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

Systèmes de transport intelligents — Systèmes de conduite automatisée à basse vitesse pour des itinéraires prédéfinis (LSAD) — Exigences de performance, exigences du système et procédures de test de performance

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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 of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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 commercial areas, business or university campus areas and other low-speed environments.

A vehicle that is driven by the LSAD system (which can include interaction with infrastructure) can potentially have many benefits, like providing safe, convenient and affordable mobility and reducing urban congestion. It can also provide increased mobility for people who are not 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 their safe deployment.

The LSAD system requirements and procedures specified herein are intended to assist manufacturers of the LSAD systems in incorporating minimum safety requirements into their designs and to 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 the operational design domain,

— system requirements,

— minimum performance requirements, and

— performance test procedures

for the safe operation of low-speed automated driving (LSAD) systems for operation on predefined routes. LSAD systems are designed to operate at Level 4 automation (see ISO/SAE PAS 22736), within specific operational design domains (ODD).

This document applies to automated driving system-dedicated vehicles (ADS-DVs) and can also be utilized by dual-mode vehicles (see ISO/SAE PAS 22736). This document does not specify sensor technology present in vehicles driven by 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 vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 4: Requirements for bicyclist targets*

ISO 26262 (all parts), *Road vehicles — Functional safety*

ISO 21448:—[1], *Road vehicles — Safety of the intended functionality*

ISO/SAE PAS 22736:—[2], *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 terms and definitions given in ISO/SAE PAS 22736 and the following apply.

1) Under preparation. Stage at the time of publication: ISO/DIS 21448:2021.

2) Under preparation. Stage at the time of publication: ISO/SAE PRF PAS 22736:2021.

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
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, can result in an imminent collision

3.2
predefined route
trajectory defined before start of a trip to be traversed by the vehicle driven by the LSAD system, from a point of origin to one (or many) destination(s)

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

3.3
minimal risk manoeuvre
MRM
tactical or operational manoeuvre triggered and executed by the LSAD system to achieve minimal risk condition

3.4
trip segment
travel from point of origin to destination or from one destination to another destination in a trip

Note 1 to entry: A trip may comprise multiple trip segments.

3.5
drivable area
manoeuvrable area around the *predefined route* (3.2) where the LSAD system is capable of operating

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

3.6
pedal cyclist
human-vehicle combination consisting of a human riding on top of a wheel frame with a steering mechanism, brakes, two pedals for propulsion (optionally with motor assist pedalling) that does not require a licence for use on public roads

3.7
day-time
condition where the ambient illuminance is greater than 2 000 lx

3.8
night-time
condition where the ambient illuminance is less than 1 lx

3.9
standstill
vehicle state when vehicle speed is at 0 m/s

3.10
low-speed automated driving systems
LSAD
automated driving system that has a maximum speed of 8,89 m/s

3.11
low ambient lighting condition
ambient light between *day-time* (3.7) and *night-time* (3.8)

4 Symbols and abbreviated terms

θ	angle between pedestrian trajectory and vehicle trajectory while in straight section of the evaluation path
ADS-DV	automated driving system-dedicated vehicle
DDT	dynamic driving task
e-stop	emergency stop
LSAD	low-speed automated driving
MaaS	mobility as a service
MRC	minimal risk condition
ODD	operational design domain
R	radius of curvature of trajectory in drivable area
RTI	request to intervene
S_{lat1}	width of drivable area
S_{lat2}	lateral distance between SV and pedestrian starting point
S_{lat3}	lateral distance between SV and target vehicles (TV_1 and TV_2)
S_{lat4}	width of reduced drivable area
S_{long}	longitudinal distance of drivable area
S_{long2}	longitudinal distance of evaluation path from situation C
S_{long3}	longitudinal distance between point 1 and point 4
S_{long4}	longitudinal distance between point 1 and point 4 where MRM is triggered
S_{long5}	longitudinal distance between point 4 and end of evaluation path
SV	subject vehicle
$T_{ped\_to\_Pt2}$	time taken by pedestrian to reach point 2
$T_{pc\_to\_Pt2}$	time taken by pedal cyclist to reach point 2
$TV_{(1, 2)}$	target vehicle (1, 2)
V2X	vehicle to - X
V_{LSAD}	velocity for the LSAD system
V_{LSAD_max}	maximum velocity for the LSAD system
V_{pc}	velocity of pedal cyclist

V_{pc_max}	maximum velocity of pedal cyclist
V_{ped}	velocity of pedestrian
V_{ped_max}	maximum velocity of pedestrian
V_{sv_max}	maximum velocity of subject vehicle
VRU	vulnerable road users
DDT	dynamic driving task

5 Example use case for an LSAD system deployment

Vehicles driven by LSAD systems may be used as a part of a larger (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 a trip destination from the dispatcher via wireless communication, 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. The term "dispatcher" in this document refers to the driverless operation dispatcher (see ISO/SAE PAS 22736).

