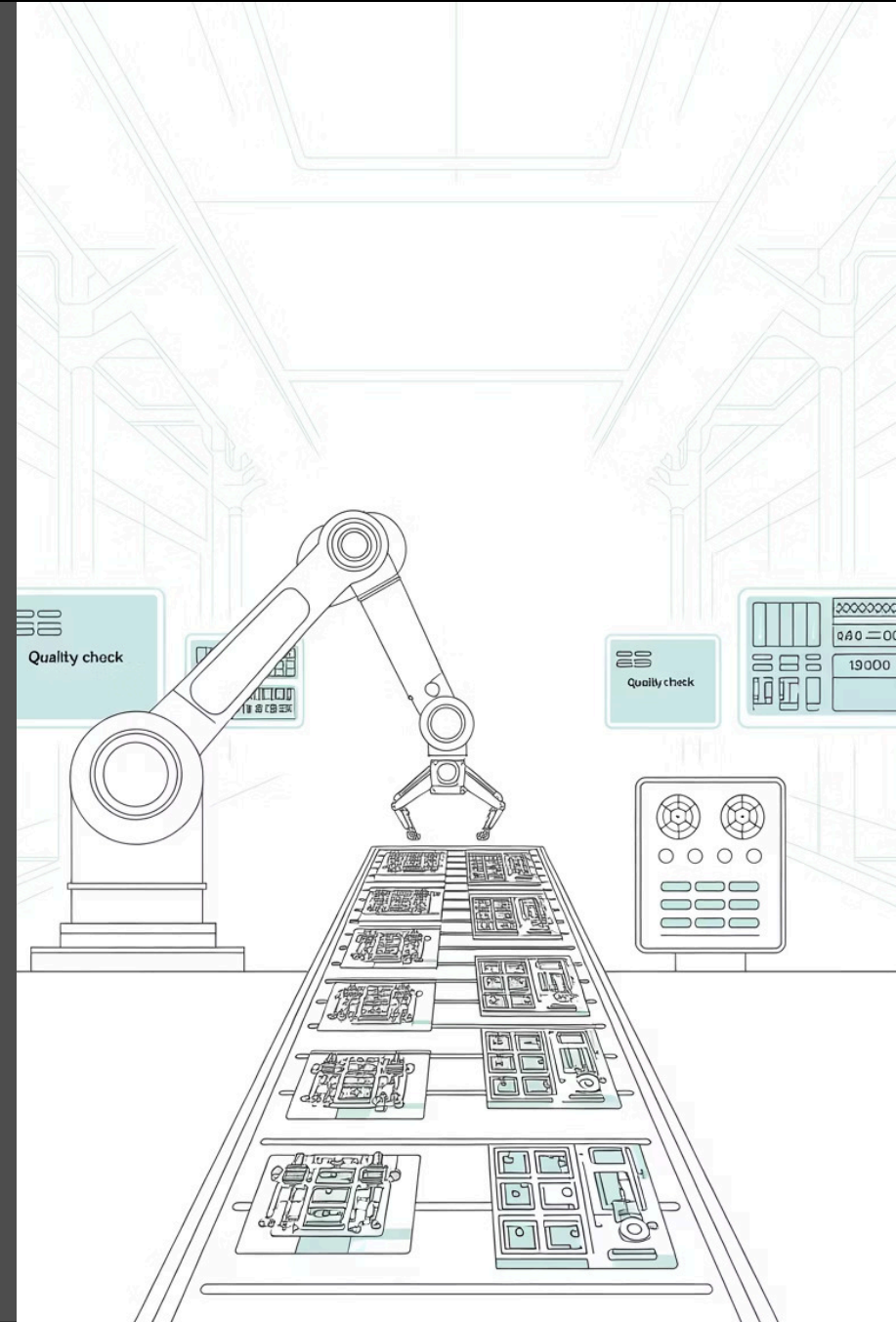


# 7.2.2 Industrial Survey on Prognostics: Understanding Context, Challenges, and Implementation Perspectives

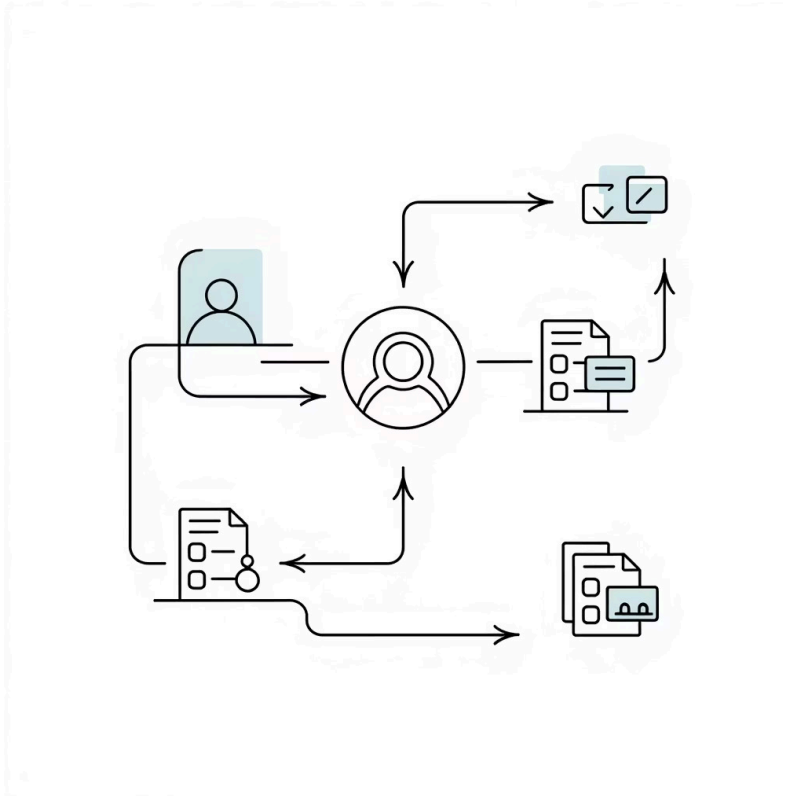
This comprehensive industrial survey examines the current state of prognostics implementation across various industrial sectors, providing insights into professional perspectives, implementation challenges, and future expectations. Through structured interviews and questionnaire responses from industry professionals, this study reveals the gap between academic prognostics research and practical industrial applications, offering valuable guidance for both researchers and practitioners in the field.



# Survey Methodology and Objectives



# Survey Framework and Research Objectives



The industrial survey on prognostics was designed with multiple strategic objectives to bridge the gap between academic research and industrial practice. The primary goal involves understanding how industrial professionals perceive prognostics technology and its potential applications within their operational contexts.

The questionnaire development focused on extracting comprehensive insights about professional profiles, application domain challenges, and implementation barriers. Key areas of investigation include current prognostics implementation status, perceived added value, obstacles to adoption, and expectations from the academic community.

The interview structure was carefully designed to capture both quantitative data about implementation rates and qualitative insights about decision-making processes, risk assessments, and strategic considerations that influence prognostics adoption in industrial environments.

# Core Research Objectives and Framework

1

## Questionnaire and Interview Objectives

Establishing clear research goals to understand industrial prognostics adoption patterns, implementation challenges, and strategic alignment between organizational needs and technological capabilities. The framework aims to capture both quantitative metrics and qualitative insights regarding prognostics value proposition.

2

## Professional Context Analysis

Comprehensive profiling of interviewees' professional backgrounds, organizational roles, and decision-making authority regarding prognostics investments. This includes understanding their technical expertise, budget responsibilities, and strategic influence within their organizations.

3

## Domain-Specific Challenges

Identification of sector-specific issues and challenges that drive prognostics adoption decisions. This encompasses operational pain points, regulatory requirements, competitive pressures, and technical constraints that shape prognostics implementation strategies.

