PHM System Insights from General Atomics

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GENERAL ATOMICS ELECTROMAGNETICS

Overview

- Introduction to General Atomics
- GA's PHM System Applications
- Successes and Lessons Learned

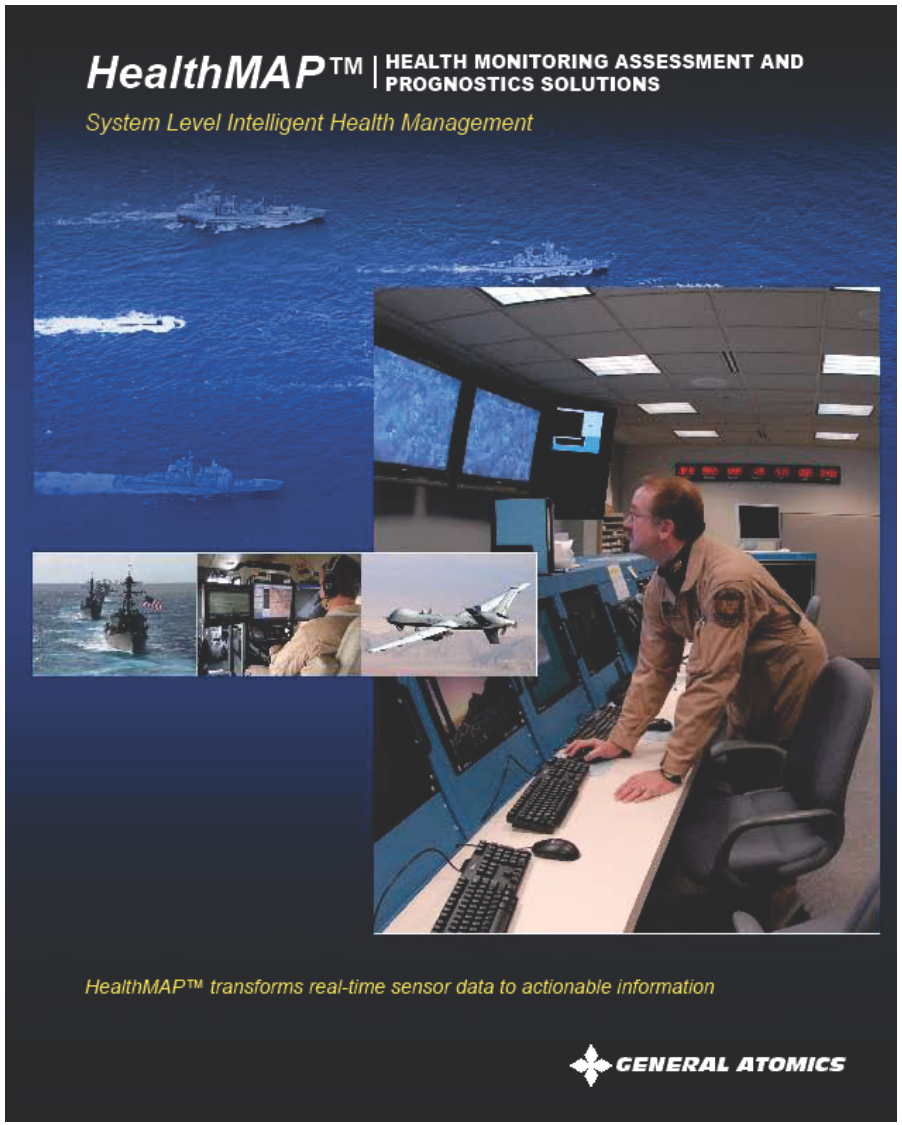
General Atomics Is A Diverse High Technology Company

GENERAL ATOMICS
ELECTROMAGNETICS

GA Intelligent Systems

- **Data Aggregation, Management, Analysis, and Visualization Architectures**
- **Advanced Algorithm Development for Control, Detection, Prediction, and Recognition**
  - Digital Signal Processing in time and frequency domains
  - Neural and statistical classifiers
  - Kalman filtering and parameter estimation
  - Bayesian Belief Networks and Sensor Fusion
  - Genetic Algorithm based search
  - Neuro-Fuzzy Systems
- **Health Monitoring, Assessment, and Prognostics (HealthMAP™) Systems**
- **Adaptive Control and Optimization Systems**
- **Expert Systems based Situational Awareness and Decision Support**
- **Intelligent Automation and Enterprise Reasoning Systems**
- **DoD Battlefield Simulation, Planning and Rehearsal Systems, Biometrics**
- **Test Automation Systems**
- **Automated Maintenance Advisory Systems**
- **Autonomous Vehicle Software Systems**
  - Autonomy
  - Internal and External Awareness Systems
  - Mission planning and reconfiguration

