

# Avionics and e-PHM Applications Overview

The Electronic Systems Prognostics (e-PHM) Group at Impact Technologies develops and deploys solutions for automated electronic systems health assessment that integrate collaborative diagnostic and prognostic techniques from multiple engineering disciplines including signal processing and physics of failure methods. Impact is a pioneer in e-PHM techniques for various avionics power supplies, digital systems, power drive systems and mixed RF/Digital systems. Our core e-PHM technologies integrate techniques such as statistical reliability, damage accumulation modeling, physics of failure modeling, signal processing, feature extraction, and automated reasoning algorithms. These advanced prognostic/diagnostic algorithms utilize intelligent data fusion architectures to optimally combine sensor data with probabilistic component models to achieve the best decisions on the overall health of electronic components and systems.

Some of the diagnostics and prognostics programs across the DoD and industry act as related experience to support this effort. The following sections provide a brief description of a few relevant programs.

1.	Prognostics and Health Management (PHM) for Digital Electronics.....	2
2.	EMA Flight Control Actuator Prognostics .....	3
3.	e-PHM for Information Technology (IT) and Network Services.....	3
4.	Diagnostics and Prognostics for High Frequency Avionic Systems.....	4
5.	Diagnostics and Prognostics for GPS Systems .....	4
6.	e-PHM Technologies for Switch-Mode Power Supplies.....	5
7.	Apache Target Acquisition and Designation Sight (TADS) .....	5
8.	Integrated Diagnostics and Open Architecture for Avionics.....	6
9.	Verification and Validation of e-PHM Technologies .....	7

# 1. Prognostics and Health Management (PHM) for Digital Electronics

Impact Technologies has developed integrated diagnostic/prognostic technologies for assessing the remaining useful life of aircraft digital electronic boards. Implementation of this e-PHM concept builds on a foundation of usage monitoring, incipient fault detection, and physics-of-failure modeling to enable an ability to relate circuit health state information including operational history and detection of incipient faults to accurate RUL predictions at any point in the component's life cycle. Impact has been successful in detecting discernable degraded health states of critical digital components, specifically the processor, prior to Built-In Test (BIT) detection. Current development efforts are targeting on-board deployment for JSF systems and fielding of off-board technology to automatic test equipment (ATE) applications.

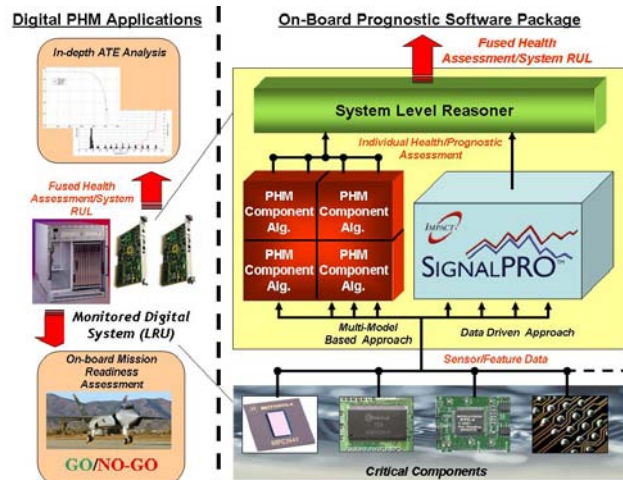


Figure 1 – Digital PHM Concept Overview

In addition, Impact has formulated an in-depth understanding of the prevalent failure mechanisms and the associated physics of failure effecting semiconductor devices, specifically targeting those found on avionic systems. Specific fault-to-failure and system dependency inference models were developed and initially tuned based on accelerated failure testing and fault injection simulation efforts to provide increased confidence in the developed technologies and the prognostic output. Impact Technologies' SignalPro™ analysis engine was used to evaluate electronics system performance by employing a combination of signal processing, statistics, and data-driven modeling techniques. Two models, a combined failure model and life consumption model have been developed and evaluated. The combination of different failure or aging mechanisms produces a cumulative effect contributed to the combined failure model. A life consumption model has been derived from the physics-of-failure research regarding MOSFET failure mechanisms.

