

STRUCTURING AND COMMUNICATION OF HUMS DATA

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Abstract

Health and Usage Monitoring Systems (HUMS) are condition monitoring systems for rotorcraft. A HUMS records data such as vibration, flight data parameters and cockpit alarms, transferring it to a ground station computer after each flight. A ground station contains an historical data record of each aircraft, in some cases their entire life span. The day-to-day data analysis of this data, which is performed by the ground station itself after each flight, includes both vibration-based fault diagnosis and load-cycle-based prognosis for critical components.

It is in some cases necessary to perform more in-dept analysis of the HUMS data. This work is typically performed by the HUMS or airframe OEM, and involves tapping into the data reservoir of a HUMS ground station using third party numeric analysis tools. Supporting several HUMS versions from different manufacturers poses a problem when interfacing with third party tools, as each HUMS version typically has its own data storage format.

This paper outlines a common interface to HUMS data reservoirs. The interface enabling third party tools to access data from any proprietary storage without having built-in support for each data format. This is achieved by a layered architecture, where a data driver is developed for each data format. All though each data driver is designed to handle different data, all drivers have the same programmatic interface. This makes the underlying HUMS data structure transparent to the analysis tool, greatly simplifying development and integration.

1 Introduction

The purpose of a Health and Usage Monitoring System (HUMS) is to foresee mechanical faults before they become critical. To achieve this, a HUMS works both proactively and reactively. The proactive part, usually referred to as usage monitoring, monitors the actual usage spectrum of the aircraft. This involves calculating fatigue cycles on critical components such as rotors, gearboxes and engines. Fatigue cycles are metrics which describes the stress a component has been under more accurately than simply using flight time. Further, the usage monitoring system logs any in-flight warnings such as gearbox overtorque and engine overheat. The purpose of alarm and cycle logging is to keep track of events causing component degradation, and estimate the remaining safe life of critical components based in this information.

The reactive part of the HUMS, usually referred to as health monitoring, attempts to detect the presence of mechanical degradation before the damage becomes critical. This is achieved through a sensor network covering most dynamic components such as rotors, gearboxes, external shafts and engines. For the current generation HUMS, these sensors are mainly limited to acceleration and angular speed sensors. These sensors are used for recording the vibration signature of dynamic components. The vibration recordings are then analyzed to detect the presence of any anomalies in the drive-train.

For the continued evolution of the Health and Usage Monitoring Systems, it is of vital importance to be able to aggregate the experience already obtained by the systems currently in use. This poses several technical challenges, as each commercial system organizes its data storage in different ways. This paper presents a solution to fuse the data from different systems and versions into a common knowledge base, so that this data can be accessed through a single interface. Such a tool is essential for extracting and aggregating the experience obtained through all HUMS solutions currently and formerly in use.

2 Analysis Process

All though each HUMS solution on the market does things slightly different, the overall process is usually the same. This includes the datatypes that are recorded or derived by the HUMS. The fundamental data sources for usage monitoring are the flight data parameters, i.e. information like airspeed,

altitude and engine torque. These are used for generating event markers like engine overheat and rotor overspeed. The usage monitoring function also calculates usage cycles, and generates event markers for components reaching their retirement age in terms of accumulated cycles. Each marker is stored with the contextual informations relevant to its type.

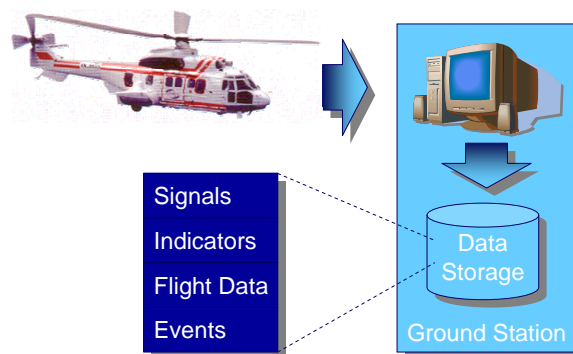


Fig. 1: HUMS analysis process.

