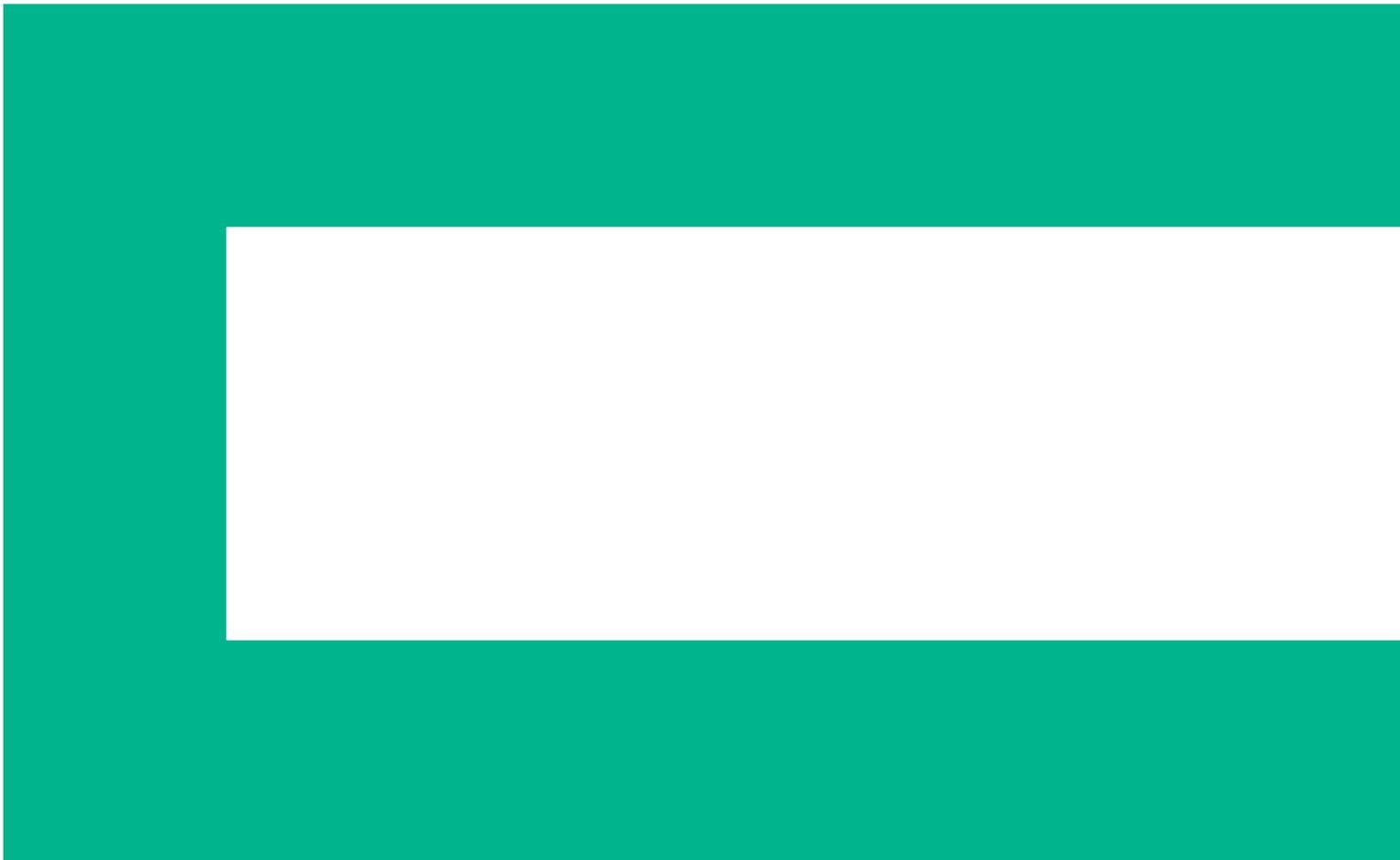# Predictive maintenance: machine condition monitoring meets the IoT

It's the end of "rule-of-thumb" maintenance—and a new era of opportunity

Executive summary

The ultra-connected **Internet of Things** (IoT) has created a surge of new interest in—and innovation around—machine condition monitoring solutions.

