WEEK 1 : Intro to Cloud Computing

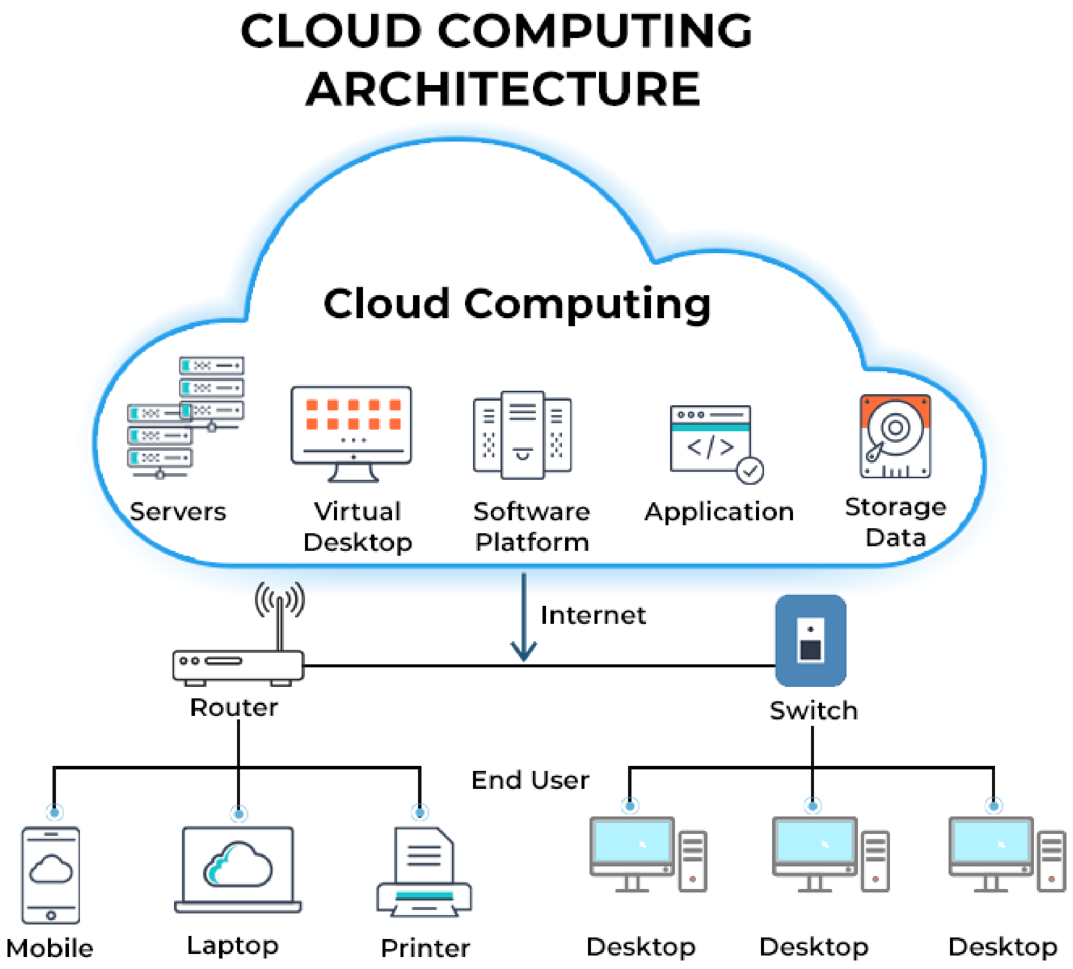
Course Schedules

Details Schedules

No	Week	Course			
		Course Titles	Theory	Practical Labs	Discussion
1	Week 1 06-Sep-2025	Intro to Cloud Computing	AWS services overview for ML (S3, EC2, IAM) ML lifecycle on AWS	AWS Free Tier setup (IAM, EC2, S3) Hands-on: launching EC2 Jupyter setup on EC2	
2	Week 2	Containerization & Serverless ML Pipelines	Intro to Docker + AWS ECR (Elastic Container Registry) Serverless Concepts	Build a simple ML inference container using Lambda, API gateway	
3	Week 3	Big Data Processing with PySpark & EMR	What is Big Data? PySpark concepts and EMR overview	Local Spark Setup and data preprocessing using pyspark	
4	Week 4	Model Development with SageMaker	Amazon SageMaker intro Built-in algorithms & Estimators	Tabular model training with built-in XGBoost Model tuning and logging	

WEEK 1

Why Cloud Computing ?



Resource Limitation

1. If we try to train a large deep learning model on a personal laptop, what computational bottlenecks will we face?

Cost

2. Suppose training is not frequent; maybe once a month. From an economic standpoint, is it efficient to invest in expensive hardware, or is a rental model better?

Scalability

3. Now imagine an application experiences a sudden 100x increase in users. How can we design infrastructure to elastically adjust to demand instead of collapsing?

Compliance

4. In certain industries, data must remain in specific countries due to regulatory requirements. How can infrastructure adapt to such constraints?

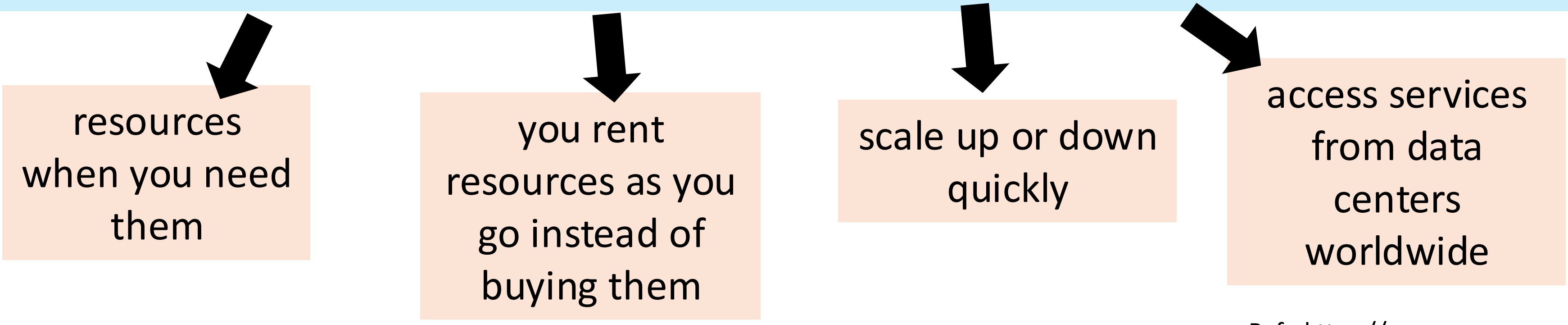
These four problems ; compute bottlenecks, cost, scaling, compliance — are exactly what cloud computing was invented to solve

1. What is Cloud Computing ?

“”Cloud computing is the on-demand delivery of IT resources over the Internet with pay-as-you-go pricing. Instead of buying, owning, and maintaining physical data centres and servers, you can access technology services, such as computing power, storage, and databases, on an as-needed basis from a cloud provider like Amazon Web Services (AWS).”” ***FROM AWS***

IN SHORT

- *“Cloud computing = on-demand delivery of IT resources via the internet with pay-as-you-go pricing.”*
- Keywords => **on-demand**, **pay-as-you-go**, **scalable**, **global**.



resources when you need them

you rent resources as you go instead of buying them

scale up or down quickly

access services from data centers worldwide

Ref : https://aws.amazon.com/what-is-cloud-computing/

Types of Cloud Computing

The three main types of cloud computing -

On Premises
You own and manage everything: servers, storage, networking, OS, applications

IaaS (Infrastructure as a Service)
You rent raw infrastructure (compute, storage, networking). You install OS, frameworks, apps.

PaaS (Platform as a service)
You rent a managed environment — provider handles OS, runtime, scaling. You just deploy code or models.

SaaS (Software as a Service)
You use the software directly via the internet. No need to manage infra, runtime, or code.

Every day life examples -

Cooking at home from scratch

- You buy your own stove, fridge, ingredients.
- You cook, serve, and clean everything.
- *Full control, full responsibility.*

Renting an empty kitchen

- The landlord gives you the kitchen space (electricity, water)
- You bring your own oven recipes and cook your own meal.
- *You control the cooking, but someone else owns the building*

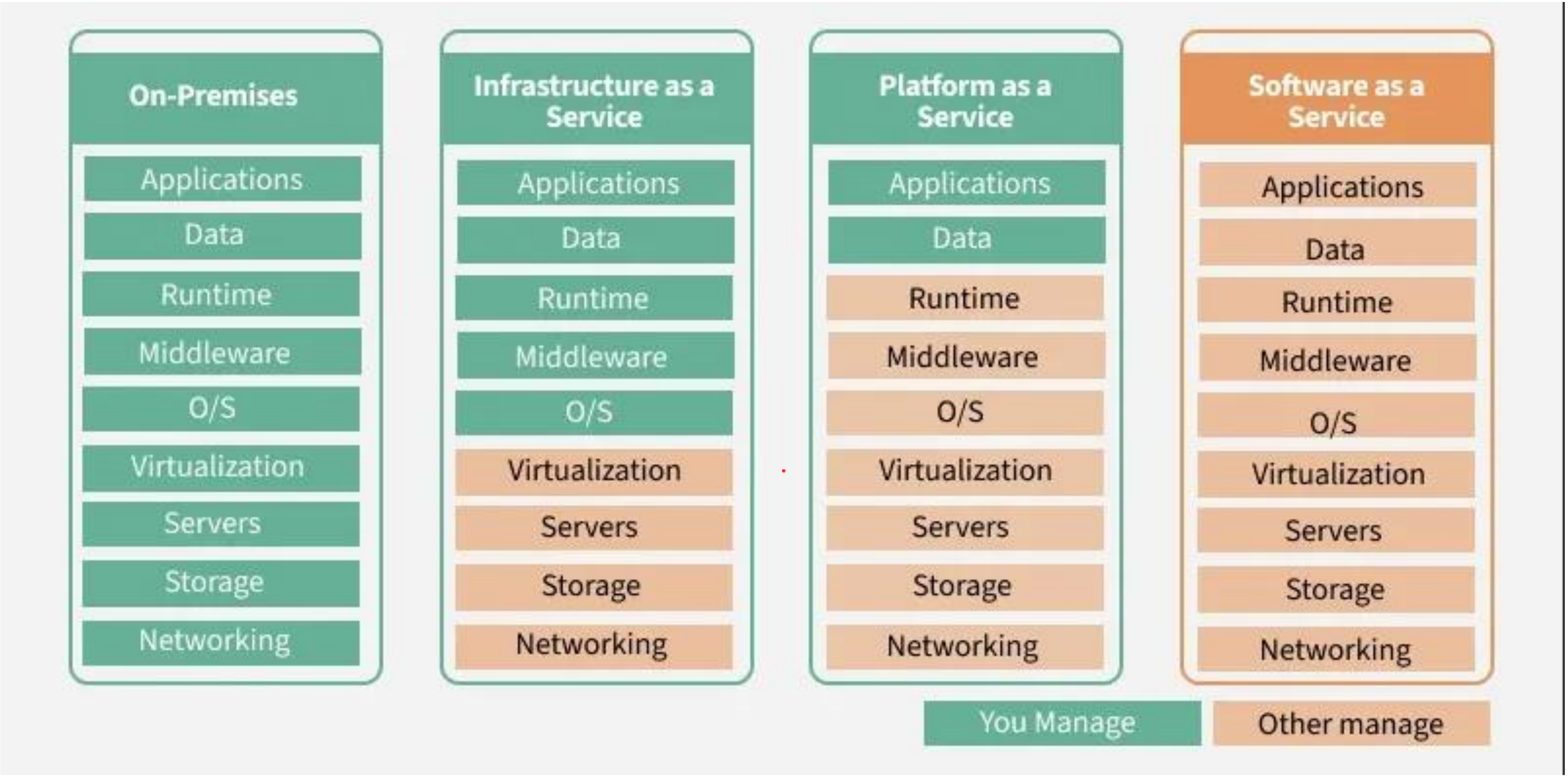
Using a ready-to-use kitchen (with tools & oven)

- The kitchen comes with oven, mixer, utensils.
- You just bring ingredients and bake your cake.
- *You focus on the recipe, not setting up the kitchen.*

Ordering food via GrabFood / Foodpanda

- You just order, food arrives ready to eat.
- No cooking, no cleaning.
- *Everything is handled for you. you only consume the service.*

Each type of cloud computing provides different levels of control, flexibility, and management so that you can select the right set of services for your needs.



On-Premises	Infrastructure as a Service	Platform as a Service	Software as a Service
🟩 Applications	🟩 Applications	🟩 Applications	🟧 Applications
🟩 Data	🟩 Data	🟩 Data	🟧 Data
🟩 Runtime	🟩 Runtime	🟧 Runtime	🟧 Runtime
🟩 Middleware	🟩 Middleware	🟧 Middleware	🟧 Middleware
🟩 O/S	🟩 O/S	🟧 O/S	🟧 O/S
🟩 Virtualization	🟧 Virtualization	🟧 Virtualization	🟧 Virtualization
🟩 Servers	🟧 Servers	🟧 Servers	🟧 Servers
🟩 Storage	🟧 Storage	🟧 Storage	🟧 Storage
🟩 Networking	🟧 Networking	🟧 Networking	🟧 Networking

🟩 You Manage 🟧 Other manage

Ref : https://www.geeksforgeeks.org/software-engineering/difference-between-iaas-paas-and-saas/

Now that you get the food analogy… what do you think the equivalent examples would be for **Machine Learning**?

Machine Learning Scenario

On Premises

IaaS (Infrastructure as a Service)

PaaS (Platform as a service)

SaaS (Software as a Service)

- *You buy your own GPU servers, install TensorFlow, set up networking, manage everything yourself.*
- *You rent AWS EC2 GPU instances and use S3 for storage. You install ML libraries yourself and run training.*
- *You use AWS SageMaker — AWS gives you Jupyter notebooks, pre-installed ML frameworks, and managed training jobs. You focus only on the model and data.*
- *You call AWS Rekognition API for image classification, or AWS Translate for language translation. You don't train anything; you just consume the ML service.*

No	Types of Cloud Computing	AWS Services
1	**On Premises**	-
2	**IaaS**	EC2 (Compute), S3 (Storage), IAM (Security)
3	**PaaS**	SageMaker (end to end ML platform), AWS Glue (ETL Preprocesing)
4	**SaaS**	Rekoginition (image/video analysis), Comprehend (NLP), Translate, Polly (tts)

DISCUSSION 1: Cloud Strategy

You are building a real-time fraud detection system for a mobile payment app serving **500,000 monthly users** across Southeast Asia. The app requires **low-latency predictions (<300ms)** and needs to comply with **local data residency laws** (e.g., in Singapore and Indonesia).

