Event Data Recorder – Pre Crash Data Validation of Toyota Products

VEHICLE RESEARCH AND TEST CENTER
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U.S Department of Transportation
National Highway Traffic Safety Administration

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This report provides supplementary information to NHTSA Report No. NHTSA-NVS-2011-ETC, "Technical Assessment of Toyota Electronic Throttle Control (ETC) Systems," January 2011.

The Vehicle Research and Testing Center (VRTC) conducted track testing of several Toyota vehicles equipped with independent instrumentation in order to validate the pre-crash elements of the installed Toyota EDR modules for:

- Brake-light switch status
- Accelerator pedal position/voltage
- Vehicle speed

Test vehicles were:

- Two 2007 Toyota Camrys
- One 2008 Toyota Highlander

Tests involved impacting the rear of a moving target vehicle in order to "wake-up" the EDR/airbag control module without deploying an airbag and record the event data. In total, 28 events were recorded using this method. Events were recorded with little to no damage to the tested vehicles and resulted in 100% of the data for brake pedal status, accelerator pedal, and vehicle speed being accurately reported and stored in the vehicle EDRs.

16. Abstract

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1.0 INTRODUCTION

This test program was performed at the Vehicle Research and Test Center (VRTC) in response to a request by the Office of Defects Investigation (ODI), National Highway Traffic Safety Administration (NHTSA). The ODI requested that the VRTC develop and execute a test program that would confirm or nullify the accuracy of the pre-crash data stored in the supplemental restraint system (SRS) electronic control unit (ECU) control module used in vehicles produced by Toyota Motor North America Inc. for supplemental use in crash event evaluations. These tests apply specifically to digitally produced data transmitted to and stored within a component of the SRS that Toyota refers to as the event data recorder (EDR). The scope of this report is limited to data integrity related to the accelerator pedal voltages, pedal mounted- brake light switch states, and vehicle ground speeds leading up to a triggering event, also referred to as pre-crash (or pre-collision) data. Other pre-crash data as well as post-crash (post-collision) data were not evaluated in this report.

2.0 BACKGROUND

The term supplemental restraint system (SRS) commonly refers to the overall air bag system of a motor vehicle. The term is derived from the Federal Motor Vehicle Safety Standard No. 208 that states "The owner's manual shall include a statement to the effect that the vehicle is equipped with an air bag and lap/shoulder belt at both front outboard seating positions, and that the air bag is a supplemental restraint at those seating positions."[1]

The SRS typically contains crash sensors, an electronic control unit (ECU), and air bags. The crash sensors report data about the dynamic conditions of the vehicle to the SRS ECU. In the event that the sensors report acceleration changes consistent with a crash sequence, the ECU uses the data to trigger the inflation of the appropriate air bags.

The SRS ECU performs up to three basic functions. The first and primary function is to activate the airbags when a crash event is detected. The second is to monitor the SRS for malfunctioning components, report any faults, disable the system if necessary, and alert the driver about the malfunction. The third and only more recently available function is to store some or all of the data being reported immediately before and/or immediately after the time of a crash.

This report is limited to the collection and accuracy of data immediately before the crash from Toyota products. Therefore, the term EDR will be used in reference to the functional aspect of the SRS ECU that collects data reported immediately before the crash. Specifically, on Toyota products tested, the pre-crash data is digitally transmitted to the EDR via the vehicle's controller area network (CAN) bus from other vehicle systems. Alternatively, the post-crash data that records the change in velocity as a result of the crash is recorded by accelerometers used in the SRS. Post-crash data validation was not within the scope of these tests because it is recorded differently and offers relatively less useful information regarding causes of crashes.

The EDR system is continually sampling data from various systems available on the CAN bus anytime the vehicle is operating. The sample frequency is once per second. The memory for the sample data is sufficient to store five seconds of sampling data and at the end of five seconds, the oldest sampling time is deleted and overwritten to facilitate recording of the next newest data

[1] Code of Federal Regulations 49 Transportation: Part 571.208 S4.5.1

sampling. This creates a renewing five second memory that updates every second, while also deleting data more than five seconds old every second. In the event that the vehicle experiences rapid acceleration, either negative or positive, beyond what the car would normally be capable of achieving, collision sensors (accelerometers) register the level of acceleration and transmit this to the SRS/EDR. This triggers the EDR to lock the five seconds of data and store it as an event. While this is occurring, the EDR has the capability to continue to store another five seconds of data for an additional event, which is useful when the vehicle strikes multiple obstacles in a single crash or if the vehicle experiences more than one crash during its useful life. The two events can be overlapping and the EDR is capable of recording a limited time between event triggers, measured in milliseconds. Additionally, not all crashes merit airbag deployment. The EDR can be triggered to capture and store an event even if the crash is not of sufficient severity to deploy the air bags. When this occurs, the EDR stores a file referred to as a "non-deployment" event. While the EDR is capable of storing up to two of these events, if a third event occurs the oldest event will be overwritten. This is not the case in an airbag deployment event, where the data is permanently locked and cannot be overwritten by a further event.

3.0 OBJECTIVE

The objective of this testing was to verify the accuracy of data collected by Event Data Recorders (EDR's) in Toyota products regarding accelerator pedal application, brake pedal application, and vehicle speed in the five seconds preceding a crash.

4.0 TEST VEHICLES

4.1 Test Vehicles Information

A total of three test vehicles were chosen from the available inventory of Toyota vehicles present at VRTC. Selection was based on model years 2007 or newer where the EDR is equipped with pre-crash data recording capability. These vehicles included a 2007 Camry SE, 2007 Camry LE, and a 2008 Highlander SUV (listed in Table 1 below). Prior to testing, the EDRs of all the test vehicles were interrogated using an EDR read-out tool (ROT) (shown in Figure 1) provided by the manufacturer to confirm functionality of the units and clear any historical data stored.

Table 1 – Test Vehicles

Vehicle ID	Vehicle Model Year	Vehicle Model	Trim Level	Engine	VIN	Mileage
4D	2007	Camry	SE	L4	4T1BE46K574XXXXXX	89,964
10D	2007	Camry	LE	V6	4T1BK46K97UXXXXXX	53,322
Highlander	2008	Highlander	LE	V6	JTEDS41A382XXXXXX	??

Figure 1 – Toyota EDR Readout Tool

4.2 Vehicle Instrumentation

The VRTC instrumented each test vehicle with an independent data acquisition instrumentation package (shown in Figure 2 and Figure 3) that uses dedicated analog devices to record brake

pedal application, commanded accelerator position, and Global Positioning System (GPS) based vehicle speed.

Figure 2 - NHTSA Data Acquisition System – Front View

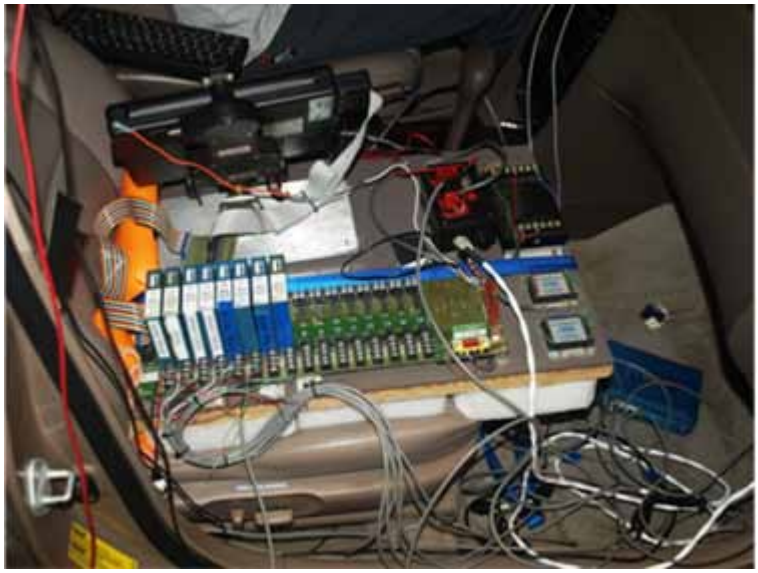


Figure 3 - NHTSA Data Acquisition System – Rear View

4.3 Vehicle Preparation

The driver and passenger air bags were removed for safety. The resistance of the air bag squib circuit was measured and a resistor of equal value was installed in its place. Each test vehicle had the fascia removed from the impact zone to limit any damage. A 64-inch section of four

inch by four inch steel box tubing was mounted to each vehicle at the front bumper mounting points as shown in Figure 4.