The confluence of better and cheaper sensors, broader connectivity, more sophisticated analytics, less expensive storage, and multi-cloud technology has opened up new opportunities for replacing "rule-of-thumb" maintenance. Instead of making broad-based maintenance decisions based upon historical data from similar devices, a real-time data-driven predictive maintenance approach minimizes unplanned downtime and improves employee and factory efficiency. The result is that organizations can prevent unplanned downtime by having fine-tuned visibility into their operations and the ability to automatically sense warning signs that indicate equipment failure or reduced performance.

By connecting equipment, organizations can capture massive volumes of data from sensors and other connected devices, so they can not only cut unplanned downtime and its associated costs, but also create new operational efficiencies, exploit new opportunities in supply chain optimization, and accelerate their overall digital transformation strategies.

This paper takes a closer look at the opportunities, challenges, and real-world examples of integrating the IoT into machine condition monitoring.

Why machine condition monitoring is suddenly sexy

Machine condition monitoring technology has been around for decades, aimed at optimizing machine performance and minimizing unplanned downtime. Since the arrival of the IoT, however, there has been a groundswell of energy and growth around machine condition monitoring. The market is now valued at more than $2 billion and is expected to grow at more than double its previous pace—with a CAGR of 7% through 2022.[1]

The advent of the IoT has reshaped and accelerated the machine condition monitoring/predictive maintenance market for four key reasons:

- **Role reversal**. Traditionally, condition monitoring and predictive maintenance has relied at least as much on the human element as on technology. In many cases, data collection is supplemented with physical inspections by highly trained specialists, who determine whether anything "seems" out of place based on the way things look, sound, smell, or feel. The result has been an expensive, time-consuming model that does not scale well in the digital age. In addition, transferring sensing knowledge to other workers is no small task: It takes many years to understand how these sights and sounds indicate equipment performance and also to transfer that knowledge to others. The IoT automates and adds intelligence to machine condition monitoring and allows humans to focus on higher-value tasks related to optimizing operations.

- **New cost economics**. By minimizing the need for human involvement, expanding connectivity, and simplifying the use of automation and analytics, the IoT redefines the cost model of machine condition monitoring and makes deployment of new solutions both financially practical and more valuable to the business. At the same time, pressure to reduce CAPEX costs for IoT deployments are real, and new capabilities to deploy edge infrastructure can be consumed as operational expenses.

- **Upward trajectory**. The IoT is still in its infancy, with plenty of untapped potential remaining for machine condition monitoring. While Gartner famously predicted that the IoT will include 21 billion interconnected devices by 2020,[2] the vast majority of those devices are not connected to the Internet today, and only 1% of IoT data is being used (mostly for alarms or real-time control).[3] The opportunities for IoT-based machine condition monitoring are likely to grow rapidly—both for the makers of "things" that dispense data and the users of things that consume data.

Mining company improves production quality through pattern recognition
A leading raw materials company turned to **Falkonry**, a provider of pattern-based artificial intelligence technology, to improve operational performance through pattern recognition of motor failure. To get to advanced pattern recognition, enterprise-level computing is required, but it also must withstand the temperatures and dust levels. The capital equipment used in mining is huge, expensive, and often uses protocols not typically used in traditional IT environments. However, looking at some simple metrics such as time series data from machines used in the refining process, the advanced techniques that Falkonry uses can identify potential issues without actually touching the process machinery. The improvement in production quality has been so significant that the company is exploring additional pattern-recognition opportunities today.

[1] **marketsandmarkets.com**, November 2016.

[2] Gartner, November 10, 2015.

[3] McKinsey Global Institute: "IoT: Mapping the Value Beyond the Hype," June 2015.

- **Edge intelligence**. In the connected world, devices are becoming increasingly intelligent, allowing organizations to gain new data sets and make decisions where devices live. On this "**intelligent edge**," data from connected devices and sensors can provide deep context to analytics systems (i.e., location or status). In addition, advances in computing power and decreasing costs allow organizations to put more power where devices live, to gain real-time insights, create digital twins, or to analyze data that often lacks a quality connection to centralized data analytics.

New use cases, new opportunities

As billions of IoT devices continue to interconnect and intercommunicate, and as independent software-defined innovations are introduced for performing condition monitoring, new IoT-related use cases are emerging. For example:

- **Expanding the use of predictive maintenance**. Predictive maintenance allows companies to detect potential trouble, diagnose the issue, and take remedial action before performance degrades or downtime occurs—and that has tremendous business value. It not only cuts downtime and its associated costs, but also increases productivity per hour (for example by scheduling maintenance and repairs to optimize work windows). It also decreases support costs because manufacturers can provide service without always having to send a trained technician into the field.

