Hewlett Packard
Enterprise

Real-Time Analysis and Condition Monitoring with Predictive Maintenance

Transforming Data into Value with HPE Edgeline

Part Number: 873730-002a
Published: February 2017

Notices

Acknowledgments

Contents

Solution overview

Terabytes of data from industrial systems are constantly being generated out on the edge. Tapping in to this data source is key in driving better business outcomes through IoT. For example, modern oil platforms are bristling with more than 100,000 sensors and actuators that need real-time monitoring. Industrial pumps generate dozens of performance parameters so potential failures can be prevented if they are identified fast enough. Automobile manufacturing equipment produces large amounts of real-time data which, if processed fast enough, can identify defects before cars leave the assembly line. These and dozens of other use cases point to the need for processing horsepower and storage at the network edge for real-time insights that were previously only available from data center-based compute platforms.

Flowserve, Hewlett Packard Enterprise, National Instruments, and PTC have collaborated to create an industrial condition monitoring solution that runs in real time entirely at the network edge. The solution brings together leading edge pump technology combined with the latest data acquisition methods, secure wireless, edge computing, and analytics platforms. Plant owners and operators can now economically instrument all of their machines and instruments to proactively detect and diagnose faults for optimal performance, longer uptime, and lower mean time to repair.

There is a connected, predictive, and practical future emerging enabled by IoT. The combination of rapidly advancing technology, cost effective data acquisition and analysis allows plant operators to instrument equipment that is key to day to day operations. This has changed how customers and the industry think about "wired" and "wireless" devices. In addition, computing solutions are becoming more practical and cost effective with time and experience. There is a need even today for data acquisition solutions that are highly flexible, fast, reliable, and well suited to customers' industrial operating environments. Plant operators can connect their plant equipment directly, and in near real-time, to the key decision makers who can take appropriate action. Actions could include whether it be to continue operation, repair, or replace a piece of equipment to improve a system's performance.

Figure 1: Modern oil platform

"IDC predicts that by 2019 at least 40% of IoT-created data will be stored, processed, analyzed, and acted upon close to, or at the edge of, the network. In so doing, streaming analytics will merge with machine learning and be trained on data lakes, marts, and content stores, accelerated by discrete or integrated processors. Companies are now driving better business outcomes by leveraging IoT to accelerate business by transforming data into insight."

- IDC FutureScape: Worldwide Internet of Things 2017 Predictions, Carrie MacGillivray, VP, IoT & Mobility, IDC Web Conference, November 8, 2016

How does it work?

The solution automates data acquisition using local sensors capturing analog data, to a real-time data analytics engine running on a data center-class compute platform. Actuators for system control can be added as needed. A video of the solution in action can be seen **here**. (HPE Technology, 2016)

