Assigned Session: A 1 Prognostics

Presenting Author: Mike Roemer **Ser:** 42

Organization: Impact Technologies, A Sikorsky Innovations Company

Country:

Paper Title: **Fault Prognosis and Uncertainty Management with Particle Filter**

Co Authors: Jon DeCastro, Michael Roemer, George Vachtsevanos

Abstract:

Effective uncertainty management processes are essential elements in the design of prognostic modules for IVHM applications. Due to the stochastic nature of fault progression, uncertainty representation and management methods that are mathematically rigorous, robust and verifiable are needed for any prognosis algorithms to be deployed in real world applications. In recent years, particle filter-based prognosis algorithms have been developed and became popular in many reported prognosis applications. This paper presents a novel Risk-Sensitive PF (RSPF) framework that complements the benefits of the classic approach, by representing the probability of rare and costly events within the formulation of the nonlinear dynamic equation that describes the evolution of the fault condition in time and particularly representing and managing uncertainty in long-term predictions with a novel outer feedback correction loops.

Performance metrics and a generic Verification and Validation (V&V) methodology were developed and testing was conducted on recorded crack growth data and battery aging data. A Pioneer 3-AT mobile robot platform were developed and utilized for performance evaluation and demonstration. Real-time prognostic information prediction state of charge of the battery with its uncertainty measures is utilized by a mission planner to optimize the robot's mission based on current and future system health. Successful field trials have been conducted. Results are presented in this paper.

Assigned Session: A 1 Prognostics

Presenting Author: Edwin Sutrisno **Ser:** 41

Organization: Center for Advanced Life Cycle Engineering

Country:

Paper Title: **Anomaly Detection for Insulated Gate Bipolar Transistor (IGBT) Under Power Cycling Using a K-Nearest Neighbor Technique**

Co Authors: Qingguo Fan, Diganta Das, and Michael Pecht

Abstract:

Insulated Gate Bipolar Transistor (IGBT) is a power transistor used in medium to high power applications such as hybrid cars, railway traction motors, switch mode power supplies, and wind turbines. As IGBTs find acceptance in large and complex systems, the ability to detect anomalies and predict impending failures in IGBTs can provide a key advantage by driving down cost of maintenance and improving system availability and safety. In this study, power cycling tests are performed and current, voltage, and temperature data on IGBT samples are collected. Several operation parameters are extracted from the data and are analyzed with a k-Nearest Neighbor (kNN) anomaly detection algorithm. It is shown that the kNN algorithm successfully detects faults before the IGBTs enter a degradation stage leading to latchup.

Assigned Session: A 1 Prognostics

Presenting Author: Patrick Kalgren **Ser:** 47

Organization: Impact Technologies, A Sikorsky Innovations Company

Country:

Paper Title: **Low Computational Cost Prognostic Algorithm for Embeddable Applications**

Co Authors: Irtaza Barlas, Irfan Ali, Patrick Kalgren and M.J. Roemer

Abstract:

A set of strategies is evaluated for extended data-trending suitable for embedded applications. Algorithms capable of running in real-time in small microcontrollers for diagnostics are proposed taking into account the capabilities and limitations of such platforms. The algorithms are evaluated based on a pre-weighted scheme and their respective effectiveness is compared by an “evaluation module” which selects the best performing algorithms. The proposed platform is evaluated using vibration data from a progressive failure.

Assigned Session: A 1 Prognostics

Presenting Author: Christian Bernet **Ser:** 21

Organization: RWTH Aachen University - IMR

Country: Germany

Paper Title: **Sensor-based Realtime Numeric Simulation for a Condition-forecast-oriented Maintenance Strategy**

Co Authors: Christian Bernet Markus Schütz Karl Nienhaus

Abstract:

The target of this paper is to present the development of an analysis-tool combining the scope of a sensor based condition monitoring and the numeric simulation of components in real time. The numerical simulation extends the observation of components that are not or cannot be monitored by sensors. Thus the remaining service life of component parts can be forecasted. The direct connection of a maintenance planning system enables the automatic collection and processing of the acquired data for a direct transfer to the maintenance engineer. The way to achieve the described functionality is a data analysis of the monitored machine. This automated data analysis and the extraction of characteristic values are described as well. Thus, critical forces for components, even for parts that are not part of the sensor based condition monitoring, can be identified, maintenance activities can be planned on-demand and on time so that unplanned breakdowns can be avoided.

Assigned Session: A 1 Prognostics

Presenting Author: Wenyu Zhao **Ser:** 22

Organization: Center for Intelligent Maintenance Systems

Country:

Paper Title: **A Study of Machining Process Power Monitoring and Product Quality Prediction**

Co Authors:

Abstract:

The adoption of power sensor and power data analysis techniques has been expanding in the area of machine condition monitoring. Besides typical power usage analytics, machine health status and component degradation are the emerging merits of power data to provide more insights in the machine and process performance. This paper presents a methodology to monitor power consumption of a milling process and predict part quality based on a correlation model developed. A power sensor is instrumented at the main power supply of a three-axis horizontal milling center to manufacture a batch of typical aerospace components having a circular boss and bore features. A batch of 48 components is produced, where tool wear, product quality, power consumption and real-time machining parameters are measured and monitored. The tool change is performed based on quality requirements and tolerance information. The boss and bore diameter is measured for each part using on-machine probing and compared with its nominal value, wherein the difference is used as the part quality metric. Effective power data in kilowatt from all cycles is analyzed and meaningful features are extracted from the power signal. The feature deviations from the baseline are used to interpret the performance degradation of each tool over cycles. The deviation trend is considered as correlated with the change in the part quality, verifying that power data and its features can be used to infer the part quality using correlation model. In the future, the presented work can be validated with further testing and improved to be adaptive with multiple manufacturing process regimes. To conclude, the framework of using power data to predict machine performance in terms of health condition and part quality is highly beneficial to manage maintenance, scheduling and product quality.

Assigned Session: A 1 Prognostics

Presenting Author: Nick Williard **Ser:** 39

Organization: Center for Advanced Life Cycle Engineering

Country:

Paper Title: **Model Based Battery Management System for Condition Based Maintenance**

Co Authors: Wei He, Michael Osterman and Michael Pecht

Abstract:

A generalized approach for combining state of charge (SOC) and state of health (SOH) techniques together to create a self-adaptive battery monitoring system is discussed. First, previously published techniques and their feasibility for on-line SOC and SOH estimation are reviewed. Then, a method of utilizing SOH predictions to update the SOC estimator in order to minimize drift due to capacity loss and cell degradation is given. This method is demonstrated by combing an equivalent circuit model to estimate SOC with an empirical/data driven model of capacity fade to estimate SOH. The method is validated with data obtained through cycle life testing of a lithium-ion battery. Parameters for the equivalent circuit model are initially extracted from electrochemical impedance spectroscopy data and are updated by least squares fitting and future SOH predictions. Lastly the results of SOC and SOH estimations are translated into terms that can be easily interpreted by an electric vehicle user so that the presented method can be implemented into an onboard fuel gauge and condition based maintenance system.

Assigned Session: B 1 Failure Prevention for Materials and Structures

Presenting Author: Robert Tryon **Ser:** 23

Organization: VEXTEC Corporation

Country:

Paper Title: **Computational Durability Simulation for Superalloy Turbine Disks**

Co Authors:

Abstract:

Commercial FEA doesn't have the capability to directly analyze component durability. This is because commercial FEA predict stress and strain at each element in the model but not durability. VEXTEC has developed a simulation approach which extends commercial FEA by superimposing a representation of the material durability within each of the FEA elements. Realistic three dimensional material complexities can now be assigned to each FEA element – with true microstructure variability being simulated on an element by element basis. Industry has become pervasively accustomed to using FEA generated stress-maps as a means for component design and life cycle management. Extended with a new technological means, the future is that commercial FEA is being extended so that life cycle probability maps can be just as readily viewed and used as a more insightful design basis. The capability is demonstrated on a turbine disk as the component. This presentation will overview the simulation set-up work, the processing approach and the end results that came out of the durability simulation. This project was used to show that designers & manufacturers can have the ability to tailor the microstructure in various sections of the disk to provide the necessary strength desired at each location.

Assigned Session: B 1 Failure Prevention for Materials and Structures

Presenting Author: Greg Schoeppner **Ser:** 49

Organization: Materials and Manufacturing Directorate, US Air Force Research Laboratory

Country:

Paper Title: **Accelerating Materials Insertion by Evolving the DoD Materials Qualification-Transition Paradigm**

Co Authors:

Abstract:

The development of advanced materials are foundational to a majority of the key breakthrough technologies since the start of the industrial revolution. Yet today the DoD enterprise that discovers, develops, and transitions structural materials is at a crossroads. The practices and processes for material qualification and transition that were established through the 20th century were developed under a very different environment than what is expected for the future. The insertion of new structural materials for DoD applications has become much more difficult and less frequent, with materials themselves increasingly becoming a constraint on the design process. The materials that are being developed today and those envisioned for the future will not be served by the historic qualification and transition processes of past programs due to the changing defense acquisition model. The defense materials community and associated stakeholders must work together to evolve current practices if they are to effectively exploit new emerging material concepts for national defense initiatives. Recently, experts gathered to discuss and address these challenging materials transition issues. The presentation summarizes the background to the changing materials transition paradigm, future challenges, stressors on current practices, recommendations for going forward, and some best industry practices.

Assigned Session: B 1 Failure Prevention for Materials and Structures

Presenting Author: Ed Habtour **Ser:** 78

Organization: US Army Research Laboratory: Vehicle Technology Directorate

Country:

Paper Title: **Damage Accumulation Rate Computation in the Frequency Domain Due to Random Loading Using FEM-RFC Model**

Co Authors: Mark Paulus: Naval Undersea Warfare Center Division, Keyport, Washington
Abhijit Dasgupta: Department of Mechanical Engineering, University of Maryland, College Park, Maryland

Abstract:

Modern military aerial and ground vehicles have given rise to a host of new reliability problems in due to random vibration loading. The loading environments generated in these systems vary randomly in both time and space over wide range of frequencies. Such loads can cause severe vibration fatigue damage leading to catastrophic failure. Modeling the fatigue damage under such complex environment is difficult and expensive in the time domain. A general model that combines the Finite Element Method (FEM) with the Rate of Frequency Change model is developed to predict fatigue life of structures experiencing random vibration using only frequency domain information. Execution of the combined FEM-RFC model requires only the input power spectral density, damping factor and material properties. In the FEM-RFC model the damage accumulation rate is computed in the frequency domain using Linear Elastic Fracture Mechanics (LEFM). The model has been validated, analytically and experimentally using a cracked cantilever beam. Integrating the FEM with the RFC model allows the model to be extrapolated to more complex geometries for which closed-form stress intensity values are not available. The model may be extended to accelerated life testing, virtual qualification and life-cycle assessment. It can be used as a degradation model to analyze the relative severities of complex structures under harsh vibration environments. No explicit knowledge of the time history is needed. Such an approach may reduce the computation time and cost required to run a fully explicit FEM analysis.

