OCAS-DRI-FCW-18-03
NEW CAR ASSESSMENT PROGRAM
FORWARD COLLISION WARNING CONFIRMATION TEST

2018 Hyundai Sonata

DYNAMIC RESEARCH, INC.
355 Van Ness Avenue, STE 200
Torrance, California 90501

11 June 2018

Final Report

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

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

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16. Abstract These tests were conducted on the subject 2018 Hyundai Sonata in accordance with the specifications of the Office of Crash Avoidance Standards most current Test Procedure in docket NHTSA-2006-26555 to confirm the performance of a forward collision warning system. The vehicle passed the requirements of the test for the slower moving POV and decelerating POV scenarios, but failed the requirements of the test for the stopped POV scenario.			
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Section I
INTRODUCTION

This test evaluates the ability of a forward collision warning (FCW) system to detect and alert drivers to potential hazards in the path of the vehicle as specified in the New Car Assessment Program "Forward Collision Warning Confirmation", February 2013. Three driving scenarios are utilized to assess this technology. In the first test, a subject vehicle (SV) approaches a stopped principle other vehicle (POV) in the same lane of travel. The second test begins with the SV initially following the POV at the same constant speed. After a short while, the POV stops suddenly. The third test consists of the SV, traveling at a constant speed, approaching a slower moving POV, which is also being driven at a constant speed.

Section II
DATA SHEETS

FORWARD COLLISION WARNING

DATA SHEET 1: TEST SUMMARY

2018 Hyundai Sonata

VIN: *5NPE34AF0JH6xxxx*

Test Date: *2/6/2018*

Forward Collision Warning setting: *Early*

Test 1 -	Subject Vehicle Encounters Stopped Principal Other Vehicle:	***Fail***
Test 2 -	Subject Vehicle Encounters Decelerating Principal Other Vehicle:	***Pass***
Test 3 -	Subject Vehicle Encounters Slower Principal Other Vehicle:	***Pass***
	Overall:	***Fail***

Notes:

FORWARD COLLISION WARNING

DATA SHEET 2: VEHICLE DATA

(Page 1 of 2)

2018 Hyundai Sonata

TEST VEHICLE INFORMATION

VIN: *5NPE34AF0JH6xxxx*

Body Style: *Sedan* Color: *Silver*

Date Received: *1/30/2018* Odometer Reading: *5 mi*

Engine: *2.4 L Inline 4*

Transmission: *Automatic*

Final Drive: *FWD*

Is the vehicle equipped with:

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

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Hyundai Motor Manufacturing Alabama LLC*

Date of manufacture: *11/21/2017*

DATA FROM TIRE PLACARD:

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

Rear: *215/55 R17*

Recommended cold tire pressure: Front: *235 kPa (34 psi)*

Rear: *235 kPa (34 psi)*

FORWARD COLLISION WARNING

DATA SHEET 2: VEHICLE DATA

(Page 2 of 2)

2018 Hyundai Sonata

TIRES

Tire manufacturer and model: *Kumho Solus TA31*

Front tire size: *215/55 R17*

Rear tire size: *215/55 R17*

VEHICLE ACCEPTANCE

Verify the following before accepting the vehicle

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

X Tires and wheel rims are the same as listed.

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

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

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

FORWARD COLLISION WARNING

DATA SHEET 3: TEST CONDITIONS (Page 1 of 2)

2018 Hyundai Sonata

GENERAL INFORMATION

Test date: *2/6/2018*

AMBIENT CONDITIONS

Air temperature: *23.3 C (74 F)*

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

X Wind speed ≤ 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: *235 kPa (34 psi)*

Rear: *235 kPa (34 psi)*

FORWARD COLLISION WARNING

DATA SHEET 3: TEST CONDITIONS (Page 2 of 2)

2018 Hyundai Sonata

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*508.5 kg (1121 lb)*	Right Front	*473.6 kg (1044 lb)*
Left Rear	*347.9 kg (767 lb)*	Right Rear	*344.7 kg (760 lb)*
		Total:	*1674.7 kg (3692 lb)*

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

(Page 1 of 3)

2018 Hyundai Sonata

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.

The vehicle provides both visual and audible alerts.
The audible alert consists of a series of repeated beeps whose primary frequency is approximately 1498 Hz.
The visual alert is provided to the driver via the center of the instrument panel in front of the driver. The visual alert consists of a picture of the front end of a vehicle about to collide with the rear end of a second vehicle with an exclamation point in between and the words "Forward Warning" above.

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

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2018 Hyundai Sonata

Is the vehicle equipped with a switch whose purpose is to render FCW inoperable?

X Yes

____ No

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

Using the buttons located on the right hand side of the steering wheel and the display in the center of the instrument panel in front of the driver select the following: Driving Assist --> AEB (Automatic Emergency Brake) --> check box indicates system on/off.

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

X Yes

____ No

If yes please provide a full description

The range of the FCW alert can be changed between Early/Normal/Late.

To adjust the range, use the buttons on the right hand side of the steering wheel and the display in the center of the instrument panel in front of the driver. Select: Driving Assist --> FCW (Fwd. Collision Warning) --> Late/Normal/Early.

Are there other driving modes or conditions that render FCW inoperable or reduce its effectiveness?

X Yes

____ No

If yes please provide a full description.

FCW can be inoperable in the following conditions :

- *The radar or the camera is contaminated with foreign substances. It heavily rains or snows.*
- *There is interruption by electric waves.*
- *There is severe irregular reflection from the radar. The driver's view is unclear due to the backlight, the 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.*

FCW can be inoperable in the following driving modes:

- *The gear status is 'P'(Parking) or 'R'(Reverse).*
- *The velocity of the subject vehicle is under the minimum velocity, and over the maximum velocity.*

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

- *The radar sensor or camera is blocked with a foreign object or debris*
- *Inclement weather such as heavy rain or snow obscures the field of view of the radar sensor or camera*
- *There is interference by electromagnetic waves*
- *There is severe irregular reflection from the radar sensor*
- *The vehicle in front is too small to be detected by the camera recognition system (for example a motorcycle or a bicycle, etc.)*
- *The vehicle in front is an oversize vehicle or trailer that is too big to be detected by the camera recognition system (for example a tractor trailer, etc.)*
- *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)*
- *The vehicle in front does not have their rear lights properly turned ON*
- *The outside brightness changes suddenly, for example when entering or exiting a tunnel*
- *The vehicle in front is driving erratically*
- *Driving on a curve*
- *Driving on a slope*
- *Changing lanes*
- *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 AEB system may not be able to detect the cargo extending from the vehicle.*

Notes:

Section III

TEST PROCEDURES

A. Test Procedure Overview

Three test procedures were used, as follows:

Test 1. Subject Vehicle (SV) Encounters Stopped Principal Other Vehicle (POV) on a Straight Road
Test 2. Subject Vehicle Encounters Decelerating Principal Other Vehicle
Test 3. Subject Vehicle Encounters Slower Principal Other Vehicle

With the exception of trials associated with Test 1, all trials were performed with SV and POV 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. Except for Test 2, the brake lights of the POV were not illuminated.

In order to pass the test, if the FCW system provides a warning timing adjustment for the driver, at least one setting must meet the criterion of the test procedure. Therefore, if the vehicle was equipped with a warning timing adjustment, only the most "conservative" (earliest warning) setting was tested.

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 FCW function to detect a stopped lead vehicle, as depicted in Figure 1.

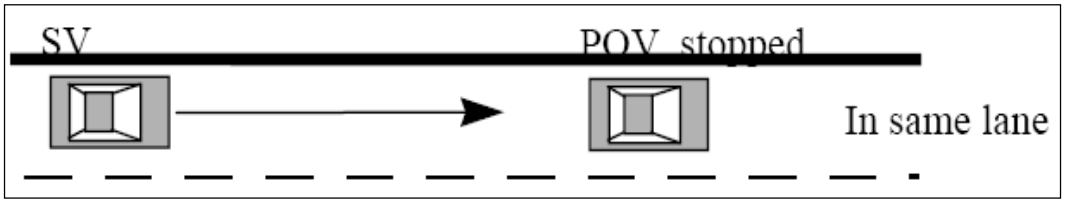


Figure 1. Depiction of Test 1

a. Alert Criteria

In order to pass the test, the FCW alert must be issued when the time-to-collision (TTC) is at least 2.1 seconds. (Note: TTC values were computed in accordance with Ref 1). The TTC for this test was calculated by considering the speeds of the subject vehicle (SV) and the lead vehicle (POV) at the time of the FCW alert (i.e., when the SV and POV speeds are nominally equal to 45 and 0 mph (72.4 and 0 kph), respectively).

b. 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 the SV approaches the rear of the POV.

The SV was driven at a nominal speed of 45 mph (72.4 kph) in the center of the lane of travel, toward the parked POV. The test began when the SV was 492 ft (150 m) from the POV and ended when either of the following occurred:

- The required FCW alert occurred.
- The TTC to the POV fell to less than 90 percent of the minimum allowable range (i.e., TTC = 1.9 sec) for the onset of the required FCW alert.

The SV driver then steered and/or braked to keep the SV from striking the POV.

For an individual test trial to be valid, the following was required throughout the test:

- The SV vehicle speed could not deviate from the nominal speed by more than 1.0 mph (1.6 kph) for a period of three seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.
- The SV driver could not apply any force to the brake pedal before the required FCW alert occurred, or before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.

- The lateral distance between the centerline of the SV, relative to the centerline of the POV, in road coordinates, could not exceed 2.0 ft (0.6 m).

- The yaw rate of the SV could not exceed ±1 deg/sec during the test.

Nominally, the Test 1 series was comprised of seven individual trials. The FCW system must satisfy the TTC alert criteria for at least five of the seven test trials.

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

The SV in this test initially followed the POV at a constant time gap, and then the POV suddenly decelerated, as depicted in Figure 2. The test evaluates the ability of the FCW to recognize a decelerating lead vehicle and to issue an alert to SV driver in a timely manner.

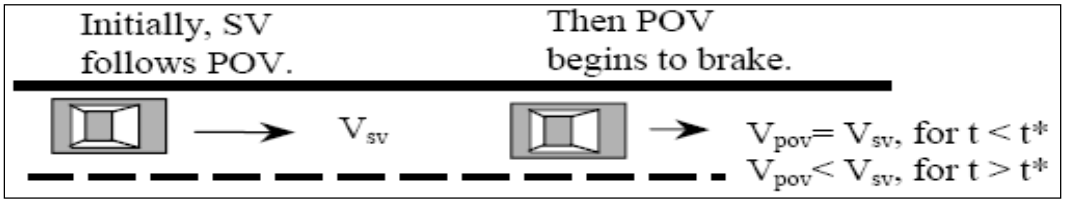


Figure 2. Depiction of Test 2

a. Alert Criteria

In order to pass the test, the FCW alert must be issued when TTC is at least 2.4 seconds. The TTC for this test, a prediction of the time it would take for the SV to collide with the POV, was calculated by considering three factors at the time of the FCW alert: (1) the speed of the SV, (2) the speed of the POV, and (3) the deceleration of the POV[1].

[1]To simplify calculation of the TTC for Test 2, the deceleration of the POV is assumed to remain constant from the time of the FCW alert until the POV comes to a stop (i.e., a "constant" rate of slowing is assumed).

b. Procedure

Test 2 began with the SV and the POV traveling on a straight, flat road at a constant speed of 45.0 mph (72.4 kph), in the center of the lane of travel. The headway from the SV to the POV was nominally maintained at 98.4 ft (30 m) until the POV braking was initiated.

The test began approximately 7 seconds before the driver of the POV started a braking maneuver in which the POV brakes were rapidly applied and modulated such that a constant deceleration of 0.3 g was achieved within 1.5 seconds after braking is initiated. The test ended when either of the following conditions was satisfied:

- The required FCW alert occurred.
- The TTC to the POV fell to less than 90% of the minimum allowable range (i.e., TTC = 2.2 sec) for the onset of the required FCW alert.

The SV driver then steered and/or braked to keep the SV from striking the POV.

For an individual test trial to be valid, the following was required throughout the test:

- The initial POV vehicle speed could not deviate from the nominal speed by more than 1.0 mph (1.6 kph) for a period of 3 seconds prior to the initiation of POV braking.
- The speed of the SV could not deviate from the nominal speed by more than 1.0 mph (1.6 kph) for a period of 3 seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.
- The lateral distance between the centerline of the SV, relative to the centerline of the POV, in road coordinates, could not exceed 2.0 ft (0.6 m).
- The yaw rates of the SV and POV could not exceed ±1 deg/sec during the test.

- The POV deceleration level was nominally required to be 0.3 g within 1.5 seconds after initiation of POV braking. The acceptable error magnitude of the POV deceleration was ±0.03g, measured at the time the FCW alert first occurred. An initial overshoot beyond the deceleration target was acceptable, however the first local deceleration peak observed during an individual trial could not exceed 0.375 g for more than 50 ms. Additionally, the deceleration could not exceed 0.33 g over a period defined from (1) 500 ms after the first local deceleration peak occurs, to (2) the time when the FCW alert first occurred.

- The tolerance for the headway from the SV to the POV was ±8.2 ft (±2.5 m), measured at two instants in time: (1) three seconds prior to the time the POV brake application was initiated, and (2) at the time the POV brake application was initiated.

- SV driver could not apply any force to the brake pedal before the required FCW alert occurred, or before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.

Nominally, the Test 2 series was comprised of seven individual trials. The FCW system must satisfy the TTC alert criteria for at least five of the seven test trials.

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

This test examines the ability of the FCW system to recognize a slower lead vehicle being driven with a constant speed and issue a timely alert. As depicted in Figure 3, the scenario was conducted with a closing speed equal to 25.0 mph (40.2 kph).

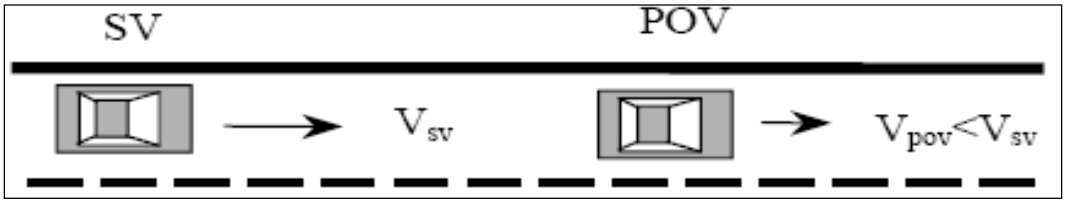


Figure 3. Depiction of Test 3

a. Alert Criteria

In order to pass the test, the FCW alert must be issued when TTC is at least 2.0 seconds. The TTC for this test, a prediction of the time it would take for the SV to collide with the POV, was calculated by considering the speeds of the SV and POV at the time of the FCW alert.

b. Procedure

Throughout the test, the POV was driven at a constant 20.0 mph (32.2 kph) in the center of the lane of travel.

The SV was driven at 45.0 mph (72.4 kph), in the center lane of travel, toward the slow-moving POV.

The test began when the headway from the SV to the POV was 329 ft (100 m) and ended when either of the following occurred:

- The required FCW alert occurred.
- The TTC to the POV fell to less than 90% of the minimum allowable range (i.e., TTC = 1.8 sec) for the onset of the required FCW alert.

The SV driver then steered and/or braked to keep the SV from striking the POV.

For an individual test trial to be valid, the following was required throughout the test:

- The SV vehicle speed could not deviate from the nominal speed by more than 1.0 mph (1.6 kph) for a period of 3 seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.
- Speed of the POV could not deviate from the nominal speed by more than 1.0 mph (1.6 kph) during the test.
- The lateral distance between the centerline of the SV, relative to the centerline of the POV, in road coordinates, could not exceed 2.0 ft (0.6 m).

- The yaw rates of the SV and POV could not exceed ±1 deg/sec during the test.

- SV driver could not apply any force to the brake pedal before the required FCW alert occurred, or before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.

Nominally, the Test 3 series was comprised of seven individual trials. The FCW system must satisfy the TTC alert criteria for at least five of the seven test trials.

B. Principal Other Vehicle

The vehicle used as the Principal Other Vehicle (POV) was a 2000 Honda Accord. This satisfied the test requirement of Ref 1 that the POV be a mid-size sedan. The vehicle had a rear license plate in order to provide a suitable representative radar profile. Vehicle loading consisted of the driver plus equipment and instrumentation.

C. Automatic Braking System

The POV was equipped with an automatic braking system, which was used in Test 2. The braking system consisted of the following components:

- High pressure nitrogen bottle, strapped to the front passenger seat, with regulator and pressure gauges.
- Pneumatic piston-type actuator, with solenoid valve
- "Pickle" switch to activate brakes

D. Instrumentation

Table 1 lists the sensors, signal conditioning and data acquisition equipment used for these tests.

TABLE 1. 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: 6/8/2017 Due: 6/8/2018
Platform Scales	Vehicle Total, Wheel, and Axle Load	1200 lb/platform 5338 N/	0.5% of applied load	Intercomp SWI	1110M206352	By: DRI Date: 2/1/2018 Due: 2/1/2019
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; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Accels ± 10g, Angular Rat	Accels .01g, Angular Rate	Oxford Inertial +		By: Oxford Technical Solutions
					2182	Date: 10/16/2017 Due: 10/16/2019
					2176	Date: 3/9/2016 Due: 3/9/2018
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

TABLE 1. TEST INSTRUMENTATION AND EQUIPMENT (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
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
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: 1/4/2018 Due: 1/4/2019

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

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 signals types is a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 2.

