© 2016 IJSRST | Volume 2 | Issue 6 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Integrated Vehicle Health Management System for Fighter Aircraft

Lakshman Singh, Prof. Nar Singh, Prof. Alpana Srivastava
Defence PSU Hindustan Aeronautics Limited, Avionics Division-Korwa, Amethi, Uttar Pradesh, India

ABSTRACT

Fighter Aircraft being of national importance so is fast readiness at air-bases, maintenance & repair activity play very important role. The paper discuss configuration and basic structure of *Integrated Vehicle Health Management (IVHM)*[1] and two different model of IVHM. With the detail discussion of fault *Diagnosis*[2] and *Prognosis*[3] paper end by outline the challenges of IVHM and present status of IVHM in HAL.
Keywords/Tags- *Integrated Vehicle Health Management (IVHM)*; *Diagnosis* and *Prognosis*

I. INTRODUCTION

A fighter aircraft is more than a great looking flying machine equipped with lethal weapons & mind-blogging array of avionics & optoelectronics system. It is a fountainhead of cutting edge technologies, from the new composites to advanced designing, situation awareness & electronic warfare system, high end software, communication systems & optoelectronics systems. Buying an aircraft or it manufacturing under TOT or indigenous is nothing but dealing with a superb piece of machinery & keeping it running, so user should be able to control every aspect of the evolution of the aircraft & its systems. It is not just about a having a fighter aircraft equipped with advance avionics systems but also its maintenance. The primary goal of an aircraft is to complete its designated mission and most of the systems on board are allotted distributed functionalities towards achieving-the same. However down the line there exists the need for a system which monitors the status of the platform itself and thereby supplements roles like crew alerting or maintenance scheduling. This although does not figure in the primary roles but if the impact of this on the overall serviceability and mission capability of aircraft is accounted for, it presents astonishingly high criticality.

In this regards for fast readiness of aircraft at air-bases, maintenance & repair activity play very important role. Hence, adherence to laid-down time frame should be the most important focus area for aircraft maintenance. This again would depend upon the infrastructure, manpower, domain knowledge & methodology used. Here we are going to discuss the total solution for speedy maintenance via analysing the collected data of aircraft health by different sensors. In this context paper discuss Integrated Vehicle Health Management (IVHM) methodology for maintenance of aircraft.

II. METHODS AND MATERIAL

A. Configurations & Basic Structure of IVHM systems

IVHM systems are highly integrated systems that include advanced smart sensors, diagnostic and prognostics software for sensors / components, reasoning algorithms for subsystem and system level managers, advanced on-board and ground based mission and maintenance planners, and a host of other software and hardware technologies. These hardware and software technologies will be embedded in the aircraft subsystems, maintenance operations, and mission operations elements, and do provide both real-time and life-cycle vehicle health information which will enable informed decision making and logistics management. Knowledge databases of the vehicle health state will be continuously referred to for reporting of critical failure modes, and routinely updated and reported for life cycle condition trending.

One of the primary goals of Integrated Vehicle Health Management (IVHM) is to detect, diagnose, predict, and mitigate adverse events during the flight of an aircraft, regardless of the subsystem from which the adverse event arises. In this regard various sensors are used to collect the aircraft critical parameters. These parameters are then analyzed by on-board and ground processors. The major functionalities of the IVHM system are

<u>Data acquisition/ measurement:</u> This includes data collection from various systems or sensors installed across the board.

<u>Data extraction:</u> The data collected needs to be processed to convert it in to a form suitable for analyses. This also needs to include aspects like noise removal and multiplexing

<u>Data Interpretation:</u> The available data needs to be analyzed using various analytical models and compared with the database before arriving at decision w.r.t system health. Various diagnostics and prognostics algorithms are to be executed to interpret the data available.

<u>Action based on the interpretation results:</u> This included logging data and informing the concerned systems and personnel about the same.

<u>Interaction:</u> The analyses results and recommendations need to be shared with the ground maintenance crew for taking rectification action. Also the data base update needs to be undertaken based on ground crew maintenance actions taken.

