OCAS-DRI-CIB-19-14
NEW CAR ASSESSMENT PROGRAM
CRASH IMMINENT BRAKE SYSTEM CONFIRMATION TEST

2019 Kia Forte

DYNAMIC RESEARCH, INC.
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10 May 2019

Final Report

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

U. S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Office of Crash Avoidance Standards
1200 New Jersey Avenue, SE
West Building, 4th Floor (NRM-200)
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16. Abstract These tests were conducted on the subject in accordance with the specifications of the Office of Crash Avoidance Standards most current Test Procedure in docket NHTSA-2015-0006-0025; CRASH IMMINENT BRAKE SYSTEM PERFORMANCE EVALUATION FOR THE NEW CAR ASSESSMENT PROGRAM, October 2015. The vehicle passed the requirements of the test for all four CIB test scenarios and all speeds.			
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Section I
OVERVIEW AND TEST SUMMARY

Crash Imminent Brake (CIB) systems are a subset of Automatic Emergency Braking (AEB) systems. CIB systems are designed to avoid, or mitigate rear-end crashes, by automatically applying subject vehicle brakes when the system determines that, without intervention, a rear-end crash will occur. CIB systems typically work as an extension of Forward Collision Warning (FCW) systems, which alert the driver to the possibility of a collision unless driver action is taken. CIB systems employ sensors capable of detecting vehicles in the forward path. Current CIB technology typically involves RADAR, LIDAR, or vision-based (camera) sensors, and measurement of vehicle operating conditions such as speed, driver steering and brake application, etc. Algorithms in the system's Central Processing Unit (CPU) use this information to continuously monitor the likelihood of a rear-end crash and command a brake actuator to apply the brakes when necessary.

The method prescribed by the National Highway Traffic Safety Administration (NHTSA) to evaluate CIB performance on the test track[1] involves three 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 false positive scenarios are used to evaluate the propensity of a CIB system to inappropriately activate in a non-critical driving scenario that does not involve a forward vehicle or present a safety risk to the SV occupant(s).

The purpose of the testing reported herein was to objectively quantify the performance of a Crash Imminent Brake system installed on a 2019 Kia Forte. This test is part of the New Car Assessment Program to assess Crash Imminent Brake Systems sponsored by the National Highway Traffic Safety Administration under Contract No. DTNH22-14-D-00333.

[1] NHTSA-2015-0006-0025; Crash Imminent Brake System Performance Evaluation for the New Car Assessment Program, October 2015.

Section II
DATA SHEETS

CRASH IMMINENT BRAKE

DATA SHEET 1: TEST RESULTS

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2019 Kia Forte

SUMMARY RESULTS

VIN: *3KPF54AD0KE0xxxx*

Test Date: *3/4/2019*

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:

CRASH IMMINENT BRAKE

DATA SHEET 2: VEHICLE DATA

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2019 Kia Forte

TEST VEHICLE INFORMATION

VIN: *3KPF54AD0KE0xxxx*

Body Style: *Sedan* Color: *Fire Orange*

Date Received: *2/25/2019* Odometer Reading: *133 mi*

Engine: *2 L Inline 4*

Transmission: *IVT*

Final Drive: *FWD*

Is the vehicle equipped with:

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

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *KIA Motors Mexico S.A. DE C.V.*

Date of manufacture: *12/18*

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: *225/45R17*

Rear: *225/45R17*

Recommended cold tire pressure: Front: *230 kPa (33 psi)*

Rear: *230 kPa (33 psi)*

CRASH IMMINENT BRAKE

DATA SHEET 2: VEHICLE DATA

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2019 Kia Forte

TIRES

Tire manufacturer and model: *Kumho Majesty Solus*

Front tire size: *225/45R17*

Rear tire size: *225/45R17*

VEHICLE ACCEPTANCE

Verify the following before accepting the vehicle:

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

X Tires and wheel rims are the same as listed.

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

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

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

CRASH IMMINENT BRAKE

DATA SHEET 3: TEST CONDITIONS

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2019 Kia Forte

GENERAL INFORMATION

Test date: *3/4/2019*

AMBIENT CONDITIONS

Air temperature: *13.3 C (56 F)*

Wind speed: *2.6 m/s (5.8 mph)*

X Windspeed ≤ 10 m/s (22 mph)

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

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

VEHICLE PREPARATION

Verify the following:

All non consumable fluids at 100 % capacity : **X**

Fuel tank is full: **X**

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

Front: *230 kPa (33 psi)*

Rear: *230 kPa (33 psi)*

CRASH IMMINENT BRAKE

DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2019 Kia Forte

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*450.0 kg (992 lb)*	Right Front	*422.7 kg (932 lb)*
Left Rear	*301.2 kg (664 lb)*	Right Rear	*286.7 kg (632 lb)*
		Total:	*1460.6 kg (3220 lb)*

CRASH IMMINENT BRAKE

DATA SHEET 4: CRASH IMMINENT BRAKE SYSTEM OPERATION

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2019 Kia Forte

Name of the CIB option, option package, etc.

Forward Collision-Avoidance Assist (FCA)

System setting used for test (if applicable): *Early*

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

Per manufacturer supplied information:

- *Partial Braking*
  - *Stationary Target: 5 mph minimum*
  - *Moving Target: 5 mph minimum*
- *Full Braking*
  - *Stationary Target: 5 mph minimum*
  - *Moving Target: 5 mph minimum*

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

Per manufacturer supplied information

- *Partial Braking*
  - *Stationary Target: 47 mph maximum*
  - *Moving Target: 112 mph maximum*
- *Full Braking*
  - *Stationary Target: 34 mph maximum*
  - *Moving Target: 50 mph maximum*

Does the vehicle system require an initialization sequence/procedure?

No

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

No

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

- **X** Warning light
- **X** Buzzer or audible alarm
- ____ Vibration
- ____ Other

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

There are 2 different warnings displayed in the cluster as follows:

- *1st warning: "Collision Warning"*
- *2nd warning: "Emergency Braking"*

The system also provides audio warnings:

- *1st warning: repeated beeps*
- *2nd warning: continuous tone*

Is there a way to deactivate the system?

- **X** Yes
- ____ No

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

Controls on the right side of the steering wheel are used to interact with the vehicle User Settings Menu. From the top Menu:

Driver Assistance

Check or uncheck "Forward Collision Avoidance" to turn the system on or off.

The FCA (AEB) system reactivates upon each ignition cycle.

Is the vehicle equipped with a control whose purpose is to adjust the range setting or otherwise influence the operation of CIB? **X** Yes ___ No

If yes, please provide a full description.

Controls on the right side of the steering wheel are used to interact with the vehicle User Settings Menu. From the top Menu:

Driver Assistance

Check "Forward Collision Avoidance to turn the system on

Select: Early, Normal or Late

The FCA (AEB) system reactivates upon each ignition cycle.

Are there other driving modes or conditions that render CIB inoperable or reduce its effectiveness? **X** Yes ___ No

If yes, please provide a full description.

In certain situations, the radar sensor or the camera may not be able to detect the vehicle ahead. In these cases, the FCA system may not operate. The driver must pay careful attention in the following situations where the FCA operation may be limited:

Recognizing vehicles

- *The radar or the camera is contaminated with foreign substances.*
- *It heavily rains or snows.*
- *There is electromagnetic interference*
- *Something in the path of travel deflects the radar waves*
- *The vehicle in front has a narrow body. (i.e. motor cycle and bicycle)*
- *The driver's view is not clear due to backlight, reflected light, or darkness.*
- *The camera cannot contain the full image of the vehicle in front.*
- *The vehicle in front is a special vehicle, such as a heavily-loaded truck or a trailer.*

(continued next page)

- *The outside brightness is greatly changed, such as entering/exiting a tunnel.*
- *The vehicle driving is unstable.*
- *The radar/camera sensor recognition is limited.*
- *The driver's field of view is not well illuminated (either too dark or too much reflection or too much backlight that obscures the field of view)*
- *There is severe irregular reflection from the radar sensor*
- *The vehicle in front is driving erratically*
- *The vehicle is driven near areas containing metal substances such as a construction zone, railroad, etc.*
- *Backlight is reflected in the direction of the vehicle (including front light from the vehicle ahead)*
- *Moisture on the windshield is not completely removed or frozen.*
- *The weather is misty.*
- *The vehicle in front does not turn ON the rear lights, does not have rear lights, has asymmetric rear lights, or has rear lights out of angle.*

Driving on a curve

- *The FCA performance may be limited while driving on a curve.*
- *The FCA may not recognize the vehicle in front even if in the same lane.*
- *The FCA system may recognize a vehicle in an adjacent lane when driving on a curved road. In this case, the system may apply the brake.*

Driving on a slope

- *The FCA performance may be limited while driving upward or downward on a slope, and may not recognize a vehicle in front in the same lane.*

(continued next page)

Changing lanes

- *When a vehicle changes lanes in front of you, the FCA system may not immediately detect the vehicle, especially if the vehicle changes lanes abruptly.*
- *When driving in stop-and-go traffic, and a stopped vehicle in front of you merges out of the lane, the FCA system may not immediately detect the new vehicle that is now in front of you.*

Recognizing the vehicle

- *If the vehicle in front of you has cargo that extends rearward from the cab, or when the vehicle in front of you has higher ground clearance, additional special attention is required. The FCA system may not be able to recognize the cargo extending from the vehicle.*

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 CIB system to detect and respond to a stopped lead vehicle in the immediate forward path of the SV, as depicted in Figure 1.

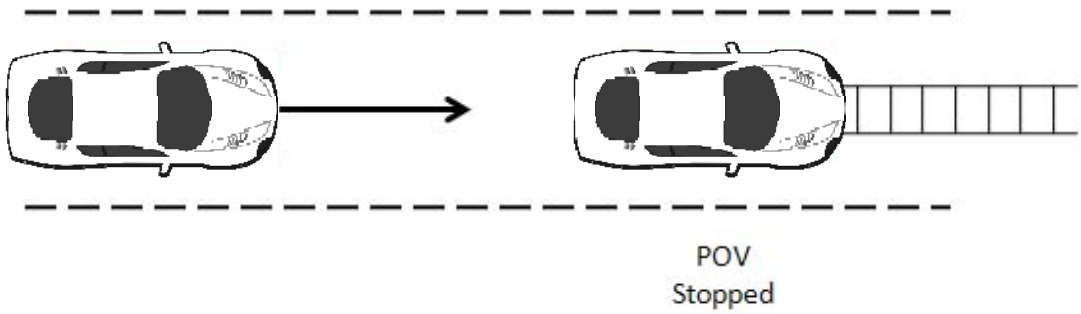


Figure 1. Depiction of Test 1

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 approached 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 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).

b. Criteria

In order to pass the test, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 9.8 mph (15.8 km/h) for at least five of seven valid test trials.

The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

- If SV-to-POV contact occurred during a test trial, the CIB speed reduction was calculated by subtracting the SV speed at the time of SV-to-POV contact (i.e., when longitudinal range became zero) from the average SV speed calculated from t_{FCW}-100 ms to t_{FCW}.
- If SV-to-POV contact did not occur during a test trial (i.e., CIB intervention prevented the crash), the SV speed at a time of SV-to-POV contact was taken to be zero. The speed reduction is therefore equal to the SV speed at t_{FCW}.

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

This test evaluates the ability of the CIB 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.

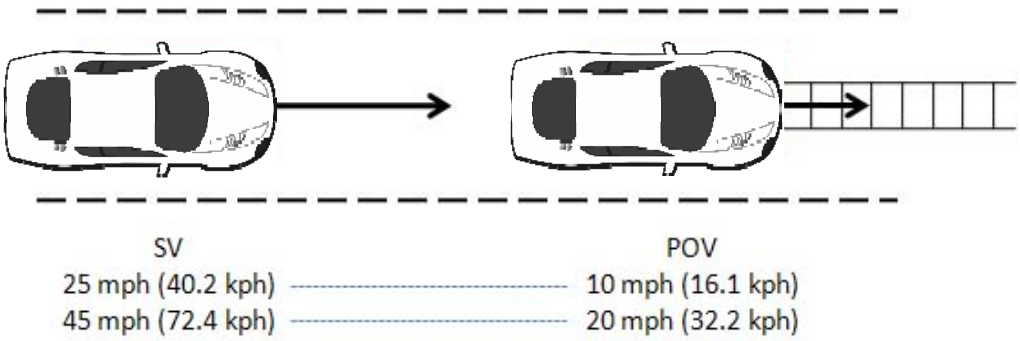


Figure 2. Depiction of Test 2

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 (40.2kph), 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 test concluded when either:

- The SV came into contact with the POV or
- 1 second after the speed of the SV becomes 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 lateral distance between the centerline of the SV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.

- The SV speed could not deviate more than ±1.0 mph (±1.6 km/h) during an interval defined by TTC = 5.0 seconds to t_{FCW}.

- The POV speed could not deviate more than ±1.0 mph (±1.6 km/h) during the validity period.

b. Criteria

For the test series, in which the initial SV speed was 25 mph, the condition for passing was that there be no SV-POV impact for at least five of the seven valid test trials.

In order to pass the test series for which the initial speed of the SV was 45 mph, the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 9.8 mph (15.8 km/h) for at least five of seven valid test trials. The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

1. If SV-to-POV contact occurred during a test trial, the CIB speed reduction was calculated by subtracting the SV speed at the time of SV-to-POV contact (i.e., when longitudinal range became zero) from the average SV speed calculated from t_{FCW}-100 ms to t_{FCW}.

2. If SV-to-POV contact did not occur during a test trial (i.e., CIB intervention prevented the crash), the CIB speed reduction was calculated by subtracting the SV speed at the minimum longitudinal SV-POV range during the validity period from the SV speed at t_{FCW}.

3. TEST 3 – SUBJECT VEHICLE ENCOUNTERS DECELERATING PRINCIPAL OTHER VEHICLE

This test evaluates the ability of the CIB 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.

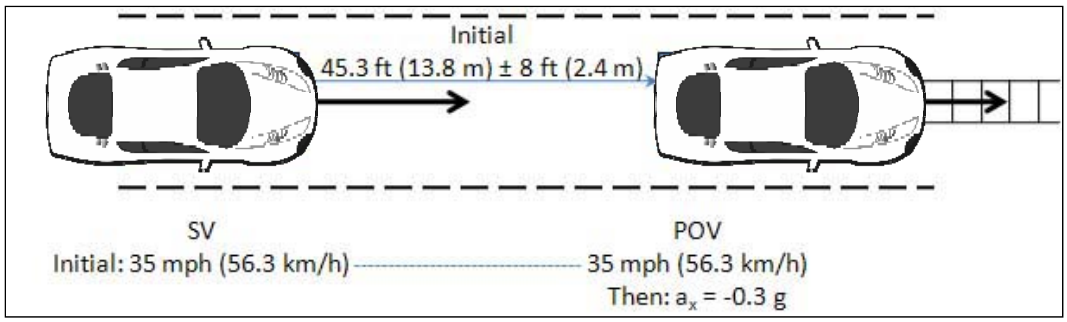


Figure 3. Depiction of Test 3 with POV Decelerating

a. Procedure

The SV ignition was cycled prior to each test run. For this test scenario, both the POV and SV were driven at a constant 35.0 mph (56.3 kph) in the center of the lane, with a headway of 45.3 ft (13.8 m) ± 8 ft (2.4 m). Once these conditions were met, the POV tow vehicle brakes were applied to achieve 0.3 ± 0.03 g of deceleration. The test concluded when either:

- The SV came into contact with the POV or
- For the decelerating POV, 1 second after minimal longitudinal SV-POV distance occurred or
- For the POV decelerating to stop case, 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 lateral distance between the centerline of the SV and the center of the travel lane could not deviate more than ±1 ft (0.3 m) during the validity period.

- The headway between the SV and POV must have been constant from the onset of the applicable validity period to the onset of POV braking.

- The SV and POV speed could not deviate more than ±1.0 mph (1.6 km/h) during an interval defined by the onset of the validity period to the onset of POV braking.

- The SV- POV headway distance could not deviate more than ±8 ft (2.4 m) during an interval defined by the onset of the validity period to the onset of POV braking.

- The average POV deceleration could not deviate by more than ±0.03 g from the nominal 0.3 g deceleration during the interval beginning at 1.5 seconds after the onset of POV braking and ending either 250 ms prior to the POV coming to a stop or the SV coming into contact with the POV.

Criteria

In order to pass the decelerating POV test series the magnitude of the SV speed reduction attributable to CIB intervention must have been ≥ 10.5 mph (16.9 kph) for at least five of seven valid test trials. The magnitude of the SV speed reduction attributable to CIB intervention was calculated in one of two ways, depending on whether a test trial concluded with the SV colliding with the POV.

1. If SV-to-POV contact occurred during a test trial, the CIB speed reduction was calculated by subtracting the SV speed at the time of SV-to-POV contact (i.e., when longitudinal range becomes zero) from the average SV speed calculated from t_{FCW} - 100 ms to t_{FCW}.

2. If SV-to-POV contact did not occur during a test trial (i.e., CIB intervention prevents the crash), the CIB speed reduction was calculated by subtracting the SV speed at the minimum longitudinal SV-to-POV range during the applicable validity period from the SV speed at t_{FCW}.

4. TEST 4 – FALSE POSITIVE SUPPRESSION

The false positive suppression test series evaluates the ability of a CIB 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 CIB is not necessary and should be suppressed. The test condition is nearly equivalent to that previously defined for Test 1, the stopped POV condition, but with an STP in the SV forward path in lieu of a POV.

a. Procedure

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

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} where:
    - For SV test speed of 25 mph, TTC = 5.1 seconds is taken to occur at an SV-to-STP distance of 187 ft (57 m).
    - For SV test speed of 45 mph, TTC = 5.1 seconds is taken to occur at an SV-to-STP distance of 337 ft (106 m).

- If the SV did not present an FCW alert before the end of the validity period, SV speed could not deviate more than ±1.0 mph (±1.6 km/h) from TTC = 5.1 s to the end of the validity period.

If an FCW alert was presented, the driver released the throttle pedal within 500 ms of the alert. If no alert was presented, the driver did not release the throttle pedal until the end of the validity period. The SV driver then braked to a stop.

b. Criteria

In order to pass the False Positive test series the magnitude of the SV deceleration reduction attributable to CIB intervention must have been ≤ 0.50 g 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 either haptic or audible, and the onset of the alert was determined by post-processing the test data.

For systems that implement audible or haptic alerts, part of the pre-test instrumentation verification process was 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 was accomplished in order to identify the center frequency around which a band-pass filter was 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 was a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 1.

Table 1. Audible and Tactile Warning Filter Parameters

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

2. General Validity Criteria

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

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

3. Validity Period

The valid test interval began:

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

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

Test 3: 3 seconds before the onset of POV braking

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

The valid test interval ended:

Test 1: When either of the following occurred:

- The SV came into contact with the POV (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.

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

- 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.
- 1 second after minimal longitudinal SV-POV distance occurred.

Test 4: At the instant the front most part of SV reached a vertical plane defined by the leading edge of the STP first encountered by the SV (i.e., just before it was driven onto the STP).

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 that defines 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

CIB 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).

The 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 CIB sensors, including cameras, radar and lidar.
  - 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 km/h).
  - Accurately control the lateral position of the POV within the travel lane.
  - Allow the POV to move away from the SV after an impact occurs.

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 allows 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 engage the rail assembly through detents to prevent relative motion during run-up to test speeds and 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, 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 away

from the SV. The forward end of the rail has a cushioned 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. Automatic Braking System

The POV was equipped with an automatic braking system, which was used in Test 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.

E. Instrumentation

Table 2 lists the sensors, signal conditioning, and data acquisition equipment used for these tests.

TABLE 2. 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
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in-vehicle)	00440100989	NA
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities;	Accels ± 10g, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +		By: Oxford Technical Solutions
					2182	Date: 10/16/2017 Due: 10/16/2019

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
	Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles				2176	Date: 4/11/2018 Due: 4/11/2020

TABLE 2. TEST INSTRUMENTATION AND EQUIPMENT

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

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

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

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

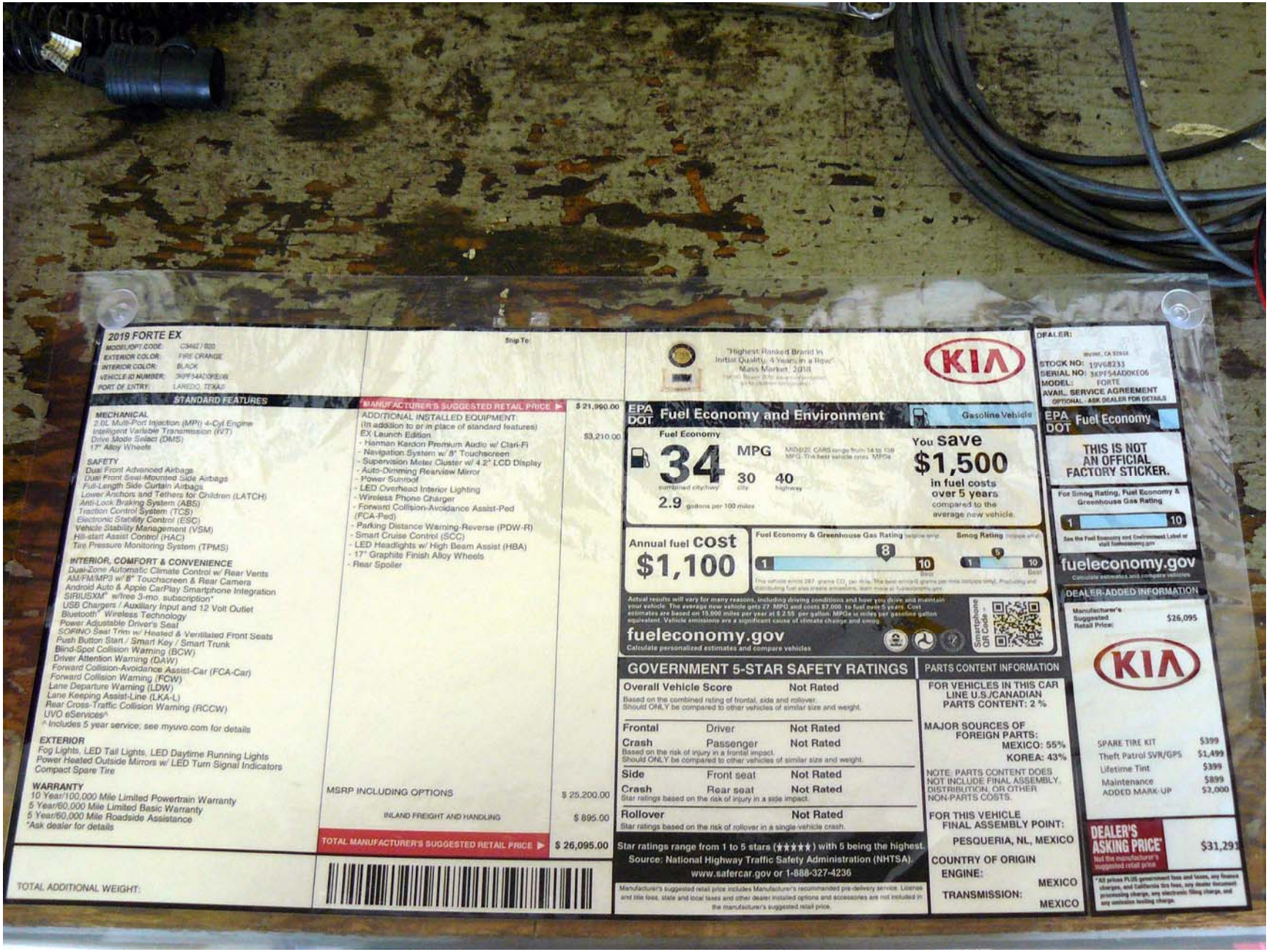


Figure A3. Window Sticker (Monroney Label)

Figure A4. Vehicle Certification Label

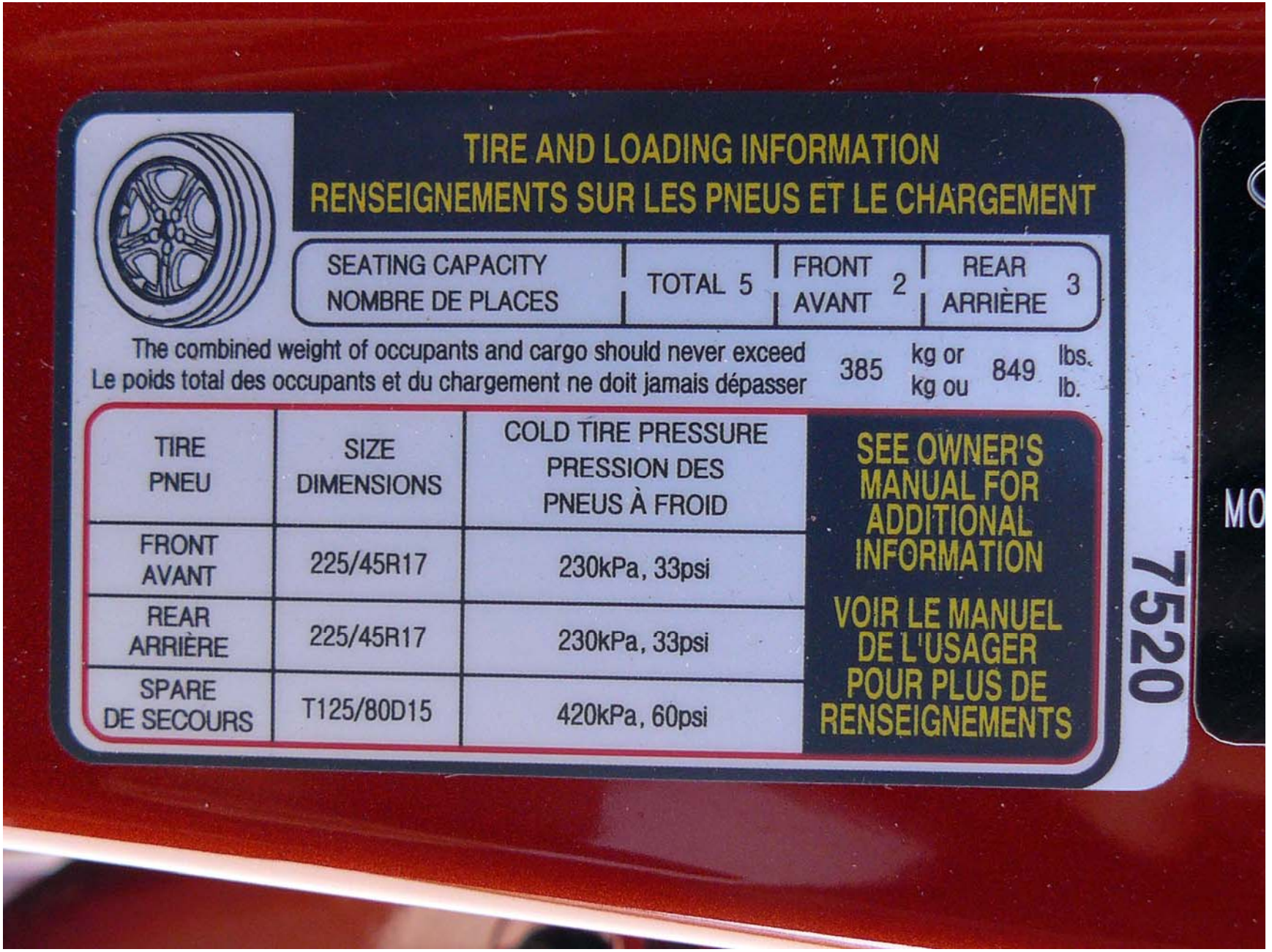


Figure A5. Tire Placard

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

Figure A7. Load Frame/Slider of SSV

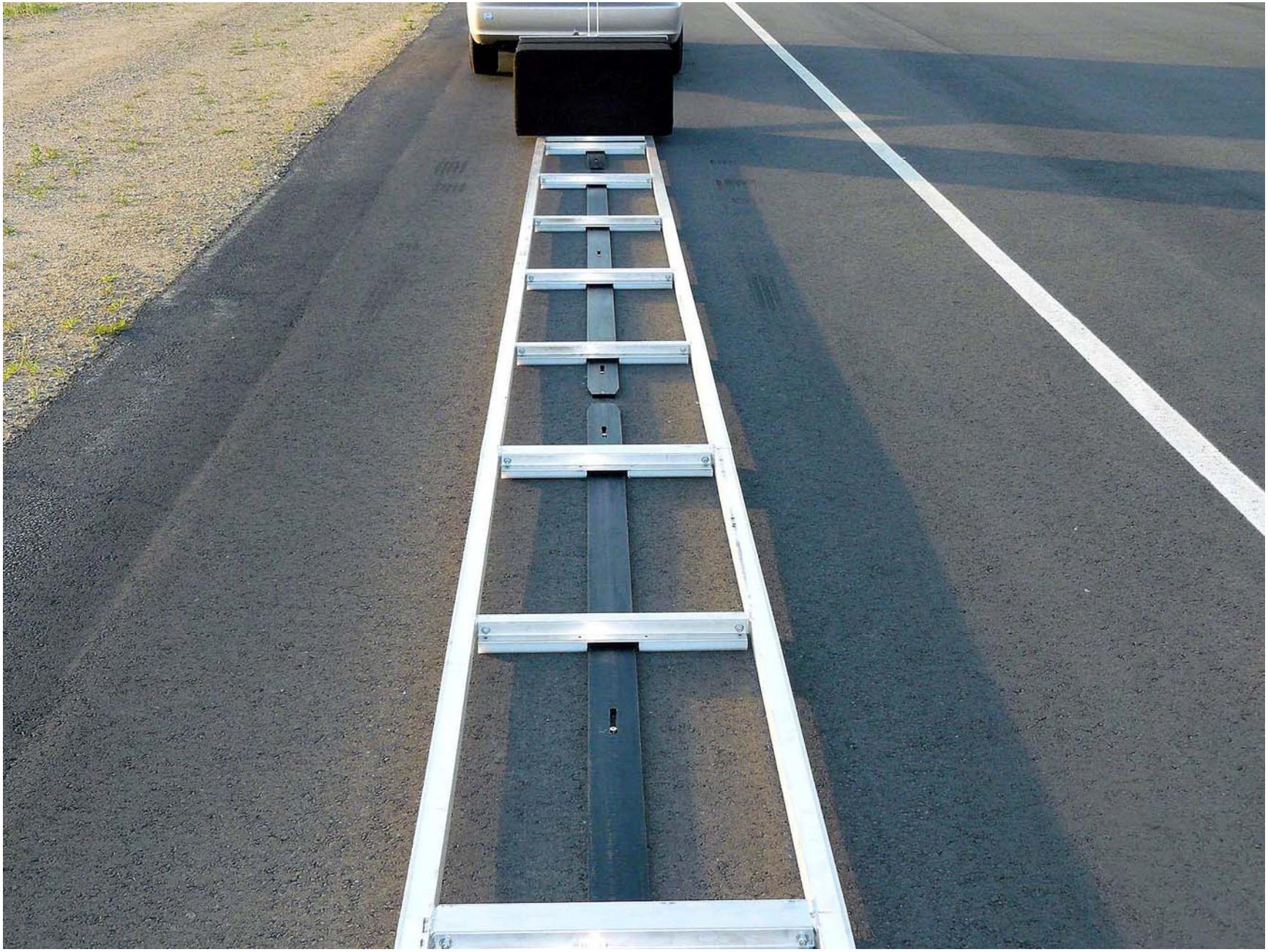


Figure A8. Two-Rail Track and Road-Based Lateral Restraint Track

Figure A9. Steel Trench Plate

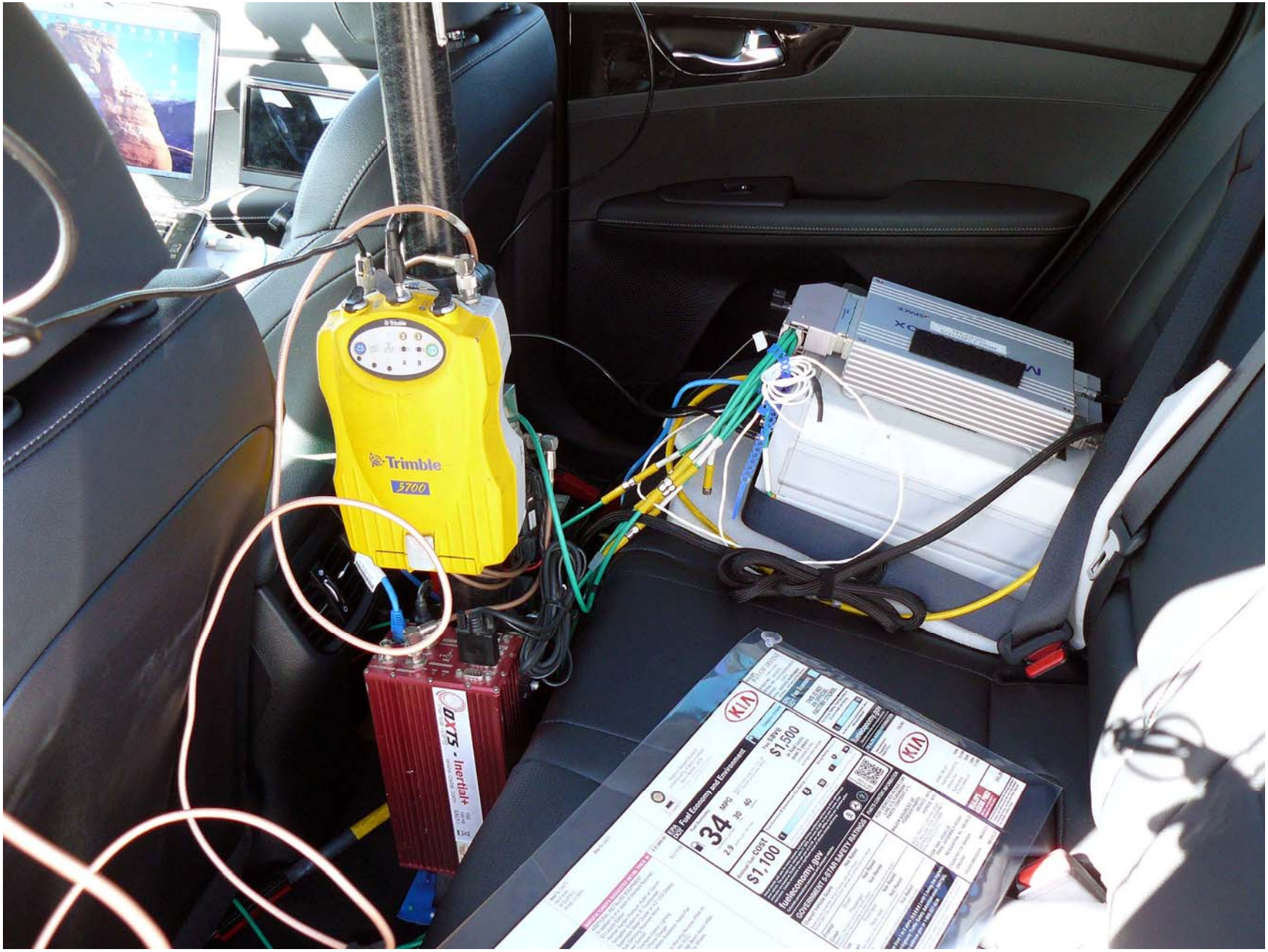


Figure A10. DGPS, Inertial Measurement Unit and MicroAutoBox Installed in Subject Vehicle

