DSC 102
Systems for Scalable Analytics

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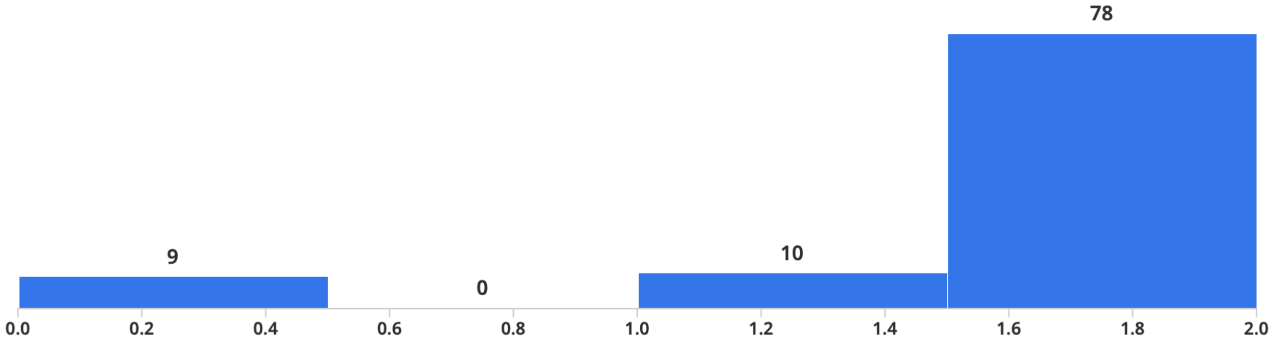
Topic 2: Basics of Cloud Computing

Admin

- Practice midterms coming, PA due Saturday
- PA0 extra-credit bounty: 270 seconds
- In Class Activity 2 and 3 Scores Posted
- ICA 2 was a gimme... still a few late submissions, misses on the prompt, unsubmitted
- ICA 3:

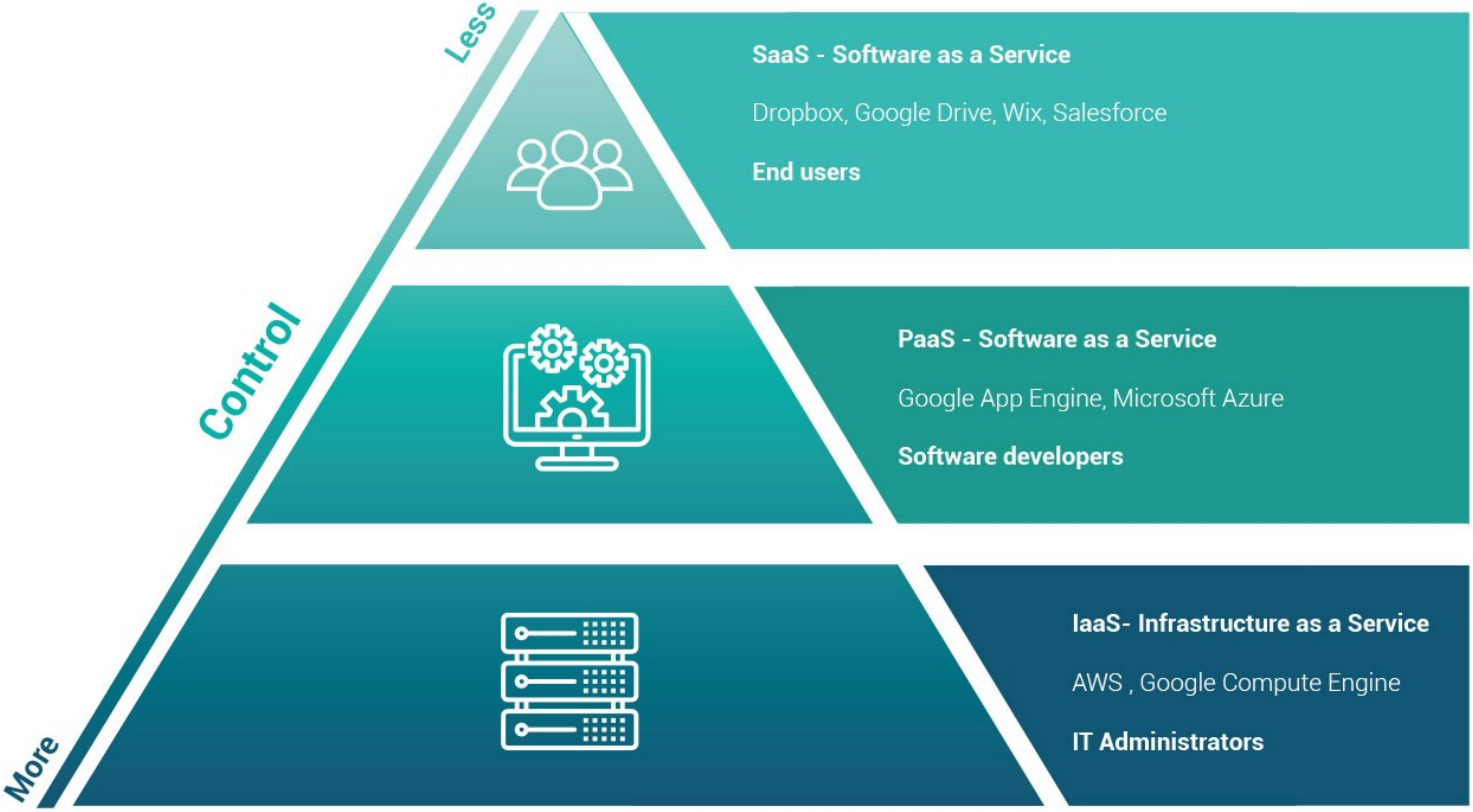


Minimum	Median	Maximum	Mean	Std Dev ?
0.0	2.0	2.0	1.71	0.63

Cloud Computing

- Compute, storage, memory, networking, etc. are virtualized and exist on *remote servers*; *rented* by application users
- Main pros of cloud vs on-premise clusters:
  - **Manageability**: Managing hardware is not user's problem
  - **Pay-as-you-go**: Fine-grained pricing economics based on actual usage (granularity: seconds to years!)
  - **Elasticity**: Can dynamically add or reduce capacity based on actual workload's demand
- Infrastructure-as-a-Service (IaaS); Platform-as-a-Service (PaaS); Software-as-a-Service (SaaS)

Cloud Computing



SaaS - Software as a Service

Dropbox, Google Drive, Wix, Salesforce

End users

PaaS - Software as a Service

Google App Engine, Microsoft Azure

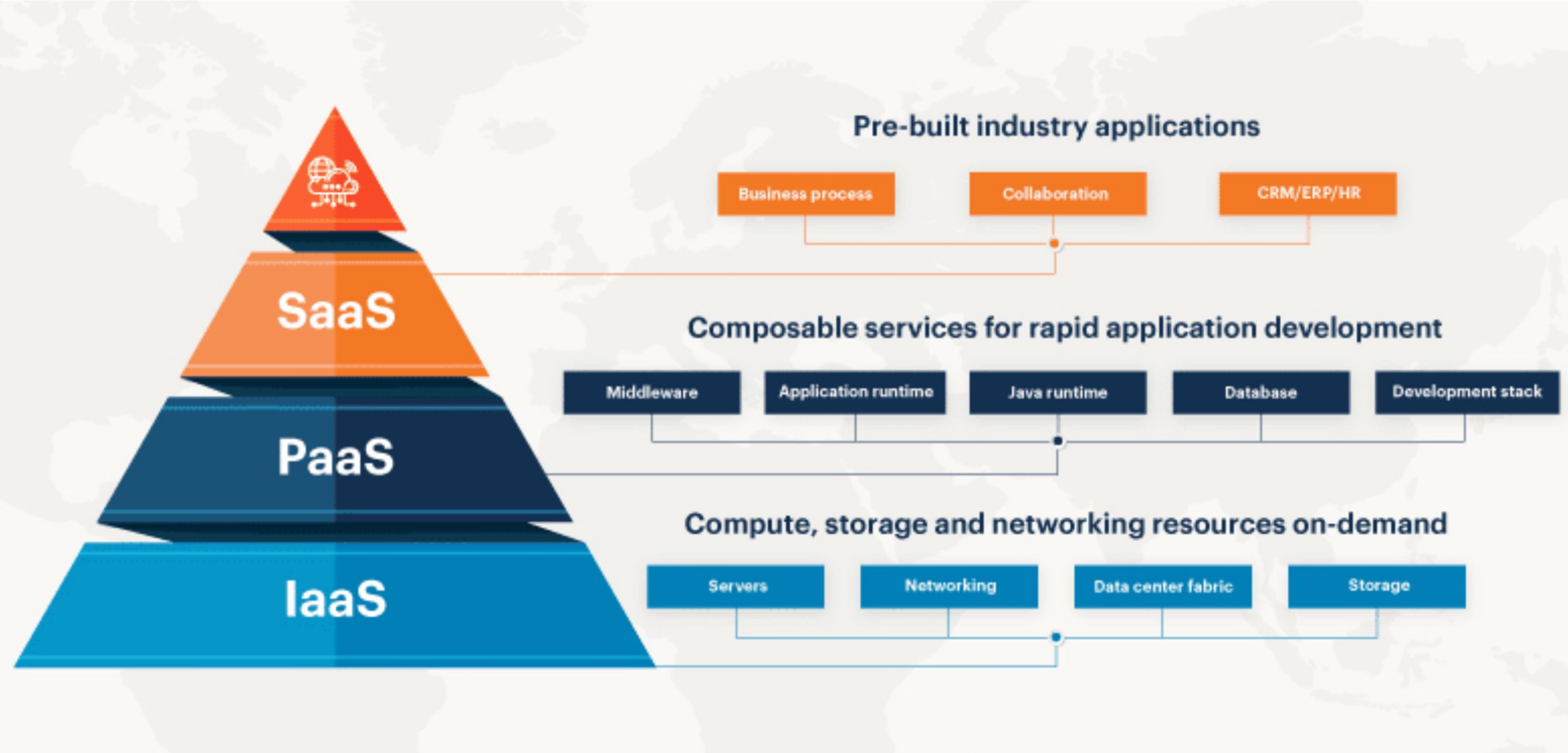
Software developers

IaaS- Infrastructure as a Service

AWS , Google Compute Engine

IT Administrators

Cloud Computing



Example: AWS Cloud Services

- **IaaS**:
  - **Compute**:
    - Elastic Compute Cloud (EC2)
    - Elastic Container Service (ECS)
    - Serverless compute engines:
      Fargate (serverless containers), Lambda (serverless functions)
  - **Storage**:
    - Simple storage service (S3)
    - Elastic Block Store (EBS)
    - Elastic File System (EFS)
    - Glacier (storage classes)
  - **Networking**:
    - CloudFront (low latency content delivery)
    - Virtual Private Cloud (VPC)

