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# AWS Cloud Development Kit (AWS CDK) v2

## Developer Guide

### Version 2

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# **AWS Cloud Development Kit (AWS CDK) v2: Developer Guide**

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# What is the AWS CDK?

Welcome to the *AWS Cloud Development Kit (AWS CDK) Developer Guide*. This document provides information about the AWS CDK, a framework for defining cloud infrastructure in code and provisioning it through AWS CloudFormation.

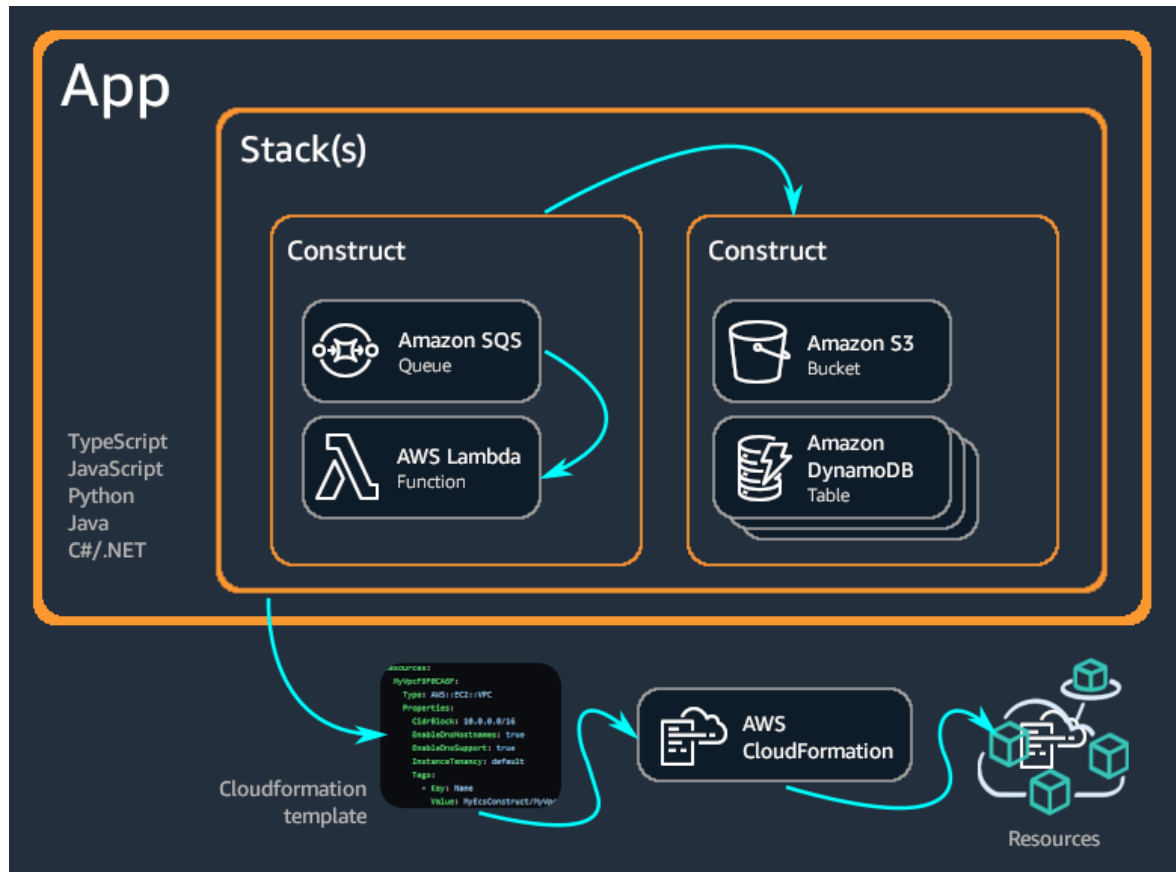
## Note

The CDK has been released in two major versions, v1 and v2. This is the Developer Guide for AWS CDK v2. The earlier CDK v1 entered maintenance on June 1, 2022. Support for CDK v1 will end on June 1, 2023.

The AWS CDK lets you build reliable, scalable, cost-effective applications in the cloud with the considerable expressive power of a programming language. This approach yields many benefits, including:

- Build with high-level constructs that automatically provide sensible, secure defaults for your AWS resources, defining more infrastructure with less code.
- Use programming idioms like parameters, conditionals, loops, composition, and inheritance to model your system design from building blocks provided by AWS and others.
- Put your infrastructure, application code, and configuration all in one place, ensuring that at every milestone you have a complete, cloud-deployable system.
- Employ software engineering practices such as code reviews, unit tests, and source control to make your infrastructure more robust.
- Connect your AWS resources together (even across stacks) and grant permissions using simple, intent-oriented APIs.
- Import existing AWS CloudFormation templates to give your resources a CDK API.
- Use the power of AWS CloudFormation to perform infrastructure deployments predictably and repeatedly, with rollback on error.
- Easily share infrastructure design patterns among teams within your organization or even with the public.

The AWS CDK supports TypeScript, JavaScript, Python, Java, C#/.Net, and Go. Developers can use one of these supported programming languages to define reusable cloud components known as [Constructs \(p. 84\)](#). You compose these together into [Stacks \(p. 108\)](#) and [Apps \(p. 103\)](#).



## Why use the AWS CDK?

It's easier to show than to explain! Here's some CDK code that creates an Amazon ECS service with AWS Fargate launch type (this is the code we use in the [the section called "ECS" \(p. 244\)](#)).

TypeScript

```
export class MyEcsConstructStack extends Stack {
  constructor(scope: App, id: string, props?: StackProps) {
    super(scope, id, props);

    const vpc = new ec2.Vpc(this, "MyVpc", {
      maxAzs: 3 // Default is all AZs in region
    });

    const cluster = new ecs.Cluster(this, "MyCluster", {
      vpc: vpc
    });

    // Create a load-balanced Fargate service and make it public
    new ecs_patterns.ApplicationLoadBalancedFargateService(this, "MyFargateService", {
      cluster: cluster, // Required
      cpu: 512, // Default is 256
      desiredCount: 6, // Default is 1
      taskImageOptions: { image: ecs.ContainerImage.fromRegistry("amazon/amazon-ecs-sample") },
      memoryLimitMiB: 2048, // Default is 512
    });
  }
}
```

```
        publicLoadBalancer: true // Default is false
    });
}
}
```

## JavaScript

```
class MyEcsConstructStack extends Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    const vpc = new ec2.Vpc(this, "MyVpc", {
      maxAzs: 3 // Default is all AZs in region
    });

    const cluster = new ecs.Cluster(this, "MyCluster", {
      vpc: vpc
    });

    // Create a load-balanced Fargate service and make it public
    new ecs_patterns.ApplicationLoadBalancedFargateService(this, "MyFargateService", {
      cluster: cluster, // Required
      cpu: 512, // Default is 256
      desiredCount: 6, // Default is 1
      taskImageOptions: { image: ecs.ContainerImage.fromRegistry("amazon/amazon-ecs-sample") },
      memoryLimitMiB: 2048, // Default is 512
      publicLoadBalancer: true // Default is false
    });
  }
}

module.exports = { MyEcsConstructStack }
```

## Python

```
class MyEcsConstructStack(Stack):

    def __init__(self, scope: Construct, id: str, **kwargs) -> None:
        super().__init__(scope, id, **kwargs)

        vpc = ec2.Vpc(self, "MyVpc", max_azs=3) # default is all AZs in region

        cluster = ecs.Cluster(self, "MyCluster", vpc=vpc)

        ecs_patterns.ApplicationLoadBalancedFargateService(self, "MyFargateService",
            cluster=cluster, # Required
            cpu=512, # Default is 256
            desired_count=6, # Default is 1
            task_image_options=ecs_patterns.ApplicationLoadBalancedTaskImageOptions(
                image=ecs.ContainerImage.from_registry("amazon/amazon-ecs-sample")),
            memory_limit_mib=2048, # Default is 512
            public_load_balancer=True) # Default is False
```

## Java

```
public class MyEcsConstructStack extends Stack {

    public MyEcsConstructStack(final Construct scope, final String id) {
        this(scope, id, null);
    }
}
```

```
public MyEcsConstructStack(final Construct scope, final String id,
    StackProps props) {
    super(scope, id, props);

    Vpc vpc = Vpc.Builder.create(this, "MyVpc").maxAzs(3).build();

    Cluster cluster = Cluster.Builder.create(this, "MyCluster")
        .vpc(vpc).build();

    ApplicationLoadBalancedFargateService.Builder.create(this, "MyFargateService")
        .cluster(cluster)
        .cpu(512)
        .desiredCount(6)
        .taskImageOptions(
            ApplicationLoadBalancedTaskImageOptions.builder()
                .image(ContainerImage
                    .fromRegistry("amazon/amazon-ecs-sample"))
                .build()).memoryLimitMiB(2048)
        .publicLoadBalancer(true).build();
}
```

#### C#

```
public class MyEcsConstructStack : Stack
{
    public MyEcsConstructStack(Construct scope, string id, IStackProps props=null) :
    base(scope, id, props)
    {
        var vpc = new Vpc(this, "MyVpc", new VpcProps
        {
            MaxAzs = 3
        });

        var cluster = new Cluster(this, "MyCluster", new ClusterProps
        {
            Vpc = vpc
        });

        new ApplicationLoadBalancedFargateService(this, "MyFargateService",
            new ApplicationLoadBalancedFargateServiceProps
            {
                Cluster = cluster,
                Cpu = 512,
                DesiredCount = 6,
                TaskImageOptions = new ApplicationLoadBalancedTaskImageOptions
                {
                    Image = ContainerImage.FromRegistry("amazon/amazon-ecs-sample")
                },
                MemoryLimitMiB = 2048,
                PublicLoadBalancer = true,
            });
    }
}
```

#### Go

```
func NewMyEcsConstructStack(scope constructs.Construct, id string, props
    *MyEcsConstructStackProps) awscdk.Stack {

    var sprops awscdk.StackProps

    if props != nil {
        sprops = props.StackProps
    }

    stack := awscdk.NewStack(scope, "MyEcsConstructStack", sprops)

    vpc := vpc.New(stack, "MyVpc", &vpcProps{
        MaxAzs: 3,
    })

    cluster := cluster.New(stack, "MyCluster", &clusterProps{
        Vpc: vpc,
    })

    fargateService := fargateService.New(stack, "MyFargateService", &fargateServiceProps{
        Cluster: cluster,
        Cpu: 512,
        DesiredCount: 6,
        TaskImageOptions: &taskImageOptions{
            Image: containerImage.FromRegistry("amazon/amazon-ecs-sample"),
        },
        MemoryLimitMiB: 2048,
        PublicLoadBalancer: true,
    })
}
```

```
}

stack := awscdk.NewStack(scope, &id, &sprops)

vpc := awsec2.NewVpc(stack, jsii.String("MyVpc"), &awsec2.VpcProps{
  MaxAzs: jsii.Number(3), // Default is all AZs in region
})

cluster := awsecs.NewCluster(stack, jsii.String("MyCluster"), &awsecs.ClusterProps{
  Vpc: vpc,
})

awsecspatterns.NewApplicationLoadBalancedFargateService(stack,
jsii.String("MyFargateService"),
&awsecspatterns.ApplicationLoadBalancedFargateServiceProps{
  Cluster:      cluster,          // required
  Cpu:          jsii.Number(512), // default is 256
  DesiredCount: jsii.Number(5),   // default is 1
  MemoryLimitMiB: jsii.Number(2048), // Default is 512
  TaskImageOptions: &awsecspatterns.ApplicationLoadBalancedTaskImageOptions{
    Image: awsecs.ContainerImage_FromRegistry(jsii.String("amazon/amazon-ecs-sample")),
  },
},
  PublicLoadBalancer: jsii.Bool(true), // Default is false
})

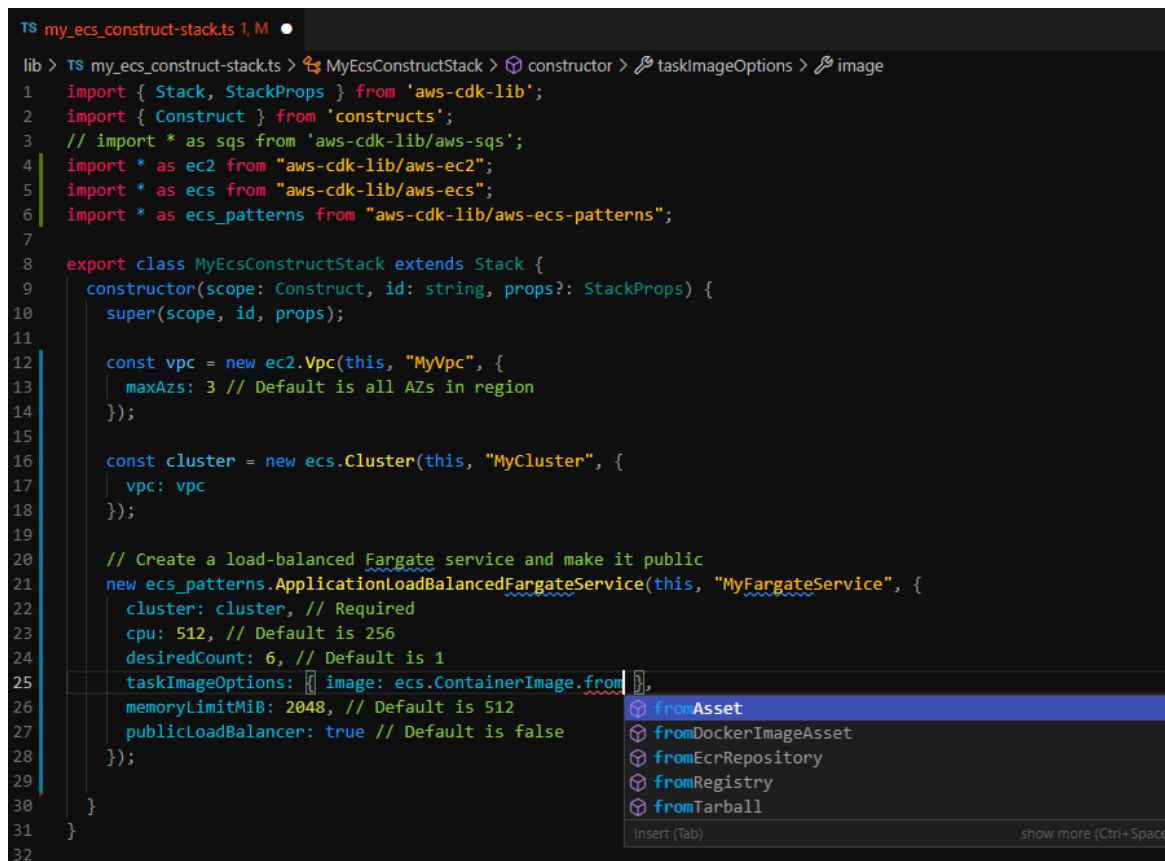
return stack
}
```

This class produces an AWS CloudFormation [template of more than 500 lines](#); deploying the AWS CDK app produces more than 50 resources of the following types.

- [AWS::EC2::EIP](#)
- [AWS::EC2::InternetGateway](#)
- [AWS::EC2::NatGateway](#)
- [AWS::EC2::Route](#)
- [AWS::EC2::RouteTable](#)
- [AWS::EC2::SecurityGroup](#)
- [AWS::EC2::Subnet](#)
- [AWS::EC2::SubnetRouteTableAssociation](#)
- [AWS::EC2::VPCGatewayAttachment](#)
- [AWS::EC2::VPC](#)
- [AWS::ECS::Cluster](#)
- [AWS::ECS::Service](#)
- [AWS::ECS::TaskDefinition](#)
- [AWS::ElasticLoadBalancingV2::Listener](#)
- [AWS::ElasticLoadBalancingV2::LoadBalancer](#)
- [AWS::ElasticLoadBalancingV2::TargetGroup](#)
- [AWS::IAM::Policy](#)
- [AWS::IAM::Role](#)
- [AWS::Logs::LogGroup](#)

And let's not forget... code completion within your IDE or editor!

```
TS my_ecs_construct-stack.ts 1, M
lib > TS my_ecs_construct-stack.ts > MyEcsConstructStack > constructor > taskImageOptions > image
1 import { Stack, StackProps } from 'aws-cdk-lib';
2 import { Construct } from 'constructs';
3 // import * as sqs from 'aws-cdk-lib/aws-sqs';
4 import * as ec2 from 'aws-cdk-lib/aws-ec2';
5 import * as ecs from 'aws-cdk-lib/aws-ecs';
6 import * as ecs_patterns from 'aws-cdk-lib/aws-ecs-patterns';
7
8 export class MyEcsConstructStack extends Stack {
9   constructor(scope: Construct, id: string, props?: StackProps) {
10     super(scope, id, props);
11
12     const vpc = new ec2.Vpc(this, "MyVpc", {
13       maxAzs: 3 // Default is all AZs in region
14     });
15
16     const cluster = new ecs.Cluster(this, "MyCluster", {
17       vpc: vpc
18     });
19
20     // Create a load-balanced Fargate service and make it public
21     new ecs_patterns.ApplicationLoadBalancedFargateService(this, "MyFargateService", {
22       cluster: cluster, // Required
23       cpu: 512, // Default is 256
24       desiredCount: 6, // Default is 1
25       taskImageOptions: { image: ecs.ContainerImage.from },
26       memoryLimitMiB: 2048, // Default is 512
27       publicLoadBalancer: true // Default is false
28     });
29   }
30 }
31
32
```



## Developing with the AWS CDK

It's easy to [get set up \(p. 9\)](#) and [write your first CDK app \(p. 16\)](#). Short code examples are available throughout this Guide in the AWS CDK's supported programming languages: TypeScript, JavaScript, Python, Java, and C#. Longer examples are available [in our GitHub repository](#).

The [AWS CDK Toolkit \(p. 309\)](#) is a command line tool for interacting with CDK apps. Developers can use the AWS CDK Toolkit to synthesize artifacts such as AWS CloudFormation templates and to deploy stacks to development AWS accounts. You can also **diff** against a deployed stack to understand the impact of a code change.

The [AWS Construct Library \(p. 84\)](#) offers constructs for each AWS service, many with "rich" APIs that provide high-level abstractions. The aim of the AWS Construct Library is to reduce the complexity and glue logic required when integrating various AWS services to achieve your goals on AWS.

### Note

There is no charge for using the AWS CDK, but you might incur AWS charges for creating or using AWS [chargeable resources](#). These might include running Amazon EC2 instances or using Amazon S3 storage. Use the [AWS Pricing Calculator](#) to estimate charges for the use of various AWS resources.

## The Construct Programming Model

The Construct Programming Model (CPM) extends the concepts behind the AWS CDK into additional domains. Other tools using the CPM include:

- [CDK for Terraform](#) (CDKtf)
- [CDK for Kubernetes](#) (CDK8s)
- [Projen](#), for building project configurations

[Construct Hub](#) is an online registry where you can find and publish construct libraries for CDKs like the AWS CDK.

## Additional documentation and resources

In addition to this guide, the following other resources are available to AWS CDK users:

- [API Reference](#)
- [AWS CDK Workshop](#)
- [cdk.dev](#) community hub, including a Slack channel
- [AWS CDK Examples](#)
- [CDK Patterns](#)
- [Awesome CDK](#)
- [AWS Solutions Constructs](#)
- [AWS Developer Blog](#) CDK category
- [Stack Overflow](#)
- [GitHub Repository](#)
  - [Issues](#)
  - [Examples](#)
  - [Documentation Source](#)
  - [License](#)
  - [Releases](#)
    - [AWS CDK OpenPGP key \(p. 360\)](#)
    - [jsii OpenPGP key \(p. 361\)](#)
- [AWS CDK Sample for Cloud9](#)
- [AWS CloudFormation Concepts](#)
- [AWS Glossary](#)

## Resources for serverless apps with CDK

These tools can work with the AWS CDK to simplify serverless application development and deployment.

- [AWS Serverless Application Model](#)
- [AWS Chalice](#), a Python serverless microframework

## Contributing to the AWS CDK

Because the AWS CDK is open source, the team encourages you to contribute to make it an even better tool. For details, see [Contributing](#).

## About Amazon Web Services

Amazon Web Services (AWS) is a collection of digital infrastructure services that developers can use when developing their applications. The services include computing, storage, database, and application synchronization (messaging and queueing).

AWS uses a pay-as-you-go service model. You are charged only for the services that you — or your applications — use. Also, to make AWS useful as a platform for prototyping and experimentation, AWS offers a free usage tier. In the tier, services are free below a certain level of usage. For more information about AWS costs and the free usage tier, see [Test-Driving AWS in the Free Usage Tier](#).

To obtain an AWS account, go to [aws.amazon.com](https://aws.amazon.com), and then choose **Create an AWS Account**.



# Getting started with the AWS CDK

This topic introduces you to important AWS CDK concepts and describes how to install and configure the AWS CDK. When you're done, you'll be ready to create [your first AWS CDK app \(p. 16\)](#).

## Your background

The AWS Cloud Development Kit (AWS CDK) lets you define your cloud infrastructure as code in one of its supported programming languages. It is intended for moderately to highly experienced AWS users.

Ideally, you already have experience with popular AWS services, particularly [AWS IAM Identity Center \(successor to AWS Single Sign-On\)](#). You might also have experience working with AWS resources programmatically.

Familiarity with [AWS CloudFormation](#) is also useful, because the output of an AWS CDK program is an AWS CloudFormation template.

Finally, you should be proficient in the programming language you intend to use with the AWS CDK.

## Key concepts

The AWS CDK is designed around a handful of important concepts. We will introduce a few of these here briefly. Follow the links to learn more, or see the Concepts topics in this guide's Table of Contents.

An AWS CDK [app \(p. 103\)](#) is an application written in TypeScript, JavaScript, Python, Java, C# or Go that uses the AWS CDK to define AWS infrastructure. An app defines one or more [stacks \(p. 108\)](#). Stacks (equivalent to AWS CloudFormation stacks) contain [constructs \(p. 84\)](#). Each construct defines one or more concrete AWS resources, such as Amazon S3 buckets, Lambda functions, or Amazon DynamoDB tables.

Constructs (and also stacks and apps) are represented as classes (types) in your programming language of choice. You instantiate constructs within a stack to declare them to AWS, and connect them to each other using well-defined interfaces.

The AWS CDK includes the CDK Toolkit (also called the CLI), a command line tool for working with your AWS CDK apps and stacks. Among other functions, the Toolkit provides the ability to do the following:

- Convert one or more AWS CDK stacks to AWS CloudFormation templates and related assets (a process called *synthesis*)
- Deploy your stacks to an AWS account and Region

The AWS CDK includes a library of AWS constructs called the AWS Construct Library, organized into various modules. The library contains constructs for each AWS service. The main CDK package is called `aws-cdk-lib`, and it contains the majority of the AWS Construct Library. It also contains base classes like `Stack` and `App` that are used in most CDK applications.

The actual package name of the main CDK package varies by language.

TypeScript

Install	<code>npm install aws-cdk-lib</code>
Import	<code>import * as cdk from 'aws-cdk-lib';</code>

## JavaScript

Install	<code>npm install aws-cdk-lib</code>
Import	<code>const cdk = require('aws-cdk-lib');</code>

## Python

Install	<code>python -m pip install aws-cdk-lib</code>
Import	<code>import aws_cdk as cdk</code>

## Java

Add to pom.xml	<code>Group software.amazon.awscdk; artifact aws-cdk-lib</code>
Import	<code>import software.amazon.awscdk.App; (for example)</code>

## C#

Install	<code>dotnet add package Amazon.CDK.Lib</code>
Import	<code>using Amazon.CDK;</code>

## Go

Install	<code>go get github.com/aws/aws-cdk-go/awscdk/ v2</code>
Import	<code>import (     "github.com/aws/aws-cdk-go/awscdk/v2" )</code>

### Note

If you created a CDK project using **cdk init**, you don't need to manually install `aws-cdk-lib`.

Constructs come in three fundamental flavors:

- **AWS CloudFormation-only** or L1 (short for "layer 1"). These constructs correspond directly to resource types defined by AWS CloudFormation. In fact, these constructs are automatically generated from the AWS CloudFormation specification. Therefore, when a new AWS service is launched, the AWS CDK supports it a short time after AWS CloudFormation does.

AWS CloudFormation resources always have names that begin with `Cfn`. For example, for the Amazon S3 service, `CfnBucket` is the L1 construct for an Amazon S3 bucket.

All L1 resources are in `aws-cdk-lib`.

- **Curated** or L2. These constructs are carefully developed by the AWS CDK team to address specific use cases and simplify infrastructure development. For the most part, they encapsulate L1 resources, providing sensible defaults and best practice security policies. For example, `Bucket` is the L2 construct for an Amazon S3 bucket.

Libraries may also define supporting resources needed by the primary L2 resource. Some services have more than one L2 namespace in the Construct Library for organizational purposes.

`aws-cdk-lib` contains L2 constructs that are designated stable, i.e., ready for production use. If a service's L2 support is still under development, its constructs are designated experimental and provided in a separate module.

- **Patterns** or L3. Patterns declare multiple resources to create entire AWS architectures for particular use cases. All the plumbing is already hooked up, and configuration is boiled down to a few important parameters.

As with L2 constructs, L3 constructs that are ready for production use (stable) are included in `aws-cdk-lib`, while those still under development are in separate modules.

Finally, the `constructs` package contains the `Construct` base class. It's in its own package because it's used by other construct-based tools in addition to the AWS CDK, including CDK for Terraform and CDK for Kubernetes.

Numerous third parties have also published constructs compatible with the AWS CDK. Visit [Construct Hub](#) to explore the AWS CDK construct partner ecosystem.

## Supported programming languages

The AWS CDK has first-class support for TypeScript, JavaScript, Python, Java, C#, and Go. Other JVM and .NET CLR languages may also be used, at least in theory. However, we are unable to offer support for them at this time.

To facilitate supporting so many languages, the AWS CDK is developed in one language (TypeScript). Language bindings are generated for the other languages through the use of a tool called [JSII](#).

We have taken pains to make AWS CDK app development in each language follow that language's usual conventions. This way, writing AWS CDK apps feels natural, not like writing TypeScript in Python, for example. Take a look at the following examples:

### TypeScript

```
const bucket = new s3.Bucket(this, 'MyBucket', {
  bucketName: 'my-bucket',
  versioned: true,
  websiteRedirect: {hostname: 'aws.amazon.com'}});
```

### JavaScript

```
const bucket = new s3.Bucket(this, 'MyBucket', {
  bucketName: 'my-bucket',
  versioned: true,
  websiteRedirect: {hostname: 'aws.amazon.com'}});
```

### Python

```
bucket = s3.Bucket("MyBucket", bucket_name="my-bucket", versioned=True,
  website_redirect=s3.RedirectTarget(host_name="aws.amazon.com"))
```

#### Java

```
Bucket bucket = Bucket.Builder.create(self, "MyBucket")
    .bucketName("my-bucket")
    .versioned(true)
    .websiteRedirect(new RedirectTarget.Builder()
        .hostName("aws.amazon.com").build())
    .build();
```

#### C#

```
var bucket = new Bucket(this, "MyBucket", new BucketProps {
    BucketName = "my-bucket",
    Versioned = true,
    WebsiteRedirect = new RedirectTarget {
        HostName = "aws.amazon.com"
    }
});
```

#### Go

```
bucket := awss3.NewBucket(scope, jsii.String("MyBucket"), &awss3.BucketProps {
    BucketName: jsii.String("my-bucket"),
    Versioned: jsii.Bool(true),
    WebsiteRedirect: &awss3.RedirectTarget {
        HostName: jsii.String("aws.amazon.com"),
    },
})
```

#### Note

These code snippets are intended for illustration only. They are incomplete and won't run as they are.

The AWS Construct Library is distributed using each language's standard package management tools, including NPM, PyPi, Maven, and NuGet. There's even a version of the [AWS CDK API Reference](#) for each language.

To help you use the AWS CDK in your favorite language, this guide includes the following topics for supported languages:

- [the section called "In TypeScript" \(p. 31\)](#)
- [the section called "In JavaScript" \(p. 35\)](#)
- [the section called "In Python" \(p. 41\)](#)
- [the section called "In Java" \(p. 46\)](#)
- [the section called "In C#" \(p. 50\)](#)
- [the section called "In Go" \(p. 55\)](#)

TypeScript was the first language supported by the AWS CDK, and much AWS CDK example code is written in TypeScript. This guide includes a topic specifically to show how to adapt TypeScript AWS CDK code for use with the other supported languages. For more information, see [Translating from TypeScript \(p. 76\)](#).

## Prerequisites

Here's what you need to install to use the AWS CDK.

All AWS CDK developers, even those working in Python, Java, or C#, need [Node.js](#) 14.15.0 or later. All supported languages use the same backend, which runs on Node.js. We recommend a version in [active long-term support](#). Your organization may have a different recommendation.

**Important**

Node.js versions 13.0.0 through 13.6.0 are not compatible with the AWS CDK due to compatibility issues with its dependencies.

Other prerequisites depend on the language in which you develop AWS CDK applications and are as follows.

TypeScript

- TypeScript 3.8 or later (`npm -g install typescript`)

JavaScript

No additional requirements

Python

- Python 3.7 or later including pip and virtualenv

Java

- Java Development Kit (JDK) 8 (a.k.a. 1.8) or later
- Apache Maven 3.5 or later

Java IDE recommended (we use Eclipse in some examples in this guide). IDE must be able to import Maven projects. Check to make sure that your project is set to use Java 1.8. Set the JAVA\_HOME environment variable to the path where you have installed the JDK.

C#

.NET Core 3.1 or later, or .NET 6.0 or later.

Visual Studio 2019 (any edition) or Visual Studio Code recommended.

Go

Go 1.1.8 or later.

**Note**

Third-party language deprecation: each language version is only supported until its EOL (End Of Life) shared by the vendor or community and is subject to change with prior notice.

## Authentication with AWS

You must establish how the AWS CDK authenticates with AWS when developing with AWS services. There are different ways in which you can configure programmatic access to AWS resources, depending on the environment and the AWS access available to you.

To choose your method of authentication and configure it for the AWS CDK, see [Authentication and access](#) in the *AWS SDKs and Tools Reference Guide*.

The recommended approach for new users developing locally, who aren't given a method of authentication by their employer, is to set up AWS IAM Identity Center (successor to AWS Single Sign-On). This method includes installing the AWS CLI for ease of configuration and for regularly signing in

to the AWS access portal. If you choose this method, your environment should contain the following elements after you complete the procedure for [IAM Identity Center authentication](#) in the *AWS SDKs and Tools Reference Guide*:

- The AWS CLI, which you use to start an AWS access portal session before you run your application.
- A [shared AWSconfig file](#) having a [default] profile with a set of configuration values that can be referenced from the AWS CDK. To find the location of this file, see [Location of the shared files](#) in the *AWS SDKs and Tools Reference Guide*.
- The shared config file sets the [region](#) setting. This sets the default AWS Region the AWS CDK uses for AWS requests.
- The AWS CDK uses the profile's [SSO token provider configuration](#) to acquire credentials before sending requests to AWS. The `sso_role_name` value, which is an IAM role connected to an IAM Identity Center permission set, should allow access to the AWS services used in your application.

The following sample config file shows a default profile set up with SSO token provider configuration. The profile's `sso_session` setting refers to the named [sso-session section](#). The `sso-session` section contains settings to initiate an AWS access portal session.

```
[default]
sso_session = my-sso
sso_account_id = 111122223333
sso_role_name = SampleRole
region = us-east-1
output = json

[sso-session my-sso]
sso_region = us-east-1
sso_start_url = https://provided-domain.awsapps.com/start
sso_registration_scopes = sso:account:access
```

## Start an AWS access portal session

Before accessing AWS services, you need an active AWS access portal session for the AWS CDK to use IAM Identity Center authentication to resolve credentials. Depending on your configured session lengths, your access will eventually expire and the AWS CDK will encounter an authentication error. Run the following command in the AWS CLI to sign in to the AWS access portal.

```
aws sso login
```

If your SSO token provider configuration is using a named profile instead of the default profile, the command is `aws sso login --profile NAME`. Also specify this profile when issuing `cdk` commands using the `--profile` option or the `AWS_PROFILE` environment variable.

To test if you already have an active session, run the following AWS CLI command.

```
aws sts get-caller-identity
```

The response to this command should report the IAM Identity Center account and permission set configured in the shared config file.

### Note

If you already have an active AWS access portal session and run `aws sso login`, you won't be required to provide credentials.

The sign in process may prompt you to allow the AWS CLI access to your data. Since the AWS CLI is built on top of the SDK for Python, permission messages may contain variations of the `botocore` name.

## Install the AWS CDK

Install the AWS CDK Toolkit globally using the following Node Package Manager command.

```
npm install -g aws-cdk
```

Run the following command to verify correct installation and print the version number of the AWS CDK.

```
cdk --version
```

### Note

CDK Toolkit v2 works with your existing CDK v1 projects. However, it can't initialize new CDK v1 projects. See [the section called “New prerequisites” \(p. 68\)](#) if you need to be able to do that.

## Bootstrapping

Deploying stacks with the AWS CDK requires dedicated Amazon S3 buckets and other containers to be available to AWS CloudFormation during deployment. Creating these is called [bootstrapping \(p. 195\)](#). To bootstrap, issue:

```
cdk bootstrap aws://ACCOUNT-NUMBER/REGION
```

### Tip

If you don't have your AWS account number handy, you can get it from the AWS Management Console. Or, if you have the AWS CLI installed, the following command displays your default account information, including the account number.

```
aws sts get-caller-identity
```

If you created named profiles in your local AWS configuration, you can use the `--profile` option to display the account information for a specific profile. The following example shows how to display account information for the *prod* profile.

```
aws sts get-caller-identity --profile prod
```

To display the default Region, use `aws configure get`.

```
aws configure get region  
aws configure get region --profile prod
```

## AWS CDK tools

The AWS CDK Toolkit, also known as the Command Line Interface (CLI), is the main tool you use to interact with your AWS CDK app. It executes your code and produces and deploys the AWS CloudFormation templates it generates. It also has deployment, diff, deletion, and troubleshooting capabilities. For more information, see `cdk --help` or [the section called “AWS CDK Toolkit” \(p. 309\)](#).

The [AWS Toolkit for Visual Studio Code](#) is an open source plug-in for Visual Studio Code that helps you create, debug, and deploy applications on AWS. The toolkit provides an integrated experience

for developing AWS CDK applications. It includes the AWS CDK Explorer feature to list your AWS CDK projects and browse the various components of the CDK application. [Install the plug-in](#) and learn more about [using the AWS CDK Explorer](#).

## Next steps

Where do you go now that you've dipped your toes in the AWS CDK?

- Come on in; the water's fine! Build [your first AWS CDK app \(p. 16\)](#).
- Try the [CDK Workshop](#) for a more in-depth tour involving a more complex project.
- See the [API reference](#) to begin exploring the provided constructs available for your favorite AWS services.
- Visit the [Construct Hub](#) to find constructs from the CDK community and also from AWS.
- Dig deeper into concepts like [the section called "Environments" \(p. 114\)](#), [the section called "Assets" \(p. 163\)](#), [the section called "Bootstrapping" \(p. 195\)](#), [the section called "Permissions" \(p. 177\)](#), [the section called "Context" \(p. 185\)](#), [the section called "Parameters" \(p. 151\)](#), and [Abstractions and escape hatches \(p. 210\)](#).
- Explore [Examples](#) of using the AWS CDK.

The AWS CDK is an open-source project. Want to [contribute](#)?

## Your first AWS CDK app

You've read [Getting started \(p. 9\)](#) and set up your development environment for writing AWS CDK apps? Great! Now let's see how it feels to work with the AWS CDK by building the simplest possible AWS CDK app.

In this tutorial, you'll learn about the following:

- The structure of an AWS CDK project
- How to use the AWS Construct Library to define AWS resources using code
- How to synthesize, diff, and deploy collections of resources using the AWS CDK Toolkit command line tool

The standard AWS CDK development workflow is similar to what you're already familiar with as a developer, with only a few extra steps.

1. Create the app from a template provided by the AWS CDK.
2. Add code to the app to create resources within stacks.
3. (Optional) Build the app. (The AWS CDK Toolkit does this for you if you forget.)
4. Synthesize one or more stacks in the app to create an AWS CloudFormation template.
5. Deploy one or more stacks to your AWS account.

The build step catches syntax and type errors. The synthesis step catches logical errors in defining your AWS resources. The deployment may find permission issues. As always, you go back to the code, find the problem, fix it, then build, synthesize, and deploy again.

### Tip

Don't forget to keep your AWS CDK code under version control!



This tutorial walks you through creating and deploying a simple AWS CDK app, from initializing the project to deploying the resulting AWS CloudFormation template. The app contains one stack, which contains one resource, an Amazon S3 bucket.

We'll also show what happens when you make a change and re-deploy, and how to clean up when you're done.

## Create the app

Each AWS CDK app should be in its own directory, with its own local module dependencies. Create a new directory for your app. Starting in your home directory, or another directory if you prefer, issue the following commands.

### Important

Be sure to name your project directory `hello-cdk`, *exactly as shown here*. The AWS CDK project template uses the directory name to name things in the generated code. If you use a different name, the code in this tutorial won't work.

```
mkdir hello-cdk
cd hello-cdk
```

Now initialize the app by using the **cdk init** command. Specify the desired template ("app") and programming language as shown in the following examples:

### TypeScript

```
cdk init app --language typescript
```

### JavaScript

```
cdk init app --language javascript
```

### Python

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

After the app has been created, also enter the following two commands. These activate the app's Python virtual environment and install the AWS CDK core dependencies.

```
source .venv/bin/activate
python -m pip install -r requirements.txt
```

### Java

```
cdk init app --language java
```

If you are using an IDE, you can now open or import the project. In Eclipse, for example, choose **File > Import > Maven > Existing Maven Projects**. Make sure that the project settings are set to use Java 8 (1.8).

### C#

```
cdk init app --language csharp
```

If you are using Visual Studio, open the solution file in the `src` directory.

Go

```
cdk init app --language go
```

After the app has been created, also enter the following command to install the AWS Construct Library modules that the app requires.

```
go get
```

### Tip

If you don't specify a template, the default is "app," which is the one we wanted anyway. Technically, you can omit it and save four keystrokes.

The **cdk init** command creates a number of files and folders inside the `hello-cdk` directory to help you organize the source code for your AWS CDK app. Take a moment to explore. The structure of a basic app is all there; you'll fill in the details in this tutorial.

If you have Git installed, each project you create using **cdk init** is also initialized as a Git repository. We'll ignore that for now, but it's there when you need it.

## Build the app

In most programming environments, after changing your code, you build (compile) it. This isn't strictly necessary with the AWS CDK—the Toolkit does it for you so that you can't forget. But you can still build manually whenever you want to catch syntax and type errors. For reference, here's how.

TypeScript

```
npm run build
```

JavaScript

No build step is necessary.

