



# DevOps in the Cloud:

## Case studies of Amazon.com teams & their resilient architectures

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# Amazon.com

amazon



## Welcome to Amazon.com Books!

One million titles.

(If you explore just one

### SPOTLIGHT! -- AUGUST

These are the books we  
day so please come on

### ONE MILLION TITLES

Search Amazon.com's  
a look at the books w  
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30% off the publishers

### EYES & EDITORS. A

Like to know when the  
releases a new title? E  
our human editors are  
know when especially  
in, meet Eyes, and hav

### YOUR ACCOUNT

Check the status of yo  
us. Please note that yo  
order, you will be give

The screenshot shows the Amazon.com homepage with a blue header. The main content area features a large 'Welcome to Amazon.com Books!' message. Below this, there's a search bar and a 'Browse' section with categories like Books, Electronics, Music, DVD, Kitchen & Housewares, Health & Beauty, Computer & Video Games, Toys & Games, Software, Camera & Photo, Wireless Phones, Tools & Hardware, Video, Outdoor Living, Cars, Gifts & Gift Certificates, Auctions, zShops, and Outlet. The 'More Top Sellers' section lists books like 'At the Core' by Bill Sammon and 'Cuisinart ICE-20 1 1/2-Quart Automatic Frozen Yogurt I'. The 'New Releases in Books' section features 'The Okinawa Program' by Dr. David S. S. Okinawa. The 'More New Releases' section lists books like 'In Music', 'In DVD', 'In Toys', and 'In Electronics'. The 'Palms Ship Free' section mentions free shipping on all orders.

This screenshot is similar to the previous one, showing the Amazon.com homepage. It highlights the 'Fall Blowout Sale' banner and the 'Kindle Fire HD' advertisement. The 'Shop by Department' section is also visible, listing various product categories.

This screenshot shows a different view of the Amazon.com homepage, focusing on the 'Off to College' campaign. It features a large banner for 'Off to College Prep your desk, for less' with images of school supplies. Below the banner, there are several product recommendations: 'Most-loved women's styles' (featuring a blue dress), 'Emergency supplies' (featuring a fire extinguisher and flashlight), 'Shop Off to College essentials' (featuring school furniture), 'Sign in for the best experience' (featuring a login button), 'amazon music | ARTIST MERCH SHOP' (featuring artist merchandise), 'Merch from your favorite artists' (featuring artist merchandise), 'Shop the summer shoe edit' (featuring shoes), 'Summer Cooking' (featuring kitchenware), 'Smart school savings' (featuring school supplies), and 'Stock up for college' (featuring school supplies).

aws

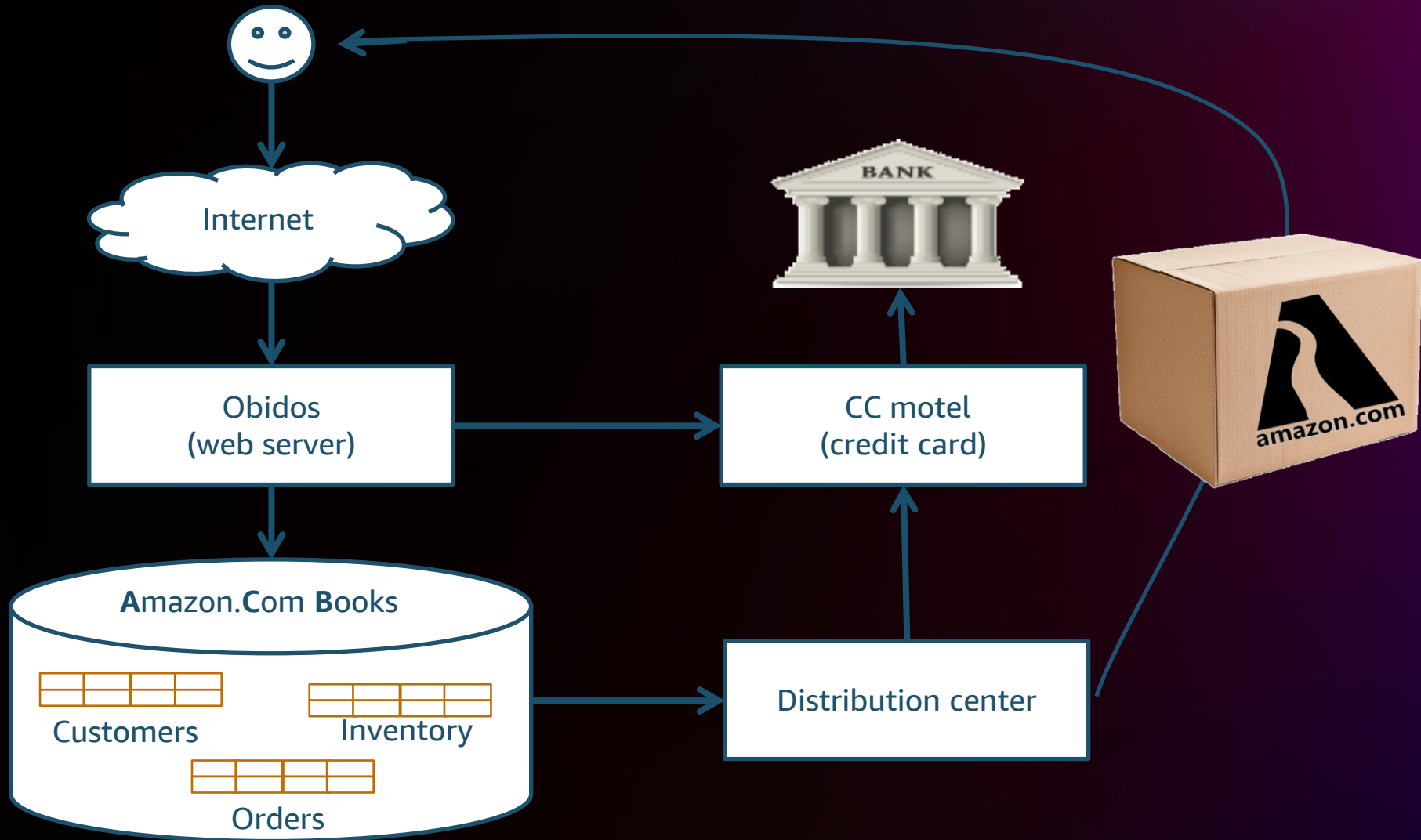
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# Let's start at the beginning

## Evolution of DevOps at Amazon.com



# Architecture 1995



# Breaking down the monolith

## Monolith



1995

### Obidos

- Code tied to data model
- All the business logic
- 12 hours to build (2000)

## Start transition to SOA



1998

### Distributed Computing Manifesto (1998)

#### Cracking the Monoliths (2000)

- Separating the presentation layer, business logic and data
- Well defined, hardened APIs

[bit.ly/distributed\\_computing\\_manifesto](https://bit.ly/distributed_computing_manifesto)

## Start of microservices



2003

### Gurupa goes live

- Replaced Obidos (decom. 2006)
- Page Assembly engine
- 100s of services → page

Deprecation almost complete: 2023



# Microservices

FOR EXAMPLE: AMAZON "DETAIL PAGE"

Hello  
Select your address

Best Sellers

Customer Service

Today's Deals

New Releases

Find a Gift

Whole Foods

Gift Cards

Free Shipping

Registry

Sell

Coupons

AmazonBasics

#FoundItG

Sign in

New customer? S

Amazon Devices

Echo & Alexa

Fire Tablets

Fire TV

Kindle

Home Security








Smart Home

Pre-Owned

Device Deals

Accessories

Device Support



All-new

fire HD8

32/64 GB storage | 12-hour battery | 2 GB RAM

prime video

NETFLIX

Disney+


amazon music

Spotify

zoom

kindle

audible



All-new Fire HD 8 tablet, 8" HD display, 32 GB, designed for portable entertainment, Black

by Amazon

★★★★★ 5,055 ratings | 1000+ answered questions

Amazon's Choice for "8 inch tablet"

Price: \$89.99 & FREE Shipping. Details

In Stock.

