

1. INTRODUCTION AND OBJECTIVES

- 1.1. The demand for essential environmental services such as public cleaning in Singapore is expected to rise with increasing urbanisation.
- 1.2. Technological advancement and innovation are critical to the development of more productive and effective public cleaning services for the future. To reduce the reliance on manpower and improve the productivity of cleaning operations, cleaning companies are encouraged to adopt new technologies and incorporate more automation into their operations.
- 1.3. NEA works with various stakeholders to: (a) build a trained and skilled workforce; (b) provide better employment standards; (c) implement progressive wages; and (d) encourage the review of work processes and greater adoption of technology, so as to raise the value and productivity of the cleaning profession.
- 1.4. In August 2014, MOT set up the Committee on Autonomous Road Transport for Singapore (CARTS) to chart the strategic direction for the deployment of Autonomous Vehicle (AV) technology in Singapore. Comprising policymakers from the relevant Singapore government agencies, thought leaders and industry captains, CARTS oversees the roadmap for AV deployment, as well as issues such as the safety and regulatory frameworks for AVs on our public roads. Four tracks for the deployment of AV technology have been identified:
 - a) Fixed and Scheduled Services: Efficient mass transport for intra and inter-town travel on a fixed route and scheduled basis;
 - b) Point-to-Point, Mobility-on-Demand Services: Shared services with dynamic routing, for point-to-point, first- and last-mile type of travel;
 - c) Freight: Carriage of goods for long-distance delivery during late night and early morning hours; and
 - d) Utility: Utility operations, e.g. road and pavement sweeping during off-peak hours.
- 1.5. In relation to the “Utility” track (track (d)), NEA and MOT are seeking Proposals from industry, Institutes of Higher Learning (IHLs) and research institutes to design and develop technologies/concepts for Autonomous Environmental Service Vehicles (AESVs) to perform autonomously the safe and efficient cleaning of roads and/or pavements.
- 1.6. This Request for Proposal (RFP) invites Proposals from interested parties on the design, development and translation of AV-enabled concepts for AESV, and the conduct of AESV demonstrations and trials. Interested parties may form a consortium comprising players in the relevant industry and/or any other parties necessary for submission of the Proposal. The Proposal is to be submitted by the main applicant or a member of each consortium.
- 1.7. The AESV concept, demonstration and trials must meet the following overall objectives:
 - a) Safety and security as a top priority at all times, with minimal disruption to the public;
 - b) Effective cleaning of public roads and/or pavements;
 - c) Reduction of reliance on manpower and improvement in productivity;
 - d) Seamless deployment and integration into existing infrastructure; and
 - e) Environmental friendliness, e.g. no undue noise and air pollution caused.

2. BACKGROUND ON CLEANING OF PUBLIC ROADS AND PAVEMENTS

- 2.1. NEA currently manages the cleaning of roads, pavements, overhead bridges, underpasses, beaches, parks, vacant lands, bus stops and other public areas. NEA also conducts regular

audits on cleaning contractors to ensure that the cleaning works are carried out satisfactorily and in accordance with cleaning schedules.

- 2.2. Cleaning works are generally manpower intensive and laborious. Cleaning contractors often have to compete for road spaces with other road users while carrying out cleaning works as such works are usually done during the day.

