Serverless Architecture for Product Defect Detection Using Computer Vision

Mohsin Khan

Solutions Architect

Amazon Web Services

@mohsink_

@mohsink-

What we will cover in this session

- Computer Vision for Industrial Use Cases

- Why is quality management important?

- Introduction to Amazon Lookout for Vision

- Solution Architecture for Product Defect Detection

- Solution Demo

- Resources

aws

Computer Vision for Industrial Use Cases

Inspection Point
Inspection Point
Inspection Point
Inspection Point
Inspection Point

Warehouse

In/Outbound Logistics

Production

Assembly

Packaging

- Asset management
- Worker safety
- Material flow
- Code Reading

- Quality Assurance
- Process Control
- Root Cause Analysis
- Measurement
- Positioning & Guidance

Target Computer Vision Use Cases

Key Manufacturing Needs Across Common Workloads
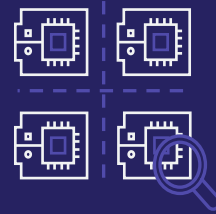
Computer Vision Applies to All Workloads!

Engineering & Design

Accelerate time to market

Lower infrastructure costs

Improve collaboration

Production & Asset Optimization

Lower costs (energy, machines, labor)

Improve machine or asset productivity

Reduce production downtime

Quality Management

Automate quality inspection

Improve inspection accuracy; reduce scrap and warranty

Reduce product defects; optimize yield

Identify & resolve Root Cause

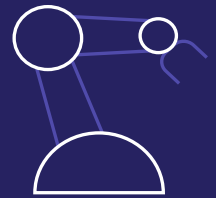## Worker Safety & Productivity

Improve employee productivity

Monitor safety

Reduce worker injuries

Supply Chain Management

Improve forecast accuracy

Reduce inventory costs

Improve capacity utilization

Smart Products & Machines

Enhance user experiences

Create new revenue streams

Improve product or service quality

aws

Quality impacts the Cost to Operations and Customers

> Many organizations will have true quality-related costs as high as 15 - 20% of sales revenue.
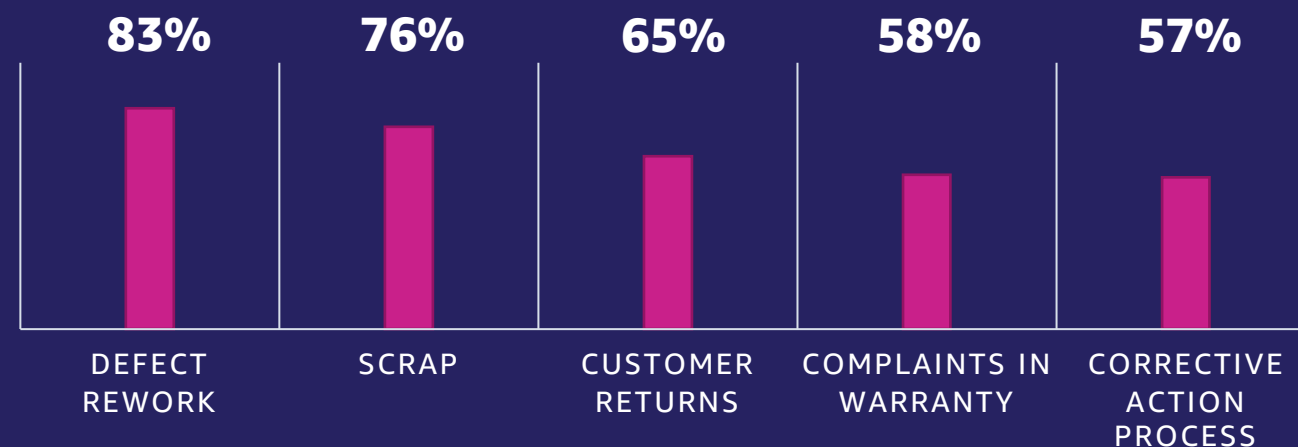>
> ABERDEEN

EXAMPLE: WARRANTY CLAIMS

In 2018, U.S. based manufacturers paid an estimated $26 billion in total claims.

Measuring cost of quality

Top five failure internal and external metrics included in cost of quality model*

83%	76%	65%	58%	57%
DEFECT REWORK	SCRAP	CUSTOMER RETURNS	COMPLAINTS IN WARRANTY	CORRECTIVE ACTION PROCESS

Five most common metrics:

› Defect rework

› Scrap

› Customer returns

› Complaints in warranty

› Corrective action process

*2019 Gartner Quality Cost of Benchmark results (Internal and External): 109 participants, Gartner, March 2020

EXAMPLE: WARRANTY CLAIMS

In 2018, U.S. based manufacturers paid an estimated $26 billion in total claims.