Figure A11. Sensors for Detecting Auditory and Visual Alerts

Figure A12. Computer Installed in Subject Vehicle

Figure A13. Brake Actuator Installed in POV System

Figure A14. AEB Visual Alert

Figure A15. AEB Setup Menus

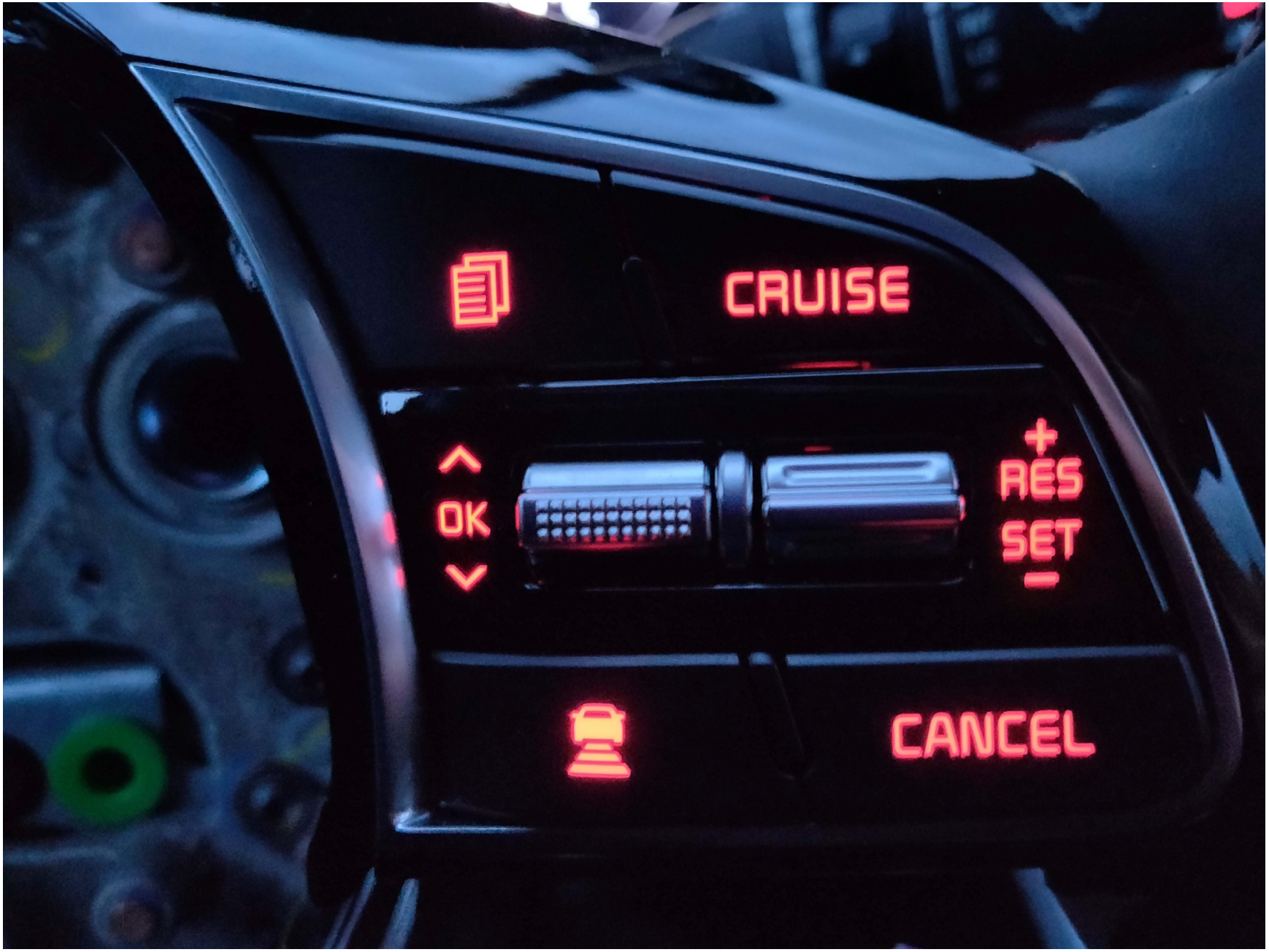


Figure A16. Steering Wheel Mounted Controls for Changing Parameters

APPENDIX B

Excerpts from Owner's Manual

Sunroof open warning light (if equipped)

This warning light blinks:

- If the driver removes the ignition key and opens the driver-side door when the sunroof is not fully closed, the warning chime will sound for a few seconds and a warning light will appear on the LCD display.

  Close the sunroof securely when leaving your vehicle.

Ice Warning Light (if equipped)

This warning light blinks 5 times and then illuminates, and also warning chime sounds 1 time:

- When the temperature on the Outside Temperature Gauge is below approximately 4°C (39.2°F) with the ignition switch or Engine Start/Stop button in the ON position.

✻ NOTICE

If the ice warning light appears while driving, you should drive more attentively and safely refraining from over-speeding, rapid acceleration, sudden braking or sharp turning, etc.

Forward Collision-avoidance Assist Warning light (FCA, if equipped)

This indicator light illuminates:

- When there is a malfunction with the FCA.

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

FORWARD COLLISION-AVOIDANCE ASSIST (FCA) (CAMERA + RADAR TYPE) (IF EQUIPPED)

The FCA system is designed to detect and monitor the vehicle ahead or detect a pedestrian in the roadway through radar signals and camera recognition to warn the driver that a collision is imminent, and if necessary, apply emergency braking.

⚠ WARNING

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

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

System setting and activation

System setting

When the ignition switch is turned on, Forward Collision-Avoidance Assist (FCA) automatically gets activated. The system can be deactivated if the driver cancels the system from the instrument panel as follows : 'User settings → Driving assist → Forward Collision-Avoidance Assist'

The warning light illuminates on the LCD display, when you cancel the FCA system. The driver can monitor the FCA ON/OFF status on the LCD display. Also, the warning light illuminates when the ESC (Electronic Stability Control) is turned off. When the warning light remains ON with the FCA activated, have the system checked by a professional workshop. Kia recommends to visit an authorised Kia dealer/service partner.

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

- EARLY - When this condition is selected, the initial Forward Collision Warning is activated earlier than normal. This setting maximizes the amount of distance between the vehicle or pedestrian ahead before the initial warning occurs. If the 'EARLY' condition feels too sensitive, change it into 'NORMAL'. When the vehicle ahead suddenly stops, the warning may seem to activate later even if the 'EARLY' condition was selected.
- NORMAL - When this condition is selected, the initial Forward Collision Warning is activated normally. Compared to EARLY mode, this setting allows for a shorter amount of distance between the vehicle or pedestrian ahead before the initial warning occurs.
- LATE - When this condition is selected, the initial Forward Collision Warning is activated later than normal. This setting reduces the amount of distance between the vehicle or pedestrian ahead before the initial warning occurs. Select this condition only when traffic is light, and you are driving slowly.

Prerequisite for activation

The FCA gets ready to be activated, when the FCA is selected on the LCD display, and when the following prerequisites are satisfied.

- The ESC is ON.
- The driving speed is over 10 km/h (6 mph). (However, FCA is activated within certain driving speed.)
- When recognizing a vehicle or the pedestrian in front. (However, FCA deactivate according to conditions in front and vehicle systems, but it notices only certain warnings.)
- The FCA automatically deactivates upon canceling the ESC. When the ESC is cancelled, the FCA cannot be activated on the LCD display. In this situation, the FCA warning light will illuminate.

⚠ WARNING

- **The FCA automatically activates upon placing the ignition switch to the ON position. The driver can deactivate the FCA by canceling the system setting on the LCD display.**
- **The FCA automatically deactivates upon canceling the ESC. When the ESC is cancelled, the FCA cannot be activated on the LCD display.**

  The FCA warning light will illuminate, but it does not indicate a malfunction of the system.
- **Set or cancel FCA with controlling switches on steering wheel after stopping the vehicle in the safe place for your safety.**

FCA warning message and system control

The FCA system produces warning messages, warning alarms, and emergency braking based on the risk of a frontal collision, such as when a vehicle ahead suddenly brakes.

The driver can select the initial warning activation time in the User Settings in the LCD display. The options for the initial Forward Collision-Avoidance Assist include Early, Normal or Late initial warning time.

Collision Warning! (1st warning)

OBDM058065N

This warning message appears on the LCD display with a warning chime.

Additionally, some vehicle system intervention occurs by the engine management system to help decelerate the vehicle.

- Your vehicle speed may decelerate moderately.
- The FCA system limitedly controls the brakes to preemptively mitigate impact from a collision.

Emergency braking! (2nd warning)

OBDM058066N

This warning message appears on the LCD display with a warning chime.

Additionally, some vehicle system intervention occurs by the engine management system to help decelerate the vehicle.

- The FCA system limitedly controls the brakes to preemptively mitigate impact from a collision. The brake control is maximized just before a collision.

Brake operation

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

⚠ CAUTION

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

⚠ WARNING

The FCA system is a supplemental system and cannot completely stop the vehicle in all situations and avoid all collisions. It is the responsibility of the driver to safely drive and control the vehicle.

⚠ WARNING

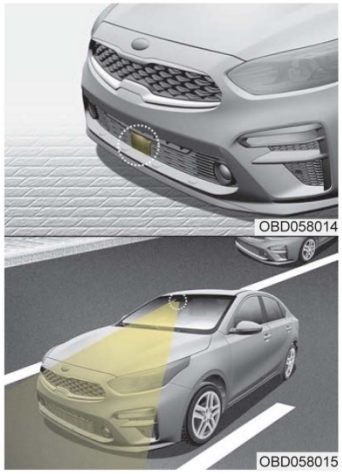
The FCA system assesses the risk of a collision by monitoring several variables, such as the distance to the vehicle ahead, the speed of the vehicle ahead, and the driver's operation of the vehicle.

Certain conditions such as inclement weather and road conditions may affect the operation of the FCA system.

⚠ WARNING

Never deliberately drive dangerously to activate the system as such conduct increases the risk of an accident.

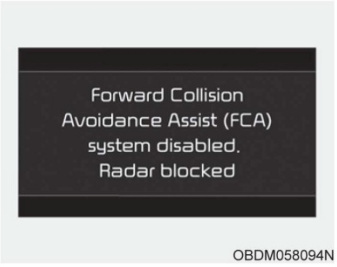
Sensor to detect the distance from the vehicle in front (front radar/camera)



By detecting the vehicle or pedestrian ahead the vehicle, the sensor helps to operate the Forward Collision-Avoidance Assist when the vehicle is at risk of a collision.

In order for the FCA system to operate properly, always make sure the sensor or sensor cover is clean and free of dirt, snow, and debris. Dirt, snow, or foreign substances on the lens may adversely affect the sensing performance of the sensor.

Warning message and warning light



OBDM058094N

When the sensor is covered or the sensor lens is dirty with foreign substances, such as snow or rain, the FCA system may not be able to detect vehicles. In this case, a warning message ("Forward Collision-Avoidance Assist (FCA) system disabled. Radar blocked") will appear to notify the driver. Remove the foreign substances to allow the FCA system to function property.

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

The FCA may not properly operate in an area (e.g. open terrain), where any Vehicles or substances are not detected after turning ON the engine.

✻ NOTICE

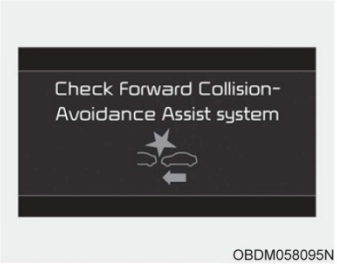
- **Do not install any accessories, such as license plate molding or sticker, on the sensor area. Nor arbitrarily replace the bumper. Those may adversely affect the sensing performance.**
- **Always keep the sensor/bumper area clean.**
- **Use only soft clothes to wash the vehicle. Also, do not spray highly-pressurized water on the sensor installed on the bumper.**
- **Be careful not to apply unnecessary force on the frontal sensor area. When the sensor moves out of the correct position due to external force, the system may not normally operate and may not provide a warning light or message. In this case, have the vehicle inspected by an authorized Kia dealer.**
- **Use only the genuine Kia sensor cover. Do not arbitrarily apply paint on the sensor cover.**

(Continued)

(Continued)

- **Do not tint the window or install stickers, or accessories around the inside mirror where the camera is installed.**
- **Make sure the frontal camera installation point does not get wet.**
- **Do not impact or arbitrarily remove any radar/camera components.**
- **Do not place reflective objects(white paper or mirror etc.) on the dashboard.**
  The system may unnecessarily activate or deactivate due to reflection of the sunlight.
- **Excessive audio system volume may prevent occupants from hearing the FCA system warning alarm.**

System malfunction



OBDM058095N

- When the FCA is not working properly, the FCA warning light (⚠) will illuminate and the warning message will appear for a few seconds. After the message disappears, the master warning light (⚠) will illuminate. In this case, have the vehicle inspected by an authorized Kia dealer.

- The FCA system will get deactivated for the sake of driver's safety when the ESC warning light comes on. The FCA warning message will appear at the same time, too. But that doesn't necessarily mean the malfunction of the FCA system. Both FCA warning light and warning message will disappear once the ESC warning light issue is resolved.

⚠ WARNING

- **The FCA is only a supplemental system for the driver's convenience. It is the driver's responsibility to control the vehicle. Do not solely depend on the FCA system. Rather, maintain a safe braking distance, and, if necessary, depress the brake pedal to lower the driving speed.**
- **The FCA may unnecessarily produce the warning message and the warning alarms. Also, due to sensing limitations the FCA may not produce alarms in certain situations. Read the section "Limitation of the system" for more information.**
- **When there is a malfunction with the FCA, the FCA braking control does not operate upon detecting a collision risk even with other braking systems normally operating.**

(Continued)

(Continued)

- **The FCA system only recognizes vehicles and pedestrians in front of it while driving forward. It does not identify any animals or vehicles in the opposite direction.**
- **The FCA does not recognize cross-traffic or parked vehicles presenting a side profile.**
- **If the vehicle in front stops suddenly, you may have less control of the brake system. Therefore, always keep safe distance between your vehicle and the vehicle in front of you.**
- **The FCA system may activate during braking and the vehicle may stop suddenly. And the load in the vehicle may endanger passengers. Therefore, always be mindful of the load volume in the vehicle.**

(Continued)

(Continued)

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

(Continued)

(Continued)

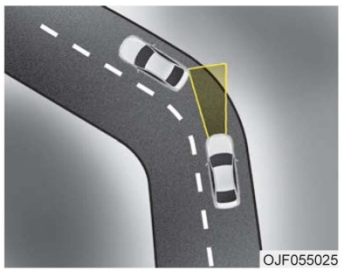
- **The FCA system may not activate according to driving condition, traffic on the road, weather, road condition, etc.**
- **The FCA system may not activate to all types of vehicles.**

Limitation of the system

The FCA system is designed to monitor the vehicle ahead through radar signals and camera recognition to warn the driver that a collision is imminent, and if necessary, apply emergency braking. In certain situations, the radar sensor or the camera may not be able to detect the vehicle ahead. In these cases, the FCA system may not operate. The driver must pay careful attention in the following situations where the FCA operation may be limited:

Recognizing vehicles

- The radar or the camera is contaminated with foreign substances.
- It heavily rains or snows.
- There is electromagnetic interference
- Something in the path of travel deflects the radar waves
- The vehicle in front has a narrow body. (i.e. motor cycle and bicycle)
- The driver's view is not clear due to backlight, reflected light, or darkness.
- The camera cannot contain the full image of the vehicle in front.
- The vehicle in front is a special vehicle, such as a heavily-loaded truck or a trailer.
- The outside brightness is greatly changed, such as entering/exiting a tunnel.
- The vehicle driving is unstable.
- The radar/camera sensor recognition is limited.
- The driver's field of view is not well illuminated (either too dark or too much reflection or too much backlight that obscures the field of view)
- There is severe irregular reflection from the radar sensor
- The vehicle in front is driving erratically
- The vehicle is driven near areas containing metal substances such as a construction zone, railroad, etc.
- Backlight is reflected in the direction of the vehicle (including front light from the vehicle ahead)
- Moisture on the windshield is not completely removed or frozen.
- The weather is misty.
- The vehicle in front does not turn ON the rear lights, does not have rear lights, has asymmetric rear lights, or has rear lights out of angle.

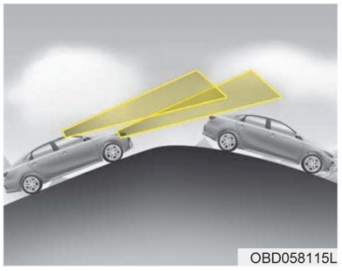


- Driving on a curve

The FCA performance may be limited while driving on a curve. The FCA may not recognize the vehicle in front even if in the same lane.It may produce the warning message and the warning alarm prematurely, or it may not produce the warning message or the warning alarm at all. When driving on a curve, exercise caution, maintain a safe braking distance, and if necessary, depress the brake pedal to reduce your driving speed in order to maintain a safe distance.


OJF055026

The FCA system may recognize a vehicle in an adjacent lane when driving on a curved road. In this case, the system may apply the brake. Always pay attention to road and driving conditions while driving. If necessary, depress the brake pedal to reduce your driving speed in order to maintain a safe distance. Also, when necessary, you may depress the accelerator pedal to prevent the system from unnecessarily decelerating your vehicle. Always check the traffic conditions around the vehicle.

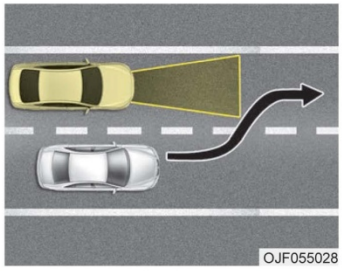

OBD058115L

- Driving on a slope

The FCA performance may be limited while driving upward or downward on a slope, and may not recognize a vehicle in front in the same lane. It may produce the warning message and the warning alarm prematurely, or it may not produce the warning message and the warning alarm at all.

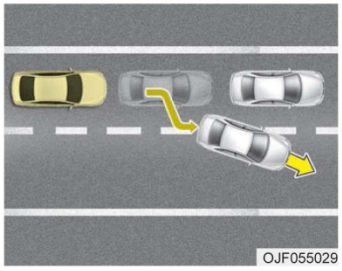
When the FCA suddenly recognizes the vehicle in front while passing over a slope, you may experience sharp deceleration.

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

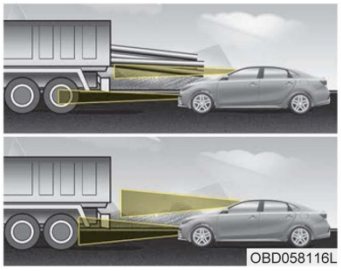

OJF055028

- Changing lanes

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


OJF055029

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


OBD058116L

- Recognizing the vehicle

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

Recognizing pedestrians

- The pedestrian is not fully detected by the camera sensor, or the pedestrian does not walk in the upright position.
- The pedestrian moves very fast.
- The pedestrian abruptly appears in front.
- The pedestrian is wearing clothing that easily blends into the background, making it difficult to be detected.
- The outside is too bright or too dark.
- The vehicle drives at night or in the darkness.
- There is an item similar to a person's body structure.
- The pedestrian is small.
- The pedestrian has impaired mobility.
- It is difficult to distinguish the pedestrian from the surroundings.
- The sensor recognition is limited.

- There is a group of pedestrians.
- If a sudden change in the sensor recognition takes place while passing through a speed bump,
- When the vehicle is severely shaken,
- When driving around circular intersection after the vehicle in front,
- If the front of the camera lens is contaminated by front glass tinting, film, water repellent coating, damage on glass, or foreign matter (sticker, insect, etc.)
- The radar or camera or camera lens is damaged.
- If the headlights of a vehicle are not used at night or in a tunnel section, or the light is too weak
- If street light or the light of a vehicle coming from a opposite direction is reflected or when sunlight is reflected by the water on the road surface
- When the back light is projected in the direction of the vehicle's motion (including the headlights of vehicles)
- Road sign, shadow on the road, tunnel entrance, toll gate, partial pavement
- If the windshield has moisture on its surface or if windshield freezes,
- Driving in the fog.
- When objects are out of the sensing range of the sensor or radar.

⚠ WARNING

- **Do not use the FCA system when towing a vehicle. Cancel the FCA in the User Settings on the LCD display before towing. Brake application by the FCA system while towing may adversely affect your safety.**
- **Use extreme caution when the vehicle in front of you has cargo that extends rearward from the cab, or when the vehicle in front of you has higher ground clearance.**
- **The FCA system is designed to detect and monitor the vehicle ahead or detect a pedestrian in the roadway through radar signals and camera recognition. It is not designed to detect bicycles, motorcycles, or smaller wheeled objects such as luggage bags, shopping carts, or strollers.**

(Continued)

(Continued)

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

✻ NOTICE

- **When replacing or reinstalling the windscreen, front bumper or radar/camera after removal, have the vehicle inspected by an authorized Kia dealer.**
- **In some instances, the FCA system may be canceled when subjected to electromagnetic interference.**

APPENDIX C

Run Log

Subject Vehicle: **2019 Kia Forte** Test Date: **3/4/2019**

Principal Other Vehicle: **SSV**

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
									Performed 2 abs stops prior to the start of the test (45 mph)
1	Static Run								
2	**Stopped POV**	Y	1.60	7.61	25.5	1.08	0.87	Pass	
3		Y	1.55	6.34	25.0	1.04	0.83	Pass	
4		Y	1.61	7.83	25.6	1.04	0.93	Pass	
5		Y	1.56	3.51	25.1	1.05	0.75	Pass	
6		Y	1.53	4.86	23.9	1.04	0.77	Pass	
7		Y	1.61	7.12	25.3	1.03	0.86	Pass	
8		Y	1.60	6.27	24.9	1.02	0.84	Pass	
9	Static Run								
10	**Slower POV, 25 vs 10**	Y	1.52	4.98	13.8	0.98	0.68	Pass	
11		Y	1.52	4.88	14.0	1.02	0.63	Pass	
12		Y	1.51	4.98	14.2	1.03	0.72	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
13		Y	1.57	4.86	14.3	1.03	0.64	Pass	"Radar blocked" error popped up midway through run.
14		Y	1.59	4.57	14.4	0.98	0.65	Pass	
15		Y	1.65	2.30	15.4	0.88	0.75	Pass	
16		Y	1.58	4.86	15.1	0.97	0.68	Pass	"Radar blocked" error popped up midway through run.
17	Static Run								
18	**Slower POV, 45 vs 20**	Y	2.26	6.49	24.9	0.83	1.20	Pass	
19		Y	2.30	5.31	25.7	0.86	1.13	Pass	
20		Y	2.30	9.42	25.8	0.89	1.21	Pass	
21		Y	2.27	6.50	25.0	0.92	1.11	Pass	
22		Y	2.26	8.02	25.2	0.91	1.14	Pass	"Radar blocked" error popped up midway through run.
23		Y	2.31	6.75	25.3	0.87	1.16	Pass	
24		Y	2.31	10.02	25.1	0.89	1.23	Pass	
25	Static run								
26	**Braking POV, 35**	N							SV yaw
27		N							POV speed
28		Y	1.59	11.13	18.9	1.06	1.04	Pass	

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
29		N							POV brakes
30		N							SV yaw
31		Y	1.56	6.07	21.1	0.94	1.05	Pass	
32		Y	1.64	10.22	21.5	0.94	1.25	Pass	
33		Y	1.78	7.86	23.4	0.94	1.18	Pass	
34		Y	1.68	7.16	22.3	0.96	1.15	Pass	
35		Y	1.67	10.71	22.5	0.96	1.27	Pass	
36		Y	1.68	13.78	21.9	0.96	1.43	Pass	
37	Static Run								
38	STP - Static Run								
39	**STP False Positive, 25**	Y				0.01		Pass	
40		Y				0.01		Pass	
41		Y				0.01		Pass	
42		Y				0.01		Pass	
43		Y				0.01		Pass	
44		Y				0.01		Pass	
45		Y				0.02		Pass	
46	STP - Static Run								

Run	Test Type	Valid Run?	FCW TTC (s)	Min. Distance (ft)	Speed Reduction (mph)	Peak Decel. (g)	CIB TTC (s)	Pass/Fail	Notes
47	**STP False Positive, 45**	Y				0.02		Pass	
48		Y				0.02		Pass	
49		Y				0.02		Pass	
50		N							Throttle
51		Y				0.02		Pass	
52		Y				0.01		Pass	
53		N							SV speed
54		Y				0.01		Pass	
55		Y				0.00		Pass	
56	STP - Static Run								

APPENDIX D

Time History Plots

LIST OF FIGURES

Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from both the Subject Vehicle (SV) and the Principal Other Vehicle (POV), as well as pass/fail envelopes and thresholds. The following is a description of data types shown in the time history plots, as well as a description of the color codes 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 STP 25 mph (Steel trench plate run over at 25 mph)
- False Positive STP 45 mph (Steel trench plate run over at 45 mph)

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 (gap) 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 Principal Other Vehicle (if any). For CIB tests, the speed reduction experienced by the Subject Vehicle 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). For CIB tests, the TTC (sec) at the moment of first CIB activation is displayed to the right of the subplot in green. Also, the peak value of Ax for the SV is shown on the subplot.

- Accelerator Pedal Position (0-1) – normalized position of the accelerator pedal. A green dot is displayed if the accelerator pedal was released within 0.5 seconds of the onset of the FCW warning.

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

Envelopes and Thresholds

Some of the time history plot figures contain either green or yellow envelopes and/or black threshold lines. These envelopes and thresholds are used to programmatically and visually determine the validity of a given test

run. Envelope and threshold exceedances are indicated with either red shading or red asterisks, and red text is placed to the right side of the plot indicating the type of exceedance. Such exceedances indicate either that the test was invalid or that the requirements of the test were not met (i.e., failure of the AEB system).

For plots with green envelopes, in order for the test to be valid, the time-varying data must not exceed the envelope boundaries at any time. 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 displayed. If no impact occurs, a green circle is displayed at the moment of minimum distance. If impact occurs, a red asterisk is displayed at the moment of impact.

For the Ax plot, if the scenario is an AEB brake to stop scenario, a vertical dashed black line is displayed for all plots indicating the moment of first POV braking. The yellow envelope in this case is relevant to the POV braking only. The left edge of the envelope is at 1.5 seconds after the first POV braking. A solid black threshold line extends horizontally 0.5 seconds to the left of the envelope. This threshold line represents the time during which the Ax of the Principal Other Vehicle must first achieve 0.27 g (the upper edge of the envelope). A green circle or red asterisk is displayed at the moment the POV brake level achieves 0.27 g. A green circle indicates that the test was valid (the threshold was crossed during the appropriate interval) and a red asterisk indicates that the test was invalid (the threshold was crossed outside of the appropriate interval). Additionally, for the CIB tests, a dashed black threshold line indicating an Ax of -0.15 g is given to define the onset of CIB activation. When the Subject Vehicle's Ax crosses this threshold, the CIB TTC is calculated and displayed.

Color Codes

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

Color codes can be broken into four categories:

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

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

2. Validation envelope and threshold color codes:
   - Green envelope = time varying data must be within the envelope at all times in order to be valid
   - Yellow envelope = time varying data must be within limits at left and/or right ends
   - Black threshold (Solid) = time varying data must cross this threshold in the time period shown in order to be valid
   - Black threshold (Dashed) = for reference only – this can include warning level thresholds, TTC thresholds, and acceleration thresholds

3. Individual data point color codes:
   - Green circle = passing or valid value at a given moment in time
   - Red asterisk = failing or invalid value at a given moment in time

4. Text color codes:
   - Green = passing or valid value
   - Red = failing or invalid value

Examples of time history plots for each test type (including passing, failing and invalid runs) are shown in Figure 1 through Figure 9. Figures 1 through 6 show passing runs for each of the 6 test types. Figures 7 and 8 show examples of invalid runs. Figure 9 shows an example of a valid test that failed the CIB requirements.

Time history data plots for the tests of the vehicle under consideration herein are provided beginning with Figure 10.