HealthMAP PHM Framework



- RCM Focused PHM Design Methodology
- Distributed Intelligent Data Acquisition
- PHM Modeled Data Repository and Management
- Hierarchical, Expert System Model-based Reasoner
- Distributed Event Detection and Feature Extraction
- Bayesian Information Fusion
- Model-based Fault Isolation and Root Cause Analysis
- Empirical and Statistical Prognostic Algorithms
- Supervisory Layer for Advisement and Decision Support
- Standards-based Interfacing
- Integration with Logistics Systems, IETMs

GA HealthMAP Applications – Fielded and In Work

- FAA ARTCC Critical Power Systems (Fielded)
- Naval Shipboard ALRE Systems (Fielded)
- NASA Rocket Engine Test Stands and facilities (Fielded)
- Hardware-in-the-loop Testbed Systems (Fielded)
- Chemical, Oil, and Gas Production Plants (Fielded)
- Battlefield Management Systems (Fielded)
- Manufacturing Operations (Fielded)
- Army Biometric Systems (Fielded)
- Railgun Pulsed Power Systems (In Test)
- Navy Shipboard Hybrid Electric Drive Systems (In Test)
- Power Conversion Systems (In Design)
- Electric Drive Systems (Mining, Wind Energy) (In Design)
- Unmanned Vehicle Systems (In Design)
- Magnetically Levitated Trains (In Design)
- Nuclear Power Plant Protection and PHM (In Design)
- Enterprise-wide Management (In Design)

