OCAS-DRI-LDW-14-002

NCAP LANE DEPARTURE WARNING CONFIRMATION TEST

2014 BMW X5

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

13 February 2014

Final Report

Prepared Under Contract No.:DTNH22-08-D-00095

U. S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Office of Crash Avoidance Standards
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Prepared By: John Lenkeit

Approved By: Nadine Wong

Approval Date: 13 February 2014
These tests were conducted on the subject 2014 BMW X5 in accordance with the specifications of the Office of Crash Avoidance Standards most current Test Procedure in docket NHTSA-2006-26555 to confirm the performance of a lane departure warning system. The vehicle passed the requirements of the test for all three lane marking types and for both directions.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. DATA SHEETS</td>
<td>2</td>
</tr>
<tr>
<td>A. Data Sheet 1: Test Summary</td>
<td>3</td>
</tr>
<tr>
<td>B. Data Sheet 2: Vehicle Data</td>
<td>4</td>
</tr>
<tr>
<td>C. Data Sheet 3: Test Conditions</td>
<td>6</td>
</tr>
<tr>
<td>D. Data Sheet 4: Lane Departure Warning System Operation</td>
<td>8</td>
</tr>
<tr>
<td>III. TEST PROCEDURES</td>
<td>11</td>
</tr>
<tr>
<td>A. Test Procedure Overview</td>
<td>11</td>
</tr>
<tr>
<td>B. Lane Delineation Markings</td>
<td>12</td>
</tr>
<tr>
<td>C. Test Validity</td>
<td>15</td>
</tr>
<tr>
<td>D. Pass/Fail Criteria</td>
<td>15</td>
</tr>
<tr>
<td>E. Instrumentation</td>
<td>16</td>
</tr>
<tr>
<td>Appendix A Photographs</td>
<td>A-1</td>
</tr>
<tr>
<td>Appendix B Excerpts from Owner’s Manual</td>
<td>B-1</td>
</tr>
<tr>
<td>Appendix C Run Logs</td>
<td>C-1</td>
</tr>
<tr>
<td>Appendix D Time Histories</td>
<td>D-1</td>
</tr>
</tbody>
</table>
The purpose of the testing reported herein was to confirm the performance of a Lane Departure Warning (LDW) system installed on a 2014 BMW X5. The LDW system for this vehicle provides a tactile alert implemented via a vibration felt in the steering wheel. The vehicle passed the requirements of the test for all three lane marking types and for both directions.

The test procedure is described in detail in the NHTSA Document "LANE DEPARTURE WARNING SYSTEM CONFIRMATION TEST" from March of 2010. Its purpose is to confirm the performance of Lane Departure Warning (LDW) systems installed on light vehicles with gross vehicle weight ratings (GVWR) of up to 10,000 lb. Current LDW technology relies on sensors to recognize a lane delimiting edge line. As such, the test procedures described in the document rely on painted or taped lines or Botts Dots being present on the test course to emulate those found on public roadways. Although it is impossible to predict what technologies could be used by future LDW systems (e.g., magnetic markers, RADAR reflective striping, ultra violet paint, infra red, etc.), it is believed that minor modifications to these procedures, when deemed appropriate, could be used to accommodate the evaluation of alternative or more advanced LDW systems.
Section II
DATA SHEETS
LANE DEPARTURE WARNING
DATA SHEET 1: TEST SUMMARY
2014 BMW X5

VIN: 5UXKR2C57E0Cxxxx

Test Date: 12/11/2013

Lane Departure Warning setting: On

Test 1 – Continuous White Line Left: Pass Right: Pass

Test 2 – Dashed Yellow Line Left: Pass Right: Pass

Test 3 – Botts Dots Left: Pass Right: Pass

Overall: Pass
TEST VEHICLE INFORMATION

VIN: 5UXKR2C57E0Cxxxx

Body Style: SUV  Color: Black

Date Received: 12/9/2013  Odometer Reading: 12 mi

Engine: 3 L Inline 6

Transmission: Automatic

Final Drive: RWD

Is the vehicle equipped with:

ABS X Yes ___ No

Adaptive Cruise Control X Yes ___ No

Collision Mitigating Brake System X Yes ___ No

DATA FROM VEHICLE’S CERTIFICATION LABEL

Vehicle manufactured by: Bayerische Motoren Werke AG

Date of manufacture: 09/2013

DATA FROM TIRE PLACARD:

Tires size as stated on Tire Placard: Front: 255/50R19

Rear: 255/50R19

Recommended cold tire pressure: Front: 250 kPa (35 psi)

Rear: 300 kPa (44 psi)
LANE DEPARTURE WARNING
DATA SHEET 2: GENERAL TEST AND VEHICLE PARAMETER DATA

2014 BMW X5

TIRES

Tire manufacturer and model: *Michelin Latitude Tour HP*

Front tire size: *255/50R19*

Rear tire size: *255/50R19*

VEHICLE ACCEPTANCE

Verify the following before accepting the vehicle

- [X] All options listed on the “window sticker” are present on the test vehicle
- [X] Tires and wheel rims are the same as listed.
- [X] There are no dents or other interior or exterior flaws.
- [X] The vehicle has been properly prepared and is in running condition.
- [X] Verify that spare tire, jack, lug wrench, and tool kit (if applicable) is located in the vehicle cargo area.
LANE DEPARTURE WARNING
DATA SHEET 3: TEST CONDITIONS (Page 1 of 2)
2014 BMW X5

GENERAL INFORMATION

Test date: 12/11/2013

AMBIENT CONDITIONS

Air temperature: 10.0 C (50 F)

Wind speed: 1.5 m/s (3.5 mph)

X Wind speed ≤ 10 m/s (22 mph)

