



AEROSPACE RECOMMENDED PRACTICE

ARP6275™

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Superseding ARP6275

Determination of Costs and Benefits from Implementing an Integrated Vehicle Health Management System

RATIONALE

This Aerospace Recommended Practice (ARP) provides insights on how to perform a cost benefit analysis (CBA) to determine the return on investment that would result from implementing an integrated health management (HM) system on an air vehicle. The word “integrated” refers to the combination or “roll up” of sub-systems health management tools to create a platform-centric system. The document describes the complexity of features that can be considered in the analysis and the different tools and approaches for conducting a CBA, and it differentiates between military and commercial applications. This document is intended to help those who might not necessarily have a deep technical understanding or familiarity with HM systems but want to either quantify or understand the economic benefits (i.e., the value proposition) that an HM system could provide. Prognostics is a capability within some HM systems that provides an estimation of remaining useful life (RUL) or time to failure and so prognostic health management is used where this predictive element exists. IVHM refers to an integrated vehicle level system deployed on a fleet of platforms and might, but not necessarily, include predictive elements.

This revision (Rev. A) to ARP6275 is for the purpose of reflecting the cancellation of the duplicative and superseded ARP4176A. The opportunity is also taken to make updates and editorial enhancements, as well as correcting grammatical and punctuation errors.

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1. SCOPE

This Aerospace Recommended Practice (ARP) provides insights on how to perform a cost versus benefit (C/B) analysis (CBA) to determine the return on investment that would result from implementing an integrated health management (HM) system on an air vehicle. The word “integrated” refers to the combination or “roll up” of sub-systems health management tools to create a platform-centric system. This document describes the complexity of features that can be considered in the analysis and the different tools and approaches for conducting a CBA, and it differentiates between military and commercial applications. This document is intended to help those who might not have a deep technical understanding or familiarity with HM systems but want to either quantify or understand the economic benefits (i.e., the value proposition) that an HM system could provide. Prognostics is a capability within some HM systems that provides an estimation of remaining useful life (RUL) or time to failure and so prognostic health management (PHM) is used where this predictive element exists. IVHM refers to an integrated vehicle level system deployed on a fleet of platforms and might, but not necessarily, include predictive elements.

1.1 Purpose

This ARP is not a standard or legal document because the approaches towards the end objective are many and varied. The document has been compiled to help the increasing number of people who want to compute an HM CBA prior to implementing such a system on a platform.

1.2 Approach

The approach taken was to identify the parameters that were relevant for consideration in a cost/benefit analysis so that the boundaries of a specific problem could be defined from the outset. Several recent and worthy papers presented at conferences on the subject matter were studied and as much information as possible was obtained from the aerospace manufacturers and the DoD to identify tools and techniques that they might have used to good effect. The various methods were assessed by the SAE HM-1 Technical Committee team for their application to specific scenarios (e.g., military or commercial operation, legacy or new engines) and the parameters utilized by each scenario. The end result is a document that offers the reader various solution paths so that the one most appropriate to the specific situation can be used or adapted.

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.

AIR1871	Lessons Learned from Developing, Implementing, and Operating a Health Management System for Propulsion and Drive Train Systems
AIR4061	Guidelines for Integrating Typical Engine Health Management Functions within Aircraft Systems
AIR4175	A Guide to the Development of a Ground Station for Engine Condition Monitoring
AIR5871	Prognostics for Gas Turbine Engines
ARP1587	Aircraft Gas Turbine Engine Health Management System Guide

Jennions, I.K., "Integrated Vehicle Health Management: Perspectives on an Emerging Field," SAE International, Warrendale, PA, ISBN 978-0-7680-6432-2, 2011, doi:10.4271/R-405.

Jennions, I.K., "Integrated Vehicle Health Management: Business Case Theory and Practice," SAE International, Warrendale, PA, ISBN 978-0-7680-7645-5, 2012, doi:10.4271/R-414.

2.1.2 Other Documents

Reference 1 Army Implementation of CBM: 2012 Update, Presented by Chris Smith, Army Aviation and Missile Command. Annual Conference of the Society for Machinery Failure Prevention Technology (MFPT), April 25, 2012, Dayton OH. Available from Society for MFPT, 5100 Springfield St., Ste 420, Dayton OH 45431-1264 (937)-256-2285, www.mfpt.org.