Python

No build step is necessary.

Java

```
mvn compile -q
```

Or press Control-B in Eclipse (other Java IDEs may vary)

C#

```
dotnet build src
```

Or press F6 in Visual Studio

Go

```
go build
```

## List the stacks in the app

To verify that everything is working correctly, list the stacks in your app.

```
cdk ls
```

If you don't see `HelloCdkStack`, make sure you named your app's directory `hello-cdk`. If you didn't, go back to [the section called "Create the app" \(p. 17\)](#) and try again.

## Add an Amazon S3 bucket

At this point, your app doesn't do anything because the stack it contains doesn't define any resources. Let's add an Amazon S3 bucket.

The CDK's Amazon S3 support is part of its main library, `aws-cdk-lib`, so we don't need to install another library. We can define an Amazon S3 bucket in the stack using the [Bucket](#) construct.

TypeScript

In `lib/hello-cdk-stack.ts`:

```
import * as cdk from 'aws-cdk-lib';
import { aws_s3 as s3 } from 'aws-cdk-lib';

export class HelloCdkStack extends cdk.Stack {
  constructor(scope: cdk.App, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    new s3.Bucket(this, 'MyFirstBucket', {
      versioned: true
    });
  }
}
```

JavaScript

In `lib/hello-cdk-stack.js`:

```
const cdk = require('aws-cdk-lib');
const s3 = require('aws-cdk-lib/aws-s3');

class HelloCdkStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    new s3.Bucket(this, 'MyFirstBucket', {
      versioned: true
    });
  }
}

module.exports = { HelloCdkStack }
```

Python

In `hello_cdk/hello_cdk_stack.py`:

```
import aws_cdk as cdk
import aws_cdk.aws_s3 as s3
```

```
class HelloCdkStack(cdk.Stack):  
  
    def __init__(self, scope: cdk.App, construct_id: str, **kwargs) -> None:  
        super().__init__(scope, construct_id, **kwargs)  
  
        bucket = s3.Bucket(self, "MyFirstBucket", versioned=True)
```

## Java

In `src/main/java/com/myorg/HelloCdkStack.java`:

```
package com.myorg;  
  
import software.amazon.awscdk.*;  
import software.amazon.awscdk.services.s3.Bucket;  
  
public class HelloCdkStack extends Stack {  
    public HelloCdkStack(final App scope, final String id) {  
        this(scope, id, null);  
    }  
  
    public HelloCdkStack(final App scope, final String id, final StackProps props) {  
        super(scope, id, props);  
  
        Bucket.Builder.create(this, "MyFirstBucket")  
            .versioned(true).build();  
    }  
}
```

## C#

In `src/HelloCdk/HelloCdkStack.cs`:

```
using Amazon.CDK;  
using Amazon.CDK.AWS.S3;  
  
namespace HelloCdk  
{  
    public class HelloCdkStack : Stack  
    {  
        public HelloCdkStack(App scope, string id, IStackProps props=null) :  
            base(scope, id, props)  
        {  
            new Bucket(this, "MyFirstBucket", new BucketProps  
            {  
                Versioned = true  
            });  
        }  
    }  
}
```

## Go

In `hello-cdk.go`:

```
package main  
  
import (  
    "github.com/aws/aws-cdk-go/awscdk/v2"  
    "github.com/aws/aws-cdk-go/awscdk/v2/awss3"  
    "github.com/aws/constructs-go/constructs/v10"
```

```
"github.com/aws/jsii-runtime-go"
)

type HelloCdkStackProps struct {
    awscdk.StackProps
}

func NewHelloCdkStack(scope constructs.Construct, id string, props *HelloCdkStackProps)
    awscdk.Stack {
    var sprops awscdk.StackProps
    if props != nil {
        sprops = props.StackProps
    }
    stack := awscdk.NewStack(scope, &id, &sprops)

    awss3.NewBucket(stack, jsii.String("MyFirstBucket"), &awss3.BucketProps{
        Versioned: jsii.Bool(true),
    })

    return stack
}

func main() {
    defer jsii.Close()

    app := awscdk.NewApp(nil)

    NewHelloCdkStack(app, "HelloCdkStack", &HelloCdkStackProps{
        awscdk.StackProps{
            Env: env(),
        },
    })

    app.Synth(nil)
}

func env() *awscdk.Environment {
    return nil
}
```

Bucket is the first construct that we've seen, so let's take a closer look. Like all constructs, the Bucket class takes three parameters.

- **scope:** Tells the bucket that the stack is its parent: it is defined within the scope of the stack. You can define constructs inside of constructs, creating a hierarchy (tree). Here, and in most cases, the scope is this (self in Python), meaning the construct that contains the bucket: the stack.
- **Id:** The logical ID of the Bucket within your AWS CDK app. This (plus a hash based on the bucket's location within the stack) uniquely identifies the bucket across deployments. This way, the AWS CDK can update it if you change how it's defined in your app. Here, it's "MyFirstBucket." Buckets can also have a name, which is separate from this ID (it's the `bucketName` property).
- **props:** A bundle of values that define properties of the bucket. Here we've defined only one property: `versioned`, which enables versioning for the files in the bucket.

All constructs take these same three arguments, so it's easy to stay oriented as you learn about new ones. And as you might expect, you can subclass any construct to extend it to suit your needs, or if you want to change its defaults.

#### Tip

If a construct's props are all optional, you can omit the props parameter entirely.

Props are represented differently in the languages supported by the AWS CDK.

- In TypeScript and JavaScript, props is a single argument and you pass in an object containing the desired properties.
- In Python, props are passed as keyword arguments.
- In Java, a Builder is provided to pass the props. There are two: one for BucketProps, and a second for Bucket to let you build the construct and its props object in one step. This code uses the latter.
- In C#, you instantiate a BucketProps object using an object initializer and pass it as the third parameter.

## Synthesize an AWS CloudFormation template

Synthesize an AWS CloudFormation template for the app, as follows.

```
cdk synth
```

If your app contained more than one stack, you'd need to specify which stack or stacks to synthesize. But since it only contains one, the CDK Toolkit knows you must mean that one.

### Tip

If you received an error like `--app is required...`, it's probably because you are running the command from a subdirectory. Navigate to the main app directory and try again.

The `cdk synth` command executes your app, which causes the resources defined in it to be translated into an AWS CloudFormation template. The displayed output of `cdk synth` is a YAML-format template. Following, you can see the beginning of our app's output. The template is also saved in the `cdk.out` directory in JSON format.

```
Resources:
  MyFirstBucketB8884501:
    Type: AWS::S3::Bucket
    Properties:
      VersioningConfiguration:
        Status: Enabled
      UpdateReplacePolicy: Retain
      DeletionPolicy: Retain
      Metadata: ...
```

Even if you aren't familiar with AWS CloudFormation, you can find the bucket definition and see how the versioned property was translated.

### Note

Every generated template contains a `AWS::CDK::Metadata` resource by default. (We haven't shown it here.) The AWS CDK team uses this metadata to gain insight into how the AWS CDK is used, so that we can continue to improve it. For details, including how to opt out of version reporting, see [Version reporting \(p. 311\)](#).

The `cdk synth` generates a perfectly valid AWS CloudFormation template. You could take it and deploy it using the AWS CloudFormation console or another tool. But the AWS CDK Toolkit can also do that.

## Deploying the stack

To deploy the stack using AWS CloudFormation, issue:

```
cdk deploy
```

As with `cdk synth`, you don't need to specify the name of the stack since there's only one in the app.

It is optional (though good practice) to synthesize before deploying. The AWS CDK synthesizes your stack before each deployment.

If your code has security implications, you'll see a summary of these and need to confirm them before deployment proceeds. This isn't the case in our stack.

`cdk deploy` displays progress information as your stack is deployed. When it's done, the command prompt reappears. You can go to the [AWS CloudFormation console](#) and see that it now lists `HelloCdkStack`. You'll also find `MyFirstBucket` in the Amazon S3 console.

You've deployed your first stack using the AWS CDK—congratulations! But that's not all there is to the AWS CDK.

## Modifying the app

The AWS CDK can update your deployed resources after you modify your app. Let's change the bucket so it can be automatically deleted when deleting the stack. This involves changing the bucket's `RemovalPolicy`. Also, use the `autoDeleteObjects` property to ask the AWS CDK to delete the objects from the bucket before destroying it. (AWS CloudFormation doesn't delete S3 buckets that contain any objects.)

### TypeScript

Update `lib/hello-cdk-stack.ts`.

```
new s3.Bucket(this, 'MyFirstBucket', {
  versioned: true,
  removalPolicy: cdk.RemovalPolicy.DESTROY,
  autoDeleteObjects: true
});
```

### JavaScript

Update `lib/hello-cdk-stack.js`.

```
new s3.Bucket(this, 'MyFirstBucket', {
  versioned: true,
  removalPolicy: cdk.RemovalPolicy.DESTROY,
  autoDeleteObjects: true
});
```

### Python

Update `hello_cdk/hello_cdk_stack.py`.

```
bucket = s3.Bucket(self, "MyFirstBucket",
    versioned=True,
    removal_policy=cdk.RemovalPolicy.DESTROY,
    auto_delete_objects=True)
```

### Java

Update `src/main/java/com/myorg/HelloCdkStack.java`.

```
Bucket.Builder.create(this, "MyFirstBucket")
    .versioned(true)
    .removalPolicy(RemovalPolicy.DESTROY)
    .autoDeleteObjects(true)
```

```
.build();
```

C#

Update `src/HelloCdk/HelloCdkStack.cs`.

```
new Bucket(this, "MyFirstBucket", new BucketProps
{
    Versioned = true,
    RemovalPolicy = RemovalPolicy.DESTROY,
    AutoDeleteObjects = true
});
```

Go

Update `hello-cdk.go`.

```
awss3.NewBucket(stack, jsii.String("MyFirstBucket"), &awss3.BucketProps{
    Versioned:      jsii.Bool(true),
    RemovalPolicy:  awscdk.RemovalPolicy_DESTROY,
    AutoDeleteObjects: jsii.Bool(true),
})
```

Here, we haven't written any code that, in itself, changes our Amazon S3 bucket. Instead, our code defines the desired state of the bucket. The AWS CDK synthesizes that state to a new AWS CloudFormation template. Then, it deploys a change set that makes only the changes necessary to reach that state.

To see these changes, we'll use the `cdk diff` command.

```
cdk diff
```

The AWS CDK Toolkit queries your AWS account for the last-deployed AWS CloudFormation template for the `HelloCdkStack`. Then, it compares the last-deployed template with the template it just synthesized from your app. The output should look like the following.

```
Stack HelloCdkStack
IAM Statement Changes
#####
#   # Resource                               # Effect # Action                               # Principal
#   # Condition #
#####
# + # ${Custom::S3AutoDeleteObject} # Allow # sts:AssumeRole #
#   # Service:lambda.amazonaws.com #   #
#   # sCustomResourceProvider/Role #   #
#   # .Arn} #   #
#   #   #   #
#####
# + # ${MyFirstBucket.Arn} # Allow # s3:DeleteObject* # AWS:
#   # ${Custom::S3AutoDeleteOb #   #
#   # ${MyFirstBucket.Arn}/* #   # s3:GetBucket* #
#   # jectsCustomResourceProvider/ #   #
#   # #   # s3:GetObject* # Role.Arn}
#   # #   # s3:List* #
#   # #   #
#####
IAM Policy Changes
```



```
#####
#   # Resource                                     # Managed Policy ARN
#
#####
# + # ${Custom::S3AutoDeleteObjectsCustomResourceProvider/Ro # {"Fn::Sub": "arn:
${AWS::Partition}:iam::aws:policy/serv #
#   # le}                                     # ice-role/
AWSLambdaBasicExecutionRole"}
#####
(NOTE: There may be security-related changes not in this list. See https://github.com/aws/
aws-cdk/issues/1299)

Parameters
[+] Parameter
  AssetParameters/4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392/S3Bucket
  AssetParameters4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392S3BucketBF7A7F3F:
  {"Type": "String", "Description": "S3 bucket for asset
  \"4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392\""}
[+] Parameter
  AssetParameters/4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392/
  S3VersionKey
  AssetParameters4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392S3VersionKeyFAF93626:
  {"Type": "String", "Description": "S3 key for asset version
  \"4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392\""}
[+] Parameter
  AssetParameters/4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392/
  ArtifactHash
  AssetParameters4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392ArtifactHashE56CD69A:
  {"Type": "String", "Description": "Artifact hash for asset
  \"4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392\""}

Resources
[+] AWS::S3::BucketPolicy MyFirstBucket/Policy MyFirstBucketPolicy3243DEFD
[+] Custom::S3AutoDeleteObjects MyFirstBucket/AutoDeleteObjectsCustomResource
  MyFirstBucketAutoDeleteObjectsCustomResourceC52FCF6E
[+] AWS::IAM::Role Custom::S3AutoDeleteObjectsCustomResourceProvider/Role
  CustomS3AutoDeleteObjectsCustomResourceProviderRole3B1BD092
[+] AWS::Lambda::Function Custom::S3AutoDeleteObjectsCustomResourceProvider/Handler
  CustomS3AutoDeleteObjectsCustomResourceProviderHandler9D90184F
[~] AWS::S3::Bucket MyFirstBucket MyFirstBucketB8884501
## [~] DeletionPolicy
# ## [-] Retain
# ## [+] Delete
## [~] UpdateReplacePolicy
## [-] Retain
## [+] Delete
```

This diff has four sections.

- **IAM Statement Changes and IAM Policy Changes** - These permission changes are there because we set the `AutoDeleteObjects` property on our Amazon S3 bucket. The auto-delete feature uses a custom resource to delete the objects in the bucket before the bucket itself is deleted. The IAM objects grant the custom resource's code access to the bucket.
- **Parameters** - The AWS CDK uses these entries to locate the Lambda function asset for the custom resource.
- **Resources** - The new and changed resources in this stack. We can see the previously mentioned IAM objects, the custom resource, and its associated Lambda function being added. We can also see that the bucket's `DeletionPolicy` and `UpdateReplacePolicy` attributes are being updated. These allow the bucket to be deleted along with the stack, and to be replaced with a new one.

You may be curious about why we specified `RemovalPolicy` in our AWS CDK app but got a `DeletionPolicy` property in the resulting AWS CloudFormation template. The AWS CDK uses a

different name for the property. This is because the AWS CDK default is to retain the bucket when the stack is deleted, while AWS CloudFormation's default is to delete it. For more information, see [the section called "Removal policies" \(p. 138\)](#).

It's informative to compare the output of `cdk synth` here with the previous output. You can see the many additional lines of AWS CloudFormation template that the AWS CDK generated for us based on these relatively small changes.

### Important

All AWS CDK v2 deployments use dedicated AWS resources to hold data during deployment. Therefore, your AWS account and Region must be [bootstrapped \(p. 195\)](#) to create these resources before you can deploy. If you haven't already bootstrapped, issue the following command:

```
cdk bootstrap aws://ACCOUNT-NUMBER/REGION
```

Now let's deploy.

```
cdk deploy
```

The AWS CDK warns you about the security policy changes we've already seen in the diff. Enter `y` to approve the changes and deploy the updated stack. The CDK Toolkit updates the bucket configuration as you requested.

```
HelloCdkStack: deploying...
[0%] start: Publishing
4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392:current
[100%] success: Published
4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392:current
HelloCdkStack: creating CloudFormation changeset...
0/5 | 4:32:31 PM | UPDATE_IN_PROGRESS | AWS::CloudFormation::Stack | HelloCdkStack User
Initiated
0/5 | 4:32:36 PM | CREATE_IN_PROGRESS | AWS::IAM::Role
| Custom::S3AutoDeleteObjectsCustomResourceProvider/Role
(CustomS3AutoDeleteObjectsCustomResourceProviderRole3B1BD092)
1/5 | 4:32:36 PM | UPDATE_COMPLETE | AWS::S3::Bucket | MyFirstBucket
(MyFirstBucketB8884501)
1/5 | 4:32:36 PM | CREATE_IN_PROGRESS | AWS::IAM::Role
| Custom::S3AutoDeleteObjectsCustomResourceProvider/Role
(CustomS3AutoDeleteObjectsCustomResourceProviderRole3B1BD092) Resource creation Initiated
3/5 | 4:32:54 PM | CREATE_COMPLETE | AWS::IAM::Role
| Custom::S3AutoDeleteObjectsCustomResourceProvider/Role
(CustomS3AutoDeleteObjectsCustomResourceProviderRole3B1BD092)
3/5 | 4:32:56 PM | CREATE_IN_PROGRESS | AWS::Lambda::Function
| Custom::S3AutoDeleteObjectsCustomResourceProvider/Handler
(CustomS3AutoDeleteObjectsCustomResourceProviderHandler9D90184F)
3/5 | 4:32:56 PM | CREATE_IN_PROGRESS | AWS::S3::BucketPolicy | MyFirstBucket/
Policy (MyFirstBucketPolicy3243DEFD)
3/5 | 4:32:56 PM | CREATE_IN_PROGRESS | AWS::Lambda::Function
| Custom::S3AutoDeleteObjectsCustomResourceProvider/Handler
(CustomS3AutoDeleteObjectsCustomResourceProviderHandler9D90184F) Resource creation
Initiated
3/5 | 4:32:57 PM | CREATE_COMPLETE | AWS::Lambda::Function
| Custom::S3AutoDeleteObjectsCustomResourceProvider/Handler
(CustomS3AutoDeleteObjectsCustomResourceProviderHandler9D90184F)
3/5 | 4:32:57 PM | CREATE_IN_PROGRESS | AWS::S3::BucketPolicy | MyFirstBucket/
Policy (MyFirstBucketPolicy3243DEFD) Resource creation Initiated
4/5 | 4:32:57 PM | CREATE_COMPLETE | AWS::S3::BucketPolicy | MyFirstBucket/
Policy (MyFirstBucketPolicy3243DEFD)
4/5 | 4:32:59 PM | CREATE_IN_PROGRESS | Custom::S3AutoDeleteObjects
| MyFirstBucket/AutoDeleteObjectsCustomResource/Default
(MyFirstBucketAutoDeleteObjectsCustomResourceC52FCF6E)
```

```
5/5 | 4:33:06 PM | CREATE_IN_PROGRESS | Custom::S3AutoDeleteObjects
| MyFirstBucket/AutoDeleteObjectsCustomResource/Default
(MyFirstBucketAutoDeleteObjectsCustomResourceC52FCF6E) Resource creation Initiated
5/5 | 4:33:06 PM | CREATE_COMPLETE | Custom::S3AutoDeleteObjects
| MyFirstBucket/AutoDeleteObjectsCustomResource/Default
(MyFirstBucketAutoDeleteObjectsCustomResourceC52FCF6E)
5/5 | 4:33:08 PM | UPDATE_COMPLETE_CLEANUP | AWS::CloudFormation::Stack | HelloCdkStack
6/5 | 4:33:09 PM | UPDATE_COMPLETE | AWS::CloudFormation::Stack | HelloCdkStack

# HelloCdkStack

Stack ARN:
arn:aws:cloudformation:REGION:ACCOUNT:stack/HelloCdkStack/UNIQUE-ID
```

## Destroying the app's resources

Now that you're done with the quick tour, destroy your app's resources to avoid incurring any costs from the bucket you created, as follows.

```
cdk destroy
```

Enter **y** to approve the changes and delete any stack resources.

### Note

If we didn't change the bucket's `RemovalPolicy`, the stack deletion would complete successfully, but the bucket would become orphaned (no longer associated with the stack).

## Next steps

Where do you go now that you've dipped your toes in the AWS CDK?

- Try the [CDK Workshop](#) for a more in-depth tour involving a more complex project.
- Dig deeper into concepts like [the section called "Environments" \(p. 114\)](#), [the section called "Assets" \(p. 163\)](#), [the section called "Permissions" \(p. 177\)](#), [the section called "Context" \(p. 185\)](#), [the section called "Parameters" \(p. 151\)](#), and [Abstractions and escape hatches \(p. 210\)](#).
- See the [API reference](#) to begin exploring the CDK constructs available for your favorite AWS services.
- Visit [Construct Hub](#) to discover constructs created by AWS and others.
- Explore [Examples](#) of using the AWS CDK.

The AWS CDK is an open-source project. Want to [contribute](#)?

# Working with the AWS CDK

The AWS Cloud Development Kit (AWS CDK) lets you define your AWS cloud infrastructure in a general-purpose programming language. Currently, the AWS CDK supports TypeScript, JavaScript, Python, Java, C#, and Go. It is also possible to use other JVM and .NET languages, though we are unable to provide support for every such language.

## Note

This Guide does not currently include instructions or code examples for Go aside from [the section called "In Go" \(p. 55\)](#).

We develop the AWS CDK in TypeScript and use [JSII](#) to provide a "native" experience in other supported languages. For example, we distribute AWS Construct Library modules using your preferred language's standard repository, and you install them using the language's standard package manager. Methods and properties are even named using your language's recommended naming patterns.

## AWS CDK prerequisites

To use the AWS CDK, you need an AWS account and a corresponding access key. If you don't have an AWS account yet, see [Create and Activate an AWS Account](#). To find out how to obtain an access key ID and secret access key for your AWS account, see [Understanding and Getting Your Security Credentials](#). To find out how to configure your workstation so the AWS CDK uses your credentials, see [Setting Credentials in Node.js](#).

## Tip

If you have the [AWS CLI](#) installed, the simplest way to set up your workstation with your AWS credentials is to open a command prompt and type:

```
aws configure
```

All AWS CDK applications require Node.js 10.13 or later, even if you work in Python, Java, C#, or Go. You may download a compatible version at [nodejs.org](#). We recommend the [active LTS version](#). Node.js versions 13.0.0 through 13.6.0 are not compatible with the AWS CDK due to compatibility issues with its dependencies.

After installing Node.js, install the AWS CDK Toolkit (the cdk command):

```
npm install -g aws-cdk
```

## Note

If you get a permission error, and have administrator access on your system, try `sudo npm install -g aws-cdk`.

Test the installation by issuing `cdk --version`.

If you get an error message at this point, try uninstalling (`npm uninstall -g aws-cdk`) and reinstalling. As a last resort, delete the `node_modules` folder from the current project and also from the global `node_modules` folder. To figure out where this folder is, issue `npm config get prefix`.

## Language-specific prerequisites

The specific language you work in also has its own prerequisites, described in the corresponding topic listed here.

- [the section called “In TypeScript” \(p. 31\)](#)
- [the section called “In JavaScript” \(p. 35\)](#)
- [the section called “In Python” \(p. 41\)](#)
- [the section called “In Java” \(p. 46\)](#)
- [the section called “In C#” \(p. 50\)](#)
- [the section called “In Go” \(p. 55\)](#)

### Note

Third-party Language Deprecation: language version is only supported until its EOL (End Of Life) shared by the vendor or community and is subject to change with prior notice.

## AWS Construct Library

The AWS CDK includes the AWS Construct Library, a collection of constructs organized by AWS service. The library's constructs are mainly in a single module, colloquially called `aws-cdk-lib` because that's its name in TypeScript. The actual package name of the main CDK package varies by language.

### TypeScript

Install	<code>npm install aws-cdk-lib</code>
Import	<code>const cdk = require('aws-cdk-lib');</code>

### JavaScript

Install	<code>npm install aws-cdk-lib</code>
Import	<code>const cdk = require('aws-cdk-lib');</code>

### Python

Install	<code>python -m pip install aws-cdk-lib</code>
Import	<code>import aws_cdk as cdk</code>

### Java

Add to pom.xml	<code>Group software.amazon.awscdk; artifact aws-cdk-lib</code>
Import	<code>import software.amazon.awscdk.App; (for example)</code>

C#

Install	<code>dotnet add package Amazon.CDK.Lib</code>
Import	<code>using Amazon.CDK;</code>

### Note

Experimental constructs are provided as separate modules.

The [AWS CDK API Reference](#) provides detailed documentation of the constructs (and other components) in the library. A version of the API Reference is provided for each supported programming language.

Each module's reference material is broken into the following sections.

- *Overview*: Introductory material you'll need to know to work with the service in the AWS CDK, including concepts and examples.
- *Constructs*: Library classes that represent one or more concrete AWS resources. These are the "curated" (L2) resources or patterns (L3 resources) that provide a high-level interface with sane defaults.
- *Classes*: Non-construct classes that provide functionality used by constructs in the module.
- *Structs*: Data structures (attribute bundles) that define the structure of composite values such as properties (the `props` argument of constructs) and options.
- *Interfaces*: Interfaces, whose names all begin with "I", define the absolute minimum functionality for the corresponding construct or other class. The CDK uses construct interfaces to represent AWS resources that are defined outside your AWS CDK app and referenced by methods such as `Bucket.fromBucketArn()`.
- *Enums*: Collections of named values for use in specifying certain construct parameters. Using an enumerated value allows the CDK to check these values for validity during synthesis.
- *CloudFormation Resources*: These L1 constructs, whose names begin with "Cfn", represent exactly the resources defined in the CloudFormation specification. They are automatically generated from that specification with each CDK release. Each L2 or L3 construct encapsulates one or more CloudFormation resources.
- *CloudFormation Property Types*: The collection of named values that define the properties for each CloudFormation Resource.

## Interfaces vs. construct classes

The AWS CDK uses interfaces in a specific way that might not be obvious even if you are familiar with interfaces as a programming concept.

The AWS CDK supports using resources defined outside CDK applications using methods such as `Bucket.fromBucketArn()`. External resources cannot be modified and may not have all the functionality available with resources defined in your CDK app using e.g. the `Bucket` class. Interfaces, then, represent the bare minimum functionality available in the CDK for a given AWS resource type, *including external resources*.

When instantiating resources in your CDK app, then, you should always use concrete classes such as `Bucket`. When specifying the type of an argument you are accepting in one of your own constructs, use the interface type such as `IBucket` if you are prepared to deal with external resources (that is, you won't need to change them). If you require a CDK-defined construct, specify the most general type you can use.

Some interfaces are minimum versions of properties or options bundles associated with specific classes, rather than constructs. Such interfaces can be useful when subclassing to accept arguments that you'll

pass on to your parent class. If you require one or more additional properties, you'll want to implement or derive from this interface, or from a more specific type.

**Note**

Some programming languages supported by the AWS CDK don't have an interface feature. In these languages, interfaces are just ordinary classes. You can identify them by their names, which follow the pattern of an initial "I" followed by the name of some other construct (e.g. `IBucket`). The same rules apply.

## Working with the AWS CDK in TypeScript

TypeScript is a fully-supported client language for the AWS CDK and is considered stable. Working with the AWS CDK in TypeScript uses familiar tools, including Microsoft's TypeScript compiler (`tsc`), [Node.js](#) and the Node Package Manager (`npm`). You may also use [Yarn](#) if you prefer, though the examples in this Guide use NPM. The modules comprising the AWS Construct Library are distributed via the NPM repository, [npmjs.org](#).

You can use any editor or IDE. Many AWS CDK developers use [Visual Studio Code](#) (or its open-source equivalent [VSCodium](#)), which has excellent support for TypeScript.

### Prerequisites

To work with the AWS CDK, you must have an AWS account and credentials and have installed Node.js and the AWS CDK Toolkit. See [AWS CDK Prerequisites \(p. 28\)](#).

You also need TypeScript itself (version 3.8 or later). If you don't already have it, you can install it using `npm`.

```
npm install -g typescript
```

**Note**

If you get a permission error, and have administrator access on your system, try `sudo npm install -g typescript`.

Keep TypeScript up to date with a regular `npm update -g typescript`.

**Note**

Third-party language deprecation: language version is only supported until its EOL (End Of Life) shared by the vendor or community and is subject to change with prior notice.

### Creating a project

You create a new AWS CDK project by invoking `cdk init` in an empty directory.

```
mkdir my-project
cd my-project
cdk init app --language typescript
```

Creating a project also installs the [aws-cdk-lib](#) module and its dependencies.

`cdk init` uses the name of the project folder to name various elements of the project, including classes, subfolders, and files. Hyphens in the folder name are converted to underscores. However, the name should otherwise follow the form of a TypeScript identifier; for example, it should not start with a number or contain spaces.

## Using local tsc and cdk

For the most part, this guide assumes you install TypeScript and the CDK Toolkit globally (`npm install -g typescript aws-cdk`), and the provided command examples (such as `cdk synth`) follow this assumption. This approach makes it easy to keep both components up to date, and since both take a strict approach to backward compatibility, there is generally little risk in always using the latest versions.

Some teams prefer to specify all dependencies within each project, including tools like the TypeScript compiler and the CDK Toolkit. This practice lets you pin these components to specific versions and ensure that all developers on your team (and your CI/CD environment) use exactly those versions. This eliminates a possible source of change, helping to make builds and deployments more consistent and repeatable.

The CDK includes dependencies for both TypeScript and the CDK Toolkit in the TypeScript project template's `package.json`, so if you want to use this approach, you don't need to make any changes to your project. All you need to do is use slightly different commands for building your app and for issuing cdk commands.

Operation	Use global tools	Use local tools
Initialize project	<code>cdk init --language typescript</code>	<code>npx aws-cdk init --language typescript</code>
Build	<code>tsc</code>	<code>npm run build</code>
Run CDK Toolkit command	<code>cdk ...</code>	<code>npm run cdk ...</code> or <code>npx aws-cdk ...</code>

`npx aws-cdk` runs the version of the CDK Toolkit installed locally in the current project, if one exists, falling back to the global installation, if any. If no global installation exists, `npx` downloads a temporary copy of the CDK Toolkit and runs that. You may specify an arbitrary version of the CDK Toolkit using the `@` syntax: `npx aws-cdk@2.0 --version` prints `2.0.0`.

### Tip

Set up an alias so you can use the `cdk` command with a local CDK Toolkit installation.

macOS/Linux

```
alias cdk="npx aws-cdk"
```

Windows

```
doskey cdk=npx aws-cdk $*
```

## Managing AWS Construct Library modules

Use the Node Package Manager (`npm`) to install and update AWS Construct Library modules for use by your apps, as well as other packages you need. (You may use `yarn` instead of `npm` if you prefer.) `npm` also installs the dependencies for those modules automatically.

Most AWS CDK constructs are in the main CDK package, named `aws-cdk-lib`, which is a default dependency in new projects created by `cdk init`. "Experimental" AWS Construct Library modules, where higher-level constructs are still under development, are named like `@aws-cdk/SERVICE-NAME-alpha`. The service name has an `aws-` prefix. If you're unsure of a module's name, [search for it on NPM](#).



### Note

The [CDK API Reference](#) also shows the package names.

For example, the command below installs the experimental module for AWS CodeStar.

```
npm install @aws-cdk/aws-codestar-alpha
```

Some services' Construct Library support is in more than one namespace. For example, besides `aws-route53`, there are three additional Amazon Route 53 namespaces, `aws-route53-targets`, `aws-route53-patterns`, and `aws-route53resolver`.

Your project's dependencies are maintained in `package.json`. You can edit this file to lock some or all of your dependencies to a specific version or to allow them to be updated to newer versions under certain criteria. To update your project's NPM dependencies to the latest permitted version according to the rules you specified in `package.json`:

```
npm update
```

In TypeScript, you import modules into your code under the same name you use to install them using NPM. We recommend the following practices when importing AWS CDK classes and AWS Construct Library modules in your applications. Following these guidelines will help make your code consistent with other AWS CDK applications as well as easier to understand.

- Use ES6-style import directives, not `require()`.
- Generally, import individual classes from `aws-cdk-lib`.

```
import { App, Stack } from 'aws-cdk-lib';
```

- If you need many classes from `aws-cdk-lib`, you may use a namespace alias of `cdk` instead of importing the individual classes. Avoid doing both.

```
import * as cdk from 'aws-cdk-lib';
```

- Generally, import AWS service constructs using short namespace aliases.

```
import { aws_s3 as s3 } from 'aws-cdk-lib';
```

## AWS CDK idioms in TypeScript

### Props

All AWS Construct Library classes are instantiated using three arguments: the *scope* in which the construct is being defined (its parent in the construct tree), an *id*, and *props*. Argument *props* is a bundle of key/value pairs that the construct uses to configure the AWS resources it creates. Other classes and methods also use the "bundle of attributes" pattern for arguments.

In TypeScript, the shape of props is defined using an interface that tells you the required and optional arguments and their types. Such an interface is defined for each kind of props argument, usually specific to a single construct or method. For example, the [Bucket](#) construct (in the `aws-cdk-lib/aws-s3` module) specifies a props argument conforming to the [BucketProps](#) interface.

If a property is itself an object, for example the [websiteRedirect](#) property of `BucketProps`, that object will have its own interface to which its shape must conform, in this case [RedirectTarget](#).

If you are subclassing an AWS Construct Library class (or overriding a method that takes a props-like argument), you can inherit from the existing interface to create a new one that specifies any new props your code requires. When calling the parent class or base method, generally you can pass the entire props argument you received, since any attributes provided in the object but not specified in the interface will be ignored.

A future release of the AWS CDK could coincidentally add a new property with a name you used for your own property. Passing the value you receive up the inheritance chain can then cause unexpected behavior. It's safer to pass a shallow copy of the props you received with your property removed or set to undefined. For example:

```
super(scope, name, {...props, encryptionKeys: undefined});
```

Alternatively, name your properties so that it is clear that they belong to your construct. This way, it is unlikely they will collide with properties in future AWS CDK releases. If there are many of them, use a single appropriately-named object to hold them.

## Missing values

Missing values in an object (such as props) have the value `undefined` in TypeScript. Version 3.7 of the language introduced operators that simplify working with these values, making it easier to specify defaults and "short-circuit" chaining when an undefined value is reached. For more information about these features, see the [TypeScript 3.7 Release Notes](#), specifically the first two features, Optional Chaining and Nullish Coalescing.

## Building, synthesizing, and deploying

Generally, you should be in the project's root directory when building and running your application.

Node.js cannot run TypeScript directly; instead, your application is converted to JavaScript using the TypeScript compiler, `tsc`. The resulting JavaScript code is then executed.

The AWS CDK automatically does this whenever it needs to run your app. However, it can be useful to compile manually to check for errors and to run tests. To compile your TypeScript app manually, issue `npm run build`. You may also issue `npm run watch` to enter watch mode, in which the TypeScript compiler automatically rebuilds your app whenever you save changes to a source file.

The [stacks \(p. 108\)](#) defined in your AWS CDK app can be synthesized and deployed individually or together using the commands below. Generally, you should be in your project's main directory when you issue them.

- `cdk synth`: Synthesizes a AWS CloudFormation template from one or more of the stacks in your AWS CDK app.
- `cdk deploy`: Deploys the resources defined by one or more of the stacks in your AWS CDK app to AWS.

You can specify the names of multiple stacks to be synthesized or deployed in a single command. If your app defines only one stack, you do not need to specify it.

```
cdk synth          # app defines single stack
cdk deploy Happy Grumpy  # app defines two or more stacks; two are deployed
```

You may also use the wildcards `*` (any number of characters) and `?` (any single character) to identify stacks by pattern. When using wildcards, enclose the pattern in quotes. Otherwise, the shell may try to expand it to the names of files in the current directory before they are passed to the AWS CDK Toolkit.

```
cdk synth "Stack?"    # Stack1, StackA, etc.  
cdk deploy "*Stack"   # PipeStack, LambdaStack, etc.
```

### Tip

You don't need to explicitly synthesize stacks before deploying them; `cdk deploy` performs this step for you to make sure your latest code gets deployed.

For full documentation of the `cdk` command, see [the section called “AWS CDK Toolkit” \(p. 309\)](#).

## Working with the AWS CDK in JavaScript

JavaScript is a fully-supported client language for the AWS CDK and is considered stable. Working with the AWS CDK in JavaScript uses familiar tools, including [Node.js](#) and the Node Package Manager (npm). You may also use [Yarn](#) if you prefer, though the examples in this Guide use NPM. The modules comprising the AWS Construct Library are distributed via the NPM repository, [npmjs.org](https://npmjs.org).

You can use any editor or IDE. Many AWS CDK developers use [Visual Studio Code](#) (or its open-source equivalent [VSCodium](#)), which has good support for JavaScript.

## Prerequisites

To work with the AWS CDK, you must have an AWS account and credentials and have installed Node.js and the AWS CDK Toolkit. See [AWS CDK Prerequisites \(p. 28\)](#).

JavaScript AWS CDK applications require no additional prerequisites beyond these.

### Note

Third-party language deprecation: language version is only supported until its EOL (End Of Life) shared by the vendor or community and is subject to change with prior notice.

## Creating a project

You create a new AWS CDK project by invoking `cdk init` in an empty directory.

```
mkdir my-project  
cd my-project  
cdk init app --language javascript
```

Creating a project also installs the [aws-cdk-lib](#) module and its dependencies.

`cdk init` uses the name of the project folder to name various elements of the project, including classes, subfolders, and files. Hyphens in the folder name are converted to underscores. However, the name should otherwise follow the form of a JavaScript identifier; for example, it should not start with a number or contain spaces.

## Using local cdk

For the most part, this guide assumes you install the CDK Toolkit globally (`npm install -g aws-cdk`), and the provided command examples (such as `cdk synth`) follow this assumption. This approach makes it easy to keep the CDK Toolkit up to date, and since the CDK takes a strict approach to backward compatibility, there is generally little risk in always using the latest version.

Some teams prefer to specify all dependencies within each project, including tools like the CDK Toolkit. This practice lets you pin such components to specific versions and ensure that all developers on your team (and your CI/CD environment) use exactly those versions. This eliminates a possible source of change, helping to make builds and deployments more consistent and repeatable.

The CDK includes a dependency for the CDK Toolkit in the JavaScript project template's `package.json`, so if you want to use this approach, you don't need to make any changes to your project. All you need to do is use slightly different commands for building your app and for issuing `cdk` commands.

Operation	Use global CDK Toolkit	Use local CDK Toolkit
Initialize project	<code>cdk init --language javascript</code>	<code>npx aws-cdk init --language javascript</code>
Run CDK Toolkit command	<code>cdk ...</code>	<code>npm run cdk ...</code> or <code>npx aws-cdk ...</code>

`npx aws-cdk` runs the version of the CDK Toolkit installed locally in the current project, if one exists, falling back to the global installation, if any. If no global installation exists, `npx` downloads a temporary copy of the CDK Toolkit and runs that. You may specify an arbitrary version of the CDK Toolkit using the `@` syntax: `npx aws-cdk@1.120 --version` prints `1.120.0`.

#### Tip

Set up an alias so you can use the `cdk` command with a local CDK Toolkit installation.

macOS/Linux

```
alias cdk="npx aws-cdk"
```

Windows

```
doskey cdk=npx aws-cdk $*
```

## Managing AWS Construct Library modules

Use the Node Package Manager (npm) to install and update AWS Construct Library modules for use by your apps, as well as other packages you need. (You may use `yarn` instead of `npm` if you prefer.) `npm` also installs the dependencies for those modules automatically.

