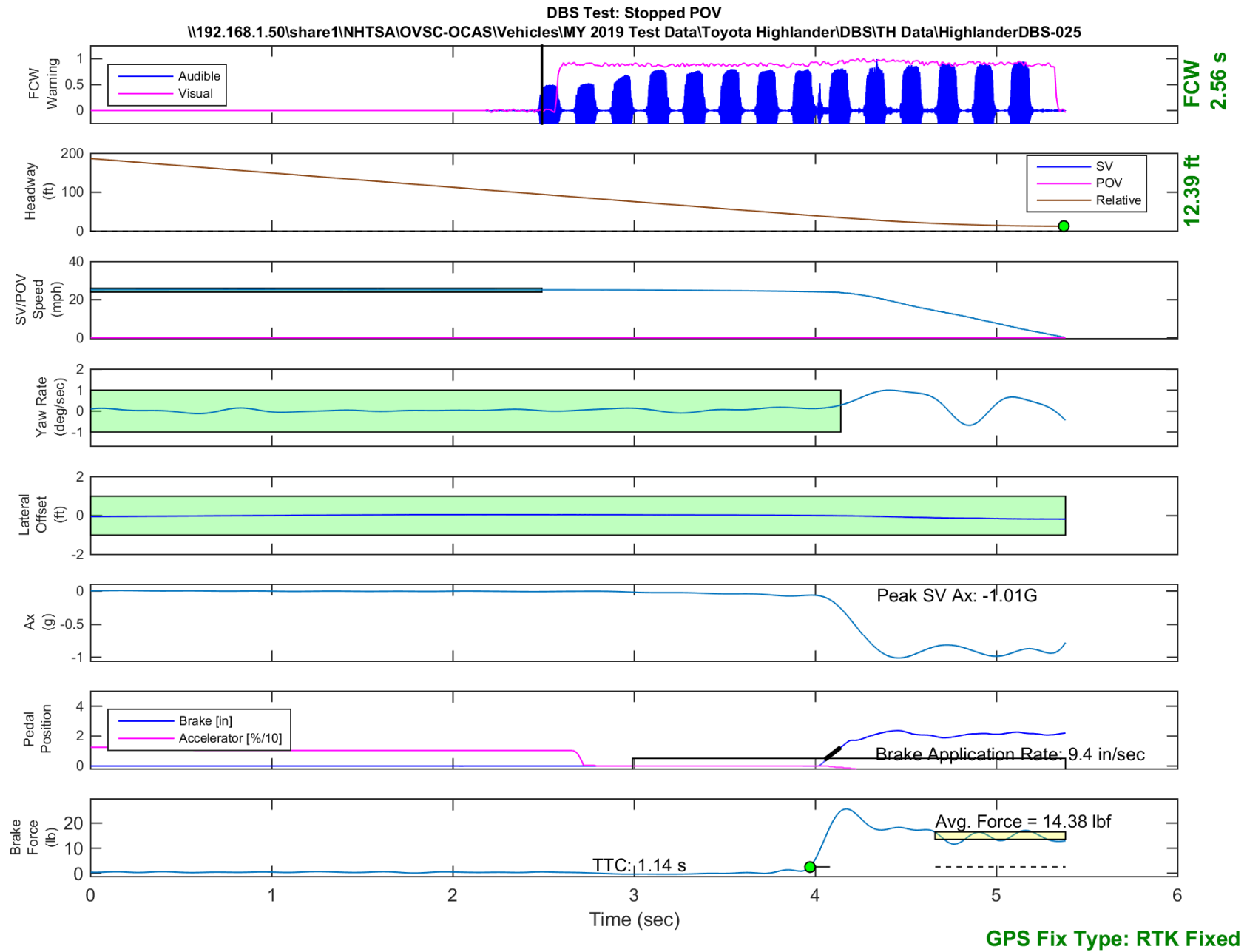


Figure E16. Time History for DBS Run 25, SV Encounters Stopped POV

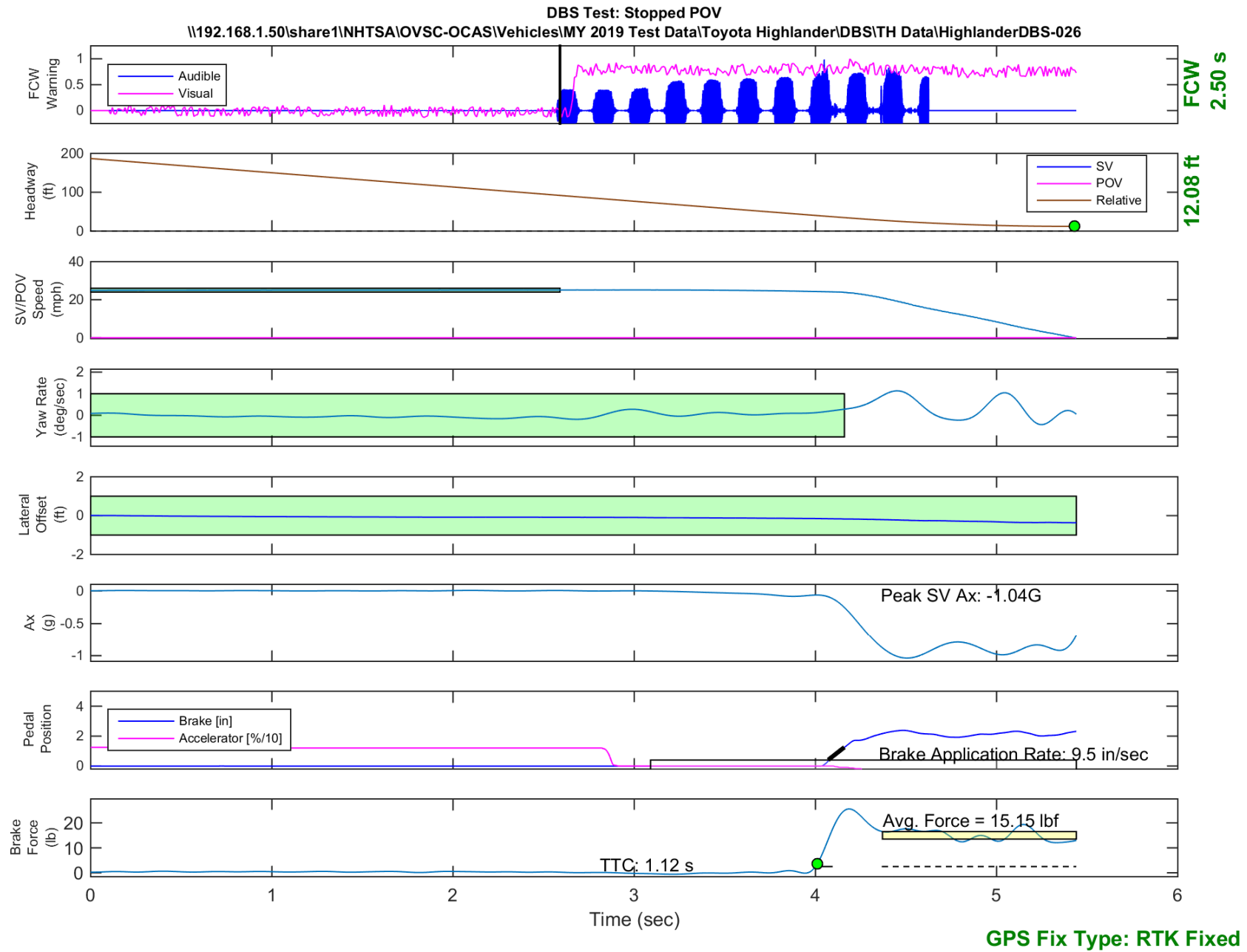


Figure E17. Time History for DBS Run 26, SV Encounters Stopped POV

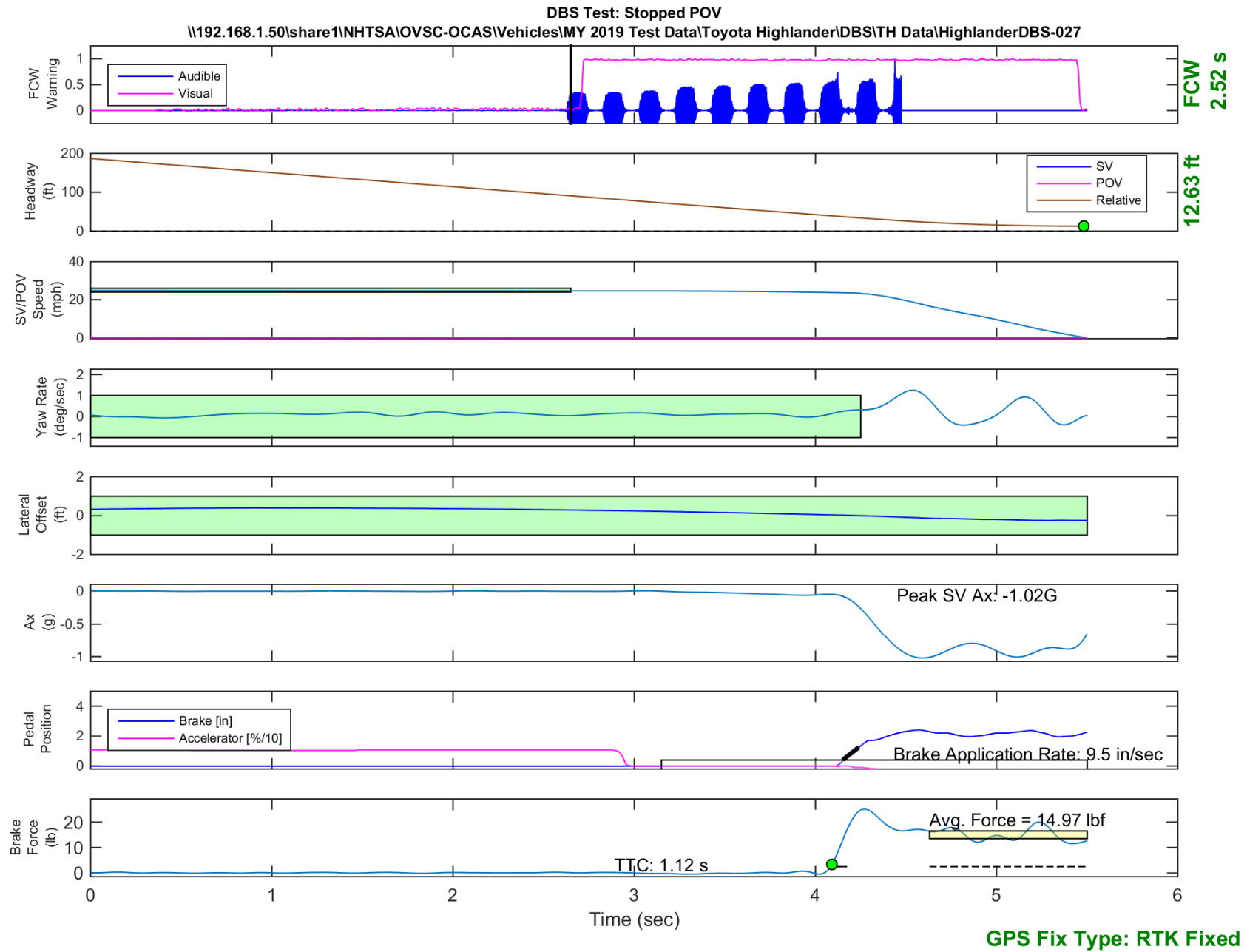


Figure E18. Time History for DBS Run 27, SV Encounters Stopped POV

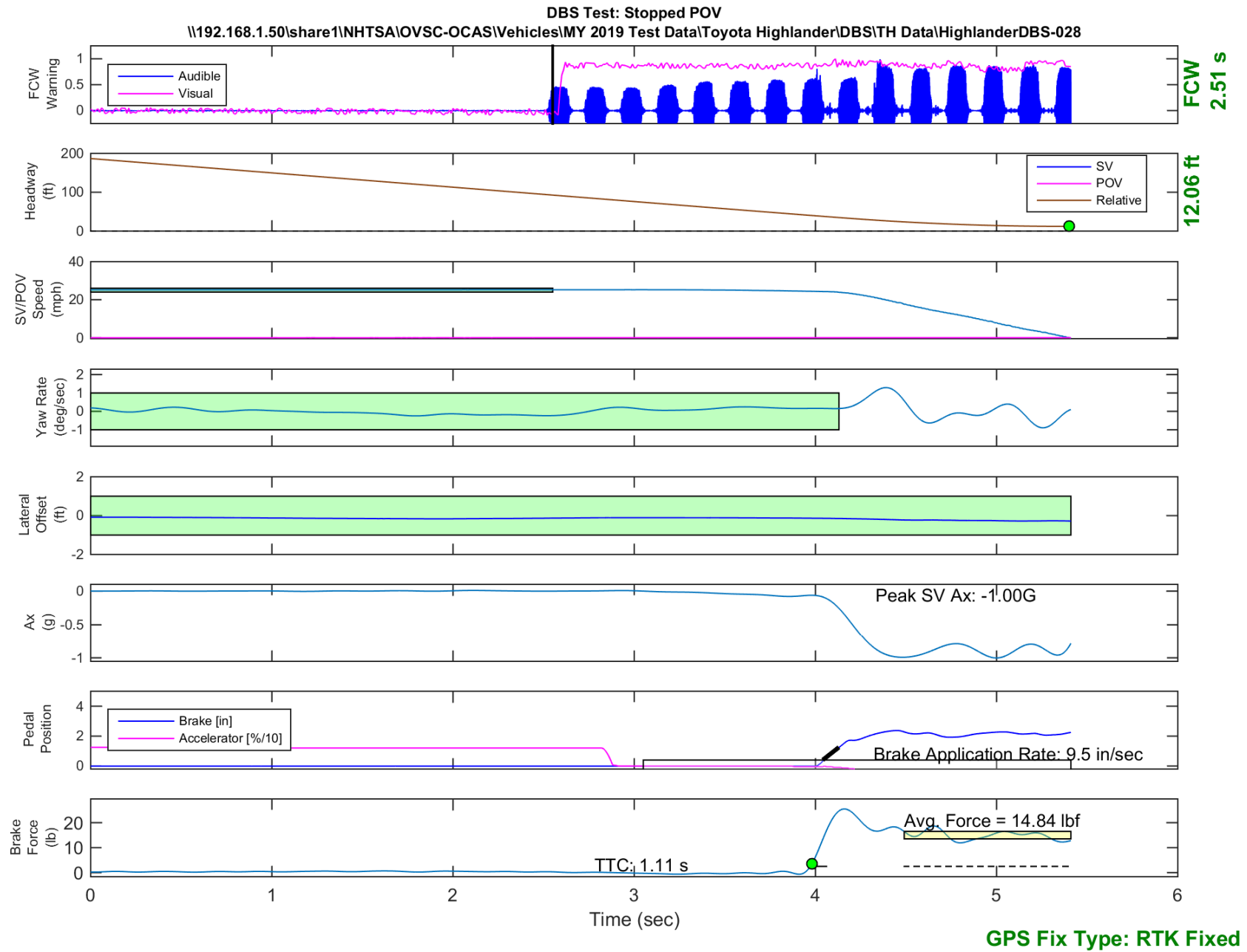


Figure E19. Time History for DBS Run 28, SV Encounters Stopped POV

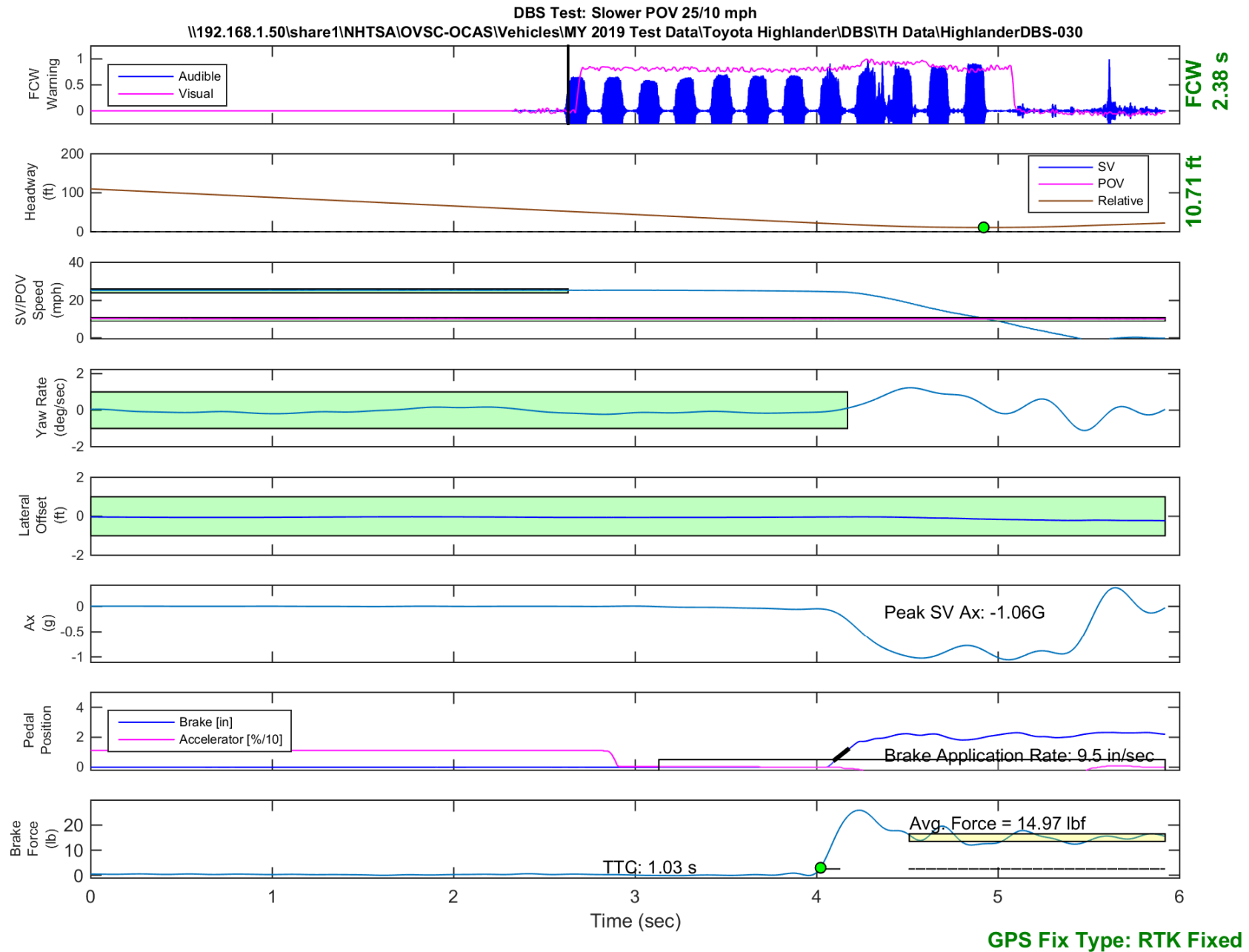


Figure E20. Time History for DBS Run 30, SV Encounters Slower POV, SV 25 mph, POV 10 mph

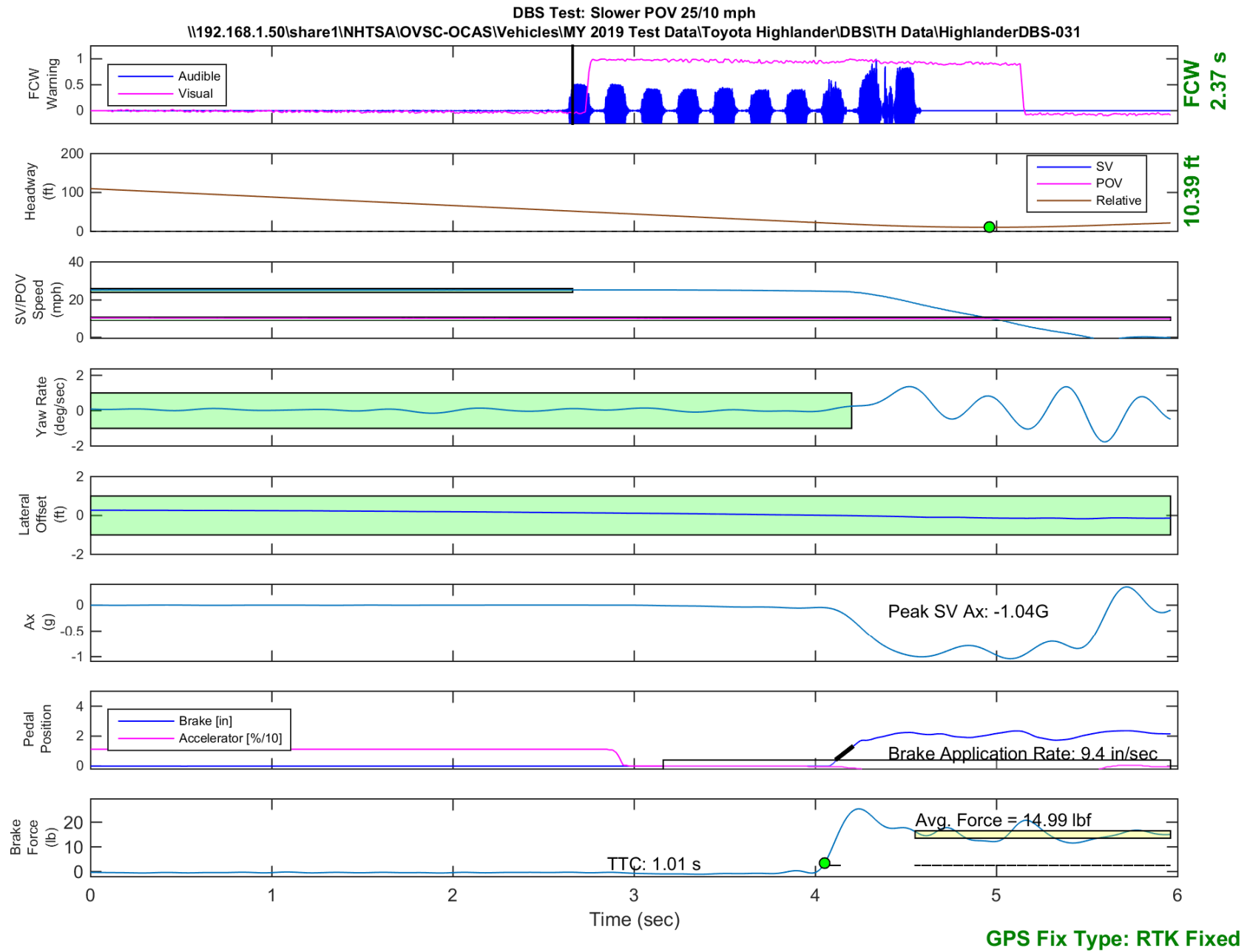


Figure E21. Time History for DBS Run 31, SV Encounters Slower POV, SV 25 mph, POV 10 mph

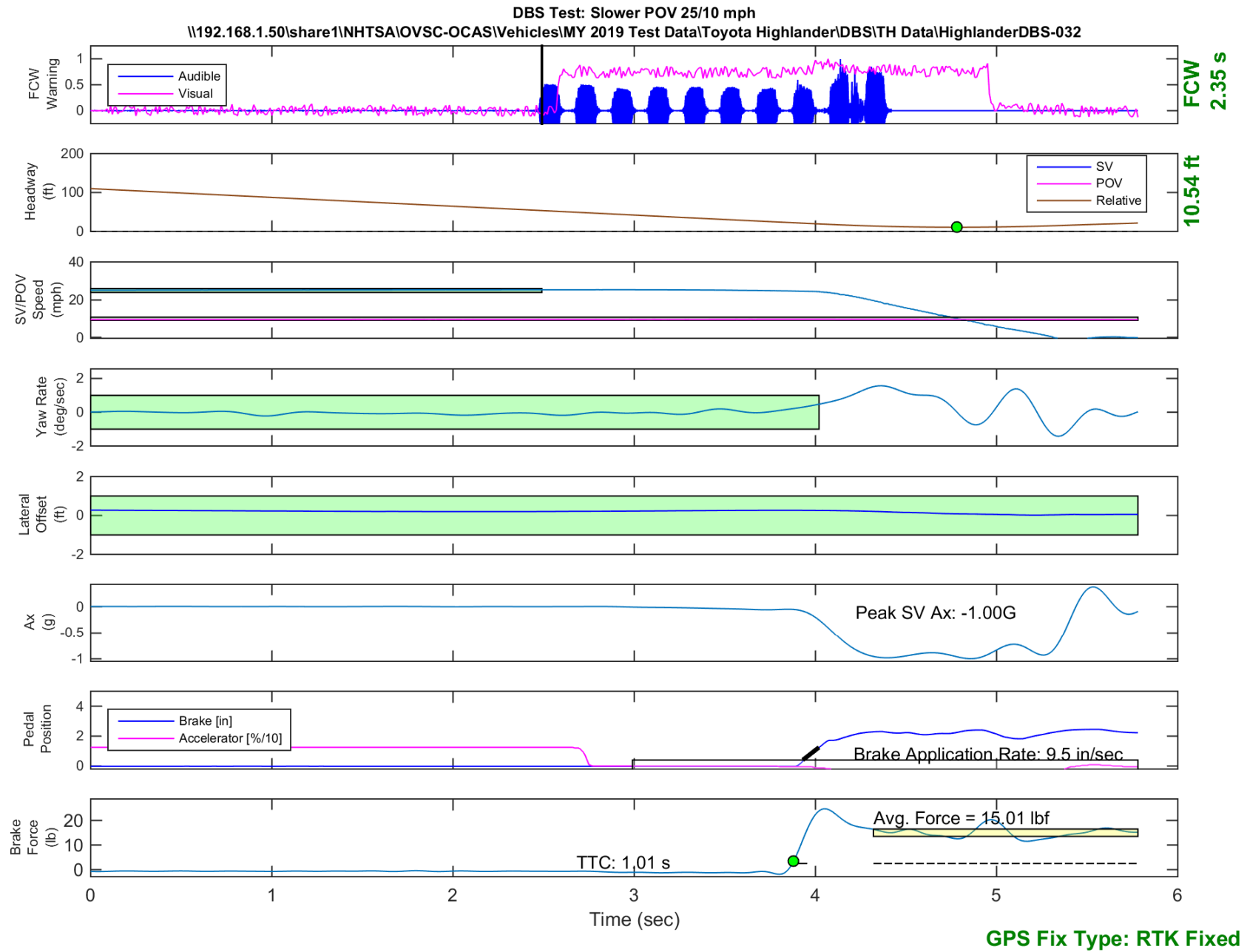


Figure E22. Time History for DBS Run 32, SV Encounters Slower POV, SV 25 mph, POV 10 mph

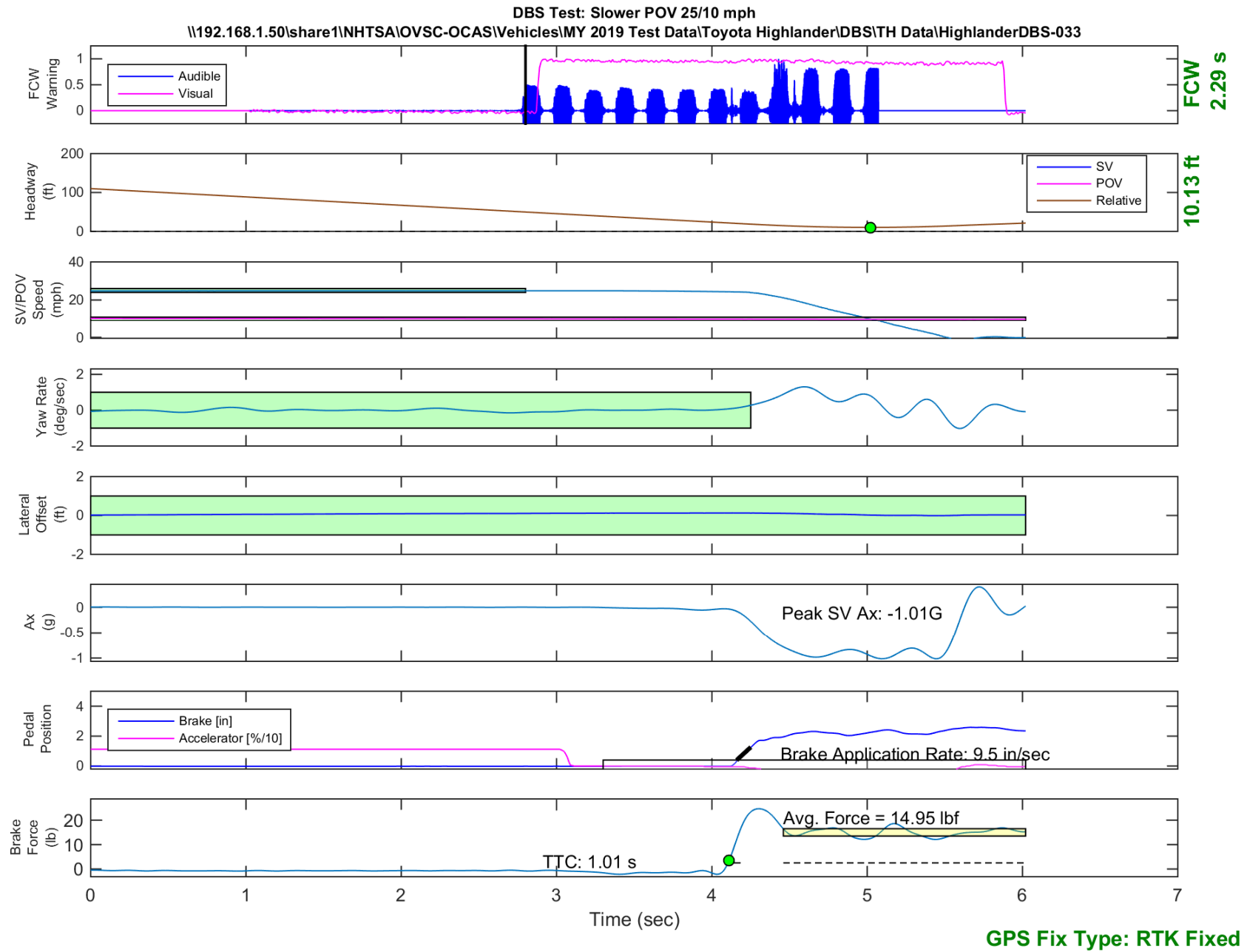


Figure E23. Time History for DBS Run 33, SV Encounters Slower POV, SV 25 mph, POV 10 mph

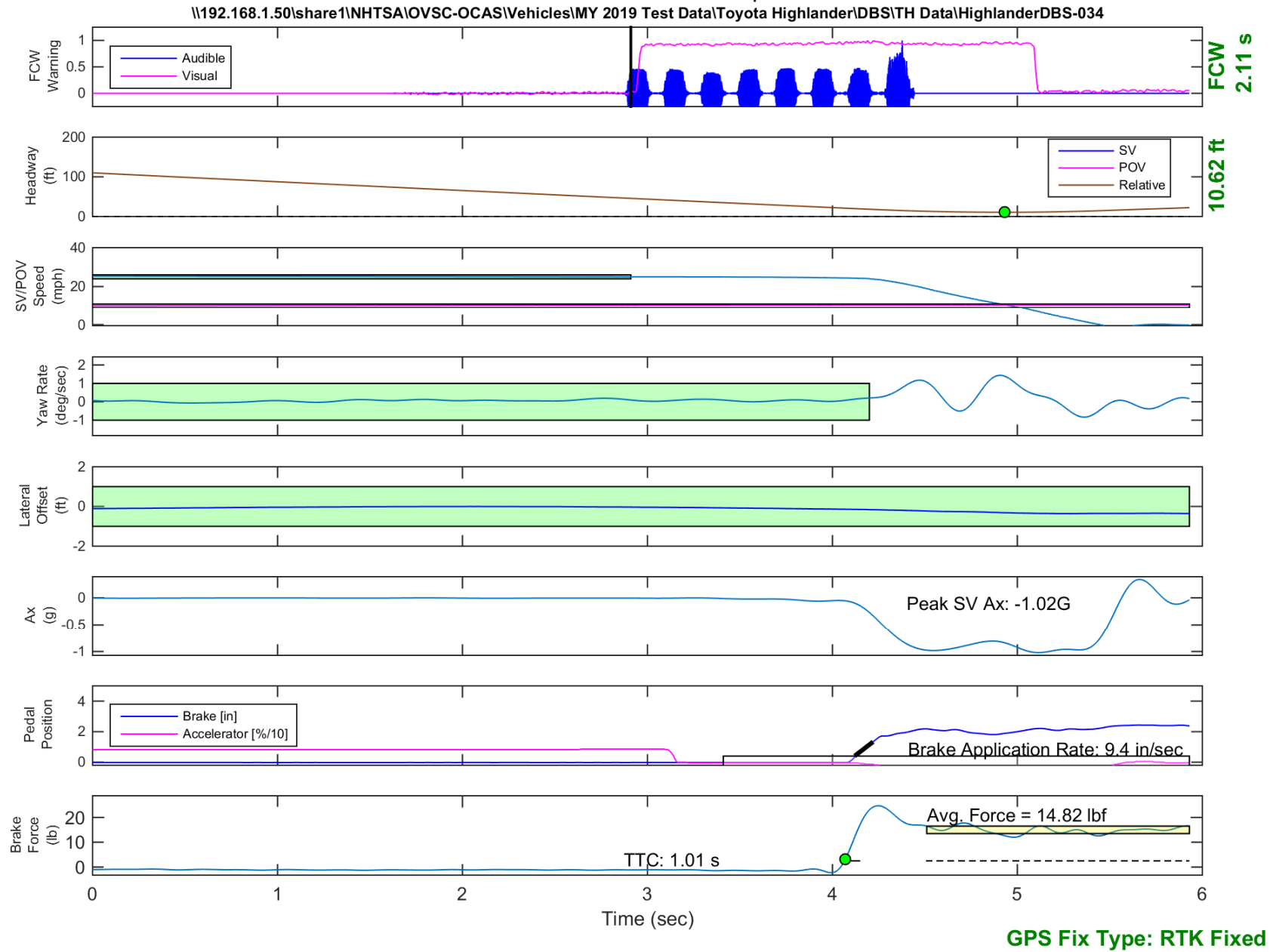


Figure E24. Time History for DBS Run 34, SV Encounters Slower POV, SV 25 mph, POV 10 mph

