Assigned Session: Lunchtime Talk

Presenting Author: Cameron Sinclair **Ser:** 31

Organization: BINDT

Country: UK

Paper Title: **How to Improve Safety, Reliability and Growth: A Personal UK View of the Testing and Monitoring Landscape**

Co Authors:

Abstract:

In this presentation I will describe a testing and monitoring landscape with reference to four premises that I think are key:

a) Organisations such as BINDT help improve the safety and reliability of plant and equipment and stimulate growth in the supply chain.
b) Non-destructive testing (or NDE, if you prefer), condition monitoring and structural health monitoring are three sides of the same thing and add value if they link seamlessly to engineering critical assessment (diagnostics and prognostics).
c) The education and professional development of people is key to advancing the science and practice of testing and monitoring and, in the UK, academic, vocational and professional qualifications are integrated.
d) Personnel certification 'best practice' is a combination of 3rd party or 'central' certification and 2nd party or employer-based certification.

This testing and monitoring landscape is something of an ideal, or aspiration if you will, but it is something that BINDT is striving to achieve in the UK and elsewhere. I will also talk about how the 'as is' landscape compares to this aspiration, in the UK and elsewhere.

Assigned Session: A 1 Diagnostics

Presenting Author: Jae Myung Yoon **Ser:** 18

Organization: University of Illinois at Chicago

Country:

Paper Title: **Planetary Gearbox Fault Detection Using Acoustic Emission Sensor**

Co Authors: Jae Yoon, Brandon Van Hecke, and David He

Abstract:

Vibration sensors and corresponding analysis methods have been utilized as the industry standard for planetary gearbox (PGB) fault diagnosis over the past years. However, acoustic emission (AE) analysis based methodologies recently have captured growing acceptance with its higher sensitivity toward the initiation of physical failure than vibratory analysis. In this paper, an investigation on PGB fault detection using an AE sensor is reported. The investigation includes the development of a heterodyne based AE data acquisition (DAQ) system, Hilbert-Huang transform (HHT) based rotating machinery signal analysis method, and condition indicators (CIs) for PGB fault feature extraction. First, the heterodyne technique is hardware-implemented for AE signals to be down shifted so that the typical sampling frequency choice of 2~10 MHz becomes 100 kHz. Next, the PGB health related information is obtained through HHT based signal analysis followed by computation of condition indicators (CIs) to extract PGB fault feature. The fault features are further utilized in fault detection with supervised learning algorithms. The proposed methodologies are validated with a set of seeded fault tests performed on a PGB test rig in a laboratory. The results in this paper show promising PGB fault detection using AE signal analysis.

Assigned Session: A 1 Diagnostics

Presenting Author: Prashanth Dalawai **Ser:** 12

Organization: Indian Institute of Technology Kanpur

Country: India

Paper Title: **Non-Stationary Signal Analysis for Health Monitoring of an Internal Combustion Engine**

Co Authors: Prashanth Dalawai, Nalinaksh Vyas, and N Kishore

Abstract:

Signals of an internal combustion engine are non-linear and non-stationary in nature, formed by many random operations, transient events and varying speeds. Stationary and averaged signals are inefficient to quantify the structural defect of an internal combustion engine, since the random noise, several operations within an engine cycle and varying transmission paths have significant contribution. In this paper, an event based signal analysis is proposed as a novel tool for monitoring the structural defect characteristics of an internal combustion engine. A systematic framework is developed for the parameter estimation from the simulated non-stationary signals that resembles engine's vibro-acoustic signature. Framework is then implemented on the vibro-acoustic signals of an actual engine and health conditions are quantified. The engine cycle events are identified at steady speeds and the modal parameters are estimated using system identification approach on wavelet ridge. Results indicate that the proposed framework for monitoring the parameter is effective in diagnosing mechanical faults of an engine. The vibro-acoustic parameters provide the capabilities in monitoring the critical health of an engine.

Assigned Session: A 1 Diagnostics

Presenting Author: Jae Myung Yoon **Ser:** 29

Organization: University of Illinois at Chicago

Country:

Paper Title: **On the Use of Acoustic Emission Sensors with Low Sampling Rate for Low Speed Bearing Fault Diagnostics**

Co Authors: Brandon Van Hecke, Jae Yoon, and David He

Abstract:

For low speed bearing fault diagnosis found in industries such as paper mills, biological applications and in the wind turbine industry, AE based techniques are developed because vibratory centered approaches often prove to be ineffective for low speed analysis. In this paper, a new methodology for low speed bearing diagnosis is presented. This AE based technique starts with a heterodyne based frequency reduction approach that affords the ability to sample AE signals at a rate comparable to vibration centered methodologies. Then, using an incoming tachometer signal, the low sampled AE signal is time synchronously resampled to account for possible fluctuations in shaft speed and bearing slippage. The resampling approach also has the purpose of providing the ability to segment the AE signal according to shaft crossing times such that an even number of data points are available to compute a single spectral average which is used to extract features and evaluate numerous CIs for bearing fault diagnosis. Current averaging based noise reduction approaches to bearing analysis require the computation of multiple averages for each bearing fault type. In addition, all AE centered approaches to low speed bearing analysis presented in literature require high sampling rates and most focus on fault detection or lack the ability to diagnose all bearing fault types. The presented technique is validated using the AE signals of seeded fault steel bearings on a bearing test rig. The results in this paper indicate that the low sampled AE signals in combination with the presented approach can be utilized to effectively extract condition indicators to diagnose all four bearing fault types at multiple low shaft speeds below 10 Hz.

Assigned Session: A 1 Diagnostics

Presenting Author: Preston Johnson **Ser:** 62

Organization: National Instruments

Country:

Paper Title: **The Full Spectrum, a Dual Channel Measurement Used in Vibration Diagnostics**

Co Authors:

Abstract:

Dual channel measurements are popular in vibration diagnostic applications when it is important to understand the relative motion of components within a rotating machine. In particular, orbit analysis with the orbit plot, and full spectrum analysis with a full spectrum plot use two vibration sensors located in the same radial plane, typically positioned 90 degrees apart. Orbit plots provide a graphical representation of the shaft center motion. The full spectrum is the spectrum of an orbit, providing vibration levels at each order or harmonic of rotational speed. This presentation provides definitions of orbit and full spectrum analysis, and illustrates the concepts with sample and field sampled data.

Assigned Session: A 1 Diagnostics

Presenting Author: Fred Discenzo **Ser:** 69

Organization: Rockwell Automation, Advanced Technology

Country:

Paper Title: **A Pragmatic Approach to Machinery Diagnostics**

Co Authors:

Abstract:

Assigned Session: B 1 Health Management Successes, Perspectives and Practice

Presenting Author: Chris Hockley **Ser:** 6

Organization: Cranfield University, EPSRC Centre for Through-Life Engineering Services

Country: UK

Paper Title: The Hidden Delta for Maintenance Effectiveness

Co Authors: Chris Hockley and Piotr Sydor

Abstract:

Maintenance Managers will always strive to be efficient and most believe that they and their organisations are both efficient and effective in delivering the maintenance service. Yet there are costs which can still be driven out within the organisation and are often not realised, or worse still not admitted. Managers who are proactive in reducing waste, whether it be waste of resources, waste of time or waste of effort in their organisations, are the ones who get noticed. Yet many managers will not admit or even realise that maintenance can be improved still further by addressing the problem of faults which cannot be found – the problem of No-Fault-Found (NFF) or Fault Not Found (FNF). Research work undertaken with the EPSRC Centre for Through-Life Engineering Services (TES) at Cranfield has identified a range of factors that contribute to the issues that mask and cover the size of the problem. Most organisations greatly underestimate the level of effort which is expended on the NFF problem and the costs escalate as items progress down the support chain. To be successful in reducing these costs requires an admission that there is waste in the first place and sometimes it is difficult depending on the type of waste identified or perceived. An admission that there is a problem however, is the first step in its reduction and the best way to make that first step is the use of a benchmarking tool. Such a tool for NFF has been developed by the EPSRC TES Centre and is a powerful way of harnessing the knowledge of all the key players in the organisation. It allows an organisation to internally audit its processes and attitudes, and also provides identification of where effort can first be focussed for maximum and best effect.

Assigned Session: B 1 Health Management Successes, Perspectives and Practice

Presenting Author: Thomas Lagö **Ser:** 3

Organization: QirraSound Technologies Europe AB

Country: Sweden

Paper Title: **Experiences from CBM Educational Approaches in Sweden**

Co Authors: Thomas Lagö, Tommy Forsell, Alan Boyer, and Valdi Ivancic

Abstract:

Sweden has been viewed as having a high level educational system. However, in recent PISA tests, Sweden has received a very low grade. This paper will describe some of the challenges that Swedish educational systems have today. Swedish universities have lost their accreditation in Europe due to the downgrade in its quality and management system. Joint efforts in between teams in Sweden, England and the USA, an initiative to create good educational platforms has been outlined. The suggested approach will be described and how a team consisting of international experts, Swedish and European institutes, plus teams in the USA that will collaborate to change this paradigm. The need for well educated, and certified personnel is vast and this initiative is a response to that. The Swedish company SenseGraphics [1] offer an open software platform that enables “touch and feel.” This is often referred to as “haptics” originated from the Greek words haptikos and hapthesthai, which means to grasp or to touch. They have already, together with partners, implemented simulators for medical, dental and other applications. Qirra Sound has developed a platform for reinforced sound that is able to make sound so realistic that it does not feel like there are any loudspeakers. This technology is very useful in educational simulators where the sound and vibration aspect would be included. In Sweden, another project known as VISIR™ (Virtual Instrument Systems in Reality) was initiated to disseminate an online laboratory concept created using open source technologies in collaboration with other universities and organizations. The concept adds remote operation capabilities to traditional instructional laboratories, making them more accessible, irrespective of whether the students are on campus or mainly off campus. This paper will discuss educational concepts combining technologies for CBM applications and how that would benefit students worldwide.

