The Fusion of Data from Existing On-Board Monitoring and Instrumentation Systems to Achieve More Accurate Usage Monitoring

H.G. (Greg) Cook
Technical Enabling Services
MOD DPA-DLO, Fleetlands
Fareham Road, Gosport
Hants PO13 0FL
UNITED KINGDOM

ahm4@aim.mod.uk

1.0 INTRODUCTION

Under a duty of care and in-line with the UK Civil Aviation Authority requirements for large helicopters, in 2000 the UK Ministry of Defence (MOD) introduced a Health and Usage Monitoring System (HUMS) for one of its helicopter fleets. Subsequently, the MOD fitted HUMS to several other helicopter fleets, and has an intention for future fits too.

To date the emphasis has been on the Health Monitoring aspects of HUMS, in particular with respect to automated rotor track and balance, and the analysis of drive-train vibration. This has led to some significant successes with the detection of failing gearboxes.

The need to maximise the exploitation of the HUMS data in terms of cost/benefit, improved availability and improved airworthiness, however, has led to a growing emphasis in developing prognostic capability with the further possibility of a move from preventive maintenance to condition based maintenance.

The vast amount of data available, together with the rapid improvements in computer processing speed and storage capacity has also led to prognostics being significantly more viable than in the past.

There are a number of definitions of prognostics but for the purposes of this discussion paper it is proposed that “prognostics is the estimate of remaining useful life from the initial diagnosis of a component/system fault.”

The estimate of remaining useful life does have to take into account the rate of degradation of the failing component, and in turn, this requires an objective view of the degree of severity, or otherwise, of the future usage of that component/system. In a similar way, in order to make this forecast it is necessary to fully understand the usage that underlies the initial development of the fault.

2.0 USAGE MONITORING

Currently usage is measured by the pilot’s watch, yet, an integral part of the HUMS is the Flight Data Recorder (FDR) which in the case of one helicopter type involves the acquisition of over 130 engineering parameters containing a potential wealth of information to support diagnostics, but also capable of interpretation to give a more objective view of usage, and this on an individual aircraft basis.

An objective view of individual aircraft usage is also likely to impact on the lifing of aircraft components in terms of cost benefits through extending usage, or improving airworthiness through identification of particularly adverse usage that might lead to early component failure.

The move from a safe-life approach for helicopter components to a damage tolerance approach would be facilitated by a more objective view of usage. Again with likely benefits in through life cost reduction and improvements in airworthiness.

3.0 FLEET USAGE MANAGEMENT SYSTEM

Over a number of years the UK MOD has worked closely with MJA Dynamics (now known as GE Aviation – Southampton) to develop the Fleet Usage Management System (FUMS). FUMS development has focused on three main areas:

a) Usage Monitoring.

b) Data Fusion (DF).

c) Intelligent Health Monitoring (IHM).

For the purpose of this paper only those aspects of FUMS related to Usage Monitoring will be discussed.

4.0 FUMS – USAGE MONITORING

FUMS uses two methods to monitor aircraft usage:

a) Comparison of the Actual Usage Spectrum with the Design Usage spectrum based on Flight Regime Recognition analysis of the aircraft's FDR data. (See Figure 1). From a comparison of the actual and design usage spectra shown in Figure 1 it can be seen that for the 156 flights monitored the aircraft spent more time on the ground than was anticipated, significantly less time in straight and level flight and more time low level flying. The significance of this, particularly with respect to lifing issues, can only be fully assessed by taking into account the Design Authorities assessment of the flight loads associated with the flight regimes.

b) Usage Indices (UIs), based on a rainflow analysis technique, are used to quantify the cyclic nature of certain key parameters such as indicated airspeed, control movements, engine temperatures and pressures, and pressure altitude. The results are summarised as a single figure for each parameter for each flight, the higher the figure the higher the "severity" of use (see Figure 2). Each bar, in the bar chart in Figure 2, shows the usage index for a flight based on indicated airspeed. Initial investigation of the high severity value shown by the yellow bar can be carried out by viewing the actual indicated airspeed record for that flight shown by the blue line graph. In this case the reason for the high severity score is the large number of take-offs and landings, GAG cycles.