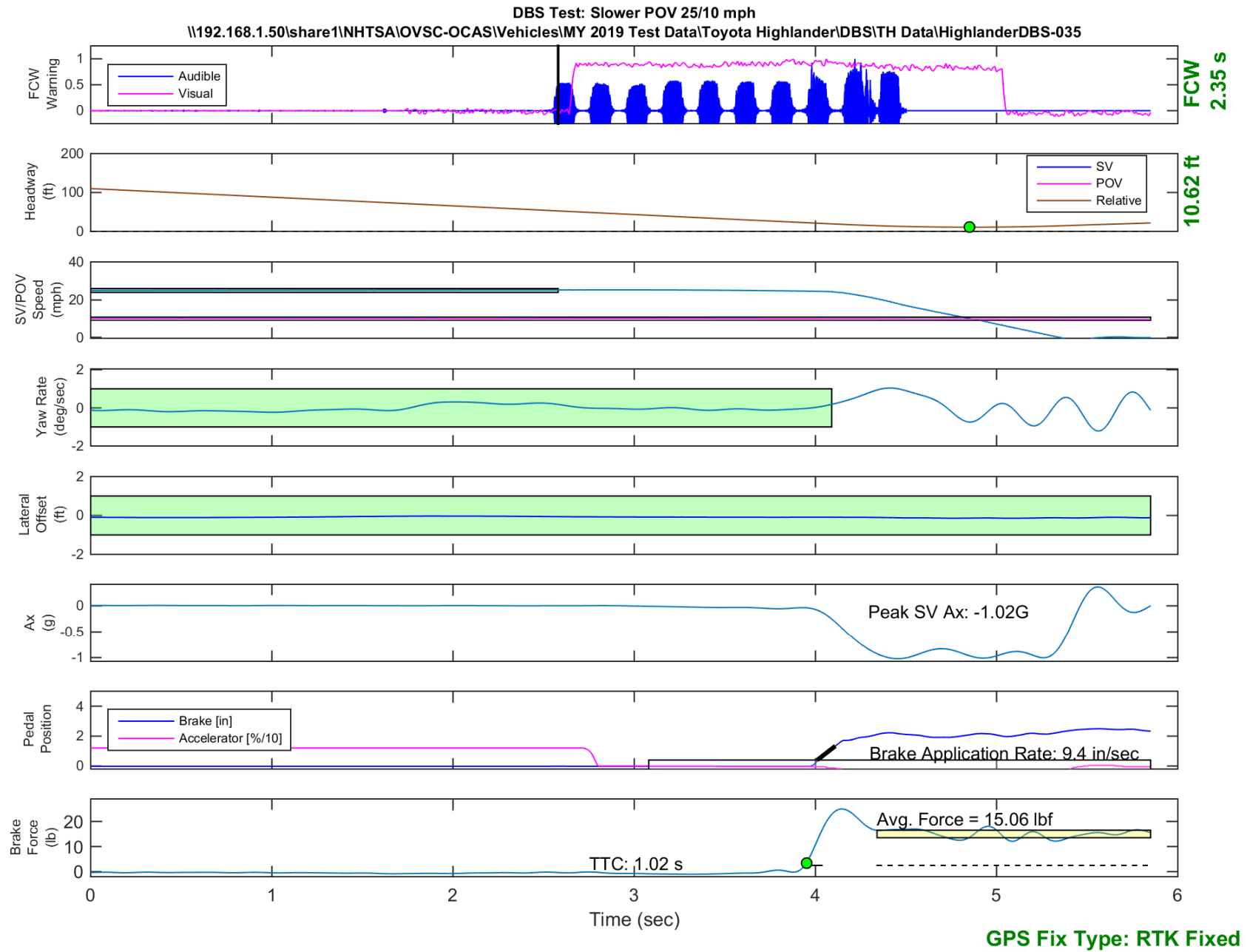


Figure E25. Time History for DBS Run 35, SV Encounters Slower POV, SV 25 mph, POV 10 mph

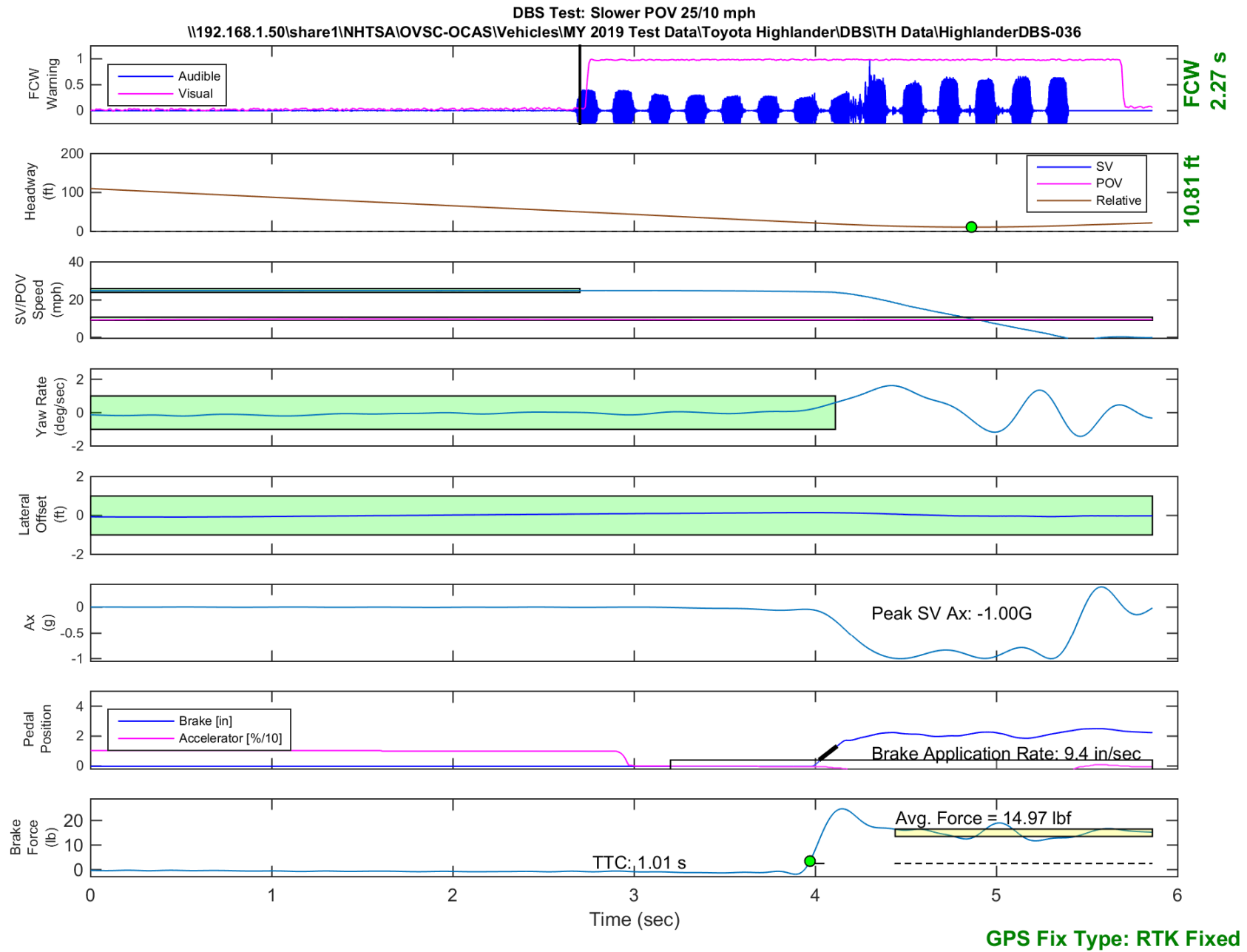


Figure E26. Time History for DBS Run 36, SV Encounters Slower POV, SV 25 mph, POV 10 mph

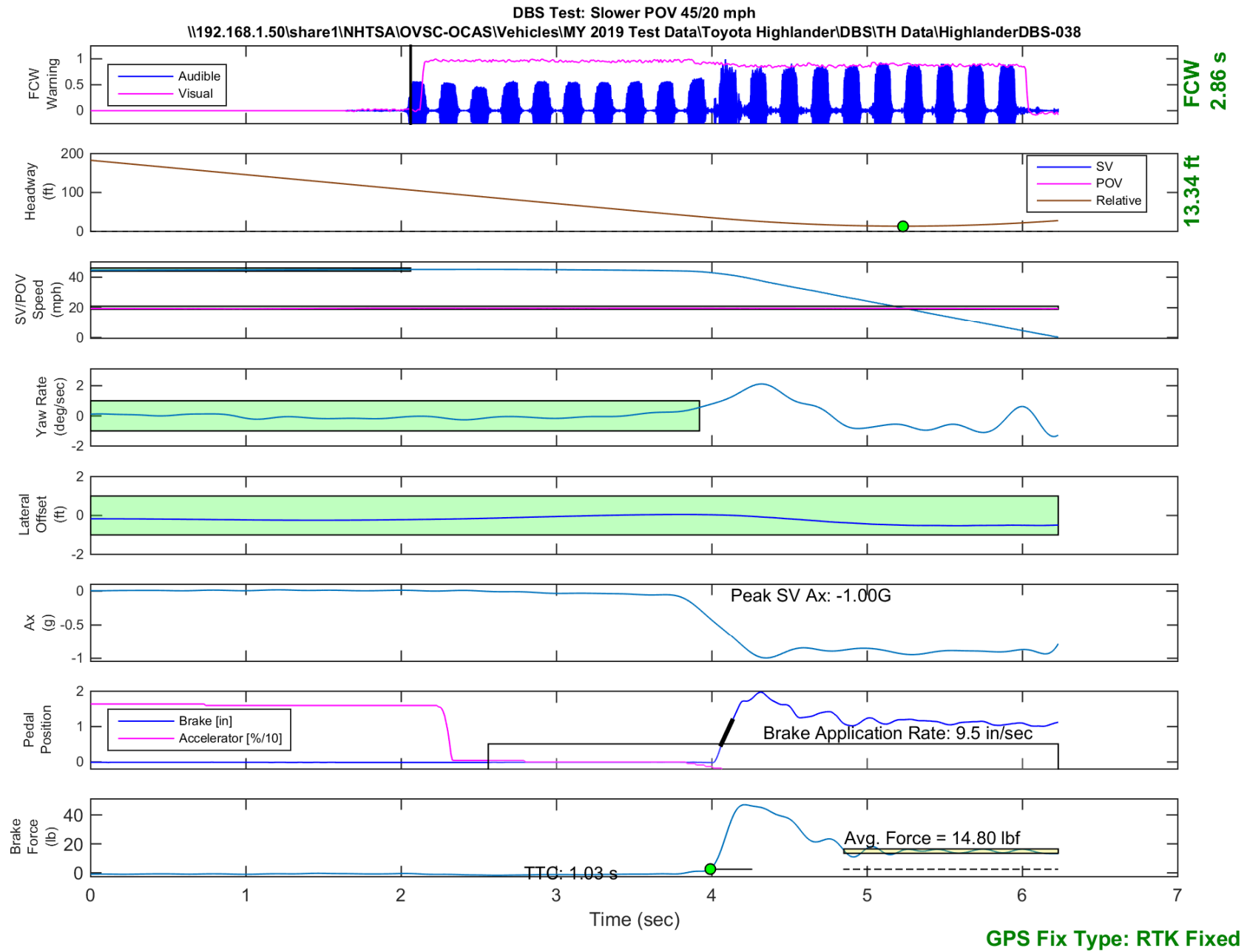


Figure E27. Time History for DBS Run 38, SV Encounters Slower POV, SV 45 mph, POV 20 mph

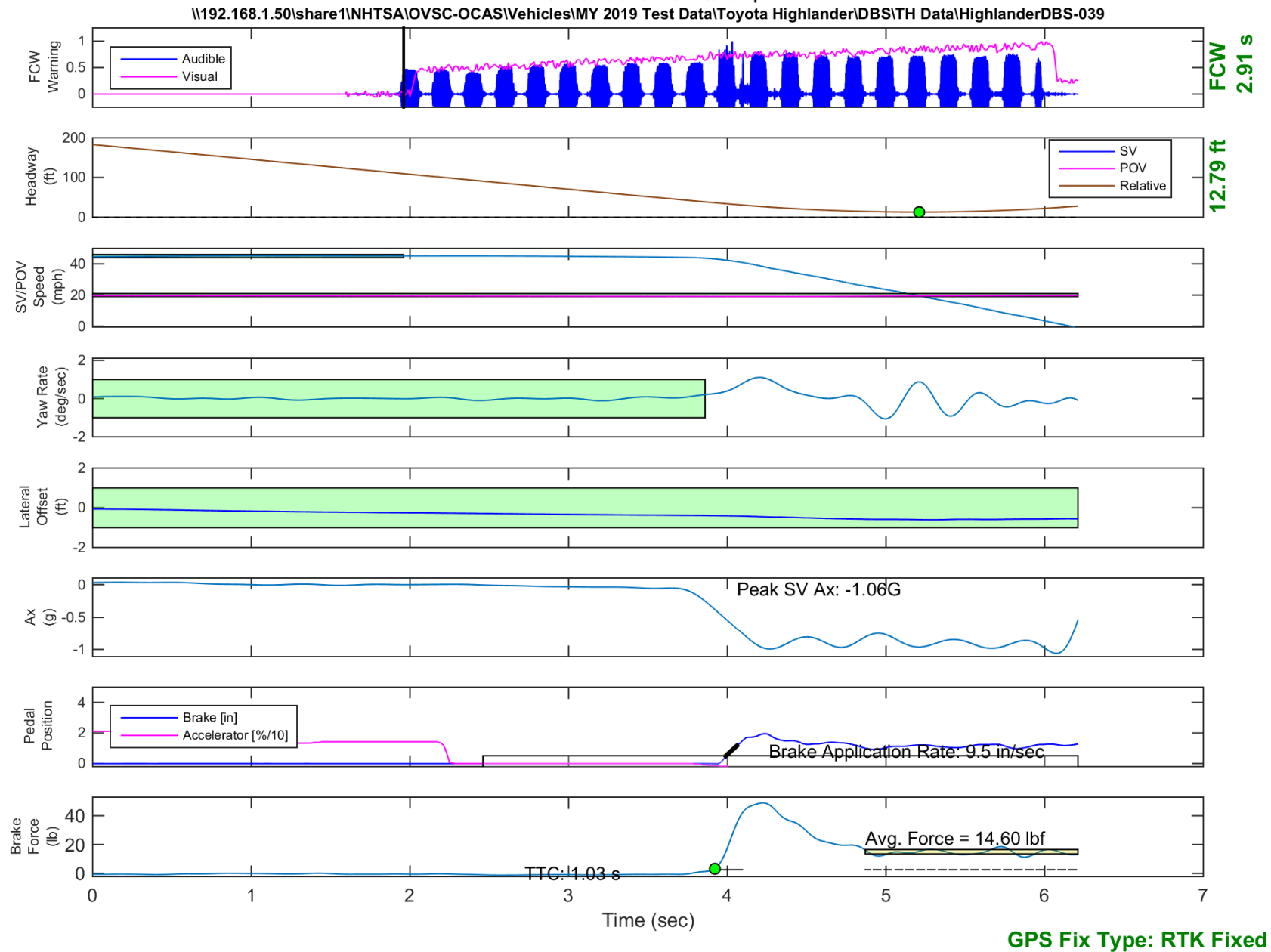


Figure E28. Time History for DBS Run 39, SV Encounters Slower POV, SV 45 mph, POV 20 mph

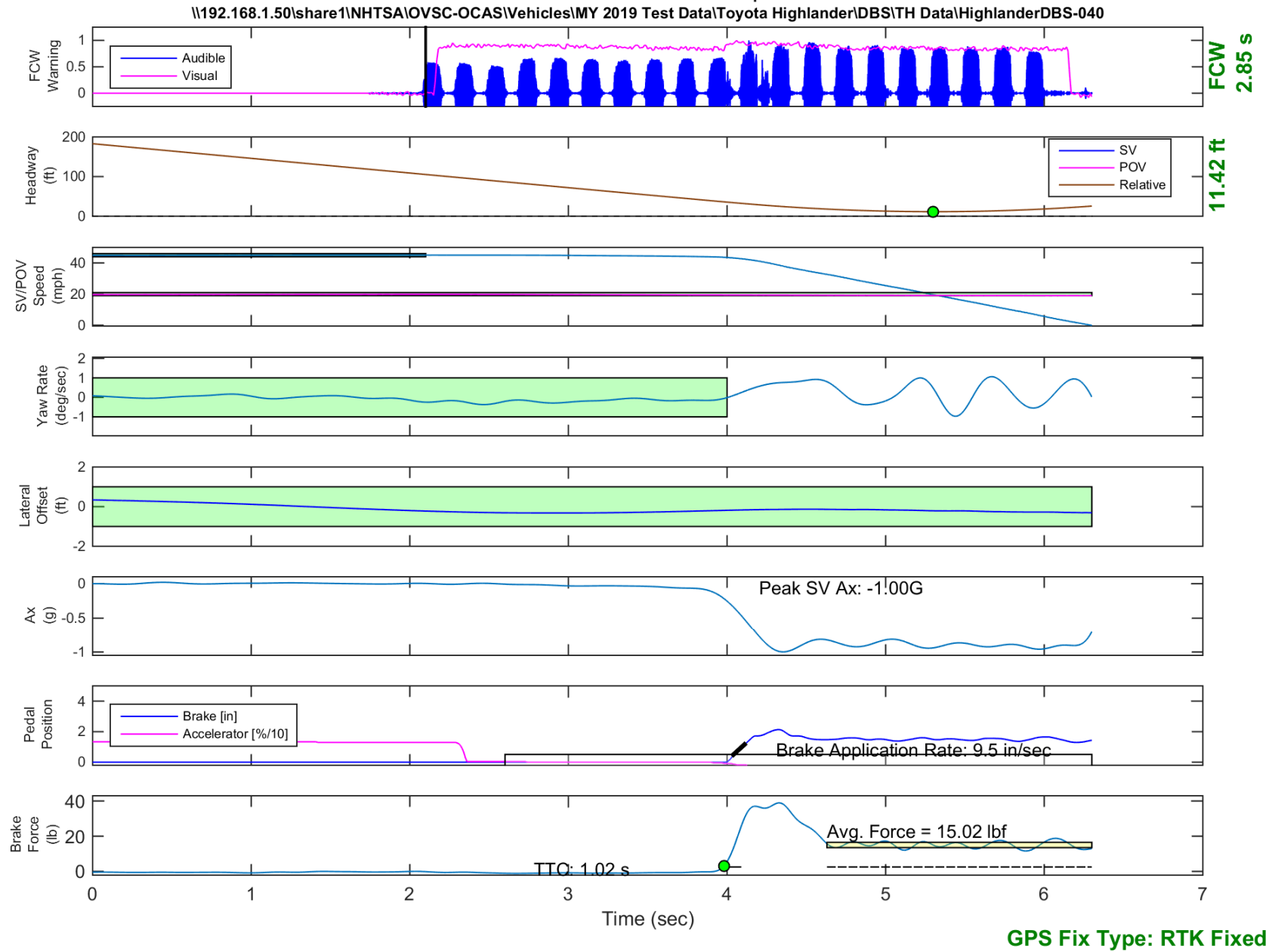


Figure E29. Time History for DBS Run 40, SV Encounters Slower POV, SV 45 mph, POV 20 mph

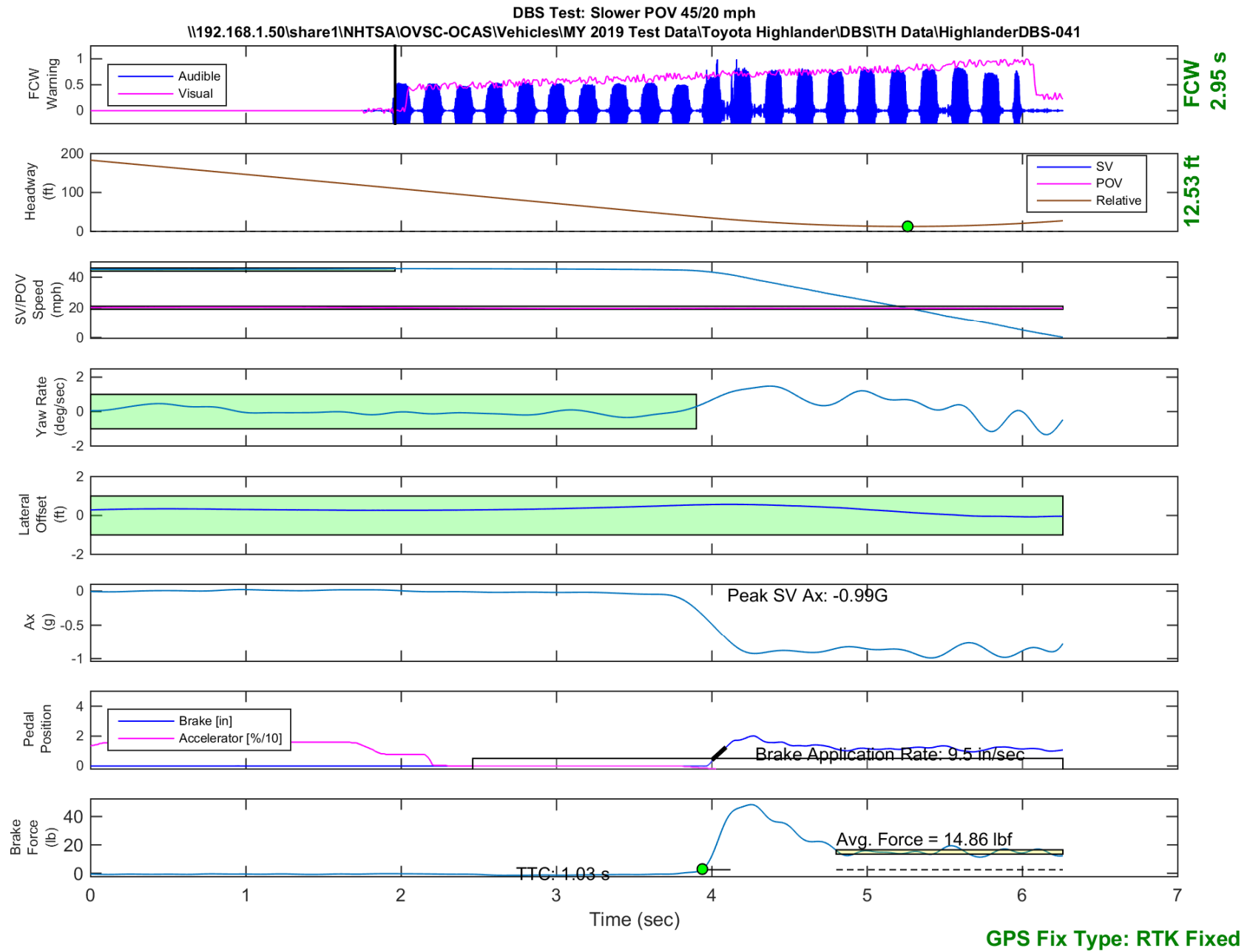


Figure E30. Time History for DBS Run 41, SV Encounters Slower POV, SV 45 mph, POV 20 mph

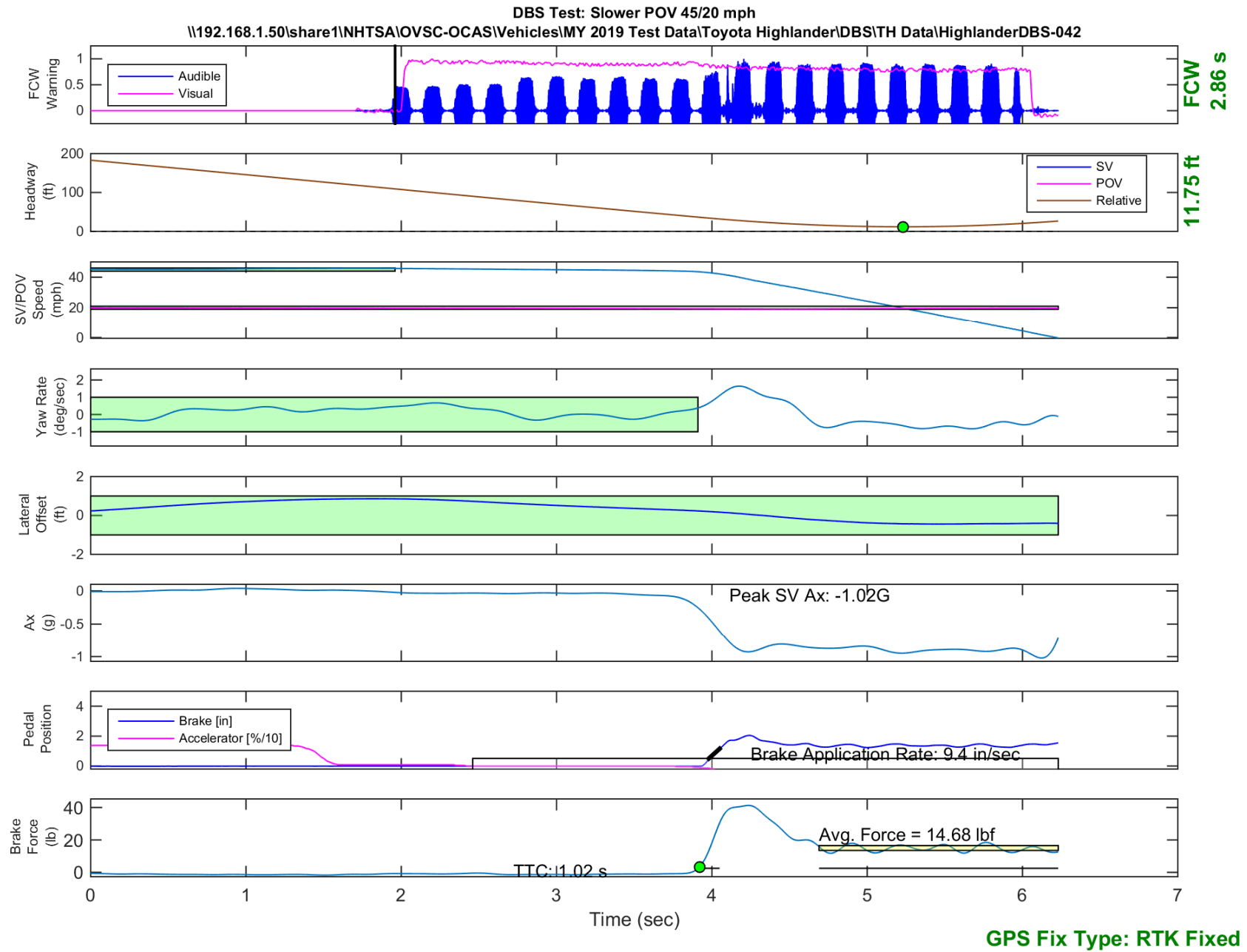


Figure E31. Time History for DBS Run 42, SV Encounters Slower POV, SV 45 mph, POV 20 mph

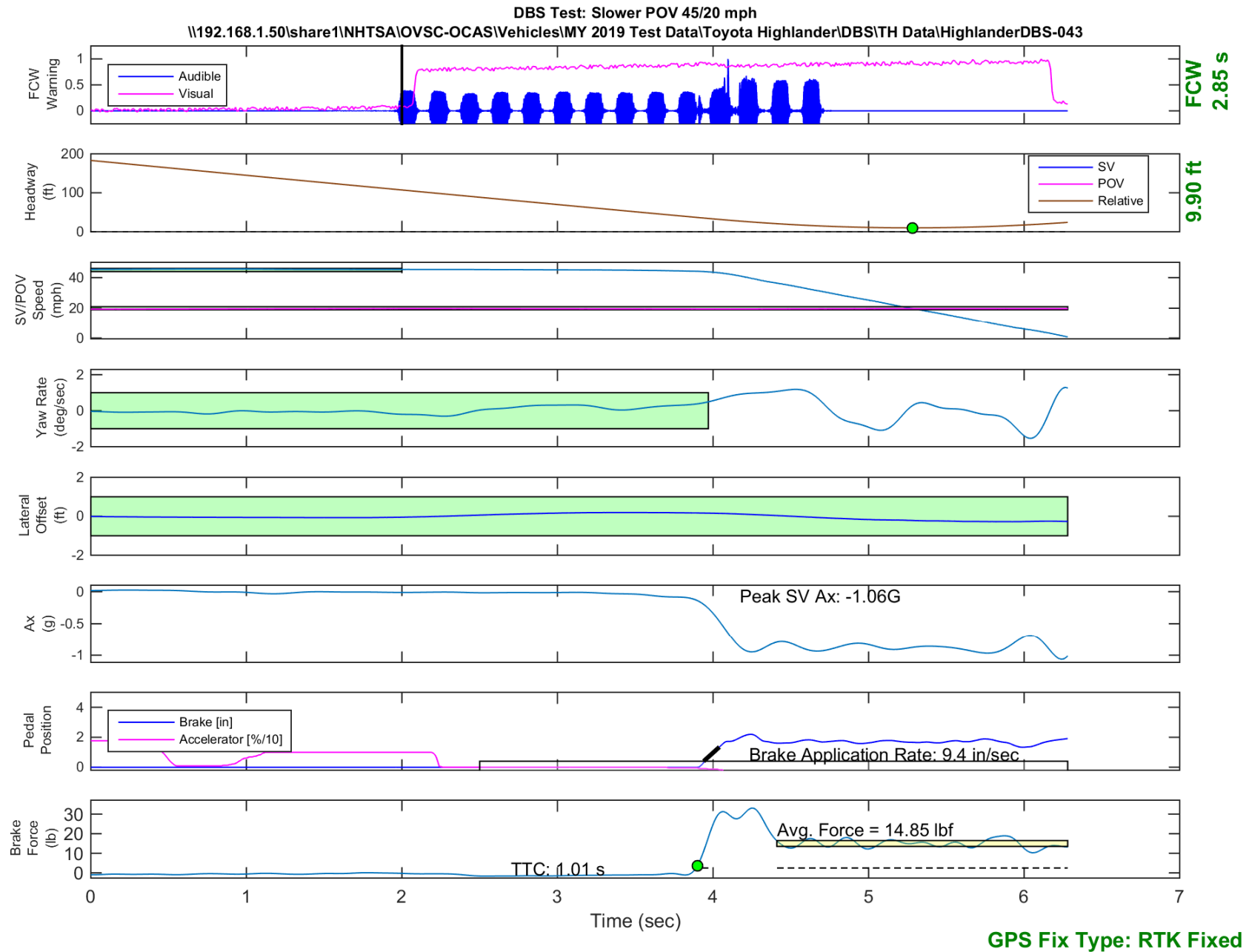


Figure E32. Time History for DBS Run 43, SV Encounters Slower POV, SV 45 mph, POV 20 mph

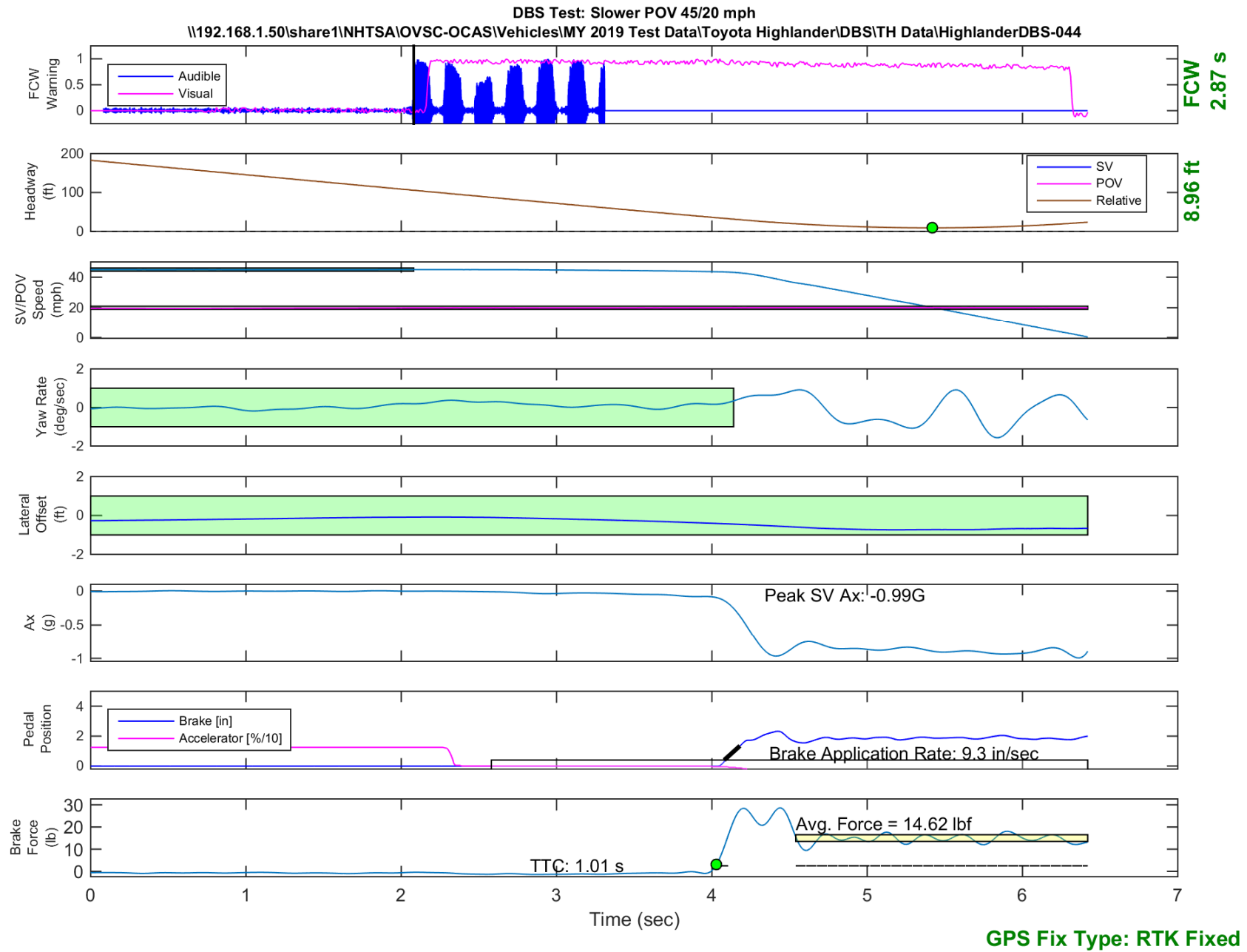


Figure E33. Time History for DBS Run 44, SV Encounters Slower POV, SV 45 mph, POV 20 mph