Arrives: Monday, Aug 10 Details

Fastest delivery: Friday, Aug 7 Details

Ships from and sold by Amazon.com Services LLC.

Style: Fire HD 8

Fire HD 8

Fire HD 8 Plus

Fire HD 8 Plus + Wireless Charging Dock

Digital Storage Capacity: 32 GB

32 GB


64 GB


Offer Type: With Special Offers


With Special Offers


Without Special Offers


Color: Black











Special offers display on your device's lockscreen. Learn more

Qty: 1

Add to Cart

Buy Now

Secure transaction

☐ This is a gift

☒ Link to my Amazon account to simplify setup. Why is this important?

Select delivery location

Add Additional Items

☐ Amazon Standing Case: Charcoal Black \$29.99

☐ Extended Warranty: 2 year \$16.99

☐ Themed cases made for Amazon: Mickey No Bad Days \$34.99

☐ Screen Protector: Clear \$12.99

☐ Memory Card: 32 GB \$49.99 \$8.49

☐ Made for Amazon clear case

Start of microservices



2003

Gurupa goes live  
Page Assembly engine  
100s of services → page



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# Amazon “detail page” has 100s of service calls

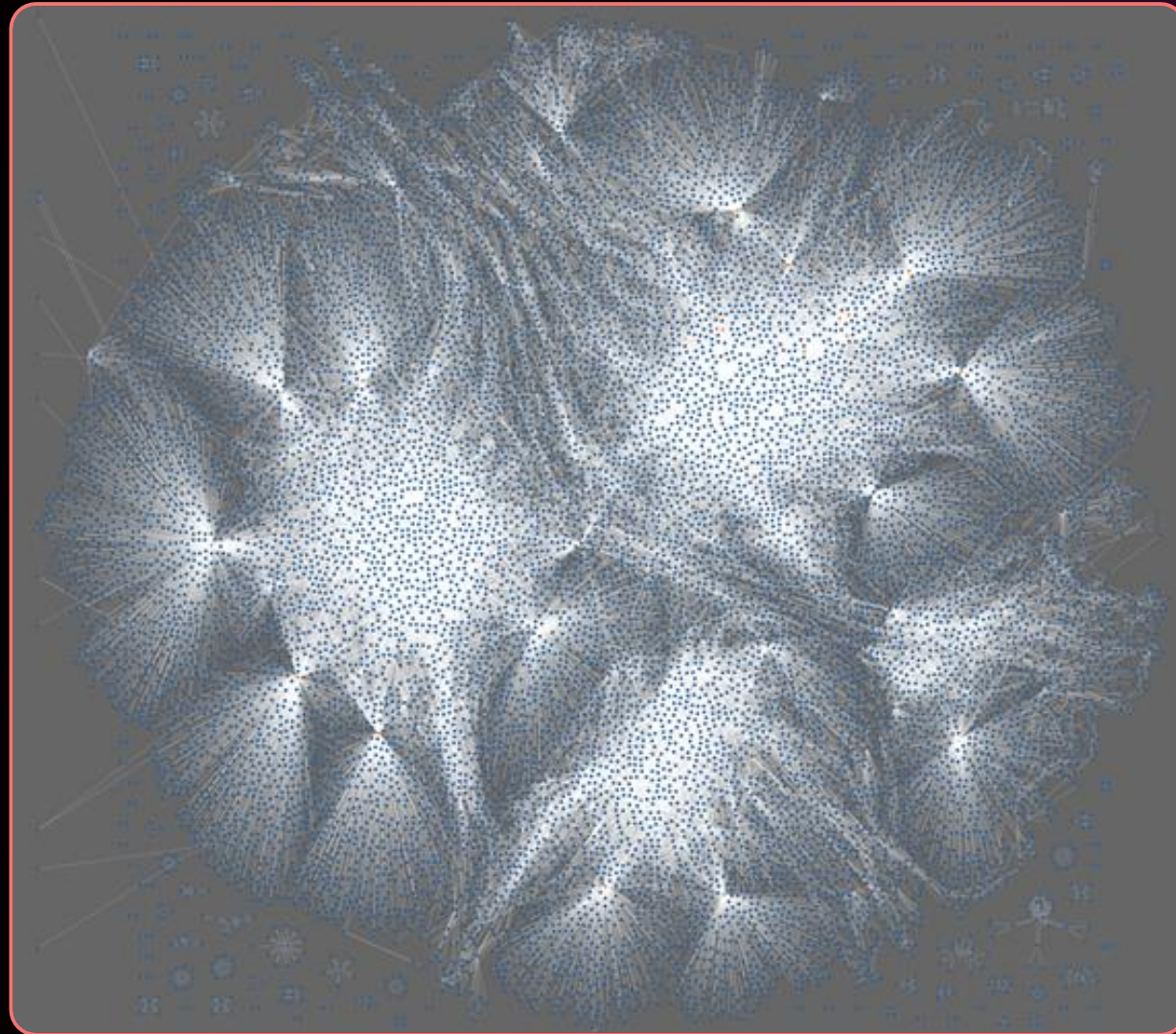
Case study

The image shows a screenshot of the Amazon product detail page for the "All-new Fire HD 8 tablet". The page content includes the product title, a description ("8" HD display, 32 GB, designed for portable entertainment, Black"), storage options ("32/64 GB storage"), a star rating ("5,052 ratings"), and an "Amazon's Choice" badge. Overlaid on the right side of the page is the Chrome DevTools component inspector, which lists numerous service calls for various components. Red arrows point from the main title and several components in the inspector back to the corresponding elements on the page. The service calls listed in the inspector include:

- imageBlock (DYNAMIC) ViewModel DebugInfoError
- title (DYNAMIC) ViewModel DebugInfoError
- bylineInfo (DYNAMIC) ViewModel DebugInfoError
- averageCustomerReviews (DYNAMIC) ViewModel DebugInfoError
- ask (DYNAMIC) ViewModel
- acBadge (DYNAMIC) ViewModel DebugInfoError

**Specialized teams & platforms - Enabling teams to do more**  
**Independent development and deployment**  
**Increased resilience - graceful degradation**

# Architecture 2023





# Two-pizza teams



Multi-disciplinary

Full ownership and autonomy

Choose the tech

Build it, Run it

**Culture of collaboration and ownership**  
**Shared goal of delivering value to the customer**

# DevOps is culture

Amazon **Leadership Principles** guide Amazon's culture

## Customer Obsession:

Start with customer and work backwards



1995  
(Amazon founded)

**Deliver and improve value to the customer at faster pace, reliably**

## Insist on Highest Standards:

Ensure defects do not get sent down the line



2003  
(Game Days)

**Continuous experimentation and learning**

## Ownership:

Never say "that's not my job"



before 2005  
(Seth joins)

**Collaboration & ownership  
Shared goals**

# Doing DevOps before “DevOps”

**Customer Obsession:** Start with customer and work backwards



**Insist on Highest Standards:** Ensure defects do not get sent down the line



**Ownership:** Never say “that’s not my job”



“DevOps”



2009

DevOpsDays,  
Ghent, Belgium

“Chaos”



2010

Netflix Chaos Monkey


*Case study*


# Chaos experimentation

How specialized teams & platforms enable teams to do more



# Amazon Search







Deliver to Seth  
Sammamish 98074

All ▾


chaos engineering



 ▾

Hello, Seth  
Account & Lists ▾

Returns  
& Orders

 Cart

# Amazon Search

All chaos engineering



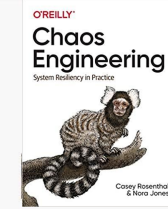
over 1,000 results for "chaos engineering"

- Over 300 million active customers
- Over 84K RPS during Prime Day 2022 US



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## RESULTS



Chaos Engineering: System Resiliency in Practice

by Casey Rosenthal and Nora Jones | Apr 28, 2020

★★★★☆ ~ 156

Paperback

\$41<sup>70</sup> \$69.99

✓prime Get it as soon as Wed, Sep 14

FREE Shipping by Amazon

Only 1 left in stock - order soon.