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

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

VEHICLE PREPARATION

Verify the following:

All non consumable fluids at 100 % capacity: X

Fuel tank is full: X

Tire pressures are set to manufacturer's recommended cold tire pressure:

Front: 250 kPa (35 psi)

Rear: 300 kPa (44 psi)
WEIGHT

Weight of vehicle as tested including driver and instrumentation

Left Front: 529.3 kg (1167 lb)  
Left Rear: 581.1 kg (1281 lb)

Right Front: 543.4 kg (1198 lb)  
Right Rear: 575.2 kg (1268 lb)

Total: 2229.0 kg (4914 lb)
LANE DEPARTURE WARNING
DATA SHEET 4: LANE DEPARTURE WARNING SYSTEM OPERATION

2014 BMW X5

How is the Forward Collision Warning presented to the driver? (Check all that apply)

- Warning light
- Buzzer or audible alarm
- Vibration
- Other

Describe the method by which the driver is alerted. For example, if the warning is a light, where is it located, its color, size, words or symbol, does it flash on and off, etc. If it is a sound, describe if it is constant beep or a repeated beep. If it is a vibration, describe where it is felt (e.g., pedals, steering wheel), the dominant frequency (and possibly magnitude), the type of warning (light, audible, vibration, or combination) etc.

*The driver is alerted via a tactile alert felt in the steering wheel as the vehicle passes over the lane markings. The primary frequency of the vibration is approximately 51 Hz.*
Is the vehicle equipped with a switch whose purpose is to render LDW inoperable?  

- [x] Yes  
- [ ] No

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

A switch located in the middle of the center console underneath the switch for hazard lights allows the system to be turned off. The switch has a picture of a vehicle as seen from above surrounded by a illuminated green light. Pressing the switch once brings up the "Intelligent Safety" menu. Once in the "Intelligent Safety" menu, the user can select "Lane Departure Warning" and toggle the system between "On" and "Off" by pressing the switch once.

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

- [x] Yes  
- [ ] No

If yes please provide a full description
Are there other driving modes or conditions that render LDW inoperable or reduce its effectiveness?  

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

If yes please provide a full description.

**Functional Limitations:**

- **Heavy fog, rain, snowfall**
- **In the event of worn, poorly visible, merging, diverging, or multiple lane marking such as in construction areas**
- **When lane markings are covered in snow, ice, dirt or water**
- **In tight curves or on narrow lanes**
- **When the lane markings are covered by objects**
- **When driving very close to the vehicle in front of you**
- **When driving toward bright lights**
- **When the windshield behind the interior rearview mirror is fogged over, dirty or covered with stickers, etc.**
- **During the calibration process of the camera immediately after vehicle shipment**
Section III
TEST PROCEDURES

A. Test Procedure Overview

Each LDW test involved one of three lane marking types: solid white lines, dashed yellow lines, or Botts Dots. Lane departures were done both to the left and to the right, and each test condition was repeated five times, as shown in Table 1.

<table>
<thead>
<tr>
<th>Lane Geometry</th>
<th>Line Type</th>
<th>Departure Direction</th>
<th>Number of Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td>Solid</td>
<td>L</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Dashed</td>
<td>L</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Botts Dots</td>
<td>L</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>5</td>
</tr>
</tbody>
</table>

Prior to the start of a test series involving a given lane marking type and departure direction combination, the accuracy of the distance to lane marking measurement was verified. This was accomplished by driving the vehicle to the approximate location at which the lane departure would occur and placing the tire at the lane marking edge of interest (i.e., distance to lane marking = 0). The real-time display of distance to the lane marking was then observed to verify that the measured distance was within the tolerance (5 cm). If the measured distance was found to be greater than the tolerance, the instrumentation setup was checked and corrected, if necessary. If the measured distance was found to be within the tolerance, the instrumentation setup was considered appropriate and the test series was begun.

To begin the maneuver, the vehicle was accelerated from rest to a test speed of 72.4 km/h (45 mph), while being driven in a straight line parallel to the lane marking of interest, with the centerline of the vehicle approximately 1.83m (6.0 ft) from the lane edge (i.e., such that the vehicle would pass through the center of the start gate). The test speed was achieved at least 60 m (200 ft) before the start gate was reached. Striking any start gate cones was not permitted, and any run in which a cone was struck was considered to be invalid. Also, during the initialization and test phases, the test driver avoided using turn
signals and avoided applying any sudden acceleration, sudden steering or sudden braking, and any use of the turn signals, sudden acceleration, sudden steering or sudden braking invalidated the test trial.

Data collection began with the vehicle at least 60 m (200 ft) from the start gate, which was configured using a pair of non-reflective, low-contrast color traffic cones. A second set of cones, placed 6 m (20 ft) longitudinally before the start gate, was used to guide the driver into the start gate. The lateral width between the cone pairs was 20 cm (8 in) greater than the width of the vehicle, and the centerline of each pair was laterally offset from the lane marking by 1.8 m (6 ft).

Once the driver passed the gate, the driver manually input sufficient steering to achieve a lane departure with a target lateral velocity of 0.5 m/s with respect to the lane line. As shown in Fig 1, two additional non-reflective cones were used to guide the driver in making this steering maneuver. Throughout the maneuver the driver modulated the throttle, or used cruise control, as appropriate, such that vehicle speed remained at constant speed. The test was considered complete when the vehicle crossed at least 1 m (3.3 ft) over the lane edge boundary.

Data collected included vehicle speed, position, and yaw rate. In addition to cone strikes, vehicle speed and yaw rate data were used to identify invalid runs as described in Section C below. Data from trials where speed or yaw rate were outside of the performance specification were not considered valid.

