The Current Test Company

REPORT

TITLE:

Prognostics and Health Management in Electronic Systems

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1 Aim

The goal of this report is to document the results of a survey towards **e**lectronic **P**rognostics and **H**ealth **M**onitoring (ePHM), its application, solutions and tools. The report provides the following information:

1. An overview of the different types of ePHM
2. A list of the companies involved in ePHM
3. A list of membership opportunities
4. A list of available ePHM software tools
5. Other information sources on ePHM
6. Future events

2 Terminology & Abbreviations

ATE Automatic Test Equipment

BIST Built-In Self-Test

CALCE Computer Aided Life Cycle Engineering

CBM Condition based maintenance - the application and integration of appropriate processes, technologies, and knowledge-based capabilities to improve the reliability and maintenance effectiveness of systems and components.

COTS Commercial off-the-shelf is a term for software or hardware, generally technology or computer products, that are ready-made and available for sale, lease, or license to the general public. They are often used as alternatives to in-house developments or one-off government-funded developments. The use of COTS is being mandated across many government and business programs, as they may offer significant savings in procurement and maintenance. However, since COTS software specifications are written by external sources, government agencies are sometimes wary of these products because they fear that future changes to the product will not be under their control.

DARPA The Defense Advanced Research Projects Agency (USA) is the central research and development organization for the Department of Defense. It manages and directs selected basic and applied research and development projects for DoD, and pursues research and technology where risk and payoff are both very high and where success may provide dramatic advances for traditional military roles and missions.

DFT Design for Test

DoD Department of Defense (USA)

ESA European Space Agency

ePHM Electronic Prognostics and Health Management

FMEF Failure Mode Effects Analysis

In-situ a Latin phrase meaning in the place. In the aerospace industry equipment on board aircraft must be tested "in situ" or in place to confirm everything functions properly as a system. Individually each piece may work but interference from nearby equipment may create problems not anticipated. Special test equipment is available for this "in situ" testing.

ISO International Standards Organization

JSF Joint Strike Fighter

HASS Highly Accelerated Lift Testing

MOSFET Metal-oxide-semiconductor Field Effect Transistor

MTBF Mean Time Between Failures

MTTF Mean Time to Failure, also MTFF - mean time to first failure or MTBF - mean time between failures

NASA National Aeronautics and Space Administration

PHM Prognostics and Health Management

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PoF	Physics-of-failure
R&D	Research and Development
RUL	Remaining Useful Life
SBIR	The Small Business Innovation Research - program was established by US Congress in 1982 with a statutory purpose to strengthen the role of innovative small business concerns. Prognostics is one of topics for SBIR
SOW	Statement of Work
STTR	The Small Business Technology Transfer - program is a sister program to SBIR, established by US Congress in 1992 with a similar statutory purpose as SBIR. Prognostics is one of topics for STTR.

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3 What is ePHM?

Prognostic stands for predictive diagnosis, whereby information of particular parameters that have a relation to the lifetime and healthyness of a component or system are captured on particular moment in time, allowing to make decision on the health of the component or the system at a particular moment in time as well as determining the remaining useful life or time span of useful operation for a component or a system.

Prognostics and health management is an engineering discipline, which involves diagnostic and health management solutions that identify problems before they start to impact the component or system operation and before they become expensive to remedy, enabling guaranteed levels of availability and reducing life-cycle costs.

Technical approaches to prognostics can be categorized broadly into *data-driven* approaches, *model-based* approaches, and *hybrid* approaches. Data-driven techniques utilize monitored operational data related to system health. Data-driven approaches are appropriate when the understanding of first principles of system operation is not comprehensive or when the system is sufficiently complex that developing an accurate model is prohibitively expensive. Therefore, principal advantages to data driven approaches is that they can be often be deployed quicker and cheaper compared to other approaches. The disadvantage is that data driven approaches may have wider confidence intervals than other approaches and that they require a substantial amount of data for training.

Model-based prognostics attempts to incorporate physical understanding/models of the system into the estimation of remaining useful life (RUL). Modeling physics can be accomplished at different levels, for example, micro (material) and macro (mathematical) levels.

Hybrid approaches attempt to leverage the strength from both data-driven approaches as well as model-based approaches. In reality, it is rare that the fielded approaches are completely either purely data-driven or purely model-based. More often than not, model-based approaches include some aspects of data-driven approaches and data-driven approaches glean available information from models.

PHM is generally an expensive method from a design perspective (similar to particular DFT methodologies) as it requires always additional means and overhead, therefore it is suited preferably for critical applications such as aerospace, military, medical, nuclear and automotive. Once such measurers are in place they pay-back themselves easily during the application. The prognostics on mechanical systems are well established nowadays. Mechanical PHM is based on standard industrial sensors: pressure, temperature, vibration, flow and acceleration, whose input is processed. Although some procedures and know-how of mechanical prognostics can be reused, the prognostics on electronic systems are much less established due to its complexity. Relatively easiest is prognostics of single electronic elements such as capacitor or battery as a supply. When the electronic system is more complex, the overhead dedicated to prognostics can be quite large.

