Assigned Session: A1 Signal Analysis 1

Presenting Author: Kranthi Mamidisetty **Ser:** 67

Organization: The University of Akron

Country:

Paper Title: **Influence-graph Based Techniques for System-level Diagnostics**

Co Authors: Kenneth A Loparo, Case Western Reserve University and Fred M Discenzo, Rockwell Automation

Abstract:

The ability to detect and isolate a faulty component in a system is an important problem that presents several challenges. The consistency-based approach proposed by researchers who emphasize Artificial Intelligence based techniques and the analytical redundancy relations based approach proposed by researchers who emphasize control theoretic foundations are the two main approaches reported in the literature. We present an approach that is based on influence-graphs. The technique is embodied as a distributed protocol. Using a composable conveyor system as a representative example, we demonstrate the effectiveness of the approach.

Assigned Session: A1 Signal Analysis 1

Presenting Author: David He **Ser:** 43

Organization: University of Illinois-Chicago

Country:

Paper Title: **An Integrated Approach for Hybrid Ceramic Bearing Life Prognostics**

Co Authors: Jinghua Ma

Abstract:

This paper presents an integrated prognostics methodology with an application to hybrid ceramic bearing life prediction. When vibration analysis and grease debris analysis are used independently, only 30-40% of faults can be diagnosed. The presented methodology takes particle filtering as a framework to combine vibration analysis with grease debris analysis. One important advantage of the particle filtering framework is that it allows the information from different measurement sources to be fused in a rigorous way. When oil debris and vibration analysis are integrated within one framework, the trending of the fault features can be improved significantly. The integration enhances the machine condition monitoring performance and makes remaining useful life prediction more reliable.

Assigned Session: A1 Signal Analysis 1

Presenting Author: Stan Bognatz **Ser:** 46

Organization: M&B Engineered Solutions, Inc

Country:

Paper Title: **Applying Modal Analysis to Improve Machinery Reliability**

Co Authors:

Abstract:

This paper discusses the benefits of using experimental modal analysis (EMA) and operating deflection shape (ODS) analysis to better understand rotating machinery vibration problems. We explore structural dynamics that are difficult to visualize using standard vibration analysis techniques, and show how EMA & ODS analysis can help resolve those problems. We also show how accurate and detailed models are needed to fully capture a complex structure's dynamic activity, and how combining ODS and transient speed vibration analysis can be used as an effective modal analysis substitute on turbo-machinery. The author also introduces the new concept of a Non-Operating ODS.

Assigned Session: A1 Signal Analysis 1

Presenting Author: Ruoyu Li **Ser:** 44

Organization: University of Illnois at Chicago

Country:

Paper Title: **Hilbert-Huang Transform based Acoustic Emission Signal Quantification for Rotational Machine Health Monitoring and Diagnostics**

Co Authors: Ruoyu Li

Abstract:

Acoustic emission (AE) based techniques are becoming an attracting alternatives for rotational machine health monitoring and diagnostics due to the advantages of the AE signals over the extensively used vibration signals. In the filed of rotational machine health monitoring and diagnostics, in comparison with vibration based methods, the AE based techniques are in their infant stage of the development. From the perspective of machine health monitoring and diagnostics, developing a systematic method for quantification of acoustic emission signals is important. In this paper, a Hilbert-Huang transform based acoustic emission signal quantification methodology for rotational machine health monitoring and diagnostics is presented. The methodology incorporates a threshold based de-noising technique into Hilbert-Huang transform to increase the signal-to-noise ratio. A gear fault detection case study is conducted on a notational split-torque gearbox using acoustic emission signals to demonstrate the effectiveness of the methodology.

Assigned Session: A1 Signal Analysis 1

Presenting Author: Suri Ganeriwala **Ser:** 47

Organization: Spectra Quest Inc

Country:

Paper Title: **Using Modal Analysis for Detection of Cracks in Wind Tubine Blades**

Co Authors: Jun Yang

Abstract:

Assuring structural integrity of wind turbine blades is critical for lowering the operation and mentainance cost of the wind turbines. Physical properties of a mechanical structure are strongly related to its structural resonances and mode shapes of vibration. Therefore, any change in a structure's physical properties is expected to cause a shift in its resonance frequencies and mode shapes. This paper will present test results from several different wind turbine blades with different cracks induced in them. Results show that the modes of the blade are significantly affected by the cracks. The modal parameters: modal frequency, damping, and mode shape change more significantly with a more severe crack. It is shown that using changes in modal parameters to indicate physical damage to turbine blades could be implemented in an on-line continuous monitoring system for wind turbines.

Assigned Session: A1 Signal Analysis 1

Presenting Author: Bob Randall **Ser:** 74

Organization: University of New South Wales

Country: Australia

Paper Title: **Editing Time Signals using the Real Cepstrum**

Co Authors: Nader Sawalhi

Abstract:

It has long been thought that to use the cepstrum for editing time signals it would be necessary to use the complex cepstrum. The latter includes both the amplitude and phase information from the spectrum, so that after editing it is possible to return to the time domain. However, in order to generate the complex cepstrum it is necessary to unwrap the phase to make it a continuous function of frequency. This is often possible for transfer functions, with well-behaved and continuous phase, but in general it is not possible for stationary response signals, normally excited by periodic and stationary random components, neither of which have continuous phase. However, there are a number of applications where editing a time signal consists primarily in changing its amplitude characteristics, but not its phase, and then the real cepstrum can be used for the editing. The original phase is retained and combined with the edited amplitude information to regenerate edited time signals. This paper describes a number of different applications, including removal of selected discrete frequency components. This can be useful for leaving bearing signals in the residual signal, or enhancing resonances for operational modal analysis. It also allows a very efficient pre-whitening of the signal, with many applications, including bearing diagnostics.

Assigned Session: B1 Failure Analysis - Corrosion Prevention

Presenting Author: Tom Considine **Ser:** 13

Organization: US Army Research Laboratory

Country:

Paper Title: **Accelerated Corrosion and Immersion Testing of 13mm Diameter Grade 10.9 Bolts for Use with Bolt-on Armors**

Co Authors: Thomas Braswell

Abstract:

This experiment examined the effect of selected coatings and pretreatments on 13mm Grade 10.9 bolts immersed in a 5% NaCl solution as well as placed in GM9540P accelerated corrosion testing chambers as they were fastened to various combinations of sets of CARC painted and unpainted 5059 Al and CARC painted RHA steel plates in an attempt to evaluate the corrosion prevention properties of each selected coating and pretreatment while simulating the practical applications of bolt-on armor. Five candidate finishes (zinc plating IAW ASTM-B633 with hexavalent chromium conversion coating as control) were tested in replicate sets of assemblies. In the immersion phase of testing, each bath was heated to 75ºF and the salt solution was agitated in order to prevent stagnation and ensure equal heating. Testing was completed over 500 hours, with visual and potential inspections at 1, 2, 4, 8, and 24 hours, and once every 24 hours following that. Accelerated corrosion testing was programmed for 120 cycles GM9540 with inspection for corrosion creep at 20 cycle intervals. Corrosion creep in this experiment was defined visually as frosting for the onset of corrosion and red rust in the percentage of the fastener affected yielding separate observations. Each of the pretreatments are assessed and compared in terms of corrosion inhibition.

Assigned Session: B1 Failure Analysis - Corrosion Prevention

Presenting Author: Elizabeth Charleton **Ser:** 48

Organization: Army Research Lab

Country:

Paper Title: **Corrosion Performance and Coating Characterization of Two Novel Anodic Coatings on Aluminum Armor Alloys**

Co Authors: Elizabeth A. Charleton, Steven M. Kilczewski, John V. Kelley, Paul Huang

Abstract:

Various sized samples of Al 2024-T351 and Al 5083 were coated with a proprietary Silicon (Si) and Silver (Ag) coating to determine if the coating would be a better alternative to corrosion resistance applicable for military use. Although these are anodic coatings, the specific process and final coating composition are unknown. Two coatings with a range of thicknesses were provided. Each sample was then coated with a CARC primer prior to testing. Each was tested utilizing Electric Impedance Spectroscopy, Salt Fog Spray, and Pull-off Adhesion testing. Samples were evaluated according to ASTM standards and recorded. As with any coating, 2024 aluminum proves to be more of a challenge for protection against corrosion because of the localized pitting caused by the copper in the alloy chemistry. In attempting to anodize 2XXX series aluminum alloys, the electrolyte used in the process (which is unknown) likely initiated galvanic activity between the copper and aluminum and prevented the growth of a uniform anodic coating.

Assigned Session: B1 Failure Analysis - Corrosion Prevention

Presenting Author: Alan Rose **Ser:** 80

Organization: Elsyca

Country:

Paper Title: **Software Design Tool Predicts Galvanic Corrosion Rates on Complex Assemblies**

Co Authors:

Abstract:

Corrosion impacts the safety and readiness of DoD assets and annually consumes an estimated $22Bn. Galvanic corrosion is particularly dangerous since it can occur between components that are not directly connected and often arises as a result of decisions made across a number of departments and functions within an OEM. A further complexity is the component operational environment. What might be an appropriate material choice for operation in the desert may not be suitable for operation in a jungle environment.

There is a requirement for a common, robust platform that can be easily used across an engineering enterprise. Elsyca GalvanicMaster software can quickly predict corrosion rates on assemblies of mixed materials. This is not a simple look-up of anodic/cathodic areas and material galvanic potentials but an implementation of Finite Element Analysis (FEA) techniques to solve potential distribution on complex geometries as a function of material/media polarization and environment.

Engineering information can be quickly shared across the design function, permanently capturing all aspects of material choice, design and operational environment to assess lifetime corrosion rates and ensure they are within the product performance specification. Users of this corrosion prediction technology require no knowledge of FEA as the analysis process is automated. The user simply identifies the materials and chooses the operational environment. The 3D output clearly shows the corrosion rates, significantly speeding up the design process and reducing risk of in-field corrosion failures.

Assigned Session: B1 Data Analysis and Decision Support

Presenting Author: Harlan Shober **Ser:** 83

Organization: RJ LeeGroup Inc

Country:

Paper Title: **Data Discovery and Mashup**

Co Authors:

Abstract:

A Net-Centric architecture is one that enables the information sharing amongst and throughout highly distributed enterprises. In this type of data ecosystem the data and services are left on and provided by the systems of record or the data owners.

However, simply exposing the information to the extended community does not make it usable. Consumers have to be able to find the information and tailor it to their need.

Enter Enterprise Mashups. A mashup is a web application that combines data from two or more web resources into a new web resource which itself is consumable. Enterprise mashups are those that are used to facilitate enterprise business processes. By making the data discoverable and mashable an enterprise provides for the quick, collaborative, social creation of new content.

This presentation addresses the use of mashups in commercial and DoD data management solutions. What are the challenges and advantages to including data discovery and mashup capabilities in your project? What should you know before you start?

Assigned Session: B1 Data Analysis and Decision Support

Presenting Author: Dennis Moore **Ser:** 85

Organization: RJ LeeGroup Inc

Country:

Paper Title: **RCM and eShop**

Co Authors:

Abstract:

ETOW Shop Optimization seeks to increase the reliability of systems, before they are maintained, by aligning the available modules and components at a given maintenance facility as well as equipment from other facilities. Aligning reliability driving assets across multiple systems to maximize the overall reliability of the systems increases system reliability and creates a positive impact in fleet-wide maintenance costs and weapon system availability.

The presentation will describe the development of the eShop tool, its practical application as a solution for aligning jet engine modules and the application of similar concepts to other fielded engineered systems. Finally the presentation will describe the cost savings benefits of the implementation of such technologies to enable the extended sustainment of such systems.