Figure 4 - 2007 Toyota Camry as Tested

The target vehicle for all tests was a 2006 Toyota Tacoma. It was equipped in the rear with a heavy impact bumper (shown in Figure 5). The height of the rear bumper was adjusted to match the height of the front tubing on each test vehicle. Adjustments were made by adding ballast weight to the box of the pick-up truck.

Figure 5 - 2006 Toyota Tacoma Target Vehicle

5.0 TEST PROCEDURE

For this validation, it was essential that actual events occur to accurately reproduce the vehicle dynamics and sensory timing experienced in a collision. Therefore, each vehicle did experience a real collision with all systems functioning.

The VRTC conducted a series of vehicle to vehicle light impacts on all of the test vehicles. The rear (instrumented test) vehicle pushed the lead (target) vehicle (shown in Figure 6) to a velocity between 20 and 30 miles per hour and then slowed slightly to create a space between the vehicles. The test vehicle then accelerated into the rear (impact zone shown in Figure 7) of the lead vehicle with a differential speed of approximately 2-5 miles per hour. During this maneuver, the driver varied both brake and accelerator input to test and monitor the activity of the pre-crash data.

Figure 6 - Target Vehicle and 2008 Toyota Highlander Test Vehicle

Figure 7 – Vehicle Impact Zone

When a triggering event (crash) occurred that activated the five second pre-crash data lock on the EDR, the data regarding the brake, accelerator, and vehicle speed were recorded. For the test, a controlled crash maneuver was executed to trigger the EDR to record the information. The independent data acquisition system was continually recording throughout the test. Following the maneuver, the data from both the EDR and the independent data acquisition computer were compared for agreement and thus verification.

6.0 RESULTS

The three test vehicles collected collision data according to the following matrix (Table 2):

Table 2 – Validation Test Sequence

Vehicle	Validation Test	Strike Sequence	Overall Number of Tests
Camry 4D	1	1	1
	1	2	2
	2	1	3
	2	2	4
Camry 10D	1	1	5
	1	2	6
	2	1	7
	2	2	8
Highlander	1	1	9
	1	2	10
	2	1	11
	2	2	12
	3	1	13
	3	2	14

The pre-crash data regarding vehicle speed, brake pedal switch status, and accelerator pedal voltage are measured by various vehicle systems and communicated via the CAN bus to the EDR. Data point measurements are refreshed at the following rates by the respective vehicle systems:

- Vehicle speed – Refresh available for sampling every 500 milliseconds (0.500 seconds);
- Brake pedal switch status – Reported when switch state changes (immediately available for sampling);
- Accelerator pedal voltage – Refresh available for sampling every 512 milliseconds (0.512 seconds).

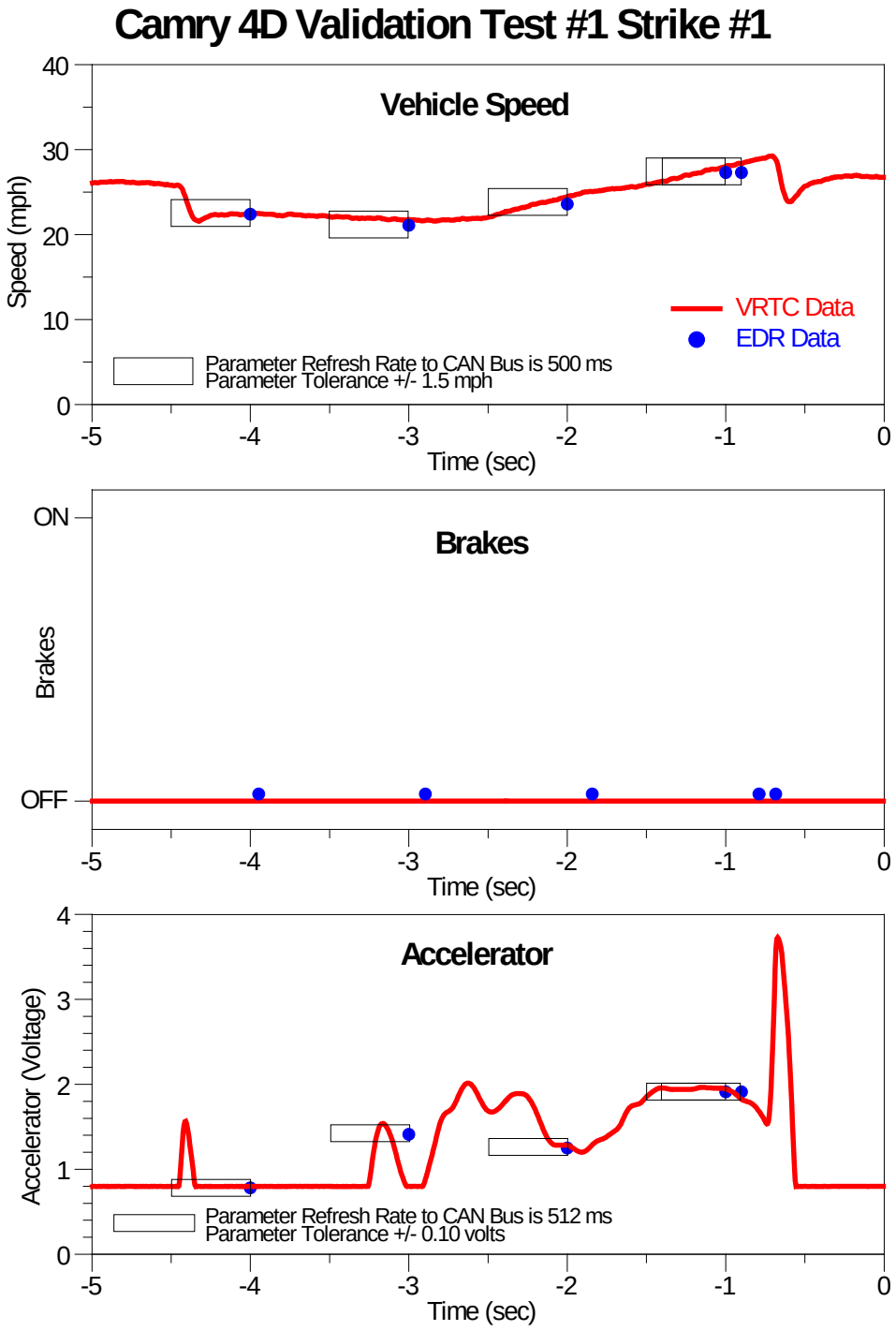
Even though these data are available on the system network, the sample rate of the Toyota EDR is limited to one cycle per second, or one (1) Hertz, meaning that data stored could be up to about one-half second old.

The sample rate of NHTSA's independent data acquisition system was operated at a much higher rate of 200 cycles per second or 200 Hertz. Plotted results illustrate the comparison between the NHTSA data acquisition system to the EDR data from each Toyota vehicle, and are available for all tests in Appendix A, where red lines indicate the recording activity of the NHTSA equipment and blue dots represent the activity of the Toyota EDR. Note the blue dots are depicted with a trailing 0.5 second box that represents the potential lag caused by the computer's relatively low sample rate. In other words, what is sampled by a EDR computer only once per second could have occurred slightly in the past, with the maximum reporting delay being bound by the corresponding box on the graph. Vehicle speed tolerance was set at +/- 1.5 miles per hour. Vehicle brake status was an on/off state and therefore had no tolerance. Vehicle accelerator voltages ranged from 0-4 volts and were given a tolerance of +/- 0.1 volts (+/- 2.5%). The data showed 100% agreement on all data points, accounting for tolerances and time delay limitations.

7.0 CONCLUSION

The data comparison between the NHTSA equipment and the Toyota EDR indicate no errors in the measurement and storage of pre-crash data, evidenced by about 200 collected data points. Therefore, there is no basis to reject the validity of the EDR pre-crash data.

