AC 139-7-7 (Rev 1)
31 July 2025

Civil Aviation Authority of Singapore

Advisory Circular

GUIDANCE ON THE USE OF AUTONOMOUS VEHICLES AT THE AIRSIDE

GENERAL

Advisory Circulars (ACs) are issued by the Director-General of Civil Aviation (DGCA) from time to time to provide practical guidance or certainty in respect of the statutory requirements for aviation safety. ACs contain information about standards, practices and procedures acceptable to CAAS. An AC may be used, in accordance with section 11 of the Air Navigation Act 1966 (ANA), to demonstrate compliance with a statutory requirement. The revision number of the AC is indicated in parenthesis in the suffix of the AC number.

PURPOSE

This AC provides the guidance and information for the experimentation and use of autonomous vehicle (AV) technology at the airside.

APPLICABILITY

This AC applies to an operator who intends to or holds an aerodrome certificate or heliport certificate (also known as an “aerodrome operator”).

RELATED REGULATIONS

This AC relates specifically to Regulation 11, Regulation 34 and Regulation 35 of the Air Navigation (139 – Aerodromes) Regulations (“ANR-139”).

RELATED ADVISORY CIRCULARS

- AC 139-2-1 Guidance on aerodrome manual or heliport manual
- AC 139-3-2 Guidance on reporting and investigation requirements
- AC 139-5-1 Safety performance indicators and target monitoring
- AC 139-6-1 Guidance on training and competency requirements of operational and maintenance personnel
- AC 139-7-2 Guidance on movement in airside
- AC 139-7-3 Guidance on emergency planning

CANCELLATION

This AC supersedes AC 139-7-7(0) dated 10 May 2023. This revision provides more guidance on the use of autonomous vehicles at the airside, including AV testing frameworks that an aerodrome operator may use to validate AV performance at the airside, depending on whether the AV had been deployed at other airports or public roads.

EFFECTIVE DATE

This AC is effective from 31 July 2025.

OTHER REFERENCES

- Technical Reference 68 – Autonomous Vehicles issued by the Singapore Standards Council

1 USE OF AUTONOMOUS VEHICLES AT THE AIRSIDE

1.1 Autonomous vehicle (AV) technologies are evolving rapidly and are expected to be increasingly adopted at the airside due to potential benefits such as increased efficiency, security and safety.

1.2 The use of AV at the airside may impact the existing measures for safe movement of persons and vehicles, as well as aerodrome operations or maintenance procedures. As with any new equipment, vehicle or process at the aerodrome, the aerodrome operator must ensure that AV operations are implemented in accordance with the applicable regulations in the ANR-139. Besides the guidance in the related ACs, the aerodrome operator should also follow the guidance and information in this AC for the experimentation and use of AV technology at the airside to demonstrate compliance with Regulation 34 of ANR-139.

1.3 In this AC,

"AV developer" means the person responsible for creating an AV or its components. In the case of developing a whole AV, this may be done either by assembling the whole vehicle or adapting a vehicle platform manufactured by others.

"AV system" means the vehicle and various associated hardware and software systems (such as those for obstacle detection, navigation, communication, or surveillance), and the procedures necessary to support the safe operation of the AV.

"AV operations" include AV trials and actual deployment.

"AV operator" means a person who, at the relevant time, is managing the operation of one or several (a fleet of) autonomous vehicles.

"Onboard safety driver" means the in-vehicle fallback-ready user with a required driving licence of a vehicle who is seated in the driver's seat or otherwise inside the vehicle actively engaged in monitoring safety.

"Remote operator" means an individual, or more than one individual, who provides remote assistance to the AV operator during a driverless operation.

2 MEASURES FOR THE SAFE MOVEMENT OF AUTONOMOUS VEHICLES AT THE AIRSIDE

2.1 The measures mentioned in Regulation 34 of the ANR-139 include:

(a) processes for the evaluation and approval of AV operations in the following areas:

(i) scope of work and proposed plans (e.g. objectives of trial/ deployment, proposed area/travel routes of the AV, number and type of AVs, timeline and milestones, details on charging the AV);

(ii) the physical aspects of vehicle operations, including the safety assessment of the AV system;

(iii) the training and competency requirements for the personnel involved in AV operations;

(iv) the maintenance of the AV system; and

(v) the testing and validation of AV performance;

(b) controls relating to autonomous driving behaviour;

(c) coordination with the airside community on AV operations;

(d) suitable and adequate airport infrastructure;

(e) management of cybersecurity risks;

(f) reporting of AV-related incidents and the investigation of such incidents;

(g) establishing a contingency plan;

(h) safety performance monitoring of AV systems and operations;

(i) monitoring AV operations at the airside in real-time and to enable the prompt resolution of operational conflicts, which should include the establishment of a central control centre:

(i) that consolidates the control and monitoring station of each AV operator;

(ii) that enhances coordination, communication and decision-making across various AV operations and AV operators at a single physical location;

(iii) that is capable of sending out an immediate alert to inform remote operators and monitoring personnel of any malfunctions, or operational irregularities (e.g., route deviations); and

(iv) management of the alertness of the onboard safety drivers and remote operators, such as use of technologies to detect inattention or preventive measures such as regular alertness checks or structured work-rest schedules.

2.2 To avoid doubt, the information to be covered in an aerodrome manual under Regulation 11 includes information relating to AV operations at the airside. The information should include but not be limited to the following sections:

(a) evaluation and approval of AV operations;

(b) training and competency requirements for AV operators including onboard safety drivers and remote operators;

(c) AV maintenance programme;

(d) contingency plan; and

(e) reporting and investigation.

2.3 For any AV that exceeds the thresholds for infractions (i.e. safety violation limits as determined by the aerodrome operator), the aerodrome operator should establish a process to withdraw or suspend its approval for the specific AV or group of AVs.

