BLIND SPOT DETECTION SYSTEM RESEARCH TEST
NCAP-DRI-BSD-20-04

2020 Hyundai Sonata SEL

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

19 November 2020

Final Report

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

U. S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
New Car Assessment Program
1200 New Jersey Avenue, SE
West Building, 4th Floor (NRM-110)
Washington, DC 20590

Prepared for the Department of Transportation, National Highway Traffic Safety Administration, under Contract No. DTNH22-14-D-00333.

Prepared By: J. Lenkeit, Program Manager
S. Judy, Test Engineer

Date: 19 November 2020

1. Report No. NCAP-DRI-BSD-20-04	2. Government Accession No.	3. Recipient's Catalog No.	
4.Title and Subtitle Final Report of Blind Spot Detection System Testing of a 2020 Hyundai Sonata SEL.		5. Report Date 19 November 2020	
		6. Performing Organization Code DRI	
7. Author(s) J. Lenkeit, Program Manager S. Judy, Test Engineer		8. Performing Organization Report No. DRI-TM-20-109	
9. Performing Organization Name and Address Dynamic Research, Inc. 355 Van Ness Ave, STE 200 Torrance, CA 90501		10. Work Unit No.	
		11. Contract or Grant No. DTNH22-14-D-00333	
12. Sponsoring Agency Name and Address U.S. Department of Transportation National Highway Traffic Safety Administration 1200 New Jersey Avenue, SE, West Building, 4th Floor (NRM-110) Washington, DC 20590		13. Type of Report and Period Covered Final Test Report July - September 2020	
		14. Sponsoring Agency Code NRM-110	
15. Supplementary Notes			
16. Abstract These tests were conducted on the subject 2020 Hyundai Sonata SEL in accordance with the specifications of the National Highway Traffic Safety Administration's most current Test Procedure in docket NHTSA-2019-0102-0010, BLIND SPOT DETECTION SYSTEM CONFIRMATION TEST, to confirm the performance of a Blind Spot Detection system. The preliminary BSD requirements were met for 61 out of 71 valid test runs.			
17. Key Words Blind Spot Detection, BSD, New Car Assessment Program, NCAP		18. Distribution Statement Copies of this report are available from the following: NHTSA Technical Reference Division National Highway Traffic Safety Administration 1200 New Jersey Avenue, SE Washington, DC 20590	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 155	22. Price

TABLE OF CONTENTS

Section I

INTRODUCTION

This test evaluates Blind Spot Detection (BSD) systems on light vehicles with gross vehicle weight ratings (GVWR) of under 10,000 pounds as specified in the National Highway Traffic Safety Administration's (NHTSA's) "Blind Spot Detection System Confirmation Test", dated June 2019. BSD technology uses sensors to detect the presence of other vehicles in the equipped vehicle's left and right blind zone. The procedures described herein emulate two straight-road, real-world scenarios in which the Subject Vehicle (SV) blind zone is breached by a single Principal Other Vehicle (POV). Although it is impossible to predict what technologies could be used by future BSD systems, it is believed that minor modifications to these procedures, when deemed appropriate, could be used to accommodate the evaluation of alternative or more advanced BSD systems.

The BSD system tests described in this document and prescribed by NHTSA involve two different test scenarios: 1) straight lane converge and diverge maneuvers and 2) straight lane pass-by. In the first scenario, the POV is driven at the same speed as the SV, at a constant headway. After a brief period of steady-state driving, the POV enters, then exits the SV blind zone from the side of the vehicle. In the second scenario, the POV is driven by the SV in an adjacent lane at a speed greater than the SV. During this pass-by, the POV enters, then exits the SV blind zone. In both scenarios, BSD performance is assessed by comparing the proximity of the POV to the SV at the time of the BSD alert to the SV blind zone. The test scenarios are conducted at multiple speeds, and on both sides of the vehicle, to the left and right, as indicated in the specific test methodologies.

Section II

DATA SHEETS

BLIND SPOT DETECTION

DATA SHEET 1: TEST RESULTS SUMMARY

(Page 1 of 1)

2020 Hyundai Sonata SEL

VIN: *5NPEF4JA7LH04xxxx*

Test Date: *8/18/2020*

System Setting: *Warning only*

	Number of valid test runs for which acceptability criteria[1] were:		
	Met	**Not met**	**Valid trials**
Test 1 - Straight Lane Converge and Diverge			
45 mph - Left	*4*	*3*	*7*
45 mph - Right	*0*	*7*	*7*
Overall Test 1:	*4*	*10*	*14*
Test 2 - Straight Lane Pass-by			
POV 50 mph - Left	*7*	*0*	*7*
POV 50 mph - Right	*6*	*0*	*6*
POV 55 mph - Left	*7*	*0*	*7*
POV 55 mph - Right	*8*	*0*	*8*
POV 60 mph - Left	*7*	*0*	*7*
POV 60 mph - Right	*8*	*0*	*8*
POV 65 mph - Left	*8*	*0*	*8*
POV 65 mph - Right	*6*	*0*	*6*
Overall Test 2:	*57*	*0*	*57*
Overall:	***61***	***10***	***71***

[1] The acceptability criteria listed herein are used only as a guide to gauge system performance, and are identical to the Pass/Fail criteria given in NHTSA's most current Test Procedure in docket NHTSA-2019-0102-0010, BLIND SPOT DETECTION SYSTEM CONFIRMATION TEST.

BLIND SPOT DETECTION

DATA SHEET 2: VEHICLE DATA

(Page 1 of 1)

2020 Hyundai Sonata SEL

TEST VEHICLE INFORMATION

VIN: *5NPEF4JA7LH04xxxx*

Body Style: *Sedan* Color: *Quartz White*

Date Received: *7/27/2020* Odometer Reading: *36 mi*

DATA FROM VEHICLE'S CERTIFICATON LABEL

Vehicle manufactured by: *Hyundai Motor Manufacturing Alabama, LLC*

Date of manufacture: *Mar/04/20*

Vehicle Type: *Passenger Car*

DATA FROM TIRE PLACARD

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

Rear: *215/55R17*

Recommended cold tire pressure: Front: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

TIRES

Tire manufacturer and model: *Michelin Primacy A/S*

Front tire size: *215/55R17 94V*

Rear tire size: *215/55R17 94V*

Front tire DOT prefix: *B33F 09LX*

Rear tire DOT prefix: *B33F 09LX*

BLIND SPOT DETECTION

DATA SHEET 3: TEST CONDITIONS

(Page 1 of 2)

2020 Hyundai Sonata SEL

GENERAL INFORMATION

Test date: *8/18/2020*

AMBIENT CONDITIONS

Air temperature: *37.2 C (99 F)*

Wind speed: *3.6 m/s (8.1 mph)*

X Windspeed ≤ 10 m/s (22 mph)

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

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

All tests were also conducted such that there were no overhead signs, bridges, or other significant structures over, or near, the testing site. Except for the POV, each trial shall be conducted with no vehicles, obstructions, or stationary objects within one lane width of either side the SV path.

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: *240 kPa (35 psi)*

Rear: *240 kPa (35 psi)*

WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front:	*479.4 kg (1057 lb)*	Right Front:	*459.0 kg (1012 lb)*
Left Rear:	*315.2 kg (695 lb)*	Right Rear:	*308.4 kg (680 lb)*
		Total:	*1562.0 kg (3444 lb)*

BLIND SPOT DETECTION

DATA SHEET 4: BLIND SPOT DETECTION SYSTEM OPERATION

(Page 1 of 5)

2020 Hyundai Sonata SEL

General Information

Name of the BSD option, option package, etc., as shown on the Monroney label:

Listed on Monroney label as Blind Spot Collision-Avoidance Assist (BCA).

Described in Owner's Manual as Blind Spot Collision Warning (BCW). BCA/BCW comes standard on SEL, SEL Plus, and Limited trims.

Type and location of sensors the system uses:

Blind-Spot Collision Warning system uses rear corner radar sensors (2) mounted inside the bumper covering.

System setting used for test (if applicable):

Warning only

Timing set to Normal

Method(s) by which the driver is alerted

X Visual

	Type	Location	Description
X	Symbol	*Outer portion of outside mirrors*	*Blind spot alert symbol*
____	Word		
____	Graphic		

X Audible - Description

Repeated beep

____ Haptic

____	Steering Wheel	____	Seatbelt
____	Pedals	____	Steering Torque
____	Seat	____	Brake Jerk

Description of alert:

First stage alert

If a vehicle is detected within the boundary of the system, a warning light will illuminate on the side view mirror and the heads up display (if equipped).

Once the detected vehicle is no longer within the blind spot area, the warning will turn off according to the driving conditions of the vehicle.

Second stage alert

A warning chime to alert the driver will activate when:

1. *A vehicle has been detected in the blind spot area by the radar system AND,*
2. *The turn signal is applied (same side as where the vehicle is being detected).*

When this alert is activated, the warning light on the side view mirror and the heads up display (if equipped) will also blink. And a warning chime will sound.

If you turn off the turn signal indicator, the second stage alert will be deactivated.

Once the detected vehicle is no longer within the blind spot area, the warning will turn off according to the driving conditions of the vehicle.

System Function

What is the speed range over which the system operates?

Minimum: 30 km/h (20 mph)

Maximum: Maximum vehicle speed

If the system requires an initialization sequence/procedure, please provide a description of the process required to initialize the system.

The BSD system does not require initialization.

If the system requires the driver to operate their turn signal indicator during lane change in order to activate, please provide a description.

If the turn signal is not activated, and a vehicle is in the blind spot, the alerts in the mirror will light continuously. Under the same conditions, if the turn signal is activated, the alerts in the mirror will flash on and off and a repeated beep auditory alert will sound.

If the vehicle is equipped with a method to activate/deactivate the system(s) please provide a description of how this is accomplished. If the system is deactivated by this method, does it reactivate upon each ignition cycle?

Controls on the right side of the steering wheel are used to interact with setup menus displayed in the instrument panel. The hierarchy is:

User Settings

Driver Assistance

Blind Spot Safety – select:

Active Assist

Warning Only

Off

If the system is deactivated, it will remain deactivated upon each ignition cycle.

See Owner's Manual pages 4-26, 4-41, and 6-68 shown in Appendix B, pages B-4, B-5, and B-9. See also Appendix A, Figures A12 through A14.

If the vehicle is equipped with a method to adjust the range setting/sensitivity or otherwise influence the operation of BSD, please provide a description.

However, the following optional settings can be selected by means of controls on the right side of the steering wheel. The menu selections are displayed in the right side of the instrument panel. The menu hierarchy is:

User settings

Driver Assistance

Blind-Spot Safety - select:

Active Assist

Warning Only

Off

Warning Timing - select:

Normal

Late

Warning Volume - select

Low

Medium

High

See Owner's Manual pages 4-22, 4-26, 4-41, 6-68 and 6-69 shown in Appendix B, pages B-3, B-4, B-5, B-9 and B-10. See also Appendix A, Figures A12 through A14.

If the system deactivates due to damage to the sensors, how is this indicated to the driver?

For BSD, the following warning message will appear: "Check Blind-Spot Collision Warning (BCW) system."

BLIND SPOT DETECTION

DATA SHEET 4: BLIND SPOT DETECTION SYSTEM OPERATION

(Page 5 of 5)

2020 Hyundai Sonata SEL

If the system deactivates due to repeated BSD activations:

- How is this indicated to the driver?
- Can deactivation be avoided (e.g., by cycling the ignition after each BSD activation)?
- How can the system be reactivated?

The BSD/BSI systems will not deactivate due to repeated activations.

If the system deactivates or its effectiveness is reduced due to periods of inactivity:

- How is this indicated to the driver?
- Can deactivation be avoided?
- How can the system be reactivated?

In general, the system will not deactivate or reduce effectiveness due to inactivity while driving.

If there are other driving modes or conditions (such as weather) that render the system inoperable or reduce its effectiveness please provide a description.

System limitations are described in the Owner's Manual pages 6-75 through 6-78 and 6-127 through 6-128. These pages are shown in Appendix B pages B-16 through B-21.

Notes:

Section III

TEST PROCEDURES

A. Test Procedure Overview

Two test scenarios were used, as follows:

Test 1. Straight Lane Converge and Diverge
Test 2. Straight Lane Pass-by

An overview of each of the test procedures follows.

For the purposes of this document, headway is defined as the longitudinal distance from the front-most point of the POV to the rearmost point of the SV, regardless of the relative lateral (lane) positions of the SV and POV. When the front-most part of the POV is ahead of the rearmost point on the SV, the headway is negative.

1. TEST 1 – STRAIGHT LANE CONVERGE AND DIVERGE

The Straight Lane Converge and Diverge Test evaluates the ability of the Blind Spot Detection (BSD) system to detect and respond to a vehicle that enters and exits the blind zone from a lane outside of the blind zone area. This test scenario is depicted in Figure 1. In this scenario, the test begins with the POV two lanes away from the SV. After both vehicles have reached their designated speeds and headway overlap, the POV begins a single lane change maneuver so that it is travelling in the lane next to the SV and holds this relative position for at least 2.5 seconds. The POV then begins a lane change maneuver back to its original lane, moving outside of the SV's blind zone.

This test was performed with the POV on both the left- and right-hand sides of the SV. The SV and POV turn signals were not active during any of the tests.

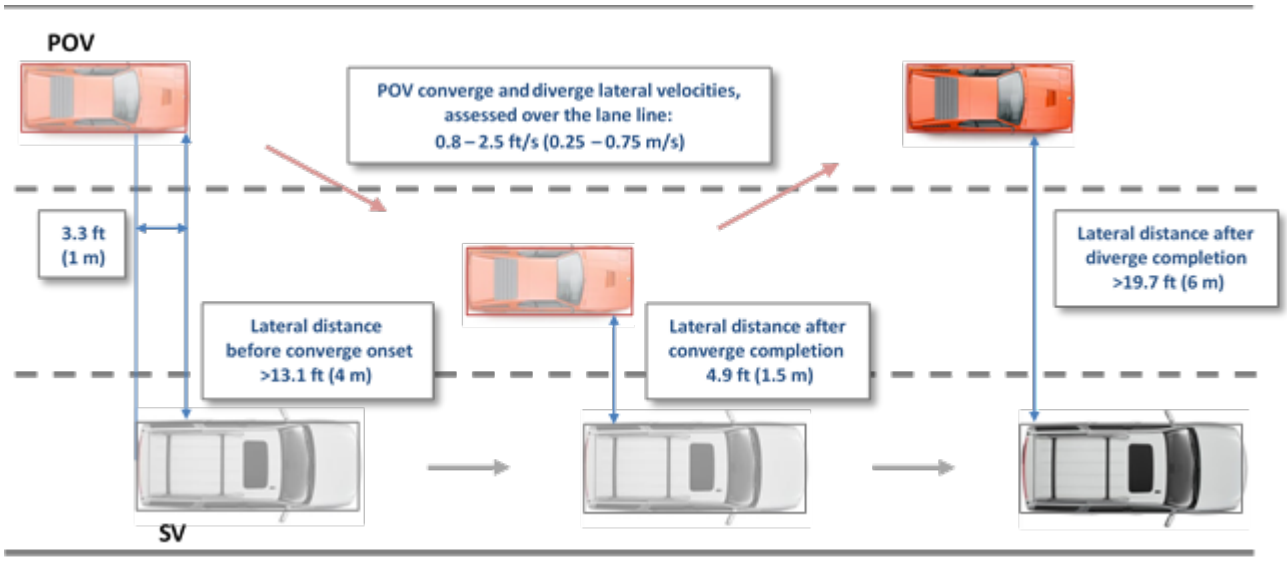


Figure 1. Straight Lane Converge and Diverge Test
(POV converge and diverge from the left is shown)

a. Procedure

The SV began in the center of a travel lane, with its longitudinal axis oriented parallel to the roadway edge. The POV began two lanes away from the SV, with its longitudinal axis oriented parallel to the roadway edge. Both vehicles then accelerated to a nominal speed of 45 mph (72.4 km/h). The nominal speed and specified headway overlap between the front bumper of the POV and the rear bumper of SV was maintained, within tolerance, throughout the test. As shown in Figure 1, the specified headway for this test was -3.3 ft (-1.0 m) resulting in a longitudinal overlap. The specified speed for both the SV and POV was 45 mph (72.4 km/h).

Once the specified speed and headway were stabilized and maintained for at least 2.5 seconds, the POV performed a “converge” lane change into the lane adjacent to the SV using a lateral velocity between 0.8 ft/s and 2.5 ft/s (0.25 to 0.75 m/s).

Once the lane change was completed, the POV continued in a straight line for at least 2.5 seconds, and then performed a “diverge” lane change back into its original lane using a lateral velocity between 0.8 ft/s and 2.5 ft/s (0.25 to 0.75 m/s).

The test concluded once the POV was back in its original lane and had been driving straight for at least 1.0 second.

The validity period for this test started 2.5 seconds prior to initiating the first POV lane change and ended 1.0 second after completion of the final POV lane change. For an individual test trial to be valid, the following requirements must have been met throughout the validity period:

- The SV and POV speeds could not deviate from the specified speed by more

than 1.0 mph (1.6 km/h) during the entire test trial interval.

- The SV yaw rate could not exceed ±1 deg/s for the entire test interval.
- The POV yaw rate could not exceed ±1 deg/s when not performing a lane change maneuver.
- The POV lateral velocity during a lane change maneuver must have been 0.8 to 2.5 ft/s (0.25 to 0.75 m/s), assessed at the instant the vehicle first crossed the lane line separating the initial and adjacent travel lanes.
- The headway overlap from the front of the POV to the rear of the SV bumper must have been within 3.3 ± 1.6 ft (1.0 ± 0.5 m) for the entire test interval.
- The lateral offset between the widest point of the SV (not including side mirrors) and the widest point of the POV (not including side mirrors) must have been
    - greater than 13.1 ft (4 m) before the POV begins the converge lane change,
    - within 4.9 ± 1.6 ft (1.5 ± 0.5 m) when the POV is in the lane adjacent to the SV, and
    - greater than 19.7 ft (6 m) after the POV completes the diverge lane change.

After the test validity period ended, the SV driver manually applied force to the brake pedal, bringing the vehicle to a stop, and placed the transmission in park. The POV was also braked to a stop, and the test trial was complete.

b. Number of Test Trials

Seven valid trials per POV approach direction were performed for the Straight Lane Converge and Diverge Test scenario, for a total of 14 tests overall. If the test conductor performed more than 7 trials per approach direction within this scenario, the first 7 trials satisfying all test tolerances per approach direction were used to assess the SV performance.

c. Evaluation Criteria

The performance requirement for this series of tests is that the BSD system must be presented by a time no later than 300 ms after any part of the POV enters the SV blind zone defined by the intersections of lines A, C, D, and E for left side tests and of lines A, C, F, and G for right side tests (as shown in Figure 3), and shall remain on while any part of the POV resides within the SV blind zone. During the diverge portion of the test scenario, the BSD alert may remain active when the lateral distance between the SV and the POV is greater than 9.8 ft (3 m) but less than or equal to 19.7 ft (6 m). The BSD shall not be active once the lateral distance between the SV and the POV is greater than 19.7 ft (6 m).

Test 2 – Straight Lane Pass-by

This test evaluates the ability of the BSD system to detect and respond to a vehicle which approaches and then passes by the SV in an adjacent lane. This test scenario, depicted in Figure 2, was performed with the POV on both the left- and right-hand side of the SV, with four different POV speed configurations on each side: 50 mph, 55 mph, 60 mph, and 65 mph.

The SV and POV turn signals were not active during any of the tests.

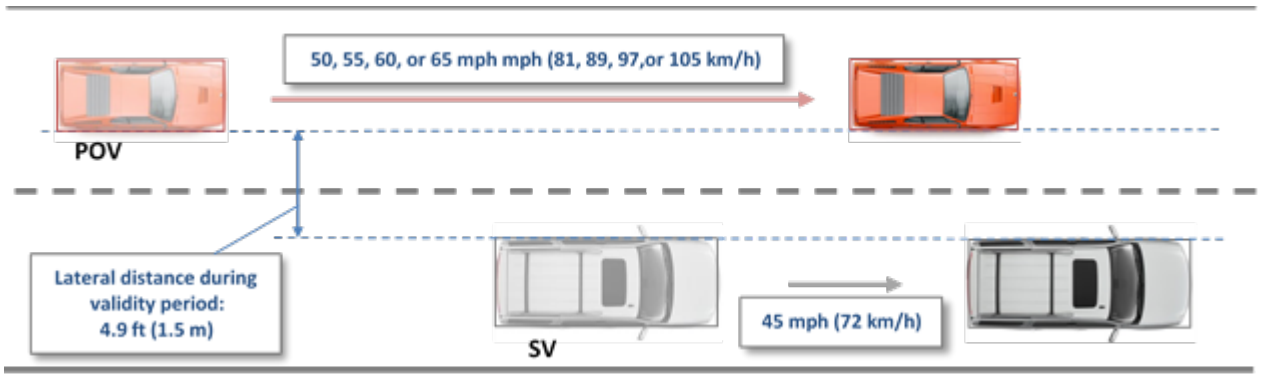


Figure 2. Straight Lane Pass-by Test
(Left-side POV Pass-by)

a. Procedure

The SV is started in the center of a travel lane, with its longitudinal axis oriented parallel to the roadway edge. The POV is started in an adjacent lane on either the left or right side of the SV, with its longitudinal axis oriented parallel to the roadway edge, and behind the SV blind zone area.

The SV is then accelerated to a nominal speed of 45 mph (72.4 km/h) and the POV is accelerated to a nominal speed of either 50 mph (80.5 km/h), 55 mph (88.5 km/h), 60 mph (96.6 km/h), or 65 mph (104.6 km/h) depending on the test configuration. Both vehicles continue straight in their respective lanes.

The Straight Lane Pass-by Test parameters are defined in Table 1. The test validity period begins 4.0 seconds before the front-most part of the POV passes beyond a plane defined by the rear-most part of the SV perpendicular to the SV centerline. The test validity period ends 2.0 seconds after the rear-most point of the POV passes beyond a plane defined by the front-most point of the SV perpendicular to the SV centerline.

Table 1. Straight Lane Pass-by Test Scenarios

Parameter	Test Scenario			
	Straight Lane 45/50	Straight Lane 45/55	Straight Lane 45/60	Straight Lane 45/65
SV Speed	45 ± 1 mph (72.4 ± 1.6 km/h)	45 ± 1 mph (72.4 ± 1.6 km/h)	45 ± 1 mph (72.4 ± 1.6 km/h)	45 ± 1 mph (72.4 ± 1.6 km/h)
POV Speed	50 ± 1 mph (80.5 ± 1.6 km/h)	55 ± 1 mph (88.5 ± 1.6 km/h)	60 ± 1 mph (96.6 ± 1.6 km/h)	65 ± 1 mph (104.6 ± 1.6 km/h)
Differential Speed	5 ± 1 mph (8.0 ± 1.6 km/h)	10 ± 1 mph (16.1± 1.6 km/h)	15 ± 1 mph (24.1 ± 1.6 km/h)	20 ± 1 mph (32.2 ± 1.6 km/h)
Starting Headway Distance (nominally a 4 second gap) at validity period onset	29.3 ft (8.9 m)	58.7 ft (17.9 m)	88.0 ft (26.8 m)	117.3 ft (35.8 m)

For an individual test trial to be valid, the following requirements must have been met throughout the validity period:

- The SV speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during the entire test interval.
- The POV speed could not deviate from the nominal speed by more than 1.0 mph (1.6 km/h) during the entire test interval.
- The SV yaw rate could not exceed ±1 deg/s for the entire test interval.
- The POV yaw rate could not exceed ±1 deg/s for the entire test interval.
- The lateral offset between the widest point of the SV (not including side mirrors) and the widest point of the POV (not including side mirrors) must have been within 4.9 ± 1.6 ft (1.5 ± 0.5 m) for the entire test interval.

After the test validity period ended, the SV driver manually applied force to the brake pedal, bringing the vehicle to a stop, and placed the transmission in park. The POV was also braked to a stop, and the test trial was complete.

b. Number of Test Trials

Seven valid trials for each POV pass-by side and speed were performed for the Straight Lane Pass-by Test scenario, for a total of 56 test trials overall. If the test conductor performed more than 7 trials per approach direction within this scenario, the first 7 trials satisfying all test tolerances per test condition were used to assess the SV performance.

c. Evaluation Criteria

The performance requirement for this series of tests is that the BSD alert must be presented by a time no later than 300 ms after the front-most part of the POV enters the blind zone defined by the intersections of lines A, C, D, and E for left side tests and of lines A, C, F, and G for right side tests, and shall remain on while the frontmost point of the POV lies behind line A. The BSD alert shall not be active once the longitudinal distance between the front-most part of the SV and the rear-most part of the POV exceeds the BSD termination distances specified in Table 2.

Table 2. Straight Lane Pass-by BSD Evaluation Criteria

SV Speed	POV Speed	BSD Onset Headway[1] (SV ahead of POV)	BSD Termination Distance[2] (POV ahead of SV)
45 ± 1 mph (72.4 ± 1.6 km/h)	50 ± 1 mph (80.5 ± 1.6 km/h)	Within 300 ms after $\overline{BC}$ = 18.3 ft (5.6 m)	>7.3 ft (2.2 m)
	55 ± 1 mph (88.5 ± 1.6 km/h)	Within 300 ms after $\overline{BC}$ = 36.7 ft (11.2 m)	>14.7 ft (4.5 m)
	60 ± 1 mph (96.6 ± 1.6 km/h)	Within 300 ms after $\overline{BC}$ = 55.0 ft (16.8 m)	>22.0 ft (6.7 m)
	65 ± 1 mph (104.6 ± 1.6 km/h)	Within 300 ms after $\overline{BC}$ = 73.3 ft (22.4 m)	>29.3ft (8.9 m)

[1] The BSD onset headway is the longitudinal distance when the rear-most part of the SV is ahead of the front-most part of the POV. The BSD onset headway criteria nominally corresponds to 2.5 seconds before the front-most part of the POV passes by the rear-most part of the SV.

[2] The BSD termination distance is the longitudinal distance when the rear-most part of the POV is ahead of the front-most part of the SV. The BSD termination distance criteria nominally corresponds to 1 second after the rear-most part of the POV passes by the front-most part of the SV.

B. Pre-Test Initialization and Calibration

A zero calibration was performed to align the lateral and longitudinal zero for the vehicles immediately before and after testing. The “zero position” was determined by positioning the SV and POV such that the centerline of the front-most location of the POV was aligned with the centerline of the rearmost location of the SV. Longitudinally, the front-most point of the front bumper of the POV was placed at the rear-most point of the rear bumper of the SV.

Static calibrations were then performed by placing the SV and POV transmissions in park, where applicable. Data were then collected for approximately 10 seconds using data from at least six GPS satellites. If the pre-test and post-test zero-positions reported by the data acquisition system differed by more than ±2 in (±5 cm) then the tests performed between the pre-test and post-test static calibrations were repeated.

C. Vehicle’s Blind Zone

The SV blind zones, for the purpose of this test, are defined by two rectangular regions adjacent to the sides of the SV, as shown in Figure 3.

The width of each rectangle is 8.2 ft (2.5 m) and is represented by lines parallel to the longitudinal centerline of the vehicle. The width of the rectangle begins 1.6 ft (0.5 m) from the outermost edge of the SV’s body, excluding the side view mirrors.

The length of the rectangle starts at the rearmost portion of the SV’s side view mirrors, perpendicular to the longitudinal centerline of the vehicle, and continues to a distance dependent on the differential speed between the SV and POV or SOV. To calculate the distance for the length of the rectangle that extends beyond the rear bumper of the SV, the following equation is used and corresponds to the length from point B to point C in Figure 3.

$$\overline{BC} = 2.5\Delta v\ (ft/s\ to\ ft)$$

where,

> Δv is the differential speed between the POV and the SV. A positive Δv indicates that the POV is travelling faster than the SV.

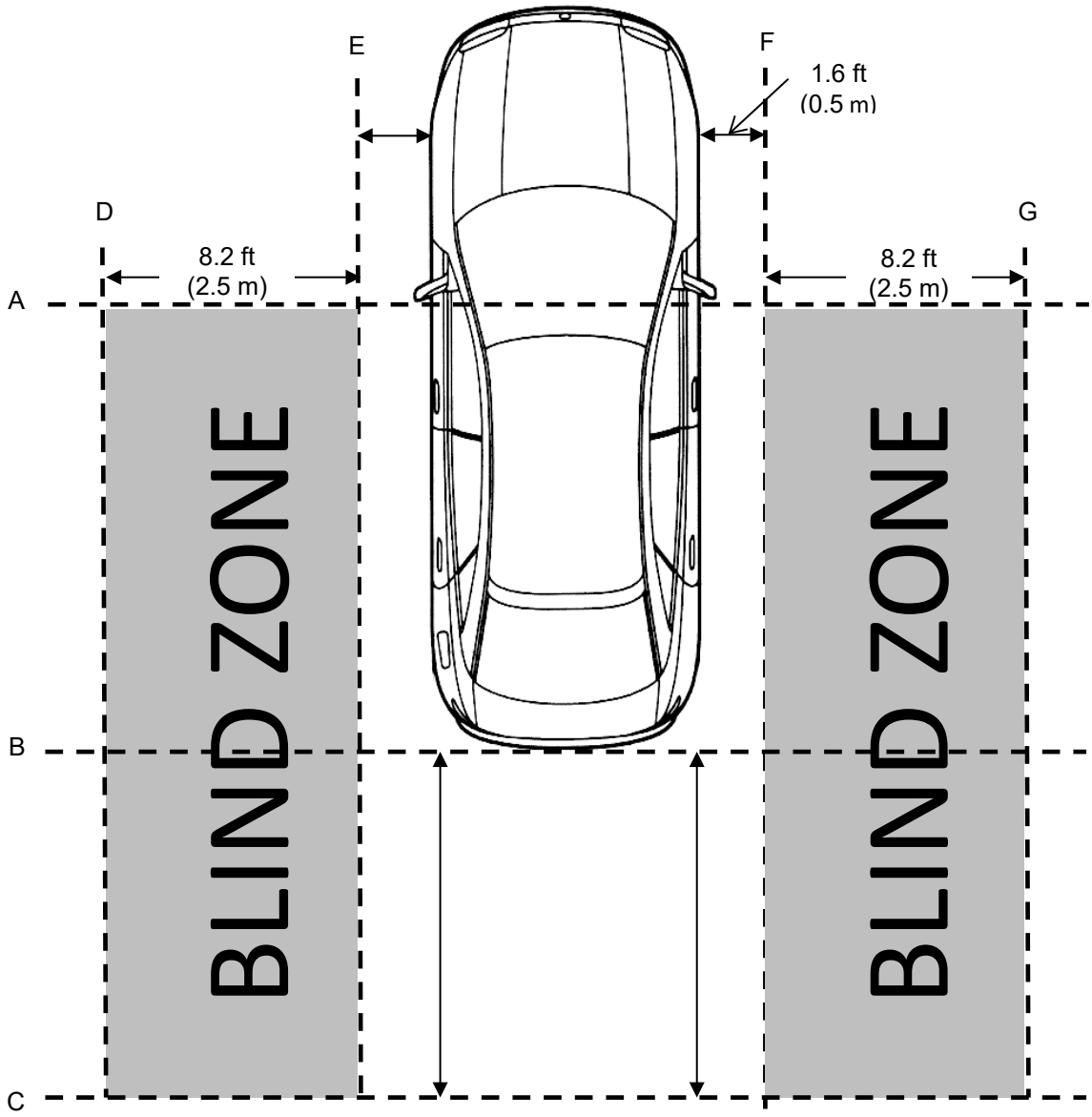


Figure 3. Vehicle Blind Zone Areas

Table 3 details the difference in length from point B to point C of the blind zone for the different speeds used in the tests.

Table 3. B to C Blind Zone Distance

SV-to-POV Differential Speed	B to C Distance (Nominal TTC = 2.5s)
5 ± 1 mph (8.0 ± 1.6 km/h)	18.3 ft (5.6 m)
10 ± 1 mph (16.1 ± 1.6 km/h)	36.7 ft (11.2 m)
15 ± 1 mph (24.1 ± 1.6 km/h)	55.0 ft (16.8 m)
20 ± 1 mph (32.2 ± 1.6 km/h)	73.3 ft (22.4 m)

For the Straight Lane Converge and Diverge Test scenario where there is no speed differential between the SV and POV, the B to C distance is given as 9.8 ft (3 m).

D. Principal Other Vehicle

The vehicle used as the Principal Other Vehicle (POV) was a 2006 Acura RL. This vehicle met the test requirements that the POV be a high-production mid-sized passenger car from 175 to 197 in (445 to 500 cm) long, and 70 to 76 in (178 to 193 cm) wide, measured at the widest part of the vehicle, exclusive of signal lamps, marker lamps, outside rearview mirrors, flexible fender extensions, and mud flaps, determined with doors and windows closed and the wheels in the straight-ahead position. Vehicle loading consisted of the driver plus equipment and instrumentation.

E. Throttle Controller

The POV was equipped with a programmable throttle controller which was used during the Straight Lane Converge and Diverge test scenarios to modulate both speed and headway overlap between the SV and the POV. The throttle controller system consisted of the following components:

- Electronically controlled servo motor, mounted on an aluminum rail system and installed in the vehicle
- Real time computer (Arduino)

- Laptop computer, used to program and enable the throttle controller

F. Instrumentation

Table 4 lists the sensors, signal conditioning, and data acquisition equipment used for these tests.

Table 4. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
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	N/A
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 Rate ±100 deg/s, Angle >45 deg, Velocity >200 km/h	Accels .01g, Angular Rate 0.05 deg/s, Angle 0.05 deg, Velocity 0.1 km/h	Oxford Inertial +	2258	By: Oxford Technical Solutions Date: 5/3/2019 Due: 5/3/2021
				Oxford xNAV 550	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	N/A
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	N/A	N/A

Table 4. Test Instrumentation and Equipment (continued)

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model	Serial Number	Calibration Dates Last Due
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor	N/A	N/A
Accelerometer	Acceleration (to measure time at alert)	±5g	≤ 3% of full range	Silicon Designs, 2210-005	N/A	N/A
Tire Pressure Gauge	Vehicle Tire Pressure	0-100 psi	< 1% error between 20 and 100 psi	Omega DPG8001	18111410000	By: DRI Date: 5/4/2020 Due: 5/4/2021
Platform Scales	Vehicle Total, Wheel, and Axle Load	2200 lb/platform	0.1% of reading	Intercomp SW wireless	0410MN20001	By: DRI Date: 4/20/2020 Due: 4/20/2021
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
Throttle Controller	Arduino based, servo actuated controller for managing POV speed	DRI developed	N/A

APPENDIX A

Photographs

LIST OF FIGURES

Figure A1. Front View of Subject Vehicle

Figure A2. Rear View of Subject Vehicle

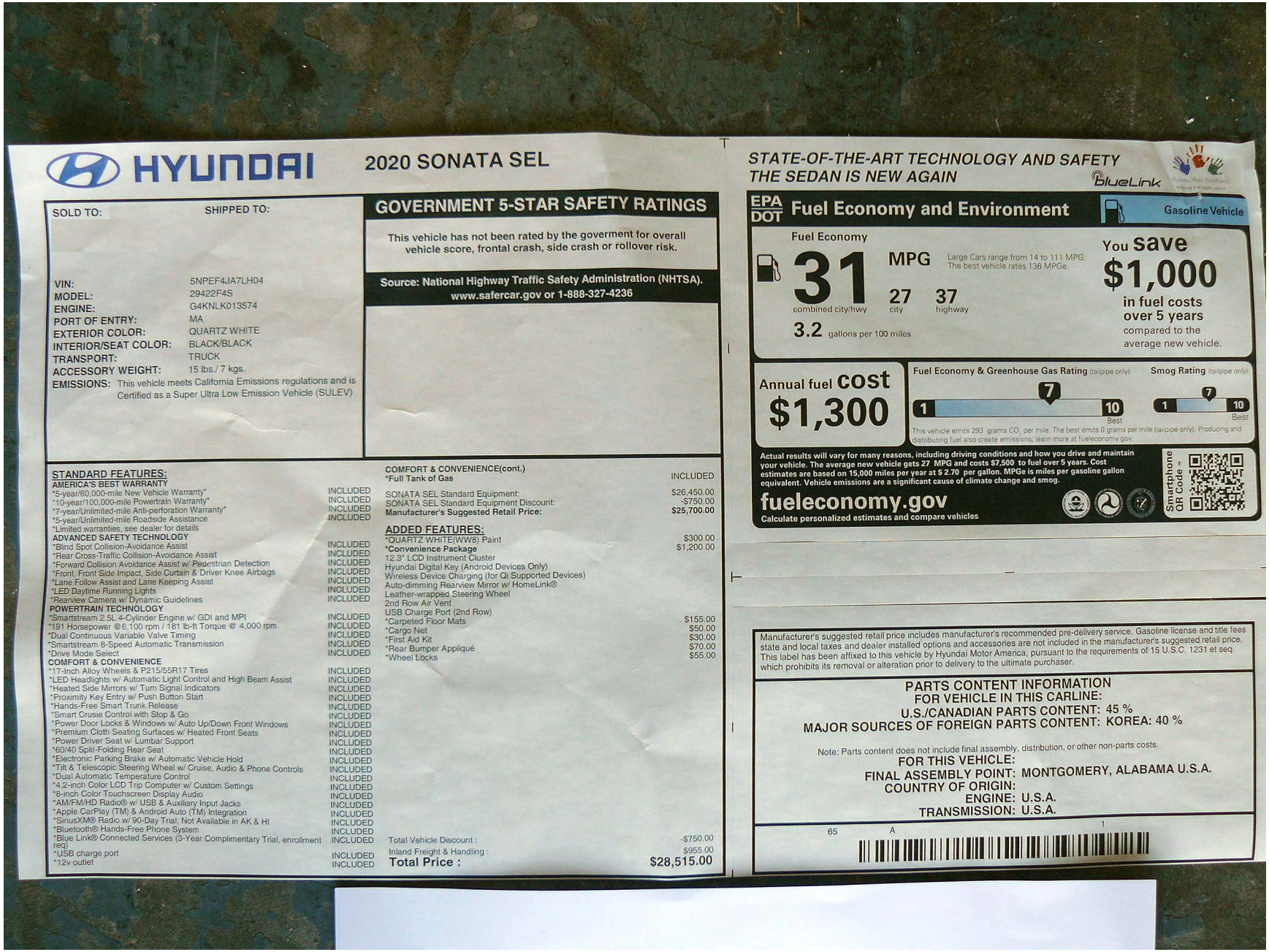


Figure A3. Window Sticker (Monroney Label)

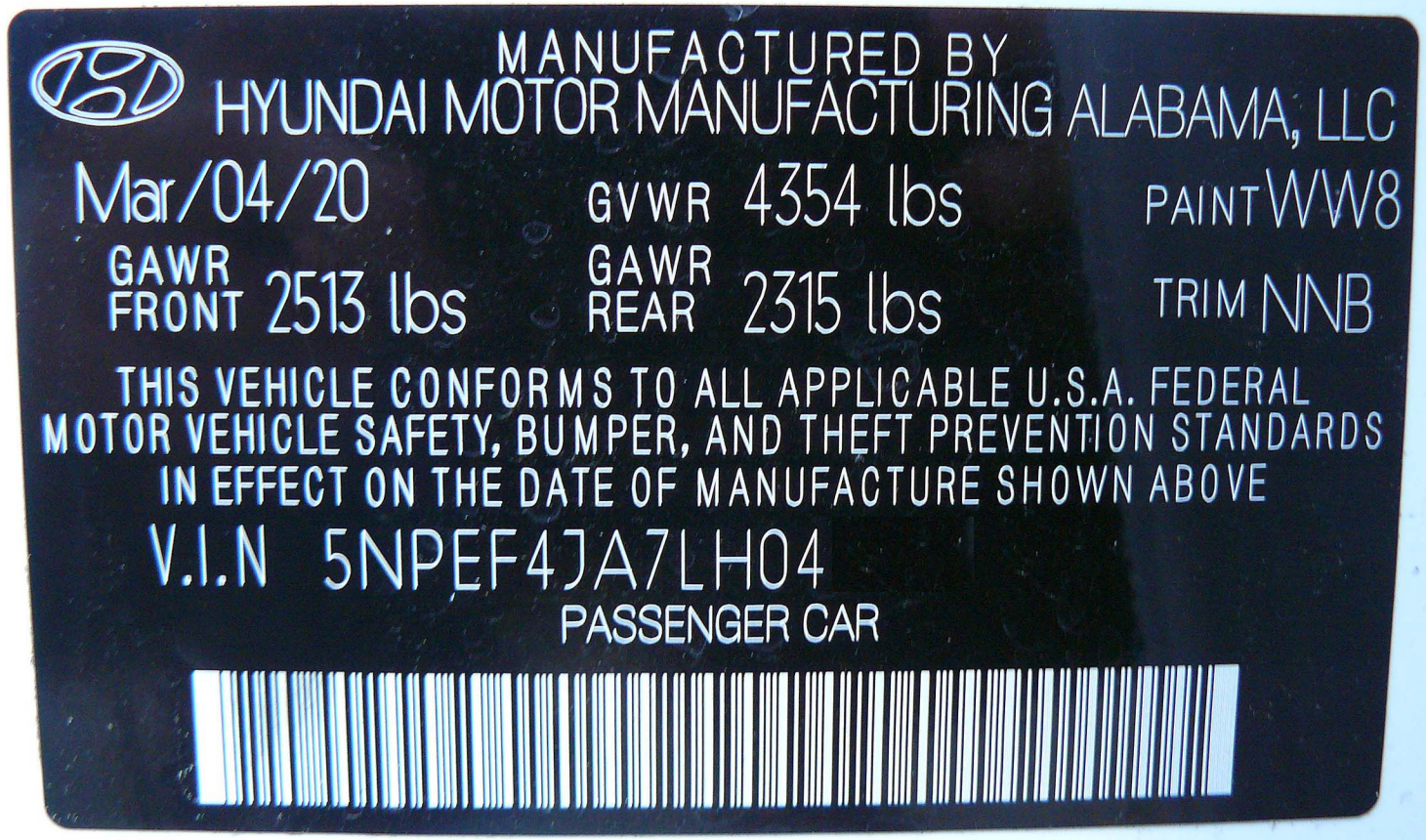


Figure A4. Vehicle Certification Label

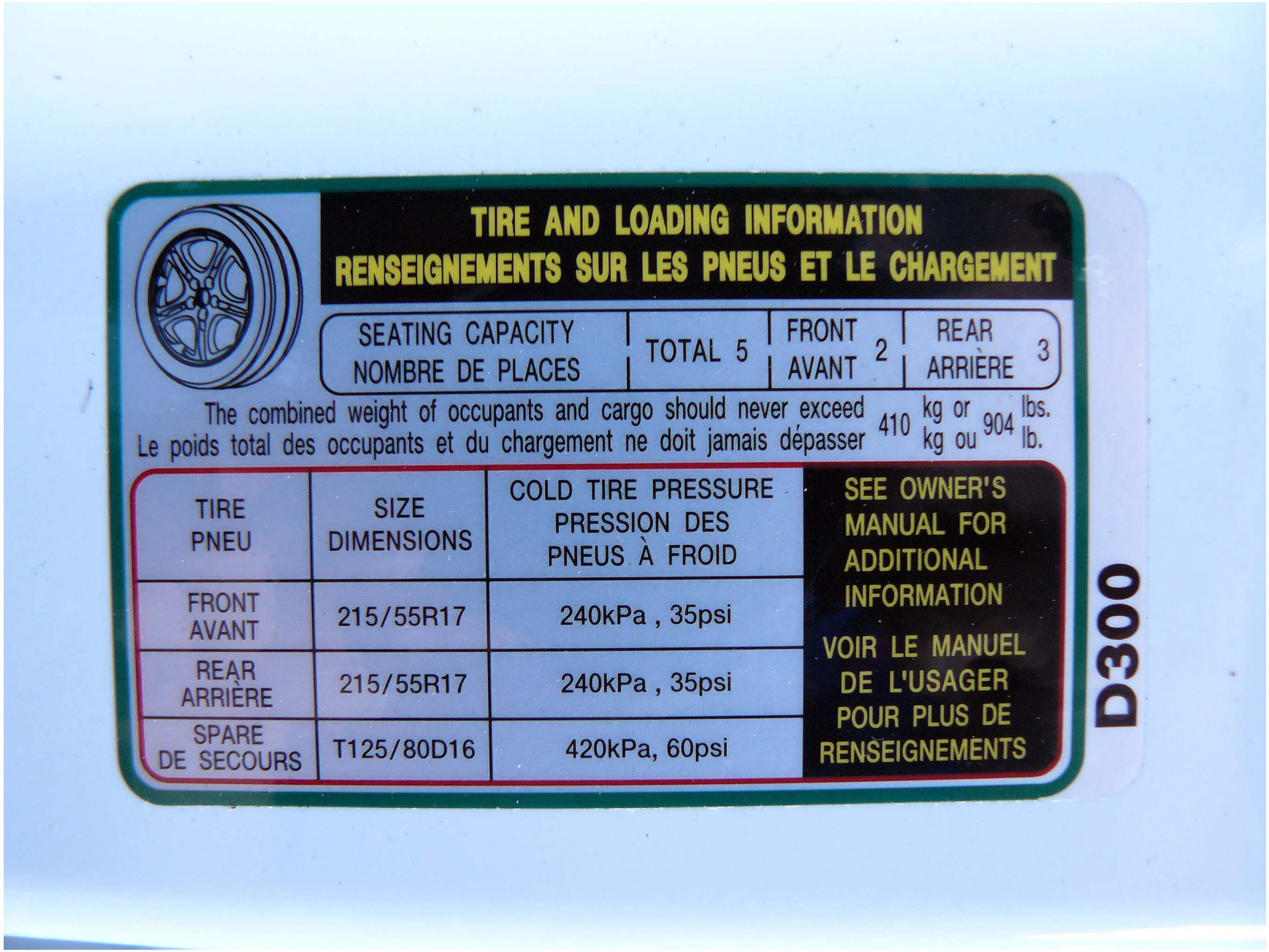


Figure A5. Tire Placard

Figure A6. Front View of Principal Other Vehicle

Figure A7. Rear View of Principal Other Vehicle

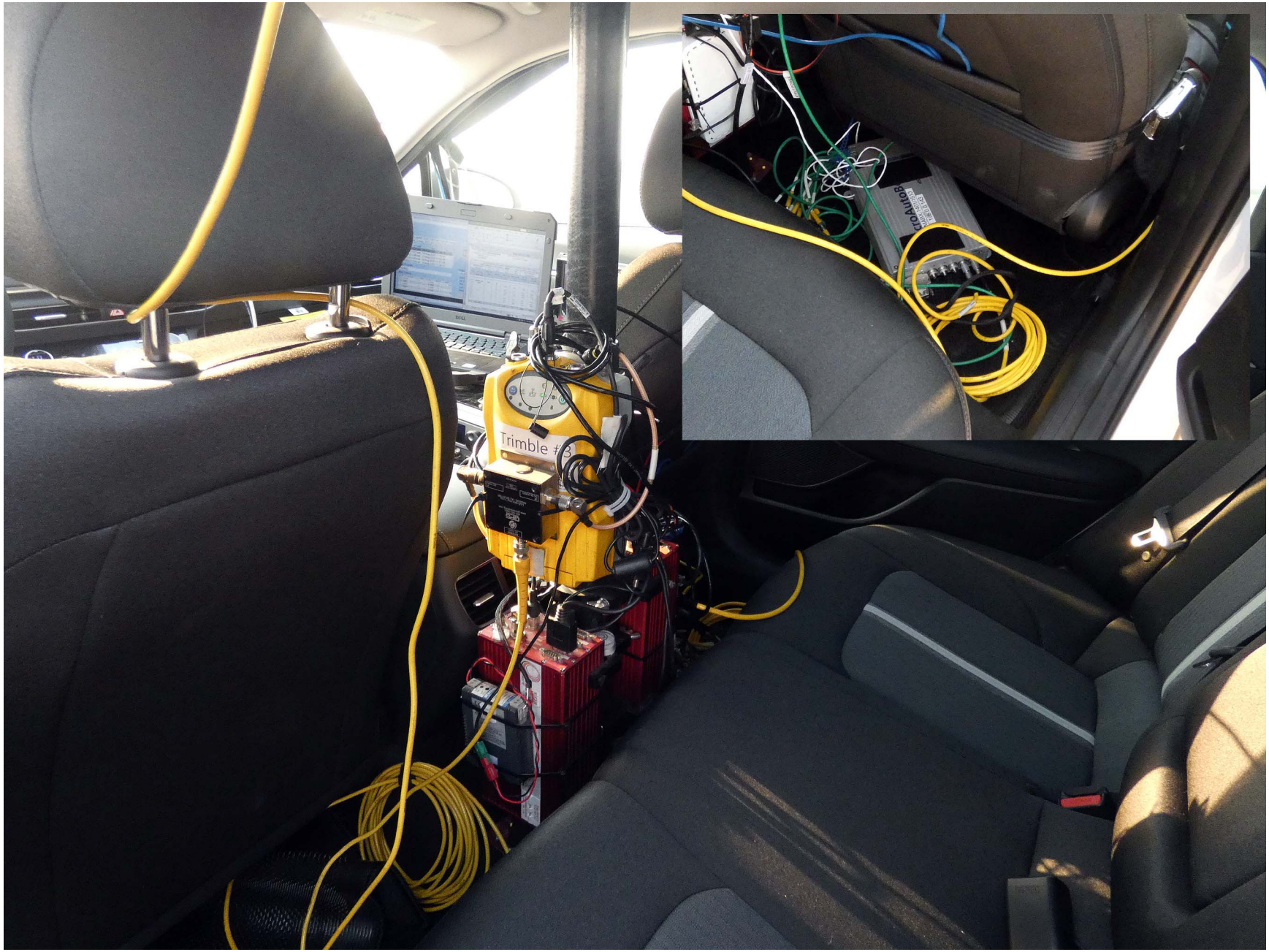


Figure A8. DGPS, Inertial Measurement Unit, and MicroAutoBox Installed in Subject Vehicle

Figure A9. Sensors for Detecting Visual Alerts

Figure A10. Sensors for Detecting Auditory Alerts

Figure A11. Computer Installed in Subject Vehicle

Figure A12. System Setup Menus (1 of 2)

Figure A13. System Setup Menus (2 of 2)

Figure A14. Controls for Interacting with System Menus

Figure A15. Visual Alert

APPENDIX B

Excerpts from Owner's Manual

Master Warning Light

This indicator light illuminates:

When there is a malfunction in operation in any of the following systems:

- Forward Collision-Avoidance Assist system malfunction (if equipped)
- Forward Collision-Avoidance Assist radar blocked (if equipped)
- Blind-Spot Collision Warning system malfunction (if equipped)
- Blind-Spot Collision Warning radar blocked (if equipped)
- High Beam Assist malfunction (if equipped)
- Lamp malfunction (if equipped)
- Smart Cruise Control malfunction (if equipped)
- Tire Pressure Monitoring System (TPMS) malfunction (if equipped)

To identify the details of the warning, look at the LCD display.