Reference 2 "Metrics, Models, and Scenarios for Evaluating PHM Effects on Logistics Support." Presented by Joel Luna, Frontier Technology, Annual Conference of the Prognostics and Health Management Society, San Diego, 2009. Available from the PHM Society, www.phmsociety.org.

DO-160G "Environmental Conditions and Test Procedures for Airborne Equipment." Published by RTCA Inc.

DO-178C "Software Considerations in Airborne Systems and Equipment Certification." Published by RTCA Inc.

DO-248A "Final Report for Clarification of DO-178B." Published by RTCA Inc.

DO-254 "Design Assurance Guidance for Airborne Electronic Hardware." Published by RTCA Inc.

DO-278B "Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems." Published by RTCA Inc.

DO-330 "Software Tool Qualification Consideration." Published by RTCA Inc.

2.2 Acronyms

ACARS Aircraft Communications Addressing and Reporting System

ACMS Aircraft Condition Monitoring System

AHEAD Aircraft Health Analysis and Diagnostics

AHTMS Aircraft Health and Trend Monitoring System

AOG Aircraft on Ground

AMM Aircraft Maintenance Manual

ASCII American Standard Code for Information Interchange

ATP Acceptance Test Procedure

CAS Crew Advisory System

CBA Cost/Benefit Analysis

CBM Condition-Based Maintenance

DAL Design Assurance Level

DoD Department of Defense

DSC Digital Source Collector

FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects, and Criticality Analysis
FOQA	Flight Operations Quality Assurance
HM	Health Management
HUMS	Health and Usage Monitoring System
IFSD	In-Flight Shutdown
IVHM	Integrated Vehicle Health Management System
JSF	Joint Strike Fighter program (F-35 variants)
LLP	Life-Limited Part
LRU	Line-Replaceable Unit
MEL	Minimum Equipment List
MRO	Maintenance, Repair, and Overhaul
NDI	Non-Destructive Inspection
NFF	No Fault Found
NRE	Non-Recurring Engineering
OEM	Original Equipment Manufacturer
OOOI	Out, Off, On, In
POC	Proof of Concept
PoD	Probability of Detection
PHM	Prognostics and Health Management
PTCRB	Certification organization defining test specifications and methods to ensure device interoperability on global wireless communication networks
ROI	Return on Investment
SER	Scheduled Engine Removal
TOW	Time on Wing
UER	Unscheduled Engine Removal
WIP	Work in Progress

3. INTRODUCTION

3.1 Motivation for Implementing an Integrated Health Management System

While aircraft condition monitoring has been utilized in various forms since the late 1960s (e.g., at the launch of Boeing 747 operations) and with steadily increasing capability since the 1970s, prognostics and health management (PHM) tools and capabilities have come from relative infancy in the early 1990s to now being sufficiently mature to implement on airborne systems. Additionally, modern aircraft components have become much more proficient at providing their health status to a higher management system thus allowing a PHM system to achieve its end goals of predicting necessary maintenance and reducing unnecessary maintenance activities. The components not only provide status indications but also operating data that can be analyzed. This rapid progress in “predictive” technology was mainly the result of the pull by the DoD’s Joint Strike Fighter (JSF) Program, which became the F-35 Lightning II aircraft. With affordability at the core of the program, the U.S. Navy agreed to accept a single-engine aircraft for carrier-based operations if a PHM system was able to provide warning of system failure at least one flight prior to the actual event. This predictive or “just in time” capability had been identified back in the late 1960s (ARP1587) but now there was a stated program requirement as opposed to a serious desire. In the case of the JSF, for example, the ability to predict the need to do maintenance or remove an engine just before it is about to fail in service is sufficient justification to accept the implementation of a PHM system without further economic analysis, but it doesn’t consider the driving intent or original motivation for implementing a PHM system. For a commercial operator, the same is true for a major system component, such as a bleed system valve or an air conditioning pack. The base-line reason or initial motivation for considering implementation of a PHM system is where the analysis needs to start. The initial driving force for the JSF program was to maintain a previously experienced and accepted level of safety with the added benefit of reduced redundancy (one engine instead of two) and/or conservatism. In contrast, the commercial aviation world sees the benefits of a PHM system primarily in terms of economics. Commercial airline OEMs and operators typically meet or exceed the safety requirements put upon them by the regulatory authorities so PHM for increased safety is not a prominent driver for commercial operators. However, where safety can be improved as an associated benefit from some other action, then clearly this should be pursued by operators and manufacturers. This is most apparent in the rotary wing community, especially in oil and gas operations, where increased safety was the original driver, and still is the prominent driver, for a HUMS (Health and Usage Monitoring System). So, regardless of whether the driver is safety or economics, there are many aspects that are common to both when considering implementation of a PHM system on a platform, as discussed in the next section. The high level process flow (or architecture) of a typical PHM system is illustrated in Figure 1.