Typical ePHM commercial applications are: Automotive, Medical, GPS, COTS Microprocessors / Microcontrollers, DSP chips, ASIC, RFIC, Power Supplies ...

The benefits of ePHM arise from two main areas: the pool of assets on which it is deployed can achieve higher rates of net availability and the cost of supporting those assets can be reduced. The following benefits are expected from ePHM. These benefits are especially significant in all high-value, low volume electronic equipment where there is substantial cost associated with loss of availability.

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- Reduced costs. One of the benefits to having a PHM system will be the reduced cost to maintain the system. Maintenance costs of complex systems can be extremely large, especially for a fleet of systems. PHM provides savings through a couple of different channels; the first is through Condition Based Maintenance practices and the second is through a more automated maintenance and logistics support system.

- Improved application life time prior to replacement. By having a PHM system in place the health of the system monitored at any moment in time and remaining useful lifetime can be calculated allowing to move from a time-fixed maintenance scheduling to an application triggered maintenance scheme. Moreover it allows the application to issues warnings as well if health risks would manifest themselves prior to planned maintenance points.

- Increased Revenue. There are many ways that a PHM system can help to increase the revenue stream of a business. If a product seller can offer a more reliable product to their customers, they will be able to gain a larger market share and therefore increase revenue.

- Increase Safety. The cost benefits are not the only important benefits of a PHM system, another potentially more important is the increased safety gained by using a PHM system. A PHM system will predict/prevent catastrophic failures of critical system components, this prediction of failure can be used to shut down or reconfigure a system to properly accommodate the fault of provide an orderly shut down before a catastrophic failure happens. This is especially important for aerospace industry.

- Reduced Downtime. How useful a system is, can often be associated with the amount of system downtime, along with unexpected downtime. Reducing the amount of total downtime will ultimately increase how much output can be obtained by a system and how often this output can be expected.

- Improved Fleet-Wide Decision Support. When PHM is employed on a large number of systems (Fleet), there are many more benefits that just multiplying the benefits for an individual system by the number of systems in the feet. PHM systems will provide detailed insight into the operation of every single component of the fleet; therefore specific decisions can now be made in a variety of different situations.

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4 Companies and organisations involved in ePHM

4.1 ePHM solutions and tool providers

4.1.1 Ridgetop Group Incorporated

http://www.ridgetop-group.com

Ridgetop Group Inc. is the world leader in providing advanced electronic prognostics and health management (PHM) solutions, semiconductor IP blocks, and built-in self-test (BIST) solutions for critical applications. Founded in 2000 with the purpose of introducing revolutionary tools to improve performance of mission-critical electronic systems, Ridgetop has built an impressive list of customers in North America, Europe, and Asia.

With a strong management team and world-class technical staff, Ridgetop has established a stellar reputation serving its government and commercial customers with "best of class" solutions. Their technical staff members have impressive credentials and experience from leading firms such as IBM, Bell Labs, Honeywell, and Burr-Brown (now Texas Instruments).

Ridgetop also maintains strong linkages with leading universities that add depth and leverage to their internal research capabilities. This relationship provides a true "win-win" situation for developing new and advanced techniques for dealing with difficult electronic problems.

There is a close cooperation between Ridgetop Group and Q-Star Test with respect to the development and marketing of ePHM solutions.

4.1.2 Qualtech Systems Incorporated (QSI)

http://www.teamqsi.com

Founded in 1993, Qualtech Systems, Inc. (QSI) is a recognized leader in advanced diagnostics and health management software solutions. QSI has received awards from NASA (2002 & 2008 Space Act Award) and Aviation Week and Space Technology ("Technology Innovations 2002") and was named a Deloitte LLP Connecticut "Fast 50" company. Qualtech Systems is a recipient of the prestigious NASA Space Act Award.

In the course of completing dozens of projects for NASA and the military, QSI has developed and deployed diagnostic tools for modeling, analysis, embedded run-time diagnostics, and remote (telemaintenance) or field maintenance and repair that are proven, mature, and being deployed in large-scale commercial operations.

QSI is experienced in building, integrating, customizing, and working with customers to:

- Build the business case
- Help implement the solution into existing infrastructure and work flow
- Maximize return on investment
- Enable every technician to perform to the same high standard

QSI is highly regarded by its customers for quality software and engineering service. The company's quality management system is certified to ISO9001:2000 quality standards.

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4.1.3 Impact Technologies

http://www.impact-tek.com

Impact Technologies, LLC is a world-class engineering firm that provides a wide range of products and services for analyzing, predicting, and managing the health of critical systems. We are recognized experts in product development and implementation using our suite of advanced diagnostic and prognostic solutions that can be applied across the aerospace, land-based equipment, power, and defense industries. Impact Technologies develops diagnostic, prognostic and health monitoring technologies for systems ranging from stealth fighter aircraft, jet engines and compressors to electronic components. Impact is a pioneer in PHM techniques for Power Supplies, Digital Systems and RF/ Digital Systems.

