

# AWS DevOps Digital Guide

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## 1 Introduction to AWS and DevOps

Welcome to the **AWS DevOps Digital Guide**, designed for engineers, architects, and IT professionals. This book will help you master AWS services, DevOps principles, automation, and cost optimization through practical examples and clear explanations.

### 1.1 What is AWS DevOps?

**AWS DevOps** is the practice of implementing DevOps principles on Amazon Web Services. It allows automation of deployments, efficient monitoring, and cost optimization.

### 1.2 Key Benefits

- **Automation:** Infrastructure as Code, CI/CD pipelines
- **Scalability:** Horizontal & vertical scaling
- **Security:** IAM, KMS, MFA
- **Cost Optimization:** Budgets, Reserved/Spot instances, S3 lifecycle
- **Monitoring:** CloudWatch, CloudTrail, SNS notifications

### 1.3 Core AWS DevOps Services

- **Compute:** EC2, Lambda, ECS, EKS
- **Storage:** S3, EBS, EFS
- **Networking:** VPC, Route53, ELB
- **CI/CD:** CodePipeline, CodeBuild, CodeDeploy
- **Monitoring:** CloudWatch, CloudTrail

## 1.4 AWS CLI Commands Example

### Configure AWS CLI:

```
$ aws configure
AWS Access Key ID [None]: AKIAEXAMPLE
AWS Secret Access Key [None]: abc123EXAMPLEKEY
Default region name [None]: us-east-1
Default output format [None]: json
```

### Output:

Configuration saved successfully.

### List S3 Buckets:

```
$ aws s3 ls
```

### Output:

```
2025-09-01 00:00:00 my-first-bucket
2025-09-01 01:20:10 my-second-bucket
```

**Tip:** Use `--query` and `--output table` to make CLI outputs more readable. Example:

```
$ aws ec2 describe-instances --query "Reservations[*].Instances[*].[InstanceId,State]"
```

## 2 IAM and Security

IAM (Identity and Access Management) controls access to AWS services securely. It allows you to create users, groups, roles, and policies for fine-grained permission management.

### 2.1 Core Concepts

- **Users:** Individual accounts for human users or services.
- **Groups:** Collection of users with shared permissions.
- **Roles:** Temporary credentials for applications, services, or cross-account access.
- **Policies:** JSON documents defining permissions.

## 2.2 Creating IAM Users and Groups

Create a new IAM user:

```
$ aws iam create-user --user-name DevOpsUser
```

Output:

```
{
  "User": {
    "UserName": "DevOpsUser",
    "UserId": "AIDAEXAMPLEID",
    "Arn": "arn:aws:iam::123456:user/DevOpsUser",
    "CreateDate": "2025-09-01T10:00:00Z"
  }
}
```

Create a group:

```
$ aws iam create-group --group-name DevOpsGroup
```

Output:

```
{
  "Group": {
    "GroupName": "DevOpsGroup",
    "GroupId": "AGPAEXAMPLEID",
    "Arn": "arn:aws:iam::123456:group/DevOpsGroup",
    "CreateDate": "2025-09-01T10:05:00Z"
  }
}
```

## 2.3 Attaching Policies to Users or Groups

Attach Administrator Access policy to user:

```
$ aws iam attach-user-policy --user-name DevOpsUser --policy-arn arn:aws:iam::aws:policy/AdministratorAccess
```

Output:

```
Successfully attached policy AdministratorAccess to user DevOpsUser
```

## 2.4 Creating Roles for EC2

Create a role for EC2:

```
$ aws iam create-role --role-name EC2Role --assume-role-policy-document file://trust
```

Output:

```
{
  "Role": {
    "RoleName": "EC2Role",
    "RoleId": "AROEXAMPLEID",
    "Arn": "arn:aws:iam::123456:role/EC2Role",
    "CreateDate": "2025-09-01T10:10:00Z"
  }
}
```

## 2.5 Security Best Practices

- Follow the **least privilege principle**.
- Enable **MFA** for all users with sensitive access.
- Rotate access keys regularly.
- Monitor and review **CloudTrail logs** frequently.

# 3 EC2 Instances, Key Pairs, and Security Groups

## 3.1 Introduction to EC2

Amazon EC2 (Elastic Compute Cloud) provides scalable virtual servers. Key concepts:

- **Instance Types:** t2.micro, m5.large, etc.
- **AMI (Amazon Machine Image):** Pre-configured OS and software.
- **Key Pairs:** Secure SSH login credentials.
- **Security Groups:** Virtual firewall for instances.

## 3.2 Launching an EC2 Instance

Launch a new EC2 instance using AWS CLI:

```
$ aws ec2 run-instances
--image-id ami-0abcdef1234567890
--count 1
--instance-type t2.micro
--key-name DevOpsKey
--security-group-ids sg-0abc1234def567890
--subnet-id subnet-0ab12c345def67890
```

Output:

```
{
  "Instances": [
    {
      "InstanceId": "i-0abcdef1234567890",
      "ImageId": "ami-0abcdef1234567890",
      "State": {"Code": 0, "Name": "pending"},
      "InstanceType": "t2.micro",
      "KeyName": "DevOpsKey",
      "SubnetId": "subnet-0ab12c345def67890",
      "SecurityGroups": [{"GroupName": "DevOpsSG", "GroupId": "sg-0abc1234def567890"}]
    }
  ]
}
```

## 3.3 Creating Key Pairs

Create a new key pair for SSH access:

```
$ aws ec2 create-key-pair --key-name DevOpsKey
$ aws ec2 create-key-pair --key-name DevOpsKey --query KeyMaterial --output text > D
```

Output:

```
<PrivateKey data saved in DevOpsKey.pem>
```

**Tip:** Always set correct permissions for the key file before using SSH:

```
$ chmod 400 DevOpsKey.pem
```

### 3.4 Creating Security Groups

Create a security group:

```
$ aws ec2 create-security-group
  --group-name DevOpsSG
  --description "DevOps EC2 Security Group"
  --vpc-id vpc-0abcd1234efgh5678
```

Output:

```
{
  "GroupId": "sg-0abc1234def567890"
}
```

### 3.5 Adding Inbound Rules

Allow SSH (port 22) access:

```
$ aws ec2 authorize-security-group-ingress
  --group-id sg-0abc1234def567890
  --protocol tcp
  --port 22
  --cidr 0.0.0.0/0
```

Output:

```
{
  "Return": true
}
```

**Allow HTTP (port 80) access:**

```
$ aws ec2 authorize-security-group-ingress
  --group-id sg-0abc1234def567890
  --protocol tcp
  --port 80
  --cidr 0.0.0.0/0
```

**Output:**

```
{
  "Return": true
}
```

**Tip:** Limit SSH access to your IP for security instead of 0.0.0.0/0.

## 4 EBS Volumes, Snapshots, and AMI Management

### 4.1 Introduction to EBS

Amazon Elastic Block Store (EBS) provides persistent block storage for EC2 instances. Key concepts:

- **Volume Types:** General Purpose SSD (gp3), Provisioned IOPS SSD (io2), Magnetic.
- **Snapshots:** Point-in-time backups of volumes.
- **Attachment:** Volumes must be attached to EC2 instances.

### 4.2 Creating an EBS Volume

**Create a new 8GB EBS volume:**

```
$ aws ec2 create-volume
  --size 8
  --region us-east-1
  --availability-zone us-east-1a
  --volume-type gp3
```

**Output:**

```
{
  "AvailabilityZone": "us-east-1a",
  "VolumeId": "vol-0abcd1234ef567890",
  "Size": 8,
  "State": "creating",
  "VolumeType": "gp3"
}
```

### 4.3 Attaching an EBS Volume to EC2

**Attach the volume to an EC2 instance:**

```
$ aws ec2 attach-volume
--volume-id vol-0abcd1234ef567890
--instance-id i-0abcdef1234567890
--device /dev/sdf
```

**Output:**

```
{
  "State": "attaching",
  "AttachTime": "2025-09-01T12:00:00Z",
  "InstanceId": "i-0abcdef1234567890",
  "VolumeId": "vol-0abcd1234ef567890",
  "Device": "/dev/sdf"
}
```

### 4.4 Creating a Snapshot of EBS Volume

**Create a snapshot for backup:**

```
$ aws ec2 create-snapshot
--volume-id vol-0abcd1234ef567890
--description "Backup of DevOps EBS volume"
```



**Output:**

```
{
  "SnapshotId": "snap-0abc1234def567890",
  "State": "pending",
  "VolumeId": "vol-0abcd1234ef567890",
  "StartTime": "2025-09-01T12:30:00Z",
  "Description": "Backup of DevOps EBS volume"
}
```

## 4.5 Creating an AMI from EC2 Instance

**Create an Amazon Machine Image (AMI):**

```
$ aws ec2 create-image
  --instance-id i-0abcdef1234567890
  --name "DevOpsServerAMI"
  --description "AMI for DevOps EC2 server"
```

**Output:**

```
{
  "ImageId": "ami-0abc1234def567890"
}
```

## 4.6 Listing Snapshots and AMIs

**List all snapshots in your account:**

```
$ aws ec2 describe-snapshots --owner-ids self
```

**Output:**

```
[
  {
    "SnapshotId": "snap-0abc1234def567890",
    "VolumeId": "vol-0abcd1234ef567890",
    "State": "completed",
    "StartTime": "2025-09-01T12:30:00Z"
  }
]
```

**List all AMIs you own:**

```
$ aws ec2 describe-images --owners self
```

**Output:**

```
{
  "Images": [
    {
      "ImageId": "ami-0abc1234def567890",
      "Name": "DevOpsServerAMI",
      "State": "available",
      "CreationDate": "2025-09-01T12:45:00Z"
    }
  ]
}
```

**Tip:** Use snapshots to recover from accidental data loss and to create new AMIs quickly.

## 5 VPC, Subnets, and Internet Gateway Setup

### 5.1 Introduction to VPC

A Virtual Private Cloud (VPC) allows you to provision a logically isolated section of AWS Cloud. Key concepts:

- **VPC:** Virtual network with CIDR block.
- **Subnet:** Subdivision of VPC to group resources.

- **Internet Gateway (IGW):** Enables internet connectivity for VPC.
- **Route Table:** Controls traffic routing in the VPC.

## 5.2 Creating a VPC

Create a new VPC:

```
$ aws ec2 create-vpc
  --cidr-block 10.0.0.0/16
```

Output:

```
{
  "Vpc": {
    "VpcId": "vpc-0abc1234def567890",
    "State": "pending",
    "CidrBlock": "10.0.0.0/16",
    "IsDefault": false
  }
}
```

## 5.3 Creating Subnets

Create a public subnet:

```
$ aws ec2 create-subnet
  --vpc-id vpc-0abc1234def567890
  --cidr-block 10.0.1.0/24
  --availability-zone us-east-1a
```

**Output:**

```
{
  "Subnet": {
    "SubnetId": "subnet-0abcd1234ef567890",
    "VpcId": "vpc-0abc1234def567890",
    "CidrBlock": "10.0.1.0/24",
    "AvailabilityZone": "us-east-1a",
    "State": "available"
  }
}
```

## 5.4 Creating an Internet Gateway (IGW)

**Create an Internet Gateway:**

```
$ aws ec2 create-internet-gateway
```

**Output:**

```
{
  "InternetGateway": {
    "InternetGatewayId": "igw-0abc1234def567890",
    "Attachments": []
  }
}
```

## 5.5 Attaching IGW to VPC

**Attach Internet Gateway to the VPC:**

```
$ aws ec2 attach-internet-gateway
--vpc-id vpc-0abc1234def567890
--internet-gateway-id igw-0abc1234def567890
```

**Output:**

```
{
  "Return": true
}
```

## 5.6 Creating a Route Table and Route to IGW

Create a route table:

```
$ aws ec2 create-route-table
--vpc-id vpc-0abc1234def567890
```

Output:

```
{
  "RouteTable": {
    "RouteTableId": "rtb-0abc1234def567890",
    "VpcId": "vpc-0abc1234def567890",
    "Routes": [
      {"DestinationCidrBlock": "10.0.0.0/16", "GatewayId": "local"}
    ]
  }
}
```

Add route to IGW:

```
$ aws ec2 create-route
--route-table-id rtb-0abc1234def567890
--destination-cidr-block 0.0.0.0/0
--gateway-id igw-0abc1234def567890
```

Output:

```
{
  "Return": true
}
```

## 5.7 Associating Subnet with Route Table

Associate subnet with route table:

```
$ aws ec2 associate-route-table
--subnet-id subnet-0abcd1234ef567890
--route-table-id rtb-0abc1234def567890
```

**Output:**

```
{
  "AssociationId": "rtbassoc-0abc1234def567890"
}
```

**Tip:** Always check subnet's route table to ensure proper internet connectivity for public resources.

## 6 NAT Gateway, Private Subnets, and Elastic IPs

### 6.1 Introduction

In a VPC setup, NAT Gateways allow instances in private subnets to access the internet for updates or downloads without exposing them publicly. Key concepts:

- **Private Subnet:** Subnet without direct internet access.
- **NAT Gateway:** Enables internet access for private instances.
- **Elastic IP (EIP):** Static public IP to associate with NAT or EC2.