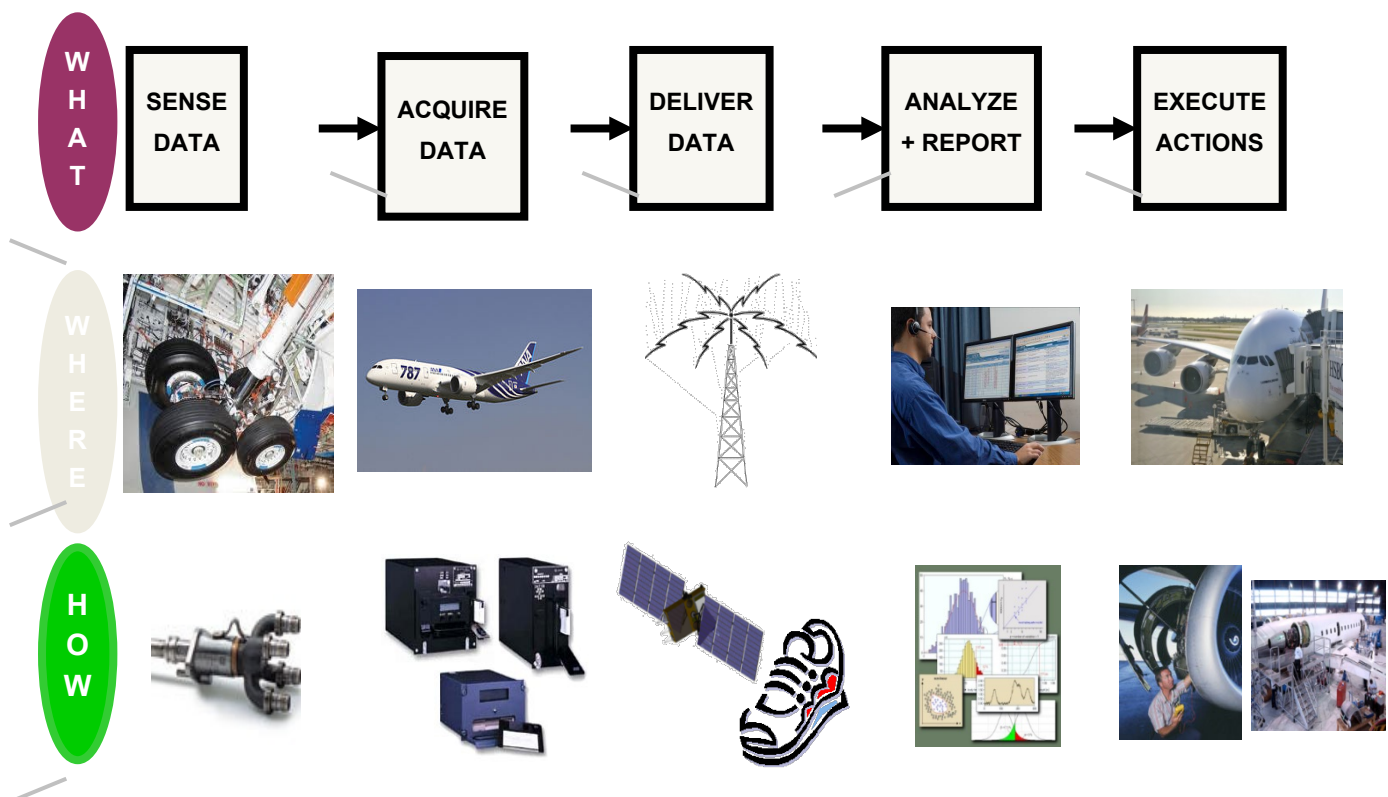


Figure 1 - A typical PHM high-level process flow
(Image courtesy of Pratt&Whitney)

