

# ED-331

## GUIDANCE FOR THE USE OF AUTOMATED GROUND MOVEMENT EQUIPMENT TO MOVE VTOL AIRCRAFT WITH PASSENGERS ONBOARD AT VERTIPOINTS

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**FEBRUARY 2025**

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## CHAPTER 1

### INTRODUCTION

#### 1.1 PURPOSE AND SCOPE

##### 1.1.1 Purpose

This document provides guidance for the safe operation of automated ground movement equipment (GME) for vertical take-off and landing (VTOL) aircraft with can also be used for the GME operations without passengers as it already considers high level of safety in operations. The content in this document complements the EUROCAE Guidance for Vertiport Operators and Operations (ED-299) and provides a foundation for the subsequent development of technical standards for automated GME.

##### 1.1.2 Scope

The scope of this document is confined to the safe operations of automated GME for VTOL aircrafts.

This document:

- Describes high level operational concept and automation concept of the automated GME.
- Applies existing definitions and levels of automation adapted from the automotive sector as baseline.
- Describes process steps of overall operations for the deployed GME depending on the level of automation designed for the equipment.
- Provides guidance on the risk assessment that operators of automated GME should follow to ensure safe GME operations.

This document does not provide mechanical design standards e.g., interfaces to VTOL aircraft, technical specification for the automated GME and software requirements for automation.

**NOTE:** *GME in this document henceforth refers to the automated GME.*

##### 1.1.3 Assumptions and Considerations

- Automated GME may be operated by vertiport operators, VTOL aircraft operators or a ground handling entity.
- Existing aircraft towing and pushback processes, risks and standards should be considered when establishing automated GME concept of operations (ConOps) at vertiports.
- VTOL aircraft could come in multiple designs and configurations. A GME should, where feasible, be interoperable across VTOL aircraft types and its landing gears.
- This document should be used in conjunction with relevant industry standards for GME, GSE standards in aviation, vertiports standards and autonomy standards to enable safe operation of automated GME at a vertiport.

#### 1.2 REFERENCES

|                    |                                                                                                                                                        |
|--------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| [ED-299]           | EUROCAE "Guidance for Vertiport Operators and Operations"                                                                                              |
| [SAE J3016]        | Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles                                                    |
| EASA [PTS-VPT-DSN] | Prototype Technical Specifications for the Design of VFR Vertiports for Operation with Manned VTOL-Capable Aircraft Certified in the Enhanced Category |

## CHAPTER 2

### GME OPERATIONAL CONCEPT

#### 2.1

#### INTRODUCTION

The automated ground movement equipment (GME) is a ground support equipment used to perform automated ground movement. The GME is responsible for performing the ground movement task. The automation software is responsible for the monitoring the GME, the operational design domain and fleet management tasks which includes job allocation, waypoint calculation, conflict management etc.

operations take place on the infrastructure components referenced herein:

- FATO (final approach take-off area): A defined area over which the final phase of the approach manoeuvre to hover or landing is completed and from which the take-off manoeuvre is commenced.
- TLOF (Touchdown and lift-off area): An area where a VTOL-capable aircraft may touchdown or lift-off on the vertiport.
- Taxiway: It is intended to permit the surface movement of a VTOL-capable aircraft either under its own power or by means of ground movement equipment.
- Stand: A designated area on the vertiport to permit the safe loading and off-loading of passengers and/or cargo, as well as the servicing of VTOL-capable aircraft without interfering with the apron traffic.
- GME service roads: the network of roads on the vertiport apron that allow GMEs to move around the vertiport. These roads are exclusively used by GMEs for a variety of essential services and are separated where possible from taxiways, other service roads and FATOs to ensure the safe and efficient movement of GME within the vertiport.