Assigned Session: B 1 Failure Prevention for Materials and Structures

Presenting Author: Marc Pepi **Ser:** 8

Organization: US Army Research Laboratory

Country:

Paper Title: **Ultrasonic Shot Peening as a Field Deployable Alternative to Conventional Shot Peening**

Co Authors: Brian Gabriel US Army Research Laboratory Dr. Doug Wolfe Penn State University – Applied Research Laboratory

Abstract:

The work herein describes efforts made to determine the feasibility of ultimately utilizing a table top ultrasonic shot peening (USP) piece of equipment in a maintenance depot setting. To accomplish this, aluminum specimens were fabricated and subjected to conventional as well as ultrasonic shot peening, as well as laboratory tests, including; surface roughness and residual stress. Although the residual stress profiles of the USP samples were slightly different from those generated from conventionally peened samples, it was determined that each method yielded similar compressive stresses and depths of penetration. Even with these positive results, it was determined that the unit tested would probably not stand up to a depot environment, as it was not very robust.

Assigned Session: B 1 Failure Prevention for Materials and Structures

Presenting Author: Matt Motyka **Ser:** 66

Organization:

Country:

Paper Title: **Investigation of Failed Missile System Launcher Bolts**

Co Authors:

Abstract:

U.S. Army Research Laboratory was requested to investigate the cause of failure on several missile system launcher bolts found failed shortly after installation. Two failed bolts and two intact bolts were submitted for evaluation. Optical and electron microscopy, energy dispersive spectroscopy, metallography, hardness testing and a review of the manufacturing specifications were conducted while assessing the failure. The bolts were found to have failed at the head/shank interface from a hydrogen embrittlement mechanism. These bolts were NAS1351-10H52P bolts manufactured in accordance with National Aerospace Standard NAS1351. There are three specific requirements for hydrogen embrittlement to occur; a susceptible material, stress (either residual or externally applied), and a source of hydrogen. Although there is considerable debate in the technical community over the specific strength level at which steel becomes susceptible to hydrogen, there is general consensus that 180 ksi is well over the threshold. The source of stress in this work is obviously the clamp up torque applied to the bolts. The source of the hydrogen, since the bolts were new, was a manufacturing process. The most likely cause was an insufficient bake relief after the cadmium plating process. SAE-AMS-QQ-P-416 governs cadmium plating and ASTM-F-519 governs hydrogen embrittlement evaluation of plating processes and service environments. The requirement for material at this strength level is to bake relieve after plating at 375ºF +/- 25ºF for 23 hours minimum within 4 hours of the plating process. The “within 4 hours” requirement is sometimes where things can go wrong. The amount of blocky and cracked intergranular morphology observed on the fracture surfaces was not overwhelming. In other words, there exist far worse cases where the entire fracture surface is blocky and intergranular. This was indicative of two things. Some form of bake relief was likely performed that relieved some of the imparted hydrogen from the plating process (but it was inadequate in either time, temperature, or 4-hour window after plating), otherwise the hydrogen damage would have been far worse. Secondly, it demonstrates how important it is to follow the exact procedures. After the 4-hour window, longer times or higher temperature does not relieve the hydrogen damage. Yet, even the most out of control plating bath procedure would likely be adequately hydrogen relieved by baking at 375ºF +/- 25ºF for 23 hours minimum within 4 hours of the plating process. Every high strength steel has a threshold for accepting imparted hydrogen, based on a number of parameters. Once that threshold is exceeded, excess hydrogen migrates to the grain boundaries of the steel over time with stress or increased temperature, and the material fractures at far lower than expected values under an applied or residual tensile stress. ARL has examined cases that were in service for over 10 years before failing, and others with as low as 15% of the ultimate tensile strength applied.

Assigned Session: B 1 Failure Prevention for Materials and Structures

Presenting Author: Casey Holycross **Ser:** 12

Organization: US Air Force Research Laboratory

Country:

Paper Title: **Comparison of Fatigue Life Results between Load Controlled Coupon Specimens**

Co Authors: Tommy George, Casey Holycross

Abstract:

Due to the desire of gas turbine engine component designers to develop a material based fatigue life assessment model from simple geometry specimen data, the effects of specimen geometry and machining procedures on fatigue life results are observed. Two specific fatigue specimen geometries are observed in this study: a rectangular cross-section (plate stock) and circular cross-section (round stock) dogbones. The analysis is conducted by correlating the different geometry effects of each specimen to their corresponding fatigue life results. The key geometry effects used in this correlation are the slipping of grains at the sharp edges of the plate stock specimens versus uniformly bordered grains on the surface of bar stock specimens, and surface area to cross-sectional area ratio. These effects are quantified statistically to assess the difference between the fatigue life results of each specimen. Therefore, a model with the capability of using empirical fatigue life data from round stock specimens to predict fatigue life of plate stock specimens, and vice versa, is generated. Benefits of this empirical data life determining model will serve as a benchmark for future work in predicting fatigue of complex geometries using simple dogbone specimens.

Assigned Session: C 1 Data Mining and Management

Presenting Author: Doug Farrell **Ser:** 2

Organization: National Instruments

Country:

Paper Title: **Data Management Techniques for Predictive Monitoring and Prognostics**

Co Authors:

Abstract:

By their very nature, predictive maintenance and machine monitoring generate astronomical amounts of data from the various sensors measuring machine parameters. A single system with five accelerometers measuring at 50 kHz sample rate results in 600 GB of data per week. Clearly a solution is needed that makes this data easier to digest without sacrificing the granularity desired in the history of the machine's health.

This paper will examine and discuss techniques for responsible data reduction and proper storage formats for making the data easily searchable and useful, including the technical data management storage management (TDMS). It will also discuss the advantages of using the TDMS data storage format for transferring information between the steps of a prognostics algorithm.

Assigned Session: C 1 Data Mining and Management

Presenting Author: Harlan Shober **Ser:** 69

Organization: RJ Lee Group Inc

Country:

Paper Title: **Saving Man Years, Big Data Techniques, and Your Data**

Co Authors:

Abstract:

“Big data is data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or doesn't fit the structures of your database architectures.” Many organizations do not even realize that they have a Big Data problem. They spend tens of millions to extract, transform and load there data into relational data bases without knowing the current and future uses of that data. Much of the data that is collected could, and should, be managed with new strategies.

This presentation will discuss your organizations top 10 most pressing data issues from “Data being collected by your content experts before a complete strategy for storing such data is complete” to “Organizations’ inability to handle the volume, velocity, and variety of data that is being collected today”.

Discussed will be the former CIA director Michael Hayden categorization of the data management lifecycle and its impact on data collection strategies.

Finally, this presentation will explain how applying these new “Big Data” management strategies to your organization’s data issues can save your organization time and money while still meeting the requirements of the defined data management lifecycle.

Assigned Session: C 1 Data Mining and Management

Presenting Author: Doug Farrell **Ser:** 3

Organization: National Instruments

Country:

Paper Title: **Cloud Computing in the World of Machine Failure Prevention**

Co Authors:

Abstract:

Machine failure prevention is built on the effective storage and analysis of data. The more data and analysis that can be performed, the higher the confidence value of the diagnosis or prognosis of the machine. As demand for data storage and computing horsepower increase, we find ourselves increasingly at the mercy of performing more and more data management and with less and less time to perform actual machine diagnostics. Through the use of cloud computing, much of this data management can be outsourced, without having to rely on the politics or red tape associated with creating new IT infrastructure internally.

This paper will discuss the architectures and advantages of cloud computing in a machine diagnostics setting including scalable remote data storage and processing power. Caveats and recommended best practices will also be covered including the options available for use by engineers and researchers today.

Assigned Session: C 1 Data Mining and Management

Presenting Author: Matt Sedlak **Ser:** 85

Organization: RJ Lee Group Inc

Country:

Paper Title: **An Information Management Implementation for RDT&E Centers using Big Data techniques**

Co Authors:

Abstract:

The United States Department of Defense (DoD) ground based Research, Development, Test and Evaluation (RDT&E) centers founding mission is to assure United States military technological weapons superiority has been achieved. A more current need that some of the RDT&E centers can fulfill is producing more weapon systems with increased efficiencies and reduced costs. The main cost of modern weapons system acquisition is re-engineering costs, which account for more than 50% of acquisition costs in the majority of procurements. The number one cause of re-engineering costs is undertaking weapons systems acquisition without all necessary technologies at a Technical Readiness Level 6 (TRL 6). Certain RDT&E center Test facilities have more than 50 years of test data and many million hours of human expertise and knowledge that can be applied to move necessary technologies to TRL 6 or higher, hence greatly reduce or even eliminate re-engineering costs. For one large program such as the Joint Strike Force (JSF) fighter plane, the re-engineering cost alone exceeded $50 Billion.

For certain RDT&E centers, their expanded definition of IT encompasses data acquisition, processing, analysis, storage, transport, instrumentation, computers, control systems and related software and hardware. Grouping all electronic components required for testing makes a technical IT needs analysis possible for the future missions that complements and builds on the facilities, experience and information investment of the previous mission.

This presentation will discuss an information management solution that is currently being implemented using “Big Data” techniques to address the RDT&E centers need for data integration and knowledge discovery of DoD weapons system Engine and Flight Test data.

The expected benefits include increasing the RDT&E center’s ability to provide insightful analysis at all stages of an Engine and Flight acquisition program thus reducing risk while eliminating waste and unnecessary costs that contribute to the USAF and DoD’s longer-term goal to generate greater efficiencies and capabilities ($100B cost savings in the next 5 years).

Assigned Session: C 1 Data Mining and Management

Presenting Author: Dick Holzwarth **Ser:** 91

Organization: Air Force Research Laboratory

Country:

Paper Title: **Airframe Digital Twin: Creating Virtual Replicas of Every Aircraft in the Fleet**

Co Authors:

Abstract:

Assigned Session: A 2 Condition-Based Maintenance 1

Presenting Author: Jack Poley **Ser:** 25

Organization: Kittiwake Americas, Inc

Country:

Paper Title: **The Metamorphosis of Oil Analysis**

Co Authors:

Abstract:

Oil analysis (OA) was considerably modernized in the late 1940s when American railroads began testing diesel engine oils for wear metals, shifting the focus of lube testing to machine condition, rather then the lubricant's condition. While the latter was still of importance for most effective diagnostics, maximizing machine protection and production was now the new goal. OA has, until quite recently, been mostly a remotely rendered service: the Customer sends a sample to a Lab and the Lab returns a report to the Customer. While this process has worked with good effect for over 60 years, it has always had inherent weaknesses due to its remoteness from the Machine. Technology over the last decade however has developed to a state where the OA model has shifted from a remote activity to a highly integrated concept, featuring three distinct aspects or "Tiers" in the testing paradigm, which includes real-time data acquisition. Tier 1 (Online): Real-time monitoring occurs when sensors of varying types are placed in the oil circuit, or a slipstream thereof. Immediate feedback is available. Tier 2 (Onsite): Though sensors produce a variety of information, it is almost always necessary to vet the readings, once they reach 'abnormal' levels. This can often be accomplished at the machines' location. As with the advent of sensors, modern technology has produced numbers of compact testing instruments and kits that function Onsite, requiring substantially less cost, sample volume, test equipment footprint and skills sets to utilize effectively. Tier 3 (Offsite): Offsite testing, the initial format in OA, consists of samples submitted to a full-service Lab for analysis. While Tier 3 testing is still necessary, its position and role is, perforce, beginning to change. Ever-increasing complexity and costs in machinery and lubricants maintenance has fueled interest and demand for Tier 1 testing, adding fresh duties and importance to Tier 2 testing while re-defining the role of traditional Tier 3 testing.