Example: AWS Cloud Services

- **PaaS**:
  - **Database/Analytics Systems**:

    Aurora, Redshift, Neptune, ElastiCache, DynamoDB, Timestream, EMR, Athena
  - **Blockchain**: QLDB
  - **IoT**: Greengrass
  - **ML/AI**: SageMaker*
- **SaaS**:
  - **ML/AI**:

    SageMaker*, Elastic Inference, Lex, Polly, Translate, Transcribe, Textract, Rekognition, Ground Truth
  - **Business Apps**:

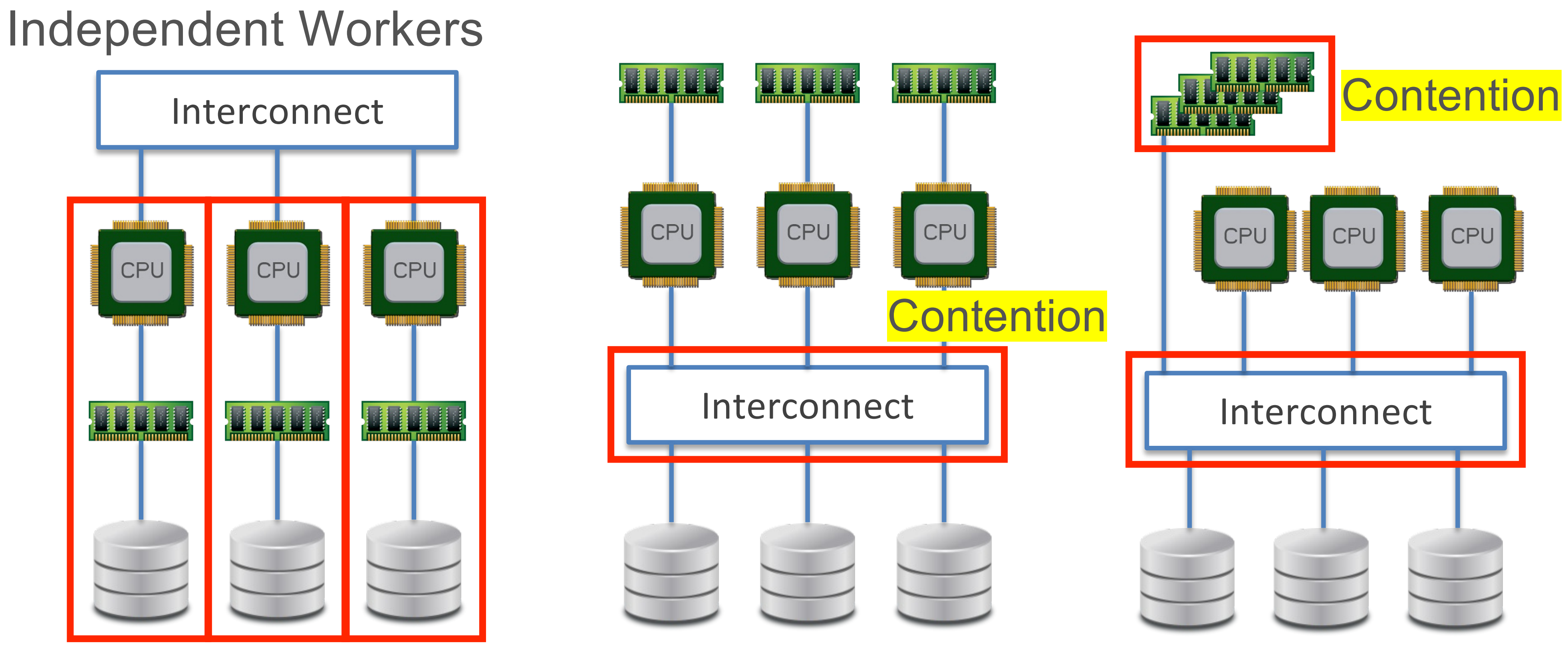
    Chime, WorkDocs, WorkMail

*SageMaker has elements of both PaaS and SaaS

Evolution of Cloud Infrastructure

- **Data Center**: Physical space from which a cloud is operated
- **3 generations of data centers/clouds:**
  - **Cloud 1.0 (Past)**: Networked servers; user rents servers (time-sliced access) needed for data/software
  - **Cloud 2.0 (Current)**: “Virtualization” of networked servers; user rents amount of resource capacity; cloud provider has a lot more flexibility on provisioning (multi-tenancy, load balancing, more elasticity, etc.)
  - **Cloud 3.0 (Ongoing Research)**: “Serverless” and disaggregated resources all connected to fast networks

3 Paradigms of Multi-Node Parallelism



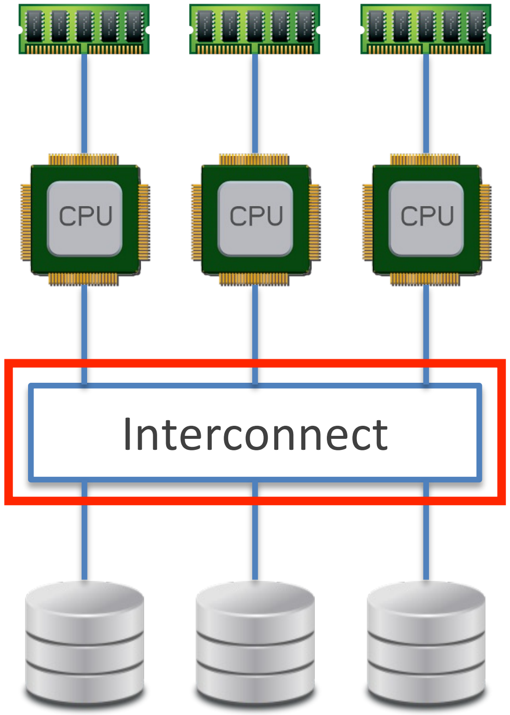
Shared-Nothing Parallelism

Shared-Disk Parallelism

Shared-Memory Parallelism

Most parallel RDBMSs (Teradata, Greenplum, Redshift), Hadoop, and Spark use shared-nothing parallelism