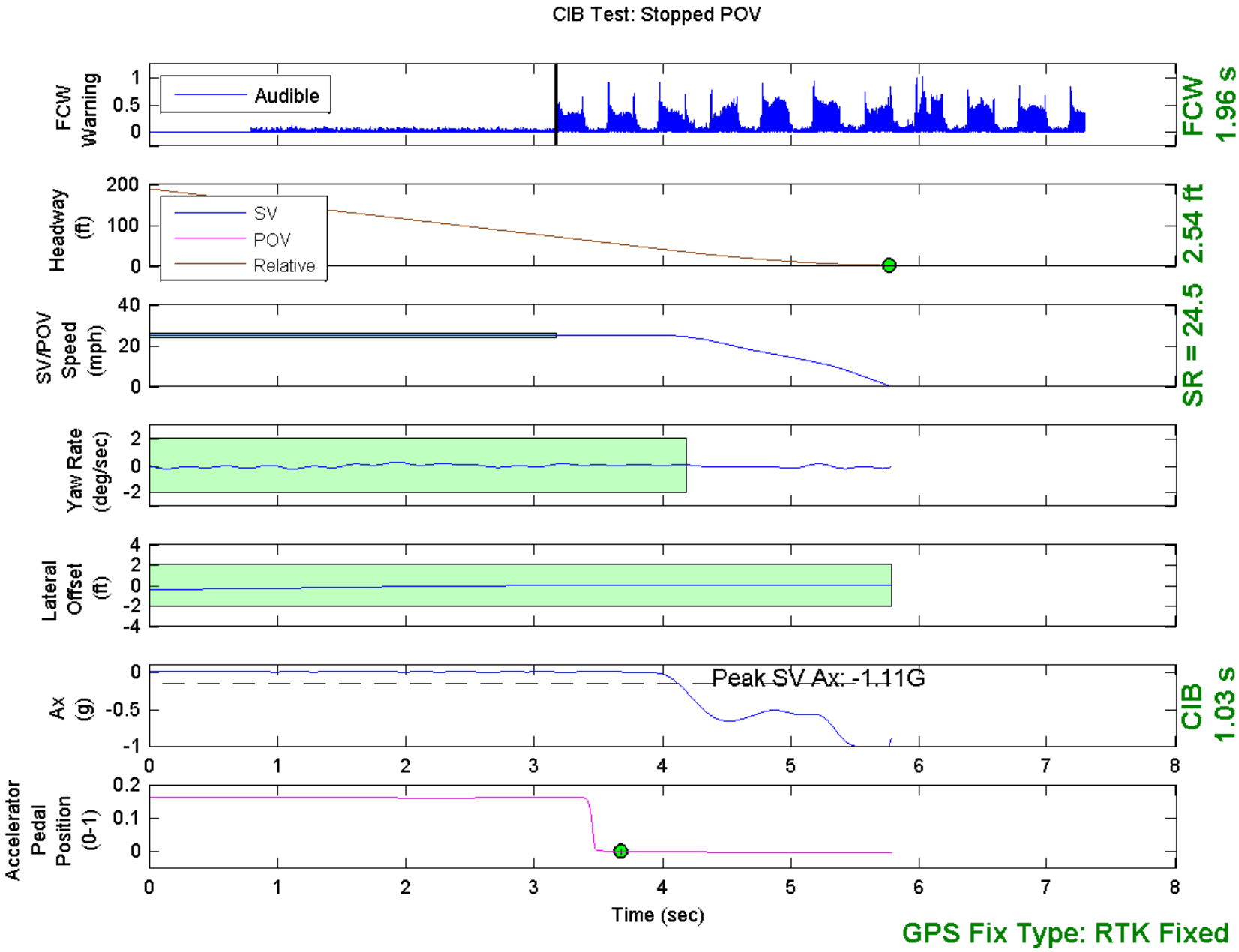


Figure D1. Example Time History for Stopped POV, Passing

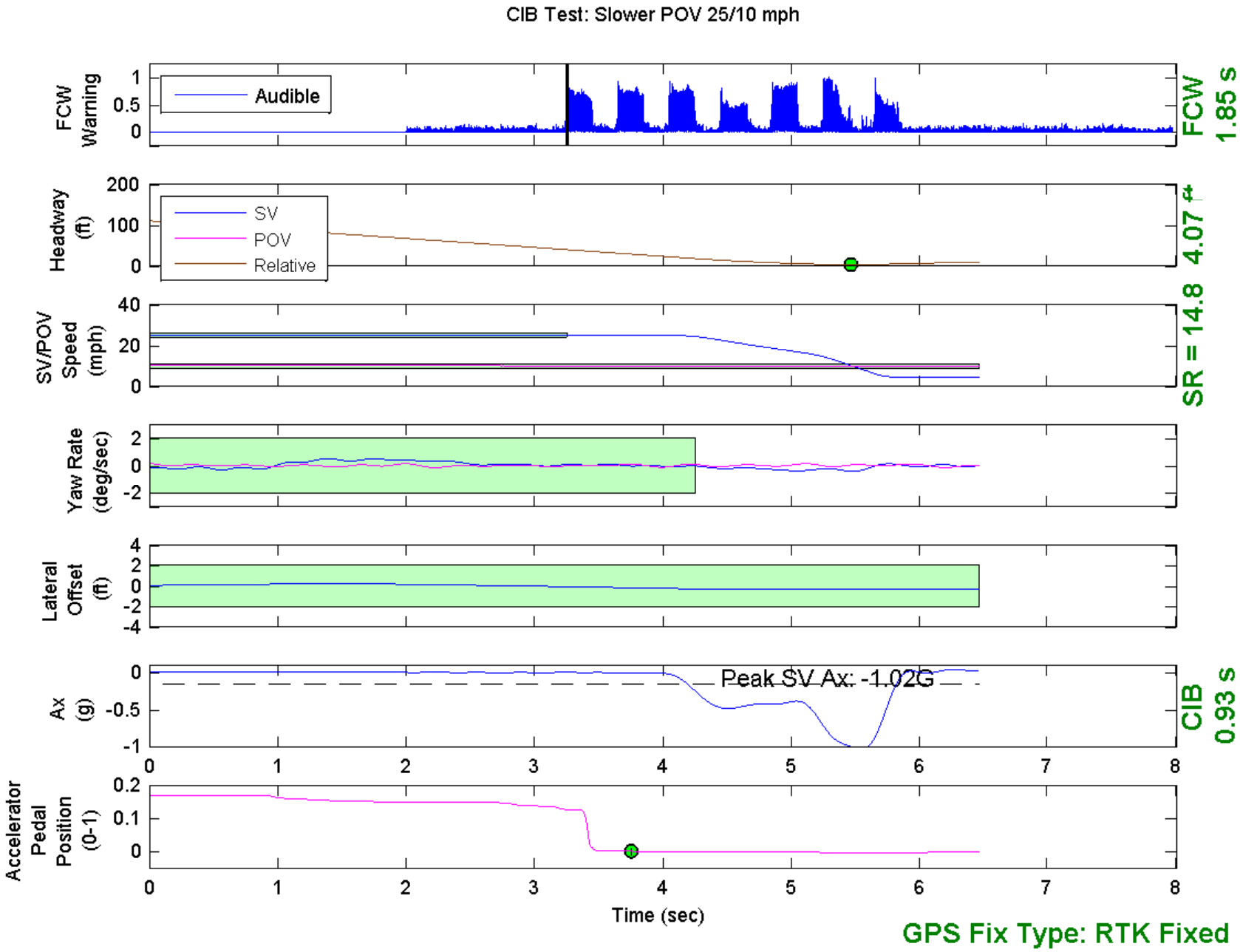


Figure D2. Example Time History for Slower POV 25 vs. 10, Passing

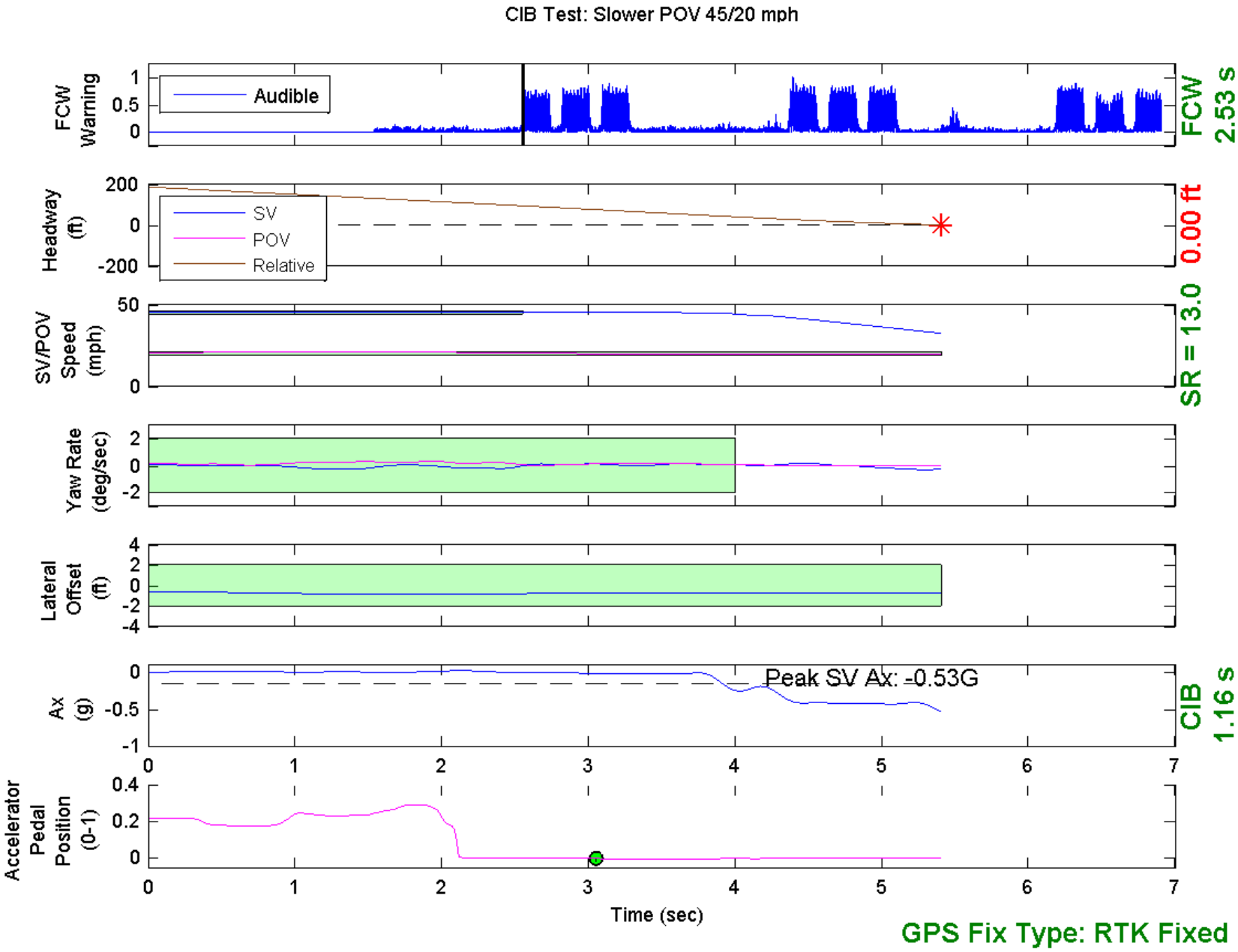


Figure D3. Example Time History for Slower POV 45 vs. 20, Passing

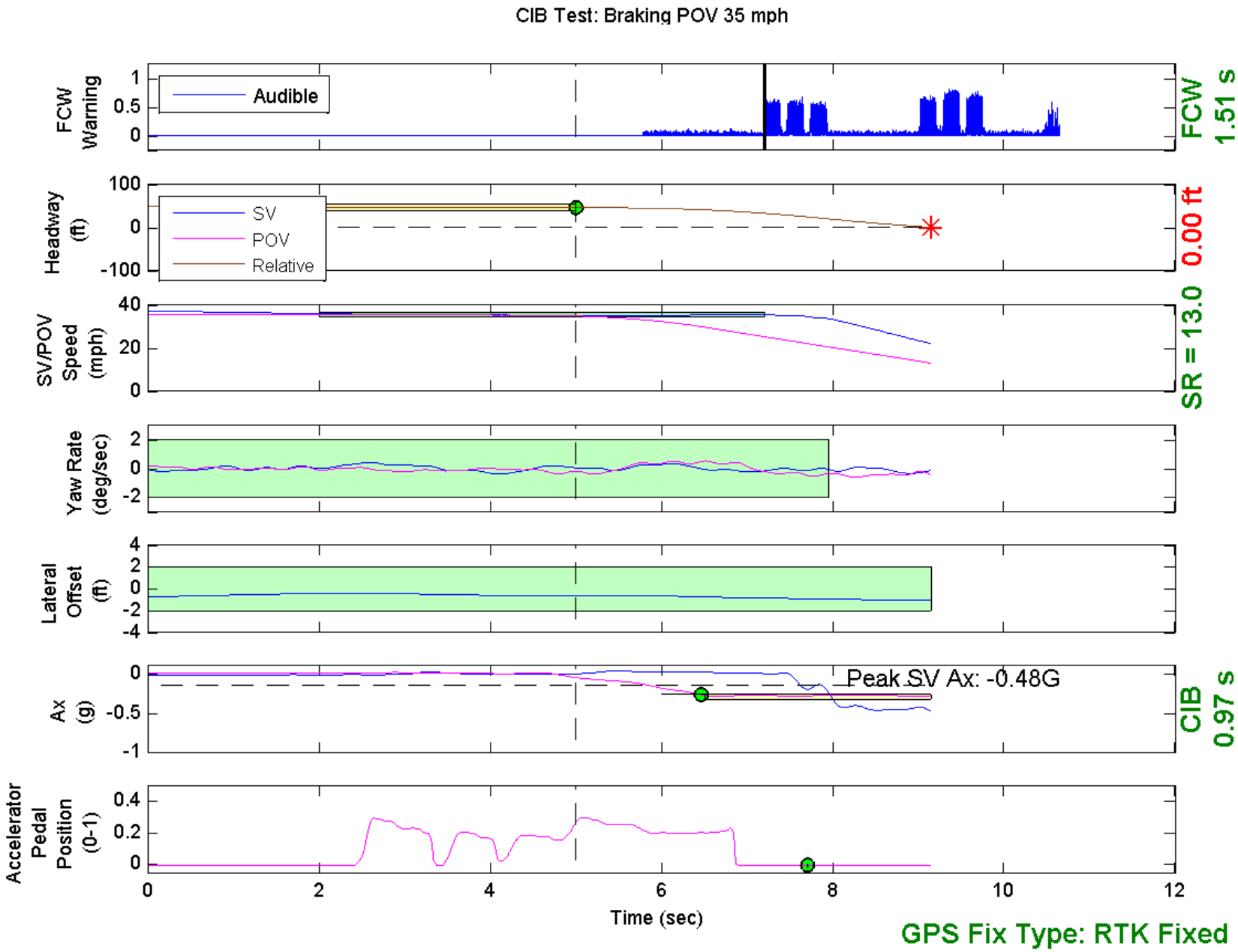


Figure D4. Example Time History for Braking POV 35, Passing

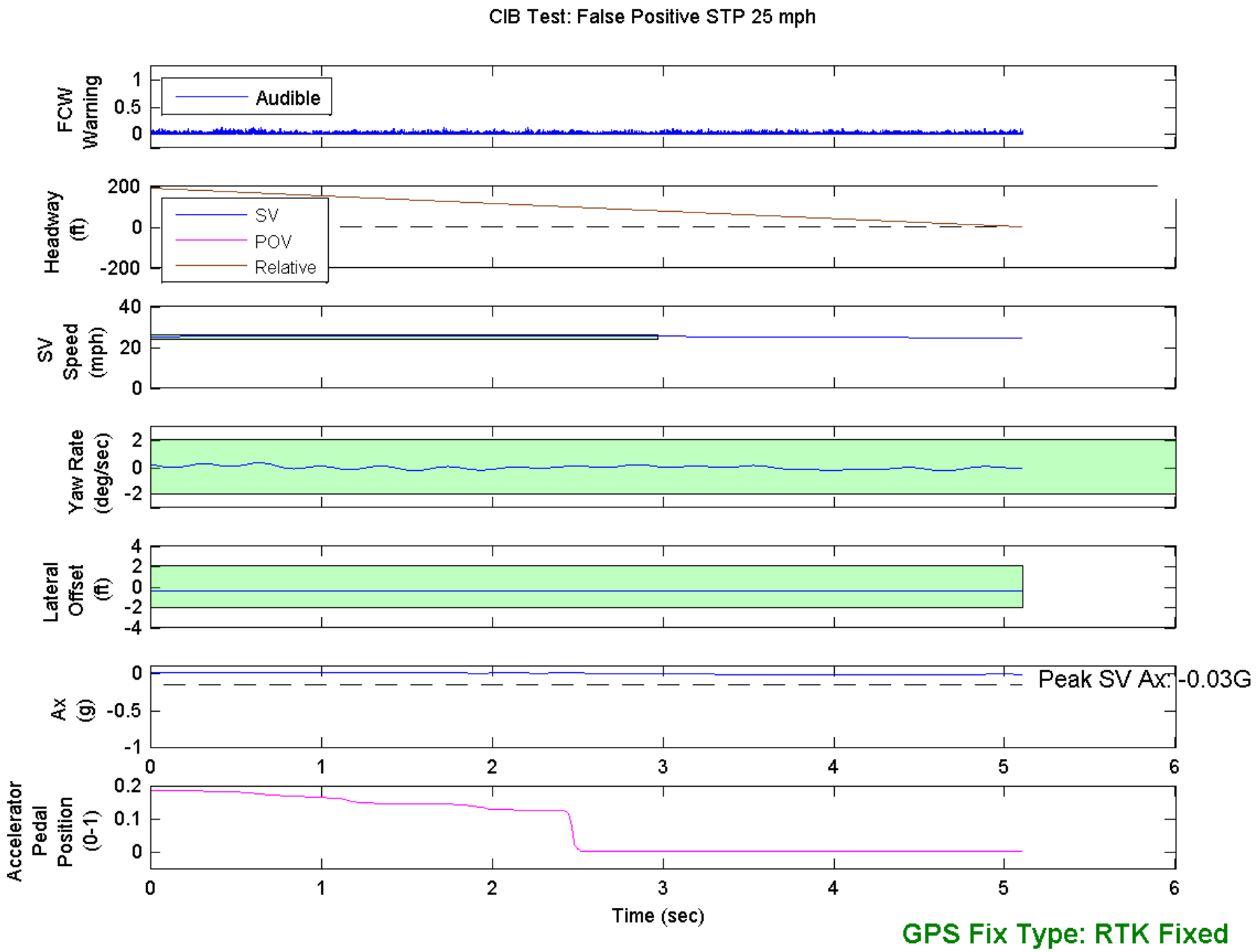


Figure D5. Example Time History for False Positive STP 25, Passing

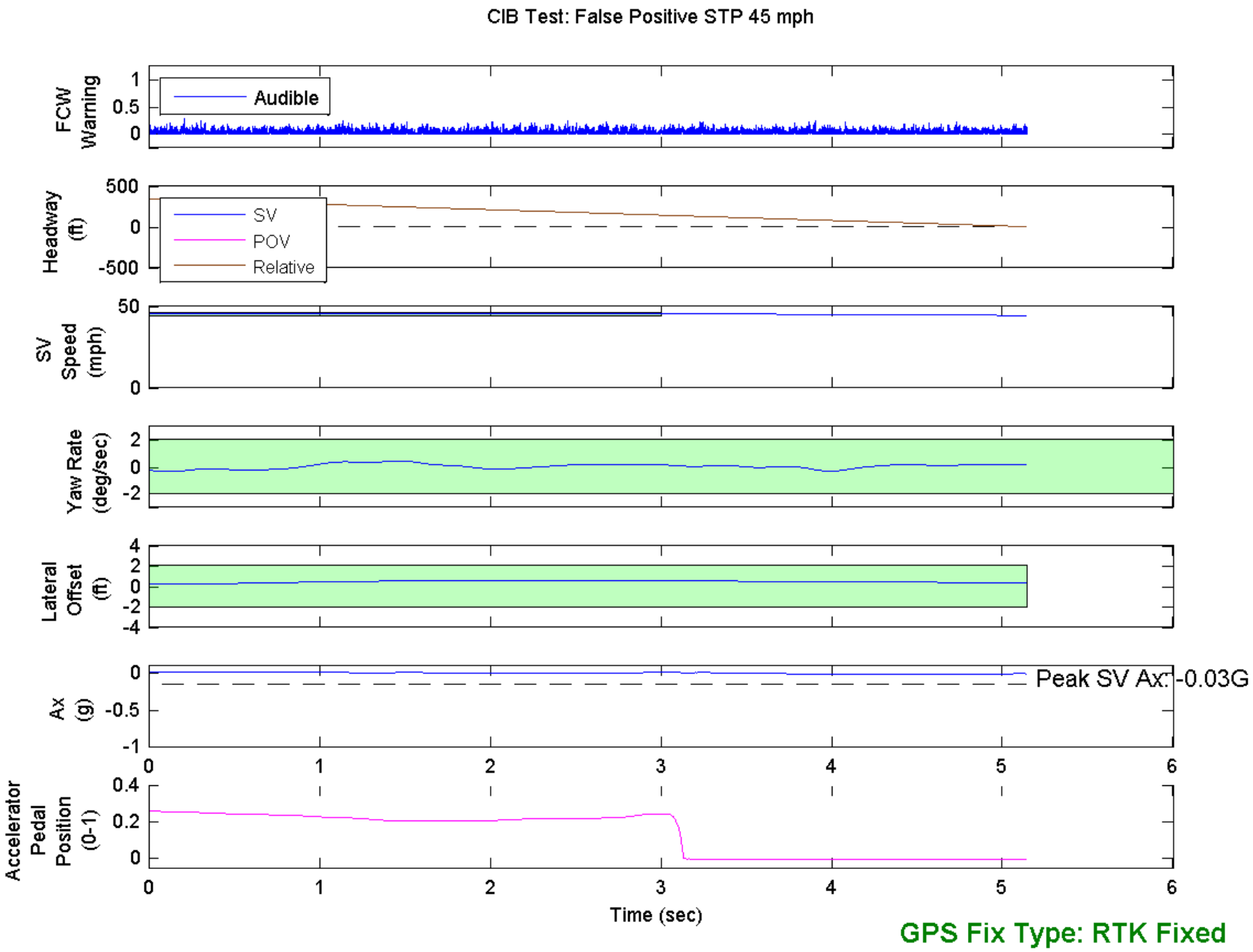


Figure D6. Example Time History for False Positive STP 45, Passing

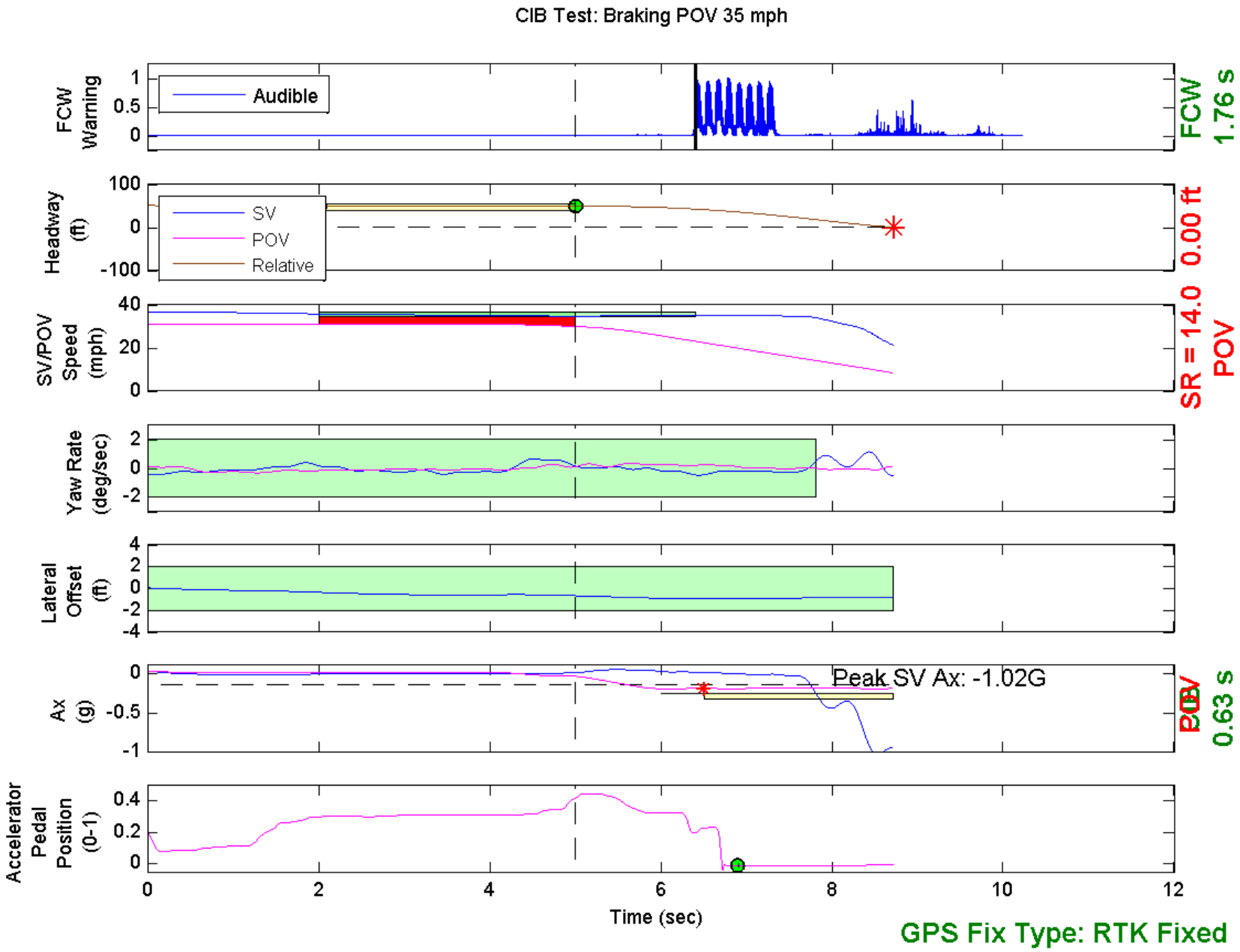


Figure D7. Example Time History Displaying Various Invalid Criteria

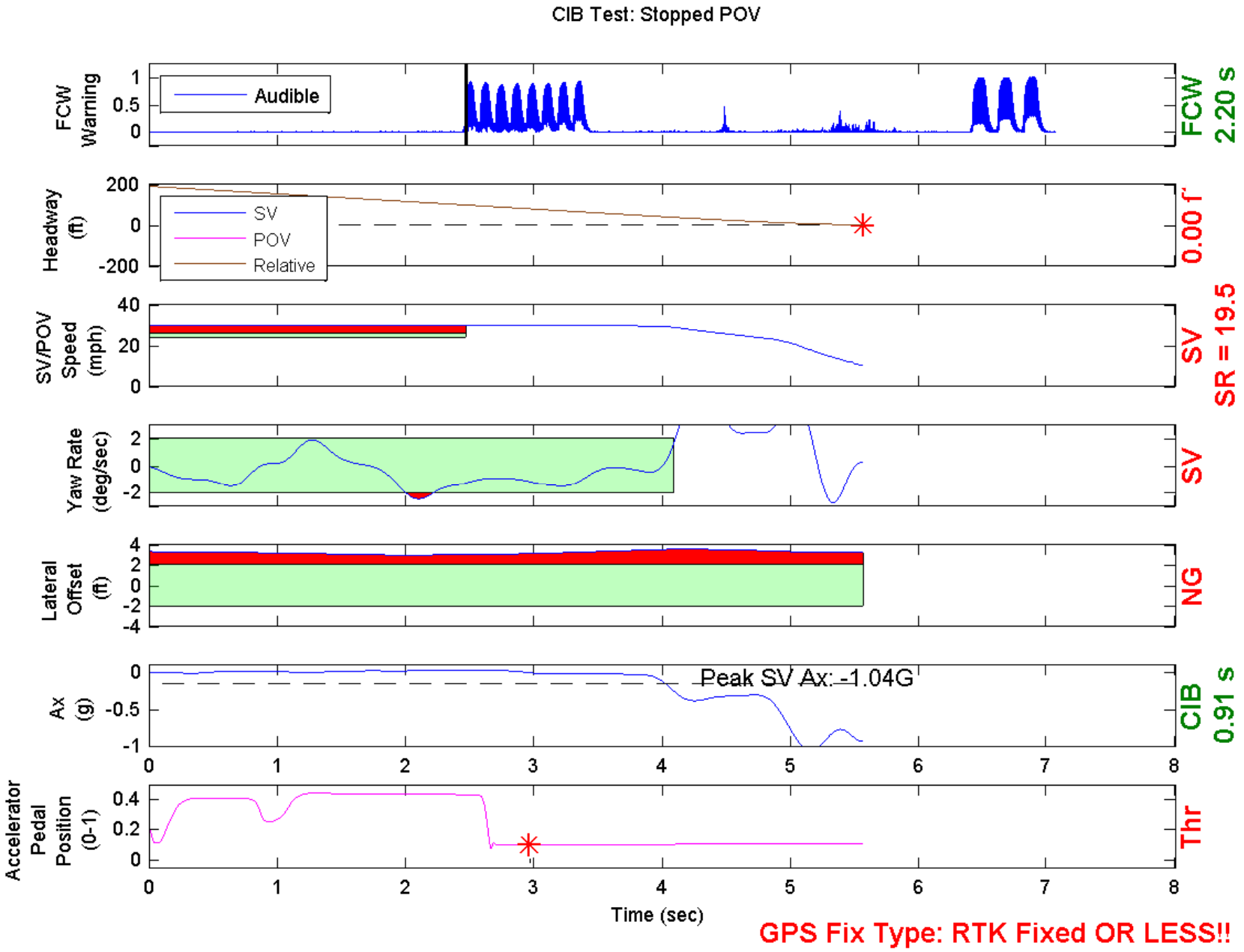


Figure D8. Example Time History Displaying Various Invalid Criteria

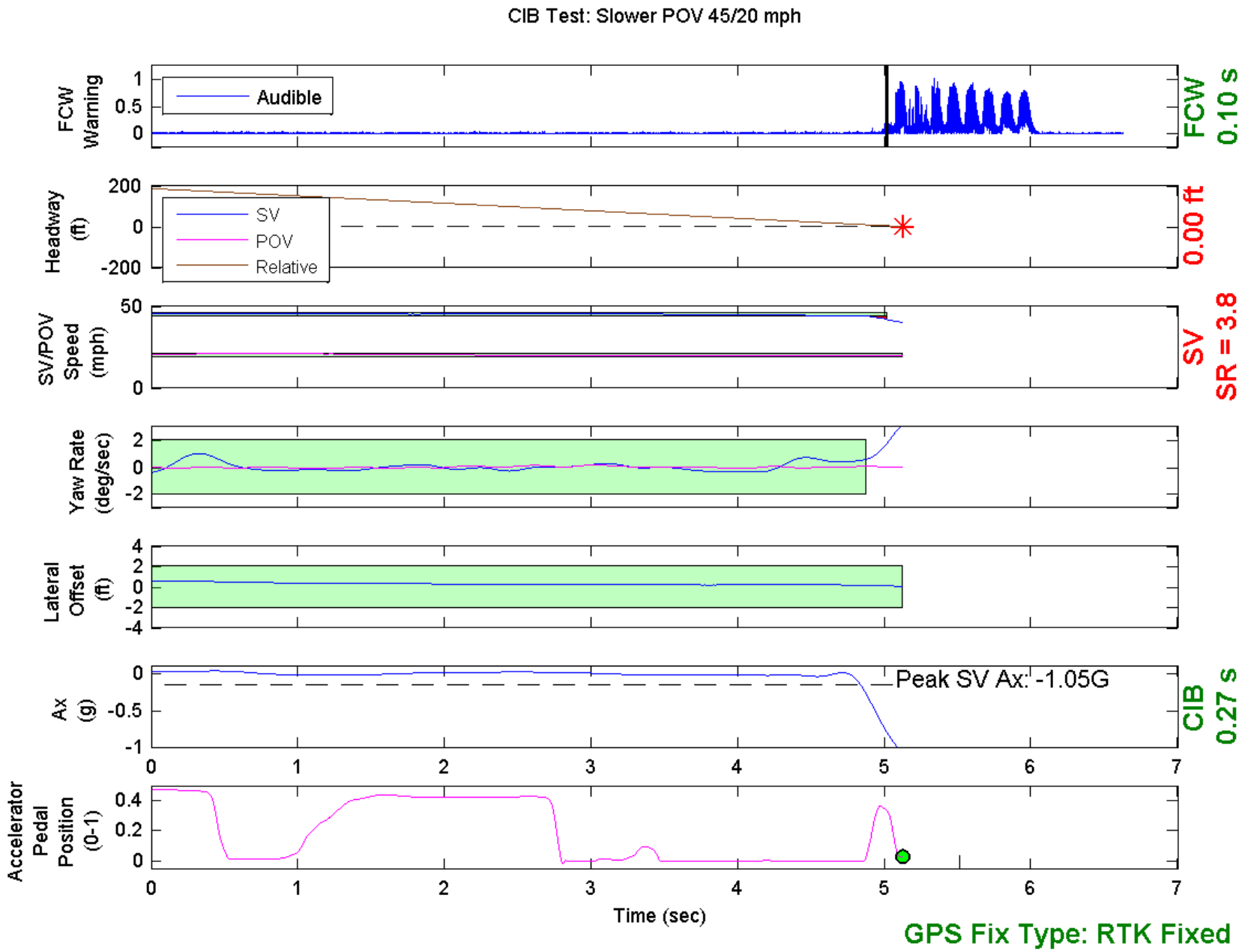