Assigned Session: B1 Data Analysis and Decision Support

Presenting Author: Chao Liu **Ser:** 27

Organization: Department of Thermal Engineering, Tsinghua University

Country: P. R. China

Paper Title: **Dimensionality Reduction Analysis in Condition Classification of Prognostics**

Co Authors: Dongxiang Jiang

Abstract:

In order to maintain the separability of different fault onsets, more characteristic parameters need to be used to establish the feature space with multiple possible faults. Usually, the dimensions of feature space have a positive correlation with the number of faults. Describing multiple faults in visualization is more difficult and the classification bounds with hyperplanes are less convenient to realize. Therefore implementing dimensionality reduction approaches in original feature space is beneficial for fault diagnosis and prognostics. Multidimensional Scaling (MDS) has been widely studied and used for dimensionality reduction as well as Principal Component Analysis (PCA). When these methods are applied in the prognostics process, the effectiveness needs validation with the reason that the deterioration features in degradations are different from the faults onsets that in diagnostics. The paper analyzes the nonlinear dimensionality reduction methods including Self-Organizing Map (SOM) and Isometric feature mapping (Isomap). Based on the deterioration data in an engine, the effects of these methods are analyzed.

Assigned Session: B1 Data Analysis and Decision Support

Presenting Author: Dennis Moore **Ser:** 94

Organization: RJ LeeGroup Inc

Country:

Paper Title: **DoD Acquisition Process**

Co Authors:

Abstract:

Assigned Session: C1 Electronic and Power Systems Health Management 1

Presenting Author: Mohammed Alam **Ser:** 26

Organization: CALCE, University of Maryland

Country:

Paper Title: **Early Detection of Avalanche Breakdown in Embedded Capacitors using SPRT**

Co Authors: Michael Azarian, Michael Osterman and Michael Pecht

Abstract:

In this work prognostics of avalanche breakdown in an embedded planar capacitor dielectric is addressed. Embedded planar capacitors are thin laminates embedded in a multilayered printed wiring board (PWB) that functions both as a power-ground plane and as a parallel plate capacitor. The capacitor laminate consisted of an epoxy-barium titanate (BaTiO3) composite dielectric of 8 microns thickness sandwiched between two layers of copper. Accelerated temperature and voltage aging tests (at 125 C and 285 V) were conducted on the embedded planar capacitor and three electrical parameters, capacitance, dissipation factor, and insulation resistance were measured in-situ. The failure mode observed was a sharp drop in the insulation resistance indicating avalanche breakdown. There was no trend in the values of insulation resistance before failure making the detection of these failures challenging. However it was observed that in some capacitors the value of dissipation factor started to fluctuate before insulation resistance failures. A statistical hypotheses test known as sequential probability ratio test (SPRT) was applied on the dissipation factor data to predict the insulation resistance failures.

Assigned Session: C1 Electronic and Power Systems Health Management 1

Presenting Author: Irfan Ali **Ser:** 56

Organization: Impact Technologies, LLC

Country:

Paper Title: **Towards an Online Early Diagnostic for Capacitors**

Co Authors: Antonio Ginart, Irfan Ali, Jose Celaya^, Irtaza Barlas, Patrick Kalgren, Scott Poll* ^ SGT NASA Ames Research Center * NASA Ames Research Center

Abstract:

There is a growing concern about the reliability of critical equipment controlled by power electronic components and drives. The migration from traditional electromechanical and hydraulic drives in critical equipment to power electronic drives is the main cause for these reliability concerns. Examples of this migration can be observed in the aeronautics industry such as the “fly by wire” (aircraft control) initiative and in the automotive industry as the electric steering wheel concept. Furthermore, there is a strong push in the aeronautics industry to produce complete solid-state based power converters. Similar approach is taken by the military to implement the main parts of hybrid vehicles. The trend discussed above can be observed in the design of main power drives in industrial and military sectors. A critical component of the military sector strategy to meet these objectives is to implement automated health state awareness and prediction tools that can accurately anticipate failures, predict the remaining useful life, and in many cases, accommodate fault tolerant techniques to the identified faults. The most frequent failure in power electronics converters are related to capacitor failures. It should be emphasized that the capacitor failures can produce the collapse of the entire power system, and worse, can also start fires. This paper will study detecting fault initiation, fault-to-failure progression, and online monitoring of the critical problems associated with aging capacitors. This paper will explore non-traditional applications of differential current sensors to detect capacitor degradation. The problem of detecting capacitor degradation is that the current signatures that can potentially describe these phenomena are very small in comparison to the regular load currents, and hence cannot be easily characterized. This paper presents a novel method to detect these small current signatures using differential current sensors. Based on this measurement, the equivalent series resistance (ESR) model of capacitance losses can be established with acceptable precision. Effectively tracking this increase in losses, over time, determines the aging process of the capacitor and provides an important tool for the timely replacement if the capacitor begins to deteriorate.

Assigned Session: C1 Electronic and Power Systems Health Management 1

Presenting Author: Ken Anderson **Ser:** 24

Organization: Universal Synaptics Corp

Country:

Paper Title: **The Right Stuff for Aging Electronics, Intermittence, No Fault Found**

Co Authors: Brent A. Sorensen, Cheryl S. Chambers

Abstract:

For those in the avionics repair and maintenance business, the acronyms NFF (No Fault Found) and CND (Cannot Duplicate) are, unfortunately, all too familiar terms. After several decades of frustration with this illusive phenomenon, it continues to consume an enormous amount of test and diagnostic effort and is the source of considerable cost and discomfort within the multi-level avionics repair model.

In this paper we will outline the problem of intermittence and its testing difficulties. More importantly, we will describe the unique equipment and process which has produced overwhelming success in Intermittence / NFF resolution and MTBF extension. Working with Total Quality Systems, (TQS) Ogden, Utah, we implemented our team-developed overhaul system called IFDIS (Intermittent Fault Detection and Isolation System) which incorporates all the necessary testing procedures and technological capabilities that are proving to be critical to the resolution of the chronic intermittent / NFF problem

Assigned Session: C1 Electronic and Power Systems Health Management 1

Presenting Author: Irfan Ali **Ser:** 52

Organization: Impact Technologies, LLC

Country:

Paper Title: **RUL Evaluation Based On Thermal Estimation of Fault-Tolerant Drive Systems**

Co Authors: Irfan N. Ali, Antonio Ginart, Patrick W. Kalgren, and Michael J. Roemer

Abstract:

A consistent push in recent towards a “more electrical” approach for drive systems in the aerospace and automotive industries has fueled interest in condition monitoring and prediction of impending electronic system failures. This paper extends a methodology based on temperature and class of the winding that estimates the changing remaining useful life of the actuator in real time. This paper explores methods to estimate the temperature and the hottest point in the actuator winding based on lumped thermal model of the system. The thermal model presents a simplified process that accounts for precise actuator losses using the measurement of the phase current and external temperature. The remaining useful life estimation is based on an Arrhenius and Power Law models with variable coefficient depending on the level of stress the actuator is exposed to, corresponding to the fault tolerant technique applied. The methodology developed here is intended for a standalone system but is fast enough so that, if required, can be embedded in the actuator microcontroller providing vital information about the sustainability and duration of the fault tolerant technique applied.

Assigned Session: C1 Electronic and Power Systems Health Management 1

Presenting Author: Jun Dai **Ser:** 20

Organization: Center for Advanced Life Cycle Engineering (CALCE)

Country:

Paper Title: **Risks to Telecommunication Equipment under Free Air Cooling Conditions and Their Mitigation**

Co Authors: Diganta Das Jon Fitch Server & Storage Reliability, Dell Inc, One Dell Way, MS RR5-19, Round Rock, TX 78682 Michael Pecht

Abstract:

The telecommunication industry is concerned about the energy costs of its operating infrastructure, i.e., base stations and data centers, and the associated gas emission has already accounted for about 2% of the total emission in the world. At present, more than one half of the total energy consumption of data centers is devoted to the power and cooling infrastructure that supports electronic equipment. One significant method of saving energy is an approach called “fresh air cooling,” where the ambient air is used to cool the equipment directly, thereby reducing the energy consumed in cooling and conditioning the air. However, the impact of this approach on the performance and reliability of telecommunication equipment is a concern. The implementation of fresh air cooling changes the operating environment, including temperature, humidity and contamination, which may have a significant impact on the performance and reliability of telecom equipment. This paper presents the challenges posed by fresh air cooling and presents a multi-stage process for evaluating and mitigating the potential risks arising from this new operating environment.

Assigned Session: D1 Health Management Tools and Capabilities

Presenting Author: Sonia Vohnout **Ser:** 9

Organization: Ridgetop Group, Inc.

Country:

Paper Title: **An Innovative Cable Failure Detection and PHM Toolset**

Co Authors: James Hofmeister, Patrick Edwards

Abstract:

Cabling degradation represents a large part of complex system-maintenance budgets. These systems are often used in very harsh environments and require improved methods of fault detection and isolation. Submarines, unmanned underwater vehicles (UUVs) surface ships, aircraft, ground vehicles and industrial machines that encounter vibration or adverse environmental conditions can benefit from a tool that can rapidly assess the integrity of the cabling, and pinpoint problems caused by degradation in the field. This paper presents a non-destructive, ruggedized toolset consisting of a personal hand-held device that uses an innovative, compact Power Draw Correlation Technique to detect damage to multi-conductor Submersible High Data Rate (SubHDR) cables. The toolset also consists of an innovative adaptive time-to-failure (ATTF) prognostic algorithm to generate accurate remaining useful life (RUL) estimates for detected damaged cables, such as those in the sensor masts of Virginia class submarines. An electronic-based, handheld device to detect degradation, such as a broken wire strand in a multi-strand conductor in submersible high-data rate (SubHDR) cables, greatly reduces maintenance costs and improves mission reliability. For example, SubHDR cables, such as those used in the sensor masts on the Virginia class of submarines, are integral to the sensor masts, yet physical inspection requires removal and disassembly of the large, heavy masts themselves. The prognostic algorithm provides fast, accurate time-to-failure (TTF) and remaining useful life (RUL) estimates supports condition-based maintenance (CBM) methodologies: as opposed to the costly and time-consuming immediate removal and replacement of a mast that, although the SubHDR cable is damaged, its damage might not be large enough to cause cable failure before completion of the next mission. The new electronic-based detection method can readily be adapted for commercial use, including multi-strand cables that are not submersible or integrated in antennas.

Assigned Session: D1 Health Management Tools and Capabilities

Presenting Author: Thomas Lagö **Ser:** 42

Organization: TechFuzion

Country:

Paper Title: **HAPTICS as a Platform for CM Technology Deployment and Training**

Co Authors: Ingvar Gustavsson, Johan Zackrisson, Lars Håkansson and Ingvar Claesson, Blekinge Institute of Technology, Ronneby, SE-37225, Sweden; Jay Nkuna, Thomas Lagö and Henrik Åkesson, Acticut International AB

Abstract:

The need for new educational platforms enabling a better ability to illustrate and verify different method's capabilities is substantial. Within sound and vibration, and especially within Condition Based Monitoring (CBM) such methods could find its place. With VISIR, (Virtual Instrument Systems In Reality, a Blekinge Institute of Technology initiative), an educational platform containing objects that can be connected, instrumentation for sound and vibration measurements plus a real "sound and feel experience" using haptics can be created. This mean that students can sense the vibrations in their fingers and hear them! Web-based experimentation is an excellent supplement to traditional lab sessions. The students can access lab stations outside the laboratory and perform experiments around the clock. It is possible to design virtual instructors in software which will protect the equipment from careless use; also theft of equipment will not be a problem. Interfaces enabling students to recognize on their own computer screen the instruments and other equipment in the local laboratory may easily be created. Apart from the fact that each student or team of students works remotely in a virtual environment with no face-to-face contact with an instructor or other students in the laboratory, the main difference between a lab session in the remote laboratory described here and a session in a local laboratory is that it is not possible for students to manipulate physical equipment e.g. wires and electronic components with their fingers in a remote laboratory. However, students can, for example, sit at home in peace and quiet and learn how to use the instrumentation in the same way as in a noisy local laboratory where time is limited. The paper will outlined the concept for such a platform using the Open Source Code and Open Platform approach that VISIR has adopted with applicability to Condition Based Monitoring applications.