For VTOL operations, the task of GME is to bring the VTOL aircraft from the TLOF to Stands and vice versa using the taxiways and GME service roads. The guidance on the use of GME service roads is discussed in section 2.4. The GME service roads are meant to be used by a GME which is not transporting a VTOL aircraft. During the arrival of an aircraft at a TLOF, the GME can ideally use the service road to position itself near the TLOF without blocking the taxiway and without interfering with any other aircraft surface movement. Similarly, during departure of a VTOL aircraft, the GME can return to stands or to next job using the service roads after placing the aircraft on the TLOF. When the GME is not in use for example when waiting for a new job, it can be parked/ charged at the GME depot. Following figure shows an example of a generic vertiport for automated GME operations.

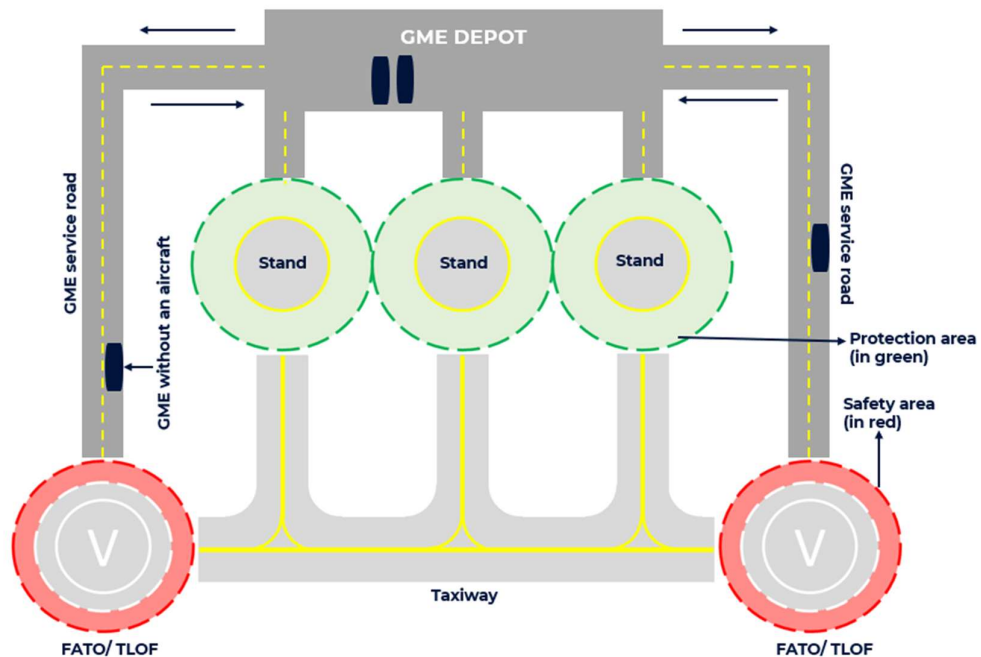


**FIGURE 2-1: EXAMPLE OF GENERIC VERTIPORT WITH 2 FATO / TLOF (WITH SAFETY AREA IN RED), 3 STANDS (WITH PROTECTION AREA IN GREEN), SERVICE ROADS AND GME DEPOT**

## 2.2 EQUIPMENT FOR VTOL GROUND MOVEMENT

Expected equipment to support VTOL aircraft ground movement include:

### (i) Ground movement equipment:

It is expected that these vehicles will interface with the VTOL aircraft at designated position on its landing gear system. The landing gear could be wheeled or skids depending on the design of the VTOL aircraft.

### (ii) Ground movement equipment control device:

It is expected that these vehicles will be supervised and partially controlled by a ground movement equipment operator (GMEO) with a control device. The device has a digital interface for the GMEO through radio, mobile, tablet, or desktop devices, and can communicate with the GME via radio frequency, cellular networks, Wi-Fi, Dedicated Short Range Communications, satellite connectivity, Vehicle-to-Everything, or Bluetooth. The GMEO can control partial or full movement of the vehicle through the device. It allows the GMEO to visualize GME movements and operations, while providing fallback options during VTOL aircraft coupling procedures.