Assigned Session: A 2 Condition-Based Maintenance 1

Presenting Author: Adrian Messer **Ser:** 34

Organization: UE Systems Inc

Country:

Paper Title: **Ultrasound Assisted Lubrication Best Practices**

Co Authors:

Abstract:

When you consider that as many as 60 to 80 percent of all bearing failures are lubrication related , this represents an area where many opportunities lie where these types of bearing failures can be avoided by utilizing predictive technologies such as ultrasound. Lubrication related failures includes both over and under lubrication. Also, the use of the improper lubricant can greatly decrease the life expectancy of the bearing. Consulting your lubricant provider for recommendations for the correct lubricant for your application is critical.

Typical lubrication programs rely solely on a timed based interval. This interval is set up is usually based on either the bearing/equipment manufacturer's recommended amounts, or the recommendations from the lubricator based on how much grease they have been applying at each PM. The tendency for time based lubrication routes is to over lubricate. Additionally, what if the bearing already has enough grease? If the bearing already has enough lubricant, more grease will be applied during a scheduled PM. Another question that should be asked is what if the bearing needs more grease than what is being applied during the scheduled PM?
Adding ultrasound monitoring to standard lubrication best practices that are already in place can help to reduce the number of failures due to over and under lubrication of bearings. The advantages of condition based lubrication rather than a time based lubrication approach are fewer bearing failures, extended motor & bearing life, and a decrease in the amount of lubricant used. All of these add up to potential savings in maintenance costs, man-hours spent lubricating, and improved asset availability.

Assigned Session: A 2 Condition-Based Maintenance 1

Presenting Author: Junda Zhu **Ser:** 32

Organization: University of Illinois at Chicago

Country:

Paper Title: **Survey of Lubrication Oil Condition Monitoring, Diagnostics, and Prognostics Techniques and Systems**

Co Authors: Junda Zhu Eric Bechhoefer, NRG Systems

Abstract:

Recently, an increasing demand for performance assessment of lubrication oil has been noticed. Considerable techniques and systems in lubrication oil condition monitoring have been developed and successfully utilized in many applications such as gasoline/diesel engines, gearboxes and etc. This paper provides an overview of the existing lubrication oil condition monitoring solutions and their characteristics along with the classification and evaluation of each technique. The reviewed techniques are analyzed and classified into four categories: electrical (magnetic), physical, chemical and optical techniques. The characteristic of each solution and its sensing technique is evaluated with a set of properties which are crucial for oil health monitoring, diagnostics and prognostics. A comprehensive comparison among a wide ranges of different lubrication oil condition monitoring solutions are conducted.

Assigned Session: A 2 Condition-Based Maintenance 1

Presenting Author: Matt Sedlak **Ser:** 68

Organization: RJ Lee Group Inc

Country:

Paper Title: **Reliability Centered Maintenance and the Application of Data Driven Automated Workflow into Engineering and Maintenance Disciplines**

Co Authors:

Abstract:

Reliability Centered Maintenance focuses highly structured consequence evaluation and policy selection algorithms to enhance preventative maintenance planning. While it incorporates precise and easily understood criteria for deciding which (if any) proactive maintenance tasks are feasible and worth doing, it is only through the implementation of those processes that an RCM engineering or maintenance plan will realize the benefits.

This presentation will discuss a structured approach to standardizing and automating the alert, notification and recording of actions taken related to an RCM decision. In addition, this presentation will describe how the capture of these data points at the time of execution will provide valuable feedback into a continual improvement process focused on getting more out of the RCM strategy as it evolves. All this effort provides focus on the end goal of allowing the operations organization to get better at what it does.

Assigned Session: A 2 Condition-Based Maintenance 1

Presenting Author: Chris Hockley **Ser:** 71

Organization: The Defence Academy, UK

Country: United Kingdom

Paper Title: **Current Research Activity on the Impact of No Fault Found (NFF) On Maintenance Effectiveness through Life**

Co Authors:

Abstract:

Maintenance Effectiveness and Efficiency need to be one hundred percent if service and availability are to be delivered to customer's expectations. However, the occurrence of faults where the cause cannot be determined, usually described in the UK as No Fault Found (NFF) and in USA as Retest OK (RTOK) can often be a huge and disruptive pressure on the successful delivery of support to the customer. The NFF problem affects many industries and often in different ways, yet good lessons are often not being shared. What is clearly not in doubt is that huge sums of money are still being wasted by not sharing best practice and not understanding the true cost of the problem. This paper will provide a summary of the NFF problem and explain the common causes; it will describe the impact and some of the solutions identified in the project underway at the EPSRC Centre for Innovative Manufacturing in Through-life Engineering Services at Cranfield University to research the problem across different industries

Assigned Session: B 2 Failure Analysis

Presenting Author: Debbie Aliya **Ser:** 35

Organization: Aliya Analytical

Country:

Paper Title: **Case Studies Using an Epistemologically Derived Systems Thinking Approach in a Failure Prevention Consulting Practice**

Co Authors:

Abstract:

How much work is enough work? How do we know that we have “done diligence” when we are planning a protocol for a machinery failure prevention project? Usually such projects are an outgrowth of a serious failure event of a series of events. If the consequences of even repeated failures are minimal, maybe spending a few hours to review the situation with eyeballs and brain, examining the machinery and some historical documentation, is enough. This gives a minimum of two ways to view the situation. If both eyeballs and brain point to the same place or at least don’t contradict each other, then we can take action and move on. However, if the failure can lead to major consequences, we probably need to do more up front work, before taking action to “prevent recurrence.” No single viewpoint can determine the answer to this question. A business decision, based on which criteria will be examined and in how much detail, must be made. The business decision will be made in an ethical manner when an evolving, non-linear, transparent ethical hierarchy is used to flexibly plan the work scope.

Assigned Session: B 2 Failure Analysis

Presenting Author: Robert Tryon **Ser:** 14

Organization: VEXTEC Corporation

Country:

Paper Title: **Accelerated Corrosion Testing for Coated Turbine Compressor Blades Using Small Turbine Engine Capabilities**

Co Authors: Richard Holmes, Thomas Brooks

Abstract:

Not all corrosion resistant blade coatings are developed and applied equally well. Conventionally used laboratory testing cannot adequately replicate the realistic engine environment well enough to identify which coatings work from those that do not from a durability perspective. Full-scale engine testing costs are staggering and access to full-scale engine testing is limited. Rarely is such testing practical for coating development and prove out. The most often used alternative is laboratory corrosion resistance testing. Static lab testing is the most commonly used procedure -while inexpensive, the results produced simply do not represent the dynamic environment of a real operating engine. Even additional “fog testing” - placing coated specimens in a cloud of caustic vapors – does not at all represent the true interaction of temperature, gas stream velocity, blade velocity and caustic vapor in the actual engine environment. The USAF provided VEXTEC with the seed funding to develop a more effective and inexpensive alternative to conventional laboratory (static) corrosion testing. VEXTEC built a small scale turbine test rig to reproduce the type of corrosion desired by the USAF. VEXTEC’s test rig was able to reproduce the corrosion on the USAF turbine blades and further evaluate three different types of coatings for the USAF to mitigate the corrosion issues being experienced. The test was effective at producing the desired results and was performed in an accelerated time frame. The presentation for the 2012 conference will discuss the small turbine test set-up and results obtained from this corrosion testing case study.

Assigned Session: B 2 Failure Analysis

Presenting Author: Bob Ware **Ser:** 75

Organization: AFRL/RXSA

Country:

Paper Title: **Air Force Analysis of Failures Induced by Manufacturing Variability**

Co Authors:

Abstract:

Analysis of failures at the Air Force Research Laboratory has identified various causal factors, including manufacturing variability. Three examples will be presented to illustrate how inadequate control of manufacturing processes resulted in defects which compromised performance, sometimes with tragic consequences. The first case history will describe improper manufacturing of a forward longeron on a fighter aircraft. The defects contributed to fatigue and fracture, ultimately resulting in loss of the aircraft. Similar conditions were identified in other aircraft in the fleet. The second study will describe metallurgical alterations induced during drilling of a titanium fan disk. This defect led to disk fracture in a commercial airliner resulting in two civilian fatalities. The final example will describe high speed machining of a emergency egress door on a transport aircraft. Vibrations induced during the machining process resulted in cracking of the component. The manufacturing process had to be modified in order to produce uncracked components. Collectively, these case histories underscore the need for improved monitoring of manufacturing processes to prevent manufacturing induced defects. Effective process monitoring, in conjunction with appropriate nondestructive inspections, can minimize the safety risks associated with manufacturing induced defects.

Assigned Session: B 2 Failure Analysis

Presenting Author: Rudy Scavuzzo **Ser:** 11

Organization: Engineering Consultants Group, Inc.

Country:

Paper Title: **Effect of Ground Surface Depth in Helical Compression Spring Stresses**

Co Authors: Chance M. Kleineke2 Joseph L. Hoffmann2, PE

Abstract:

A prevalent coal mill design uses stiff compression springs to force rolls onto a rotating bowl to grind coal prior to combustion in a boiler. The springs are usually plain end (constant pitch) with ground flats at each end. Preloads on these springs are typically 10,000lb to 40,000lb. These springs most often fail in fatigue near the ground flat at ends of the spring. Detailed finite element analyses show that stress concentrations are developed near the flat surface at each end of the spring.

First, this paper presents some field experience of spring failures. Then, a parametric study of the depth of the ground of a typical spring showing the effect of this geometry change on spring wire stress concentrations is presented. Modeling the solid volume of the helical spring wire with a mechanical drawing program was developed. This geometry was imported into a finite element program for the rest of the modeling. A cutting plane was used to depict the ground flat. The resulting volume was then meshed with solid finite elements. A force was applied to the ground flat area of one end to stress the spring while the other spring end is constrained in all six degrees of freedom. Some typical spring failures that occurred in the field are presented showing agreement between the predicted location of the stress concentration and the failures.

Assigned Session: B 2 Failure Analysis

Presenting Author: Chance Kleineke **Ser:** 72

Organization: Engineering Consultants Group, Inc.

Country:

Paper Title: **Static and Dynamic Analysis of a Coal Bowl Mill**

Co Authors: Chance Kleineke Engineering Consultants Group, Inc 3394 Market Street Akron, OH 44333

Abstract:

The presentation presents the development of the finite element model that is used for both static and dynamic analyses. The static analysis of the system shows critical stresses are developed in the mill shaft if there is a broken spring used to preload the rollers. At times, shaft failures occur due to these bending moments on the shaft. Dynamic loading can also amplify these static loads In addition, a dynamic analysis of the system was rum by approximating the sliding between the rolls and bowl by pinning the bottom of the rolls to the bowl. Using small angular displacements of the bowl and shaft, the calculated motions of the rollers are found to be similar to measurements but the calculated magnitudes and much less than measured values.