### 6.2 Allocate an Elastic IP

**Allocate a new Elastic IP:**

```
$ aws ec2 allocate-address --domain vpc
```

**Output:**

```
{
  "PublicIp": "203.0.113.25",
  "AllocationId": "eipalloc-0abc1234def567890"
}
```

### 6.3 Create a NAT Gateway

**Create NAT Gateway in a public subnet:**

```
$ aws ec2 create-nat-gateway
--subnet-id subnet-0abcd1234ef567890
--allocation-id eipalloc-0abc1234def567890
```

**Output:**

```
{
  "NatGateway": {
    "NatGatewayId": "nat-0abc1234def567890",
    "State": "pending",
    "SubnetId": "subnet-0abcd1234ef567890",
    "VpcId": "vpc-0abc1234def567890",
    "NatGatewayAddresses": [
      {"PublicIp": "203.0.113.25", "AllocationId": "eipalloc-0abc1234def567890"}
    ]
  }
}
```

## 6.4 Create Private Subnet

**Create a private subnet:**

```
$ aws ec2 create-subnet
--vpc-id vpc-0abc1234def567890
--cidr-block 10.0.2.0/24
--availability-zone us-east-1a
```

**Output:**

```
{
  "Subnet": {
    "SubnetId": "subnet-0abcd5678efgh1234",
    "VpcId": "vpc-0abc1234def567890",
    "CidrBlock": "10.0.2.0/24",
    "AvailabilityZone": "us-east-1a",
    "State": "available"
  }
}
```

## 6.5 Create a Route Table for Private Subnet

Create a route table:

```
$ aws ec2 create-route-table
--vpc-id vpc-0abc1234def567890
```

Output:

```
{
  "RouteTable": {
    "RouteTableId": "rtb-0abcd5678efgh1234",
    "VpcId": "vpc-0abc1234def567890"
  }
}
```

## 6.6 Add Route to NAT Gateway

Add route for private subnet to NAT Gateway:

```
$ aws ec2 create-route
--route-table-id rtb-0abcd5678efgh1234
--destination-cidr-block 0.0.0.0/0
--nat-gateway-id nat-0abc1234def567890
```

Output:

```
{
  "Return": true
}
```

## 6.7 Associate Private Subnet with Route Table

Associate private subnet with the route table:

```
$ aws ec2 associate-route-table
--subnet-id subnet-0abcd5678efgh1234
--route-table-id rtb-0abcd5678efgh1234
```



**Output:**

```
{
  "AssociationId": "rtbassoc-0abcd5678efgh1234"
}
```

**Tip:** NAT Gateways are billed hourly. Use them only when necessary for cost optimization.

## 7 Security Groups, NACLs, and Bastion Hosts

### 7.1 Introduction

Securing your AWS environment is crucial. Security Groups (SG) and Network ACLs (NACLs) help control traffic. Bastion Hosts allow secure SSH access to instances in private subnets. Key concepts:

- **Security Groups:** Stateful firewall for EC2 instances.
- **Network ACLs (NACLs):** Stateless subnet-level firewall.
- **Bastion Host:** Jump server for accessing private instances.

### 7.2 Security Group Example

Create a security group for private instances:

```
$ aws ec2 create-security-group
  --group-name PrivateSG
  --description "Security group for private instances"
  --vpc-id vpc-0abc1234def567890
```

**Output:**

```
{
  "GroupId": "sg-0abcd5678efgh1234"
}
```

## 7.3 Add Inbound Rule for Bastion Access

Allow SSH from bastion host IP:

```
$ aws ec2 authorize-security-group-ingress
  --group-id sg-0abcd5678efgh1234
  --protocol tcp
  --port 22
  --cidr 203.0.113.25/32
```

Output:

```
{
  "Return": true
}
```

## 7.4 Network ACLs (NACLs)

Create a Network ACL:

```
$ aws ec2 create-network-acl --vpc-id vpc-0abc1234def567890
```

Output:

```
{
  "NetworkAcl": {
    "NetworkAclId": "acl-0abc1234def567890",
    "VpcId": "vpc-0abc1234def567890"
  }
}
```

## 7.5 Add NACL Rules

**Allow inbound HTTP/HTTPS:**

```
$ aws ec2 create-network-acl-entry
  --network-acl-id acl-0abc1234def567890
  --rule-number 100
  --protocol tcp
  --port-range From=80,To=443
  --egress false
  --rule-action allow
```

**Output:**

```
{
  "Return": true
}
```

**Deny all other inbound traffic:**

```
$ aws ec2 create-network-acl-entry
  --network-acl-id acl-0abc1234def567890
  --rule-number 200
  --protocol -1
  --egress false
  --rule-action deny
```

**Output:**

```
{
  "Return": true
}
```

## 7.6 Bastion Host Setup

**Launch a Bastion Host in public subnet:**

```
$ aws ec2 run-instances
  --image-id ami-0abcdef1234567890
  --count 1
  --instance-type t2.micro
  --key-name DevOpsKey
  --security-group-ids sg-0abc1234def567890
  --subnet-id subnet-0abcd1234ef567890
```

**Output:**

```
{
  "Instances": [
    {
      "InstanceId": "i-0abcdef5678901234",
      "State": {"Code": 0, "Name": "pending"},
      "InstanceType": "t2.micro",
      "KeyName": "DevOpsKey"
    }
  ]
}
```

**Tip:** Use Bastion Host to SSH into private instances using:

```
$ ssh -i DevOpsKey.pem ec2-user@<Private-Instance-IP> -J ec2-user@<Bastion-IP>
```

## 8 RDS Setup, Subnet Groups, and Security

### 8.1 Introduction

Amazon RDS (Relational Database Service) allows you to run managed databases in AWS. Key concepts:

- **RDS Instance Types:** db.t2.micro, db.m5.large, etc.
- **Subnet Groups:** Defines which subnets RDS instances can use.
- **Security:** Controlled via Security Groups and IAM roles.

## 8.2 Create an RDS Subnet Group

Create a DB Subnet Group:

```
$ aws rds create-db-subnet-group
--db-subnet-group-name DevOpsSubnetGroup
--db-subnet-group-description "Subnet group for RDS instances"
--subnet-ids subnet-0abcd1234ef567890 subnet-0abcd5678efgh1234
```

Output:

```
{
  "DBSubnetGroup": {
    "DBSubnetGroupName": "DevOpsSubnetGroup",
    "DBSubnetGroupDescription": "Subnet group for RDS instances",
    "SubnetIds": [
      "subnet-0abcd1234ef567890",
      "subnet-0abcd5678efgh1234"
    ]
  }
}
```

## 8.3 Launch an RDS Instance

Create a MySQL RDS instance:

```
$ aws rds create-db-instance
--db-instance-identifier DevOpsDB
--db-instance-class db.t2.micro
--engine mysql
--master-username admin
--master-user-password Admin1234
--allocated-storage 20
--vpc-security-group-ids sg-0abcd5678efgh1234
--db-subnet-group-name DevOpsSubnetGroup
```

**Output:**

```
{
  "DBInstance": {
    "DBInstanceIdentifier": "DevOpsDB",
    "DBInstanceStatus": "creating",
    "DBInstanceClass": "db.t2.micro",
    "Engine": "mysql",
    "MasterUsername": "admin"
  }
}
```

## 8.4 Check RDS Instance Status

Check if RDS instance is available:

```
$ aws rds describe-db-instances
--db-instance-identifier DevOpsDB
```

**Output:**

```
{
  "DBInstances": [
    {
      "DBInstanceIdentifier": "DevOpsDB",
      "DBInstanceStatus": "available",
      "Endpoint": {
        "Address": "devopsdb.abcdefgh.us-east-1.rds.amazonaws.com",
        "Port": 3306
      },
      "DBInstanceClass": "db.t2.micro"
    }
  ]
}
```

## 8.5 RDS Security Best Practices

- Enable encryption at rest using KMS.
- Apply security group rules to restrict access.

- Enable automated backups and snapshots.
- Regularly rotate master credentials.

**Tip:** Use private subnets for RDS instances to prevent direct internet exposure.

## 9 S3 Buckets, Versioning, and Lifecycle Policies

### 9.1 Introduction

Amazon S3 (Simple Storage Service) is a scalable object storage service. Key concepts:

- **Buckets:** Containers for storing objects.
- **Versioning:** Keep multiple versions of objects.
- **Lifecycle Policies:** Automate deletion or transition of objects.

### 9.2 Create an S3 Bucket

Create a new S3 bucket:

```
$ aws s3 mb s3://my-devops-bucket
```

Output:

```
make_bucket: my-devops-bucket
```

### 9.3 Enable Versioning on Bucket

Enable versioning:

```
$ aws s3api put-bucket-versioning
--bucket my-devops-bucket
--versioning-configuration Status=Enabled
```

Output:

```
{}
```

## 9.4 Upload an Object to S3

Upload a file to S3 bucket:

```
$ aws s3 cp myfile.txt s3://my-devops-bucket/
```

Output:

```
upload: ./myfile.txt to s3://my-devops-bucket/myfile.txt
```

## 9.5 List Objects in S3 Bucket

List all objects:

```
$ aws s3 ls s3://my-devops-bucket/
```

Output:

```
2025-09-01 12:00:00  myfile.txt
```

## 9.6 S3 Lifecycle Policy Example

Create a lifecycle policy to transition objects to Glacier:

```
$ aws s3api put-bucket-lifecycle-configuration
--bucket my-devops-bucket
--lifecycle-configuration '{
  "Rules": [
    {
      "ID": "ArchiveToGlacier",
      "Status": "Enabled",
      "Prefix": "",
      "Transitions": [
        {"Days": 30, "StorageClass": "GLACIER"}
      ]
    }
  ]
}'
```



**Output:**

```
{}
```

## 9.7 S3 Best Practices

- Enable bucket versioning for critical data.
- Use server-side encryption (SSE) for security.
- Implement lifecycle policies to optimize storage costs.
- Apply bucket policies and IAM roles for secure access.

**Tip:** Use `--recursive` option for bulk uploads and downloads.

# 10 CloudWatch Monitoring, Alarms, and Logs

## 10.1 Introduction

Amazon CloudWatch allows you to monitor AWS resources and applications in real-time. Key concepts:

- **Metrics:** Quantitative data about resources (CPU, Memory, Network).
- **Alarms:** Trigger actions based on thresholds.
- **Logs:** Centralized logging for troubleshooting and analysis.

## 10.2 List CloudWatch Metrics

**List available metrics:**

```
$ aws cloudwatch list-metrics
```

#### Sample Output:

```
{
  "Metrics": [
    {
      "Namespace": "AWS/EC2",
      "MetricName": "CPUUtilization",
      "Dimensions": [{"Name": "InstanceId", "Value": "i-0abcdef5678901234"}]
    }
  ]
}
```

### 10.3 Create a CloudWatch Alarm

#### Create alarm for high CPU utilization:

```
$ aws cloudwatch put-metric-alarm
--alarm-name HighCPU
--metric-name CPUUtilization
--namespace AWS/EC2
--statistic Average
--period 300
--threshold 80
--comparison-operator GreaterThanThreshold
--evaluation-periods 2
--alarm-actions arn:aws:sns:us-east-1:123456789012:NotifyMe
--dimensions Name=InstanceId,Value=i-0abcdef5678901234
```

#### Output:

```
{}
```

### 10.4 Enable CloudWatch Logs for EC2

#### Install CloudWatch agent on EC2:

```
$ sudo yum install amazon-cloudwatch-agent -y
```

**Configure CloudWatch agent:**

```
$ sudo /opt/aws/amazon-cloudwatch-agent/bin/amazon-cloudwatch-agent-config-wizard
```

**Start the CloudWatch agent:**

```
$ sudo systemctl start amazon-cloudwatch-agent  
$ sudo systemctl enable amazon-cloudwatch-agent
```

## 10.5 View Logs in CloudWatch

**List log groups:**

```
$ aws logs describe-log-groups
```

**View log streams:**

```
$ aws logs describe-log-streams --log-group-name /var/log/messages
```

**Get latest logs:**

```
$ aws logs get-log-events  
  --log-group-name /var/log/messages  
  --log-stream-name <log-stream-name>  
  --limit 20
```

## 10.6 Best Practices

- Set meaningful thresholds for alarms to avoid false positives.
- Use tags to organize metrics and logs.
- Centralize logs across multiple accounts for better observability.
- Archive old logs to S3 for long-term storage.