Assigned Session: D1 Health Management Tools and Capabilities

Presenting Author: Girija Parthasarathy **Ser:** 61

Organization: Honeywell

Country:

Paper Title: **Readiness Approach for Propulsion Engine LRUs**

Co Authors: Dinkar Mylaraswamy, Onder Uluyol, Kyusung Kim (Honeywell), Sonia Vohnout and Bruce Thompson (Army AATD)

Abstract:

To achieve the U.S. Army's 2013 aircraft-level CBM metrics (50% reduction in inspections/flight hour, a 12% reduction in maintenance labor/flight hour, and less than 5% false removal rates), a reduction in operational surprises for mechanical line replaceable unit (LRU), as well as better isolation for electrical subsystems is required. Anecdotal comments from field service personnel indicate that 40-60% Digital Engine Control Unit (DECU) removals were unwarranted. The Honeywell team has developed a collection of technologies, called RAPEL (Readiness Approach for Propulsion Engine LRUs), to meet this challenge. The team used a holistic approach that monitors engine functions at both steady state and transient conditions. The underlying algorithms capture key information features in real time and assess the health of engine LRUs that may cause in-flight engine shutdowns (IFSD), sluggish response, loss of power control (LOPC) during a mission, or an engine no-start (INOPS) during the next mission. We demonstrated breadboard validation of these technologies using Honeywell's HTS900 and AGT1500 engines.

Assigned Session: D1 Health Management Tools and Capabilities

Presenting Author: Leonard Bond **Ser:** 35

Organization: Pacific Northwest National Laboratory

Country:

Paper Title: **Diagnostics and Prognostics Tools for Assessing Remaining Useful Life of Nuclear Power Plant Materials**

Co Authors: Jeffrey W. Griffin, Jacob Fricke, Charles H. Henager Jr., Mukul Dixit and Leonard J. Bond

Abstract:

In recent years, there has been renewed interest in expanding the use of nuclear power to provide sustainable, carbon-free energy. As part of these activities in the USA, there are major initiatives focused on “life extension” for existing light-water nuclear power reactors (LWR) from 60 to 80 (or 100) years. A central issue in life extension for the current fleet of LWRs is the early detection and monitoring of materials degradation. A related issue is the ability to estimate remaining useful life (RUL) of components and systems based on condition assessment or degradation information. For early detection of degradation, novel nondestructive (i.e., without destroying the utility of the specimen) tests that are suitable for continuous monitoring over extended time periods are needed, as are new techniques for data integration. This paper discusses the development and application of advanced diagnostics and prognostics tools to the LWR life extension problem.

Assigned Session: D1 Health Management Tools and Capabilities

Presenting Author: Hyunseok Oh **Ser:** 32

Organization: Center for Advanced Life Cycle Engineering (CALCE), University of Maryland

Country:

Paper Title: **Estimation of Fan Bearing Degradation Using Acoustic Emission Analysis and Mahalanobis Distance**

Co Authors: Michael H. Azarian, Michael Pecht

Abstract:

In order to estimate health conditions of fan bearings and predict their remaining life before failure, relevant features associated with their degradation must be identified. There are few published papers that deal with the selection of relevant features from acoustic emission signals for health condition estimation and life prediction of bearings in cooling fans.

For this study, acoustic emission signals were measured periodically during stress tests of cooling fans, from which a total of fifteen different acoustic emission features were extracted. Correlation coefficients between the acoustic emission features and stress duration were calculated in order to identify features which were associated with bearing degradation. The distinguishing characteristics of acoustic emission features were also described. By using a health index based on a Mahalanobis distance integrating the acoustic emission features selected from the correlation analysis, the health conditions of fan bearings were estimated over the duration of the stress test. Failure analysis of as-received and failed fan bearings was conducted to identify physical defects on surfaces of bearing elements and relate the evolution of the physical defects to the generation of acoustic emission. The approach presented in this paper helps to identify acoustic emission features associated with the evolution of the physical condition of fan bearings.

Assigned Session: A2 Signal Analysis 2

Presenting Author: Thomas Lagö **Ser:** 40

Organization: TechFuzion

Country:

Paper Title: **Classification Prognostics and Condition Based Maintenance (CBM) of Rolling Element Bearings based on Evolutionary Algorithm Optimisations of Kohonen's Self-Organising Maps**

Co Authors: Jay Nkuna, Dr. Henrik Åkesson

Abstract:

Condition monitoring of rolling element bearings is common practice in industry today. Unsuspected failure of these bearings are the main cause of breakdown in rotating machinery, thus creating the need to practice reliable estimation of a bearing remaining life through the detection of developing bearing defects. Reports have been made that the maintenance trend in industry is to replace the bearings in order to avoid costly machinery failure at an average operational bearing life of 10%. This leaves an estimated 80% to 90% of bearing life being wasted. For maintenance cost savings an emphasis is made for an improved reliable condition monitoring system for rolling element bearings that will enable timed maintenance overhauls after an extended operational bearing life is achieved. Estimation of bearing remaining life presents a challenge to maintenance personnel in optimizing and automating their vibration monitoring systems.

Vibration condition monitoring methods are widely used in industry today where FFT analysis is the common technique applied. The FFT assumes stationary signals, and proves difficult to handle transient and time-varying signals. The FFT approach reduces the data to smaller sets, to an extent that if key parameters are lost it will be impossible to classify correctly the bearing defects. A combination of the FFT (linear frequency spectrum) and Octaves (logarithmic frequency spectrum) enables classification of vibration with a much better accuracy. Vibration measurement based on the FFT and Octaves signal processing techniques, is used to create an input data set to an unsupervised neural network to monitor, identify and classify defects. Self-Organizing Feature Maps, enables parallel processing of multiple features in the input data set. This paper presents a method that provides a visual prognostic classification of bearing damage and bearing remaining life through an automated system that combines linear frequency spectrum, logarithmic frequency spectrum and neural networks. From the results a robust approach to Condition Based Monitoring is achieved and applied through a CBM framework. The system will allow intelligent, automated diagnostic and prognostic programs for rolling element bearings to provide maintenance practitioners with an understanding of the condition of their machinery today and an assurance of its operational state tomorrow.

Assigned Session: A2 Signal Analysis 2

Presenting Author: John Judd **Ser:** 50

Organization: Dynamic Measurements LLC

Country:

Paper Title: **The Use of the Multiple Discriminant Predictive Analysis ™ Approach to Automate Conformance to ISO 10816-2**

Co Authors:

Abstract:

"Standards for evaluation of vibration severity are considered one of the most important activities of ISO/TC108. Unfortunately, due to the range of machinery categories and classifications, it may also be the most confusing." J Michael Robichaud, PEng, Bretech Engineering Ltd

ISO Standard 10816-2 provides guidelines for establishing the operating condition of rotating machinery based on vibration measurements made on non-rotating elements. It is one of the most widely utilized and cited International standards. Yet, as Engineer Robichaud points out, its general nature in covering a broad range of machinery types does create some confusion and suggests that thoughtful care and expertise are often required in applying it to specific machine types.

This presentation will review some of the standard's guidelines and provide the presenter's view on some potential for errors in interpretation. It will also offer some suggestions on how to avoid problems while assuring the reliability level and extended machine life that ISO 10816 is intended to provide.

The presentation will also describe an approach using Multiple Discriminant Predictive Analysis (TM) that allows the user to address these problems and provides methodology to continuously monitor conformance to ISO 10816 standards in a partially or fully automated fashion. The author will encourage participation, comments and input on user experience.

Assigned Session: A2 Signal Analysis 2

Presenting Author: Joe Sheeley **Ser:** 7

Organization: Arnold AFB, AEDC

Country:

Paper Title: The Effect of Speed Variations on Machinery Vibrational Analysis

Co Authors: Frank Steinle, D.Eng

Abstract:

Because many faults in machinery are manifested at predictable frequencies, the Fast Fourier Transform (FFT) – which allows determination of a signal's frequency content – is a primary tool employed in machinery monitoring. Electronic data collection and analysis devices (frequency analyzers) are employed by predictive maintenance personnel throughout industry and government facilities. Despite the requirement for stationary signals in Fourier transform theory, the FFT is often applied to systems with fluctuating speeds, largely because no better tool is available. It has been found that diagnosis of machinery components requiring detection of high frequencies such as gearboxes is very difficult because of the many frequencies appearing in the region of interest that are not related to gearbox health. These spectrum lines are normally attributed to causes such as vibrations from other nearby components (such as bearings) and their harmonics and sidebands. In this study, a simple simulation consisting of a motor and a gearbox is created to allow analysis of the effect of speed variations on frequency analysis. Simulations are run with random changes in speed, and data are sampled by "virtual" accelerometers. It is found that relatively small variations in motor speed can shift high-frequency spikes in frequency and reduce their magnitude due to energy spreading over several frequency bins. The use of the Hilbert Huang Transform (HHT), designed for use with transient signals and providing an instantaneous frequency estimate, is tested as an alternative to Short Time Fourier Transforms and other techniques. It is found that this technique is better suited for analysis of signals not meeting the stationary signal criteria although there are issues in separating closely spaced frequencies. A technique that utilizes direct fitting of sinusoids in a piecewise manner is presented as a way to address this issue.

Assigned Session: A2 Signal Analysis 2

Presenting Author: Mohammad Azarbayejani **Ser:** 63

Organization: University of Texas-Pan American, Civil Engineering Department

Country:

Paper Title: **Wavelet and Fast Fourier Transforms as Hierarchical Processing Tools to Monitor an RC bridge at Interstate 40**

Co Authors: Mahmoud Reda Taha Dep. of Civil Engineering, University of New Mexico, Albuquerque, NM

Abstract:

Signal processing tools are necessary components of a structural health monitoring (SHM) system to extract features from raw signals that can differentiate between healthy and damaged states. Damage feature extraction is a challenging task when monitoring bridges since the damage typically initiates at a small scale but needs to be probed in the large structure. An innovative wireless monitoring system was designed and installed on a reinforced concrete (RC) bridge at Interstate 40. In this system, two different signal processing tools were used for a hierarchical damage feature extraction in the bridge.

Fast Fourier Transform (FFT) is used to differentiate between healthy and damaged states of the bridge in the frequency domain. As damage propagates in the bridge, a significant reduction in stiffness can take place and the main frequency components of the monitored signal decrease. Since the change in frequency due to damage can only be observed when a significant damage takes place, an alternative signal processing tool, wavelet multi resolution analysis (WMRA) is used in a hierarchical fashion with FFT to identify damage at a low scale. The application of the two methods for health monitoring on a reinforced concrete bridge on interstate 40 is presented.

Keywords: structural health monitoring, signal processing, fast Fourier transform and wavelet multi resolution analysis.

Assigned Session: A2 Signal Analysis 2

Presenting Author: David Corelli **Ser:** 15

Organization: IMI Sensors

Country:

Paper Title: **Understanding High Frequency Measurement and Demodulation**

Co Authors:

Abstract:

High frequency vibration analysis is routinely used to diagnose machine problems in predictive maintenance programs. A popular and effective high frequency technique is demodulation. While it is used by many, it is not generally understood very well. This paper looks at problems associated with making accurate high frequency measurements and shows step-by-step how demodulated time waveforms and spectra are computed. Finally, an example is presented that shows how demodulated data identifies rolling element bearing, gear, and other repetitive impulsive faults earlier than normal data.

Bio: David Corelli holds a Bachelor of Science degree in Systems Engineering from Wright State University and a Master of Science degree in Mechanical Engineering from The University of Alabama. He has over 36 years of experience in vibration analysis and instrumentation. He has worked as a test engineer for the Air Force Avionics Laboratory and as a Field Engineer for Hewlett Packard, Entek, and IRD Mechanalysis. Dave is a Category IV Vibration Analyst in accordance with ISO 18436-2. He is on the Board of Directors and is Chairman of the Certification Committee for the Vibration Institute. He is currently the Director of Application Engineering for PCB Piezotronics.