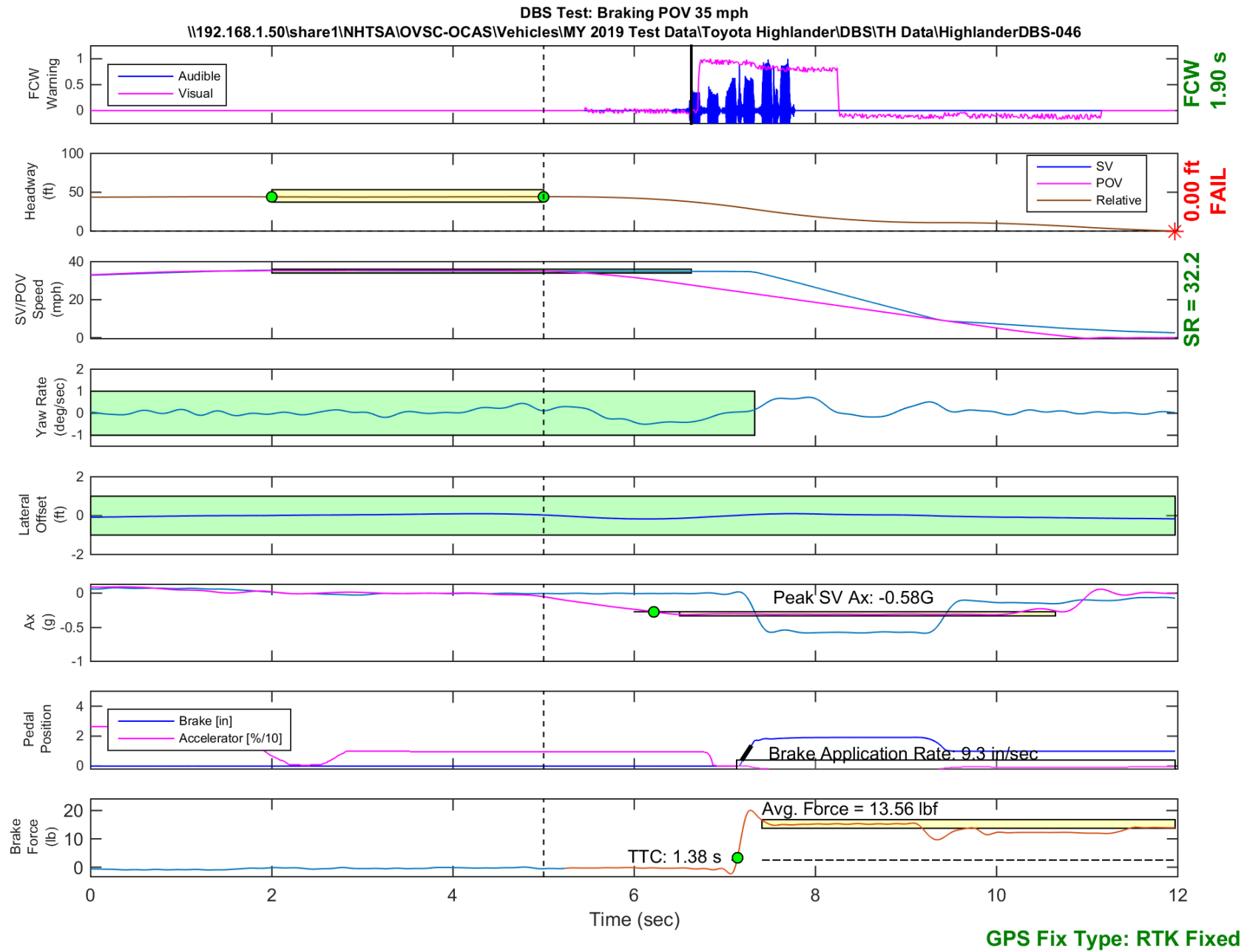


Figure E34. Time History for DBS Run 46, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

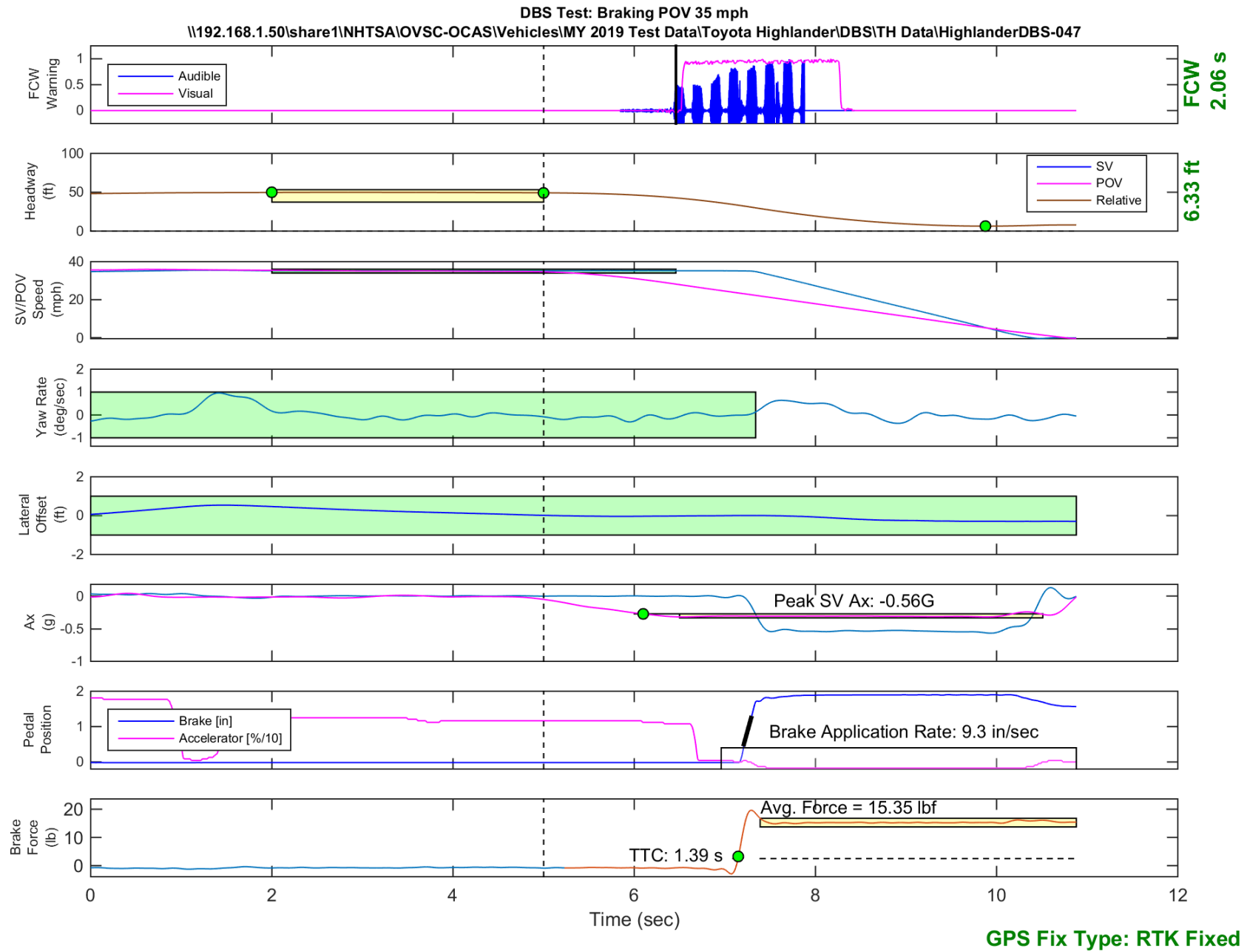


Figure E35. Time History for DBS Run 47, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

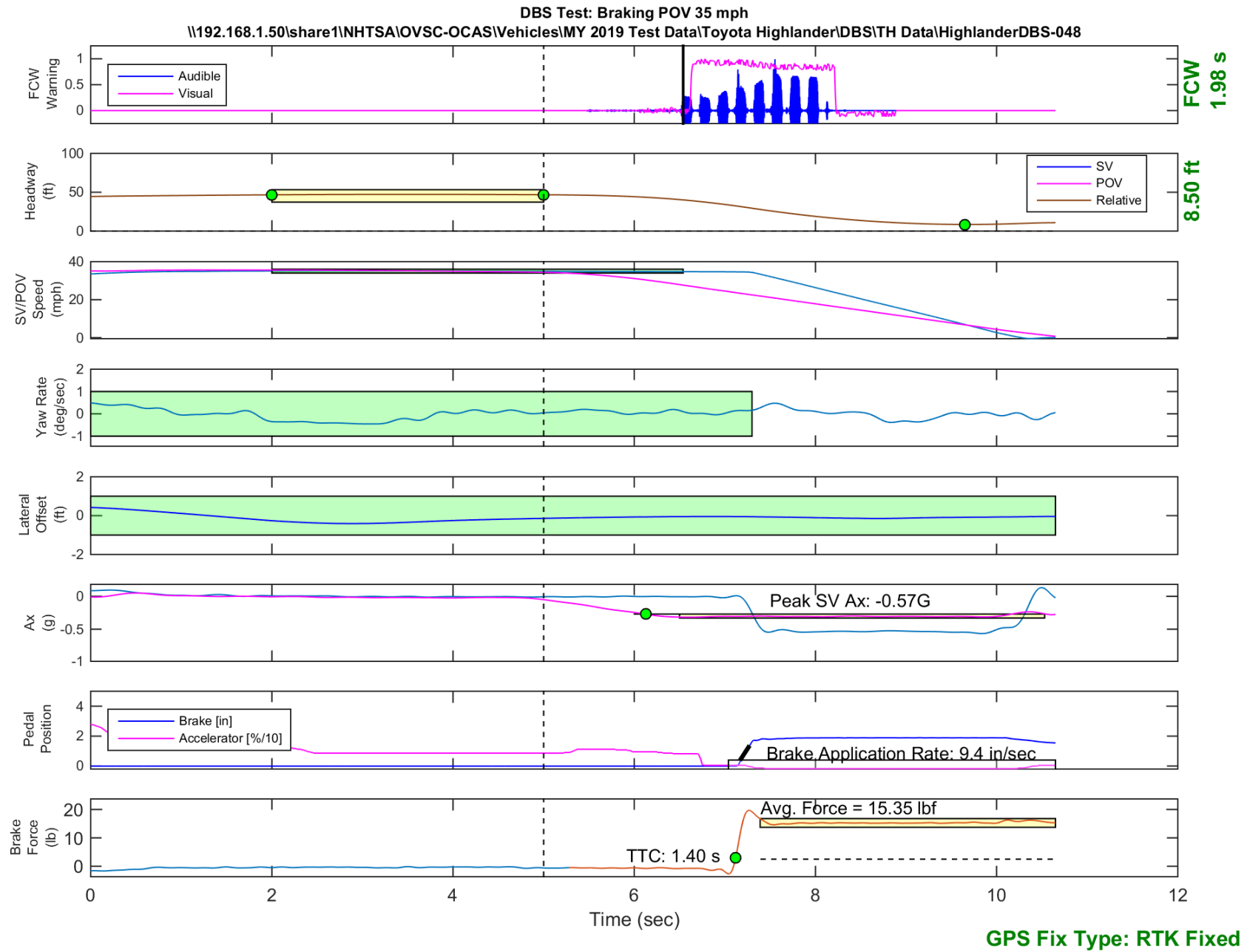


Figure E36. Time History for DBS Run 48, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

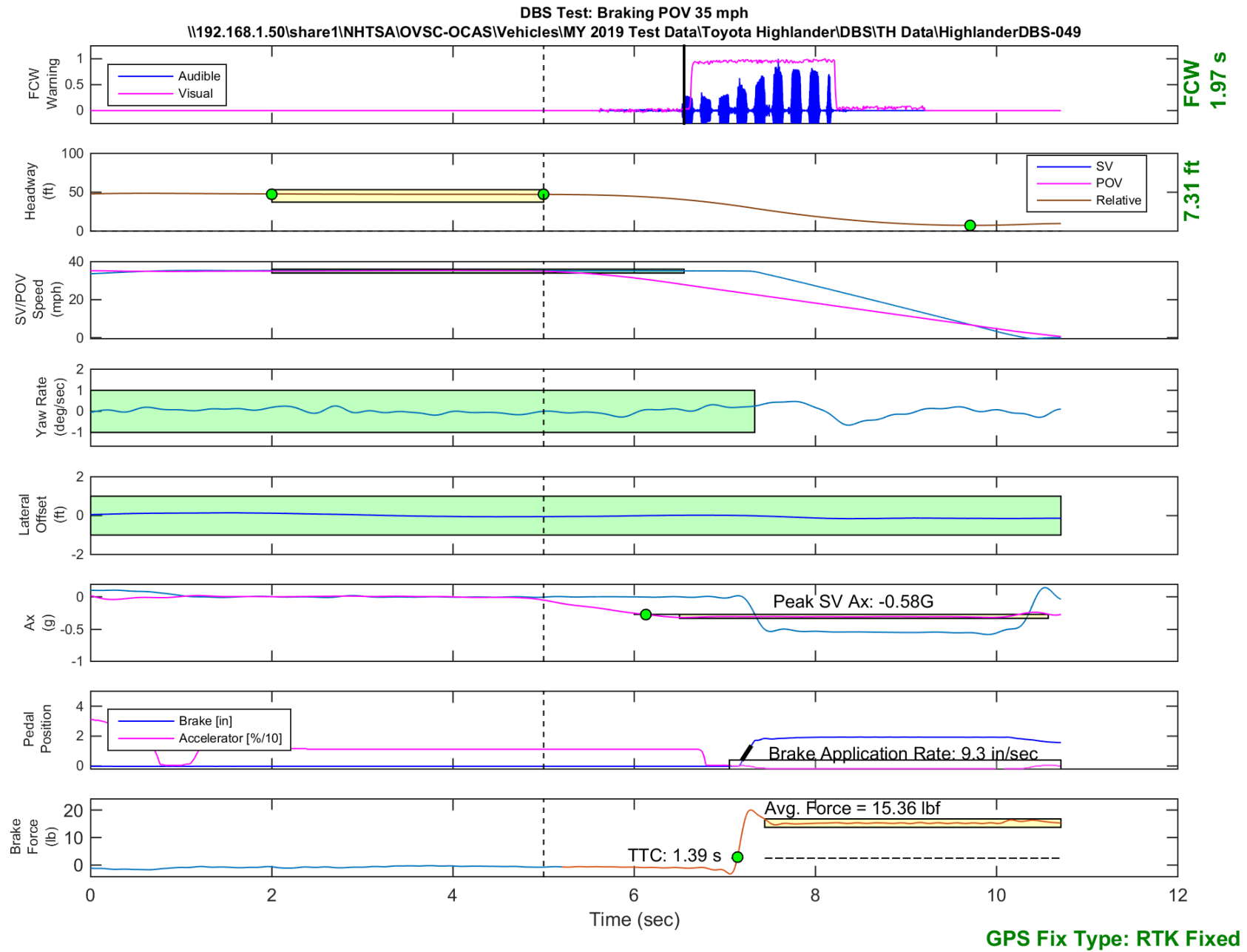


Figure E37. Time History for DBS Run 49, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

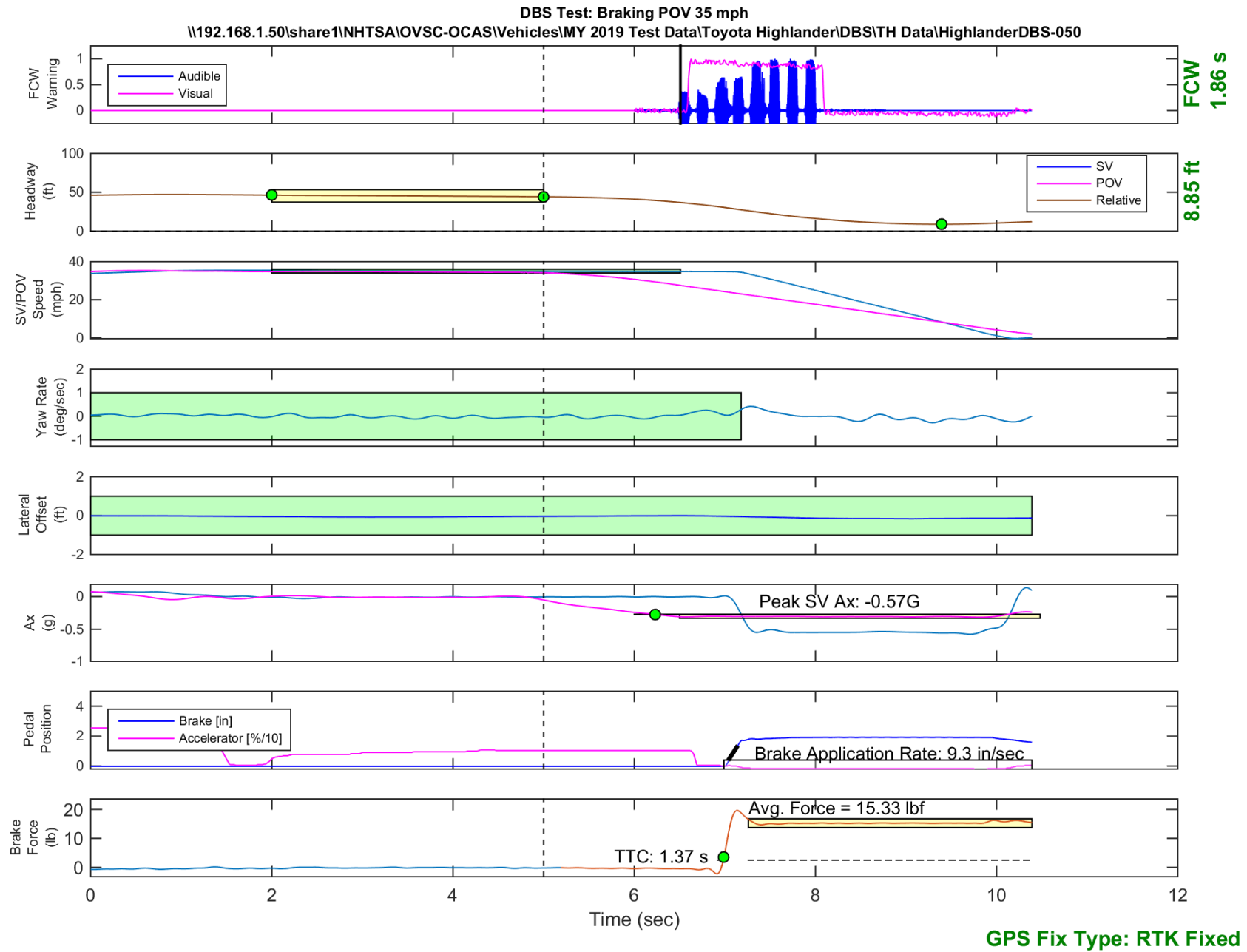


Figure E38. Time History for DBS Run 50, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

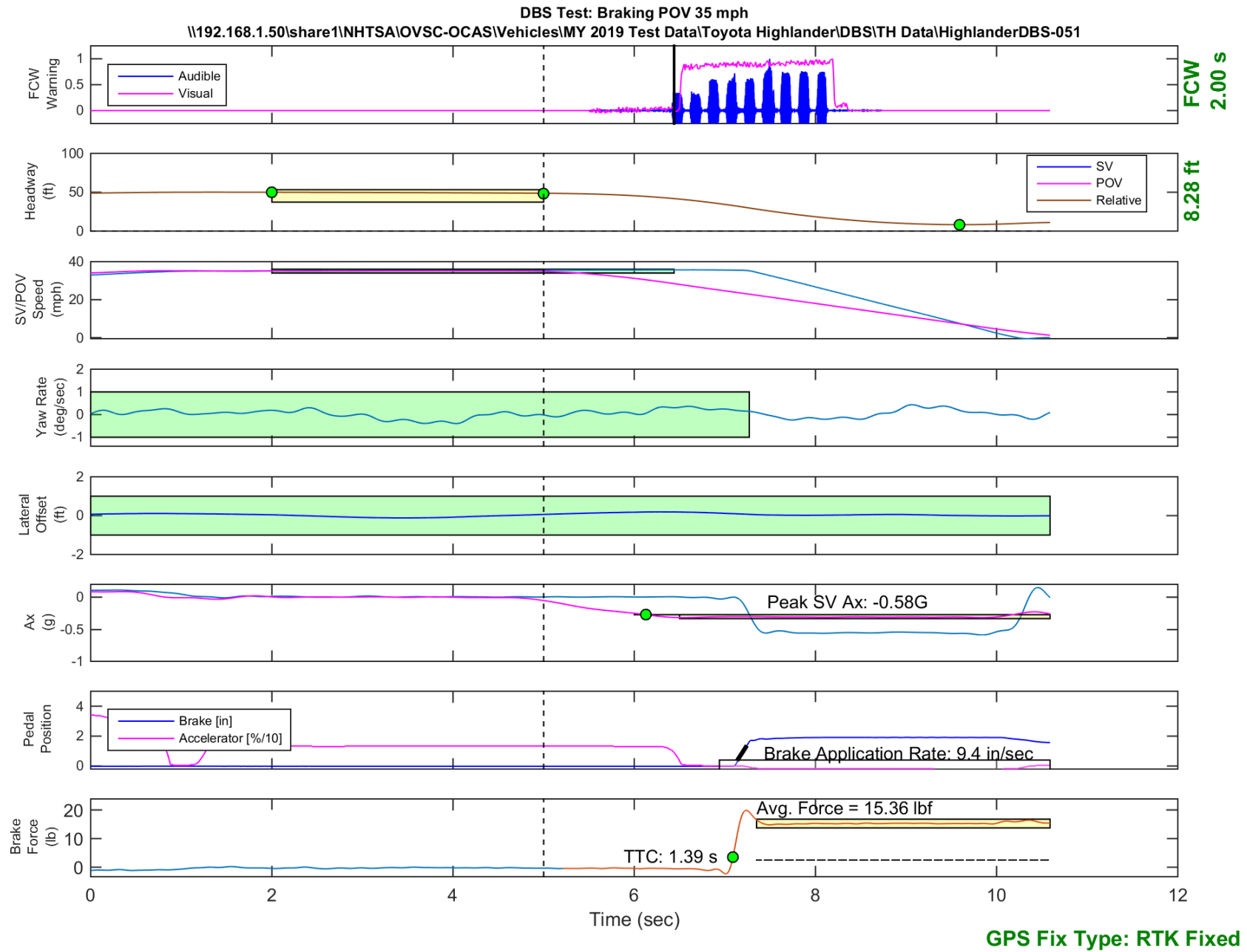


Figure E39. Time History for DBS Run 51, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

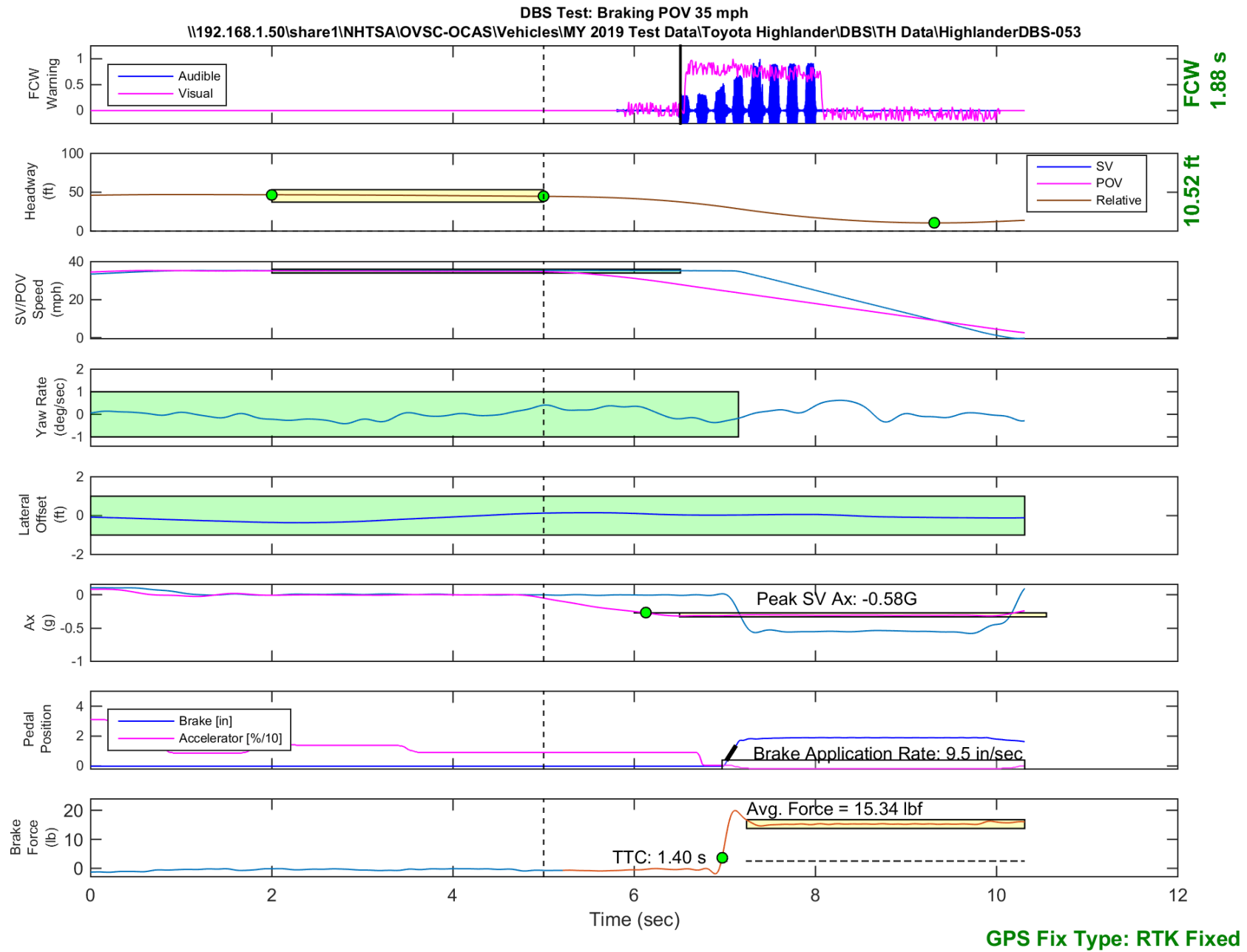


Figure E40. Time History for DBS Run 53, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

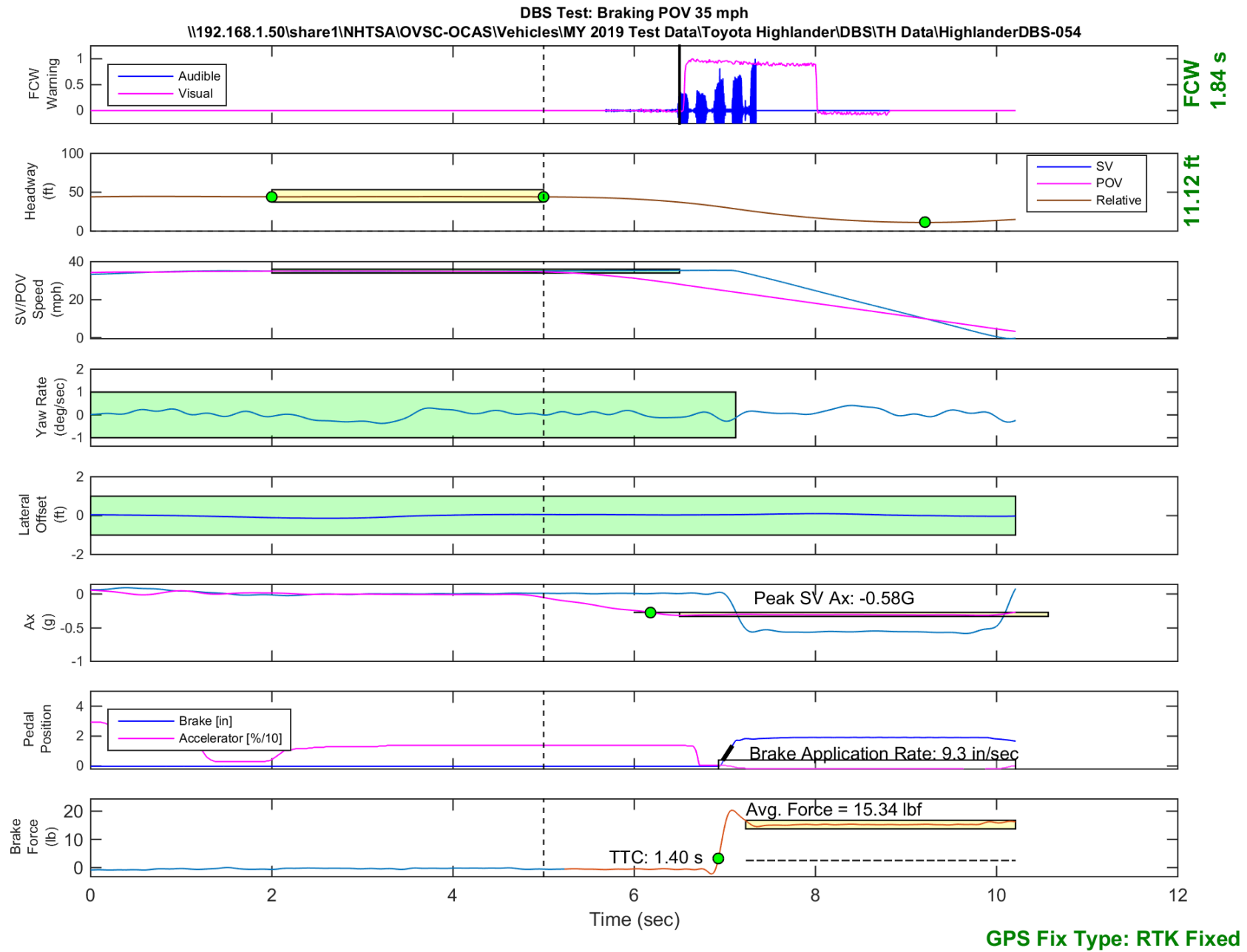


Figure E41. Time History for DBS Run 54, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