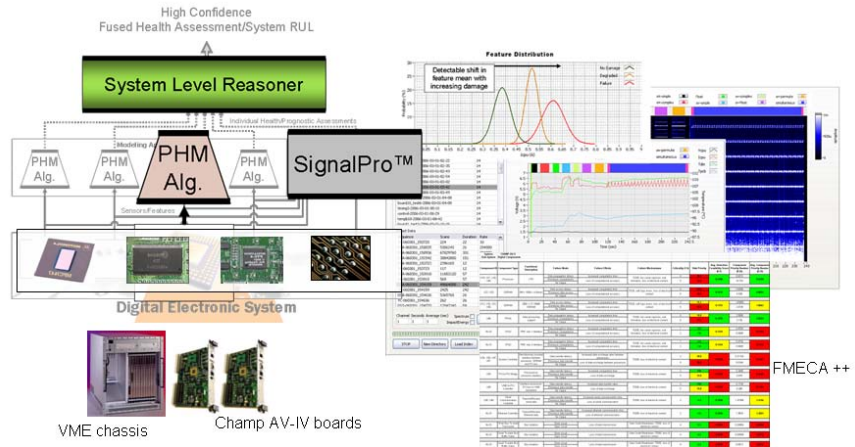


Figure 2 – Digital PHM Concept Overview

## 2. EMA Flight Control Actuator Prognostics

Impact Technologies, in partnership with Lockheed Martin and Parker Hannifin Corporation have developed a suite of prognostic techniques for flight control actuator electronics. Electro-magnetic actuator electronic units utilized within many of our programs support a robust initiated and continuous Built In Test (BIT) capability. Based on a rigorous and comprehensive analysis simulation and associated highly accelerated life testing (HALT) program the Impact PHM algorithms were able to detect incipient faults, identify failures and provide prognostic information before the faults are identified by the BITs. A detailed FMECA++ engineering analysis (combination of traditional FMECA and PHM element combined) has been performed on many different units including the individual printed circuit boards to select the appropriate critical components for the study. Specific seeded fault and HALT tests have been conducted to characterize and trend the system level effects of critical component degradation. The developed diagnostic and prognostic models have shown to be capable of providing health state and remaining useful life information.



Figure 3 – Example EMA Actuator System

## 3. e-PHM for Information Technology (IT) and Network Services

Impact Technologies has developed an innovative prognostics solution for information technology networks within dynamic operating environments. Through passive system monitoring and state classification, baseline IT network performance Quality of Service (QoS) metrics were recorded and analyzed for a healthy network state. Impacts ReasonPro™ health reasoning algorithms were capable of detecting any network anomalies, with an additional on-line diagnostic test being performed to deduce if additional, or more significant potential problems exist. The system isolates all faults, which are subjected to an off-line diagnostic test to determine potential sub-component related fixes, remaining useful life (RUL) of the component, and system-level effects.

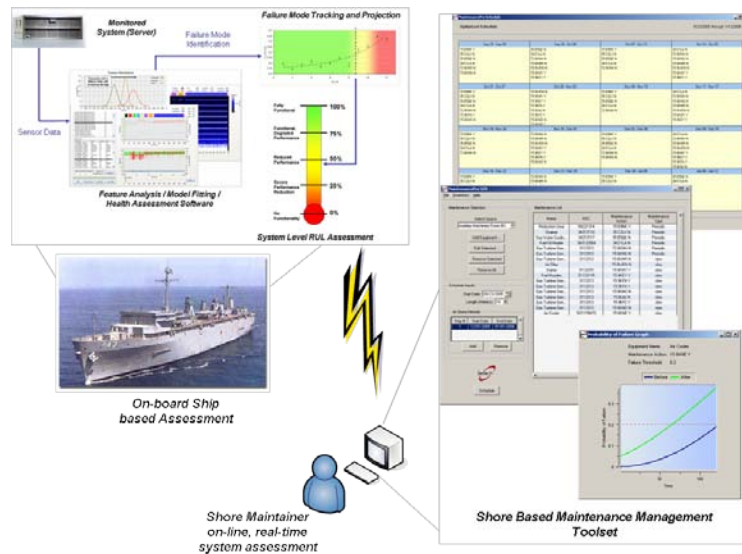


Figure 4 – Concept Diagram for PHM for Afloat and IT systems

This program has also established a link with predictive based maintenance tools. Real-time network analysis allows an unprecedented level of maintenance upkeep. The ability to diagnose an entire network from multiple locations, with the support of additional on-board PHM monitoring, is the next step of truly fault tolerant network infrastructures.