Table 2. Audible and Tactile Warning Filter Parameters

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

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

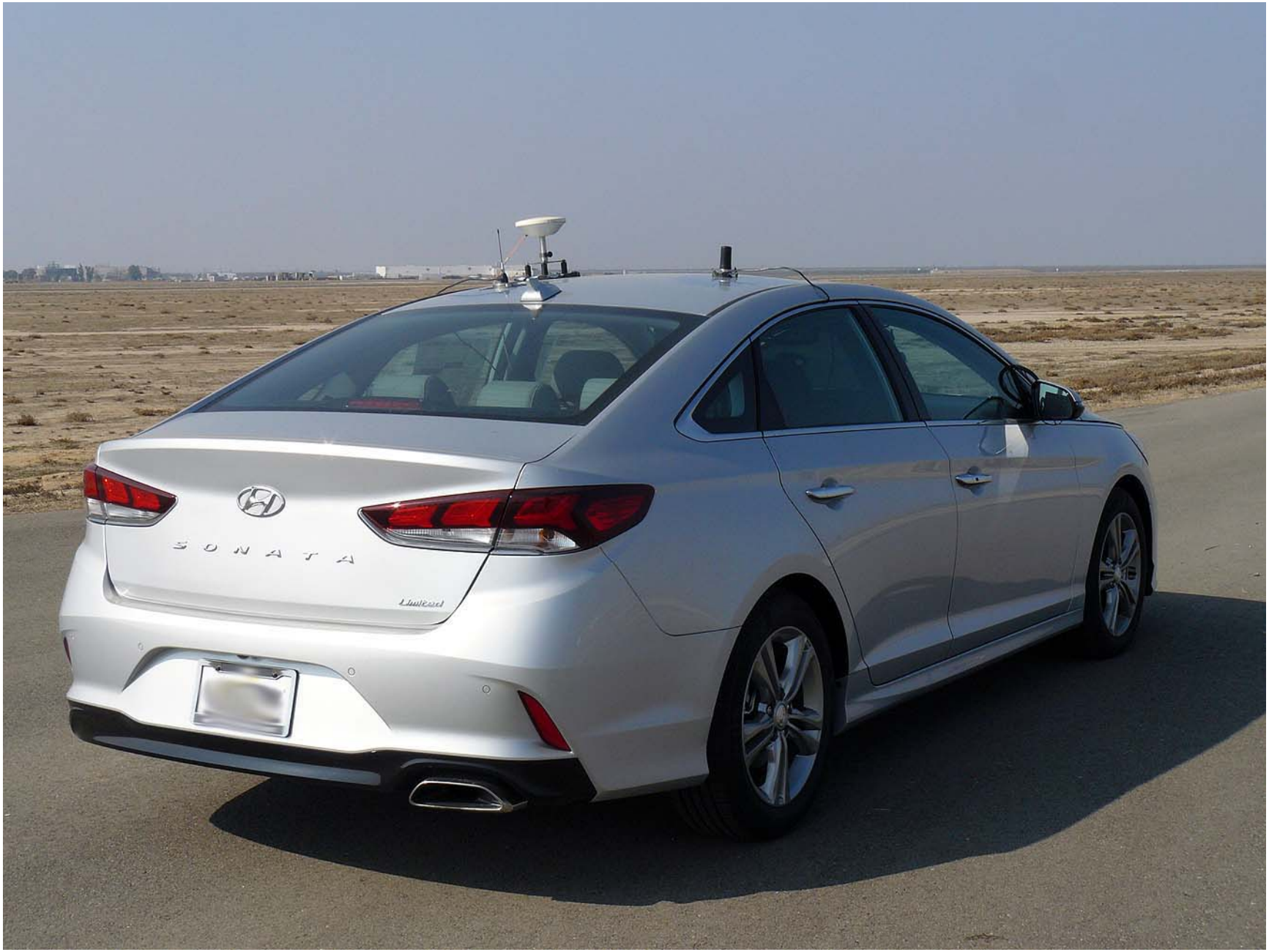


Figure A2. Rear View of Subject Vehicle

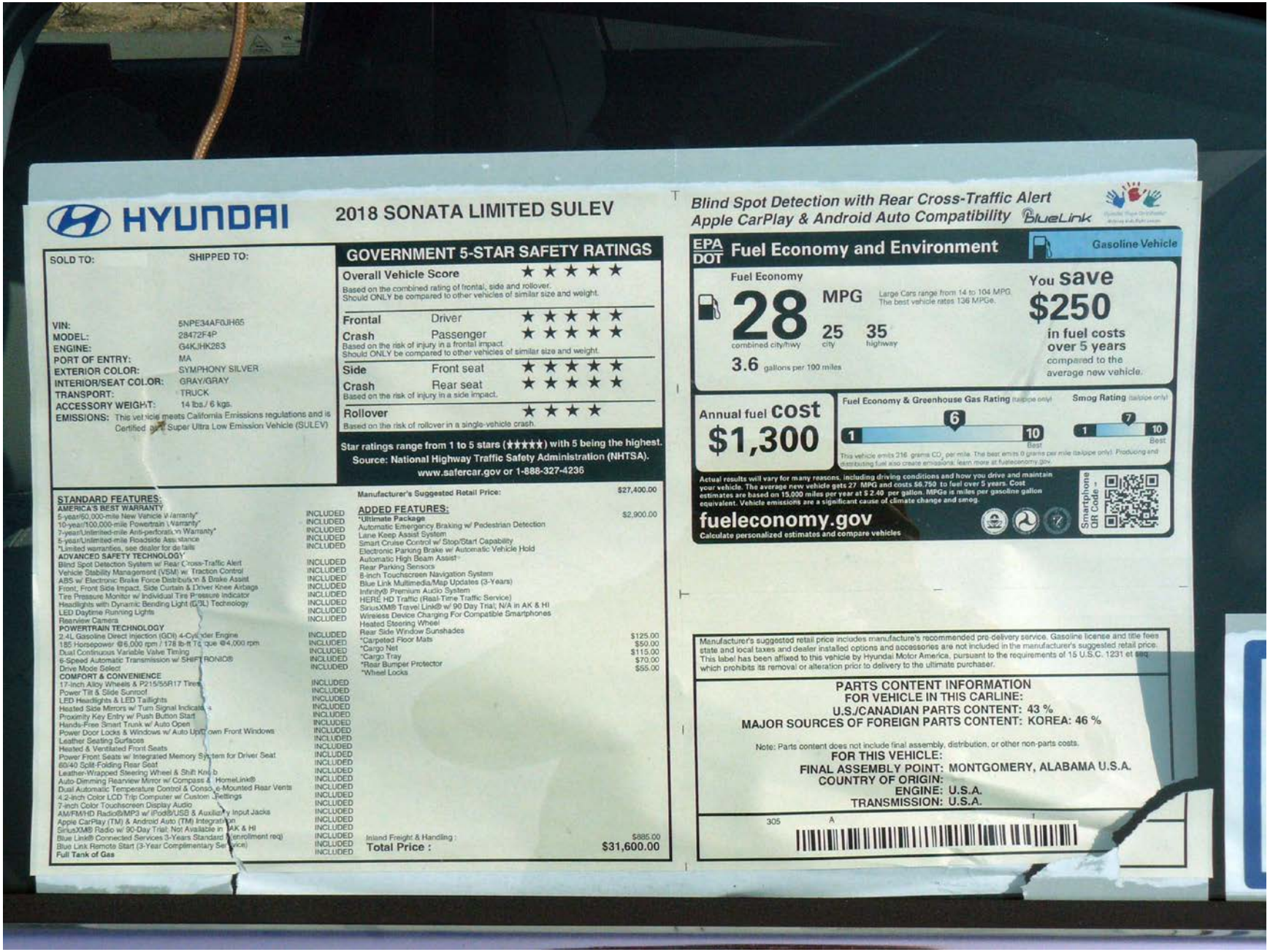


Figure A3. Window Sticker (Monroney Label)

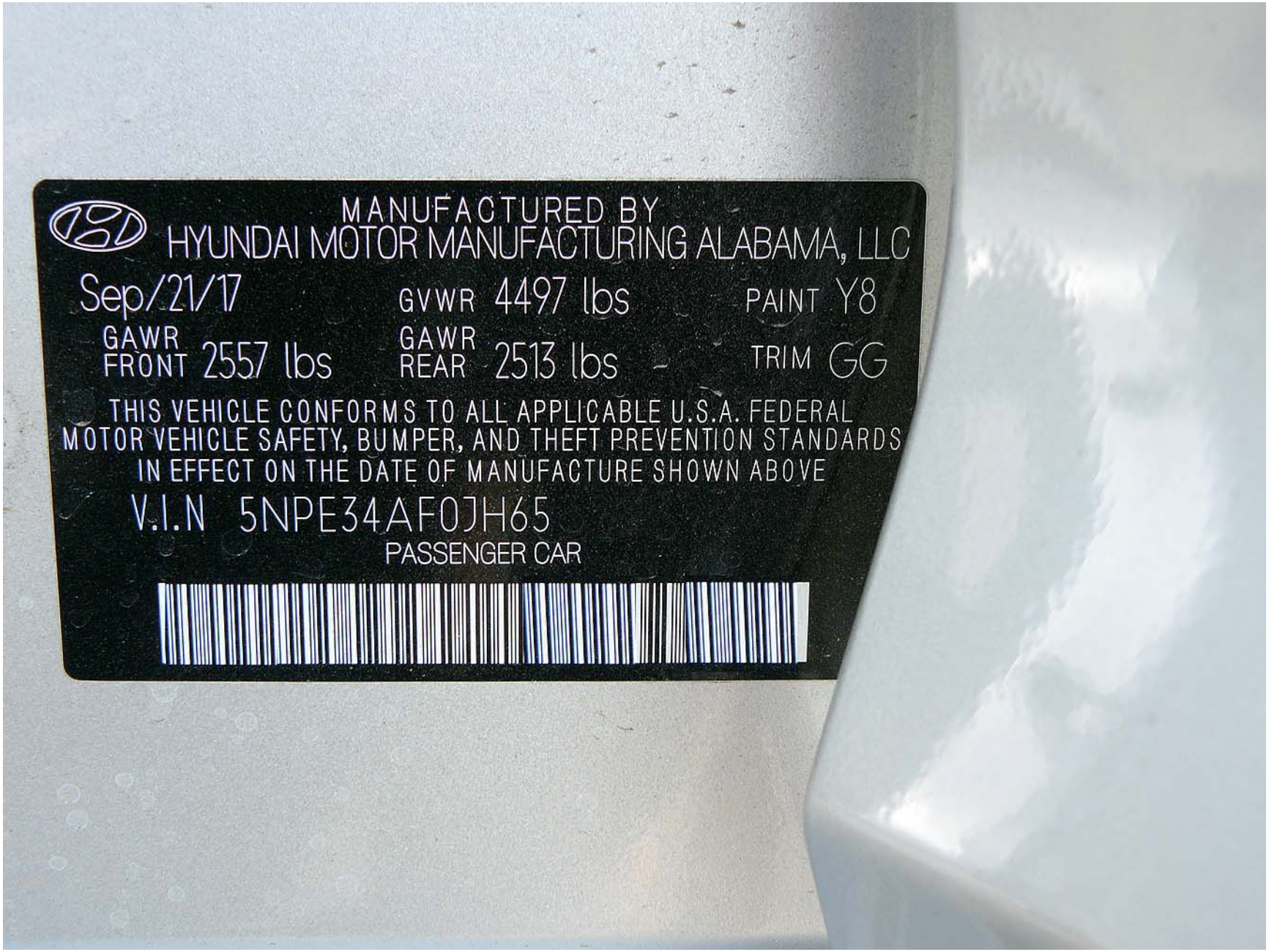


Figure A4. Vehicle Certification Label

Figure A5. Front View of Principal Other Vehicle

Figure A6. Rear View of Principal Other Vehicle

Figure A7. DGPS and Inertial Measurement Unit Installed in Subject Vehicle

Figure A8. MicroAutoBox Installed in Subject Vehicle

Figure A9. Sensor for Detecting Auditory Alerts

Figure A10. Computer Installed in Subject Vehicle

Figure A11. Brake Actuation System Installed in Principal Other Vehicle

Figure A12. Controls for Interacting With System Setup

Figure A13. FCW Visual Displays

Figure A14. FCW System Setting Menus

APPENDIX B

Excerpts from Owner's Manual

AUTOMATIC EMERGENCY BRAKING (AEB) (IF EQUIPPED)

The Automatic Emergency Braking (AEB) system is designed to help detect and monitor the vehicle ahead or help 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.

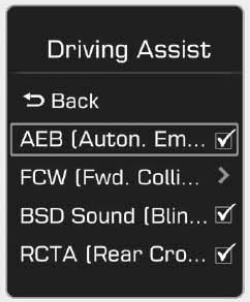
⚠ WARNING

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

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

System setting and activation

System setting



OLF057454N

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

The warning light illuminates on the LCD display, when you cancel the AEB system. The driver can monitor the AEB ON/OFF status on the LCD display. If the warning light remains ON when the AEB is activated, have the system checked by an authorized HYUNDAI dealer.

OLF057595N/OLF057594N

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

- FAST - 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.
- NORMAL - When this condition is selected, the initial Forward Collision Warning is activated normally. This setting allows for a nominal amount of distance between the vehicle or pedestrian ahead before the initial warning occurs.
- SLOW - When this condition is selected, the initial Forward Collision Warning is activated later than normal. This setting reduces the amount of distance between the vehicle or pedestrian ahead before the initial warning occurs.

Prerequisite for activation

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

- The ESC is activated.
- To enable the system to detect pedestrians ahead, the vehicle driving speed must be between 5 - 40 mph (8 - 65 km/h).
- To enable the system to detect a vehicle ahead, the vehicle driving speed must be between 5 - 110 mph (8 - 180 km/h).

When traveling above 50 mph (80 km/h), the AEB system only initiates partial braking. This is to prevent unintended full braking to stop in the middle of the highway.

⚠ WARNING

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

AEB warning message and system control

The AEB produces warning messages and warning alarms in accordance with the collision risk levels. Also, it controls the brakes in accordance with the collision risk levels.

Forward Warning (1st warning)

OLF057452N

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

The driver can select the initial warning activation time in the User Settings in the Driver LCD display. The options for the initial Forward Collision Warning include FAST, NORMAL, or SLOW initial warning time.

Collision Warning (2nd warning)

OLF057583N

- 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.
  - If the detected vehicle in front is driving slower than 50 mph (80 km/h), your vehicle speed may decelerate sharply to avoid a collision. If the detected vehicle in front is driving faster than 50 mph (80 km/h), your vehicle speed may decelerate moderately.
  - If your vehicle is traveling less than 40 mph (65 km/h) and a pedestrian is detected within the Collision Warning (2nd warning) stage, your vehicle speed may decelerate sharply to avoid a collision.

Emergency braking (3rd warning)

OLF057584N

- This warning message appears on the LCD display with a warning alarm.
- Additionally, automatic emergency braking of the vehicle is applied in order to avoid a collision.
  - If your vehicle is traveling less than 40 mph (65 km/h) and a pedestrian is detected within the Emergency Braking stage, automatic emergency braking of the vehicle is applied. In this condition, your vehicle speed will decelerate sharply to avoid a collision.
  - When your vehicle drives slower than 40 mph (65 km/h) with a passer-by in front, the driving speed may abruptly decrease. When your vehicle drives faster than 40 mph (65 km/h) with a pedestrian in front, the AEB does not operate.

Brake operation

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

⚠ CAUTION

The driver should always use extreme caution while operating the vehicle, whether or not there is a warning message or alarm from the AEB system.

⚠ WARNING

The braking control cannot completely stop the vehicle nor avoid all collisions. The driver should hold the responsibility to safely drive and control the vehicle.

⚠ WARNING

The AEB system logic operates within certain parameters, such as the distance from the vehicle or pedestrian ahead, the speed of the vehicle ahead, and the driver's vehicle speed. Certain conditions such as inclement weather and road conditions may affect the operation of the AEB system.

AEB front radar sensor


OLF057032N

In order for the AEB system to operate properly, always make sure the radar sensor lens 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 radar.

Warning message and warning light

OLF057599N

When the sensor lens cover is blocked with dirt, snow, or debris, the AEB system operation may stop temporarily. If this occurs, a warning message will appear on the LCD display. Remove any dirt, snow, or debris and clean the radar sensor lens cover before operating the AEB system.

NOTICE

- **Do not apply foreign objects such as a bumper sticker or a bumper guard near the radar sensor. Doing so may adversely affect the sensing performance of the radar.**
- **Always keep the radar sensor and lens cover clean and free of dirt and debris.**
- **Use only a soft cloth to wash the vehicle. Do not spray pressurized water directly on the sensor or sensor cover.**
- **Be careful not to apply unnecessary force on the radar sensor or sensor cover. If the sensor is forcibly moved out of proper alignment, the AEB system may not operate correctly. In this case, a warning message may not be displayed. Have the vehicle inspected by an authorized HYUNDAI dealer.**

(Continued)

(Continued)

- **If the front bumper becomes damaged in the area around the radar sensor, the AEB system may not operate properly. Have the vehicle inspected by an authorized HYUNDAI dealer.**
- **Use only genuine HYUNDAI parts to repair or replace a damaged sensor or sensor cover. Do not apply paint to the sensor cover.**

System malfunction

OLF057473N

- When the AEB is not working properly, the AEB 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 HYUNDAI dealer.
- The AEB warning message may appear along with the illumination of the ESC warning light.

⚠ WARNING

- **The AEB is only a supplemental system for the driver's convenience. The driver should hold the responsibility to control the vehicle operation. Do not solely depend on the AEB system. Rather, maintain a safe braking distance, and, if necessary, depress the brake pedal to reduce the driving speed.**
- **In certain instances and under certain driving conditions, the AEB system may activate prematurely. This initial warning message appears on the LCD display with a warning chime.**

  Also, in certain instances the front radar sensor or camera recognition system may not detect the vehicle or pedestrian ahead. The AEB system may not activate and the warning message will not be displayed.