**Tip:** Combine CloudWatch Alarms with SNS to receive instant notifications on critical events.

## 11 CodePipeline, CodeBuild, and CI/CD Basics

## 11.1 Introduction

AWS CodePipeline and CodeBuild enable automated Continuous Integration and Continuous Deployment (CI/CD). Key concepts:

- **CodePipeline:** Orchestrates the build, test, and deployment process.
- **CodeBuild:** Compiles source code, runs tests, and produces artifacts.
- **CI/CD:** Automates code delivery and reduces manual errors.

## 11.2 Create a CodeBuild Project

Create a CodeBuild project:

```
$ aws codebuild create-project
  --name DevOpsBuildProject
  --source type=GITHUB,location=https://github.com/user/repo.git
  --artifacts type=NO_ARTIFACTS
  --environment type=LINUX_CONTAINER,image=aws/codebuild/standard:5.0,computeType=BU
```

Output:

```
{
  "project": {
    "name": "DevOpsBuildProject",
    "arn": "arn:aws:codebuild:us-east-1:123456789012:project/DevOpsBuildProject",
    "created": "2025-09-01T14:00:00Z"
  }
}
```

## 11.3 Create a Simple CodePipeline

Create pipeline with source, build, and deploy stages:

```
$ aws codepipeline create-pipeline
  --pipeline file://pipeline-definition.json
```

### Output:

```
{
  "pipeline": {
    "name": "DevOpsPipeline",
    "version": 1,
    "created": "2025-09-01T14:05:00Z"
  }
}
```

## 11.4 Example pipeline-definition.json

```
{
  "pipeline": {
    "name": "DevOpsPipeline",
    "roleArn": "arn:aws:iam::123456789012:role/AWSCodePipelineServiceRole",
    "stages": [
      {
        "name": "Source",
        "actions": [
          {
            "name": "SourceAction",
            "actionTypeId": {
              "category": "Source",
              "owner": "ThirdParty",
              "provider": "GitHub",
              "version": "1"
            },
            "outputArtifacts": [{"name": "SourceArtifact"}],
            "configuration": {
              "Owner": "user",
              "Repo": "repo",
              "Branch": "main",
              "OAuthToken": "*****"
            }
          }
        ]
      }
    ]
  },
  {
```

```

    "name": "Build",
    "actions": [
      {
        "name": "BuildAction",
        "actionTypeId": {
          "category": "Build",
          "owner": "AWS",
          "provider": "CodeBuild",
          "version": "1"
        },
        "inputArtifacts": [{"name": "SourceArtifact"}],
        "outputArtifacts": [{"name": "BuildArtifact"}],
        "configuration": {"ProjectName": "DevOpsBuildProject"}
      }
    ]
  }
]
}
}

```

## 11.5 CI/CD Best Practices

- Use separate AWS accounts or stages for dev, test, and prod.
- Integrate automated tests in the build stage.
- Keep pipelines declarative and version-controlled.
- Monitor pipeline status with CloudWatch events and SNS notifications.

**Tip:** Always use IAM roles with least privilege for pipeline and build projects.

## 12 ECS and Fargate Deployment Basics

### 12.1 Introduction

Amazon ECS (Elastic Container Service) allows you to run and manage Docker containers on AWS. Fargate is a serverless compute engine for ECS that eliminates the need to manage EC2 instances. Key concepts:

- **Task Definition:** Blueprint for your container(s) including CPU, memory, and Docker image.

- **Service:** Manages running tasks and ensures desired count.
- **Cluster:** Logical grouping of tasks or services.

## 12.2 Create ECS Cluster

Create a new ECS cluster:

```
$ aws ecs create-cluster --cluster-name DevOpsCluster
```

Output:

```
{
  "cluster": {
    "clusterName": "DevOpsCluster",
    "clusterArn": "arn:aws:ecs:us-east-1:123456789012:cluster/DevOpsCluster",
    "status": "ACTIVE"
  }
}
```

## 12.3 Register a Task Definition

Register a simple Fargate task definition:

```
$ aws ecs register-task-definition
--family DevOpsTask
--network-mode awsvpc
--requires-compatibilities FARGATE
--cpu 256
--memory 512
--container-definitions '[
  {
    "name": "web-app",
    "image": "nginx:latest",
    "portMappings": [{"containerPort": 80, "protocol": "tcp"}]
  }
]'
```

**Output:**

```
{
  "taskDefinition": {
    "taskDefinitionArn": "arn:aws:ecs:us-east-1:123456789012:task-definition/DevOpsTask",
    "family": "DevOpsTask",
    "revision": 1
  }
}
```

## 12.4 Run ECS Fargate Service

**Create a Fargate service:**

```
$ aws ecs create-service
--cluster DevOpsCluster
--service-name WebAppService
--task-definition DevOpsTask
--desired-count 2
--launch-type FARGATE
--network-configuration '{
  "awsvpcConfiguration": {
    "subnets": ["subnet-0abcd1234ef567890"],
    "securityGroups": ["sg-0abcd5678efgh1234"],
    "assignPublicIp": "ENABLED"
  }
}'
```

**Output:**

```
{
  "service": {
    "serviceName": "WebAppService",
    "status": "ACTIVE",
    "desiredCount": 2,
    "runningCount": 2
  }
}
```



## 12.5 Best Practices for ECS + Fargate

- Use IAM roles for tasks to limit permissions.
- Enable CloudWatch logging for container output.
- Set up auto-scaling policies based on CPU/memory metrics.
- Use multiple availability zones for high availability.

**Tip:** Fargate simplifies container management but monitor costs for high-scale deployments.

## 13 Lambda Functions, IAM Roles, and Event Triggers

### 13.1 Introduction

AWS Lambda allows you to run code without provisioning or managing servers. Key concepts:

- **Lambda Function:** Your code executed on-demand.
- **IAM Role:** Permissions for Lambda to access AWS resources.
- **Event Trigger:** Initiates Lambda execution automatically.

### 13.2 Create an IAM Role for Lambda

Create IAM role for Lambda with basic execution policy:

```
$ aws iam create-role --role-name LambdaExecRole
--assume-role-policy-document '{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Principal": {"Service": "lambda.amazonaws.com"},
            "Action": "sts:AssumeRole"
        }
    ]
}'
```

**Attach AWSLambdaBasicExecutionRole policy:**

```
$ aws iam attach-role-policy
  --role-name LambdaExecRole
  --policy-arn arn:aws:iam::aws:policy/service-role/AWSLambdaBasicExecutionRole
```

**Output:**

```
Successfully created role LambdaExecRole
Successfully attached policy AWSLambdaBasicExecutionRole
```

### 13.3 Create a Lambda Function

**Create Lambda function using Python:**

```
$ aws lambda create-function
  --function-name DevOpsHello
  --runtime python3.9
  --role arn:aws:iam::123456789012:role/LambdaExecRole
  --handler lambda_function.lambda_handler
  --zip-file fileb://lambda_function.zip
```

**Output:**

```
{
  "FunctionName": "DevOpsHello",
  "FunctionArn": "arn:aws:lambda:us-east-1:123456789012:function:DevOpsHello",
  "Runtime": "python3.9",
  "Role": "arn:aws:iam::123456789012:role/LambdaExecRole",
  "Handler": "lambda_function.lambda_handler"
}
```

### 13.4 Invoke Lambda Function

**Invoke Lambda function:**

```
$ aws lambda invoke
  --function-name DevOpsHello
  output.txt
```

### Output:

```
{
  "StatusCode": 200,
  "ExecutedVersion": "$LATEST"
}
```

## 13.5 Add Event Trigger (S3 Upload)

Add S3 event to trigger Lambda on object creation:

```
$ aws s3api put-bucket-notification-configuration
--bucket my-devops-bucket
--notification-configuration '{
  "LambdaFunctionConfigurations": [
    {
      "LambdaFunctionArn": "arn:aws:lambda:us-east-1:123456789012:function:D",
      "Events": ["s3:ObjectCreated:*"]
    }
  ]
}'
```

## 13.6 Best Practices for Lambda

- Keep Lambda functions small and single-purpose.
- Use environment variables for configuration.
- Monitor execution using CloudWatch Logs.
- Use IAM roles with least privilege to access resources.
- Consider cost for high-frequency invocations.

**Tip:** Combine Lambda with S3, DynamoDB, and SNS for event-driven architectures.

# 14 CloudFormation Basics and Stack Deployment

## 14.1 Introduction

AWS CloudFormation allows you to model, provision, and manage AWS resources using code. Key concepts:

- **Template:** JSON or YAML file defining AWS resources.
- **Stack:** Collection of resources created and managed as a single unit.
- **Change Set:** Preview changes before updating stacks.

## 14.2 Create a Simple CloudFormation Template

```
AWSTemplateFormatVersion: '2010-09-09'
Description: DevOps Sample EC2 Instance
Resources:
  DevOpsEC2:
    Type: AWS::EC2::Instance
    Properties:
      InstanceType: t2.micro
      ImageId: ami-0abcdef1234567890
      KeyName: DevOpsKey
```

## 14.3 Deploy CloudFormation Stack

Create a new stack:

```
$ aws cloudformation create-stack
  --stack-name DevOpsStack
  --template-body file:///devops-template.yaml
```

Output:

```
{
  "StackId": "arn:aws:cloudformation:us-east-1:123456789012:stack/DevOpsStack/abcd"
}
```

## 14.4 Check Stack Status

Describe stack events and status:

```
$ aws cloudformation describe-stacks --stack-name DevOpsStack
```

#### Sample Output:

```
{
  "Stacks": [
    {
      "StackName": "DevOpsStack",
      "StackStatus": "CREATE_COMPLETE",
      "CreationTime": "2025-09-01T15:00:00Z"
    }
  ]
}
```

## 14.5 Update a Stack using Change Set

#### Create a change set:

```
$ aws cloudformation create-change-set
--stack-name DevOpsStack
--change-set-name UpdateInstanceType
--template-body file://devops-template-update.yaml
--change-set-type UPDATE
```

#### Execute the change set:

```
$ aws cloudformation execute-change-set
--stack-name DevOpsStack
--change-set-name UpdateInstanceType
```

## 14.6 CloudFormation Best Practices

- Keep templates modular and reusable.
- Use parameters and mappings to customize stacks.
- Version control templates using Git.
- Monitor stack events and logs for errors.
- Test templates in dev/test accounts before production deployment.

**Tip:** Use CloudFormation drift detection to monitor manual changes in resources.

## 15 Elastic Beanstalk Basics and Application Deployment

### 15.1 Introduction

AWS Elastic Beanstalk is a Platform-as-a-Service (PaaS) that simplifies application deployment. Key concepts:

- **Application:** Container for environments and versions.
- **Environment:** Deployed instances of an application.
- **Version:** Specific code bundle deployed to environment.

### 15.2 Create an Elastic Beanstalk Application

Create a new application:

```
$ aws elasticbeanstalk create-application
--application-name DevOpsApp
--description "Sample DevOps Application"
```

Output:

```
{
  "Application": {
    "ApplicationName": "DevOpsApp",
    "Description": "Sample DevOps Application",
    "DateCreated": "2025-09-01T16:00:00Z"
  }
}
```

## 15.3 Create an Environment and Deploy Application

Deploy a web application using Python:

```
$ aws elasticbeanstalk create-environment
  --application-name DevOpsApp
  --environment-name DevOpsAppEnv
  --solution-stack-name "64bit Amazon Linux 2 v5.4.7 running Python 3.9"
  --version-label v1
  --option-settings file://options.json
```

Output:

```
{
  "EnvironmentName": "DevOpsAppEnv",
  "EnvironmentId": "e-abc123xyz",
  "Status": "Launching",
  "Health": "Green"
}
```

## 15.4 Update Application Version

Upload new version to S3 and deploy:

```
$ aws elasticbeanstalk create-application-version
  --application-name DevOpsApp
  --version-label v2
  --source-bundle S3Bucket="my-devops-bucket",S3Key="app-v2.zip"

$ aws elasticbeanstalk update-environment
  --environment-name DevOpsAppEnv
  --version-label v2
```

## 15.5 Elastic Beanstalk Best Practices

- Use separate environments for dev, test, and prod.
- Enable enhanced health monitoring for better visibility.
- Store application versions in S3 for version control.
- Use environment variables for configuration instead of hardcoding.