#### 4. Diagnostics and Prognostics for High Frequency Avionic Systems

Impact Technologies has developed a real-time diagnostic/prognostic system that can assess anomalous events and determine the remaining useful life of high frequency aircraft electronic systems. The initial application for this technology was a global positioning system (GPS) receiver module. The monitoring and software package incorporates an innovative approach utilizing existing system operational data, anomalous event detection and classification, and advanced failure mode and effect modeling to provide a highly reliable component health assessment and failure prediction capability. This “circuit as sensor” approach enables a PHM solution that minimizes or eliminates the need for additional sensor and data acquisition equipment. The system developments were accomplished through

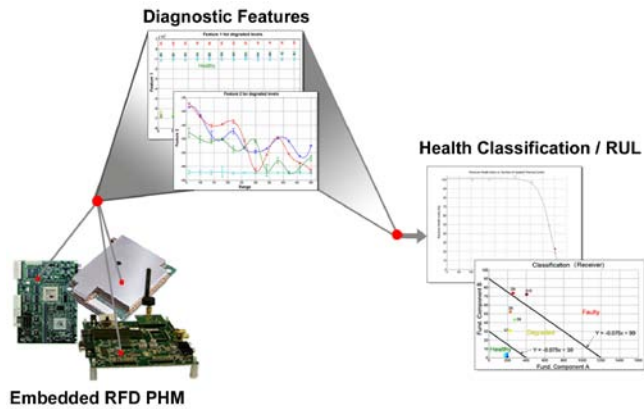


Figure 5 – Concept Diagram for RF/D Systems PHM

extensive accelerated failure testing and integrated system modeling and simulation utilizing a unique RF/D modeling, simulation, and demonstration test bench. The programs have culminated in an embedded prototype modular RF/D PHM software package implemented for commercial GPS, parameterized and reconfigurable for demonstrated functionality for other RF/D applications such as software defined radio and radar guidance.

#### 5. Diagnostics and Prognostics for GPS Systems

Impact Technologies has also developed a real-time diagnostic/prognostic system to assess anomalous events and determine the remaining useful life of global positioning system (GPS) devices. Device modeling with equivalent circuit SPICE (Simulation Program with Integrated Circuit Emphasis) and mathematical physics of failure models describe parameter degradation resulting from damage accumulation for each device. Prognostic features derived from system-level models and extracted from the GPS operational communication data stream (NMEA 0183 protocol) update life usage and failure progression models to provide an indication of health state without the need for additional sensors. These statistical parameters, verified through accelerated failure testing, provided a prognostic capability for the high frequency analog circuitry using data and measurement devices consisting solely of the GPS unit itself and the existing satellite constellation. The solution has applicability to a broad class of mixed digital/analog circuitry including radar and software defined radio. The technologies

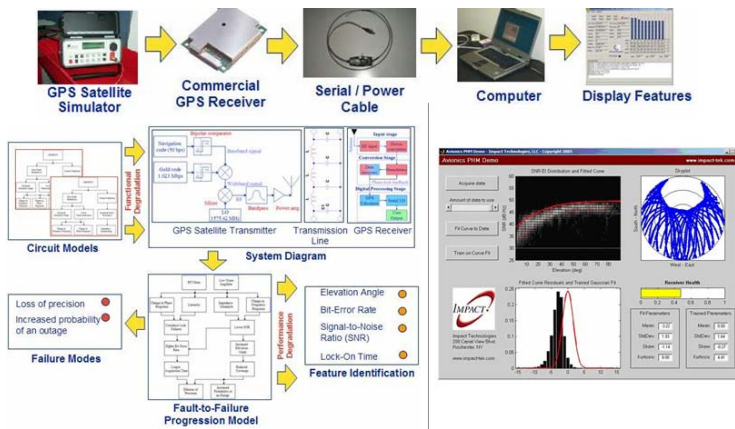


Figure 6 – GPS Receiver Health Index

has applicability to a broad class of mixed digital/analog circuitry including radar and software defined radio. The technologies

developed in the PHM-IC program can augment Digital RF PHM for greater prediction horizon and a higher confidence result.