For health monitoring, the fundamental data sources are the vibration recordings. From the recording from each component, a set of condition indicators are derived. These are parameterizations of the raw vibration signals, and are closely correlated with the state of the underlying assets. The indicators are aggregated by a classification system able to detect the presence of mechanical degradation. A set of event markers are produced by the classification system. This set of markers represents observations of assumed mechanical degradation, and compliments the set of markers representing anticipated faults generated by the usage monitoring.

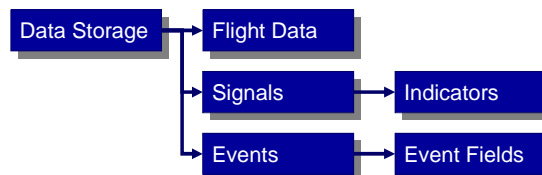


Fig. 2: Basic datatypes.

This makes a total of five datatypes for the HUMS. Two fundamental once; flight data parameters and vibration recordings, and three derived once; indicators, event markers and event marker fields. The event marker fields are the contextual informations accompanying each event marker. The work distribution between the airborne segment and the ground station is proprietary to each HUMS solution. Regardless, all five datatypes will eventually end up in the data storage of the ground station.

3 Architectural Layers

All though the data from every HUMS can be generalized into a set of standard datatypes, the storage format is proprietary to each HUMS. Most HUMS solutions on the market today use either a proprietary directory / file structure or a third party SQL database. Event though SQL databases has standard interfaces, the table structure is still proprietary to each HUMS version.

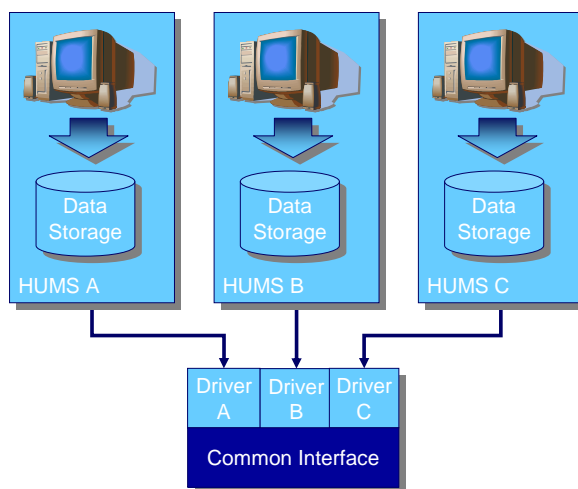


Fig. 3: Data interface layers.

This barrier has been overcome by developing a data storage driver for each supported HUMS version. A storage driver is an implementation of standardized Application Program Interface (API). The functions defined in the API provides the necessary tools to connect to a data storage, enumerate

the elements of each datatype, and extract the underlying data. All though the inner workings of each driver is very different, the outside interfaces are identical.

The common interface layer exposes this standardized interface to any third party application through ActiveX. This layer accepts connection requests from any third party application, loads the driver corresponding to the HUMS version provided in the connection request, and connects to the specified target data source. Once a connection is open, the third party application can interrogate data objects within any supported HUMS data reservoir without any knowledge about its underlying structure.

All HUMS data drivers support remote connection, meaning that data source and target application need not be running on the same computer. For HUMS solutions relying on a third party SQL database, remote access is managed by the database engine and connectivity drivers. For proprietary directory / file structured data reservoirs, remote access is provided through standard file sharing protocols. This way, remote access is provided without having to install any additional software on the data reservoir servers. This is an important point, as ground station software today exist for a variety of hardware and operating system platforms which in some cases are in the process of becoming obsolete, thus rendering development of any additional platform specific software unpractical.

For communication across Internet, data are channeled through Virtual Private Networks (VPN). VPN is an open technology which ties together two Internet connected Local Area Networks (LAN) so that they appear as one. A VPN tunnel ensures protection of both end networks, provides authentication of both parties, and allows encryption of all data transferred through the tunnel. Again, this is achieved using only standard protocols which is supported by all platforms.