Revisiting Parallelism in the Cloud

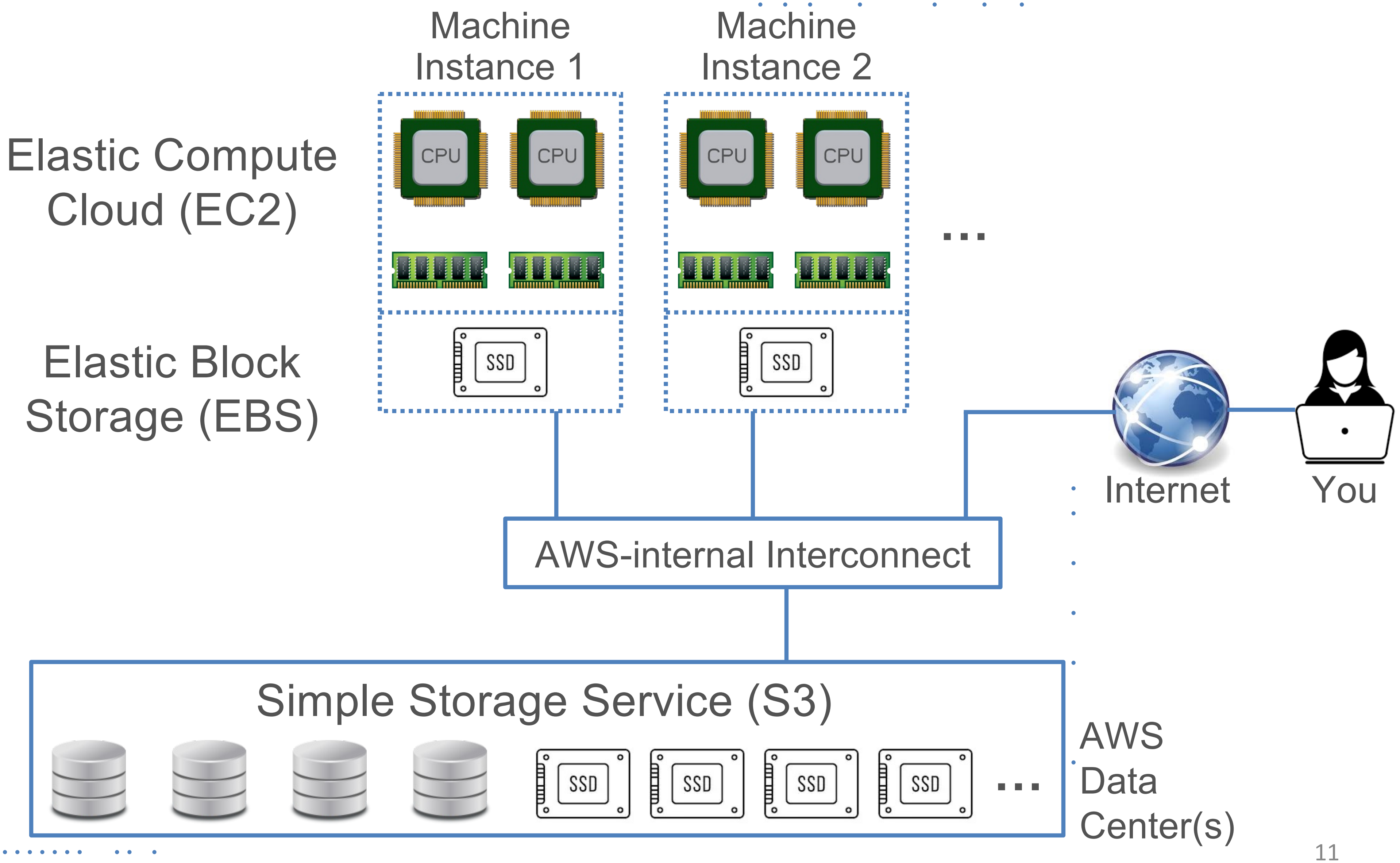


Shared-Disk Parallelism

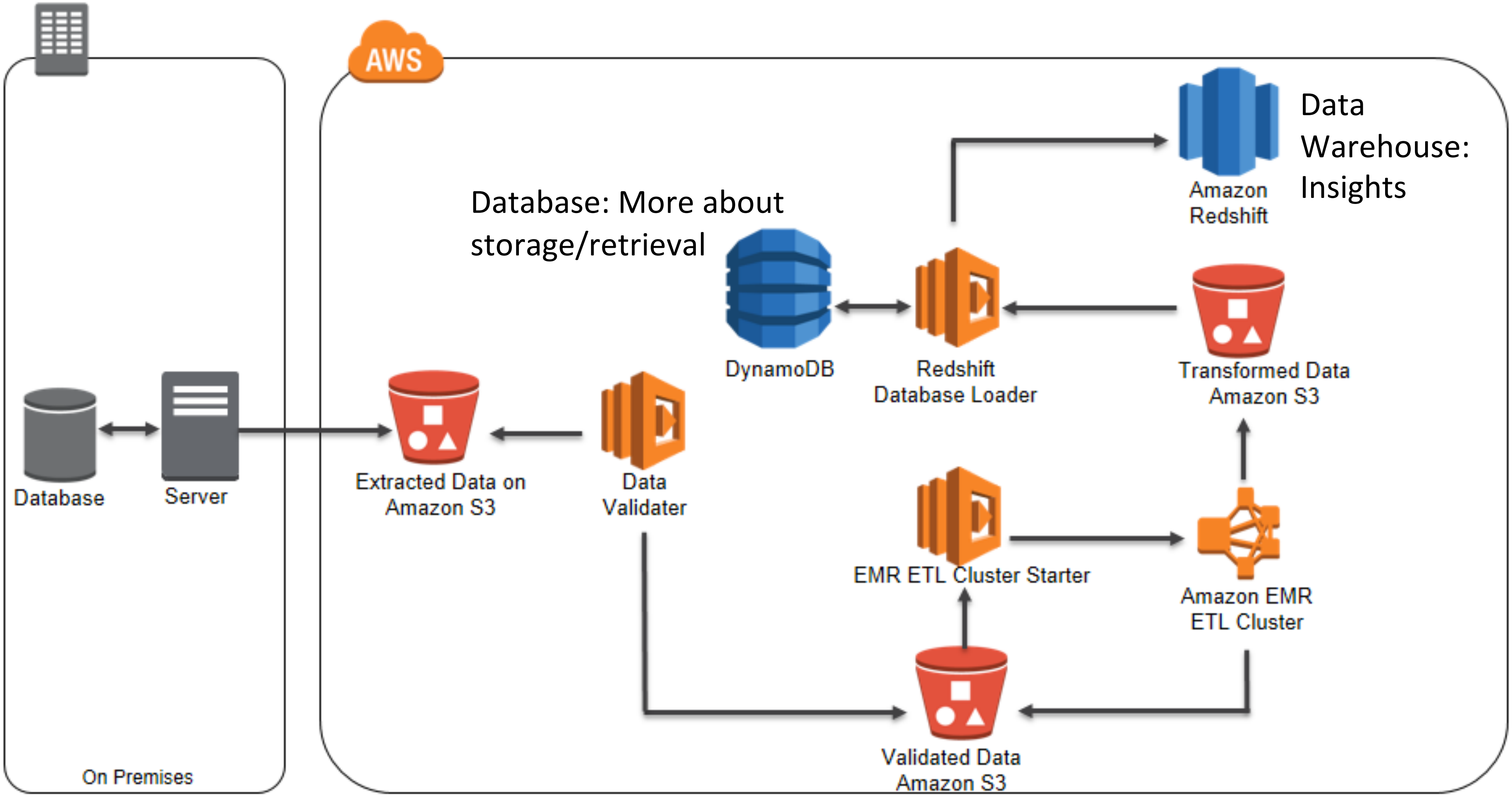
Modern networks in data centers have become much faster: In terms of gigabit Ethernet connection speeds, one can find speeds in the order of magnitude 100GbE to even TbE!

- **Decoupling** of compute+memory from storage is common in cloud
  - *Hybrids* of shared-disk parallelism + shared-nothing parallelism
  - E.g, store datasets on S3 and read as needed to local EBS

Example: AWS Services for PA1


Machine Instance 1
Machine Instance 2
Elastic Compute Cloud (EC2)
CPU
CPU
CPU
CPU
...
Elastic Block Storage (EBS)
SSD
SSD
Internet
You
AWS-internal Interconnect
Simple Storage Service (S3)
SSD
SSD
SSD
SSD
...
AWS Data Center(s)

Example: AWS DB/Analytics Services

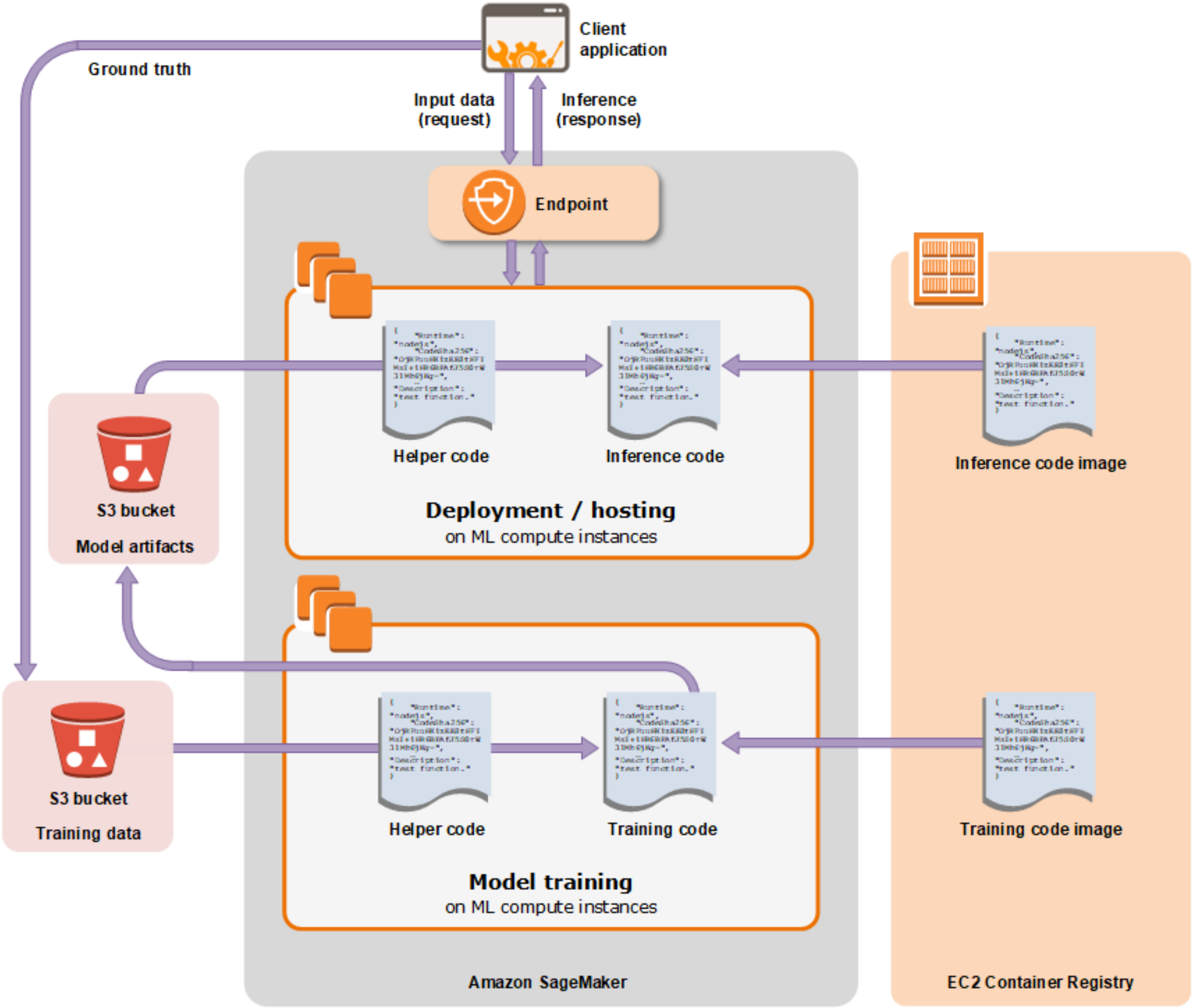


Database: More about storage/retrieval

Data Warehouse: Insights

https://aws.amazon.com/blogs/big-data/automating-analytic-workflows-on-aws/

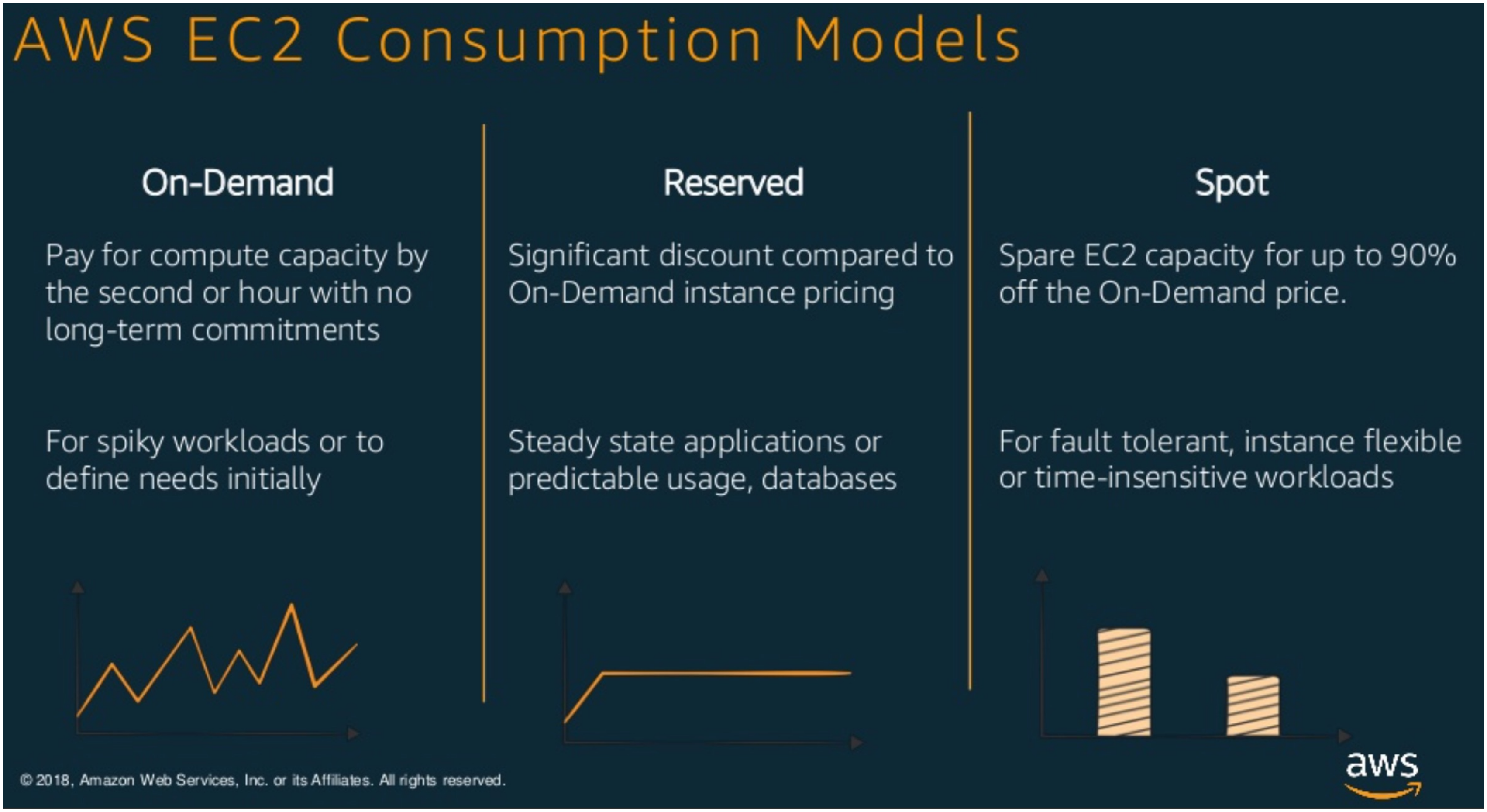
Example: AWS ML Services



https://docs.aws.amazon.com/sagemaker/latest/dg/how-it-works-training.html

New Cloud Renting Paradigms

- ❖ Cloud 2.0's flexibility enables radically different paradigms
- ❖ AWS example below; Azure and GCP have similar gradations