Most AWS CDK constructs are in the main CDK package, named `aws-cdk-lib`, which is a default dependency in new projects created by `cdk init`. "Experimental" AWS Construct Library modules, where higher-level constructs are still under development, are named like `aws-cdk-lib/SERVICE-NAME-alpha`. The service name has an `aws-` prefix. If you're unsure of a module's name, [search for it on NPM](#).

#### Note

The [CDK API Reference](#) also shows the package names.

For example, the command below installs the experimental module for AWS CodeStar.

```
npm install @aws-cdk/aws-codestar-alpha
```

Some services' Construct Library support is in more than one namespace. For example, besides `aws-route53`, there are three additional Amazon Route 53 namespaces, `aws-route53-targets`, `aws-route53-patterns`, and `aws-route53resolver`.

Your project's dependencies are maintained in `package.json`. You can edit this file to lock some or all of your dependencies to a specific version or to allow them to be updated to newer versions under certain criteria. To update your project's NPM dependencies to the latest permitted version according to the rules you specified in `package.json`:

```
npm update
```

In JavaScript, you import modules into your code under the same name you use to install them using NPM. We recommend the following practices when importing AWS CDK classes and AWS Construct Library modules in your applications. Following these guidelines will help make your code consistent with other AWS CDK applications as well as easier to understand.

- Use `require()`, not ES6-style `import` directives. Older versions of Node.js do not support ES6 imports, so using the older syntax is more widely compatible. (If you really want to use ES6 imports, use [esm](#) to ensure your project is compatible with all supported versions of Node.js.)
- Generally, import individual classes from `aws-cdk-lib`.

```
const { App, Stack } = require('aws-cdk-lib');
```

- If you need many classes from `aws-cdk-lib`, you may use a namespace alias of `cdk` instead of importing the individual classes. Avoid doing both.

```
const cdk = require('aws-cdk-lib');
```

- Generally, import AWS Construct Libraries using short namespace aliases.

```
const { s3 } = require('aws-cdk-lib/aws-s3');
```

## AWS CDK idioms in JavaScript

### Props

All AWS Construct Library classes are instantiated using three arguments: the *scope* in which the construct is being defined (its parent in the construct tree), an *id*, and *props*, a bundle of key/value pairs that the construct uses to configure the AWS resources it creates. Other classes and methods also use the "bundle of attributes" pattern for arguments.

Using an IDE or editor that has good JavaScript autocomplete will help avoid misspelling property names. If a construct is expecting an `encryptionKeys` property, and you spell it `encryptionkeys`, when instantiating the construct, you haven't passed the value you intended. This can cause an error at synthesis time if the property is required, or cause the property to be silently ignored if it is optional. In the latter case, you may get a default behavior you intended to override. Take special care here.

When subclassing an AWS Construct Library class (or overriding a method that takes a props-like argument), you may want to accept additional properties for your own use. These values will be ignored by the parent class or overridden method, because they are never accessed in that code, so you can generally pass on all the props you received.

A future release of the AWS CDK could coincidentally add a new property with a name you used for your own property. Passing the value you receive up the inheritance chain can then cause unexpected behavior. It's safer to pass a shallow copy of the props you received with your property removed or set to `undefined`. For example:

```
super(scope, name, {...props, encryptionKeys: undefined});
```

Alternatively, name your properties so that it is clear that they belong to your construct. This way, it is unlikely they will collide with properties in future AWS CDK releases. If there are many of them, use a single appropriately-named object to hold them.

## Missing values

Missing values in an object (such as props) have the value undefined in JavaScript. The usual techniques apply for dealing with these. For example, a common idiom for accessing a property of a value that may be undefined is as follows:

```
// a may be undefined, but if it is not, it may have an attribute b
// c is undefined if a is undefined, OR if a doesn't have an attribute b
let c = a && a.b;
```

However, if a could have some other "falsy" value besides undefined, it is better to make the test more explicit. Here, we'll take advantage of the fact that null and undefined are equal to test for them both at once:

```
let c = a == null ? a : a.b;
```

### Tip

Node.js 14.0 and later support new operators that can simplify the handling of undefined values. For more information, see the [optional chaining](#) and [nullish coalescing](#) proposals.

## Synthesizing and deploying

The [stacks \(p. 108\)](#) defined in your AWS CDK app can be synthesized and deployed individually or together using the commands below. Generally, you should be in your project's main directory when you issue them.

- `cdk synth`: Synthesizes a AWS CloudFormation template from one or more of the stacks in your AWS CDK app.
- `cdk deploy`: Deploys the resources defined by one or more of the stacks in your AWS CDK app to AWS.

You can specify the names of multiple stacks to be synthesized or deployed in a single command. If your app defines only one stack, you do not need to specify it.

```
cdk synth                # app defines single stack
cdk deploy Happy Grumpy  # app defines two or more stacks; two are deployed
```

You may also use the wildcards `*` (any number of characters) and `?` (any single character) to identify stacks by pattern. When using wildcards, enclose the pattern in quotes. Otherwise, the shell may try to expand it to the names of files in the current directory before they are passed to the AWS CDK Toolkit.

```
cdk synth "Stack?"      # Stack1, StackA, etc.
cdk deploy "*Stack"     # PipeStack, LambdaStack, etc.
```

### Tip

You don't need to explicitly synthesize stacks before deploying them; `cdk deploy` performs this step for you to make sure your latest code gets deployed.

For full documentation of the `cdk` command, see [the section called "AWS CDK Toolkit" \(p. 309\)](#).

## Using TypeScript examples with JavaScript

[TypeScript](#) is the language we use to develop the AWS CDK, and it was the first language supported for developing applications, so many available AWS CDK code examples are written in TypeScript. These code examples can be a good resource for JavaScript developers; you just need to remove the TypeScript-specific parts of the code.

TypeScript snippets often use the newer ECMAScript `import` and `export` keywords to import objects from other modules and to declare the objects to be made available outside the current module. Node.js has just begun supporting these keywords in its latest releases. Depending on the version of Node.js you're using (or wish to support), you might rewrite imports and exports to use the older syntax.

Imports can be replaced with calls to the `require()` function.

### TypeScript

```
import * as cdk from 'aws-cdk-lib';
import { Bucket, BucketPolicy } from 'aws-cdk-lib/aws-s3';
```

### JavaScript

```
const cdk = require('aws-cdk-lib');
const { Bucket, BucketPolicy } = require('aws-cdk-lib/aws-s3');
```

Exports can be assigned to the `module.exports` object.

### TypeScript

```
export class Stack1 extends cdk.Stack {
  // ...
}

export class Stack2 extends cdk.Stack {
  // ...
}
```

### JavaScript

```
class Stack1 extends cdk.Stack {
  // ...
}

class Stack2 extends cdk.Stack {
  // ...
}

module.exports = { Stack1, Stack2 }
```

### Note

An alternative to using the old-style imports and exports is to use the [esm](#) module.

Once you've got the imports and exports sorted, you can dig into the actual code. You may run into these commonly-used TypeScript features:

- Type annotations
- Interface definitions

- Type conversions/casts
- Access modifiers

Type annotations may be provided for variables, class members, function parameters, and function return types. For variables, parameters, and members, types are specified by following the identifier with a colon and the type. Function return values follow the function signature and consist of a colon and the type.

To convert type-annotated code to JavaScript, remove the colon and the type. Class members must have some value in JavaScript; set them to `undefined` if they only have a type annotation in TypeScript.

#### TypeScript

```
var encrypted: boolean = true;

class myStack extends cdk.Stack {
    bucket: s3.Bucket;
    // ...
}

function makeEnv(account: string, region: string) : object {
    // ...
}
```

#### JavaScript

```
var encrypted = true;

class myStack extends cdk.Stack {
    bucket = undefined;
    // ...
}

function makeEnv(account, region) {
    // ...
}
```

In TypeScript, interfaces are used to give bundles of required and optional properties, and their types, a name. You can then use the interface name as a type annotation. TypeScript will make sure that the object you use as, for example, an argument to a function has the required properties of the right types.

```
interface myFuncProps {
    code: lambda.Code,
    handler?: string
}
```

JavaScript does not have an interface feature, so once you've removed the type annotations, delete the interface declarations entirely.

When a function or method returns a general-purpose type (such as `object`), but you want to treat that value as a more specific child type to access properties or methods that are not part of the more general type's interface, TypeScript lets you *cast* the value using `as` followed by a type or interface name. JavaScript doesn't support (or need) this, so simply remove `as` and the following identifier. A less-common cast syntax is to use a type name in brackets, `<LikeThis>`; these casts, too, must be removed.

Finally, TypeScript supports the access modifiers `public`, `protected`, and `private` for members of classes. All class members in JavaScript are public. Simply remove these modifiers wherever you see them.



Knowing how to identify and remove these TypeScript features goes a long way toward adapting short TypeScript snippets to JavaScript. But it may be impractical to convert longer TypeScript examples in this fashion, since they are more likely to use other TypeScript features. For these situations, we recommend [Sucrase](#). Sucrase won't complain if code uses an undefined variable, for example, as `tsc` would. If it is syntactically valid, then with few exceptions, Sucrase can translate it to JavaScript. This makes it particularly valuable for converting snippets that may not be runnable on their own.

## Migrating to TypeScript

Many JavaScript developers move to [TypeScript](#) as their projects get larger and more complex. TypeScript is a superset of JavaScript—all JavaScript code is valid TypeScript code, so no changes to your code are required—and it is also a supported AWS CDK language. Type annotations and other TypeScript features are optional and can be added to your AWS CDK app as you find value in them. TypeScript also gives you early access to new JavaScript features, such as optional chaining and nullish coalescing, before they're finalized—and without requiring that you upgrade Node.js.

TypeScript's "shape-based" interfaces, which define bundles of required and optional properties (and their types) within an object, allow common mistakes to be caught while you're writing the code, and make it easier for your IDE to provide robust autocomplete and other real-time coding advice.

Coding in TypeScript does involve an additional step: compiling your app with the TypeScript compiler, `tsc`. For typical AWS CDK apps, compilation requires a few seconds at most.

The easiest way to migrate an existing JavaScript AWS CDK app to TypeScript is to create a new TypeScript project using `cdk init app --language typescript`, then copy your source files (and any other necessary files, such as assets like AWS Lambda function source code) to the new project. Rename your JavaScript files to end in `.ts` and begin developing in TypeScript.

## Working with the AWS CDK in Python

Python is a fully-supported client language for the AWS CDK and is considered stable. Working with the AWS CDK in Python uses familiar tools, including the standard Python implementation (CPython), virtual environments with `virtualenv`, and the Python package installer `pip`. The modules comprising the AWS Construct Library are distributed via [pypi.org](#). The Python version of the AWS CDK even uses Python-style identifiers (for example, `snake_case` method names).

You can use any editor or IDE. Many AWS CDK developers use [Visual Studio Code](#) (or its open-source equivalent [VSCodium](#)), which has good support for Python via an [official extension](#). The IDLE editor included with Python will suffice to get started. The Python modules for the AWS CDK do have type hints, which are useful for a linting tool or an IDE that supports type validation.

## Prerequisites

To work with the AWS CDK, you must have an AWS account and credentials and have installed Node.js and the AWS CDK Toolkit. See [AWS CDK Prerequisites \(p. 28\)](#).

Python AWS CDK applications require Python 3.6 or later. If you don't already have it installed, [download a compatible version](#) for your operating system at [python.org](#). If you run Linux, your system may have come with a compatible version, or you may install it using your distro's package manager (`yum`, `apt`, etc.). Mac users may be interested in [Homebrew](#), a Linux-style package manager for macOS.

### Note

Third-party language deprecation: language version is only supported until its EOL (End Of Life) shared by the vendor or community and is subject to change with prior notice.

The Python package installer, `pip`, and virtual environment manager, `virtualenv`, are also required. Windows installations of compatible Python versions include these tools. On Linux, `pip` and `virtualenv` may be provided as separate packages in your package manager. Alternatively, you may install them with the following commands:

```
python -m ensurepip --upgrade
python -m pip install --upgrade pip
python -m pip install --upgrade virtualenv
```

If you encounter a permission error, run the above commands with the `--user` flag so that the modules are installed in your user directory, or use `sudo` to obtain the permissions to install the modules system-wide.

#### Note

It is common for Linux distros to use the executable name `python3` for Python 3.x, and have `python` refer to a Python 2.x installation. Some distros have an optional package you can install that makes the `python` command refer to Python 3. Failing that, you can adjust the command used to run your application by editing `cdk.json` in the project's main directory.

#### Note

On Windows, you may want to invoke Python (and **pip**) using the **py** executable, the [Python launcher for Windows](#). Among other things, the launcher allows you to easily specify which installed version of Python you want to use.

If typing **python** at the command line results in a message about installing Python from the Windows Store, even after installing a Windows version of Python, open Windows' Manage App Execution Aliases settings panel and turn off the two App Installer entries for Python.

## Creating a project

You create a new AWS CDK project by invoking `cdk init` in an empty directory.

```
mkdir my-project
cd my-project
cdk init app --language python
```

`cdk init` uses the name of the project folder to name various elements of the project, including classes, subfolders, and files. Hyphens in the folder name are converted to underscores. However, the name should otherwise follow the form of a Python identifier; for example, it should not start with a number or contain spaces.

To work with the new project, activate its virtual environment. This allows the project's dependencies to be installed locally in the project folder, instead of globally.

```
source .venv/bin/activate
```

#### Note

You may recognize this as the Mac/Linux command to activate a virtual environment. The Python templates include a batch file, `source.bat`, that allows the same command to be used on Windows. The traditional Windows command, `.venv\Scripts\activate.bat`, works, too. If you initialized your AWS CDK project using CDK Toolkit v1.70.0 or earlier, your virtual environment is in the `.env` directory instead of `.venv`.

#### Important

Activate the project's virtual environment whenever you start working on it. Otherwise, you won't have access to the modules installed there, and modules you install will go in the Python global module directory (or will result in a permission error).

After activating your virtual environment for the first time, install the app's standard dependencies:

```
python -m pip install -r requirements.txt
```

## Managing AWS Construct Library modules

Use the Python package installer, **pip**, to install and update AWS Construct Library modules for use by your apps, as well as other packages you need. **pip** also installs the dependencies for those modules automatically. If your system does not recognize **pip** as a standalone command, invoke **pip** as a Python module, like this:

```
python -m pip PIP-COMMAND
```

Most AWS CDK constructs are in `aws-cdk-lib`. Experimental modules are in separate modules named like `aws-cdk.SERVICE-NAME.alpha`. The service name includes an *aws* prefix. If you're unsure of a module's name, [search for it at PyPI](#). For example, the command below installs the AWS CodeStar library.

```
python -m pip install aws-cdk.aws-codestar-alpha
```

Some services' constructs are in more than one namespace. For example, besides `aws-cdk.aws-route53`, there are three additional Amazon Route 53 namespaces, named `aws-route53-targets`, `aws-route53-patterns`, and `aws-route53resolver`.

### Note

The [Python edition of the CDK API Reference](#) also shows the package names.

The names used for importing AWS Construct Library modules into your Python code look like the following.

```
import aws_cdk.aws_s3 as s3
import aws_cdk.aws_lambda as lambda_
```

We recommend the following practices when importing AWS CDK classes and AWS Construct Library modules in your applications. Following these guidelines will help make your code consistent with other AWS CDK applications as well as easier to understand.

- Generally, import individual classes from top-level `aws_cdk`.

```
from aws_cdk import App, Construct
```

- If you need many classes from the `aws_cdk`, you may use a namespace alias of `cdk` instead of importing individual classes. Avoid doing both.

```
import aws_cdk as cdk
```

- Generally, import AWS Construct Libraries using short namespace aliases.

```
import aws_cdk.aws_s3 as s3
```

After installing a module, update your project's `requirements.txt` file, which lists your project's dependencies. It is best to do this manually rather than using `pip freeze`. `pip freeze` captures the current versions of all modules installed in your Python virtual environment, which can be useful when bundling up a project to be run elsewhere.

Usually, though, your `requirements.txt` should list only top-level dependencies (modules that your app depends on directly) and not the dependencies of those libraries. This strategy makes updating your dependencies simpler.

You can edit `requirements.txt` to allow upgrades; simply replace the `==` preceding a version number with `~=` to allow upgrades to a higher compatible version, or remove the version requirement entirely to specify the latest available version of the module.

With `requirements.txt` edited appropriately to allow upgrades, issue this command to upgrade your project's installed modules at any time:

```
pip install --upgrade -r requirements.txt
```

## AWS CDK idioms in Python

### Language conflicts

In Python, `lambda` is a language keyword, so you cannot use it as a name for the AWS Lambda construct library module or Lambda functions. The Python convention for such conflicts is to use a trailing underscore, as in `lambda_`, in the variable name.

By convention, the second argument to AWS CDK constructs is named `id`. When writing your own stacks and constructs, calling a parameter `id` "shadows" the Python built-in function `id()`, which returns an object's unique identifier. This function isn't used very often, but if you should happen to need it in your construct, rename the argument, for example `construct_id`.

### Arguments and properties

All AWS Construct Library classes are instantiated using three arguments: the *scope* in which the construct is being defined (its parent in the construct tree), an *id*, and *props*, a bundle of key/value pairs that the construct uses to configure the resources it creates. Other classes and methods also use the "bundle of attributes" pattern for arguments.

*scope* and *id* should always be passed as positional arguments, not keyword arguments, because their names change if the construct accepts a property named *scope* or *id*.

In Python, *props* are expressed as keyword arguments. If an argument contains nested data structures, these are expressed using a class which takes its own keyword arguments at instantiation. The same pattern is applied to other method calls that take a structured argument.

For example, in a Amazon S3 bucket's `add_lifecycle_rule` method, the `transitions` property is a list of `Transition` instances.

```
bucket.add_lifecycle_rule(  
    transitions=[  
        Transition(  
            storage_class=StorageClass.GLACIER,  
            transition_after=Duration.days(10)  
        )  
    ]  
)
```

When extending a class or overriding a method, you may want to accept additional arguments for your own purposes that are not understood by the parent class. In this case you should accept the arguments you don't care about using the `**kwargs` idiom, and use keyword-only arguments to accept

the arguments you're interested in. When calling the parent's constructor or the overridden method, pass only the arguments it is expecting (often just `**kwargs`). Passing arguments that the parent class or method doesn't expect results in an error.

```
class MyConstruct(Construct):
    def __init__(self, id, *, MyProperty=42, **kwargs):
        super().__init__(self, id, **kwargs)
        # ...
```

A future release of the AWS CDK could coincidentally add a new property with a name you used for your own property. This won't cause any technical issues for users of your construct or method (since your property isn't passed "up the chain," the parent class or overridden method will simply use a default value) but it may cause confusion. You can avoid this potential problem by naming your properties so they clearly belong to your construct. If there are many new properties, bundle them into an appropriately-named class and pass it as a single keyword argument.

## Missing values

The AWS CDK uses `None` to represent missing or undefined values. When working with `**kwargs`, use the dictionary's `get()` method to provide a default value if a property is not provided. Avoid using `kwargs[...]`, as this raises `KeyError` for missing values.

```
encrypted = kwargs.get("encrypted")          # None if no property "encrypted" exists
encrypted = kwargs.get("encrypted", False)    # specify default of False if property is
missing
```

Some AWS CDK methods (such as `tryGetContext()` to get a runtime context value) may return `None`, which you will need to check explicitly.

## Using interfaces

Python doesn't have an interface feature as some other languages do, though it does have [abstract base classes](#), which are similar. (If you're not familiar with interfaces, Wikipedia has [a good introduction](#).) TypeScript, the language in which the AWS CDK is implemented, does provide interfaces, and constructs and other AWS CDK objects often require an object that adheres to a particular interface, rather than inheriting from a particular class. So the AWS CDK provides its own interface feature as part of the [JSII](#) layer.

To indicate that a class implements a particular interface, you can use the `@jsii.implements` decorator:

```
from aws_cdk import IAspect, IConstruct
import jsii

@jsii.implements(IAspect)
class MyAspect():
    def visit(self, node: IConstruct) -> None:
        print("Visited", node.node.path)
```

## Type pitfalls

Python uses dynamic typing, where all variables may refer to a value of any type. Parameters and return values may be annotated with types, but these are "hints" and are not enforced. This means that in Python, it is easy to pass the incorrect type of value to a AWS CDK construct. Instead of getting a type error during build, as you would from a statically-typed language, you may instead get a runtime error

when the JSII layer (which translates between Python and the AWS CDK's TypeScript core) is unable to deal with the unexpected type.

In our experience, the type errors Python programmers make tend to fall into these categories.

- Passing a single value where a construct expects a container (Python list or dictionary) or vice versa.
- Passing a value of a type associated with a layer 1 (CfnXxxxxx) construct to a L2 or L3 construct, or vice versa.

The AWS CDK Python modules do include type annotations, so you can use tools that support them to help with types. If you are not using an IDE that supports these, such as [PyCharm](#), you might want to call the [MyPy](#) type validator as a step in your build process. There are also runtime type checkers that can improve error messages for type-related errors.

## Synthesizing and deploying

The [stacks \(p. 108\)](#) defined in your AWS CDK app can be synthesized and deployed individually or together using the commands below. Generally, you should be in your project's main directory when you issue them.

- `cdk synth`: Synthesizes a AWS CloudFormation template from one or more of the stacks in your AWS CDK app.
- `cdk deploy`: Deploys the resources defined by one or more of the stacks in your AWS CDK app to AWS.

You can specify the names of multiple stacks to be synthesized or deployed in a single command. If your app defines only one stack, you do not need to specify it.

```
cdk synth          # app defines single stack
cdk deploy Happy Grumpy  # app defines two or more stacks; two are deployed
```

You may also use the wildcards `*` (any number of characters) and `?` (any single character) to identify stacks by pattern. When using wildcards, enclose the pattern in quotes. Otherwise, the shell may try to expand it to the names of files in the current directory before they are passed to the AWS CDK Toolkit.

```
cdk synth "Stack?"    # Stack1, StackA, etc.
cdk deploy "**Stack"   # PipeStack, LambdaStack, etc.
```

### Tip

You don't need to explicitly synthesize stacks before deploying them; `cdk deploy` performs this step for you to make sure your latest code gets deployed.

For full documentation of the `cdk` command, see [the section called “AWS CDK Toolkit” \(p. 309\)](#).

## Working with the AWS CDK in Java

Java is a fully-supported client language for the AWS CDK and is considered stable. You can develop AWS CDK applications in Java using familiar tools, including the JDK (Oracle's, or an OpenJDK distribution such as Amazon Corretto) and Apache Maven.

The AWS CDK supports Java 8 and later. We recommend using the latest version you can, however, because later versions of the language include improvements that are particularly convenient for

developing AWS CDK applications. For example, Java 9 introduces the `Map.of()` method (a convenient way to declare hashmaps that would be written as object literals in TypeScript). Java 10 introduces local type inference using the `var` keyword.

#### Note

Most code examples in this Developer Guide work with Java 8. A few examples use `Map.of()`; these examples include comments noting that they require Java 9.

You can use any text editor, or a Java IDE that can read Maven projects, to work on your AWS CDK apps. We provide [Eclipse](#) hints in this Guide, but IntelliJ IDEA, NetBeans, and other IDEs can import Maven projects and can be used for developing AWS CDK applications in Java.

It is possible to write AWS CDK applications in JVM-hosted languages other than Java (for example, Kotlin, Groovy, Clojure, or Scala), but the experience may not be particularly idiomatic, and we are unable to provide any support for these languages.

## Prerequisites

To work with the AWS CDK, you must have an AWS account and credentials and have installed Node.js and the AWS CDK Toolkit. See [AWS CDK Prerequisites \(p. 28\)](#).

Java AWS CDK applications require Java 8 (v1.8) or later. We recommend [Amazon Corretto](#), but you can use any OpenJDK distribution or [Oracle's JDK](#). You will also need [Apache Maven](#) 3.5 or later. You can also use tools such as Gradle, but the application skeletons generated by the AWS CDK Toolkit are Maven projects.

#### Note

Third-party language deprecation: language version is only supported until its EOL (End Of Life) shared by the vendor or community and is subject to change with prior notice.

## Creating a project

You create a new AWS CDK project by invoking `cdk init` in an empty directory.

```
mkdir my-project
cd my-project
cdk init app --language java
```

`cdk init` uses the name of the project folder to name various elements of the project, including classes, subfolders, and files. Hyphens in the folder name are converted to underscores. However, the name should otherwise follow the form of a Java identifier; for example, it should not start with a number or contain spaces.

The resulting project includes a reference to the `software.amazon.awscdk` Maven package. It and its dependencies are automatically installed by Maven.

If you are using an IDE, you can now open or import the project. In Eclipse, for example, choose **File > Import > Maven > Existing Maven Projects**. Make sure that the project settings are set to use Java 8 (1.8).

## Managing AWS Construct Library modules

Use Maven to install AWS Construct Library packages, which are in the group `software.amazon.awscdk`. Most constructs are in the artifact `aws-cdk-lib`, which is added to new Java projects by default. Modules for services whose higher-level CDK support is still being developed are in separate "experimental" packages, named with a short version (no AWS or Amazon prefix) of

their service's name. [Search the Maven Central Repository](#) to find the names of all AWS CDK and AWS Construct Module libraries.

#### Note

The [Java edition of the CDK API Reference](#) also shows the package names.

Some services' AWS Construct Library support is in more than one namespace. For example, Amazon Route 53 has its functionality divided into `software.amazon.awscdk.route53`, `route53-patterns`, `route53resolver`, and `route53-targets`.

The main AWS CDK package is imported in Java code as `software.amazon.awscdk`. Modules for the various services in the AWS Construct Library live under `software.amazon.awscdk.services` and are named similarly to their Maven package name. For example, the Amazon S3 module's namespace is `software.amazon.awscdk.services.s3`.

We recommend writing a separate Java `import` statement for each AWS Construct Library class you use in each of your Java source files, and avoiding wildcard imports. You can always use a type's fully-qualified name (including its namespace) without an `import` statement.

If your application depends on an experimental package, edit your project's `pom.xml` and add a new `<dependency>` element in the `<dependencies>` container. For example, the following `<dependency>` element specifies the CodeStar experimental construct library module:

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>codestar-alpha</artifactId>
  <version>2.0.0-alpha.10</version>
</dependency>
```

#### Tip

If you use a Java IDE, it probably has features for managing Maven dependencies. We recommend editing `pom.xml` directly, however, unless you are absolutely sure the IDE's functionality matches what you'd do by hand.

## AWS CDK idioms in Java

### Props

All AWS Construct Library classes are instantiated using three arguments: the *scope* in which the construct is being defined (its parent in the construct tree), an *id*, and *props*, a bundle of key/value pairs that the construct uses to configure the resources it creates. Other classes and methods also use the "bundle of attributes" pattern for arguments.

In Java, props are expressed using the [Builder pattern](#). Each construct type has a corresponding props type; for example, the `Bucket` construct (which represents an Amazon S3 bucket) takes as its props an instance of `BucketProps`.

The `BucketProps` class (like every AWS Construct Library props class) has an inner class called `Builder`. The `BucketProps.Builder` type offers methods to set the various properties of a `BucketProps` instance. Each method returns the `Builder` instance, so the method calls can be chained to set multiple properties. At the end of the chain, you call `build()` to actually produce the `BucketProps` object.

```
Bucket bucket = new Bucket(this, "MyBucket", new BucketProps.Builder()
    .versioned(true)
    .encryption(BucketEncryption.KMS_MANAGED)
    .build());
```



Constructs, and other classes that take a props-like object as their final argument, offer a shortcut. The class has a `Builder` of its own that instantiates it and its props object in one step. This way, you don't need to explicitly instantiate (for example) both `BucketProps` and a `Bucket`—and you don't need an import for the props type.

```
Bucket bucket = Bucket.Builder.create(this, "MyBucket")
    .versioned(true)
    .encryption(BucketEncryption.KMS_MANAGED)
    .build();
```

When deriving your own construct from an existing construct, you may want to accept additional properties. We recommend that you follow these builder patterns. However, this isn't as simple as subclassing a construct class. You must provide the moving parts of the two new `Builder` classes yourself. You may prefer to simply have your construct accept one or more additional arguments. You should provide additional constructors when an argument is optional.

## Generic structures

In some APIs, the AWS CDK uses JavaScript arrays or untyped objects as input to a method. (See, for example, AWS CodeBuild's [BuildSpec.fromObject\(\)](#) method.) In Java, these objects are represented as `java.util.Map<String, Object>`. In cases where the values are all strings, you can use `Map<String, String>`.

Java does not provide a way to write literals for such containers like some other languages do. In Java 9 and later, you can use [java.util.Map.of\(\)](#) to conveniently define maps of up to ten entries inline with one of these calls.

```
java.util.Map.of(
    "base-directory", "dist",
    "files", "LambdaStack.template.json"
)
```

To create maps with more than ten entries, use [java.util.Map.ofEntries\(\)](#).

If you are using Java 8, you could provide your own methods similar to these.

JavaScript arrays are represented as `List<Object>` or `List<String>` in Java. The method `java.util.Arrays.asList` is convenient for defining short Lists.

```
List<String> cmds = Arrays.asList("cd lambda", "npm install", "npm install typescript")
```

## Missing values

In Java, missing values in AWS CDK objects such as props are represented by `null`. You must explicitly test any value that could be `null` to make sure it contains a value before doing anything with it. Java does not have "syntactic sugar" to help handle null values as some other languages do. You may find Apache ObjectUtil's [defaultIfNull](#) and [firstNonNull](#) useful in some situations. Alternatively, write your own static helper methods to make it easier to handle potentially null values and make your code more readable.

## Building, synthesizing, and deploying

The AWS CDK automatically compiles your app before running it. However, it can be useful to build your app manually to check for errors and to run tests. You can do this in your IDE (for example, press Control-B in Eclipse) or by issuing `mvn compile` at a command prompt while in your project's root directory.

Run any tests you've written by running `mvn test` at a command prompt.

The [stacks \(p. 108\)](#) defined in your AWS CDK app can be synthesized and deployed individually or together using the commands below. Generally, you should be in your project's main directory when you issue them.

- `cdk synth`: Synthesizes a AWS CloudFormation template from one or more of the stacks in your AWS CDK app.
- `cdk deploy`: Deploys the resources defined by one or more of the stacks in your AWS CDK app to AWS.

You can specify the names of multiple stacks to be synthesized or deployed in a single command. If your app defines only one stack, you do not need to specify it.

```
cdk synth                # app defines single stack
cdk deploy Happy Grumpy # app defines two or more stacks; two are deployed
```

You may also use the wildcards `*` (any number of characters) and `?` (any single character) to identify stacks by pattern. When using wildcards, enclose the pattern in quotes. Otherwise, the shell may try to expand it to the names of files in the current directory before they are passed to the AWS CDK Toolkit.

```
cdk synth "Stack?"      # Stack1, StackA, etc.
cdk deploy "**Stack"     # PipeStack, LambdaStack, etc.
```

#### Tip

You don't need to explicitly synthesize stacks before deploying them; `cdk deploy` performs this step for you to make sure your latest code gets deployed.

For full documentation of the `cdk` command, see [the section called "AWS CDK Toolkit" \(p. 309\)](#).

## Working with the AWS CDK in C#

.NET is a fully-supported client language for the AWS CDK and is considered stable. C# is the main .NET language for which we provide examples and support. You can choose to write AWS CDK applications in other .NET languages, such as Visual Basic or F#, but AWS offers limited support for using these languages with the CDK.

You can develop AWS CDK applications in C# using familiar tools including Visual Studio, Visual Studio Code, the `dotnet` command, and the NuGet package manager. The modules comprising the AWS Construct Library are distributed via [nuget.org](https://nuget.org).

We suggest using [Visual Studio 2019](#) (any edition) on Windows to develop AWS CDK apps in C#.

## Prerequisites

To work with the AWS CDK, you must have an AWS account and credentials and have installed Node.js and the AWS CDK Toolkit. See [AWS CDK Prerequisites \(p. 28\)](#).

C# AWS CDK applications require .NET Core v3.1 or later, [available here](#).

#### Note

Third-party language deprecation: language version is only supported until its EOL (End Of Life) shared by the vendor or community and is subject to change with prior notice.

The .NET toolchain includes `dotnet`, a command-line tool for building and running .NET applications and managing NuGet packages. Even if you work mainly in Visual Studio, this command can be useful for batch operations and for installing AWS Construct Library packages.

## Creating a project

You create a new AWS CDK project by invoking `cdk init` in an empty directory.

```
mkdir my-project
cd my-project
cdk init app --language csharp
```

`cdk init` uses the name of the project folder to name various elements of the project, including classes, subfolders, and files. Hyphens in the folder name are converted to underscores. However, the name should otherwise follow the form of a C# identifier; for example, it should not start with a number or contain spaces.

The resulting project includes a reference to the `Amazon.CDK.Lib` NuGet package. It and its dependencies are installed automatically by NuGet.

## Managing AWS Construct Library modules

The .NET ecosystem uses the NuGet package manager. The main CDK package, which contains the core classes and all stable service constructs, is `Amazon.CDK.Lib`. Experimental modules, where new functionality is under active development, are named like `Amazon.CDK.AWS.SERVICE-NAME.Alpha`, where the service name is a short name without an AWS or Amazon prefix. For example, the NuGet package name for the AWS IoT module is `Amazon.CDK.AWS.IoT.Alpha`. If you can't find a package you want, [search Nuget.org](https://search.nuget.org).

### Note

The [.NET edition of the CDK API Reference](#) also shows the package names.

Some services' AWS Construct Library support is in more than one module. For example, AWS IoT has a second module named `Amazon.CDK.AWS.IoT.Actions.Alpha`.

The AWS CDK's main module, which you'll need in most AWS CDK apps, is imported in C# code as `Amazon.CDK`. Modules for the various services in the AWS Construct Library live under `Amazon.CDK.AWS`. For example, the Amazon S3 module's namespace is `Amazon.CDK.AWS.S3`.

We recommend writing C# using directives for the CDK core constructs and for each AWS service you use in each of your C# source files. You may find it convenient to use an alias for a namespace or type to help resolve name conflicts. You can always use a type's fully-qualified name (including its namespace) without a `using` statement.

NuGet has four standard, mostly-equivalent interfaces; you can use the one that suits your needs and working style. You can also use compatible tools, such as [Paket](#) or [MyGet](#).

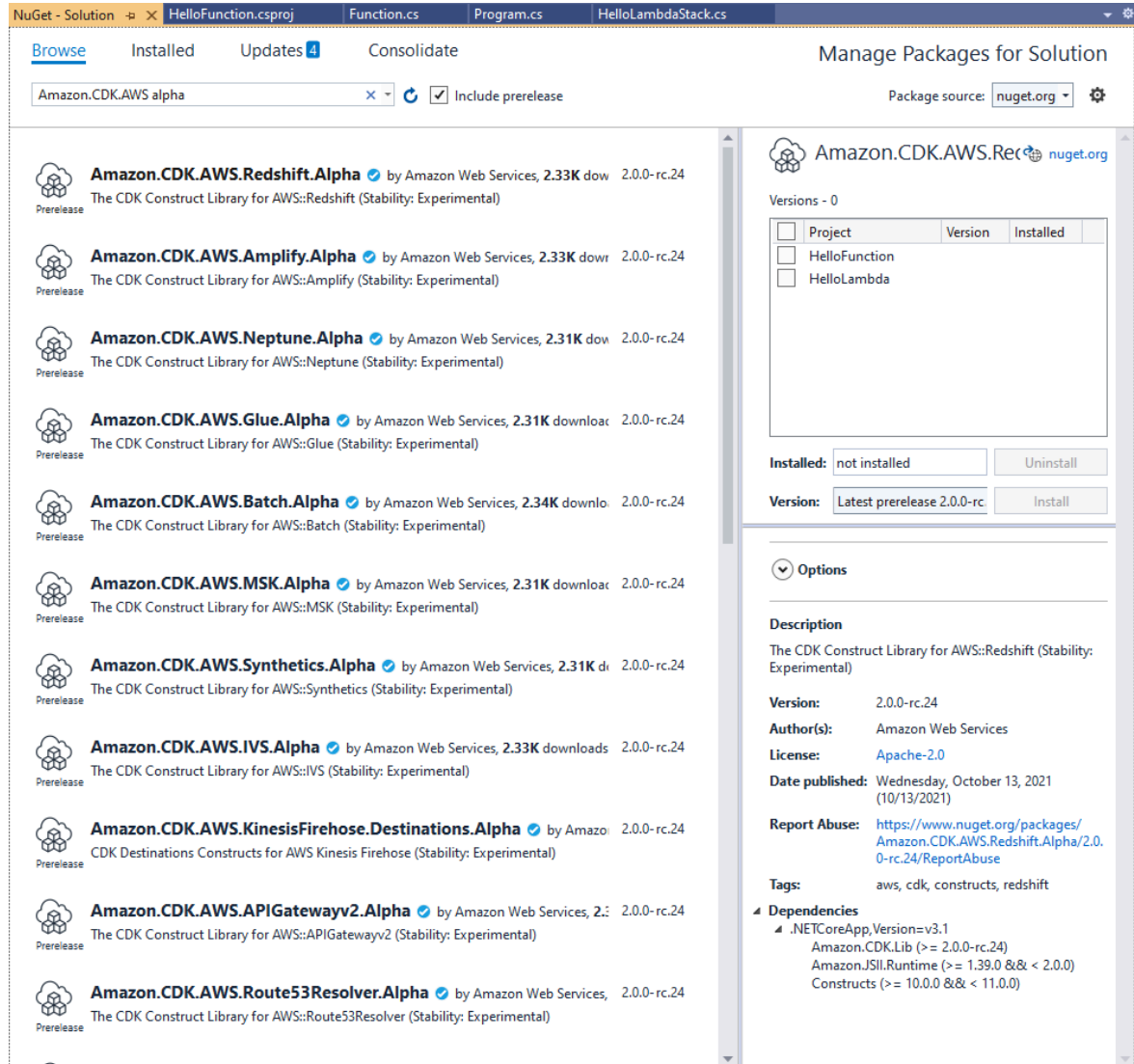
## The Visual Studio NuGet GUI

Visual Studio's NuGet tools are accessible from **Tools > NuGet Package Manager > Manage NuGet Packages for Solution**. Use the **Browse** tab to find the AWS Construct Library packages you want to install. You can choose the desired version, including pre-release versions of your modules and add them to any of the open projects.

### Note

All AWS Construct Library modules deemed "experimental" (see [the section called "Versioning" \(p. 229\)](#)) are flagged as pre-release in NuGet and have an `alpha` name suffix.

# AWS Cloud Development Kit (AWS CDK) v2 Developer Guide Managing AWS Construct Library modules



Look on the **Updates** page to install new versions of your packages.

## The NuGet console

The NuGet console is a PowerShell-based interface to NuGet that works in the context of a Visual Studio project. You can open it in Visual Studio by choosing **Tools > NuGet Package Manager > Package Manager Console**. For more information about using this tool, see [Install and Manage Packages with the Package Manager Console in Visual Studio](#).

## The dotnet command

The dotnet command is the primary command-line tool for working with Visual Studio C# projects. You can invoke it from any Windows command prompt. Among its many capabilities, dotnet can add NuGet dependencies to a Visual Studio project.

Assuming you're in the same directory as the Visual Studio project (.cspj) file, issue a command like the following to install a package. Note that since the main CDK library is included when you create a project, you should ever only need to explicitly install experimental modules. Experimental modules require you to specify an explicit version number.