- Monitor logs and events for troubleshooting deployment issues.

**Tip:** Use rolling deployments to minimize downtime during updates.

## 16 CloudTrail and Auditing for Compliance

### 16.1 Introduction

AWS CloudTrail allows you to monitor, log, and retain account activity across your AWS infrastructure. Key concepts:

- **Trail:** Configuration to capture and store API activity.
- **Event:** Records of API calls including user, time, source IP, and parameters.
- **Log File Validation:** Ensures integrity of logs for auditing.

### 16.2 Create a CloudTrail Trail

Create a new CloudTrail trail:

```
$ aws cloudtrail create-trail
  --name DevOpsTrail
  --s3-bucket-name my-devops-logs
  --include-global-service-events
```

Output:

```
{
  "Name": "DevOpsTrail",
  "S3BucketName": "my-devops-logs",
  "IncludeGlobalServiceEvents": true,
  "IsMultiRegionTrail": false
}
```

### 16.3 Start Logging

Enable CloudTrail logging:

```
$ aws cloudtrail start-logging --name DevOpsTrail
```



**Output:**

```
{
  "ResponseMetadata": {
    "HTTPStatusCode": 200
  }
}
```

## 16.4 View Trail Events

**Lookup events for auditing:**

```
$ aws cloudtrail lookup-events
--lookup-attributes AttributeKey=Username,AttributeValue=DevOpsUser
--max-results 5
```

**Sample Output:**

```
{
  "Events": [
    {
      "EventId": "abcd1234-ef56-7890-gh12-ijkl34567890",
      "EventName": "CreateBucket",
      "Username": "DevOpsUser",
      "EventTime": "2025-09-01T17:00:00Z",
      "Resources": [{"ResourceName": "my-first-bucket"}]
    }
  ]
}
```

## 16.5 CloudTrail Best Practices

- Enable multi-region trails for complete coverage.
- Encrypt logs using SSE-KMS for security.
- Enable log file validation for compliance auditing.
- Integrate with CloudWatch Logs to monitor events in real-time.
- Regularly review trails for unusual activity.

**Tip:** Use CloudTrail insights to detect unusual API activity patterns automatically.

## 17 AWS Config: Resource Inventory and Compliance

### 17.1 Introduction

AWS Config helps you track AWS resource configurations, compliance, and changes over time. Key concepts:

- **Configuration Recorder:** Records resource configurations continuously.
- **Delivery Channel:** Sends recorded configurations to an S3 bucket.
- **Rules:** Evaluate resource configurations against desired policies.

### 17.2 Set Up AWS Config Recorder

Create a configuration recorder:

```
$ aws configservice put-configuration-recorder
--configuration-recorder '{
    "name": "DevOpsRecorder",
    "roleARN": "arn:aws:iam::123456789012:role/ConfigRole",
    "recordingGroup": {
        "allSupported": true,
        "includeGlobalResourceTypes": true
    }
}'
```

### 17.3 Set Up Delivery Channel

Create delivery channel to S3 bucket:

```
$ aws configservice put-delivery-channel
--delivery-channel '{
    "name": "DevOpsChannel",
    "s3BucketName": "my-config-bucket"
}'
```

## 17.4 Start Recording Configurations

Start configuration recorder:

```
$ aws configservice start-configuration-recorder
--configuration-recorder-name DevOpsRecorder
```

Output:

```
{
  "ResponseMetadata": {
    "HTTPStatusCode": 200
  }
}
```

## 17.5 Add AWS Config Rules for Compliance

Add a managed rule to check S3 bucket encryption:

```
$ aws configservice put-config-rule
--config-rule '{
  "ConfigRuleName": "s3-bucket-encrypted",
  "Description": "Check whether S3 buckets have encryption enabled",
  "Scope": {},
  "Source": {
    "Owner": "AWS",
    "SourceIdentifier": "S3_BUCKET_SERVER_SIDE_ENCRYPTION_ENABLED"
  }
}'
```

Output:

```
{
  "ConfigRule": {
    "ConfigRuleName": "s3-bucket-encrypted",
    "ConfigRuleArn": "arn:aws:config:us-east-1:123456789012:config-rule/config-r
  }
}
```

## 17.6 AWS Config Best Practices

- Enable all supported resource types to track comprehensive inventory.
- Integrate Config with CloudWatch Events for real-time alerts.
- Use managed rules for common compliance standards (PCI, HIPAA, CIS).
- Periodically review compliance dashboards to enforce governance.
- Store historical configurations for audit and rollback purposes.

**Tip:** Combine AWS Config with CloudTrail for end-to-end auditing and governance.

## 18 Amazon SNS: Notifications and Messaging

### 18.1 Introduction

Amazon SNS is a fully managed pub/sub messaging service for sending notifications. Key concepts:

- **Topic:** Logical access point for publishing messages.
- **Subscription:** Receivers of messages (email, SMS, Lambda, SQS).
- **Publisher:** Sends messages to a topic.

### 18.2 Create SNS Topic

Create a new topic:

```
$ aws sns create-topic --name DevOpsNotifications
```

Output:

```
{
  "TopicArn": "arn:aws:sns:us-east-1:123456789012:DevOpsNotifications"
}
```

## 18.3 Subscribe to SNS Topic

Subscribe email endpoint to topic:

```
$ aws sns subscribe
  --topic-arn arn:aws:sns:us-east-1:123456789012:DevOpsNotifications
  --protocol email
  --notification-endpoint user@example.com
```

## 18.4 Publish a Message

Send a notification to topic subscribers:

```
$ aws sns publish
  --topic-arn arn:aws:sns:us-east-1:123456789012:DevOpsNotifications
  --message "AWS DevOps Alert: Deployment Successful"
```

**Tip:** Combine SNS with CloudWatch alarms for automated notifications.

# 19 Amazon SQS and EventBridge: Event-Driven Architectures

## 19.1 Amazon SQS (Simple Queue Service)

SQS allows decoupling of components using message queues. Key concepts:

- **Queue:** Stores messages until consumed by a receiver.
- **Producer:** Sends messages to queue.
- **Consumer:** Receives and processes messages.

## 19.2 Create an SQS Queue

Create a standard queue:

```
$ aws sqs create-queue --queue-name DevOpsQueue
```

**Output:**

```
{
  "QueueUrl": "https://sqs.us-east-1.amazonaws.com/123456789012/DevOpsQueue"
}
```

## 19.3 Send and Receive Messages

**Send message to SQS queue:**

```
$ aws sqs send-message
--queue-url https://sqs.us-east-1.amazonaws.com/123456789012/DevOpsQueue
--message-body "Deploy App Version 2"
```

**Receive message from queue:**

```
$ aws sqs receive-message
--queue-url https://sqs.us-east-1.amazonaws.com/123456789012/DevOpsQueue
```

## 19.4 Amazon EventBridge (CloudWatch Events)

EventBridge allows routing events from AWS services or custom applications. Key concepts:

- **Rule:** Defines which events trigger actions.
- **Target:** Lambda, SQS, SNS, or other services that respond to events.

## 19.5 Create EventBridge Rule

Route S3 upload events to Lambda:

```
$ aws events put-rule
  --name DevOpsS3UploadRule
  --event-pattern '{
    "source": ["aws.s3"],
    "detail-type": ["Object Created"]
  }'

$ aws events put-targets
  --rule DevOpsS3UploadRule
  --targets '[
    {
      "Id": "LambdaTarget",
      "Arn": "arn:aws:lambda:us-east-1:123456789012:function:DevOpsHello"
    }
  ]'
```

## 19.6 Best Practices

- Use SNS for fan-out messaging to multiple subscribers.
- Use SQS for decoupling and reliable message processing.
- Use EventBridge for event-driven automation and workflows.
- Monitor queue length and delivery failures for troubleshooting.

# 20 Amazon DynamoDB: Basics and Tables

## 20.1 Introduction

DynamoDB is a fully managed NoSQL database offering high performance at scale. Key concepts:

- **Table:** Collection of items (rows).
- **Item:** Single record in a table.
- **Attribute:** Data fields in an item.
- **Primary Key:** Unique identifier for items (Partition Key, optionally Sort Key).

## 20.2 Create a DynamoDB Table

Create a table with Partition Key "UserId":

```
$ aws dynamodb create-table
  --table-name DevOpsUsers
  --attribute-definitions AttributeName=UserId,AttributeType=S
  --key-schema AttributeName=UserId,KeyType=HASH
  --provisioned-throughput ReadCapacityUnits=5,WriteCapacityUnits=5
```

Output:

```
{
  "TableDescription": {
    "TableName": "DevOpsUsers",
    "TableStatus": "CREATING"
  }
}
```

## 20.3 Check Table Status

Describe table:

```
$ aws dynamodb describe-table --table-name DevOpsUsers
```

Output:

```
{
  "Table": {
    "TableName": "DevOpsUsers",
    "TableStatus": "ACTIVE",
    "ItemCount": 0
  }
}
```

## 21 DynamoDB CRUD Operations



## 21.1 Add Item

Insert an item into DevOpsUsers:

```
$ aws dynamodb put-item
  --table-name DevOpsUsers
  --item '{"UserId": {"S": "U1001"}, "Name": {"S": "Sainath"}, "Role": {"S": "DevOps"}}
```

Output:

```
{}
```

## 21.2 Read Item

Get an item by UserId:

```
$ aws dynamodb get-item
  --table-name DevOpsUsers
  --key '{"UserId": {"S": "U1001"}}'
```

Output:

```
{
  "Item": {
    "UserId": {"S": "U1001"},
    "Name": {"S": "Sainath"},
    "Role": {"S": "DevOps"}
  }
}
```

## 21.3 Update Item

Update the Role of a user:

```
$ aws dynamodb update-item
  --table-name DevOpsUsers
  --key '{"UserId": {"S": "U1001"}}'
  --update-expression "SET Role = :r"
  --expression-attribute-values '{"r": {"S": "Senior DevOps"}}'
```

## 21.4 Delete Item

Delete a user by UserId:

```
$ aws dynamodb delete-item
  --table-name DevOpsUsers
  --key '{"UserId": {"S": "U1001"}}'
```

## 22 DynamoDB Advanced Features

### 22.1 Global Secondary Index (GSI)

Add a GSI on "Role" attribute:

```
$ aws dynamodb update-table
  --table-name DevOpsUsers
  --attribute-definitions AttributeName=Role,AttributeType=S
  --global-secondary-index-updates '[
    {
      "Create": {
        "IndexName": "RoleIndex",
        "KeySchema": [{"AttributeName": "Role", "KeyType": "HASH"}],
        "Projection": {"ProjectionType": "ALL"},
        "ProvisionedThroughput": {"ReadCapacityUnits": 5, "WriteCapacityUnits": 5}
      }
    }
  ]'
```

### 22.2 Query by GSI

Query users by Role:

```
$ aws dynamodb query
  --table-name DevOpsUsers
  --index-name RoleIndex
  --key-condition-expression "Role = :r"
  --expression-attribute-values '{":r": {"S": "DevOps"}}'
```

## 22.3 Best Practices

- Choose partition keys wisely to avoid hot partitions.
- Use GSIs sparingly for flexible queries.
- Monitor read/write capacity and enable auto-scaling.
- Use DynamoDB Streams for event-driven architectures.
- Enable point-in-time recovery (PITR) for backups.

## 23 Amazon RDS: Relational Database Service Basics

### 23.1 Introduction

Amazon RDS is a managed relational database service supporting multiple engines (MySQL, PostgreSQL, MariaDB, Oracle, SQL Server). Key concepts:

- **DB Instance:** Managed database server.
- **DB Snapshot:** Backup of the DB instance.
- **Multi-AZ:** High availability with failover support.
- **Read Replica:** Offload read queries for scalability.