4.1.4 Global Strategic Solutions (GSS)

http://www.gssllc.net

Global Strategic Solutions LLC was formed in 2005 to develop and commercialize cutting-edge software technology products and services to enable public and private sector organizations to transition to Condition Based Maintenance Systems

Collaborating with Federal Research Centers and academia, the Company's objective is to seek commercialization, in the federal and private sectors, of the technology developed through federally-sponsored Research and Development (R&D) programs. GSS partners with University Research Centers in seeking new, innovative ways to transfer the results of their focused research and extend their application to real-world problems. To complement our technical expertise and resources, we have standing business relationships with OEMs and members of academia who are recognized experts in their particular scientific discipline

The Company is currently engaged in pioneering software technologies and developing advanced health management solutions for use in defense, commercial aviation, energy, and transportation systems.

Global Strategic Solutions LLC was awarded an SBIR by the U.S. Navy to develop a prognostic application for the JSF Tactical Information and Communication systems

4.1.5 DSI International

http://www.dsiintl.com

DSI International offers creative, customer-focused solutions to intelligent diagnostic design and provides expert technical services to support all Diagnostic and Systems Engineering goals. DSI International is the leading provider of state-of-the-art design tools, centered on the powerful eXpress diagnostic modeling and analysis software tool, enabling rapid and accurate system diagnostics design development, knowledge capture, trade study analysis, and redesign.

4.1.6 Dearborn Group Incorporated

http://www.dgtech.com

Dearborn Group Technology (DG) specializes in the design and development of intelligent software and hardware protocol interface devices for the in-vehicle and controller area network markets.

Throughout its history, Dearborn Group (DG) has played a significant role in the growth of in-vehicle and controller area (CAN) networking. DG was the first company to introduce vehicle networking in the automotive industry with a variety of sought-out tools and expertise. Since then, it has brought its

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technology into many industries worldwide. DG has developed an excellent reputation among automotive manufacturers delivering quality products, training, and services worldwide.

Dearborn Group has successfully brought its technology into many industries including automotive, heavy-duty truck and bus, industrial control, robotics, mass transportation, agriculture, and construction, among others.

Their hardware and software products are used by a variety of customers: test engineers, development engineers, production engineers, and service technicians, among others. Their customers use DG interfaces to manipulate messages over various multiplex networks. They also provide custom, end-of-line testing equipment for electronic modules with network interfaces. Our products are currently utilized in the automotive, heavy-duty truck and bus, industrial control, robotics, mass transportation, agriculture, and construction industries.

4.1.7 Center for Intelligent Maintenance Systems (IMS)

http://www.imscenter.net

Center for Intelligent Maintenance Systems – The vision for the Center for Intelligent Maintenance Systems is to enable products and systems to achieve and sustain near-zero breakdown performance, and ultimately transform the traditional maintenance practices from "fail and fix " to "predict and prevent" methodology. The Center is focused on frontier technologies in embedded and remote monitoring, prognostics technologies, and intelligent decision support tools and has coined the trademarked Watchdog Agent® prognostics tools and Device-to-Business (D2B) infotronics platform for e-maintenance systems.

4.2 ePHM users

4.2.1 Honeywell Aerospace

http://www.honeywell.com/aero

Honeywell Aerospace is a leading global provider of integrated avionics, engines, systems and service solutions for aircraft manufacturers, airlines, business and general aviation, military, space and airport operations.

Their primary focus is to enhance customer value by making flight safer, more reliable and more cost-effective through their unique capabilities in sophisticated avionics, flight safety products and systems, propulsion engines, auxiliary power units and wheels and brakes and their strong aftermarket service and support. We are committed to redefining customer- supplier relationships across a broad array of core competencies, including power, guidance, navigation, safety, communication and services - all through a spirit of partnership.

Their aerospace products can be found on virtually every type of aircraft in use, in nearly every region of the world. In the air and on the ground, Honeywell systems and components reflect cutting-edge technology incorporated from their product development efforts. These efforts contribute to Honeywell's unequalled variety of products and services, which in turn lead to greater customer satisfaction.

4.2.2 Centre for Advanced Life Cycle Engineering (CALCE)

http://www.prognostics.umd.edu

The Center for Advanced Life Cycle Engineering (CALCE), the largest electronic products and systems research center focused on electronics reliability, is dedicated to providing a knowledge and resource base to support the development of competitive electronic components, products and

systems. CALCE is part of the University of Maryland. CALCE is recognized as a founder and driving force behind the development and implementation of physics-of-failure (PoF) approaches to reliability, as well as a world leader in accelerated testing, electronic parts selection and management, and supply-chain management. CALCE is at the forefront of international standards development for critical electronic systems having chaired the development of several reliability and part selection standards. CALCE is staffed by over 100 faculty, staff and students, and in 1999 became the first academic research facility in the world to be ISO 9001 certified. Collectively, CALCE researchers have authored over 35 internationally acclaimed textbooks and well over 1000 research publications relevant to electronics reliability. Over the last 15 years, CALCE has invested over $75 million in developing methodologies, models, and tools that address the design, manufacture, analysis, and management of electronic systems.

4.2.3 BAE Systems

http://www.baesystems.com

BAE Systems is the premier global defence, security and aerospace company delivering a full range of products and services for air, land and naval forces, as well as advanced electronics, security, information technology solutions and customer support services.

