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16. Abstract

The work described in this report was performed to (1) assess the feasibility of using a preliminary version of NHTSA's intersection safety assist (ISA) draft research test procedure to facilitate objective and repeatable test track evaluations of the technology, and (2) to develop refinements needed to improve test performability, where necessary. Three test scenarios were used, principal other vehicle (POV) straight across subject vehicle (SV) path, POV left turn across SV path, and SV left turn across POV path. Each scenario had sub-scenarios with different vehicle speed combinations, crash-imminent and near-miss test choreography, and provisions to support evaluations of up to three levels of automation. One passenger car equipped with certain ISA features was used to assess the performability of each test scenario. For each scenario, the proximity of the SV to the POV at specific impact and near-miss evaluation points was summarized.

While the protocols described in the preliminary version of NHTSA's ISA draft research test procedure were generally found to be performable, some criteria used to assess test validity were not satisfied. Revisions to improve test performability have been made, and have been incorporated into NHTSA's September 2019 ISA draft test procedure. These revisions, along with updates applied to the test equipment and an improved understanding of the parameters used to better optimize its use, are believed to have largely reconciled the ability to produce valid trials for each test condition.

The SV provided ISA interventions during most tests where the POV accelerated from rest and was driven straight across the path of the SV. None of these interventions were sufficient to prevent the SV from impacting the POV. No ISA interventions were observed during trials performed with near-miss timing, regardless of test condition.

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Executive Summary

The work described in this report was performed to (1) assess the feasibility of using a preliminary version of NHTSA's intersection safety assist (ISA) draft research test procedure to facilitate objective and repeatable test track evaluations of the technology, and (2) to develop refinements needed to maximize test performability, where necessary. Different varients of ISA systems are currently available on some light vehicles sold in the United States; however, no production vehicle was equipped with an ISA system capable of responding to all test scenarios described in the preliminary ISA draft test procedure at the time this work was performed.

The preliminary ISA draft test procedure, assembled for internal use within NHTSA, was comprised of three test scenarios: principal other vehicle (POV) straight across subject vehicle (SV) path, POV left turn across SV path, and SV left turn across POV path. Each scenario had three sub-scenarios comprised of different vehicle speed combinations. All tests were performed with two intersection-based choreographies: "crash-imminent" where the SV impacts the POV if the ISA system does not intervene, and "near-miss" where the SV narrowly misses the POV to assess whether the system reacts/intervenes in situations where it is not required to do so.

A 2017 Mercedes-Benz E300 4matic was used as the SV for the work described in this report. This vehicle's ISA is intended to help the driver avoid, or reduce the severity of, intersection-based collisions in certain straight crossing path scenarios by automatically applying the brakes in crash-imminent situations. This ISA system was not designed to respond to either left turn across path (LTAP) scenario defined in the preliminary ISA draft test procedure.

The SV was evaluated in three levels of automation: level 0 with manual steering and manual speed control, level 1 with manual steering and adaptive cruise control (ACC) in operation, and level 2 with ACC and lane centering control both in operation.

To safely perform the tests described in this report, a global vehicle target (GVT), secured to a low profile robotic vehicle (LPRV), was used as the POV during all near-miss trials, and for straight-crossing path trials performed with crash-imminent timing. Since the SV ISA was not expected to intervene during LTAP-based evaluations, the GVT/LPRV combination was only used for one LTAP sub-scenario with crash-imminent timing; the remainder of these trials only used the LPRV as the POV. This allowed for the test accuracy, repeatability, and general performability of these scenarios to be assessed without excessive wear on the SV and test equipment since a trial that would have resulted in an SV-to-POV impact would simply conclude with the SV being driven over the LPRV-based POV. Equipment to robotically operate the steering, braking, and accelerator was installed in the SV, although the number of parameters controlled during a given test condition depended on the SV level of automation (e.g., all three parameters may have been used during a test performed in automation level 0, but none would be used in automation level 2).

While the protocols described in the preliminary version of NHTSA's ISA draft research test procedure were generally found to be performable, some of the criteria used to assess whether a trial was valid (i.e., able to satisfy all test conduct requirements) were not satisfied for each test performed. To address this, revisions to improve test performability have been made, and incorporated into NHTSA's September 2019 ISA draft test procedure (NHTSA, 2019b). These revisions, along with updates applied to the software used to program the robotic controllers, and an improved understanding of the parameters used to better optimize the closed-loop operation of these controllers, are believed to have largely reconciled the ability to produce valid trials for each test condition.

With regards to the SV performance, ISA interventions were observed during 11 of 12 Scenario 1-B POV straight across SV path trials (i.e., tests where the POV was accelerated from rest and into the path of the SV). None of these interventions were effective enough to prevent the SV from impacting the POV. Rather, the SV speed at impact was reduced by 1.2 to 18.0 mph (1.9 to 28.9 km/h) overall during the trials where ISA interventions occurred. No ISA interventions were observed during trials performed with near-miss timing, regardless of test condition.

1.0 INTRODUCTION

ISA is an advanced driver assistance system designed to actively help the driver avoid an intersection-based collision with another vehicle that is approaching, or has entered, the forward path of their vehicle. If a collision is deemed to be imminent by the ISA system, it is expected that the system will automatically apply the brakes to avoid (or mitigate) the collision. To help structure its test track evaluations of ISA system performance, NHTSA developed a draft test procedure for research purposes. Referred to as the "preliminary ISA draft test procedure," this internal document outlined a process by which system operation and effectiveness could be objectively assessed.

The work described in this report was used to assess the performability of the preliminary test procedures. The experience gained from this effort was used to improve test methodology, and to better define the criteria used to determine whether a test trial is acceptably performed. These adjustments have been incorporated into an updated document known as NHTSA's September 2019 ISA draft research test procedure (NHTSA, 2019b).

2.0 TEST PROTOCOL

In this section, the SV and the POV used for the work described in this report are described. A description of the test equipment, and a brief overview of each ISA test scenario specified in the preliminary ISA draft test procedure, is also provided.

2.1. Subject Vehicle

A 2017 Mercedes-Benz E300 4matic (shown in **Figure 2-1**, and subsequently referred to as the Mercedes E300 for brevity) was used as the SV for the work described in this report. This vehicle was selected because it was, at the time the testing was performed, one of the few U.S.-specficiation production vehicles known by NHTSA to be available with technology designed to identify and respond to potential straight across path collisions in scenarios where a POV approachs the SV from either side of an intersection.[1]

Figure 2-1: Mercedes-Benz E300.

If an imminent collision is predicted by this system, the vehicle's "Active Brake Assist With Cross-Traffic Functionality" feature is designed to automatically apply the brakes to help avoid, or reduce the severity of, the impact. Conversely, if the system predicts an SV-to-POV collision is not expected to occur, the feature is not expected to be activated. The Mercedes E300 user manual states the system is active at speeds between 4 to 43.5 mph (7 to 70 km/h) (Mercedes-Benz, 2017).

2.2. Principal Other Vehicle

To safely perform the tests described in this report, the POV was either a GST system comprised of a GVT revision F secured to the top of a LPRV, or just the LPRV alone. The GVT, shown in **Figure 2-2**, is constructed from foam panels and vinyl skins designed to separate upon impact. The LPRV, shown in **Figure 2-3**, is a robotic platform that provides accurate closed-loop control of the POV relative to the SV or roadway, and can be safely driven over by the SV should an impact with the POV occur. The GST system is designed to look as realistic as possible to the sensors used by advanced driver safety assistance systems such as ISA, and is strikeable from any approach aspect. Detailed GVT revision F specifications are provided in a European New Car Assessment Program (Euro NCAP) technical bulletin (Euro NCAP, 2018).

[1] The only other vehicles were other Mercedes-Benz models equipped with the same technology.

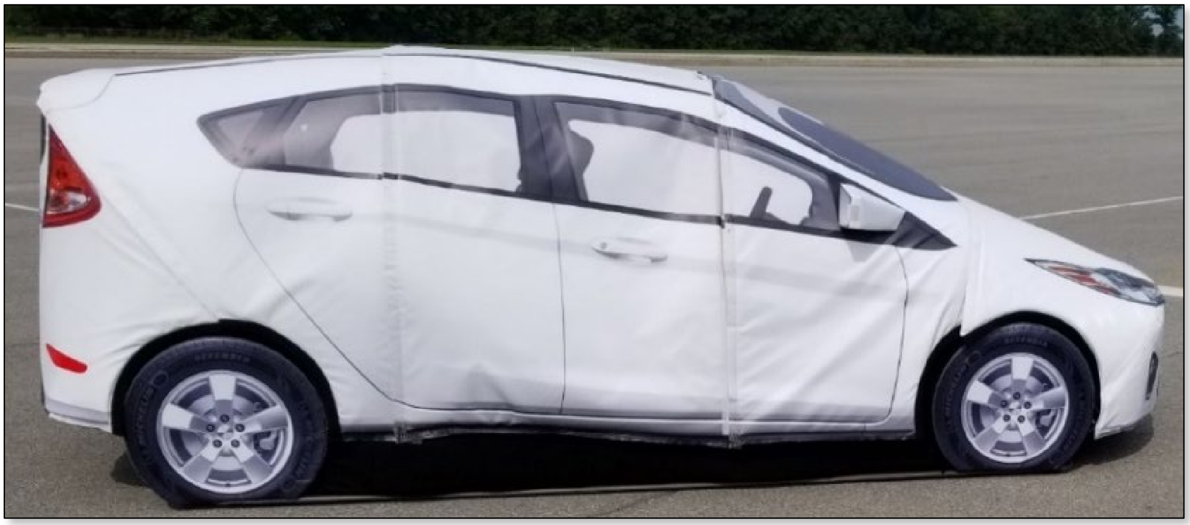
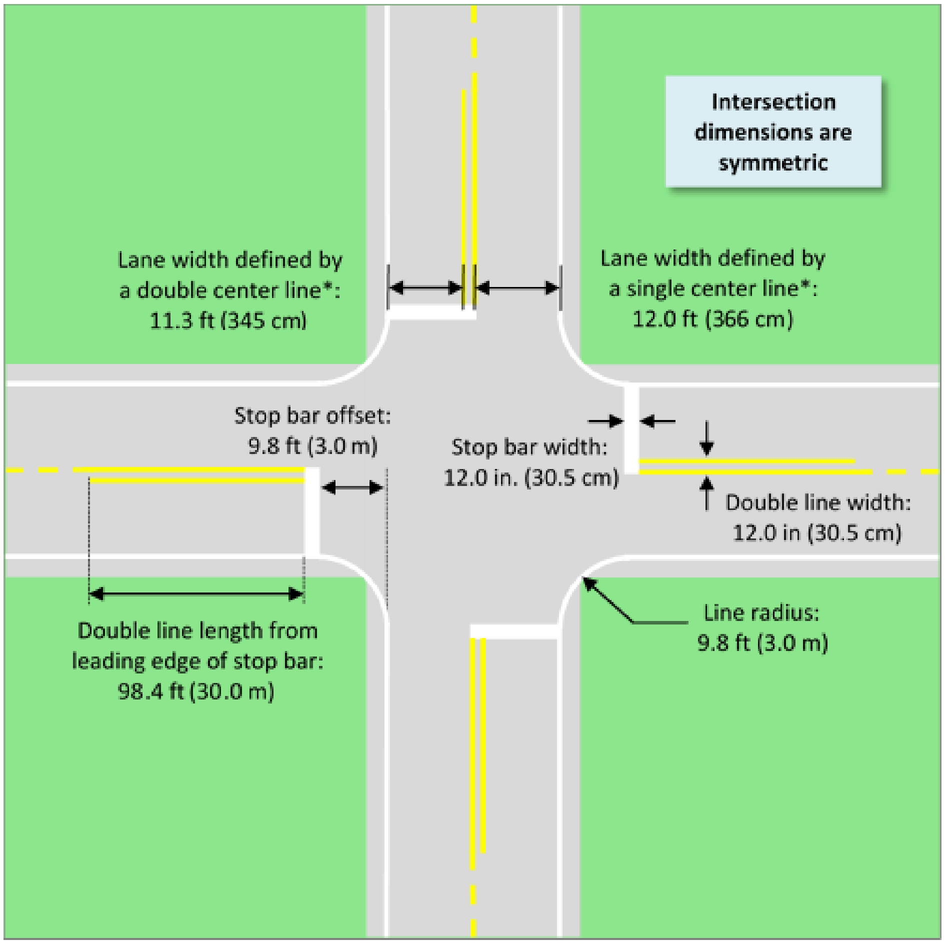


Figure 2-2: Guided soft target revision F.