  Equally important, **predictive maintenance makes it possible** for companies to understand the true condition of their industrial machines in a much more nuanced way. You can quickly determine not just whether a machine is broken or requires service, but which components are most likely to fail, where and when failures are likely to occur, how a specific failure would impact production or response time goals, what remedial actions could be undertaken proactively, and how to prioritize those actions.

  Today, as mechanical systems become more complex and incorporate more advanced technology, the value of predictive maintenance is steadily increasing. By cutting failure rates even a small percentage, predictive maintenance can deliver huge financial results. According to a recent Aberdeen Group study, predictive maintenance is delivering significant results to real-world "best-in-class" companies, including reducing unplanned downtime to 3.5%, improving overall equipment effectiveness to 89%, and reducing maintenance costs by 13% year over year.[4]

- **Extending the value to smaller machines**. As the cost of sensors, storage, connectivity to data lakes, and even analytics solutions continues to decline, it becomes increasingly practical to apply machine condition monitoring to smaller and smaller machines.

  Once reserved for only the largest industrial applications—oil platforms with hundreds of thousands of sensors, industrial pumps generating hundreds of performance parameters, aircraft engines and safety-critical automotive systems—IoT-based machine condition monitoring solutions are now financially practical for refrigerators, air conditioners, and small appliances.

- **Introducing new pricing models**. In the recent past, manufacturers sold a piece of equipment and the relationship with the customer went dormant after the 90-day warranty period or support period was up. Today that relationship can be extended for the lifetime of the equipment, and as a result manufacturers are realizing that they can now move to different pricing models.

  For example, rather than charging an upfront fee for a machine you can now charge per use, or charge for activation. This presents new opportunities for manufacturers to increase their revenue and strengthen their relationships with customers at the same time.

[4] Aberdeen Group, "Maintenance, Repair, and Operations: The Rise and Role of Remote Assets," July 2015.

HIROTEC eliminates manual inspection
HIROTEC Group, one of the world's largest private production companies, **wanted to tackle a perennial challenge: unplanned downtime**. So it paired an IoT platform from HPE partner PTC with HPE Edgeline systems. Now HIROTEC can utilize machine learning to predict—and prevent—failures in critical systems like its exhaust system inspection lines. The solution also enables HIROTEC to perform analysis of historical data so that it can understand production facility performance and find ways to drive improvements. The company has also essentially eliminated manual inspection time—enabling technicians to focus on tasks that drive more value to production workflows.

- **Creating opportunities for non-traditional market participants**. The new breed of IoT-infused machine condition monitoring solutions doesn't only benefit traditional machine makers and equipment owners—they can also create new sources of value for non-traditional players. For example, insurance companies are very interested in these solutions because the more control a manufacturer has over the quality of its product and the greater its ability to track everything pertaining to the performance of the machine itself, the less liability it is exposed to. That makes it more financially attractive to underwrite that manufacturer's product.

- **Accelerating digital transformation**. Most enterprises today are engaged in **digital transformation** aimed at exploiting the enormous new opportunities of digital business. However, many of these initiatives stall or are delayed because costs exceed projections and funding dries up. In fact, 64% of business leaders say their transformation initiative is behind schedule.[5] IoT-based machine condition monitoring solutions have the potential to free up budget by improving productivity and operational efficiency. As an equipment manufacturer, you may also choose to develop services to monitor and maintain your products at customer sites.

- **Strengthening security**. Strong defense against today's cyber security threats is a critical requirement for all IoT deployments, particularly when it comes to operational technologies where the data is rich with insights about core processes and machine performance, with the potential to control equipment. Most new IT deployments consider security a given as most products have security integrated. IoT deployments will need to account for devices that may be decades old, and must take into consideration the security of these old machines and the connection they use to transmit the data, as well as the access to storage by other applications and stakeholders, at the outset. The advent of new security technology is capable of increasing both IoT visibility and security of the IoT solution components. The net result is the ability to deploy advanced machine condition monitoring solutions with peace of mind—and actually improve the overall security posture of operations.

Advice for exploring the opportunities

The move to IoT-based machine condition monitoring can be complex, involving a wide range of considerations and undertakings—from redesigning business processes to reskilling employees and investing in new tools and technologies. Here are a few guidelines for getting started, based on the experiences of HPE experts in serving real-world customers.

