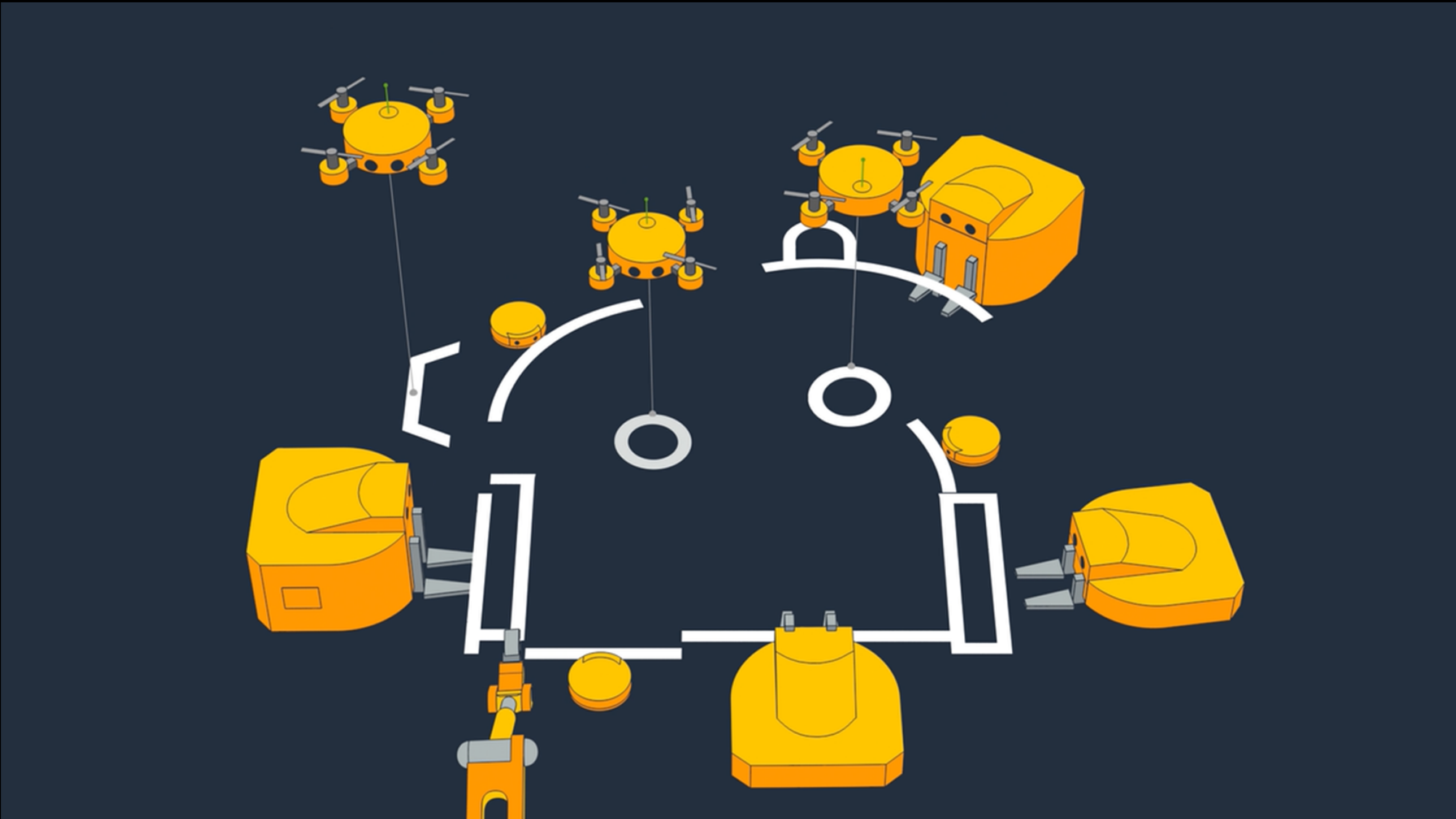

Role of the Cloud in the Future of Robotics

Roger S. Barga
GM, AWS Robotics

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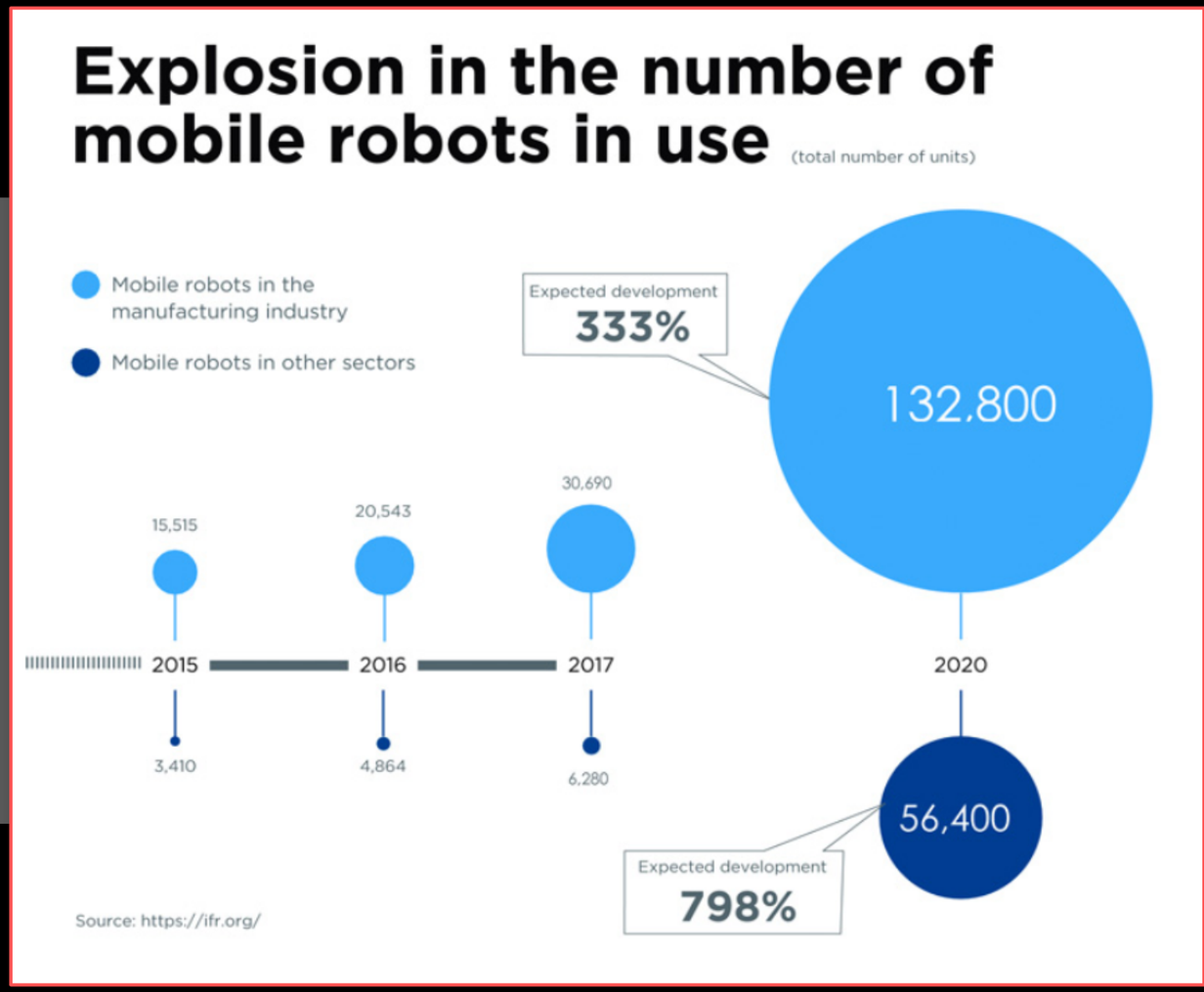
Mobile Robotics

We are at an inflection point
Expected growth in the use of mobile robots will increase by almost tenfold over the next two to three years



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Mobile Robotics

By **2023**

it's estimated that mobile autonomous robots will emerge as the standard for logistic and fulfillment processes

By **2030**

70% of all mobile material handling equipment will be autonomous

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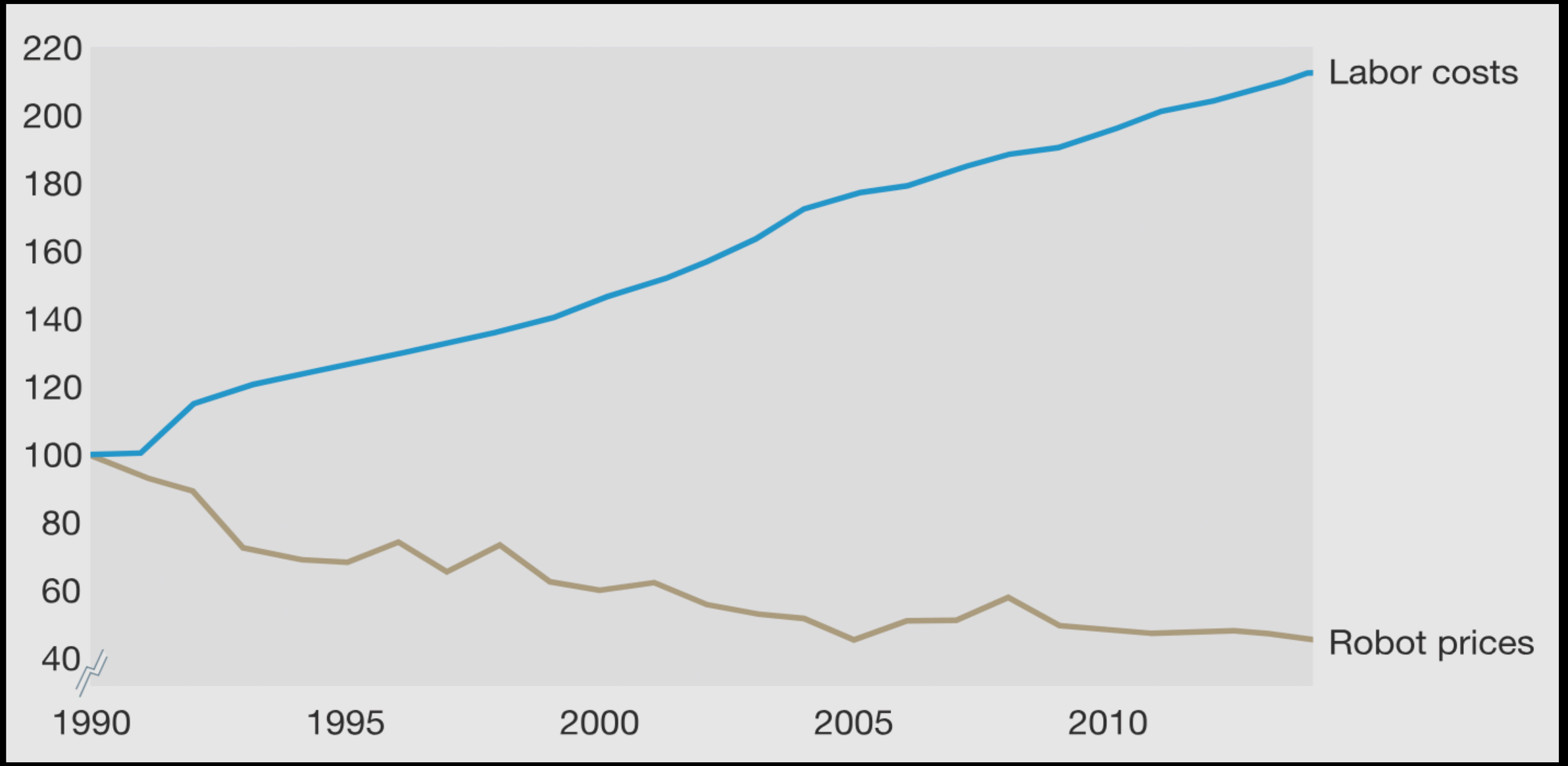
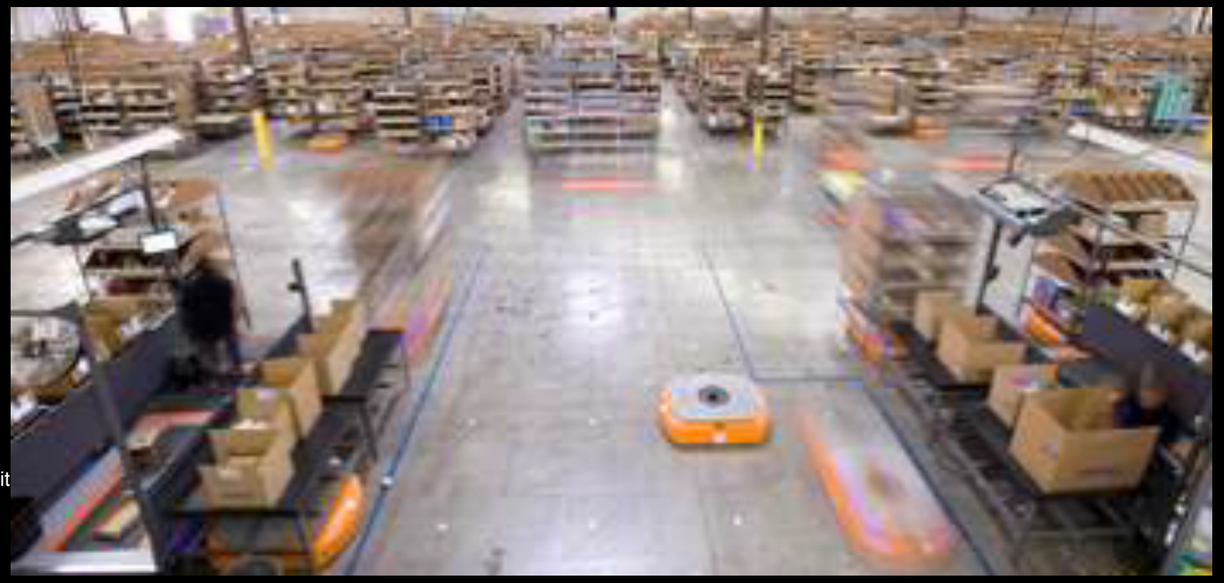
The Pull of Economics