4 Common Storage

The continuous research into fault detection algorithms requires large amounts of vibration data in order to understand how mechanical faults affect the vibration signatures of the transmission system. Testrig experiments are expensive, and are not necessarily representative for the vibration signatures recorded in flight. It is thus essential for a HUMS OEM to gather as much authentic HUMS data as possible. Such data can be extracted from the op-

erator ground stations using the solution presented in the previous section.

An additional technical challenge is finding efficient means of storing large quantities of data from several systems. By default, a HUMS OEM must keep one data reservoir available for each system and version in order to provide its researchers with access to the relevant data. Further, some ground station data reservoirs have limited capacity due to their design, meaning that a large number of data storage servers are necessary to host the data from an entire fleet of aircraft.

This problem has been overcome by the development of a common data storage. The common data storage is based on the generalized HUMS data format introduced in the previous sections, and is thus capable of storing data from any system for which a data reservoir driver exist. Further, this data storage solution is scaled to store all data ever recorded by an entire fleet. Consequently, it provides researchers with a single interface into all data recorded by all supported systems, greatly simplifying data management tasks for the HUMS OEM.

A data synchronization tool allows data to be transferred from a source ground station to the common data storage. The synchronization tool has its own graphical user interface (GUI) for selecting source and target connection credentials. In addition, it has an ActiveX programmatic interface allowing integration into other computer systems, such as web fronts.

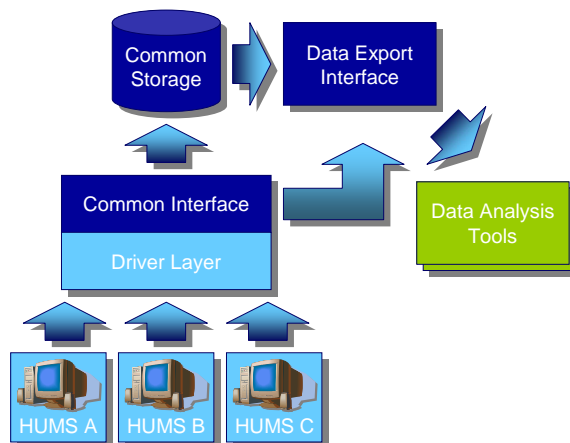


Fig. 4: Global dataflow.

Rather than interfacing directly with the common data storage at SQL level, third party applications gain access through a data export interface.

The data export interface is an ActiveX component allowing third party application to programmatically enumerate the objects within the common storage and extract the underlying data. It has also a GUI allowing the extraction of data into applications which do not have their own GUI for data object management. Further, the data export interface offers a mechanism for connecting directly to a ground station data reservoir through the common interface layer. This is especially convenient in support situations, as it allows HUMS OEM support personnel to tap directly into an operators ground station using specialist data analysis tools.

5 Discrepancy Reporting

Historical HUMS data is of little use if the states of the assets corresponding to the data recordings are not known. In order to extract any knowledge about the correlation between mechanical states and vibration signatures, both the states and their corresponding signatures must be known. In the context of pattern recognition, this is known as marked training sets. In order to have the historical HUMS data from an aircraft correctly marked, it is necessary to know when the operator experienced mechanical problems, as well as the nature of the problems.

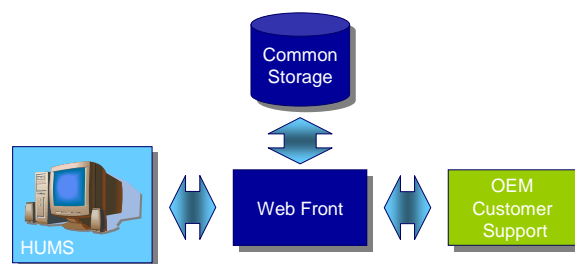


Fig. 5: Discrepancy reporting and follow-up.

This has led to the development of a discrepancy reporting system. The discrepancy reporting system allows operators to file a report online when ever an anomaly is suspected. Any such report will be handled by an expert at the HUMS OEM advising the operator of the appropriate action. This is a two-way communication process where the operator and the HUMS expert works together to locate the origin of the problem. Once the problem is

identified and the appropriate actions taken, the HUMS expert will set a marker in the common storage database explaining the uncovered anomaly, if any. This marker will be stored for future reference with all communication made during the fault isolation process.