Would you choose a **cloud-based ML pipeline** or an **on-premise setup**? Justify your decision with respect to **latency, security, DevOps complexity, cost, and data compliance**.

My Response (Cloud is Preferable)

Latency

- **<300ms prediction latency** is realistic using AWS services like **Lambda**, **SageMaker endpoints**, or even **Edge deployment (SageMaker Neo)**.
- AWS supports regional endpoint deployment (e.g., Singapore, Jakarta) to minimize network roundtrip delays.
- On-prem latency could be slightly lower, but managing low-latency infrastructure in multiple countries is operationally painful.

Security & Data Compliance

- Local data residency laws can be met using **AWS region-specific S3 buckets**, **VPC controls**, and **KMS** for encryption.
- IAM roles and logging help maintain strong access control and auditing.
- On-prem would offer tighter control but would **increase complexity and staffing needs**, especially across multiple jurisdictions.

DevOps & Maintenance

- In the cloud, I can automate model deployment and versioning with **CI/CD pipelines (e.g., CodePipeline + Lambda + S3)**.
- Scaling to 500K users becomes trivial with **autoscaling EC2 or Lambda**, which would be much harder on-prem without large DevOps investment.

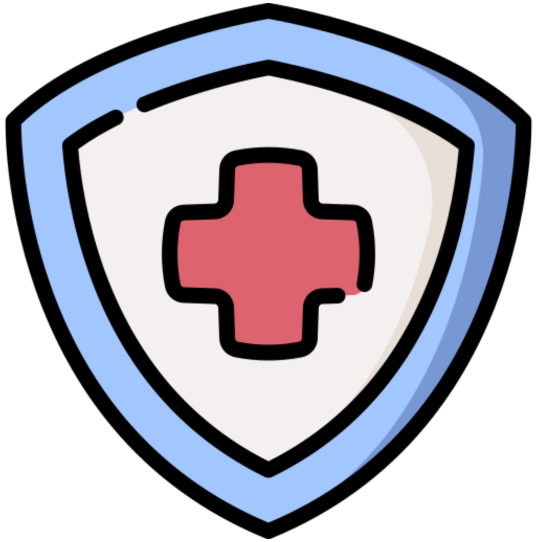
Cost

- **Cloud is more cost-efficient** for variable workloads. I can use **spot instances for training** and **serverless inference** to reduce idle cost.
- On-prem would require purchasing hardware upfront for peak capacity — expensive and inefficient for a mid-scale use case.

A **cloud-first strategy with regional AWS configurations** gives the best balance of **performance, security, and compliance** for this specific use case. On-prem might be justified for *highly classified or ultra-low latency* systems, but not here.

DISCUSSION 2: Cloud Strategy

You’re working for a **national healthcare agency** building a long-term ML system for **medical image classification (e.g., tumor detection)**. The system processes **sensitive MRI/CT scan data** from multiple hospitals, must operate in a **secure and air-gapped environment**, and is expected to run continuously for **at least 5 year**.



Due to regulatory policies, **patient data cannot leave the physical infrastructure**. Would you choose a **cloud-based setup** or an **on-premise architecture**? Justify your choice.

My Response (On Prem is Preferable)

Data Privacy & Compliance

- Health data is **extremely sensitive**. The scenario explicitly states that **data cannot leave the infrastructure**, which makes most public cloud options (even regionally hosted ones) **non-compliant**.
- AWS and other cloud providers offer HIPAA-compliant services, but **regulatory approval** for handling medical images often requires **physical air-gapped systems** in national infrastructure.

Security Control

- On-prem allows **total control over network traffic**, **access permissions**, and **hardware-based encryption**.
- There's no reliance on third-party APIs or internet access; important for **zero-trust or classified healthcare systems**.

Cost Predictability

- For a **5-year deployment**, on-prem hardware amortized over time could be **cheaper** than cloud usage (especially for **GPU-heavy inference or training workloads** like medical imaging).
- Cloud's pay-as-you-go becomes **less attractive** when usage is **steady and high-volume** for years.

Integration with Hospital Infrastructure

- Hospitals may already use **local PACS servers**, proprietary image formats, and specific network configurations that integrate better with an on-prem setup.
- On-prem simplifies integration and avoids costly data transfer or translation layers required in cloud.

Risk Tolerance

- In critical systems (like national health), **dependency on external vendors** for model hosting, service uptime, or API changes may be unacceptable.
- On-prem gives full-stack control and avoids vendor lock-in.

For sensitive, regulated, long-term medical ML systems, on-premise deployment offers compliance, security, control, and cost stability that cloud infrastructure cannot match.

DISCUSSION 3: Cloud Strategy

Scenario-based Question:

You’re building an ML pipeline to **detect phishing websites** by taking screenshots of URLs and comparing them to known company logos and UI layouts (e.g., fake login pages).
Each day, the system ingests **thousands of URLs**, renders them (headless browser), takes a screenshot, and passes it through a **CV model (e.g., ResNet or ViT)** to assess visual similarity.

You’re deciding whether to run this **on-prem** or in the **cloud**.

My Response (On Prem is Preferable)

Scalability

- Screenshot rendering + image inference is compute-intensive.
- Cloud (e.g., AWS Lambda + ECS + SageMaker) scales up quickly for bursty, parallel inference.

URL Access and Threat Intel

- Since you're scraping **live URLs**, running in the cloud may avoid local network exposure.
- You can route traffic through **VPC NAT gateways**, restrict domains, and avoid hitting the internal corp network.

Pay-per-user Cost Model

If you're only running inference during peak attack windows or using event-driven triggers (e.g., AWS EventBridge), cloud billing stays low.

My Response (On Prem is Preferable)

WEEK 1 : AWS Service Overview for ML (IAM, S3, EC2)

AWS IAM

→ Aws

Learning Objectives

- Understand **IAM core concepts** (Users, Roles, Policies, Permissions)
- Learn **principle of least privilege** in an ML context
- Explore **how IAM affects ML lifecycle stages** (e.g., access to S3, EC2, SageMaker)
- Hands-on: Create users, roles, groups and policies
- Discussion:
  - Design a **secure IAM strategy for a production ML pipeline**
  - Analyze real-world IAM misconfigurations and **simulate attacks**

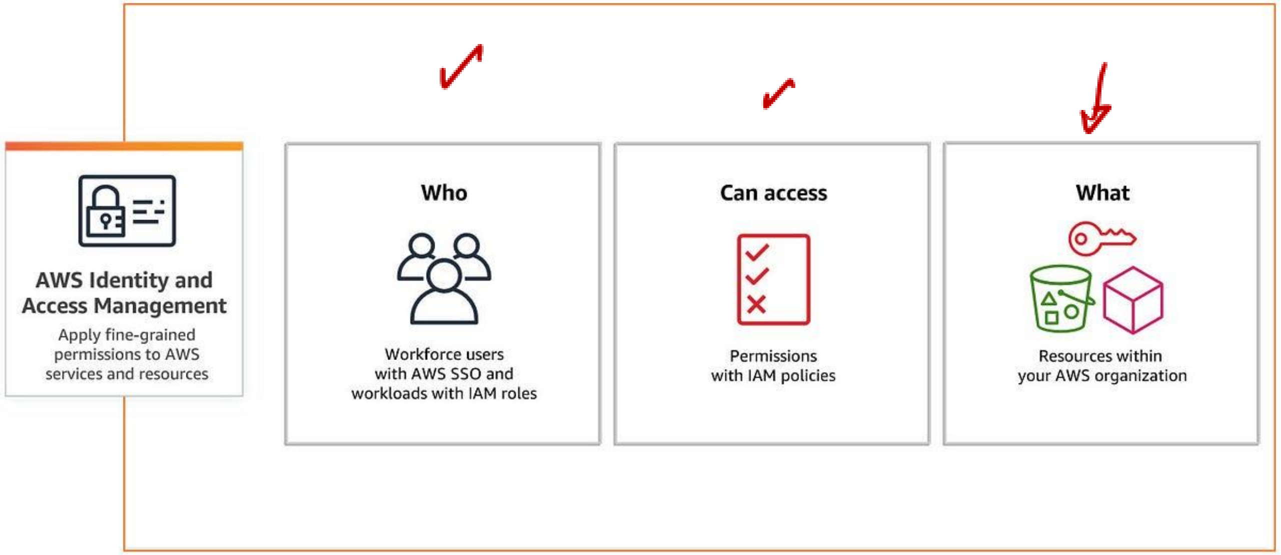
1. AWS IAM

IAM stands for Identity and Access Management

It was released in 2011 and is a tool for managing ***who can access your AWS resources and what they can do with them***.

Think in terms of:

- **Identity**: *Who* is making the request? (User, Role, Service)
- **Access**: *What* are they trying to do? (s3:GetObject, ec2:StartInstances, etc.)
- **Resource**: *Which* object? (arn:aws:s3:::your-bucket/data.csv)



AWS Identity and Access Management

Apply fine-grained permissions to AWS services and resources

Who

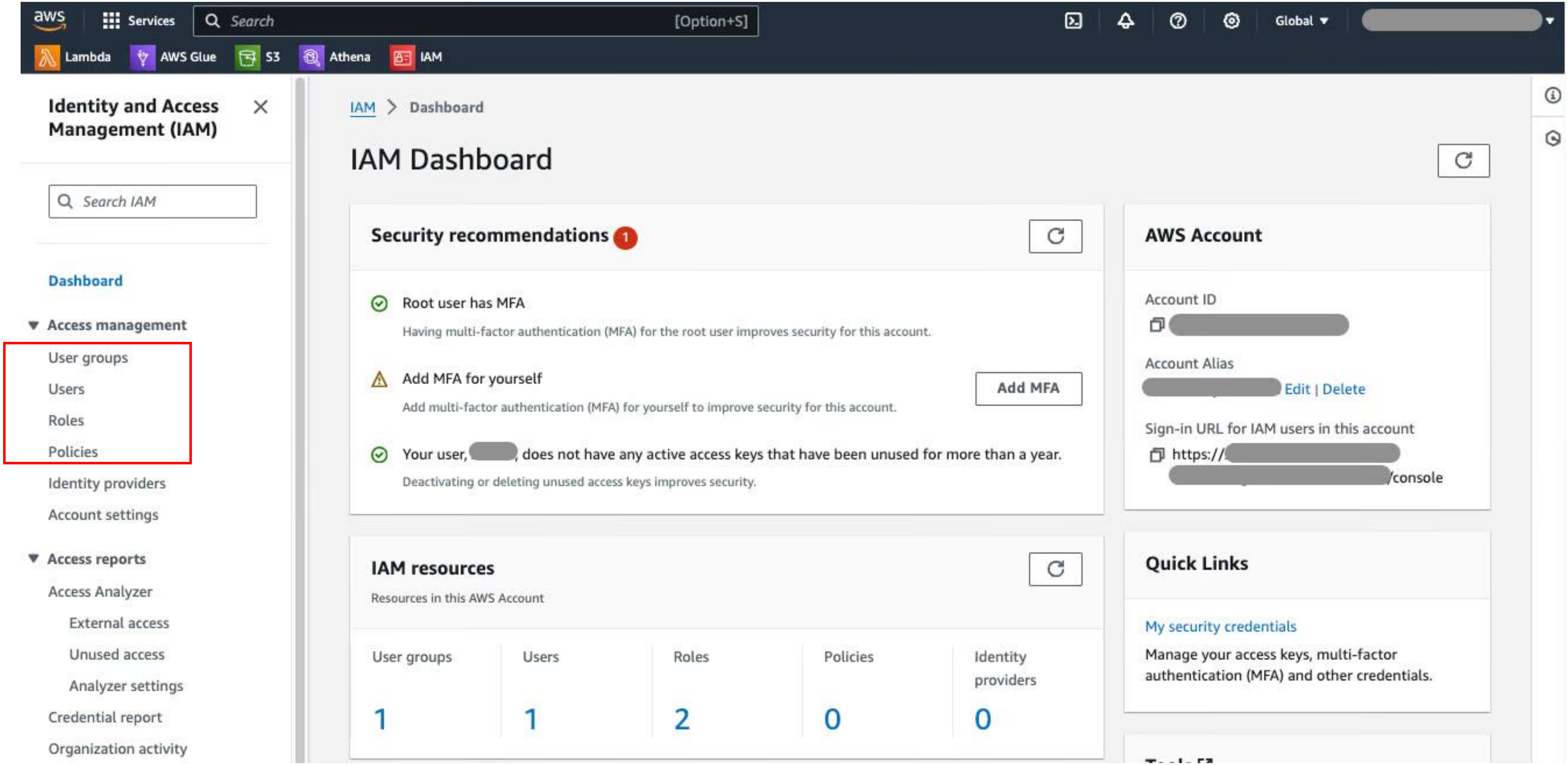
Workforce users with AWS SSO and workloads with IAM roles

Can access

Permissions with IAM policies

What

Resources within your AWS organization



Identity and Access Management (IAM)

Search IAM

Dashboard

▼ Access management

- User groups
- Users
- Roles
- Policies
- Identity providers
- Account settings

▼ Access reports

- Access Analyzer
  - External access
  - Unused access
  - Analyzer settings
- Credential report
- Organization activity

IAM > Dashboard

IAM Dashboard

Security recommendations 1

✓ Root user has MFA

Having multi-factor authentication (MFA) for the root user improves security for this account.

⚠ Add MFA for yourself

Add multi-factor authentication (MFA) for yourself to improve security for this account.

Add MFA

✓ Your user, [redacted], does not have any active access keys that have been unused for more than a year.

Deactivating or deleting unused access keys improves security.

AWS Account

Account ID

[redacted]

Account Alias

[redacted] Edit | Delete

Sign-in URL for IAM users in this account

https://[redacted]/console

IAM resources

Resources in this AWS Account

User groups	Users	Roles	Policies	Identity providers
1	1	2	0	0

Quick Links

My security credentials

Manage your access keys, multi-factor authentication (MFA) and other credentials.