More Buying Choices

\$34.98 (37 used & new offers)

Kindle

\$40<sup>84</sup> \$59.99

Available instantly

## SIMILAR BOOKS



Building Secure and Reliable Systems: Best Practices for Designing, Implementing, and Maintaining Systems  
by Heather Adkins, Betsy Beyer, et al.

★★★★☆ ~ 108

Paperback

\$50<sup>99</sup> \$69.99

Save \$2.55 with coupon

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More Buying Choices

\$36.74 (38 used & new offers)



Site Reliability Engineering: How Google Runs Production Systems  
by Jennifer Petoff, Niall Murphy, et al.

★★★★☆ ~ 801

Paperback

\$28<sup>15</sup> \$59.99

✓prime

More Buying Choices

\$12.96 (67 used & new offers)



Implementing Service Level Objectives: A Practical Guide to SLIs, SLOs, and Error Budgets  
by Alex Hidalgo

★★★★☆ ~ 63

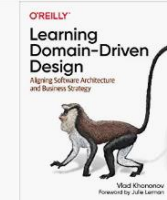
Paperback

\$31<sup>30</sup> \$59.99

✓prime

More Buying Choices

\$26.00 (53 used & new offers)



Learning Domain-Driven Design: Aligning Software Architecture and Business Strategy  
by Vlad Khononov

★★★★☆ ~ 98

Paperback

\$37<sup>49</sup> \$59.99

Save \$1.87 with coupon

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More Buying Choices

\$32.40 (41 used & new offers)

## MORE RESULTS

Best Seller



Sponsored

Engineers Survival Guide: Advice, tactics, and tricks After a decade of working at Facebook, Snapchat, and Microsoft

by Merih Taze | Nov 28, 2021

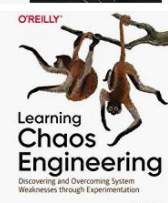
★★★★☆ ~ 83

Paperback

\$29<sup>99</sup> \$39.99

✓prime Get it as soon as Sun, Sep 11

FREE Shipping by Amazon



Learning Chaos Engineering: Discovering and Overcoming System Weaknesses Through Experimentation

by Russ Miles | Aug 6, 2019

★★★★☆ ~ 27

Paperback

\$37<sup>99</sup> \$59.99

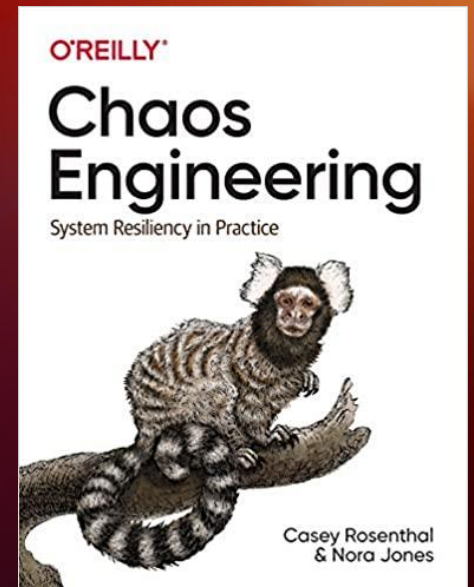
✓prime Get it as soon as Sat, Sep 10

FREE Shipping by Amazon

**“Chaos Engineering is the discipline of experimenting on a system in order to build confidence in the system’s capability to withstand turbulent conditions in production.”**

**“Principles of Chaos Engineering”**

<http://principlesofchaos.org>



# Search resilience team

Operational excellence engineering organization

**We drive the resilience of Amazon Search services**

**Serving over 40 backend services – many 2PTs**

- Enable running chaos experiments in production
- Building tooling to improve automation of chaos experiments