4.2.4 NAVY SBIR/STTR

http://www.navysbir.com

SBIR - The Small Business Innovation Research (SBIR) program was established by Congress in 1982 with a statutory purpose to strengthen the role of innovative small business concerns (SBCs) in Federally-funded research or research and development (R/R&D). Specific program purposes are to: (1) Stimulate technological innovation; (2) use small business to meet Federal R/R&D needs; (3) foster and encourage participation by socially and economically disadvantaged SBCs in working in technological innovation; and (4) increase private sector commercialization of innovations derived from Federal R/R&D, thereby increasing competition, productivity and economic growth.

STTR - The Small Business Technology Transfer (STTR) program is a sister program to SBIR, established by Congress in 1992 with a similar statutory purpose as SBIR. A major difference in the two programs is that the STTR requires the small business to have a research partner consisting of a University, Federally Funded Research and Development Center (FFRDC), or a qualified non-profit research institution. In STTR, the small business must be the prime contractor and perform at least 40% of the work, with the research partner performing at least 30% of the work. The balance can be done by either party and/or a third party.

Although the Navy's SBIR and STTR programs are a component of the overall Department of Defense (DoD) SBIR/STTR program, the Navy's program is targeted at addressing the needs and areas of interest to the Navy and its System Commands (SYSCOMS).

4.2.5 Intelligent Automation Incorporated (IAI)

http://www.i-a-i.com

Intelligent Automation, Inc. (IAI) is a woman-owned firm founded in 1987 by Drs. Leonard and Jacqueline Haynes. Since then, IAI has enjoyed consistent growth and has expanded into an organization of over 120 researchers and technical staff. IAI is headquartered in Rockville, Maryland and serves public and private sector clients throughout the United States and internationally.

Throughout its history, IAI has maintained its character as a diverse R&D "think tank." The interests of their scientists and engineers span a broad range of domains from distributed intelligent systems,

sensors, signal processing, robotics, manufacturing, forensics, and transportation to education, training, and information technologies. Building on their research strengths, we have established service capabilities in their core technology areas. While their interests are varied, the center of their work is the development and application of artificial intelligence-based techniques. Historically, much of their work has been funded by the U.S. Government through fully open and competitive research contracts and through competitive awards from the Small Business Innovation Research (SBIR) program. IAI's success is reflected by its selection in both 2000 and 2007 to receive the prestigious Tibbett's Award from the Small Business Administration (SBA) and the Small Business Technology Council (SBTC) for excellence in technology research and commercialization. In recent years the company has evolved to become a developer of productized services and technologies and an important R&D provider to major first-tier integrators including BAE Systems, Boeing, CSC, EDS, Honeywell, Lockheed Martin, Motorola, Northrop Grumman, and Raytheon as well as to commercial firms within the United States and internationally.

IAI is very effective at developing technologies from their conception through the design, building, and testing of prototype systems. Their basic approach to commercializing their technology is to team with partners who have existing products, strong marketing positions and capabilities, and reputations as producers of related products. IAI's technologies in the marketplace today include two- and three-dimensional forensics imaging equipment used for matching bullets, platforms, and tools for the development of agent-based systems; scheduling systems for complex and dynamically changing environments; tools for fault diagnosis and prognosis in complex systems; ad hoc mobile network protocols; and automated tutoring systems for literacy training.

IAI continues to maintain its core focus as an R&D company responding to the complex technological requirements of their Government and their commercial clients. We are actively focusing on transitioning their technology to major Government and commercial programs and are aggressively seeking partners to assist in the commercialization of their technology for current and future market niches.

IAI was awarded an SBIR by the U.S. Navy to Enhanced Prognostic Model for Digital Electronics

4.2.6 National Defense Industrial Association (NDIA)

http://www.ndia.org

National Defense Industrial Association is America's leading Defense Industry association promoting national security. NDIA is proud to provide a legal and ethical forum for the exchange of information between Industry and Government on National Security issues. Their members foster the development of the most innovative and superior equipment, training and support for NDIA's warfighters and first responders through NDIA's divisions, local chapters, affiliated associations and events.

4.2.7 Vextec

http://www.vextec.com

VEXTEC Corporation is a managed services company that provides manufacturing, aerospace, and electronics companies with accurate, invaluable information about the behavior and life expectancy of their components, systems, and product lots or even fleets. This information has profound economic and strategic implications for every aspect of a business, from product development to warranty costs. Even at this early stage, the company has an impressive track record of successful deployments. VECTEC is a specialist in reliability of solder joints.

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4.2.8 SatCon Technology Corporation (Satcon)

http://www.satcon.com

Satcon develops innovative power conversion solutions and provides system design services for utility-scale renewable energy plants. Featuring the widest range of power ratings in the industry, Satcon inverters provide the critical bridge between clean energy sources and large-scale power grids, helping companies meet the rising demand for clean energy with unparalleled efficiency and profitably. Rugged, reliable, and backed by world-class warranty and support programs, Satcon solutions are chosen by the world's leading businesses and utility companies to convert renewable energy into efficient and stable power.

With an emphasis on transitioning advanced technology into compelling products, Satcon develops power conversion electronics, power management and distribution systems, hybrid electric vehicle technology, electric machinery, and advanced electronic material applications. The Satcon Applied Technology Division has more than 150 patents and has received more than 150 Small Business Innovation Research (SBIR) awards from the Department of Energy, the Department of Defense, and NASA.