GA Health Monitoring Assessment & Prognostics (HealthMAP™) Timeline and Roadmap

HealthMAP™ - steady growth

2003 - 2005

Health Monitoring for FAA Power Distribution Systems

S/W installed in FAA Air Route Traffic Control (ARTCC) centers

FAA

2006 - 2007

ALRE AAG

NASA SSC ISHM for Rocket Engine Test Stands (RETS) 7

ALRE

NASA RETS

2008

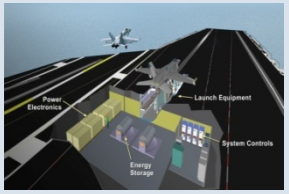
NASA SSC ISHM Toolkit

ALRE - AAG

ALRE - EMALS Automated Test Analysis

Mobile PFN

US NAVY



2009

Mobile PFN

UAV - MQ9 Prototype

ALRE - AAG
EMALS - Automated Test Analysis

NASA SSC Katrina Mitigation

US ARMY Modeling and Simulation for Biometrics

Mobile PFN

2010

Mining Truck Prototype

ALRE - EMALS Logistics

UAV - MQ9

Blitzer Mobile PFN

US ARMY Modeling and Simulation for Biometrics

NASA SSC Katrina Mitigation

ALRE - AAG

UAV

Blitzer

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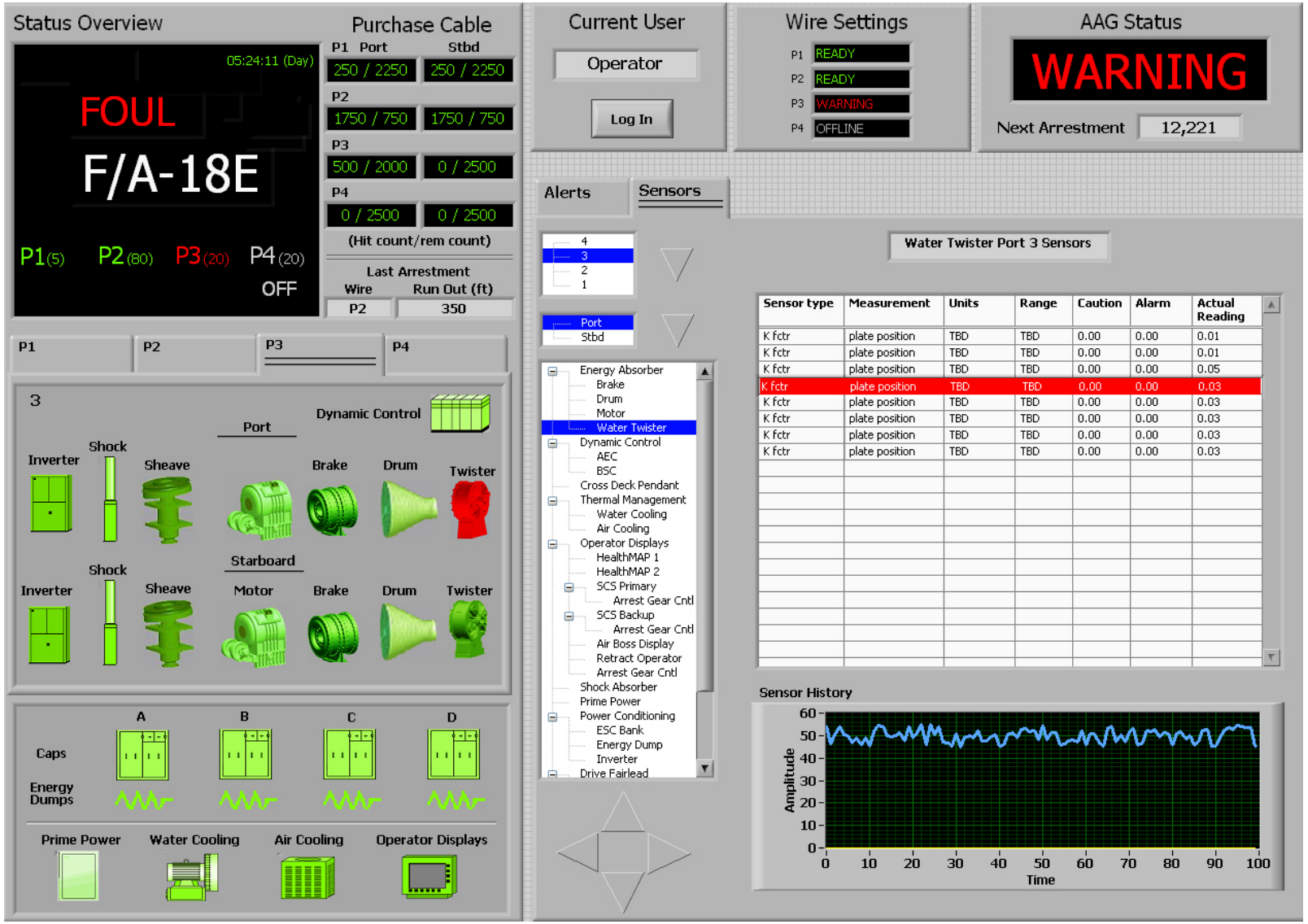
Examples – Advanced Arresting Gear PHM



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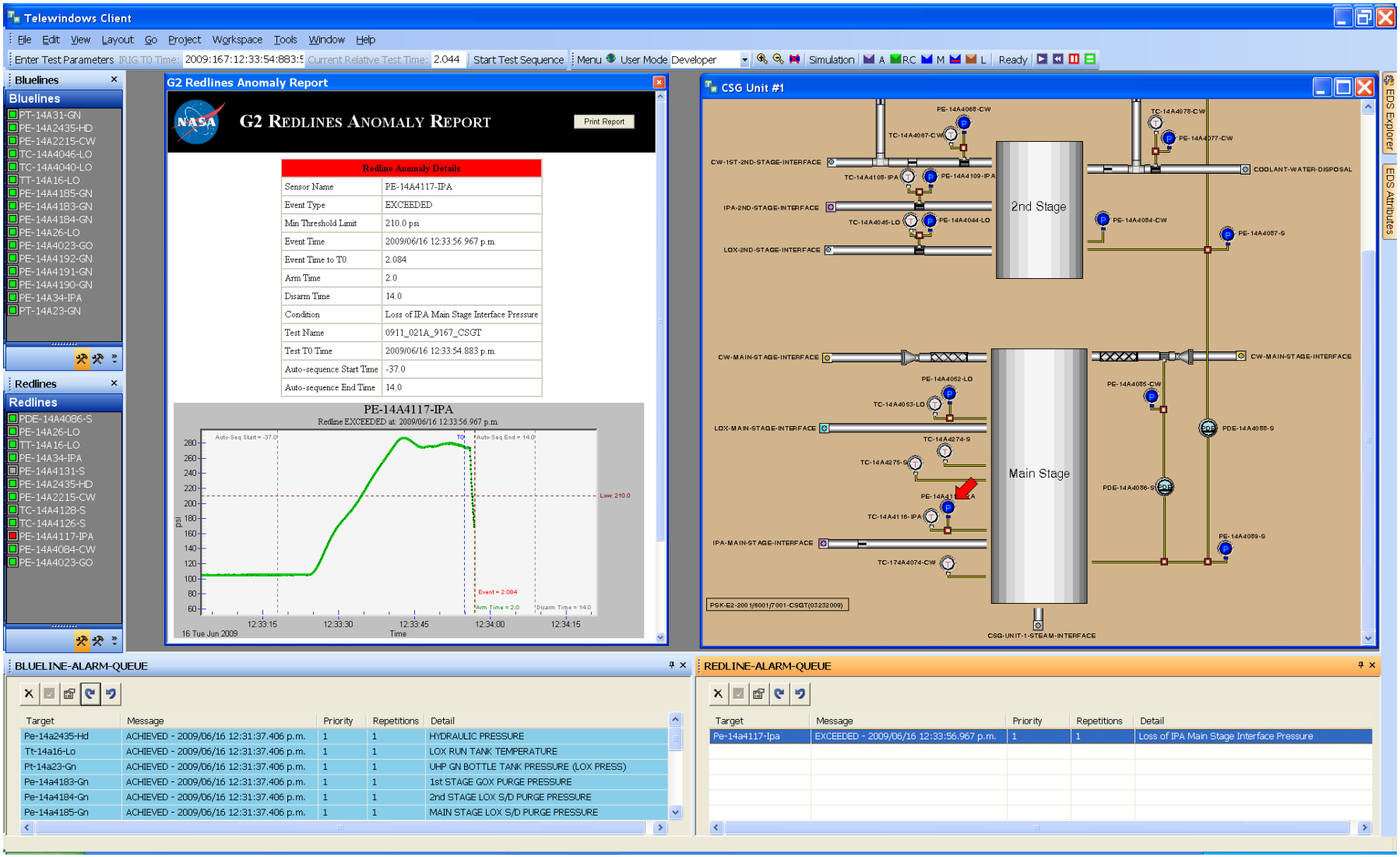
Examples – NASA RETS (SSC) Anomaly Detection