Assigned Session: B 2 Failure Analysis

Presenting Author: Dongxiang Jiang **Ser:** 73

Organization: Tsinghua University

Country: China

Paper Title: **Failure Mechanism and Fault Diagnosis of Power Equipment**

Co Authors: Chao LIU, Jie CHEN State Key Laboratory of Control and Simulation of Power System and Generation Equipment, Department of Thermal Engineering, Tsinghua University, Beijing 100084, P. R. China

Abstract:

Due to the large size and the high cost in power plants, failures occurred of power equipment will cause significant loss. And the power outage may cause severe consequences. Therefore fault diagnosis is essential in power equipment as well as the failure mechanism. Based on the failures and faults occurred in China in recent years, this presentation analyzes the cracks, rubbing, abrasion, creep, and bending failure mechanisms of large-size steam turbines and the typical failure mechanisms in wind turbines. Finite Element Analysis (FEA) is applied to analyze the load response and the local stress. The coupled vibration is solved with the detailed rotor model and the synchronous generator model in the crack failure of the steam turbine caused by the grid disturbance. The creep analysis is carried out with the thermal loads of the steam flow in the bending fault of the rotor. The failure mechanisms are determined and failure prevention approaches are proposed. The presentation also introduces the fault experiments of the rotating machinery in the laboratory, including the fault tests on a small wind turbine test rig, the fault tests on a rotor test rig and the faults tests on a gearbox test rig. The signal processing methods are analyzed with the test data and the fault diagnostic methods are studied including the wavelet decomposition, Intrinsic Time-scale Decomposition (ITD), neural network approaches, data mining and rule-based systems.

Assigned Session: C 2 Health Management Architectures

Presenting Author: Jean-Baptiste Leger **Ser:** 43

Organization: PREDICT & DIAG 21

Country: France

Paper Title: **New Approaches for Ships Fleet-wide Management and Naval Mission Prognostics**

Co Authors: Flavien Peysson (1)(2) Claude Allemand, DCNS claude.allemand@dcnsgroup.com DCNS, BP 517, 83041 Toulon Cedex 9, France Mustapha Ouladsine(2), LSIS UMR CNRS mustapha.ouladsine@lsis.org Laboratoire des Sciences de l'Information et des Systèmes, Aix-Marseille University, UMR CNRS 6168, Domaine Universitaire de St-Jerôme, 13397 Marseille Cedex 20, France Benoît Iung (1)(2), CRAN UMR CNRS benoit.iung@cran.uhp-nancy.fr Centre de Recherche en Automatique de Nancy (CRAN), Nancy Université, UMR 7039 CNRS-UHP-INPL,UMR 7039 CNRS-UHP-INPL, Faculté des Sciences-1er Cycle - BP239, 54506 Vandoeuvre-Les-Nancy Cede, France --- (1) The authors are all members of the French DIAG 21 Association (www.diag21.com). Pr Iung is co-chairing the prognostic working group. (2) The authors are members of the PHM Society.

Abstract:

Ships are large complex systems composed of multiple heterogeneous subsystems and equipments interconnected to accomplish various missions. In civilian and defense naval domains, ships are usually operated as a fleet. Thus, in order to enhance maintenance efforts and facilitate the decision-making process, it is necessary at the fleet level to provide managers and engineers with a complete summary of information and keep them updated regarding both the global health of the fleet and the present status of their maintenance efforts. Moreover, fleet-wide performance is a daily concern for which mission readiness and maintenance management need to implement proactive strategies, mainly supported by a prognostic process. This paper deals with generic approaches of fleet-wide management and mission-based prognostic in order to anticipate the health of fleet equipments.

Assigned Session: C 2 Health Management Architectures

Presenting Author: Surya Kunche **Ser:** 38

Organization: Center for Advanced Life Cycle Engineering

Country:

Paper Title: **A Review of PHM System's Architectural Frameworks**

Co Authors: Chaochao Chen, Michael Pecht

Abstract:

The need for a Prognostics and Health Management (PHM) system is propelled by increasing demand for condition based maintenance for systems to reduce cost of maintenance and mitigate risk. The use of multiple algorithms for PHM for a variety of systems presents challenges for PHM system developers in terms of integration and interfacing of various components, including hardware and software. A PHM system comprises of several elements including sensors, computing hardware and software algorithms for fault detection, diagnostics, prognostics and decision support. Thus there is a need for an architectural framework to help system developers and integrators for faster system development and deployment.

An architectural framework provides a blueprint to enable the constituent subsystems to serve the overall purpose of the system. This also facilitates the interoperability of PHM systems with various applications. It provides a holistic view of the system for system developers and thereby forms the basis for building a system or serves as a guide for system modeling, integration and testing. This paper reviews the architectures proposed in literature for a PHM system. The architectural frameworks proposed for various PHM applications are also discussed and reviewed. The reviewed frameworks integrate various functionalities of the PHM system including data acquisition, signal processing, feature extraction, anomaly detection, diagnostics, prognostics and decision support. The architectures are categorized as either functional or physical architectures. The advantages and shortcomings of these proposed frameworks are also discussed.

Assigned Session: C 2 Health Management Architectures

Presenting Author: J B Schroeder **Ser:** 65

Organization: AFRL/RBCC

Country:

Paper Title: **Space Sortie Production; the Role of HM in Creating the Factory of the Future**

Co Authors: Greg Moster

Abstract:

The DoD, in partnership with Industry, are pursuing enterprising initiatives to replicate the operations and logistics associated with modern day air travel, in the space domain. The future vision is for space vehicles to land, be turned round within 24 hours, and re-launched. This realization of this vision is going to rely heavily on the extensive R&D into Prognostics and Health Management (PHM) undertaken during the past 20 years. The health and condition of all systems are going to need to be known when the space vehicle is on the platform being readied for launch, and at all times during operation and while being turned around. Moreover, the rocket that assists the space vehicle into orbit, will need to perform challenging maneuvers after detaching so that it can return safely to earth for re-use. Prior knowledge that the rocket's systems are in sound health, right down to the last actuator, is needed before the maneuvers are attempted. The presentation will address the HM tools and capabilities that will need to be integrated into the Space vehicle, and its ground support facilities, such that accurate and reliable information on the state of the vehicle is always available to the operators and maintainers.

Assigned Session: C 2 Health Management Architectures

Presenting Author: Jim Lally **Ser:** 94

Organization: PCB Piezotronics Inc

Country:

Paper Title: **In Pursuit of Flight - 1914 Style: Transatlantic Flying Boat by Curtiss**

Co Authors:

Abstract:

Assigned Session: A 3 Signal Analysis

Presenting Author: Thomas Lagö **Ser:** 55

Organization: TechFuzion

Country:

Paper Title: **Proper Amplitude Estimation Strategies for CBM Applications**

Co Authors:

Abstract:

In many CBM applications, the basic assumptions for the analysis used is forgotten or "ignored." This can lead to large amplitude errors and completely mislead the analysis. This will most likely be devastating for prognosis since the amplitude errors are likely to be very large. This paper describes some of these errors and how this can lead to wrong conclusions and or results. By understanding these errors and why they exist, it is possible to mitigate and/or minimize their impact on the end results. Common challenges could be improper selection of anti-aliasing filters and/or sampling rate versus the filter bandwidth and roll-off rate. Another challenge is related to that signals analyzed do not obey the proper properties and hence large amplitude errors could become the result. In this paper, an example of 100,000 percent amplitude error is presented and this actually happens in real life more often that one might expect. The background to the challenges is discussed and proper solutions or strategies to avoid such errors are presented.

Assigned Session: A 3 Signal Analysis

Presenting Author: Preston Johnson **Ser:** 1

Organization: National Instruments

Country:

Paper Title: **Time Synchronous Averaging of Non-integer Multiples**

Co Authors:

Abstract:

Time synchronous averaging (TSA) is an important technique for machine condition monitoring. By removing random noise and non related signal components from a time domain signal, TSA allows for cleaner analysis and diagnosis of machine faults. One of the limitations of current TSA techniques however is that they require a trigger, often the tachometer signal of a rotating machine, to determine what data is averaged together. This unfortunately, results in averaged time domain chunks that can only be integer multiples of the tachometer frequency which is often only one rotational cycle long. This paper will introduce and discuss a technique that allows for non-integer rotational cycle multiples of time domain data to be averaged through an angle clock time synchronous averaging method.

Assigned Session: A 3 Signal Analysis

Presenting Author: Gianluca Nicchiotti **Ser:** 60

Organization: Meggitt SA

Country: Switzerland

Paper Title: **The Role of Hough Transform for Automatic Interpretation of Spectral Correlation Diagrams**

Co Authors: Gaëtan Giner Ecole d'Ingenieurs et d'Architectes de Fribourg

Abstract:

Cyclostationarity analysis has been proved to be very effective to detect and classify rolling bearing faults. To detect 2nd order cyclostationarity properties in signals, spectral correlation density diagrams are computed. They are frequency- frequency diagram, where peaks are associated to the bearing fault frequencies.

In spectral correlation diagrams peaks due to bearing faults present typical rhomboidal patterns. However spectral correlation diagrams can result pretty complex to interpret when bearing faults are at the initial stages. From a prognostics stand point, the detection of bearing defects at an early stage is fundamental to track the fault evolution.

Hough transform is a feature extraction technique used in image processing. It allows identifying arbitrary shapes within an image (straight lines or circles) in presence of low SNR values.

This paper presents a novel approach for the analysis of spectral correlation density diagrams based on Hough transform. The integration of Hough transform within the framework of the spectral correlation analysis aims at improving the detection and classification of bearing defects patterns at the initial stage of the fault.

A fully automated method for detection and classification of bearing faults will be presented. In such strategy the coherent (complex) Hough transform has the role to improve the robustness of the detection and the classification stage.

Assigned Session: A 3 Signal Analysis

Presenting Author: Joe Sheeley **Ser:** 82

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

Country:

Paper Title: **Features of a Useful Plant Machinery Online Monitoring System**

Co Authors:

Abstract:

The evaluation of machinery condition using vibration analysis and other monitoring techniques has long been the niche of highly skilled analysts who rely on their experience, reason, and the remarkable ability of the human mind to spot patterns in data to detect faults. The shear expense of data collection equipment, along with limitations in hardware data storage and processing capability have also lead to all but the most rudimentary parameter monitoring being done either on a periodic route-based schedule or on an as-needed basis by an analyst with a hand-held data collector. Increases in processor capacity and data storage, coupled with cost-saving technologies such as wireless sensors, have started to enable the cost-effective adoption of online data collection for detailed vibration analysis, at least for high-value systems. The increased collection of data in itself will not improve monitoring unless an effective process for evaluating those data is established. This has lead to the need for the creation of software tools to increase the efficiency of existing analysts in terms of both automation of some aspects of machinery diagnostics and to facilitate data processing and viewing. Flight vehicles – helicopters in particular – have been using automated systems for health monitoring and diagnostics for several years. While it is tempting to attempt to simply utilize those systems for plant machinery monitoring, there are special aspects of plant operations that must be considered in monitoring system design. In particular, there are tens to hundreds of different machines in the typical plant, versus hundreds of copies of the same air vehicle design in operation, and there is little or no control by the vibration analyst over when and how plant machinery will be run. In addition, while the criticality of the reliability of air vehicles may justify the availability of trained personnel to analyze data soon after it is collected, many plant machinery owners may have a limited technical staff or need to rely upon consultants as needed for in-depth diagnostics. In this paper the special requirements of an online plant machinery monitoring system will be presented along with design concepts that meet those requirements. The specific need for fast setup for new machine train types is addressed through the use of libraries of machines that include commonly used condition indicators and industry best-practices alarm setting. The requirement that time in the plant be minimized is addressed through close integration of the monitoring system code and the users' desktop program allowing for rapid field setups and data collection. Finally specific data processing algorithms, viewer s for the outputs of those algorithms, and methods to facilitate the creation of condition indicators from those screens are presented.