Figure 2-3: Low profile robotic vehicle.

2.3. Test Facility

All tests were performed at a simulated intersection located on the Vehicle Dynamics Area at the Transportation Research Center, Inc., in East Liberty, Ohio. A depiction of the four-way intersection used in this evaluation is presented in **Figure 2-4**. The lines used to delineate each lane, and to define the intersection, meet the Federal Highway Administration (FMWA) specifications defined in the Manual on Uniform Traffic Control Devices (FHWA, 2012). The intersection itself was defined by solid white edge lines, solid white stop bars, and double yellow center lines. The lanes leading up to the intersection were defined by solid white edge lines and a single dashed yellow center line. The width of the lane lines was approximately 4 in. (10 cm).



*Measured from center of the 4" (102 mm) lane lines.

Figure 2-4: Four-way intersection used for ISA evaluations.

2.4. Test Scenarios and Matrix

The preliminary ISA draft test procedure uses three test scenarios designed to objectively and effectively assess ISA performance; one straight-crossing path scenario, and two left turn across path scenarios.

- All tests were performed with either "crash-imminent" or "near-miss" choreography. "Crash-imminent" timing was designed to elicit ISA interventions from the SV; if no ISA intervention occurred, an SV-to-POV collision would occur. "Near-miss" timing resulted in the SV narrowly missing the POV to assess whether the system would intervene in situations where it is not required to do so.
- For scenarios in which either the SV, POV, or both vehicles entered the intersection at speed (i.e., as opposed to accelerating from rest at a stop bar), the moving vehicle was required to maintain a steady state of speed for three seconds prior to crossing the intersection stop bar in its respective travel lane.
- Unless initially at rest at a stop bar, each vehicle was driven straight in its respective travel lane prior to entering the intersection.
- Unless the initial conditions prevented it, each test scenario was performed using three levels of automation: level 0, level 1, and level 2. Level 0 used manual steering and

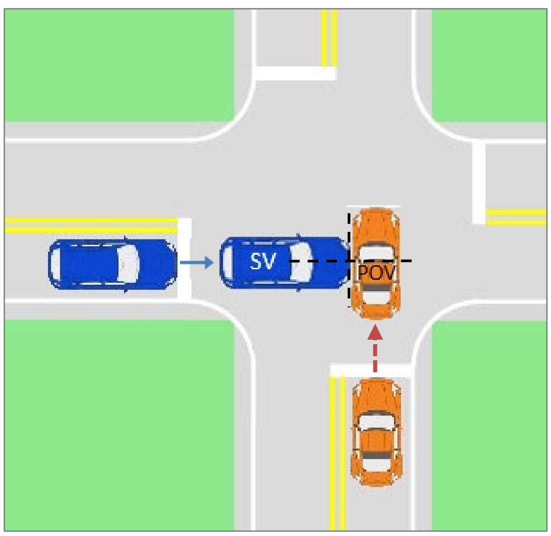
manual speed control. Level 1 used manual steering and ACC. Level 2 used lane centering control and ACC.

- Three trials per sub-scenario combination were performed.

2.4.1. ISA Scenario 1: POV Straight Across SV Path

The ISA Scenario 1 tests were designed to evaluate an ISA system's ability to detect and respond to a POV driven straight across the SV's forward path.

- "Crash-imminent" choreography resulted in the front center of the SV impacting the POV at its longitudinal center point if no SV ISA intervention occurs (see **Figure 2-5** left).
- "Near-miss" choreography resulted in the front center of the SV to be located 6.6 ft (2 m) behind the rearmost part of the POV when the front center of the SV crosses a vertical plane defined by the side of the POV parallel to the POV longitudinal centerline (see **Figure 2-5** right).



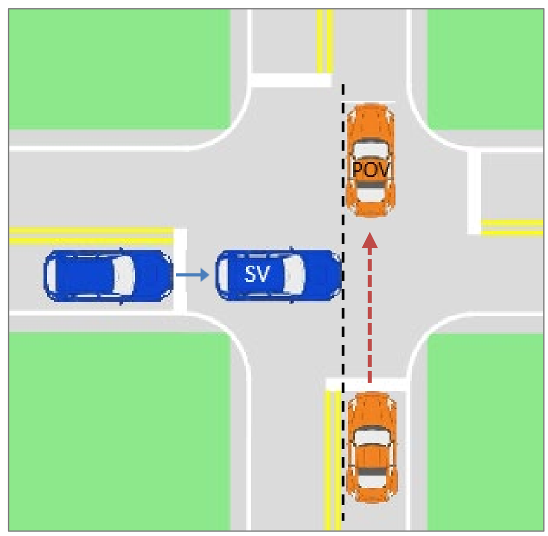


Figure 2-5: Scenario 1 crash-imminent (left) and near-miss (right) tests.

Although the preliminary ISA draft test procedure specified that the POV shall approach from the left or right side of the SV, the work described in this report was limited to trials performed with POV approaches from only one side due to test facility space constraints. Scenario 1-A and 1-B trials were evaluated with a right-side POV approach, while Scenario 1-C trials were performed with a left-side POV approach. The vehicle speed combinations for each sub-scenario are shown in **Table 2-1**.

The specific way a given ISA Scenario 1 test was performed not only depended on the SV-to-POV speed combination and choreography, but also what level of automation the SV was operated in. For example, Scenario 1-C was not performed when the SV is operated in automation level 1 or 2 since accelerating the vehicle from rest, with the timing needed to execute the tests accurately and consistently, was not believed to be possible.[2]

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[2] Even if this was possible, system responsiveness (e.g., time to engage, longitudinal acceleration, jerk, etc.) was expected to be SV-dependent. This is problematic since the choreography used for these maneuvers must be tightly controlled to ensure the desired crash-imminent and near-miss timing is realized.

Table 2-1: Scenario 1 Test Speed Combinations

ISA Scenario	Vehicle Speeds	
	SV	POV
S1-A	25 mph (40.2 km/h)	25 mph (40.2 km/h)
S1-B	25 mph (40.2 km/h)	0 ⇨25 mph (0 ⇨ 40.2 km/h)
S1-C	0 ⇨25 mph (0 ⇨ 40.2 km/h)	25 mph (40.2 km/h)

2.4.2. ISA Scenario 2: POV Left Turn Across SV Path

The ISA Scenario 2 tests were designed to evaluate an ISA system's ability to detect and respond to a POV that turns left across the SV's forward path.

- For Scenario 2, "crash-imminent" choreography resulted in (1) the front center of the SV being in alignment with the longitudinal centerline of the POV when (2) any part of a polygon used to define the SV front contacted any part of a polygon used to define the right side of the POV if no SV ISA intervention occurred (see **Figure 2-6** left).[3]
- "Near-miss" choreography resulted in the front-most part of the SV reaching a vertical plane defined by the right side of the POV, parallel to the POV longitudinal centerline once the POV's turn has been completed, and the front center of the SV being 6.6 ft (2 m) behind the rearmost part of the POV (see **Figure 2-6** right).

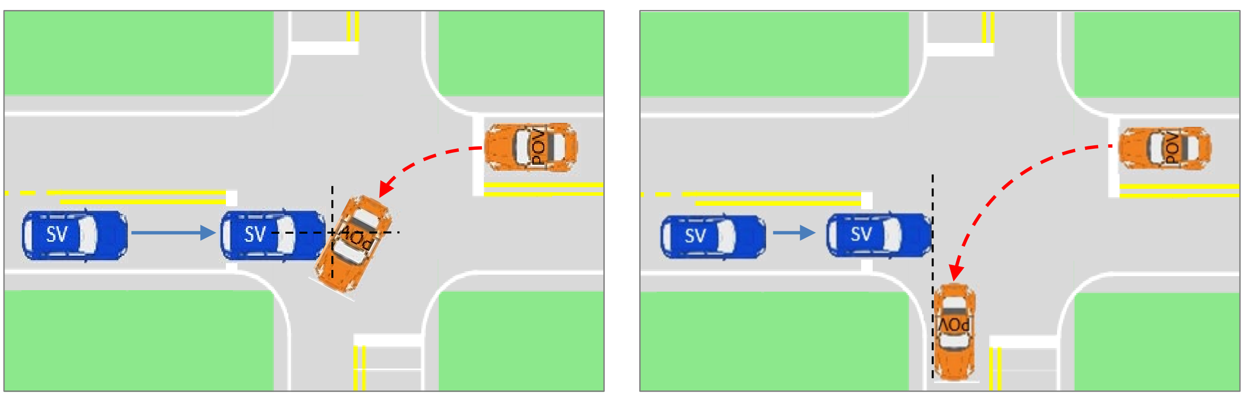


Figure 2-6: Scenario 2 crash-imminent (left) and near-miss (right) tests.

The vehicle speed combinations for each sub-scenario used in this study are shown in **Table 2-2**. For each Scenario 2 test, the desired SV speed was specified to be 25 mph (40.2 km/h). Although the preliminary ISA draft test procedure also specified that the POV shall be operated at 25 mph (40.2 km/h), then decelerate at 0.26 g (2.53 m/s^2) with the timing needed to achieve 15 mph (24.1 km/h) at the instant it reached the stop bar in its travel lane during the conduct of Scenarios 2-A and 2-C, the short length of the

[3] The Scenario 2 crash-imminent choreography described in **Figure 2-6** was specified in the preliminary ISA draft test procedure, and was used for the work described in this report. Since the completion of this work, the Scenario 2 crash-imminent choreography has been simplified. Details regarding this change are available in Section 4.0 of this report.

approach lanes leading to the intersection used in this study limited the POV test speed to only 15 mph (24.1 km/h) during the conduct of these tests. The target POV speed of 25 mph (40.2 km/h) remained for Scenario 2-B, but only because it was not possible to accelerate the POV at the desired 0.127g (1.25 m/s^2) from rest to that speed before a test termination (i.e., end of test) condition was satisfied.

Table 2-2: Scenario 2 Test Speed Combinations

ISA Scenario	Vehicle Speeds	
	SV	POV
S2-A	25 mph (40.2 km/h)	15 mph (24.1 km/h)
S2-B	25 mph (40.2 km/h)	0 ⇨25 mph (0 ⇨ 40.2 km/h)
S2-C	0 ⇨25 mph (0 ⇨ 40.2 km/h)	15 mph (24.1 km/h)

The specific way a given ISA Scenario 2 test was performed not only depended on the SV-to-POV speed combination and choreography, but also the level automation the SV was operated in. For the reasons previously explained in Section 2.4.1, Scenario 2-C was not performed when the SV is operated in automation levels 1 or 2.

2.4.3. ISA Scenario 3: SV Left Turn Across POV Path

The ISA Scenario 3 tests were designed to evaluate an ISA system's ability to detect and respond to a POV while the SV is driven left across the POV's forward path.