As there may be more than one predefined route 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.

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

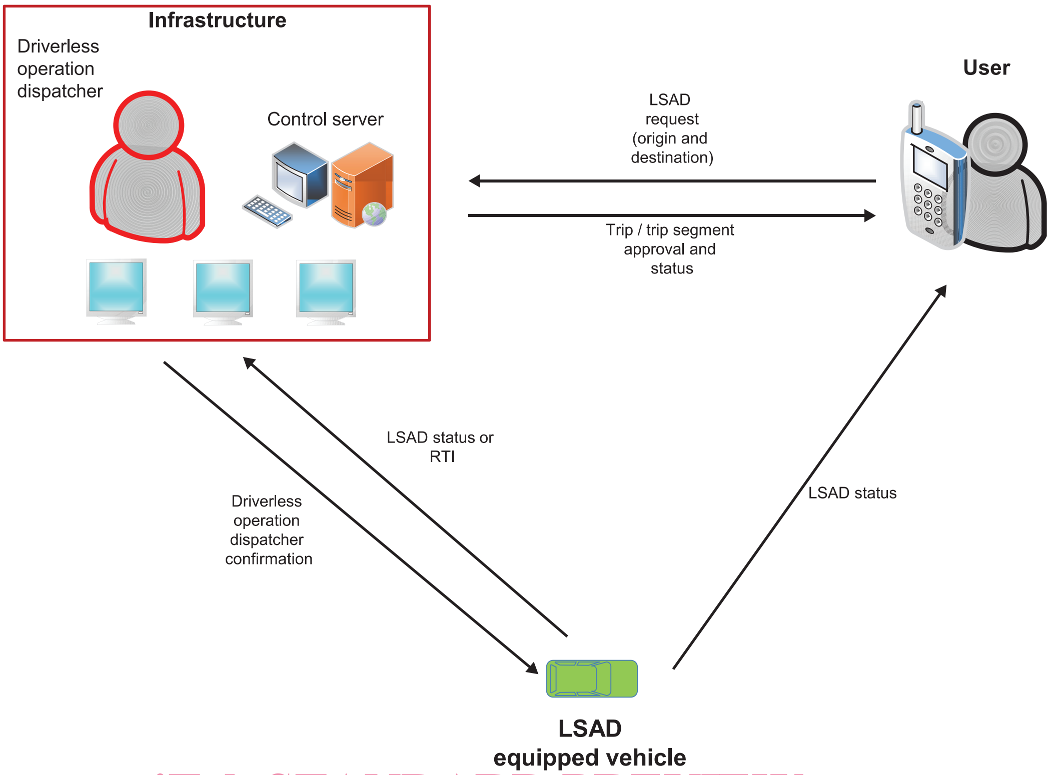
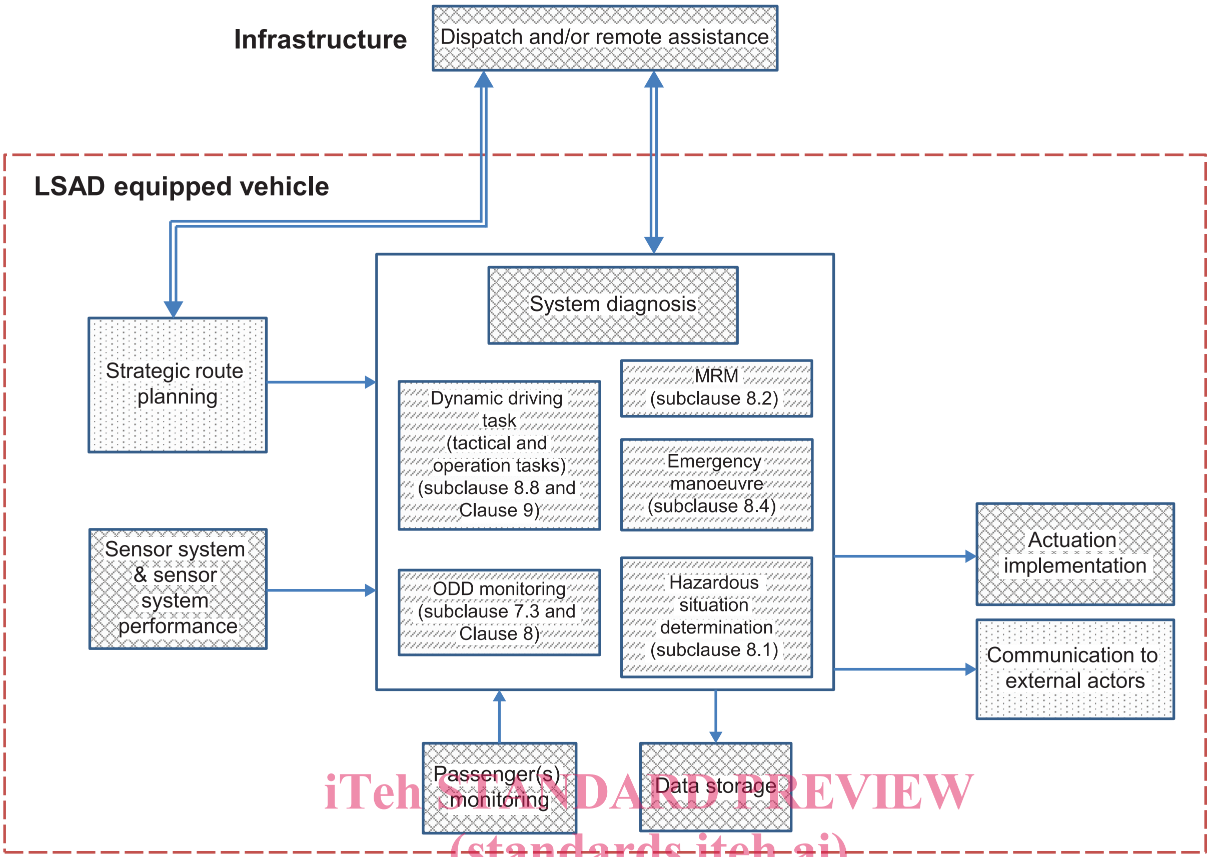