Assigned Session: A 3 Signal Analysis

Presenting Author: Suri Ganeriwala **Ser:** 84

Organization: SpectraQuest Inc

Country:

Paper Title: **Enhancing Bearing Fault Diagnosis Using Cepstrum Pre-whitening Technique**

Co Authors: Suri Ganeriwala, Jun Yang, and Ruoyu Li

Abstract:

Bearings are critical component in rotational machinery. The vibration signals generated by bearings are impulsive, non-periodic, and low amplitude. The signals are often buried in the high-amplitude components like imbalance and misalignment and random vibrations associated with friction, cavitation and other sources. These effects make it difficult to identify bearing fault frequencies in the vibration data acquired for bearing fault diagnosis. To improve the diagnostics, it is important to increase the bearing fault signal-to-noise ratio. In this paper, a cepstrum pre-whitening technique was used to remove the periodic components of the vibration signal to increase the bearing fault signal-to-noise ratio. And then envelope analysis with the filter bands optimized was applied to extract the fault features of the bearing. Bearing fault vibration signals with different types of seeded faults and damage severities were collected on a machinery fault simulator and a drive train diagnostics simulator (DDS). The test results have proven the effectiveness of the presented methodology. The performance of the presented methodology was also compared with the traditional envelope analysis.

Assigned Session: A 3 Signal Analysis

Presenting Author: Preston Johnson **Ser:** 86

Organization: National Instruments

Country:

Paper Title: **From Signal Processing to Prognostics**

Co Authors:

Abstract:

Next generation machine failure prediction technologies are incorporating prognostics technologies. These technologies build on signal processing of vibration time waveforms, process parameters, and operating conditions of the machine. For prognostics algorithms to work well, the signal processing algorithms need to be applied correctly and the results need to be reliable. This paper provides a survey of signal processing techniques as applied to specific machine component with a focus on the output and use with prognostics technologies. Signal processing techniques surveyed include vibration time series statistics, Fourier transform, Order Analysis, Cepstrum, Wavelet, Time Synchronous Averaging, and Envelope Spectrum. Prognostics algorithms include clustering, logistic regression, support vector machine, statistical pattern recognition, self organizing map, and Gaussian mixture

Assigned Session: B 3 Applications of Condition Monitoring/Health Management

Presenting Author: Chris Smith **Ser:** 63

Organization: Integrated Material Management Center, CBM

Country:

Paper Title: **Army Implementation of CBM: 2012 Update**

Co Authors:

Abstract:

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

Assigned Session: B 3 Applications of Condition Monitoring/Health Management

Presenting Author: Eric Olson **Ser:** 88

Organization: Mechanical Solutions Inc

Country:

Paper Title: **Health Management and Condition Based Maintenance – An Industrial Perspective**

Co Authors:

Abstract:

Assigned Session: B 3 Applications of Condition Monitoring/Health Management

Presenting Author: Wenyu Zhao **Ser:** 89

Organization: Center for Intelligent Maintenance Systems

Country:

Paper Title: **IMS Successes in Applications**

Co Authors:

Abstract:

Assigned Session: B 3 Applications of Condition Monitoring/Health Management

Presenting Author: Mark Walker **Ser:** 90

Organization: General Atomics – Electromagnetic Systems Division

Country:

Paper Title: **PHM Applications within General Atomics - HOLDING TITLE**

Co Authors:

Abstract:

Assigned Session: B 3 Applications of Condition Monitoring/Health Management

Presenting Author: Wade Clark **Ser:** 87

Organization: The GBS Group

Country:

Paper Title: **A Case Study in Wireless Data Collection, Visual Analytics and Health Management**

Co Authors: Wade Clark, Martin Mannion

Abstract:

Practical application of an automated near real time wireless data acquisition system collecting maintenance event data from a fleet of high speed passenger trains operating in the USA. The acquisition system enriches this data by adding GPS latitude/longitude coordinates along with geofencing and train speed. Web based visual analytics tools are used to explore event data to identify high level patterns and low level cause and effects. Specifically, interactive dashboards are used by a Functional Failure Analysis Team to quickly locate and understand functional failures on a system and subsystem level. Most importantly, functional failures that cross system boundaries can now be easily identified and studied with these dashboards. The new system knowledge gained by visually exploring this enriched data has enabled the operator to transition from a reactionary breakdown culture to a proactive reliability centered culture. The operator is now able to manage fleet health and can quickly identify an unhealthy asset that should be removed from revenue service thus avoiding an operational delay. The net result of this effort has been a reduction in train terminations by 29%, annulments by 50% and the addition of two more assets into revenue service resulting in increased ticket sales.

Assigned Session: B 3 Applications of Condition Monitoring/Health Management

Presenting Author: Subrat Nanda **Ser:** 92

Organization: GE Global Research

Country:

Paper Title: **PHM Technologies: Learning from Applications & Design**

Co Authors:

Abstract:

Assigned Session: D 3 Condition-Based Maintenance 2

Presenting Author: Erik Webster **Ser:** 64

Organization: Impact Technologies, A Sikorsky Innovations Company

Country:

Paper Title: **Prognostics Using Existing Data**

Co Authors:

Abstract:

Impact Technologies, working in collaboration with the US Air Force Warner Robins Air Logistics Center (WR-ALC), is developing a Prognostics and Health Management (PHM) approach to enable eventual widespread deployment of machinery prognostics across both commercial and DoD industrial manufacturing environments. The technology is being developed under a contract for the US Air Force that aims to provide transformational technology enabling the US Air Force to effectively embrace a more agile, cost effective maintenance management strategy.

The work presented in this paper is aligned with the USAF Depot Maintenance Strategic Plan, directly supporting several of the Continuous Process Improvement Initiatives (CPI) it outlines. Additionally, it supports the DoD CBM+ initiative by improving reliability and maintenance effectiveness of DoD operations and support systems.

This paper discusses techniques that leverage archived data, in combination with experience-based prognostic approaches and traditional reliability tools, to predict current and future probability of failure in light of past and future planned usage and rudimentary condition monitoring and inspection practices implemented on most industrial equipment.

Assigned Session: D 3 Condition-Based Maintenance 2

Presenting Author: Brendan Geels **Ser:** 76

Organization: Colorado School of Mines

Country:

Paper Title: **Reliability Model Development and Sensor System Optimization of the Gearbox Reliability Collaborative's 750kW Test Gearbox**

Co Authors: John Steele (Colorado School of Mines), Shuangwen Sheng (National Renewable Energy Laboratory)

Abstract:

Reliable and cost competitive wind turbines (WT) will play a significant role in the emerging market for renewable energy. WT's have traditionally been designed with robustness in mind in order to achieve a 20 year lifespan. However due to large variations in loading conditions, operators have been reporting premature failures within critical components such as the gearbox. Improvements in WT gearbox availability have been made in recent years with the introduction of condition monitoring systems. However, the complexity of the gearbox combined with a lack of available sensor data that covers failure events has made accurate fault detection and prognostics difficult. In order to improve WT gearbox availability and the accuracy of condition monitoring systems, an in-depth understanding of failure mode causality and effects must be developed. This can be achieved, in part, by building and analyzing a detailed reliability model. This paper will present the development of a WT gearbox reliability model using PHM Technology's Maintenance Aware Design environment (MADe), which allows for the creation of a Bond Graph-style energy flow model. The model is based on the Gearbox Reliability Collaborative's 750 kW test gearbox, and is used to simulate a cascade of failures which were recently experienced by this gearbox. A Failure Mode Effects and Criticality Analysis (FMECA) report and an analysis of optimal, cost-effective, sensor placement are also generated via the MADe software. Detailed reliability models of WT gearboxes will help improve understanding of the cascading effects of common failure modes and is an important first step in refining operation and maintenance practices, subsequently improving the turbine availability, within the wind industry.

Assigned Session: D 3 Condition-Based Maintenance 2

Presenting Author: Michael Bryant **Ser:** 29

Organization: University of Texas at Austin

Country:

Paper Title: **Model-based Fault Diagnostics of Induction Motor and Centrifugal Pump**

Co Authors: Jihoon Choi, SAMSUNG ELECTRONICS CO.,LTD. Mohsen Nakhaeinejad

Abstract:

As a machine ages, its components degrade. Parameter values in a model must change with ageing, for the model to continue to mimic machine behavior. If the model's parameters have a direct physical correspondence to components, tracking parameters can achieve condition monitoring. A system dynamics model consisting of differential equations derived from a bond graph model, will describe behavior of a squirrel cage induction motor and centrifugal pump system. The parameter values were be estimated by comparing simulations to sensor-measured system data, then altering (tuning) parameters until simulations overlay data. Faults such as a damaged stator circuit and pump leaks will be introduced, and located and assessed by parameter estimation. Finally, motor-pump health to perform its function will be assessed by applying to the motor-pump system, concepts from communications engineering that assess a communication system's ability to transmit and receive signals without undue error, despite faults in the form of noise.

Assigned Session: D 3 Condition-Based Maintenance 2

Presenting Author: Mitchell Lebold **Ser:** 44

Organization: The Applied Research Lab/ Penn State Univ

Country:

Paper Title: **Powertrain Diagnostics - Part 1 - Detecting Injector Deactivation Failure Modes in Diesel Engines Using Simple Time Domain Approaches**

Co Authors: Jonathan Bednar, Mitchell Lebold, Scott Pflumm, and Jeffrey Banks Applied Research Laboratory at, The Pennsylvania State University Kenneth Fisher and Joseph Stempnik VEA-CBM Team US Army RDECOM - TARDEC

Abstract:

This report documents the investigation of fuel injector fault detection methods for a seven liter diesel engine. This effort was conducted for the Tank Automotive Research Development Engineering Center (TARDEC) Condition Based Maintenance (CBM) team. The task of this investigation was to develop algorithms capable of real-time detection of injector misfire events. The purpose of this task was to enable TARDEC's Engine Control Management (ECM) research and development efforts to evaluate the technical feasibility of integrating automated on-board condition monitoring algorithms with future ECM monitoring and control operations.

During this investigation, it has been shown that multiple techniques can correctly detect and identify injector cylinder misfiring. Each individual technique has its own advantages, and this investigation focused on signal processing methods that would be suitable for embedding in an engine controller or processor. The list below includes six injector fault analysis approaches that were evaluated for this effort:

1. Injector signal analysis
2. Cylinder head vibration analysis
3. Crankshaft speed analysis in time domain
4. Crankshaft speed analysis in order domain
5. FFT classifier selection technique
6. Time domain classification technique

This paper highlights the first three diagnostics techniques. On-platform tests are suggested for technique validation and future development of these initial findings.