1. **View this as a collaborative effort and involve all stakeholders**, including IT, data scientists, plant management, developers, security providers, business change analysts, consultants, vendors, and business leaders. In many cases, different stakeholders have perspectives that are extremely useful to other stakeholders; for example, operating technology staff can help educate IT staff about key considerations and vice versa, making sure the right machines can communicate the right ways using the right protocols.

2. **Don't underestimate the complexity**. In many cases data resides in multiple places and in multiple forms, and current staff often doesn't have the training to know how to extract, integrate, and use all the data. Invest in the education and support your organization needs to develop data acquisition and data analytics capabilities. Reaching out to external sources can help transfer knowledge and know-how to the internal resources during the development phases.

3. **Make sure you have the right data** and that you can accurately interpret that data. Re-architecting your infrastructure is only helpful if it allows for the collection, analysis, and action to solve your organization's objectives. In the IoT era, the most voluminous and valuable data is at the edge. Don't hesitate to develop a strategy and get the assistance you need in assessing your data acquisition, integration, and management strategies.

"…By 2019 at least 43% of IoT-created data will be stored, processed, analyzed, and acted upon close to, or at the edge of, the network… Companies are now driving better business outcomes by leveraging IoT to accelerate business by transforming data into insight."[6]

– IDC

4. **Focus on the business value**, not the technological "wow factor." This will also help you avoid the mistake commonly made in technology-focused projects: piecemeal solutions implemented in a disjointed way, leading to siloes of incompatible capabilities and data. It is important to keep a singular business objective in mind—reduce costs, improve efficiency and productivity, reduce design cycle times, improve customer response times, and/or innovate. IoT has the capability to expand the business value; this should be approached in a gradual and programmatic manner.

5. **Start with implementations that deliver quick wins**—meaning obvious and measurable business results, but ensure that the small projects can be scaled and are compatible with future plans. Evolve gradually with future scalability in mind. A focused proof of concept or pilot with clear-cut business objectives will help validate the objectives and identify impact on the business that can be addressed before a large-scale deployment can be undertaken.

6. **Ensure that the infrastructure can deliver actionable data to accomplish business objectives**. This includes consideration of infrastructure elements such as:

   a. Network: Extensible wired and wireless networks can help ensure that onboarded devices can be secured, remediated, and monitored for anomalous behavior. The network should also be able to pull contextual information to augment what is already known about devices, including location.

   b. Platforms: Data platforms must be able to pull data from many different data sources and protocols to be able to merge and correlate data streams.

   c. Data growth: With the addition of new sensors and devices, your organization's data will likely grow. There are two challenges to address. First, ensure that the infrastructure can grow with your data. Second, look at techniques to analyze data at the edge (near sensors) to process and direct action before it needs to be sent to a data center. Use the data center for building machine learning and to address anomalies. Data can be stored at the edge or the cloud where it is needed for analytics.

7. **Understand and address the impact on the business**. This technology will impact what you do, how employees act, and how data grows. There will be a transition from moving from decisions made by sight, touch, and smell, to those informed by data from sensors. Additionally, now systems can detect many things that we once relied only upon our senses to identify, and they can take automated action. Employees' roles may change, and you will need to educate all employees, especially those impacted, to use new sensing technologies to augment their vast experiences.

How can HPE and our partners help

HPE fully appreciates that effective blending of IoT and machine condition monitoring capabilities requires a comprehensive approach—one that encompasses every consideration from industrial sensor selection to connectivity technology to data acquisition and analysis to security and location services to professional services and support capabilities. HPE is uniquely capable of delivering solutions that incorporate these elements, whether sourced directly from HPE or from our strong and growing IoT partner ecosystem. Our solutions, along with our partners' solutions for machine condition monitoring and predictive maintenance include:

HPE Edgeline Converged Edge Systems provide data center-like compute power that can aggregate and process data, produce real-time insights, and perform deep analytics while sending raw or aggregated data to the cloud for further processing. The ruggedized specifications of Edgeline systems are geared for deployment within industrial settings such as factory floors, oil platforms, and power-generation facilities on the edge between machine sensors and the IT network.

