AWS Architecture Monthly

Manufacturing

February 2021

Notices

Editor's note

How is operational data being used to transform manufacturing? Steve Blackwell, AWS Worldwide Tech Leader for manufacturing, speaks about considerations for architecting for manufacturing, considerations for Industry 4.0 applications and data, and AWS for Industrial.

We hope you'll find this edition of Architecture Monthly useful. My team would like your feedback, so please give us a rating and include your comments on the Amazon Kindle page. You can view past issues and reach out to aws-architecture-monthly@amazon.com anytime with your questions and comments.

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Jane Scolieri, Managing Editor

Ask an Expert

Steve Blackwell, Technical Leader for Manufacturing at Amazon Web Services

What are some considerations when architecting manufacturing workloads; is there a difference between cloud vs. on-premises?

When it comes to architecting in the cloud for manufacturing, and more specifically factory applications that support production processes, certain constraints must be considered. These range from non-functional requirements for application availability, low latency, and connectivity with industrial assets connected to operational technology (OT) networks. Because of this, the industrial edge is a required component of extending the AWS Cloud into industrial environments and architecture for manufacturing. Conceptually, the industrial edge (or Edge as it is sometime referred to) is compute and storage infrastructure within the four walls of a factory. The Edge can be an industrial PC (IPC) or a collection of industrial PCs and a gateway on the shop floor. Or it could be a virtual server farm running in the local data center. Architecturally, Edge provides some core capabilities:

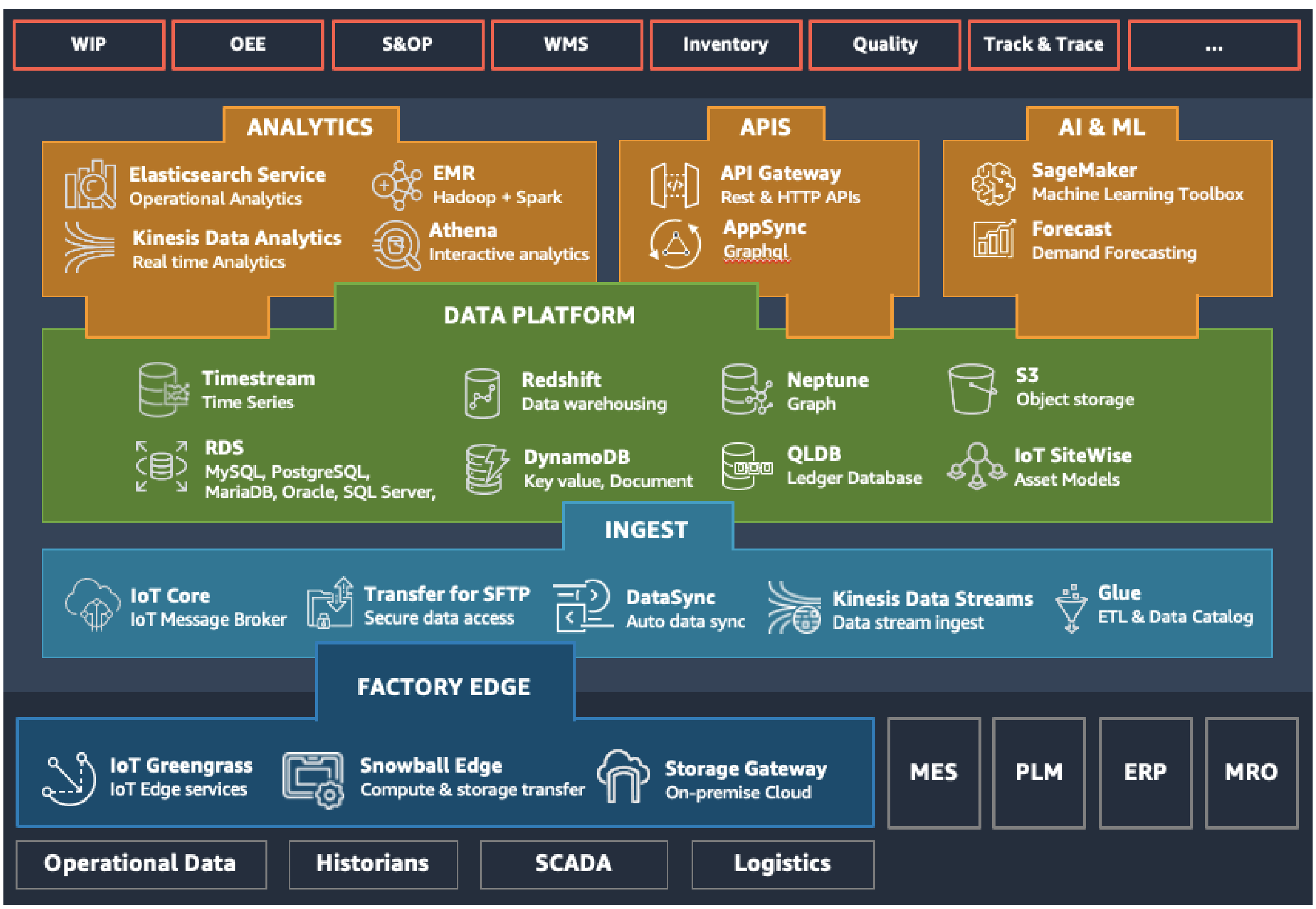
1) **It enables communication and data ingestion from industrial assets.** Depending on the age of a factory, manufacturers will have devices such as PLCs (Programmable Logic Controller) and DCSs (Distributed Control System) connected to the industrial networks. They can be from multiple vendors, ranging from brand new to over 15 years old. These devices communicate using field bus and industrial protocols such as OPC UA, EtherNet/IP, and Modbus. Because those protocols are not Internet friendly, the Edge provides a bridge using protocol connectors between the device and the cloud applications. As an example, this means data can be ingested from PLCs using OPC UA, converted into MQTT messages, and sent to the Cloud.

2) **It provides low latency integration with industrial processes.** One of the many advantages of cloud for manufacturing is providing a scalable, low-cost data lake, which can be used to build datasets. With these datasets, machine learning models can be trained to identify defects or anomalies for inspection quality checks using computer vision. To minimize latency of the prediction while deploying these models, the inference must happen as close to the data source and production process as possible. With an Edge infrastructure, manufacturers have the ability for models to be trained in the cloud and be deployed into the factories for low latency inference.

3) It provides hosting for production critical applications and data. As a trend, manufacturing applications are transforming from monolithic apps to cloud native microservice applications. Availability and recovery requirements still must be met for production critical manufacturing processes, such as a WAN outage or low-bandwidth connections. Edge provides a platform for hosting of these critical microservices as part of an overall hybrid application architecture while utilizing capabilities within the cloud including scalable storage, on-demand compute resources and machine learning services.

What architectural patterns can be applied to manufacturing for application modernization?

Manufacturing application modernization through building applications in the cloud, needs to provide unambiguous access to data, real-time insights, agility and scalability. This is why we developed the Manufacturing Service Bus (MSB), an architectural framework for Industry 4.0 applications.



The MSB is composed of four layers that provides abstraction and enables dependency for a microservice application architectures. The first layer is the 'Factory Edge', which connects to factory floor devices, assets, and systems. It supports the real-time streaming of time series data (IIoT), batch uploading, or replication of unstructured data to the AWS Cloud.