2.4 Different areas/locations of the airside may present varying levels of risks; the aerodrome operator should establish operational restrictions based on the location(s) of AV operations and its related risk level. The AV trial or deployment should only be limited to approved areas/locations granted by the aerodrome operator.

2.5 The aerodrome operator should determine considerations (e.g. changes to airside driving rules, airside layout, operating locations, etc.) that might impact the earlier safety risk assessment to ensure that the safety assessment continues to be valid.

2.6 The aerodrome operator should ensure that the mitigating measures as identified in the safety risk assessment are carried out.

2.7 The aerodrome operator should regularly review its airside rules and regulations and update them as necessary to facilitate safe AV operations at the airside.

3 PHYSICAL ASPECTS OF VEHICLE OPERATIONS

3.1 For the purposes of evaluating the physical aspects of the vehicle operations, the physical aspects of the AV to be considered for safe airside operations should include the following:

(a) battery bank of an electric AV that is certified to comply with international automotive standards such as UNECE R100 and R136;

(b) ability to display standardised and clear indications to onboard safety driver, remote operator[1] and airside staff on whether the AV is in autonomous, manual[2] or failure mode;

(c) ability to send prominent aural and visual alerts to onboard safety driver or remote operator when faults occur or autonomous operation is not possible, including the detection of a technology failure[3];

(d) ability to allow manual override by the onboard safety driver or deactivation of its autonomous mode by the remote operator at any time, particularly essential in situations where the AV encounters hazardous situations beyond its operational capabilities and requires human intervention to ensure safety and an appropriate response;

(e) equipped with systems that provide accurate and effective geo-location capabilities along with comprehensive situational awareness, including obstacle detection, that allow effective monitoring and management of AV operations from a remote location;

(f) equipped with an inward facing camera to continuously record the actions of the onboard safety driver;

(g) equipped with a secured, tamper-proof system to record at a minimum, the set of operational data fields specified in Appendix A;

(h) clearly and consistently marked and lit to be easily identifiable by airside staff; and

(i) ability to automatically verify that its navigation and obstacle detection equipment are functioning properly.

3.2 The data recorder mentioned in subparagraph (g) of paragraph 3.1 should always be in operation when the AV is in use to capture:

(a) information in real-time; and

(b) data with sufficient accuracy and resolution to support effective analysis of the AV's safety performance and other relevant safety assessments.

3.3 The data recorded should be stored electronically for at least 30 days after recording.

3.4 For the purpose of evaluating the AV operation, the aerodrome operator should review if the AV system meets the following technical specifications and certifications (Refer to Appendix B for the list of industry standards and certification for AVs):

(a) vehicle safety inspection certificate of the AV from an accredited assessment body;

[1] The role of the remote operator is to issue commands to the AV, such as directing it to proceed or stop its mission. The AV should only execute the command if it is assessed the command to be safe.
[2] Manual mode refers to the AV being physically driven by a driver, like any conventional vehicle.
[3] Technology failure is defined by any failure which requires the safety operator to take control of the vehicle and could include hardware failure (loose connections, etc), software failure, etc.

(b) description of the industry standards for the AV technologies, systems and/or solutions used, basic design and components of the AV, basic design and function of the software in the AV, and modifications made to the AV;

(c) tests carried out either by the manufacturer or an accredited assessment body to determine that the safety and security features of the AV are safe for use at the airside, including the charging of the AV;

(d) systems used to guide and control the AV would not interfere with radio communications and air navigation systems; and

(e) communication protocols used by the AV and its systems (as coordinated with the air navigation service provider) would not interfere with radio communications and air navigation systems.

4 TRAINING AND COMPETENCY REQUIREMENTS OF PERSONNEL INVOLVED IN AV OPERATIONS

4.1 The aerodrome operator should have processes to ensure that:

(a) the personnel involved in AV operations (i.e. onboard safety drivers and remote operators) are trained and competent to monitor, control, and intervene in the operations of the specific AV model, before the personnel is assigned to operate that AV. Such personnel should:

(i) hold a valid Airfield Driving Permit issued by the aerodrome operator;

(ii) have completed a training programme, including those provided by the AV developers. This programme should minimally consist of initial training, practical skill tests, regular refresher training, and training relating to new updates of the operation of AV and its systems; and

(iii) have been assessed to be competent to operate the AV by the OEM/AV developer.

(b) the training materials for the personnel involved in AV operations should cover, but not be limited to, the following:

(i) details of the characteristics and technical performance of the related AVs, as well as the conditions imposed on the AV trials or deployment;

(ii) basic skills relating to AV operations such as:

(1) operating conditions under which the AV system of the AV is specifically designed to function and the corresponding limitations;

(2) basic vehicle operation;

(3) night operation of the AV;

(4) (4) response to vehicle faults;

(5) (5) emergency response, such as achieving a minimal risk condition;

(6) response to adverse weather conditions;

(7) handling procedures after vehicle collision;

(8) transition between manual control and autonomous control;

(9) minimise risk conditions and manoeuvres (e.g. remove the AV from active lanes before coming to stop); and

(10) hazard perception (e.g. aware of the change of road conditions).

(iii) relevant skills for daily inspection before the operation of AV, such as:

(1) checking of vehicle components and AV system functionalities before operations; and

(2) verification of the proper operation of the data recording system.

(iv) measures to prevent fatigue/inattention/carelessness to onboard safety drivers and remote operators, such as:

(1) anti-fatigue driving awareness;

(2) avoiding distracted and careless techniques while driving; and

(3) drug and alcohol impairment awareness, including regulated controlled substances.

(b) training for remote operator in addition to those in sub-paragraph(b) of this paragraph, should also include the following:

(i) actions required after receiving the alert signal from the AV system;

(ii) actions required to maintain situational awareness during the remote monitoring of the AV performance during the trial or deployment; and

(iii) fail-safe/mitigation measures in place to prevent a hazard, incident or undesired event due to any connectivity and/or control issues caused by network latency or communication breakdown during the trial or deployment of AV, and how to safely use any hands-free short-range communications, where required.

