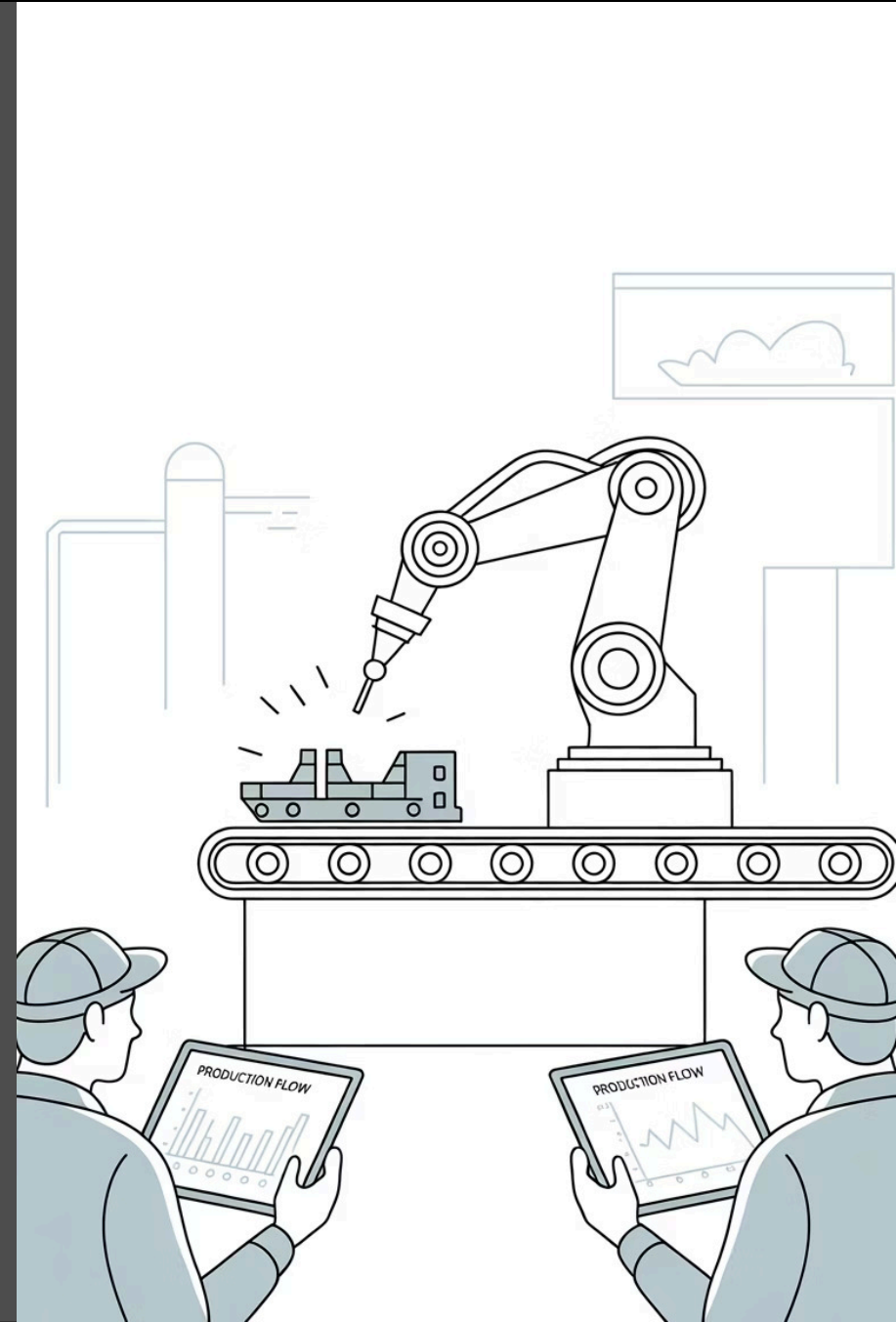
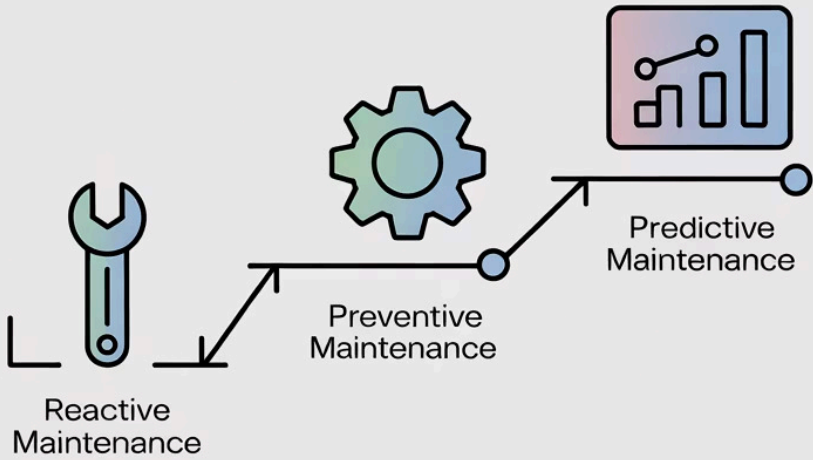