- **Aruba** provides IoT remote monitoring solutions from physical layer connectivity (wired and wireless) through protocol conversion, authentication, encryption, secure tunneling, role- and policy-based access, and supervisory analytics. In addition, functionality can be layered on top of the networking devices. Device access and security policy enforcement can be accomplished (**ClearPass**), navigation apps (**Meridian and ALE**), and networking device behavior can be monitored and automatically remediated (**Niara**).

- **HPE Pointnext** offers services for transforming IoT visions into IoT reality, including advisory, transformation, professional, and support services that can **take projects from ideation through to operations**.

The HPE IoT ecosystem also includes:

- **Falkonry** provides pattern recognition software for time-series data (Splunk, IoT, PI Systems, IT).

- **Flowserve** delivers a complete portfolio of reliable, IoT-ready valves, pumps, and seals.

- **National Instruments** provides software that controls valves (such as those in the Flowserve pumps) on-site or remotely over a secure wireless network. **CompactRIO** offers systems for data acquisition and data conversion in hazardous environments. **LabVIEW** provides system design software.

- **PTC** provides technology solutions (including augmented reality and digital twinning) that transform how products are created and serviced, including **PTC ThingWorx**, a complete development platform for IoT, including augmented reality.

Other vendors in the ecosystem include **GE Predix**, **Deloitte**, **ABB**, and **OSIsoft**, among others.

The diagram below illustrates how these elements work together with HPE Edgeline systems to enable predictive maintenance.
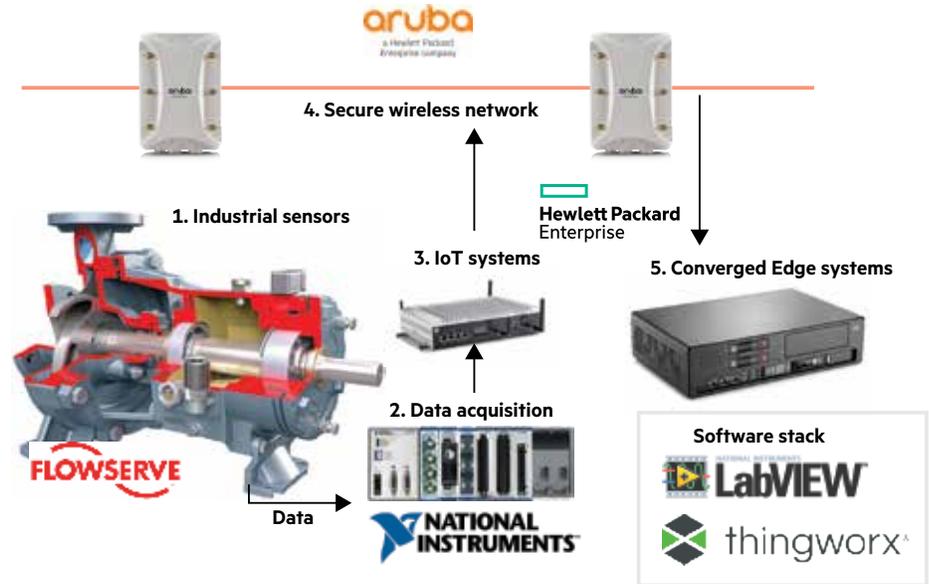
In the diagram above, HPE Edgeline products bring data center-grade computing to the network edge. Used in conjunction with a secure Aruba wireless network and application software from National Instruments and PTC, Edgeline can transform data into insights faster and more economically than was previously possible. Flowserve leverages this powerful compute capability to optimize the operational lifecycle of its pumps, improving run time performance and opening a window into the impact of service issues on operational life. **These insights enable site engineers to repair and replace parts before a failure occurs**, keeping processing running and maximizing the throughput of their oil and gas customers.

Working with its partners, HPE has also created a variety of reference architectures, including a predictive maintenance solution reference architecture, a condition/inventory monitoring reference architecture, and an IoT application platform solution reference architecture, which can be coupled with IoT consulting and services with HPE Pointnext. These architectures unburden customers from the complexities of piecing it together themselves and creating comprehensive IT infrastructure for machine condition monitoring.

Conclusion

As the opportunities for harnessing the IoT for machine condition monitoring emerge and evolve, we urge you to explore the possibilities and take maximum advantage. HPE offers a unique combination of experience, expertise, and exposure in all verticals. Our real-world clients have translated the "promise" into actual results. We would be honored to help your organization do the same; and we're here to help you every step of the way.

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