Figure D9. Example Time History for a Failed Run

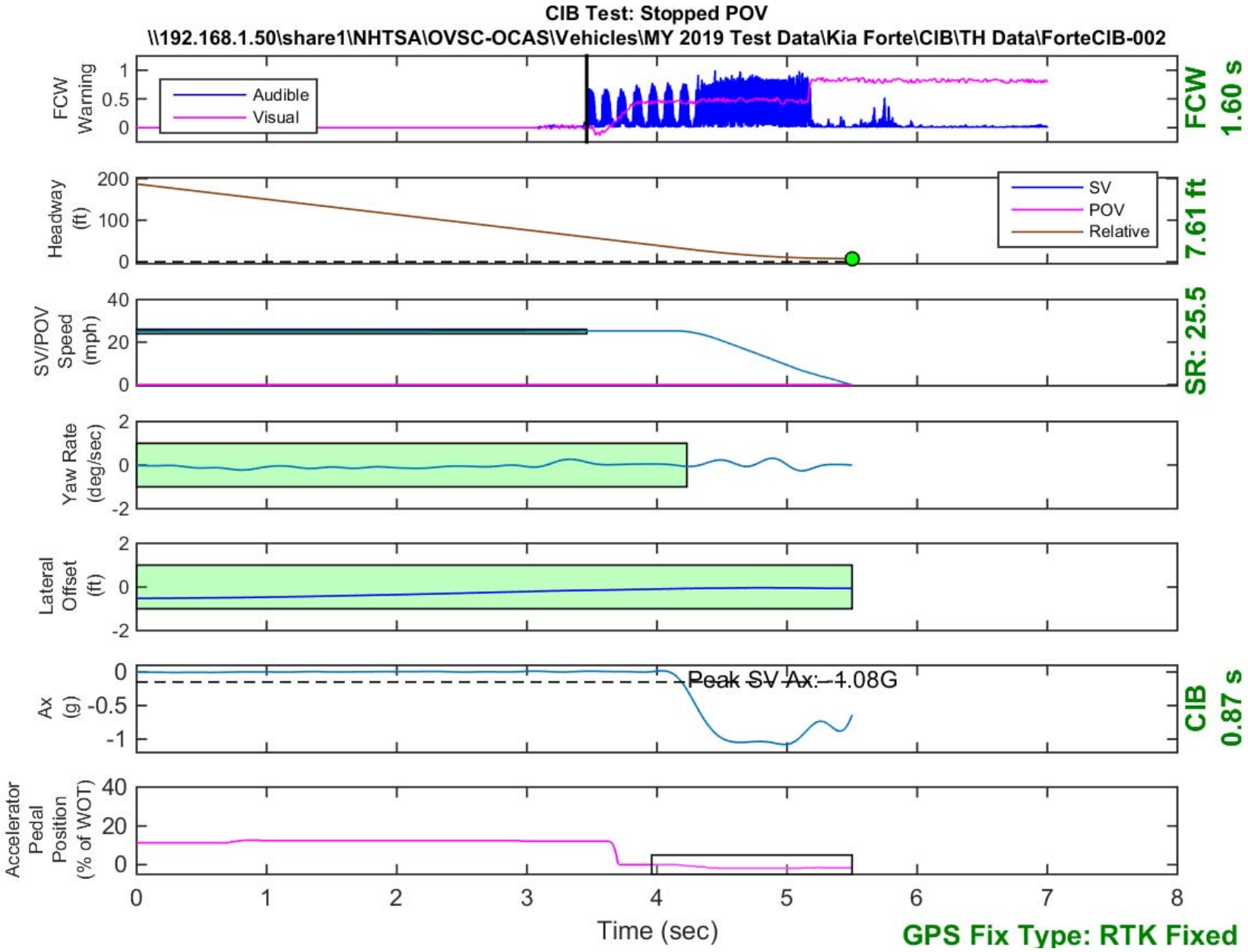


Figure D10. Time History for CIB Run 2, SV Encounters Stopped POV

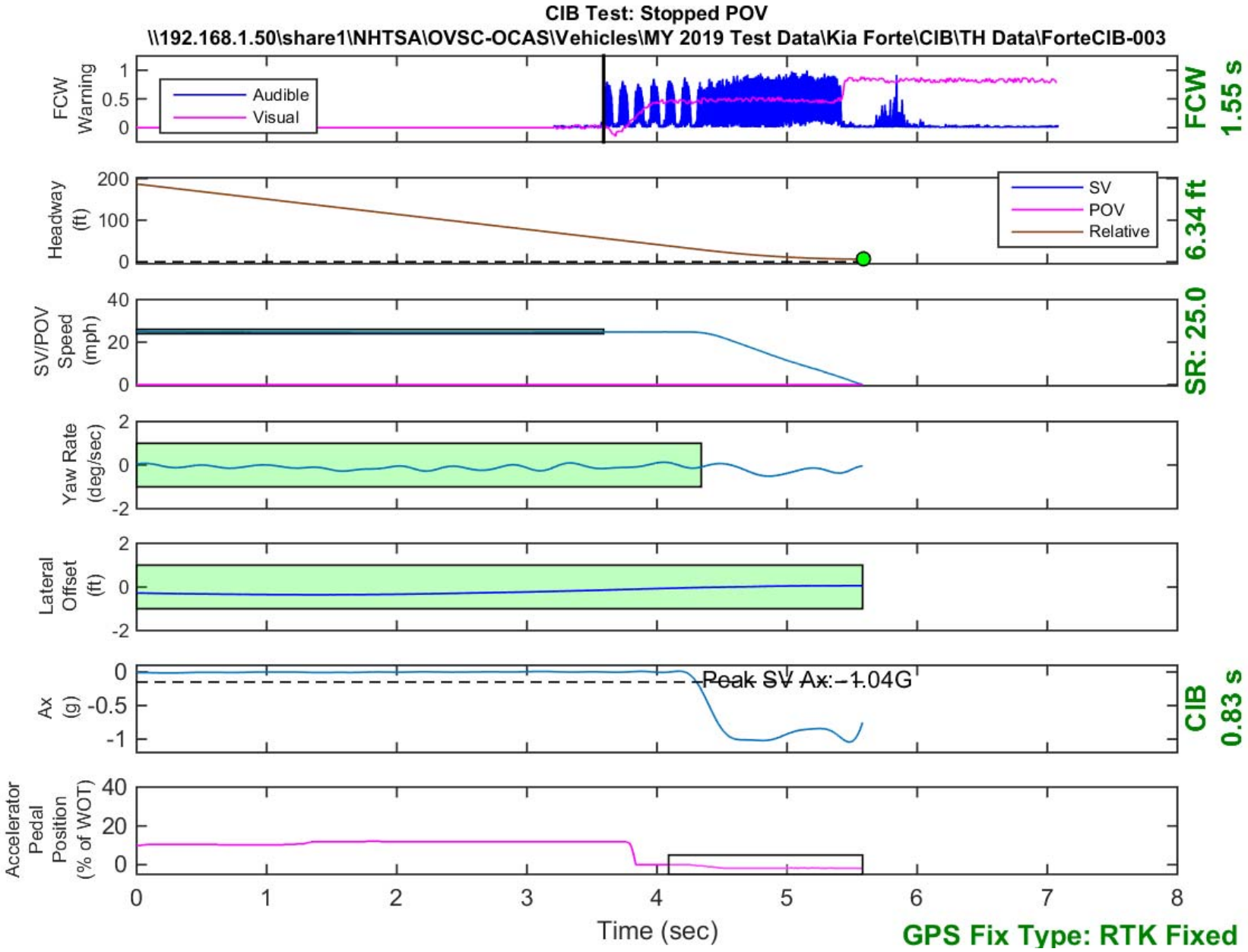


Figure D11. Time History for CIB Run 3, SV Encounters Stopped POV

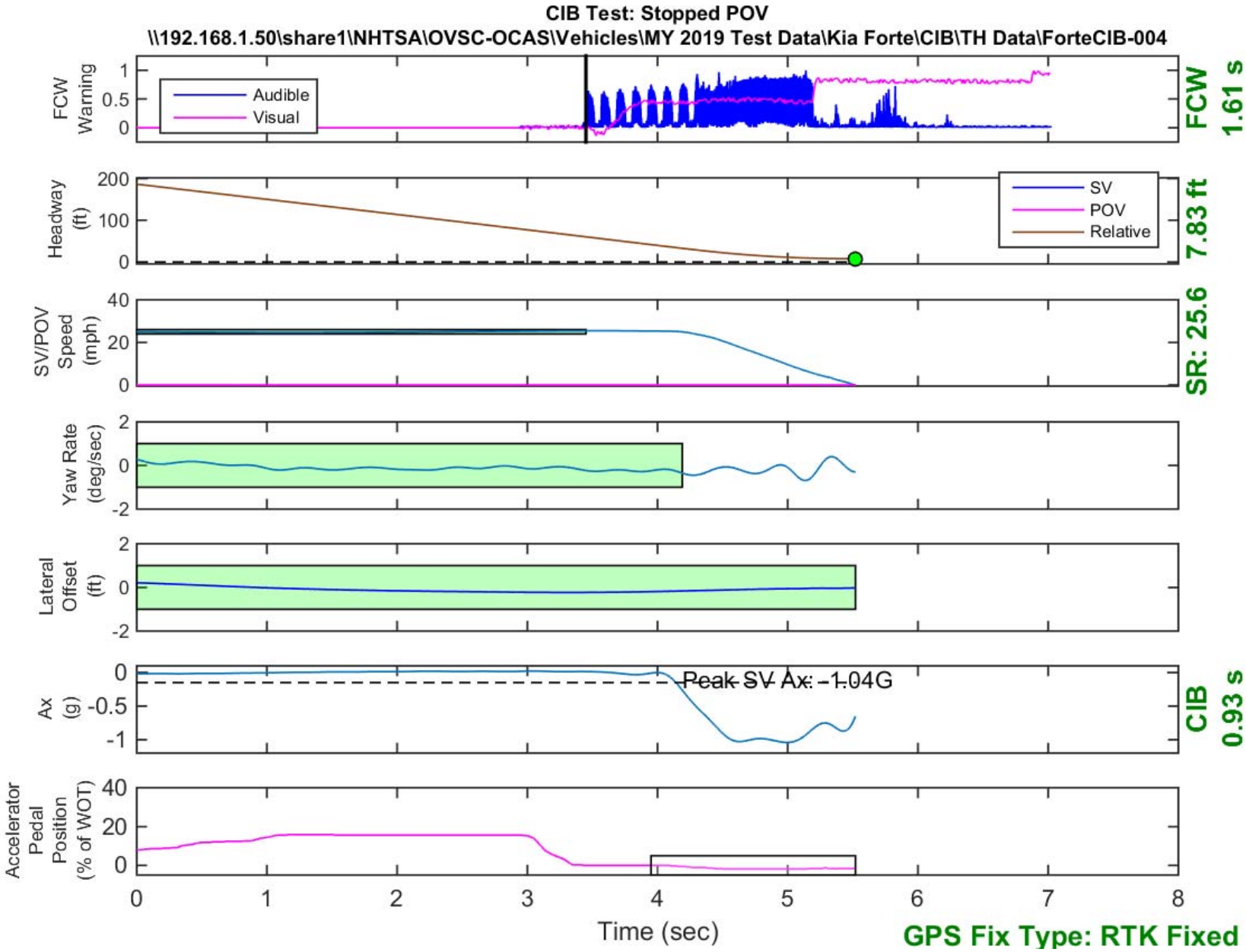


Figure D12. Time History for CIB Run 4, SV Encounters Stopped POV

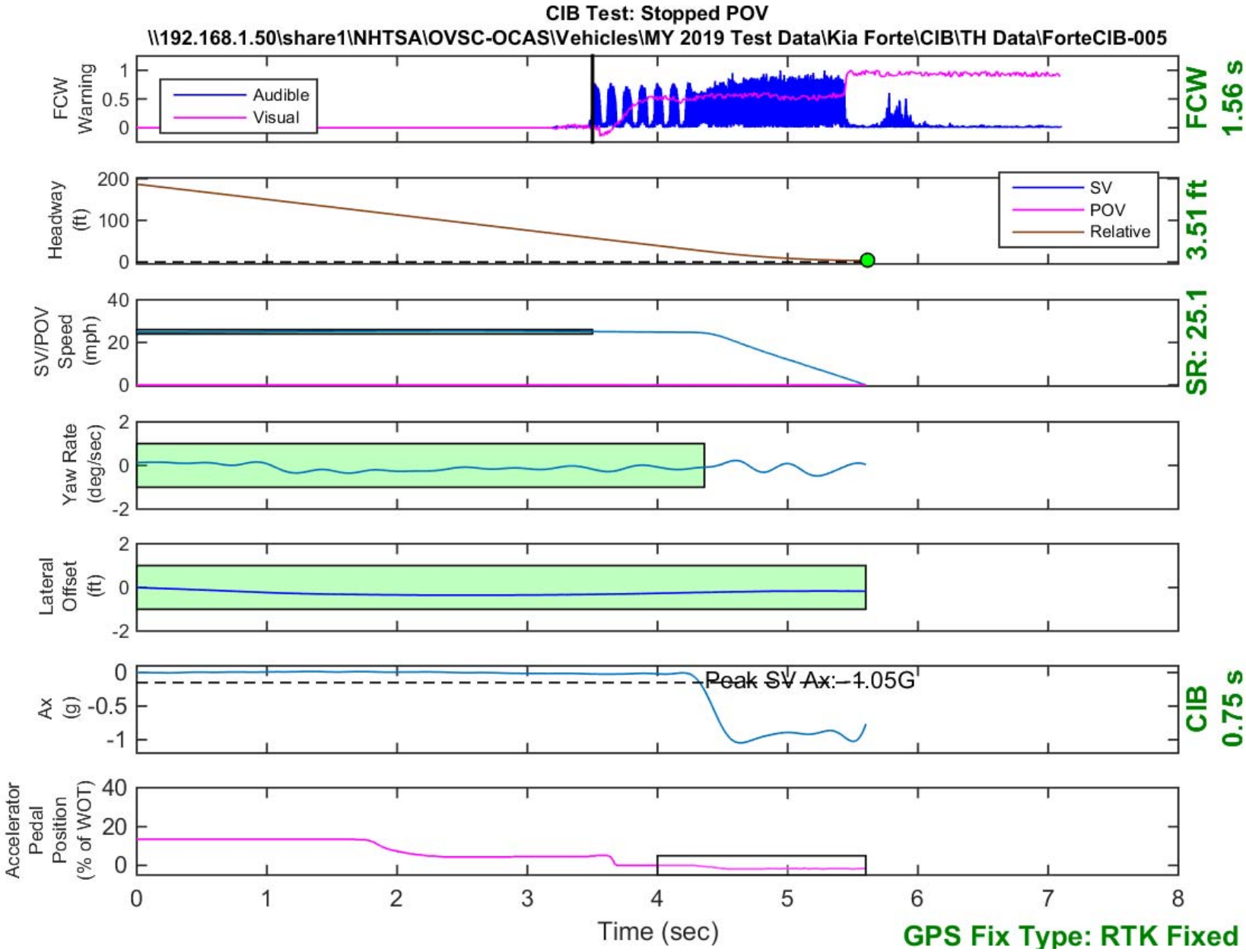


Figure D13. Time History for CIB Run 5, SV Encounters Stopped POV

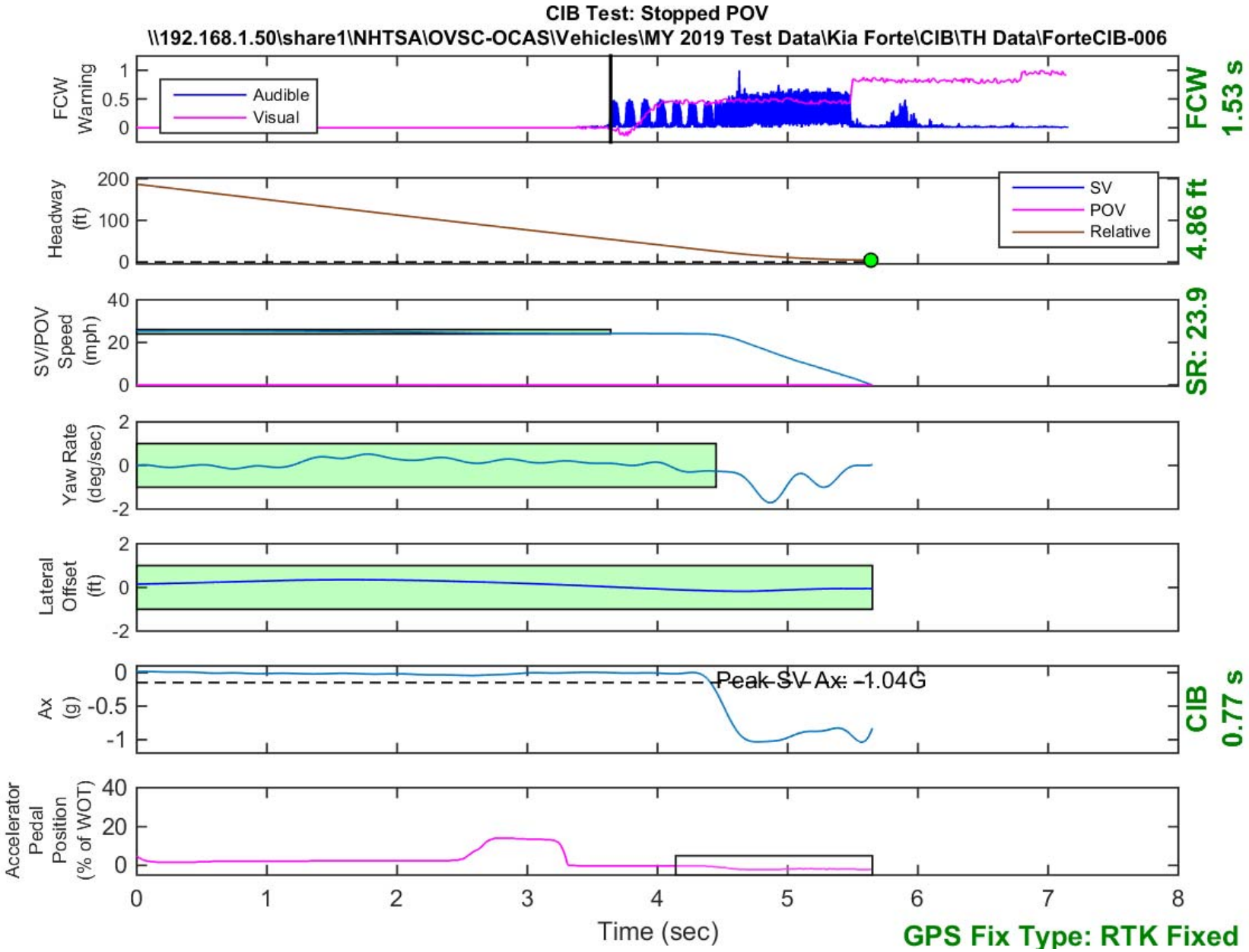


Figure D14. Time History for CIB Run 6, SV Encounters Stopped POV

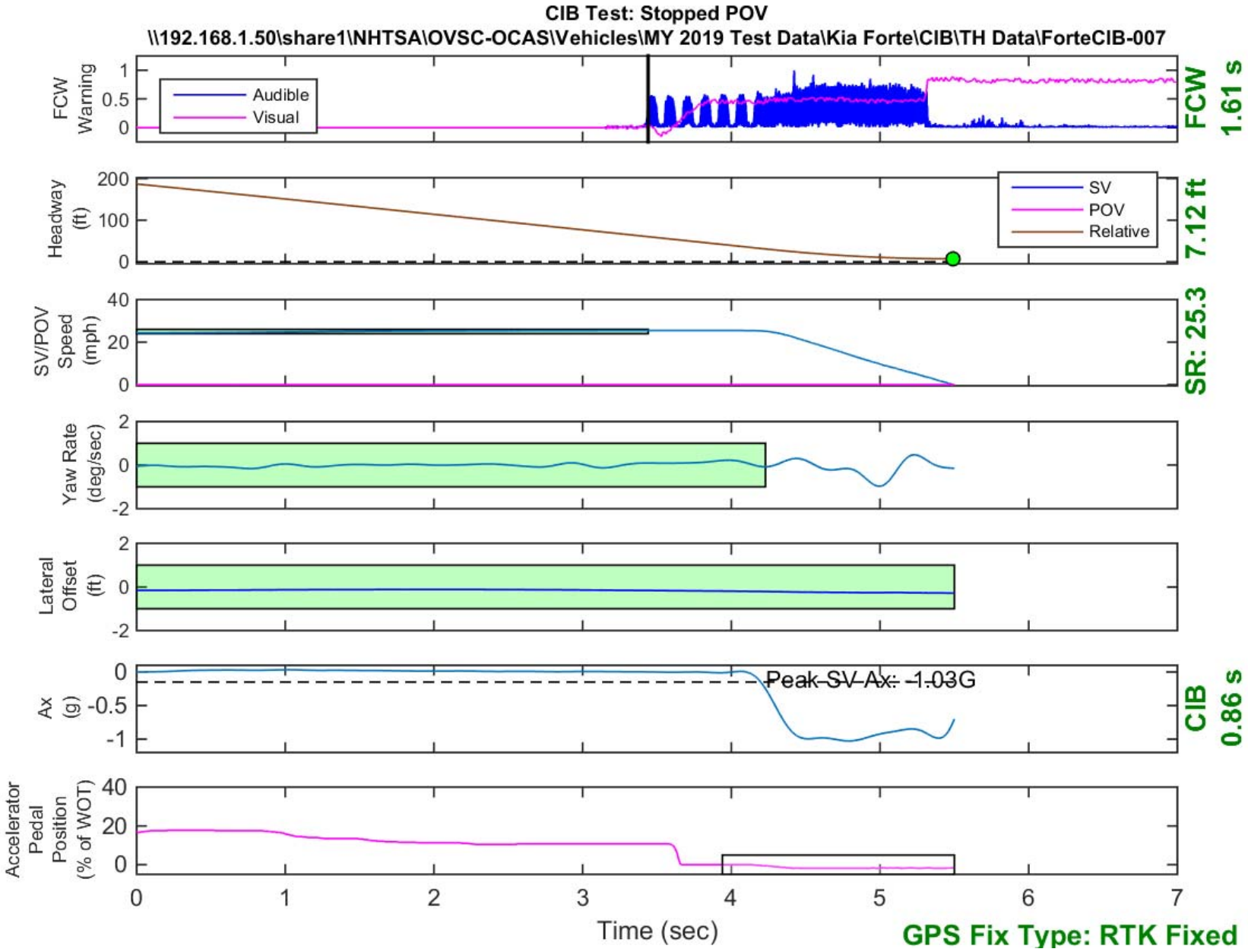


Figure D15. Time History for CIB Run 7, SV Encounters Stopped POV

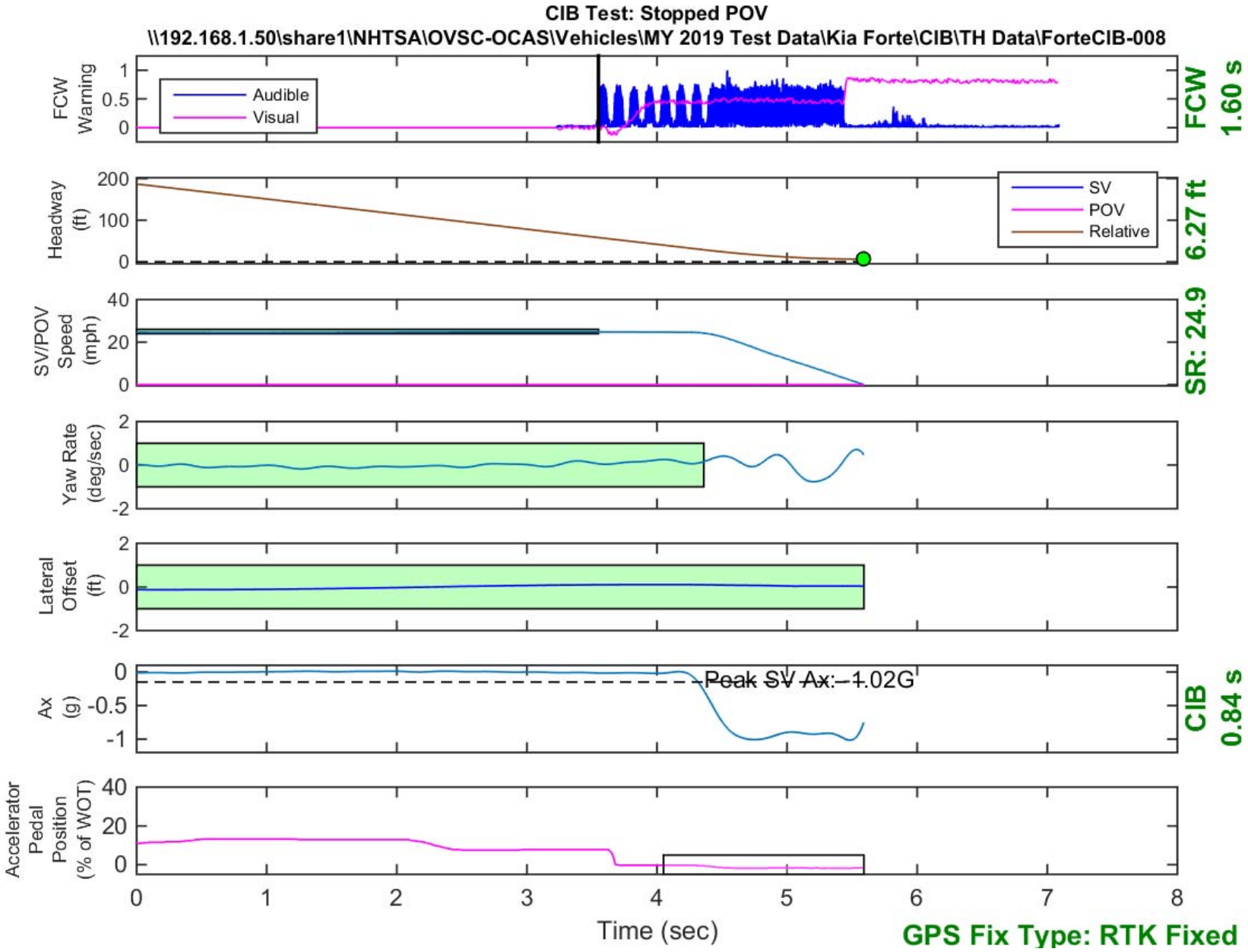


Figure D16. Time History for CIB Run 8, SV Encounters Stopped POV

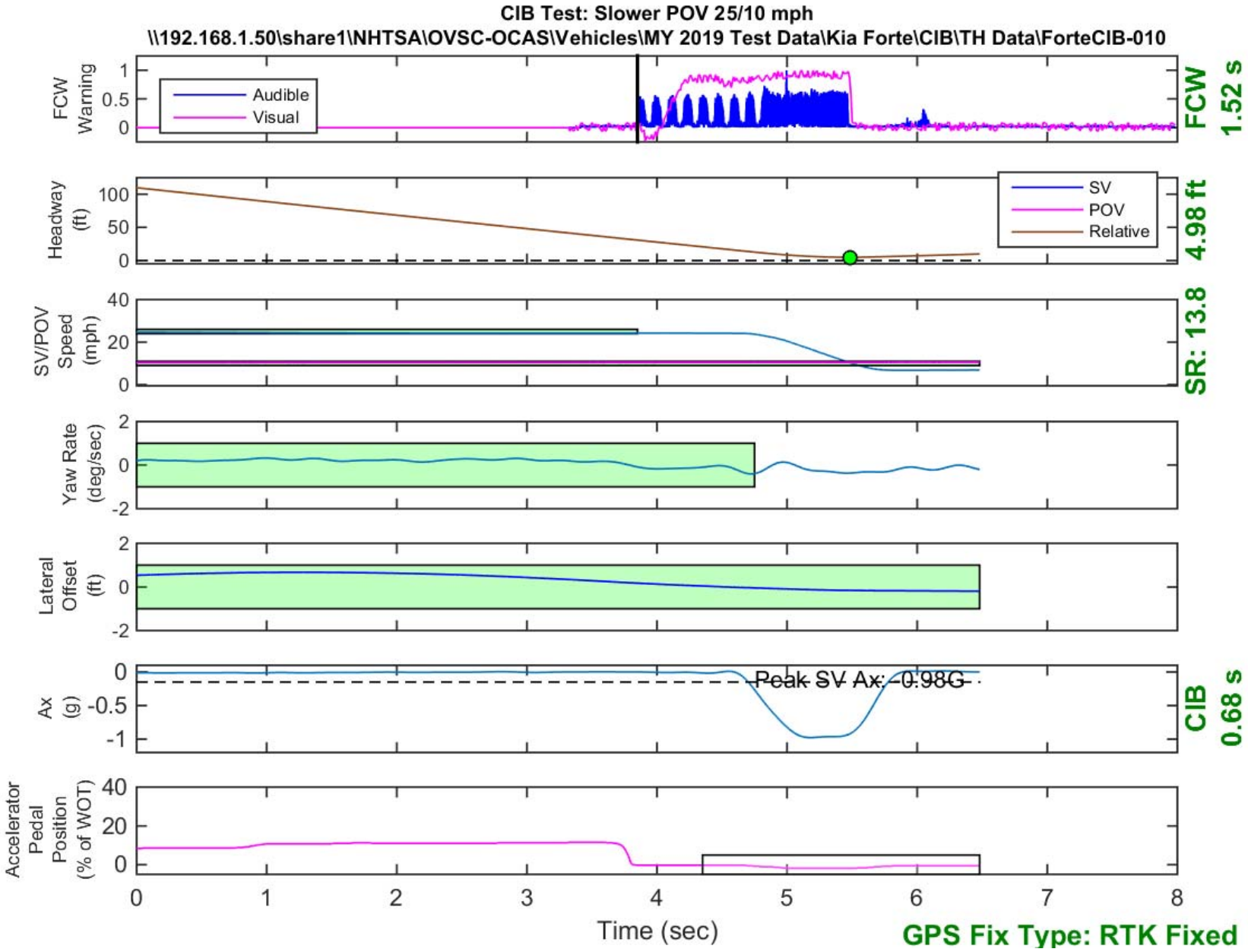


Figure D17. Time History for CIB Run 10, SV Encounters Slower POV, SV 25 mph, POV 10 mph