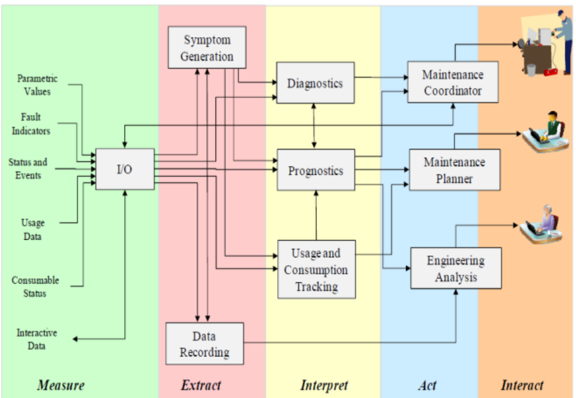

Figure 1. Basic Structure of IVHM

The aims of IVHM are to enable better management of vehicle and vehicle fleet health.

- Improve safety through use of diagnostics and prognostics to fix faults before they are an issue.
- Improve availability through better maintenance scheduling
- Improve reliability through a more thorough understanding of the current health of the system and prognosis based maintenance
- Reduce total cost of maintenance through reduction of unnecessary maintenance and reduction of unscheduled maintenance

B. IVHM Fault Diagnosis

Fault diagnosis can be defined as the process of detecting, isolating, and identifying an impending or incipient failure condition while the affected component (subsystem, system) is still operational even though at a degraded mode. There are numerous techniques available for implementation of Fault diagnosis. These can be analytical methods or embedded real time intelligence ones or either statistical methodology.

All these require formulating highly matching process or semi quantitative or approximate system models. From a modelling perspective the IVHM system needs to embed either highly accurate process models, semi-quantitative models, or qualitative models. A simpler system could also be based on the past system performance data alone to arrive at fault diagnosis.

Fault diagnosis methods are divided in two types based on the procedure that is adopted for the arriving at previous state; one is model based and the other is data based, based on the process knowledge that is required a priori. The priori process background knowledge applied is the key factor in determining the fault diagnosis procedure. All procedures depend on the information correlation between the observed failures and precursor indications of that failure. This can be done by having a reference database which is built based on the system details and design. This requires the developer to understand the basic operational process of each system. Previous results obtained with the process are other source of database. Such database is known as shallow or past performance based knowledge. In model-based methods, the priori knowledge is categorized in to qualitative and quantitative subgroups. The fundamental knowledge of the system is the base for formulating the model. In quantitative models the mathematical dependencies between the inputs and outputs are implemented and these replicate the actual system. However the qualitative model expresses these as qualitative functions. For the data-driven methods the extensive data generated from past performance of the system is the key base. There is certain degree of commonality between the two techniques but the knowledge of the system process is the key basis for fault diagnosis.

C. IVHM Prognosis

Prognosis is the ability to predict accurately and precisely the remaining useful life of a failing component or subsystem. It is the Achilles' heel of the condition-based maintenance/prognostic health management (CBM/PHM) system. Prognosis entails large-grain uncertainty. Long-term prediction of the fault evolution to the point that may result in a failure requires means to represent and manage the inherent uncertainty. Uncertainty representation implies the ability to model various forms of uncertainty stemming from a variety of sources, whereas uncertainty management concerns itself with the methodologies and tools needed to continuously "shrink" the uncertainty bounds as more data become available

Prognosis can be generally classified into-

1. Usage Based Prognosis: This approach incorporates reliability data, life usage models and varying degrees of measured or proxy data. Forecast is based on actual usage when possible. Incipient fault detection may not be available due to sensor or fault mode coverage limitations.

2. Condition Based Prognosis: This approach incorporates utilizing the assessed health or diagnostic fault classifier output to predict a failure evolution. Feature trending or physics of failure based prediction can be then used. Incipient fault detection and diagnostic isolation is absolutely necessary in this.

Prognosis techniques typically combine measured data with data driven embedded model in standalone or combination with a mathematical model to arrive at the predicted condition of the system being monitored. The prognosis based on the physical model takes in to consideration the mathematical model along with the historical database and typical patterns exhibited by the system during faults to arrive at accurate predictions. The algorithms for these need to be built to cover all possible anomalies or failures that can be expected from a system, Hence a very detailed knowledge of the systems is required to generate the prognostic algorithms. Prognosis is also instrumental in arriving at the balance useful life of the systems in order to decide if immediate grounding for maintenance is needed or ops can be continued till next major grounding.

