TECHNOLOGY & SYSTEMS

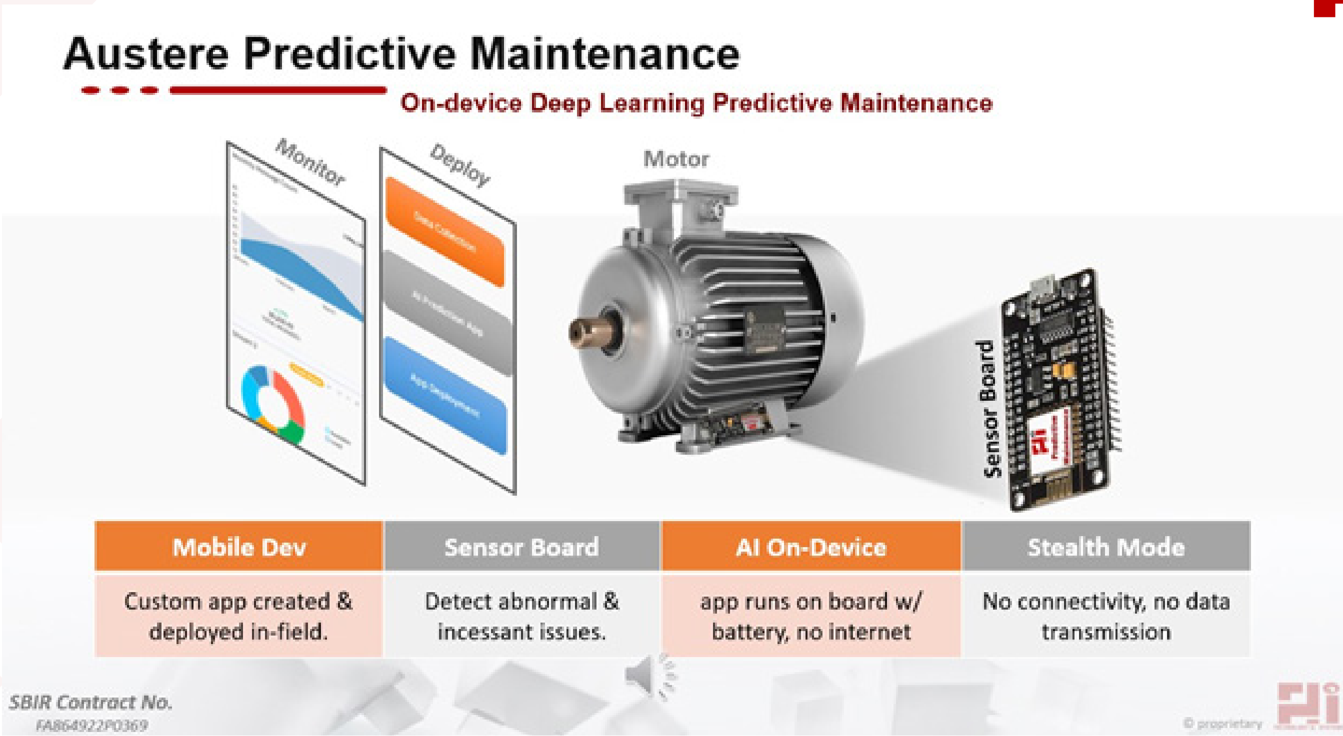
CASE STUDIES OF PREDICTIVE MAINTENANCE

for Motors & Pumps

Motors and Pumps are vital to industries including water treatment and wastewater facilities, power generation, oil and gas, food processing and more. In the oil and gas industry, the uptime of industrial pumps is especially critical. The total world consumption of global petroleum and other liquid fuels averaged 92.30 million barrels per day in 2020, according to the U.S. Energy Information Administration. That total has risen by approximately 5 million in 2021 and will continue to grow in 2022. Any unplanned downtime can impact the ability to meet this growth.

There are three basic types of pumps, and they are classified by how they transport fluid: positive-displacement, centrifugal and axial-flow. Pumps can experience several different types of failures, including cavitation, bearing failures and seal failures, among others. In oil and gas, conditions in which pumps operate are often challenging, dirty and hazardous, resulting in wear and tear. Failure of these pumps not only results in unexpected operation delays and increased costs, but it can lead to dangerous oil and gas leaks, impacting labor safety and the environment. To avoid these unexpected failures, many companies increase preventative maintenance and create aggressive inspection schedules. These practices, however, can sometimes lead to unnecessary part replacement, maintenance costs and labor.

Others may rely on condition-based maintenance, which focuses on maintenance performed after monitoring real-time data and detecting unacceptable condition levels. However, this may not come with the advanced warning needed to prevent impending failure events or avoid downtime. By taking a predictive approach, past maintenance data and current sensor measurements can be used to determine early signs of failure, allowing companies to perform maintenance only at the exact time it is needed.



