

**NEW CAR ASSESSMENT PROGRAM
FORWARD COLLISION WARNING CONFIRMATION TEST
NCAP-DRI-FCW-20-08**

2020 Hyundai Elantra Value Edition

DYNAMIC RESEARCH, INC.

355 Van Ness Avenue, STE 200
Torrance, California 90501



9 June 2020

Final Report

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

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National Highway Traffic Safety Administration
New Car Assessment Program
1200 New Jersey Avenue, SE
West Building, 4th Floor (NRM-110)
Washington, DC 20590**

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Prepared By: J. Lenkeit and N. Watanabe
Program Manager Test Engineer
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16. Abstract These tests were conducted on the subject 2020 Hyundai Elantra Value Edition in accordance with the specifications of the New Car Assessment Program's (NCAP) most current Test Procedure in docket NHTSA-2006-26555-0134 to confirm the performance of a forward collision warning system. The vehicle passed the requirements of the test for all three FCW test scenarios.			
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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's "Forward Collision Warning Confirmation" test procedure, dated 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 RESULTS SUMMARY

(Page 1 of 1)

2020 Hyundai Elantra Value Edition

VIN: 5NPD84LF0LH54xxx

Test Date: 3/12/2020

Forward Collision Warning setting: Warning only

Test 1 - Subject Vehicle Encounters Stopped Principal Other Vehicle:	<u>Pass</u>
Test 2 - Subject Vehicle Encounters Decelerating Principal Other Vehicle:	<u>Pass</u>
Test 3 - Subject Vehicle Encounters Slower Principal Other Vehicle:	<u>Pass</u>

Overall: **Pass**

Notes:

FORWARD COLLISION WARNING

DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2020 Hyundai Elantra Value Edition

TEST VEHICLE INFORMATION

VIN: 5NPD84LF0LH54xxxx

Body Style: Sedan

Color: Lakeside Blue

Date Received: 3/9/2020

Odometer Reading: 25 mi

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: Hyundai Motor Manufacturing Alabama, LLC

Date of manufacture: Sep/24/19

Vehicle Type: Passenger Car

DATA FROM TIRE PLACARD

Tires size as stated on Tire Placard: Front: 205/55R16

Rear: 205/55R16

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

Rear: 230 kPa (33 psi)

TIRES

Tire manufacturer and model: Nexen Npriz AH8

Front tire specification: 205/55R16 91H

Rear tire specification: 205/55R16 91H

Front tire DOT prefix: UA8X BMHL

Rear tire DOT prefix: UA8X BMHL

FORWARD COLLISION WARNING
DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Hyundai Elantra Value Edition

GENERAL INFORMATION

Test date: 3/12/2020

AMBIENT CONDITIONS

Air temperature: 18.9 C (66 F)

Wind speed: 5.1 m/s (11.5 mph)

X Wind speed \leq 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)

FORWARD COLLISION WARNING
DATA SHEET 3: TEST CONDITIONS

(Page 2 of 2)

2020 Hyundai Elantra Value Edition

WEIGHT

Weight of vehicle as tested including driver and instrumentation:

Left Front: 448.1 kg (988 lb)

Right Front: 421.4 kg (929 lb)

Left Rear: 299.4 kg (660 lb)

Right Rear: 273.5 kg (603 lb)

Total: 1442.4 kg (3180 lb)

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

(Page 1 of 3)

2020 Hyundai Elantra Value Edition

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

Forward Collision-Avoidance Assist (FCA)

Forward Collision Warning Setting used in test: Warning only

Type and location of sensor(s) the system uses:

Camera and radar fusion. The camera is located behind the windshield near the rearview mirror and the radar is located behind the front grill.

How is the Forward Collision Warning presented to the driver? Warning light
(Check all that apply) 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 warning message shown in Appendix A, Figure A14 appears on the LCD display with a warning chime.

The audible alert is a tone of pulsed tone of 1650 Hz pulsed approximately eight times per second.

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

(Page 2 of 3)

2020 Hyundai Elantra Value Edition

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

No

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

The system can be switched off by means of settings menus presented on the center touch screen display (Appendix A, Figure A13). The hierarchy is:

User Settings

Driver Assistance

Forward Safety

Select "Off"

The system resets to "On" when the ignition is cycled.

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

No

If yes, please provide a full description.

The system alert timing can be changed by means of settings menus presented on the center touch screen display (Appendix A, Figure A13). The hierarchy is:

User Settings

Driver Assistance

Warning Timing

Select "Normal" or "Later"

FORWARD COLLISION WARNING

DATA SHEET 4: FORWARD COLLISION WARNING SYSTEM OPERATION

(Page 3 of 3)

2020 Hyundai Elantra Value Edition

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.

The Limitations of the system are described in the Owner's Manual pages 5-81 through 5-85. These are shown in Appendix B, pages B-12 through B-16.

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)

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.

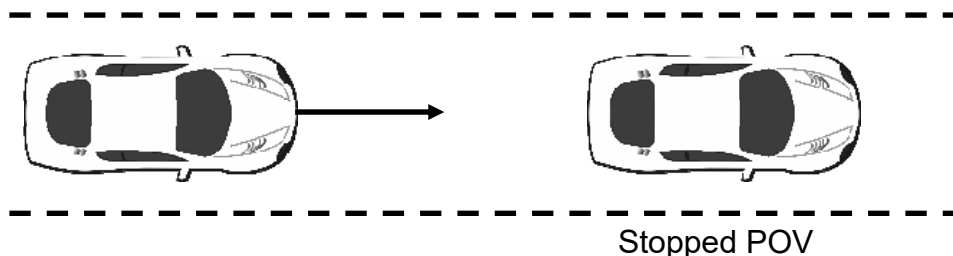


Figure 1. Depiction of Test 1

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. The TTC for this test was calculated by considering the speeds of the SV and the 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 km/h), 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 that the SV approaches the rear of the POV.

The SV was driven at a nominal speed of 45 mph (72.4 km/h) 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% 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 km/h) for a period of three seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90% 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 (1) the required FCW alert occurred or (2) the range fell to less than 90% 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.

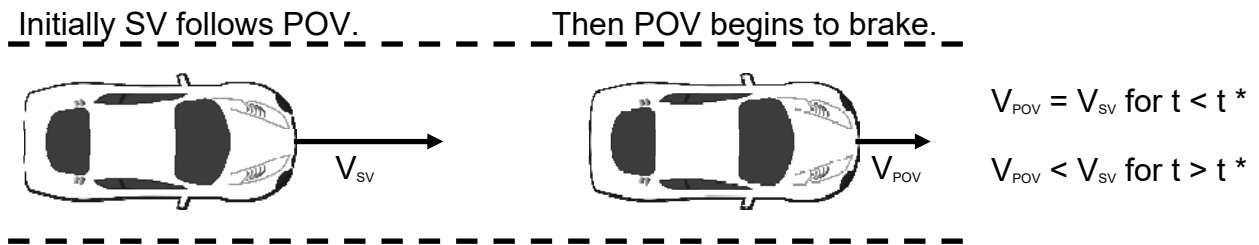


Figure 2. Depiction of Test 2

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 POV¹.

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 km/h), 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.

¹To 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).

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 km/h) 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 km/h) for a period of 3 seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90% 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 $\pm 0.03g$, 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 500 ms after the first local deceleration peak occurs, to 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 (1) the required FCW alert occurred or (2) the range fell to less than 90% 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 to issue a timely alert. As depicted in Figure 3, the scenario was conducted with a closing speed equal to 25.0 mph (40.2 km/h).

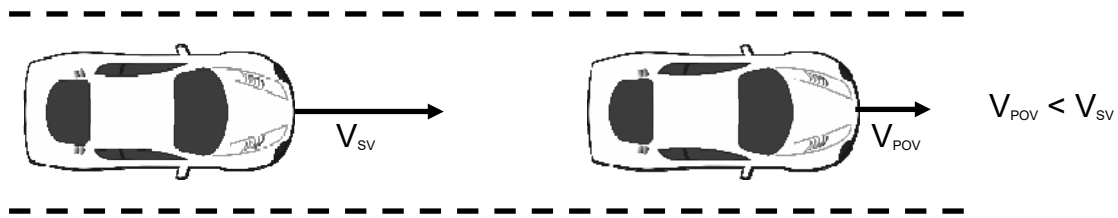


Figure 3. Depiction of Test 3

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 km/h) in the center of the lane of travel.

The SV was driven at 45.0 mph (72.4 km/h), 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., $TT = 1.8$ 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 km/h) for a period of 3 seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90% 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 km/h) 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 (1) the required

FCW alert occurred or (2) before the range fell to less than 90% 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 2006 Acura RL. This satisfied the test requirement 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: 7/3/2019 Due: 7/3/2020
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform 5338 N/	0.5% of applied load	Intercomp SWI	1110M206352	By: DRI Date: 1/6/2020 Due: 1/6/2021
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
					2258	Date: 5/3/2019 Due: 5/3/2021
					015386	Date: 8/8/2019 Due: 8/8/2021
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 auditory 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 visual alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	NA	NA
Accelerometer	Acceleration (to measure time at haptic 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: 1/6/2020 Due: 1/6/2021
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).			dSPACE 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 band-pass filter used for these warning signal 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	Passband Frequency Range
Audible	5 th	3 dB	60 dB	Identified Center Frequency \pm 5%
Tactile	5 th	3 dB	60 dB	Identified Center Frequency \pm 20%

APPENDIX A

Photographs

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Figure A1. Front View of Subject Vehicle



Figure A2. Rear View of Subject Vehicle



2020 ELANTRA VALUE EDITION

SOLD TO: _____ SHIPPED TO: _____

VIN: 5NPD84LF0LH54
 MODEL: 484B2F4P
 ENGINE: G4NHKK025086
 PORT OF ENTRY: MA
 EXTERIOR COLOR: LAKESIDE BLUE
 INTERIOR/SEAT COLOR: GRAY/GRAY
 TRANSPORT: TRUCK
 ACCESSORY WEIGHT: 12 lbs. / 6 kgs.

EMISSIONS: This vehicle meets California Emissions regulations and is Certified as a Super Ultra Low Emission Vehicle (SULEV)

GOVERNMENT 5-STAR SAFETY RATINGS

Overall Vehicle Score ★ ★ ★ ★ ▲

Based on the combined rating of frontal, side and rollover. Should ONLY be compared to other vehicles of similar size and weight.

▲ Safety Concern: Visit www.safercar.gov or call 1-888-327-4236 for more details.

Frontal	Driver	★ ★ ★ ★
Crash	Passenger	★ ★ ★ ★
Based on the risk of injury in a frontal impact. Should ONLY be compared to other vehicles of similar size and weight.		
Side	Front seat	★ ★ ★ ★ ★
Crash	Rear seat	★ ★ ★ ★ ▲
Based on the risk of injury in a side impact.		
Rollover		★ ★ ★ ★
Based on the risk of rollover in a single-vehicle crash.		

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

STANDARD FEATURES:
 AMERICA'S BEST WARRANTY
 5-year/100,000-mile New Vehicle Warranty*
 10-year/100,000-mile Powertrain Warranty*
 7-year/Unlimited-mile Anti-perforation Warranty*
 5-year/Unlimited-mile Roadside Assistance*
 *Limited warranties, see dealer for details

ADVANCED SAFETY TECHNOLOGY
 Forward Collision-Avoidance Assist
 Lane Keep Assist & Driver Attention Warning
 Blind-Spot Collision Warning
 Rear Cross-Traffic Collision Warning
 Front, Front Side Impact, Side Curtain & Driver Knee Airbags
 Electronic Stability Control (ESC) w/ Traction Control
 ABS w/ Electronic Brake Force Distribution & Brake Assist

POWERTRAIN TECHNOLOGY
 2.0L 147 HP, 132 lbs-ft Torque, DOHC 4-Cylinder
 Dual Continuous Variable Valve Timing
 Smartstream Intelligent Variable Transmission
 4-Wheel Disc Brakes

EXTERIOR
 16-Inch Alloy Wheels with 205/55 R16 Tires
 Power Sunroof
 Heated Outside Mirrors & Door Handle Approach Lights

COMFORT & CONVENIENCE
 7" Display Audio System w/ AM/FM/HD Radio® & 6 Speakers
 SiriusXM Radio w/90 Day Trial. Not Available in AK & HI
 Android Auto (TM) & Apple CarPlay (TM)
 Blue Link® Connected Services 3-years Standard (enrollment req.)
 Blue Link Remote Start (3-year Complimentary Service)
 Dual Automatic Temperature Control w/ Auto Defogger
 Bluetooth Hands-free Phone System
 Steering Wheel Mounted Audio & Cruise Controls
 Leather-wrapped Steering Wheel & Shift Knob
 Auto Headlamp Control & 3.5" TFT Mono Cluster Display
 Heated Front Seats
 Auto-up Driver Window & Illuminated Vanity Mirrors
 Rearview Camera w/ Dynamic Guidelines
 Hands-free Smart Trunk Release
 Proximity Key w/ Push Button Start & Immobilizer
 Temporary Compact Spare Tire
 Full Tank of Gas

Manufacturer's Suggested Retail Price: \$20,600.00

ADDED FEATURES:

*Carpeted Floor Mats	\$135.00
*Cargo Net	\$50.00
*Cargo Tray	\$115.00
*Rear Bumper Applique	\$70.00

Inland Freight & Handling : \$930.00
Total Price : \$21,900.00

A bold sedan that's big on features and safety
 New Intelligent Variable Transmission



EPA DOT Fuel Economy and Environment Gasoline Vehicle

Fuel Economy

34 MPG
 combined city/hwy

30 city
 40 highway

2.9 gallons per 100 miles

Midsize Cars range from 12 to 136 MPG. The best vehicle rates 136 MPGe.

You save \$1,500
 in fuel costs over 5 years compared to the average new vehicle.

Annual fuel cost \$1,200

Fuel Economy & Greenhouse Gas Rating (tailpipe only) **8**

Smog Rating (tailpipe only) **7**

This vehicle emits 264 grams CO₂ per mile. The best emits 9 grams per mile (tailpipe only). Posturing and driving fuel also create greenhouse gases and global warming.

Actual results will vary for many reasons, including driving conditions and how you drive and maintain your vehicle. The average new vehicle gets 27 MPG and costs \$7,500 to fuel over 5 years. Cost estimates are based on 15,000 miles per year at \$ 2.70 per gallon. MPGe is miles per gallon gasoline equivalent. Vehicle emissions are a significant cause of climate change and smog.

fuelconomy.gov
 Calculate personalized estimates and compare vehicles

Smartphone QR Code

Manufacturer's suggested retail price includes manufacturer's recommended pre-delivery service. Gasoline license and title fees state and local taxes and dealer installed options and accessories are not included in the manufacturer's suggested retail price. This label has been affixed to this vehicle by Hyundai Motor America, pursuant to the requirements of 15 U.S.C. 1231 et seq. which prohibits its removal or alteration prior to delivery to the ultimate purchaser.

PARTS CONTENT INFORMATION FOR VEHICLE IN THIS CARLINE:
 U.S./CANADIAN PARTS CONTENT: 45 %
 MAJOR SOURCES OF FOREIGN PARTS CONTENT: KOREA: 35 %
 MEXICO: 20 %

Note: Parts content does not include final assembly, distribution, or other non-parts costs.

FOR THIS VEHICLE:
 FINAL ASSEMBLY POINT: MONTGOMERY, ALABAMA U.S.A.
 COUNTRY OF ORIGIN:
 ENGINE: U.S.A.
 TRANSMISSION: MEXICO



Figure A3. Window Sticker (Monroney Label)



MANUFACTURED BY
HYUNDAI MOTOR MANUFACTURING ALABAMA, LLC

Sep/24/19

GVWR 3924 lbs

PAINT VU

GAWR
FRONT 2183 lbs

GAWR
REAR 2094 lbs

TRIM PK

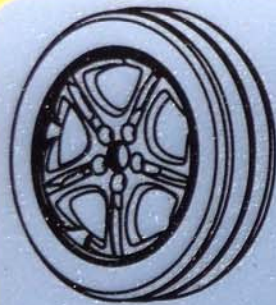
THIS VEHICLE CONFORMS TO ALL APPLICABLE U.S.A. FEDERAL
MOTOR VEHICLE SAFETY, BUMPER, AND THEFT PREVENTION STANDARDS
IN EFFECT ON THE DATE OF MANUFACTURE SHOWN ABOVE

V.I.N 5NPD84LF0LH54

PASSENGER CAR



Figure A4. Vehicle Certification Label



TIRE AND LOADING INFORMATION RENSEIGNEMENTS SUR LES PNEUS ET LE CHARGEMENT

SEATING CAPACITY NOMBRE DE PLACES	TOTAL 5	FRONT AVANT 2	REAR ARRIÈRE 3
--------------------------------------	---------	------------------	-------------------

The combined weight of occupants and cargo should never exceed 385 kg or 849 lbs.
Le poids total des occupants et du chargement ne doit jamais dépasser 385 kg ou 849 lb.

TIRE PNEU	SIZE DIMENSIONS	COLD TIRE PRESSURE PRESSION DES PNEUS À FROID
FRONT AVANT	205/55R16	230kPa, 33psi
REAR ARRIÈRE	205/55R16	230kPa, 33psi
SPARE DE SECOURS	T125/80D15	420kPa, 60psi

**SEE OWNER'S
MANUAL FOR
ADDITIONAL
INFORMATION**

**VOIR LE MANUEL
DE L'USAGER
POUR PLUS DE
RENSEIGNEMENTS**

E620

Figure A5. Tire Placard



Figure A6. Front View of Principal Other Vehicle



Figure A7. Rear View of Principal Other Vehicle



Figure A8. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle



Figure A9. Sensor for Detecting Visual Alerts



Figure A10. Sensor for Detecting Auditory Alerts



Figure A11. Computer Installed in Subject Vehicle



Figure A12. Brake Actuation System Installed in Principal Other Vehicle



Figure A13. FCW System Setting Menus



Figure A14. FCW Visual Alert

APPENDIX B

Excerpts from Owner's Manual

Forward Collision Avoidance Assist Warning Light (if equipped)



This warning light illuminates :

- When you set the ignition switch or Engine Start/Stop button to the ON position.
 - It illuminates for approximately 3 seconds and then goes off.
- When there is a malfunction with FCA. In this case, have your vehicle inspected by an authorized dealer of HYUNDAI.

For more details, refer to "Forward Collision-Avoidance Assist (FCA) system" in chapter 5.

Lane Keeping Assist (LKA) System Indicator Light (if equipped)



This indicator light illuminates:

- [Green] When the system operating conditions are satisfied.
- [White] The system operating conditions are not satisfied.
- [Yellow] When there is a malfunction with the lane keeping assist system.
 - If this occurs, have your vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Lane Keeping Assist (LKA) system" in chapter 5.

Headlight Warning Light (if equipped)



This warning light illuminates:

This warning light illuminates if one of the exterior bulbs (headlamp, DRL, turn signal lamp, stop lamp, etc.) is not operating properly. One of the bulbs may need to be replaced. If the vehicle is equipped with LED headlamps, have the vehicle inspected by an authorized HYUNDAI dealer.

i Information

When replacing the bulb, use the same wattage bulb.

For more details, refer to "BULB WATTAGE" in chapter 8.

Check High Beam Assist (HBA) system (if equipped)

This warning message is displayed if there is a problem with the High Beam Assist (HBA) system. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "High Beam Assist (HBA) system" in chapter 3.

Check Forward Collision Avoidance Assist system (if equipped)

This warning message is displayed if there is a problem with the Forward Collision-Avoidance Assist (FCA) system. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Forward Collision-Avoidance Assist (FCA) system" in chapter 5.

Check Blind-Spot Collision Warning (BCW) system (if equipped)

This warning message is displayed if there is a problem with the Blind-Spot Collision Warning system. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Blind-Spot Collision Warning or Rear Cross-Traffic Collision Warning (RCCW) System" in chapter 5.

Check Smart Cruise Control System (if equipped)

This warning message is displayed if there is a problem with the Smart Cruise Control system. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Smart Cruise Control" in chapter 5.

Check Driver Attention Warning (DAW) system (if equipped)

This warning message is displayed if there is a problem with the Driver Attention Warning (DAW). Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Driver Attention Warning (DAW)" in chapter 5.

Check Lane Keeping Assist (LKA) system (if equipped)

This warning message is displayed if there is a problem with the Check Lane Keeping Assist (LKA) system. Have the vehicle inspected by an authorized HYUNDAI dealer.

For more details, refer to "Check Lane Keeping Assist (LKA) system" in chapter 5.

FORWARD COLLISION AVOIDANCE (FCA) SYSTEM (IF EQUIPPED)

The Forward Collision-Avoidance Assist (FCA) system is designed to help detect and monitor the vehicle ahead in the roadway through camera recognition to warn the driver that a collision is imminent, and if necessary, apply emergency braking.

The camera type FCA system detects the vehicle ahead in the roadway through camera.

⚠ 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.
- Drive at posted speed limits and accordance to road conditions.
- Always drive cautiously to prevent unexpected and sudden situations from occurring. The Forward Collision-Avoidance system may not always stop the vehicle completely and is only intended to help mitigate a collision that is imminent.

System Setting and Activation

System setting



- Setting Forward Safety function

The driver can activate the FCA by placing the ignition switch to the ON position and by selecting:

'User Settings → Driver Assistance → Forward Safety'

- If you select "Active Assist", the FCA system activates. The FCA produces warning messages and warning alarms in accordance with the collision risk levels. Braking assist will be applied in accordance with the collision risk.

5

Driving your vehicle

- If you select "Warning Only", the FCA system activates and produces only warning alarms in accordance with the collision risk levels. Braking assist will not be applied in this setting.
- If you select "Off", the FCA system deactivates,



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. If the warning light remains ON when the FCA is activated, have the system checked by an authorized HYUNDAI dealer.



• Setting Warning Timing

The driver can select the initial warning activation time on the LCD display.

Go to the 'User Settings → Driver Assistance → Warning Timing → Normal/Later'.

The options for the initial Forward Collision Warning includes the following:

- Normal :
When this option is selected, the initial Forward Collision Warning is activated sensitively. If you feel the warning activates too early, set the Forward Collision Warning to 'Later'.

Even though, 'Normal' is selected if the front vehicle suddenly stops the initial warning activation time may not seem fast.

- Later :
When this option is selected, the initial Forward Collision Warning is activated later than normal. This setting reduces the amount of distance between the vehicle ahead before the initial warning occurs.

Select 'Later' when traffic is light and when driving speed is slow.

i Information

If you change the warning timing, the warning time of other systems may change. Always be aware before changing the warning timing.

Prerequisite for activation

The FCA system is on and ready when 'Active Assist' or 'Warning Only' under Forward Safety is selected in the LCD display and when the following prerequisites are satisfied:

- The ESC (Electronic Stability Control) is on.
- Driving speed exceeds approximately 6mph (10 km/h) (The FCA is only activated within a certain speed range.)
- The system detects a vehicle in front, which may collide with your vehicle. (The FCA may not be activated or may sound a warning alarm in accordance with the driving situation or vehicle condition.)

⚠ WARNING

- **FCA automatically activates upon placing the ignition switch to the ON position. The driver can deactivate FCA by canceling the system setting in the cluster LCD display. To avoid driver distractions, do not attempt to set or cancel the FCA while driving the vehicle.**
- **FCA automatically deactivates upon canceling ESC. When ESC is canceled, FCA cannot be activated in the cluster LCD display. The FCA warning light will illuminate which is normal.**

FCA Warning Message and Brake Control

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

Collision Warning (First warning)



OAD058119N

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 in a collision.

- If you select "Warning Only", the FCA system activates and produces only warning alarms in accordance with the collision risk levels. You should control the brake directly because the FCA system do not control the brake.

Emergency Braking (Second warning)



OAD058120N

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 in a collision. The brake control is maximized just before a collision.

- If you select "Warning Only", the FCA system activates and produces only warning alarms in accordance with the collision risk levels. You should control the brake directly because the FCA system do not control the brake.

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 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 accelerator pedal, or when the driver abruptly operates the steering wheel.
- The FCA 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 FCA system.
- After the brake control is activated, the driver must immediately depress the brake pedal and check the surroundings. The brake activation by the system lasts for about 2 seconds.
- If any other warning sound such as seat belt warning chime is already generated, the Forward Collision-Avoidance Assist (FCA) system warning may not sound.
- Playing the vehicle audio system at high volume may prevent occupants from hearing the system warning sounds.

⚠ WARNING

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

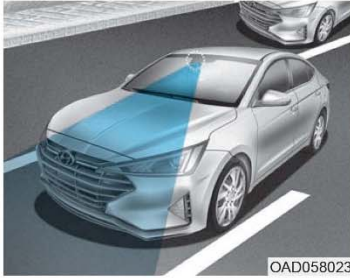
⚠ WARNING

The FCA system logic operates within certain parameters, such as the distance from the vehicle 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 FCA system.

⚠ WARNING

Never deliberately drive dangerously to activate the system.

FCA Sensor



In order for the FCA system to operate properly, always make sure the camera is clean and free of dirt, snow, and debris.

Dirt, snow, or foreign substances on the sensor cover or sensor may adversely affect the sensing performance of the sensor.

NOTICE

- **NEVER** install any accessories or stickers on the front windshield, or tint the front windshield.
- **NEVER** place any reflective objects (i.e. white paper, mirror) over the crash pad. Any light reflection may prevent the system from functioning properly.
- Pay extreme caution to keep the camera dry.
- **NEVER** disassemble the camera assembly, or apply any impact on the camera assembly.
- If the sensor is forcibly moved out of proper alignment, the FCA system may not operate correctly. In this case, a warning message may not be displayed. Have the vehicle inspected by an authorized HYUNDAI dealer.

i Information

Have the system checked by an authorized HYUNDAI dealer when:

- The windshield glass is replaced.

Warning message and warning light

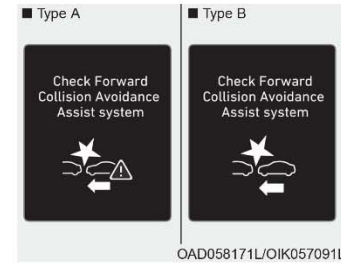


Forward Collision Avoidance Assist (FCA) system disabled. Camera obscured

When the front camera is blocked with dirt, snow, or debris, the FCA system operation not be able to detect other vehicles. If this occurs, a warning message will appear on the LCD display. The system will operate normally when such dirt, snow or debris is removed.

FCA may not properly operate in an area (e.g. open terrain) where any objects or vehicles are not detected after turning on the engine.

System Malfunction



Check Forward Collision Avoidance Assist system

- When 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 HYUNDAI dealer.
- The FCA warning message may appear along with the illumination of the ESC (Electronic Stability Control) warning light.

5

Driving your vehicle

Both FCA warning light and warning message will disappear once the ESC warning light issue is resolved.

⚠ WARNING

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

Also due to sensing limitations, in certain situations, the front camera recognition system may not detect the vehicle ahead. The FCA system may not activate and the warning message may not be displayed.

- If there is a malfunction with the FCA system, the Forward Collision avoidance assist system is not applied even though the braking system is operating normally.
- If the vehicle in front stops suddenly, you may have less control of the brake system. Therefore, always keep a 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 shifting loose objects toward the passengers. Always keep loose objects secured.