### 23.2 Create RDS Database Instance

Create MySQL RDS instance:

```
$ aws rds create-db-instance
--db-instance-identifier DevOpsRDS
--db-instance-class db.t3.micro
--engine mysql
--master-username admin
--master-user-password MyPassword123
--allocated-storage 20
--backup-retention-period 7
--publicly-accessible
```

**Output:**

```
{
  "DBInstance": {
    "DBInstanceIdentifier": "DevOpsRDS",
    "DBInstanceStatus": "creating"
  }
}
```

## 24 RDS Backup and Restore

### 24.1 Create DB Snapshot

Take snapshot of RDS instance:

```
$ aws rds create-db-snapshot
--db-instance-identifier DevOpsRDS
--db-snapshot-identifier DevOpsRDSBackup1
```

**Output:**

```
{
  "DBSnapshot": {
    "DBSnapshotIdentifier": "DevOpsRDSBackup1",
    "DBInstanceIdentifier": "DevOpsRDS",
    "Status": "creating"
  }
}
```

### 24.2 Restore from Snapshot

Restore DB from snapshot:

```
$ aws rds restore-db-instance-from-db-snapshot
--db-instance-identifier DevOpsRDSRestore
--db-snapshot-identifier DevOpsRDSBackup1
```

## 25 RDS Read Replicas

## 25.1 Create Read Replica

Create a read replica of DevOpsRDS:

```
$ aws rds create-db-instance-read-replica
--db-instance-identifier DevOpsRDSReplica
--source-db-instance-identifier DevOpsRDS
```

Output:

```
{
  "DBInstance": {
    "DBInstanceIdentifier": "DevOpsRDSReplica",
    "DBInstanceStatus": "creating"
  }
}
```

## 25.2 Best Practices for RDS

- Enable Multi-AZ for production workloads.
- Schedule automated backups and retain snapshots.
- Use read replicas to scale read-heavy applications.
- Monitor CPU, storage, and connections with CloudWatch.
- Use IAM roles for RDS access when possible.

## 26 RDS Security and Maintenance

## 26.1 Enable Encryption

Create encrypted RDS instance:

```
$ aws rds create-db-instance
  --db-instance-identifier DevOpsRDSEncrypted
  --db-instance-class db.t3.micro
  --engine mysql
  --master-username admin
  --master-user-password MyPassword123
  --allocated-storage 20
  --storage-encrypted
  --kms-key-id arn:aws:kms:us-east-1:123456789012:key/abcd-1234
```

## 26.2 Apply Patches and Maintenance

Apply pending maintenance:

```
$ aws rds apply-pending-maintenance-action
  --resource-identifier arn:aws:rds:us-east-1:123456789012:db:DevOpsRDS
  --apply-action system-update
  --opt-in-type immediate
```

## 26.3 Best Practices

- Enable encryption for sensitive data.
- Keep automated backups enabled with retention period.
- Schedule maintenance windows during low traffic periods.
- Use monitoring and alarms for performance and storage.

# 27 Amazon EKS: Kubernetes on AWS

## 27.1 Introduction

Amazon EKS is a managed Kubernetes service for deploying, managing, and scaling containerized applications. Key concepts:

- **Cluster:** Control plane to manage worker nodes and Kubernetes resources.

- **Node Group:** EC2 instances running containers in the cluster.
- **Fargate:** Serverless compute for running containers without managing nodes.

## 28 EKS Cluster Creation

Create EKS cluster using AWS CLI:

```
$ aws eks create-cluster
--name DevOpsEKS
--role-arn arn:aws:iam::123456789012:role/EKSClusterRole
--resources-vpc-config subnetIds=subnet-123,subnet-456,securityGroupIds=sg-123
```

Output:

```
{
  "cluster": {
    "name": "DevOpsEKS",
    "status": "CREATING"
  }
}
```

## 29 EKS Node Groups

Create managed node group:

```
$ aws eks create-nodegroup
--cluster-name DevOpsEKS
--nodegroup-name DevOpsNodes
--subnets subnet-123 subnet-456
--instance-types t3.medium
--scaling-config minSize=2,maxSize=5,desiredSize=2
```

### 29.1 Best Practices

- Use multiple subnets for high availability.
- Enable autoscaling for workload fluctuations.
- Tag nodes for cost allocation and monitoring.

## 30 EKS Fargate Profiles

Create Fargate profile for serverless workloads:

```
$ aws eks create-fargate-profile
--cluster-name DevOpsEKS
--fargate-profile-name DevOpsFargate
--pod-execution-role-arn arn:aws:iam::123456789012:role/EKSFargateRole
--subnets subnet-123 subnet-456
--selectors namespace=default
```

## 31 EKS Cluster Autoscaling

Enable cluster autoscaler using Helm:

```
$ helm repo add autoscaler https://kubernetes.github.io/autoscaler
$ helm install cluster-autoscaler autoscaler/cluster-autoscaler
--namespace kube-system
--set autoDiscovery.clusterName=DevOpsEKS
--set awsRegion=us-east-1
```

## 32 ConfigMaps in Kubernetes

Create ConfigMap for application config:

```
$ kubectl create configmap app-config
--from-literal=LOG_LEVEL=DEBUG
--from-literal=ENV=DEV
```

View ConfigMap:

```
$ kubectl get configmap app-config -o yaml
```



## 33 Secrets in Kubernetes

Create Secret for sensitive info:

```
$ kubectl create secret generic db-secret
--from-literal=username=admin
--from-literal=password=MySecret123
```

View Secret (base64 encoded):

```
$ kubectl get secret db-secret -o yaml
```

## 34 Deploy Applications on EKS

Create Deployment and Service:

```
$ kubectl apply -f deployment.yaml
$ kubectl apply -f service.yaml
```

Sample Deployment Status:

NAME	READY	UP-TO-DATE	AVAILABLE	AGE
devops-app	3/3	3	3	2m

## 35 EKS Best Practices

- Always use IAM roles for service accounts (IRSA).
- Separate workloads between node groups and Fargate profiles.
- Enable logging with CloudWatch Container Insights.
- Use namespaces and labels for organization and RBAC policies.
- Regularly update worker nodes and control plane versions.

## 36 AWS CodePipeline: Continuous Integration and Deployment

## 36.1 Introduction

AWS CodePipeline is a fully managed CI/CD service that automates build, test, and deployment phases. Key concepts:

- **Pipeline:** Defines workflow from source to deployment.
- **Stage:** Logical division of pipeline steps (Source, Build, Deploy).
- **Action:** Individual tasks within a stage.

## 36.2 Create a Pipeline

Create a new CodePipeline using AWS CLI:

```
$ aws codepipeline create-pipeline --cli-input-json file://pipeline.json
```

Output:

```
{
  "pipeline": {
    "name": "DevOpsPipeline",
    "roleArn": "arn:aws:iam::123456789012:role/CodePipelineRole",
    "artifactStore": { "type": "S3", "location": "devops-pipeline-artifacts" }
  }
}
```

## 37 AWS CodeBuild: Build and Test

### 37.1 Introduction

CodeBuild is a fully managed build service for compiling code, running tests, and producing artifacts. Key concepts:

- **Project:** Defines source, build commands, and environment.
- **Environment:** OS, runtime, and compute type.
- **Buildspec:** YAML file defining build commands.

## 37.2 Create a CodeBuild Project

Create CodeBuild project using AWS CLI:

```
$ aws codebuild create-project \
  --name DevOpsBuild \
  --source type=GITHUB,location=https://github.com/username/repo \
  --artifacts type=NO_ARTIFACTS \
  --environment type=LINUX_CONTAINER,computeType=BUILD_GENERAL1_SMALL,image=aws/codebuild-ubuntu:latest
```

## 37.3 Build Project

Start a build:

```
$ aws codebuild start-build --project-name DevOpsBuild
```

Sample Output:

```
{
  "build": {
    "id": "DevOpsBuild:12345-abcde-67890",
    "buildStatus": "IN_PROGRESS"
  }
}
```

# 38 AWS CodeDeploy: Deployment Automation

## 38.1 Introduction

CodeDeploy automates deployment to EC2, Lambda, or ECS. Key concepts:

- **Application:** Container for deployment artifacts.
- **Deployment Group:** Target instances for deployment.
- **Revision:** Application version to deploy.

## 38.2 Create CodeDeploy Application

Create application and deployment:

```
$ aws deploy create-application --application-name DevOpsApp

$ aws deploy create-deployment \
  --application-name DevOpsApp \
  --deployment-group-name DevOpsGroup \
  --revision revisionType=S3,s3Location={bucket=devops-artifacts,bundleType=zip,key=
```

## 38.3 Best Practices

- Use versioning and S3 for deployment artifacts.
- Test in staging before deploying to production.
- Monitor deployment status using AWS CLI or console.
- Combine with CodePipeline for end-to-end CI/CD automation.

# 39 AWS CloudFormation: Infrastructure as Code

## 39.1 Introduction

CloudFormation allows you to define AWS infrastructure as code using JSON or YAML templates. Key concepts:

- **Stack:** Collection of AWS resources deployed as a single unit.
- **Template:** JSON or YAML file defining resources.
- **Change Set:** Preview changes before applying them to stacks.

## 40 Creating a CloudFormation Stack

Deploy stack using AWS CLI:

```
$ aws cloudformation create-stack \
  --stack-name DevOpsStack \
  --template-body file:///devops-template.yaml \
  --parameters ParameterKey=InstanceType,ParameterValue=t3.micro
```

**Output:**

```
{  
  "StackId": "arn:aws:cloudformation:us-east-1:123456789012:stack/DevOpsStack/abc123"  
}
```

## 41 Update and Delete CloudFormation Stacks

**Update stack:**

```
$ aws cloudformation update-stack \  
  --stack-name DevOpsStack \  
  --template-body file://devops-template.yaml
```

**Delete stack:**

```
$ aws cloudformation delete-stack --stack-name DevOpsStack
```

## 42 Stack Outputs and Resources

**View stack outputs:**

```
$ aws cloudformation describe-stacks --stack-name DevOpsStack
```

**List resources in stack:**

```
$ aws cloudformation list-stack-resources --stack-name DevOpsStack
```

## 43 AWS Cost Management and Billing

### 43.1 Introduction

Effective cost management is essential for AWS workloads. Key tools:

- **Cost Explorer:** Analyze historical costs.
- **Budgets:** Set spending thresholds.
- **Tags:** Allocate costs by project, department, or team.

## 44 AWS Cost Explorer

Enable Cost Explorer and view costs:

```
$ aws ce get-cost-and-usage \  
  --time-period Start=2025-09-01,End=2025-09-30 \  
  --granularity MONTHLY \  
  --metrics "BlendedCost" "UnblendedCost"
```

Sample Output:

```
{  
  "ResultsByTime": [  
    {  
      "TimePeriod": {"Start": "2025-09-01", "End": "2025-09-30"},  
      "Total": {"BlendedCost": {"Amount": "50.25", "Unit": "USD"}}  
    }  
  ]  
}
```

## 45 AWS Budgets

Create a monthly budget:

```
$ aws budgets create-budget \  
  --account-id 123456789012 \  
  --budget file://monthly-budget.json
```

**Tip:** Use SNS notifications to alert when budget thresholds are reached.

## 46 AWS Resource Tagging

Tag EC2 instance for cost allocation:

```
$ aws ec2 create-tags \  
  --resources i-0123456789abcdef0 \  
  --tags Key=Project,Value=DevOpsGuide
```

## 46.1 Best Practices

- Tag all resources with Project, Environment, and Owner.
- Use tags in Cost Explorer and billing reports.
- Enforce tagging via AWS Config rules.

## 47 Reserved Instances and Savings Plans

- Purchase Reserved Instances (RI) for long-term workloads to save costs.
- Use Savings Plans for compute flexibility across EC2, Lambda, and Fargate.
- Monitor usage and adjust commitments accordingly.

## 48 Cost Optimization Tips

- Right-size instances using CloudWatch metrics.
- Turn off unused resources (EC2, RDS, EBS).
- Use Spot instances for non-critical workloads.
- Enable S3 lifecycle policies to move old data to Glacier.
- Automate budget alerts and monitoring.

## 49 Cost Reports and Analytics

**Generate cost report by service:**

```
$ aws ce get-cost-and-usage \
  --time-period Start=2025-09-01,End=2025-09-30 \
  --granularity MONTHLY \
  --group-by Type=DIMENSION,Key=SERVICE
```

### Sample Output:

```
{
  "ResultsByTime": [
    {
      "Groups": [
        {"Keys": ["AmazonEC2"], "Metrics": {"BlendedCost": {"Amount": "20.10"}}},
        {"Keys": ["AmazonS3"], "Metrics": {"BlendedCost": {"Amount": "5.25"}}}
      ]
    }
  ]
}
```

## 50 AWS Billing and Cost Management Summary

- Monitor and optimize AWS costs using Cost Explorer, Budgets, and Tags.
- Implement automation to reduce wastage and overprovisioning.
- Use Reserved Instances and Savings Plans for predictable workloads.
- Review monthly reports to identify trends and optimize usage.