(Continued)

(Continued)

- **If there is a malfunction with the AEB system, the automatic emergency braking is not applied even though the braking system is operating normally.**
- **The AEB system operates only to help detect vehicles or pedestrians in front of the vehicle.**

  The AEB system does not operate when the vehicle is in reverse.

  The AEB system is not designed to detect other objects on the road such as animals.

  The AEB system does not detect cross traffic vehicles that are approaching.

  The AEB system cannot detect the driver approaching the side view of a parked vehicle (for example on a dead end street.)

(Continued)

(Continued)

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 distance.

Limitations of the system

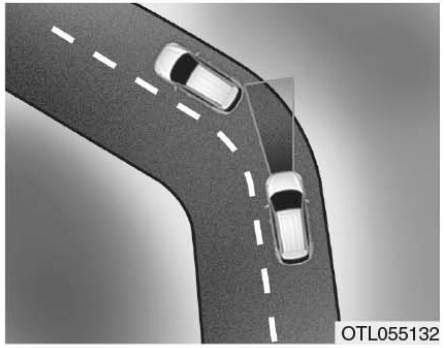
The Automatic Emergency Braking (AEB) system is designed to help monitor the vehicle ahead or a pedestrian in the roadway through radar signals and camera recognition to warn the driver that a collision is imminent, and if necessary, apply emergency braking.

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

Detecting vehicles

The sensor may be limited when:

- The radar sensor or camera is blocked with a foreign object or debris
- Inclement weather such as heavy rain or snow obscures the field of view of the radar sensor or camera
- There is interference by electromagnetic waves
- There is severe irregular reflection from the radar sensor
- The vehicle in front is too small to be detected by the camera recognition system (for example a motorcycle or a bicycle, etc.)
- The vehicle in front is an oversize vehicle or trailer that is too big to be detected by the camera recognition system (for example a tractor trailer, etc.)
- 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)
- The vehicle in front does not have their rear lights properly turned ON
- The outside brightness changes suddenly, for example when entering or exiting a tunnel
- The vehicle in front is driving erratically


OTL055132

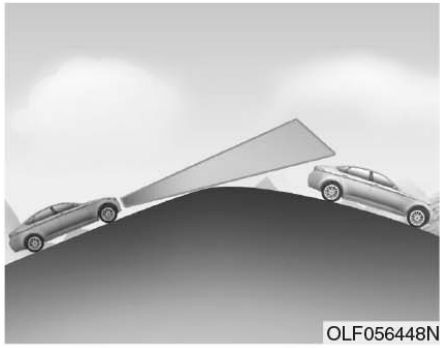
- Driving on a curve

The performance of the AEB system may be limited when driving on a curved road.

In certain instances on a curved road, the AEB system may activate prematurely.

Also, in certain instances the front radar sensor or camera recognition system may not detect the vehicle traveling on a curved road.

In these cases, the driver 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.

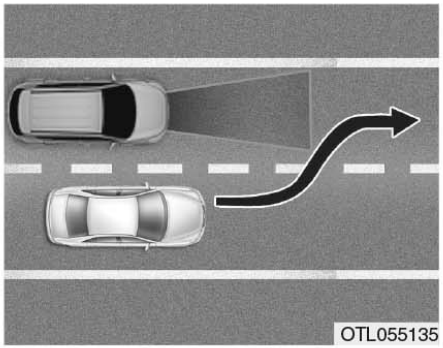

OLF056448N

- Driving on a slope

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

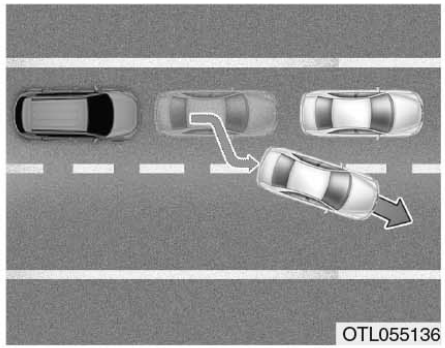
When the AEB suddenly recognizes the vehicle in front while passing over a slope, you may experience sharp deceleration.

Always keep your eyes forward while driving upward or downward on a slope, and, if necessary, depress the brake pedal to reduce your driving speed in order to maintain distance.

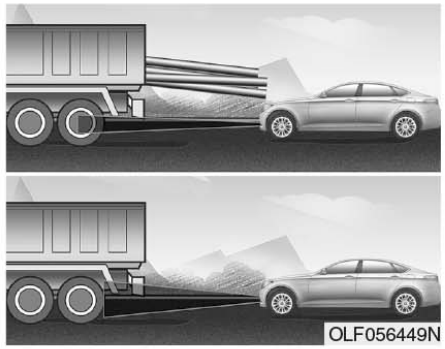


- Changing lanes

When a vehicle changes lanes in front of you, the AEB 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.



When driving in stop-and-go traffic, and a stopped vehicle in front of you merges out of the lane, the AEB 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.



- Detecting the vehicle in front of you

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 AEB system may not be able to detect the cargo extending from the vehicle. In these instances, you must maintain a safe braking distance from the rearmost object, and if necessary, depress the brake pedal to reduce your driving speed in order to maintain distance.

Detecting pedestrians

The sensor may be limited when:

- The pedestrian is not fully detected by the camera recognition system, for example, if the pedestrian is leaning over or is not fully walking upright
- The pedestrian is moving very quickly or appears abruptly in the camera detection area

  The pedestrian is wearing clothing that easily blends into the background, making it difficult to be detected by the camera recognition system
- The outside lighting is too bright (e.g. when driving in bright sunlight or in sun glare) or too dark (e.g. when driving on a dark rural road at night)
- It is difficult to detect and distinguish the pedestrian from other objects in the surroundings, for example, when there is a group of pedestrians or a large crowd

⚠ WARNING

- **Do not use the Automatic Emergency Braking system when towing a vehicle. Application of the AEB system while towing may adversely affect the safety of your vehicle or the towing vehicle**
- **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 AEB system is designed to help 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.**
- **Never try to test the operation of the AEB system. Doing so may cause severe injury or death.**

ⓘ Information

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

ⓘ Information

This device complies with Part 15 of the FCC rules.

Operation is subject to the following two conditions:

1. **This device may not cause harmful interference, and**
2. **This device must accept any interference received, including interference that may cause undesired operation.**

APPENDIX C

Run Log

Subject Vehicle: **2018 Hyundai Sonata** Date: 2/6/2018

Principal Other Vehicle: 2000 Honda Accord

Run	Test Type	Valid Run?	TTCW Sound (sec)	TTCW Light (sec)	TTCW Margin (sec)	Pass/Fail	Notes
1	**Slower POV, 45 vs 20**	Y	2.66		0.66	Pass	
2		Y	2.69		0.69	Pass	
3		Y	2.67		0.67	Pass	
4		Y	2.71		0.71	Pass	
5		Y	2.72		0.72	Pass	
6		Y	2.64		0.64	Pass	
7		Y	2.76		0.76	Pass	
8	**Braking POV, 45**	Y	2.69		0.29	Pass	
9		Y	2.78		0.38	Pass	
10		Y	2.76		0.36	Pass	
11		N					POV speed
12		Y	2.74		0.34	Pass	
13		Y	2.71		0.31	Pass	
14		Y	2.77		0.37	Pass	
15		Y	2.75		0.35	Pass	

Subject Vehicle: **2018 Hyundai Sonata** Date: 2/6/2018

Principal Other Vehicle: 2000 Honda Accord

Run	Test Type	Valid Run?	TTCW Sound (sec)	TTCW Light (sec)	TTCW Margin (sec)	Pass/Fail	Notes
16	**Stopped POV**	Y			-2.10	Fail	No warning issued
17		Y	2.55		0.45	Pass	
18		Y			-2.10	Fail	No warning issued
19		Y			-2.10	Fail	No warning issued
20		Y			-2.10	Fail	No warning issued

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 and the Principal Other Vehicle, as well as pass/fail envelopes and thresholds. The following is a description of data types shown in the time history plots, as well as a description of the color code indicating to which vehicle the data pertain.

Time History Plot Description

Each time history plot consists of data pertinent 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:

- FCW Test 1 – Stopped POV (SV at 45 mph)
- FCW Test 2 – Braking POV (Both vehicles at 45 mph with a 30 m gap, POV brakes at 0.3 g)
- FCW Test 3 – Slower Moving POV (SV at 45 mph, POV at 20 mph)

Time history figures include the following sub-plots:

- 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 of the following:
    - Filtered, rectified, and normalized sound signal. The vertical scale is 0 to 1.
    - Filtered, rectified, and normalized acceleration (e.g., haptic alert, such as steering wheel vibration). The vertical scale is 0 to 1.
    - Light sensor signal
- TTC (sec) – indicates the Time to Collision as calculated up to the point of FCW alert issuance. The value of TTCW (Time to Collision at Warning) is given numerically on the right side of the figure. A passing value is indicated in green, while a failing value is indicated in red.
- SV Speed (mph) – speed of the Subject Vehicle

- POV Speed (mph) – speed of the Principal Other Vehicle
- Yaw Rate (deg/sec) – yaw rate of both the Subject Vehicle and Principal Other Vehicle
- Lateral Offset (ft) – lateral offset within the lane from the Subject Vehicle to the Principal Other Vehicle
- Ax (g) – Longitudinal acceleration of both the Subject Vehicle and Principal Other Vehicle
- Headway (ft) – Longitudinal separation between front of Subject Vehicle to rear of Principal Other Vehicle (Exclusive to test type 2)

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

Each of the time history plot figures can 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.

Green envelopes indicate that the time-varying data should 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.

Yellow envelopes indicate that the time-varying data should not exceed the envelope only at the left and/or right ends. Exceedances at the left or right extent of a yellow envelope are indicated by red asterisks.

For the warning plot, a dashed black threshold line indicates the threshold used to determine the onset of the FCW alert. The alert is considered on the first time the alert signal crosses this threshold line.

For the TTC plot, a dashed black threshold line indicates the minimum allowable TTC for the given test scenario. If the FCW alert occurs before this minimum allowable TTC, a green dot appears. However, if there is no alert or the alert occurs after the minimum allowable TTC, a red asterisk is shown on the plot.

For the Ax plot, a dashed black threshold line is given for at a value of -0.05 g. For a test run to be valid, the longitudinal acceleration of the Subject Vehicle must not fall below this threshold (i.e. the driver cannot apply any brakes). Additionally, for test type 2, the plot indicating the longitudinal acceleration of the Principal Other Vehicle includes a yellow envelope indicating the deceleration (0.3 g ± 0.03 g) allowed while braking. Exceedance of this threshold is indicated with red asterisks at the beginning and/or end of the threshold boundary.

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. Instantaneous samplings
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 not exceed this threshold in order to be valid
   - Black threshold (Dashed) = for reference only – this can include warning level thresholds, TTC thresholds, and acceleration thresholds

3. Instantaneous sampling 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 D1 through Figure D6. Actual time history data plots for the vehicle under consideration are provided subsequently.