Modern Automation in Warehouse

- Autonomous robots
- Robots search for items, bring to a human
- Robots co-ordinate to achieve a system goa
- Many orders fulfilled simultaneously
- Increases productivity
- Maximizes throughput



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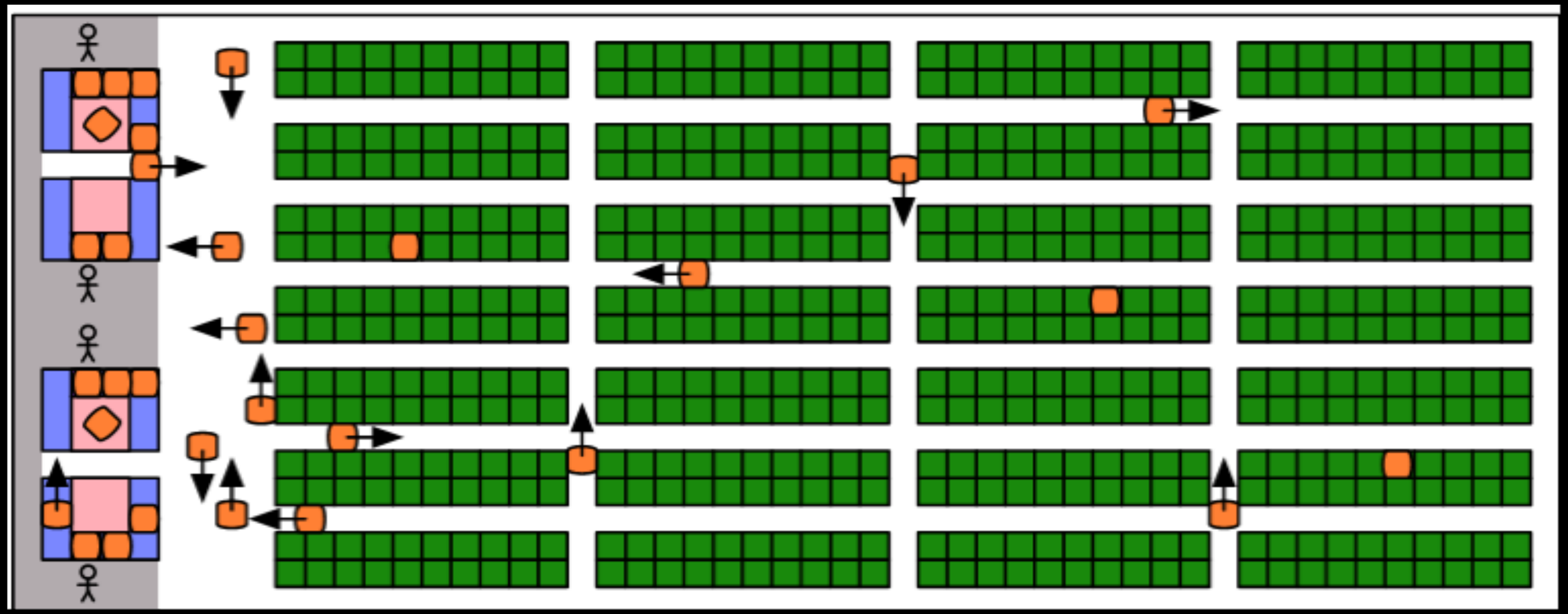
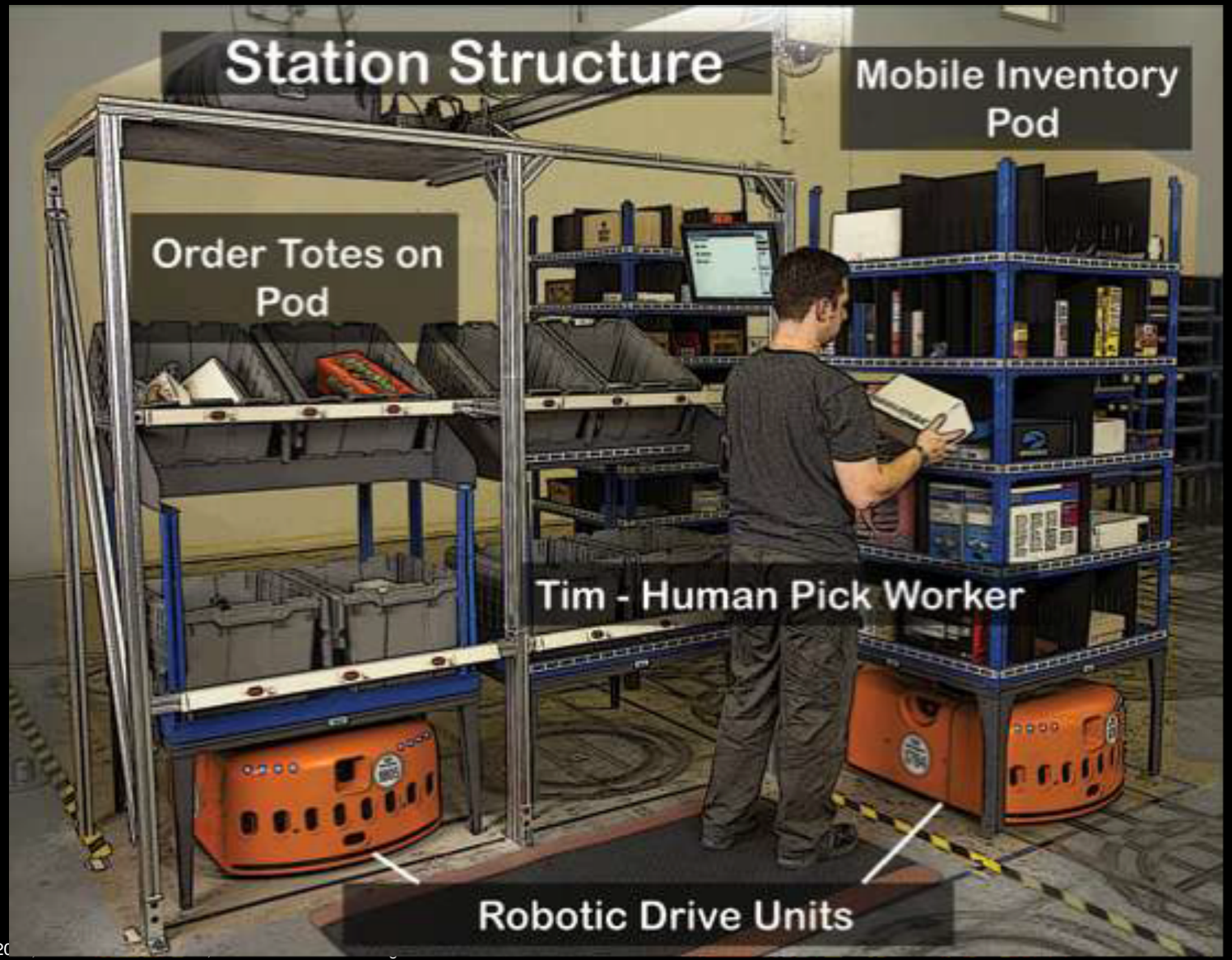
System Layout



Green: Storage Area
Orange: Mobile Robots
Blue: Stations

Kiva Robots and Pods



© 20

and yet...

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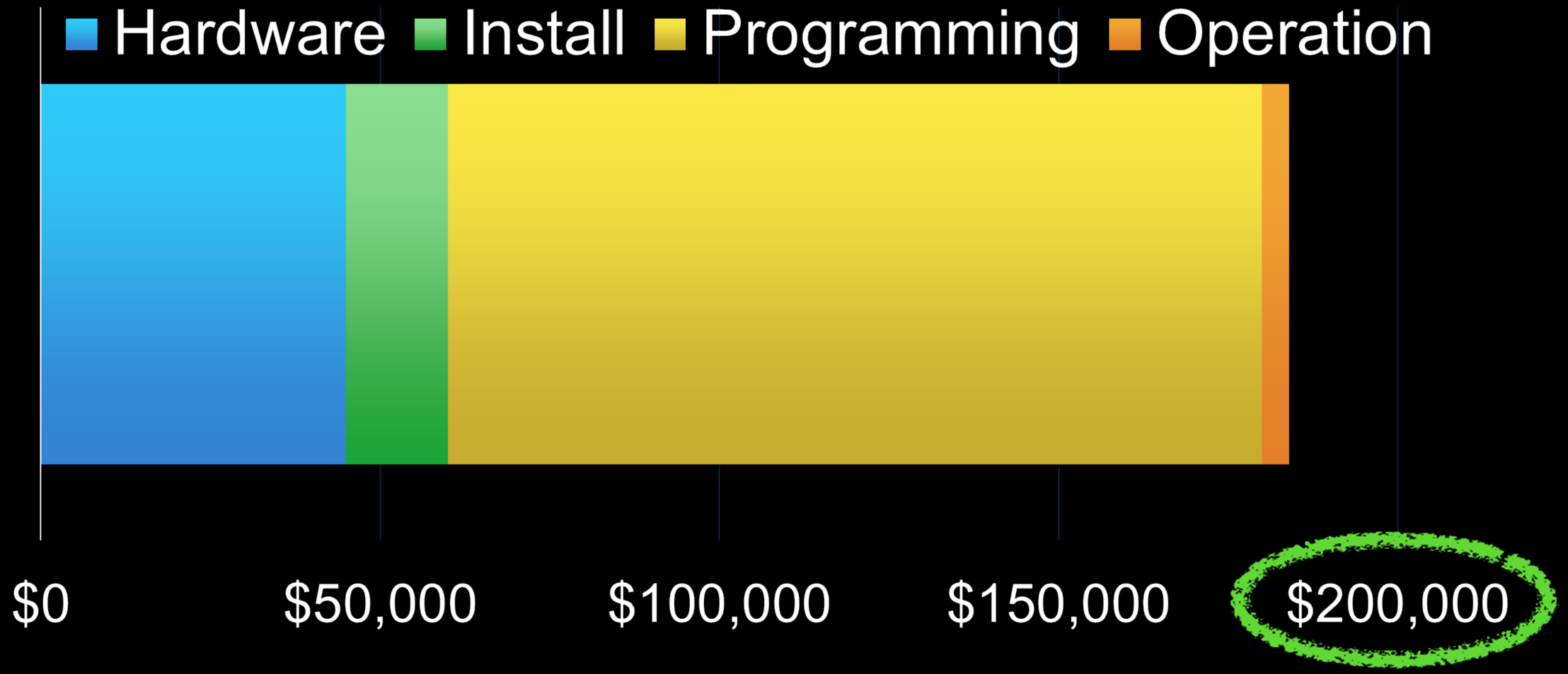
Cost breakdown of a robotic work cell



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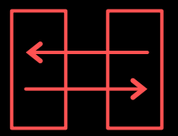
Where does the time go?