4.2.9 Joint Strike Fighter Program (JSF)

http://www.jsf.mil

The Joint Strike Fighter (JSF) Program, formerly the Joint Advanced Strike Technology (JAST) Program, is the Department of Defense's focal point for defining affordable next generation strike aircraft weapon systems for the Navy, Air Force, Marines, and our allies. The focus of the program is affordability -- reducing the development cost, production cost, and cost of ownership of the JSF family of aircraft.

4.2.10 National Aeronautics and Space Administration (NASA)

http://www.nasa.gov

National Aeronautics and Space Administration. NASA is a rich source of prognostics info.

4.2.11 DARPA

http://www.darpa.mil

The Defense Advanced Research Projects of The Departmend of Defence. Funding several research projects on PHM especially PHM of JSF program.

4.2.12 Lockheed Martin Corporation

http://www.lockheedmartin.com

Lockheed Martin Corporation. Using PHM technology in their aeronautics, space, electronic and information systems.

4.2.13 SBAC

http://www.sbac.co.uk

The Society of British Aerospace Companies (SBAC) is the UK's national trade association representing companies supplying civil air transport, defence, homeland security and space.

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4.2.14 Failure Analysis company (FA)

http://www.failureanalysisco.com

Failure Analysis company - a world leader in Telemetry Prognostics for the satellite, launch vehicle, missile, aircraft, computer, defense, medical, automotive, medical and electrical power generating industries.

4.2.15 Aerospace Innovation and Growth Team (AeIGT)

http://www.aeigt.co.uk

Aerospace Innovation and Growth Team (UK) - the initiative AeIGT was launched to ensure the UK aerospace industry maintained its global strength and developed world class technologies. The AeIGT is a partnership between UK Government, industry and academia, with the vision that by 2022 the UK will offer a global aerospace industry, the world's most innovative and productive location, leading to sustainable growth for all its stakeholders.

4.2.16 Aerospace Innovation Network (AIN)

http://www.sbac.co.uk/pages/19038027.asp#aGroup_1

Aerospace Innovation Network (UK) - it is a research network carrying out jointly funded research projects. AINs are led by a single UK company and are open to all industry and academia operating in the UK. An AIN is a nominated set of networked research institutions with distributed research facilities.

4.2.17 Boeing

http://www.boeing.com

Boeing is the world's leading aerospace company and the largest manufacturer of commercial jetliners and military aircraft combined. Boeing designs and manufactures also electronic and defense systems, and advanced information and communication systems. As a major service provider to NASA, Boeing operates the Space Shuttle and International Space Station. Boeing has a long tradition of aerospace leadership and innovation and PHM is one of many topics on which Boeing is focused.

4.2.18 PHM Society

http://www.phmsociety.org

Non-profit organization dedicated to the advancement of PHM as an engineering discipline. The Society advocates open and timely access to scientific information, international and multidisciplinary participation, and community collaboration. Extending the reach of PHM science and technology to a broad range of application areas is another goal of the PHM Society.

4.2.19 The Reliability Information Analysis Center (RIAC)

http://www.quanterion.com/riac

The Reliability Information Analysis Center - a Department of Defense center Sponsored by the Defense Technical Information Center.

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5 Membership opportunities

5.1 Center for Intelligent Maintenance Systems (IMS)

http://www.imscenter.net

There are two kinds of memberships: full Membership - annual membership fee is $40K. Affiliated Membership - annual membership fee is $12K. It is primary for small business (employees less than 500 people)

5.2 National Defense Industrial Association (NDIA)

http://www.ndia.org/Content/ContentGroups/Divisions1/Systems_Engineering/Integrated_Diagnostics_Committee.htm

NDIA provides individuals from academia, government, the military services, small businesses, prime contractors, and the international community, the opportunity to network effectively with the government - industry team, keep abreast of the latest in technology developments, and address and influence issues as well as government policies critical to the health of the defense industry and the preservation of our national security. Annual individual membership is for $35

5.3 Society for Machinery Failure Prevention Technology (MFPT)

http://www.mfpt.org

Society for Machinery Failure Prevention Technology. Focused on machinery, but useful for electronics PHM too. Minimum Corporate Membership Fee of $1000

5.4 Society of British Aerospace Companies (SBAC)

http://www.sbac.co.uk

The society of british aerospace companies. Membership only for UK based companies aerospace - including manufacturers, manufacturing suppliers, service companies and airport operators.

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6 Prognostics SW tools

6.1 RidgeTop Group Design Tools

http://www.ridgetop-group.com

Real-Time BIST Detector for BGA Faults in Field Programmable Gate Arrays (FPGAs) - This paper introduces a solder-joint built-in-self-test (SJ BIST) for detecting high-resistance and intermittent faults in operational, fully programmed field programmable gate arrays (FPGAs)

Return-On-Investment (ROI) for Electronic Prognostics in High Reliability Telecom Applications - This paper was presented at the 2006 INTELEC Conference in Rhode Island and defines the approach and methodology for deployment of prognostics in Telecom power supplies.