## 2.3 VTOL GROUND MOVEMENT ROLES AND COMMUNICATION

Expected roles to support VTOL aircraft ground movement include:

### (i) GME operator (GMEO)

- Appropriately trained and competent in VTOL aircraft ground movement methods.
- Operating the GME safely and in accordance with ground movement vehicle and infrastructure requirements and procedures.
- Communication with the pilot to ensure safe completion of all VTOL aircraft ground movement missions.
- Acting in accordance with equipment and VTOL aircraft and vertiport emergency plans and procedures.
- Ensuring GME is serviceable and suitable for VTOL aircraft types.

### (ii) Pilot in Command (PIC)

- The PIC has the final authority to the operation of the VTOL aircraft and should be in communication with the GMEO when the VTOL aircraft is coupled with the GME.
- Appropriately trained and competent in VTOL aircraft ground movement methods including coordination and communication with the GME and GMEO.
- It is expected that the GMEO and the pilot will require communication whilst completing ground movement tasks. Common communication methods may include standard hand signals, use of headsets, radios, digital mobile devices, or similar.

## **2.4 GUIDANCE FOR GME SERVICE ROADS**

GME that is coupled to a VTOL aircraft with/ without PAX onboard should follow dedicated paths for aircraft movement such as taxiways, lead in lines, ground guidance markings etc.

GME that is not coupled to a VTOL aircraft should follow dedicated paths for GME movement such as service roads.

If service roads are not available, use of dedicated path used by aircraft should be agreed between the GMEO and vertiport operator.

As the ground movement operation is part of the Vertiport operator's responsibility, the vertiport operator is responsible for establishing the traffic rules and conducting the safety risk assessments for the operations of GME with and without an aircraft connected. This is especially important in the case of different VTOL types and their ground operations.

### **2.4.2 GME and GMEO movement on the Vertiport apron**

- GME and the GMEO should use the taxiways and GME service roads according to the traffic rules defined by the vertiport operator unless otherwise authorized by the vertiport operator.
- GMEO and GME, when coupled to a VTOL aircraft should always move along the marked taxiway.

### **2.4.3 Taxiway and service road priorities**

- When a service road crosses the taxiway:
- Movement on the taxiway should have the highest priority.
- GME and the GMEO should always follow signs and marking defined by the vertiport while crossing the taxiway.
- GME and the GMEO should always cross the taxiways according to the traffic rules established by the vertiport operator.

## **2.5 GME PROCESS STEPS**

The following table shows the general process steps for GME operations without considering the automation. The process steps corresponding to the automation levels are discussed in section 4.4.

TABLE 2-1. GENERAL PROCESS STEPS FOR GME OPERATIONS

|                   |                                         |                                                                                                           |
|-------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------|
| <b>Arrivals</b>   | <b>Aircraft approach and landing</b>    | Ground movement task is allocated                                                                         |
|                   |                                         | GME moving and positioning to designated area near safety area of FATO                                    |
|                   | <b>GME coupling</b>                     | Clearance for entering the safety area and FATO and positioning to the aircraft                           |
|                   |                                         | Approach to the aircraft in the FATO                                                                      |
|                   |                                         | Clearance to couple the GME to aircraft                                                                   |
|                   |                                         | GME alignment with interfacing point and coupling with the aircraft (includes a braking sequence for GME) |
|                   |                                         | GME coupling with the aircraft confirmed                                                                  |
|                   | <b>Aircraft ground movement</b>         | Clearance for ground movement of aircraft                                                                 |
|                   |                                         | Aircraft and GME follows brake release sequence (exact sequencing depends on the aircraft and GME type)   |
|                   |                                         | Ground moving of aircraft to the parking stands                                                           |
|                   | <b>GME decoupling/ aircraft parking</b> | Aircraft positioning to its assigned parking stand                                                        |
|                   |                                         | Aircraft and GME follow brake sequence (exact sequencing depends on the aircraft and GME type)            |
|                   |                                         | GME may be charged during the aircraft turnaround                                                         |
|                   |                                         | OR                                                                                                        |
|                   |                                         | Clearance for GME decoupling                                                                              |
|                   |                                         | GME decoupling from the aircraft and vacating the parking stands                                          |
| <b>Departures</b> | <b>Aircraft pre-departure</b>           | Ground movement task is allocated                                                                         |
|                   | <b>Aircraft coupling (optional)</b>     | GME positioning to the designated area around parking stand                                               |
|                   |                                         | Clearance for GME coupling                                                                                |
|                   |                                         | GME alignment with interfacing point and coupling with the aircraft                                       |
|                   |                                         | GME coupling with the aircraft confirmed OR:                                                              |
|                   |                                         | The GME is already coupled to the aircraft and is disconnected from any charging infrastructure           |
|                   | <b>Aircraft ground movement</b>         | Clearance for ground movement                                                                             |
|                   |                                         | Aircraft and GME follows brake release sequence (exact sequencing depends on the aircraft and GME type)   |
|                   |                                         | Ground Movement of aircraft to the FATO (may include pushback component)                                  |
|                   |                                         | Positioning to the designated safety area near FATO initiated                                             |
|                   | <b>Entering FATO and de-coupling</b>    | Clearance for entering the FATO                                                                           |
|                   |                                         | Aircraft positioning to inside the FATO and engaging brake sequence                                       |
|                   |                                         | Clearance for GME decoupling                                                                              |
|                   |                                         | GME releasing the brake sequence, decoupling from the aircraft and vacating the FATO                      |