Appendix A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Vehicle Speed
Speed (mph)
40
30
20
10
0
VRTC Data
EDR Data
Parameter Refresh Rate to CAN Bus is 500 ms
Parameter Tolerance +/- 1.5 mph
-5
-4
-3
-2
-1
0
Time (sec)
Brakes
ON
OFF
Brakes
Time (sec)
Accelerator
Accelerator (Voltage)
4
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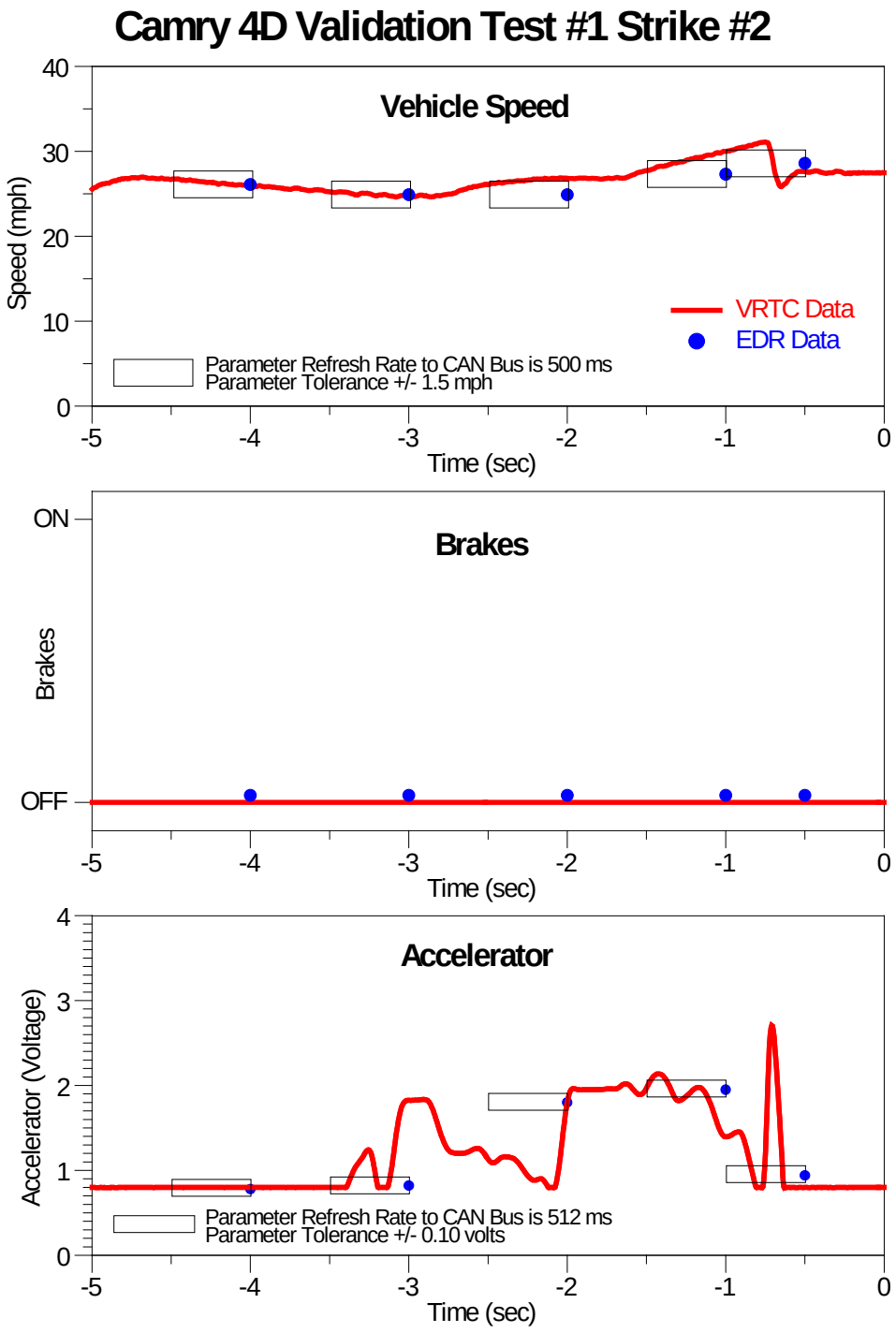
Parameter Tolerance +/- 0.10 volts
Time (sec)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30
20
10
0
VRTC Data
EDR Data
Parameter Refresh Rate to CAN Bus is 500 ms
Parameter Tolerance +/- 1.5 mph
-5
-4
-3
-2
-1
0
Time (sec)
Brakes
ON
OFF
Brakes
Time (sec)
Accelerator
Accelerator (Voltage)