**B. Lane Delineation Markings**

The Office of Crash Avoidance Standards’ Test Procedure for the confirmation of a lane departure warning system contains a requirement that all lane markings
meet USDOT specifications as described in the Manual on Uniform Traffic Control Devices (MUTCD) and be considered in “very good condition”.

1. Lane Marker Width

The width of the edge line marker was 10 to 15 cm (4 to 6 in). This is considered to be a normal width for longitudinal pavement markings under Section 3A.05 of the MUTCD.

2. Line Marking Color and Reflectivity

Lane marker color and reflectivity met all applicable standards. These standards include those from the International Commission of Illumination (CIE) for color and the American Society for Testing and Materials (ASTM) on lane marker reflectance.

3. Line Styles

The tests described in this document required the use of three lane line configurations: continuous solid white, discontinuous dashed yellow, and discontinuous with raised pavement markers.

- Continuous White Line
  A continuous white line is defined as a white line that runs for the entire length of the test course.

- Dashed Yellow Line
  As stated in the Manual on Uniform Traffic Control Devices (MUTCD), and as shown in Figure 2, a discontinuous dashed yellow line is defined as by a series of 3 m (10 ft) broken (dashed) yellow line segments, spaced 9.1 m (30 ft) apart.

- Raised Pavement Marker Line (Botts Dots)
  California Standard Plans indicates raised pavement markers are commonly used in lieu of painted strips for marking roads in California. Other states, mainly in the southern part of the United States, rely on them as well. These markers may be white or yellow, depending on the specific application, following the same basic colors of their analogous white and yellow painted lines. Following the California 2006 Standard Plans, three types of raised pavement markings are used to form roadway lines. It is believed that these types of roadway markings are the hardest for an LDW sensor system to process. Type A and Type AY are non-reflective circular domes that are approximately 10 cm (4 in) in diameter and approximately 1.8 cm (0.7
in) high. Type C and D are square markings that are retro reflective in two directions measuring approximately 10 x 10 x 5 cm (4 x 4 x 0.5 in), and Type G and H that are the same as C and D only retro reflective in a single direction.

For the tests described in this document, raised pavement markers were set up following California Standard Plan A20A, Detail 4 as shown in Figure 3. Note that in this figure, the squares are Type D yellow reflectors and the circles are yellow Type AY discs.
C. **Test Validity**

1. **Speed**

   All LDW tests were conducted at 72.4 km/h (45 mph). Test speed was monitored and a test was considered valid if the test speed remained within ± 2 km/h (± 1.2 mph) of the 72.4 km/h (45 mph) target speed. It was required that the speed must remain within this window from the start of the test until any part of the vehicle crossed a lane line by 1 m (3.3 ft) or more.

2. **Lateral Velocity**

   All tests were conducted with a lateral velocity of 0.1 to 0.6 m/s (0.3 to 2.0 ft/s), measured with respect to the lane line at the time of the alert. To assist the test driver in being able to efficiently establish the target lateral velocity, cones were positioned in the manner shown in Figure 1.

3. **Yaw Rate**

   It was required that the magnitude of the vehicle’s yaw rate could not exceed 1.0 deg/sec at any time during lane departure maneuver, from the time the vehicle passes through the start gate to the instant the vehicle has crossed a lane line by 1 m (3.3 ft).

D. **Pass/Fail Criteria**

   The measured test data were used to determine the pass/fail outcome for each trial. The outcome was based on whether the LDW produced an appropriate alert during the maneuver. In the context of this test procedure, a lane departure is said to occur when any part of the two dimensional polygon used to represent the test vehicle breaches the inboard lane line edge (i.e., the edge of the line closed to the vehicle before the departure occurs). In the case of tests performed in this procedure, the front corner of the polygon, defined as the intersection of center of the front wheels (longitudinally) with the outboard edge of the front tire (laterally), crossed the line edge first. So, for example, if the vehicle departed its lane to the left, the left front corner of the polygon would first breach the lane line edge.

   For an individual trial to be considered a “pass”:

   o Test speed, lateral velocity, and yaw rate validity conditions must be satisfied.
   o The LDW alert must not occur when the lateral position of the vehicle
is greater than 0.75 m (2.5 ft) from the lane line edge (i.e., prior to the lane departure).
- The LDW alert must occur before the lane departure exceeds 0.3 m (1.0 ft).

For an overall “Pass” the LDW system must satisfy the pass criteria for 3 of 5 individual trials for each combination of departure direction and lane line type (60 percent), and pass 20 of the 30 trials overall (66 percent).

