



AEROSPACE INFORMATION REPORT

AIR6897™

Issued

2020-08

Battery Management Systems for Rechargeable Lithium Batteries Used in Aerospace Standards

RATIONALE

Unlike traditional aerospace batteries with aqueous-based electrolyte (lead-acid, nickel-cadmium, and nickel-metal hydride), rechargeable lithium batteries (RLBs) must incorporate a battery management system (BMS) to achieve an acceptable degree of reliability and safety as required for aerospace applications. The primary function of the BMS is to monitor the state of the cells and protect them from harmful conditions such as overvoltage, undervoltage, overcurrent, and overtemperature. Other typical functions of the BMS include cell balancing, state of charge estimation, state of health estimation, and built-in test. Optional functions that can be part of the BMS include prognostics for end of life, external communication, and data logging. The performance and reliability of the BMS is critical to successful adoption of RLBs for aerospace applications. However, at present, there are no documents that provide recommended practices or standardized requirements for the design and verification of BMS functionality in aerospace RLBs.

1. SCOPE

This AIR provides basic background information and guidance for design and development of BMS architectures to be used in RLBs for aerospace applications. This guidance applies to batteries that are considered "installed" equipment and are intended to be part of the original or supplemental type certification or military airframe qualification.

1.1 Purpose

The purpose of this AIR is to provide a framework for developing a standardized approach for BMS design and development along with qualification/certification of RLBs that incorporate the BMS.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP4754 Guidelines for Development of Civil Aircraft and Systems

ARP4761 Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

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2.1.2 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA DO-160G Environmental Conditions and Test Procedures for Airborne Equipment

RTCA DO-178C Software Considerations in Airborne Systems and Equipment Certification

RTCA DO-254 Design Assurance Guidance for Airborne Electronic Hardware

RTCA DO-311A Minimum Operational Performance Standards for Rechargeable Lithium Batteries and Battery Systems

2.1.3 Other Publications

"Battery Management Systems for Large Lithium-Ion Battery Packs," by Andrea, D., Artech House (2010).

DOT/FAA Advisory Circular AC 25.1360-1, "Protection Against Injury," dated 10/22/2007.

MIL-PRF-29595A, "Battery and Cells, Lithium, Rechargeable, Aircraft, General Specification for," dated 4/26/2011.

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 Other Publications

"Successful Early Detection of Incipient Internal Short Circuits in Li-Ion Batteries and Prevention of Thermal Runaway," by Barnett, B., McCoy, C., Ofer, D., and Sriramulu, S., Electrochemical Society Extended Abstracts, MA2016-03 257.

"Implementation of Internal Short Circuit Detection for Enhanced Safety in DOD Batteries," by McCoy, C., Sriramulu, S., Barnett, B., and Kotal, T., 48th Power Sources Conference, Session 7, June 2018.

"Detection of Internal Short Circuit in Lithium Ion Battery Using Model-Based Switching Model Method," by Seo, M., Goh, T., Park, M., Koo, G., and Kim, S.W., Energies 2017, 10, 76.

"FreedomCAR Battery Test Manual for Plug-in Hybrid Electric Vehicles," by Belt, J.R., INL/EXT-07-12536, Rev 2, December 2010.

"Critical review of state of health estimation methods of Li-ion batteries for real applications," by Berecibar, M., Gandiaga, I., Villarreal, I., Omar, N., Van Mierlo, J., and Van den Bossche, P., Renewable and Sustainable Energy Reviews, 56, 572-587, 2016.

"A multi time-scale state-of-charge and state-of-health estimation framework using nonlinear predictive filter for lithium-ion battery pack with passive balance control," Hua, Y., Cordoba-Arenas, A., Warner, N., and Rizzoni, G., Journal of Power Sources, 280, 293-312, 2015.

2.3 Definitions

BATTERY: Generic term for an electrochemical energy storage device.

BATTERY SYSTEM: Top-level configuration for installations that include multiple battery packs or a dedicated battery charger.

CELL: Individual electrochemical unit, consisting of anode, cathode, separator, and electrolyte contained within a sealed casing.

MODULE: Sub-assembly of cells that are electrically connected in series or parallel, or a combination thereof. It may include BMS or BMS components. Battery packs may or may not include modules.

PACK: Assembly of cells or modules that are electrically connected in series, in parallel, or a combination thereof, along with the BMS. It represents the fully packaged article that is installed in the aerospace vehicle.

3. CURRENT PRACTICE

Virtually all RLBs that are currently available incorporate a BMS. The BMS can range from a very simple design to a very complex design. For aerospace applications, the BMS is critical for achieving the reliability and safety requirements of installed equipment. Therefore, the BMS in an aerospace battery pack tends to be on the complex side. For certification purposes, the BMS is required to meet the Development Assurance Level (DAL) consistent with the failure condition classification of the installed battery pack. Obviously, a BMS designed to meet DAL Level A will be considerably more complex than one designed to meet DAL Level D or E (refer to ARP4754 and ARP4761).

