HUMS are NOT a Magic Bullet

Graham F. Forsyth [1]

[1] *Formerly in what is now Aerospace Division, Defence Science and Technology Organisation, PO Box 4331, Melbourne, Victoria, 3001, Australia*

Abstract

There is a widespread trend to offer HUMS on new and upgraded equipment. However, one point seems to be often overlooked.

HUM systems are only as good as the data management and data utilisation implemented. If the HUMS data are not actually used or only used on features which do not have high returns, the HUMS is an expensive waste.

Some years ago, DSTO introduced a software tool called HUMSSave which illustrates not only the features of a HUMS which lead to savings but which areas are essential to make the HUMS worthwhile.

This paper looks at a procedure to make sure a HUMS is being well utilised to make sure it does have a positive impact.

Keywords: HUMS Data Management, Data Utilisation, XML.

Introduction

Even before the Wright Brothers flew, it was known that aircraft need to be monitored to be safe. Early monitoring was done by hand and ranged from checking operation of engines (e.g. full power on either magneto) and control surfaces (e.g. co-pilot or engineer watched while pilot moved the controls) to counting numbers of take-offs and landings and even recording the time spent at or above some critical power setting. These requirements increased markedly when the concept of fatigue became understood; fatigue needed either an accurate record of cycles in loads (and hence strains) for high cycle fatigue or accurate monitoring of regimes for low cycle fatique.[*]

Health and Usage Monitoring Systems are designed to incorporate as many monitoring functions as are needed for a specific aircraft (or class of aircraft) into one system. Normally, HUMS are considered as comprising two parts; the airborne recording system and sensors, and the off-aircraft HUMS Data System. However, it has become apparent that the off-aircraft part is actually two functions, the HUMS Data Management System (which records and stores the data downloaded by the HUMS) and the HUMS Information System (which

* It is beyond the scope of this paper to discuss the difference between low and high cycle fatigue except to comment that counting of high cycle fatigue involves a large number of simple cycles whereas counting of low cycle fatigue involves a smaller number of complicated strain patterns. The example of counting take-offs and/or landings is an example of the low cycle case.

allows the data to be accessed, compared, plotted, interpolated (e.g. to assess remaining life) but not changed.

BACKGROUND.

Early in 1954, the Queen was due to arrive at my school[1] by helicopter. All the children in the school were very excited and I thought the Queen (and Prince Phillip) was very brave to fly in a helicopter. A plane flew over and took photos of all the children arranged to make out the school name (I was in the second "I") and the Queen arrived shortly after. The small children were handed out flags on sticks to wave, I kept my Aussie Jack for many years but most of my class got Union Jacks[2].

In actual fact, the helicopter[3] had been grounded because one of the fleet was found to have a cracked drive shaft to the rear rotor. I thought at the time that the Queen was a very brave young lady to fly in a helicopter, I still do!

HELICOPTER HuMS.

The unreliability of early helicopters sprang largely (but not exclusively) from the engine which were usually based on aircraft piston engines but more highly stressed. The switch to more powerful gas turbine engines moved the weak point from the engine to the transmission. Transmission failure caused a number of helicopter crashes in the late 1960s and early 1970s, and late in the 1970s Mechanical Engineering Division of Aeronautical Research Laboratories convinced the Royal Australian Navy to record vibration on a small number of Westland Wessex helicopters at regular intervals. Unfortunately, simple FFT analysis of this vibration data did not detect a growing failure and a Wessex of the RAN crashed in Bass Strait late in 1983.

The first HuMS units were invented to fix this specific problem of helicopter transmission failure and thus were largely concerned with the Health rather than the Usage component even though many of the failures were due to metal fatigue. Each of the competing units was validated against their ability to correctly detect the problem in recordings of the RAN Wessex. By October 1986, there were at least three algorithms (due to Ron Stewart, Derek Astridge and Peter McFadden) which could reliably detect the Wessex failure sufficiently before failure. At the 41st meeting of the Mechanical Failures Prevention Group[1] at Patuxent River Naval Air Station, a panel chaired by Paul Howard decided to call these new tools Health and Usage Monitoring Systems or HUMS.

