



From development to production

Accelerating robotic development
with cloud computing

Bobbie Couhbor

Solutions Architect – Digital Innovation and Emerging Technologies
Amazon Web Services

The screenshot shows an Amazon product page for Softsoap Antibacterial Liquid Soap Refill. At the top, the Amazon logo and navigation bar are visible. The search bar contains the text "hand soap antibacterial". The product title is "SOFTSOAP Antibacterial Liquid Soap Refill, Fresh Citrus, 2 x 1.5 Liter Bottles, Bathroom Soap, Bulk Moisturizing Antibacterial Set". The price is \$25.95 (\$12.98 / Count). The product has a 4.5-star rating from 629 reviews. A callout box highlights the price and delivery information: "FREE delivery Tomorrow, November 28. Order within 2 hrs 8 mins. Details". The callout also shows the "Add to Cart" and "Buy Now" buttons. The product image shows two large bottles of light blue liquid soap. The bottom of the page shows the AWS logo and copyright information.







Functionality simulated for illustrative purposes.

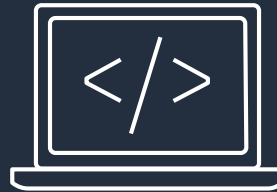
Developers want the same experience



Same high-
performance
infrastructure



Same
operational
consistency



Same services
and APIs

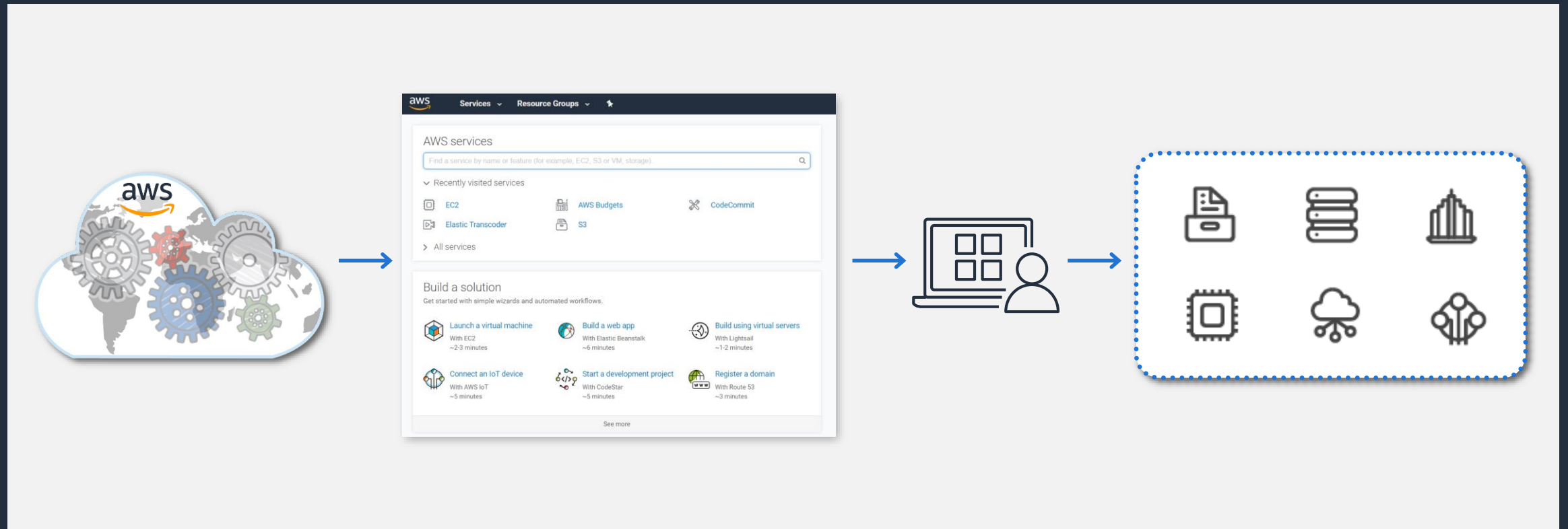


Same
automation,
deployments,
and security
controls



Same pace of
innovation as
in the cloud

Cloud Computing Services





FROM DEVELOPMENT TO PRODUCTION - ACCELERATING ROBOTIC DEVELOPMENT WITH CLOUD COMPUTING

ANALYTICS

ANALYTICS	STREAMING
DATA EXCHANGE	ETL
DATA LAKE	HADOOP/SPARK
DATA PIPELINES	INTERACTIVE SQL QUERIES
DATA WAREHOUSE	VISUALIZATIONS
ELASTICSEARCH	

AR + VR

AR/VR EXPERIENCES

AWS COST MANAGEMENT

ANALYZE AWS COSTS
COST & USAGE BUDGETS
COST & USAGE REPORTS
RESERVED INSTANCES REPORTING

APPLICATION INTEGRATION

EMAIL	SEARCH
MESSAGE BROKER	TRANSCODING
QUEUEING & NOTIFICATIONS	WORKFLOW

BUSINESS APPLICATIONS

EMAIL & CALENDARING	UNIFIED COMMUNICATIONS
ONLINE MEETINGS	VOICE-ENABLED WORKPLACE
SHARING & COLLABORATION	

BLOCKCHAIN

BLOCKCHAIN TEMPLATES
LEDGER DATABASE
MANAGED BLOCKCHAIN

CUSTOMER ENGAGEMENT

CONTACT CENTER
EMAIL MARKETING
USER ENGAGEMENT ACROSS CHANNELS

COMPUTE

COMPUTE	CONTAINERS
AUTO SCALING	CONTAINER SERVICE
BATCH JOBS	MANAGED KUBERNETES
EVENT-DRIVEN SERVERLESS COMPUTING	STORE & RETRIEVE DOCKER IMAGES
INSTANCE TYPES	
MANAGED VIRTUAL PRIVATE SERVERS	
MANAGED REPOSITORY FOR SERVERLESS APPS	
RUN & MANAGE WEB APPS	
SERVERLESS COMPUTE	
VIRTUAL SERVERS	

DATABASE

REAL-TIME DATABASES	PURPOSE-BUILT DATABASES
HIGH-PERFORMANCE RELATIONAL DATABASE BUILT FOR THE CLOUD	DOCUMENT DATABASE
MANAGED MARIADB	GRAPH DATABASE
MANAGED MYSQL	IN-MEMORY CACHING
MANAGED ORACLE	KEY-VALUE STORE DATABASE
MANAGED POSTGRES	LEDGER DATABASE
MANAGED SQL SERVER	TIME SERIES DATABASE

DEVELOPER TOOLS

ANALYZE & DEBUG
APPLICATION LIFECYCLE MANAGEMENT
AUTHORING
BUILD & TEST
CONTAINERS
DEVOPS RESOURCE MANAGEMENT
ONE-CLICK APP DEVELOPMENT
PATCHING
PIPELINE ORCHESTRATION
RESOURCE TEMPLATES
TRIGGERS

END USER COMPUTING

APP STREAMING
DESKTOP COMPUTING
MOBILE ACCESS
STORAGE & COLLABORATION

HYBRID ARCHITECTURE

AWS SERVICES ON PREMISES	INTEGRATED NETWORKING
DATA INTEGRATION	INTEGRATED RESOURCE & DEPLOYMENT MANAGEMENT
INTEGRATED DEVICES & EDGE SYSTEMS	VMWARE CLOUD ON AWS
INTEGRATED IDENTITY & ACCESS	

GAME TECH

CROSS-PLATFORM 3D GAME ENGINE
GAME SERVER HOSTING

INFRASTRUCTURE

AVAILABILITY ZONES
CUSTOM HARDWARE
DATA CENTER INFRASTRUCTURE
GLOBAL NETWORK BACKBONE
POINTS OF PRESENCE
POWER INFRASTRUCTURE
REGIONS

INTERNET OF THINGS (IOT)

RULES ENGINE
DEVICE ANALYTICS
DEVICE GATEWAY
DEVICE SDK
DEVICE SHADOWS
EVENT DETECTION & RESPONSE
LOCAL COMPUTE
LOCAL DATA COLLECTION
MANAGEMENT & SECURITY
MICROCONTROLLER OPERATING SYSTEM
REGISTRY
VISUAL APPLICATIONS DEVELOPMENT

MACHINE LEARNING

ML FRAMEWORKS	SAGEMAKER
DEEP LEARNING AMIs & CONTAINERS	AUTOMATIC MODEL TUNING
HARDWARE ACCELERATION	DATA LABELING
ML AT THE EDGE	HOSTED NOTEBOOKS
TENSORFLOW, PYTORCH, MXNET	ML MARKETPLACE
	MODEL HOSTING
	MODEL OPTIMIZATION
AI SERVICES	MODEL TRAINING
CHATBOTS	PRE-BUILT ALGORITHMS
ENTITY EXTRACTION	TOPIC MODELING
FACE ANALYTICS	DEEP LEARNING MODELS
FACE SEARCH	REINFORCEMENT LEARNING
FORECASTING	SPOT INSTANCES
IMAGE LABELING	BATCH PREDICTIONS
NATURAL LANGUAGE PROCESSING	REAL-TIME PREDICTIONS
PERSONALIZATION & RECOMMENDATION	
SENTIMENT ANALYSIS	
SPEECH TRANSCRIPTION	
TEXT & DATA EXTRACTION	
TEXT TO SPEECH	
TRANSLATION	
VIDEO & IMAGE ANALYSIS	
CONTENT MODERATION	

MANAGEMENT & GOVERNANCE

ACTIVITY & API USAGE TRACKING	MONITORING
CHATBOT	PROVISIONING
CONFIGURATION TRACKING	RESOURCE TEMPLATES
GOVERNANCE	SECURITY RECOMMENDATIONS
INVENTORY TRACKING	SERVER MANAGEMENT
LICENSE MANAGER	SERVICE CATALOG
MANAGE POLICIES	SYSTEMS MANAGER
MANAGE RESOURCES	