Low Tire Pressure Warning Light (if equipped)

This warning light illuminates:

- When you place the ignition in the ON position.
  - It illuminates for approximately 3 seconds and then goes off.
- When one or more of your tires are significantly underinflated. (The location of the underinflated tires is displayed on the LCD display.)

For more information, refer to "Tire Pressure Monitoring System (TPMS)" in chapter 7.

This warning light remains ON after blinking for approximately 60 seconds, or repeatedly blinks ON and OFF in 3 second intervals:

When there is a malfunction with the TPMS.

In this case, have the vehicle inspected by an authorized HYUNDAI dealer as soon as possible.

For more information, refer to "Tire Pressure Monitoring System (TPMS)" in chapter 7.

WARNING

Safe Stopping

- **The TPMS cannot alert you to severe and sudden tire damage caused by external factors.**
- **If you notice any vehicle instability, immediately take your foot off the accelerator pedal, apply the brakes gradually with light force, and slowly move to a safe position off the road.**

Electronic Stability Control (ESC) Indicator Light

This indicator light illuminates:

- When you place the ignition switch to the ON position.
  - The Electronic Stability Control indicator light illuminates for about 3 seconds and then goes off.
- Whenever there is a malfunction with the ESC system.

  If this occurs, have the vehicle inspected by an authorized HYUNDAI dealer.

This indicator light blinks:

While the ESC is operating.

For more information, refer to “Electronic Stability Control (ESC)” in chapter 6.

Master warning mode

OIK047173L

This warning light informs the driver the following situations.

- Forward Collision-Avoidance Assist system malfunction (if equipped)
- Forward Collision-Avoidance Assist radar blocked (if equipped)
- Blind-Spot Collision Warning system malfunction (if equipped)
- Blind-Spot Collision Warning radar blocked (if equipped)
- High Beam Assist malfunction (if equipped)
- Lamp malfunction (if equipped)
- Smart Cruise Control malfunction (if equipped)
- Tire Pressure Monitoring System (TPMS) malfunction (if equipped)

The Master Warning Light illuminates if one or more of the above warning situations occur. At this time, a Master Warning icon (⚠) will appear beside the User Settings icon (⚙), on the LCD display.

If the warning situation is solved, the master warning light will be turned off and the Master Warning icon will disappear.

User settings mode

OIK047148L

In this mode, you can change the settings of the instrument cluster, doors, lamps, etc.

1. Head-Up Display
2. Driver Assistance
3. Door
4. Lights
5. Sound
6. Convenience
7. Service interval
8. Other
9. Language
10. Reset

The information provided may differ depending on which functions are applicable to your vehicle.

2. Driver Assistance

Items	Explanation
Lane Safety	To adjust Lane Keeping Assist system function. • Lane Keeping Assist • Lane Departure Warning • Off **For more information, refer to the “Lane Keeping Assist (LKA)” in chapter 6.**
Blind-Spot Safety	• Blind-Spot View To activate or deactivate the Blind-Spot View. • Active assist • Warning only • Off **For more information, refer to “Blind-Spot Collision Warning (BCW)" or "Blind-Spot Collision-Avoidance Assist (BCA)” in chapter 6.**
Parking Safety	• Surround View Monitor Auto On • Parking Distance Warning Auto ON • Rear Cross-Traffic Safety To Activate or deactivate the Rear Cross-Traffic Collision-Avoidance Assist function. • Active Assist • Warning only • Off **For more information, refer to “Rear Cross-Traffic Collision-Avoidance Assist (RCCA) system” in chapter 6.**

2. Driver Assistance

Items	Explanation
Driving Assist	• Highway Driving Assist To activate or deactivate the Highway Driving Assist (HDA). **For more information, refer to the “Highway Driving Assist (HDA)" in chapter 6.** • Highway Auto Curve Slowdown To activate or deactivate the Highway Auto Curve Slowdown (NSCC). **For more information, refer to the Highway "Auto Curve Slowdown (NSCC)" in chapter 6.**
Warning Timing	To adjust the warning timing of the driver assistance system. • Normal / Late
Warning Volume	To adjust the warning volume of the driver assistance system. • High / Medium / Low
Driver Attention Warning	• Leading Vehicle Departure Alert To activate or deactivate the Leading vehicle departure alert. • Inattentive Driving Warning To activate or deactivate the Driver Attention Warning (DAW). **For more information, refer to the “Driver Attention Warning (DAW)” in chapter 6.**
Forward safety	To adjust the Forward Collision-Avoidance Assist function. • Active Assist • Warning only • Off **For more information, refer to the "Forward Collision-Avoidance Assist (FCA)" in chapter 6.**
Lane Safety	To adjust Lane Keeping Assist system function. • Lane Keeping Assist • Lane Departure Warning • Off **For more information, refer to the “Lane Keeping Assist (LKA)” in chapter 6.**
Blind-Spot Safety	• Blind-Spot View To activate or deactivate the Blind-Spot View. • Active assist • Warning only • Off **For more information, refer to "Blind-Spot Collision-Avoidance Assist (BCA)" in chapter 6.**
Parking Safety	• Parking Distance Warning Auto ON • Rear Cross-Traffic Safety To Activate or deactivate the Rear Cross-Traffic Collision-Avoidance Assist function. • Active Assist • Warning only • Off **For more information, refer to “Rear Cross-Traffic Collision-Avoidance Assist (RCCA) system” in chapter 6.**

HEAD UP DISPLAY (HUD) (IF EQUIPPED)

ODN8A059054

The Head-Up Display is an optional feature that allows the driver to view information projected onto a transparent screen while still keeping your eyes safely on the road ahead while driving.

Precautions while using the head up display

It may sometimes be difficult to read information on the head up display in the following situations.

- The driver is improperly positioned in the driver's seat.
- The driver wears polarizing-filter sunglasses.
- An object is located above the head up display cover.
- The vehicle is driven on a wet road.
- Any improper lighting accessory is installed inside the vehicle, or there is incoming light from outside of the vehicle.
- The driver wears glasses.
- The driver wears contact lenses.

When it is difficult to read the head up display information, adjust the head up display angle or the head up display brightness level in the User Settings mode. For more information, refer to "LCD Display" in this chapter.

WARNING

- **Do not tint the front windshield glass or add other types of metallic coating. Otherwise, the head up display image may be invisible.**
- **Do not place any accessories on the crash pad or attach any objects on the windshield glass.**
- **The Blind-spot Collision Warning system warnings on the head up display are supplemental. Do not solely depend on them to change lanes. Always take a look around before changing lanes.**

NOTICE

When replacing the front windshield glass of the vehicle equipped with the head up display, replace it with a windshield glass designed for the head up display operation. Otherwise, duplicated images may be displayed on the windshield glass.

Head-up display ON/OFF

OIK047152N

To activate the head up display, select 'Enable Head-Up Display' on the User Settings mode on the instrument cluster LCD display.

If you do not select 'Enable Head-Up Display', the head up display will be deactivated.

If your vehicle is equipped with additional navigation, please refer to the infotainment system manual separately supplied.

Head-up display information

1. Turn-by-turn (TBT) navigation information
2. Road information
3. Speedometer
4. Cruise system set speed
5. Smart Cruise Control information
6. Lane Following Assist system information
7. Lane Keeping Assist system information
8. Blind-spot Collision Warning system information
9. Highway Driving Assist system information

The information provided may differ depending on which functions are applicable to your vehicle.

Information

If you select the Turn By Turn (TBT) navigation information as Head-Up Display contents, the Turn By Turn (TBT) navigation information will not be displayed in the instrument cluster LCD display.

Head-up display setting

On the LCD display, you can change the head up display settings as follows.

- Enable Head-up display
- Display Height
- Rotation
- Brightness
- Content Selection
- Speed Size
- Speed Color

For more information, refer to “LCD Display” in chapter 4. If your vehicle is equipped with additional navigation, please refer to the infotainment system manual separately supplied.

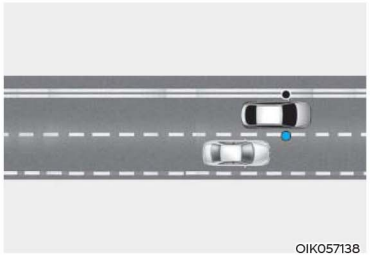
BLIND-SPOT COLLISION WARNING (BCW) / BLIND-SPOT COLLISION-AVOIDANCE ASSIST (BCA) (IF EQUIPPED)

System Description

Blind-Spot Collision Warning

Blind-Spot Collision Warning system uses rear corner radar sensors to monitor and warn the driver of an approaching vehicle in the driver's blind spot area.

(1) Blind-spot vehicle warning

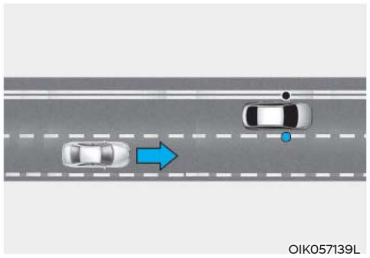


BCW system detects and warns vehicles in blind-spot.

The blind spot detection range varies relative to vehicle speed.

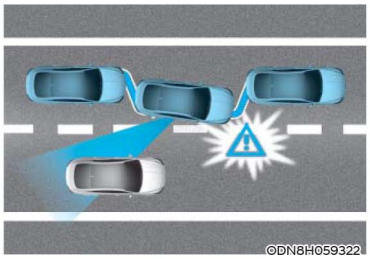
Note that if your vehicle is traveling much faster than the vehicles around you, the warning will not occur.

(2) Fast approach vehicle warning



BCW system will alert you when a vehicle is detected approaching in an adjacent lane at a high rate of speed. If the driver activates the turn signal when the system detects an oncoming vehicle, the system sounds an audible alert.

Blind-Spot Collision-Avoidance Assist



Blind-Spot Collision-Avoidance Assist system detects the front lane through the front view camera installed on the upper front windshield and detects the side/ rear areas through rear corner radars.

Blind-Spot Collision-Avoidance Assist system may activate the Electronic Stability Control (ESC) in accordance with a colliding possibility with an approaching vehicle while changing lanes. It is to lower the colliding risk or help mitigate the colliding damage.

WARNING

- **Always be aware of road conditions while driving and be alert for unexpected situations even though the Blind-Spot Collision Warning system and Blind-Spot Collision-Avoidance Assist system are operating.**
- **Blind-Spot Collision Warning system and Blind-Spot Collision-Avoidance Assist system are supplemental systems to assist you. Always pay attention, while driving, for your safety. Do not entirely rely on the systems or an accident may occur.**
- **Blind-Spot Collision Warning system and Blind-Spot Collision-Avoidance Assist system are not substitutes for proper and safe driving. Always drive safely and use caution when changing lanes or backing up the vehicle.**

  Blind-Spot Collision Warning system and Blind-Spot Collision-Avoidance Assist system may not detect every object alongside the vehicle.

System Setting and Activation

System setting

- The driver can activate the system by placing the ignition switch to the ON position and by selecting 'User Settings → Driver Assistance → Blind-Spot Safety'
  - BCA and BCW turn on and get ready to be activated when 'Active assist' is selected. Then, if a vehicle approaches the driver's blind spot area a warning sounds or braking power is applied.
  - BCW turns on and gets ready to be activated when 'Warning only' is selected. Then, if a vehicle approaches the driver's blind spot area a warning sounds. Braking assist will not be applied in this setting.
  - If you select "Off", BCW system deactivates.
- If the engine is turned off then on again, the system maintains the previous state.
- The driver can select the initial warning activation time in the User Settings in the LCD display or infotainment system display by selecting 'User Settings → Driver Assistance → Warning Timing'.

- The options for the initial Blind-Spot Collision Warning includes the following:
  - Normal:

    When this condition is selected, the initial Blind-Spot Collision Warning is activated normally. If this setting feels sensitive change the option to 'Later'.

    The warning activation time may feel late if a vehicle at the side or rear abruptly accelerates.
  - Later:

    Select this warning activation time when the traffic is light and you are driving in a low speed.

Information

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

- The driver can select the warning volume of Blind-Spot Collision Warning in the User Settings in the LCD display or infotainment system display by selecting 'User Settings → Driver Assistance → Warning Volume → High/Medium/Low'.

Information

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

Operating Conditions

The system enters the ready status, when 'Active Assist' or 'Warning Only' is selected and the following conditions are satisfied:

- Active Assist

(1) Blind-Spot Collision-Avoidance Assist system will activate when:
  - Vehicle speed is between 40 mph and 112 mph (60 km/h and 180 km/h).
  - The system detects both of the lane lines.
  - An approaching vehicle is detected next to or behind your vehicle.

(2) Blind-Spot Collision Warning system will activate when:

The vehicle speed is above about 20 mph (30 km/h).

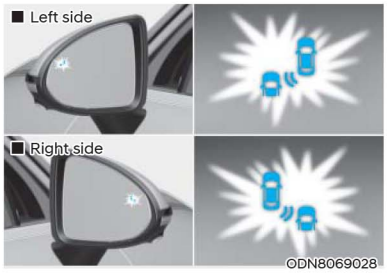
- Warning Only

(1) Blind-Spot Collision Warning system will activate when:
  - The vehicle speed is above 20 mph (30 km/h).

※ Blind-Spot Collision-Avoidance Assist system is not activated.

Warning and System Control

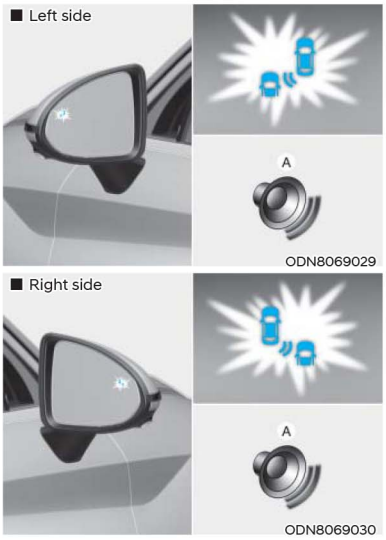
Blind-Spot Collision Warning



First stage alert

If a vehicle is detected within the boundary of the system, a warning light will illuminate on the side view mirror and the head up display (if equipped).

Once the detected vehicle is no longer within the blind spot area, the warning will turn off according to the driving conditions of the vehicle.



[A] : Warning sound

Second stage alert

A warning chime to alert the driver will activate when:

1. A vehicle has been detected in the blind spot area by the radar system AND.
2. The turn signal is applied (same side as where the vehicle is being detected).

When this alert is activated, the warning light on the side view mirror and the head up display (if equipped) will also blink. And a warning chime will sound.

If you turn off the turn signal indicator, the second stage alert will be deactivated.

Once the detected vehicle is no longer within the blind spot area, the warning will turn off according to the driving conditions of the vehicle.

WARNING

- **The warning light on the side view mirror will illuminate whenever a vehicle is detected at the rear side by the system.**

  To avoid accidents, do not focus only on the warning light and neglect to see the surrounding of the vehicle.
- **Drive safely even though the vehicle is equipped with Blind-Spot Collision-Avoidance Assist system. Do not solely rely on the system but check your surrounding before changing lanes or backing the vehicle up.**
- **The system may not alert the driver in some conditions so always check your surroundings while driving.**

CAUTION

- **The driver should always use extreme caution while operating the vehicle, whether or not the warning light on the side view mirror illuminates or there is a warning alarm.**
- **Playing the vehicle audio system at high volume may offset the Blind-Spot Collision Warning system warning sounds.**
- **The warning of Blind-Spot Collision-Avoidance Assist system may not sound while other system's warning sounds.**

Blind-Spot Collision-Avoidance Assist

Blind-Spot Collision-Avoidance Assist system may apply braking power, when an approaching vehicle is detected within a certain distance next to or behind your vehicle.

It gently applies braking power on the tire, which is located in the opposite side of the possibly-colliding point. The instrument cluster will inform the driver of the system activation.

Blind-Spot Collision-Avoidance Assist system is automatically deactivated when:

- The vehicle drives a certain distance away
- The vehicle direction is changed against the possible-colliding point
- The steering wheel is abruptly moved
- The brake pedal is depressed
- After a certain period of time

The driver should drive the vehicle in the middle of the vehicle lanes to keep the system in the ready status.

When the vehicle drives too close to one side of the vehicle lanes, the system may not properly operate.

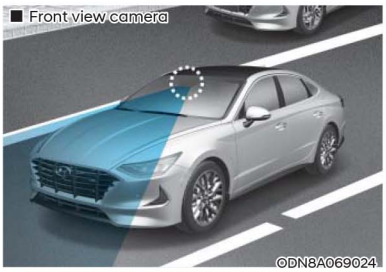
In addition, the system may not properly control your vehicle in accordance with driving situations. Thus, always pay close attention to road situations.

WARNING

- **The driver is responsible for accurate steering.**
- **Do not unnecessarily operate the steering wheel, when Blind-Spot Collision-Avoidance Assist system is in operation.**
- **Always pay extreme caution while driving. The Blind-Spot Collision-Avoidance Assist system may not operate or unnecessarily operate in accordance with your driving situations.**
- **Blind-Spot Collision-Avoidance Assist system is not a substitute for safe driving practices, but a convenience function only. It is the responsibility of the driver to always drive cautiously to prevent unexpected and sudden situations from occurring. Pay attention to the road conditions at all times.**

Detecting Sensors (Front view camera and Rear corner radar)

■ Front view camera



ODN8A069024

■ Rear corner radars

ODN8069031L

Front view camera

The front view camera is a sensor detecting the lane. If the sensors are covered with snow, rain or foreign substance, the system may temporarily be cancelled and not work properly until the system is cancelled due to the degradation of the sensor's detection performance. Always keep the sensor clean.

※ Refer to Lane Keeping Assist (LKA) for cautions for the front view camera.

Rear corner radar

The rear corner radars are the sensors inside the rear bumper for detecting the side and rear areas. Always keep the rear bumper clean for proper operation of the system.

CAUTION

- **The system may not work properly when the bumper has been damaged, or if the rear bumper has been replaced or repaired.**
- **The sensing range differs somewhat according to the width of the road. When the road is narrow, the system may detect other vehicles in the next lane. On the other hand, when the road is wide, the system may not detect vehicles on both lanes and may not warn.**
- **The system may turn off due to strong electromagnetic waves.**
- **Always keep the sensors clean.**
- **NEVER arbitrarily disassemble the sensor component nor apply any impact on the sensor component.**
- **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 system may not operate correctly. In this case, a warning message may not be displayed. Have the vehicle inspected by an authorized HYUNDAI dealer.**
- **Do not apply foreign objects such as a bumper sticker or a bumper guard near the radar sensor or apply paint to the sensor area. Doing so may adversely affect the performance of the sensor.**
- **NEVER install any accessories or stickers on the front windshield, nor tint the front windshield.**
- **Pay extreme caution to keep the front view camera out of water.**
- **NEVER locate any reflective objects (i.e. white paper, mirror) over the crash pad. Any light reflection may cause a malfunction of the system.**

Warning message

OIK057092L

Blind-Spot Collision Warning (BCW) system disabled.
Radar blocked

This warning message may appear when:

- One or both of the sensors on the rear bumper is blocked by dirt or snow or a foreign object.
- Driving in rural areas where the sensor does not detect another vehicle for an extended period of time.
- When there is inclement weather such as heavy snow or rain.
- A trailer or carrier or another object is installed around the rear view radars.

If any of these conditions occur, the system will turn off automatically.

When BCW canceled warning message is displayed in the cluster, check to make sure that the rear bumper is free from any dirt or snow in the areas where the sensors are located. Remove any dirt, snow, or foreign material that could interfere with the radar sensors.

After any dirt or debris is removed, the system should operate normally after about 10 minutes of driving the vehicle.

If the system still does not operate normally have your vehicle inspected by an authorized HYUNDAI dealer.

Information

Turn off BCW, BCA and RCCW, RCCA system (if equipped) when a trailer or carrier is installed.

- **Deactivate BCW, BCA system by deselecting `User Settings → Driver Assistance → Blind-Spot Safety → Off'**
- **Deactivate RCCW, RCCA system by deselecting 'User Settings → Driver Assistance → Parking Safety → Rear Cross-Traffic Safety'**

■ Type A

OAD058169L

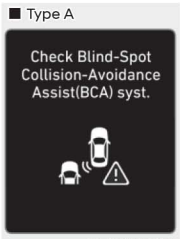
■ Type B

OTM058151L

Check Blind-Spot Collision Warning (BCW) system

If there is a problem with BCW system, a warning message will appear. The system will turn off automatically. BCA will not operate also if BCW system turns off due to malfunction. Have the vehicle inspected by an authorized HYUNDAI dealer.

■ Type A



OTM058087L

■ Type B

ODN8059289L

Check Blind-Spot Collision-Avoidance Assist (BCA) system

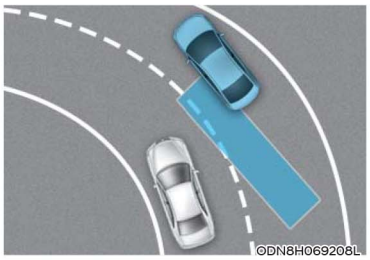
If there is a problem with BCA system, a warning message will appear. The system will turn off automatically. BCW will still operate even if BCA system turns off due to malfunction. Have the vehicle inspected by an authorized HYUNDAI dealer.

Limitations of the System

The driver must be cautious in the below situations, because the system may not detect other vehicles or objects in certain circumstances.

- The system may not work around 15 seconds after starting the vehicle or the initialization or rebooting of the front view camera.
- When a trailer or carrier is installed.
- The vehicle drives in inclement weather such as heavy rain or snow.
- The sensors are polluted with rain, snow, mud, etc.
- The rear bumper where the sensors are located is covered with a foreign object such as a bumper sticker, a bumper guard, a bike rack, etc.
- The rear bumper is damaged, or the sensor is out of the original default position.
- The vehicle height gets lower or higher due to heavy loading in a trunk, abnormal tire pressure, etc.
- When the temperature of the rear bumper is high.
- When the sensors are blocked by other vehicles, walls or parking-lot pillars.
- The vehicle drives on a curved road.
- The vehicle drives through a tollgate.
- The road pavement (or the peripheral ground) abnormally contains metallic components (i.e. possibly due to subway construction).
- There is a fixed object near the vehicle, such as a guardrail.

- While going down or up a steep road where the height of the lane is different.
- Driving on a narrow road where trees or grass or overgrown.
- Driving in rural areas where the sensor does not detect another vehicle or structure for an extended period of time.
- Driving on a wet road.
- Driving on a road where the guardrail or wall is in double structure.
- A big vehicle is near such as a bus or truck.
- When the other vehicle approaches very close.
- When the other vehicle passes at a very fast speed.
- While changing lanes.
- If the vehicle has started at the same time as the vehicle next to you and has accelerated.
- When the vehicle in the next lane moves two lanes away from you OR when the vehicle two lanes away moves to the next lane from you.
- A motorcycle or bicycle is near.
- A flat trailer is near.
- If there are small objects in the detecting area such as a shopping cart or a baby stroller.
- If there is a low height vehicle such as a sports car.
- The brake pedal is depressed.
- ESC (Electronic Stability Control) is activated.
- ESC (Electronic Stability Control) malfunctions.
- The tire pressure is low or a tire is damaged.
- The brake is reworked.
- The vehicle abruptly changes driving direction.
- The vehicle makes sharp lane changes.
- The vehicle sharply stops.
- Temperature is extremely low around the vehicle.
- The vehicle severely vibrates while driving over a bumpy road, uneven/ bumpy road, or concrete patch.
- The vehicle drives on a slippery surface due to snow, water puddle, or ice.
- Lane Keeping Assist does not operate normally. (if equipped)
- For more information, refer to “Lane Keeping Assist (LKA)” in this chapter.



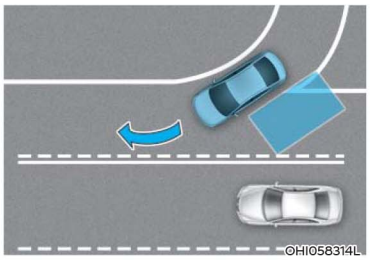
- Driving on a curve

  BCW and BCA systems may not operate properly when driving on a curved road. In certain instances, the system may not detect the vehicle in the next lane.

  Always pay attention to road and driving conditions, while driving.

BCW and BCA systems may not operate properly when driving on a curved road. In certain instances, the system may recognize a vehicle in the same lane.

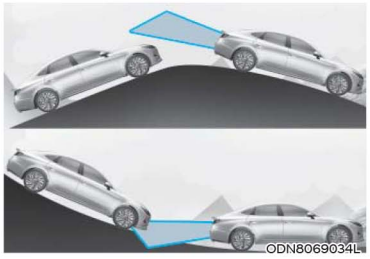
Always pay attention to road and driving conditions, while driving.



- Driving where the road is merging/ dividing

  BCW and BCA systems may not operate properly when driving where the road is merging/dividing. In certain instances, the system may not detect the vehicle in the next lane.

  Always pay attention to road and driving conditions, while driving.

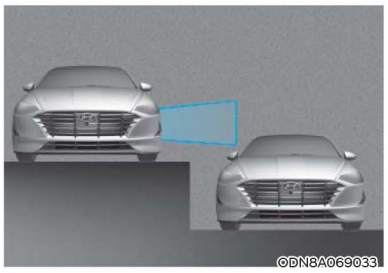


- Driving on a slope

  BCW and BCA systems may not operate properly when driving on a slope. In certain instances the system may not detect the vehicle in the next lane.

  Also, in certain instances, the system may wrongly recognize the ground or structures.

  Always pay attention to road and driving conditions, while driving.

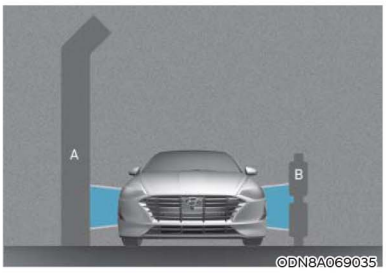


- Driving where the heights of the lanes are different

  BCW and BCA systems may not operate properly when driving where the heights of the lanes are different.

  In certain instances, the system may not detect the vehicle on a road with different lane heights (i.e. underpass joining section, grade separated intersections, etc.).

  Always pay attention to road and driving conditions, while driving.



[A] : Noise barrier, [B] : Guardrail

- Driving where there is a structure beside the road

  BCW and BCA systems may not operate properly when driving where there is structure beside the road.

  In certain instances, the system may wrongly recognize the structures (i.e. noise barriers, guardrail, double guardrail, median strip, bollard, street light, road sign, tunnel wall, etc.) beside the road.

  Always pay attention to road and driving conditions, while driving.

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.**

Detecting Sensors

The rear corner radars are the sensors inside the rear bumper for detecting the side and rear areas. Always keep the rear bumper clean for proper operation of the system.

CAUTION

- **The system may not work properly when the bumper has been damaged, or if the rear bumper has been replaced or repaired.**
- **The system may turn off due to strong electromagnetic waves.**
- **Always keep the sensors clean.**
- **NEVER arbitrarily disassemble the sensor component nor apply any impact on the sensor component.**
- **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 system may not operate correctly. In this case, a warning message may not be displayed. Have the vehicle inspected by an authorized HYUNDAI dealer.**
- **Do not apply foreign objects such as a bumper sticker or a bumper guard near the radar sensor or apply paint to the sensor area. Doing so may adversely affect the performance of the sensor.**

Warning message

Blind-Spot Collision Warning (BCW) system disabled. Radar blocked

This warning message may appear when:

One or both of the sensors on the rear bumper is blocked by dirt or snow or a foreign object.

Driving in rural areas where the sensor does not detect another vehicle for an extended period of time.

When there is inclement weather such as heavy snow or rain.

If any of these conditions occur, the system will turn off automatically.

When BCW canceled warning message is displayed in the cluster, check to make sure that the rear bumper is free from any dirt or snow in the areas where the sensor is located. Remove any dirt, snow, or foreign material that could interfere with the radar sensors.

After any dirt or debris is removed, the system should operate normally after about 10 minutes of driving the vehicle.

If the system still does not operate normally have your vehicle inspected by an authorized HYUNDAI dealer.

Information

Turn off BCW, BCA and RCCA system when a trailer or carrier is installed.

Deactivate BCW and BCA system by selecting "User Settings → Driver Assistance → Blind-Spot Safety → Off"

Deactivate RCCW and RCCA system by deselecting "User Settings → Driver Assistance → Parking Safety → Rear Cross-Traffic Safety".

■ Type A

OAD058169L

■ Type B

OTM058151L

Check Blind-Spot Collision Warning (BCW) system

If there is a problem with BCW system, a warning message will appear. The system will turn off automatically. RCCW and RCCA will not operate also if BCW system turns off due to malfunction. Have the vehicle inspected by an authorized HYUNDAI dealer.

Limitations of the System

The driver must be cautious in the below situations, because the system may not detect other vehicles or objects in certain circumstances.

- When a trailer or carrier is installed.
- The vehicle drives in inclement weather such as heavy rain or snow.
- The radar sensor is polluted with rain, snow, mud, etc.
- The rear bumper where the radar sensors are located is covered with a foreign object such as a bumper sticker, a bumper guard, a bike rack, etc.
- The rear bumper is damaged, or the sensor is out of the original default position.

APPENDIX C

Run Log

Subject Vehicle: **2020 Hyundai Sonata SEL** Date: 8/18/2020

Test Engineer: S. Judy

Run	Test Type	BSD Side (L/R)	Valid Run?	BSD On (ft)	BSD Off (ft)	Acceptability Criteria met[2]			Notes
						BSD On	BSD Off	Overall	
1	**Static Run**								
40	**Converge/ Diverge**	**Right**	Static						
41			N						Headway, lateral speed
42			N						Yaw, lateral speed
43			N						POV speed, yaw, lateral speed
44			N						Yaw, lateral speed
45			N						Ran out of track
46			N						Lateral speed
47			N						Lateral speed
48			N						Yaw, lateral speed
49			N						Ran out of track
50			Y	-0.8	6.3	No	Yes	No	
51			Y	-0.4	6.5	No	Yes	No	
52			Y	-4.9	6.9	No	Yes	No	
53			N						Lateral speed
54			N						POV speed, yaw, lateral speed

[2] The acceptability criteria listed herein are used only as a guide to gauge system performance, and are identical to the Pass/Fail criteria given in NHTSA's most current Test Procedure in docket NHTSA-2019-0102-0010, BLIND SPOT DETECTION SYSTEM CONFIRMATION TEST.

Run	Test Type	BSD Side (L/R)	Valid Run?	BSD On (ft)	BSD Off (ft)	Acceptability Criteria met[2]			Notes
						BSD On	BSD Off	Overall	
55	Converge/ Diverge	Right	N						POV speed, yaw
56			Y	-0.3	6.0	No	Yes	No	
57			Y	-0.4	6.2	No	Yes	No	
58			Y	-0.4	6.4	No	Yes	No	
59			Y	-0.5	5.7	No	Yes	No	
60	Converge/ Diverge	Left	N						Yaw, lateral speed
61			N						Ran out of track
62			N						Ran out of track
63			N						Yaw
64			N						Lateral speed
65			N						Yaw, lateral speed
66			N						Yaw, lateral speed, lateral distance
67			N						Yaw, lateral speed, lateral distance
68			N						Lateral speed
69			N						Ran out of track
70			N						POV speed
71			N						Lateral speed
72			N						Yaw, lateral speed
73			N						POV speed, lateral speed
74			N						Lateral speed
75			Y	1.1	6.5	Yes	Yes	Yes	

Run	Test Type	BSD Side (L/R)	Valid Run?	BSD On (ft)	BSD Off (ft)	Acceptability Criteria met[2]			Notes
						BSD On	BSD Off	Overall	
76	Converge/ Diverge	Left	Y	0.5	6.2	Yes	Yes	Yes	
77			Y	1.0	6.1	Yes	Yes	Yes	
78			Y	0.5	5.0	Yes	Yes	Yes	
79			N						Ran out of track
80			Y	-3.0	4.6	No	Yes	No	
81			N						Lateral speed
82			Y	-3.5	5.6	No	Yes	No	
83			N						Yaw
84			N						Lateral speed
85			N						Lateral speed
86			N						Yaw, lateral speed
87			N						Lateral speed
88			N						POV speed, yaw, lateral speed
89			N		`				Ran out of track
90			N						Yaw
91			N						Lateral speed
92			N						Yaw, lateral speed
93			N						Yaw
94			N						Yaw
95			Y	-3.4	5.6	No	Yes	No	

Run	Test Type	BSD Side (L/R)	Valid Run?	BSD On (ft)	BSD Off (ft)	Acceptability Criteria met[2]			Notes
						BSD On	BSD Off	Overall	
2	Straight Lane 45/50	Right	N						Light sensor problem
3			N						Light sensor problem
4			N						Light sensor problem
5			Y	14.8	15.9	Yes	Yes	Yes	
6			Y	13.5	15.4	Yes	Yes	Yes	
7			N						SV speed
8			Y	11.6	16.5	Yes	Yes	Yes	
9			N						Lateral distance
10			Y	13.7	16.2	Yes	Yes	Yes	
11			Y	17.1	15.8	Yes	Yes	Yes	
12			Y	19.6	16.6	Yes	Yes	Yes	
96	Straight Lane 45/50	Left	N						Lateral distance
97			Y	16.6	17.0	Yes	Yes	Yes	
98			Y	12.8	16.1	Yes	Yes	Yes	
99			N						POV speed
100			Y	15.8	12.6	Yes	Yes	Yes	
101			Y	15.6	15.9	Yes	Yes	Yes	
102			Y	15.7	17.7	Yes	Yes	Yes	
103			Y	11.4	17.2	Yes	Yes	Yes	
104			Y	13.6	17.5	Yes	Yes	Yes	

Run	Test Type	BSD Side (L/R)	Valid Run?	BSD On (ft)	BSD Off (ft)	Acceptability Criteria met[2]			Notes
						BSD On	BSD Off	Overall	
13	Straight Lane 45/55	Right	Y	34.0	20.6	Yes	Yes	Yes	
14			Y	30.3	18.9	Yes	Yes	Yes	
15			Y	31.4	19.8	Yes	Yes	Yes	
16			Y	35.5	21.0	Yes	Yes	Yes	
17			N						POV speed
18			Y	29.9	19.9	Yes	Yes	Yes	
19			Y	29.9	20.2	Yes	Yes	Yes	
20			Y	33.5	19.7	Yes	Yes	Yes	
21			Y	27.5	19.7	Yes	Yes	Yes	
105	Straight Lane 45/55	Left	Y	30.0	20.0	Yes	Yes	Yes	
106			Y	30.9	20.2	Yes	Yes	Yes	
107			Y	27.5	20.4	Yes	Yes	Yes	
108			Y	27.7	21.2	Yes	Yes	Yes	
109			Y	28.7	21.0	Yes	Yes	Yes	
110			Y	30.2	21.8	Yes	Yes	Yes	
111			Y	32.5	21.2	Yes	Yes	Yes	
22	Straight Lane 45/60	Right	Y	45.4	25.3	Yes	Yes	Yes	
23			Y	48.6	25.2	Yes	Yes	Yes	
24			Y	42.6	14.1	Yes	Yes	Yes	
25			Y	46.7	26.4	Yes	Yes	Yes	
26			Y	47.3	24.8	Yes	Yes	Yes	

Run	Test Type	BSD Side (L/R)	Valid Run?	BSD On (ft)	BSD Off (ft)	Acceptability Criteria met[2]			Notes
						BSD On	BSD Off	Overall	
27	**Straight Lane 45/60**	**Right**	Y	47.0	24.0	Yes	Yes	Yes	
28			Y	48.0	24.2	Yes	Yes	Yes	
29			Y	49.5	24.0	Yes	Yes	Yes	
112	**Straight Lane 45/60**	**Left**	Y	48.8	25.5	Yes	Yes	Yes	
113			Y	46.7	27.5	Yes	Yes	Yes	
114			Y	48.9	25.6	Yes	Yes	Yes	
115			Y	47.4	28.7	Yes	Yes	Yes	
116			Y	45.2	25.0	Yes	Yes	Yes	
117			Y	47.3	18.5	Yes	Yes	Yes	
118			Y	49.8	25.3	Yes	Yes	Yes	
30	**Straight Lane 45/65**	**Right**	Y	68.8	36.0	Yes	Yes	Yes	
31			Y	67.1	44.8	Yes	Yes	Yes	
32			N						POV speed
33			N						POV speed
34			Y	59.7	24.4	Yes	Yes	Yes	
35			N						POV speed
36			N						POV speed
37			Y	65.6	25.5	Yes	Yes	Yes	
38			Y	65.3	24.0	Yes	Yes	Yes	
39			Y	68.5	25.6	Yes	Yes	Yes	

Run	Test Type	BSD Side (L/R)	Valid Run?	BSD On (ft)	BSD Off (ft)	Acceptability Criteria met[2]			Notes
						BSD On	BSD Off	Overall	
119	Straight Lane 45/65	Left	Y	52.7	39.0	Yes	Yes	Yes	
120			Y	63.9	40.8	Yes	Yes	Yes	
121			N						Lateral distance
122			Y	56.7	17.1	Yes	Yes	Yes	
123			Y	70.2	29.7	Yes	Yes	Yes	
124			Y	60.7	33.9	Yes	Yes	Yes	
125			N						POV speed, lateral distance
126			Y	62.2	36.7	Yes	Yes	Yes	
127			Y	61.9	27.3	Yes	Yes	Yes	
128			Y	65.8	47.1	Yes	Yes	Yes	

APPENDIX D

Time History Plots

LIST OF FIGURES

Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from both the Subject Vehicle (SV) and Principal Other Vehicle (POV) with overlaid pass/fail and validity envelopes and thresholds.

Several of the plots include green envelopes (boxes) that are provided to verify test validity. For plots with green envelopes, the test is valid if the time-varying data is completely within the envelope boundaries.

Plots shown herein are grouped by test type and are presented sequentially within a given test type. Each time history plot consists of data relevant to the test type under consideration, and therefore the data channels plotted vary according to test type. The test types (shown in the plot titles) include:

- Straight Lane Converge/Diverge
- Straight Lane Pass-by (SV at 45 mph, POV at 50 mph)
- Straight Lane Pass-by (SV at 45 mph, POV at 55 mph)
- Straight Lane Pass-by (SV at 45 mph, POV at 60 mph)
- Straight Lane Pass-by (SV at 45 mph, POV at 65 mph)

Sub-plots

Time history figures include the following sub-plots:

- BSD Warning – displays the Blind Spot Detection alert (which can be audible, visual, or haptic). Depending on the type of BSD 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 (i.e., haptic alert, such as steering wheel vibration). The vertical scale is 0 to 1.
    - Normalized light sensor signal. The vertical scale is 0 to 1.

    The magenta envelopes indicate pass/fail criteria. For a test to meet the BSD-on criterion, the trace must be greater than a threshold of 0.5 and completely within the first envelope. The envelope begins 300 ms after the POV enters the SV Blind Zone and ends when the POV is no longer in the SV Blind Zone for

Converge/Diverge tests and when the front-most part of the POV is in front of line A[1] for Straight Lane Pass-by test.

For a test to meet the BSD-off criterion, the trace must be less than a threshold of 0.5 and completely within the second envelope. The envelope begins when the lateral distance between the POV and SV is greater than 6 m (19.7 ft) for Converge/Diverge Tests and when the longitudinal distance between the rear-most part of the POV and the front-most part of the SV exceeds the BSD termination headway specified in Table 4 of the test procedure. The envelope ends at the end of the test.

The bold black vertical lines indicate BSD-on and BSD-off. The value shown for BSD-on represents the distance[2] between the POV and 300 ms into SV's Blind Zone. A negative value means the BSD warning activated after 300 ms of the POV entering the SV's blind zone and the warning was late. The value shown for BSD-off for Converge/Diverge tests represents the lateral distance between the POV and SV relative to the 6 m (19.7 ft) BSD-off requirement. The value shown for BSD-off for Pass-by tests represents the longitudinal distance between the POV and SV relative to the BSD termination headway for a given test speed. A negative value means the BSD warning deactivated after the lateral distance between the POV and SV was greater than 6 m (19.7 ft) for Converge/Diverge tests or the longitudinal distance between the POV and SB was greater than the BSD termination headway for Pass-by tests and the warning was late.

- Headway (ft) – for Converge/Diverge tests, this is the longitudinal distance from the front of the POV to the rear of the SV. A negative value for headway indicates that the front of the POV is forward relative to the rear of the SV. For Straight Lane Pass-by tests, two headway traces are shown. The distance from the front of the POV to the rear of the SV is shown in *black* and the distance from the front of the SV to the rear of the POV is shown in *green*. Additionally, there are colored markers with values to indicate critical events.
    - Yellow Marker – BSD warning activates
    - Black Marker – POV enters the SV Blind Zone
    - Cyan Marker – 300 ms after the POV enters the SV Blind Zone
    - Red Marker – POV exits the SV Blind Zone
    - Green Marker – BSD warning deactivates
    - Blue Marker – BSD termination headway

[1] Line A is defined as the line that connects the rearmost part of the SV side mirror housings and runs perpendicular to the SV's longitudinal centerline
[2] Lateral distance for Converge and Diverge Scenarios and longitudinal distance for Pass-by Scenarios

- SV Speed (mph) – speed of the SV.
- POV Speed (mph) – speed of the POV.
- Yaw Rate (deg/sec) – yaw rate of the SV and POV. Overlapping validity envelopes are shown for the Converge/Diverge tests. The darker green indicates the validity envelope for the POV.
- Lateral Distance (ft) – lateral distance from the widest point (not including side mirrors) on the side of the SV to the widest point (not including side mirrors) on the side of the POV.
- Lateral Velocity (ft/s) – lateral velocity of the POV for Converge/Diverge tests only. Bold vertical black lines are provided to indicate the allowable lateral velocity range. A green dot indicates a valid value.

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. Pass/Fail envelopes, validation envelopes and thresholds
3. Individual data points
4. Text

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

2. Pass/Fail envelopes, validation envelopes and threshold color codes:
   - Magenta envelope = time varying data must be within the envelope at all times for a passing run
   - Green envelope = time varying data must be within the envelope at all times in order to be valid

- Black threshold (Solid) = time varying data must cross this threshold in the time period shown in order to be valid

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

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

Other Notations

- No Wng – No warning was detected.
- On Late – Indicates that the BSD warning activated after the allowable criteria.
- Off Early – Indicates that the BSD warning deactivated before the allowable criteria.
- Off Late – Indicates that the BSD warning deactivated after the allowable criteria.
- 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.

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 the Straight Lane Converge/Diverge and Straight Lane Pass-by are shown in Figures D1 through D4. These show examples of passing and failing runs for both test types. Time history data plots for the tests of the vehicle under consideration herein are provided beginning with Figure D5.