AWS IAM

SSO

Ec2, lambda

S3 Full

↓ Deny

These are the four essential components of IAM:

1

User

Users are individuals or applications that need access to your AWS resources. Each user receives unique credentials, such as passwords and access keys.

Group

Groups are collections of users. Instead of assigning permissions to each user individually, you can put users in groups and assign permissions to the group. This makes it easier to manage permissions for multiple users at once.

Role

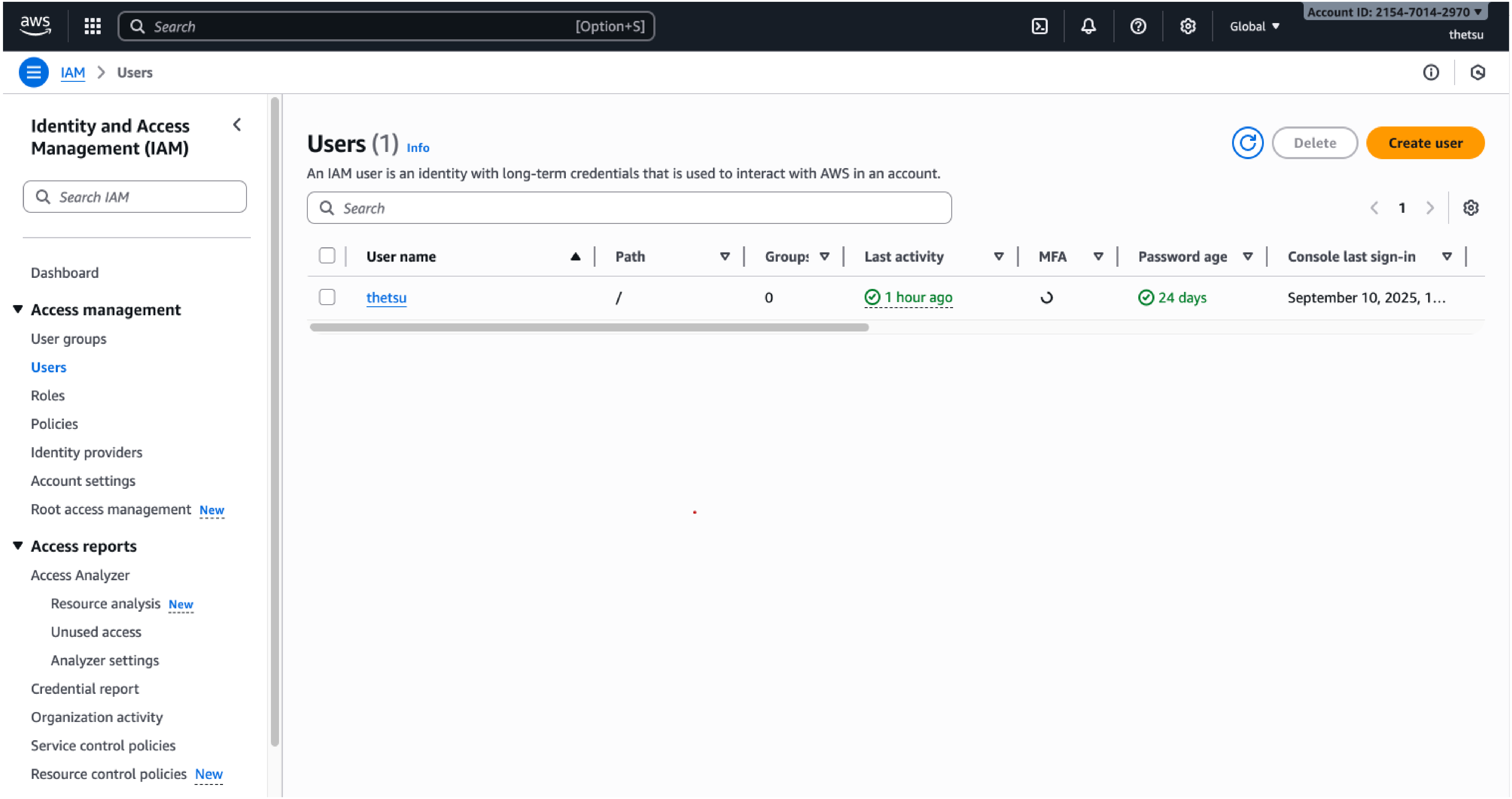
Roles are meant to be assumed by anyone who needs them instead of being associated with a single person. For example, an EC2 instance can “assume a role” to access S3 buckets without needing permanent credentials. Roles use temporary security credentials that automatically expire, which is great in terms of security.

Policy

Policies are JSON documents that define permissions. They specify what actions are allowed or denied on which resources. Policies can be attached to users, groups, or roles.

User

Users are individuals or applications that need access to your AWS resources.

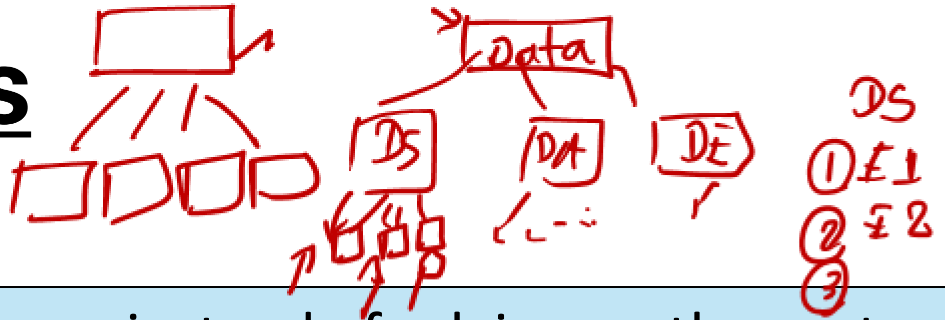


Users (1) Info

An IAM user is an identity with long-term credentials that is used to interact with AWS in an account.

□	User name ▲	Path	Group:	Last activity	MFA	Password age	Console last sign-in
□	thetsu	/	0	✓ 1 hour ago		✓ 24 days	September 10, 2025, 1...

IAM User Best Practices



1. Don’t use root as a user — Create the IAM user instead of relying on the root user account
2. Create individual IAM users — No shared accounts ;each person gets their own IAM user.

→ E1 E2

3. Assign Policies to groups, not directly to all IAM users
4. Enable MFA (Multi-Factor Authentication) for all IAM users.
5. Rotate credentials regularly.
6. Give IAM users console or programmatic access only if required
7. Remove inactive users, review permission to make sure they align with current job needs.

IAM – Lab 1

Create the IAM User

Group

Similar to user (an identity with permission)

Does not have credentials (password or keys)

Assumable, temporarily, by anyone who needs it.

https://youtu.be/hAk-7ImN6iM?si=PauhosND60Lu6wxT

IAM ~~User~~ Group Best Practices

1. Assign Policies to groups, not directly to all IAM users
2. Follow least-privilege principal at group level.
3. Rotate credentials regularly.
4. Remove inactive groups, review permission to make sure they align with current job needs.

IAM – Lab 2

Create the IAM Group

✓

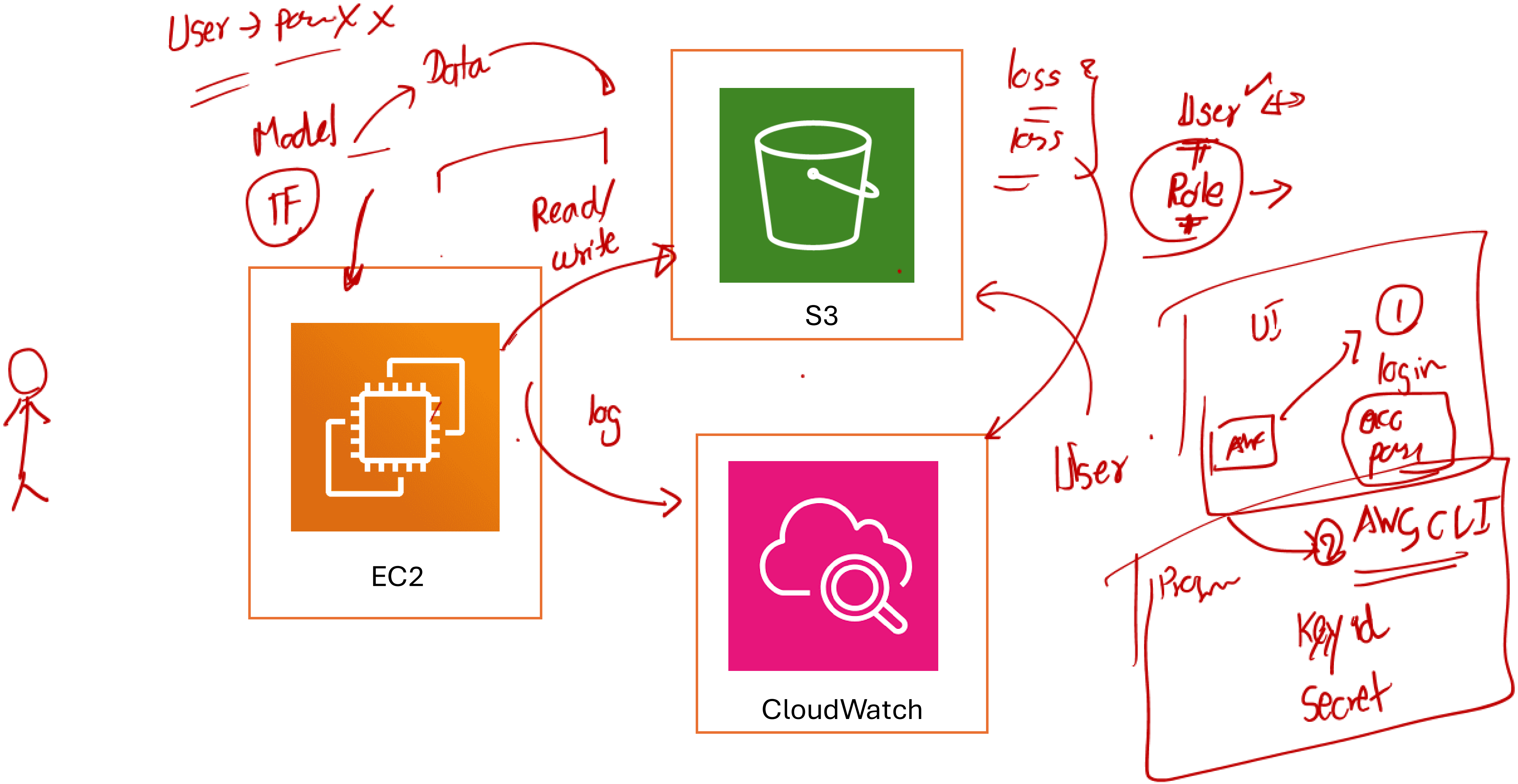
Role

Similar to user (an identity with permission)

Does not have credentials (password or keys)

Assumable, temporarily, by anyone who needs it.

https://youtu.be/hAk-7ImN6iM?si=PauhosND60Lu6wxT


User → perm X X
Model
Data
TF
Read/write
EC2
S3
log
CloudWatch
loss &
loss
User
Role
User
UI
①
login
AWS
acc perm
② AWS CLI
Prog
Key id
Secret

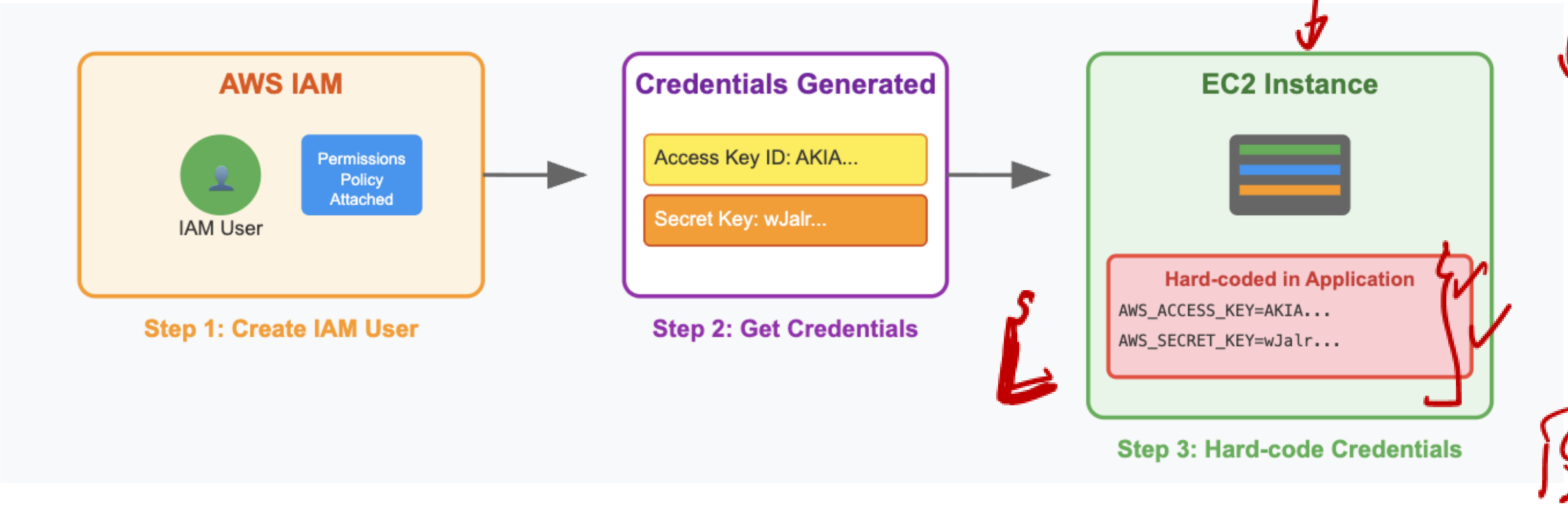
Option 1

Sklearn

Python → boto3 → AWS Services

Read S3 EC2

1. Create an IAM user for the application with appropriate permissions
2. Hard-code user credentials in the application or on the EC2 instance's file system and retrieve them at runtime.