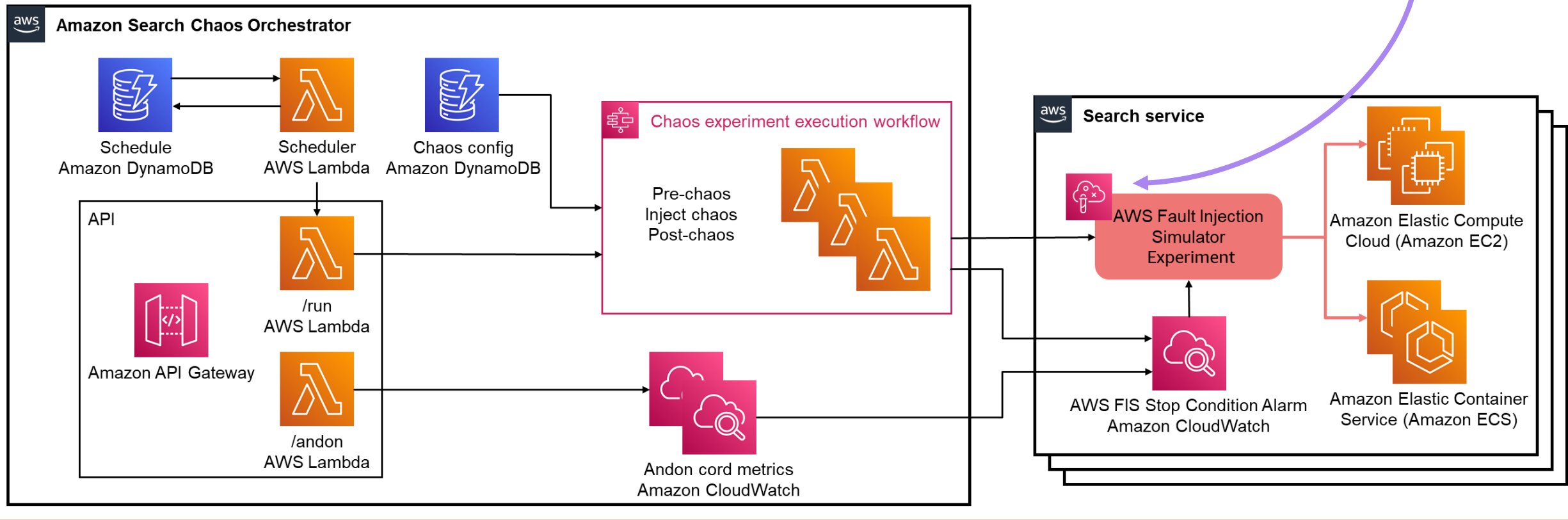




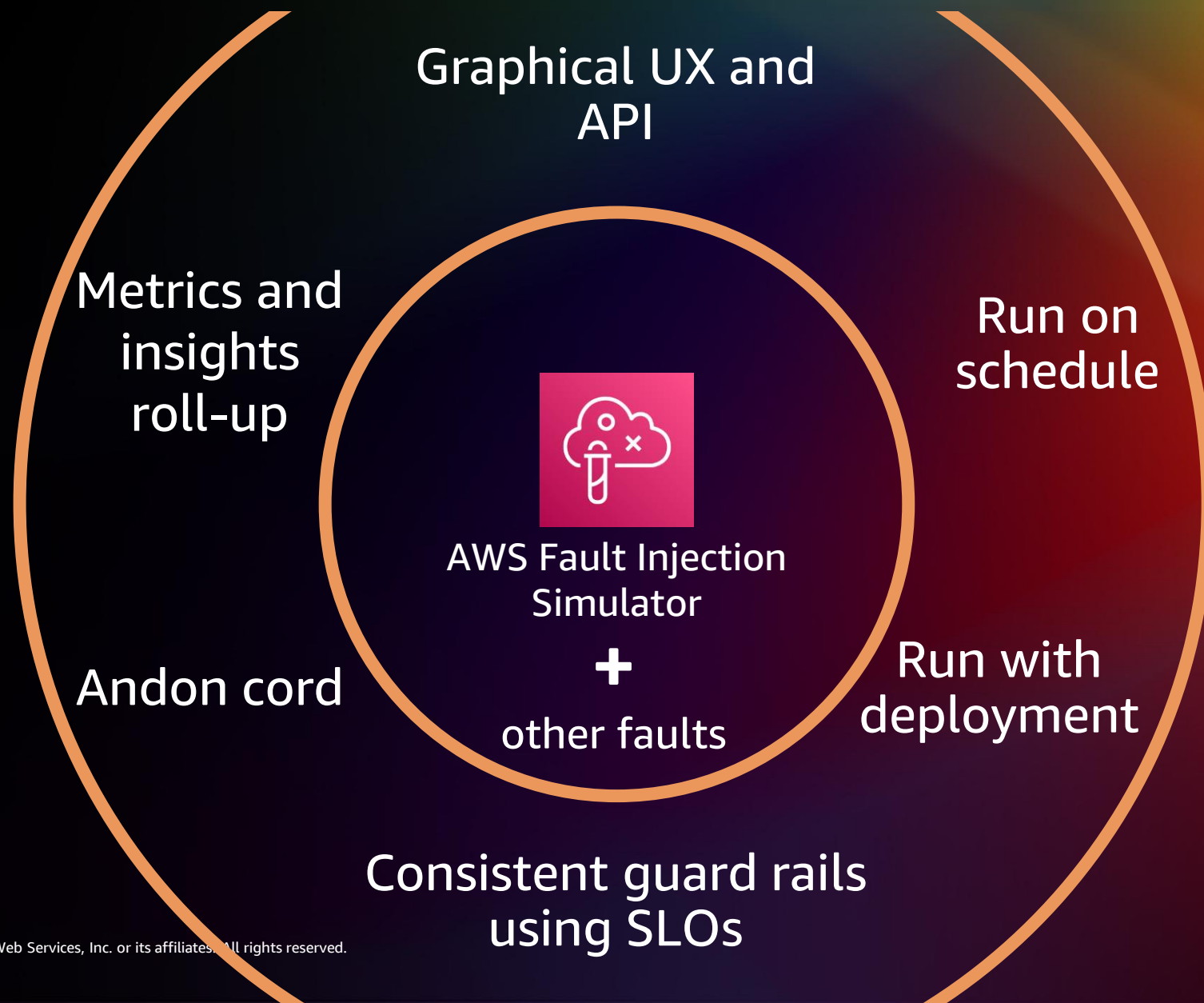
# Chaos experimentation orchestrator



AWS Fault Injection Simulator



# Scale across 40+ Search services



# Types of fault injection

All AWS Fault Injection Simulator events, including:

- Amazon ECS drain container instance
- Terminate Amazon EC2 instances
- Latency injection
- Network port black hole

Plus other actions:

- Load tests
- Emergency lever actuation

Rapid processes that allows system to recover from stress or impact



AWS Fault Injection  
Simulator

# Emergency lever for Search

RAPID PROCESS THAT ALLOWS SYSTEM TO RECOVER FROM STRESS OR IMPACT

## RESULTS



Sponsored

3-in-1 STEM Remote Control Building Kits- Tracked Car/Robot/Tank, 2.4Ghz Rechargeable RC Racer Toy Set Gift for 8...

★★★★★ ~ 1,639

\$59<sup>98</sup> ~~\$64.97~~

Ships to Japan

Ages: 8 years and up



LEGO Ideas Vincent Van Gogh – The Starry Night 21333 Building Set; 3D Art Build-and-Display Model Kit for Adults (2,316...

★★★★★ ~ 1

\$259<sup>00</sup>

Ships to Japan

Usually ships within 1 to 3 weeks.

Ages: 17 years and up



LEGO Star Wars: A New Hope Imperial Star Destroyer 75252 Building Kit (4,784 Pieces)

★★★★★ ~ 1,030

Ages: 16 years and up



LEGO B 10300...  
Details

★★★★

Ages:

## LATEST ARRIVALS



LEGO Ideas Vincent Van Gogh – The Starry Night 21333 Building Set; 3D Art Build-and-Display Model Kit for Adults (2,316 Pieces)

\$259<sup>00</sup>



LEGO Technic Monster Jam Grave Digger 42118 Model Building Kit for Boys and Girls Truck Toys, New 2021 (212 Pieces)

\$16<sup>00</sup> ~~\$19.99~~



LEGO Halloween Owl

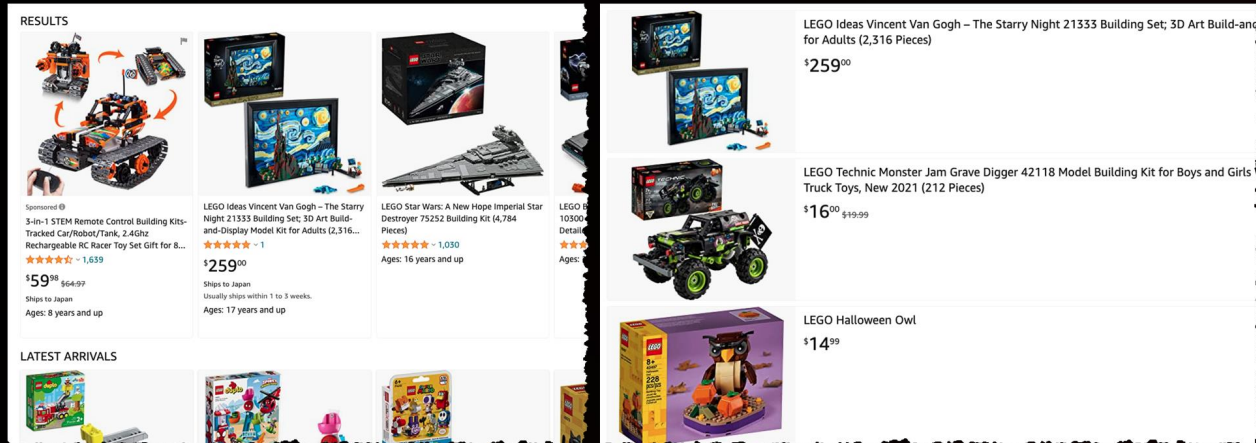
\$14<sup>99</sup>



# Chaos engineering with emergency levers

Hypothesis – The lever works. It enables Search to handle the stress

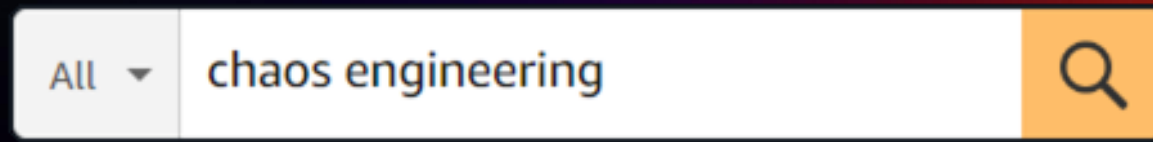
- Inject stress: Load generation
- Pull lever: Disable non-critical features



# Chaos experimentation

How specialized teams & platforms enable teams to do more

Amazon Search

A screenshot of the Amazon search bar. It features a dropdown menu on the left with the word "All" and a downward arrow. The main search input field contains the text "chaos engineering". To the right of the input field is an orange button with a white magnifying glass icon.