4

## Change Management and Progress Areas

Exploration of organizational change levers and improvement opportunities related to prognostics deployment. This includes cultural barriers, technical readiness, resource allocation, and strategic alignment factors that influence successful implementation.



# Survey Participants and Data Collection

# Survey Participation and Professional Profiles

**20**

## **Direct Interviews**

Individual comprehensive interviews conducted with industry professionals across various sectors

**15**

## **Panel Responses**

Additional responses gathered from industrial panel exchanges on prognostics development

**5**

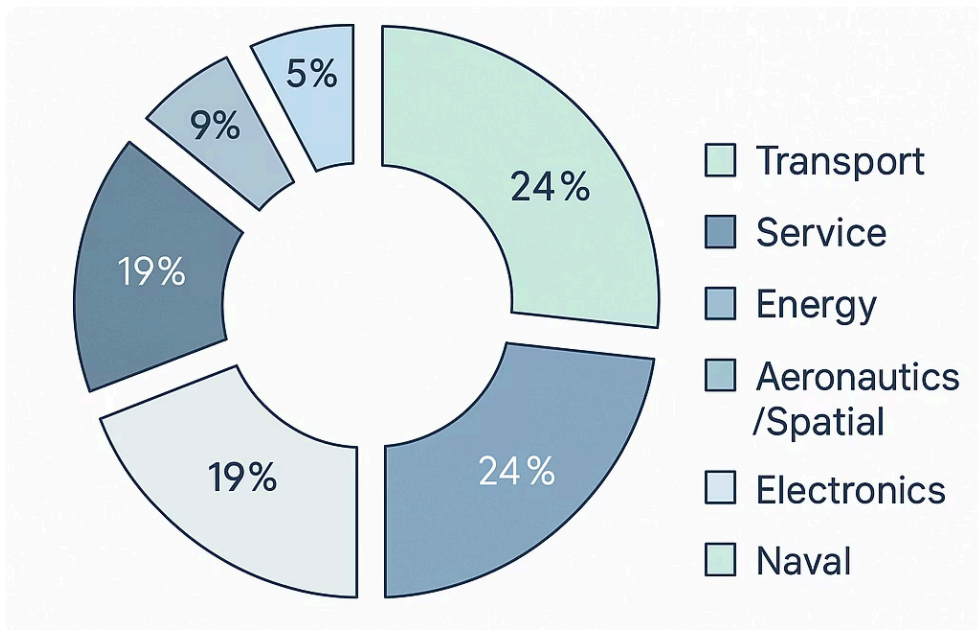
## **Core Areas**

Design, Manufacturing, Integration, Operation, and Maintenance domains represented

The survey captured responses from a diverse cross-section of industrial professionals representing the entire product lifecycle spectrum. Participants included design engineers who integrate prognostics considerations from the earliest development phases, manufacturing specialists focused on production optimization, integration experts managing system-level implementations, operations managers overseeing day-to-day functionality, and maintenance professionals directly responsible for asset reliability.

This comprehensive representation ensures that the survey findings reflect multiple perspectives on prognostics implementation, from strategic planning through operational execution. The participant diversity also reveals varying levels of prognostics maturity across different industrial domains and organizational roles.

# Survey Participation and Professional Profiles



The industrial distribution of participants in the Survey on Prognostics Implementation. Transport and Service each represent 24%, followed by Energy and Aeronautics/Spatial (19% each). Smaller shares come from Electronics, Machine Tools, and Naval.

Participants span the full product lifecycle—design, manufacturing, integration, operation, and maintenance—ensuring diverse perspectives and highlighting varying levels of prognostics maturity across sectors.

# Data Collection Approach

To gain a comprehensive view of industrial perspectives on the implementation of prognostics, the survey employed a dual methodology. Approximately 20 detailed responses were collected through structured individual interviews, providing in-depth qualitative insights into organizational challenges and strategic considerations. Additionally, 15 responses were gathered during exchanges within specialized industry panels focused on prognostics applications.