Discrepancy reporting procedures already exists in some form or another for most HUMS OEMs. The advantage of the online reporting system is that it cuts response time for the support personnel significantly. Further, it provides automatic logging of discrepancy reports, facilitating statistical studies and correlation with HUMS data. This combination of a HUMS data storage facility and a discrepancy database allows researchers and support personnel to extract and investigate the vibration signatures corresponding to specific mechanical problems through the click of a button. When managing data from an entire fleet of aircraft, each aircraft producing hundreds of condition indicators for thousands of ours every year, it is essential to have data management at this level in order to keep oversight.

6 Benefits

This data storage facility is meant to benefit both researchers and support personnel. The key advantage for support personnel is the speed and flexibility of the discrepancy reporting system, allowing faster response to operator requests. This is supplemented by the common interface which gives instant access operators' HUMS data. Instant access means that support personnel can view an operator's HUMS data directly, rather than explicitly requesting the operator to send the necessary data. This results in reduced workload for the operator and shorter response time for support personnel. An additional benefit is that the periodic data transfer from operator to the HUMS OEM no longer requires the intervention of the operator, again reducing operator workload.

The motivation for providing researchers with this tool is, as already mentioned, to facilitate research into the correlation between vibration signatures and drive-train failure modes. Further, the discrepancy database permits data mining operations like calculating fault detection frequencies and false alarm frequencies. Such frequencies can be calculated across indicators, components and rotorcraft models. This helps the HUMS OEM gain a better understanding of the effectiveness of each HUMS function, so that research can be focused on the most significant weak-points. It also gives support

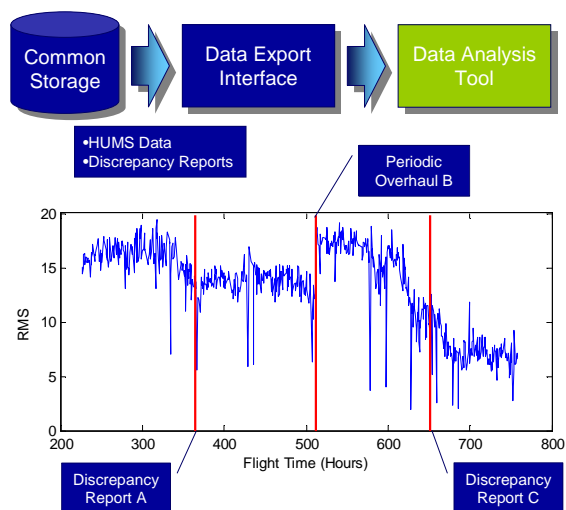


Fig. 6: Condition indicator with discrepancy markers.

services a better situation awareness concerning problem distribution across operators, aircraft and aircraft models.

7 Concluding Remarks

Most in-service difficulties associated with Health and Usage Monitoring Systems can be attributed to their complexity. The number of components monitored and the number of failure modes these systems are designed to detect are immense. This makes it highly challenging to monitor the performance and reliability of each sub-function, and poses the risk of HUMS OEMs being buried in discrepancy reports and raw HUMS data without being able to extract the knowledge hidden within.

The solutions presented in this paper are an attempt to counter these problems by aiding the HUMS OEM in organizing the incoming data, and extracting its essence. This is done by addressing the problem of fusing data extracted from different systems, correlating this data with discrepancy logs, and exporting it to third party numerical analysis tools. All though the two latter points are already addressed by certain OEMs in some form or another, data fusion across systems is an area which so far has received little attention. This is however a vital point, given the number of solutions in

service today. For the continued evolutions of HUMS, it is essential to be able to exploit the knowledge accumulated by older systems when developing the next generation technology.

The tradeoffs from better data handling are both short and long term. On a short horizon, these methods provide better support services for the HUMS OEM by reducing response time for the support personnel as well as reducing operator workload. In the long run, better data handling will result in a better situation awareness for the HUMS OEM, making it easier to adapt the systems to customer demand.