E. Instrumentation

Table 2 lists the sensors, signal conditioning and data acquisition equipment used for these tests.
<table>
<thead>
<tr>
<th>Type</th>
<th>Output</th>
<th>Range</th>
<th>Accuracy, Other Primary Specs</th>
<th>Mfr, Model</th>
<th>Serial Number</th>
<th>Calibration Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tire Pressure Gauge</td>
<td>Vehicle Tire Pressure</td>
<td>0-100 psi 0-690 kPa</td>
<td>0.5 psi 3.45 kPa</td>
<td>Ashcroft, D1005PS</td>
<td>1039350</td>
<td>1/23/2013 1/23/2014</td>
</tr>
<tr>
<td>Platform Scales</td>
<td>Vehicle Total, Wheel, and Axle Load</td>
<td>8000 lb 35.6 kN</td>
<td>± 1.0% of applied load</td>
<td>Intercomp, SWII</td>
<td>NT2888</td>
<td>1/30/2013 1/30/2014</td>
</tr>
<tr>
<td>Differential Global Positioning System</td>
<td>Position, Velocity</td>
<td>Latitude: ±90 deg</td>
<td>Horizontal Position:</td>
<td>Trimble GPS Receiver,</td>
<td>00440100989</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Longitude: ±180 deg</td>
<td>Vertical Position: ±2 cm</td>
<td>5700 (base station and in-vehicle)</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Altitude: 0-18 km</td>
<td>Velocity: 0.05 km/h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Velocity: 0-1000 knots</td>
<td></td>
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<tr>
<td></td>
<td>and Vertical Accels; Lateral,</td>
<td>Longitude: ±180 deg</td>
<td>Velocity: 0.05 km/h</td>
<td></td>
<td>2176</td>
<td>2/7/2012 2/7/2014</td>
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<tr>
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<td>Longitudinal and Vertical Velocities;</td>
<td>Altitude: 0-18 km</td>
<td>Accel: ±0.01% of full range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roll, Pitch, Yaw Rates; Roll, Pitch,</td>
<td>Velocity: 0-1000 knots</td>
<td>Angular Rate: ±0.01 deg/s</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Yaw Angles</td>
<td>Accel: ±100 m/s²</td>
<td>Angular Disp: ±180 deg</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Real-Time Calculation of Position and</td>
<td>Distance and Velocity to lane</td>
<td>Lateral Lane Dist: ±30 m</td>
<td>Lateral Distance to Lane</td>
<td>Oxford Technical Solutions (OXTS), RT-Range</td>
<td>97</td>
<td>NA</td>
</tr>
<tr>
<td>Velocity Relative to Lane Markings (LDW)</td>
<td>markings (LDW) and POV (FCW)</td>
<td>Lateral Lane Velocity:</td>
<td>Lane Marking: ±2 cm</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>±20 m/sec</td>
<td>Lateral Velocity to Lane</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Longitudinal Range to</td>
<td>Marking: ±0.02 m/sec</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>POV: ±200 m</td>
<td>Longitudinal Range: ±3 cm</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Longitudinal Range Rate:</td>
<td>Longitudinal Range Rate: ±0.02 m/sec</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Output</td>
<td>Range</td>
<td>Accuracy, Other Primary Specs</td>
<td>Mfr, Model</td>
<td>Serial Number</td>
<td>Calibration Dates Last Due</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>---------------------------------------------</td>
<td>------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>----------------------------------</td>
<td>---------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td><strong>Data Acquisition System</strong></td>
<td>Record Time; Position; Velocity; Distance to lane markings; Headway distance; Closing Velocity; Lateral, Longitudinal, and Vertical Accels; Roll, Yaw, and Pitch Rates; Roll, Yaw and Pitch Angles.</td>
<td>Sufficient to meet or exceed individual sensors</td>
<td>Sound digitized at 10 kHz, all other channels digitized at 100 Hz. Accuracy is sufficient to meet or exceed individual sensors</td>
<td>SoMat, eDaq ECPU processor</td>
<td>MSHLB.03-2476</td>
<td>4/24/13</td>
</tr>
<tr>
<td><strong>Microphone</strong></td>
<td>Sound (to measure time at alert)</td>
<td>Max SPL: 139 dB/SPL Frequency Response: 40 Hz – 20 kHz</td>
<td>≤ 3 dB over Freq. Resp. Range</td>
<td>Sennheiser, e614</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Light Sensor</strong></td>
<td>Light intensity (to measure time at alert)</td>
<td>Spectral Bandwidth: 440-800 nm</td>
<td>Rise time &lt; 10 msec</td>
<td>DRI designed and developed Light Sensor</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Accelerometer</strong></td>
<td>Acceleration (to measure time at alert)</td>
<td>±5g</td>
<td>≤ 3% of full range</td>
<td>Silicon Designs, 2210-005</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Coordinate Measurement Machine</strong></td>
<td>Inertial Sensing System Coordinates</td>
<td>0-8 ft 0-2.4 m</td>
<td>±.0020 in. ±.051 mm (Single point articulation accuracy)</td>
<td>Faro Arm, Fusion</td>
<td>UO8-05-08-06636</td>
<td>1/4/2013 1/4/2014</td>
</tr>
</tbody>
</table>
As part of the pre-test instrumentation verification process, the tonal frequency of the audible warning or the vibration frequency of the tactile warning (if present) was determined through use of the PSD (Power Spectral Density) function in Matlab. This was accomplished in order to identify the center frequency around which a band-pass filter was applied to subsequent audible or tactile warning data so that the beginning of such warnings could be programmatically determined. The bandpass filter used for these warning signals was a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 3.

Table 3. Audible and Tactile Warning Filter Parameters

<table>
<thead>
<tr>
<th>Warning Type</th>
<th>Filter Order</th>
<th>Peak-to-Peak Ripple</th>
<th>Minimum Stop Band Attenuation</th>
<th>Pass-Band Frequency Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audible</td>
<td>5\textsuperscript{th}</td>
<td>3 dB</td>
<td>60 dB</td>
<td>Identified Center Frequency ± 5%</td>
</tr>
<tr>
<td>Tactile</td>
<td>5\textsuperscript{th}</td>
<td>3 dB</td>
<td>60 dB</td>
<td>Identified Center Frequency ± 20%</td>
</tr>
</tbody>
</table>
APPENDIX A