3.2 Fundamental Considerations Preceding the Cost/Benefit Analysis

The initial entry point for considering the implementation of a PHM system on any piece of equipment is to identify and define which specific failures or modes of failure should be detected. The PHM system will thus be configured to identify degradations that will lead to a failure that is either unsafe, expensive, leads to mission compromise or failure, or creates major inconvenience to the operator or its customers. Examples of such are engine disk bursts, or landing gear non-deployment, or sub-system failures that can lead to route diversions. These incidents are not only costly for the operator but also cause major inconvenience to the customers. There are many other failures which could be termed innocuous in that they are easily repairable, don't pose an in-flight hazard, or are inexpensive to fix, but it is important to evaluate possible failure propagation in the original failure modes and effects analysis (FMEA) or the more quantitative, failure modes, effects, and criticality analysis (FMECA) to ensure they do not lead to larger costlier issues in the future. Many airline passengers experience such frustration with failures of their overhead seat lighting, and personal entertainment malfunctions. Other failures are typically remedied by "quick fixes" to the aircraft, conducted by maintenance personnel while the aircraft is at the gate, but which might nonetheless still delay the plane's departure. In the general aviation world, especially the business aircraft, many operators attach a high price tag to an unscheduled "event," especially one that causes passengers to be delayed. Experience shows that any failure can be detected in its incipient phase if the parameters associated with the degradation that precede the failure are being monitored and analyzed. The reality is that many failures or modes of failure are not monitored because the designers, operators, or maintenance personnel have determined that to do so is not worthwhile, or not technically feasible. However, during the operating life of a fleet of aircraft, technological advances in data collection, fusion, and analysis may then allow previously undetectable failure modes to be detected. Additionally, different failure modes come to light, or regulations change to affect maintenance and inspections, or the modus operandi of the platform/system changes that, in turn, can change the ways and means that components are monitored. In other words, PHM on a system is a "living thing" and needs to be flexible, adaptable, and easily updated to accommodate these continuous changes. Nonetheless, the unavoidable starting point is to define the failures in the system that need to be mitigated (for whatever reason), determine how those failures can be anticipated at a sufficiently early stage (from data generated during system operation), and identify the sensors and analytical tools (PHM) that will reliably provide the necessary information. From that point, a cost/benefit analysis can be initiated.

4. FACTORS INFLUENCING COST/BENEFIT STUDIES AND ANALYSES

4.1 PHM System Complexity

Nowadays, a PHM system can be as complex as a customer requires. Manufacturers at all levels (i.e., from component level to final integrator and provider of the platform to the customer) have an interest in providing a platform efficient operation especially if a usage-based overhaul or parts management contract is in place. Consequently, the amount of data the manufacturer needs, to achieve the contract terms, increases significantly. This is predominant in the commercial world. In the near future, PHM systems will be utilized to monitor and trend aircraft sub-systems. For example, landing gear retraction can be evaluated over time; if the time taken for the landing gear to retract is increasing, the interacting systems can be monitored to accurately diagnose the root cause. Similarly, slowly increasing asymmetry over time of flight control surfaces such as flaps, ailerons and spoilers and rudder positions is important to know not only from a flying perspective but also a desire for fuel efficiency, especially on long-haul flights. In the case of control surface asymmetry, airline operators are interested to the extent that they will monitor fuel consumption on a tail number basis and perform checks on the control surface positions of the planes with the worst fuel consumption because they see the need to do so; they are practicing condition-based maintenance (CBM) based on fuel consumption changes. The cost/benefit analysis of a PHM system is thus highly dependent on the requirements of the end customer yet, up to now, HM systems in general have been largely provided by the airplane manufacturers who have typically pre-determined the capabilities. However, ever changing priorities, such as an increased interest in fuel savings by the operators, are likely to introduce additional, new features or new functionalities to meet the operator's defined needs. An example would be more sophisticated monitoring of control surface positions, especially any synchronization issues when they are being deployed. While the system would be operating satisfactorily, and safely, and meeting operating specifications, it might not be optimized for fuel efficiency. The interface to the aircraft will also need some degree of customization. This includes the degree of "on-board" analysis of the data and real-time action compared with downloading data at some later date and processing it in a ground software station. Thus, the user needs to determine, at the outset, the desired capabilities of a PHM system and build a CBA from that base-line. If the specific needs are not able to be precisely defined, then several scenarios could be created and a CBA computed for each, which would reveal the trade-offs between system complexity and return on investment.