Picture 1: An example of a deployed solution for predictive monitoring and failure detection of critical mud pumps in the oil and gas industry. (Images courtesy of Predictronics)

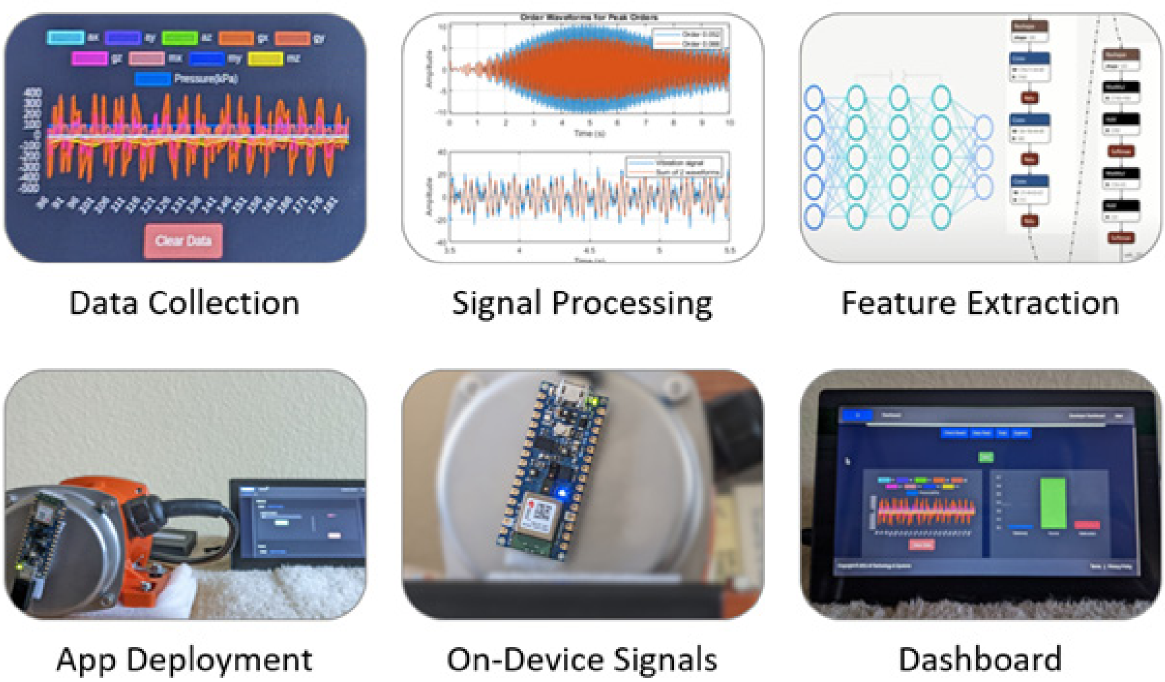
PREDICTIVE MAINTENANCE CHALLENGES

Developing and deploying a predictive maintenance solution for pumps is challenging. It requires a combination of sensing and instrumentation expertise, domain knowledge, and a practical perspective on applying machine learning and analytics for predictive monitoring. The instrumentation aspect is crucial since this data will be analyzed and will serve as the foundation of the actionable information. The decisions made from this information include what maintenance actions are needed and when they should be taken given the current pump health, as well as any trends or patterns that could emerge.

Vibration is typically the most crucial signal to use for monitoring the condition of a pump, but information on the rotating or reciprocating motion is also useful, especially for performing the more advanced signal processing methods. In addition, pressure and flow rate measurements are important for understanding pump operation and providing context for understanding the vibration data. A balance must be struck between the benefit of including these important measurements versus the hardware and implementation costs of doing so. This challenge is especially true for vibration sensors. Domain expertise is needed to place a minimal set of sensors to keep the hardware cost down and monitor the pump properly and accurately.

When handling the analytics, it is challenging to apply machine learning for this application without any domain-specific preprocessing and signal processing steps. Typically, pump failures are rare, so using a supervised machine learning model is not typically practical. Instead, a combination of domain-specific feature extraction methods for the vibration signals coupled with a baseline-based anomaly index machine learning algorithm is a more reasonable approach. The deployment and user interface should be closely aligned with the industrial use case and expected user, as well as the problem being solved. For some applications, it is not feasible to transmit the data to a remote monitoring center or central server, requiring the analytics and deployment to be performed closer to the data source.

Additionally, the frequency of data collection and the speed of both the data analytics processing and the reporting of asset health information would vary based on the industrial application and use case. These aspects should be evaluated during the initial project phase. By following requirements and best practices, solution developers can formulate the appropriate approach and the solution that should be considered and ultimately implemented.

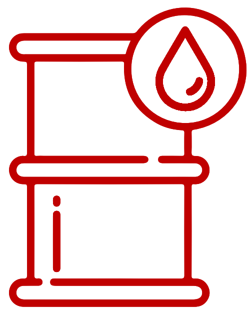


Picture 2: An illustration of a standardized process for analyzing mud pump data to drive failure detection and health prediction.

