SIXTH DSTO INTERNATIONAL CONFERENCE ON HEALTH AND USAGE MONITORING

DAY 1 – TUESDAY 10 MARCH 2009

HUMS – OPENING KEYNOTE
Session Chair – Joanna Kappas
Session Room – You Yangs 1

0930-1000
Getting The Rights Things Done In Developing Enterprise Health Management Systems
Roger Vodicka
Joint Strike Fighter Program Office, Arlington VA, USA

Abstract A comprehensive Prognostic and Health Management (PHM) system is currently being developed for the Joint Strike Fighter program. PHM is a key enabler for the Autonomic Logistics concept that will provide next generation decision support capabilities across areas such as maintenance, supply, training, flight operations, manufacturing, business management and sustaining engineering. An Enterprise approach to Health Management poses a number of challenges in order to successfully integrate at the sub-system, system, individual aircraft and fleet level. Lessons learned from past programs have highlighted the need to focus on key areas in developing such highly integrated systems. These include areas such as requirements and verification, enterprise wide architecture design, data management, planning for maturation and successful engagement and integration with all stakeholders. In addition, there is a need to apply new approaches to successfully transition emerging technologies to platforms and systems of record. A common reference model/framework and systems engineering process for enabling the transition of HM technologies is presented and is based on five key pillars including business, architecture, S&T capability, infrastructure and implementation.

CONDITION-BASED MAINTENANCE
Session Chair – Graham Forsyth
Session Room – You Yangs 1

1030-1100
An introduction to Condition Based Maintenance using reliability assessment methods
P.L. Maisonneuve
Eurocopter TZSG, Maintenance & diagnostic research, Aéroport Marseille Provence, 13725 Marignane, France

Abstract
This paper describes the methodologies implemented in the general maintenance policy within Eurocopter. The development of an optimized and customized maintenance program is supported by relevant data record with on-board monitoring systems like HUMS (Health and Usage Monitoring System) or FDCR (Flight Data Continues Recording). Currently, the maintenance planning documents support tasks which are based on fixed intervals, defined by calculations made during design phase. The fixed intervals are calculated under a hypothesis which considers server operational conditions, and a reliability estimate of associated components. The estimation of these intervals could be improved through on-line monitoring of environmental and usage parameters. The development of Condition Based Maintenance (CBM) starts with the identification of the data required for the implementation of a health-based maintenance policy to control all degradation modes of dynamic parts. Then relevant parameters have to be identified in order to measure and estimate the condition of mechanical parts. The condition based maintenance function is processing flight and usage data in order to evaluate the degradations via advanced reliability assessment models and methods. Then the health assessment provides inputs to the decision support cell which define new maintenance interval based on actual component condition. In this approach, the vibration monitoring was used to confirm the prognosis made by the environment and usage data analysis. The purpose of this paper is to provide the required inputs for the definition of the future health management structure that will achieve customized maintenance planning adapted to the actual usage of the aircraft.

1100-1130
Reading the Tea Leaves: Considerations for the Analysis of Aircraft Oil Filter Debris
Andrew Becker
Air Vehicles Division, Defence Science and Technology Organisation, PO Box 4331, Melbourne, Victoria, 3001, Australia

Abstract
The oil filter is a valuable source of information about the health of oil-wetted components in aircraft machinery, but is generally under-utilized. Historically, the analysis of aircraft oil filter debris was time consuming and not really suited to in-field assessment. In particular, the military context (regular deployments to remote localities or to sea) presents its own set of challenges for extracting useful information from oil filters. Additionally, the introduction of fine oil filtration on some aircraft machinery has rendered traditional Spectrometric Oil Analysis (SOA) ineffective, leaving the filter and magnetic chip detector to provide information about oil-wetted component health. The two primary difficulties associated with oil filter analysis are extracting the debris in a reliable and controlled manner and interpreting the debris to assess whether maintenance action is required. A description of a recent filter patch trial on a portion of the Royal Australian Air Force (RAAF) PC9/A fleet is presented together with some considerations for the regular analysis of aircraft oil filter debris in the military environment.

1130-1200
Prognostics-Based Product Reliability Monitoring
Michael Pecht
Center for Advanced Life Cycle Engineering (CALCE) University of Maryland, College Park, MD 20742

Abstract
Prognostics is a method that permits the assessment of product reliability under its actual application conditions. While there are various methods to perform prognostics, including physics of failure and data-driven methods, these methods have some key disadvantages. This paper presents a fusion prognostics approach, which combines or “fuses together” the physicsof-failure and data-driven methods, to enable increasingly better estimates of remaining useful life. This new approach has advantages for both non-operating and usage conditions because it can utilize environmental loads as well as operating data from the product. The approach also improves the determination of root cause failure mechanisms that cause product failure.