In the propulsion arena, which has historically tended to be the lead sub-system for HM, mandated vibration monitoring resulted in vibration monitoring systems being installed on engines and aircraft in the seventies. In more recent times, ETOPS (extended twin engine operations) drove the need for an EHM system in commercial fixed wing operations, especially those across water, as was also the case for rotorcraft operating in support of offshore oil rigs. For airframe systems, the drivers are not so clear cut and there are no mandates to equip a fleet with an HM system. Instead, once the HM capabilities are visible and demonstrated to the airplane OEMs or the operators, then business cases start to be generated because the capability has generated new, perceived needs. In other words, capabilities sometimes generate needs as opposed to needs generating the development of new capabilities. However, some regulation-driven PHM functionality does exist today on airframes. For example, for emergency battery backup systems, there is a requirement to show the state of charge (SoC) indication before a flight so that the flight crew can be assured that the battery can be used during an emergency to restart the engine or to provide power for other essential electrical functions. This is an example of a PHM system specific to the airframe.

4.2 Usage: The Considerations and Differences between Categories of Operators

Military and commercial aircraft operate in starkly contrasting flight regimes and this makes a large difference when considering the cost/benefit approach to take. First and foremost, commercial operators fly similar operations every day, whereas military aircraft are typically conducting flying training and preparatory operational missions on a normal basis until a major exercise or combat/war scenario is brought to bear, at which time the intensity of operations increases significantly for an unknown period of time (could be several days to several years). Generally, military airplanes fly into and out of the same base on a daily basis whereas commercial planes are typically crossing the country or world where maintenance facilities at non-hub locations are often less comprehensive. A combat military PHM system is generally more complex (with armament systems, sophisticated radar, and self-defense measures, etc.) and will in many cases take into account many more failure modes, even though some might have a very remote probability of occurrence. The commercial carrier, on the other hand, would typically want a less complex system, capable of detecting gradually changing trends with a well understood and predictable set of failure modes but with extremely high reliability so as to minimize false alerts. Additionally, the “detection window” required for commercial aircraft is likely to be much longer than military (maybe 25 to 50 flying hours compared with five to ten for military) because of the higher usage rate and the longer flight durations. An aircraft on the ground for a commercial operator is earning no revenue; a military aircraft on the ground, while not available for its intended use, has no monetary loss attached to it. In short, the military is focused on mission success and the commercial operations are most interested in schedule reliability and cost of operations. For these reasons, and others that can similarly be identified, the rationale and approach to PHM costs and benefits are vastly different between commercial and military operators. Business jets and cargo operations, while subsets of commercial-type operations, are sufficiently different from airline passenger operations to necessitate the design of their own health management systems. Factors such as fleet size, the unique demands of the business jet passenger and the non-human payload on cargo airplanes drive quite different requirements from an HM system. For business jets, availability, which is driven by reliability, is the most important factor, certainly more so than cost considerations, and arguably higher than for either military or other commercial operations. For any of the four main types of airplane operations cited above, different cost-benefit models and approaches are needed so that one which best suits the specific circumstances can be utilized. The differences in operational scenarios across the various types of operator could be addressed by a generic CBA model in which the importance or weighting of different cost/benefit elements could be adjusted, though there are many other factors, such as those covered earlier, that may necessitate building a customized solution.