- The FCA system may not activate if the driver applies the brake pedal to avoid collision.
- The brake control may be insufficient, possibly causing a collision, if a vehicle in front abruptly stops. Always pay extreme caution.
- The FCA system may not activate according to the road conditions, inclement weather, driving conditions or traffic conditions.
- Occupants may get injured, if the vehicle abruptly stops by the activated FCA system. Pay extreme caution.
- The FCA system does not detect all vehicles.

⚠ WARNING

- The FCA system operates only to detect vehicles in front of the vehicle.
- The FCA system does not operate when the vehicle is in reverse.
- The FCA system is not designed to detect other objects on the road such as animals.
- The FCA system does not detect vehicles in the opposite lane.
- The FCA system does not detect cross traffic vehicles that are approaching.
- The FCA system cannot detect the driver approaching the side view of a parked vehicle (for example on a dead end street).

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 or to stop the vehicle.

Limitations of the System

The Forward Collision Avoidance Assist (FCA) system is designed to monitor the vehicle ahead on the roadway through camera recognition to warn the driver that a collision is imminent, and if necessary, apply emergency braking.

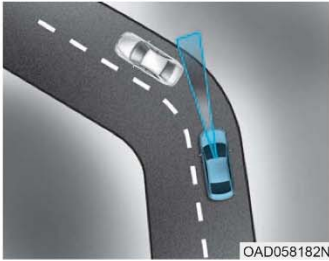
In certain situations, the camera may not be able to detect the vehicle ahead. In these cases, the FCA system may not operate normally. The driver must pay careful attention in the following situations where the FCA operation may be limited.

Detecting vehicles

The sensor may be limited when:

- The camera is blocked with a foreign object or debris
- Inclement weather such as heavy rain or snow obscures the field of view of the camera
- There is interference by electromagnetic waves
- The vehicle is on unpaved or uneven rough surfaces, or road with sudden gradient changes.
- The vehicle drives through a construction area, on an unpaved road, or above metal materials, such as a railway
- The vehicle in front is too small to be detected (for example a motorcycle or a bicycle, etc.)
- The camera'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 camera does not recognize the entire vehicle in front.

- 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 vehicle in front does not have rear lights or the rear lights are not turned ON or the rear lights are located unusually.
- The outside brightness changes suddenly, for example when entering or exiting a tunnel
- The vehicle is moving underground level or inside a building
- The vehicle drives inside a building, such as a basement parking lot
- The adverse road conditions cause excessive vehicle vibrations while driving
- You are on a roundabout and the vehicle in front circles
- The camera lens is contaminated due to tinted, filmed or coated windshield, damaged glass, or stuck of foreign matter (sticker, bug, etc.) on the glass
- The camera is damaged.
- The brightness outside is too low such as when the headlamps are not on at night or the vehicle is going through a tunnel.
- Light coming from a street light or an oncoming vehicle is reflected on a wet road surface such as a puddle in the road
- The field of view in front is obstructed by sun glare
- The shadow is on the road by a median strip, trees, etc.
- The vehicle drives through a toll-gate.
- The windshield glass is fogged up; a clear view of the road is obstructed
- The camera sensor recognition is limited
- The rear part of the vehicle in front is not normally visible (for example, the vehicle is spinning or the vehicle is overturned)
- The sensor recognition changes suddenly when passing over a speed bump
- The vehicle in front is driving erratically
- The vehicle in front is moving vertically to the driving direction
- The vehicle in front is stopped vertically
- The vehicle in front is driving towards your vehicle or reversing



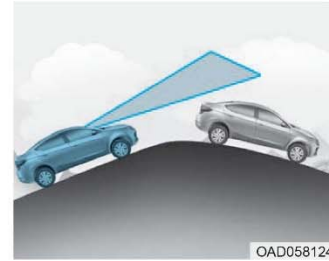
OAD058182N

- Driving on a curve
The performance of the FCA system may be limited when driving on a curved road.
In certain instances on a curved road, the FCA system may activate prematurely.
Also, in certain instances the front 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.



OAD058183N

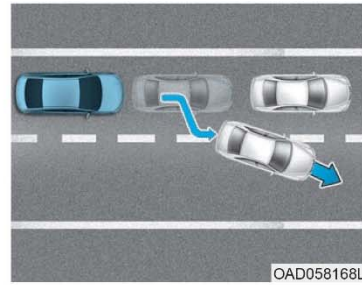
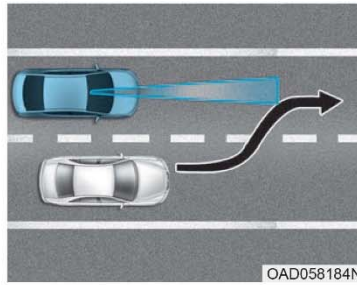
- The FCA system may recognize a vehicle in the next lane when driving on a curved road.
In this case, the system may unnecessarily alarm the driver and apply the brake.
Always pay attention to road and driving conditions, while driving. If necessary, depress the brake pedal to reduce your driving speed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



OAD058124L

- Driving on a slope
The performance of the FCA 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 FCA suddenly recognizes the vehicle in front while passing over a slope, you may experience sharp deceleration.

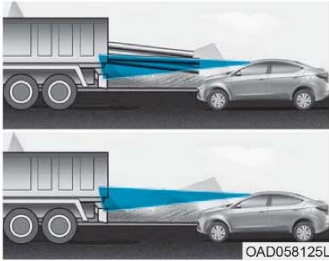
Always keep your eyes forward while driving upward or downward on a slope, and, if necessary, depress the brake pedal to reduce your driving speed in order to maintain distance.



- 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.

When driving in stop-and-go traffic, and a 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.



- 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 FCA 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.

i Information

In some instances, the FCA system may be canceled when subjected to electromagnetic interference.

i 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.
2. This device must accept any interference received, including interference that may cause undesired operation.

⚠ WARNING

- Do not use the Forward Collision Avoidance Assist (FCA) system when towing a vehicle. Application of the FCA 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 FCA system is designed to detect and monitor the vehicle ahead in the roadway through camera recognition. It is not designed to detect pedestrians, bicycles, motorcycles, or smaller wheeled objects such as luggage bags, shopping carts, or strollers.
- Never try to test the operation of the FCA system. Doing so may cause severe injury or death.

APPENDIX C

Run Log

Subject Vehicle: **2020 Hyundai Elantra Value Edition**

Test Date: **3/12/2020**

Principal Other Vehicle: **2006 Acura RL**

Run	Test Type	Valid Run?	TTCW Sound (sec)	TTCW Light (sec)	TTCW Margin (sec)	Pass/Fail	Notes
1	Test 1: Stopped POV	N					Control Desk issues, no signal
2		Y	2.43	2.34	0.33	Pass	
3		Y	2.60	2.49	0.50	Pass	
4		Y	2.49	2.39	0.39	Pass	
5		N					Control Desk issues, no signal
6		N					Control Desk issues, no signal
7		Y	2.48	2.41	0.38	Pass	
8		Y	2.51	2.39	0.41	Pass	
9		Y	2.54	2.44	0.44	Pass	
10		Y	2.56	2.48	0.46	Pass	
18	Test 2: Decelerating POV, 45	Y	2.59	2.48	0.19	Pass	
19		Y	2.50	2.43	0.10	Pass	
20		Y	2.56	2.46	0.16	Pass	
21		Y	2.54	2.41	0.14	Pass	
22		N					SV yaw
23		Y	2.54	2.45	0.14	Pass	
24		Y	2.65	2.55	0.25	Pass	
25		Y	2.48	2.38	0.08	Pass	

Run	Test Type	Valid Run?	TTCW Sound (sec)	TTCW Light (sec)	TTCW Margin (sec)	Pass/Fail	Notes
11	Test 3: Slower POV, 45 vs 20	Y	2.50	2.42	0.50	Pass	
12		Y	2.56	2.47	0.56	Pass	
13		Y	2.76	2.66	0.76	Pass	
14		Y	2.49	2.42	0.49	Pass	
15		Y	2.58	2.48	0.58	Pass	
16		Y	2.68	2.59	0.68	Pass	
17		Y	2.49	2.38	0.49	Pass	

APPENDIX D

Time History Plots

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Description of Time History Plots

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

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 – Decelerating 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 ($0.3 \text{ g} \pm 0.03 \text{ g}$) 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

Other Notations

- ENV – For Ax plots only, indicates that the envelope for the POV braking was exceeded.
- NG – Indicates that the value for that variable was outside of bounds and therefore “No Good”.
- No Wng – No warning was detected.
- POV – Indicates that the value for the Principal Other Vehicle was out of bounds.
- SV – Indicates that the value for the Subject Vehicle was out of bounds.
- SR – Shows the speed reduction value.
- Thr – Indicates that the requirements for the throttle were not met.

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.

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.

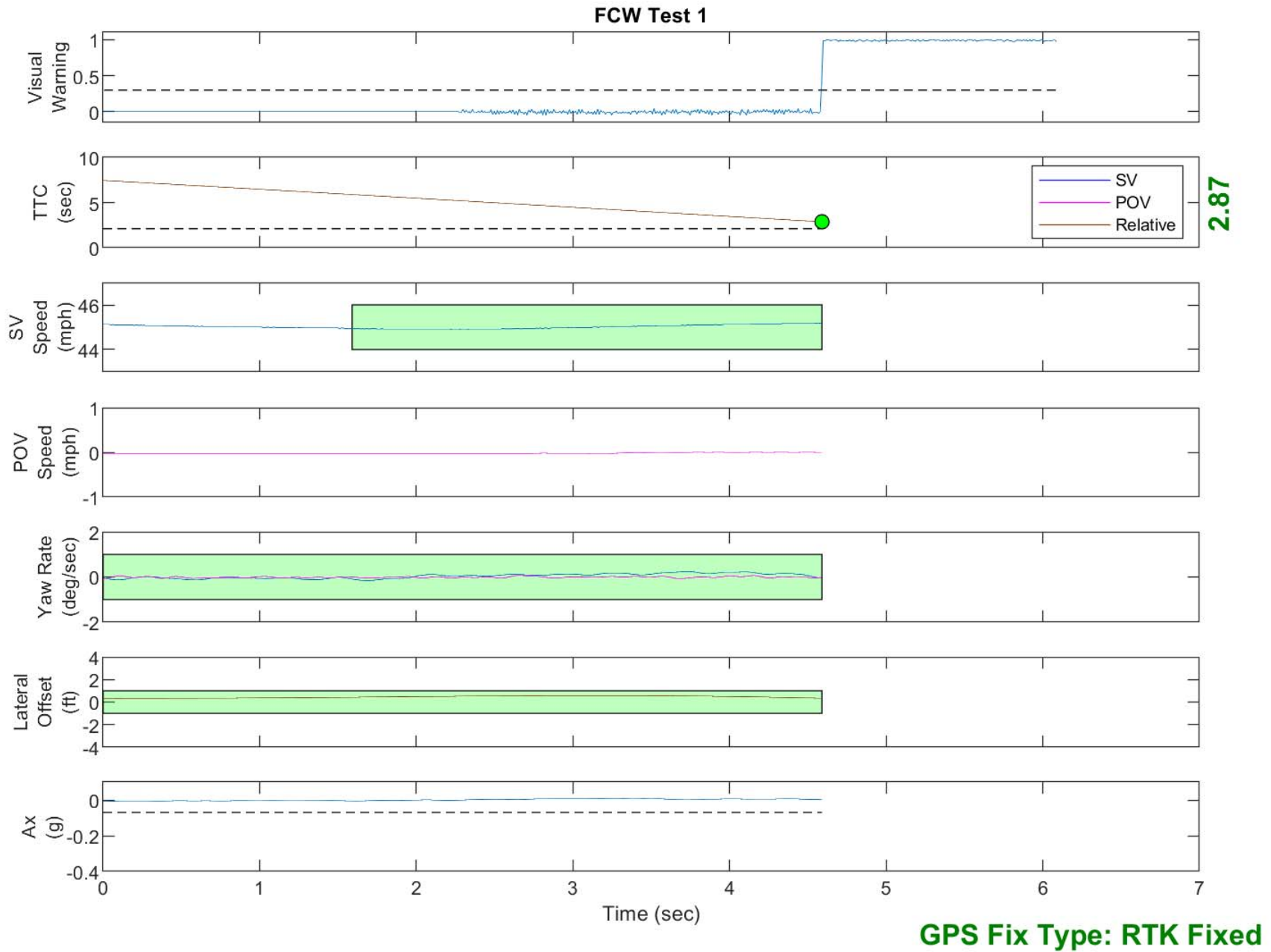


Figure D1. Example Time History for Test Type 1, Passing

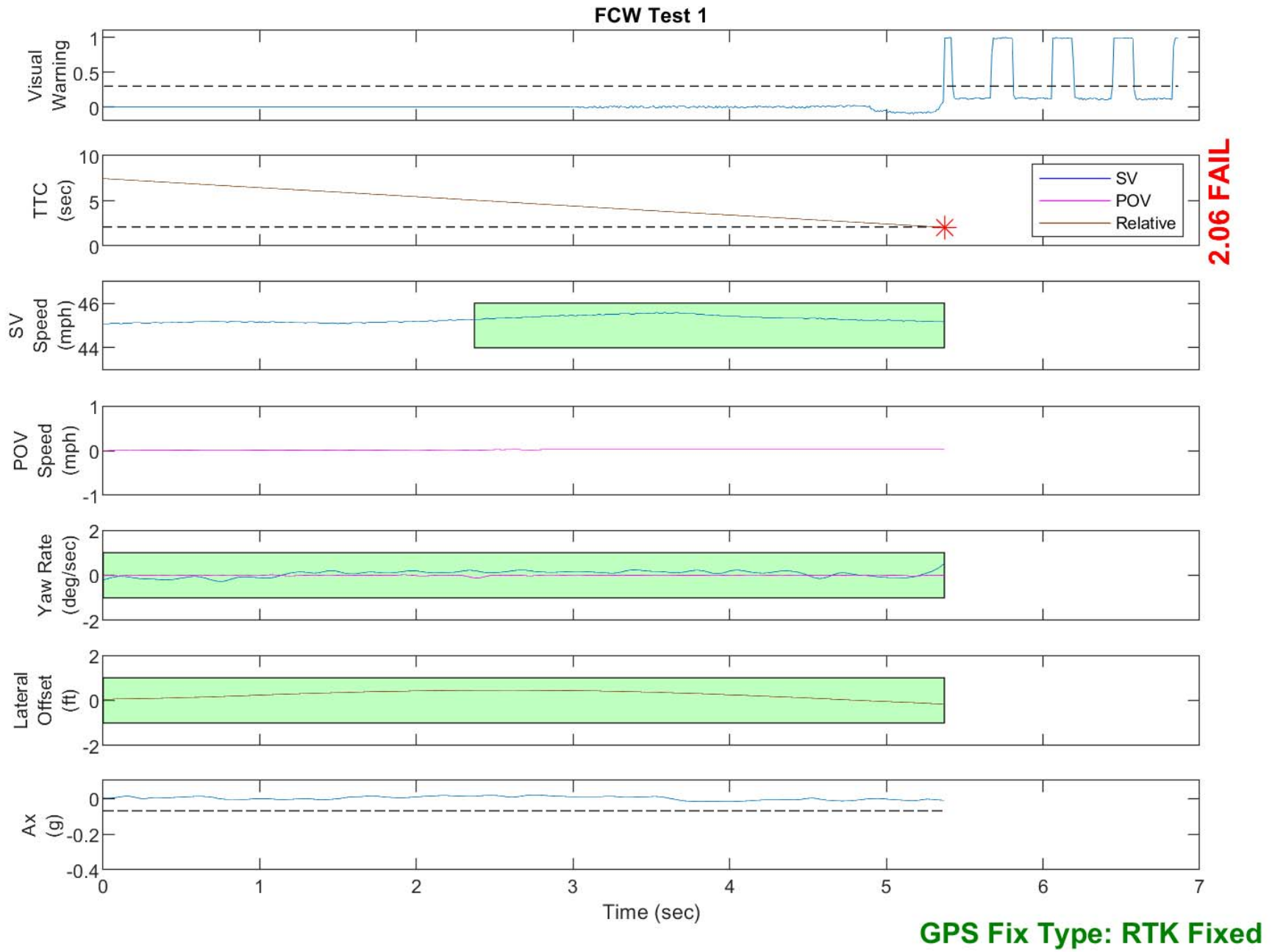
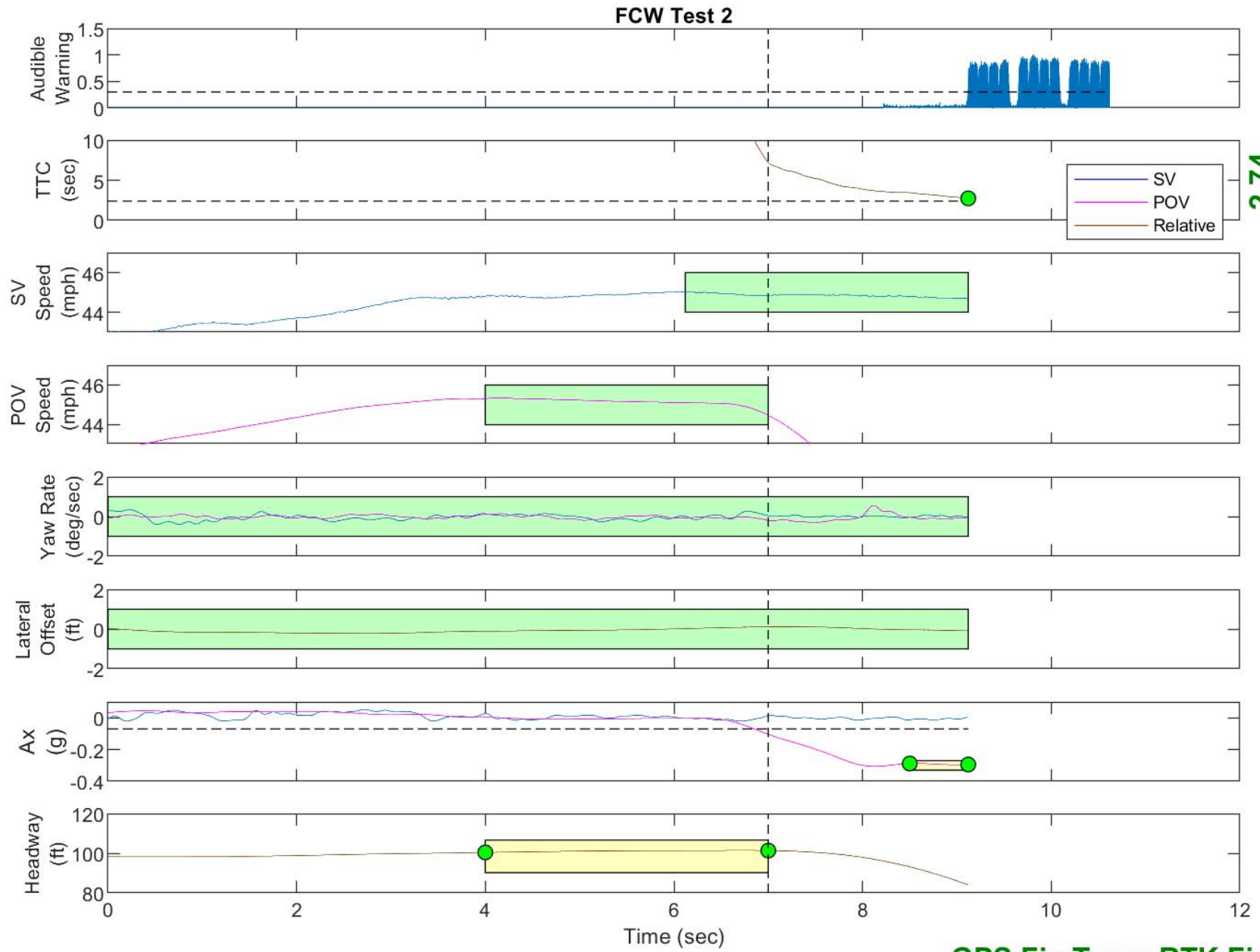
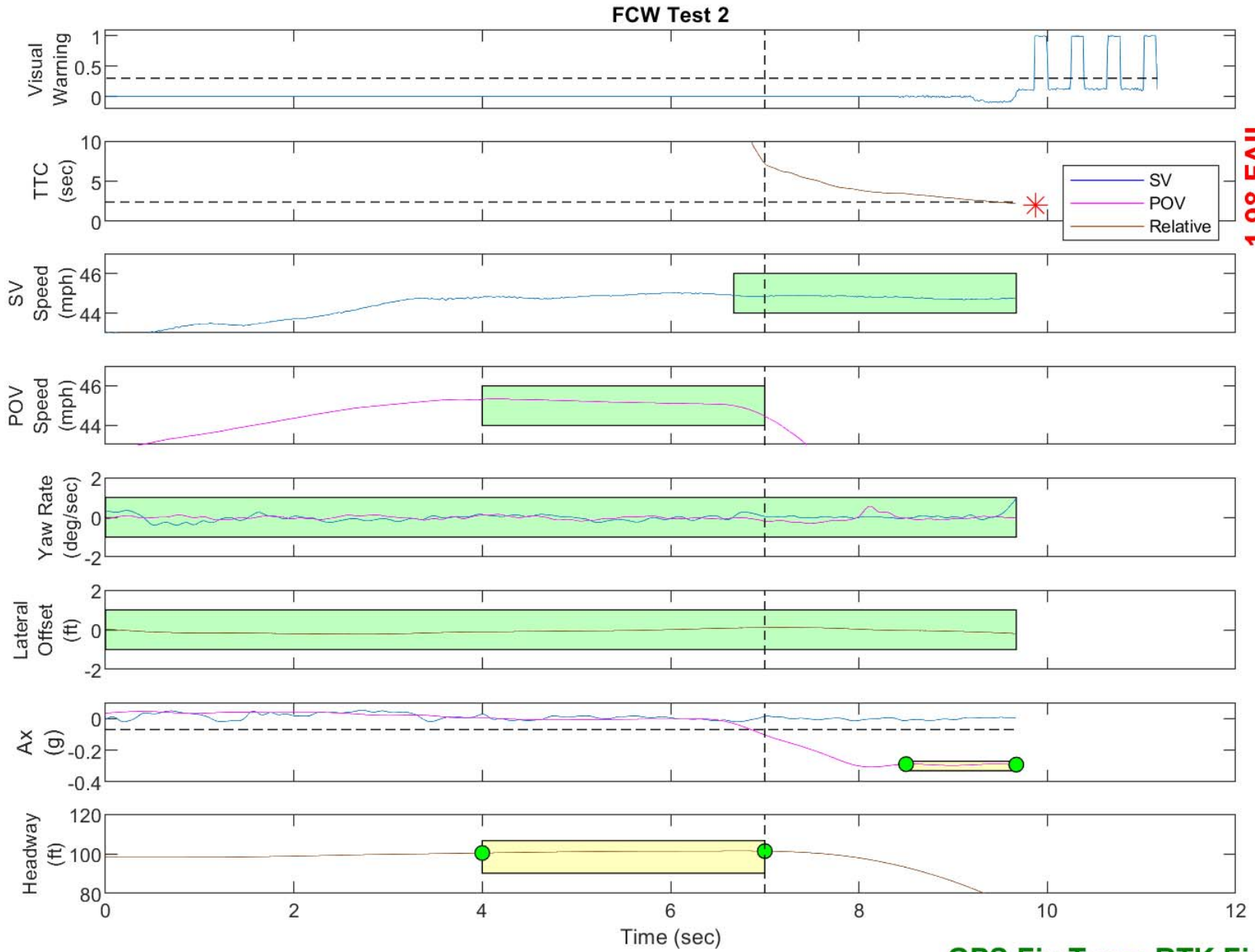