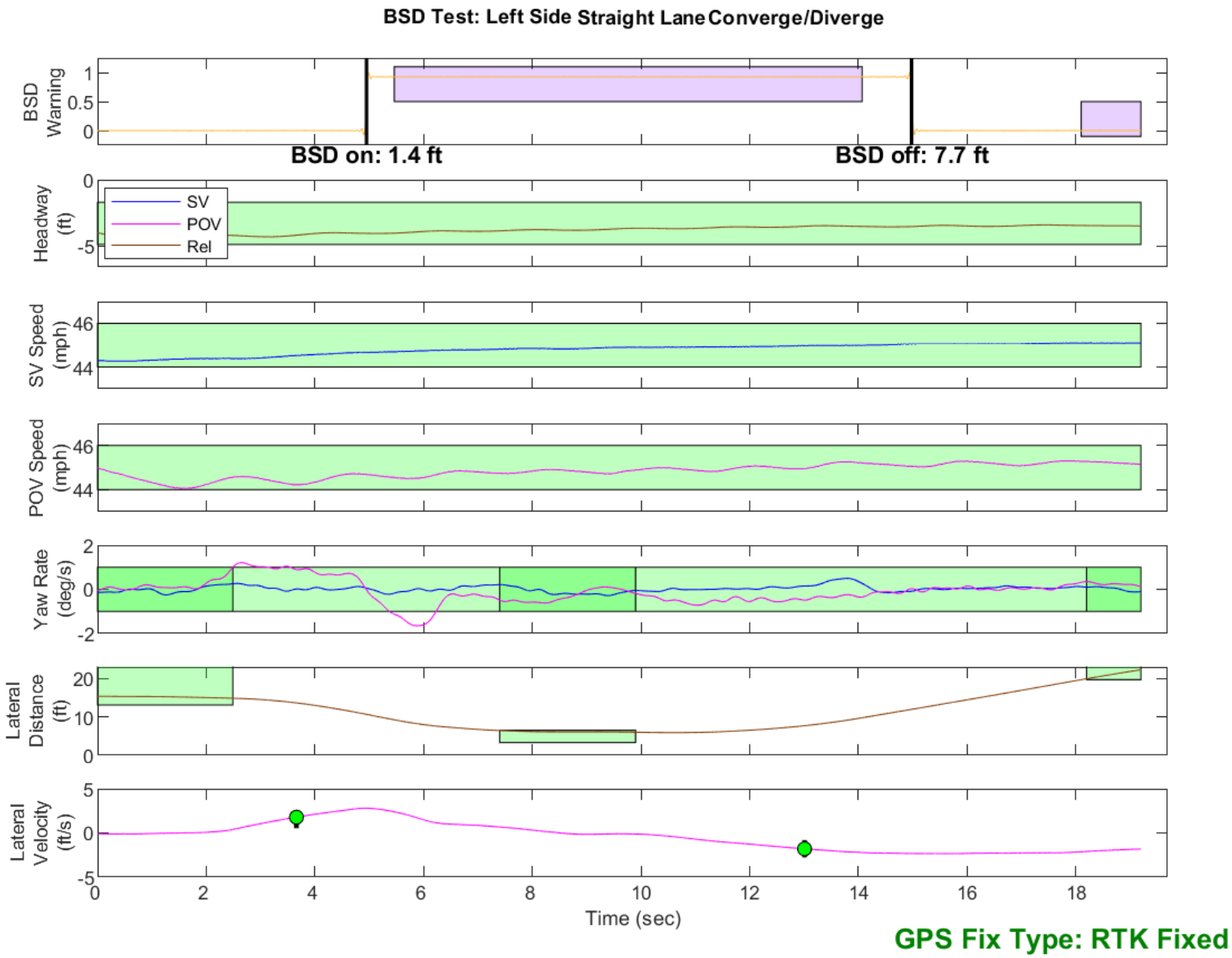


Figure D1. Example Time History for Straight Lane Converge/Diverge Test, Passing

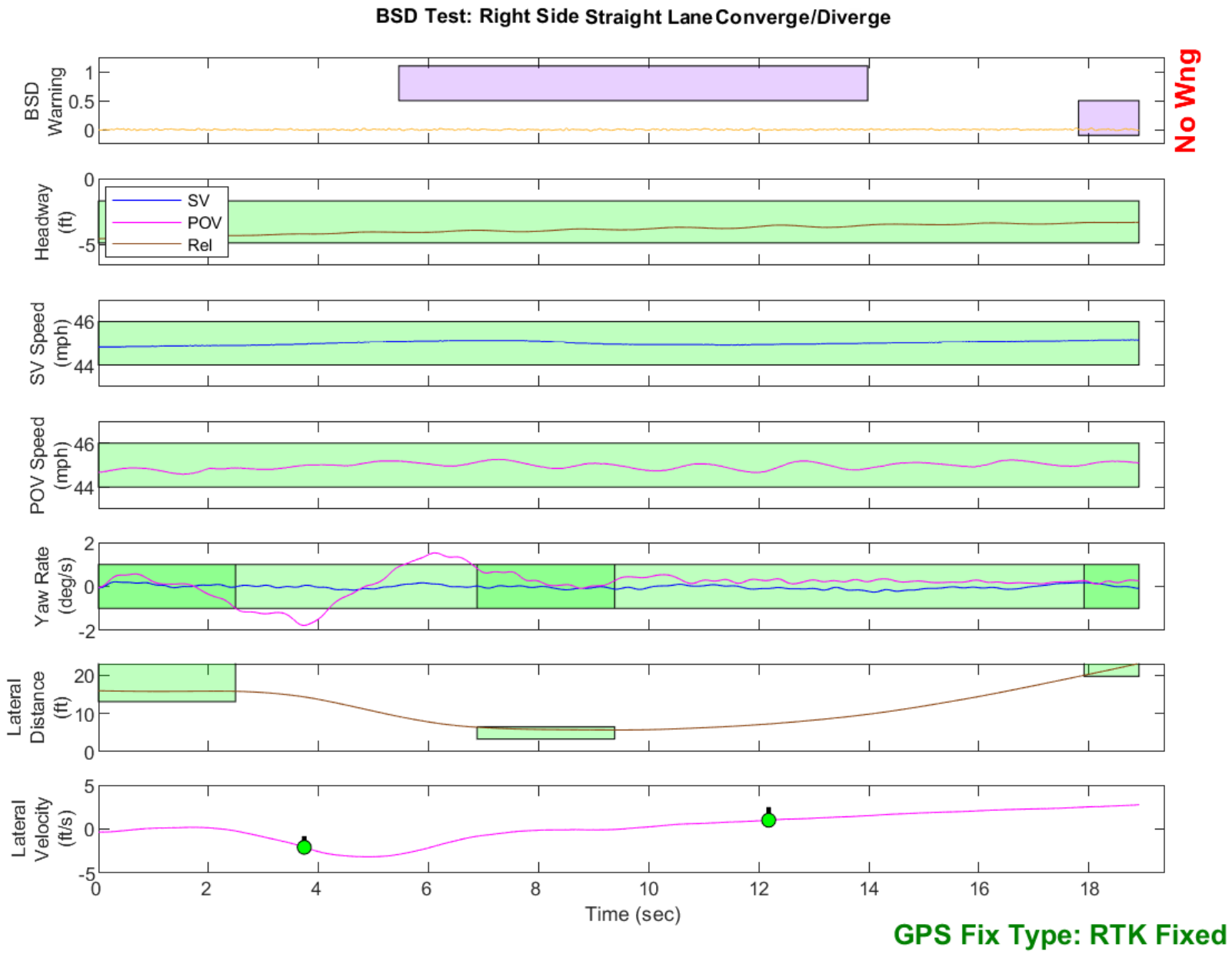


Figure D2. Example Time History for Straight Lane Converge/Diverge Test, Failing

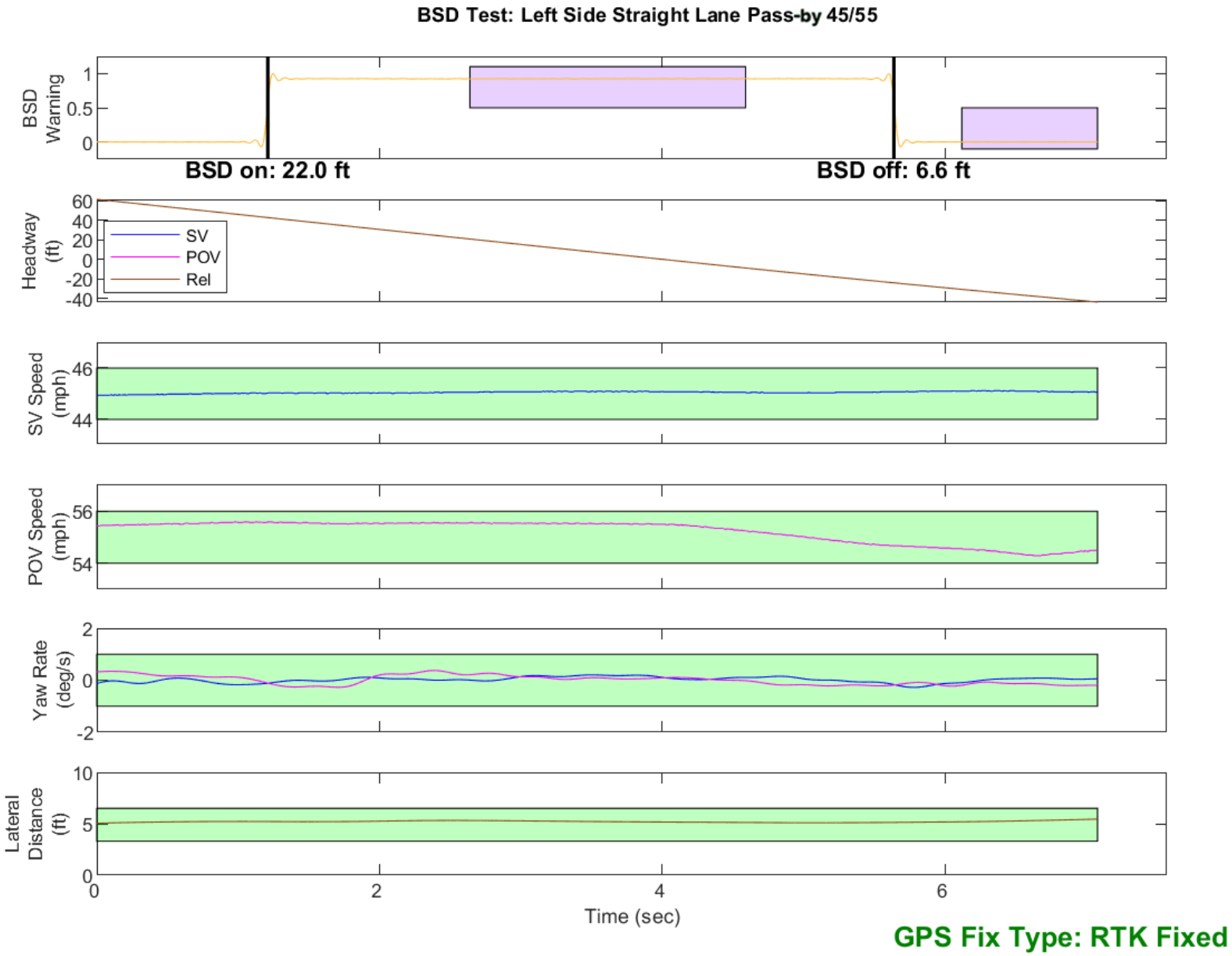


Figure D3. Example Time History for Straight Lane Pass-By Passing

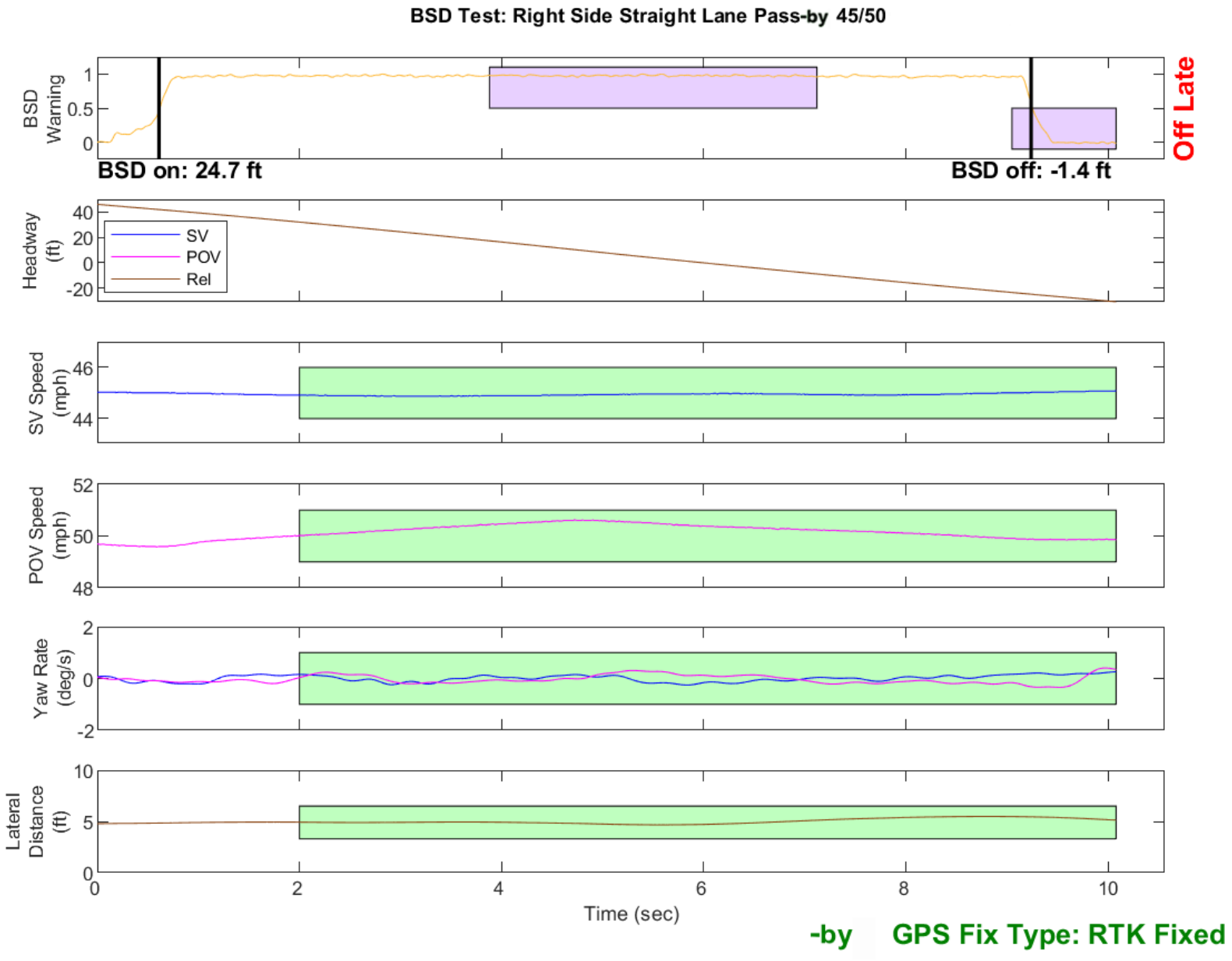


Figure D4. Example Time History for Straight Lane Pass-by Test, Failing

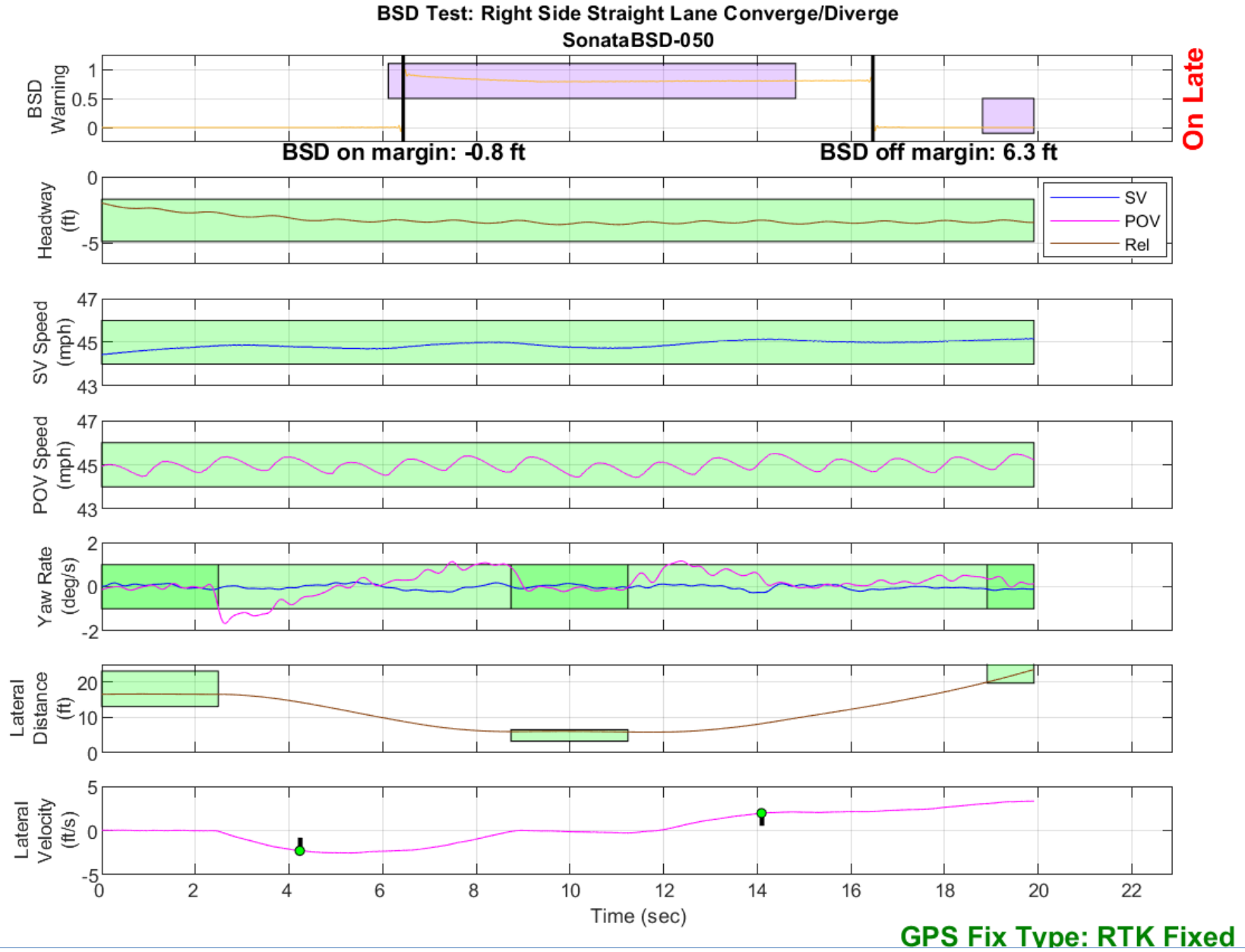


Figure D5. BSD Run 50, Straight Lane Converge/Diverge

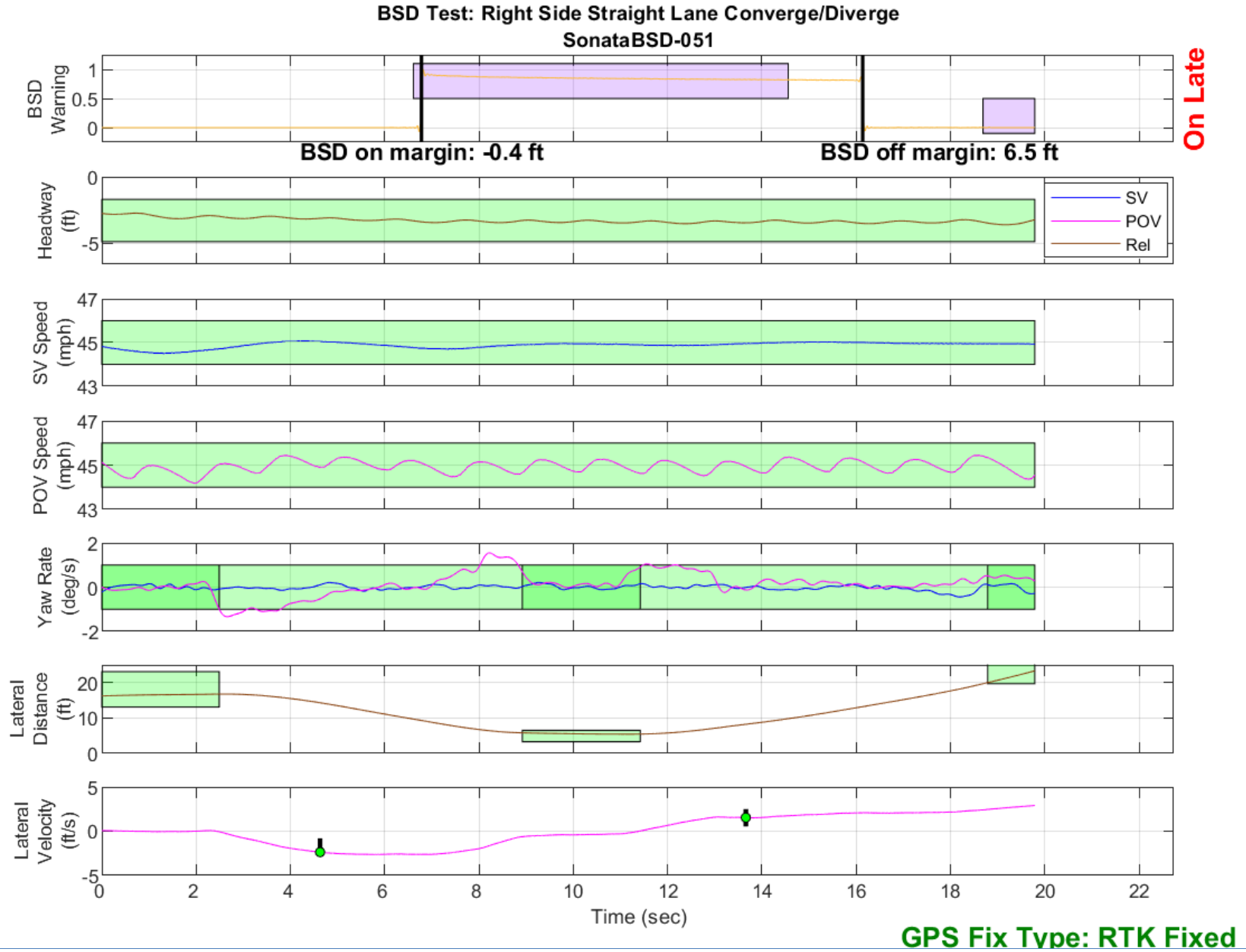


Figure D6. BSD Run 51, Straight Lane Converge/Diverge

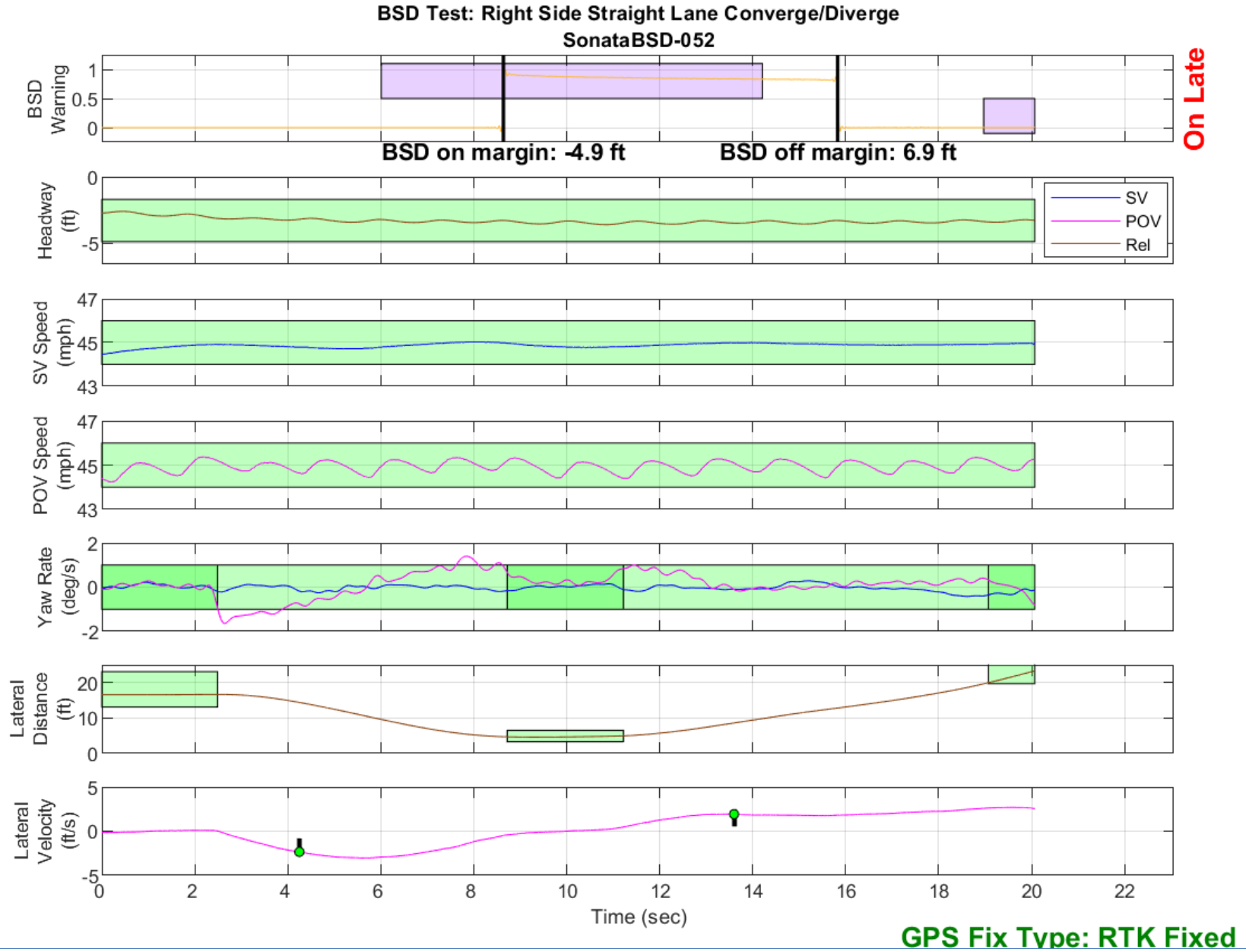


Figure D7. BSD Run 52, Straight Lane Converge/Diverge

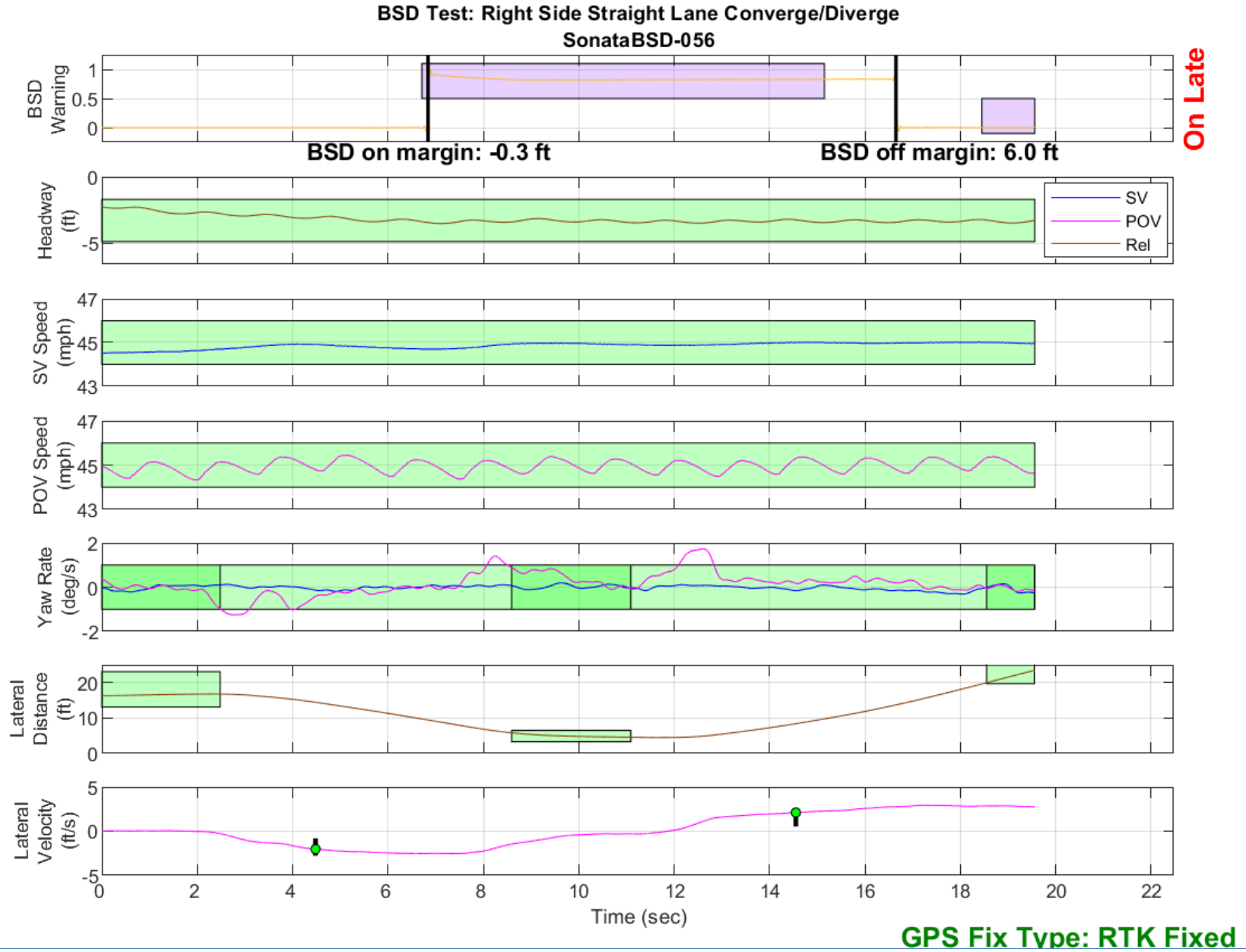


Figure D8. BSD Run 56, Straight Lane Converge/Diverge

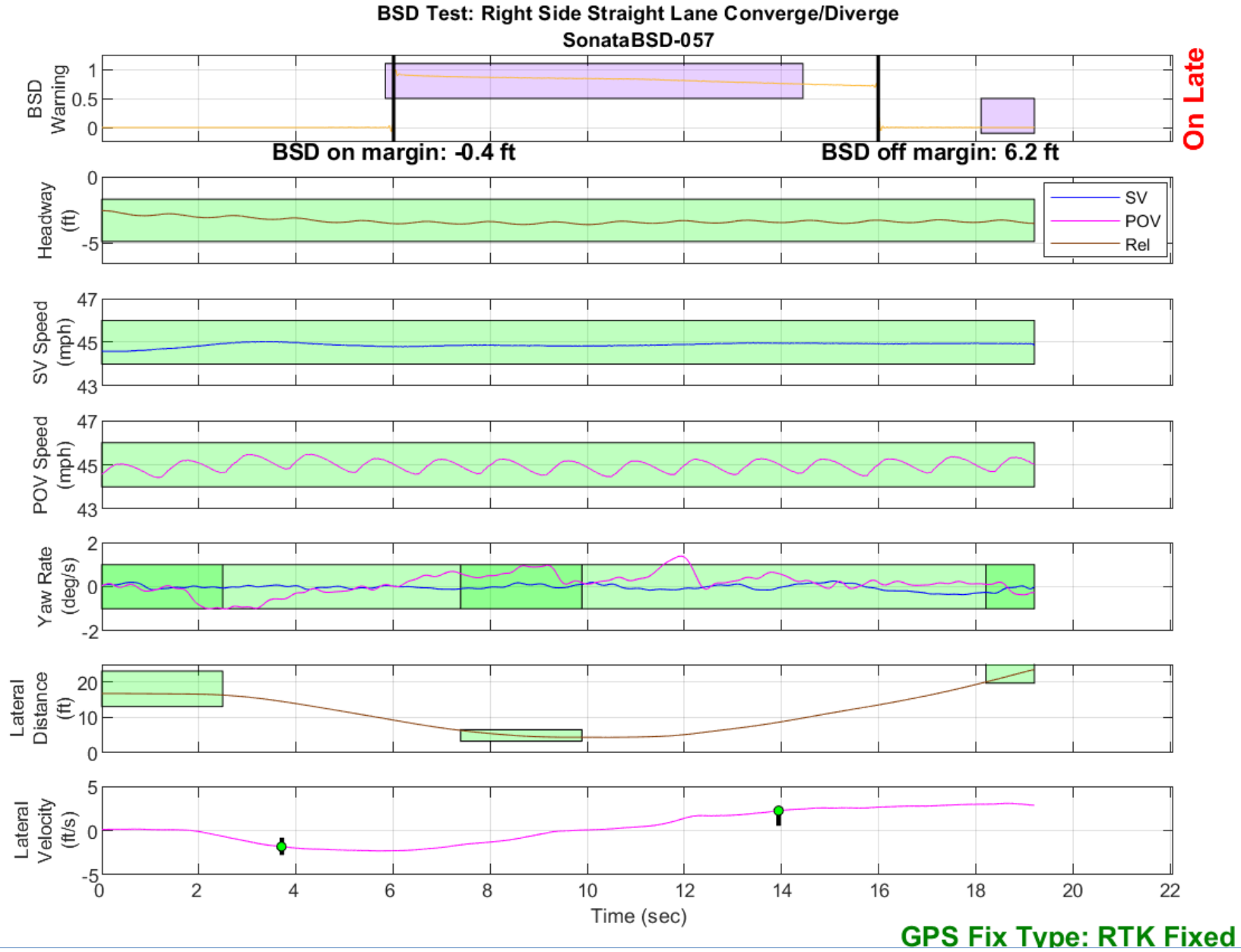


Figure D9. BSD Run 57, Straight Lane Converge/Diverge

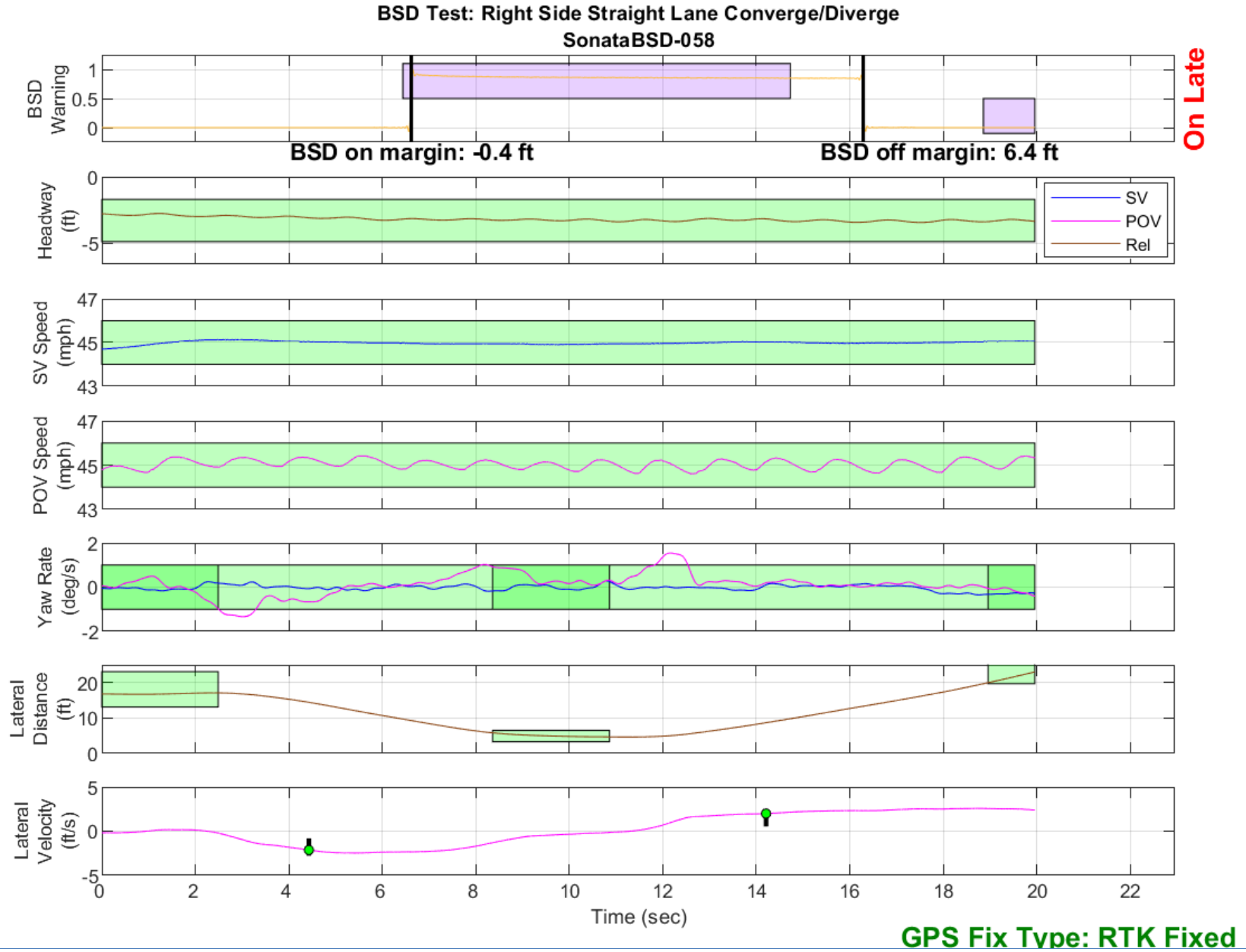


Figure D10. BSD Run 58, Straight Lane Converge/Diverge

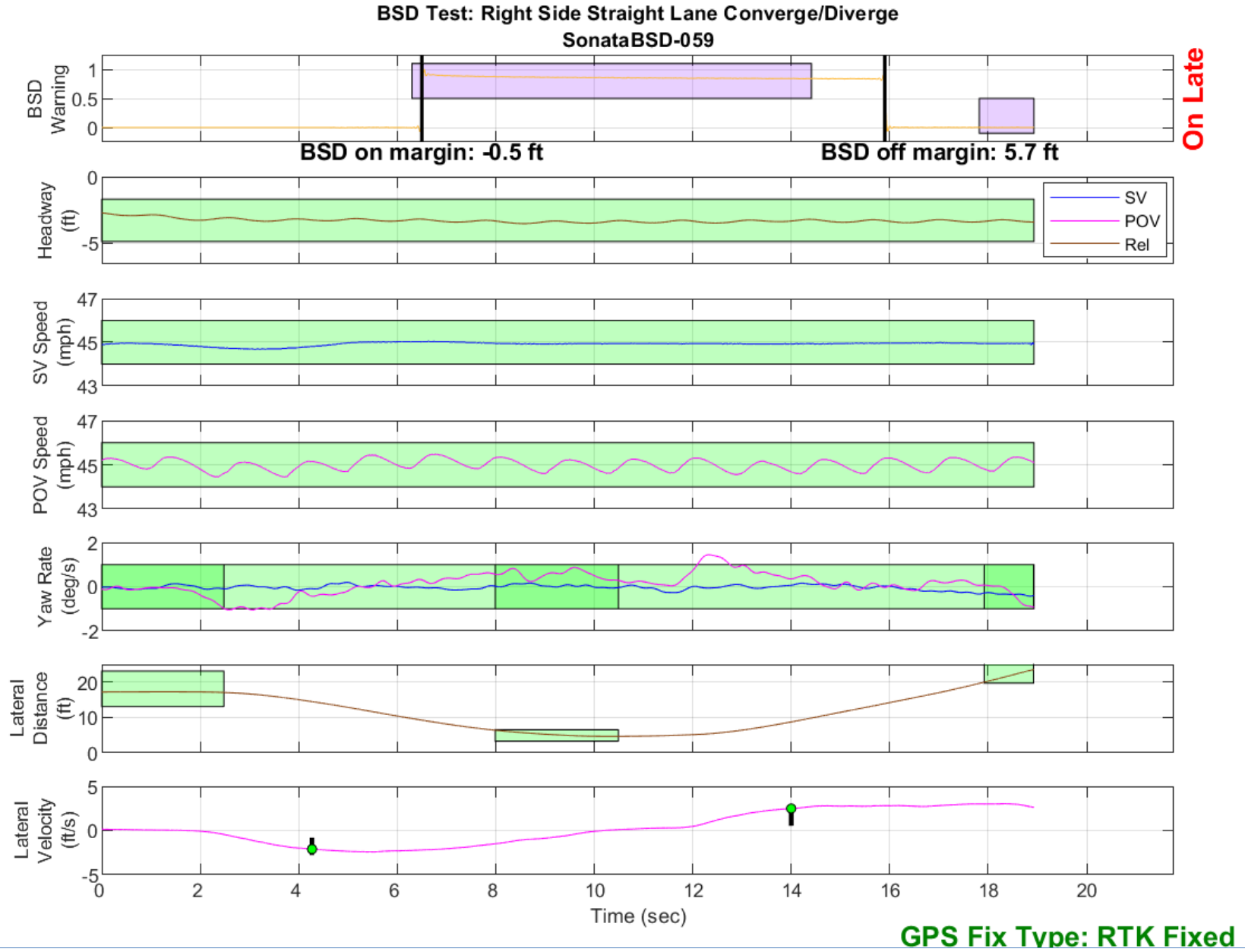


Figure D11. BSD Run 59, Straight Lane Converge/Diverge

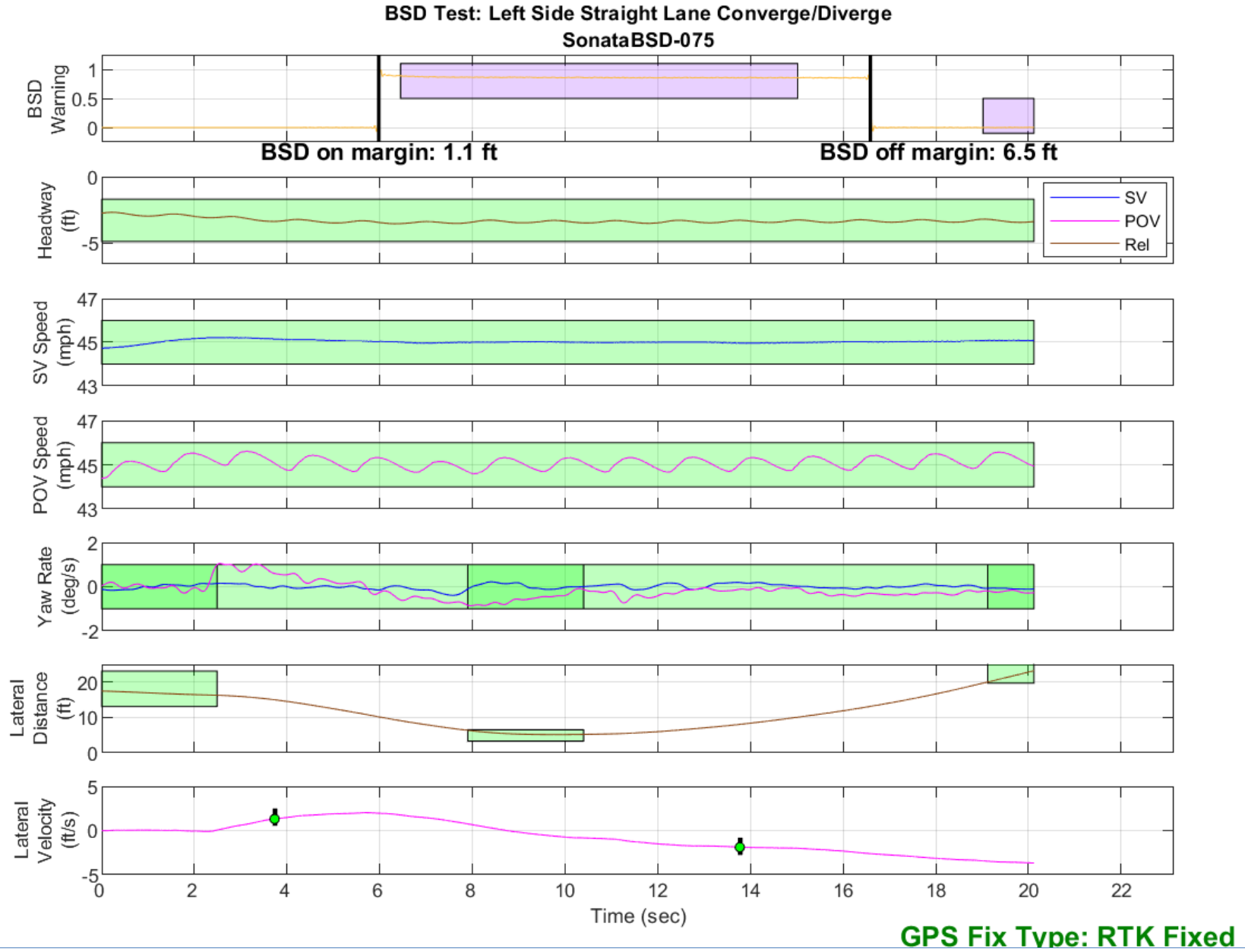


Figure D12. BSD Run 75, Straight Lane Converge/Diverge

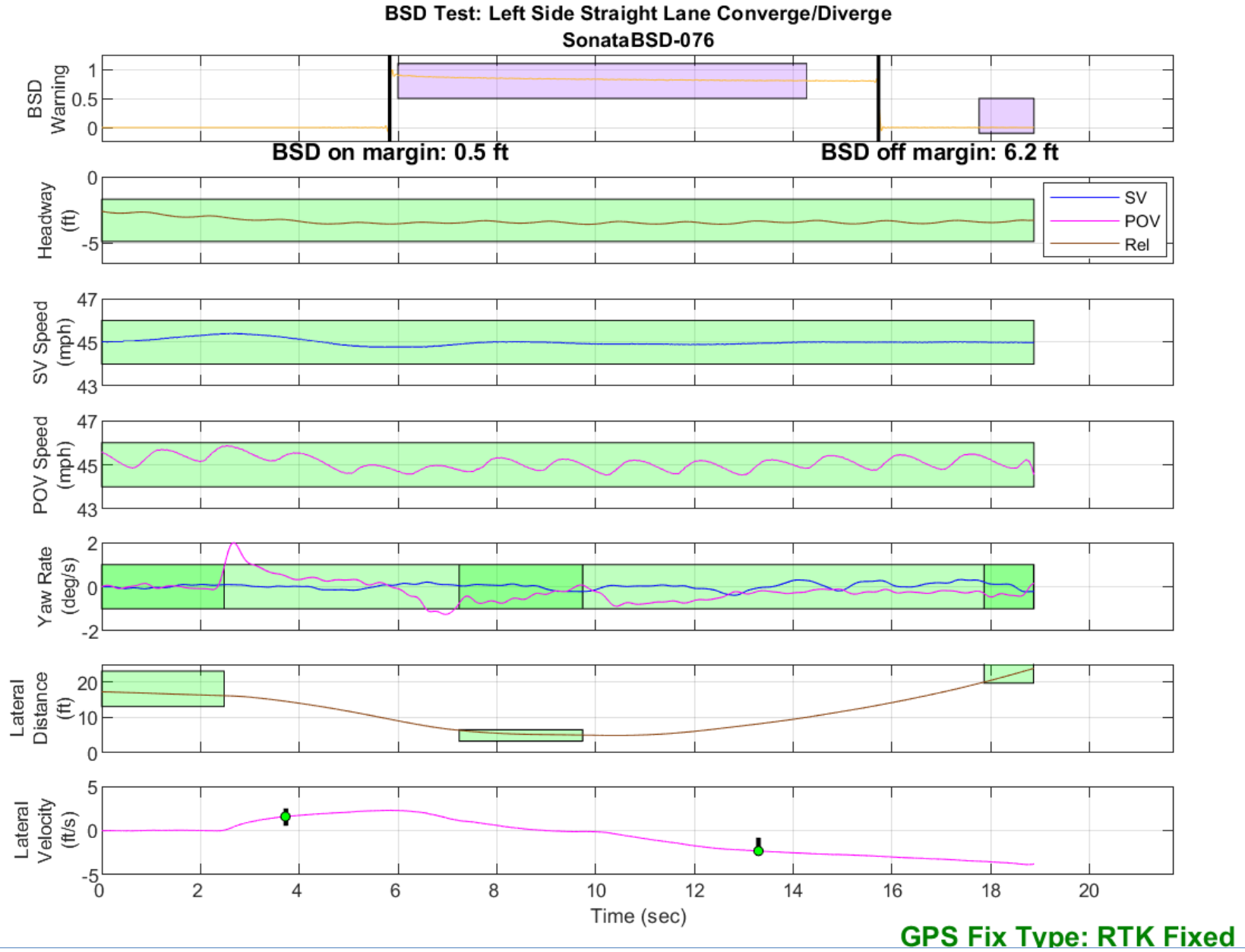


Figure D13. BSD Run 76, Straight Lane Converge/Diverge

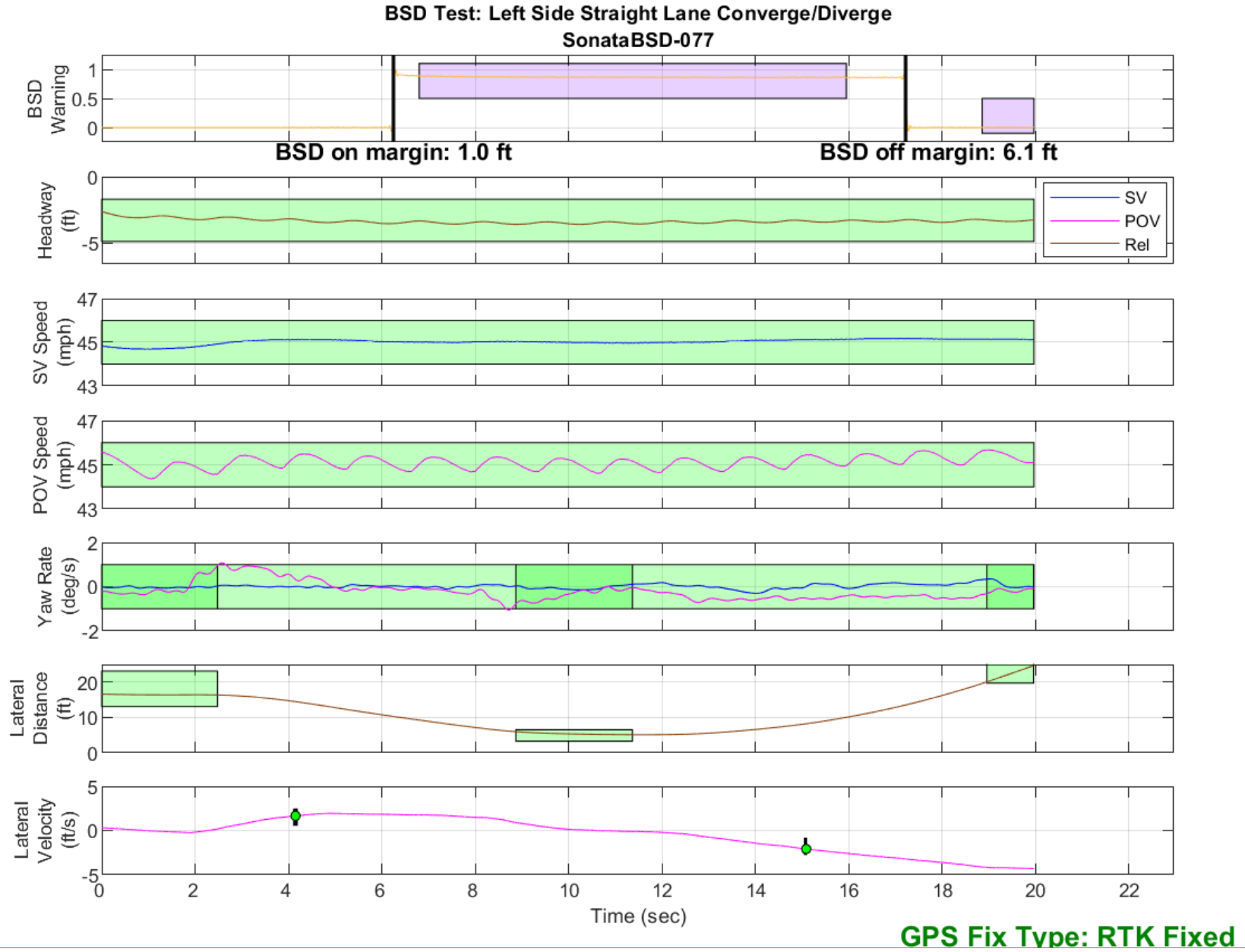


