DRAFT INTERNATIONAL STANDARD
ISO/DIS 22737

ISO/TC **204** Secretariat: **ANSI**

Voting begins on: **2020-07-21** Voting terminates on: **2020-10-13**

Intelligent transport systems — Low-speed automated driving (LSAD) systems for predefined routes — Performance requirements, system requirements and performance test procedures

ICS: 35.240.60; 03.220.20

Reference number
ISO/DIS 22737:2020(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 204, Working Group WG 14 , Vehicle Roadway Warning/Control Systems.

Introduction

The move towards automated driving systems is leading to a shift in the way people, goods and services are transported. One such new mode of transport is Low-Speed Automated Driving (LSAD) systems which operate on predefined routes. LSAD systems will be used for applications like last-mile transportation, transport in business or university campus areas and other low speed environments.

A vehicle that is driven by the LSAD system (which may include interaction with infrastructure) could potentially have many benefits like providing safe, convenient and affordable mobility and, reducing urban congestion. It would also provide increased mobility for people who may not be able to drive. However, with different applications of LSAD systems in the industry worldwide, there is a need to provide guidance for manufacturers, operators, end users and regulators to ensure safe deployment of LSAD systems.

The LSAD system requirements and procedures specified herein will assist manufacturers of LSAD systems in the incorporation of minimum safety requirements in their designs and allow end users, operators and regulators to reference a minimum set of performance requirements in their procurements.

Intelligent transport systems — Low-speed automated driving (LSAD) systems for predefined routes — Performance requirements, system requirements and performance test procedures

1 Scope

This document specifies requirements for operational design domain, system requirements, minimum performance requirements and performance test procedures for safe operation of Low-Speed Automated Driving (LSAD) systems which will operate on predefined routes. Low-Speed Automated Driving (LSAD) systems are designed to operate at Level 4 automation[1], within specific Operational Design Domains (ODD)[1].

This document applies to Automated Driving System-Dedicated Vehicles (ADS-DVs)[1], and also can be utilized by dual-mode vehicles[1]. Furthermore, this document doesn't specify sensor technology present in vehicles driven by the LSAD systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19206-2, *Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 2: Requirements for pedestrian targets*

ISO 19206-3, *Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions – Part 3: Requirements for passenger vehicle 3D targets*

ISO 19206-4, *Road vehicle – Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions –Part 4: Requirements for bicyclist targets*

ISO 2575:2010, *Road vehicles — Symbols for controls, indicators and tell-tales*

ISO 26262, *Road vehicles — Functional safety*

ISO/PAS 21448, *Road vehicles — Safety of the intended functionality*

ISO/SAE 22736, *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

For the purposes of this document, the terms and definitions given in ISO/SAE 22736 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
Hazardous Situation
A condition whereby the position, orientation and motion of an obstacle (e.g. pedal cyclists, pedestrians, vehicles etc.) relative to the position, orientation and motion of the vehicle driven by the LSAD system, may result in an imminent collision.

3.2
Predefined route
Trajectory defined before start of a trip[1] to be traversed by the vehicle driven by the LSAD system, from point of origin to one (or many) destination(s).

Note 1 to entry: A single trip of vehicle driven by the LSAD system may have many destinations. Predefined route will have a length and curvature but not width.

3.3
Minimal-Risk Manoeuvre
A tactical or operational manoeuvre triggered and executed by the LSAD system to achieve minimal risk condition[1]

3.5
Trip segment
Travel from point of origin to destination or one destination to another destination in a trip. A trip may comprise of multiple trip segments.

3.6
Drivable area
Manoeuvrable area around the predefined route where the LSAD system is capable of operating.

Note 1 to entry: The width of the drivable area may vary along the predefined route.

3.7
Pedal cyclist
A human-vehicle combination consisting of a human riding on top of a wheel frame having a steering mechanism, brakes, two pedals for propulsion (optionally with motor assist pedalling) that does not require a license for use on public roads.