## 51 AWS Lambda: Serverless Compute

### 51.1 Introduction

AWS Lambda allows running code without provisioning or managing servers. Key features:

- Event-driven execution
- Automatic scaling
- Pay-per-use pricing



## 52 Creating a Lambda Function

Create Lambda function using AWS CLI:

```
$ aws lambda create-function \  
  --function-name DevOpsFunction \  
  --runtime python3.9 \  
  --role arn:aws:iam::123456789012:role/LambdaExecRole \  
  --handler lambda_function.lambda_handler \  
  --zip-file fileb://function.zip
```

Output:

```
{  
  "FunctionName": "DevOpsFunction",  
  "Runtime": "python3.9",  
  "Role": "arn:aws:iam::123456789012:role/LambdaExecRole",  
  "Handler": "lambda_function.lambda_handler",  
  "State": "Active"  
}
```

## 53 EventBridge Triggers

### 53.1 Introduction

EventBridge (formerly CloudWatch Events) allows triggering Lambda functions based on events.

Create rule to trigger Lambda every day at 10 AM:

```
$ aws events put-rule \  
  --name DailyTrigger \  
  --schedule-expression "cron(0 10 * * ? *)"
```

Add Lambda as target:

```
$ aws events put-targets \  
  --rule DailyTrigger \  
  --targets "Id"="1","Arn"="arn:aws:lambda:us-east-1:123456789012:function:DevOpsFun"
```

## 54 API Gateway: REST APIs for Lambda

### 54.1 Introduction

API Gateway allows exposing Lambda functions as RESTful APIs with authorization and throttling.

Key features:

- Create REST or HTTP APIs
- Integrate with Lambda, ECS, or other endpoints
- Enable authentication (Cognito, IAM, Lambda Authorizers)

## 55 API Gateway Integration

**Create API Gateway REST API:**

```
$ aws apigateway create-rest-api --name DevOpsAPI
```

**Integrate Lambda function with API:**

```
$ aws apigateway put-integration \  
  --rest-api-id abc123 \  
  --resource-id xyz789 \  
  --http-method POST \  
  --type AWS_PROXY \  
  --integration-http-method POST \  
  --uri arn:aws:apigateway:us-east-1:lambda:path/2015-03-31/functions/arn:aws:lambda:us-east-1:123456789012:function:my-lambda
```

## 56 Lambda Authorizers

- Used for custom authentication for API Gateway
- Can validate tokens or headers

## Create Lambda authorizer:

```
$ aws apigateway create-authorizer \
--rest-api-id abc123 \
--name DevOpsAuth \
--type TOKEN \
--authorizer-uri arn:aws:apigateway:us-east-1:lambda:path/2015-03-31/functions/arn:aws:lambda:us-east-1:123456789012:function:devops-auth:qualifier=prod:version=1:invokeOnly \
--identity-source method.request.header.Authorization
```

## 57 AWS Step Functions: Workflow Automation

## 57.1 Introduction

Step Functions allows building state machines for orchestrating multiple AWS services.

Key features:

- Visual workflows
- Parallel execution
- Error handling and retries

## 58 Creating Step Functions

Define state machine in JSON:

```
{
  "Comment": "DevOps Workflow",
  "StartAt": "Task1",
  "States": {
    "Task1": {
      "Type": "Task",
      "Resource": "arn:aws:lambda:us-east-1:123456789012:function:DevOpsFunction",
      "Next": "Task2"
    },
    "Task2": {
      "Type": "Task",
      "Resource": "arn:aws:lambda:us-east-1:123456789012:function:AnotherFunction",
      "End": true
    }
  }
}
```

## 59 Deploy Step Function

Create state machine using AWS CLI:

```
$ aws stepfunctions create-state-machine \
  --name DevOpsWorkflow \
  --definition file://state-machine.json \
  --role-arn arn:aws:iam::123456789012:role/StepFunctionsRole
```

## 60 Step Functions Best Practices

- Use meaningful state names for clarity
- Implement retries and catch blocks for error handling
- Keep workflows modular with separate Lambda functions
- Monitor executions using CloudWatch Logs

## 61 Amazon SQS: Simple Queue Service

### 61.1 Introduction

Amazon SQS is a fully managed message queuing service that enables decoupling microservices, distributed systems, and serverless applications. It allows **asynchronous communication** between components, ensuring messages are not lost and systems remain resilient.

### 61.2 Key Features

- **Standard Queues:** High throughput, at-least-once delivery, best-effort ordering.
- **FIFO Queues:** Exactly-once processing, preserves message order.
- **Dead-letter Queues (DLQ):** Capture messages that cannot be processed successfully.
- **Visibility Timeout:** Temporarily hides messages from other consumers to avoid duplicate processing.

### 61.3 CLI Commands with Outputs

Create Standard Queue:

```
$ aws sqs create-queue --queue-name DevOpsQueue
```

**Output:**

```
{
  "QueueUrl": "https://sqs.us-east-1.amazonaws.com/123456789012/DevOpsQueue"
}
```

Send a message:

```
$ aws sqs send-message \
  --queue-url https://sqs.us-east-1.amazonaws.com/123456789012/DevOpsQueue \
  --message-body "Deploy task started"
```

**Output:**

```
{
  "MD5OfMessageBody": "fae0b27c451c728867a567e8c1bb4e53",
  "MessageId": "1234abcd-5678-efgh-9012-ijkl34567890"
}
```

## 61.4 Best Practices

- Use DLQs for error handling.
- FIFO queues for order-sensitive workflows.
- Monitor CloudWatch metrics: NumberOfMessagesSent/Received.

## 61.5 Use Case

CI/CD pipeline pushes deployment tasks to SQS. Multiple worker Lambdas process messages in parallel without overloading resources.

## 61.6 Interview Tips

Explain differences between Standard and FIFO queues, visibility timeout, DLQs, and integration with Lambda.

# 62 Amazon SNS: Simple Notification Service

## 62.1 Introduction

SNS is a fully managed **pub/sub messaging service**. It allows sending notifications to multiple endpoints, such as email, SMS, SQS, and Lambda.

## 62.2 Key Features

- Broadcast messages to multiple subscribers.
- Integrates with SQS, Lambda, and HTTP/S endpoints.
- Supports filtering policies and message attributes.
- Reliable delivery with retries.

## 62.3 CLI Commands with Outputs

Create a topic:

```
$ aws sns create-topic --name DevOpsTopic
```

Output:

```
{  
  "TopicArn": "arn:aws:sns:us-east-1:123456789012:DevOpsTopic"  
}
```

**Subscribe email endpoint:**

```
$ aws sns subscribe \  
  --topic-arn arn:aws:sns:us-east-1:123456789012:DevOpsTopic \  
  --protocol email \  
  --notification-endpoint admin@example.com
```

## 62.4 Use Case

Send deployment alerts to team email/SMS whenever a new Lambda executes or EC2 instance changes state.

## 62.5 Best Practices

- Use message attributes for filtering.
- Combine SNS + SQS for decoupled architectures.
- Monitor using CloudWatch metrics: NumberOfMessagesPublished/Delivered.

# 63 Event-driven Architectures on AWS

## 63.1 Introduction

Event-driven architecture allows building **loosely coupled applications** that react to events rather than polling continuously.

## 63.2 AWS Services

- **SQS:** Queue messages between components.
- **SNS:** Broadcast messages to multiple subscribers.
- **EventBridge:** Trigger Lambda or other services on specific events.
- **Lambda:** Serverless execution on events.

### 63.3 Example

- Developer pushes code to S3 (EventBridge triggers Lambda)
- Lambda processes files and sends success notifications to SNS
- SQS queues failed messages for retry processing

## 64 Amazon CloudFront: Content Delivery Network

### 64.1 Introduction

CloudFront is a **global CDN** that delivers web content with low latency and high transfer speeds.

### 64.2 Key Features

- Edge caching for static and dynamic content.
- Integrates with S3, EC2, ALB, and Lambda@Edge.
- HTTPS support and custom domain names.
- Real-time metrics and logging.

### 64.3 CLI Commands

Create distribution pointing to S3 bucket:

```
$ aws cloudfront create-distribution \
  --origin-domain-name my-bucket.s3.amazonaws.com
```

### 64.4 Best Practices

- Set appropriate TTL for caching objects.
- Use Lambda@Edge for request/response modification.
- Enable logging for security and analytics.

### 64.5 Use Case

Deliver static website hosted on S3 globally with low latency and HTTPS.



## 65 CloudFront Caching Strategies

- Cache static content for long durations.
- Use Cache-Control headers for dynamic content.
- Invalidate cache for updates using CLI or console:

```
$ aws cloudfront create-invalidation \  
  --distribution-id EDFDVBD632BHDS5 \  
  --paths "/index.html" "/css/*"
```

## 66 Amazon Route 53: DNS Service

### 66.1 Introduction

Route 53 is a scalable DNS service with routing policies, health checks, and domain registration.

### 66.2 Key Features

- Latency-based routing
- Weighted routing
- Failover routing
- Health checks and alarms

### 66.3 CLI Examples

Create Hosted Zone:

```
$ aws route53 create-hosted-zone \  
  --name example.com \  
  --caller-reference "unique123"
```

## 67 Route 53 Health Checks

- Monitor endpoint health and automatically failover.
- CLI to create health check:

```
$ aws route53 create-health-check \  
  --caller-reference "hc1" \  
  --health-check-config IPAddress=192.0.2.44,Port=80,Type=HTTP
```

## 68 Failover Routing

- Primary site receives traffic if healthy.
- Secondary site receives traffic if primary fails.
- Integrate with CloudWatch for automatic switching.

## 69 Elastic Load Balancing (ELB)

### 69.1 Introduction

ELB distributes incoming traffic across multiple targets for high availability.

### 69.2 Types

- Classic Load Balancer
- Application Load Balancer (ALB) – HTTP/HTTPS, path-based routing
- Network Load Balancer (NLB) – TCP/UDP, low latency

## 70 Application Load Balancer (ALB)

CLI to create ALB:

```
$ aws elbv2 create-load-balancer \  
  --name DevOpsALB \  
  --subnets subnet-123 subnet-456 \  
  --security-groups sg-12345678 \  
  --scheme internet-facing
```

### 70.1 Best Practices

- Use path-based routing for microservices.
- Enable WAF for security.
- Monitor target health with CloudWatch.

## 71 Network Load Balancer (NLB)

CLI to create NLB:

```
$ aws elbv2 create-load-balancer \
  --name DevOpsNLB \
  --type network \
  --subnets subnet-123 subnet-456
```

### 71.1 Best Practices

- Use for TCP/UDP traffic with extremely low latency.
- Combine with Auto Scaling groups for high availability.
- Monitor using CloudWatch metrics: ActiveFlowCount, NewFlowCount.

## 72 Summary

- Use SQS + SNS + EventBridge for event-driven applications.
- CloudFront accelerates global content delivery.
- Route 53 ensures DNS reliability with health checks and failover.
- ELB (ALB/NLB) distributes traffic efficiently, ensuring high availability.

## 73 Auto Scaling Groups (ASG)

### 73.1 Introduction

Auto Scaling Groups automatically adjust the number of EC2 instances based on demand, ensuring high availability, cost efficiency, and scalability.

### 73.2 Key Features

- Automatic scaling up/down based on metrics.
- Integration with ELB to distribute traffic.
- Health checks and instance replacement.
- Launch templates or configurations for standardization.

### 73.3 CLI Commands

#### Create Launch Configuration:

```
$ aws autoscaling create-launch-configuration \
  --launch-configuration-name DevOpsLaunchConfig \
  --image-id ami-12345678 \
  --instance-type t2.micro \
  --key-name DevOpsKeyPair \
  --security-groups sg-12345678
```

#### Create Auto Scaling Group:

```
$ aws autoscaling create-auto-scaling-group \
  --auto-scaling-group-name DevOpsASG \
  --launch-configuration-name DevOpsLaunchConfig \
  --min-size 1 --max-size 5 \
  --desired-capacity 2 \
  --vpc-zone-identifier subnet-123,subnet-456
```

### 73.4 Metrics Policies

- Scale out if CPU  $\geq$  70%.
- Scale in if CPU  $\leq$  20%.
- Monitor metrics via CloudWatch.

### 73.5 Best Practices

- Use Launch Templates over configurations for flexibility.
- Combine ASG with ELB for health-aware routing.
- Monitor scaling activities and set alarms for unusual behavior.

### 73.6 Use Case

Web application receives variable traffic. ASG ensures 2–5 EC2 instances run automatically based on load.

### 73.7 Interview Tips

Explain differences between Launch Configuration and Launch Template, metrics-based policies, and health check integration.

## 74 AWS Secrets Manager

### 74.1 Introduction

Secrets Manager securely stores, rotates, and manages secrets such as database credentials, API keys, and passwords.