- For Scenario 3 "crash-imminent" choreography resulted in the left front corner of the SV impacting the front left corner of the POV (see **Figure 2-7** left).[4]
- "Near-miss" choreography resulted in the front-most part of the POV reaching a vertical plane defined by the right side of the SV, parallel to the SV longitudinal centerline once the SV's turn has been completed, and the front center of the POV being 6.6 ft (2 m) behind the rearmost part of the SV (see **Figure 2-7** right).

[4] The Scenario 3 crash-imminent choreography described in **Figure 2-7** was specified in the preliminary ISA draft test procedure, and was used for the work described in this report. Since the completion of the work, the Scenario 3 crash-imminent choreography has been adjusted to be more consistent with the revised version of Scenario 2. Details regarding this change are available in Section 4.0 of this report.

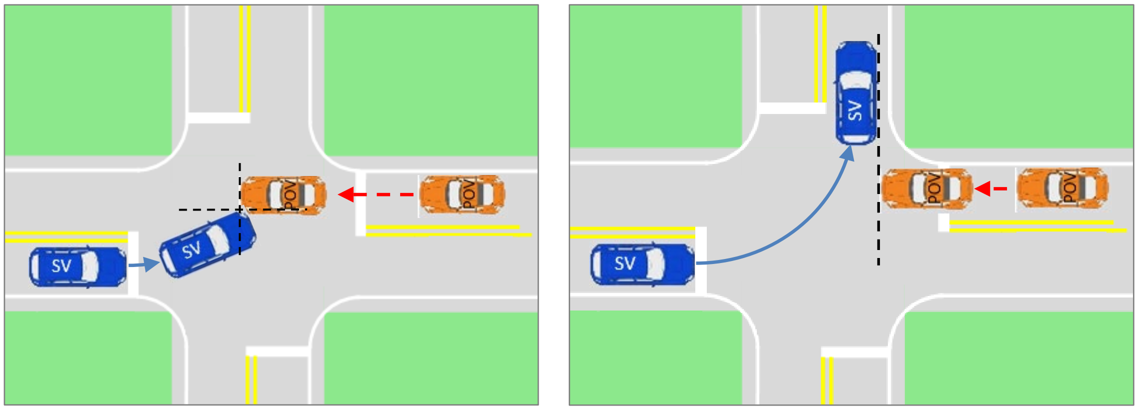


Figure 2-7: Scenario 3 crash-imminent (left) and near-miss (right) choreography.

The vehicle speed combinations for each sub-scenario used in this study are shown in **Table 2-3**. For each Scenario 3 test, the desired POV speed was specified to be 25 mph (40.2 km/h). Although the preliminary ISA draft test procedure specified that the SV shall be operated at 25 mph (40.2 km/h), then decelerate at 0.26 g (2.53 m/s^2) with the timing needed to achieve 15 mph (24.1 km/h) at the instant it reached the stop bar in its travel lane during the conduct of Scenarios 3-A and 3-B, the short length of the approach lanes leading to the intersection used in this study limited the SV test speed to only 15 mph (24.1 km/h) during the conduct of these tests. The target SV speed of 25 mph (40.2 km/h) remained for Scenario 3-C, but only because it was not only possible to accelerate the SV at the desired 0.127g (1.25 m/s^2) from rest to that speed before a test termination (i.e., end of test) condition was satisfied.

Table 2-3: Scenario 3 Test Speed Combinations

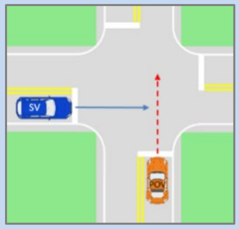
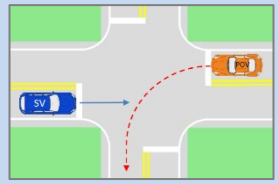
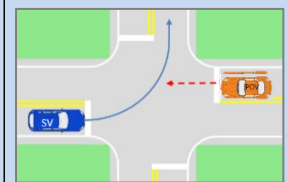
ISA Scenario	Vehicle Speeds	
	SV	POV
S3-A	15 mph (24.1 km/h)	25 mph (40.2 km/h)
S3-B	15 mph (24.1 km/h)	0 ⇨25 mph (0 ⇨ 40.2 km/h)
S3-C	0 ⇨25 mph (0 ⇨ 40.2 km/h)	25 mph (40.2 km/h)

The specific way a given ISA Scenario 3 test was performed depended on the SV-to-POV speed combination and choreography, and what level of automation the SV was operated in. In agreement with the specifications provided in the preliminary ISA draft test procedure, Scenario 3 tests were only performed with the SV operating in automation level 0 for the work described in this report.

2.4.4. Test Matrix

The test matrix describing the work performed in this study is shown in **Table 2-4**. Cells shaded in black were not part of the test matrix defined in the preliminary ISA draft test procedure, and were therefore excluded from tests performed in this study. The cells described as “TNP,” Scenarios 2-A and 2-B trials performed in automation levels 1 and 2 with crash-imminent timing, were also not performed to reduce unnecessary wear of SV and test equipment. Additional details regarding this omission are provided in Section 3.3 of this report.

Table 2-4: Intersection Safety Assist Test Matrix

		Scenario 1 			Scenario 2 			Scenario 3 		
Choreography	**Automation Level**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Near-Miss	0	✓	✓	✓	✓	✓	✓	✓	✓	✓
	1	✓	✓		✓	✓				
	2	✓	✓		✓	✓				
Crash-Imminent	0	✓	✓	✓	✓	✓	✓	✓	✓	✓
	1	✓	✓		TNP	TNP				
	2	✓	✓		TNP	TNP				

2.5. Test Validity Criteria

The preliminary ISA draft test procedure included tolerances based on those used by NHTSA within the agency's other advanced driver assistance system (ADAS) draft research test procedures, and provided an objective way by which to determine whether the ISA protocols could be accurately performed as specified. These "validity criteria," presented in **Appendix A**, were assessed for each trial performed in this study, and were used to assess whether parameters such as the steady state approach of the vehicles towards the intersection, vehicle speeds, path tolerances, and yaw rates of each trial where within an acceptable range.

The period over which the test tolerances were to be maintained is referred to as the validity period. For tests where the SV was initially stopped, the valid test interval began three seconds before the SV accelerated from rest. For tests where the SV was not initially stopped, the valid test interval began three seconds before the SV reached the intersection stop bar located in the SV travel lane. Regardless of whether a test trial was performed with crash-imminent or near-miss SV-to-POV timing, the valid test interval ended when the SV impacted the POV; or 3 seconds after the SV has avoided the SV-to-POV impact.

In addition to confirming the applicable test tolerances were satisfied, accelerator pedal position and brake pedal force data were recorded to verify the driver did not press either pedal during tests performed in automation level 1 and 2. These checks were used to eliminate the potential for a driver's manually applied inputs from inadvertently confounding the test outcome.

2.6. Test Equipment

The test equipment used in this study consisted of a GVT, LPRV, robotic controllers for SV steering, brake, and accelerator operation, the instrumentation needed to measure the test input conditions and outputs, and a data acquisition system.

2.6.1. SV Robotic Steering Controller

A robotic controller was attached to the SV steering wheel to maximize the accuracy and repeatability by which it could remain centered within the travel lane while approaching the intersection, and perform left turns across the path of the POV, where applicable, during tests performed in automation level 0. For this study, an SR15 Orbit steering robot from AB Dynamics was used; a lightweight, low torque steering controller that mounts directly to the steering wheel without the need to remove the air bag (see **Figure 2-8** for a typical installation example).

2.6.2. SV Robotic Brake and Throttle Controllers

When the test validation work described in this report was initiated, the longitudinal speed of the SV was not robotically controlled. This often resulted in SV speed exceeding the tolerances defined in the preliminary ISA draft test procedure, and therefore a significant number of non-valid tests. To address this, a CBAR600 robotic brake and throttle controller (also from AB Dynamics) was installed in the SV. In addition to improving the consistency of the SV inputs affected by manual (driver) operation, this controller also facilitated closed-loop control of the SV and POV to ensure they correctly arrived at the desired crash-imminent and near-miss evaluation points with the intended choreography. As shown in **Figure 2-9**, the brake and throttle controller was attached to the lower front edge of the driver's seat.

Figure 2-8: Example of a robotic steering controller installation.

Figure 2-9: Example of a robotic brake and throttle controller installation.

2.6.3. Inertial and GPS Measurements

The SV and POV (LPRV) were instrumented with Oxford Technical Solutions (OxTS) RT 3002 units to provide the accelerations, rotational rates, speeds, and positions of each vehicle. Differential corrections were applied to the GPS data to maximize position accuracy. Paired with an OxTS Range S system and LPRV control software, relative ranges and velocities between the SV and POV were also collected.

3.0 TEST RESULTS

Results from the ISA tests performed in this study are provided in this section. Unless noted otherwise, three trials of each test condition were conducted, and basic descriptive statistics to assess repeatability are provided. A summary of the validity criteria satisfied by each test trial specified in the preliminary ISA draft test procedure is provided in **Appendix B**.

3.1. Comments Regarding Repeatability

The process used to assess the test vehicle choreography during each trial was similar, but the final SV-to-POV proximity and orientation differed for trials performed with near-miss versus crash-imminent timing. A tolerance of ±0.8 ft (0.25 m) from the desired value, a path deviation allowance specified in other NHTSA ADAS draft research test procedures, was used to provide an objective measure by which the final SV-to-POV position accuracy could be assessed (NHTSA, 2019a, 2019c, 2019d).

3.1.1. Near-Miss Repeatability

As described in Sections 2.4.1, 2.4.2, and 2.4.3 of this report, achieving a near-miss distance of 6.6 ft (2 m) was desired. Sections 3.2, 3.3, and 3.4 present the SV-to-POV near-miss distances observed during the tests performed in Scenarios 1, 2, and 3, respectively. Deviations from the desired near-miss values, and the associated averages and standard deviations, are also provided for each test series. For these results, a negative "actual versus desired" difference means the front center of the SV arrived at the plane defined by the near side of the POV before it was 6.6 ft (2 m) away from the POV rear. Conversely, a positive difference means the SV reached the near-miss evaluation point later than desired; after the SV was 6.6 ft (2 m) away from the POV rear.

3.1.2. Crash-Imminent Repeatability

To quantify the repeatability observed during trials performed with crash-imminent timing, the distance between the actual versus desired SV-to-POV impact points was compared. From a test conduct perspective, and assuming no ISA intervention occurs, the difference between these points should ideally be zero.

- The Scenario 1 tests performed with crash-imminent timing were designed to have the front center of the SV impact the side of the POV at its longitudinal center. A negative "actual versus desired" difference means the SV struck the POV earlier than desired; ahead of the POV's longitudinal center (i.e., towards the front of the POV). Conversely, a positive difference means the SV struck the POV later than desired; behind the POV's longitudinal center (towards the rear of the POV).
- For Scenario 2 crash-imminent tests, the location where the right front corner of the SV impacted the turning POV was first determined using the desired crash-imminent choreography defined in section 2.4.2 (i.e., when the front center of the SV and right-side longitudinal center of the POV were aligned), as shown in **Figure 3-1**. The SV impact location along the right side of the POV during the conduct of the test trials was then compared to this reference location to quantify test repeatability, as shown in **Figure 3-2**.
- For Scenario 3, the front left corner of the SV was designed to impact the front left corner of the SV if no ISA intervention occurred. The resultant distance between the actual impact points was therefore used to assess SV-to-POV impact repeatability.

