

ED-309

GUIDANCE ON VTOL ENERGY LEVEL INFORMATION PROVIDED TO THE CREW

LEGAL NOTICE

This document is the exclusive intellectual and commercial property of EUROCAE. It is presently commercialised by EUROCAE. This electronic copy is delivered to your company/organisation for internal use exclusively. In no case it may be re-sold, hired, lent or exchanged outside your company. It may not be reproduced, in whole or in parts, without prior written permission by EUROCAE.

FEBRUARY 2023

FOREWORD

1. This document was developed by EUROCAE Working Group 112 “Vertical Take off and Landing (VTOL)” and was approved by EUROCAE on 01 February 2023.
2. This document was prepared following a lean development process, as per EUROCAE Council decision 304-3.
3. EUROCAE, an international non-profit organisation, is the European leader in the development of worldwide recognised standards for aviation. This is achieved by utilising the expertise from our members and stakeholders across the global aviation community.
4. EUROCAE standards are developed following an open, transparent and consensus-based process, governed by process and quality management principles, which are clearly documented and is in line with the World Trade Organisation (WTO) Technical Barriers to Trade (TBT) Agreement, Annex 3 “Code of Good Practice for the Preparation, Adoption and Application of Standards”.
5. EUROCAE standards and other deliverables are recommendations and best industry practices. EUROCAE is not an official body of the European governments. EUROCAE standards are intended to complement and support the regulatory and certification framework.
6. Whilst efforts are made during the standards-development process to avoid the inclusion of proprietary information and material, some of the elements of this document may be the subject of patent, copyright or other proprietary rights. EUROCAE shall not be held responsible for identifying any such rights. Trade names and similar terms used within this document do not constitute an endorsement by EUROCAE thereof.
7. Copies of this document may be obtained from:

EUROCAE

9 – 23 rue Paul Lafargue

93200 Saint-Denis

France

Telephone: +33 1 49 46 19 65

Email: eurocae@eurocae.net

Website: www.eurocae.net

TABLE OF CONTENTS

FOREWORD	i
TABLE OF CONTENTS	ii
TABLE OF FIGURES	ii
TABLE OF TABLES	ii
CHAPTER 1 INTRODUCTION	1
1.1 Purpose and Scope	1
1.2 Applications	1
1.3 Assumptions	1
1.4 Definitions and Abbreviations	2
1.5 References	2
1.6 Relationship to SC VTOL	2
1.7 Relationship to other documents	2
1.8 Definition of energy storage system limiting factors	2
1.9 Definition of battery state observation and prediction	3
1.9.1 Energy System States Observation.....	3
1.9.2 Pre-flight Prediction of States	4
1.9.3 In-flight State Prediction	6
CHAPTER 2 FUNCTIONAL REQUIREMENTS.....	8
2.1 General requirements.....	8
2.2 Energy indication requirements.....	8
2.2.1 Indication of the deviation of the current SOF from the planned SOF	8
2.2.2 Predicted surplus SOF at Destination	9
2.2.3 SOF trend information	9
2.2.4 Current SOF indication	9
WG-112 SG-6 MEMBERSHIP.....	1
IMPROVEMENT SUGGESTION FORM	6

TABLE OF FIGURES

Figure 1-1: Battery states observation	3
Figure 1-2: Evolution of state of function.....	4
Figure 1-3: Pre-flight prediction of the SOF.....	5
Figure 1-4: Pre-flight planned SOF profiles.....	5
Figure 1-5: Energy reserve breakdown	6
Figure 1-6: In-flight energy system states prediction	6
Figure 1-7: In-flight prediction profiles and information to be used to provide indications	7

TABLE OF TABLES

TABLE 1-1: List of Abbreviations	2
--	---

CHAPTER 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

This document provides means of compliance with the EASA SC-VTOL requirement VTOL.2615 (a) regarding lift/thrust instruments related to the energy state.

It defines compliance methodologies for the energy level information that should be presented to the crew during the flight planning and execution phase for electrical Vertical Take-off and Landing (eVTOL) aircraft.

This document is focused on electrical propulsion, as this type of lift/thrust has specific challenges that require new strategies to be put in place to enable safe operations.

Energy Storage Systems (ESS) is recognised to be limited in capability to provide the same level of certainty of the available usable energy, as compared to conventional fuel-based systems.

Power that can be delivered from the ESS to the lift/thrust units is not constant and varies in relation to several parameters, that include the State of Function (SOF) and State of Health (SOH).

The energy required to complete a flight considering the applicable reserves will be dependent also on the planned power demand profile.

The margin between the amount of available energy and predicted energy at a given point during the flight, should be estimated, and clearly displayed as it is an important information to support decision making by the crew.

There should be clear indications of how this margin changes as the crew choose/change the destination/alternate vertiport, increase/decrease speed, change or are asked to change cruise altitude or encounter/update different external ambient conditions (winds, OAT).

Interpreting the observed available energy as well as predicting the surplus at the end of the flight given the mentioned above factors would require continuous complex calculations, which the flight crew most likely will not be able to perform, without additional supporting tools and indications.

Uncertainties in energy observation and prediction introduced with electrical propulsion can be managed by either increasing the safety margins when calculating the energy requirements for a flight, reducing considerably the range of eVTOLs, or increasing the accuracy of the prediction of the difference or margins between available and required energy (energy margin).