Figure D2. Example Time History for Test Type 1, Failing



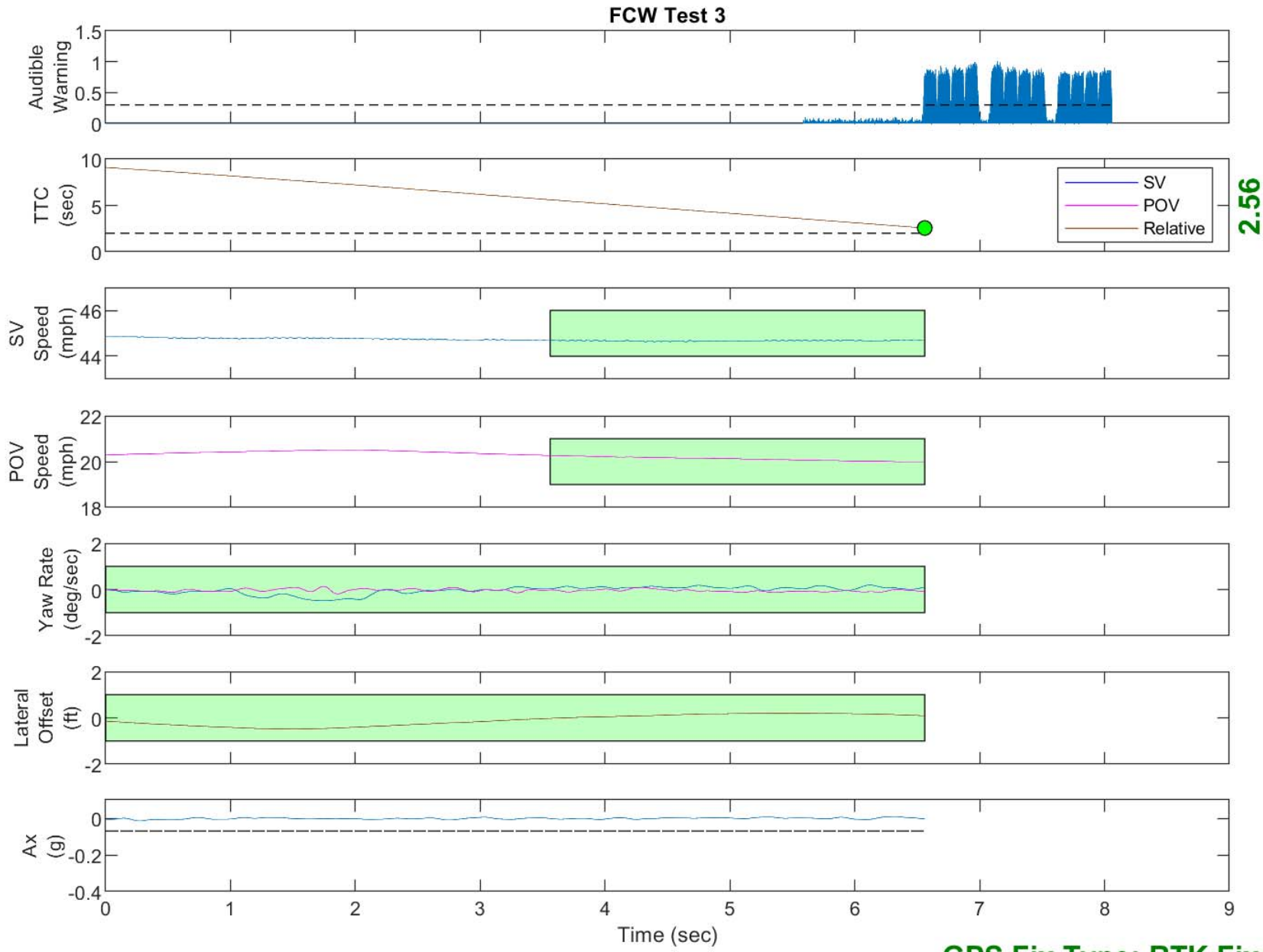
GPS Fix Type: RTK Fixed

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



GPS Fix Type: RTK Fixed

Figure D4. Example Time History for Test Type 2, Failing



2.56

GPS Fix Type: RTK Fixed

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

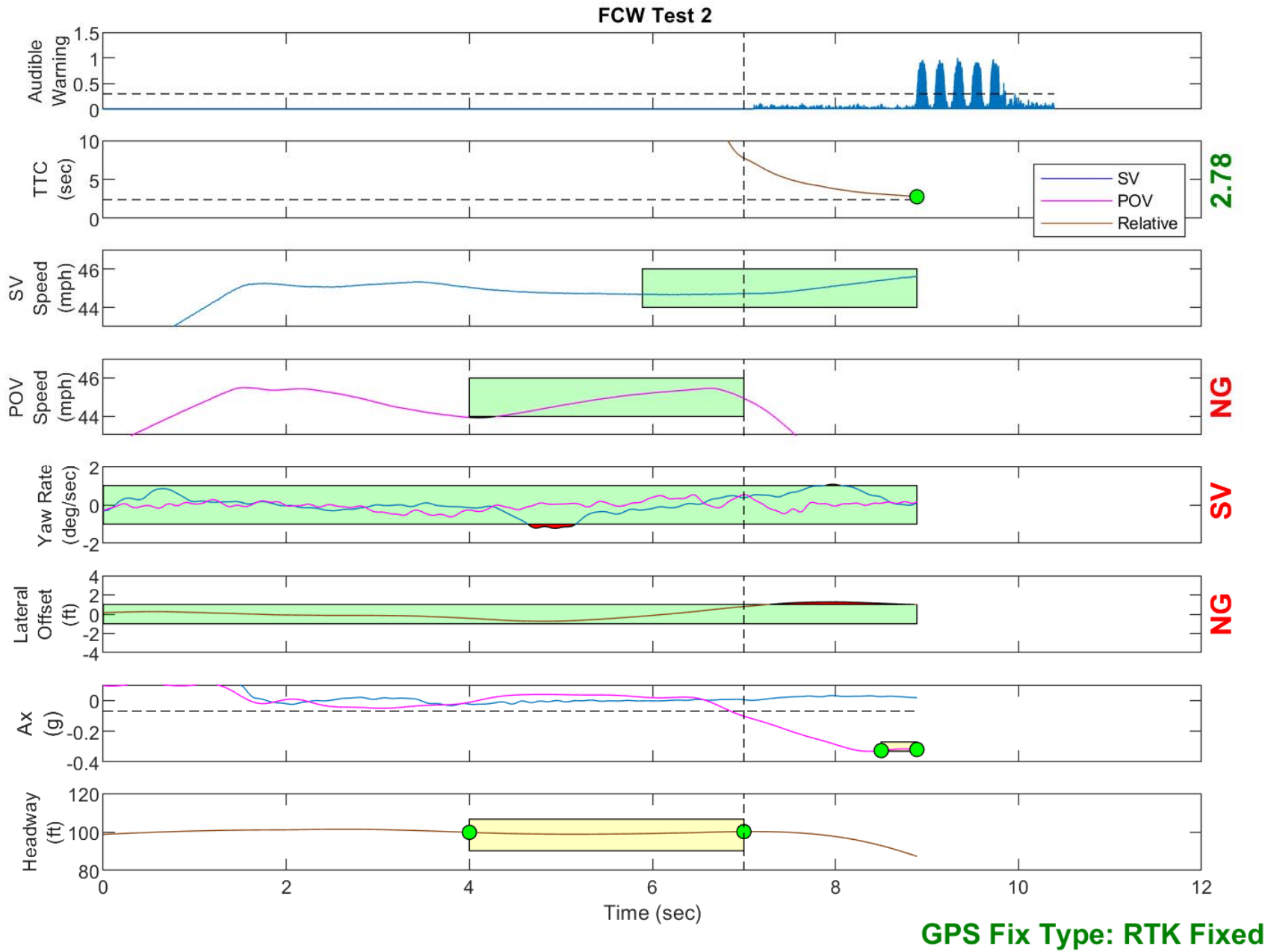


Figure D6. Example Time History Displaying Various Invalid Criteria

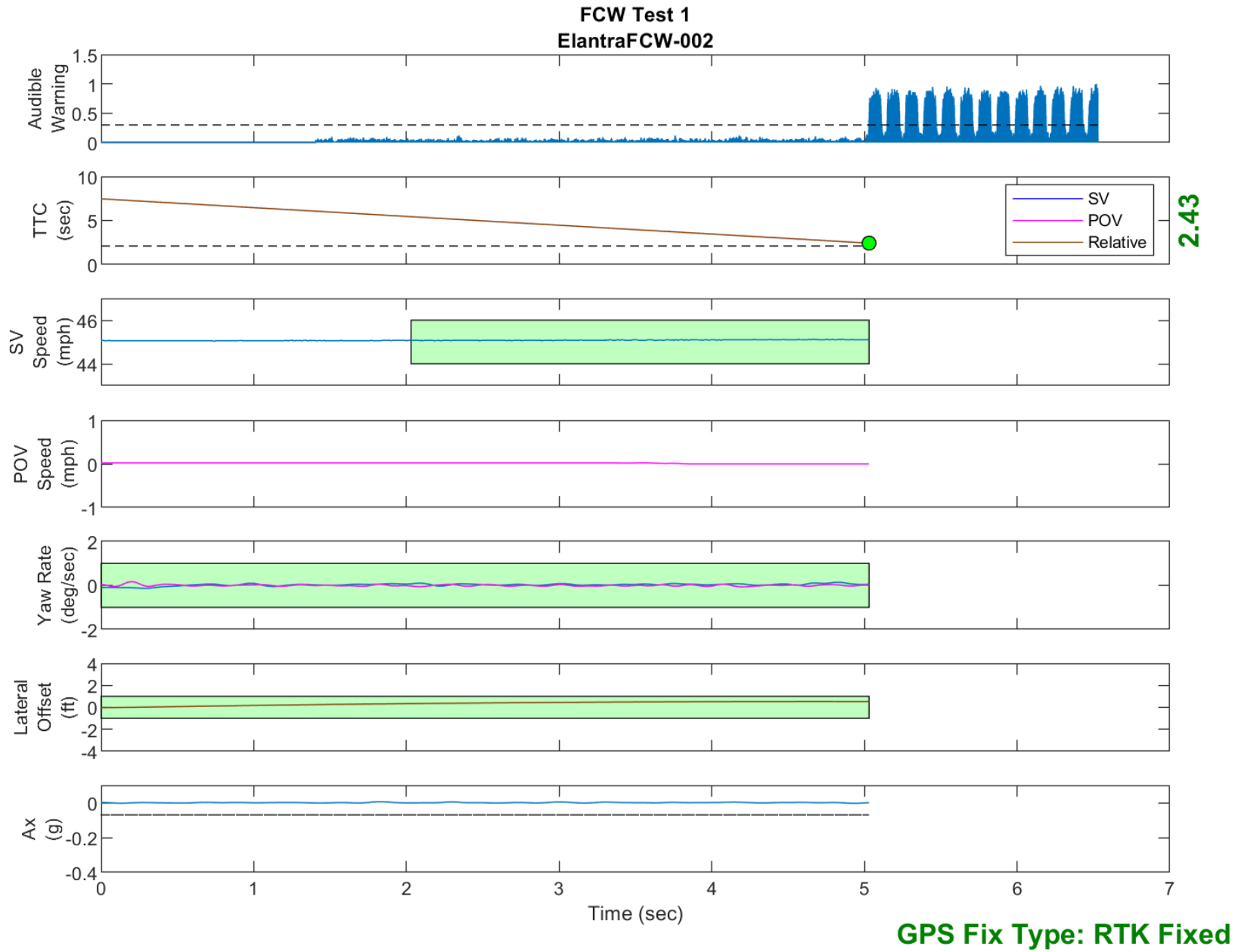


Figure D7. Time History for Run 2, FCW Test 1, Audible Warning

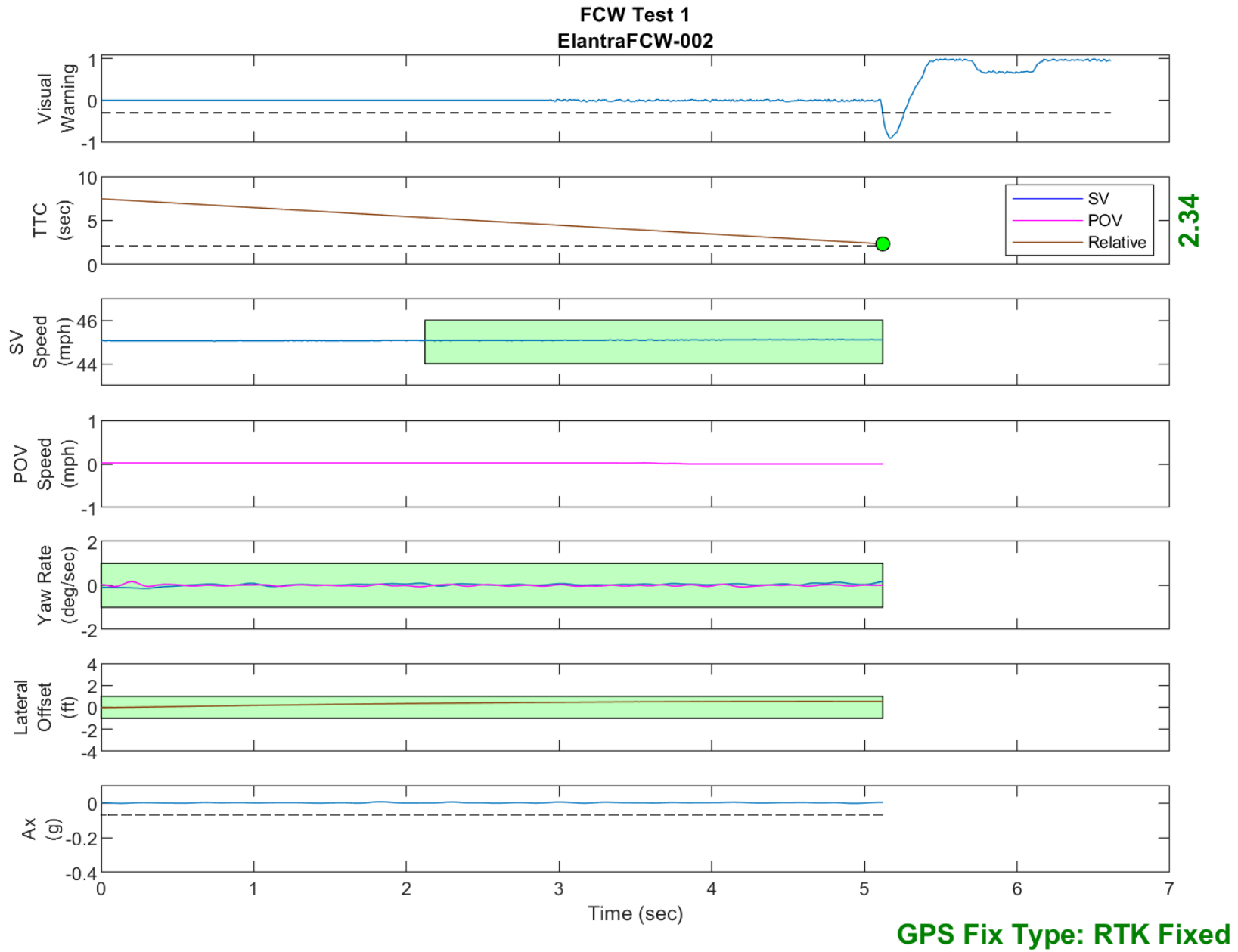


Figure D8. Time History for Run 2, FCW Test 1, Visual Warning

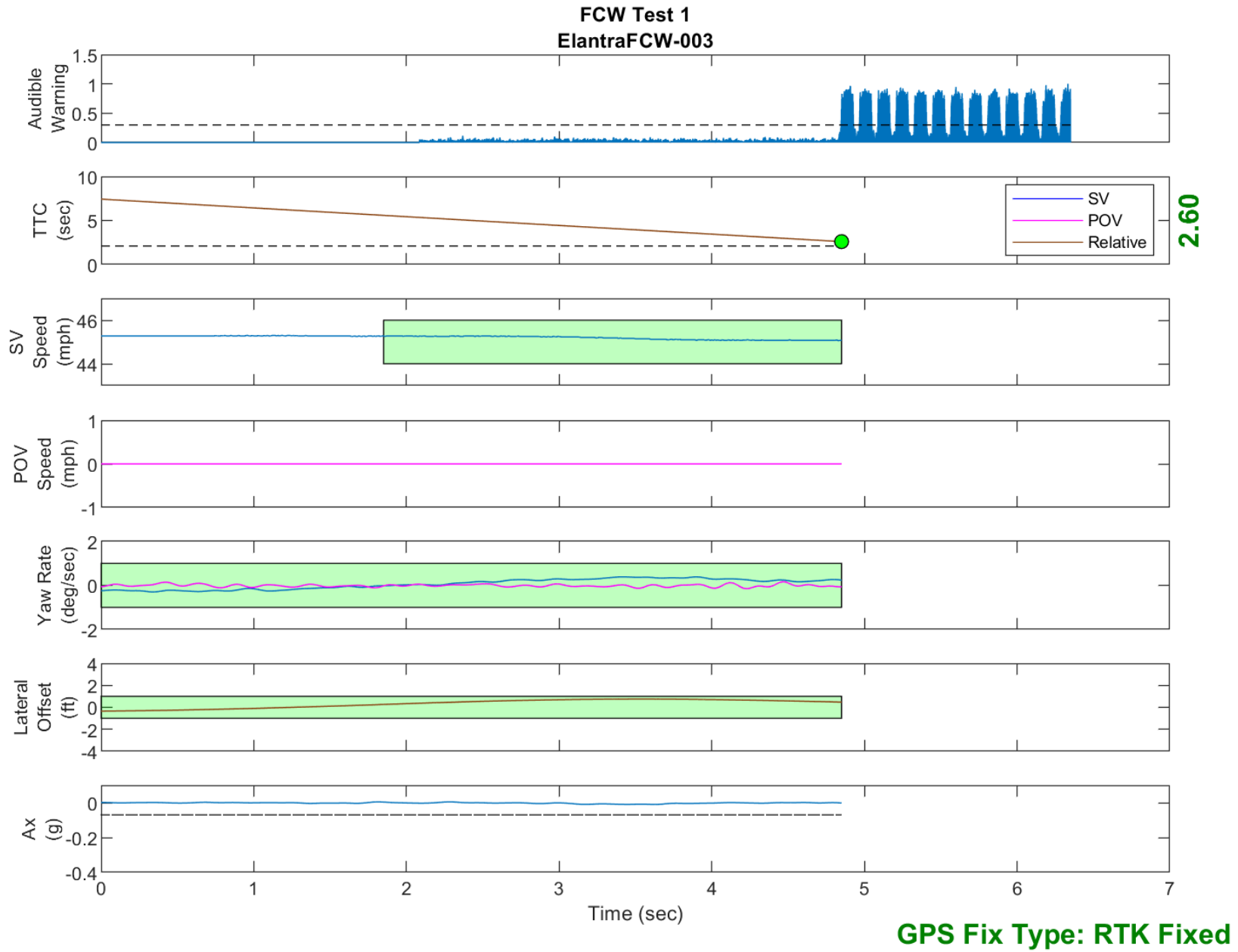


Figure D9. Time History for Run 3, FCW Test 1, Audible Warning

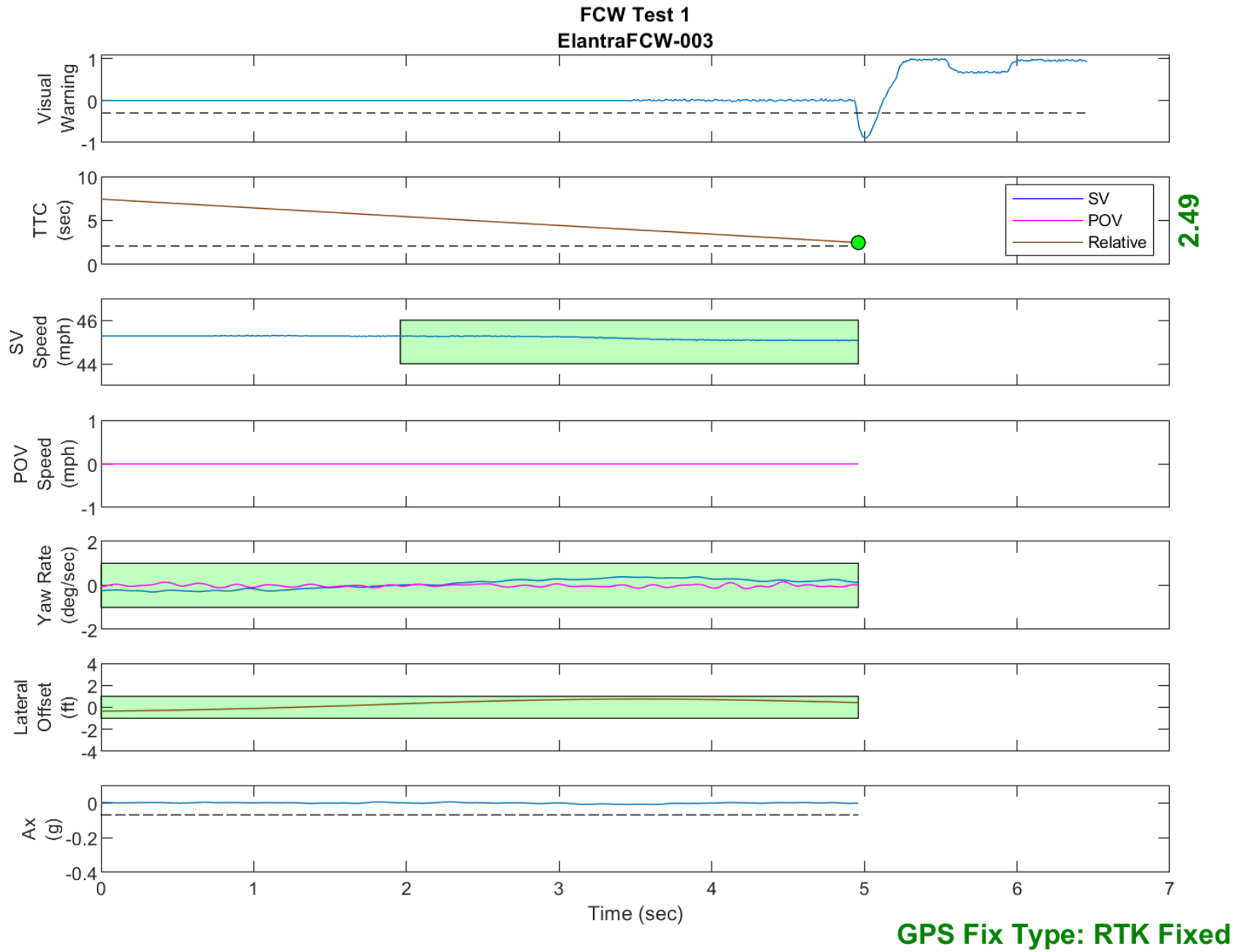