Assigned Session: B2 Data/Knowledge Management

Presenting Author: Fred Discenzo **Ser:** 66

Organization: Rockwell Automation

Country:

Paper Title: **Test Stand Links Manufacturing with In-field Failure Prevention**

Co Authors: Kenneth A. Loparo, Ph.D., Professor, Case Western Reserve University and Dukki Chung, Ph.D., Program Manager, Rockwell Automation, Advanced Technology; and Matthew Kirsch

Abstract:

Rotating machines are manufactured according to precise, well-defined specifications to insure reliable, safe, and efficient operation. These machines are important elements in automobiles, industrial machines, commercial equipment, aircraft and shipboard systems. An extensive body of knowledge, algorithms and techniques has been developed for monitoring critical motors in the field during operation to prevent unexpected failure and to reduce maintenance and repair costs. The diagnostics and prognostics for installed machines can be enhanced by establishing a performance baseline for the machine immediately after manufacturing and using this information for subsequent machinery diagnostics and prognostics.

Existing condition monitoring techniques and algorithms can be re-deployed and packaged to provide a manufacturing test stand with analytic capability for full machinery characterization prior to shipment. Machinery as-built performance data may be retained in a central database or integrated with the machinery in memory and remain with the machine for its lifetime serving as “birth certificate” data. The ability to combine historical as-built information with data captured during the operation of installed machinery over time can enhance the ability to detect subtle changes and improve prognostic performance. The analytic test stand will also provide the needed acceptance testing for quality control and will provide valuable information to permit analyzing up-stream manufacturing processes and assessing variability in the manufacturing process.

Assigned Session: B2 Data/Knowledge Management

Presenting Author: Harlan Shober **Ser:** 84

Organization: RJ LeeGroup Inc

Country:

Paper Title: **LabSpaces and Tri-store, Swift and Federated Security: An Architecture for Scientific Data Management**

Co Authors:

Abstract:

Someone once said: “We are drowning in data, but starving of information”. This is particularly true for scientific data. The statement can also be applied to typical business data, although in these scenarios, there has been more time to learn. Data architectures have been implemented, data warehouses created and data mining methods performed in order to extract information from the data. So why aren’t these solutions studied and applied to scientific data? The solution can be to setup a scientific data management architecture.

Scientists typically limit the meaning of data management to the mere physical data storage and access layer, but the scope is actually much broader, it is about meaning and content. Many problems exist when trying to use traditional data management methods to manage scientific data needs which can be compared to trying to fit a square peg into a round hole. Some of these challenges are listed below:

• Limited file and directory naming schemes exist and project data repositories are often big flat directories.
• The entire file(s) must be retrieved to ascertain relevance.
• No access to important metadata that is stored in scientists' notebooks and heads.
• Un-owned data with dubious content after the end of project, study or thesis.
• Forensic analysis often deals with various types and formats of data that are structured and unstructured such as text files, binary files, spreadsheets, images, databases, and documents in electronic and paper form.

The increasing amount of scientific data collections size not only brings about many problems, but also creates many new opportunities. One of the biggest opportunities is the reuse of existing data for new studies. Another virtuous effect can be called "transparent discovery". If the data is well described and the data access method is quite flexible, the user can establish unexpected correlations between data items thus facilitating serendipitous discoveries.

This presentation will describe the three critical elements of a scientific hypermedia database and discuss methods that RJ Lee Group (RJLG) has used to implement a feature rich set of tools for exposing, utilizing and discovering data sources that address the problem of scientific data management. The ideas discussed are generally applicable to any kind of scientific data management project that require the integration, discovery and use of various types and forms of data for computational and visualization purposes.

Assigned Session: B2 Data/Knowledge Management

Presenting Author: Christopher Davies **Ser:** 11

Organization: U.S. Army Materiel Systems Analysis Activity

Country:

Paper Title: **Methods for Analyzing Vehicular Data to Implement Condition Based Maintenance**

Co Authors: Daniel Jones, ManTech-SRS Technologies; Thomas Kilby

Abstract:

Implementing a condition based maintenance (CBM) program on a vehicle can result in many benefits such as reducing maintenance costs, increasing safety, increasing vehicle performance, and limiting vehicle downtime. One difficulty faced when developing a CBM program for a vehicle is how to determine the conditions that will be used to indicate maintenance should be performed. For the case where vehicle bus data will be used to determine the conditions, methods are presented for how to conduct an overview of available data and identify the operating modes of the vehicle. Strategies for how to identify the vehicle's normal operating range by plotting time series data, the operating modes, and relationships between measured parameters are described. Finally, it is shown how to determine the vehicle failure modes using the vehicle bus data and logged maintenance events. This paper will show that vehicle bus data may be used in the development and implementation of a CBM program by describing data analysis strategies that will identify the conditions that indicate maintenance should be performed on the vehicle.

Assigned Session: B2 Data/Knowledge Management

Presenting Author: Douglas Farrell **Ser:** 34

Organization: National Instruments

Country:

Paper Title: How Does My Choice of ADC Effect My Vibration Measurement?

Co Authors:

Abstract:

Data acquisition technology has changed drastically in the past 20 years. There are several different possible architectures that can be used to build a modern. Each type of ADC has different tradeoffs to consider. Accelerometer measurements have different concerns depending on the type of accelerometer and the actual real world signal being measured. To select an appropriate ADC it is crucial to understand the concerns and critical parts of the accelerometer signal. The most generally used ADC for accelerometer measurements is a Delta Sigma ADC. Learn how this now ubiquitous ADC technology works and what goes into developing a data acquisition device around it. Discover how using this ADC technology has allowed 24 bit signal acquisition to become the expected standard. The easy to access 24 bit technology has allowed accelerometer measurements to become more informative while being easier than ever to implement. Input range considerations are far less important when 24 bit ADCs allow for higher dynamic range. Determining the true dynamic range of a data acquisition system requires testing and measurement but increasing the bits of resolution does result in higher dynamic range. This in turn allows the information buried in the overall noise of a vibration signal to be found. A final consideration when selecting a type of ADC to use in vibration acquisition is the signals that must be generated to use that ADC. Successive approximiation ADCs have less demanding timing requirements than Delta Sigma or integrating ADCs. In the end selecting the right ADC will be about the needs of the measurement. Come learn about 5 different types of ADCs and why they are appropriate for different kind of applications. See the requirements for using the most common ones in vibration applications and understand all that is going on in your data acquisition instruments.

Assigned Session: B2 Data/Knowledge Management

Presenting Author: Douglas Farrell **Ser:** 60

Organization: National Instruments

Country:

Paper Title: **Manage Assets Without Suffering a Data Explosion**

Co Authors: Alan Armstead

Abstract:

Asset monitoring from military vehicles to fruit juice compressors is now an expected norm. Machines that ten years ago would have been run to burnout are now monitored like precious resources. This presents two key issues. How do we monitor these machines and the purpose of this paper; how do we deal with all the data. Continuously monitoring a single machine will quickly result in gigabytes of data unless the data acquisition system and file storage system has an effective way to identify data that can be removed. To accomplish this the embedded monitoring system cannot simply be a data logger. It must be a smart data logger that allows operators to see trends of important information while only storing the fundamental raw data when suspicious events are occuring. Come see a description of possible metrics that can be used to distinguish normal and suspicious data. Also see a demonstration of a system performing the embedded analysis necessary to calculate these metrics and save or delete data continuously.

Assigned Session: B2 Data/Knowledge Management

Presenting Author: Amit Deshpande **Ser:** 1

Organization: TechSolve, Inc.

Country:

Paper Title: CNC Integrated Manufacturing Data Management

Co Authors: James Neidhart

Abstract:

Traditionally, manufacturing data management at the shop-floor level consists of machine controller data being transported, stored, and then analyzed on a central server for various key performance indicators. The raw data is transported using standard networking technologies like Profibus, Ethernet, Modbus, or RS-232. The method involves external data acquisition and analysis system, internal communication networks, appropriate network bandwidth, cables, and software resources. Today, machine tool controllers are getting more open and have separate systems for real-time motion control and human-machine interface. The data storage capability, computation power, and ability to exchange information in a standardized format between the motion control unit and PC are becoming robust in machine tool controller technology. In this paper, we examine a computer numeric control (CNC) integrated data collection methodology that effectively manages manufacturing data, process violations, alarm management, and quality control within the controller itself. The proposed methodology eliminates the need for an external device for data collection and has a potential to provide a platform for implementing user-defined alarms and customizable process violation alerts. The system architecture, implementation, benefits, limitations, and future work needed for the controller-integrated smart manufacturing control and information system is explained.

Assigned Session: D2 Health Management Strategies

Presenting Author: Bob Randall **Ser:** 73

Organization: University of New South Wales

Country: Australia

Paper Title: **Decomposition of Structural Vibration for Wind Turbine Diagnosis**

Co Authors: Nader Sawalhi, UNSW William Marscher, Thomas Walter, & Jeremy Weiss MSI

Abstract:

The authors are developing a technique for the detection of faults in wind turbine transmissions based upon vibration time-frequency data collected at the base of the wind turbine support structure. Such a technique is of great practical use since many wind turbines are under warranty contract to OEM's or are covered by liability insurers, neither of whom permit diagnosticians to instrument (even enter for inspection) the nacelles. In any event, in-nacelle inspections do involve a degree of risk to personnel, and take extra time and care, and therefore involve added maintenance cost. The new procedure is expected to allow wind turbine individual gears and bearings to be tracked in terms of distress, with potential for determination of remaining useful life, on an on-going basis.

Assigned Session: D2 Health Management Strategies

Presenting Author: Preston Johnson **Ser:** 31

Organization: National Instruments

Country:

Paper Title: **Wind Turbine Instrumented Surveys Help Identify Service Needs**

Co Authors: Michael Lenz, Frontier Pro Services, mlenz@frontierpro.com

Abstract:

Rapid adoption of wind energy continues around the world. New manufacturers and new machine designs appear frequently. As frequently as new designs appear on the market, existing wind turbine warranties expire. Operators and wind turbine service teams are now taking advantage of end-of-warranty surveys to verify current health of wind turbine components. This survey effort, allows wind farm operators to make warranty claims prior to warranty expiration. An end-of-warranty survey includes performance analysis of supervisory data as well as mechanical and electrical sensory measurement campaigns. The measurement campaign consists of typical vibration analysis, along with stress, strain, power quality and temperature measurements. The measurement campaign is long enough to provide measurements under a number of operating conditions. However, cost and equipment size constraints require the measurement campaign be conducted with smaller and all inclusive measurement systems in order to reduce the cost of the measurement survey. Measurements are compared with commissioning measurements, recent trends, wind turbine specifications, installed sensors for validation and survey's of like wind turbine models. These comparison reports underscore outliers in the wind turbine fleet and facilitate joint manufacturer and operator participation in any end-of-warranty repairs and maintenance activities.

Assigned Session: D2 Health Management Strategies

Presenting Author: Mark Walker **Ser:** 41

Organization: General Atomics

Country:

Paper Title: **Monitoring System for Storm Readiness and Recovery of Test Facilities: Integrated System Health Management (ISHM) Approach**

Co Authors: Jon Morris and Mark Turowski, Jacobs Technology, Stennis Space Center, MS. Richard Franzl, Smith Research Company, Stennis Space Center, MS. Mark Walker, Ravi Kapadia, and Meera Venkatesh, General Atomics, San Diego, CA. John Schmalzel, Rowan University, NJ

Abstract:

The paper describes the concept, design, and implementation of a monitoring system that is rooted in recent advances in the area of integrated system health management (ISHM). The motivation for a monitoring system was to enable a safe and effective return to normal operations after damaging events such as Hurricane Katrina, as well as to improve readiness in preparation for such events. The system's uniqueness is derived from its architecture that embodies management of data, information, and knowledge (DIaK) distributed across elements of the system. The architecture also defines systems as networked intelligent elements with distributed processing capability, and enables systematic augmentation of monitoring capability as well a scalability to monitor additional systems. Furthermore, the monitoring system allows near real-time analysis; and includes databases that can be accessed for detailed visualization and analysis, as needed.