**Continuous Experimentation and Learning**  
**Specialized teams & platforms - Enabling teams to do more**  
**Continuous integration**  
**Increased resilience - graceful degradation**

Case study

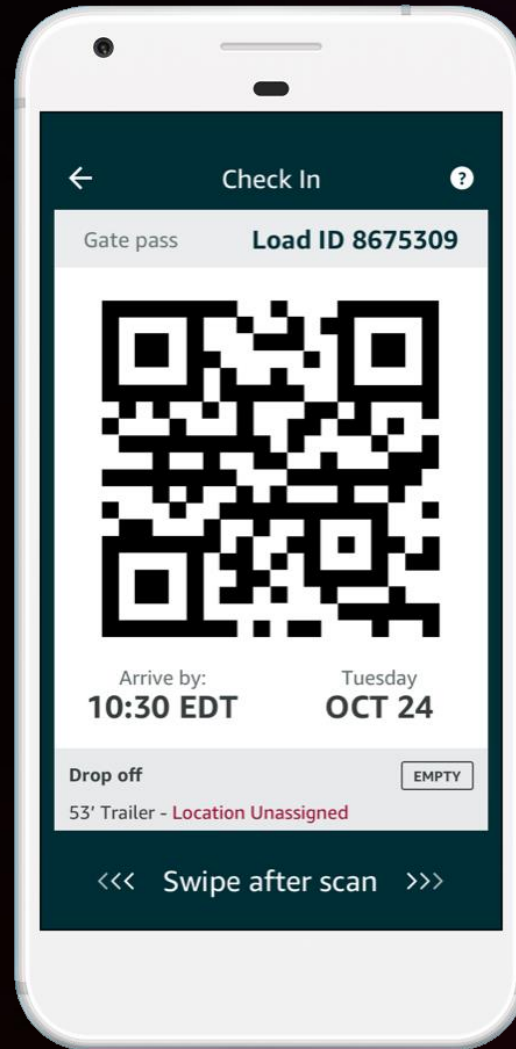
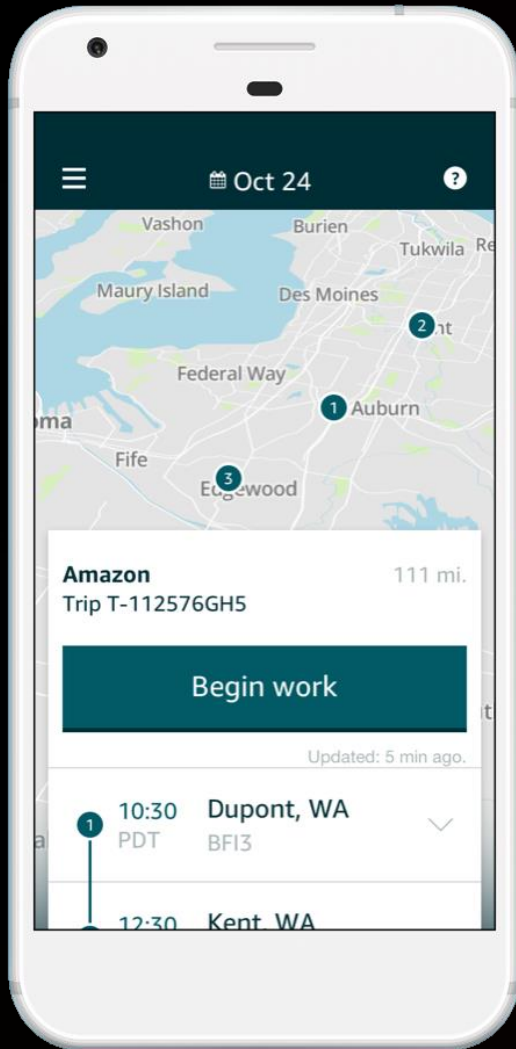
# Responding to customer impacting issues

## Delivering value with cooperation and ownership



# Amazon Relay app

FOR IOS AND ANDROID

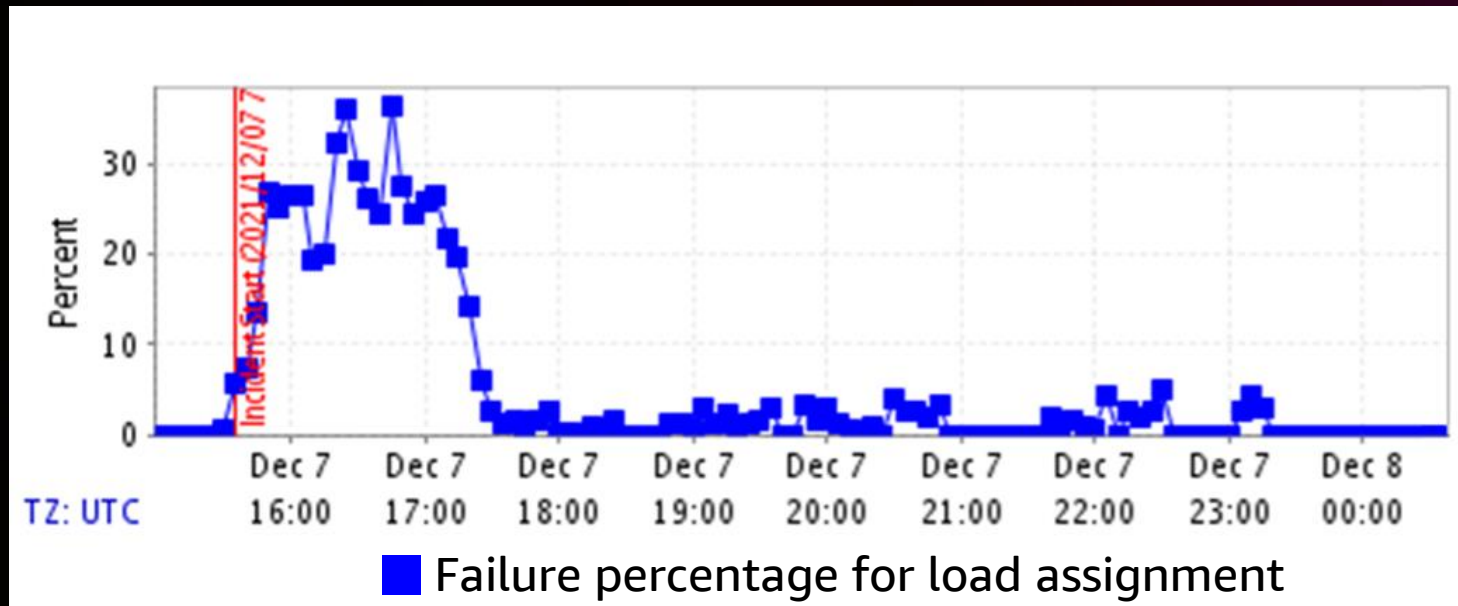




# A problem with resilience

Amazon Simple Notification Service (Amazon SNS) service disruption



Some drivers could not get new load assignments



# COE for this event

## Correction of error (COE)

- Deep dive
  - Blameless
  - Generates **action items**
- ...To ensure no future impact

Title ▲	Status ▼
 <a href="#">Complete Relay App Resiliency Review</a>	✔ Complete
<a href="#">Create Critical Input/Output Metric Dashboard</a>	✔ Complete
 <a href="#">Create multi-region design for Relay services</a>	✔ Complete
<a href="#">Plan to create and test new AWS IAM roles</a>	✔ Complete
<a href="#">Review AWS IAM roles for Amazon S3 access</a>	✔ Complete
<a href="#">Update all AWS IAM roles to be compliant with AWS IAM best practices</a>	✔ Complete

# Relay mobile resiliency review

“Preserve physical operational continuity in all cases, even if the experience is degraded”

“Don’t let stuff pile up on the loading dock”

1. Identify critical functions
2. Design solutions so critical functions remain operational
3. Adapt system to degrade gracefully