Days spent setting up and configuring

Many prototyping iterations

Requires machine learning expertise for intelligent functions

Months to building a realistic simulation environment



Duplicated efforts integrating an application management system

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AWS RoboMaker
DevOps for Robotics

A service that makes it easy for developers to develop, test, and deploy robotics applications, as well as build intelligent robotics functions using cloud services

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Robot Operating System (ROS)

Most widely used software framework for teaching and learning about robotics – over 16 million .deb (Linux Debian) packages downloaded in 2018, a 400% increase since 2014

Founded in Stanford labs over 10 year ago, now managed by the Open Source Robotics Foundation (OSRF)

Global open-source community supports two products—Robot Operating System (ROS) and Gazebo

ROS

A set of software libraries and tools, from drivers to algorithms, that help developers build robot applications

Gazebo

Robust physics engine, high-quality graphics, and programmatic and graphical interfaces to help developers simulate robots

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ROS 2 Technical Steering Committee

amazon

Apex.AI

arm

BOSCH
Invented for life

intel

LG

Microsoft

open robotics

ROBOTIS

TARDEC

TOYOTA
RESEARCH INSTITUTE

Robot Operating System (ROS)

Why ROS 2?

Designed for Production

Drawing on a decade of experience establishing ROS 1, ROS2 was built from the ground up to be used in production, including high reliability and safety critical systems.

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Robot Operating System (ROS)

Why ROS 2?

Designed for Production

Multi-Platform

ROS2 has first class support for Linux, Windows, and macOS. Allows for ports to new platforms, such as real-time and embedded OSs.

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Robot Operating System (ROS)

Why ROS 2?

Designed for Production

Multi-Platform

No Vendor Lock-In

ROS2 middleware (rmw) layer at the core of ROS2 embodies key abstractions required for a distributed system based on publish-subscribe semantics.

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Robot Operating System (ROS)

Why ROS 2?

Designed for Production

Multi-Platform

No Vendor Lock-In

Built on Open Standards

Communications method in ROS2 use industry standard DDS and RTPS, both widely deployed in a variety of industrial applications, from factories to space.

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Robot Operating System (ROS)

Why ROS 2?

Designed for Production

Multi-Platform

No Vendor Lock-In

Built on Open Standards

Permissive Open Source License

ROS2 licensed under Apache 2.0 License, with ported ROS1 code under the 3-clause (or “new”) BSD License.

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Robot Operating System (ROS)

Why ROS 2?

Designed for Production

Multi-Platform

No Vendor Lock-In

Built on Open Standards

Permissive Open Source License

Global Community

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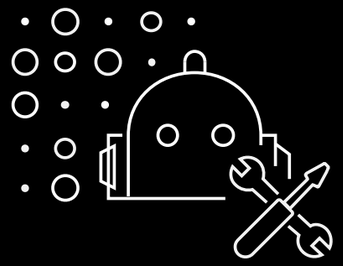
AWS RoboMaker

Development Environment



Cloud Extensions for ROS

Simulation

Fleet Management

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AWS RoboMaker

Development Environment

- Start development with zero setup effort
- Create a RoboMaker development environment with a single click of a button
- Includes pre-installed RoboMaker cloud extensions and sample robotics applications
- Automatic download, compile and configuration of operating system, development software, and ROS

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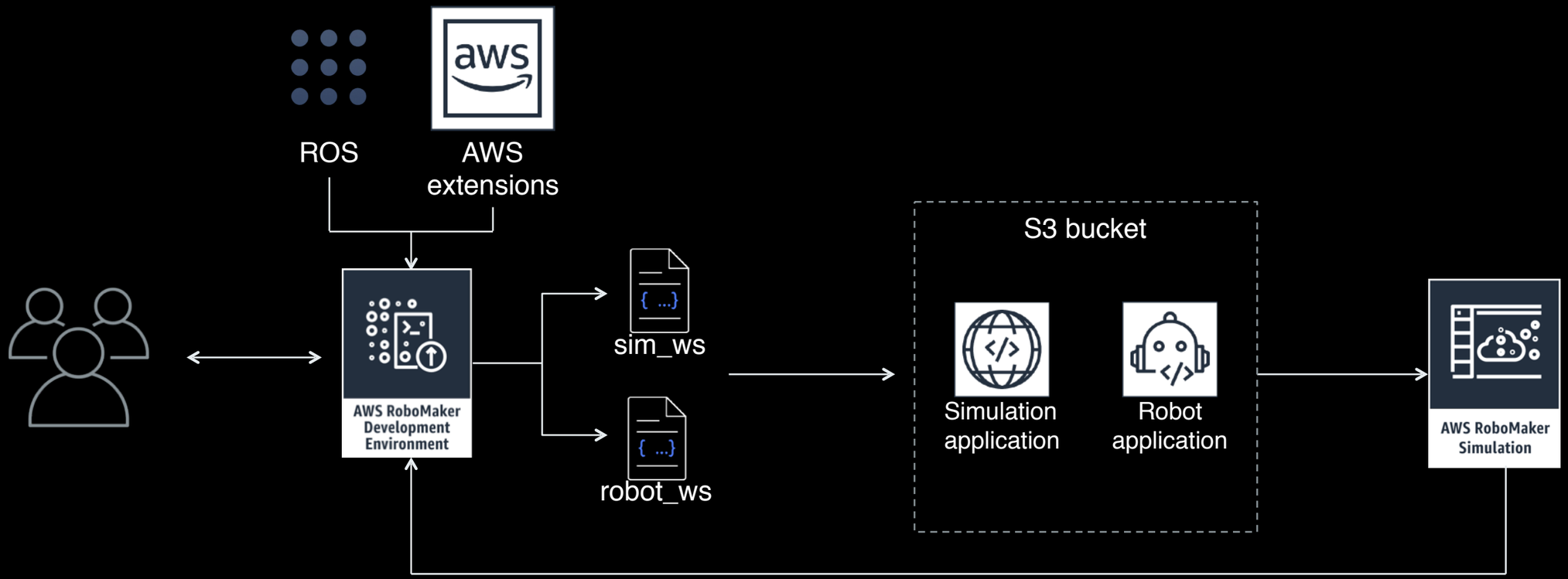
AWS RoboMaker

Development Environment



Develop *Build* *Bundle* *Simulate*

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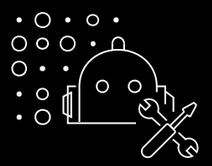


AWS RoboMaker

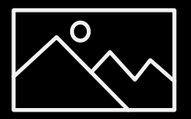
Cloud Extensions for ROS

Cloud extensions written as ROS packages automatically create connections and make API calls to AWS services, such as Amazon Lex, Amazon Polly, Amazon Kinesis Video Streams, Amazon Rekognition, and Amazon CloudWatch

LEX
speech
recognition

POLLY
speech
generation

KINESIS
VIDEO
STREAMS
video streams



REKOGNITION
image and video
analysis

CLOUDWATCH
logging and monitoring

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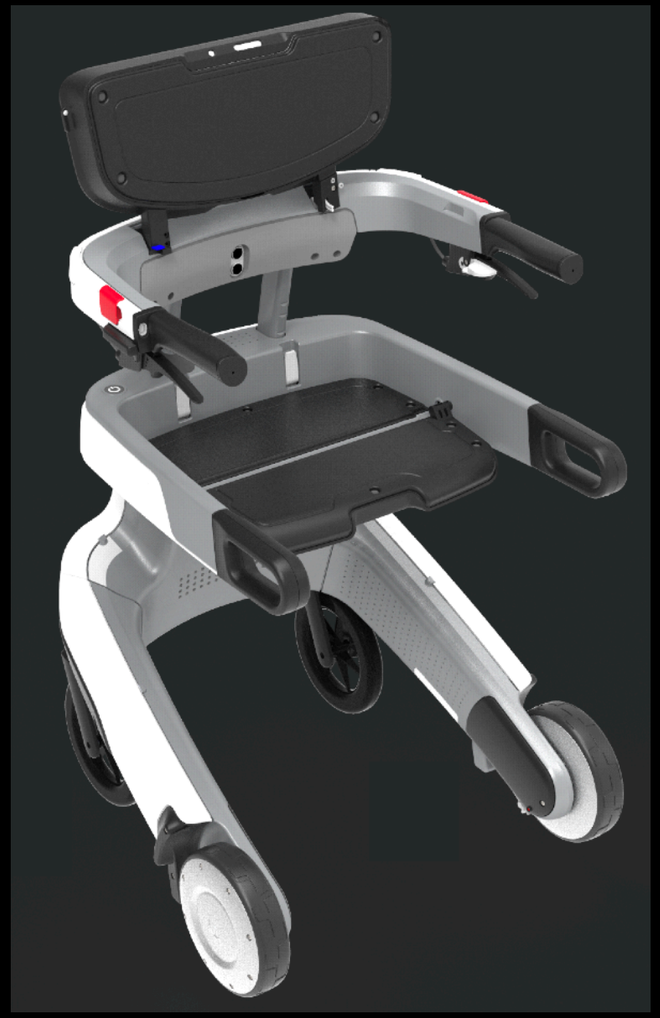
LEAN
EMPOWERING
ASSISTANT



- 72 Sensors
- Low-end CPU
- Cloud support
- Redundancy & Safety
- Open source ROS & ROL
- End-to-End custom design

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Cloud Powered Future

RoboMaker: Simulations and parameter tuning
RoboMaker-Kinesis: Real-time data streaming
RoboMaker-Lex-Polly: Enhanced interactivity
EC2/S3: Remote portal and Deployment