(d) onboard safety drivers should also complete driving training described in subparagraph (c).

4.2 The practical skills test mentioned in paragraph 4.1(a)(ii) should test the competency of the onboard safety drivers or remote operators in the following areas:

(a) hazard perception and response;

(b) safe and effective handovers and interventions;

(c) responses to unexpected vehicle performance;

(d) responses to emergency and incident; and

(e) ability to maintain concentration and situation awareness.

4.3 The practical skills test should be conducted:

(a) in a controlled environment, with conditions that closely resembles actual AV operations and scenarios; and

(b) if the onboard safety driver or remote operator has not operated the AV for a prolonged period of time.

4.4 The frequency of conducting the practical skills test should consider the following:

(a) changes in the nature and scale to AV operations e.g. changes to the safety-critical functions in the AV system, Operational Design Domain (ODD), number of AVs; and

(b) the scenarios for the AV operations, e.g. changes in operating environment, routing.

4.5 The following results of the practical skills test should be documented:

(a) details of tests assessing the ability to manage the areas specified in paragraph 4.3; and

(b) any faults being identified during the skills test, as well as the reasons for failing the test.

5 MAINTENANCE OF AV

5.1 The aerodrome operator should have a process to evaluate that the AV systems are maintained in a good condition. Some of the considerations in the evaluation include the review of the following:

(a) conduct of AV maintenance programme in accordance with OEM/AV developer's requirements, e.g. life limited part monitoring and replacement, scope and frequency of periodic maintenance activities;

(b) maintenance activities such as:

(i) verify that the installation of LiDARs, cameras, other sensors and attached equipment /device are secure;

(ii) verify that the signal and power connections of hardware systems, such as controllers and sensors, are functioning properly;

(iii) calibrate the sensor position and attitude parameters of the perception system;

(iv) verify that the drive-by-wire chassis is functioning properly;

(v) verify that the vehicle takeover function is operating properly; and

(vi) verify that the function of the minimal risk manoeuvre switching is functioning properly.

(c) conduct of daily pre-serviceability checks on operational AVs to ensure the sensors and vehicle are fit for use, such as:

(i) verify that the data recorder, LiDAR, cameras, integrated navigation system, and other sensors are functioning properly;

(ii) verify that the AV control system is functioning properly;

(iii) check whether the autonomous driving terminal is displaying any failure warning;

(iv) check whether the vehicle instrument panel displays any warning;

(v) verify that the lamps and direction indicators are functioning properly;

(vi) verify that the braking system is functioning properly;

(vii) verify that the steering system is functioning properly;

(viii) verify that the tire pressure and condition are normal;

(ix) verify that the horn (if any) is functioning properly;

(x) check for any leaks from the AV;

(xi) verify that the rear-view mirror/ camera position is appropriate;

(xii) verify that the vehicle's headlamps, rear lamps, and windows are clean; and

(xiii) verify that fuel or battery power level is sufficient for operations.

6 AUTONOMOUS DRIVING BEHAVIOUR

6.1 Aerodrome operator should verify that the AV has demonstrated suitable autonomous driving behaviour, as detailed in Appendix C, in various environmental conditions and traffic scenarios before approving the AV to be deployed into the airside, particularly the following:

(a) compliance with relevant airside traffic rules and regulations;

(b) taking prompt and appropriate action so as not to impede the movement of emergency vehicles, such as pulling over to the side of the road or adjusting its speed and position to allow the emergency vehicles to pass through traffic; and

(c) identify network abnormalities, technology failures and cyberattacks and come to a safe stop until the onboard safety driver or the remote operator has securely taken over the AV.

7 TEST AND VALIDATION OF AV PERFORMANCE

7.1 In the evaluation of AV operations, the aerodrome operator should have processes that test and validate the AV performance. New AV models should undergo AV trials

to ensure the reliable and safe function of the AV. Appendix D - Test and validation of AV performance details the two main frameworks and phases for the AV trials.

7.2 The testing scenarios during the AV trials should consider the following:

(a) validate compliance with the requirements stated in Physical Aspects of the Vehicle (refer to paragraph 3);
(b) validate compliance with the requirements stated in Autonomous Driving Behaviours (refer to paragraph 6 and Appendix C); and
(c) validate compliance with specific procedures that the AV needs to carry out as part of its tasks (e.g. docking to joint cargo pallet loader (JCPL) or pallet dollies).

7.3 The aerodrome operator should establish the detailed test items in accordance with Appendix D to validate AV performance on new routes or in a new environment.

7.4 The aerodrome operator's review of the proposed areas and travel routes for AV trial or deployment should consider the following:

(a) vehicular traffic volume;

(b) complexity of the aerodrome operations;

(c) weather conditions (e.g. rain and visibility);

(d) size of AV;

(e) type/complexity of AV operations;

(f) AV trial test parameters;

(g) sufficient power and charging points for the AVs;

(h) adequate wireless data network; and

(i) adequate infrastructure to enable AVs to access the identified areas or facilities.

8 COORDINATION WITH RELEVANT PARTIES

8.1 The aerodrome operator should inform the airside community and relevant stakeholders on trials and deployment of AVs at the airport for the community's overall awareness. Such information include:

(a) proposed trial and deployment information, including the capabilities and roles of the AVs, time and location, types of AVs in operation (description and pictorial/photograph);

(b) planned routes of AV operations;

(c) concept of operations of AV operations;

(d) distinctive characteristics of AV behaviour (if any);

(e) new airside rules related to AVs (if any);

(f) best practices when working together with AVs;

(g) highlight areas to exercise caution when driving or working near AVs;

(h) traffic arrangement for AVs (e.g. new traffic lights, areas reserved for AVs);

(i) contact information of the AV operator or aerodrome operator for enquiries and feedback, or to report of any accident or malfunction of AV; and

(j) actions to be taken by the AV operator or aerodrome operator in the event of an accident or incident involving an AV.