.py

model-train

prep

boto3

S3

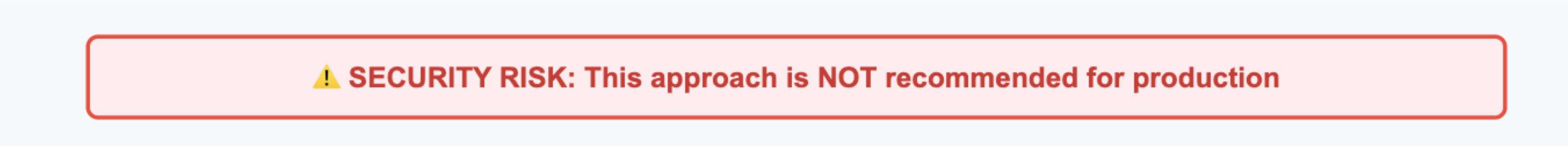
boto3

AWS

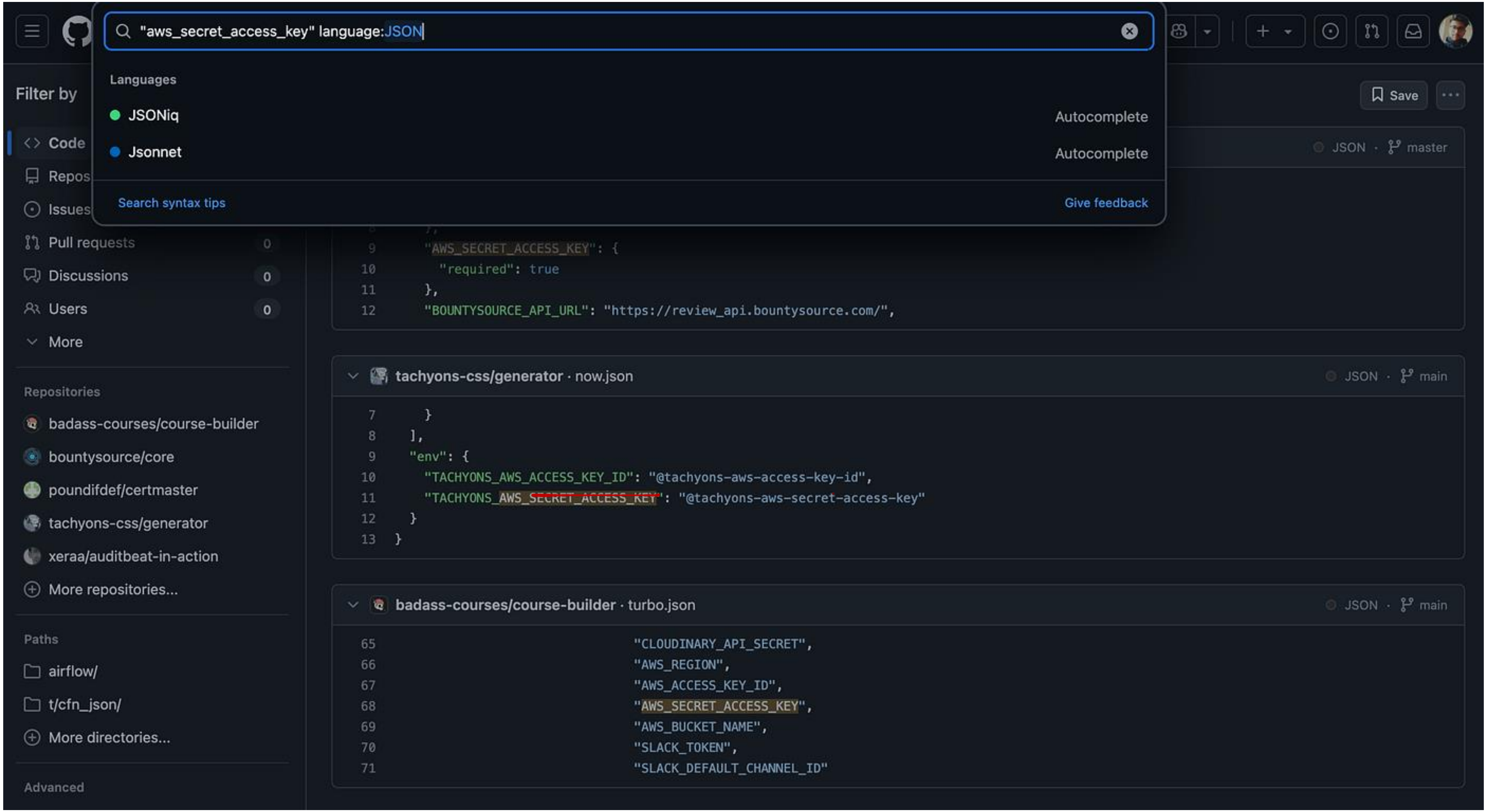
Really ???

Imagine you create an IAM user called ml-app-user with S3 full access. Then you copy its Access Key + Secret Key into your code, or you drop them into /home/ec2-user/credentials.txt. Now your app can run… but what’s the risk?

1. If code is pushed to GitHub → **credentials leaked**.
2. If EC2 instance is compromised → attacker **steals the keys**.
3. Hard-coded keys are **long-lived** → attacker has permanent access.
4. Difficult to **rotate/revoke** credentials without breaking the app.



⚠️ **SECURITY RISK: This approach is NOT recommended for production**



"aws_secret_access_key" language:JSON

```
    "AWS_SECRET_ACCESS_KEY": {
      "required": true
    },
    "BOUNTYSOURCE_API_URL": "https://review_api.bountysource.com/",
```

tachyons-css/generator · now.json

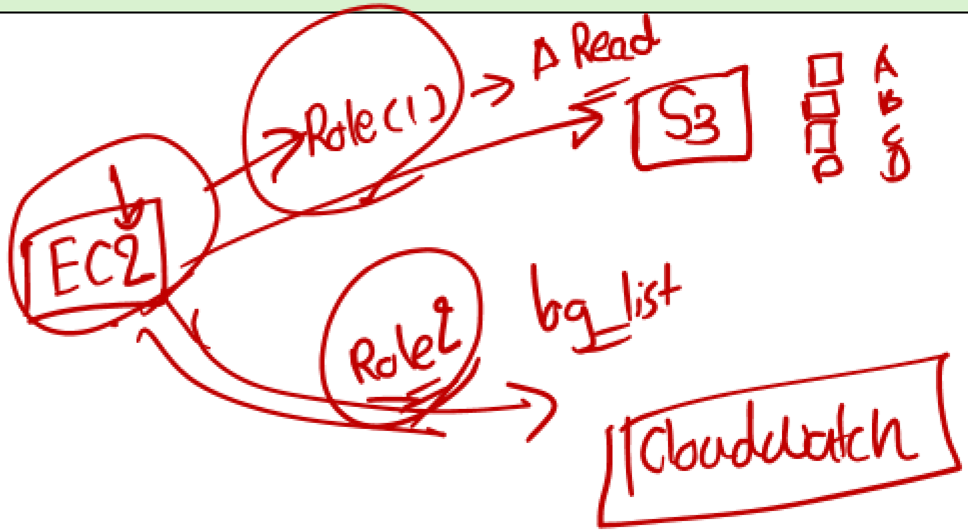
```
      }
    ],
    "env": {
      "TACHYONS_AWS_ACCESS_KEY_ID": "@tachyons-aws-access-key-id",
      "TACHYONS_AWS_SECRET_ACCESS_KEY": "@tachyons-aws-secret-access-key"
    }
  }
```

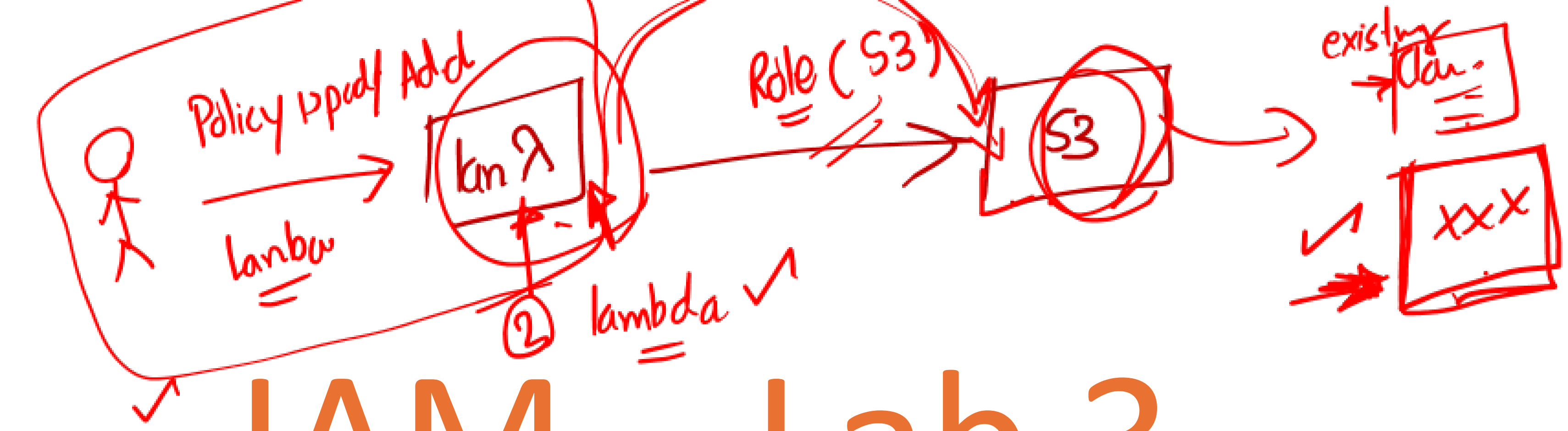
badass-courses/course-builder · turbo.json

```
                              "CLOUDINARY_API_SECRET",
                              "AWS_REGION",
                              "AWS_ACCESS_KEY_ID",
                              "AWS_SECRET_ACCESS_KEY",
                              "AWS_BUCKET_NAME",
                              "SLACK_TOKEN",
                              "SLACK_DEFAULT_CHANNEL_ID"
```

Option 2

1. Create an IAM role for the application with appropriate permissions
2. When creating the EC2 instance, assign it this role
3. No credentials required





IAM – Lab 3

User

EC2 → Role

land.