Extended Frequency-Domain Modeling Capabilities for VHDL-AMS - This paper presents frequency domain modeling extensions for an analog VHDL-AMS subset in the scope of Harmonic Balance simulation.

Return-On-Investment (ROI) for Electronic Prognostics in Mil/Aero Systems - This paper was presented at the Autotestcon Conference and describes a methodology for quantifying the return-on-investment (ROI) for the adoption of Electronic Prognostics in Mil/Aero systems.

Practical Application of PHM/Prognostics to COTS Power Converters - This paper was presented at the IEEE Aerospace Conference and describes a methodology for implementing electronic prognostics on a DC to DC forward converter.

In-situ Sensors for Product Reliability Monitoring - This paper, co-written with CALCE (University of Maryland) describes an in-situ sensor (prognostic monitor) approach, which can be used to estimate the accumulated damage and the remaining life of semiconductor devices.

Prognostic Techniques for Semiconductor Failure Modes - This paper surveys the problems involved, and recommends a methodology for the inclusion of pre-calibrated prognostic cells that can be co-located with a host circuit to provide an early-warning of a system failure, so that appropriate corrective action can be taken.

RINCON - A Rigorous Tool for Accurate RF/Microwave modeling and simulation. - A key benefit of creating a new analysis tool is the ability to incorporate recent advances in modeling technology to provide the RF/Microwave Designer with enhanced capabilities. Using VHDL-AMS as a base, the Authors have developed a powerful Modeling/Simulation tool with unparalleled modeling capabilities for rigorous and accurate modeling of complex devices.

VHDL Approach Improves Nonlinear Simulation - A new approach to harmonic-balance simulation uses a frequency-domain-extended standardized modeling language to support the use of black boxes in simulations.

6.2 ePHM Design™

http://www.impact-tek.com/Data/Publications/ePHM.pdf

Prognostic Health Management Design Software. Impact Technologies, Electronic Systems PHM group, develops failure prediction technologies for electronic systems. With demonstrated success in Power Electronics, Radio Frequency, Digital, and Motor/Generator domains, Impact's array of technologies is customizable to diverse application domains. Incorporating dynamic physics of failure modeling with advanced usage and signal monitoring, Impact provides robust, real-time solutions for ePHM. Building on a suite of diagnostic reasoning software for improved fault isolation, and

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incorporating advanced, physics-based, dynamic failure modeling with signal and usage monitoring, permits Impact to rapidly develop and deploy PHM systems connecting operational, maintenance, and logistics elements to provide effective condition-based maintenance solutions for avionics, vetronics, and power electronics.

6.3 eXpress

http://www.dsiintl.com/weblogic/Products.aspx

System capture and diagnostic development with a simple and intuitive graphical design interface. Design Capture, for both up-front and legacy designs. Diagnostics and Testability Analysis. Prognostics Design Influence. Reliability Engineering Support. Maintainability Engineering Support. Validation and Verification. Sensor Optimization and Trade-off Studies

6.4 Diag-ML

http://www.diag-ml.com

The diagnostic markup language. The Diag-ML Format was conceptualized mid 2001 by a consortium of public and private companies interested in producing a non-proprietary language for describing diagnostic procedures, designs, tests, and data. Key Benefits: Easily Extended, Parsed and Transformed, Avoidance of Obsolescence, Proven. Applications for Diag-ML include: Transfer of Knowledge to Run-Time Systems. Diagnostic and Prognostic Knowledge Capture. System- and Subsystem-Level Diagnostics and Prognostics. Third-Party Diagnostic and Testability Assessment. Static, Dynamic and Rule-Based Diagnostics / Prognostics. Diagnostic Flowcharts and Fault Trees. Export to Maintenance-based Simulations. Remote Diagnostic / Prognostic Engines

6.5 Watchdog Agent Toolbox

http://wumrc.engin.umich.edu/research/_file/IMS_files/wap.pdf

The Watchdog Agent™ Toolbox is a software program that has been created to assess and predict system performance in various conditions and easily assess which combination of algorithms is the best fit for a particular application.

6.6 VPS-MICRO

http://www.vextec.com/prod_micro.html

VEXTEC's proprietary virtual prototyping software tool VPS-MICRO™ simulates this kind of real material behavior including electronic materials - especialy reliability of solder joint.

6.7 MBIT

http://www.dot21rts.com/products/mbit%20datasheet.pdf

Motorola Built-In Test (MBIT) is an off-the-shelf software infrastructure designed to verify the correct operation of Motorola Computer Group hardware and enable the incorporation of system-level diagnostics. MBIT is available in two versions—board-level MBIT and system-level MBIT.