Figure D10. Time History for Run 3, FCW Test 1, Visual Warning

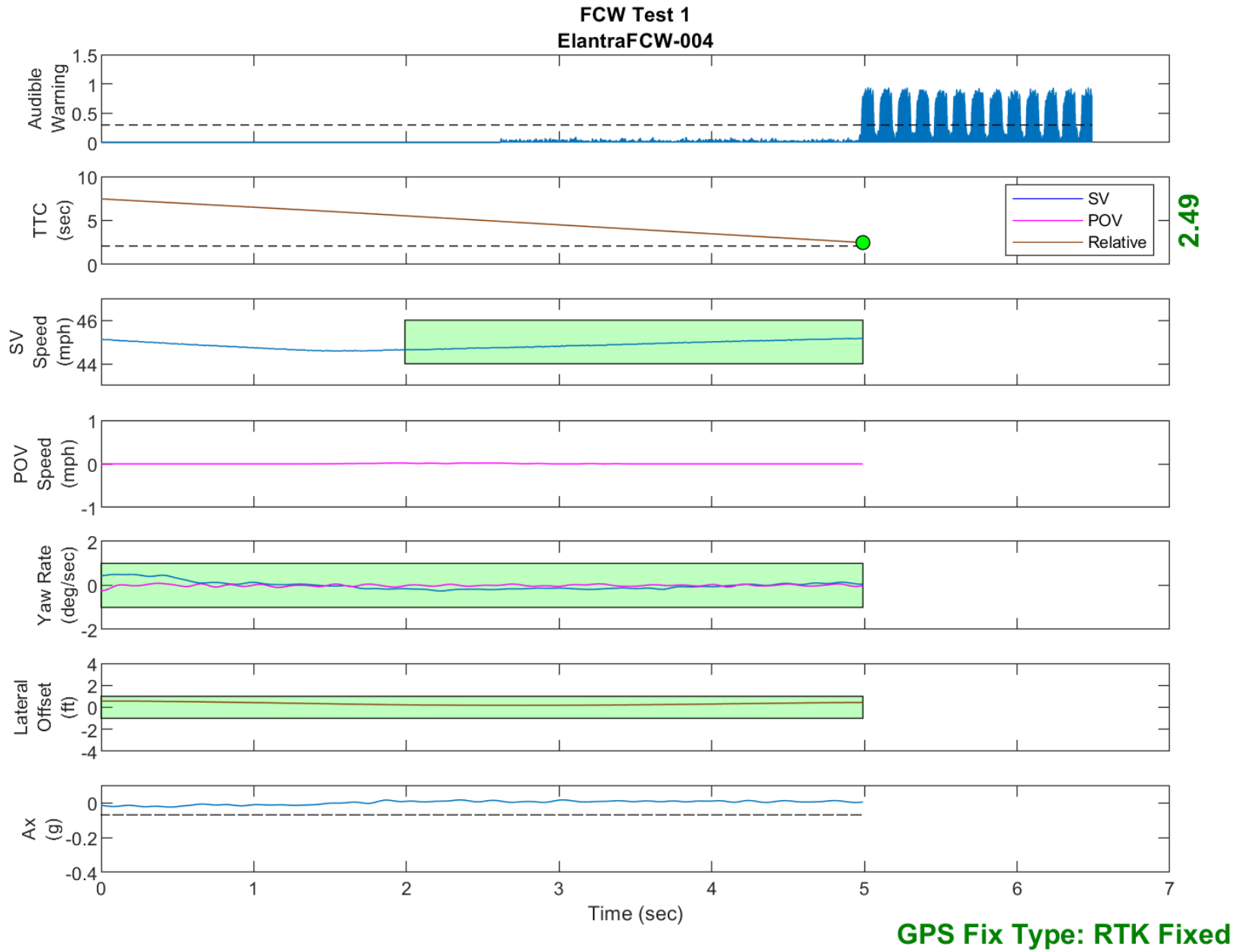


Figure D11. Time History for Run 4, FCW Test 1, Audible Warning

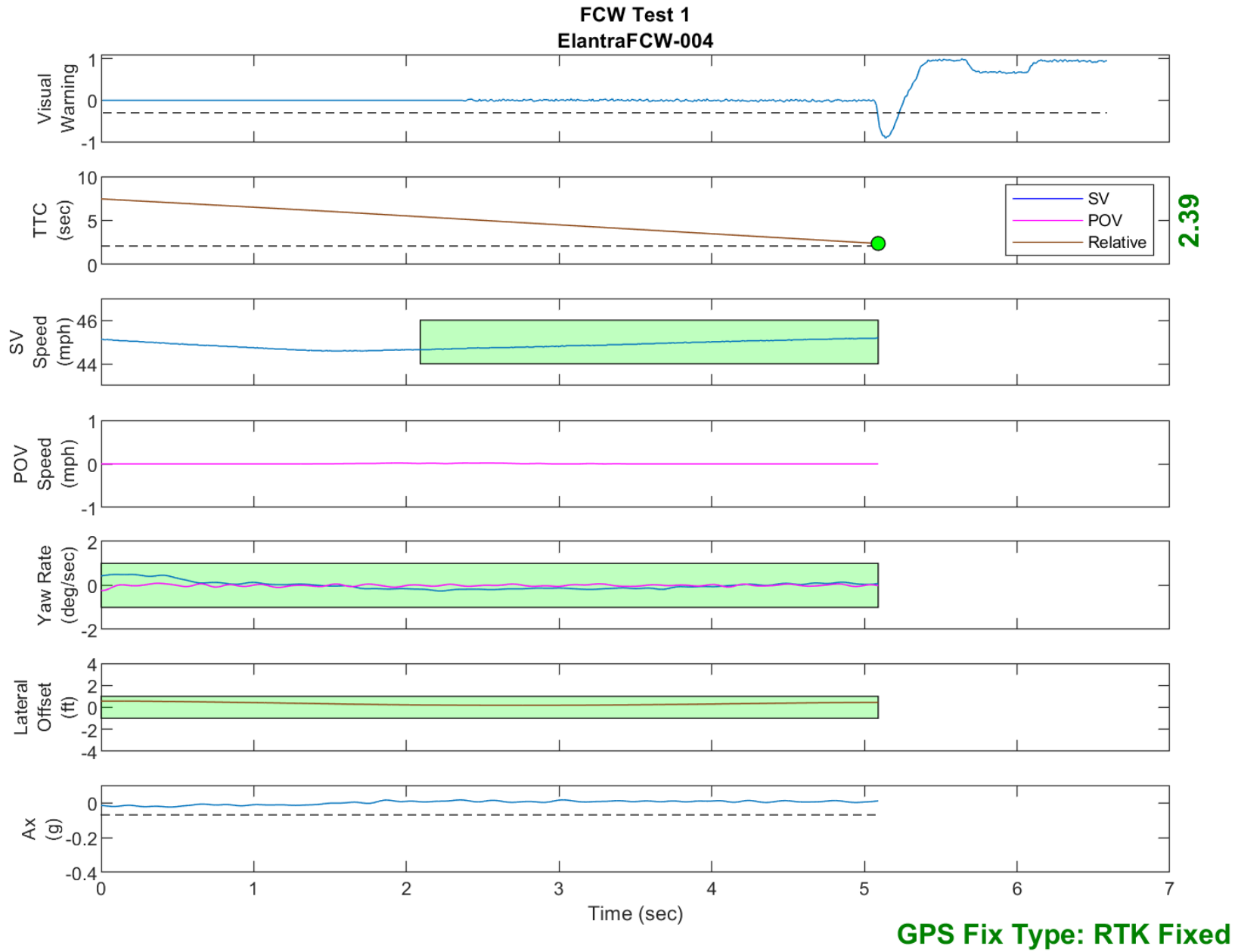


Figure D12. Time History for Run 4, FCW Test 1, Visual Warning

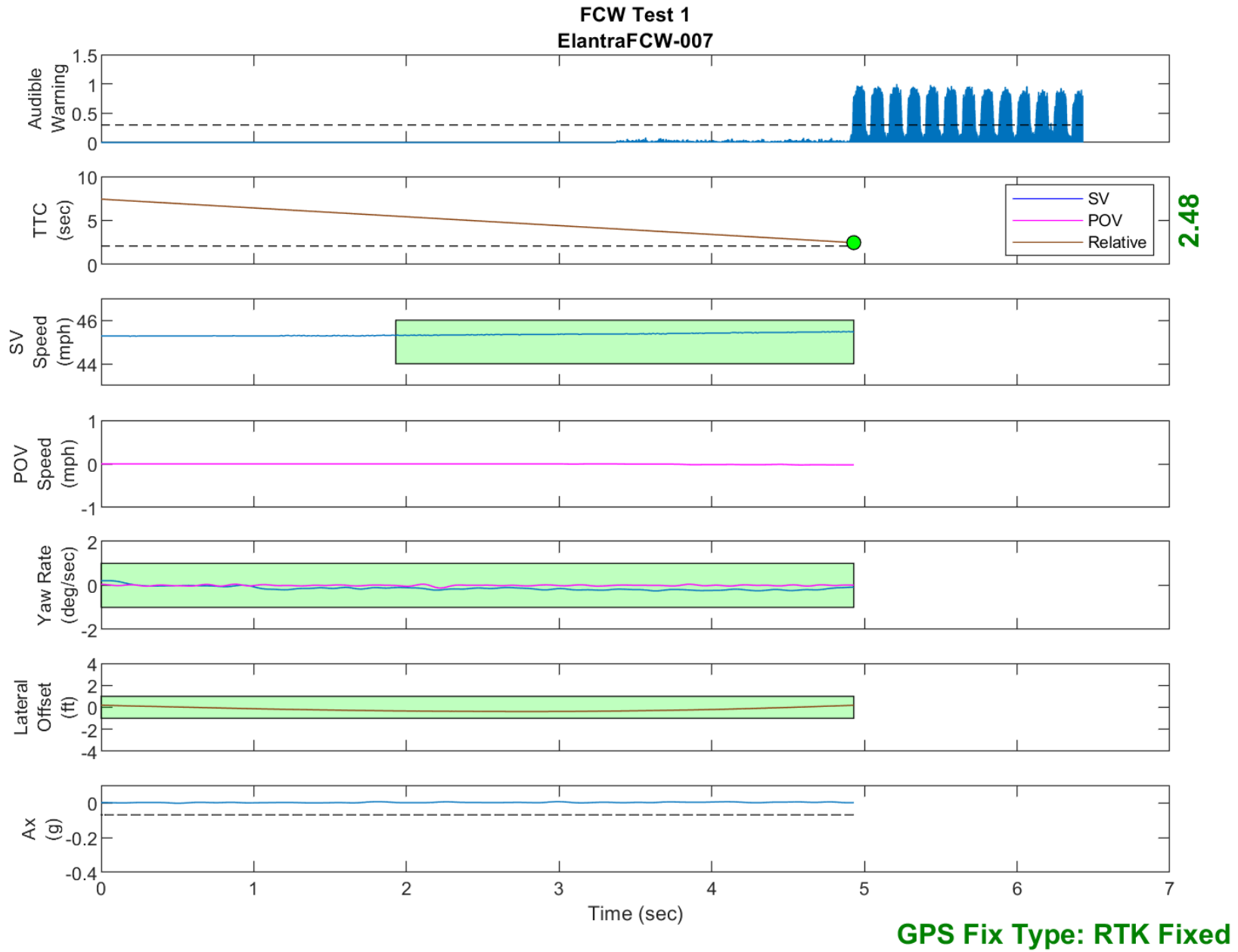


Figure D13. Time History for Run 7, FCW Test 1, Audible Warning

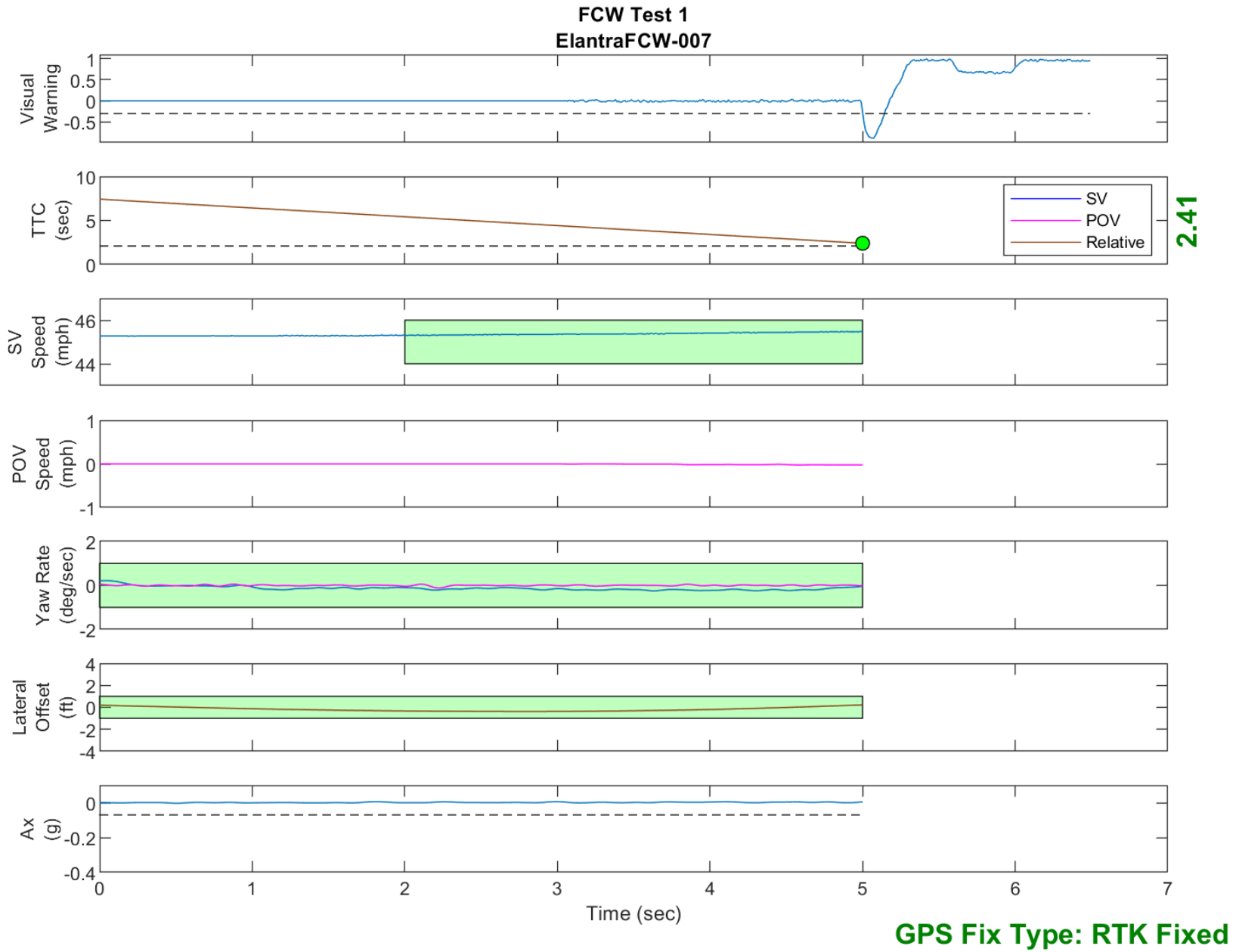


Figure D14. Time History for Run 7, FCW Test 1, Visual Warning

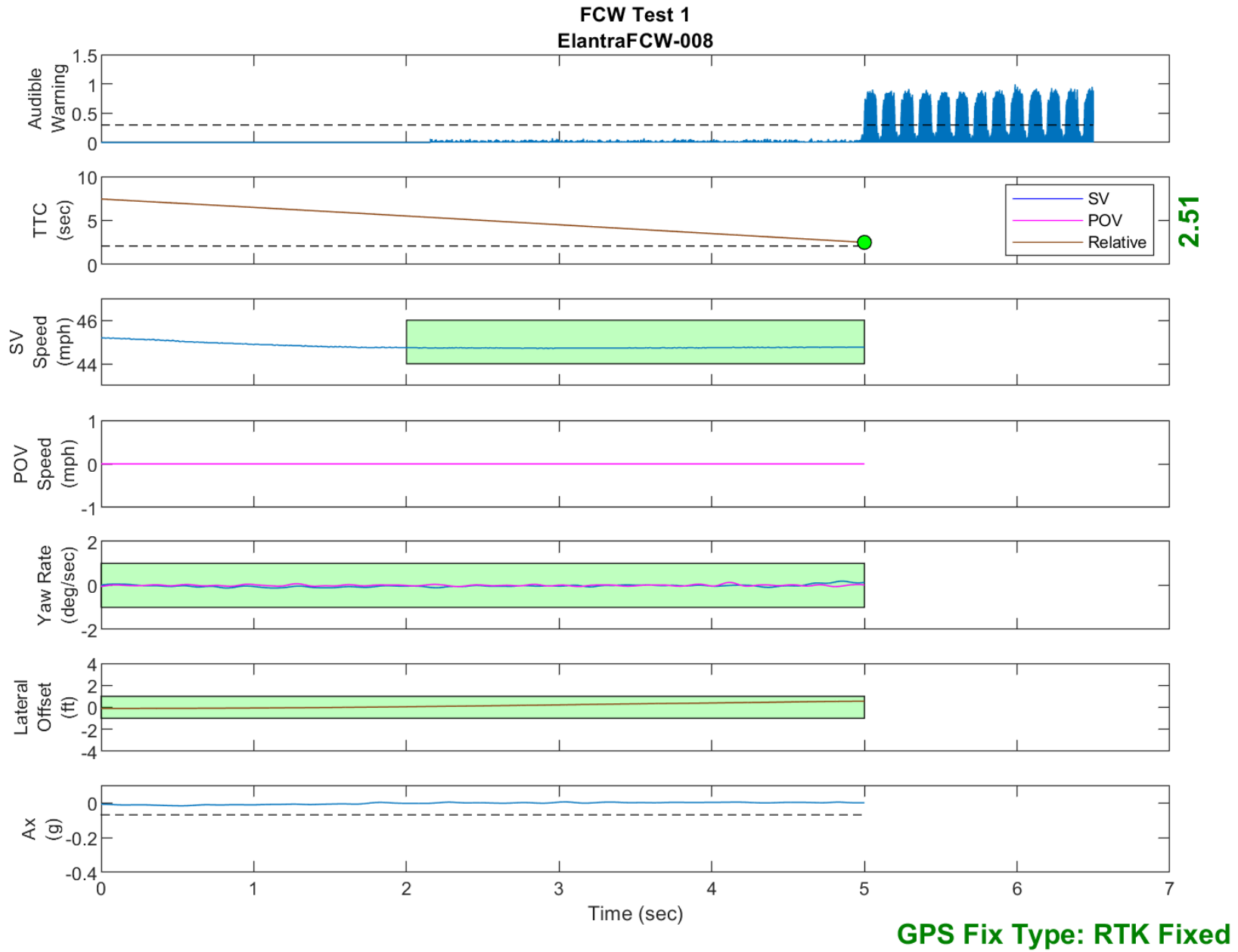


Figure D15. Time History for Run 8, FCW Test 1, Audible Warning

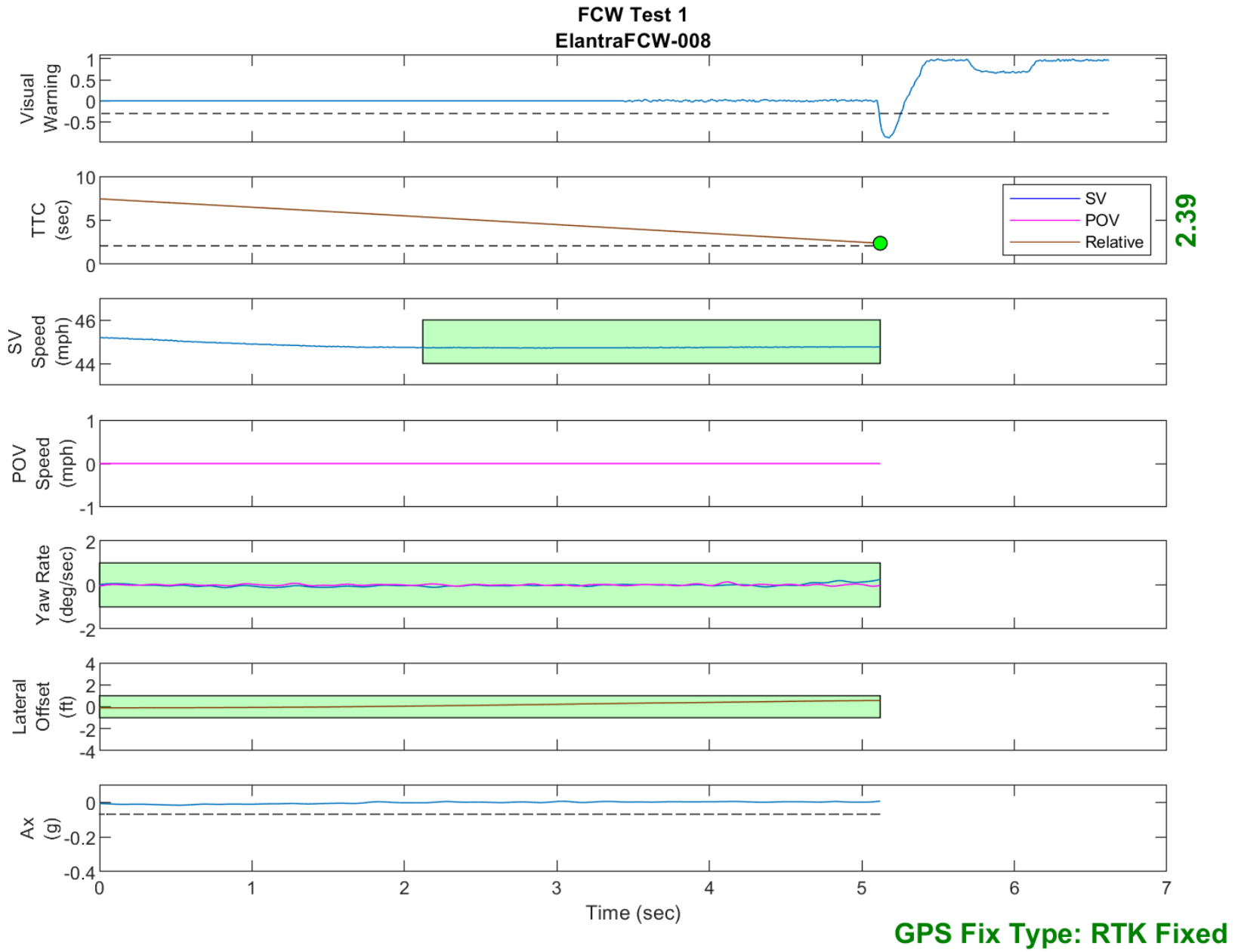


Figure D16. Time History for Run 8, FCW Test 1, Visual Warning

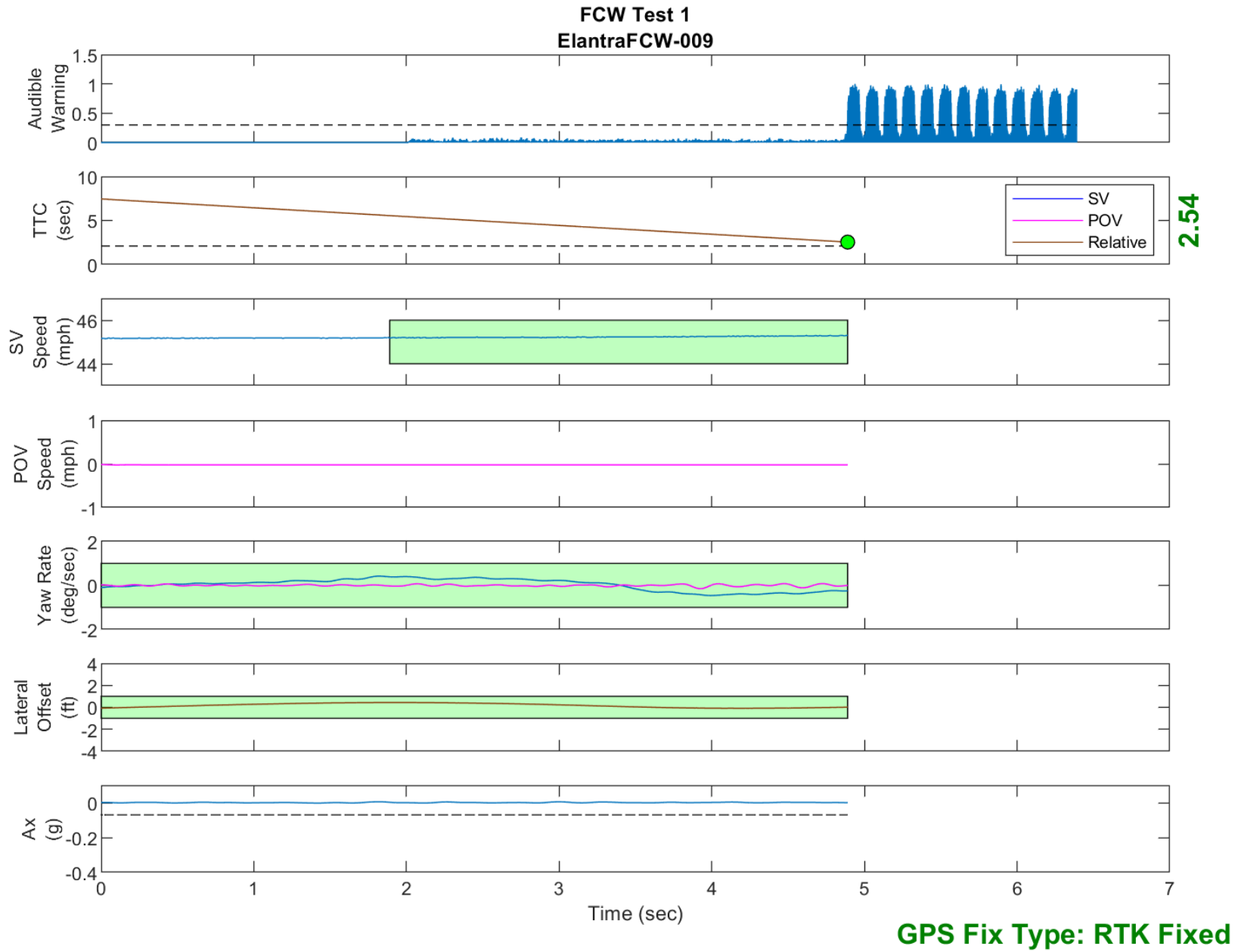


Figure D17. Time History for Run 9, FCW Test 1, Audible Warning

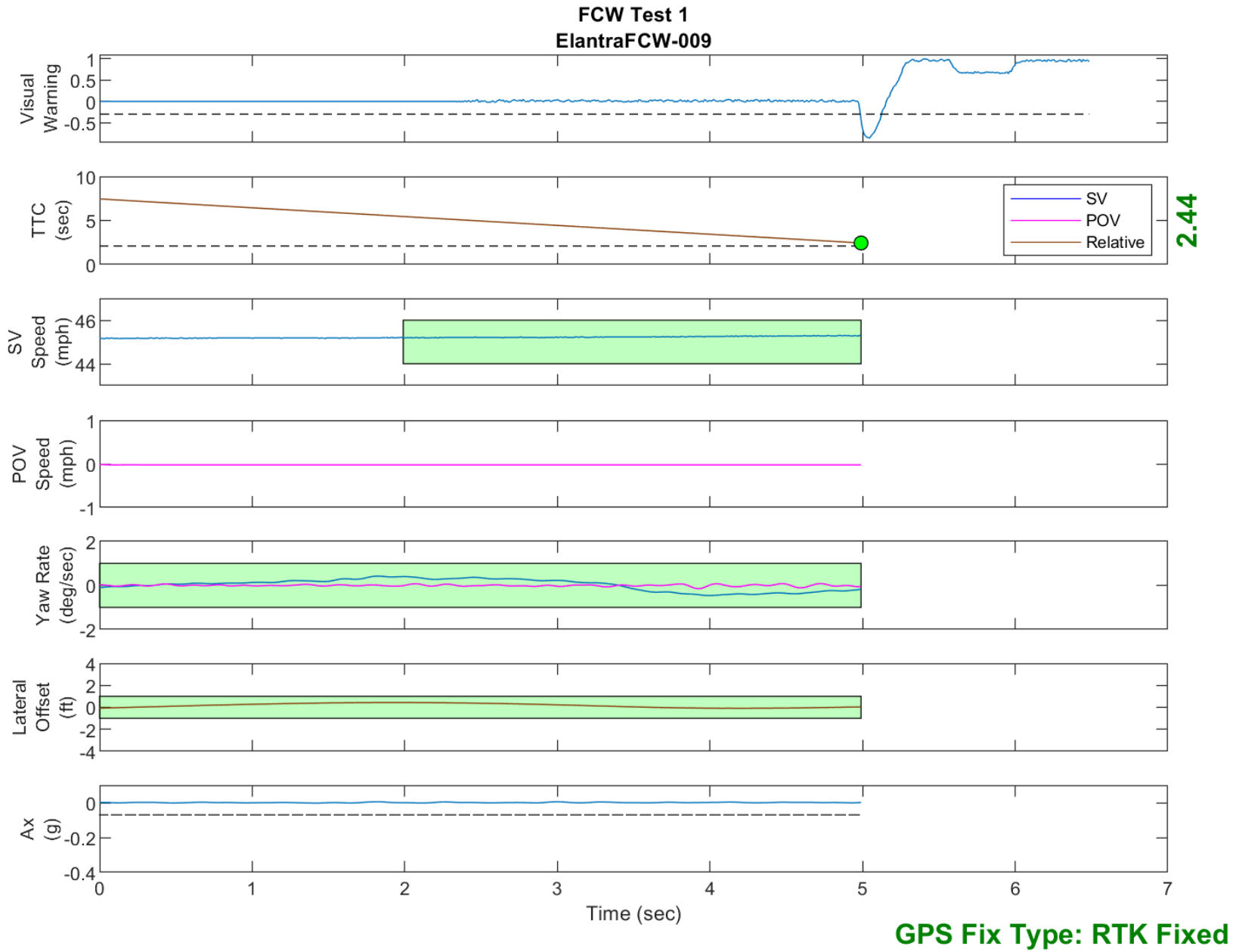