### 74.2 Key Features

- Automatic secret rotation.
- Integrated with Lambda for custom rotation logic.
- Fine-grained access control using IAM.
- Secure retrieval via AWS SDK/CLI.

### 74.3 CLI Commands

Create Secret:

```
$ aws secretsmanager create-secret \
  --name DevOpsDBSecret \
  --secret-string '{"username":"admin","password":"P@ssw0rd"}'
```

Retrieve Secret:

```
$ aws secretsmanager get-secret-value \
  --secret-id DevOpsDBSecret
```

### 74.4 Best Practices

- Rotate secrets automatically every 30–60 days.
- Use IAM policies to restrict access.
- Avoid hardcoding credentials in code or scripts.

### 74.5 Use Case

Lambda function retrieves DB credentials from Secrets Manager, eliminating the need to store them in code.

## 74.6 Interview Tips

Explain difference between Secrets Manager and Parameter Store, and how rotation works.

# 75 AWS Systems Manager Parameter Store

## 75.1 Introduction

Parameter Store provides centralized storage for configuration data and secrets with encryption support.

## 75.2 Key Features

- Store plaintext or encrypted values.
- Version control of parameters.
- Integrated with CloudFormation, Lambda, and EC2.

## 75.3 CLI Commands

**Create Parameter:**

```
$ aws ssm put-parameter \  
  --name "/devops/db/username" \  
  --value "admin" \  
  --type "SecureString"
```

**Retrieve Parameter:**

```
$ aws ssm get-parameter \  
  --name "/devops/db/username" \  
  --with-decryption
```

## 75.4 Best Practices

- Use Parameter Store for configs and Secrets Manager for credentials.
- Encrypt sensitive data using KMS.
- Version control critical parameters.

## 75.5 Use Case

EC2 instances or Lambda functions read database credentials and configuration parameters securely from Parameter Store.

## 76 Encryption with AWS

### 76.1 Introduction

AWS provides encryption at rest (S3, EBS, RDS) and in transit (TLS/HTTPS).

### 76.2 Key Points

- Use KMS keys for centralized key management.
- Enable default encryption on S3 buckets and EBS volumes.
- Rotate keys periodically for security compliance.

### 76.3 CLI Example: Encrypt S3 Bucket

```
$ aws s3api put-bucket-encryption \
  --bucket my-devops-bucket \
  --server-side-encryption-configuration '{"Rules":[{"ApplyServerSideEncryptionByDefa
```

## 77 VPC Peering

### 77.1 Introduction

VPC Peering connects two VPCs privately using AWS network without internet gateway, VPN, or firewall.

### 77.2 CLI Commands

Create VPC Peering Connection:

```
$ aws ec2 create-vpc-peering-connection \
  --vpc-id vpc-11111111 \
  --peer-vpc-id vpc-22222222
```

## 77.3 Best Practices

- Use route tables to allow traffic between VPCs.
- Avoid overlapping CIDR ranges.
- Monitor peering connections for health and usage.

## 78 AWS Transit Gateway

### 78.1 Introduction

Transit Gateway connects multiple VPCs and on-prem networks through a single gateway for simplified network management.

### 78.2 CLI Commands

```
$ aws ec2 create-transit-gateway \  
--description "DevOpsTransitGateway" \  
--options "AmazonSideAsn=64512"
```

### 78.3 Use Case

Connect 10+ VPCs in multiple accounts for centralized routing and security policies.

## 79 VPC Security: Security Groups NACLs

- Security Groups: Virtual firewall for instances, stateful.
- NACLs: Network-level firewall, stateless, controls subnet traffic.
- Combine Security Groups + NACLs for defense-in-depth.

### 79.1 CLI Example: Security Group

```
$ aws ec2 create-security-group \  
--group-name DevOpsSG \  
--description "Security group for DevOps" \  
--vpc-id vpc-11111111
```



## 80 Elastic Beanstalk

### 80.1 Introduction

Elastic Beanstalk automates application deployment, capacity provisioning, load balancing, scaling, and monitoring.

### 80.2 CLI Example: Deploy App

```
$ eb init DevOpsApp --platform python-3.9 --region us-east-1
$ eb create DevOpsApp-env
```

### 80.3 Best Practices

- Use environment variables for secrets/configs.
- Monitor health via Beanstalk console and CloudWatch.
- Version control deployments to rollback if needed.

## 81 Application Deployment in Beanstalk

- Upload code package (.zip or .war).
- Auto-deploy via CLI or console.
- Integration with CI/CD pipelines using CodePipeline.

### 81.1 CLI Example: Deploy New Version

```
$ eb deploy
```

## 82 Monitoring Logs

- Monitor application health and instance metrics.
- Configure alarms in CloudWatch for CPU, latency, errors.
- Enable enhanced logging for troubleshooting.

### 82.1 Use Case

Deploy Python web app, auto-scale based on traffic, monitor logs and metrics for health and errors.

## 82.2 Interview Tips

Explain difference between Elastic Beanstalk and ECS, monitoring strategies, and CI/CD integration.

## 83 Amazon RDS: Relational Database Service

### 83.1 Introduction

Amazon RDS is a fully managed relational database service supporting multiple engines: MySQL, PostgreSQL, MariaDB, Oracle, and SQL Server. It automates provisioning, patching, backup, and scaling.

### 83.2 Key Features

- Multi-AZ deployment for high availability.
- Automated backups and snapshots.
- Read replicas for horizontal scaling.
- Monitoring via CloudWatch.

### 83.3 CLI Commands

Create MySQL Database:

```
$ aws rds create-db-instance \  
  --db-instance-identifier DevOpsRDS \  
  --db-instance-class db.t3.micro \  
  --engine mysql \  
  --master-username admin \  
  --master-user-password P@ssw0rd \  
  --allocated-storage 20
```

Output:

```
{  
  "DBInstance": {  
    "DBInstanceIdentifier": "DevOpsRDS",  
    "DBInstanceStatus": "creating",  
    "Engine": "mysql",  
    ...
```

```
}  
}
```

### 83.4 Best Practices

- Use Multi-AZ deployment for production.
- Enable automated backups and snapshot retention.
- Monitor CPU, storage, and connections via CloudWatch.

### 83.5 Use Case

Deploy MySQL database for web application with automated failover and backups.

### 83.6 Interview Tips

Explain difference between Multi-AZ and Read Replica, automated backup vs snapshot, and scaling strategies.

## 84 Amazon Aurora

### 84.1 Introduction

Aurora is a MySQL and PostgreSQL-compatible high-performance relational database with **up to 5x faster** throughput and managed replication.

### 84.2 Key Features

- Multi-AZ replication with 6-way durability.
- Auto-scaling storage.
- Global databases for cross-region replication.
- Backtrack to restore to specific point in time.

### 84.3 CLI Commands

Create Aurora Cluster:

```
$ aws rds create-db-cluster \  
  --db-cluster-identifier DevOpsAurora \  
  --engine aurora-mysql \  
  --availability-zone us-east-1a
```

```
--master-username admin \  
--master-user-password P@ssw0rd
```

## 84.4 Use Case

Global web application needing high availability and low latency.

# 85 RDS Backup and Restore

## 85.1 Automated Backups

Enable automatic backups for point-in-time recovery:

```
$ aws rds modify-db-instance \  
--db-instance-identifier DevOpsRDS \  
--backup-retention-period 7
```

## 85.2 Manual Snapshot

```
$ aws rds create-db-snapshot \  
--db-snapshot-identifier DevOpsRDS-Snapshot \  
--db-instance-identifier DevOpsRDS
```

## 85.3 Restore from Snapshot

```
$ aws rds restore-db-instance-from-db-snapshot \  
--db-instance-identifier RestoredDB \  
--db-snapshot-identifier DevOpsRDS-Snapshot
```

# 86 Multi-AZ Deployment

## 86.1 Introduction

Multi-AZ RDS ensures high availability by replicating instances synchronously across availability zones.

## 86.2 CLI Commands

Enable Multi-AZ:

```
$ aws rds modify-db-instance \  
  --db-instance-identifier DevOpsRDS \  
  --multi-az \  
  --apply-immediately
```

## 86.3 Best Practices

- Use for production workloads.
- Monitor failover events in CloudWatch.
- Combine with automated backups.

# 87 Read Replicas

## 87.1 Introduction

Read replicas improve read scalability and offload queries from primary database.

## 87.2 CLI Commands

```
$ aws rds create-db-instance-read-replica \  
  --db-instance-identifier DevOpsRDS-Replica \  
  --source-db-instance-identifier DevOpsRDS
```

## 87.3 Use Case

High-traffic web applications require multiple read replicas for reporting or analytics queries.

# 88 Amazon DynamoDB

## 88.1 Introduction

DynamoDB is a fully managed NoSQL database with single-digit millisecond latency.

## 88.2 Key Features

- Serverless with auto-scaling.
- Global tables for cross-region replication.
- Integrated with Lambda and API Gateway.

## 88.3 CLI Commands

Create Table:

```
$ aws dynamodb create-table \  
  --table-name DevOpsTable \  
  --attribute-definitions AttributeName=ID,AttributeType=S \  
  --key-schema AttributeName=ID,KeyType=HASH \  
  --provisioned-throughput ReadCapacityUnits=5,WriteCapacityUnits=5
```

## 88.4 CRUD Operations

Insert Item:

```
$ aws dynamodb put-item \  
  --table-name DevOpsTable \  
  --item '{"ID":{"S":"123"},"Name":{"S":"TestUser"}}'
```

Query Item:

```
$ aws dynamodb get-item \  
  --table-name DevOpsTable \  
  --key '{"ID":{"S":"123"}}'
```

# 89 Amazon Redshift

## 89.1 Introduction

Redshift is a fully managed data warehouse for analytics workloads.

## 89.2 Key Features

- Columnar storage for fast queries.
- Integrates with S3, Glue, QuickSight.
- Automated snapshots and scaling.

## 89.3 CLI Commands

Create Cluster:

```
$ aws redshift create-cluster \  
  --cluster-identifier DevOpsRedshift \  
  --node-type dc2.large \  
  --master-username admin \  
  --master-user-password P@ssw0rd \  
  --number-of-nodes 2
```

## 89.4 Connect and Query

- Connect using SQL clients via JDBC/ODBC.
- Load data from S3 using COPY command.

# 90 AWS Glue

## 90.1 Introduction

Glue is a serverless ETL service that discovers, prepares, and transforms data for analytics.

## 90.2 Key Features

- Automatic schema discovery with Glue Crawlers.
- ETL jobs using Python or Spark.
- Integration with S3, Redshift, DynamoDB.

## 90.3 CLI Commands

Create Glue Crawler:

```
$ aws glue create-crawler \  
  --name DevOpsCrawler \  
  --role AWSGlueServiceRole \  
  --database-name devopsdb \  
  --targets S3Targets=[{Path="s3://my-bucket/"}]
```

## 90.4 Create and Run ETL Job

CLI Example:

```
$ aws glue create-job \  
  --name DevOpsETLJob \  
  --role AWSGlueServiceRole \  
  --command Name=glueetl,ScriptLocation=s3://scripts/etl_script.py \  
  --max-capacity 2
```

#### **Run Job:**

```
$ aws glue start-job-run --job-name DevOpsETLJob
```

## **90.5 Use Case**

ETL pipeline processes raw S3 logs into structured data in Redshift for analytics.

## **90.6 Best Practices**

- Use version-controlled scripts for reproducibility.
- Monitor job logs and failures in CloudWatch.
- Partition data in S3 for optimized processing.

## **90.7 Interview Tips**

Explain the difference between glue and lambda, ETL concepts, and integration with Redshift/S3.

# **91 AWS CloudFormation: Infrastructure as Code**

## **91.1 Introduction**

CloudFormation allows you to define AWS resources using **\*\*JSON** or **YAML** templates\*\*, enabling automated, repeatable infrastructure deployment.

## **91.2 Key Features**

- Create, update, and delete entire stacks.
- Version-controlled infrastructure.
- Supports almost all AWS resources.
- Rollback on failure to maintain stability.



## 91.3 CLI Commands

### Create Stack:

```
$ aws cloudformation create-stack \  
  --stack-name DevOpsStack \  
  --template-body file://template.yaml \  
  --parameters ParameterKey=InstanceType,ParameterValue=t2.micro
```

### Output Example:

```
{  
  "StackId": "arn:aws:cloudformation:us-east-1:123456789012:stack/DevOpsStack/abc123"  
}
```

### Update Stack:

```
$ aws cloudformation update-stack \  
  --stack-name DevOpsStack \  
  --template-body file://template.yaml \  
  --parameters ParameterKey=InstanceType,ParameterValue=t2.small
```

## 91.4 Best Practices

- Store templates in version control (Git).
- Modularize templates using nested stacks.
- Test in a dev environment before production deployment.