AWS EC2 Consumption Models

On-Demand

Pay for compute capacity by the second or hour with no long-term commitments

For spiky workloads or to define needs initially

Reserved

Significant discount compared to On-Demand instance pricing

Steady state applications or predictable usage, databases

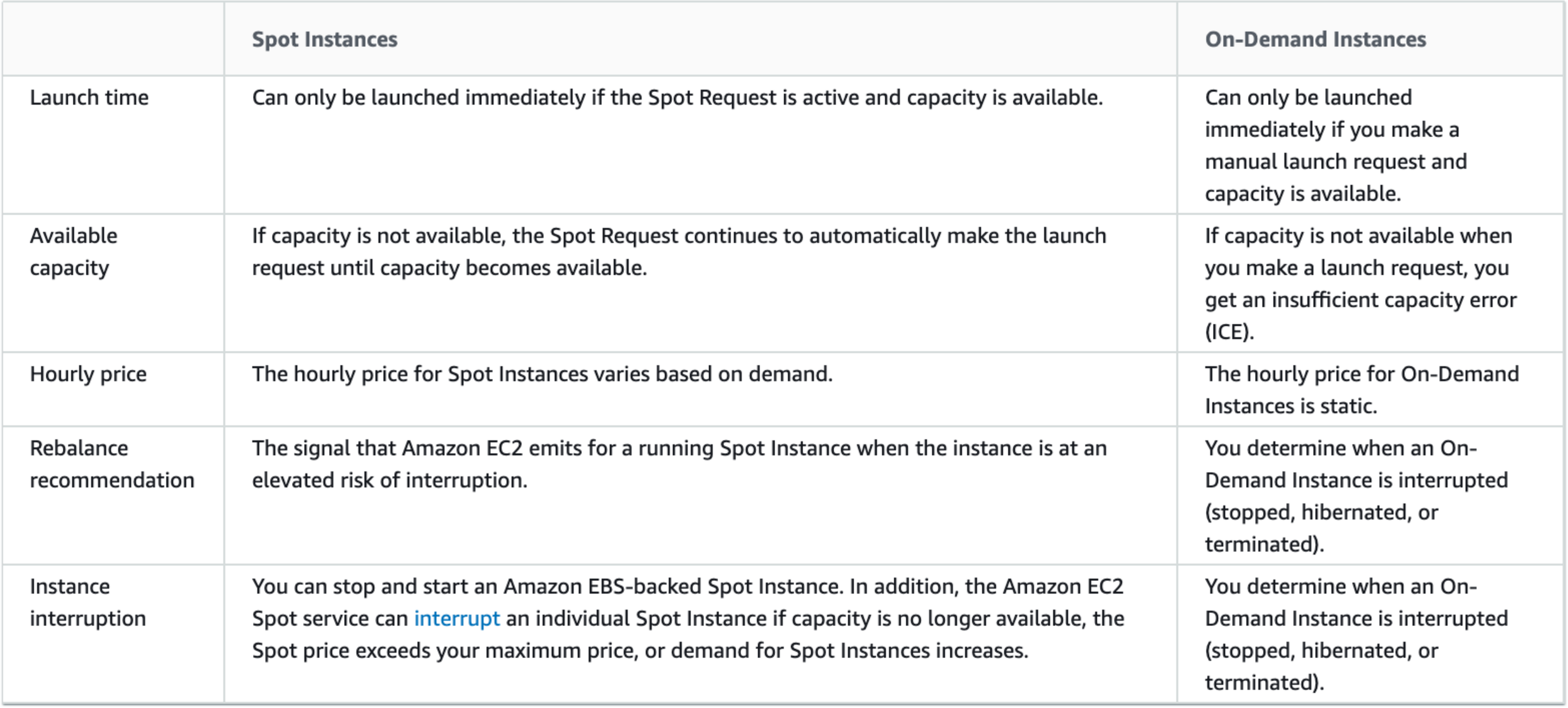
Spot

Spare EC2 capacity for up to 90% off the On-Demand price.

For fault tolerant, instance flexible or time-insensitive workloads

https://www.slideshare.net/AWSUsersGroupBengalu/amazon-ec2-spot-instances

More on Spot vs On-Demand

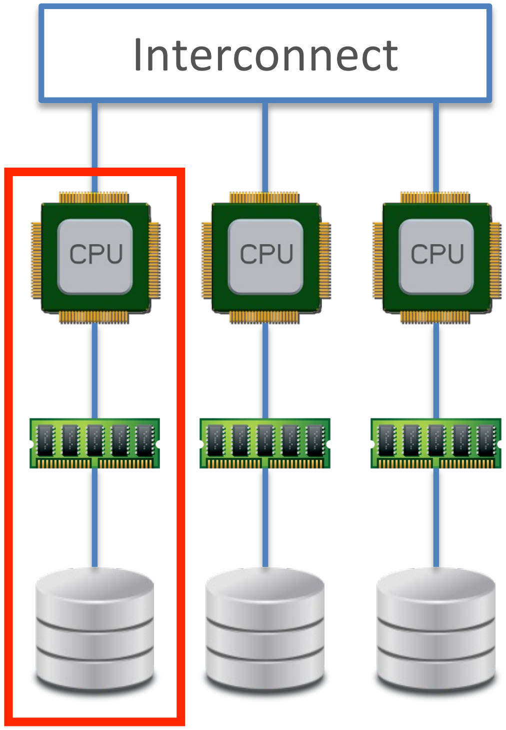


	Spot Instances	On-Demand Instances
Launch time	Can only be launched immediately if the Spot Request is active and capacity is available.	Can only be launched immediately if you make a manual launch request and capacity is available.
Available capacity	If capacity is not available, the Spot Request continues to automatically make the launch request until capacity becomes available.	If capacity is not available when you make a launch request, you get an insufficient capacity error (ICE).
Hourly price	The hourly price for Spot Instances varies based on demand.	The hourly price for On-Demand Instances is static.
Rebalance recommendation	The signal that Amazon EC2 emits for a running Spot Instance when the instance is at an elevated risk of interruption.	You determine when an On-Demand Instance is interrupted (stopped, hibernated, or terminated).
Instance interruption	You can stop and start an Amazon EBS-backed Spot Instance. In addition, the Amazon EC2 Spot service can interrupt an individual Spot Instance if capacity is no longer available, the Spot price exceeds your maximum price, or demand for Spot Instances increases.	You determine when an On-Demand Instance is interrupted (stopped, hibernated, or terminated).

https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/using-spot-instances.html

New Cloud Renting Paradigms

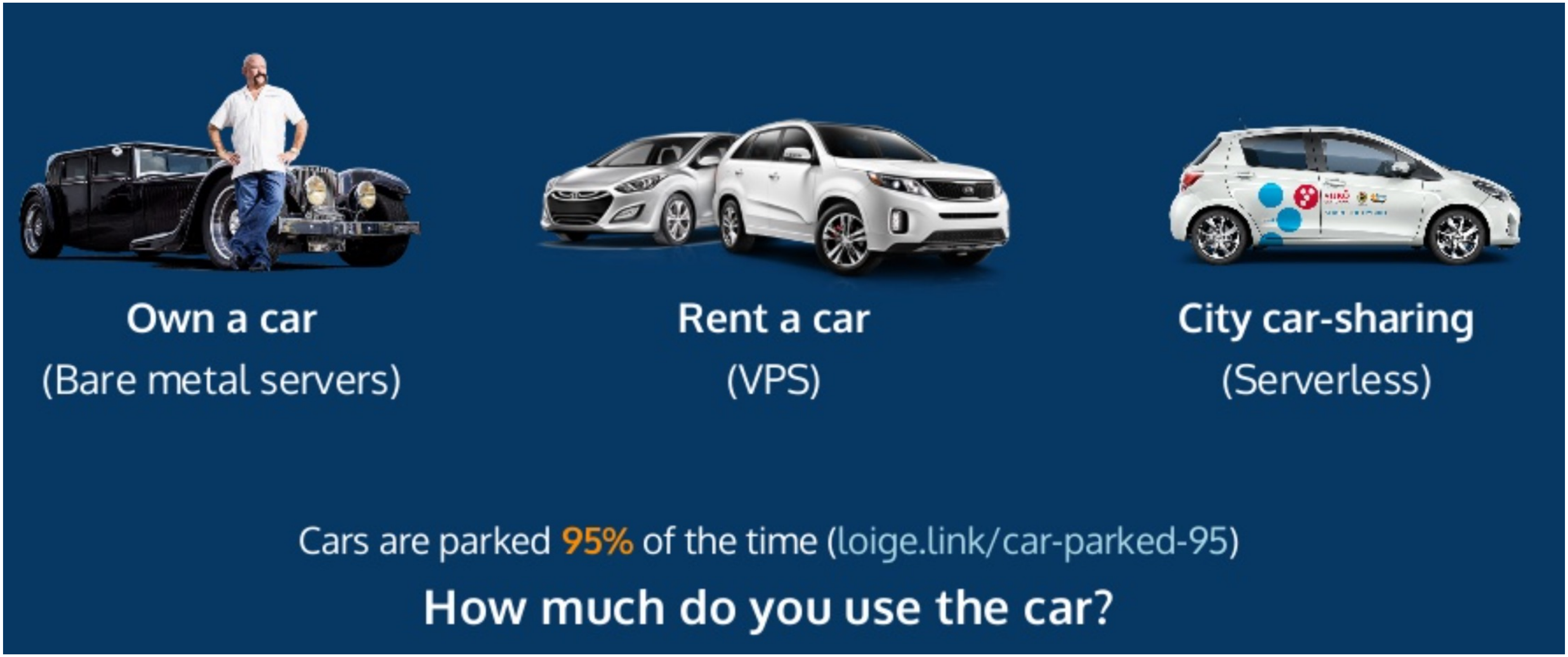
Such bundling means some applications might under-utilize some resources!