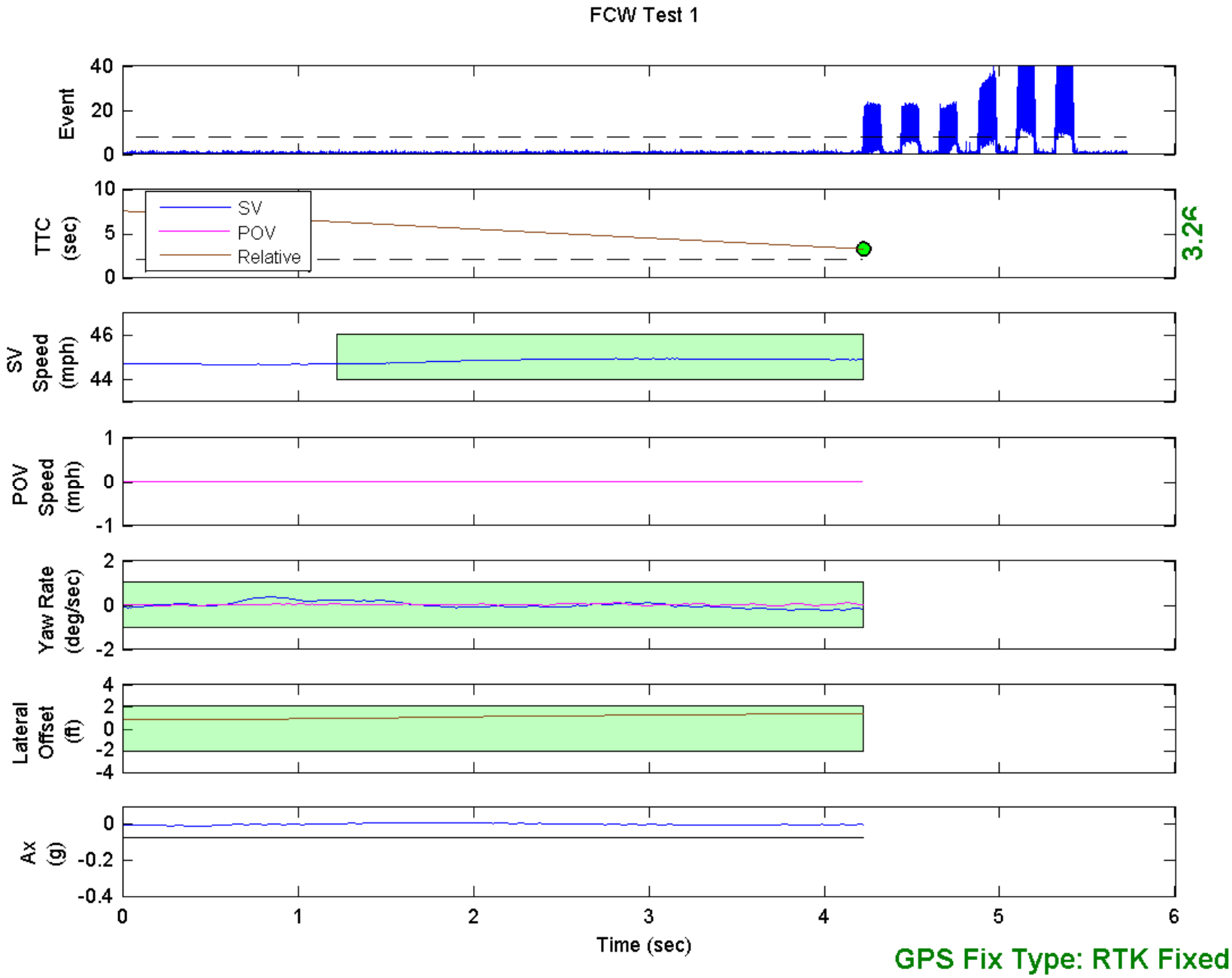


Figure D1. Example Time History for Test Type 1, Passing

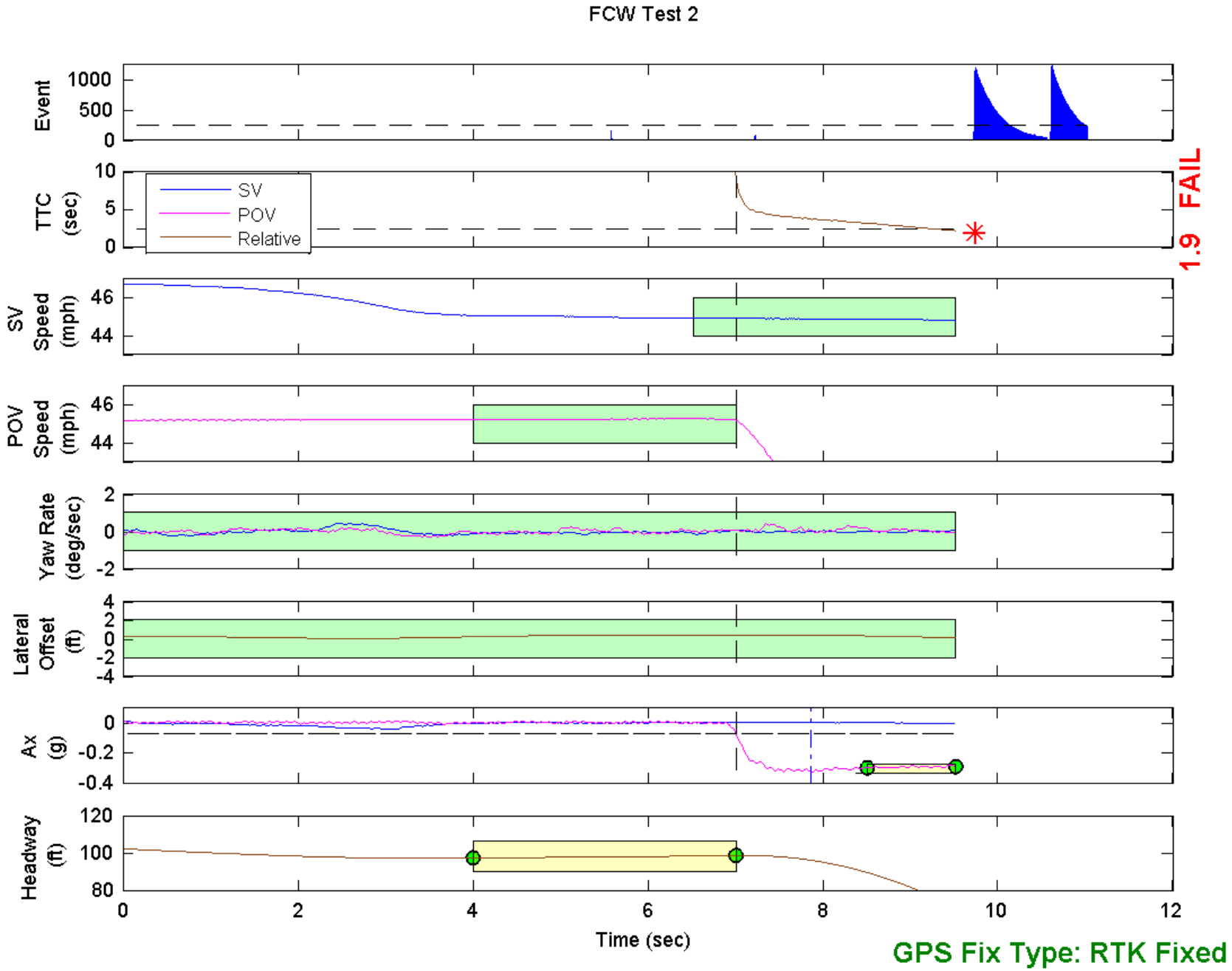


Figure D2. Example Time History for Test Type 2, Failing

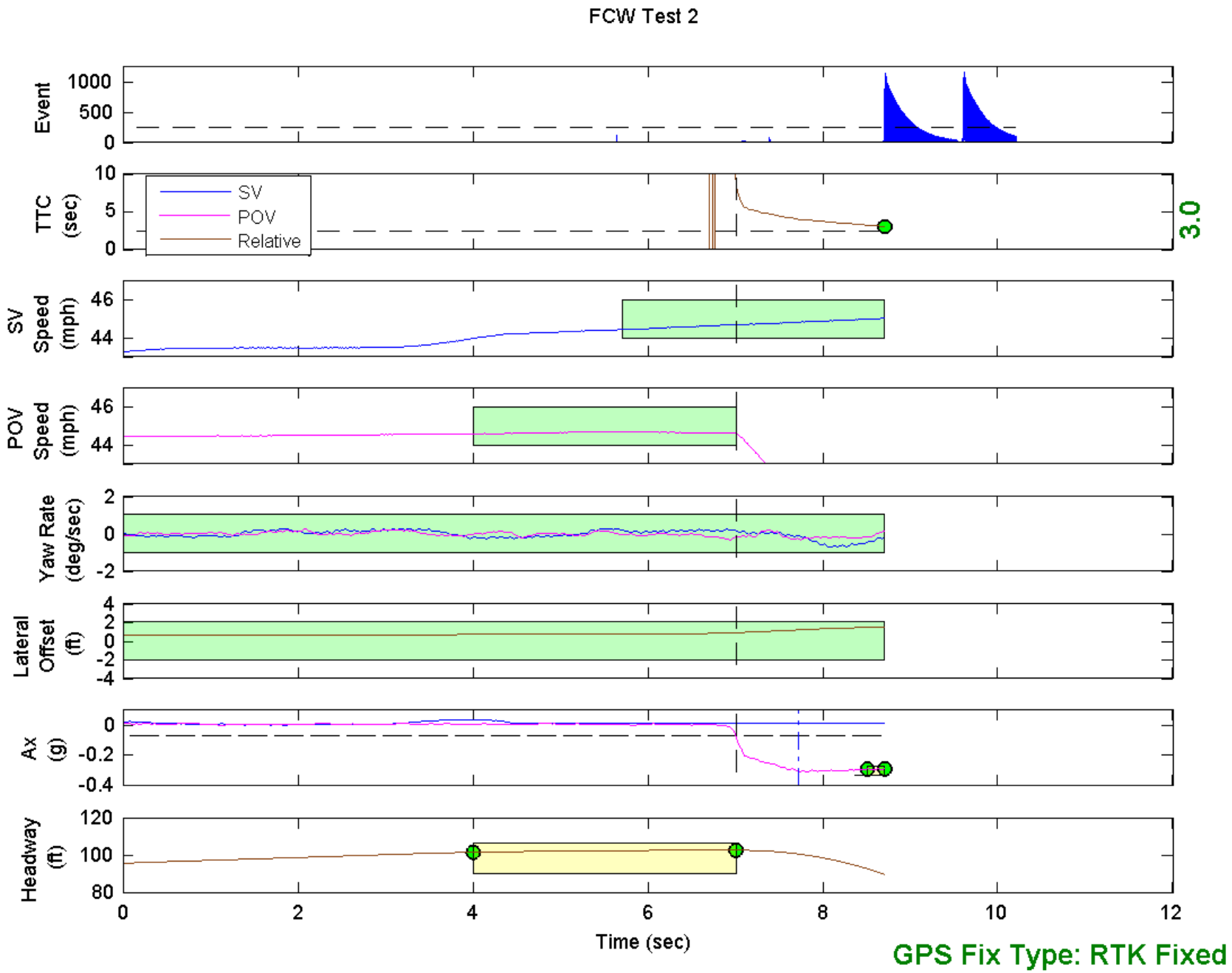


Figure D3. Example Time History for Test Type 2, Passing

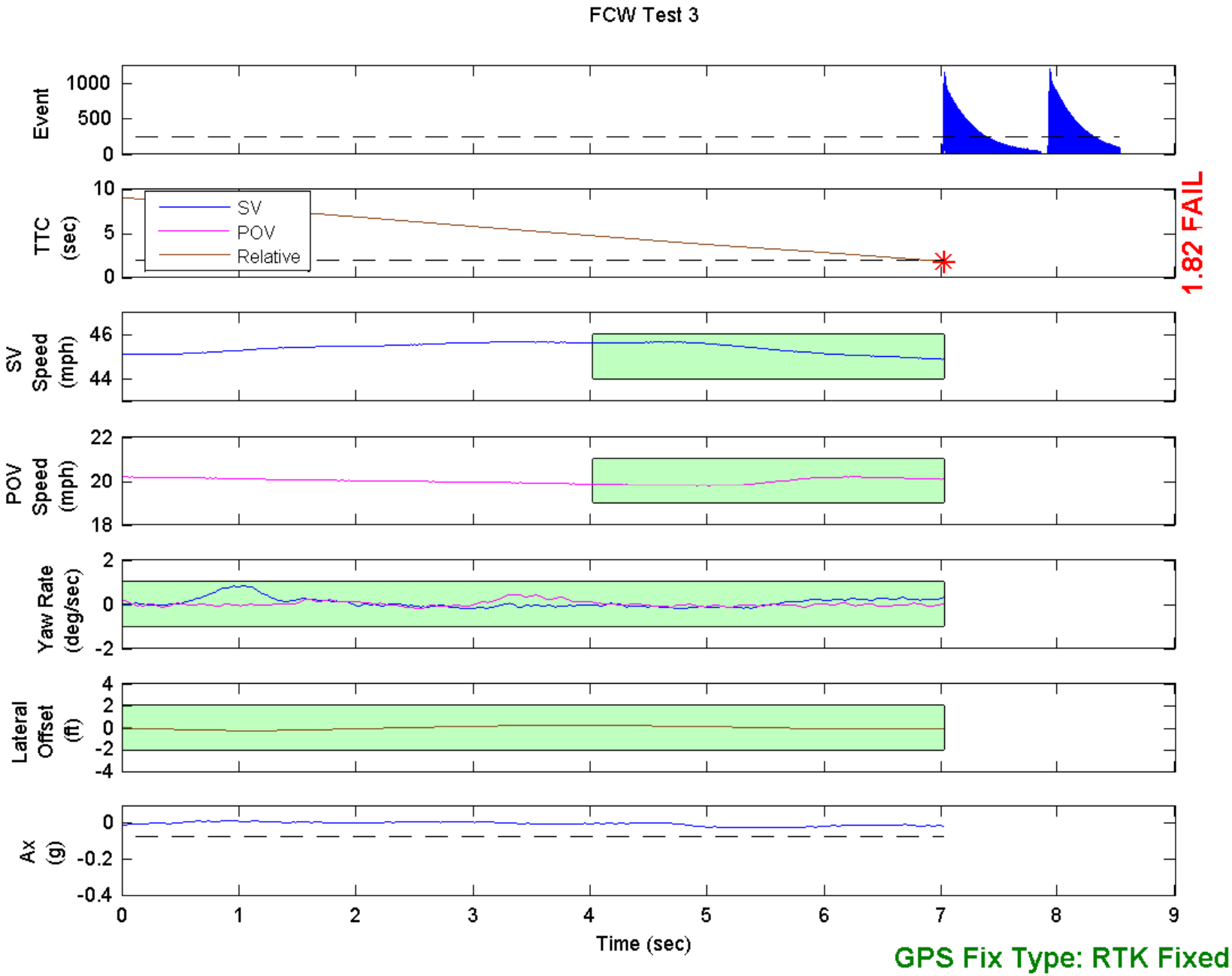


Figure D4. Example Time History for Test Type 3, Failing

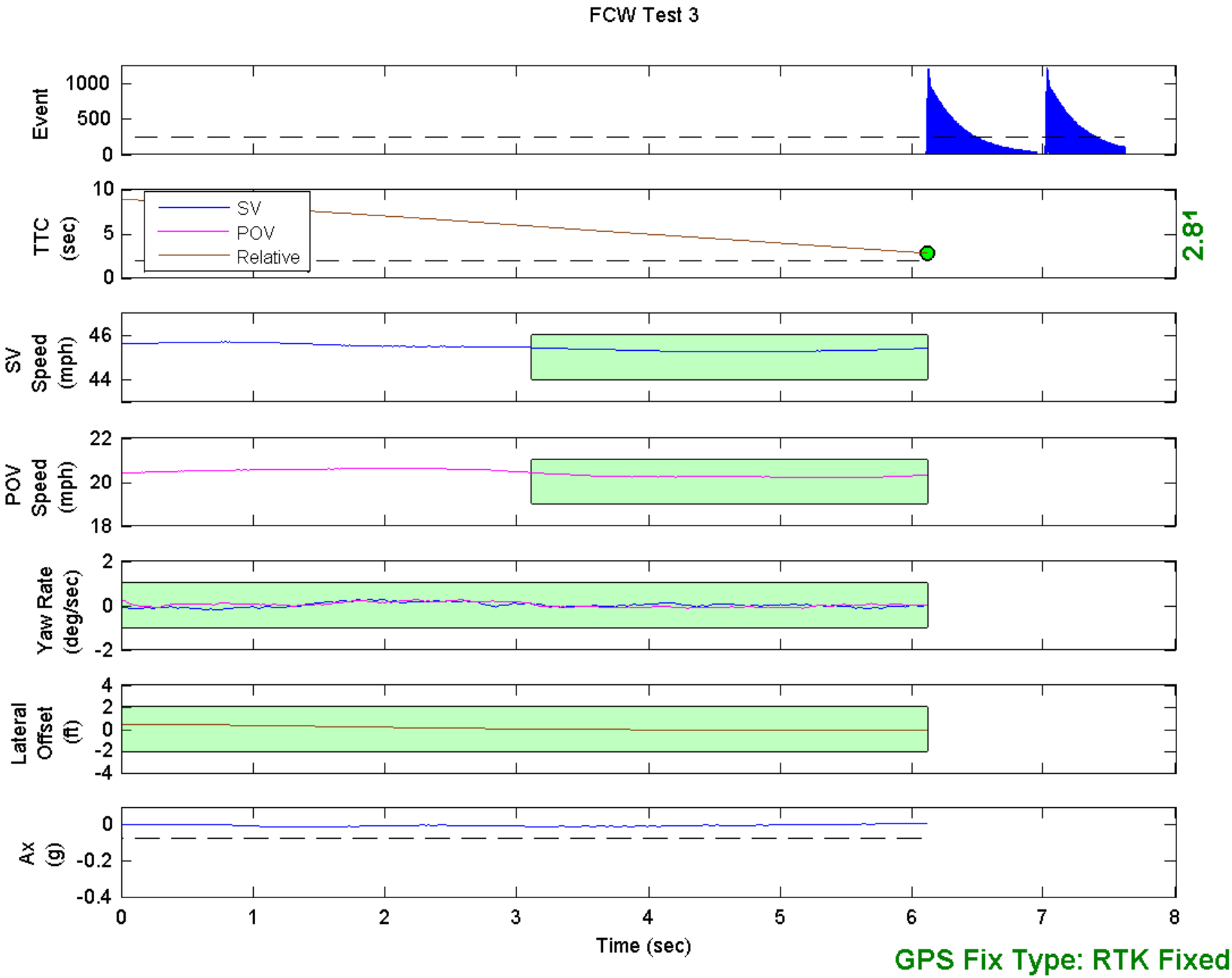


Figure D5. Example Time History for Test Type 3, Passing

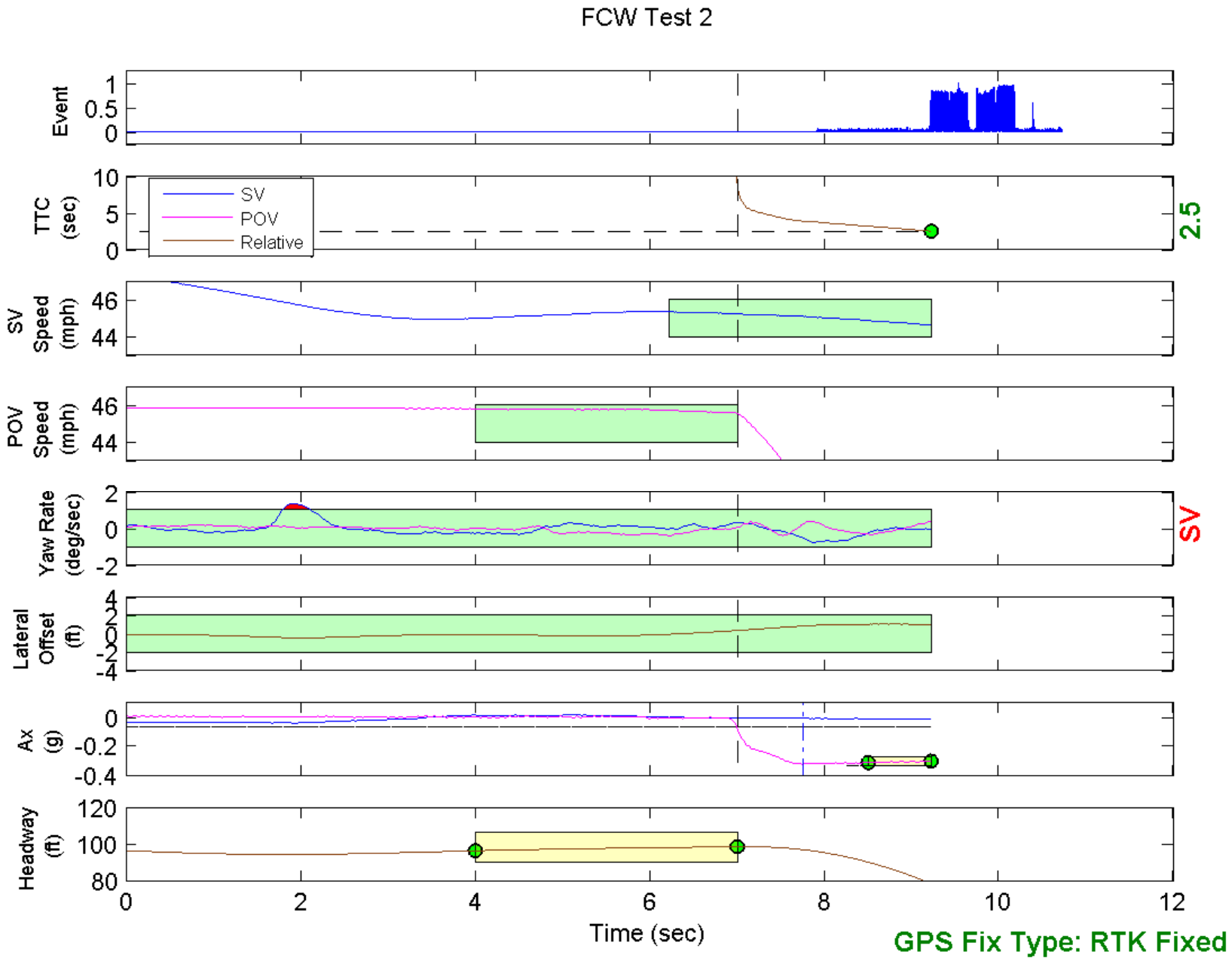


Figure D6. Example Time History for Test Type 2, Invalid Run Due to Subject Vehicle Yaw Rate