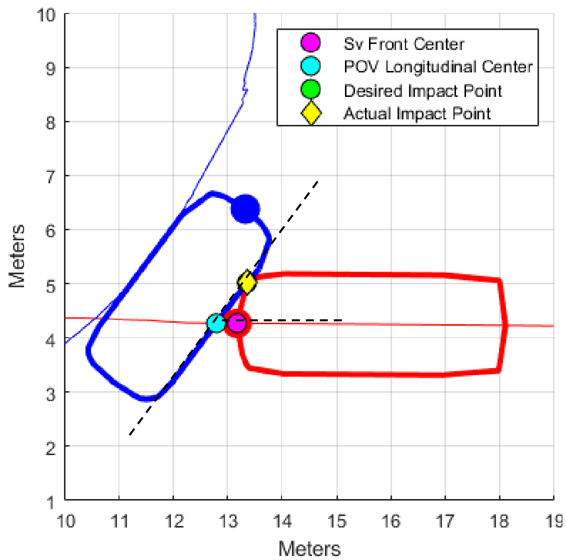


Figure 3-1: Desired SV-to-POV orientation at the time of impact during Scenario 2.

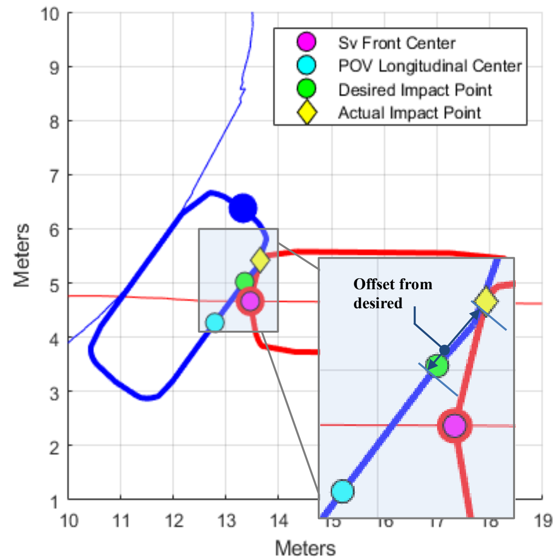


Figure 3-2: SV-to-POV orientation at the time of impact during a representative Scenario 2 trial.

3.2. Scenario 1 Test Results (POV Straight Across SV Path)

Test results from the Scenario 1 trials are provided in **Tables 3-1 to 3-6**. Discussions of each sub-scenario are provided in sections 3.2.1 to 3.2.3, and a summary is provided in section 3.2.4.

3.2.1. Scenario 1-A Test Results

For each Scenario 1-A test trial, the near-miss distances and offsets from desired are presented in **Table 3-1**. Additionally, the test series averages and standard deviations are provided.

Table 3-1: Scenario 1-A Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	8.0 (2.43)	1.4 (0.43)	2.9 (0.89)	1.7 (0.52)	None
2		9.1 (2.77)	2.5 (0.77)			None
3		11.3 (3.46)	4.7 (1.46)			None
1	1	9.5 (2.89)	2.9 (0.89)	3.1 (0.96)	0.2 (0.07)	None
2		9.9 (3.02)	3.3 (1.02)			None
3		9.8 (2.98)	3.2 (0.98)			None
1	2	10.0 (3.06)	3.4 (1.06)	3.5 (1.07)	0.1 (0.03)	None
2		10.2 (3.10)	3.6 (1.10)			None
3		10.0 (3.06)	3.4 (1.06)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

The actual versus desired near-miss differences observed during the trials performed with the SV in automation level 0 ranged from 1.4 to 4.7 ft (0.43 to 1.46 m), and was broad enough to contain the entire range of differences from the tests performed in automation levels 1 and 2. The differences observed during trials performed in automation levels 1 and 2 were consistent within their respective test groups, as indicated by the low standard deviations of 0.2 ft (0.07 m) and 0.1 ft (0.03 m). No ISA system warnings or brake interventions occurred during conduct of the Scenario 1-A near-miss tests.

The Scenario 1-A crash-imminent test results are listed in **Table 3-2**. SV speed reduction, the SV speed at the time of POV impact, and the offsets of the SV front center from the desired point at impact (i.e., the longitudinal center of the POV) are listed for each trial. Additionally, the averages and standard deviations of the desired impact point offsets are provided for each test series.

The ISA system did not present any alerts or provide any speed reductions during the Scenario 1-A evaluation with crash-imminent timing. The intended impact point offsets varied from -18.4 to 23.7 in. (-0.47 to 0.60 m) across each of the three automation levels tested. The actual versus desired impact point differences were within the ±0.8 ft (0.25 m) tolerance used to assess path validity during 2 of 9 trials overall.

Table 3-2: Scenario 1-A Crash-Imminent Results

Trial	Automation Level	Offsets From POV Center; inch (m)			SV Speed at Impact; mph (km/h)	ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Average	Std. Dev.		
1	0	-18.3 (-0.46)	-15.0 (-0.38)	2.9 (0.07)	25.0 (40.3)	None
2		-13.1 (-0.33)			24.7 (39.7)	None
3		-13.7 (-0.35)			25.7 (41.3)	None
1	1	-18.4 (-0.47)	-9.6 (-0.24)	7.9 (0.20)	25.2 (40.5)	None
2		-3.2 (-0.08)			25.1 (40.4)	None
3		-7.1 (-0.18)			25.1 (40.4)	None
1	2	-10.6 (-0.27)	11.0 (0.28)	18.8 (0.48)	25.0 (40.3)	None
2		23.7 (0.60)			24.9 (40.0)	None
3		19.9 (0.51)			25.1 (40.4)	None

3.2.2. Scenario 1-B Test Results

The Scenario 1-B near-miss results are presented in **Table 3-3**. For this test series, the range of actual versus desired near-miss differences observed during trials performed in automation 1 were completely within the 9.1 to 9.7 ft (2.8 to 3.0 m) range defined by the automation level 2 results, and both were consistent within their respective test groups.

While similar, the 7.4 to 8.7 ft (2.3 to 2.7 m) range of differences observed during the near-miss trials performed in automation level 0 did not overlap those from either of the two other automation levels. The actual versus desired near-miss differences varied from 0.8 to 3.1 ft (0.25 to 0.95 m) overall, and 1 of 9 trials was within the ±0.8 ft (0.25 m) tolerance used to assess path validity. No ISA system warnings or brake interventions occurred during the Scenario 1-B tests.

Table 3-3: Scenario 1-B Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	7.4 (2.25)	0.8 (0.25)	1.5 (0.48)	0.7 (0.21)	None
2		8.7 (2.65)	2.1 (0.65)			None
3		8.4 (2.56)	1.8 (0.56)			None
1	1	9.3 (2.83)	2.7 (0.83)	2.7 (0.83)	0.0 (0.01)	None
2		9.3 (2.82)	2.7 (0.82)			None
3		9.4 (2.85)	2.8 (0.85)			None
1	2	9.7 (2.95)	3.1 (0.95)	2.8 (0.88)	0.3 (0.09)	None
2		9.5 (2.90)	2.9 (0.90)			None
3		9.1 (2.78)	2.5 (0.78)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

The Scenario 1-B crash-imminent test results are presented in **Table 3-4**. In this scenario, ISA interventions were observed during 8 of the 9 trials performed; during all but one test performed in automation level 2. When an ISA intervention occurred, the average speed reduction varied from 10.2 to 15.6 mph (16.4 to 25.1 km/h) across the automation levels, and from 1.2 to 18.0 mph (1.9 to 29.0 km/h) overall. When it did not, the SV struck the POV 21.4 in. (0.54 m) after the desired point on the POV.

Table 3-4: Scenario 1-B Crash-Imminent Results

Trial	Automation Level	Offset From POV Center; inch (m)	SV Speed at Impact; mph (km/h)	ISA Speed Reduction; mph (km/h)		
				Indiv. Trial	Average	Std. Dev.
1	0	n/a	7.4 (12.0)	17.6 (28.3)	15.6 (25.1)	1.7 (2.7)
2		n/a	9.9 (15.9)	15.1 (24.3)		
3		n/a	10.8 (17.4)	14.2 (22.9)		
1	1	n/a	7.0 (11.3)	18.0 (29.0)	10.2 (16.4)	8.5 (13.7)
2		n/a	13.8 (22.2)	11.2 (18.0)		
3		n/a	23.8 (38.3)	1.2 (1.9)		
1	2	n/a	10.6 (17.1)	14.4 (23.2)	12.4[1] (20.0)	2.9[1] (4.7)
2		n/a	14.6 (23.5)	10.4 (16.7)		
3		21.4 (0.54)	25.0 (40.2)	None		

[1.] Result excludes data from the single trial with no ISA intervention.

Note that in **Table 3-4**, the offset from POV center metric is only meaningful for the test during which no ISA intervention occurred since the POV transitioned from closed- to open-loop just prior to entering the intersection. While this avoids having the POV speed being reduced if an ISA intervention slows the SV (the scenario was intended to facilitate an assessment of the SV ISA operation in the presence of a POV crossing in front of it at a constant speed), it also affects the SV-to-POV choreography that insures the SV strikes the POV at the correct location if no ISA intervention occurs.

3.2.3. Scenario 1-C Test Results

The Scenario 1-C near-miss test results are listed in **Table 3-5**. Here, range of actual versus desired near-miss differences was -2.6 to -2.1 ft (-0.77 to -0.64 m). As noted in section 2.4.1 of this report, this test series could only be performed by the SV when operating in automation level 0. No ISA system warnings or brake interventions occurred during conduct of the Scenario 1-C tests performed with near-miss timing.

Table 3-5: Scenario 1-C Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	4.5 (1.36)	-2.1 (-0.64)	-2.3 (-0.70)	0.2 (0.07)	None
2		4.0 (1.23)	-2.6 (-0.77)			None
3		4.3 (1.32)	-2.3 (-0.68)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

The Scenario 1-C crash-imminent test results are listed in **Table 3-6**. For this test series, the offset distance from the desired impact point between the SV and POV varied from -85.9 to -52.7 in. (-2.18 to -1.34 m). No ISA system warnings or brake interventions occurred during conduct of the Scenario 1-C tests performed with crash-imminent timing.

Table 3-6: Scenario 1-C Crash-Imminent Results

Trial	Automation Level	Offsets From POV Center; inch (m)			SV Speed at Impact; mph (km/h)	ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Average	Std. Dev.		
1	0	-85.9 (-2.18)	-67.4 (-1.71)	16.9 (0.43)	8.9 (14.3)	None
2		-63.7 (-1.62)			8.6 (13.8)	None
3		-52.7 (-1.34)			8.3 (13.4)	None

3.2.4. Scenario 1 Test Results Summary

In summary, of all the validity conditions contained within the preliminary ISA draft research test procedure, satisfying the SV-to-POV orientation at the desired near-miss and crash-imminent evaluation points was the most challenging for Scenario 1. The actual versus desired differences exceeded the ±0.8 ft (0.25 m) tolerance used to assess path validity during 20 of 21 trials performed with near-miss timing, and during 11 of 13 trials performed with crash-imminent timing and no ISA brake intervention. It is unclear if or how this variability may have affected the test outcome for trials performed in either condition.

With regards to SV ISA operation, the vehicle's ISA system did not issue warnings, or provide brake interventions, during any Scenario 1 near-miss trial. For the crash-imminent tests, the ISA brake interventions only occurred during tests performed in Scenario 1-B, where it did so for 8 of 9 trials. No ISA warnings or ISA brake interventions were observed during Scenario 1-A and 1-C trials performed with crash-imminent timing.

3.3. Scenario 2 POV Left Turn Across SV Path

Test results from the Scenario 2 trials are provided in **Tables 3-7 to 3-12**. Discussions of each sub-scenario are provided in sections 3.3.1 to 3.3.3, and a summary is provided in section 3.3.4.

Note: Although the Mercedes E300 used for the tests described in this report was equipped with an ISA system, it was not designed to respond to left turn across path scenarios. For this reason, Scenario 2 tests with crash-imminent timing were only performed in automation level 0, and Scenarios 2-A and 2-C were only performed with the LPRV as the POV (i.e., without the GVT secured on top of it).[5] This allowed for the accuracy, repeatability, and general performability of the Scenario 2 test conditions to be assessed without excessive wear on the SV and test equipment since a trial that would have resulted in an SV-to-POV impact would simply conclude with the SV being driven over the LPRV-based POV.