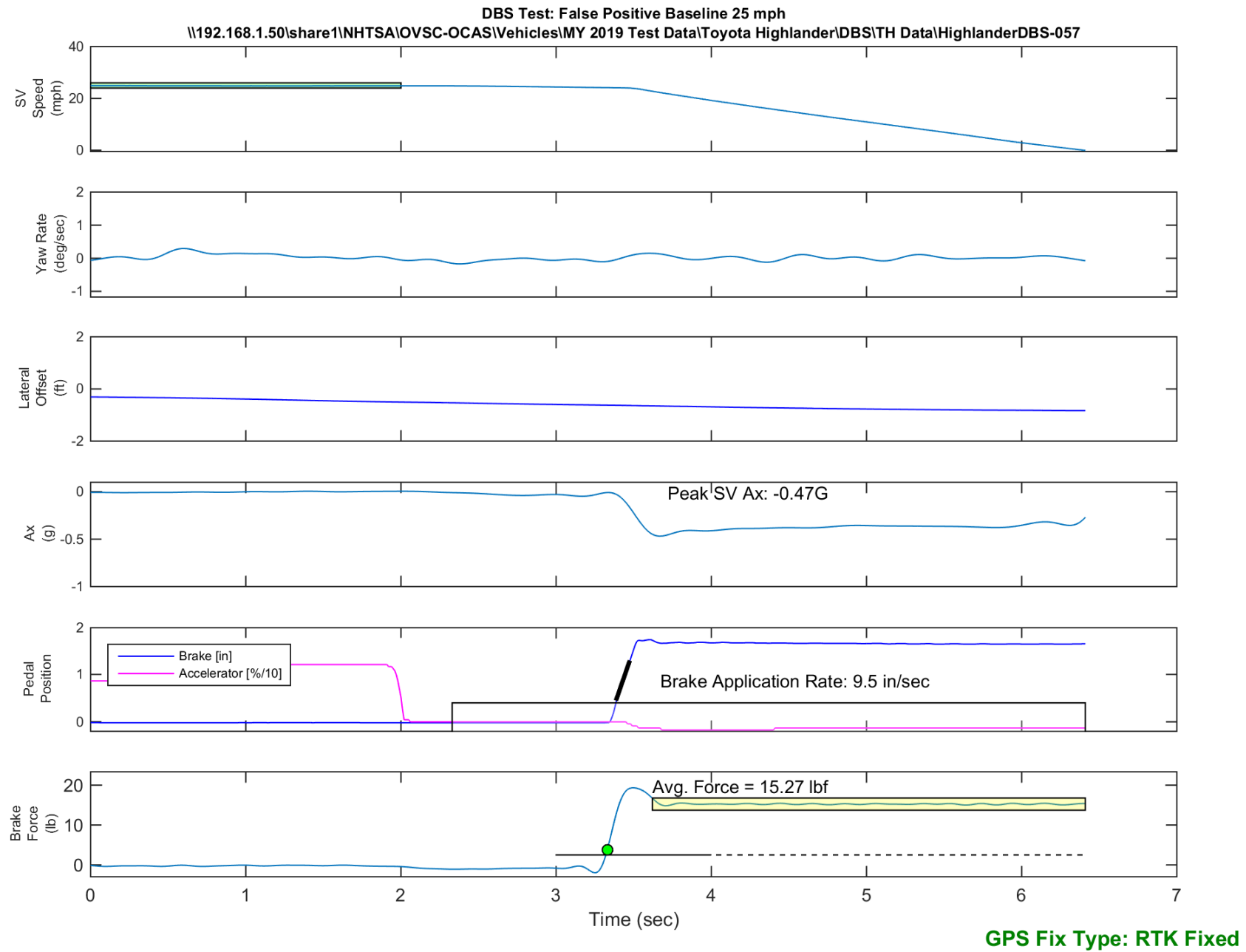


Figure E42. Time History for DBS Run 57, False Positive Baseline, SV 25 mph

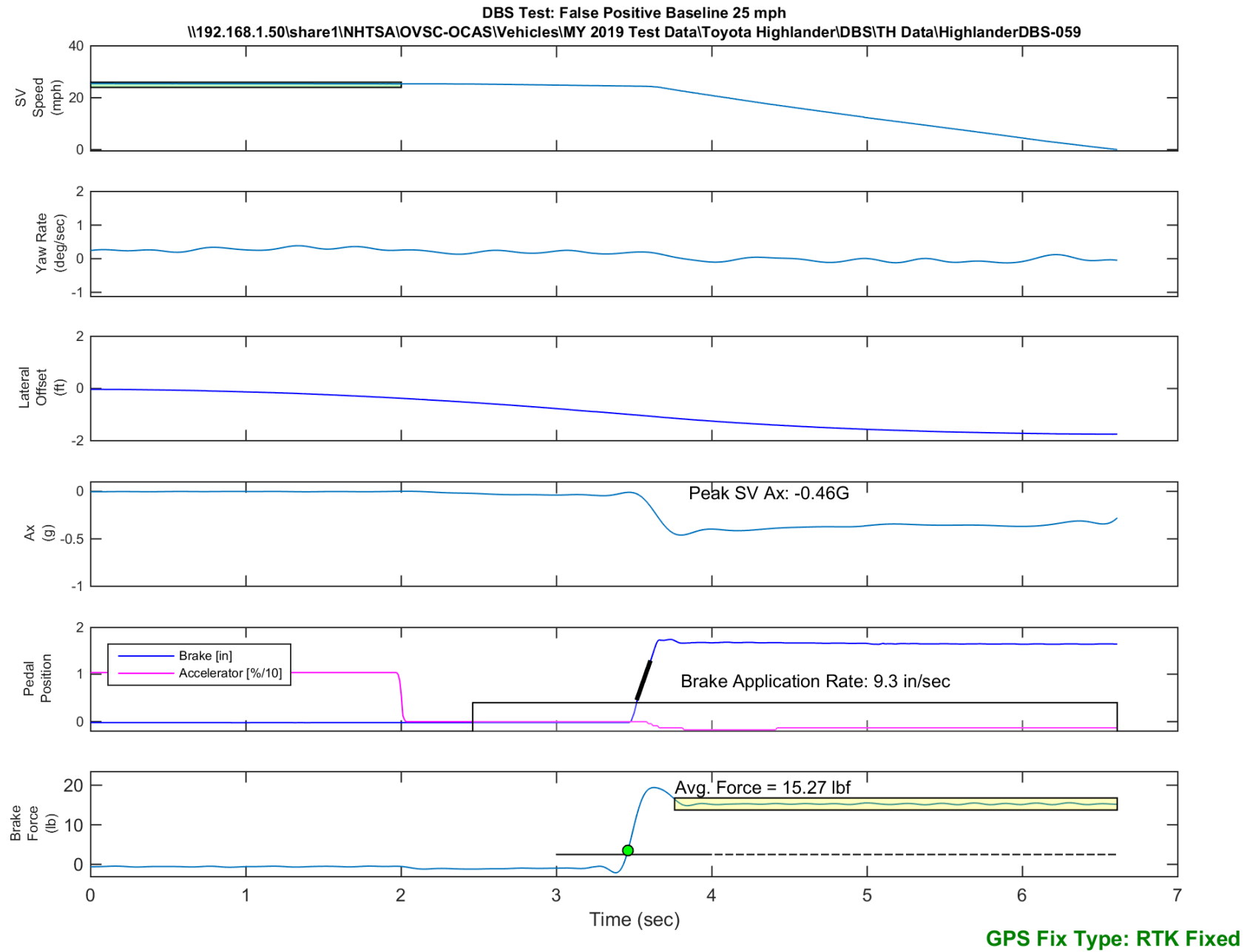


Figure E43. Time History for DBS Run 59, False Positive Baseline, SV 25 mph

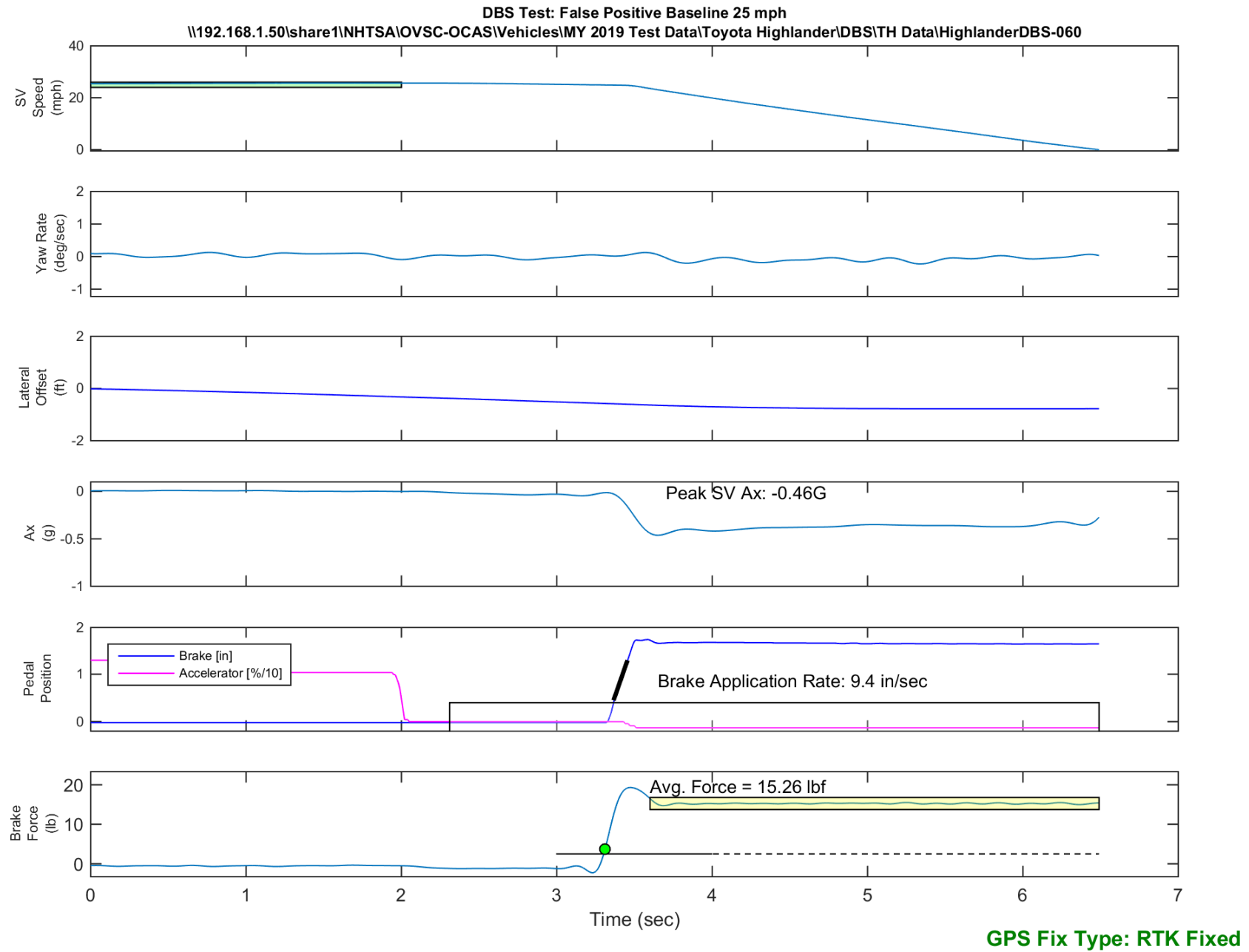


Figure E44. Time History for DBS Run 60, False Positive Baseline, SV 25 mph

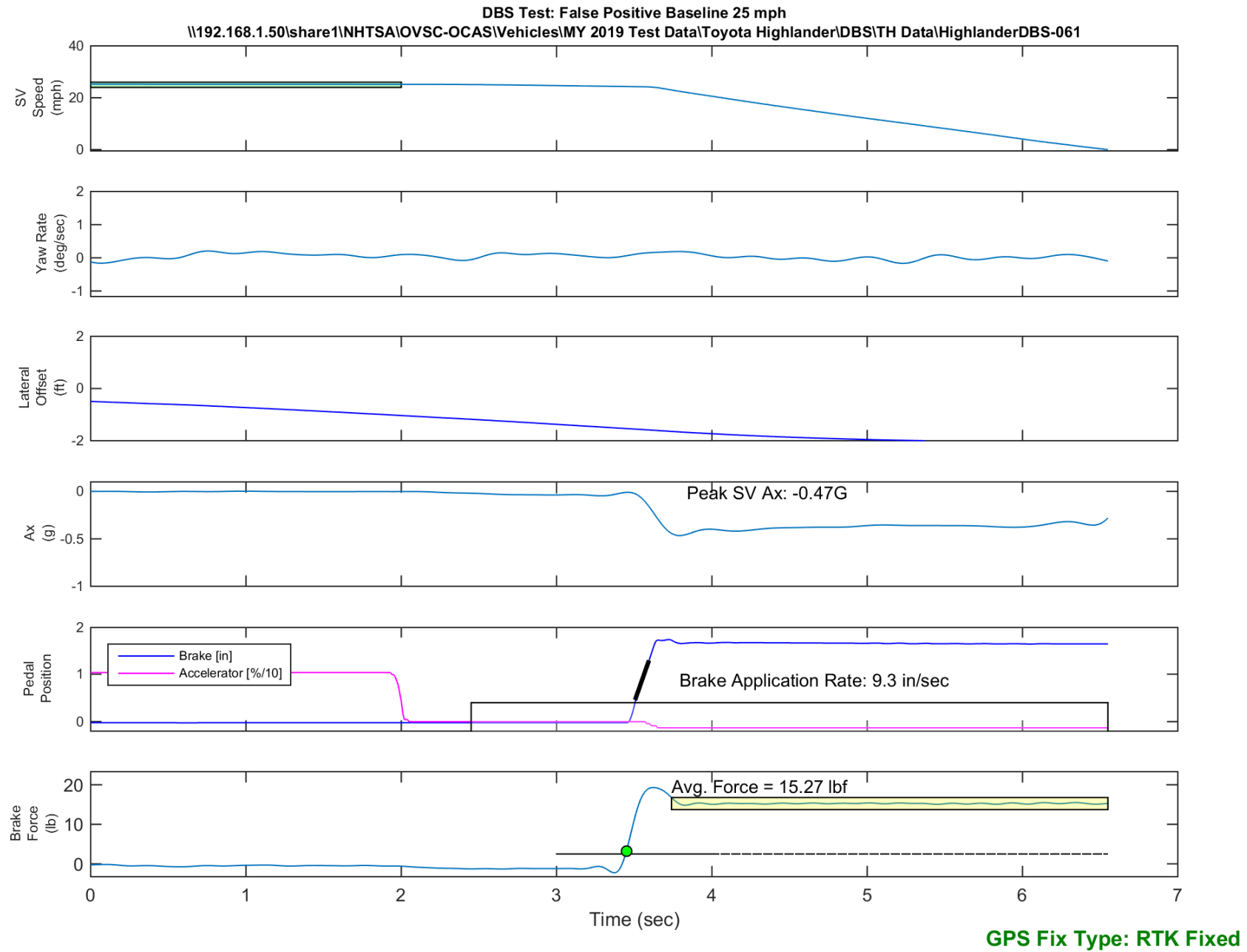


Figure E45. Time History for DBS Run 61, False Positive Baseline, SV 25 mph

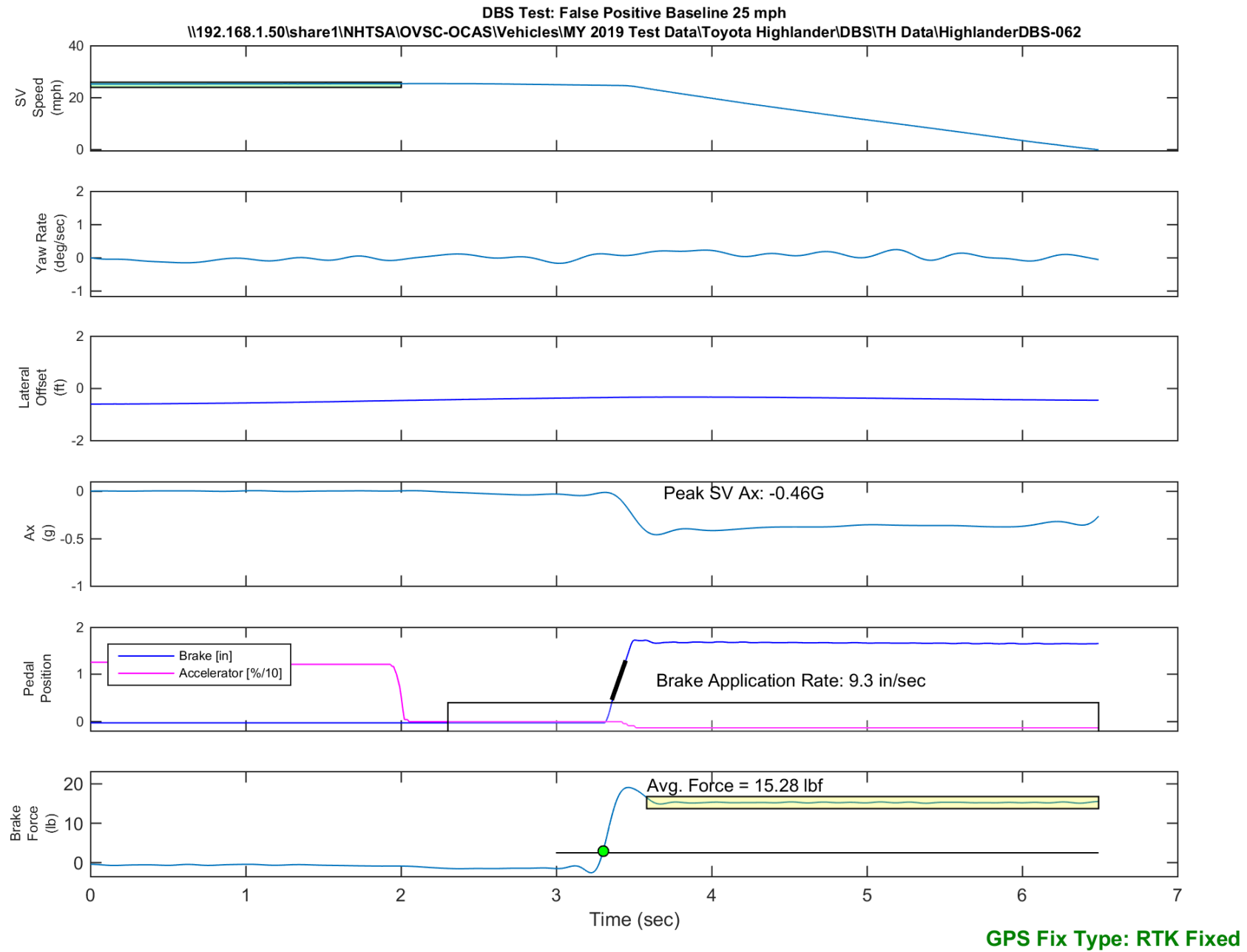


Figure E46. Time History for DBS Run 62, False Positive Baseline, SV 25 mph

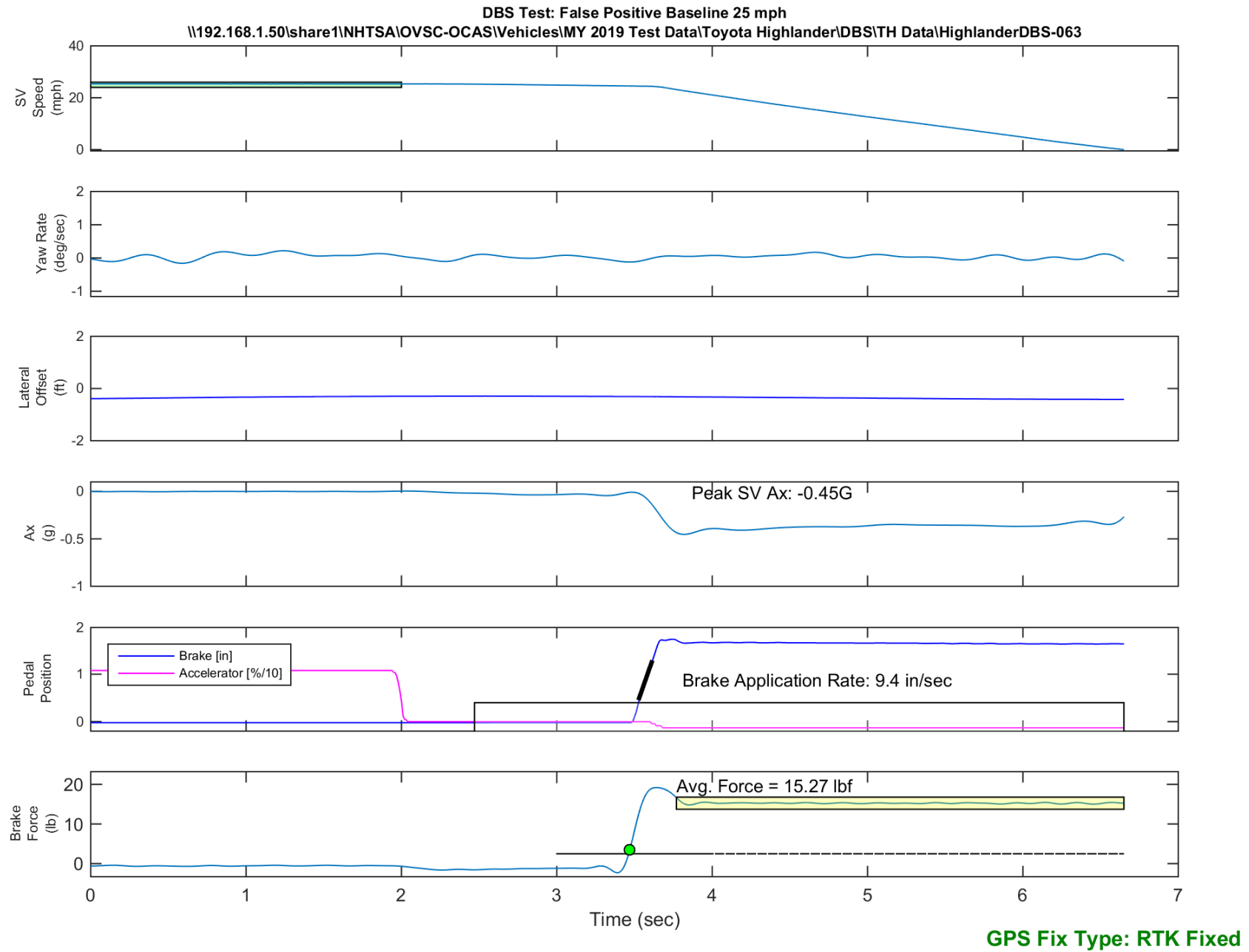


Figure E47. Time History for DBS Run 63, False Positive Baseline, SV 25 mph

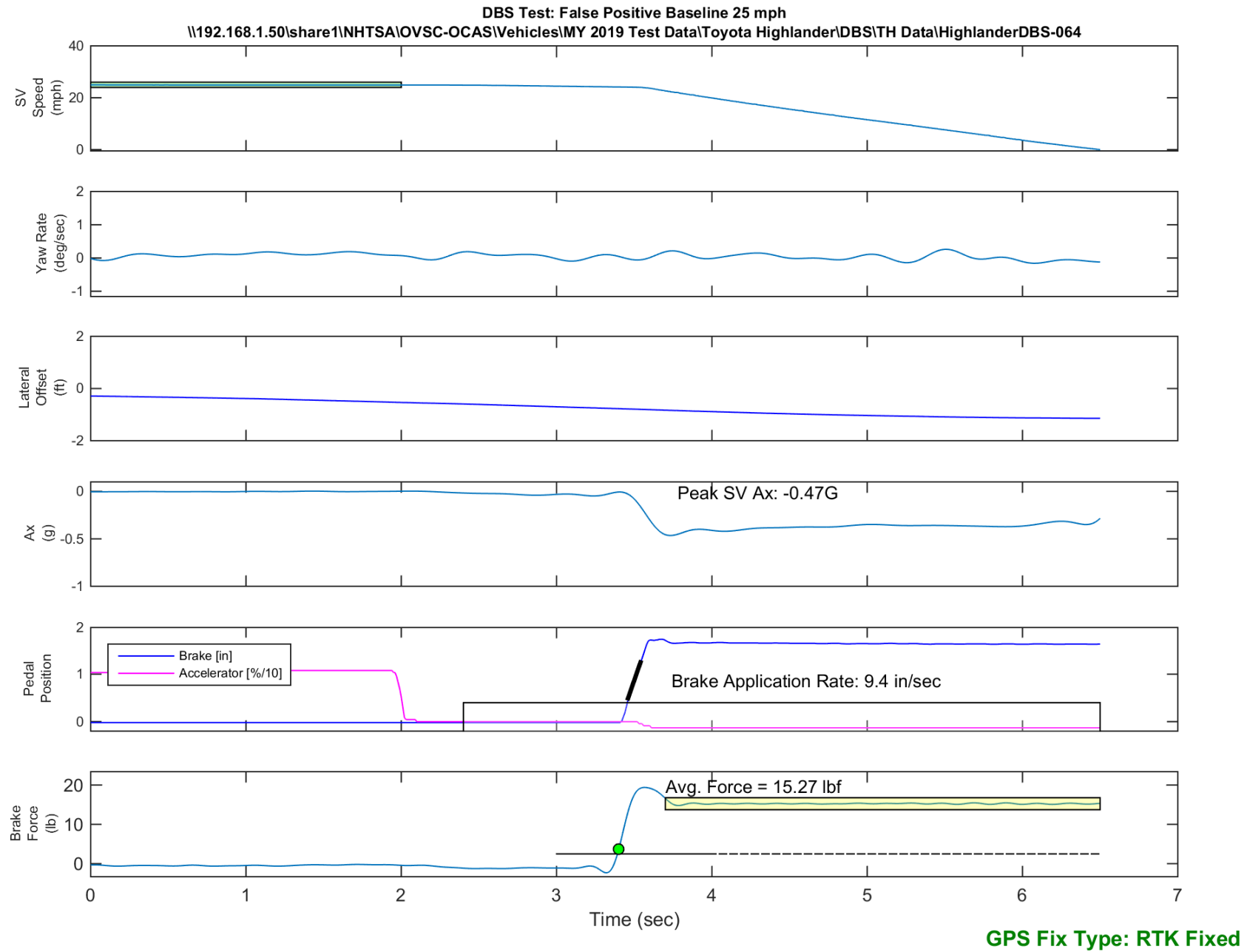


Figure E48. Time History for DBS Run 64, False Positive Baseline, SV 25 mph

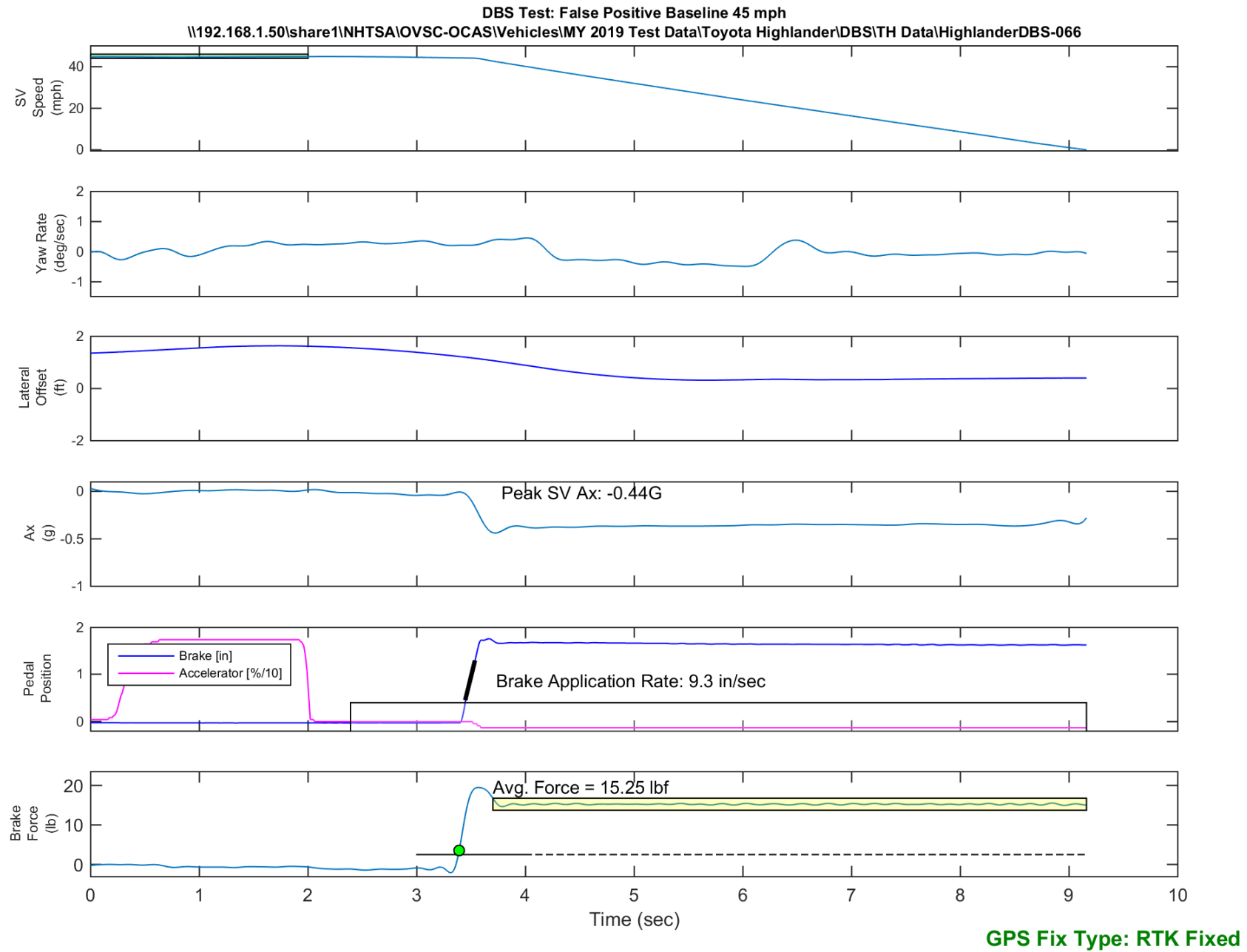


Figure E49. Time History for DBS Run 66, False Positive Baseline, SV 45 mph

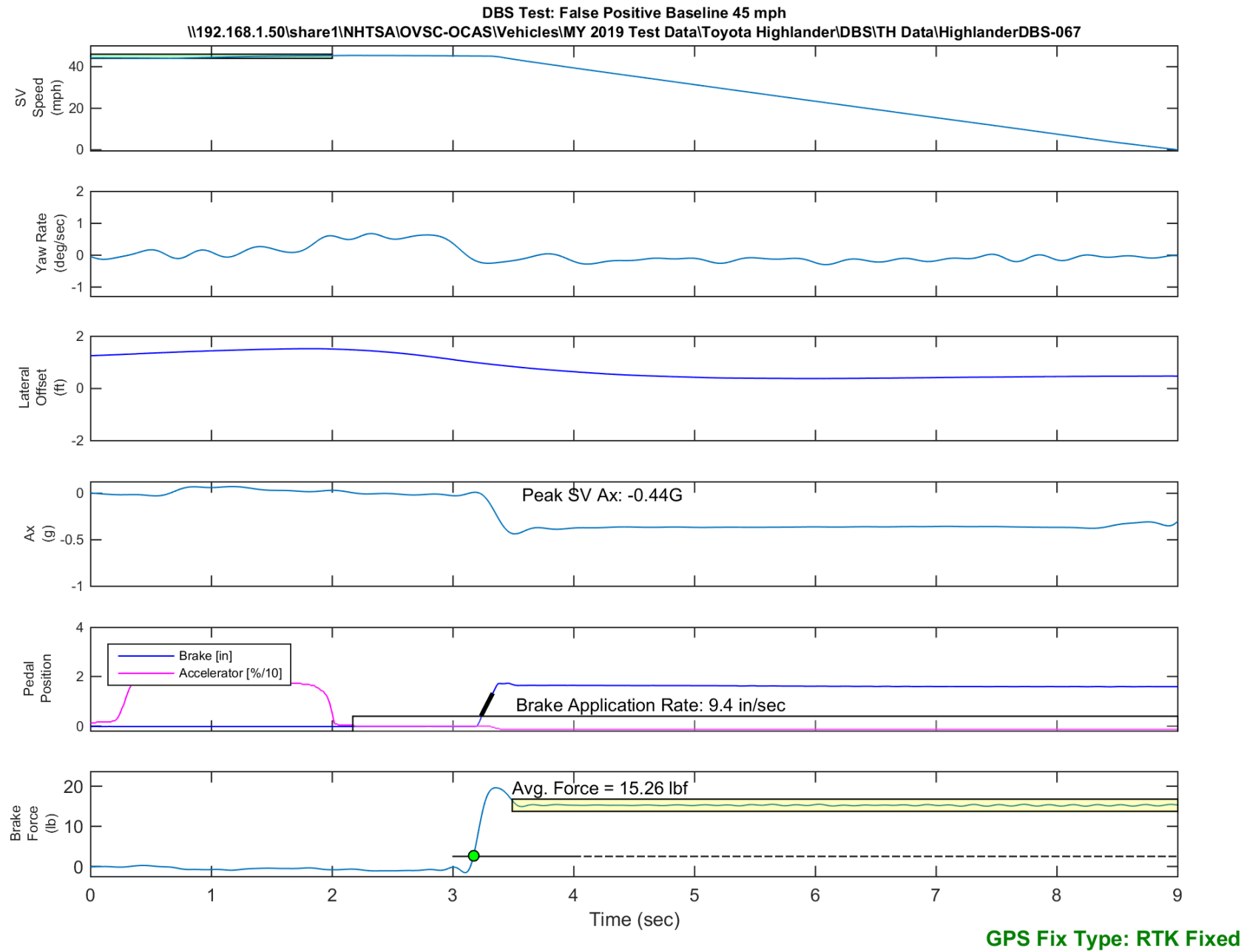


Figure E50. Time History for DBS Run 67, False Positive Baseline, SV 45 mph

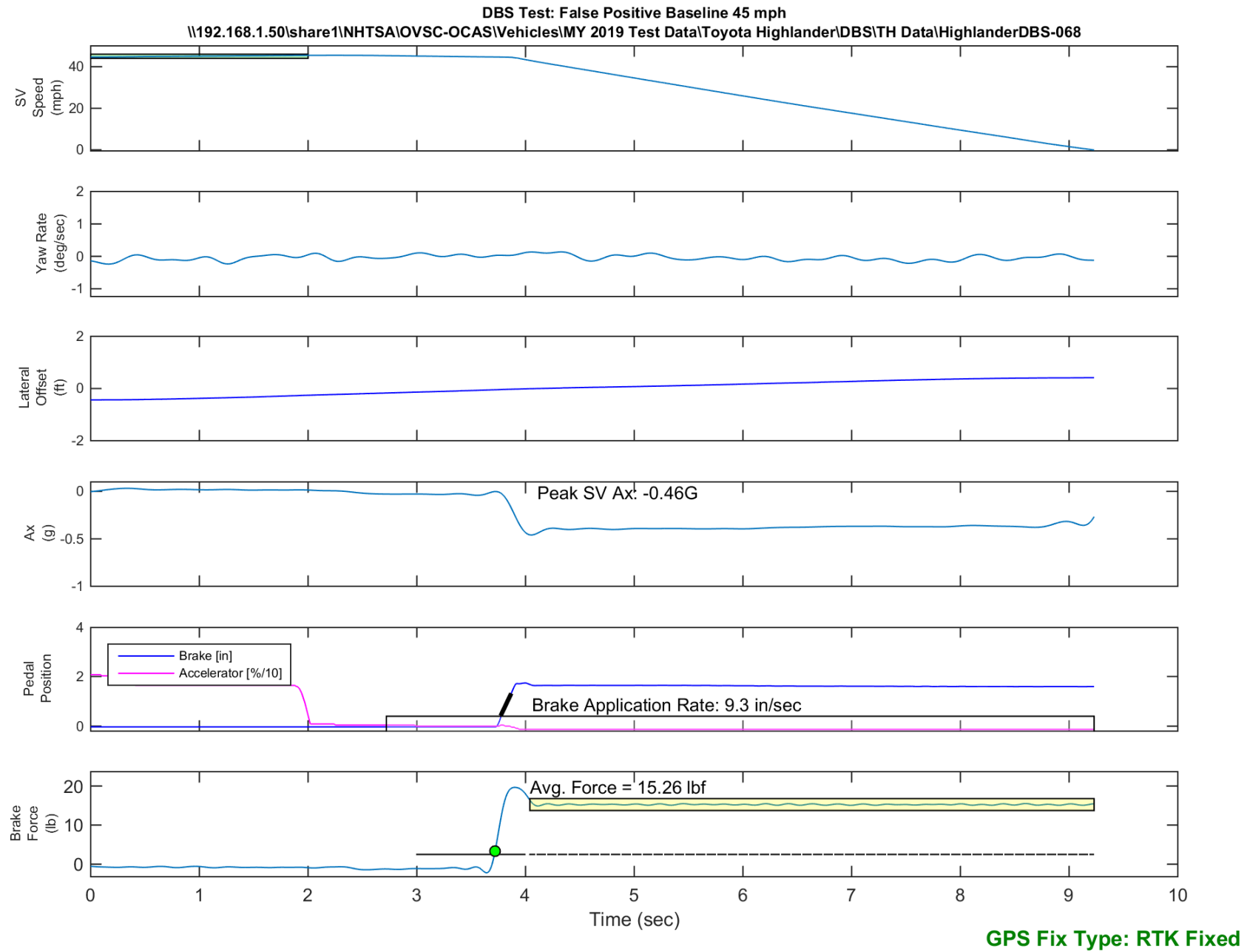