Figure D18. Time History for Run 9, FCW Test 1, Visual Warning

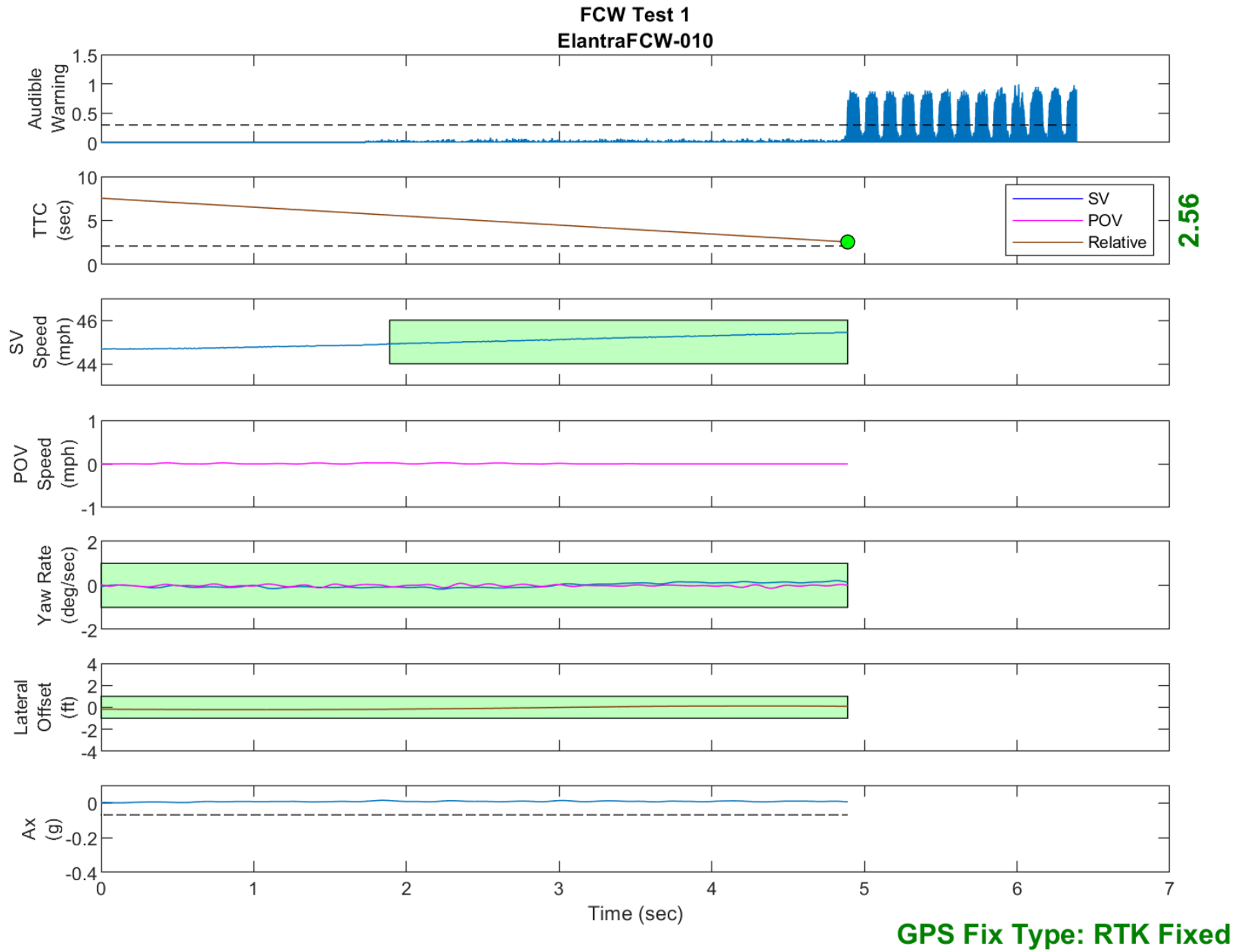


Figure D19. Time History for Run 10, FCW Test 1, Audible Warning

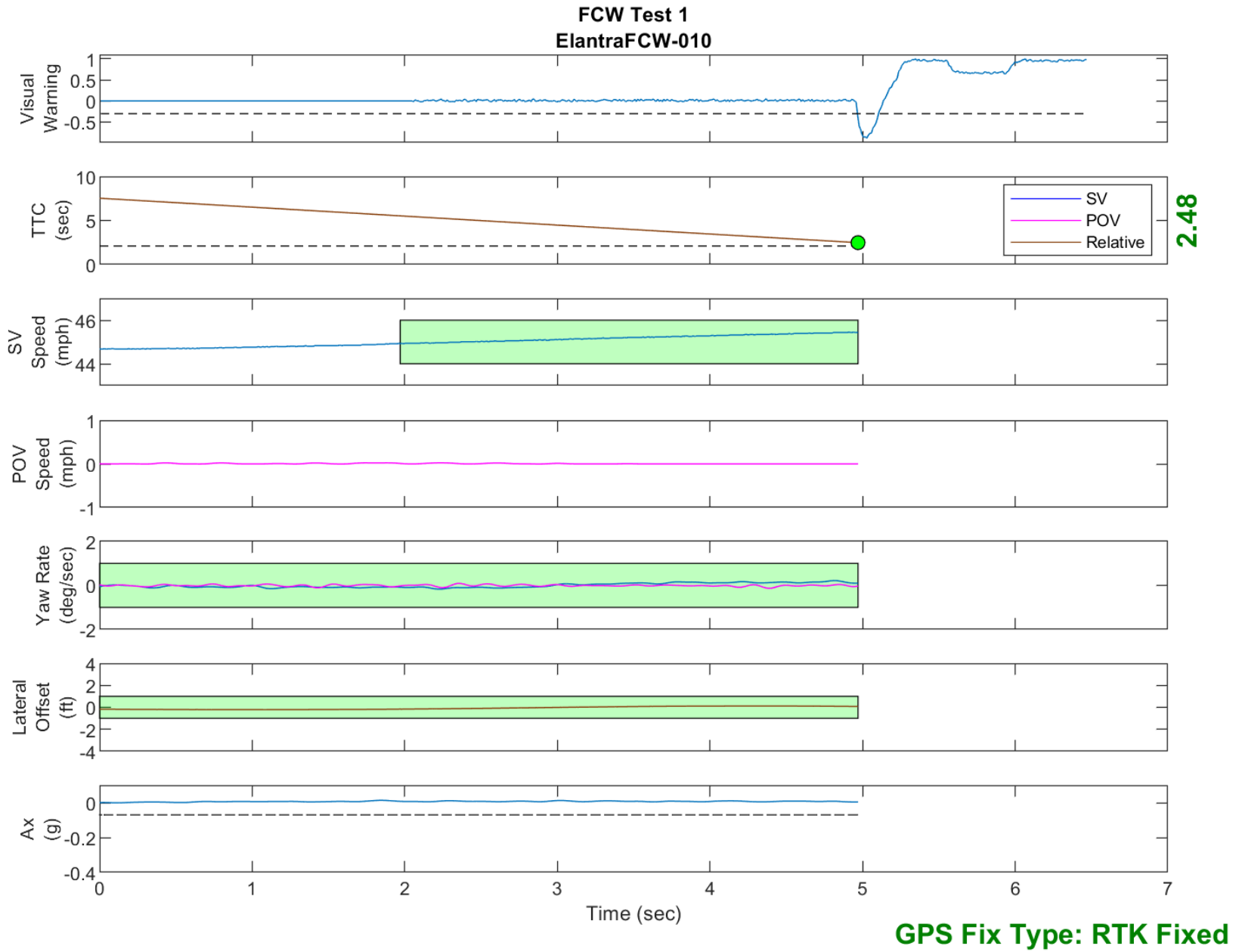


Figure D20. Time History for Run 10, FCW Test 1, Visual Warning

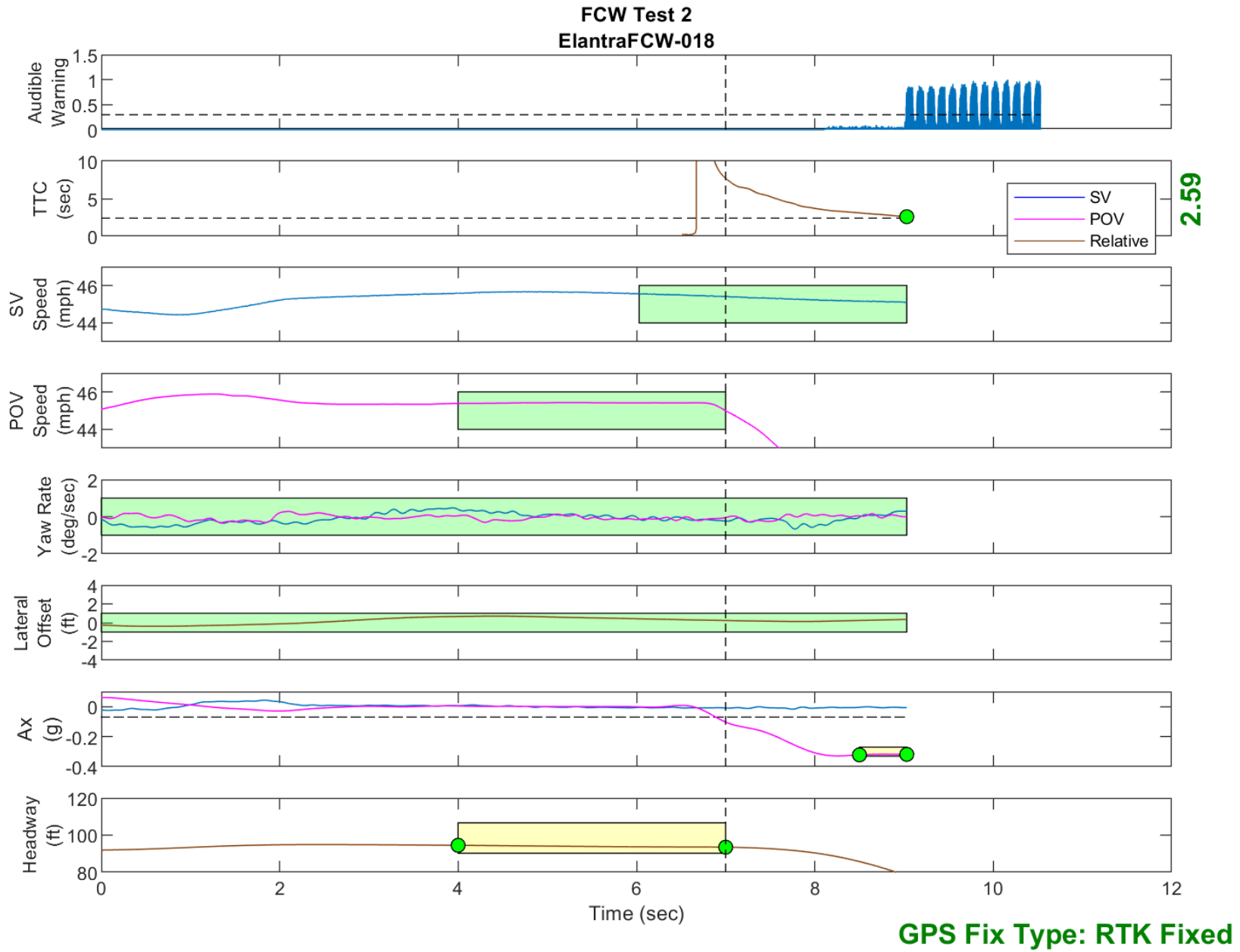


Figure D21. Time History for Run 18, FCW Test 2, Audible Warning

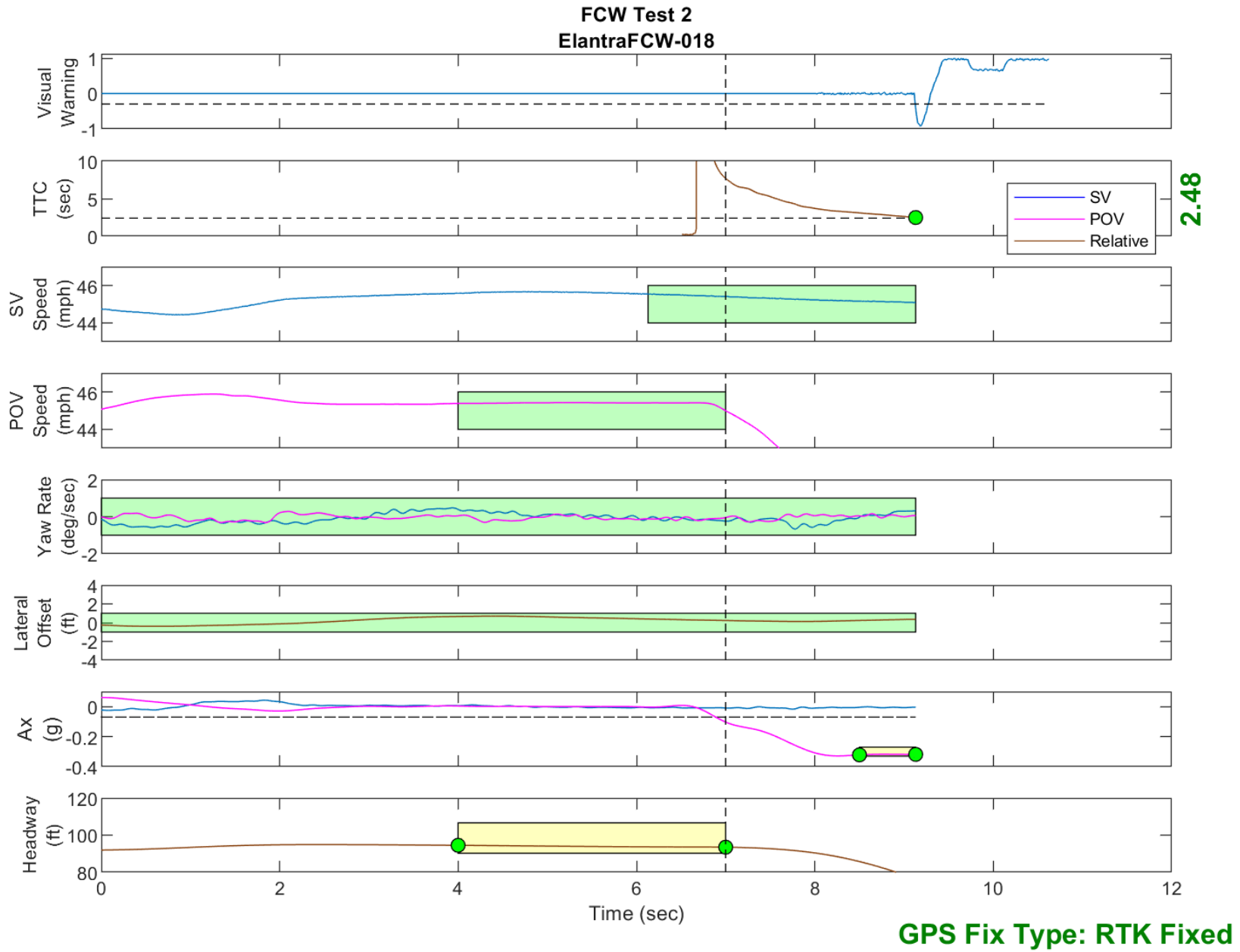


Figure D22. Time History for Run 18, FCW Test 2, Visual Warning

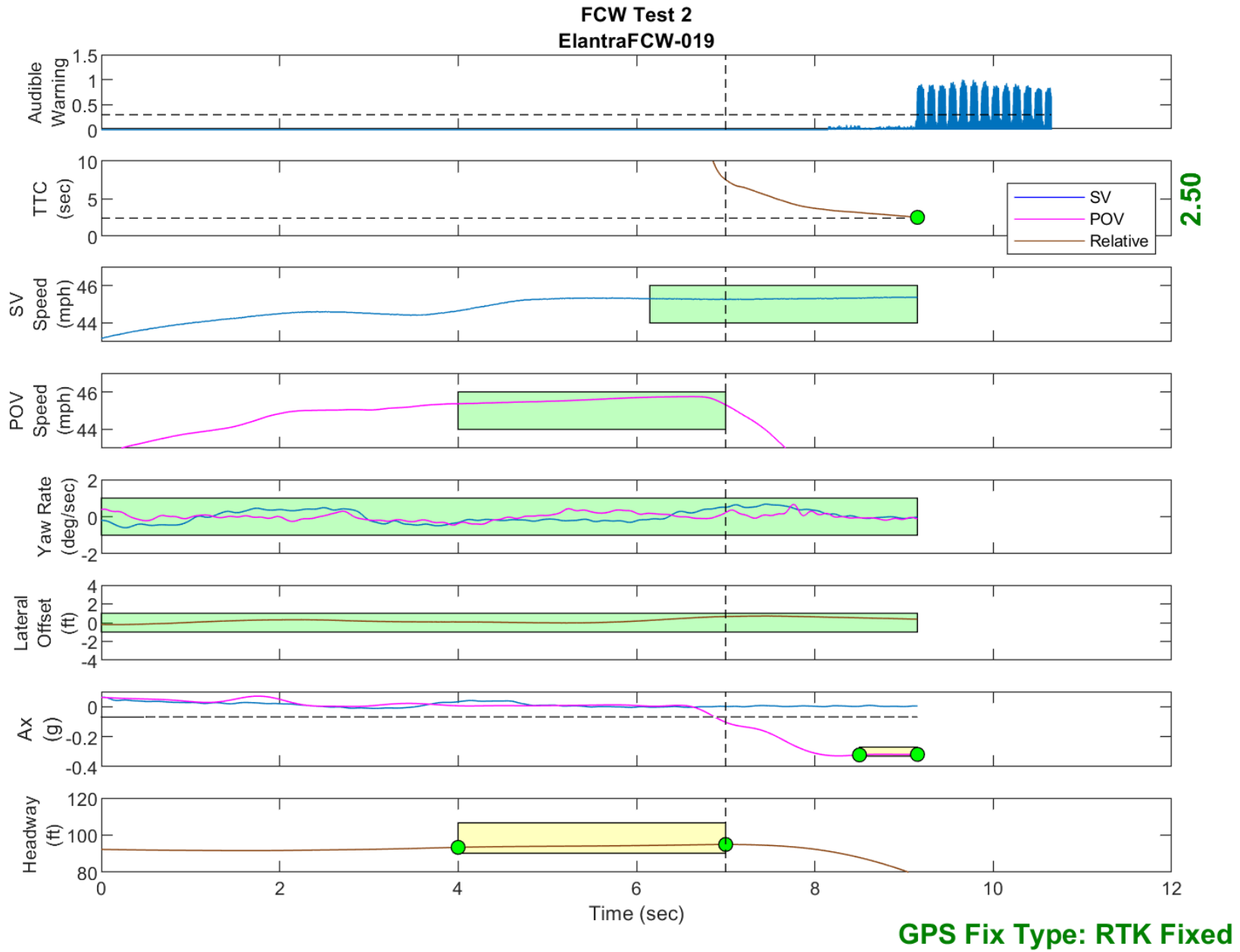


Figure D23. Time History for Run 19, FCW Test 2, Audible Warning

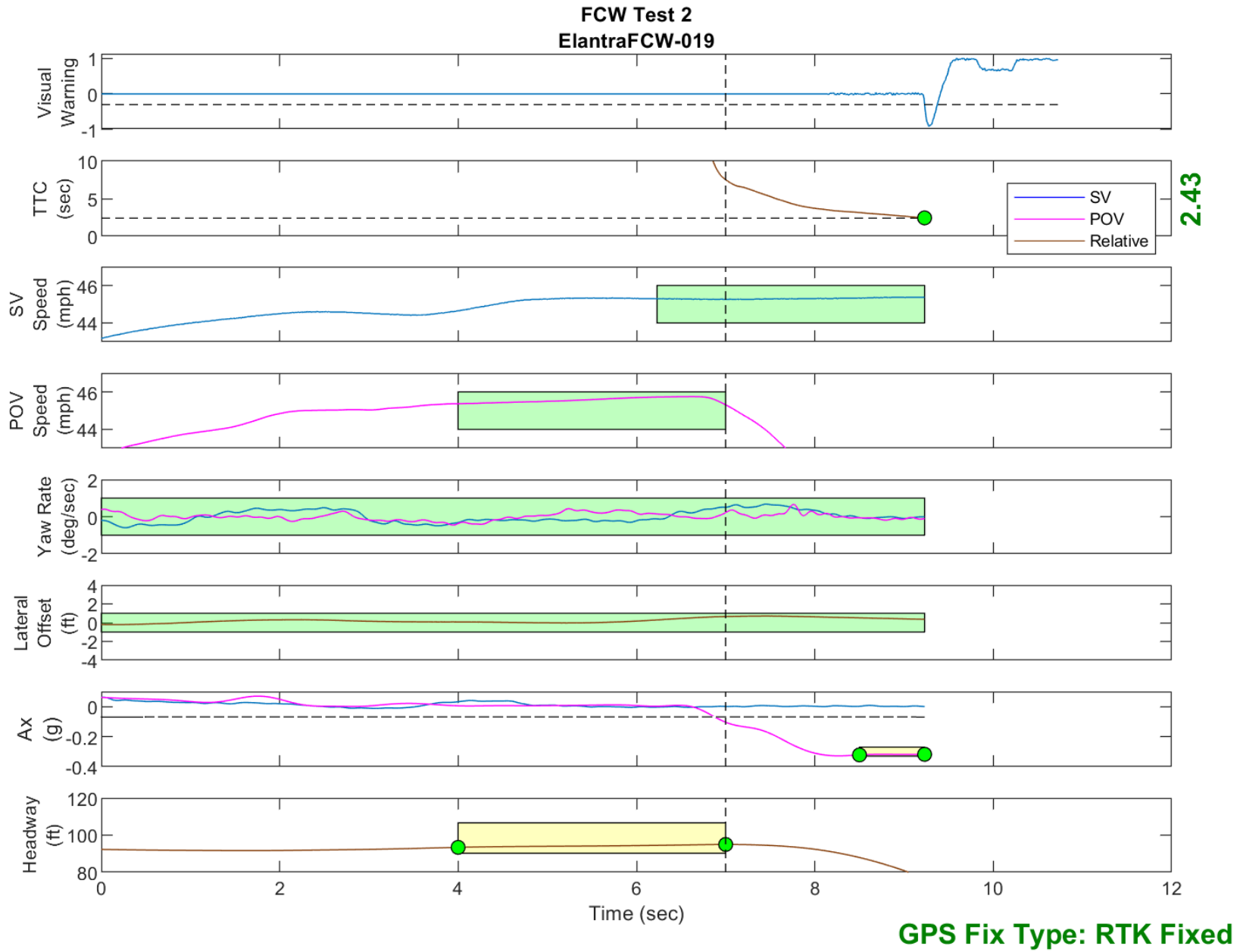


Figure D24. Time History for Run 19, FCW Test 2, Visual Warning

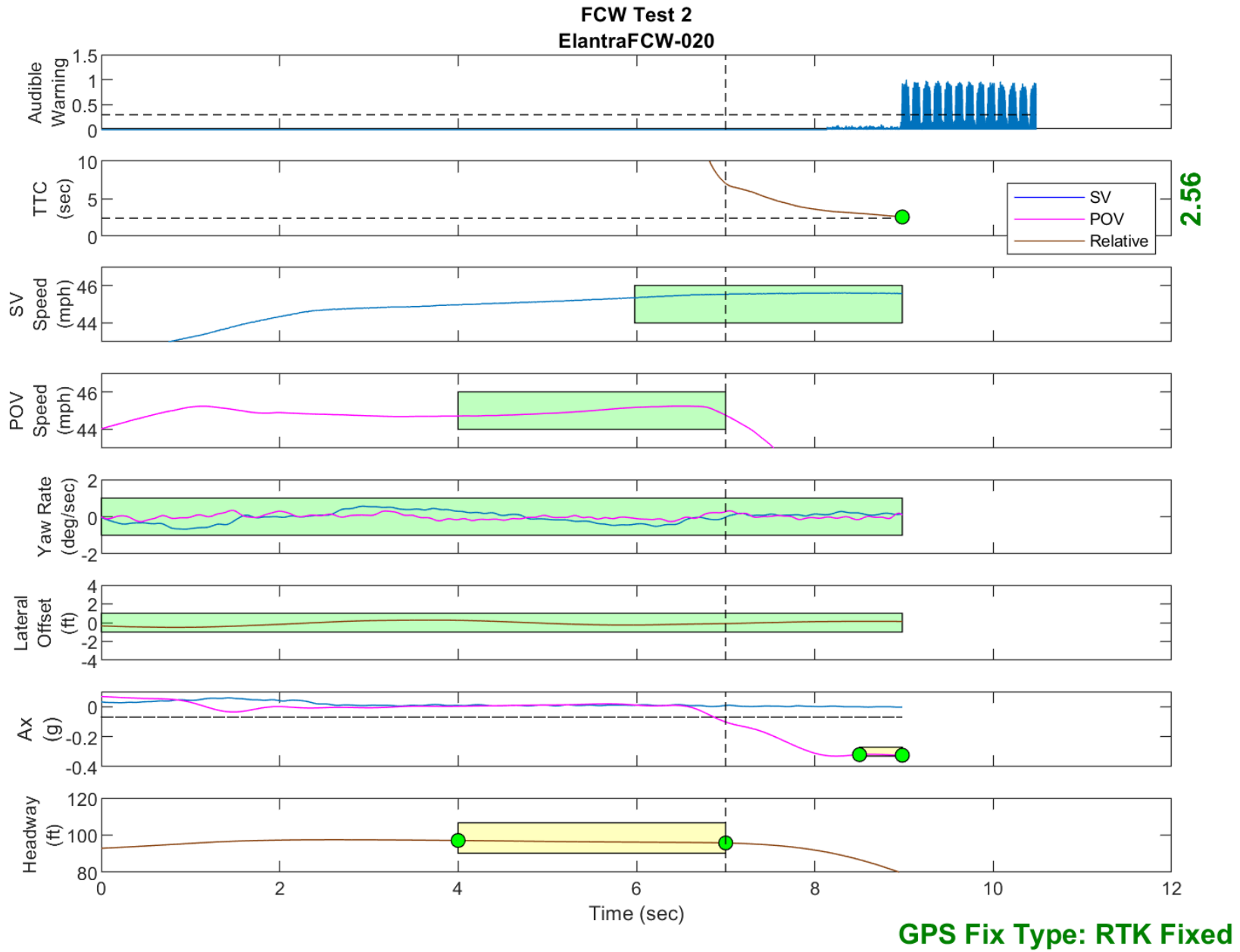


Figure D25. Time History for Run 20, FCW Test 2, Audible Warning