The second layer is the 'Ingest' layer. This provides services to ingest a variety of manufacturing data types, independently of source and type, into the Data Platform. For example:

- Streaming of device telemetry (IIoT)
- Syncing batch files from factory machines
- Exporting Production Orders from ERP systems or Bill of Materials (BoM) from a PLM system
- Replicating Data Historian data and asset models

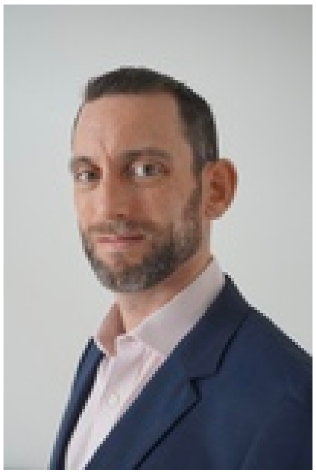
The third layer is the 'Data Platform', which is the core layer. This provides storage for all types of data (relational structured, unstructured, and time series), data catalogs and ETL tools. It can also include metadata stores to provide context of the data using asset models and data relationship graphs.

The fourth layer is the 'Consumer Layer' and provides three building blocks for integration for the applications into the data platform layer. This is via abstraction from the data stores. It allows the applications to consume data as needed, by providing services to perform analytics, machine learning or direct access via APIs.

In the recent AWS announcement for AWS for Industrial, there were a few specific services launched. How do these get integrated into the manufacturing service bus?

The services within AWS for Industrial were designed specifically for developers, engineers, and operators at industrial sites. We want to simplify the process of building and deploying Artificial Intelligence, Machine Learning and analytics applications into factories. This improves operational efficiency, quality, and agility. The four new services are: AWS Panorama (Device SDK and AWS Panorama Appliance), Amazon Lookout for Vision, Amazon Monitron, and Amazon Lookout for Equipment. They fit into specific layers of the manufacturing service bus. Amazon Lookout for Equipment and Amazon Lookout for Vision are AI services and are part of the AI/ML building block of the consumer layer. Both services ingest data from an Amazon S3 bucket in the data platform layer and are accessible via their APIs. This enables operational applications, such as predictive maintenance or automated inspection to consume anomaly detection predictions for sensor and image data. The AWS Panorama Appliance is part of the Factory Edge layer. It is physically connected to the factory network to ingest image data from existing cameras into the data platform. It also enables deployment of machine learning models into factories where the application requires edge inference. Finally, Amazon Monitron is an end-to-end service that provides physical sensors and a gateway. This ingests vibration and temperature telemetry data into the data platform. It also has a mobile application to visualize the data as part of the analytical building block of the consumer layer.

About the expert



Steve Blackwell is the Worldwide Technical Leader for Manufacturing at Amazon Web Services. He leads the AWS Manufacturing Technical Community and defines the technical strategy and solutions for manufacturing working with the AWS service, sales enablement, training, and partner teams. He is responsible for understanding the use cases for the manufacturing industry and developing the AWS-based technical solutions that address those needs working with customers, partners, and integrating third-party solutions. He is the author of the “Manufacturing Reference Architecture, which is a blueprint of how to build Smart Factories, Smart Products, and Manufacturing Data Lakes on AWS.

Case Study

Amazon Prime Air's Drone Takes Flight with AWS and Siemens

Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing, and electronics design meet tomorrow. Its solutions help companies of all sizes create and leverage digital twins that provide organizations with new insights, opportunities, and levels of automation to drive innovation. For more information on Siemens Digital Industries Software products and services, visit www.sw.siemens.com/plm

Executive Summary

Amazon Prime Air developed a working drone design by running simulations using Siemens' Simcenter STAR-CCM+ with high performance computing (HPC) on Amazon Web Services (AWS). The on-demand access to nearly unlimited infrastructure and fast networking for scalable HPC on AWS ensured that the project stuck to the timeframe. Simcenter STAR-CCM+ on AWS helped Prime Air streamline its engineering workflows, which resulted in additional efficiency gains.

Challenge

Amazon Prime Air needed to design and build a drone for unmanned deliveries. Simulating the aerodynamics required two main components. First, it needed a computational fluid dynamics (CFD) solution that could run individual and batches of simulations. Second, it needed HPC infrastructure that offered a large, on-demand capacity of instances and ran on a fast, high-bandwidth network to support the workstreams.

Solution

Prime Air chose Siemens' Simcenter STAR-CCM+, part of the Simcenter portfolio, as its multiphysics CFD solution for aerodynamic design. Simcenter STAR-CCM+ is built for parallel efficiency, which allowed Prime Air to speed up its CFD simulations by running them on a large number of cores. Additionally, Simcenter STAR-CCM+ allowed Prime Air to streamline its engineering simulation workflow. The breadth of HPC solutions available from AWS provided the flexibility needed to deliver against tight timelines. It used AWS ParallelCluster, the AWS-supported open source cluster management tool, to manage the deployment of Amazon Elastic Compute Cloud (Amazon EC2) compute optimized instances.

Benefits

Using Simcenter STAR-CCM+ on AWS enabled Prime Air engineers to characterize the aerodynamics of aircraft across its full flight envelope, a simulation campaign that consisted of thousands of different operating conditions and added up to more than 30 million hours of AWS compute time. Additional analysis helped them identify critical flight conditions that they examined further in real time through remote visualization and post-processing, eliminating the need to transfer large data sets and own expensive dedicated workstations.

The HPC services on AWS made it easy for them to scale to a large number of cores and access on-demand compute power for analysis—without getting stuck in long queues. They were also able to scale down the instances after running simulations. As a result, Prime Air confidently moved to a working drone design in a compressed timeline.

Prime Air Rises to the Challenge Using CFD on AWS

Prime Air's goal is to deliver packages to customers that weigh five pounds or less in under 30 minutes using drones. The Prime Air team designed and built its own drone using CFD, a branch of fluid dynamics that uses numerical analysis and data to solve problems of how fluids, like air, move under different conditions around an aircraft.

Prime Air chose Siemens' Simcenter STAR-CCM+ as its complete multiphysics solution for CFD. Simcenter STAR-CCM+ is built for parallel efficiency, which allowed Prime Air to speed up its simulations by running them on a large number of cores. Additionally, Simcenter STAR-CCM+ Application Programming Interfaces (API) allowed Prime Air to automate and streamline its engineering workflow.

Building an aircraft using CFD involves digitally predicting aerodynamic performance. Thousands of such CFD simulations are typically needed to generate an aerodynamic database (ADB) to ensure performance across all flight conditions and develop an aircraft control system. The scale and speed of these simulations necessitates HPC resources. However, many on-premise datacenters have capacity and availability constraints on HPC resources that lead to long queues. Engineers must wait their turn and only use the resources allocated to them, which doesn't leave them much room to modify the test plan once their simulations have been launched.

> "Our focus should not be on designing and developing HPC infrastructure, but on designing and developing aircraft. By choosing Simcenter STAR-CCM+ on AWS for our workflow, we were able to put the focus where it belongs."
>
> - Vedran Coralic, Senior Applied Scientist, Amazon Prime Air

Engineers Access HPC Resources On-Demand with AWS Cloud Services

Prime Air chose to deploy Simcenter STAR-CCM+ on AWS in order to scale compute power up and down as needed. With AWS, engineers can run simulations without having to wait in a queue or pay for excess capacity. AWS offers a large breadth of HPC services that give customers flexibility when it comes to choosing how best to support their application and deliver the time-to-results their engineers need. Prime Air chose these ready-to-use, nearly unlimited, scalable HPC services on AWS to help it get started fast and focus on what it does best.