Photographs
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure A1.</th>
<th>Front View of Subject Vehicle</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure A2.</td>
<td>Rear View of Subject Vehicle</td>
<td>A-4</td>
</tr>
<tr>
<td>Figure A3.</td>
<td>Window Sticker (Monroney Label)</td>
<td>A-5</td>
</tr>
<tr>
<td>Figure A4.</td>
<td>Vehicle Certification Label</td>
<td>A-6</td>
</tr>
<tr>
<td>Figure A5.</td>
<td>DGPS and Inertial Measurement Unit Installed in Subject Vehicle</td>
<td>A-7</td>
</tr>
<tr>
<td>Figure A6.</td>
<td>Data Acquisition System Installed in Subject Vehicle</td>
<td>A-8</td>
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<td>Figure A7.</td>
<td>Computer Installed in Subject Vehicle</td>
<td>A-9</td>
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<td>Figure A8.</td>
<td>Sensor for Detecting Haptic Alert</td>
<td>A-10</td>
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<td>Figure A9.</td>
<td>LDW Visual Display</td>
<td>A-11</td>
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<td>Figure A10.</td>
<td>Intelligent Safety Button, LDW On/Off</td>
<td>A-12</td>
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<tr>
<td>Figure A11.</td>
<td>LDW On/Off Menus</td>
<td>A-13</td>
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</table>
Figure A2. Rear View of Subject Vehicle
Figure A3. Window Sticker (Monroney Label)
Figure A4. Vehicle Certification Label
Figure A5. DGPS and Inertial Measurement Unit Installed in Subject Vehicle
Figure A6. Data Acquisition System Installed in Subject Vehicle
Figure A7. Computer Installed in Subject Vehicle
Figure A8. Sensor for Detecting Haptic Alert
Figure A9. LDW Visual Display
Figure A10. Intelligent Safety Button, LDW On/Off
Figure A11. LDW On/Off Menus
APPENDIX B

Excerpts from Owner’s Manual
## Overview: indicator/warning lamps

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Function or system</th>
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<tbody>
<tr>
<td>✅</td>
<td>Turn signal.</td>
</tr>
<tr>
<td>🚀</td>
<td>Parking brake.</td>
</tr>
<tr>
<td>🎯</td>
<td>Parking brake in Canadian models.</td>
</tr>
<tr>
<td>⏸️</td>
<td>Automatic hold.</td>
</tr>
<tr>
<td>🕯️</td>
<td>Front fog lamps.</td>
</tr>
<tr>
<td>🇨🇦</td>
<td>High beams.</td>
</tr>
<tr>
<td>🇨🇦</td>
<td>High-beam Assistant.</td>
</tr>
<tr>
<td>🎯</td>
<td>Parking lamps, headlamp control.</td>
</tr>
<tr>
<td>🚅</td>
<td>Vehicle detection, Active Cruise Control: collision warning.</td>
</tr>
<tr>
<td>🚅</td>
<td>Cruise control.</td>
</tr>
<tr>
<td>🚅</td>
<td>Lane departure warning.</td>
</tr>
<tr>
<td>🚅</td>
<td>DSC Dynamic Stability Control.</td>
</tr>
<tr>
<td>🚅</td>
<td>DSC Dynamic Stability Control or DTC Dynamic Traction Control</td>
</tr>
<tr>
<td>🚅</td>
<td>Tire Pressure Monitor.</td>
</tr>
<tr>
<td>🚅</td>
<td>Flat Tire Monitor.</td>
</tr>
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</table>

## Symbol Function or system

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Function or system</th>
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<tr>
<td>🌟</td>
<td>Safety belts.</td>
</tr>
<tr>
<td>🎯</td>
<td>Airbag system.</td>
</tr>
<tr>
<td>🎯</td>
<td>Steering system.</td>
</tr>
<tr>
<td>🎯</td>
<td>Engine functions.</td>
</tr>
<tr>
<td>🎯</td>
<td>Engine functions in Canadian models.</td>
</tr>
<tr>
<td>🎯</td>
<td>Brake system.</td>
</tr>
<tr>
<td>🎯</td>
<td>Brake system in Canadian models.</td>
</tr>
<tr>
<td>🔴</td>
<td>ABS Antilock Brake System.</td>
</tr>
<tr>
<td>🔴</td>
<td>ABS Antilock Brake System in Canadian models.</td>
</tr>
<tr>
<td>🚫</td>
<td>At least one Check Control message is displayed or is stored.</td>
</tr>
</tbody>
</table>

### Text messages

Text messages in combination with a symbol in the instrument cluster explain a Check Control message and the meaning of the indicator and warning lamps.

### Supplementary text messages

Additional information, such as on the cause of a fault or the required action, can be called up via Check Control.

The supplementary text of urgent messages is automatically displayed on the Control Display.
Controls  Safety

Prewarning

- The yellow symbol is displayed when a person is detected in the central area, arrow 1, immediately in front of the vehicle. The yellow symbol is displayed when a person in the extended area, arrow 2, is moving from the right or left towards the central area.
- The displayed symbol can vary with the people detected. Intervene actively by braking or making an evasive maneuver.

- When animals are detected, an animal symbol is displayed. The symbol also shows the side of the road on which the animal was detected. Intervene actively by braking or making an evasive maneuver.

Acute warning

- The red symbol is displayed and a signal sounds. Intervene immediately by braking or making an evasive maneuver.
- With animals no acute warning occurs.

Display in the Head-up Display

- The warning is displayed simultaneously in the Head-up Display and on the instrument cluster. The displayed symbol can vary with the people detected. When animals are detected, an animal symbol is displayed.

System limits

Basic limits

System operation is limited in situations such as the following:
- On steep hills, in steep depressions or in tight curves.
- When the camera is dirty or the protective glass is damaged.
- In heavy fog, rain or snowfall.
- At very high external temperatures.

Limits of pedestrian and animal detection

In some situations, it may occur that pedestrians are detected as animals or animals as pedestrians.

Small animals are not detected by the object detection function, even if they are clearly visible in the image.

Limited detection:
- People or animals who are fully or partially covered, especially when their heads are covered.
- People who are not in an upright position, e.g., lying down.
- Cyclists on unconventional bicycles (e.g., recumbent bicycles).
- After physical damage to the system, e.g., after an accident.