3.8
Day-time
A condition where the ambient illuminance is greater than 2,000lx.

3.9
Night-time
A condition where the ambient illuminance is less than 1lx.

3.10
Standstill
Vehicle in standstill mode requires vehicle speed is at 0 m/s.

3.11
Low ambient lighting condition
Ambient light between day-time and night-time.

4 Symbols (and abbreviated terms)

LSAD	Low-Speed Automated Driving
MaaS	Mobility as a Service
SV	Subject Vehicle

V_{LSAD_max}	Maximum velocity for the LSAD system
ADS-DV	Automated Driving System – Dedicated Vehicle
VRU	Vulnerable Road Users
MRM	Minimal Risk Manoeuvre
MRC	Minimal Risk Condition
DDT	Dynamic Driving Task
ODD	Operational Design Domain
V2X	Vehicle to - X
e-stop	Emergency stop

5 Example Use Case for LSAD system deployment

Vehicles driven by LSAD systems may potentially be used as a part of a larger Mobility as a Service (MaaS) system. Figure 1 depicts an example system architecture of such a MaaS system. However, the scope of this document is restricted to the LSAD system installed in a vehicle in Figure 1.

As per the example in Figure 1, the LSAD system receives trip destination from the dispatcher via wireless communication, who/which in turn receives a destination request from the user (through a web portal or a mobile app. The dispatcher or the control centre processes the destination request and provides a trip/trip segment confirmation to the user and commands the vehicle driven by the LSAD system to proceed. Dispatcher in this document refers to the Driverless Operation Dispatcher [1].

As there may be more than one predefined routes to reach the destination, the selected predefined route may be: 1) provided by the dispatcher/control centre 2) selected by the user via a user-interface on a mobile app or on-board the LSAD system equipped vehicle 3) selected by the LSAD system itself.

LSAD system periodically provides its status (e.g. system health, trip status) to the user and the dispatcher/control server.