These Helicopter-mainly systems have been referred to as "small u" HuMS. Within a few years, these systems had produced a safety improvement in helicopters fitted with them of about 30. This is a remarkable improvement, we cannot expect that any current system will show this much improvement because we hope all helicopters are now much more reliable anyway. It is worth noting at this point that most outputs from these predominantly mechanical Health monitoring systems are from the airborne system – the ground systems required are largely for validation and testing although some work considered fitting Expert Systems to further analyse the HUMS results. [2]

---

1 Ironside, at that time the largest primary school in Queensland and one of the largest in Australia.
2 Union Jack means a small Union Flag fixed directly on a Jack Stick.
3 I believed it was a Westland Wasp but it was a Bristol Sycamore Mk 50 of which RAN had 3.

AIRCRAFT and HELICOPTER HUMS

The introduction of full health and usage (large U) HUMS into service has been largely done by the aircraft/helicopter manufacturers. Specifically, there have been few cases where operators have fitted HUMS to existing helicopters or fixed-wing aircraft after the initial helicopter HuMS efforts in the late 1980s and 1990s predominately in the North Sea oil fields.

The problem with the factory fit approach lies in the need for compatibility with existing data management. As mentioned in the Introduction, Health and Usage Monitoring Systems are designed to incorporate as many monitoring functions as are needed for a specific aircraft (or class of aircraft) into one system. In 1996, DSTO prepared a document which examined the areas likely to produce savings from a HUMS [3] and from that created a software program which demonstrated which HUMS features would be or would not be cost effective for a specific HUMS configuration in a specific aircraft. [4] This was later extended to cover land vehicles, ships and indeed fixed high-value machinery. [5,6]

As also mentioned in the Introduction, HUMS are normally considered as comprising two parts; the airborne recording system and sensors, and the off-aircraft HUMS Data System. However, it has become apparent that the off-aircraft part is actually two functions, the HUMS Data Management System (which records and stores the data downloaded by the HUMS) and the HUMS Information System (which allows the data to be accessed, compared, plotted, interpolated (e.g. to assess remaining life) but not changed. Further, in the initial largely Health Monitoring case, the “Flight Critical” software is largely confined to the airborne system while for many arrangements with extensive usage components, all three parts of the software may be Flight Critical.

HEALTH AND USAGE MANAGEMENT SYSTEMS

The HUMS Information System, the third part of the HUMS Software, has become so important that many modern HUMS are referred to as “Health and Usage Management Systems”. The importance of understanding data management will be illustrated by an example, unfortunately not a unique event.

Why a Mis-Used HUMS Can Cost You Money (and Safety)

Implementation of an HUMS for fatigue life limited items depends on the HUMS data for both cost saving and safety. A few years ago, a problem with data management on the AE2100 engine in the C-130J aircraft reduced available engine life to below that expected; below in fact engine life of the previous T56 engine. This was due specifically to worst case usage needing to be applied because actual data was not available. As expected, worst case was worse than average which is by itself worse than actual for half the fleet (by definition of average).

This is an important lesson. If fatigue life limited items are to be managed by using the HUMS to accumulate counts and exchanging that part when the maximum count is reached, the process to do that is flight critical. Safety and cost both depend on the process being achieved. When we designed the HUMSsave program we did not realise that data management issues could lead to the HUMS costing money.

This particular problem has been fixed [7] but presents a lesson to avoid such a problem with subsequent installations.

How HUMS is SUPPOSED to Save You Money

The HUMSSAVE model applies a monetary value to everything and to every event. Of course, this undervalues a number of significant factors such as loss of life, loss of aircraft (or vehicle) and even disruption of mission but, that aside, it demonstrates that information collected by a HUMS can be very valuable indeed.

The point which seems to be often missed is that this information is not only valuable, it may be flight critical.

If parts of the aircraft engine or aircraft structure are being lifed using data collected by the HUMS the data must be treated with great care. This implies that the design of the ground system for managing HUMS data can be as important as that of the airborne part.

Some time ago, I suggested the use of XML to manage HUMS data.[8] XML is an example of a markup language which handles both documents and data.

In the 1970s and 1980s, markup languages were invented to allow first text and later pictures and drawings to be handled by basic computer systems which often couldn't even manage case properly. The advent of desk-top publishing with WYSIWYG (what you see is what you get) seemed to have consigned markup back to the newspaper composing room where it originated. However, it soon became obvious the features of markup allowed consistent display of information both at different times (temporal) and different places (spacial).

The US Military decided to demand that all electronic manuals be provided in a markup language and specified an open standard called SGML (standard generalized markup language, ISO 8879: 1986) in 1986. SGML is a standard for markup languages rather than a markup language itself.