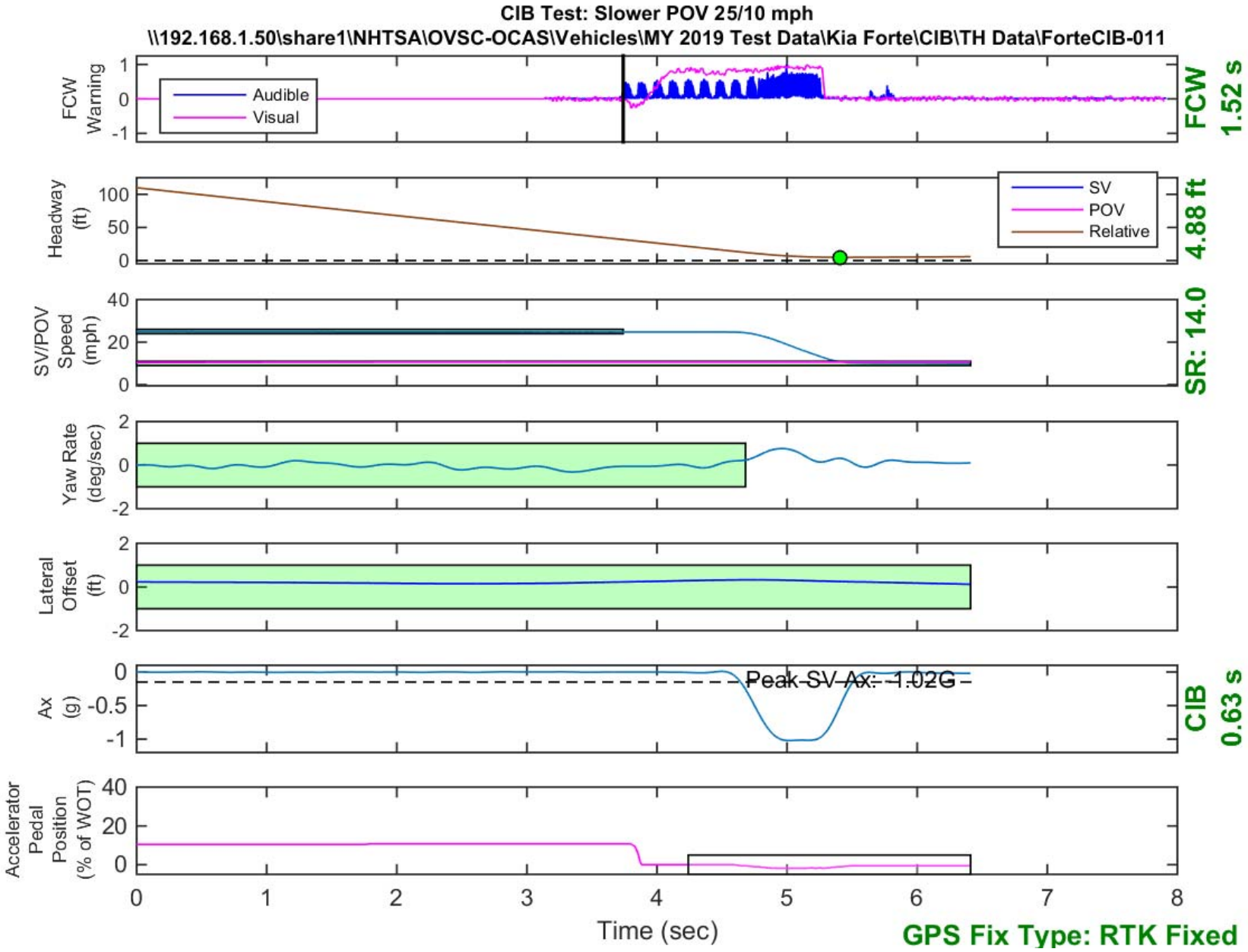


Figure D18. Time History for CIB Run 11, SV Encounters Slower POV, SV 25 mph, POV 10 mph

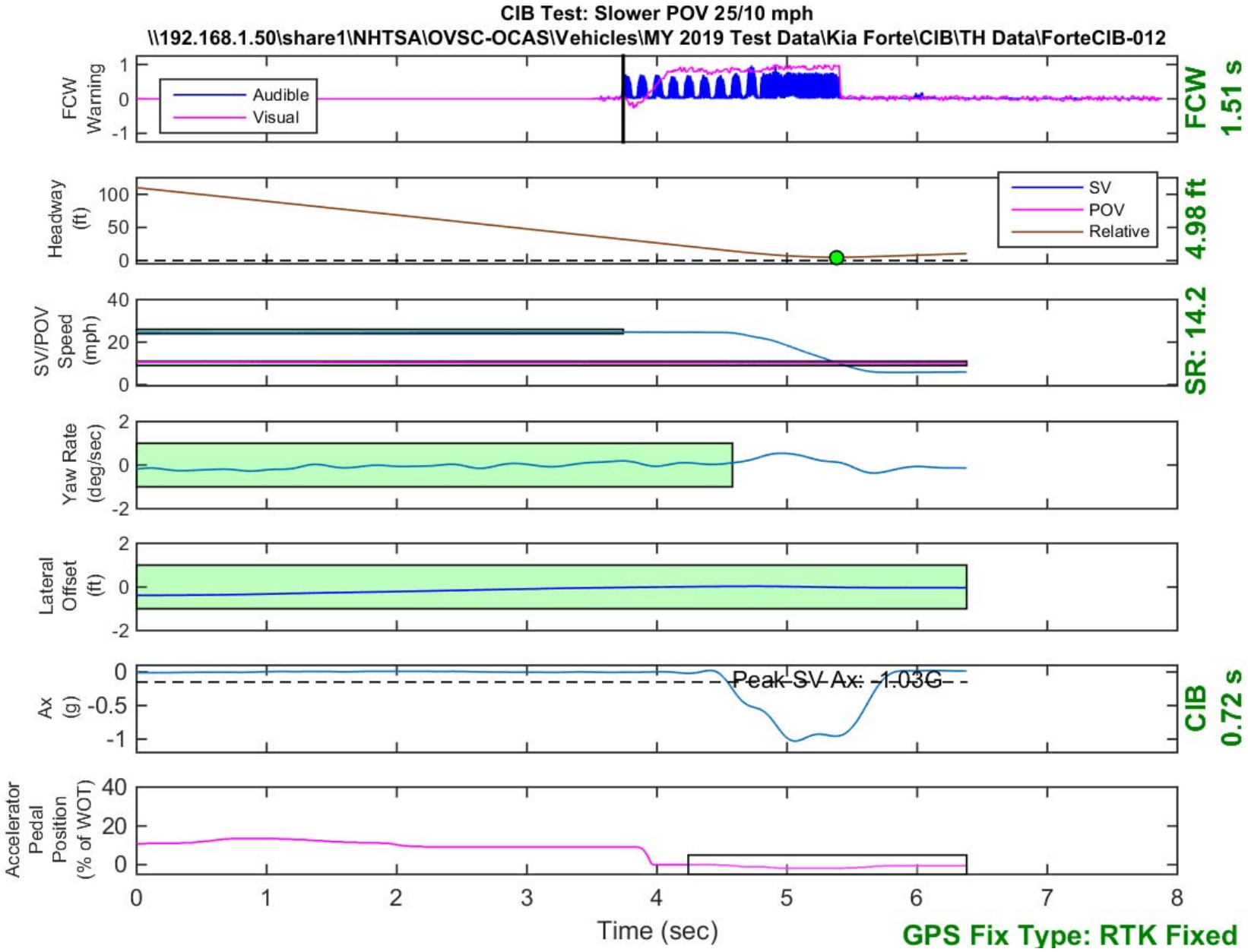


Figure D19. Time History for CIB Run 12, SV Encounters Slower POV, SV 25 mph, POV 10 mph

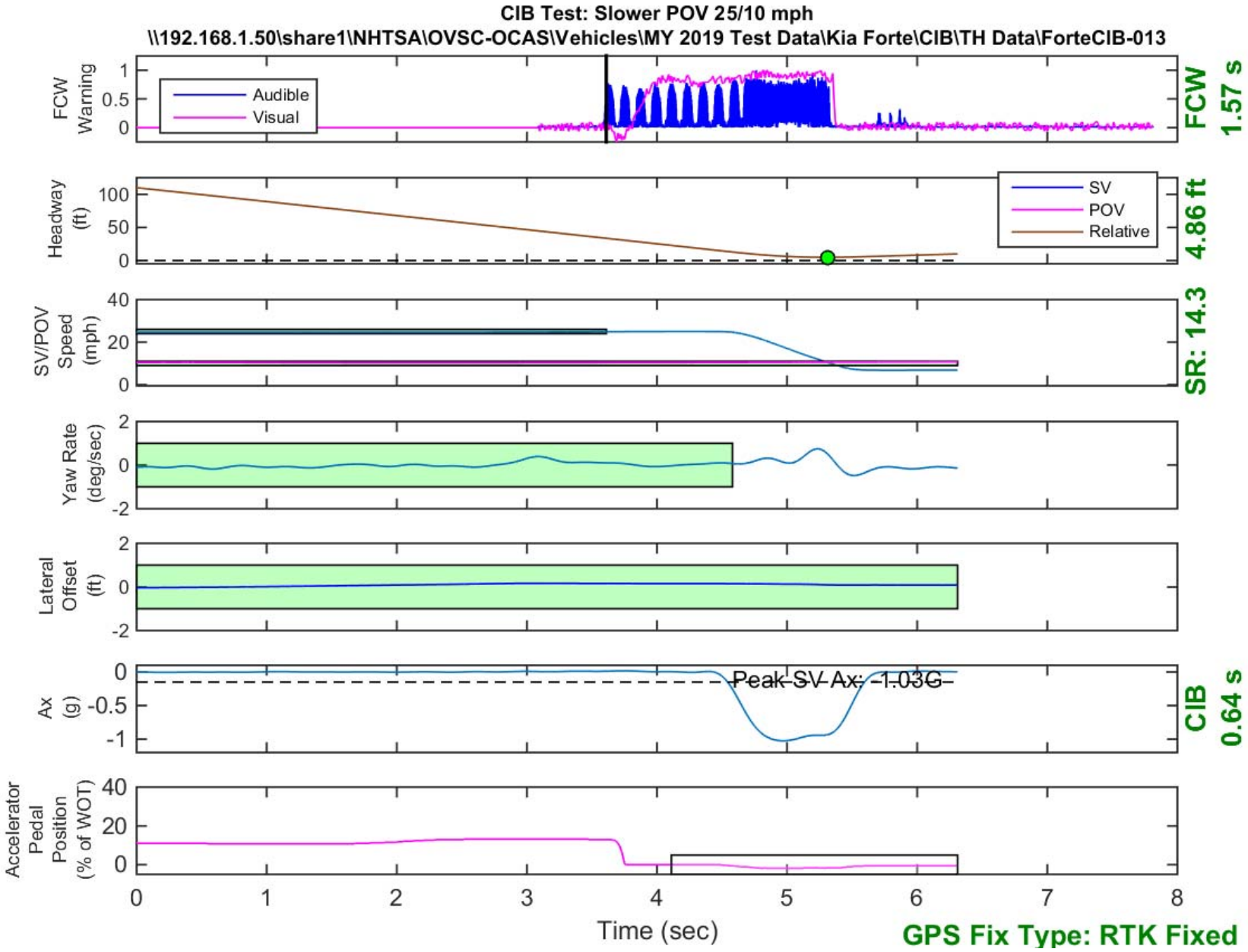


Figure D20. Time History for CIB Run 13, SV Encounters Slower POV, SV 25 mph, POV 10 mph

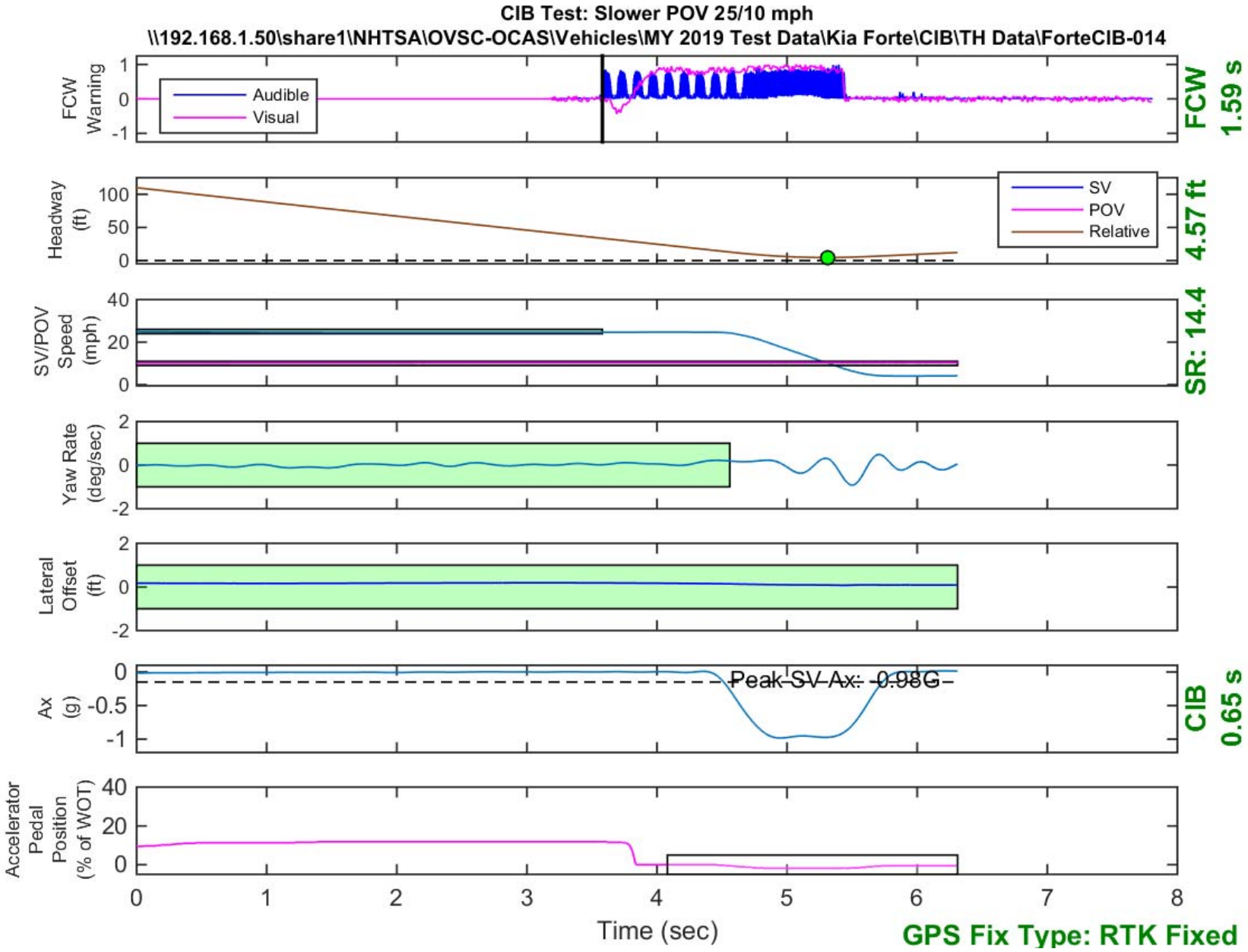


Figure D21. Time History for CIB Run 14, SV Encounters Slower POV, SV 25 mph, POV 10 mph

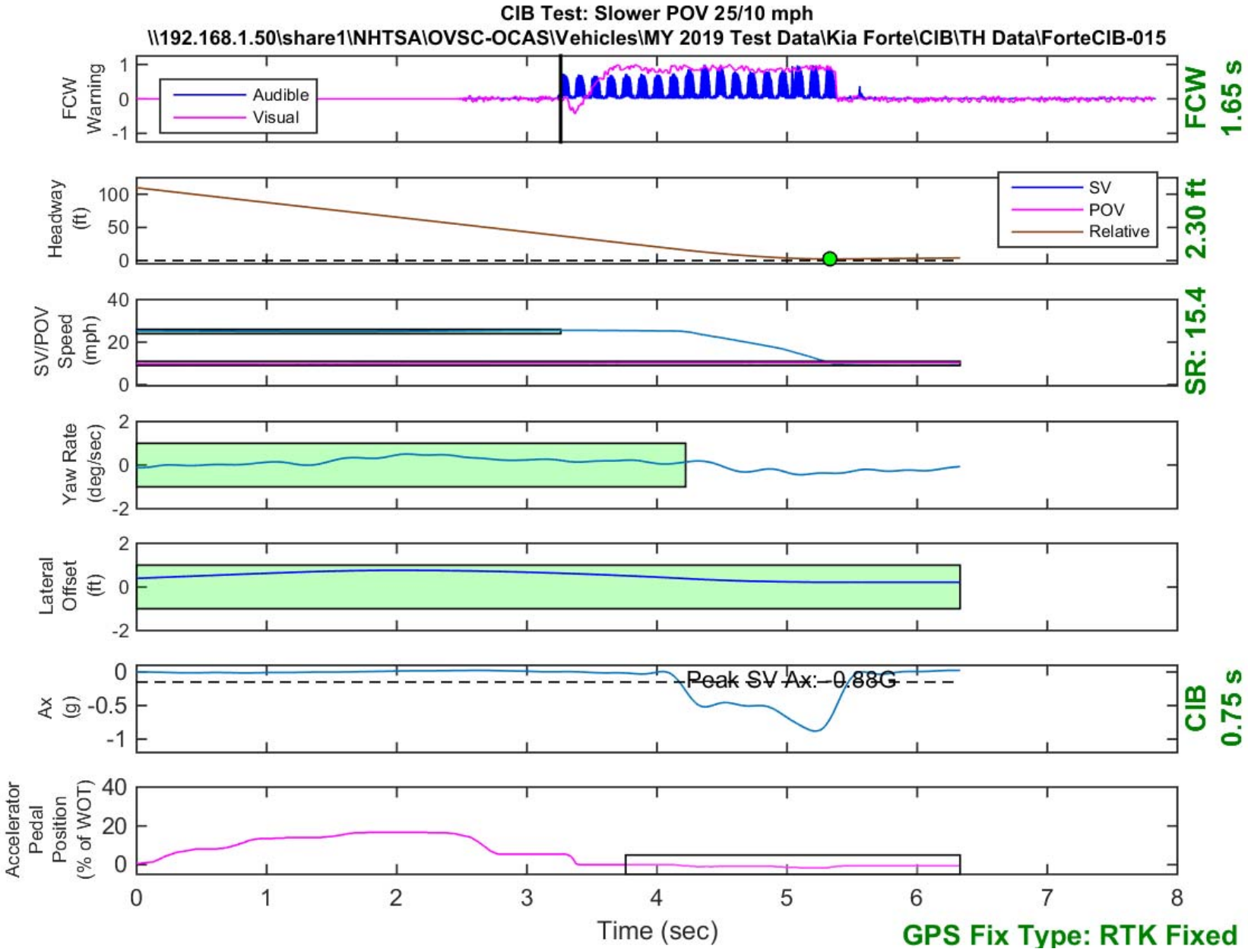


Figure D22. Time History for CIB Run 15, SV Encounters Slower POV, SV 25 mph, POV 10 mph

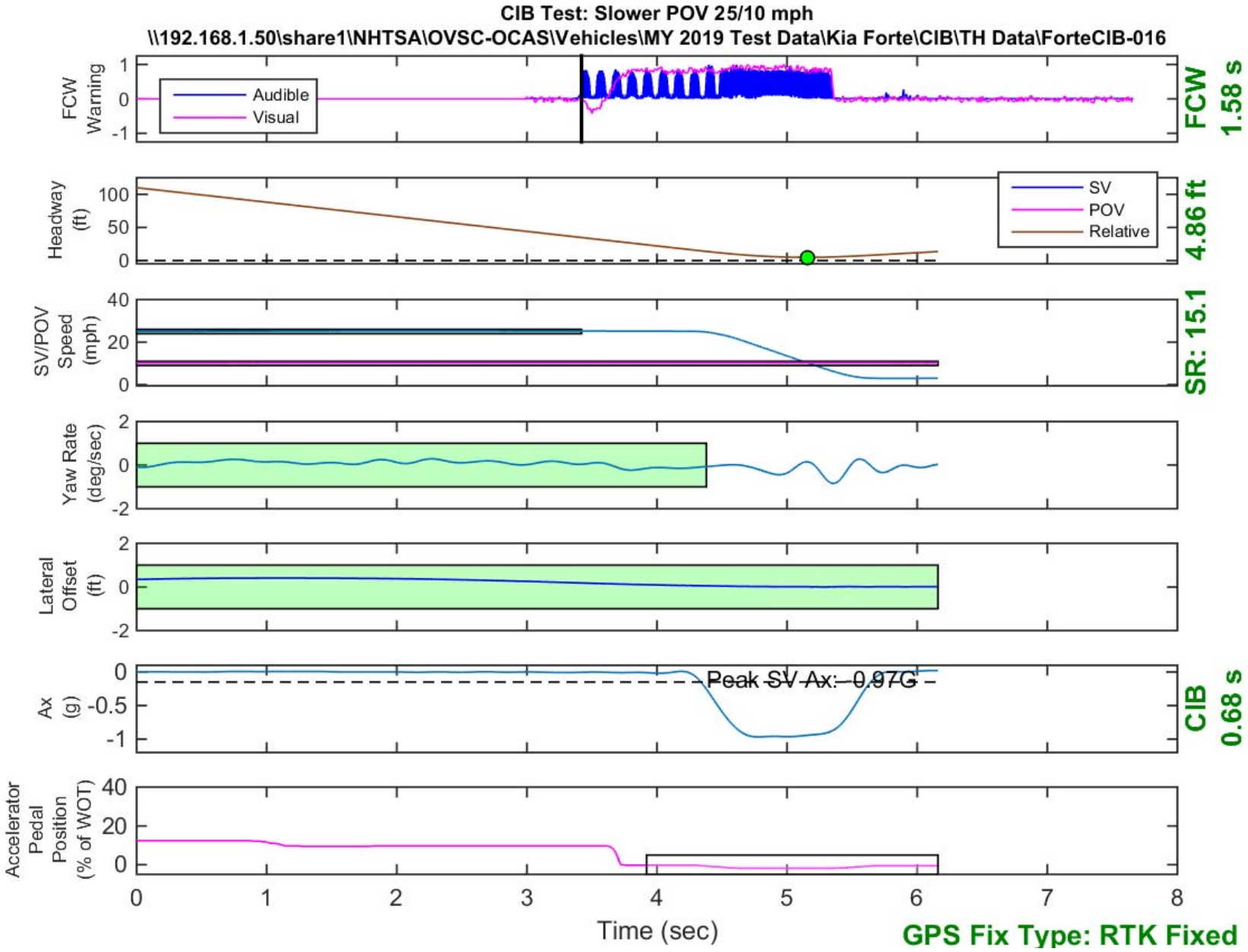


Figure D23. Time History for CIB Run 16, SV Encounters Slower POV, SV 25 mph, POV 10 mph

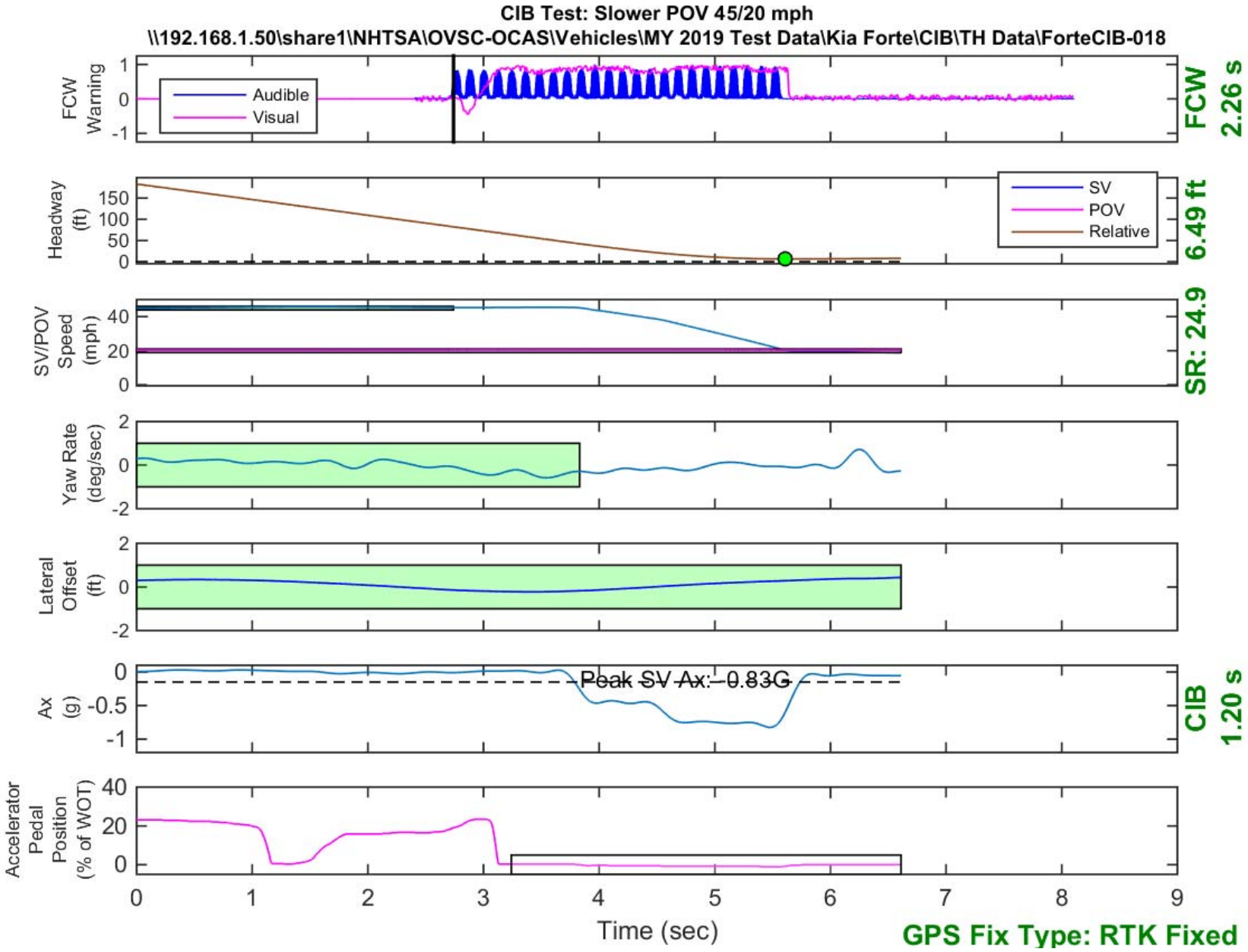


Figure D24. Time History for CIB Run 18, SV Encounters Slower POV, SV 45 mph, POV 20 mph

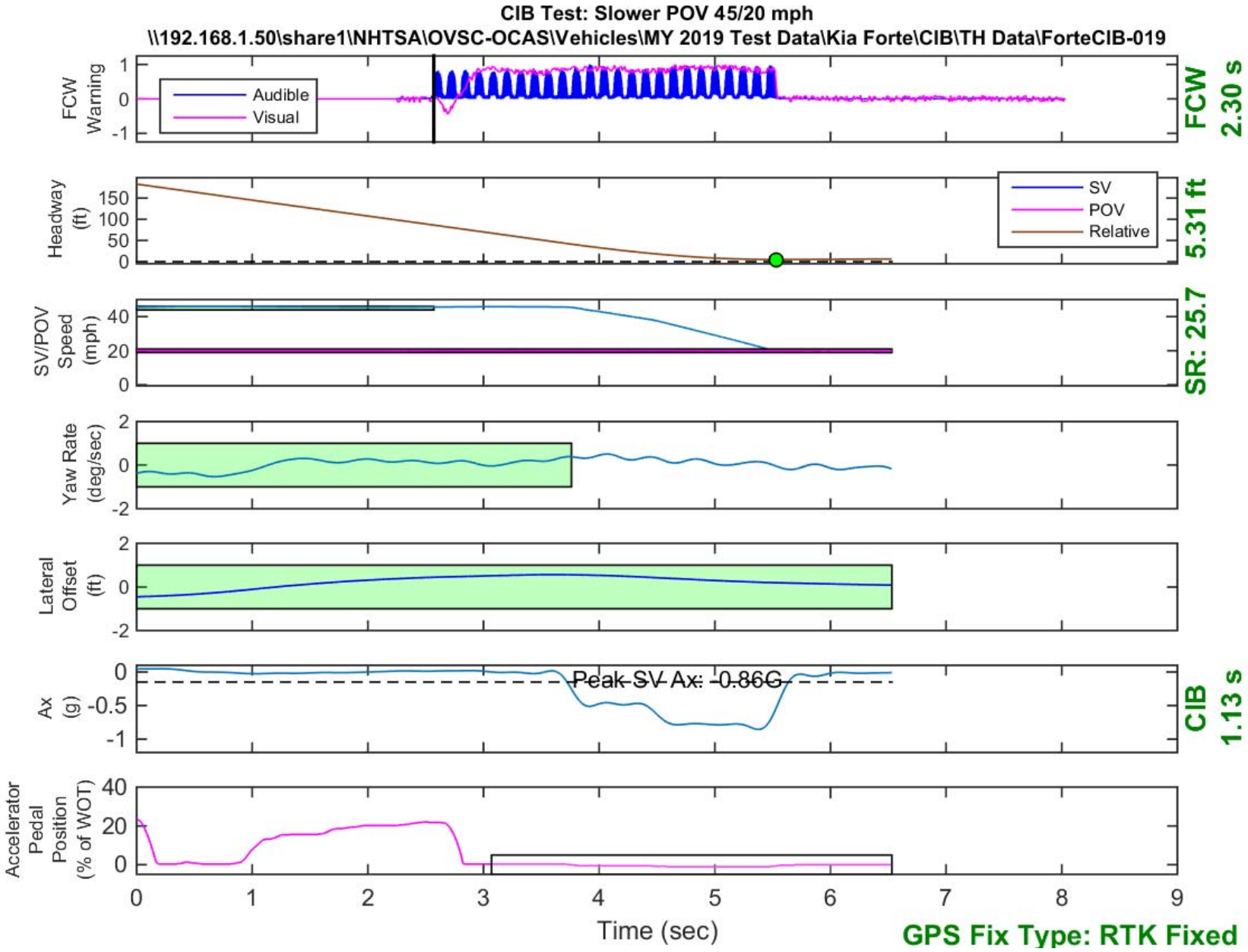


Figure D25. Time History for CIB Run 19, SV Encounters Slower POV, SV 45 mph, POV 20 mph

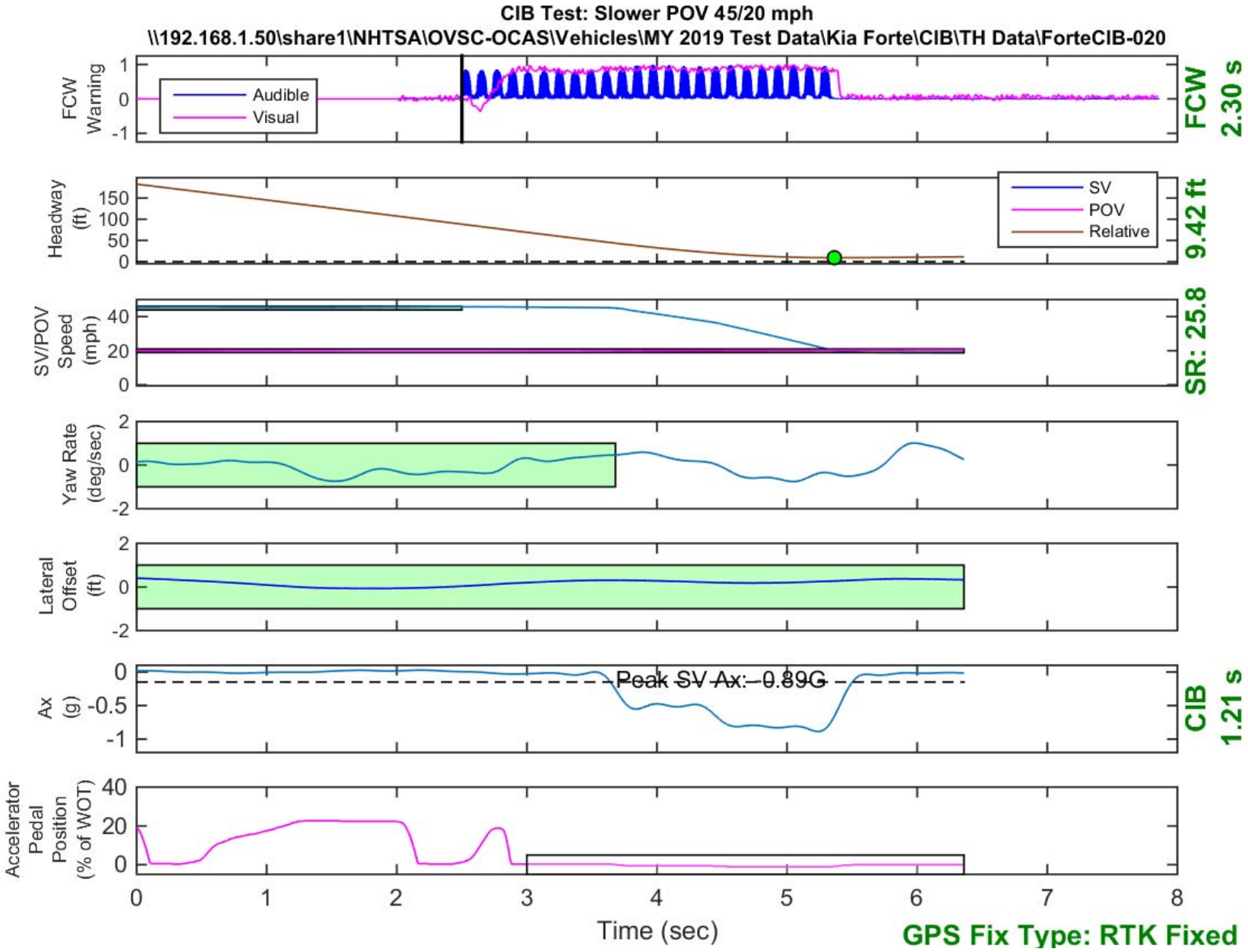


Figure D26. Time History for CIB Run 20, SV Encounters Slower POV, SV 45 mph, POV 20 mph