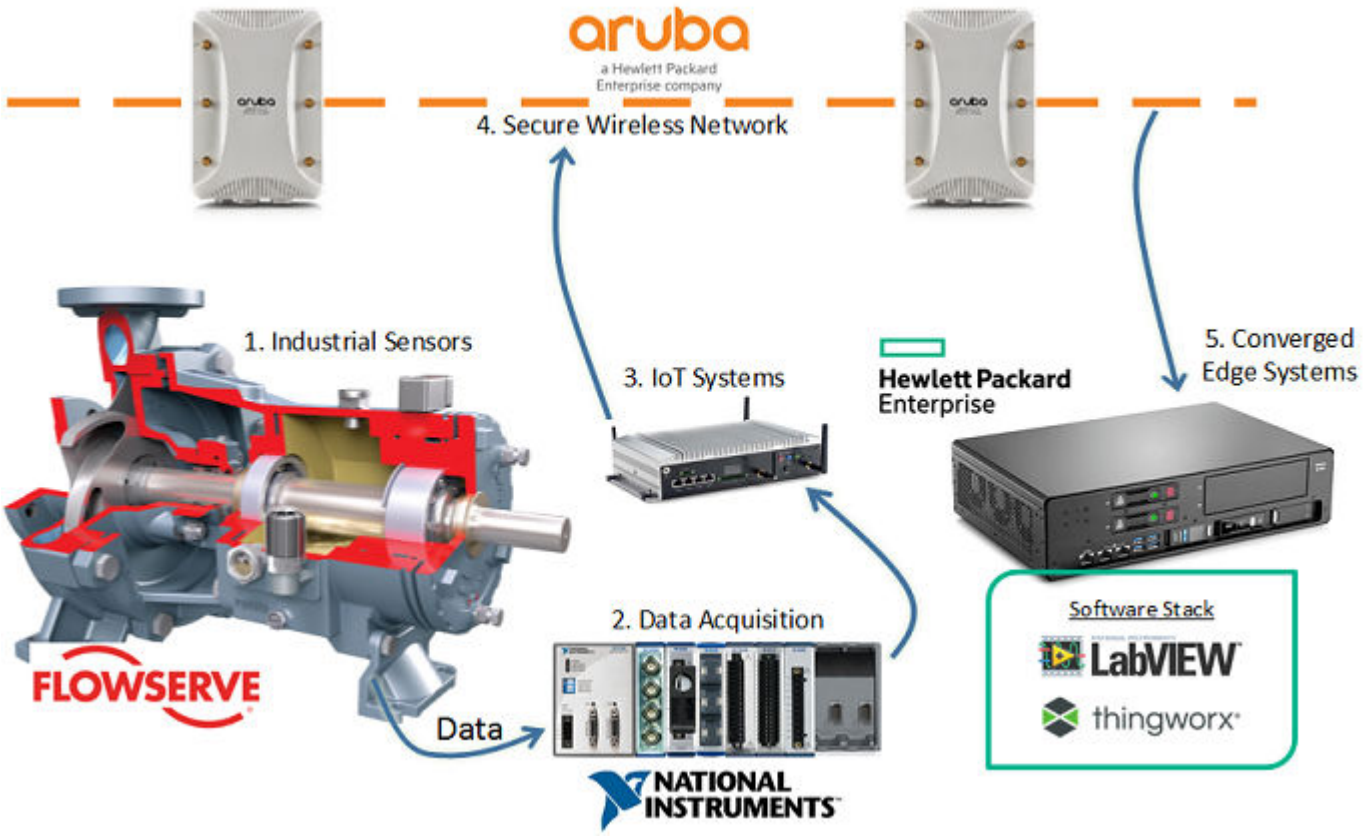

Figure 2: Solution Diagram and Data Path

In this solution, the sensors are added to the industrial equipment for continuous analog data capture and actuators can be added as needed for further system control. Sensors and optional actuators are connected to a National Instruments RIO or DAQ data acquisition system for pre-processing and normalization, and then to either an Edgeline IoT System for transmission over the network or to an Edgeline Converged Edge System. The secure wireless network consists of Class 1 Division 1 access points - combining ruggedized Aruba APs mounted in explosion proof housings made by Extronics - located around the customer facility. The wireless network provides secure connectivity up to classified Top Secret if required for government deployments, manages quality of service, and provides location-based services.

HPE Edgeline Converged Edge Systems operate National Instruments and PTC software used in real-time data acquisition, analytics, condition monitoring, and system control to the industrial equipment. Real-time operating results are compared with ideal pump performance, and if suboptimal operation is detected the software identifies necessary corrective action. The Edgeline Converged Edge System is powerful enough to run near real-time computational fluid dynamics models and other known failure mode models, using machine learning to identify the type and source of the problem and its impact on the pump's service life.

After data is processed by the Edgeline Converged Edge System, it can be forwarded to a data center via the Aruba secure wireless network. If the optionally available cloud service is enabled, then the system will also check the operating conditions of similar pumps and processes to determine if the anomaly is known or new. The system can notify maintenance staff of problems using built-in Bluetooth or the plant's distributed control system (DCS) via secure Wi-Fi.

HPE Edgeline Converged Edge Systems integrate unprecedented edge compute, data capture and control, datacenter-class security, device and systems management, as well as large storage capacity to provide heavy-duty analytics and insights to the edge. This enables businesses to make real-time decisions and add value to their operational processes to result in better business outcomes. The Edgeline EL1000 also prevents cloud lock-in by not having to send data back to the cloud or data center. It addresses latency, bandwidth, cost, security, duplication, corruption, and compliance issues, enabling three critical components of savings and success-time, money, and time to action.

Industrial instrumentation

When creating an IoT solution, it is important to first identify the industrial system to monitor and analyze, how data will be used, and the business use case(s) that may be driving the transformation effort. In this solution, a need to provide real-time condition monitoring, anomaly detection, and predictive maintenance were the business use cases to improve upon for an industrial pump system. It is also important to identify the data to capture when beginning to instrument industrial equipment. For example, in this solution vibration, temperature, flow rate, voltage, and current were the data metrics used to monitor conditions and detect anomalies within the industrial system. Once the data type is determined then the industrial equipment can be instrumented with the appropriate sensors.

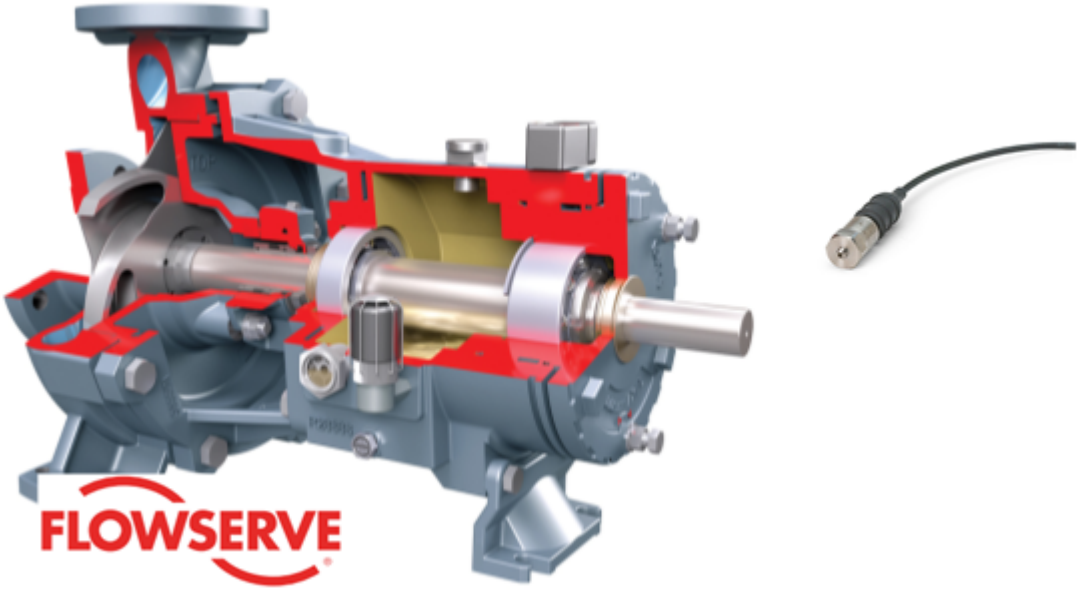

Figure 3: Connecting Industrial Sensors to Flowserve Pump

Equipment control is an additional feature in order to remotely monitor, maintain, and take action when necessary for the industrial systems. Valves in the Flowserve pump can be controlled via National Instruments software or from a remote location over the secure wireless network. Every facility has rules regarding remote device control, so the system is flexible enough to permit or block remote control based on local rules.