4.3 Legacy Versus New Platforms

There is a big difference in approach between applying a PHM system compared to a mature or “legacy” platform to one in the design stage. Firstly, older legacy platforms typically have more antiquated data bus and data recording capabilities, requiring investment in more complex ground systems to do off-board processing. Newer platforms have more centralized data collection and processing and computing power, and are thus able to perform more HM functions on board. Ground systems to support these types of platforms can also be complex, as they strive to implement more complex algorithms to deal with the exponentially growing data quantity available for analysis on modern vehicles. Secondly, while the legacy platform has, depending on age in service, typically demonstrated some failure modes and certainly generated a wealth of data, there is understandable reluctance (because of the cost and disruption) to retrofit a PHM system to such an operational fleet. While one can gain a sense that the qualitative costs/benefits are increased by the mere thought of fleet modification, the PHM system could be specifically designed to address sub-system failure modes that had been demonstrated in operational service, as opposed to those defined at the outset. Moreover, the available fleet data provides insight into the number of occurrences of the various failure modes and an experience base of the resulting costs or disruptions. These data enable the cost/benefit case to be not only more carefully computed but also more believable based on the fact that the data are “real” as opposed to conjecture. For a fleet that is still to be introduced into service, implementation of a PHM system in the design stage is undisputedly the optimum time, both from ease of embodiment and ROI. However, there is likely to be neither operational data on which to help define the PHM system design nor real reliability data to predict the number of failures that the PHM system is going to “prevent” or predict. This makes a cost/benefit analysis more difficult to not only compute but also to generate with sufficient fidelity. On the other hand, many of the hardware costs of a PHM system may be already cost justified, based on other business needs or at least shared with other needs making the effort much easier. The earlier reference (3.2) to a PHM system being a “living thing” as opposed to a “fit and forget” capability is thus apparent for both new and legacy systems. The sustainment, which includes the continual evolution of the PHM system, is therefore a cost element that needs to be included in the CBA for both.

In legacy commercial platforms, the Aircraft Communications Addressing and Reporting System (ACARS) has been the (very limited) standard character-based ASCII system for air to ground communication of onboard issues reported by the flight crew. Additionally, flight operations quality assurance (FOQA) is a process which uses data captured in flight at around 1 Hz, and subsequently trended on the ground, to monitor how the plane is flown, handled, and operating. Software development to capture the data sets has been necessary and, in some cases, modifications to the flight data recorder or ACMS (aircraft condition monitoring system) have been pursued to capture data in a particular format so as to be sent over the ACARS. This has required software modifications on the aircraft and on the ground operations hardware to enable the data to be received and handled. Some airplane OEMs maintain that retrospective addition of sensors or HM algorithms is still viable, depending, of course, on the motivation. One particular OEM cited the addition of a sensor to collect an extra parameter onto the data bus that was driven by HM needs. Thus, it is important not to over-generalize and assume that retrofits are not economically practical. While it will usually be a tougher case to justify, the ease of installation onto a legacy system and the benefits derived can conspire to make the case. The situation can be further complicated by which party is perceiving the benefits. Once again, the motivation can be OEM driven or operator inspired and while both will have different perspectives, it matters little; if one of them sees the benefits sufficiently to propose the introduction of a PHM system, then the two parties collaborating to explore the optimum scope, the system’s degree of complexity and its implementation will probably generate the best end result.