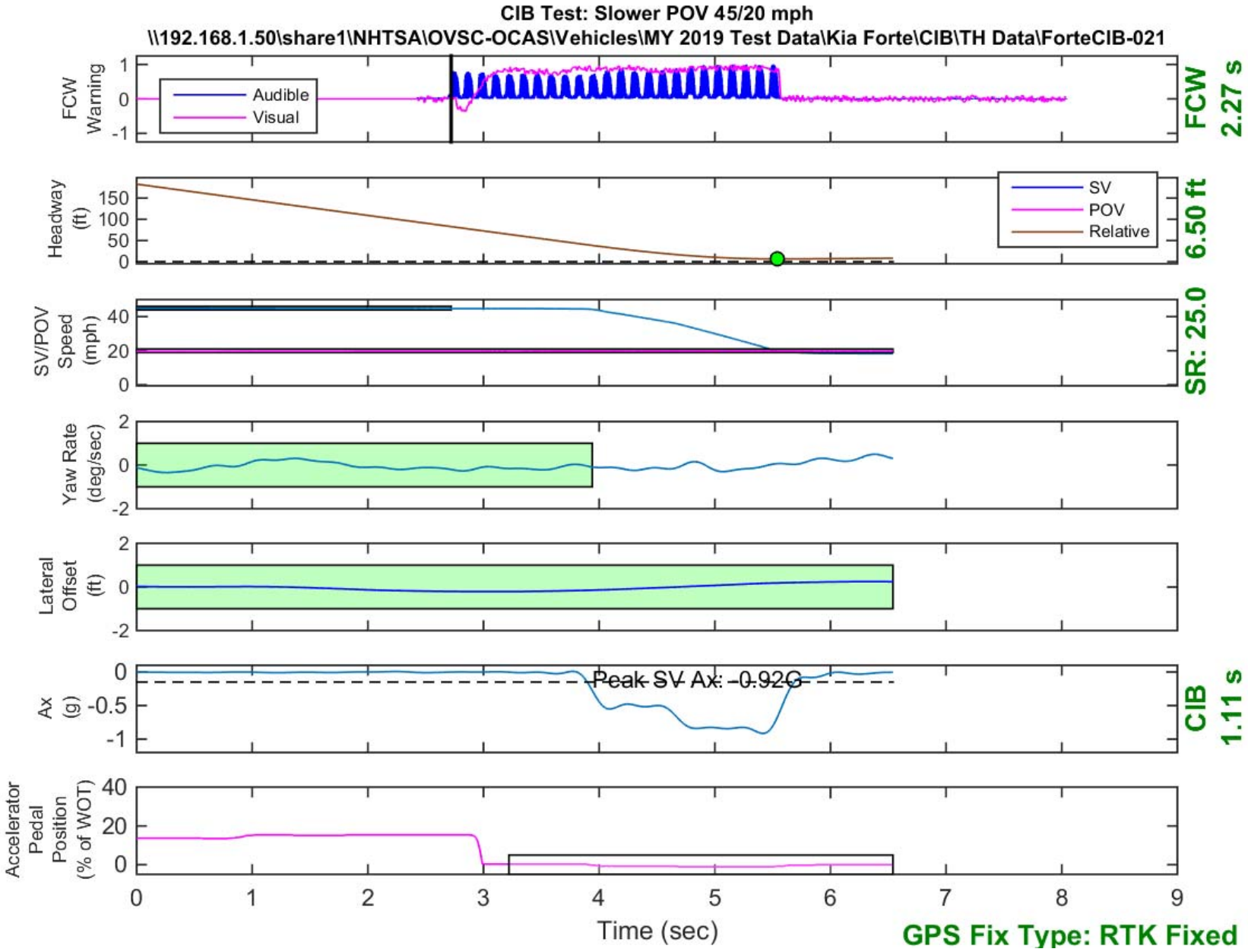


Figure D27. Time History for CIB Run 21, SV Encounters Slower POV, SV 45 mph, POV 20 mph

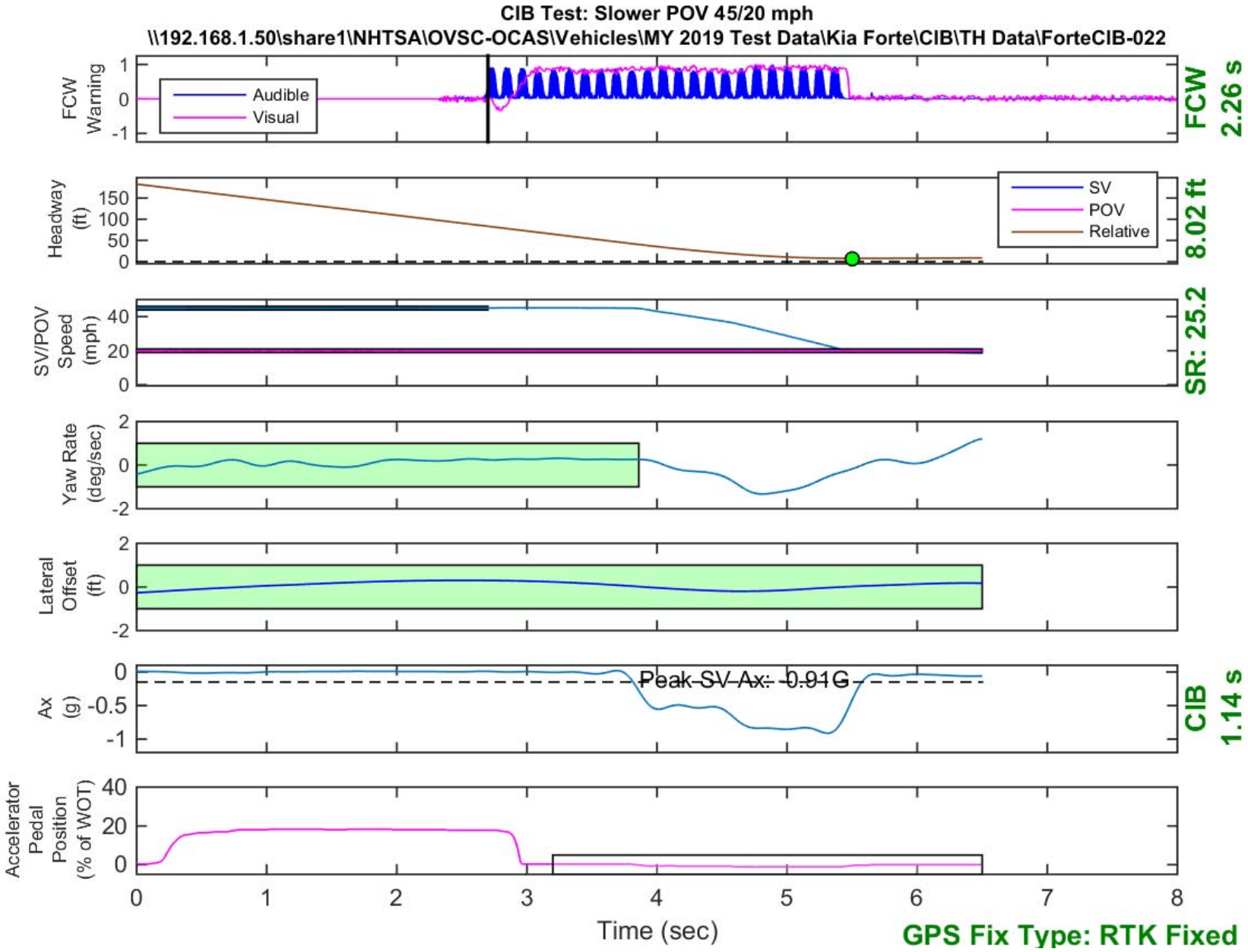


Figure D28. Time History for CIB Run 22, SV Encounters Slower POV, SV 45 mph, POV 20 mph

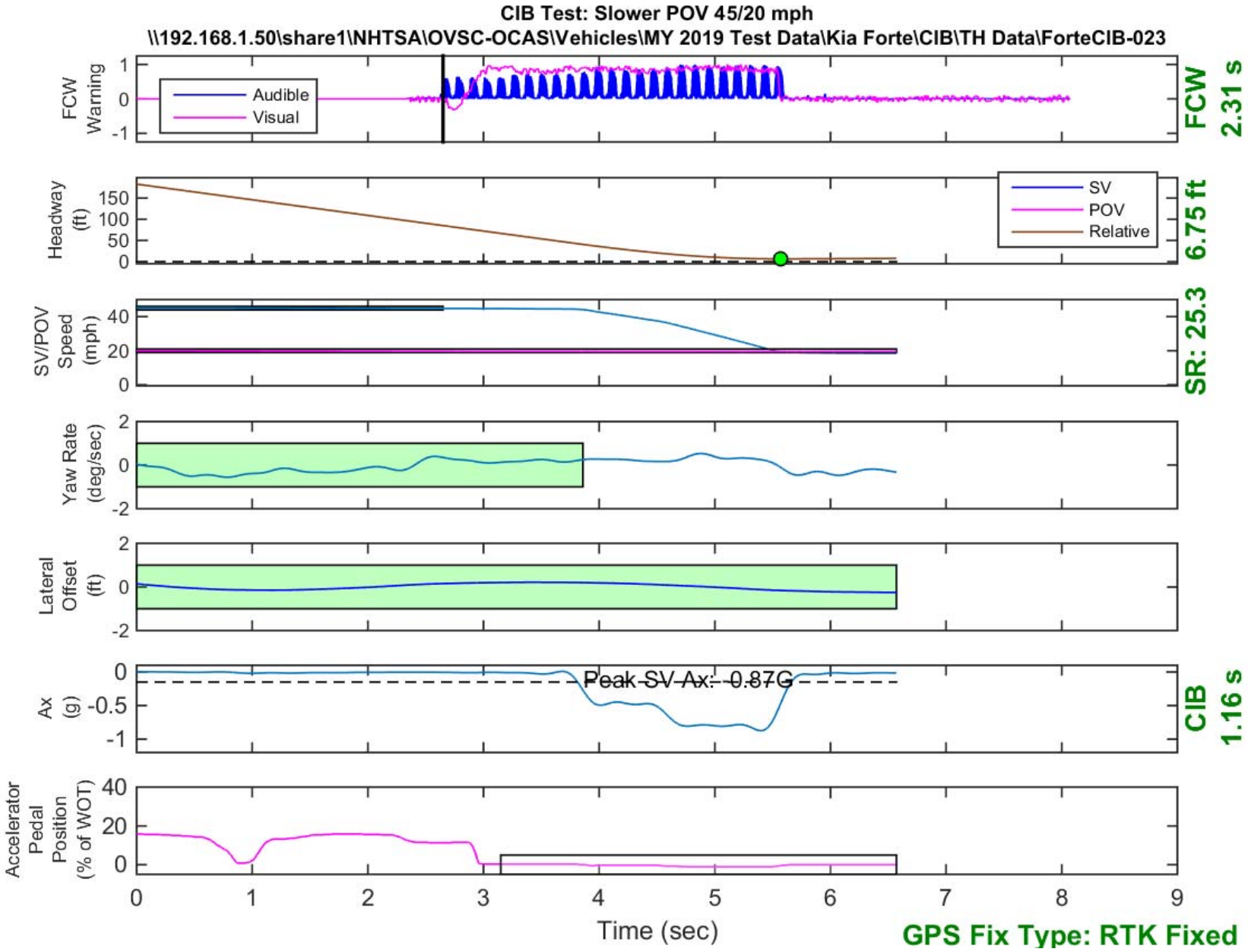


Figure D29. Time History for CIB Run 23, SV Encounters Slower POV, SV 45 mph, POV 20 mph

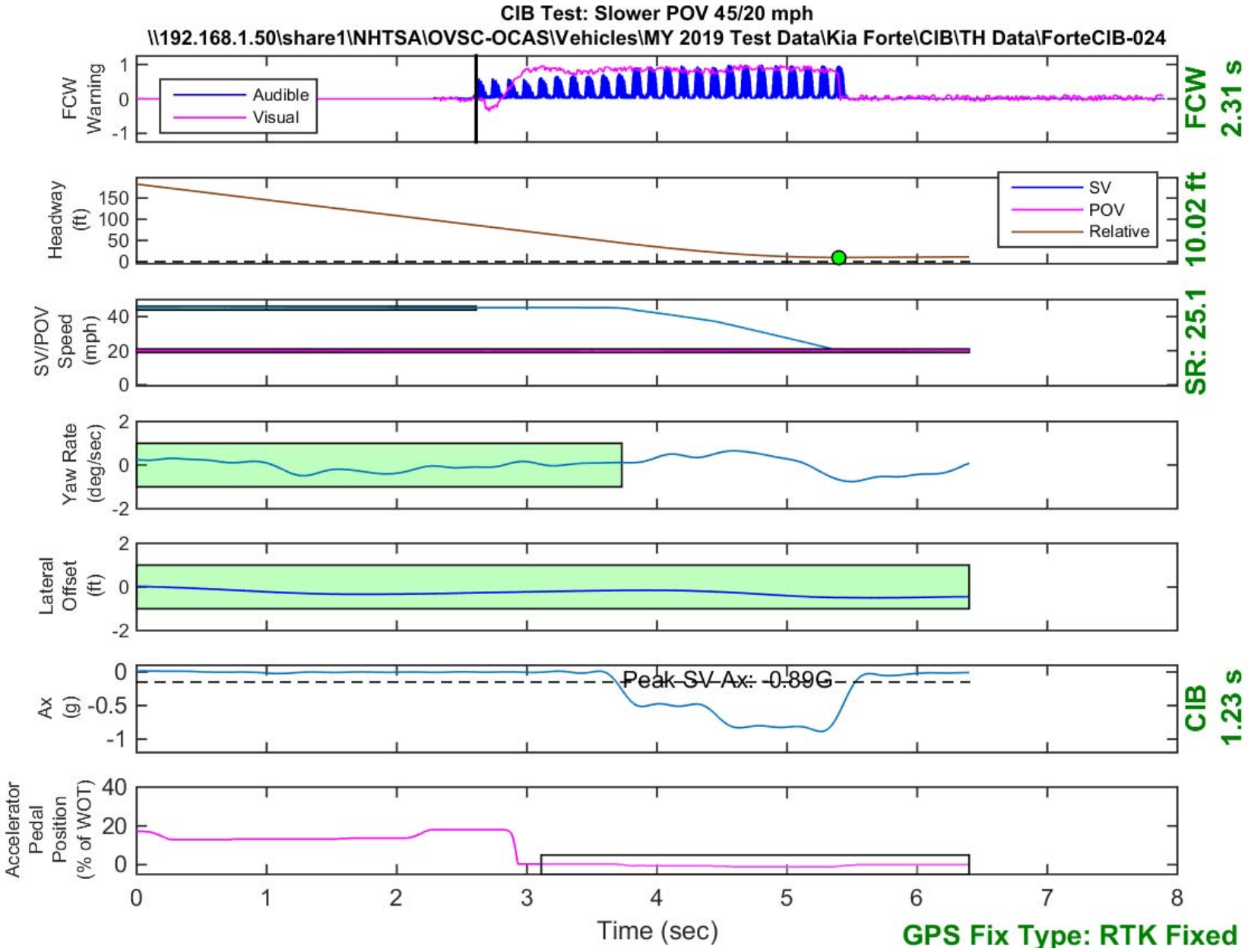


Figure D30. Time History for CIB Run 24, SV Encounters Slower POV, SV 45 mph, POV 20 mph

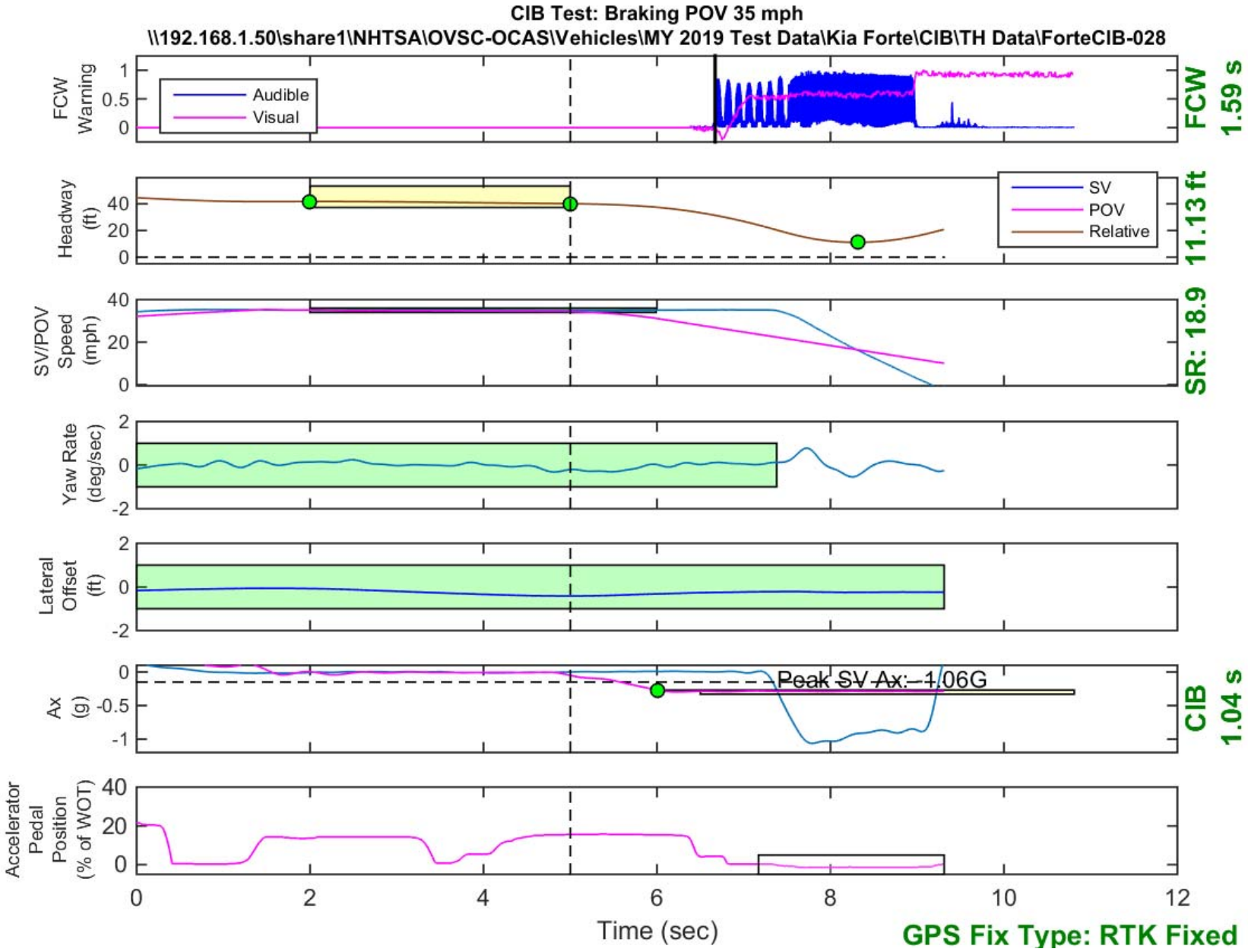


Figure D31. Time History for CIB Run 28, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

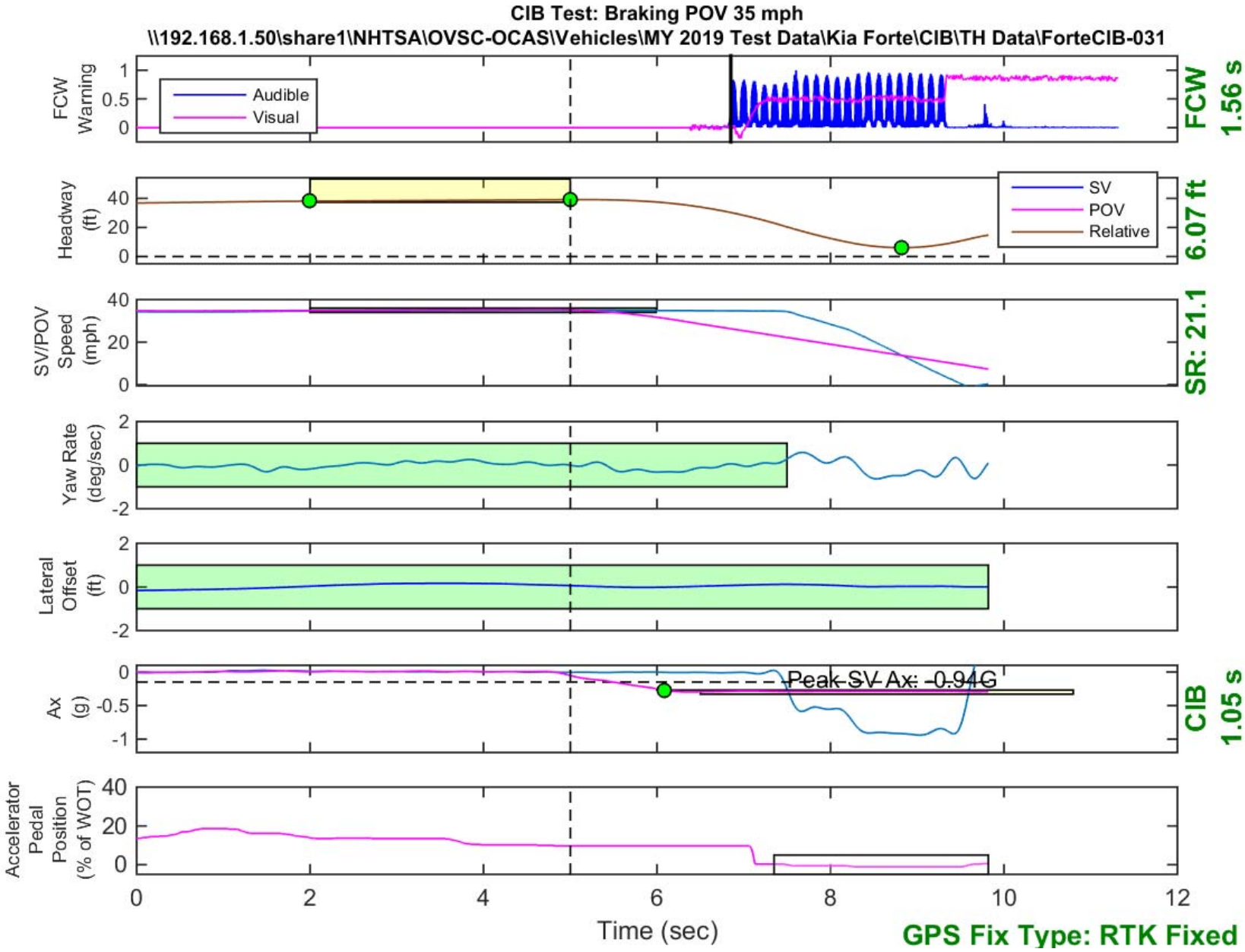


Figure D32. Time History for CIB Run 31, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

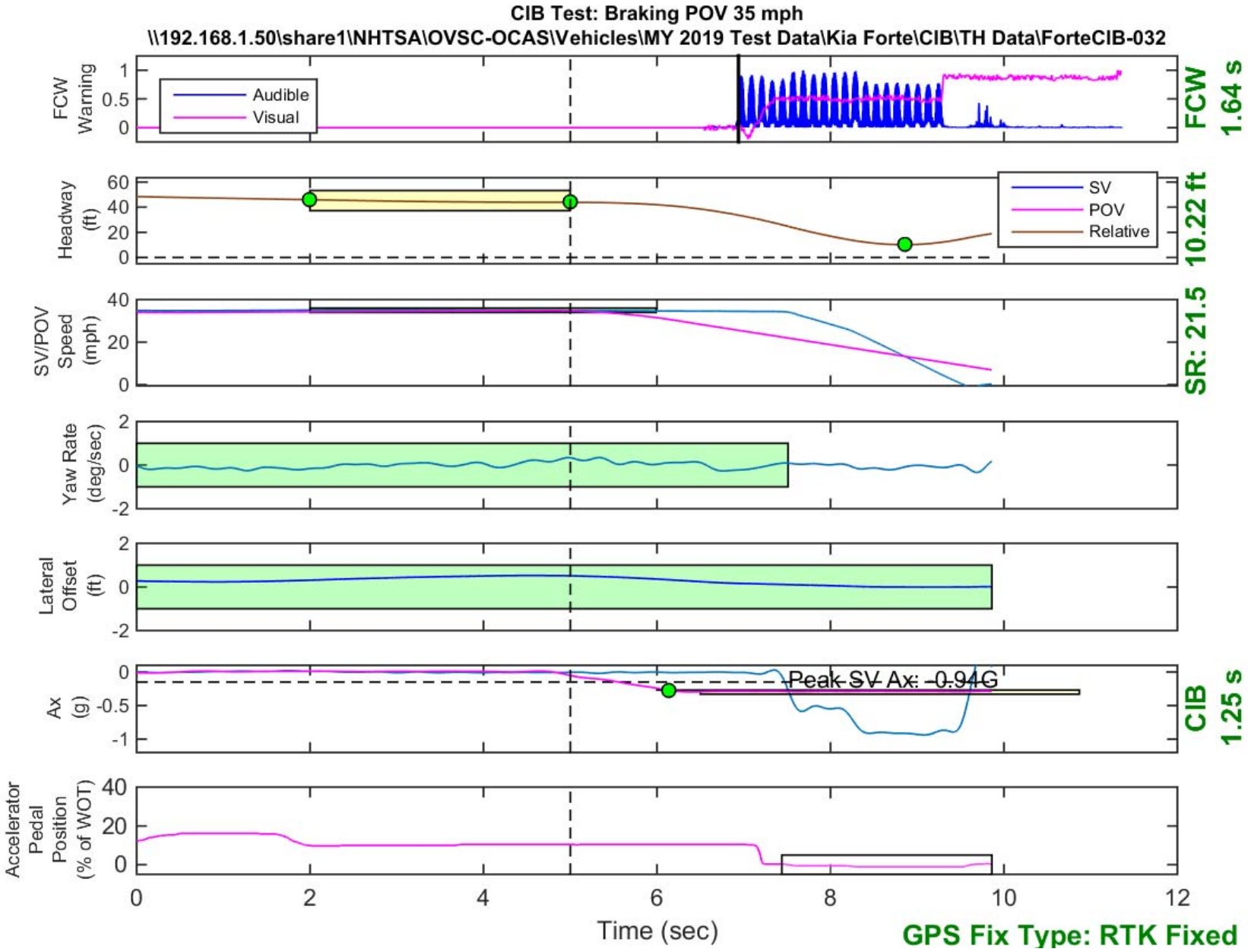


Figure D33. Time History for CIB Run 32, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

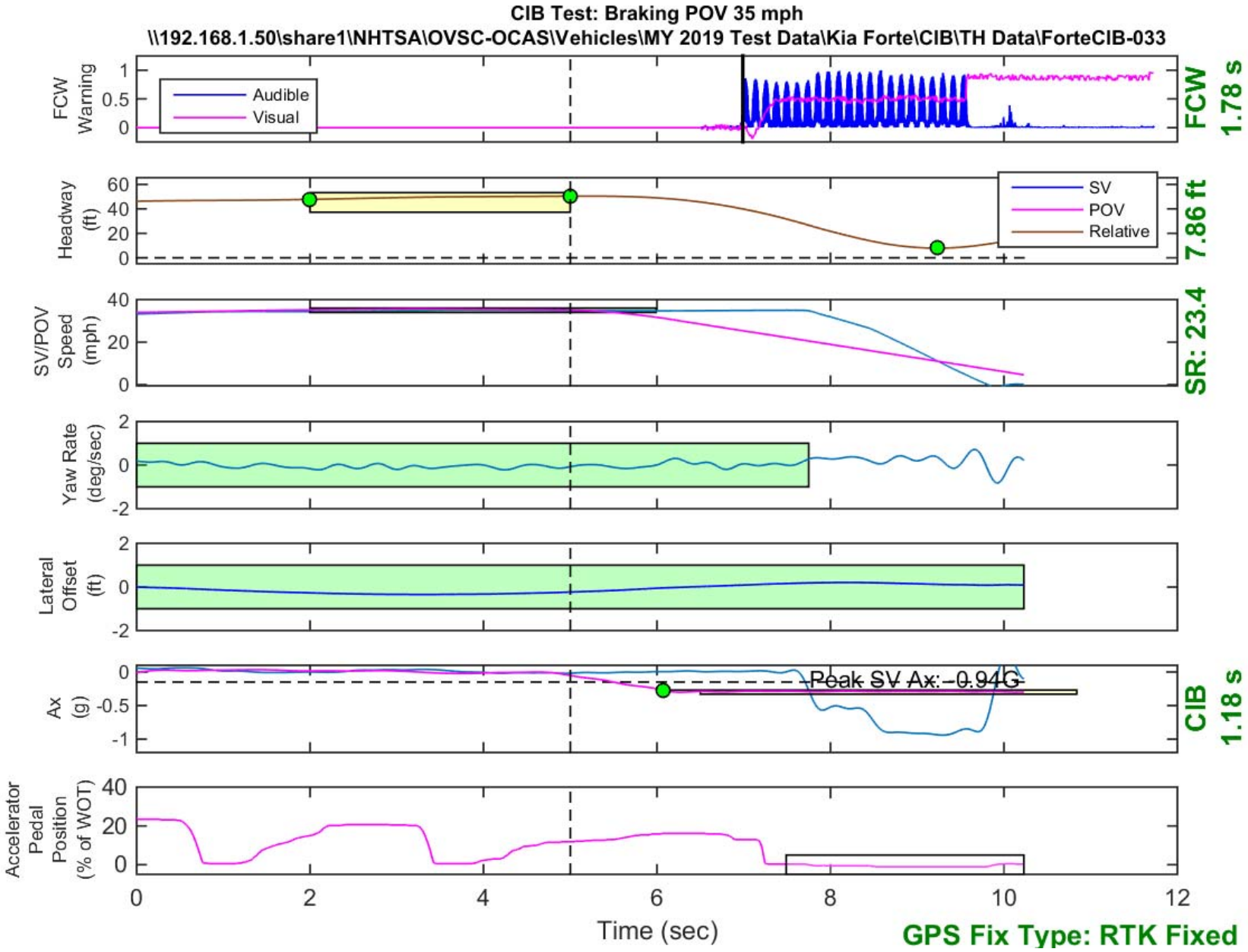


Figure D34. Time History for CIB Run 33, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