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Successful Results (Medium Scale Complexity)

- **Improved Requirements Derivation Phase (3 months)**
  - FMEA still lacking in utility, aided by IPT based analysis for PHM
  - RCM methodology helps to ensure clear requirements statements, as well as stakeholder acceptance and understanding – but increase in budget not often accepted.
- **Model-based Reasoner can be employed early in design cycle**
  - allows for Rapid Prototyping and diagnosis validation (~1 month) independent from event detection
- **Generic Platform reduces software life cycle costs, leveraging software reuse, model libraries**
  - Most Significant area of benefit
- **Dynamic FMEA can be achieved, assuming requirements are properly assessed**
  - Validation cycle remains the bottleneck, especially for first-of-a-kind
- **Integration with enterprise data and object model to database schema mapping**
  - Common architecture allows for common data management methodologies
- **Integration with external user interfaces (IETMs, Maintainer's Worksatation, Operator Displays) has been demonstrated, but currently constrained by IETM viewer and CONOPS**

- **18 month cycle - design to deployment**

Lessons Learned

- **High Level PHM Requirements increasingly common, but usually ill specified and ill conceived**
  - "…shall diagnose and/or predict critical failure modes…"
  - Stakeholders don't have unified understanding of what or why
  - Expectation on PHM team to propose "useful" Prognostics
    - And we always say "OK"…
  - Requirements typically not derived from proper RCM analysis
  - Component centric and based on old-school sensor suites
  - Capability offset by budget overruns during early phases
  - Prognostics Requirements verification procedures not understood
  - Often reduced in scope and complexity
    - Reduced to thresholds or "if then else"
- **New Construction / First of a Kind**
  - Good opportunity to get PHM in from onset
  - Lack of reliability data, lack of historical data makes it difficult to specify Prognostics functionality
  - FMEA typically done in vacuum and restricted to Reliability assessment
  - Tuning depends on simulation – usually lacking in accuracy or fidelity
  - Prognostics capability not supported by analysis or available data

Lessons Learned

- **Reduced success when FMEA and Sensor Selection not properly driven by PHM Objectives**
- **At best, PHM Software is considered a necessary evil rather than an invaluable system component**
  - Excruciating test and validation cycles
  - Need to demonstrate that "this isn't your Grandpa's software development"
    - PHM focused tools and design process is the key
- **Actual performance not validated until late in life cycle**
  - Budget inadequate for tardy test and tune
  - Forces costly design changes (ECR, ECN, bureaucracy…Arggh!)
  - Programs of record not suitable for sandbox engineering
- **Event Detection algorithms still hard to develop, but can be properly decoupled from Reasoner algorithms and behavior**
- **Ensure PHM infrastructure is in place first, add advanced Capability**
  - Get sensors placed, data aggregated, sensors validated, data visualized, and low level data processing algorithms in place
- **Infrastructure modernization and improved CONOPS necessary to exploit PHM integration with Logisitics Systems**
  - Need better integration and cross pollination between engineering organizations

GA PHM Capability Enhancements

- **Comprehensive design methodology**
- **Access to suite of tools that facilitate the design, implementation, validation, and deployment of next generation PHM systems**
- **Resources with expertise in systems engineering, instrumentation, data acquisition architectures, failure modes and effects analysis, diagnostic and prognostic reasoning, software engineering and the use of advanced tools**

Design Methodology + Domain Experience + PHM focused Tools =

- **Reduction in time and cost for**
  - specifying
  - implementing
  - deploying PHM systems

Conclusion

Questions?

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