```
dotnet add package Amazon.CDK.AWS.IoT.Alpha -v VERSION-NUMBER
```

You may issue the command from another directory by including the path to the project file, or to the directory that contains it, after the add keyword. The following example assumes that you are in your AWS CDK project's main directory.

```
dotnet add src/PROJECT-DIR package Amazon.CDK.AWS.IoT.Alpha -v VERSION-NUMBER
```

To install a specific version of a package, include the `-v` flag and the desired version.

To update a package, issue the same `dotnet add` command you used to install it. For experimental modules, again, you must specify an explicit version number.

For more information about managing packages using the `dotnet` command, see [Install and Manage Packages Using the dotnet CLI](#).

## The nuget command

The `nuget` command line tool can install and update NuGet packages. However, it requires your Visual Studio project to be set up differently from the way `cdk init` sets up projects. (Technical details: `nuget` works with `Packages.config` projects, while `cdk init` creates a newer-style `PackageReference` project.)

We do not recommend the use of the `nuget` tool with AWS CDK projects created by `cdk init`. If you are using another type of project, and want to use `nuget`, see the [NuGet CLI Reference](#).

## AWS CDK idioms in C#

### Props

All AWS Construct Library classes are instantiated using three arguments: the *scope* in which the construct is being defined (its parent in the construct tree), an *id*, and *props*, a bundle of key/value pairs that the construct uses to configure the resources it creates. Other classes and methods also use the "bundle of attributes" pattern for arguments.

In C#, props are expressed using a props type. In idiomatic C# fashion, we can use an object initializer to set the various properties. Here we're creating an Amazon S3 bucket using the `Bucket` construct; its corresponding props type is `BucketProps`.

```
var bucket = new Bucket(this, "MyBucket", new BucketProps {  
    Versioned = true  
});
```

#### Tip

Add the package `Amazon.JSII.Analyzers` to your project to get required-values checking in your props definitions inside Visual Studio.

When extending a class or overriding a method, you may want to accept additional props for your own purposes that are not understood by the parent class. To do this, subclass the appropriate props type and add the new attributes.

```
// extend BucketProps for use with MimeBucket  
class MimeBucketProps : BucketProps {  
    public string MimeType { get; set; }  
}
```

```
// hypothetical bucket that enforces MIME type of objects inside it
class MimeBucket : Bucket {
    public MimeBucket( readonly Construct scope, readonly string id, readonly
        MimeBucketProps props=null) : base(scope, id, props) {
        // ...
    }
}

// instantiate our MimeBucket class
var bucket = new MimeBucket(this, "MyBucket", new MimeBucketProps {
    Versioned = true,
    MimeType = "image/jpeg"
});
```

When calling the parent class's initializer or overridden method, you can generally pass the props you received. The new type is compatible with its parent, and extra props you added are ignored.

A future release of the AWS CDK could coincidentally add a new property with a name you used for your own property. This won't cause any technical issues using your construct or method (since your property isn't passed "up the chain," the parent class or overridden method will simply use a default value) but it may cause confusion for your construct's users. You can avoid this potential problem by naming your properties so they clearly belong to your construct. If there are many new properties, bundle them into an appropriately-named class and pass them as a single property.

## Generic structures

In some APIs, the AWS CDK uses JavaScript arrays or untyped objects as input to a method. (See, for example, AWS CodeBuild's [BuildSpec.fromObject\(\)](#) method.) In C#, these objects are represented as `System.Collections.Generic.Dictionary<String, Object>`. In cases where the values are all strings, you can use `Dictionary<String, String>`. JavaScript arrays are represented as `object[]` or `string[]` array types in C#.

### Tip

You might define short aliases to make it easier to work with these specific dictionary types.

```
using StringDict = System.Collections.Generic.Dictionary<string, string>;
using ObjectDict = System.Collections.Generic.Dictionary<string, object>;
```

## Missing values

In C#, missing values in AWS CDK objects such as props are represented by `null`. The null-conditional member access operator `?.` and the null coalescing operator `??` are convenient for working with these values.

```
// mimeType is null if props is null or if props.MimeType is null
string mimeType = props?.MimeType;

// mimeType defaults to text/plain. either props or props.MimeType can be null
string MimeType = props?.MimeType ?? "text/plain";
```

## Building, synthesizing, and deploying

The AWS CDK automatically compiles your app before running it. However, it can be useful to build your app manually to check for errors and run tests. You can do this by pressing F6 in Visual Studio or by issuing `dotnet build src` from the command line, where `src` is the directory in your project directory that contains the Visual Studio Solution (`.sln`) file.

The [stacks \(p. 108\)](#) defined in your AWS CDK app can be synthesized and deployed individually or together using the commands below. Generally, you should be in your project's main directory when you issue them.

- `cdk synth`: Synthesizes a AWS CloudFormation template from one or more of the stacks in your AWS CDK app.
- `cdk deploy`: Deploys the resources defined by one or more of the stacks in your AWS CDK app to AWS.

You can specify the names of multiple stacks to be synthesized or deployed in a single command. If your app defines only one stack, you do not need to specify it.

```
cdk synth                # app defines single stack
cdk deploy Happy Grumpy # app defines two or more stacks; two are deployed
```

You may also use the wildcards `*` (any number of characters) and `?` (any single character) to identify stacks by pattern. When using wildcards, enclose the pattern in quotes. Otherwise, the shell may try to expand it to the names of files in the current directory before they are passed to the AWS CDK Toolkit.

```
cdk synth "Stack?"      # Stack1, StackA, etc.
cdk deploy "**Stack"     # PipeStack, LambdaStack, etc.
```

#### Tip

You don't need to explicitly synthesize stacks before deploying them; `cdk deploy` performs this step for you to make sure your latest code gets deployed.

For full documentation of the `cdk` command, see [the section called "AWS CDK Toolkit" \(p. 309\)](#).

## Working with the AWS CDK in Go

Go is a fully-supported client language for the AWS CDK and is considered stable. Working with the AWS CDK in Go uses familiar tools. The Go version of the AWS CDK even uses Go-style identifiers.

Unlike the other languages the CDK supports, Go is not a traditional object-oriented programming language. Go uses composition where other languages often leverage inheritance. We have tried to employ idiomatic Go approaches as much as possible, but there are places where the CDK charts its own course.

This topic explains the ins and outs of working with the AWS CDK in Go. See the [announcement blog post](#) for a walkthrough of a simple Go project for the AWS CDK.

## Prerequisites

To work with the AWS CDK, you must have an AWS account and credentials and have installed Node.js and the AWS CDK Toolkit. See [AWS CDK Prerequisites \(p. 28\)](#).

The Go bindings for the AWS CDK use the standard [Go toolchain](#), v1.18 or later. You can use the editor of your choice.

#### Note

Third-party language deprecation: language version is only supported until its EOL (End Of Life) shared by the vendor or community and is subject to change with prior notice.

## Creating a project

You create a new AWS CDK project by invoking `cdk init` in an empty directory.



```
mkdir my-project
cd my-project
cdk init app --language go
```

`cdk init` uses the name of the project folder to name various elements of the project, including classes, subfolders, and files. Hyphens in the folder name are converted to underscores. However, the name should otherwise follow the form of a Go identifier; for example, it should not start with a number or contain spaces.

The resulting project includes a reference to the core AWS CDK Go module, `github.com/aws/aws-cdk-go/awscdk/v2`, in `go.mod`. Issue **go get** to install this and other required modules.

## Managing AWS Construct Library modules

In most AWS CDK documentation and examples, the word "module" is often used to refer to AWS Construct Library modules, one or more per AWS service, which differs from idiomatic Go usage of the term. The CDK Construct Library is provided in one Go module with the individual Construct Library modules, which support the various AWS services, provided as Go packages within that module.

Some services' AWS Construct Library support is in more than one Construct Library module (Go package). For example, Amazon Route 53 has three Construct Library modules in addition to the main `awsroute53` package, named `awsroute53patterns`, `awsroute53resolver`, and `awsroute53targets`.

The AWS CDK's core package, which you'll need in most AWS CDK apps, is imported in Go code as `github.com/aws/aws-cdk-go/awscdk/v2`. Packages for the various services in the AWS Construct Library live under `github.com/aws/aws-cdk-go/awscdk/v2`. For example, the Amazon S3 module's namespace is `github.com/aws/aws-cdk-go/awscdk/v2/awss3`.

```
import (
    "github.com/aws/aws-cdk-go/awscdk/v2/awss3"
    // ...
)
```

Once you have imported the Construct Library modules (Go packages) for the services you want to use in your app, you access constructs in that module using, for example, `awss3.Bucket`.

## AWS CDK idioms in Go

### Field and method names

Field and method names use camel casing (`likeThis`) in TypeScript, the CDK's language of origin. In Go, these follow Go conventions, so are Pascal-cased (`LikeThis`).

### Cleaning up

In your main method, use `defer jsii.Close()` to make sure your CDK app cleans up after itself.

### Missing values and pointer conversion

In Go, missing values in AWS CDK objects such as property bundles are represented by `nil`. Go doesn't have nullable types; the only type that can contain `nil` is a pointer. To allow values to be optional, then, all CDK properties, arguments, and return values are pointers, even for primitive types. This applies



to required values as well as optional ones, so if a required value later becomes optional, no breaking change in type is needed.

When passing literal values or expressions, use the following helper functions to create pointers to the values.

- `jsii.String`
- `jsii.Number`
- `jsii.Bool`
- `jsii.Time`

For consistency, we recommend that you use pointers similarly when defining your own constructs, even though it may seem more convenient to, for example, receive your construct's `id` as a string rather than a pointer to a string.

When dealing with optional AWS CDK values, including primitive values as well as complex types, you should explicitly test pointers to make sure they are not `nil` before doing anything with them. Go does not have "syntactic sugar" to help handle empty or missing values as some other languages do. However, required values in property bundles and similar structures are guaranteed to exist (construction fails otherwise), so these values need not be `nil`-checked.

## Constructs and Props

Constructs, which represent one or more AWS resources and their associated attributes, are represented in Go as interfaces. For example, `awss3.Bucket` is an interface. Every construct has a factory function, such as `awss3.NewBucket`, to return a struct that implements the corresponding interface.

All factory functions take three arguments: the scope in which the construct is being defined (its parent in the construct tree), an `id`, and `props`, a bundle of key/value pairs that the construct uses to configure the resources it creates. The "bundle of attributes" pattern is also used elsewhere in the AWS CDK.

In Go, `props` are represented by a specific struct type for each construct. For example, an `awss3.Bucket` takes a `props` argument of type `awss3.BucketProps`. Use a struct literal to write `props` arguments.

```
var bucket = awss3.NewBucket(stack, jsii.String("MyBucket"), &awss3.BucketProps{
    Versioned: jsii.Bool(true),
})
```

## Generic structures

In some places, the AWS CDK uses JavaScript arrays or untyped objects as input to a method. (See, for example, AWS CodeBuild's [BuildSpec.fromObject\(\)](#) method.) In Go, these objects are represented as slices and an empty interface, respectively.

The CDK provides variadic helper functions such as `jsii.Strings` for building slices containing primitive types.

```
jsii.Strings("One", "Two", "Three")
```

## Developing custom constructs

In Go, it is usually more straightforward to write a new construct than to extend an existing one. First, define a new struct type, anonymously embedding one or more existing types if extension-like semantics are desired. Write methods for any new functionality you're adding and the fields necessary to hold the

data they need. Define a props interface if your construct needs one. Finally, write a factory function `NewMyConstruct()` to return an instance of your construct.

If you are simply changing some default values on an existing construct or adding a simple behavior at instantiation, you don't need all that plumbing. Instead, write a factory function that calls the factory function of the construct you're "extending." In other CDK languages, for example, you might create a `TypedBucket` construct that enforces the type of objects in an Amazon S3 bucket by overriding the `s3.Bucket` type and, in your new type's initializer, adding a bucket policy that allows only specified filename extensions to be added to the bucket. In Go, it is easier to simply write a `NewTypedBucket` that returns an `s3.Bucket` (instantiated using `s3.NewBucket`) to which you have added an appropriate bucket policy. No new construct type is necessary because the functionality is already available in the standard bucket construct; the new "construct" just provides a simpler way to configure it.

## Building, synthesizing, and deploying

The AWS CDK automatically compiles your app before running it. However, it can be useful to build your app manually to check for errors and to run tests. You can do this by issuing `go build` at a command prompt while in your project's root directory.

Run any tests you've written by running `go test` at a command prompt.

The [stacks \(p. 108\)](#) defined in your AWS CDK app can be synthesized and deployed individually or together using the commands below. Generally, you should be in your project's main directory when you issue them.

- `cdk synth`: Synthesizes a AWS CloudFormation template from one or more of the stacks in your AWS CDK app.
- `cdk deploy`: Deploys the resources defined by one or more of the stacks in your AWS CDK app to AWS.

You can specify the names of multiple stacks to be synthesized or deployed in a single command. If your app defines only one stack, you do not need to specify it.

```
cdk synth                # app defines single stack
cdk deploy Happy Grumpy  # app defines two or more stacks; two are deployed
```

You may also use the wildcards `*` (any number of characters) and `?` (any single character) to identify stacks by pattern. When using wildcards, enclose the pattern in quotes. Otherwise, the shell may try to expand it to the names of files in the current directory before they are passed to the AWS CDK Toolkit.

```
cdk synth "Stack?"      # Stack1, StackA, etc.
cdk deploy "**Stack"     # PipeStack, LambdaStack, etc.
```

### Tip

You don't need to explicitly synthesize stacks before deploying them; `cdk deploy` performs this step for you to make sure your latest code gets deployed.

For full documentation of the `cdk` command, see [the section called "AWS CDK Toolkit" \(p. 309\)](#).

Typically, the CDK supports the language's standard or official package management tool, if there is one, or its most popular or widely supported one if not. You might also be able to use other tools, especially if they interoperate with the supported tools, although our ability to support alternatives is limited.

Language	Supported package management tool
TypeScript/JavaScript	NPM (Node Package Manager) or Yarn
Python	PIP (Package Installer for Python)
Java	Maven
C#	NuGet
Go	Go modules

The projects generated by **cdk init** specify dependencies for the CDK core libraries and stable constructs.

# TypeScript and JavaScript

When you install a package using **npm install**, NPM records it in `package.json` for you.

```
nodeLinker: node-modules
```

## Applications

```
{
  "name": "my-package",
```

```
"version": "0.1.0",
"bin": {
  "my-package": "bin/my-package.js"
},
"scripts": {
  "build": "tsc",
  "watch": "tsc -w",
  "test": "jest",
  "cdk": "cdk"
},
"devDependencies": {
  "@types/jest": "^26.0.10",
  "@types/node": "10.17.27",
  "jest": "^26.4.2",
  "ts-jest": "^26.2.0",
  "aws-cdk": "2.16.0",
  "ts-node": "^9.0.0",
  "typescript": "~3.9.7"
},
"dependencies": {
  "aws-cdk-lib": "2.16.0",
  "constructs": "^10.0.0",
  "source-map-support": "^0.5.16"
}
}
```

For deployable CDK apps, `aws-cdk-lib` must be specified in the `dependencies` section of `package.json`. You can use a caret (^) version number specifier to indicate that you will accept later versions than the one specified as long as they are within the same major version.

Specify exact versions for alpha construct library modules, which have APIs that may change. Do not use ^ or ~ since later versions of these modules may bring API changes that can break your app.

Specify versions of libraries and tools needed to test your app (for example, the `jest` testing framework) in the `devDependencies` section of `package.json`. Optionally, use ^ to specify that later compatible versions are acceptable.

## Construct libraries

If you're developing a construct library, specify its dependencies via a combination of the `peerDependencies` and `devDependencies` sections, as shown in the following example `package.json` file.

```
{
  "name": "my-package",
  "version": "0.0.1",
  "peerDependencies": {
    "aws-cdk-lib": "^2.14.0",
    "@aws-cdk/aws-appsync-alpha": "2.10.0-alpha",
    "constructs": "^10.0.0"
  },
  "devDependencies": {
    "aws-cdk-lib": "2.14.0",
    "@aws-cdk/aws-appsync-alpha": "2.10.0-alpha",
    "constructs": "10.0.0",
    "jsii": "^1.50.0",
    "aws-cdk": "^2.14.0"
  }
}
```

In `peerDependencies`, use a caret (^) to specify the lowest version of `aws-cdk-lib` that your library works with. This maximizes the compatibility of your library with a range of CDK versions.

Specify exact versions for alpha construct library modules, which have APIs that may change. Using `peerDependencies` makes sure that there is only one copy of all CDK libraries in the `node_modules` tree.

In `devDependencies`, specify the tools and libraries you need for testing, optionally with `^` to indicate that later compatible versions are acceptable. Specify exactly (without `^` or `~`) the lowest versions of `aws-cdk-lib` and other CDK packages that you advertise your library be compatible with. This practice makes sure that your tests run against those versions. This way, if you inadvertently use a feature found only in newer versions, your tests can catch it.

### Warning

`peerDependencies` are installed automatically only by NPM 7 and later. If you are using NPM 6 or earlier, or if you are using Yarn, you must include the dependencies of your dependencies in `devDependencies`. Otherwise, they won't be installed, and you will receive a warning about unresolved peer dependencies.

## Installing and updating dependencies

Run the following command to install your project's dependencies.

### NPM

```
# Install the latest version of everything that matches the ranges in 'package.json'
npm install

# Install the same exact dependency versions as recorded in 'package-lock.json'
npm ci
```

### Yarn

```
# Install the latest version of everything that matches the ranges in 'package.json'
yarn upgrade

# Install the same exact dependency versions as recorded in 'yarn.lock'
yarn install --frozen-lockfile
```

To update the installed modules, the preceding **`npm install`** and **`yarn upgrade`** commands can be used. Either command updates the packages in `node_modules` to the latest versions that satisfy the rules in `package.json`. However, they do not update `package.json` itself, which you might want to do to set a new minimum version. If you host your package on GitHub, you can configure [Dependabot version updates](#) to automatically update `package.json`. Alternatively, use [npm-check-updates](#).

### Important

By design, when you install or update dependencies, NPM and Yarn choose the latest version of every package that satisfies the requirements specified in `package.json`. There is always a risk that these versions may be broken (either accidentally or intentionally). Test thoroughly after updating your project's dependencies.

## Python

In Python, you specify dependencies by putting them in `requirements.txt` (for applications) or `setup.py` (for construct libraries). Dependencies are then managed with the PIP tool. PIP is invoked in one of the following ways:

```
pip command options
python -m pip command options
```

The **python -m pip** invocation works on most systems; **pip** requires that PIP's executable be on the system path. If **pip** doesn't work, try replacing it with **python -m pip**.

**cdk init --language python** creates a virtual environment for your new project. This lets each project have its own versions of dependencies, and also a basic `requirements.txt` file. You must activate this virtual environment (**source .venv/bin/activate**) each time you begin working with the project.

## Applications

An example `requirements.txt` follows. Because PIP does not have a dependency-locking feature, we recommend that you use the `==` operator to specify exact versions for all dependencies, as shown here.

```
aws-cdk-lib==2.14.0
aws-cdk.aws-appsync-alpha==2.10.0a0
```

Installing a module with **pip install** does not add it to `requirements.txt`; you should do that yourself. If you want to upgrade to a later version of a dependency, edit its version number in `requirements.txt`.

To install or update your project's dependencies after creating or editing `requirements.txt`, issue:

```
python -m pip install -r requirements.txt
```

### Tip

The **pip freeze** command outputs the versions of all installed dependencies in a format that can be written to a text file. This can be used as a requirements file with `pip install -r`. This file is convenient for pinning all dependencies (including transitive ones) to the exact versions that you tested with. To avoid problems when upgrading packages later, use a separate file for this, such as `freeze.txt` (not `requirements.txt`). Then, regenerate it when you upgrade your project's dependencies.

## Construct libraries

In libraries, dependencies are specified in `setup.py`, so that transitive dependencies are automatically downloaded when the package is consumed by an application. Otherwise, every application that wants to use your package needs to copy your dependencies into their `requirements.txt`. An example `setup.py` is shown here.

```
from setuptools import setup

setup(
    name='my-package',
    version='0.0.1',
    install_requires=[
        'aws-cdk-lib==2.14.0',
    ],
    ...
)
```

To work on the package for development, create or activate a virtual environment, then run the following command.

```
python -m pip install -e .
```

Although PIP automatically installs transitive dependencies, there can only be one installed copy of any one package. The version that is specified highest in the dependency tree is selected; applications always have the last word in what version of packages get installed.

## Java

In Java, dependencies are specified in `pom.xml` and installed using Maven. The `<dependencies>` container includes a `<dependency>` element for each package. Following is a section of `pom.xml` for a typical CDK Java app.

### Tip

Many Java IDEs have integrated Maven support and visual `pom.xml` editors, which you may find convenient for managing dependencies.

```
<dependencies>
  <dependency>
    <groupId>software.amazon.awscdk</groupId>
    <artifactId>aws-cdk-lib</artifactId>
    <version>2.14.0</version>
  </dependency>
  <dependency>
    <groupId>software.amazon.awscdk</groupId>
    <artifactId>appsync-alpha</artifactId>
    <version>2.10.0-alpha.0</version>
  </dependency>
</dependencies>
```

Maven does not support dependency locking. Although it's possible to specify version ranges in `pom.xml`, we recommend you always use exact versions to keep your builds repeatable.

Maven automatically installs transitive dependencies, but there can only be one installed copy of each package. The version that is specified highest in the POM tree is selected; applications always have the last word in what version of packages get installed.

Maven automatically installs or updates your dependencies whenever you build (**`mvn compile`**) or package (**`mvn package`**) your project. The CDK Toolkit does this automatically every time you run it, so generally there is no need to manually invoke Maven.

## C#

In C# AWS CDK apps, you manage dependencies using NuGet. NuGet has four standard, mostly equivalent interfaces; you can use the one that suits your needs and working style. You can also use compatible tools, such as [Paket](#) or [MyGet](#) or even edit the `.csproj` file directly.

NuGet does not let you specify version ranges for dependencies. Every dependency is pinned to a specific version.

After updating your dependencies, Visual Studio will use NuGet to retrieve the specified versions of each package the next time you build. If you are not using Visual Studio, use the **`dotnet restore`** command to update your dependencies.

## Editing the project file directly

Your project's `.csproj` file contains an `<ItemGroup>` container that lists your dependencies as `<PackageReference>` elements.

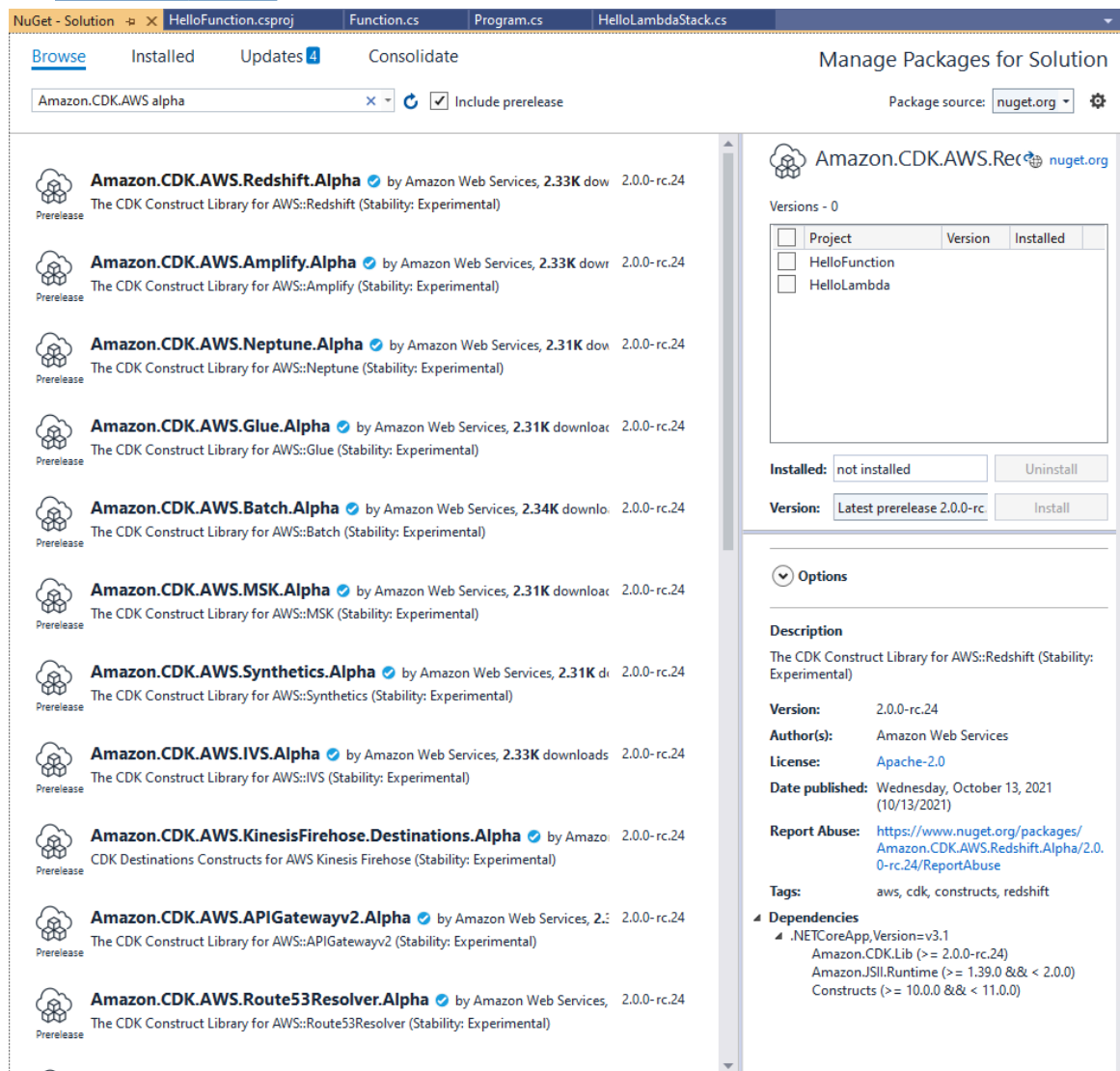
```
<ItemGroup>
  <PackageReference Include="Amazon.CDK.Lib" Version="2.14.0" />
  <PackageReference Include="Constructs" Version="%constructs-version%" />
</ItemGroup>
```

## The Visual Studio NuGet GUI

Visual Studio's NuGet tools are accessible from **Tools > NuGet Package Manager > Manage NuGet Packages for Solution**. Use the **Browse** tab to find the AWS Construct Library packages you want to install. You can choose the desired version, including prerelease versions of your modules, and add them to any of the open projects.

### Note

All AWS Construct Library modules deemed "experimental" (see [the section called "Versioning" \(p. 229\)](#)) are flagged as prerelease in NuGet and have an alpha name suffix.



Look on the **Updates** page to install new versions of your packages.

## The NuGet console

The NuGet console is a PowerShell-based interface to NuGet that works in the context of a Visual Studio project. You can open it in Visual Studio by choosing **Tools > NuGet Package Manager > Package Manager Console**. For more information about using this tool, see [Install and Manage Packages with the Package Manager Console in Visual Studio](#).



## The dotnet command

The dotnet command is the primary command line tool for working with Visual Studio C# projects. You can invoke it from any Windows command prompt. Among its many capabilities, dotnet can add NuGet dependencies to a Visual Studio project.

Assuming you're in the same directory as the Visual Studio project (.csproj) file, issue a command like the following to install a package. Because the main CDK library is included when you create a project, you only need to explicitly install experimental modules. Experimental modules require you to specify an explicit version number.

```
dotnet add package Amazon.CDK.AWS.IoT.Alpha -v VERSION-NUMBER
```

You can issue the command from another directory. To do so, include the path to the project file, or to the directory that contains it, after the add keyword. The following example assumes that you are in your AWS CDK project's main directory.

```
dotnet add src/PROJECT-DIR package Amazon.CDK.AWS.IoT.Alpha -v VERSION-NUMBER
```

To install a specific version of a package, include the -v flag and the desired version.

To update a package, issue the same dotnet add command you used to install it. For experimental modules, again, you must specify an explicit version number.

For more information about managing packages using the dotnet command, see [Install and Manage Packages Using the dotnet CLI](#).

## The nuget command

The nuget command line tool can install and update NuGet packages. However, it requires your Visual Studio project to be set up differently from the way cdk init sets up projects. (Technical details: nuget works with Packages.config projects, while cdk init creates a newer-style PackageReference project.)

We do not recommend the use of the nuget tool with AWS CDK projects created by cdk init. If you are using another type of project, and want to use nuget, see the [NuGet CLI Reference](#).

## Go

In Go, dependencies versions are defined in go.mod. The default go.mod is similar to the one shown here.

```
module my-package

go 1.16

require (
    github.com/aws/aws-cdk-go/awscdk/v2 v2.16.0
    github.com/aws/constructs-go/constructs/v10 v10.0.5
    github.com/aws/jsii-runtime-go v1.29.0
)
```

Package names (modules, in Go parlance) are specified by URL with the required version number appended. Go's module system does not support version ranges.

Issue the **go get** command to install all required modules and update `go.mod`. To see a list of available updates for your dependencies, issue **go list -m -u all**.

# Migrating to AWS CDK v2

Version 2 of the AWS Cloud Development Kit (AWS CDK) is designed to make writing infrastructure as code in your preferred programming language easier. This topic describes the changes between v1 and v2 of the AWS CDK.

## Tip

To identify stacks deployed with AWS CDK v1, use the [awscdk-v1-stack-finder](#) utility.

The main changes from AWS CDK v1 to CDK v2 are as follows.

- AWS CDK v2 consolidates the stable parts of the AWS Construct Library, including the core library, into a single package, `aws-cdk-lib`. Developers no longer need to install additional packages for the individual AWS services they use. This single-package approach also means that you don't have to synchronize the versions of the various CDK library packages.

L1 (CfnXXXX) constructs, which represent the exact resources available in AWS CloudFormation, are always considered stable and so are included in `aws-cdk-lib`.

- Experimental modules, where we're still working with the community to develop new [L2 or L3 constructs \(p. 84\)](#), are not included in `aws-cdk-lib`. Instead, they're distributed as individual packages. Experimental packages are named with an alpha suffix and a semantic version number. The semantic version number matches the first version of the AWS Construct Library that they're compatible with, also with an alpha suffix. Constructs move into `aws-cdk-lib` after being designated stable, permitting the main Construct Library to adhere to strict semantic versioning.

Stability is specified at the service level. For example, if we begin creating one or more [L2 constructs \(p. 84\)](#) for Amazon AppFlow, which at this writing has only L1 constructs, they first appear in a module named `@aws-cdk/aws-appflow-alpha`. Then, they move to `aws-cdk-lib` when we feel that the new constructs meet the fundamental needs of customers.

Once a module has been designated stable and incorporated into `aws-cdk-lib`, new APIs are added using the "BetaN" convention described in the next bullet.

A new version of each experimental module is released with every release of the AWS CDK. For the most part, however, they needn't be kept in sync. You can upgrade `aws-cdk-lib` or the experimental module whenever you want. The exception is that when two or more related experimental modules depend on each other, they must be the same version.

- For stable modules to which new functionality is being added, new APIs (whether entirely new constructs or new methods or properties on an existing construct) receive a `Beta1` suffix while work is in progress. (Followed by `Beta2`, `Beta3`, and so on when breaking changes are needed.) A version of the API without the suffix is added when the API is designated stable. All methods except the latest (whether beta or final) are then deprecated.

For example, if we add a new method `grantPower()` to a construct, it initially appears as `grantPowerBeta1()`. If breaking changes are needed (for example, a new required parameter or property), the next version of the method would be named `grantPowerBeta2()`, and so on. When work is complete and the API is finalized, the method `grantPower()` (with no suffix) is added, and the `BetaN` methods are deprecated.

All the beta APIs remain in the Construct Library until the next major version (3.0) release, and their signatures will not change. You'll see deprecation warnings if you use them, so you should move to the final version of the API at your earliest convenience. However, no future AWS CDK 2.x releases will break your application.

- The `Construct` class has been extracted from the AWS CDK into a separate library, along with related types. This is done to support efforts to apply the Construct Programming Model to other domains. If

you are writing your own constructs or using related APIs, you must declare the `constructs` module as a dependency and make minor changes to your imports. If you are using advanced features, such as hooking into the CDK app lifecycle, more changes may be needed. For full details, [see the RFC](#).

- Deprecated properties, methods, and types in AWS CDK v1.x and its Construct Library have been removed completely from the CDK v2 API. In most supported languages, these APIs produce warnings under v1.x, so you may have already migrated to the replacement APIs. A complete [list of deprecated APIs](#) in CDK v1.x is available on GitHub.
- Behavior that was gated by feature flags in AWS CDK v1.x is enabled by default in CDK v2. The earlier feature flags are no longer needed, and in most cases they're not supported. A few are still available to let you revert to CDK v1 behavior in very specific circumstances. For more information, see [the section called "Updating feature flags" \(p. 69\)](#).
- With CDK v2, the environments you deploy into must be bootstrapped using the modern bootstrap stack. The legacy bootstrap stack (the default under v1) is no longer supported. CDK v2 furthermore requires a new version of the modern stack. To upgrade your existing environments, re-bootstrap them. It is no longer necessary to set any feature flags or environment variables to use the modern bootstrap stack.

### Important

The modern bootstrap template effectively grants the permissions implied by the `--cloudformation-execution-policies` to any AWS account in the `--trust` list. By default, this extends permissions to read and write to any resource in the bootstrapped account. Make sure to [configure the bootstrapping stack \(p. 198\)](#) with policies and trusted accounts that you are comfortable with.

## New prerequisites

Most requirements for AWS CDK v2 are the same as for AWS CDK v1.x. Additional requirements are listed here.

- For TypeScript developers, TypeScript 3.8 or later is required.
- A new version of the CDK Toolkit is required for use with CDK v2. Now that CDK v2 is generally available, v2 is the default version when installing the CDK Toolkit. It is backward-compatible with CDK v1 projects, so you don't need to keep the earlier version installed unless you want to create CDK v1 projects. To upgrade, issue `npm install -g aws-cdk`.

## Upgrading from AWS CDK v2 Developer Preview

If you're using the CDK v2 Developer Preview, you have dependencies in your project on a Release Candidate version of the AWS CDK, such as `2.0.0-rc1`. Update these to `2.0.0`, then update the modules installed in your project.

TypeScript

```
npm install or yarn install
```

JavaScript

```
npm install or yarn install
```

Python

```
python -m pip install -r requirements.txt
```

#### Java

```
mvn package
```

#### C#

```
dotnet restore
```

#### Go

```
go get
```

After updating your dependencies, issue `npm update -g aws-cdk` to update the CDK Toolkit to the release version.

## Migrating from AWS CDK v1 to CDK v2

To migrate your app to AWS CDK v2, first update the feature flags in `cdk.json`. Then update your app's dependencies and imports as necessary for the programming language that it's written in.

### Updating to a recent v1

We are seeing a number of customers upgrading from an old version of AWS CDK v1 to the most recent version of v2 in one step. While it is certainly possible to do that, you would be both upgrading across multiple years of changes (that unfortunately may not all have had the same amount of evolution testing we have today), as well as upgrading across versions with new defaults and a different code organization.

For the safest upgrade experience and to more easily diagnose the sources of any unexpected changes, we recommend you separate those two steps: first upgrade to the latest v1 version, then make the switch to v2 afterwards.

### Updating feature flags

Remove the following v1 feature flags from `cdk.json` if they exist, as these are all active by default in AWS CDK v2. If their old effect is important for your infrastructure, you will need to make source code changes. See [the list of flags on GitHub](#) for more information.

- `@aws-cdk/core:enableStackNameDuplicates`
- `aws-cdk:enableDiffNoFail`
- `@aws-cdk/aws-ecr-assets:dockerIgnoreSupport`
- `@aws-cdk/aws-secretsmanager:parseOwnedSecretName`
- `@aws-cdk/aws-kms:defaultKeyPolicies`
- `@aws-cdk/aws-s3:grantWriteWithoutAcl`
- `@aws-cdk/aws-efs:defaultEncryptionAtRest`

A handful of v1 feature flags can be set to `false` in order to revert to specific AWS CDK v1 behaviors; see [the section called "Reverting to v1 behavior" \(p. 191\)](#) or the list on GitHub for a complete reference.

For both types of flags, use the `cdk diff` command to inspect the changes to your synthesized template to see if the changes to any of these flags affect your infrastructure.

## CDK Toolkit compatibility

CDK v2 requires v2 or later of the CDK Toolkit. This version is backward-compatible with CDK v1 apps. Therefore, you can use a single globally installed version of CDK Toolkit with all your AWS CDK projects, whether they use v1 or v2. An exception is that CDK Toolkit v2 only creates CDK v2 projects.

If you need to create both v1 and v2 CDK projects, **do not install CDK Toolkit v2 globally**. (Remove it if you already have it installed: `npm remove -g aws-cdk`.) To invoke the CDK Toolkit, use **npm** to run v1 or v2 of the CDK Toolkit as desired.

```
npx aws-cdk@1.x init app --language typescript
npx aws-cdk@2.x init app --language typescript
```

### Tip

Set up command line aliases so you can use the **cdk** and **cdk1** commands to invoke the desired version of the CDK Toolkit.

macOS/Linux

```
alias cdk1="npx aws-cdk@1.x"
alias cdk="npx aws-cdk@2.x"
```

Windows

```
doskey cdk1=npx aws-cdk@1.x $*
doskey cdk=npx aws-cdk@2.x $*
```

## Updating dependencies and imports

Update your app's dependencies, then install the new packages. Finally, update the imports in your code.

TypeScript

### Applications

For CDK apps, update `package.json` as follows. Remove dependencies on v1-style individual stable modules and establish the lowest version of `aws-cdk-lib` you require for your application (2.0.0 here).

Experimental constructs are provided in separate, independently versioned packages with names that end in `alpha` and an alpha version number. The alpha version number corresponds to the first release of `aws-cdk-lib` with which they're compatible. Here, we have pinned `aws-cdk-lib` to `v2.0.0-alpha.1`.

```
{
  "dependencies": {
    "aws-cdk-lib": "^2.0.0",
    "@aws-cdk/aws-codestar-alpha": "2.0.0-alpha.1",
    "constructs": "^10.0.0"
  }
}
```

## Construct libraries

For construct libraries, establish the lowest version of `aws-cdk-lib` you require for your application (2.0.0 here) and update `package.json` as follows.

Note that `aws-cdk-lib` appears both as a peer dependency and a dev dependency.