Figure E51. Time History for DBS Run 68, False Positive Baseline, SV 45 mph

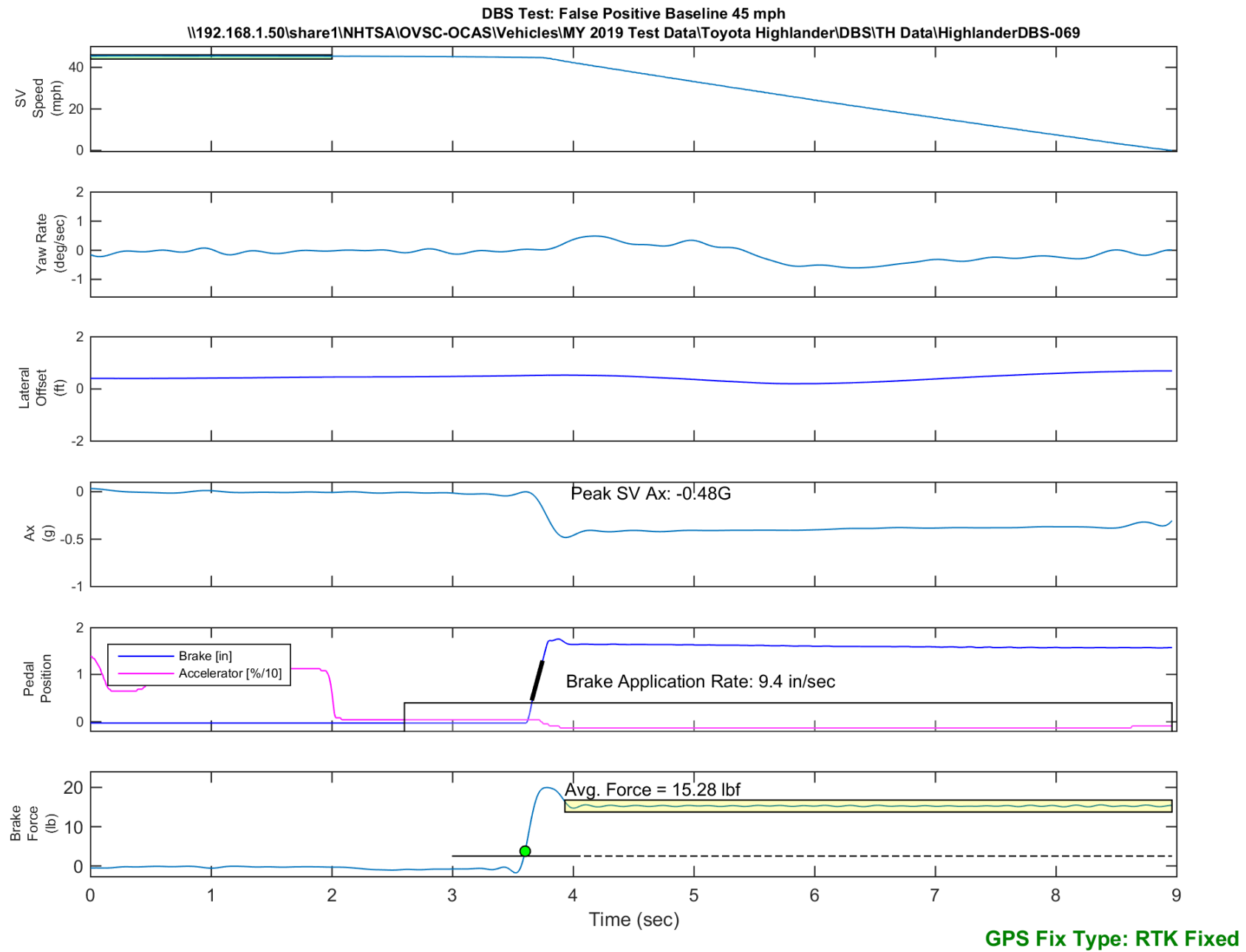


Figure E52. Time History for DBS Run 69, False Positive Baseline, SV 45 mph

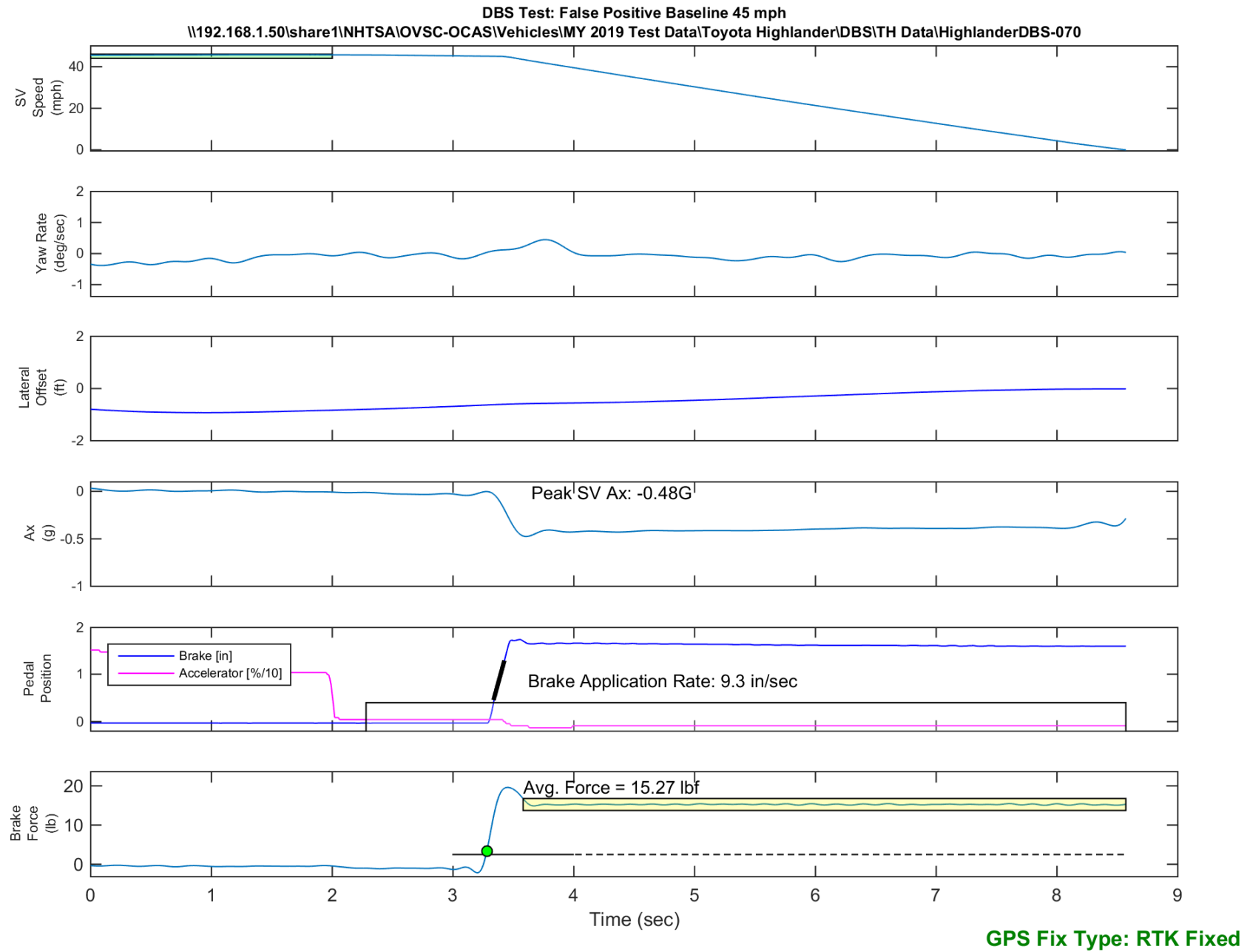


Figure E53. Time History for DBS Run 70, False Positive Baseline, SV 45 mph

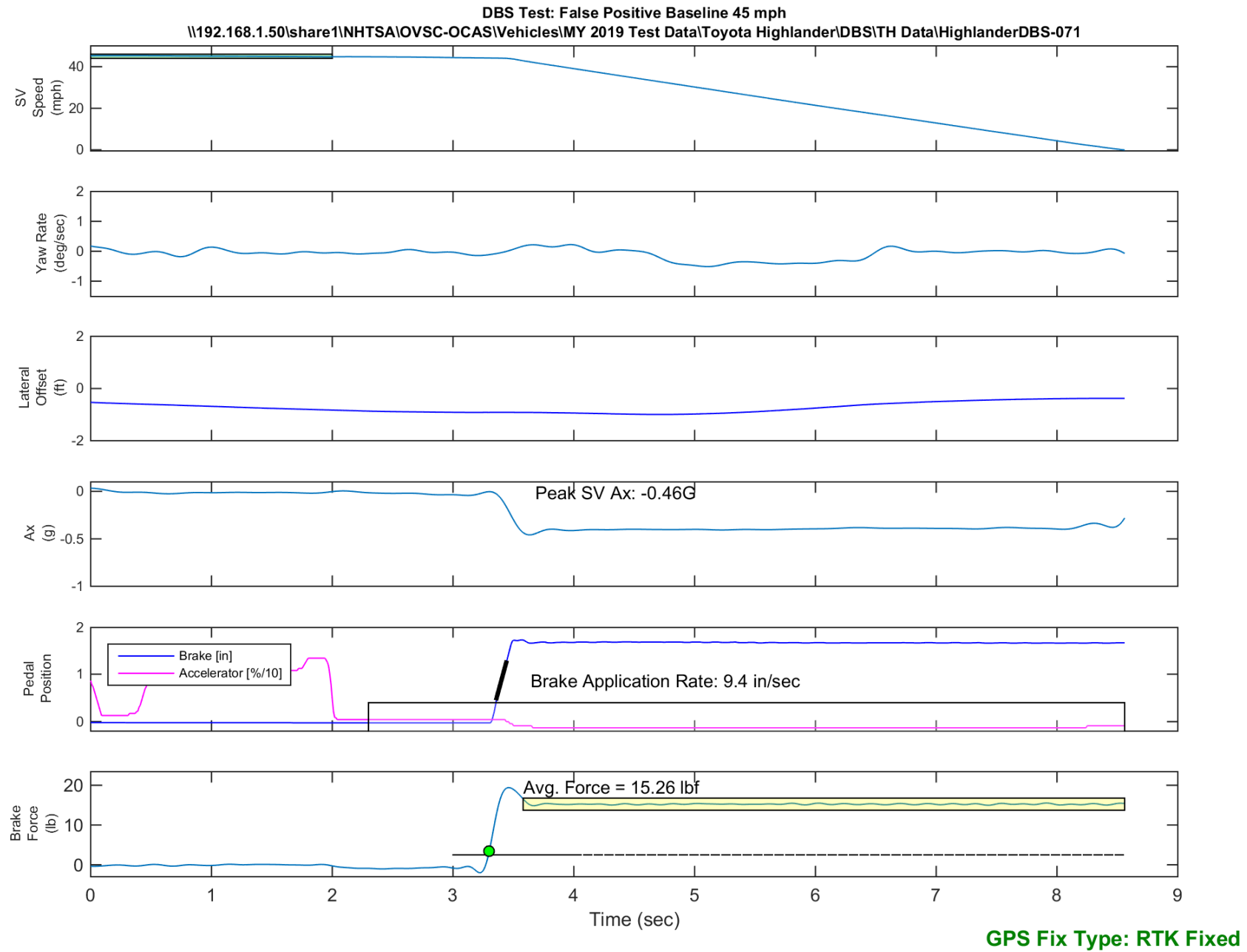


Figure E54. Time History for DBS Run 71, False Positive Baseline, SV 45 mph

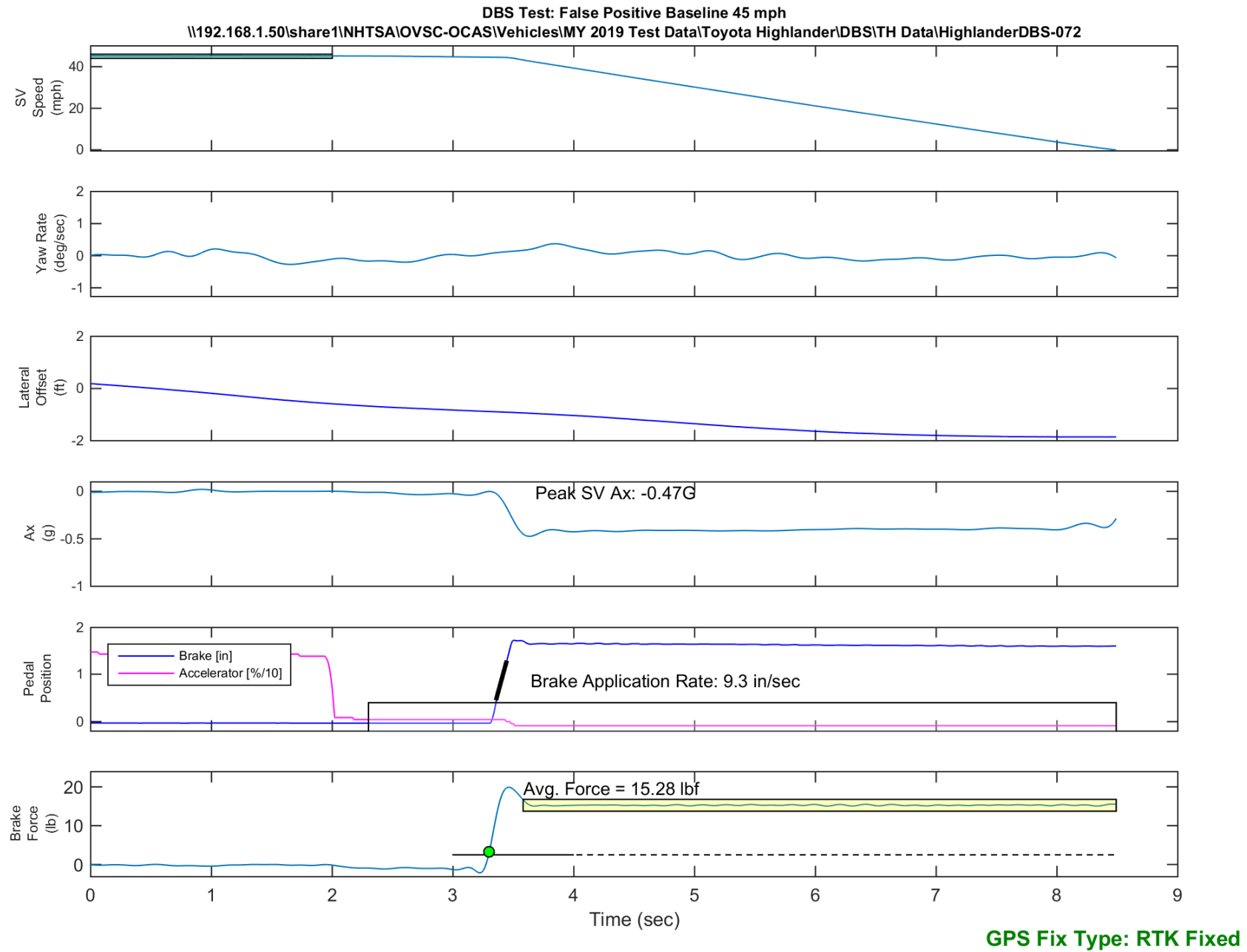


Figure E55. Time History for DBS Run 72, False Positive Baseline, SV 45 mph

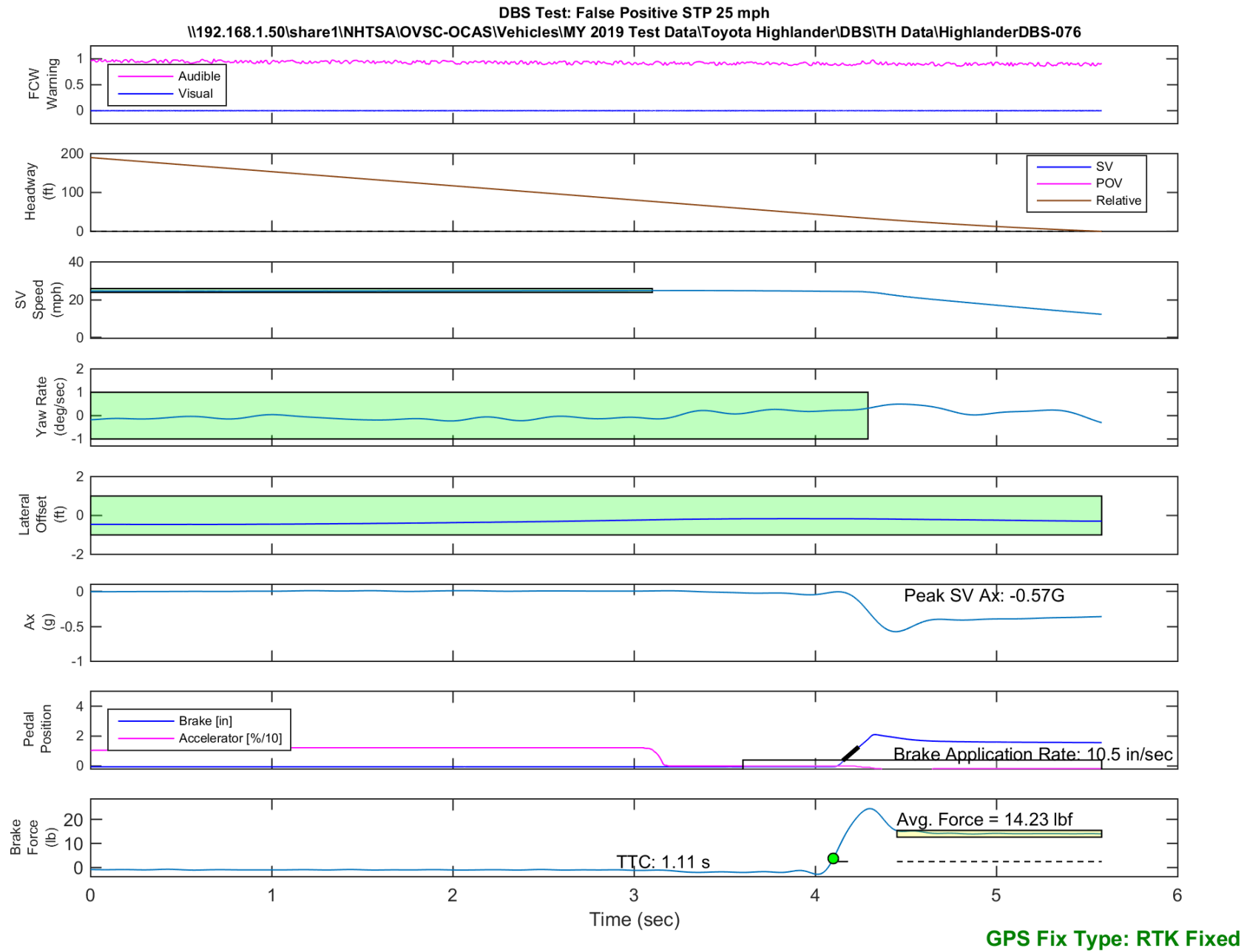


Figure E56. Time History for DBS Run 76, SV Encounters Steel Trench Plate, SV 25 mph

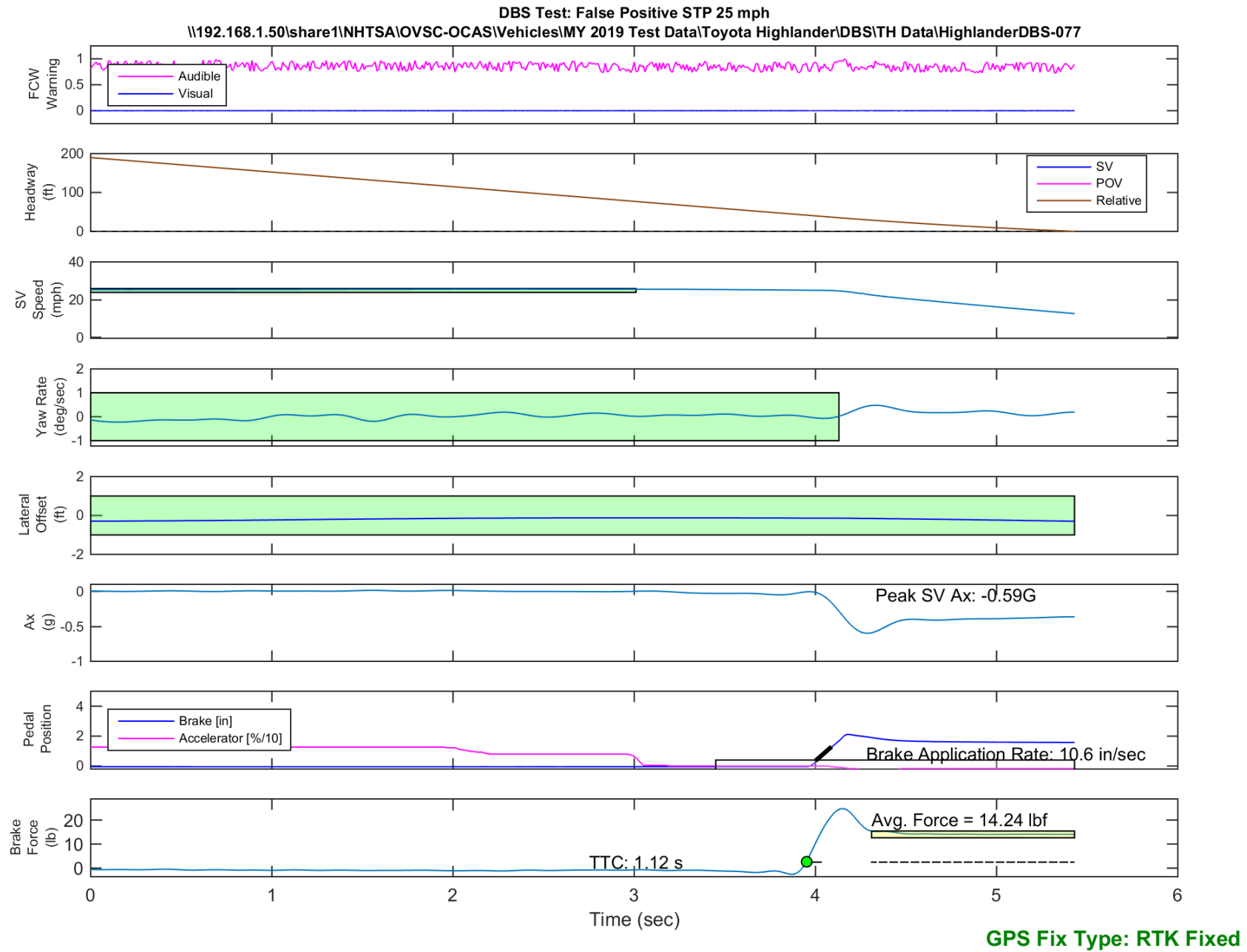


Figure E57. Time History for DBS Run 77, SV Encounters Steel Trench Plate, SV 25 mph

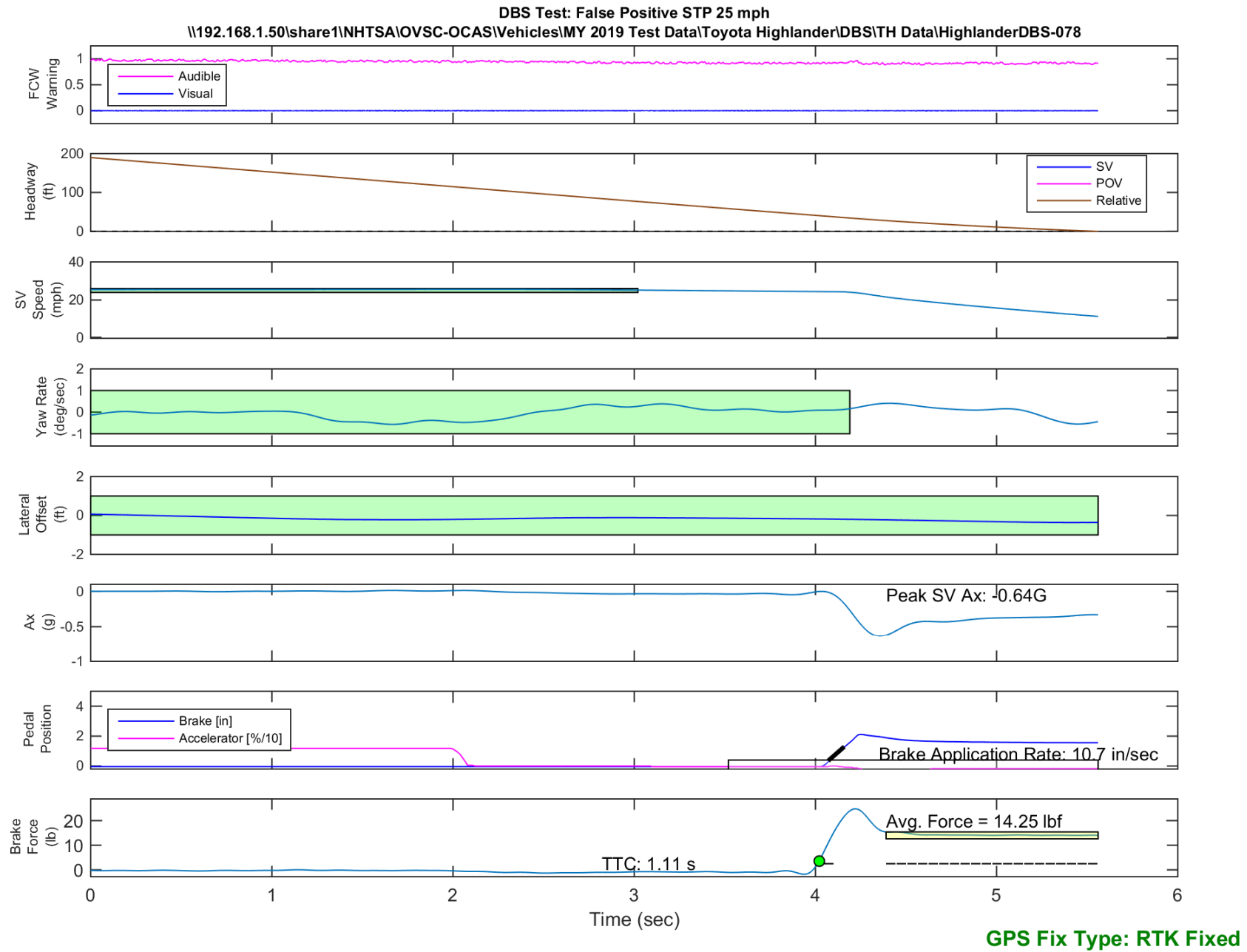
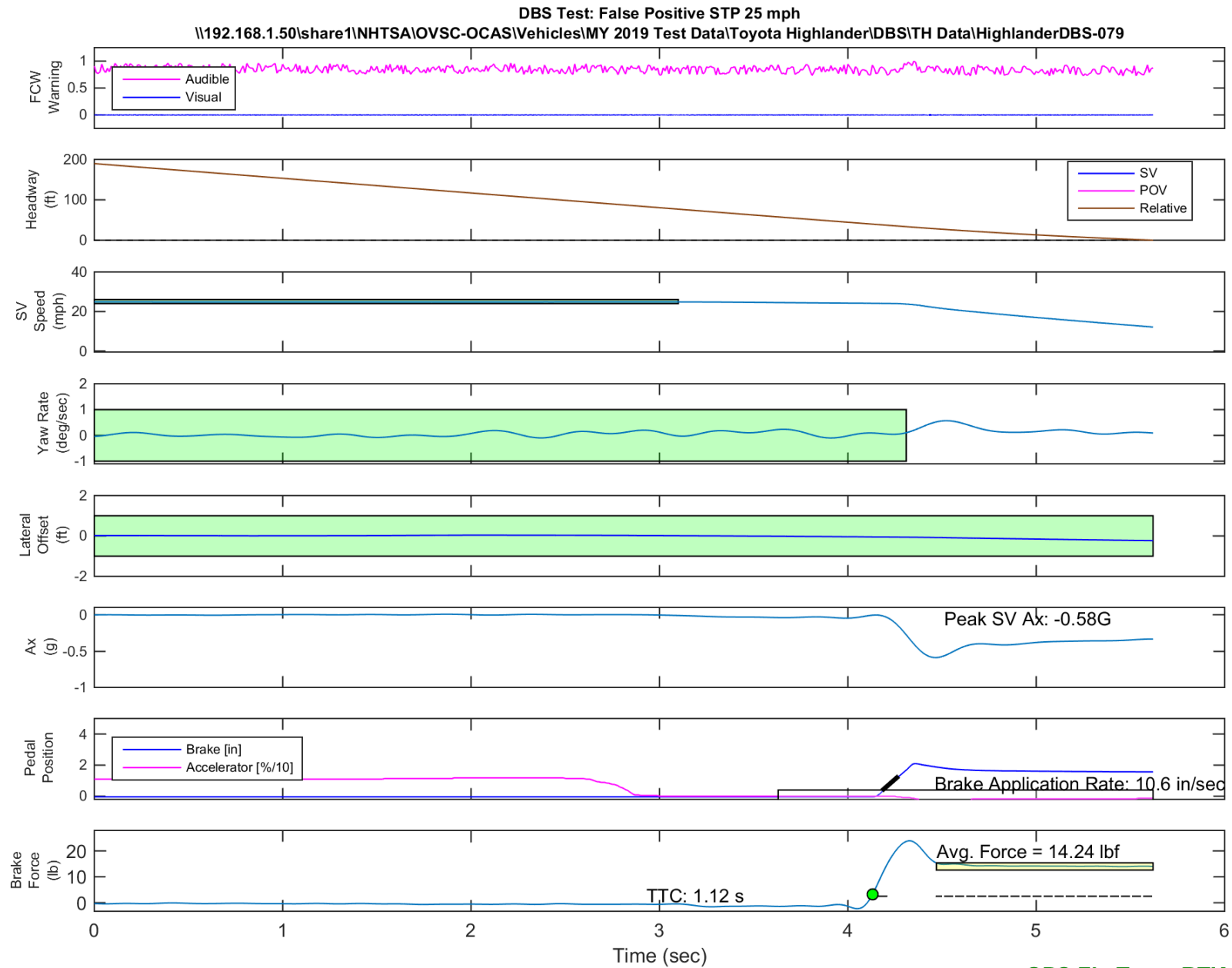


Figure E58. Time History for DBS Run 78, SV Encounters Steel Trench Plate, SV 25 mph



GPS Fix Type: RTK Fixed

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

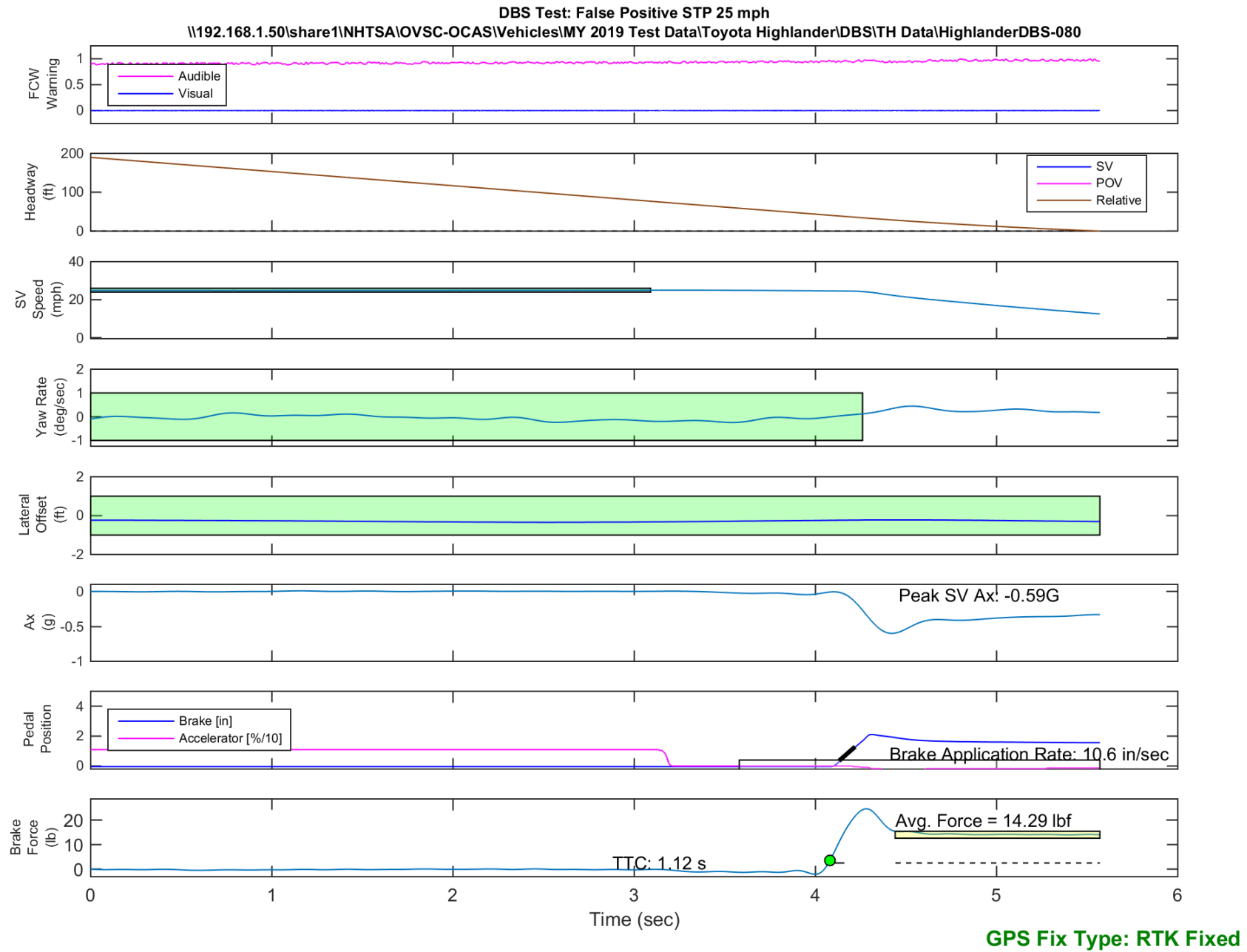
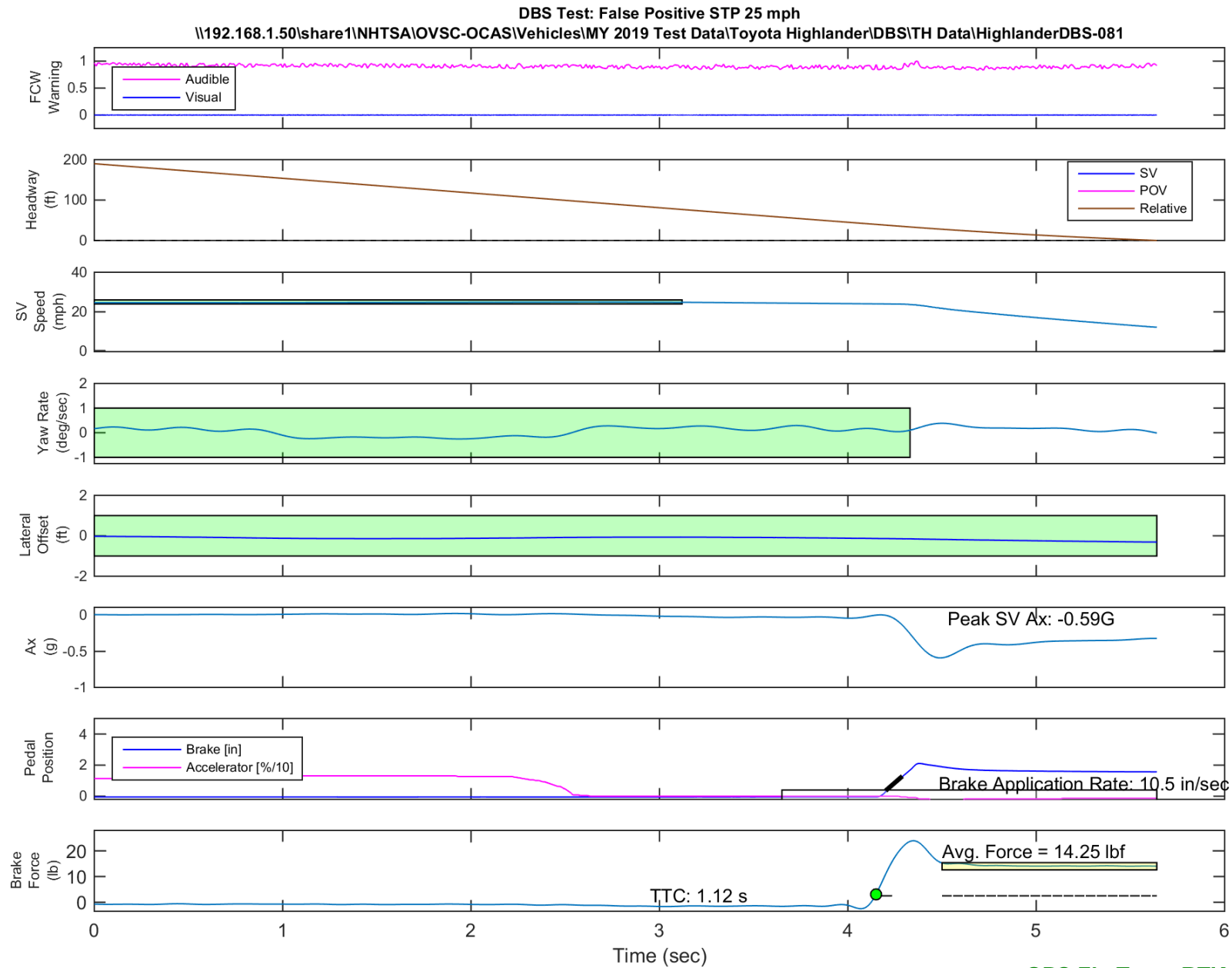