Analysis: Walking gait of patient

Prediction: Recovery progression

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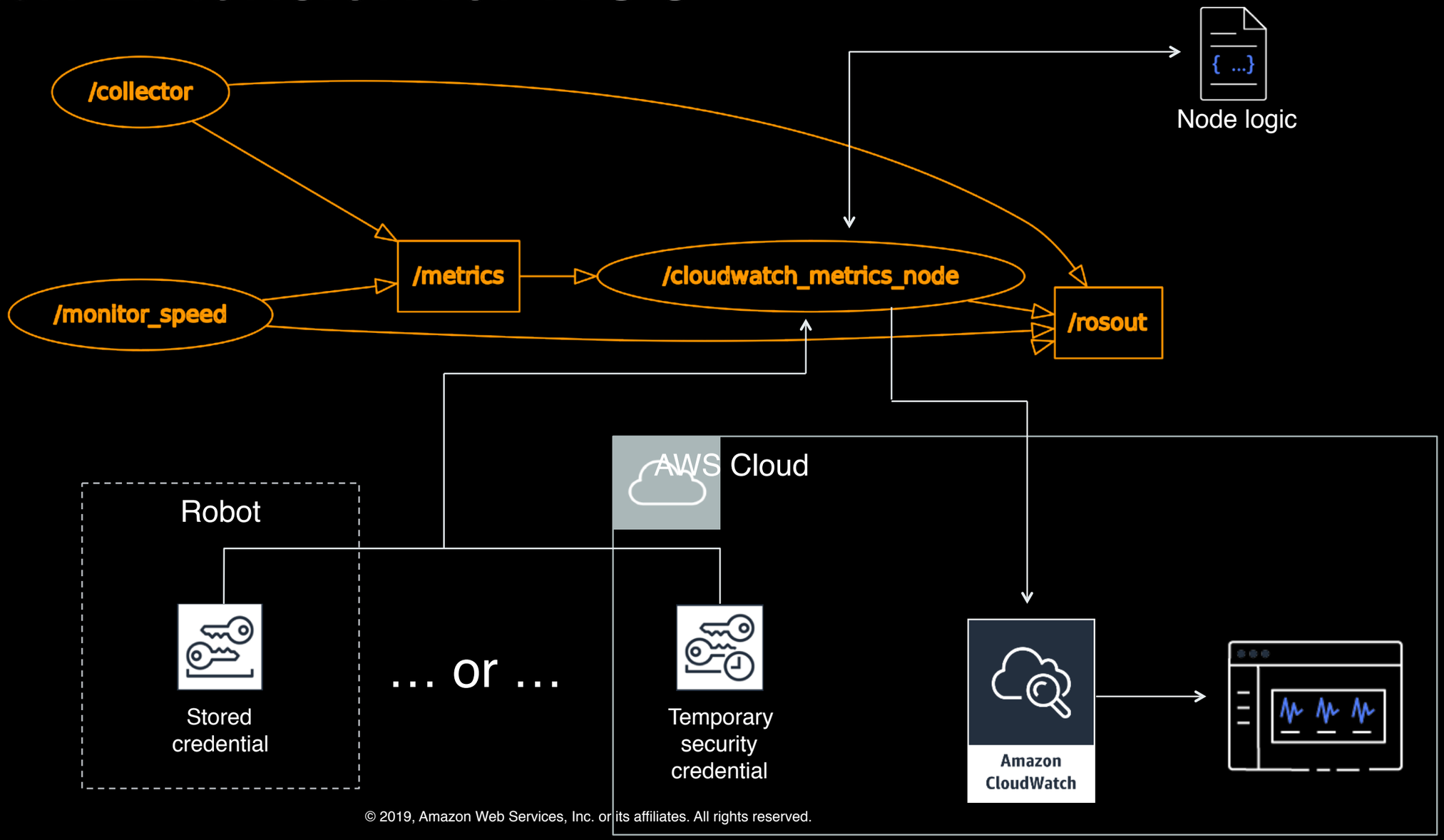
AWS RoboMaker

CloudWatch Extension for ROS

ROS Nodes and topics



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AWS RoboMaker

Simulation

- Pre-built virtual 3D worlds or bring your own
- Zero infrastructure to provision, configure or manage.
- Run multiple simulations in parallel
- Auto-scale based on simulation complexity
- Pay-as-you-go simulation resource consumption

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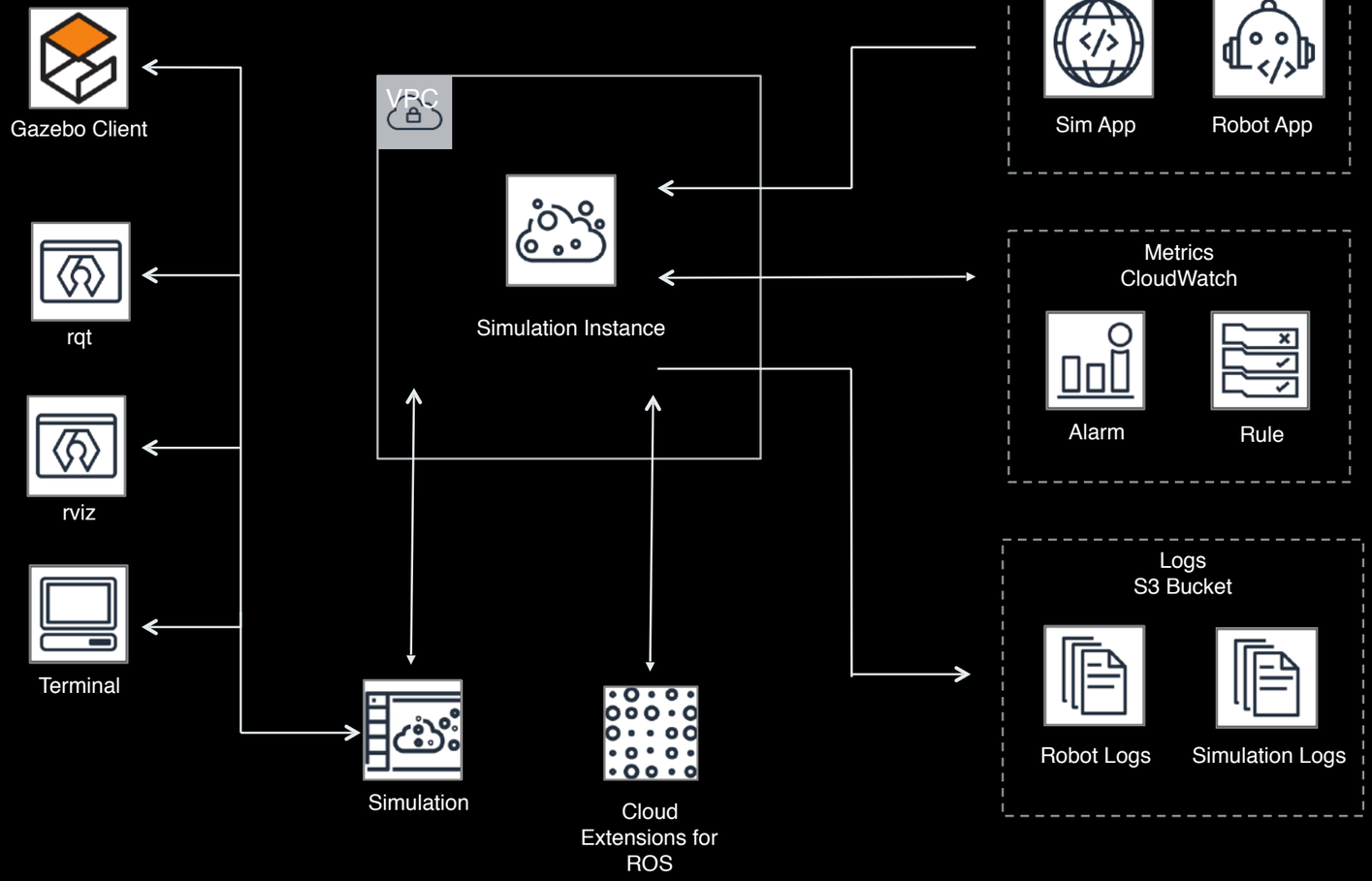
AWS RoboMaker

Simulation



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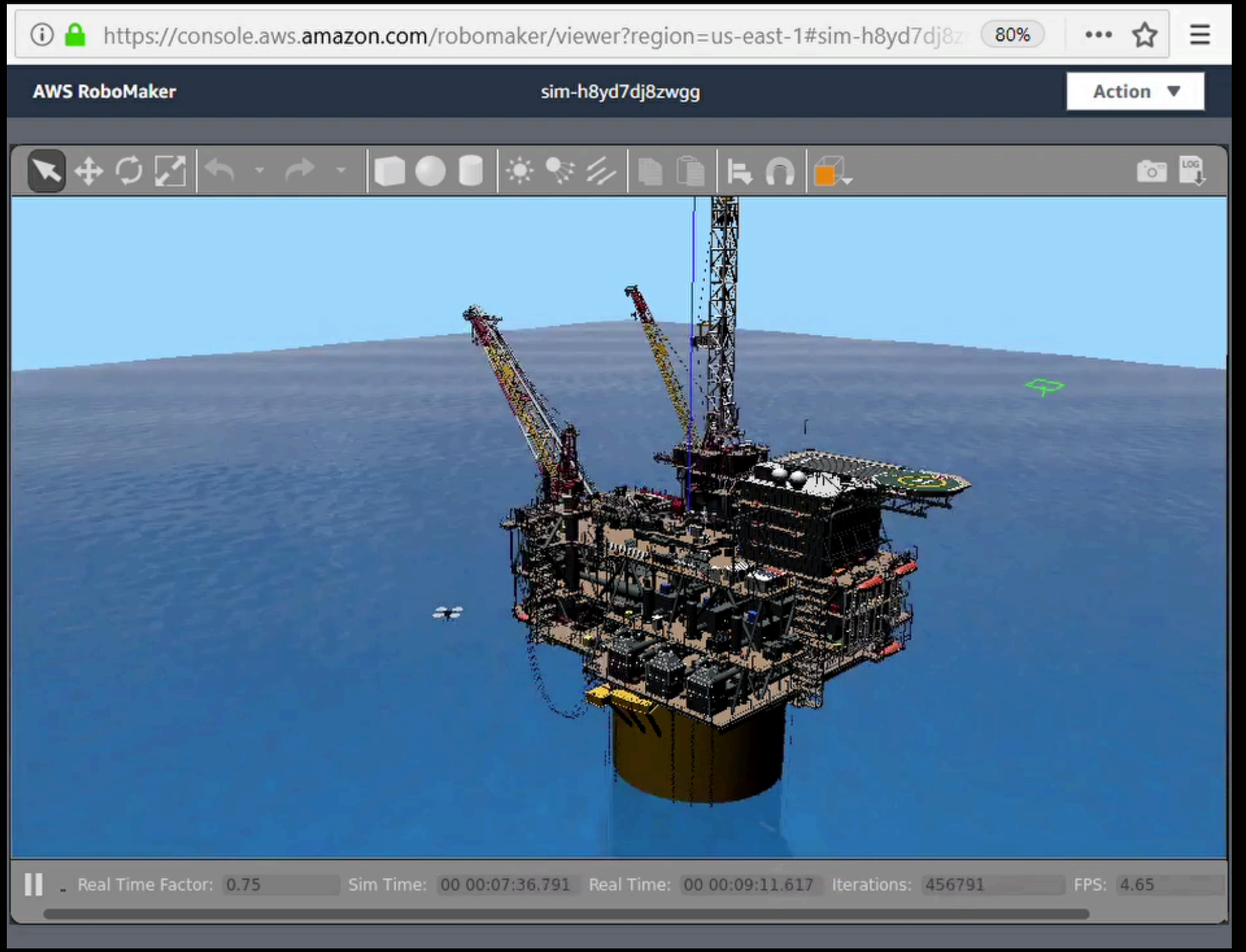

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https://console.aws.amazon.com/robomaker/viewer?region=us- 80%

