Abstract:

Condition-based maintenance (CBM) is a maintenance practice that involves regular monitoring of the mechanical condition of components of interest, processing of information collected, and then decision-making to ensure both maximizing the time interval between repairs and minimizing the number of unscheduled failures. CBM also offers early detection of failure which can prevent major breakdowns and repairs. Vibration monitoring is one of the effective techniques for condition monitoring, while Health and Usage Monitoring System (HUMS) is a powerful tool for aviation industry which monitors health status and trending data. Vibration Monitoring Unit (VMU) and Modernized Signal Processing Unit (MSPU) are two forms of HUMS used in AH-64 aircraft to implement CBM enabled environment. The tangible and intangible benefits of applying CBM concepts through HUMS in Army aviation is already well established. This dissertation aims to propose methods for further evaluation of value added to the system by implementing HUMS and CBM methodologies.

This research involves two major case studies which addresses the two categories of benefits: tangible and intangible. Tangible benefits are measurable in monetary value, whereas intangibles are not. Reduction in part cost, and maintenance flight hours, increase in flight hour, decrease in mission aborts etc. are various form of tangible benefits. Intangible benefits are seen as an important indicator of overall effectiveness of CBM implementation. This creates incentives for Army personnel at all levels to adopt this practice. This is measured from the survey responses of Army maintainers, crews and pilots. But as survey responses are subject to dynamic human behavior, this a continuous evaluation process which should be repeated time-to-time. The first case study presents a step in the direction of better understanding of how mission benefit areas like morale, sense of safety etc. are perceived by army personnel who fly and maintain Army aircraft equipped with HUMS. In this case study, a Likert-scale based survey responses have been statistically analyzed with an aim to reduce the survey response time keeping the accuracy unaffected. Maintainers, crews and pilots who are familiar with HUMS and also use the system to implement CBM methodologies, took part in that survey. The survey questions are designed to assess behavioral traits of the users towards the intangible benefits like morale, operational readiness, performance, sense of safety and sense of time savings. Some of these questions are directly focused to a single intangible benefit indicator, some are focused to two or more. First, survey questions are grouped into five categories assuming that they are all focused to single benefit indicator at a time and the average response score for each of the benefit indicator was calculated. It has been observed that a linear increasing
correlation exists between performance and each of the remaining intangible benefit indicator. Using 80% of sample data as test set, a multiple linear regression model has been proposed where performance is expressed as a function of morale, operational readiness, sense of safety and sense of time savings. While proposing the model, it has been statistically assessed that the sample follows normal distribution, the residuals have zero mean and have a constant variance. The hypothesis testing performed later also indicates that there is very strong evidence for morale and sense of safety towards performance. However, collinearity has been observed between performance and rest of the benefit indicators. Due to the presence of collinearity, it is hard to understand the predictive effect of benefit indicators over performance. The most influencing benefit indicator was identified from a comprehensive statistical analysis which agrees with the result of hypothesis test performed earlier. Finally, the proposed model was validated using a ten-fold cross validation using rest 20% of data as test set with a correlation coefficient of 0.95.

US Army is currently the world’s largest user of HUMS. This system requires cost to install, monitor and maintain. It is important to measure whether the benefit outweighs the cost. The goal of the second case study is to address the possible sources of benefits, estimate costs in forms of investments, quantify them in monetary values and finally measure the effectiveness though estimating return on investment. The significance of this study lies in its data collection, interpretation and analysis process. In this case study, a framework has been established to measure how well leadership can afford HUMS implementation and CBM practice. First, cost variables have been determined to measure the investment cost, direct cost and operating cost for a 14-year timeline of HUMS deployment and CBM practice on AH-64 aircraft in SCARNG. The timeline has been divided into three phases: VMU-phase, MSPU-phase and investment phase. The investment cost includes equipment cost i.e. cost of HUMS and man-hour cost to install the system into aircraft. The direct cost is calculated in form of replacement part cost, while operating cost consists of maintenance test flight cost, partially mission capable maintenance cost and not-mission capable supply cost. All the cost variables for direct and operating cost are calculated using unit level maintenance log, flight records, document control register and FED LOG. All the data sources are heavily text-based information. An in-depth knowledge on aircraft maintenance is required to understand those records. NLP has been used for information extraction and interpretation. The benefit of HUMS deployment is then calculated from the cost savings in MSPU-phase to VMU-phase. The calculated ROI of 742% signifies the HUMS deployment and CBM practice in AH-64 aircraft as a success with a great margin of profit.

Research results described in this dissertation establish a step forward towards the evaluation of value added to the system by implementing HUMS and CBM methodologies. This work ends with conclusions and recommendations for future research.