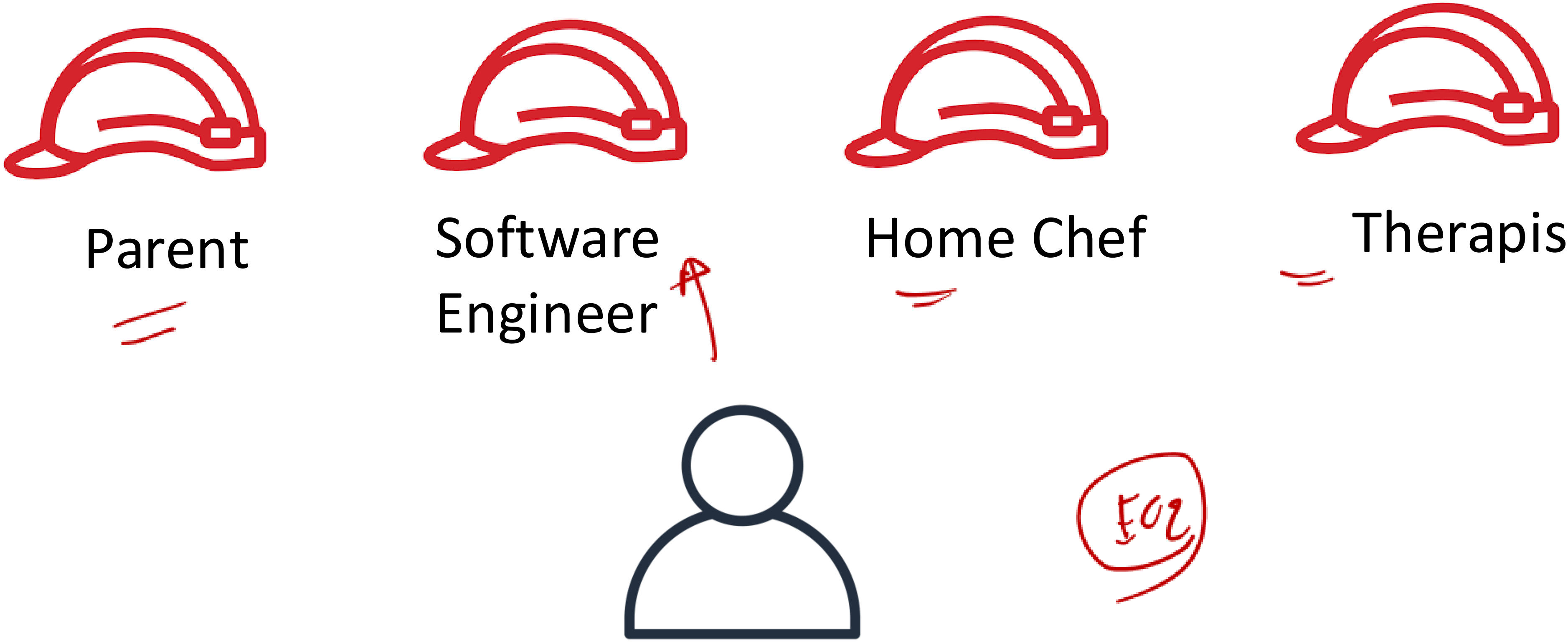
Create the IAM Role

- Lambda Functions Setup to access S3

.py →

Real Life Analogy

Roles: hats you put on temporarily depending on context



Parent

Software Engineer

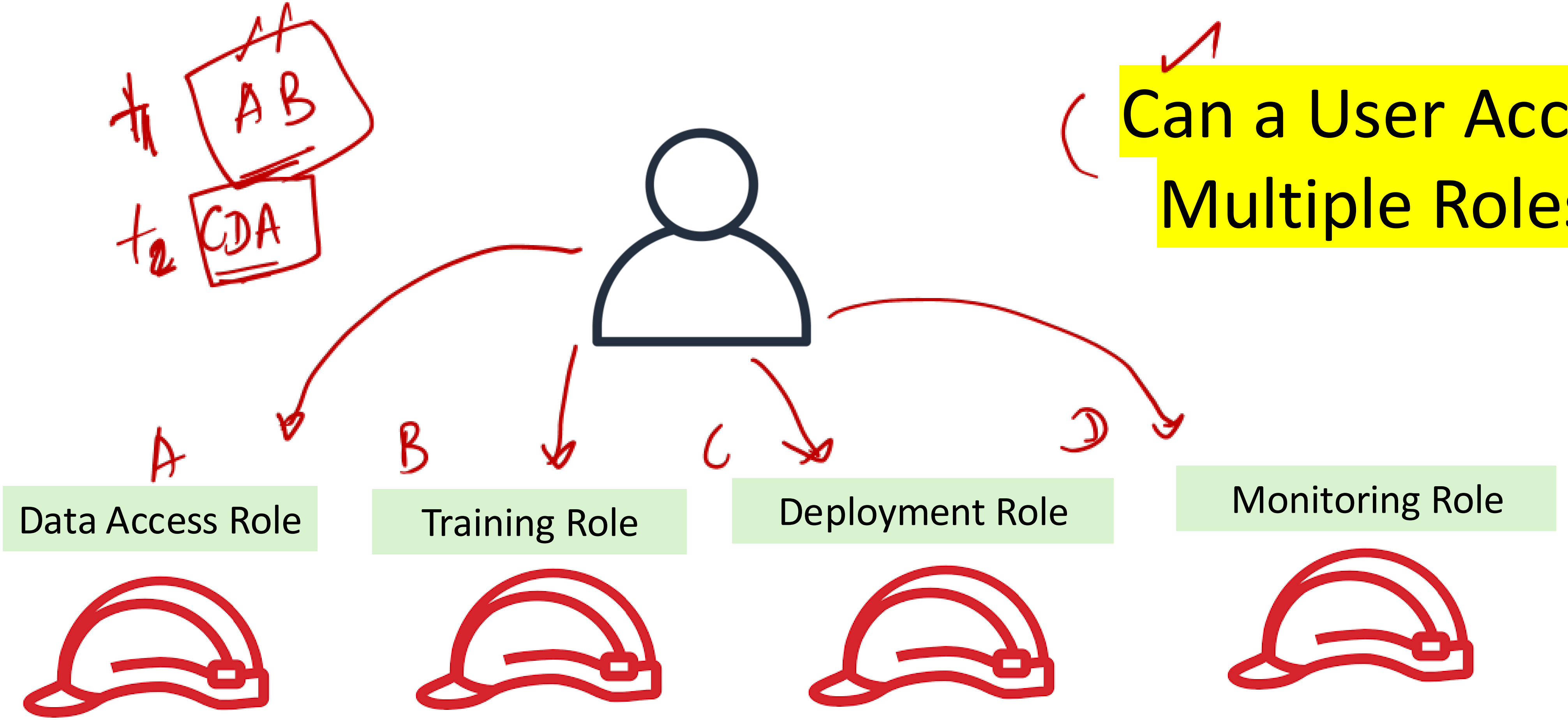
Home Chef

Therapist

for

identity (you, always the same person)

Can a User Access Multiple Roles?



Data Access Role

Training Role

Deployment Role

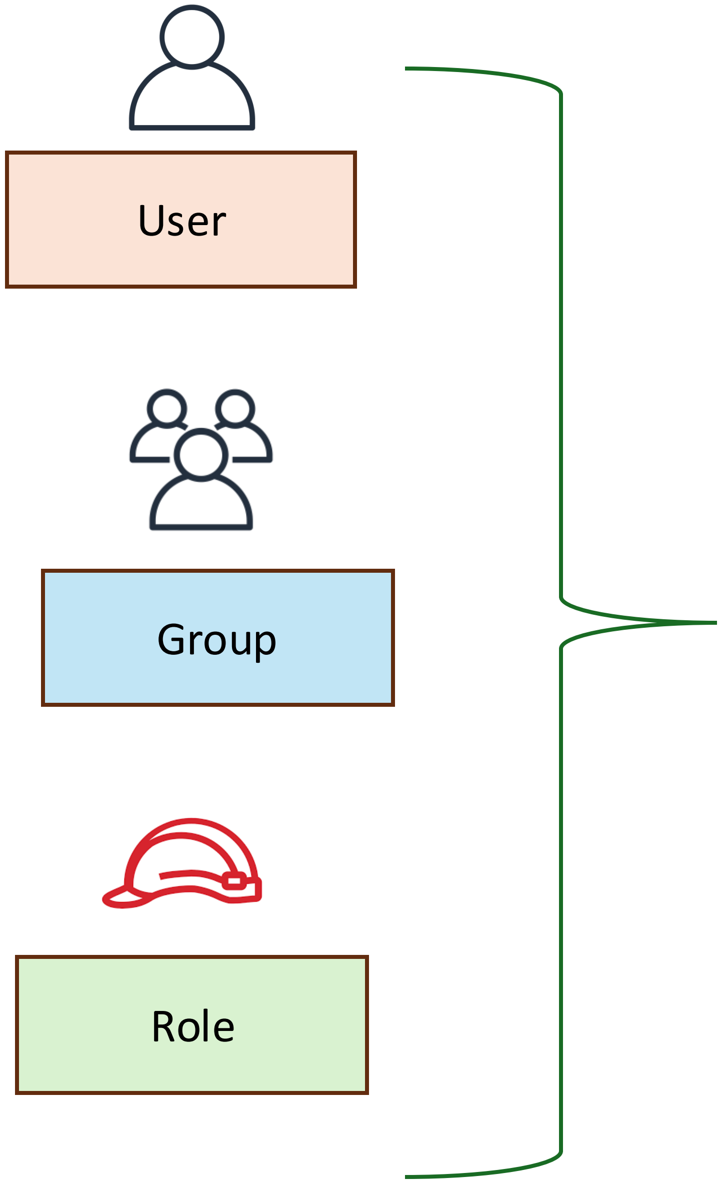
Monitoring Role

read/write datasets in **S3**

Used by **SageMaker** training jobs to spin up compute and access training data.

Used by **SageMaker Endpoints / EC2 / ECS** to serve trained ML models.

Allows CloudWatch/SageMaker Model Monitor to log metrics and detect drift



User

Group

Role

Identities (the ‘Who’)

There is nothing we can do

Policies

Who can do what to which resources and when

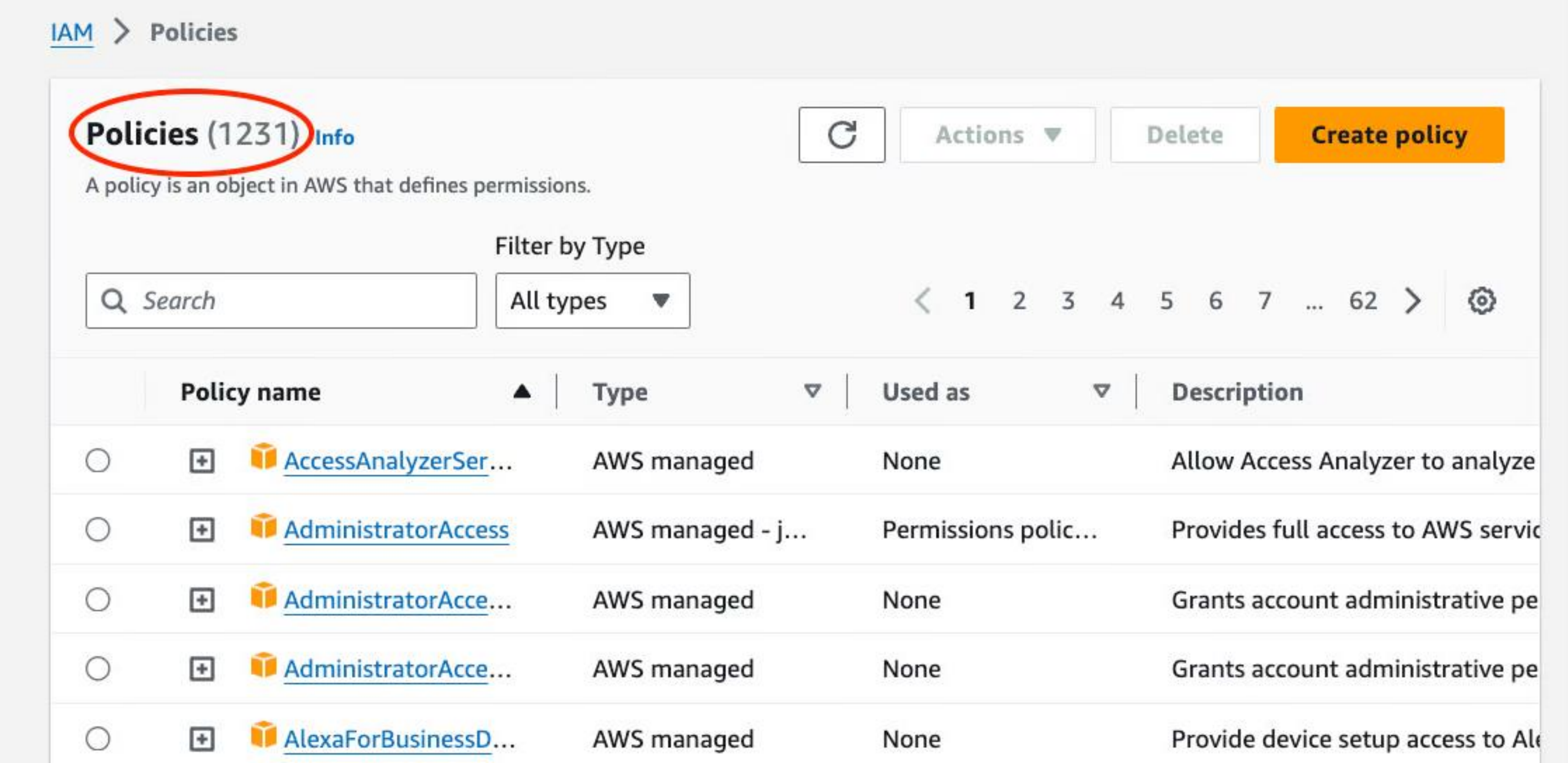
Policy 1

"Allow a Lambda function to access a Dynamo table"

Policy 2

"Allow a user to start and stop EC2 instances"

https://youtu.be/hAk-7ImN6iM?si=PauhosND60Lu6wxT



Policies (1231) Info

A policy is an object in AWS that defines permissions.

Filter by Type: All types ▼

	Policy name ▲	Type	Used as	Description
○	AccessAnalyzerSer…	AWS managed	None	Allow Access Analyzer to analyze
○	AdministratorAccess	AWS managed - j…	Permissions polic…	Provides full access to AWS servic
○	AdministratorAcce…	AWS managed	None	Grants account administrative pe
○	AdministratorAcce…	AWS managed	None	Grants account administrative pe
○	AlexaForBusinessD…	AWS managed	None	Provide device setup access to Ale

IAM Policy

As an example, here's the JSON document for the AWS-managed policy named "AmazonS3FullAccess":

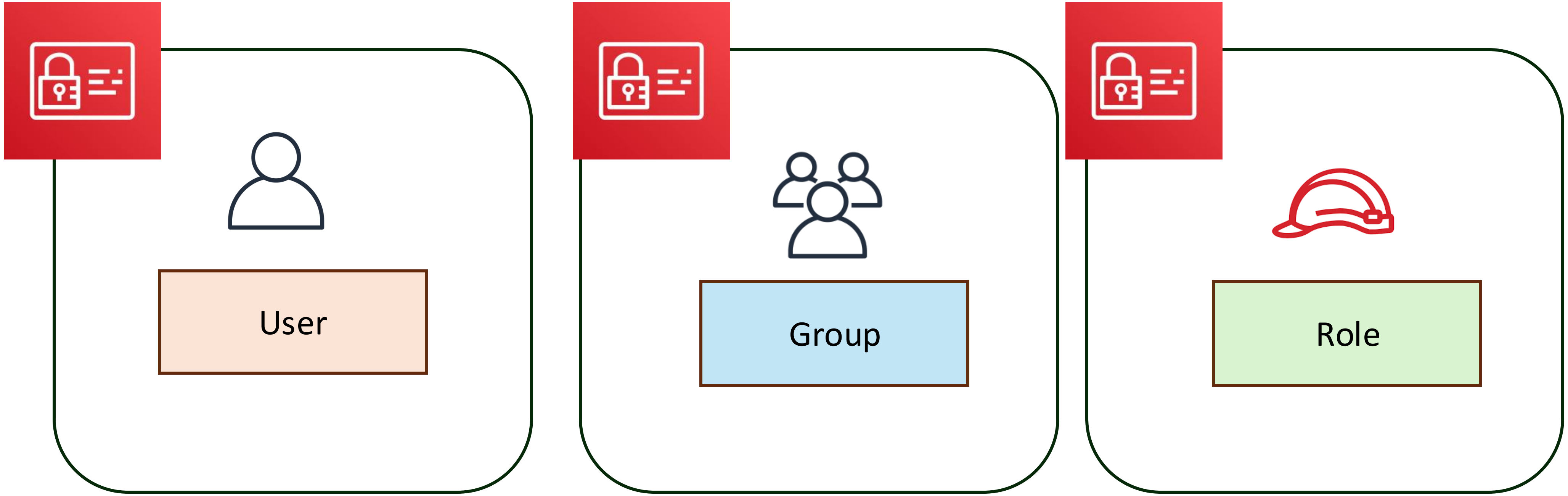
Note : this is not ideal in real-word scenario since
the policy is too permissive.

```
{
   "Version": "2012-10-17",
   "Statement": [
      {
         "Effect": "Allow",
         "Action": "s3:*",
         "Resource": "*"
      }
   ]
}
```

- The Version element specifies the policy's language version.
- The Statement is where the "meat" of the policy is. A single policy can have multiple statements. Each statement includes a few essential fields:
    - **Effect**: This field specifies whether the statement allows or denies access. It can be either **"Allow" or "Deny."**
    - **Action**: This defines what actions are allowed or denied. Actions are usually the operations you can perform on a resource. AWS has specific actions for each service, so you must specify them correctly.
    - **Resource**: This specifies the AWS resources the actions apply to. Resources are identified using Amazon Resource Names (ARNs), which uniquely identify a resource.