Running on the cloud allows engineers to go as fast as they want by using as many cores as they need whenever they need them—without incurring excessive costs or slowing down others who need access at the same time.

“On AWS, we can run when we want, with however many cores we want, and get results in the same day. We’re not bottlenecked by capacity,” said Vedran Coralic, Senior Applied Scientist at Prime Air. “And we don’t have to think of everything we’ll need from a simulation ahead of run time. We can always pull it up on AWS after it has been completed and query the flow in real time. By running Simcenter STAR-CCM+ on AWS, my team can move as fast as the program needs it to.”

Improved HPC Management and Performance Enables Greater Innovation

Prime Air designed its environment for running CFD using AWS ParallelCluster, the open source cluster management tool. AWS ParallelCluster simplifies the deployment of launching the Siemens’ Simcenter STAR-CCM+ environment on AWS by using a configuration file to provision all resources in the HPC environment (e.g. virtual private cloud, shared file system, etc.). It supports various popular HPC job schedulers like Slurm, which manage jobs and scale clusters up and down in response to the workload.

To achieve the speeds needed for its CFD simulations, Prime Air provisioned clusters with Amazon EC2 compute optimized instances, using the latest in the market at the time, to optimally support its HPC workloads. Given the sheer volume capacity available through AWS, Coralic hypothesized that they could probably run all of their ADB simulations in one shot on AWS. “Running Simcenter STAR-CCM+ on AWS lets us evaluate new ideas quickly and spend more time investigating results and less time waiting for them,” said Coralic.

With the recent launch of Amazon EC2 C5n instances, the Prime Air team tested AWS ParallelCluster deployments of C5n.18xlarge Intel instances with Elastic Fabric Adapter

(EFA). EFA is a network interface custom built by AWS that provides operating system (OS) bypass capabilities to Amazon EC2 instances, thereby enabling customers to run applications with low-latency, high-throughput inter-node communications at scale.

“Based on initial benchmarks, we believe that moving to C5n instances with EFA for the next ADB will allow us to complete it two times faster,” explained Coralic, “because we can scale out to twice as many cores without degrading computational efficiency or substantially increasing the compute cost.”

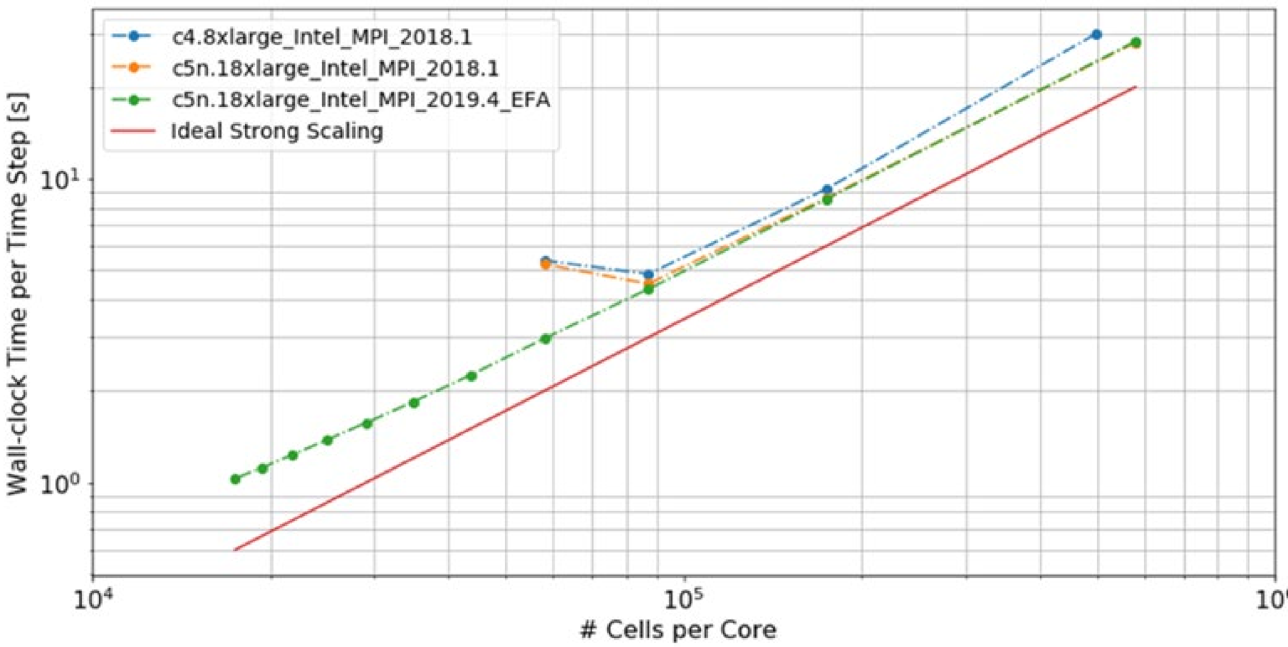


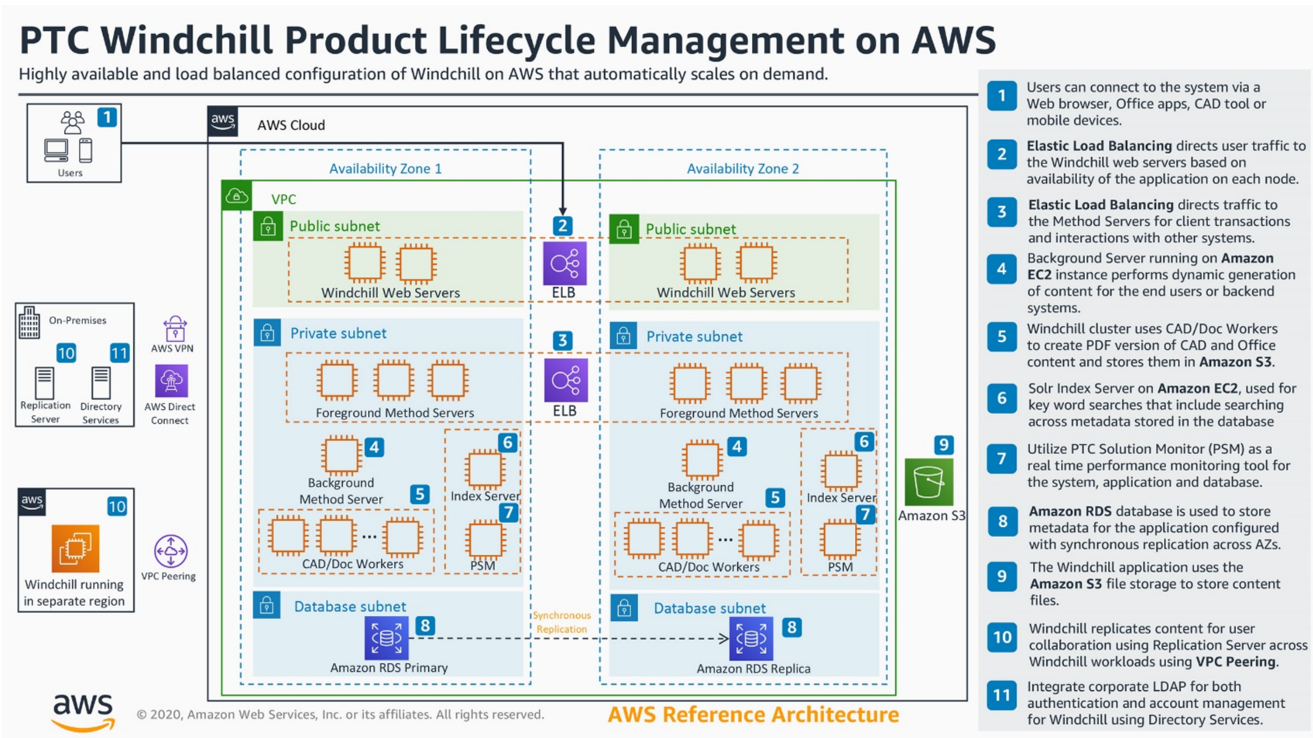
Figure 1: The plot shows that Prime Air will be able to scale its future CFD simulations to 50,000 cells/core and beyond, with negligible loss in computational efficiency. This is made possible by EFA, which is supported by the newer generation compute instances, C5n, as shown by the green curve. Without EFA, Prime Air was only able to scale down to 100,000 cells/core as depicted by the blue and orange curves.