3.3.1. Scenario 2-A Test Results

The Scenario 2-A near-miss results are presented in **Table 3-7**. For this test series, the 3.3 to 4.3 ft (1.02 to 1.33 m) range of near-miss differences from desired were consistent overall, differing by no more than 1.0 ft (0.30 m) across all test conditions, and as indicated by the low within-series standard deviations of 0.1 to 0.5 ft (0.04 to 0.14 m). No ISA system warnings or brake interventions occurred during conduct of the Scenario 2-A near-miss tests.

Table 3-7: Scenario 2-A Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	10.0 (3.05)	3.4 (1.05)	3.8 (1.17)	0.5 (0.14)	None
2		10.2 (3.12)	3.6 (1.12)			None
3		10.9 (3.33)	4.3 (1.33)			None
1	1	10.1 (3.09)	3.5 (1.09)	3.4 (1.05)	0.1 (0.04)	None
2		10.0 (3.04)	3.4 (1.04)			None
3		9.9 (3.02)	3.3 (1.02)			None
1	2	10.6 (3.23)	4.0 (1.23)	3.9 (1.21)	0.2 (0.06)	None
2		10.7 (3.26)	4.1 (1.26)			None
3		10.3 (3.15)	3.7 (1.15)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

The Scenario 2-A crash-imminent test results are listed in **Table 3-8**. As previously mentioned, these tests were only performed with the SV operating in automation level 0, and no ISA interventions were

[5] Scenario 2-B tests were performed prior to those performed with Scenario 2-A or 2-C, during which the full GST system (GVT plus LPRV) was used as the POV. For these tests, the ISA system did not intervene, which resulted in the SV impacting the POV without any speed reduction.

expected during the tests performed in this sub-scenario since the SV was not designed to respond to the LTAP scenario and the POV was just the LPRV. As such, these trials were only performed to assess test performability, accuracy, and repeatability. For this test series, the offset distance from the desired impact point between the SV and POV varied from 4.6 in to 19.0 in. (0.12 to 0.48 m). As anticipated, no ISA system warnings or brake interventions occurred during conduct of the Scenario 2-A tests performed with crash-imminent timing.

Table 3-8: Scenario 2-A Crash-Imminent Results

Trial	Automation Level	Offsets From Desired Impact Point; inch (m)			SV Speed at Impact; mph (km/h)	ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Average	Std. Dev.		
1	0	19.0 (0.48)	13.1 (0.33)	7.5 (0.19)	25.5 (41.0)	None
2		4.6 (0.12)			24.4 (39.3)	None
3		15.6 (0.40)			24.8 (40.0)	None

3.3.2. Scenario 2-B Test Results

The Scenario 2-B near-miss results are presented in **Table 3-9**. For this test series, the range of actual versus desired near-miss differences observed during trials performed in automation levels 1 and 2 were completely within the -1.0 to 0.3 ft (-0.29 to 0.10 m) range defined by the automation level 0 results, and both were consistent within their respective test groups, as indicated by the low standard deviations of 0.1 ft (0.03 m) and 0.1 ft (0.04 m). No ISA system warnings or brake interventions occurred during conduct of the Scenario 2-B near-miss tests.

Table 3-9: Scenario 2-B Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	6.9 (2.10)	0.3 (0.10)	-0.2 (0.04)	0.7 (0.22)	None
2		6.8 (2.07)	0.2 (0.07)			None
3		5.6 (1.71)	-1.0 (-0.29)			None
1	1	6.0 (1.83)	-0.6 (-0.17)	-0.6 (-0.17)	0.1 (0.03)	None
2		6.1 (1.86)	-0.5 (-0.14)			None
3		5.9 (1.79)	-0.7 (-0.21)			None
1	2	5.7 (1.73)	-0.9 (-0.27)	-0.8 (-0.23)	0.1 (0.04)	None
2		5.9 (1.80)	-0.7 (-0.20)			None
3		5.9 (1.80)	-0.7 (-0.20)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

Results from the Scenario 2-B crash-imminent trials performed in automation level 0 with the GST-based POV (i.e., the only Scenario 2 sub-scenario performed with crash-imminent timing and the GVT secured to the top of the LPRV) are listed in **Table 3-10**. The actual versus desired impact point differences varied from 43.0 to 60.9 in. (1.09 to 1.55 m). No ISA system warnings or brake interventions occurred during Scenario 2-B trials performed with crash-imminent timing.

Table 3-10: Scenario 2-B Crash-Imminent Results

Trial	Automation Level	Offsets From Desired Impact Point; inch (m)			SV Speed at Impact; mph (km/h)
		Indiv. Trial	Average	Std. Dev.	
1	0	60.9 (1.55)	54.6 (1.39)	10.1 (0.26)	25.0 (40.2)
2		59.8 (1.52)			24.7 (39.8)
3		43.0 (1.09)			24.1 (38.8)

3.3.3. Scenario 2-C Test Results

The Scenario 2-C near-miss test results are presented in **Table 3-11**. Although each of the three tests were believed to have been correctly performed, data post-processing revealed that usable data were only available for two trials.[6] For these two trials, the actual versus desired near-miss differences ranged from -4.0 to -3.5 ft (-1.21 to -1.05 m). No ISA system warnings or brake interventions occurred during conduct of the Scenario 2-C near-miss tests.

Table 3-11: Scenario 2-C Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	3.1 (0.95)	-3.5 (-1.05)	-3.7 (-1.13)	0.4 (0.12)	None
2		2.6 (0.79)	-4.0 (-1.21)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

The Scenario 2-C crash-imminent test results are listed in **Table 3-12**. As previously mentioned, these tests were only performed with the SV operating in automation level 0, and no ISA interventions were expected during the tests performed in this sub-scenario since the SV was not designed to respond to the LTAP scenario and the POV was just the LPRV. For this test series, the actual versus desired impact point differences varied from 12.7 to 19.3 in. (0.32 to 0.49 m), with a low standard deviation of 3.7 in. (0.09 m). No ISA system warnings or brake interventions occurred during conduct of the Scenario 2-C tests performed with crash-imminent timing.

Table 3-12: Scenario 2-C Crash-Imminent Results

Trial	Automation Level	Offsets From Desired Impact Point; inch (m)			SV Speed at Impact; mph (km/h)
		Indiv. Trial	Average	Std. Dev.	
1	0	19.3 (0.49)	16.9 (0.43)	3.7 (0.09)	10.8 (17.3)
2		12.7 (0.32)			11.3 (18.1)
3		18.7 (0.48)			11.1 (17.9)

[6] Three Scenario 2-C trials were performed with near-miss choreography, however the test data from one of these tests was found to be corrupt during post-processing.

3.3.4. Scenario 2 Test Results Summary

In agreement with the Scenario 1 test observations, satisfying the SV-to-POV orientation at the desired near-miss and crash-imminent evaluation points was also the most challenging aspect for satisfying Scenario 2 test validity. The actual versus desired differences exceeded the ±0.8 ft (0.25 m) tolerance used to assess path validity during 13 of 20 trials performed with near-miss timing, and during 8 of 9 trials performed with crash-imminent timing. As was the case for Scenario 1, it is unclear if or how this variability may have affected the test outcome for trials performed in either condition, however since the SV used in this study was not designed to respond to the LTAP scenario, it is not expected to be a confounding factor for the Scenario 2 tests described in this report (i.e., it is not expected to have affected the operation of the SV ISA system).

With regards to SV ISA operation, the vehicle's ISA system did not issue warnings, or provide brake interventions, during any Scenario 2 trial, regardless of whether near-miss or crash-imminent timing was used.

3.4. Scenario 3: SV Left Turn Across POV Path

Test results from the Scenario 3 trials are provided in **Tables 3-13 to 3-18**. Discussions of each sub-scenario are provided in sections 3.4.1 to 3.4.3, and a summary is provided in section 3.4.4.

Regarding Scenario 3 test conduct:

- All trials were performed in automation level 0 for the reason previously mentioned in section 2.4.4.
- For the reasons previously mentioned in section 3.3, trials performed with crash-imminent timing only used the LPRV as the POV. This helped facilitate an assessment of how accurately the Scenario 3 test conditions could be performed without excessive wear on the SV and/or test equipment.
- Trials with crash-imminent timing were performed once per each sub-scenario. The Scenario 3 evaluations occurred after the Scenario 1 and 2 tests had been performed, and occurred during a period when poor weather conditions were frequent. Thus, fewer tests could be conducted.

3.4.1. Scenario 3-A Test Results

The Scenario 3-A near-miss results are presented in **Table 3-13**. For this test series, the actual versus desired near-miss differences ranged from -2.0 to -0.5 ft (-0.58 to -0.15 m). No ISA warning or brake intervention occurred during the conduct of these trials.

Table 3-13: Scenario 3-A Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	5.3 (1.61)	-1.3 (-0.39)	-1.3 (-0.38)	0.7 (0.22)	None
2		6.1 (1.85)	-0.5 (-0.15)			None
3		4.6 (1.42)	-2.0 (-0.58)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

Results from the single Scenario 3-A crash-imminent trial performed in this study are listed in **Table 3-14**. The offset from the desired POV impact point was -8.3 in (-0.21 m). No warning or intervention by the ISA system was observed during this trial.

Table 3-14: Scenario 3-A Crash-Imminent Results

Trial	Automation Level	Offsets From Desired Impact Point; inch (m)			SV Speed at Impact; mph (km/h)	ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Average	Std. Dev.		
1	0	-8.3 (-0.21)	n/a	n/a	14.7 (23.7)	None

3.4.2. Scenario 3-B Test Results

The Scenario 3-B near-miss results are presented in **Table 3-15**. For this test series, the actual versus desired near-miss difference range of 2.3 to 2.5 ft (0.72 to 0.78 m) was very consistent, as indicated by a maximum within series difference of 0.2 ft (0.06 m) and a standard deviation of 0.1 ft (0.03 m). No ISA warning or brake intervention occurred during the conduct of these trials.

Table 3-15: Scenario 3-B Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	9.1 (2.78)	2.5 (0.78)	2.5 (0.76)	0.1 (0.03)	None
2		9.1 (2.78)	2.5 (0.78)			None
3		8.9 (2.72)	2.3 (0.72)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

Results from the single Scenario 3-B crash-imminent trial performed in this study are listed in **Table 3-16**. The offset from the desired POV impact point was 4.1 in (0.10 m). No warning or intervention by the ISA system occurred during this test.

Table 3-16: Scenario 3-B Crash-Imminent Results

Trial	Automation Level	Offsets From Desired Impact Point; inch (m)			SV Speed at Impact; mph (km/h)	ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Average	Std. Dev.		
1	0	4.1 (0.10)	n/a	n/a	14.8 (23.5)	None

3.4.3. Scenario 3-C Test Results

The Scenario 3-C near-miss results are presented in **Table 3-17**. For this test series, the actual versus desired near-miss differences ranged from 4.7 to 6.3 ft (1.45 to 1.94 m). No ISA warning or brake intervention occurred during the conduct of these trials.

Table 3-17: Scenario 3-C Near-Miss Results

Trial	Automation Level	Near-Miss Distances; ft (m)				ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Difference From Desired[1]	Average Difference	Difference Std. Dev.	
1	0	11.3 (3.45)	4.7 (1.45)	5.4 (0.67)	0.8 (0.25)	None
2		12.9 (3.94)	6.3 (1.94)			None
3		11.9 (3.62)	5.3 (1.62)			None

[1]The desired near-miss distance is 6.6 ft (2 m).