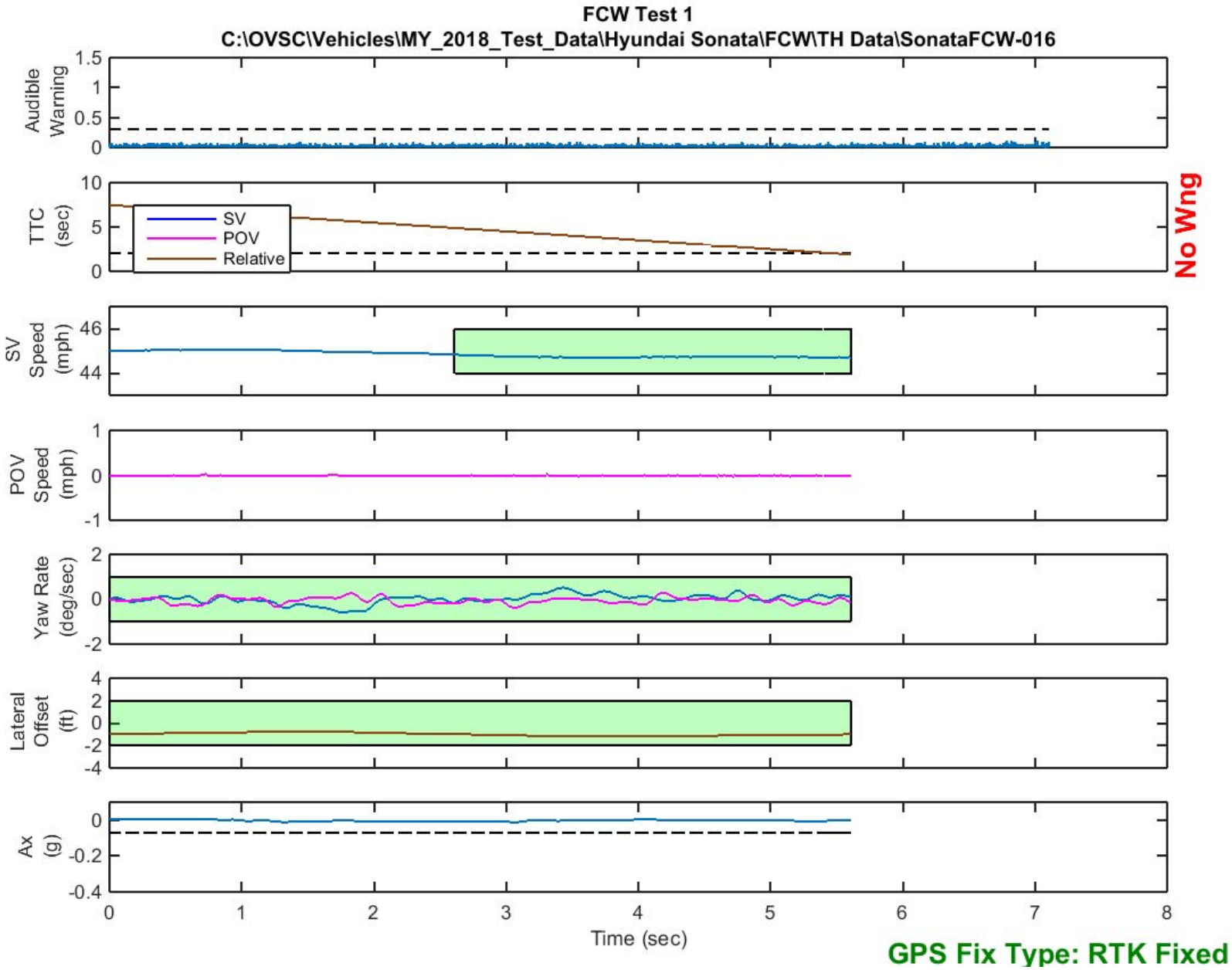


Figure D7. Time History for Run 16, FCW Test 1, Audible Warning

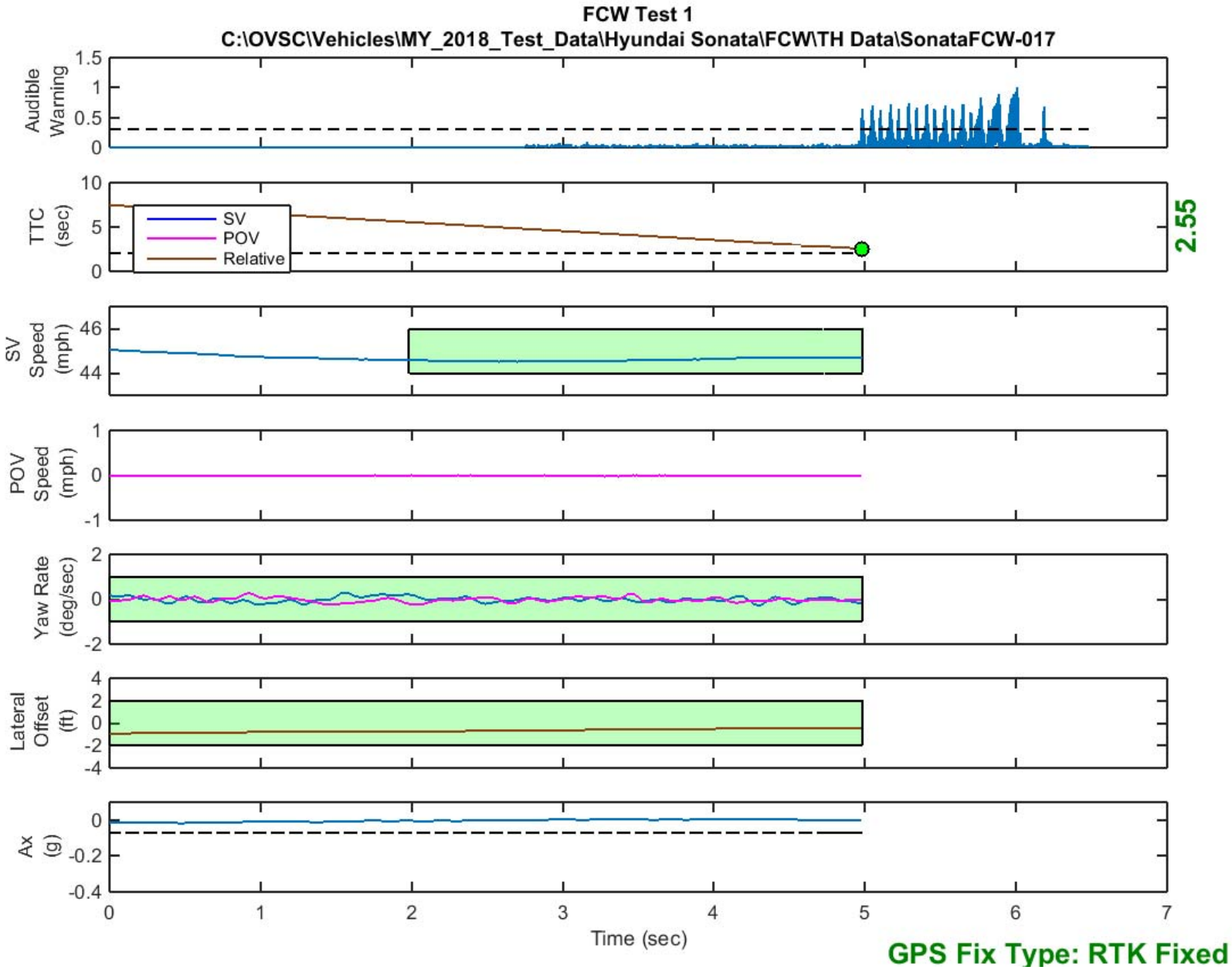


Figure D8. Time History for Run 17, FCW Test 1, Audible Warning

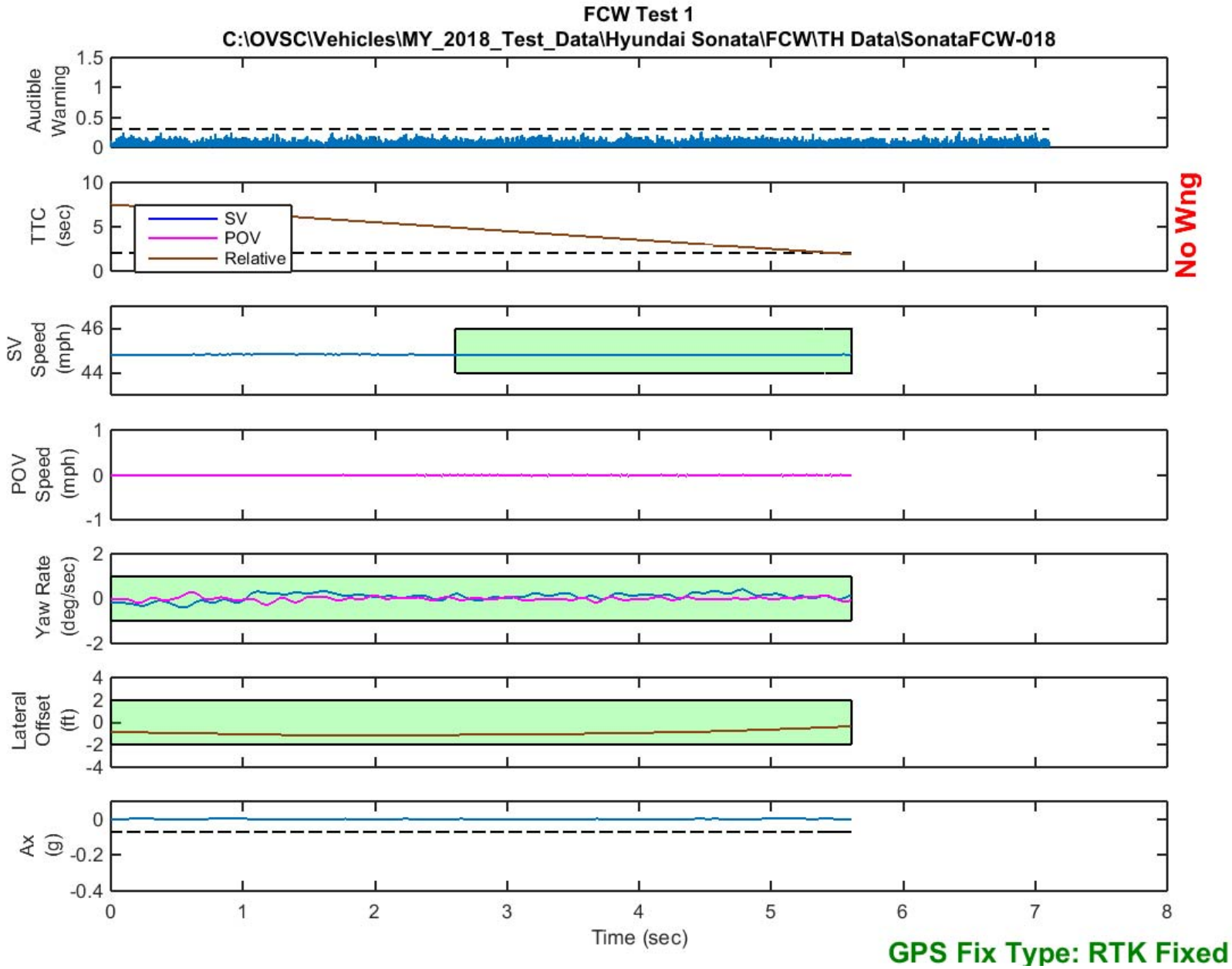


Figure D9. Time History for Run 18, FCW Test 1, Audible Warning

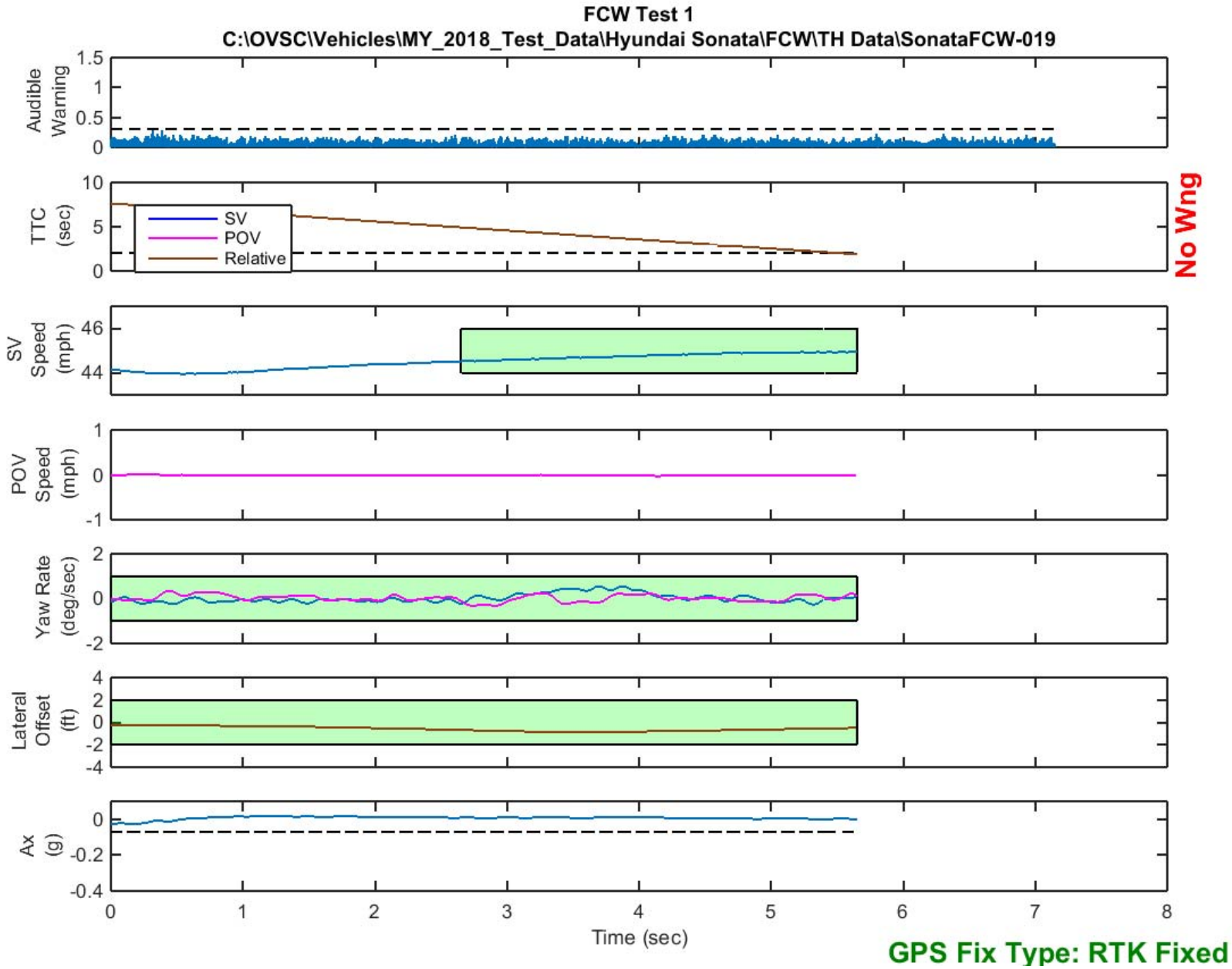


Figure D10. Time History for Run 19, FCW Test 1, Audible Warning

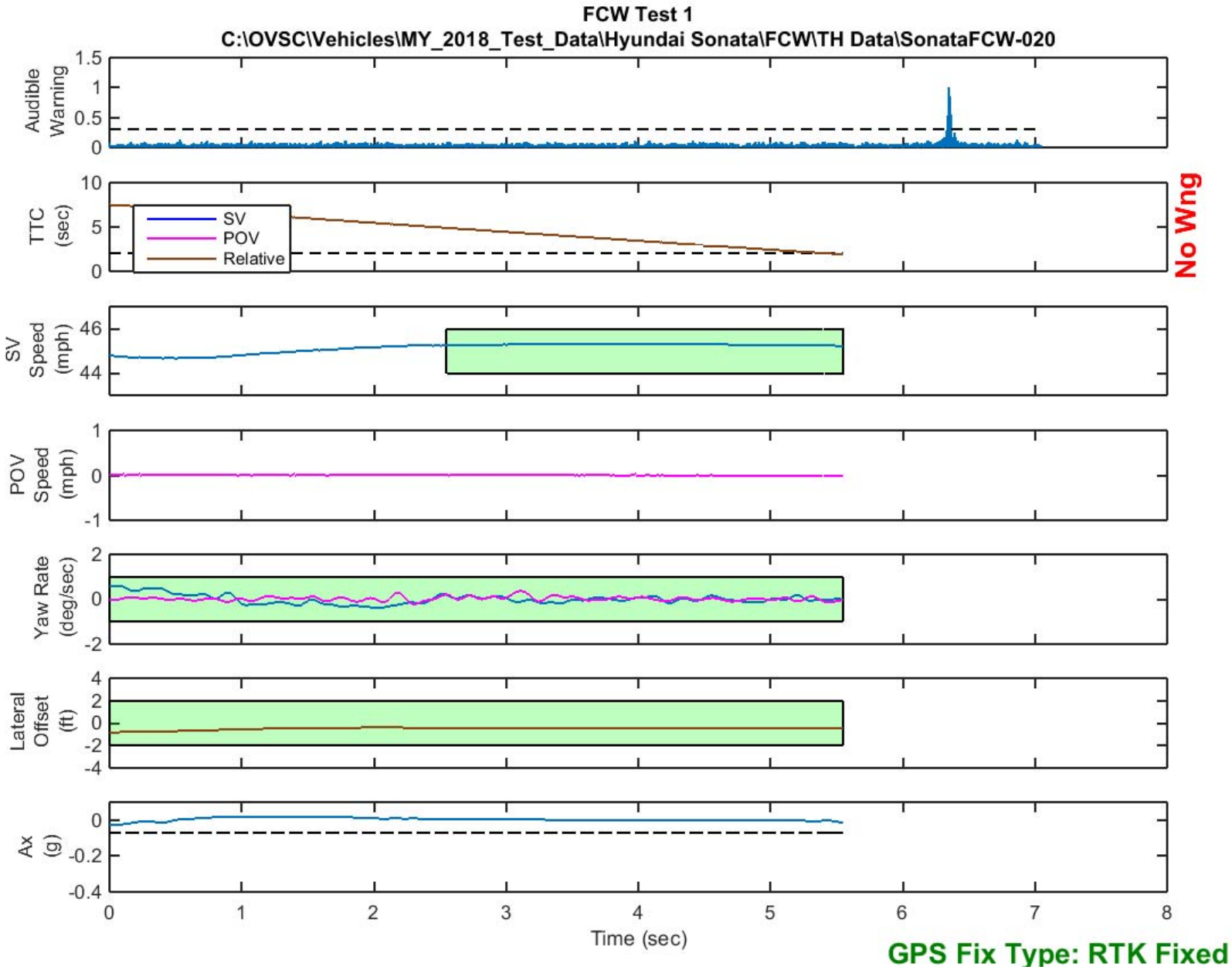


Figure D11. Time History for Run 20, FCW Test 1, Audible Warning