3. PROJECT REQUIREMENTS

- 3.1. The project scope is for the Proposer to design, develop and demonstrate that the Proposer's AESV system is able to clean roads and/or pavements in a safe and effective manner. Proposers may propose separate solution(s) or a combined solution that is able to meet the operational requirements for sweeping both roads and pavements. In this connection, the Proposer shall undertake a study of the dimensions of street furniture and public infrastructure (e.g. kerb height, pavement width, covered walkway height), to size their AESV to ensure maximum access of the machine in public areas.
- 3.2. Proposers shall propose a project period that is not longer than eighteen (18) months, inclusive of a public road trial period that is not shorter than six (6) months.
- 3.3. The Proposer shall provide a detailed project schedule (e.g. project time-line, Gantt chart) of major project activities and the milestone checkpoints. The Proposer shall give a description of each milestones and deliverables of the project.
- 3.4. The Proposer shall state their background, qualifications and provide the relevant track records and capabilities of each individual researcher in the team, details of current and/or successful implementation of identical or similar technologies, their international standing and any unique competitive advantages that they bring to the team in achieving the project's objectives. Detailed Curriculum Vitae (CV) of the Principal Investigator and the project team members shall be attached as supporting documents with each Proposal.
- 3.5. If a Proposer or Proposer's Consortium does not include any member from the Environmental Services Industry, the Proposer shall state how it would obtain operational inputs for the design, development and trial of the AESV in order to meet operational cleaning requirements.
- 3.6. The Proposer shall be self-sufficient in all aspects of this project. There will be no Authority-Furnished Equipment (AFE) or Government-Furnished Equipment (GFE) provided. The Host Institution shall be responsible for the installation/maintenance and removal of temporary information/road/pavement signs and equipment during the trials. The Proposer shall obtain the necessary approvals from the relevant authorities for the use and modification of any public space, amenity, equipment and facility needed for the trials and for the use of its AESVs, other equipment and/or vehicles for the trials.
- 3.7. The Proposer shall state the concept of how their AESV system will be operated/used, the number of manpower required (including maintenance tasks) and underlying assumptions for external systems needed for their AESV system to work.
- 3.8. The Proposer shall comply with the Workplace Safety and Health Act & the provisions of the Workplace Safety and Health Act Subsidiary Legislations and any amendment(s) or re-enactment(s) thereto.
- 3.9. The Proposer shall be on the bizSAFE programme that promotes workplace safety and health, and has attained bizSAFE Level 3 or higher. Information on the bizSAFE programme developed by the Workplace Safety and Health Council can be found on www.wshc.sg.

4. SPECIFIC REQUIREMENTS

- 4.1. Operational requirements. The AESV shall be capable of cleaning roads and/or pavements; collecting debris, litter and leaves from the roads and/or pavements; and dispose of the stored litter automatically without much human intervention.
- 4.2. The road areas to be cleaned include but are not limited to left- and right-side kerbs, road dividers/medians, chevrons, bus bays and cul-de-sacs. Sample photographs of areas to be cleaned are shown in Annex D. While on the road, the AESV may encounter obstacles such as, but not limited to, road humps, potholes, fallen branches, parked cars, pedestrians and cyclists. The Proposer shall state how the AESV and/or the system will react to such obstacles and continue its cleaning operation after avoiding or overcoming the obstacles.
- 4.3. Pavements includes park connectors, any adjoining grass verges and concrete slabs placed above closed drains which may not always be flat, even surfaces. For example, there may be tree roots, humps, service lids, damaged footpaths and broken tiles segmenting the roads and pavements. Sample photographs of pavement conditions are shown in Annex D. When following specified cleaning routes, the solution should be able to manoeuvre and perform cleaning functions on public pathways with uneven surfaces, grass verges and muddy terrain. The weight of an AESV designed for travelling on pavements built on top of closed drains must not exceed the maximum design loading of 5kN/m².
- 4.4. The power plant of the pavement AESV shall preferably be electrical or running on a suitable energy source that allows for self-charging. The operating range of the pavement AESV shall be no less inferior to current human-operated pavement sweepers.
- 4.5. The AESV shall be monitored and operable from an offsite control station, with preferably no personnel onsite except for maintenance. The AESV shall have a high degree of autonomy that allows a single personnel to remotely monitor and control it, and the personnel should be able to monitor and operate a fleet of AESVs simultaneously. Although full autonomy is desirable, some form of human intervention may be allowed for difficult terrain and exceptional cases. The Proposer shall state the exceptional scenarios that would require the intervention of an on-site/off-site personnel. Prior to achieving full autonomous operation, the AESV shall allow for a safety operator, either inside the vehicle or in close proximity on-site, to take over full control manually. The AESV shall also provide an option to revert to manual control in event of technical glitches or emergencies.
- 4.6. The control station shall allow the operating personnel to input cleaning routes and schedules with map displays and overlays of various sensor information. The control station shall provide audible and visual alerts to the operating personnel when there are anomalies detected by the sensors installed on the AESV. The control station shall adopt a scalable architecture with the potential to meet a future need for controlling and monitoring of a fleet of AESVs from a single control station by a single operator. Fleet coordination and dynamic route optimisation functions are preferred but not required for this stage of the RFP.
- 4.7. The AESV shall be able to maintain continuous and reliable communications with its control station such that the control station is able to monitor and control the AESV effectively. The Proposer shall specify the mode of communication between the AESV and its control station and the type of data exchanged. The control station shall be Robot Operating System (ROS) compliant or compatible to allow information to be shared with external systems.
- 4.8. The Proposer shall specify the vehicle-to-vehicle and vehicle-to-infrastructure (examples of such infrastructure would include control station, lamp posts or road kerbs on which sensors are installed) communications necessary for the AESV to operate. The Proposer is to indicate clearly the type(s) of communication systems used; equipment for supporting this type of communication; and the type(s) and purpose(s) of information or data exchanged.
- 4.9. The Proposer shall provide a support system for the cleaning process, from start to end, using the AESV. The support system should include the design, development and provision of a docking station for secure storage, a charging station for efficient refueling and a tipping/emptying

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station to facilitate the cleaning operation of the AESV. These stations may be standalone or co-located with the control station. Depending on the operating range of the machine and the routing, the AESV support system may comprise more than one charging station if necessary to enable the machine to achieve a higher productivity gain. The Proposer shall indicate if their AESV is able to perform the above functions autonomously with minimal human intervention.