Figure D14. BSD Run 77, Straight Lane Converge/Diverge

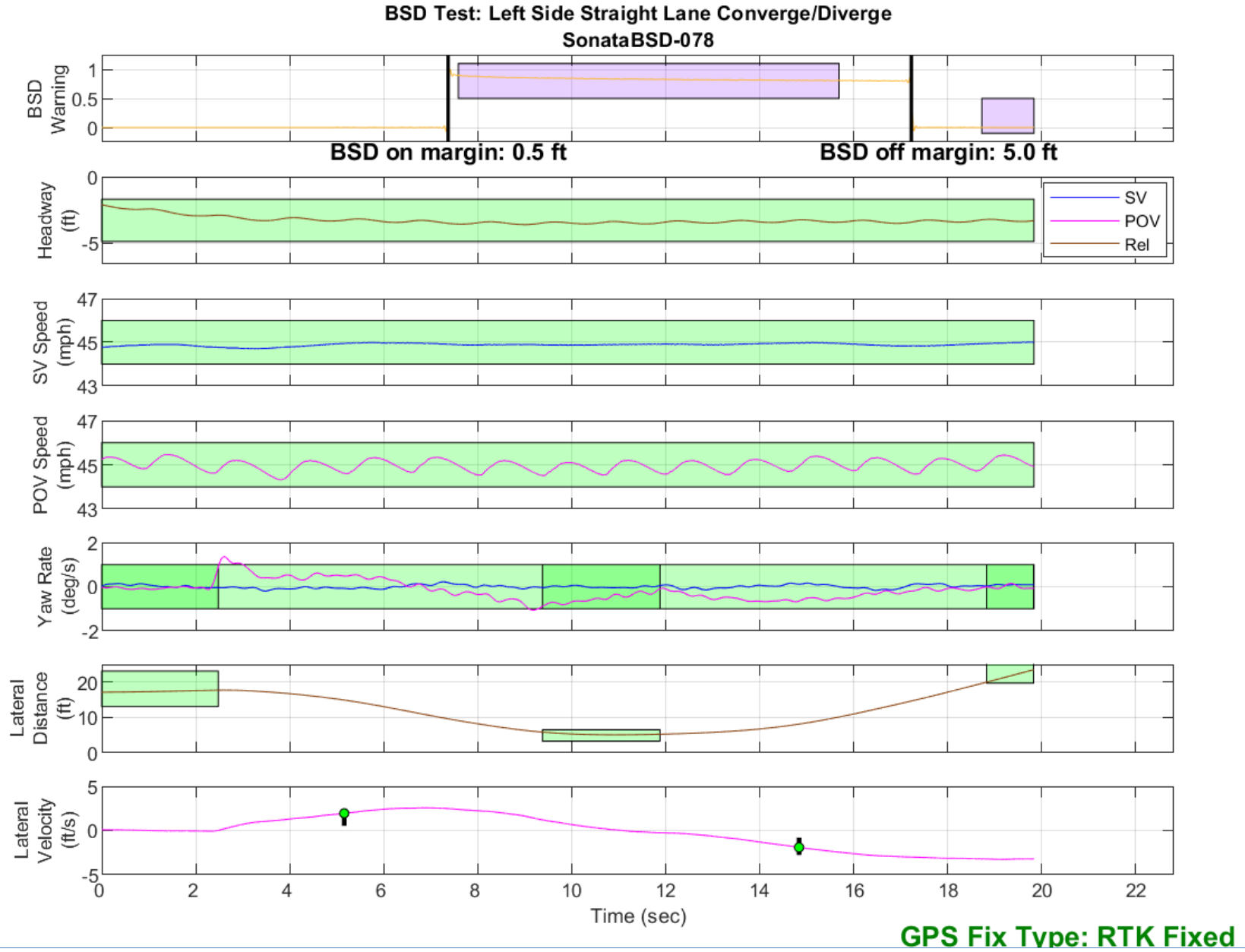


Figure D15. BSD Run 78, Straight Lane Converge/Diverge

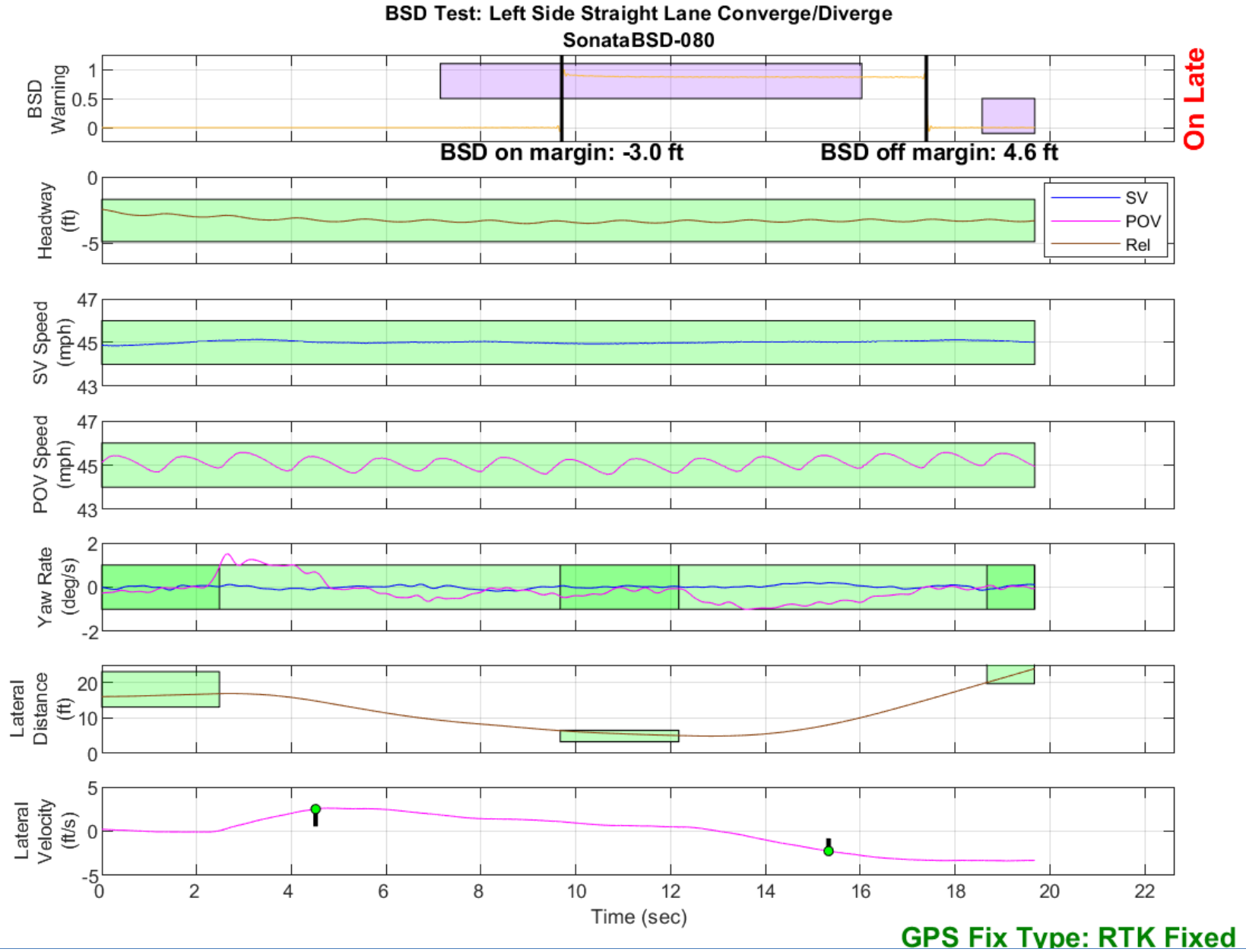


Figure D16. BSD Run 80, Straight Lane Converge/Diverge

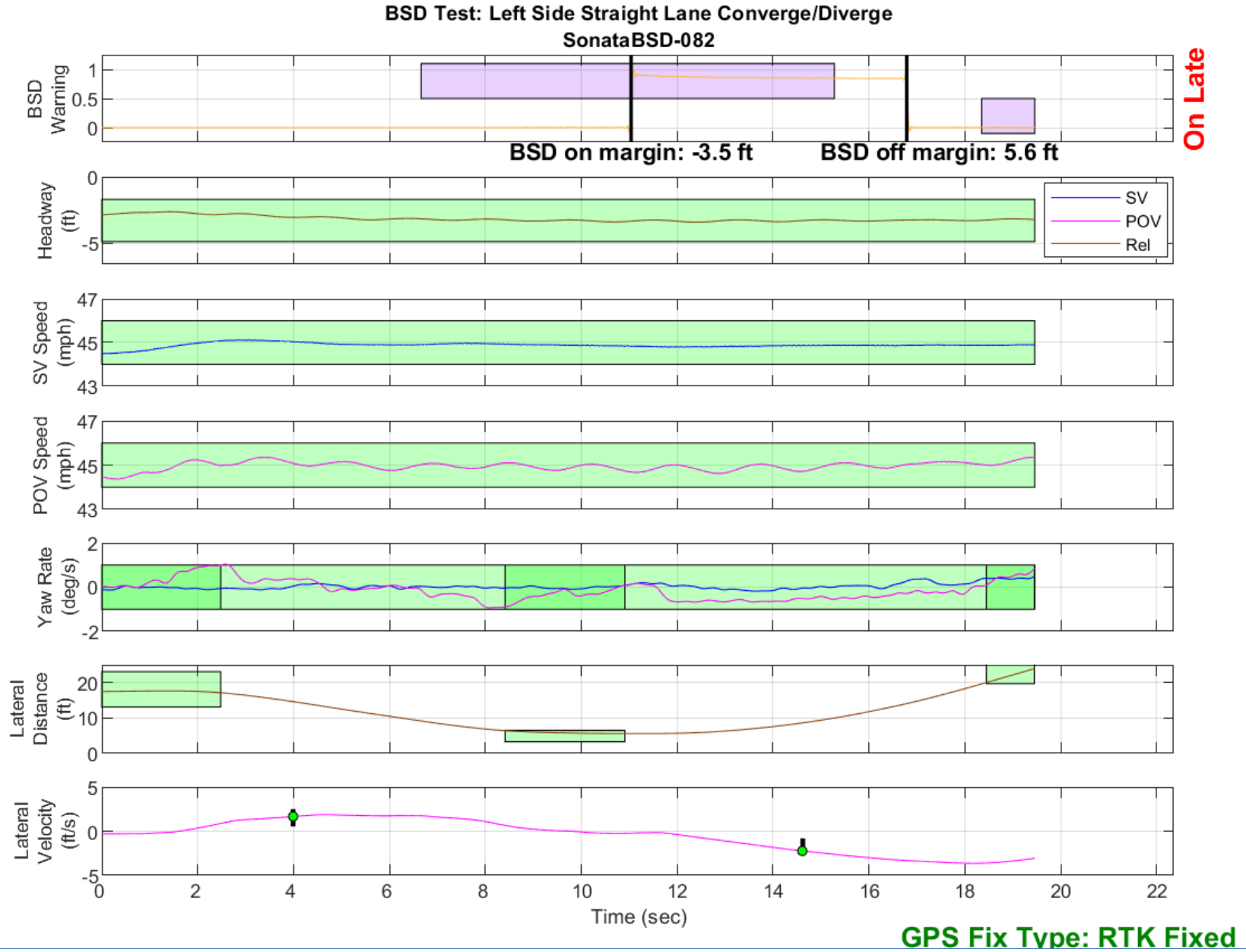


Figure D17. BSD Run 82, Straight Lane Converge/Diverge

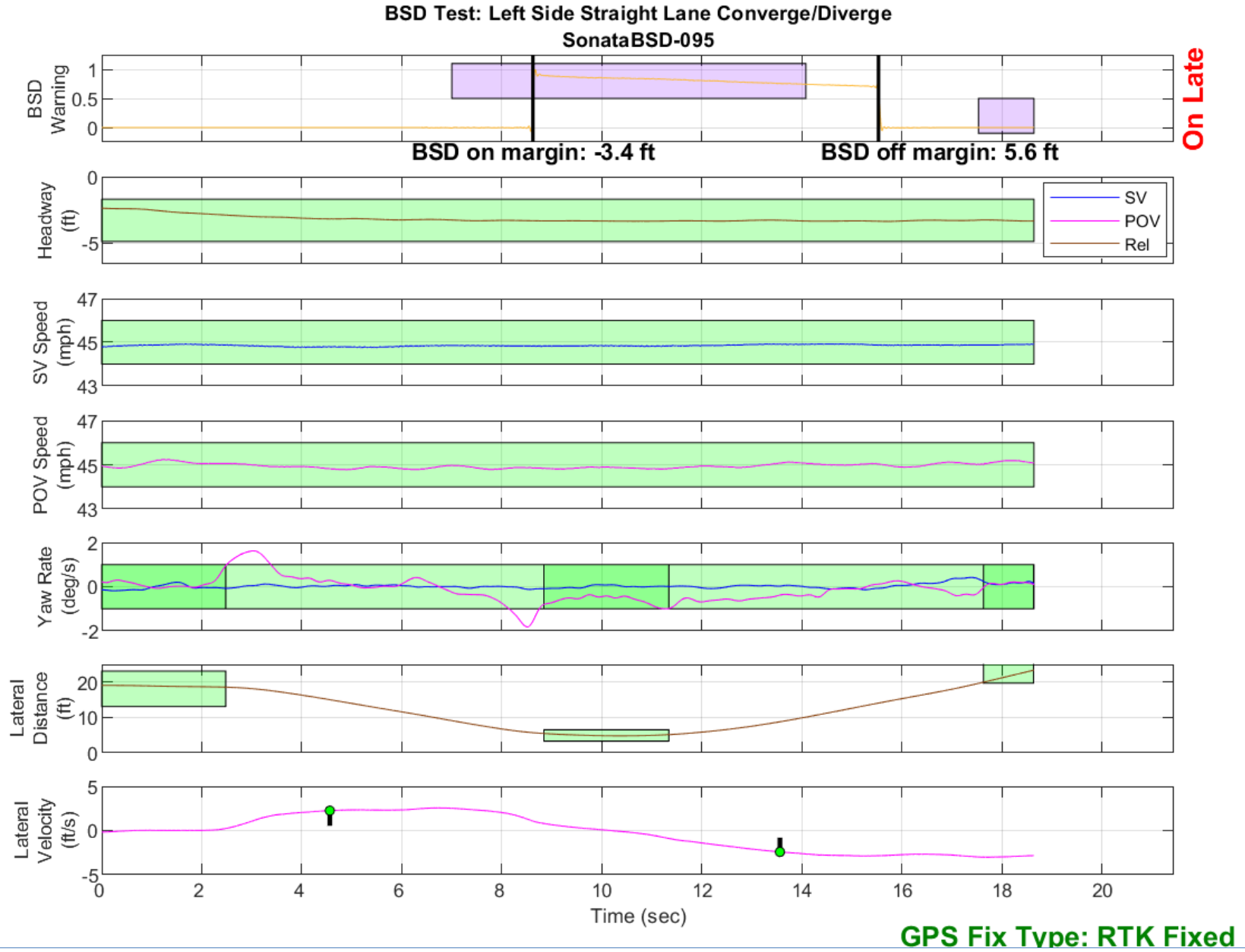


Figure D18. BSD Run 95, Straight Lane Converge/Diverge

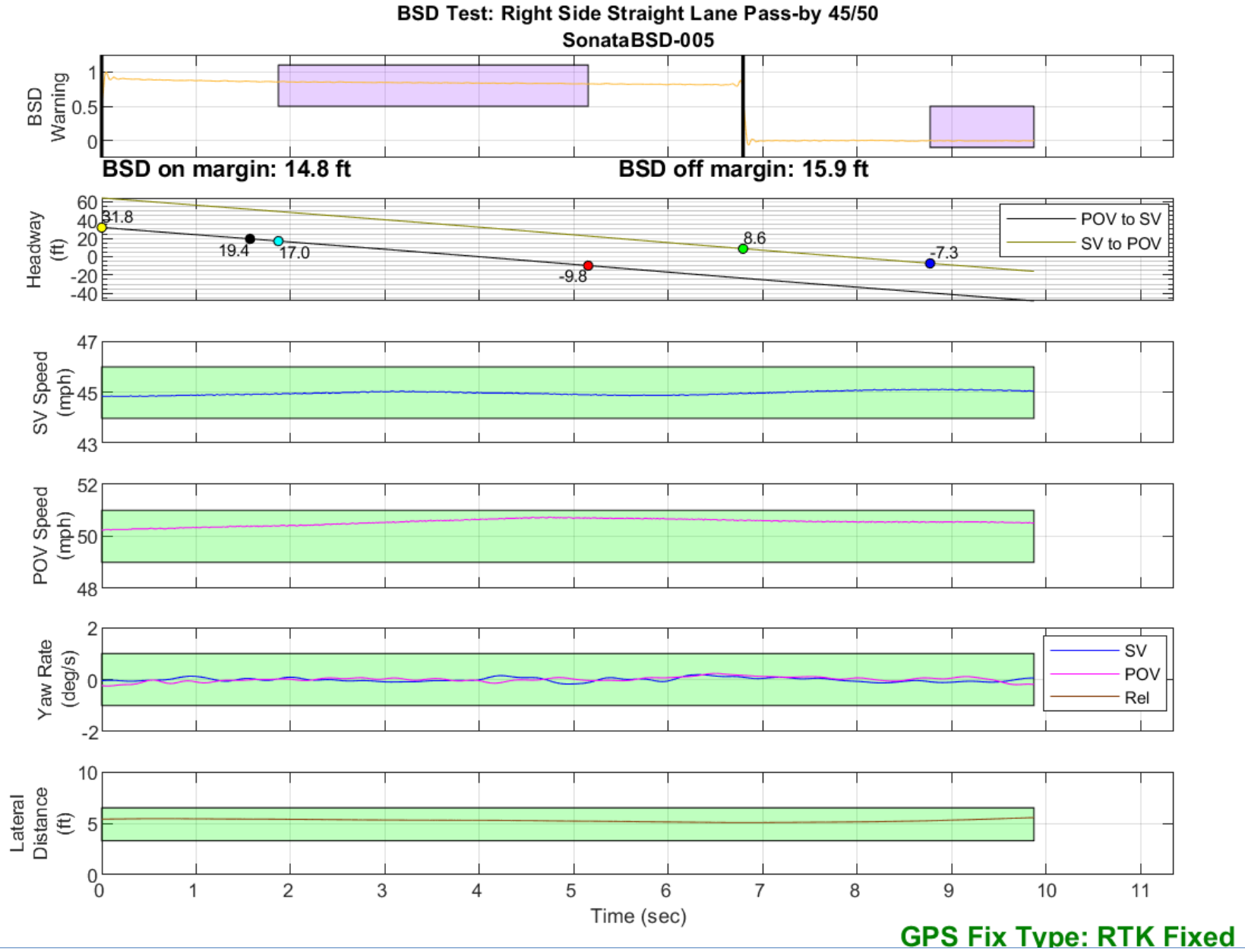


Figure D19. BSD Run 5, Straight Lane Pass-by, SV 45 mph, POV 50 mph

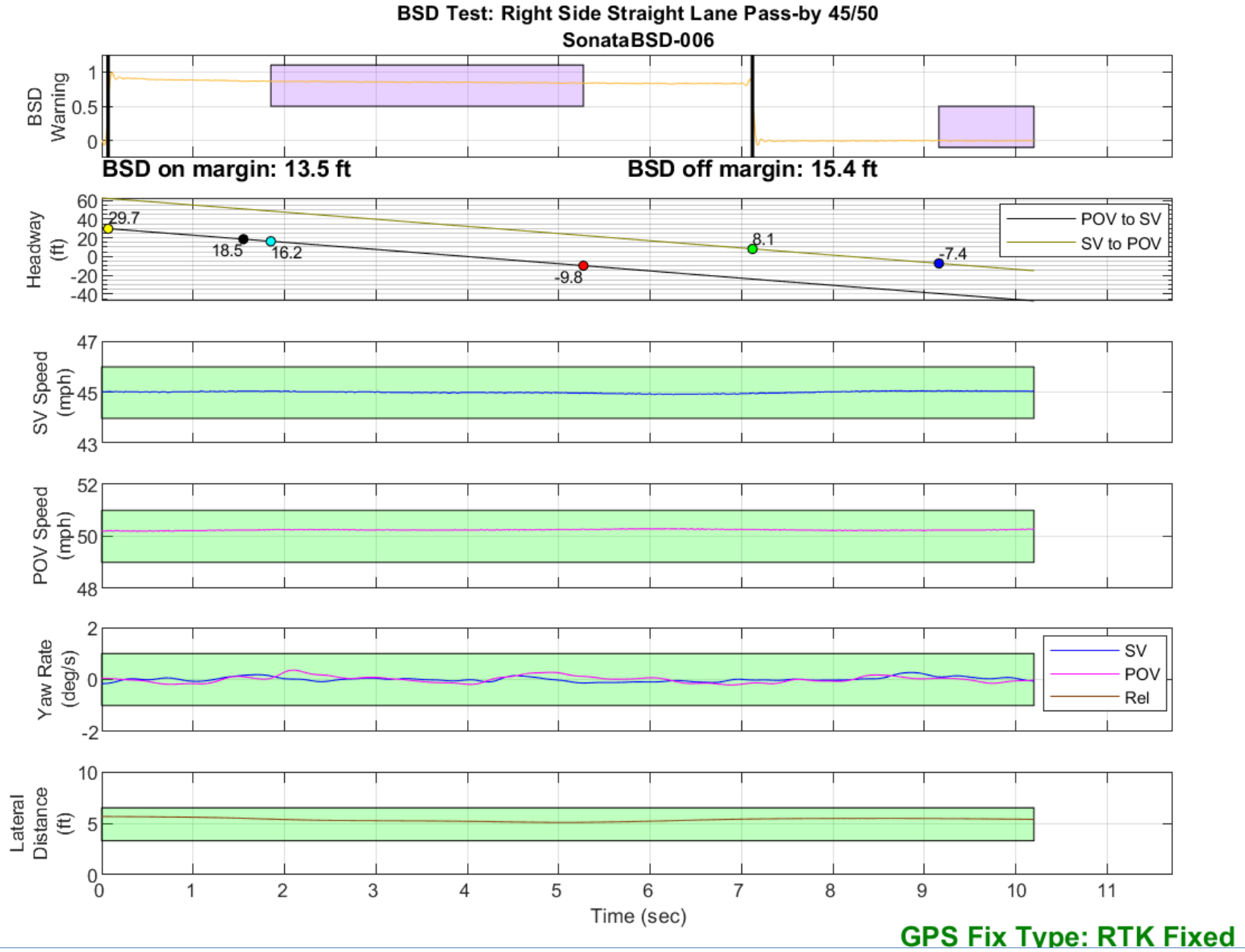


Figure D20. BSD Run 6, Straight Lane Pass-by, SV 45 mph, POV 50 mph

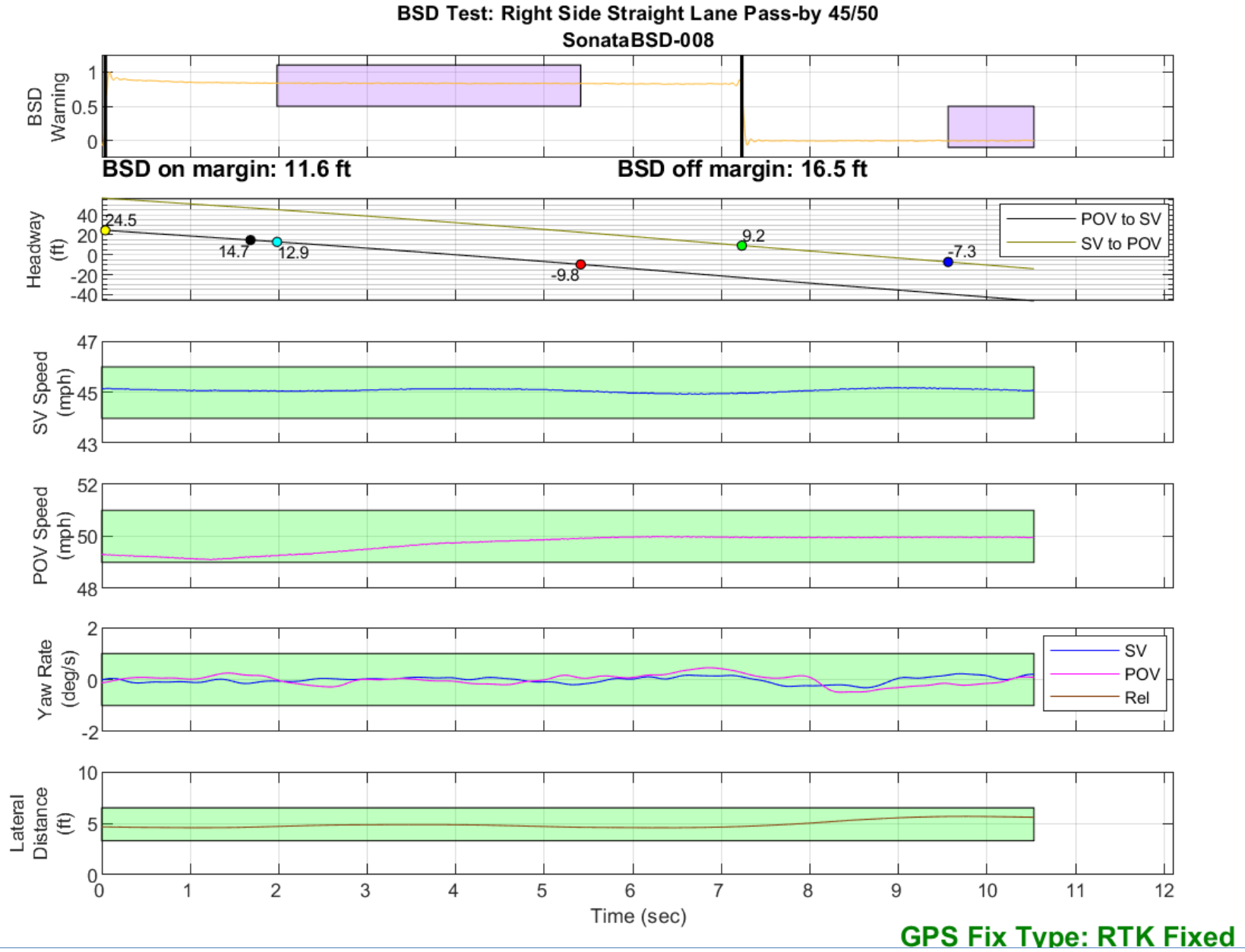


Figure D21. BSD Run 8, Straight Lane Pass-by, SV 45 mph, POV 50 mph

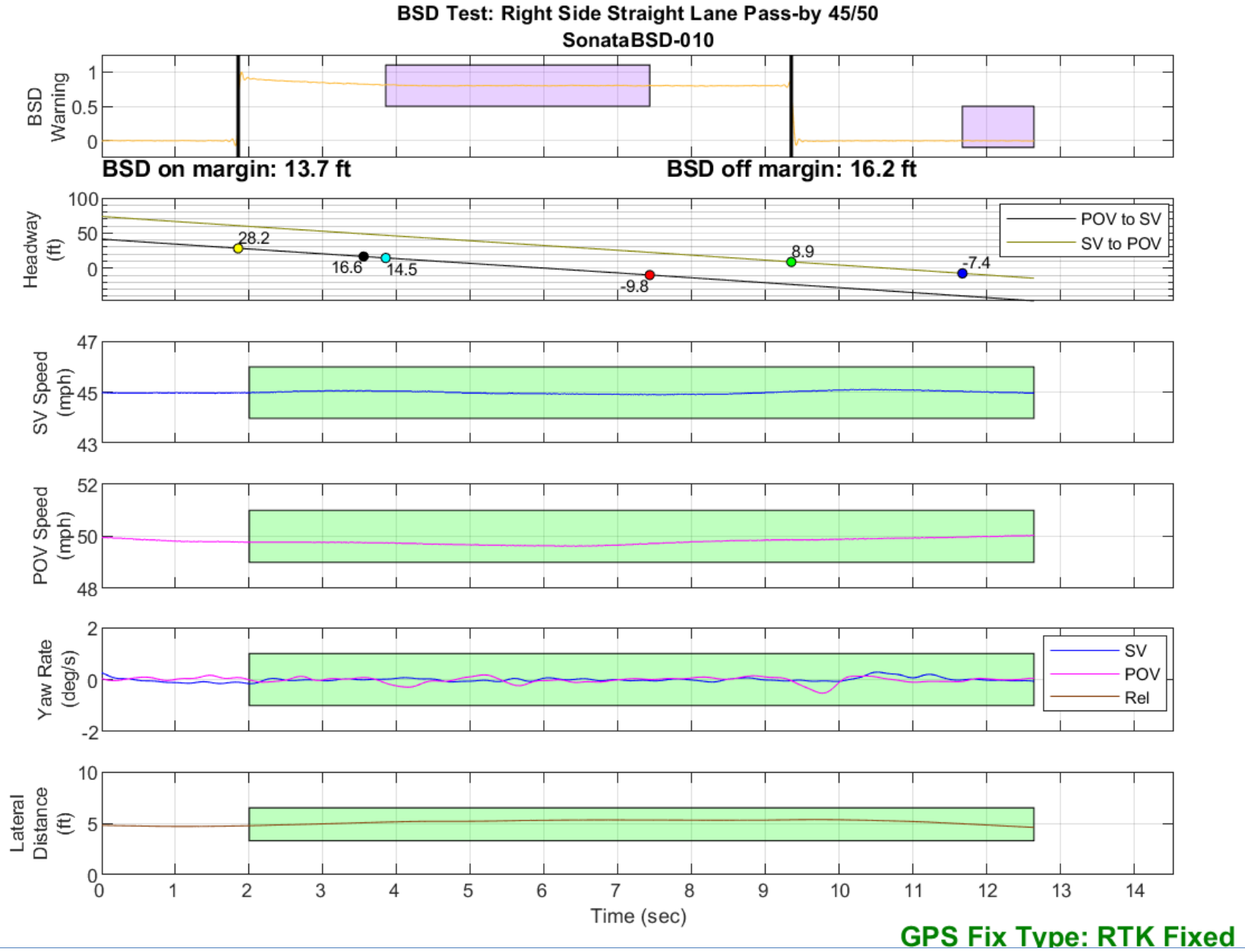


Figure D22. BSD Run 10, Straight Lane Pass-by, SV 45 mph, POV 50 mph

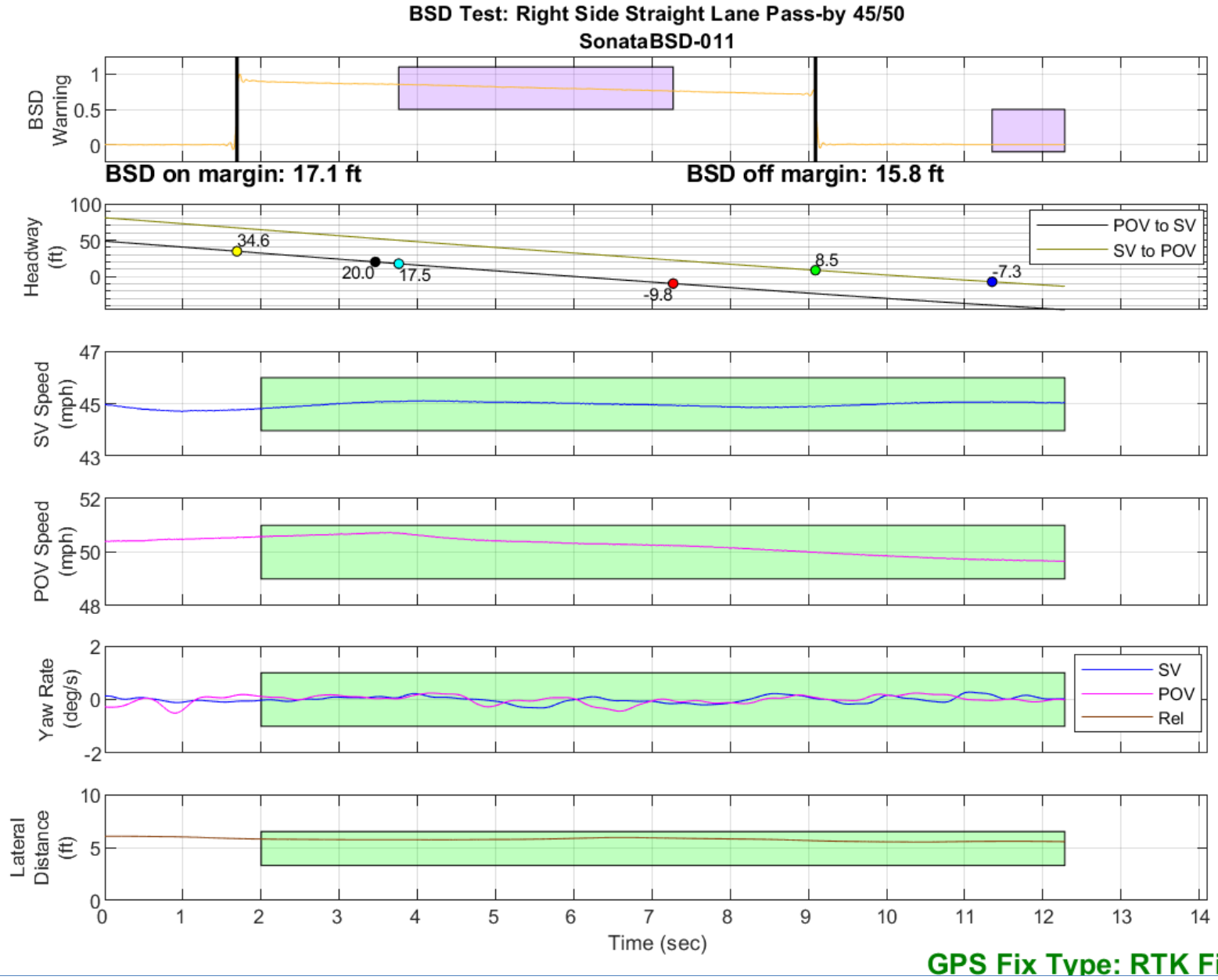


Figure D23. BSD Run 11, Straight Lane Pass-by, SV 45 mph, POV 50 mph

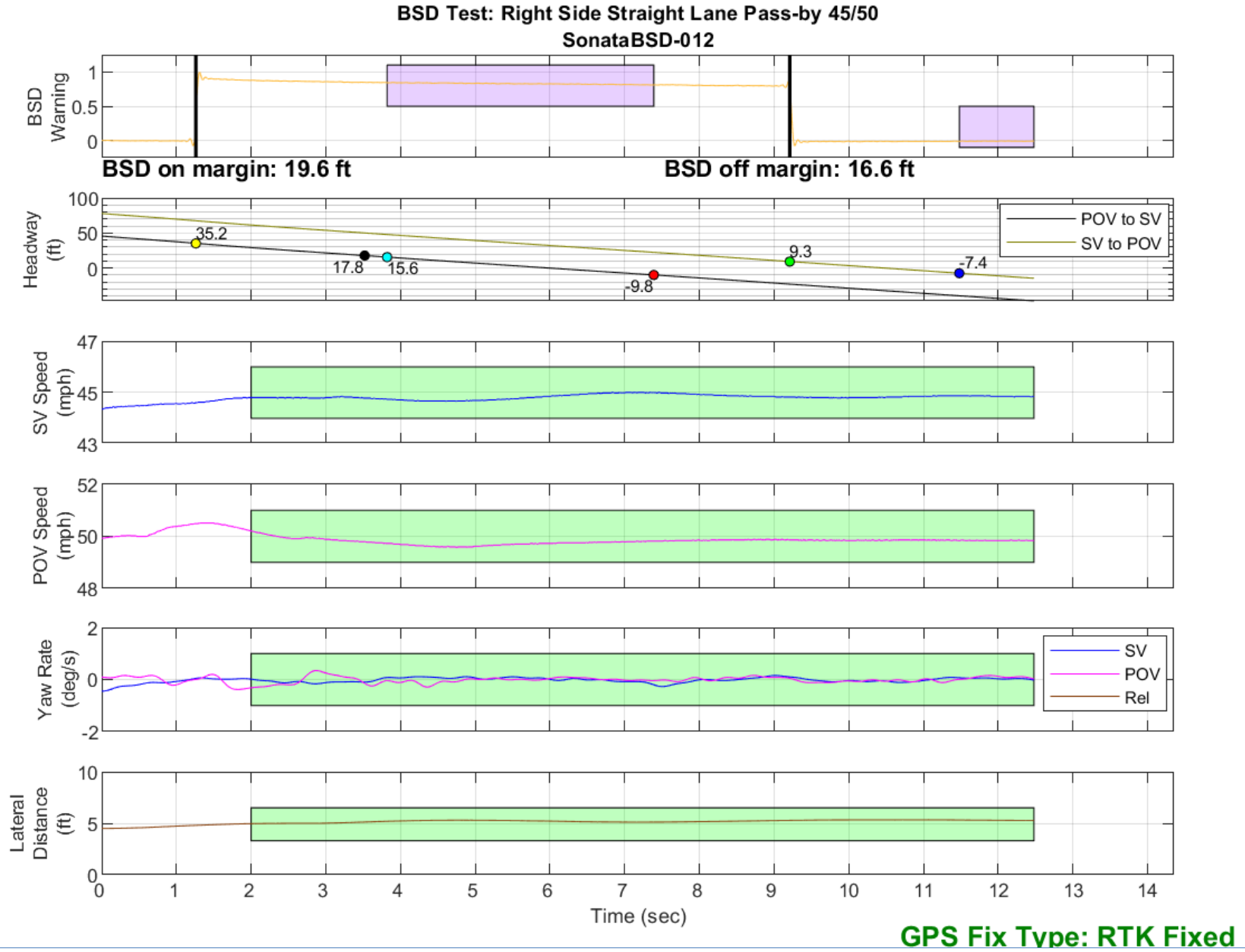


Figure D24. BSD Run 12, Straight Lane Pass-by, SV 45 mph, POV 50 mph

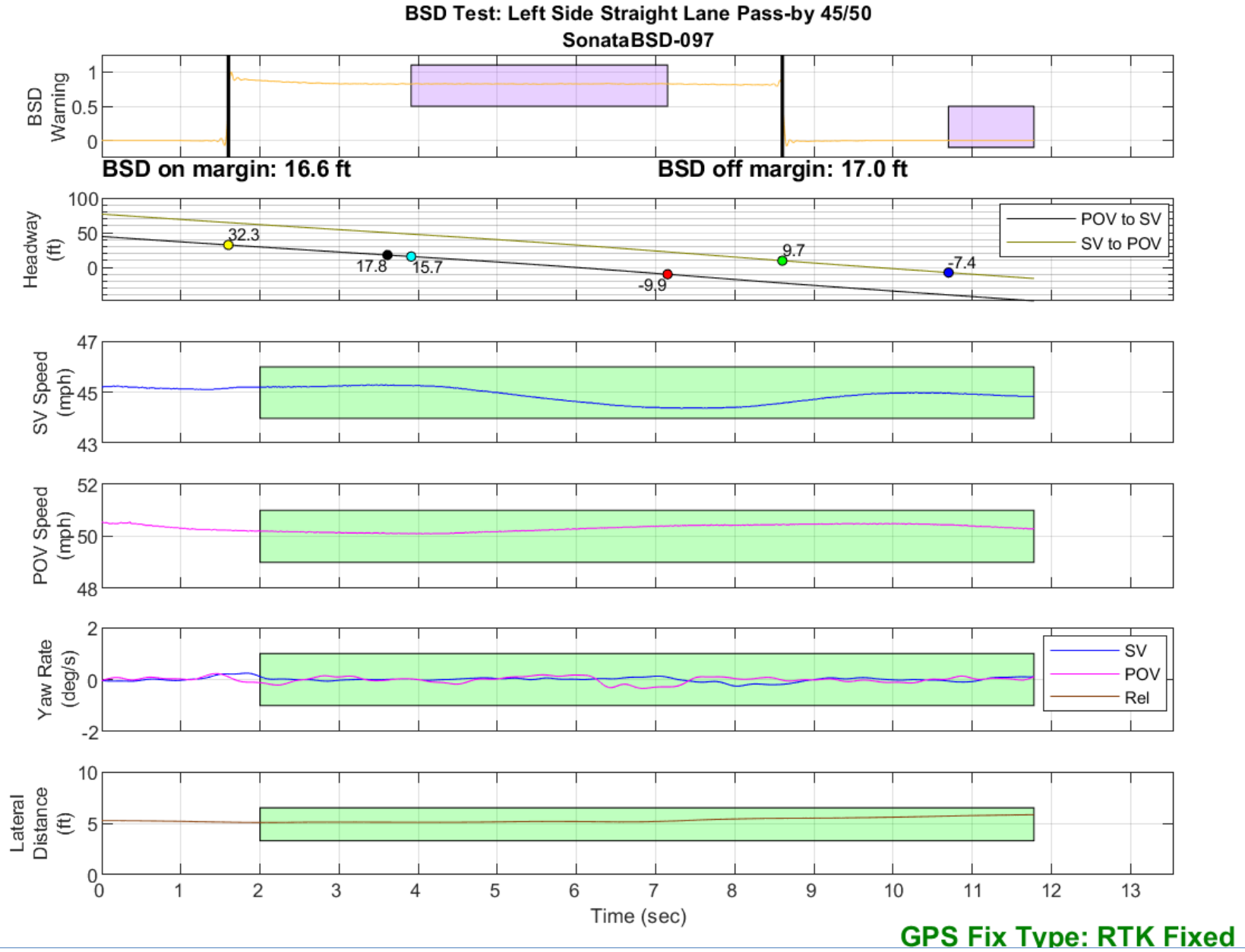


Figure D25. BSD Run 97, Straight Lane Pass-by, SV 45 mph, POV 50 mph

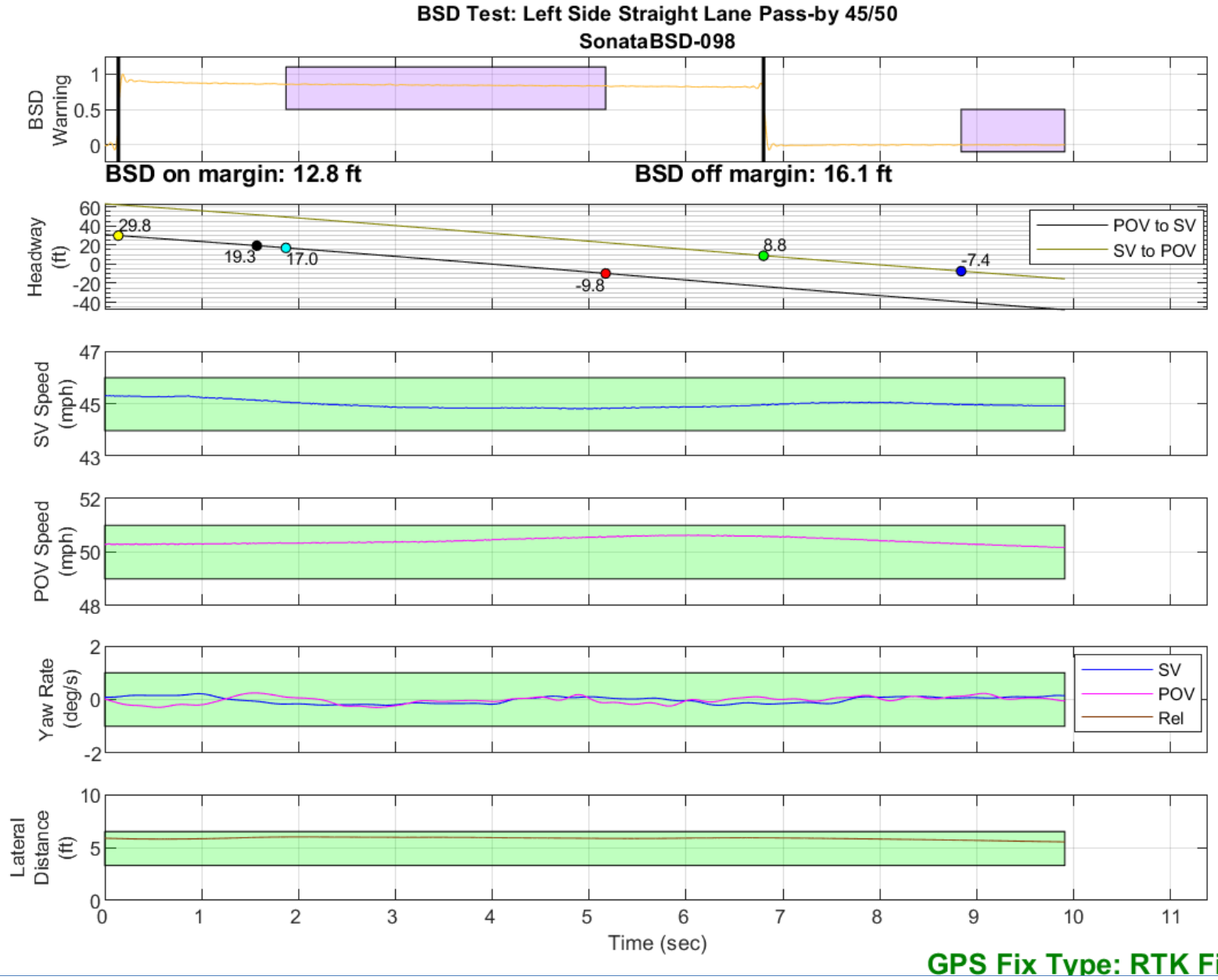


Figure D26. BSD Run 98, Straight Lane Pass-by, SV 45 mph, POV 50 mph