Assigned Session: D 3 Condition-Based Maintenance 2

Presenting Author: Mitchell Lebold **Ser:** 7

Organization: The Applied Research Lab/ Penn State Univ

Country:

Paper Title: **Powertrain Diagnostics - Part 2 - Detecting Injector Deactivation Failure Modes in Diesel Engines Using a Crankshaft Speed Order Domain Approach**

Co Authors: Applied Research Laboratory: Scott Pflumm, Jeff Banks, and Jonathan Bednar
VEA-CBM Team US Army RDECOM - TARDEC: Ken Fisher and Joe Stempnik

Abstract:

This report documents the investigation of fuel injector fault detection methods for a seven liter diesel engine. This effort was conducted for the Tank Automotive Research Development Engineering Center (TARDEC) Condition Based Maintenance (CBM) team. The task of this investigation was to develop algorithms capable of real-time detection of injector misfire events. The purpose of this task was to enable TARDEC's Engine Control Management (ECM) research and development efforts to evaluate the technical feasibility of integrating automated on-board condition monitoring algorithms with future ECM monitoring and control operations.

During this investigation, it has been shown that multiple techniques can correctly detect and identify injector cylinder misfiring.

Each individual technique has its own advantages, and this investigation focused on signal processing methods that would be suitable for embedding in an engine controller or processor. The list below includes six injector fault analysis approaches that were evaluated for this effort :

1. Injector signal analysis
2. Cylinder head vibration analysis
3. Crankshaft speed analysis in time domain
4. Crankshaft speed analysis in order domain
5. FFT classifier selection technique
6. Time domain classification technique

This paper only highlights the crankshaft speed order domain technique.

Assigned Session: D 3 Condition-Based Maintenance 2

Presenting Author: Chuck Blatchley **Ser:** 5

Organization: Pittsburg State University

Country:

Paper Title: **Effects of Cosmic Rays on SLA Wear Monitoring**

Co Authors:

Abstract:

The surface layer activation technique (SLA) has been used for several decades to precisely monitor wear of mechanical parts in engines and other machinery. In this technique, a thin surface layer of a material is made slightly radioactive by irradiation in a particle accelerator. As the activated surface wears during operation, residual activity in the part is measured by gamma ray spectrometry to precisely determine surface loss without shutdown. For reliable comparisons of later gamma emissions to the starting level, all sources of variability except for surface removal must be either eliminated, minimized, or corrected, including natural decay, behavior of the nucleonics, and background radiation. A persistent diurnal change in signal has now been identified as an effect of atmospheric tides on the cosmic ray background. This will allow corrections for changes in the cosmic ray background.

Assigned Session: A 4 Electronic and Power Systems Health Management

Presenting Author: Patrick Kalgren **Ser:** 53

Organization: Impact Technologies, A Sikorsky Innovations Company

Country:

Paper Title: **Embeddable Parametric Health Characterization of Power Drive**

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

Abstract:

Efficiency is one of the features that have been traditionally used as a parameter to evaluate the health of power drives. Even though it has great potential as health indicator, it also has the drawback of its large variance based on the load. Normalized power losses in the power converters have been used a more stable indicator that remains relatively constant for different loads. In this regard, successful accomplishments have been shown in power supplies (DC/DC converters) but there are large variations for this parameter for lower load currents. In this paper, a generalized approached is developed that includes other types of converters such as AC/AC, DC/AC, and rectifier (AC/DC). In order to accomplish this goal, the fundamental characterization I-V curve of power device is conducted with piecewise-linear approximation model that supports a general equation development for power losses based on the current. The results are extended to the complete power converter whose final characterization is based on two parts: 1) constant parameter and 2) a parameter that is load dependent. Simulation and experimental results are presented that corroborate the theoretical underpinnings.

Assigned Session: A 4 Electronic and Power Systems Health Management

Presenting Author: Thomas Lagö **Ser:** 57

Organization: TechFuzion

Country:

Paper Title: **Rapid Methods for Production Line Testing of Small Electrical Motors**

Co Authors:

Abstract:

In order to verify quality it is not uncommon that human listening tests are used to find challenges with e.g. small electrical motors. There are many disadvantages with human ears in a production line. Hence, the need for a more objective system design has been demanded. This paper discussed a system approach enabling very rapid testing in a production line with any sensors being mounted. The system is capable in dealing with the extreme background noise and electrical and EMI noise emissions. By using the proposed design and concept, a rapid testing has been accomplished yet with a high quality. The system has been tested in a production line and verified versus a series of production line testers. The paper will discuss some of the challenges with such a system but also how these challenges have been dealt with.

Assigned Session: A 4 Electronic and Power Systems Health Management

Presenting Author: Dennis Grosjean **Ser:** 74

Organization: Innovative Scientific Solutions Inc

Country:

Paper Title: **Arc-Fault Protection for 270-Vdc Power Equipment**

Co Authors: Daniel Schweickart, Air Force Research Laboratory, Wright Patterson AFB, OH

Abstract:

Unwanted electrical arcing is never beneficial, but can be particularly damaging in medium-to-high voltage dc environments. Recent advances in motor-control and switching technologies have created distinct weight and power advantages in the use of 270-Vdc brushless motors in aircraft. At this dc voltage level, the propensity of arcing to continue undetected for significant periods of time creates a need to monitor and mitigate arcing conditions. Arc-fault technology is currently being applied to ac-power distribution circuits, but arc-detection algorithms applicable to dc circuits are not yet sufficiently developed to be useful in practical, electrically noisy aircraft environments. The present state-of-the-art of arc-fault detection will be presented along with the causal relationships of the gas-discharge physics. Requirements for useful, reliable implementation—along with verification through standardized testing—will be discussed.

Assigned Session: A 4 Electronic and Power Systems Health Management

Presenting Author: Sonia Vohnout **Ser:** 19

Organization: Physical Optics Corporation

Country:

Paper Title: **Uptime Improvements for Photovoltaic Power Inverters**

Co Authors: Patrick Edwards and Neil Kunst

Abstract:

For optimum performance, the expansion of solar energy installations requires a robust and reliable infrastructure of panels, inverters and system control. Because of the geographically distributed and sometimes remote deployment of these solar power installations, reliability and performance is paramount to wider-scale adoption of these systems. Thus, it is very important to monitor the performance and identify any degradation of the critical system components early so mitigating actions can be taken. The most critical component in a solar energy system is the power inverter. The power inverter converts the DC output voltage of the panels to AC, which supports connections to the utility power grid, or to individual household power needs, depending on the size of the installation. This paper presents an innovative reliability-prediction system for photovoltaic (PV) solar power inverters. The significance of the innovation is that by supporting overall power system health management strategies and reducing maintenance costs for deployed systems by an estimated 20%, this system can save at least $26 billion a year in losses from power interruptions due to power grid failures. With savings of this magnitude, manufacturers and power providers can reduce their costs of products and services, therefore reducing the cost per kW to the consumer. Consumers in remote and isolated communities will also benefit from affordable and reliable off-grid power systems. The approach described in this paper includes hardware and software components that are easily integrated into existing inverter platforms, and provide state of health (SoH) and accurate remaining useful life (RUL) estimates. One of the best features of the approach is its modularity and easy applicability to various inverter configurations. We also will describe a real installation and remote data gathering system installed at a local solar facility.

Assigned Session: A 4 Electronic and Power Systems Health Management

Presenting Author: Patrick Kalgren **Ser:** 48

Organization: Impact Technologies, A Sikorsky Innovations Company

Country:

Paper Title: **Embeddable Platform for Modern Power Quality Monitoring**

Co Authors: Antonio Ginart, Irfan Ali, Patrick Kalgren, Mike Roemer

Abstract:

The use of a simple but powerful algorithm can be the answer for everyday diverse and pervasive power system monitoring. Traditional indicators for AC system fall short of being a representative of the more diverse and complex DC and AC systems found today. The L1 norm algorithm has provided an alternative to fill the need for this type of monitoring. L1 consists of the summation of the absolute value of the difference in samples for different window length. With the right manipulation of the window length, the results have proven to be similar to Haar wavelet but significantly less computationally intensive. This paper study has evaluated embeddable platforms that can carry out this type of monitoring without imposing a significant addition to the footprint of the system in terms of complexity, cost, size and weight. In order to so we selected a Digilent chipKIT Max32 board that has the possibility of 16 10-bit analog inputs, 58 digital I/O pins, multiple SPI/I2C hardware-controlled pins, 80MHz clock, 512K Flash memory, and is compatible with the wide array of code samples and extension “shields” from the Arduino community. Additionally, this platform utilizes a modified version of the easy-to-use Wiring programming language and IDE. We believe this offers the most in terms of compatibility with other embedded devices and allows us to monitor multiple analog signals at very low cost. The platform is tested by monitoring the power quality of the voltage in an aerospace system of 28 Volts DC. The system is tested for a several seeded faults including reduction of capacitance filter. The results are satisfactory, showing the viability of this type of system for modern power quality monitoring.

Assigned Session: A 4 Electronic and Power Systems Health Management

Presenting Author: Preeti Chauhan **Ser:** 79

Organization: University of Maryland

Country:

Paper Title: **Canary Approach for Monitoring BGA Interconnect Reliability under Temperature Cycling**

Co Authors: Preeti Chauhan, Michael Osterman and Michael Pecht

Abstract:

Solder interconnect reliability is a major concern for electronic products since these are often the most critical elements in determining the reliability of electronics. Thermal fatigue, caused by temperature swings and mismatches between the coefficients of thermal expansion (CTEs) of the mounted semiconductor packages and the application board, is one of the leading causes of failure in solder interconnects. While simulation models exist for predicting the thermal fatigue failure of solder interconnects, reliability prediction is challenging due to the wide variation in usage profiles. One of the approaches to address this challenge is the canary approach. The canary approach consists of creating a component or circuit incorporated into or in the vicinity of the target component, where a detectable event is driven by the same or similar mechanism that precedes a functional failure of the target component. Thus, a canary provides monitoring and prognostics for failure of the target component.

This paper presents a physics of failure (PoF)-based canary approach for reliability prediction of ball grid arrays (BGAs) under temperature cycling. The canary is formed by a BGA resistance net consisting of outer solder interconnects and is used to predict failure in the resistance net formed by inner solder interconnects. Thus, an existing circuit in the BGA is utilized as a canary. The approach is beneficial because there is no additional circuit needed, which provides real estate benefits along with the reliability prediction capability.

Assigned Session: B 4 Health Management Tools and Capabilities

Presenting Author: Radu Pavel **Ser:** 13

Organization: TechSolve, Inc.

Country:

Paper Title: **Machine Tool Health Characterization Using Condition Monitoring and Prognostic Based Technologies**

Co Authors:

Abstract:

The efforts to improve machine tool use and effectiveness in manufacturing are dependent on the ability to prevent or minimize unscheduled downtime. Although various technologies for machinery health monitoring and characterization have been successfully implemented for equipment as simple as pumps, and as complex as airplane engines, the applicability of such technologies to machine tools was insufficiently explored. For over five years, TechSolve has dedicated resources for identification, evaluation, development, validation, and transition to industry of advanced health assessment technologies for the machine tool. TechSolve has teamed up with academic and industrial organizations to address the complex aspects of machine health characterization. A number of test-beds have been developed by TechSolve to allow extensive application of degradation and faults for evaluation and development of targeted technologies. This paper presents an overview of the work conducted in collaboration with Intelligent Maintenance Systems (IMS) of the University of Cincinnati, Frontier Technology, Incorporated (FTI), and Siemens Corporation. The paper highlights the main results of the investigations, including limitations and challenges encountered during the evaluation trials of the technologies.