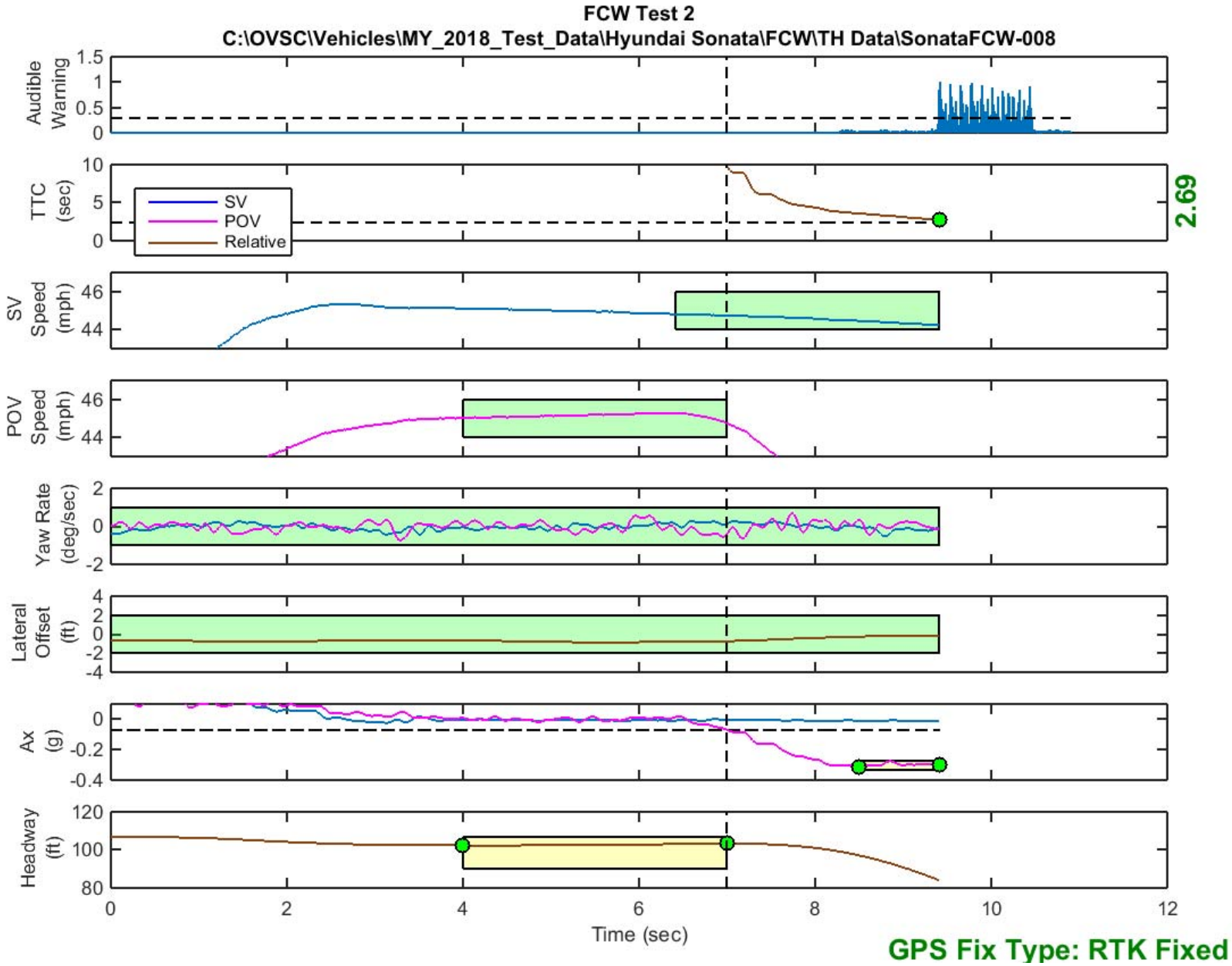


Figure D12. Time History for Run 8, FCW Test 2, Audible Warning

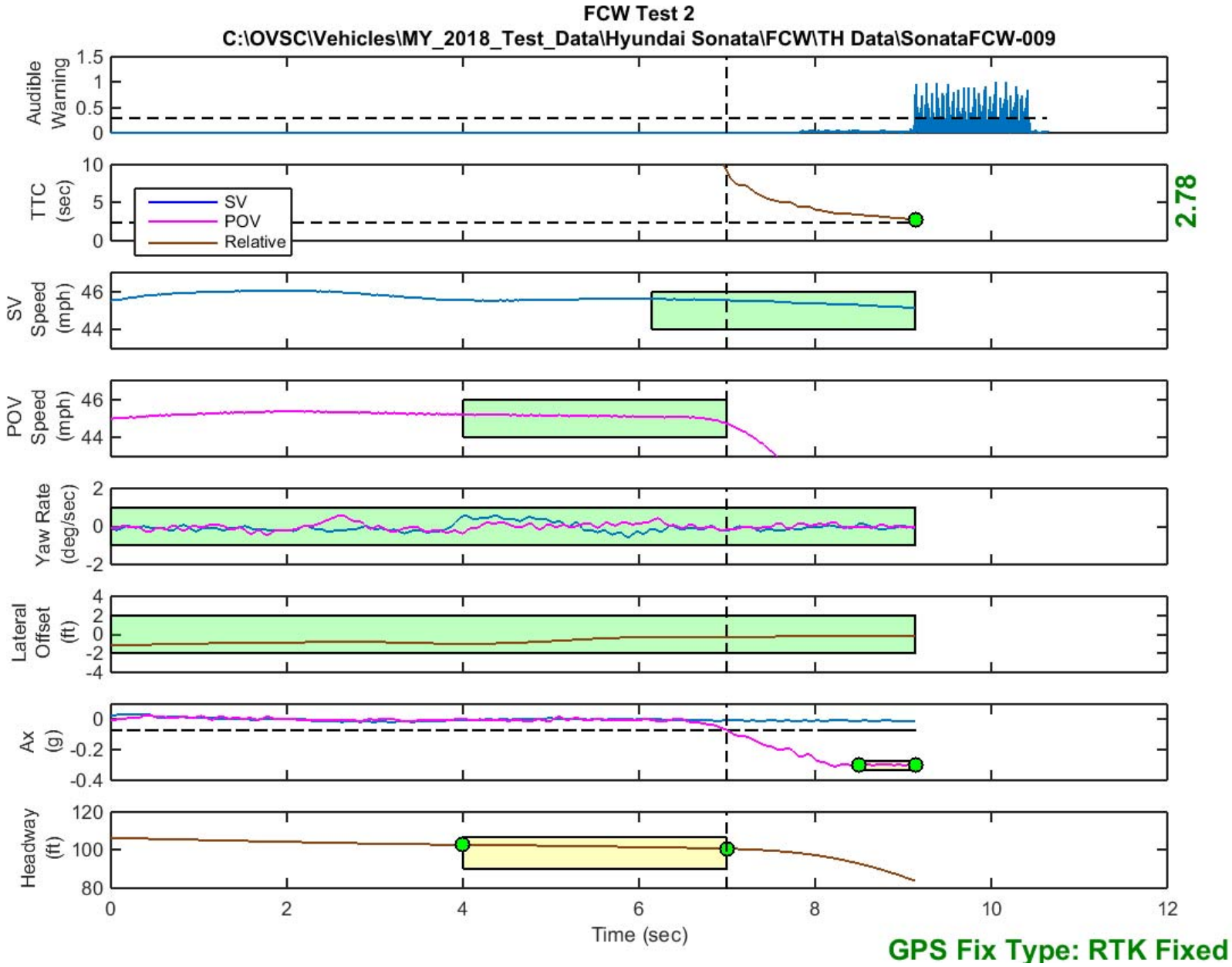


Figure D13. Time History for Run 9, FCW Test 2, Audible Warning

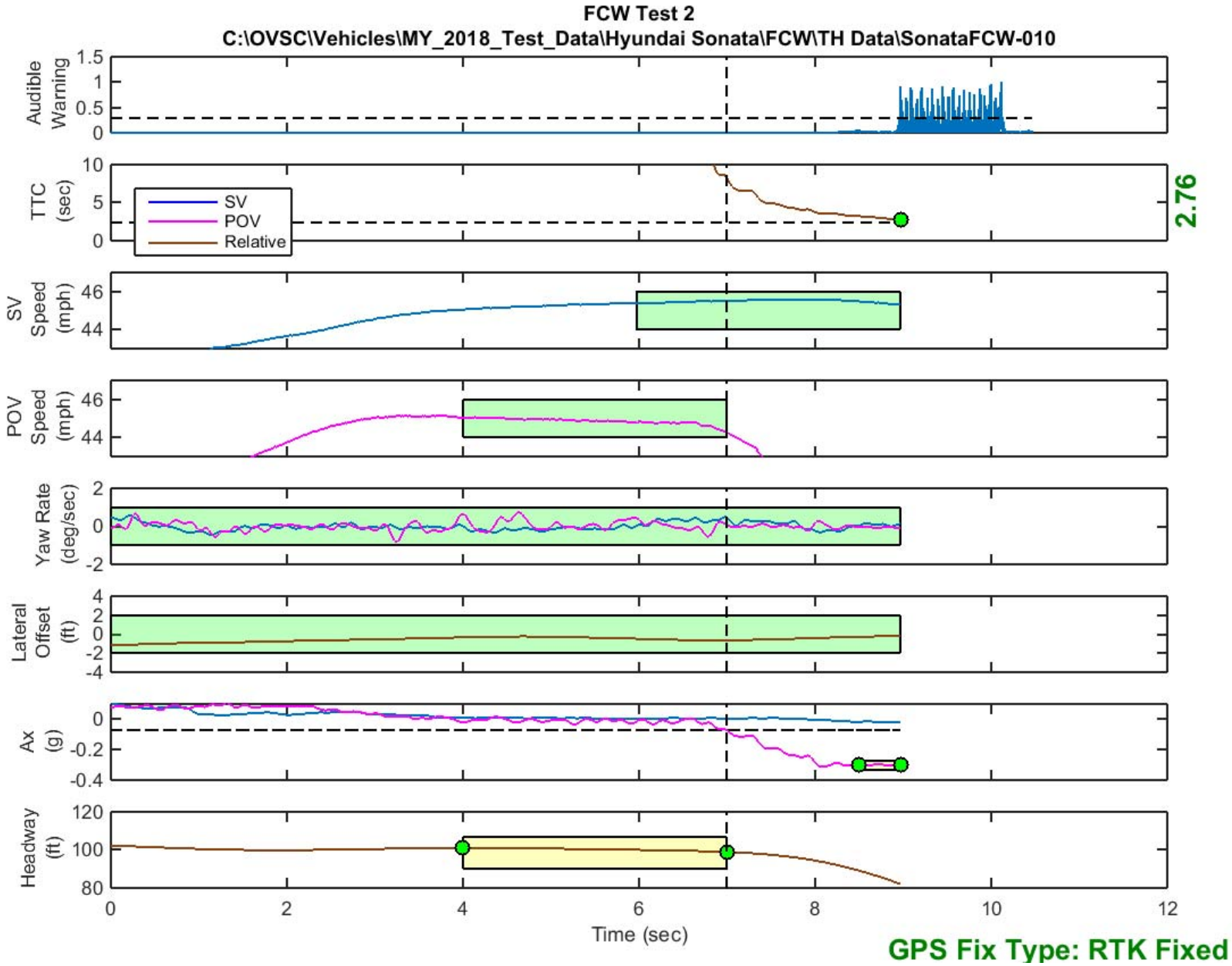


Figure D14. Time History for Run 10, FCW Test 2, Audible Warning

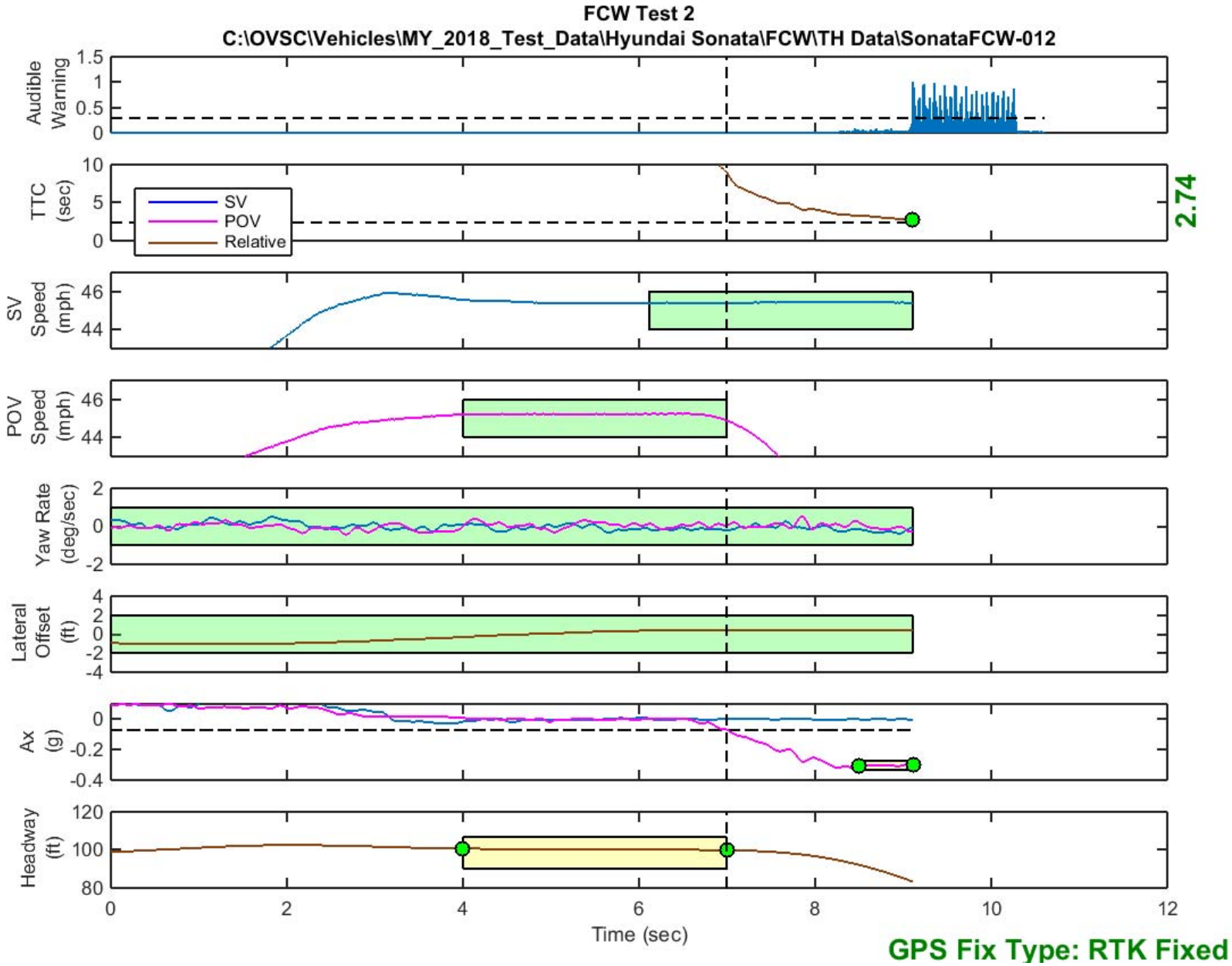


Figure D15. Time History for Run 12, FCW Test 2, Audible Warning

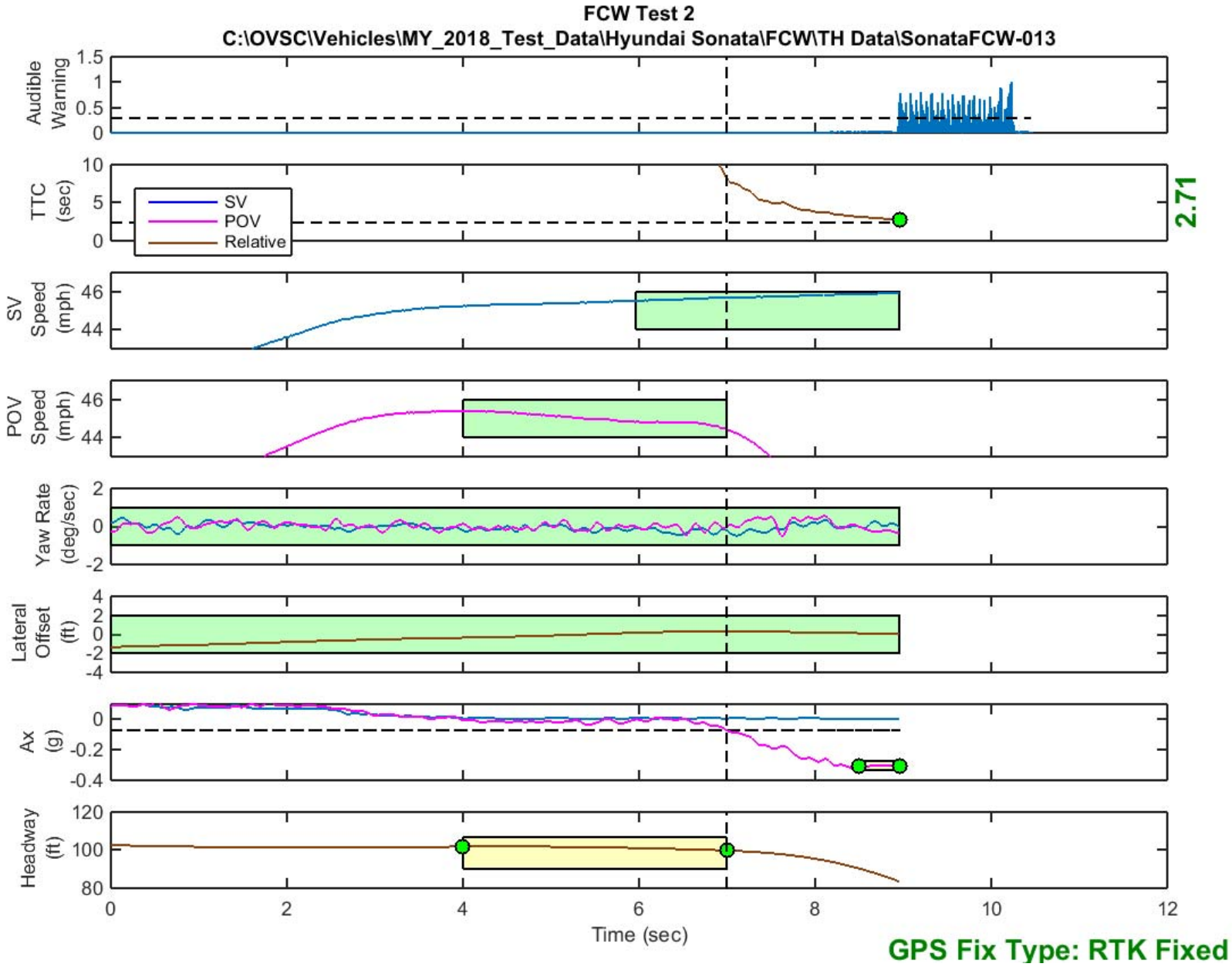