Data security, connectivity, and location based services

The Internet of Things is inherently untrustworthy, and the objective of the Aruba Connect and Protect architecture is to assert trust where it does not exist today. This is achieved by inserting layers of protective services starting with physical layer connectivity and extending through protocol conversion, authentication, encryption, secure tunneling, role- and policy-based access, and ending with supervisory analytics.

The architecture is based on the Aruba Adaptive Trust model, a defensive framework that leverages contextual information from a multitude of sources to scrutinize user and device security posture before and after they connect. Adaptive Trust dispels the old notion of a fixed security perimeter that surrounds the physical network, which no longer applies because devices can now connect and work from practically anywhere.

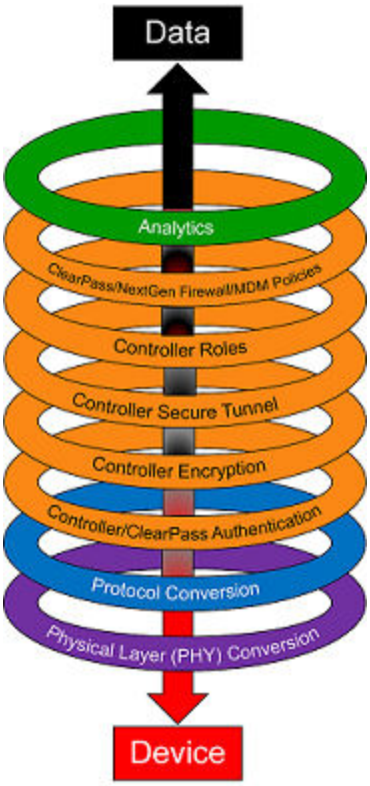

Figure 4: Aruba IoT Connect and Protect Architecture

Following the red-black architecture model, untrusted devices are shown in red at the bottom of the Connect and Protect architecture. Their identity and the data they generate are not yet trusted. If the legacy devices don't use standard IP networking then PHY and protocol conversion are applied in the Edgeline IoT System or Converged Edge System. The objective is to modify device communications so that modern protective services, represented by the orange rings, can then be applied.

Access rules and context—collectively called "policies"—determine how, when, and where IoT Devices can access network resources. IoT policy management, network access control, and endpoint compliance for IoT Devices, and the technicians that support them, are handled by the Aruba ClearPass Access Management System.

The ClearPass IoT Device Profiler automatically discovers and classifies IoT Devices, regardless of device type, using a variety of contextual data including MAC OUIs, DHCP fingerprints, and other identity-centric device data. Upon connection, unmanaged non-802.1X devices are classified as known or unknown to the

network based on the presence of their MAC address in an external or internal database. Stored profiling signatures identify device profile changes and dynamically modify authorization privileges. For example, if a Windows PC tries to masquerade as a Flowserve pump, the policy manager will automatically deny access.

ClearPass authentication services validate the authenticity of any IoT Device connecting to the network, locally or remotely. Authentication can be managed independently by ClearPass or in conjunction with existing AAA resources already in use. Both single and two-factor authentication are supported assuming the IoT Device is capable of responding to a two-factor challenge.

Since attacks can have many origins, a holistic approach to IoT device threat prevention must operate at every level of the network - from profiling IoT Devices to governing when and how they access the network, applications, and northbound Internet traffic. ClearPass achieves this by sharing policies and threat notifications with MDM, EMM, SIEM, and northbound next-gen firewalls. Each platform operates at a different point of enforcement, and working in concert they address IoT threat scenarios at every network level.

If a more advanced IoT Device with an operating system is used then ClearPass endpoint posture assessment will ensure compliance with access authorization policies before the device connects, for example, the device is not allowed to connect unless it has the latest anti-virus, anti-spyware, firewall, and peer-to-peer application policy settings. Automatic remediation services enable non-compliant IoT Devices to become compliant and then connect without manual intervention. More information about Aruba ClearPass can be found **here**.

ClearPass works in conjunction with Aruba's wireless, wired, and remote access solutions to provide security wherever a device or user connects. Wireless offers the greatest flexibility because it supports both fixed devices like pumps, and mobile devices for maintenance personnel such as laptops and tablets. For high security government applications Aruba offers TAA compliant FIPS 140-2 solutions that support IoT application up to classified Top Secret.

Aruba wireless can operate point-to-point, point-to-multipoint, and in a mesh. In mesh mode the wireless signal hops from access point to access point until arriving at its final destination, extending the range of wireless communication. Access points are available in ruggedized indoor and watertight outdoor versions, and with explosion proof enclosures for use in Class 1 Division 1 areas.

More information about Aruba networking products can be found **here**.

Ruggedized Wi-Fi Access Point For IoT Applications

Extronics Class I. Div. 1 Enclosurefor Aruba Access Points

Figure 5: Aruba networking products

Location-based services

Aruba location-based services enable users to answer three key questions that are applicable across a broad range of applications: Where am I? Where are they? Where is it? The solutions enable workers to find machines in need of service, find each other during a mustering event, and locate spare parts in a logistics facility.