MARKETPLACE

ANALYTICS	MACHINE LEARNING
DATA PRODUCTS	NETWORKING
DATABASES	OPERATING SYSTEMS
DEVOPS	SECURITY
IOT	STORAGE

MEDIA SERVICES

LIVE VIDEO TRANSPORT	VIDEO PERSONALIZATION & MONETIZATION
MEDIA STORAGE	VIDEO PROCESSING & DELIVERY
TRANSCODING	VIDEO STREAMING ANALYSIS
VIDEO ORIGINATION & PACKAGING	

MIGRATION & TRANSFER

APPLICATION MIGRATION
DATABASE MIGRATION
EXABYTE-SCALE MIGRATION
ONLINE DATA TRANSFER
SCHEMA CONVERSION
SERVER MIGRATION
TRANSFER FOR SFTP

MOBILE

API GATEWAY	MOBILE APP TESTING
DEVELOPMENT FRAMEWORK	SINGLE INTEGRATED CONSOLE
IDENTITY	SYNC
MOBILE ANALYTICS	TARGETED PUSH NOTIFICATIONS

NETWORKING & CONTENT DELIVERY

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PRIVATE CONNECTION TO APPS
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SERVICE DISCOVERY
VIRTUAL PRIVATE CLOUD

ROBOTICS

CLOUD ROBOTICS

SATELLITE

SATELLITE OPERATIONS

SECURITY, IDENTITY, & COMPLIANCE

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DDOS PROTECTION
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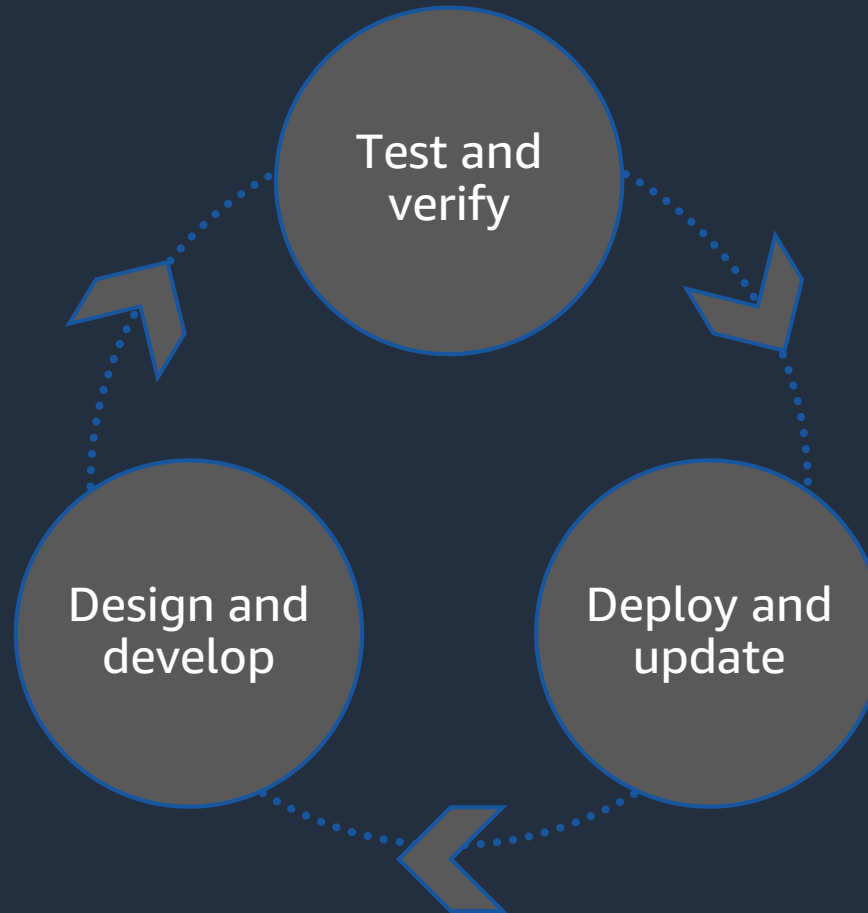
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Robotics development lifecycle