Figure 1 — Example system architecture — LSAD in a MaaS system

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 document.



Key

functional requirements defined in this document

optional features not defined in this document

functional requirements not defined in this document

Figure 2 — Example system architecture — Individual LSAD system

7 Basic requirements

7.1 General

The LSAD system shall perform the dynamic driving task (see ISO/SAE PAS 22736). The implementation of the strategic driving tasks (see ISO/SAE PAS 22736) is left to the manufacturer's discretion. However, the LSAD system shall operate in predefined routes only. The maximum operational speed of an LSAD system engaged vehicle shall be equal to or less than 8,89 m/s or 32 km/h. However, this may be significantly reduced based on special conditions (selected as per the discretion of the driverless operation dispatcher [ISO/SAE PAS 22736]) mentioned in this document, for example time of day, visibility, day of week, rainfall, snow, fog, ice on roads etc.).

The LSAD system shall use sensors in order to enable part of the dynamic driving task. 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 the ISO 26262 series and ISO 21448.

7.2 Minimum operating capabilities

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

a) follow a predefined route to the destination (8.3),

b) detect a hazardous situation (8.1),

c) initiate braking and/or steering, to mitigate and/or avoid collision with obstacles (9.1, 9.2),

d) perform minimal risk manoeuvre (8.2),

e) inform the dispatcher about the fault state of the LSAD system (e.g. binary flag) (8.4),

f) provide warnings to road users in case of a hazardous situation.

7.3 Operational design domains (ODDs)

Every LSAD system shall have its ODD defined by the manufacturer. The ODD limitations for an LSAD system shall specify at least the following attributes:

a) Low speed: the speed of an LSAD system shall be equal to or less than 8,89 m/s or 32 km/h.

b) Areas of application: for example, 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 can be specified by lane markings or speed restriction or physical demarcation. (See Annex D for examples).

c) Predefined routes: routes defined within the LSAD system before operation of the LSAD system. An 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 the dispatcher to not result in a hazardous situation.

d) Lighting conditions in the area of application.

e) Weather conditions.

f) Road conditions.

g) Presence or absence of VRUs.

h) Potential presence of static obstacles in the drivable area.

