Realizing the Value of Digitalized Collaboration in Pursuit of Predictive Maintenance
EXECUTIVE SUMMARY

With the oilfield of the future on the horizon, the biggest operators and original equipment manufacturers (OEMs) on the Norwegian Continental Shelf are working together to achieve ambitious, interdisciplinary goals. Digitalization has become both inspiration and fuel for these partnerships.

Siemens, the manufacturing giant and tech pioneer, has been using technology to innovate on standard operational models for decades. Today, they deploy all kinds of technology to improve CAPEX and OPEX, working to nail down sustainable solutions that improve safety and environmental performance in the longer term. With each customer, their goal is to deliver a full set of digitalized services, including project planning and execution, process control, integrated operations, condition based maintenance and lifecycle management of new facilities.

Their work with Aker BP is an exciting, current example of a partnership deepened by digitalization. Siemens was an integral partner in the conception and construction of Aker BP’s offshore projects on the Ivar Aasen oil field (first oil 2016). They continue to provide cutting-edge services for Ivar Aasen in operation, including data-driven condition monitoring, a leap toward the holy grail of predictive maintenance.

This groundbreaking advance is only possible due to the active collaboration of multiple parties and the easy interoperation of their products. And this, in turn, requires the capacity to share various, large data sets simply and securely.

Aker BP’s determination to extract the full value from their wealth of process data set the stage. With the help of the Cognite Data Platform (CDP), Aker BP liberated their data from numerous source systems and made it available in one, connected place. Siemens supplied the technology to ensure data quality and produce visualizations that would allow Aker BP’s team to make the most informed operational decisions. Best of all, the streamlined integration of two specialized high-tech products from different companies--the SOGO IMS and the CDP--revealed new opportunities to discard old limitations and maximize the value of big data for their joint customers.

The digitalized future will be defined by this kind of ecosystem. Where each player has the chance to specialize and deliver their own best product or service. Integrated with the specialties of partner companies to create vibrant, complex solutions to the industrial world’s most plaguing problems.
INTRODUCTION

The Ivar Aasen oil field in the North Sea ranks among the largest recent oil discoveries on the Norwegian Continental Shelf (NCS). From the beginning, Aker BP, the largest independent oil and gas operator in Europe, approached the project with a new kind of vision, one that embraced technology at every level.

“The ‘Internet of Things’ (IoT) is driving the rapid pace of digital adoption across multiple industries. The oil and gas industry is beginning a transformation of its own, increasingly looking toward data-driven solutions to boost performance, enhance efficiency and ultimately, to reduce costs.”

-- Siemens

To develop Ivar Aasen with a technological infrastructure advanced enough to handle full digitalization, they contracted with Siemens Oil and Gas Offshore (SOGO) to engineer and deliver extensive systems that drive automation, power, and information management.

The delivery from Siemens included the design, supply, and installation of electrical, instrumentation, control and telecom systems, from the preliminary phase to first oil. From there, Siemens held a strong position to support Aker BP’s ongoing digitalization priorities, including using their data to optimize equipment maintenance schedules and improve onsite safety and efficiency. But first they needed to address several of the typical stumbling blocks related to projects involving big industrial data.

This paper will explain the way Siemens tackled these problems, first by developing a new method of data collection called “time stamping” and then by integrating their IMS with the Cognite Data Platform (CDP). In particular, we’ll examine the way the interoperability of the CDP with the SOGO system and dashboards enables Condition Monitoring and pushes the industry toward the lucrative possibility of Predictive Maintenance.

And we’ll consider another exciting byproduct of this project.
Lack of infrastructure has long rendered a great deal of industrial data effectively irrelevant. Either it could only be collected at intervals with limited values attached, or it could not be connected to other relevant data without tedious manual processes. But the inherent incompleteness of what could be collected made certain data-driven insights essentially impossible. And these insights were potentially the most crucial, such as determining causal links between conditional data and equipment failure.