Assigned Session: B 1 Health Management Successes, Perspectives and Practice

Presenting Author: Junda Zhu **Ser:** 19

Organization: Renewable NRG Systems

Country:

Paper Title: **The Impact of Wind Speed and Direction Variation on the Performance of the Condition Monitoring System**

Co Authors: Junda Zhu, Tom Nostrand, and Bruno Boucher

Abstract:

It is well known that an operating wind turbine endures various wind speed and direction changes on regular occasions. Load control as well as active pitch and yaw control, continuously adjust parameters to cope with these changes. It is also a challenge for the Condition Monitoring System (CMS) to effectively manage this variation. This paper investigates the impact of wind speed and direction on the turbine component condition indicators and effectively the health indictors calculated by customized algorithm within the TurbinePHD CMS. The wind speed and direction data are collected by the SCADA system provided by Techno Center. By comparing and correlating the synchronized dataset from both the CMS and SCADA system, one will be able to observe how condition indicators behaves against wind speed and direction fluctuation (turbulence, sheer and veer) as well as the possible solution to stabilize the CMS performance. A comprehensive selection of condition indicators will be investigated in this paper covers major components including shafts, gears and bearings as well as generators across the wind turbine drive train assembly.

Assigned Session: B 1 Health Management Successes, Perspectives and Practice

Presenting Author: Eric Bechhoefer **Ser:** 40

Organization: Green Power Monitoring Systems LLC

Country:

Paper Title: **An Actuarial Approach to the Remaining Useful Life Estimation**

Co Authors: Eric Bechhoefer, Rune Schlanbusch, and Tor Inge Waag

Abstract:

In many instances, condition monitoring equipment has not yet been installed on machinery. Yet operators still need guidance as to when to perform maintenance which is better than what is offered by the equipment manufactures. For these system, running hours, counts, or some other measure of usage may be available. This data, along with failure rate data, can provide an expected time to failure, and the estimated remaining useful life. The failure rate (even small sample size) is used to estimate the shape and scale parameters for the Weibull distribution. Then the conditional expectation of the truncated survival function of the Weibull is used to estimate the time to failure. This is an actuarial technique to solve the conditional survival function problem of: given that the equipment has survived to time x, what is that probability of the equipment surviving to time x + y. The inverse cumulative distribution of the truncated survival function can then be used to estimate the remaining useful life, that is: a time such that the conditional likelihood of failure is small, such as 5 percent. The 90% confidence of the shape and scale parameters are then used to give a bound on the remaining useful life.

Assigned Session: B 1 Health Management Successes, Perspectives and Practice

Presenting Author: David Gil-Carton **Ser:** 16

Organization: CIC bioGUNE

Country: Spain

Paper Title: **Neuro-Fuzzy Control for Cryo Electron Microscopy Data Acquisition on a JEOL Transmission Electron Microscope**

Co Authors: David Gil-Carton, Mikel Valle, Aitor Garrido, Izaskun Garrido and Iñigo Miguel

Abstract:

We report the development of software system involving a novel neuro-fuzzy control scheme that automates single-particle cryo electron microscopy (cryo-EM) data acquisition on modern JEOL Transmission Electron Microscopes (TEM). Data acquisition in TEM is the first crucial step during the single-particle analysis workflow. Importantly, the demand for large number of two dimensional images requires reliable and efficient automation of image data collection. The software system described here was developed to overcome the vulnerability of other software packages to non-ideal properties of TEM microscopes, such as specimen drift or non-reproducible sample holder movements. The making of this system involved two main steps: the development of an user-friendly graphical user interface (GUI) for the remote control of the electron microscope and the digital camera; and the use of an intelligent system for the sequential selection of hole areas in prefabricated EM grids. The software system uses different computer vision algorithms and provides useful information (regarding contrast transfer function analysis, ice-embedded single-particles detection, and ice quality validation) in real time. This work describes a different approach to partially automate single-particle cryo-EM data acquisition under low dose conditions, and also presents a neuro-fuzzy logic control system with neuro-adaptive learning capabilities. A Mamdani-type fuzzy inference system (FIS) takes decisions during the microscopy session as part of the control system by the use of a set of fuzzy IF–THEN control rules that replace microscope-expert's knowledge. The fuzzy inference system (FIS) was updated according to the given input/output data set obtained during different cryo-EM data acquisition sessions. Two adaptive network-based fuzzy inference systems (ANFIS) were trained to automate the selection of valid single-particles from each cryo-EM image and to detect ice-contamination in real-time. The novelty of this approach relies on the combination of computer vision with complex fuzzy logic algorithms, a combination that allows the system to choose the best strategy to overcome several different problems during a routine microscopy session. The application to cryo-EM data acquisition on our non-ideal electron microscope demonstrates the goodness and effectiveness of this intelligent software system to navigate through prefabricated EM grids as an experienced microscopist. The method is validated in real-time cryo-EM data acquisition for single particle approach of bacterial ribosomes.

Assigned Session: A 2 Signal Analysis

Presenting Author: Suri Ganeriwala **Ser:** 59

Organization: SpectraQuest Inc

Country:

Paper Title: **A Systematic Processing of a Gearbox Vibration Signal with Defective Rolling Element Bearing**

Co Authors: Nader Sawalhi and Suri Ganeriwala

Abstract:

This paper provides a detailed signal processing and analysis of a vibration signal measured from a gearbox driven by a three phase motor, which is controlled by a variable frequency drive (VFD). The vibration signal being processed was obtained from a test rig with a faulty bearing, thus the signal represents a rich content of different types of signals. The processing starts by a visual examination of the time domain signal with the tachometer overlaid. Time-frequency analysis was then performed using Morlet wavelets to examine the signals for time varying events and to give more insight into the signal content. Speed fluctuations were next estimated based on information from the tachometer and compared to the ones obtained from the signal itself. Since detailed information gears is often not available in industrial settings, order tracking and harmonics/sidebands cursors were used to deduce this information from the data. Finally, bearing diagnosis was performed on the residual signal obtained by removing the discrete components. The signal was enhanced by whitening the signal, removing the transfer path effect using minimum entropy deconvolution (MED).

Assigned Session: A 2 Signal Analysis

Presenting Author: Thomas Lagö **Ser:** 32

Organization: QirraSound Technologies Europe AB

Country: Sweden

Paper Title: **Cepstrum Analysis Basics for the Interested**

Co Authors: Thomas Lagö and Alan Boyer

Abstract:

Many papers present Cepstrum analysis and rather advanced methods for harmonic and modulation signal extraction. This paper will give a good overview of the main principles for Cepstrum analysis and what different methods can help out with what and why. A main feature of Cepstrum analysis is to transform multiplicative components like modulation into additive signals. It is the same principle as when we use logarithms to convert multiplications to additions. This main feature is the foundation for Cepstrum analysis and signal components that are "multiplicative" in its nature are good candidates for Cepstrum analysis. The difference in between different Cepstrum methods will be outlined and explained, like Power Cepstrum, Complex Cepstrum etc. Phase unwrapping is often a challenging part of Cepstrum analysis and this will be discussed and methods outlined. Examples and references to other scientific areas will also be given where similar approaches have been successfully used for many years.

Assigned Session: A 2 Signal Analysis

Presenting Author: Bob Randall **Ser:** 57

Organization: University of New South Wales

Country: Australia

Paper Title: **Blind Enhancement of Modal Information in Time Signals Using the Real Cepstrum**

Co Authors:

Abstract:

A relatively new advance in cepstrum analysis in recent years is the realisation that time signals can be modified using the real cepstrum (operating on the log amplitude spectrum only) by combining the modified amplitude spectrum with the original phase spectrum. One application area opened up by this is the ability to multiply the cepstrum of a stationary signal by an exponential window, thus increasing the damping of all modes by a given amount (which can be compensated for) and often removing much other information such as discrete frequency forcing functions. The resulting modally enhanced data are ideal for operational modal analysis, since most other disturbing influences are eliminated or greatly reduced. Another is in bearing diagnostics, where information on bearing faults is often carried by high frequency resonances and masked by discrete frequency components from gears. On the other hand, the modal information can alternatively be subtracted (in the cepstrum) leaving a signal dominated by discrete forcing frequencies, for example from gears, and the processed signals are then much less sensitive to speed variation, for example amplitude modulation given by the passage of gearmesh frequencies through resonances. This process is beneficial for gear diagnostics in a variable speed situation. The only factor to be decided is the time constant of the exponential window, but this can usually be based on the original damping of the lowest mode of interest in the system, and this can often be estimated by inspection or otherwise.

Assigned Session: A 2 Signal Analysis

Presenting Author: Thomas Lagö **Ser:** 33

Organization: QirraSound Technologies Europe AB

Country: Sweden

Paper Title: **Real-Time Fast Tracking of Varying RPM Using an On-Line Method without a Tachometer**

Co Authors: Thomas Lagö and Alan Boyer

Abstract:

When analyzing data from a machine with a varying rpm (rotations per minute), it is common to use a tachometer sensor, reading the rpm. In production line applications where real-time data is needed, the time to mount such a sensor is too long. The same applies to vibration and other sensors as ease of mounting must be simple and quick. A new approach needs to be introduced in order to be cost effective and streamlined. By estimating the rpm from the spectral data on-line and using an a-priori based model, it is possible to create rpm related data and then extend it to order domain. This requires an enormous understanding of FFT and its properties. Examples and data from a project in the automotive industry will be presented and discussed. This project implementation can inspire other applications to acquire data and perform order analysis without using a tachometer sensor or other rpm information while still discovering the varying spectral components.