## 6. e-PHM Technologies for Switch-Mode Power Supplies

Impact Technologies, has developed a robust and generic PHM software package for assessing the remaining useful life of aircraft electronic system power supplies. Complementary prognostic techniques including analysis of projected operating conditions by physics-based component aging models and empirical (trending) models are used to develop verifiable prognostic models. Accelerated failure tests are used to validate empirical relationships with physics-based component models to determine key PHM features. One such test focused on the linear relationship between the pulse-width modulation (PWM) duty cycle and transistor temperature. Over time, the linear relationship offset as a result of accumulating transistor damage. The change in the offset over time was used to detect incipient faults and assess remaining useful life of the switching-transistor.

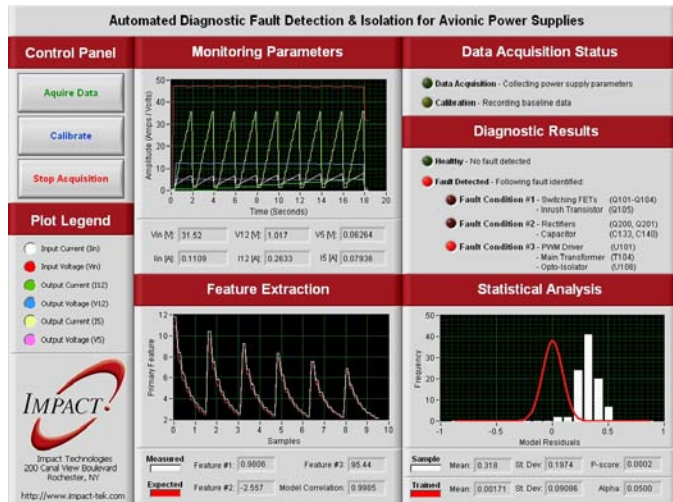


Figure 7 – Power Supply PHM User Interface

## 7. Apache Target Acquisition and Designation Sight (TADS)

Impact Technologies, with the cooperation of the Army (AMRDEC – Engineering Support) analyzed the TADS Laser Transceiver Unit (LTU) based on operational data collected from units deployed in Iraq. Impact developed a demonstration of an automated prognostic capability for the mission critical electronic targeting system onboard the Army Apache Attack Helicopter (AH-64D). The analysis encompassed two complimentary implementations: an embedded prognostics case and an at-wing prognostics case both leveraged, Impact developed commercial software packages and system-level modeling to utilize existing system operational data to provide a prognostic capability. The targeting system provided added benefit as the test case since it offered a good representation of other aircraft electronic subsystems. Figure 9