Figure E60. Time History for DBS Run 80, SV Encounters Steel Trench Plate, SV 25 mph



GPS Fix Type: RTK Fixed

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

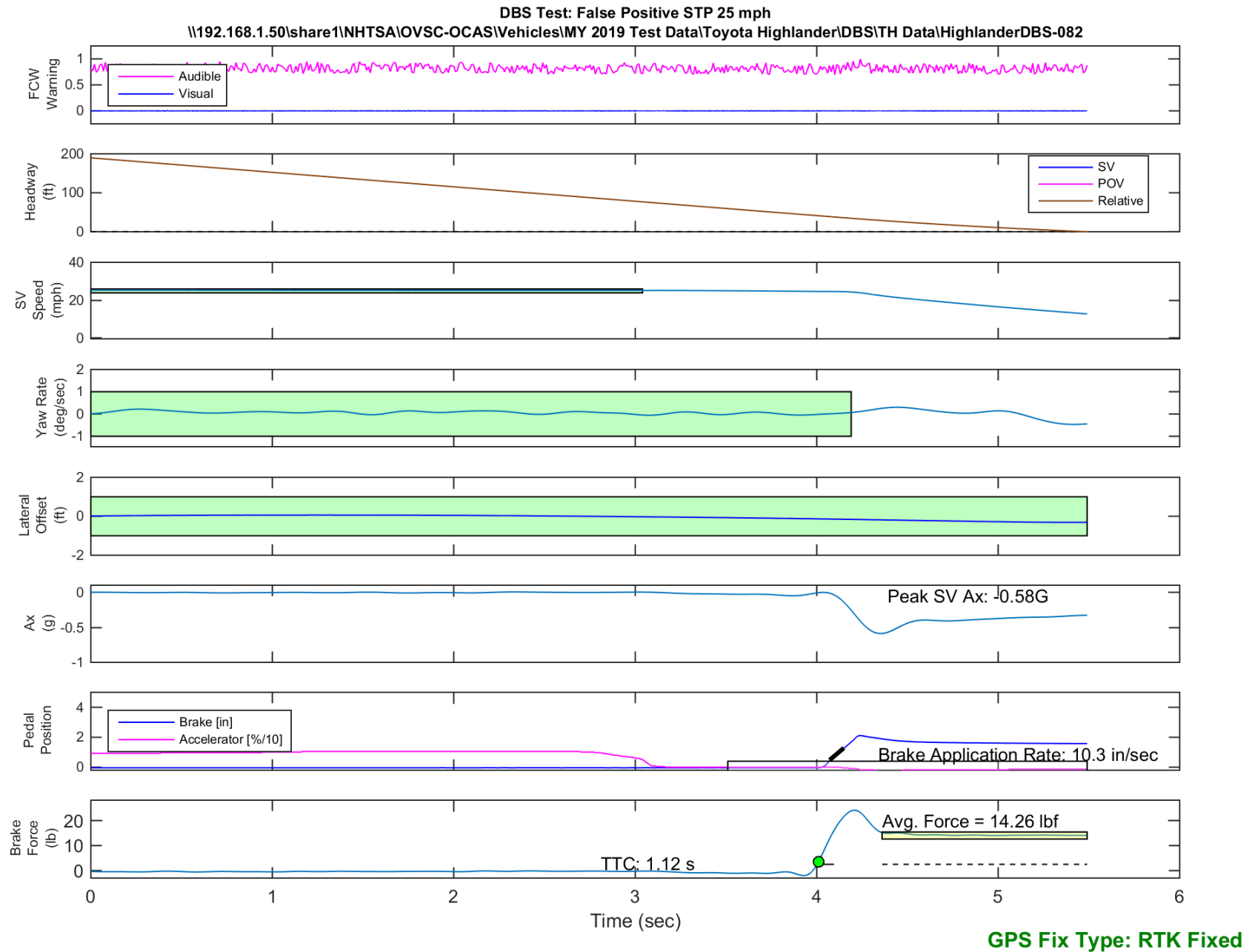


Figure E62. Time History for DBS Run 82, SV Encounters Steel Trench Plate, SV 25 mph

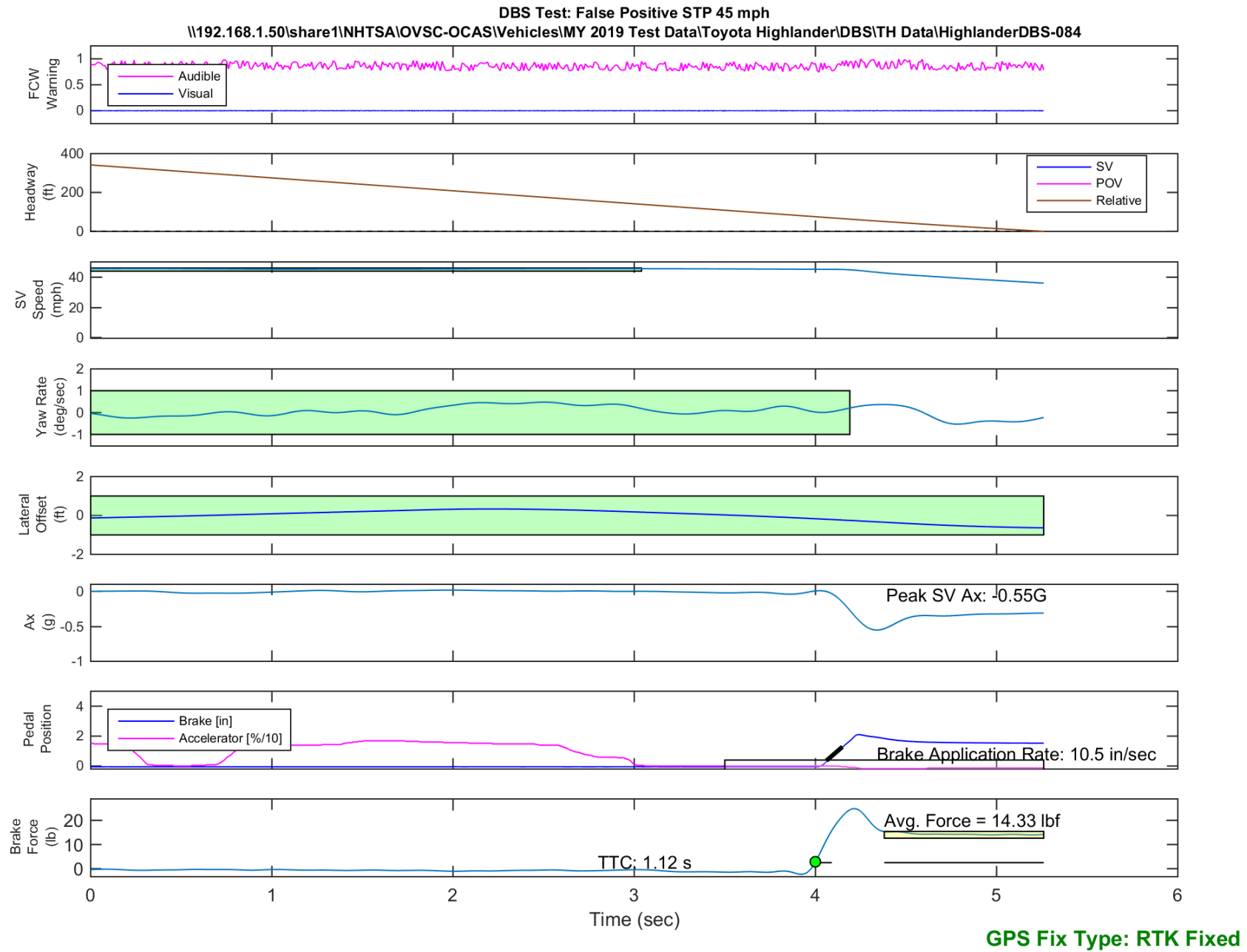


Figure E63. Time History for DBS Run 84, SV Encounters Steel Trench Plate, SV 45 mph

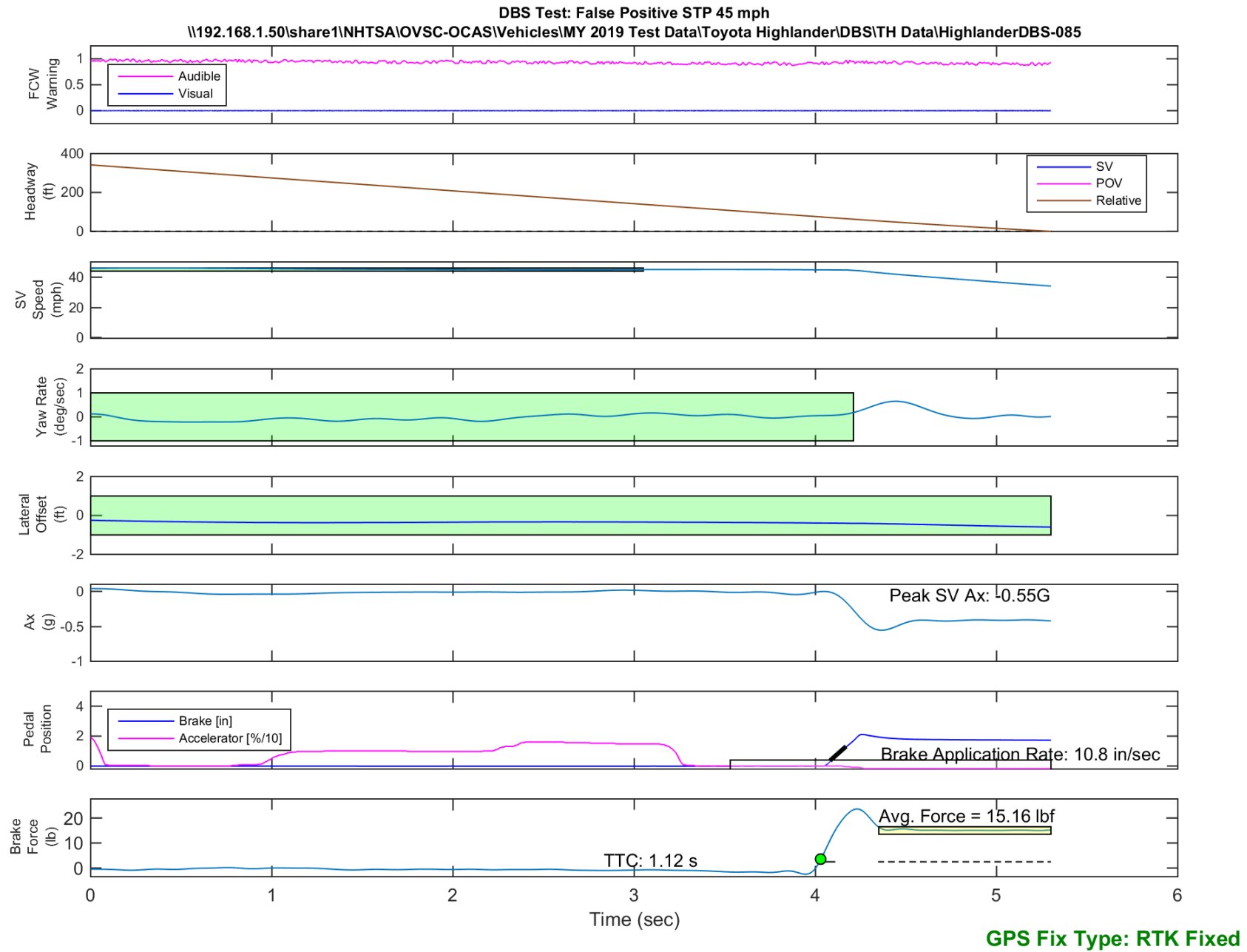


Figure E64. Time History for DBS Run 85, SV Encounters Steel Trench Plate, SV 45 mph

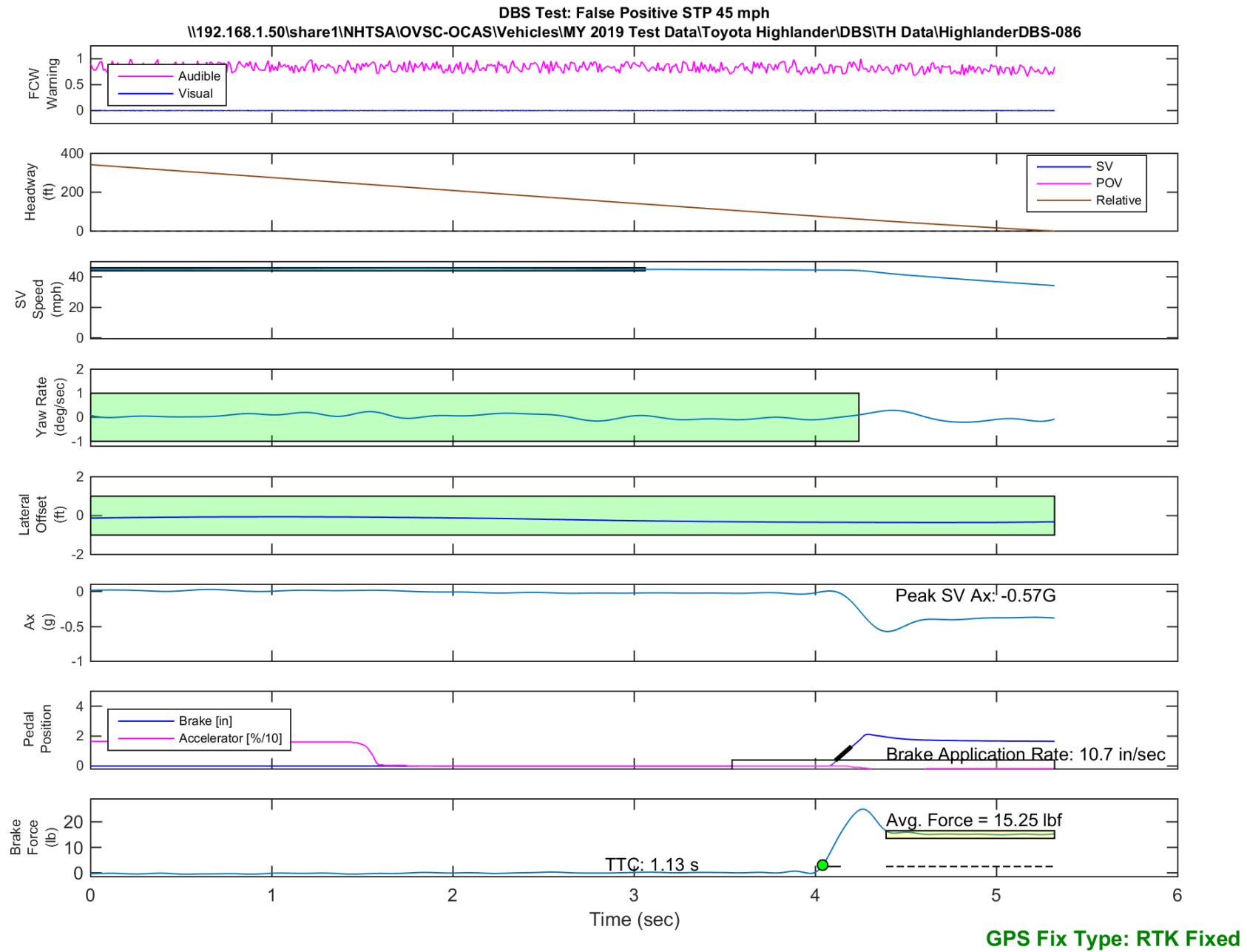


Figure E65. Time History for DBS Run 86, SV Encounters Steel Trench Plate, SV 45 mph

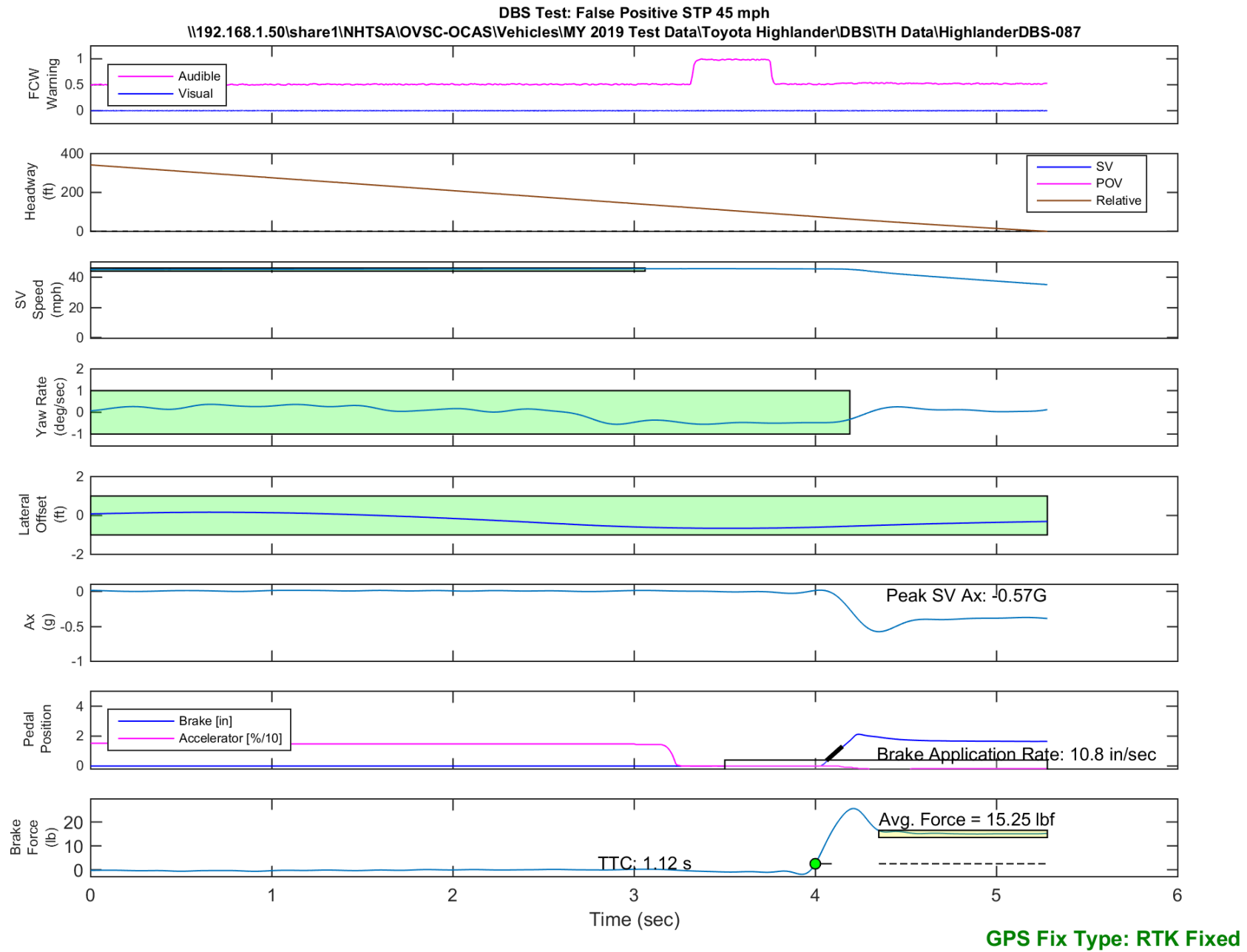


Figure E66. Time History for DBS Run 87, SV Encounters Steel Trench Plate, SV 45 mph

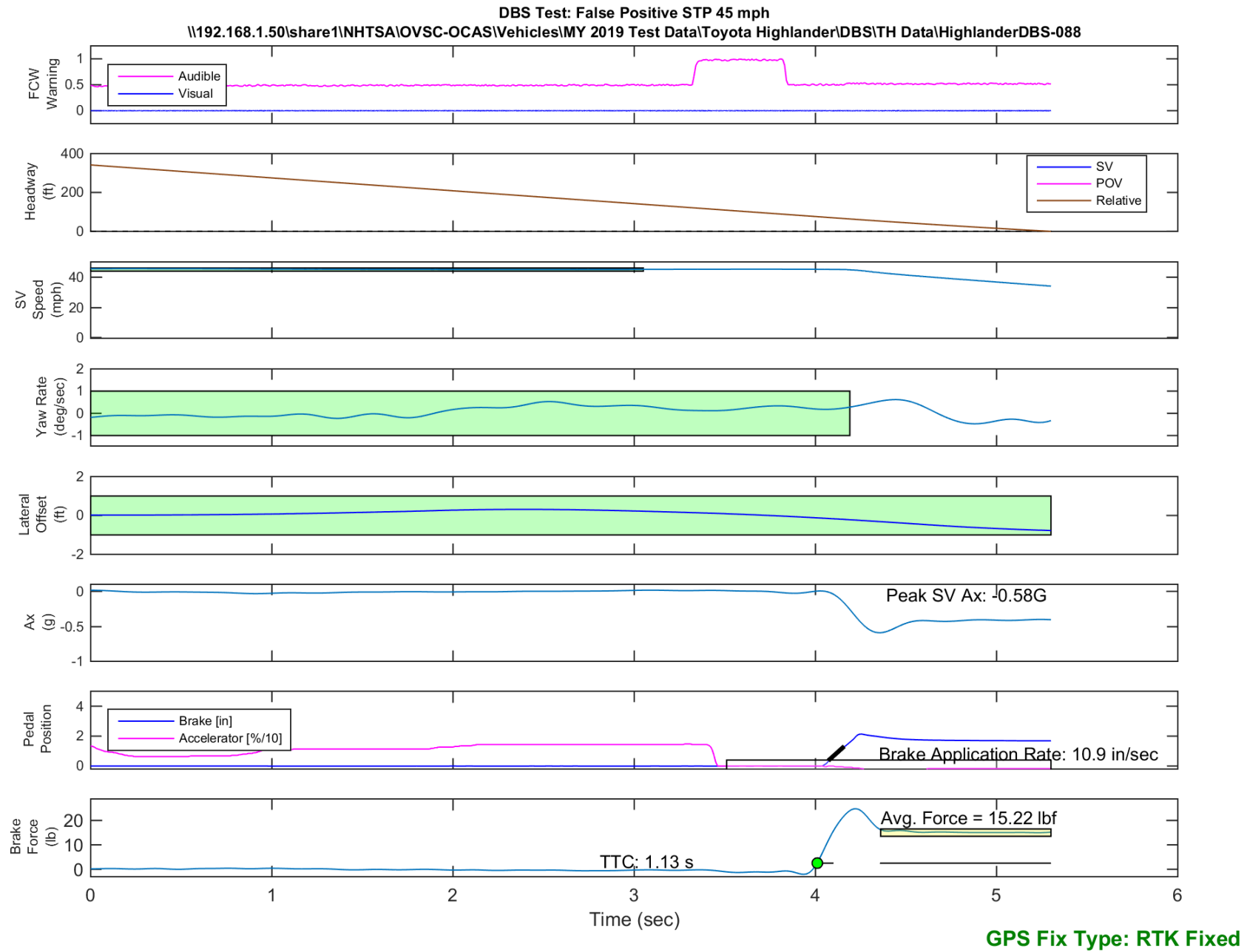


Figure E67. Time History for DBS Run 88, SV Encounters Steel Trench Plate, SV 45 mph

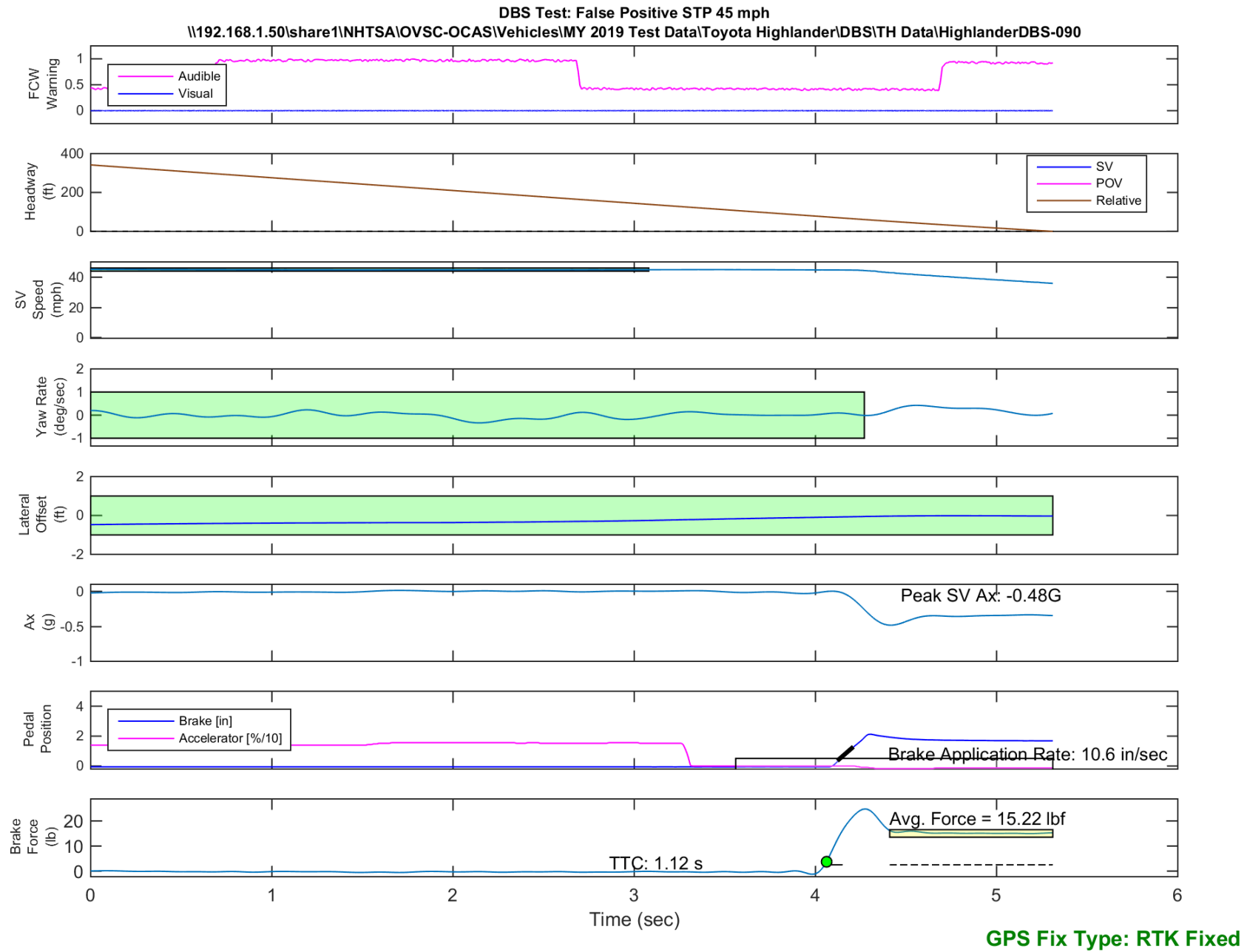
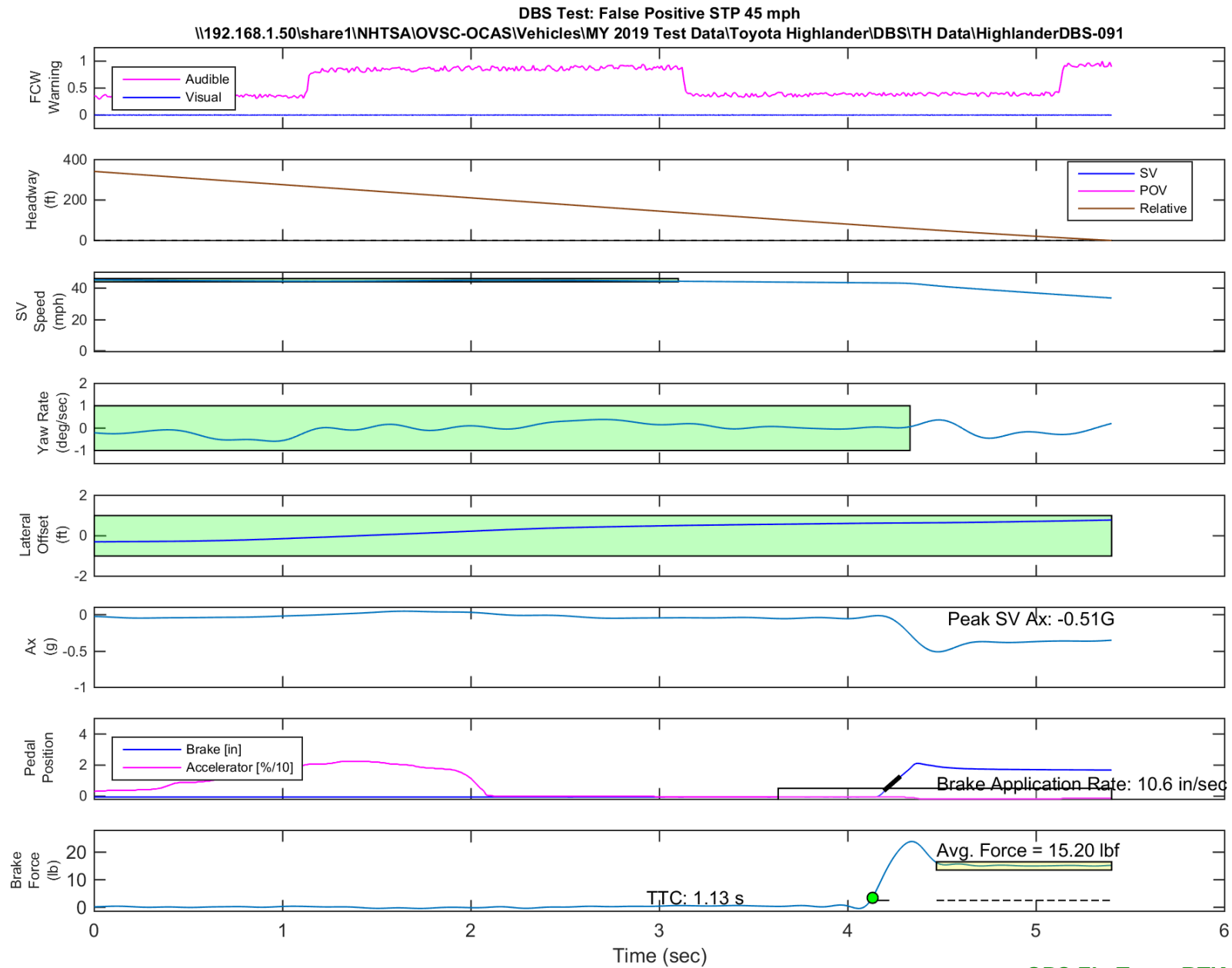


Figure E68. Time History for DBS Run 90, SV Encounters Steel Trench Plate, SV 45 mph



GPS Fix Type: RTK Fixed

Figure E69. Time History for DBS Run 91, SV Encounters Steel Trench Plate, SV 45 mph

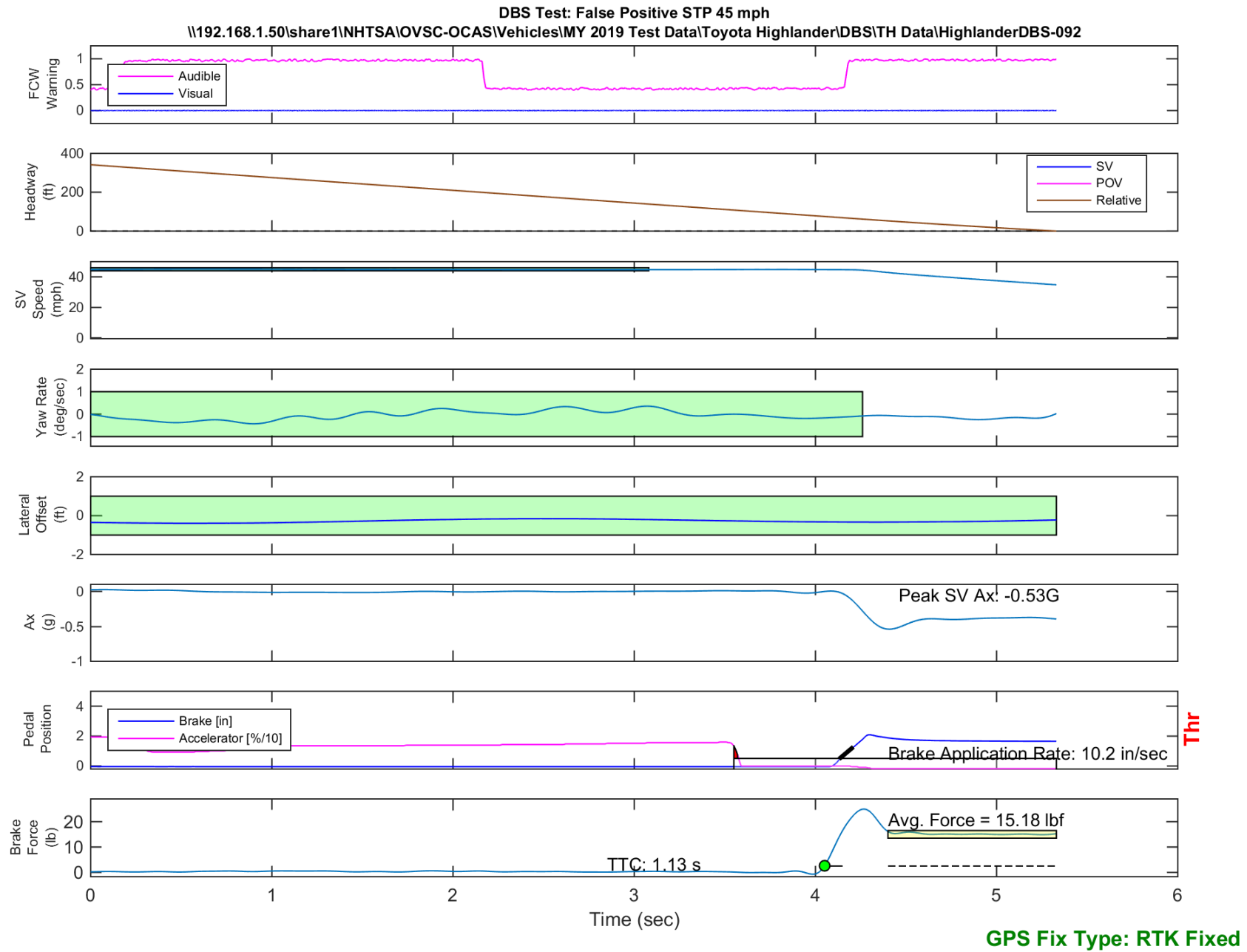


Figure E70. Time History for DBS Run 92, SV Encounters Steel Trench Plate, SV 45 mph