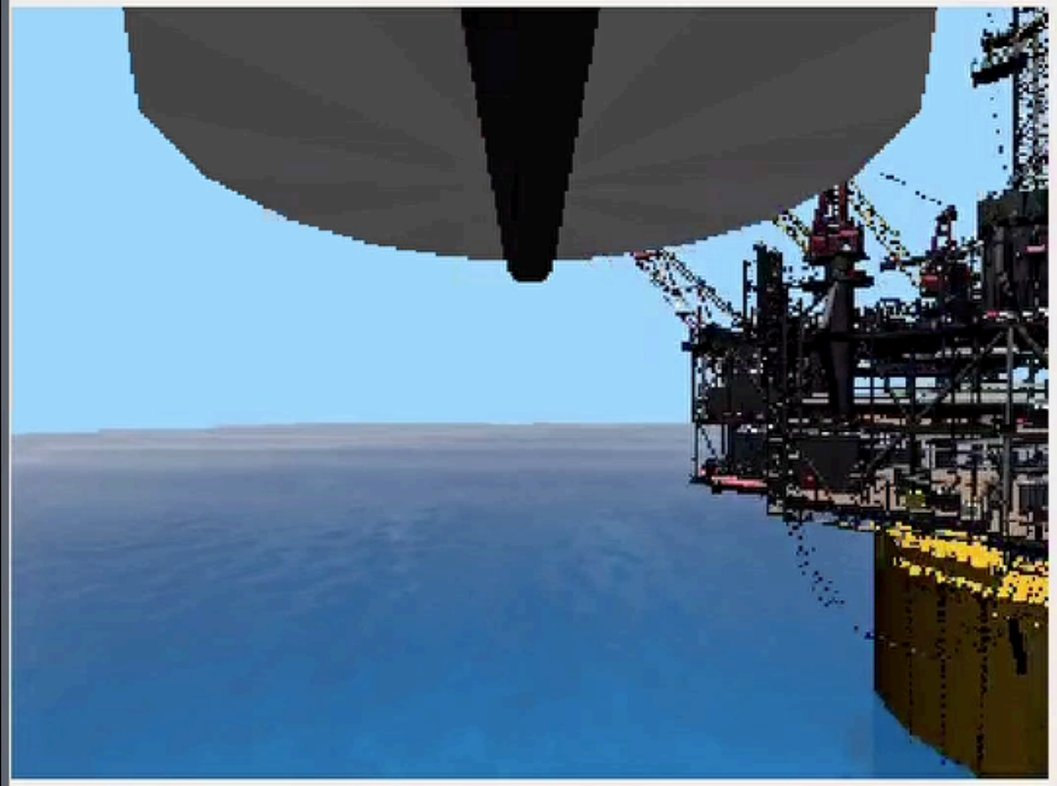
AWS RoboMaker sim-h8yd7dj8zwgg Action

File Plugins Running Perspectives Help

Image View

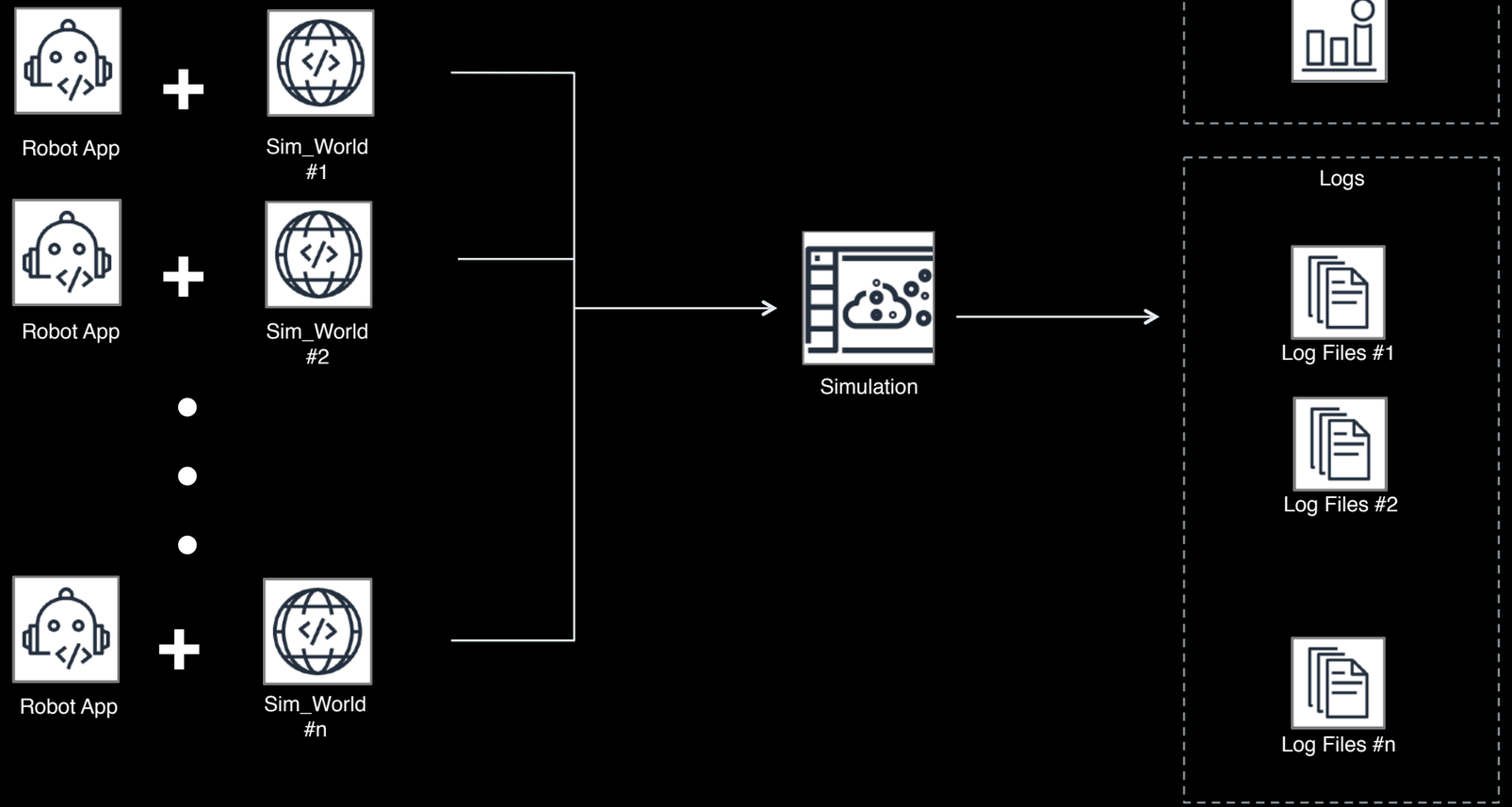
/front_cam/camera/image 0 10.00m

front_cam/camera/image_mouse_left Smooth scaling 0°



AWS RoboMaker

Simulation



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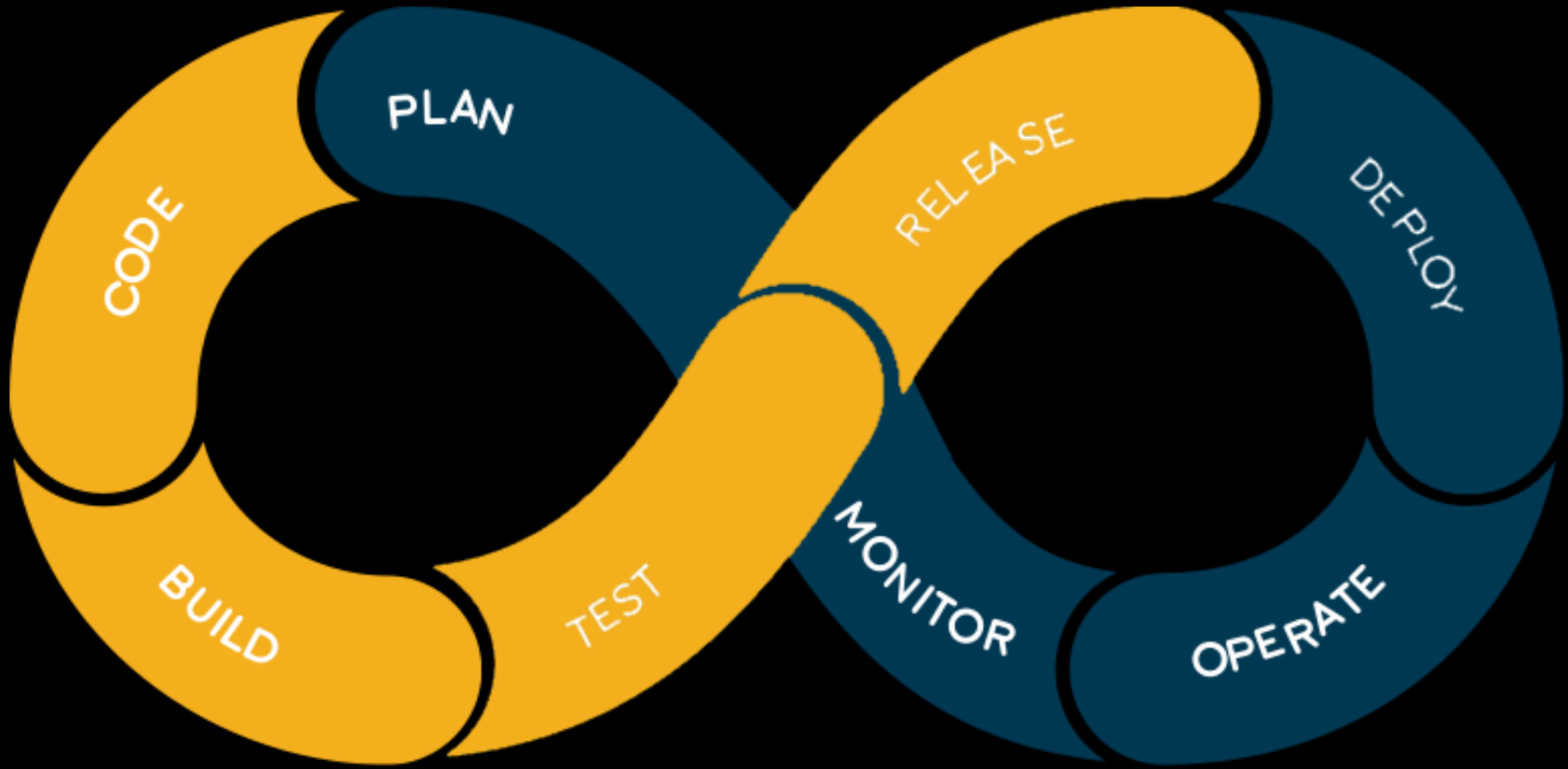
AWS RoboMaker

Simulation for CI/CD



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AWS RoboMaker

Fleet Management

- Integrated with AWS Greengrass
- Built-in robot registry, security, and fault-tolerance for updates
- Digital Twin for your robot
- Deploy robotics application over-the-air with just a few clicks from AWS Management Console

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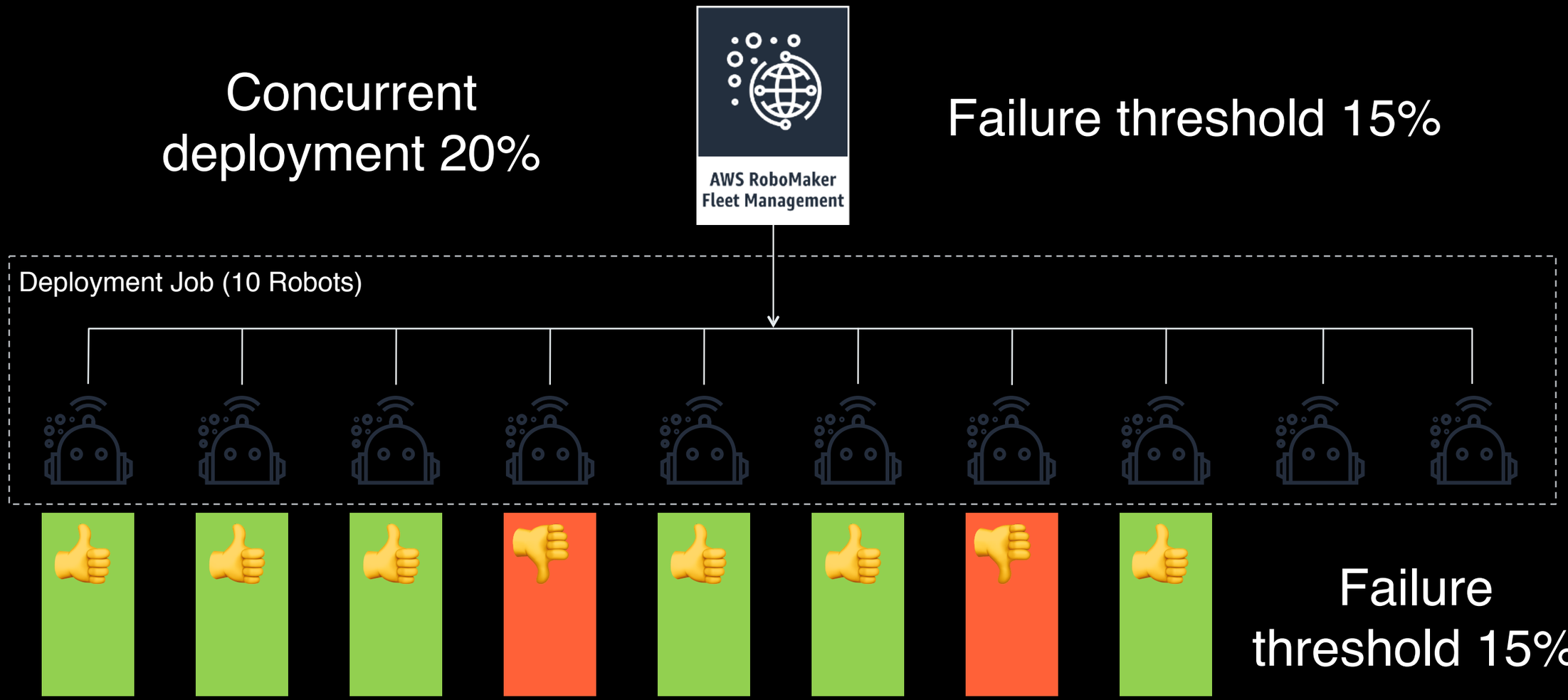
AWS RoboMaker