Aruba's self-navigation, or wayfinding, solution called Meridian provides self-guided maps, geofencing to indicate when an area is entered or exited, and push messaging services to alert when entering a dangerous area. The service makes use of the following components:

- Beacons - Bluetooth Low Energy (BLE) devices that trigger an app when the device comes within range
- Meridian Application - runs on a smart phone or tablet
- Meridian Service - manages system configuration and mapping

Figure 6: Meridian IoT Wayfinding Solution

Meridian wayfinding enables contractors, auditors, and visitors to navigate industrial sites without assistance, conserving operational and administrative resources. Upon arriving at the target destination, additional information can be displayed, such as machine user and service guides, and maintenance records.

More information about Aruba Meridian and beacon solution can be found **here**.

Data acquisition with National Instruments

Connected sensors and industrial systems require a data acquisition device for analog data acquisition and conversion from analog to digital format. The analog to digital conversion occurs on controller modules connected to each sensor input and then presented upstream for data acquisition software to interface with. Data acquisition software, for example National Instruments LabVIEW™, is used in the solution as the foundation to acquire data and interface with the FPGA within the data acquisition device. NI LabVIEW software is a graphical programming platform which simplifies the visualization, creation, and coding of data acquisition systems. NI LabVIEW can either be embedded directly on the NI cRIO controller, or be installed on HPE Edgeline edge compute systems.

Data acquisition systems from National Instruments come in many different forms based on how data will be acquired and converted for upstream analysis systems. This section will review three options for data acquisition used in this solution.

Data Acquisition using CompactRIO

The first option is for each data acquisition device to run an embedded version of LabVIEW for a one-to-one data acquisition model between industrial system and data acquisition device. In this case, sensors and actuators can be directly connected to real-time embedded controllers, interfaced via a wireless link, or with an FPGA which provide the analog to digital data conversion locally. NI CompactRIO™ systems are used for this type of data acquisition and data conversion in a hazardous environment. Vibration, flow, temperature, and power data is then forwarded through HPE Edgeline IoT Systems to upstream HPE Edgeline Converged Edge Systems for real-time data analysis.

Embedded data acquisition using a cRIO-9068 controller:

Figure 7: cRIO-9068 controller

CompactRIO with Wi-Fi

If a wired network connection to upstream analysis systems is not available, National Instruments also offers wireless data acquisition options using the cRIO-9037 as shown in the following figure. In this option multiple cRIO-9037 systems can be remotely managed by LabVIEW within a single HPE Edgeline system when scaling to multiple data acquisition devices.

Data acquisition using a cRIO-9037 Wi-Fi enabled controller:

Figure 8: cRIO-9037 Wi-Fi enabled controller

Direct Data Ingest using PXI

In addition to cRIO, there are options for remote data acquisition devices installed near industrial equipment to be remotely managed within a single Edgeline system.

Edgeline converges data acquisition, control, and analysis with enterprise-class computing and remote management into a single system using Edgeline EL1000 and EL4000 Converged Edge Systems. The EL1000 and EL4000 can direct ingest industrial sensor data via a PXI or PXIe card inserted into the Edgeline chassis. See the Edge Computing using HPE Converged Edge Systems section of this document to see an example of how data acquisition is used with a direct PXIe connection to Edgeline Converged Edge Systems.

More information about PXI can be found **here**.

The following figure depicts the NI-9154 MXI-Express RIO chassis when in use with PXI-based data ingest on HPE Edgeline EL1000 Converged Edge Systems.

Figure 9: NI-9154 MXI-Express RIO chassis

Data forwarding using HPE Edgeline IoT Systems

The NI RIO systems are connected to the HPE Edgeline Converged Edge Systems either indirectly through HPE Edgeline IoT Systems, through a network connection, or directly through PXI/PXIe. HPE Edgeline systems aggregate and forward real-time data to upstream analytics systems. These systems provide multiple connectivity options including Bluetooth Low-Energy, cellular, wi-fi, Ethernet, serial, GPIO, and PoE for industrial devices, sensors, and data acquisition systems in hazardous areas, extreme weather, or remote environments. Edgeline IoT systems come in two forms based on the compute requirements. They also have sufficient processing power to preprocess data prior to forwarding it upstream.

Figure 10: HPE Edgeline EL10 with dual-core Intel Atom

Figure 11: HPE Edgeline EL20 with dual-core Intel i5

Edge computing using HPE Converged Edge Systems

The need to quickly analyze and drive business decisions based on real-time data accentuates the need for edge computing. HPE has created unique systems that are purpose-built for converging real-time data acquisition, enterprise-class computing, and remote manageability. HPE Edgeline systems are energy-efficient, ruggedized platforms with a broad range of network connectivity and data acquisition options to accommodate even the most complex industrial applications and use cases. Chassis type, number of servers, number of CPU cores, memory, and storage can all be tailored to site requirements.

HPE Edgeline EL1000 Converged Edge System

A single HPE EL1000 Converged Edge System with an HPE ProLiant m510 server cartridge can provide data acquisition, condition monitoring, machine learning, and predictive maintenance capabilities for a complex real-time industrial pump application without requiring cloud connectivity. There were three data acquisition methods tested.

The first method used a network connected NI cRIO-9068 embedded controller for remote data acquisition. The second method utilized a cRIO-9037 controller for wireless data transmission to the HPE Converged Edge System. The third method utilized direct data ingest on the HPE ProLiant m510 server cartridge using a PXIe card connected to the NI-9154 MXI-Express RIO chassis. This method used less than two cores of the HPE ProLiant m510 server cartridge during data acquisition. In all cases, data acquisition, control, and real-time data analysis were converged onto the same HPE ProLiant m510 server cartridge.

