

Health Ready Components-Unlocking the Potential of IVHM

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ABSTRACT

Health Ready Components are essential to unlocking the potential of Integrated Vehicle Health Management (IVHM) as it relates to real-time diagnosis and prognosis in order to achieve lower maintenance costs, greater asset availability, reliability and safety. IVHM results in reduced maintenance costs by providing more accurate fault isolation and repair guidance. IVHM results in greater asset availability, reliability and safety by recommending preventative maintenance and by identifying anomalous behavior indicative of degraded functionality prior to detection of the fault by other detection mechanisms. The cost, complexity and effectiveness of the IVHM system design, deployment and support depend, to a great extent, on the degree to which components and subsystems provide the run-time data needed by IVHM and the design time semantic data to allow IVHM to interpret those messages.

A great benefit can be achieved if a common approach is developed to assist suppliers in the development of "health-ready" components and systems and to simplify the process by which integrators use these capabilities to deploy IVHM applications. In this context, the term "health ready" refers to a component or system that implements the required set of IVHM run-time interfaces and provides the associated semantic data in an appropriate format. The SAE Aerospace Recommended Practice ARP6268 document is being developed to achieve this objective. The ARP is being developed within the framework of the SAE HM-1 committee by a team with both aerospace and automotive engineering backgrounds.

The intent of the ARP is to provide practitioners with a structured methodology for specifying, characterizing and exposing the inherent component or subsystem IVHM functions by using a common functional reference model, through the exchange of design-time data and the application of standard vehicle data communications interfaces.

This paper provides an overview of the motivation and rationale behind the ARP and a summary of the ARP methodology describing how it would be applied by integrators and suppliers of components and subsystems in the aerospace and automotive sectors.

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INTRODUCTION

IVHM systems are ushering in a new paradigm for diagnosis and prognosis and the concept of "health ready components" will be essential. The SAE ARP6268 document addresses existing barriers to the successful implementation of IVHM technology in the aerospace

sector. However, the APR can also be applied to the automotive, commercial and military vehicle sectors. Original Equipment Manufacturers (OEMs) in all of these sectors are heavily dependent upon a large number of component and system suppliers, many of which are shared across these sectors.



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The advent of IVHM technology has accentuated the need for a new model that encourages better coordination and communication between the OEM and its suppliers in order to achieve the operational, safety and economic benefits desired.

ARP6268 seeks to provide uniform requirements, practices and methods to address the sharing of critical component/subsystem run-time messages and supporting design-time information to facilitate real-time platform level communication and implementation of the supplemental IVHM functions. In the past, component suppliers were primarily operating in the diagnosis-only paradigm in which the focus was to facilitate the detection and identification of the root cause(s) once a failure had occurred. In the new IVHM paradigm, which also supports prognosis, the supplier must also facilitate health monitoring and tracking of system degradation severity to prevent a given component from degrading to the point where it goes outside its operational performance envelope.

An overview for the application of the ARP recommendations to a typical program is shown below:

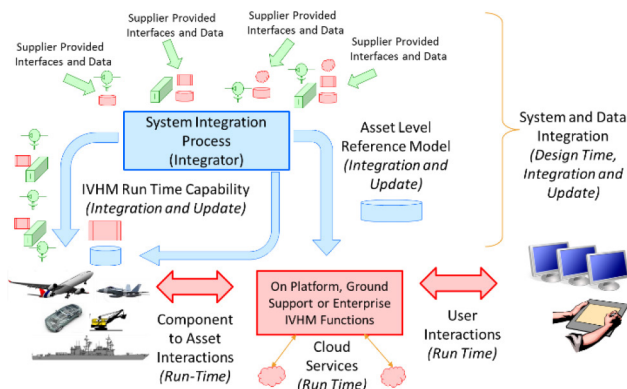


Figure 1. Overall ARP Application Process

It is important to note that suppliers may provide any combination of components (green icon), controllers (green icon), software (red icon) and services (red icon). In the paradigm of health ready components, all of these are accompanied by descriptive data (red icon) that allows these functions to be integrated to provide a coherent picture of the overall health status of the asset and an estimate of the cost/benefit of each candidate diagnostic/maintenance action.