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7 Other information resources on prognostics

7.1 Books

Intelligent Fault Diagnosis and Prognosis for Engineering Systems

http://eu.wiley.com/WileyCDA/WileyTitle/productCd-047172999X.html

7.2 Magazines

Aviation Week, http://www.aviationweek.com, Aviation Week & Space Technology

Aviation Today, http://www.aviationtoday.com, Online magazine

7.3 Dedicated websites

http://www.testability.com Testability.com is an information site serving the Testability, Diagnostics, Prognostics and Health Management disciplines with relevant history and terminology. Design for Diagnosability (DFD) along with Design for Testability (DFT) and Design for Test (DFT) are terms that are often used interchangeably. This site aims to be a resource that better describes these disciplines, their purpose, boundaries and differences as relevant to the Diagnostic Engineering Process.

http://www.tmworld.com TMWorld.com is a comprehensive website solely dedicated to providing information for engineers involved in electronics test and measurement across various industries including communications, aerospace and defense, and consumer electronics. Engineers can access technical information specifically geared for on-the-job application, as well as industry news, coverage on the latest standards and technologies, application notes, product specifications, how-to articles, industry events, blogs and contests. TMWorld.com is written and edited by industry-respected editors, all previous engineers themselves TMWorld.com is the online extension of Test & Measurement World --the leading publication for engineers involved in the electronic test, measurement, and inspection. Published for over 25 years, T&MW is regarded as the industry leader and has been voted the most-preferred publication in the industry in over 43 independent readership studies. T&MW provides practical content and industry updates for engineers and engineering managers worldwide.

http://prognosticshealthmanagement.com small website on PHM

http://www.designfortestability.com small website on design for testability

http://www.phminfo.com various info incl papers and user forum on PHM

8 Prognostic related events

8.1 54th Annual Reliability & Maintainability Symposium (RAMS)

http://www.rams.org

The theme of the 54th Reliability & Maintainability Symposium — RAMS 2008 is "Dawn to Dusk — Life Cycle Prescriptions." In today's highly competitive global environment, we are continually challenged to improve reliability, and at the same time shorten design cycles,reduce costs and increase customer satisfaction. One of the challenges facing companies and organizations is to assure reliability throughout the product lifecycle from conception of an idea, through planning, design, testing and warranting performance. Reliability, maintainability, safety and durability are all very important in a product's life cycle as we look forays to meet the challenges presented by today's highly competitive global markets. Great selection of technical papers as well as panel discussions that cover some popular subjects. RAMS is a unique experience where you can get a mixture of tutorials for education, attend paper presentations that demonstrate the application of the information presented in one or more tutorials, and to share in the insight of industry and government leaders as they participate on the panels. RAMS offers the attendee the opportunity to network with Reliability professionals from around the world in this four-day event.

8.2 2008 IEEE Aerospace Conference

http://www.aeroconf.org

The 2008 conference will be the 29th in a series of annual weeklong winter engineering conferences designed for aerospace experts, academia, military personnel and industry leaders in a stimulating and thought-provoking environment. The conference promotes interdisciplinary understanding of aerospace systems, their underlying science and technology, and their applications to government and commercial endeavors. Attendees enjoy exceptional access to authors and invited speakers in a unique setting, fertile ground for developing lasting relationships benefiting participants, their organizations, and the engineering, scientific and aerospace communities far beyond the conference. Papers are peer reviewed and typically provide the technical depth characteristic of journal articles; CD-ROM Proceedings are distributed at the conference.

8.3 RCM - 2008 / EAM - 2008 / MTrain - 2008

http://www.maintenanceconference.com/rcm/index.htm

Please join us for EAM-2008 the Enterprise Asset Management Summit, March 18-20, 2008, in exciting Las Vegas. EAM-2008 is collocated with RCM-2008 — The Reliability Centered Maintenance Managers' Forum and MTrain-2008 — The Maintenance Training and Recruiting Conference — providing three times the value and learning opportunities.The Reliability Centered Maintenance Managers' Forum is a focused RCM event where maintenance and reliability professionals learn from each other through a series of informative learning sessions, short courses, networking opportunities and optional full day workshops. EAM-2007 is the only event dedicated to Enterprise Asset Management and Computerized Maintenance Information Management including Maintenance Inventory, Maintenance Planning & Scheduling and Maintenance Work Management. The Maintenance Training Conference is focused on providing information on building the most effective maintenance and reliability training program possible — using proven techniques that create value added maintenance professionals. Participants will discover exciting new ideas and learn helpful techniques for implementing or improving maintenance training programs.

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8.4 Maintenance and Reliability Technology Summit 2008

http://www.martsconference.com/

The Maintenance & Reliability Technology Summit (MARTS) is the premier event for professionals and features technical and business sessions, workshops and technical exhibits. MARTS workshops have been designed from the ground up to provide comprehensive educational and professional development opportunities. All-day workshops are scheduled both pre-conference (April 14) and post-conference (April 17). Most workshops qualify for Continuing Education Units (CEUs). Conferences are scheduled over two days (Tuesday, April 15 and Wednesday, April 16) to cover concurrent tracks each day: Executive, Lubrication, Technologies, Energy and Reliability Practices. The latest products, technologies and services will be displayed over two full days. Company representatives will be on hand to demonstrate their products and services. See the www.MARTSconference.com Web site for an updated listing of exhibitors.

8.5 E-32 Aerospace Propulsion Systems Health Management

http://www.sae.org

The SAE E-32 Engine Condition Monitoring committee addresses all facets of aircraft and helicopter engine condition monitoring and rotorcraft HUMS (Health and Usage Monitoring Systems) by gathering and analyzing requirements for the various types of aircraft gas turbines and rotorcraft. The group is dedicated to creating, preparing and maintaining all relevant specifications, standards and requirements for engine condition monitoring systems. Participants in the SAE E-32 committee include OEMs, suppliers, processors, consulting firms, government and others across the aerospace and defence industries.