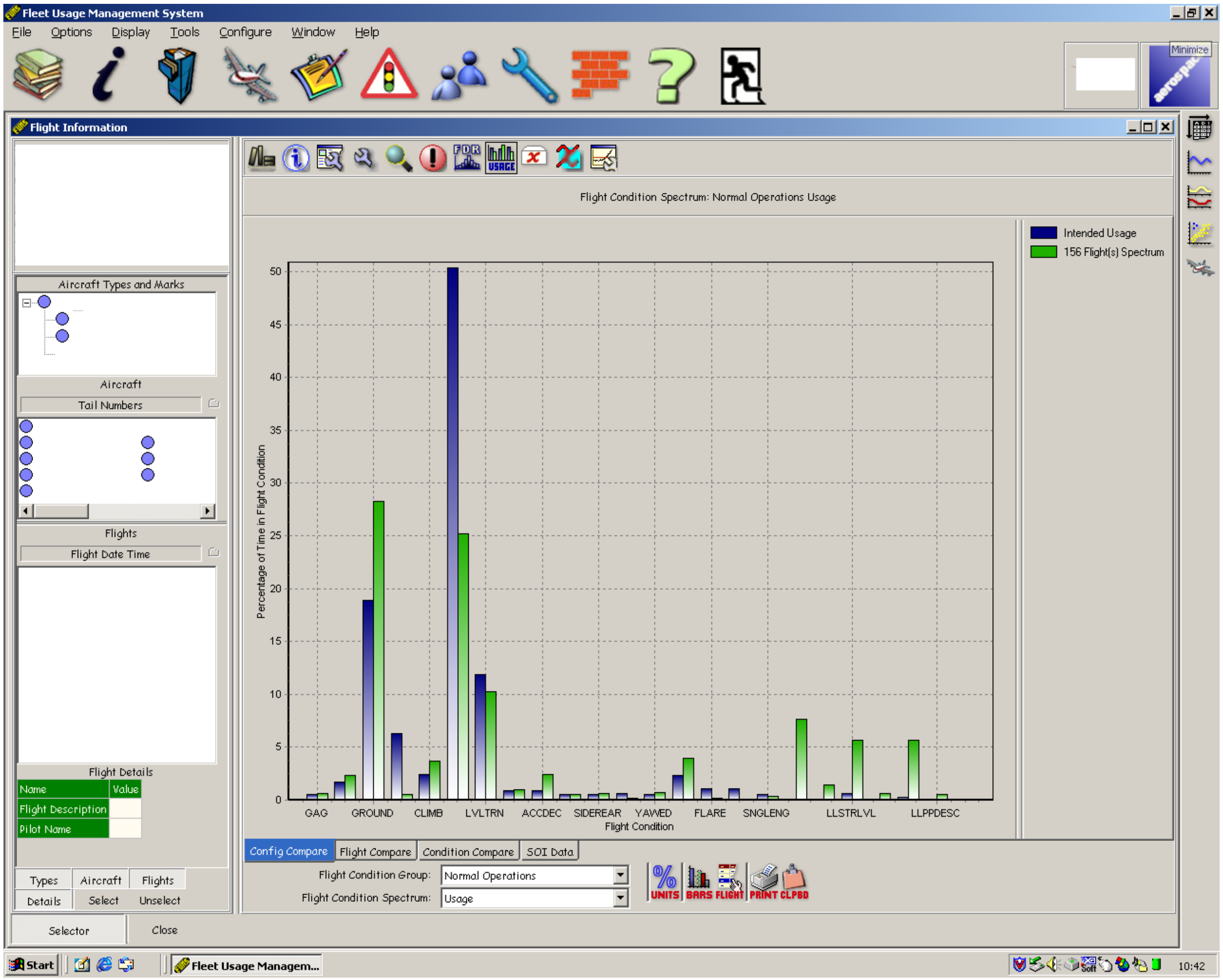

Figure 1: Comparison of Actual Usage Spectrum (green) and the Design Usage Spectrum (blue).