- 4.10. The AESV shall be able to operate in the day and night. When operating at night, the AESV shall not cause undue disturbance to the surrounding such as emitting excessive light or noise.
- 4.11. The AESV shall be able to operate under normal weather conditions of Singapore and in slightly hazy and light rain ($\leq 2.5\text{mm/hr}$) conditions. In the event of heavy rain, severe haze/fog or other extreme weather conditions, the AESV should be able to travel autonomously to the nearest safe location and resume operations only after the rain has stopped. The Proposer shall specify the conditions in which such safety feature of the AEVS is activated and identify the safe locations for the AESV.
- 4.12. The AESV shall comply with local traffic rules as stipulated in the Road Traffic Act (Ch 276) and the Active Mobility Act 2017 and the Subsidiary Legislations authorised by these Acts. The AESV shall be capable of detecting static and dynamic obstacles and avoid collision with these obstacles when travelling along its planned path. It shall also be able to detect and avoid collision with pets, small animals and human traffic such as pedestrians, cyclists and other road users on footpaths and roads. Where applicable, the AESV shall be able to overtake obstacles safely.
- 4.13. The AESV shall be constructed of materials that are able to withstand weathering and are easy to clean. Parts that are subjected to wear and tear shall be removable and easily repaired and/or replaced as part of a routine maintenance regime.
- 4.14. Self-driving capabilities at high speeds are **not required** for this project. The AESV shall move at an optimal speed which is suitable for cleaning roads and/or pavements efficiently. The Proposer shall specify the maximum and cruising speeds of the AESV in km/h.
- 4.15. The Proposer may assume that the AESV is deployed from a docking station located in the designated cleaning area. The Proposer may co-located the docking station with the control station, charging/refuelling station and/or the emptying/tipping station. The Proposer shall provide these facilities for pre-trial and public road trial as part of the Services rendered.
- 4.16. The AESV shall be equipped with the following features:

Function	AESV for Road Sweeping	AESV for Pavement Sweeping
Cleaning Function	<ul style="list-style-type: none"> On-board brooms/brushes to sweep the curb sides of the road Conveyor and/or suction vacuums to suck up the swept debris such as leaves and debris Water sprays to wet the road to reduce dust Able to clean at least 60km of roads without charging/refuelling or returning to station Operate continuously for at least 4hrs in a single full charge/ fuel tank Self-charging/refuelling and able to return to station automatically for charging/refuelling before battery/fuel runs out Automatic tipping/emptying with minimal trips to tipping/emptying station [optional but desirable] 	<ul style="list-style-type: none"> Conveyor and/or suction vacuums to suck up the swept debris such as leaves and debris Water sprays to wet the path to reduce dust Able to clean at least 20km of pavements without charging/refuelling or returning to station Operate continuously for at least 4hrs in a single full charge/ fuel tank Self-charging/refuelling and able to return to station automatically for charging/refuelling before battery/fuel runs out Automatic tipping/emptying with minimal trips to tipping/emptying station [optional but desirable]