Figure D16. Time History for Run 13, FCW Test 2, Audible Warning

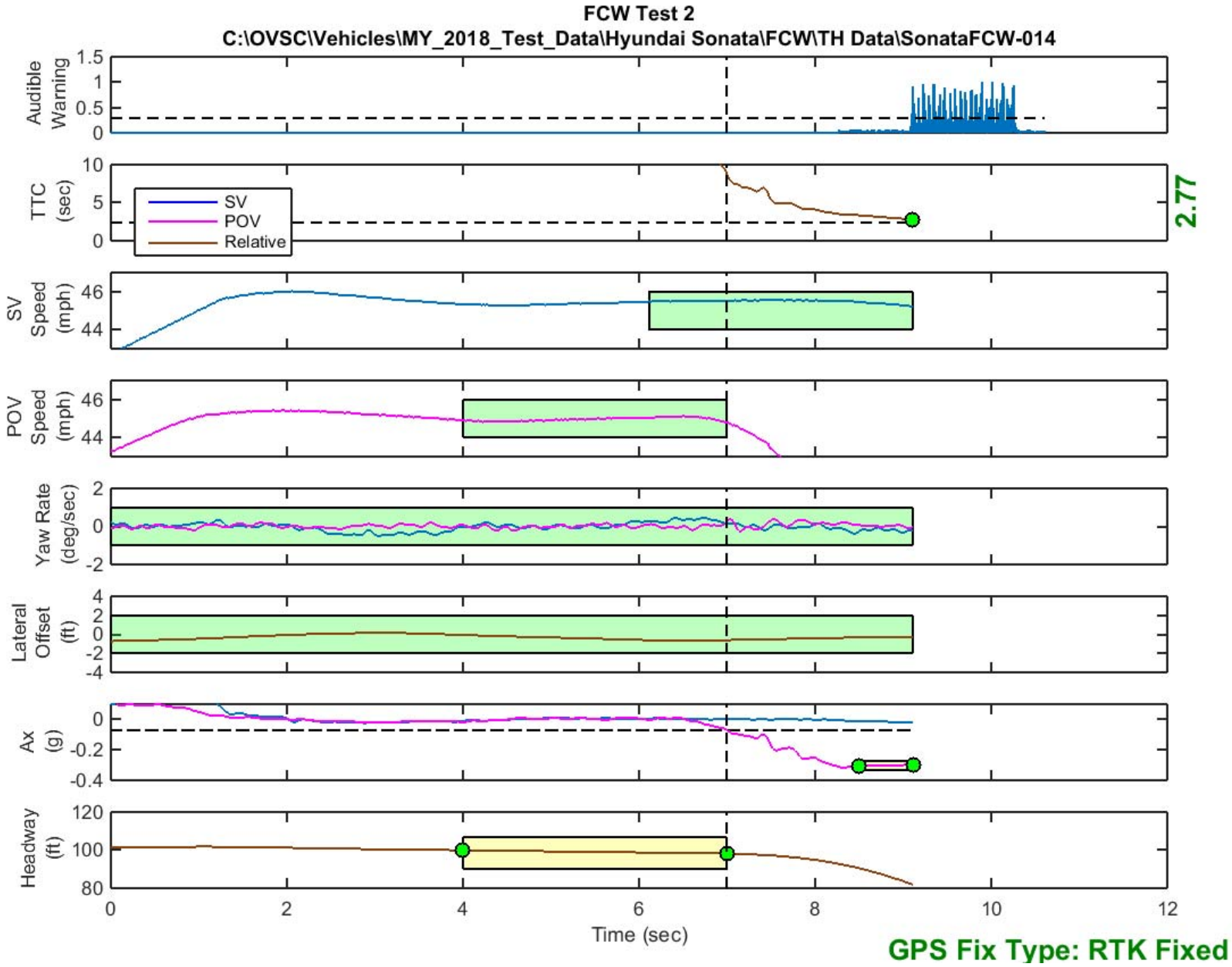


Figure D17. Time History for Run 14, FCW Test 2, Audible Warning

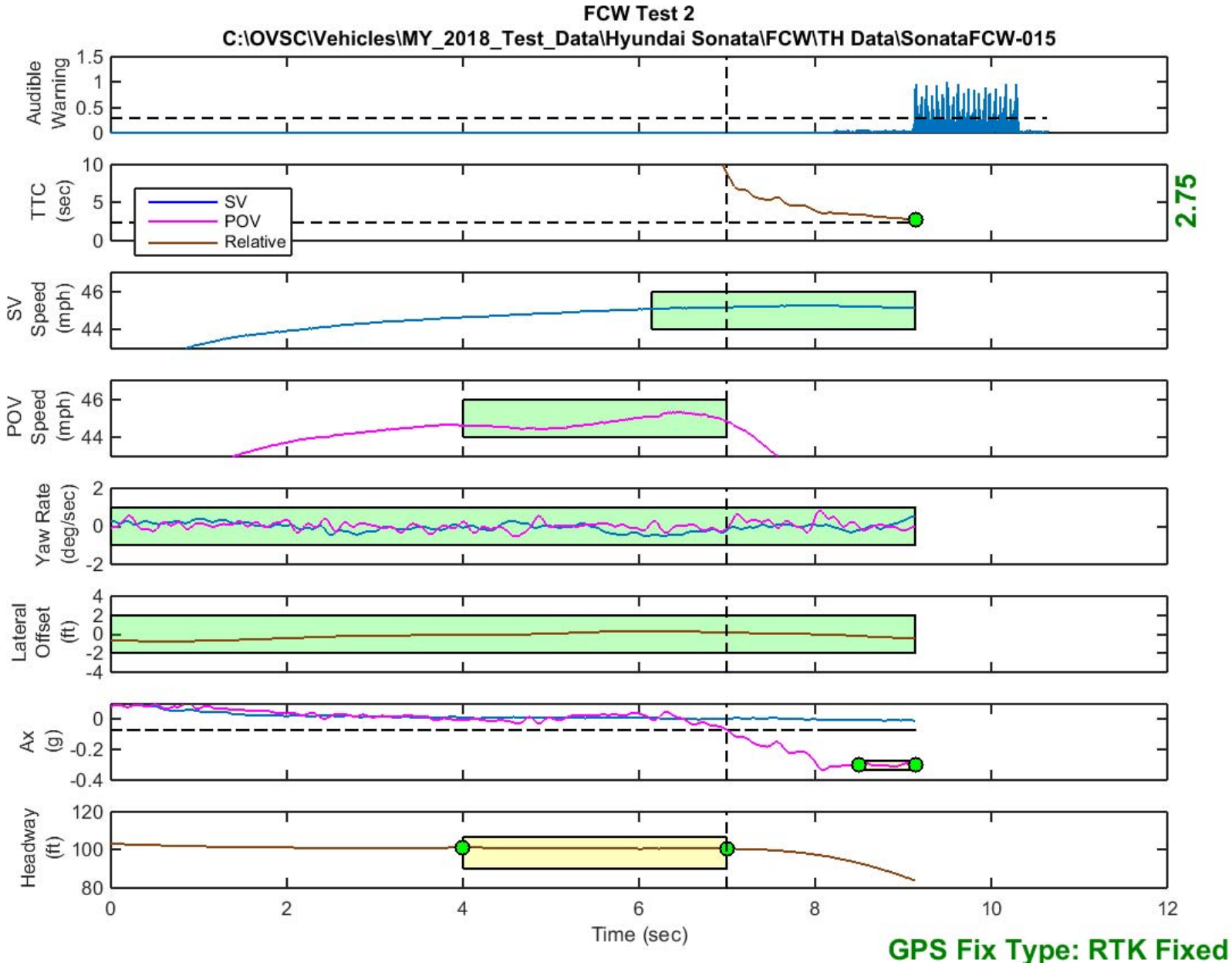


Figure D18. Time History for Run 15, FCW Test 2, Audible Warning

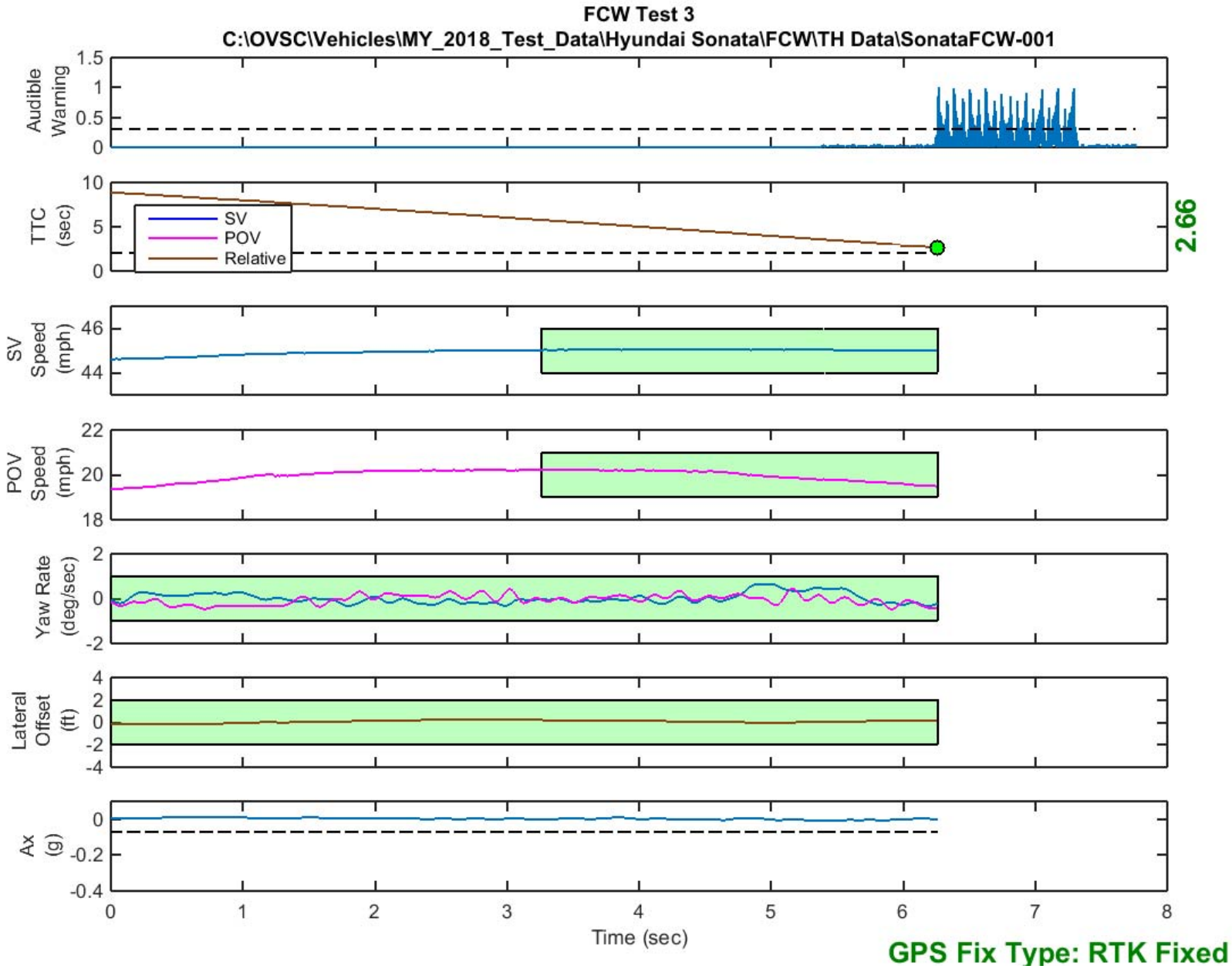


Figure D19. Time History for Run 1, FCW Test 3, Audible Warning

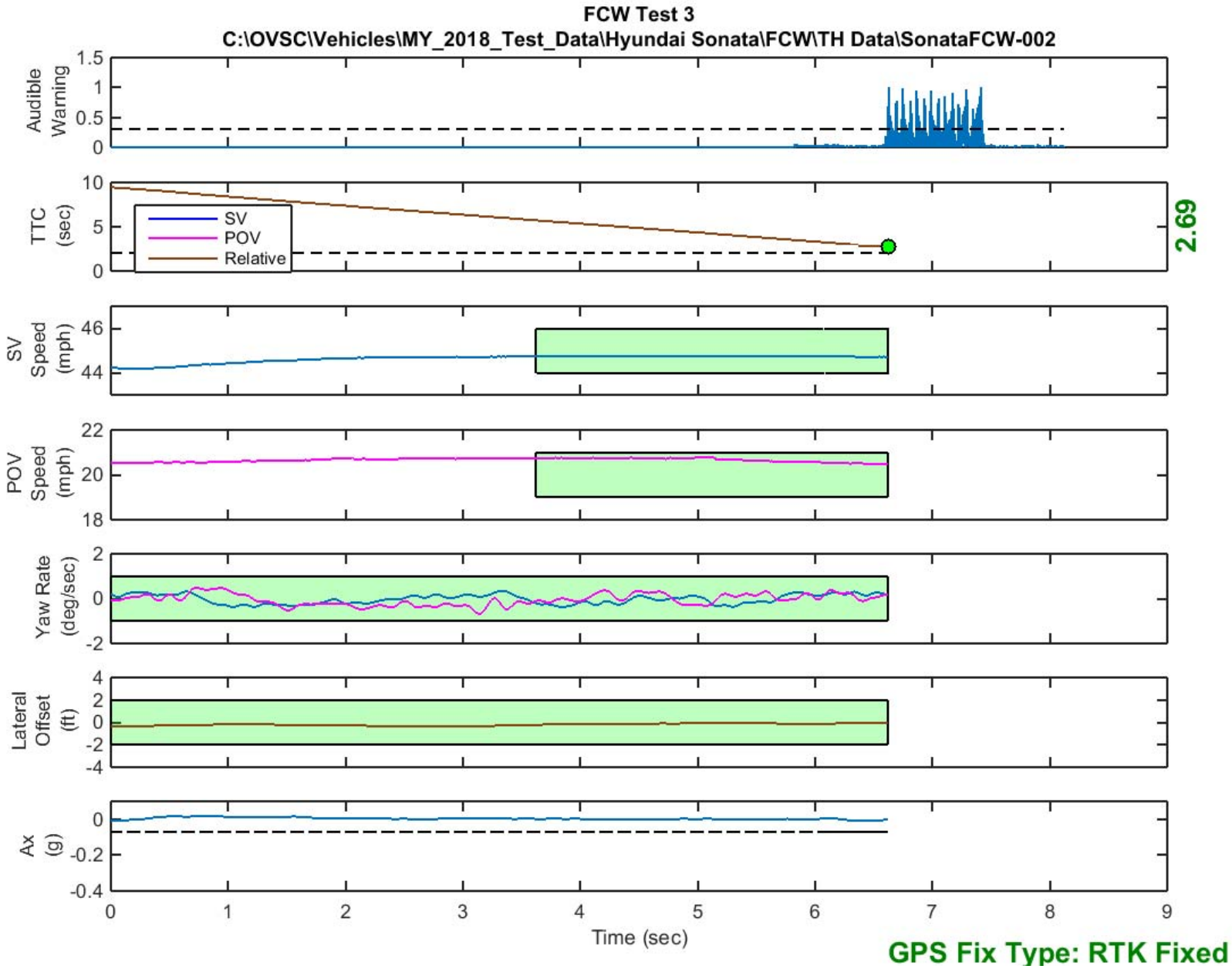


Figure D20. Time History for Run 2, FCW Test 3, Audible Warning

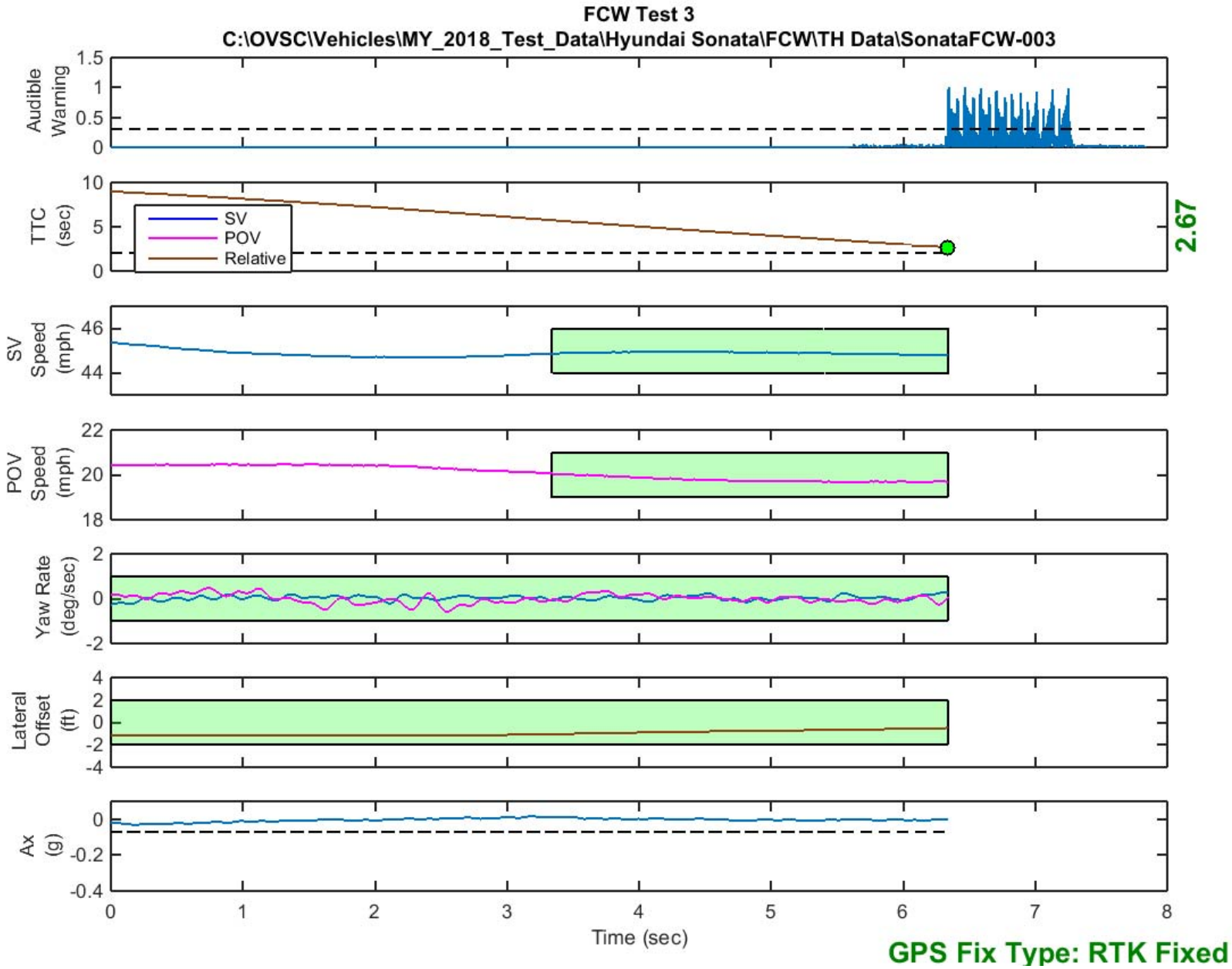


