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Health Management Design Considerations for an All Electric Aircraft

Robin.K.Sebastian[a, b*], Dr. Suresh Perinpinayagam[b], Raj Choudhary[b].

[a]*Hindustan Aeronoutics Limited, Bangalore,Aircraft Reasearch and Design Centre, Karnataka,560037,India.*
[b]*IVHM Center, Cranfield University, Bedfordshire,MK43 0AL,UK.*

* Corresponding author. Tel.: +44 7404710740; *E-mail address:* robinksebastian@yahoo.co.in, robin.kuttikkadan-sebastian@cranfield.ac.uk

Abstract

This paper explains the On-board IVHM system for a State-Of-the-Art "All electric aircraft" and explores implementing practices for analysis based design, illustrations and development of IVHM capabilities. On implementing the system as an on board system will carry out fault detection and isolation, recommend maintenance action, provides prognostic capabilities to highest possible problems before these became critical. The vehicle Condition Based Maintenance (CBM) and adaptive control algorithm development based on an open architecture system which allow "Plug in and Plug off" various systems in a more efficient and flexible way.

The scope of the IVHM design included consideration of data collection and communication from the continuous monitoring of aircraft systems, observation of current system states, and processing of this data to support proper maintenance and repair actions. Legacy commercial platforms and HM applications for various subsystems of these aircraft were identified. The list of possible applications was down-selected to a reduced number that offer the highest value using a QFD matrix based on the cost benefit analysis. Requirements, designs and system architectures were developed for these applications. The application areas considered included engine, tires and brakes, pneumatics and air conditioning, generator, and structures. IVHM design program included identification of application sensors, functions and interfaces; IVHM system architecture, descriptions of certification requirements and approaches; the results of a cost/benefit analyses and recommended standards and technology gaps. The work concluded with observations on nature of HM, the technologies, and the approaches and challenges to its integration into the current avionics, support system and business infrastructure.

The IVHM design for All Electric Hybrid Wing Body (HWB) Aircraft has a challenging task of addressing and resolving the shortfalls in the legacy IVHM framework. The challenges like sensor battery maintenance, handling big data from SHM, On-Ground Data transfer by light, Extraction of required features at sensor nodes/RDCUs, ECAM/EICAS Interfaces, issues of certification of wireless SHM network has been addressed in this paper. Automatic Deployable Flight Data recorders are used in the design of HWB aircraft in which critical flight parameters are recorded.

The component selection of IVHM system including software and hardware have been based on the COTS technology. The design emphasis on high levels of reliability and maintainability. The above systems are employed using IMA and integrated on AFDX data bus. The design activities has to pass through design reviews on systematic basis and the overall approach has been to make system highly lighter, effective "All weather" compatible and modular. It is concluded from the study of advancement in IVHM capabilities and new service offerings that IVHM technology is emerging as well as challenging. With the inclusion of adaptive control, vehicle condition based maintenance and pilot fatigue monitoring, IVHM evolved as a more proactively involved on-board system.

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Keywords: CBM;CAD,HWB,DMO,IVHM,OSA-CBM

1. Overview

The aeronautical industry has, for several years, involved in addressing and solving the shortfalls in the legacy aircraft design, which has now been cultured to the point of shrinking revenues. The conventional airliner in which commuters are held in tubular fuselage carried by wings with larger aspect ratio, propelled by traditional turboshaft engines and stabilized by aft tail, there is little scope for refining or improving the aerodynamic and propulsive efficiency.

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Moreover, in the new era of air transport demanding lower direct operating cost, more environmentally compassionate aircraft with fewer noise and CO-2 emission, compatibility to alternate fuel and higher capacity commuting, for which conventional configuration will not support the airline infrastructure. There has been reluctance to depart from a direct advancement of prevailing technology, the reason for which will not be discussed here, however, it is now appropriate to study the possibility of alternate solutions [1].

The novel concept of Hybrid Wing Body (HWB) is considered as one of the possible solution, in which the fuselage and wing merge together to form a tailless aircraft analogous to a flying wing with enlarged centre section for carrying the commuters. Whilst there have been sequences of curiosity in flying wing and blended wing body aircraft design over the past few years .It is only recently that a stronger knowledge about the configuration has been attained. Thus understanding shared with a number of new expertise has unlocked the way for a novel configuration. Perhaps capable of offering a quantum leap in aircraft efficiency and performance[2].