USAGE MONITORING 1
Session Chair – SQNLDR Brian Rowe
Session Room – You Yangs 5

1030-1100
Super Hornet Usage Monitoring
Wing Commander Paul Parolo
Australian Super Hornet Project Office

Abstract
No abstract available at time of printing.

1100-1130
Characterization of Rotorcraft Recorded Maneuver/Regime Usage Variability
Dr. Suresh Moon
L-3 Communications,MD

Abstract
The rotary wing aircraft usage spectrum consists of maneuver durations and occurrences per 100 flight hours. These are derived from broad mission requirements and typical usage spectrums provided in Aeronautical Requirements 56. Over the years, the U.S. Navy (USN) has fielded Structural Usage Monitoring (SUM) systems on AH-1W, H-46, H-3, H-60, V-22,and H-53 to record maneuvers onboard or by post processing using a regime

recognition algorithm. Significant variations in maneuver usage from aircraft to aircraft were observed. The variability in different maneuvers such as level flight, hover, turns, climb, descent, dive, pull-up, etc., was modeled with Weibull distributions, and Weibull parameters were determined. The Weibull distribution characteristic value and slope vary from rotorcraft to rotorcraft for identical maneuvers and is dependent on the rotorcraft mission. The Kolmogorov-Smirnov goodness of fit test was conducted to confirm the distribution fit. The Weibull cumulative distributions of different regimes were used to investigate the effect of usage variation on reliability required to implement Condition Based Maintenance (CBM).

1130-1200
Development of a Flight Manoeuvre Recognition Program for the S-70A-9 Black Hawk Helicopter Using Information from the Flight Data Recorder
Christ Dore
DSTO

Abstract
Accurate flight manoeuvre recognition enables an operator to quantify the usage of an aircraft, or fleet of aircraft, and hence make predictions as to the fatigue implications of that usage. This paper details the development of a flight manoeuvre recognition program for the Australian Regular Army's S-70A-9 Black Hawk helicopter that uses data from the Flight Data Recorder (FDR). The paper provides an overview of the program structure and also highlights the key functions and challenges in developing the program, namely the extraction of key flight parameters from the FDR data and the development of critical manoeuvre definitions. The program has been tested using data collected from a flight loads survey in 2000, with 96.2% of manoeuvres being accurately recognised. The results indicate that the information recorded on the S-70A-9 Black Hawk's FDR is acceptable for flight manoeuvre recognition.

HELICOPTER HUMS
Session Chair – Andy Becker, DSTO
Session Room – You Yangs 1

1400-1430
Advanced HUMS Capabilities for Offshore Operations
Brian Larder, Dr Rob Callan and Steve Boakes
GE Aviation Systems Limited

Abstract
This paper describes the development of an advanced HUMS (Health & Usage Monitoring System) anomaly detection system, produced in support of a UK Civil Aviation Authority (CAA) research programme to demonstrate the intelligent analysis of helicopter HUMS Vibration Health Monitoring (VHM) data. The primary goals of the work are to improve HUMS fault detection capability and enhance system usability. A data driven modelling approach utilises existing HUMS data to define models of 'normal' behaviour, which can then be used to detect 'abnormal' or 'anomalous' behaviour that may be associated with a defect. This anomaly modelling capability has been implemented in a web-based system and trialed on Bristow Helicopter's North Sea Super Puma fleet. The trial confirmed that the system represents a significant advance in HUMS data analysis, resulting in enhanced fault detection performance. The system has both corroborated existing HUMS indications and highlighted anomalous data that were not seen by the existing HUMS.

1430-1500
Advances in RTB Data Analysis
Richard Hunt
Helitune

Abstract
No abstract available at time of printing.