8.2 The aerodrome operator should also work with the AV operator(s) to establish regular engagements with the airside community and other parties to seek their suggestions and concerns on AV operations.

9 INFRASTRUCTURE REQUIREMENTS

9.1 Airport infrastructure such as wireless data transceiver stations should be installed along AV routes to ensure consistent, reliable, high speed, low latency wireless data network for AVs to communicate with its control centre and for the remote operator to monitor the status of the AVs in real time.

9.2 It is important that the wireless data network does not interfere with communication channels used by air navigation systems.

9.3 The areas reserved for AVs, e.g. designated parking spaces, handover and takeover zones, should be clearly marked in a distinct and conspicuous manner.

9.4 To ensure that the AV is able to safely navigate a road diversion, blind spots or busy interactions, the implementation of traffic measures such as traffic marshallers, traffic lights, or sensors along the AV routes, may be considered.

9.5 The implementation of Vehicle-to-Everything (V2X) communication systems, integrating traffic lights with AVs should be considered, to provide real-time traffic signal phase and timing information and enable AVs to optimise their actions safely and efficiently.

10 CYBERSECURITY

10.1 The aerodrome operator should meet the following industry and international cybersecurity standards for AVs that are operating at the airside. These include the following:

(a) ISO/SAE 21434;

(b) TR68: Part 3; and

(c) ISO 27001

11 REPORTING AND INVESTIGATION

11.1 An AV operation is considered as a vehicle operation at the airside. The reporting requirements on vehicle operations in the ANR-139 also applies to an AV operation. Refer to AC 139-3-2: Guidance on Reporting and Investigation Requirements for guidance.

11.2 Examples of such incidents involving an AV include:

(a) collision between the AV and people, other vehicles, airside infrastructure, ground handling equipment, or any other objects; and

(b) deviation from the AV's planned route.

12 CONTINGENCY PLAN

12.1 The contingency plan should be submitted by the AV operator for the aerodrome operator's review before the commencement of its AV trials or deployment.

12.2 The aerodrome operator should ensure there are contingency plans by different AV operators and are integrated with the aerodrome operator's emergency plan established under Regulation 35 of the ANR-139.

12.3 The AV operator's contingency plans should minimally cover the following emergency situations:

(a) malfunction and technical failures of AV and AV equipment e.g. vehicle, systems (hardware and software, sensors, navigational errors, communication failures, command and control issues);

(b) cybersecurity attacks on AV systems including unauthorised access and malware attacks;

(c) AV fires;

(d) AV accidents (Collisions resulting in fatalities/injuries to persons and damage to infrastructure and facilities);

(e) absence of onboard safety driver and/or remote operator;

(f) failures of external systems, e.g. communication, infrastructure, and the control centre; and

(g) weather-related emergencies (e.g. heavy rain) that may affect safe AV's operations.

12.4 The contingency plans should also properly address the emergency situations by including the following:

(a) procedures to respond to AV malfunction, technical failures, system errors, or exhibiting unexpected behaviours;

(b) procedures for establishing the necessary communications with emergency services and relevant stakeholders;

(c) mechanisms to activate the remote or physical taking over of AV to intervene and override the autonomous function of the AV;

(d) protocols to detect and respond to cybersecurity attacks including unauthorised access, malware attacks on AV systems;

(e) procedures for collecting the relevant data and reporting the details of the emergency situations to CAAS and relevant authorities; and

(f) training of personnel involved in AV operations to familiarise them with the contingency plans and readiness to effectively respond to these situations.

12.5 If the aerodrome operator's preliminary findings indicate that the autonomous driving function of the AV is directly responsible for the accident or incident, all trials or AV operations with the same model should stop as soon as possible.

12.6 For any AV trials or operation that were suspended due to an incident or accident, the aerodrome operator should only restart the AV trial or operation when:

(a) all the safety issues have been resolved to the satisfaction of the aerodrome operator;

(b) it is determined that the accident or incident is not contributed by the AV; or

(c) it is determined that the cause of the accident or incident is not systematic across the fleet.

12.7 The aerodrome operator should ensure alignment of the AV operator's contingency plans with the details in AC 139-7-3: Guidance on the emergency planning.

13 SAFETY PERFORMANCE MONITORING

13.1 To facilitate the safety performance monitoring, the aerodrome operator should ensure that AV operators establish the necessary means to record safety performance data of AV systems and operations. The safety data to be collected, processed and analysed is as stated in Appendix A.

13.2 The aerodrome operator should establish a standard set of safety data that AV operators should submit to the aerodrome operator monthly.

13.3 The aerodrome operator should process and analyse the data to identify potential risks and increasing safety trends (accidents/incidents) and detect any precursor events. For any safety issues detected, the aerodrome operator will need to identify and implement the necessary mitigating measures to address them.

13.4 To track and monitor the safety performance of every AV, the aerodrome operator should establish a set of leading and lagging safety performance indicators, alerts and targets relating to AV operations for CAAS' approval. Refer to AC139-5-1: Safety Performance Indicators and Target Monitoring for guidance.

APPENDIX A – DATA RECORDING

1. The data recorder should capture minimally the following key information:

(a) Date and time;

(b) Vehicle location (in latitude and longitude);

(c) Speed of the vehicle;

(d) Status of the vehicle, including whether the vehicle is operating in manual mode, autonomous mode, teleoperation mode, or a mixture of modes;

(e) Occurrences where the AV driver (may be onboard or remote) overrides the autonomous mode, including the types of override;

(f) Steering, braking, acceleration, force of impact etc. from various sensors on the AV;

(g) Camera or video footage captured by –

(i) an internal facing camera, where applicable (capturing the inputs to the AV, controls, and partial part of front windscreen); and

(ii) an external front and rear facing camera.