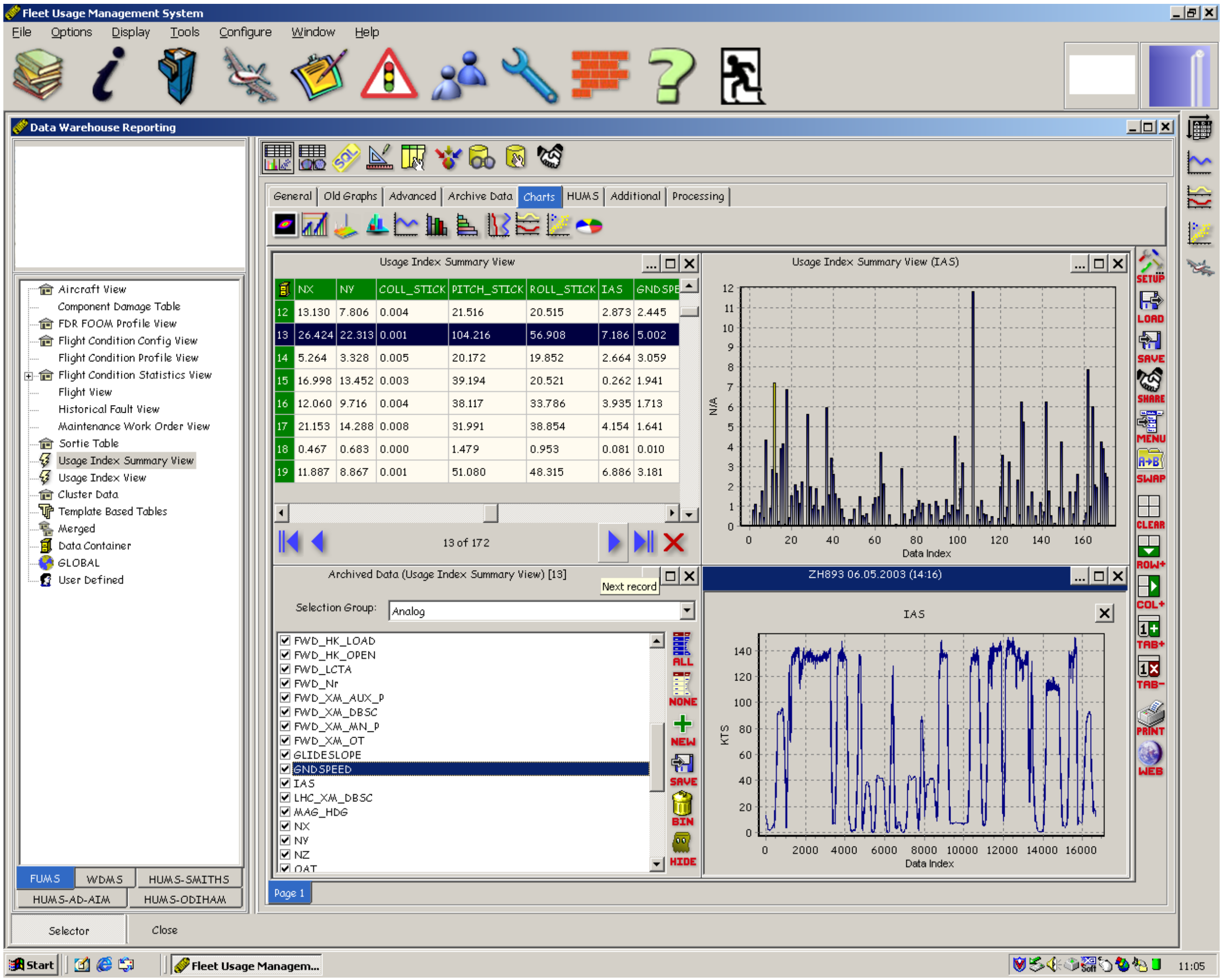

Figure 2: Usage Index Summary View.