See the Data Acquisition with National Instruments section of this document for more information on the data acquisition methods used in the solution. All data analysis components including data modeling, machine learning, real-time data analysis, and predictive maintenance was performed locally in real-time on the EL1000 without requiring connectivity to the cloud or a remote datacenter. In the case of events and status changes, connectivity to the cloud can be integrated directly from the EL1000 to order parts, request service, dispatch technicians, and upload status or model changes to remote operation centers.

The versatile Edgeline chassis can be wall or rack mounted, and the wide temperature range supports a host of operating environments. HPE Edgeline EL1000 and EL4000 enables enterprise-class out of band remote manageability through HPE Integrated Lights-Out technology embedded directly on HPE ProLiant server cartridges.

Figure 12: HPE Edgeline EL1000 Converged Edge System

HPE Edgeline EL4000 Converged Edge System

The HPE EL4000 chassis supports up to four HPE ProLiant m510 server cartridges, for a total of 64 Intel Xeon cores. This flexible design allows the unit to scale the monitoring solution across a large number of

industrial systems or for configuring redundancy within the solution. The EL4000 operates in the same manner as an EL1000 with the exception that it has redundant power options.

Figure 13: HPE Edgeline EL4000 Converged Edge System

Performance and scalability

Real-time analysis and condition monitoring of a single pump can be accomplished using a single ProLiant m510 server cartridge. Up to three pump systems can be simultaneously monitored by an 8-core server cartridge, and scaled to six pump systems using a single 16-core HPE ProLiant m510 server cartridge. The following matrix presents how many cores are required for different sized pump applications.

HPE Edgeline Chassis	Server Core Count	Server Memory	# of Monitored Pumps
EL1000	8	32 GB	3
EL1000	16	64 GB	6
EL4000	4 x 8	4 x 32 GB	12
EL4000	4 x 16	4 x 64 GB	24

Real-time data analysis and condition monitoring

ThingWorx by PTC provides condition monitoring and real-time data analysis of industrial systems, as well as machine learning and power predictive maintenance metrics for devices like the Flowserve industrial pump. ThingWorx is an IoT platform that reduces time, cost, and risk required to build innovative industrial IoT solutions and applications that meet a variety of IoT use cases. ThingWorx running on the HPE Edgeline EL1000 Converged Edge System creates the backbone for condition monitoring, analysis, and predictive maintenance of real-time systems running at the edge.

ThingWorx was deployed using four cores of the HPE ProLiant m510 server cartridge running in the HPE Edgeline EL1000 Converged Edge System. Anomaly detection and predictive maintenance works by creating a known or working model of an industrial system or set of data. ThingWorx trains data models by collecting real-time data of industrial systems and correlating the data into expected ranges of values for the model. ThingWorx then analyzes and compares the current states of industrial systems to the trained models in order to detect system anomalies and determine equipment maintenance predictions. Once an anomalous state change occurs within the monitored system ThingWorx in near real-time identifies the anomalies, followed by root-causing the condition such as misalignment, cavitation, or low flow, and then updates the maintenance predictions used by service technicians. This type of monitoring provides continuous condition monitoring and predictive maintenance recommendations for industrial pump systems.

Normal operation during real-time analysis and condition monitoring of a single industrial pump required a single HPE ProLiant m510 server cartridge. Performance was stable at less than a combined 30% CPU usage for data acquisition, real-time analysis, and condition monitoring which means up to three pump systems could be monitored by the same 8-core server cartridge, and even increased to six pump systems using the 16-core version of the HPE ProLiant m510 server cartridge. During the occasional data modeling and training periods the system may utilize a higher amount of resources than during normal operation and should be planned for accordingly.

More information about ThingWorx can be found **here**.

Augmented reality and data visualization

PTC's Vuforia technology is an augmented reality application that can be used to build new, immersive user experiences in order to transform the way users create, operate, and service products. In industrial pump applications, Vuforia delivers augmented reality and real-time visualization of data, anomalies, and predictions. Connecting over a secure Aruba wi-fi network, Vuforia enables mobile service technicians and system engineers to view a digitized version of internal system details, current data points, anomalies, and predictions all while monitoring and maintaining industrial systems in real time.

More information about PTC's Vuforia AR Platform can be found **here**.

The following figures show ThingWorx and Vuforia in use for real-time analysis, condition monitoring, and predictive maintenance of an industrial pump system. The operational status, predictions, and alerts continuously update as the states of the pump changes. The immersive user experience through Vuforia can be seen from a mobile device at the pump. Vuforia will also continuously display the real-time operational status, predictions, and alerts as they occur.