7.1.1 Introduction

Good morning everyone. We're here today to discuss a rapidly evolving field that is changing asset management across various industries: Prognostics and Health Management, or PHM. This advanced approach represents a paradigm shift from traditional reactive maintenance strategies to proactive, data-driven methodologies that optimize asset availability, reduce operational costs, and significantly improve safety outcomes across industrial operations.





Maintenance Strategy Evolution

Understanding Traditional Approaches

Traditional Maintenance Strategies: The Foundation

To understand how PHM provides a superior solution, we must first examine the traditional maintenance paradigms that have dominated industrial operations for decades. Each approach represents an evolutionary step in maintenance philosophy, with increasing sophistication in planning and execution.

1

Reactive Maintenance (Run-to-Failure)

The most basic maintenance approach where intervention occurs only after equipment failure. While this strategy minimizes upfront maintenance costs, it often results in the highest total cost of ownership due to unplanned downtime, emergency repairs, potential safety incidents, and cascading failures that can damage interconnected systems. Organizations typically experience 3-5 times higher costs compared to planned maintenance approaches.

2

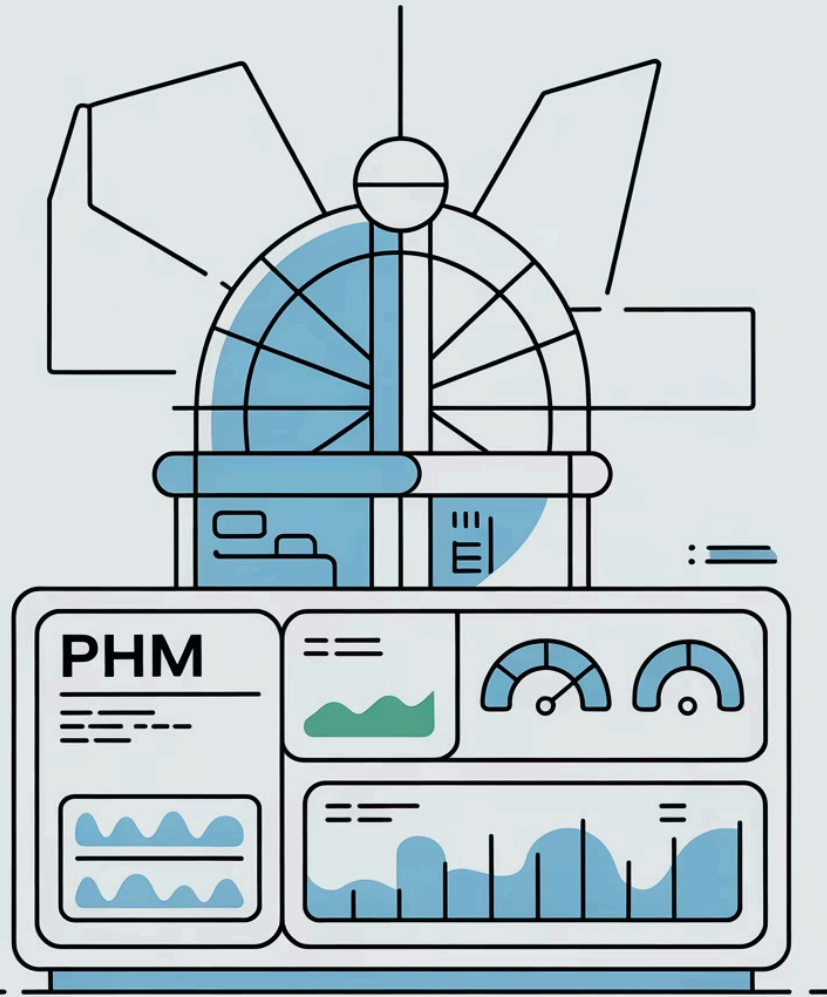
Preventive Maintenance (Time-Based)