https://www.datacamp.com/tutorial/aws-identity-and-access-management-iam-guide

There is nothing we can do



User

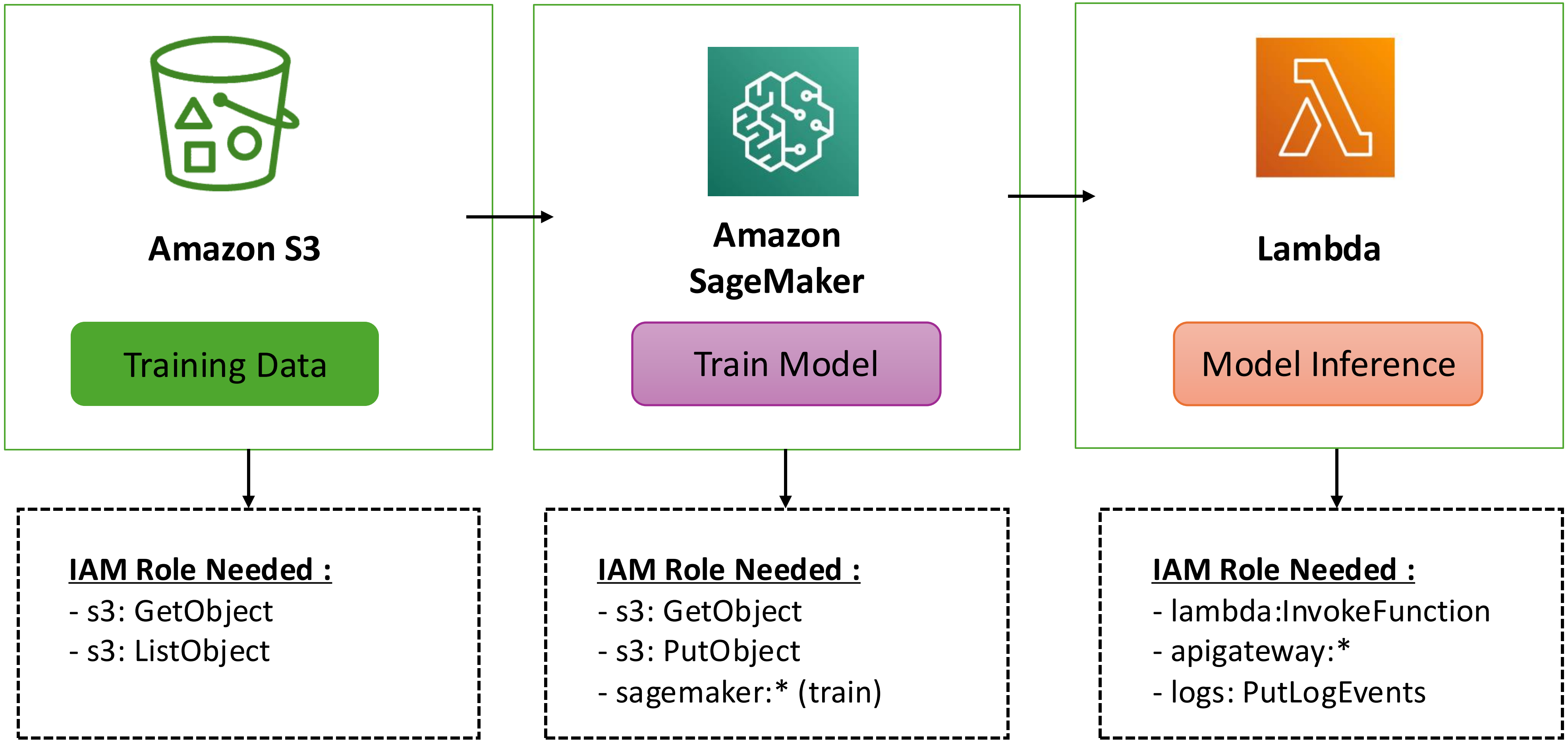
Group

Role

Policies

Who can do what to which resources and when

Attach the policies to the identities



Amazon S3

Training Data

IAM Role Needed :
- s3: GetObject
- s3: ListObject

Amazon SageMaker

Train Model

IAM Role Needed :
- s3: GetObject
- s3: PutObject
- sagemaker:* (train)

Lambda

Model Inference

IAM Role Needed :
- lambda:InvokeFunction
- apigateway:*
- logs: PutLogEvents

Every arrow above requires **explicit IAM permissions**. If even one is missing or misconfigured, your ML pipeline breaks silently or fails mid-way.

→ S3FullAccess

→ Read

✓ ✗

IAM – Lab 4

Create the IAM Policy

- Create the IAM policy to see the S3Bucket

IAM – Lab 5

Create the IAM Policy

- S3 Read-only Access from Ec2

IAM, S3, EC2

Week 1 – Part 2

S3 (Simple Storage Service)

Where data is kept, until someone with the right key asks for it.

1. AWS S3 (Simple Storage Service)

Learning Objectives

- **Understand S3 basics**: Buckets, objects, and versioning
- **Data Partitioning**
- **Learn how S3 integrates with the ML lifecycle**:
  - Data ingestion → Training → Inference → Logging
- **Explore S3 access control**: Bucket policies vs. IAM policies
- **Hands-on**: Upload datasets to S3 and assign correct bucket policies
- **Discussion**: Design a secure and scalable S3 storage structure for an ML project

Think of S3 as the **warehouse** of your ML system.
It stores the raw material (data), the finished goods (models), and the operational logs (for QA).
Your job? Make sure it’s **organized, secure, and scalable** — or everything else falls apart

	Stage	Usage Example
1	Data Collection	Store raw CSV, JSON, images, video, logs
2	Preprocessing	Upload clean feature sets, transformed files
3	Training	Models pull training data directly from S3 (via SageMaker or EC2)
4	Model Output	Store .pt, .pkl, or model.joblib after training
5	Serving Input	Upload new data for predictions
6	Predictions Log	Store model predictions or inference logs for audit/debug

Amazon S3 - Overview

- Amazon S3 allows people to store objects (files) in "buckets" (directories)
- Buckets must have a globally unique name
- Objects (files) have a Key. The key is the FULL path:
  - <my_bucket>/my_file.txt
  - <my_bucket>/my_folder1/another_folder/my_file.txt
- This will be interesting when we look at partitioning
- Max object size is 5TB
- Object Tags (key / value pair – up to 10) – Mini metadata (key/value) per object useful for security / lifecycle

AWS doesn't just charge for storage. You're charged for data transfer and *how often* you read/write too. Efficient formats can literally save hundreds of dollars on big jobs

REF : Slides from AWS Machine Learning Course

Common File Formats Used in ML with S3

	Format	Usage Example
1	csv	Tabular datasets, fast for small-medium jobs
2	Parquet	Columnar format; efficient for large data (via Spark/SageMaker)
3	JSON	Good for logs or structured text data
4	Images	JPEG, PNG — used in CV tasks (e.g., stored in s3://bucket/images/)
5	Models Files	.pt, .pkl. .joblib, .h5, etc – saved/loaded during training

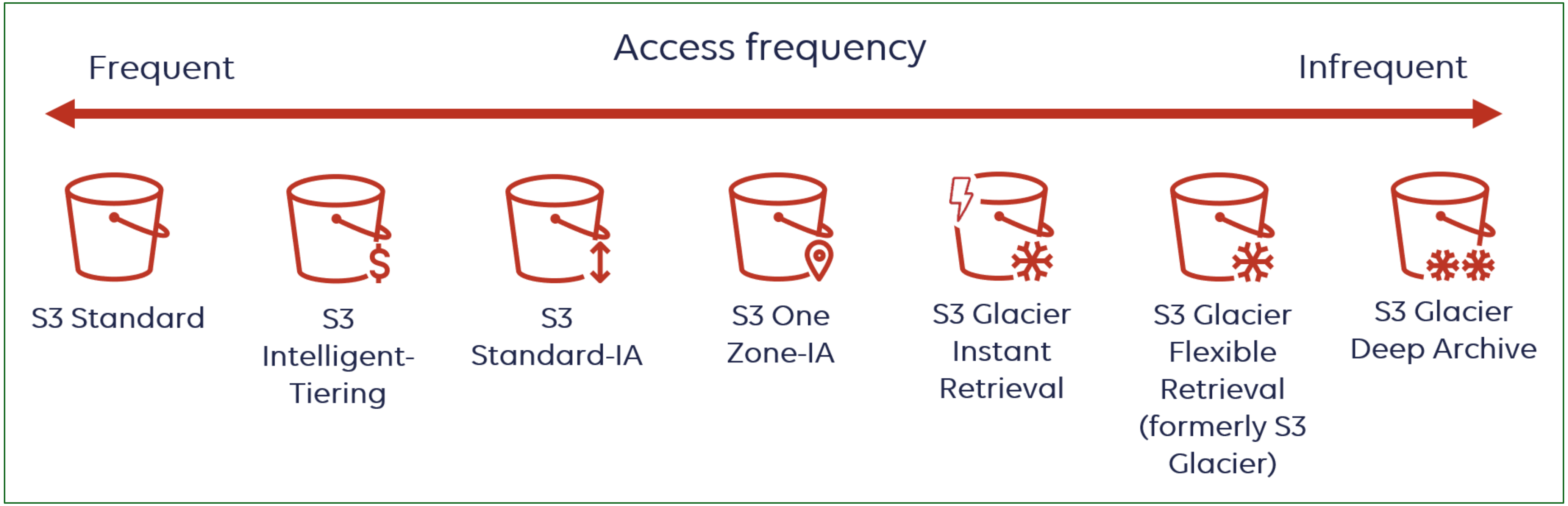
- S3 charges per GB stored and per GB retrieved
- CSV may be "easy", but it's expensive for big data ML
- Use **Parquet** for large tabular data — better compression & cheaper compute (especially with PySpark/SageMaker)
- For images, **always compress** (e.g., JPEG over PNG or BMP)
- Split large datasets into **smaller chunks** to parallelize reading in training jobs (SageMaker/EC2)

Amazon S3 Data Partitioning

Partitioning = Splitting large datasets into smaller, logically organized chunks.

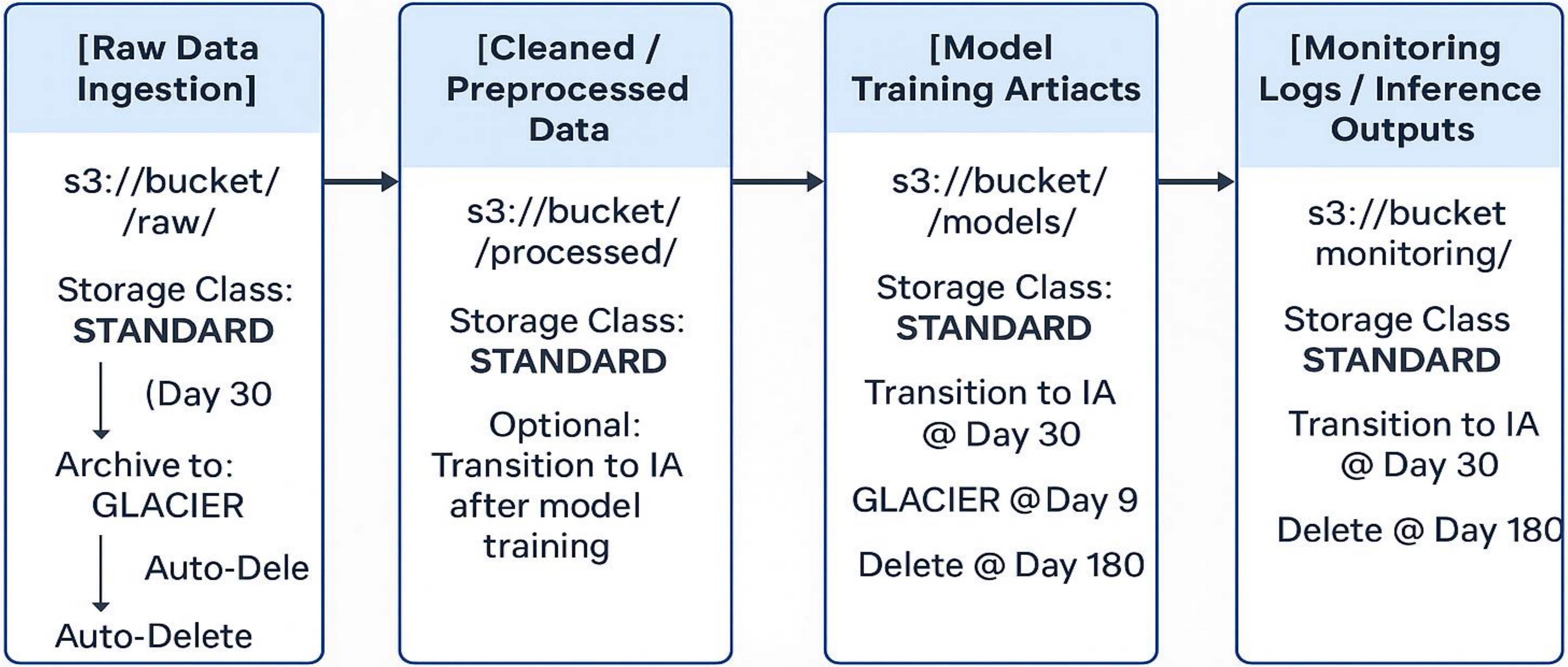
Benefits	Explanation
Faster training	Load only relevant data(e.g one region/date)
Lower cost	Minimize I/O and compute time
Parallelism	Train or process data in parallel across multiple workers
Easier filtering	Only read partions than match condition (e.g date=2024-07-04)

S3 Storage Classes



Can move between classes manually or using S3 Lifecycle configurations

S3 Lifecycle Policies in the Machine Learning Lifecycle



[Raw Data Ingestion]

s3://bucket/ /raw/

Storage Class: **STANDARD**

(Day 30

Archive to: GLACIER

Auto-Dele

Auto-Delete

[Cleaned / Preprocessed Data

s3://bucket/ /processed/

Storage Class: **STANDARD**

Optional: Transition to IA after model training

[Model Training Artiacts

s3://bucket/ /models/

Storage Class: **STANDARD**

Transition to IA @ Day 30

GLACIER @Day 9

Delete @ Day 180

[Monitoring Logs / Inference Outputs

s3://bucket monitoring/

Storage Class **STANDARD**

Transition to IA @ Day 30

Delete @ Day 180

Discussion Question

"You are building a fraud detection model using 2 years of credit card transaction logs (≈5TB). The data includes

- *timestamp,*
- *location,*
- *merchant type,*
- *transaction amount, and*
- *customer ID.*

How would you design your S3 data partitioning strategy to reduce cost, improve training speed, and support model retraining over time?"