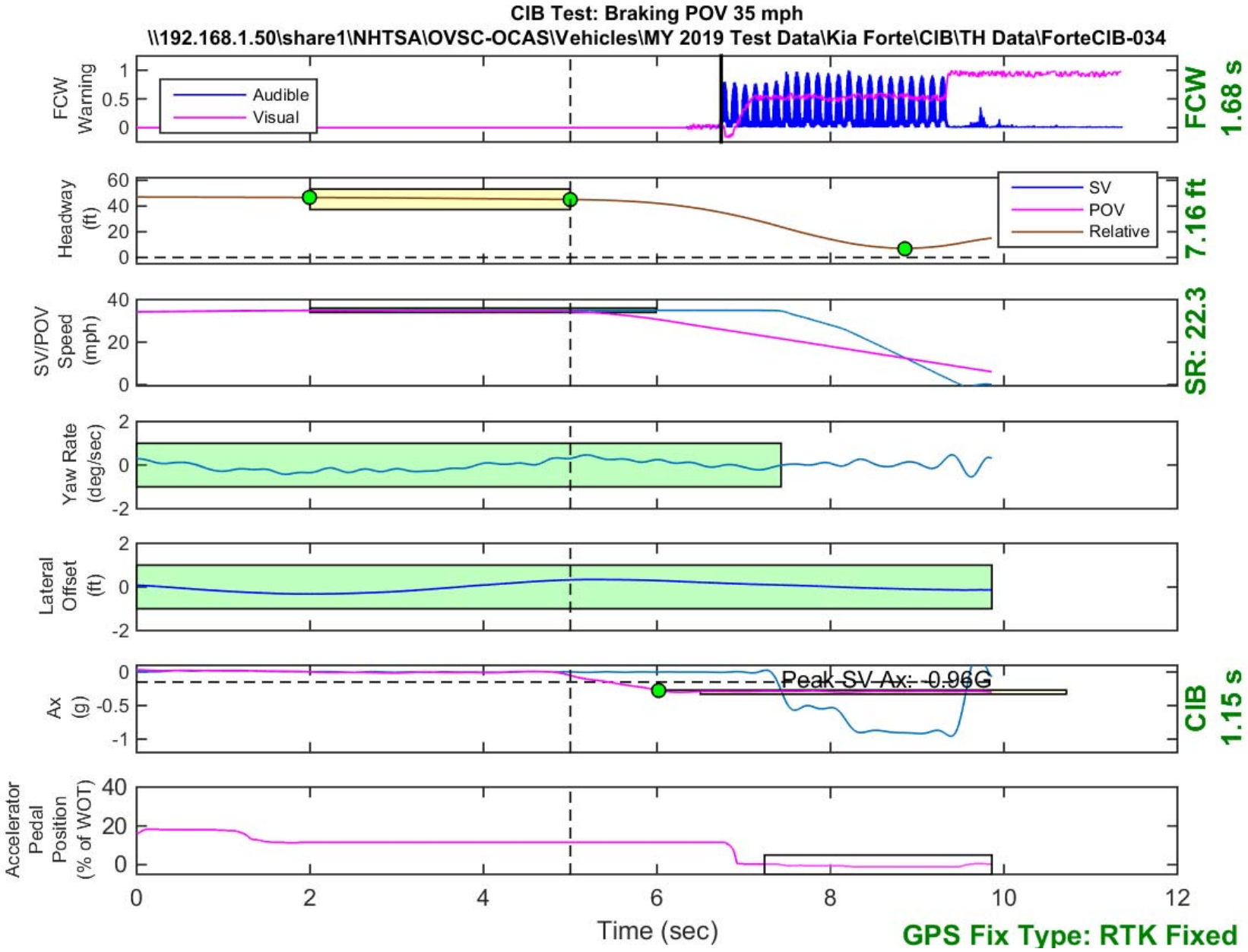


Figure D35. Time History for CIB Run 34, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

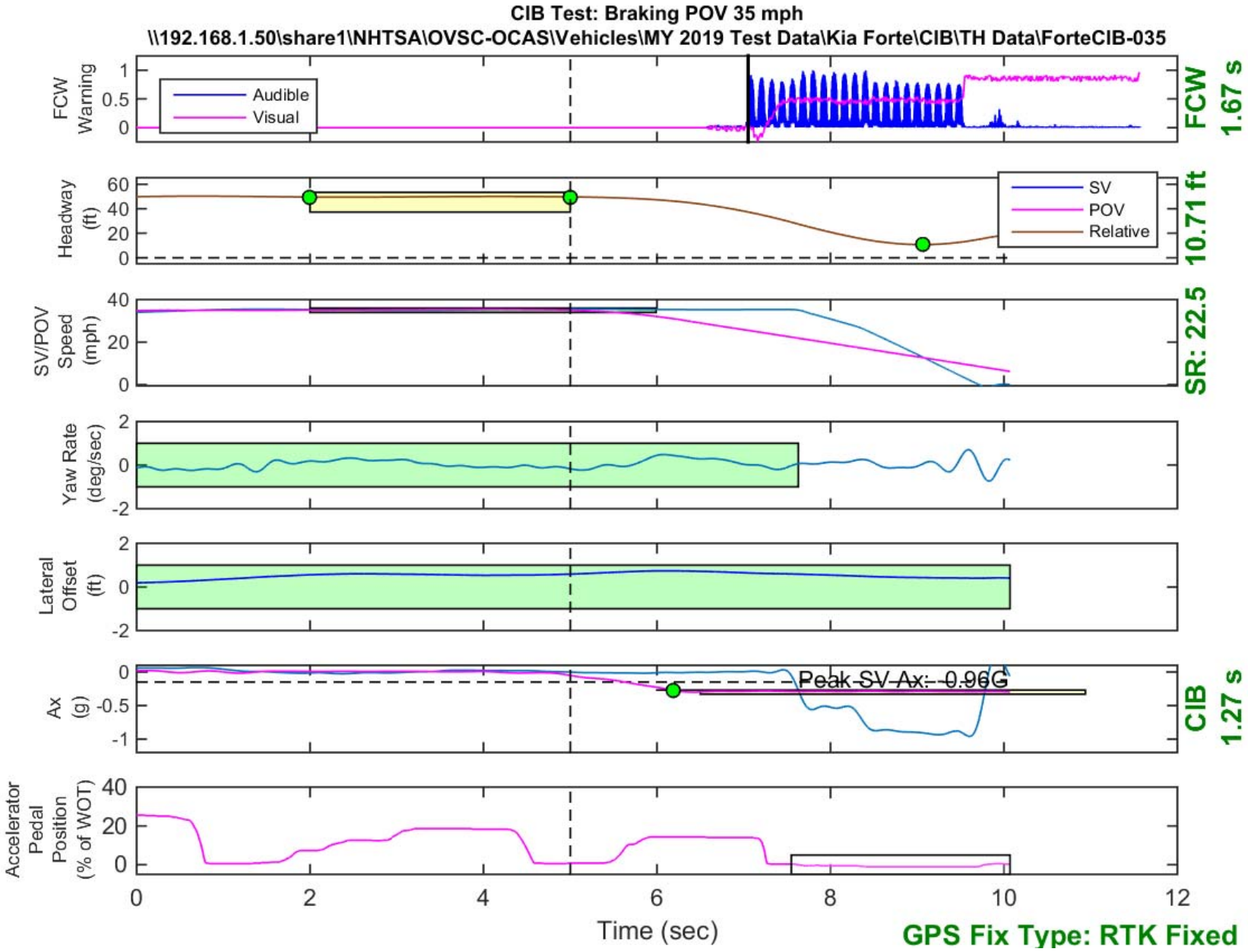


Figure D36. Time History for CIB Run 35, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

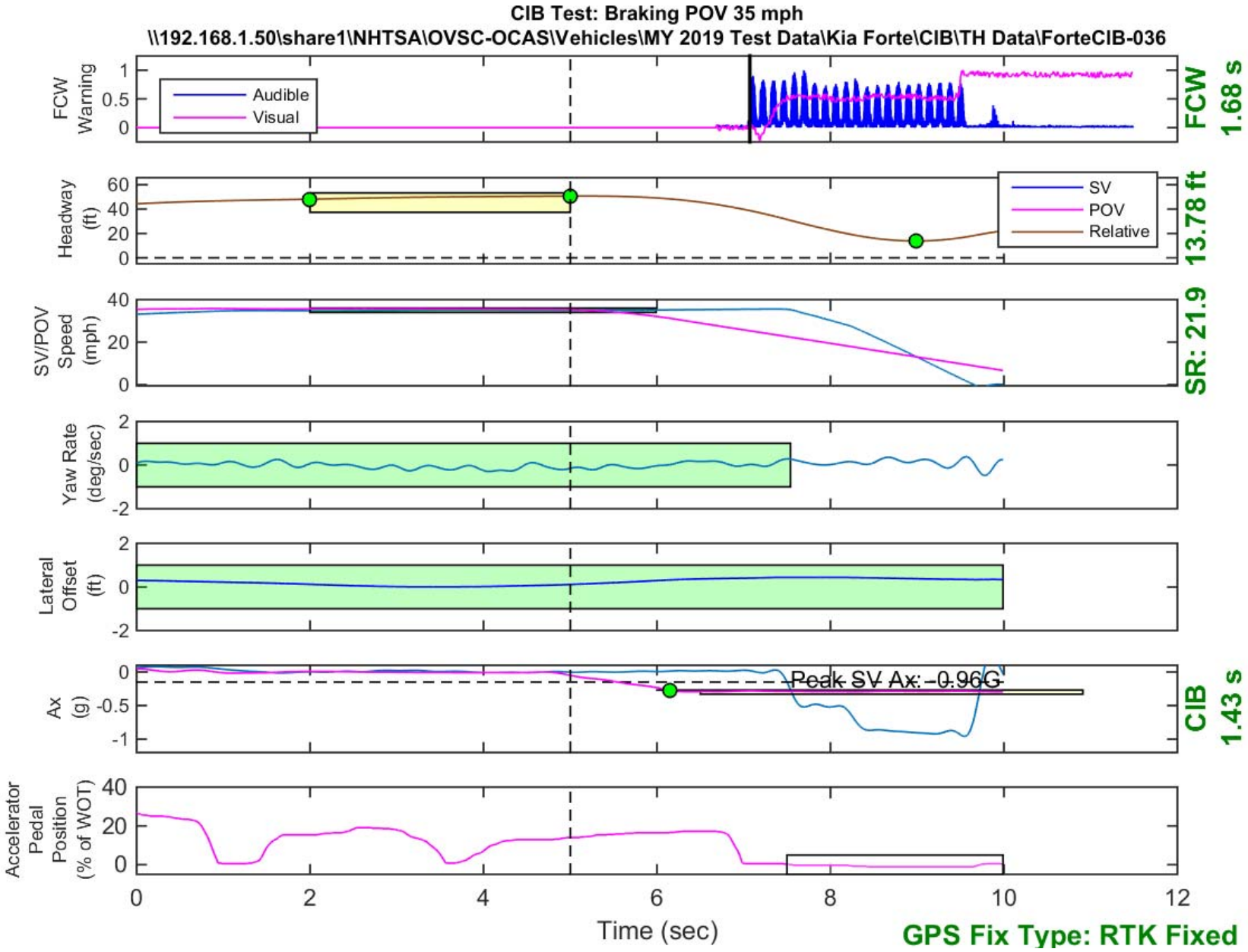


Figure D37. Time History for CIB Run 36, SV Encounters Decelerating POV, SV 35 mph, POV 35 mph

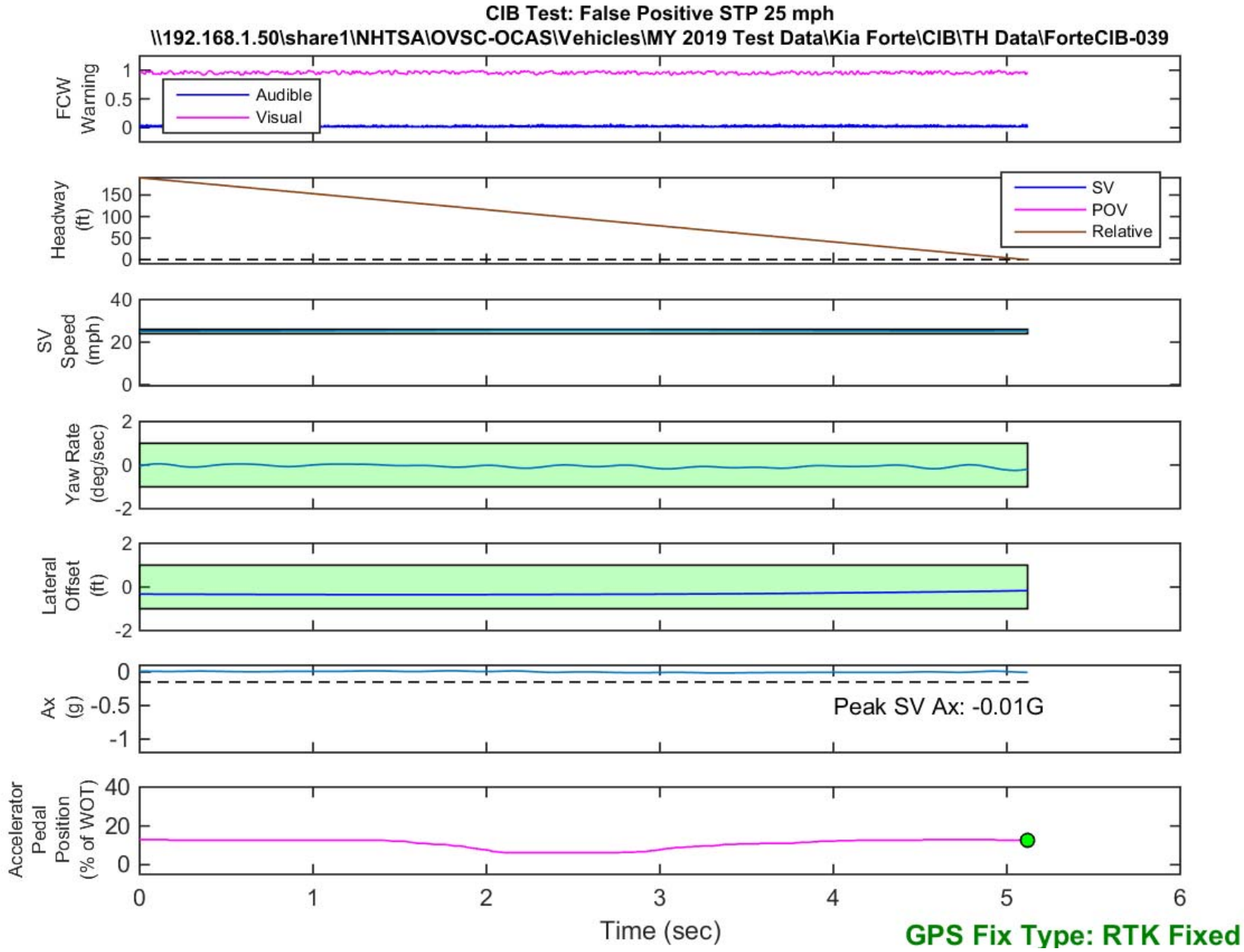


Figure D38. Time History for CIB Run 39, SV Encounters Steel Trench Plate, SV 25 mph

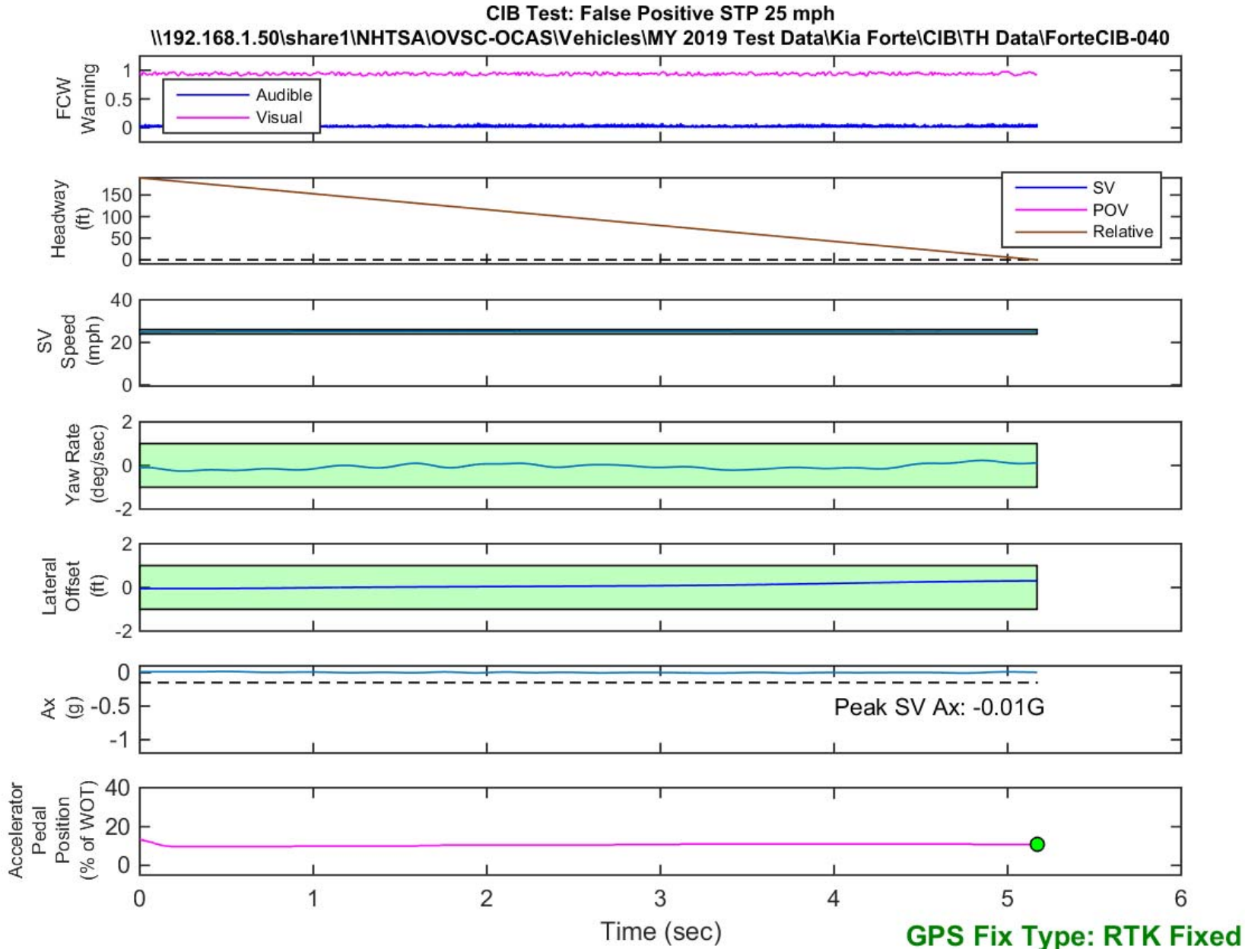


Figure D39. Time History for CIB Run 40, SV Encounters Steel Trench Plate, SV 25 mph

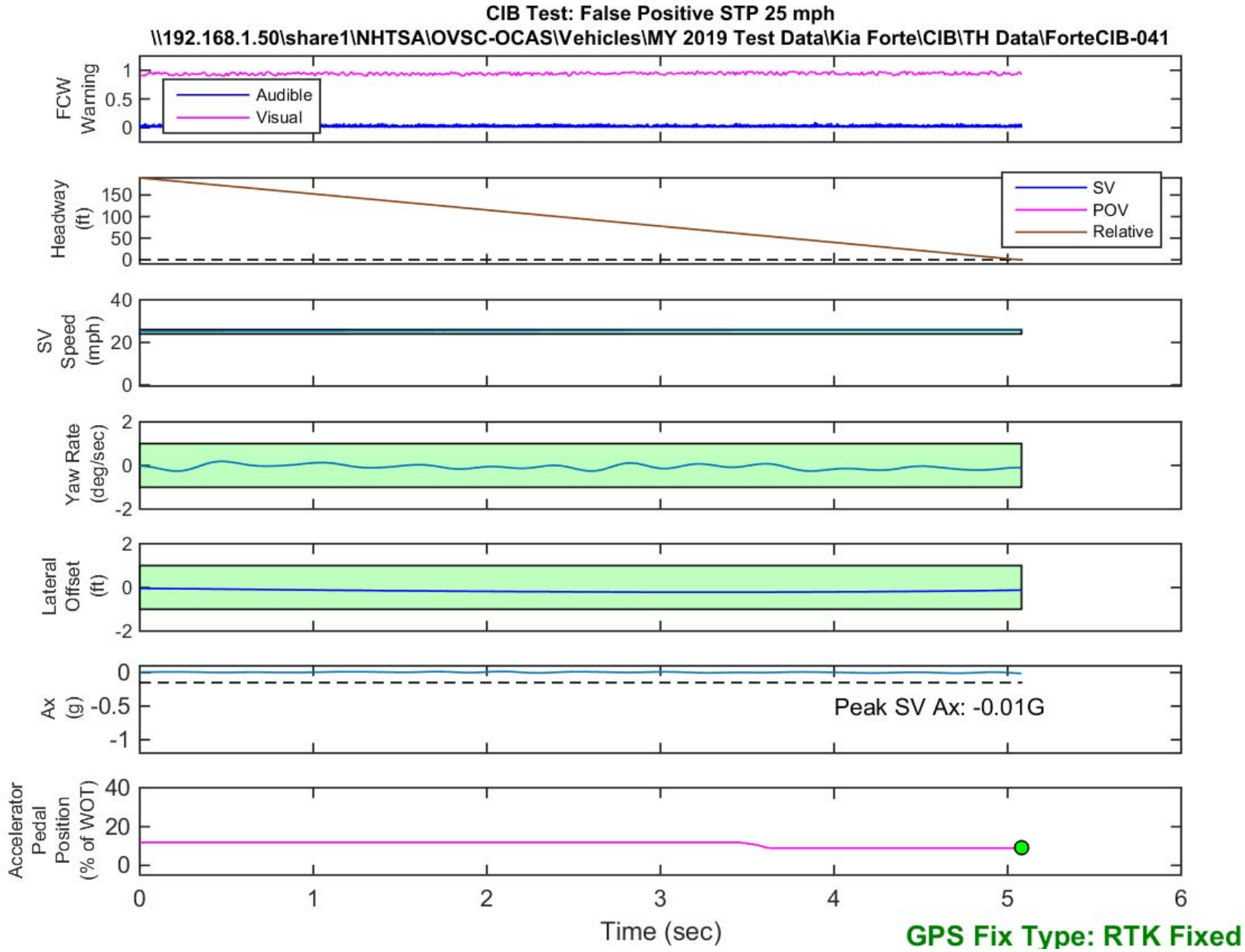


Figure D40. Time History for CIB Run 41, SV Encounters Steel Trench Plate, SV 25 mph

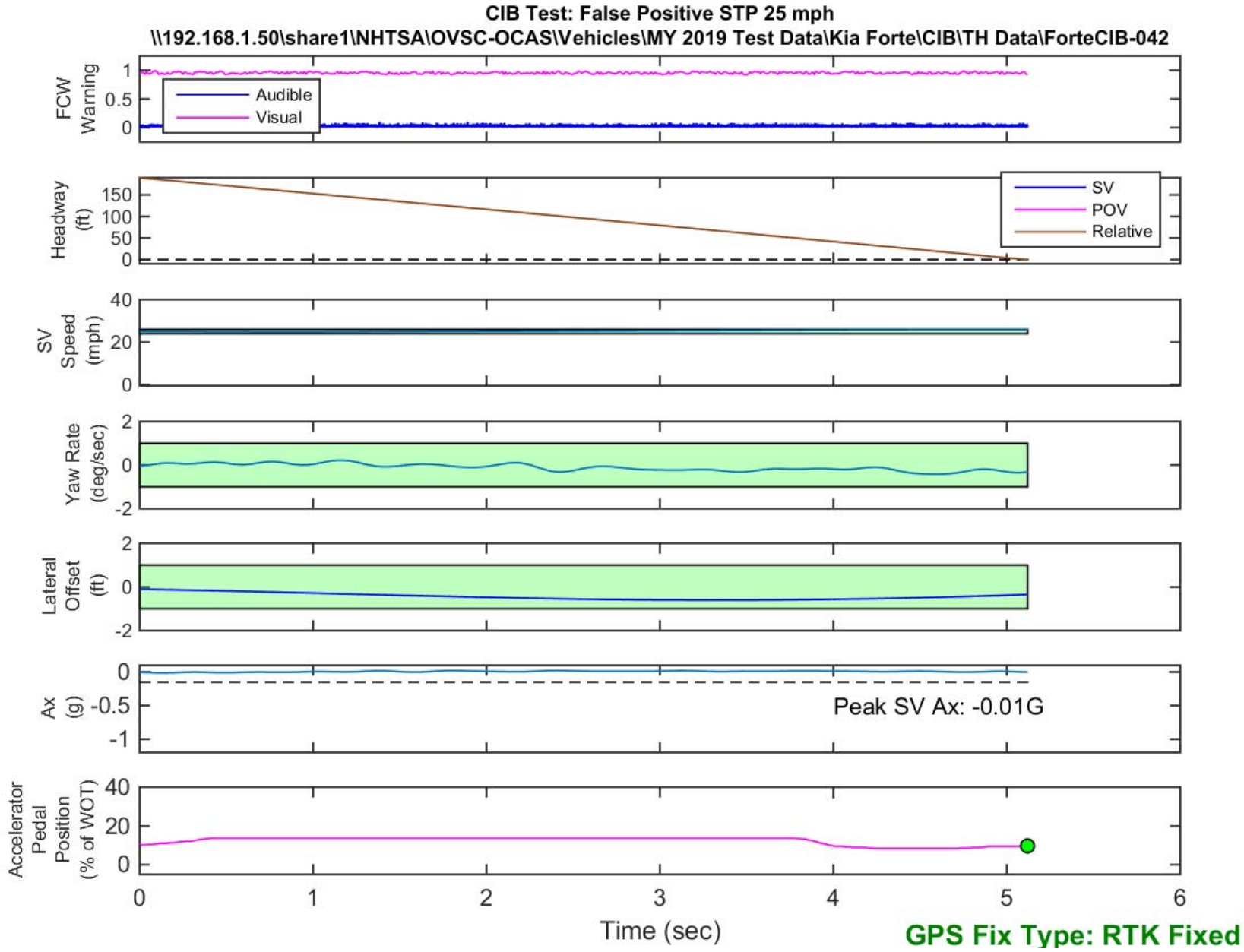


Figure D41. Time History for CIB Run 42, SV Encounters Steel Trench Plate, SV 25 mph

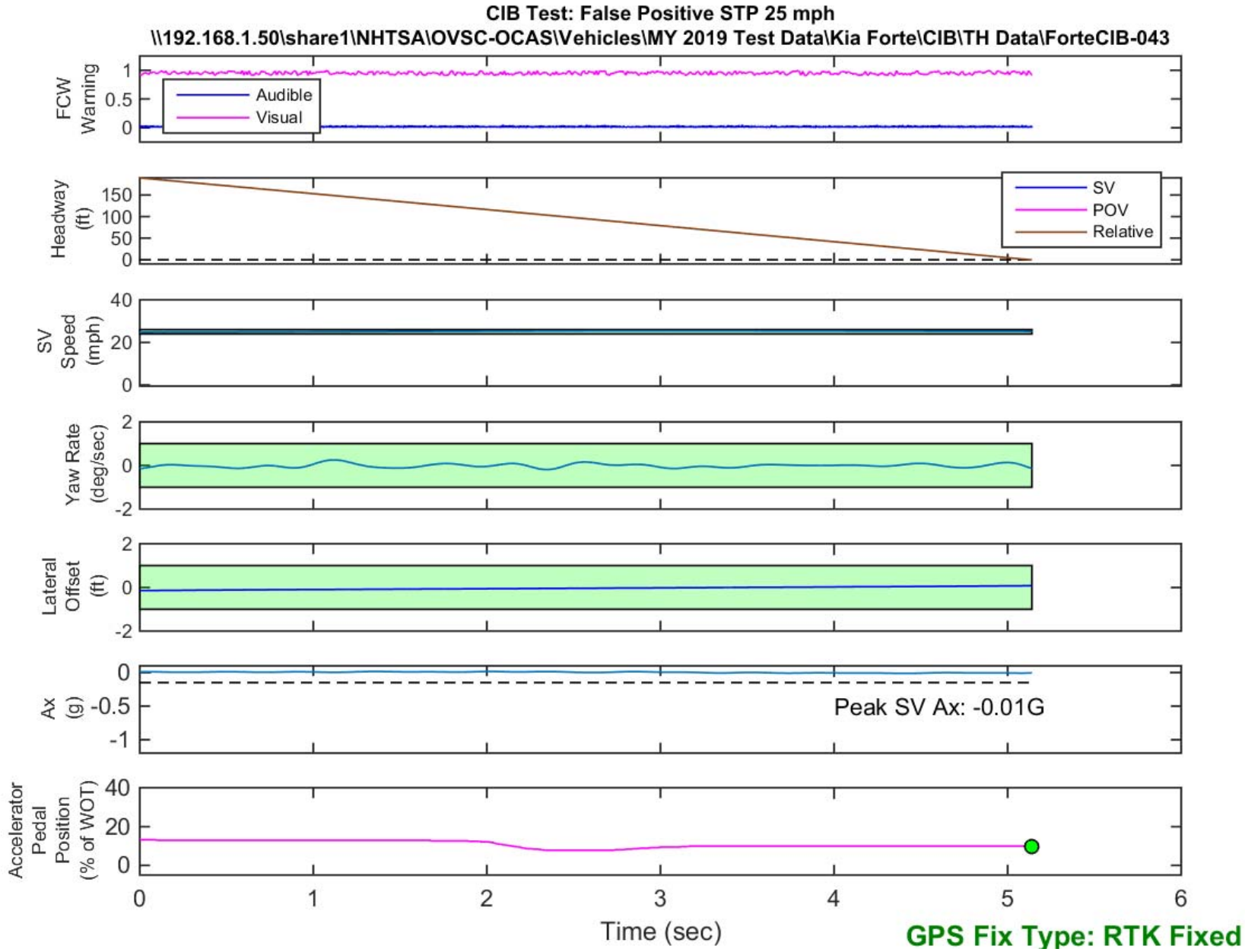


Figure D42. Time History for CIB Run 43, SV Encounters Steel Trench Plate, SV 25 mph

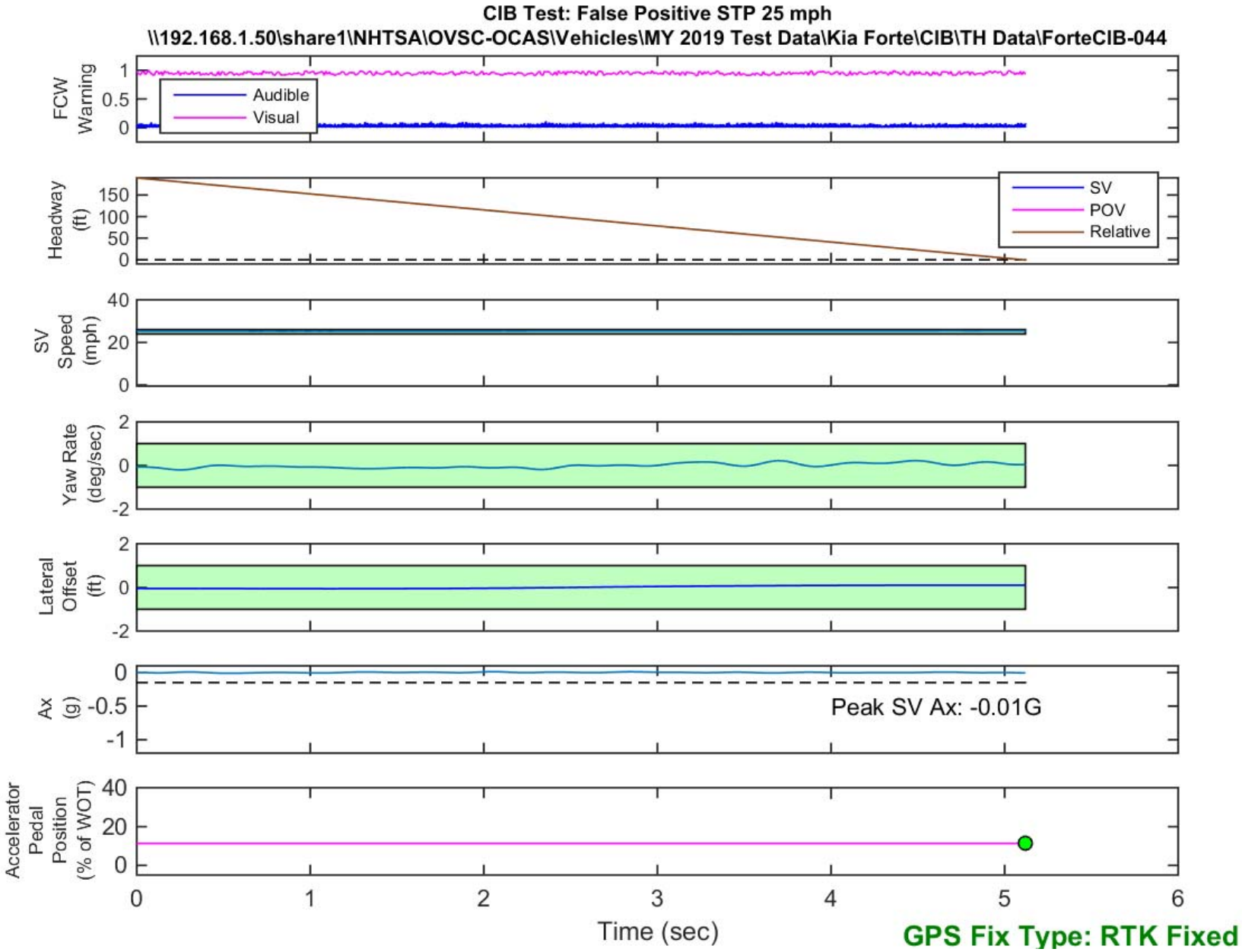


Figure D43. Time History for CIB Run 44, SV Encounters Steel Trench Plate, SV 25 mph