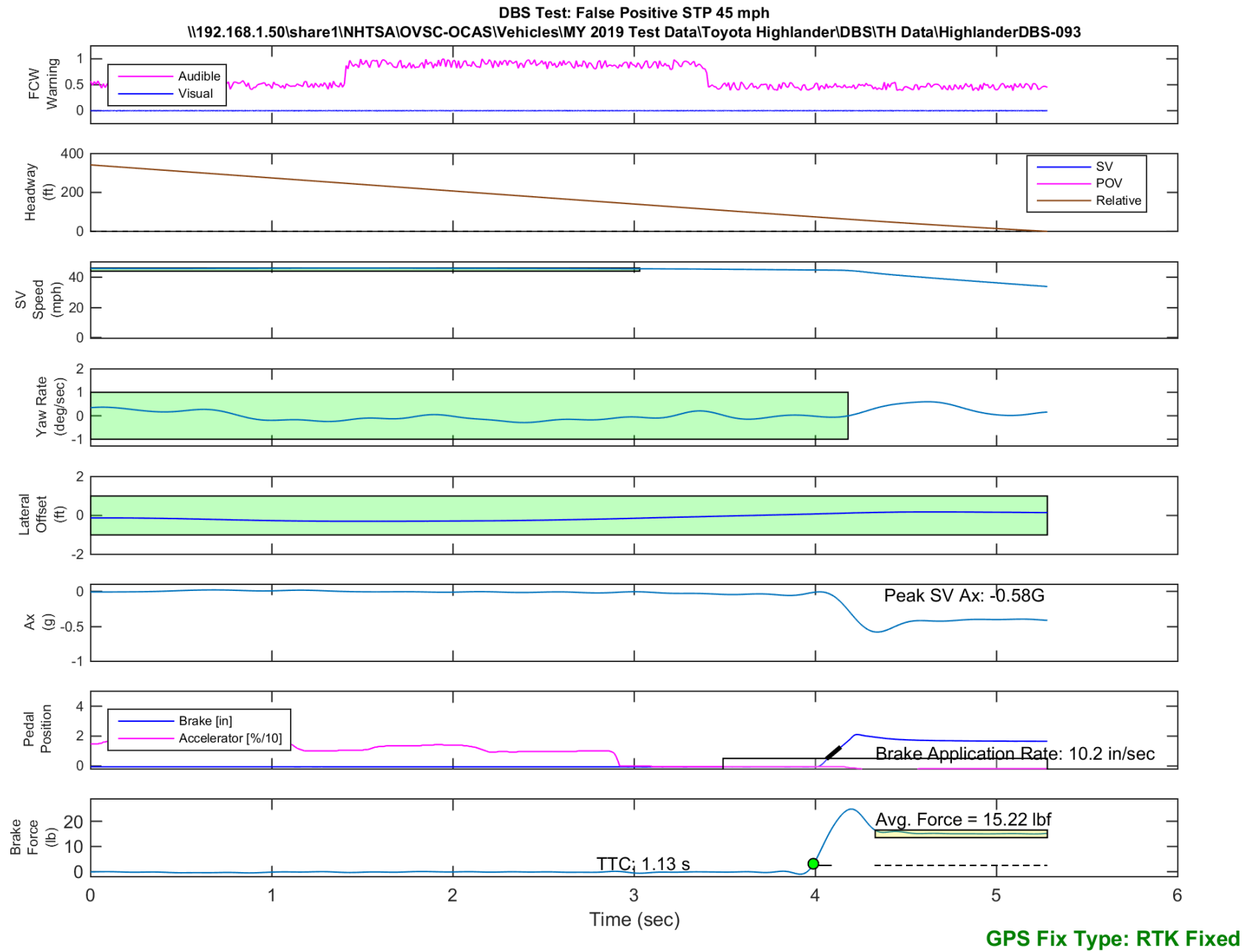


Figure E71. Time History for DBS Run 93, SV Encounters Steel Trench Plate, SV 45 mph

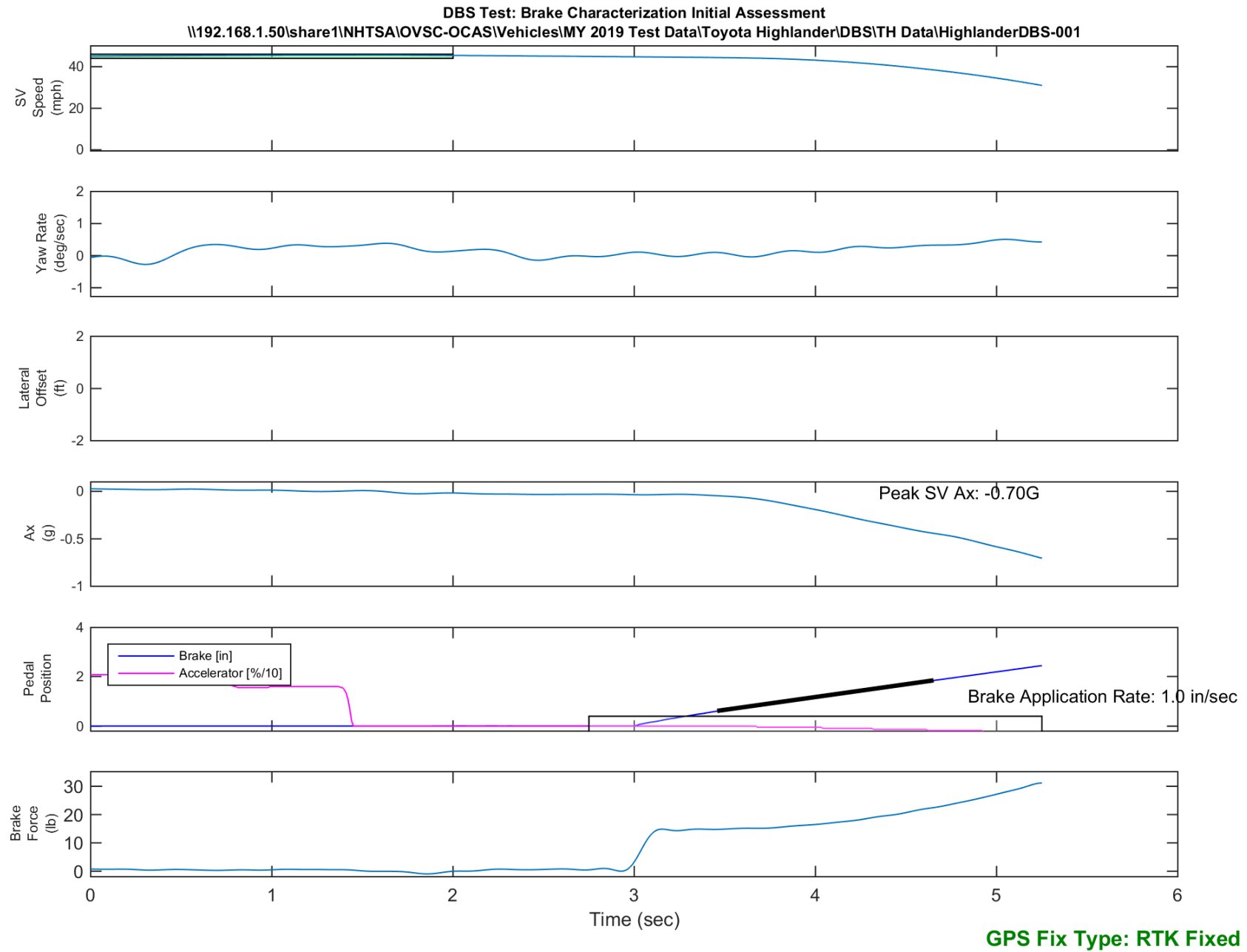


Figure E72. Time History for DBS Run 1, Brake Characterization Initial

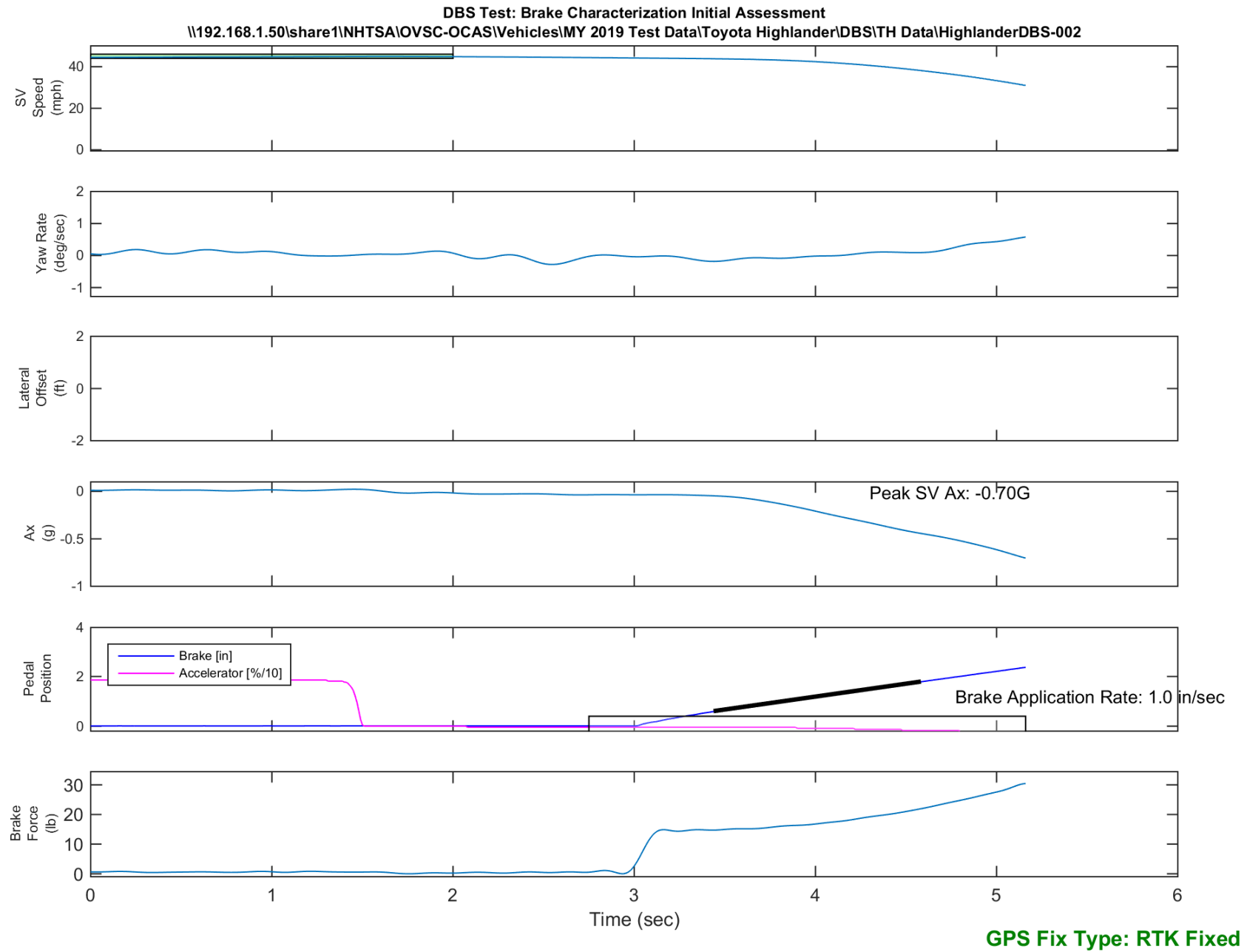


Figure E73. Time History for DBS Run 2, Brake Characterization Initial

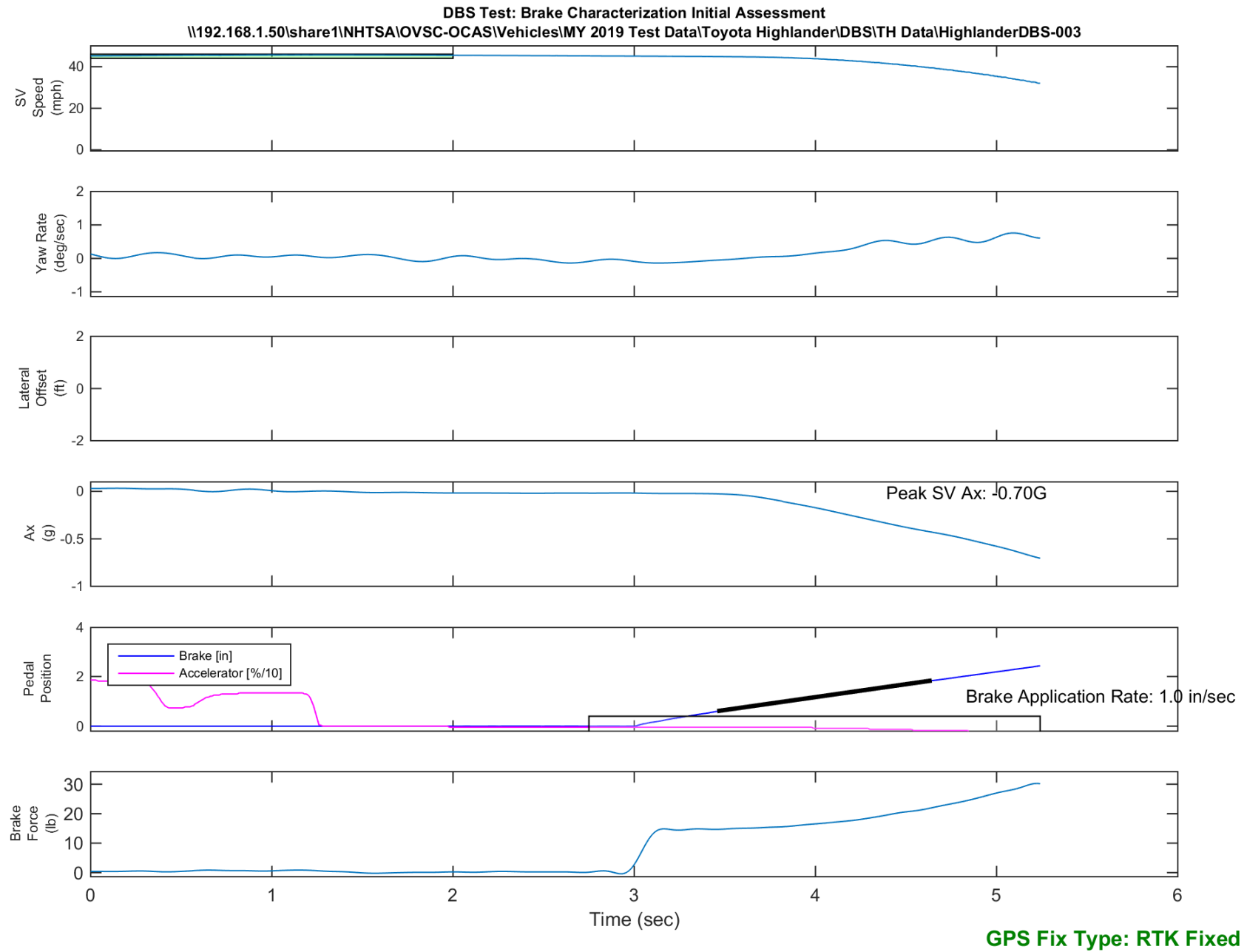


Figure E74. Time History for DBS Run 3, Brake Characterization Initial

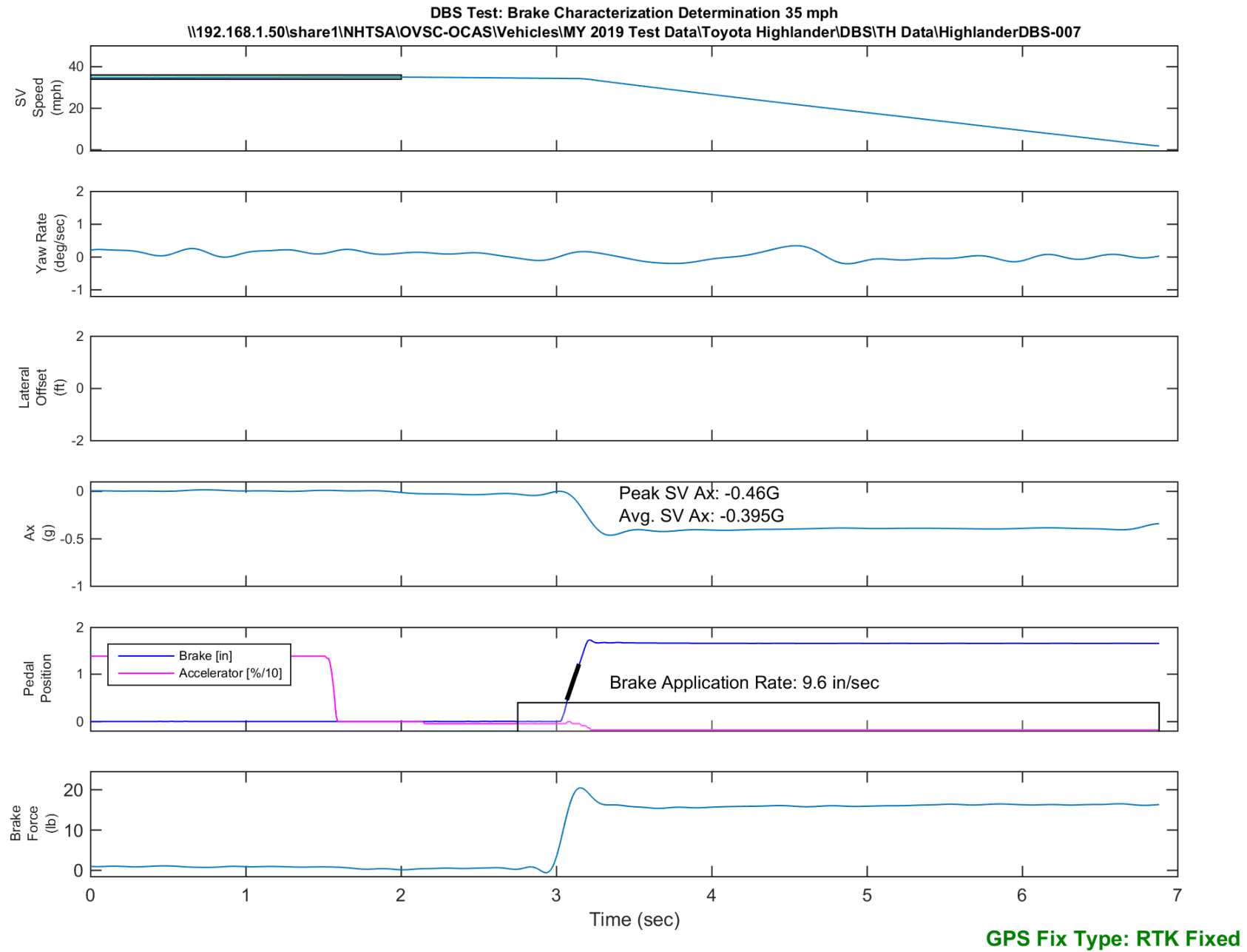


Figure E75. Time History for DBS Run 7, Brake Characterization Determination 35 mph

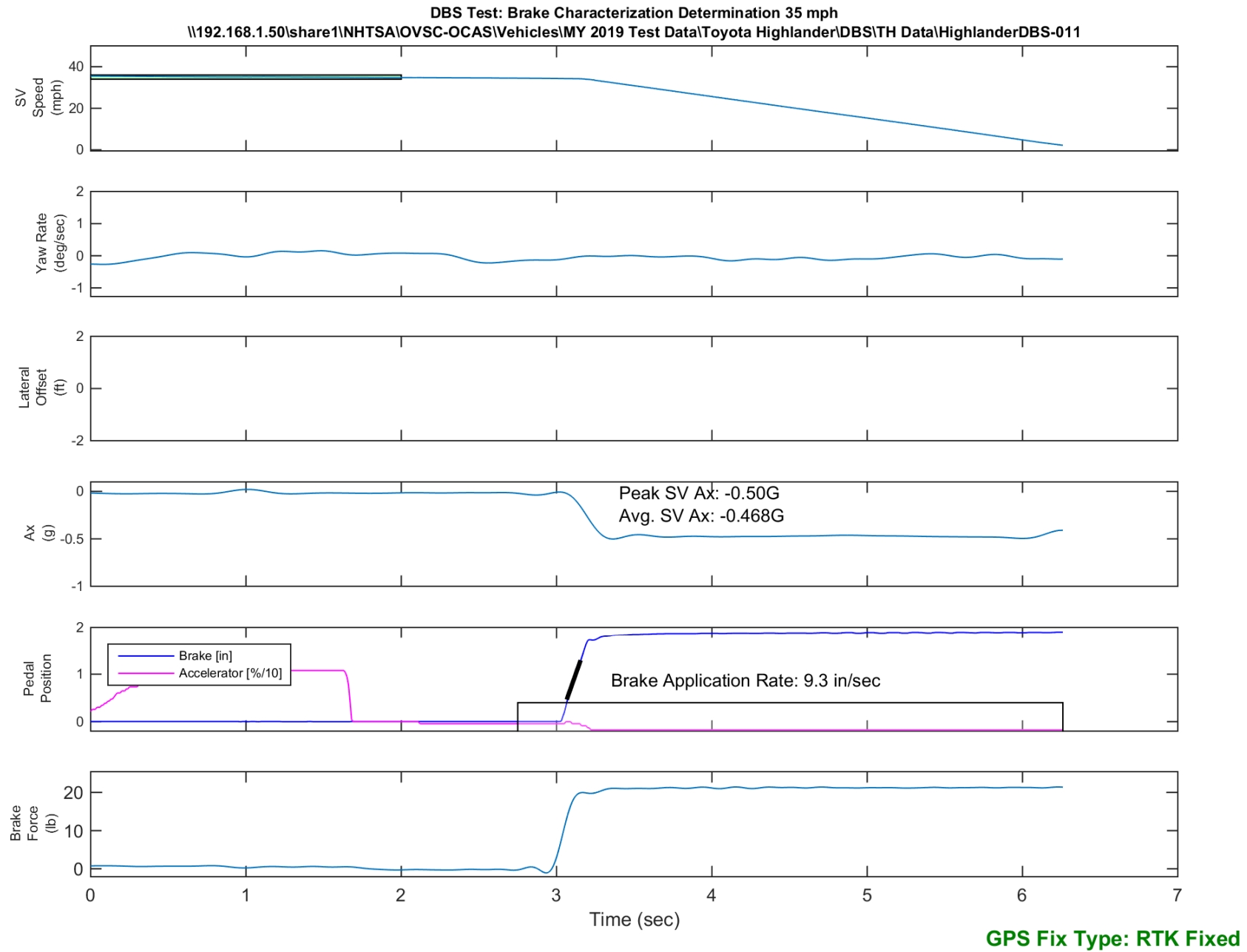


Figure E76. Time History for DBS Run 11, Brake Characterization Determination 35 mph

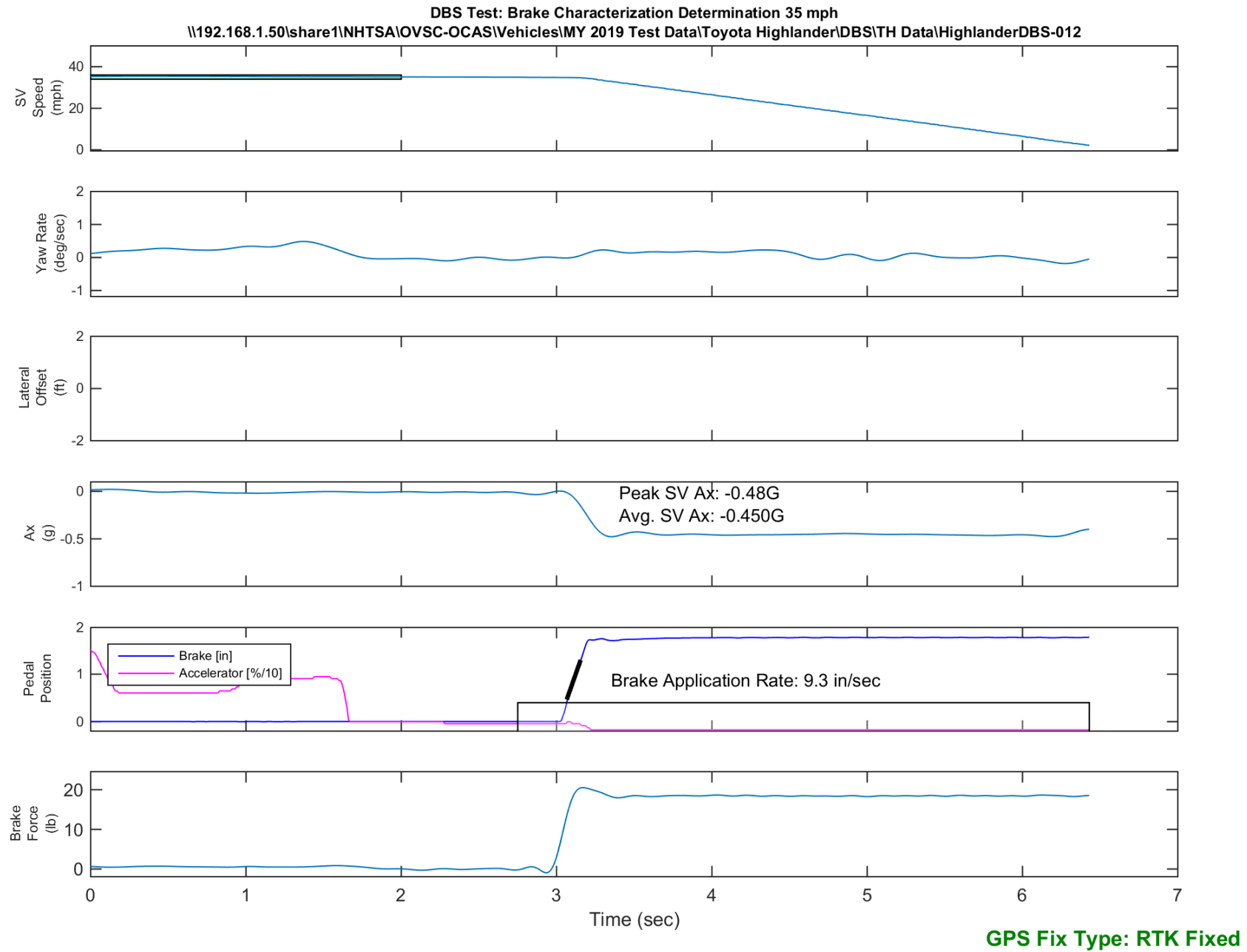


Figure E77. Time History for DBS Run 12, Brake Characterization Determination 35 mph

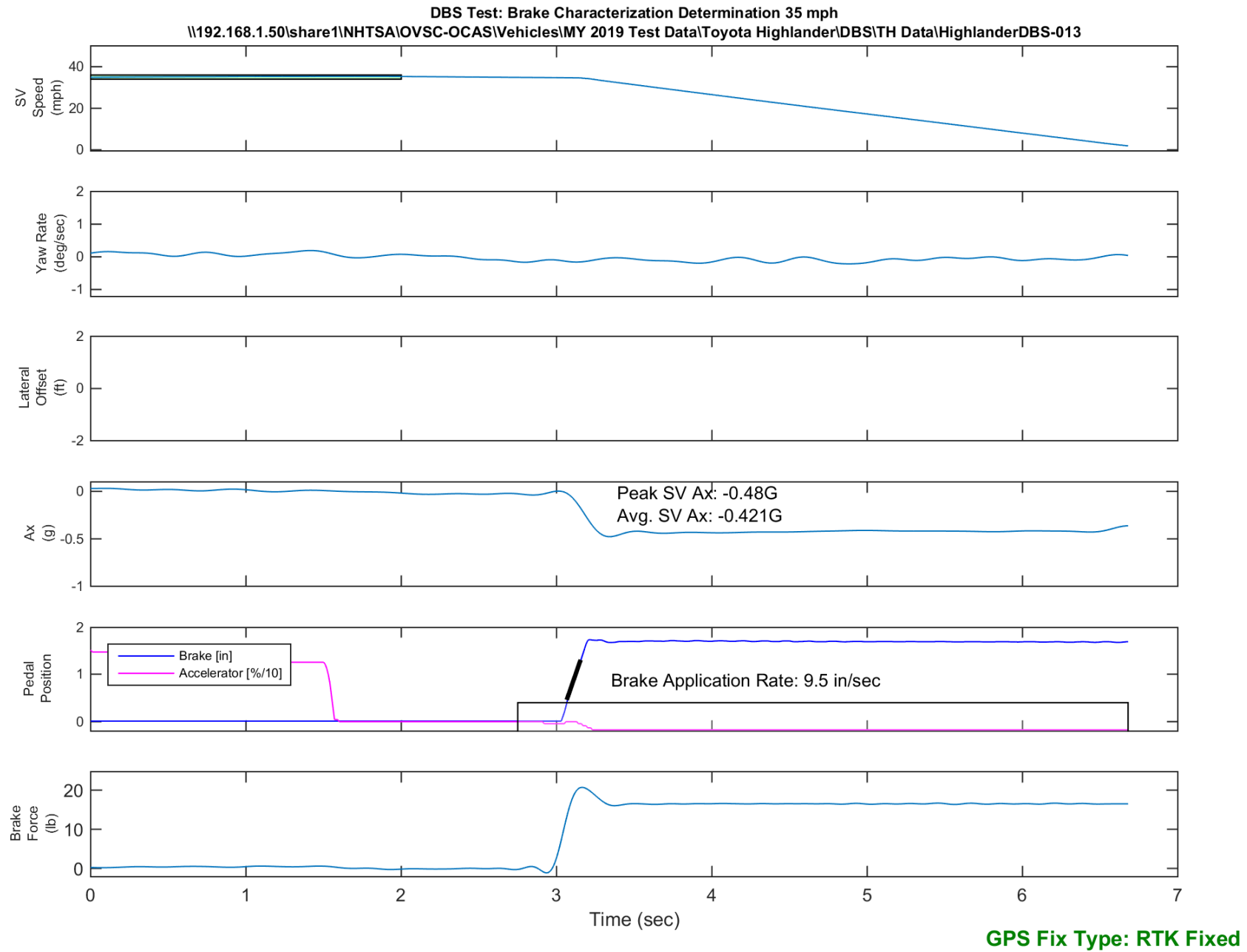


Figure E78. Time History for DBS Run 13, Brake Characterization Determination 35 mph

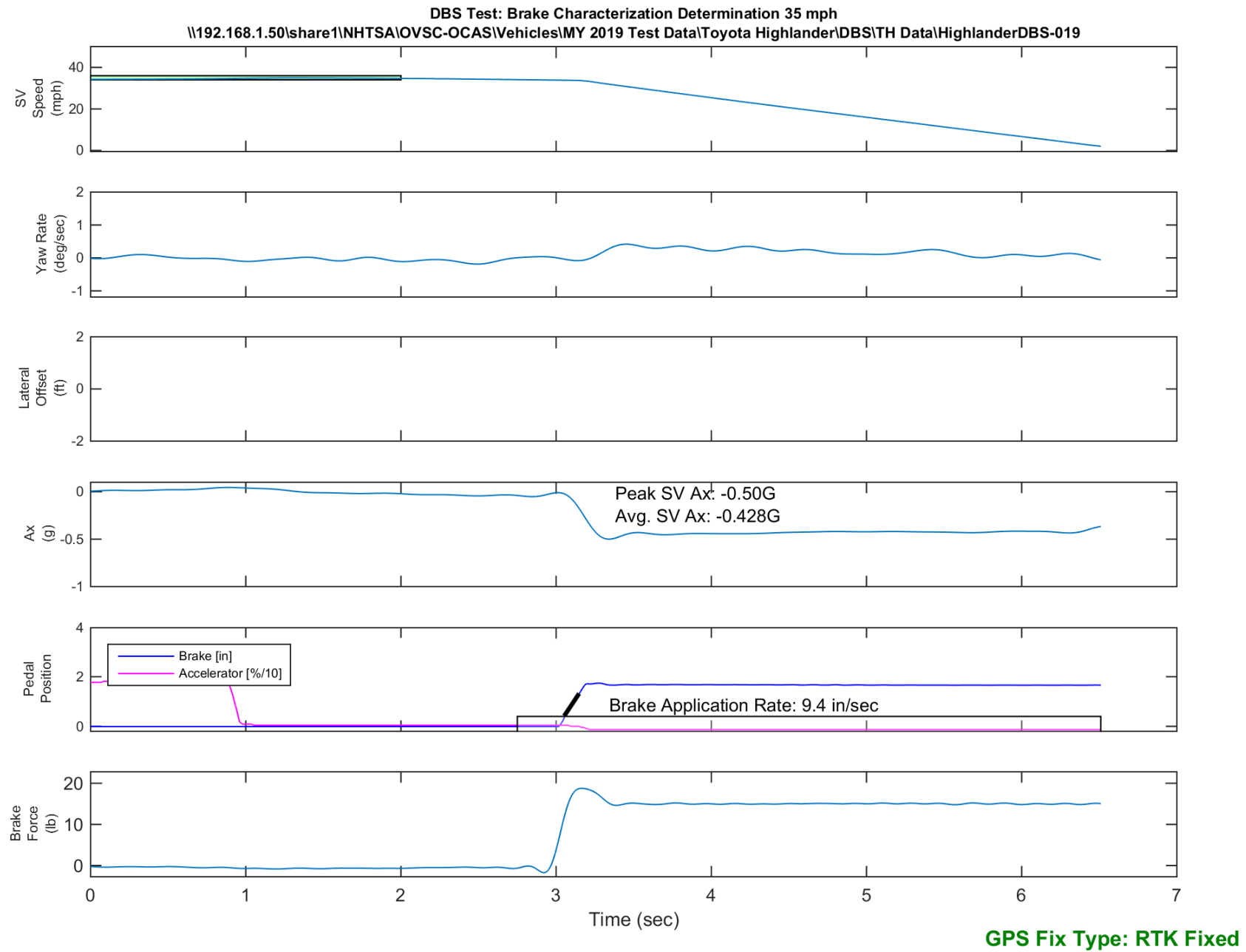


Figure E79. Time History for DBS Run 19, Brake Characterization Determination 35 mph