5.0 USAGE SPECTRUM

Currently the Royal Air Force are required to carry out a Manual Data Recording Exercise every three years in order to assess the Actual Usage Spectrum, and then supply the results for comment to the appropriate Design Authority. FUMS provides the potential to carry out that assessment at anytime, and also for specific theatres of operation, specific squadrons or specific operating bases.

The Actual Usage Spectrum is a simplified summary of flight regimes to facilitate manual recording. Typically, when carrying out a flight loads survey for a prototype aircraft the Design Authority would look at well over a hundred flight regimes. FUMS can be set up to readily monitor this refined spectrum for individual flights, and by linking this data directly with the flight loads the fatigue damage for individual lifed components can be measured. Conceivably the weighted amalgamation of the fatigue increments could be used as a single parameter indication of “severity”. This single parameter could then be used to investigate correlation of component failures with “severity” of use and thus provide the bases of a prognostic/condition based maintenance approach.

6.0 FATIGUE SYNTHESIS

FUMS usage indices can provide a very good basis for the synthesis of fatigue, and hence a virtual fatigue meter for lifed components or critical aircraft structure (See Figure 3).

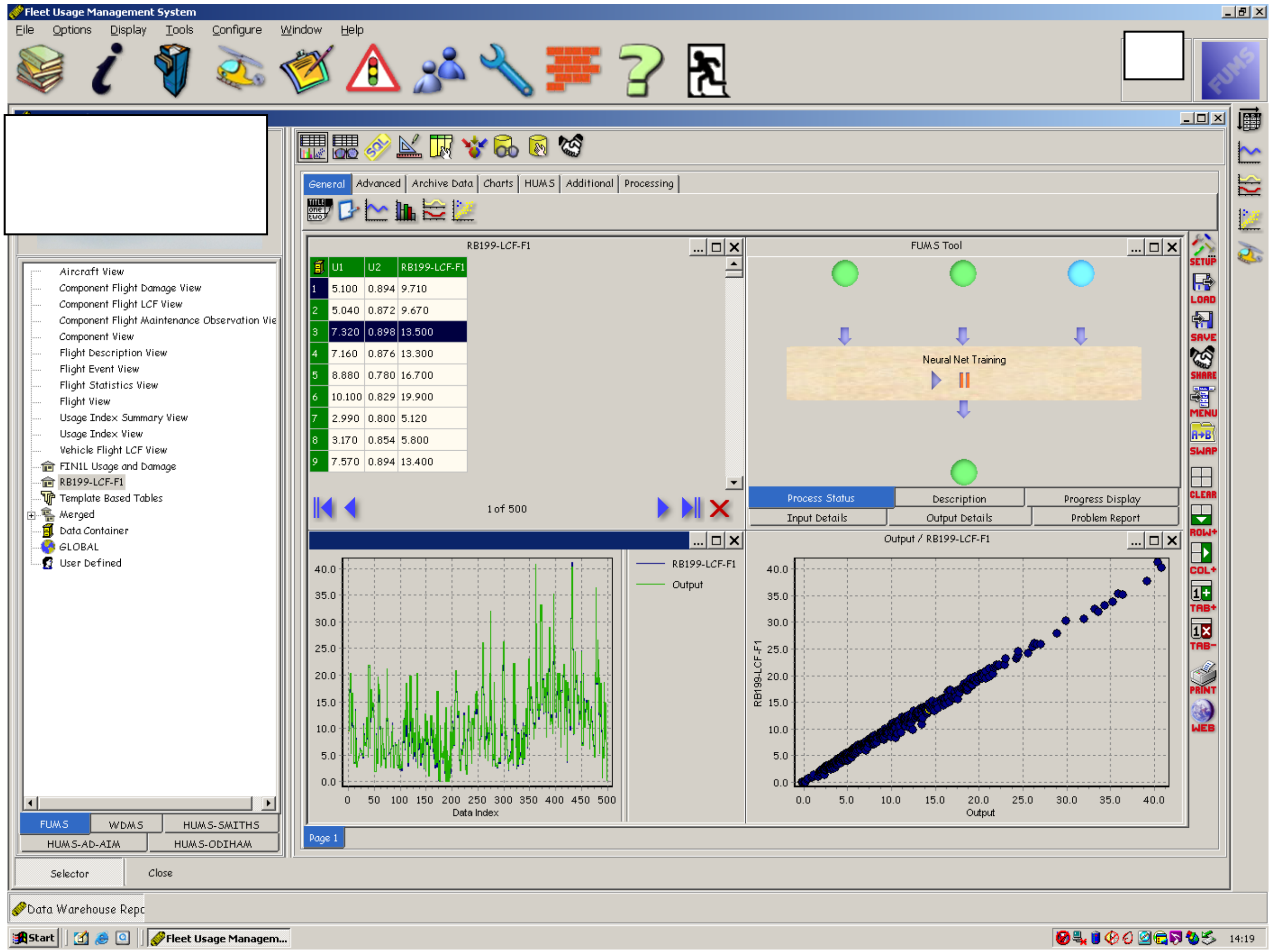

Figure 3: Synthesis of Fatigue for an Engine Component using a Neural Network and UIs.

Figures 3 and 4 show the results of a collaborative work between MOD, GE Aviation, BAe and Rolls Royce. Two usage indices, U1 and U2 based on two compressor shaft speeds, were calculated for each of 500 flights. The two UIs were input to a neural network. The target training data for the neural network consisted of the Rolls Royce calculated low cycle fatigue increment for a specific engine component for each flight.