Consider, for instance, adding an “embedded reasoner” to an unmanned air vehicle (UAV) that will perform prognostics and health management for all the systems on the platform. While improved availability and reduced maintenance benefits can be computed, the negative effect on the platform’s range or “time on station” can also be determined, based on the additional weight of the on-board system and the potentially reduced fuel load capacity. Herein is the complexity. If the embedded reasoner is retrofitted to an existing platform, resulting in added weight, then the downside is the reduced number of minutes that the UAV can loiter at the area of interest; this has to be weighed against the qualitative benefits of improved availability, reduced maintenance, etc. But if the reasoner system is implemented during the design of the UAV, then it might be that the redundancies and conservatism inherent in the original design can be removed or reduced (e.g., single flight control actuators instead of dual, vehicle structural weight, etc.). The end result could be that introducing a PHM system and its associated weight, actually reduces overall platform weight and possibly cost of manufacture and improves platform capability and performance (such as time on station). That said, the safety assessment process exists in civil aviation to guarantee that the probability of occurrence of faults is proportional to the inverse of its severity. One way to guarantee that is to add redundancies. Currently, it is not an acceptable procedure to take credit for PHM in the safety assessment process, i.e., the regulations that define the safety assessment process do not comprise the use of PHM in that way. On the other hand, HUMS, which has been established for decades, has enabled at least one operator to be granted maintenance credits (which is an earlier step than being able to remove a redundancy) and has occurred because there are regulations that define the possibility of getting maintenance credits by using HUMS. This is important for those considering to perform a CBA for IVHM to understand that the potential benefit is currently a long term possibility. Additionally, building in capacity at the outset for introducing smart software updates that would increase PHM capability in the future, depending on how the new platform performs as it ages, would be prudent as software is typically easier and cheaper to retrofit than hardware.

4.4 Impact on Design

In the current era, the aircraft manufacturer needs to design the aircraft with PHM in mind, and, in so doing, press suppliers of LRUs or sub-systems to ask themselves these two questions: “What data would I need to determine whether my LRU/sub-system is failing?” and “If I could collect data to trend my LRU/sub-system over time, would I be able to remove and replace the faulty component just prior to a failure?” These questions impact how engineers design their systems on a more detailed level than just taking into account the weight and cost of a PHM system. This is not easy to do, but it is a necessary step if the PHM system is to be at its optimum effectiveness. It also generates more initial costs, but these should be seen as an investment as they will generate a greater set of benefits. As discussed in the prior paragraph, the benefits are likely to be shared, albeit to varying or different extents, by both OEM and operator. Interestingly, besides the OEM and operator, third parties may also benefit (e.g., by providing IVHM related services). If a third party is going to provide services, instead of the OEM (because the OEM may not be willing or interested in providing IVHM services), then the OEM might have a lesser interest in adding PHM features to the aircraft, so the level of the OEM’s interest in the after-market activities might well influence the design of the PHM system. Additionally, the business case must be clear for suppliers. Sometimes, suppliers are risk-sharing partners in the development of a new aircraft. If the business case to suppliers is not clear, than adding PHM features to components and sub-systems may become excessively costly.

4.5 Performance Versus Reliability or Sustainment

For commercial platforms, increasing a fleet’s performance and capability is not usually as important as cost-effective sustainment of the fleet throughout the life cycle. For business aircraft, increasing dispatch reliability and availability is a key focus area. For military systems, however, technology upgrades and increases in performance or capability usually trump fleet modifications, even if those modifications might greatly benefit life cycle costs. Such an example is fleet implementation of a new radar for the F-15E in the 2005 to 2015 timeframe at a cost of about \$800M, a program that for the available funding competitively beats out other sustainment initiatives (such as replacement of pyrotechnic bomb racks with pneumatic bomb racks despite the highly attractive cost/benefit analysis, or implementation of PHM systems). The point is that the strength of a CBA is not the only thing that determines whether a PHM system is implemented on a platform or not. An extremely strong CBA case could still be insufficient to win the necessary funding for implementation. Other considerations can come into play including affordability, public perception (e.g., of a safety issue), contractual commitments, customer acceptance, etc. As discussed in 3.1, civil/commercial operators will be more driven by economics than in the military world, where maintenance is measured by labor-hours per flight-hour, but not necessarily paid for by the hour (the military personnel are seen as a sunk and set cost, irrespective of hours worked). Winning the military fight against adversaries is uppermost. Nonetheless, the complex interaction of these two contrasting scenarios can be easily sensed and vigorously debated. A PHM system could be advocated in military applications based on the system’s contribution to “win the fight” through reduced or zero “surprises” during the operation of the weapon system (i.e., improving “mission assuredness” and/or “readiness”), a meaningless factor in commercial aviation. Calculating or assigning a monetary cost/benefit to, say, a one percent increase in platform availability, readiness, or mission success is extremely complex and arguably the most nebulous factor to calculate. This is because the value of availability is surrounded by subjectivity; understandably, availability means different things to different operators and entities. The issue is discussed further in 6.7.2.