Design and Develop



Kinesis Video Streams with WebRTC for teleoperation and supervision



Low-latency
peer to peer



Browser-
based
teleoperation



Fine-grained
access
control

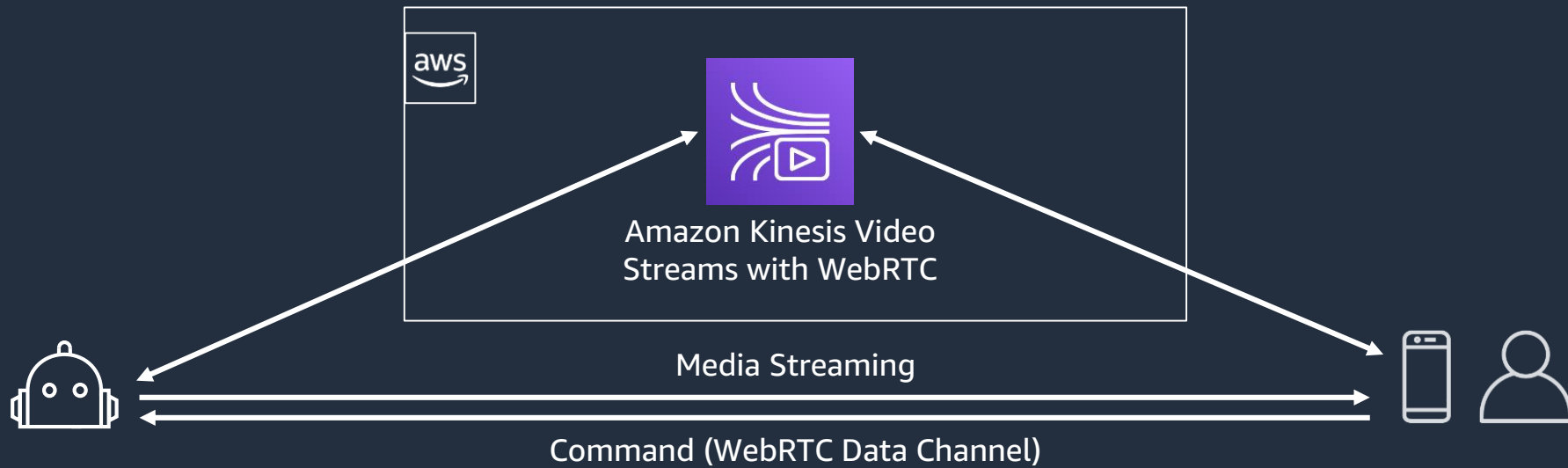


Low device
footprint



OS agnostic

Remote command and control





Incognito

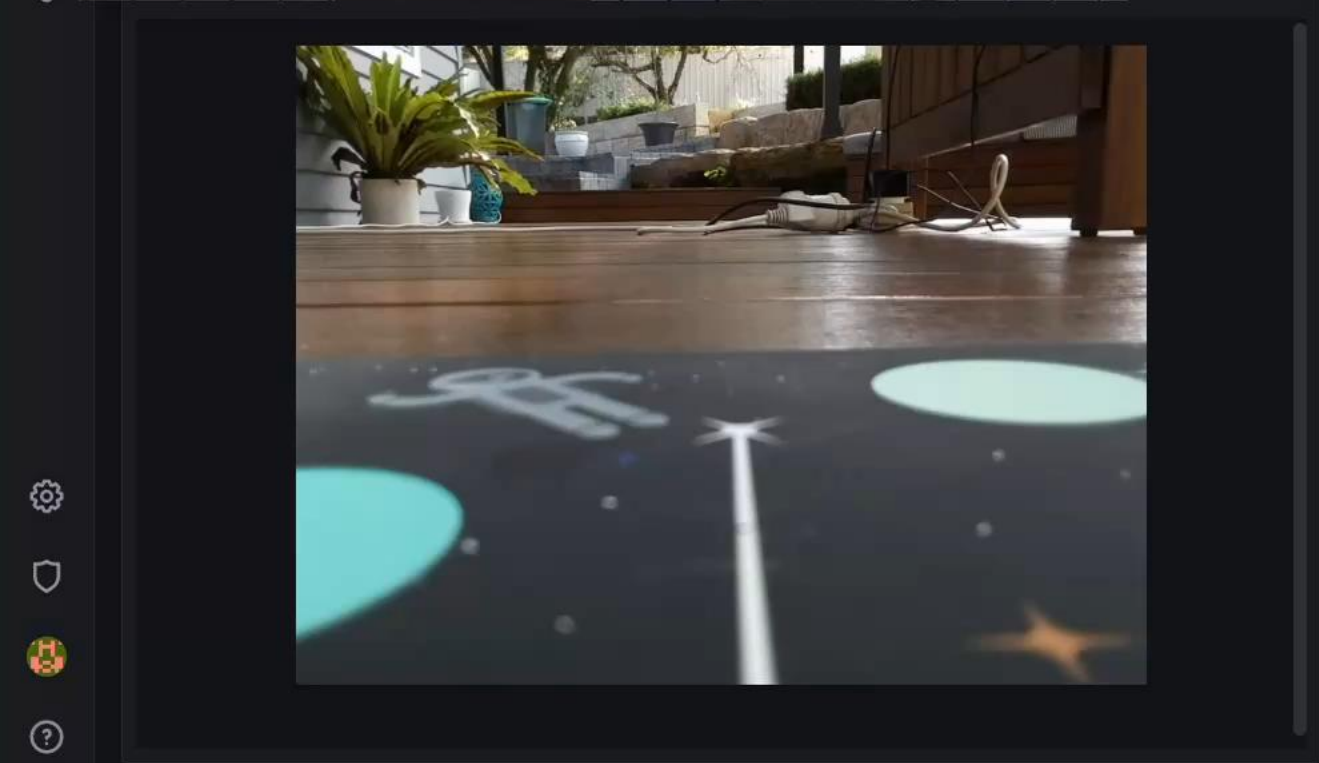
Last 5 minutes

Temperature 3 °C

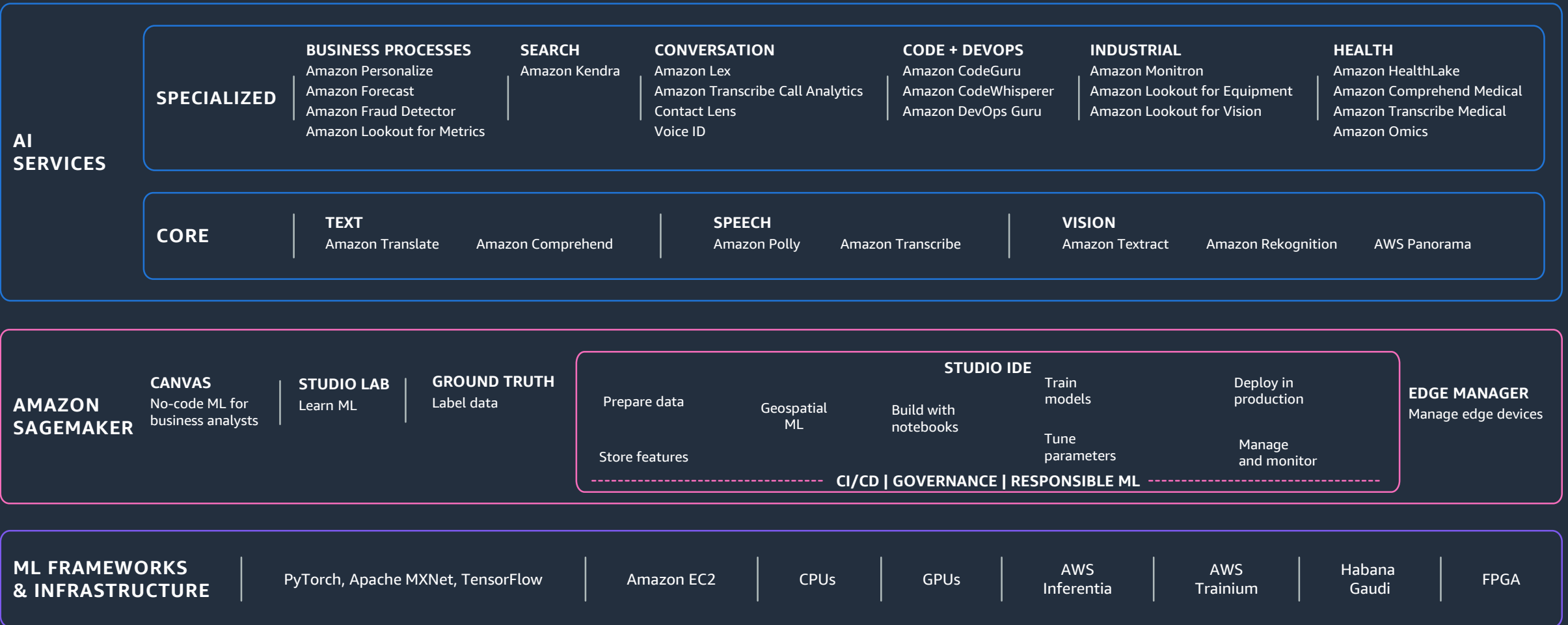
Humidity 48.0 %H

Power 7.38 MW

Turbine Anomalies

A dark-themed dashboard interface. At the top right, there are browser navigation icons and the text 'Incognito'. Below that is a toolbar with icons for charts, a save icon, a settings gear, a clock showing 'Last 5 minutes', a search icon, a refresh icon, and a full-screen icon. The main content area features three large circular gauges: 'Temperature 3 °C' (partially visible), 'Humidity 48.0 %H' (blue), and 'Power 7.38 MW' (green). To the right of these is a wind rose chart with a color scale from 0 to 1. Below the gauges is a large panel titled 'Turbine Anomalies' which is currently empty.

The AWS AI/ML stack



Amazon Rekognition Image and Video



OBJECT, SCENE, AND ACTIVITY



CUSTOM LABELS



CONTENT MODERATION



TEXT



PPE DETECTION



FACE DETECTION AND ANALYSIS



FACE COMPARE & SEARCH



CELEBRITY RECOGNITION



VIDEO SEGMENTS



LIVE STREAM VIDEO



PATHING

Case study: Robot Care Systems

Problem

- Constrained hardware for intelligent capabilities on device
- Costly and time-consuming to build ML capabilities from scratch

Solution

- Offload intelligent capabilities to the cloud
- Built a conversational interface with Amazon Lex
- Built a facial recognition capability with Amazon Rekognition

Business benefits

- Reduced robotic development from months to days
- Reduced hardware costs





AMAZON

SageMaker

Build, train, and deploy ML models for any use case with fully managed infrastructure, tools, and workflows

END-TO-END ML JOURNEY



BUILD



TRAIN



DEPLOY

Amazon SageMaker

PREPARE

- Geospatial:** Visual geospatial data
- Ground Truth:** Create high quality datasets for ML
- Data Wrangler:** Aggregate and prepare data for ML
- Processing:** Built-in Python, BYO R/Spark
- Feature Store:** Store, catalog, search, and reuse features
- Clarify:** Detect bias and understand model predictions



Data Scientist ML Engineer



Business Analyst

BUILD

- Studio Notebooks & Notebook Instances:** Fully managed Jupyter Notebooks with elastic compute
- Studio Lab:** Free ML development environment
- Built-in Algorithms:** Integrated tabular, NLP, and vision algorithms
- JumpStart:** UI based discovery, training, and deployment of models, solutions, and examples
- Autopilot:** Automatically create ML models with full visibility
- Bring Your Own:** Bring your own container and algorithms
- Local Mode:** Test and prototype on your local machine

Studio | RStudio

Integrated development environment (IDE) for ML

MLOps: Pipelines | Projects | Model Registry
Workflow automation, CI/CD for ML, central model catalog

Canvas

Generate accurate machine learning predictions—no code required

Governance

Model cards, Dashboard, Permissions

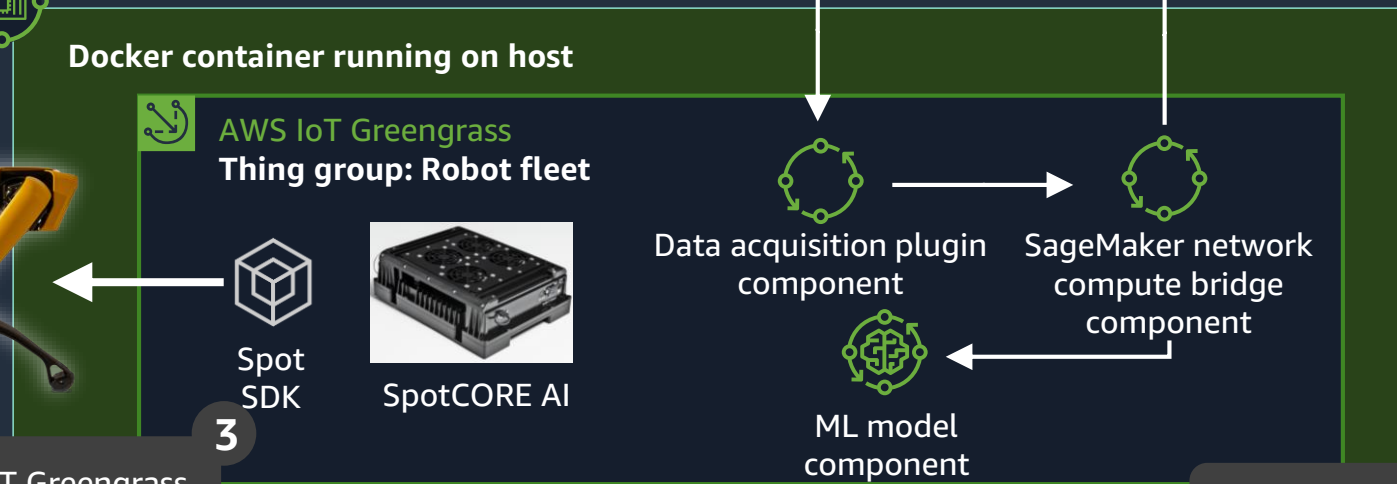
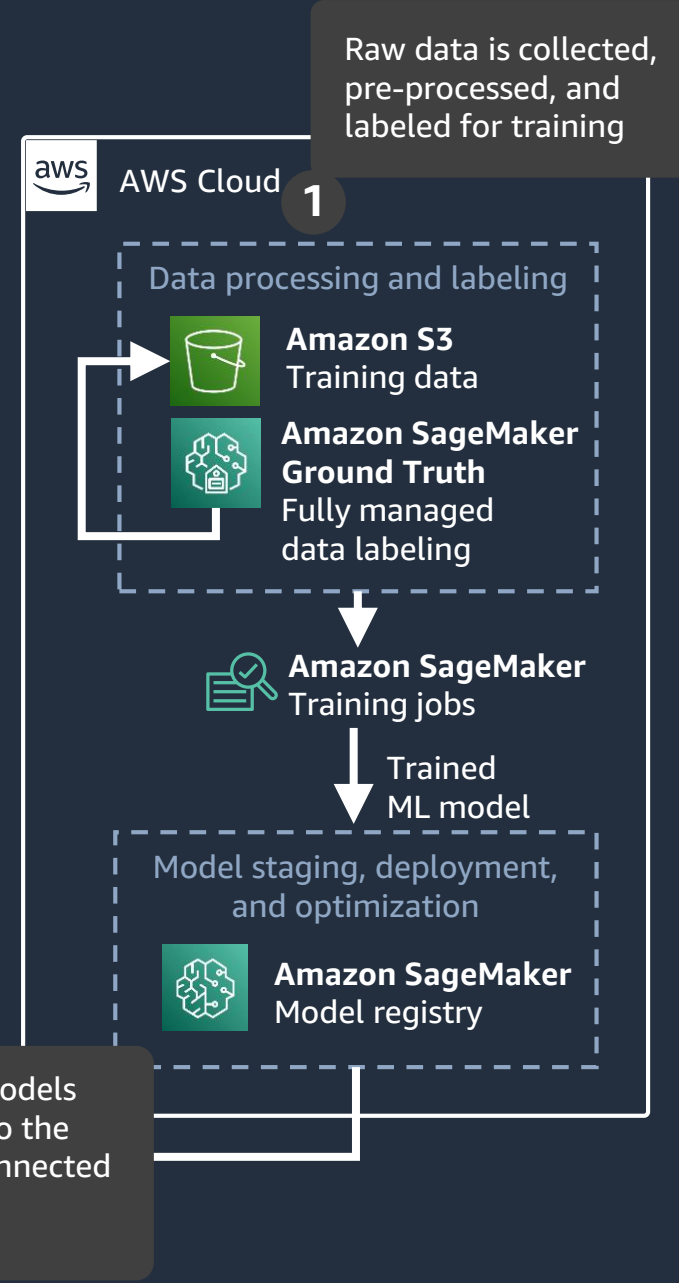
TRAIN & TUNE

- Fully Managed Training:** Broad hardware options, easy to setup and scale
- Distributed Training Libraries:** High performance training for large datasets and models
- Training Compiler:** Faster deep learning model training
- Automatic Model Tuning:** Hyperparameter optimization
- Managed Spot Training:** Reduce training cost by up to 90%
- Debugger and Profiler:** Debug and profile training runs
- Experiments:** Track, visualize, and share model artifacts across teams
- Customization Support:** Integrate with popular open-source frameworks and libraries

DEPLOY & MANAGE

- Fully Managed Deployment:** Ultra low latency, high throughput inference
- Real-Time Inference:** For steady traffic patterns
- Serverless Inference:** For intermittent traffic patterns
- Asynchronous Inference:** For large payloads or long processing times
- Batch Transform:** For offline inference on batches of large datasets
- Multi-Model Endpoints:** Reduce cost by hosting multiple models per instance
- Multi-Container Endpoints:** Reduce cost by hosting multiple containers per instance
- Shadow Testing:** Validate model performance in production
- Inference Recommender:** Automatically select compute instance and configuration
- Model Monitor:** Maintain accuracy of deployed models
- Kubernetes & Kubeflow Integration:** Simplify Kubernetes-based ML
- Edge Manager:** Manage and monitor models on edge devices

FROM DEVELOPMENT TO PRODUCTION - ACCELERATING ROBOTIC DEVELOPMENT WITH CLOUD COMPUTING

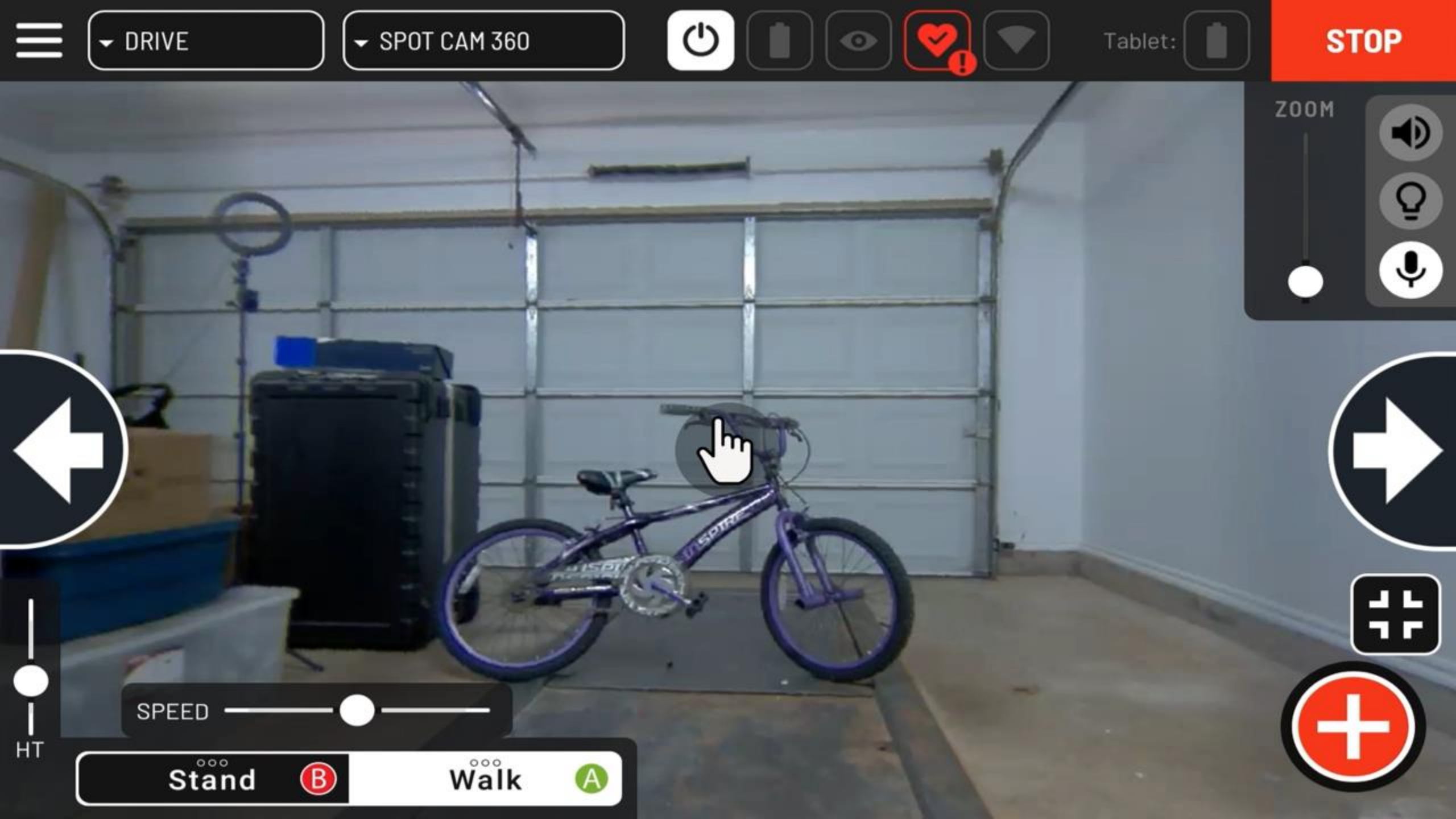


3 The AWS IoT Greengrass components running in a container interact with the Spot SDK

2 Updated ML models are deployed to the robot when connected using AWS IoT Greengrass V2

Model deployment





DRIVE

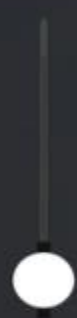
SPOT CAM 360



Tablet:

STOP

ZOOM

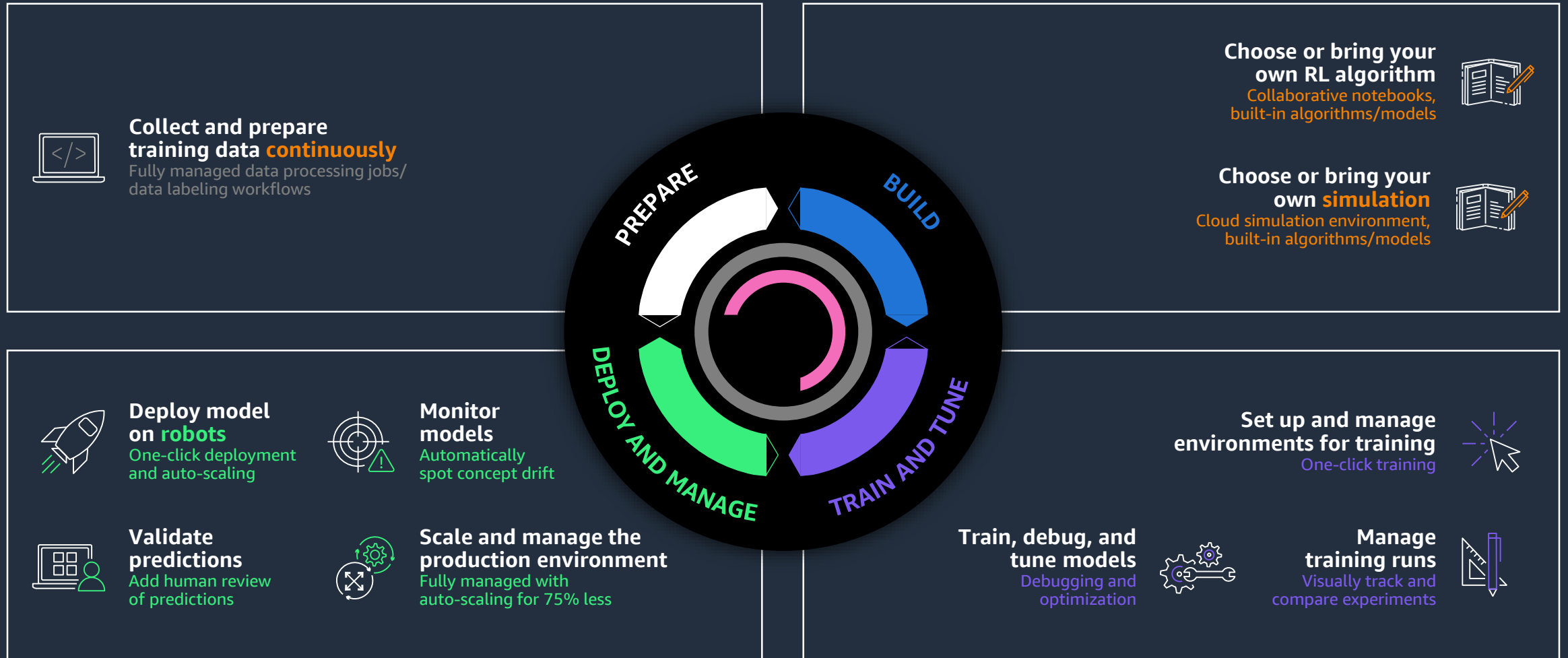


SPEED

HT

Stand Walk

SageMaker Reinforcement Learning



WEB-BASED IDE FOR ML AUTOMATICALLY BUILD AND TRAIN MODELS

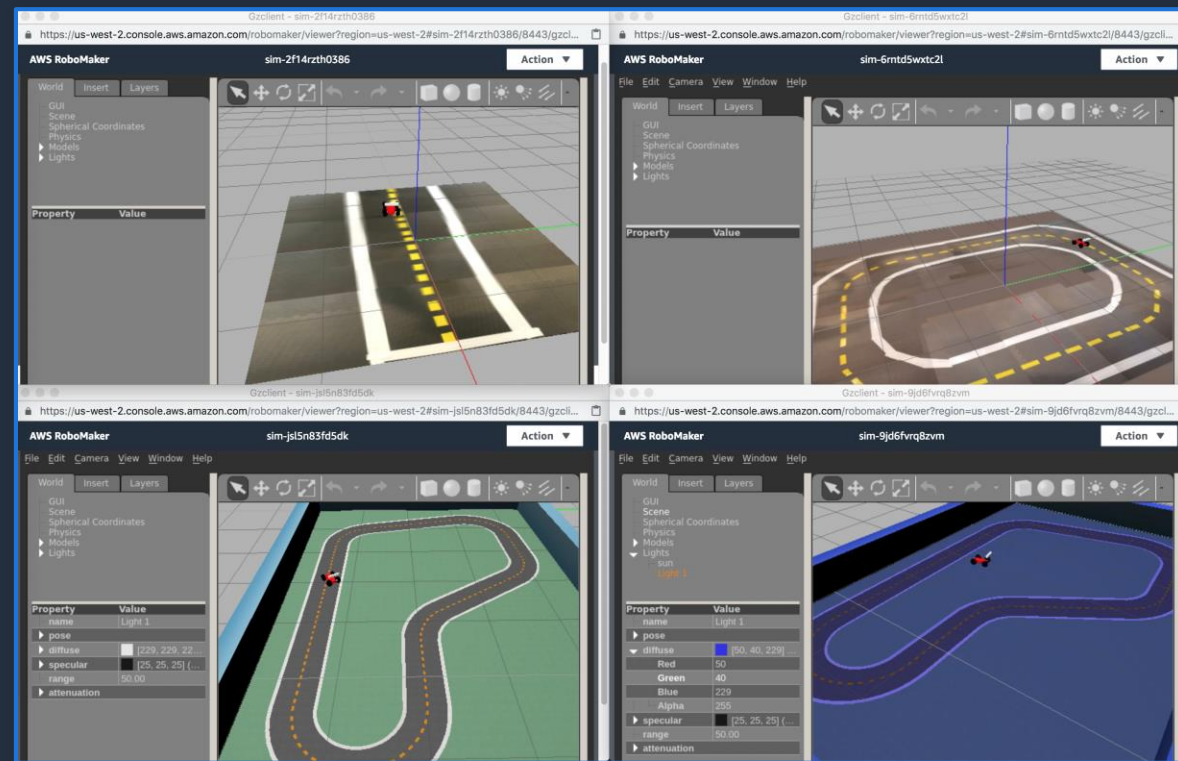
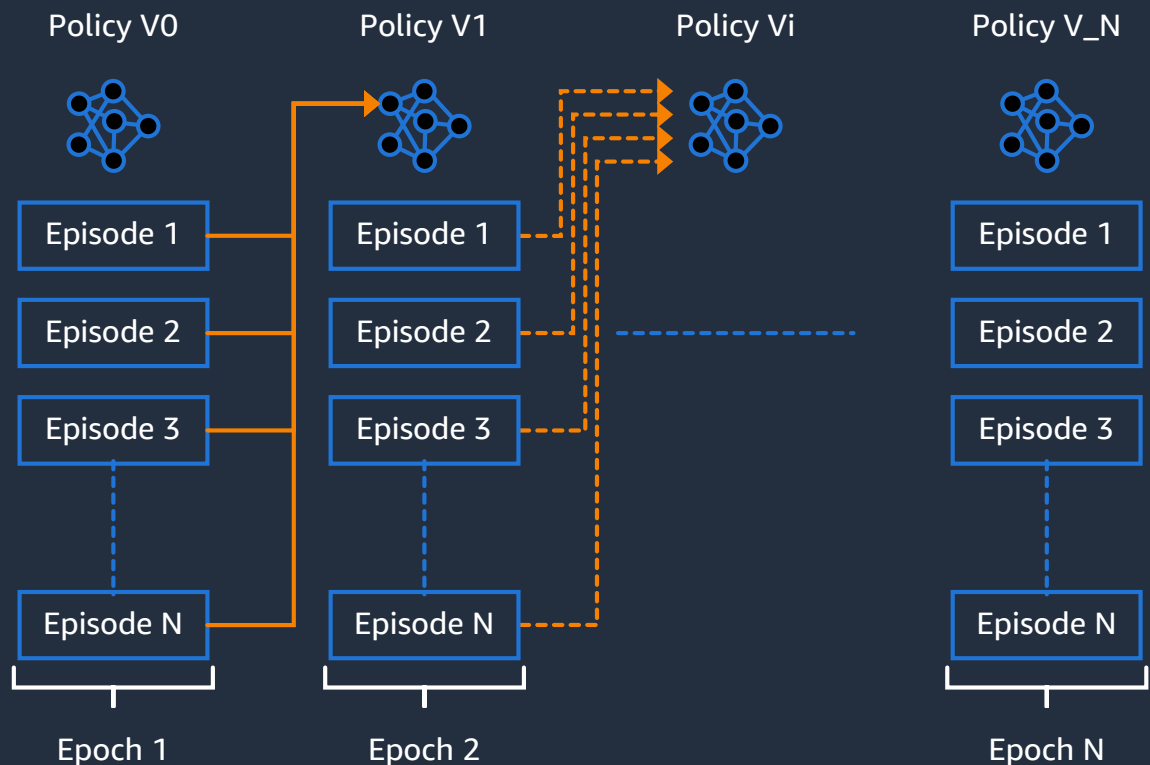


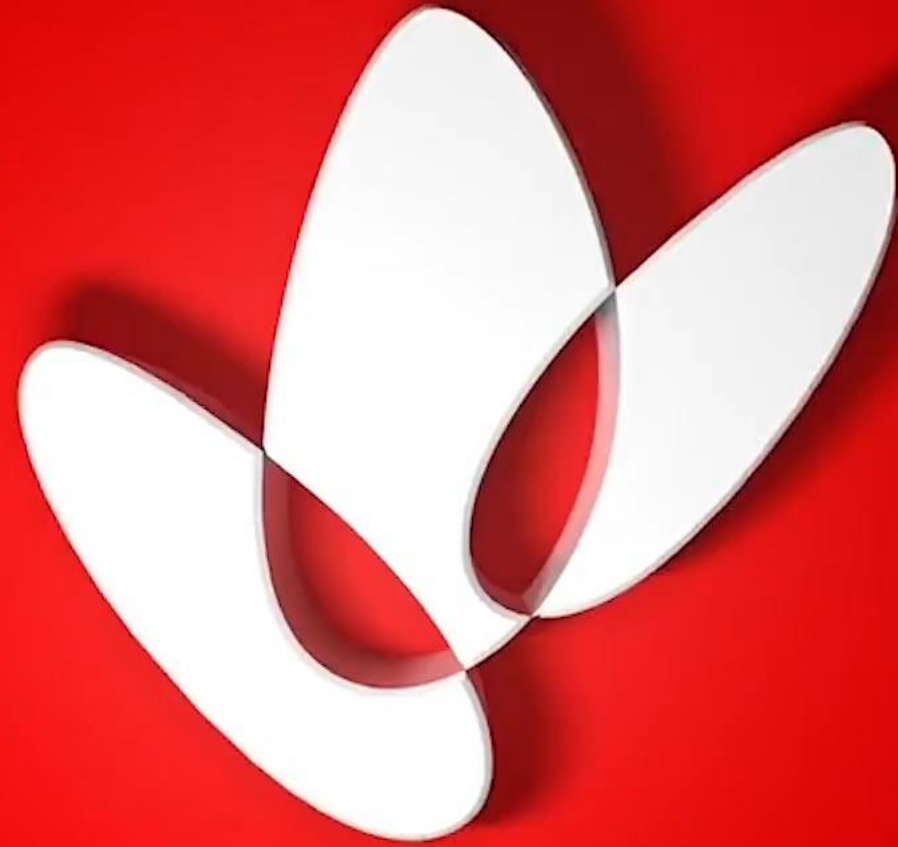
Scaling Simulation Environments

Faster training

Run a large number of simulations in parallel

Run at faster than real-time speed





Test and Verify



Release process stages



- Check-in source code
- Peer review new code

- Compile code
- Unit tests
- Style checkers
- Create container images and function deployment packages

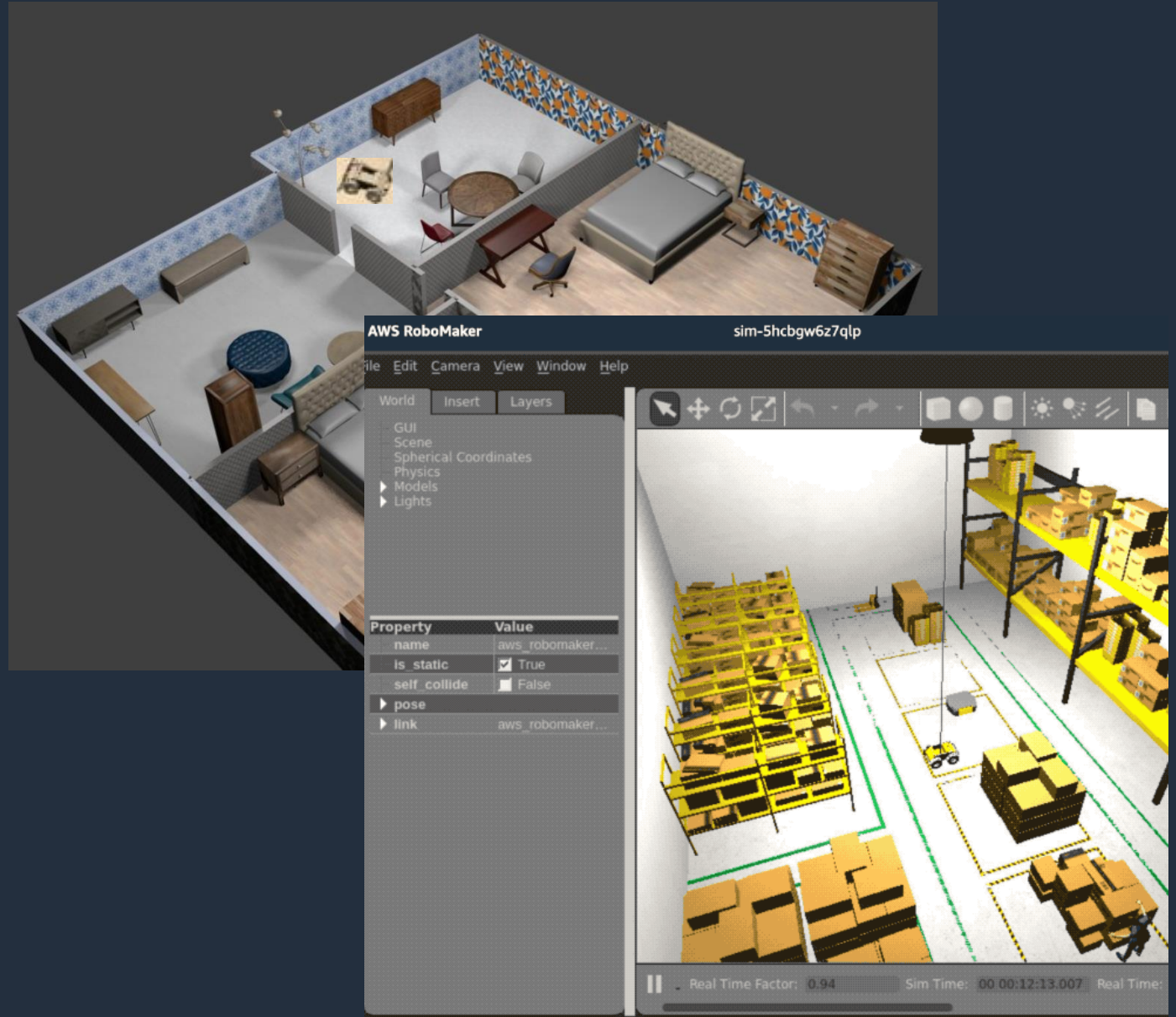
- Integration testing with other systems
- Load testing
- UI testing
- Security testing

- Deploy to production environments
- Monitor code in production to quickly detect errors

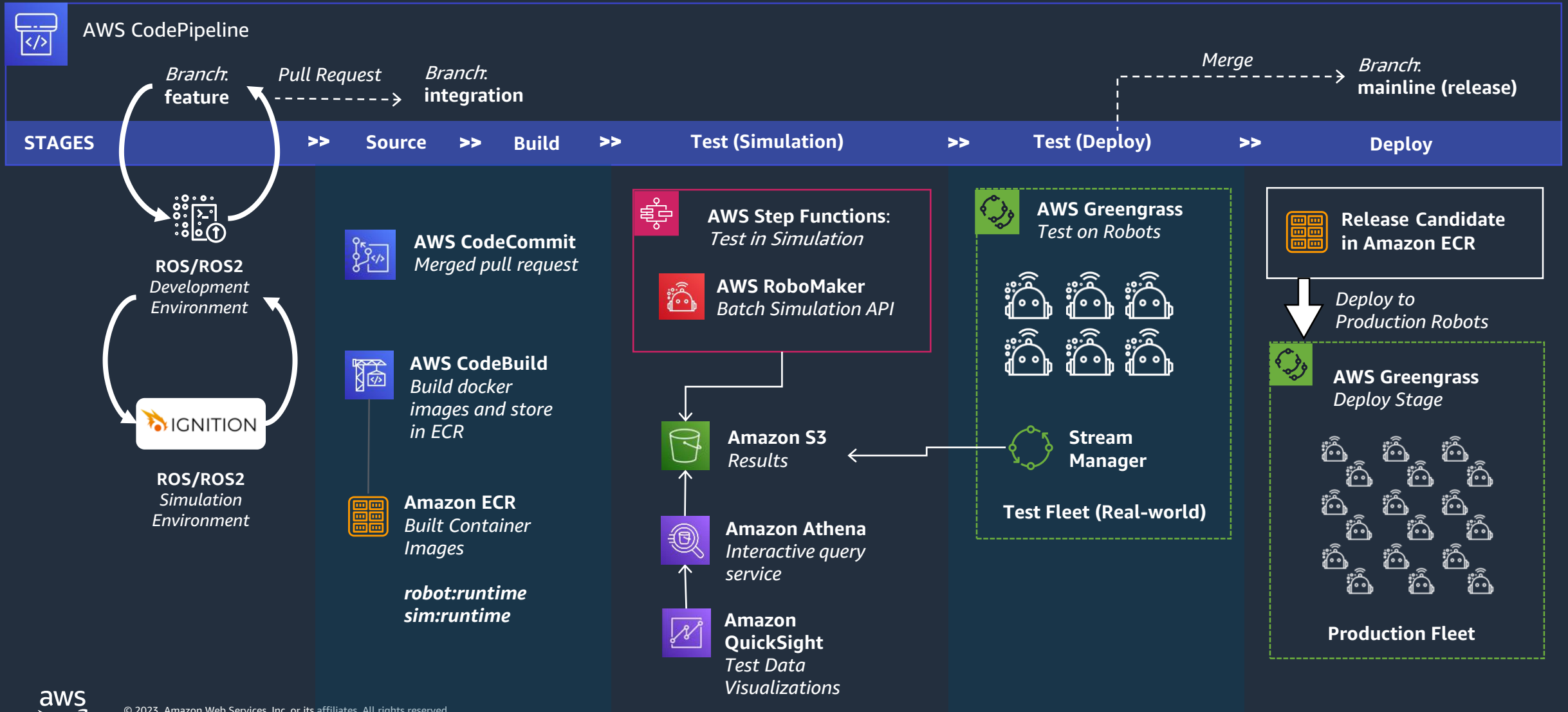
AWS RoboMaker

Key features

- Serverless container-based high fidelity simulations with an API
- GUI applications over a browser
- Batch simulation
- CI/CD for robotics



Example Solution: Robot Application CI/CD Pipeline with AWS



Case study: Regression testing

Problem

- Limited test coverage for different floor layouts and scenarios
- Costly and time-consuming to test
- Late bug discovery in the field

Solution

- iRobot built a CI/CD pipeline for large-scale and automated testing using the AWS RoboMaker simulation service
- More than 40 automated tests on each code commit and more than 500 automated tests for each release candidate

Business benefits

Much faster testing and release cycle (1 hour vs. 3 weeks for testing 70 complex localization scenarios)





Deploy and Update

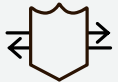


AWS IoT architecture



Analytics
Services

How can I make sense of my IoT data and take appropriate actions?



Connectivity
and Control
Services

How can I control, manage, and secure my devices at scale?

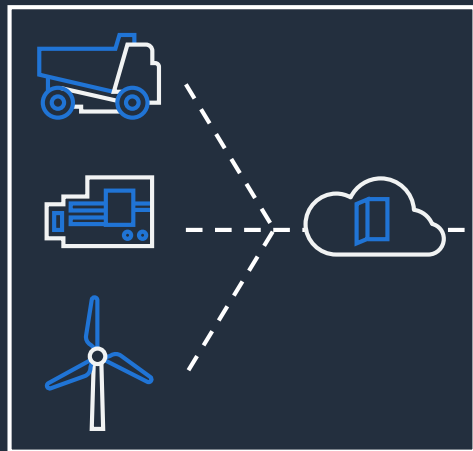


Device
Software

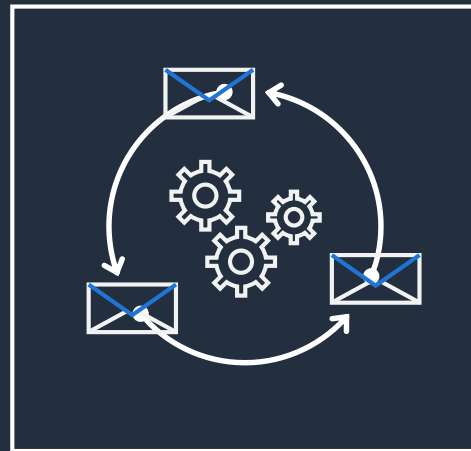
How can I build devices that operate at the edge?

AWS IoT Core

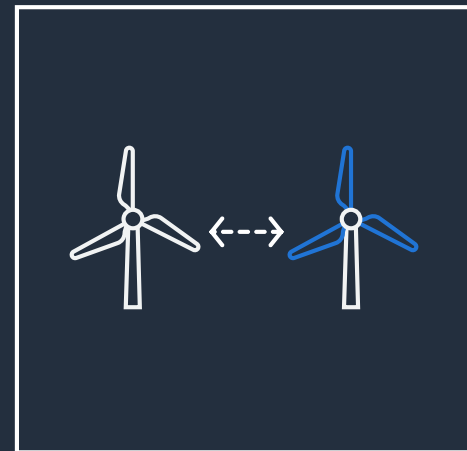
AWS IoT Core is a managed service that lets connected devices easily and securely interact with cloud applications and other devices



To securely connect devices to the AWS cloud & other devices at scale



To route, process, and act upon data from connected devices



To enable applications to interact with devices even when they are offline



To fully integrate with other AWS services to reason on top of the data (Analytics, Databases, AI, etc.)