Figure D21. Time History for Run 3, FCW Test 3, Audible Warning

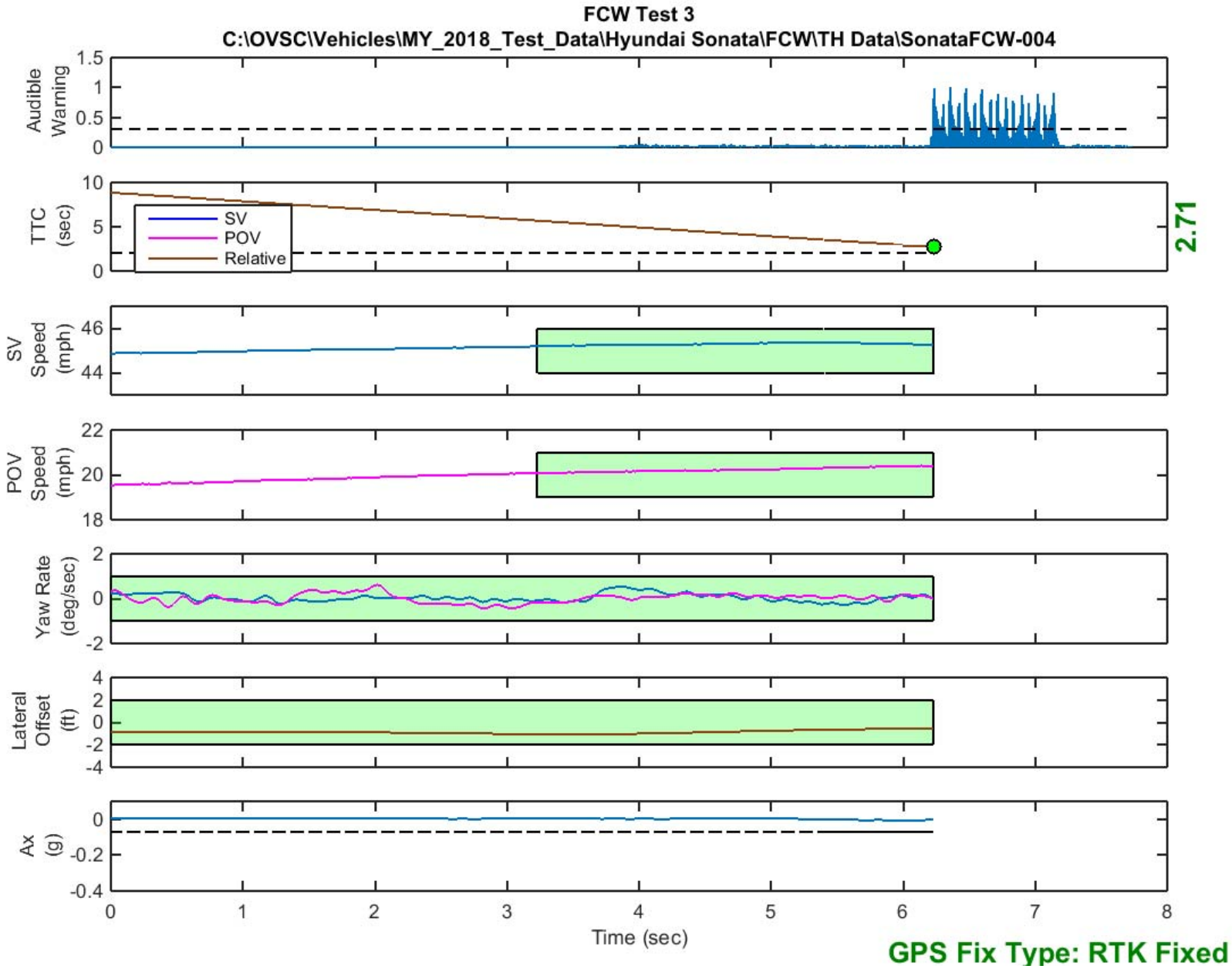


Figure D22. Time History for Run 4, FCW Test 3, Audible Warning

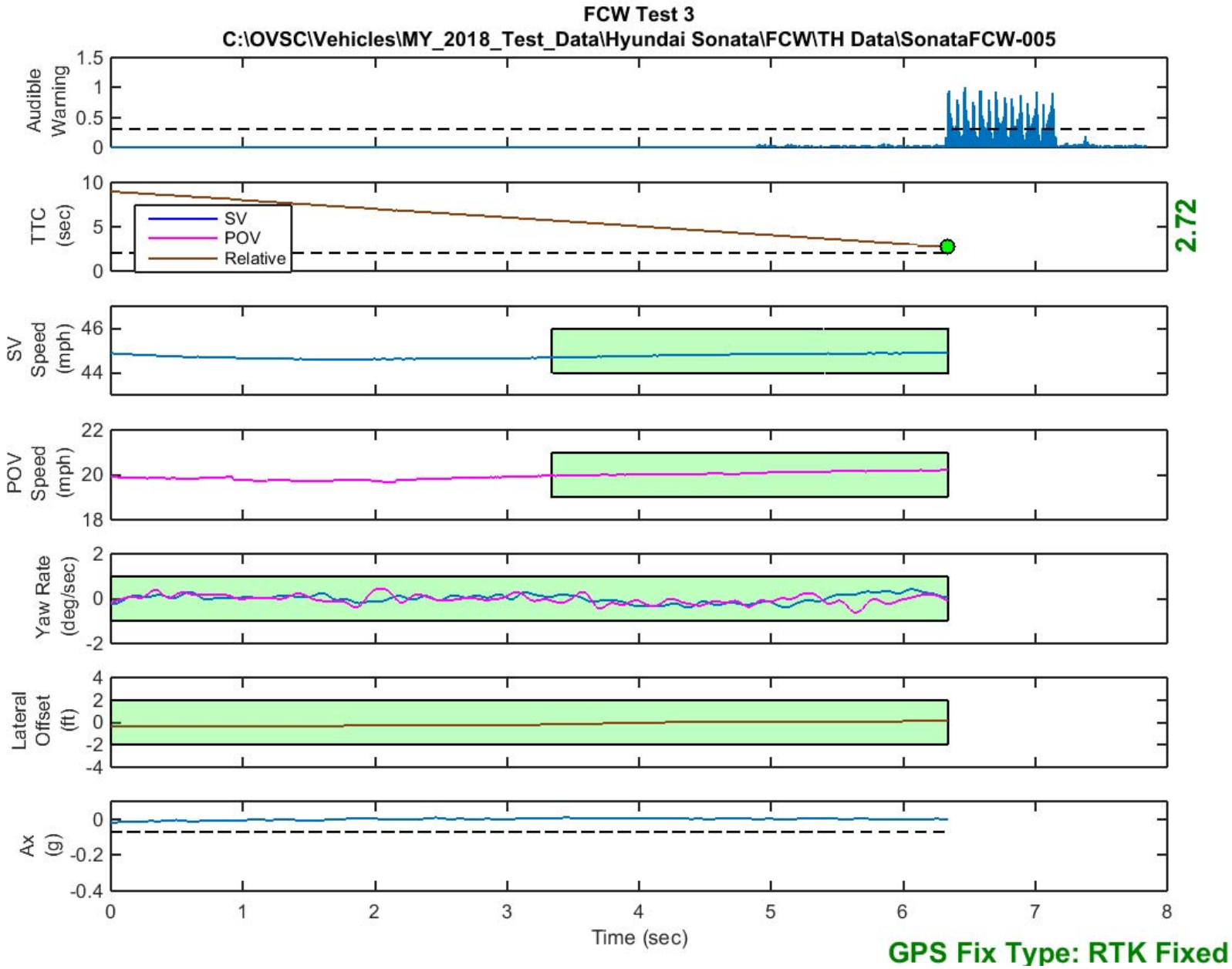


Figure D23. Time History for Run 5, FCW Test 3, Audible Warning

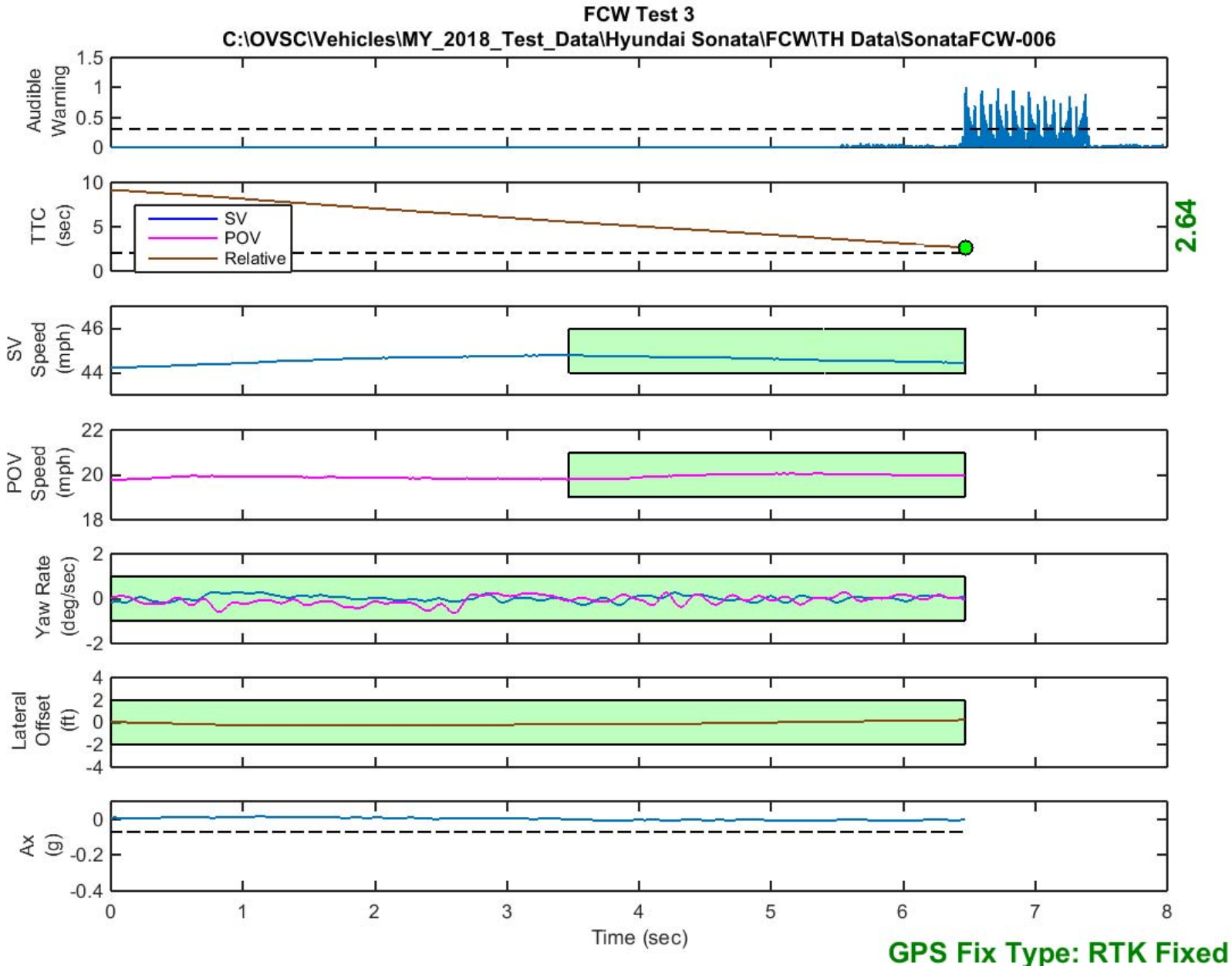


Figure D24. Time History for Run 6, FCW Test 3, Audible Warning

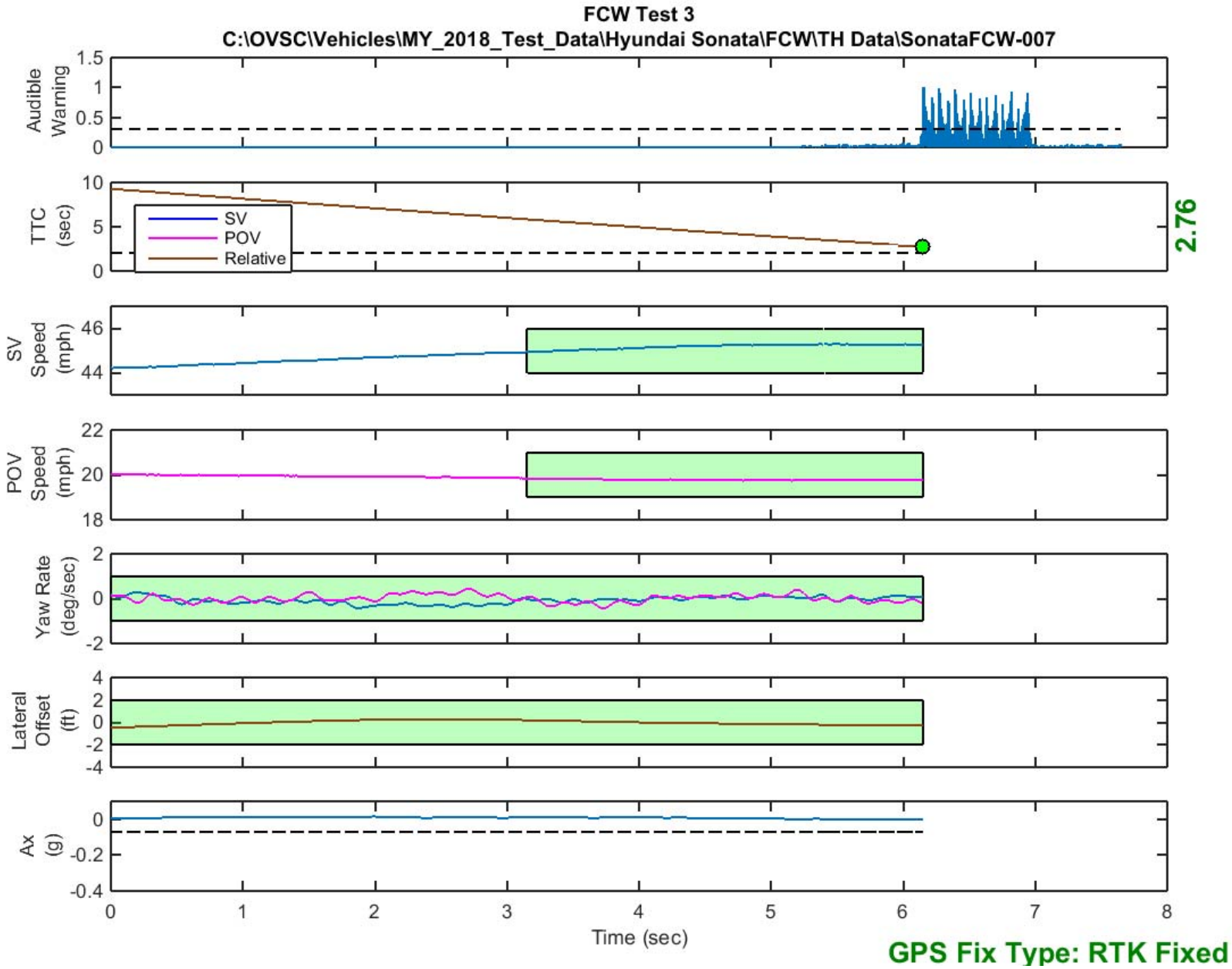


Figure D25. Time History for Run 7, FCW Test 3, Audible Warning