THE RATIONALE BEHIND THE ARP

While the aerospace and automotive industries have made progress in developing and deploying service oriented, remote monitoring solutions to support specific subsystems on a vehicle, the widespread application of IVHM, in its full sense, has been slow in taking root.

The notion of “Health-Ready Components” was coined in the context of high volume vehicle manufacturing (aerospace, automotive, etc.) where an OEM is responsible for the design and build of the total

vehicle but which is also highly dependent upon suppliers or component manufacturers for a wide variety of components or subsystems which are essential to the final vehicle.

With the advent of IVHM systems, it became apparent that OEMs could not fully achieve the potential of IVHM without the active help and support of its component/system suppliers. The greater burden of IVHM solutions properly falls on the OEM who is generally responsible for performing the vehicle integration function. However, in an effort to create more comprehensive IVHM solutions with minimal duplication of effort and greatest efficiency of operation, it was felt that suppliers would need clear, consistent guidance from the OEMs on how best to support the integration of their components into the overall IVHM solution. Figure 1 provides an overview of the overall concept behind the ARP

The principal motivation for the ARP is to facilitate the introduction of enhanced IVHM functionality provided by supplier products to meet the needs of end users as well as government regulators in a cost effective manner. The authors observe that market forces will ultimately drive the need to achieve the benefits of IVHM which will inevitably drive new requirements to which suppliers must ultimately abide. Therefore, the ARP aims to address two primary objectives:

1. Encourage the introduction of a much greater degree of IVHM functionality to be provided in future vehicles at a much lower cost.
2. Avoid infringing upon the need for equipment suppliers and integrators to protect their intellectual property (IP).

These objectives could potentially be in conflict if not properly addressed because some of the mechanisms through which the goal is to be achieved may require that some amount of intellectual property be provided relative to the component in order to enable the IVHM functionality desired. This ARP addresses this concern by suggesting several alternative strategies by which a supplier can choose to deliver the required IVHM functionality and associated data, while also protecting their legitimate IP. In summary:

- The supplier may implement the minimal set of the required IVHM functionality and provide the full set of required supporting data to the integrator.
- The supplier may implement a larger percentage of the required IVHM functionality and provide a proportionally smaller amount of supporting data.
- The supplier may complement the IVHM functionality provided by their equipment with cloud-based support software or health monitoring services that further extend the required functionality. This may be applicable where real time response is not required on-board the vehicle itself or at the point of maintenance. This approach also requires a proportionally smaller amount of supporting data.

It is important to note that even in the case where a supplier provides the full set of required IVHM functionality for their equipment, the ARP requires that they provide a minimal set of supplemental data. This “minimal” set of data is to provide the semantic information required for application by higher level functions on the platform or diagnostic procedures and business processes employed by the vehicle operator.

IVHM HEALTH-READY FUNCTIONALITY

Health-ready components are expected to embody the following features to varying degrees:

- Sensor mechanisms to continuously monitor critical system functions and environmental parameters;
- Raw sensor data acquisition and data processing that produce health state parameters or indicators;
- State detection and health assessment functions which can synthesize health state information to define system degradation severity levels (e.g., normal, warning, critical);
- Prognostic algorithms to predict remaining useful life (RUL) also known as “performance life remaining” (PLR) for the degraded system;
- Built-In Test (BIT) that can provide the status of electronics and sensors at the start up, periodically or at the request of vehicle level system (a BIT is equivalent to a Diagnostic Trouble Code or DTC in the automotive sector);
- Enhanced diagnostic functions that correlate health state data including Built-In Test (BIT) results across system functions or subsystems; and a
- Communications interface module to transmit raw and health state data to the data acquisition subsystem, data recorder or vehicle control system.