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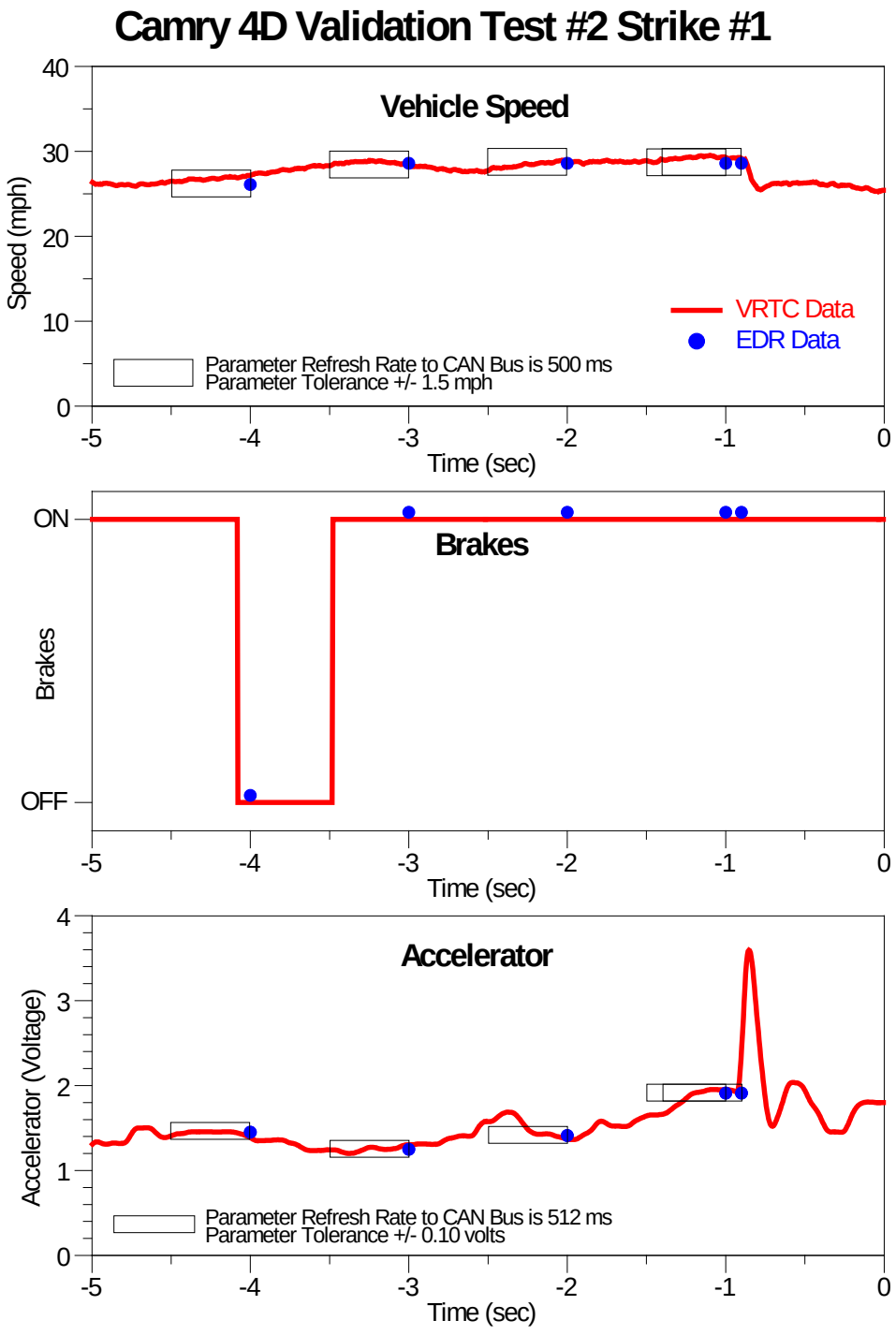
Parameter Tolerance +/- 0.10 volts
Time (sec)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Vehicle Speed
Speed (mph)
40
30
20
10
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VRTC Data
EDR Data
Parameter Refresh Rate to CAN Bus is 500 ms
Parameter Tolerance +/- 1.5 mph
-5
-4
-3
-2
-1
0
Time (sec)
Brakes
ON
OFF
Brakes
Time (sec)
Accelerator
Accelerator (Voltage)
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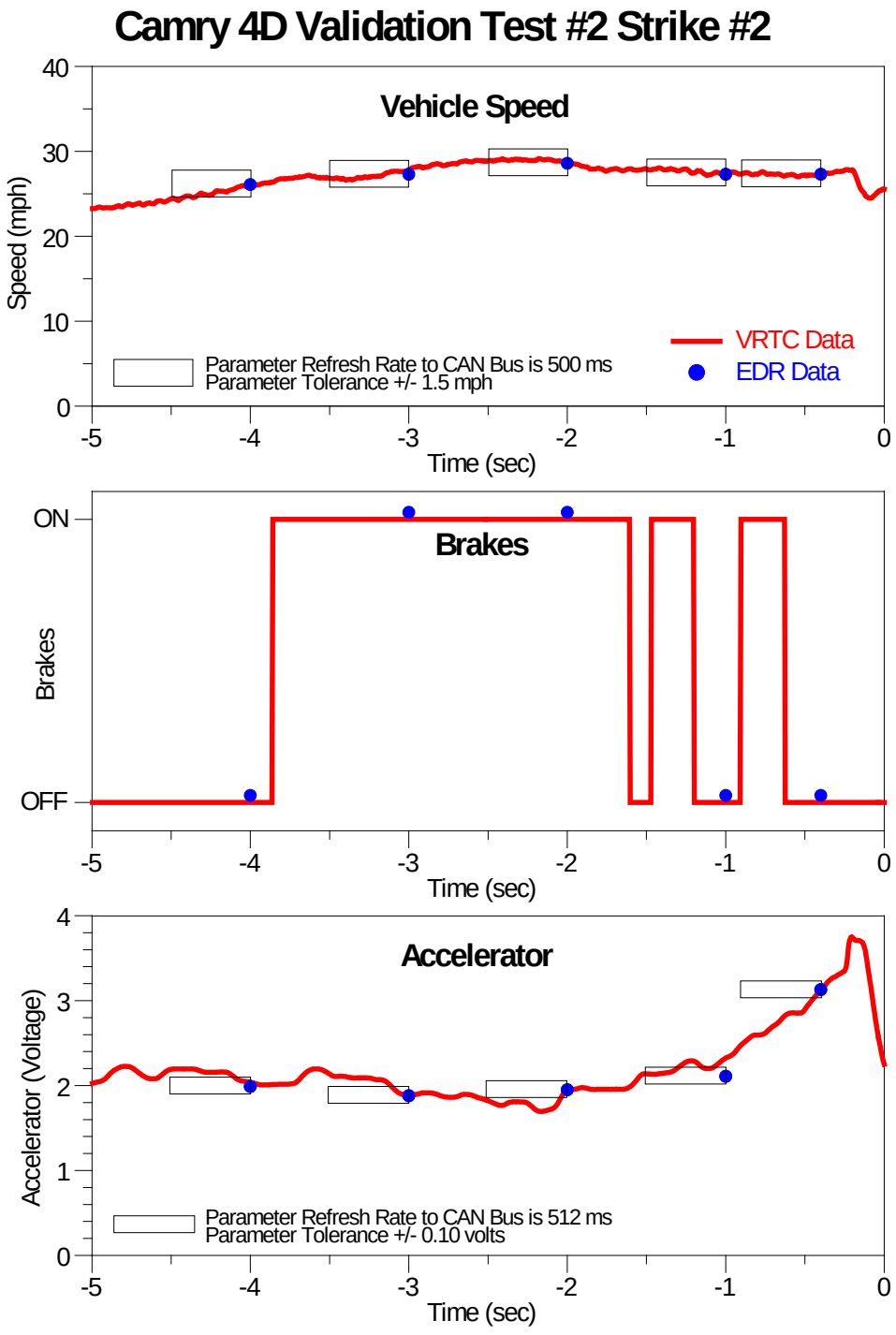
Time (sec)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Speed (mph)
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Time (sec)