Results from the single Scenario 3-C crash-imminent trial performed in this study are listed in **Table 3-18**. The offset from the desired POV impact point was 2.7 in (0.07 m). No warning or intervention by the ISA system occurred during this test.

Table 3-18: Scenario 3-C Crash-Imminent Results

Trial	Automation Level	Offsets From Desired Impact Point; inch (m)			SV Speed at Impact; mph (km/h)	ISA Speed Reduction; mph (km/h)
		Indiv. Trial	Average	Std. Dev.		
1	0	2.7 (0.07)	n/a	n/a	11.0 (17.7)	None

3.4.4. Scenario 3 Test Results Summary

For Scenario 3, satisfying the SV-to-POV orientation at the desired near-miss and crash-imminent evaluation points continued to present the most challenging test validity criteria. Each of the three trials with crash-imminent timing were performed with actual versus desired differences within the ±0.8 ft (0.25 m) tolerance used to assess path validity, however 8 of 9 trials performed with near-miss timing were not. As was the case for the other two scenarios, it is unclear if or how this variability may have affected the test outcome for trials performed in either condition.

With regards to SV ISA operation, the vehicle's ISA system did not issue warnings, or provide brake interventions, during any Scenario 3 trial, regardless of whether near-miss or crash-imminent timing was used.

3.5. Comments Regarding Test Validity

The test speeds, paths, and relative position of the POV to the SV, for each test condition, were configured within the software used for the LPRV and steering, brake, and accelerator robots prior to arriving at the test track. However, review of the first few track-based trials, for a given test condition, typically indicated that additional, iterative adjustments (i.e., reprogramming of the test) were necessary before the best possible choreography could be achieved. The test validity results described in this section relate to the trials performed after the iterative adjustments had been performed. In other words, these trials provided the "best" results attainable with the software and equipment familiarization level available at the time these tests were performed.[7]

[7]Since the tests described in this report were completed, achieving better SV-to-POV choreography has been improved by using updated software and adjusting applicable parameters within the respective LPRV and SV robotic controller configuration files. It is believed that these improvements, along with an increased familiarity of

As previously described in Section 2.5, the test validity criteria described in **Appendix A** were assessed for each trial performed in this study. A summary of these results is provided for each trial in **Appendix B**.

The validity criteria pertaining to the SV yaw rate, path, and speed were largely satisfied, as were the checks used to insure the SV operator did not manually apply inputs to the brake or accelerator pedals within the test validity period. However, satisfying certain tolerances during certain test conditions was, at times, problematic.

- POV speed tolerances were exceeded during each trial performed with near-miss timing during the Scenario 2-A and 3-C evaluations, and during each of the Scenario 2-A trials performed with crash-imminent timing.
- SV speed tolerances were exceeded during each trial performed with near-miss timing during the Scenario 3-A evaluations.
- POV lateral path tolerances were exceeded during each trial performed with near-miss timing during the Scenario 2-B evaluations.
- SV lateral path tolerances were exceeded during each trial performed with near-miss timing during the Scenario 3-C evaluations.

3.5.1. SV and POV Speed

Since completion of the testing described in this report, two changes have contributed to increased SV and POV speed accuracy. Increasing the distance for the vehicles to accelerate to test speed was found to better allow the control software to achieve a consistent speed throughout the validity period. Experimenters also have received additional training about how to better optimize the brake and throttle robot programming for the vehicle the equipment has been installed into.

3.5.2. SV and POV Lateral Path Tolerances

The SV exceeded its lateral path tolerance (see **Table B-1** in **Appendix B**) during each of the three Scenario 3-C trials performed with near-miss timing when accelerating from rest while making its left turn. With one exception (1 of 9 Scenario 1-A trials performed with crash-imminent timing), the Scenario 3-C trials performed with near-miss timing were the only tests where SV was unable to satisfy the 0.8 ft (0.25 m) tolerance used to assess lateral path validity.

Similarly, the POV exceeded its lateral path tolerance (again, see **Table B-1** in **Appendix B**) during each of the nine Scenario 2-B trials performed with near-miss timing when accelerating from rest while making its left turn. With one exception (1 of 9 Scenario 2-A trials performed with near-miss timing), the Scenario 2-B trials performed with near-miss timing were the only tests where POV was unable to satisfy the 0.8 ft (0.25 m) tolerance used to assess lateral path validity.

Examples of the SV and POV path following errors, observed during conduct of Scenario 3-C and 2-B trials with near-miss timing, are shown in the bottom panes of **Figures 3-3 and 3-4**, respectively. The ideal paths are based off the left turn path described in the preliminary draft ISA test procedure, and where programmed into the applicable path-following robot. In **Figure 3-3**, the actual SV path deviates from the ideal from the onset of the turn, and its path error increases as the test progresses due to the SV turning radius being too tight. Conversely, in **Figure 3-4**, while the actual POV path also deviates from the ideal from the onset of the turn, its path error increases as the test progresses due to the SV turning radius being too large.

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how to better optimize the programing used for a given test scenario, have largely reconciled the validity problems described in sections 3.2, 3.3, and 3.4 of this report.

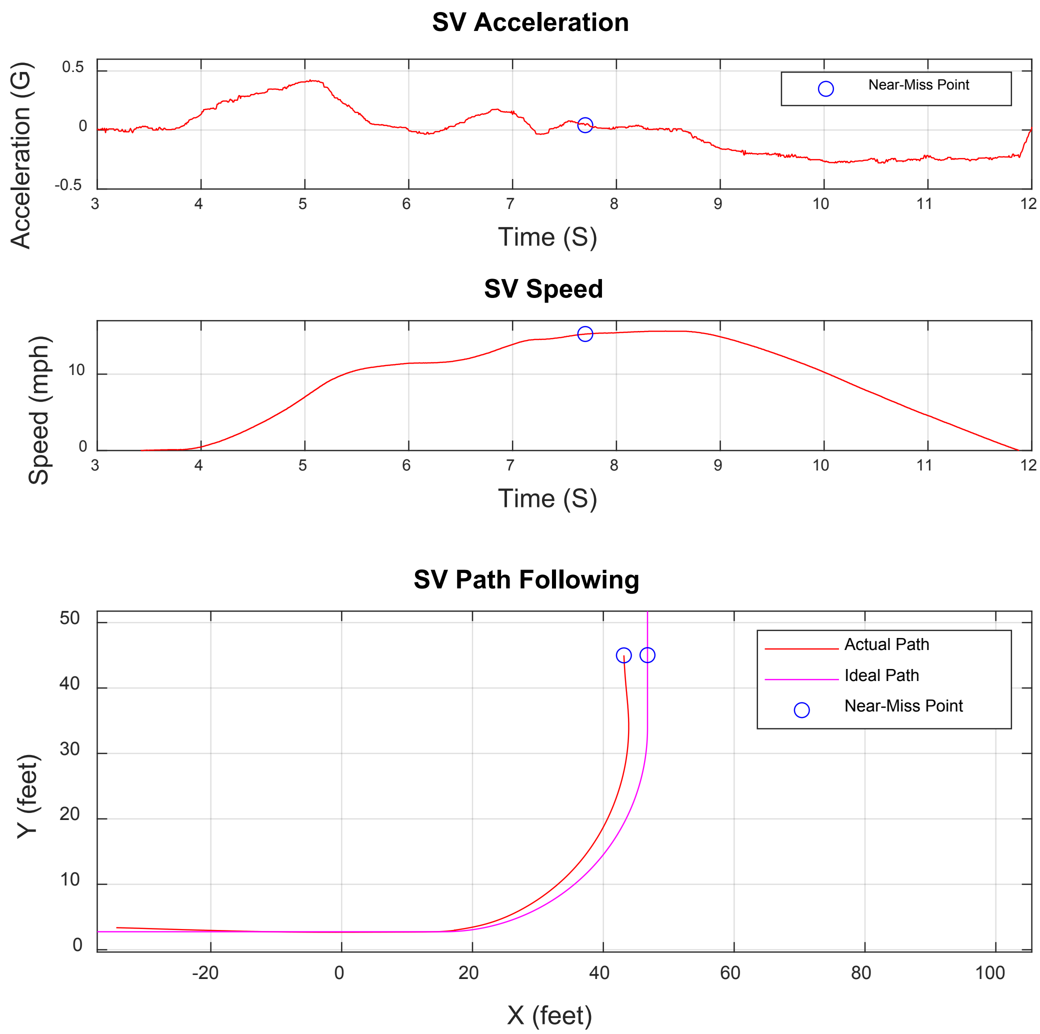

Figure 3-3: SV left turn across POV path following error (Scenario 3-C).

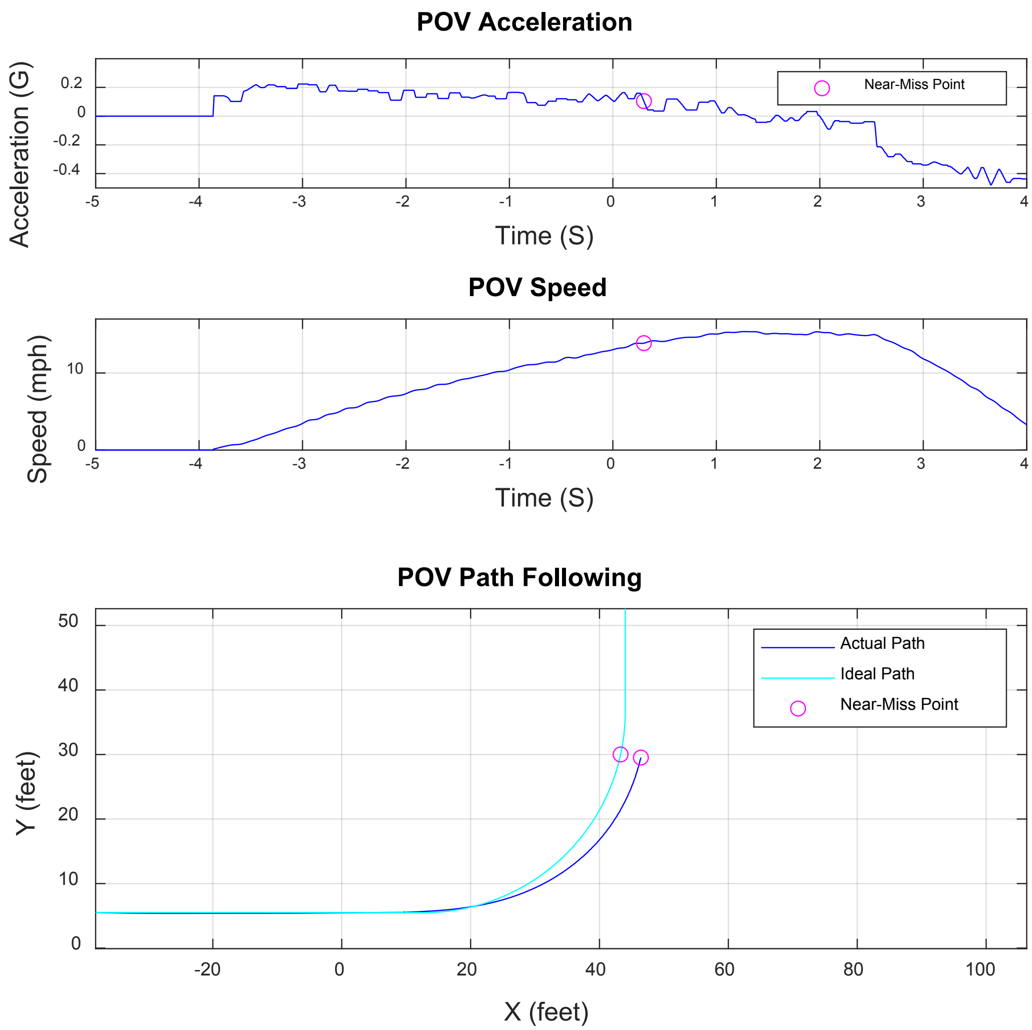

Figure 3-4: POV left turn across SV path following error (Scenario 2-B).

