Prognostics and Health Management (PHM)

Failure Prediction to Optimally Balance Maintenance and Operations

Highlights

Why is PHM Important?

- PHM can lower maintenance costs while increasing operational availability and utilization:
    - PHM has the potential to save billions of dollars in maintenance and operation costs to the U.S. economy every year
- Required by DoD policy (DoD Instruction 4151.22):
    - Include…for all new weapon systems
    - Implement…where technically feasible and beneficial
- PHM efforts will promote R&D of sensor hardware and decision algorithms in general as well as further their application in other areas

What are the Objectives for Developing this Capability?

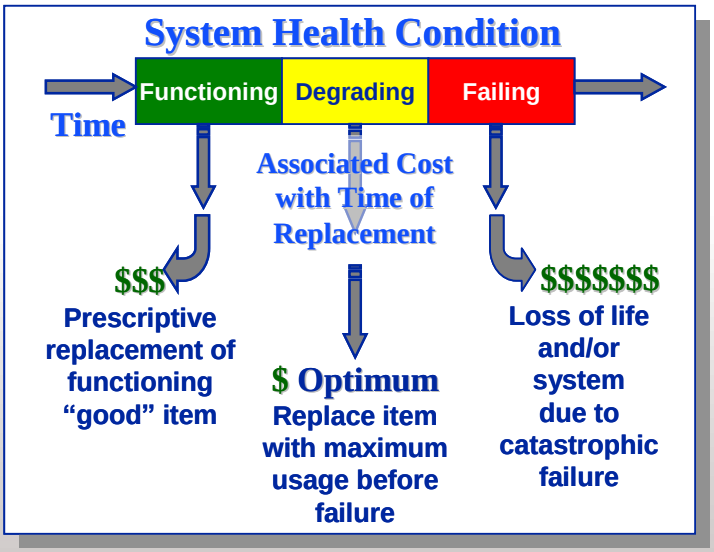
- Enhance national, energy, and economic security by providing Department of Defense, Department of Energy, and industrial customers with tools to lower sustainment costs and raise readiness
- Transition from suboptimal reactive maintenance and logistics strategies to optimal proactive strategies
- Take advantage of cumulative technological advances in sensors, electronics, computers, and algorithms as well as in data storage, transmission, and handling

What are the research areas?

- Sensor design and application: mechanical, chemical, and electrical
- Physics of failure modeling and simulation
- Algorithms for feature extraction, anomaly detection, problem diagnosis, and prediction of time-to-failure
- Application to power electronics and military systems
- Development of wireless, low-power sensor nodes for retrofitting existing systems
- Optimal maintenance scheduling and consequence analysis algorithms

Prognostics and Health Management Overview

Maintenance of critical systems is clearly important, but it also entails significant costs in terms of parts, labor, and loss of operational availability. Maintenance based on regular intervals is likely to be performed more often than needed, leading to correspondingly higher costs. However, waiting until a critical system fails is likely to lead to even higher costs because of mission interruption, added logistical difficulties, and possibly the loss of entire systems or even human life. Ideally, maintenance could be scheduled between these two extremes to minimize overall costs.



Prognostics and health management (PHM) is an advanced approach to minimize maintenance costs while maximizing operational availability and utilization of critical systems. PHM seeks to develop sensor hardware and algorithms to detect anomalies, diagnose problems that cause the anomalies, and compute a probability distribution of time to failure. Given this distribution along with operational constraints and objectives for the system, maintenance activities can be scheduled to achieve the optimal cost and utilization.

Prognostics and Health Management (PHM)

Key Features

Detection

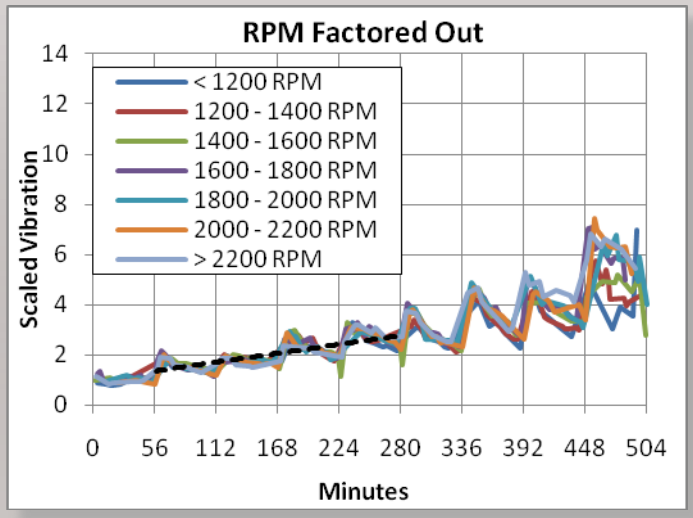
- Algorithms for feature extraction from sensor data
- Algorithms for detecting anomalies from features
- Data fusion for multiple sensor data streams
- Rapid establishment of baseline behavior
- Statistically significant changes from baseline behavior detected

Diagnosis

- Resource allocation
- Maintenance strategies
- Technology management roadmaps
- Spares inventories
- Design for manufacture, sustainment, and availability
- Investment strategies

Prognosis

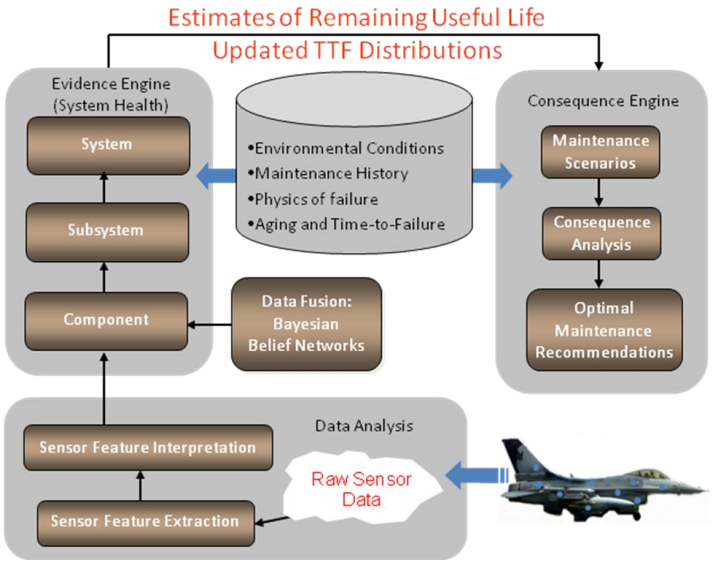
- Algorithms for estimating remaining useful life or time to failure
- Consideration of usage and maintenance history
- Seeded fault testing for classifier training
- Trend determination for forecasting time of failure based on previous tests and operational experience
- Kalman filtering or particle filtering for physics-based models of failure



Key Features Continued

Health Management

- Optimal maintenance scheduling accounting for:
  - Time variations of demand, price, and resource availability
  - Operational status of a larger fleet or system
  - Risk of failure or possible operational changes



Key Benefits

Lower Maintenance Costs

- Components are not repaired or replaced prematurely
- Unscheduled maintenance becomes scheduled maintenance
- Scheduled maintenance can be planned for when and where parts and personnel will be available

Increased Operational Availability and Utilization

- Longer intervals between preventive maintenance
- Fewer cases of extended disruption caused by unscheduled maintenance
- Scheduled maintenance can be planned for times when demand is low

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