1500-1530
A Description of the MRH 90 Health and Usage Monitoring System
James Fay
Australian Aerospace Limited

Abstract
MRH 90 is one of the newest aircraft to have entered service with the Australian Defense Force (ADF). Initially, it has replaced the UH-1 Iroquois but as production continues it will replace the Sea King and Blackhawk helicopters as well. This will result in an eventual fleet of 46 aircraft. The MRH 90 is delivered equipped with an integral Health and Usage Monitoring System (HUMS). This system provides information to the aircrew, maintainers and aircraft fleet managers to aid in the diagnosis and rectification of short term issues. It also collects trending data that is employed by the aircraft fleet managers and aircraft structural integrity program in the long term management of the individual aircraft and the entire aircraft fleet. Being integral to the aircraft, the MRH 90's HUMS draw on the aircraft's own systems for the provision of data that relates to health and usage. This minimizes the need for dedicated sensors and also reduces maintenance burden imposed by the HUMS by minimizing the need for non-essential specialist equipment to be carried on operational aircraft. This presentation will provide a detailed description of the Health and Usage Monitoring System on the MRH 90 Helicopter. It will outline how the data is generated on the aircraft and how the data is collected and collated for the management of individual MRH 90 aircraft and the fleet as a whole.

USAGE MONITORING II
Session Chair - TBC
Session Room – You Yangs 5

1400-1430
Roadmap for Helicopter Life Usage
Catherine Cheung
National Research Council Canada Institute for Aerospace Research, Canada

Abstract
This paper presents a roadmap for the development of a long-term helicopter life usage monitoring strategy that allows for more precise monitoring of individual aircraft and component usage and consequently enables more accurate determination of critical component fatigue lives. This strategy incorporates the physics-based lifing methodology Holistic Structural Integrity Process (HOLSIP) to assess the structural integrity of aircraft components throughout their entire life cycle. The HOLSIP framework takes into consideration all factors that may affect structural integrity, such as cyclic and environmentalrelated age degradation, which are absent in current life cycle paradigms. HOLSIP was originally developed for fixed-wing aircraft and now is being extended to helicopters. The roadmap outlines the development of the processes and techniques required to integrate comprehensive usage and loads data with HOLSIP to more accurately determine the life consumption of helicopter components.

1430-1500
Architecture for Dynamic Component Life Tracking in Advanced HUMS, RFID, and Direct Load Sensor Environment
Nagaraha Iyyer
Technical Data Analysis, Inc. 7600A Leesburg Pike, Ste 204, Falls Church, VA 22043, USA

Abstract
The United States Navy (USN) is shifting towards condition-based maintenance (CBM) of fatigue critical dynamic components on rotorcraft, which requires more efficient methods for component identification, usage history recording, and fatigue life tracking. This paper presents a method developed by Technical Data Analysis, Inc. (TDA) to track usage and history of all uniquely serialized components throughout their lifetime, so that component life limits and applicable maintenance data are correctly and continuously assessed.
The end goal of this project is one integrated system for component tracking, fatigue lifing, and prognostics and trending, leveraging Health and Usage Monitoring System (HUMS) and direct loads sensing data to track actual component usage and loads. Presented here is a twofold strategy for achieving this integrated component tracking

system via a Radio Frequency Identification (RFID) network and a comprehensive web-based application that interfaces with the RFID network and the USN's various data management systems.

1500-1530
The Optimization of exploiting fatigue-life resources of the PZL-130 Orlik's structure
Andrzej Leski
Instytut Techniczny Wojsk Lotniczych (Air Force Institute of Technology), Warsaw, Poland

Abstract
The PZL-130 ORLIK trainers are operated by the Polish Air Force on to the 'safe life' principle. Since the very beginning of operating these aircraft all of them have been furnished with digital flight data recorders. Therefore, after 20 years' service all the collected data can be used to find – individually - fatigue wear of any structure. Hence, it is possible to verify original assumptions made about the predicted service lives of aircraft. The results gained are expected to prove helpful in the optimization of service-life resources still left.

DATA MANAGEMENT
Session Chair – Graham Forsyth
Session Room – You Yangs 1

1600-1630
HISDES: a shared multinational Helicopter Integrated Supportability Data Exchange System for the NH-90
Lex Ten Have
NLR, The Netherlands

Abstract
No abstract available at time of printing.

1630-1700
Open-Source Development of an Automated Maintenance Environment (AME) for lower cost, collaborative implementation of CBM+
Joe Schmidley
S Navy, Space and Naval Warfare Systems Command – Systems Center Pacific (SPAWARSYSCEN - Pacific), 53560 Hull St, San Diego, CA 92152