Visual inspection for quality assurance – Manual Inspection

MANUAL INSPECTION

Inline inspection

MANUAL INSPECTION

End of Line inspection

ADVANTAGES

- ✓ Agile
- ✓ Flexible

CHALLENGES

- › Limits throughput
- › Subjective
- › Incomplete
- › Feedback loop is slower

Visual inspection for quality assurance – Machine Vision

MACHINE VISION

Inline inspection

MACHINE VISION

Offline inspection

ADVANTAGES

✓ Fast, repeatable

✓ Lowers cost of inspection

✓ Feedback loop is faster

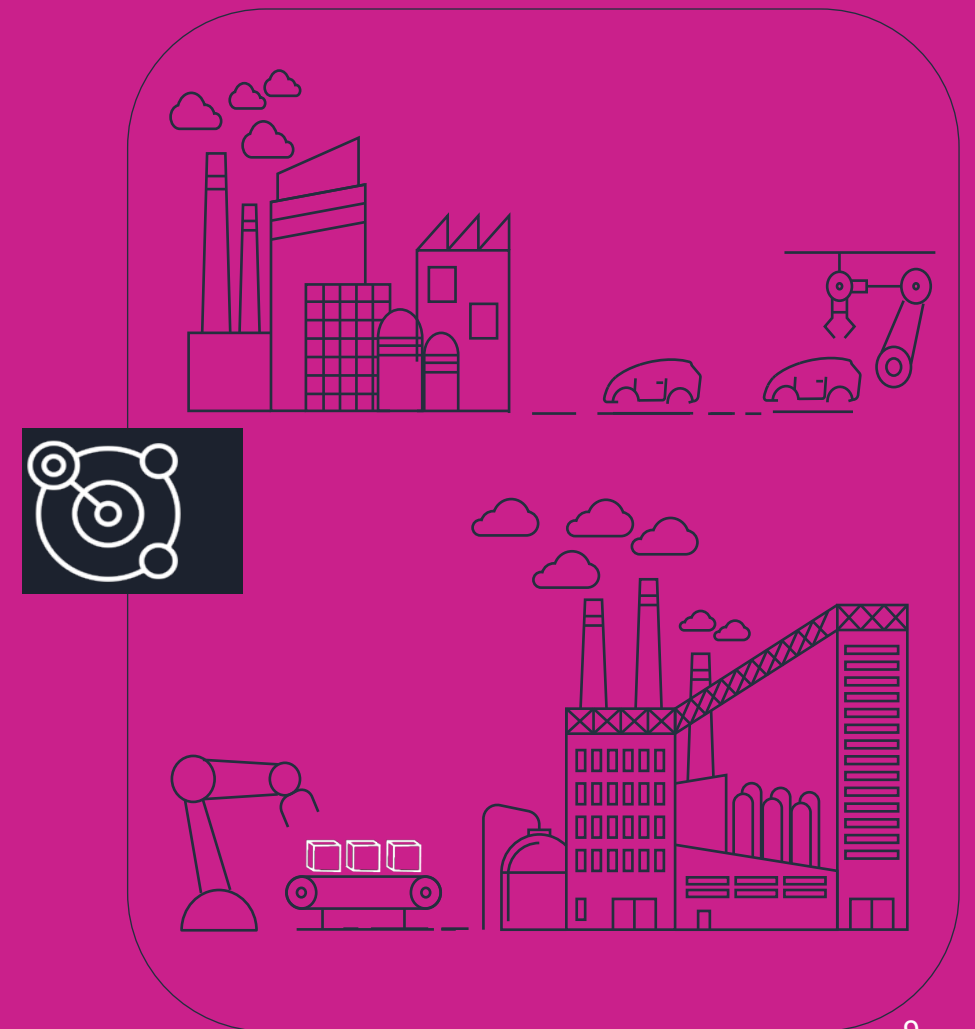**CHALLENGES**

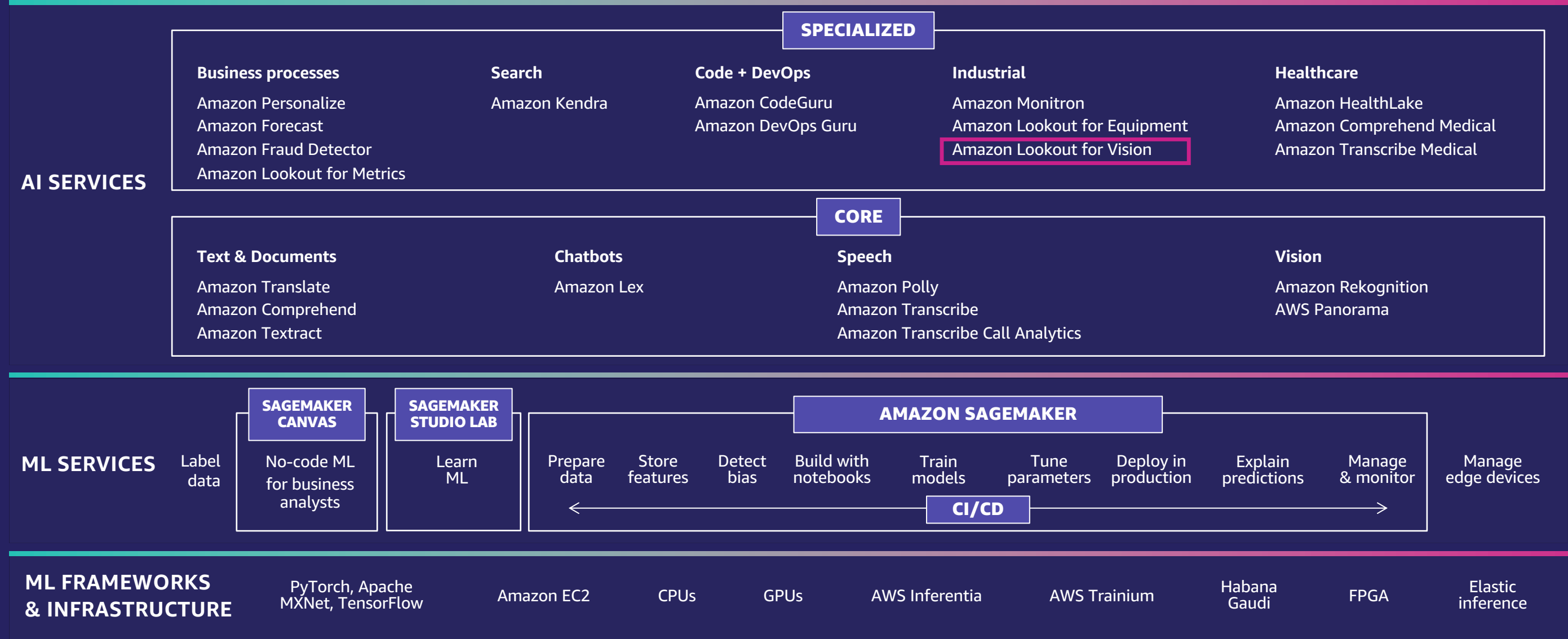› High upfront costs

› Inflexible

› Limits coverage

Amazon Lookout for Vision

A machine learning service that uses computer vision to automate visual inspection of product defects
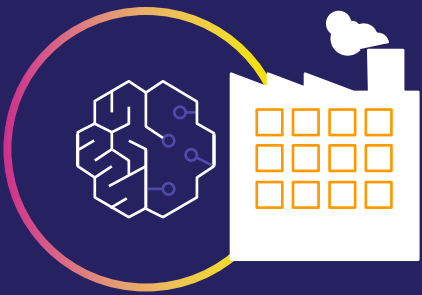
aws

The AWS AI/ML stack
Broadest and most complete set of machine learning capabilities

AI SERVICES

SPECIALIZED

Business processes	**Search**	**Code + DevOps**	**Industrial**	**Healthcare**
Amazon Personalize	Amazon Kendra	Amazon CodeGuru	Amazon Monitron	Amazon HealthLake
Amazon Forecast		Amazon DevOps Guru	Amazon Lookout for Equipment	Amazon Comprehend Medical