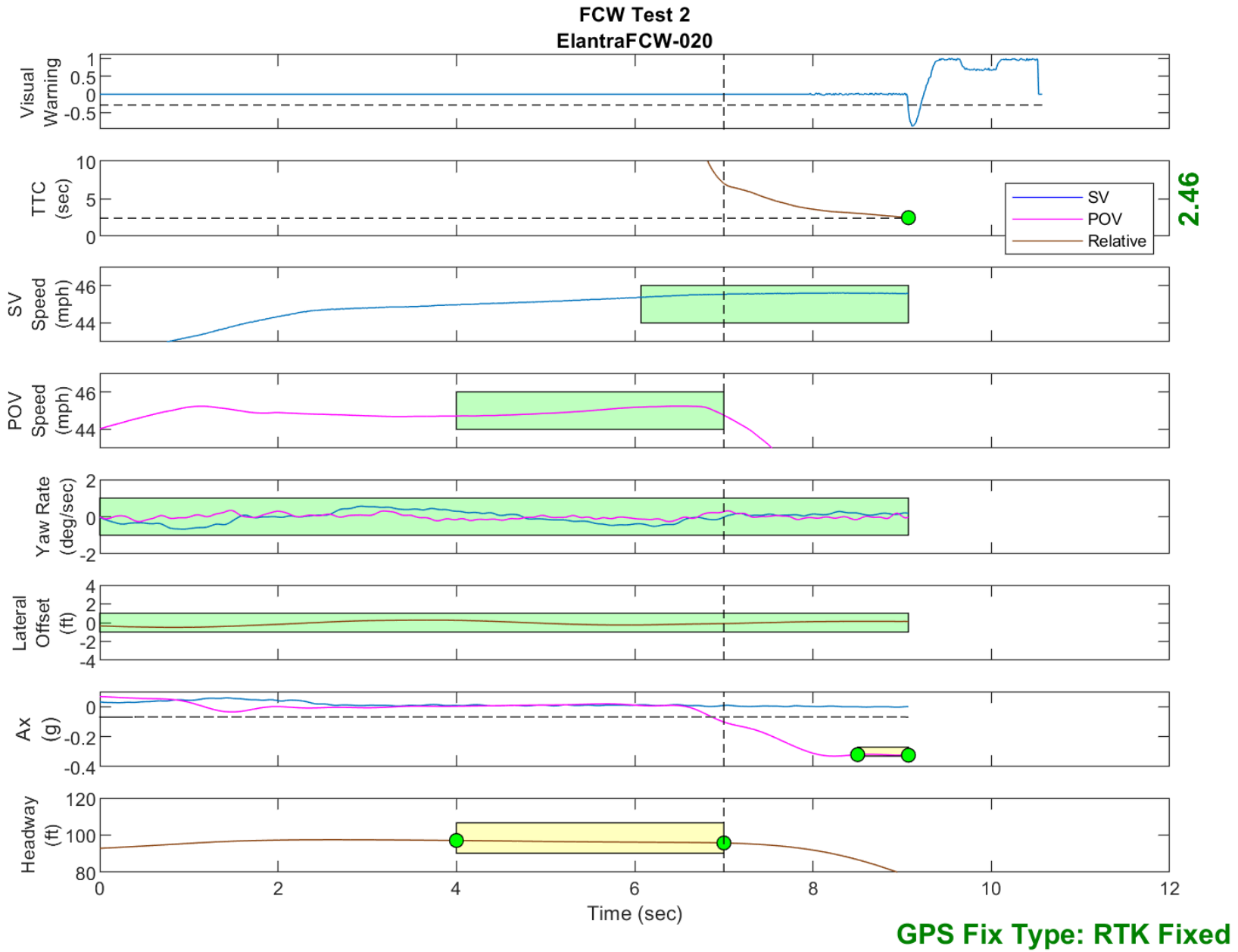


Figure D26. Time History for Run 20, FCW Test 2, Visual Warning

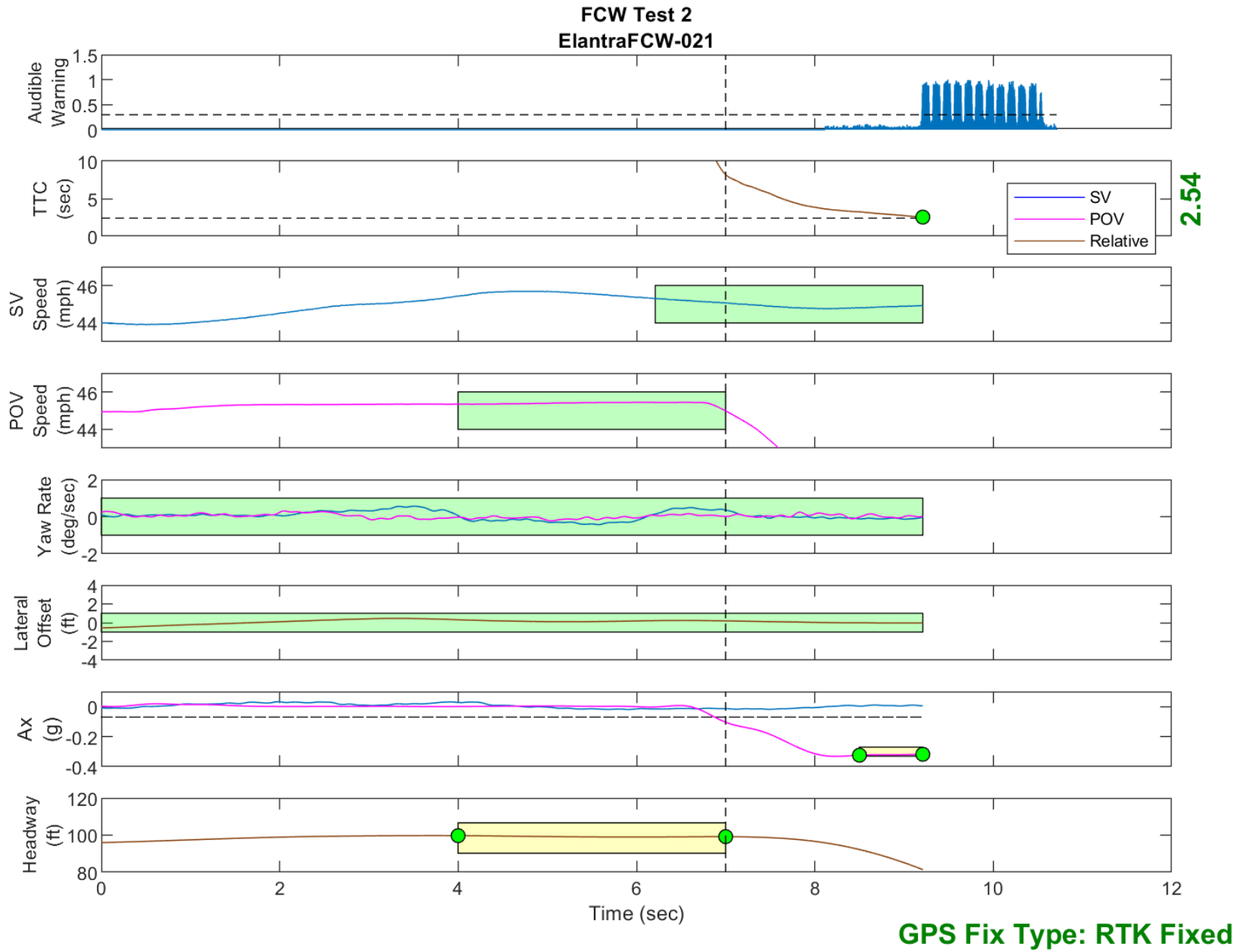


Figure D27. Time History for Run 21, FCW Test 2, Audible Warning

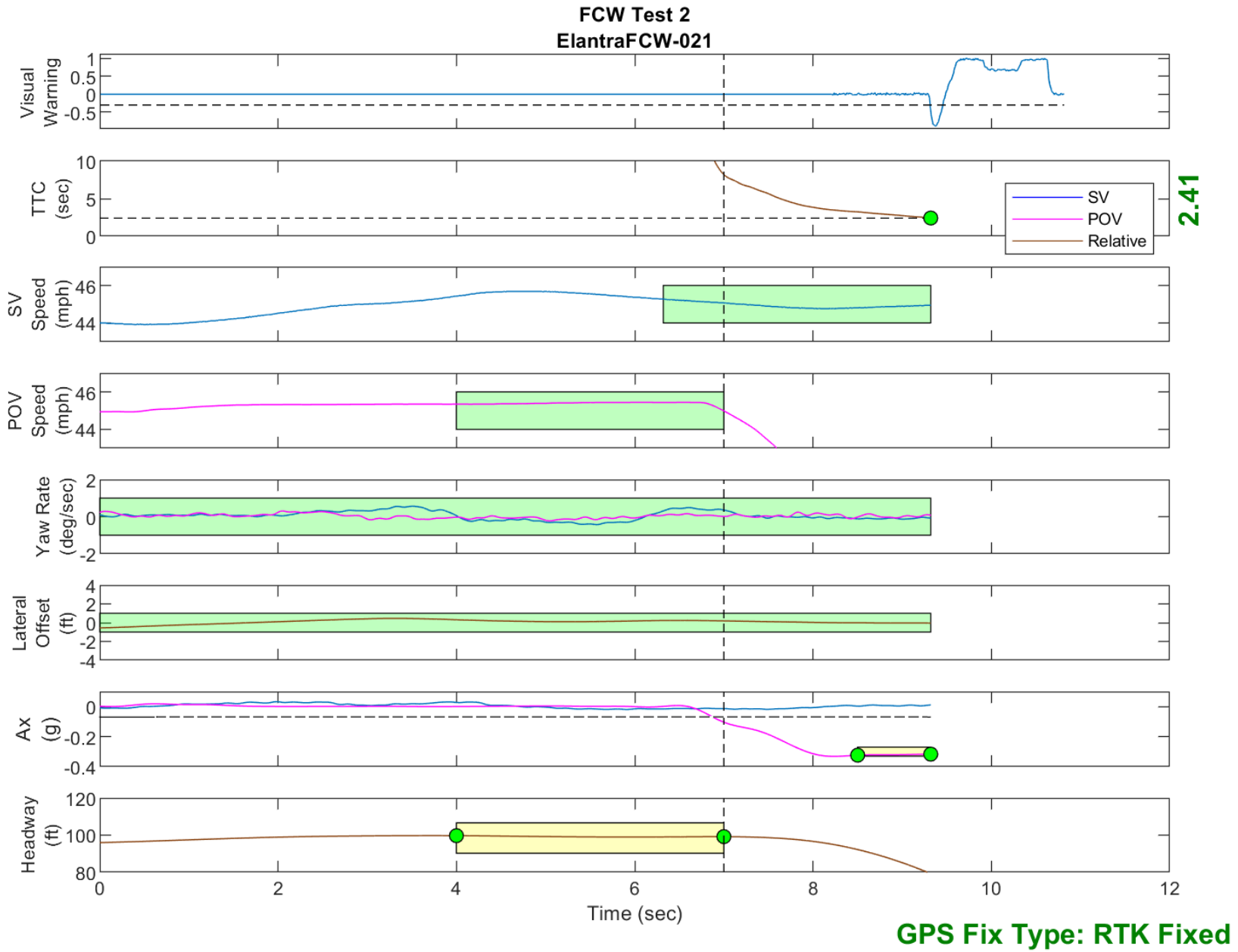


Figure D28. Time History for Run 21, FCW Test 2, Visual Warning

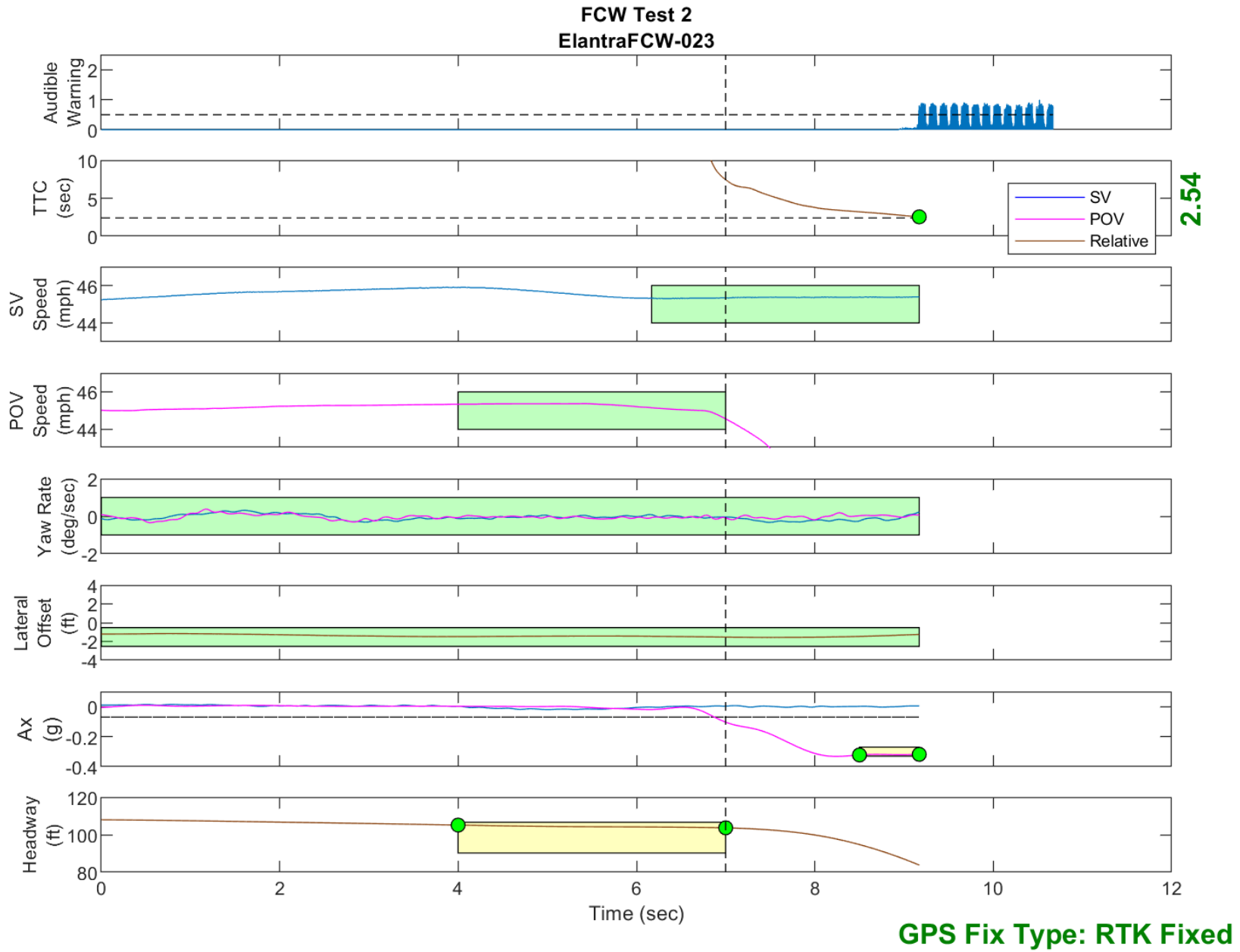


Figure D29. Time History for Run 23, FCW Test 2, Audible Warning

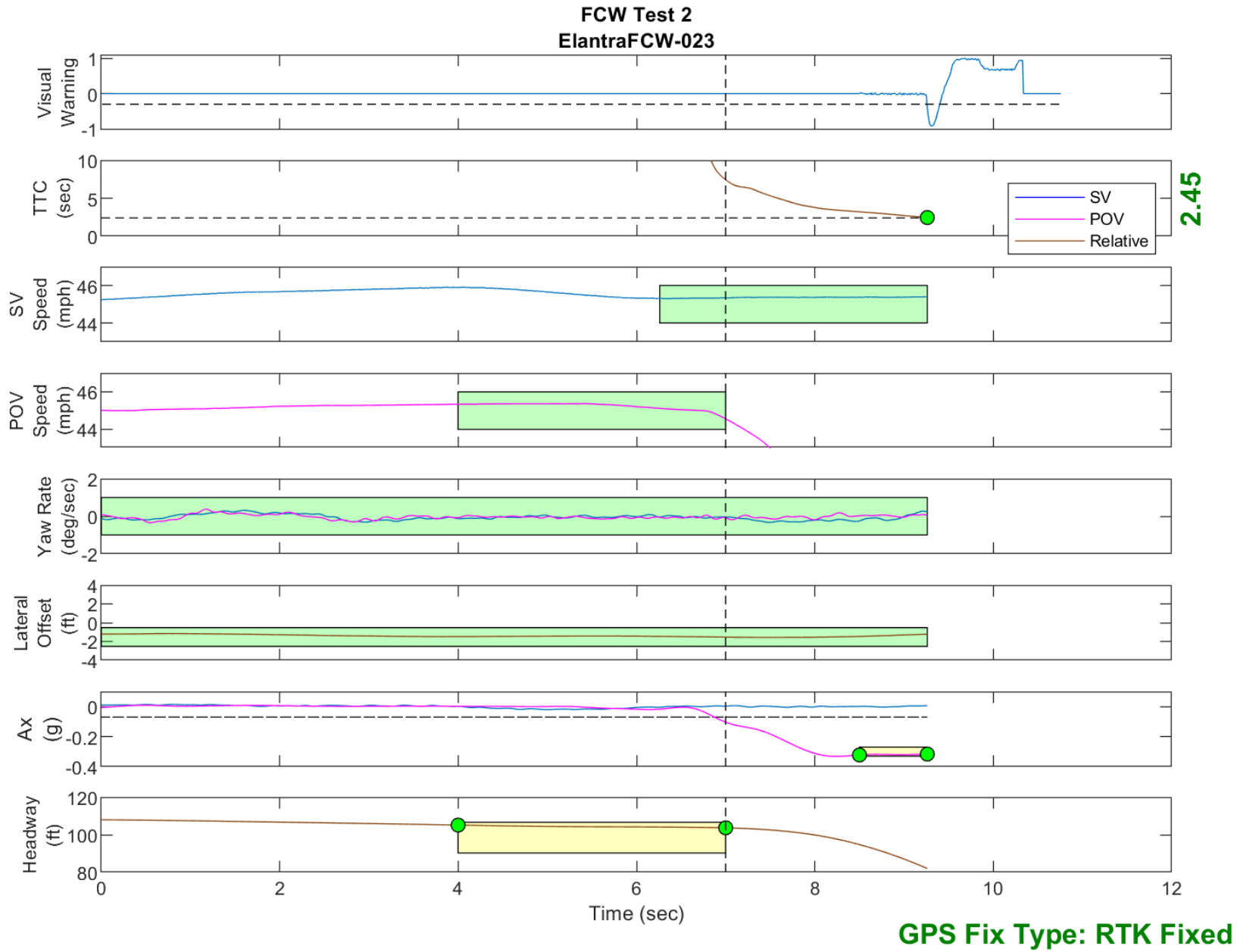


Figure D30. Time History for Run 23, FCW Test 2, Visual Warning

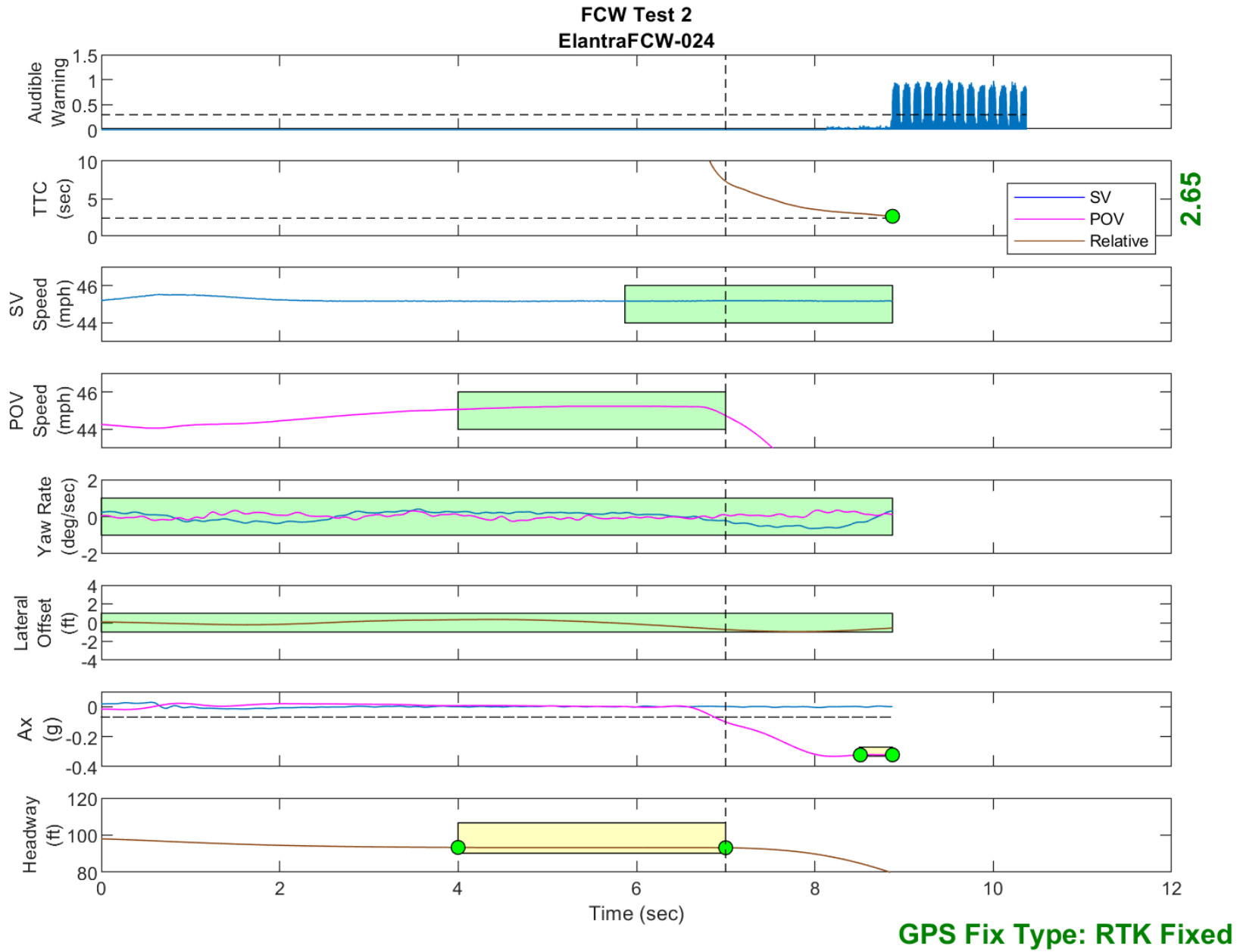


Figure D31. Time History for Run 24, FCW Test 2, Audible Warning

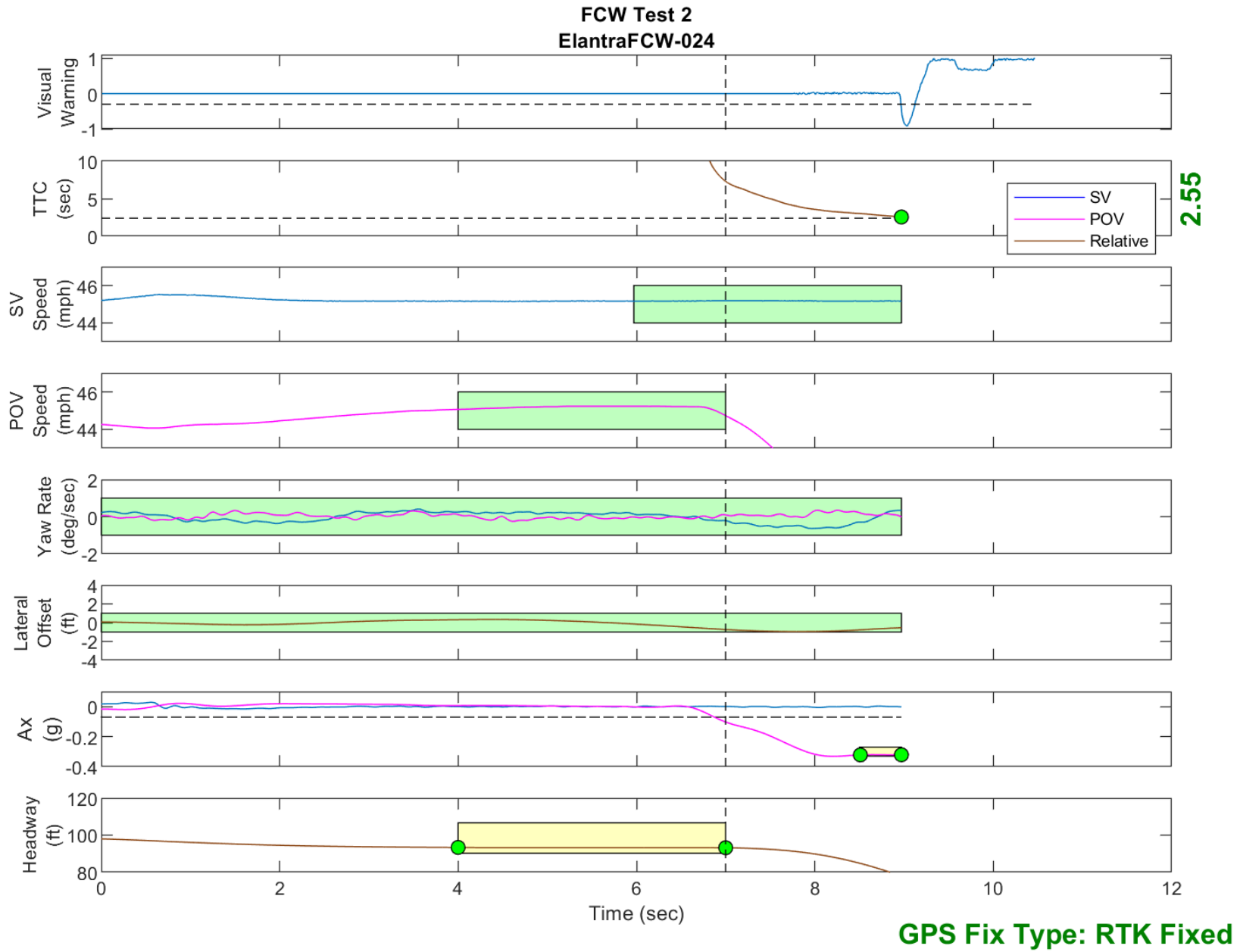


Figure D32. Time History for Run 24, FCW Test 2, Visual Warning

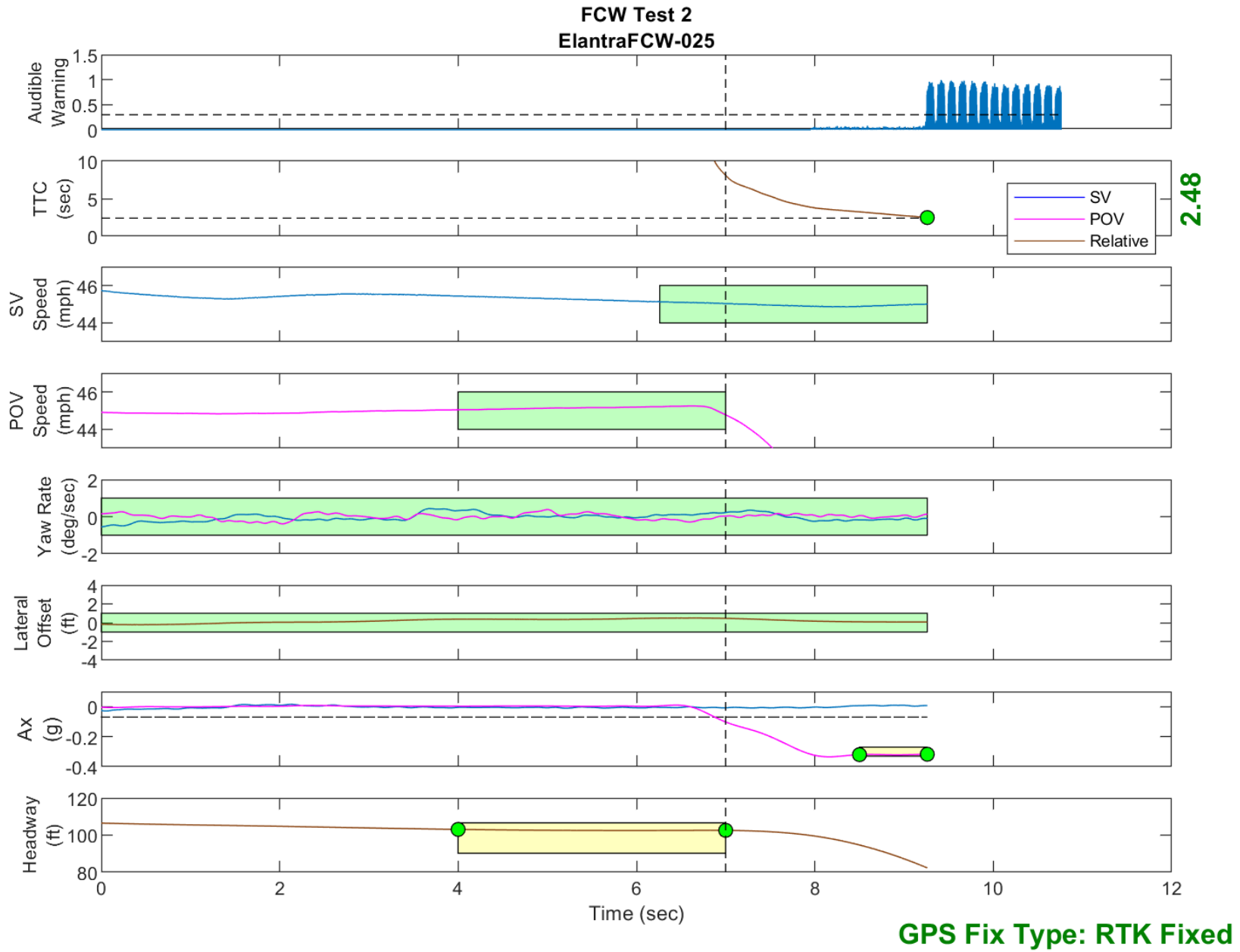