Systematic maintenance performed at predetermined intervals based on manufacturer recommendations, historical data, or regulatory requirements. This approach significantly reduces unexpected failures and extends equipment life. However, it can lead to over-maintenance, unnecessary part replacements, and increased operational costs when components are serviced before actually needed, resulting in 20-30% of maintenance activities being performed prematurely.

3

Condition-Based Maintenance (CBM)

Maintenance decisions based on actual equipment condition determined through monitoring techniques such as vibration analysis, thermography, oil analysis, and ultrasonic testing. CBM optimizes maintenance timing by performing interventions only when condition indicators suggest impending issues. This approach reduces unnecessary maintenance by 30-50% compared to time-based strategies while maintaining high equipment reliability.



PHM: The Next Evolution

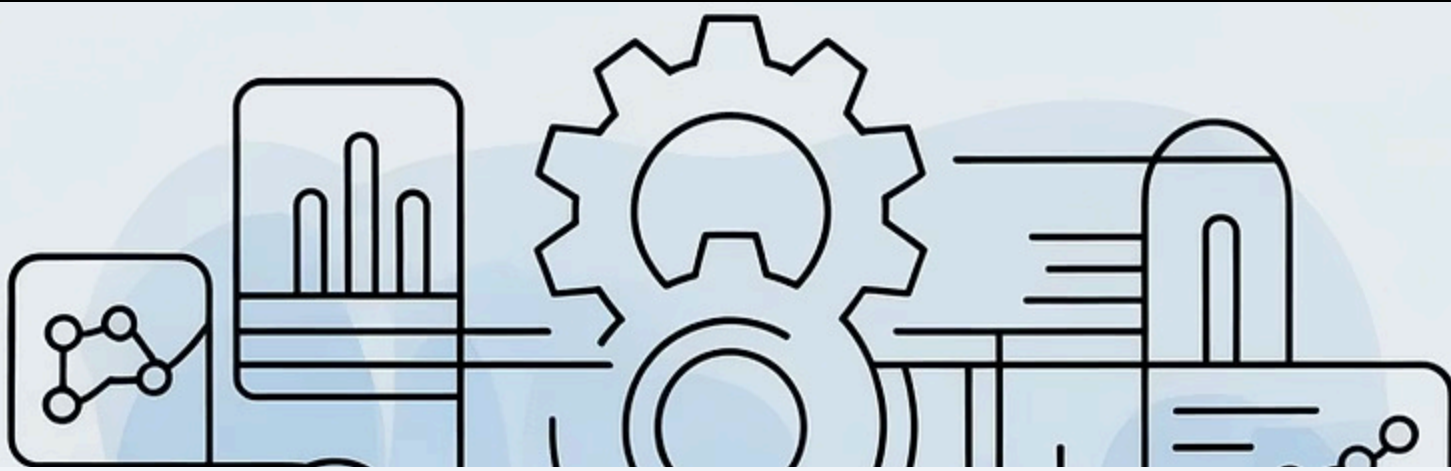
Advanced Predictive Maintenance

Prognostics and Health Management: The Advanced Solution

Prognostics and Health Management represents the most sophisticated maintenance paradigm, leveraging advanced data analytics, machine learning algorithms, and IoT sensor networks to predict equipment failures before they occur. Unlike traditional approaches that react to current conditions, PHM proactively forecasts future equipment states and optimizes maintenance schedules accordingly.