CASE STUDIES

1. OIL & GAS:

A global oil and gas company specializing in automated drilling rigs and derrick components wanted to develop an on-site mud pump maintenance solution. Contractors wanted to reduce unplanned downtime and unexpected failures. In addition to preventing these error events, the company wanted to distinguish between high drive, overdrive, malfunction due to maintenance issues and anomalies due to bearing and lubrication issues. The main roadblock was access to the network to send the data back to the cloud. AITS solution helped in the process with no additional software, hardware, gateways, security and connectivity.



The customer worked with AITS to identify these anomalies, troubleshoot pump failures, and use inductive error data collected in the test bench to validate the solution running on board with no connectivity requirements.

2. MINING:

The opportunity most spoken of nowadays as part of this drive to improve productivity and efficiency of the mining industry is that of predictive maintenance. Operation mechanics of a major mining vendor perform valve adjustment of a mining haul truck under a preventative maintenance plan. It is typically a 12-hour activity undertaken at regular intervals of a few months. Analysis of data collected via sensors on the vehicle, on intake and exhaust valve opening and closing events can help identify the specific valves that require adjustments and reduce the activity's overall duration to under 3 hours. For a large mine, this translates into millions of dollars in savings.

The mining vendor worked with a consultant and AITS to identify maintenance needs on a predictive basis, troubleshoot failures, and use error data collected in the test bench to validate the solution running on board with no connectivity requirements.

PREDICTIVE MAINTENANCE

The user provided the analytics company with a year's worth of historical data from test bed data sets and sensors on the piston, suction and discharge mechanisms on two pumps in the field. The team of analytics experts was able to pull crucial features from the data by considering vibration patterns in the frequency and time-frequency domain. These features were integral to the development of health assessment models. The models then helped determine key indicators of pump seal failure, as well as establish the accuracy and necessity of the sensors.

By using advanced signal processing and vibration-based pattern recognition, the health monitoring system was able to detect and diagnose pump failures. This solution provided a baseline health assessment, failure identification and pattern recognition diagnosis capabilities.

OUTCOMES

The predictive analytics company was able to identify potential issues, as well as establish the best locations for sensor placement. The final solution predicted mud pump failure at least one day in advance, providing the data needed to take action and proactively perform maintenance. This approach helped reduce downtime, increase productivity, improve safety and prevent leaks.

GETTING STARTED

1. Criticality analysis is essential in order to select the pumps for which predictive maintenance solutions can best be applied and to choose a solution that can provide the most value.
2. After determining the target pumps, the most critical failure modes should be identified, along with any relevant maintenance records for unplanned and planned downtime.
3. Determine what data has been collected, if any, and review what data could be available from the pump's controller.
4. Based on the data and common failure modes, determine sensor placement and what, if any, additional sensors need to be added to the monitored pumps for the predictive solution.

These initial steps are essential when partnering with a technology provider and can help companies develop and adopt a predictive maintenance solution for their pumps that is robust and accurate.

SOLUTION

In Field Predictive maintenance - is a condition-driven preventive maintenance solution that is designed to work with low devices on equipment in situ at remote/electricity/internet devoid locations for the machinery and equipment. End to end "In Field Predictive Maintenance" solution includes a mobile device with touch screen and a sensor board. Sensor board is mounted on motor/equipment and connected to mobile devices to gather sensor data specific to the motor/equipment.

Mobile devices are connected to a sensor-board on motor/equipment with USB or BLE protocol to receive sensor data, train/test AI models, compile and deploy firmware to monitor health. Our solution provides high value to machinery and equipment operating in austere environments since it runs on battery and requires no Internet connection. By accurately predicting the actual failures, we can achieve maintenance cost reductions, increased productivity, and efficient utilization of budget and resources.

AITS solution uses machine learning to optimize maintenance schedules and provide analysis and recommendations at both a component and system level. It is capable of integrating historical structures (e.g., sensor reports) and datasets.

APPLICATIONS

Deep learning analysis of vibration harmonics is critical to monitoring the health of many equipment including the ones shown in table below.

Air Pump	Turbine	Conveyor Belt	Air Conditioner	Boiler Burner
Generator	Air Filter	Transformer	Vibration Table	Brewing Engine
Air Compressor	Cold Room	Mixer	Vacuum	Elevator
Re-fusion Oven	Water Pump	Gearbox	Cryo Pump	...

Table: Equipment suitable for vibration based health monitor

It can detect faults like unbalance, misalignment, bearing issues, looseness, gear problem, bent shaft, cracked shaft, damaged rotor bar and many more.

DIFFERENTIATORS

The solution is designed for industry 4.0 machines and equipment installed in austere environments with no access to electricity and Internet.

1. Non tech users can deploy the solution with a few touch buttons in a matter of minutes.
2. End to end “In Field Predictive Maintenance” solution is created, deployed and used in the field.
3. Runs with no-cloud or no-Internet connection.
4. Sensor board firmware is customized for each motor/machine in the field leading to higher accuracy.
5. Low energy solution runs on battery for several months.