1.2 APPLICATIONS

Compliance with this guidance by manufacturers, installers and users is recommended as a means of assuring that systems will satisfactorily perform its intended function(s) under all conditions normally encountered in routine aircraft operations.

Any regulatory application of this document in whole or in part is the sole responsibility of appropriate government agencies.

1.3 ASSUMPTIONS

This document is intended as means of compliance to the EASA SC-VTOL requirement VTOL.2615 (a) for lift/thrust instruments related to the energy state and margins.

It defines information that shall be presented to the crew in support of its decisions making regarding energy state and margins.

It does not address aspects of energy system design or performance calculation methodologies (for determination of accessible energy in battery system see [2]).

Requirements regarding energy planning and replanning are covered in [3].

It is also assumed that the representation and management of the displayed information is consistent with the below listed industry accepted recommended practices and the recommended practices for the design and installation of the displays:

- SAE AS8034C Minimum Performance Standard for Airborne Multipurpose Electronic Displays
- EASA AMC 25-11 Electronic Flight Displays
- EASA AMC 23.1311-1C Installation of Electronic Display in CS-23 Airplanes
- SAE ARP 4102/4 Flight Deck Alerting System
- SAE ARP 4102/7 Electronic displays
- SAE ARP 4032 Human Engineering Considerations in the Application of Colour to Electronic Aircraft Displays
- SAE ARP 4102 Flight Deck Panel, Controls and Displays

The equipment implementing the energy level information display to the crew and its installation on the aircraft shall meet the objectives set in VTOL.2510 of SC-VTOL [1].

1.4

DEFINITIONS AND ABBREVIATIONS

TABLE 1-1: LIST OF ABBREVIATIONS

ESS	Energy Storage System
EVTOL	Electrical Vertical Take-Off and Landing
SOC	State of Charge
SOF	State of Function
SOH	State of Health

1.5

REFERENCES

- [1] Special Condition: Vertical Take-Off and Landing (VTOL) Aircraft // EASA, Doc. No: SC-VTOL-01, Issue: 1, Date: 2 July 2019.
- [2] ED-289 – Guidance on Determination of Accessible Energy in Battery Systems for eVTOL Applications // EUROCAE, April 2021.
- [3] “Introduction of a regulatory framework for the operation of drones” // Notice of Proposed Amendment 2022-06, EASA.

1.6

RELATIONSHIP TO SC VTOL

Whilst this standard was developed with a particular view to the European legal framework, namely the EASA Special Condition VTOL [1], it may be applied to support other regulatory frames.

As regards the EASA SC VTOL, this standard supports the showing of compliance with the following requirements and/or complements the following related Means of Compliance: VTOL.2615 (a).

1.7

RELATIONSHIP TO OTHER DOCUMENTS

- ED-289 – Guidance on determination of accessible energy in battery systems for eVTOL applications.

1.8

DEFINITION OF ENERGY STORAGE SYSTEM LIMITING FACTORS

Aspects of providing accessible energy for the planned flight are covered in the EUROCAE document ED-289 “Guidance on determination of accessible energy in battery systems for eVTOL applications”, which provides information on the limiting factors of an electric energy system, as well as defining terms that are also used within this document, such as: “State of Function” (SOF) and “State of Health” (SOH).

ED-289 [2] also covers aspects of physical limits and corresponding safety tolerances and buffers with respect to the ESS.

1.9 DEFINITION OF BATTERY STATE OBSERVATION AND PREDICTION

Limitations of battery systems and the ability to predict energy consumption and availability to be used by electrical lift/thrust systems are covered in ED-289 [2].

The information presented in this section is intended to provide background information regarding energy system state observation and predictions.

1.9.1 Energy System States Observation

ESS SOF are continuously observed using measurements from battery sensors and compared to expected values during the flight.

Logical diagram of the energy system state observation is shown in the Figure 1-1.

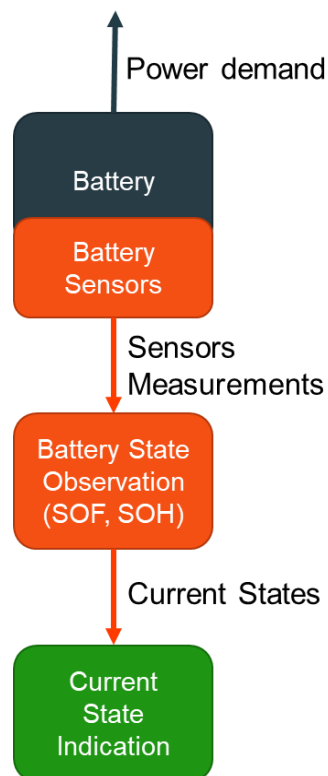


FIGURE 1-1: BATTERY STATES OBSERVATION

Observed current battery states (SOF and SOH) are then used to provide indication to the crew.

If observed states of function are approaching predefined safety limits associated with the low energy, the alert will be provided to the crew and corresponding operational procedure will be initiated.

However, if the currently observed SOF is far from its safety limits, direct indication of the current state alone does not provide sufficient information about its capability to support the remaining flight.

During the flight, observed states are changing due to the continuous power demand from the lift/thrust system.

Evolution in time of the observed SOF because of the applied power demand can be represented as shown in the Figure 1-2. Note that typical evolution of State of Charge is used as an example in these graphs, while other SOF may evolve differently.

Hereinafter, the “Current SOF”, as well as other SOF related values used for indication, are the remaining values with respect to all necessary safety related buffers.