D. IVHM Model

A. ISO 13374 Model

This work, published by the International Standards Organization (ISO) as ISO 13374, establishes general guidelines for information flow between processing blocks for Condition Monitoring and Diagnostics of Machines. The six blocks of ISO 13374 functional decomposition as well as their connections are shown in Figure 2. In this model, the lower three blocks provide low-level, application specific functions. At the lowest level, the Data Acquisition or DA block converts sensor output digital data. The next level, the Data Manipulation or DM block implements low-level signal processing of raw measurements from the DA block. The State Detection or SD level supports modelling of normal operation, and the detection of operational abnormalities. The upper three blocks of the model provide decision support to operations and maintenance personnel based on the health of the target system. Within this group, the Health Assessment or HA function provides fault diagnostics and health condition assessment. The Prognostics Assessment or PA level forecasts health condition based on current data and projected usage loads and computes remaining useful life. Finally, the Advisory Generation or AG level provides actionable information related to the health of the target system.

The ISO 13374 standard was initially developed for non-aerospace applications which were generally simpler than those found in an aerospace setting. It is used by the aerospace IVHM community as a basis for standardizing

IVHM functionality but it is anticipated that future work will substantially increase its ability to address the complexities of aerospace IVHM systems.

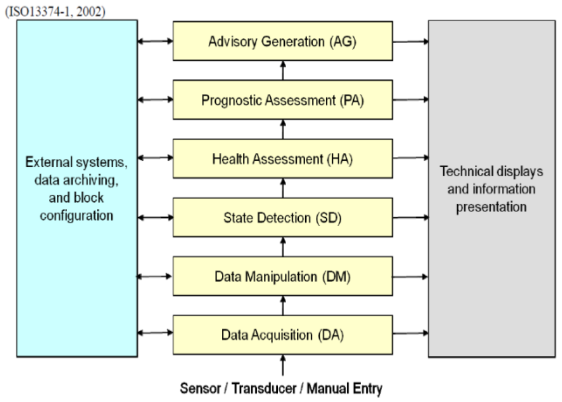

Figure 2. ISO 13374 Model of IVHM

E. IVHM Deployment Considerations

In addition to the functional model, IVHM systems can be partitioned hierarchically to reflect the type of asset they support and how they interact with that asset. This hierarchy reflects that fact that an IVHM system is composed of elements that are embedded on the platform they support and are also deployed into ground infrastructure. The ground infrastructure elements provide information to maintenance crews and enterprise level functions such as maintenance control, tech support, engineering and maintenance planning. To meet the increased data collection and data processing requirements associated with better handling of intermittent faults and wide scale prognostic estimation, the on-platform IVHM elements will move away from a centralized IVHM toward one that is substantially distributed.

One another IVHM Model of Honeywell's which is Vehicle Integrated Prognostic Reasoner (VIPR) (NASA Contract NNL09AD44T) is to detect faults and failures at the aircraft level, enable isolation of these faults, and estimate remaining useful life (Fig-3). All these functions are aimed at meeting the goal of automated mitigation and increasing aviation safety. Faults can arise in one or more aircraft subsystems. Their effects in one system may propagate to other subsystems, and faults may interact. VIPR must be able to handle these and provide an accurate diagnostic and prognostic state for the aircraft. A Hierarchical Model of a large scale IVHM system that distributes the IVHM functionality is shown below:

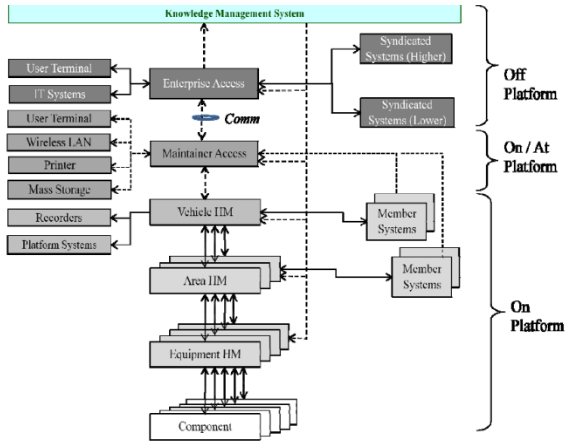

Figure 3. IVHM Model of Honeywell

In this model, the various types of IVHM elements are shown in the center column of the figure with the elements that support lower level assets at the bottom of this stack and the elements that support the highest-level assets/fleets shown at the top. The figure also identifies the various types of external systems with which the various IVHM products interact. The principle elements in the model are described below:

1) Component – The lowest level elements of an asset for which the IVHM system gathers data, assesses health and/or directs maintenance actions.
2) Equipment Health Manager (EHM) – Software that provides data analysis, data logging, diagnosis, prognosis, coordination and reporting functions within the context of a functional control component. This function typically reports its results to an AHM of VHM.
3) Area Health Manager (AHM) – Software that receives data from lower level EHMs and other Member Systems and provides data analysis, data logging, diagnosis, prognosis, coordination and reporting functions. Area Health Managers consolidate data for a portion of the aircraft such as an engine, the flight control system, or other major system. This function typically reports its results to a VHM.
4) Vehicle Health Manager (VHM) - Software that receives data from lower level AHMs, EHMs and other Member Systems and provides data analysis, data logging, diagnosis, prognosis, coordination and reporting functions. Vehicle Health Managers

consolidate data for a portion of the aircraft such as an engine, the flight control system, or other major system. This function typically reports its results to the maintainer and enterprise
layers.

5) Maintainer Access – Software loaded onto embedded or portable hardware to support interactions with crew and maintainers at the asset. This element interacts with the VHM element to acquire automatically reported evidence and with maintainers to acquire manually collected evidence. This element is focused on one asset at a time. This function reports its results to the Enterprise Access element.

6) Enterprise Access - Software loaded onto IT servers or stationary hardware to assess fleet health, support aircraft operations and to plan maintenance actions and material requirements for specific assets.

7) Member Systems – IVHM Software loaded into components to allow them to provide some of the functionality provided by the EHM and AHM IVHM elements.

8) Syndicated Systems – Distributed IVHM Systems that provide some or all of the functionality provided by the Enterprise Access element. These systems allow the supplier for an aspect of the aircraft to provide specialized, expert level support for an asset to a higher level system that provides broader, more general support. An example could be an Airline Level System that interacts with a system that provides specific support for a type of aircraft which further interacts with a system that provides specific support for the engines, another that supports the APUs, another that support the flight controls, etc.

9) Platform Systems – Displays, Communication Infrastructure, Mass Storage and other capabilities provided by the platform that are used by IVHM for display, data transfer or data storage.

10) Recorders – Hardware that provides crash survivable or removable mass storage.

11) IT Systems – Electronic Document, Database Management, Work Control, Planning, Record Keeping and Cost Accounting Systems that share data and/or functions used by IVHM.

12) Knowledge Management – IVHM functionality to construct and maintain the large amount of fault model data and other configuration data required to adapt the IVHM system to a specific asset and operational environment. Knowledge Management functions include tools to support the initial design of the asset and construction of the initial fault models as well as tools to update the fault models as actual fault events reveal need for improvement.

III. RESULTS AND DISCUSSION

A. IVHM Challenges

From the study of various healths management strategies it is clear that in most of these the fault diagnosis and isolation are done on independent LRU level. The data monitoring and analyses doesn't expand its scope to system level or aircraft level as a whole. But an effective IVHM system has to integrate the real time analyses capability to cover all the aircraft sensors, instrumentation along with sub systems and this all sums up to ultimately monitor the aircraft as a whole.

The IVHM system can assist the aircraft or platform in possessing higher degree of automation which in turn will make the operations safer and easier for the crew and aircraft. . The design and implementation of effective IVHM system calls for stronger research of existing technology capabilities and their inherent limitations as well. The scope needs to cover innovation and thorough V & V techniques in order to introduce real time flight ops capability in to IVHM.