## CHAPTER 3

### GME AUTOMATION CONCEPT

#### 3.1

#### INTRODUCTION

The framework of this automation concept is derived from SAE's taxonomy (SAE J3016) related to automated driving systems used in the automotive industry. The SAE framework provides descriptive definitions used in the vehicle automation systems and provides six levels of automation ranging from no automation to full automation. The SAE taxonomy describes the role of automation system in the Dynamic Driving Task and tactical function to operate a vehicle in a dynamic environment.

The functions of an automated GME are similar to an automated vehicle as referred to in SAE J3016. In addition to the DDT, the GME has an extra task of coupling and decoupling with VTOL aircraft which is referred to as Aircraft Interface Task (AIT) in this guidance document. This guidance document addresses the role of different levels of automation functions with respect to GME operations.

The SAE taxonomy also describes the role of Operational Design Domains (ODDs) i.e., operating conditions for the automation system. Unlike the ODDs specified for the self-driving automobile industry, the operational domain of GME will be highly controlled due to a controlled vertiport environment. Operations such as VTOL towing, maintenance towing, and operational navigation across the vertiport will all be sequenced and closely coordinated between GME operators (GMEOs), pilots, and other vertiport staff. Furthermore, visual cues on the vertiport such as taxiway lines, FATO markings and hold lines serve as navigational aids for mapping and SLAM-based functionalities. Some vertiports may explore installing additional markers and tags for computer vision-based recognition or introduce precise localization systems such as RTK base stations. The current physical space of vertiports for this matter is comprehensively labelled, where future systems can build in further constraints into the environment and help introduce additional safety redundancies into the ODD. Thus, the operational domain of the GME will be less uncertain with fewer edge cases when compared to the ODDs referred to in SAE taxonomy concerning automobiles on public roads. This premise forms the basis for vertiport operators to introduce higher automation levels with a higher degree of certainty for ensuring airside safety.

The automated GME can be partially operated or supervised by a GMEO operator. The GMEO is the responsible entity for GME missions on a vertiport or aerodrome. The role of the GMEO in the automation ConOps is described in CHAPTER 3. Apart from the DDT and AIT, GME automation includes two major tasks namely, Fleet

Management Task and System Monitoring Task which are described in Section 2.1. The following figure shows all modules in the GME automation.

