
Prognostics and Health Management (PHM): A Key PBL Enabler

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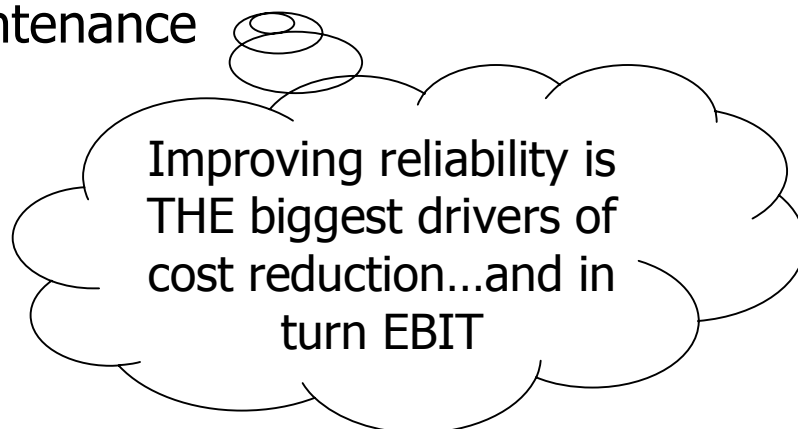
- PHM Definition
- Traditional Maintenance Approaches Versus Condition-Based Maintenance
- Characteristics Of PHM System
- PHM Technologies
- Why Should You Care About PHM
- When Should You Start PHM Design
- PBL Risks Associated With PHM

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What Is PHM

- An equipment asset management approach that:
 - Reduces maintenance frequency: inspections and time-based schedules
 - Utilizes accurate monitoring, incipient fault detection, and prediction of impending faults to establish Remaining Useful Life (RUL) of equipment
 - Supports back-office dependant demand forecasting of maintenance services and repair/service parts
 - Supports condition-based maintenance versus Corrective or Preventive Maintenance



The Problem With Corrective Maintenance Approaches

- Unanticipated systems downtime
 - Loss of availability during corrective maintenance sessions
 - Mission disruption
- Bigger footprint
 - More parts to cover risk
 - More maintenance personnel
 - More support equipment
- Greater O&S costs
 - Higher material asset investment
 - Greater depot repair expenditures
 - Higher costs for transportation, distribution, stocking and restocking

The Problem With Corrective Maintenance Approaches

- Perception of higher availability
 - Downtime for preventive maintenance may be greater than for corrective maintenance
 - Gaming the systems (planned maintenance not factored into availability calculations)
- Larger footprint
 - More replacement parts to cover maintenance induced failures and replacement of not-failed components
 - More maintainers to cover planned maintenance
 - May require more systems in float
- High O&S costs
 - Depot expenditures to cover “No-evidence-of-failure-found” and associated costs to inspect and restock
 - Greater reverse logistics costs to collect, package and ship not-failed components and subsystems