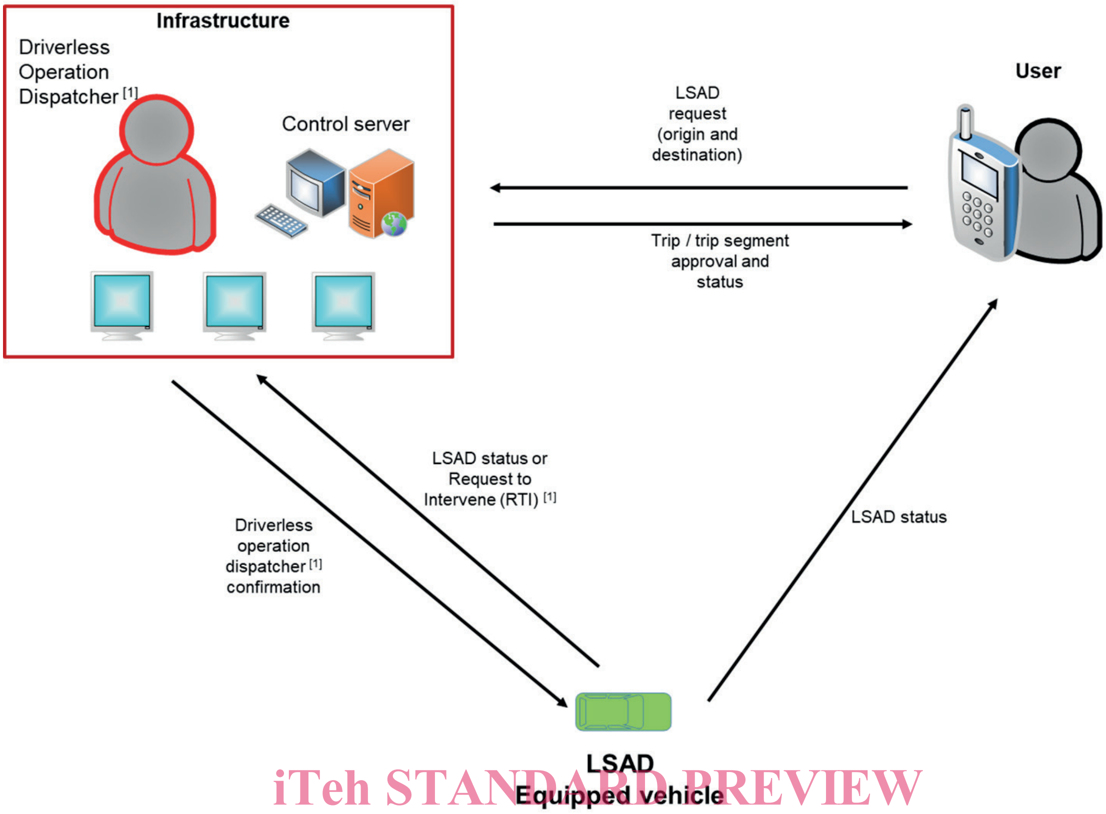
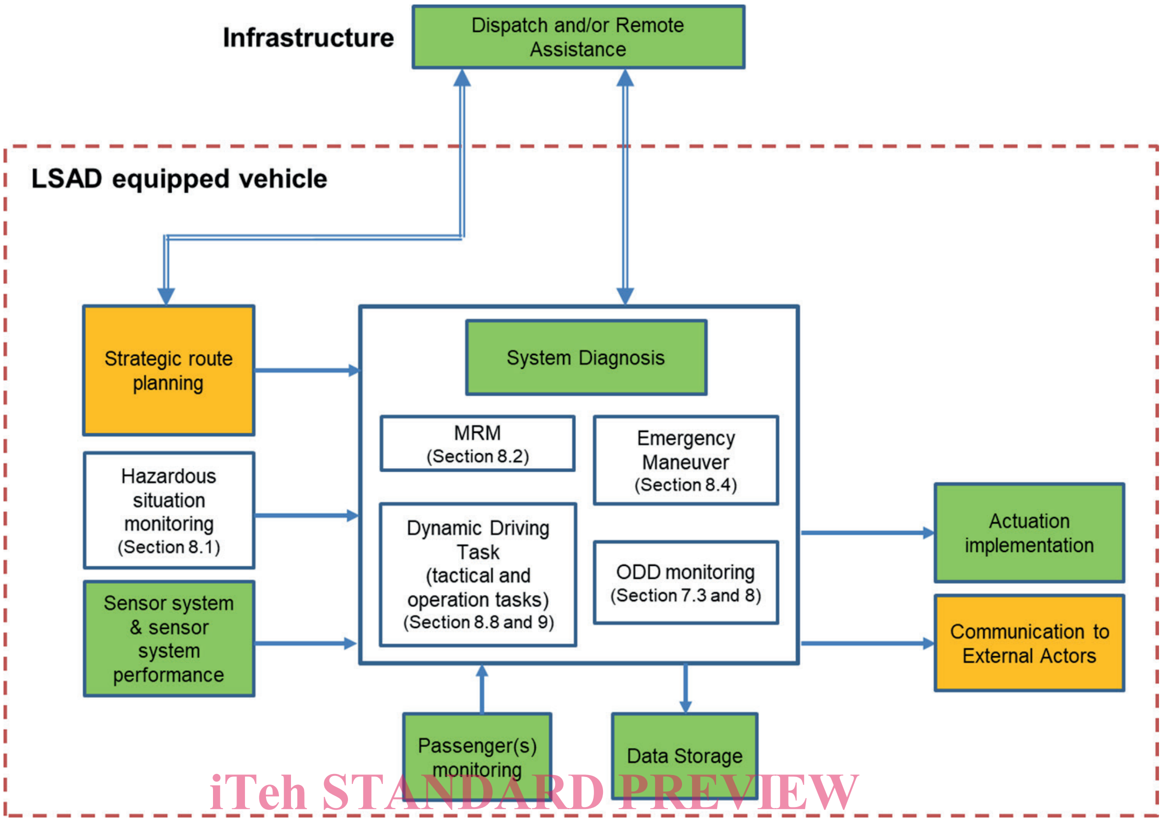


Figure 1 — Example System Architecture - LSAD in a MaaS system

6 LSAD System Architecture

Figure 2 represents the system architecture of an individual LSAD system. Figure 2 also highlights the components from the LSAD system architecture that are covered within the scope of this standard.