Assigned Session: D2 Health Management Strategies

Presenting Author: David Pack **Ser:** 88

Organization: Logistics and Readinenss Center, CECOM LCMC, US Army

Country:

Paper Title: **CECOM LCMC CBM+ Strategy**

Co Authors:

Abstract:

Assigned Session: D2 Health Management Strategies

Presenting Author: Ken Eizenga **Ser:** 89

Organization: AFRL/RBCC

Country:

Paper Title: **Towards a Safe & Reliable Operation of Cyber Physical Systems**

Co Authors:

Abstract:

Assigned Session: D2 Health Management Strategies

Presenting Author: Shawn Sheng **Ser:** 33

Organization: National Renewable Energy Laboratory (NREL)

Country:

Paper Title: **Wind Turbine Drivetrain Condition Monitoring - an Overview**

Co Authors: Paul Veers

Abstract:

Wind energy is presently the fastest growing renewable energy source in the world. However, the industry still experiences premature turbine component failures, which lead to increased operation and maintenance (O&M) costs and subsequently, increased cost of energy (COE). To make wind power more competitive, it is necessary to reduce turbine downtime and increase reliability. Condition monitoring may help by reducing the chances of catastrophic failures, enabling cost-effective operation and maintenance practices, and providing inputs to improve turbine operation, control strategy, and component design. As compared with other applications, the wind industry started recognizing the benefits and importance of condition monitoring relatively late. However, interest has increased so much that a workshop was organized by the National Renewable Energy Laboratory (NREL) in 2009 as a response. This paper provides an overview of wind turbine drivetrain condition monitoring based on workshop presentations and additional references. Since the gearbox has been shown to have the longest downtime and is the most costly subsystem to maintain throughout a turbine's 20 years of design life, it has been chosen as the main targeted subsystem of this study. Wind turbine drivetrain condition monitoring practices, challenges, and future research opportunities will be addressed in detail.

Assigned Session: A3 Sensors

Presenting Author: Jack Poley **Ser:** 19

Organization: Kittiwake Americas, Inc

Country:

Paper Title: **Metallic Wear Debris Sensors: Promising Developments in Failure Prevention for Wind Turbine Gearsets and Similar Remotely Situated Components**

Co Authors:

Abstract:

Wind turbines are frequently located in remote, hard-to-reach locations, making it difficult to apply traditional oil analysis sampling of the machine's critical gearset at timely intervals. These devices are excellent candidates for oil circuit sensors designed to monitor machine condition in vivo. Online sensor technology has come of age with products now capable of identifying the onset of wear in time to avoid or mitigate failure. Online oil analysis is now viable, and can be integrated with onsite and traditional remote lab testing to vet sensor alarms. An automated Intelligent Agent to evaluate the cumulative data from all tests and inspections provides comprehensive diagnostics. The result is a sophisticated, real-time monitoring package for remote machinery. Independent research, some of which is presented herein, strongly suggest the viability of sensors in today's wind turbine gearsets.

Assigned Session: A3 Sensors

Presenting Author: Hyungdae Lee **Ser:** 54

Organization: Impact Technologies LLC

Country:

Paper Title: **Dynamic Strain Sensor Calibration for Sustainable Life and Usage Monitoring**

Co Authors: Jeremy Sheldon, Matt Watson, Carl Palmer Timothy Fallon (Naval Air Systems Command)

Abstract:

Strain sensors provide a critical function in determining whether or not an aircraft is safe to fly or must be retired. Specifically, strain sensors are utilized on in-service aircraft to obtain the load histories of various parts and structures. This load history data is then used by structural fatigue life tracking methods to determine how much structural life has been consumed and to make decisions regarding the ability to safely operate the aircraft. However the usefulness of the strain data can be compromised by the inability to consistently manufacture and install the sensors, and aircraft-to-aircraft variations in the structures themselves. As such, variations in strain readings greater than 10% are typical in aircraft applications. This variation must be accounted for in order to improve fatigue life tracking and enhance decisions on the sustainability of the aircraft. Frequent and accurate calibration is thus necessary to ensure accurate aircraft fatigue usage estimates, which will in turn reduce the need/cost of purchasing new aircraft (resulting from the retiring of aircraft with remaining useful life) and, more importantly, reducing the risk associated with flying unsafe aircraft. However, current strain sensor calibration methods are inadequate. For example, the ideal calibration approach involves placing the entire aircraft in a full scale test rig and applying known loads to the structure. This approach is extremely expensive and time-consuming when performed on an aircraft-to-aircraft basis. Alternately, the aircraft could be flown in tightly prescribed maneuvers where loads can be fairly well determined. However, this approach is far less accurate and in some cases, it is difficult to prescribe repeatable maneuvers (loads) for certain sections of the aircraft. As such, a need exists for a cost/time-effective means to calibrate strain gauges on each aircraft with an accuracy that is comparable to the full scale test rig approach. To address these issues, the authors are developing an innovative strain sensor calibration system that uses a portable device to 1) apply a low level and localized dynamic load near the strain gauge, 2) measure the load and structural responses from an integrated force sensor and the strain gauge itself, 3) evaluate the measurements relative to a reference structure, and 4) provide a calibration factor for each individual strain sensor. This paper presents an overview of the approach and describes experimental results for both baseline (static) and dynamic excitation tests, including the implemented test and analysis procedures. The authors also identify and evaluate various factors that affect the accuracy of the approach, including load repeatability, sensor configuration, excitation force, measurement error, data acquisition considerations, analysis methods, etc. An accuracy goal of 1% has been set for the calculated calibration factors on simpler structures and 2% on trial parts of increasing complexity. Tests were thus conducted to verify test repeatability and evaluate calibration accuracy. Key Words: Strain Sensor Calibration; Fatigue Life Tracking; Usage Monitoring; Periodic Excitation; Impact Excitation; Structural Health Management

Assigned Session: A3 Sensors

Presenting Author: Bill Nickerson **Ser:** 45

Organization: Impact-RLW Systems

Country:

Paper Title: **Trustworthy Wireless Sensors**

Co Authors: John Munro and Wayne Manges, Oak Ridge National Laboratory

Abstract:

Our purpose is to dispel misconceptions and myths about wireless sensor networks and provide information to facilitate their successful introduction. The information is not specific to any particular wireless solution. The paper provides background on the fundamental opportunities and challenges associated with wireless in the industrial environment and enough knowledge to allow you to decide whether to evaluate wireless for particular applications. The fundamental premise is that wireless technology will become common in the condition monitoring environment, but care while the technology evolves is appropriate. Hopefully, this paper will contribute to your understanding.

This paper is a summary of a Technical Report produced by the ISA: Trustworthiness in Wireless Industrial Automation: Part I – Information for End Users and Regulators [1]. It is the first of a two-part report series. The first part, on which this paper is based, is written primarily for the end user and regulator. It has been approved for publication and will be released early in 2011. The companion document will be written primarily for manufacturers, vendors, designers, integrators, operators, and maintainers and will contain substantially more technical detail. Its release date should be in the second half of 2011.

Assigned Session: A3 Sensors

Presenting Author: Ed Guevara **Ser:** 81

Organization: US Navy Military Sealift Command

Country:

Paper Title: **Changing the Way You Look at Oil: Real-Time Diagnostics for the Military Sealift Command**

Co Authors: Patrick F. Henning (Spectro)

Abstract:

The Military Sealift Command (MSC), across its fleet of 90+ ships, has developed a comprehensive oil analysis program that relies heavily on daily shipboard testing as well as onshore laboratory analysis. One of the key cost drivers in this system are the shipboard testing protocols, which require provision for consumables, hazardous waste logistics, and trained personnel to carry out the testing. To address these cost drivers, we have undertaken a validation analysis of a new shipboard testing system which can perform all the mandated testing, but which eliminates the need for hazardous chemicals and consumables to perform the analysis, while greatly simplifying the testing process and avoiding generation of unnecessary hazardous wastes. Such a system can cut the time needed to carry out the testing by greater than 50%. If these features are validated, implementing the system would provide immediate benefit to the MSC.

We have carried out this analysis in two steps: First, in order to test the operability of the system hardware and its ability to provide quality analysis shipboard, we undertook two short sea trials where the ship's engineers used the equipment alongside the existing equipment. At the same time, analyzed samples were pulled for correlation to laboratory analysis. The results of this first step showed that the system could provide quality results, while at the same time operate reliably. Most importantly, it showed the capability of easing the burden on the engineers as far as preparing for and carrying out testing. The second step, a long-term sea trail of the system, has been successfully ongoing for nine (9) months. This involves using the new system in place of the existing shipboard test equipment and validating the performance and long-term durability of the system. This is being accomplished through comparing a sampling of the results to offshore lab analysis, and feedback surveys from those onboard who are using the equipment. In this paper, we will discuss these results, feedback from the ship's engineers and future considerations for deploying such systems

Assigned Session: A3 Sensors

Presenting Author: Bruce Nelson **Ser:** 75

Organization: Battenkill Technologies, Inc.

Country:

Paper Title: **Corrosion Sensors and ISIS; a Sensor Based Approach to Condition Based Maintenance of Tanks and Voids on US Navy Ships**

Co Authors: Ted Lemieux, Paul Slebodnick, John Wegand, Diane Lysogorski

Abstract:

Tank and void inspections and the preservation of these spaces following inspection result in significant maintenance expenditures on US Navy Ships. The costs to prepare a tank or void for human entry and inspection involves certifying the tanks safe for human entry (gas free), cleaning of these tanks and installing scaffolding to afford the efficient inspection of these spaces. It is estimated that the costs for preparing tanks for manual inspection range from $ 16 K to $ 32 K. Since the late 1990's the Naval Research Laboratory has explored the use of Corrosion Sensor based Tank Monitoring Systems and the Insertable Stalk Inspection System (ISIS) as a means to reduce requirements for manned entry into tanks and voids when inspecting tanks and voids on US Navy Ships. These systems provide a means for providing information on the condition of a tank or void while eliminating requirements for gas freeing, cleaning and preparing the tanks for manual inspection.

In 2010, the US Navy's Corrosion Control Assessment and Maintenance Manual (CCAMM) was modified to afford the use of the Corrosion Sensor based Tank Monitoring Systems and for increased use of ISIS as a means of assessing the condition of tanks and voids on US Navy Ships. The Corrosion Sensor Tank Monitoring Systems afford a means to determine if a tank is actively corroding without requirements for entering or opening the tank. ISIS provides a means to perform a visual inspection of a tank or void without requirements to certify the tank safe for human entry or for cleaning and preparing the tank for manned inspection.

The presentation will provide descriptions of these two NRL developed technologies and will also describe how they are used together to provide improved assessments of tank and void condition. The paper will describe the recent changes in the CCAMM and discuss how the use of these systems can reduce the costs of tank and void inspections while providing improved data and information regarding the condition of tanks and voids on US Navy Ships.

Assigned Session: B3 Economic/Business Case Studies and Analysis

Presenting Author: Joel Luna **Ser:** 16

Organization: Frontier Technology Inc

Country:

Paper Title: **Integrated Methodology and Tools for Health Management (HM) Business Case Analysis (BCA)**

Co Authors:

Abstract:

The implementation of health management capabilities is generally regarded as a promising enabler for improving operations, maintenance, and supply support of complex systems. Nonetheless, using health management to improve operation and support of systems requires making a business case for its adoption, showing how health management can improve operational capability or make support more efficient and cost effective. It is the goal of this paper to first define a seven-step process for identifying and characterizing what benefits can result from implementing health management, and then identify methods and tools within that process which can be used to provide a robust business case. An example is provided for the integrated use of decision analysis, logistics simulation, and cost analysis to define and quantify health management benefits.

