Presenting Author: George Vachtsevanos **Ser:** 1

Organization: Impact Technologies/Georgia Institute of Technology

Country:

Paper Title: **An Integrated System Health Management Methodology: Beyond Fault Diagnosis and Failure Prognosis**

Co Authors:

Abstract:

This Workshop introduces an integrated health management approach to critical vehicle systems and other industrial processes that combines effectively in real-time concepts from the Prognostics and Health Management (PHM) and fault-tolerant control areas for improved asset autonomy and sustainment. The military and industrial communities are actively seeking and pursuing the development and utility of new autonomy and sustainment technologies for their critical assets and the design/deployment of next generation platforms that exhibit attributes of safety, availability, reliability, maintainability and affordability. The ultimate goal is the design and operation of high-confidence systems that deliver capability as designed. To achieve this goal, the emphasis needs to expand beyond the notion of reliability and prognostics and focus on system integrity management. Integrity management is viewed in this workshop as maintenance of the operational response of high-valued assets in the presence of adverse internal (faults/failures) or external (icing, extreme wind gusts, etc.) events. The term “integrity” refers to characteristics of durability, redundancy, survivability, safety, reliability and availability for such critical assets as aircraft, spacecraft, UAVs in the execution of a “mission.” As an example, a fault-tolerant or control reconfiguration system architecture presupposes the presence of a severe fault or failure and the strategy is to accommodate the fault/failure with other means, preserving the operational integrity of the asset for the duration of a mission. System/component failure and malfunctions are recognized as contributing factors to aircraft loss-of-control in flight. Despite the growing demand for improved reliability, safety and availability of dynamic systems, little work has been published discussing the specific role of prognosis in trolled systems. We propose a novel methodology for the fault-tolerant design of critical subsystems and systems, such as an Electro-Mechanical Actuator (EMA) and associated control surfaces, which takes advantage of on-line, real-time estimates of the Remaining Useful Life (RUL) of a failing component and reconfigures the available control authority by trading off system performance with control activity. The primary goal is to complete critical mission objectives within a time window dictated by prognostic algorithms so that the fault mode is accommodated and an acceptable level of performance maintained for the duration of the mission. The proposed fault-tolerant control design is applicable to a variety of application domains. We will discuss a fault diagnosis and failure prognosis framework that builds upon mathematically rigorous concepts from estimation theory – an emerging and powerful methodology in Bayesian theory called Particle Filtering that is particularly useful in dealing with difficult non-linear and/or non-Gaussian problems. The underlying principle of the failure prognosis methodology is based on particle filtering in combination with streaming sensor data and appropriate fault/degradation models. A hierarchical fault-tolerant control architecture is comprised of three levels that perform control reconfiguration at the component level, redistribution of the available control authority at the subsystem level and mission adaptation at the highest echelon of the control hierarchy. The intent is to trade-off system performance with Remaining Useful Life so that the latter may be extended beyond the required mission profile thus avoiding a potential catastrophic event. The enabling technologies take advantage of Model Predictive Control techniques, fault adaptive control methods and search algorithms to execute control reconfiguration, redistribution and mission adaptation, respectively. Prognostic and system constraints are entering into the optimization problem. The proposed fault-tolerant control architecture is applied, tested and evaluated on an Electro-Mechanical Actuator driving a typical aircraft control surface. Note: I will use segments of my book Intelligent Fault Diagnosis and Prognosis of Engineering Systems, Wiley 2006

Presenting Author: George Vachtsevanos **Ser:** 2

Organization: Impact Technologies/Georgia Institute of Technology

Country:

Paper Title: **An Integrated Integrity Management Approach for Improved System Autonomy**

Co Authors:

Abstract:

This workshop introduces an integrated health management approach to critical aircraft/rotorcraft systems that addresses effectively in real-time concepts from the Prognostics and Health Management (PHM) area for improved asset autonomy and sustainment. The Department of Defense is actively seeking and pursuing the development and utility of new autonomy and sustainment technologies for military assets and the design/deployment of next generation platforms that exhibit attributes of safety, availability, reliability, maintainability and affordability. The ultimate goal is the design and operation of high-confidence systems that deliver capability as designed. To achieve this goal, the emphasis needs to expand beyond the notion of reliability and prognostics and focus on system integrity management. Integrity management is viewed in this presentation as maintenance of the operational response of high-valued assets in the presence of adverse internal (faults/failures) or external (icing, extreme wind gusts, etc.) events. The term “integrity” refers to characteristics of durability, redundancy, survivability, safety, reliability and availability for such critical assets as aircraft, spacecraft, UAVs in the execution of a “mission.” The fault diagnosis and failure prognosis framework builds upon mathematically rigorous concepts from estimation theory – an emerging and powerful methodology in Bayesian theory called Particle Filtering that is particularly useful in dealing with difficult non-linear and/or non-Gaussian problems. The underlying principle of the failure prognosis methodology is based on particle filtering in combination with streaming sensor data and appropriate fault/degradation models. The proposed PHM architecture is applied, tested and evaluated on an Electro-Mechanical Actuator driving a typical aircraft control surface.

Presenting Author: George Vachtsevanos **Ser:** 3

Organization: Impact Technologies/Georgia Institute of Technology

Country:

Paper Title: **An Intelligent Approach to Life Cycle and Risk Management of Critical Military and Industrial Systems**

Co Authors:

Abstract:

This workshop introduces a novel approach to life cycle and risk management of critical processes with emphasis on the optimum deployment of emerging Prognostics and Health Management (PHM) and Condition Based Maintenance (CBM) technologies to re-worked or re-manufactured systems. Sustainment of critical systems/processes is a major concern of the industrial community. The cost of sustaining such assets as aircraft, ground vehicles, CNC machines, etc. is exceeding the cost of purchasing new ones. New and innovative technologies are emerging to address the sustainment problem. Condition-Based Maintenance and Prognostics and Health Management are assisting to maintain equipment only when needed, increase equipment availability and uptime and reduce maintenance costs. Life cycle and risk management technologies have been employed extensively over the past years in order to extend the useful life of critical system components (engine, drive systems, spindle, motor, etc.) and eliminate or postpone the need for purchasing new systems/processes. It is anticipated that re-worked systems may perform "as if they are new" or even "better than new". There is anecdotal evidence from the industrial world that such systems/components have a longer life time than their new counterparts. This workshop introduces new strategies in order to optimize maintenance practices, reduce costs and minimize time to overhaul without compromising the operational integrity of critical assets. These strategies take advantage of new life cycle management and risk management technologies to achieve stated objectives. Classical Reliability Centered Maintenance (RCM) (Weibull distributions, among others) theory employs loss models and estimates the failure probability of critical components/systems. System life optimization after re-work relies on classical reliability models, sensor data and data mining tools as well as physics-based simulations to estimate reliably the useful life of re-engineered components/systems. Approaches to risk management are key to analysis and design of life management practices for such systems. Risk measurement, i.e. establishing a data collection framework and appropriate measurement metrics to calculate risk, risk valuation, i.e. converting data to information via data mining tools, and risk control, i.e. changing the risk profile through CBM/PHM technologies, are the essential constituent modules of a rigorous risk management approach. We introduce the development of algorithms and methods that combine features from the areas of probabilistic design to simulate degradation of re-worked components/systems, renewal theory and loss models based on life cycle and risk analysis methods to optimize the life estimates of re-engineered systems. We demonstrate the approach with actual process data.

Presenting Author: Debbie Aliya **Ser:** 4

Organization: Aliya Analytical

Country:

Paper Title: **Foundations of Thinking Skill Optimization**

Co Authors:

Abstract:

Optimizing our decision making ability is a result of clarity of analytical thought and knowing what we want to accomplish. This is as true for small tasks as it is for bigger strategic action plans, as true for tasks to be done at work or at home, for professional effectiveness or meeting our personal goals for a life well lived.

David Levy's now classical book, "Tools for Critical Thinking: Metathoughts for Psychology" has been called "The Thinking Person's Self Help Book." The tutorial presenter will share content from some of the chapters from this book as she has modified them for the working engineer rather than for the psychologists for whom it was written. Recognizing how the words we use to structure our thoughts keep us from seeing all the possibilities inherent in any given situation is the first step on the path of optimizing our thinking. Other "meta-thoughts" we will examine include the ideas of multiple simultaneous levels of events, key to failure analysis, and defining characteristics by their opposites. This last "meta-thought" is a "golden key" to unlocking creativity as well as a platinum key to better human relations