Amazon Fraud Detector			Amazon Lookout for Vision	Amazon Transcribe Medical
Amazon Lookout for Metrics				

CORE

Text & Documents	**Chatbots**	**Speech**	**Vision**
Amazon Translate	Amazon Lex	Amazon Polly	Amazon Rekognition
Amazon Comprehend		Amazon Transcribe	AWS Panorama
Amazon Textract		Amazon Transcribe Call Analytics	

ML SERVICES

SAGEMAKER CANVAS

SAGEMAKER STUDIO LAB

AMAZON SAGEMAKER

Label data	No-code ML for business analysts	Learn ML	Prepare data	Store features	Detect bias	Build with notebooks	Train models	Tune parameters	Deploy in production	Explain predictions	Manage & monitor	Manage edge devices

CI/CD

ML FRAMEWORKS & INFRASTRUCTURE

PyTorch, Apache MXNet, TensorFlow	Amazon EC2	CPUs	GPUs	AWS Inferentia	AWS Trainium	Habana Gaudi	FPGA	Elastic inference

aws

AWS Industrial AI Services
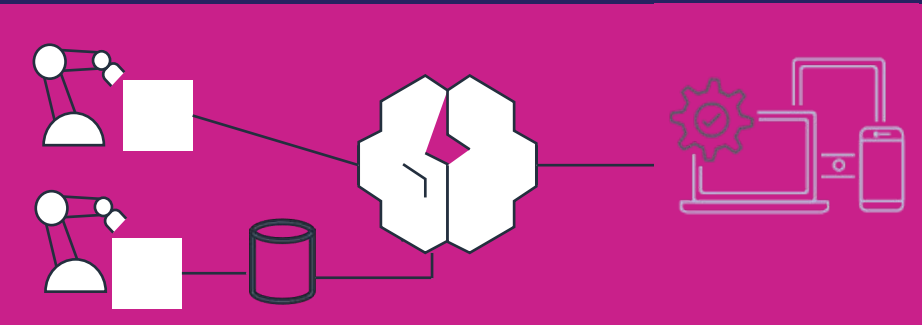
Automated Quality Management
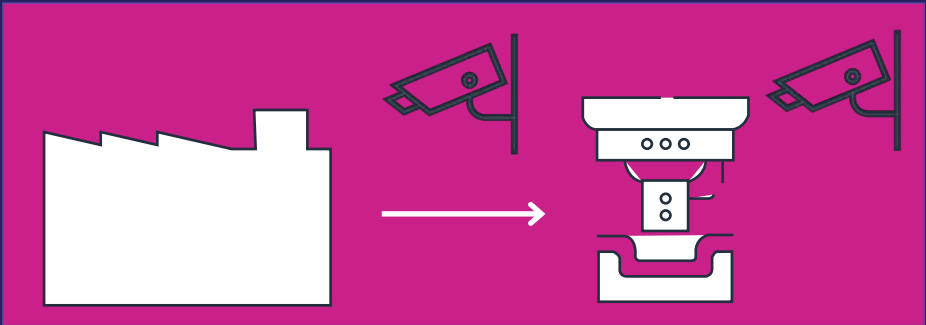
Solution: Deploy cameras along the production line to scale automated visual inspection and improve real time product quality verification and root cause analysis.