Sample Answer

S3 Data Partitioning Strategy for Fraud Detection

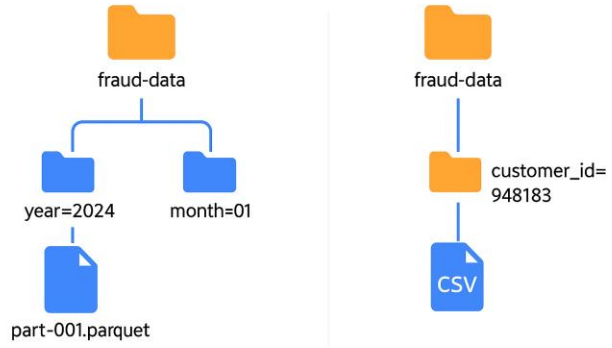
```
s3://fraud-detection-bucket/
── raw-data/
|   ── year=2023/month=01/day=01/
|   ── year=2023/month=01/day=02/
|   ── year=2024/month=12/day=31/
── processed-data/
|   ── year=2023/month=01/
|   ── year=2024/month=12/
── model-artifacts/
    ── training-runs/2024-01-15/
    ── production-models/v1.2/
```

1. Cost Optimization:

- **Lifecycle policies**: Move data older than 30 days to IA, 90+ days to Glacier
- **File format**: Use Parquet with Snappy compression (60-80% size reduction vs JSON)
- **File sizing**: Target 128-512MB files to optimize for both S3 costs and query performance
- **Delete incomplete multipart uploads** after 7 days

2. Training Speed Improvements:

- **Date partitioning** enables efficient incremental training (load only recent months)
- **Parquet columnar format** allows reading only needed columns (timestamp, amount, merchant_type)



Good Partitioning **Bad Partitioning**

Week 1 – Part 3

Amazon
EC2

3.1 AWS EC2

Learning Objectives

- **Understand EC2 basics**

EC2

Amazon Elastic Compute Cloud (EC2) is AWS's core computing service that provides **resizable compute capacity in the cloud**. Think of it as **renting computers on-demand** instead of buying and maintaining your own servers.

Simple Analogy

Imagine you need a computer for a project:

Traditional Way

Buy a physical computer, set it up, maintain it, and it sits idle when not in use

EC2 way

Rent exactly the computer power you need, when you need it, and pay only for what you use

Why do ML Engineer need EC2 ?

Challenges

- Training a deep learning model = Lots of computing power
- Processing big datasets = More memory than your laptop has
- Model inference at scale = Need multiple servers
- Peak demand vs. normal usage = Expensive to own enough hardware

How Ec2 Solve this problem

- **Scalable:** Need more power? Launch bigger instances
- **Flexible:** Different workloads need different hardware
- **Cost-effective:** Pay only for what you use, when you use it
- **Fast:** New "computer" ready in minutes, not weeks
- **Global:** Run anywhere in the world

Scenario 1 : Data Scientist Development

Problem: "My laptop takes 6 hours to train this model"
EC2 Solution: Launch GPU instance, train in 30 minutes, shut down
Cost: $3 instead of buying $3,000 GPU

Scenario 2 : Batch Data Processing

Problem: "I need to process 100GB of customer data monthly"
EC2 Solution: Launch powerful instance for 2 hours monthly
Cost: $5/month instead of $5,000 server

Scenario 3 : Model Serving

Problem: "My ML API needs to handle 1000 requests/second"
EC2 Solution: Auto-scale from 1 to 10 instances based on traffic
Cost: Pay for actual usage, not peak capacity 24/7

Scenario 4 : Experimentation

Problem: "I want to test 10 different algorithms"
EC2 Solution: Launch 10 instances simultaneously, run all tests
Time: 1 hour instead of 10 hours sequential

Core EC2 Concepts

Instance = Virtual Computer

An EC2 instance is a virtual computer running in AWS data centers. Each instance has:

- CPU: Processing power for computations
- Memory (RAM): For holding data while processing
- Storage: Disk space for your data and applications
- Network: Internet connection and bandwidth

Instance Types = Different "Computer Specs"

Just like buying a laptop, you choose specs based on your needs:

1. General Purpose (t3, m5): Balanced CPU/memory - good for development
2. Compute Optimized (c5, c6): High CPU - great for data preprocessing
3. Memory Optimized (r5, r6): Lots of RAM - perfect for big datasets
4. GPU Instances (p3, g4): Graphics cards - essential for deep learning

Regions and Availability Zones

- Region: Geographic area (e.g., US East, Europe, Asia)
- Availability Zone: Data center within a region
- Why it matters: Choose regions close to your users for better performance

EC2 Pricing Models

1. On-Demand (Pay-as-you-go)

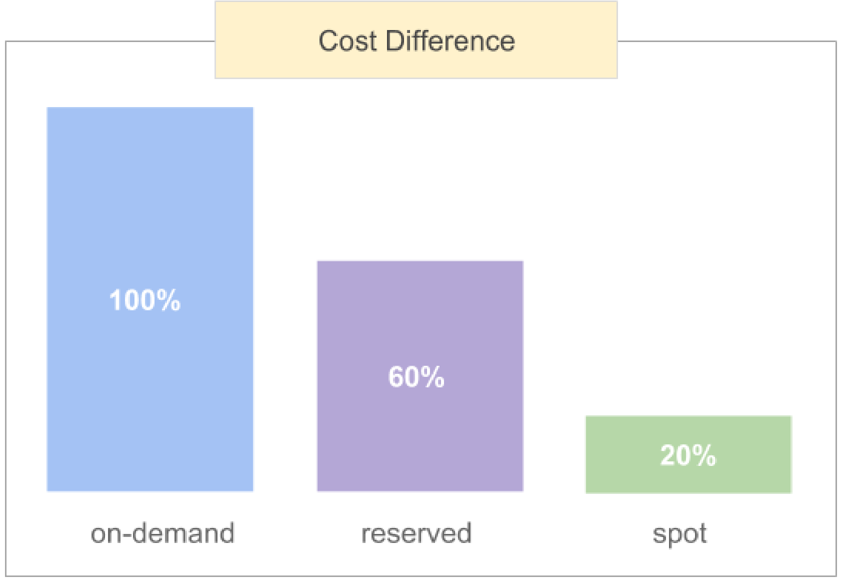
- **What:** Pay by the hour/second with no commitment
- **Best for:** Development, testing, unpredictable workloads
- **Example:** $0.50/hour for a GPU instance

2. Spot Instances (Up to 90% cheaper)

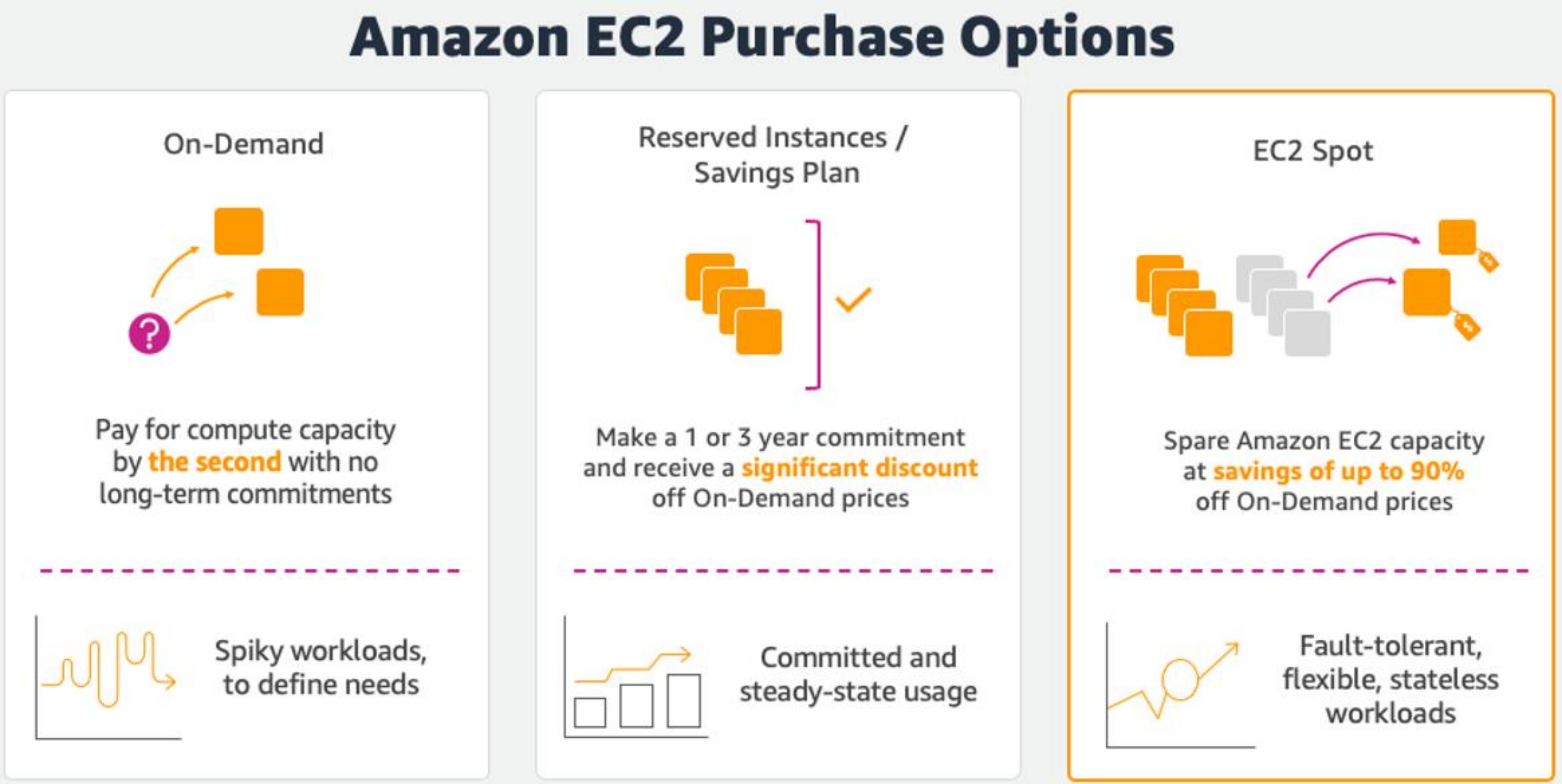
- **What:** Bid on unused EC2 capacity
- **Best for:** Training jobs that can handle interruptions
- **Example:** Same GPU for $0.15/hour (but might be terminated)

3. Reserved Instances (1–3-year commitment)

- **What:** Pay upfront for significant discounts
- **Best for:** Production workloads with predictable usage
- **Example:** Same GPU for $0.30/hour with 1-year commitment



https://blog.boltops.com/2018/07/13/on-demand-vs-reserved-vs-spot-aws-ec2-pricing-comparison/



Amazon EC2 Purchase Options

On-Demand

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

Spiky workloads, to define needs

Reserved Instances / Savings Plan

Make a 1 or 3 year commitment and receive a **significant discount** off On-Demand prices

Committed and steady-state usage

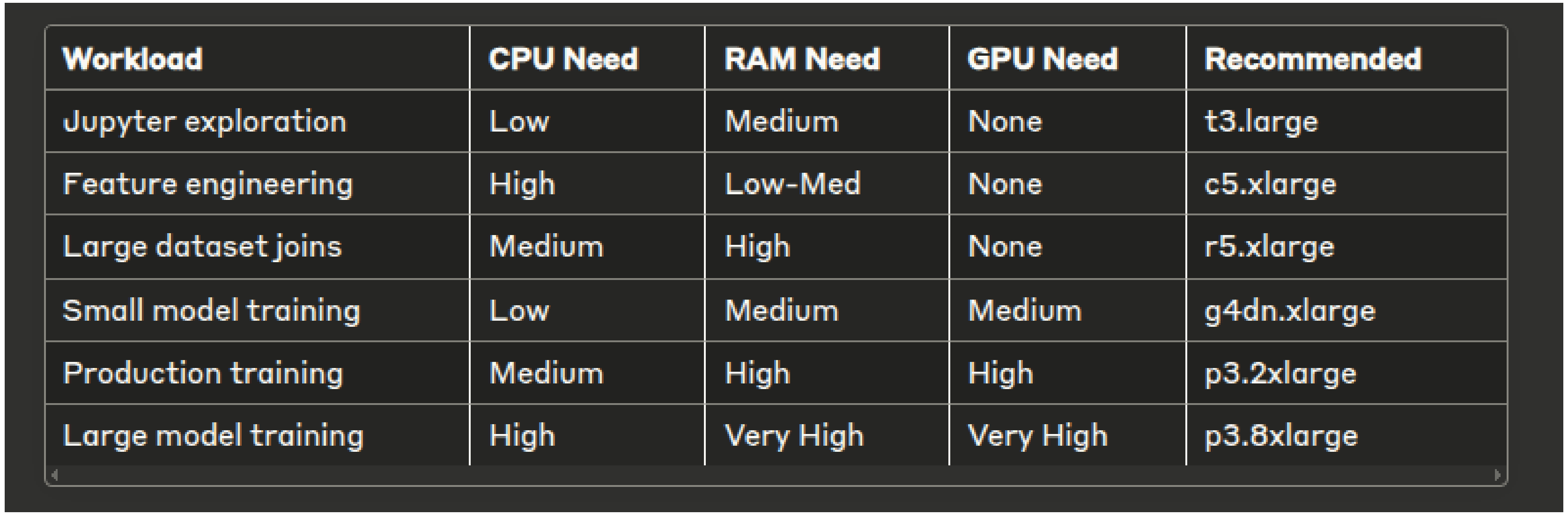
EC2 Spot

Spare Amazon EC2 capacity at **savings of up to 90%** off On-Demand prices

Fault-tolerant, flexible, stateless workloads

Specific Instance and Tech Spec

- **t2/t3/t4g** - General Purpose (cheap experiments)
- **c5/c6** - Compute Optimized (data preprocessing)
- **r5/r6** - Memory Optimized (big data in-memory)
- **p3/p4/g4/g5** - GPU Instances (deep learning training)