- 1** Approximately 20 responses directly from individual interviews
- 2** Approximately 15 responses from exchanges during the industry panel on prognostics



# Key Survey Findings and Industrial Perspectives



# Critical Survey Findings and Industry-Academia Gap

The survey reveals significant disconnects between academic prognostics research and industrial implementation realities. Industrial professionals view prognostics not as an end goal but as a component within broader decision-making frameworks such as Prognostics and Health Management (PHM) and Condition-Based Maintenance Plus (CBM+).



## **Implementation Status Disparity**

Only a subset of surveyed professionals actively utilize prognostics capabilities. For many others, prognostics remains a long-term strategic objective, an aspirational goal, or perceived as a potential risk due to uncertain return on investment and implementation complexity.



## **Communication Barriers**

Several industrial representatives declined to discuss prognostics implementation, indicating either competitive sensitivity or uncertainty about the technology's strategic implications for their organizations.

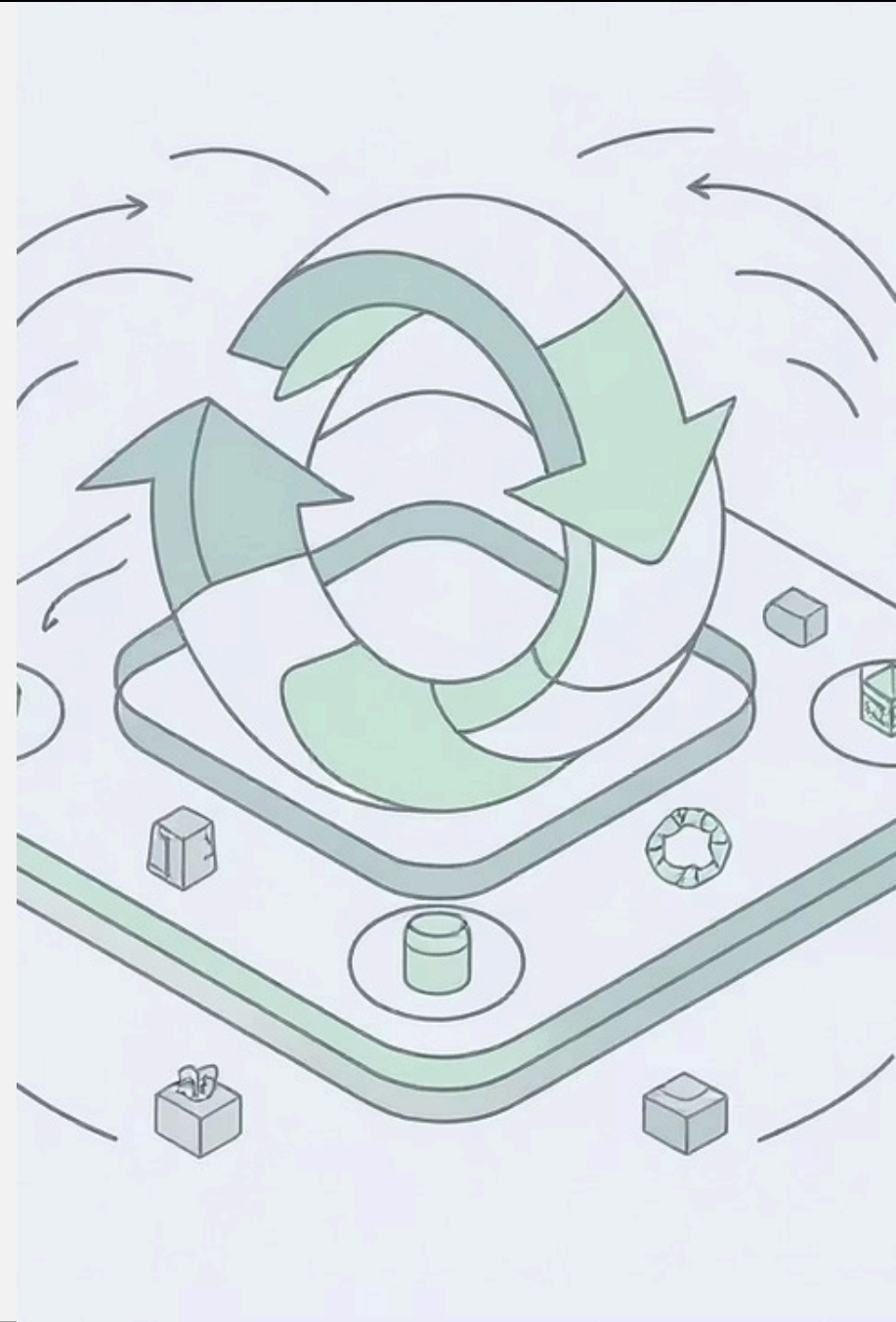


## **Historical Maintenance Evolution Parallel**

The prognostics adoption challenge mirrors the historical transition from corrective to preventive maintenance, suggesting similar organizational and cultural barriers to implementation.

A predominant theme emerged linking prognostics implementation to service-oriented business models, indicating that successful adoption often requires fundamental shifts in how companies conceptualize their value propositions and customer relationships.

# Service-Oriented Prognostics Applications



# Prognostics Integration in Service-Oriented Business Models

The survey identifies a strong association between prognostics development and service-oriented business models. Organizations increasingly recognize prognostics not merely as a maintenance tool but as an enabler of advanced service offerings and circular economy principles. This shift represents a fundamental transformation from traditional product-centric to service-centric value propositions.