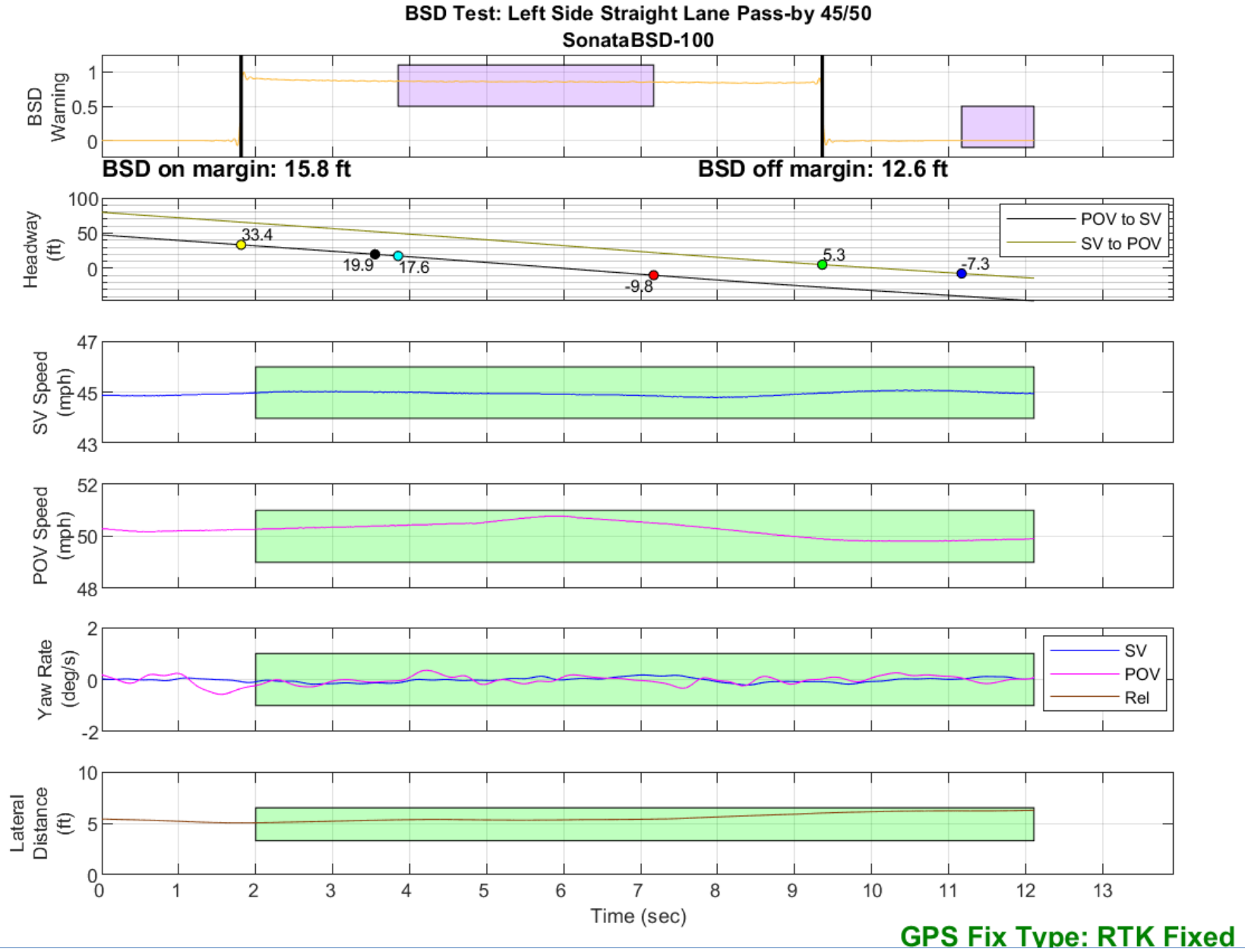


Figure D27. BSD Run 100, Straight Lane Pass-by, SV 45 mph, POV 50 mph

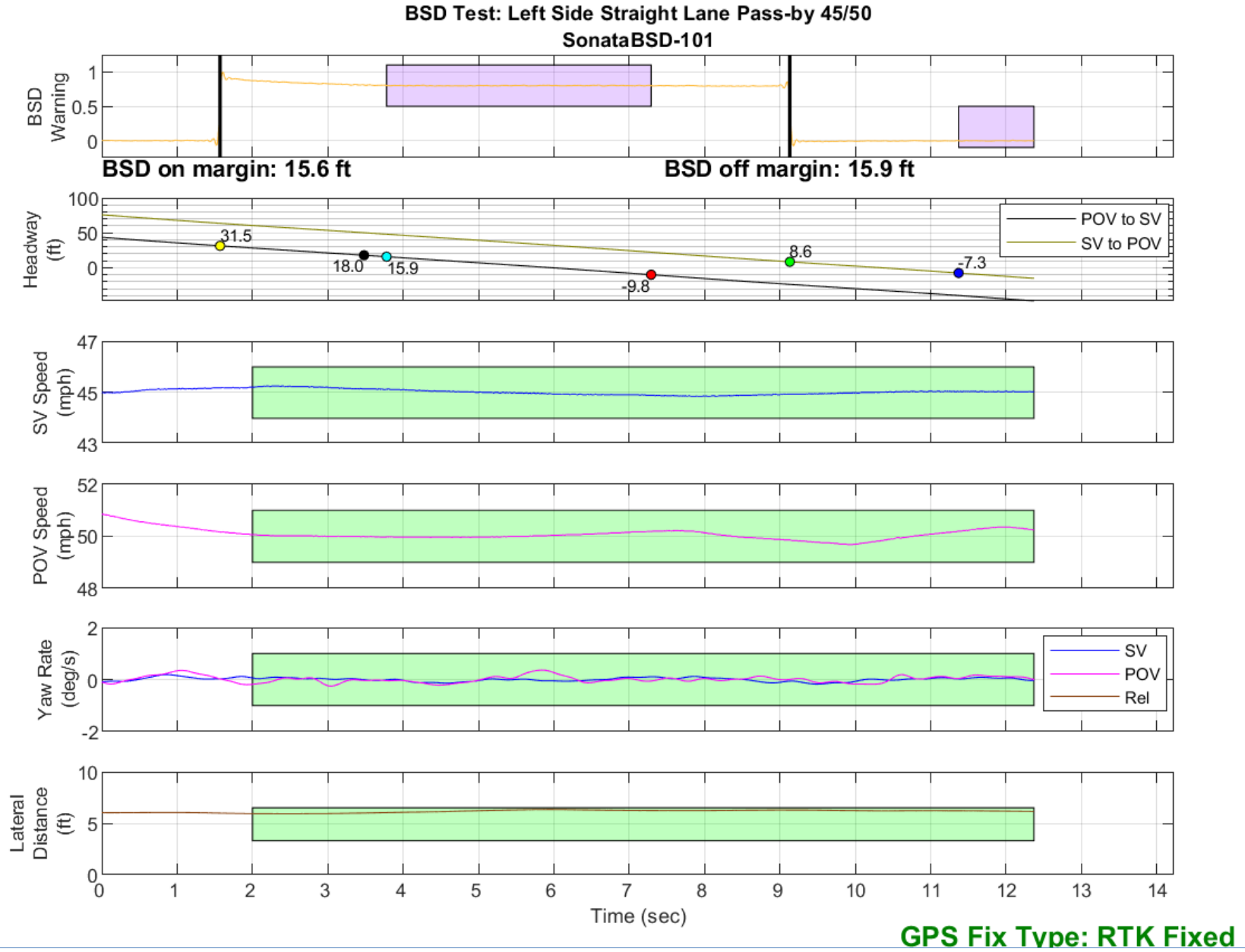


Figure D28. BSD Run 101, Straight Lane Pass-by, SV 45 mph, POV 50 mph

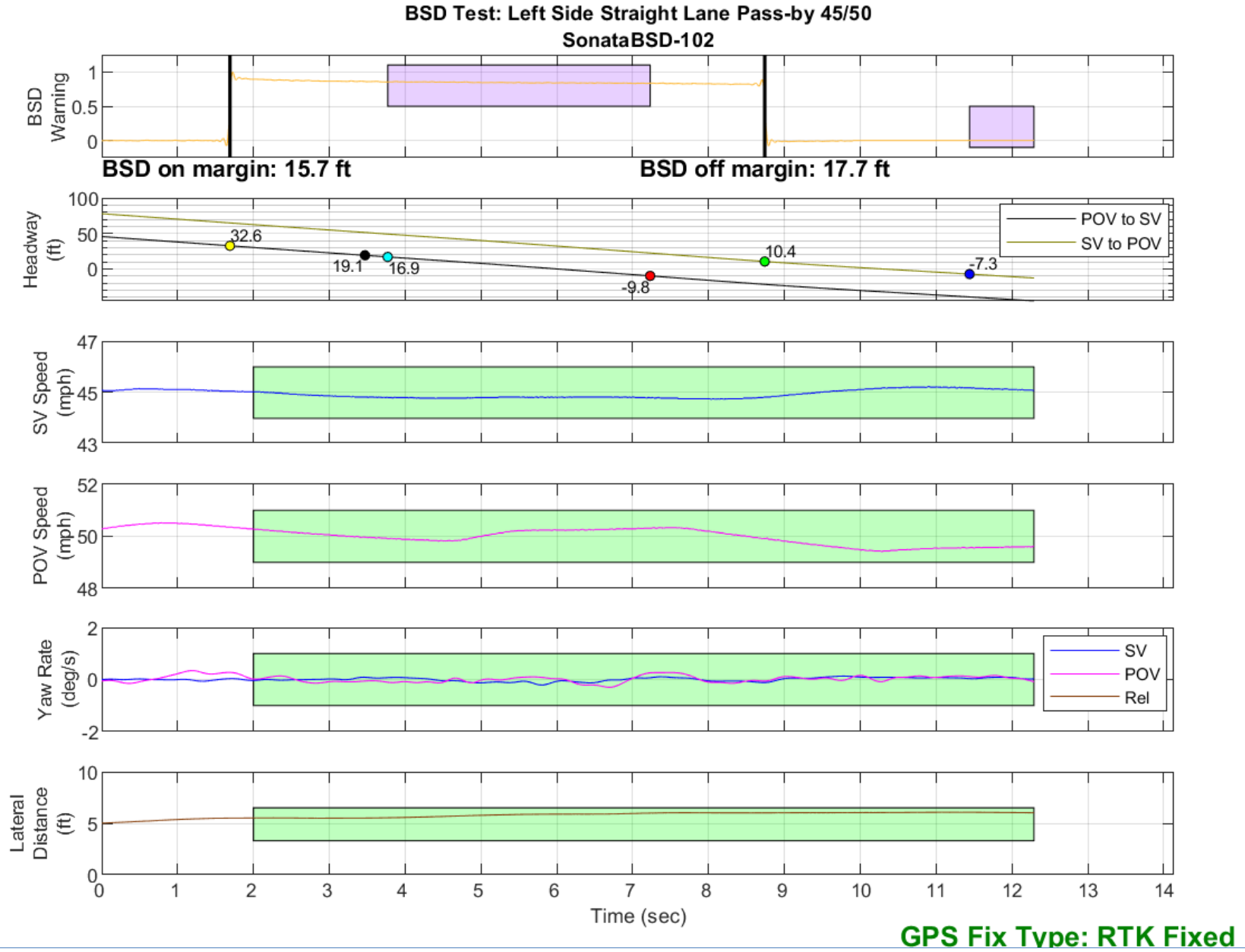


Figure D29. BSD Run 102, Straight Lane Pass-by, SV 45 mph, POV 50 mph

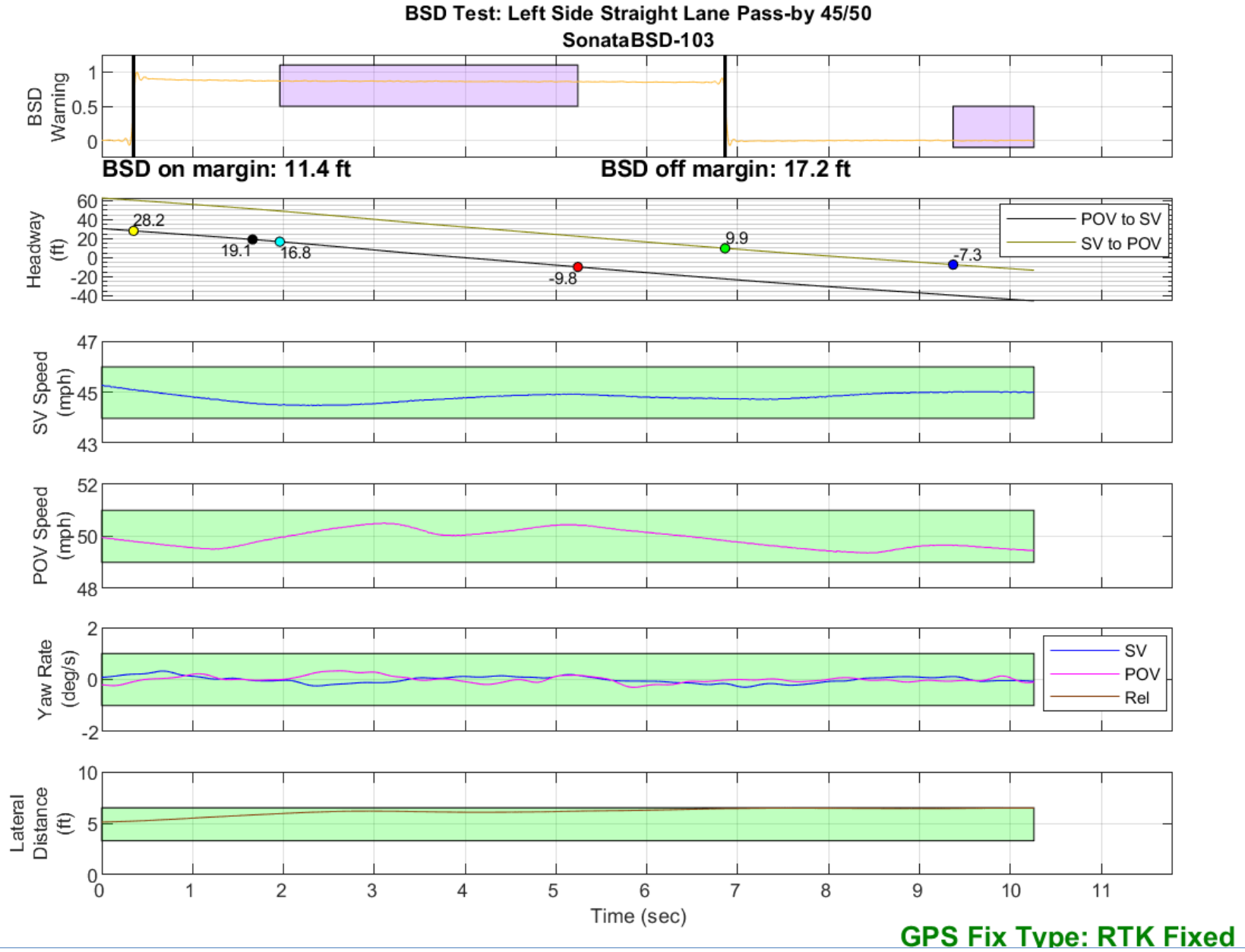


Figure D30. BSD Run 103, Straight Lane Pass-by, SV 45 mph, POV 50 mph

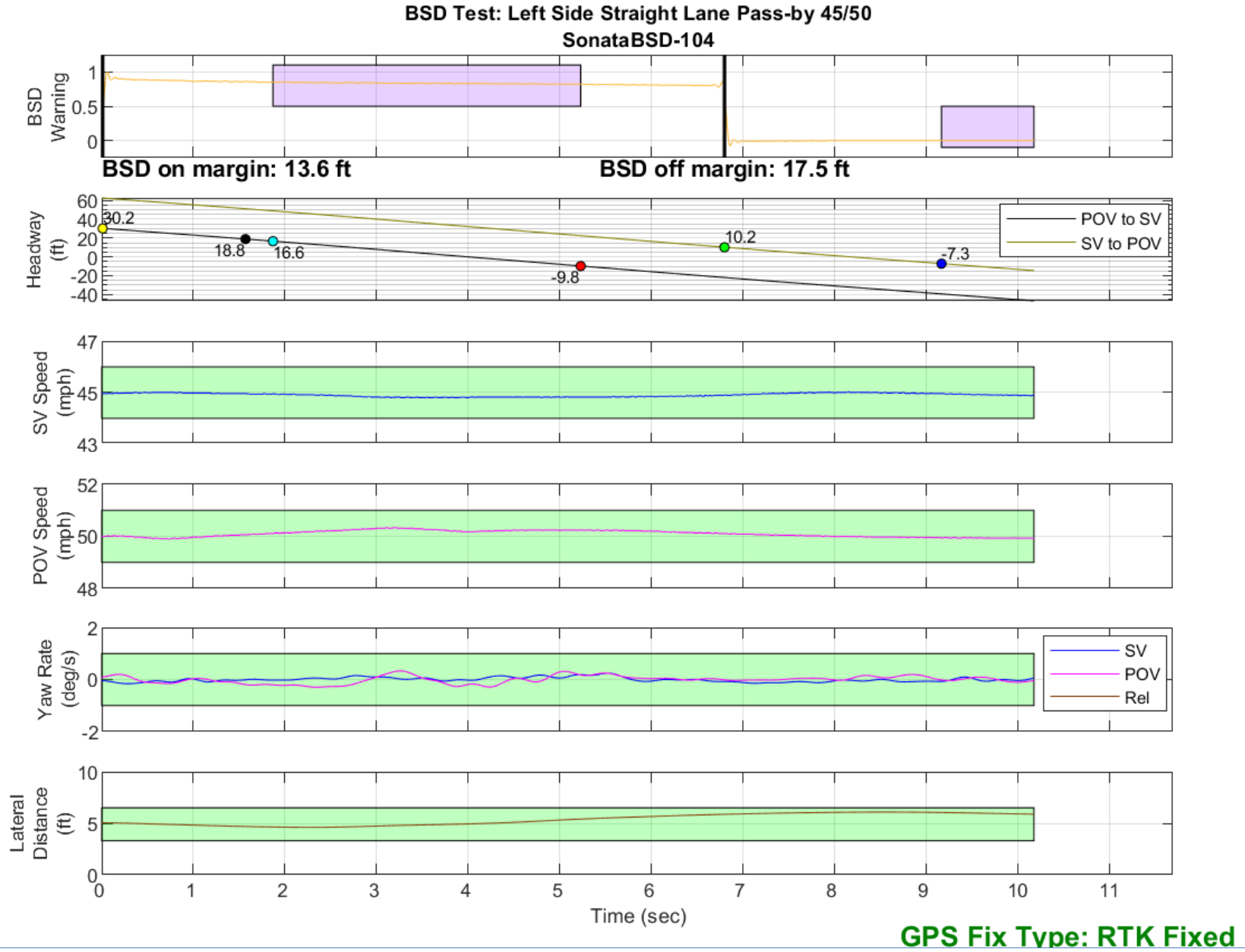


Figure D31. BSD Run 104, Straight Lane Pass-by, SV 45 mph, POV 50 mph

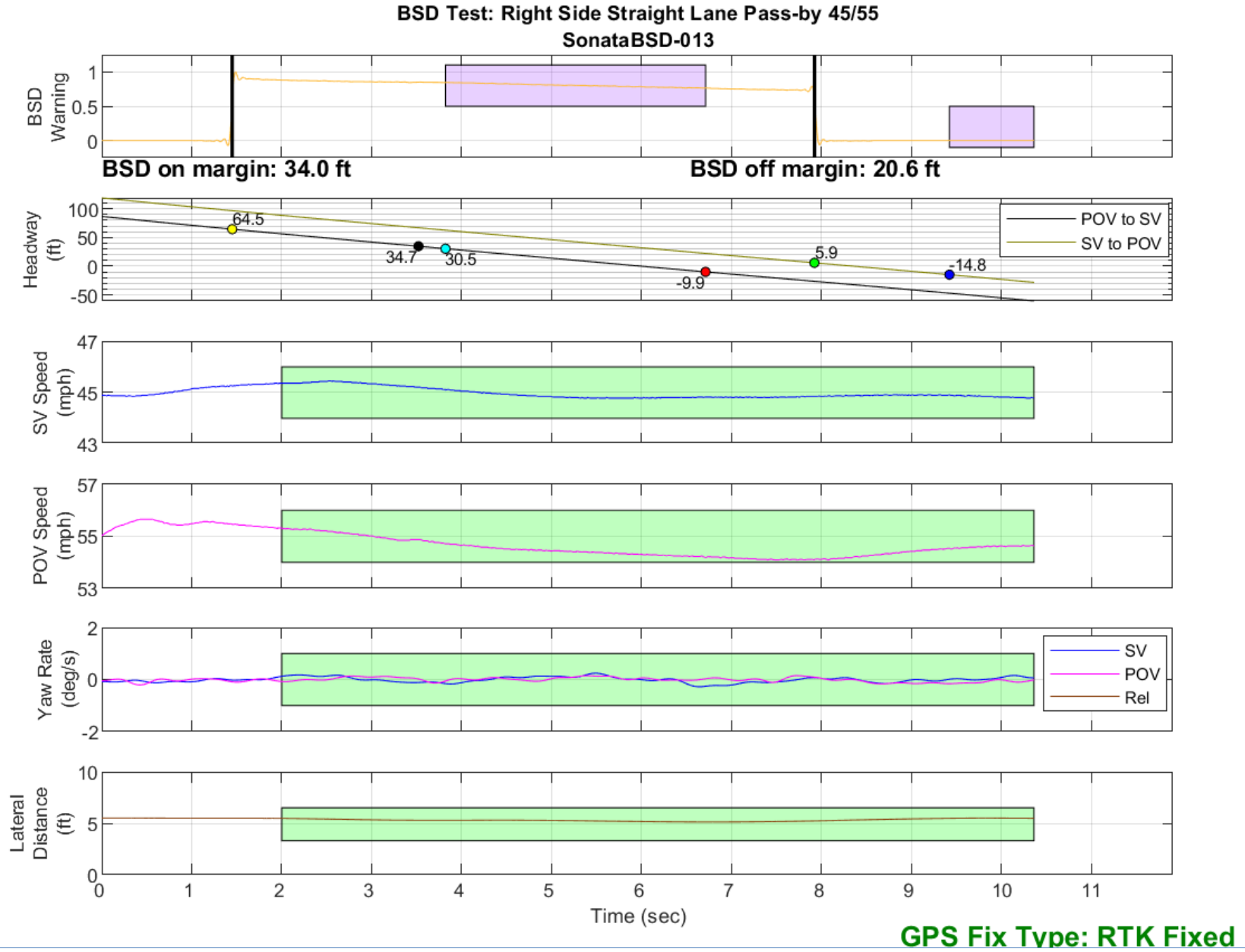


Figure D32. BSD Run 13, Straight Lane Pass-by, SV 45 mph, POV 55 mph

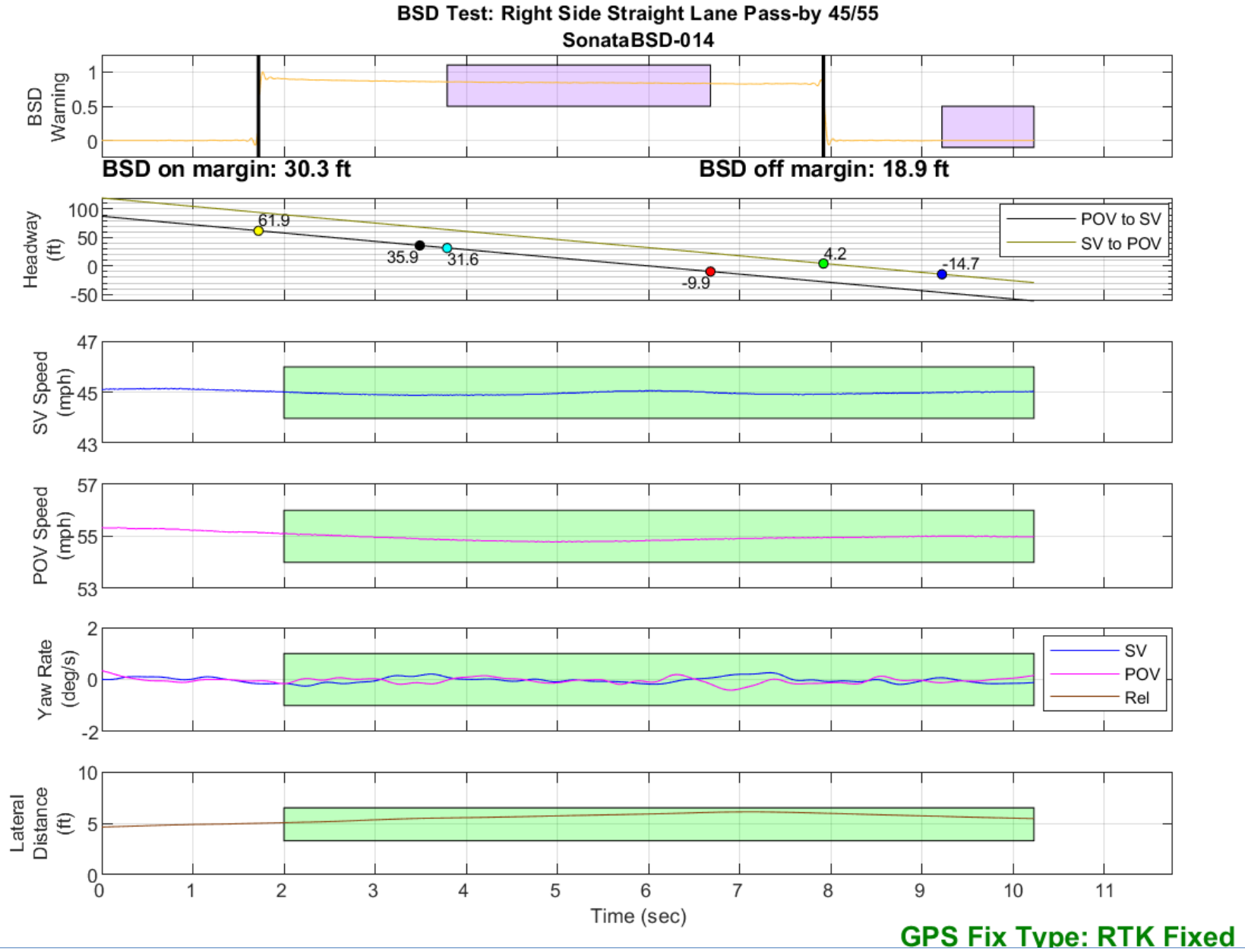


Figure D33. BSD Run 14, Straight Lane Pass-by, SV 45 mph, POV 55 mph

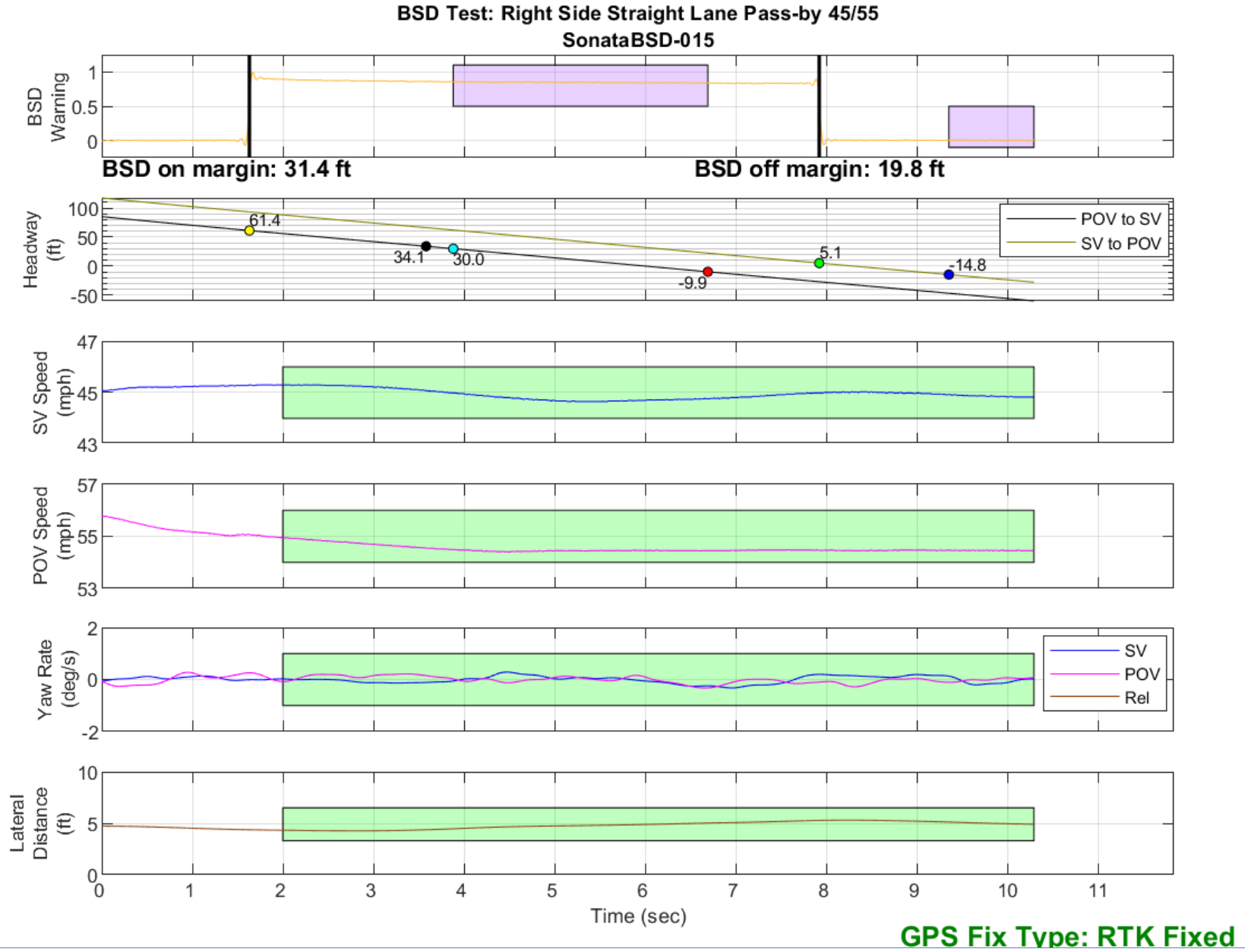


Figure D34. BSD Run 15, Straight Lane Pass-by, SV 45 mph, POV 55 mph

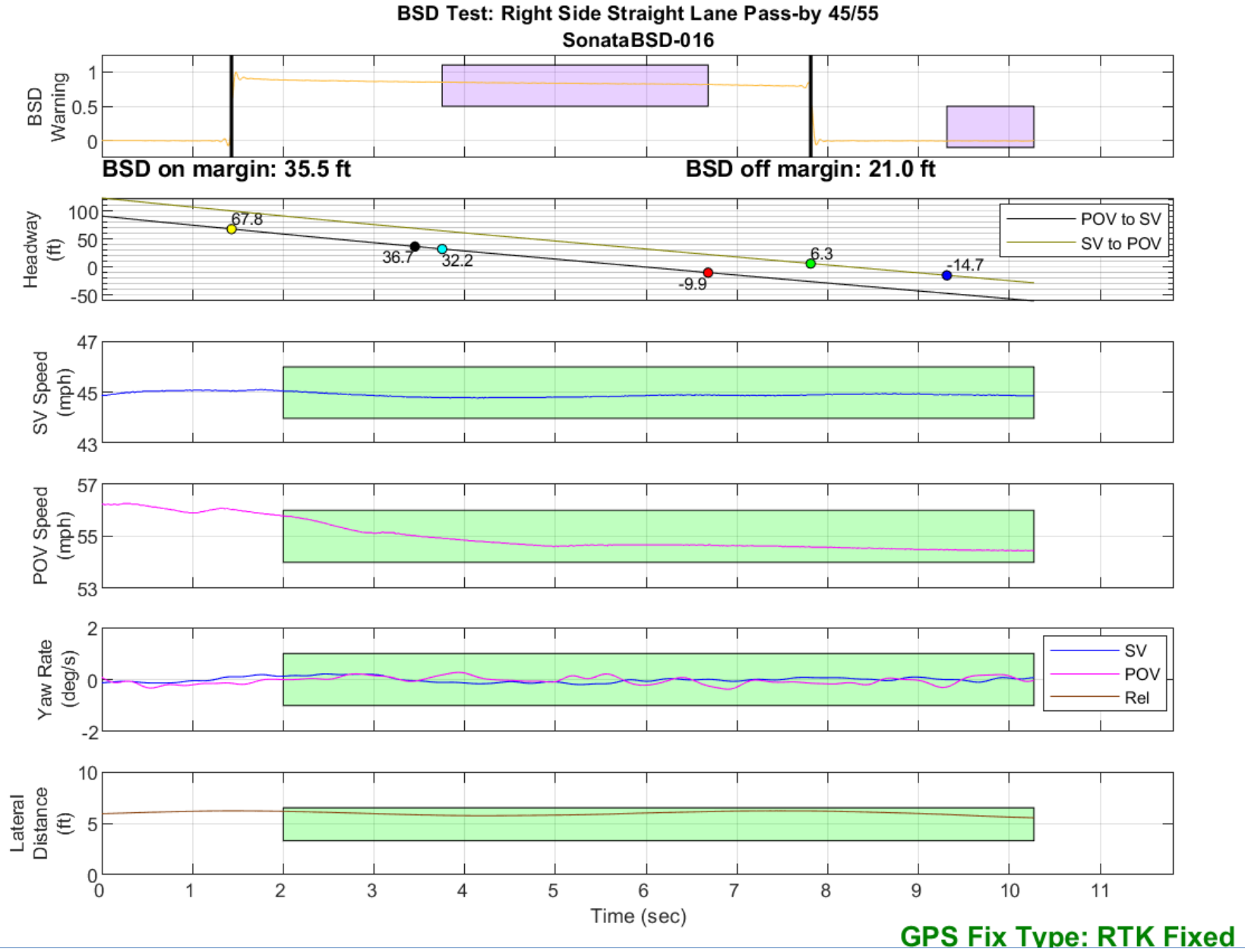


Figure D35. BSD Run 16, Straight Lane Pass-by, SV 45 mph, POV 55 mph

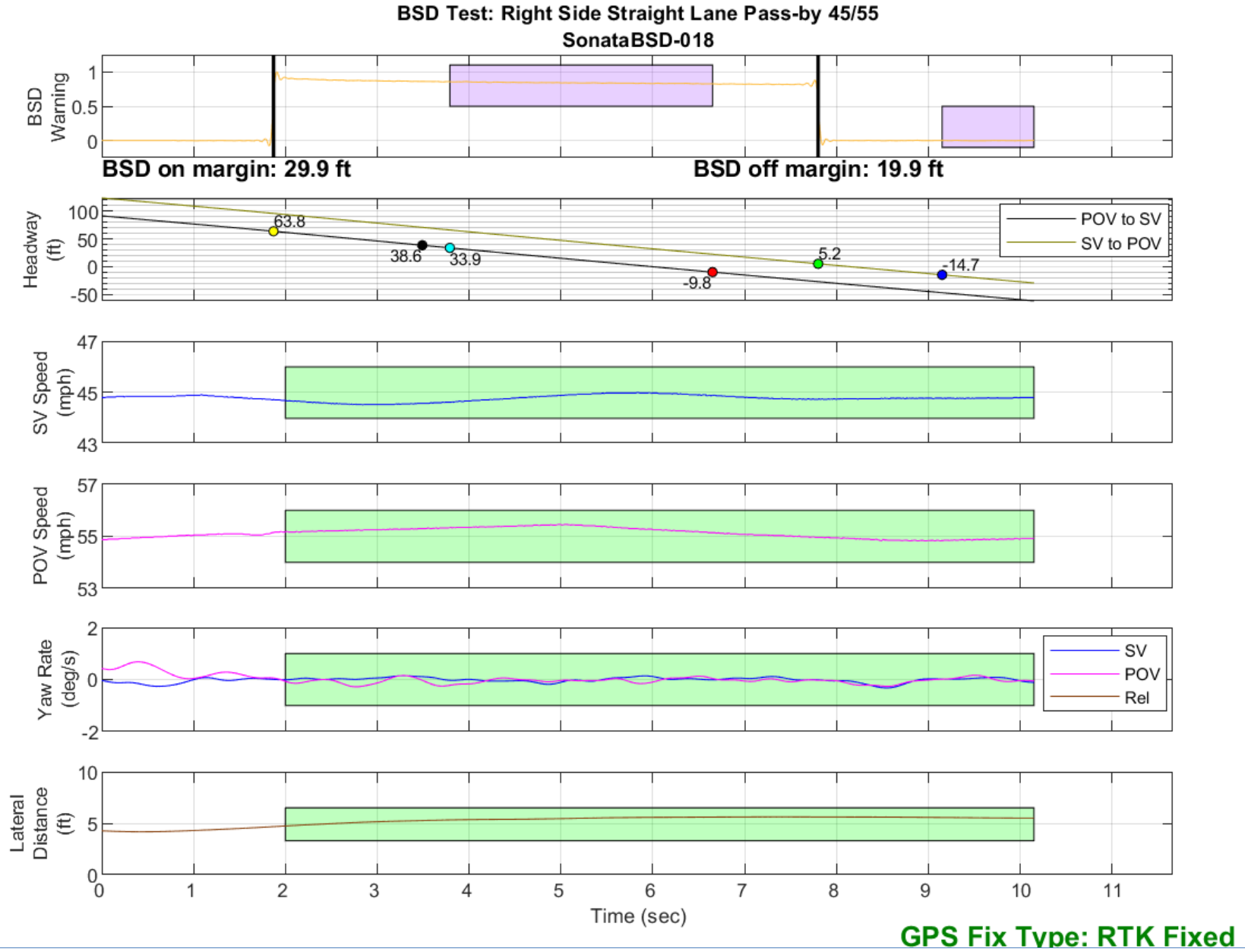


Figure D36. BSD Run 18, Straight Lane Pass-by, SV 45 mph, POV 55 mph

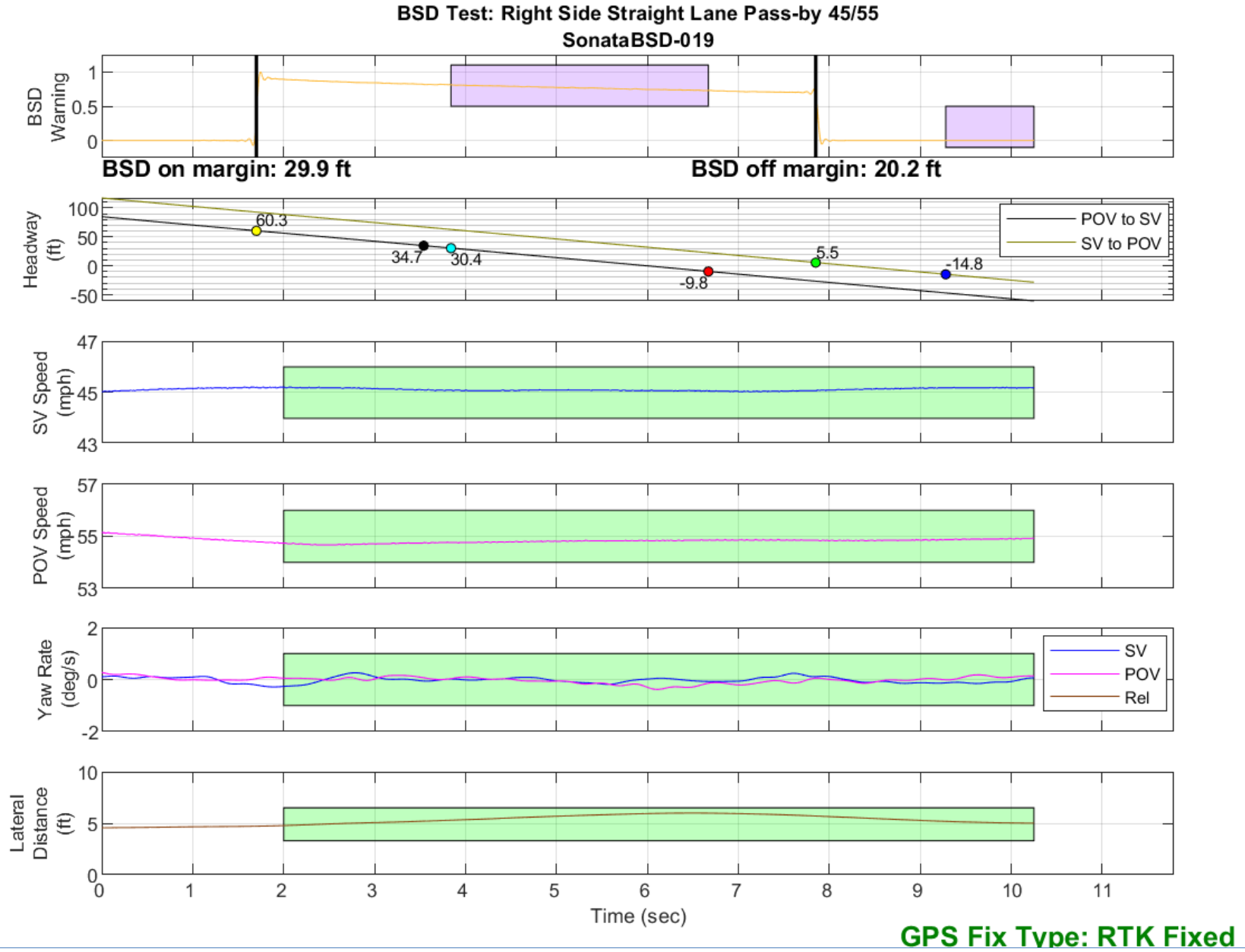


Figure D37. BSD Run 19, Straight Lane Pass-by, SV 45 mph, POV 55 mph

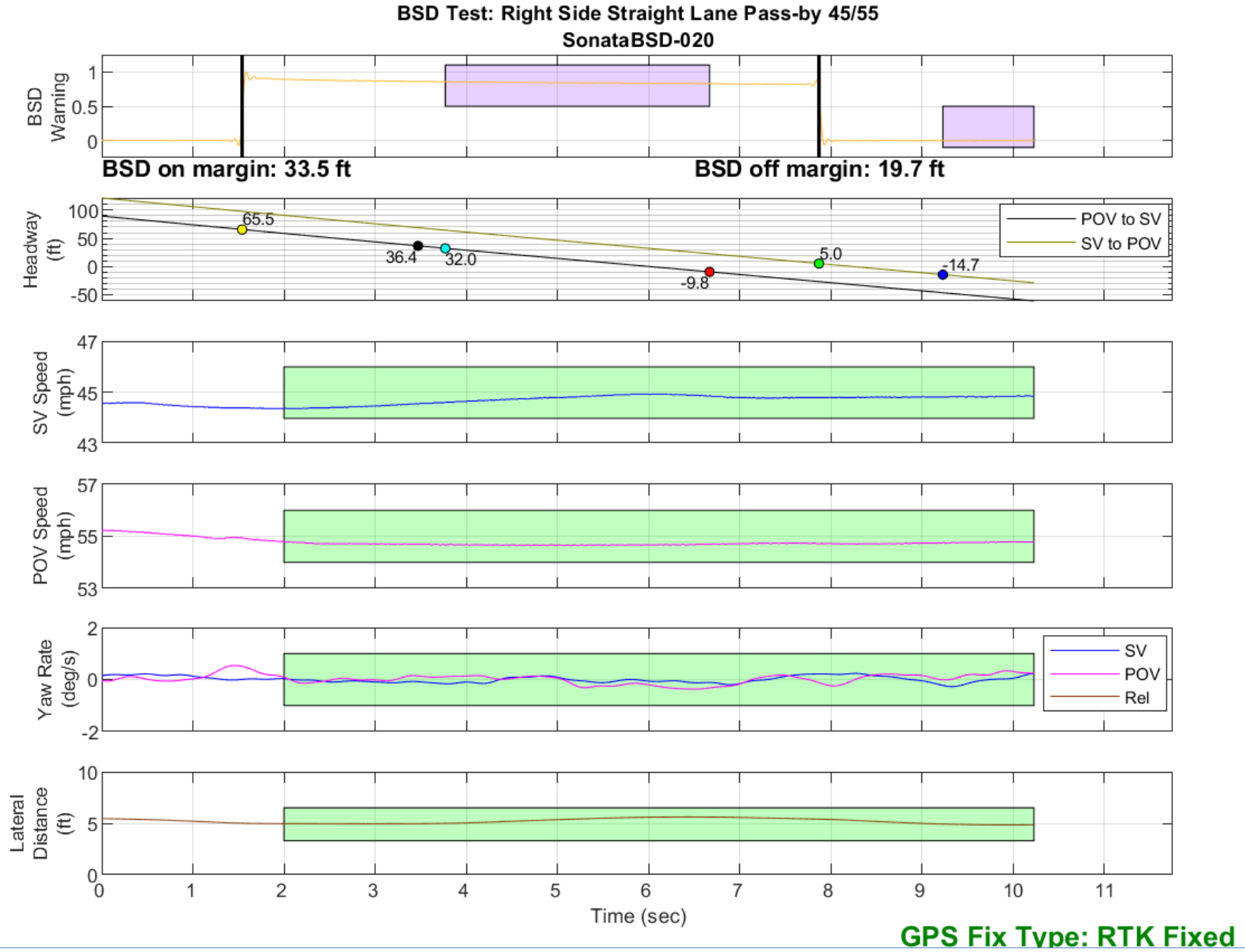


Figure D38. BSD Run 20, Straight Lane Pass-by, SV 45 mph, POV 55 mph

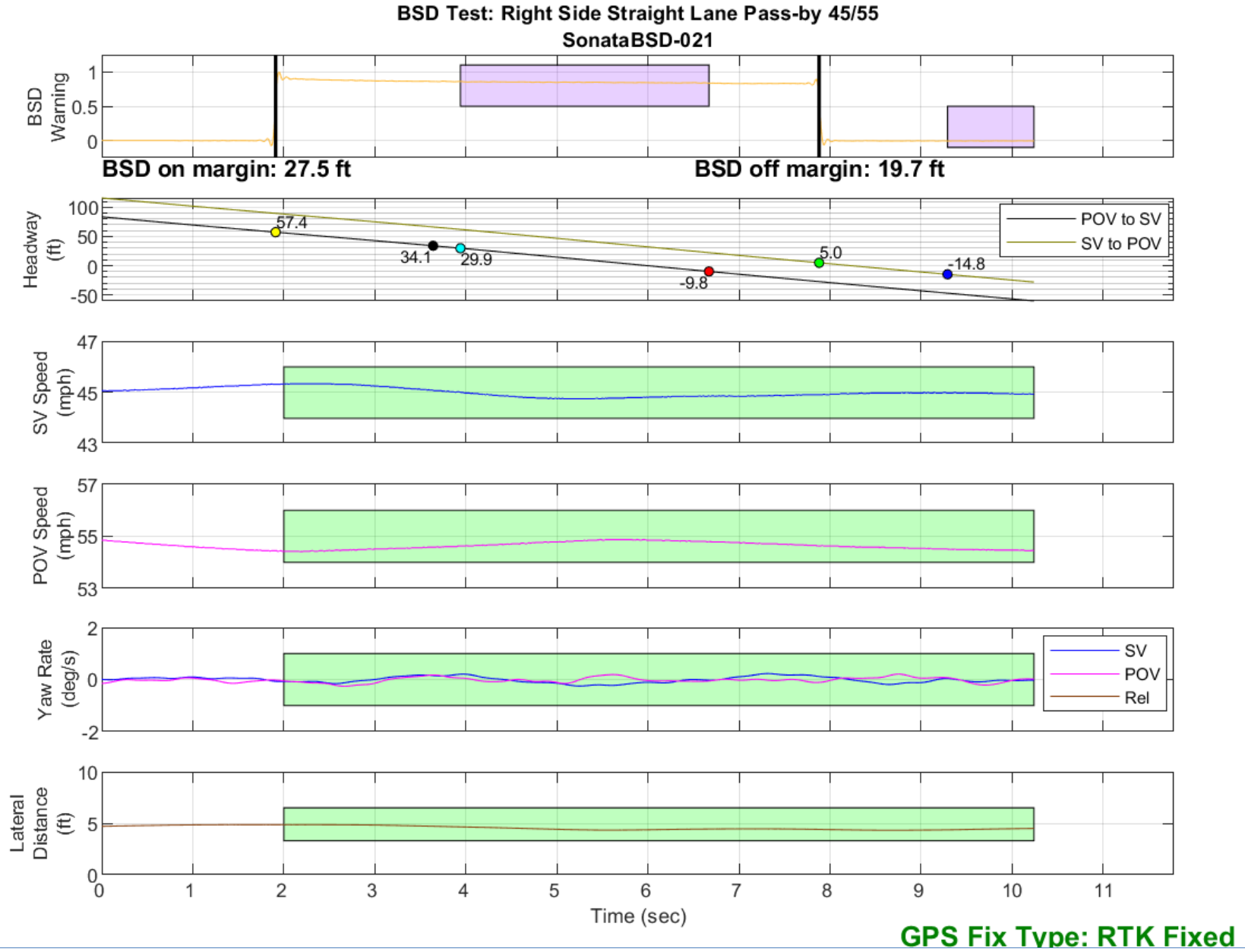