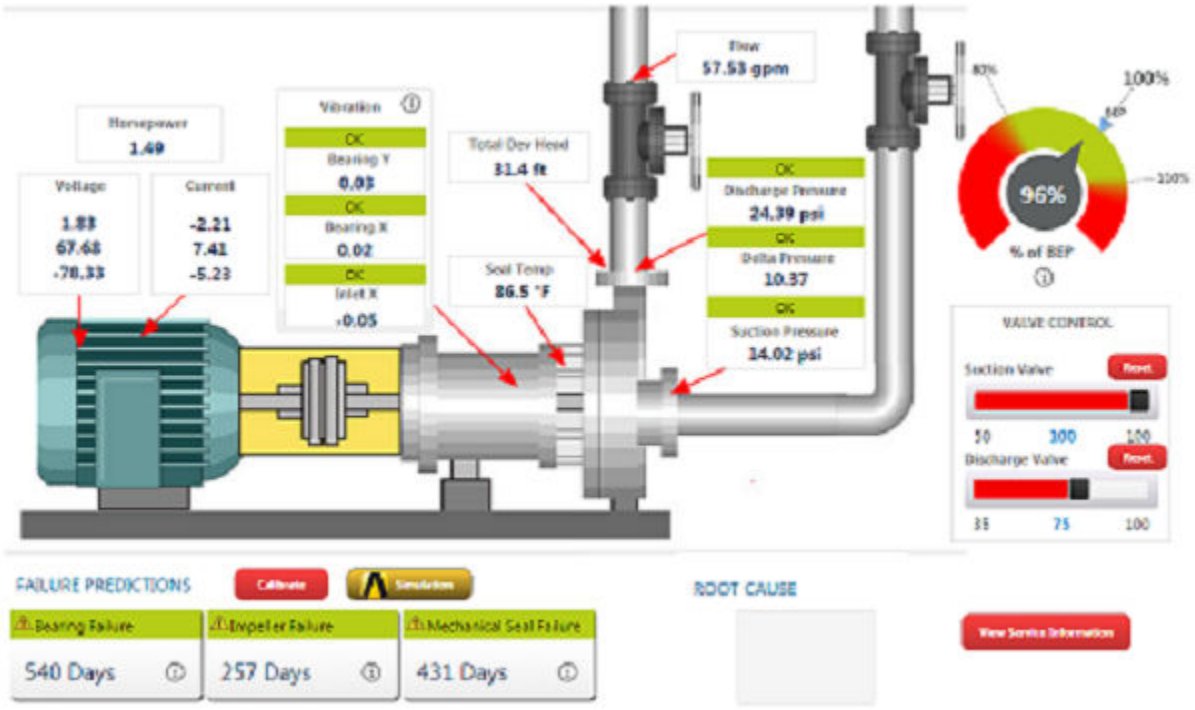

Figure 14: ThingWorx Dashboard showing real-time analytics and predictive maintenance

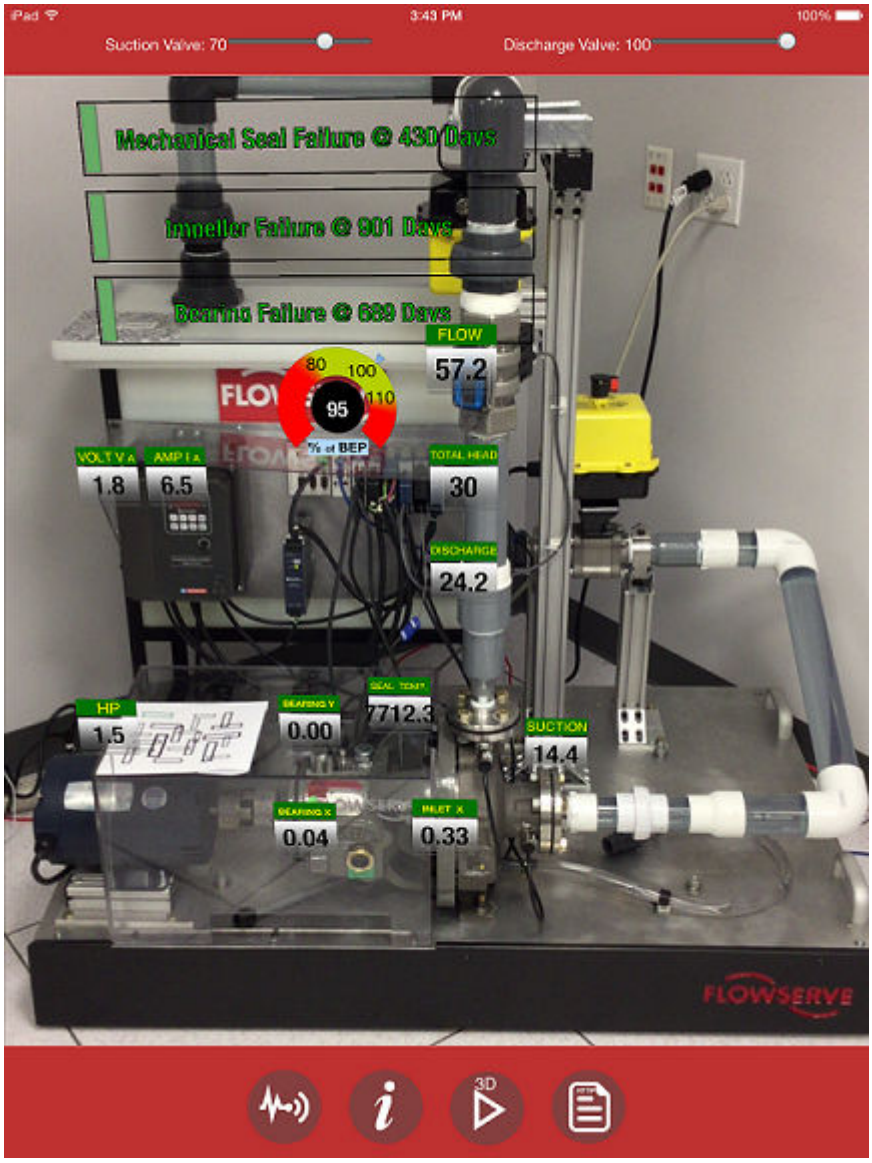

Figure 15: Vuforia immersive user experience from a mobile device

Conclusion

HPE Edgeline products bring data center-grade computing to the network edge, delivering real-time insights that drive efficiency and productivity. Used in conjunction with a secure Aruba wireless network, and powerful 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 their 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.