Read Case Study online

Reference Architecture

PTC Windchill Product Lifecycle Management on AWS

Highly available and load balanced configuration of Windchill on AWS that automatically scales on demand.



Find Reference Architecture online

Blog

How Genie® (a Terex® brand) improved paint quality using AWS IoT SiteWise

by Asim Kumar Sasmal, David McClellan, P.E., Engineering Manager and *Jason Crozier*, Cloud Architect at *Terex*.

Genie®, a Terex® Brand, is a global manufacturer of lifting and material handling products and services delivering lifecycle solutions that maximize customer return on investment.

In this post, we discuss how Genie used an AWS IoT SiteWise based solution to ingest, organize, and analyze critical process parameters from the paint system. This solution identified inconsistent and improper pretreatment parameters in near real-time and enabled Genie to apply necessary corrective actions to improve the downstream paint quality of Genie lifts.

AWS IoT SiteWise is a managed service to collect, organize, and analyze data from sensors, equipment, machines, programmable logic controllers (PLC) on the plant floor at scale.

About the Use Case

Genie had a high priority need to collect data from the paint pretreatment process in near real-time. This was due to increased paint-related defects as reported by Genie Customers. The data revealed that the paint pretreatment process was one key contributor to the paint-related defects.

Before using AWS, Genie used manual methods to collect shop floor data stored on hand written logs or electronic spreadsheets. Process instrumentation was in place but the readable outputs from this instrumentation were not being used. Genie was moving toward a traditional database-based solution to house the process instrumentation data and developing in-house websites to visualize the data.

The following principles were critical for the solution:

- Data must be stored for up to 10-years for historical trend analysis
- Genie team members must be able to dive deep into the historical data for specific dates of manufacturing

- Data must be visualized in near real-time on a dashboard, so machine operators and Engineering can react quickly to irregular trends or out of bound conditions for the key process parameters and key performance indicators (KPI)
- Paint operators must be able to manually enter collected data from the shop floor such as results from a chemical testing process (titration)
- The solution must be able to generate alerts and send notifications in near real-time for out of bound operating conditions to take necessary corrective actions
- Solution must be scalable and repeatable for rapid deployment globally at scale

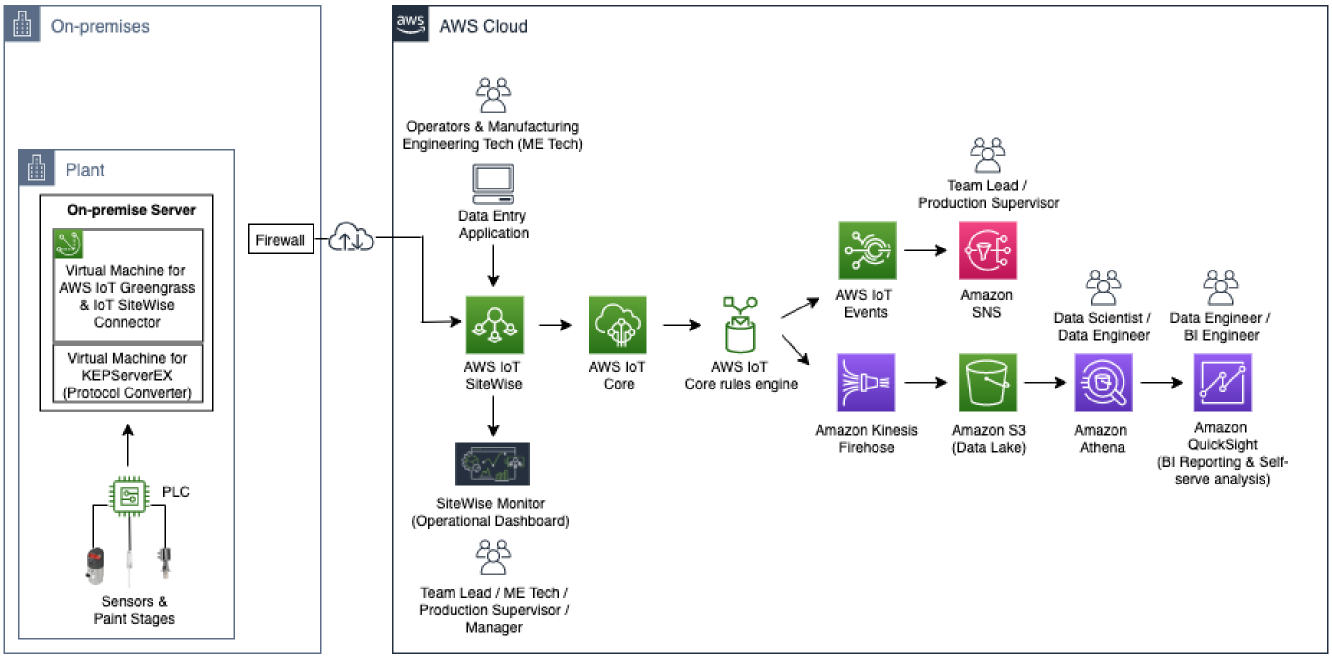
After collaborating with [AWS Professional Services] for the pilot solution, we also quickly realized the potential of unlimited analytics opportunities for data-driven insights. We could do this by connecting related enterprise data from systems such as Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES), with the operational data from manufacturing.