# Relay app goes multi-Region

AWS REGIONS – NORTH AMERICA

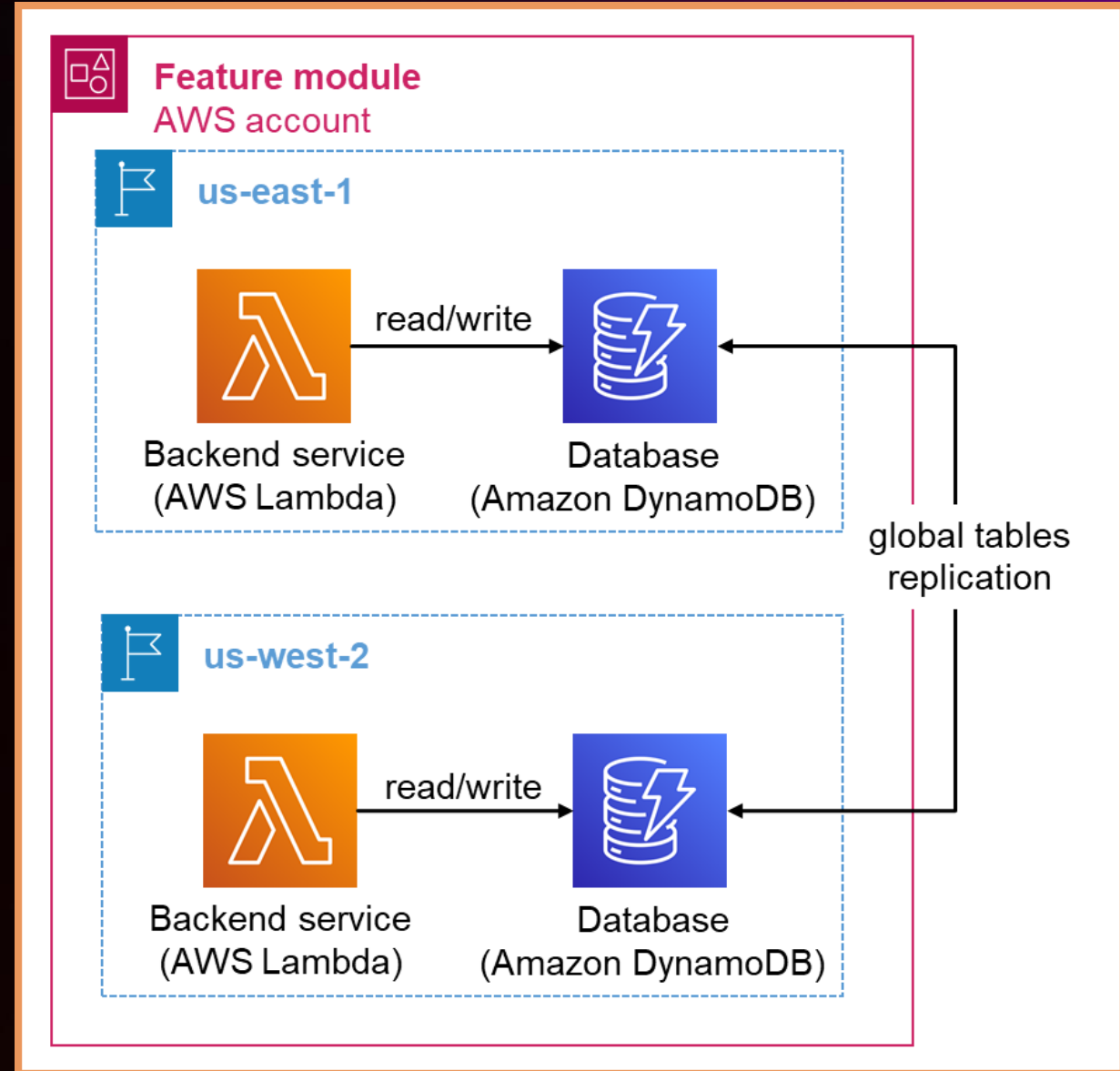
2. Design solutions so critical functions remain operational



# Multi-Region solution – Modules

## Multi-Region design

- Independent services
- Owned by autonomous two-pizza teams



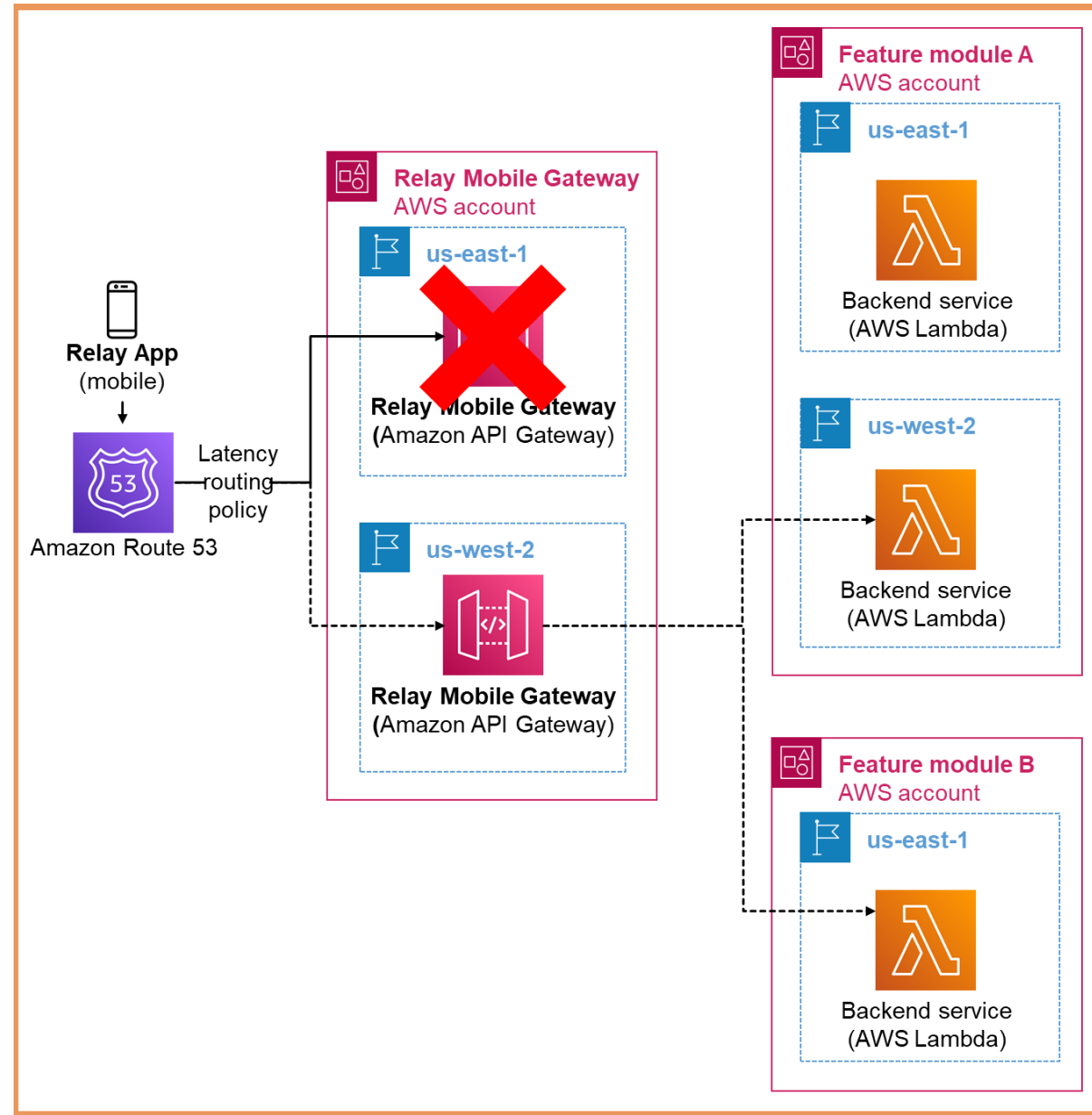


# Design for resilience

No shared ownership of code or infrastructure between teams

Failover: move all requests to one Region

- Gateway
  - All traffic directed to us-west-2
- Modules
  - Critical ones are multi-Region



# Testing resilience

GAME DAY

Prepare for "peak"  
aka "holiday season"





# Testing resilience

GAME DAY

Prepare for “peak”