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Function	AESV for Road Sweeping	AESV for Pavement Sweeping
	<ul style="list-style-type: none"> Assess road cleanliness to adjust vehicle speed and/or cleaning actuators accordingly [optional but desirable] 	<ul style="list-style-type: none"> Assess pavement cleanliness to adjust vehicle speed and/or cleaning actuators accordingly [optional but desirable]
Navigation function	<ul style="list-style-type: none"> Able to stop immediately whenever there is a human, vehicle or animal blocking its path and resume the operation after the human, vehicle or animal has moved away Take appropriate actions when encountering obstacles to avoid collision with the obstacles Visual and audible alarms to alert a human or an animal moving into its path Obey traffic rules and regulations Maintain speeds of below 20km/h at the designated cleaning area to perform road sweeping and cleaning Follow pre-scheduled cleaning routes Lift up the conveyor/ vacuum system when going over a road hump Able to identify curves/ bends on the road, i.e. follow the road kerb closely Able to decide autonomously when to follow kerbs/edges and when not to (e.g. when encountering left-turning lanes) Return to a station located in the cleaning area to empty its hopper, charge/refuel and top up supplies 	<ul style="list-style-type: none"> Able to stop immediately whenever there is a human, vehicle or animal blocking its path and resume the operation after the human, vehicle or animal has moved away Take appropriate actions when encountering obstacles to avoid collision with the obstacles Visual and audible alarms to alert a human or an animal moving into its path Obey traffic rules, regulations and guidelines governing movement on pavement and pedestrian walkways Cross regulated and unregulated pedestrian crossings Maintain speeds of below 15km/h at the designated cleaning area to perform pavement sweeping and cleaning Follow pre-scheduled cleaning routes Return to a station located in the cleaning area to empty its hopper, charge/refuel and top up supplies
Reporting function	<ul style="list-style-type: none"> Sensors/system to detect obstacles that it comes across during cleaning Global Navigation Satellite System (GNSS) tracker (or other suitable technology or solutions) to track location and speed of the AESV Video cameras in the front and back of the AESV to monitor road cleanliness Application of analytics or additional sensors to automatically assess road cleanliness [optional but desirable] Sensors to detect the successful activation/deactivation of cleaning tools on the vehicle such 	<ul style="list-style-type: none"> Sensors/system to detect obstacles that it comes across during cleaning GNSS tracker (or other suitable technology or solutions) to track location and speed of the AESV Video cameras in the front and back of the AESV to monitor pavement cleanliness Application of analytics or additional sensors to automatically assess pavement cleanliness [optional but desirable] Sensors to detect the successful activation/deactivation of cleaning tools on the vehicle such as brooms, vacuums and water sprays

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Function	AESV for Road Sweeping	AESV for Pavement Sweeping
	as brooms, vacuums and water sprays	
Communication function	<ul style="list-style-type: none"> • Transmit data from onboard sensors and cameras and receive commands from control station • Transmit location of vehicle every second • Transmit video footages at minimally 15 frames per second (fps) 	<ul style="list-style-type: none"> • Transmit data from onboard sensors and cameras and receive commands from control station. • Transmit location of vehicle every second • Transmit video footages at minimally 15 fps
Fleet management function	<ul style="list-style-type: none"> • Manage deployment of AESV, including options to override the pre-scheduled cleaning route, stop the AESV and deploy the AESV back to the control station or deploy AESV on an alternative pre-scheduled cleaning route • Mission planning of cleaning routes and schedules • Map display with relevant sensor information overlays to monitor operation • Visual and audible warnings to alert operating personnel of any anomaly to AESV's operation 	<ul style="list-style-type: none"> • Manage deployment of AESV, including options to override the pre-schedule cleaning route, stop the AESV and deploy the AESV back to the control station or deploy AESV on an alternative pre-scheduled cleaning route • Mission planning of cleaning routes and schedules • Map display with relevant sensor information overlays to monitor operation • Visual and audible warnings to alert operating personnel of any anomaly to AESV's operation

- 4.17. Software requirements. The Proposer shall state if its software and software development process meets any established standard and the standard which was met. (e.g. IEEE 12207, MIL-STD 882E)
- 4.18. Where any existing software do/does not comply with any standard, the Proposer shall highlight such specific software and explain (through design and testing) why such software do/does not adversely affect the overall system performance and safety.
- 4.19. The Proposer shall provide information on the computer architecture in the form of a system software block diagram.
- 4.20. The Proposer shall provide development methodology/approaches and tools used in the design, coding and testing of the system software.
- 4.21. The Proposer shall provide its configuration identification process, configuration control and configuration accounting procedures.
- 4.22. The Proposer shall state how the software handles exception events (e.g. dynamic obstacles) in which it either (a) requires human action or (b) takes action automatically.
- 4.23. The Host Institution shall ensure that the delivered system is free from all malware, which includes computer viruses, worms, Trojan horses, rootkits and any other malicious and unwanted software.
- 4.24. The Host Institution shall provide a list of known software bugs in its software, the impact/severity of these software bugs and any mitigation measure or workaround, if any.