```
{
  "peerDependencies": {
    "aws-cdk-lib": "^2.0.0",
    "constructs": "^10.0.0"
  },
  "devDependencies": {
    "aws-cdk-lib": "^2.0.0",
    "constructs": "^10.0.0",
    "typescript": "~3.9.0"
  }
}
```

### Note

You should perform a major version bump on your library's version number when releasing a v2-compatible library, because this is a breaking change for library consumers. It is not possible to support both CDK v1 and v2 with a single library. To continue to support customers who are still using v1, you could maintain the earlier release in parallel, or create a new package for v2.

It's up to you how long you want to continue supporting AWS CDK v1 customers. You might take your cue from the lifecycle of CDK v1 itself, which entered maintenance on June 1, 2022 and will reach end-of-life on June 1, 2023. For full details, see [AWS CDK Maintenance Policy](#).

## Both libraries and apps

Install the new dependencies by running `npm install` or `yarn install`.

Change your imports to import `Construct` from the new `constructs` module, core types such as `App` and `Stack` from the top level of `aws-cdk-lib`, and stable `Construct Library` modules for the services you use from namespaces under `aws-cdk-lib`.

```
import { Construct } from 'constructs';
import { App, Stack } from 'aws-cdk-lib';           // core constructs
import { aws_s3 as s3 } from 'aws-cdk-lib';         // stable module
import * as codestar from '@aws-cdk/aws-codestar-alpha'; // experimental module
```

### JavaScript

Update `package.json` as follows. Remove dependencies on v1-style individual stable modules and establish the lowest version of `aws-cdk-lib` you require for your application (2.0.0 here).

Experimental constructs are provided in separate, independently versioned packages with names that end in `alpha` and an alpha version number. The alpha version number corresponds to the first release of `aws-cdk-lib` with which they're compatible. Here, we have pinned `aws-codestar` to `v2.0.0-alpha.1`.

```
{
  "dependencies": {
    "aws-cdk-lib": "^2.0.0",
    "@aws-cdk/aws-codestar-alpha": "2.0.0-alpha.1",
    "constructs": "^10.0.0"
  }
}
```

```
}
```

Install the new dependencies by running `npm install` or `yarn install`.

Change your app's imports to do the following:

- Import `Construct` from the new `constructs` module
- Import core types, such as `App` and `Stack`, from the top level of `aws-cdk-lib`
- Import AWS Construct Library modules from namespaces under `aws-cdk-lib`

```
const { Construct } = require('constructs');
const { App, Stack } = require('aws-cdk-lib');           // core constructs
const s3 = require('aws-cdk-lib').aws_s3;               // stable module
const codestar = require('@aws-cdk/aws-codestar-alpha'); // experimental module
```

## Python

Update `requirements.txt` or the `install_requires` definition in `setup.py` as follows.  
Remove dependencies on v1-style individual stable modules.

Experimental constructs are provided in separate, independently versioned packages with names that end in `alpha` and an alpha version number. The alpha version number corresponds to the first release of `aws-cdk-lib` with which they're compatible. Here, we have pinned `aws-codestar` to `v2.0.0alpha1`.

```
install_requires=[
    "aws-cdk-lib>=2.0.0",
    "constructs>=10.0.0",
    "aws-cdk.aws-codestar-alpha>=2.0.0alpha1",
    # ...
],
```

### Tip

Uninstall any other versions of AWS CDK modules already installed in your app's virtual environment using `pip uninstall`. Then install the new dependencies with `python -m pip install -r requirements.txt`.

Change your app's imports to do the following:

- Import `Construct` from the new `constructs` module
- Import core types, such as `App` and `Stack`, from the top level of `aws_cdk`
- Import AWS Construct Library modules from namespaces under `aws_cdk`

```
from constructs import Construct
from aws_cdk import App, Stack           # core constructs
from aws_cdk import aws_s3 as s3         # stable module
import aws_cdk.aws_codestar_alpha as codestar # experimental module

# ...

class MyConstruct(Construct):
    # ...

class MyStack(Stack):
    # ...
```



```
s3.Bucket(...)
```

## Java

In `pom.xml`, remove all `software.amazon.awscdk` dependencies for stable modules and replace them with dependencies on `software.constructs` (for `Construct`) and `software.amazon.awscdk`.

Experimental constructs are provided in separate, independently versioned packages with names that end in `alpha` and an `alpha` version number. The `alpha` version number corresponds to the first release of `aws-cdk-lib` with which they're compatible. Here, we have pinned `aws-codestar` to `v2.0.0-alpha.1`.

```
<dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>aws-cdk-lib</artifactId>
  <version>2.0.0</version>
</dependency><dependency>
  <groupId>software.amazon.awscdk</groupId>
  <artifactId>code-star-alpha</artifactId>
  <version>2.0.0-alpha.1</version>
</dependency>
<dependency>
  <groupId>software.constructs</groupId>
  <artifactId>constructs</artifactId>
  <version>10.0.0</version>
</dependency>
```

Install the new dependencies by running `mvn package`.

Change your code to do the following:

- Import `Construct` from the new `software.constructs` library
- Import core classes, like `Stack` and `App`, from `software.amazon.awscdk`
- Import service constructs from `software.amazon.awscdk.services`

```
import software.constructs.Construct;
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.amazon.awscdk.App;
import software.amazon.awscdk.services.s3.Bucket;
import software.amazon.awscdk.services.codestar.alpha.GitHubRepository;
```

## C#

The most straightforward way to upgrade the dependencies of a C# CDK application is to edit the `.csproj` file manually. Remove all stable `Amazon.CDK.*` package references and replace them with references to the `Amazon.CDK.Lib` and `Constructs` packages.

Experimental constructs are provided in separate, independently versioned packages with names that end in `alpha` and an `alpha` version number. The `alpha` version number corresponds to the first release of `aws-cdk-lib` with which they're compatible. Here, we have pinned `aws-codestar` to `v2.0.0-alpha.1`.

```
<PackageReference Include="Amazon.CDK.Lib" Version="2.0.0" />
<PackageReference Include="Amazon.CDK.AWS.Codestar.Alpha" Version="2.0.0-alpha.1" />
<PackageReference Include="Constructs" Version="10.0.0" />
```

Install the new dependencies by running `dotnet restore`.

Change the imports in your source files as follows.

```
using Constructs;                // for Construct class
using Amazon.CDK;                // for core classes like App and Stack
using Amazon.CDK.AWS.S3;         // for stable constructs like Bucket
using Amazon.CDK.CodeStar.Alpha; // for experimental constructs
```

Go

Issue **go get** to update your dependencies to the latest version and update your project's `.mod` file.

## Testing your migrated app before deploying

Before deploying your stacks, use `cdk diff` to check for unexpected changes to the resources. Changes to logical IDs (causing replacement of resources) are **not** expected.

Expected changes include but are not limited to:

- Changes to the `CDKMetadata` resource.
- Updated asset hashes.
- Changes related to the new-style stack synthesis. Applies if your app used the legacy stack synthesizer in v1. (CDK v2 does not support the legacy stack synthesizer.)
- The addition of a `CheckBootstrapVersion` rule.

Unexpected changes are typically not caused by upgrading to AWS CDK v2 in itself. Usually, they're the result of deprecated behavior that was previously changed by feature flags. This is a symptom of upgrading from a version of CDK earlier than about 1.85.x. You would see the same changes upgrading to the latest v1.x release. You can usually resolve this by doing the following:

1. Upgrade your app to the latest v1.x release
2. Remove feature flags
3. Revise your code as necessary
4. Deploy
5. Upgrade to v2

### Note

If your upgraded app is undeployable after the two-stage upgrade, [report the issue](#).

When you are ready to deploy the stacks in your app, consider deploying a copy first so you can test it. The easiest way to do this is to deploy it into a different Region. However, you can also change the IDs of your stacks. After testing, be sure to destroy the testing copy with **`cdk destroy`**.

## Troubleshooting

**TypeScript 'from' expected or ';' expected error in imports**

Upgrade to TypeScript 3.8 or later.

Run **`cdk bootstrap`**

If you see an error like the following:

```
# MyStack failed: Error: MyStack: SSM parameter /cdk-bootstrap/hnb659fds/version not
  found. Has the environment been bootstrapped? Please run 'cdk bootstrap' (see https://
docs.aws.amazon.com/cdk/latest/guide/bootstrapping.html)
    at CloudFormationDeployments.validateBootstrapStackVersion (.../aws-cdk/lib/api/
cloudformation-deployments.ts:323:13)
    at processTicksAndRejections (internal/process/task_queues.js:97:5)
MyStack: SSM parameter /cdk-bootstrap/hnb659fds/version not found. Has the environment
  been bootstrapped? Please run 'cdk bootstrap' (see https://docs.aws.amazon.com/cdk/latest/
guide/bootstrapping.html)
```

AWS CDK v2 requires an updated bootstrap stack, and furthermore, all v2 deployments require bootstrap resources. (With v1, you could deploy simple stacks without bootstrapping.) For complete details, see [the section called “Bootstrapping” \(p. 195\)](#).

## Finding v1 stacks

When migrating your CDK application from v1 to v2, you might want to identify the deployed AWS CloudFormation stacks that were created using v1. To do this, run the following command:

```
npx awscdk-v1-stack-finder
```

For usage details, see the awscdk-v1-stack-finder [README](#).

# Translating TypeScript AWS CDK code to other languages

TypeScript was the first language supported for developing AWS CDK applications. Therefore, a substantial amount of example CDK code is written in TypeScript. If you are developing in another language, it might be useful to compare how AWS CDK code is implemented in TypeScript and your language of choice. This can help you use these examples.

For more details on working with the AWS CDK in its supported programming languages, see:

- [the section called “In TypeScript” \(p. 31\)](#)
- [the section called “In JavaScript” \(p. 35\)](#)
- [the section called “In Python” \(p. 41\)](#)
- [the section called “In Java” \(p. 46\)](#)
- [the section called “In C#” \(p. 50\)](#)
- [the section called “In Go” \(p. 55\)](#)

## Importing a module

### TypeScript/JavaScript

TypeScript supports importing either an entire namespace, or individual objects from a namespace. Each namespace includes constructs and other classes for use with a given AWS service.

```
// Import main CDK library as cdk
import * as cdk from 'aws-cdk-lib'; // ES6 import preferred in TS
const cdk = require('aws-cdk-lib'); // Node.js require() preferred in JS

// Import specific core CDK classes
import { Stack, App } from 'aws-cdk-lib';
const { Stack, App } = require('aws-cdk-lib');

// Import AWS S3 namespace as s3 into current namespace
import { aws_s3 as s3 } from 'aws-cdk-lib'; // TypeScript
const s3 = require('aws-cdk-lib/aws-s3'); // JavaScript

// Having imported cdk already as above, this is also valid
const s3 = cdk.aws_s3;

// Now use s3 to access the S3 types
const bucket = s3.Bucket(...);

// Selective import of s3.Bucket
import { Bucket } from 'aws-cdk-lib/aws-s3'; // TypeScript
const { Bucket } = require('aws-cdk-lib/aws-s3'); // JavaScript

// Now use Bucket to instantiate an S3 bucket
const bucket = Bucket(...);
```

## Python

Like TypeScript, Python supports namespaced module imports and selective imports. Namespaces in Python look like `aws_cdk.xxx`, where `xxx` represents an AWS service name, such as `s3` for Amazon S3. (Amazon S3 is used in these examples).

```
# Import main CDK library as cdk
import aws_cdk as cdk

# Selective import of specific core classes
from aws_cdk import Stack, App

# Import entire module as s3 into current namespace
import aws_cdk.aws_s3 as s3

# s3 can now be used to access classes it contains
bucket = s3.Bucket(...)

# Selective import of s3.Bucket into current namespace
from aws_cdk.s3 import Bucket

# Bucket can now be used to instantiate a bucket
bucket = Bucket(...)
```

## Java

Java's imports work differently from TypeScript's. Each import statement imports either a single class name from a given package, or all classes defined in that package (using `*`). Classes may be accessed using either the class name by itself if it has been imported, or the *qualified* class name including its package.

Libraries are named like `software.amazon.awscdk.services.xxx` for the AWS Construct Library (the main library is `software.amazon.awscdk`). The Maven group ID for AWS CDK packages is `software.amazon.awscdk`.

```
// Make certain core classes available
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.App;

// Make all Amazon S3 construct library classes available
import software.amazon.awscdk.services.s3.*;

// Make only Bucket and EventType classes available
import software.amazon.awscdk.services.s3.Bucket;
import software.amazon.awscdk.services.s3.EventType;

// An imported class may now be accessed using the simple class name (assuming that
// name
// does not conflict with another class)
Bucket bucket = Bucket.Builder.create(...).build();

// We can always use the qualified name of a class (including its package) even without
// an
// import directive
software.amazon.awscdk.services.s3.Bucket bucket =
    software.amazon.awscdk.services.s3.Bucket.Builder.create(...)
        .build();

// Java 10 or later can use var keyword to avoid typing the type twice
var bucket =
    software.amazon.awscdk.services.s3.Bucket.Builder.create(...)
        .build();
```

## C#

In C#, you import types with the `using` directive. There are two styles. One gives you access to all the types in the specified namespace by using their plain names. With the other, you can refer to the namespace itself by using an alias.

Packages are named like `Amazon.CDK.AWS.xxx` for AWS Construct Library packages. (The core module is `Amazon.CDK`.)

```
// Make CDK base classes available under cdk
using cdk = Amazon.CDK;

// Make all Amazon S3 construct library classes available
using Amazon.CDK.AWS.S3;

// Now we can access any S3 type using its name
var bucket = new Bucket(...);

// Import the S3 namespace under an alias
using s3 = Amazon.CDK.AWS.S3;

// Now we can access an S3 type through the namespace alias
var bucket = new s3.Bucket(...);

// We can always use the qualified name of a type (including its namespace) even
// without a
// using directive
var bucket = new Amazon.CDK.AWS.S3.Bucket(...)
```

## Go

Each AWS Construct Library module is provided as a Go package.

```
import (
    "github.com/aws/aws-cdk-go/awscdk/v2"      // CDK core package
    "github.com/aws/aws-cdk-go/awscdk/v2/awss3" // AWS S3 construct library module
)

// now instantiate a bucket
bucket := awss3.NewBucket(...)

// use aliases for brevity/clarity
import (
    cdk "github.com/aws/aws-cdk-go/awscdk/v2"      // CDK core package
    s3 "github.com/aws/aws-cdk-go/awscdk/v2/awss3"  // AWS S3 construct library
    module
)

bucket := s3.NewBucket(...)
```

# Instantiating a construct

AWS CDK construct classes have the same name in all supported languages. Most languages use the `new` keyword to instantiate a class (Python and Go do not). Also, in most languages, the keyword `this` refers to the current instance. (Python uses `self` by convention.) You should pass a reference to the current instance as the `scope` parameter to every construct you create.

The third argument to an AWS CDK construct is `props`, an object containing attributes needed to build the construct. This argument may be optional, but when it is required, the supported languages handle

it in idiomatic ways. The names of the attributes are also adapted to the language's standard naming patterns.

### TypeScript/JavaScript

```
// Instantiate default Bucket
const bucket = new s3.Bucket(this, 'MyBucket');

// Instantiate Bucket with bucketName and versioned properties
const bucket = new s3.Bucket(this, 'MyBucket', {
  bucketName: 'my-bucket',
  versioned: true,
});

// Instantiate Bucket with websiteRedirect, which has its own sub-properties
const bucket = new s3.Bucket(this, 'MyBucket', {
  websiteRedirect: {host: 'aws.amazon.com'}});
```

### Python

Python doesn't use a new keyword when instantiating a class. The properties argument is represented using keyword arguments, and the arguments are named using `snake_case`.

If a props value is itself a bundle of attributes, it is represented by a class named after the property, which accepts keyword arguments for the subproperties.

In Python, the current instance is passed to methods as the first argument, which is named `self` by convention.

```
# Instantiate default Bucket
bucket = s3.Bucket(self, "MyBucket")

# Instantiate Bucket with bucket_name and versioned properties
bucket = s3.Bucket(self, "MyBucket", bucket_name="my-bucket", versioned=True)

# Instantiate Bucket with website_redirect, which has its own sub-properties
bucket = s3.Bucket(self, "MyBucket", website_redirect=s3.WebsiteRedirect(
    host_name="aws.amazon.com"))
```

### Java

In Java, the props argument is represented by a class named `XxxxProps` (for example, `BucketProps` for the `Bucket` construct's props). You build the props argument using a builder pattern.

Each `XxxxProps` class has a builder. There is also a convenient builder for each construct that builds the props and the construct in one step, as shown in the following example.

Props are named the same as in TypeScript, using `camelCase`.

```
// Instantiate default Bucket
Bucket bucket = Bucket(self, "MyBucket");

// Instantiate Bucket with bucketName and versioned properties
Bucket bucket = Bucket.Builder.create(self, "MyBucket")
    .bucketName("my-bucket").versioned(true)
    .build();

# Instantiate Bucket with websiteRedirect, which has its own sub-properties
```

```
Bucket bucket = Bucket.Builder.create(self, "MyBucket")
    .websiteRedirect(new websiteRedirect.Builder()
        .hostname("aws.amazon.com").build())
    .build();
```

## C#

In C#, props are specified using an object initializer to a class named `XxxxProps` (for example, `BucketProps` for the `Bucket` construct's props).

Props are named similarly to TypeScript, except using `PascalCase`.

It is convenient to use the `var` keyword when instantiating a construct, so you don't need to type the class name twice. However, your local code style guide may vary.

```
// Instantiate default Bucket
var bucket = Bucket(self, "MyBucket");

// Instantiate Bucket with BucketName and Versioned properties
var bucket = Bucket(self, "MyBucket", new BucketProps {
    BucketName = "my-bucket",
    Versioned = true});

// Instantiate Bucket with WebsiteRedirect, which has its own sub-properties
var bucket = Bucket(self, "MyBucket", new BucketProps {
    WebsiteRedirect = new WebsiteRedirect {
        HostName = "aws.amazon.com"
    }
});
```

## Go

To create a construct in Go, call the function `NewXxxxxxx` where `Xxxxxxx` is the name of the construct. The constructs' properties are defined as a struct.

In Go, all construct parameters are pointers, including values like numbers, Booleans, and strings. Use the convenience functions like `jsii.String` to create these pointers.

```
// Instantiate default Bucket
bucket := awss3.NewBucket(stack, jsii.String("MyBucket"), nil)

// Instantiate Bucket with BucketName and Versioned properties
bucket1 := awss3.NewBucket(stack, jsii.String("MyBucket"), &awss3.BucketProps{
    BucketName: jsii.String("my-bucket"),
    Versioned:  jsii.Bool(true),
})

// Instantiate Bucket with WebsiteRedirect, which has its own sub-properties
bucket2 := awss3.NewBucket(stack, jsii.String("MyBucket"), &awss3.BucketProps{
    WebsiteRedirect: &awss3.RedirectTarget{
        HostName: jsii.String("aws.amazon.com"),
    }
})
```

# Accessing members

It is common to refer to attributes or properties of constructs and other AWS CDK classes and use these values as, for example, inputs to build other constructs. The naming differences described previously for methods apply here also. Furthermore, in Java, it is not possible to access members directly. Instead, a getter method is provided.



### TypeScript/JavaScript

Names are camelCase.

```
bucket.bucketArn
```

### Python

Names are snake\_case.

```
bucket.bucket_arn
```

### Java

A getter method is provided for each property; these names are camelCase.

```
bucket.getBucketArn()
```

### C#

Names are PascalCase.

```
bucket.BucketArn
```

### Go

Names are PascalCase.

```
bucket.BucketArn
```

## Enum constants

Enum constants are scoped to a class, and have uppercase names with underscores in all languages (sometimes referred to as SCREAMING\_SNAKE\_CASE). Since class names also use the same casing in all supported languages except Go, qualified enum names are also the same in these languages.

```
s3.BucketEncryption.KMS_MANAGED
```

In Go, enum constants are attributes of the module namespace and are written as follows.

```
awss3.BucketEncryption_KMS_MANAGED
```

## Object interfaces

The AWS CDK uses TypeScript object interfaces to indicate that a class implements an expected set of methods and properties. You can recognize an object interface because its name starts with `I`. A concrete class indicates the interfaces that it implements by using the `implements` keyword.

## TypeScript/JavaScript

### Note

JavaScript doesn't have an interface feature. You can ignore the `implements` keyword and the class names following it.

```
import { IAspect, IConstruct } from 'aws-cdk-lib';

class MyAspect implements IAspect {
  public visit(node: IConstruct) {
    console.log('Visited', node.node.path);
  }
}
```

## Python

Python doesn't have an interface feature. However, for the AWS CDK you can indicate interface implementation by decorating your class with `@jsii.implements(interface)`.

```
from aws_cdk import IAspect, IConstruct
import jsii

@jsii.implements(IAspect)
class MyAspect():
    def visit(self, node: IConstruct) -> None:
        print("Visited", node.node.path)
```

## Java

```
import software.amazon.awscdk.IAspect;
import software.amazon.awscdk.IConstruct;

public class MyAspect implements IAspect {
    public void visit(IConstruct node) {
        System.out.format("Visited %s", node.getNode().getPath());
    }
}
```

## C#

```
using Amazon.CDK;

public class MyAspect : IAspect
{
    public void Visit(IConstruct node)
    {
        System.Console.WriteLine($"Visited ${node.Node.Path}");
    }
}
```

## Go

Go structs do not need to explicitly declare which interfaces they implement. The Go compiler determines implementation based on the methods and properties available on the structure. For example, in the following code, `MyAspect` implements the `IAspect` interface because it provides a `Visit` method that takes a `construct`.

```
type MyAspect struct {
}
```

```
func (a MyAspect) Visit(node constructs.IConstruct) {  
    fmt.Println("Visited", *node.Node().Path())  
}
```

# Concepts

This topic describes some of the concepts (the why and how) behind the AWS CDK. It also discusses the AWS Construct Library.

AWS CDK apps are composed of building blocks known as [Constructs \(p. 84\)](#), which are composed together to form [stacks](#) and [apps](#).

## Constructs

Constructs are the basic building blocks of AWS CDK apps. A construct represents a "cloud component" and encapsulates everything AWS CloudFormation needs to create the component.

### Note

Constructs are part of the Construct Programming Model (CPM). They're also used by other tools such as CDK for Terraform (CDKtf), CDK for Kubernetes (CDK8s), and Projen.

A construct can represent a single AWS resource, such as an Amazon Simple Storage Service (Amazon S3) bucket. A construct can also be a higher-level abstraction consisting of multiple related AWS resources. Examples of such components include a worker queue with its associated compute capacity, or a scheduled job with monitoring resources and a dashboard.

The AWS CDK includes a collection of constructs called the AWS Construct Library, containing constructs for every AWS service. [Construct Hub](#) is a resource to help you discover additional constructs from AWS, third parties, and the open-source CDK community.

### Important

In AWS CDK v1, the Construct base class was in the CDK core module. In CDK v2, there is a separate module called constructs that contains this class.

## AWS Construct library

The AWS CDK includes the [AWS Construct Library](#), which contains constructs representing AWS resources.

This library includes constructs that represent all the resources available on AWS. For example, the [s3.Bucket](#) class represents an Amazon S3 bucket, and the [dynamodb.Table](#) class represents an Amazon DynamoDB table.

### L1 constructs

There are three different levels of constructs in this library, beginning with low-level constructs, which we call *CFN Resources* (or **L1**, short for "layer 1"). These constructs directly represent all resources available in AWS CloudFormation. CFN Resources are periodically generated from the [AWS CloudFormation Resource Specification](#). They are named **CfnXyz**, where Xyz is name of the resource. For example, [CfnBucket](#) represents the [AWS::S3::Bucket](#) AWS CloudFormation resource. When you use Cfn resources, you must explicitly configure all resource properties. This requires a complete understanding of the details of the underlying AWS CloudFormation resource model.

### L2 constructs

The next level of constructs, **L2**, also represent AWS resources, but with a higher-level, intent-based API. They provide similar functionality, but incorporate the defaults, boilerplate, and glue logic you'd be writing yourself with a CFN Resource construct. AWS constructs offer convenient defaults and reduce

the need to know all the details about the AWS resources they represent. They also provide convenience methods that make it simpler to work with the resource. For example, the [s3.Bucket](#) class represents an Amazon S3 bucket with additional properties and methods, such as [bucket.addLifecycleRule\(\)](#), which adds a lifecycle rule to the bucket.

### L3 constructs

Finally, the AWS Construct Library includes **L3** constructs, which we call *patterns*. These constructs are designed to help you complete common tasks in AWS, often involving multiple kinds of resources. For example, the [aws-ecs-patterns.ApplicationLoadBalancedFargateService](#) construct represents an architecture that includes an AWS Fargate container cluster employing an Application Load Balancer. The [aws-apigateway.LambdaRestApi](#) construct represents an Amazon API Gateway API that's backed by an AWS Lambda function.

For more information about how to navigate the library and discover constructs that can help you build your apps, see the [API Reference](#).

## Composition

*Composition* is the key pattern for defining higher-level abstractions through constructs. A high-level construct can be composed from any number of lower-level constructs. In turn, those could be composed from even lower-level constructs, which eventually are composed from AWS resources.

From a bottom-up perspective, you use constructs to organize the individual AWS resources that you want to deploy. You use whatever abstractions are convenient for your purpose, with as many layers as you need.

Composition lets you define reusable components and share them like any other code. For example, a team can define a construct that implements the company's best practice for a DynamoDB table with backup, global replication, automatic scaling, and monitoring. The team can share the construct with other teams in their organization, or publicly.

Teams can use this construct in their preferred programming language like they would use any other library package to define their tables and comply with best practices. When the library is updated, developers will get access to the new version's bug fixes and improvements through the workflows they already have for their other types of code.

## Initialization

Constructs are implemented in classes that extend the [Construct](#) base class. You define a construct by instantiating the class. All constructs take three parameters when they are initialized:

- **scope** — The construct's parent or owner, either a stack or another construct, which determines its place in the [construct tree \(p. 102\)](#). You should usually pass `this` (or `self` in Python), which represents the current object, for the scope.
- **id** — An [identifier \(p. 141\)](#) that must be unique within this scope. The identifier serves as a namespace for everything that's defined within the current construct. It's used to generate unique identifiers such as [resource names \(p. 128\)](#) and AWS CloudFormation logical IDs.
- **props** — A set of properties or keyword arguments, depending upon the language, that define the construct's initial configuration. In most cases, constructs provide sensible defaults, and if all props elements are optional, you can omit the **props** parameter completely.

Identifiers need only be unique within a scope. This lets you instantiate and reuse constructs without concern for the constructs and identifiers they might contain, and enables composing constructs into higher-level abstractions. In addition, scopes make it possible to refer to groups of constructs all at once. Examples include for [tagging](#), or specifying where the constructs will be deployed.

## Apps and stacks

We call your CDK application an *app*, which is represented by the AWS CDK class [App](#). The following example defines an app with a single stack that contains a single Amazon S3 bucket with versioning enabled:

### TypeScript

```
import { App, Stack, StackProps } from 'aws-cdk-lib';
import * as s3 from 'aws-cdk-lib/aws-s3';

class HelloCdkStack extends Stack {
  constructor(scope: App, id: string, props?: StackProps) {
    super(scope, id, props);

    new s3.Bucket(this, 'MyFirstBucket', {
      versioned: true
    });
  }
}

const app = new App();
new HelloCdkStack(app, "HelloCdkStack");
```

### JavaScript

```
const { App, Stack } = require('aws-cdk-lib');
const s3 = require('aws-cdk-lib/aws-s3');

class HelloCdkStack extends Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    new s3.Bucket(this, 'MyFirstBucket', {
      versioned: true
    });
  }
}

const app = new App();
new HelloCdkStack(app, "HelloCdkStack");
```

### Python

```
from aws_cdk import App, Stack
import aws_cdk.aws_s3 as s3
from constructs import Construct

class HelloCdkStack(Stack):

    def __init__(self, scope: Construct, id: str, **kwargs) -> None:
        super().__init__(scope, id, **kwargs)

        s3.Bucket(self, "MyFirstBucket", versioned=True)

app = App()
HelloCdkStack(app, "HelloCdkStack")
```

### Java

```
import software.amazon.awscdk.*;
```

```
import software.amazon.awscdk.services.s3.*;

public class HelloCdkStack extends Stack {
    public HelloCdkStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public HelloCdkStack(final Construct scope, final String id, final StackProps
props) {
        super(scope, id, props);

        Bucket.Builder.create(this, "MyFirstBucket")
            .versioned(true).build();
    }
}
```

## C#

```
using Amazon.CDK;
using Amazon.CDK.AWS.S3;

namespace HelloCdkApp
{
    internal static class Program
    {
        public static void Main(string[] args)
        {
            var app = new App();
            new HelloCdkStack(app, "HelloCdkStack");
            app.Synth();
        }
    }

    public class HelloCdkStack : Stack
    {
        public HelloCdkStack(Construct scope, string id, IStackProps props=null) :
base(scope, id, props)
        {
            new Bucket(this, "MyFirstBucket", new BucketProps { Versioned = true });
        }
    }
}
```

## Go

```
func NewHelloCdkStack(scope constructs.Construct, id string, props *HelloCdkStackProps)
awsdk.Stack {
    var sprops awscdk.StackProps
    if props != nil {
        sprops = props.StackProps
    }
    stack := awscdk.NewStack(scope, &id, &sprops)

    awss3.NewBucket(stack, jsii.String("MyFirstBucket"), &awss3.BucketProps{
        Versioned: jsii.Bool(true),
    })

    return stack
}
```

As you can see, you need a scope within which to define your bucket. Resources eventually need to be deployed as part of an AWS CloudFormation stack into an AWS [environment \(p. 114\)](#). The environment

covers a specific AWS account and AWS Region. AWS constructs, such as `s3.Bucket`, must be defined within the scope of a [Stack](#).

Stacks in AWS CDK apps extend the **Stack** base class, as shown in the previous example. The following example is a common pattern when creating a stack within your AWS CDK app. It shows how to extend the **Stack** class, define a constructor that accepts **scope**, **id**, and **props**, and invoke the base class constructor via `super` with the received **scope**, **id**, and **props**.

#### TypeScript

```
class HelloCdkStack extends Stack {
  constructor(scope: App, id: string, props?: StackProps) {
    super(scope, id, props);

    //...
  }
}
```

#### JavaScript

```
class HelloCdkStack extends Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    //...
  }
}
```

#### Python

```
class HelloCdkStack(Stack):

    def __init__(self, scope: Construct, id: str, **kwargs) -> None:
        super().__init__(scope, id, **kwargs)

        # ...
```

#### Java

```
public class HelloCdkStack extends Stack {
    public HelloCdkStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public HelloCdkStack(final Construct scope, final String id, final StackProps
props) {
        super(scope, id, props);

        // ...
    }
}
```

#### C#

```
public class HelloCdkStack : Stack
{
    public HelloCdkStack(Construct scope, string id, IStackProps props=null) :
base(scope, id, props)
    {
        //...
    }
}
```



```
}
```

## Using L1 constructs

Once you have defined a stack, you can populate it with resources by instantiating constructs. First, we'll do it with an L1 construct.

L1 constructs are exactly the resources defined by AWS CloudFormation—no more, no less. You must provide the resource's required configuration yourself. Here, for example, is how to create an Amazon S3 bucket using the `CfnBucket` class. (You'll see a similar definition using the `Bucket` class in the next section.)

### TypeScript

```
const bucket = new s3.CfnBucket(this, "MyBucket", {  
  bucketName: "MyBucket"  
});
```

### JavaScript

```
const bucket = new s3.CfnBucket(this, "MyBucket", {  
  bucketName: "MyBucket"  
});
```

### Python

```
bucket = s3.CfnBucket(self, "MyBucket", bucket_name="MyBucket")
```

### Java

```
CfnBucket bucket = new CfnBucket.Builder().bucketName("MyBucket").build();
```

### C#

```
var bucket = new CfnBucket(this, "MyBucket", new CfnBucketProps  
{  
    BucketName= "MyBucket"  
});
```

### Go

```
awss3.NewCfnBucket(stack, jsii.String("MyBucket"), &awss3.CfnBucketProps{  
    BucketName: jsii.String("MyBucket"),  
})
```

Construct properties that aren't simple Booleans, strings, numbers, or containers are handled differently in the supported languages.

### TypeScript

```
const bucket = new s3.CfnBucket(this, "MyBucket", {  
  bucketName: "MyBucket",  
  corsConfiguration: {  
    corsRules: [{  
      allowedOrigins: ["*"],
```

```
        allowedMethods: ["GET"]
    }]
}
});
```

#### JavaScript

```
const bucket = new s3.CfnBucket(this, "MyBucket", {
  bucketName: "MyBucket",
  corsConfiguration: {
    corsRules: [{
      allowedOrigins: ["*"],
      allowedMethods: ["GET"]
    }]
  }
});
```

#### Python

In Python, these properties are represented by types defined as inner classes of the L1 construct. For example, the optional property `cors_configuration` of a `CfnBucket` requires a wrapper of type `CfnBucket.CorsConfigurationProperty`. Here we are defining `cors_configuration` on a `CfnBucket` instance.

```
bucket = CfnBucket(self, "MyBucket", bucket_name="MyBucket",
    cors_configuration=CfnBucket.CorsConfigurationProperty(
        cors_rules=[CfnBucket.CorsRuleProperty(
            allowed_origins=["*"],
            allowed_methods=["GET"]
        )]
    )
)
```

#### Java

In Java, these properties are represented by types defined as inner classes of the L1 construct. For example, the optional property `corsConfiguration` of a `CfnBucket` requires a wrapper of type `CfnBucket.CorsConfigurationProperty`. Here we are defining `corsConfiguration` on a `CfnBucket` instance.

```
CfnBucket bucket = CfnBucket.Builder.create(this, "MyBucket")
    .bucketName("MyBucket")
    .corsConfiguration(new
        CfnBucket.CorsConfigurationProperty.Builder()
            .corsRules(Arrays.asList(new
                CfnBucket.CorsRuleProperty.Builder()
                    .allowedOrigins(Arrays.asList("*"))
                    .allowedMethods(Arrays.asList("GET"))
                    .build())
            .build())
    .build();
```

#### C#

In C#, these properties are represented by types defined as inner classes of the L1 construct. For example, the optional property `CorsConfiguration` of a `CfnBucket` requires a wrapper of type `CfnBucket.CorsConfigurationProperty`. Here we are defining `CorsConfiguration` on a `CfnBucket` instance.

```
var bucket = new CfnBucket(this, "MyBucket", new CfnBucketProps
```

```
{
  BucketName = "MyBucket",
  CorsConfiguration = new CfnBucket.CorsConfigurationProperty
  {
    CorsRules = new object[] {
      new CfnBucket.CorsRuleProperty
      {
        AllowedOrigins = new string[] { "*" },
        AllowedMethods = new string[] { "GET" },
      }
    }
  }
};
```

#### Go

In Go, these types are named using the name of the L1 construct, an underscore, and the property name. For example, the optional property `CorsConfiguration` of a `CfnBucket` requires a wrapper of type `CfnBucket_CorsConfigurationProperty`. Here we are defining `CorsConfiguration` on a `CfnBucket` instance.