Assigned Session: A 2 Signal Analysis

Presenting Author: Suri Ganeriwala **Ser:** 58

Organization: SpectraQuest Inc

Country:

Paper Title: **Interference of Variable Frequency Drive (VFDs) on Rotating Machine Fault Diagnosis Using Vibration Analysis**

Co Authors: Suri Ganeriwala

Abstract:

VFDs are the most commonly used modes to drive induction motors in applications requiring speed variations. However, vibration analysis for fault diagnosis of such systems poses serious challenges as the signatures are complicated due to the inherent design of the VFD. But VFD signal contains rich information that can be used as tool for machinery fault diagnosis. This paper will explain the basic operation of a typical VFD and present vibration and motor current signatures of machines operated using VFDs. VFDs control motor speed by varying the frequency of supply line frequency. This is done in three stages. Firstly, the line voltage signal is rectified to obtain a DC signal. This is then smoothened and finally, the constant DC voltage is used to construct a pseudo AC voltage using a set of transistors, which act like switches (gates). The switching frequency, or carrier frequency, interferes with vibration signal. The vibration signal as a result of using the VFD contains discrete frequencies spaced at the carrier frequency and its harmonics. Each peak also contains sidebands around the carrier frequency (and its harmonics) spaced at both the rotor speed and the stator field frequency. There are side bands associated with other rotational discrete frequencies such as gears and gearmesh frequencies. These side bands provide a vital diagnostics information. Analysts examining high frequency content of their data signals needs to be aware of the carrier frequencies and the associated side bands. By understanding these issues one use them for diagnostics purposes.

Assigned Session: A 2 Signal Analysis

Presenting Author: Nakandhrakumar Ramasamy **Ser:** 37

Organization: Hindustan University

Country: India

Paper Title: **Tool Wear Monitoring in Drilling By Spectral Analysis of Vibration Signals and Verification through Finite Element Analysis**

Co Authors: Nakandhrakumar Ramasamy, D Dinakaran, J Pattabiraman, S Sathishkumar, M Gopal

Abstract:

Experimental study conducted on high speed steel twist drill wherein the effect of the interaction between the tool wear and the vibration that occurs during the process is investigated, are reported. The vibration behavior of the workpiece system is characterized by a number of frequencies computed using Finite Element Analysis (FEA), each of which corresponds to a particular mode of workpiece system. The amplitudes of vibration signals in the range of frequencies from 5.5 to 6 kHz are proportional to tool wear and significant changes in linear pattern indicate the worn-out state of tool. So, this approach is effective for monitoring tool wear. The power spectral analysis of vibration signal indicates the changes in individual frequencies and is used for identifying the frequency range of monitoring tool wear. The tool wear causes the vibration in the workpiece which corresponds to 4th mode of workpiece.

Assigned Session: B 2 Condition Based Maintenance

Presenting Author: Rodrigo Teixeira **Ser:** 8

Organization: University of Alabama in Huntsville

Country:

Paper Title: **High-Accuracy Diagnostics from HUMS in Noisy Environments**

Co Authors: Rodrigo Teixeira, Kari Morris, and Christian Sautter

Abstract:

Condition Based Maintenance (CBM) of military helicopters are tracked by Condition Indicators (CI) calculated from Health Usage and Monitoring Systems (HUMS) vibration sensors. Many CIs have been developed and implemented, yet success has been partial at best, owing to their sensitivity to noises and artifacts that invariably corrupt measurements under real-life operations. Here we report a sequential Monte Carlo algorithm operating a stochastic non-linear model that includes a description of fault evolution. This algorithm estimates fault magnitudes and probabilities, which were compared to component removals validated by tear down analyses. We obtained a high accuracy rate (~96%) over all available data. Data encompassed a 6-year operational history of an entire US military helicopter fleet. These results demonstrate the excellent artifact rejection enabled by this approach, which handles probabilities rigorously to detect fault processes from noise-limited signals. Consequently, our decision support tool could detect faults early and accurately. This technology could drive a significant reduction in maintenance costs by making faults evident and reducing NEOFs (false positives).

Assigned Session: B 2 Condition Based Maintenance

Presenting Author: Daniel Wade **Ser:** 48

Organization: United States Army AMRDEC

Country:

Paper Title: **Machine Learning Algorithms for HUMS Improvement on Rotorcraft Components**

Co Authors:

Abstract:

The United States Army has implemented a rotorcraft Condition Based Maintenance (CBM) program based on monitoring recorded aircraft parameters and vibration signatures. The data from these Health and Usage Monitoring Systems (HUMS) has been stored for over a decade while Army Engineers have used the information to design features that indicate a need for maintenance, extend component life, or reduce the number of operational precautionary landings. The features, or Condition Indicators (CIs), developed and fielded today are designed to detect particular failure modes. These CIs are associated with fleet wide thresholds optimized by Receiver Operating Characteristic [1] curves to reduce fleet wide false alerts and missed detections. This has resulted in a large lookup table of CI/threshold pairs programmed into the aircraft ground stations which are associated with a list of either mandatory or optional maintenance actions. As has been published in the past, CIs can be notoriously noisy from reading to reading due to variables that physically affect vibration but which may not be incorporated in the CI calculation. For example, drive train torque is not used as an input to vibration CI algorithms but is well known to be an important normalizing factor [2]. Furthermore, it has been demonstrated that there is relation between measurements and component history, such as the slope of CI magnitude versus time or step changes caused by maintenance [3,4,5]. The Army Aviation Engineering Directorate has therefore proposed a method to improve HUMS performance through machine learning algorithms. Extensive effort has been put into standardizing CBM processes for Army rotorcraft [6]. Accordingly, machine learning procedures benefitting a HUMS program within the Army or any other branch of the DoD should also be verified to meet standard requirements accepted by the DoD. The purpose of this presentation will be twofold: 1) to outline procedures necessary for training machine learning algorithms from existing data such that output performance is validated prior to algorithm fielding, and 2) to present preliminary results for existing Army datasets processed IAW this approved process for both unsupervised data discovery and supervised machine learning. The supervised machine in this case will make a categorization (healthy/faulted) of the incoming component data. To document the necessary procedures, a process flow and concept of operations will be described down to the rigorous details associated with major assumptions and model choices. The presentation will focus on the importance of data selection/population distribution, reducing the dimensionality of data sets, using features selected by subject matter experts (e.g., currently deployed CIs) versus feature subsets identified using unsupervised machine learning methods, training data splits/vaults, types of individual and ensemble classification models, and procedures for internal cross validation for model selection. It will also cover important overarching machine learning practices that seek to maintain the integrity of the process, which include safeguarding against data snooping and establishing credible bounds on generalization error. Furthermore, the process of tuning features based on component history will be discussed and incorporated into the machine learning program. Preliminary results of the unsupervised data discovery process are showing extremely important relationships between features that have never been used to improve the HUMS. An example of the unsupervised process is the Density-Based Spatial Clustering of Applications with Noise (DBSCAN) clustering routine applied to the Apache Nose Gearbox. The DBSCAN clustering is used to optimize the number of unique classifications of the existing data from an unsupervised perspective. Additional unsupervised techniques are also being used to reduce the complexity of the dataset, including Principal Component Analysis and Expectation Maximization. The presentation will show results for machine learning on existing datasets, specifically, the Apache nose gearbox and the T700 series turbine engine currently fielded on both the Apache and Black Hawk. Nose gearbox results will demonstrate the leveraging of machine learning to benefit components for which vibration CIs are currently considered mature [6], while the T700 dataset contains a minimal amount of vibration data in comparison. For this reason, the T700 dataset results will emphasize machine learning principles applied almost solely

to parametric data, i.e., state and usage data including torque, temp, etc., but not vibration data. 1. Dempsey, Paula J. "Signal Detection Theory Applied to Helicopter Transmission Diagnostic Thresholds". Glenn Research Center, Cleveland, OH, NASA/TM—2008-215262. 2. Sheldon, Jeremy. David G Kasper. Mark W Davis. "A Multilayered Approach for Enhancing Rotorcraft Drive System Diagnostics". American Helicopter Society 70th Annual Forum. Montréal, Québec, Canada. 20-22 May, 2014. 3. Krick, Steven M. Daniel R Wade. Kenneth Pipe. "Evaluation of a Novel Dynamic Thresholding and Trend Alert Generation Technology on a HUMS-Equipped Fleet". American Helicopter Society 68th Annual Forum. Fort Worth, TX. 1-3 May, 2012. 4. Krick, Steven M. Daniel R Wade. "Development of Engineering Standards for Dynamic Thresholding and Trend Alert Technology for Application to a HUMS-Equipped Fleet". American Helicopter Society Specialists Meeting for Airworthiness, CBM, and HUMS. Huntsville, AL. February 2013. 5. Bechhoefer, Eric. Andreas Bernhard. David He. Pat Banerjee. "Use of Hidden Semi-Markov Models in the Prognostics of Shaft Failure". American Helicopter Society 62nd Annual Forum. Phoenix, AZ. 9-11 May 2006. 6. AMCOM Standardization Office. Aeronautical Design Standard 79D Handbook (ADS-79D-HDBK) Condition Based Maintenance Systems for US Army Aircraft Systems. 7 MAR 13.

Assigned Session: B 2 Condition Based Maintenance

Presenting Author: Kevin Albarado **Ser:** 53

Organization: Dynetics, Inc.

Country:

Paper Title: **Advanced Neural-Networks for Mechanical Health Diagnostics**

Co Authors: Kevin Albarado, Andrew Wilson, and Daniel Wade

Abstract:

The United States Army has implemented a rotorcraft Condition Based Maintenance (CBM) program based on monitoring recorded aircraft parameters and vibration signatures. The data from these Health and Usage Monitoring Systems (HUMS) has been stored for over a decade while Army Engineers have used the information to design features that indicate a need for maintenance, extend component life, or reduce the number of operational precautionary landings. The features developed and fielded today are designed to detect particular failure modes; however, they can be notoriously noisy from reading to reading due to recorded but unaccounted-for variables. This paper addresses these issues directly through the use of regularization and class weights applied to advanced neural networks. These modified neural networks allow the use of unaccounted-for variables due to the high degree of nonlinearity they can capture.