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- 4.25. Possible trial area. The Proposer shall conduct the public trials in the current designated AV trial area of Buona Vista/One-North. The map showing the trial area can be found in Annex E. The Proposer may also propose to trial in other parts of Singapore, subject to agreement by the relevant authorities.
- 4.26. Requirements for AV trials. The Host Institution shall apply for the necessary licenses from the Land Transport Authority (LTA) to operate the AESVs on public roads. All AESVs trialing on public roads will be assessed for basic AV capabilities and whether safety operators are capable of taking over full control of the AVs immediately before it is allowed to be further tested and trialled in a small scale testbed environment. During the assessment, trial participants will need to demonstrate items like braking in AV mode, having a vehicle fault alert system and for the safety operator to manually take over control of the vehicle from AV mode when required.
- 4.27. The Proposer may refer to the AV application form at the following link:
https://www.lta.gov.sg/content/dam/ltaweb/corp/RoadsMotoring/files/Autonomous%20Vehicles%20Application%20Form_Jan%202015.pdf
- 4.28. The Host Institution shall provide access to its system and facilitate viewing and monitoring of the AESVs when required by the Grantor.

5. SAFETY REQUIREMENTS

- 5.1. The Proposer shall comply with the Road Traffic (Autonomous Motor Vehicles) Rules 2017 and other relevant Singapore laws, rules and regulations. The Host Institution shall appoint a system safety engineer to manage and address the public safety aspects of the trials and demonstrations. Safety assessment reports and documentation shall be prepared for the relevant safety committees for the clearance prior to the conduct of trials and demonstrations.
- 5.2. The Host Institution shall have a qualified safety operator inside the AESV (for road cleaning) or in close proximity of the AESV (for pavement cleaning travelling below walking pace), to be ready to take over control of the vehicle at any time during the trials.
- 5.3. The Host Institution shall ensure that any relevant devices are securely installed/ attached to the AESV and will not pose a danger to anyone at all times.
- 5.4. The Host Institution shall submit its Risk Assessment for the Services before commencement of the project inclusive of trials and whenever there are subsequent changes and as and when required by the Agency.
- 5.5. The Host Institution shall be responsible for the safe recovery of the AESV in case of breakdowns/accidents and shall provide a vehicle recovery procedure in its test plan.
- 5.6. The Host Institution shall ensure that it has the necessary insurance coverage throughout the undertaking of this R&D project. For the period of a trial, there must be a policy of insurance (at least third party liability against death of or bodily injury to any person, including property damage) in force for each approved vehicle.

6. CYBERSECURITY REQUIREMENTS

- 6.1. The Proposer shall provide information in the following areas with regards to cybersecurity:
- a) Security by design;
 - b) Risk assessment and management;
 - c) Security anomalies and threat detection; and
 - d) Incident response.

- 6.2. Security by Design. As part of the cyber-physical system development lifecycle, Proposers are required to provide the following information:
- a) Threat risk and Safety assessment – as part of the design process, to outline the threat scenarios, and the resultant risk and impact. It should also include also overall safety which covers, among others, safety risk assessments of both the system and vehicles as well as safety to commuters, operators and maintenance personnel. This also includes measures and/or standards to protect the all components of the system and vehicles to ensure smooth operations. This shall cover cybersecurity threats, such as the jamming of signals between fleet management system (FMS), vehicle-to-infrastructure and AV, sensor spoofing and jamming, hacking, etc., threat analysis and solutions to identified threats.
 - b) Standards and Best practices – Proposers should state the adoption of any AV cybersecurity standards and methodology, stating the appropriate references.
 - c) Design of AV and associated FMS – complete description of the design and explanation of how it addresses the cyber security threats. Proposers should provide an overview of privacy controls derived or considered in design phases.
 - d) Acceptance Security Testing – comprehensive testing plan and certification requirement for roadworthiness of the AV and its associated FMS, especially with respect to potential hostile cybersecurity environment. Proposers are also to provide recommendations on the Vehicle Safety Requirements, Assessment and Inspection process for AVs to be deployed for the public road trial.
- 6.3. Risk Assessment and Management. Proposers should also state the risk assessment and management measures throughout its lifecycle from concept phase through production, operation, service, and decommissioning, to address how the risks are managed and mitigated throughout the lifecycle of the system and vehicle.
- 6.4. Security Anomaly and Threat Detection. In the context of the dynamic cybersecurity threat landscape, Proposers should outline its system and methodology to detect security anomalies and threats, so as to proactively address potential risk and safety concerns.
- 6.5. Incident Response. Proposers should outline the system, process and tools in system response. It should also include forensic investigation and tools required to expediently determine and identify the cause of the incident.
- 6.6. Host Institution shall ensure the AESV is adequately protected against the following types of threats to ensure authenticity, confidentiality, integrity, availability, non-repudiation and accountability of data, service and access:
- a) Malware;
 - b) Denial-of-service;
 - c) Spoofing;
 - d) Replay, interception and modification of data;
 - e) Insider attacks;
 - f) Password guessing attacks;
 - g) Web vulnerability attacks including OWASP top ten;¹
 - h) Weak encryption attacks; and
 - i) Any other threats which may undermine infocomm technology security.