Fleet Management

Concurrent deployment 20%



Failure threshold 15%

Failure threshold 15%

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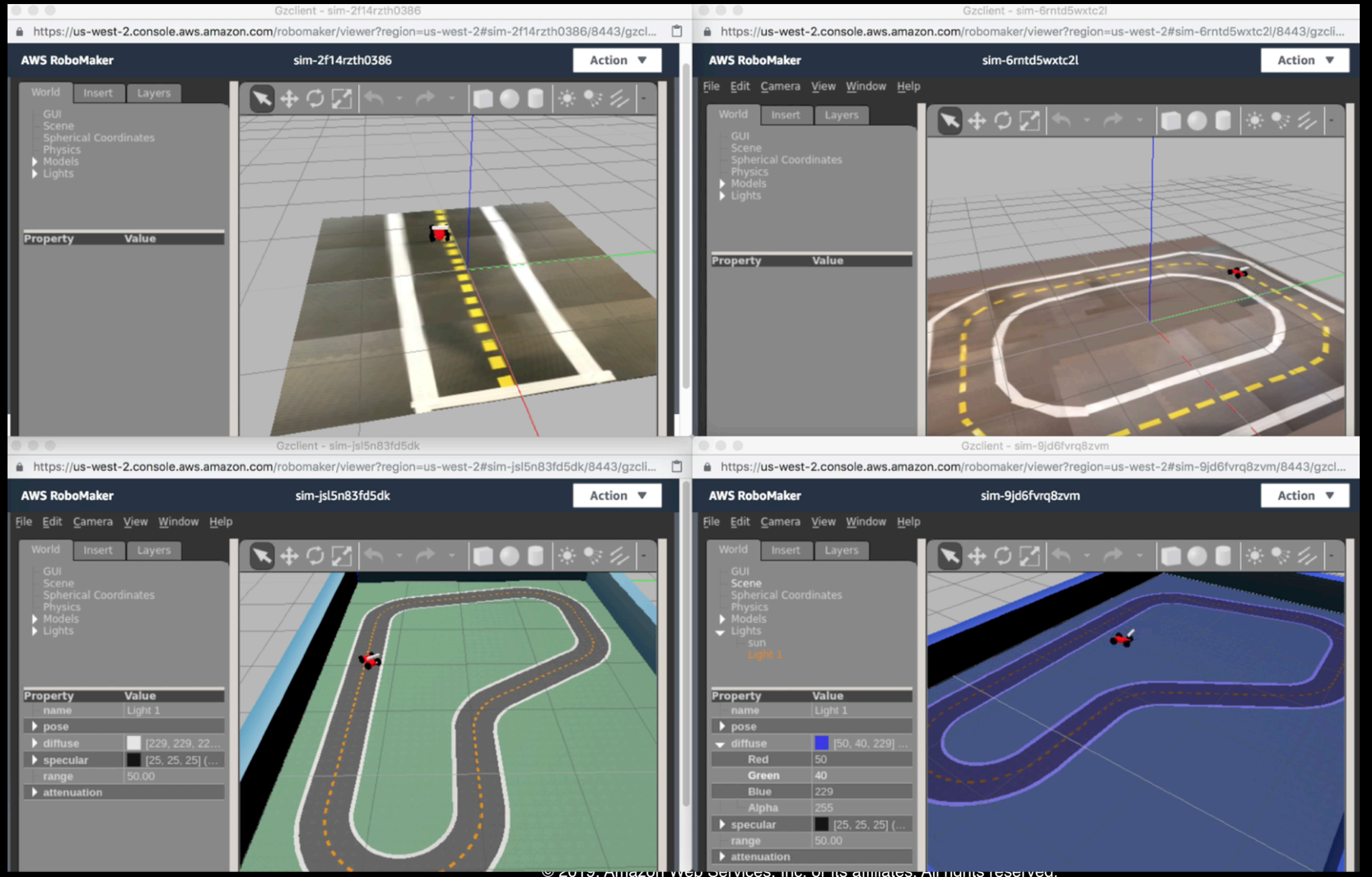
What if you could prepare your robot to navigate or perform some action without writing code?

AWS RoboMaker

Reinforcement Learning for AWS DeepRacer



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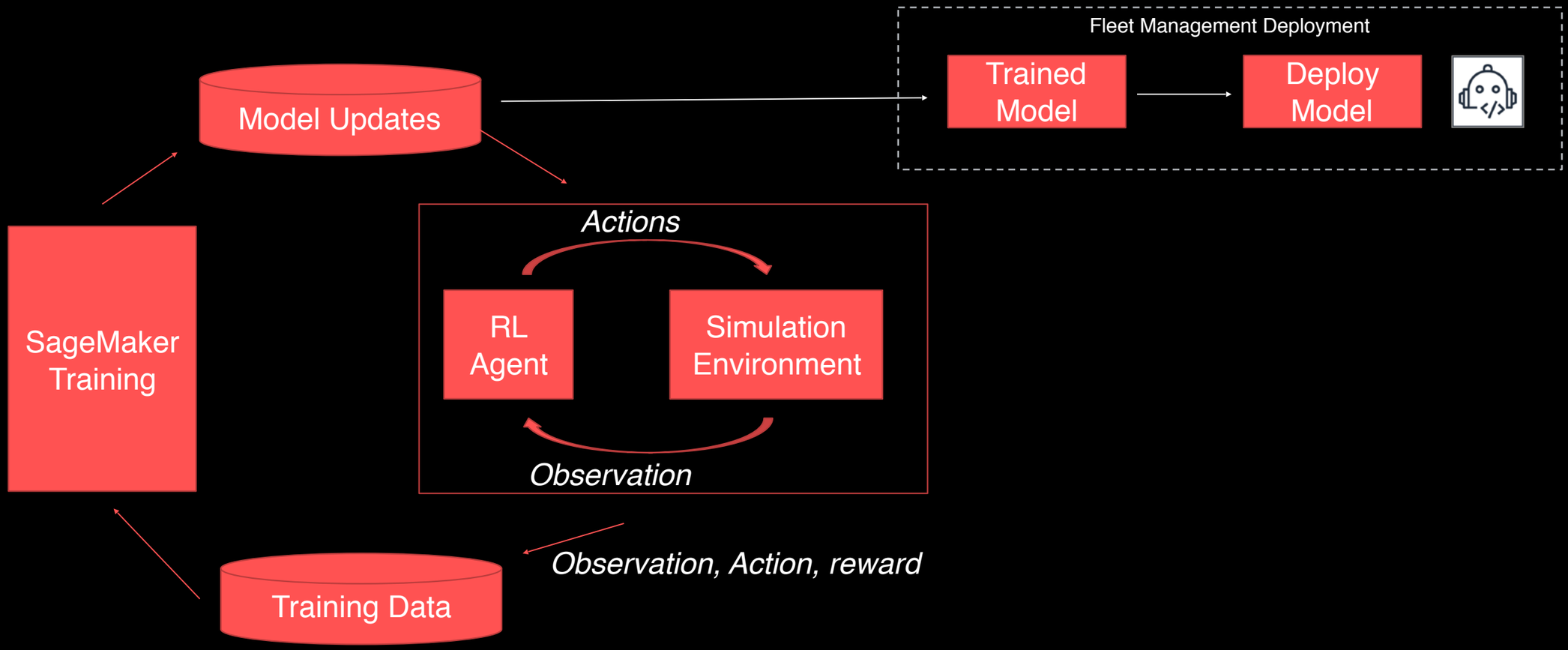
AWS RoboMaker

Evaluate and deploy trained models



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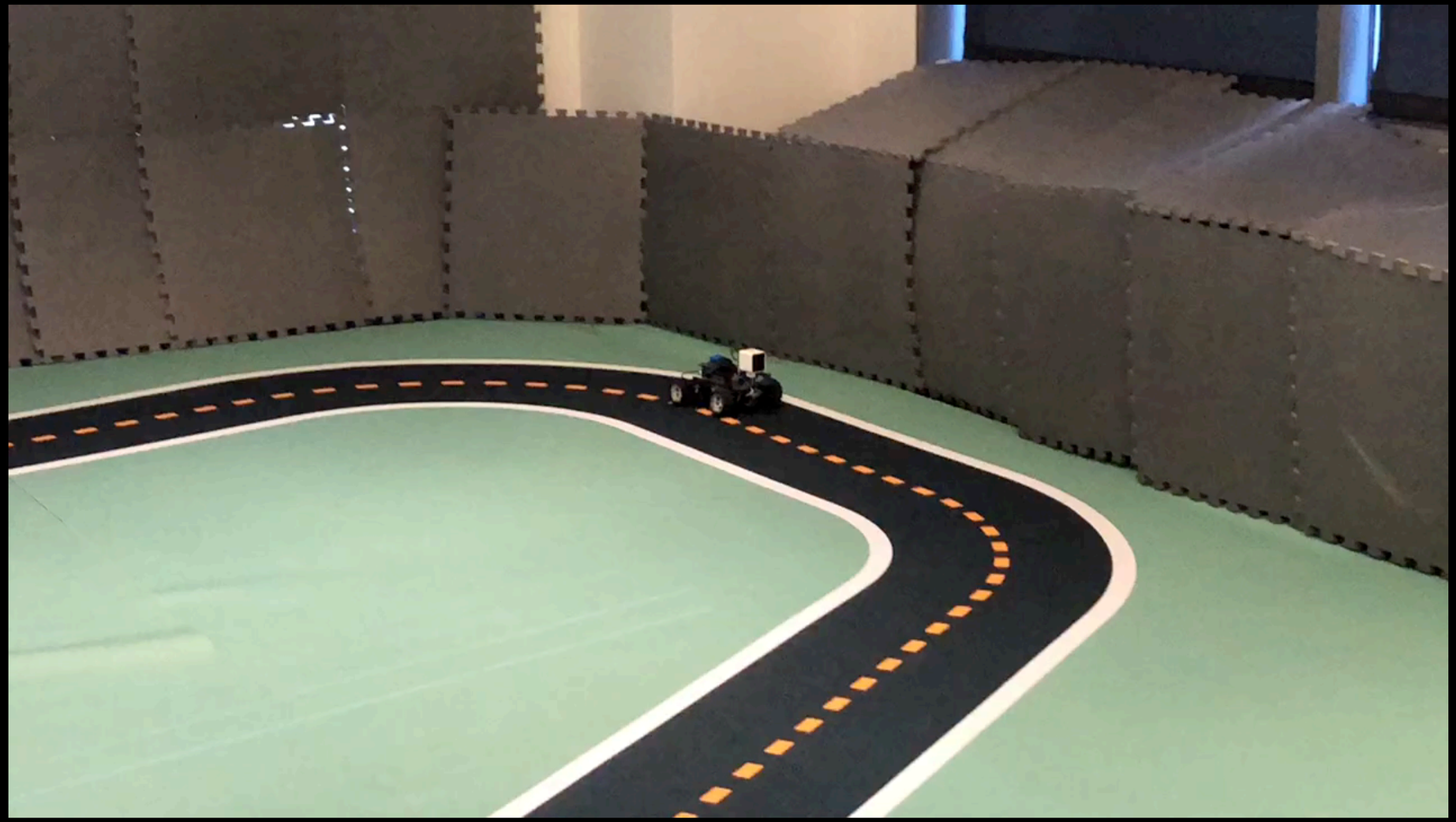
Successful Simulation to Real Transfer