## Product Lifecycle Integration

- **Design Phase Integration:** PHM Engineering principles embedded from initial product development stages
- **Experience Data Utilization:** Return of experience data leveraged for continuous prognostics model improvement
- **Performance Validation:** Prognostics capabilities demonstrate delivery of expected performance metrics during normal operations
- **Quality Enhancement:** Component degradation mastery improves overall product quality and reliability

## Economic and Service Considerations

- **Circular Economy Alignment:** Service-selling business models require reliable product performance throughout extended lifecycles
- **Maintenance Cost Control:** Prognostics enables sophisticated maintenance cost optimization strategies
- **Performance Metrics:** Impact assessment through Cost of Ownership (CoO), Overall Equipment Effectiveness (OEE), and Return on Investment (ROI) calculations
- **Service Differentiation:** Advanced prognostics capabilities create competitive advantages in service markets

The integration of prognostics into service-oriented models fundamentally changes the relationship between manufacturers and customers, shifting from product transactions to performance partnerships. This transformation requires sophisticated prognostics capabilities to ensure service delivery commitments are met while maintaining profitability.



# Implementing Prognostics

# Critical Implementation Challenges and Technical Obstacles

## Technology-Specific Limitations

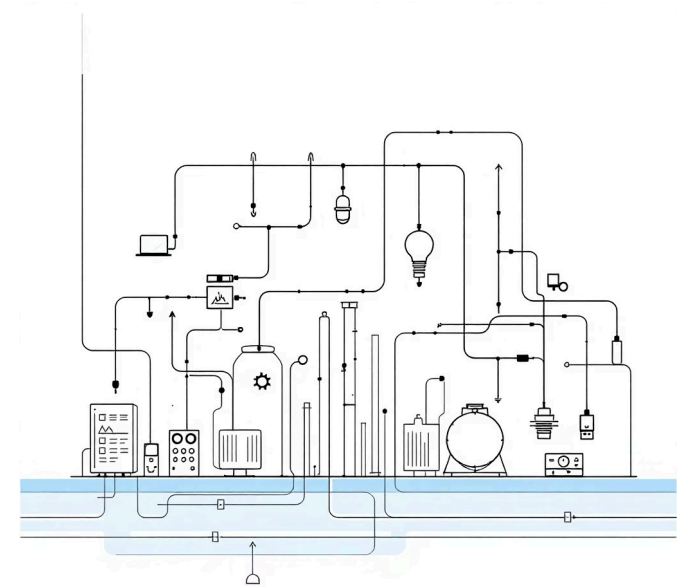
Prognostics implementation varies significantly based on the underlying technologies and degradation mechanisms being monitored. Current applications are largely restricted to well-understood components such as engines and bearings, where degradation patterns are well-characterized and predictable. This limitation constrains broader prognostics deployment across complex systems with diverse failure modes.