```
awss3.NewCfnBucket(stack, jsii.String("MyBucket"), &awss3.CfnBucketProps{
  BucketName: jsii.String("MyBucket"),
  CorsConfiguration: &awss3.CfnBucket_CorsConfigurationProperty{
    CorsRules: []awss3.CorsRule{
      awss3.CorsRule{
        AllowedOrigins: jsii.Strings("*"),
        AllowedMethods: &[]awss3.HttpMethods{"GET"},
      },
    },
  },
},
})
```

#### Important

You can't use L2 property types with L1 constructs, or vice versa. When working with L1 constructs, always use the types defined for the L1 construct you're using. Do not use types from other L1 constructs (some may have the same name, but they are not the same type). Some of our language-specific API references currently have errors in the paths to L1 property types, or don't document these classes at all. We hope to fix this soon. In the meantime, remember that such types are always inner classes of the L1 construct they are used with.

## Using L2 constructs

The following example defines an Amazon S3 bucket by creating an instance of the [Bucket](#) class, an L2 construct.

#### TypeScript

```
import * as s3 from 'aws-cdk-lib/aws-s3';

// "this" is HelloCdkStack
new s3.Bucket(this, 'MyFirstBucket', {
  versioned: true
});
```

#### JavaScript

```
const s3 = require('aws-cdk-lib/aws-s3');
```

```
// "this" is HelloCdkStack
new s3.Bucket(this, 'MyFirstBucket', {
  versioned: true
});
```

#### Python

```
import aws_cdk.aws_s3 as s3

# "self" is HelloCdkStack
s3.Bucket(self, "MyFirstBucket", versioned=True)
```

#### Java

```
import software.amazon.awscdk.services.s3.*;

public class HelloCdkStack extends Stack {
    public HelloCdkStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public HelloCdkStack(final Construct scope, final String id, final StackProps
props) {
        super(scope, id, props);

        Bucket.Builder.create(this, "MyFirstBucket")
            .versioned(true).build();
    }
}
```

#### C#

```
using Amazon.CDK.AWS.S3;

// "this" is HelloCdkStack
new Bucket(this, "MyFirstBucket", new BucketProps
{
    Versioned = true
});
```

#### Go

```
import (
    "github.com/aws/aws-cdk-go/awscdk/v2/awss3"
    "github.com/aws/jsii-runtime-go"
)

// stack is HelloCdkStack
awss3.NewBucket(stack, jsii.String("MyFirstBucket"), &awss3.BucketProps{
    Versioned: jsii.Bool(true),
})>
```

The [AWS Construct Library](#) includes constructs that represent many AWS resources.

#### Note

`MyFirstBucket` is not the name of the bucket that AWS CloudFormation creates. It is a logical identifier given to the new construct. See [Physical Names](#) for details.

## Configuration

Most constructs accept props as their third argument (or in Python, keyword arguments), a name/value collection that defines the construct's configuration. The following example defines a bucket with AWS Key Management Service (AWS KMS) encryption and static website hosting enabled. Since it does not explicitly specify an encryption key, the `Bucket` construct defines a new `kms.Key` and associates it with the bucket.

### TypeScript

```
new s3.Bucket(this, 'MyEncryptedBucket', {
  encryption: s3.BucketEncryption.KMS,
  websiteIndexDocument: 'index.html'
});
```

### JavaScript

```
new s3.Bucket(this, 'MyEncryptedBucket', {
  encryption: s3.BucketEncryption.KMS,
  websiteIndexDocument: 'index.html'
});
```

### Python

```
s3.Bucket(self, "MyEncryptedBucket", encryption=s3.BucketEncryption.KMS,
  website_index_document="index.html")
```

### Java

```
Bucket.Builder.create(this, "MyEncryptedBucket")
    .encryption(BucketEncryption.KMS_MANAGED)
    .websiteIndexDocument("index.html").build();
```

### C#

```
new Bucket(this, "MyEncryptedBucket", new BucketProps
{
    Encryption = BucketEncryption.KMS_MANAGED,
    WebsiteIndexDocument = "index.html"
});
```

### Go

```
awss3.NewBucket(stack, jsii.String("MyEncryptedBucket"), &awss3.BucketProps{
    Encryption: awss3.BucketEncryption_KMS,
    WebsiteIndexDocument: jsii.String("index.html"),
})
```

AWS constructs are designed around the concept of "sensible defaults." Most constructs have a minimal required configuration, enabling you to quickly get started while also providing full control over the configuration when you need it.

## Interacting with constructs

Constructs are classes that extend the base [Construct](#) class. After you instantiate a construct, the construct object exposes a set of methods and properties that let you interact with the construct and pass it around as a reference to other parts of the system.

The AWS CDK framework doesn't put any restrictions on the APIs of constructs. Authors can define any API they want. However, the AWS constructs that are included with the AWS Construct Library, such as `s3.Bucket`, follow guidelines and common patterns. This provides a consistent experience across all AWS resources.

Most AWS constructs have a set of [grant \(p. 178\)](#) methods that you can use to grant AWS Identity and Access Management (IAM) permissions on that construct to a principal. The following example grants the IAM group `data-science` permission to read from the Amazon S3 bucket `raw-data`.

### TypeScript

```
const rawData = new s3.Bucket(this, 'raw-data');
const dataScience = new iam.Group(this, 'data-science');
rawData.grantRead(dataScience);
```

### JavaScript

```
const rawData = new s3.Bucket(this, 'raw-data');
const dataScience = new iam.Group(this, 'data-science');
rawData.grantRead(dataScience);
```

### Python

```
raw_data = s3.Bucket(self, 'raw-data')
data_science = iam.Group(self, 'data-science')
raw_data.grant_read(data_science)
```

### Java

```
Bucket rawData = new Bucket(this, "raw-data");
Group dataScience = new Group(this, "data-science");
rawData.grantRead(dataScience);
```

### C#

```
var rawData = new Bucket(this, "raw-data");
var dataScience = new Group(this, "data-science");
rawData.GrantRead(dataScience);
```

### Go

```
rawData := awss3.NewBucket(stack, jsii.String("raw-data"), nil)
dataScience := awsiam.NewGroup(stack, jsii.String("data-science"), nil)
rawData.GrantRead(dataScience, nil)
```

Another common pattern is for AWS constructs to set one of the resource's attributes from data supplied elsewhere. Attributes can include Amazon Resource Names (ARNs), names, or URLs.

The following code defines an AWS Lambda function and associates it with an Amazon Simple Queue Service (Amazon SQS) queue through the queue's URL in an environment variable.

## TypeScript

```
const jobsQueue = new sqs.Queue(this, 'jobs');
const createJobLambda = new lambda.Function(this, 'create-job', {
  runtime: lambda.Runtime.NODEJS_18_X,
  handler: 'index.handler',
  code: lambda.Code.fromAsset('./create-job-lambda-code'),
  environment: {
    QUEUE_URL: jobsQueue.queueUrl
  }
});
```

## JavaScript

```
const jobsQueue = new sqs.Queue(this, 'jobs');
const createJobLambda = new lambda.Function(this, 'create-job', {
  runtime: lambda.Runtime.NODEJS_18_X,
  handler: 'index.handler',
  code: lambda.Code.fromAsset('./create-job-lambda-code'),
  environment: {
    QUEUE_URL: jobsQueue.queueUrl
  }
});
```

## Python

```
jobs_queue = sqs.Queue(self, "jobs")
create_job_lambda = lambda_.Function(self, "create-job",
    runtime=lambda_.Runtime.NODEJS_18_X,
    handler="index.handler",
    code=lambda_.Code.from_asset("./create-job-lambda-code"),
    environment=dict(
        QUEUE_URL=jobs_queue.queue_url
    )
)
```

## Java

```
final Queue jobsQueue = new Queue(this, "jobs");
Function createJobLambda = Function.Builder.create(this, "create-job")
    .handler("index.handler")
    .code(Code.fromAsset("./create-job-lambda-code"))
    .environment(java.util.Map.of( // Map.of is Java 9 or later
        "QUEUE_URL", jobsQueue.getQueueUrl()))
    .build();
```

## C#

```
var jobsQueue = new Queue(this, "jobs");
var createJobLambda = new Function(this, "create-job", new FunctionProps
{
    Runtime = Runtime.NODEJS_18_X,
    Handler = "index.handler",
    Code = Code.FromAsset(@".\create-job-lambda-code"),
    Environment = new Dictionary<string, string>
    {
        ["QUEUE_URL"] = jobsQueue.QueueUrl
    }
});
```

Go

```
createJobLambda := awslambda.NewFunction(stack, jsii.String("create-job"),
&awslambda.FunctionProps{
    Runtime: awslambda.Runtime_NODEJS_18_X(),
    Handler: jsii.String("index.handler"),
    Code:     awslambda.Code_FromAsset(jsii.String(".\\create-job-lambda-code"), nil),
    Environment: &map[string]*string{
        "QUEUE_URL": jsii.String(*jobsQueue.QueueUrl()),
    },
})
```

For information about the most common API patterns in the AWS Construct Library, see [the section called “Resources” \(p. 121\)](#).

## Writing your own constructs

In addition to using existing constructs like `s3.Bucket`, you can also write your own constructs, and then anyone can use them in their apps. All constructs are equal in the AWS CDK. An AWS CDK construct (such as `s3.Bucket` or `sns.Topic`) behaves the same as a construct from a third-party library published via NPM, Maven, or PyPI. Constructs published to your company's internal package repository also behave the same way.

To declare a new construct, create a class that extends the [Construct](#) base class, in the `constructs` package, then follow the pattern for initializer arguments.

The following example shows how to declare a construct that represents an Amazon S3 bucket. The S3 bucket sends an Amazon Simple Notification Service (Amazon SNS) notification every time someone uploads a file into it.

TypeScript

```
export interface NotifyingBucketProps {
    prefix?: string;
}

export class NotifyingBucket extends Construct {
    constructor(scope: Construct, id: string, props: NotifyingBucketProps = {}) {
        super(scope, id);
        const bucket = new s3.Bucket(this, 'bucket');
        const topic = new sns.Topic(this, 'topic');
        bucket.addObjectCreatedNotification(new s3notify.SnsDestination(topic),
            { prefix: props.prefix });
    }
}
```

JavaScript

```
class NotifyingBucket extends Construct {
    constructor(scope, id, props = {}) {
        super(scope, id);
        const bucket = new s3.Bucket(this, 'bucket');
        const topic = new sns.Topic(this, 'topic');
        bucket.addObjectCreatedNotification(new s3notify.SnsDestination(topic),
            { prefix: props.prefix });
    }
}

module.exports = { NotifyingBucket }
```



## Python

```
class NotifyingBucket(Construct):

    def __init__(self, scope: Construct, id: str, *, prefix=None):
        super().__init__(scope, id)
        bucket = s3.Bucket(self, "bucket")
        topic = sns.Topic(self, "topic")
        bucket.add_object_created_notification(s3notify.SnsDestination(topic),
                                              s3.NotificationKeyFilter(prefix=prefix))
```

## Java

```
public class NotifyingBucket extends Construct {

    public NotifyingBucket(final Construct scope, final String id) {
        this(scope, id, null, null);
    }

    public NotifyingBucket(final Construct scope, final String id, final BucketProps
props) {
        this(scope, id, props, null);
    }

    public NotifyingBucket(final Construct scope, final String id, final String prefix)
{
        this(scope, id, null, prefix);
    }

    public NotifyingBucket(final Construct scope, final String id, final BucketProps
props, final String prefix) {
        super(scope, id);

        Bucket bucket = new Bucket(this, "bucket");
        Topic topic = new Topic(this, "topic");
        if (prefix != null)
            bucket.addObjectCreatedNotification(new SnsDestination(topic),
                NotificationKeyFilter.builder().prefix(prefix).build());
    }
}
```

## C#

```
public class NotifyingBucketProps : BucketProps
{
    public string Prefix { get; set; }
}

public class NotifyingBucket : Construct
{
    public NotifyingBucket(Construct scope, string id, NotifyingBucketProps props =
null) : base(scope, id)
    {
        var bucket = new Bucket(this, "bucket");
        var topic = new Topic(this, "topic");
        bucket.AddObjectCreatedNotification(new SnsDestination(topic), new
NotificationKeyFilter
        {
            Prefix = props?.Prefix
        });
    }
}
```

## Go

```
type NotifyingBucketProps struct {
    awss3.BucketProps
    Prefix *string
}

func NewNotifyingBucket(scope constructs.Construct, id *string, props
    *NotifyingBucketProps) awss3.Bucket {
    var bucket awss3.Bucket
    if props == nil {
        bucket = awss3.NewBucket(scope, jsii.String(*id+"Bucket"), nil)
    } else {
        bucket = awss3.NewBucket(scope, jsii.String(*id+"Bucket"), &props.BucketProps)
    }
    topic := awssns.NewTopic(scope, jsii.String(*id+"Topic"), nil)
    if props == nil {
        bucket.AddObjectCreatedNotification(awss3notifications.NewSnsDestination(topic))
    } else {
        bucket.AddObjectCreatedNotification(awss3notifications.NewSnsDestination(topic),
        &awss3.NotificationKeyFilter{
            Prefix: props.Prefix,
        })
    }
    return bucket
}
```

### Note

Our `NotifyingBucket` construct inherits not from `Bucket` but rather from `Construct`. We are using composition, not inheritance, to bundle an Amazon S3 bucket and an Amazon SNS topic together. In general, composition is preferred over inheritance when developing AWS CDK constructs.

The `NotifyingBucket` constructor has a typical construct signature: `scope`, `id`, and `props`. The last argument, `props`, is optional (gets the default value `{}`) because all props are optional. (The base `Construct` class does not take a `props` argument.) You could define an instance of this construct in your app without props, for example:

## TypeScript

```
new NotifyingBucket(this, 'MyNotifyingBucket');
```

## JavaScript

```
new NotifyingBucket(this, 'MyNotifyingBucket');
```

## Python

```
NotifyingBucket(self, "MyNotifyingBucket")
```

## Java

```
new NotifyingBucket(this, "MyNotifyingBucket");
```

## C#

```
new NotifyingBucket(this, "MyNotifyingBucket");
```

## Go

```
NewNotifyingBucket(stack, jsii.String("MyNotifyingBucket"), nil)
```

Or you could use props (in Java, an additional parameter) to specify the path prefix to filter on, for example:

## TypeScript

```
new NotifyingBucket(this, 'MyNotifyingBucket', { prefix: 'images/' });
```

## JavaScript

```
new NotifyingBucket(this, 'MyNotifyingBucket', { prefix: 'images/' });
```

## Python

```
NotifyingBucket(self, "MyNotifyingBucket", prefix="images/")
```

## Java

```
new NotifyingBucket(this, "MyNotifyingBucket", "/images");
```

## C#

```
new NotifyingBucket(this, "MyNotifyingBucket", new NotifyingBucketProps  
{  
    Prefix = "/images"  
});
```

## Go

```
NewNotifyingBucket(stack, jsii.String("MyNotifyingBucket"), &NotifyingBucketProps{  
    Prefix: jsii.String("images/"),  
})
```

Typically, you would also want to expose some properties or methods on your constructs. It's not very useful to have a topic hidden behind your construct, because users of your construct aren't able to subscribe to it. Adding a topic property lets consumers access the inner topic, as shown in the following example:

## TypeScript

```
export class NotifyingBucket extends Construct {  
    public readonly topic: sns.Topic;  
  
    constructor(scope: Construct, id: string, props: NotifyingBucketProps) {  
        super(scope, id);  
        const bucket = new s3.Bucket(this, 'bucket');  
        this.topic = new sns.Topic(this, 'topic');  
        bucket.addObjectCreatedNotification(new s3notify.SnsDestination(this.topic),  
        { prefix: props.prefix });  
    }  
}
```

## JavaScript

```
class NotifyingBucket extends Construct {

  constructor(scope, id, props) {
    super(scope, id);
    const bucket = new s3.Bucket(this, 'bucket');
    this.topic = new sns.Topic(this, 'topic');
    bucket.addObjectCreatedNotification(new s3notify.SnsDestination(this.topic),
    { prefix: props.prefix });
  }
}

module.exports = { NotifyingBucket };
```

## Python

```
class NotifyingBucket(Construct):

    def __init__(self, scope: Construct, id: str, *, prefix=None, **kwargs):
        super().__init__(scope, id)
        bucket = s3.Bucket(self, "bucket")
        self.topic = sns.Topic(self, "topic")
        bucket.add_object_created_notification(s3notify.SnsDestination(self.topic),
        s3.NotificationKeyFilter(prefix=prefix))
```

## Java

```
public class NotifyingBucket extends Construct {

    public Topic topic = null;

    public NotifyingBucket(final Construct scope, final String id) {
        this(scope, id, null, null);
    }

    public NotifyingBucket(final Construct scope, final String id, final BucketProps
props) {
        this(scope, id, props, null);
    }

    public NotifyingBucket(final Construct scope, final String id, final String prefix)
{
        this(scope, id, null, prefix);
    }

    public NotifyingBucket(final Construct scope, final String id, final BucketProps
props, final String prefix) {
        super(scope, id);

        Bucket bucket = new Bucket(this, "bucket");
        topic = new Topic(this, "topic");
        if (prefix != null)
            bucket.addObjectCreatedNotification(new SnsDestination(topic),
            NotificationKeyFilter.builder().prefix(prefix).build());
    }
}
```

## C#

```
public class NotifyingBucket : Construct
{
```

```
    public readonly Topic topic;

    public NotifyingBucket(Construct scope, string id, NotifyingBucketProps props =
null) : base(scope, id)
    {
        var bucket = new Bucket(this, "bucket");
        topic = new Topic(this, "topic");
        bucket.AddObjectCreatedNotification(new SnsDestination(topic), new
NotificationKeyFilter
        {
            Prefix = props?.Prefix
        });
    }
}
```

## Go

To do this in Go, we'll need a little extra plumbing. Our original `NewNotifyingBucket` function returned an `awss3.Bucket`. We'll need to extend `Bucket` to include a `topic` member by creating a `NotifyingBucket` struct. Our function will then return this type.

```
type NotifyingBucket struct {
    awss3.Bucket
    topic awssns.Topic
}

func NewNotifyingBucket(scope constructs.Construct, id *string, props
*NotifyingBucketProps) NotifyingBucket {
    var bucket awss3.Bucket
    if props == nil {
        bucket = awss3.NewBucket(scope, jsii.String(*id+"Bucket"), nil)
    } else {
        bucket = awss3.NewBucket(scope, jsii.String(*id+"Bucket"), &props.BucketProps)
    }
    topic := awssns.NewTopic(scope, jsii.String(*id+"Topic"), nil)
    if props == nil {
        bucket.AddObjectCreatedNotification(awss3notifications.NewSnsDestination(topic))
    } else {
        bucket.AddObjectCreatedNotification(awss3notifications.NewSnsDestination(topic),
&awss3.NotificationKeyFilter{
            Prefix: props.Prefix,
        })
    }
    var nbucket NotifyingBucket
    nbucket.Bucket = bucket
    nbucket.topic = topic
    return nbucket
}
```

Now, consumers can subscribe to the topic, for example:

## TypeScript

```
const queue = new sqs.Queue(this, 'NewImagesQueue');
const images = new NotifyingBucket(this, '/images');
images.topic.addSubscription(new sns_sub.SqsSubscription(queue));
```

## JavaScript

```
const queue = new sqs.Queue(this, 'NewImagesQueue');
const images = new NotifyingBucket(this, '/images');
```

```
images.topic.addSubscription(new sns_sub.SqsSubscription(queue));
```

#### Python

```
queue = sqs.Queue(self, "NewImagesQueue")
images = NotifyingBucket(self, prefix="Images")
images.topic.add_subscription(sns_sub.SqsSubscription(queue))
```

#### Java

```
NotifyingBucket images = new NotifyingBucket(this, "MyNotifyingBucket", "/images");
images.topic.addSubscription(new SqsSubscription(queue));
```

#### C#

```
var queue = new Queue(this, "NewImagesQueue");
var images = new NotifyingBucket(this, "MyNotifyingBucket", new NotifyingBucketProps
{
    Prefix = "/images"
});
images.topic.AddSubscription(new SqsSubscription(queue));
```

#### Go

```
queue := awssqs.NewQueue(stack, jsii.String("NewImagesQueue"), nil)
images := NewNotifyingBucket(stack, jsii.String("MyNotifyingBucket"),
    &NotifyingBucketProps{
        Prefix: jsii.String("/images"),
    })
images.topic.AddSubscription(awssnssubscriptions.NewSqsSubscription(queue, nil))
```

## The construct tree

As we've already seen, in AWS CDK apps, you define constructs "inside" other constructs using the scope argument passed to every construct. In this way, an AWS CDK app defines a hierarchy of constructs known as the *construct tree*.

The root of this tree is your app—that is, an instance of the App class. Within the app, you instantiate one or more stacks. Within stacks, you instantiate either AWS CloudFormation resources or higher-level constructs, which may themselves instantiate resources or other constructs, and so on down the tree.

Constructs are *always* explicitly defined within the scope of another construct, so there is no doubt about the relationships between constructs. Almost always, you should pass `this` (in Python, `self`) as the scope, indicating that the new construct is a child of the current construct. The intended pattern is that you derive your construct from [Construct](#), then instantiate the constructs it uses in its constructor.

Passing the scope explicitly allows each construct to add itself to the tree, with this behavior entirely contained within the [Construct base class](#). It works the same way in every language supported by the AWS CDK and does not require introspection or other "magic."

#### Important

Technically, it's possible to pass some scope other than `this` when instantiating a construct. You can add constructs anywhere in the tree, or even in another stack in the same app. For example, you could write a mixin-style function that adds constructs to a scope passed in as an argument. The practical difficulty here is that you can't easily ensure that the IDs you choose for

your constructs are unique within someone else's scope. The practice also makes your code more difficult to understand, maintain, and reuse. It is almost always better to find a way to express your intent without resorting to abusing the scope argument.

The AWS CDK uses the IDs of all constructs in the path from the tree's root to each child construct to generate the unique IDs required by AWS CloudFormation. This approach means that construct IDs only need to be unique within their scope, rather than within the entire stack as in native AWS CloudFormation. However, if you move a construct to a different scope, its generated stack-unique ID changes, and AWS CloudFormation won't consider it the same resource.

The construct tree is separate from the constructs that you define in your AWS CDK code. However, it's accessible through any construct's `node` attribute, which is a reference to the node that represents that construct in the tree. Each node is a [Node](#) instance, the attributes of which provide access to the tree's root and to the node's parent scopes and children.

- `node.children` – The direct children of the construct.
- `node.id` – The identifier of the construct within its scope.
- `node.path` – The full path of the construct including the IDs of all of its parents.
- `node.root` – The root of the construct tree (the app).
- `node.scope` – The scope (parent) of the construct, or undefined if the node is the root.
- `node.scopes` – All parents of the construct, up to the root.
- `node.uniqueId` – The unique alphanumeric identifier for this construct within the tree (by default, generated from `node.path` and a hash).

The construct tree defines an implicit order in which constructs are synthesized to resources in the final AWS CloudFormation template. Where one resource must be created before another, AWS CloudFormation or the AWS Construct Library generally infers the dependency. They then make sure that the resources are created in the right order.

You can also add an explicit dependency between two nodes by using `node.addDependency()`. For more information, see [Dependencies](#) in the *AWS CDK API Reference*.

The AWS CDK provides a simple way to visit every node in the construct tree and perform an operation on each one. For more information, see [the section called “Aspects” \(p. 192\)](#).

## Apps

As described in [the section called “Constructs” \(p. 84\)](#), to provision infrastructure resources, all constructs that represent AWS resources must be defined, directly or indirectly, within the scope of a [Stack](#) construct. An [App](#) is a container for one or more stacks: it serves as each stack's scope. Stacks within a single App can easily refer to each others' resources (and attributes of those resources). The AWS CDK infers dependencies between stacks so that they can be deployed in the correct order. You can deploy any or all of the stacks defined within an app at with a single `cdk deploy` command.

The following example declares a stack class named `MyFirstStack` that includes a single Amazon S3 bucket.

TypeScript

```
class MyFirstStack extends Stack {
  constructor(scope: Construct, id: string, props?: StackProps) {
    super(scope, id, props);

    new s3.Bucket(this, 'MyFirstBucket');
```

```
}  
}
```

#### JavaScript

```
class MyFirstStack extends Stack {  
  constructor(scope, id, props) {  
    super(scope, id, props);  
  
    new s3.Bucket(this, 'MyFirstBucket');  
  }  
}
```

#### Python

```
class MyFirstStack(Stack):  
  
    def __init__(self, scope: Construct, id: str, **kwargs):  
        super().__init__(scope, id, **kwargs)  
  
        s3.Bucket(self, "MyFirstBucket")
```

#### Java

```
public class MyFirstStack extends Stack {  
    public MyFirstStack(final Construct scope, final String id) {  
        this(scope, id, null);  
    }  
  
    public MyFirstStack(final Construct scope, final String id, final StackProps props)  
    {  
        super(scope, id, props);  
  
        new Bucket(this, "MyFirstBucket");  
    }  
}
```

#### C#

```
public class MyFirstStack : Stack  
{  
    public MyFirstStack(Stack scope, string id, StackProps props = null) : base(scope,  
        id, props)  
    {  
        new Bucket(this, "MyFirstBucket");  
    }  
}
```

However, this code has only *declared* a stack. For the stack to actually be synthesized into an AWS CloudFormation template and deployed, it must be instantiated. And, like all CDK constructs, it must be instantiated in some context. The App is that context.

## The app construct

To define the previous stack within the scope of an application, use the [App](#) construct. The following example app instantiates a `MyFirstStack` and produces the AWS CloudFormation template that the stack defined.



### TypeScript

```
const app = new App();
new MyFirstStack(app, 'hello-cdk');
app.synth();
```

### JavaScript

```
const app = new App();
new MyFirstStack(app, 'hello-cdk');
app.synth();
```

### Python

```
app = App()
MyFirstStack(app, "hello-cdk")
app.synth()
```

### Java

```
App app = new App();
new MyFirstStack(app, "hello-cdk");
app.synth();
```

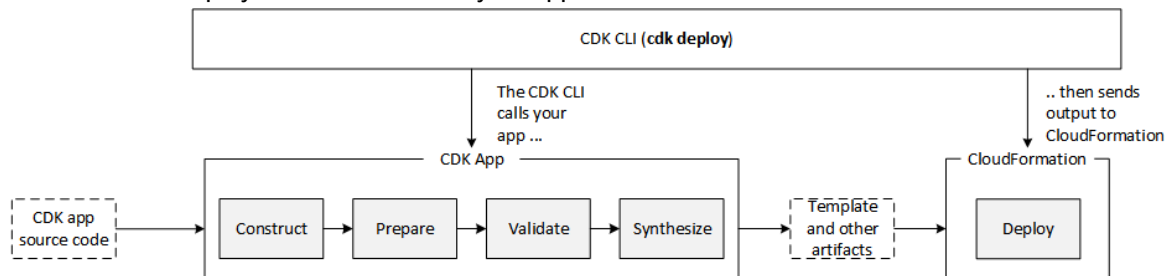
### C#

```
var app = new App();
new MyFirstStack(app, "hello-cdk");
app.Synth();
```

The App construct doesn't require any initialization arguments, because it's the only construct that can be used as a root for the construct tree. You can now use the App instance as a scope for defining a single instance of your stack.

## App lifecycle

The following diagram shows the phases that the AWS CDK goes through when you call the **cdk deploy**. This command deploys the resources that your app defines.



An AWS CDK app goes through the following phases in its lifecycle.

#### 1. Construction (or Initialization)

Your code instantiates all of the defined constructs and then links them together. In this stage, all of the constructs (app, stacks, and their child constructs) are instantiated and the constructor chain is executed. Most of your app code is executed in this stage.

## 2. Preparation

All constructs that have implemented the `prepare` method participate in a final round of modifications, to set up their final state. The preparation phase happens automatically. As a user, you don't see any feedback from this phase. It's rare to need to use the "prepare" hook, and generally not recommended. Be very careful when mutating the construct tree during this phase, because the order of operations could impact behavior.

## 3. Validation

All constructs that have implemented the `validate` method can validate themselves to ensure that they're in a state that will correctly deploy. You will get notified of any validation failures that happen during this phase. Generally, we recommend performing validation as soon as possible (usually as soon as you get some input) and throwing exceptions as early as possible. Performing validation early improves diagnosability as stack traces will be more accurate, and ensures that your code can continue to execute safely.

## 4. Synthesis

This is the final stage of the execution of your AWS CDK app. It's triggered by a call to `app.synth()`, and it traverses the construct tree and invokes the `synthesize` method on all constructs. Constructs that implement `synthesize` can participate in synthesis and emit deployment artifacts to the resulting cloud assembly. These artifacts include AWS CloudFormation templates, AWS Lambda application bundles, file and Docker image assets, and other deployment artifacts. [the section called "Cloud assemblies" \(p. 106\)](#) describes the output of this phase. In most cases, you won't need to implement the `synthesize` method.

## 5. Deployment

In this phase, the AWS CDK Toolkit takes the deployment artifacts cloud assembly produced by the synthesis phase and deploys it to an AWS environment. It uploads assets to Amazon S3 and Amazon ECR, or wherever they need to go. Then, it starts an AWS CloudFormation deployment to deploy the application and create the resources.

By the time the AWS CloudFormation deployment phase (step 5) starts, your AWS CDK app has already finished and exited. This has the following implications:

- The AWS CDK app can't respond to events that happen during deployment, such as a resource being created or the whole deployment finishing. To run code during the deployment phase, you must inject it into the AWS CloudFormation template as a [custom resource \(p. 218\)](#). For more information about adding a custom resource to your app, see the [AWS CloudFormation module](#), or the [custom-resource](#) example.
- The AWS CDK app might have to work with values that can't be known at the time it runs. For example, if the AWS CDK app defines an Amazon S3 bucket with an automatically generated name, and you retrieve the `bucket.bucketName` (Python: `bucket_name`) attribute, that value is not the name of the deployed bucket. Instead, you get a Token value. To determine whether a particular value is available, call `cdk.isUnresolved(value)` (Python: `is_unresolved`). See [the section called "Tokens" \(p. 145\)](#) for details.

# Cloud assemblies

The call to `app.synth()` is what tells the AWS CDK to synthesize a cloud assembly from an app. Typically you don't interact directly with cloud assemblies. They are files that include everything needed to deploy your app to a cloud environment. For example, it includes an AWS CloudFormation template for each stack in your app. It also includes a copy of any file assets or Docker images that you reference in your app.

See the [cloud assembly specification](#) for details on how cloud assemblies are formatted.

To interact with the cloud assembly that your AWS CDK app creates, you typically use the AWS CDK Toolkit, a command line tool. But any tool that can read the cloud assembly format can be used to deploy your app.

The CDK Toolkit needs to know how to execute your AWS CDK app. If you created the project from a template using the `cdk init` command, your app's `cdk.json` file includes an `app` key. This key specifies the necessary command for the language that the app is written in. If your language requires compilation, the command line performs this step before running the app, so you can't forget to do it.

#### TypeScript

```
{
  "app": "npx ts-node --prefer-ts-exts bin/my-app.ts"
}
```

#### JavaScript

```
{
  "app": "node bin/my-app.js"
}
```

#### Python

```
{
  "app": "python app.py"
}
```

#### Java

```
{
  "app": "mvn -e -q compile exec:java"
}
```

#### C#

```
{
  "app": "dotnet run -p src/MyApp/MyApp.csproj"
}
```

If you didn't create your project using the CDK Toolkit, or if you want to override the command line given in `cdk.json`, you can use the `--app` option when issuing the `cdk` command.

```
cdk --app 'executable' cdk-command ...
```

The *executable* part of the command indicates the command that should be run to execute your CDK application. Use quotation marks as shown, since such commands contain spaces. The *cdk-command* is a subcommand like **synth** or **deploy** that tells the CDK Toolkit what you want to do with your app. Follow this with any additional options needed for that subcommand.

The CLI can also interact directly with an already-synthesized cloud assembly. To do that, pass the directory in which the cloud assembly is stored in `--app`. The following example lists the stacks defined in the cloud assembly stored under `./my-cloud-assembly`.

```
cdk --app ./my-cloud-assembly ls
```

# Stacks

The unit of deployment in the AWS CDK is called a *stack*. All AWS resources defined within the scope of a stack, either directly or indirectly, are provisioned as a single unit.

Because AWS CDK stacks are implemented through AWS CloudFormation stacks, they have the same limitations as in [AWS CloudFormation](#).

You can define any number of stacks in your AWS CDK app. Any instance of the `Stack` construct represents a stack. This can be defined in one of the following ways:

- Directly within the scope of the app, like the `MyFirstStack` example shown previously
- Indirectly by any construct within the tree

For example, the following code defines an AWS CDK app with two stacks.

## TypeScript

```
const app = new App();

new MyFirstStack(app, 'stack1');
new MySecondStack(app, 'stack2');

app.synth();
```

## JavaScript

```
const app = new App();

new MyFirstStack(app, 'stack1');
new MySecondStack(app, 'stack2');

app.synth();
```

## Python

```
app = App()

MyFirstStack(app, 'stack1')
MySecondStack(app, 'stack2')

app.synth()
```

## Java

```
App app = new App();

new MyFirstStack(app, "stack1");
new MySecondStack(app, "stack2");

app.synth();
```

## C#

```
var app = new App();
```

```
new MyFirstStack(app, "stack1");
new MySecondStack(app, "stack2");

app.Synth();
```

To list all the stacks in an AWS CDK app, run the **cdk ls** command, which for the previous AWS CDK app would have the following output.

```
stack1
stack2
```

When you run the **cdk synth** command for an app with multiple stacks, the cloud assembly includes a separate template for each stack instance. Even if the two stacks are instances of the same class, the AWS CDK emits them as two individual templates.

You can synthesize each template by specifying the stack name in the **cdk synth** command. The following example synthesizes the template for **stack1**.

```
cdk synth stack1
```

This approach is conceptually different from how AWS CloudFormation templates are normally used, where a template can be deployed multiple times and parameterized through [AWS CloudFormation parameters](#). Although AWS CloudFormation parameters can be defined in the AWS CDK, they are generally discouraged because AWS CloudFormation parameters are resolved only during deployment. This means that you cannot determine their value in your code.

For example, to conditionally include a resource in your app based on a parameter value, you must set up an [AWS CloudFormation condition](#) and tag the resource with it. The AWS CDK takes an approach where concrete templates are resolved at synthesis time. Therefore, you can use an **if** statement to check the value to determine whether a resource should be defined or some behavior should be applied.

#### Note

The AWS CDK provides as much resolution as possible during synthesis time to enable idiomatic and natural usage of your programming language.

Like any other construct, stacks can be composed together into groups. The following code shows an example of a service that consists of three stacks: a control plane, a data plane, and monitoring stacks. The service construct is defined twice: once for the beta environment and once for the production environment.

TypeScript

```
import { App, Stack } from 'aws-cdk-lib';
import { Construct } from 'constructs';

interface EnvProps {
  prod: boolean;
}

// imagine these stacks declare a bunch of related resources
class ControlPlane extends Stack {}
class DataPlane extends Stack {}
class Monitoring extends Stack {}

class MyService extends Construct {

  constructor(scope: Construct, id: string, props?: EnvProps) {

    super(scope, id);
```

```
// we might use the prod argument to change how the service is configured
new ControlPlane(this, "cp");
new DataPlane(this, "data");
new Monitoring(this, "mon"); }

}

const app = new App();
new MyService(app, "beta");
new MyService(app, "prod", { prod: true });

app.synth();
```

### JavaScript

```
const { App, Stack } = require('aws-cdk-lib');
const { Construct } = require('constructs');

// imagine these stacks declare a bunch of related resources
class ControlPlane extends Stack {}
class DataPlane extends Stack {}
class Monitoring extends Stack {}

class MyService extends Construct {

  constructor(scope, id, props) {

    super(scope, id);

    // we might use the prod argument to change how the service is configured
    new ControlPlane(this, "cp");
    new DataPlane(this, "data");
    new Monitoring(this, "mon");
  }
}

const app = new App();
new MyService(app, "beta");
new MyService(app, "prod", { prod: true });

app.synth();
```

### Python

```
from aws_cdk import App, Stack
from constructs import Construct

# imagine these stacks declare a bunch of related resources
class ControlPlane(Stack): pass
class DataPlane(Stack): pass
class Monitoring(Stack): pass

class MyService(Construct):

    def __init__(self, scope: Construct, id: str, *, prod=False):

        super().__init__(scope, id)

        # we might use the prod argument to change how the service is configured
        ControlPlane(self, "cp")
        DataPlane(self, "data")
        Monitoring(self, "mon")

app = App();
```

```
MyService(app, "beta")
MyService(app, "prod", prod=True)

app.synth()
```

#### Java

```
package com.myorg;

import software.amazon.awscdk.App;
import software.amazon.awscdk.Stack;
import software.constructs.Construct;

public class MyApp {

    // imagine these stacks declare a bunch of related resources
    static class ControlPlane extends Stack {
        ControlPlane(Construct scope, String id) {
            super(scope, id);
        }
    }

    static class DataPlane extends Stack {
        DataPlane(Construct scope, String id) {
            super(scope, id);
        }
    }

    static class Monitoring extends Stack {
        Monitoring(Construct scope, String id) {
            super(scope, id);
        }
    }

    static class MyService extends Construct {
        MyService(Construct scope, String id) {
            this(scope, id, false);
        }

        MyService(Construct scope, String id, boolean prod) {
            super(scope, id);

            // we might use the prod argument to change how the service is configured
            new ControlPlane(this, "cp");
            new DataPlane(this, "data");
            new Monitoring(this, "mon");
        }
    }

    public static void main(final String argv[]) {
        App app = new App();

        new MyService(app, "beta");
        new MyService(app, "prod", true);

        app.synth();
    }
}
```

#### C#

```
using Amazon.CDK;
using Constructs;
```

```
// imagine these stacks declare a bunch of related resources
public class ControlPlane : Stack {
    public ControlPlane(Construct scope, string id=null) : base(scope, id) { }
}

public class DataPlane : Stack {
    public DataPlane(Construct scope, string id=null) : base(scope, id) { }
}

public class Monitoring : Stack
{
    public Monitoring(Construct scope, string id=null) : base(scope, id) { }
}

public class MyService : Construct
{
    public MyService(Construct scope, string id, Boolean prod=false) : base(scope, id)
    {
        // we might use the prod argument to change how the service is configured
        new ControlPlane(this, "cp");
        new DataPlane(this, "data");
        new Monitoring(this, "mon");
    }
}

class Program
{
    static void Main(string[] args)
    {
        var app = new App();
        new MyService(app, "beta");
        new MyService(app, "prod", prod: true);
        app.Synth();
    }
}
```

This AWS CDK app eventually consists of six stacks, three for each environment:

```
$ cdk ls

betacpDA8372D3
betadataE23DB2BA
betamon632BD457
prodcP187264CE
proddataF7378CE5
prodmon631A1083
```

The physical names of the AWS CloudFormation stacks are automatically determined by the AWS CDK based on the stack's construct path in the tree. By default, a stack's name is derived from the construct ID of the `Stack` object. However, you can specify an explicit name by using the `stackName` prop (in Python, `stack_name`), as follows.

#### TypeScript

```
new MyStack(this, 'not:a:stack:name', { stackName: 'this-is-stack-name' });
```

#### JavaScript

```
new MyStack(this, 'not:a:stack:name', { stackName: 'this-is-stack-name' });
```



### Python

```
MyStack(self, "not:a:stack:name", stack_name="this-is-stack-name")
```

### Java

```
new MyStack(this, "not:a:stack:name", StackProps.builder()  
    .StackName("this-is-stack-name").build());
```

### C#

```
new MyStack(this, "not:a:stack:name", new StackProps  
{  
    StackName = "this-is-stack-name"  
});
```

## Stack API

The [Stack](#) object provides a rich API, including the following:

- `Stack.of(construct)` – A static method that returns the **Stack** in which a construct is defined. This is useful if you need to interact with a stack from within a reusable construct. The call fails if a stack cannot be found in scope.
- `stack.stackName` (Python: `stack_name`) – Returns the physical name of the stack. As mentioned previously, all AWS CDK stacks have a physical name that the AWS CDK can resolve during synthesis.
- `stack.region` and `stack.account` – Return the AWS Region and account, respectively, into which this stack will be deployed. These properties return one of the following:
  - The account or Region explicitly specified when the stack was defined
  - A string-encoded token that resolves to the AWS CloudFormation pseudo parameters for account and Region to indicate that this stack is environment agnostic

For information about how environments are determined for stacks, see [the section called “Environments” \(p. 114\)](#).

- `stack.addDependency(stack)` (Python: `stack.add_dependency(stack)`) – Can be used to explicitly define dependency order between two stacks. This order is respected by the **cdk deploy** command when deploying multiple stacks at once.
- `stack.tags` – Returns a [TagManager](#) that you can use to add or remove stack-level tags. This tag manager tags all resources within the stack, and also tags the stack itself when it's created through AWS CloudFormation.
- `stack.partition`, `stack.urlSuffix` (Python: `url_suffix`), `stack.stackId` (Python: `stack_id`), and `stack.notificationArn` (Python: `notification_arn`) – Return tokens that resolve to the respective AWS CloudFormation pseudo parameters, such as { "Ref": "AWS::Partition" }. These tokens are associated with the specific stack object so that the AWS CDK framework can identify cross-stack references.
- `stack.availabilityZones` (Python: `availability_zones`) – Returns the set of Availability Zones available in the environment in which this stack is deployed. For environment-agnostic stacks, this always returns an array with two Availability Zones. For environment-specific stacks, the AWS CDK queries the environment and returns the exact set of Availability Zones available in the Region that you specified.
- `stack.parseArn(arn)` and `stack.formatArn(comps)` (Python: `parse_arn`, `format_arn`) – Can be used to work with Amazon Resource Names (ARNs).

- `stack.toJsonString(obj)` (Python: `to_json_string`) – Can be used to format an arbitrary object as a JSON string that can be embedded in an AWS CloudFormation template. The object can include tokens, attributes, and references, which are only resolved during deployment.
- `stack.templateOptions` (Python: `template_options`) – Use to specify AWS CloudFormation template options, such as Transform, Description, and Metadata, for your stack.

## Nested stacks

The [NestedStack](#) construct offers a way around the AWS CloudFormation 500-resource limit for stacks. A nested stack counts as only one resource in the stack that contains it. However, it can contain up to 500 resources, including additional nested stacks.

The scope of a nested stack must be a `Stack` or `NestedStack` construct. The nested stack doesn't need to be declared lexically inside its parent stack. It is necessary only to pass the parent stack as the first parameter (scope) when instantiating the nested stack. Aside from this restriction, defining constructs in a nested stack works exactly the same as in an ordinary stack.

At synthesis time, the nested stack is synthesized to its own AWS CloudFormation template, which is uploaded to the AWS CDK staging bucket at deployment. Nested stacks are bound to their parent stack and are not treated as independent deployment artifacts. They aren't listed by `cdk list`, and they can't be deployed by `cdk deploy`.

References between parent stacks and nested stacks are automatically translated to stack parameters and outputs in the generated AWS CloudFormation templates, as with any [cross-stack reference](#) (p. 123).

### Warning

Changes in security posture are not displayed before deployment for nested stacks. This information is displayed only for top-level stacks.

## Environments

Each `Stack` instance in your AWS CDK app is explicitly or implicitly associated with an environment (env). An environment is the target AWS account and Region into which the stack is intended to be deployed. The Region is specified using a Region code. For a list, see [Regional endpoints](#).

### Note

You must [bootstrap](#) (p. 195) each environment you will deploy CDK stacks into. Bootstrapping provisions certain AWS resources that are used during deployment.

If you don't specify an environment when you instantiate a stack, the stack is said to be *environment-agnostic*. AWS CloudFormation templates synthesized from such a stack will try to use deploy-time resolution on environment-related attributes such as `stack.account`, `stack.region`, and `stack.availabilityZones` (Python: `availability_zones`).

### Tip

If you're using the standard AWS CDK development template, your stacks are instantiated in the same file where you instantiate the App object.

#### TypeScript

The file named after your project (for example, `hello-cdk.ts`) in your project's bin folder.

#### JavaScript

The file named after your project (for example, `hello-cdk.js`) in your project's bin folder.

### Python

The file `app.py` in your project's main directory.

### Java

The file named `ProjectNameApp.java`, for example `HelloCdkApp.java`, nested deep under the `src/main` directory.

### C#

The file named `Program.cs` under `src\ProjectName`, for example `src\HelloCdk\Program.cs`.

In an environment-agnostic stack, any constructs that use Availability Zones will see two AZs, allowing the stack to be deployed to any Region.

When using **cdk deploy** to deploy environment-agnostic stacks, the AWS CDK CLI uses the specified AWS CLI profile to determine where to deploy. If no profile is specified, the default profile is used. The AWS CDK CLI follows a protocol similar to the AWS CLI to determine which AWS credentials to use when performing operations in your AWS account. See [the section called "AWS CDK Toolkit" \(p. 309\)](#) for details.

For production stacks, we recommend that you explicitly specify the environment for each stack in your app using the `env` property. The following example specifies different environments for its two different stacks.

### TypeScript

```
const envEU = { account: '2383838383', region: 'eu-west-1' };
const envUSA = { account: '8373873873', region: 'us-west-2' };

new MyFirstStack(app, 'first-stack-us', { env: envUSA });
new MyFirstStack(app, 'first-stack-eu', { env: envEU });
```

### JavaScript

```
const envEU = { account: '2383838383', region: 'eu-west-1' };
const envUSA = { account: '8373873873', region: 'us-west-2' };

new MyFirstStack(app, 'first-stack-us', { env: envUSA });
new MyFirstStack(app, 'first-stack-eu', { env: envEU });
```

### Python

```
env_EU = cdk.Environment(account="8373873873", region="eu-west-1")
env_USA = cdk.Environment(account="2383838383", region="us-west-2")

MyFirstStack(app, "first-stack-us", env=env_USA)
MyFirstStack(app, "first-stack-eu", env=env_EU)
```

### Java

```
public class MyApp {

    // Helper method to build an environment
    static Environment makeEnv(String account, String region) {
        return Environment.builder()
            .account(account)
            .region(region)
```

```
        .build();
    }

    public static void main(final String argv[]) {
        App app = new App();

        Environment envEU = makeEnv("8373873873", "eu-west-1");
        Environment envUSA = makeEnv("2383838383", "us-west-2");

        new MyFirstStack(app, "first-stack-us", StackProps.builder()
            .env(envUSA).build());
        new MyFirstStack(app, "first-stack-eu", StackProps.builder()
            .env(envEU).build());

        app.synth();
    }
}
```

## C#

```
Amazon.CDK.Environment makeEnv(string account, string region)
{
    return new Amazon.CDK.Environment
    {
        Account = account,
        Region = region
    };
}

var envEU = makeEnv(account: "8373873873", region: "eu-west-1");
var envUSA = makeEnv(account: "2383838383", region: "us-west-2");

new MyFirstStack(app, "first-stack-us", new StackProps { Env=envUSA });
new MyFirstStack(app, "first-stack-eu", new StackProps { Env=envEU });
```

When you hardcode the target account and Region as shown in the preceding example, the stack is always deployed to that specific account and Region. To make the stack deployable to a different target, but to determine the target at synthesis time, your stack can use two environment variables provided by the AWS CDK CLI: `CDK_DEFAULT_ACCOUNT` and `CDK_DEFAULT_REGION`. These variables are set based on the AWS profile specified using the **--profile** option, or the default AWS profile if you don't specify one.

The following code fragment shows how to access the account and Region passed from the AWS CDK CLI in your stack.

## TypeScript

Access environment variables via Node's process object.

### Note

You need the `DefinitelyTyped` module to use `process` in TypeScript. `cdk init` installs this module for you. However, you should install this module manually if you are working with a project created before it was added, or if you didn't set up your project using `cdk init`.