Assigned Session: B 2 Condition Based Maintenance

Presenting Author: David Siegel **Ser:** 13

Organization: Predictronics Corp

Country:

Paper Title: **Degradation Analysis of Ball Screw Lubrication Starvation Using Sensor-Less and Sensor-Rich Approaches**

Co Authors: Wenjing Jin, David Siegel, and Jay Lee

Abstract:

As the key component in motion control system, ball screw's accuracy directly determines the precision capability of the whole manufacturing system. Lubrication starvation happens very frequently and is vital to ball screw performance. In this study, laboratory experiments have been conducted on full size ball screws to simulate lubrication starvation. This research is focused on comparing sensor-less method and sensor-rich method and providing the systematic approach for lubrication detection. In sensor-less approach, only motor output speed and torque signals are acquired. Two health assessment algorithms, self-organizing map-minimum quantization error (SOM-MQE), logistic regression (LR), are benchmarked based on how early they can detect potential lubrication starvation. The results accuracy reaches as high as 87.7%. The second approach, sensor-rich method, uses the external accelerometers to measure the vibration at the position of interest. Similarly, SOM-MQE and MD (Mahalanobis Distance) algorithm is used to calculate degradation value. However, the degradation value generated from the vibration signals shows some specific patterns that can match with failure problems. Thus a systematic degradation pattern recognition approach is provided to diagnose the bad lubrication, which is also benchmarked with the other decision tree methods.

Assigned Session: B 2 Condition Based Maintenance

Presenting Author: Scott Pflumm **Ser:** 4

Organization: Applied Research Laboratory At The Pennsylvania State University

Country:

Paper Title: **Vehicle Payload Estimation Investigation Using Vehicle Data Bus Parameters**

Co Authors: Scott Pflumm, Michael Roemer, Jeffrey Banks, and Jason Duncan

Abstract:

The TACOM Integrated Logistics Support Center (ILSC) has been conducting a Pilot Program with 1740 Tactical Wheeled Vehicles (TWV) to demonstrate the value of CBM+ for the U.S. Army ground vehicle community. One of the primary objectives of the program is to develop data analysis techniques to convert existing vehicle sensor data into information that could be used to inprove the life cycle sustainment of the platforms. The subject of this paper is one such example. There are no vehicle load sensors on the TWV fleet but the ability to estimate the load carried by each vehicle over their lifetime could be useful for powertrain condition monitoring, brake life models, tire wear models, and determining the need for overhaul, which are all objectives of CBM+. Original Equipment Manufacturers (OEMs) also have a design interest in knowing how their vehicles are being loaded. This paper describes the experimental and analytical implementation pertaining to the testing of two simple mass estimation algorithms. The objective of this work was to quantify estimation accuracy using only vehicle data bus parameters from the SAE J1708/J1939 data buses. Both approaches are based on lumped parameter vehicle models and were tested using data taken on a Heavy Expanded Mobility Tactical Truck (HEMTT A4). The HEMTT was driven on three terrain types: paved flat surface, paved hill surface and unimproved flat surface. On each terrain type the HEMTT was driven with both no tow load and while towing a High Mobility Multipurpose Wheeled Vehicle (HMMWV). Percent error ranged from 2% - 380%. The second algorithm incorporating GPS signals for inclination calculation reported percent error ranging from 4-46% relative to the benchmark weigh scale value.

Assigned Session: E 2 Failure Analysis

Presenting Author: Bob Ware **Ser:** 25

Organization: US Air Force Research Laboratory

Country:

Paper Title: **Uncontained Electrical Fault in an Aircraft Fuel Pump**

Co Authors:

Abstract:

A military large body aircraft was lost during ground maintenance due to a fuel tank explosion. Investigators were able to demonstrate the suspected ignition scenario: uncontained electrical arcing within the cast aluminum pump housing. A detailed review of the pump overhaul process revealed missed opportunities to preserve the airworthiness of the pump. A systematic approach to ensure critical overhaul observations regarding component integrity are appropriately assessed will be presented.

Assigned Session: E 2 Failure Analysis

Presenting Author: Dr J Pattabiraman **Ser:** 35

Organization: Former Professor, Dean, Principal of Engineering Colleges

Country: India

Paper Title: **Integrated Approach to Engineering Design and Analysis, Vibration Failure Analysis, Prevention and Life Extension Using Feedback Control System Concept**

Co Authors: J Pattabiraman

Abstract:

The paper proposes an integrated approach to life cycle management of mechanical systems considering the four core processes of Design cycle analysis, Vibration signature analysis, Failure analysis and prevention, Residual life assessment and life extension. The application is suited for component level as well as large systems like thermal and nuclear power plants. In those cases life cycle management involves developing a strategy for economic and safety related operations for an extended period of life. The subjects of design cycle analysis, vibration and signature analysis, failure analysis and failure prevention and life management have hitherto been dealt with in isolation and decisions were taken pertaining to that restricted field. It is the author's considered opinion that a better and more comprehensive decision can emerge if the results of isolated analyses are considered in an integrated manner at once using the interdependence of parameters considered in each study. A model is evolved linking the above mentioned analyses using a feedback control system model where the output of each study and its influence on the input of the other study is rationally considered. The decisions arrived at from such an integrated control system model would be more holistic than those arrived at from results arising out of separate studies.

Assigned Session: E 2 Failure Analysis

Presenting Author: Nanfei Wang **Ser:** 17

Organization: Tsinghua University

Country: China

Paper Title: **Finite Element Analysis on Damping Characteristics for Vibro-Impact of Integral Shroud Blade**

Co Authors: Nanfei Wang, Dongxiang Jiang and Jingming Chen

Abstract:

By using theoretical and experimental methods,dynamic characteristics of turbine blades with integral shroud are studied,the mechanism of vibro-impact and the effective factors of integral shroud blades are mainly presented. On the theoretical research,a nonlinear damping model has been used to complete the establishment of a three-dimensional solid unit integral dynamics equation collision damping blade.With the help of 3D software Solidworks,the solid models of blade is built.With the aid of FEA software ANSYS,the dynamics and static characteristics of single blade are obtained.Meanwhile,by building the model to set different shroud clearance and exciting force amplitude,the relationship between stress of blade root and influence of such dimensions as blade shroud clearance and exciting force amplitude is demonstrated.Finally,the experiments on blade vibration and dynamics characteristics are carried out by utilizing the rotor experiment tabel and a test system. The resules of the analysis indicate that the collision structural is an ideal damping structure.Smaller the gap,better the damping effects.The dynamical stress is insensitive to the exciting force,which means that the peak stress changes little at a certain clearance.

Assigned Session: E 2 Structural Life Management

Presenting Author: Onome Scott-Emuakpor **Ser:** 2

Organization: Air Force Research Laboratory

Country:

Paper Title: **Multiaxial Fatigue Behavior Study on Vibration and Servohydraulic Loaded Aluminum**

Co Authors:

Abstract:

Understanding multiaxial fatigue stress state is critical for accurate assessment of gas turbine engine components as multiaxial loading can severely decrease operation life. The effects of bi or multi axis loads are often assessed with servohydraulic axial-torsional loadframes which, depending on delta load and displacement, operates at fixed frequencies less than 100Hz. This frequency is well below that of high pressure compressor or turbine blades rotating through flow disturbances during engine operations. Blades are often designed to bypass Campbell crossings at high responding modes (first bend and first torsion); meaning, crossing resonant and driving frequencies on a Campbell diagram could be two orders of magnitude higher than a servohydraulic loadframe maximum capability. Frequency rate is known to affect crack propagation characteristics due to the amount of crack tip exposure to atmosphere. Therefore, the work proposed investigates differences and/or similarities between high frequency vibration based fatigue results to low freqeunct axial-torsional. The vibration test will be conducted on plates cut from cold-rolled aluminum 6061-T6 stock, and axial-torsion will be conducted on specimens made from both extruded rod and tube.

Assigned Session: E 2 Structural Life Management

Presenting Author: Gang Wang **Ser:** 9

Organization: University of Alabama in Huntsville

Country:

Paper Title: **Lamb Wave Based Damage Detection Using PZT Fiber Sensor Array**

Co Authors:

Abstract:

Because of their electro-mechanical coupling property, piezoelectric materials have been widely used for sensing and actuation applications. Piezoelectric materials have been used as surface-mount sensors to measure physical movement or strain by directly bonding or embedding piezoelectric thin sheets onto the structure. Piezoelectric ceramics are perhaps the most popular piezoelectric materials for sensing purpose. In particular, sensors made of piezoelectric ceramic patches have recently gained increasing popularities in the field of structural health monitoring. For example, recent research works on Lead-Zirconate-Titanate (PZT) sensor has made it a quite promising technique for nondestructive evaluation (NDE) applications. In this paper, a PZT fiber (i.e., d33 effect) sensor array is proposed to conduct Lamb wave based damage detection in panel-like structures by exploring its best directional sensing capability. Advanced interrogation scheme will be developed based on the ensemble empirical mode decomposition (EEMD) approach to effectively determine Lamb wave propagation characteristics, damage location, and damage extent. Comprehensive tests will be conducted to validate the proposed damage detection concept and evaluate the performance of the PZT fiber array in a plate structure. We expect to extend the same concept to other engineering structures for structural health monitoring application after successful demonstration in this study.

Assigned Session: E 2 Structural Life Management

Presenting Author: Mohammad Azarbayejani **Ser:** 41

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

Country:

Paper Title: **Integration of an Effective SHM System in a Model Steel Bridge**

Co Authors: Mohammad Azarbayejani, Sebastian Salinas, Francisco Cantu, and David Renteria

Abstract:

Since 19th century, more than three hundred bridges have collapse all over the world. Engineers for all over the world are trying to stop these catastrophes, implementing systems that can detect with time these kinds of catastrophes. A Structural health monitoring system was implemented in the University of Texas Pan-American. The damage in a model steel bridge has been evaluated using accelerometers and strain gauges. Different damage scenarios have been detected in this system, being able to detect the differences between those states. With the implementation of this effective SHM system, the signals created by the sensors can be read in a securely web domain. These signals are interpreted with different types of algorithms, making easier for the Engineers to detect when the bridge is in a heavy damage state. A finite element model of this steel bridge was created, making possible the simulation of a future state of the bridge. Monte Carlo simulation was implemented in this finite element model. This method allows us to predict the damage severity on the bridge, making it possible to take proper precautions and decisions with time of anticipation. The lifetime of the bridge is detected with the Monte Carlo simulation. This effective SHM system can be implemented in real bridges, detecting with anticipation any kind of irregularity in the bridge.