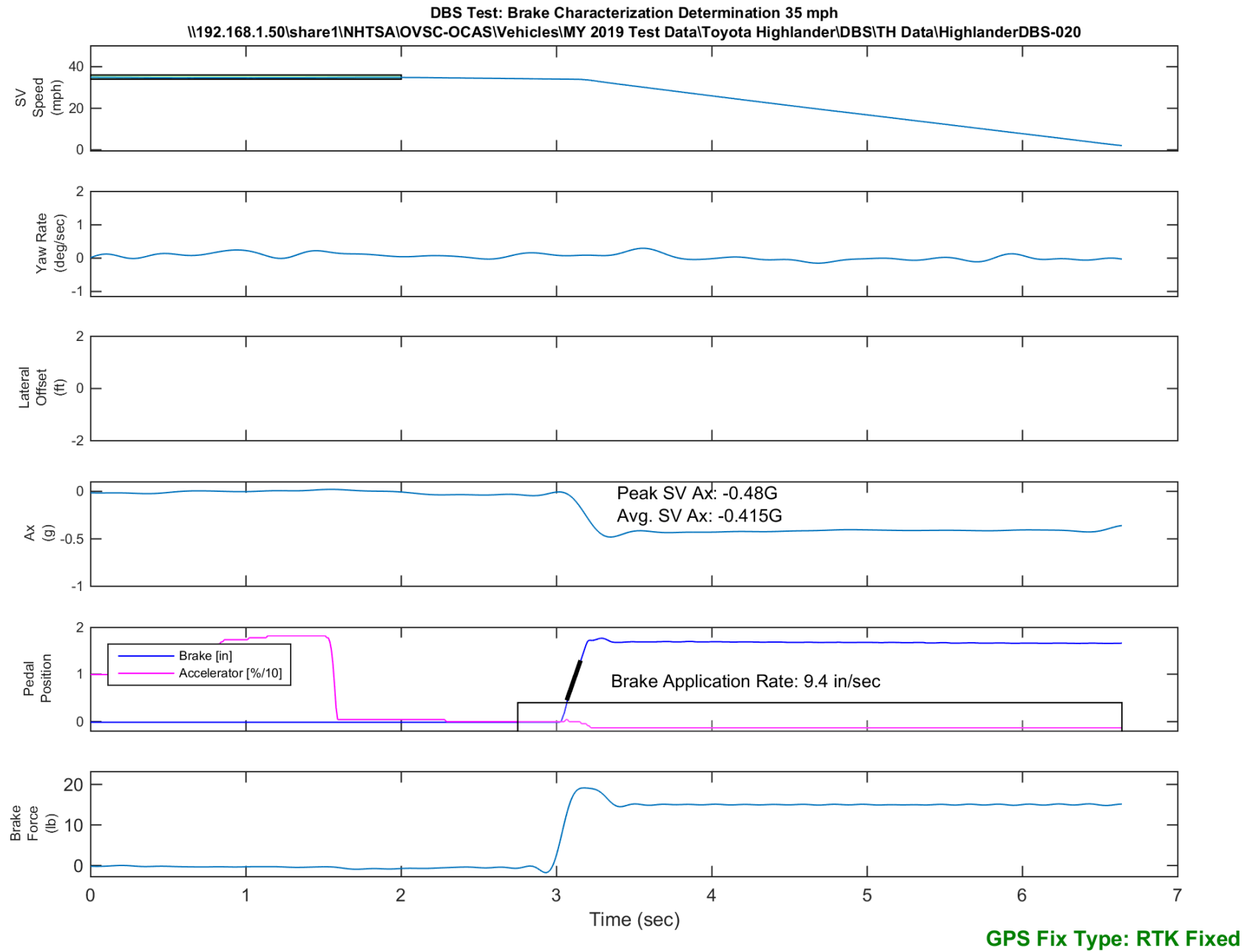


Figure E80. Time History for DBS Run 20, Brake Characterization Determination 35 mph

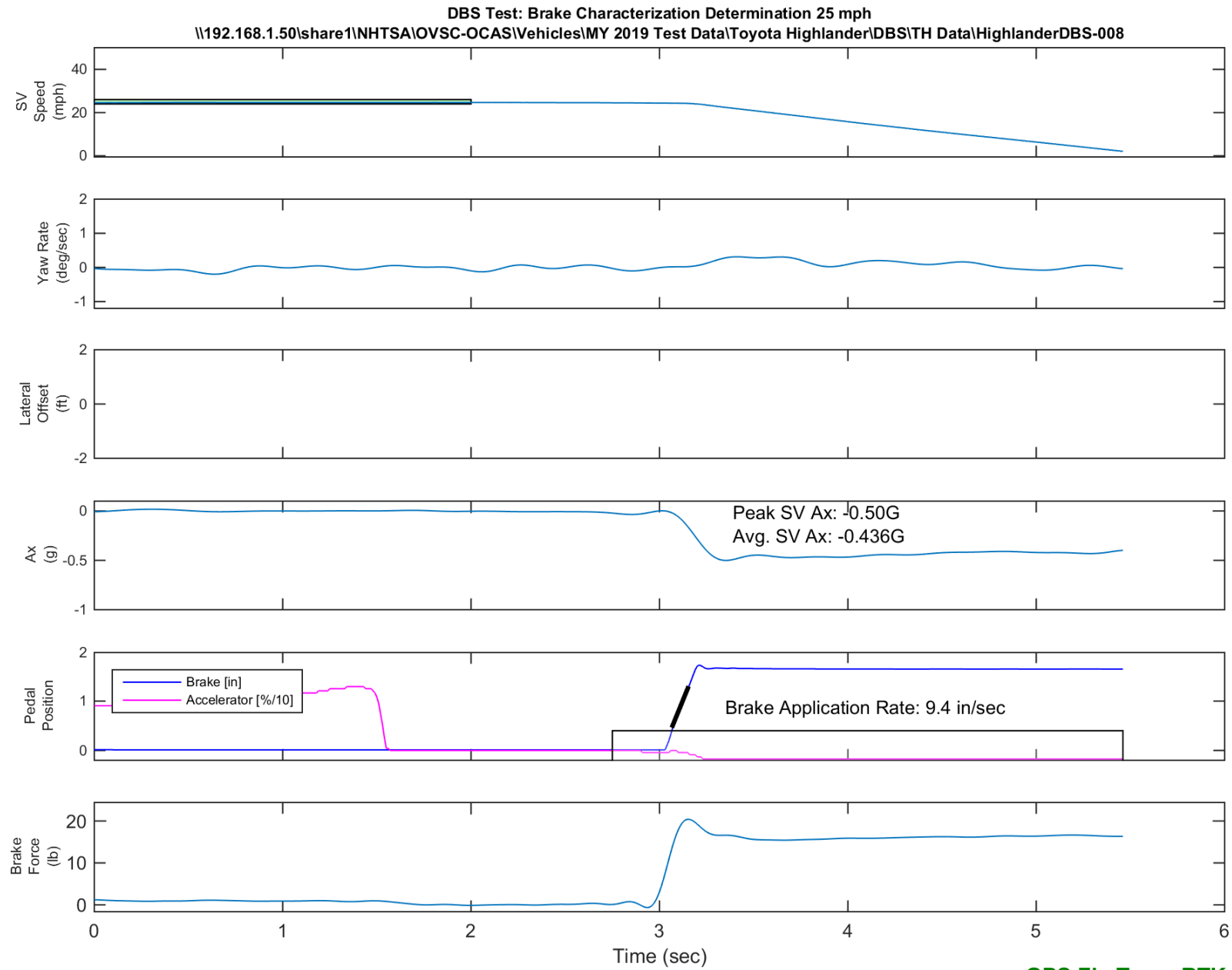


Figure E81. Time History for DBS Run 8, Brake Characterization Determination 25 mph

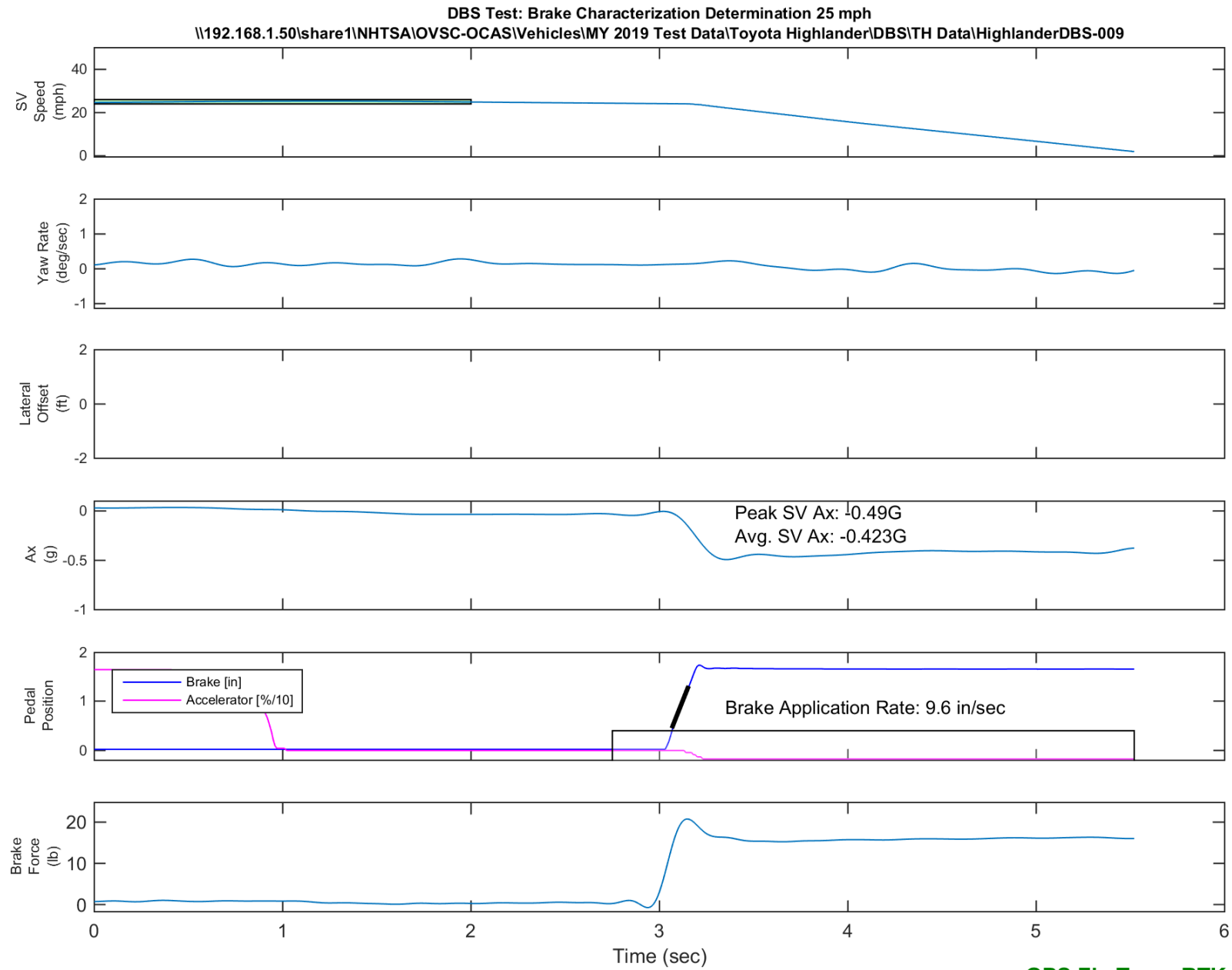


Figure E82. Time History for DBS Run 9, Brake Characterization Determination 25 mph

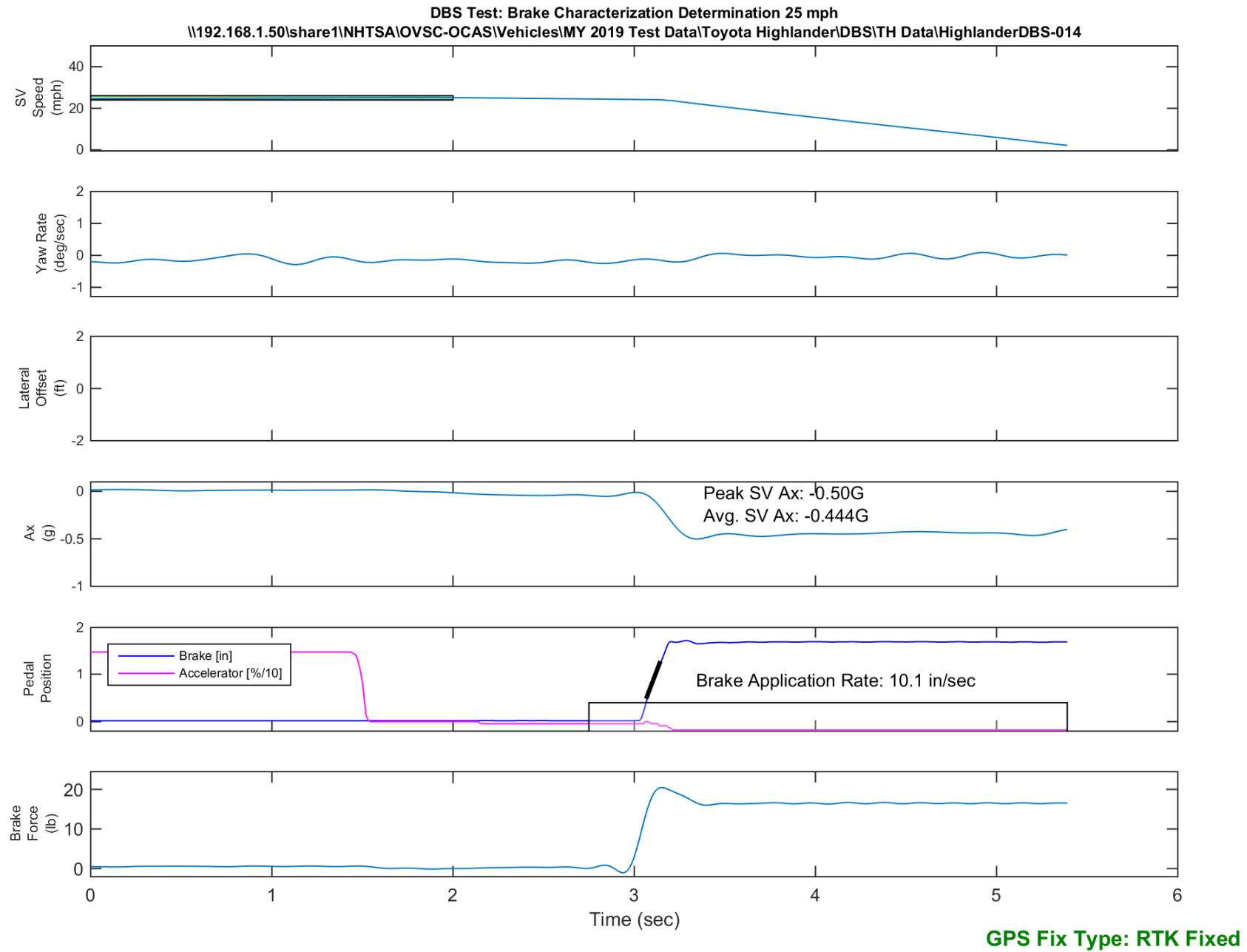
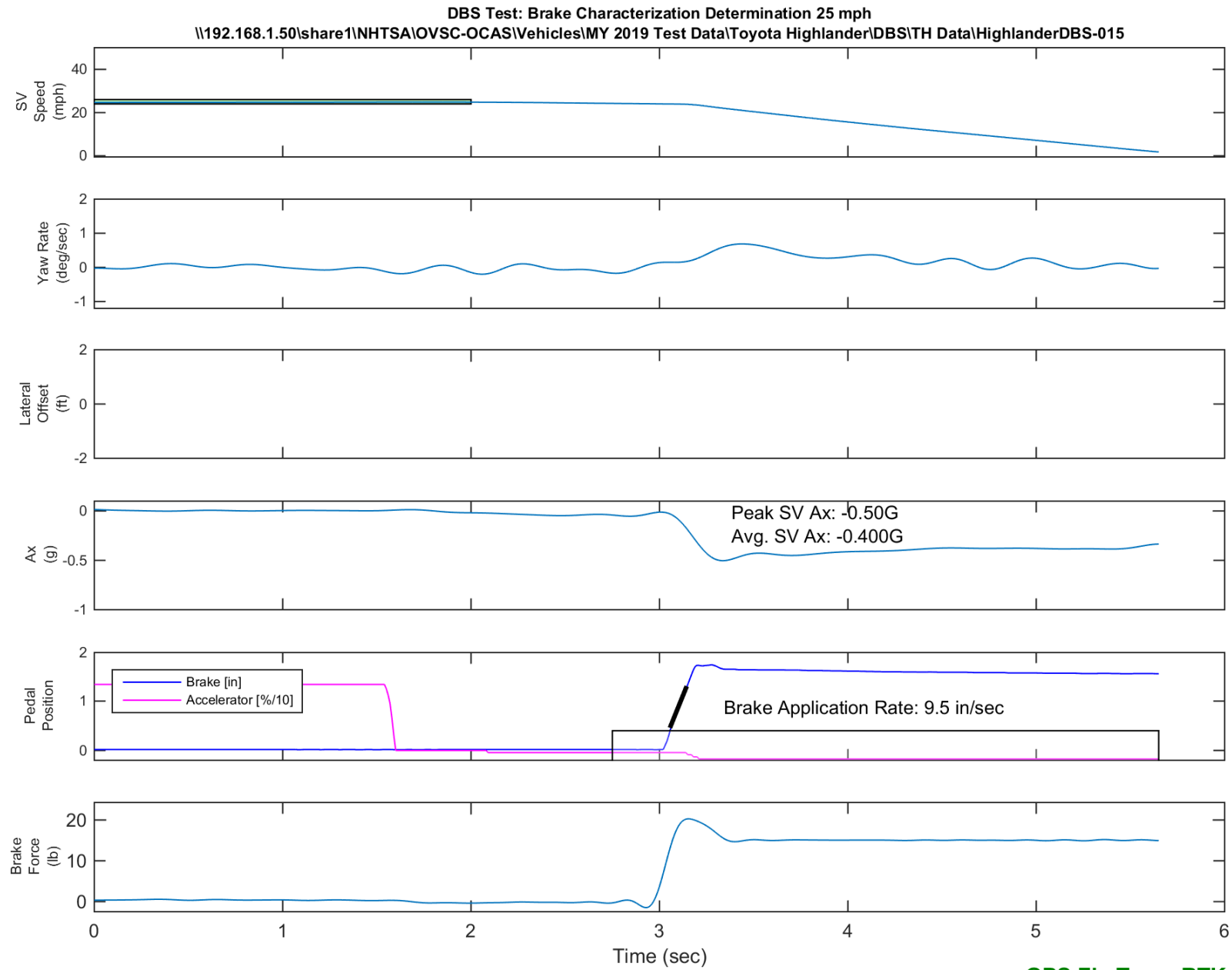
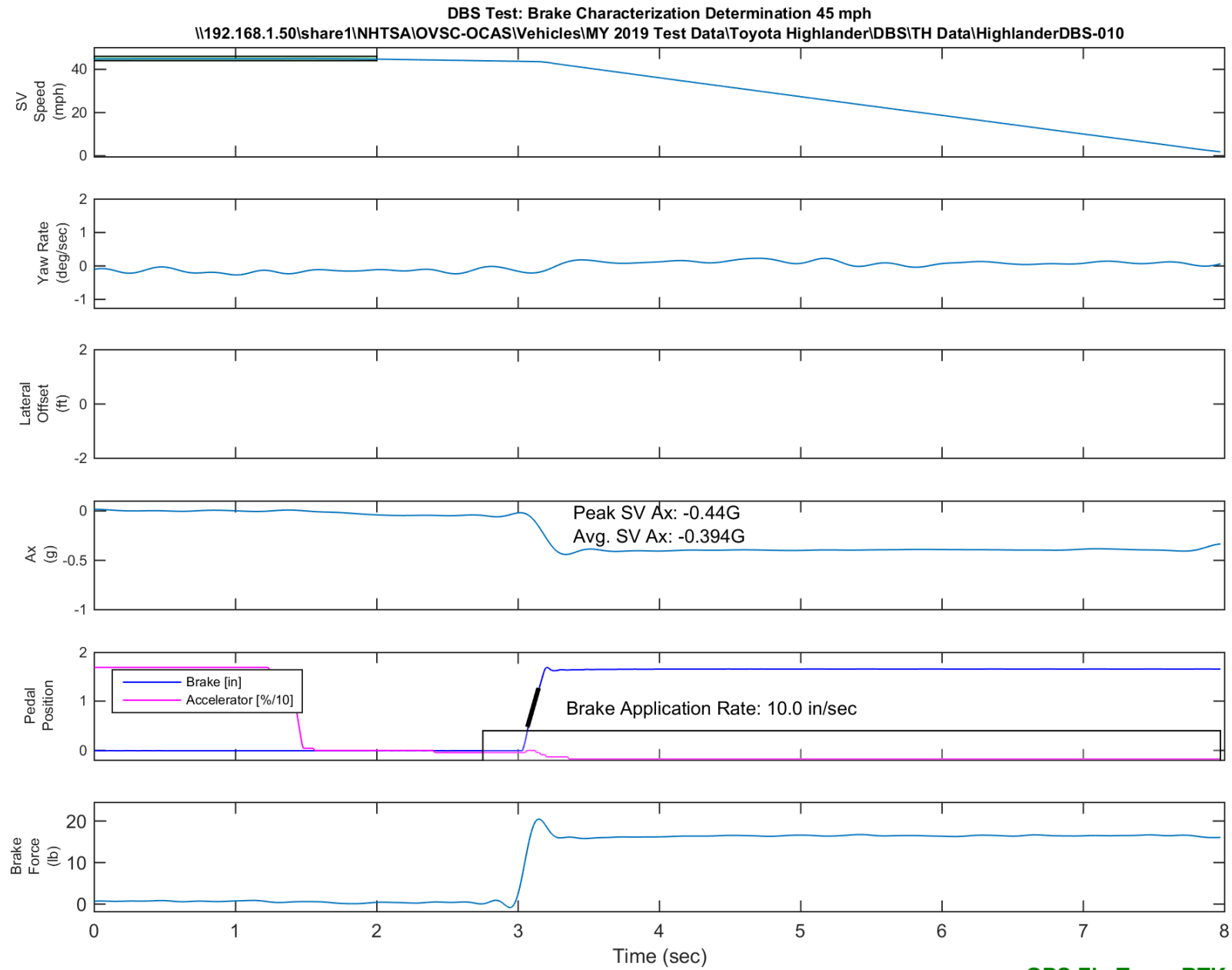


Figure E83. Time History for DBS Run 14, Brake Characterization Determination 25 mph



GPS Fix Type: RTK Fixed

Figure E84. Time History for DBS Run 15, Brake Characterization Determination 25 mph



GPS Fix Type: RTK Fixed

Figure E85. Time History for DBS Run 10, Brake Characterization Determination 45 mph

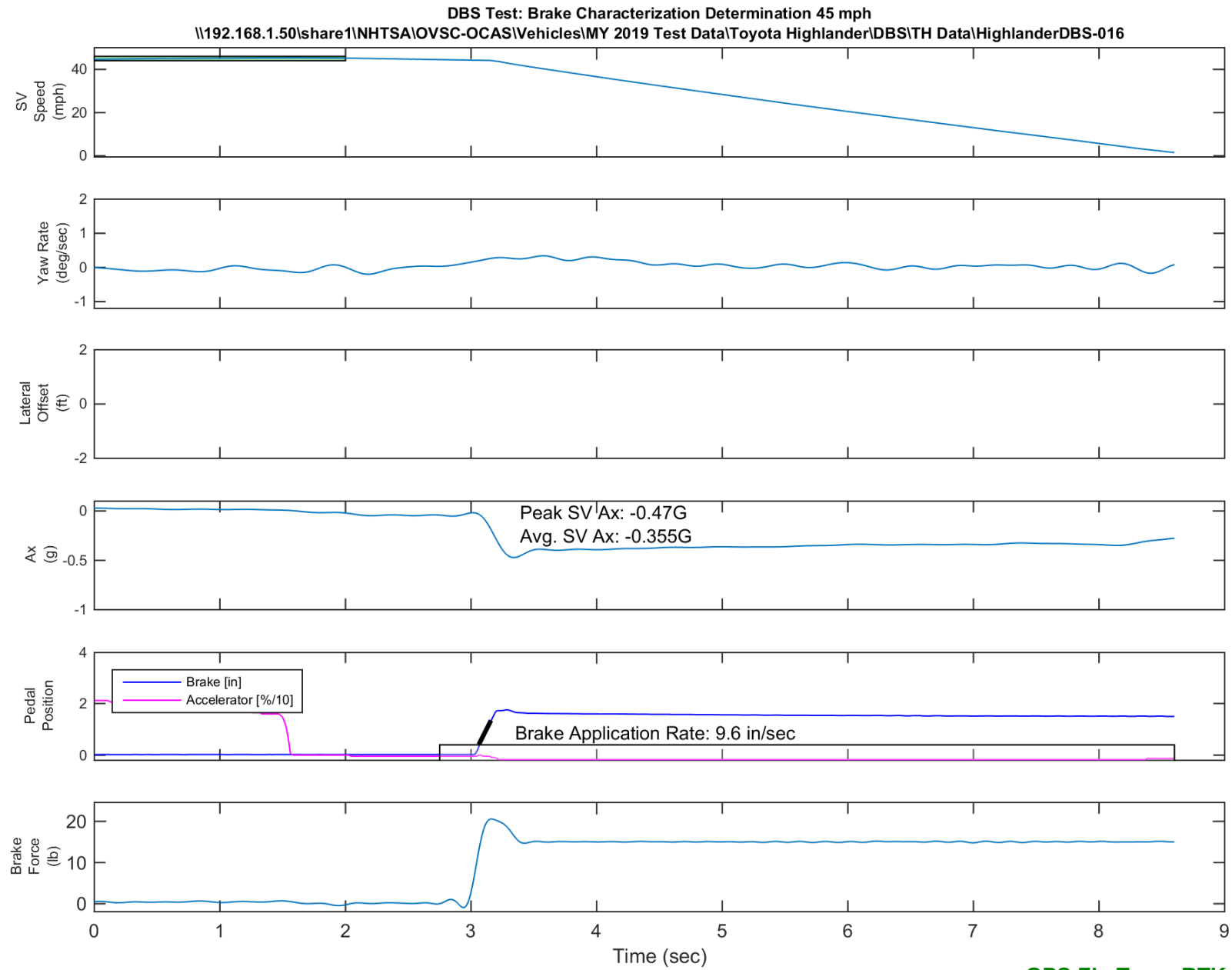


Figure E86. Time History for DBS Run 16, Brake Characterization Determination 45 mph

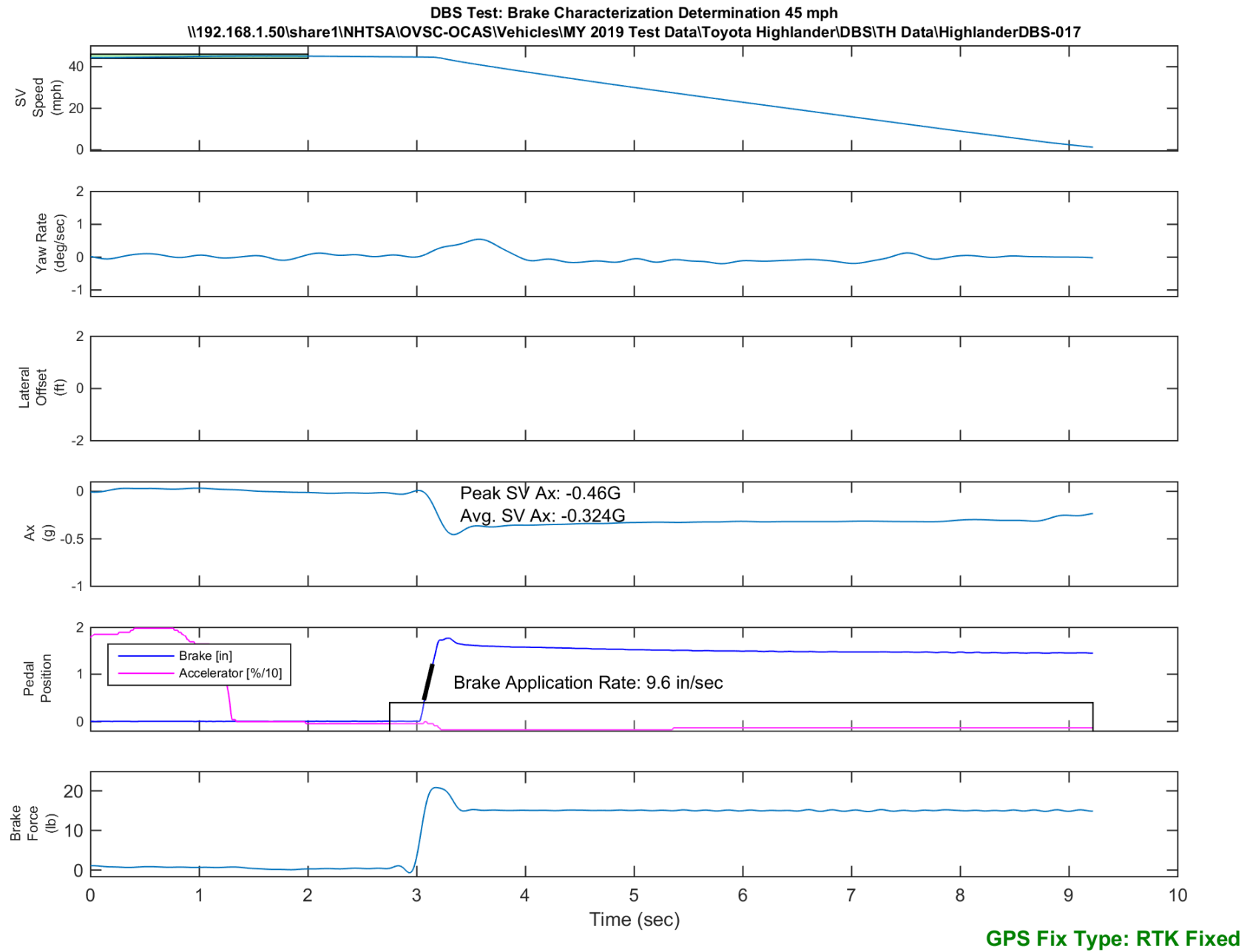


Figure E87. Time History for DBS Run 17, Brake Characterization Determination 45 mph

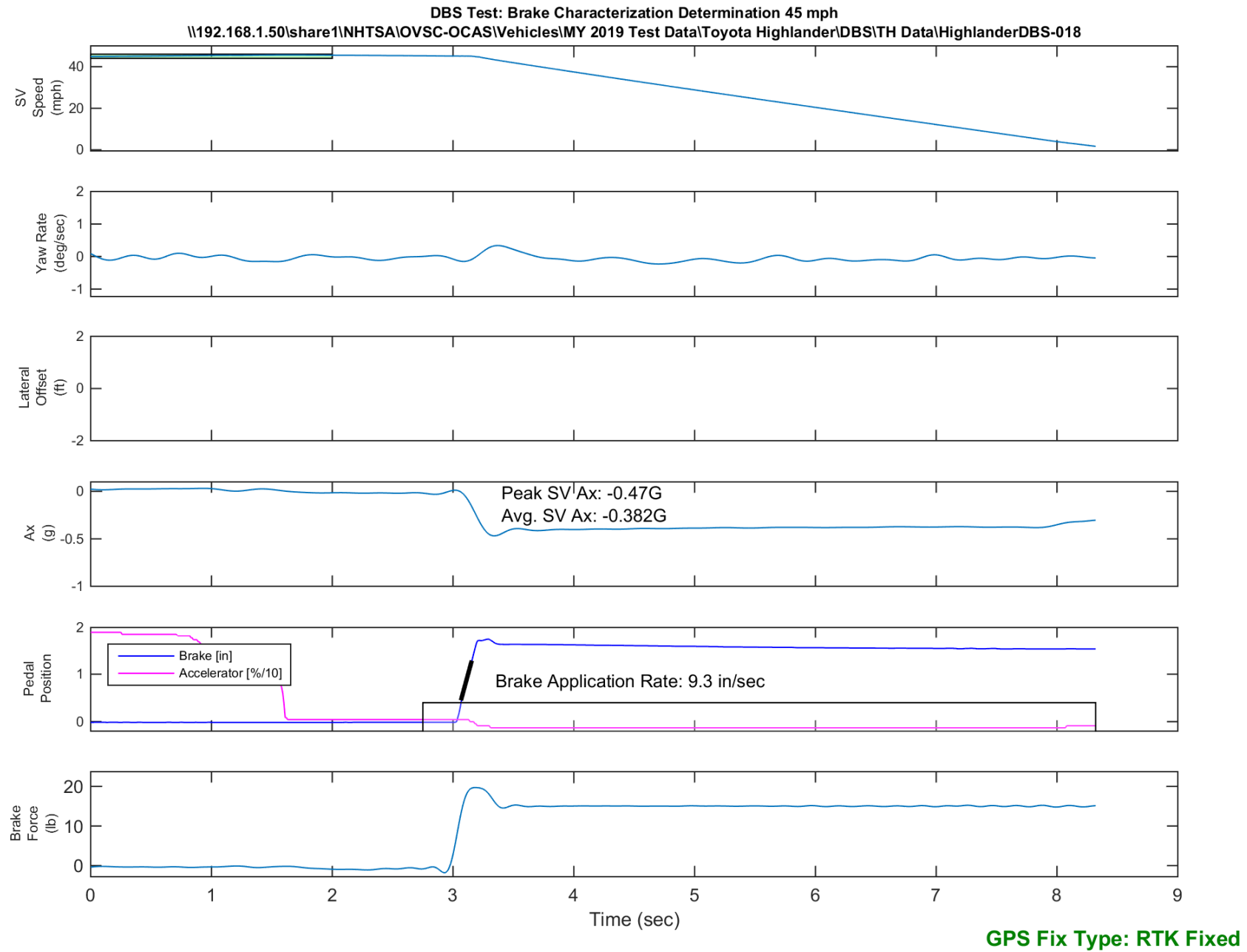


Figure E88. Time History for DBS Run 18, Brake Characterization Determination 45 mph