Assigned Session: B3 Economic/Business Case Studies and Analysis

Presenting Author: Gilbert Haddad **Ser:** 51

Organization: CALCE- Center for Advanced Life Cycle Engineering

Country:

Paper Title: **A Real Options Optimization Model to Meet Availability Requirements for Offshore Wind Turbines**

Co Authors: Peter Sandborn, Michael Pecht

Abstract:

This paper provides an optimization model based on Real Options (RO) and stochastic dynamic programming for the availability maximization of an offshore wind farm with prognostic capabilities. Alternative energy sources such as offshore wind turbines are promising technologies, but they are capital intensive projects, and the economics of the project depend heavily on the wind resources, and the availability of the turbines. Prognostics and health management (PHM) is an enabling technology that potentially allows for reduced life cycle cost through a transition from cycle or time based to demand-based maintenance, performance based logistics, and condition-based maintenance. This is especially important for offshore wind farms that require non-traditional resources for maintenance, and are often located in sites that are not always accessible. The proposed model uses information from the PHM system in order to allocate appropriate investments in maintenance while maintaining a specified availability requirement. The RO theory provides promising means to address the economic aspects of PHM after prognostic indication, and assessing the cost required for meeting availability requirements.

Assigned Session: B3 Economic/Business Case Studies and Analysis

Presenting Author: Greg Hood **Ser:** 5

Organization: Rockwell Automation

Country:

Paper Title: **Maximize Return on Assets through Integrated Condition Monitoring**

Co Authors:

Abstract:

Present Paper Published by PlantServices: http://www.plantservices.com/articles/2009/217.html Discuss the importance of Integrated Data, within an Asset Management Solution to increase Return on Net Assets (RONA). Focus on Condition Monitoring Data integrated into the plant control systems, as well as higher level enterprise systems.

Assigned Session: B3 Economic/Business Case Studies and Analysis

Presenting Author: Chris Hockley **Ser:** 4

Organization: The Defense Academy

Country: United Kingdom

Paper Title: **Implementation of Condition Based Maintenance (CBM) and Health & Usage Monitoring Systems (HUMS) in the UK Defence Land Environment**

Co Authors: Laura Lacey, Systems Engineering Group, Informatics and Systems Engineering Department, Cranfield University, College of Management & Technology. The Defence Academy

Abstract:

Despite the launch of a United Kingdom (UK) Ministry of Defence (MOD) policy and a Defence Standard in 2004 for Health and Usage Monitoring Systems (HUMS) in the military land environment, little progress has been made. Reasons are considered as to why military vehicles are so far behind the technology and capability found in commercial vehicles and cars, which have on-board and interrogative systems fitted as standard so that their operators can benefit from higher vehicle availability and their maintenance staff can plan the most cost-effective maintenance. Without HUMS, progress in the UK military land environment to adopt Condition Based Maintenance (CBM) has not been developed; the reasons and solutions are considered.

The paper first looks briefly at the history of HUMS and CBM for vehicles in the UK military land environment and how the policies have, or have not been implemented. Using some examples, the progress and problems encountered are considered, such as engaging the operational user community to show the benefits of improved availability and the difficulty of making the convincing HUMS business case for the military acquisition process.

The paper finally considers current developments and research activity by Cranfield University at the Defence College of Management and Technology which aims to use HUMS and CBM to deliver a predictive maintenance capability and a reduced logistics footprint for the military operator using expert knowledge elicitation and HUMS data in a probabilistic graphical modelling solution

Assigned Session: B3 Economic/Business Case Studies and Analysis

Presenting Author: Loren Cleven **Ser:** 78

Organization: Azima|DLI

Country:

Paper Title: **Achieving Exceptional Benefits to Costs through Condition Based Maintenance: How Two of the Largest CBM Programs Learned to Predict Machinery Failures and Save Millions**

Co Authors: Tim Kelley

Abstract:

This paper describes two condition based maintenance (CBM) programs. The first project is a long-standing aircraft carrier fleet Machinery Condition Analysis (MCA) program that uses vibration analysis to provide timely and accurate information on condition and operational readiness of rotating machinery. This program consistently demonstrates the large, potential savings of condition based over time based maintenance methodology. The second is a commercial program for a large industrial gas company; the contract was one of the largest in the condition monitoring industry and indicates a growing trend for leading companies to instill consistency, benchmarked practices, demonstrated return on investment and a top-down emphasis on reliability as it pertains to predictive capabilities.

Assigned Session: B3 Economic/Business Case Studies and Analysis

Presenting Author: Dennis Moore **Ser:** 86

Organization: RJ LeeGroup Inc

Country:

Paper Title: **Simulator Solutions for "Self Correcting" Maintenance Systems**

Co Authors:

Abstract:

The predictability in assessing an engine's shop direct maintenance cost is largely a result of the significant reliability improvements inherent in today's engine technology and a result of the introduction of on-condition maintenance. Engine on-condition maintenance seeks to do away with "hard-time" interval removal and prescribes routine monitoring of key operational parameters to drive removal.

A by-product of these reliability improvements and the on-condition maintenance philosophy is a greater reliance on software and statistical analysis to predict the frequency of engine shop visit events and their corresponding shop visit costs. Estimating an appropriate direct maintenance cost therefore, requires careful forecasting of the equipments on-wing life as well as an accurate assessment of its capability to achieve that life and understanding the costs involved in improving that capability.

An engines on-wing life is heavily influenced by its engine operating temperature, thrust rating, life limited parts, operational severity and maturity. Factors influencing an engines shop visit or off-wing costs consist of build policies, time-on-wing considerations (ATOW, target ETOW, CPFH, etc…) as well as organizational considerations or "Business Rules" defined at the base, Major Command and staff levels.

The requirement of any reliability software is to be able to statistically describe any of the data elements that can be used to drive a prediction of on-wing life and/or identify direct maintenance cost. This multi-faceted approach can then provide useful information to optimization software, cost or ATOW forecasting software or other useful tools that will provide engine program management and their customers the ability to accurately assess the condition of fielded systems, understand their capabilities and identify long term management needs to maintain and improve the performance of these systems through out their intended life and beyond.

Assigned Session: C3 Systems Engineering

Presenting Author: John Lucero **Ser:** 90

Organization: NASA John H Glenn Research Center

Country:

Paper Title: **Systems Engineering: A Fundamental Discipline Full of Controversial Opinions**

Co Authors:

Abstract:

Assigned Session: C3 Systems Engineering

Presenting Author: Bob Ware **Ser:** 59

Organization: AFRL/RXSAS

Country:

Paper Title: Aircraft Mishap Prevention using the USAF MECSIP process

Co Authors:

Abstract:

There are many competing priorities for limited aircraft operating and maintenance resources. Balancing the demands of cost, schedule, and performance can be demanding enough during acquisition, without also having to consider affordable reliability and safety over the entire life cycle of a weapons system. The author describes case histories of aircraft mishap investigations illustrating these underlying trends which, if left unchecked, can compromise reliability and safety. These unsafe trends include increased reliance on models, manufacturing variability, changes in usage, and material substitutions driven by environmental reform. While a host of novel tools hold out the hope of addressing these challenges, care must be exercised to avoid unintended negative consequences. The USAF Mechanical Equipment and Subsystems Integrity Program (MECSIP) provides a framework which can be used to address these challenges in a methodical and robust way and also to capitalize on the advantages of new tools developed to ensure safety, availability and sustainability.

Assigned Session: C3 Systems Engineering

Presenting Author: Allen Revels **Ser:** 91

Organization: Advanced Virtual Engine Test Cell (AVETEC)

Country:

Paper Title: **Systems Integration and Planning for Disparate Technologies**

Co Authors:

Abstract:

As defined by NPR 7123.1A, Systems engineering requires the application of a systematic, disciplined engineering approach that is quantifiable, recursive, iterative, and repeatable for the development, operation, maintenance, and disposal of systems integrated into a whole throughout the life cycle of a project or program.
This definition clearly states the objectives of systems engineering and provides a well-defined and organized methodology to plan, document, and implement the process. This implementation covers the life cycle of the developed product and is readily applied to technology integration. The fundamental question is how to apply these tools and techniques to technologies that are often developed in isolation into a single, integrated product. This often involves development from organizations that are geographically dispersed and as well as components at varying readiness levels.
This presentation provides insight into applying engineering techniques to systems integration, including challenges, considerations, limitation, and lessons learned when applying systems integration and planning for disparate technologies using a systems engineering approach.

Assigned Session: D3 Prognostics and Health Management 1

Presenting Author: Sony Mathew **Ser:** 18

Organization: CALCE / University of Maryland

Country:

Paper Title: **Identification of Failure Mechanisms to Enhance Prognostic Outcomes**

Co Authors: Mohammed Alam, Michael Pecht

Abstract:

Predicting the reliability of a system in its actual life-cycle conditions and estimating its time to failure is helpful in decision making to mitigate system risks. There are three approaches to prognostics: the physics-of-failure approach, the data-driven approach, and the fusion approach. A key requirement in all these approaches is identification of the appropriate parameter(s) to monitor to gather data that can be used to assess impending failure. This paper presents a physics-of-failure approach, which uses failure modes, mechanisms and effects analysis (FMMEA) to enhance prognostics planning and implementation. This paper also presents the fusion approach to prognostics and the applicability of FMMEA to this approach. An example case of generating FMMEA information and using that to identify appropriate parameters to monitor is presented.

Assigned Session: D3 Prognostics and Health Management 1

Presenting Author: Shunfeng Cheng **Ser:** 21

Organization: CALCE, University of Maryland College Park

Country:

Paper Title: **Prognostics for Polymer Positive Temperature Coefficient Resettable Fuses**

Co Authors: Kwok Tom Army Research Laboratory, Michael Pecht Center for Advanced Life Cycle Engineering (CALCE) University of Maryland College Park

Abstract:

As a circuit protection device, polymer positive-temperature-coefficient (PPTC) resettable fuses have been widely used in over current or over temperature circuit-protection designs in computers, automotive circuits, telecommunications equipment, and medical devices. Failure of a resettable fuse can cause abnormal operation of and damage to a circuit. Prognostics for a resettable fuse can enable the advance warning of the failure of the fuse and the prediction of its remaining useful life; therefore, the operator can take action to maintain or replace the component to reduce the damage to the circuit and the unnecessary operations to reset the fuses. This paper identifies the potential failure precursor parameters of a polymer positive-temperature-coefficient resettable fuse, uses cross-validation combined sequential probability ratio test (CV-SPRT) method to monitor the precursors in-situ, and uses autoregressive integrated moving average (ARIMA) model to predict the failure based on the precursors.

Assigned Session: D3 Prognostics and Health Management 1

Presenting Author: Eric Strong **Ser:** 25

Organization: University of Tennessee

Country:

Paper Title: **Feasibility of Prognostics for Transformer Remaining Useful Life Predictions**

Co Authors: Jamie Coble, Siobhan O'Reilly, J Wesley Hines

Abstract:

Transformer failures can cause expensive repairs and business interruptions, costing between $1 million to $6 million per failure [1]. Prognostics can be used to predict and avoid these failures. Several failure modes and aging factors were investigated: solid insulation failure, oil contamination, moisture accumulation, and partial discharges. A computer program was developed to simulate transformer degradation data. The simulated data was analyzed using several prognostic techniques. A general path model found a mean absolute error of 45.8 weeks, a kernel regression model had a mean absolute error of 29.2 weeks, and a neural network model had a mean absolute error of 22.7 weeks. The success of these prognostic techniques on simulated data indicates that transformers are viable candidates for prognostics.

Assigned Session: A4 Electronic and Power Systems Health Management 2

Presenting Author: Irfan Ali **Ser:** 57

Organization: Impact Technologies, LLC

Country:

Paper Title: **Travel Waves Based Intermittent Disconnection Detection**

Co Authors: Irfan Ali, Irtaza Barlas, Jonathan W. Goldin, Patrick Kalgren and Michael Roemer

Abstract:

This paper explores a non-traditional use of differential current sensor to detect intermittent disconnection problems in connectors. An intermittent disconnect, often resulting in an arc, creates an imbalance which is manifested in the current. Using a leakage current sensor, the intermittent disconnections can be detected. This current measurement technique explores the possibility for an online detection methodology.