The integration of the SOGO IMS and the CDP pioneers new levels of data Completeness and Context, all streamed through the Cloud and, therefore, born to scale. By breaking down these barriers, Siemens and Cognite have set a new standard for realizing the true value of industrial data. And they’ve demonstrated how ripe the partner ecosystem is for innovation. How rewarding it can be to work together to solve problems facing the industry as a whole.
SIEMENS INFORMATION MANAGEMENT SYSTEM (IMS)

Thanks to the digitalized infrastructure at Ivar Aasen, Aker BP can monitor their offshore equipment from a twin onshore control room in Trondheim, Norway, more than 1,000 kilometers away. The Siemens IMS and dashboards enable the onshore team to visualize real-time data streaming from thousands of sensors. The team can then provide maintenance, engineering support, and expert analysis based on the same condition monitoring data available on the platform within milliseconds. This includes data related to electrical and rotating equipment, valves, process control, automation, instruments, telecom, and safety.

Tackling the Data Problem

Data is only as useful as it is accessible, readable and open for connection with other relevant data. In the industrial space, the development of sensor technology to gather data has outpaced the technology necessary to transform that data into useful information.

Process operations generate data via the thousands of sensors on a single oil platform. Unfortunately, this data is usually trapped in a disparate set of source systems, restricting access and limiting insight. The quality of the data is also often in question; legacy systems use outdated techniques (e.g., time sampling) or lack the infrastructure to identify essential data and support data collection at scale.

Time sampling is the traditional method for collecting process data; a standing query pulls conditional data from the system every few seconds. This data feeds into a process historian database on the platform. Operators can access the data to create reports, but until recently, both the analytics and insights were only available after the fact.

The time sampling method came with a couple of other problems, as well. For example, sampling might catch one anomaly but miss another; if an anomaly occurs between samplings, it would go undetected.
Data quality – the basis for reliable analysis

How to capture all these types of data?

- Process values
- Events
- Parameters
- Alarm limits
- Setpoints

Original Data with polling interval

Data picked up through polling

Data picked up through changes (event driven) Not necessarily more data
The limits of legacy technology pass along those limitations to the quality of the data they collect. Such data cannot be complete. Nor can it be easily connected to other relevant data to provide the crucial context necessary for operators to understand events. Let alone to fix them or to prevent them.

Usually, an offshore worker attempting to analyze data after equipment failure needs to log in to several different systems to find all the time series data, work orders, maintenance records, etc., related to that piece of equipment. Often that individual doesn’t have the right credentials to access all these systems immediately and must, therefore, take the time to seek authorization or ask someone else to send records via email. Even after the worker has all the information they believe they need, analysis must be done manually.

The result: A limited view, available long after the fact, prone to human error. And a procedure too arduous to scale.

Maximizing data quality

The SOGO IMS and dashboards are designed to fix this problem. Siemens’s transformative technology begins by maximizing the quality of collected data, then deploys machine learning models on top of those high quality data sets.

First, they innovated on the collection of time series data by utilizing “time stamping”. Rather than pulling snippets of data at preset intervals, limiting recorded values to sample/log, the time stamping method looks for and collects performance-related events in the data and records each with a time stamp. Siemens can now log all changes (e.g., process values, parameters, setpoints, alarm limits, etc.) and relate them more completely to the equipment and to each other.

"With time stamps... the sequence of an event series can be seen clearly, making it easier to identify and distinguish correlation and causation. This can accelerate troubleshooting by making data analysis more precise, reliable and insightful. For example, the Condition Monitoring algorithms for On/Off valves monitor the trends in traveling time and can identify early on if a valve starts moving more slowly." (M. Ileby, Aker BP & E. Knutsen, Siemens. “Data-driven remote condition monitoring optimizes offshore maintenance, reduces costs”. World Oil. Dec 2017.)
Using the time stamping method, there’s no longer a need to pull in endless strings of data at preset intervals while equipment is operating normally. Suddenly, all collected data becomes relevant data, because it connects to a change in conditions for the equipment. Better still, as the changes are time-stamped, the potential for insights on correlation and causation takes shape. And it’s possible to use machine learning to analyze this increasingly rich data, relieving that burden for the human worker.

Having solved the puzzle of collecting a verified set of useful, high quality sensor data, Siemens prepared to respond to the problem of context.