Figure D33. Time History for Run 25, FCW Test 2, Audible Warning

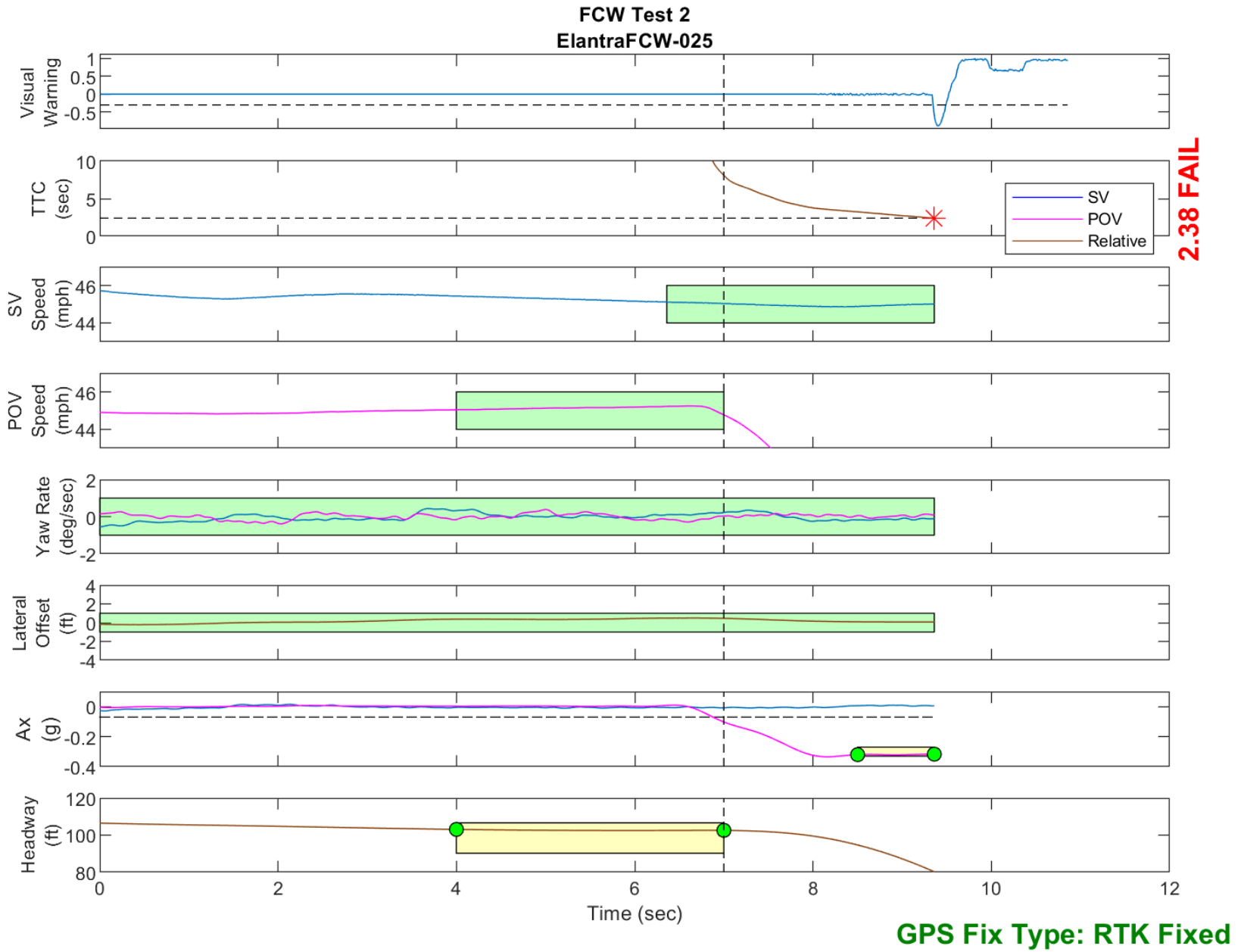


Figure D34. Time History for Run 25, FCW Test 2, Visual Warning

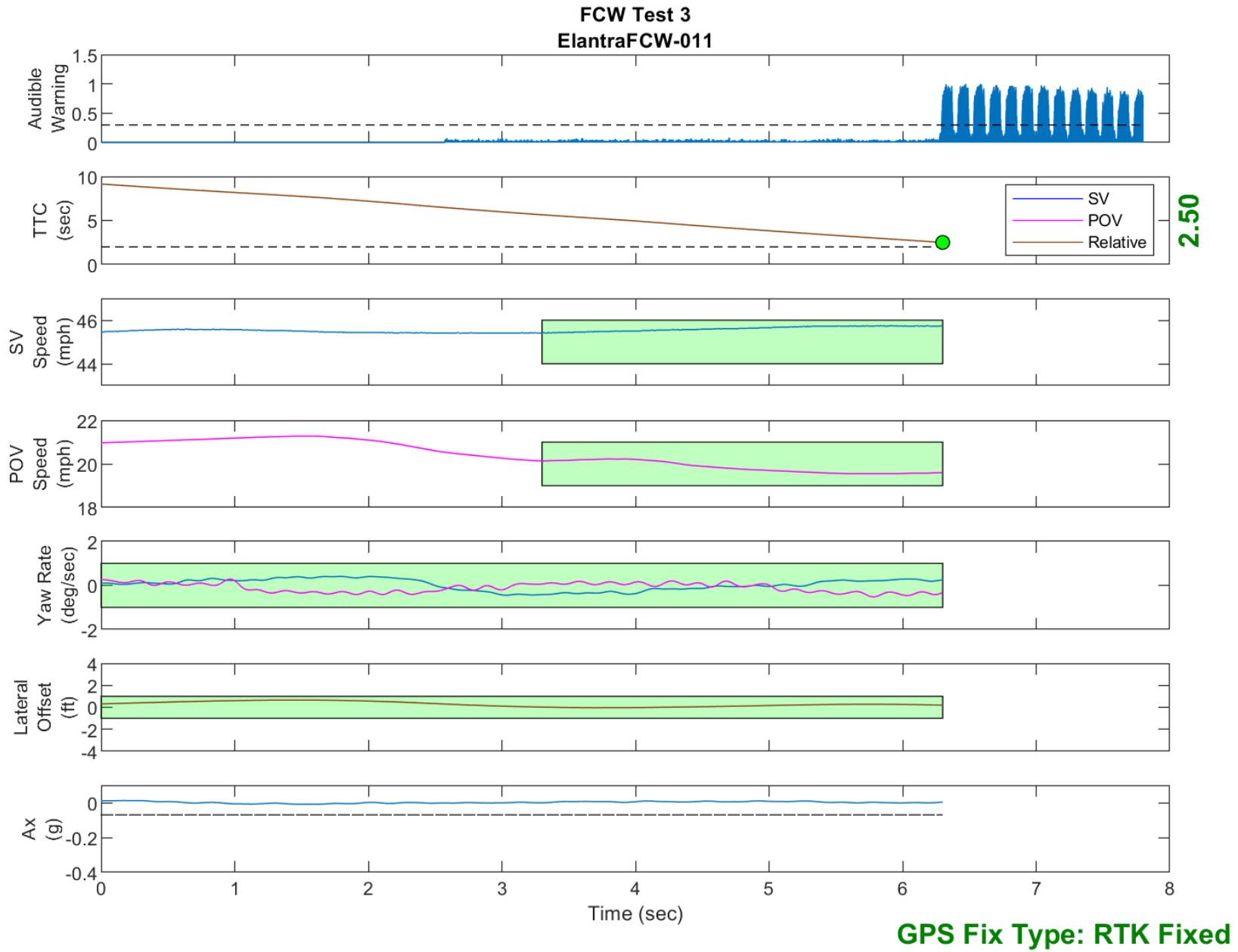


Figure D35. Time History for Run 11, FCW Test 3, Audible Warning

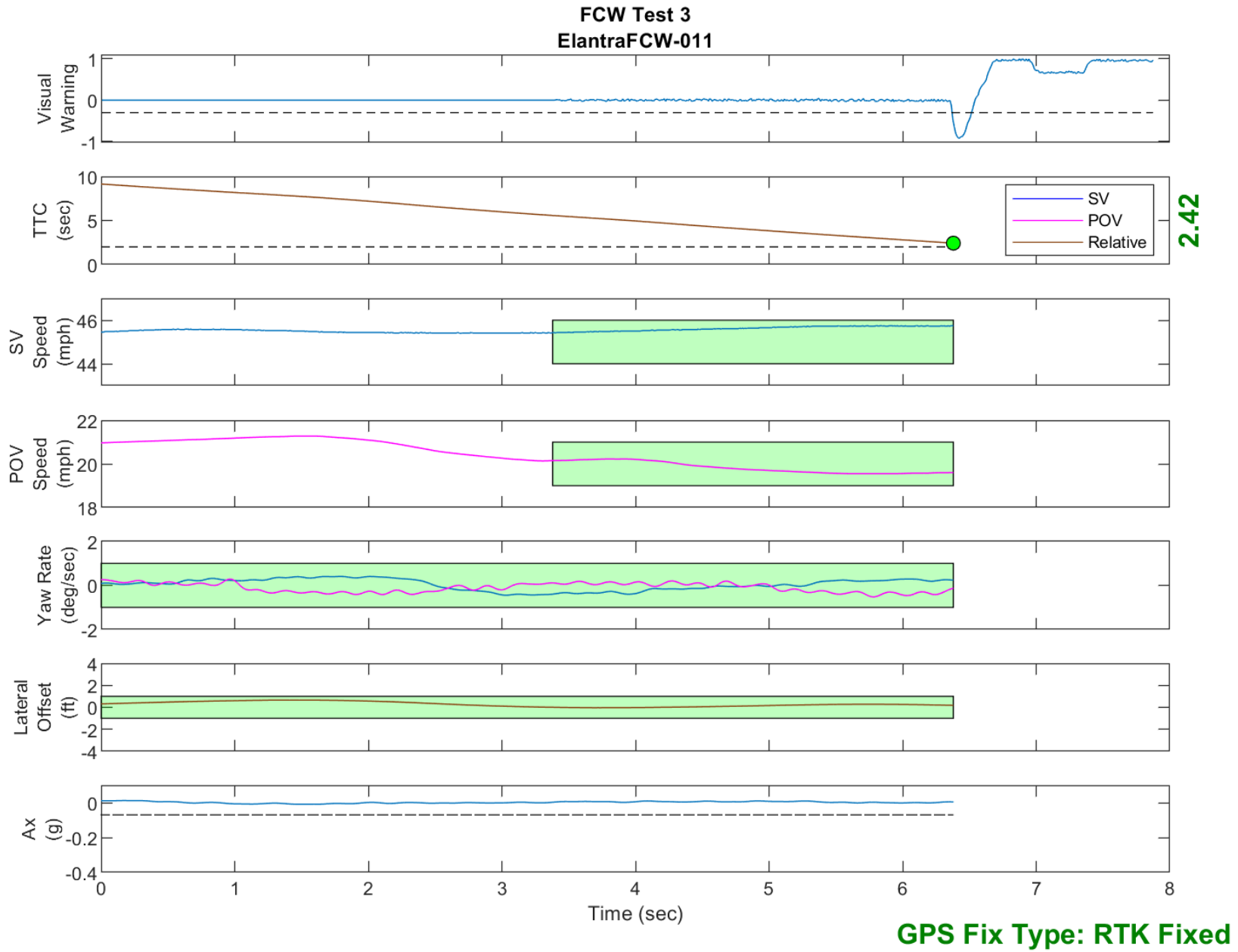


Figure D36. Time History for Run 11, FCW Test 3, Visual Warning

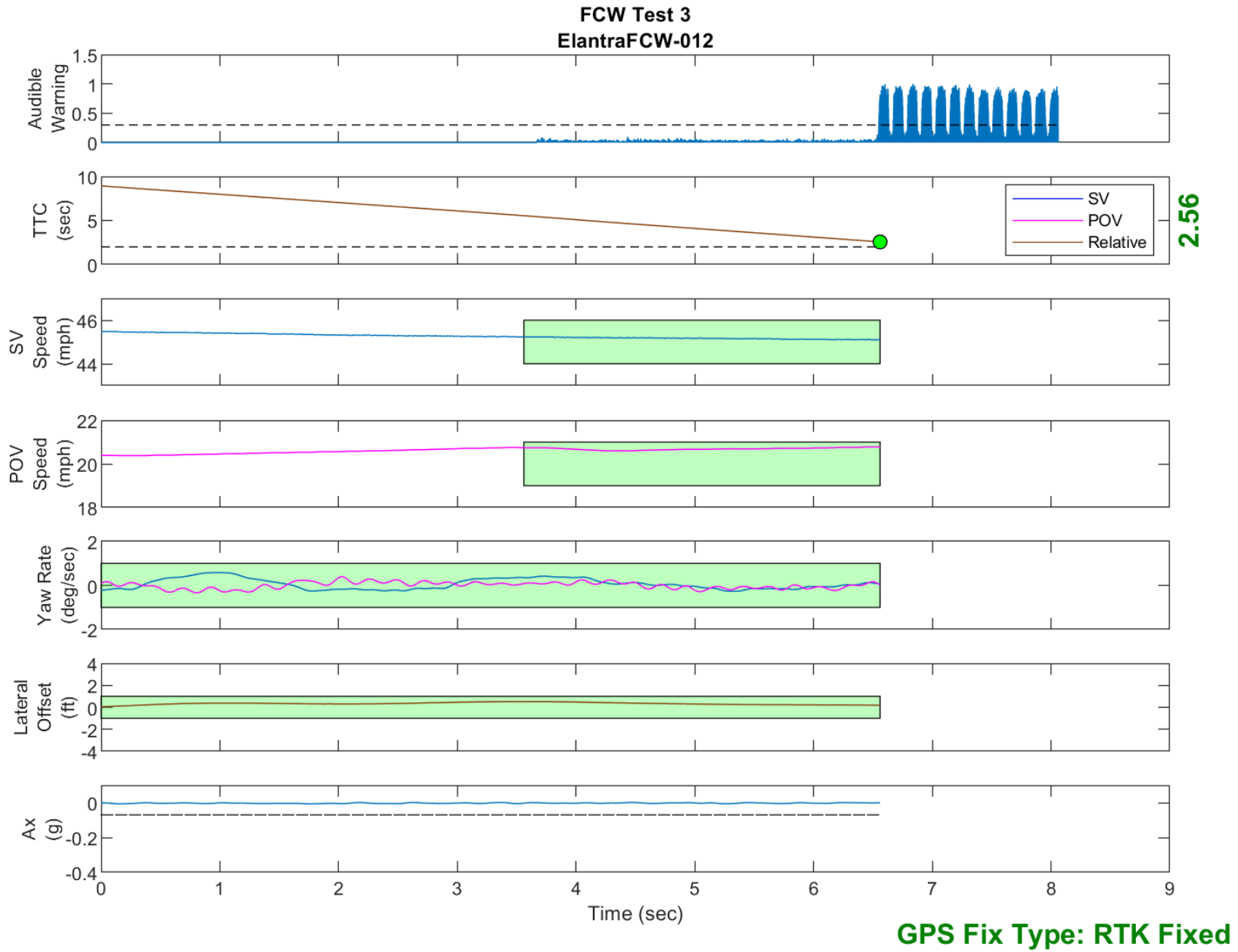


Figure D37. Time History for Run 12, FCW Test 3, Audible Warning

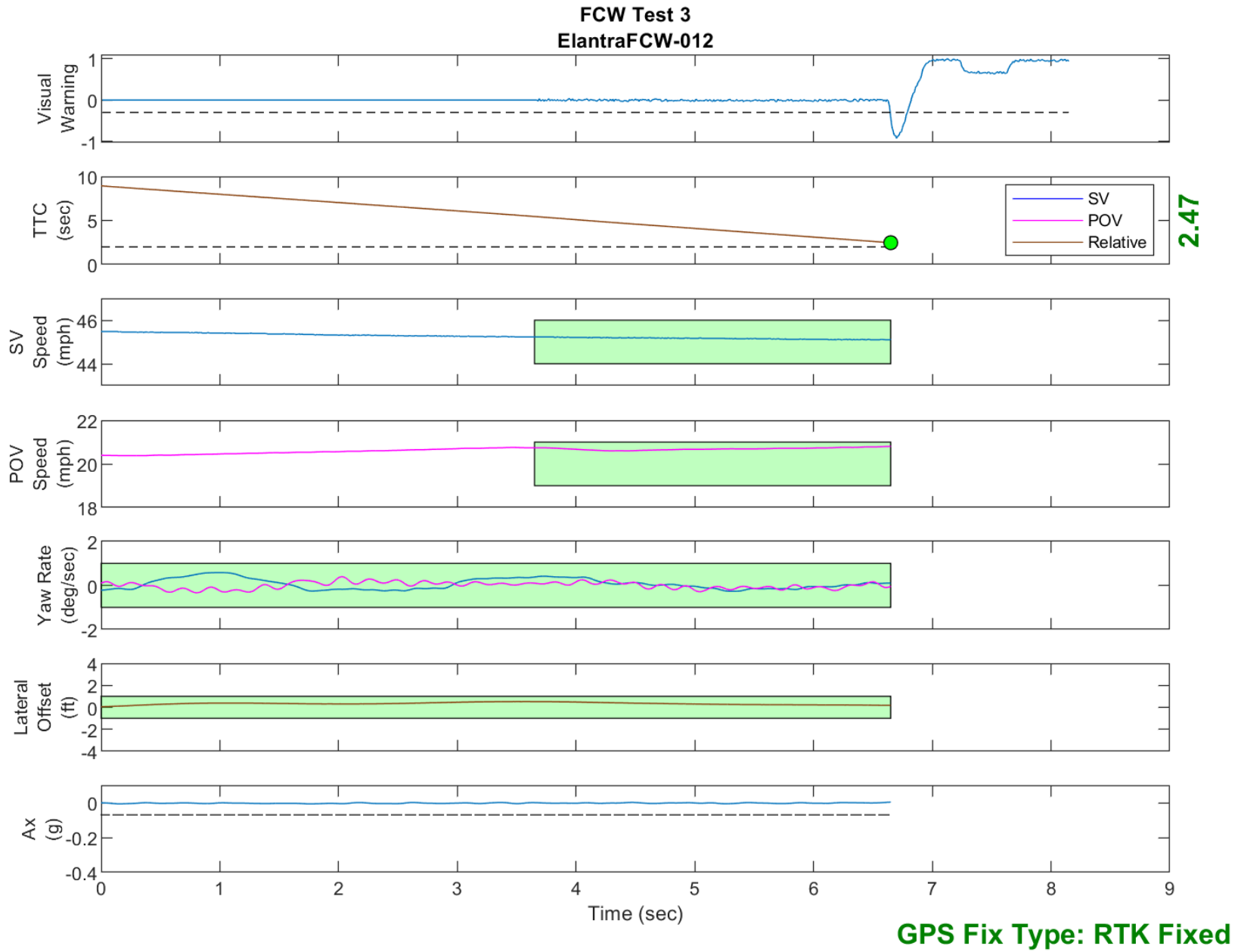


Figure D38. Time History for Run 12, FCW Test 3, Visual Warning

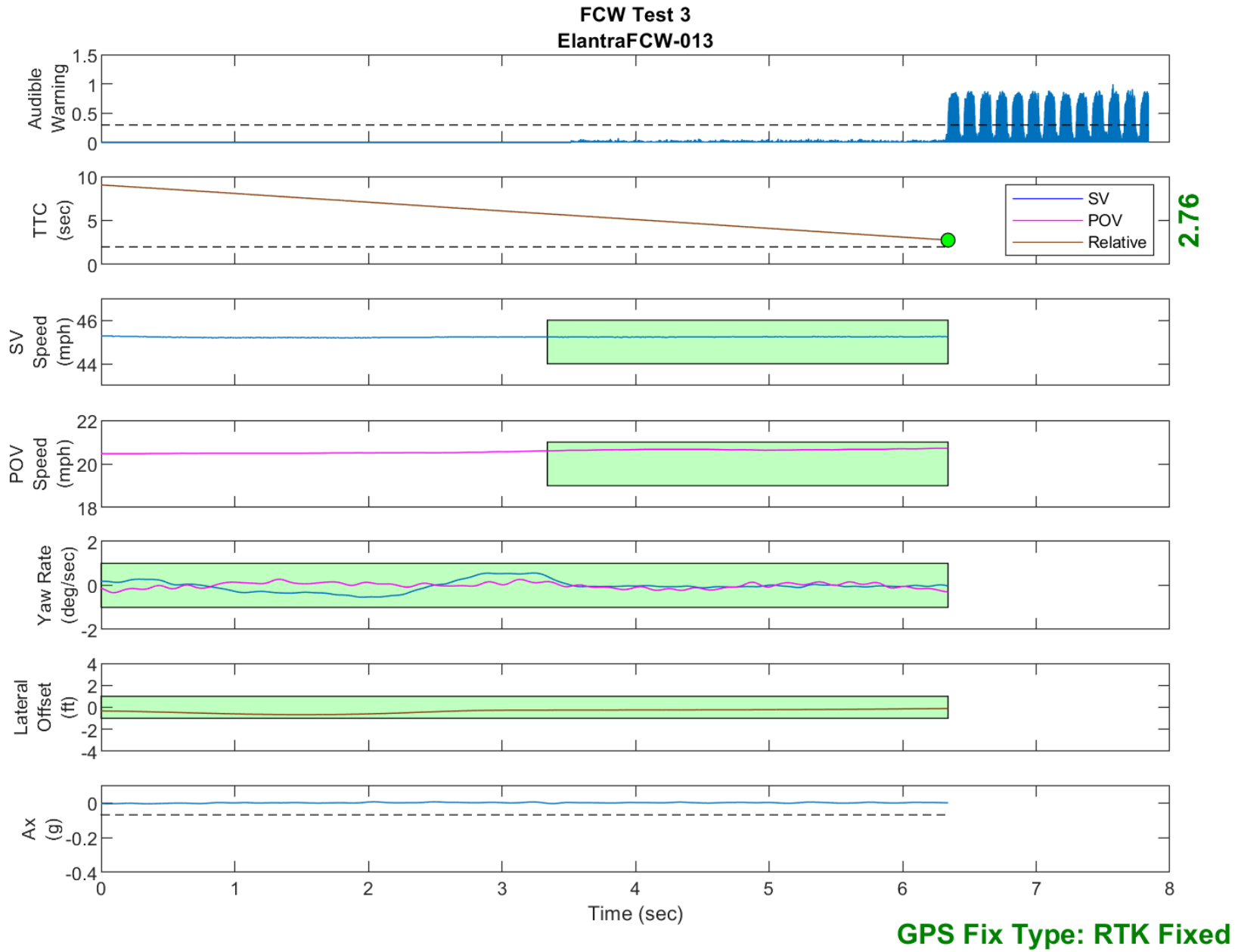


Figure D39. Time History for Run 13, FCW Test 3, Audible Warning

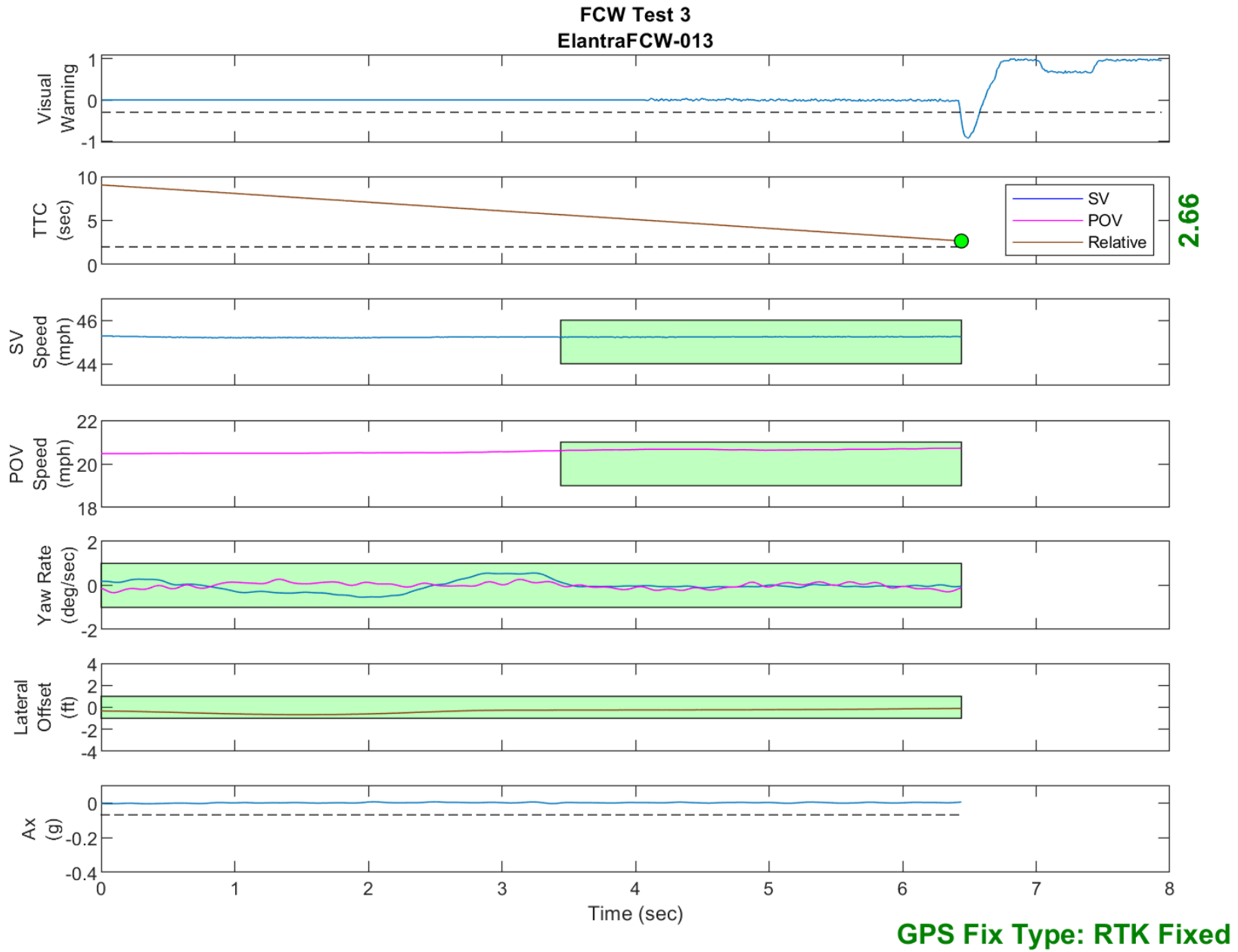


Figure D40. Time History for Run 13, FCW Test 3, Visual Warning

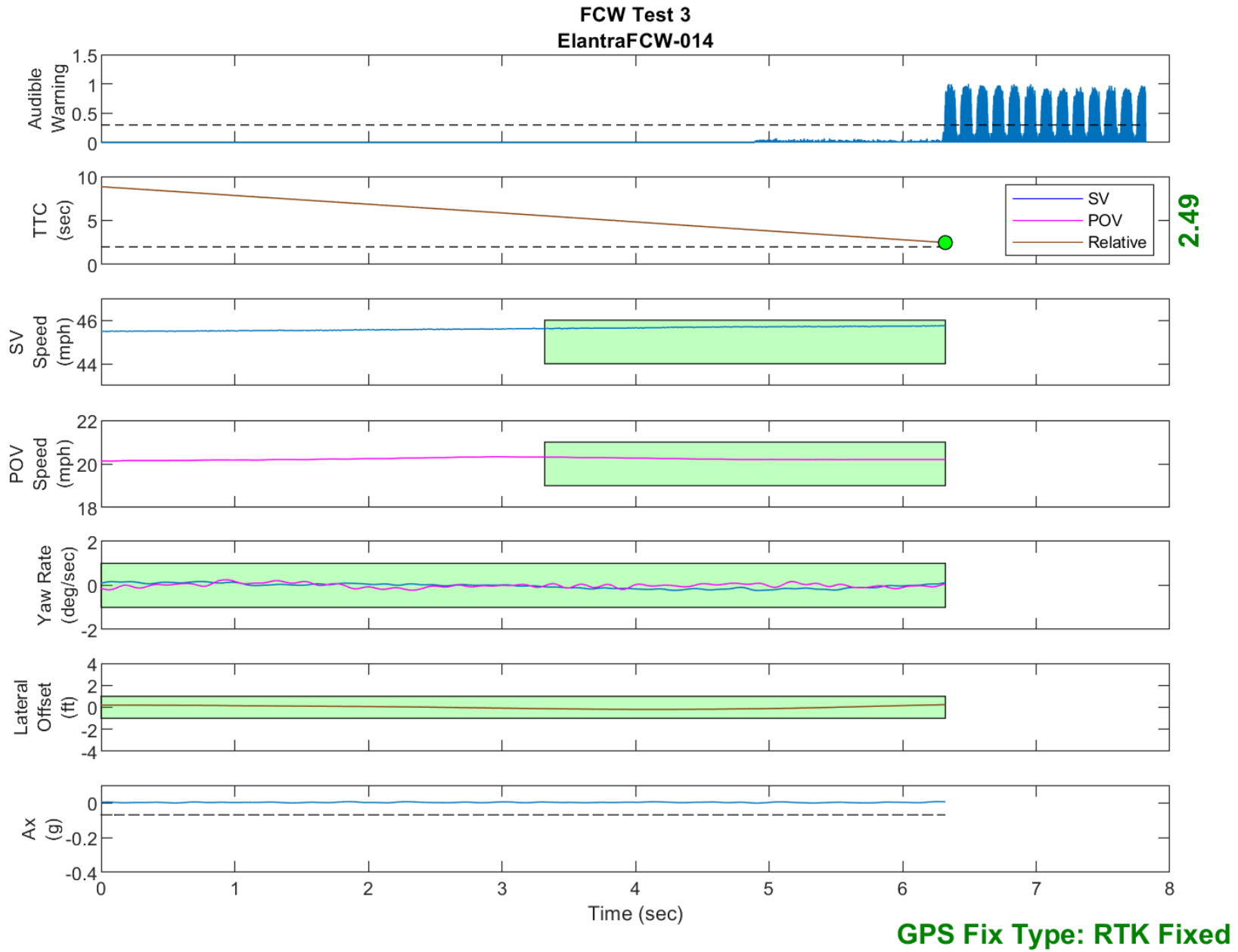