Shared-Nothing Parallelism

- **Serverless** paradigm gaining traction for some applications, e.g., online ML prediction serving on websites
- User gives a program (function) to run and specifies CPU and DRAM needed
- Cloud provider abstracts away all resource provisioning entirely
- Higher resource efficiency; much cheaper, often by 10x vs Spot instances
- Aka *Function-as-a-Service* (FaaS)

Car Analogy for Serverless Cloud



Own a car

(Bare metal servers)

Rent a car

(VPS)

City car-sharing

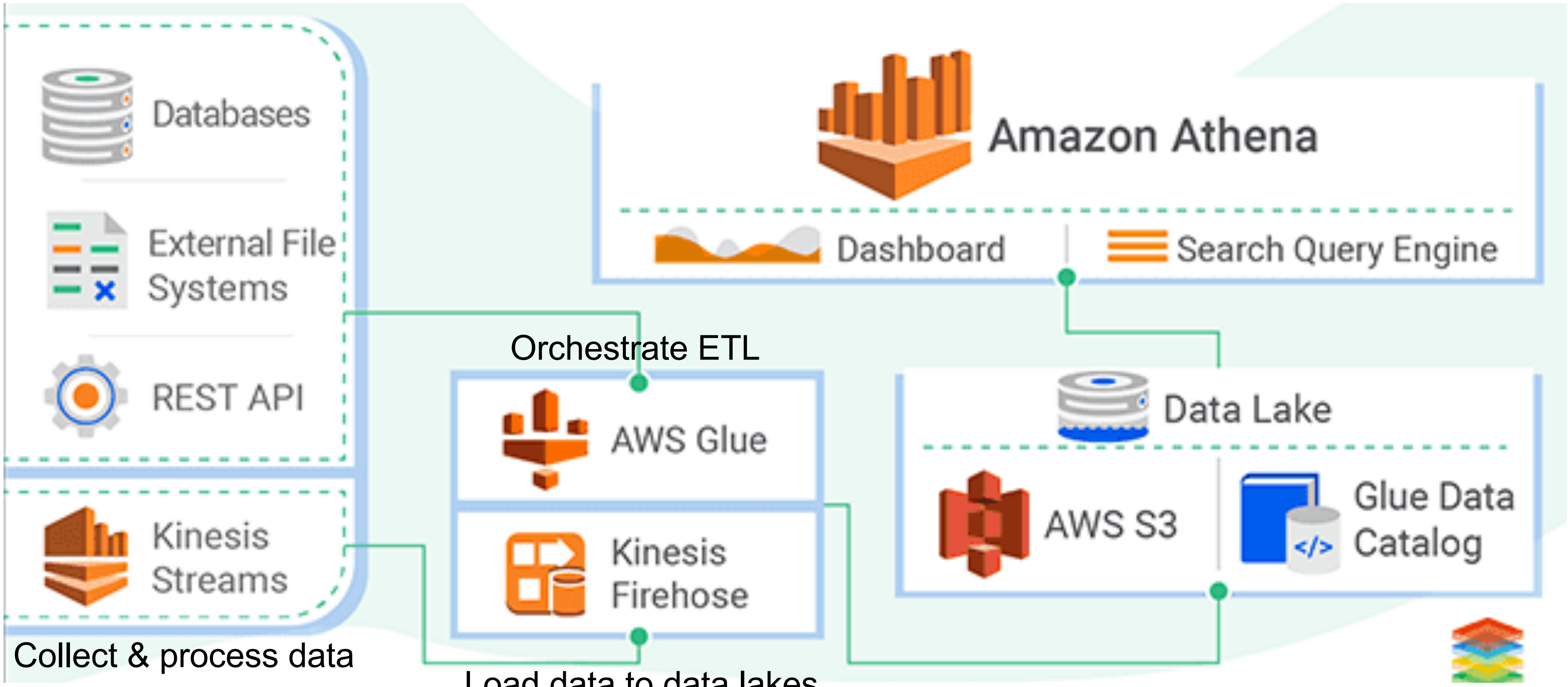
(Serverless)

Cars are parked **95%** of the time (loige.link/car-parked-95)

How much do you use the car?

https://www.slideshare.net/loige/building-a-serverless-company-with-nodejs-react-and-the-serverless-framework-jsday-2017-verona

Example: Serverless RDBMS on AWS



Orchestrate ETL

Collect & process data

Load data to data lakes, warehouses, services

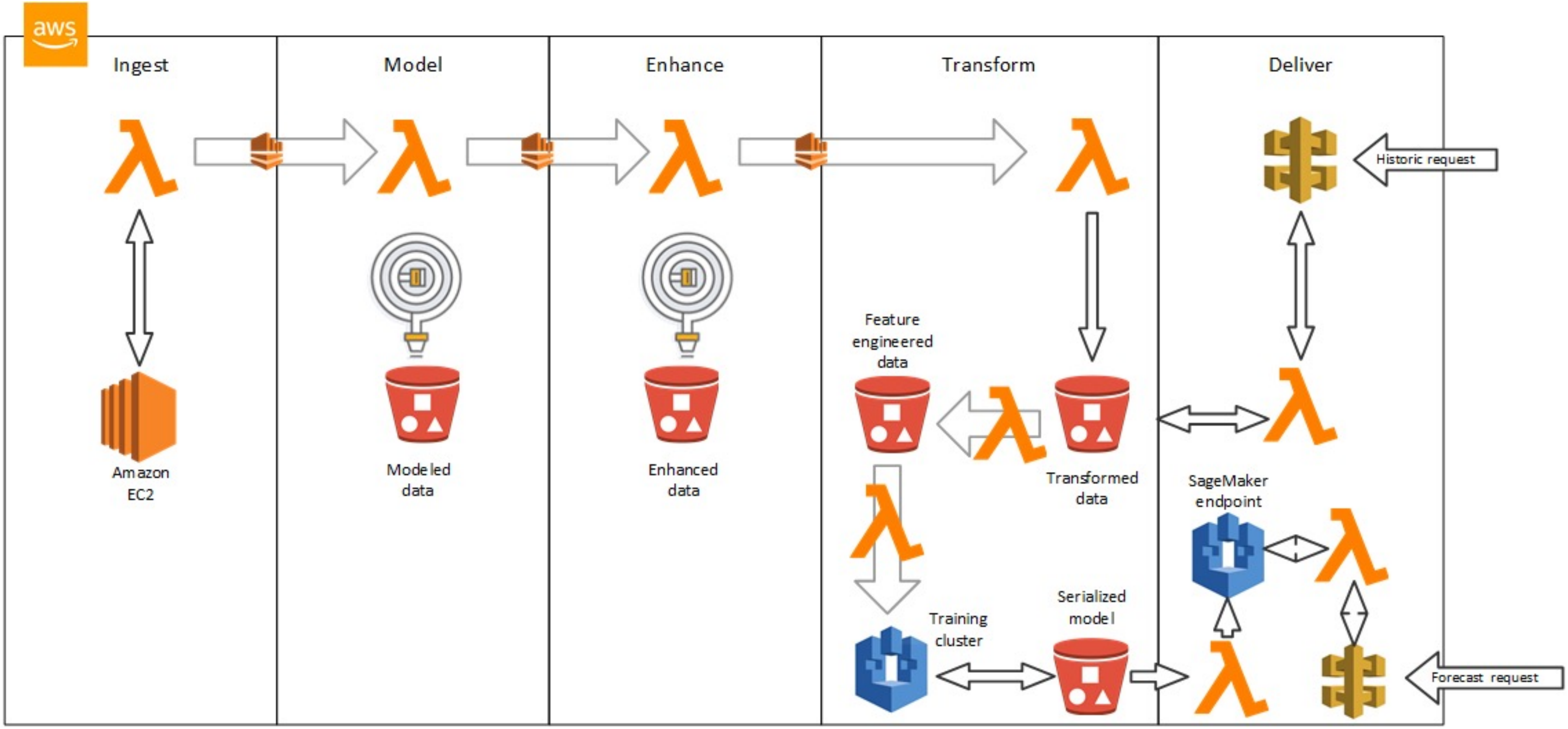
Remote read of data from S3

Schema-on-read
Many data formats

Simple interactive queries

https://www.xenonstack.com/blog/amazon-athena-quicksight/

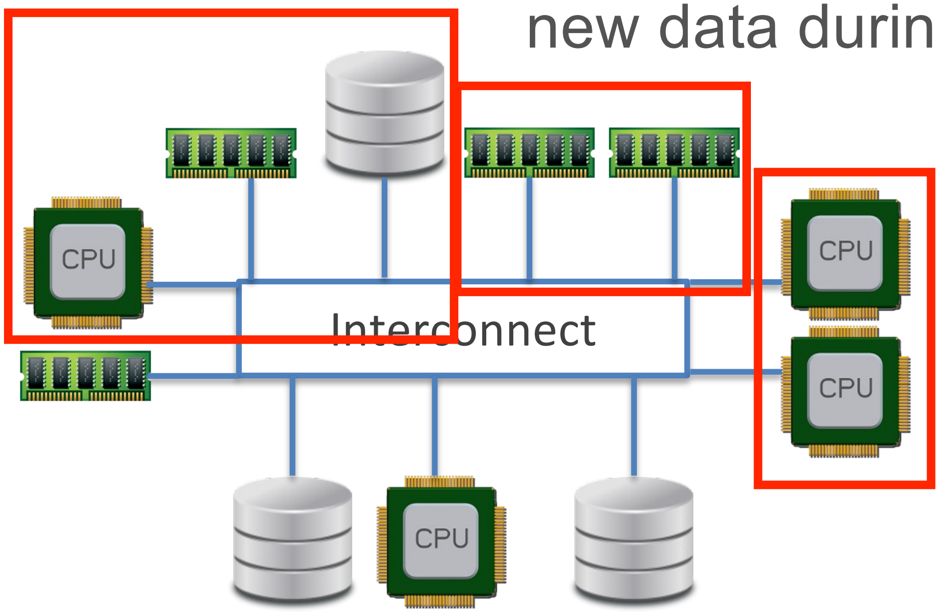
Example: Serverless ML app. on AWS



https://aws.amazon.com/quickstart/architecture/predictive-data-science-sagemaker-and-data-lake/

Disaggregation: Glimpse into the Future?