```
npm install @types/node
```

```
new MyDevStack(app, 'dev', {
    env: {
        account: process.env.CDK_DEFAULT_ACCOUNT,
```

```
    region: process.env.CDK_DEFAULT_REGION
  });
```

### JavaScript

Access environment variables via Node's process object.

```
new MyDevStack(app, 'dev', {
  env: {
    account: process.env.CDK_DEFAULT_ACCOUNT,
    region: process.env.CDK_DEFAULT_REGION
  });
```

### Python

Use the os module's environ dictionary to access environment variables.

```
import os
MyDevStack(app, "dev", env=cdk.Environment(
    account=os.environ["CDK_DEFAULT_ACCOUNT"],
    region=os.environ["CDK_DEFAULT_REGION"]))
```

### Java

Use `System.getenv()` to get the value of an environment variable.

```
public class MyApp {

    // Helper method to build an environment
    static Environment makeEnv(String account, String region) {
        account = (account == null) ? System.getenv("CDK_DEFAULT_ACCOUNT") : account;
        region = (region == null) ? System.getenv("CDK_DEFAULT_REGION") : region;

        return Environment.builder()
            .account(account)
            .region(region)
            .build();
    }

    public static void main(final String argv[]) {
        App app = new App();

        Environment envEU = makeEnv(null, null);
        Environment envUSA = makeEnv(null, null);

        new MyDevStack(app, "first-stack-us", StackProps.builder()
            .env(envUSA).build());
        new MyDevStack(app, "first-stack-eu", StackProps.builder()
            .env(envEU).build());

        app.synth();
    }
}
```

### C#

Use `System.Environment.GetEnvironmentVariable()` to get the value of an environment variable.

```
Amazon.CDK.Environment makeEnv(string account=null, string region=null)
{
```

```
return new Amazon.CDK.Environment
{
    Account = account ??
    System.Environment.GetEnvironmentVariable("CDK_DEFAULT_ACCOUNT"),
    Region = region ??
    System.Environment.GetEnvironmentVariable("CDK_DEFAULT_REGION")
};
}

new MyDevStack(app, "dev", new StackProps { Env = makeEnv() });
```

The AWS CDK distinguishes between not specifying the `env` property at all and specifying it using `CDK_DEFAULT_ACCOUNT` and `CDK_DEFAULT_REGION`. The former implies that the stack should synthesize an environment-agnostic template. Constructs that are defined in such a stack cannot use any information about their environment. For example, you can't write code like `if (stack.region === 'us-east-1')` or use framework facilities like [Vpc.fromLookup](#) (Python: `from_lookup`), which need to query your AWS account. These features don't work at all until you specify an explicit environment; to use them, you must specify `env`.

When you pass in your environment using `CDK_DEFAULT_ACCOUNT` and `CDK_DEFAULT_REGION`, the stack will be deployed in the account and Region determined by the AWS CDK CLI at the time of synthesis. This lets environment-dependent code work, but it also means that the synthesized template could be different based on the machine, user, or session that it's synthesized under. This behavior is often acceptable or even desirable during development, but it would probably be an anti-pattern for production use.

You can set `env` however you like, using any valid expression. For example, you might write your stack to support two additional environment variables to let you override the account and Region at synthesis time. We'll call these `CDK_DEPLOY_ACCOUNT` and `CDK_DEPLOY_REGION` here, but you could name them anything you like, as they are not set by the AWS CDK. In the following stack's environment, alternative environment variables are used if they're set. If they're not set, they fall back to the default environment provided by the AWS CDK.

#### TypeScript

```
new MyDevStack(app, 'dev', {
  env: {
    account: process.env.CDK_DEPLOY_ACCOUNT || process.env.CDK_DEFAULT_ACCOUNT,
    region: process.env.CDK_DEPLOY_REGION || process.env.CDK_DEFAULT_REGION
  });
```

#### JavaScript

```
new MyDevStack(app, 'dev', {
  env: {
    account: process.env.CDK_DEPLOY_ACCOUNT || process.env.CDK_DEFAULT_ACCOUNT,
    region: process.env.CDK_DEPLOY_REGION || process.env.CDK_DEFAULT_REGION
  });
```

#### Python

```
MyDevStack(app, "dev", env=cdk.Environment(
    account=os.environ.get("CDK_DEPLOY_ACCOUNT", os.environ["CDK_DEFAULT_ACCOUNT"]),
    region=os.environ.get("CDK_DEPLOY_REGION", os.environ["CDK_DEFAULT_REGION"])
```

#### Java

```
public class MyApp {
```

```
// Helper method to build an environment
static Environment makeEnv(String account, String region) {
    account = (account == null) ? System.getenv("CDK_DEPLOY_ACCOUNT") : account;
    region = (region == null) ? System.getenv("CDK_DEPLOY_REGION") : region;
    account = (account == null) ? System.getenv("CDK_DEFAULT_ACCOUNT") : account;
    region = (region == null) ? System.getenv("CDK_DEFAULT_REGION") : region;

    return Environment.builder()
        .account(account)
        .region(region)
        .build();
}

public static void main(final String argv[]) {
    App app = new App();

    Environment envEU = makeEnv(null, null);
    Environment envUSA = makeEnv(null, null);

    new MyDevStack(app, "first-stack-us", StackProps.builder()
        .env(envUSA).build());
    new MyDevStack(app, "first-stack-eu", StackProps.builder()
        .env(envEU).build());

    app.synth();
}
```

#### C#

```
Amazon.CDK.Environment makeEnv(string account=null, string region=null)
{
    return new Amazon.CDK.Environment
    {
        Account = account ??
            System.Environment.GetEnvironmentVariable("CDK_DEPLOY_ACCOUNT") ??
            System.Environment.GetEnvironmentVariable("CDK_DEFAULT_ACCOUNT"),
        Region = region ??
            System.Environment.GetEnvironmentVariable("CDK_DEPLOY_REGION") ??
            System.Environment.GetEnvironmentVariable("CDK_DEFAULT_REGION")
    };
}

new MyDevStack(app, "dev", new StackProps { Env = makeEnv() });
```

With your stack's environment declared this way, you can write a short script or batch file like the following to set the variables from command line arguments, then call `cdk deploy`. Any arguments beyond the first two are passed through to `cdk deploy` and can be used to specify command line options or stacks.

#### macOS/Linux

```
#!/usr/bin/env bash
if [[ $# -ge 2 ]]; then
    export CDK_DEPLOY_ACCOUNT=$1
    export CDK_DEPLOY_REGION=$2
    shift; shift
    npx cdk deploy "$@"
    exit $?
else
    echo 1>&2 "Provide account and region as first two args."
```

```
    echo 1>&2 "Additional args are passed through to cdk deploy."  
    exit 1  
fi
```

Save the script as `cdk-deploy-to.sh`, then execute `chmod +x cdk-deploy-to.sh` to make it executable.

#### Windows

```
@findstr /B /V @ %~dpnx0 > %~dpn0.ps1 && powershell -ExecutionPolicy Bypass %~dpn0.ps1  
%*  
@exit /B %ERRORLEVEL%  
if ($args.length -ge 2) {  
    $env:CDK_DEPLOY_ACCOUNT, $args = $args  
    $env:CDK_DEPLOY_REGION, $args = $args  
    npx cdk deploy $args  
    exit $lastExitCode  
} else {  
    [console]::error.WriteLine("Provide account and region as first two args.")  
    [console]::error.WriteLine("Additional args are passed through to cdk deploy.")  
    exit 1  
}
```

The Windows version of the script uses PowerShell to provide the same functionality as the macOS/Linux version. It also contains instructions to allow it to be run as a batch file so it can be easily invoked from a command line. It should be saved as `cdk-deploy-to.bat`. The file `cdk-deploy-to.ps1` will be created when the batch file is invoked.

Then you can write additional scripts that call the "deploy-to" script to deploy to specific environments (even multiple environments per script):

#### macOS/Linux

```
#!/usr/bin/env bash  
# cdk-deploy-to-test.sh  
./cdk-deploy-to.sh 123457689 us-east-1 "$@"
```

#### Windows

```
@echo off  
rem cdk-deploy-to-test.bat  
cdk-deploy-to 135792469 us-east-1 %*
```

When deploying to multiple environments, consider whether you want to continue deploying to other environments after a deployment fails. The following example avoids deploying to the second production environment if the first doesn't succeed.

#### macOS/Linux

```
#!/usr/bin/env bash  
# cdk-deploy-to-prod.sh  
./cdk-deploy-to.sh 135792468 us-west-1 "$@" || exit  
./cdk-deploy-to.sh 246813579 eu-west-1 "$@"
```

#### Windows

```
@echo off
```



```
rem cdk-deploy-to-prod.bat
cdk-deploy-to 135792469 us-west-1 %* || exit /B
cdk-deploy-to 245813579 eu-west-1 %*
```

Developers could still use the normal `cdk deploy` command to deploy to their own AWS environments for development.

## Resources

As described in [the section called “Constructs” \(p. 84\)](#), the AWS CDK provides a rich class library of constructs, called *AWS constructs*, that represent all AWS resources.

To create an instance of a resource using its corresponding construct, pass in the scope as the first argument, the logical ID of the construct, and a set of configuration properties (props). For example, here's how to create an Amazon SQS queue with AWS KMS encryption using the [sqs.Queue](#) construct from the AWS Construct Library.

### TypeScript

```
import * as sqs from '@aws-cdk/aws-sqs';

new sqs.Queue(this, 'MyQueue', {
  encryption: sqs.QueueEncryption.KMS_MANAGED
});
```

### JavaScript

```
const sqs = require('@aws-cdk/aws-sqs');

new sqs.Queue(this, 'MyQueue', {
  encryption: sqs.QueueEncryption.KMS_MANAGED
});
```

### Python

```
import aws_cdk.aws_sqs as sqs

sqs.Queue(self, "MyQueue", encryption=sqs.QueueEncryption.KMS_MANAGED)
```

### Java

```
import software.amazon.awscdk.services.sqs.*;

Queue.Builder.create(this, "MyQueue").encryption(
    QueueEncryption.KMS_MANAGED).build();
```

### C#

```
using Amazon.CDK.AWS.SQS;

new Queue(this, "MyQueue", new QueueProps
{
    Encryption = QueueEncryption.KMS_MANAGED
});
```

```
});
```

Some configuration props are optional, and in many cases have default values. In some cases, all props are optional, and the last argument can be omitted entirely.

## Resource attributes

Most resources in the AWS Construct Library expose attributes, which are resolved at deployment time by AWS CloudFormation. Attributes are exposed in the form of properties on the resource classes with the type name as a prefix. The following example shows how to get the URL of an Amazon SQS queue using the `queueUrl` (Python: `queue_url`) property.

### TypeScript

```
import * as sqs from '@aws-cdk/aws-sqs';

const queue = new sqs.Queue(this, 'MyQueue');
const url = queue.queueUrl; // => A string representing a deploy-time value
```

### JavaScript

```
const sqs = require('@aws-cdk/aws-sqs');

const queue = new sqs.Queue(this, 'MyQueue');
const url = queue.queueUrl; // => A string representing a deploy-time value
```

### Python

```
import aws_cdk.aws_sqs as sqs

queue = sqs.Queue(self, "MyQueue")
url = queue.queue_url # => A string representing a deploy-time value
```

### Java

```
Queue queue = new Queue(this, "MyQueue");
String url = queue.getQueueUrl(); // => A string representing a deploy-time value
```

### C#

```
var queue = new Queue(this, "MyQueue");
var url = queue.QueueUrl; // => A string representing a deploy-time value
```

See [the section called “Tokens” \(p. 145\)](#) for information about how the AWS CDK encodes deploy-time attributes as strings.

## Referencing resources

Many AWS CDK classes require properties that are AWS CDK resource objects (resources). For example, an Amazon ECS resource requires a reference to the cluster on which it runs. An Amazon CloudFront distribution requires a reference to the bucket containing the source code. To satisfy these requirements, you can refer to a resource in one of two ways:

- By passing a resource defined in your CDK app, either in the same stack or in a different one

- By passing a proxy object referencing a resource defined in your AWS account, created from a unique identifier of the resource (such as an ARN)

If a construct property represents another AWS construct, its type is that of the interface type of that construct. For example, the Amazon ECS service takes a property `cluster` of type `ecs.ICluster`; the CloudFront distribution takes a property `sourceBucket` (Python: `source_bucket`) of type `s3.IBucket`.

You can directly pass any resource object of the proper type defined in the same AWS CDK app. The following example defines an Amazon ECS cluster and then uses it to define an Amazon ECS service.

#### TypeScript

```
const cluster = new ecs.Cluster(this, 'Cluster', { /*...*/ });
const service = new ecs.Ec2Service(this, 'Service', { cluster: cluster });
```

#### JavaScript

```
const cluster = new ecs.Cluster(this, 'Cluster', { /*...*/ });
const service = new ecs.Ec2Service(this, 'Service', { cluster: cluster });
```

#### Python

```
cluster = ecs.Cluster(self, "Cluster")
service = ecs.Ec2Service(self, "Service", cluster=cluster)
```

#### Java

```
Cluster cluster = new Cluster(this, "Cluster");
Ec2Service service = new Ec2Service(this, "Service",
    new Ec2ServiceProps.Builder().cluster(cluster).build());
```

#### C#

```
var cluster = new Cluster(this, "Cluster");
var service = new Ec2Service(this, "Service", new Ec2ServiceProps { Cluster =
    cluster });
```

## Referencing resources in a different stack

You can refer to resources in a different stack as long as they are defined in the same app and are in the same AWS account and Region. The following pattern is generally used:

- Store a reference to the construct as an attribute of the stack that produces the resource. (To get a reference to the current construct's stack, use `Stack.of(this)`.)
- Pass this reference to the constructor of the stack that consumes the resource as a parameter or a property. The consuming stack then passes it as a property to any construct that needs it.

The following example defines a stack `stack1`. This stack defines an Amazon S3 bucket and stores a reference to the bucket construct as an attribute of the stack. Then the app defines a second stack,

stack2, which accepts a bucket at instantiation. stack2 might, for example, define an AWS Glue Table that uses the bucket for data storage.

#### TypeScript

```
const prod = { account: '123456789012', region: 'us-east-1' };

const stack1 = new StackThatProvidesABucket(app, 'Stack1', { env: prod });

// stack2 will take a property { bucket: IBucket }
const stack2 = new StackThatExpectsABucket(app, 'Stack2', {
  bucket: stack1.bucket,
  env: prod
});
```

#### JavaScript

```
const prod = { account: '123456789012', region: 'us-east-1' };

const stack1 = new StackThatProvidesABucket(app, 'Stack1', { env: prod });

// stack2 will take a property { bucket: IBucket }
const stack2 = new StackThatExpectsABucket(app, 'Stack2', {
  bucket: stack1.bucket,
  env: prod
});
```

#### Python

```
prod = core.Environment(account="123456789012", region="us-east-1")

stack1 = StackThatProvidesABucket(app, "Stack1", env=prod)

# stack2 will take a property "bucket"
stack2 = StackThatExpectsABucket(app, "Stack2", bucket=stack1.bucket, env=prod)
```

#### Java

```
// Helper method to build an environment
static Environment makeEnv(String account, String region) {
    return Environment.builder().account(account).region(region)
        .build();
}

App app = new App();

Environment prod = makeEnv("123456789012", "us-east-1");

StackThatProvidesABucket stack1 = new StackThatProvidesABucket(app, "Stack1",
    StackProps.builder().env(prod).build());

// stack2 will take an argument "bucket"
StackThatExpectsABucket stack2 = new StackThatExpectsABucket(app, "Stack",
    StackProps.builder().env(prod).build(), stack1.bucket);
```

#### C#

```
Amazon.CDK.Environment makeEnv(string account, string region)
{
    return new Amazon.CDK.Environment { Account = account, Region = region };
}
```

```
}  
  
var prod = makeEnv(account: "123456789012", region: "us-east-1");  
  
var stack1 = new StackThatProvidesABucket(app, "Stack1", new StackProps { Env =  
    prod });  
  
// stack2 will take a property "bucket"  
var stack2 = new StackThatExpectsABucket(app, "Stack2", new StackProps { Env = prod,  
    bucket = stack1.Bucket});
```

If the AWS CDK determines that the resource is in the same account and Region, but in a different stack, it automatically synthesizes AWS CloudFormation [exports](#) in the producing stack and an [Fn::ImportValue](#) in the consuming stack to transfer that information from one stack to the other.

## Resolving dependency deadlocks

Referencing a resource from one stack in a different stack creates a dependency between the two stacks. This makes sure that they're deployed in the right order. After the stacks are deployed, this dependency is concrete. After that, removing the use of the shared resource from the consuming stack can cause an unexpected deployment failure. This happens if there is another dependency between the two stacks that force them to be deployed in the same order. It can also happen without a dependency if the producing stack is simply chosen by the CDK Toolkit to be deployed first. The AWS CloudFormation export is removed from the producing stack because it's no longer needed, but the exported resource is still being used in the consuming stack because its update is not yet deployed. Therefore, deploying the producer stack fails.

To break this deadlock, remove the use of the shared resource from the consuming stack. (This removes the automatic export from the producing stack.) Next, manually add the same export to the producing stack using exactly the same logical ID as the automatically generated export. Remove the use of the shared resource in the consuming stack and deploy both stacks. Then, remove the manual export (and the shared resource if it's no longer needed) and deploy both stacks again. The stack's [exportValue\(\)](#) method is a convenient way to create the manual export for this purpose. (See the example in the linked method reference.)

## Referencing resources in your AWS account

Suppose you want to use a resource already available in your AWS account in your AWS CDK app. This might be a resource that was defined through the console, an AWS SDK, directly with AWS CloudFormation, or in a different AWS CDK application. You can turn the resource's ARN (or another identifying attribute, or group of attributes) into a proxy object. The proxy object serves as a reference to the resource by calling a static factory method on the resource's class.

When you create such a proxy, the external resource **does not** become a part of your AWS CDK app. Therefore, changes you make to the proxy in your AWS CDK app do not affect the deployed resource. The proxy can, however, be passed to any AWS CDK method that requires a resource of that type.

The following example shows how to reference a bucket based on an existing bucket with the ARN **arn:aws:s3::my-bucket-name**, and an Amazon Virtual Private Cloud based on an existing VPC having a specific ID.

TypeScript

```
// Construct a proxy for a bucket by its name (must be same account)  
s3.Bucket.fromBucketName(this, 'MyBucket', 'my-bucket-name');  
  
// Construct a proxy for a bucket by its full ARN (can be another account)  
s3.Bucket.fromBucketArn(this, 'MyBucket', 'arn:aws:s3::my-bucket-name');
```

```
// Construct a proxy for an existing VPC from its attribute(s)
ec2.Vpc.fromVpcAttributes(this, 'MyVpc', {
  vpcId: 'vpc-1234567890abcde',
});
```

#### JavaScript

```
// Construct a proxy for a bucket by its name (must be same account)
s3.Bucket.fromBucketName(this, 'MyBucket', 'my-bucket-name');

// Construct a proxy for a bucket by its full ARN (can be another account)
s3.Bucket.fromBucketArn(this, 'MyBucket', 'arn:aws:s3::my-bucket-name');

// Construct a proxy for an existing VPC from its attribute(s)
ec2.Vpc.fromVpcAttributes(this, 'MyVpc', {
  vpcId: 'vpc-1234567890abcde'
});
```

#### Python

```
# Construct a proxy for a bucket by its name (must be same account)
s3.Bucket.from_bucket_name(self, "MyBucket", "my-bucket-name")

# Construct a proxy for a bucket by its full ARN (can be another account)
s3.Bucket.from_bucket_arn(self, "MyBucket", "arn:aws:s3::my-bucket-name")

# Construct a proxy for an existing VPC from its attribute(s)
ec2.Vpc.from_vpc_attributes(self, "MyVpc", vpc_id="vpc-1234567890abcdef")
```

#### Java

```
// Construct a proxy for a bucket by its name (must be same account)
Bucket.fromBucketName(this, "MyBucket", "my-bucket-name");

// Construct a proxy for a bucket by its full ARN (can be another account)
Bucket.fromBucketArn(this, "MyBucket",
    "arn:aws:s3::my-bucket-name");

// Construct a proxy for an existing VPC from its attribute(s)
Vpc.fromVpcAttributes(this, "MyVpc", VpcAttributes.builder()
    .vpcId("vpc-1234567890abcdef").build());
```

#### C#

```
// Construct a proxy for a bucket by its name (must be same account)
Bucket.FromBucketName(this, "MyBucket", "my-bucket-name");

// Construct a proxy for a bucket by its full ARN (can be another account)
Bucket.FromBucketArn(this, "MyBucket", "arn:aws:s3::my-bucket-name");

// Construct a proxy for an existing VPC from its attribute(s)
Vpc.FromVpcAttributes(this, "MyVpc", new VpcAttributes
{
    VpcId = "vpc-1234567890abcdef"
});
```

Let's take a closer look at the [Vpc.fromLookup\(\)](#) method. Because the `ec2.Vpc` construct is complex, there are many ways you might want to select the VPC to be used with your CDK app. To address this,

the VPC construct has a `fromLookup` static method (Python: `from_lookup`) that lets you look up the desired Amazon VPC by querying your AWS account at synthesis time.

To use `Vpc.fromLookup()`, the system that synthesizes the stack must have access to the account that owns the Amazon VPC. This is because the CDK Toolkit queries the account to find the right Amazon VPC at synthesis time.

Furthermore, `Vpc.fromLookup()` works only in stacks that are defined with an explicit **account** and **region** (see [the section called “Environments” \(p. 114\)](#)). If the AWS CDK tries to look up an Amazon VPC from an [environment-agnostic stack \(p. 113\)](#), the CDK Toolkit doesn't know which environment to query to find the VPC.

You must provide `Vpc.fromLookup()` attributes sufficient to uniquely identify a VPC in your AWS account. For example, there can only ever be one default VPC, so it's sufficient to specify the VPC as the default.

#### TypeScript

```
ec2.Vpc.fromLookup(this, 'DefaultVpc', {
  isDefault: true
});
```

#### JavaScript

```
ec2.Vpc.fromLookup(this, 'DefaultVpc', {
  isDefault: true
});
```

#### Python

```
ec2.Vpc.from_lookup(self, "DefaultVpc", is_default=True)
```

#### Java

```
Vpc.fromLookup(this, "DefaultVpc", VpcLookupOptions.builder()
    .isDefault(true).build());
```

#### C#

```
Vpc.FromLookup(this, id = "DefaultVpc", new VpcLookupOptions { IsDefault = true });
```

You can also use the `tags` property to query for VPCs by tag. You can add tags to the Amazon VPC at the time of its creation by using AWS CloudFormation or the AWS CDK. You can edit tags at any time after creation by using the AWS Management Console, the AWS CLI, or an AWS SDK. In addition to any tags you add yourself, the AWS CDK automatically adds the following tags to all VPCs it creates.

- *Name* – The name of the VPC.
- *aws-cdk:subnet-name* – The name of the subnet.
- *aws-cdk:subnet-type* – The type of the subnet: Public, Private, or Isolated.

#### TypeScript

```
ec2.Vpc.fromLookup(this, 'PublicVpc',
  {tags: {'aws-cdk:subnet-type': "Public"}});
```

#### JavaScript

```
ec2.Vpc.fromLookup(this, 'PublicVpc',  
  {tags: {'aws-cdk:subnet-type': 'Public'}});
```

#### Python

```
ec2.Vpc.from_lookup(self, "PublicVpc",  
  tags={"aws-cdk:subnet-type": "Public"})
```

#### Java

```
Vpc.fromLookup(this, "PublicVpc", VpcLookupOptions.builder()  
  .tags(java.util.Map.of("aws-cdk:subnet-type", "Public")) // Java 9 or later  
  .build());
```

#### C#

```
Vpc.FromLookup(this, id = "PublicVpc", new VpcLookupOptions  
  { Tags = new Dictionary<string, string> { ["aws-cdk:subnet-type"] = "Public" } });
```

Results of `Vpc.fromLookup()` are cached in the project's `cdk.context.json` file. (See [the section called “Context” \(p. 185\)](#).) Commit this file to version control so that your app will continue to refer to the same Amazon VPC. This works even if you later change the attributes of your VPCs in a way that would result in a different VPC being selected. This is particularly important if you're deploying the stack in an environment that doesn't have access to the AWS account that defines the VPC, such as [CDK Pipelines \(p. 282\)](#).

Although you can use an external resource anywhere you'd use a similar resource defined in your AWS CDK app, you cannot modify it. For example, calling `addToResourcePolicy` (Python: `add_to_resource_policy`) on an external `s3.Bucket` does nothing.

## Physical names

The logical names of resources in AWS CloudFormation are different from the names of resources that are shown in the AWS Management Console after they're deployed by AWS CloudFormation. The AWS CDK calls these final names *physical names*.

For example, AWS CloudFormation might create the Amazon S3 bucket with the logical ID **Stack2MyBucket4DD88B4F** from the previous example with the physical name **stack2mybucket4dd88b4f-iuv1rbv9z3to**.

You can specify a physical name when creating constructs that represent resources by using the property `<resourceType>Name`. The following example creates an Amazon S3 bucket with the physical name **my-bucket-name**.

#### TypeScript

```
const bucket = new s3.Bucket(this, 'MyBucket', {  
  bucketName: 'my-bucket-name',  
});
```

#### JavaScript

```
const bucket = new s3.Bucket(this, 'MyBucket', {
```



```
    bucketName: 'my-bucket-name'  
  });
```

#### Python

```
bucket = s3.Bucket(self, "MyBucket", bucket_name="my-bucket-name")
```

#### Java

```
Bucket bucket = Bucket.Builder.create(this, "MyBucket")  
    .bucketName("my-bucket-name").build();
```

#### C#

```
var bucket = new Bucket(this, "MyBucket", new BucketProps { BucketName = "my-bucket-name" });
```

Assigning physical names to resources has some disadvantages in AWS CloudFormation. Most importantly, any changes to deployed resources that require a resource replacement, such as changes to a resource's properties that are immutable after creation, will fail if a resource has a physical name assigned. If you end up in that state, the only solution is to delete the AWS CloudFormation stack, then deploy the AWS CDK app again. See the [AWS CloudFormation documentation](#) for details.

In some cases, such as when creating an AWS CDK app with cross-environment references, physical names are required for the AWS CDK to function correctly. In those cases, if you don't want to bother with coming up with a physical name yourself, you can let the AWS CDK name it for you. To do so, use the special value `PhysicalName.GENERATE_IF_NEEDED`, as follows.

#### TypeScript

```
const bucket = new s3.Bucket(this, 'MyBucket', {  
  bucketName: core.PhysicalName.GENERATE_IF_NEEDED,  
});
```

#### JavaScript

```
const bucket = new s3.Bucket(this, 'MyBucket', {  
  bucketName: core.PhysicalName.GENERATE_IF_NEEDED  
});
```

#### Python

```
bucket = s3.Bucket(self, "MyBucket",  
    bucket_name=core.PhysicalName.GENERATE_IF_NEEDED)
```

#### Java

```
Bucket bucket = Bucket.Builder.create(this, "MyBucket")  
    .bucketName(PhysicalName.GENERATE_IF_NEEDED).build();
```

#### C#

```
var bucket = new Bucket(this, "MyBucket", new BucketProps
```

```
{ BucketName = PhysicalName.GENERATE_IF_NEEDED });
```

## Passing unique identifiers

Whenever possible, you should pass resources by reference, as described in the previous section. However, there are cases where you have no other choice but to refer to a resource by one of its attributes. Example use cases include the following:

- When you are using low-level AWS CloudFormation resources
- When you need to expose resources to the runtime components of an AWS CDK application, such as when referring to Lambda functions through environment variables

These identifiers are available as attributes on the resources, such as the following.

### TypeScript

```
bucket.bucketName  
lambdaFunc.functionArn  
securityGroup.groupArn
```

### JavaScript

```
bucket.bucketName  
lambdaFunc.functionArn  
securityGroup.groupArn
```

### Python

```
bucket.bucket_name  
lambda_func.function_arn  
security_group_arn
```

### Java

The Java AWS CDK binding uses getter methods for attributes.