Amazon Lookout for Vision

Real-time Condition Monitoring

Solution: Collect and analyze data in real-time to identify anomalies, quickly diagnose root causes, and prevent unplanned downtime.
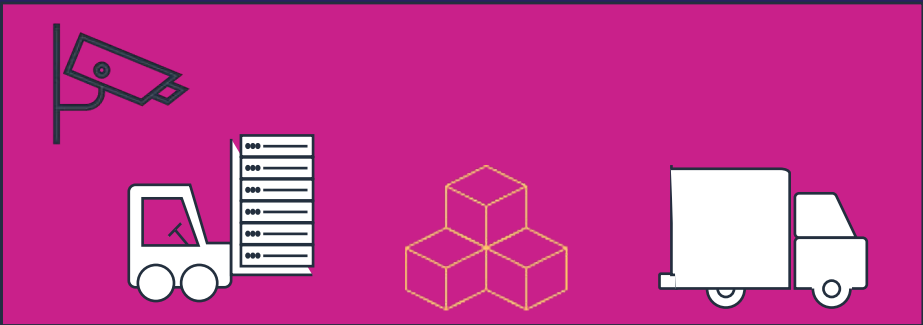
Amazon Lookout for Equipment

Amazon Monitron

Manufacturing Automation

Solution: Leverage the power of ML to automate the process of recognizing inbound trucks, counting boxes on pallets, and reading labels with your existing security cameras.

AWS Panorama

Computer Vision at Scale

Create

Access to sufficient images of product defects

Time to train/validate/ test ML models

Today's Challenges:

Run

Deploy ML models into existing technology architecture and infrastructure

Computing and security requirements

Maintain

Limited support for improving ML models at the plant

Adapt to changes to production processes and environment at the local level

Amazon Lookout for Vision

Create custom ML model with as few as 30 images, without ML expertise

Run custom ML models in the cloud using existing machine vision and lower resolution cameras

Process engineer, quality manager, and operator provide feedback for ML models in real time

Quality Management
Amazon Lookout for Vision Use Cases
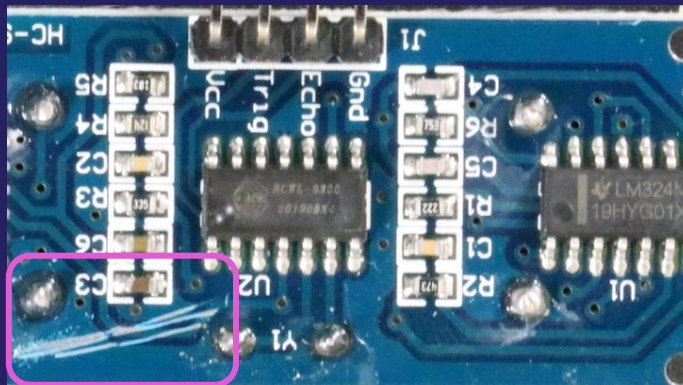
Anomaly

Scratch
(surface defect)
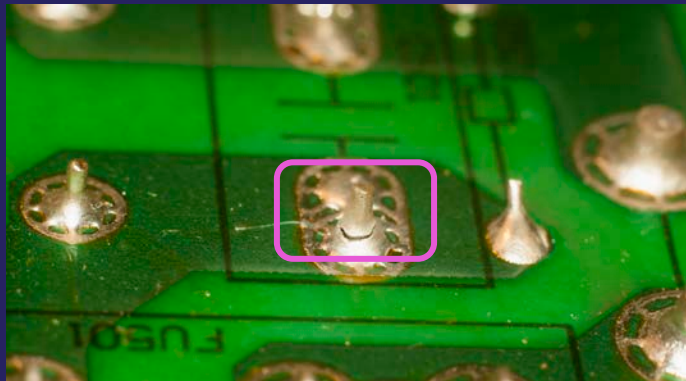
Anomaly

Improper solder   (shape defect)

Anomaly

Absence/Presence;
Misalignment/Placement

Anomaly

Defect Count, Change,
Consistency

Example

Printed circuit board

Example

Printed circuit board

Example

Blister Pack

Example

Steel coil

aws

Quality Management with Amazon Lookout for Vision

Typical End Users

Director of Quality

VP of Operations

Users' Key Concerns

Scrap	Warranty
Rework	Customer Sat
KPI: Yield	KPI: Throughput

Solution Highlights

✓ Increase Speed of Deployment

✓ Low Setup Costs

✓ Continuously Improving

Input

Capture, process, and load training images into Amazon Lookout for Vision

Amazon Lookout for Vision

Identify product defects using computer vision to automate quality inspection

Label images to create, train, and tune your defect detection model

Use the dashboard to monitor defects and improve processes

Automate

Find defects, automate inspection, and receive notifications

Continuous improvement

Verify model predictions and make continuous improvements with the Amazon Lookout for Vision console or with Amazon A2I

Make decisions with more accuracy and in less time

**Amazon Lookout for Vision provides a binary image classification inference result,
then the user takes the following actions**