Solution Walkthrough

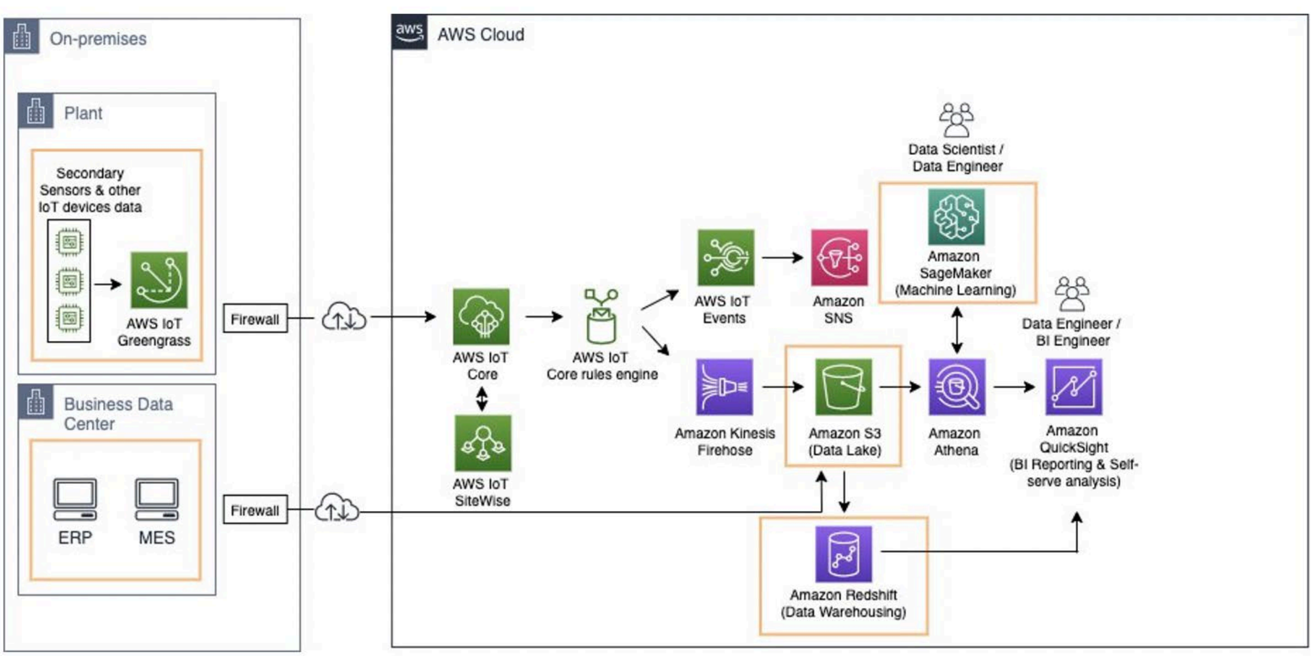
Genie and AWS Professional Services deployed an end-to-end production ready solution in eight weeks for the manufacturing operations, delivering real business outcomes. The following are core functions delivered by the solution:

- Securely connect the plant floor to AWS
- Ingest paint pre-treatment process data to AWS in near real-time
- Ingest manually collected data (such as titration results) from the shop floor to AWS
- Create virtual assets of the sensors and key processes from the shop floor in the AWS Cloud
- Visualize KPIs for the assets in near real-time to identify inconsistent and improper paint pretreatment
- Monitor operating conditions in near real-time, create alerts, and send notifications for corrective actions
- Enable Business Intelligence (BI) reporting for trend analysis and dive deep on historical data of up to 10-years

The following diagram illustrates the end-to-end solution deployed along with the AWS services used:



This solution is foundational for Genie's digital innovation journey. The following diagram illustrates how the solution can be extended to other enterprise data (ERP, MES, secondary sensors, other IoT devices) to perform advanced analytics such as Machine Learning and Data Warehousing on product, enterprise, and manufacturing data for optimizing operations.



This solution walkthrough consists of the following considerations:

1. Plant to AWS connectivity
2. Security first
3. Ingesting data into AWS
4. Creating asset-hierarchy in the cloud
5. Storing data in the cloud
6. Creating alerts and send notifications for out of bound conditions
7. Visualizing KPIs in near real-time and performing historical analysis
8. Repeatable for rapid deployment at scale globally

Plant to AWS connectivity

The management of the edge gateway remotely was a key requirement for the AWS IoT Greengrass service and KEPServerEX software running on the gateway. Not all industrial edge gateways provide a remote access controller, thereby requiring manual in-person intervention for a power recycle. To satisfy the requirement, an on-premise server was chosen with the following specifications:

- Form Factor 1U
- Short Chassis depth to place into a network Rack
- Rugged server with dust filters for survival in the manufacturing shop floor
- Remote access controller allowing remote management regardless of the OS state
- Ability to deploy AWS IoT Greengrass for multiple manufacturing sites via existing setup with a golden image
- Setup for automatic failover

For high availability (HA), the on-premise server was joined to the existing remote access controller that enabled faster failover using regularly taken backups, reducing downtime. The backup can be restored when needed to the existing on-premises servers and retain the same IP address avoiding configuration updates for AWS IoT Greengrass. The automatic failover can be configured on the existing setup. While the entire process instrumentation connectivity from the shop floor to KEPServerEX was established in a few hours, live data streaming into AWS IoT SiteWise in the cloud happened within a week.

Security first

Security is job zero at Genie. A secure network topology and authentication system were implemented. AWS IoT Greengrass uses X.509 certificates, AWS IoT policies, and IAM policies and roles to secure the applications that run on the edge gateway locally. Refer to Security in AWS IoT Greengrass to learn more on how security on AWS is a shared responsibility.

Read full Blog post online

Solution

Amazon Virtual Andon

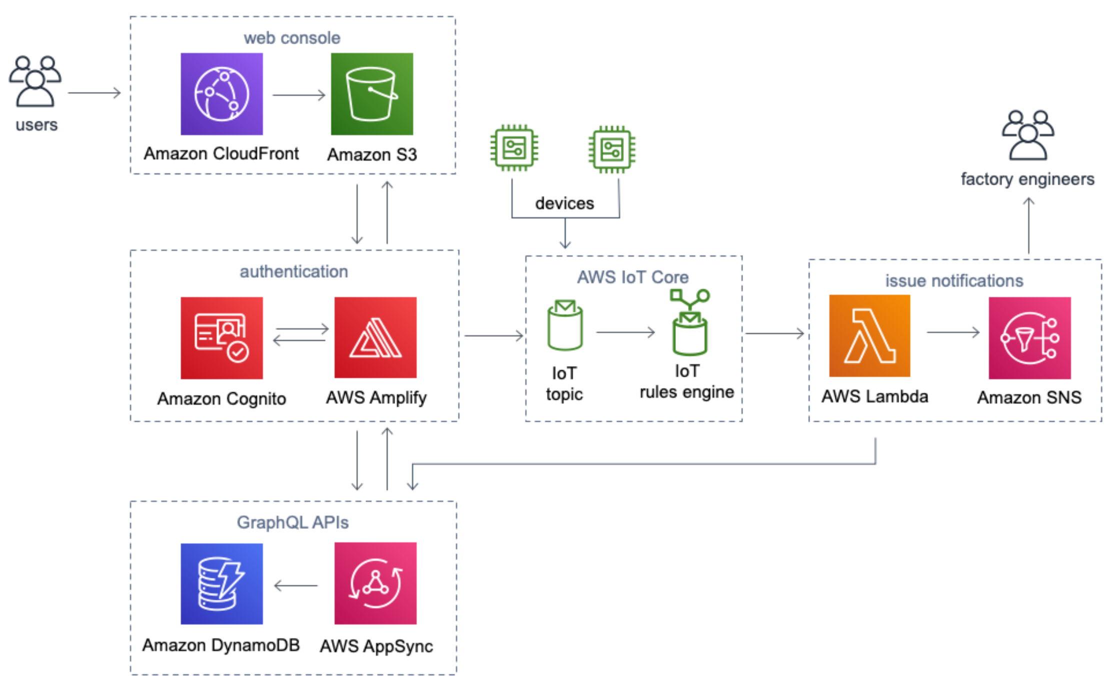
Amazon Virtual Andon

What does this AWS Solutions Implementation do?