The other challenges are:

- To upgrade IVHM to embed Real-time decision taking capability and provide flight decisions
- Having high precision diagnostics capability to which will allow to pin point faults to the exact system of origin.
- Having high precision prognostics capability
- Mission abort determination capability -this will include providing Go/Nu Go commands as part of pre-flight checks.
- Reducing false alarms which happen due to lack of accuracy of the system models and database built in the IVHM system.
- Embed Pilot in loop operation capability in the IVHM system. Also if the system if made highly critical it has be to be designed to be fail safe which can be a challenging design task in itself.
- The lack of pilot health monitoring capability in the IVHM system.

B. VIII. HAL and IVHM

It is well known that "False Alarms" can make systems appear to be very unreliable, and can take several maintenance hours per flying hour. Although various LRUs have significantly high MTBF as per the manufacturers specifications but when they all operate in an integrated mode, the failure rates observed show unreliable patterns. A supersonic fighter like the Mirage or the Sukhoi, on average logs close to 25 maintenance man hours per flying hour. At squadron level the sortie rates are affected as equipment is taken offline for testing and repair. The cost of maintenance and support of the current generation aircraft usually far exceeds the delivered cost.

HAL also now is entering in to life cycle support based contracts wherein the maintenance will be responsibility of HAL and the associated financial implications have to be addressed in the ab initio cost calculations itself. Therefore the higher the maintenance time and costs, the significant the stress will be on the account books of HAL.

Also the forthcoming projects like the Multirole transport aircraft, FGFA etc will have extremely complicated aircraft systems and the maintenance mechanism of these will play an important role in the aircraft design. The customer will demand the implementation of a prognostic health management philosophy as against the existing maintenance trend. Hence it will be in the best interest of both IAF and HAL, that IVHM as a system is introduced in the existing and forthcoming aircraft projects, thereby supporting autonomous logistics, higher mission availability and dramatic reduction in overall maintenance cost.

IV. CONCLUSION

Aircraft maintenance is an area of significant importance because maintaining an aircraft in a good condition increases aviation safety and improper maintenance contributes to a significant proportion of aviation accidents and incidents. The aviation industry could not function without the contribution of maintenance activity of aircraft. The IVHM methodology for Aircraft maintenance is demand in aviation industry.

V. REFERENCES

[1] ISO. Geneva, Switzerland, 2002, ISO 13374-1, Condition monitoring and diagnostics of machines – Data processing, communication and presentation – Part 1: General Guidelines

[2] Aaseng, G.B. Blueprint for an integrated vehicle health management system. In proceedings of the 20th Digital Avionics Systems Conference, Daytona Beach, Florida, USA, 14–18 October, vol. 1, pp. 3.C.1-1-3.C.1-11

[3] Jennions, I.K, Integrated Vehicle Health Management: Perspectives on an Emerging Field Benedettini.; T S Baines.;H W Lightfoot. and R.M.Greenough.; "State-Of-The-Art In Integrated Vehicle Health Management", Proceedings of the Institution of Mechanical Engineers Part G Journal of Aerospace Engineering, 03/01/2009

[4] P.A. Scandura.; "Integrated Vehicle Health Management As A System Engineering Discipline", 24th Digital Avionics Systems Conference, 2005 Paris, D.E. ; Trevino, L.C. ; Watson, M.D. ; Marshall Space Flight Center, AL ;"A Framework For Integration Of IVHM Technologies For Intelligent Integration For Vehicle Management", Proceedings of Aerospace Conference, 2005 IEEE Issue Date : 5-12 March 2005 On page(s): 3843 .

[5] Tim Felke.; George D. Hadden.; David A Miller.; "Architectures For Integrated Vehicle Health Management" AIAA Infotech@Aerospace 2010 , Atlanta, Georgia 20 - 22 April 2010.

[6] Gary Bird.; Michael Christensen.; Daniel Lutz.; Philip A. Scandura Jr. ;"Use Of Integrated Vehicle Health Management In The Field Of Commercial Aviation" ,First International Forum on Integrated System Health Engineering and Management in Aerospace, Honeywell International, Phoenix, Arizona November, 2005.

[7] Prashant Singh Bhadoria, ARDC, HAL-Bangalore; Aircraft Integrated Vehicle Health Management System by Conference on Technological Challenges in Aerospace Industry for current and Future Programs of HAL, HMA 21-22 Feb 2012