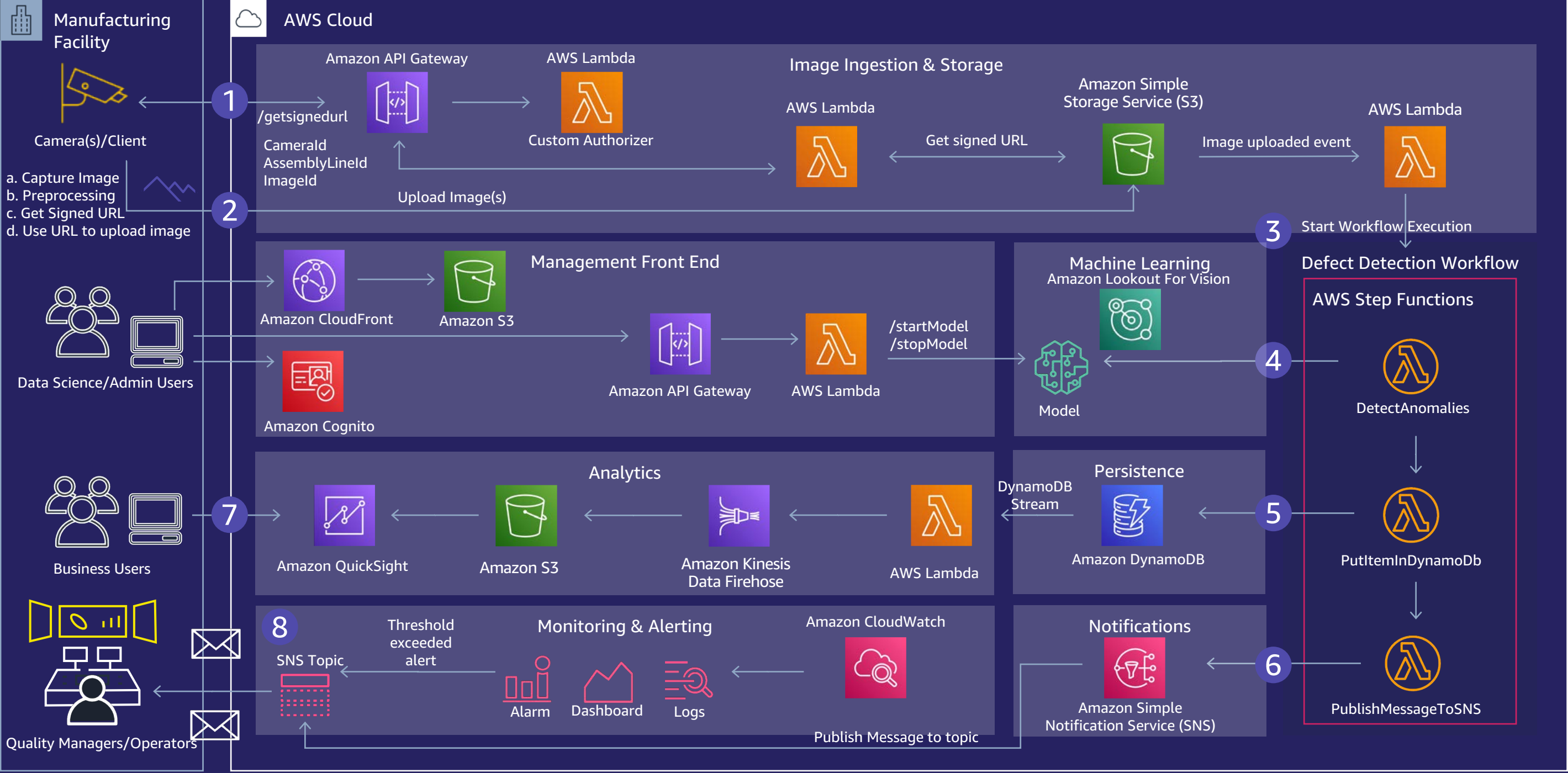| Decision	Customer Disposition
Classify	Inference result indicates that the production unit is defective (anomalous). The defect(s) is examined by the operator or quality manager and classified. Example: Silicon Wafer defect is a bubble on the wafer surface.
Grade	The classified defect(s) is examined by the quality manager and a determination of whether the production unit meets customer specification is made.
Bin Product and Ship	Quality manager decides whether to ship the production unit(s) to specified customer or to a different customer based on specifications. Information about the defect may or may not be included with shipment.
Rework	Quality manager uses information about defect types and patterns to decide whether to rework the product and ship to specified customer or a different customer.
Scrap or Recycle	Quality manager determines that the production unit does not meet minimum specifications and rework is not an option and choose to scrap or recycle the production unit.
Investigate Process	Field personnel, operator, quality manager or process engineer will evaluate the anomaly and decide to not take action or to take action such as slow down the process line, reschedule incoming orders, or schedule maintenance.
Improve ML model	Process engineer, quality manager, or operator will review inference results and determine what feedback to provide the ML model

Solution Architecture
for Product Defect Detection

Solution Architecture

Manufacturing Facility

Camera(s)/Client

a. Capture Image
b. Preprocessing
c. Get Signed URL
d. Use URL to upload image

Data Science/Admin Users

Business Users

Quality Managers/Operators

AWS Cloud

Image Ingestion & Storage

Amazon API Gateway

AWS Lambda
Custom Authorizer

/getsignedurl
CameraId
AssemblyLineId
ImageId

1

2

Upload Image(s)