The Amazon Virtual Andon solution provides a scalable Andon system to help optimize processes, support the transition to predictive maintenance, and prevent future issues. This solution provides a workflow to help users monitor manufacturing workstations for an event, log the event, and then route the event to the correct engineer for resolution in real-time. This solution is fully customizable and allows users to update the solution in real-time as issues arise.

AWS Solutions Implementation overview

The diagram below presents the architecture you can automatically deploy using this solution's implementation guide and accompanying AWS CloudFormation template.



Amazon Virtual Andon architecture

The AWS CloudFormation template provides an Amazon CloudFront web interface that deploys into an Amazon Simple Storage Service (Amazon S3) bucket configured for web hosting. AWS AppSync GraphQL APIs and AWS Amplify power the web interface. An Amazon Cognito user pool enables the solution's administrators to register users and groups using the web interface. Amazon DynamoDB tables store the factory data.

An AWS IoT rule engine helps users monitor manufacturing workstations or devices for events, and then routes the events to the correct engineer for resolution in real-time.

Authorized users can interact with and receive notifications from this solution. An AWS Lambda function and Amazon Simple Notification Service (Amazon SNS) send emails and SMS notifications.

View Implementation Guide online

Whitepaper

Achieve Production Optimization with AWS Machine Learning

Abstract

During the last decade, artificial intelligence (AI) and machine learning (ML) have been introduced into the manufacturing sector, enabling efficiency in processes, driving sustainability, supporting safer working environments, and increasing quality and productivity. AI and ML–enabled manufacturing can offer innovation and optimizations by providing manufacturing systems fault detection and prediction, optimal use of raw materials, parts and resources, exploiting heterogeneous big data analysis and an interconnected manufacturing enterprise. This paper provides an introduction of how machine learning can be used to optimize OEE through the identification, prediction, and prevention of unplanned downtime, fewer quality issues, and improved productivity.

Overall Equipment Effectiveness

Across discrete and process manufacturing, one of the main metrics used to gauge manufacturing productivity is Overall Equipment Effectiveness (OEE). There are a multitude of books and websites that explain and give examples of OEE but in summary OEE is a percentage that represents the productivity of a plant, line or manufacturing machine. The OEE percentage is made up of the percentages of quality, throughput or performance, and the availability or non-stoppage time as shown in the following formula:

$$OEE = Availability\ x\ Performance\ x\ Quality$$

With the detailed calculation being:

$$OEE = \frac{(Planned\ Prod.Time - Stoppage\ Time)}{Planned\ Production\ Time}\ x\ \frac{(Cycle\ Time\ x\ Cycles)}{Run\ Time}\ x\ \frac{Good\ Count}{Total\ Count}$$

By focusing on the factors that influence the variables of availability, performance, and quality, we can improve OEE. It is generally accepted that OEE greater than 85% is considered world class, with most manufacturers operating in the 60% range.[1]

ML and OEE

If we could measure and reduce downtime (improve availability), reduce defects (improve quality), and improve the productivity of a factory, line, or machine, then we can increase OEE. To accomplish this, you need process and production data to measure and analyze the manufacturing processes so that insights can be drawn for improvements. Manufacturing operational data sources can be factory machine telemetry data, operational MES (Manufacturing Execution System) data, maintenance records from asset management systems and production planning data from the ERP (Enterprise Resource Planning) system as examples or even manually collected data in logbooks. This is where the concept of a manufacturing data lakes comes in as it provides a cloud-based platform which scales and enables the central storage and analysis of these data sets. By having the manufacturing data in a data lake allows the data scientist to correlate, analyze and train the machine learning models for anomaly detection and predictions which can then be used to monitor and control the three OEE variables. The application of these machine learning models into the manufacturing process where processes can be automated is where the value comes, and this is generally referred to as the artificial intelligence (AI) piece of the process. This is not an overnight exercise but a gradual journey of learning which will enable manufacturers to optimize their physical manufacturing process through the predictions of the machine learning models. For some manufacturers the ultimate goal is to be a 'lights out' manufacturing enterprise using AI and machine learning predictions to automate decisions or augment manual process steps and upon gaining confidence on the ML model, the models can directly invoke control points changes in the manufacturing process.

Manufacturing use cases

There are many use cases for the application of AI and ML in manufacturing, from autonomous robots for material movement to digital twins, but for this whitepaper we focus on the cases that have a direct correlation to OEE improvements. These use cases can be grouped into two main categories: operational planning and manufacturing operations.

Operational planning

For operational planning use cases, the application of AI and ML is around simulation and forecasting for manufacturing processes and demand planning. By using historical data and external data sets as inputs the use cases are:

- Process simulation, determining the required capacity to improve cycle times and reduced production line interruptions
- Operational forecasting, forward planning on labor and material to support the next X months of manufacturing

- The application of ML in supply chain is justifiable as a topic on its own and therefore this paper won't focus on it in regards to OEE improvements. But as a side note, supply chain as an input can have a variance on production planning and material supply and therefore OEE

Manufacturing operations

When it comes to manufacturing operations use cases for AI and ML the application is on the factory floor and using machine telemetry, process sensors and augmented object data like images for:

- Improving machine availability by:
  - Reducing manual machine intervention
  - Implementing prescriptive maintenance
- Improving machine performance by:
  - Providing automatic setting/recipe management control
  - Optimizing processes through simulations
  - Fine tuning variables to optimize machine speeds, process parameters, energy use as examples
  - Identification of shortstops and micro stoppages and eliminating them
- Improving output quality by:
  - Detecting potential defects through process measurement monitoring
  - Automated visual inspection
  - Anomaly detection and defect analysis of inline test