Assigned Session: A4 Electronic and Power Systems Health Management 2

Presenting Author: Mike Xiong **Ser:** 72

Organization: Cranfield University

Country: United Kingdom

Paper Title: **Diagnosis and Prognosis Health Management for Aircraft Electrical Power System**

Co Authors: Dr. A. Savvaris Cranfield University

Abstract:

Electrical Power Systems (EPS) play a critical role in both military and commercial aircraft. Especially with the development of the More Electric Technology, critical systems such as flight control surface actuation and fuel delivery now rely increasingly on EPS. Generally, EPS consists of power generation, power management and distribution subsystems, and it is now the fundamental system for normal operation of the whole aircraft. In order to provide on-board systems with reliability, maintainability and to meet safety requirements, advanced Health Management (HM) system for EPS, which includes diagnostic and prognostic capabilities, is required. An in-depth study of the critical EPS component failure modes showed that major components of power generation and management subsystems such as batteries have incorporated some fundamental Health Management techniques, normally considered to be a health monitoring technique, to detect and isolate faults. However, prognostic health management capability has rarely been employed by on-board systems, especially in the field of commercial aviation. For a given aircraft, EPS would normally include processors embedded in digital controllers such as Generator Control Unit (GCU) and Battery Controller, which have enabled the capabilities to monitor the health of the whole system. Since the data transmitted to and from these components could be used to characterize the system or component operating states, a potential opportunity has been already provided to perform a health management function for EPS. In this paper, existing techniques of diagnosis and prognosis functions were investigated first to ascertain appropriate approaches. The main issues and design considerations have been outlined in the system function development. Finally, an advanced Diagnosis and Prognosis Health Management architecture for Aircraft Electrical Power System was proposed.

Assigned Session: A4 Prognostics and Health Management 2

Presenting Author: Michael Bryant **Ser:** 36

Organization: University of Texas at Austin

Country:

Paper Title: **Model-Based Diagnostics and Prognostics of Machinery**

Co Authors: Mohsen Nakhaeinejad, Jaewon Choi, Sankar Rengarajan, Ted Costuros

Abstract:

A model-based diagnostic technique to detect, isolate and assess machine faults is presented and applied to motors. Signals measured from the real machine are compared to simulations derived from physics-based models of the machine. To make simulations match measured signals, parameters of the models are adjusted or “tuned”. A direct physical correspondence between the model’s parameters and real system elements permits the tuned parameters to locate faults and simplifies classification of faults. The degree to which faults in a degraded machine alters power and signal flows through the machine, indicates machine health. An analogy is formed between a machine and a communications channel, to apply powerful theorems from communications theory to assess machine functional health. For prognosis of machine health and functionality, parameter variations observed over time can be extrapolated into the future, and simulations of the model with extrapolated parameter values can be performed, enabling model simulations to forecast future machine behavior. A Graphical User Interface (GUI) permits a machine operator to select specific sensor outputs, desired parameters, and specific faults to tailor the diagnostics system to a specific machine or design. The aforementioned model based diagnostics techniques are computed behind the interface. In this article, these techniques are applied to motors. Motor voltages, currents, and speeds are measured, and parameters including stator resistance, rotor resistance and magnetic field features are tuned to detect and isolate shorted turns and broken rotor bars. Then functional health of degraded motors is assessed.

Assigned Session: A4 Prognostics and Health Management 2

Presenting Author: David Siegel **Ser:** 76

Organization: University of Cincinnati

Country:

Paper Title: **A Particle Filtering Approach to Remaining Useful Life Prediction of Aircraft Engines**

Co Authors: Wenyu Zhao, Hassan Al-Atat and Jay Lee; Manish Kumar

Abstract:

Fault diagnosis and prognosis of machinery, in particular aircraft engines, has been an important area of research for many years. Various techniques for combining multi-sensor information from gas turbine aircraft engines and diagnosing various faults or detecting anomalies have been used; however research in the prediction of the future health state or remaining useful life is less developed. In this paper, a general particle filtering approach is developed that recursively estimates the future health state and provides a distribution for the predicted health state based on the number of particles selected. Based on a criteria for defining what an unacceptable level of performance or degradation level for the monitored system, the remaining useful life can be estimated with an associated distribution; this provides not just an estimated value but also a distribution which allows the uncertainty in the prediction to be provided. The prognostic filtering remaining useful life framework is applied to an aircraft engine application; in which 21 sensor values are provided as well as three operating values to indicate the particular flight regime the data was collected. The particle filtering method is tested on 100 data sets in which the data sets contain the complete degradation history of an aircraft engine unit until a failure threshold is reached. The prediction results for this application are accurate when the prediction is made 40 cycles or less away from the true remaining useful life and are increasing more accurate for predictions closer in the time horizon; similarly the distribution is less spread for predictions closer in the time horizon. The general particle filtering remaining useful life framework for system level prognostics can be extended and applied to other applications including the prediction the life of components such as rolling element bearings or gears as well as purely electrical components such as batteries. Future work looks to further refine the prognostic method and apply the general framework to the previously mentioned component level applications.

Assigned Session: A4 Prognostics and Health Management 2

Presenting Author: Tyler Skirtich **Ser:** 77

Organization: Center for Intelligent Maintenance Systems

Country:

Paper Title: **A Systematic Health Monitoring and Fault Identification Methodology for Machine Tool Feed Axis**

Co Authors: David Siegel, Jay Lee; Radu Pavel

Abstract:

Considering the importance of monitoring the condition of a machine tool feed axis, a method for detecting and diagnosing faults in a ball screw type feed axis system is presented. The proposed approach uses a fixed-cycle monitoring routine in order to minimize the effects of the vastly different working conditions. To further reduce the effect of operating conditions, the machine monitoring approach segments the data based on the table load and machine warm-up time. Temporal and frequency domain features extracted from the vibration, position, torque, and temperature signals are investigated as inputs into a health assessment monitoring algorithm. A feature selection process is conducted to select the best subset of features for discriminating between the healthy and faulty conditions using the Fisher criterion. Lastly, local health assessment models using a self-organizing map algorithm are developed in each operating regime. The method was then investigated experimentally using a feed axis test-bed with various seeded faults. Results of the investigation show that this health monitoring approach using the self organizing map algorithm is able to detect most of the faults. Further work looks to refine the approach to improve the detection results as well as to evaluate various methods for fault identification.

Assigned Session: B4 Failure Analysis - Engineering Solutions for Failure Prevention/Case Hist

Presenting Author: Geetha Chary **Ser:** 12

Organization: U.S. Army Materiel Systems Analysis Activity

Country:

Paper Title: **Improving the Reliability in the Next Generation of US Army Platforms Through Physics of Failure Analysis**

Co Authors: Ed Habtour and Gary Drake

Abstract:

Published studies and audits have documented that a significant number of U.S. Army systems are failing to demonstrate established reliability requirements. In order to address this issue, the Army developed a new reliability policy in December 2007 which encourages use of cost-effective reliability best practices. The intent of this policy is to improve reliability of Army systems and material, which in turn will have a significant positive impact on mission effectiveness, logistics effectiveness and life-cycle costs. Under this policy, the Army continues to successfully apply physics of failure (PoF) modeling to a wide variety of vehicles and electronics systems. At the US Army Materiel Systems Analysis Activity (AMSAA), PoF analyses are conducted to support contractors, program managers (PMs) and engineers on systems in all stages of acquisition from design, to test and evaluation (T&E) and fielded systems.

This paper discusses using the PoF approach to improve reliability of military products. Physics of failure is a science-based approach to reliability that uses modeling and simulation to eliminate failures early in the design process by addressing root-cause failure mechanisms in a Computer-Aided Engineering environment. The PoF approach involves modeling the root causes of failure such as fatigue, fracture, wear, and corrosion. Computer-aided design (CAD) tools have been developed to address various loads, stresses, failure mechanisms, and failure sites. This paper focuses on understanding the cause and effect of physical processes and mechanisms that cause degradation and failure of materials and components. A reliability assessment case study of circuit cards consisting of dense circuitry is discussed. System level dynamics models, component finite element models and fatigue-life models were used to reveal the underlying physics of the hardware in its mission environment. Outputs of these analyses included forces acting on the system, displacements of components, accelerations, stress levels, weak points in the design and probable component life. This information may be used during the design process to make design changes early in the acquisition process when changes are easier to make and much more time and cost effective.

Design decisions and corrective actions made early in the acquisition phase leads to improved efficiency and effectiveness of the T&E process. The intent is to make fixes prior to T&E which will reduce test time and cost, allow more information to be obtained from test and improve test focus. PoF analyses may be conducted for failure occurring during test to better understand the underlying physics of the problem and identify the root cause of failures which may lead to better fixes for problems discovered, reduced test-fix-test iterations and reduced decision risk. The same analyses and benefits mentioned above may be applied to systems which are exhibiting failures in the field.

Assigned Session: B4 Failure Analysis - Engineering Solutions for Failure Prevention/Case Hist

Presenting Author: Onome Scott-Emuakpor **Ser:** 17

Organization: Air Force Research Laboratory

Country:

Paper Title: **Incorporation of a Probabilistic Monotonic Strain Energy Analysis to a Lifing Method**

Co Authors: Tommy George, and Charles Cross; Todd Letcher and Dr M-H Herman Shen, The Ohio State University

Abstract:

The proposed work analyzes the possibility of improving the capabilities of an energy-based fatigue life prediction method. The improvement being addressed is regarding the variation of empirical monotonic strain energy density calculations and the effects on the energy-based fatigue life prediction capability. Since the prediction method was developed from the concept that the strain energy accumulated during both monotonic failure and an entire fatigue process are equal, meaning the strain energy accumulated during monotonic failure is a physical damage quantity, it was important to understand the variation of monotonic strain energy density. The process for incorporating this variation into the prediction method explores a probabilistic, 3-sigma analysis that is applicable for all deterministic methods of measuring experimental monotonic strain energy density. The accuracy of the probabilistic energy-based lifing method was admirably assessed by comparison with experimental fatigue life results, between 103 and 105 cycles, conducted on Titanium 6Al-4V specimens at room temperature.

Assigned Session: B4 Failure Analysis - Engineering Solutions for Failure Prevention/Case Hist

Presenting Author: Ed Habtour **Ser:** 2

Organization: U.S. Army Materiel Systems Analysis Activity

Country:

Paper Title: **Novel Approach to Improve Electronics Reliability in the Next Generation of US Army Small Unmanned Ground Vehicles Under Complex Vibration Conditions**

Co Authors: Cholmin Choi, , Michael Osterman and Abhijit Dasgupta Center for Advanced Life Cycle Engineering (CALCE) David Mortin US Army Materiel Systems Analysis Activity (AMSAA)

Abstract:

The functionality of next-generation the US Army's platforms, such as the Small Unmanned Ground Vehicles (SUGV) and Small Unmanned Arial Vehicles (SUAV), is strongly dependent on the reliability of electronically-rich devices. Thus, the performance and accuracy of these systems will be dependent on the life cycle of electronics. These electronic systems and the critical components in them experience extremely harsh environments such as shock and vibration fatigue. Therefore, it is imperative to identify the failure mechanisms of these components through experimental and virtual failure assessment. One of the key challenges in re-creating life-cycle vibration conditions during design and qualification testing in the lab is the re-creation of simultaneous multi-axial excitation that the product experiences in the field. Instead, the common practice is to use sequential single-axis excitation in different axes or uncontrolled multi-axial vibration on repetitive shock shakers. Consequently, the dominant failure modes in the field are sometimes very difficult to duplicate in a laboratory test. This paper presents the joint effort by the US Army Materiel Systems Analysis Activity (AMSAA) and the Center of Advanced Life Cycle Engineering (CALCE) at the University of Maryland to develop test methods and analytical models that better capture unforeseen design defects prior to the qualification phase, by better replication of the life-cycle vibration conditions. One approach was to utilize a novel Multi-Degrees of Freedom (M-DoF) electrodynamic shaker to ruggedize designs for fatigue damage due to random vibration. The merits of vibration testing methods with six-DoF shaker and cost saving associated with such an approach will be addressed in this paper. There is potential for M-DoF to detect critical design flaws earlier in the development cycle than has been traditionally possible with existing shaker technologies; and therefore produce more cost effective, reliable and safe systems for the warfighters.