Condition-Based Maintenance Provides a Balance Approach

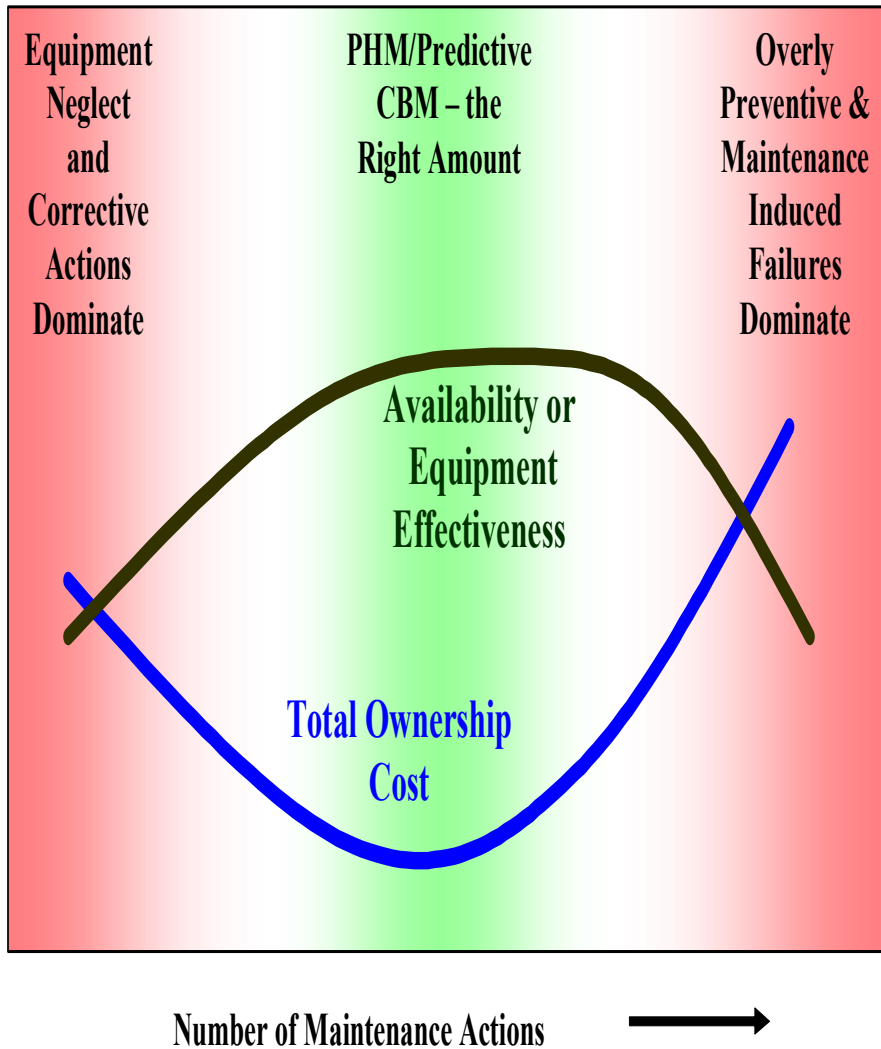
- Higher availability
 - Maintenance and Supply Support based on system/component Remaining Useful Life (RUL) predictions established through real-time monitoring of system
- Smaller footprint
 - Push packages in anticipation of changes in system health status
 - Smaller inventories
 - Less maintenance personnel
- Lower O&S costs
 - Ability to pinpoint reliability improvement opportunities
 - Eliminate NEOF
 - Eliminate maintenance induced failures
 - Reduce reverse logistics costs
 - Reduces depot repair expenditures
 - Allows material asset investment optimization over time