## 91.5 Use Case

Deploy multi-tier web applications with EC2, RDS, and S3 using a single CloudFormation template.

## 91.6 Interview Tips

Explain difference between CloudFormation and Terraform, benefits of IaC, rollback policies, and nested stacks.

# 92 AWS CDK: Cloud Development Kit

## 92.1 Introduction

CDK allows developers to define cloud infrastructure using **programming languages** like Python, TypeScript, or Java.

## 92.2 Key Features

- Strongly typed constructs for resources.
- Reusable components for multiple projects.
- Synthesizes templates for CloudFormation deployment.

## 92.3 CLI Commands

**Initialize CDK App (Python):**

```
$ cdk init app --language python
```

**Add Resources:**

```
from aws_cdk import aws_s3 as s3, core

bucket = s3.Bucket(self, "DevOpsBucket",
                    versioned=True,
                    removal_policy=core.RemovalPolicy.DESTROY)
```

**Deploy CDK Stack:**

```
$ cdk deploy
```

## 92.4 Best Practices

- Use version control for CDK code.
- Leverage constructs for reusable patterns.
- Test changes locally using CDK diff before deployment.

## 92.5 Use Case

Programmatically deploy S3, Lambda, and API Gateway resources with code-based constructs.

## 92.6 Interview Tips

Be ready to explain difference between CDK, CloudFormation, and Terraform, pros of programmatic IaC, and how to integrate with CI/CD pipelines.

## 93 Cost Optimization and Billing

### 93.1 Introduction

AWS cost management ensures efficient resource usage and reduces unnecessary spending.

### 93.2 Key Features

- AWS Budgets and Cost Explorer for tracking expenses.
- Reserved Instances, Spot Instances, and Savings Plans for savings.
- Tagging resources for cost allocation.
- Cost anomaly detection.

### 93.3 CLI Commands

Get Cost and Usage:

```
$ aws ce get-cost-and-usage \
  --time-period Start=2025-09-01,End=2025-09-30 \
  --granularity MONTHLY \
  --metrics "BlendedCost" "UsageQuantity"
```

Output Example:

```
{
  "ResultsByTime": [
    {
      "TimePeriod": {"Start": "2025-09-01", "End": "2025-09-30"},
      "Total": {"BlendedCost": {"Amount": "120.50", "Unit": "USD"}}
    }
  ]
}
```

### 93.4 Best Practices

- Use tagging to allocate costs to teams/projects.
- Implement Reserved Instances for predictable workloads.
- Utilize Spot Instances for short-lived or batch workloads.
- Continuously monitor usage with Cost Explorer and budgets.

### 93.5 Use Case

Automate monthly cost reports, enforce budgets, and reduce unused resource costs using tagging.

### 93.6 Interview Tips

Explain differences between On-Demand, Reserved, and Spot Instances, and describe cost-saving strategies in AWS.

## 94 AWS Security Best Practices and Compliance

### 94.1 Introduction

Security and compliance are critical in AWS DevOps, ensuring protection of resources and meeting regulatory requirements.

### 94.2 Key Practices

- IAM Policies: Apply least privilege and role-based access.
- Enable MFA for all privileged users.
- Regularly rotate access keys and secrets.
- Monitor CloudTrail logs for auditing.
- Use GuardDuty, Security Hub, and Config Rules.

### 94.3 CLI Commands

**Attach Policy to User:**

```
$ aws iam attach-user-policy \  
  --user-name DevOpsUser \  
  --policy-arn arn:aws:iam::aws:policy/AdministratorAccess
```

**Enable MFA for User:**

```
$ aws iam enable-mfa-device \  
  --user-name DevOpsUser \  
  --serial-number arn:aws:iam::123456:mfa/DevOpsUser \  
  --authentication-code1 123456 \  
  --authentication-code2 654321
```

## 94.4 Best Practices

- Use IAM roles instead of long-lived credentials.
- Enable logging and monitoring for all accounts.
- Regularly audit policies and remove unused permissions.

## 94.5 Use Case

Maintain compliance in multi-account AWS environments by enforcing MFA, least privilege, and CloudTrail monitoring.

## 94.6 Interview Tips

Explain IAM policy types, best practices for DevOps security, and how to implement compliance checks using AWS Config and CloudTrail.

# 95 AWS IAM Policies: Access Control and Best Practices

## 95.1 Introduction

IAM Policies are **JSON documents** that define **permissions** for AWS resources. They are attached to **users, groups, or roles** to control access securely.

## 95.2 Types of IAM Policies

- **Managed Policies:** AWS-provided or customer-managed reusable policies.
- **Inline Policies:** Policies embedded directly into a single user, group, or role.
- **Permission Boundaries:** Upper limit of permissions for IAM entities.

## 95.3 Key Concepts

- **Effect:** Allow or Deny permissions.
- **Action:** Specifies which actions (e.g., s3:PutObject, ec2:StartInstances) are allowed or denied.
- **Resource:** Specifies which resources the actions apply to.
- **Condition:** Optional JSON object to apply conditional access.

## 95.4 CLI Commands Examples

### Attach Managed Policy to User:

```
$ aws iam attach-user-policy \  
  --user-name DevOpsUser \  
  --policy-arn arn:aws:iam::aws:policy/AdministratorAccess
```

### Output Example:

```
{  
  "ResponseMetadata": {  
    "RequestId": "abc123-example",  
    "HTTPStatusCode": 200,  
    ...  
  }  
}
```

### Create Custom Managed Policy:

```
$ aws iam create-policy \  
  --policy-name DevOpsS3ReadOnly \  
  --policy-document file:///s3-readonly-policy.json
```

### s3-readonly-policy.json:

```
{  
  "Version": "2012-10-17",  
  "Statement": [  
    {  
      "Effect": "Allow",  
      "Action": ["s3:GetObject", "s3:ListBucket"],  
      "Resource": ["arn:aws:s3::my-bucket", "arn:aws:s3::my-bucket/*"]  
    }  
  ]  
}
```

### Attach Custom Policy to Group:

```
$ aws iam attach-group-policy \  
  --group-name DevOpsGroup \  
  --policy-arn arn:aws:iam::123456789012:policy/DevOpsS3ReadOnly
```

## 95.5 Best Practices

- Follow the **Principle of Least Privilege**: only grant necessary permissions.
- Prefer **Managed Policies** for reusability and simplicity.
- Use **Permission Boundaries** for controlled delegation.
- Rotate and audit credentials regularly.
- Monitor IAM actions with **CloudTrail**.

## 95.6 Use Cases

- Allow developers read-only access to S3 buckets.
- Assign Lambda functions roles with limited permissions.
- Separate production vs development access using groups and policies.

## 95.7 Interview Tips

- Explain **Managed vs Inline policies**.
- Describe **Policy evaluation logic** (Allow  $\wedge$  Deny  $\wedge$  Default Deny).
- Discuss **Permission boundaries** and their advantages.
- Demonstrate creating and attaching a custom IAM policy.

# 96 Top 10 Real-Time AWS DevOps Interview Scenarios with Solutions

## 96.1 Scenario 1: Automate EC2 Deployment using CLI

**Problem:** Deploy a new EC2 instance in a specific VPC with a security group and key pair.

**Solution:**

```
$ aws ec2 run-instances \
--image-id ami-0abcdef1234567890 \
--count 1 \
--instance-type t2.micro \
--key-name DevOpsKey \
```

```
--security-group-ids sg-0123456789abcdef0 \  
--subnet-id subnet-0abc1234def567890
```

#### Output Example:

```
{  
  "Instances": [  
    {  
      "InstanceId": "i-0123456789abcdef0",  
      "State": {"Name": "pending"},  
      ...  
    }  
  ]  
}
```

#### Notes:

- Always check availability of AMI in the chosen region.
  - Security groups define port access (e.g., 22 for SSH, 80 for HTTP).
- 

## 96.2 Scenario 2: Setup Auto Scaling for Web Application

**Problem:** Automatically scale EC2 instances based on CPU utilization.

#### Solution:

```
$ aws autoscaling create-auto-scaling-group \  
--auto-scaling-group-name WebAppASG \  
--launch-configuration-name WebAppLC \  
--min-size 1 \  
--max-size 5 \  
--vpc-zone-identifier subnet-0abc1234
```

#### Best Practices:

- Use CloudWatch alarms to trigger scaling.
  - Define both min and max limits to avoid over-provisioning.
-



## 96.3 Scenario 3: Implement S3 Bucket Lifecycle Policy

**Problem:** Move old objects to Glacier for cost optimization.

**Solution:**

```
$ aws s3api put-bucket-lifecycle-configuration \
  --bucket my-bucket \
  --lifecycle-configuration file:///lifecycle.json
```

**lifecycle.json Example:**

```
{
  "Rules": [
    {
      "ID": "ArchiveOldObjects",
      "Prefix": "",
      "Status": "Enabled",
      "Transitions": [
        {
          "Days": 30,
          "StorageClass": "GLACIER"
        }
      ]
    }
  ]
}
```

**Notes:** Reduces storage costs for infrequently accessed data.

---

## 96.4 Scenario 4: Create IAM Role for Lambda with S3 Access

**Problem:** Lambda function needs to read objects from an S3 bucket.

**Solution:**

```
$ aws iam create-role --role-name LambdaS3Role \
  --assume-role-policy-document file:///trust-policy.json
$ aws iam attach-role-policy \
  --role-name LambdaS3Role \
  --policy-arn arn:aws:iam::aws:policy/AmazonS3ReadOnlyAccess
```

**Notes:** Always follow least privilege principle.

---

## 96.5 Scenario 5: Deploy Serverless Application using CloudFormation

**Problem:** Automate deployment of Lambda + API Gateway.

**Solution:**

```
$ aws cloudformation deploy \
  --stack-name ServerlessApp \
  --template-file serverless-template.yaml \
  --capabilities CAPABILITY_NAMED_IAM
```

**Best Practices:**

- Use parameters for environment-specific configuration.
  - Test stacks in dev account before production.
- 

## 96.6 Scenario 6: Monitor EC2 and Set Alarm

**Problem:** Alert when CPU exceeds 70%.

**Solution:**

```
$ aws cloudwatch put-metric-alarm \
  --alarm-name HighCPU \
  --metric-name CPUUtilization \
  --namespace AWS/EC2 \
  --statistic Average \
  --period 300 \
  --threshold 70 \
  --comparison-operator GreaterThanThreshold \
  --dimensions Name=InstanceId,Value=i-0123456789abcdef0 \
  --evaluation-periods 2 \
  --alarm-actions arn:aws:sns:us-east-1:123456789012:NotifyMe
```

**Notes:** Helps proactive resource scaling and troubleshooting.

---

## 96.7 Scenario 7: Implement CloudFront with S3 Origin

**Problem:** Serve static website content with low latency globally.

**Solution:**

```
$ aws cloudfront create-distribution \  
--origin-domain-name my-bucket.s3.amazonaws.com
```

**Best Practices:**

- Use caching behaviors to reduce origin load.
  - Enable HTTPS for secure content delivery.
- 

## 96.8 Scenario 8: Deploy RDS with Multi-AZ for High Availability

**Problem:** Ensure database uptime with Multi-AZ deployment.

**Solution:**

```
$ aws rds create-db-instance \  
--db-instance-identifier mydb \  
--db-instance-class db.t3.micro \  
--engine mysql \  
--allocated-storage 20 \  
--master-username admin \  
--master-user-password password \  
--multi-az
```

**Notes:** Automatic failover ensures minimal downtime.

---

## 96.9 Scenario 9: Implement Cost Optimization with Spot Instances

**Problem:** Reduce EC2 cost for batch jobs.

**Solution:**

```
$ aws ec2 request-spot-instances \  
--instance-count 2 \  
--type "one-time" \  
--launch-specification file://spot-spec.json
```

**Notes:** Use Spot for non-critical workloads; combine with Auto Scaling.

---

## 96.10 Scenario 10: CI/CD Pipeline using CodePipeline and CodeBuild

**Problem:** Automate deployment from GitHub to EC2.

**Solution:**

```
# Create Pipeline
$ aws codepipeline create-pipeline --cli-input-json file://pipeline.json
# Trigger Build
$ aws codebuild start-build --project-name DevOpsProject
```

**Best Practices:**

- Integrate testing before deployment.
- Use versioning for rollback.

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## Author's Note

**Thank You for reading this AWS DevOps Digital Guide!**

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*"Dream, dream, dream. Dreams transform into thoughts and thoughts result in action."*

– APJ Abdul Kalam