## Upstream Process Dependencies

Effective prognostics requires robust Condition Monitoring (CM) and Health Management (HM) systems as foundational elements. The relevance and reliability of these upstream systems directly impact prognostics accuracy and value. Organizations must consider the integration of CM and HM systems within their overall engineering framework, ensuring data quality and system interoperability.

## Information System Challenges

Standardization and interoperability issues, particularly regarding OSA/CBM (Open System Architecture/Condition-Based Maintenance) frameworks, create significant implementation barriers. Organizations struggle with indicator definition, data aggregation across different abstraction levels, and integration of heterogeneous monitoring systems.



# Engineering Integration and Design Considerations

## PHM Engineering Approach

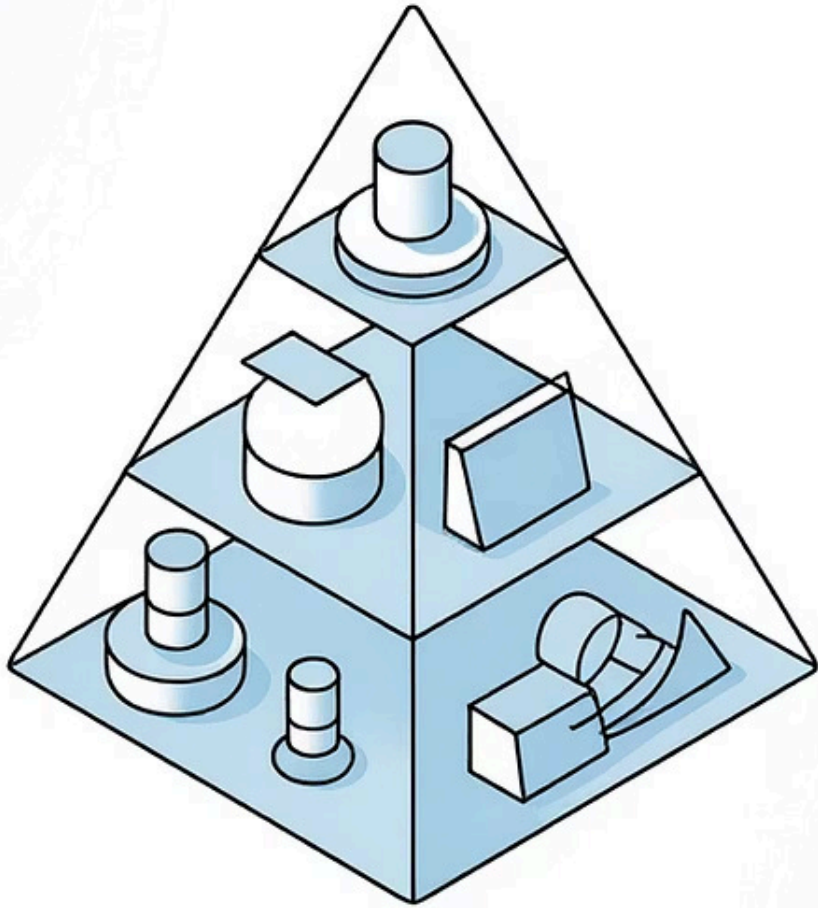
The survey emphasizes that prognostics integration during the design phase is crucial for maximizing value creation. Without early-stage prognostics consideration, the added value becomes significantly limited. This requires a systems thinking approach to PHM Engineering, where prognostic capabilities are architected into the product from conception rather than retrofitted as an afterthought.

## Metrics and Assessment Framework

Organizations require comprehensive metrics frameworks, such as those proposed by Saxena (2008), to assess prognostics impact on both internal operational metrics and external business indicators including ROI, OEE, and maintenance cost reduction. These metrics must account for temporal scale variations and provide meaningful performance indicators across different organizational levels.

## Emerging ICT Reliability Concerns

Prognostics deployment often requires emerging Information and Communication Technologies (ICT) that may not yet demonstrate established reliability records. Organizations face challenges related to system intrusiveness, particularly concerning certification issues for Integrated Vehicle Health Management (IVHM) systems, and require quantification of implementation efforts across the entire prognostics lifecycle.



# Industrial Prognostics Vision

# Five Key Industrial Prognostics Visions



## Component Availability Vision

Prognostics serves as a critical support mechanism to anticipate component failures by continuously monitoring and controlling actual and future degradation patterns according to specific operational contexts. This vision focuses on individual component health and replacement timing optimization.



## System Productivity Vision

Prognostics enables dynamic maintenance planning adaptation based not only on individual component availability but also on global system requirements and performance expectations. This holistic approach optimizes overall system productivity and operational efficiency.



## Mission Assurance Vision

Through RUL calculations, prognostics assesses system capability to achieve specific missions or determines what types of missions the system can reliably accomplish. This vision is particularly relevant for critical applications requiring high reliability and availability.



## Safety-Risk Management Vision

Prognostics provides anticipatory control to prevent degraded situations from evolving into dangerous conditions. This vision emphasizes risk mitigation and safety assurance through proactive monitoring and intervention strategies.



## Business Operations Vision

Prognostics enables service-based business models by selling performances rather than products. This includes capability to sell "flight hours," provide logistics support with anticipatory capabilities, and move toward performance-based contracts with obligation fulfillment guarantees.

# Industrial Expectations from Academic Community



## Practical Application Focus

Industry expects academic research to address real-world implementation challenges rather than purely theoretical advancements. This includes development of robust, industrially-validated prognostic algorithms that can operate reliably in harsh operational environments with uncertain and incomplete data.



## Technology Transfer Facilitation

Organizations seek stronger collaboration mechanisms to bridge the gap between academic innovations and industrial deployment. This includes joint research projects, industry-academic partnerships, and technology demonstration programs that validate prognostic solutions in operational settings.



## Standardization and Best Practices

Industry requires academic leadership in developing standardized prognostics frameworks, methodologies, and best practices that can be consistently applied across different sectors and applications. This includes standardized metrics, evaluation criteria, and implementation guidelines.

## Knowledge and Skill Development

Organizations emphasize the need for academic institutions to develop specialized prognostics curricula and professional development programs. This includes training programs for engineers, maintenance professionals, and decision-makers who must understand both the technical capabilities and business implications of prognostic technologies. Industry seeks academic partners who can provide ongoing education and knowledge transfer to support successful prognostics implementation and operation.



## **Key Findings**

## **Early Integration is Essential**

Embedding prognostics from the design phase maximizes value and prevents costly retrofiting.

## **Shift Toward Service-Oriented Models**

Prognostics is increasingly seen as a driver of advanced service offerings and circular economy practices.

## **Holistic Implementation Needed**

Success depends on integration within PHM and CBM+ frameworks, not as standalone tools.

## **Managing Uncertainty is Critical**

Robust methods are required to handle data uncertainty and provide decision-makers with reliable confidence levels.

## **Bridging Academia and Industry**

Stronger collaboration is needed to ensure research addresses real-world challenges with validated solutions.

## **Clear ROI Frameworks**

Organizations require measurable business value through metrics such as ROI, OEE, and maintenance cost reduction.