Device Shadow

Understand and control the status of your device at any time

Reporting the last known state of the device;
e.g., the last known color of the light bulb is red

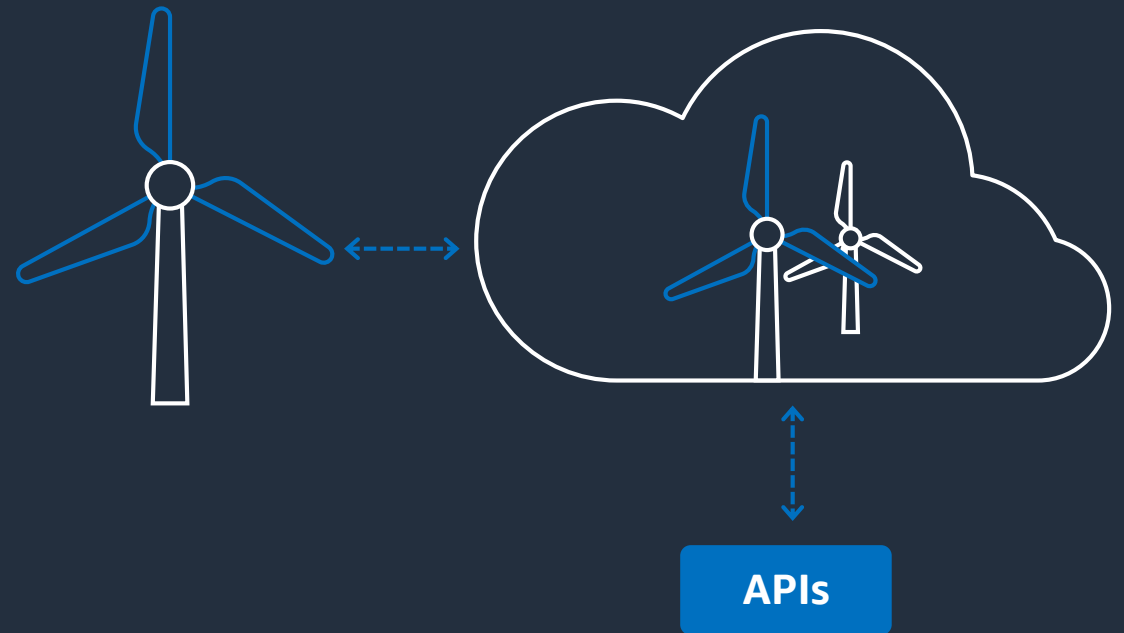
Changing the state of the device; e.g., change
the color of the light bulb to blue

Real time notification of state changes using MQTT

Asynchronous communication with offline devices

Device SDK integration for easy
implementation on devices

REST APIs for applications to interact with devices



Rules Engine

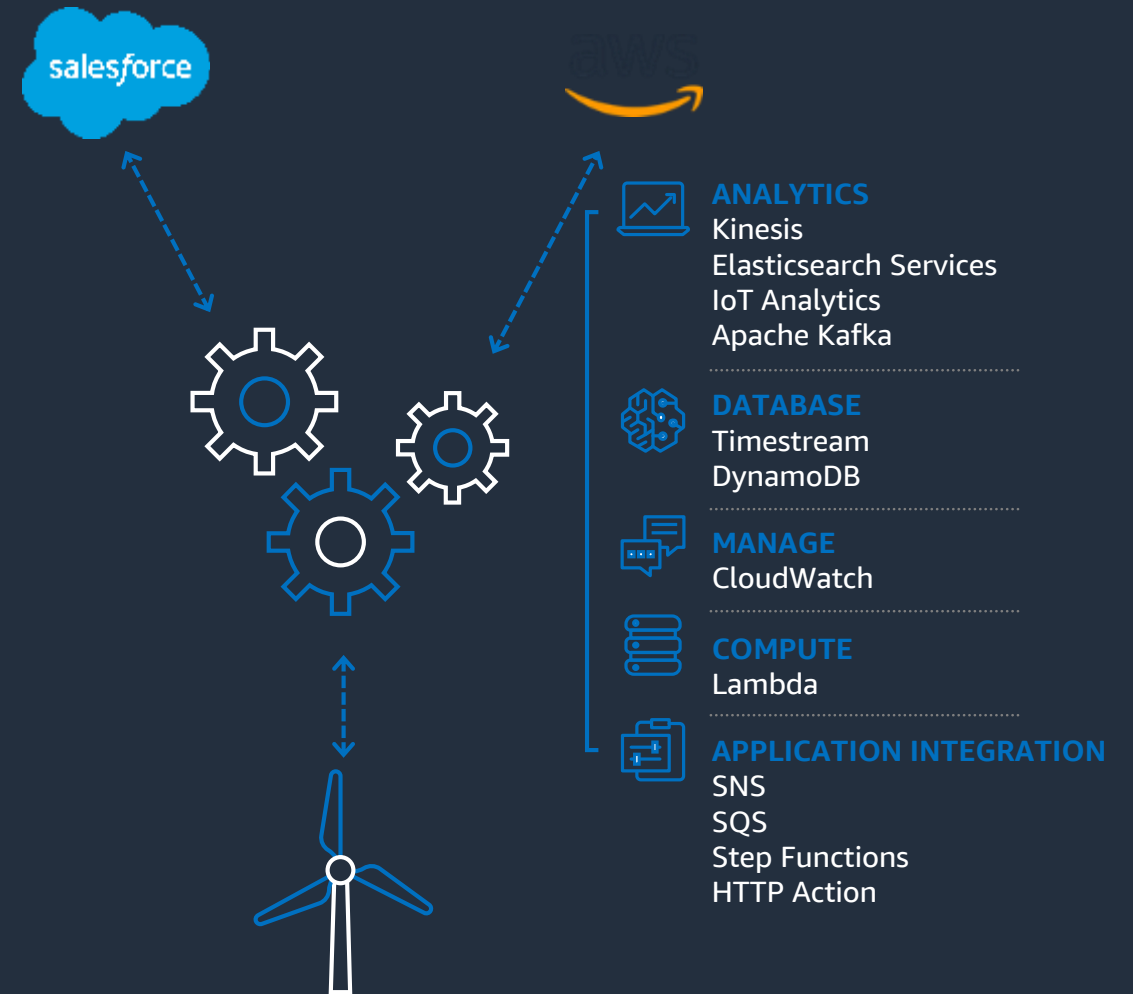
Ingest large amounts of data at a low cost, pre-process it, and make it available to 20+ services for analytics, reporting, and visualization

Transform — built in functions for math, string manipulation, dates, Protobuf decoding, etc.

Filter — use the WHERE clause to capture only the data you want.

Take actions - specify what to do when a rule is triggered. For example, send you device's location data to Amazon Location Service.

Route — send your data to over 20 AWS services and third-party services like Salesforce, etc.



AWS IoT Greengrass

Security—at-rest and in-transit



Security

- Encrypting data in-transit/at-rest
- Encrypted communication
- Support for Hardware Security Module



Device Development

- Portability across hardware, OS and programming languages
- Simplified fleet provisioning
- Prebuilt components



Deploying and Running Edge Devices

- Message Queuing Telemetry Transport Support (MQTT)
- AI/ML models deployed for inference at the edge
- Container Support
- Intermittent or offline operation



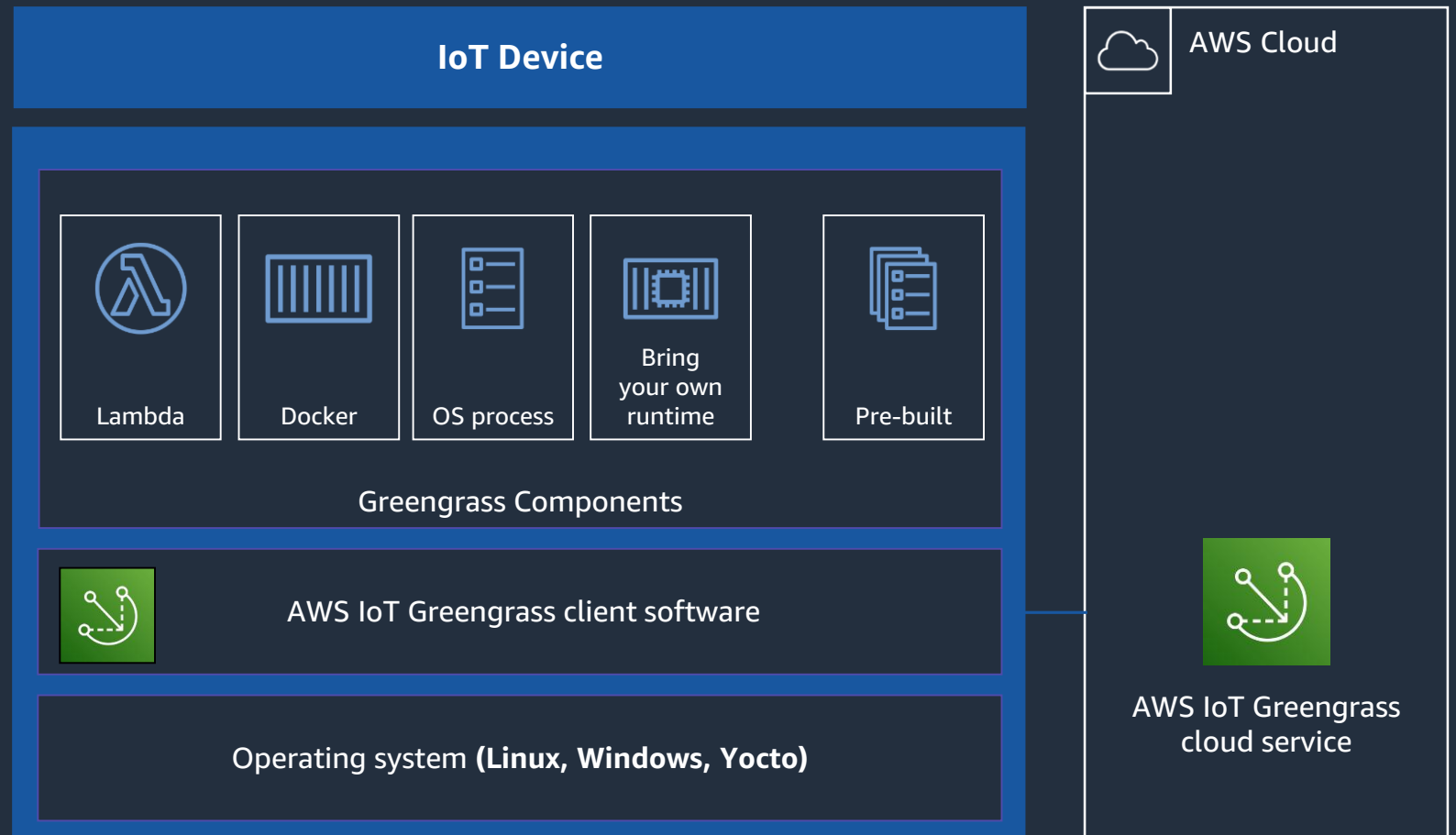
Managing Edge Devices

- Fleet and Device Software Management at scale
- Over-the-Air (OTA) Support

AWS IoT Greengrass Components

Key features

- Open source client software
- Device-side dev tools—iterate quickly with CLI and local console
- Portability across HW(ARM/x86), OS, languages (C/C++, Java, Python, JS/Node)
- Apps consist of modular components– use pre-built components or your own software (new or legacy code)
- Software catalog on GitHub with components such as data streaming to Amazon KVS, Modbus TCP protocol support, local InfluxDB time-series database