PHM integrates multiple data sources including vibration signatures, temperature profiles, acoustic emissions, electrical parameters, and operational history to create comprehensive equipment health models. These models continuously learn from new data, improving prediction accuracy over time. The system can identify subtle degradation patterns that human operators might miss, enabling intervention weeks or months before traditional methods would detect issues.

The economic impact of PHM implementation is substantial: organizations typically achieve 10-20% reduction in maintenance costs, 20-50% decrease in unplanned downtime, and 5-15% increase in asset utilization. Additionally, PHM enhances safety by predicting potential failures that could result in accidents or environmental incidents, making it particularly valuable in high-risk industries such as aerospace, nuclear power, and chemical processing.



Key PHM Terminology

Essential Definitions and Concepts

PHM Terminology: Building a Common Understanding

Before diving deeper into PHM methodologies, it's crucial to establish a shared understanding of key terminology. These definitions form the foundation for all PHM discussions and implementations, ensuring clear communication among multidisciplinary teams including engineers, data scientists, maintenance professionals, and management.



Fault

A deviation from the intended behavior, performance specification, or acceptable operating range of a system or component. Faults can be incipient (developing slowly over time), intermittent (occurring sporadically), or permanent (causing immediate system degradation). Understanding fault characteristics is essential for developing appropriate detection algorithms and response strategies.



Fault Detection

The automated process of identifying that a fault has occurred within a system, typically through statistical analysis of sensor data, pattern recognition algorithms, or threshold monitoring. Modern fault detection systems employ machine learning techniques to distinguish between normal operational variations and actual anomalies, reducing false positive rates while maintaining high sensitivity to real faults.



Fault Diagnostics

The systematic process of determining the specific type, root cause, location, and severity of a detected fault. Diagnostics combines domain expertise with data analysis to provide actionable information for maintenance planning. Advanced diagnostic systems can differentiate between multiple potential fault modes and recommend appropriate corrective actions based on fault characteristics and operational context.

Advanced PHM Concepts: Prognostics and RUL

Prognostics

The most sophisticated aspect of PHM, prognostics involves predicting the future health state of systems and estimating when failures are likely to occur. This forward-looking capability enables organizations to transition from reactive and scheduled maintenance to truly predictive strategies.

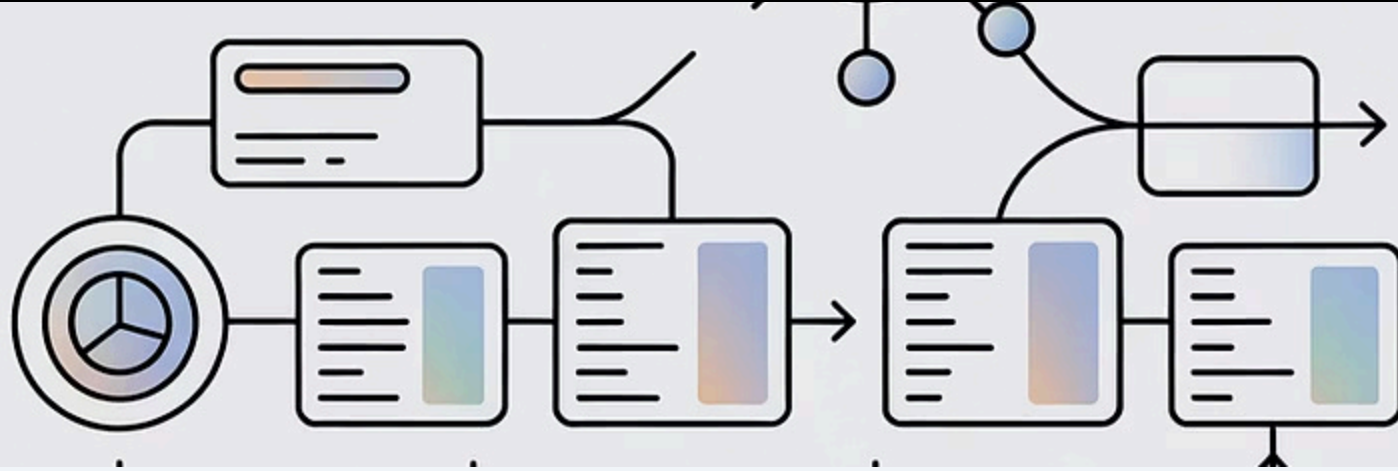
Prognostic algorithms analyze historical degradation patterns, current condition indicators, and future operating scenarios to project equipment health trajectories. Common approaches include physics-based models that simulate component wear mechanisms, data-driven models that learn patterns from historical data, and hybrid approaches that combine both methodologies for enhanced accuracy.