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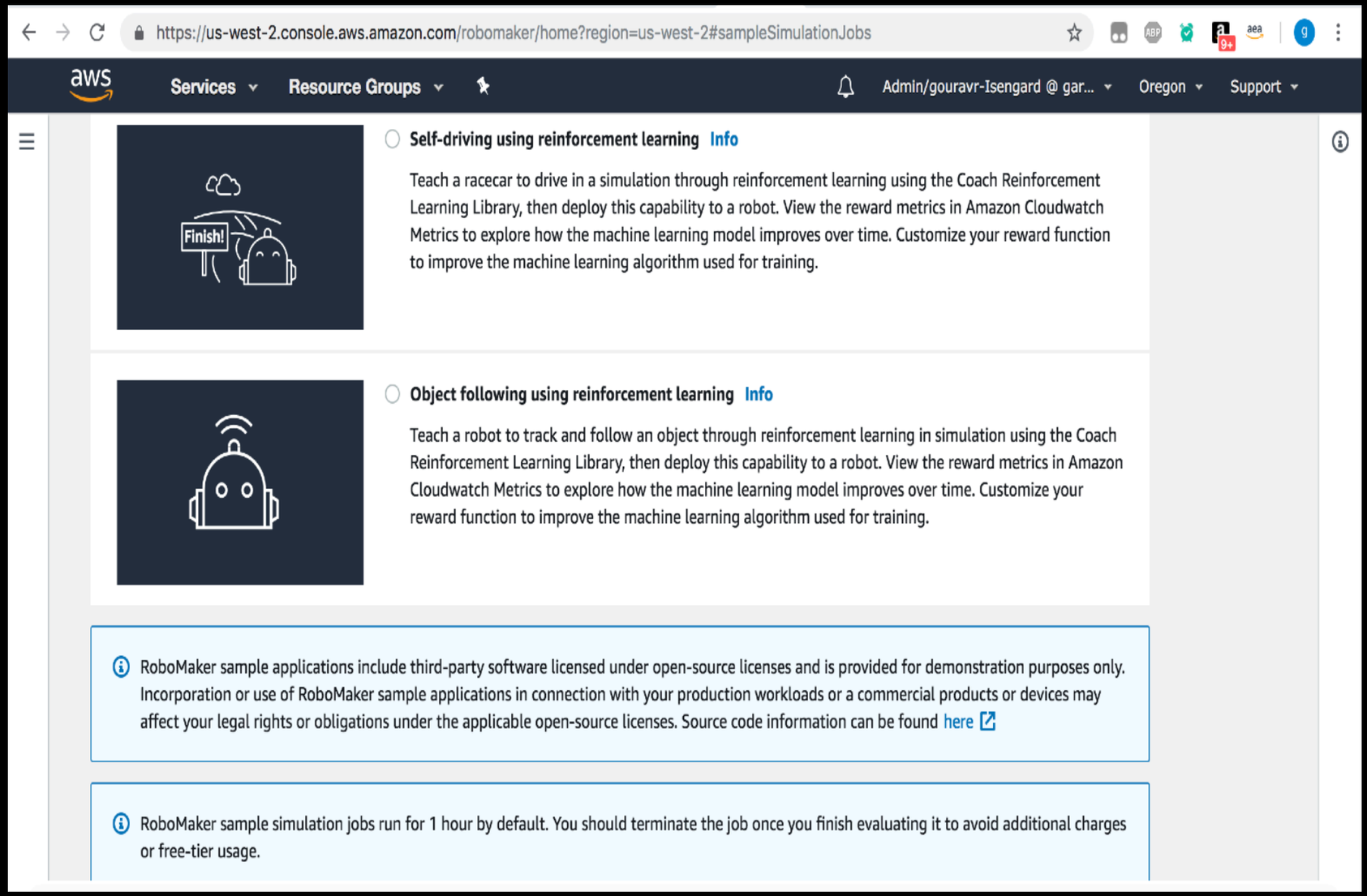
AWS RoboMaker

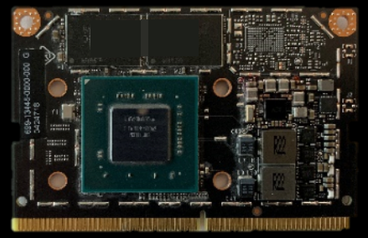
One Click Sample Applications Available



JETSON - ROBOTICS

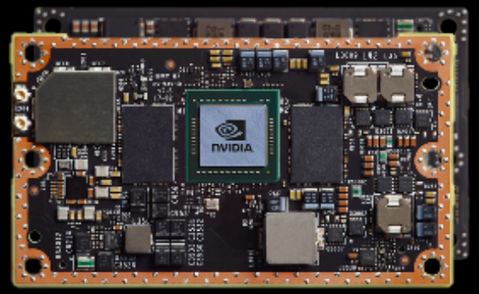
The Jetson Family

From AI at the Edge to Autonomous Machines

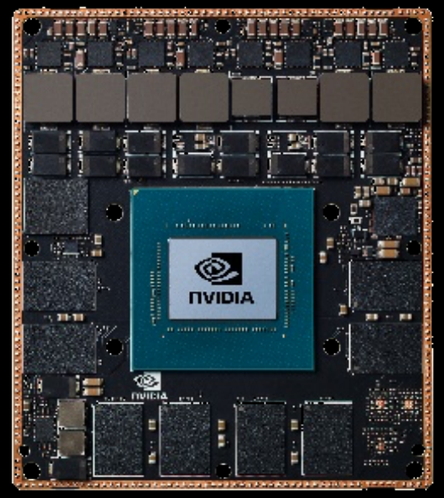


JETSON NANO
5 - 10W
0.5 TFLOPS (FP16)
45mm x 70mm
$129

JETSON TX1 → JETSON TX2 4 GB
7 - 15W
1 – 1.3 TFLOPS (FP16)
50mm x 87mm
$299



JETSON TX2 8GB | Industrial
7 – 15W
1.3 TFLOPS (FP16)
50mm x 87mm
$399 - $749



JETSON AGX XAVIER
10 – 30W
10 TFLOPS (FP16) | 32 TOPS (INT8)
100mm x 87mm
$1099

AI at the edge

Fully autonomous machines

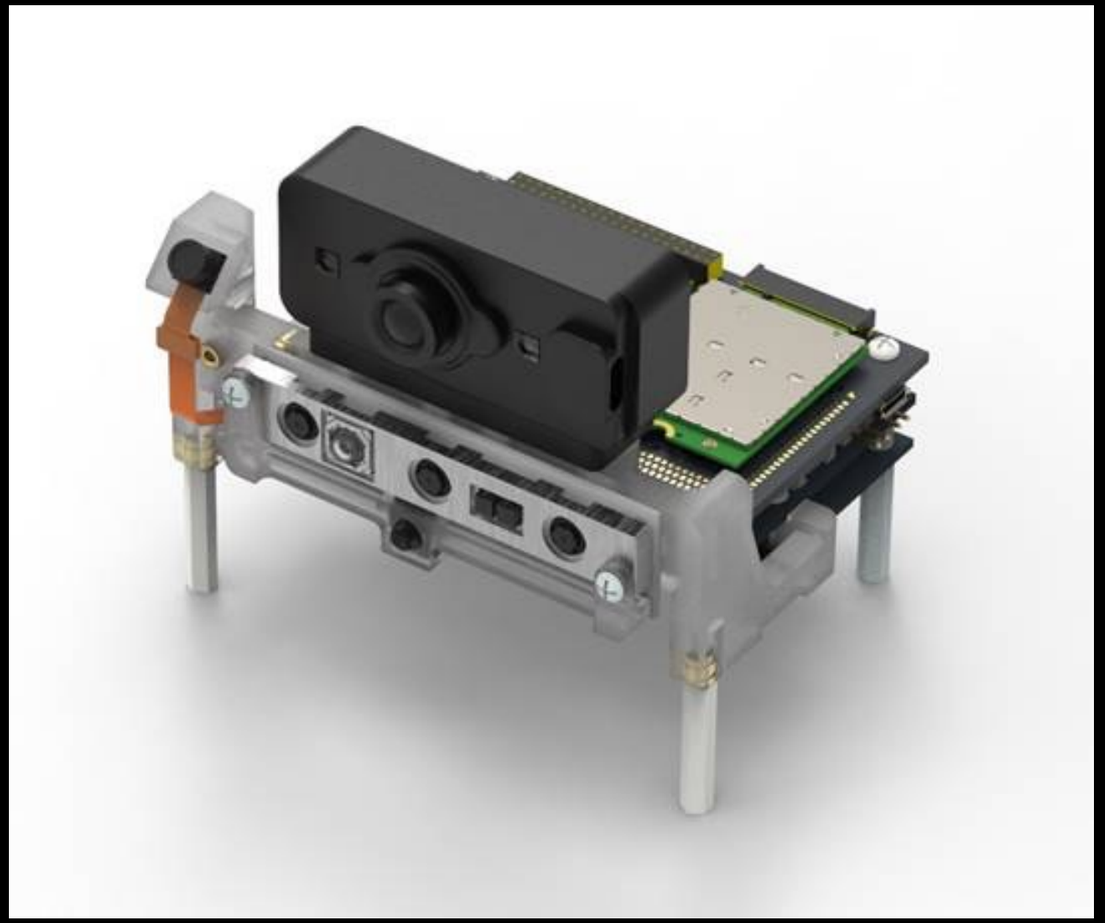
Multiple devices - Same software

Qualcomm® Robotics RB3 Platform

Qualcomm Robotics Platform is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.

Qualcomm® Robotics RB3 Platform

Dedicated platform to build smart, power-efficient and cost-effective robots



- For large industrial and enterprise robots to small battery-operated one's with challenging power and thermal dissipation requirements.
- High-performance heterogeneous computing with Qualcomm® SDA/SDM845
- Qualcomm® Artificial Intelligence (AI) Engine for on-device machine learning
- Computer vision
- Vault-like security
- Wi-Fi and cellular connectivity (4G/LTE, CBRS and support for 5G)
- Supports flexible commercialization choices: dev board/kit, SOM, chip-on-board
- Linux, ROS, AWS RoboMaker