No display on the rear screen

The image from Night Vision with people detection cannot be displayed on the rear screen.

Lane departure warning

The concept

Starting at a specific speed, this system alerts you when the vehicle on streets with lane markings is about to leave the lane. Depending on the country-specific version of the vehicle, the speed is between 35 mph/55 km/h and 45 mph/70 km/h. If the system is switched on below this speed, a message appears in the instrument cluster.

The steering wheel begins vibrating gently in the event of warnings. The time of the warning
may vary depending on the current driving situation.
The system does not provide a warning if the turn signal is set before leaving the lane.

Notes

Personal responsibility
The system cannot serve as a substitute for the driver’s personal judgment of the course of the road and the traffic situation.
In the event of a warning, do not jerk the steering wheel, as you may lose control of the vehicle.

At a glance

Button in the vehicle

Keep the windshield in the area behind the interior rear view mirror clean and clear.

Switching on/off
Some Intelligent Safety systems are automatically active after each engine start via the start/stop button.

Press the button:
A panel appears on the Control Display. Adjustments can be made. The individual settings are stored for the remote control currently in use.

Press the button briefly:
> Intelligent Safety systems are individually switched off according to individual setting.
> LED lights up orange or goes out depending on the individual setting.
Press the button again:
> All Intelligent Safety systems are switched on.
> The LED lights up green.

Hold the button down:
> All Intelligent Safety systems are switched off.
> The LED goes out.

Display in the instrument cluster

Lines: system is activated.

Arrows: at least one lane marking was detected and warnings can be issued.

Issued warning
If you leave the lane and if a lane marking has been detected, the steering wheel begins vibrating.
If the turn signal is set before changing the lane, a warning is not issued.
End of warning
The warning ends:
▷ Automatically after approx. 3 seconds.
▷ When returning to your own lane.
▷ When braking hard.
▷ When using the turn signal.

System limits
The system may not be fully functional in the following situations:
▷ In heavy fog, rain or snowfall.
▷ In the event of worn, poorly visible, merging, diverging, or multiple lane markings such as in construction areas.
▷ When lane markings are covered in snow, ice, dirt or water.
▷ In tight curves or on narrow lanes.
▷ When the lane markings are covered by objects.
▷ When driving very close to the vehicle in front of you.
▷ When driving toward bright lights.
▷ When the windshield in front of the interior rearview mirror is fogged over, dirty or covered with stickers, etc.
▷ During calibration of the camera immediately after vehicle shipment.

Active Blind Spot Detection

The concept

Two radar sensors below the rear bumper monitor the area behind and next to the vehicle at speeds above approx. 30 mph/50 km/h.

The system indicates whether there are vehicles in the blind spot, arrow 1, or approaching from behind on the adjacent lane, arrow 2.

The lamp in the exterior mirror housing lights up dimly.

Before you change lanes after setting the turn signal, the system issues a warning in the situations described above.

The lamp in the housing of the exterior mirror flashes and the steering wheel vibrates.

Notes

⚠️ Personal responsibility
The system does not serve as a substitute for the driver's personal judgment of the traffic situation.
Be aware of the traffic situation and the vehicle's surroundings at all times, otherwise an accident is still possible despite all warnings.
APPENDIX C

Run Log
Subject Vehicle: **2014 BMW X5**  
Date: **12/11/2013**  
Driver: N. Wong

<table>
<thead>
<tr>
<th>Run</th>
<th>Lane Marking Type</th>
<th>Departure Direction</th>
<th>Valid Run?</th>
<th>Distance at HapticAlert (ft)</th>
<th>Pass/Fail</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solid</td>
<td>Left</td>
<td>Y</td>
<td>0.46</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>Y</td>
<td>0.45</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>Y</td>
<td>0.43</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
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<td>0.19</td>
<td>Pass</td>
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<td>5</td>
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<td>0.46</td>
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<tr>
<td>6</td>
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<td>0.23</td>
<td>Pass</td>
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<td>7</td>
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<td>0.29</td>
<td>Pass</td>
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<td>8</td>
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<td>0.76</td>
<td>Pass</td>
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</table>
Subject Vehicle: **2014 BMW X5**

Date: 12/11/2013

Driver: N. Wong

<table>
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<th>Lane Marking Type</th>
<th>Departure Direction</th>
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<td>Pass</td>
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<td>Pass</td>
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</table>
Subject Vehicle: **2014 BMW X5**  
Date: 12/11/2013  
Driver: N. Wong

<table>
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<th>Lane Marking Type</th>
<th>Departure Direction</th>
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<td>Pass</td>
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<td>0.34</td>
<td>Pass</td>
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</tr>
<tr>
<td>31</td>
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### Run Lane Marking Type Departure Direction Valid Run? Distance at HapticAlert (ft) Pass/Fail Notes

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<th>Departure Direction</th>
<th>Valid Run?</th>
<th>Distance at HapticAlert (ft)</th>
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<tr>
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<td></td>
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</table>
APPENDIX D