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Accelerator (Voltage)
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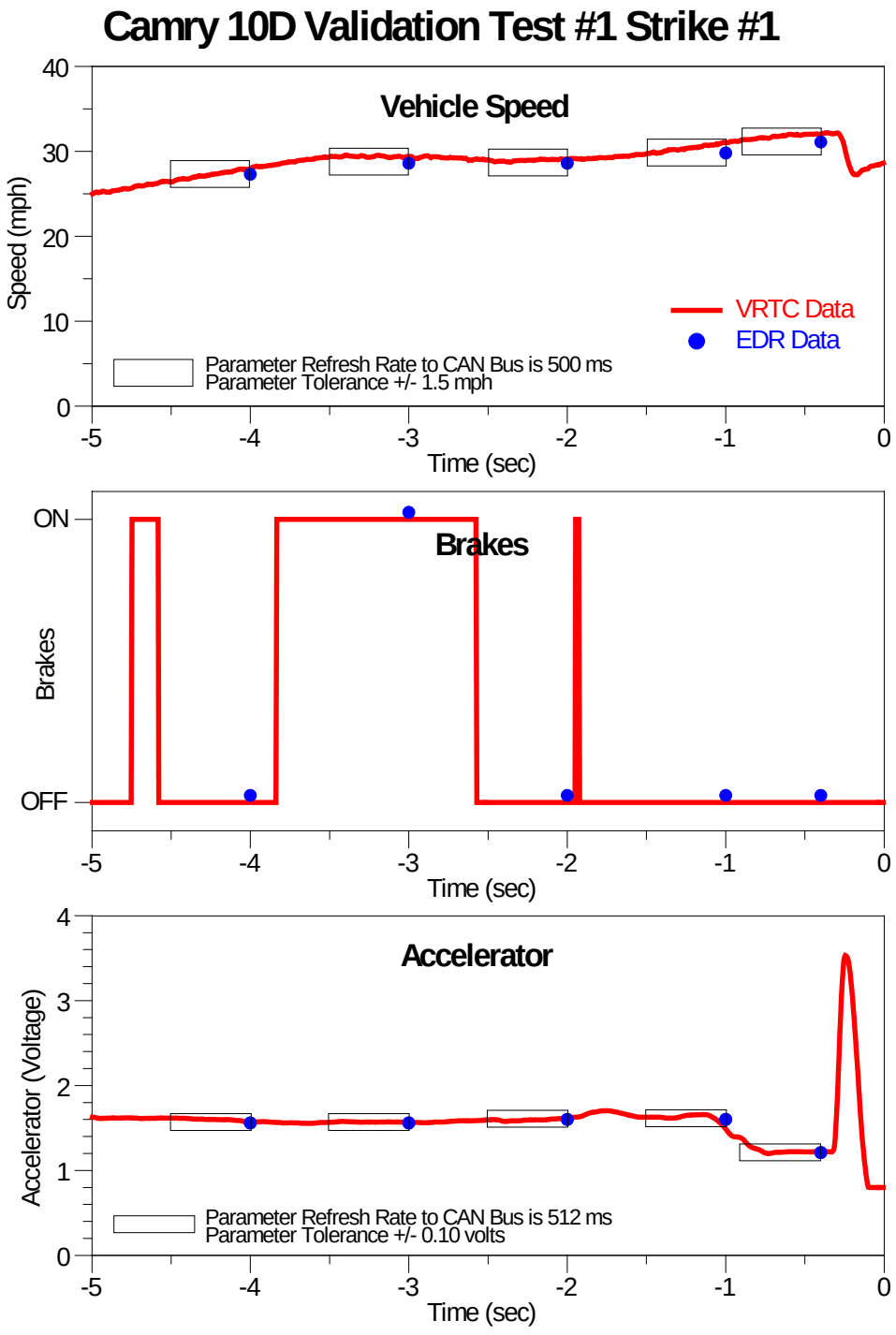
Time (sec)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Vehicle Speed
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EDR Data
Parameter Refresh Rate to CAN Bus is 500 ms
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Brakes
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Accelerator
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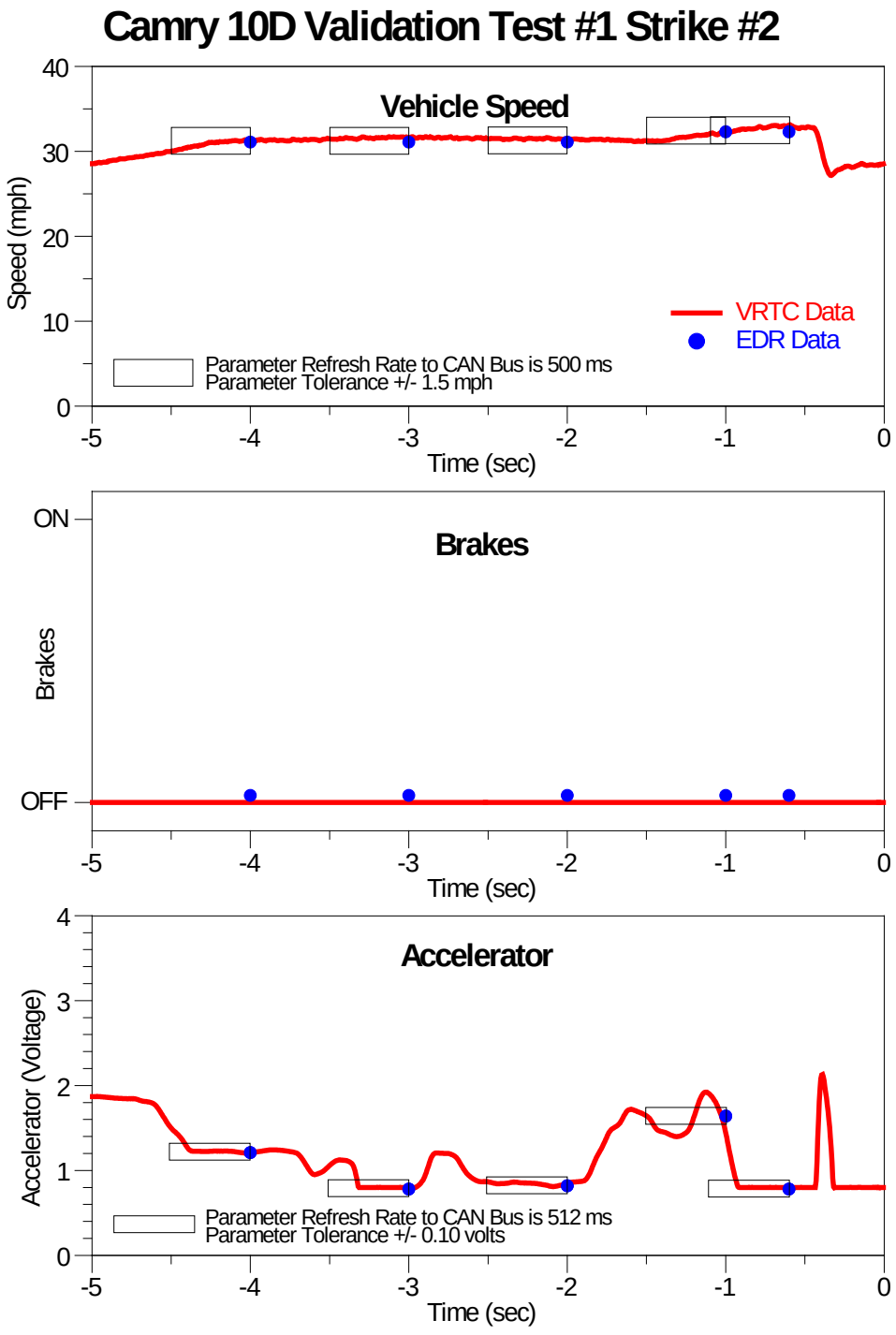
Time (sec)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Vehicle Speed
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EDR Data
Parameter Refresh Rate to CAN Bus is 500 ms