Figure D39. BSD Run 21, Straight Lane Pass-by, SV 45 mph, POV 55 mph

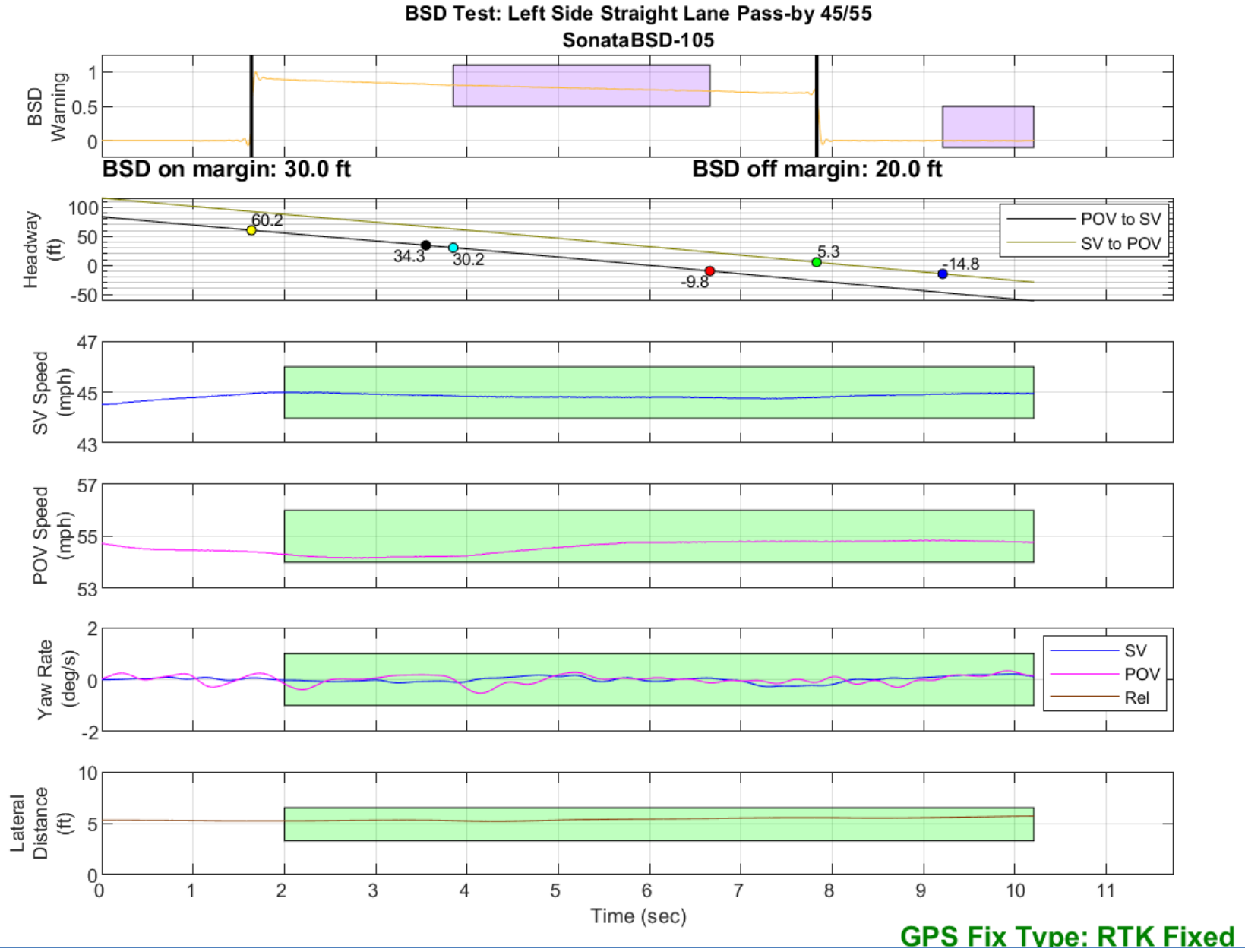


Figure D40. BSD Run 105, Straight Lane Pass-by, SV 45 mph, POV 55 mph

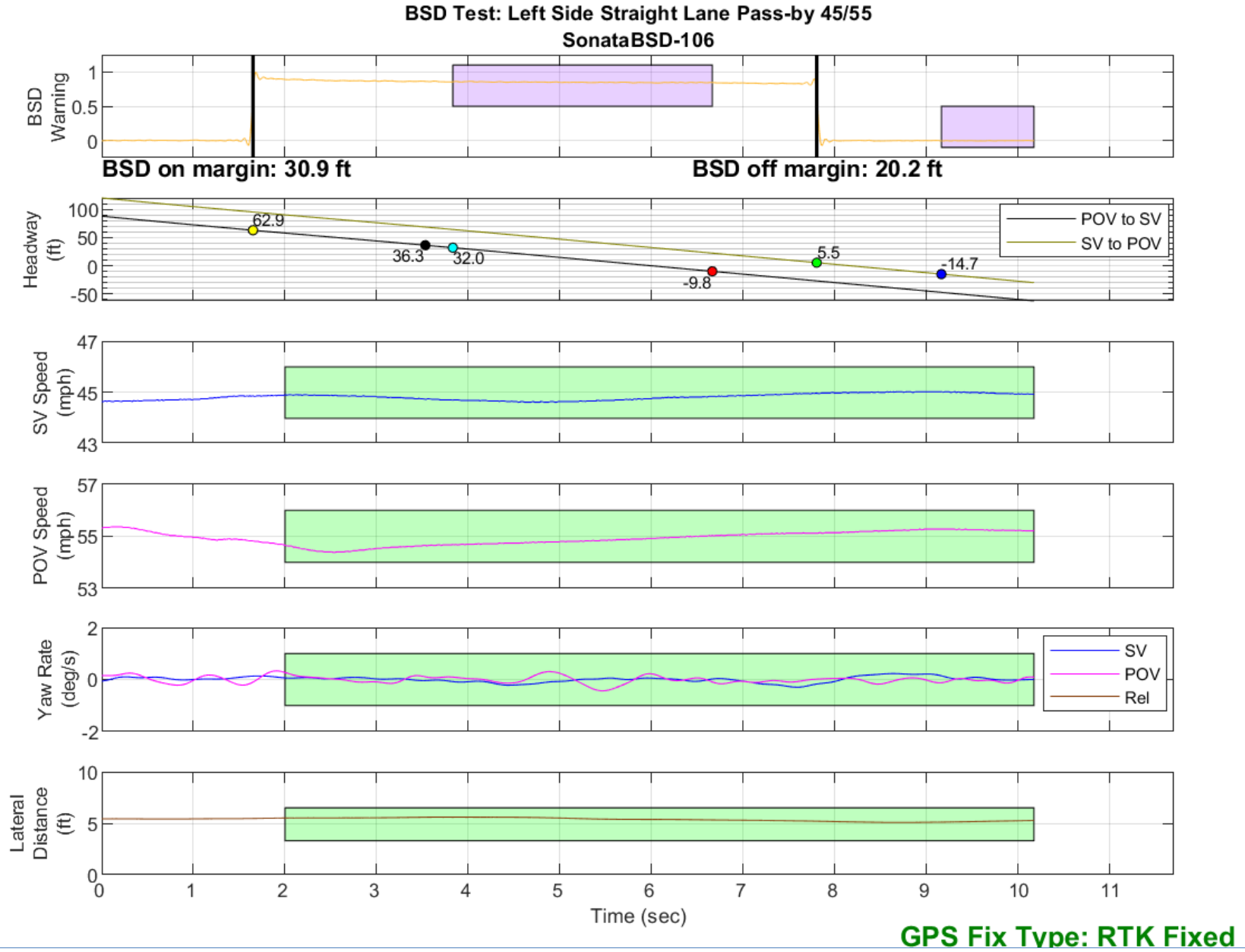


Figure D41. BSD Run 106, Straight Lane Pass-by, SV 45 mph, POV 55 mph

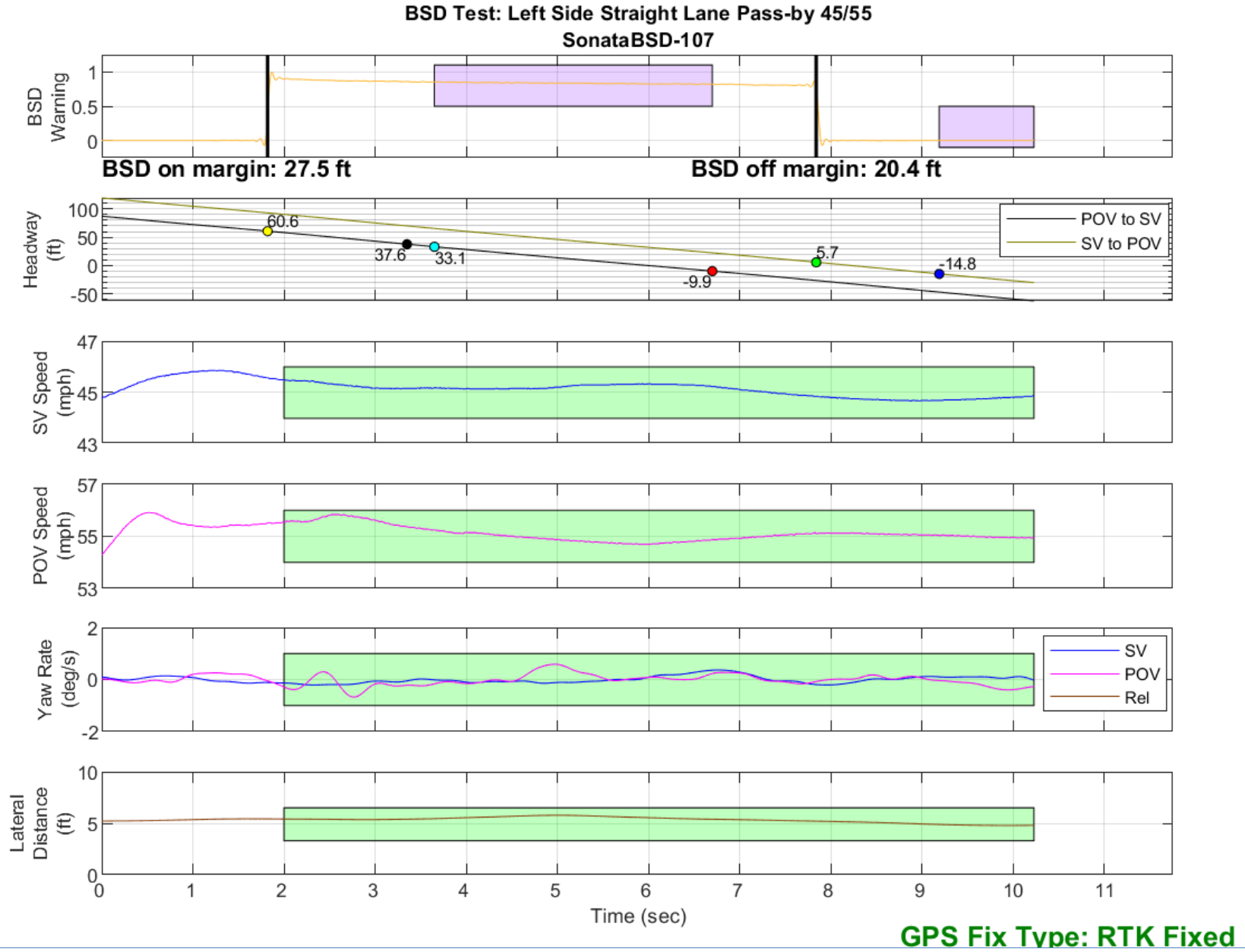


Figure D42. BSD Run 107, Straight Lane Pass-by, SV 45 mph, POV 55 mph

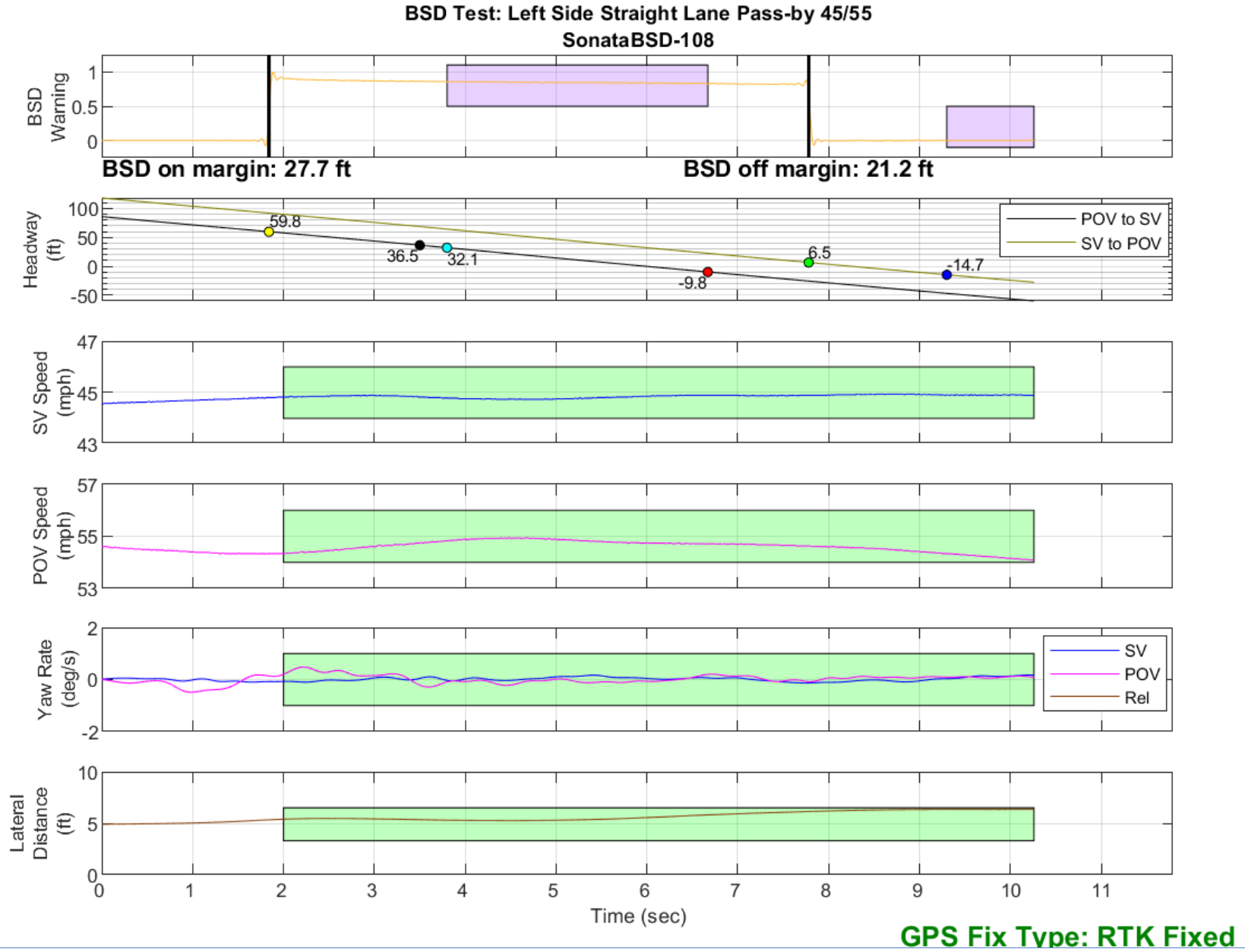


Figure D43. BSD Run 108, Straight Lane Pass-by, SV 45 mph, POV 55 mph

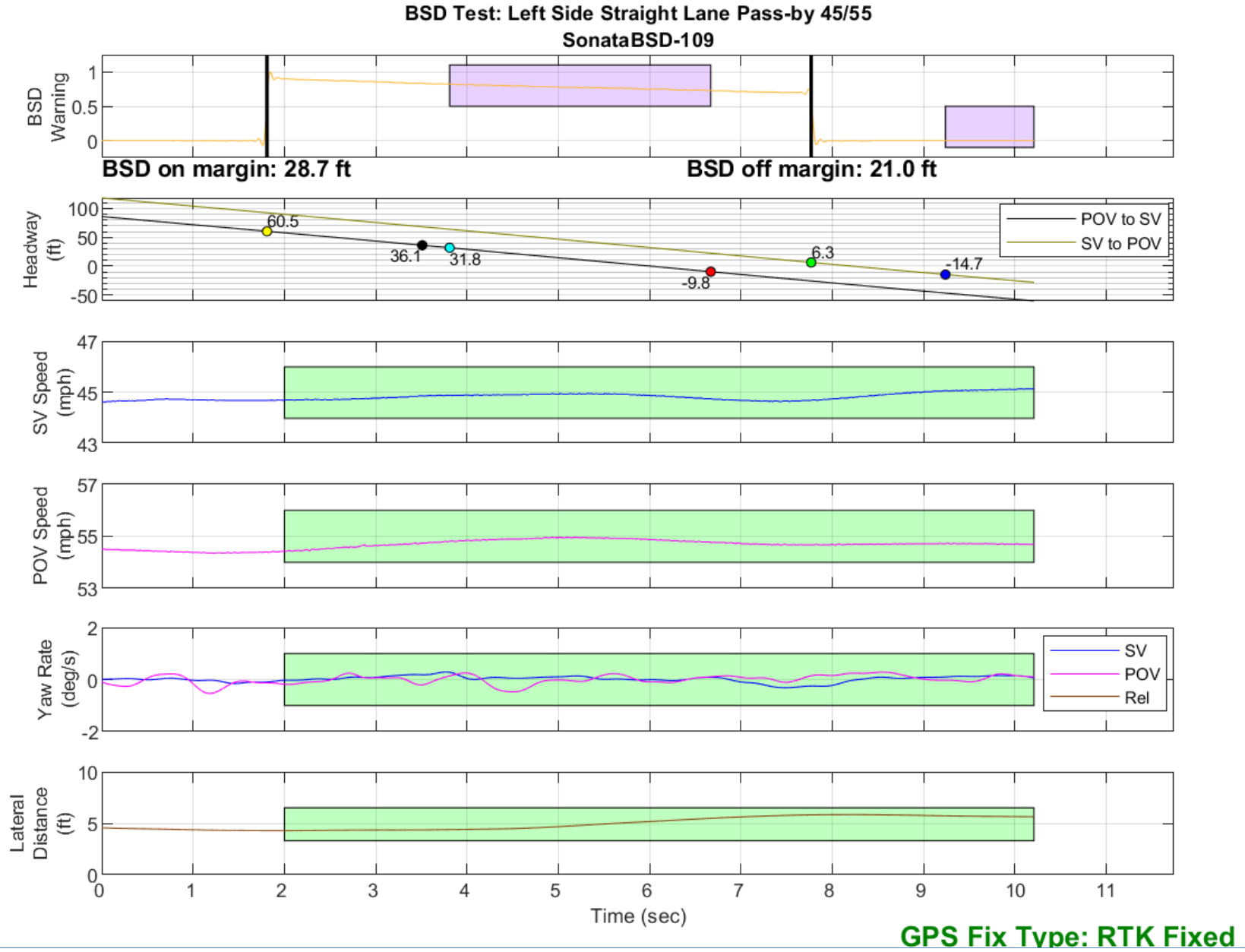


Figure D44. BSD Run 109, Straight Lane Pass-by, SV 45 mph, POV 55 mph

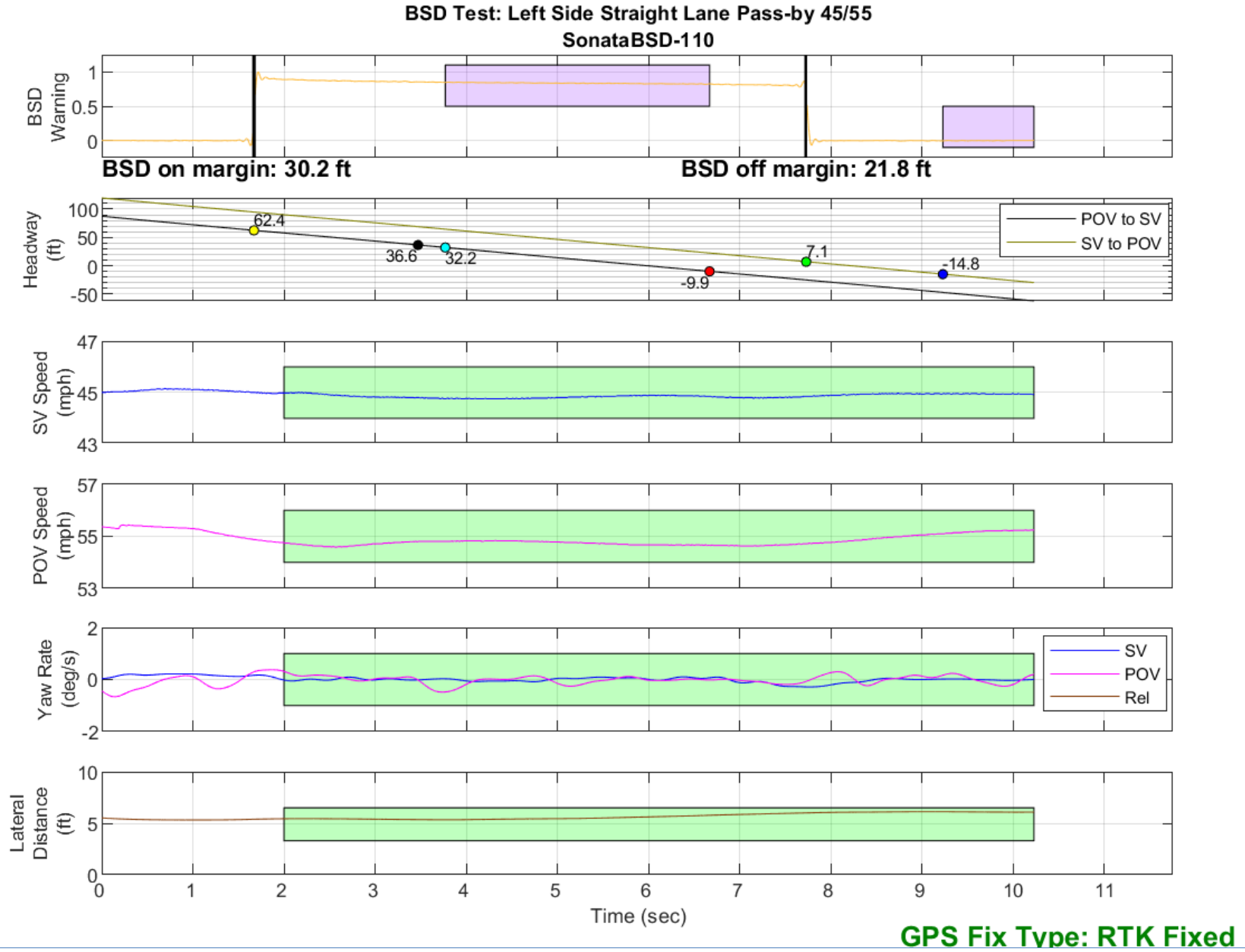


Figure D45. BSD Run 110, Straight Lane Pass-by, SV 45 mph, POV 55 mph

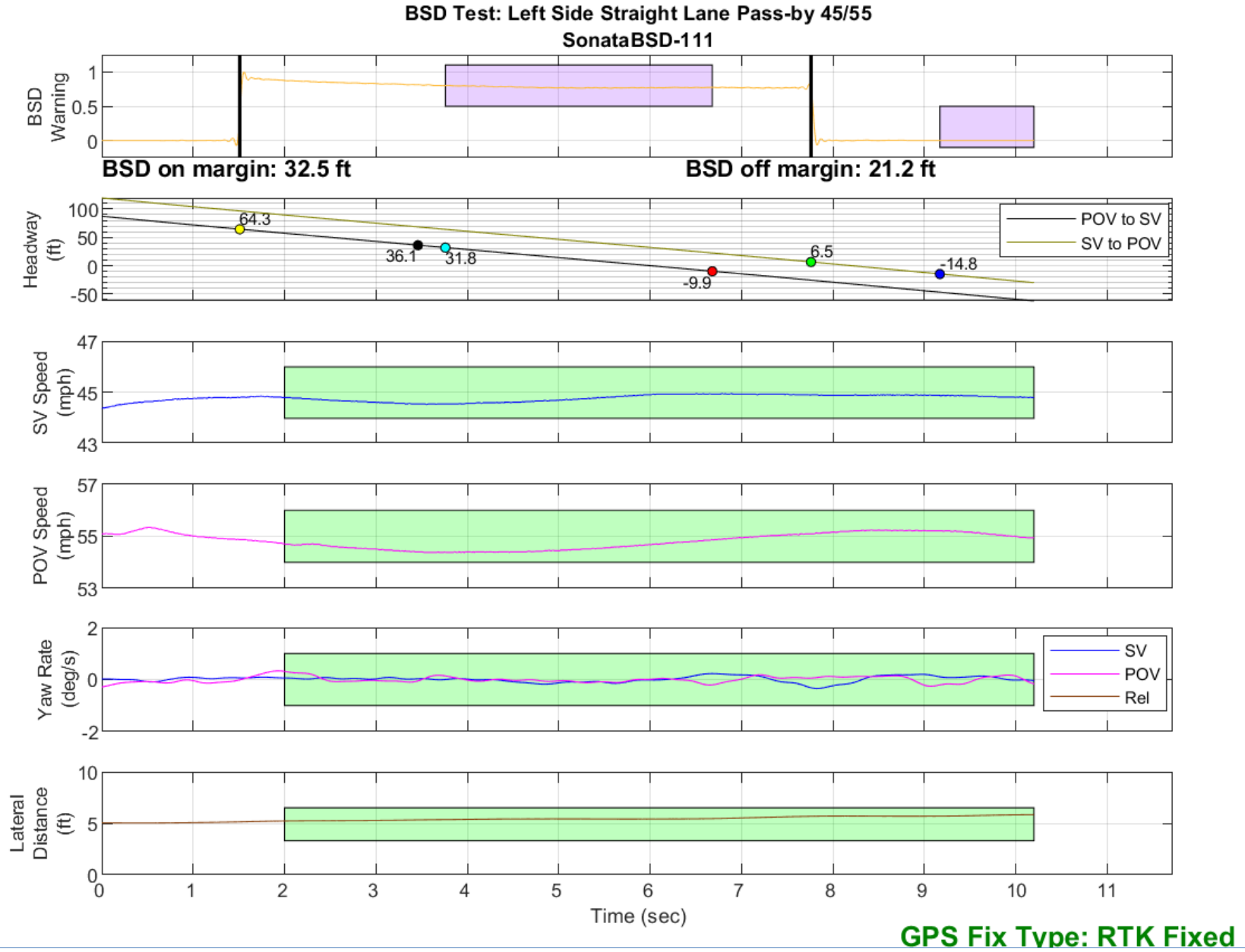


Figure D46. BSD Run 111, Straight Lane Pass-by, SV 45 mph, POV 55 mph

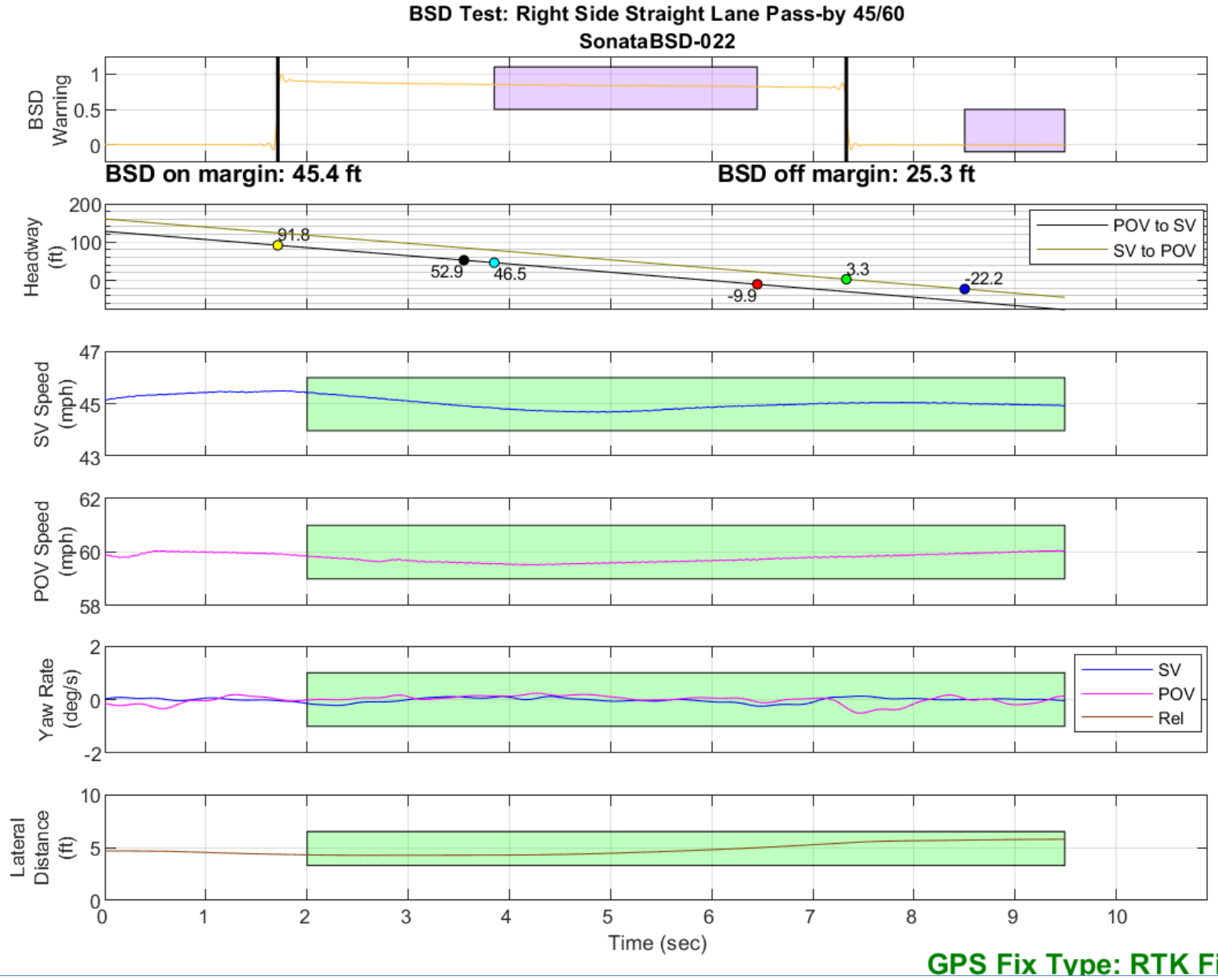


Figure D47. BSD Run 22, Straight Lane Pass-by, SV 45 mph, POV 60 mph

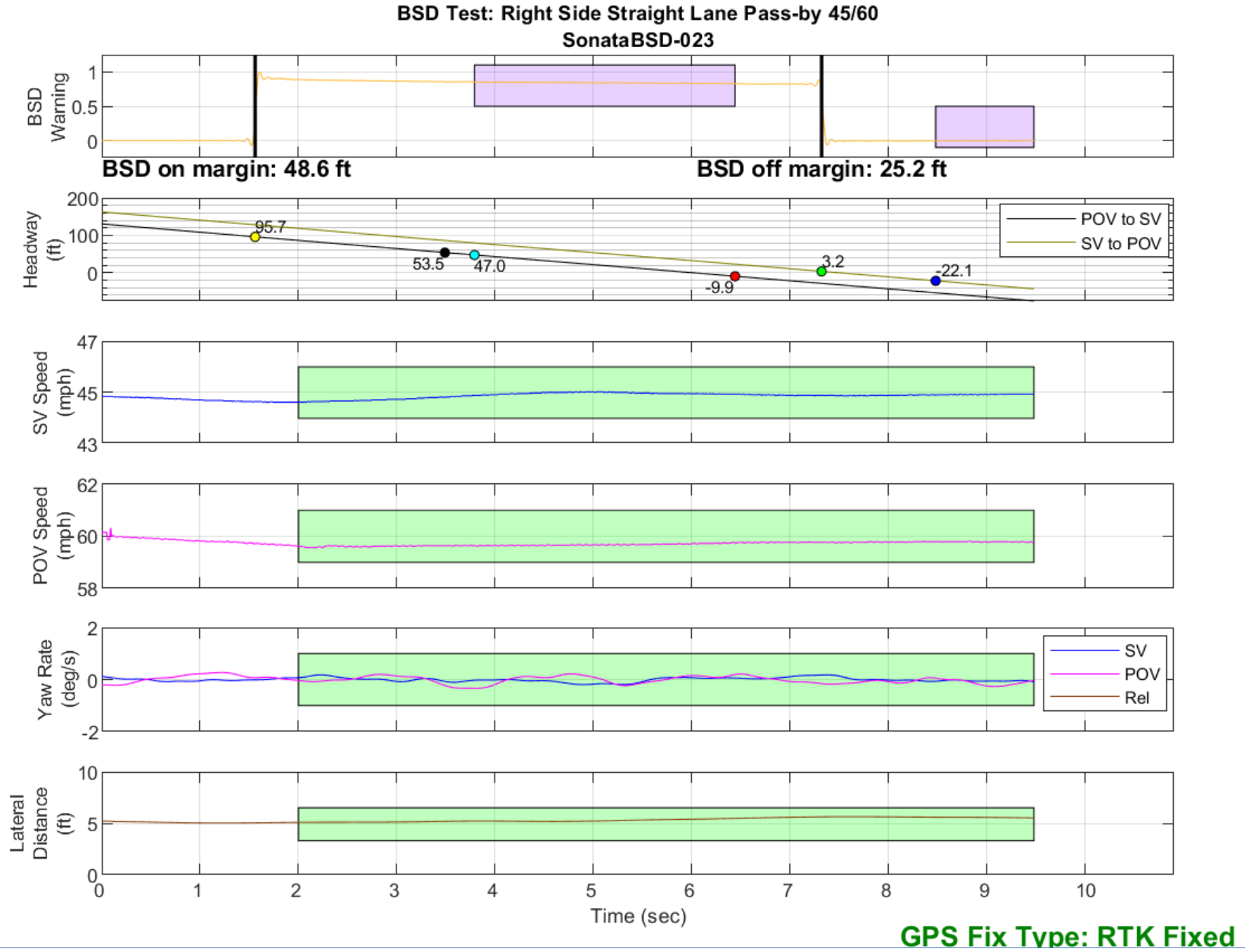


Figure D48. BSD Run 23, Straight Lane Pass-by, SV 45 mph, POV 60 mph

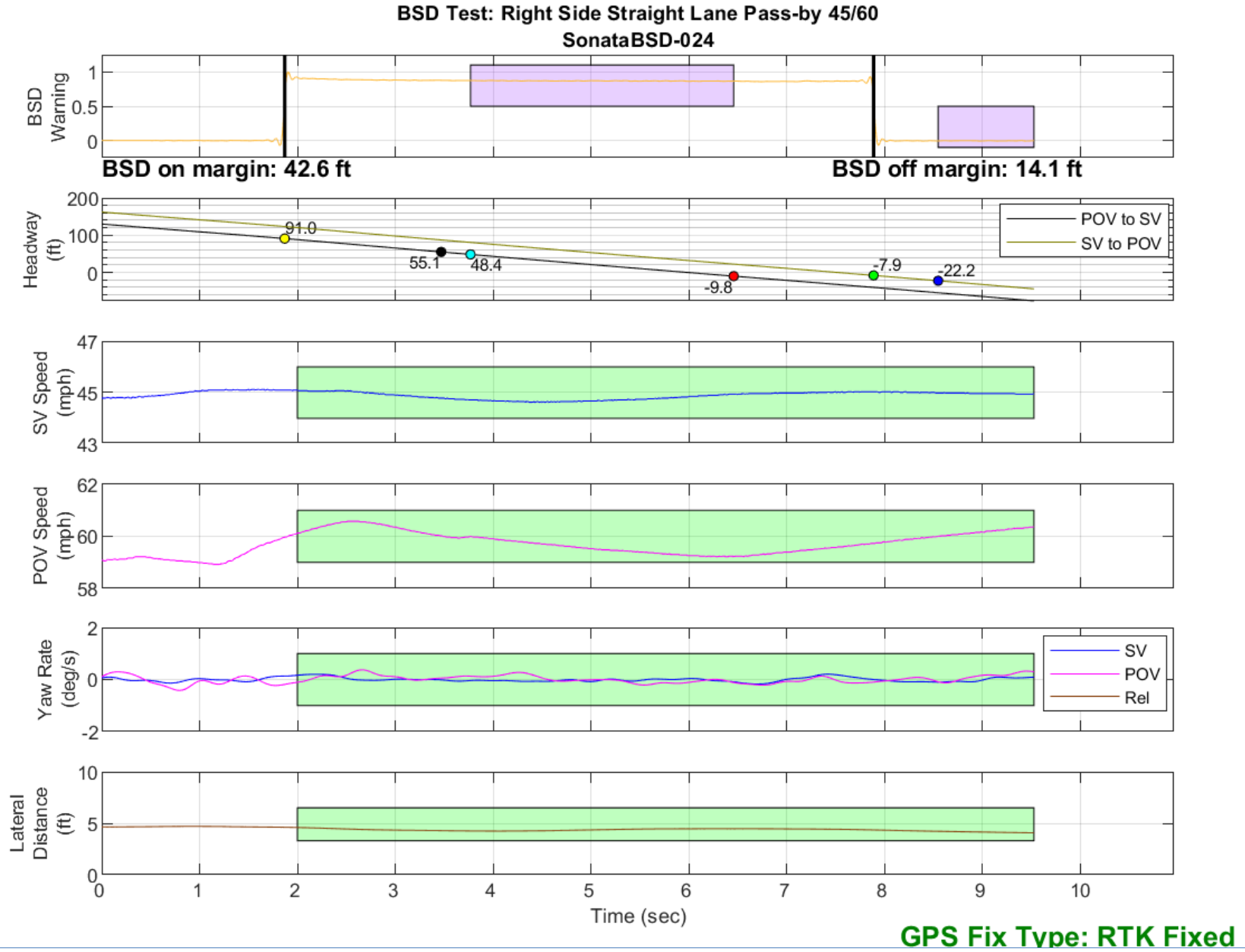


Figure D49. BSD Run 24, Straight Lane Pass-by, SV 45 mph, POV 60 mph

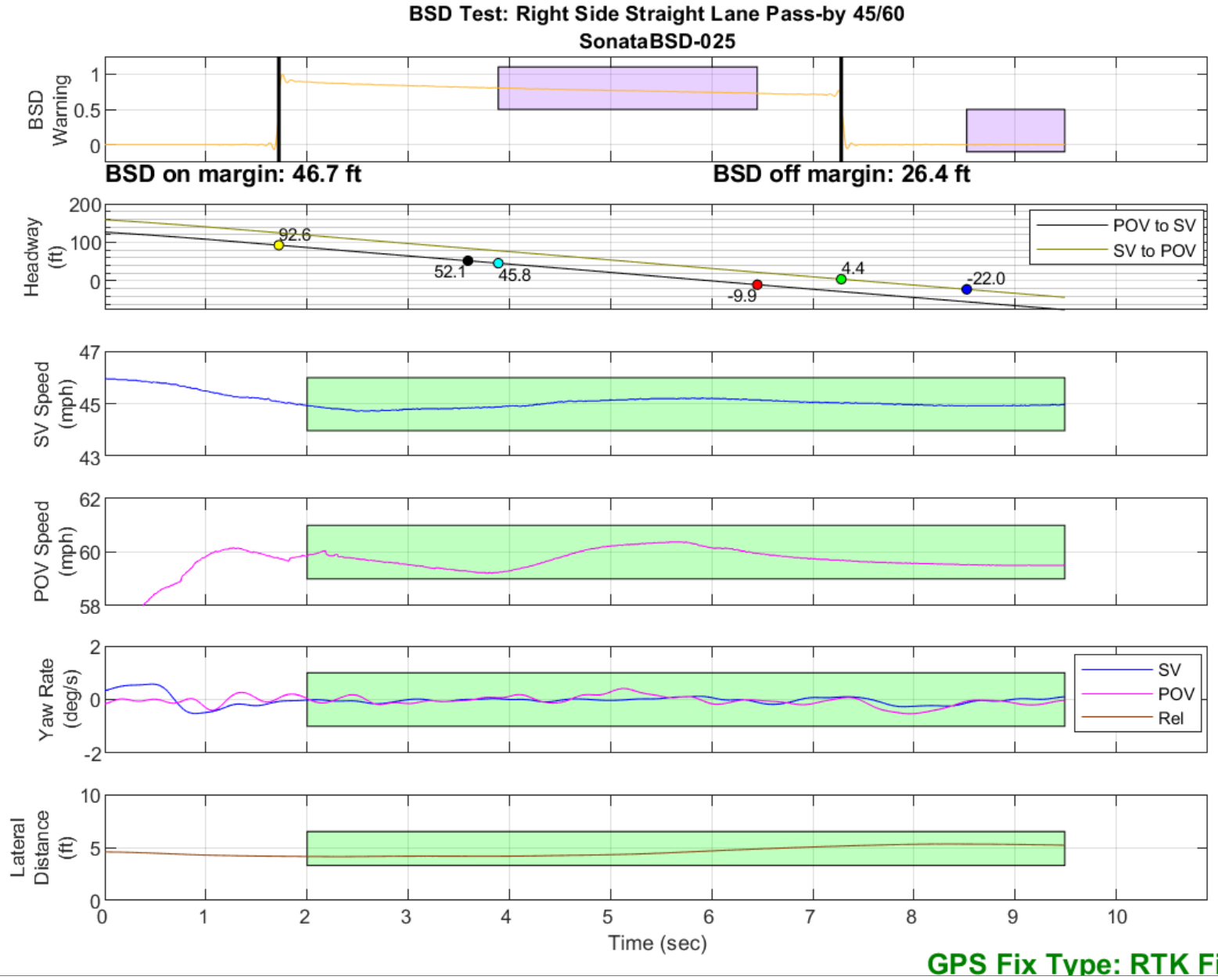


Figure D50. BSD Run 25, Straight Lane Pass-by, SV 45 mph, POV 60 mph

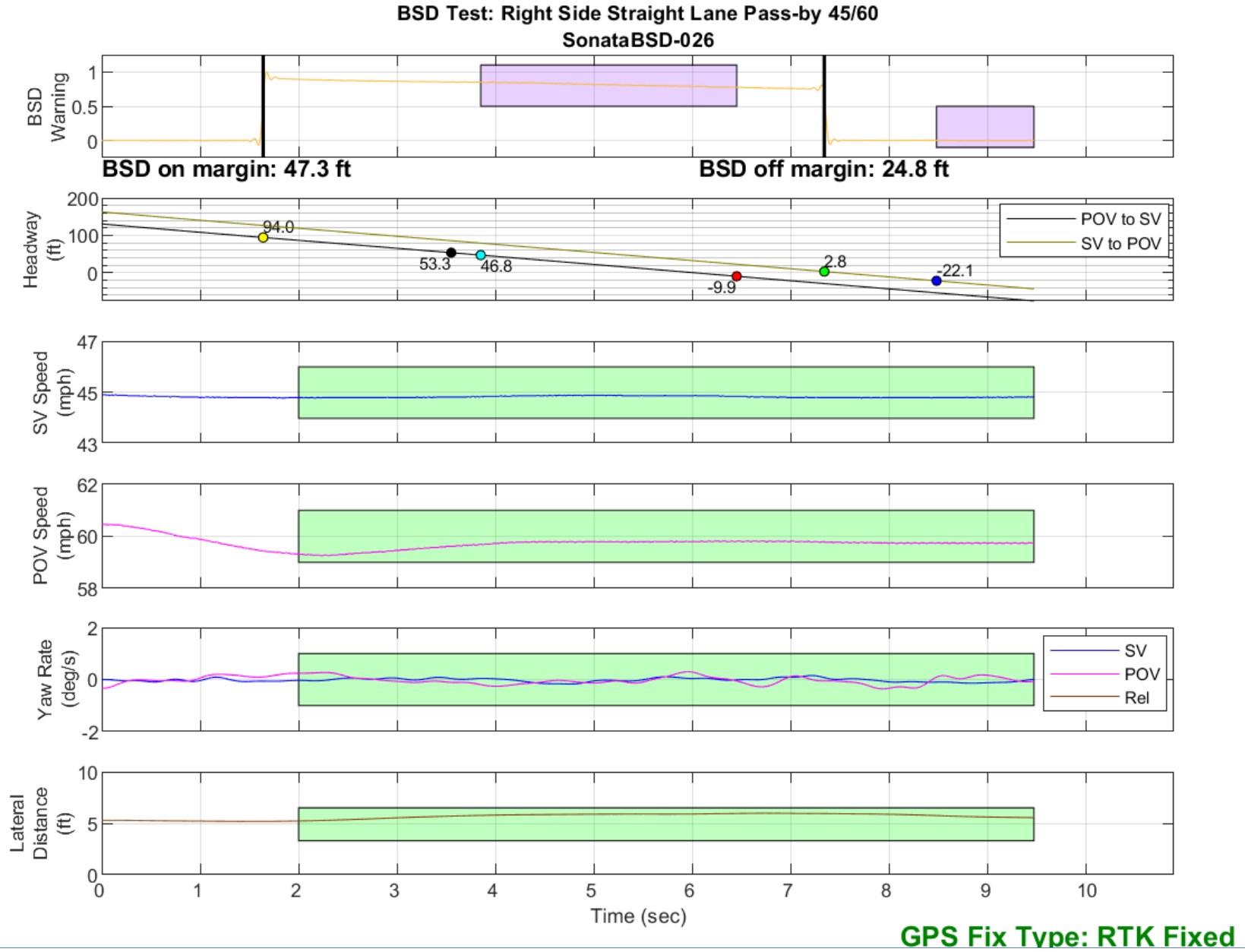