Perhaps the best known implementation of the SGML standard was HTML, the language of the web as the first 4 versions of HTML complied with the ISO standard. (HTML Version 5 has some features which do not comply.) HTML is largely focussed on spacial consistency (available world-wide) whereas the US Military documents were largely focused on temporal consistency (available across many years). The programs used to read HTML files are called browsers and the same browser can read and display many different files. No longer does the program used to manage a bank account differ from the one used to read a book. [9]

Extensible Markup Language (XML) is a specific implementation of SGML for either documents or data. XML data files have markup information inside them so they can be utilised on their own. Unlike binary data files such as produced by older computer programs like Fortran, XML files are far more robust; the level of damage which makes a Fortran data file unreadable may damage a small fraction of the data points in an XML file. This document was produced in XML.

In an ideal world, HUMS would produce XML files which could be read by a browser so data from different aircraft types can be easily managed.

HOW TO MAKE SURE HUMS ACTUALLY WORK.

The example for the AE2100 above is not unique but also not something that needs repeating. In fact, that problem was widely repeated across the list of C-130J operators, largely because of the piece-wise nature in which the system was delivered. The following process needs to occur at some stage, preferably very early in the aircraft life cycle. The process then needs to be repeated until every item is covered.

1. Create a list of all structural and engine components which need to be "lifed" and then check that the Aircraft Maintenance Management System (CAMM2 for Australia) tracks changes to every one of these items.
2. Create a list which matches each item on the first list with the relevant HUMS data items and check there are no missing items.
3. Validate that the HUMS Ground Software allows access to all the data on list 2.
4. Validate that the HUMS Ground Software actually totals life for all these components or can be extended to do so.

Early versions of the C-130J ground software did not make any of these steps easy.

CONCLUSION.

I first started programming and using computers 50 years ago. Within a few years of that start, the aim of many users was to create self-learning information systems which allowed access to information not just data. 50 years later, the only area where that appears to be happening is in financial aspects; e.g. either of the two main supermarket chains can predict which items are most likely to be in the trolleys of specific shoppers. More precisely, the supermarket chain I use recently sent me a personally-tailored list of specials, every one of which I had purchased in the previous 6 months. Love this or hate it, it is an example of the power of using information, not just data.

In the 1980s it was believed that engineering would be the great beneficiary of such technology. One of the reasons it hasn't been is a lack of overall vision on managing data and information.

In general, my impression is that the power of computers has grown massively over the last 50 years but the usefulness has not grown as much as expected. The challenge now is to make HUMS data into useful information.

References

1. Forsyth, G.F., "Report on an overseas visit in Oct/Nov 1986 to review maintenance procedures for F404 engine Electrical Control Unit and related matters", ARL-PROP-TM-450, November 1989 pp 14-15.
2. "Report of a visit to Europe in June 1992 concerning the application of AI to helicopter transmission health monitoring", G.F. Forsyth, ARL-PROP-NOTE-1/93, January 1993.
3. "Guidance Paper No. 3 - HUMS Cost-Benefit Analysis Methodology", Australian Defence Organisation Working Party on Strategic Planning for Helicopter Accident Data Recording and HUMS, May 1996.
4. "HUMS Econometric Model", Version 1 by Richard Adams in 1995, Versions 2 and 3 by G.F. Forsyth, software package released as either a two-floppy set or as a CD-ROM, April 1997.
5. “HUMSSAVE 4 – An Upgraded Econometric Model for Cost/Benefit Studies of HUMS”. Graham F. Forsyth and Eric CJ Lee, DSTO Australia, Proceedings of HUMS2003, February, 2003 *
6. “Generic Economic Benefits Model for ADF B-Vehicles HUMS”, E. C. J. Lee, Air Vehicles Division, DSTO Australia, Proceedings of HUMS2007, February 2007. *
7. “RAAF C-130J Engine Health Management”, Andrew Wade, Department Of Defence, AUSTRALIA, Proceedings of HUMS2013, February 2013. *
8. “Case for XML as the Format for Long-term Storage of HUMS Data”, Forsyth, Graham F, DSTO, Proceedings of HUMS2005. *
9. "Markup Languages - A Modern Lazarus", by Graham F. Forsyth, Paper published by DECUS Australia inc, August 1995.

* Items available from Papers page of www.HUMSConference.com.au website.