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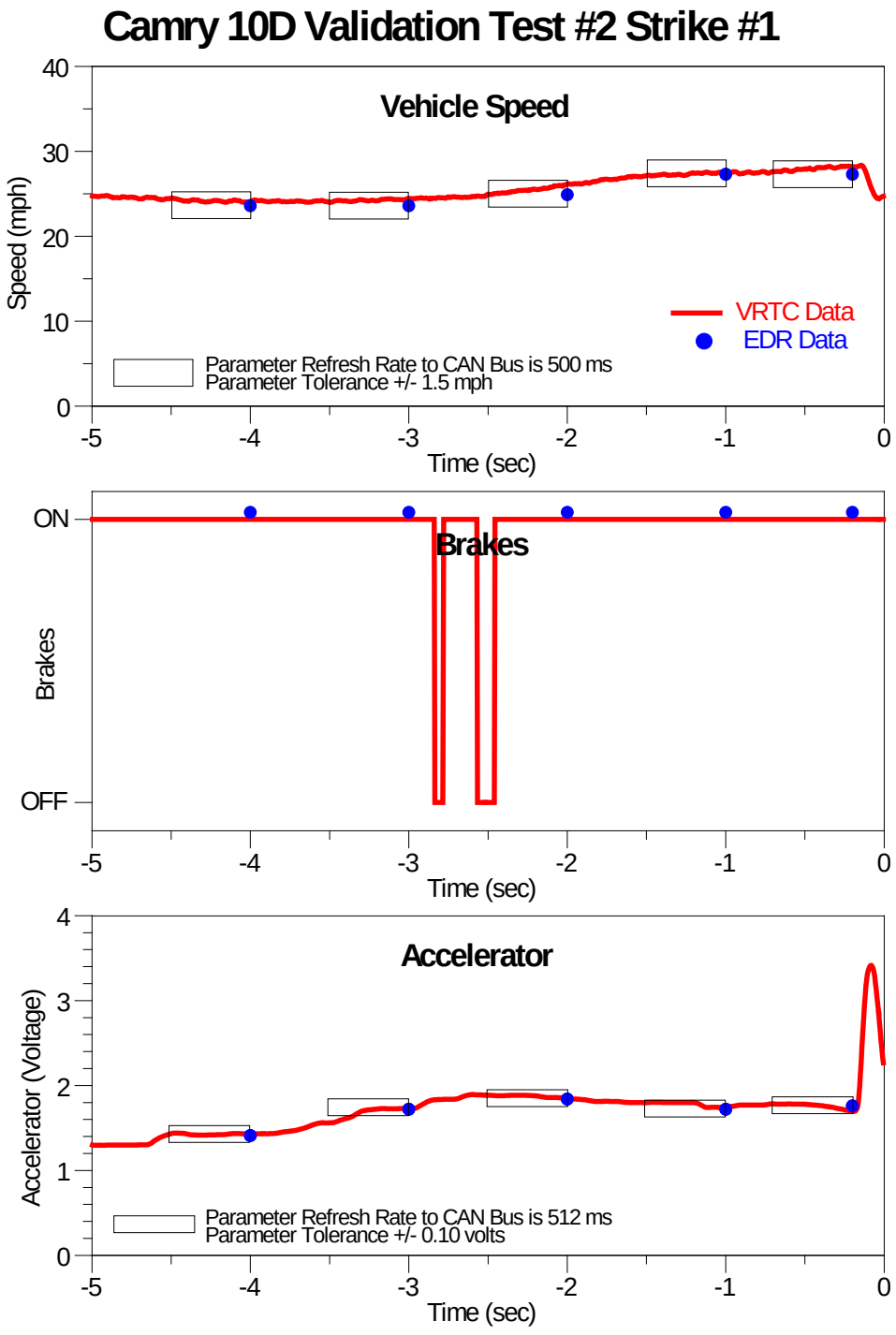
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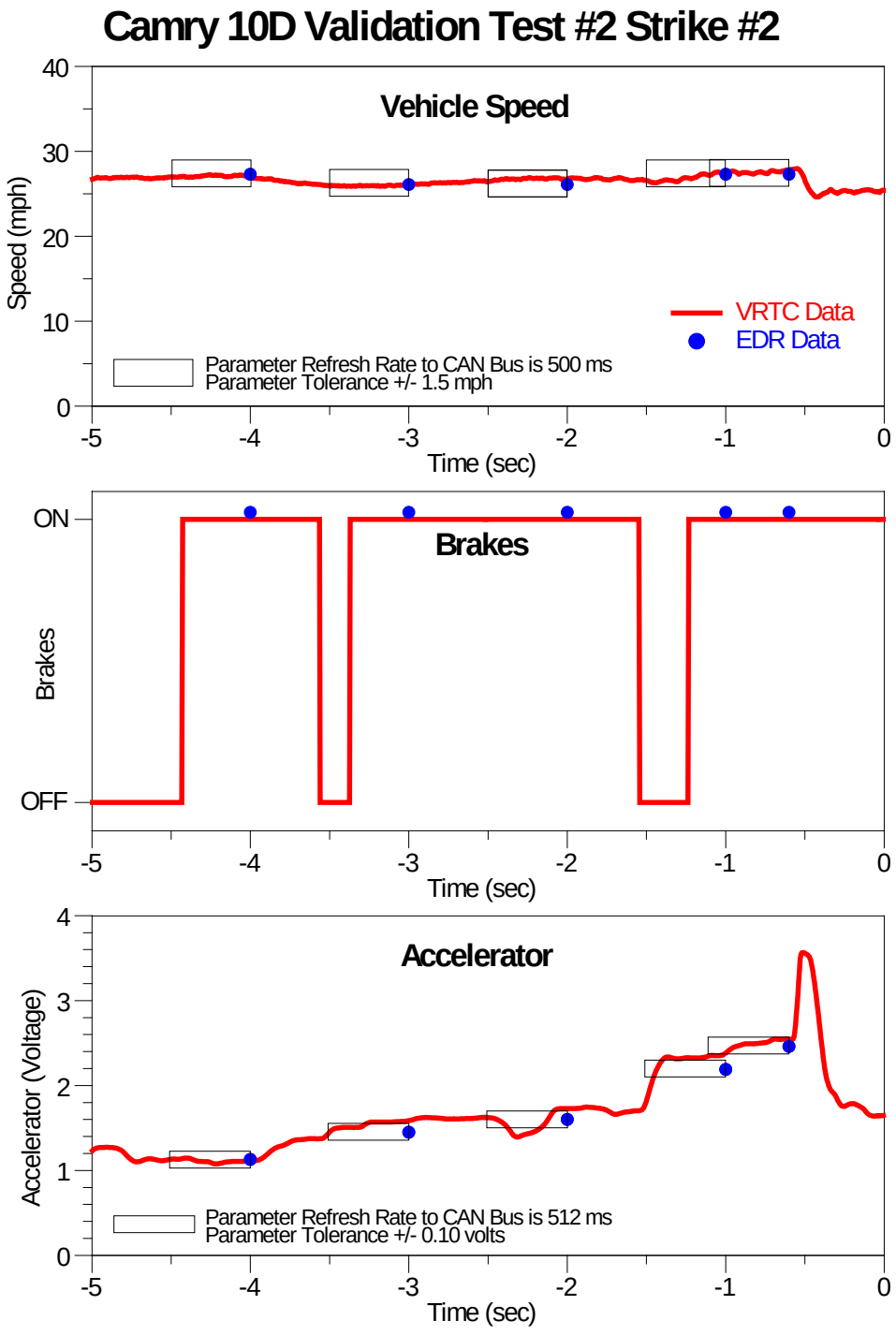
Time (sec)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Speed (mph)
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VRTC Data
EDR Data
Parameter Refresh Rate to CAN Bus is 500 ms
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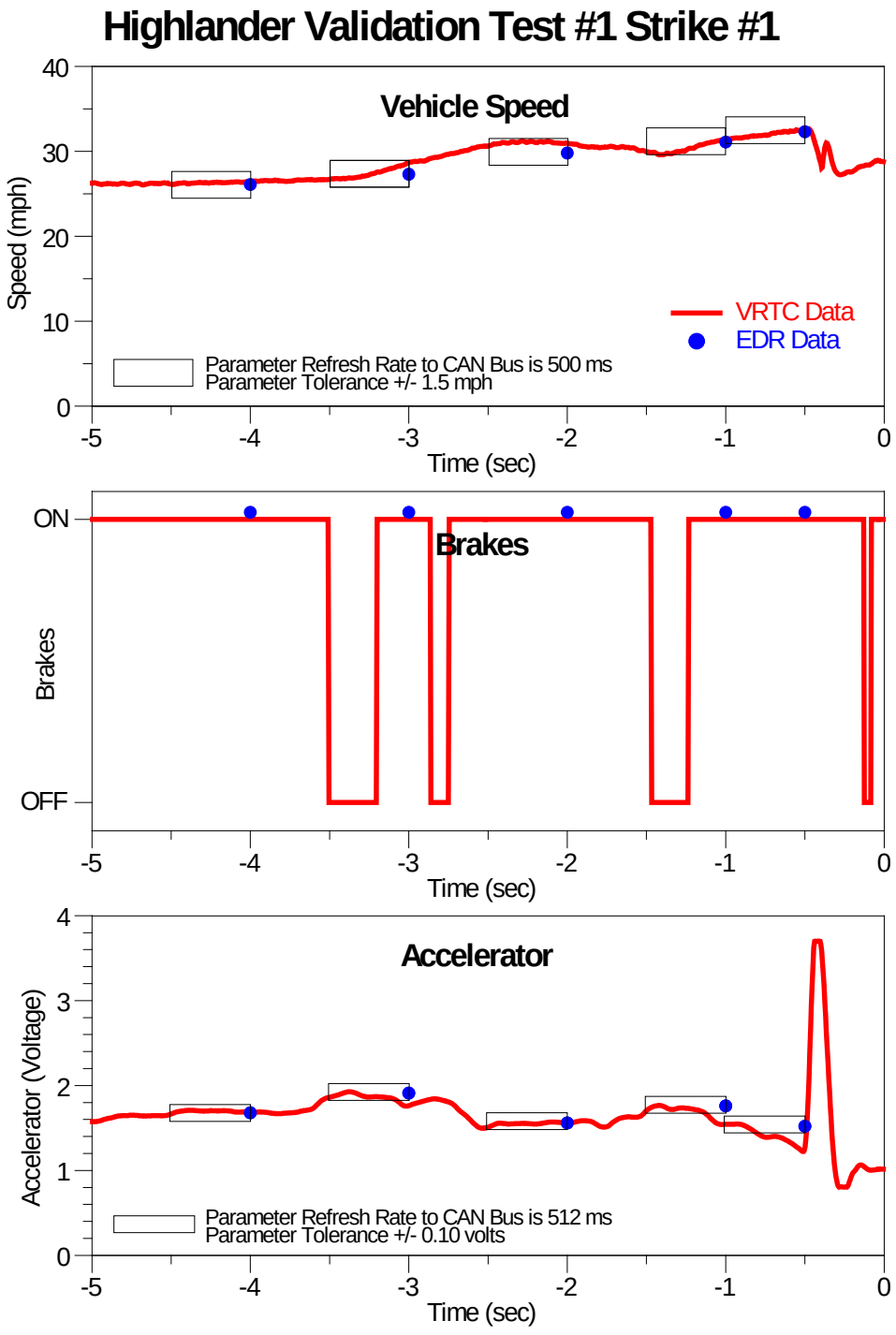
Time (sec)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Vehicle Speed
Speed (mph)
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VRTC Data
EDR Data
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Parameter Tolerance +/- 1.5 mph