Abstract
This paper reviews the experience of the Comprehensive Automated Maintenance Environment - Optimized (CAMEO) team in developing the V-22 Osprey's Automated Maintenance Environment (AME) product. The initial product consolidates the Interactive Electronic Technical Manual (IETM) with the Automated Maintenance Environment Ground Station (AMEGS) for reduced Information Technology (IT) footprint and increased maintainer efficiency. Additional enhancements, either in-work or planned, include usage based fatigue tracking of airframes and all dynamic components, advanced data-mining and analysis tools for enhanced diagnostics and prognostics (CBM+), UID/RFID integration, Military Flight Operations Quality Assurance (MFOQA) integration, and S1000D compliant technical data. The open-source nature of this project allows great flexibility to accomplish goals even with rapidly changing technology or shifting program priorities, and also facilitates collaboration with other programs that may be interested in leveraging part or all of their AME and CBM+ solution from what has already been developed in CAMEO. **Keywords:** Condition Based Maintenance (CBM+), Prognostics and Diagnostics, Open Source, Collaboration, Automated Maintenance Environment (AME), Automated Logistics Environment (ALE), Interactive Electronic Technical Manual (IETM), Ground Station.

1700-1730
The language of FMEA: on the effective use and reuse of FMEA data
S. D. Rudov-Clark
PHM Technology Pty Ltd

Abstract
Practical uses of Failure Modes and Effects Analysis (FMEA) range from the identification of potential design defects and safety hazards, to maintenance planning, diagnostics and Prognostics and Health Management (PHM). According to the broadly accepted standard for FMEA, MILSTD-1629A, a successful FMEA is one that conducted in a timely manner, so that the results can be used to identify potential design flaws and thus mitigate the risk or criticality of a system in its early stages. This paper reviews and compares the current usage of terminology to define functions and failures in accordance with those defined in MIL-STD-1629A. It is argued that inconsistencies in the interpretation and application of such terms has reduced the effectiveness of FMEA, and that a standardised functional and failure taxonomy can alleviate this problem. The functional and failure taxonomies proposed in this paper were created for use in an automated FMEA generation software product. The taxonomy is used to build a functional system model upon which Fuzzy Cognitive Maps are based to predict the system-wide effects of failure. The challenge was to develop a taxonomy that would achieve consistent, repeatable results in automated functional FMEA and enable a wider application and sharing of the FMEA results. The intention was to create a software package that could be used in a concurrent engineering environment, and provide reusable, shareable models for use across Design, Reliability and Maintenance (R&M) and Prognostics and Health Management (PHM) departments within an organisation.

SENSOR TECHNOLOGIES I
Session Chair – David Forrester, DSTO
Session Room – You Yangs 5

1600-1630
WISD - Wireless Intelligent Sensing Devices
Nick Lieven
Department of Aerospace Engineering, University of Bristol, UK

Abstract
WISD is a collaborative technology programme funded by the DTI/TSB. The programme comprises a series of demonstrators to de-risk wireless instrumentation for long term condition monitoring in harsh environments. Novel algorithms for reduction of data transmission requirement and identification of wear features have been demonstrated. Hardware platforms to carry these have also been developed and tested. New power harvesting devices have been developed to explore local power generation from vibration. Aircraft-ready wireless communication hardware and power saving protocols have been proven with a demonstration on a Lynx aircraft. The outcome of the work is a demonstrator on integrated wireless sensing with embedded algorithms for simple feature extraction.

1630-1700
Integrating Model-based Shaft Coupling Prognostics with Vibration Diagnostic Features
Carl S. Byington
Impact Technologies

Abstract
Flexible power transmission couplings play a major part in the drive train of rotorcraft, STOVL aircraft (such as the F-35 Joint Strike Fighter), and other land, sea, and marine propulsion systems. These components are generally subject to high torque, rotational speeds, and temperatures, which results in high static and dynamic loads that make them susceptible to degradation and failure. Additionally, couplings are susceptible to accelerated failures, mainly driven by high cyclic stresses induced by extreme shaft misalignment and secondary causes like improper assembly, fastener damage, lubricant loss, etc. Damage to other drive train components can also lead to increased vibration and misalignment, which in turn induces coupling failure. The authors have developed real-time, embedded software to enable continuous coupling monitoring and overcome drawbacks associated with

inspections and preventative removals. Application of these technologies will establish an economical, safe, and effective maintenance-scheduling regime for couplings.