¹ <https://www.owasp.org>

- 6.7. Roadworthiness and Security Assurance Test (Cybersecurity). The Proposer shall:
- a) Propose vulnerability assessment, and grey/blackbox testing in the context of potential cybersecurity threats/attacks. It should include the overall framework, threat scenarios, and test specifications.
 - b) Propose additional security assurance tests to address safety and privacy concerns. It should include the overall framework, threat scenarios, and test specifications.
 - c) Test and demonstrate the cyber security capability and roadworthiness both at an AV platform level as well as at the system level.
- 6.8. The Host Institution shall promptly rectify any vulnerabilities identified resulting from vulnerability assessments and penetration tests during the trials.
- 6.9. The Proposer shall submit a security implementation plan catering to the cybersecurity requirements (e.g. anti-virus, application white-listing, Programmable Logic Controller (PLC) application firewall).

7. PHYSICAL SECURITY REQUIREMENTS

- 7.1. The Proposer shall describe how the AESV, control station, docking station, tipping/emptying station and all other equipment and installations are to be protected from theft, vandalism, sabotage and other acts of mischief.
- 7.2. The Proposer shall state the security measures and/or features to prevent its AESV from being hijacked, sabotaged, immobilised or caused to malfunction or function in a dangerous manner when it is operating without a safety operator or any onsite personnel.

8. DATA LOGGING REQUIREMENTS

- 8.1. All AESVs shall be fitted with data recorders provided by the Host Institution. These records shall capture all essential system events and machine states to facilitate troubleshooting and problem diagnosis. The data to record shall include but not limited to the following:
- a) Date;
 - b) Time (in twenty-four (24)-hour format);
 - c) GPS coordinates at one-second intervals when the AESV is running, and at intervals of 1-hour when the engine/motor is switched off;
 - d) Speed, at one (1)-second intervals;
 - e) Driverless Mode, i.e. whether on or off;
 - f) Steering, at one (1)-second intervals;
 - g) Braking, at one (1)-second intervals;
 - h) Acceleration, at one (1)-second intervals;
 - i) Force or magnitude of impact (in the event of an incident);
 - j) History log, detailing any manual override by the safety operator while the AESV is operating in its driverless mode, and the nature/type of the override;
 - k) Weather Conditions;
 - l) Video Footage; and
 - m) Vehicle-to-Vehicle and Vehicle-to-Infrastructure communications status.

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- 8.2. All data recorded by the data recorder shall not be edited, and shall provide a complete audit trail into the operations and dynamics of every process leading to a failure.
- 8.3. The Host Institution shall facilitate the retrieval and analysis of the data log files from the data recorders as soon as possible when required by the relevant authorities.
- 8.4. Recorded data shall be available for retrieval by the relevant authorities for at least 3 months. Subject to the prior-mentioned retrieval period, the data recorder shall have a file management system so that once the data recorder storage is full, manual intervention is not required to clear previous data log files.
- 8.5. The Host Institution shall provide a log analyser application software that runs on a standard Windows operating environment and allows the systematic playback of the event and machine states logs with a visual pictorial representation of the vehicles.
- 8.6. The recorded data shall be supplemented by a vehicle log that captures details of all personnel that are involved in the trial and system maintenance history.

9. DOCUMENTATION REQUIREMENTS

- 9.1. The Host Institution shall provide comprehensive documents that clearly set out the design requirements, specification and test procedures. The Proposer shall indicate in its project timeline the first delivery of these Documentation and shall continue to deliver regular updated revisions, or upon request of the Grantor, until the end of this R&D project.
- 9.2. Documentation shall contain the following:

Requirement and Design Specification Documentation

- a) System Hardware Design and Specifications Document;
- b) System Software Operational Specifications Document;
- c) System Software Functional Specifications Document;
- d) System-Vehicle Control Unit (VCU) Interface Control Document;
- e) Vehicle-Vehicle Interface Control Document;
- f) Vehicle-Infrastructure Interface Control Document;
- g) Safety Risk Assessment and Mitigation Measures Document;
- h) System Configuration, Operation and Maintenance Manual Document: This manual shall cover the technical background and the maintenance approach to be adopted, and shall include the following essential information:
 - i. Technical description of the System covering setup, configuration, functional, and maintenance aspects;
 - ii. Detailed technical description of all hardware, software and inter-connecting modules and cables;
 - iii. Schematic diagrams pertaining to the setup and installation of the System;
 - iv. Detailed hardware and software installation requirements and procedures;
 - v. Detailed procedures for routine maintenance of the System and administration;
 - vi. Detailed procedures for troubleshooting, fault tracing and repair;
 - vii. Detailed description of the maintenance tools required to upkeep the System;
 - viii. Spare parts and consumables list with order reference, part numbers and equivalents available from other third party sources; and

- ix. Relevant pamphlets, drawings, shop drawings, product catalogues, technical write-ups, standards and other references;

Test Specification Documentation

- i) Vehicle Qualification Test Plan and Procedures; and
 - j) System Qualification Test Plan and Procedures.
- 9.3. All Documentation shall be in English.
- 9.4. All Documentation shall be professionally bound or filed. It shall be in standard format size and legibly printed on good quality paper. There shall be no incoherence, illegibility or smudging in the text, drawings, diagrams and illustrations. The Host Institution shall supply both the amendable and Portable Document Format (PDF) softcopies of the documentation to the Grantor in a compact disc or other portable storage media.
- 9.5. All Documentation shall employ a logical volume numbering system with separate volumes for each classification of sub-systems. If the amount of material in any sub-system warrant separate volumes, there shall be several sub-volumes for that sub-system. Each piece of Documentation shall have a logically arranged table of contents, list of illustrations, figures, symbols, tables and references. All Documentation shall employ proper page numbering, on a sectional basis, across all volumes.
- 9.6. The Grantor reserves the right to request for such additional documentation from the Host Institution, if the Grantor deems that the existing documentation provided by the Host Institution is incomplete and unsatisfactory.

10. LICENSING REQUIREMENTS AND RESTRICTIONS

- 10.1. The Host Institution shall not operate the AESV or drive any vehicle in its driverless mode outside of the pre-trial or trial site, unless it has obtained the prior written approval of the Grantor and all other relevant authorities.
- 10.2. The Host Institution shall, at its own cost, obtain and maintain all licences, insurances, and authorisations, including permits and other governmental authorisations or certification required without any restrictions or qualifications whatsoever so as to enable the Host Institution to fulfil all its obligations under the Contract. This may include, but not limited to, the obtaining, maintaining and renewal of Special Purpose Licences, Certificates of Entitlement, Temporary Occupation Licences, drivers' licences, employment permits and any other licences or permits.

11. SPARE PARTS

- 11.1. The Host Institution shall, at all times during this R&D project, maintain in Singapore a healthy supply of spare parts (Line Replaceable Units (LRUs)) necessary to replace any damaged or defective component of the AESV.
- 11.2. The Host Institution shall bear all the costs of any replacement or damage to the AESV or its parts during the process of the trials and project period.

12. REPORTING REQUIREMENTS

- 12.1. The Host Institution shall submit no less than one set of progress reports to the Grantor every 3 months or at any time upon request by the Grantor.
- 12.2. The first report shall be submitted to the Grantor no more than 3 months from the date of award of this RFP.

12.3. The progress reports shall include the following:

- a) Progress and work done;
- b) Performance of the System compared to the targets set out;
- c) Safety records, including vehicle accidents, incidents where human intervention is required due to an unexpected failure, disruption or disengagement of the technology;
- d) Learning points and/or observations;
- e) Impact on cleaning efficiency; and
- f) Detailed compilation of data captured by the various sensor devices installed.

12.4. The Host Institution shall meet the Grantor regularly or upon request by the Grantor to provide updates on the progress of the Research and to address outstanding issues.

12.5. The Host Institution shall notify the Grantor in writing of any personnel who ceases to be employed or otherwise engaged by any Institution for the Research.

12.6. The Host Institution shall submit, to NEA for endorsement, requisitions for direct and/ or indirect costs for which the Funding is permitted to be used before submitting to the Grantor for approval on a quarterly basis.

12.7. The Host Institution shall notify the Grantor in writing of all amendments, alterations or changes that have a material effect on the scope, nature, direction or purpose of the Research as soon as possible.

12.8. The Proposer shall provide the Grantor with copies of the relevant collaboration agreement between all its Collaborators and the applicable Institutions including all amendments, modifications or revisions thereto.