Assigned Session: B 4 Health Management Tools and Capabilities

Presenting Author: Leo Liao **Ser:** 31

Organization: Siemens Corporate Research

Country:

Paper Title: **Machine Tool Feed Axis Health Monitoring Using Plug-and-Prognose Technology**

Co Authors: Radu Pavel TechSolve, Inc. 6705 Steger Drive Cincinnati, Ohio 45237 Phone: 513-948-2000 Fax: 513-948-2109 Contact author email: pavel@techsolve.org

Abstract:

Operational safety, maintenance, cost effectiveness, and asset availability have a direct impact on the competitiveness of organizations. In order to address the issues associated with the maintenance related machine downtime, various maintenance strategies have been adopted over the years. One of the most desirable approaches is condition based maintenance (CBM). Machine tools are highly complex and their systems are very often subjected to varying loads and working conditions that make health monitoring and assessment strategies difficult to implement. Siemens Corporate Research & Technology, a division of Siemens Corporation, is developing a Plug-and-Prognose (PnP) technology to monitor the health of production type machine tools. Siemens partnered with TechSolve to evaluate and validate the technology through a series of tests focused on the ability of the PnP system to effectively collect data from the machine tool's own controller and external sensors, and reliably identify the normal operation of the machine and diagnose anomalous operating states. Experimental trials conducted on the TechSolve's feed-axis test-bed and the DMU50 machine demonstrated the effectiveness of PnP technology for anomaly detection and diagnosis. A few practical issues and more experience about test design, findings, and issues encountered through the experiment are shared and discussed as well.

Assigned Session: B 4 Health Management Tools and Capabilities

Presenting Author: David Siegel **Ser:** 28

Organization: University of Cincinnati

Country:

Paper Title: **Advanced Diesel Engine Health Monitoring Algorithms for Ground Vehicles**

Co Authors: Canh Ly, Andrew Bayba, Kwok Tom, and Jay Lee.

Abstract:

This study presents a framework and evaluation of health monitoring algorithms for diesel engines used in ground vehicle applications. The framework consists of monitoring a select set of steady state operating regimes, using a non-linear or linear version of principal component analysis, and performing analysis on the residual feature set to infer the engine health state. For the linear version of the principal component analysis method, Hotelling's T2 and square prediction error (SPE) statistics are used for detecting the anomalous engine behavior. The linear PCA method is compared with a non-linear principal component method using an auto-associative neural network. The proposed monitoring approach is evaluated from a data set from baseline and seeded fault experiments from a Caterpillar C7 diesel engine tested at TARDEC. The health monitoring results are encouraging with a detection rate of 83% and no false alarms. In addition, the monitoring approach uses low cost sensors or signals currently available from the vehicle can bus, making it more attractive for in-field implementation. Refinement of the selected signal subset is being considered for improved detection results. Additional future work includes developing a set of algorithms for detection combustion related faults using vibration and instantaneous speed signals.

Assigned Session: B 4 Health Management Tools and Capabilities

Presenting Author: Eric Bechhoefer **Ser:** 26

Organization: NRG Systems

Country:

Paper Title: **A Process for Data Driven Prognostics**

Co Authors: David He, University of Illinois at Chicago The Department of Mechanical & Industrial Engineering 2039 Engineering Research Facility 842 W. Taylor Street Chicago, IL 60607 312.996.5318 phone / 312.413.0447 fax

Abstract:

A prognostic is an estimate of the remaining useful life of a monitored component. While diagnostics alone can support condition based maintenance practices, prognostics facilitates changes in logistics which can greatly reduce cost or increase readiness and availability of the monitored system. A successful prognostic requires four processes: a) feature extraction of measured data to estimate damage, b) a threshold for the feature which when exceeded it is appropriate to perform maintenance, c) given a future load profile, a model that can estimate the life of the component based on the current damage state, and d) an estimate of the confidence in the prognostic is needed. This paper outlines a process for a data driven prognostics by: describing appropriate condition indicators for gear fault, threshold setting those CIs through fusion into a component health indicator, using a state space process to estimate the remaining useful life given the current component health, and a state estimate to quantify the confidence in the estimate of the remaining useful life. Finally, an gear fault run to failure test is used as an example.

Assigned Session: B 4 Health Management Tools and Capabilities

Presenting Author: Paul Lowe **Ser:** 27

Organization: Rockwell Automation

Country:

Paper Title: **PHM and Automation Convergence**

Co Authors: Dukki Chung Pat Carle

Abstract:

Prognostics and Health Management (PHM) technologies can now be found in virtually every manufacturing plant, most building utility systems, military vehicles and even in consumer vehicles. Along with the growing use of PHM systems, there is a trend toward greater deployment of automation systems for new and challenging applications. Automation systems are being deployed for more critical processes and to manage higher speed, more complex and connected systems. New automation tools and techniques designed to address challenging new applications include higher-level programming languages, more powerful PLC (Programmable Logic Controller) architectures, distributed and cooperative control paradigms, control programming languages, and predictive control methods.

Advanced automation systems and PHM systems often target the same manufacturing process or process machinery in a plant. Significant benefits are possible by integrating automation and PHM functions that are typically implemented as separate functions and managed in separate organizations. Both the effectiveness of automation systems may be enhanced and the accuracy of diagnostics and prognostics can be improved. For example, predictive control techniques may be enhanced by modifying state prediction estimates with predicted machinery health information. Even traditional linear control techniques can be made more reliable and more robust by embedding compensating control action in the planned system control action. Alternatively, dynamic information during the control of a system can provide a stimulus-response “signature” of the system that can signal faulty operation of the system or signal the early stage of failure. Early indication of a fault or notice of an impending failure can provide a basis for protecting production machinery and help safeguard personnel and process operation.

The paper will provide a simple framework for integrating prognostics with control and extend this to higher level control and optimization. An example will be provided showing prognostics with compensating control for a motor-pump systems and for a simple actuator. This system will be then extended to encompass a paradigm of distributed intelligent controllers.

Assigned Session: B 4 Health Management Tools and Capabilities

Presenting Author: Matthew Rounds **Ser:** 24

Organization: Ridgetop Group, Inc.

Country:

Paper Title: **A Prognostics and Health Management Solution for Information Technology (IT) Networks**

Co Authors: Matthew Rounds, Robert Wagoner, and Neil Kunst

Abstract:

As computer networks become an increasingly important element of net-centric warfare, the Navy and other Department of Defense Agencies are becoming increasingly concerned with data and network reliability and availability. However, maintaining a reliable IT network on-board a warship or on the battlefield is challenging, given the wide variety of diverse hardware and software components that comprise such networks. Afloat networks must be especially robust while operating in a remote environment where expert support teams may not always be available to troubleshoot and repair a network malfunction or an anomaly that may cause degradation in system performance. This paper presents a web application called Sentinel Network™ that provides the Navy with a net-centric Prognostics and Health Management (PHM) software platform solution. The application described performs accurate network discovery, network configuration monitoring, real-time resource health monitoring of workstations/servers, uninterrupted power supply (UPS) health monitoring based on load changes, background monitoring and data collection, and switch troubleshooting. The foundation of this comprehensive PHM solution is predicated upon an extensible software platform that distributes the sensor data collection, data fusion, reasoning, and presentation tasks. Timely introduction and efficient software maintenance is contingent upon a scalable design that enables parallel development and support. The distributed software architecture described addresses these features with a modular web server design that separates the main client application from reasoner extensions and services that manage sensor data collection. For example, sensor data is collected using a simple network management protocol (SNMP) transport from workstations, servers, and UPS devices. Those devices that do not support SNMP require a gateway device or service to collect the desired data. The collected sensor data is stored to a central PHM database. The data is processed using a suite of sophisticated diagnostic and prognostic reasoners, installed on a host, that process the multivariate sensor data to isolate the root cause of the fault condition and estimate the remaining service life of the device being monitored. For UPS devices this results in an estimate for impending failure and allows a technician to make the proper repairs or replacement to sustain the network and avoid downtime. This paper also describes the results of a successful demonstration to SPAWAR at Lockheed Martin's Technology Collaboration Center-West (TCC-West). During the demonstration, the authors chose to show the prognostics capabilities using the Clary CMN-2400DPD UPS. The UPS device was monitored in real time for remaining useful life (RUL) predictions. The PHM solution presented can be used to support a variety of sensor networks such as those on-board aircraft, ground vehicles, and many other complex systems that require cannot afford unscheduled maintenance due to system or subsystem malfunctions.

Assigned Session: C 4 Sensors

Presenting Author: Bill Nickerson **Ser:** 30

Organization: Impact Technologies, A Sikorsky Innovations Company

Country:

Paper Title: **Real-world Deployment of Wireless Accelerometers**

Co Authors:

Abstract:

Impact-RLW will have deployed Sentyre(R) wireless accelerometers in at least two real-world environments aboard US Navy ships and surface mining equipment. This paper will describe the applications, challenges, system integration, and results of the deployed systems.

Assigned Session: C 4 Sensors

Presenting Author: David Corelli **Ser:** 67

Organization: IMI Sensors

Country:

Paper Title: **Extended Range RF Wireless Technology for Industrial Monitoring**

Co Authors:

Abstract:

Development of a practical, wireless, industrial vibration sensor poses a unique set of challenges and requirements, including, long distance transmission, low power consumption, and the need for long battery life. Extended Range RF (ERRF) Technology, used in the Echo(r) Wireless Vibration System, provides a unique combination of long distance data transmission with low power consumption / long battery life.

Assigned Session: C 4 Sensors

Presenting Author: Mert Bal **Ser:** 33

Organization: Miami University

Country:

Paper Title: **Collaborative Wireless Sensor Networks for Facilities Management**

Co Authors:

Abstract:

The Wireless Sensor Networks (WSN) is a key technology for distributed monitoring and control of the buildings by using a network of tiny, wireless nodes; each can sense and process various data from its environment. This technology can enhance the real-time data collection process and support facilities management in monitoring and control of buildings' functions such as: HVAC, security and lighting systems. As far as monitoring is concerned, the WSN could provide significant benefits, since they are more cost-efficient, due to the lack of wiring installations, compared to wired sensor solutions.

For large-scale implementation of WSN in buildings, the radio transmission and communication performance of the wireless nodes are challenged by the presence of concrete and metallic infrastructure, which reduce the signal strength of the wireless communication channel and create packet-losses within the data exchange. This causes significant losses on the performance of the communication and automatic positioning of the wireless nodes. This paper provides an overview on the implementations of the WSN technology into large commercial buildings to support building automation, and proposes an algorithm for collaborative networking and positioning of the wireless sensor nodes in harsh, indoor environments.