There has been a drastic improvement in the electrical propulsion technology during the recent past with the development of high efficiency electric motors, high density storage devices, and converter technology. To enlarge vehicle performance adequate to fulfil NASA's "N+3" objectives, the HWB airframe designed for 'N+2' was continued but the propulsion system upgraded using Turbo electric Distributed Propulsion (Te-DP) system[1],[2].

The aircraft is using novel technology like Distributed electric Propulsion, Cryogenic cooling and high density energy storage for which maintenance is an actual test and hence having an On-board IVHM system becomes vital for these technology.

The key to successfully developing, implementing and operating an IVHM system is to ensure its results in economic gains for those who invest time, resources, and money in it. The main economic benefits of using IVHM are maintenance cost avoidance and Increase of revenue by improving availability. There are secondary benefits such as flight testing, crew training and quality assurance. It monitors aircraft systems, subsystem structure, and propulsion system using a combination of state of the art sensor networks and prognostic and diagnostic reasoning and support the maintenance action. Also the IVHM system will monitor the pilot health and fatigue[5].

This paper addresses development of an On-board Integrated Vehicle Health Management System (IVHM) for the Hybrid Wing Body (HWB) aircraft which embeds the best capabilities like quieter, cleaner and efficient Turbo Electric Distributed Propulsion using Superconducting Generator and Motor with Cryogenic/ Liquid Hydrogen Cooling System. However it also inherits some of the worst drawbacks of Distributed Electric Propulsion concept and maintenance figures in the top ones. In view of this, having an intelligent on-board maintenance system becomes a necessity[1].

The IVHM design for Hybrid Wing Body Aircraft has a challenging task of addressing and resolving the shortfalls in the legacy IVHM framework. The challenges like sensor battery maintenance, handling big data from SHM, On-Ground Data transfer by light, Extraction of required features at sensor nodes/RDCUs, ECAM/EICAS Interfaces, issues of certification of wireless SHM network has been addressed in the thesis. Automatic Deployable Flight Data recorders are used in the design of IVHM system in which critical flight parameters are recorded.

2. Requirements

The objective of the design process is to convert customer requirements, and design constraints into a fairly satisfactory system solution. A nominal system should be designed for maintainability, availability, reliability, supportability, survivability develop-ability, safety, Interchangeability. System design shall progress in an orderly and consistent manner though a process of functional breakdown and traceability of requirements, that initiates with the system functional architecture and finally results in design specifications for the system to be engineered. The avionics system development process followed the V-model which is extensively used and established system development life cycle made in aeronautical industry.

Development of complex systems needs to be based on formal requirements management processes, including formal requirement capture, validation, allocation and verification. The V model of system/component design, implementation and verification is presented in Figure 1-1 for the IVHM case. Taking the V-model as the baseline the IVHM system design covers the requirement capture and the subsequent process.

2.1 Requirement capture and Analysis

A detailed and well documented requirement capture during the project definition phase itself is vital in any design project. Adding new requirements or realizing the same at the later stage of the project can have substantial consequence on the design process and may lead to economical and time repercussions. The aircraft level avionics requirements and certification requirements were used as the baseline to generate the aircraft level requirements of IVHM system. These requirements were further classified in to two category such as functional and nonfunctional.

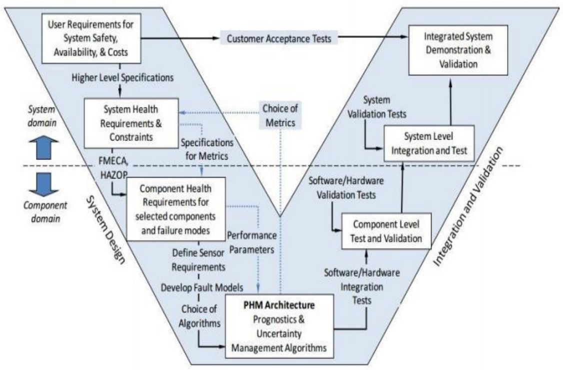

Fig 1-1 V Model for IVHM development [4]