- Logical next step in serverless direction: full **resource disaggregation**! That is, compute, memory, storage, etc. are all network-attached and elastically added/removed



Add more memory to load new data during execution

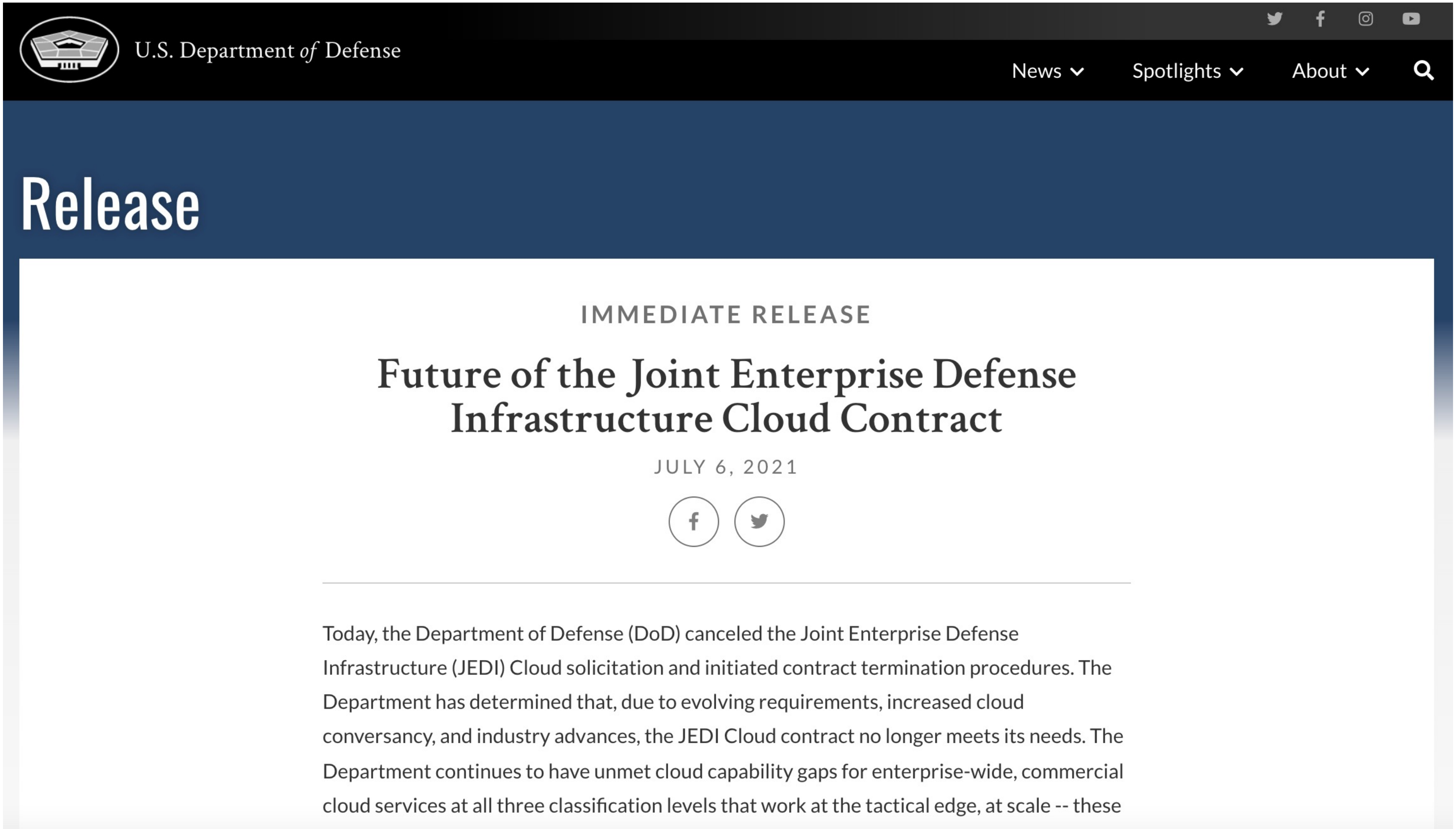
Add more CPUs to better parallelize new computation

Ongoing Research: Fulfill this promise with low latency!

...Is all this complexity worth it?!...

- Depends on user's/application's Pareto tradeoffs! :)
- **On-premise** cluster are still common in large enterprises, healthcare, and academia; "hybrid clouds" too
- Recall main pros of cloud: manageability, cost, and elasticity
- Some main cons of cloud (vs on-premise):
  - **Complexity** of composing cloud APIs and licenses; data scientists must keep relearning; "CloudOps" teams
  - **Cost** over time can *crossover* and make it costlier!
  - Easier to **waste money** accidentally on the fly
  - **"Lock-in"** by cloud vendor
  - **Privacy**, **security**, and **governance** concerns
  - **Internet disruption** or **unplanned downtime**, e.g., AWS outage in 2015 made Netflix, Tinder, etc. unavailable!

...Is all this complexity worth it?!...



Release

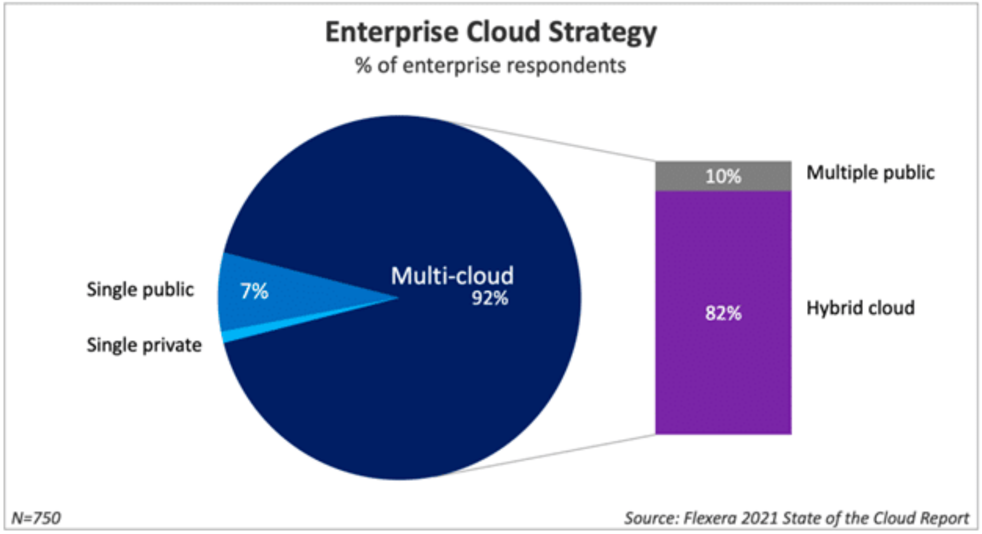
IMMEDIATE RELEASE

Future of the Joint Enterprise Defense Infrastructure Cloud Contract

JULY 6, 2021

Today, the Department of Defense (DoD) canceled the Joint Enterprise Defense Infrastructure (JEDI) Cloud solicitation and initiated contract termination procedures. The Department has determined that, due to evolving requirements, increased cloud conversancy, and industry advances, the JEDI Cloud contract no longer meets its needs. The Department continues to have unmet cloud capability gaps for enterprise-wide, commercial cloud services at all three classification levels that work at the tactical edge, at scale -- these