(h) Weather condition (such as precipitation, etc.);

(i) Operation commands of vehicle lamps and indicators;

(j) Vehicle ignition device operation (if applicable);

(k) Any intervention command by AV operator;

(l) Vehicle remote control command (if applicable);

(m) Network parameters (e.g. data transmission delay and available bandwidth);

(n) Vehicle fault and alarm information (if any); and

(o) In the event of an incident/accident, the AV should capture the data 90 seconds before and 30 seconds after the accident in addition to the information above:

(i) External environment perception data and response status; and

(ii) Video and voice monitoring in the vehicle reflecting the status of the AV operator and human-computer interaction

2. If AV recorder is unable to store additional data, the AV should come to a safe stop.

APPENDIX B – LIST OF INDUSTRY STANDARDS AND CERTIFICATIONS FOR AV

List of certifications and standards that may be applied to Autonomous Vehicle/Systems/Component

Reference	Title
IEC 62443-3-3	Industrial communication networks. Network and system security
ISO 9001:2015	Quality management systems requirements
ISO/IEC/IEEE 12207:2017	Systems and software engineering – Software life cycle processes
ISO 10007:2017	Quality management – Guidelines for configuration management
ISO/IEC 17024:2012(en)	Conformity assessment – General requirements for bodies operation certification of persons
ISO 26262:2018	Road vehicles – Functional safety
ISO/ PAS 21448:2019	Road vehicles – Safety of the intended functionality
SAE J3016_202104	Taxonomy and Definitions for Terms Related to driving automation systems for on-road motor vehicles
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 62278	Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS)
ISO 14001	Environmental management systems
ISO/IEC 17000	Conformity assessment – Vocabulary and general principles
CMMI	Capability Maturity Model Integration
ISO 45001	Occupational health and safety management

APPENDIX C – AUTONOMOUS DRIVING BEHAVIOUR

Speed

1. An AV should adjust its speed to account for crossing pedestrians, emergency vehicles to pass through, road surface conditions, current and upcoming object sensor detection and visibility to other road and airside users.

2. An AV should not collide with any road or airside user.

Safety distance

3. An AV should maintain an appropriate and pre-determined safety distance between the AV and other stationary or mobile objects (e.g. equipment infrastructure, facilities, road, airside user) for every stage of its intended operations and each area it operates in, such as:

   (a) safety distance between the AV and objects at the equipment staging area, equipment parking area, etc.;

   (b) safety distance between AV and a leading vehicle, if the leading vehicle comes to a complete stop, the AV is able to come to a stop safely behind the vehicle;

   (c) when other vehicles are observed to be cutting into its lane, the AV responds proactively to maintain a safe following distance; and

   (d) when at a stop line, the AV's foremost point should not be more than 1.5m away before the nearest edge of the stop line.

Manoeuvres

4. An AV should follow the traffic signals, traffic signs and road markings (i.e. stop or move as directed).

5. An AV should maintain lane discipline as required by the road markings, unless performing a lane change or overtaking.

6. When performing a lane change, an AV should –

   (a) ensure that the lane change manoeuvre does not force any vehicles to take potentially unsafe evasive action;

   (b) signal at least 3 seconds in advance before initiating a lane change manoeuvre; and

   (c) cancel the signal after the lane change manoeuvre is completed.

7. When overtaking, an AV should –

   (a) ensure that the lane change manoeuvre does not force any vehicles to take potentially unsafe evasive action; and

   (b) only move into a lane for oncoming traffic if the intended path is safe and clear of traffic.

8. An AV should slow down when another vehicle is trying to overtake the AV.

9. An AV should not overtake another vehicle at the following locations:

   (a) a pedestrian crossing;

   (b) a road junction;

   (c) a corner or a bend; and

   (d) on a steep slope or incline.

10. An AV should not overtake another vehicle when –

   (a) the vehicle in front is about to overtake another vehicle in front of it;

   (b) the vehicle in front is changing from the left to the right lane; or

   (c) the vehicle in front of it increases its speed.

11. An AV should only U-turn when –

   (a) there is sufficient safety distance from the traffic coming from the opposite direction; and

   (b) there are no other vehicles, turning together with an AV on its right.

12. When at pedestrian crossings, an AV should –

   (a) give way to pedestrians;

   (b) slow down and prepare to stop if a pedestrian appears from outside its field of vision or occlusion at pedestrian crossings; and

   (c) proceed to move off only after a pedestrian is detected to be off the road.

13. When negotiating junctions, an AV should adopt the following performance:

   (a) An AV should slow down its speed and follow the “give way” rules found in the rules on airside vehicles and drivers when negotiating non-signalised junctions;

   (b) An AV should keep to the lane corresponding to its lane before turning at a signalised or non-signalised junction;

   (c) An AV should enter the lane that permits the intended direction of turn as indicated by road markings;

   (d) An AV should signal its intention at least 3 seconds before entering the lane which permits the intended direction of turn and keep the signal on till the turn is completed;

   (e) An AV should first stop to allow pedestrians to cross the road when turning left at a signalised junction; and

(f) When turning right at a signalised junction, an AV should first stop at a safe distance away from opposing traffic and proceed only when there are neither oncoming vehicles in the opposite direction nor pedestrians.

Traffic control measures

14. An AV should be capable of responding safely and appropriately to traffic control measures including but not limited to road works, authorised personnel directing traffic and emergency situations.

Right of way

15. An AV that is travelling should always look out for and give way to –

(a) aircraft taxiing, on tow, or on pushback; and

(b) emergency vehicles.

Traffic signs and road markings

16. An AV should adhere to all traffic signs and road markings that are found in rules on airside vehicles and drivers. They include:

(a) airside roadway markings;

(b) aircraft stand markings;

(c) traffic signs; and

(d) work zone signs.

Malfunction

17. During a malfunction, the AV should be able to –

(a) safe stop on a parking area; and

(b) safe stop along the kerb.