Workload	CPU Need	RAM Need	GPU Need	Recommended
Jupyter exploration	Low	Medium	None	t3.large
Feature engineering	High	Low-Med	None	c5.xlarge
Large dataset joins	Medium	High	None	r5.xlarge
Small model training	Low	Medium	Medium	g4dn.xlarge
Production training	Medium	High	High	p3.2xlarge
Large model training	High	Very High	Very High	p3.8xlarge

General Purpose	**t3.medium** - $0.0416/hour	2 vCPUs (1 physical core), 4GB RAM Baseline: 20% CPU, can burst to 100% Use case: Small experiments, Jupyter notebooks **When to choose:** Development, testing, cost-sensitive workloads **Avoid for:** Sustained CPU-intensive tasks
	t3.large - $0.0832/hour	2 vCPUs (1 physical core), 8GB RAM Same burst model, better for memory-hungry notebooks **Sweet spot for:** Data exploration, small model training
Compute Optimized	**c5.large** - $0.085/hour	2 vCPUs (1 physical core), 4GB RAM 3.0 GHz Intel Xeon Platinum Use case: CPU-bound preprocessing, feature engineering **Performance:** ~25% faster than t3.large for sustained loads
	c5.xlarge - $0.17/hour	4 vCPUs (2 physical cores), 8GB RAM **Best for:** Parallel data processing, scikit-learn jobs **Parallel efficiency:** Linear scaling up to physical core count
	c5.4xlarge - $0.68/hour	16 vCPUs (8 physical cores), 32GB RAM **When to choose:** Large-scale feature engineering, distributed training coordination

Memory Optimized	**r5.large** - $0.126/hour	2 vCPUs, **16GB RAM** Use case: In-memory data processing, large pandas DataFrames **Memory-to-vCPU ratio:** 8:1 (vs 4:1 for general purpose)
	r5.xlarge - $0.252/hour	4 vCPUs, **32GB RAM** **Sweet spot for:** Medium datasets (5-20GB), joins, aggregations
	r5.4xlarge - $1.008/hour	16 vCPUs, **128GB RAM** **When to choose:** Your dataset + intermediate results > 50GB
	g4dn.xlarge - $0.526/hour	4 vCPUs, 16GB RAM, **1x NVIDIA T4 (16GB GPU memory)** **Best for:** Small-medium models, inference, prototyping **GPU specs:** 2,560 CUDA cores, 320 Tensor cores **Model capacity:** BERT-base, ResNet-50, small transformers
	p3.2xlarge - $3.06/hour	8 vCPUs, 61GB RAM, **1x NVIDIA V100 (16GB GPU memory)** **Performance:** 3-4x faster training than T4 **Best for:** Production model training, large CNNs **GPU specs:** 5,120 CUDA cores, 640 Tensor cores
	p3.8xlarge - $12.24/hour	32 vCPUs, 244GB RAM, **4x NVIDIA V100 (64GB total GPU memory)** **Best for:** Large language models, distributed training **Multi-GPU efficiency:** 85-95% scaling for well-optimized models

EC2 – Lab 1

Let’s create the new EC2 Instance.

EC2 – Activity 2

Detail cost calculation.

Cost Optimization Framework for EC2

Hourly Cost = (Instance Rate) + (EBS Rate × GB) + (Data Transfer)
Daily Cost = Hourly Cost × Hours per Day
Monthly Cost = Daily Cost × Days per Month
Annual Cost = Monthly Cost × 12

Spot Savings = On-Demand Cost × (1 - Spot Discount) × Interruption Factor
Reserved Savings = On-Demand Cost × (1 - Reserved Discount)

Example 1: Model Training Comparison

Scenario: Training a computer vision model for 8 hours

Option A: p3.2xlarge On-Demand

- Instance cost: $3.06/hour × 8 hours = $24.48
- EBS cost: 100GB gp3 × 8 hours = $0.0133 × 8 = $0.11
- Data transfer: 50GB from S3 = $0.90
- Total: $25.49

Example 1: Model Training Comparison

Example 2: Data Preprocessing Pipeline

Scenario: Processing 500GB dataset daily for 1 month

Option A: c5.4xlarge On-Demand (2 hours daily)

- Instance: $0.68/hour × 2 hours × 30 days = $40.80
- EBS: 1TB gp3 storage × 30 days = $0.08/GB × 1000GB × 30 = $2,400/month ÷ 30 = $80
- Monthly total: $120.80

EC2 – Activity 3

Access S3 bucket from Ec2 instance

EC2 – Activity 4

Access S3 bucket from Ec2 instance via instance profile

Access S3 bucket from Ec2 instance via instance profile

Step1 : Create the Policy and Create the role

- **Create role for EC2**
- IAM → **Roles** → **Create role** → Trusted entity: **AWS service**, Use case: **EC2**
- Attach the **minimum** policy you need (e.g., AmazonS3ReadOnlyAccess)

Name it (e.g., EC2-S3-ReadOnly) → **Create role**

(This also creates the instance profile with the same name.)

Access S3 bucket from Ec2 instance via instance profile

Step 2: (Run on your laptop not inside EC2)

```
> aws iam create-instance-profile --instance-profile-name EC2-S3-Access-Profile
```

```
> aws iam add-role-to-instance-profile --instance-profile-name EC2-S3-Access-Profile  --role-name
```

Step 3: (Update your ec2 instance)

- Go to your ec2 instance > Action > Security Group > Update IAM

Step 4: (Verify your Ec2 can access the s3 bucket via following commands)

```
> aws s3 ls s3://sagemaker-ap-southeast-1-215470142970/fashion-mnist/train/
```

⏳ You have 15 minutes to complete this task. All resources will be cleaned up after class.

Part 5

AWS CLI

Command Line Interface

AWS CLI = Command Line Interface for AWS

- **Faster than clicking** through AWS Console
- **Scriptable and automatable** for repetitive tasks
- **Essential for production** ML workflows
- **Works great in Jupyter notebooks** and scripts

When You'll Use It:

- Upload/download datasets to/from S3
- Launch EC2 instances quickly
- Check costs and resource usage
- Automate ML pipeline tasks

Install AWS CLI

Configure Your Credentials:

```
> aws configure
```

- **Access Key ID:** Your AWS access key
- **Secret Access Key:** Your secret key
- **Default region:** us-east-1 (or your preferred region)
- **Default output format:** json (recommended)

If you're on EC2 with an IAM role, you might not need to configure credentials!

Essential S3 Commands

- **List your bucket**
  - `aws s3 ls`
- **List Contents of a Bucket**
  - `aws s3 ls s3://your-bucket-name/`
  - `aws s3 ls s3://your-bucket-name/folder/ --recursive`
- **Upload Files to S3:**
  - `aws s3 cp my_dataset.csv s3://your-bucket-name/data/`
  - `aws s3 cp ./my_folder/ s3://your-bucket-name/data/ --recursive`

Essential S3 Commands

- **Download files from S3**
  - aws s3 cp s3://your-bucket-name/data/dataset.csv ./
  - aws s3 cp s3://your-bucket-name/data/ ./local_data/ --recursive
  - aws s3 sync s3://your-bucket-name/data/ ./local_data (only newer files)
- **Sync Folders (Very Useful!):**
  - aws s3 sync ./my_project/ s3://your-bucket-name/projects/
  - aws s3 sync s3://your-bucket-name/results/ ./results/

Essential Ec2 Commands

- **Start/Stop Instances**

  -
    ```
    aws ec2 stop-instances --instance-ids i-1234567890abcdef0
    ```

  -
    ```
    aws ec2 start-instances --instance-ids i-1234567890abcdef0
    ```

  -
    ```
    aws ec2 describe-instance-status --instance-ids i-1234567890abcdef0
    ```
- Launch New Instances

  -
    ```
    aws ec2 run-instances \
      --image-id ami-0abcdef1234567890 \
      --count 1 \
      --instance-type t2.micro \
      --key-name your-key-pair \
      --security-group-ids sg-903004f8
    ```

AWS CLI in Python (Not Recommended)

```
import subprocess
import json

# Run AWS CLI command from Python
def run_aws_command(command):
    result = subprocess.run(command, shell=True, capture_output=True, text=True)
    return json.loads(result.stdout) if result.stdout else None

# Example: List S3 buckets
buckets = run_aws_command("aws s3api list-buckets")
print(f"You have {len(buckets['Buckets'])} S3 buckets")

# Example: Upload file
upload_result = run_aws_command("aws s3 cp data.csv s3://my-bucket/")
```

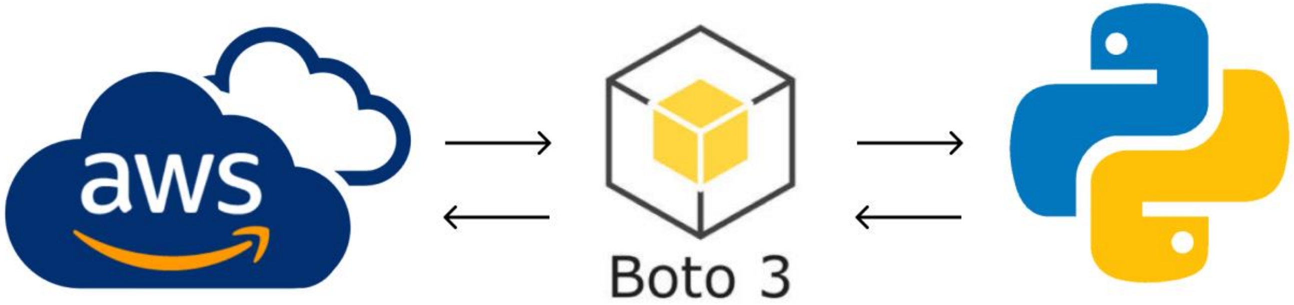
Using Boto3 (Better)

```
import boto3

# Create S3 client
s3 = boto3.client('s3')

# List buckets
buckets = s3.list_buckets()
print(f"You have {len(buckets['Buckets'])} buckets")

# Upload file
s3.upload_file('local_file.csv', 'my-bucket', 'remote_file.csv')
```

AWS CLI

Remember: AWS CLI is your friend for automation and speed. Start with these basics and add more commands as you need them!

Week 1 – Part 3



Boto3

What is boto3?

- **boto3** is the **official Python SDK (Software Development Kit) for AWS**.
- It allows Python developers to:
  - **Create**, **manage**, and **interact with AWS services** (like S3, EC2, SageMaker, IAM, etc.)
  - Automate cloud operations directly from Python scripts, notebooks, or apps

```
# AWS CLI (good for scripts)
aws s3 cp data.csv s3://bucket/

# Boto3 (better for Python programs)
import boto3
s3.upload_file('data.csv', 'bucket', 'data.csv')
```

AWS Service	Use Case	Example
S3	Stores and retrieve the data	Upload training CSVs, download model outputs
SageMaker	Model training & deployment	Launch XGBoost jobs, deploy real-time endpoints
EC2	Manage compute resources	Starts and Stops VMs
IAM	Cloud Security	Create roles for model execution
CloudWatch	Monitor logs and metrics	Track model traning logs in real time

Boto3

1. Boto3 needs AWS credentials

- **Problem**: If you don’t configure credentials, boto3 won’t know how to access AWS, and you'll get errors like ***botocore.exceptions.NoCredentialsError***.
- How to fix:

1. Use aws configure in CLI to set up your credentials locally

```
aws configure
# Enter: AWS Access Key, Secret Key, Region,
Output format
```

Or set **environment variables** in your terminal:

```
export AWS_ACCESS_KEY_ID=YOUR_KEY
export AWS_SECRET_ACCESS_KEY=YOUR_SECRET
export AWS_DEFAULT_REGION=ap-southeast-1
```

Never push .aws/credentials to GitHub.

Boto3

2. Every AWS action may incur cost

- **Problem**: Spinning up SageMaker endpoints or large EC2 instances can cost money **by the hour** — and the billing **keeps running** unless you manually stop or delete them.
- How to fix:

1. **Always terminate endpoints** after inference using:

```
sm = boto3.client("sagemaker")
sm.delete_endpoint(EndpointName="your-endpoint")
```

Most people forget to delete SageMaker endpoints and get surprise

3. You must specify the correct AWS region

Problem: If you create a bucket in one region and call boto3 from another, you’ll get cryptic 403/404 errors.

How to Fix

Or set **environment variables** in your terminal:

```
session = boto3.Session(region_name="ap-southeast-1")
s3 = session.client("s3")
```

Cross-region mistakes are one of the most frustrating bugs for beginners to debug.

Boto3 Security Best Practice

1. Don’t hardcode AWS keys in Notebooks

- Keys can leak if you upload your notebook to GitHub, email it, or even leave it in shared folders.

- Best practice:

- Use environment variables
- Or use IAM roles

2. Use IAM Roles when possible

- Especially useful in:
  - SageMaker Notebooks
  - EC2 instances
- These services can inherit IAM roles without needing manual key setup

3. Follow the “Least Privilege” principle

- Don’t give your users or notebooks full admin access
- Instead, create scoped IAM policies:
  - S3: Allow read/write to only specific buckets or prefixes
  - SageMaker: Allow only CreateTrainingJob, not full control over all services
- Example IAM policy snippet for a safe S3 + SageMaker combo:

```
{
  "Effect": "Allow",
  "Action": [
    "s3:GetObject",
    "s3:PutObject",
    "sagemaker:CreateTrainingJob",
    "sagemaker:InvokeEndpoint"
  ],
  "Resource": "*"
}
```

Boto3 – Activity1

Checkout the jupyter notebook

AWS Lambda

Serverless Computing Platform

Lambda

- **No servers to manage** - AWS handles everything
- **Event-driven** - runs code in response to triggers
- **Pay per execution** - only pay when your code runs
- **Auto-scaling** - handles 1 request or 1000 simultaneously

Traditional	Lambda
EC2 instance running 24/7	Function runs on-demand
$50/month even if unused	$0.20 per 1M requests
Manual Scaling	Automatic Scaling
Server Maintenance	Zero Maintenance

Lambda Limits (Important!):

- **Timeout:** 15 minutes max
- **Memory:** 128MB to 10GB
- **Storage:** 512MB in /tmp only
- **Best for:** Inference, preprocessing, NOT training

AWS Lambda : Activity 1

Your first ML Lambda Function

AWS Lambda : Activity 2

S3 Triggered Data Preprocessing Lambda

AWS Lambda : Activity 3

Real Time ML API with Lambda