The State of the Cloud Survey

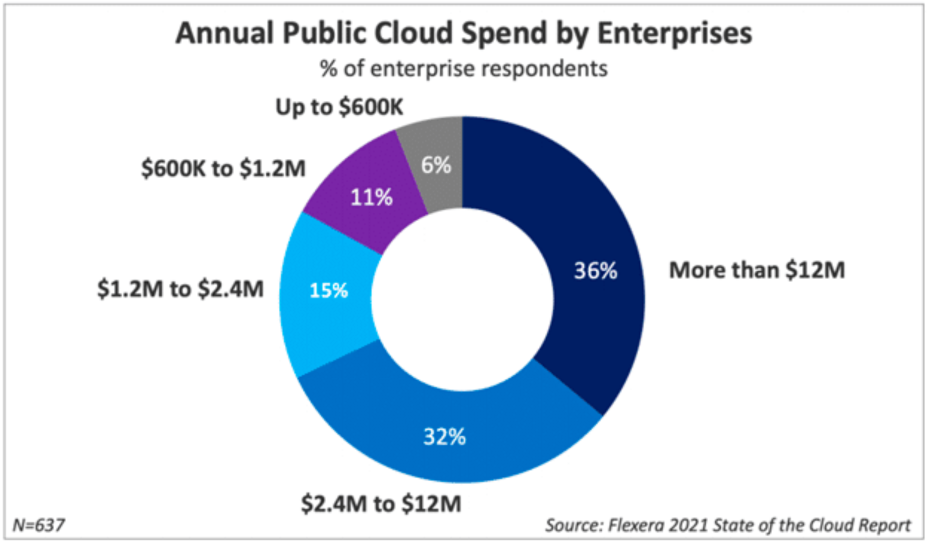


Enterprise Cloud Strategy

% of enterprise respondents

N=750

Source: Flexera 2021 State of the Cloud Report

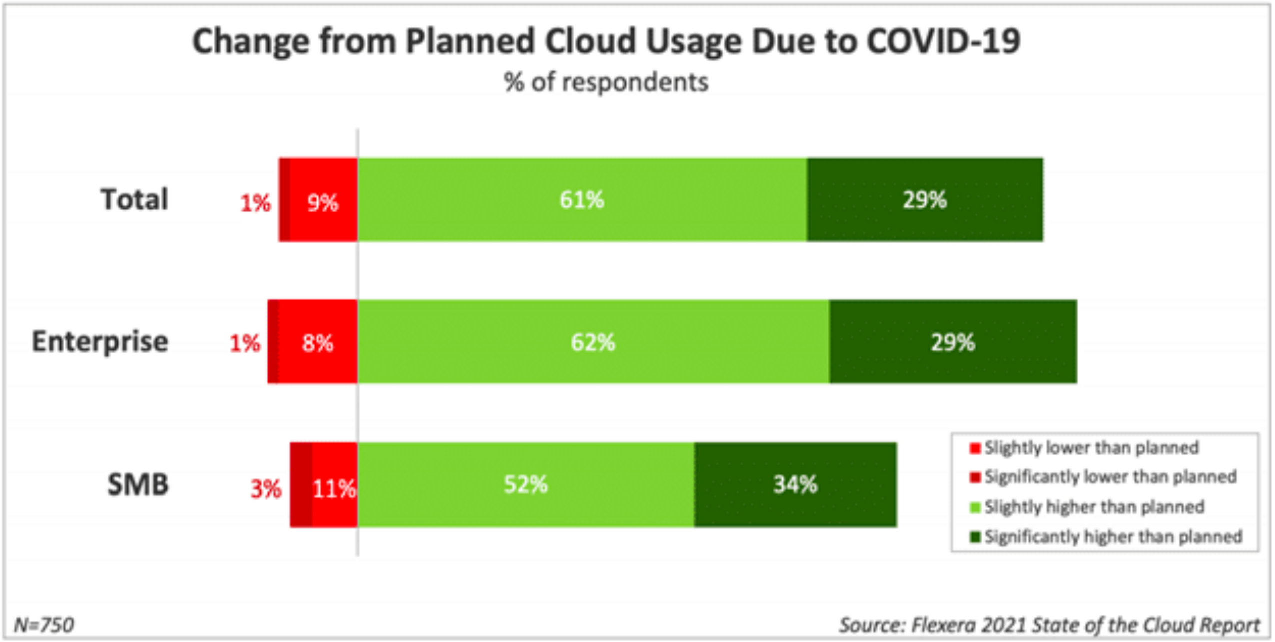


Annual Public Cloud Spend by Enterprises

% of enterprise respondents

N=637

Source: Flexera 2021 State of the Cloud Report



Change from Planned Cloud Usage Due to COVID-19

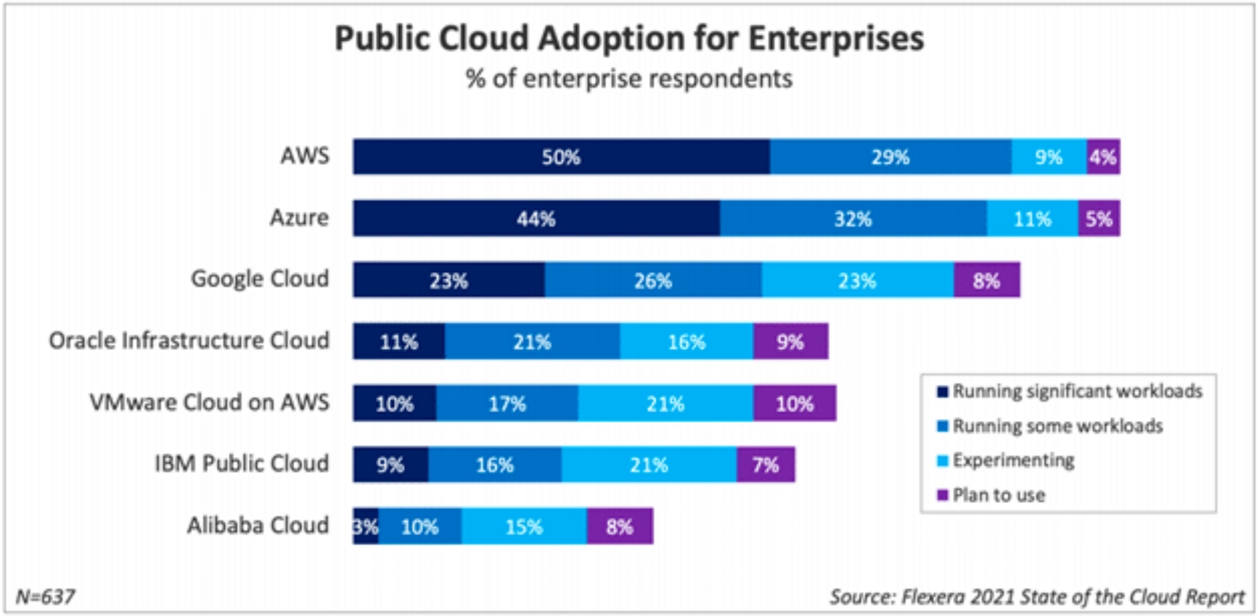
% of respondents

N=750

Source: Flexera 2021 State of the Cloud Report

https://www.flexera.com/blog/cloud/cloud-computing-trends-2021-state-of-the-cloud-report/

The State of the Cloud Survey

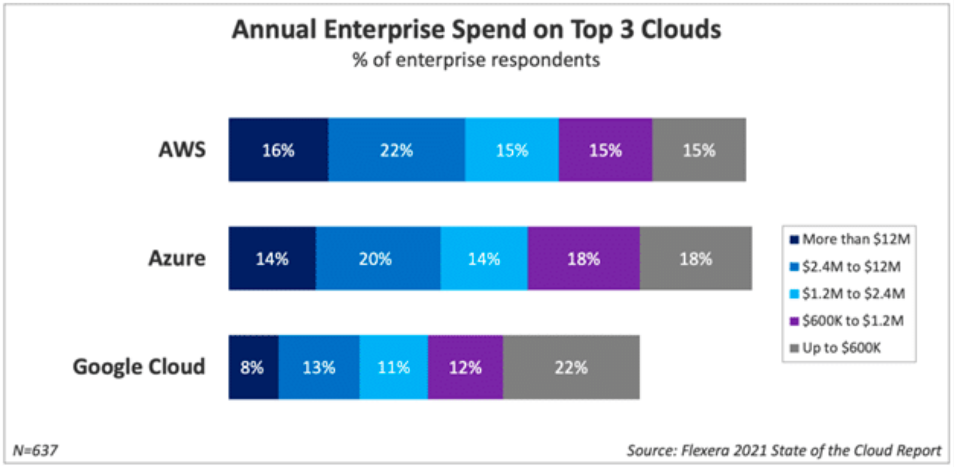


Public Cloud Adoption for Enterprises

% of enterprise respondents

N=637

Source: Flexera 2021 State of the Cloud Report

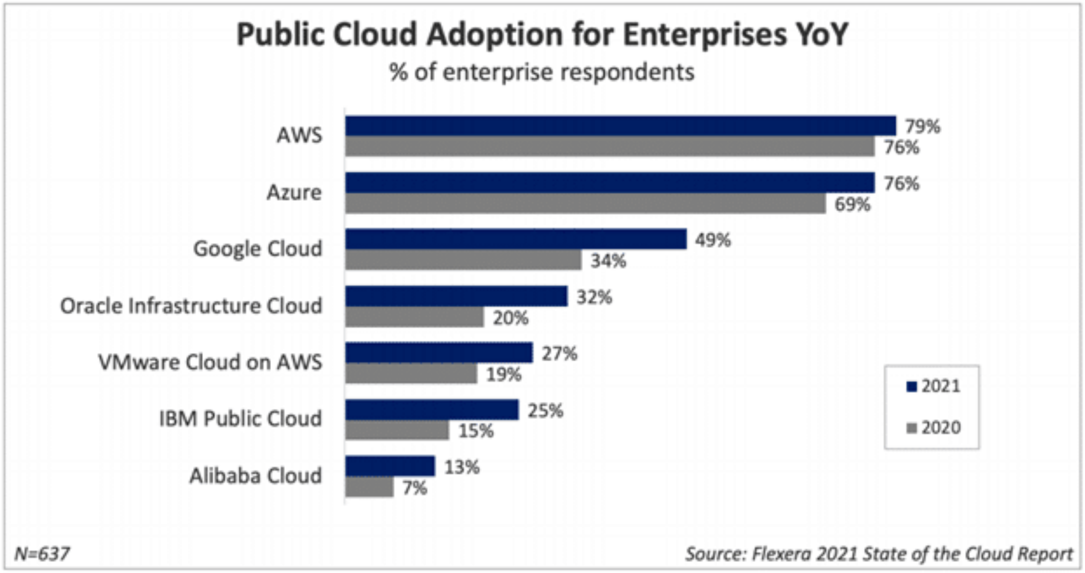


Annual Enterprise Spend on Top 3 Clouds

% of enterprise respondents

N=637

Source: Flexera 2021 State of the Cloud Report



Public Cloud Adoption for Enterprises YoY

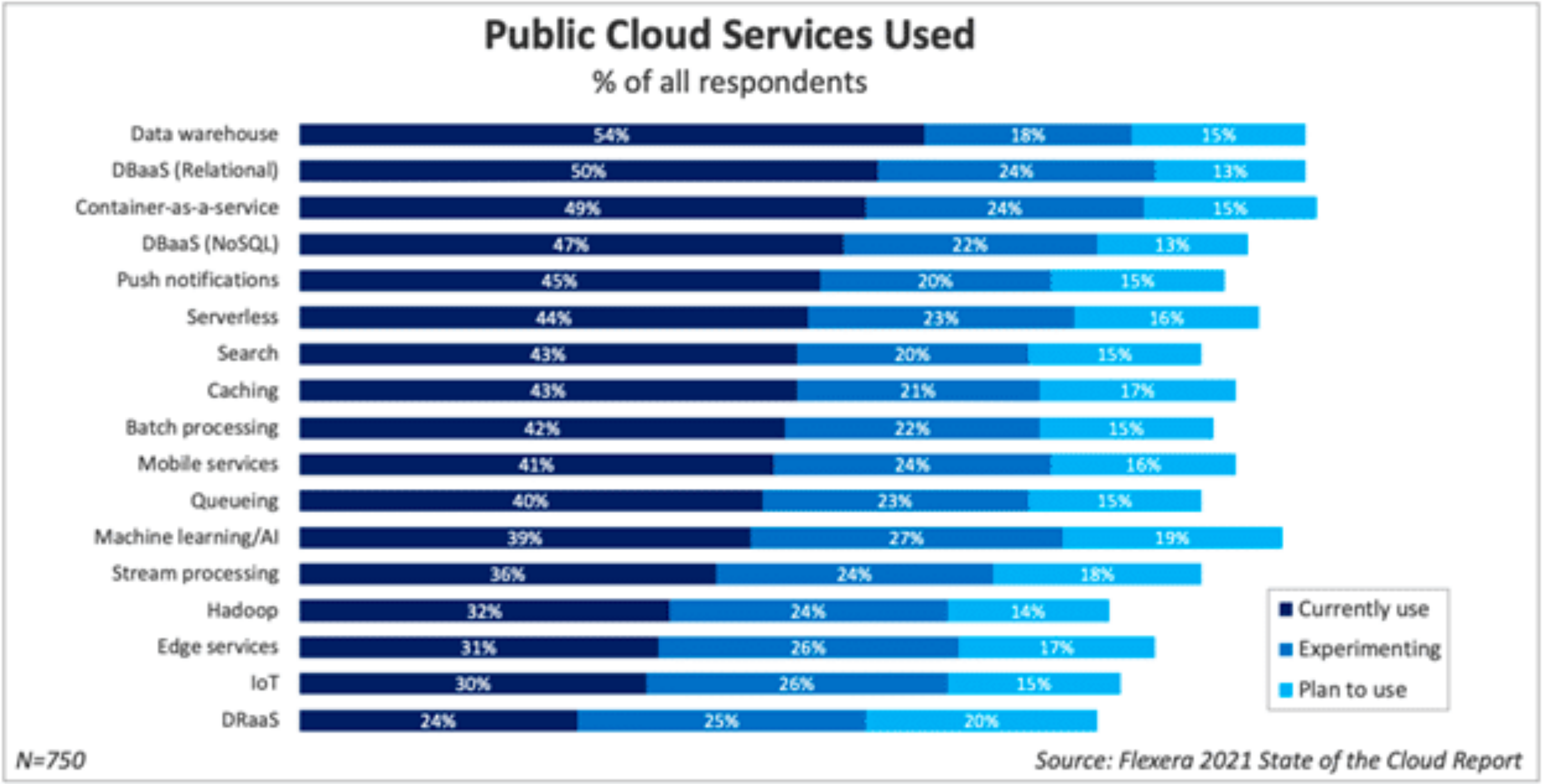
% of enterprise respondents

N=637

Source: Flexera 2021 State of the Cloud Report

https://www.flexera.com/blog/cloud/cloud-computing-trends-2021-state-of-the-cloud-report/