### Introducing the Cognite Integration

Aker BP granted Siemens access to all Ivar Aasen field data. Siemens pulled process data through their control system, and then most of the third-party equipment data bypassing the control system and going straight to the IMS. However, there remained several other systems, usually inaccessible to Siemens, that held potentially valuable data, such as work orders, work permits, document systems, HMS information (Synergi), etc. They knew combining these sources would vastly enrich their solution.

Siemens turned to Cognite, whose cloud-native industrial data platform was already in operation across Aker BP’s assets on the NCS. The Cognite Data Platform offered the capability to collect, clean, and contextualize more various kinds of data automatically and without space limitations.

With Aker BP’s authorization, Siemens redirected their system to read the company’s data from the CDP, including those libraries of documents that had previously been outside of Siemens’s scope. In the case of the Ivar Aasen project, this means 150,000 time series, 20 billion data points, and 400,000 documents collected and contextualized in the CDP, then made available through a single, secure point of entry, saving Siemens valuable time.

Siemens estimates that attempts to run point-to-point integrations with all the individual source systems and ingest their data would have taken about 1,500 hours. The process of integrating with the CDP alone--pulling in all the same data--took only 200 hours. And a lot of that time was actually spent looking at the data and deciding how best to visualize it.

The SOGO IMS automatically generated an asset hierarchy that included standard names for every piece of equipment on the Ivar Aasen platform (e.g., Heat Exchanger - 27HA0002 - Transfer Gas Cooler) based on the Norsok system. Then the CDP automatically searches through the document libraries and connects documents to their relevant pieces of equipment in the hierarchy.
Cognite calls this functionality Contextualization, the real-time structuring of sensor data in relation to process diagrams, production information, 3D-models, and event data (maintenance, incidents). Everything linked in the real world is also linked in the platform. This equips stronger machine learning applications for optimization and automatization, as well as human-facing applications, such as advanced visualizations and apps for the digital field worker.

The CDP is also fast. When running multiple calculations in parallel, the on-premise historian experienced performance issues, while the CDP’s fast, accurate performance remained unphased by additional, simultaneous calculations.

Empowered by the CDP, Siemens was ready to dial their SOGO IMS and dashboards up to eleven.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Curr</th>
<th>Measurements</th>
<th>Curr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Inlet Pressure – Pw1</td>
<td>11.14 barg</td>
<td>Water outlet Pressure – Pw2</td>
<td>2.84 barg</td>
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<td>Water Flow – VW</td>
<td>91.75 mYH</td>
<td>Water Inlet Temp – Tw1</td>
<td>6.18 °C</td>
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<tr>
<td>Water outlet Temp – Tw2</td>
<td>38.98 °C</td>
<td>Gas Inlet Pressure – Pg1</td>
<td>43.42 barg</td>
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<tr>
<td>Gas Outlet Pressure - Pg2</td>
<td>42.71 barg</td>
<td>Gas Flow - Vg</td>
<td>107212.95</td>
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<tr>
<td>Gas Inlet Temp – Tg1</td>
<td>112.54°C</td>
<td>Gas Outlet Temp – Tg2</td>
<td>58.08</td>
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<tr>
<td>Shell Pressure Drop – DPw</td>
<td>0.58 bar</td>
<td>Tube Pressure Drop – Dpg</td>
<td>0.56 bar</td>
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<td>Water Specific Heat – Cpw</td>
<td>4.19</td>
<td>Gas Specific Heat – Cpg</td>
<td>2.49</td>
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<td>Water Density (xxx12°C) – Ww</td>
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<td>Standard Gas Density - WG</td>
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<td>Rated Gas Flow – Vdg</td>
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<td>Rated Gas Flow</td>
<td>126996</td>
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<td>Clean DP Water (shell) – DPcw</td>
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<td>Rated Water Flow</td>
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<td>Design Heat Load – Qd</td>
<td>10745</td>
<td>Clean DP gas (tubes) - DPCg</td>
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**Executing the Siemens Solution**

Artificial intelligence, machine learning, and tested algorithms—the result of Siemens’s domain expertise in industrial automation and industrial IT processes—are what make the IMS visualizations intuitive and effective. With rapid access to live and historical data, regardless of original source or format, via the CDP’s single point of entry, Siemens was ready to present their powerful processing, analysis, and display capabilities to Aker BP.