Key (colour)

Functional Requirements defined in this document

Optional features not defined in this document

Functional Requirements not defined in this document

Figure 2 — System Architecture - LSAD system

7 Basic Requirements

7.1 General

The LSAD system shall perform the dynamic driving task [2]. The implementation of the strategic driving tasks[2] is left to the manufacturers' discretion. However, LSAD system shall operate in predefined routes only. The maximum operational speed of LSAD system engaged vehicle shall be equal to or less than 8.89 m/s or 32 km/h. However, this could reduce significantly based on special conditions (selected as per the discretion of the driverless operation dispatcher[2]) mentioned in this document. These special conditions may include time of day, visibility, day of week, rainfall, snow, fog, ice on roads etc.

LSAD system shall use sensors in order to enable part of the dynamic driving task [2]. This includes detecting objects, vehicles, pedestrians, buildings, pathways etc. Appropriate Hazard Analysis and Risk Assessment shall be performed for the sensor performance and failures, and other safety critical system elements. The LSAD system development shall be developed according to ISO 26262 'Road vehicles — Functional safety' and ISO/PAS 21448 'Road vehicles – Safety of the Intended functionality.

7.2 Minimum operating capabilities

Subject vehicles driven by the LSAD system shall be capable of performing the following functions:

- follow a predefined route to the destination (section 8.3)

- detect a hazardous situation (section 3.1 and 8.1)
- initiate braking and/or steering, to mitigate and/or avoid collision with obstacles (section 9.1, 9.2)
- perform Minimal Risk Manoeuvre (section 8.2)
- inform the dispatcher about the fault state of the LSAD system (e.g. binary flag) (section 8.4)
- provide warnings to road users in case of a hazardous situation

7.3 Operational Design Domains (ODDs)

Every LSAD system shall have its ODD[1] defined by the manufacturer. The operational design domain limits for LSAD system shall specify at least the following attributes:

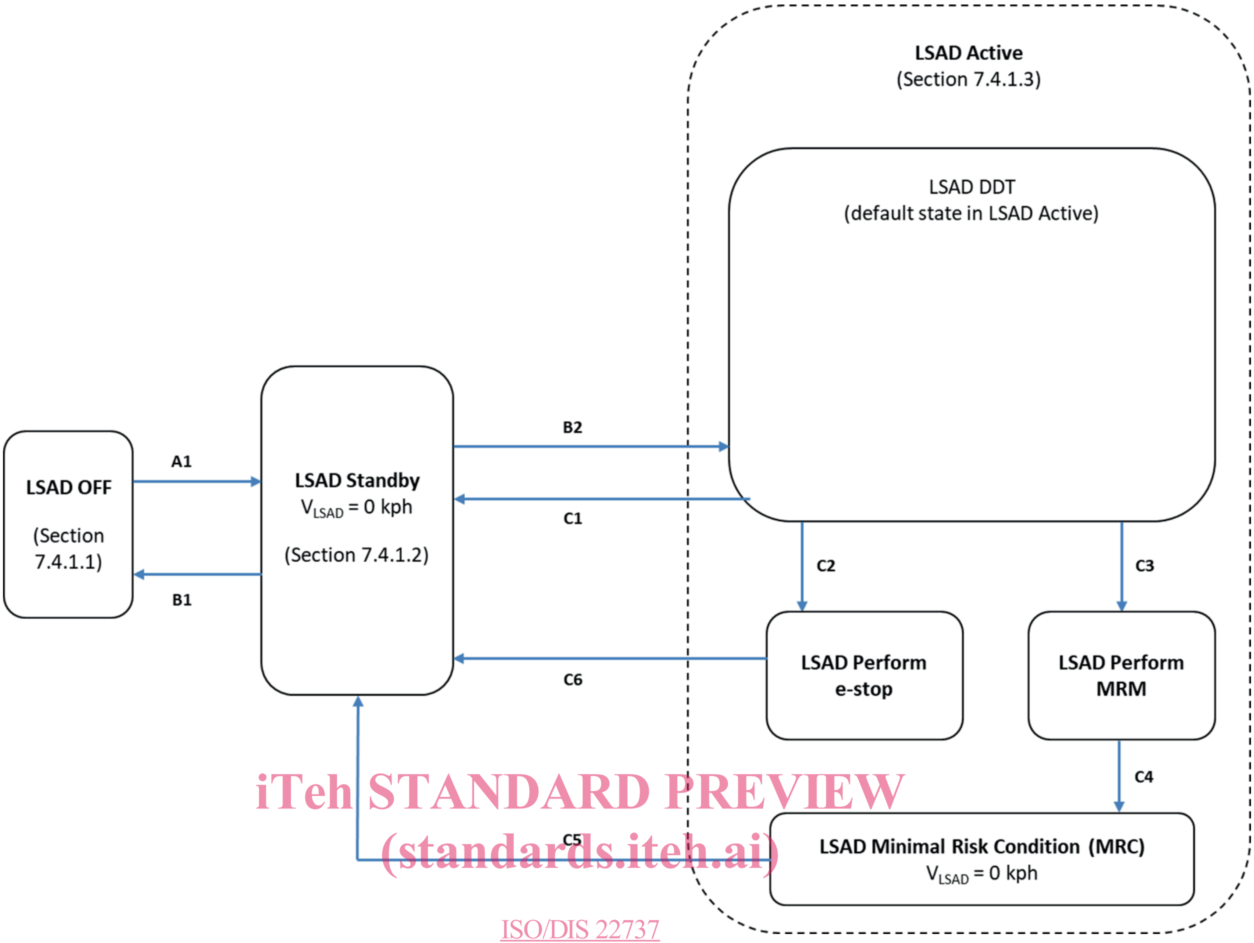
- Low speed – speed of LSAD system shall be equal to or less than 8.89 m/s or 32 km/h.
- Areas of application – e.g. either restricted access or dedicated roadways (public or private), or pedestrian / bicycle pathways, or areas from which all or some specific categories of motor vehicles are restricted. Restricted access roadways may be specified by lane markings or speed restriction or physical demarcation. (See Annex D for examples)
- Predefined routes – Routes defined within the LSAD system before operation of the LSAD system. LSAD system shall only operate on the predefined routes. Predefined routes shall be defined by relevant stakeholders in conjunction with each other (e.g. local authorities, service providers, manufacturers etc.). Any deviation from predefined routes shall be confirmed by remote dispatcher (if applicable).
- Lighting condition in the area of application
- Weather conditions
- Road conditions
- Presence or Absence of Vulnerable Road Users (VRUs)
- Potential presence of static obstacles in the drivable area
- Connectivity requirements

Either the LSAD systems or the dispatcher should select operating values (for vehicle driven by the LSAD system) for the ODD attributes based on current ODD conditions (e.g. foggy weather conditions, night time lighting condition).

NOTE: For example, a dispatcher or LSAD system may decide to restrict the maximum allowable speed on a rainy day to a lower speed as compared to a clear sunny day.

7.4 LSAD State Diagram

The LSAD system shall function according to the State Transition Diagram of Figure 3. Specific implementation, beyond the description in Figure 3 shall be the responsibility of the manufacturer.



Key

A1 Power on and self-test passed

B1 System failure or power-off dispatcher command or power turned off

B2 ODD conditions met and dispatcher engage command and data recording capability

C1 Dispatcher disengage command

C2 Passenger or dispatcher initiates emergency stop

C3 Detection of hazardous situation LSAD system is unable to handle or DDT performance relevant system failure or loss of safety critical V2X communications or imminent violation of ODD or safe to proceed confirmation authorization not received from dispatcher

C4 Vehicle is standstill, i.e. 0 m/s

C5 Confirmation to proceed to stand-by state by dispatcher

C6 Vehicle is standstill, i.e. 0 m/s and confirmation to proceed to stand-by state by dispatcher

Figure 3 — LSAD state transition diagram

7.4.1 LSAD State functional descriptions

7.4.1.1 LSAD Off

LSAD system shall not perform any aspect of the dynamic driving task in the LSAD off state.