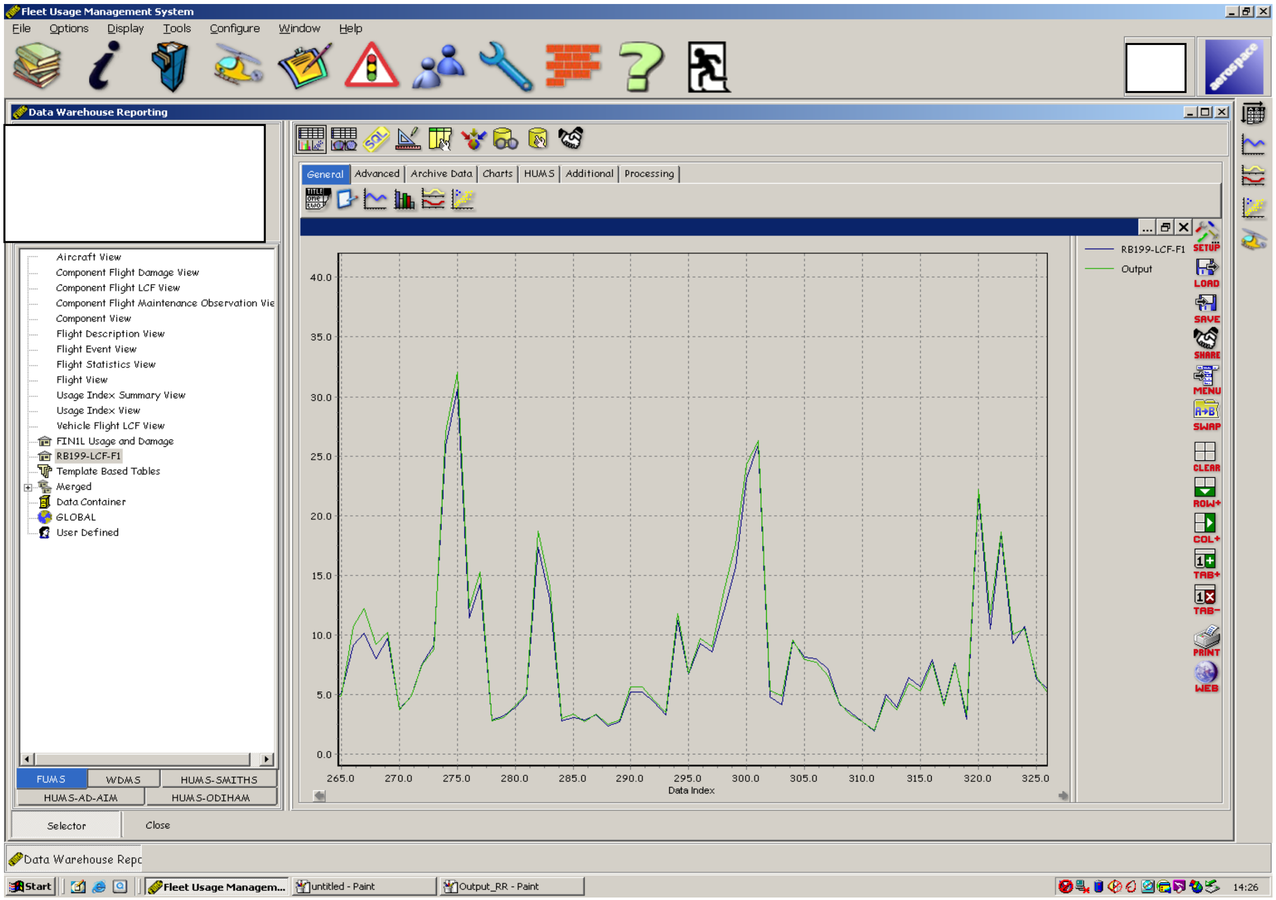

Figure 4: Results of Synthesised Fatigue.

The output of the neural network when plotted against the RR LCF data showed a very good straight-line relationship with a correlation of 0.997 after only two thousand iterations.

7.0 OTHER USAGE FACTORS

There are of course a number of factors that can impact on failure rates that cannot be identified from the FDR data, such as All Up Mass, Centre of Gravity (FUMS calculation of AUM and Cof G from FDR data is under development), operational factors, environmental factors, corrosion, pilot skills.

8.0 CONCLUSIONS

Whilst HUMS is fitted primarily as a diagnostic tool, the integrated FDR system opens up a more objective approach to identifying usage, and for individual aircraft.

Currently the UK MOD, in conjunction with Smiths Aerospace ES-S, is developing its Fleet Usage Management System to provide Data Fusion, Intelligent Health Monitoring and Usage Monitoring.

FUMS measures aircraft usage through a comparison of Actual and Design Usage Spectra, and also by analysis of the cyclic nature of certain key parameters to provide a Usage Index.

Both approaches to usage monitoring within the FUMS are capable of adaption to provide a virtual fatigue meter, and hence individual component life tracking.

9.0 DISCUSSION POINTS

Current technology enables the use of virtual fatigue meters.

FDR has been traditionally fitted to aircraft in order to facilitate accident investigation. As such, no attention has been paid to downloading FDR data as a matter of routine as would be required if it were used for usage monitoring.

How can a more objective view of individual aircraft usage be best utilised to improve availability in the near term?

DO 178-B "Software Considerations in Airborne Systems and Equipment Certification" are the generally accepted guidelines for aircraft software, but can impose considerable cost penalties when used for software used in ground station support. There is a need for a new standard particularly with the further development of usage and condition based maintenance support software.

The extension of Maintenance Free Operating Period (MFOP) approach as the route to condition based maintenance.

A move from safe-life to damage tolerance might well have financial cost advantages but would this be at the cost of an increased maintenance workload?