AWS Lambda

Get signed URL

Amazon Simple
Storage Service (S3)

Image uploaded event

AWS Lambda

3 Start Workflow Execution

Management Front End

Amazon CloudFront

Amazon S3

Amazon Cognito

Amazon API Gateway

AWS Lambda

/startModel
/stopModel

Machine Learning
Amazon Lookout For Vision

Model

4

Defect Detection Workflow

AWS Step Functions

DetectAnomalies

PutItemInDynamoDb

PublishMessageToSNS

5

6

Analytics

Amazon QuickSight

Amazon S3

Amazon Kinesis
Data Firehose

AWS Lambda

7

Persistence

DynamoDB
Stream

Amazon DynamoDB

Monitoring & Alerting

8 SNS Topic

Threshold
exceeded
alert

Alarm

Dashboard

Logs

Amazon CloudWatch

Publish Message to topic

Notifications

Amazon Simple
Notification Service (SNS)

Publish Message to topic

aws

Solution Demo

Image Upload

Source Images bucket
Stores image(s) uploaded from camera or client. Triggers an event notification whenever an image is uploaded

Defect detection workflow
Image upload initiates the AWS Step Functions workflow to detect anomaly, save inference result and send notification

Email notifications
Email notifications for any image classified as defective or is a low-confidence result

Visualization

Amazon CloudWatch and Amazon QuickSight dashboards

d3pfonb64eo5h7.cloudfront.net

Sign in to your account

Username *

makaws@amazon.com

Password *

•••••••••••••

Forget your password? **Reset password**

SIGN IN

Solution Resources

Blog: Detect manufacturing defects in real time using Amazon Lookout for Vision

- https://aws.amazon.com/blogs/machine-learning/detect-manufacturing-defects-in-real-time-using-amazon-lookout-for-vision/

GitHub: AWS Sample Solution

- https://github.com/aws-samples/amazon-lookout-for-vision-serverless-app
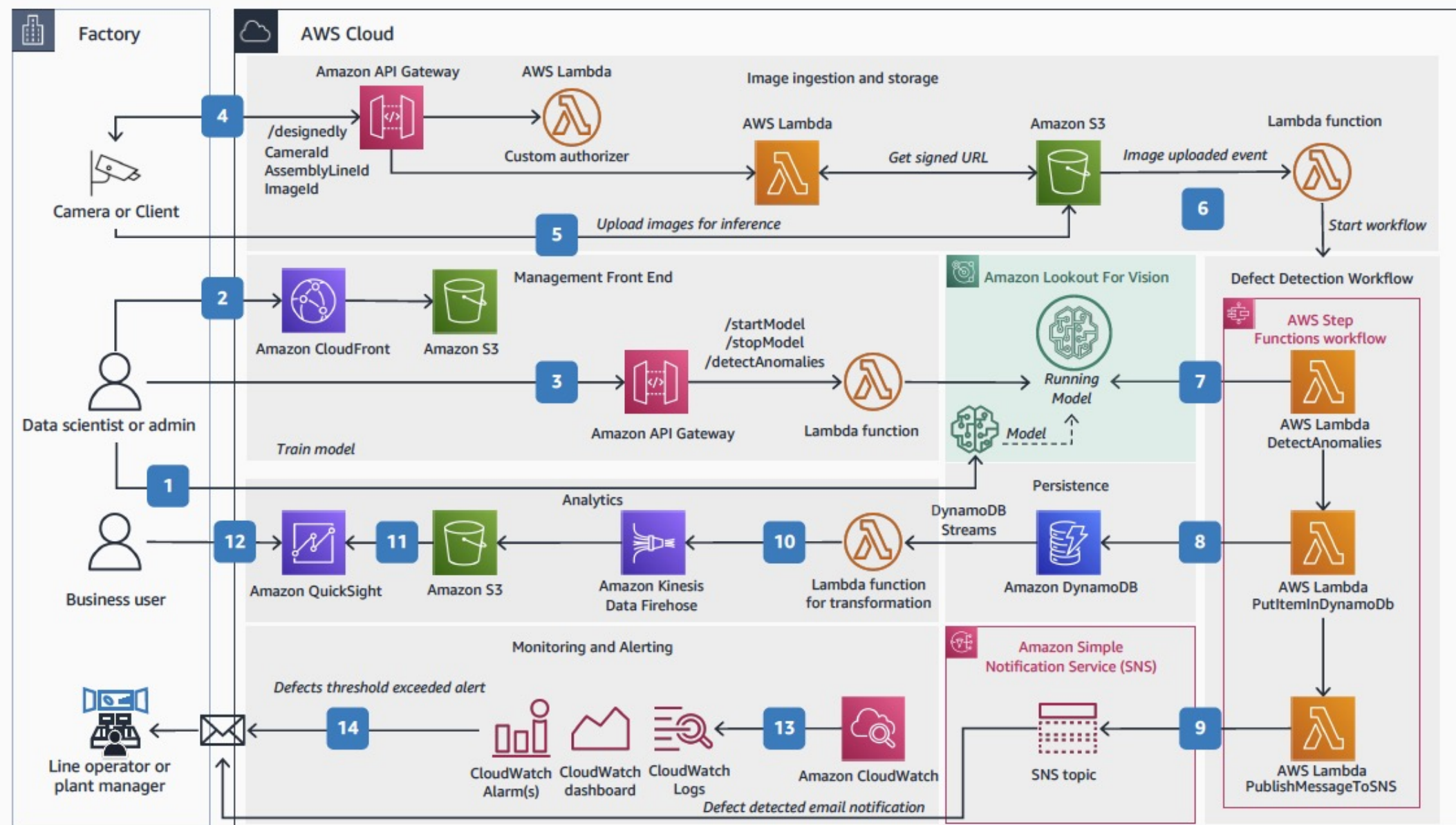
Reference Architecture