Assigned Session: A 3 Fault Detection

Presenting Author: Michael Lipsett **Ser:** 21

Organization: University of Alberta

Country: Canada

Paper Title: **Improving Leak Detection for Freight Rail Wagon Airbrakes in Cold Weather Conditions**

Co Authors: V. Poddar, Mike Lipsett

Abstract:

Freight rail airbrakes must be reliable in a wide range of weather conditions. Detection of brake issues depends on several techniques, some of which can significantly negatively affect train scheduling. Failure Modes and Effects Analysis (FMEA) identified and ranked airbrake system failures, and structured analysis led to efforts to improve condition-monitoring techniques for airbrake leakage detection prior to a train departing from the yard. Ultrasonic leak detection is presented as an alternative to manual inspection using the soap and bubble test. Experiments were conducted both in the field and in laboratory with simulated and actual airbrake components to qualitatively and quantitatively evaluate and verify the implications of detecting leaks ultrasonically in cold weather conditions. Correlations amongst operating pressure, temperature, leakage orifice size, angle distance, flow-rate, and ultrasound intensity were performed to determine interdependencies. Principal Component Analysis was then applied to rank spectral features with respect to leak size and other manipulated variables. Acoustic signatures were fairly insensitive to temperature. The contribution that the frequency ranges made to each factor was estimated to find those having significant impact on spectral feature value for different levels of a particular manipulated variable, particularly orifice leak size and measurement distance, with ideal orifices compared to actual leaking airbrake components.

Assigned Session: A 3 Fault Detection

Presenting Author: Michael Lipsett **Ser:** 20

Organization: University of Alberta

Country: Canada

Paper Title: **Classification Accuracy of Automated Railway Wheel Fault Detection Technologies**

Co Authors: Laura Ibarra, Mike Lipsett, M. Hendry

Abstract:

As railroad car wheels are subject to wear and to damage, a wide range of wayside detectors are placed on the tracks to monitor the condition of the wheels during operational service. As new inspection technologies become available, there is an increasing need to compare different methods before adopting new techniques. This paper presents a case study using historical data describing classification accuracy of different rail detector systems (hot wheel, hot bearing, and wheel impact load detectors) for in-place automated detection of wheel defects, characterized by the probabilities of correct classification. The main automated wheel inspection technologies predominant in most North American railroad networks were selected for the analysis. The raw data from sensors and maintenance data of the railway wheels were provided by operating companies. The effectiveness of classification accuracy of each technology was assessed using a Confusion Matrix analysis. The core objective of this work then is to excerpt information from existing data so that measurements of wheel findings and analysis of findings interactions can lead to identification of suitable monitoring locations, potential root causes for specific maintenance actions, and strategic maintenance planning for future events using proportional hazards modeling.

Assigned Session: A 3 Fault Detection

Presenting Author: Michael Lipsett **Ser:** 23

Organization: University of Alberta

Country: Canada

Paper Title: **Wayside Wheel Temperature Detector Data Mining to Predict Potential Sensor and Railcar Component Failures**

Co Authors: A. Marghoub Shadkar, M. Hendry, Mike Lipsett

Abstract:

Wheel Temperature Detectors are positioned wayside and measure the temperature of passing wheels of a running train to identify the wheels with temperatures higher or lower than pre-set thresholds and authenticate an alarm. As the only easily observable feature related to railcar airbrake malfunction is wheel temperature, specifying and preventing the failures and improving reliability of railcar wheel temperature detection (WTD) systems is of interest. Detector failures can cause downtime and have the potential to result in safety incidents. Looking at the detector data and recognizing whether unusual data represents a failure in a train railcar component or the detector itself is a significant matter for the railway industry. In this study, a five-year WTD field dataset and the maintenance records from a Canadian railroad have been used to analyze the trustiness of these systems. For each detector failure, the observed data of the detectors has been analyzed to see the effect of a failure on the function of a detector. Observing one detector and passing trains leads to understanding about the condition and the health of the detectors. Considering one train passed by consecutive detectors yields useful information about the health of railcars. Both approaches are considered in this analysis.

Assigned Session: A 3 Fault Detection

Presenting Author: Eric Bechhoefer **Ser:** 61

Organization: Green Power Monitoring Systems LLC

Country:

Paper Title: **Control of Signal Bandwidth to Improve Fault Detection**

Co Authors: Eric Bechhoefer

Abstract:

Vibration analysis algorithms for shaft and gear faults are predominately based on the time synchronous average (TSA). The TSA resamples the vibration data over one shaft revolution, and averages that data over the number of revolutions associated with the acquisition. This has the effect of improving Fourier analysis for that shaft (no spectral smearing due to changes in shaft speed over the acquisition) and reducing non-synchronous noise.
A number of analyses can be performed on the TSA to extract features that are indicative of faults, such as the statistics on the TSA itself, the residual analysis, energy operator and Amplitude/Frequency Modulation (AM, FM) of the TSA Narrowband Analysis. This paper discuses two bandwidth reduction technique that improve signal to noise associated with non-synchronous noise. Reduced noise improves fault detection in the TSA, and all analysis dependent on the TSA, (including residual, energy operator).
For the TSA, this analysis is validated by comparing the condition indicators of a faulted pinion with and without bandwidth reduced. This technique has other advantages for embedded and online condition monitoring systems, by significantly reducing the computational load of subsequent analysis based on the TSA. For the AM/FM analysis, an empirical rule for bandwidth selection is made that maximizes separability between a faulted and nominal pinion.

Assigned Session: A 3 Fault Detection

Presenting Author: Klaus Schug **Ser:** 64

Organization: Arnold Engineering Development Complex - Aerospace Testing Alliance (ATA)/IT0

Country:

Paper Title: **When To Replace Plant/Facility Electronics/Software**

Co Authors:

Abstract:

Periodically plant and facility subsystems must be replaced as a result of (1) either poor reliability or (2) because they have reached their end-of-service life. While poor reliability is the number one cause for disruptive Lost Test Time (LTT) events, it is end-of-service life that drives replacement. End-of-service life is characterized by several factors including loss of manufacturer's support, decreased availability of spares, technological obsolescence, inability to meet customer requirements, and poor reliability. Test System Reliability is an accepted consequence of the system's design and is determined by the hardware components, firmware and software. To understand reliability, we analyzed LTT—not the durations of LTT but instead the frequency. Our analysis indicates that the number of LTT events follows a Poisson Process. As a result, the lengths of time between two consecutive LTT events (i.e., inter arrival times) are independent and random and the inter arrival times form an exponential distribution . This knowledge enables us to compute system reliability in terms of (1) the Test System's ability to produce Operands and (2) the ratio of LTT events to total Operand hours. This information also enables us to predict the probability of receiving LTT events that may occur during a specified operating period. In conducting this study of a Wind Tunnel over the 5 year period 2008-2012, it was proven that (1) the Bathtub Reliability model is appropriate for Test Systems, (2) the system's reliability is constant from year to year if no changes are made to the system, (3) the reliability of the Test System is the product of the individual subsystem reliabilities, and (4) the system's performance from year-to-year does not change with age. Also proven was LTT is a measure of how well first level maintenance process works. LTT is not, however, a good measure of performance. This report identifies a methodology for predicting the service life remaining for each subsystem. The system engineer scores their subsystems using a set of evaluation criteria and scoring guides. The evaluation is performed annually. The decimal score is converted to years of service life remaining using a service life exponential.

Assigned Session: E 3 Failure Prevention

Presenting Author: Bin Li **Ser:** 50

Organization: Instituto Superior Tecnico

Country: Portugal

Paper Title: **Probabilistic Design Procedure for Glass Components in Concentrated Solar Power System**

Co Authors: Bin Li, L. Guerra Rosa, and J. Cruz Fernandes

Abstract:

The fracture strength of glass components is dependent on the size and distribution of flaws as well as the duration of loading. Due to the inherent brittleness and strength scatter of glass materials, conventional design approaches are generally very conservative and large safety factors are often used. However, these large safety factors are somewhat arbitrary and not satisfactory, because it is not very clear what the true factor of safety really is. It is imperative to develop integrated strength evaluation methods for glass components, which are found more and more applications as functional and structural components. Based on the weakest link theory, this paper presents a new modeling framework to consider different possible failure mechanisms (over-loading fracture and stress corrosion induced failure), in order to take into account of the size effect as well as the multi-axial stress effect (including the contact stress between the glass component and the mount assembly). Then, an integrated assessment procedure for structural glass elements is developed, which is based on the probabilistic modeling of the complex behavior of glass fracture but avoids the complexity for calculation in applications. As an example, the design strength of a glass window suitable for a solar furnace reaction chamber is highlighted. The geometry and thickness of the glass window are optimized based on the stress analysis and the probabilistic strength evaluation.