You can reap the benefits of this solution for your equipment or plant by contacting your local Hewlett Packard Enterprise representative. More information can be found **here**.

Solution hardware

This section provides a reference list of products tested in the solution. Requirements for each industrial site may vary and should be discussed with your sales representative.

Aruba components

The following equipment was used in an Aruba deployment of an industrial site. An industrial Class I. Div. 1 site covering 6 acres (24,000 m^2) could be enabled with wireless connectivity and location based services using the following model.[1]

Qty	Description	Aruba Part Number
2	Aruba 7010, 12x10/100/1000BASE-T PoE/PoE + (150W), 4x10/100/1000BASE-T, 2x1G BASE-X SFP ports, Supports up to 32AP and 2K clients. Integrated AC power supply.1	7010-US
2	NBD SUPPORT FOR 7010-US (5 YEAR)	SN5-7010-US
6	Aruba Instant IAP-325 Wireless Access Point, 802.11n/ac, 4x4:4 MU-MIMO, dual radio, integrated antennas - Restricted regulatory domain: United States	IAP-325-US
6	Aruba Instant IAP-274 Outdoor Wireless Access Point, 802.11n/ac, 3x3:3, dual radio, antenna connectors Restricted Regulatory Domain - US	IAP-274-US
6	Set of 3 (H x 1/ V x 2 Polarization) 5 GHz, Omni-directional, 5dBi, Direct-mount, N-type connectors. Pole mount, I-beam, and ceiling tile mount hardware included. Requires N-male to N-female extension cable if not used in direct mount. Outdoor use.	ANT-3X3-5005
6	Set of 3 (H x 1/ V x 2 Polarization) 2.4GHz, Omni-directional, 5dBi, Direct-mount, N-type connectors. Pole mount, I-beam, and ceiling tile mount hardware included. Requires N-male to N-female extension cable if not used in direct mount. Outdoor use.	ANT-3X3-2005
3	Battery powered Aruba beacons-50 pack	LS-BT1-50

Table Continued

Qty	Description	Aruba Part Number
75	Outdoor mounting bracket for battery powered Aruba beacon; LS-BT1	LS-BT1-NEMA
1	10,000 push notifications per year. Offered as a yearly subscription. Require purchase of Meridian subscription and Aruba beacons	SUB-PUSH-10K
1	1 Year Meridian App Platform Service Subscription for every 250,000 square feet	SUB1-MR-SWF
2	Aruba ClearPass Policy Manager 500 Virtual Appliance - RADIUS/ TACACS+ server with advanced policy control for up to 500 unique endpoints. Includes 25 endpoint Enterprise License.	CP-VA-500
2	SUPPORT FOR CP-VA-500 (5 YEARS)	SA5-CP-VA-500
1	Guest License for Aruba ClearPass Policy Manager - 100 endpoints	LIC-CP-GM-100
1	NBD SUPPORT FOR LIC-CP-GM-100 (5 YEARS)	SA5-LIC-CP-GM-100
3	HPE 1920 8G PoE+ (65W) Switch	1920 8G POE+
7	30W 802.3at POE midspan injector, 10/100/1000Base-T Ethernet	PD-9001GR-AC
25	Enterprise feature license bundle that includes one each of LIC-AP, LIC-PEF, LIC-RFP and LIC-AW. Order in multiples of this license SKU to exactly match the AP capacity license enabled per controller and Airwave or a network of controllers with centralized licensing enabled. The supported controllers include 6xx, 3xxx, M3, 70xx and 72xx running Aruba OS 6.0.x and beyond.	LIC-ENT
25	SUPPORT FOR LIC-ENT (5 YEARS)	SN5-LIC-ENT
6	Zone 1 IAP enclosure, AC/POE powered, 100/1000BaseT Ethernet, 6 x galvanized isolated RF outputs.1	iWAP107-USG-IAP274-US-C

[1] SKUs are US only.

Edgeline components

The following Edgeline equipment was used for edge computing within the solution. Configuration options vary depending on the data acquisition model as well as scalability required during deployment.

The HPE EL1000 with an HPE ProLiant m510 server cartridge was configured with the following specifications for use with the National Instruments cRIO-9068 Integrated Controller and cRIO-9037 WiFi CompactRIO Controller Chassis System data acquisition methods.

Qty	Description	HPE Part Number
1	HPE EL1000 1Gb System	853995-B21
1	HPE 500W Flex Slot Platinum Hot Plug Power Supply Kit	720478-B21
1	HPE Edgeline EL1000 Rack Rail Kit	866690-B21
1	HPE ProLiant m510 1P Xeon D-1548 CPU 128GB Configure-to-order Server Cartridge	814688-B21
4	HPE 8GB 1Rx8 PC4-2400T-R Kit (minimum)	854592-B21
1	HPE Moonshot 512GB M.2 NVMe 2280 Solid State Device (minimum)	862161-B21

The HPE EL1000 with an HPE ProLiant m510 server cartridge was configured with the following specifications for use with the PXI and National Instruments 9154 8-Slot MXI-Express RIO Chassis:

Qty	Description	HPE Part Number
1	HPE EL1000 1Gb PXI System	Contact HPE
1	HPE 500W Flex Slot Platinum Hot Plug Power Supply Kit	720478-B21
1	HPE Edgeline EL1000 Rack Rail Kit	866690-B21
1	HPE ProLiant m510 1P Xeon D-1548 CPU 128GB Configure-to-order Server Cartridge	814688-B21
4	HPE 8GB 1Rx8 PC4-2400T-R Kit (minimum)	854592-B21
1	HPE Moonshot 512GB M.2 NVMe 2280 Solid State Device (minimum)	862161-B21

The HPE EL4000 with four HPE ProLiant m510 server cartridges used for scalability and redundancy in the solution.