- https://d1.awsstatic.com/architecture-diagrams/ArchitectureDiagrams/serverless-architecture-for-product-defect-detection-using-computer-vision-ra.pdf

Serverless Architecture for Product Defect Detection Using Computer Vision

Detect product defects, get real-time notifications, and visualize insights using AWS artificial intelligence and machine learning, and serverless services

Architecture for camera-based in-line or end-of-line quality inspection. Supports automated or one-time anomaly detection using image classification in the cloud; real-time monitoring and notifications; and analytics and insights from the classification results.


Factory

AWS Cloud

Amazon API Gateway — AWS Lambda

Image ingestion and storage

Camera or Client

4 /designedly CameraId AssemblyLineId ImageId

Custom authorizer

AWS Lambda — *Get signed URL* — Amazon S3 — *Image uploaded event* — Lambda function

6 *Start workflow*

5 *Upload images for inference*

Management Front End

Data scientist or admin

2 Amazon CloudFront — Amazon S3

Train model

1

/startModel /stopModel /detectAnomalies

3 Amazon API Gateway — Lambda function

Amazon Lookout For Vision

Running Model

Model

Defect Detection Workflow

AWS Step Functions workflow

7 AWS Lambda DetectAnomalies

Analytics

Business user

12 Amazon QuickSight — **11** Amazon S3 — **10** Amazon Kinesis Data Firehose — Lambda function for transformation — DynamoDB Streams

Persistence

Amazon DynamoDB

8 AWS Lambda PutItemInDynamoDb

Monitoring and Alerting

Line operator or plant manager

Defects threshold exceeded alert

14 CloudWatch Alarm(s) — CloudWatch dashboard — CloudWatch Logs — **13** Amazon CloudWatch

Defect detected email notification

Amazon Simple Notification Service (SNS)

SNS topic — **9** AWS Lambda PublishMessageToSNS

1. Upload training data to **Amazon Lookout For Vision** or import training data from **Amazon Simple Storage Service (Amazon S3)** and train a model.

2. Admin users signup and login to a management front end website.

3. Start or stop the model or do one-time defect detection by uploading an image.

4. Camera or a client application invokes an **Amazon API Gateway** endpoint to get a signed URL from **Amazon S3**. The request is authorized by an **AWS Lambda** function and a signed URL is returned.

5. Using the signed URL, an image, along with its associated metadata, is uploaded to **Amazon S3**.

6. Image upload to the S3 bucket triggers an event notification to initiate an **AWS Step Functions** workflow.

7. Fetch image from the S3 bucket and present to **Amazon Lookout For Vision** for anomaly detection using DetectAnomalies API.

8. Store inference result and image metadata in **Amazon DynamoDB**.

9. Publish a notification to an **Amazon Simple Notification Service (Amazon SNS)** topic to send an email alert to subscribed operators and plant managers in case a defect or a low-confidence result is detected.

10. Inference results are fetched from **DynamoDB Streams**, transformed and enriched, sent to **Amazon Kinesis Data Firehose** for batching, and saved in another S3 bucket.

11. Inference results datasets are imported into **Amazon Quicksight**. This process can be scheduled based on requirements.

12. Create dashboards and analyses for business users, and gain insights from the inference results.

13. **Amazon CloudWatch** provides a single pane of glass to operators and plant managers for workload and defect detection monitoring using logs, alarms, and dashboards.

14. Alarm notifications from **Amazon CloudWatch** are sent to operators and plant managers by **Amazon SNS** whenever defects exceed a pre-defined threshold.