1700-1730
Gas Turbine Casing Response to Blade Vibrations: Analytical and Experimental results
Gareth L. Forbes
School of Mechanical and Manufacturing Engineering, University of New South Wales, Australia

Abstract
The non-intrusive measurement of blade condition within a gas turbine would be a significant aid in the maintenance and continued operation of these engines. Online condition monitoring of the blade health by non-contact measurement methods is obviously the ambition of most techniques, with a number of methods proposed, investigated and employed for such measurement. The current dominant method uses proximity probes to measure blade arrival time for subsequent processing. It has been recently proposed however, that measurement of the turbine casing vibration response could provide a means of blade condition monitoring. The casing vibration is believed to be excited pre-dominantly by (i) the moving pressure waveform around each blade throughout its motion and (ii) the moments applied by the stationary stator blades. Any changes to the pressure profile around the rotating blades, due to their vibration, will therefore in turn affect these excitation forces. Previous work has introduced an analytical model of a gas turbine casing, and simulated pressure signal associated with the rotating blades. The model has been extended in this paper to more closely represent a commercial gas turbine with experimental verification being presented for various aspects of the analytical modelling procedure.

DAY 2 – WEDNESDAY 11 MARCH 2009

HUMS APPLICATIONS
Session Chair – TBC
Session Room – You Yangs 1

0930-1000
HUMS as a Service
Auryn Hughes
Dytecna Systems Engineering,United Kingdom

Abstract
Health and Usage Monitoring Systems (HUMS) for military land platform have not yet been widely adopted by the military community. Most military platforms that are fitted with HUMS are either because of their commercial origin, or because they have been procured with a contract for reliability provided by the supplier. HUMS has had significant commercial success where the data from specific sensors has been transmitted and processed to allow comprehensive and cost saving fleet management. The commercial drivers for adoption are compelling, and an agile, revenue based organisation can implement HUMS widely. The military community does not yet understand the capability brought by a vehicle monitoring unit that captures rich information from the platform and how its value can have increased utility if it is presented to decision makers as intelligence. The constraints to widespread adoption currently are the perceived benefits of HUMS, the lack of agility of the procurement system, and the belief that an infrastructure similar to the commercial community is required to distribute and deliver the information. The enablers however all exist, from the vehicle monitoring unit and the sensors and systems from which it can gather information, the on board event based contextual processing, the ability to transmit using hosted multiple communications tools and networks and the storage and management of the information for further analysis and judgement, to allow decisions to be made. Thus a service can be delivered whether it is wholly owned, delivered by subscription, or whether the service is managed entirely. Once in place, so much more can be achieved because the service is entirely dynamic and can respond to the inevitable supplementary requirements.

1000-1030
A Rapid Operational Loads Monitoring Capability using the CMPLE (Compact Multi-Parameter Loads Evaluation) System
Steve Galea
Air Vehicles Division, DSTO

Abstract
To install commercial-off-the-shelf strain measurement systems to record in-flight strains (loads) is quite an expensive and time consuming exercise. Hence an inexpensive rapid operational loads measurement (ROLM) system to measure operational loads while minimizing aircraft downtime in order to assist in the fatigue life assessment of these critical components would be beneficial. The Defence Science and Technology Organisation (DSTO) and the Australian Defence Force (ADF) have embarked on the development of such a ROLM system. The system being developed is referred to as the Compact Multi-Parameter Loads Evaluation (CMPLE) system and consists of a bond on, peel off, inexpensive strain monitoring and recording sensing module, with supporting installation, interrogation and recharging equipment. The CMPLE sensing module is a small autonomous device which contains a battery, processor, memory, conditioning electronics and sensor; and is used to record strain and temperature or acceleration and temperature time-history data during flight.
This presentation outlines the concept and gives a description of the ROLM CMPLE system. A description is also included of a Caribou loads flight trial conducted in July 2008 with the dual aims of demonstrating the CMPLE system in field use and gaining an indication of first bending-mode loads in the main (front) spar of a Caribou horizontal tailplane. Six prototype CMPLE sensing units were installed on the Caribou to record flight strain and acceleration information and then removed within a short turn around time of one week. The trial demonstrated the practicality of measuring operational strain, acceleration and temperature, without the need for wiring, supplementary hardware, aircraft power or special mounting brackets, and with minimal aircraft downtime.