Assigned Session: B4 Failure Analysis - Engineering Solutions for Failure Prevention/Case Hist

Presenting Author: Marc Pepi **Ser:** 10

Organization: US Army Research Laboratory

Country:

Paper Title: **Solid Particle Erosion Testing of Helicopter Rotor Blade Materials**

Co Authors: Richard Squillacioti, US Army Research Laboratory; Lynne Pfledderer, Air Force Research Laboratory; Dr. Andrew Phelps, University of Dayton Research Institute

Abstract:

The Army Research Laboratory (ARL) was asked to participate in an OSD-funded erosion effort by the Coating Technology Integration Office at Wright Patterson Air Force Base. Solid particle (sand) erosion testing was conducted by the University of Dayton Research Institute (UDRI) to determine the erosion resistance of materials currently used on the leading edges of Army aviation rotor blades of aircraft in Southwest Asia (SWA). This testing and evaluation was important for two reasons; first, Iraq and Afghanistan are the primary locations of our current anti-terror operations, and second, the sands within these two countries are the worst in the world from an erosion standpoint (dry conditions + freshest grains of sand + predominantly angular quartz grains + blowing winds). The sand utilized herein is considered even more erosive than the sand from these two countries, since they contain a higher concentration of quartz than the SWA sand. In 2005, observations of actual SWA field failures of helicopter rotor blade protective tapes and coatings were compared to existing state-of-the-art, laboratory-based sand erosion data during a U.S. Army sponsored program. Laboratory-produced data did not match the severity of field-use damage, even under extremely high levels of particle loading. The need to test to erosive failure representative of this environment was determined to be paramount in establishing relative performance levels of erosion resistant protective systems being screened for potential field use. The goal of this effort was to provide two synthetic sand formulas capable of testing various polymer-based candidate rotor blade protective systems to failure. The test media was derived from characterization of sand and dust materials unique to SWA. The synthetic sand mixtures developed by this effort will be incorporated in a new test protocol for sand erosion to represent a truly “worst case” test, with extended application to other aerospace components susceptible to sand erosion damage applicable to Department of Defense (DoD) activities in most dry – hot desert regions. Comprehensive post-test analysis performed by ARL included: visual examination, mass loss calculations, erosion rate determination, surface roughness testing, volume loss calculations, scanning electron microscopy characterization, and metallography. As a result of post-test analysis, many trends were observed, with the results documented herein. The results of this testing have been used as a baseline for future testing of alternative materials and coating systems, and to prepare a solid particle erosion test standard (MIL-STD-3033).

Assigned Session: B4 Failure Analysis - Engineering Solutions for Failure Prevention/Case Hist

Presenting Author: Michael Lipsett **Ser:** 37

Organization: University of Alberta

Country: Canada

Paper Title: **Modeling Erosion Wear Rates in Slurry Flotation Cells**

Co Authors: V. Bhushan

Abstract:

In processes using slurry as the working fluid, wear due to solid particles impinging on elements of the process units is a serious reliability issue. This study considers modeling wear damage in flotation cells, which are widely used in mineral processing. Flotation cells are typically cylindrical vessels where an impeller is used to agitate the fluid, enabling the liberation of the minerals from the slurry. Some solids, particularly those entrained in the impeller stream, can impact on the wall of the cell, leading to material loss and eventually to loss of structural integrity. The problem of predicting the remaining life of the unit due to erosion requires understanding of various sub-processes: flow modeling, particle-fluid interaction, energy interactions at the surface, and the mechanism of erosion itself. In the present work, empirically developed equations for the flow field of cylindrical mixing vessel with a Rushton turbine are used in formulating a model relating and the damage accumulation rate to a simple set of measurable variables. To validate a model, a PIV technique was used to measure velocities in the flow field and near the wall on a physical model of the cell with transparent walls and particles that match the refractive index of the fluid. An Eulerian-Langrangian approach has been used to determine the particle trajectories and the effect of a squeeze film is incorporated into the model to modify the velocity distribution of particles prior to impacts. An analytical model based on equations of impulse and momentum for a particle of any shape striking a flat massive surface has been used to describe the energy lost at the walls. Finally, a damage model is developed that takes into account impact velocity, attack angle, properties of the impinging particles and the surface. This model is verified against a second physical model that measures material loss rate at different locations within the cell.

Assigned Session: B4 Failure Analysis - Engineering Solutions for Failure Prevention/Case Hist

Presenting Author: Jules Raphael **Ser:** 87

Organization: J R Technical Services, LLC

Country:

Paper Title: Characteristics of Impact Problems

Co Authors:

Abstract:

The response of a simply supported beam subjected to a transverse, high-velocity, low-impulse impact was studied with finite element analysis. Bending stresses peaked within 12 □s of initial contact between the projectile and the beam. After contact was lost the beam exhibited a brief period of damped harmonic motion until a second, lower energy impact occurred. After a second separation no further contact was observed and the beam again began damped harmonic motion. The implications for fatigue damage are qualitatively discussed.

Assigned Session: D4 Condition Based Maintenance

Presenting Author: George Wurzel **Ser:** 53

Organization: Eurocopter Deutschland GmbH

Country: Germany

Paper Title: **Use of Degradation Stages for Condition-Based Maintenance**

Co Authors: Michael Weigand, Vienna University of Technology, Institute for Engineering Design and Logistics Engineering; Andreas Doleschel, Eurocopter Deutschland GmbH Falk Hoffmann, Eurocopter Deutschland GmbH

Abstract:

One of the main goals of Condition Based Maintenance (CBM) is to reduce the overall maintenance burden for a system by replacing conventional periodic inspection tasks with on-line monitoring by a Condition Monitoring System (CMS). This paper outlines the development process for a CBM program based on an evaluation of maintenance need and monitoring capability. To adapt the CBM program to the true operational reliability of the system, which is characterized by in-service fault findings, the degradation process of a fault is divided into the four degradation stages “healthy,” “degraded – maintenance not required,” “degraded – maintenance required,” and “failed / near failure.” The maintenance need at a given operating time is described by the probability that a part will be in the condition “degraded – maintenance required.” Condition monitoring should be focused on the parts with the highest maintenance need. If a sufficient fault detection performance can be demonstrated on these parts at the critical degradation severity, the scheduled inspections can be replaced by on-line monitoring. Parts not monitored must be inspected in scheduled inspections, with a frequency according to their maintenance need.

Assigned Session: D4 Condition Based Maintenance

Presenting Author: Sonia Vohnout **Ser:** 8

Organization: Ridgetop Group, Inc.

Country:

Paper Title: **Prognostic Health Management (PHM) Solutions for Battery Packs Used in Critical Applications**

Co Authors: John Bush, Sonia Vohnout

Abstract:

Nickel-cadmium (NiCad) battery packs are absolutely necessary for providing mobile power sources in the modern-day Navy. Because the individual cells that comprise a battery only provide small voltage levels (typically 1.2 V), the cells are connected in series to add up and provide the necessary voltage. However, this cell stacking process presents problems in monitoring, charging, and discharging. The primary reliability problem with battery packs can be traced to differences in the individual cells comprising the battery. Since there are inevitable differences in the cells, a low-capacity cell can become reverse-charged as the battery pack is put under load conditions. This reverse charge greatly reduces the lifetime of the cell. Likewise, another cell can become over-charged during a battery pack charge if the battery pack's total voltage is the sole monitoring criteria for determining when to stop the charge process. The problem worsens through repeated charge/discharge cycles. Normally, only the aggregate overall voltage of the battery pack is measured, but the individual degraded cell is not isolated. In that case, no anomaly may be detected, but usage time can be greatly diminished. To avoid this problem, battery packs are routinely replaced even though they don't exhibit any problems. This is a very costly procedure and decreases operational readiness of the battery-powered equipment. This paper presents a solution that will allow remote monitoring of a battery pack in the equipment without removal from service. It could also be connected to a larger prognostic and health monitoring (PHM) or condition-based maintenance (CBM) system. In addition, the solution will improve the charging efficiency, extend the useful life, and increase overall capacity of rechargeable NiCad battery packs through a principle known as cell balancing.

Among a stack of NiCad cells, each battery will be slightly different in its state of charge (SOC) and capacity-to-energy (C/E) mismatch. Under conventional charging methods, all cells are charged (and discharged) at the same current, and the battery pack is limited by its weakest cell. However, the design presented is capable of measuring the individual cell voltages of a 20-cell series-connected battery pack. This system will consist of an Intelligent Control Module application-specific integrated circuit (ASIC), a multi-tap transformer, and solid state switches to allow any cell in a 20-cell series-connected battery pack to be monitored, balanced, and charged/discharged. Although the design discussed will be for a 20-cell battery pack, it can easily be modified to other cell lengths.

Assigned Session: D4 Condition Based Maintenance

Presenting Author: David Pack **Ser:** 93

Organization: Logistics and Readinenss Center, CECOM LCMC, US Army

Country:

Paper Title: **Influence of CBM+ Information to the Value Stream**

Co Authors:

Abstract:

Assigned Session: D4 Condition Based Maintenance

Presenting Author: Chris Smith **Ser:** 82

Organization: Army Aviation & Missile Command

Country:

Paper Title: **Army Implementation of CBM**

Co Authors:

Abstract:

CBM is a proactive maintenance program that decreases maintenance burden on Soldiers, increases platform availability and readiness, enhances safety, and reduces operations and support (O&S) costs. Our CBM program for Army Aviation leads the way for the rest of our Army and DoD. Our CBM-enabled helicopter fleets experience 4-13% better readiness rates and are able to generate an additional 2-14 more flight hours per aircraft per month. There is clear evidence that CBM technologies and procedures have avoided at least three catastrophic Class A mishaps that would have resulted in multiple fatalities and total loss of the aircraft. Analysis of past O&S cost data shows that CBM-equipped units operate for 15% less per flight hour (in terms of parts demand). Economic analysis modeling of the program into the future yields a 4.3:1 benefit-to-investment ratio. Given the way aviation reimbursable rates (aka "flying hour rates") are developed, these lower operating costs will be captured in future published rates as determined by the Training Resource Model (TRM). The Aviation CBM+ program has demonstrated compelling and supportable value, especially in terms of aircrew safety and aviation combat power. All reliable metrics of the program are trending positively and spell great promise for nascent efforts in our other commodities.

Assigned Session: D4 Condition Based Maintenance

Presenting Author: Abdel Bayoumi **Ser:** 70

Organization: University of South Carolina

Country:

Paper Title: **Object-Based Simulation for Preventative Maintenance Planning**

Co Authors: Nicholas Goodman

Abstract:

The traditional methods of planning a preventative maintenance program typically require a thorough understanding of how a given system fails. Enterprise organizations accomplish this through the well established technique called a Failure Modes, Effects, and Criticality Analysis (FMECA); however, despite its comprehensive nature, FMECAs often rely on a large number of assumptions and can easily miss unforeseen complex interactions between subsystems. Furthermore, the logistical implications of maintenance decisions are often hard to predict: common objectives such as minimizing downtime and reducing lead time without relying on excessive spare parts inventories are not easily attained. Object-oriented simulation provides an alternative approach by providing a population of virtual systems on which various maintenance practices can be tested. The ontology of these virtual systems is defined to closely match their real-world counterparts, and parameters such as failure probability distributions can be assigned for each component type. Maintenance practices such as scheduled overhaul or condition-based maintenance are then defined for each component. The combined system population is then simulated iteratively until the desired output parameters converge. The effects of particular maintenance decisions on bottom-line parameters are examined, and methods for extending the utility of this simulation to real-world system are also discussed.

Assigned Session: D4 Condition Based Maintenance

Presenting Author: Rachel Moss **Ser:** 92

Organization: GasTOPS Inc.

Country:

Paper Title: **Industrial Perspectives of CBM**

Co Authors:

Abstract:
