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Smart Manufacturing and Prognostics and Health Management (PHM)

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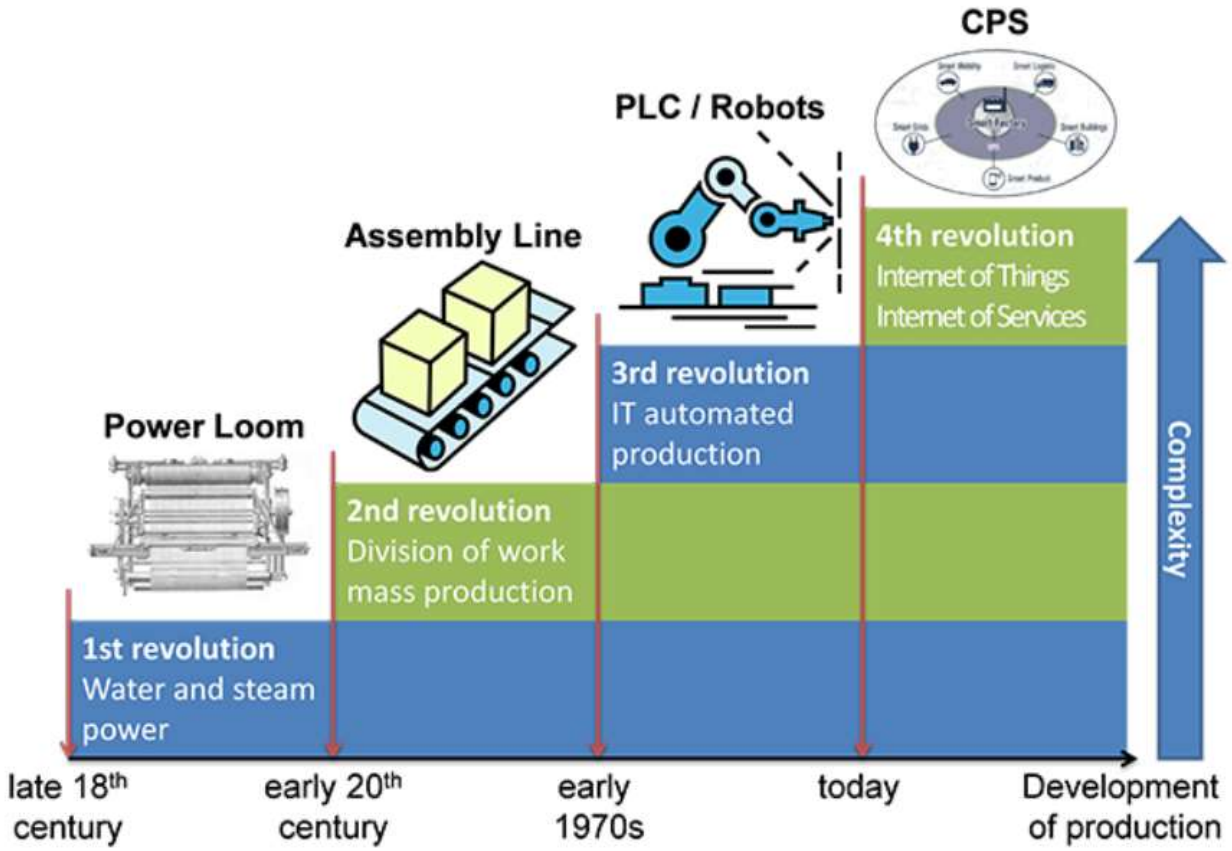
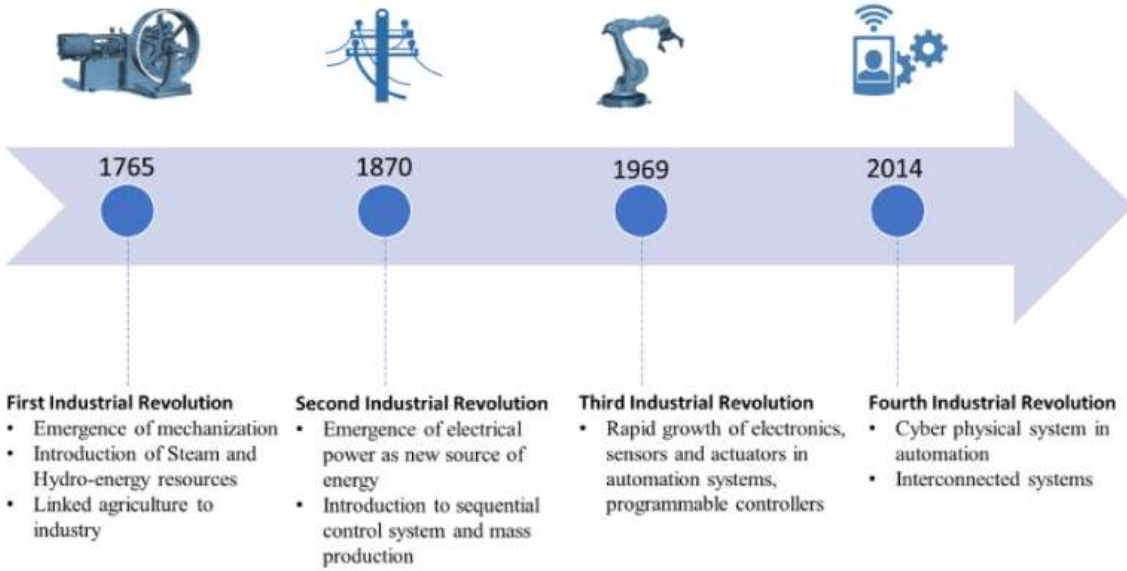
Chronology of Industrial Revolution





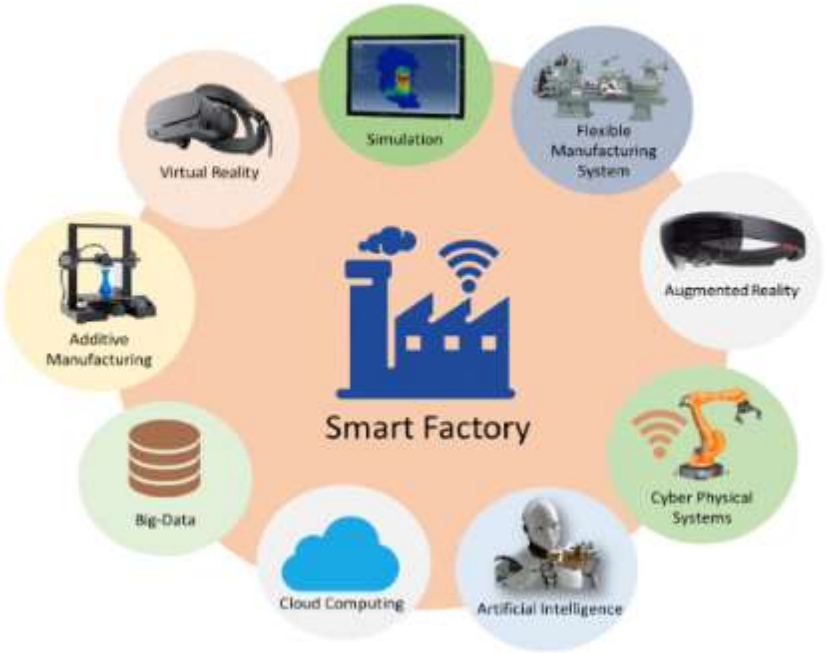
Phuyal, S., Bista, D., & Bista, R. (2020). Challenges, opportunities and future directions of smart manufacturing: a state of art review. Sustainable Futures, 2, 100023.

Smart Manufacturing Systems

- Smart Manufacturing is defined as "a data intensive application of information technology at the shop-floor level and above to enable intelligent, efficient and responsive operations"
- Use of Information and Communication Technology, data, and advanced data analytics to improve manufacturing operations at all levels of the supply network.
- Human capabilities are to be enhanced by smart customized solutions for the specific area.

Components of smart manufacturing

- Virtual reality
- Augmented reality
- Additive manufacturing
- Big data and artificial intelligence
- Internet of Things
- Simulation

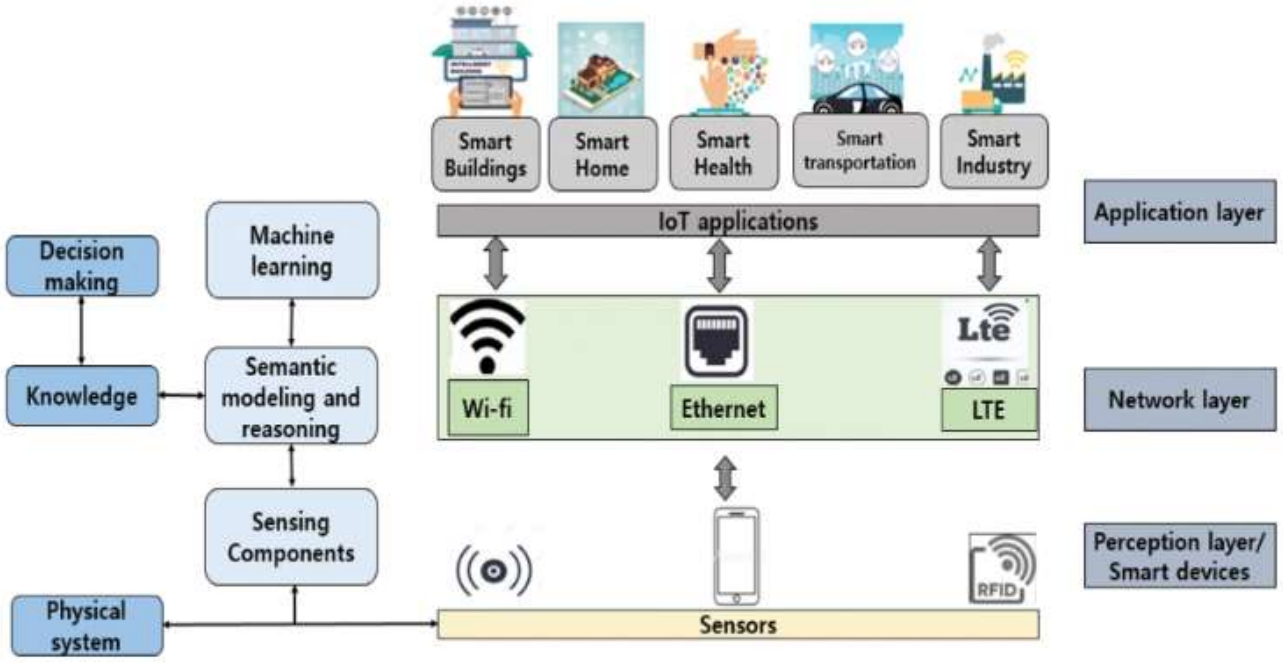


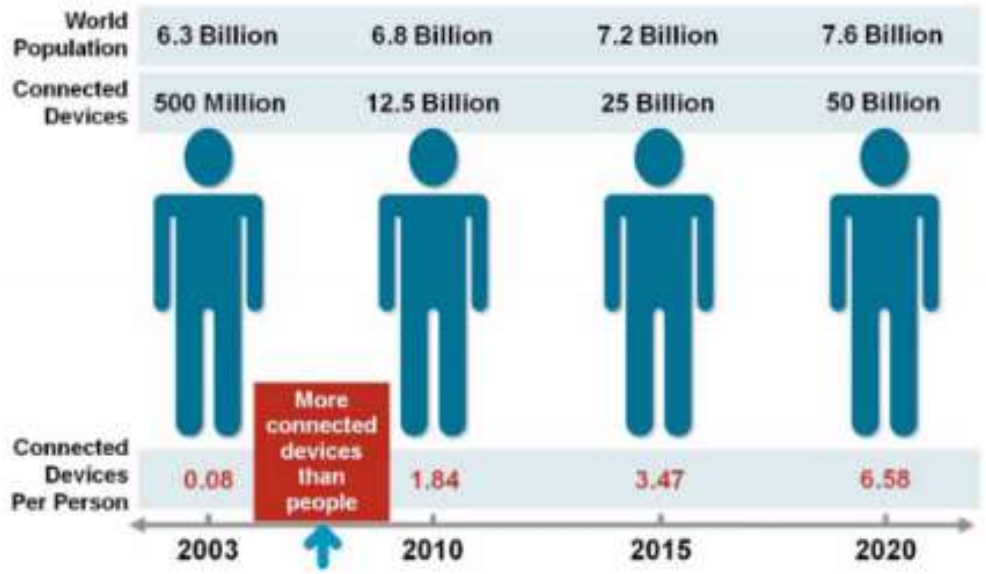
Wallace, E. & Riddick, F. (2013). *Panel on Enabling Smart Manufacturing*, APMS 2013, State College, USA.

Was manufacturing not smart, or dumb?

- No, not at all!
- The smartness was associated with the human operators and process planners – the human experts – and not inherited in the system itself.
- Experienced operators of complex machine tools who seem to know something goes wrong with a machine.
- The goal in a Smart Manufacturing is to reproduce this "gut feeling" by collecting data and analyzing it to draw conclusions.

Sensors and Internet of Things





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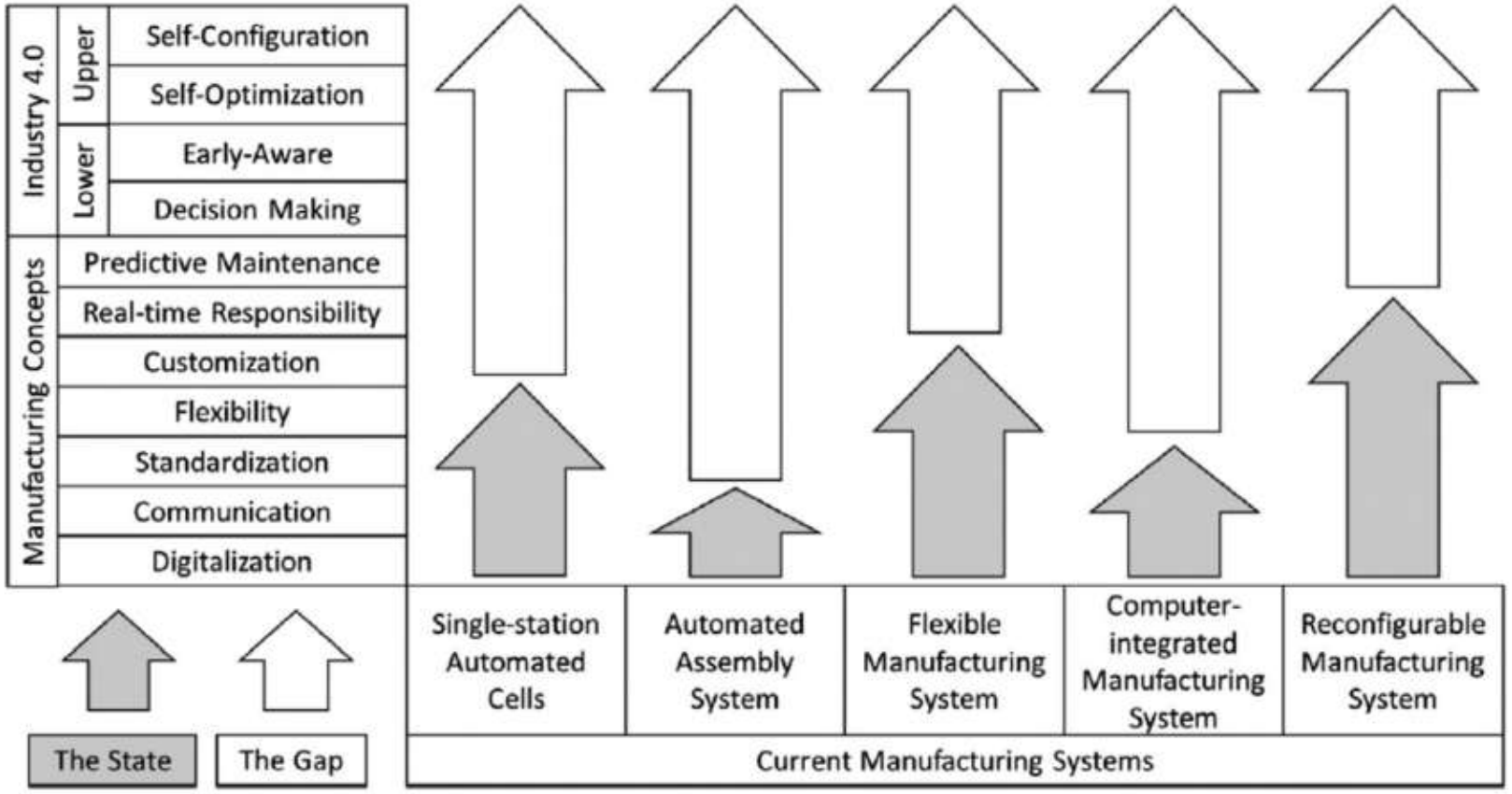
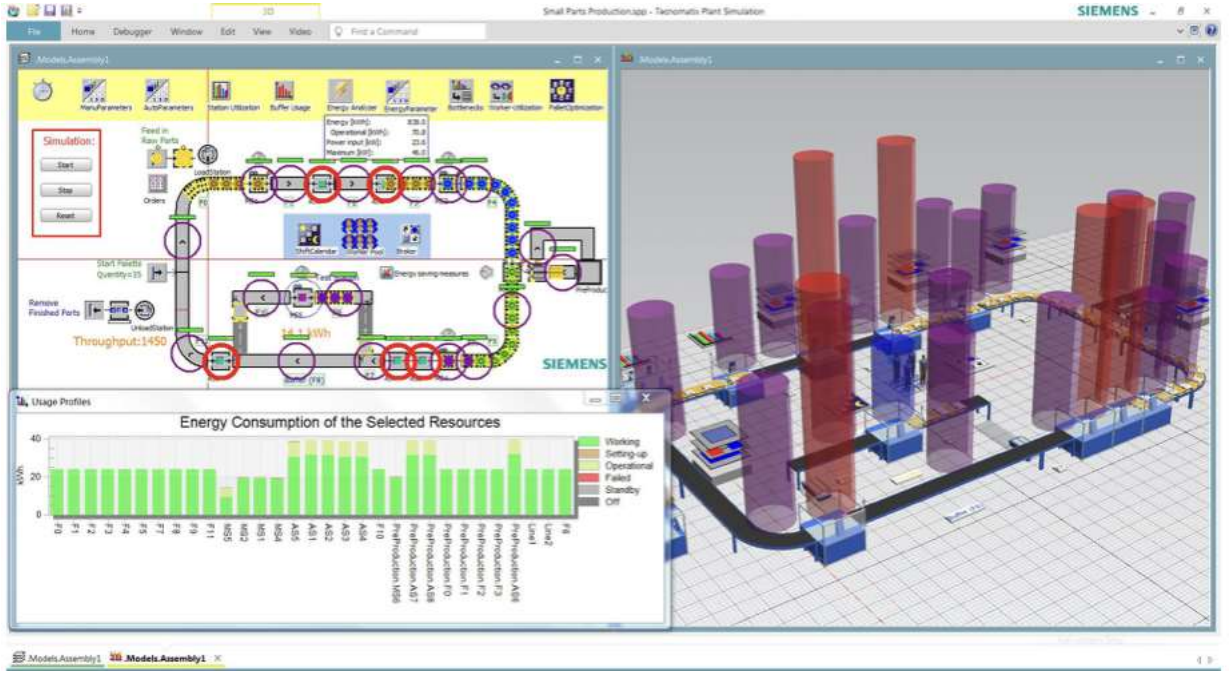
Technological Gap Between Current Manufacturing System and Industry 4.0



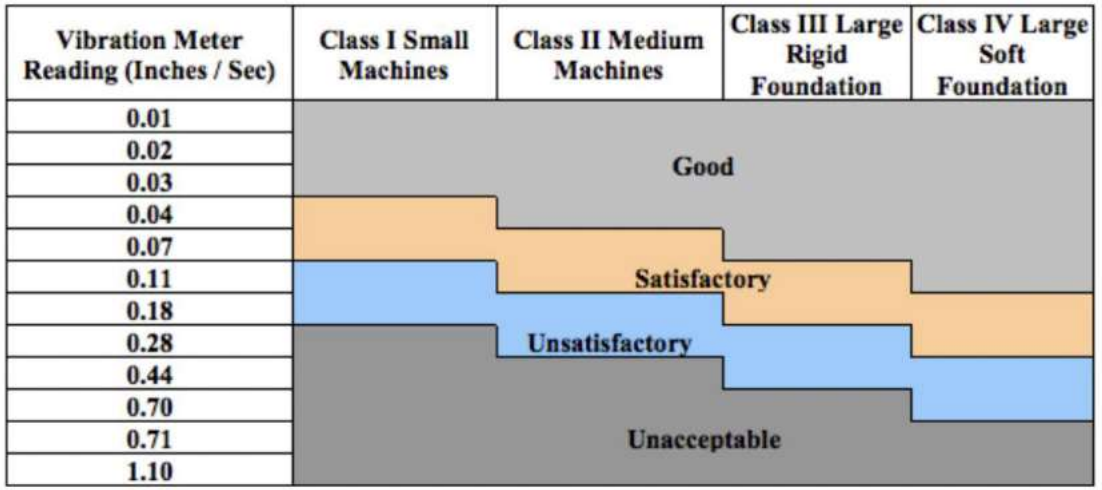
Factory Simulations

- Use plant simulation and throughput optimization to improve manufacturing performance
- Eliminate Bottlenecks and Streamline Throughput
- Optimize Energy Usage for Improved Performance



Example: motor-driven systems performance monitoring

- Sensors
  - Temperature
  - Vibration
  - Electric current or power
- Opportunities
  - Avoid machine failures and downtime
  - Better scheduling of workload
- Status
  - Contractors can install sensors
  - Intelligence more advanced than other applications
  - Still pricy



User sets vibration thresholds to trigger alerts

Evaluations and Continuous Improvement

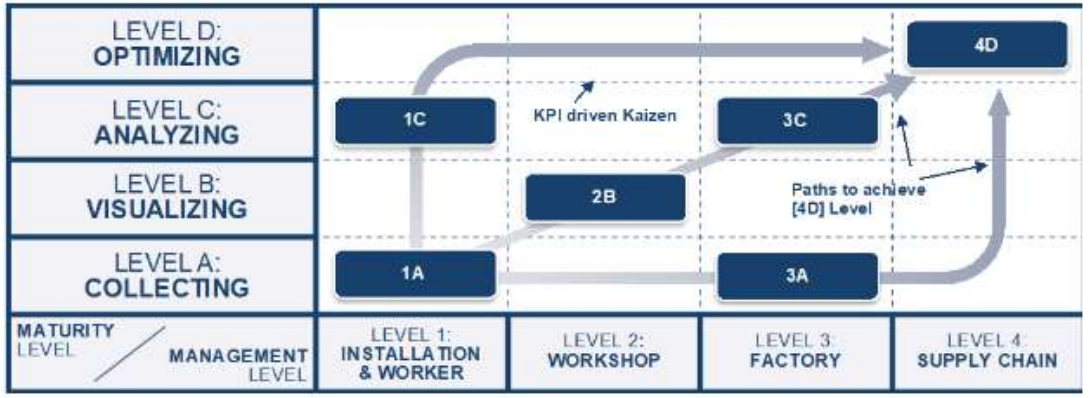
Management Levels
- Worker
- Workshop
- Factory
- Supply chain

We are likely to focus on the worker and workshop levels in this project.

Maturity Levels
- Collecting
- Visualizing
- Analyzing
- Optimizing

Beginning to collect data is a big step.

"Smart Manufacturing Kaizen Level" Matrix Tool (Source: Mitsubishi Electric)



SMKL Used to Map Improvement Trajectories (Source: Mitsubishi Electric)

Various Strategies for Smart Manufacturing

Case 1 (manufacturing or assembly line): a higher level of maturity can bring more value in one type of manufacturing operations than another.

Strategy: 1A -> 1D -> 3D

Case 2 (energy management): utility consumption data are available at an aggregated level, for example a site or a factory, but not at the line or as machine data. It might be useful to create dashboards and analyze consumption of sites with high utility consumption and then invest at the more granular line or machine level to get more understanding of and control over the energy consumption of individual machines.

Strategy: 3A -> 1A -> 1D

SMKL Used to Map Production Improvement Trajectories
(Source: Mitsubishi Electric)

SMKL Used to Map Energy Management Improvement Trajectories
(Source: Mitsubishi Electric)

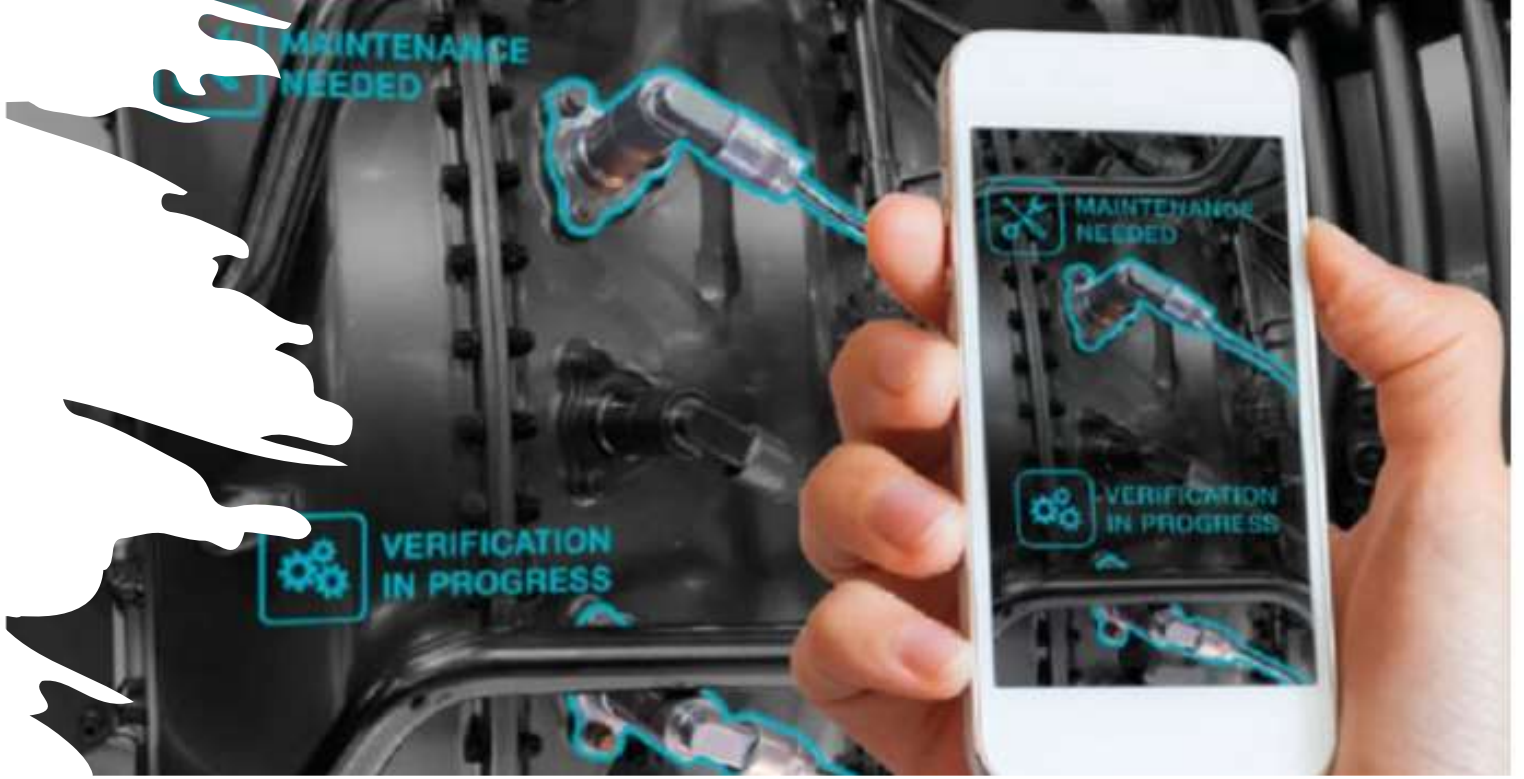
Considerations

- There are simple and cost effective energy savings and process improvement opportunities by adding:
  - Sensors
  - Internet connectivity
  - Control outputs
  - Actionable alerts and reports
  - Offerings emerging in the marketplace
- IAC research opportunities
- Often includes monthly subscription cost
- System integration
  - Compatibility of existing devices to the new devices
- Safety in human-robot collaboration
- Return of investment

Smart Manufacturing to PHM

Smart Manufacturing allows for the implementation of Prognostics and Health Management.

By utilizing the sensors installed for smart manufacturing we can gain information related to the equipment health and current operating status to improve maintenance activities.



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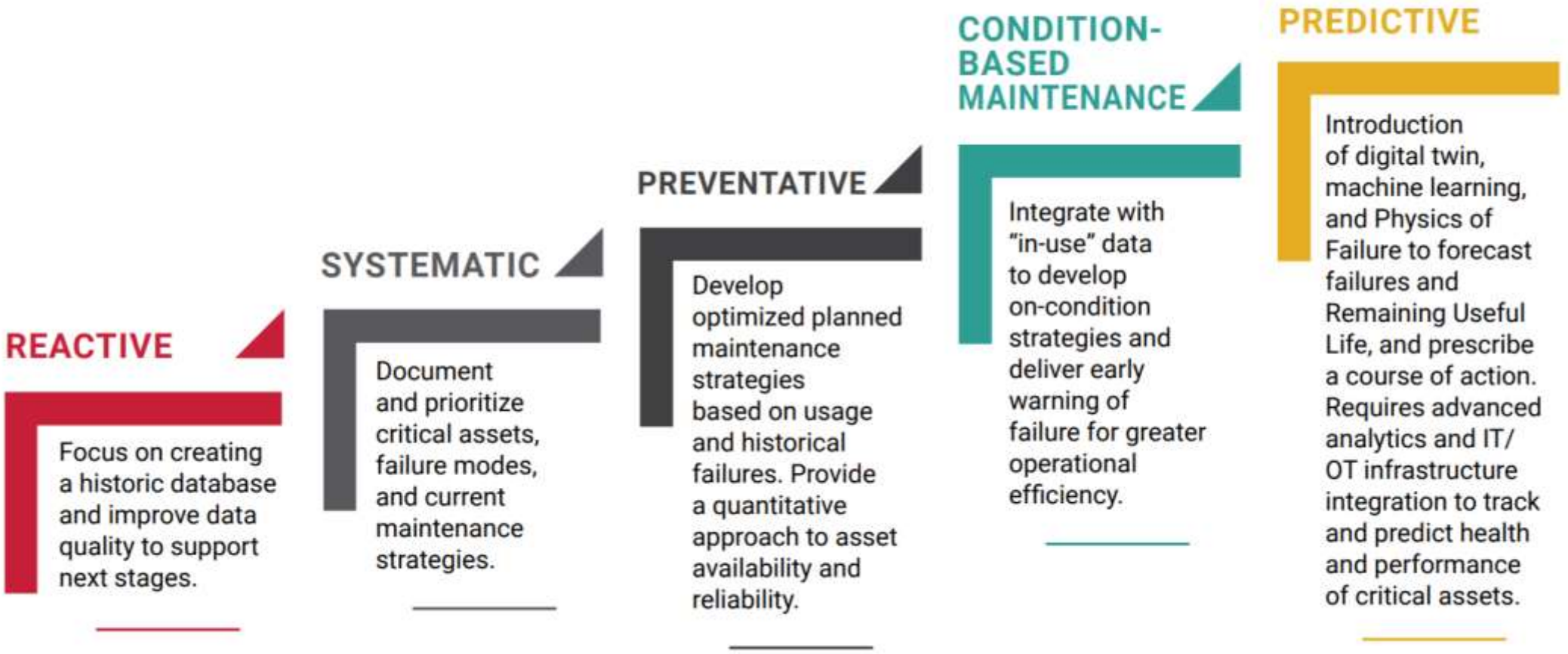
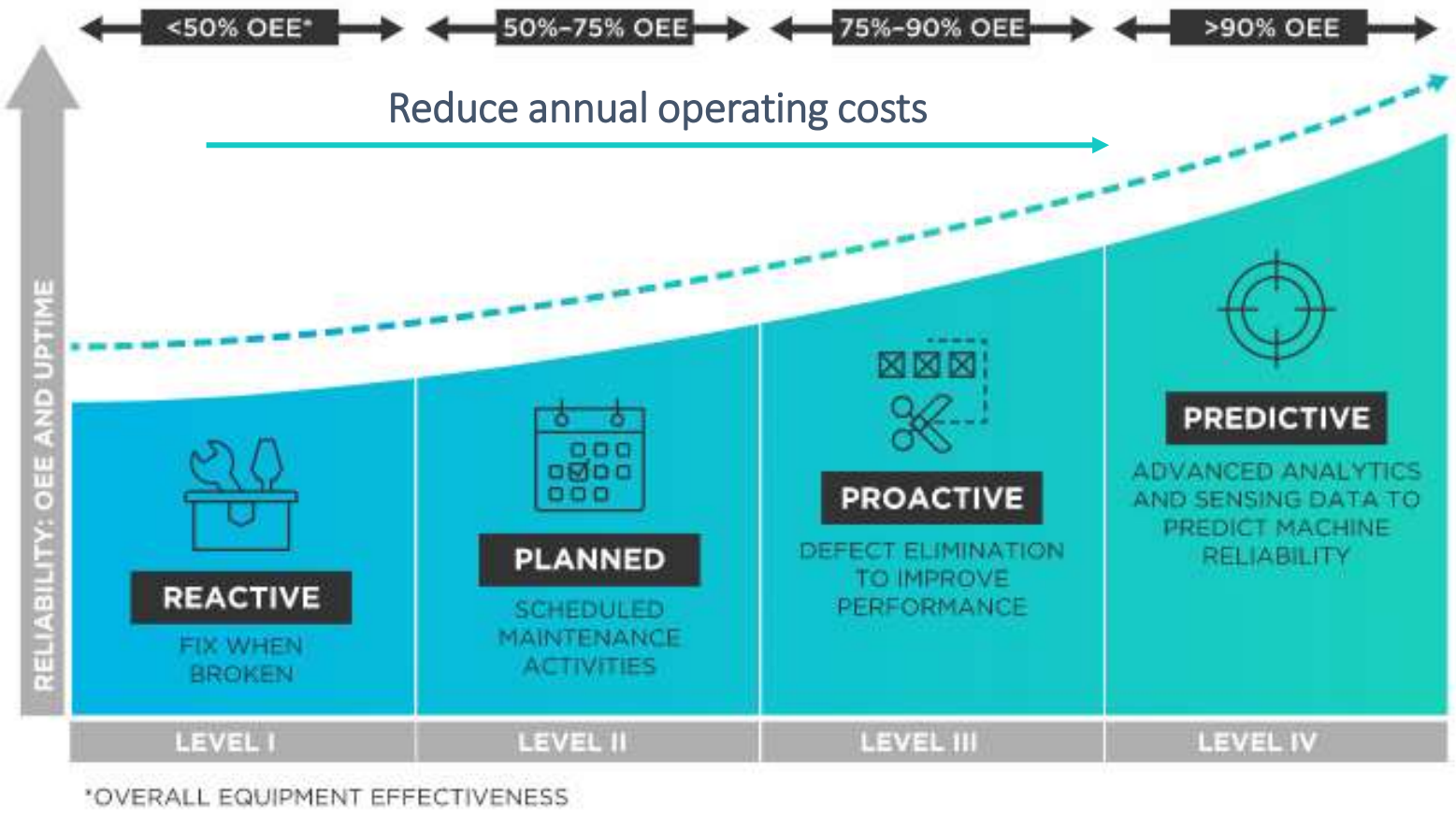
Where to Start



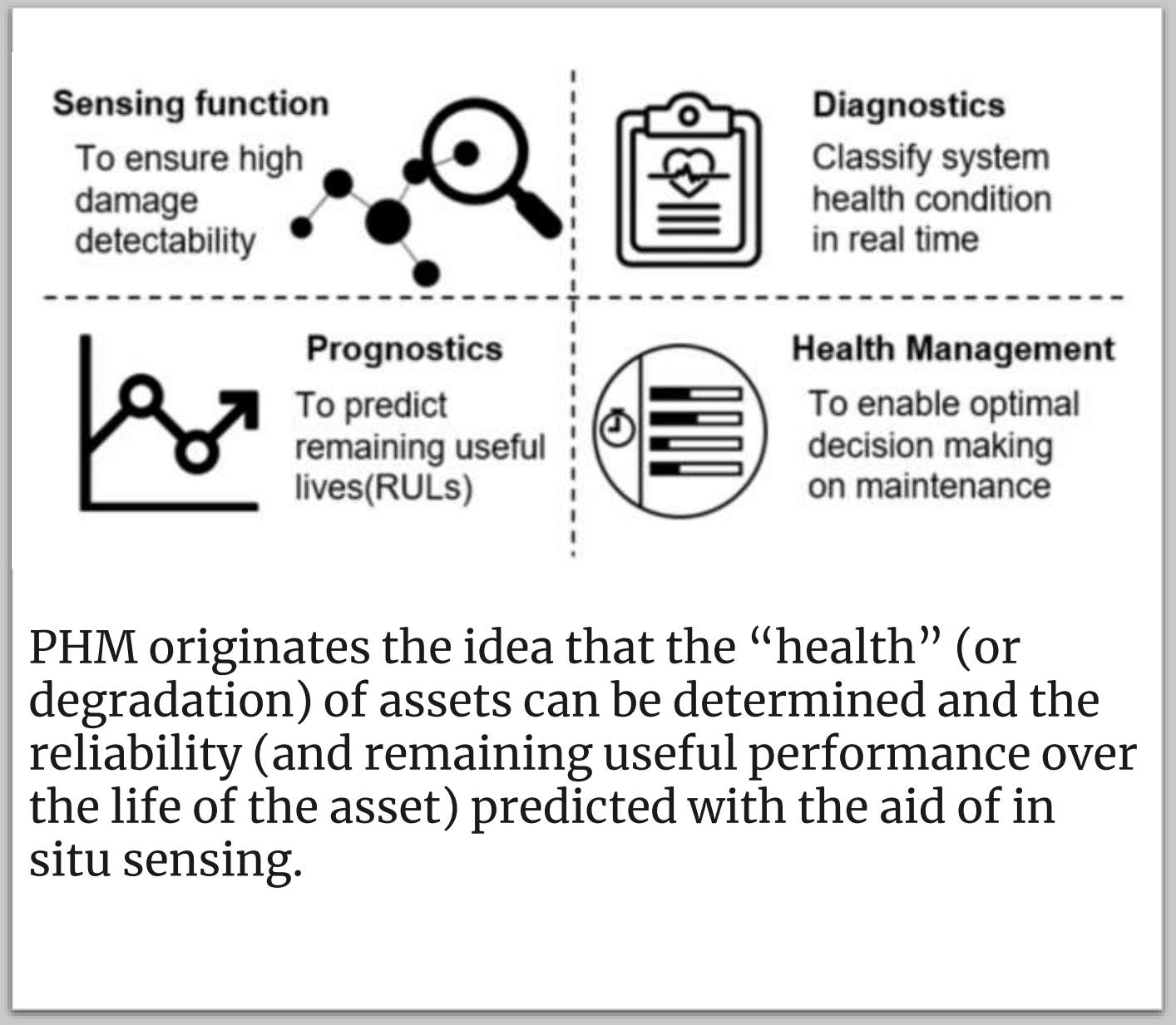
Asset Performance Maturity Curve



Prognostics and Health Management

Prognostics and Health Management (PHM) is a term that refers to the utilization of robust sensing, monitoring, and control to detect, assess, and track system health degradation and failure modes to allow for enhanced management and operational decisions.

(Jin et al., 2016; Uckun et al., 2008)

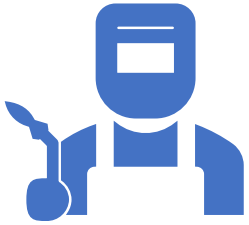


PHM originates the idea that the "health" (or degradation) of assets can be determined and the reliability (and remaining useful performance over the life of the asset) predicted with the aid of in situ sensing.

What is PHM?

- PHM has two main functions, diagnosis and prognosis.
- Diagnosis is ascertaining the current health state of the process or component and upon failure, determining the element that failed.
- Prognosis aims to estimate the future state, normally specified by the term remaining useful life (RUL).
- RUL is defined as the “estimated time until the component or machine either fails or degrades such that it no longer performs its intended function”.

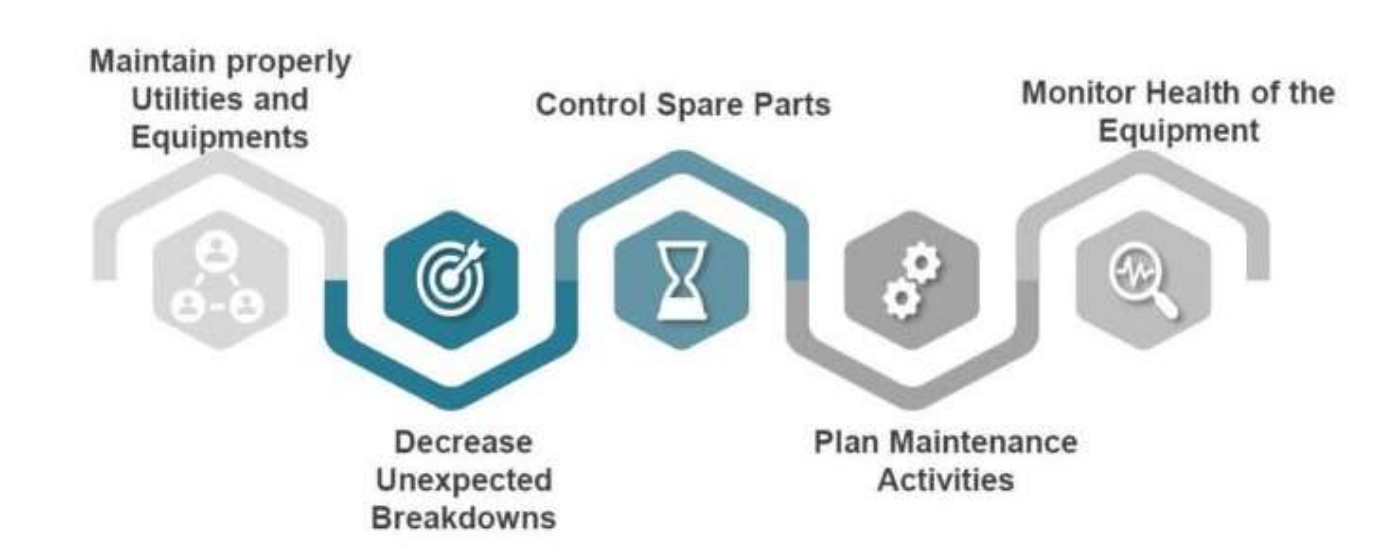
Why Do We Care?



The increasing complexity of manufacturing equipment has forced the maintenance community to shift to meet the increased quality and reliability demands (Jin et al., 2016; López et al., 2014).

A recent McKinsey report found that these transformations, when done well, can increase asset availability by 5% to 15% and reduce maintenance costs by 18% to 25%.

Benefits of PHM



- Increased system reliability and availability through condition-based maintenance
- Reduced lifecycle costs by decreasing inspection, repair, downtime, and inventory
- Reduced failure rates through proactive and appropriate maintenance at the right time
- Enhance industry competitiveness by increasing efficiency through improved capability

Challenges SMMs Face with PHM/PdM

- Don’t know where to begin
- Not enough time or money to implement a solution
- Not enough knowledge to analyze data or do anything with it
- Not enough support from management or vendors
- Too many different programs needed to see a complete picture
- Where or how to store data
- Data privacy
- Scalability

Evaluating PHM for Small and Medium Manufacturing

- How reliable do our assets need to be? What are our availability targets?
- Do our technicians have the right skills to perform the work required?
- Do we have the right spare parts in the right place at the right time?
- Are our processes well-documented, accessible, and useful?
- Do we have the right tools for the job?
- How do we determine when it's time to replace an asset rather than maintain it?
- What data do we already have that isn't being used effectively?
- Have we identified the critical assets in our production system?
- Are there some critical assets that would benefit from a PHM pilot?
- What is the value of PHM across our entire enterprise?

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PHM Readiness

A lack of readiness for implementation of new technology is linked to failure.

Increased readiness leads to increased utilization and increased probability of success.

Assessment tool for understanding an organization's readiness for PHM implementation