As noted in [Figure 2](#) below, a subsystem’s level of health readiness is a key driver in defining the IVHM system architecture. That is, the IVHM system design options depend, to a great extent, on whether or not the subsystems are “health-ready”, the enabling functions within the vehicle (On-Vehicle Tier), and the functionality of the off-board infrastructure elements (At-Vehicle and Fleet Data Services and Application Tiers). Therefore, it is important to characterize and specify [for component suppliers] the specific design-time and real-time data elements and interfaces that enable the level of health readiness in components and subsystems that are required to achieve the IVHM objectives derived from stakeholder needs.

Understanding “Health Ready Components” requires practitioners to focus on the definition of the information that must be exchanged between the layers in the IVHM system (or between lower level components/subsystems and the higher level control system.) It should be noted that particular program implementations may choose to utilize all or just a portion of the IVHM functions inherent in the particular component. Also, the ARP will not specify how each layer in the system produces or uses the data available for exchange but rather focus on the rationale and process for such exchanges.

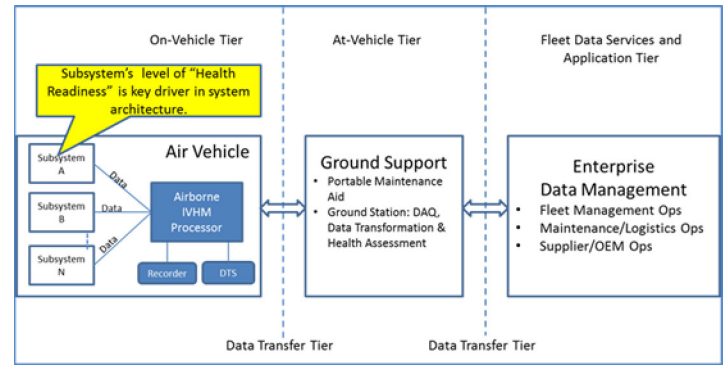


Figure 2. General IVHM System Architecture View

DEGREE OF ISO 13374 IMPLEMENTATION IN THE SUPPLIER’S COMPONENT

The first task that a supplier has to undertake is to determine the degree to which the supplier’s component or subsystem implements the required IVHM functionality and make a decision regarding providing additional data to allow the integrator or another party implement the functionality. Using a common IVHM Functional Reference Model ([Figure 3](#)), the supplier can determine (in general) the IVHM functionality supported by their component or subsystem (as-is).

IVHM Functional Block	Description
Advisory Generation (AG)	System functions provide actionable information to operational and maintenance personnel or external systems.
Prognostics Assessment (PA)	System functions provide future state of health, performance life remaining, or remaining useful life (usage) indicators.
Health Assessment (HA)	System functions provide information to determine the current state of health of equipment.
State Detection (SD)	System functions evaluate equipment state conditions against normal operating profiles and generate normal or abnormal condition indicators.
Data Manipulation (DM)	System functions process and transform the sensor data and health state information collected by the DA.
Data Acquisition (DA)	System functions collect sensor data and health state information from equipment internal monitors, vehicle data bus or data transfer system.

Figure 3. IVHM Functional Reference Model

In the above model, the lowest level, the Data Acquisition or DA block acquires the sensor output data. The next level, the Data Manipulation or DM block implements low-level signal processing of raw measurements from the DA block. For example, in rotorcraft platforms, the State Detection or SD level supports modeling of normal operation and the detection of operational abnormalities and creates a Condition Indicator (CI). A subsystem can generate multiple CIs depending on the number of its sensors. The CI(s) are communicated to the next level Health Assessment where the health of system is identified by creating a Health Indicator (HI). Depending on the type of subsystem, and its complexity of interaction with other subsystems, HA can be performed at subsystem or vehicle level. The upper three functional blocks of the model provide decision support to operations and maintenance personnel based on the health of the target system.