APPENDIX D – TEST AND VALIDATION OF AV PERFORMANCE

Framework 1: Test new AV solutions at the airside

1. **Framework 1 (see Table 1) tests AVs that are untested or have not been operating safely at the airside of other airports or on public roads.** It aims to provide assurance that these AVs can operate safely in our aerodromes. It includes comprehensive testing of the capabilities and performance of the AVs and the effectiveness of their remote-control centre in monitoring and controlling the AVs.

2. Autonomous Vehicle testing schedules should mirror their planned operational timing. This would mean that testing is conducted during the vehicle's intended service hours. For instance, if the AV service runs strictly during daylight hours, it is not necessary to conduct testing at night. However, if the AV operator later decide to modify the AV's operating schedule, such as extending the operations into evening hours, the AV should go through the relevant phases to be comprehensively tested during these new timeframes to ensure the AV can continue to operate the new conditions safely and effectively.

3. Initial phase
   The initial phase focuses on verifying the AV's basic capabilities and related regulatory compliance before it can operate in a live airside environment. It is common to have changes to software and hardware to improve performance or add functionalities as the AV goes through the various test items. To ensure that the changes implemented to pass different test items do not inadvertently have an adverse impact on the AV's performance in other test items, the AV should go through all the tests in Phase 1 at least once after it passes the final test item.

4. Society of Automotive Engineers (SAE) International Level 4 phase 1 and 2
   Phases 1 and 2 involves testing the AV in a live operational environment, as the initial test might not cover every scenario that an AV would encounter. These phases aim to validate the AV's ability to consistently handle live operational scenarios safely. The AV needs to be assessed as it carries out its tasks under normal schedules across varying environmental and weather conditions, and traffic patterns. If the criteria for rain conditions cannot be fulfilled, the AV can proceed to the next phase of testing, but the rain testing should be completed by Phase 4.

5. SAE Level 4 phase 3
   Phase 3 focuses on verifying the capabilities of the remote-control centre and the competency of the remote operators before live operations. This includes testing under normal conditions and also the following scenarios:

   (a) Remote-control centre functions are unserviceable during operations;

   (b) AV sensors are unserviceable during operations;

   (c) AV on-board cameras are unserviceable during operations;

   (d) AV is stuck behind an obstacle;

   (e) Unsafe commands issued by the remote-control centre to the AV (if relevant);

   (f) AV operations in rain (if possible);

   (g) AV operations at night (if relevant); and

(h) AV exceeded Operational Design Domain (ODD).

6. SAE Level 4 phase 4
Phase 4 validates the ability of the remote-control centre and the remote operators to consistently handle live operational scenarios safely. Testing occurs under normal schedules in varying environmental and weather conditions, and traffic patterns. If the criteria for rain conditions cannot be fulfilled, the AV can proceed to be deployed for operations without an onboard safety driver, but a safety driver should be onboard for operations in wet weather until the rain testing is fulfilled. Any changes or modifications to the hardware or software that affects the remote operator's control and monitoring of the AV may require additional testing.

7. The following conditions will apply to ensure that the AV can operate safely:

(a) Initial phase testing might have to be conducted again but without the need to reconduct the other phases if there are changes to:

(i) Sensor and/or camera hardware such as addition or removal of sensors and/or cameras, change of sensors and/or camera models or types.

(ii) Software that changes the analysis of data from sensors and/or cameras that affect the AV's safety-critical functions or operational performance capabilities. These exclude regular software updates and security patches that do not change the core functionality of the AV system

Adjustments to software parameters such as acceleration, deceleration, turning radius, signalling duration, need not go through the initial phase testing again.

(b) To ensure consistency and reliability in the respective testing phases, the pool of onboard safety drivers and remote operators should remain the same throughout the entire test duration. All replacement personnel should be similarly trained and certified competent to operate the specific AV model being tested.

(c) Where required, CAAS may request for an onsite demonstration of the AV.

(d) Any unsatisfactorily observations can result in suspension or termination of the trial and/or extension of the test duration. These may include observations that the AV's performance is not consistent with submitted track records, downtime required to address AV defects, suspension of AV activities to facilitate investigation of incidents and/or critical safety issues, and completion of the necessary remedial actions.

Table 1: Framework 1 to test new AV solutions at the airside

Conditions	**Initial phase**	**SAE Level 4 phase 1**	**SAE Level 4 phase 2**	**SAE Level 4 phase 3**	**SAE Level 4 phase 4**
	- Closed area - To ensure that the AV is safe to use prior to the start of AV trial	- After successful completion of initial phase - Operator onboard - Designated routes in live environment	- After successful completion of Phase 1 - Operator onboard - Designated routes in live environment with load/pax	- After successful completion of Phase 2 - Remote operator - Designated routes in live environment	- After successful completion of Phase 3 - Remote operator -Designated routes in live environment with load/pax
AV operator on board	Yes	Yes	Yes	Yes	Yes
*[#]Remote Operator	No	No	No	Yes	Yes
Passengers and Goods on board	No	No	Yes	No	Yes
Daylight, as applicable (Mileage/moving hours)	>700 km or 35 hrs	>1750 km or 90 hrs	>19250 km or 963 hrs	>3500 km or 175 hrs	>3500 km or 175 hrs
Night, as applicable (Mileage/moving hours)	>300 km or 15 hrs	>750 km or 38 hrs	>8250 km or 413 hrs	>1500 km or 75 hrs	>1500 km or 75 hrs
No. of incidents per 1000km based on statistical modelling	50% CL < 0.69 95% CL < 2.99 Confidence level (CL)	50% CL < 0.27 95% CL < 1.19	50% CL < 0.025 95% CL < 0.109	50% CL < 0.138 95% CL < 0.599	50% CL < 0.138 95% CL < 0.599
Job specific tasks outside of roadways, if any (e.g. loading / unloading of ULDs)	1000 cycles	2500 cycles	5000 cycles	5000 cycles	5000 cycles
Rain intensity:	NA	o 120 mins @ ≥ 3mm/5min o 30 mins @ ≥ 5mm/5min		o 120 mins @ ≥ 3mm/5min o 30 mins @ ≥ 5mm/5min	
Test Report endorsed by CAG	Yes ISO 22737:2021	Yes	Yes	Yes	Yes
Batch Testing - same AV model, AV system and config -tested and trialled	>20% of the batch of AV, with test report	each AV should accumulate > 500 km or 25 operating hrs	each AV should accumulate > 500 km or 25 operating hrs	each AV should accumulate > 500 km or 25 operating hrs	each AV should accumulate > 500 km or 25 operating hrs
Subsequent batch - same AV model, AV system and config -tested and trialled	>10% of the batch of AV, with test report	-	-	-	-