The State of the Cloud Survey


Public Cloud Services Used

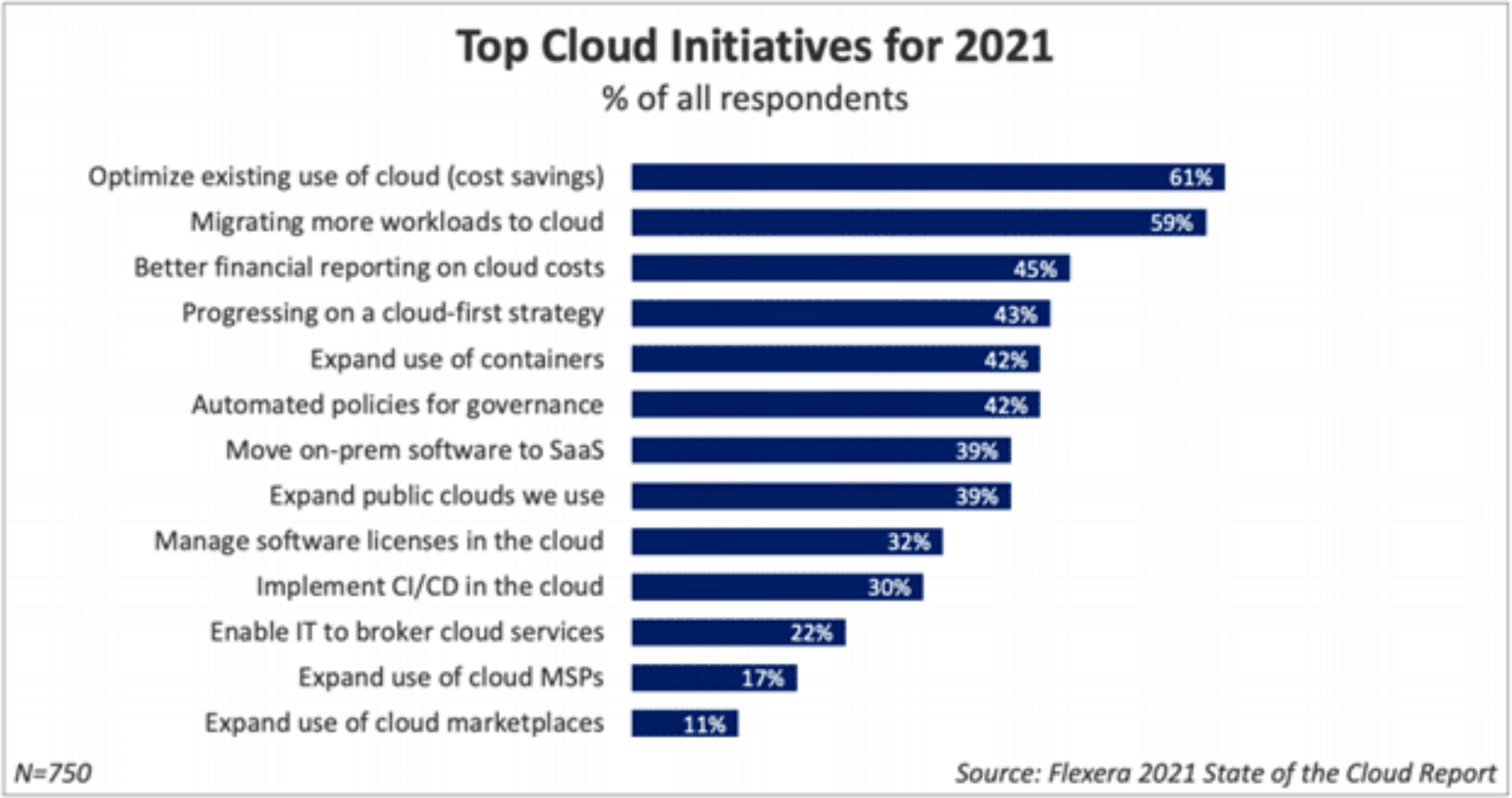
% of all respondents

N=750

Source: Flexera 2021 State of the Cloud Report

https://www.flexera.com/blog/cloud/cloud-computing-trends-2021-state-of-the-cloud-report/

The State of the Cloud Survey



Top Cloud Initiatives for 2021

% of all respondents

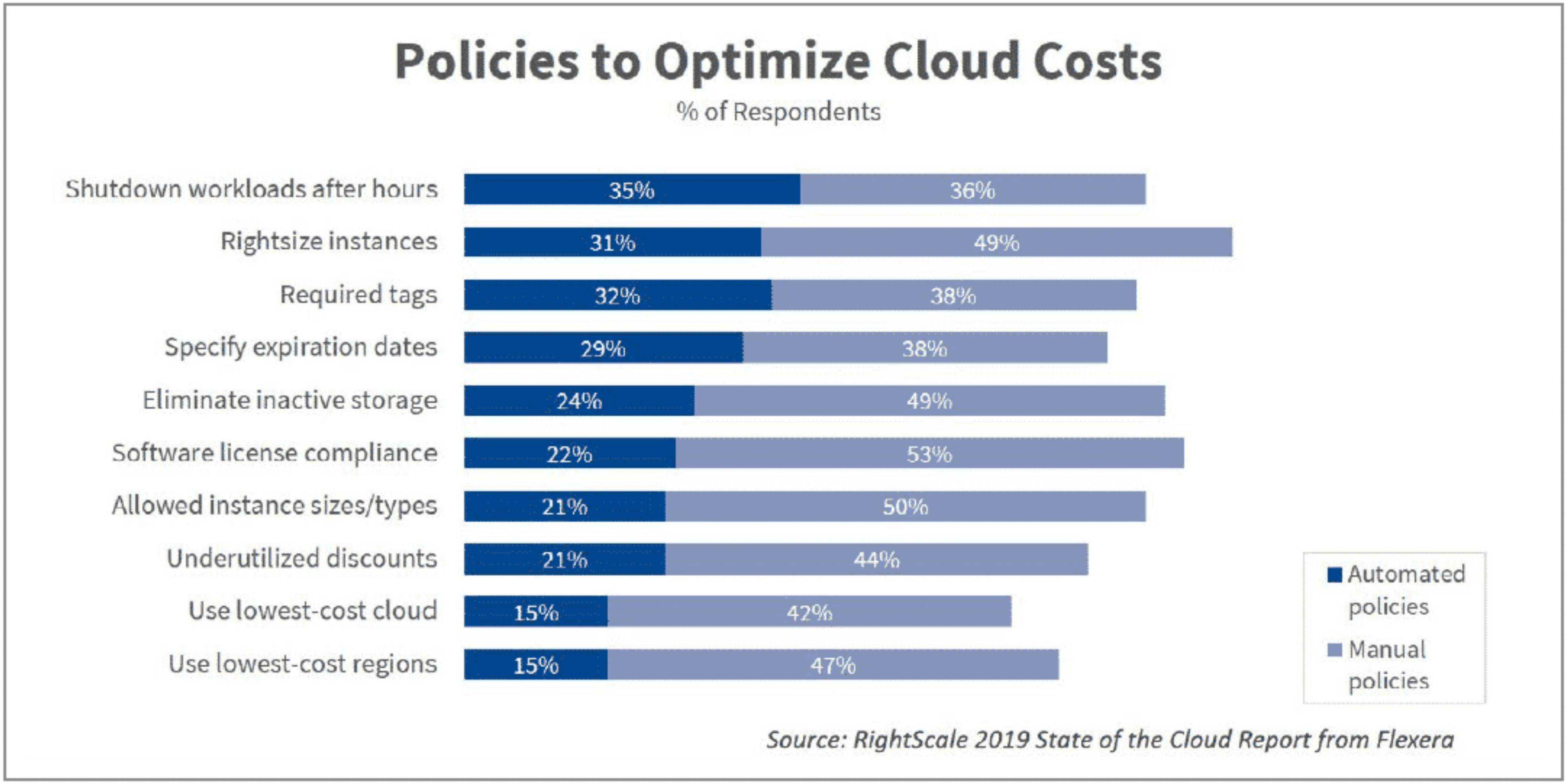
N=750

Source: Flexera 2021 State of the Cloud Report

https://www.flexera.com/blog/cloud/cloud-computing-trends-2021-state-of-the-cloud-report/

See also the latest: https://www.flexera.com/blog/cloud/cloud-computing-trends-2022-state-of-the-cloud-report/

The State of the Cloud Survey



Policies to Optimize Cloud Costs

% of Respondents

Source: RightScale 2019 State of the Cloud Report from Flexera

https://www.flexera.com/blog/cloud/2019/02/cloud-computing-trends-2019-state-of-the-cloud-survey/

Review Questions

1. What are the 3 main layers of a typical cloud? Give examples of AWS services in each layer. Which ones do your PAs use?
2. What is a benefit of separating PaaS from SaaS in cloud?
3. Briefly explain 1 pro and 1 con of Shared Disk Parallelism vs Shared Nothing Parallelism.
4. Briefly explain 1 pro and 1 con of On-Demand vs Spot instances on AWS.
5. What is so “great” about the serverless cloud anyway?
6. What is so great about “resource disaggregation” in future clouds?
7. Briefly explain 2 pros and 2 cons of cloud vs on-premise clusters.