Assigned Session: C 4 Sensors

Presenting Author: Chris Larsen **Ser:** 16

Organization: Etegent Technologies

Country:

Paper Title: **Broadband Waveguide Sensors for Use in High-Temperature, Corrosive, and Other Harsh or Difficult-to-Access Environments**

Co Authors: Stuart J. Shelley

Abstract:

Monitoring difficult-to-access components such as turbine engine main bearings or gears which are deeply buried in large transmissions is challenging due to the fact that vibration sensors generally must be mounted on the external case. The long transfer path through multiple component joints tends to attenuate the vibration signal of interest, and masking vibration from other sources further obscures these low-amplitude signals. A new waveguide-based sensing technology which carries the vibration stress waves to the desired sensor location permits high-fidelity vibration measurements of components that would otherwise be inaccessible. This sensor separates the mechanical sensing element from the electronics; the sensing element can be made of stainless steel, Inconel, or similar materials, which permits measurements in environments which are much too harsh for PZT or strain gauges. The sensing electronics can be conveniently located in a more benign location which is easily accessed for service. Waveguides have been used for harsh-environment sensing for years, such as probes which separate ultrasonic transducers from hot surfaces when doing non-destructive testing; however, many drawbacks have prevented their use as broadband vibration sensors. Methods for addressing these issues have been developed by the authors, enabling a new sensing technology for monitoring mechanical components in harsh and difficult-to-access environments.

Assigned Session: C 4 Sensors

Presenting Author: Bill Stange **Ser:** 81

Organization: AFRL/RQ

Country:

Paper Title: **An Introduction to the Need for Turbine Engine Test Cell Instrumentation Standards**

Co Authors:

Abstract:

This presentation will discuss the recently initiated effort to develop standards for a number of sensing methodologies currently planned or in use for making vital measurements on developmental turbine engines in the test cell environment. This Standards Committee was developed in conjunction with, and approved by the International Society of Automation (ISA), which bring us the ability to have the Standards we develop approved by the American National Standards Institute (ANSI). The current technologies being worked on for standardization include the Nonintrusive Stress Measurement System (NSMS), or Blade Tip Timing (BTT), Temperature Measurement using Thermographic Phosphors, Blade Tip Clearance measurement, and Wireless Data Transmission in the Test Cell Environment. We are also in the early stages of initiating a sub committee to develop standards for Dynamic Pressure Measurement in the Turbine Engine Environment.

Assigned Session: C 4 Sensors

Presenting Author: John Lucero **Ser:** 93

Organization: NASA John H Glenn Research Center

Country:

Paper Title: **Advanced Noise Control Fan Test Rig Capabilities and Trade Studies for Aero Engines**

Co Authors:

Abstract:

Assigned Session: D 4 Diagnostics

Presenting Author: Adrian Messer **Ser:** 70

Organization: UE Systems Inc

Country:

Paper Title: **New Advances in Ultrasound Condition Monitoring**

Co Authors:

Abstract:

This presentation will describe how airborne/structure borne ultrasound technology is used to improve asset reliability and reduce energy waste. Instruments based on this technology offer plant personnel the potential of inspecting practically every system and subsystem within a plant and beyond to the transmission and distribution area.

New advances in digital technology and software improve the capability of these portable instruments to trend and analyze bearing condition, detect leaks, identify and analyze electrical problems (such as corona, tracking and arcing), identify leaking valves and steam traps and provide early warning of problems in gears, pumps and motors. In addition, new software developments help report and document energy cost reduction and carbon footprint reduction

This presentation will explore the airborne/structure borne ultrasound technology and introduce new developments that will enable plant personnel to:
•improve meantime between failure and asset availability
•cut energy waste and improve a company's carbon footprint.

In order to meet the need for improving profitability, plant personnel are looking for ways to reduce operating costs and increase efficiencies while meeting constant environmental demands to reduce greenhouse gas emissions. To help meet these critical demands, effective maintenance practices must be considered as an essential component. While most "preventive", or scheduled maintenance practices are important to keeping equipment healthy, the need to monitor and trend changes in the basic condition of operating equipment is at times even more critical.

The inclusion of Condition Monitoring in plant operations can help foretell potential failure conditions in equipment providing for a planned approach to maintain operation while scheduling repairs before any interruption of service. Ultrasound technology, specifically "airborne/structure borne" ultrasound offers plant personnel the potential of inspecting practically every system and subsystem within a power plant and beyond to the transmission and distribution area as well.

Instruments based on airborne/structure borne ultrasound technology offer many opportunities for plant-wide energy conservation and condition monitoring (predictive maintenance) activities. They range from identifying potential arc flash conditions in enclosed electric equipment to preventing over- lubrication conditions in bearings to locating compressed air and other compressed gas leaks.

New advances in digital technology and software improve the capability of these portable instruments to trend and analyze bearing condition, detect leaks, identify and analyze electrical problems (such as corona, tracking and arcing), identify leaking valves and steam traps and provide early warning of problems in gears, pumps and motors. In addition, new software developments help analyze, trend, report and document survey results.

Assigned Session: D 4 Diagnostics

Presenting Author: Jing Tian **Ser:** 40

Organization: Center for Advanced Life Cycle Engineering

Country:

Paper Title: **Diagnosis of Rolling Element Bearing Fault in Bearing-Gearbox Union System using Wavelet Packet Correlation Analysis**

Co Authors: Changning Li Center for Prognostics and System Health Management City University, Hong Kong, China Michael Pecht Prognostics and Health Management Group Center for Advanced Life Cycle Engineering (CALCE) University of Maryland, College Park, MD 20742

Abstract:

The failure of rotating machinery sometimes involves several faulty components. Existence of both bearing fault and gearbox fault is widely observed and in this situation the vibration feature of the bearing fault can be masked by the faulty gearbox vibration signals. In this research, a method is proposed based on wavelet packet transform and envelope analysis to extract fault features of the rolling element bearing from the masking faulty gearbox signals. Wavelet packet of the test signal containing bearing fault information is selected by correlation analysis and the fault feature is extracted by envelope analysis. Case study shows that the proposed method can detect the outer race fault in a rolling element bearing from the masking signals of a gearbox with worn teeth. Compared with exist methods, the proposed method does not require gearbox fault information, and it reduces the amount of sensors.

Assigned Session: D 4 Diagnostics

Presenting Author: Kenny Gross **Ser:** 59

Organization: Oracle Physical Sciences Research Center

Country:

Paper Title: **Multivariate SPRT for Improved Prognostics of Enterprise Computing Systems**

Co Authors: Ram Dhanekula

Abstract:

Electronic Prognostics (EP) for business-critical and mission-critical computing systems comprises a comprehensive methodology for proactively detecting and isolating failures, recommending condition-based maintenance (CBM), and estimating in real time the remaining useful life (RUL) of critical components. Oracle's Sun Microsystems division has for the last decade been developing EP innovations for components, subsystems, and for recently introduced integrated hardware-software "appliance" systems. One technique that has found a multitude of beneficial applications since the earliest Oracle introduction of EP methodology is called the Sequential Probability Ratio Test, or SPRT. Although the SPRT dates back to the 1940s for statistical process control of industrial manufactured items, Oracle successfully adapted and applied a variation of the SPRT formalism not to tangible manufactured units rolling off an assembly line, but rather to digitized time series samples from electronic computing system internal telemetry metrics. Advantages gained from early SPRT developments for EP applications include high sensitivity for detecting the incipience or onset of a variety of mechanisms known to cause crashes/hang/failures in electronic computing systems, but with ultralow probabilities for false and missed alarms. The present paper documents a multidimensional extension of the SPRT methodology that leverages three-dimensional histograms computed from the residuals obtained by pair-wise differencing of physical telemetry variables (including temperatures, voltages, currents, fan speeds, and vibration metrics) between (1) what we call a "golden system" (i.e. a system that from best engineering judgement is free of any internal degradation modes) and (2) a monitored system with an identical internal component configuration to that of the golden system. A multivariate SPRT algorithm is introduced in this paper that attains significant synergy compared with conventional univariate SPRTs (i.e. the empirical time-to-detection metrics for subtle developing anomalies in computing systems are significantly smaller than attained for individual univariate SPRT algorithms monitoring the same variables, but with the same low false-alarm and missed-alarm probabilities.) Oracle's continuous system telemetry harness (CSTH) coupled with the new multivariate SPRT technique introduced in this paper are helping to increase component reliability margins and system availability goals while reducing (through improved root cause analysis) costly sources of "no trouble found" (NTF) events that have become a significant sparing-logistics issue across the computing industry.

Assigned Session: D 4 Diagnostics

Presenting Author: Dongxiang Jiang **Ser:** 20

Organization: Tsinghua University

Country: China

Paper Title: **Fault Classification Rules Extraction of Wind Turbine Based on C4.5 Algorithm**

Co Authors: Jie CHEN, Shaohua LI, Dongxiang JIANG, Department of Thermal Engineering, Tsinghua University, Beijing 100084, China

Abstract:

Distinguishing fault types in early time can prevent wind turbines from breaking down. C4.5 algorithm, different from ID3 algorithm, which can deal with continuous parameters, should be a choice fault diagnosis method of wind turbine. This paper strives to extract fault classification rules of wind turbine based on data collected from a small wind turbine in laboratory using C4.5 decision tree and validate the rules extracted using another set of data. According to the solution, fault types such as mass imbalance of rotor, aero-dynamic asymmetry, yaw misalignment, gearbox and bearing fault and so on can be distinguished by the method presented in this paper.

Assigned Session: D 4 Diagnostics

Presenting Author: Thomas Lagö **Ser:** 56

Organization: TechFuzion

Country:

Paper Title: **Human Listening As a Classification Tool in Production Lines**

Co Authors:

Abstract:

In order to verify quality it is not uncommon that human listening tests are used to find challenges with e.g. small electrical motors. There are many disadvantages with human ears in a production line. Data and examples from multiple applications where “golden ears” have been used is presented. The psychology in the listening exercised can totally dominate the end results. Tests were performed where the same data was used, but to the listeners, they were given different info. The results, using the same data, came out with completely different results. The paper will discuss these results and why “golden ears” believe that they can “determine the good/bad” motors but how ambiguous this can be. A discussion on what the “golden ears” are listening for and what they are “not listening to,” even if they claim differently will be discussed and related to human hearing. The results from these tests could act as a great eye opener in regards to how to deal with what some “experts” claim that they hear.

Assigned Session: D 4 Diagnostics

Presenting Author: Simon Jessop **Ser:** 80

Organization: Impact Technologies, A Sikorsky Innovations Company

Country:

Paper Title: **Advanced Automated Troubleshooting Technology**

Co Authors:

Abstract:

In a typical military or industrial environment, complex systems (machines, aircraft, etc.) experience fault/failure modes that must be diagnosed accurately and rapidly in order to sustain a high level of operational availability. Considerable downtime translates into loss of productivity and increased maintenance costs. Current diagnostic and repair techniques rely on either evidence from a machine's internal checks (fault indicator light or code) or an alert from the machine's operator. An "expert" then observes the faulty system, determines the root cause of the problem, and composes a work order to schedule people, tools/equipment, or materials for repair and maintenance. Unfortunately, these methods often do not offer sufficient information for the accurate and rapid diagnosis of the problem and rely heavily on the experience of the maintenance technician. Impact Technologies is developing an intelligent diagnostic system that utilizes dynamic reasoning and adaptive learning technologies to optimize the troubleshooting process. The system assists maintenance technicians by providing a likely cause of failure based on available evidence and suggested next tests in real time. Dynamic reasoning technologies are used to determine the most appropriate course of action for isolating the failure mode and repairing the system. The system also provides visibility into diagnosis and repair operations, which allows for improved maintenance resource management and reporting. This session provides an overview of the design and implementation of the intelligent diagnostic system.