STRUCTURAL HEALTH MONITORING I
Session Chair – Carl Bylington, Impact Technologies
Session Room – You Yangs 1

1100-1130
Strain predictions using Artificial Neural Networks for a full-scale fatigue monitoring system
Javier Gómez-Escalonilla, Jaime García, Mª Mar Andrés and José I. Armijo

Fatigue and Fracture Mechanics Department, Military Transport Aircraft Division, EADS, John Lennon Street, Getafe, Madrid, Spain

Abstract
The Military Transport Aircraft Division (MTAD) of EADS is carrying out a number of tests on several ANNs used to predict accurately strains from flight parameters. This process is part of the development of the Structural Health Monitoring System (SHMS), a parametric full-scale fatigue monitoring system that is going to be incorporated in the A330 Multirole Tanker Transport (MRTT), which will first enter into service in the Royal Australian Air Force (RAAF) with the denomination KC-30A. All the tests are based on real flight data collected from the flight tests performed by the A310 Boom Demonstrator. This aircraft is used by EADS MTAD as a testbed for aerial refuelling technologies, and carries a prototype of the SHMS. Results of these tests are provided for different structural components of the aircraft (wing, fuselage, horizontal and vertical tailplanes, engine pylon). A discussion of the involved technologies, strategies and solutions adopted to build and train the ANNs is included as well.

1130-1200
In Situ Structural Health Monitoring for Aircraft Structures
Steve Galea
Air Vehicles Division, DSTO

Abstract
Due to economic pressures, including the high cost of replacement aircraft, the military in most countries (including the US) are forced to extend the life of their aircraft. Similar problems arise for some civil operators. It is expected, therefore, that the problems of corrosion and fatigue cracking, associated with aging aircraft, will increase in severity in the future. In Australia a significant portion of the Australian Defence Force (ADF) fleet is being operated well past its design life. For example, the F/A-18 fleet will be in service until the year 2015 making them about 28 years old at retirement and the C-130H fleet is currently 30-35 years old and will be approximately 50 years old when retired. As fleets get older a greater share of the operator's resources need to be used on through-life-support of the airframe. One way of reducing costs and increasing aircraft availability is through the introduction of Condition Based Maintenance (CBM) approaches since current time-based maintenance approaches are costly and time consuming. For example corrosion related maintenance, which is responsible for a large proportion of maintenance time and expenditure in ageing military aircraft, where looking for corrosion is significant proportion of these maintenance costs. In fact, more often then not, these inspections reveal no corrosion damage and may, in fact, result in additional costs resulting from incidental damage to the structure or increased likelihood of corrosion due to the replacement of factory seals by possibly inferior less durable seals. Hence the introduction of corrosion CBM approach would result in significant cost savings in the long term.

In the context of ageing airframes, the retro-fitting of In situ Structural Health Monitoring (ISHM) systems will allow the introduction of CBM approaches for the ADF. ISHM systems are an extension of Health And Usage Monitoring Systems (HUMS), and incorporate a diagnostic capability to detect and monitor damage in aircraft structures. The DSTO has a program of work aimed at developing autonomous, robust, reliable ISHM systems with the specific aim of retro-fitting to existing aircraft. The paper describes some of the ISHM techniques being developed, evaluated and demonstrated, including:

(1) a smart patch flight demonstrator (self-diagnostic composite repair),
(2) acousto-ultrasonic techniques using low profile piezotransducers for wide-area damage detection,
(3) optical-fibre systems for loads and health monitoring and
(4) environmental monitoring for corrosion damage diagnostics.

The paper also discusses approaches taken in achieving system autonomy by the development of self-powering and wireless access techniques.

LAND VEHICLE HUMS
Session Chair – Keith Mowbray, Dytecna
Session Room – You Yangs 5

1100-1130
The Research, Development, and Fielding Of A HUMS As An Enabler For Condition-Based Maintenance On U.S. Army Wheeled Ground Vehicles
Craig A. Hershey
U.S. Army Materiel Systems Analysis Activity, USA

Abstract
The U.S. Army Materiel Systems Analysis Activity is researching, developing and implementing the tools and interfaces for enabling the U.S. Army's Condition Based Maintenance (CBM) strategy across multiple wheeled ground vehicle platforms. Generating requirements, developing HUMS and their corresponding prognostics algorithms has been difficult. Despite the difficulties, AMSAA has been successfully fielding HUMS on many Army wheeled vehicles. AMSAA's portion of the Army's CBM vision over the last two years has been developing and fielding Health and Usage Monitoring Systems and analyzing the corresponding data. The last two years of fielded

HUMS has provided invaluable usage data that otherwise did not exist anywhere in the U.S. Army. The data has been used to provide maintainers, commanders, crew, Program Managers, logisticians, decision makers and engineers with valuable information about the vehicles and a baseline for developing health prediction algorithms for a successful CBM program.

1130-1200
Event-based HUMs for Land-Vehicles
Chris Doran
Industrea

The identification of specific operating regimes for land mobile equipment from sensor data has particular relevance to measuring duty and usage from the perspective of both the vehicle and the driver. This paper outlines work currently in progress by Microelectronic Technologies Pty Ltd (MeT) to identify specific operating regimes based on data collected from a 3-axis MEMS accelerometer supplemented by GPS positioning and digital inputs linked to vehicle controls, actuators and other vehicle sensors.