Assigned Session: E 3 Failure Prevention

Presenting Author: Paula Dempsey **Ser:** 49

Organization: NASA Glenn Research Center

Country:

Paper Title: **Detection of Spiral Bevel Gear Damage Modes Using Oil Debris Particle Distributions**

Co Authors: Paula Dempsey and Robert Handschuh

Abstract:

Damage progression tests were performed in the NASA Glenn Spiral Bevel Gear Fatigue Rig. During testing, debris generated were measured with an inductance type oil debris sensor, while different classes, modes and degrees of damage occurred on the gear teeth. Debris particle counts, their approximate size and mass were measured by the oil debris sensor. Tooth damage was documented with photographs at the start of the test, when damage occurred on one gear or pinion tooth and when damage transferred to two or more teeth. American Gear Manufacturers Association (AGMA) and American Society for Testing (ASTM) standards were used to describe gear tooth damage. Discrete thresholds based on counts and mass were defined for three gear set states: Healthy, Inspect and Damage. Histograms of particle size distributions were plotted for eight tests at the three gear states. Methods to predict particle size based on gear design and operating conditions were also presented. Results found monitoring oil debris mass provided a good indication of damage progression for slow progressing fatigue failures, while monitoring counts alone did not provide a good indication. The oil debris sensor could not be used to detect scuffing failure modes. Scuffing transfers material between the meshing gears and is less likely to generate debris. If historical data is unavailable, gear geometry and operational conditions could be used to estimate a threshold on mass and average particle size for indicating a contact fatigue damage state.

Assigned Session: E 3 Failure Prevention

Presenting Author: Adrian Messer **Ser:** 7

Organization: UE Systems Inc

Country:

Paper Title: **Best Practices for Condition Monitoring Using Ultrasound**

Co Authors: Adrian Messer

Abstract:

Airborne & structure-borne ultrasound has become a must have technology for an effective predictive maintenance program. Once considered only a leak detector, ultrasound as evolved into an effective tool for equipment reliability applications such as bearings, pumps, and other rotating equipment. This presentation will give best practice information on using ultrasound to collect data, establish baseline, and alarm level indicators on assets. Information will also be presented on how ultrasound can be used for condition based lubrication in order to prevent over and under lubricated bearing failures on rolling element bearings. Data, reports, and sound file examples will be a part of the presentation.

Assigned Session: E 3 Failure Prevention

Presenting Author: Marc Pepi **Ser:** 5

Organization: US Army Research Laboratory

Country:

Paper Title: **Toxic Metal Reduction and Life Extension of Gun Barrel Liners Through Cold Sprayed Refractory Metals**

Co Authors: Blake Barnett, Matthew Trexler, Victor Champagne, and Marc Pepi

Abstract:

Modern gun barrel technology faces a number of challenges related to the use of chromium-plated steel on the interior bore surface. The amount of allowable chromium has been significantly reduced due to environmental, health, and safety concerns. Furthermore, improved munitions and propellants lead to erosion and condemnation of gun barrels well before their 10,000 round expected lifetime. This has precipitated a search for longer-lasting bore liners, such as refractory metals deposited by explosive bonding. The cost and difficulty associated with shaping these materials have made them impractical choices to date. However, Gas Dynamic Cold Spray consolidation of refractory metals and alloys was selected as an alternative to extrusion for additive manufacture of donor tubes. Tantalum and tantalum-tungsten alloy donor tubes have been produced by Cold Spray and tested for wear resistance and compatibility with the cladding process. A 1-meter (3-foot) long tube was produced to test scalability.

Assigned Session: E 3 Failure Prevention

Presenting Author: Zlatan Racic **Ser:** 38

Organization: Z-R Consulting

Country:

Paper Title: **Proactive Shop Strategy for a Successful Turbine-Generator Rotor Outage**

Co Authors: Zlatan Racic and Marin Racic

Abstract:

Standard power generation industry practices of inspection, machining, balancing, assembly and alignment have been developed and streamlined by OEMs for newly manufactured rotors, and implicitly assume that rotors are within ideal dimensional specifications. However, applying these standard practices in the service industry can fall short for rotors with eccentricities outside such specifications, and by design do not catch the errors that cause true dynamic problems, because they are assumed not to exist or their effects are fully unrecognized by "traditional industry practice" with regard to real rotordynamic behavior (not the rotordynamics theory based on a Jeffcot rotor). This misunderstanding leads to various problems, like reinstalling a "balanced" rotor from the shop only to be unable to run due to high vibrations upon installation. This can be followed by weeks of field balancing in an effort to salvage the situation.

A "successful" start up following a planned outage means that there will be no need for field balancing following the restart of the unit. There are two key processes that must be incorporated into an outage scope to ensure success. The first is to collect and evaluate (1x and 2x) total indicator runout (TIR) readings to identify any excessive bow or distributed eccentricity in the rotor body between the journals, and to verify and machine all rotor couplings and journals to within the criteria of ISO 1940. Any excessive off-squareness of the coupling faces or any taper or runout of the journals must be corrected by machining. The second key process is utilizing a new balancing method if the rotor body exceeds runout limits of ~0.002" eccentricity. Any such bowed or eccentric rotor must be balanced in a minimum of 3 balancing planes (or more accurately, 2N+1planes, where N is the highest mode reached by the rotor within its operating speed range).

Since most causes of dynamic problems on turbine-generator rotors are present even prior to starting the unit, almost any such problem can also be identified and fully prevented ahead of time during an outage if only a few improved steps of measurement and analysis and the proper balancing method are included into an outage scope. By proactively incorporating rotor TIR evaluation, making provisions for any necessary machining, balancing any bowed or eccentric rotor in 2N+1 balancing planes, and following OEM alignment procedures, a successful restart of the unit without field balancing can be assured.

Assigned Session: E 3 Failure Prevention

Presenting Author: Casey Holycross **Ser:** 68

Organization: US Air Force Research Laboratory

Country:

Paper Title: **In-situ Study of Strain Energy Density at Notch Roots Using Digital Image Correlation**

Co Authors:

Abstract:

An energy based fatigue life prediction method has been previously developed to accurately predict lifetimes of coupon specimens in excess of 105 cycles. The method has been shown to have good agreement with empirically determined room temperature high cycle fatigue (HCF) data for both Al 6061-T6 and Ti-6Al-4V in uniaxial, bending, and shear at various stress ratios. As with any life prediction method, using a testing scheme to accurately predict fatigue performance from a reduced data set greatly reduces test time and material costs. For gas turbine engine (GTE) components, these can account for a large portion of development costs, making the use of reduced order models very attractive. The stress state of these components can be difficult to characterize and simulate, as they are subjected to both low and high cycle fatigue from both mechanical and vibrational loading. Mechanical loading is generally within the low cycle fatigue (LCF) regime and attributed to throttle excursions of various flight maneuvers or engine start-up/shutdown cycles over the course of a component's lifetime typically less than 10^5 cycles. Vibrational loading causes HCF of a multiaxial stress state, and is attributed to various forced and free vibration sources manifested as high order bending or torsion modes. Understanding the interaction of these two fatigue regimes, as combined cycle fatigue, is necessary to develop robust design techniques for GTE and turbomachinery in general. This study focuses on interrogating a previously developed energy based fatigue life prediction method and extend its use to account for microscale strain localizations in LCF loading.

Using a coupled control volume (CV) and digital image correlation (DIC) approach, this study leverages full field interrogation of strain energy about strain energy localized at a machined notch. The full field strain maps computed from DIC are compared to those determined from an elastic-plastic finite element method (FEM) analysis. This study demonstrates that this approach is suitable for the notch radii chosen.

Assigned Session: A 4 Sensors

Presenting Author: Richard Roth **Ser:** 30

Organization: Etegent Technologies

Country:

Paper Title: **Mechanical Waveguide Vibration and Temperature Sensors for Monitoring Gas Turbine Engines**

Co Authors: Richard Roth, Ryan Matthews, Erik Henderson, and Oleg Lobkis

Abstract:

Failure in turbine engine main shaft bearings is one of the major causes of catastrophic failures. The traditional approach for determining bearing faults, measuring acceleration on the case of the engine, is unreliable due to the complex and changing transfer path from the bearing to the housing as well as the large number of masking noise sources within the engine.

Etegent has developed a new waveguide-based vibration sensor which is able to directly measure the bearing vibration signature, bypassing the complex transfer path and masking vibration seen in traditional techniques. The sensor operates by transmitting the bearing vibration energy from the bearing housing to a location external to the engine, where the sensing element can be easily serviced and can utilize traditional piezoelectric materials with higher sensitivity than specialty high temperature piezoelectric materials.

Etegent has successfully shown the utility of this sensor in a number of engine tests to date. The sensor has shown improved performance over case mounted accelerometers in both 250 SHP and 5000 SHP class engines with seeded defects on the thrust bearings.

This paper presents the preparations and test setup for an upcoming test on a 5000 SHP turbine engine instrumented with waveguide vibration sensors at each of the 4 main engine bearings as well as case mounted accelerometers and an oil debris monitoring system.

Assigned Session: A 4 Sensors

Presenting Author: Scott Hoover **Ser:** 52

Organization: Oxsensis Ltd

Country: UK

Paper Title: **Fiber Optic Sensors for Harsh Environment Applications**

Co Authors:

Abstract:

Optical sensor technology is finding an increasing number of applications in the Aerospace, Energy and Oil & Gas industries due its tolerance to harsh environments, including extremes of temperature, immunity to electromagnetic interference, remote sensor operation capability and intrinsic safety. This paper presents an overview of our recent progress with particular emphasis on static pressure measurement capability for harsh environments, ultra-sensitive pressure sensor for aerospace fluid systems applications, dynamic pressure sensor for gas turbine applications, highly accurate pressure sensor for use in the Oil&Gas industry and a combined acceleration and temperature sensor. Brief descriptions of the underlying operating principles will be provided together with measurement results and illustrations of potential application areas.

Assigned Session: A 4 Sensors

Presenting Author: George Zusman **Ser:** 60

Organization: ViCont, Inc.

Country:

Paper Title: **Field Programmable Vibration Sensors an Effective Approach for Machinery Protection and Monitoring**

Co Authors: George Zusman

Abstract:

Machinery and mechanical systems face potential failure when their ability to function normally is compromised due to worn components or when their operating conditions diverge from normal. Continuous monitoring of changing vibration helps avoid expensive unplanned shutdowns by detecting machinery faults before they become catastrophic events. It is known that machinery vibration changes when problems such as worn bearings, cracked gears, lack or contamination of lubricant, imbalance, looseness or misalignment occur. For such application a new generation of vibration field programmable and cost-effective sensors has been designed. In a moment the generation consist of the follow two wire loop powered sensors: Reciprocating Machinery Protector, Rolling/Ball Bearing Fault Detector, Overall velocity Vibration Transmitter and Smart Vibration Switch. All units constructed in two pin independent polarity configuration and could work directly with PLC or DCS system. All main parameters and configuration of the units could be programmed by USB programmer. The paper describes the sensors technology, operations and field application results.