Time History Plots
## LIST OF FIGURES

| Figure D1. | Example Time History for Lane Departure Warning Test, Passing | Page D-7 |
| Figure D2. | Example Time History for Lane Departure Warning Test, Failing, No Warning Issued | Page D-8 |
| Figure D3. | Example Time History for Lane Departure Warning Test, Invalid Run Due to Subject Vehicle Yaw Rate | Page D-9 |
| Figure D4. | Time History for Run 1, Solid Line, Left Departure, Haptic Warning | Page D-10 |
| Figure D5. | Time History for Run 2, Solid Line, Left Departure, Haptic Warning | Page D-11 |
| Figure D6. | Time History for Run 3, Solid Line, Left Departure, Haptic Warning | Page D-12 |
| Figure D7. | Time History for Run 4, Solid Line, Left Departure, Haptic Warning | Page D-13 |
| Figure D8. | Time History for Run 5, Solid Line, Left Departure, Haptic Warning | Page D-14 |
| Figure D9. | Time History for Run 6, Solid Line, Left Departure, Haptic Warning | Page D-15 |
| Figure D10. | Time History for Run 7, Solid Line, Left Departure, Haptic Warning | Page D-16 |
| Figure D11. | Time History for Run 8, Solid Line, Right Departure, Haptic Warning | Page D-17 |
| Figure D12. | Time History for Run 9, Solid Line, Right Departure, Haptic Warning | Page D-18 |
| Figure D13. | Time History for Run 10, Solid Line, Right Departure, Haptic Warning | Page D-19 |
| Figure D14. | Time History for Run 11, Solid Line, Right Departure, Haptic Warning | Page D-20 |
| Figure D15. | Time History for Run 12, Solid Line, Right Departure, Haptic Warning | Page D-21 |
| Figure D16. | Time History for Run 13, Solid Line, Right Departure, Haptic Warning | Page D-22 |
| Figure D17. | Time History for Run 14, Solid Line, Right Departure, Haptic Warning | Page D-23 |
| Figure D18. | Time History for Run 15, Dashed Line, Right Departure, Haptic Warning | Page D-24 |
| Figure D19. | Time History for Run 16, Dashed Line, Right Departure, Haptic Warning | Page D-25 |
| Figure D20. | Time History for Run 17, Dashed Line, Right Departure, Haptic Warning | Page D-26 |
| Figure D21. | Time History for Run 18, Dashed Line, Right Departure, Haptic Warning | Page D-27 |
| Figure D22. | Time History for Run 19, Dashed Line, Right Departure, Haptic Warning | Page D-28 |
| Figure D23. | Time History for Run 20, Dashed Line, Right Departure, Haptic Warning | Page D-29 |
| Figure D24. | Time History for Run 21, Dashed Line, Right Departure, Haptic Warning | Page D-30 |
| Figure D25. | Time History for Run 22, Dashed Line, Left Departure, Haptic Warning | Page D-31 |
Figure D26. Time History for Run 23, Dashed Line, Left Departure, Haptic Warning ................................................................. D-32
Figure D27. Time History for Run 25, Dashed Line, Left Departure, Haptic Warning ................................................................. D-33
Figure D28. Time History for Run 26, Dashed Line, Left Departure, Haptic Warning ................................................................. D-34
Figure D29. Time History for Run 27, Dashed Line, Left Departure, Haptic Warning ................................................................. D-35
Figure D30. Time History for Run 28, Dashed Line, Left Departure, Haptic Warning ................................................................. D-36
Figure D31. Time History for Run 29, Dashed Line, Left Departure, Haptic Warning ................................................................. D-37
Figure D32. Time History for Run 30, Botts Dots, Left Departure, Haptic Warning .... D-38
Figure D33. Time History for Run 31, Botts Dots, Left Departure, Haptic Warning .... D-39
Figure D34. Time History for Run 33, Botts Dots, Left Departure, Haptic Warning .... D-40
Figure D35. Time History for Run 35, Botts Dots, Left Departure, Haptic Warning .... D-41
Figure D36. Time History for Run 36, Botts Dots, Left Departure, Haptic Warning .... D-42
Figure D37. Time History for Run 37, Botts Dots, Left Departure, Haptic Warning .... D-43
Figure D38. Time History for Run 38, Botts Dots, Left Departure, Haptic Warning .... D-44
Figure D39. Time History for Run 39, Botts Dots, Right Departure, Haptic Warning ........................................................................... D-45
Figure D40. Time History for Run 40, Botts Dots, Right Departure, Haptic Warning ........................................................................... D-46
Figure D41. Time History for Run 42, Botts Dots, Right Departure, Haptic Warning ........................................................................... D-47
Figure D42. Time History for Run 43, Botts Dots, Right Departure, Haptic Warning ........................................................................... D-48
Figure D43. Time History for Run 44, Botts Dots, Right Departure, Haptic Warning ........................................................................... D-49
Figure D44. Time History for Run 45, Botts Dots, Right Departure, Haptic Warning ........................................................................... D-50
Figure D45. Time History for Run 46, Botts Dots, Right Departure, Haptic Warning ........................................................................... D-51
Description of Time History Plots

A set of time history plots is provided for each valid run in the test series. Each set of plots comprises time varying data from the Subject Vehicle, as well as pass/fail envelopes and thresholds. The following is a description of data types shown in the time history plots, as well as a description of the color code for data envelopes.

Time History Plot Description

Time history figures include the following sub-plots:
- Event – indicates timing of warning issued by LDW system. Depending on the type of LDW alert or instrumentation used to measure the alert, this can be any of the following:
  - Filtered and rectified sound signal
  - Filtered and rectified acceleration (e.g., steering wheel vibration)
  - Light sensor signal
  - Discrete on/off value
- Speed (mph) – speed of the Subject Vehicle
- Yaw Rate (deg/sec) – yaw rate of the Subject Vehicle
- Dist to Lane Edge (ft) – lateral distance (in lane coordinates) from the outer front tire bulge to the inside edge of the lane marking of interest for a given test (a positive value indicates the vehicle is completely within the lane while a negative value indicates that the outer front tire bulge has crossed over the inner lane marking edge)
- Lateral Velocity (ft/sec) – lateral velocity (in lane coordinates) of the outer front tire bulge
- Bird’s Eye View – Indicates the position of the Subject Vehicle with respect to the lane marking of interest for a given test. Green rectangles represent the Subject Vehicle’s position at approximately 2 second intervals, while the yellow rectangle indicates the position of the Subject Vehicle at the time of LDW warning issuance.
Envelopes and Thresholds

Each of the time history plot figures can contain either green or yellow envelopes and/or black threshold lines. These envelopes and thresholds are used to programmatically and visually determine the validity of a given test run. Envelope and threshold exceedances are indicated with either red shading or red asterisks, and red text is placed to the right side of the plot indicating the type of exceedance.