4.0 TEST METHODOLOGY ADJUSTMENTS

The experience gained by performing the tests described in this report lead to three significant advances in how NHTSA is able perform ISA tests, and has identified the need for an additional test tolerance.

4.1. ISA Test Conduct Improvements

First, implementing the use of updated software and improved tuning methods are expected to better support the closed loop operation of the robotic platform (POV) and steering, brake, and accelerator controller (used in the SV, when applicable), particularly in the scenarios where the SV or POV is accelerated into the path of the other vehicle while performing a left turn. Specifically, the experience gained through the conduct of the tests described in this report have significantly improved how the vehicle-to-vehicle synchronization observed on the test track can be adjusted to successfully achieve crash-imminent and near-miss distances much closer to their desired values, and within a tolerance of ±0.8 ft (0.25 m). For this reason, the September 2019 ISA draft test procedure specifies this range of values.

Secondly, the timing (i.e., SV-to-POV synchronization) used during the Scenario 2 and 3 trials performed with crash-imminent timing has been adjusted.

- Scenario 2 crash-imminent choreography was initially designed to have the path of the SV front center arrive at the right center of the POV, but the trial was taken to conclude when any part of a polygon used to define the SV front contacted any part of a polygon used to define the right side of the POV during data post-processing. In the September 2019 ISA draft test procedure, the path of the SV front center is designed to arrive at the front right corner of the POV when crash-imminent timing is used and no ISA intervention occurs. Not only is the resulting choreography less abstract, but the assessment of whether a trial was accurately performed is now universally applicable; the SV-to-POV impact point remains the same for all vehicles, and is not a function of SV width.
- Scenario 3 crash-imminent choreography was initially designed to have the path of the front left corner of the SV arrive at the front left corner of the POV. In the September 2019 ISA draft test procedure, the path of the SV front center is designed to arrive at the left corner of the POV when crash-imminent timing is used, and no ISA intervention occurs. This choreography agrees with the refinement applied to Scenario 2, and the path of the SV is now universally applicable; the SV-to-POV impact point remains the same for all vehicles and is not a function of SV width.

Thirdly, a series of synchronization checks have been specified in the September 2019 ISA draft to provide an additional way to determine if a given trial has been performed as specified (i.e., rather than relying solely on the actual versus desired position differences at the crash-imminent or near-miss assessment points). Specifically, equations that define the ideal location of one vehicle to its intersection stop bar when the other vehicle crosses its respective intersection stop bar are now included, and are expected to be particularly useful during validity assessments applied to a trial where the SV ISA intervenes, as the SV-to-POV synchronization is no longer applicable from that point.

4.2. Acceleration From an Intersection Stop Bar

The preliminary ISA draft test procedure specified an acceleration of 0.127 g (1.25 m/s^2) be used for scenarios where a vehicle accelerates from its respective intersection stop bar, however no tolerance was provided. As it directly effects the ability to achieve the desired SV-to-POV choreography during trials where it is relevant, achieving and maintaining the desired acceleration away from the stop bar is important. However, since the acceleration magnitude is small, assigning a meaningful tolerance that appropriately balances a desire to perform the most accurate test possible with what can be realistically be achieved using contemporary state-of-the-art test equipment, must be given careful consideration. The work needed to identify this tolerance has not been performed, and therefore remains a potential topic for future research.

5.0 SUMMARY AND CONCLUSIONS

The testing in this report was performed to assess the performability of the protocols described in a preliminary version of NHTSA's ISA draft research test procedure. This assessment included an evaluation of whether the tests were clearly described with no ambiguity, and could be accurately and repeatably performed.

While the test protocols were generally found to be performable, some validity criteria were not satisfied during test conduct, particularly those used to confirm the position of the SV and POV at crash-imminent or near-miss assessment points. Steps to resolve the factors contributing to the occurrence of non-valid trials have been developed, and may be the subject of future research and documentation. These steps are believed to have largely reconciled the ability to produce valid trials for each test condition, and include, but are not limited to, the following elements:

- Continued use of software updates applied at the end of the testing timeline (successively implemented during conduct of the crash-imminent trials performed in Scenario 3).
- Better optimization of the control parameters used to define the closed-loop operation of the robotic controllers used to perform the tests.
- Adjustments to the SV and POV synchronization used during the conduct of the Scenario 2 and 3 trials.

With regards to the SV's ISA system performance, ISA interventions were only observed during Scenario 1-B tests performed with crash-imminent timing (i.e., straight crossing path trials where the POV was accelerated from rest into the forward path of the SV). While ISA brake interventions were observed during 11 of 12 trials in this test condition, none were effective enough to prevent the SV from impacting the POV, regardless of automation level. Rather, the SV speed at impact was reduced between 1.2 to 18.0 mph (1.9 to 28.9 km/h) overall.

No ISA interventions were observed during trials performed with near-miss timing, regardless of test condition.

6.0 REFERENCES

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7.0 APPENDIX A

Table A-1: ISA Scenario 1 Test Specifications Used For The Work Described In This Report.

Scenario	Initial Distance to Intersection Stop Bars[1]		Acceleration From Rest	Speed Within Validity Period	Lateral Path Tolerance Within Validity Period			Yaw Rate Within Validity Period[3]	Number of Trials Per Automation Level
	Crash-Imminent Timing	Near-Miss Timing			SV (Automation Level 0 and 1[2])	SV (Automation Level 2 and 3)	POV		
S1-A	SV: 273.9 ± 1 ft (83.5 ± 0.3 m) POV: 276.6 ± 1 ft (84.3 ± 0.3 m)	SV: 273.9 ± 1 ft (83.5 ± 0.3 m) POV: 270.0 ± 1 ft (82.3 ± 0.3 m)	Unrestricted from staging point	SV: 25 ± 1 mph (40.2 ± 1.6 km/h) POV: 25 ± 1 mph (40.2 ± 1.6 km/h)	±0.8 ft (0.25 m)	n/a [4]	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3
									3
S1-B	SV: 273.9 ± 1 ft (83.5 ± 0.3 m) POV: 0 ft	SV: 273.9 ± 1 ft (83.5 ± 0.3 m) POV: 0 ft	SV: Unrestricted from staging point POV: 0.127g (1.25 m/s²) from stop bar	SV: 25 ± 1 mph (40.2 ± 1.6 km/h) POV: 0 ⇨25 ± 1 mph (0 ⇨ 40.2 ± 1.6 km/h)	±0.8 ft (0.25 m)	n/a [4]	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3
									3
S1-C	SV: 0 ft POV: 273.9 ± 1 ft (83.5 ± 0.3 m)	SV: 0 ft POV: 273.9 ± 1 ft (83.5 ± 0.3 m)	SV: 0.127g (1.25 m/s²) from stop bar POV: Unrestricted from staging point	SV: 0 ⇨25 ± 1 mph (0 ⇨ 40.2 ± 1.6 km/h) POV: 25 ± 1 mph (40.2 ± 1.6 km/h)	±0.8 ft (0.25 m)	n/a [4]	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3
									3

[1] The non-zero distances are coarse approximations that assume the vehicle(s) achieve the desired steady-state speed quickly after the acceleration from rest is complete.
[2] Where applicable.
[3] Yaw rate specifications are applicable only when the desired path of the SV is a straight line. Additionally, SV yaw rate specifications are only valid during tests performed in automation level 0 or 1.
[4] LCC actively controls the SV lateral path during tests performed in automation level 2.

Table A-2: ISA Scenario 2 Test Specifications Used For The Work Described In This Report.

Scenario	Initial Distance to Intersection Stop Bars[1]		Acceleration From Rest	Speed Within Validity Period	POV Turn Radius (when referenced from POV front center)	Lateral Path Tolerance Within Validity Period			Yaw Rate Within Validity Period[4]	Number of Trials per Automation Level
	Crash-Imminent Timing	Near-Miss Timing				SV (Automation Level 0 and 1[2])	SV (Automation Level 2)[3]	POV		
S2-A	SV: 273.9 ± 1 ft (83.5 ± 0.3 m) POV: 308.3 ± 1 ft (94.0 ± 0.3 m)	SV: 273.9 ± 1 ft (83.5 ± 0.3 m) POV: 323.6 ± 1 ft (98.6 ± 0.3 m)	Unrestricted from staging point	SV: 25 ± 1 mph (40.2 ± 1.6 km/h) POV: 15 ± 1 mph (24.1 ± 1.6 km/h)	28.2 ft (8.59 m)	±0.8 ft (0.25 m)	n/a	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3
S2-B	SV: 273.9 ± 1 ft (83.5 ± 0.3 m) POV: 0 ft	SV: 273.9 ± 1 ft (83.5 ± 0.3 m) POV: 0 ft	SV: Unrestricted from staging point POV: 0.127g (1.25 m/s^2) from stop bar	SV: 25 ± 1 mph (40.2 ± 1.6 km/h) POV: 0 ⇨25 ± 1 mph (0 ⇨ 40.2 ± 1.6 km/h)	28.2 ft (8.59 m)	±0.8 ft (0.25 m)	n/a	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3
S2-C	SV: 0 ft POV: 273.9 ± 1 ft (83.5 ± 0.3 m)	SV: 0 ft POV: 273.9 ± 1 ft (83.5 ± 0.3 m)	SV: 0.127g (1.25 m/s^2) from stop bar POV: Unrestricted from staging point	SV: 0 ⇨25 ± 1 mph (0 ⇨ 40.2 ± 1.6 km/h) POV: 15 ± 1 mph (24.1 ± 1.6 km/h)	28.2 ft (8.59 m)	±0.8 ft (0.25 m)	n/a	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3

[1] The non-zero distances are coarse approximations that assume the vehicle(s) achieve the desired steady state-speed quickly after the acceleration from rest is complete.
[2] Where applicable.
[3] LCC actively controls the SV lateral path during tests performed in automation level 2.
[4] Yaw rate specifications are applicable only when the desired path of the SV is a straight line. Additionally, SV yaw rate specifications are only valid during tests performed in automation level 0 or 1.

Table A-3: ISA Scenario 3 Test Specifications Used For The Work Described In This Report.

Scenario	Initial Distance to Intersection Stop Bar[1]		Acceleration From Rest	Speed Within Validity Period	SV Turn Radius (when referenced from POV front center)	Lateral Path Tolerance Within Validity Period			Yaw Rate Within Validity Period [5]	Number of Trials per Automation Level
	Crash-Imminent Timing	Near-Miss Timing				SV (Automation Level 0 and 1[3])	SV (Automation Level 2) [4]	POV		
S3-A	SV: 125.0 ± 1 ft (38.1 ± 0.3 m) POV: 277.3 ± 1 ft (84.5 ± 0.3 m	SV: 125.0 ± 1 ft (38.1 ± 0.3 m) POV[2]: 346.1 ± 1 ft (105.5 ± 0.3 m)	Unrestricted	SV: 15 ± 1 mph (24.1 ± 1.6 km/h) POV: 25 ± 1 mph (40.2 ± 1.6 km/h)	28.2 ft (8.59 m)	±0.8 ft (0.25 m)	n/a	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3
S3-B	SV: 125.0 ± 1 ft (38.1 ± 0.3 m) POV: 0 ft	SV: 125.0 ± 1 ft (38.1 ± 0.3 m) POV: 0 ft	SV: Unrestricted POV: 0.127g (1.25 m/s²)	SV: 15 ± 1 mph (24.1 ± 1.6 km/h) POV: 0 ⇨25 ± 1 mph (0 ⇨ 40.2 ± 1.6 km/h)	28.2 ft (8.59 m)	±0.8 ft (0.25 m)	n/a	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3
S3-C	SV: 0 ft POV: 273.9 ± 1 ft (83.5 ± 0.3 m)	SV: 0 ft POV: 273.9 ± 1 ft (83.5 ± 0.3 m)	SV: 0.127g (1.25 m/s²) POV: Unrestricted	SV: 0 ⇨25 ± 1 mph (0 ⇨ 40.2 ± 1.6 km/h) POV: 25 ± 1 mph (40.2 ± 1.6 km/h)	28.2 ft (8.59 m)	±0.8 ft (0.25 m)	n/a	±0.8 ft (0.25 m)	SV: ± 1 deg/s POV: n/a	3

[1] The non-zero distances are coarse approximations that assume the vehicle(s) achieve the desired steady-state speed quickly after the acceleration from rest is complete.
[2] Initial POV offset in the S3-A0 and S3-A1 scenarios depends on SV length and width. For the values shown in **Table 5**, SV dimensions were taken to be 193" L x 73" W (4.90 x 1.85 m)
[3] Where applicable.
[4] LCC actively controls the SV lateral path during tests performed in automation level 2.
[5] Yaw rate specifications are applicable only when the desired path of the SV is a straight line. Additionally, SV yaw rate specifications are only valid during tests performed in automation level 0 or 1.