Assigned Session: A 4 Sensors

Presenting Author: Jamie Coble **Ser:** 66

Organization: The University of Tennessee, Department of Nuclear Engineering

Country:

Paper Title: **High-Confidence Signal Validation for Online Sensor Calibration Assessment**

Co Authors:

Abstract:

Safe, efficient, and economic operation of nuclear facilities (nuclear power plants, fuel fabrication and storage, used fuel processing, etc.) relies on accurate, timely, and reliable measurement of process variables. During operation, components of nuclear facilities, including sensors, may degrade due to age, environmental exposure, and even maintenance interventions. These factors result in anomalies, such as signal drift and response time changes, in the measured signal and failure of the sensing element, and may challenge the ability to reliably distinguish between signal changes due to plant or subsystem performance deviations and those due to sensor or instrumentation issues.

The current approach to mitigating sensor degradation issues in US nuclear power plants is to periodically remove sensors from service, evaluate the calibration with false loads, recalibrate if necessary, and return the sensors to service. This approach is expensive, time-consuming, and contributes to radiation exposure for maintenance workers. Further, under this paradigm, sensor calibration is assessed only periodically, typically once every fuel cycle (18 – 24 months). This periodic assessment has been sufficient (although not optimal) for the current fleet of light water reactors, because operating history suggests that sensors do not typically experience severe degradation over the two-year cycle. As the nuclear industry moves to new plant designs with longer fuel cycles (4 years for most light water-based small modular reactors up to 40 years for some advanced reactor designs), this periodic approach becomes untenable.

Online monitoring (OLM) offers an alternative approach to sensor calibration assessment, where the data normally collected during operation for plant monitoring and control are used to assess the calibration of the sensors collecting those data. In the proposed OLM approach, empirical models of normal plant behavior are used to predict the true value of key process parameters. These predictions are compared to the measurements to determine if any mismatch exists. Our confidence in the predicted parameter value and the subsequent anomaly detection depends on our ability to accurately quantify and minimize the uncertainty in the predictions.

Building on previous work in uncertainty quantification for sensor calibration assessment [1], we are developing a Gaussian process (GP) model-based approach to signal validation. The proposed GP formulation will need to provide high confidence signal validation during both normal operation (where all sensors are accurately calibrated) and operation under degraded performance of one or more sensors. The statistical properties of the monitoring system residuals are assumed to be quite different under these two scenarios. Under unfaulted operation, residuals can be assumed to be stationary and independent; neither of these properties will hold under sensor degradation. This presentation will present the proposed GP model for signal validation. Preliminary results from applying this model to normal operational data will be presented, and ongoing work will be discussed.

References

1. Ramuhalli, P., G. Lin, S. L. Crawford, B. Konomi, B. G. Braatz, J. B. Coble, B. Shumaker and H. Hashemian (2013). Uncertainty Quantification Techniques for Sensor Calibration Monitoring in Nuclear Power Plants, Pacific Northwest National Laboratory.

Assigned Session: A 4 Sensors

Presenting Author: Chris Nemarich **Ser:** 70

Organization: US Navy Military Sealift Command HQ

Country:

Paper Title: **Optical Torque Sensor for Propulsion Engine Performance Optimization and Reliability**

Co Authors:

Abstract:

The presentation describes the proposed application of a birefringent optical torque sensor for Naval shipboard propulsion diesel engine load balance control and operating optimization. The benefits of the sensor are its ability to work on the smaller engine shaft and limited clearances on the T-ARS class propulsion diesels which has limited the use of commercially available torque sensors. The optical birefringent sensor has advantages over traditional strain gage sensors including improved accuracy and bandwidth with less maintenance. On this class of ship the diesel engines are paired to a single main reduction gear with a close coupled shaft. The optical sensor offers the ability to accurately measure the output torque of each engine independently so that engine load balance can be maintained and engine operation can be optimized. The additional benefit of the sensor is the potential to identify engine health issues by tracking fuel consumption against output over a wide operating range.

Assigned Session: B 4 Data Handling and Management

Presenting Author: Gabriele Manno **Ser:** 39

Organization: DNVGL

Country: Norway

Paper Title: **Integrated Vehicle Health Management in the Era of Big Data: A Shipping Industry Focus**

Co Authors:

Abstract:

The preseantation will focus on the emerging trends of the Indutrial internet and will investigate how these trens can change the practice of shipp asset management.

Assigned Session: B 4 Data Handling and Management

Presenting Author: Preston Johnson **Ser:** 63

Organization: National Instruments

Country:

Paper Title: **Managing Sensory Data and Flow in a Distributed Fleetwide Prognostics and Equipment Health Monitoring Application**

Co Authors:

Abstract:

We are connecting an increasing numbers of assets to our enterprise, and increasing the sources of sensory date for each asset. As our critical assets are connected to the enterprise, more opportunities emerge to mine sensory data, create information and draw conclusions. Fleet operators, equipment OEMs, and equipment service providers are increasingly challenged with selecting a data acquisition network, data storage and computing architecture that opens the possibility for automating machinery and process diagnostics, and staging prognostic applications. Armed with an understanding of sensory data sources, typical sensor analytics, and available communications paths; the equipment health management team is able to architect and deploy an open PHM system supporting multiple sensor sources, analytical algorithms, data stores, and actionable information dashboards. The PHM system often results in a distributed, networked and central private "cloud" oriented data storage and analytics system. This presentation covers design considerations in architecting the distributed, networked and cloud based PHM system and concludes with short case studies of fleetwide PHM applications.

Assigned Session: E 4 Mechatronics

Presenting Author: Sara Al Bulushi **Ser:** 47

Organization: University of Central Lancashire

Country: UK

Paper Title: **Development of an Advanced Gas Emissions Monitoring System for Oil and Gas Production Sites**

Co Authors: Sara Al Bulushi and Ahmed Onsy

Abstract:

Oil and gas industry incorporates an extensive variety of operations and supplies. This industry is one of major sources of emitting gases. Gases emitted from oil and natural gas extraction operations are extensively toxic. These gases include, Carbon Dioxide (CO2), Methane (CH4), Propane (C3H8), Hydrogen sulfide (H2S), Hydrogen (H2) and Alcohol (C2H5OH), just to mention a few. The proliferation of these gases in air creates insufficient and risky working environment for crewmembers at the rig site. Long exposure to these gases may lead to serious long-term health problems. Due to that, the significance of condition monitoring in engineering plants has increased significantly. It is beneficial to provide primary guard by employing condition-monitoring algorithms for various gas emission monitoring. This paper demonstrates reviews and critically assesses a new advanced gas emissions monitoring system (GEMS) during oil extraction operations, where gas emissions actually begin at early stages of exploration phase, continues during development phase, and finally ends up at oil production phase. The paper also presents the development of low cost online GEMS that is capable to monitor hazardous gases at oil and gas production sites. This will include the measurement of H2S-Hydrogen Sulfide, CH4-Methane, C3H8- Propane, CO2-Carbon Dioxide, C2H5OH-Alcohol and H2-Hydrogen gases. The system output utilizes wireless data transmission; Wi-Fi, GPRS and GSM to provide information to control rooms and other monitoring sites.

Assigned Session: E 4 Mechatronics

Presenting Author: Sara Al Bulushi **Ser:** 45

Organization: University of Central Lancashire

Country: UK

Paper Title: **Remotely Operated Solar Panel Automated Cleaning System**

Co Authors: Ali Al Harrasi, Ahmed Onsy, and Katerina Fragaki; presented by Sara Al Bulushi

Abstract:

Solar power involves technology for harnessing the sun's energy and converting it into a form where it can be used to generate electricity. This represents a renewable energy source that can help to meet the demand to reduce the use of non-renewable resources due to major environmental concerns and the effects of greenhouse gases on the atmosphere. Most buildings which use the solar energy as an energy source include systems that convert the sun's radiation into electricity. Two main types of technology are used to harness solar energy, which are known as passive and active. In both, the most important element is the solar panel, the characteristics of which determine the performance and quality of the system in various ways. This paper discusses the photovoltaic renewable energy sources and the effect of solar panel cleanness on its efficiency. Also, presents a design for remotely operated Solar Panel Automated Cleaning System (SPACS) which can be used to improve the performance of solar panels, especially systems that are not maintained regularly. The SPACS includes multi-sensors control system in order to achieve the system multi-operational modes. The SPACS is implemented on 100w solar panels, providing automated cleaning of the solar panel surfaces, and is tested in the laboratory environment. The next phase of testing will involve different climate conditions, including dusty and rainy weather.

Assigned Session: E 4 Mechatronics

Presenting Author: Mohamed Hagag **Ser:** 43

Organization: MTC

Country: Egypt

Paper Title: **Improved RHEX Robot Design; Towards Low Cost RHEX Robot**

Co Authors: Ehab Ali, Ahmed Onsy, Ibrahim Elsherif, and Mohamed Metwally; presented by Mohamed Hagag

Abstract:

The RHex robot is a six-legged robot inspired by biology. Since 1999, several models of this robot have been developed, focusing on areas such as: the shape of the platform; the system's sensors, actuators and main controller; the leg design, gait and locomotion; navigation and vision systems; and the robot's application. However, versions of the RHex robot developed so far include expensive components, and little published work focuses on the design of a low-cost RHex robot. This paper details the design of an academic low-cost RHex robot including the materials used for mechanical parts, sensors, actuators and the system controller. The system is currently under validation in the laboratory environment and future publications will describe its validation in different environments and using advanced sensors.