The IMS automatically generates individual “homepages” for each piece of equipment in the asset hierarchy. A worker visiting the homepage of a valve or transformer, for example, can see every bit of relevant, contextualized data for that piece of equipment. In addition, Siemens develops customized dashboards based on the client’s specific needs (e.g., Production, Maintenance, Process, HSSE).
Heat Flow vs Water Flow Rate

Overall heat transfer Coefficient Regression

Health overview

Overall health KPI over time
Key Performance Indicators

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<th></th>
<th>Curr</th>
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<th>Curr</th>
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<tr>
<td>Shell normalized Pressure Drop – DPnw</td>
<td>30.05</td>
<td>Shell % Clean</td>
<td>40.02</td>
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<tr>
<td>Tube normalized Pressure Drop – Dpng</td>
<td>8949.87</td>
<td>Tube % Clean</td>
<td>100</td>
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<tr>
<td>Temperature Efficiency – E</td>
<td>0.31</td>
<td>Overall heat transfer Coefficient – U</td>
<td>83.12 W/(m² K)</td>
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<td>Temperature Ratio – R</td>
<td>1.65</td>
<td>Logarithmic Mean Temperature Difference</td>
<td>42.82</td>
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<tr>
<td>Heath Load – Q</td>
<td>3730.55</td>
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</tbody>
</table>

Water temperature (Inlet: Tw1, Outlet: Tw2)

INLET WATER TEMPERATURE

OUTLET WATER TEMPERATURE
These dashboards reflect historical and current condition parameters via the following features:

**Advanced Analytics**

Identify performance trends and issue alerts about abnormal behavior of topside and subsea operating assets. Workers can quickly assess whether individual valves or heat exchangers, etc., are functioning in a preset “normal range” and can set up parameters that will trigger alerts for equipment that is malfunctioning. In the SRU (Sulphate Removal Unit), for example, analytics alerts workers in advance that membranes should be replaced.

**Data Visualization**

presents a vast amount of information in an easily comprehensible way. Users can quickly view high-quality, user-friendly graphs, P&IDs, and condition reports, for example, either at onshore workstations or in a control room. The Siemens IMS delivers these visualizations in both Scalable Vector Graphics (SVG) and HTML-based formats. Looking to the future, these visualizations are also accessible on a smartphone, tablet, and other devices, far more convenient to use during field maintenance.

See photo of dashboard open on the mobile device in the field.
Beating the AI/ML Hype: Delivering immediate practical value

The Siemens IMS delivers value immediately and practically. Aker BP’s workers can use the system to generate a set of deeply insightful reports that impact daily operations and save man hours.

Valve Monitoring, for example, is a report that saves companies hundreds of hours in manual clocking of valve travel times. The Shutdown Report shows whether all parts of the plant have been shut down as expected and can, therefore, be restarted safely. This saves hours of investigation work and subsequent downtime, resulting in high monetary savings.

Looking to the future, these “classic” reports evolve into dashboard applications.

Seizing the AI/ML Hype: Condition-Based Maintenance & Predictive Maintenance

At the same time, Siemens is working to realize the full potential of artificial intelligence and machine learning. Integrating with Cognite pushes them even closer to predictive maintenance and its dramatic corresponding cost savings. A game changer for the entire industry.

Historically, maintenance of oilfield assets has taken place one of two ways:

Which methods to use?

<table>
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<tr>
<th>CONDITION</th>
<th>TIME</th>
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<tbody>
<tr>
<td>Oil Analysis (months)</td>
<td>P-F INTERVAL</td>
</tr>
<tr>
<td>Vibration (weeks to months)</td>
<td></td>
</tr>
<tr>
<td>Thermography (weeks)</td>
<td></td>
</tr>
<tr>
<td>Noise (weeks)</td>
<td></td>
</tr>
<tr>
<td>Heat (days)</td>
<td></td>
</tr>
<tr>
<td>Smoke</td>
<td>F</td>
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</tbody>
</table>

Condition-Based Methods move point P (potential failure) to the earliest time possible, maximizing the P-F interval.
1. **Preventive maintenance** is performed on a fixed schedule laid out in the operator-supplier contract. But this model presumes that equipment deterioration is most directly related to the age of equipment or the last date of maintenance. That’s not always the case. Equipment may fail sooner than expected due to some invisible flaw, or it may be able to far outlast the scheduled date. Either way, the equipment owner is unable to spend their money efficiently.