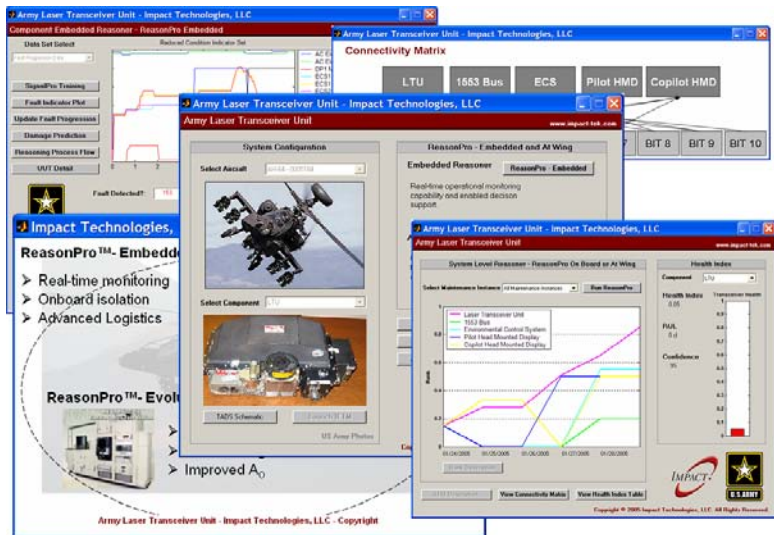
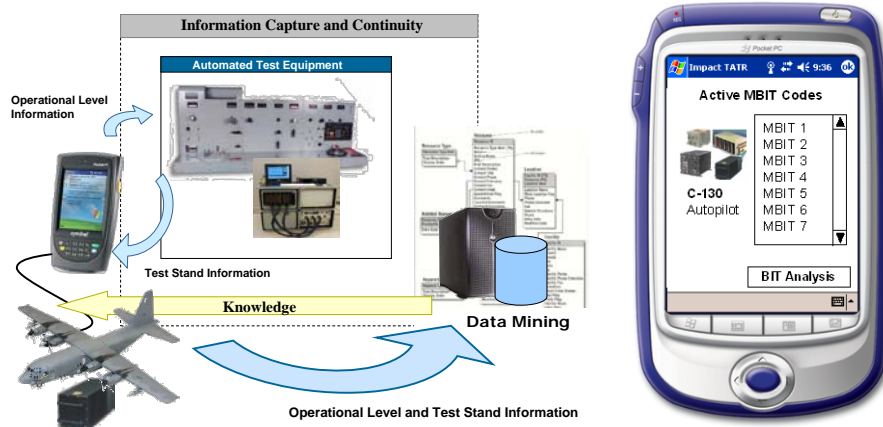


Figure 8 – Apache Target Acquisition and Designation Sight Prognostics

illustrates the demonstration software developed. This program has continued into an extended development effort to incorporate depot-level test data as ground truth for increased diagnostic and prognostic resolution and improved confidence.

## 8. Integrated Diagnostics and Open Architecture for Avionics

Impact Technologies, in collaboration with Honeywell Defense, Space & Electronic Systems, has developed and demonstrated applications of improved on-board embedded diagnostics for avionics as well as open communications architectures that enable information continuity between on-board and off-board systems or maintenance aids. The program included the development of electronic component-level BIT reasoners augmented with reliability models, system-level Bayesian reasoners, and open system architecture databases for federated, legacy aircraft. Impact's ReasonPro - At Wing™ software application provided diagnostic support to operational level maintenance workers through the implementation of diagnostic reasoners and is targeted for legacy operations. ReasonPro - At Wing™ was developed using Microsoft's .NET Compact Framework, which contains the smart device development platform for the Microsoft .NET initiative and is tailored towards the Pocket PC 2003 operating system, using the C# classes and is deployed on a Symbol 8800 rugged PDA. This program was initially focused on F/A-18 and joint avionics test platforms.



**Figure 9 – ReasonPro - At Wing™ Concept and Open System Integration with Legacy ATE**

## 9. Verification and Validation of e-PHM Technologies

Electronic Prognostic and Health Management (e-PHM) technologies are being developed to support the F-35 (JSF) autonomic logistics concept. This concept requires an integrated environment for assessing and validating decision accuracy at all levels in the PHM software hierarchy. A software environment that contains library components for all aspects of PHM technologies from the sensors through reasoners is required.

Impact Technologies has developed an advanced, open-systems software application that provides a comprehensive resource for Verification and Validation (V&V) of PHM technologies for the F-35 or other application. The PHM V&V software environment includes the resources required to assess sensor accuracy, fault detection and prediction algorithm capability, as well as reasoner technologies. The open-systems software application allows access to various data sources and PHM algorithms. In addition, this system is capable of linking up the PHM algorithm results with specific metrics developed to support maturation and validation over the system's life cycle.

Due to the adaptable nature of the V&V Test Bench software, the developed V&V modules can be applied to electrical, mechanical and fluid based systems used in a variety of commercial or DoD applications.



Figure 10 – PHM V & V