AWS IoT Greengrass prebuilt components



Public components are prebuilt; AWS provides components with common functionality that you can deploy to your robots

Examples of prebuilt AWS integrations to speed up development time



Edge ML inference frameworks

With TensorFlow or Amazon SageMaker Neo Deep Learning Runtime (DLR)

Includes pretrained models for object detection and image classification



Log manager

Automatically capture component logs in the cloud with Amazon CloudWatch Logs



Kinesis Video Streams

Read video feeds from local cameras and publish them to Kinesis Video Streams



Secure tunnels

Enable remote access to robots over secure tunneling



And more

More than 20 public components are available today

AWS IoT Greengrass OTA software updates



Configurable
deployment rate



Failure
thresholds



Timeouts

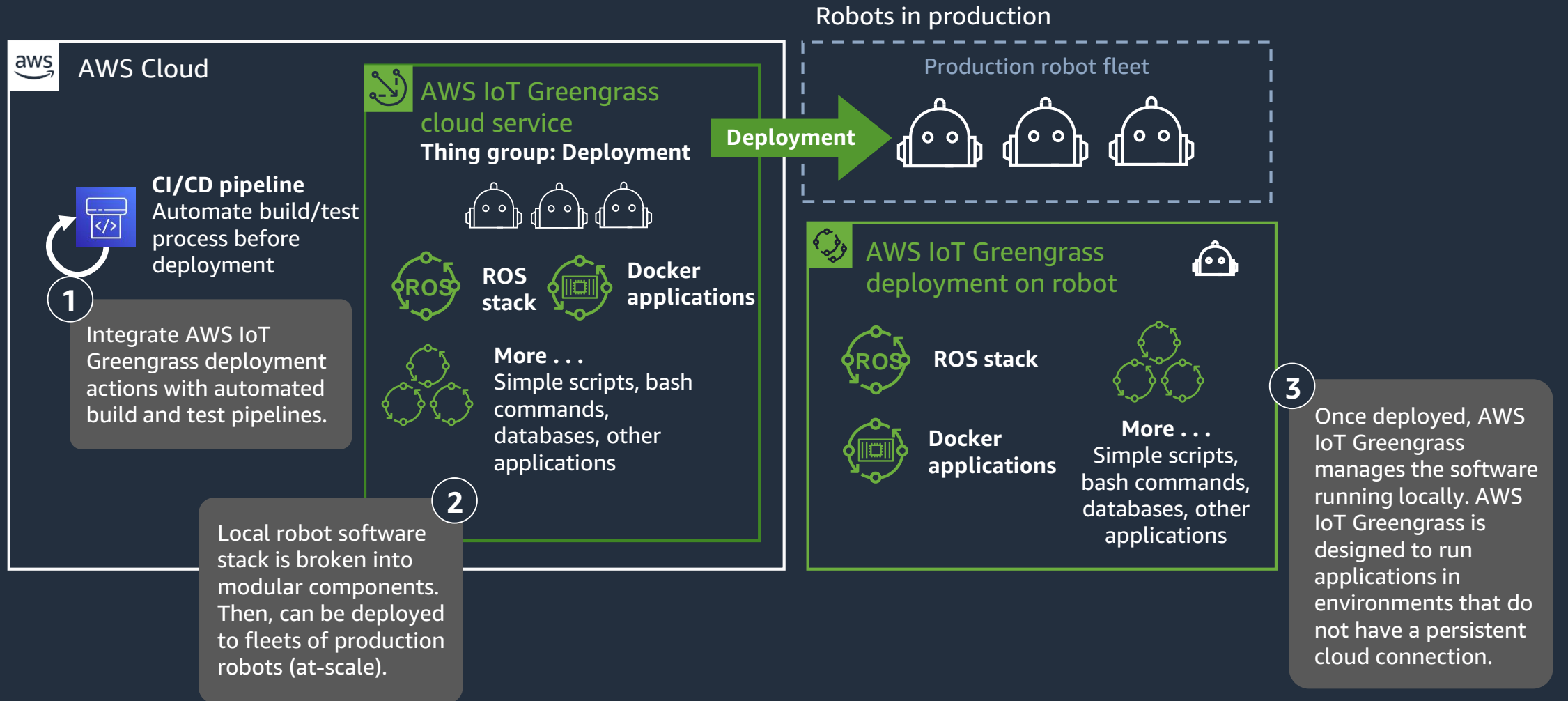


Component
rollback

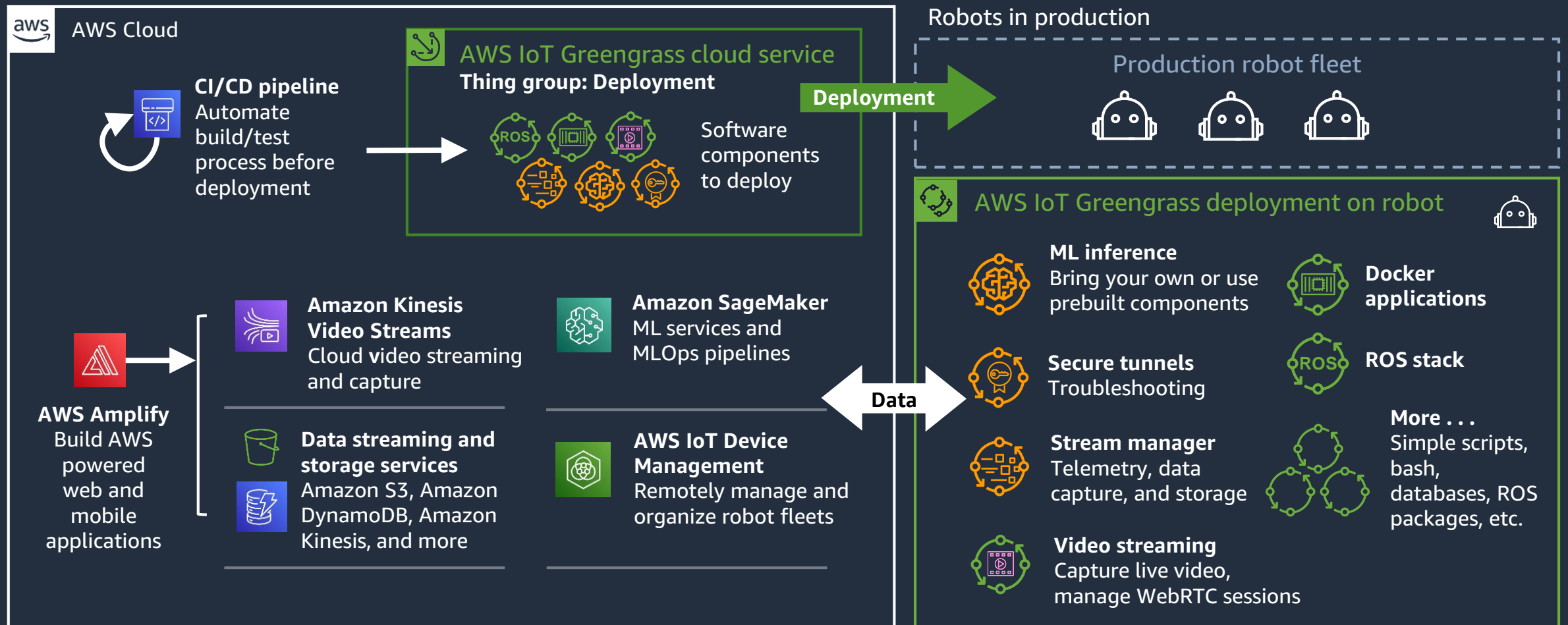


Conditional
update workflow

Deploying and managing software on robots



Building cloud-enhanced robots with AWS



ST Engineering

CHALLENGE

Technology and engineering group ST Engineering wanted to migrate its infrastructure to the cloud so it could scale to support its RaaS business model and quickly develop a cloud-based robotic fleet management software.

SOLUTION

ST Engineering migrated to the cloud and adopted AWS IoT Greengrass and Amazon Kinesis Video Streams, providing its robots with connectivity to the cloud and the capability to stream live video footage to customers.

IMPACT

- Achieved a scalable infrastructure that supports its robotic fleets
- Developed a cloud-based robotics FMS solution
- Supports a virtually unlimited amount of simultaneous live video streams

“Amazon Kinesis Video Streams is very straightforward and easy to use.”

—Yoke Kong, principal engineer of the solution team, ST Engineering



FROM DEVELOPMENT TO PRODUCTION - ACCELERATING ROBOTIC DEVELOPMENT WITH CLOUD COMPUTING



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Thank you!

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