Figure D41. Time History for Run 14, FCW Test 3, Audible Warning

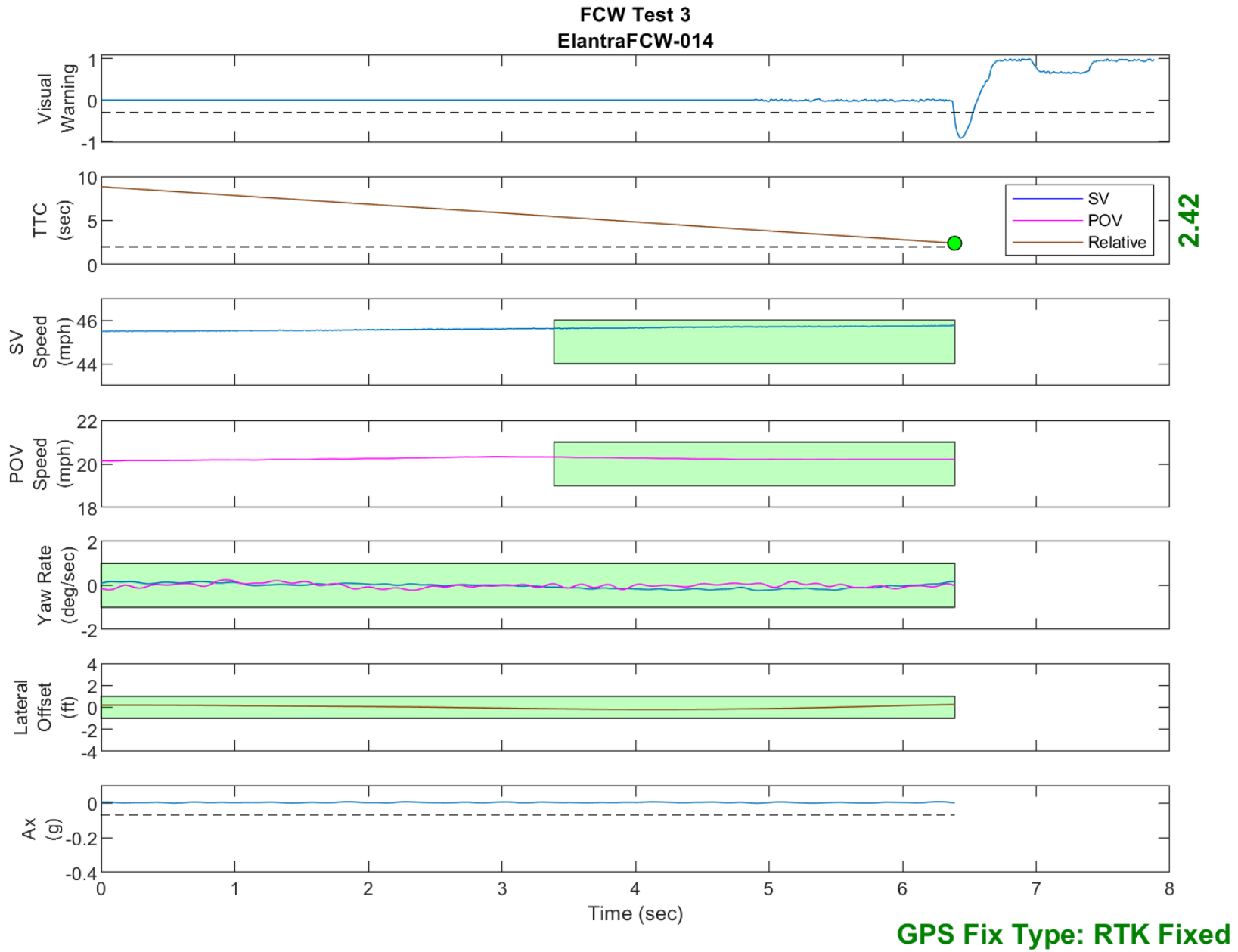


Figure D42. Time History for Run 14, FCW Test 3, Visual Warning

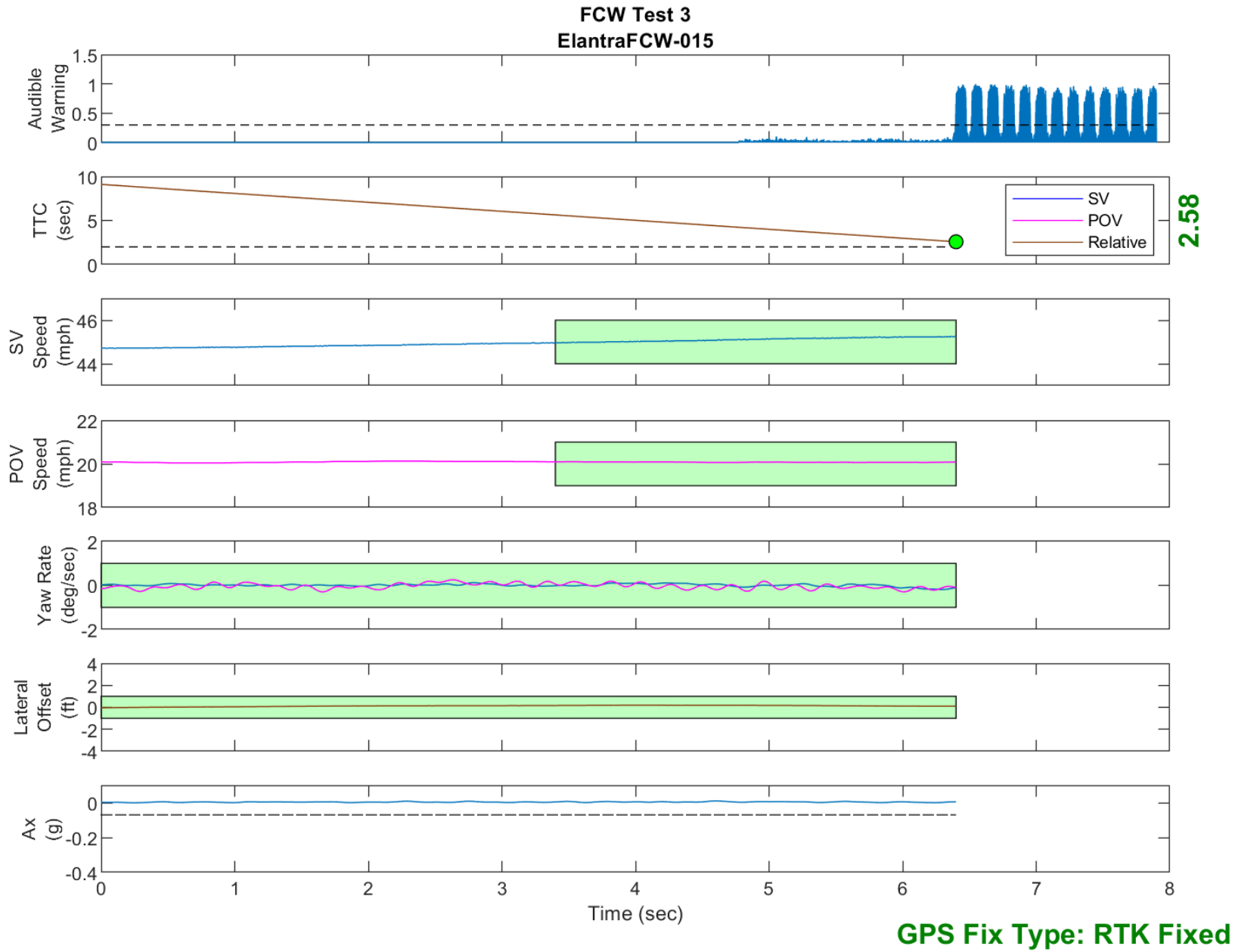


Figure D43. Time History for Run 15, FCW Test 3, Audible Warning

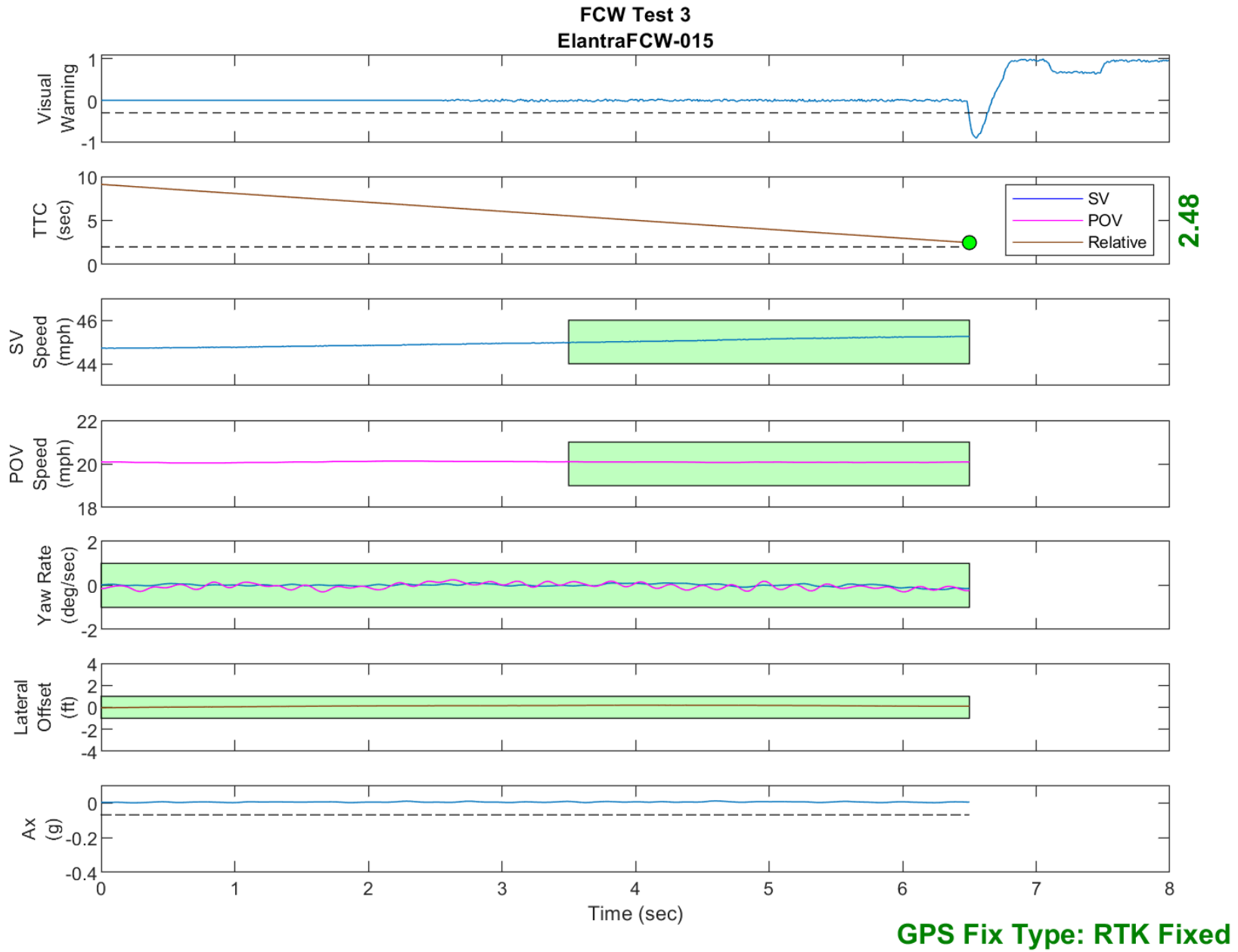


Figure D44. Time History for Run 15, FCW Test 3, Visual Warning

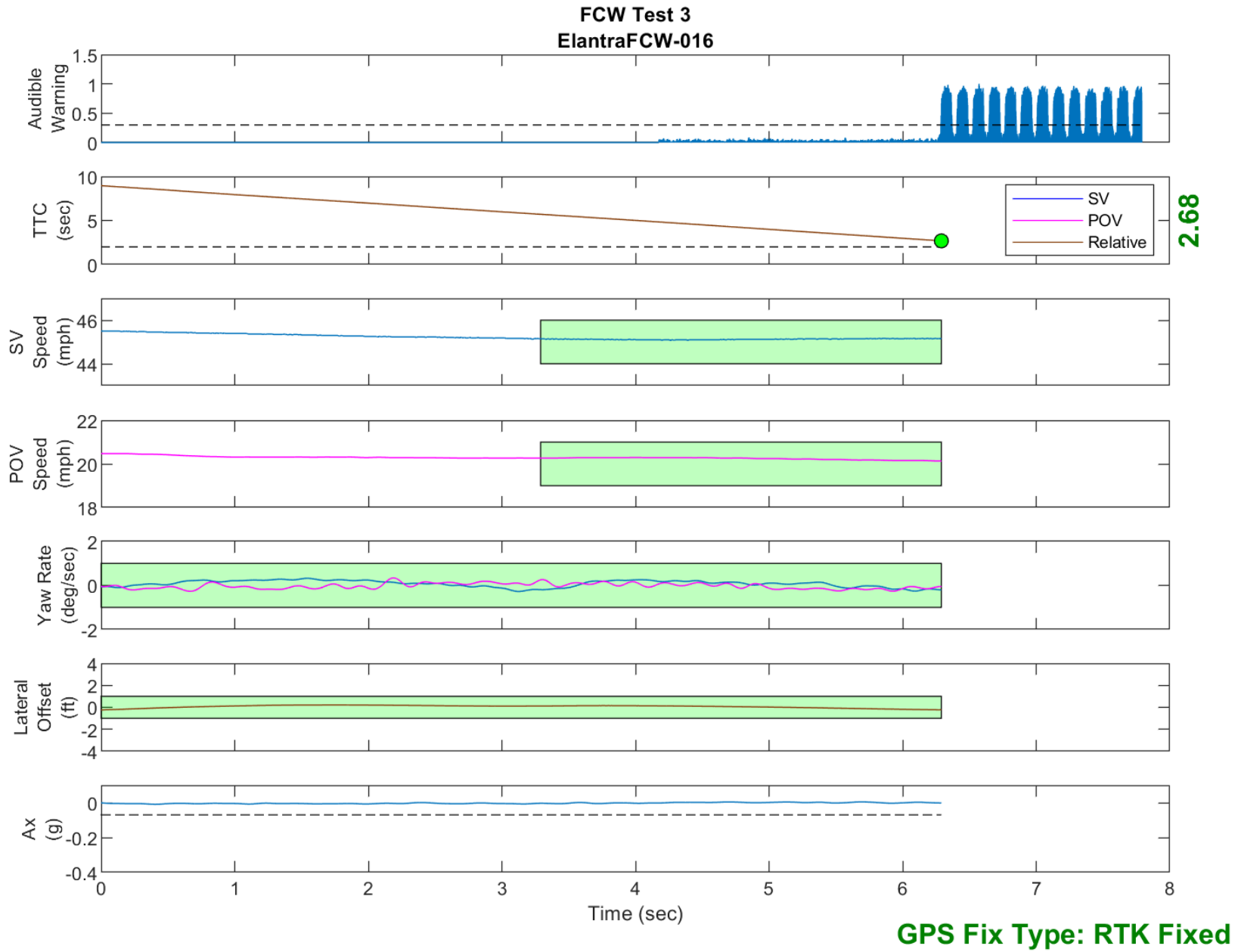


Figure D45. Time History for Run 16, FCW Test 3, Audible Warning

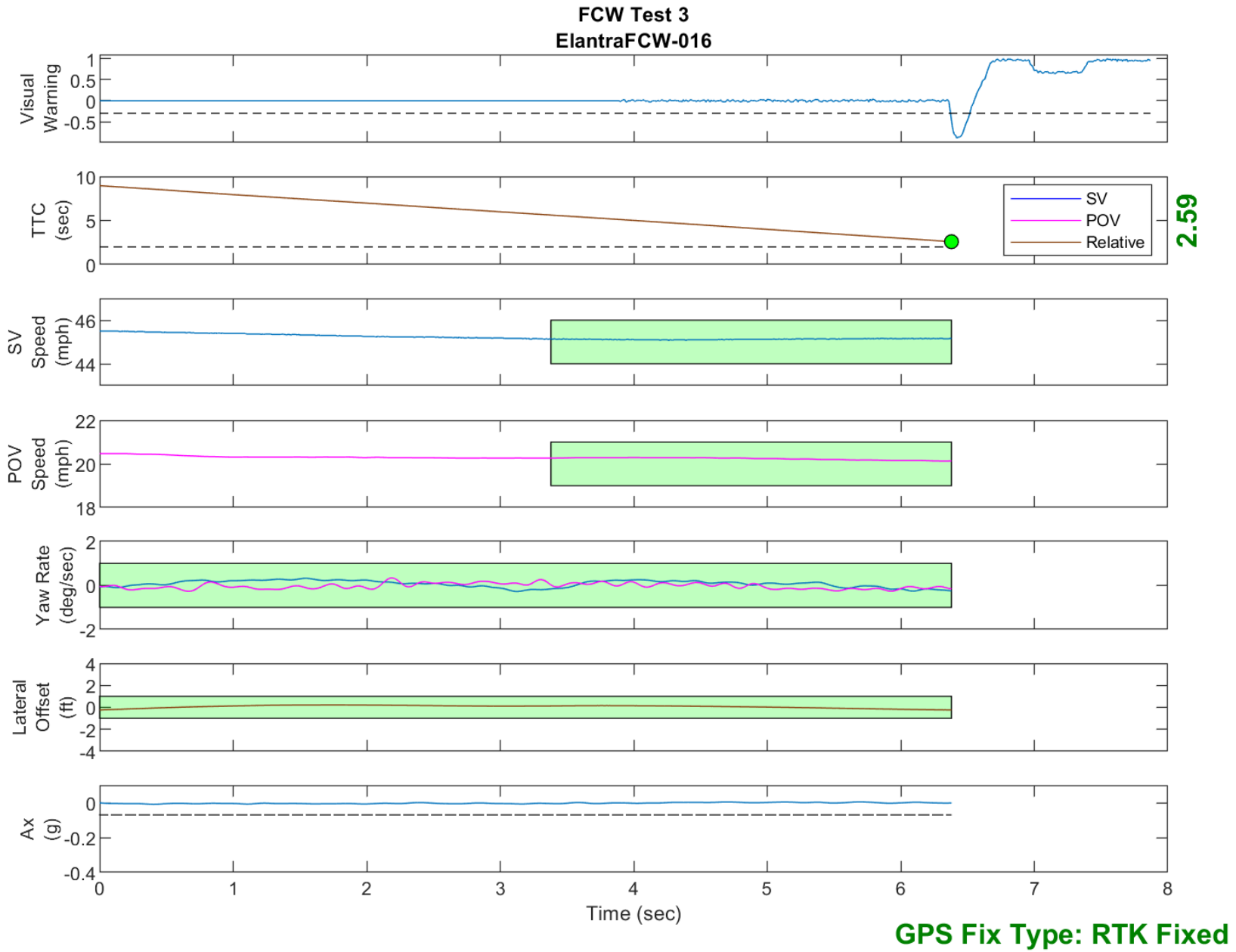


Figure D46. Time History for Run 16, FCW Test 3, Visual Warning

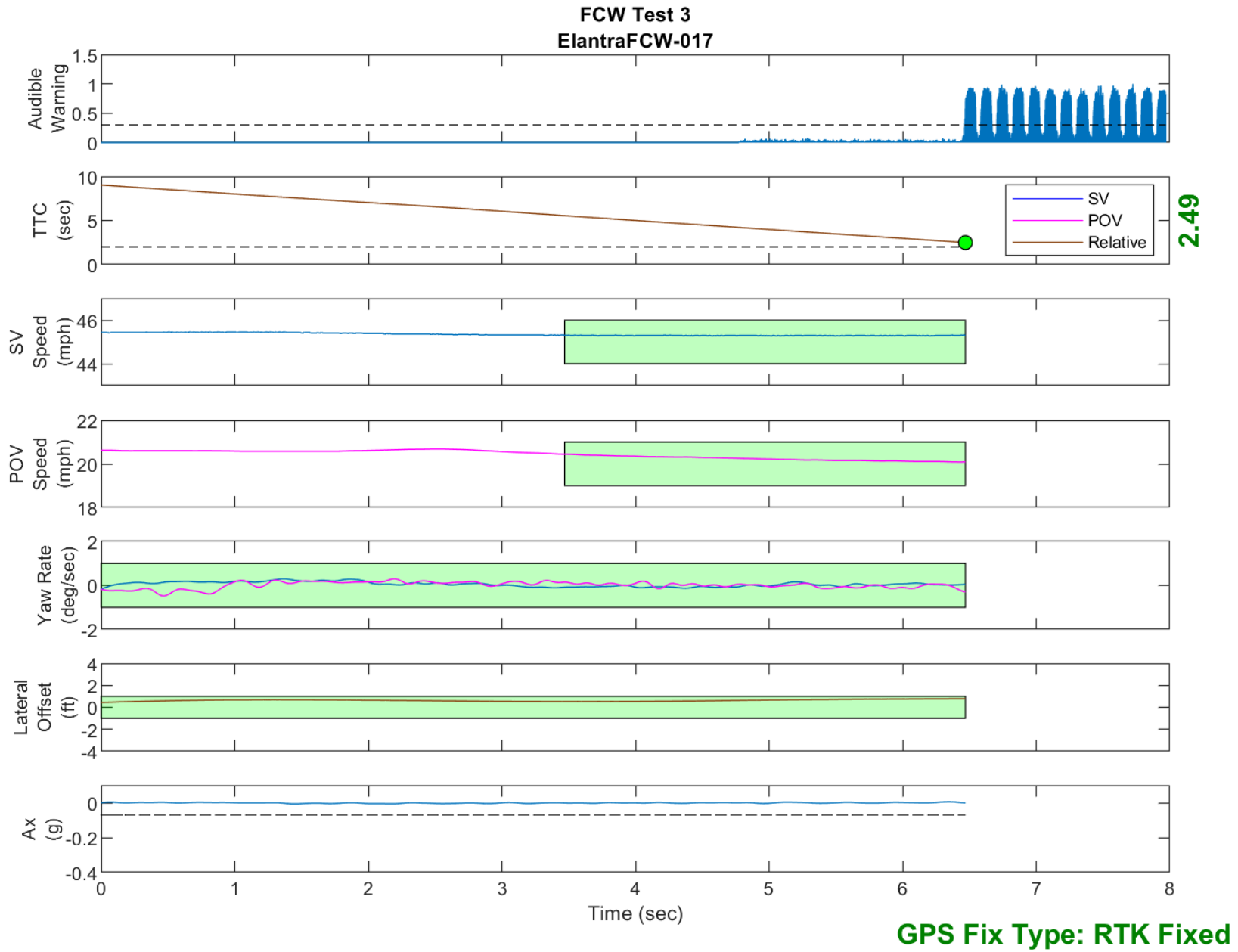


Figure D47. Time History for Run 17, FCW Test 3, Audible Warning

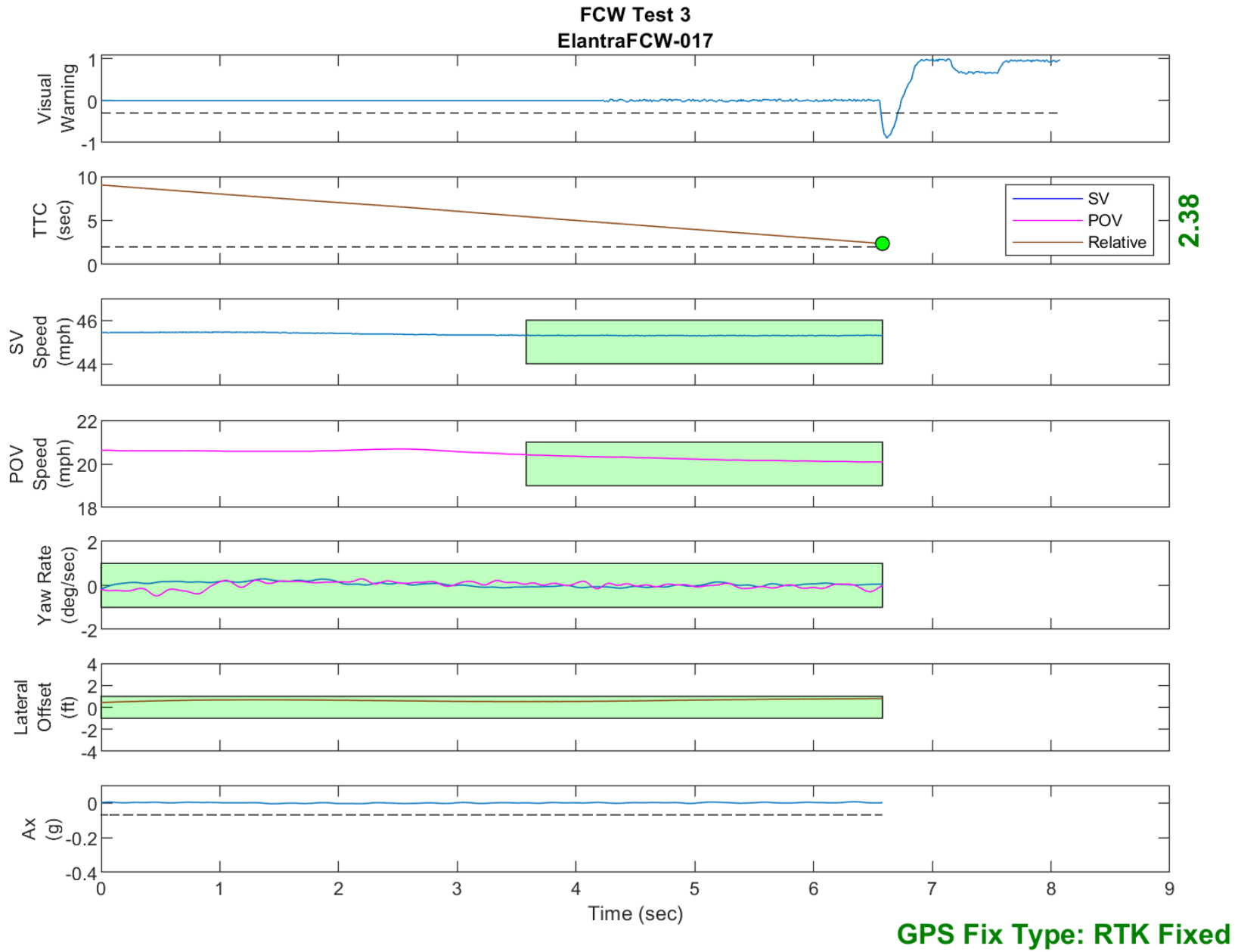


Figure D48. Time History for Run 17, FCW Test 3, Visual Warning