Qty	Description	HPE Part Number
1	HPE Edgeline EL4000 10GbE Switch System	847535-B21
2	HPE 800W Flex Slot Platinum Hot Plug Power Supply Kit	720479-B21
1	HPE Edgeline EL4000 Short Rack Rail Kit	868575-B21
4	HPE ProLiant m510 1P Xeon D-1548 CPU 128GB Configure-to-order Server Cartridge	814688-B21
16	HPE 8GB 1Rx8 PC4-2400T-R Kit (minimum)	854592-B21
4	HPE Moonshot 512GB M.2 NVMe 2280 Solid State Device (minimum)	862161-B21

National Instruments components

The following National Instruments equipment was used for data acquisition within the solution. There were three methods used depending on the data acquisition model.

Referenced cRIO-9068 Chassis Configuration:

Qty	Description	NI Part Number
1	cRIO-9068 Integrated Controller and Chassis System, Artix-7 FPGA	782663-01
1	NI PS-15 Power Supply	781093-01
1	NI 9234, 4 Input, 24-Bit, 51.2 kS/s, SW Selectable IEPE & AC/DC Module	779680-01
1	NI 9242, 250 Vrms, 24-Bit, 50 kS/s/ch, 3-Ch, AI C Series Module	783107-01
1	NI 9246, 20 A, 24-Bit, 50 kS/s/ch, 3-Ch, AI C Series Module	783920-01
1	NI 9203 Screw Term, +/-20 mA, 16-Bit, 200 kS/s, 8-Ch AI Module	779516-01
1	NI 9213 16-ch TC, 24-bit C Series Module	780493-01
1	NI 9265 Screw Term, 0 to 20 mA, 16-Bit, 100 kS/s, 4-Ch AO Module	779334-01

Referenced cRIO-9037 Chassis Configuration :

Qty	Description	NI Part Number
1	cRIO-9037, 8-Slot WiFi CompactRIO Controller	784549-01
1	NI PS-15 Power Supply	781093-01
1	NI 9234, 4 Input, 24-Bit, 51.2 kS/s, SW Selectable IEPE & AC/DC Module	779680-01
1	NI 9242, 250 Vrms, 24-Bit, 50 kS/s/ch, 3-Ch, AI C Series Module	783107-01
1	NI 9246, 20 A, 24-Bit, 50 kS/s/ch, 3-Ch, AI C Series Module	783920-01
1	NI 9203 Screw Term, +/-20 mA, 16-Bit, 200 kS/s, 8-Ch AI Module	779516-01
1	NI 9213 16-ch TC, 24-bit C Series Module	780493-01
1	NI 9265 Screw Term, 0 to 20 mA, 16-Bit, 100 kS/s, 4-Ch AO Module	779334-01

Referenced NI-9154 Chassis Configuration:

Qty	Description	NI Part Number
1	NI 9154 8-Slot MXI-Express RIO Chassis with LX50 FPGA	782457-01
1	NI PS-15 Power Supply	781093-01
1	NI 9234, 4 Input, 24-Bit, 51.2 kS/s, SW Selectable IEPE & AC/DC Module	779680-01
1	NI 9242, 250 Vrms, 24-Bit, 50 kS/s/ch, 3-Ch, AI C Series Module	783107-01
1	NI 9246, 20 A, 24-Bit, 50 kS/s/ch, 3-Ch, AI C Series Module	783920-01
1	NI 9203 Screw Term, +/-20 mA, 16-Bit, 200 kS/s, 8-Ch AI Module	779516-01
1	NI 9213 16-ch TC, 24-bit C Series Module	780493-01
1	NI 9265 Screw Term, 0 to 20 mA, 16-Bit, 100 kS/s, 4-Ch AO Module	779334-01
1	NI PXIe-8364, x1, MXI-Express Daisy-Chain Copper Interface Note: This item is installed in HPE Edgeline EL1000 Converged Edge System	781819-01
1	MXI Express Copper Cable (3m) Note: This item connects the NI-9154 chassis to PXIe-8364	N/A

References

- Hewlett Packard Enterprise. (2016). HPE Converged Edge Systems. Retrieved from **http://www.hpe.com**: **http://www.hpe.com/info/edgeline**
- Hewlett Packard Enterprise. (2016). HPE Edgeline EL1000 Converged Edge System. Retrieved from **https://www.hpe.com/us/en/product-catalog/servers/edgeline-systems/pip.hpe-edgeline-el1000-converged-iot-system.1008670396.html**
- Hewlett Packard Enterprise. (2016). HPE Edgeline EL4000 Converged Edge System. Retrieved from **https://www.hpe.com/us/en/product-catalog/servers/edgeline-systems/pip.hpe-edgeline-el4000-converged-iot-system.1008670180.html**
- HPE Technology. (2016, June 15). HPE + Flowserve: Harnessing the power of Industrial IoT and Edge Compute. YouTube. Retrieved from **https://www.youtube.com/watch?v=FE-jGO6E1Vc**
- Moor Insights & Strategy. (2016, August 01). IoT Analytics at the Edge. Retrieved from **http://www.moorinsightsstrategy.com**: **http://www.moorinsightsstrategy.com/research-paper-iot-analytics-at-the-edge/**

Learn more at

http://www.hpe.com/info/edgeline