2. **Reactive maintenance** is performed in the heat of the moment after an alarm has sounded and equipment has reached functional failure. Not only are the costs of unscheduled equipment replacement extremely high, but this kind of failure often triggers a cascade of exorbitant related costs due to corresponding the shutdown.

It’s time to turn the tables on this classic operational set-up.

3. **Condition-Based Maintenance (CBM)** allows the operator to monitor the current state of their equipment based on historic and real-time data (e.g., power, throughput, temperature, vibration). It reduces downtime risk due to equipment failure by sending alerts to the appropriate parties when equipment is operating outside the preset normal range. This can be done with a simple rule on a sensor value.

4. **Predictive Maintenance** is about predicting a future state of the equipment. It uses historic and real-time data on equipment condition to calculate equipment breakdown ahead of time and schedule the appropriate intervention. To utilize machine learning this way requires the ability to handle very large, labelled data sets.

Using the data they already have available, Oil & Gas companies can apply advanced analytics to understand the current condition of any given piece of equipment. This level of data-driven insight makes it possible for companies to avoid unnecessary maintenance (based on a calendar). Better yet, as their CBM capabilities become more accurate, they can better calculate the expected performance of their equipment and predict maintenance in advance, allowing them to organize the most efficient and cost-effective response.
Especially in offshore environments, condition-based maintenance (and eventually, predictive maintenance) has the potential to revolutionize business models and reduce bottom lines.

Here, the Cognite Data Platform provides the contextualized connection between various data and the Siemens IMS provides the comprehensive visualizations.

When equipment is operating within a normal range and live data visualizations make it clear no maintenance is necessary, Aker BP can choose to increase the interval between maintenance. Armed with the power of prediction, they can also:

- Boost safety by limiting the number of human personnel on the platform
- Order fewer replacement parts and reduce the “just in case” stock that sits gathering dust
- Deploy the appropriate crew and the necessary tools when maintenance needs do arise
- Bring down the cost of the consequences of equipment failure, namely, unplanned downtime or production slowdown

Lower Manning onboard

Do the maintenance when it is most cost-effective

CAPEX and OPEX reduction due to less staff offshore
CALL TO ACTION

Data is an essential component of the digitalized industrial future. High impact, high quality innovation in this sphere will require that the data be as open, complete and contextualized as possible. The full value of such data to the industry will require increasingly integrated solutions to increasingly complex challenges. Putting data to work, so that people are free to create and invent.

Siemens and Cognite approached the Ivar Aasen project with precisely this mindset.

The SOGO IMS and dashboards are designed with the human end user in mind. Their advanced method of event-driven data collection (i.e., time stamping) ensures that only useful information is transferred across the network, while maintaining high granularity for maximum human insight. If a measurement is stagnant, no value will be pushed from the controller, but when there is a relative rapid change, multiple data points will be pushed from the controllers, securing a reproduced signal in the historian and the CDP.

Meanwhile, the Cognite Data Platform presents a virtual representation of industrial reality--both past and present--to make it accessible and meaningful for humans and machines. Their advanced data ingestion capability and contextualization step gives Siemens access to data from equipment that is not connected to Siemens’s own control system. This includes variable speed drives, simocodes, siprotec, compressors, UPS, etc. The ability to apply the same condition monitoring functionality to this equipment, accessed through the CDP, provides a stronger basis for fleet management and smart maintenance, where service and parts may be ordered directly by connecting to CDP and/or Siemens MindSphere.

Such are the possibilities when data is collected, cleaned, contextualized and set to the tasks human workers really need.

By creating products that interoperate seamlessly and are designed to scale, both Cognite and Siemens are embracing the openness of the digitalized future. Consequently, they make it easy to support their joint customer’s pursuit of necessary, revolutionary digital transformation in a more comprehensive way.
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