Figure D51. BSD Run 26, Straight Lane Pass-by, SV 45 mph, POV 60 mph

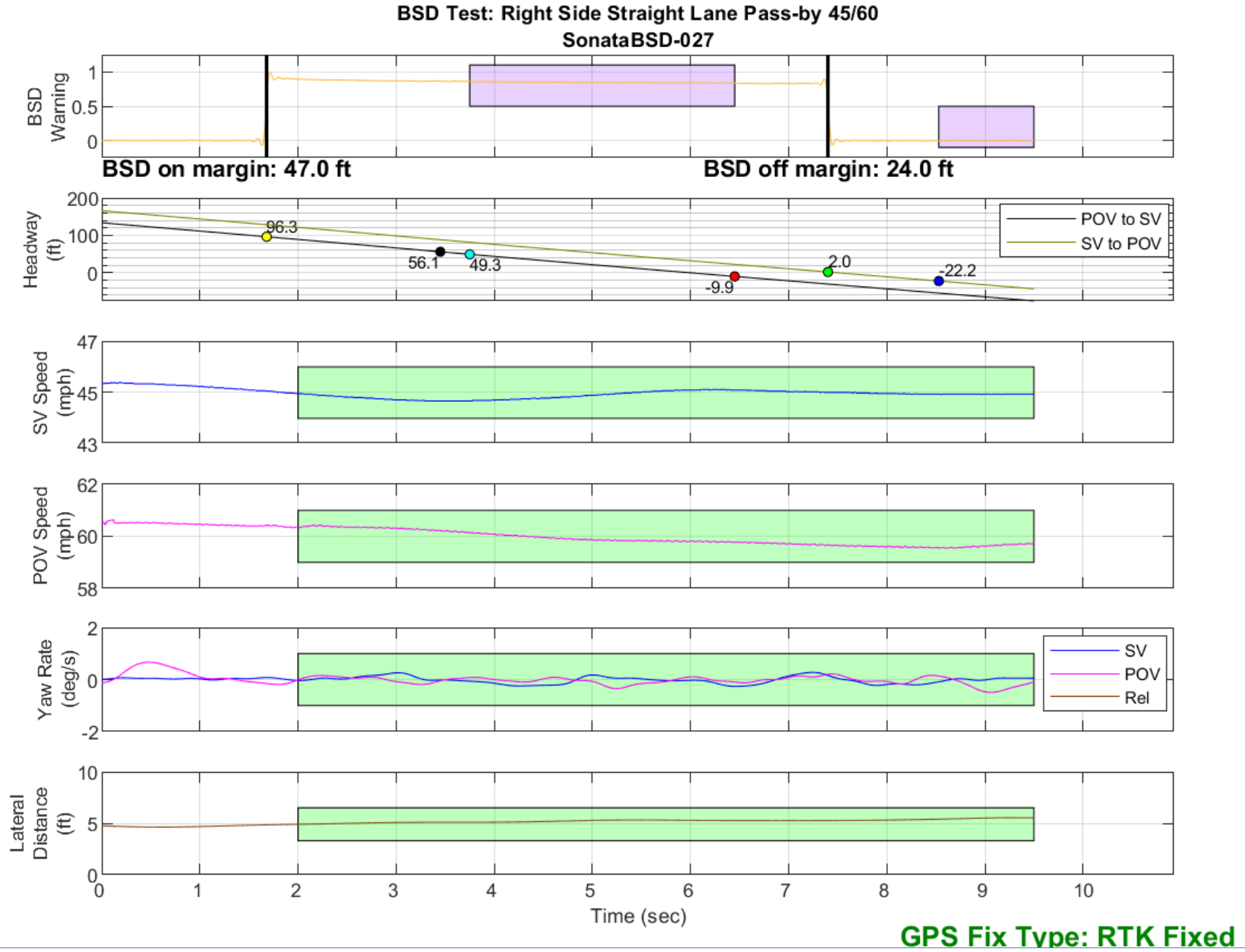


Figure D52. BSD Run 27, Straight Lane Pass-by, SV 45 mph, POV 60 mph

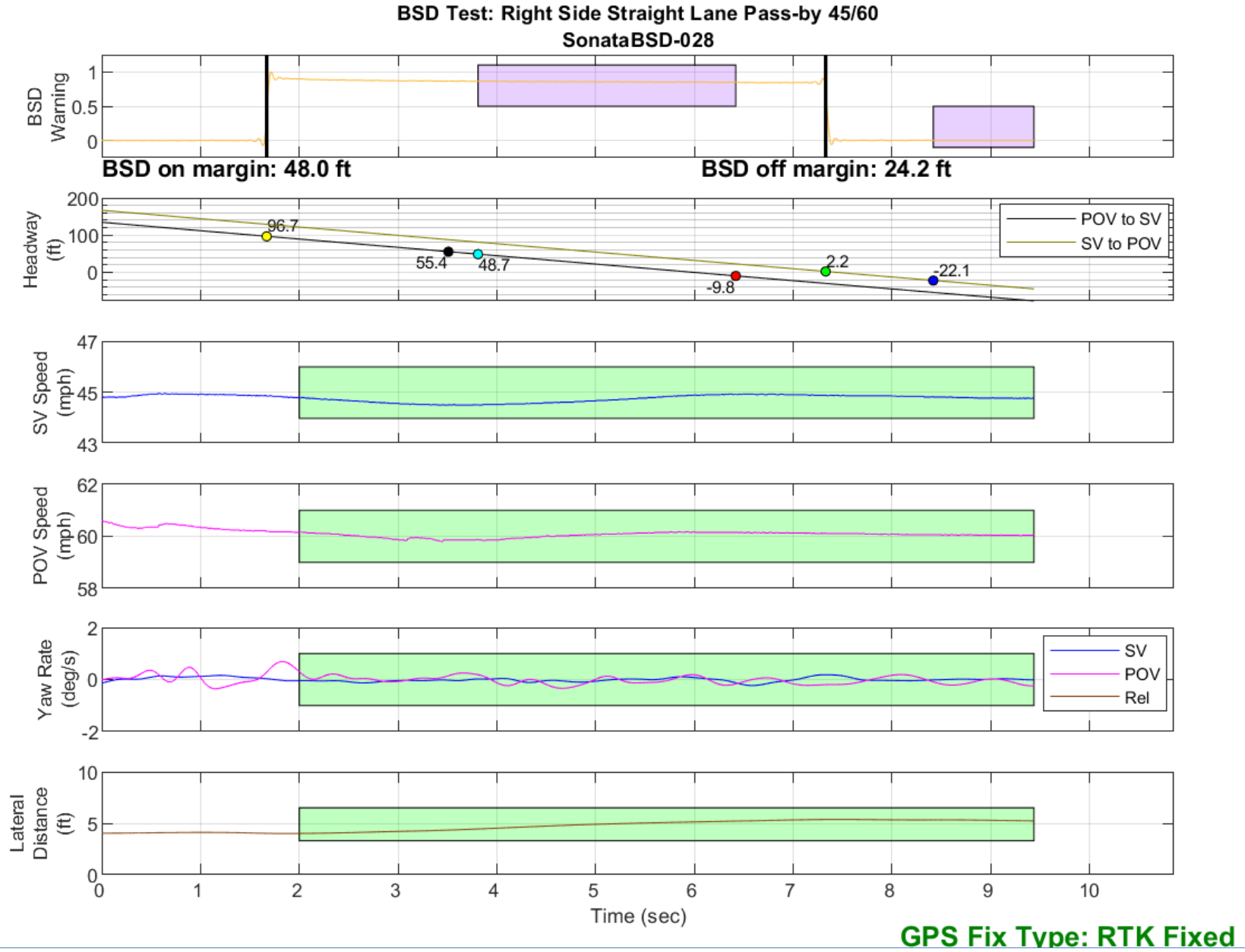


Figure D53. BSD Run 28, Straight Lane Pass-by, SV 45 mph, POV 60 mph

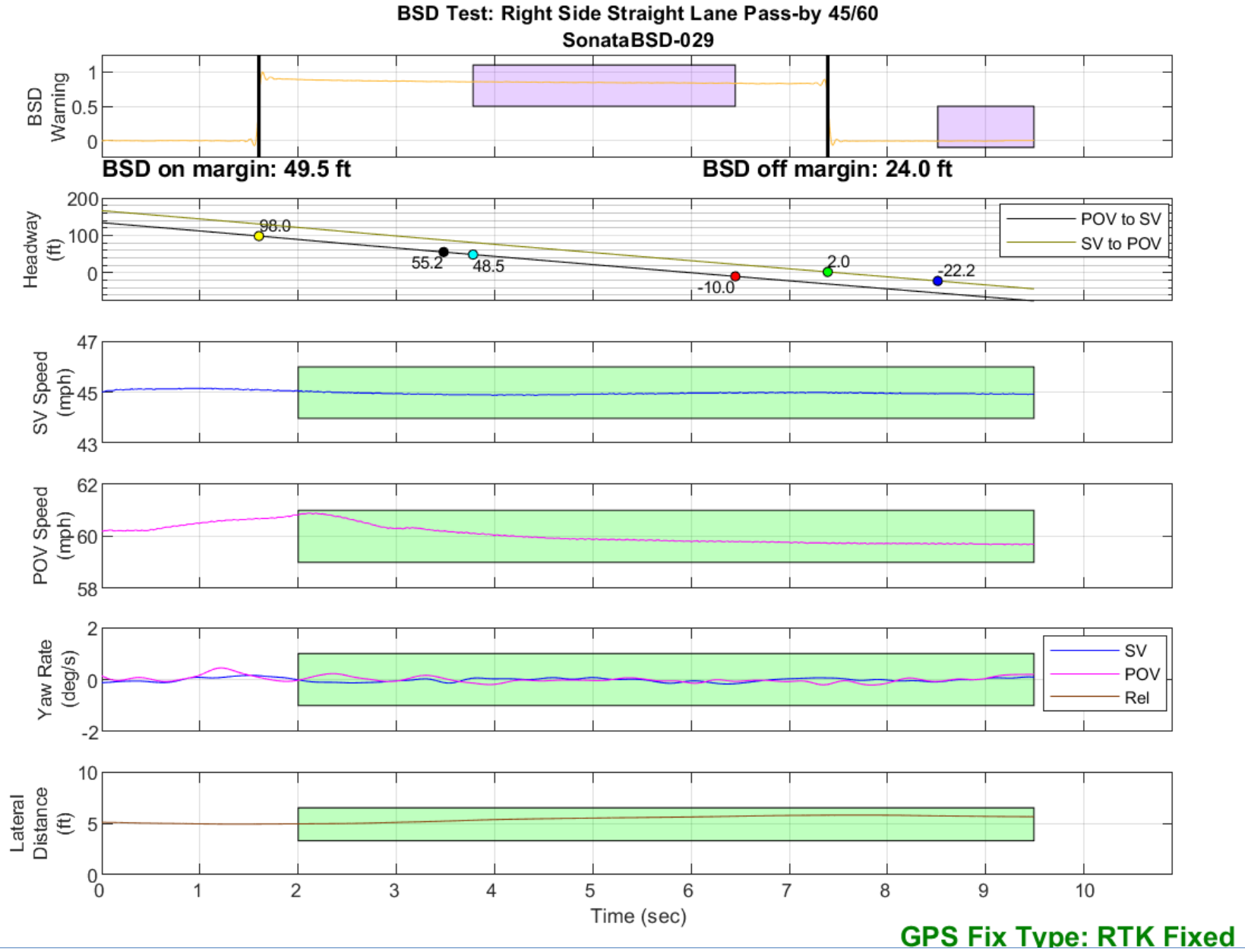


Figure D54. BSD Run 29, Straight Lane Pass-by, SV 45 mph, POV 60 mph

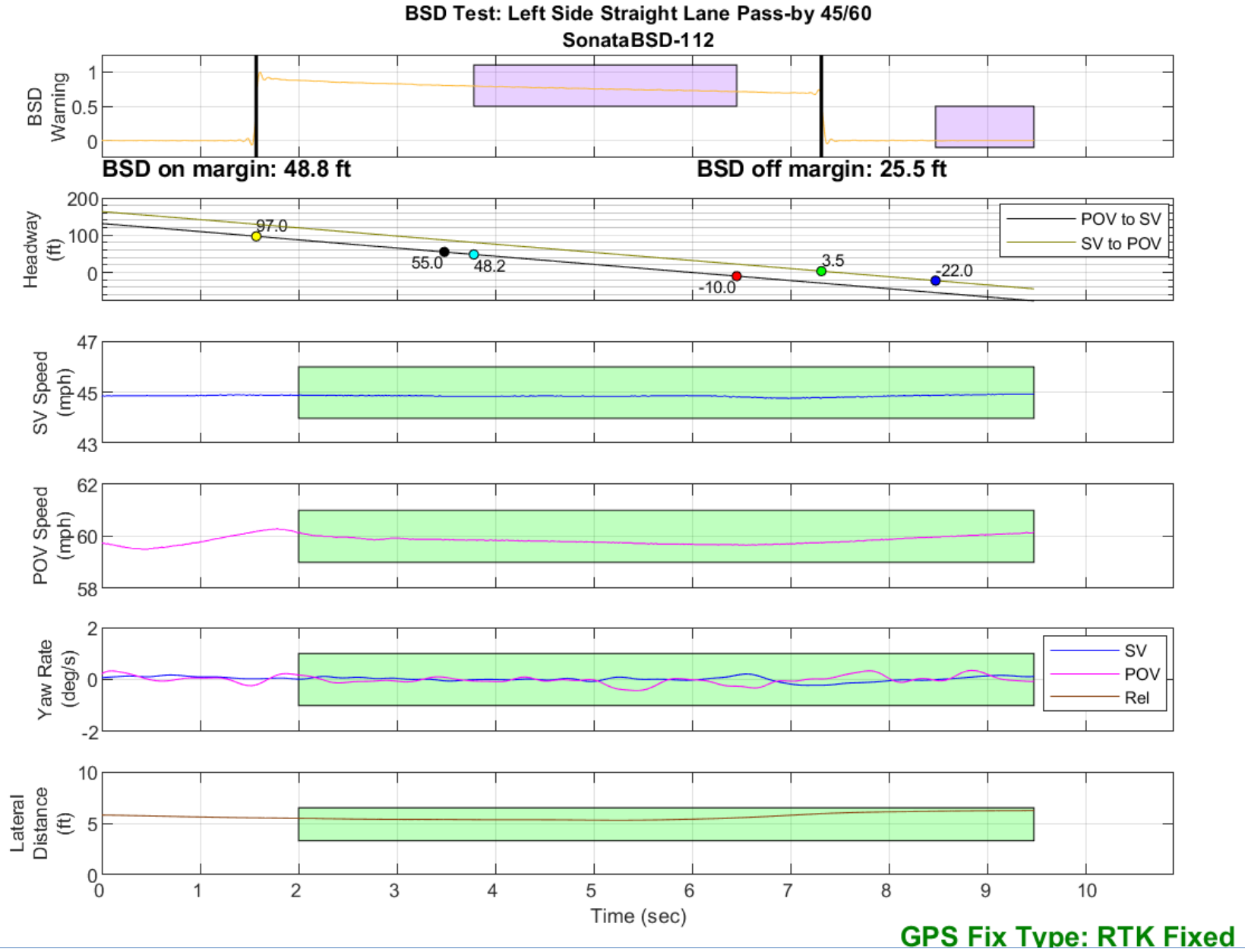


Figure D55. BSD Run 112, Straight Lane Pass-by, SV 45 mph, POV 60 mph

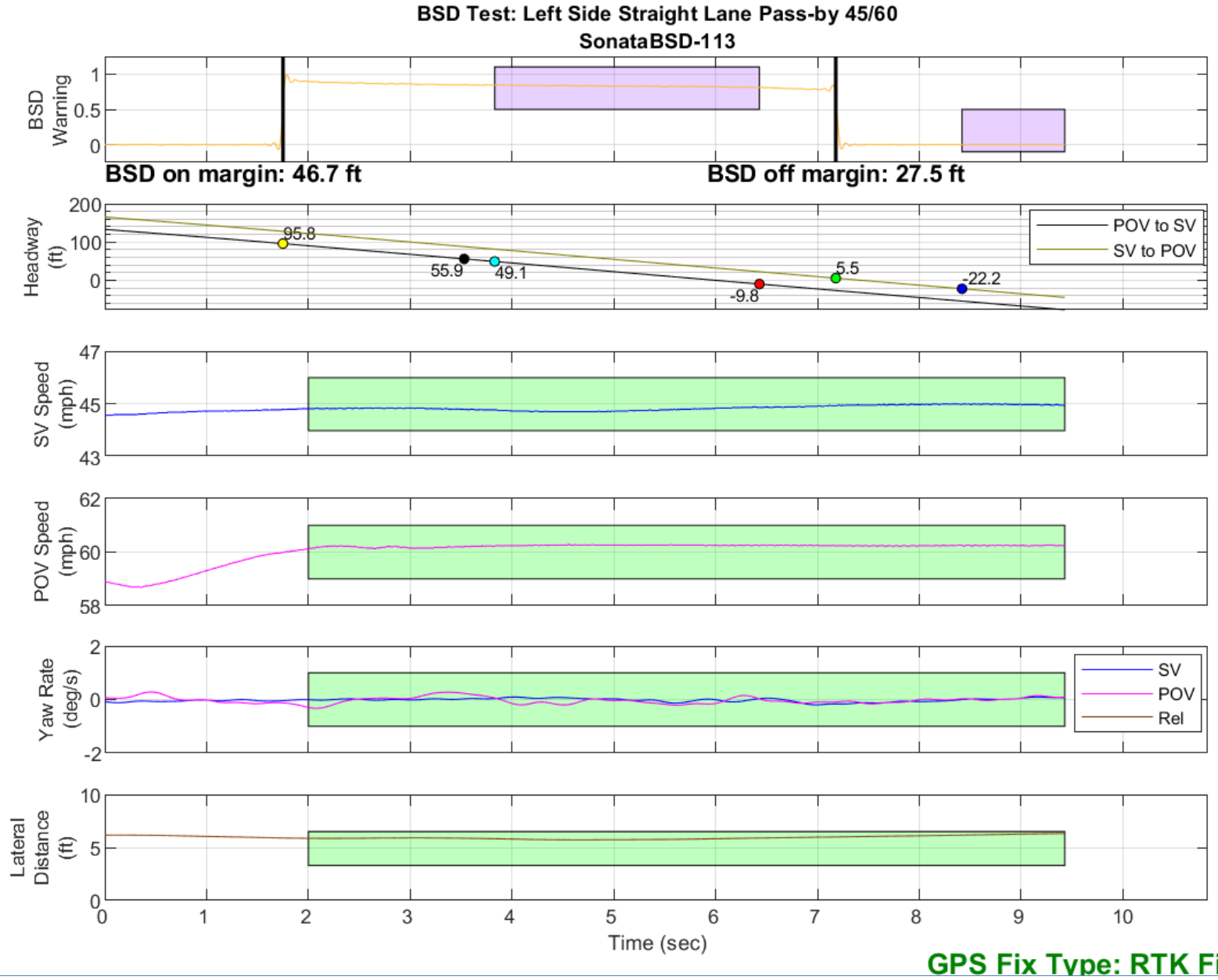


Figure D56. BSD Run 113, Straight Lane Pass-by, SV 45 mph, POV 60 mph

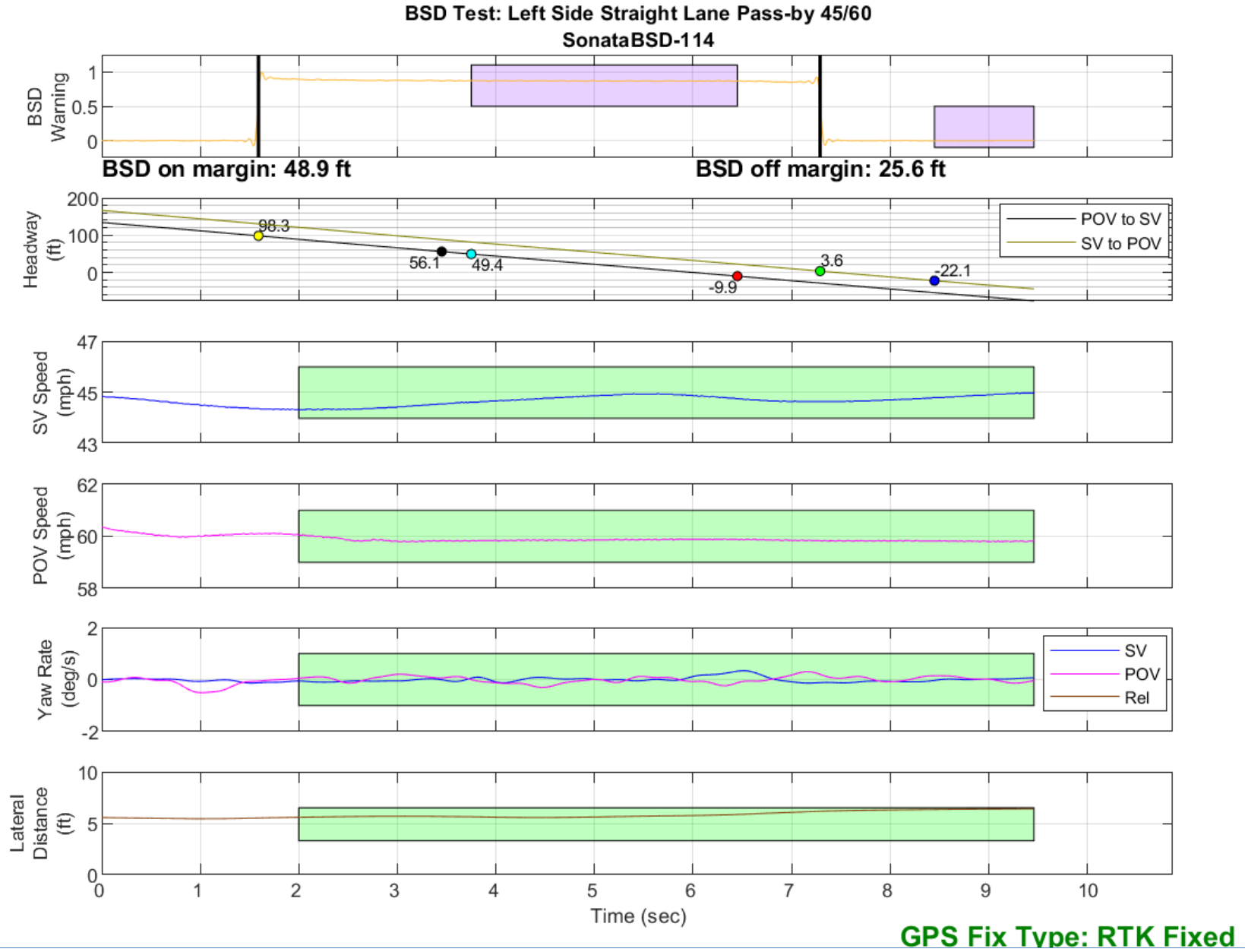


Figure D57. BSD Run 114, Straight Lane Pass-by, SV 45 mph, POV 60 mph

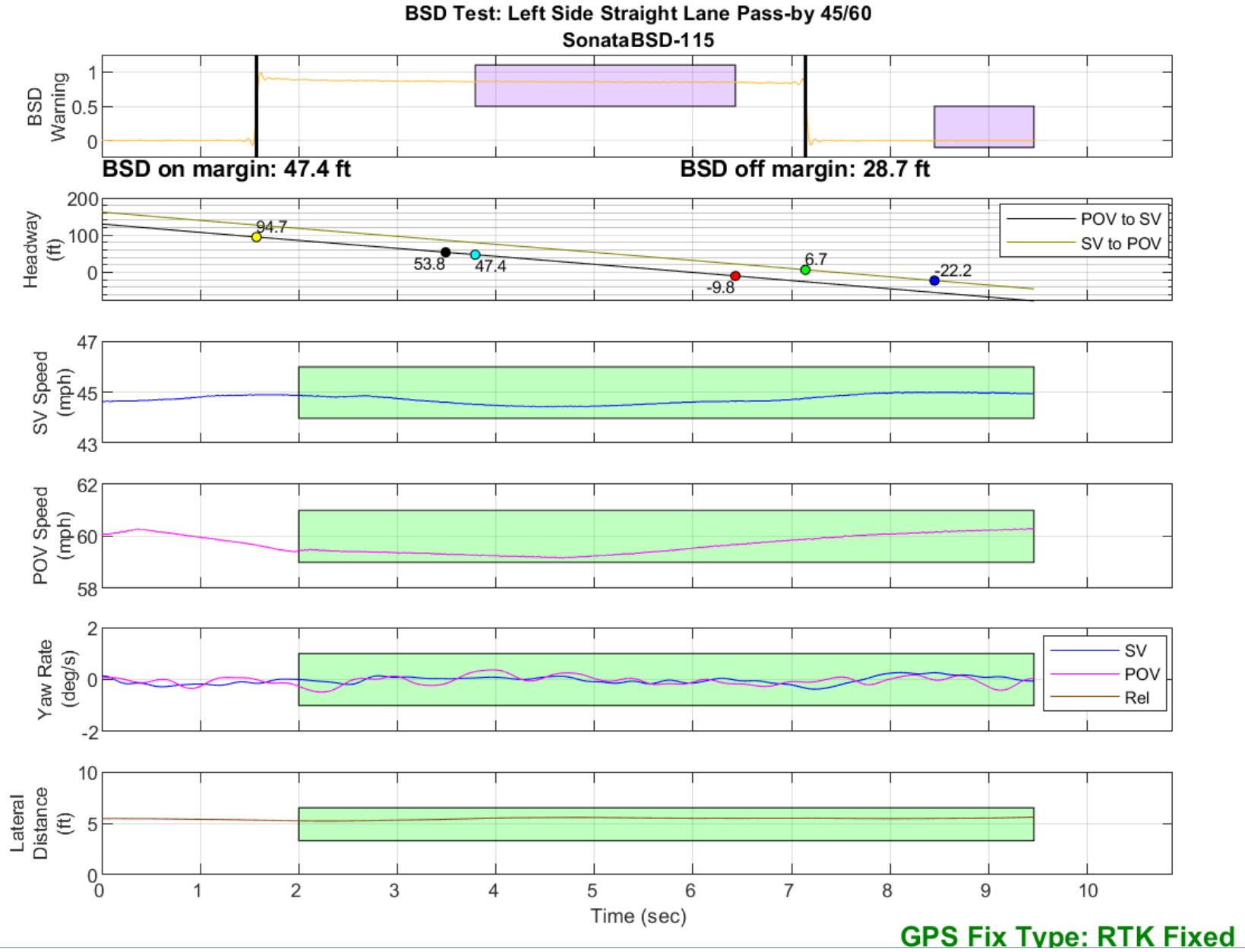


Figure D58. BSD Run 115, Straight Lane Pass-by, SV 45 mph, POV 60 mph

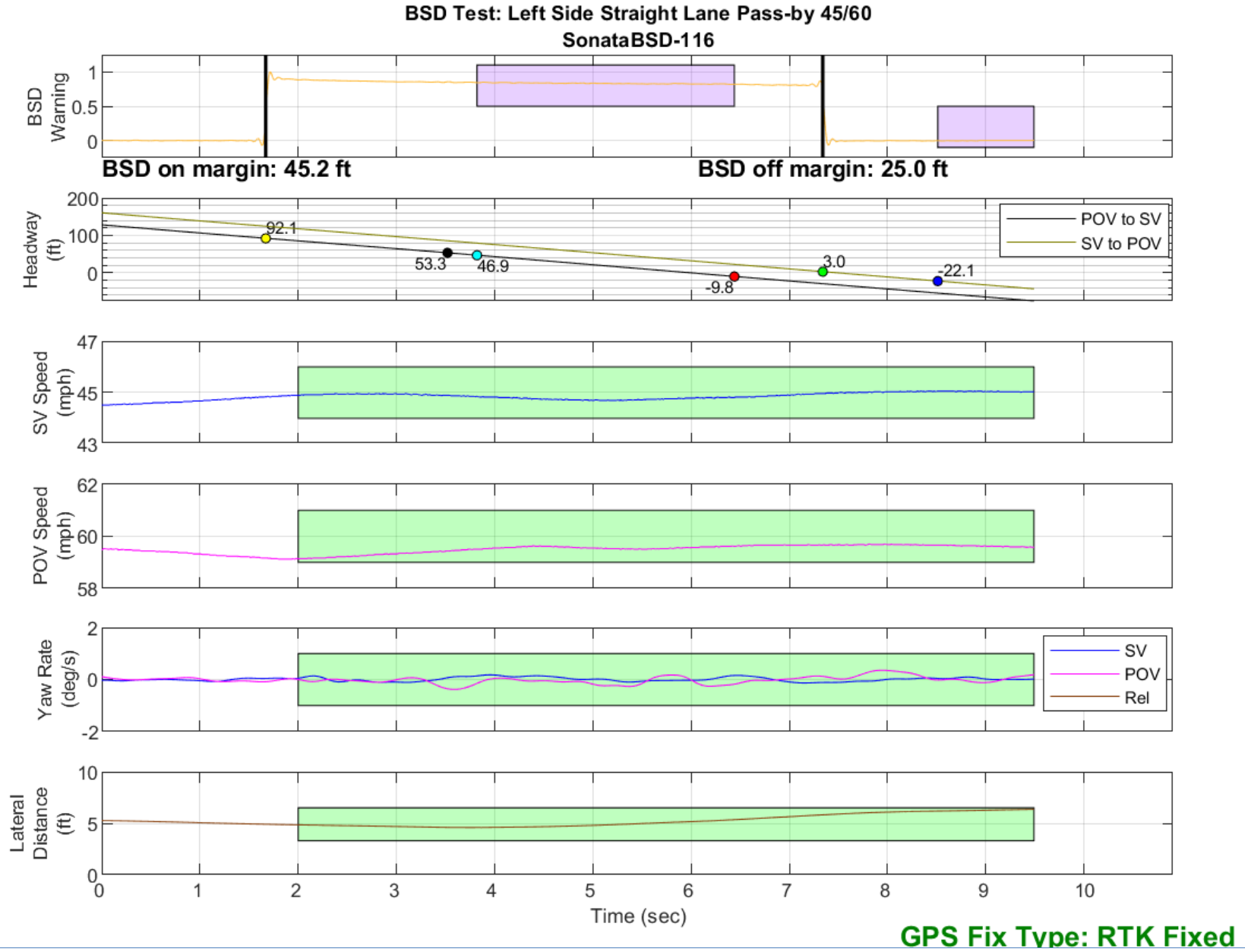


Figure D59. BSD Run 116, Straight Lane Pass-by, SV 45 mph, POV 60 mph

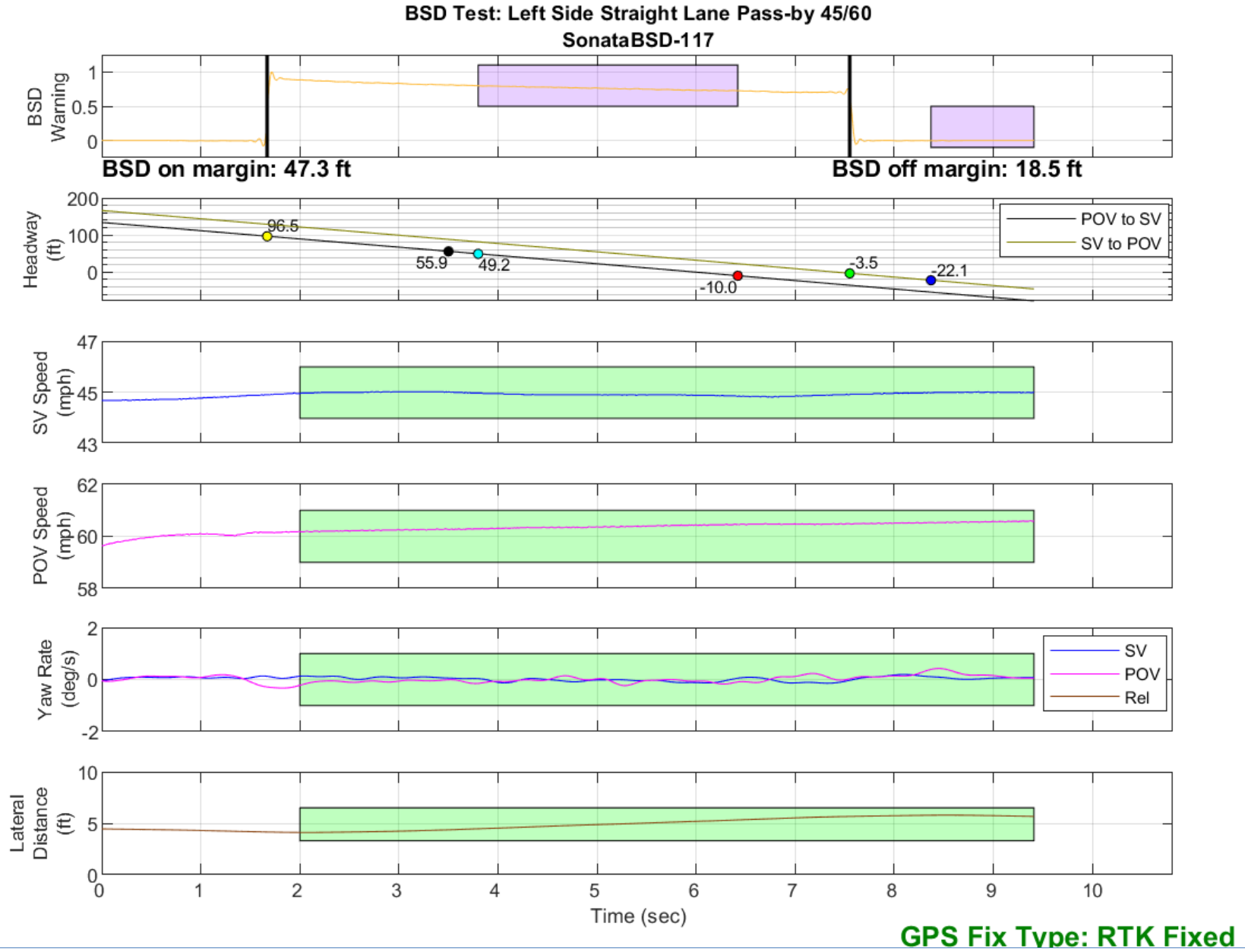


Figure D60. BSD Run 117, Straight Lane Pass-by, SV 45 mph, POV 60 mph

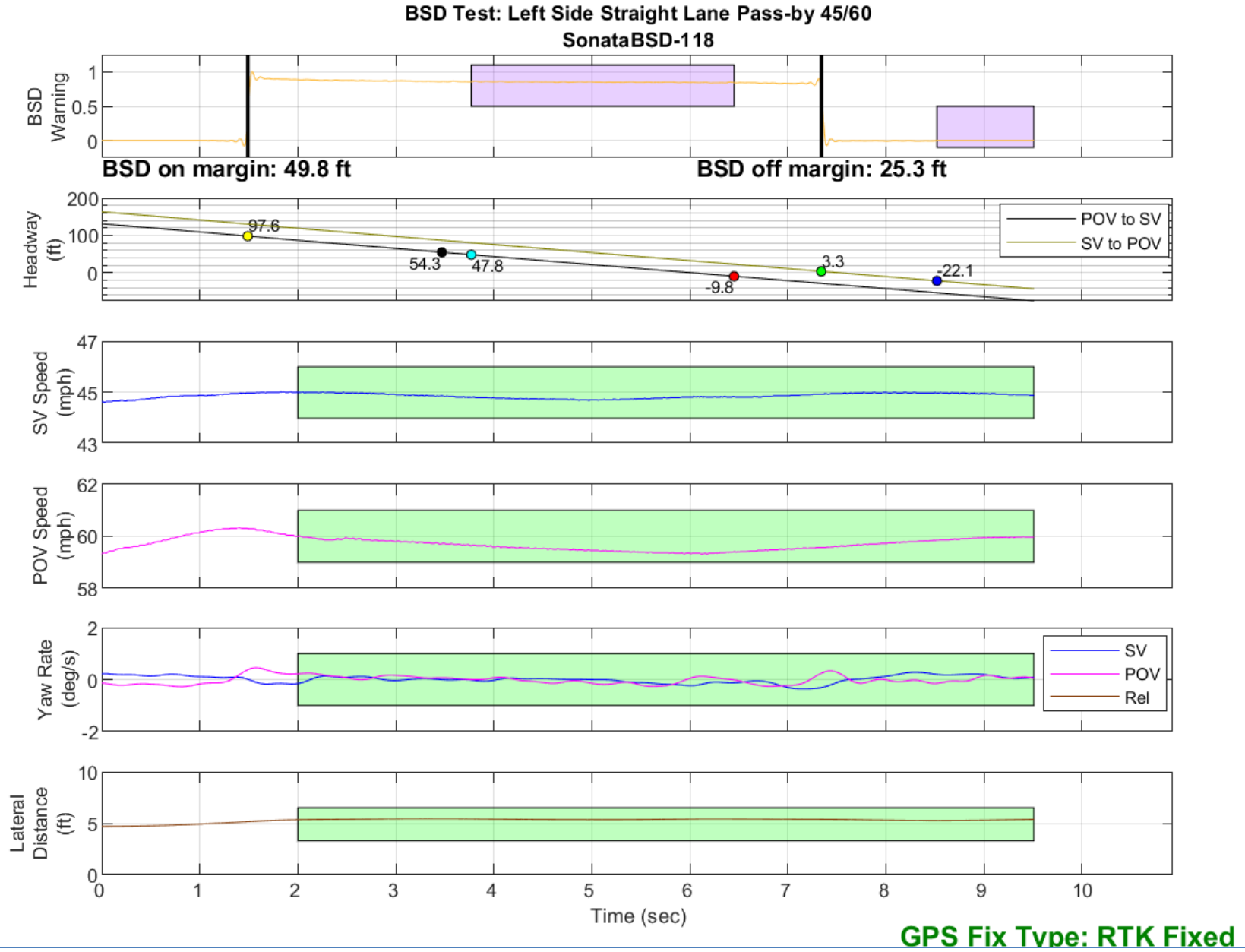


Figure D61. BSD Run 118, Straight Lane Pass-by, SV 45 mph, POV 60 mph

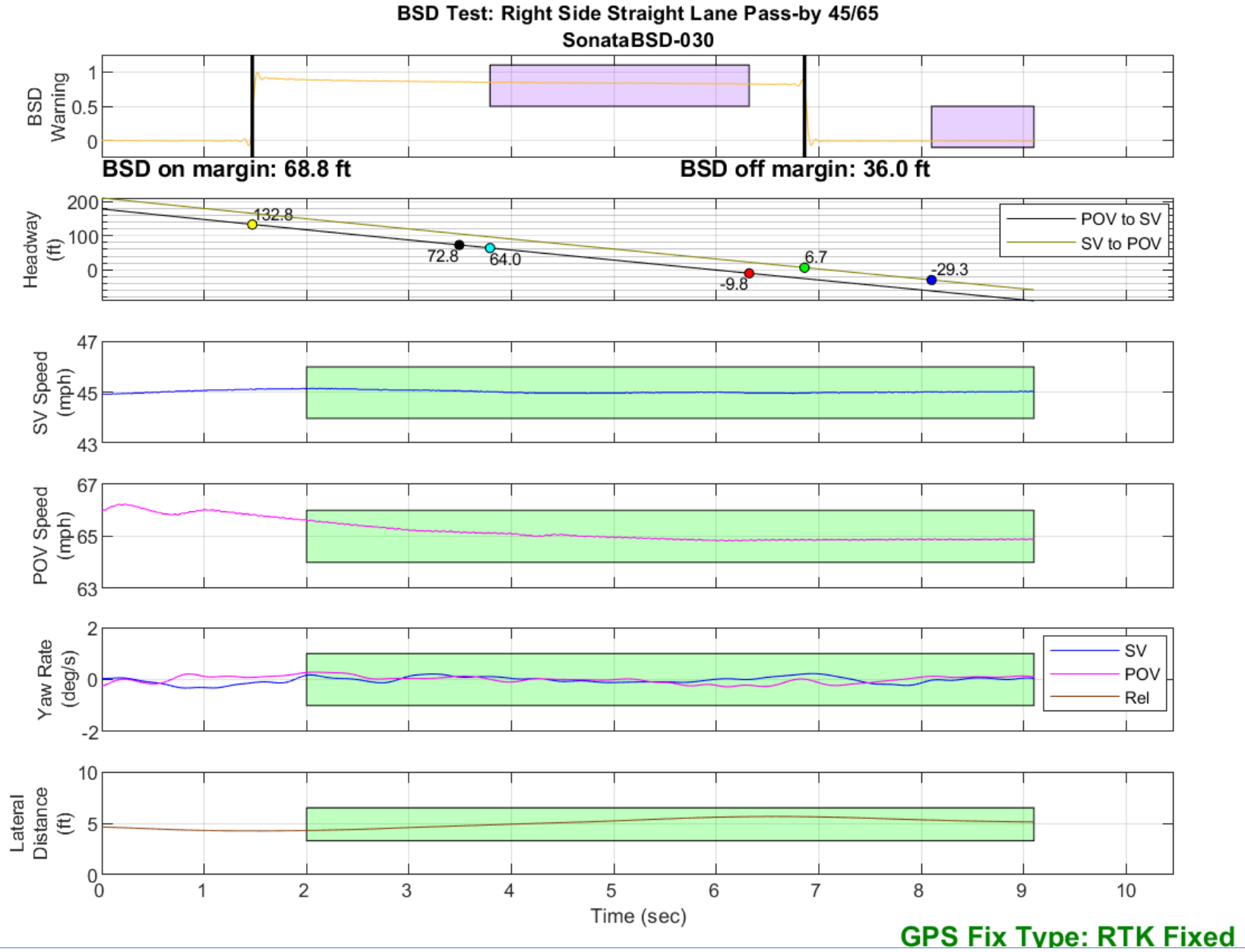


Figure D62. BSD Run 30, Straight Lane Pass-by, SV 45 mph, POV 65 mph

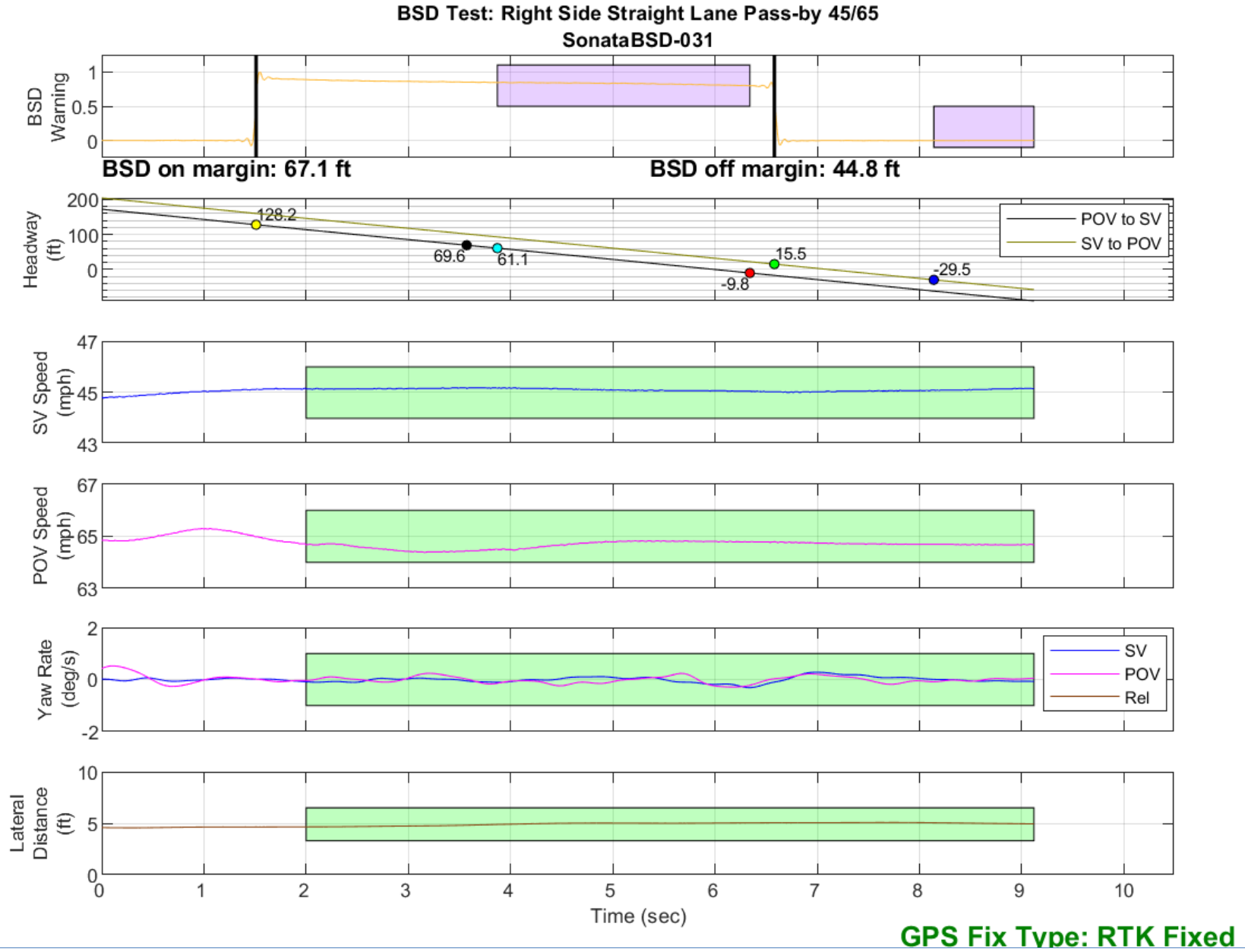


Figure D63. BSD Run 31, Straight Lane Pass-by, SV 45 mph, POV 65 mph