Passing criteria	- Demonstrate compliance with all relevant requirements at least 3 times - No changes to hardware such as sensors or cameras throughout the test duration, except that unserviceable, faulty or damaged hardware can be replaced with the same models - No contribution to any incidents	- Demonstrate compliance with all relevant requirements throughout the entire test duration - No contribution to any incidents - No interventions by onboard safety driver or remote operator to prevent an incident - No deviation from designated route - Operate safely without contravening any passing criteria mentioned above in rain conditions	- Demonstrate compliance with all relevant requirements at least 3 times - Demonstrate that the remote-control centre can effectively monitor and control the AV in real-time - Remote operator demonstrates the necessary competence and comprehensive situational awareness to monitor and operate the AV safely	- Demonstrate that the remote-control centre can effectively monitor and control the AV in real-time - Remote operator demonstrates the necessary competence and comprehensive situational awareness to monitor and operate the AV safely - Compliance with all relevant requirements throughout the entire test duration - No contribution to any incidents attributable to the AV, onboard safety driver and/or remote operator - No interventions by onboard safety driver or remote operator to prevent an incident (outside of remote centre testing) - No deviation from designated route - Operate safely in rain conditions

Framework 2: Test for deployable AV solutions at the airside

1. **Framework 2 (See Table 2) tests AVs that have been safely deployed at the airside of other airports or on public roads**. It aims to shorten the time needed to validate that these AVs are able to operate safely in our airside. It includes testing the capabilities and performance of the AVs and the effectiveness of their remote-control centre in monitoring and controlling the AVs.

2. The following pre-conditions are applicable before an AV which is deployed at the airside of other airports, can go through this testing framework:

   (a) Same AV model of same AV system* should be deployed at the airside of other airports for at least a year;

   (b) Minimum total fleet milage at the airside by the AV model should be at least 46,000km at all airports;

   (c) Minimum total cycles of job specific tasks by the fleet of the same AV model outside of roadways should be at least 43,500 at all airports; and

   (d) No aircraft or vehicular incidents attributable to the AV fleet.

3. If an operator is interested to introduce an AV which has been safely deployed on public roads, a comprehensive safety assessment should be conducted to assess whether the AV's functions and capabilities are adequate for the airside environment and is suitable to go through this testing framework.

   The following pre-conditions are applicable before the safety assessment can be conducted:

   (a) Same AV model of same AV system* should be deployed on public roads for at least a year.

   (b) Total fleet milage on the roads by the AV model should be at least 100,000km.

   (c) No vehicular incidents attributable to the AV fleet.

   ** Same AV system refers to the same hardware (e.g. sensors, processing units, mechanical components) and software (e.g. autonomous driving software, decision making algorithms) elements as well as configuration (e.g. operational capabilities, cybersecurity and emergency protocols). Any modifications to these would constitute a different AV model and system except regular software updates and security patches that do not change the core functionality, minor hardware repairs using identical replacement parts, routine maintenance and calibration, and modifications for local context (e.g. traffic rules, recognition of local visual aids and road surface conditions, calibration for local weather conditions).*

4. The test framework aims to verify the following key safety objectives:

   (a) The AV should be able to operate safely in our aerodrome and comply with the relevant local rules, such as those specified in the Airside Driving Theory Handbook, Airport By-laws and Highway Code.

   (b) The AV should be able to consistently operate safely in a live environment, under normal scheduling, and across varying environmental and weather conditions.

(c) The remote-control centre should be able to monitor and control the AVs in real-time effectively.

5. To achieve this, the test framework (refer to Table 2) contains four phases to comprehensively test the AV and its remote-control centre in our local environment.

(a) Phase 1

Phase 1 focuses on verifying the AV's basic capabilities and related regulatory compliance before it can operate in a live airside environment. It is common to have changes to software and hardware to improve performance or add functionalities as the AV goes through the various test items. To ensure that the changes implemented to pass different test items do not inadvertently have an adverse impact on the AV's performance in other test items, the AV should go through all the tests in Phase 1 at least once after it passes the final test item. In addition, the AV can only transit to Phase 2 when all passing criteria in Phase 1 are met.

(b) Phase 2

Phase 2 aims to validate the AV's ability to consistently handle live operational scenarios safely. The AV needs to be assessed over several months as it carries out its tasks under normal schedules across varying environmental and weather conditions, and traffic patterns. If the criteria for rain conditions cannot be fulfilled, the AV can proceed to the next phase of testing, but the rain testing should be completed by Phase 4.

(c) Phase 3

Phase 3 focuses on verifying the capabilities of the remote-control centre and the competency of the remote operators before live operations. This includes testing under normal conditions and also the following scenarios:

(i) Remote-control centre functions are unserviceable during operations;

(ii) AV sensors are unserviceable during operations;

(iii) AV on-board cameras are unserviceable during operations;

(iv) AV is stuck behind an obstacle;

(v) Unsafe commands issued by the remote-control centre to the AV (if relevant);

(vi) AV operations in rain (if possible);

(vii) AV operations at night (if relevant); and

(viii) AV exceeded Operational Design Domain (ODD).