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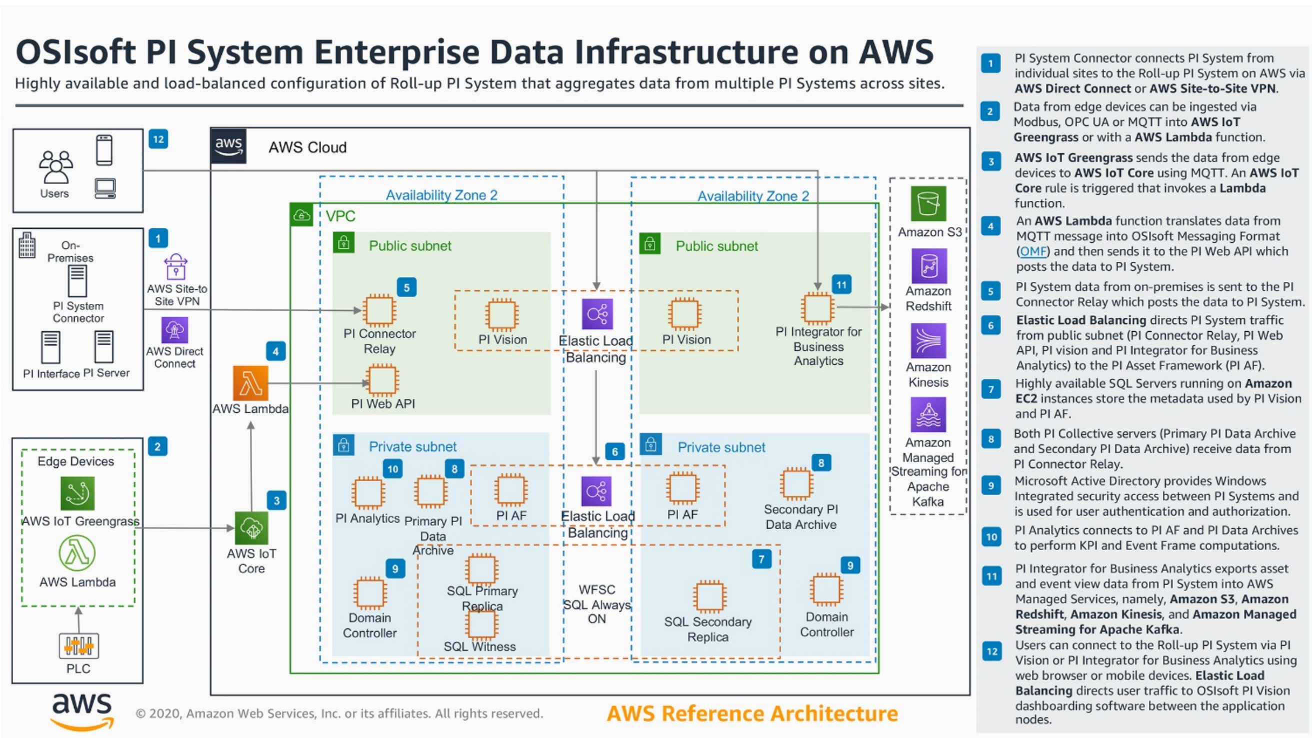
Reference Architecture

OSIsoft PI System Enterprise Data Infrastructure on AWS

Highly available and load-balanced configuration of Roll-up PI System that aggregates data from multiple PI Systems across sites.



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Blog

AWS for Industrial - Making it easy for customers to scale their industrial workloads on AWS

by Douglas Bellin, Global Lead of Business Development for Smart Factories at AWS

Increasingly, industrial customers across asset intensive industries such as manufacturing, energy, mining, transportation, and agriculture are leveraging new digital technologies to drive faster and more informed decisions in their industrial operations. 'AWS for Industrial' is a new initiative that features new and existing services and solutions from AWS and our Partners, which are built specifically for developers, engineers and operators at industrial companies. This initiative simplifies the process for customers to build or deploy innovative Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning (ML), analytics and edge solutions to achieve step change improvements in operational efficiency, quality, and agility.

Using data to drive digital transformation

To kickstart their digital transformation journey, industrial customers are looking to extract insights from their data and deliver business outcomes across the following workloads: engineering and design, production and asset optimization, quality management, worker safety and productivity, supply chain management, and smart products and machines. Industrial customers adjust the primary levers available to optimize their business operations – they can grow revenue, and they can lower costs. Growing revenue is often achieved with a faster time to market, optimized marketing strategies, or creating new revenue streams through smart product capabilities. Lowering costs can take the form of cost reduction in infrastructure, reducing operating expenses, and reducing production costs by improving productivity, machine availability or product quality.

Achieving these business outcomes is now possible with cloud tools and technologies such as data lakes, IoT, AI and ML. However, industrial customers have different preferences for how they want to solve for their use cases. Some customers have the in-house skills to build their own solutions using building block services and are looking for accelerators to simplify their deployment, others want to work with industry experienced professional services teams or consulting partners to help them build a custom solution, and others simply want to buy, deploy and configure a ready-made solution. 'AWS for Industrial' makes it easy for industrial customers to implement solutions faster using AWS no matter their preference.

Leading industrial companies, such as Volkswagen, Georgia Pacific, Invista, Carrier, and Vector, use AWS to fuel their digital transformation. Data is the connective tissue for industrial processes, and industrial customers have massive datasets that they want to leverage to drive more informed decisions to optimize their operations. While nearly any industrial process can be digitized and improved with AI/ML, the journey is often difficult for customers to navigate. These challenges include 1/ integrating data from new and legacy equipment that use different protocols and formats, 2/ organizing large amounts structured, unstructured, and disparate machine data, 3/ managing assets, device fleets and data across multiple sites, 4/ operating at the edge with minimal tolerance for latency, and 5/ the struggle to find highly skilled data scientists and AI/ML-trained developers that can build intelligent applications. This makes it tough for many companies who are early in their digital transformation journey or lack the skills to do this well. Many processes are built and documented so that the systems and workflows cannot change without a heavy investment of time and resources. This means that change in industrial processes can be slow to implement, and the impact of improvement can often take a long time to evaluate. For these reasons, industrial customers are increasingly looking for faster, simpler ways to capture and manage data from their processes, and apply ML without lengthy development times or needing specialized ML expertise.

New purpose-built AI and ML services make it easier to improve industrial operations with speed and accuracy using data

To address industrial use cases that require near real time decision making, AWS provides five new purpose-built services bringing AI and ML to industrial environments, born out of complex automation and factory operations of Amazon. These new services enable customers to use machine data to predict when equipment will require maintenance and to use computer vision (like images from existing camera feeds) to improve processes, identify bottle necks and detect anomalies, real-time – with no machine learning expertise required.

Using machine data to predict when equipment will require maintenance:

- Amazon Lookout for Equipment. AWS Lookout for Equipment is an anomaly detection service for industrial machinery. It uses data from equipment tags and sensors, and historical maintenance events to detect abnormal equipment behavior.
- Amazon Monitron. Amazon Monitron is an end-to-end system that detects abnormal behavior in industrial machinery, such as motors, gearboxes, fans, and pumps, enabling customers to implement predictive maintenance and reduce unplanned downtime. It includes sensors to measure vibration and temperature, a gateway device, and a mobile app to set up devices and track and review potential failures in equipment.

Using computer vision to improve processes, identify bottle necks and detect anomalies:

- Amazon Lookout for Vision. Amazon Lookout for Vision enables customers to spot industrial product defects and anomalies using computer vision, accurately and at scale. Customers can automate real-time visual inspection for processes like quality control and defect assessment by analyzing images from cameras that monitor the process line. Amazon Lookout for Vision identifies missing components, damage to products, irregularities in production lines, and even minuscule defects in silicon wafers such as a missing capacitor on a printed circuit board.
- AWS Panorama. AWS Panorama is a machine learning appliance and SDK, which enable customers to add computer vision (CV) to existing on-premises cameras or to new Panorama enabled cameras. It gives customers the ability to make real-time decisions to improve operations, automate monitoring of visual inspection tasks, find bottlenecks in industrial processes, and assess worker safety within facilities.
    - The AWS Panorama Appliance turns existing onsite cameras into powerful edge devices with the processing power to analyze video feeds from multiple cameras in parallel, and generate highly accurate predictions within milliseconds. With a dust resistant and waterproof appliance, customers can install devices in different environments without compromising functionality.
    - The AWS Panorama SDK enables hardware partners to build new Panorama enabled devices that run more meaningful CV models at the edge, and offer a selection of edge devices to satisfy different use cases. New Panorama enabled devices, coming soon from partners including ADLINK Technology, Axis Communications, Basler AG, Lenovo, STANLEY Security, and Vivotek.