The Maintenance Paradox

**Corrective
Maintenance**

**Condition-based
Maintenance**

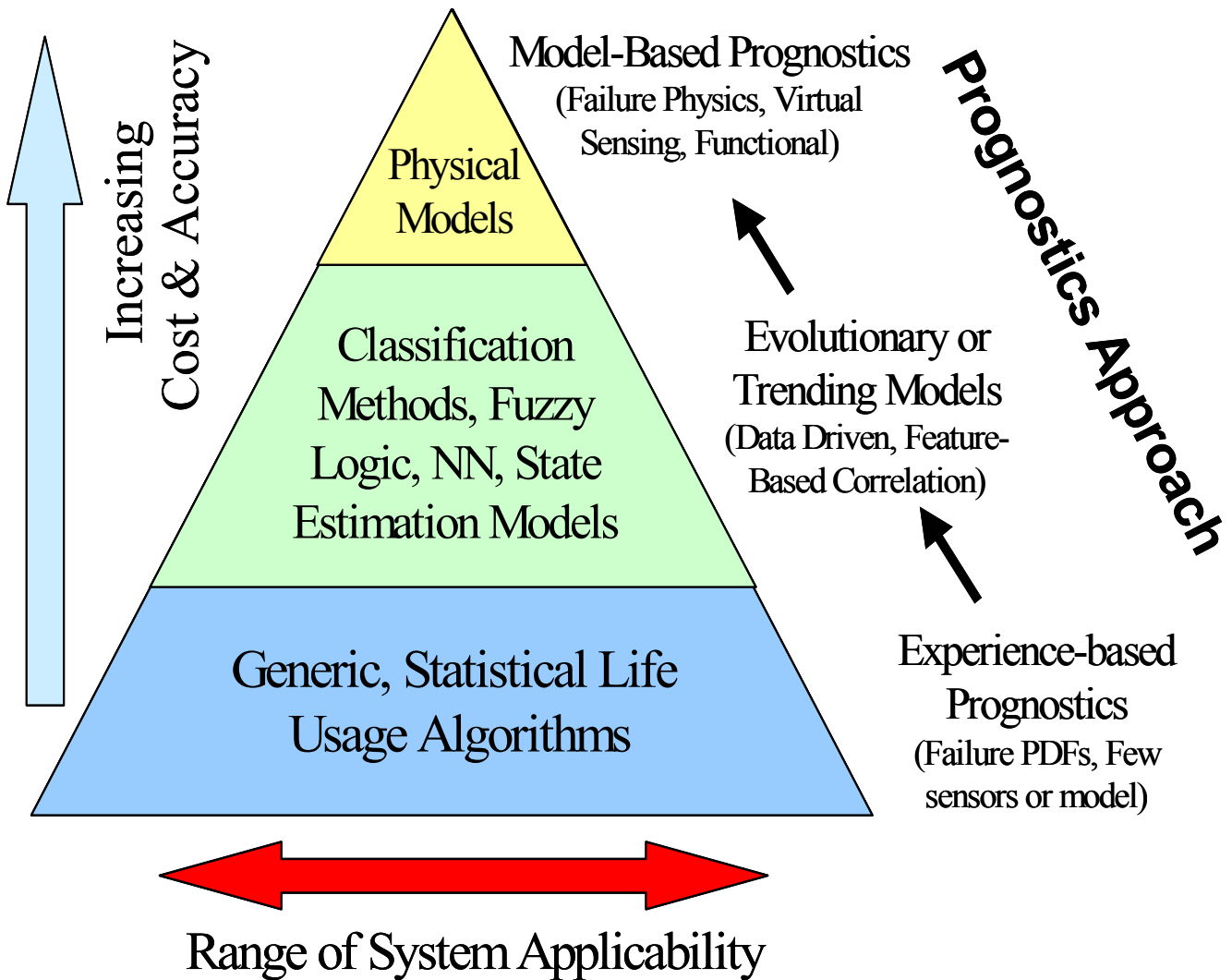
**Preventive
Maintenance**



Characteristics Of A PHM System

- Utilizes power, command, operational and safety-related sensors to provide signals (the data) for analysis (knowledge) and reasoning (context) to arrive at a prediction
- Monitors signal parameters or states that have departed from normal operating envelopes
- Identifies, localizes and determines the severity of an evolving fault condition prior to a significant functional loss
- Reliably and accurately forecasts remaining operational time to end of useful life or risk to completion of mission
- Can isolate to specific replacement unit after a fault has progressed to a functional loss of systems capability (Diagnostics)

PHM Technologies



Why Should You Care About PHM?

- As a PBL contractor you are expected to accept risks traditionally born by the government
 - Performance risk
 - Availability metrics
 - Supply support metrics
 - Reliability metrics
 - Configuration metrics, etc.
 - Investment risk
 - Infrastructure
 - Material assets

Why Should You Care About PHM?

- PHM provides a mechanism for controlling performance and investment risk
 - Better planning results based on PHM feedback to back office planning systems. Without PHM input material forecasting dependant on usage data and reliability prediction (Never met a RAM analysis that I liked!)
 - Ability to pinpoint hardware and software reliability problems early. Problem areas can be acted on before large scale impairment of inventory occurs

When Should You Start PHM Design Efforts

- PHM design efforts should start during System Design and Development (SDD) phase and run parallel to the mainstream design effort
 - 80% of Total Life Cycle Costs are fixed at the end of SDD
 - Weapons Systems need to be plumbed with a PHM baseline system by the end of SDD
 - Initial development costs relatively low when compared with TLOC
 - Avoids costly retrofits after production and deployment
 - Accuracy and Reliability of system will grow over time with minimal investment
 - May allow tradeoff of design margins if PHM design provides real time monitoring

When Should You Start PHM Design Efforts

- PHM design efforts should start during System Design and Development (SDD) phase and run parallel to the mainstream design effort
 - Most PHM algorithms can use signals already available but sensor augmentation and data publishing requirements must be determined early in the design process so that relevant PHM signals are available to support prediction
 - PHM must be synchronized with PBL planning so that PBL risks can be fairly evaluated by senior executives

PHM Risks

- No PHM design considerations incorporated because of lack of funding
 - PBL contractor dependant on reliability predictions and usage data to plan inventory investment and distribution requirements
 - PBL contractor will be forced to carry just-in-case inventory to cover risks impacting cash flow and margins
 - PBL contractor will have difficulty distinguishing true design reliability issues from workmanship issues
 - PBL contractor may be penalized for slower Mean Logistics Delay Time and reduced availability
- Accuracy and reliability of PHM system may be low initially
 - Will improve over time as knowledge base and usage data are collected and analyzed
 - Must handhold customer to continue to support rather than shifting back to “swaptronics”