Assigned Session: E 4 Mechatronics

Presenting Author: Mohamed Hagag **Ser:** 44

Organization: MTC

Country: Egypt

Paper Title: **Monitoring of Upper-Limb EMG Signal Activities Using a Low Cost System; Towards a Power-Assist Robotic Arm**

Co Authors: Ahmed Azab, Ahmed Onsy and Mohamed El-Mahlawy; presented by Mohamed Hagag

Abstract:

Many human activities depend on upper-limb motion, which can be characterized and estimated using the activation levels of the electromyography (EMG) signal of the upper-limb muscles. Researchers are devoting much effort to investigating these activities during elbow extension and flexion. Also, a few studies have concluded with the development of a power-assisted arm. However, the systems introduced so far are expensive and there are long waiting lists of people requesting such systems. The aim of the present work is to develop a power-assist arm based on the EMG signal activities of the upper-limb, and this paper describes the first part of this study focusing on the monitoring of EMG signals during upper limb activities based on the development of a low-cost system. The relationship between elbow motion and the activity level of the biceps muscle is characterised and different relevant features are logged. The new low-cost system is then validated against the Biopack specialised biomedical measurement system.

Assigned Session: A 5 Prognostics

Presenting Author: Joe Sheeley **Ser:** 34

Organization: Arnold Engineering Development Center (AEDC), US Air Force

Country:

Paper Title: **Improved Prognostics through Integration of Operational Data with Diagnostics**

Co Authors:

Abstract:

The economic goals in a typical industrial plant are to maximize equipment uptime and to minimize maintenance cost, operating costs, and spare parts inventory maintenance cost. Large plants comprise thousands of critical components, the failure of any one capable of stopping operations. Frequently, extended plant operating periods preclude maintenance from being performed. Plant failures during critical periods can be extremely costly due not only to failed component repair cost and collateral damage but also due to lost production. Equipment lifespan is typically specified under nominal operating condition from which remaining component life can be predicted from run time, in turn allowing preventative maintenance scheduling. However, accelerated aging may take place due to operation under conditions more severe than the norm, thereby invalidating runtime-based remaining life predictions. An alternative to runtime-based remaining life prediction is fault detection through condition monitoring and degradation trending, but predictions of remaining life using this technique are very poor until failure is imminent. In the current work, operating time is combined with machinery diagnostics to create an improved methodology to predict the time of machinery failure. In this technique, machinery monitoring is used to determine the current machinery health state along a component life curve. Empirical wear models built using historical operating conditions are then used to predict remaining life.

Assigned Session: A 5 Prognostics

Presenting Author: James Kozlowski **Ser:** 1

Organization: Penn State Univ/ARL

Country:

Paper Title: **Pattern Tracking for Predicting Unscheduled Maintenance Actions of Military Ground Vehicles**

Co Authors: James Kozlowski

Abstract:

As part of an effort to analyze available sensor data collected on military vehicles, such as the Heavy Equipment Transporters (HET), some tasking was dedicated to establishing if a prediction of the next unscheduled maintenance action of a vehicle could be estimated based on the available digital data bus sensor data of that vehicle and other vehicles in the fleet. Thus, the results compiled from the analysis of the available sensor data from fleet HET vehicles using techniques developed for predicting required unscheduled maintenance actions. The challenge is that the available vehicle sensor data is low bandwidth (<10 sample per second) as compared to the high bandwidth (>10,000 samples per second) data that is typically gathered for predictive algorithm and model approaches. The approach essentially mapped multiple channels of the sensor data into a subspace that produced more distinct characteristics to the changing behavior of the vehicle. The subspace data was compared to data from other vehicles that have been mapped to this same subspace. When two vehicles had a series of consecutive similar subspace mappings, the two vehicles were considered to be experiencing similar activity or potentially similar degradation of the physical health of the vehicles. This chain of consecutive subspace similarities triggered a maintenance log scan for each of the vehicles to determine the last maintenance actions. The vehicle that had the most recent maintenance action from the consecutive subspace trend was considered the impending event for the second vehicle. Next, the amount of engine load time was estimated from the first vehicle and established as the likely available engine load time of the second vehicle until the same maintenance action was required. To help prevent false positives, some filtering of the maintenance logs were required to only include those records likely to be associated with the collected sensor data. Overall, within the available sensor data provided there were not a large number of same maintenance actions (associated with the sensor data) across multiple vehicles. However, despite the limited data sets some trending was identified and represents anecdotal evidence that estimating the next potential maintenance action of a vehicle has promise for improving fleet logistics and maintenance.

Assigned Session: A 5 Prognostics

Presenting Author: Chao Liu **Ser:** 10

Organization: Department of Thermal Engineering, Tsinghua University

Country: P R China

Paper Title: **Feature Extraction in Machine Degradation with Variational Mode Decomposition**

Co Authors: Chao Liu, Dongxiang Jiang, and Wenguang Yang

Abstract:

The measured parameters change with the machine degradation, where the trends of the parameters can be applied in condition prediction. The deterioration of the parameters usually present characteristics in a monotonic or low-frequency way. As the measure signal are merged with instant signals, noise and measurement error in different frequency bands, model decomposition approaches are widely applied to separate the different bands for feature extraction. Among the model decomposition methods, Variational model decomposition is recently proposed by K. Dragomiretskiy and D. Zosso as a non-recursive model which can extract modes concurrently. Variational model decomposition presents advantages in image processing area. This work will analyze its effectiveness in degradation feature extraction and application in condition prediction in prognosis. Firstly, variational model decomposition is analyzed, where the characteristics of variational model decomposition are compared with other mode decomposition methods including empirical mode decomposition and ensemble empirical mode decomposition. Simulation data is applied to test the effectiveness of the mode decomposition methods. Secondly, field data with component degradation is collected, and the degradation feature extraction is applied with the three methods mentioned above. Thirdly, the extracted degradation features are inputted into the condition prediction model, and the prediction results are obtained and the effectiveness of variational model decomposition is tested.

Assigned Session: B 5 Health Management Tools and Capabilities

Presenting Author: Jake Siegel **Ser:** 15

Organization: Luna Inc.

Country:

Paper Title: **Aircraft Landing Gear Shock Strut Readiness Monitoring System**

Co Authors:

Abstract:

Aircraft oleo-pneumatic landing gear shock struts require a precise gas to fluid ratio to ensure proper, safe operation. Current approaches to verify the operational readiness of landing gear shock struts forgo measuring oil fluid level directly, and instead compare X-dimension (shock strut extension) to gas pressure and/or aircraft gross weight, often leading to improperly serviced shock struts. These routine gas pressure and strut extension measurements provide some insight, but cannot provide a complete assessment of shock strut readiness due to highly uncertain fluid volume. Explicitly measuring fluid volume typically involves full deflation of the strut that is time consuming and degrades aircraft operational availability. Providing direct measurement capability for fluid volume, gas pressure(s), and temperature would yield greater confidence of operational readiness, and vastly increase inspection efficiency and accuracy. To meet this need, Luna is developing a non-obtrusive, low-power, wireless shock strut readiness monitoring (SSRM) system that includes robust, embedded fluid level, pressure, and temperature sensors along with diagnostic models to translate raw sensor data into actionable metrics for a given aircraft platform. During a recently completed Air Force SBIR Phase I project, Luna developed a mockup of an F-16 nose landing gear (NLG) shock strut and demonstrated the feasibility of monitoring critical system parameters with the low-power, wireless instrumentation platform. The system is designed to permit straightforward retrofit with minimal hardware modifications. Representative results from the F-16 NLG mockup test bed are discussed.

Assigned Session: B 5 Health Management Tools and Capabilities

Presenting Author: George Zeigler **Ser:** 26

Organization: SPGS Surgelab America

Country:

Paper Title: **EMC Safety for All Sensitive Electrical Systems**

Co Authors: Daniel Soleil, George Zeigler, and Levi Zeigler

Abstract:

This paper presents a variety of factors that need to be considered concerning the application of a new electromagnetic compatibility (EMC) concept for EMC studies and also the protection that is needed for large electrically sensitive systems. This concept is called the "Zero Method" it is based upon zero volts and zero current on equipment reference conductors. The "Zero Method" can assist: hospitals, electrophysiology units, manufacturing companies, data-centers, electrical utility companies, gas companies, petroleum companies, hydroelectric plants and more to create economically and technically sound solutions to protect against electromagnetic interferences caused by lightning effects and the effects of industrial power disturbances.

During the last fifteen years, case studies have proven the "Zero Method's" efficiency and effectiveness with long-term solutions to EMC issues. These solutions not only improve safety for personnel in the facilities, but also can reduce equipment maintenance cost while improving equipment reliability.

Assigned Session: B 5 Health Management Tools and Capabilities

Presenting Author: Lex ten Have **Ser:** 36

Organization: National Aerospace Laboratory NLR

Country: Netherlands

Paper Title: **Enhancing Helicopter Health and Life Cycle Management through Shared Data Bases and Analysis Tools**

Co Authors:

Abstract:

Nine countries - operating the new military NH90 helicopter - have realized that jointly developing and operating a powerful and flexible health and life management tool can be a vital instrument for optimum helicopter fleet (health and life) management. The solution, called Supportability Data Exchange SDE, comprises of a shared helicopter operational usage and maintenance data inventory and an extensive technical toolbox available 24/7 through a secure web based service. Main functionalities of SDE are (1) automated upload and storage, dedicated analysis and standard reporting for helicopter occurrences and incidents, (2) Reliability, Availability and Maintainability (RAM) analyses and (3) structural integrity evaluations. This powerful multi-level multi-Nation implementation of a helicopter fleet life management tool provides the asset owner (e.g. defence organisation), the asset manager (e.g. weapon system manager) and the service provider (e.g. maintenance engineering dept. or OEM) with a state-of-the-art enabler for the application of Condition Based Maintenance (CBM) and Prognostics & Health Management (PHM) procedures. The present paper and presentation will cover an explanation of the backgrounds, rationale, objectives, performance, technical content and growth potential of this state-of-the-art NH90 health and life cycle management tool.