12.9. The Host Institution shall immediately inform the Grantor upon its becoming aware of the occurrence of any of the events that may lead to termination under clause 19 of "Part 1b: Terms and Conditions of a Competitive Grant".

12.10. In the event of an accident involving collision of the AESV with persons, animals or property (including vehicles), regardless whether any loss or damage has occurred, the Host Institution shall submit a preliminary report within 4 hours, a full report within 24 hours and regular updates when required thereafter. If the accident has occurred as a result of malfunction of the AESV, the Host Institution shall review and propose suggestions or improvements to avoid similar future accidents.

13. INDEMNITY REQUIREMENTS

13.1. The Host Institution shall extend clause 21.1 and 21.2 in "Part 1b: Terms and Conditions of a Competitive Grant" to NEA and MOT.

14. INTELLECTUAL PROPERTY

14.1. The Proposer shall propose an Intellectual Property (IP) framework that allows the NEA and MOT's agents/contractors to use the Research IP created from this R&D project for public service and further development of the AESV.

15. RESEARCH DELIVERABLES

15.1. The Proposer shall provide a projection of Key Performance Indicators (KPIs) according to the table below.

Deliverable	KPI	
Industry Participation	Amount of Industry Funding Received (cash and in-kind)	
Train Industry Relevant Robotics Talent (RSEs)	Number of Research Scientists and Engineers (RSEs) Trained	
Build Intellectual Capital	Number of Patents Filed or Intellectual Properties Generated	
	Number of Academic Papers Published (To indicate number of peer reviewed papers published)	

15.2. These KPIs shall be tracked by the Host Institution and reported to the Grantor at the end of the project.

16. ECONOMIC SPIN-OFFS

16.1. For proposers requesting grant to support the development costs. As a general guide, Proposer requesting for grant to support the development costs shall demonstrate their economic commitment or contribution to Singapore by describing ways in which the Proposer intend to develop and build expertise and commercial activities in Singapore, as a result of collaboration.

- a) Innovation/development activities carried out in Singapore (either by a single company or in partnership). Significance of new capabilities and development activities that will be built and carried out as a result of collaboration; number of additional professionals to be employed in Singapore and seniority of stakeholders to be based in Singapore to oversee these activities during and after the completion of the development project; role of the Singapore team versus the Proposer's other development teams globally.
- b) Business/ commercialisation activities that will be established in Singapore (either by a single company or in partnership). Creation of new business streams outside of the Proposer's core/existing business; global/regional market reach and potential of new business streams; key functions of new business based in Singapore; establishment of business activities or expansion of existing operations in Singapore to support existing business streams; number of additional professionals to be employed in Singapore and seniority of stakeholders to be based in Singapore to oversee these activities. New business streams created will be considered.

16.2. The Proposer shall provide details on new or incremental business activities that will be carried out in Singapore by the Proposer.

16.3. New or incremental business activities include but are not limited to:

- a) Research & Development: R&D activities, including in areas related to AVs and robotics. This could be carried out (i) within in-house centres of innovation/competence, and/or (ii) by establishing R&D partnerships with research institutes/ IHLs in Singapore.
- b) Regional Headquarters (RHQ): Expansion/addition of RHQ activities to support operations in the region, such as regional management, sales and marketing, finance, IT, supply chain management and repair and maintenance etc.

PART 2: Requirement Specifications

- c) Commercialisation and export potential: A business plan for the commercialisation and export of new technology, product, solutions and services developed.
- d) Other economic impact in Singapore: A detailed plan on how the Proposer intend to make a positive impact on the wider economy in Singapore, in terms of building up Singapore's holistic capabilities in AV and/or robotics-related technology. This could include additional economic activities that will arise as a result of the project.

17. EVALUATION CRITERIA

17.1. Each Proposal will be evaluated in accordance with the following criteria:

S/N	Criterion	Remarks
1	Compliance to requirement specifications	Design, develop and trial of the AESV to meet requirement specifications outlined in this "Part 2: Requirement Specifications" of this RFP
2	Experience and track record	Experience and track record in: <ul style="list-style-type: none">• Developing automated or assisted-driving technologies• Developing and implementation of Environmental Services and businesses• Relevant experience in carrying out works of similar nature and value to this RFP
3	Economic impact	For proposals requesting for grant to support the development cost: Economic impact (i.e. economic spin-offs that the Proposer outlines pursuant to Section 16 of "Part 2: Requirement Specifications" of the RFP)
4	Cost	Relative cost (to other Proposals)
5	Project duration	Completion of the design and development phase of the project within a shorter duration of time will be favoured