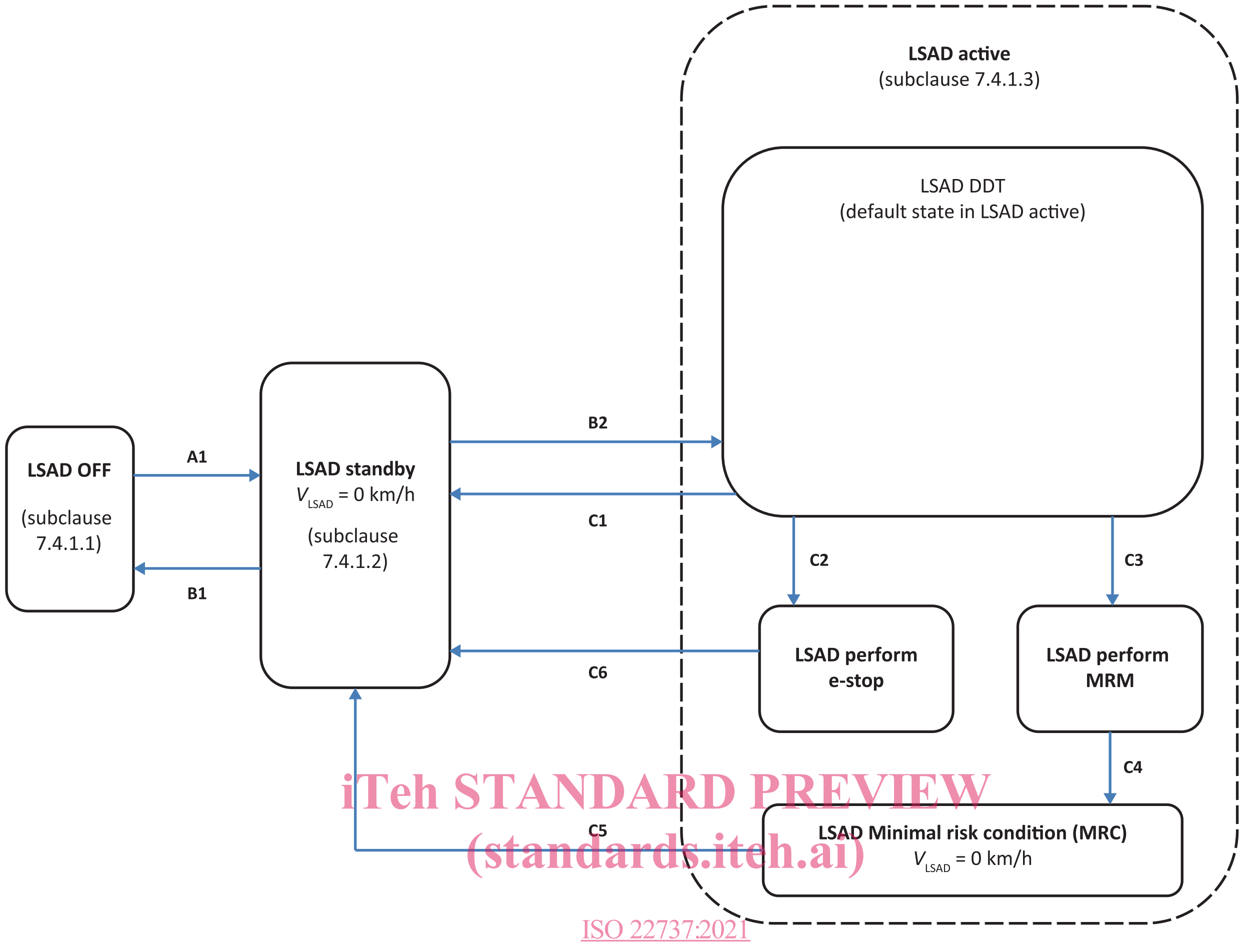
i) Connectivity requirements.

Either the LSAD systems or the dispatcher should select operating values (for a vehicle driven by the LSAD system) within the boundaries of the predefined values of the ODD attributes for the specified application based on current ODD conditions (e.g. foggy weather conditions, night-time lighting conditions).

EXAMPLE A dispatcher or an LSAD system can 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 transition 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 are met and dispatcher has sent engage ADS command and ADS equipped vehicle has data recording capability and has engaged it

C1 dispatcher disengage command

C2 passenger or dispatcher initiates emergency stop

C3 detection of hazardous situation which the 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 in standstill, i.e. 0 m/s

C5 confirmation to proceed to standby state by dispatcher

C6 vehicle is in standstill, i.e. 0 m/s, and confirmation to proceed to standby state by dispatcher

Figure 3 — LSAD state transition diagram

7.4.1 LSAD state functional descriptions

7.4.1.1 LSAD off

The 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:

a) Verify that ODD conditions are satisfied to enable a transition to LSAD active state.

b) Perform communications with dispatcher.

c) Remain in standstill.

LSAD standby state may receive an external operating command from the dispatcher selecting the operating values (e.g. nominal or degraded) for the 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-defined vehicle parameters due to external or the LSAD system's internal conditions.

7.4.1.3 LSAD active

In LSAD active state, the LSAD shall perform the DDT. The LSAD system's maximum operating speed is determined by the dispatcher or by the system itself.

LSAD active state has four sub-states:

1) **LSAD DDT sub-state:** 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. An 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, and

   — detect the imminent violation of the ODD conditions.

2) **LSAD perform e-stop sub-state**: If 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, auditory alert).

3) **LSAD perform MRM sub-state**: If any of the triggers for transition C3 are fulfilled, the LSAD system shall perform the minimal risk manoeuvre (MRM) (subclause 8.2).

4) **LSAD MRC sub-state**: In LSAD MRC state, LSAD shall:

   — be in 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):

a) Power on dispatcher command, and

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