AWS Reference Architecture

Computer Vision Based Product Quality for Manufacturing
Detect and Act on Product Defect Classification in Plants using AWS IoT and AI/ML Services
Architecture for camera based end of line quality inspection, defect detection using image classification in the cloud, alert notifications, real time actuation, and root cause analysis using process data and inferred vision results.
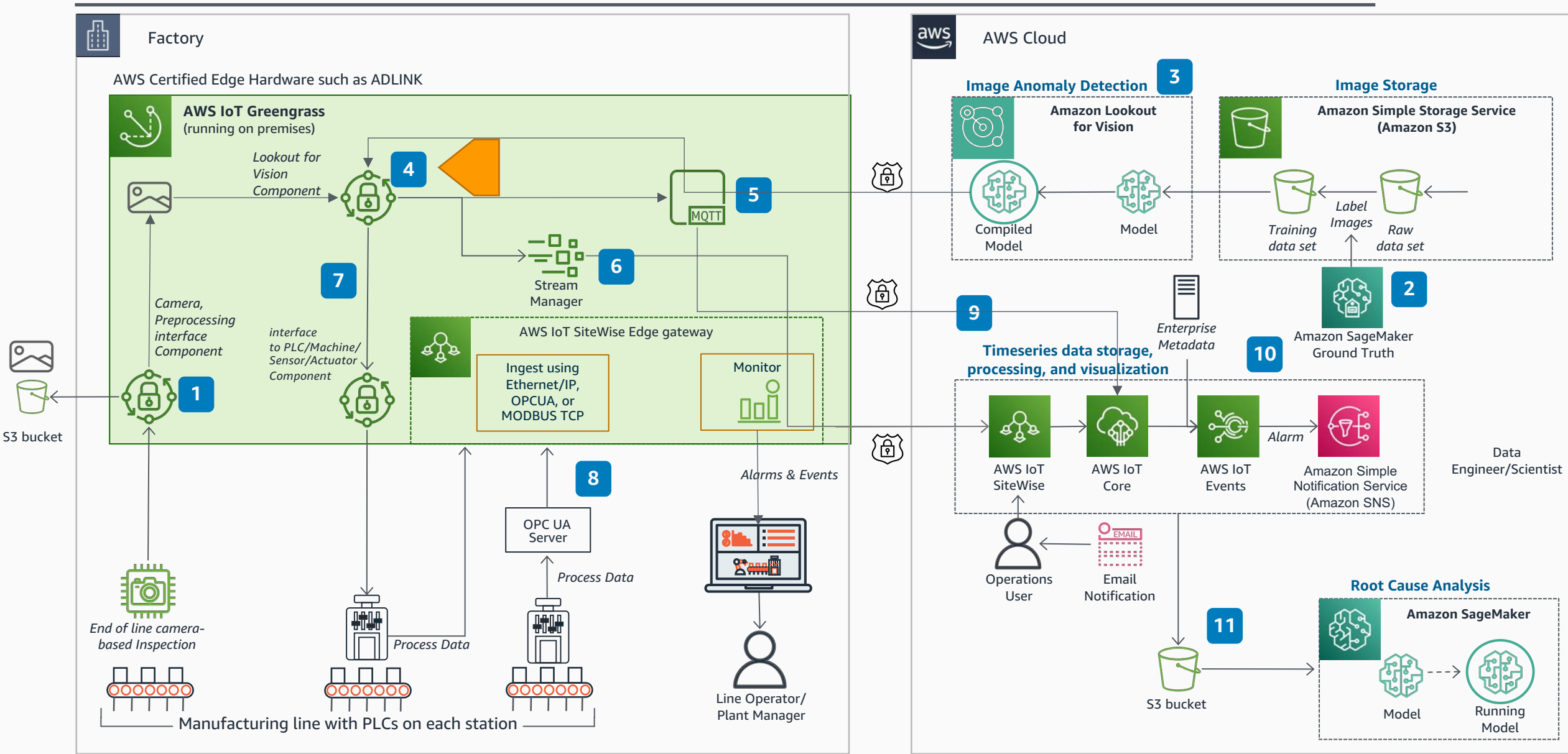
This diagram provides a solution to enable root cause analysis for product defects using machine data and end of line computer vision based inferencing.

1. Auto upload training images from the manufacturing line camera to **Amazon S3**

2. Use **Amazon SageMaker Ground Truth** to label training images

3. Begin model training using **Amazon Lookout For Vision**

4. Export (Deploy) trained model in **Amazon Lookout For Vision to Edge** for running production inferences

5. Feed live production images to quality logic running as **AWS IoT Greengrass component inference server, publish inference to AWS IoT MQTT** topic

6. Feed inference metadata to **AWS IoT Greengrass Stream Manager** for further processing and sending to **AWS IoT SiteWise** in the cloud

7. Perform automated action on machine of concern AND/OR notify plant personnel from **AWS IoT Greengrass component.**

8. Ingest process data into **AWS IoT SiteWise** gateway running on **AWS IoT Greengrass** from machine/equipment using OPC UA as the standard protocol. Modbus TCP and Ethernet IP are also natively supported

9. Configure **AWS IoT SiteWise** Gateway to forward PLC tag data to cloud.

10. Compute KPI metrics (OEE, etc.) from process data in **AWS IoT SiteWise**. Create monitoring and KPI dashboards in **SiteWise Monitor** for operations user. Create events from plant data and enterprise metadata by routing data to **AWS IoT Events** via **AWS IoT Core** and send out email or text notifications to operations user using **Amazon SNS** service

11. Feed process data and vision inference data streams to S3 for training root cause analysis models

12. Run model inference to pinpoint root cause

Resources

Amazon Lookout for Vision now supports visual inspection of product defects at the edge

- https://aws.amazon.com/blogs/machine-learning/amazon-lookout-for-vision-now-supports-visual-inspection-of-product-defects-at-the-edge/

Using Computer Vision for Product Quality Analysis in Manufacturing

- https://d1.awsstatic.com/architecture-diagrams/ArchitectureDiagrams/using-computer-vision-for-product-quality-analysis-in-plants-ra.pdf

Amazon Lookout for Vision Accelerator Proof of Concept (PoC) Kit

- https://aws.amazon.com/blogs/machine-learning/amazon-lookout-for-vision-accelerator-proof-of-concept-poc-kit/

Build an anomaly detection model from scratch with Amazon Lookout for Vision

- https://aws.amazon.com/blogs/machine-learning/build-an-anomaly-detection-model-from-scratch-with-amazon-lookout-for-vision/

Thank You

@mohsink_

@mohsink-