Green envelopes indicate that the time-varying data should not exceed the envelope boundaries at any time within the envelope. Exceedances of a green envelope are indicated by red shading in the area between the measured time-varying data and the envelope boundaries.

Yellow envelopes indicate that the time-varying data should not exceed the envelope only at the right end. Exceedances at the right extent of a yellow envelope are indicated by red asterisks. Data within the boundaries at the right extent of a yellow envelope are indicated by green circles.

Color Codes

Color codes have been adopted to easily identify the types of data, envelopes and thresholds used in the plots.

Color codes can be broken into three categories:
1. Validation envelopes and thresholds
2. Instantaneous samplings
3. Text

1. Validation envelope and threshold color codes:
   • Green envelope = time varying data must be within the envelope at all times in order to be valid
   • Yellow envelope = time varying data must be within limits at right end
   • Black threshold (Solid) = time varying data must not exceed this threshold in order to be valid
   • Black threshold (Dashed) = for reference only – this can include warning level thresholds which are used to determine the timing of the alert

2. Instantaneous sampling color codes:
   • Green circle = passing or valid value at a given moment in time
   • Red asterisk = failing or invalid value at a given moment in time
3. Text color codes:
   - Green = passing or valid value
   - Red = failing or invalid value

Examples of time history plots (including passing, failing and invalid runs) are shown in Figure D1 through Figure D3. Actual time history data plots for the vehicle under consideration are provided subsequently.
Figure D1. Example Time History for Lane Departure Warning Test, Passing

GPS Fix Type: RTK Fixed
Figure D2. Example Time History for Lane Departure Warning Test, Failing, No Warning Issued
Figure D3. Example Time History for Lane Departure Warning Test, Invalid Run Due to Subject Vehicle Yaw Rate
Figure D4. Time History for Run 1, Solid Line, Left Departure, Haptic Warning
Figure D5. Time History for Run 2, Solid Line, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D6. Time History for Run 3, Solid Line, Left Departure, Haptic Warning
Figure D7. Time History for Run 4, Solid Line, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D8. Time History for Run 5, Solid Line, Left Departure, Haptic Warning
Figure D9. Time History for Run 6, Solid Line, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D10. Time History for Run 7, Solid Line, Left Departure, Haptic Warning
Figure D11. Time History for Run 8, Solid Line, Right Departure, Haptic Warning

LDW Test
X5-8

GPS Fix Type: RTK Fixed
GPS Fix Type: RTK Fixed

Figure D12. Time History for Run 9, Solid Line, Right Departure, Haptic Warning
Figure D13. Time History for Run 10, Solid Line, Right Departure, Haptic Warning
Figure D14. Time History for Run 11, Solid Line, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D15. Time History for Run 12, Solid Line, Right Departure, Haptic Warning
Figure D16. Time History for Run 13, Solid Line, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D17. Time History for Run 14, Solid Line, Right Departure, Haptic Warning
Figure D18. Time History for Run 15, Dashed Line, Right Departure, Haptic Warning
Figure D19. Time History for Run 16, Dashed Line, Right Departure, Haptic Warning
Figure D20. Time History for Run 17, Dashed Line, Right Departure, Haptic Warning
Figure D21. Time History for Run 18, Dashed Line, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D22. Time History for Run 19, Dashed Line, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D23. Time History for Run 20, Dashed Line, Right Departure, Haptic Warning
Figure D24. Time History for Run 21, Dashed Line, Right Departure, Haptic Warning
Figure D25. Time History for Run 22, Dashed Line, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D26. Time History for Run 23, Dashed Line, Left Departure, Haptic Warning
Figure D27. Time History for Run 25, Dashed Line, Left Departure, Haptic Warning
GPS Fix Type: RTK Fixed

Figure D28. Time History for Run 26, Dashed Line, Left Departure, Haptic Warning
Figure D29. Time History for Run 27, Dashed Line, Left Departure, Haptic Warning
Figure D30. Time History for Run 28, Dashed Line, Left Departure, Haptic Warning
Figure D31. Time History for Run 29, Dashed Line, Left Departure, Haptic Warning
Figure D32. Time History for Run 30, Botts Dots, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D33. Time History for Run 31, Botts Dots, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D34. Time History for Run 33, Botts Dots, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D35. Time History for Run 35, Botts Dots, Left Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D36. Time History for Run 36, Botts Dots, Left Departure, Haptic Warning
Figure D37. Time History for Run 37, Botts Dots, Left Departure, Haptic Warning
Figure D38. Time History for Run 38, Botts Dots, Left Departure, Haptic Warning
Figure D39. Time History for Run 39, Botts Dots, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D40. Time History for Run 40, Botts Dots, Right Departure, Haptic Warning
Figure D41. Time History for Run 42, Botts Dots, Right Departure, Haptic Warning
GPS Fix Type: RTK Fixed

Figure D42. Time History for Run 43, Botts Dots, Right Departure, Haptic Warning
Figure D43. Time History for Run 44, Botts Dots, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed
Figure D44. Time History for Run 45, Botts Dots, Right Departure, Haptic Warning
Figure D45. Time History for Run 46, Botts Dots, Right Departure, Haptic Warning

GPS Fix Type: RTK Fixed