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Accelerator (Voltage)
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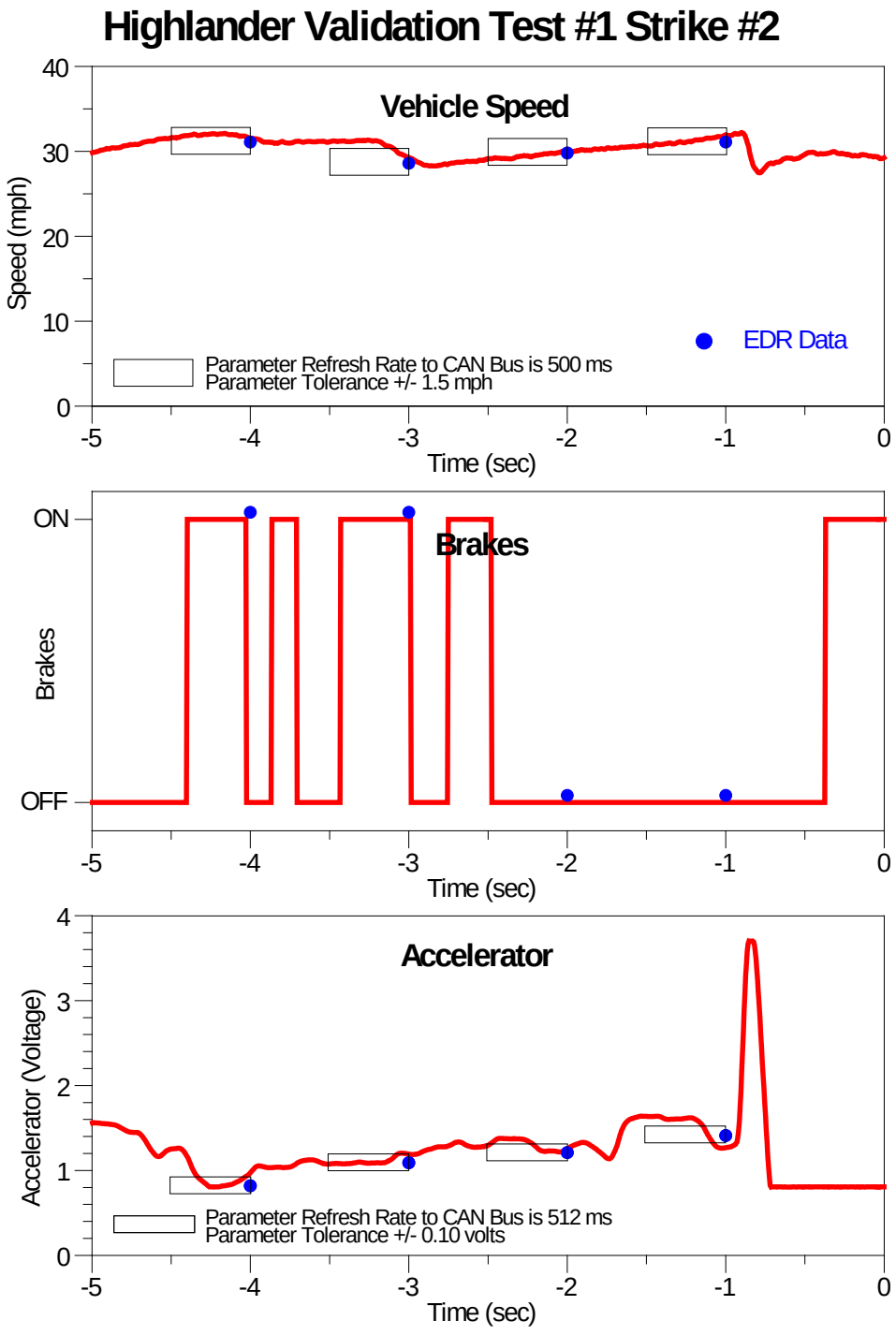
Time (sec)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Vehicle Speed
Speed (mph)
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EDR Data
Parameter Refresh Rate to CAN Bus is 500 ms
Parameter Tolerance +/- 1.5 mph
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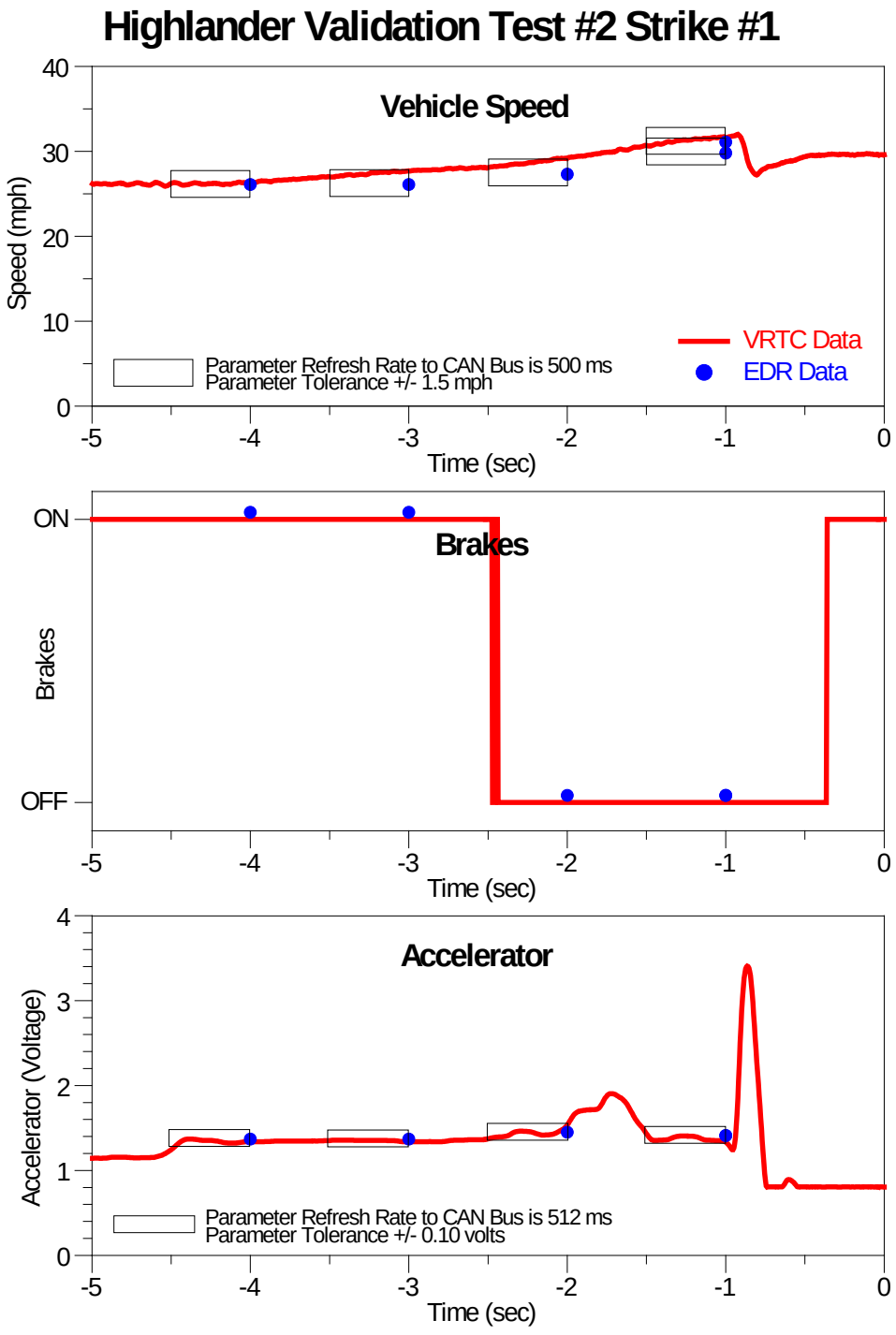
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Speed (mph)
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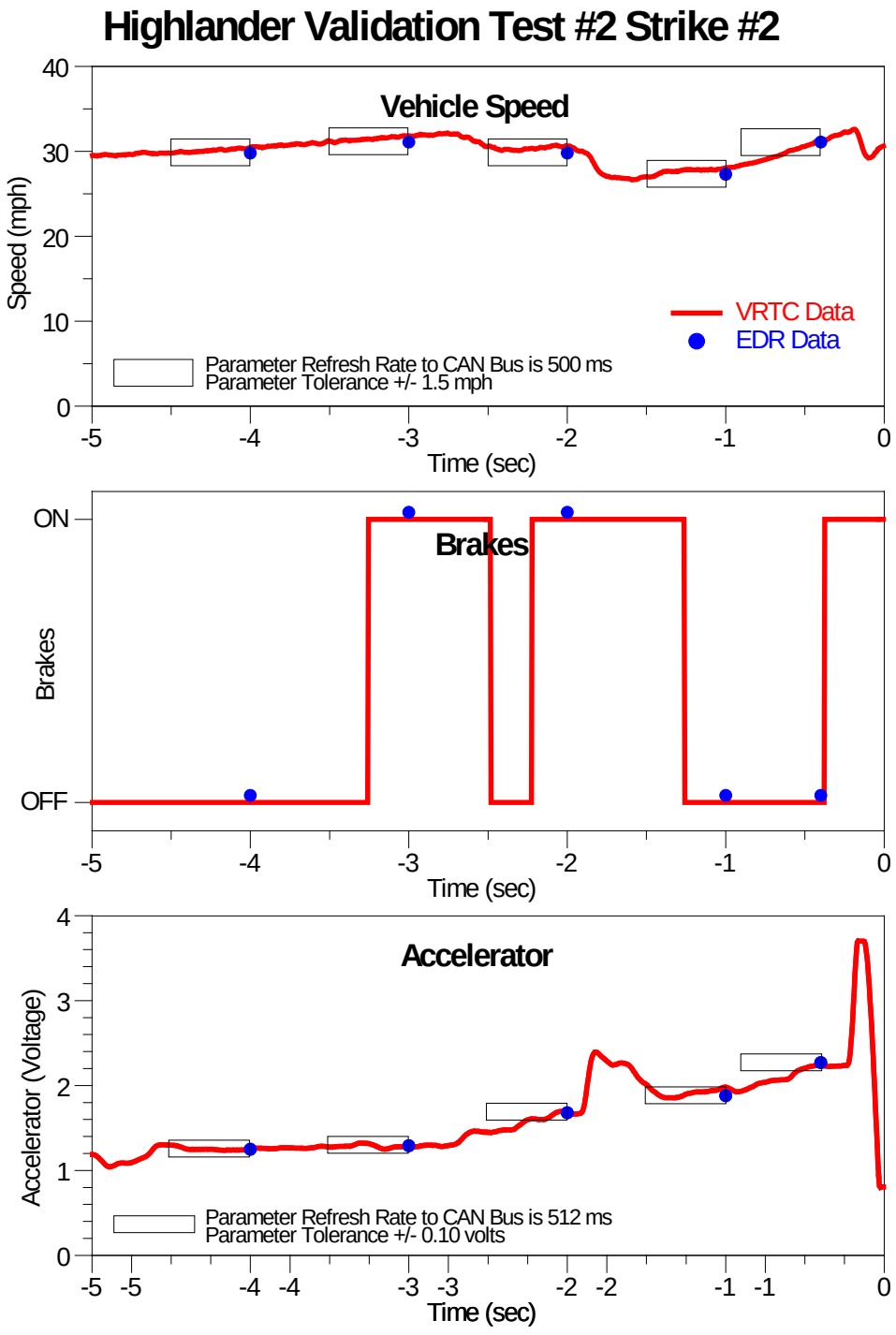
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EDR Data
