TECHNICAL REPORT

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Space systems — Space batteries — Guidelines for in-flight health assessment of lithium-ion batteries

Systèmes spatiaux - Batteries spatiales - lignes directrices pour l'évaluation en vol de la santé des batteries lithium-ion

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

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

Introduction

The charge and discharge cycle of a battery is not 100 % efficient, with each cycle side reactions can occur that eventually accumulate and cause degradation of the battery's performance. Understanding how the battery's performance changes throughout the mission is a subject of importance; and accurate determination of the battery's current SoH is essential in a large number of situations, for example:

— the routine assessment of battery performance to allow early detection of anomalies (by comparing its actual versus predicted performance);

— the setting of alarm thresholds to ensure adequate energy;

— detection of battery anomalies that can put at risk the spacecraft passivation and/or de-orbiting strategy;

— decisions regarding mission extension beyond initial target life;

— evaluating the remaining capability of a spacecraft upon occurrence of an anomaly;

— feedback to the battery manufacturer to improve the performance predictions.

However, it is often difficult to properly assess the in-flight status, due to various factors:

— Flight electrical load profiles differ significantly to load profiles used to characterize battery performance models and the battery's SoH; for example, the total available battery capacity, which is the most important parameter, is not directly accessible during flight since its simple measurement by full discharge of the battery goes against the spacecraft operational safety.

— The quality of the accessible data from telemetry is sometimes poor: insufficient telemetry resolution and/or accuracy, lack of synchronization between related parameters like current and voltage, possibly large load consumption fluctuations introducing a high level of noise, delivery of data under a form not easy to process, etc.

— The battery is operating in flight in a way that is generally very different from the test conditions at qualification or acceptance. As a consequence, if no in-flight assessment has been made at the beginning of life, the direct comparison between current in-flight status and available ground testing data can be difficult and in any case more difficult than a comparison with the initial in-flight behaviour.

— The battery is operated under time variant conditions in a large bandwidth of different time scales, e.g. switching heater circuits vs. variations of the charge profile and eclipse length for a LEO satellite with drifting orbit. Low frequency variations introduced by drifting orbits or seasons are considered for the computation of trends and averaging over several orbits.

— The processing of data to derive the health status is not straightforward and is usually performed by identifying the ageing parameters of a model. Therefore, the representativeness of this model is a key issue. In addition, even with a good model, the results are not always satisfactory.

Therefore, it has been found of interest to provide detailed information about the means currently used or envisioned to perform in-flight battery health assessment and to make recommendations to spacecraft builders, operation managers and batteries manufacturers that would make it easier. This is the subject of this document.

It is important to highlight that, according to the definition given in 3.1.1, assessing the health status allows to verify that the battery behaves as well as or possibly better than anticipated. It is not aimed at providing an evaluation of any sort of "absolute ageing" nor to predict further evolution, even if this can be the case with some methods and their on-board implementation.

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IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document provides detailed information on the various methods of assessing the health status of lithium-ion space batteries in flight and makes recommendations to battery suppliers, spacecraft manufacturers and operators to ease this assessment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 17546, *Space systems — Lithium ion battery for space vehicles — Design and verification requirements*

3 Terms, definitions and abbreviated terms

3.1 Term and definitions

For the purposes of this document, the terms and definitions given in ISO 17546 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
battery health
state of the battery, which is healthy if both the amount and the rate of degradation of its performance are lower than or equal to the predicted ones at the same time into the mission

3.2 Abbreviated terms

ADC	analogue to digital converter
BoL	beginning of life
CC	constant current
CV	constant voltage
DoD	depth of discharge
EIS	electrochemical impedance spectroscopy
EMF	electro-motive force (a.k.a. open circuit voltage)