While it is not necessary for Phase 2 to be completed before Phase 3 commences, the AV can only transit to Phase 4 when all passing criteria in Phase 3 are met. In addition, there is no limit to the number of AVs a remote operator can monitor and control if they can demonstrate consistent safe and effective management of all AVs on trial. However, changes or modifications to the hardware or software that affects the remote operator's control and monitoring of the AV may require additional testing.

(d) Phase 4

Phase 4 aims to validate the ability of the remote-control centre and the remote operator to consistently handle real operational scenarios safely. Hence, the AV needs to cover sufficient distance over several months as it carries out its tasks under normal schedules across varying environmental and weather conditions, and traffic patterns. If the criteria for rain conditions cannot be fulfilled, the AV can proceed to be deployed for operations without an onboard safety driver, but a safety driver should be onboard for operations in wet weather until the rain testing is fulfilled. Any changes or modifications to the hardware or software that affects the remote operator's control and monitoring of the AV may require additional testing.

6. The following conditions will apply to Phases 2 to 4 to ensure that the AV can operate safely:

(a) Phase 1 testing might have to be conducted again but without the need to reconduct the other phases if there are changes to:

(i) Sensor and/or camera hardware such as addition or removal of sensors and/or cameras, change of sensors and/or camera models or types.

(ii) Software that changes the analysis of data from sensors and/or cameras that affect the AV's safety-critical functions or operational performance capabilities. These exclude regular software updates and security patches that do not change the core functionality of the AV system.

Adjustments to software parameters such as acceleration, deceleration, turning radius, signalling duration, need not go through Phase 1 testing again.

(b) To ensure consistency and reliability in the respective testing phases, the pool of onboard safety drivers and remote operators should remain the same throughout the entire test duration. All replacement personnel should be similarly trained and certified competent to operate the specific AV model being tested.

(c) Where required, CAAS may request for an onsite demonstration of the AV.

(d) Any unsatisfactorily observations can result in suspension or termination of the trial and/or extension of the test duration. These may include observations that the AV's performance is not consistent with submitted track records, downtime required to address AV defects, suspension of AV activities to facilitate investigation of incidents and/or critical safety issues, and completion of the necessary remedial actions.

Table 2: Framework 2 to test deployable AV solutions at the airside

	Phase 1	Phase 2	Phase 3	Phase 4
Objective	Validate - AV's self-driving, detection and manoeuvring capabilities are able to meet the requirements in the checklists - Compliance with relevant requirements in Airside Driving Theory Handbook - Compliance with relevant Airport By-laws - Compliance with relevant Highway Code	Validate - AV can operate safely in a live environment - Reliability, repeatability, and consistency of AV performance	Validate - Capabilities of remote-control centre to effectively monitor and control the AV in real-time and able to meet the requirements in the checklists - Expectations of test items for remote centre	Validate - Reliability, repeatability, and consistency of AV's performance as well as remote-control centre's capabilities - AV can operate safely in a live environment
Location	- Controlled environment - Does not involve live operations	- Live environment - Include airside roadways, aircraft stands and BHAs, where relevant - Manoeuvring areas are not allowed	- Controlled environment - Does not involve live operations	- Live environment - Include airside roadways, aircraft stands, and BHAs, where relevant - Manoeuvring areas are not allowed
Duration	- No limit on time period - Day and / or night tests (as applicable)	- At least 12 weeks for a continuous period - Day and / or night (as applicable) - Operate based on normal schedule	- No limit on time period - Day and / or night tests (as applicable)	- At least 8 weeks for a continuous period - Day and / or night (as applicable) - Operate based on normal schedule
Assessment methodology	- Standardised checklists relating to the relevant requirements stated in the objective - Onsite observations - Include night tests (if relevant) - At least one AV to go through the full suite of tests	- Onsite observations - Data review of AV performance - Can have more than 1 AV of the same model, AV system and configuration on trial but no reduction in test duration	- Standardised checklists relating to the capabilities of the remote-control centre to effectively monitor and control the AV in real-time - Onsite observations - Include night tests (if relevant) - Can have more than 1 AV of the same model, AV system and configuration on trial.	- Onsite observations - Data review of AV performance - Can have more than 1 AV of the same model, AV system and configuration on trial but no reduction in test duration

Onboard Safety driver	Yes	Yes	Yes	Yes
Carry load/pax	No	Yes	No	Yes
Remote control centre monitoring and controlling of AV	No	Optional	Yes	Yes
Passing criteria	- Demonstrate compliance with all relevant requirements at least 3 times - No changes to software and hardware such as sensors or cameras throughout the test duration, except that unserviceable, faulty or damaged hardware can be replaced with the same models	- Demonstrate compliance with all relevant requirements throughout the entire test duration - No contribution to any incidents - No interventions by onboard safety driver or remote operator to prevent an incident - No deviation from designated route - Operate safely without contravening any passing criteria mentioned above in rain conditions o 120 mins @ ≥ 3mm/5min o 30 mins @ ≥ 5mm/5min	- Demonstrate compliance with all relevant requirements at least 3 times - Demonstrate that the remote-control centre can effectively monitor and control the AV in real-time - Remote operator demonstrates the necessary competence and comprehensive situational awareness to monitor and operate the AV safely	- Demonstrate that the remote-control centre can effectively monitor and control the AV in real-time - Remote operator demonstrates the necessary competence and comprehensive situational awareness to monitor and operate the AV safely - Compliance with all relevant requirements throughout the entire test duration - No contribution to any incidents attributable to the AV, onboard safety driver and/or remote operator - No interventions by onboard safety driver or remote operator to prevent an incident (outside of remote centre testing) - No deviation from designated route - Operate safely in rain conditions o 120 mins @ ≥ 3mm/5min o 30 mins @ ≥ 5mm/5min