IoT and storage advancements make it easy to securely collect, integrate, organize, and store massive industrial data sets even with limited connectivity

Industrial companies today have more operational data than ever before, however, securely accessing, collecting, and organizing these massive industrial data sets is difficult, and often requires new tools to improve systems and processes in industrial low-latency environments. Customers use AWS compute, storage, and database services to build their single source of data truth, and use AWS IoT services to securely collect, organize, and monitor industrial data at scale.

- AWS IoT SiteWise. AWS IoT SiteWise is a managed service that makes it easy to collect, store, organize and monitor data from industrial equipment at scale to help customers make better, data-driven decisions in optimizing their operations.
- AWS Snowcone. AWS Snowcone is the smallest member of the AWS Snow Family of edge computing, edge storage, and data transfer devices. It is ruggedized, secure, and purpose-built for use outside of a traditional data center, and Its small form factor makes it a perfect fit for tight spaces or where portability is a necessity. Customers can execute compute applications at the edge, and can ship the device with data to

AWS for offline data transfer, or can transfer data online with AWS DataSync from edge locations.

- AWS Snowball Edge. AWS Snowball Edge, a part of the AWS Snow Family, is an edge computing, data migration, and edge storage device that customers use for data collection, machine learning and processing, and storage in environments with intermittent connectivity or in extremely remote locations before shipping them back to AWS.
- AWS Outposts. AWS Outposts is a fully managed service that offers the same AWS infrastructure, AWS services, APIs, and tools to virtually any datacenter, co-location space, or on-premises facility for a truly consistent hybrid experience. AWS Outposts is ideal for workloads that require low latency access to on-premises systems, local data processing, data residency, and migration of applications with local system interdependencies.
- Amazon Lake Formation. Setting up and managing data lakes involves manual and time-consuming tasks such as loading, transforming, securing, and auditing access to data. AWS Lake Formation automates many of those manual steps and reduces the time required to build a successful data lake using Amazon S3, from months to days.

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Case Study

Arneg Predicts Customer Maintenance Needs Worldwide Using Amazon Forecast and Amazon SageMaker

Arneg SpA (Arneg) needed to evolve beyond a reactive customer service model. The company, a global leader in commercial refrigeration manufacturing, sought a failure-tolerant, scalable solution to improve its existing services and integrate with new services as its offerings expanded. To help the company evolve, Arneg turned to Amazon Web Services (AWS) and developed a predictive maintenance model using its Internet of Things (IoT) infrastructure and Amazon Forecast, a fully managed service that uses machine learning (ML) to deliver highly accurate forecasts. The new system enabled Arneg to predict maintenance needs with more than 80 percent accuracy, greatly reducing refrigeration downtime for the company's global customers.

"AWS architecture proved to be a great and powerful innovation enabler."

-Claudio Canepa, Chief Information Officer, Arneg

Shifting to a Cloud-Based Predictive Model

With a distribution network that spans more than 100 countries, Arneg and its subsidiaries are global manufacturers of freezers and refrigerators for supermarkets and have a strong and recognized positioning in the market. The nature of the business requires the company to respect strict service-level agreements. To facilitate food safety, Arneg must provide around-the-clock customer support worldwide, every day of the year. Arneg previously used its Interactive Remote Information System (IRIS), a locally hosted application, to manage alarms, service calls, and onsite work. With IRIS, refrigerators would send alarms to Arneg when they were malfunctioning—but only when the units could not maintain the strict commercial refrigeration industry standards. “Since assistance is normally only requested when a problem arises, our reaction time needs to be extremely short,” says Arneg service director Davide Zandonà. “This increases our costs and, more importantly, makes the service process less efficient.” Arneg sought to use its existing IoT infrastructure to build a more proactive solution in the cloud. “The development of new projects like predictive maintenance is actually only possible in the cloud,” says Arneg chief information officer Claudio Canepa. “The necessary computing capacity, storage, and organization time cannot be provided on premises.”

The company evaluated multiple global cloud providers and ultimately determined AWS was the best fit. “Our commitment to optimizing and evolving Arneg’s services over time requires the use of easily updatable and upgradable systems,” says Canepa. “Our comparative research identified AWS as the supplier most closely in line with our company’s needs at the time and best able to support future innovations.” Arneg’s first step was developing a proof of concept for the IRIS application on AWS, but the company quickly realized the solution needed to do more than just migrate existing data to the cloud in order to produce tangible benefits. The company identified a need to become cloud optimized, not just cloud hosted, in order to reduce costs, develop its predictive maintenance solution, and continue evolving at scale. Arneg soon realized that AWS microservices enabled it to change and improve existing IRIS functions and to get more benefit from the cloud architecture.

Shortening IoT Creation Timelines to Enable Faster Responses

Arneg’s solution involves collecting data—such as temperatures, energy consumptions, and failures—through IoT devices in freezers and refrigerators and sending that data to the cloud, where it is standardized and homogenized so that it can be processed. Arneg uses Amazon SageMaker and Amazon Forecast for its predictive model. [Amazon SageMaker] integrates ML components into a single tool set to build, train, and deploy ML models quickly. With its predictive model, Arneg collects 11 million IoT records daily and builds them into models in hours. Previously, building models on this scale took weeks or months.

The predictive model issues a notification before an event is likely to occur, which gives service teams time to monitor the equipment and notify onsite maintenance personnel in advance when necessary. “This solution enables us to provide better quality service by preventing refrigeration unit breakdowns,” says Zandonà. “This also helps optimize the cold chain, improving efficiency and energy savings for retailers while facilitating food safety for consumers.” So far, the predictive maintenance model predicts maintenance needs with 80 percent accuracy—a figure that is poised to improve as the company compiles a large amount of historical data.

Improving Customer Service

Arneg can seamlessly integrate additional services with its solution on AWS. “By optimizing response times and the required maintenance efforts, we have been able to focus more attention on product-service development and on the acquisition of new types of data,” says Zandonà. The company’s next step is to move its customer service contact center to AWS. The ongoing migration process uses Amazon Connect, an omnichannel cloud contact center that provides real-time and historical analytics as well as voice and chat functions.

The migration was driven by a need to improve call times, direct calls based on the data associated with the customer, and reduce time spent identifying, entering, and tracing customer data. “By creating complex workflows in Amazon Connect, it will be possible for us to associate data from suppliers, customers, and points of sale,” says Canepa. “This will help our operators to precompile all the information they need to open a ticket and avoid human errors in data input and flow management.” Once the solution is fully implemented, Arneg can trace requests and data analytics in near real time and create key performance indicators to help monitor and optimize service performance on a continuous basis.

Looking Ahead to Further Innovation on AWS

Looking to switch from a reactive to a preventative service model, Arneg used its IoT infrastructure as well as Amazon SageMaker and Amazon Forecast to develop a predictive model to anticipate its customers’ maintenance needs with more than 80 percent accuracy and prevent breakdowns. Arneg also saw an opportunity to automate and streamline customer service using Amazon Connect—and that’s just the start. “AWS architecture proved to be a great and powerful innovation enabler,” says Canepa. “AWS will enable Arneg to concentrate on the services we see as fundamental for our company and will enable resources normally assigned to infrastructure support, capacity analysis, and the management of complex information technology services to be redirected toward our group’s core business.”

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