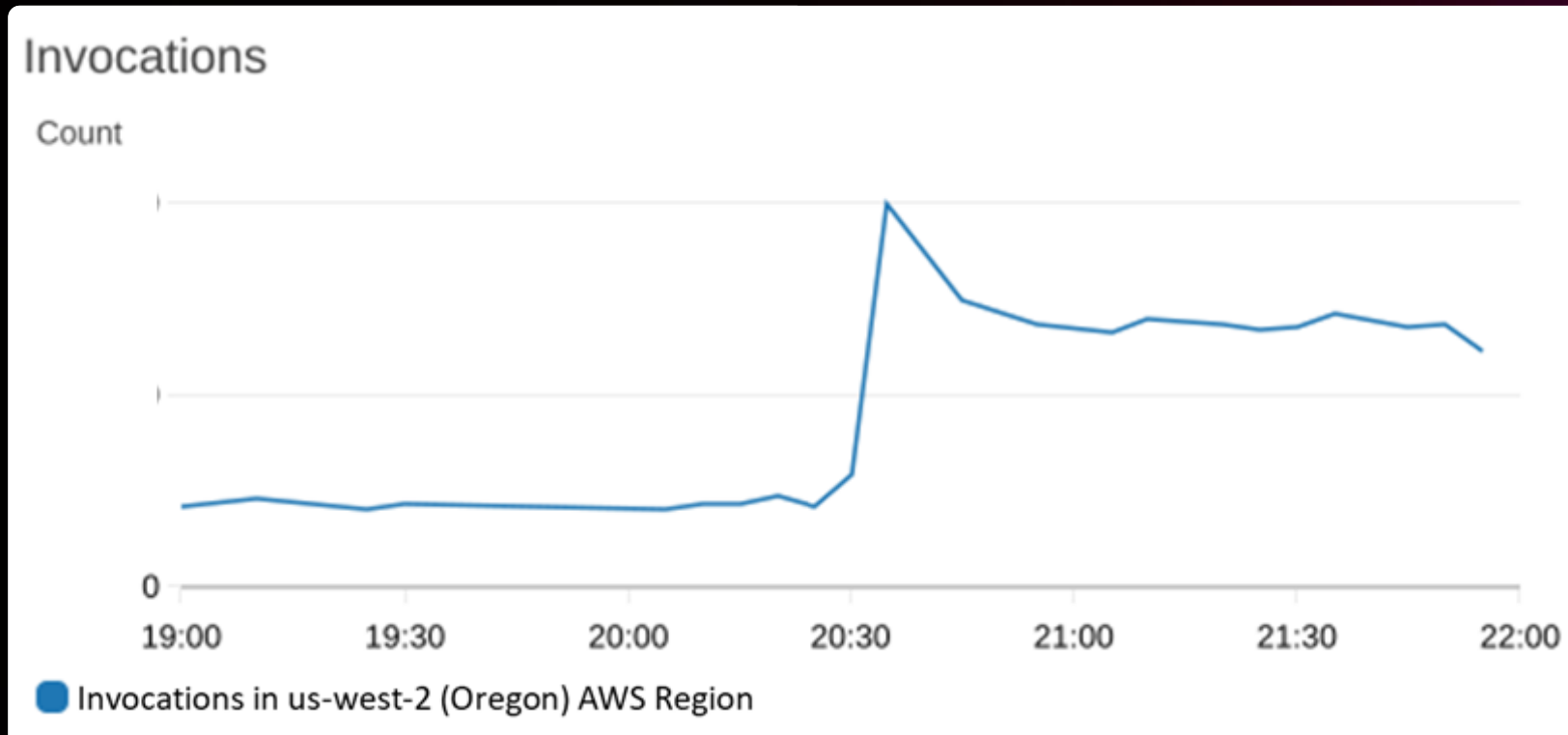
Shift 100% of traffic out of us-east-1

- Increased traffic in us-west-2 by about 350%
- No customer impact, system failures, or degraded experiences
- Less than 10 mins to fail over
- Some latency increase – within spec, work on improving



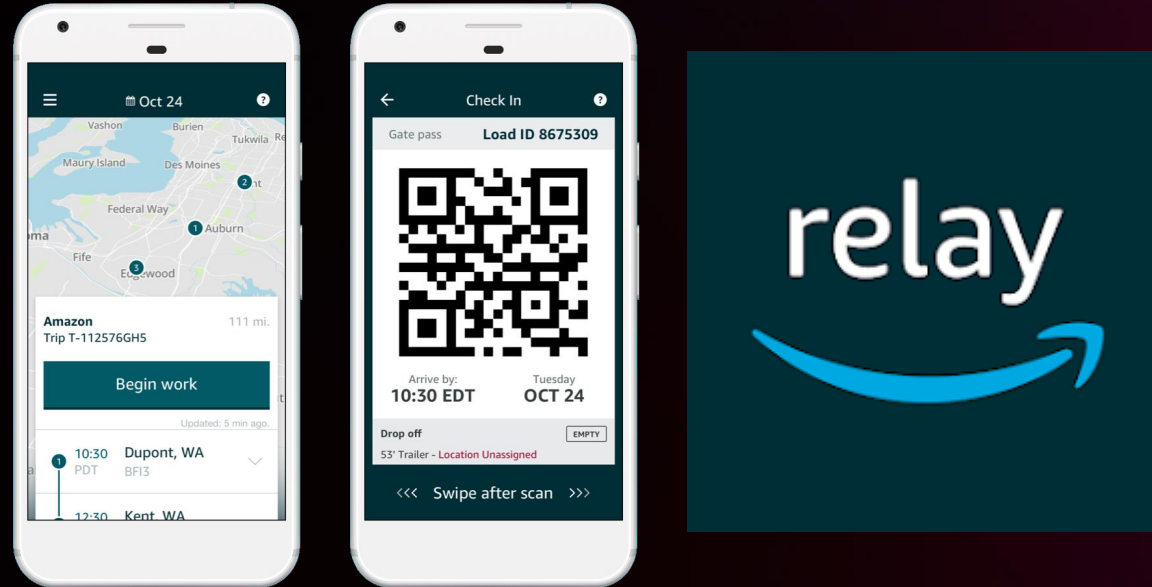
# It works!

[June 13, 2023] Between 11:49 AM PDT and 3:37 PM PDT, we experienced increased error rates and latencies for multiple AWS Services in the US-EAST-1 Region.... root cause to be an issue with a subsystem responsible for capacity management for AWS Lambda,



# Responding to customer impacting issues

Delivering value with cooperation and ownership



**Deliver value to the customer**  
**Shared responsibility and ownership**  
**Microservices architecture - quicker innovation**  
**Observability to respond to issues**



Case study

# Breaking down a monolith

## And enabling 2PT ownership

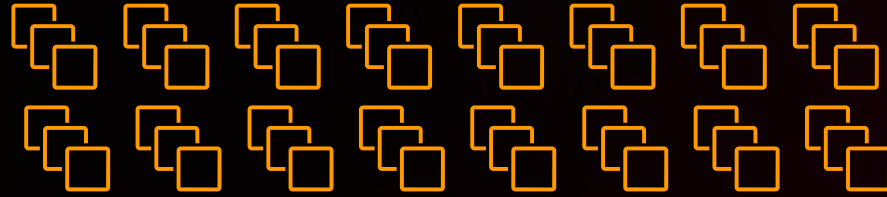


# IMDb re-architecture to serverless

## Old

- Monolith REST API

- 100s of hosts



## New

- Federated schema with microservices
- Serverless, running on AWS Lambda



# Federated schema using graphlets

## GraphQL

```
{
  name(id: "nm0000329") {
    knownFor(first: 4) {
      title {
        titleText {
          text
        }
      }
      releasedate {
        year
      }
      ratingsSummary {
        aggregateRating
      }
      primaryImage {
        url
      }
    }
  }
}
```

What is Jackie Chan (id nm0000329) known for?



AWS Lambda

tt0120812, tt0089374...