8.0 APPENDIX B

The following tables list whether the test trial passed or failed the scenario validity checks. For tests where the SV and/or POV was accelerated from rest from their respective stop bars, the speed check is listed as Accel – meaning that it is not applicable to check the speed validity.

Table B-1: Near-Miss Test Validity

Test File	Scenario	Auto. Level	SV Speed Check	POV Speed Check	SV Yaw Check	SV Brake Check	SV TPS Check	SV Path	POV Path	Near-Miss Distance; ft (m)	Offset From Desired Point; ft (m)
86	1-A	0	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS	8.0 (2.43)	1.4 (0.43)
87	1-A	0	PASS	PASS	PASS	PASS	PASS	PASS	PASS	9.1 (2.77)	2.5 (0.77)
88	1-A	0	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS	11.3 (3.46)	4.7 (1.46)
89	1-A	1	PASS	PASS	PASS	PASS	PASS	PASS	PASS	9.5 (2.89)	2.9 (0.89)
90	1-A	1	PASS	PASS	PASS	PASS	PASS	PASS	PASS	9.9 (3.02)	3.3 (1.02)
91	1-A	1	PASS	PASS	PASS	PASS	PASS	PASS	PASS	9.8 (2.98)	3.2 (0.98)
93	1-A	2	PASS	PASS	PASS	PASS	PASS	PASS	PASS	10.0 (3.06)	3.4 (1.06)
94	1-A	2	PASS	PASS	PASS	PASS	PASS	PASS	PASS	10.2 (3.10)	3.6 (1.10)
95	1-A	2	PASS	PASS	PASS	PASS	PASS	PASS	PASS	10.0 (3.06)	3.4 (1.06)
97	1-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	7.4 (2.25)	0.8 (0.25)
98	1-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	8.7 (2.65)	2.1 (0.65)
99	1-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	8.4 (2.56)	1.8 (0.56)
100	1-B	1	PASS	Accel	PASS	PASS	PASS	PASS	PASS	9.3 (2.83)	2.7 (0.83)
101	1-B	1	PASS	Accel	PASS	PASS	PASS	PASS	PASS	9.3 (2.82)	2.7 (0.82)
102	1-B	1	PASS	Accel	PASS	PASS	PASS	PASS	PASS	9.4 (2.85)	2.8 (0.85)
103	1-B	2	PASS	Accel	PASS	PASS	PASS	PASS	PASS	9.7 (2.95)	3.1 (0.95)
104	1-B	2	PASS	Accel	PASS	PASS	PASS	PASS	PASS	9.5 (2.90)	2.9 (0.90)
105	1-B	2	PASS	Accel	PASS	PASS	PASS	PASS	PASS	9.1 (2.78)	2.5 (0.78)
106	2-A	0	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	10.0 (3.05)	3.4 (1.05)
107	2-A	0	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	10.2 (3.12)	3.6 (1.12)
108	2-A	0	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS	10.9 (3.33)	4.3 (1.33)
109	2-A	1	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	10.1 (3.09)	3.5 (1.09)

Table B-1. Near-Miss Test Validity (continued)

Test File	Scenario	Auto. Level	SV Speed Check	POV Speed Check	SV Yaw Check	SV Brake Check	SV TPS Check	SV Path	POV Path	Near-Miss Distance; ft (m)	Offset From Desired Point; ft (m)
110	2-A	1	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	10.0 (3.04)	3.4 (1.04)
111	2-A	1	PASS	FAIL	PASS	PASS	PASS	PASS	FAIL	9.9 (3.02)	3.3 (1.02)
113	2-A	2	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	10.6 (3.23)	4.0 (1.23)
114	2-A	2	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	10.7 (3.26)	4.1 (1.26)
115	2-A	2	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	10.3 (3.15)	3.7 (1.15)
118	2-B	0	PASS	Accel	PASS	PASS	PASS	PASS	FAIL	6.9 (2.10)	0.3 (0.10)
119	2-B	0	PASS	Accel	PASS	PASS	PASS	PASS	FAIL	6.8 (2.07)	0.2 (0.07)
120	2-B	0	PASS	Accel	PASS	PASS	PASS	PASS	FAIL	5.6 (1.71)	-1.0 (-0.29)
121	2-B	1	PASS	Accel	PASS	PASS	PASS	PASS	FAIL	6.0 (1.83)	-0.6 (-0.17)
122	2-B	1	PASS	Accel	PASS	PASS	PASS	PASS	FAIL	6.1 (1.86)	-0.5 (-0.14)
123	2-B	1	PASS	Accel	FAIL	PASS	PASS	PASS	FAIL	5.9 (1.79)	-0.7 (-0.21)
125	2-B	2	PASS	Accel	PASS	PASS	PASS	PASS	FAIL	5.7 (1.73)	-0.9 (-0.27)
126	2-B	2	PASS	Accel	PASS	PASS	PASS	PASS	FAIL	5.9 (1.80)	-0.7 (-0.20)
127	2-B	2	PASS	Accel	PASS	PASS	PASS	PASS	FAIL	5.9 (1.80)	-0.7 (-0.20)
178	1-C	0	Accel	FAIL	PASS	PASS	PASS	PASS	PASS	4.5 (1.36)	-2.1 (-0.64)
179	1-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	4.0 (1.23)	-2.6 (-0.77)
181	1-C	0	Accel	FAIL	PASS	PASS	PASS	PASS	PASS	4.3 (1.32)	-2.3 (-0.68)
201	2-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	3.1 (0.95)	-3.5 (-1.05)
203	2-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	2.6 (0.79)	-4.0 (-1.21)
211	3-A	0	FAIL	PASS	PASS	PASS	PASS	PASS	PASS	5.3 (1.61)	-1.3 (-0.39)
212	3-A	0	FAIL	PASS	PASS	PASS	PASS	PASS	PASS	6.1 (1.85)	-0.5 (-0.15)
213	3-A	0	FAIL	PASS	PASS	PASS	PASS	PASS	PASS	4.6 (1.42)	-2.0 (-0.58)
218	3-C	0	Accel	FAIL	FAIL	PASS	PASS	FAIL	PASS	9.1 (2.78)	2.5 (0.78)
219	3-C	0	Accel	FAIL	FAIL	PASS	PASS	FAIL	PASS	9.1 (2.78)	2.5 (0.78)
220	3-C	0	Accel	FAIL	FAIL	PASS	PASS	FAIL	PASS	8.9 (2.72)	2.3 (0.72)
222	3-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	11.3 (3.45)	4.7 (1.45)
223	3-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	12.9 (3.94)	6.3 (1.94)
224	3-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	11.9 (3.62)	5.3 (1.62)

Table B-2: Crash-Imminent Test Validity

Test File	Scenario	Auto. Level	SV Speed Check	POV Speed Check	SV Yaw Check	SV Brake Check	SV TPS Check	SV Path	POV Path	Offset From Desired Impact Point; inch (m)	ISA Speed Reduction; mph (km/h)	SV-to-POV Impact?
133	1-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	n/a	17.6 (28.3)	Yes
135	1-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	n/a	15.1 (24.3)	Yes
136	1-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	n/a	14.2 (22.9)	Yes
142	1-B	1	PASS	Accel	PASS	PASS	PASS	PASS	PASS	n/a	18.0 (29.0)	Yes
143	1-B	1	PASS	Accel	PASS	PASS	PASS	PASS	PASS	n/a	11.2 (18.0)	Yes
144	1-B	1	PASS	Accel	FAIL	PASS	PASS	PASS	PASS	n/a	1.2 (1.9)	Yes
145	1-B	2	PASS	Accel	PASS	PASS	PASS	PASS	PASS	n/a	14.4 (23.2)	Yes
148	1-B	2	PASS	Accel	PASS	PASS	PASS	PASS	PASS	n/a	10.4 (16.7)	Yes
149	1-B	2	PASS	Accel	PASS	PASS	PASS	PASS	PASS	21.4 (0.54)	None	Yes
156	2-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	60.9 (1.55)	None	Yes
157	2-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	59.8 (1.52)	None	Yes
158	2-B	0	FAIL	Accel	PASS	PASS	PASS	PASS	PASS	43.0 (1.09)	None	Yes
165	1-A	0	PASS	FAIL	PASS	FAIL	PASS	PASS	PASS	-18.3 (-0.46)	None	Yes
166	1-A	0	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	-13.1 (-0.33)	None	Yes
167	1-A	0	FAIL	PASS	PASS	PASS	PASS	PASS	PASS	-13.7 (-0.35)	None	Yes
168	1-A	1	PASS	PASS	PASS	PASS	PASS	PASS	PASS	-18.4 (-0.47)	None	Yes
169	1-A	1	PASS	PASS	PASS	PASS	PASS	PASS	PASS	-3.2 (-0.08)	None	Yes
170	1-A	1	PASS	PASS	PASS	PASS	PASS	PASS	PASS	-7.1 (-0.18)	None	Yes
174	1-A	2	PASS	PASS	PASS	PASS	PASS	PASS	PASS	-10.6 (-0.27)	None	Yes
175	1-A	2	PASS	PASS	FAIL	PASS	PASS	FAIL	PASS	23.7 (0.60)	None	Yes
176	1-A	2	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	19.9 (0.51)	None	Yes
204	1-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	-85.9 (-2.18)	None	Yes
206	1-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	-63.7 (-1.62)	None	Yes
207	1-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	-52.7 (-1.34)	None	Yes
227	2-A	0	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	19.0 (0.48)	None	Yes
228	2-A	0	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS	4.6 (0.12)	None	Yes

Table B-2. Crash-Imminent Test Validity (continued)

Test File	Scenario	Auto. Level	SV Speed Check	POV Speed Check	SV Yaw Check	SV Brake Check	SV TPS Check	SV Path	POV Path	Offset From Desired Impact Point; inch (m)	ISA Speed Reduction; mph (km/h)	SV-to-POV Impact?
229	2-A	0	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	15.6 (0.40)	None	Yes
231	2-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	19.3 (0.49)	None	Yes
232	2-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	12.7 (0.32)	None	Yes
233	2-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	18.7 (0.48)	None	Yes
237	3-B	0	PASS	Accel	PASS	PASS	PASS	PASS	PASS	-8.3 (-0.21)	None	Yes
239	3-A	0	PASS	PASS	PASS	PASS	PASS	PASS	PASS	4.1 (0.10)	None	Yes
241	3-C	0	Accel	PASS	PASS	PASS	PASS	PASS	PASS	2.7 (0.07)	None	Yes

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