Techniques based on the analysis of change in vibration patterns using auto- and cross-correlation techniques have been applied to specific test cases in aviation with encouraging results. These techniques also show promise in identifying regimes of land vehicle operation ranging from simple one-dimensional measurements such as cornering forces, braking and terrain roughness to more advanced measurements of swerve, dip, roll and pitch that require analysis in three-dimensions.

In this presentation we explore the potential of using an event-based approach to measuring the pattern of usage for land-based vehicles using embedded signal processing tools & techniques. Extracting the type of event from sensor data with both time and location and examining the aggregated events with geo-spatial tools offers insight into how land-based vehicles are being operated and is a significant improvement on monitoring hours of operation (i.e. engine hours) alone. This type of information may lead to better ways to schedule maintenance but is also applicable as a training tool for new drivers and a means to monitor the effectiveness of driver training over an extended period of time. The techniques developed by MeT also have application as part of a fatigue management system for operators of all types of land-based vehicles.

STRUCTURAL HEALTH MONITORING II

Session Chair – TBC
Session Room – You Yangs 1

1400-1430
SEI Structural Data Recording System
George Grove
Systems & Electronics Inc

Abstract
Systems & Electronics, Inc. SEI has been a leader in providing cost effective Flight Data Recording Systems for military and commercial applications since 1984. The Structural Data Recording Set (SDRS), AN/ASH-37 is SEI's premier product line and more than 1400 systems have been manufactured, delivered, and installed on a variety of military aircraft types. These systems greatly enhance the operator's ability to monitor their aging aircraft fleet in order to maximize their useful life availability.

SEI has recently developed and installed an improved method for data storage and download of the acquired aircraft data. SEI is working closely with the Australian Air Force MPSPO on their P-3 Orion aircraft to upgrade their installed systems. This improvement greatly increases the overall process, improves reliability and ensures that the maintainers get the most up to date information. Vital information such as G loading and strain gage data helps the operators to record specific data about that aircraft's usage and performance. This data can be correlated with the aircraft flight regimes to reveal the frequency of occurrence and severity of each maneuver

identified. It is this information that is of particular interest to understanding component retirement time calculations and how they relate to the actual aircraft usage spectrum.

SEI is currently involved with multiple programs in which the data acquired from the SDRS is being utilized to benefit overall operational maintenance procedures. SEI is working with Embry-Riddle Aeronautical University to validate and certify their system for Usage Credit with the Federal Aviation Administration. They are working with various Armed Forces worldwide in providing critical Structural Fatigue information to assess Individual Aircraft Tracking programs with flight usage data. SEI continues to work diligently with their customers to maximize their product offering, increase the maintainer's awareness and improve the overall operational maintenance program for fleet management.

SEI was acquired by Condition Monitoring Group (CMG) in May of 2006. CMG also has within its stable of specialist companies, Helitune, the highly successful manufacturer of the Rotortuner Product Line. Helitune's expertise in Rotor Track & Balance and Vibration Analysis combined with SEI's experience in Structural Data Recording Systems enable CMG to continue providing unique customer solutions that satisfies specific aircraft type requirements.

1430-1500
Crack Initiation Detection and Crack Growth Monitoring with DMI Technology
Reginald Vachon
Direct Measurements Inc

Abstract
This paper presents some of the data on crack detection and monitoring by DMI and Northrop Grumman under a contract between DARPA and Northrop Grumman for the Structural Integrity Prognosis System (SIPS). While several other sensors and vendors are involved in SIPS, this paper focuses on the direct measurements of strain using the DMI technology. For crack detection a baseline reading is made at one point in time, and then subsequent readings of strain are acquired. Crack initiation, detection and crack monitoring are accomplished by taking strain readings periodically over time. An imbalance in strain readings around a hole containing a fastener indicates the presence of cracking, and increasing strain readings can indicate crack growth. Further crack initiation in the barrel of the hole with a fastener is possible prior to the appearance of a surface crack. In either case the theory of the DMI technology is based on the same fundamentals of engineering mechanics. This theory is reviewed and then test results using a two-hole coupon are presented.