There are two widely recognized specifications for aerospace RLBs: DO-311A and MIL-PRF-29595A. DO-311A is intended for commercial (non-military) aircraft batteries and MIL-PRF-29595A is intended for military aircraft batteries. Both of these specifications have extensive testing requirements for RLBs, but contain minimal design requirements and test methods for the BMS. This AIR is intended to provide a foundation for developing BMS design requirements and test methods.

3.1 BMS Functions

Figure 1 presents a block diagram of a representative BMS showing various functional categories and a listing of typical functions under each category. Not all of these functions will necessarily be included in each specific BMS design. Determining which BMS functions to include will depend on the specific cell characteristics and application requirements. A discussion of each function is given below.

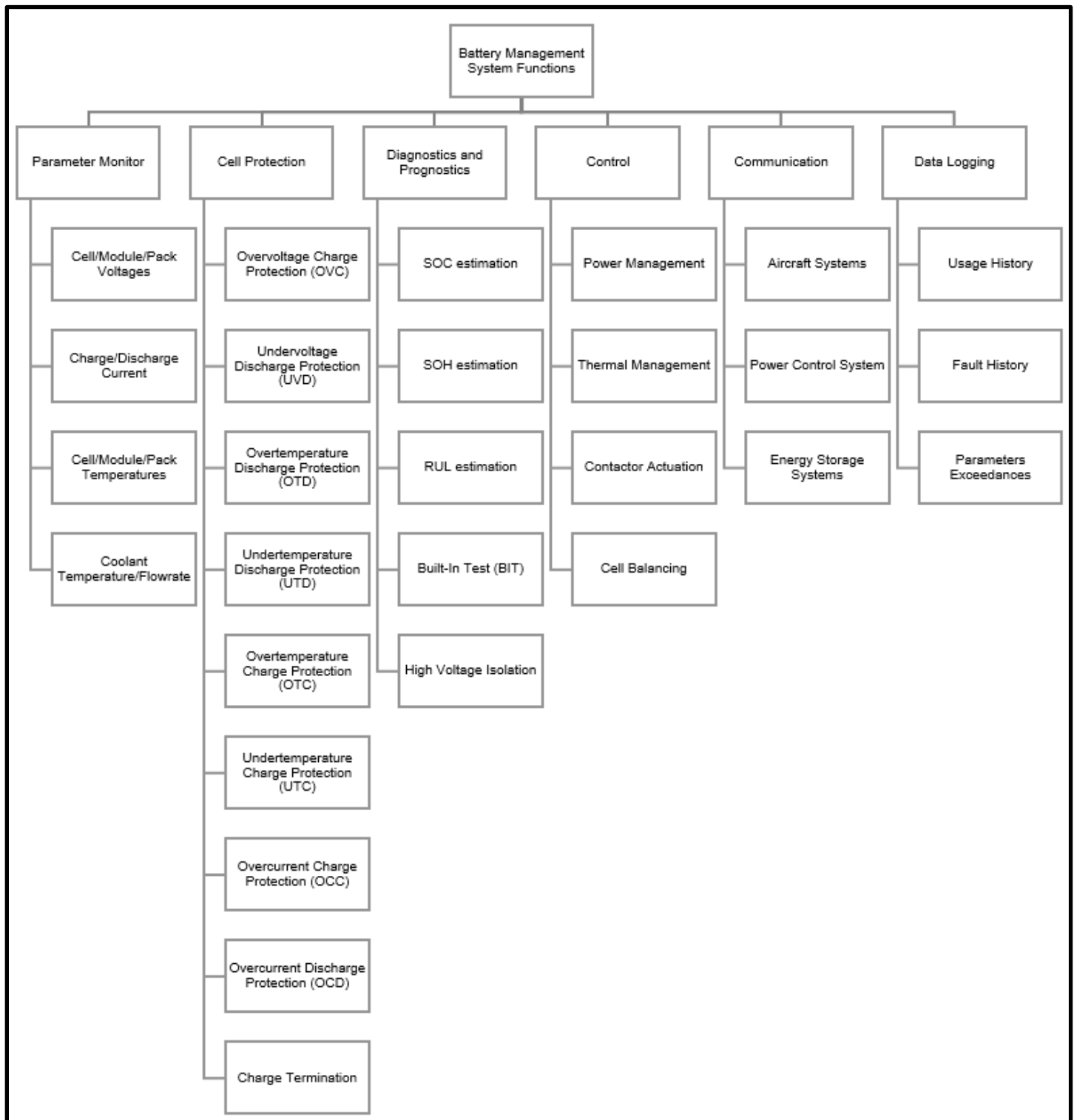


Figure 1 - BMS functions