8.6 Maintenance and Reliability Conference

http://www.engr.utk.edu/mrc/

Like previous MARCON conferences, MARCON 2008 will be a forum for all — practitioners, specialists, educators, students and managers — to exchange information on new emerging technologies as well as on tried and proven methods and techniques in the area of maintenance and reliability engineering. Cutting-edge research topics, case studies of real applications and the latest thinking in the managerial/financial aspects of the maintenance and reliability field come together in this multi-track, highly informative conference. You are invited to provide a 300- to 500-word abstract for consideration by the Technical Review Committee for presentation at MARCON 2008. MARCON 2008 should prove to be greatly beneficial for your business, featuring keynote addresses and pre-conference workshops centered around bridging classic reliability and industrial maintenance. We welcome manuscripts that correspond to this theme as well as additional topics pertaining to the field of maintenance and reliability. MARCON 2008 will be co-located with the Plant Engineering & Maintenance Show.

8.7 62nd Meeting of the Society for Machinery Failure Prevention Technology

http://www.mfpt.org/MFPT_62/62CallforPapers.htm

The 2008 MFPT 62 program theme was chosen in response to the growing importance of availability to system operators' performance, efficiency, competitiveness and, ultimately, "bottom line." The conference will thus focus on how failure prevention technologies beneficially influence availability, and therefore effectiveness, support cost and through-life value of the systems that they support. The agenda will comprise an Opening Plenary Session designed to highlight the current and future cutting-edge technology needs that challenge our technical community. Three parallel technical tracks will

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then follow for the next two and one-half days. Conference sponsors and/or exhibitors will be able to present their capabilities in a special 'New Products and Services' Session. In the planning of MFPT 62, the Program Committee will continue to promote the Society's policy of cooperation with organizations that have related technical interests. These organizations include professional societies such as SEM, STLE, ASM, IEEE and ASME; the Shock and Vibration Information Analysis Center (SAVIAC); and a number of Universities and Centers of Excellence, in particular the ISM at the University of Cincinnati.

8.8 DoD Maintenance Symposium & Exhibition

http://www.sae.org/events/dod/

Explore the latest developments in Department of Defense (DoD) weapon systems and equipment maintenance, including military and commercial maintenance technologies, information systems, and management processes. This symposium brings together government and industry representatives to exchange ideas for improving maintenance practices and procedures — via an up-to-the-minute technical program, presentations from senior-level speakers and a dynamic exhibit.

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9 Conclusions

Prognostics for electronics is an engineering discipline focused on predicting the future condition of a component and/or system of components. The science of prognostics is based on the analysis of failure modes, detection of early signs of wear and aging in complex systems and components, and correlation of these signs with an aging profile or model. Prognostics is also involved in more general approach - Prognostics and Health Management (PHM), which is a method that links studies of failure mechanisms to system lifecycle management.

While PHM on mechanical systems is well established and used in many commercial applications, PHM on electronic system is generally complex and costly. Most of research and development has been done with government support for critical military, aerospace and nuclear applications, while commercial application of PHM on electornics systems is relatively niche market involving reliability medical and automotive application (where however mechanical one is dominating again such as PHM based on engine, gear or bearing vibrations). The mechanical PHM is so established that it is used not only to prevent from unexpected failure, but is often used for normal Maintenance Logistics and System Optimization, where PHM can save costs in industry and commercial applications (e.g. it is cheaper to exchange a single bearing in time than to repair whole engine, which can be damaged due to the broken bearing).

Currently the world leading country in PHM is the USA due to the rich support for various R&D projects. EU plays a minor role in PHM, therefore there is a potential for EU companies for R&D in this field. How much EU is behind USA in prognostics can be seen on the flagships for reliability electronics – space industry. While NASA seriously considers prognostics as important method, they generated many successful projects, provide funding and generated many publications, there is basically no sign of activity or support concerning PHM on the side of ESA. One of few large European projects in which PHM was involved is the military Eurofighter Typhoon project in which British BAE Systems was involved. Despite this it seems that BAE branch in USA is involved in PHM for years already. UK has the strongest mil/aerospace industry outside USA and therefore it seems to be the technology leader in PHM in EU.

It is a fact that without government support electronic PHM can hardly succeed on the market except for the high-reliability applications. The main problem of PHM is that typically one electronic component, whose behaviour should be diagnosed and predicted needs whole electronic system for sensing, processing and evaluation. Therefore the total system with implemented PHM can reach many times more the complexity than was the original electronic component or system without PHM. In addition, proper care must be taken so that the more complex system, which involves PHM, is not less reliable at the end than the original simple system without PHM, because of aging and degradation of sensors. The problem of ePHM is not only the extra cost associated with additional HW, but also enormous R&D expenses necessary to develop proper models and SW, which evaluate, process and decide based on input form sensors. Development of the models typically needs a long term investigations and observations and processing of huge amount of statistical data from field experiments in order to validate the model and isolate the fault.

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