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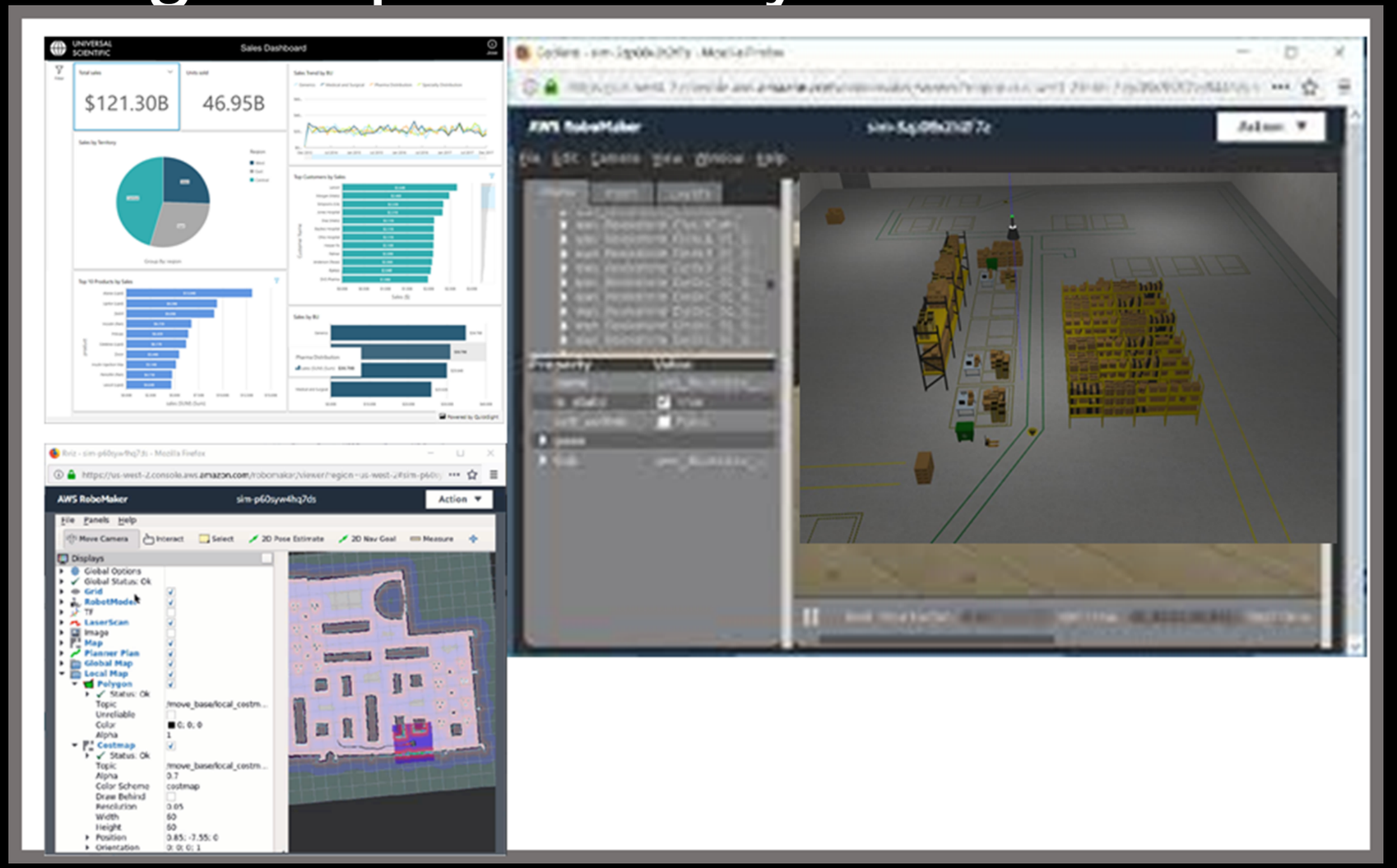
AWS RoboMaker

Rover “SwagBot” powered by AWS RoboMaker

amazon RE:MARS | AWS RoboMaker | ROVER ROBOTICS

AWS RoboMaker

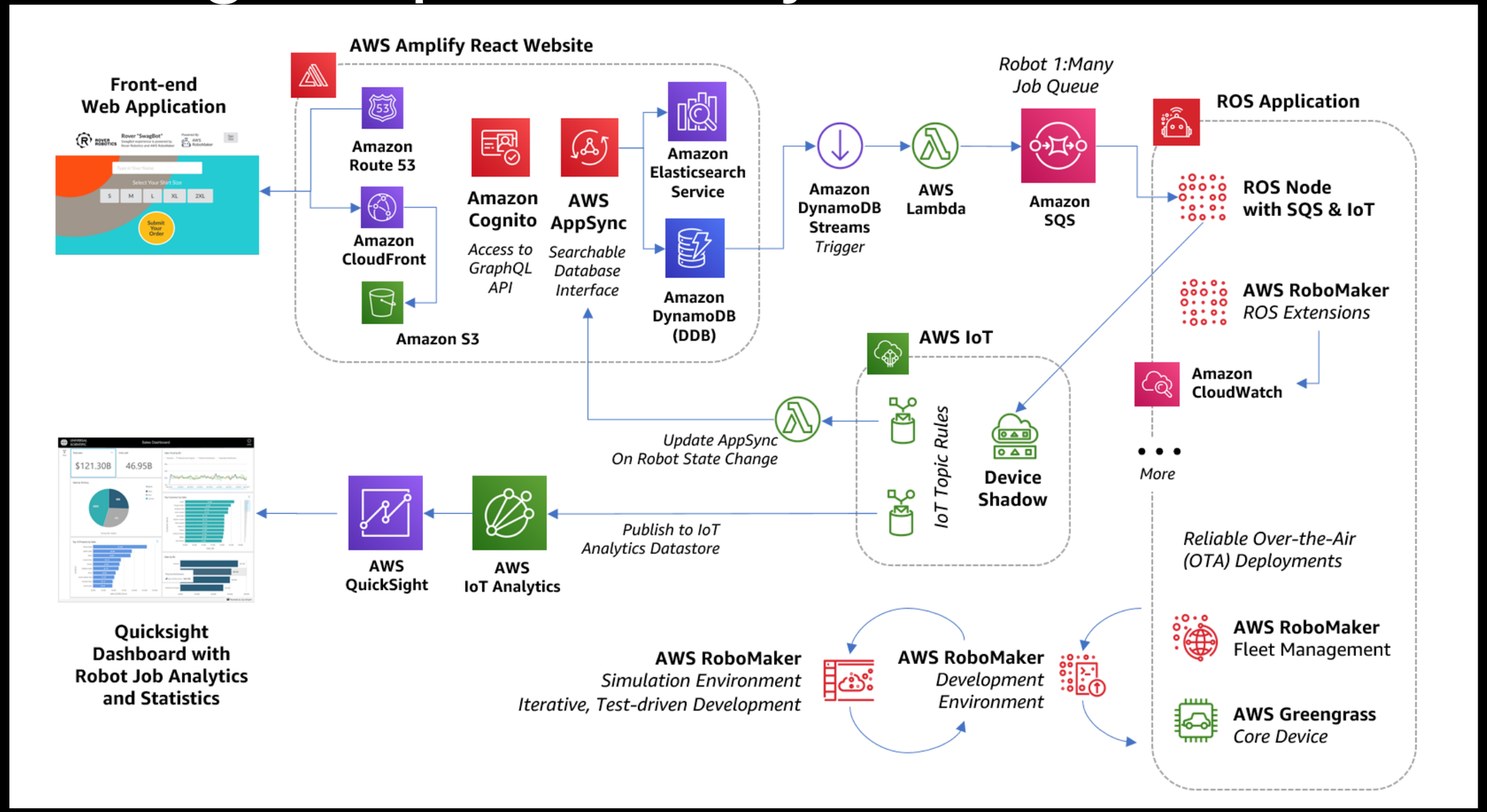
Rover “SwagBot” powered by AWS RoboMaker



amazon RE:MARS | AWS RoboMaker | ROVER ROBOTICS

AWS RoboMaker

Rover “SwagBot” powered by AWS RoboMaker



amazon RE:MARS | AWS RoboMaker | ROVER ROBOTICS

1. The user requests a t-shirt by interacting with a static, client-side react website. The website is built using the **AWS Amplify CLI** and served through **Amazon CloudFront** and **Amazon S3.** Orders are stored in an **Amazon DynamoDB** database, which the application interacts with through a GraphQL endpoint using **AWS AppSync.**

2. An **AWS Lambda** trigger on the **Amazon DynamoDB Streams** writes a message containing the retrieval job to an **Amazon Simple Queue Service (SQS)** queue.

3. The ROS application running locally on the Rover robot connects to the **Amazon SQS** queue and starts a retrieval job, reporting the state back to the **AWS IoT Device Shadow** associated with the **AWS Greengrass Core**.

4. An **AWS IoT Rule** triggers an **AWS Lambda** function on each status update, and invokes an **AWS AppSync** mutation. An **AWS AppSync** subscription in the web application automatically updates the dashboard with the new job status.

5. New robot features are developed using the **AWS RoboMaker** cloud-based IDE. During the development the new ROS code can be easily simulated in **AWS RoboMaker**.

6. Once the feature it is ready, the code is integrated into git automation processes that use **AWS RoboMaker** simulation service to test various scenarios. Then, the code is reliably deployed over-the-air (OTA) to production robot fleets using **AWS RoboMaker** fleet management.

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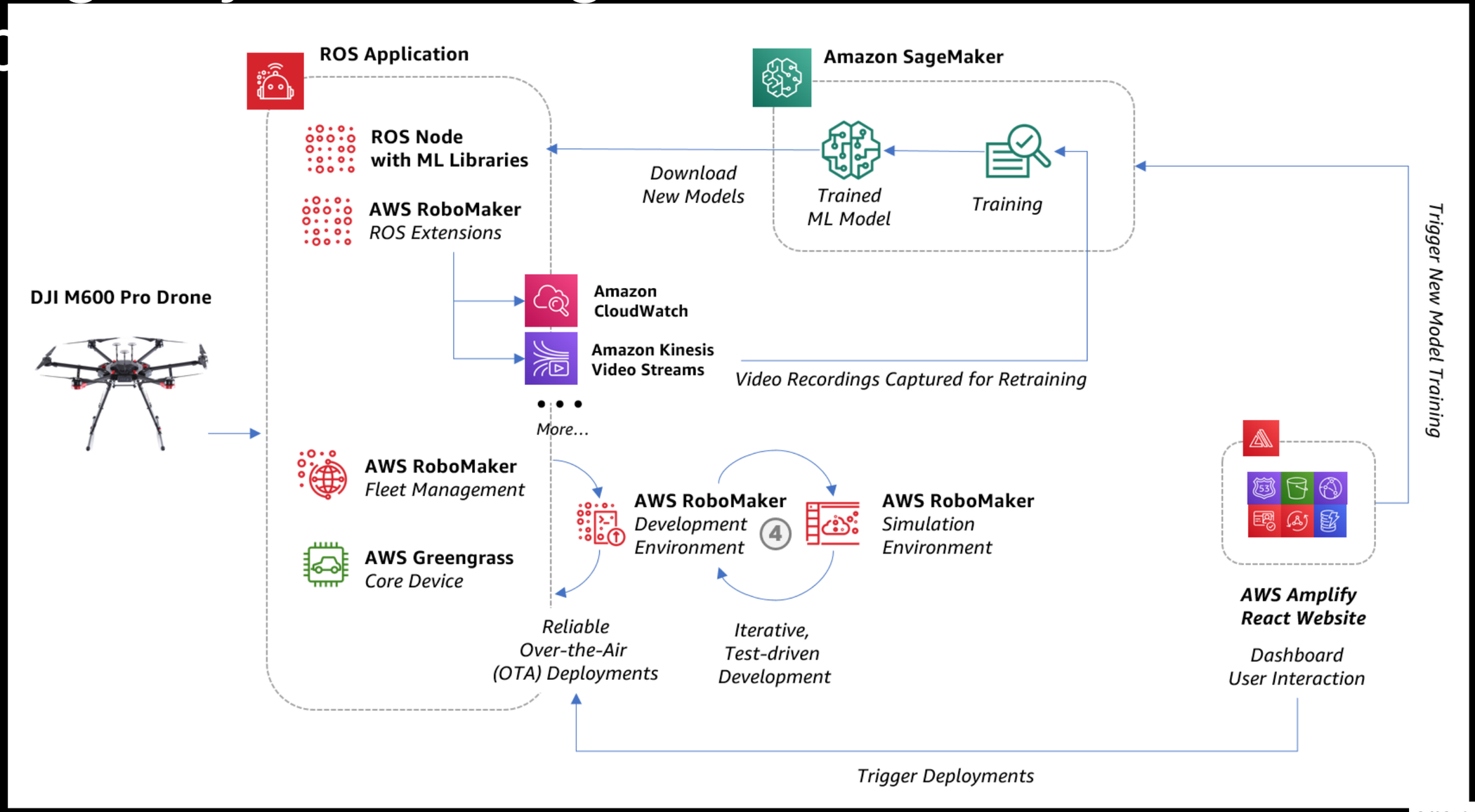
AWS RoboMaker

Emergency Monitoring Drones built on AWS Rob



AWS RoboMaker

Education and Research Partners

Role of the Cloud in the Future of Robotics

1. DEVOPS for Robotics: code, test, deploy, monitor.
2. Intelligent cloud services can enhance local processing on the robot and can improve performance over time.
3. Simulation, combined with imitation and reinforcement learning can be used to program robot actuation.
4. Cloud services enable fleet management, coordination and remote processing for digital transformation.

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