AWS Lambda

Rush Hour, Police Story...  
1998, 1985...



AWS Lambda

7.0, 7.5...



AWS Lambda

m.media-amazon.com/images...

# GraphQL query result

What is Jackie Chan (id nm0000329) known for?

something missing...?

## Known for



### Who Am I?

★ 6.8

Who Am I

1998



### Rush Hour

★ 7.0

Lee

1998



### Rush Hour 2

★ 6.6

Lee

2001



### Police Story

★ 7.5

Chan Ka Kui

1985



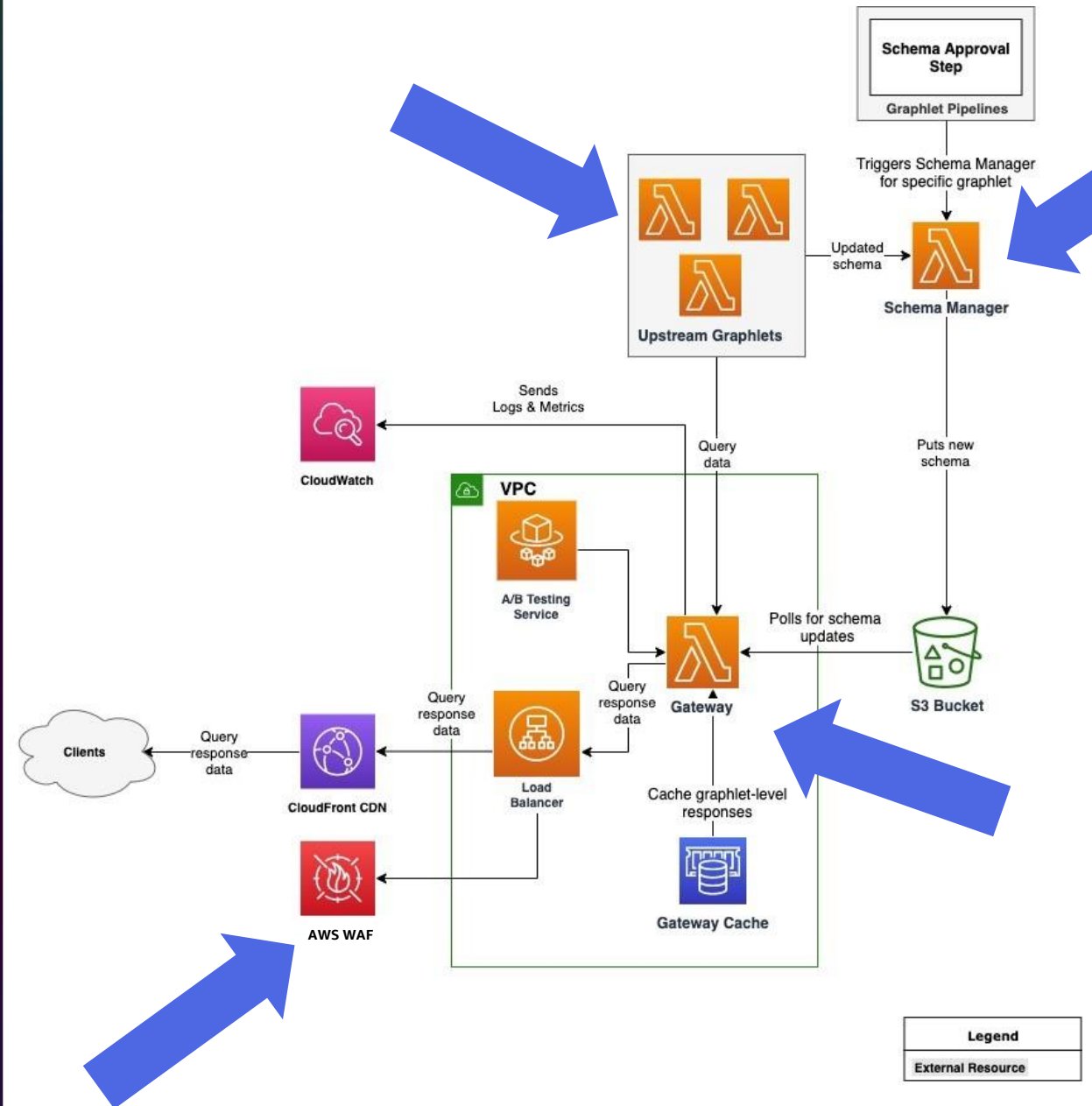
# IMDb backend architecture

Gateway

Microservices/graphlets (gray box)

Schema manager

API for front end





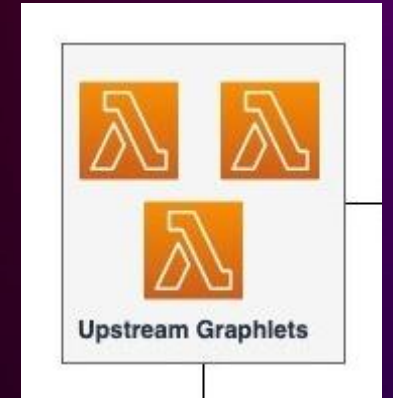
# Two-pizza team ownership



Moved business logic closer to the teams that have the right expertise

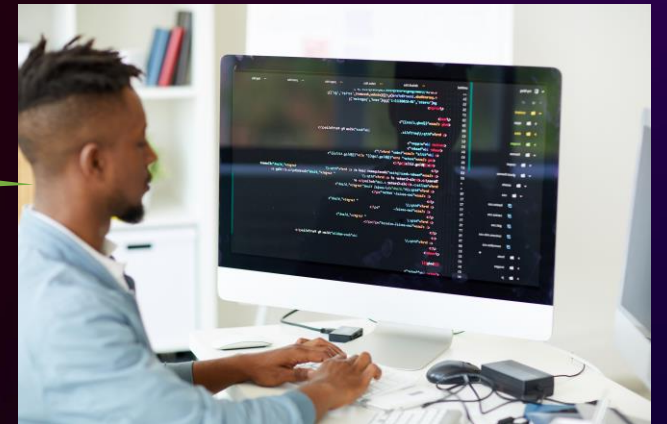
Full ownership

- Of the data in their portion of the graph
- Of partial schema and the resolvers that provide that data



Wins for development and operations

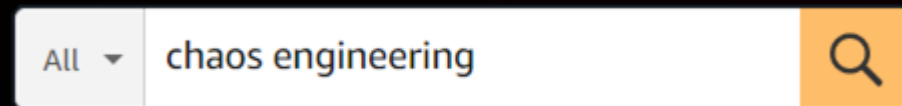
"Our ridiculously smooth oncall"



# Just some examples of many



Amazon Search



# Resources

The Distributed Computing Manifesto (1998)

[bit.ly/distributed\\_computing\\_manifesto](https://bit.ly/distributed_computing_manifesto)

Improving Business Resiliency with Chaos Engineering • Olga Hall • GOTO 2021

[youtube.com/watch?v=6NIh-GsO1Kg](https://youtube.com/watch?v=6NIh-GsO1Kg)



Big Trucks, Jackie Chan movies, and millions of boxes: How Amazon Does DevOps in Real Life

[bit.ly/amazon-devops](https://bit.ly/amazon-devops)

Any Day Can Be Prime Day: How Amazon.com Search Uses Chaos Engineering

[bit.ly/search\\_chaos\\_engineering](https://bit.ly/search_chaos_engineering)

Reliable scalability: How Amazon.com scales in the cloud - re:Invent 2022 - ARC206

[bit.ly/reliable2022](https://bit.ly/reliable2022)

7 Things About DevOps That Everyone Should Know

[bit.ly/devops7things](https://bit.ly/devops7things)



# Thank you!

Seth Eliot

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[in](https://www.linkedin.com/in/setheliot) [linkedin.com/in/setheliot](https://www.linkedin.com/in/setheliot)

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Click on  
**DevOps in the Cloud**  
choose a rating  
leave a Review