The integration of prognostics and RUL estimation creates a powerful maintenance optimization framework that can reduce lifecycle costs by 20-40% while improving system availability and safety performance across diverse industrial applications.

Remaining Useful Life (RUL)

RUL represents the estimated operational time remaining before a component or system reaches its failure threshold or requires maintenance intervention. RUL predictions are typically expressed with confidence intervals to account for uncertainty in degradation processes and future operating conditions.

Accurate RUL estimation enables optimal maintenance scheduling, spare parts inventory management, and mission planning. Organizations can balance the risk of premature failure against the cost of early intervention, maximizing asset utilization while maintaining acceptable reliability levels. Advanced RUL models consider multiple failure modes, operational stresses, and environmental factors to provide comprehensive life predictions.

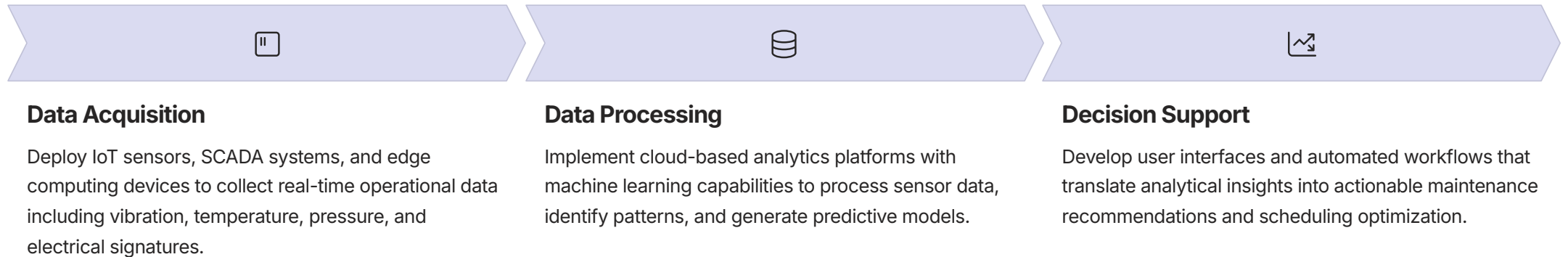


PHM Implementation

Technologies and Methodologies

PHM Technologies and Implementation Roadmap

Successful PHM implementation requires a comprehensive technology stack and systematic deployment approach. The foundation consists of sensor networks, data acquisition systems, and communication infrastructure that enable continuous monitoring of equipment health parameters.



The analytical layer employs advanced algorithms including neural networks, support vector machines, and ensemble methods to model complex equipment behavior and predict failure modes. Digital twin technology creates virtual representations of physical assets, enabling what-if scenario analysis and optimization of maintenance strategies.

Organizational readiness is equally critical, requiring training programs for maintenance teams, integration with existing enterprise systems, and development of new performance metrics focused on predictive rather than reactive indicators. Successful PHM programs typically achieve full deployment within 18-24 months, with measurable benefits appearing within the first 6-12 months of implementation.

Key Takeaway: PHM represents a fundamental shift from traditional maintenance paradigms to intelligent, data-driven asset management that optimizes reliability, reduces costs, and enables competitive advantage through superior operational performance.