7.4.1.2 LSAD Standby

In LSAD Standby state, the LSAD system shall:

- Verify that ODD conditions are satisfied to enable a transition to LSAD Active state
- Perform communications with dispatcher
- Remain standstill

LSAD Standby state may receive an external operating command from the dispatcher selecting the operating values (e.g. nominal or degraded) for LSAD system when in DDT state.

Note that nominal mode suggests the ideal performance of the vehicle driven by the LSAD system. Degraded mode suggests reduced performance on pre-define vehicle parameters due to external or LSAD system internal conditions.

7.4.1.3 LSAD Active

In LSAD Active state, LSAD shall perform the DDT. LSAD system's maximum operating speed will be determined by the dispatcher or by the system itself.

LSAD Active state has four sub-states:

- **LSAD DDT sub-state [1]:** This shall be the default sub-state in the LSAD Active state. Within the LSAD DDT sub-state, based on the discretion of the LSAD system service providers, LSAD system operating parameters may be dynamically varied. LSAD system has two basic functions in LSAD DDT sub-state:
  - Perform DDT, which includes safely following a predefined route while avoiding a collision with obstacles
  - Detect the imminent violation of the ODD conditions
- **LSAD Perform e-stop sub-state**: In case the passenger or the dispatcher requests an e-stop, in this state the LSAD system shall perform emergency deceleration to bring the vehicle driven by the LSAD system to a standstill and provide state information to the dispatcher and convey the emergency situation externally (e.g. via Hazard lights)
- **LSAD Perform Minimal Risk Manoeuvre (MRM) sub-state**: In case any of the triggers for transition C3 is fulfilled, LSAD system shall perform the Minimal Risk Manoeuvre (MRM) (clause 8.2).
- **LSAD Minimal Risk Condition (MRC) sub-state**: In LSAD MRC state, LSAD shall
  - be standstill
  - provide state information to the dispatcher.

In all LSAD Active sub-states, the LSAD system shall continuously perform system performance monitoring.

7.4.2 LSAD State transition description:

7.4.2.1 A1

Transition from LSAD OFF state to LSAD Standby state.

Trigger(s):

- Power on dispatcher command and
- Power on sequence has been completed and the system has no failures (self-test passed).

7.4.2.2 B1

Transition from LSAD Standby state to LSAD OFF state.

Trigger(s):

- Detection of a DDT Performance-relevant system failure or
- Power-off dispatcher command or power has been turned off

7.4.2.3 B2

Transition from LSAD Standby state to LSAD Active state's default state (LSAD DDT),

Trigger(s):

- LSAD system meets its ODD conditions and
- Dispatcher has commanded to transition to LSAD Active state (dispatcher engage command) and
- Data recorder (see clause 10.1) has sufficient capacity to store at least an additional safety critical event

7.4.2.4 C1

Transition from LSAD Active state's default state (LSAD DDT) to LSAD Standby state.

Trigger(s):

- Dispatcher has commanded to disengage LSAD Active state (dispatcher disengage command)

7.4.2.5 C2

Transition from LSAD DDT state (LSAD Active state's default state) to LSAD Perform e-stop state.

Trigger(s):

- Passenger or dispatcher initiates an emergency stop command

7.4.2.6 C3

Transition from LSAD DDT state to LSAD Perform MRM state.

Trigger(s):

i. Detection of a hazardous situation which the LSAD system is unable to resolve or

ii. Detection of DDT performance relevant system failure or

iii. Loss of safety critical V2X communications or

iv. Detection of imminent violation of the ODD conditions by the LSAD system or

v. Safe to Proceed confirmation authorization not received from the dispatcher (see section 7.4.3.1)

7.4.2.7 C4

Transition from LSAD Perform MRM state to LSAD Minimal Risk Condition (MRC) state.

Trigger(s):

- LSAD vehicle comes to a standstill (i.e. 0 m/s)