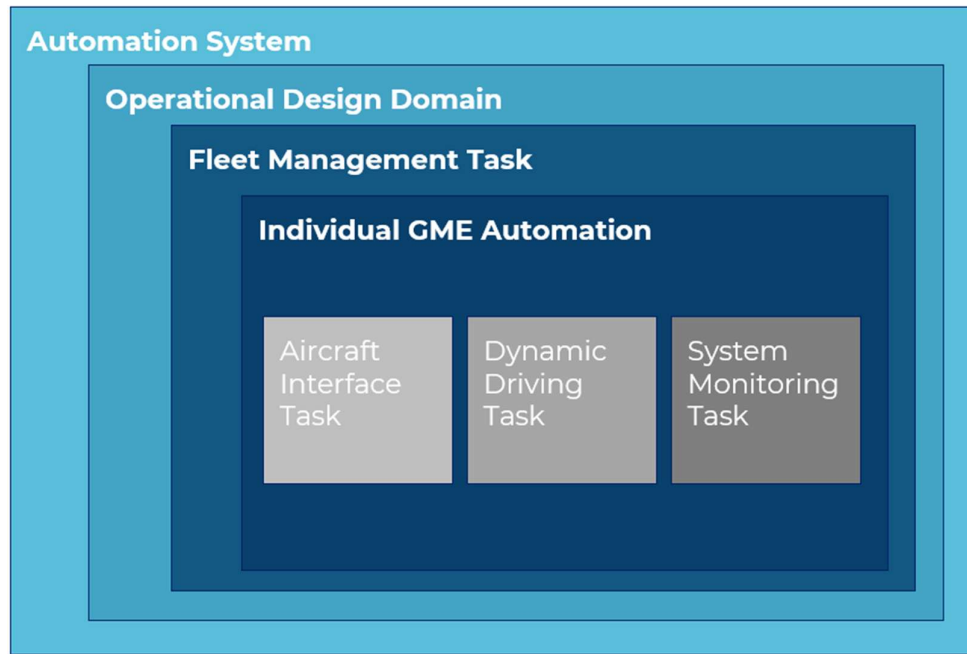


**FIGURE 3-1: GME AUTOMATION SYSTEM MODULES**

## **3.2 GME AUTOMATION MODULES AND SUB-MODULES**

### **3.2.1 Automation System**

The Automation System is the entity involved in the command and control of the GME across the vertiport apron surface. It serves as the “brain” behind the operation, ensuring that the ODD, FMT, AIT, DDT and SMT tasks are performed accordingly. The Automation System rests in a cloud-native environment and takes the form of a software program.

The Automation System consolidates the GME automation modules & sub-modules and is responsible for coordinating the traffic of GME & GMEO across stands, service roads, taxiways, and FATOs. The Automation System should be capable of reading data from air traffic control or flight data systems, whether such systems are operated by a vertiport operator, aircraft manufacturer, or air carrier. The Automation System has a digital interface for the GMEO through mobile, tablet, or desktop devices, and can communicate with the GME via cellular networks, Wi-Fi, Dedicated Short Range Communications, satellite connectivity, Vehicle-to-Everything, or Bluetooth.

The system is then responsible for scheduling and assigning jobs to both GME and GMEO to perform service needs for VTOL aircraft, whether via automated commands to GME or notifying GMEO through their devices. In doing so, the system accounts for availability of both GME and GMEO, VTOL aircraft-GME compatibility, charge levels of both GME and VTOL aircraft, and distance between stands and FATOs, among other constraints.

Specifically, GME operational statuses across the vertiport are relayed to the Automation System, where available GME with nominal charge levels are considered for the operation. The Automation System dispatches both GME & GMEO, plotting a reference trajectory between a stand and FATO. Similarly, dynamic path updates for GME are issued when necessary, by the Automation System according to potential weather warnings, air traffic/flight plan changes, or near-field obstacles/obstructions detected by the GME or GMEO.

The Automation System enables both GME & GMEO to be quickly and proactively positioned for servicing VTOL aircraft. In this regard, the system tracks and allows GMEO to visualize live interactions between GME & VTOL aircraft, whether remotely or in-situ, and monitor potential vertiport conflicts.

The automation system acts as the digital liaison with the vertiport operator, reading and writing information that is relevant to the service operations of VTOL aircraft on the vertiport.