1500-1530
Structural Integrity Assessment of Plates Using Vibration Monitoring: Theory & Simulation
Krishnakumar Shankar and Laxmikant Kannappan
University of New South Wales, Australian Defence Force Academy,Australia

Abstract
Theoretical approaches to application of frequency based vibration methods for damage detection have hitherto been restricted to one-dimensional structures. In this paper, an energy based method for damage detection in plates using frequency measurements is developed. The change in natural frequency due to a crack in the plate is related to the modal curvature at the location of the crack and the Damage Index which is a function of the crack size. A methodology for solution of the inverse algorithm is developed based on a gradient based minimisation technique, which allows the determination of the X and Y coordinates of the crack location, the crack orientation and the crack size from measured changes in frequencies. The theory and the methodology developed for damage assessment is validated using numerical simulation. The predicted damage parameters are found to be in excellent agreement with the actual values employed in the simulation.

SENSOR TECHNOLOGIES II
Session Chair – TBC
Session Room – You Yangs 5

1400-1430
Combination of Fusion and Preprocessing Techniques to Enhance Air Vehicle HUMS
Carl Byington
Impact Technologies, USA

Abstract
A Condition-Based Maintenance (CBM) program calls for transitioning from making time based part replacement decisions to performing maintenance upon evidence of need. For the U.S. Army's CBM+ plan this entails eliminating the use "time before overhaul" (TBO) definitions currently driving vehicle component maintenance schedules. Although Health and Usage Monitoring Systems (HUMS) have the potential to support this goal, their ability to diagnose component faults early is limited, and implementation of prognostics is rare. These limitations are driven partly by the sensitivity of diagnostic processes to signal noise and changes in operating conditions. A representative example is a bearing in the oil cooling subsystem of H-60 helicopters. This paper discusses certain signal processing techniques to enhance early detection capabilities, reduce false alarms in diagnosis, and provide a basis for prognostics. Actual H-60 bearing vibration data and surrogate-bearing test rig data are utilized to illustrate the advantages of the techniques presented.

1430-1500
Automated design and optimisation of sensor sets for system monitoring
S. D. Rudov-Clark
PHM Technology Pty Ltd.

Abstract
A software tool was developed for automating the design, optimisation and performance assessment of sensor sets to support the Prognostics and Health Management (PHM) of the
Joint Strike Fighter. The software (MADe) is based on a model-based simulation of failure propagation through the various subsystems of the aircraft to generate a system-level failure
modes and effects database. The failure database generated by this analysis is used to identify the monitoring requirements of the system to achieve a specified level of failure coverage. This paper outlines the analysis approach and provides a case study to demonstrate the
application of automated sensor design and optimisation.

1500-1530
Towards Wireless Sensor Usage and Health Monitoring of Helicopter Rotor Components
Nick Lieven
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Abstract
Wireless sensors offer the promise of a paradigm shift from traditional schedule-driven maintenance to condition-based maintenance of aircraft subsystems. In particular this technology will benefit applications where running cables to sensors is difficult or impossible. This is specially the case in rotary-wing aircraft. This work reports research carried out under the umbrella of the Wireless Intelligent Sensor Devices programme, supported by the UK Technology Strategy Board, to advance the development of the hardware and software required to continuously in-flight monitor the wear rate within the pitch link end bearings and fitting of the Lynx Helicopter. This shall greatly enhance the operational readiness and cost effectiveness of the helicopter. Results of this research are reported in three areas: 1) development of low power sensing interface and signal conditioning, 2) pitch link test carried out to aid the development of feature extraction and wear detection algorithms and 3) intelligent feature extraction algorithms, wear detection and results.

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SENSOR TECHNOLOGIES III
Session Chair – Tony Galati, DSTO
Session Room – You Yangs 5

1600-1630
Effects of limiting the bandwidth of the vibration signal on bearing fault detection and diagnosis using state of the art techniques
Nader Sawalhi
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Abstract
This paper discusses the effect of limiting the bandwidth of the vibration signal on detecting a bearing fault using novel processing algorithms. When the bandwidth of a signal is limited, these algorithms fail to extract the symptoms of the fault. This is due to the fact that the developed algorithms are based on maximizing the impulsiveness of the signal. If the bandwidth of the signal is limited, only one or two harmonics of the impulse train remain and the result will be close to sinusoidal, thus non-impulsive and no longer detectable using envelope analysis. Genuine discrete frequency components can be separated by using separate time synchronous averaging (TSA) adjusted for every harmonic family in the signal instead of using the discrete/random separation technique (DRS). The analysis shows that it can be possible to locate bearing defect frequencies, and modulation sidebands, by inspecting the power spectrum density (PSD) of the signal, but the results are not so definitive.