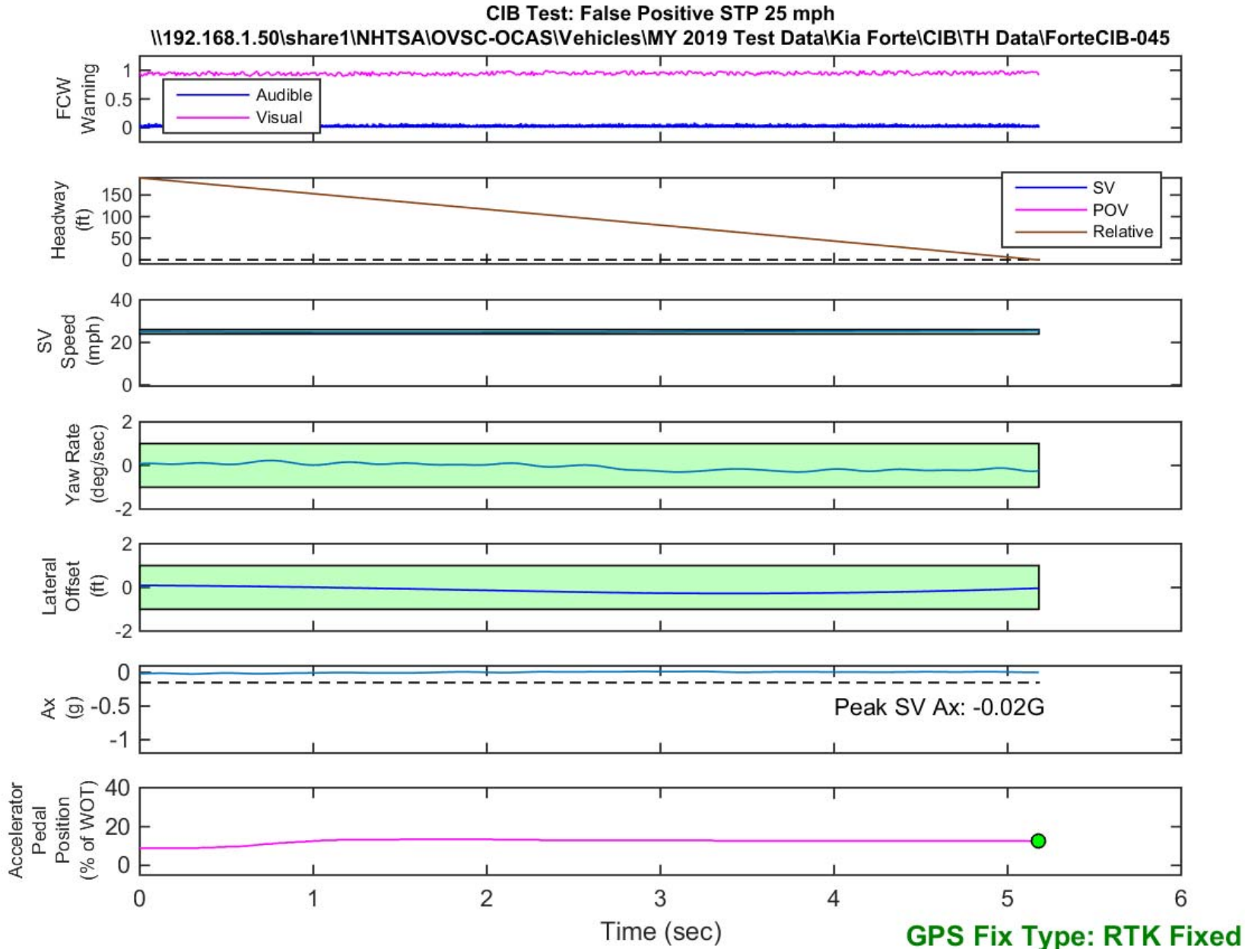


Figure D44. Time History for CIB Run 45, SV Encounters Steel Trench Plate, SV 25 mph

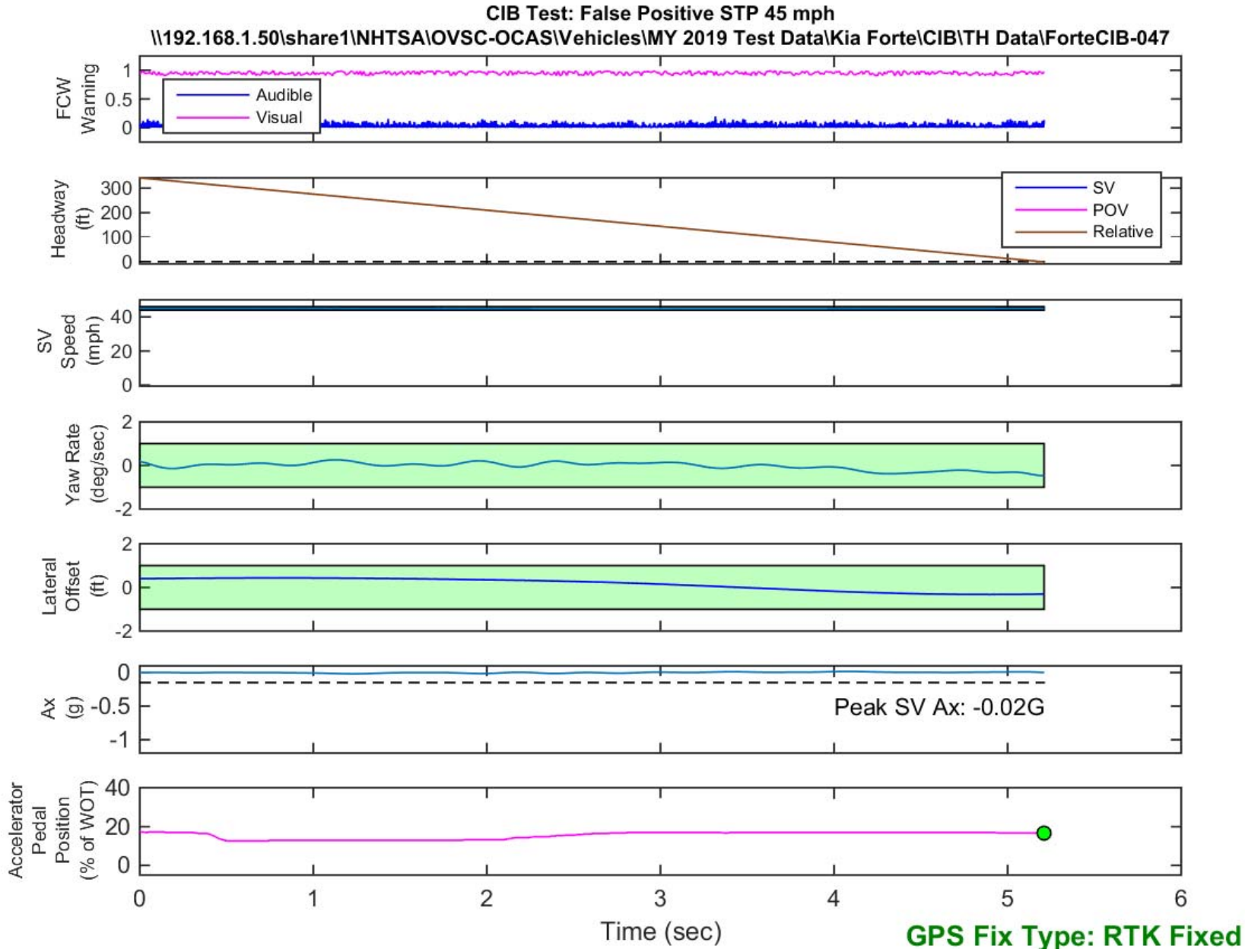


Figure D45. Time History for CIB Run 47, SV Encounters Steel Trench Plate, SV 45 mph

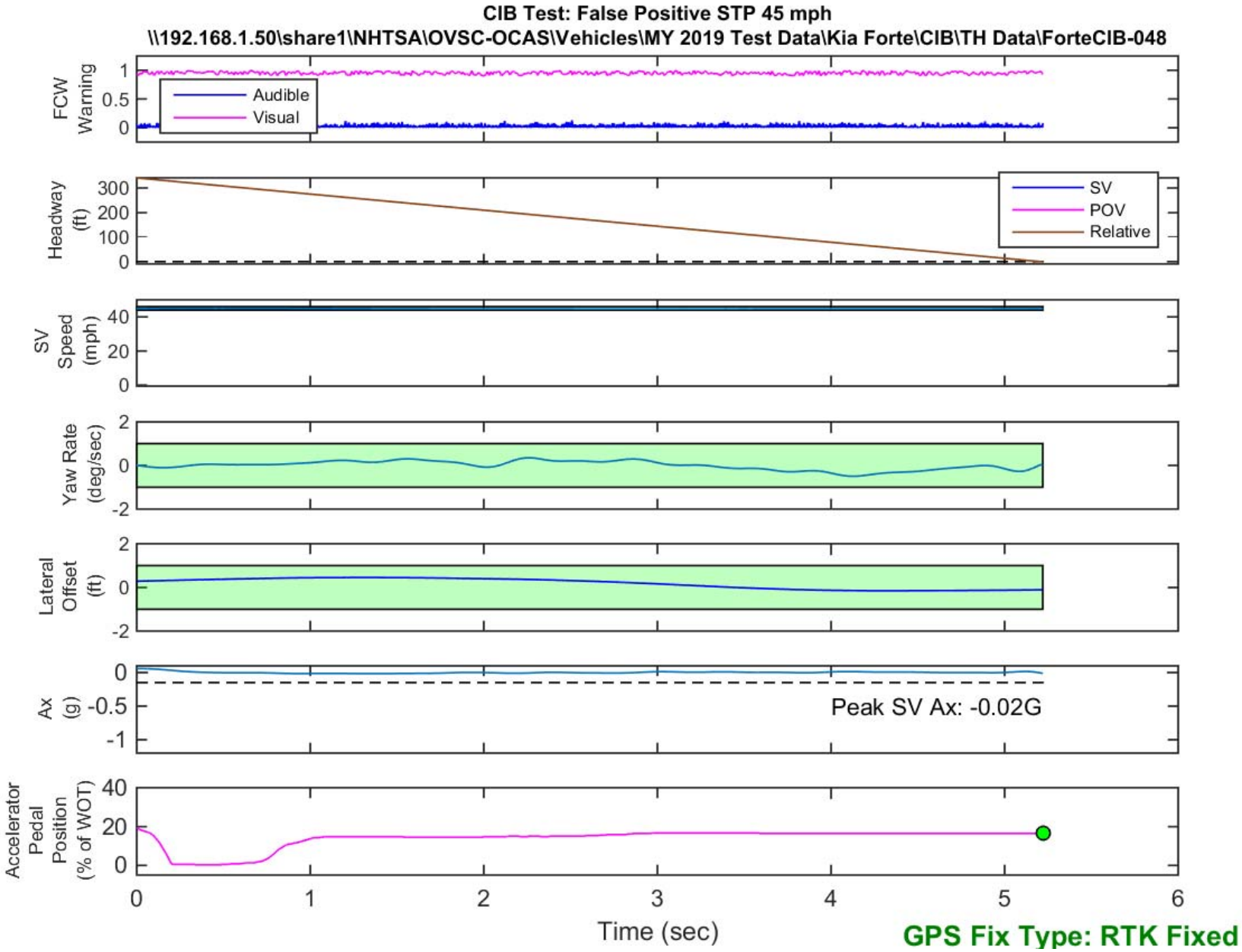


Figure D46. Time History for CIB Run 48, SV Encounters Steel Trench Plate, SV 45 mph

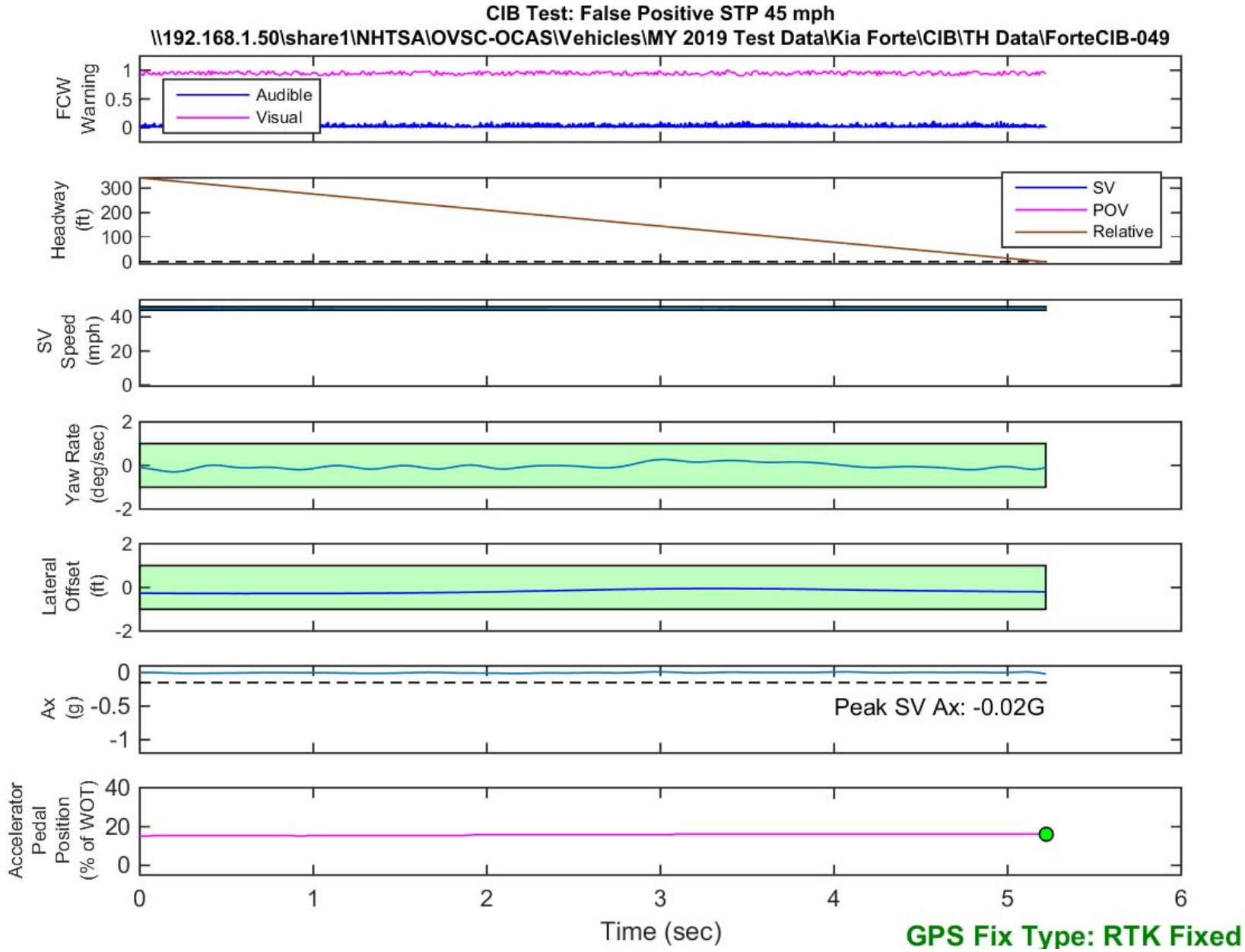


Figure D47. Time History for CIB Run 49, SV Encounters Steel Trench Plate, SV 45 mph

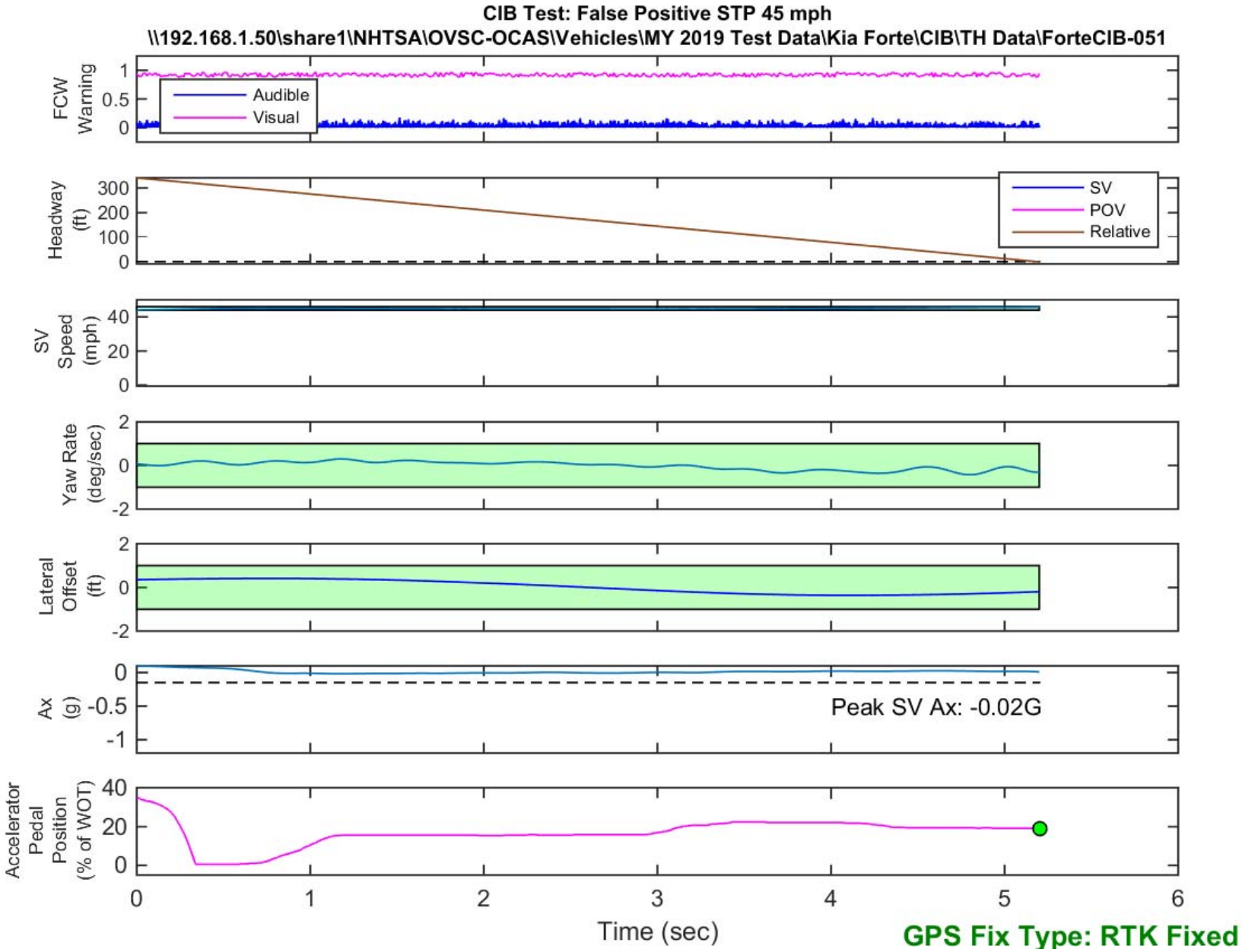


Figure D48. Time History for CIB Run 51, SV Encounters Steel Trench Plate, SV 45 mph

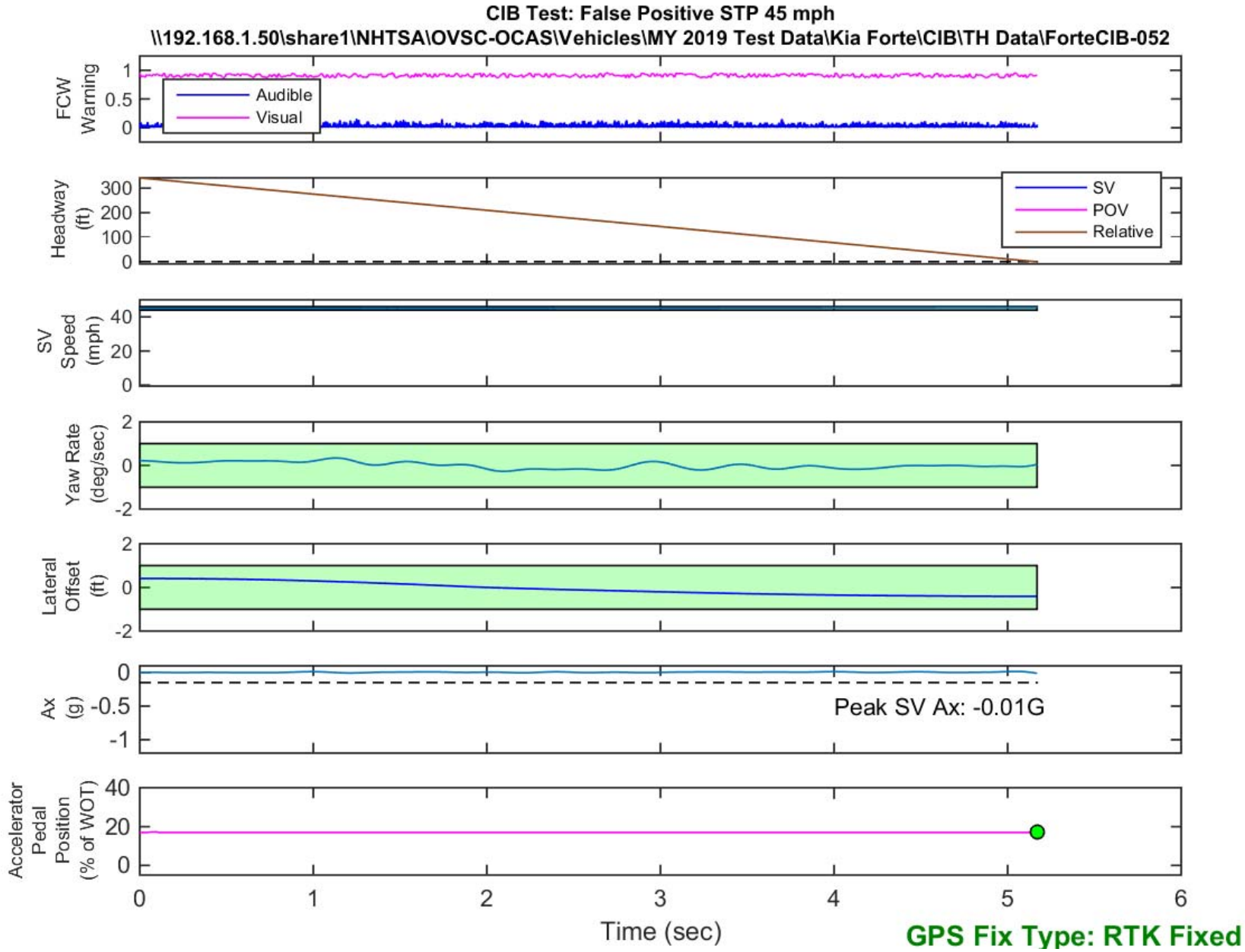


Figure D49. Time History for CIB Run 52, SV Encounters Steel Trench Plate, SV 45 mph

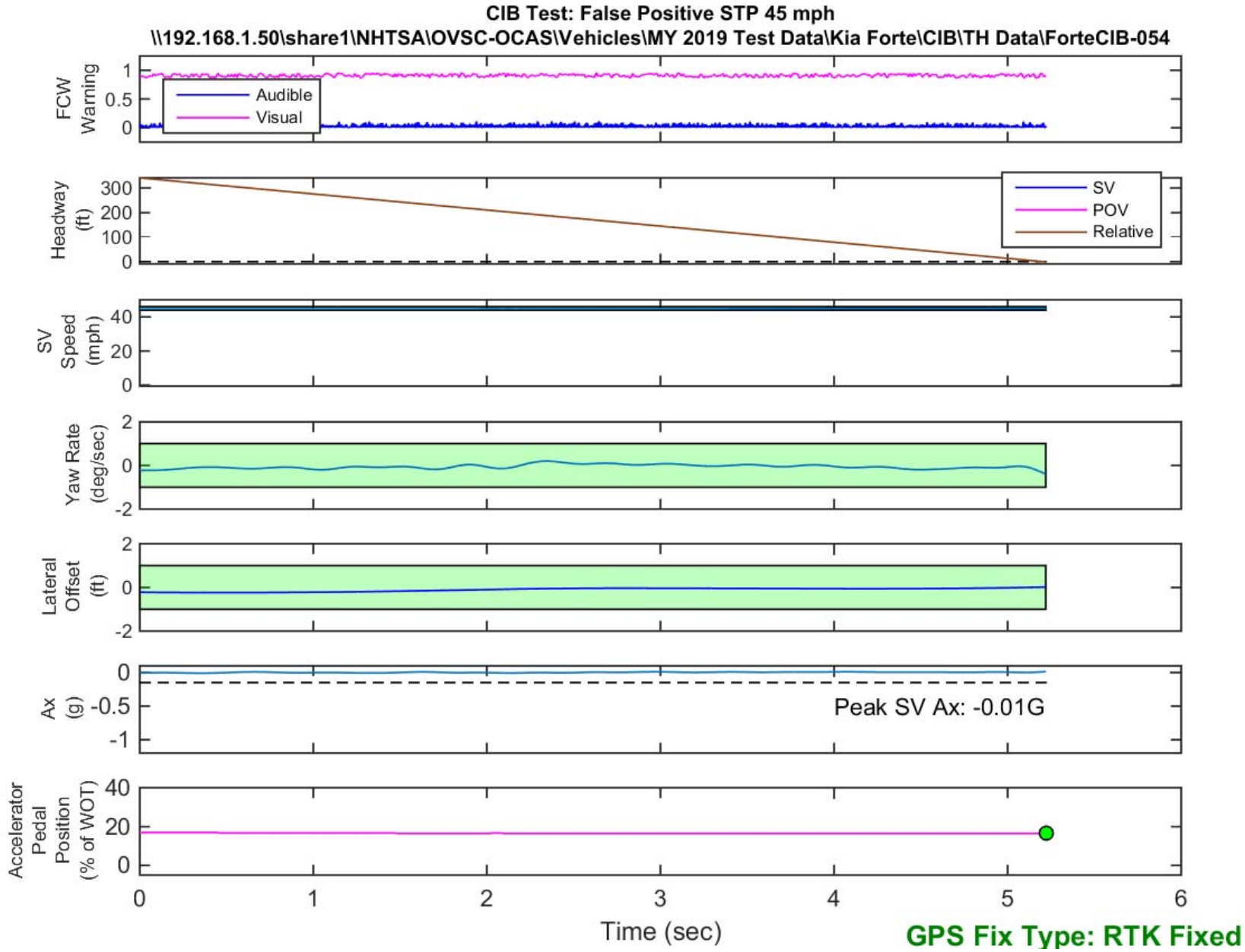


Figure D50. Time History for CIB Run 54, SV Encounters Steel Trench Plate, SV 45 mph

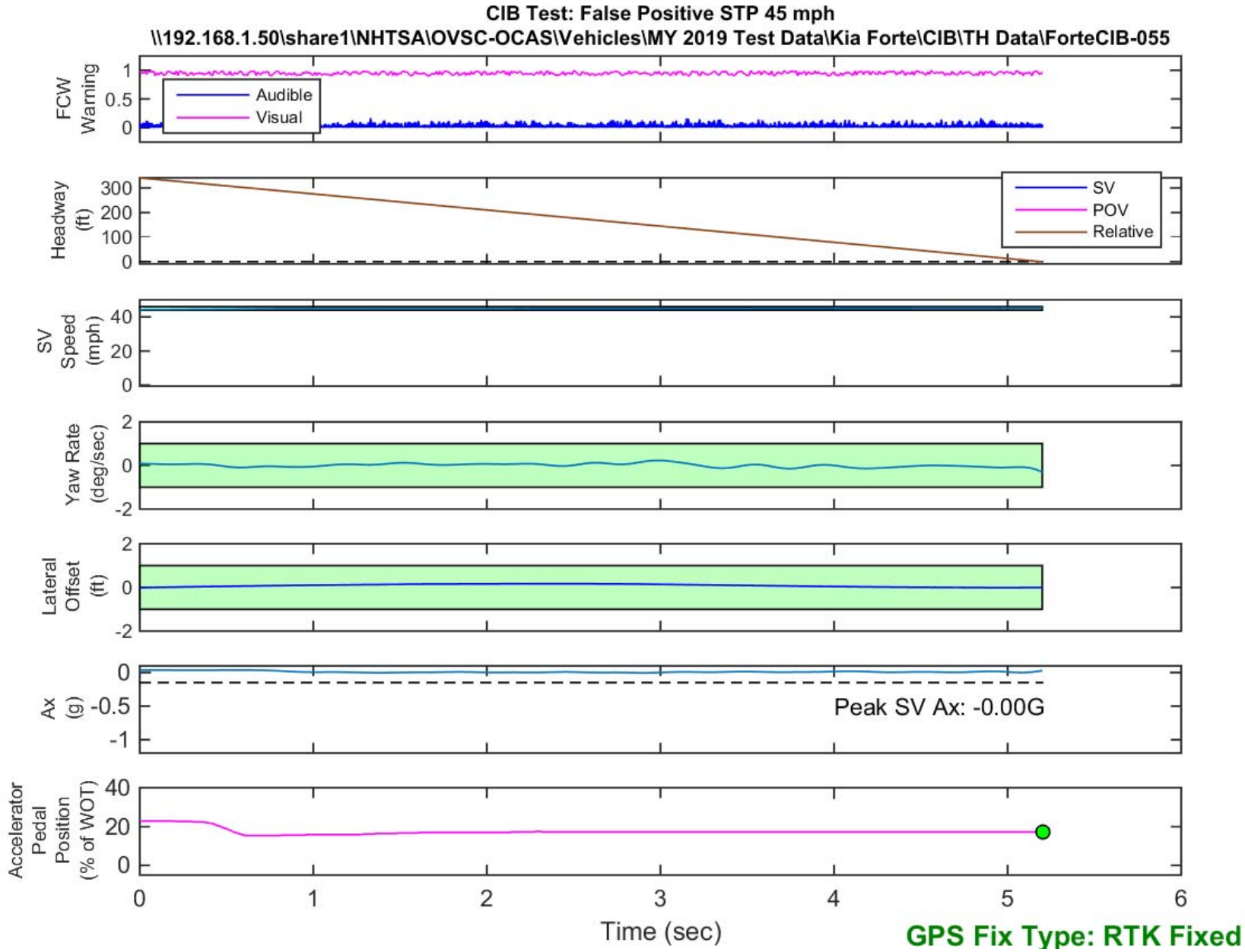


Figure D51. Time History for CIB Run 55, SV Encounters Steel Trench Plate, SV 45 mph