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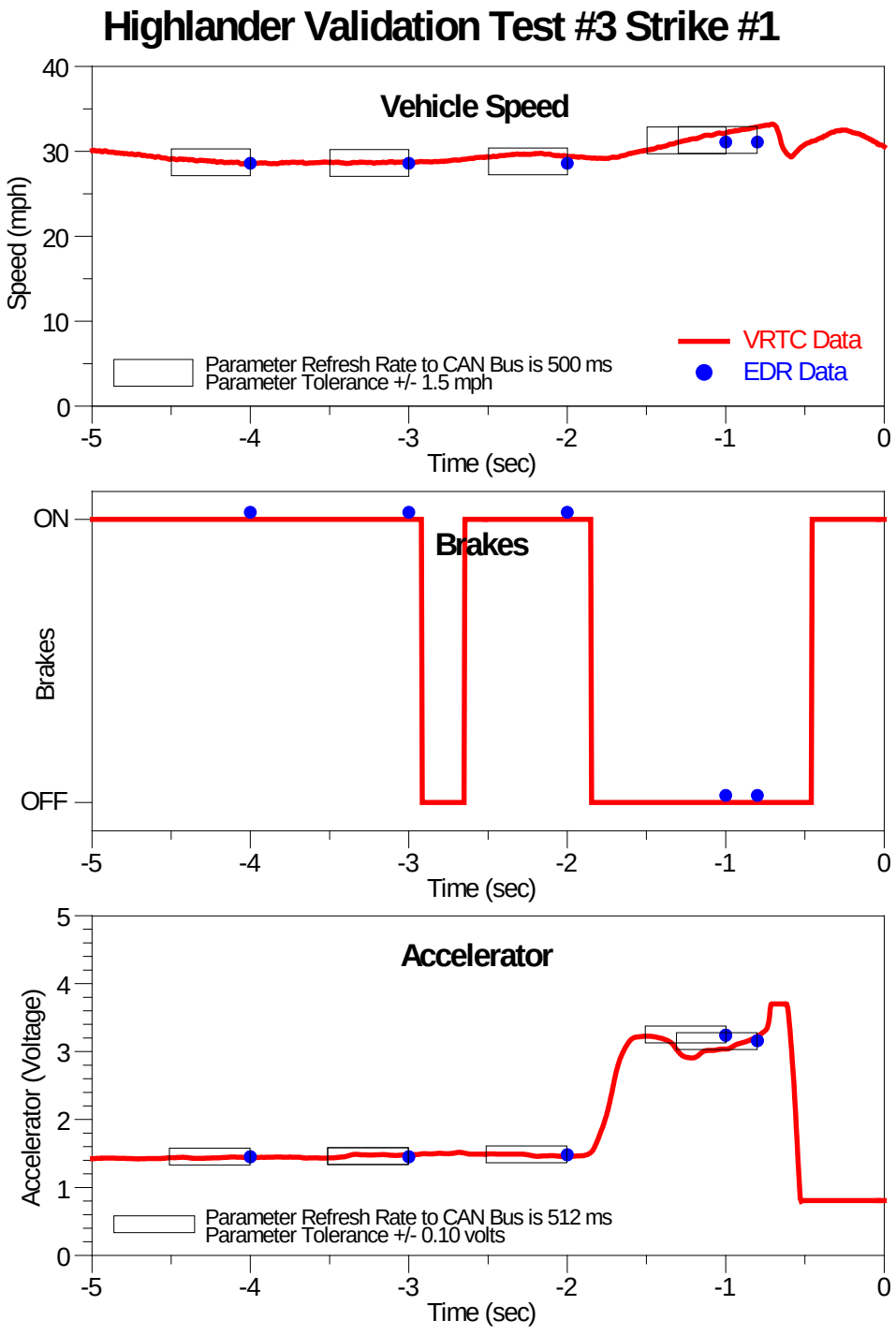
Time (sec)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Vehicle Speed
Speed (mph)
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Time (sec)
Parameter Refresh Rate to CAN Bus is 500 ms
Parameter Tolerance +/- 1.5 mph
VRTC Data
EDR Data
Brakes
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OFF
Brakes
Time (sec)
Accelerator
Accelerator (Voltage)
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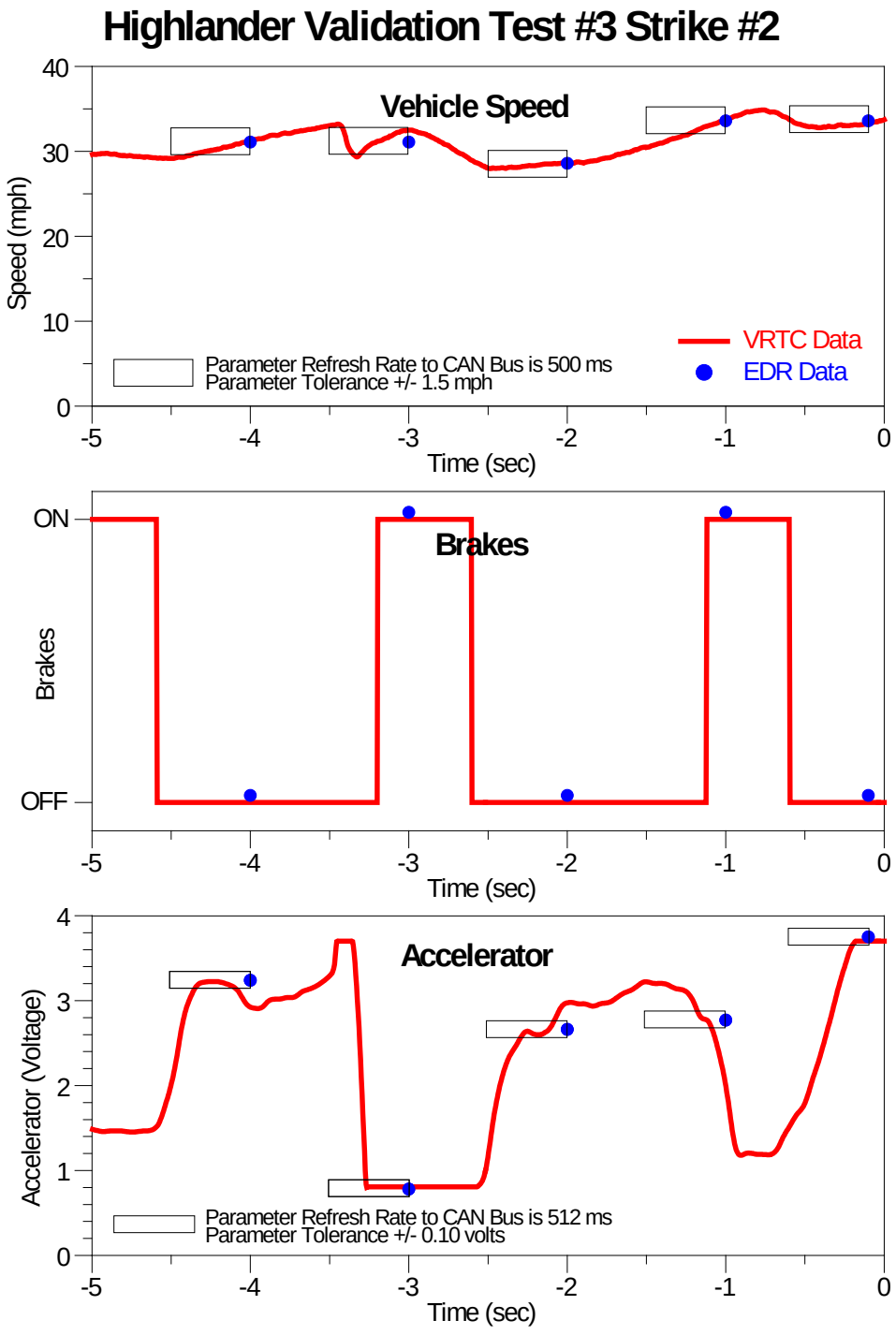
Time (sec)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Speed (mph)
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