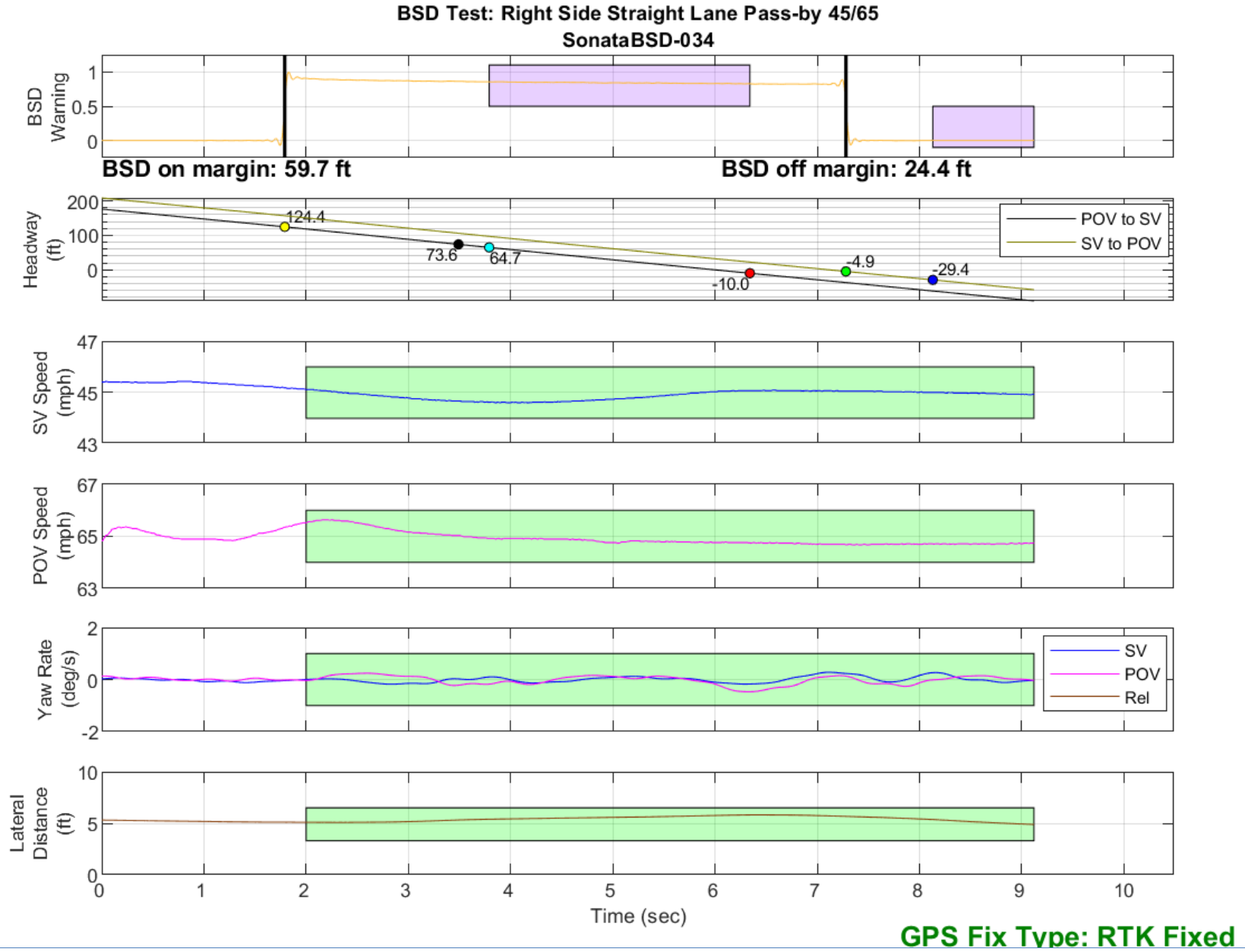


Figure D64. BSD Run 34, Straight Lane Pass-by, SV 45 mph, POV 65 mph

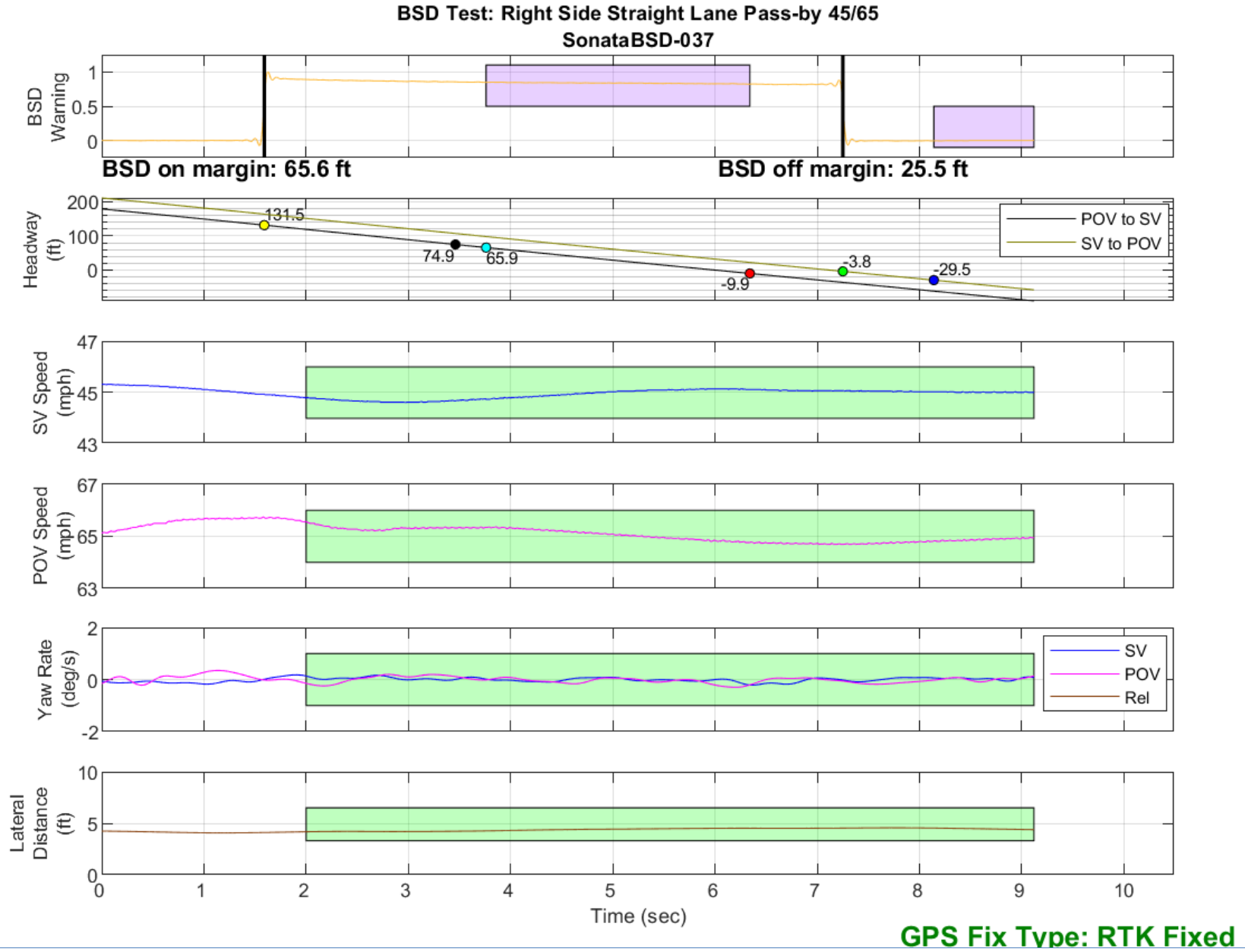


Figure D65. BSD Run 37, Straight Lane Pass-by, SV 45 mph, POV 65 mph

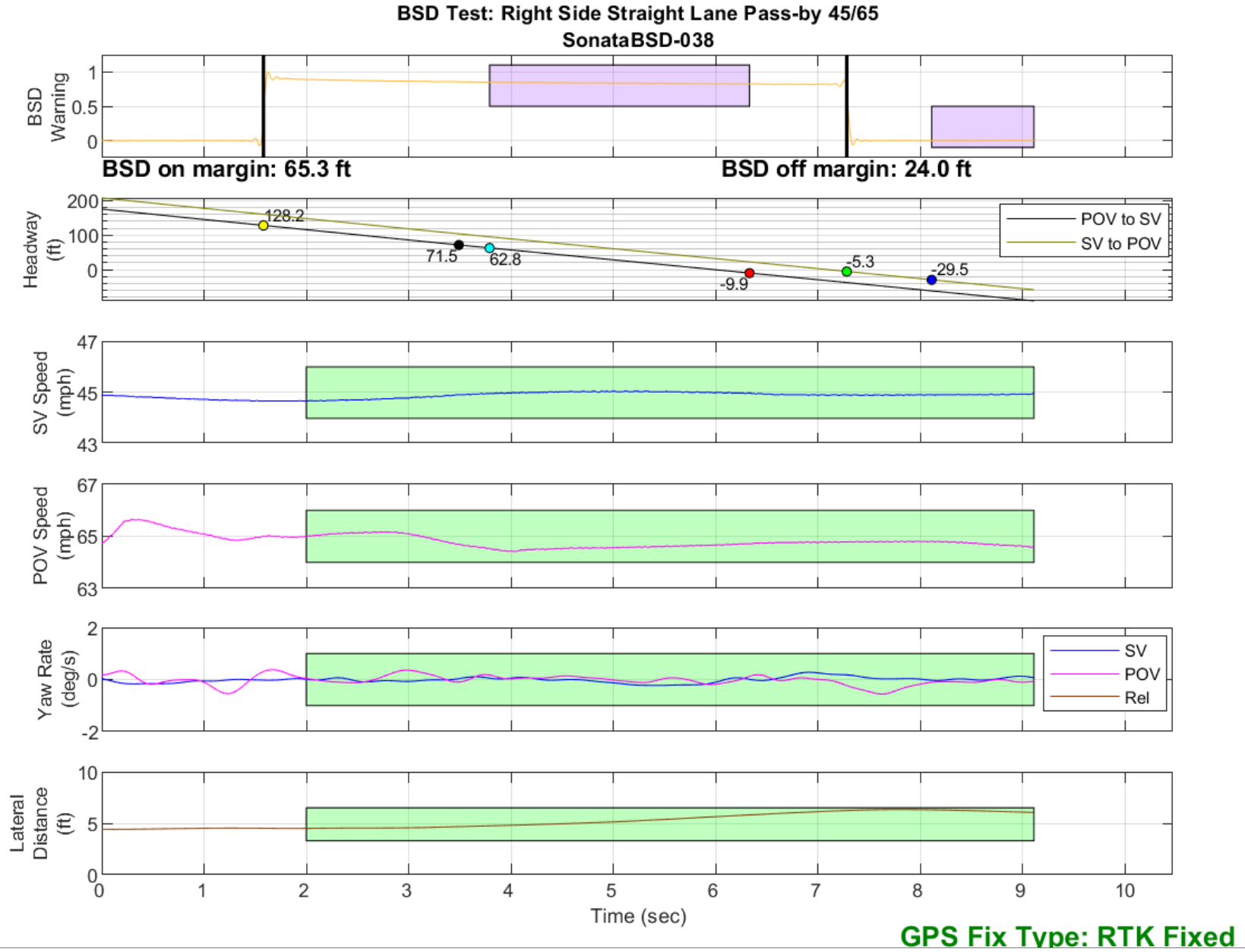


Figure D66. BSD Run 38, Straight Lane Pass-by, SV 45 mph, POV 65 mph

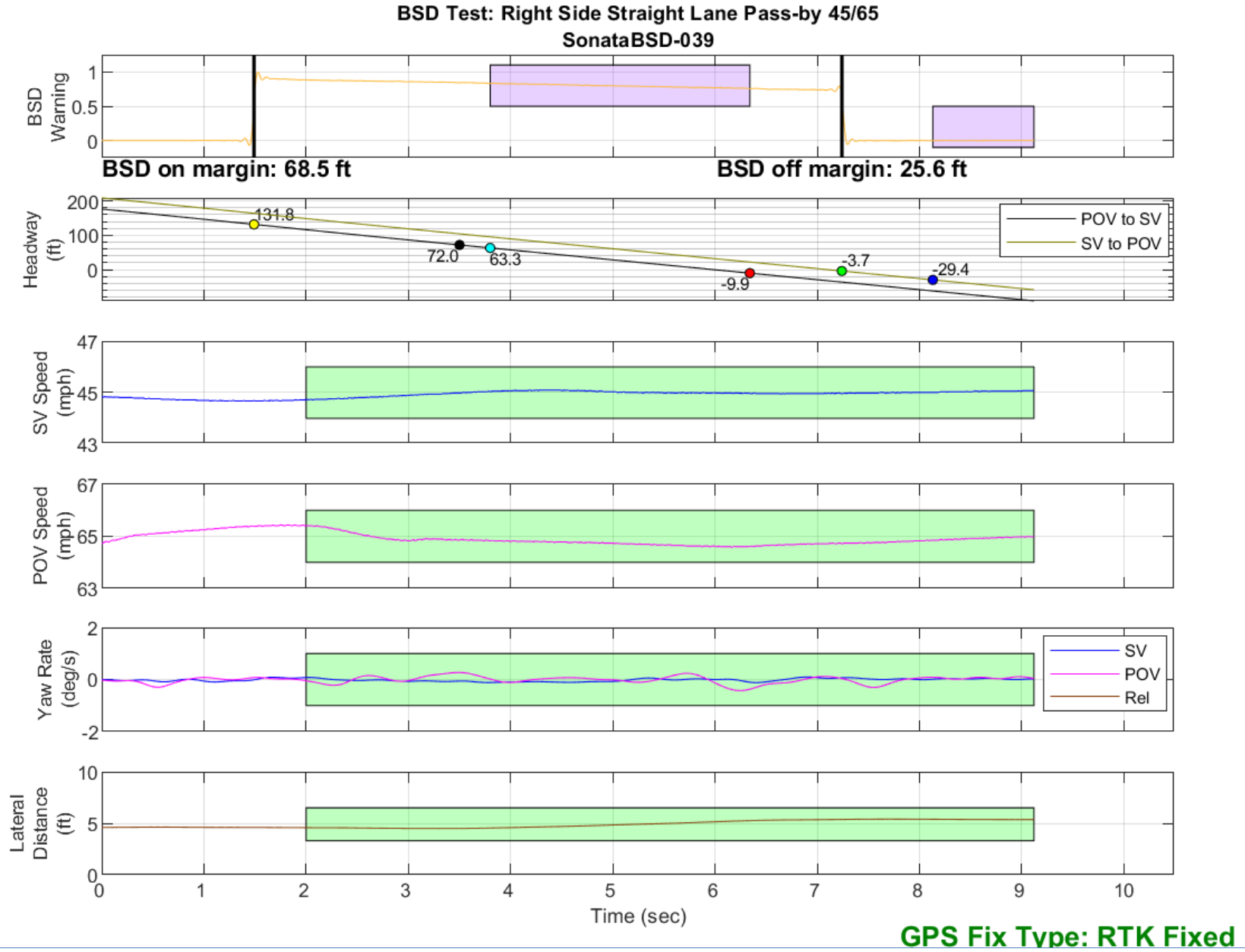


Figure D67. BSD Run 39, Straight Lane Pass-by, SV 45 mph, POV 65 mph

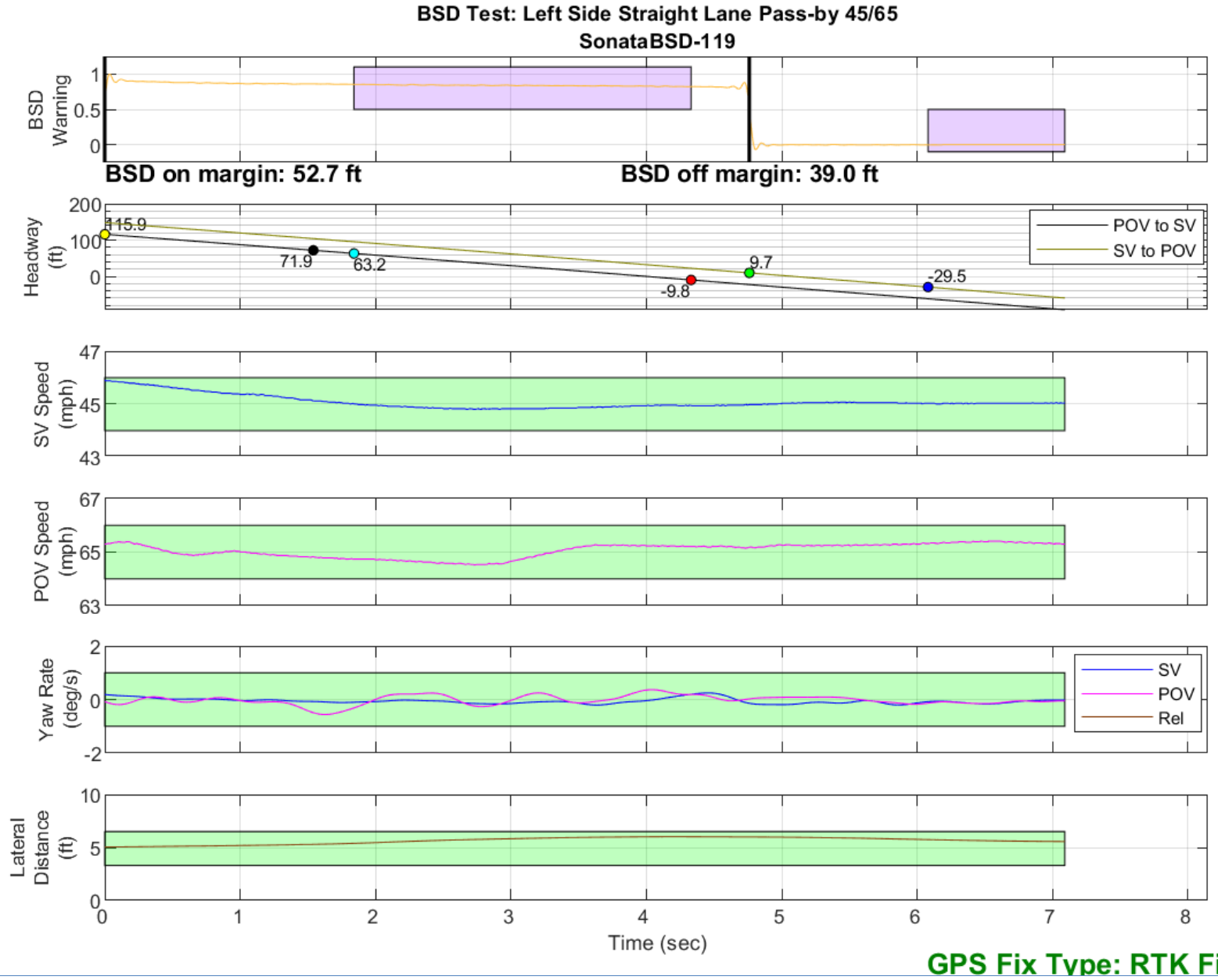


Figure D68. BSD Run 119, Straight Lane Pass-by, SV 45 mph, POV 65 mph

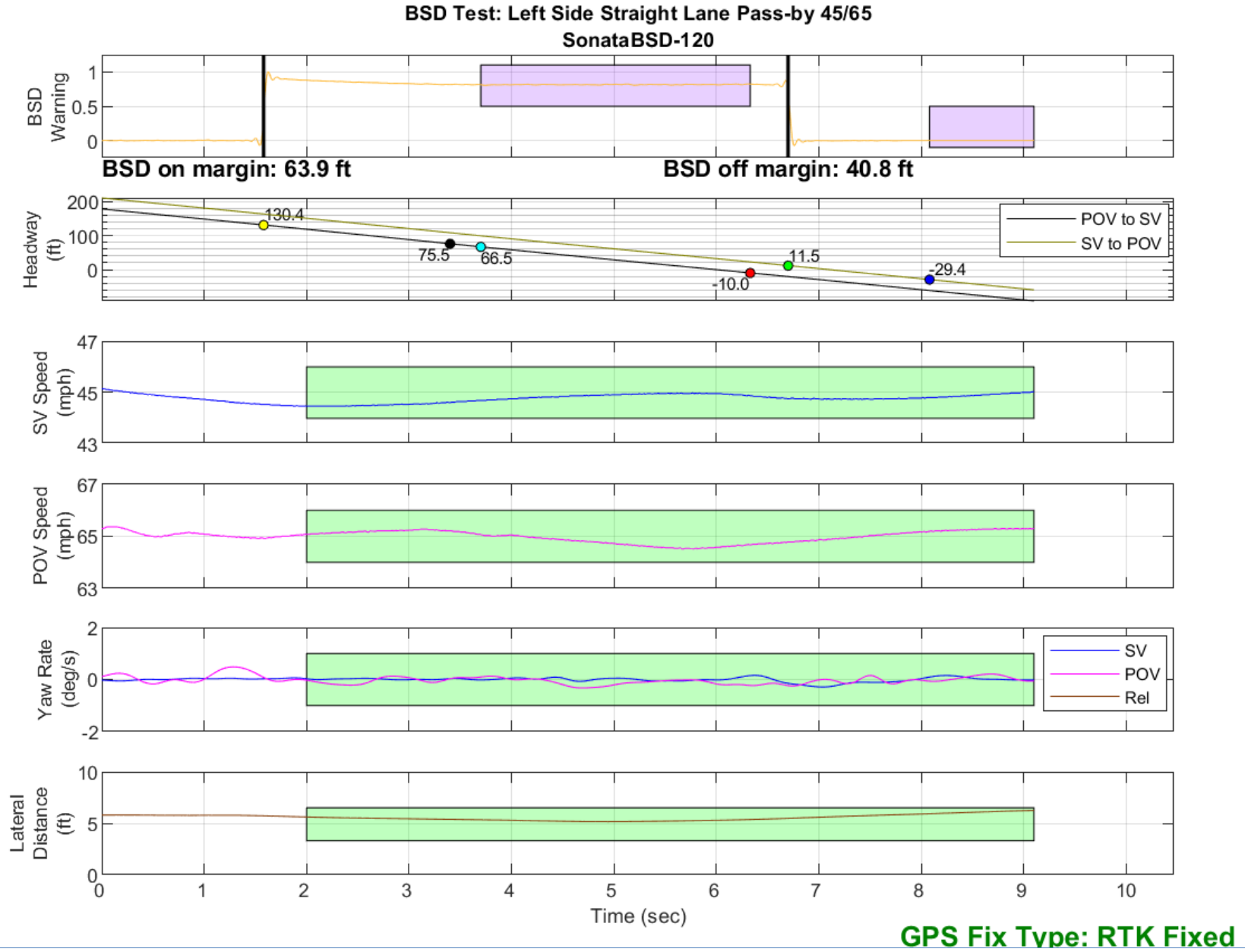


Figure D69. BSD Run 120, Straight Lane Pass-by, SV 45 mph, POV 65 mph

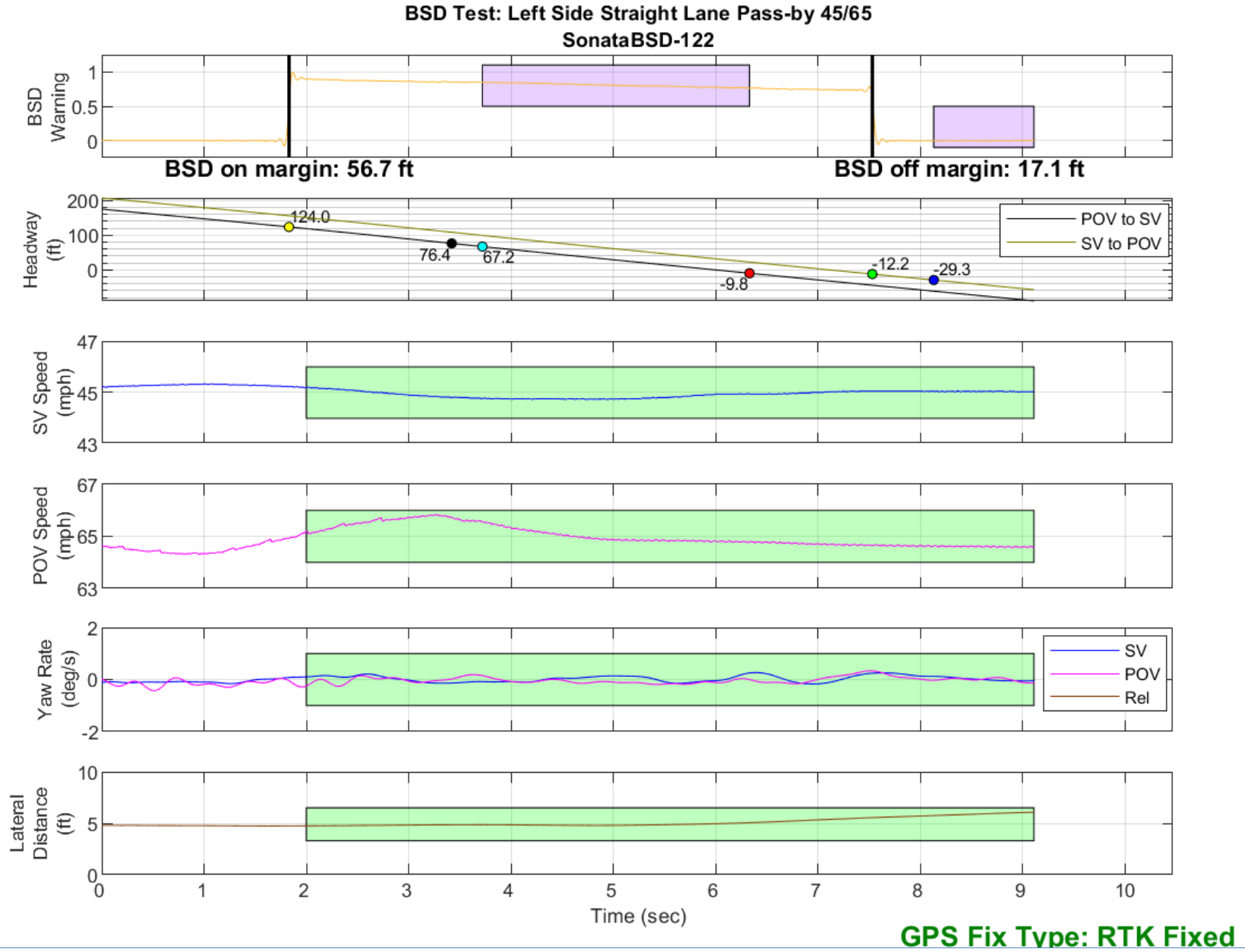


Figure D70. BSD Run 122, Straight Lane Pass-by, SV 45 mph, POV 65 mph

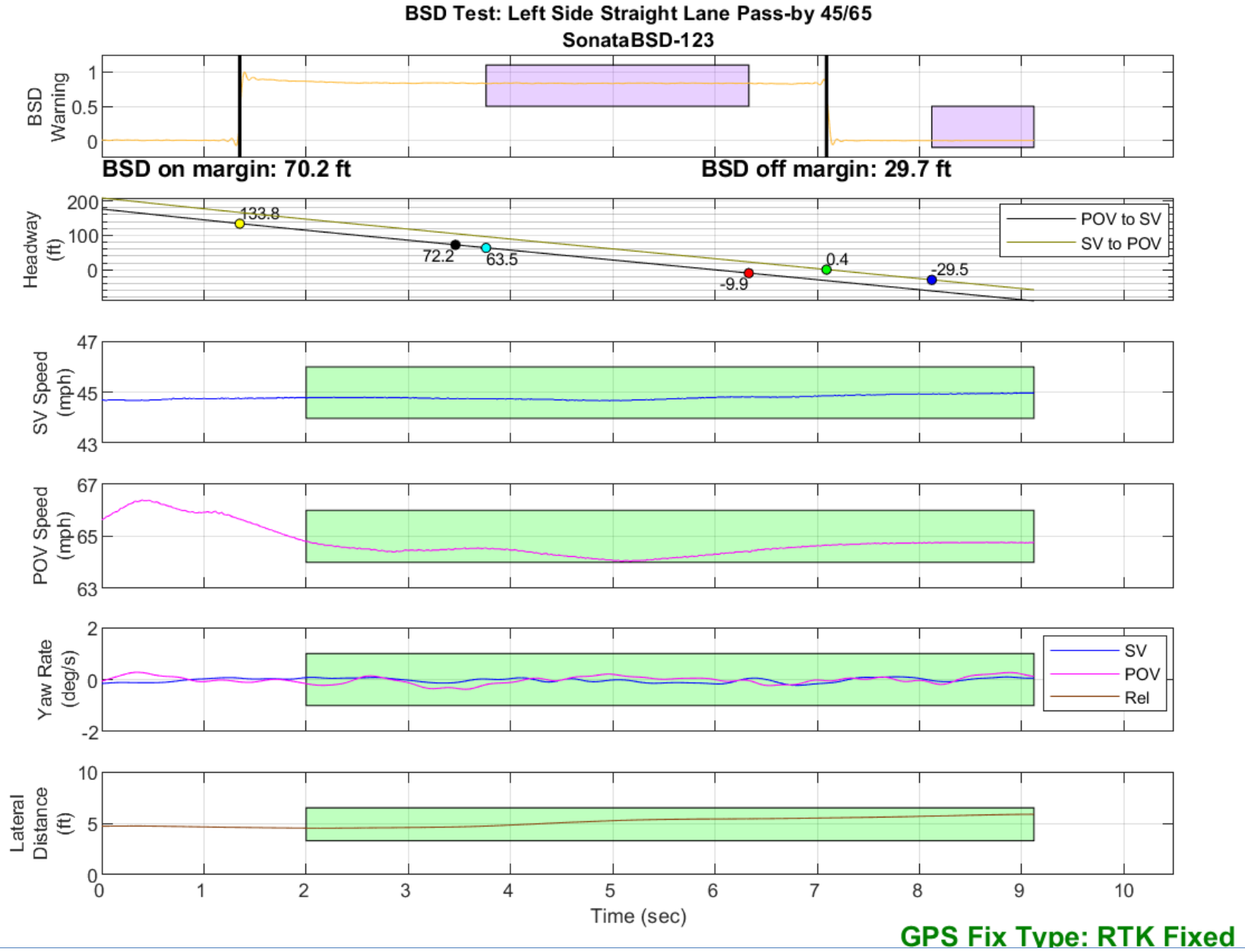


Figure D71. BSD Run 123, Straight Lane Pass-by, SV 45 mph, POV 65 mph

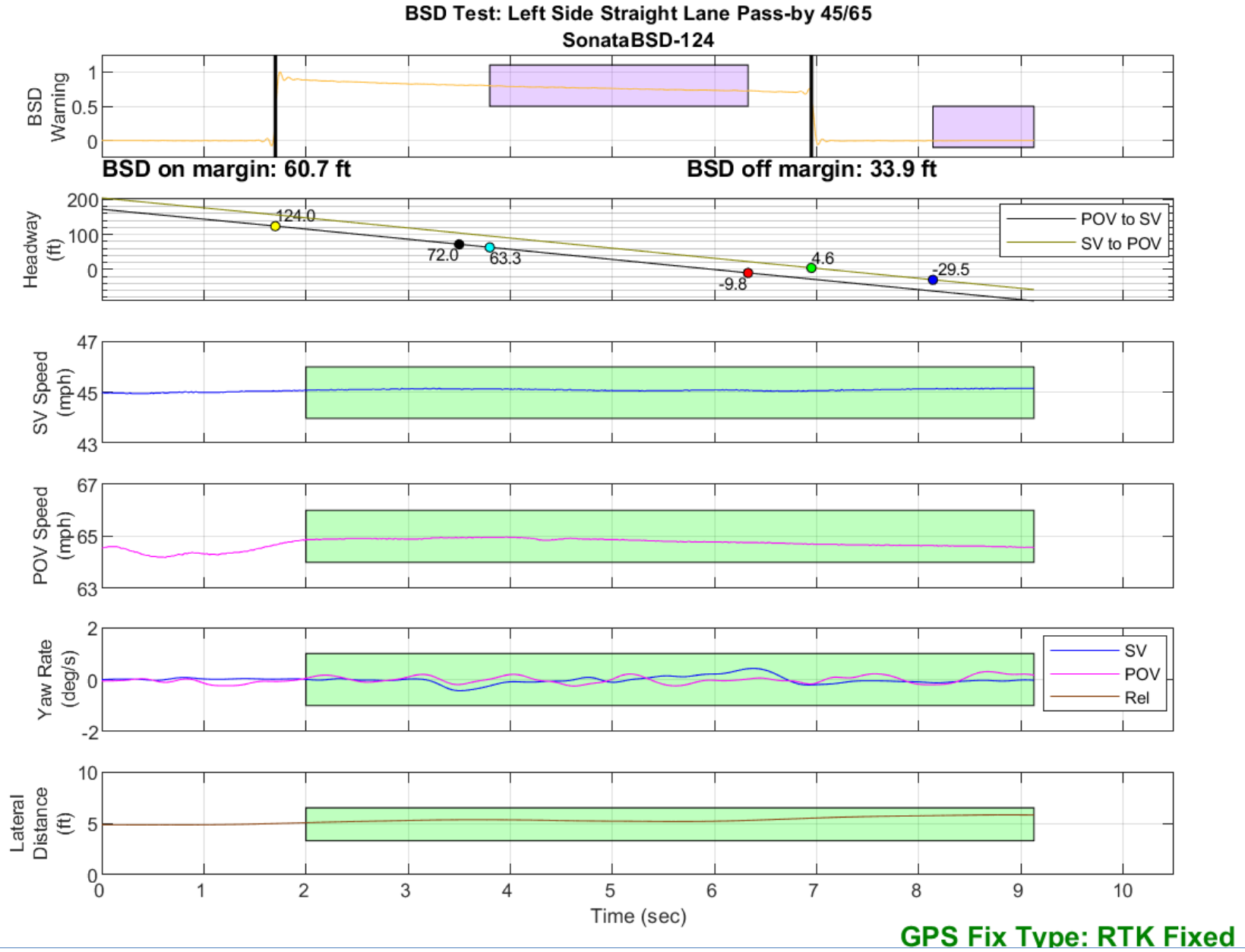


Figure D72. BSD Run 124, Straight Lane Pass-by, SV 45 mph, POV 65 mph

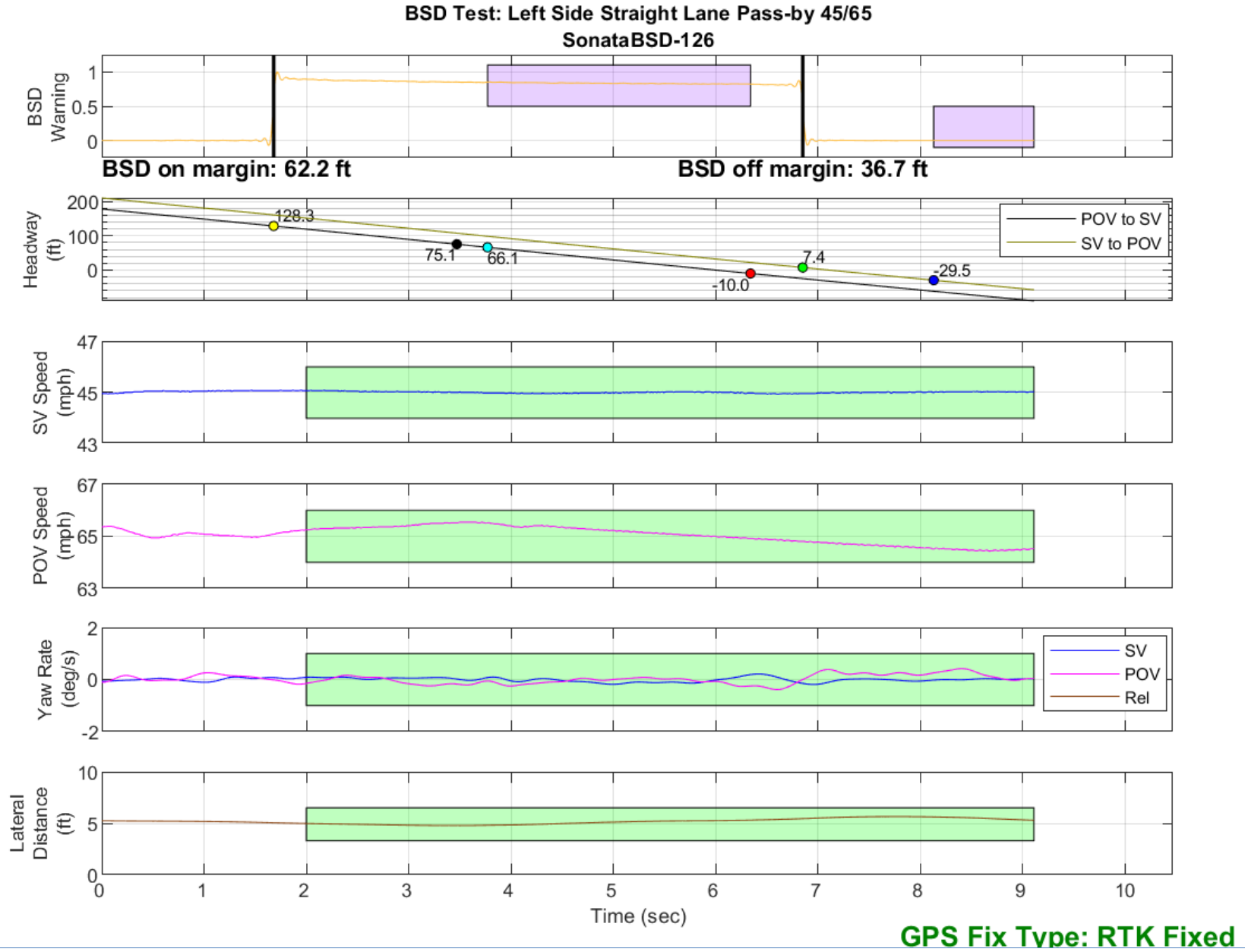


Figure D73. BSD Run 126, Straight Lane Pass-by, SV 45 mph, POV 65 mph

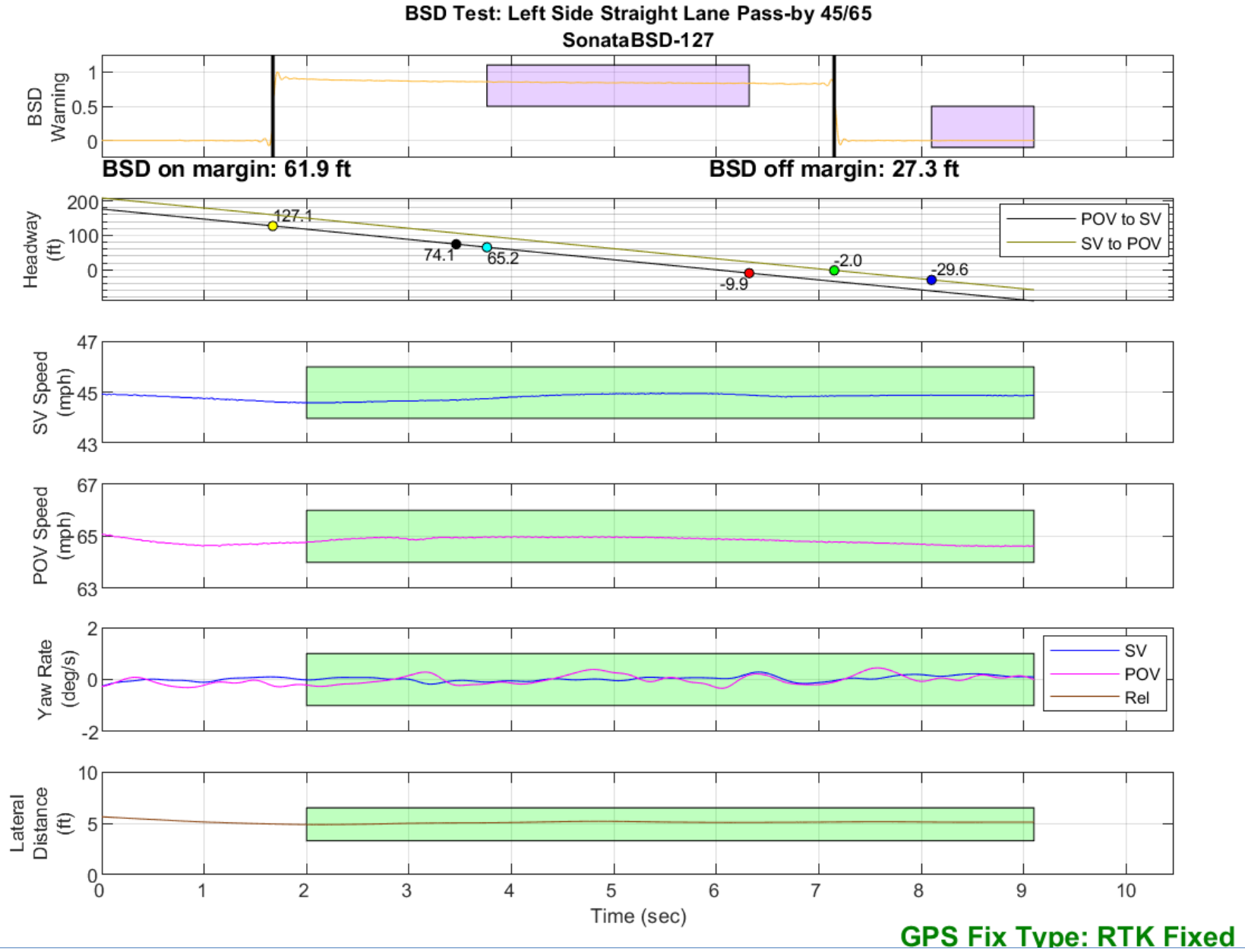


Figure D74. BSD Run 127, Straight Lane Pass-by, SV 45 mph, POV 65 mph

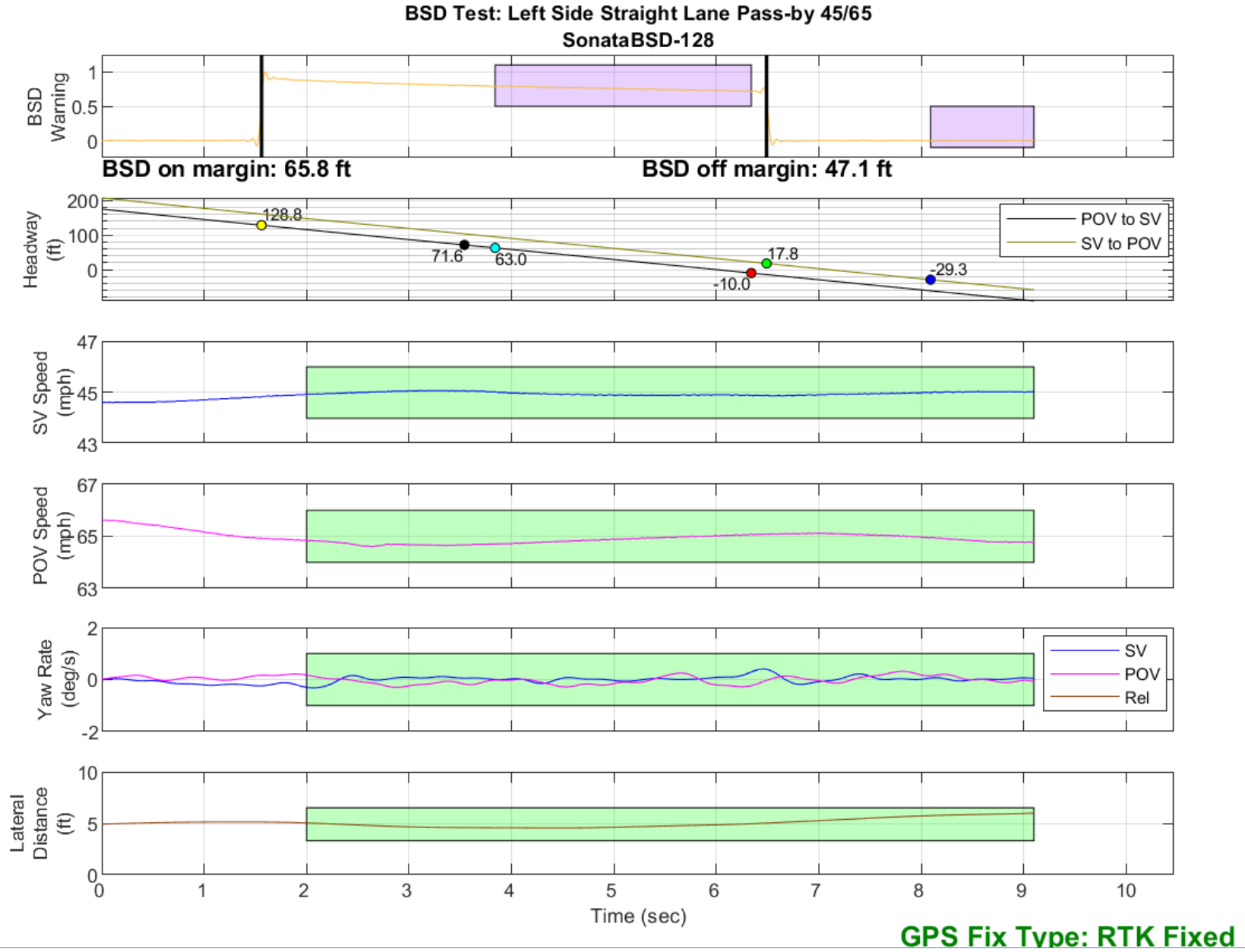


Figure D75. BSD Run 128, Straight Lane Pass-by, SV 45 mph, POV 65 mph