```
bucket.getBucketName()  
lambdaFunc.getFunctionArn()  
securityGroup.getGroupArn()
```

### C#

```
bucket.BucketName  
lambdaFunc.FunctionArn  
securityGroup.GroupArn
```

The following example shows how to pass a generated bucket name to an AWS Lambda function.

### TypeScript

```
const bucket = new s3.Bucket(this, 'Bucket');  
  
new lambda.Function(this, 'MyLambda', {  
  // ...
```

```
environment: {
  BUCKET_NAME: bucket.bucketName,
},
});
```

#### JavaScript

```
const bucket = new s3.Bucket(this, 'Bucket');

new lambda.Function(this, 'MyLambda', {
  // ...
  environment: {
    BUCKET_NAME: bucket.bucketName
  }
});
```

#### Python

```
bucket = s3.Bucket(self, "Bucket")

lambda.Function(self, "MyLambda", environment=dict(BUCKET_NAME=bucket.bucket_name))
```

#### Java

```
final Bucket bucket = new Bucket(this, "Bucket");

Function.Builder.create(this, "MyLambda")
    .environment(java.util.Map.of( // Java 9 or later
        "BUCKET_NAME", bucket.getBucketName()))
    .build();
```

#### C#

```
var bucket = new Bucket(this, "Bucket");

new Function(this, "MyLambda", new FunctionProps
{
    Environment = new Dictionary<string, string>
    {
        ["BUCKET_NAME"] = bucket.BucketName
    }
});
```

## Granting permissions

AWS constructs make least-privilege permissions achievable by offering simple, intent-based APIs to express permission requirements. Many AWS constructs offer grant methods that you can use to grant an entity (such as an IAM role or user) permission to work with the resource, without having to manually create IAM permission statements.

The following example creates the permissions to allow a Lambda function's execution role to read and write objects to a particular Amazon S3 bucket. If the Amazon S3 bucket is encrypted with an AWS KMS key, this method also grants permissions to the Lambda function's execution role to decrypt with the key.

#### TypeScript

```
if (bucket.grantReadWrite(func).success) {
```

```
} // ...
```

#### JavaScript

```
if ( bucket.grantReadWrite(func).success) {  
  // ...  
}
```

#### Python

```
if bucket.grant_read_write(func).success:  
    # ...
```

#### Java

```
if (bucket.grantReadWrite(func).getSuccess()) {  
    // ...  
}
```

#### C#

```
if (bucket.GrantReadWrite(func).Success)  
{  
    // ...  
}
```

The grant methods return an `iam.Grant` object. Use the `success` attribute of the `Grant` object to determine whether the grant was effectively applied (for example, it may not have been applied on [external resources \(p. 122\)](#)). You can also use the `assertSuccess` (Python: `assert_success`) method of the `Grant` object to enforce that the grant was successfully applied.

If a specific grant method isn't available for the particular use case, you can use a generic grant method to define a new grant with a specified list of actions.

The following example shows how to grant a Lambda function access to the Amazon DynamoDB `CreateBackup` action.

#### TypeScript

```
table.grant(func, 'dynamodb:CreateBackup');
```

#### JavaScript

```
table.grant(func, 'dynamodb:CreateBackup');
```

#### Python

```
table.grant(func, "dynamodb:CreateBackup")
```

#### Java

```
table.grant(func, "dynamodb:CreateBackup");
```

## C#

```
table.Grant(func, "dynamodb:CreateBackup");
```

Many resources, such as Lambda functions, require a role to be assumed when executing code. A configuration property enables you to specify an `iam.IRole`. If no role is specified, the function automatically creates a role specifically for this use. You can then use grant methods on the resources to add statements to the role.

The grant methods are built using lower-level APIs for handling with IAM policies. Policies are modeled as [PolicyDocument](#) objects. Add statements directly to roles (or a construct's attached role) using the `addToRolePolicy` method (Python: `add_to_role_policy`), or to a resource's policy (such as a Bucket policy) using the `addToResourcePolicy` (Python: `add_to_resource_policy`) method.

## Metrics and alarms

Many resources emit CloudWatch metrics that can be used to set up monitoring dashboards and alarms. AWS constructs have metric methods that let you access the metrics without looking up the correct name to use.

The following example shows how to define an alarm when the `ApproximateNumberOfMessagesNotVisible` of an Amazon SQS queue exceeds 100.

### TypeScript

```
import * as cw from '@aws-cdk/aws-cloudwatch';
import * as sqs from '@aws-cdk/aws-sqs';
import { Duration } from '@aws-cdk/core';

const queue = new sqs.Queue(this, 'MyQueue');

const metric = queue.metricApproximateNumberOfMessagesNotVisible({
  label: 'Messages Visible (Approx)',
  period: Duration.minutes(5),
  // ...
});
metric.createAlarm(this, 'TooManyMessagesAlarm', {
  comparisonOperator: cw.ComparisonOperator.GREATER_THAN_THRESHOLD,
  threshold: 100,
  // ...
});
```

### JavaScript

```
const cw = require('@aws-cdk/aws-cloudwatch');
const sqs = require('@aws-cdk/aws-sqs');
const { Duration } = require('@aws-cdk/core');

const queue = new sqs.Queue(this, 'MyQueue');

const metric = queue.metricApproximateNumberOfMessagesNotVisible({
  label: 'Messages Visible (Approx)',
  period: Duration.minutes(5),
  // ...
});
metric.createAlarm(this, 'TooManyMessagesAlarm', {
  comparisonOperator: cw.ComparisonOperator.GREATER_THAN_THRESHOLD,
  threshold: 100
});
```

```
// ...  
});
```

## Python

```
import aws_cdk.aws_cloudwatch as cw  
import aws_cdk.aws_sqs as sqs  
from aws_cdk.core import Duration  
  
queue = sqs.Queue(self, "MyQueue")  
metric = queue.metric_approximate_number_of_messages_not_visible(  
    label="Messages Visible (Approx)",  
    period=Duration.minutes(5),  
    # ...  
)  
metric.create_alarm(self, "TooManyMessagesAlarm",  
    comparison_operator=cw.ComparisonOperator.GREATER_THAN_THRESHOLD,  
    threshold=100,  
    # ...  
)
```

## Java

```
import software.amazon.awscdk.core.Duration;  
import software.amazon.awscdk.services.sqs.Queue;  
import software.amazon.awscdk.services.cloudwatch.Metric;  
import software.amazon.awscdk.services.cloudwatch.MetricOptions;  
import software.amazon.awscdk.services.cloudwatch.CreateAlarmOptions;  
import software.amazon.awscdk.services.cloudwatch.ComparisonOperator;  
  
Queue queue = new Queue(this, "MyQueue");  
  
Metric metric = queue  
    .metricApproximateNumberOfMessagesNotVisible(MetricOptions.builder()  
        .label("Messages Visible (Approx)")  
        .period(Duration.minutes(5)).build());  
  
metric.createAlarm(this, "TooManyMessagesAlarm", CreateAlarmOptions.builder()  
    .comparisonOperator(ComparisonOperator.GREATER_THAN_THRESHOLD)  
    .threshold(100)  
    // ...  
    .build());
```

## C#

```
using cdk = Amazon.CDK;  
using cw = Amazon.CDK.AWS.CloudWatch;  
using sqs = Amazon.CDK.AWS.SQS;  
  
var queue = new sqs.Queue(this, "MyQueue");  
var metric = queue.MetricApproximateNumberOfMessagesNotVisible(new cw.MetricOptions  
{  
    Label = "Messages Visible (Approx)",  
    Period = cdk.Duration.Minutes(5),  
    // ...  
});  
metric.CreateAlarm(this, "TooManyMessagesAlarm", new cw.CreateAlarmOptions  
{  
    ComparisonOperator = cw.ComparisonOperator.GREATER_THAN_THRESHOLD,  
    Threshold = 100,  
    // ..  
});
```

If there is no method for a particular metric, you can use the general metric method to specify the metric name manually.

Metrics can also be added to CloudWatch dashboards. See [CloudWatch](#).

## Network traffic

In many cases, you must enable permissions on a network for an application to work, such as when the compute infrastructure needs to access the persistence layer. Resources that establish or listen for connections expose methods that enable traffic flows, including setting security group rules or network ACLs.

[IConnectable](#) resources have a `connections` property that is the gateway to network traffic rules configuration.

You enable data to flow on a given network path by using `allow` methods. The following example enables HTTPS connections to the web and incoming connections from the Amazon EC2 Auto Scaling group `fleet2`.

### TypeScript

```
import * as asg from '@aws-cdk/aws-autoscaling';
import * as ec2 from '@aws-cdk/aws-ec2';

const fleet1: asg.AutoScalingGroup = asg.AutoScalingGroup(/*...*/);

// Allow surfing the (secure) web
fleet1.connections.allowTo(new ec2.Peer.anyIpv4(), new ec2.Port({ fromPort: 443,
  toPort: 443 }));

const fleet2: asg.AutoScalingGroup = asg.AutoScalingGroup(/*...*/);
fleet1.connections.allowFrom(fleet2, ec2.Port.AllTraffic());
```

### JavaScript

```
const asg = require('@aws-cdk/aws-autoscaling');
const ec2 = require('@aws-cdk/aws-ec2');

const fleet1 = asg.AutoScalingGroup();

// Allow surfing the (secure) web
fleet1.connections.allowTo(new ec2.Peer.anyIpv4(), new ec2.Port({ fromPort: 443,
  toPort: 443 }));

const fleet2 = asg.AutoScalingGroup();
fleet1.connections.allowFrom(fleet2, ec2.Port.AllTraffic());
```

### Python

```
import aws_cdk.aws_autoscaling as asg
import aws_cdk.aws_ec2 as ec2

fleet1 = asg.AutoScalingGroup( ... )

# Allow surfing the (secure) web
fleet1.connections.allow_to(ec2.Peer.any_ipv4(),
    ec2.Port(PortProps(from_port=443, to_port=443)))

fleet2 = asg.AutoScalingGroup( ... )
fleet1.connections.allow_from(fleet2, ec2.Port.all_traffic())
```

## Java

```
import software.amazon.awscdk.services.autoscaling.AutoScalingGroup;
import software.amazon.awscdk.services.ec2.Peer;
import software.amazon.awscdk.services.ec2.Port;

AutoScalingGroup fleet1 = AutoScalingGroup.Builder.create(this, "MyFleet")
    /* ... */.build();

// Allow surfing the (secure) Web
fleet1.getConnections().allowTo(Peer.anyIpv4(),
    Port.Builder.create().fromPort(443).toPort(443).build());

AutoScalingGroup fleet2 = AutoScalingGroup.Builder.create(this, "MyFleet2")
    /* ... */.build();
fleet1.getConnections().allowFrom(fleet2, Port.allTraffic());
```

## C#

```
using cdk = Amazon.CDK;
using asg = Amazon.CDK.AWS.AutoScaling;
using ec2 = Amazon.CDK.AWS.EC2;

// Allow surfing the (secure) Web
var fleet1 = new asg.AutoScalingGroup(this, "MyFleet", new asg.AutoScalingGroupProps
{ /* ... */ });
fleet1.Connections.AllowTo(ec2.Peer.AnyIpv4(), new ec2.Port(new ec2.PortProps
{ FromPort = 443, ToPort = 443 }));

var fleet2 = new asg.AutoScalingGroup(this, "MyFleet2", new asg.AutoScalingGroupProps
{ /* ... */ });
fleet1.Connections.AllowFrom(fleet2, ec2.Port.AllTraffic());
```

Certain resources have default ports associated with them. Examples include the listener of a load balancer on the public port, and the ports on which the database engine accepts connections for instances of an Amazon RDS database. In such cases, you can enforce tight network control without having to manually specify the port. To do so, use the `allowDefaultPortFrom` and `allowToDefaultPort` methods (Python: `allow_default_port_from`, `allow_to_default_port`).

The following example shows how to enable connections from any IPV4 address, and a connection from an Auto Scaling group to access a database.

## TypeScript

```
listener.connections.allowDefaultPortFromAnyIpv4('Allow public access');

fleet.connections.allowToDefaultPort(rdsDatabase, 'Fleet can access database');
```

## JavaScript

```
listener.connections.allowDefaultPortFromAnyIpv4('Allow public access');

fleet.connections.allowToDefaultPort(rdsDatabase, 'Fleet can access database');
```

## Python

```
listener.connections.allow_default_port_from_any_ipv4("Allow public access")
```



```
fleet.connections.allow_to_default_port(rds_database, "Fleet can access database")
```

#### Java

```
listener.getConnections().allowDefaultPortFromAnyIpv4("Allow public access");  
fleet.getConnections().AllowToDefaultPort(rdsDatabase, "Fleet can access database");
```

#### C#

```
listener.Connections.AllowDefaultPortFromAnyIpv4("Allow public access");  
fleet.Connections.AllowToDefaultPort(rdsDatabase, "Fleet can access database");
```

## Event handling

Some resources can act as event sources. Use the `addEventNotification` method (Python: `add_event_notification`) to register an event target to a particular event type emitted by the resource. In addition to this, `addXxxNotification` methods offer a simple way to register a handler for common event types.

The following example shows how to trigger a Lambda function when an object is added to an Amazon S3 bucket.

#### TypeScript

```
import * as s3nots from '@aws-cdk/aws-s3-notifications';  
  
const handler = new lambda.Function(this, 'Handler', { /*...*/ });  
const bucket = new s3.Bucket(this, 'Bucket');  
bucket.addObjectCreatedNotification(new s3nots.LambdaDestination(handler));
```

#### JavaScript

```
const s3nots = require('@aws-cdk/aws-s3-notifications');  
  
const handler = new lambda.Function(this, 'Handler', { /*...*/ });  
const bucket = new s3.Bucket(this, 'Bucket');  
bucket.addObjectCreatedNotification(new s3nots.LambdaDestination(handler));
```

#### Python

```
import aws_cdk.aws_s3_notifications as s3_not  
  
handler = lambda_.Function(self, "Handler", ...)  
bucket = s3.Bucket(self, "Bucket")  
bucket.add_object_created_notification(s3_not.LambdaDestination(handler))
```

#### Java

```
import software.amazon.awscdk.services.s3.Bucket;  
import software.amazon.awscdk.services.lambda.Function;  
import software.amazon.awscdk.services.s3.notifications.LambdaDestination;  
  
Function handler = Function.Builder.create(this, "Handler")/* ... */.build();
```

```
Bucket bucket = new Bucket(this, "Bucket");
bucket.addObjectCreatedNotification(new LambdaDestination(handler));
```

#### C#

```
using lambda = Amazon.CDK.AWS.Lambda;
using s3 = Amazon.CDK.AWS.S3;
using s3Nots = Amazon.CDK.AWS.S3.Notifications;

var handler = new lambda.Function(this, "Handler", new lambda.FunctionProps { .. });
var bucket = new s3.Bucket(this, "Bucket");
bucket.AddObjectCreatedNotification(new s3Nots.LambdaDestination(handler));
```

## Removal policies

Resources that maintain persistent data, such as databases, Amazon S3 buckets, and Amazon ECR registries, have a *removal policy*. The removal policy indicates whether to delete persistent objects when the AWS CDK stack that contains them is destroyed. The values specifying the removal policy are available through the `RemovalPolicy` enumeration in the AWS CDK core module.

### Note

Resources besides those that store data persistently might also have a `removalPolicy` that is used for a different purpose. For example, a Lambda function version uses a `removalPolicy` attribute to determine whether a given version is retained when a new version is deployed. These have different meanings and defaults compared to the removal policy on an Amazon S3 bucket or DynamoDB table.

Value	meaning
<code>RemovalPolicy.RETAIN</code>	Keep the contents of the resource when destroying the stack (default). The resource is orphaned from the stack and must be deleted manually. If you attempt to re-deploy the stack while the resource still exists, you will receive an error message due to a name conflict.
<code>RemovalPolicy.DESTROY</code>	The resource will be destroyed along with the stack.

AWS CloudFormation does not remove Amazon S3 buckets that contain files even if their removal policy is set to `DESTROY`. Attempting to do so is an AWS CloudFormation error. To have the AWS CDK delete all files from the bucket before destroying it, set the bucket's `autoDeleteObjects` property to `true`.

Following is an example of creating an Amazon S3 bucket with `RemovalPolicy` of `DESTROY` and `autoDeleteObjects` set to `true`.

#### TypeScript

```
import * as cdk from '@aws-cdk/core';
import * as s3 from '@aws-cdk/aws-s3';

export class CdkTestStack extends cdk.Stack {
  constructor(scope: cdk.Construct, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    const bucket = new s3.Bucket(this, 'Bucket', {
```

```
        removalPolicy: cdk RemovalPolicy.DESTROY,  
        autoDeleteObjects: true  
    });  
}  
}
```

#### JavaScript

```
const cdk = require('@aws-cdk/core');  
const s3 = require('@aws-cdk/aws-s3');  
  
class CdkTestStack extends cdk.Stack {  
    constructor(scope, id, props) {  
        super(scope, id, props);  
  
        const bucket = new s3.Bucket(this, 'Bucket', {  
            removalPolicy: cdk RemovalPolicy.DESTROY,  
            autoDeleteObjects: true  
        });  
    }  
}  
  
module.exports = { CdkTestStack }
```

#### Python

```
import aws_cdk.core as cdk  
import aws_cdk.aws_s3 as s3  
  
class CdkTestStack(cdk.Stack):  
    def __init__(self, scope: cdk.Construct, id: str, **kwargs):  
        super().__init__(scope, id, **kwargs)  
  
        bucket = s3.Bucket(self, "Bucket",  
            removal_policy=cdk RemovalPolicy.DESTROY,  
            auto_delete_objects=True)
```

#### Java

```
software.amazon.awscdk.core.*;  
import software.amazon.awscdk.services.s3.*;  
  
public class CdkTestStack extends Stack {  
    public CdkTestStack(final Construct scope, final String id) {  
        this(scope, id, null);  
    }  
  
    public CdkTestStack(final Construct scope, final String id, final StackProps props)  
    {  
        super(scope, id, props);  
  
        Bucket.Builder.create(this, "Bucket")  
            .removalPolicy(RemovalPolicy.DESTROY)  
            .autoDeleteObjects(true).build();  
    }  
}
```

#### C#

```
using Amazon.CDK;  
using Amazon.CDK.AWS.S3;
```

```
public CdkTestStack(Construct scope, string id, IStackProps props) : base(scope, id, props)
{
    new Bucket(this, "Bucket", new BucketProps {
        RemovalPolicy = RemovalPolicy.DESTROY,
        AutoDeleteObjects = true
    });
}
```

You can also apply a removal policy directly to the underlying AWS CloudFormation resource via the `applyRemovalPolicy()` method. This method is available on some stateful resources that do not have a `removalPolicy` property in their L2 resource's props. Examples include the following:

- AWS CloudFormation stacks
- Amazon Cognito user pools
- Amazon DocumentDB database instances
- Amazon EC2 volumes
- Amazon OpenSearch Service domains
- Amazon FSx file systems
- Amazon SQS queues

#### TypeScript

```
const resource = bucket.node.findChild('Resource') as cdk.CfnResource;
resource.applyRemovalPolicy(cdk.RemovalPolicy.DESTROY);
```

#### JavaScript

```
const resource = bucket.node.findChild('Resource');
resource.applyRemovalPolicy(cdk.RemovalPolicy.DESTROY);
```

#### Python

```
resource = bucket.node.find_child('Resource')
resource.apply_removal_policy(cdk.RemovalPolicy.DESTROY);
```

#### Java

```
CfnResource resource = (CfnResource)bucket.node.findChild("Resource");
resource.applyRemovalPolicy(cdk.RemovalPolicy.DESTROY);
```

#### C#

```
var resource = (CfnResource)bucket.node.findChild('Resource');
resource.ApplyRemovalPolicy(cdk.RemovalPolicy.DESTROY);
```

#### Note

The AWS CDK's `RemovalPolicy` translates to AWS CloudFormation's `DeletionPolicy`. However, the default in AWS CDK is to retain the data, which is the opposite of the AWS CloudFormation default.

# Identifiers

The AWS CDK deals with many types of identifiers and names. To use the AWS CDK effectively and avoid errors, you need to understand the types of identifiers.

Identifiers must be unique within the scope in which they are created; they do not need to be globally unique in your AWS CDK application.

If you attempt to create an identifier with the same value within the same scope, the AWS CDK throws an exception.

## Construct IDs

The most common identifier, `id`, is the identifier passed as the second argument when instantiating a construct object. This identifier, like all identifiers, only needs to be unique within the scope in which it is created, which is the first argument when instantiating a construct object.

### Note

The `id` of a stack is also the identifier that you use to refer to it in the [the section called “AWS CDK Toolkit” \(p. 309\)](#).

Let's look at an example where we have two constructs with the identifier `MyBucket` in our app. The first is defined in the scope of the stack with the identifier `Stack1`. The second is defined in the scope of a stack with the identifier `Stack2`. Because they're defined in different scopes, this doesn't cause any conflict, and they can coexist in the same app without issues.

### TypeScript

```
import { App, Stack, StackProps } from 'aws-cdk-lib';
import { Construct } from 'constructs';
import * as s3 from 'aws-cdk-lib/aws-s3';

class MyStack extends Stack {
  constructor(scope: Construct, id: string, props: StackProps = {}) {
    super(scope, id, props);

    new s3.Bucket(this, 'MyBucket');
  }
}

const app = new App();
new MyStack(app, 'Stack1');
new MyStack(app, 'Stack2');
```

### JavaScript

```
const { App, Stack } = require('aws-cdk-lib');
const s3 = require('aws-cdk-lib/aws-s3');

class MyStack extends Stack {
  constructor(scope, id, props = {}) {
    super(scope, id, props);

    new s3.Bucket(this, 'MyBucket');
  }
}

const app = new App();
new MyStack(app, 'Stack1');
new MyStack(app, 'Stack2');
```

## Python

```
from aws_cdk import App, Construct, Stack, StackProps
from constructs import Construct
from aws_cdk import aws_s3 as s3

class MyStack(Stack):

    def __init__(self, scope: Construct, id: str, **kwargs):

        super().__init__(scope, id, **kwargs)
        s3.Bucket(self, "MyBucket")

app = App()
MyStack(app, 'Stack1')
MyStack(app, 'Stack2')
```

## Java

```
// MyStack.java
package com.myorg;

import software.amazon.awscdk.App;
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.constructs.Construct;
import software.amazon.awscdk.services.s3.Bucket;

public class MyStack extends Stack {
    public MyStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public MyStack(final Construct scope, final String id, final StackProps props) {
        super(scope, id, props);
        new Bucket(this, "MyBucket");
    }
}

// Main.java
package com.myorg;

import software.amazon.awscdk.App;

public class Main {
    public static void main(String[] args) {
        App app = new App();
        new MyStack(app, "Stack1");
        new MyStack(app, "Stack2");
    }
}
```

## C#

```
using Amazon.CDK;
using constructs;
using Amazon.CDK.AWS.S3;

public class MyStack : Stack
{
    public MyStack(Construct scope, string id, IStackProps props) : base(scope, id, props)
    {
    }
}
```

```
        new Bucket(this, "MyBucket");
    }
}

class Program
{
    static void Main(string[] args)
    {
        var app = new App();
        new MyStack(app, "Stack1");
        new MyStack(app, "Stack2");
    }
}
```

## Paths

The constructs in an AWS CDK application form a hierarchy rooted in the `App` class. We refer to the collection of IDs from a given construct, its parent construct, its grandparent, and so on to the root of the construct tree, as a *path*.

The AWS CDK typically displays paths in your templates as a string. The IDs from the levels are separated by slashes, starting at the node immediately under the root `App` instance, which is usually a stack. For example, the paths of the two Amazon S3 bucket resources in the previous code example are `Stack1/MyBucket` and `Stack2/MyBucket`.

You can access the path of any construct programmatically, as shown in the following example. This gets the path of `myConstruct` (or `my_construct`, as Python developers would write it). Since IDs must be unique within the scope they are created, their paths are always unique within an AWS CDK application.

### TypeScript

```
const path: string = myConstruct.node.path;
```

### JavaScript

```
const path = myConstruct.node.path;
```

### Python

```
path = my_construct.node.path
```

### Java

```
String path = myConstruct.getNode().getPath();
```

### C#

```
string path = myConstruct.Node.Path;
```

## Unique IDs

AWS CloudFormation requires that all logical IDs in a template be unique. Because of this, the AWS CDK must be able to generate a unique identifier for each construct in an application. Resources have

paths that are globally unique (the names of all scopes from the stack to a specific resource). Therefore, the AWS CDK generates the necessary unique identifiers by concatenating the elements of the path and adding an 8-digit hash. (The hash is necessary to distinguish distinct paths, such as A/B/C and A/BC, that would result in the same AWS CloudFormation identifier. AWS CloudFormation identifiers are alphanumeric and cannot contain slashes or other separator characters.) The AWS CDK calls this string the *unique ID* of the construct.

In general, your AWS CDK app should not need to know about unique IDs. You can, however, access the unique ID of any construct programmatically, as shown in the following example.

#### TypeScript

```
const uid: string = Names.uniqueId(myConstruct);
```

#### JavaScript

```
const uid = Names.uniqueId(myConstruct);
```

#### Python

```
uid = Names.unique_id(my_construct)
```

#### Java

```
String uid = Names.uniqueId(myConstruct);
```

#### C#

```
string uid = Names.Uniqueid(myConstruct);
```

The *address* is another kind of unique identifier that uniquely distinguishes CDK resources. Derived from the SHA-1 hash of the path, it is not human-readable. However, its constant, relatively short length (always 42 hexadecimal characters) makes it useful in situations where the "traditional" unique ID might be too long. Some constructs may use the address in the synthesized AWS CloudFormation template instead of the unique ID. Again, your app generally should not need to know about its constructs' addresses, but you can retrieve a construct's address as follows.

#### TypeScript

```
const addr: string = myConstruct.node.addr;
```

#### JavaScript

```
const addr = myConstruct.node.addr;
```

#### Python

```
addr = my_construct.node.addr
```

#### Java

```
String addr = myConstruct.getNode().getAddr();
```



C#

```
string addr = myConstruct.Node.Addr;
```

## Logical IDs

Unique IDs serve as the *logical identifiers* (or *logical names*) of resources in the generated AWS CloudFormation templates for constructs that represent AWS resources.

For example, the Amazon S3 bucket in the previous example that is created within `Stack2` results in an `AWS::S3::Bucket` resource. The resource's logical ID is `Stack2MyBucket4DD88B4F` in the resulting AWS CloudFormation template. (For details on how this identifier is generated, see [the section called "Unique IDs" \(p. 143\)](#).)

### Logical ID stability

Avoid changing the logical ID of a resource after it has been created. AWS CloudFormation identifies resources by their logical ID. Therefore, if you change the logical ID of a resource, AWS CloudFormation creates a new resource with the new logical ID, then deletes the existing one. Depending on the type of resource, this might cause service interruption, data loss, or both.

## Tokens

Tokens represent values that can only be resolved at a later time in the lifecycle of an app (see [the section called "App lifecycle" \(p. 105\)](#)). For example, the name of an Amazon S3 bucket that you define in your AWS CDK app is only allocated when the AWS CloudFormation template is synthesized. If you print the `bucket.bucketName` attribute, which is a string, you see it contains something like the following.

```
${TOKEN[Bucket.Name.1234]}
```

This is how the AWS CDK encodes a token whose value is not yet known at construction time, but will become available later. The AWS CDK calls these placeholders *tokens*. In this case, it's a token encoded as a string.

You can pass this string around as if it was the name of the bucket. In the following example, the bucket name is specified as an environment variable to an AWS Lambda function.

TypeScript

```
const bucket = new s3.Bucket(this, 'MyBucket');

const fn = new lambda.Function(stack, 'MyLambda', {
  // ...
  environment: {
    BUCKET_NAME: bucket.bucketName,
  }
});
```

JavaScript

```
const bucket = new s3.Bucket(this, 'MyBucket');
```

```
const fn = new lambda.Function(stack, 'MyLambda', {
  // ...
  environment: {
    BUCKET_NAME: bucket.bucketName
  }
});
```

#### Python

```
bucket = s3.Bucket(self, "MyBucket")

fn = lambda_.Function(stack, "MyLambda",
    environment=dict(BUCKET_NAME=bucket.bucket_name))
```

#### Java

```
final Bucket bucket = new Bucket(this, "MyBucket");

Function fn = Function.Builder.create(this, "MyLambda")
    .environment(java.util.Map.of( // Map.of requires Java 9+
        "BUCKET_NAME", bucket.getBucketName()))
    .build();
```

#### C#

```
var bucket = new s3.Bucket(this, "MyBucket");

var fn = new Function(this, "MyLambda", new FunctionProps {
    Environment = new Dictionary<string, string> {
        {
            ["BUCKET_NAME"] = bucket.BucketName
        }
    }
});
```

When the AWS CloudFormation template is finally synthesized, the token is rendered as the AWS CloudFormation intrinsic `{ "Ref": "MyBucket" }`. At deployment time, AWS CloudFormation replaces this intrinsic with the actual name of the bucket that was created.

## Tokens and token encodings

Tokens are objects that implement the [IResolvable](#) interface, which contains a single `resolve` method. The AWS CDK calls this method during synthesis to produce the final value for the AWS CloudFormation template. Tokens participate in the synthesis process to produce arbitrary values of any type.

#### Note

You'll hardly ever work directly with the `IResolvable` interface. You will most likely only see string-encoded versions of tokens.

Other functions typically only accept arguments of basic types, such as `string` or `number`. To use tokens in these cases, you can encode them into one of three types by using static methods on the [cdk.Token](#) class.

- [Token.asString](#) to generate a string encoding (or call `.toString()` on the token object)
- [Token.asList](#) to generate a list encoding
- [Token.asNumber](#) to generate a numeric encoding

These take an arbitrary value, which can be an `IResolvable`, and encode them into a primitive value of the indicated type.

### Important

Because any one of the previous types can potentially be an encoded token, be careful when you parse or try to read their contents. For example, if you attempt to parse a string to extract a value from it, and the string is an encoded token, your parsing fails. Similarly, if you try to query the length of an array or perform math operations with a number, you must first verify that they aren't encoded tokens.

To check whether a value has an unresolved token in it, call the `Token.isUnresolved` (Python: `is_unresolved`) method.

The following example validates that a string value, which could be a token, is no more than 10 characters long.

#### TypeScript

```
if (!Token.isUnresolved(name) && name.length > 10) {  
    throw new Error(`Maximum length for name is 10 characters`);  
}
```

#### JavaScript

```
if ( !Token.isUnresolved(name) && name.length > 10) {  
    throw ( new Error(`Maximum length for name is 10 characters`));  
}
```

#### Python

```
if not Token.is_unresolved(name) and len(name) > 10:  
    raise ValueError("Maximum length for name is 10 characters")
```

#### Java

```
if (!Token.isUnresolved(name) && name.length() > 10)  
    throw new IllegalArgumentException("Maximum length for name is 10 characters");
```

#### C#

```
if (!Token.IsUnresolved(name) && name.Length > 10)  
    throw new ArgumentException("Maximum length for name is 10 characters");
```

If **name** is a token, validation isn't performed, and an error could still occur in a later stage in the lifecycle, such as during deployment.

### Note

You can use token encodings to escape the type system. For example, you could string-encode a token that produces a number value at synthesis time. If you use these functions, it's your responsibility to make sure that your template resolves to a usable state after synthesis.

## String-encoded tokens

String-encoded tokens look like the following.

```
${TOKEN[Bucket.Name.1234]}
```

They can be passed around like regular strings, and can be concatenated, as shown in the following example.

#### TypeScript

```
const functionName = bucket.bucketName + 'Function';
```

#### JavaScript

```
const functionName = bucket.bucketName + 'Function';
```

#### Python

```
function_name = bucket.bucket_name + "Function"
```

#### Java

```
String functionName = bucket.getBucketName().concat("Function");
```

#### C#

```
string functionName = bucket.BucketName + "Function";
```

You can also use string interpolation, if your language supports it, as shown in the following example.

#### TypeScript

```
const functionName = `${bucket.bucketName}Function`;
```

#### JavaScript

```
const functionName = `${bucket.bucketName}Function`;
```

#### Python

```
function_name = f"{bucket.bucket_name}Function"
```

#### Java

```
String functionName = String.format("%sFunction", bucket.getBucketName());
```

#### C#

```
string functionName = $"{bucket.bucketName}Function";
```

Avoid manipulating the string in other ways. For example, taking a substring of a string is likely to break the string token.

## List-encoded tokens

List-encoded tokens look like the following:

```
["#{TOKEN[Stack.NotificationArns.1234]}"]
```

The only safe thing to do with these lists is pass them directly to other constructs. Tokens in string list form cannot be concatenated, nor can an element be taken from the token. The only safe way to manipulate them is by using AWS CloudFormation intrinsic functions like [Fn.select](#).

## Number-encoded tokens

Number-encoded tokens are a set of tiny negative floating-point numbers that look like the following.

```
-1.8881545897087626e+289
```

As with list tokens, you cannot modify the number value, as doing so is likely to break the number token. The only allowed operation is to pass the value around to another construct.

## Lazy values

In addition to representing deploy-time values, such as AWS CloudFormation [parameters \(p. 151\)](#), tokens are also commonly used to represent synthesis-time lazy values. These are values for which the final value will be determined before synthesis has completed, but not at the point where the value is constructed. Use tokens to pass a literal string or number value to another construct, while the actual value at synthesis time might depend on some calculation that has yet to occur.

You can construct tokens representing synth-time lazy values using static methods on the `Lazy` class, such as [Lazy.string](#) and [Lazy.number](#). These methods accept an object whose `produce` property is a function that accepts a context argument and returns the final value when called.

The following example creates an Auto Scaling group whose capacity is determined after its creation.

TypeScript

```
let actualValue: number;

new AutoScalingGroup(this, 'Group', {
  desiredCapacity: Lazy.numberValue({
    produce(context) {
      return actualValue;
    }
  })
});

// At some later point
actualValue = 10;
```

JavaScript

```
let actualValue;

new AutoScalingGroup(this, 'Group', {
  desiredCapacity: Lazy.numberValue({
    produce(context) {
      return (actualValue);
    }
  })
});
```

```
    })  
  });  
  
  // At some later point  
  actualValue = 10;
```

## Python

```
class Producer:  
    def __init__(self, func):  
        self.produce = func  
  
actual_value = None  
  
AutoScalingGroup(self, "Group",  
    desired_capacity=Lazy.number_value(Producer(lambda context: actual_value))  
)  
  
# At some later point  
actual_value = 10
```

## Java

```
double actualValue = 0;  
  
class ProduceActualValue implements INumberProducer {  
  
    @Override  
    public Number produce(IResolveContext context) {  
        return actualValue;  
    }  
}  
  
AutoScalingGroup.Builder.create(this, "Group")  
    .desiredCapacity(Lazy.numberValue(new ProduceActualValue())).build();  
  
// At some later point  
actualValue = 10;
```

## C#

```
public class NumberProducer : INumberProducer  
{  
    Func<Double> function;  
  
    public NumberProducer(Func<Double> function)  
    {  
        this.function = function;  
    }  
  
    public Double Produce(IResolveContext context)  
    {  
        return function();  
    }  
}  
  
double actualValue = 0;  
  
new AutoScalingGroup(this, "Group", new AutoScalingGroupProps  
{  
    DesiredCapacity = Lazy.NumberValue(new NumberProducer(() => actualValue))  
});
```

```
// At some later point  
actualValue = 10;
```

## Converting to JSON

Sometimes you want to produce a JSON string of arbitrary data, and you may not know whether the data contains tokens. To properly JSON-encode any data structure, regardless of whether it contains tokens, use the method [stack.toJsonString](#), as shown in the following example.

### TypeScript

```
const stack = Stack.of(this);  
const str = stack.toJsonString({  
  value: bucket.bucketName  
});
```

### JavaScript

```
const stack = Stack.of(this);  
const str = stack.toJsonString({  
  value: bucket.bucketName  
});
```

### Python

```
stack = Stack.of(self)  
string = stack.to_json_string(dict(value=bucket.bucket_name))
```

### Java

```
Stack stack = Stack.of(this);  
String stringVal = stack.toJsonString(java.util.Map.of(    // Map.of requires Java 9+  
    put("value", bucket.getBucketName())));
```

### C#

```
var stack = Stack.Of(this);  
var stringVal = stack.ToJsonString(new Dictionary<string, string>  
{  
    ["value"] = bucket.BucketName  
});
```

## Parameters

AWS CloudFormation templates can contain [parameters](#)—custom values that are supplied at deployment time and incorporated into the template. Because the AWS CDK synthesizes AWS CloudFormation templates, it also offers support for deployment-time parameters.

Using the AWS CDK, you can define parameters, which can then be used in the properties of constructs you create. You can also deploy stacks that contain parameters.

When deploying the AWS CloudFormation template using the AWS CDK Toolkit, you provide the parameter values on the command line. If you deploy the template through the AWS CloudFormation console, you are prompted for the parameter values.

In general, we recommend against using AWS CloudFormation parameters with the AWS CDK. The usual ways to pass values into AWS CDK apps are [context values \(p. 185\)](#) and environment variables. Because they are not available at synthesis time, parameter values cannot be easily used for flow control and other purposes in your CDK app.

**Note**

To do control flow with parameters, you can use [CfnCondition](#) constructs, although this is awkward compared to native `if` statements.

Using parameters requires you to be mindful of how the code you're writing behaves at deployment time, and also at synthesis time. This makes it harder to understand and reason about your AWS CDK application, in many cases for little benefit.

Generally, it's better to have your CDK app accept necessary information in a well-defined way and use it directly to declare constructs in your CDK app. An ideal AWS CDK-generated AWS CloudFormation template is concrete, with no values remaining to be specified at deployment time.

There are, however, use cases to which AWS CloudFormation parameters are uniquely suited. If you have separate teams defining and deploying infrastructure, for example, you can use parameters to make the generated templates more widely useful. Also, because the AWS CDK supports AWS CloudFormation parameters, you can use the AWS CDK with AWS services that use AWS CloudFormation templates (such as Service Catalog). These AWS services use parameters to configure the template that's being deployed.

## Defining parameters

Use the [CfnParameter](#) class to define a parameter. You'll want to specify at least a type and a description for most parameters, though both are technically optional. The description appears when the user is prompted to enter the parameter's value in the AWS CloudFormation console. For more information on the available types, see [Types](#).

**Note**

You can define parameters in any scope. However, we recommend defining parameters at the stack level so that their logical ID doesn't change when you refactor your code.

### TypeScript

```
const uploadBucketName = new CfnParameter(this, "uploadBucketName", {
  type: "String",
  description: "The name of the Amazon S3 bucket where uploaded files will be
stored."});
```

### JavaScript

```
const uploadBucketName = new CfnParameter(this, "uploadBucketName", {
  type: "String",
  description: "The name of the Amazon S3 bucket where uploaded files will be
stored."});
```

### Python

```
upload_bucket_name = CfnParameter(self, "uploadBucketName", type="String",
    description="The name of the Amazon S3 bucket where uploaded files will be
stored.")
```

### Java

```
CfnParameter uploadBucketName = CfnParameter.Builder.create(this, "uploadBucketName")
    .type("String")
```



```
.description("The name of the Amazon S3 bucket where uploaded files will be  
stored")  
.build();
```

#### C#

```
var uploadBucketName = new CfnParameter(this, "uploadBucketName", new CfnParameterProps  
{  
    Type = "String",  
    Description = "The name of the Amazon S3 bucket where uploaded files will be  
stored"  
});
```

## Using parameters

A `CfnParameter` instance exposes its value to your AWS CDK app via a [token \(p. 145\)](#). Like all tokens, the parameter's token is resolved at synthesis time. But it resolves to a reference to the parameter defined in the AWS CloudFormation template (which will be resolved at deploy time), rather than to a concrete value.

You can retrieve the token as an instance of the `Token` class, or in string, string list, or numeric encoding. Your choice depends on the kind of value required by the class or method that you want to use the parameter with.

#### TypeScript

Property	kind of value
<code>value</code>	Token class instance
<code>valueAsList</code>	The token represented as a string list
<code>valueAsNumber</code>	The token represented as a number
<code>valueAsString</code>	The token represented as a string

#### JavaScript

Property	kind of value
<code>value</code>	Token class instance
<code>valueAsList</code>	The token represented as a string list
<code>valueAsNumber</code>	The token represented as a number
<code>valueAsString</code>	The token represented as a string

#### Python

Property	kind of value
<code>value</code>	Token class instance

Property	kind of value
value_as_list	The token represented as a string list
value_as_number	The token represented as a number
value_as_string	The token represented as a string

#### Java

Property	kind of value
getValue()	Token class instance
getValueAsList()	The token represented as a string list
getValueAsNumber()	The token represented as a number
getValueAsString()	The token represented as a string

#### C#

Property	kind of value
Value	Token class instance
ValueAsList	The token represented as a string list
ValueAsNumber	The token represented as a number
ValueAsString	The token represented as a string

For example, to use a parameter in a Bucket definition:

#### TypeScript

```
const bucket = new Bucket(this, "myBucket",  
  { bucketName: uploadBucketName.valueAsString});
```

#### JavaScript

```
const bucket = new Bucket(this, "myBucket",  
  { bucketName: uploadBucketName.valueAsString});
```

#### Python

```
bucket = Bucket(self, "myBucket",  
  bucket_name=upload_bucket_name.value_as_string)
```

#### Java

```
Bucket bucket = Bucket.Builder.create(this, "myBucket")  
  .bucketName(uploadBucketName.getValueAsString())
```

```
.build();
```

C#

```
var bucket = new Bucket(this, "myBucket")
{
    BucketName = uploadBucketName.ValueAsString
};
```

## Deploying with parameters

A generated template containing parameters can be deployed in the usual way through the AWS CloudFormation console. You are prompted for the values of each parameter.

The AWS CDK Toolkit (cdk command line tool) also supports specifying parameters at deployment. You provide these on the command line following the `--parameters` flag. You might deploy a stack that uses the `uploadBucketName` parameter, like the following example.

```
cdk deploy MyStack --parameters uploadBucketName=uploadbucket
```

To define multiple parameters, use multiple `--parameters` flags.

```
cdk deploy MyStack --parameters uploadBucketName=upbucket --parameters
downloadBucketName=downbucket
```

If you are deploying multiple stacks, you can specify a different value of each parameter for each stack. To do so, prefix the name of the parameter with the stack name and a colon.

```
cdk deploy MyStack YourStack --parameters MyStack:uploadBucketName=uploadbucket --
parameters YourStack:uploadBucketName=upbucket
```

By default, the AWS CDK retains values of parameters from previous deployments and uses them in subsequent deployments if they are not specified explicitly. Use the `--no-previous-parameters` flag to require all parameters to be specified.

## Tagging

Tags are informational key-value elements that you can add to constructs in your AWS CDK app. A tag applied to a given construct also applies to all of its taggable children. Tags are included in the AWS CloudFormation template synthesized from your app and are applied to the AWS resources it deploys. You can use tags to identify and categorize resources for the following purposes:

- Simplifying management
- Cost allocation
- Access control
- Any other purposes that you devise

### Tip

For more information about how you can use tags with your AWS resources, see the whitepaper [Tagging Best Practices](#) (PDF).

The `Tags` class includes the static method `of()`, through which you can add tags to, or remove tags from, the specified construct.

- `Tags.of(SCOPE).add()` applies a new tag to the given construct and all of its children.
- `Tags.of(SCOPE).remove()` removes a tag from the given construct and any of its children, including tags a child construct may have applied to itself.

#### Note

Tagging is implemented using [the section called “Aspects” \(p. 192\)](#). Aspects are a way to apply an operation (such as tagging) to all constructs in a given scope.

The following example applies the tag **key** with the value **value** to a construct.

#### TypeScript

```
Tags.of(myConstruct).add('key', 'value');
```

#### JavaScript

```
Tags.of(myConstruct).add('key', 'value');
```

#### Python

```
Tags.of(my_construct).add("key", "value")
```

#### Java

```
Tags.of(myConstruct).add("key", "value");
```

#### C#

```
Tags.Of(myConstruct).Add("key", "value");
```

The following example deletes the tag **key** from a construct.

#### TypeScript

```
Tags.of(myConstruct).remove('key');
```

#### JavaScript

```
Tags.of(myConstruct).remove('key');
```

#### Python

```
Tags.of(my_construct).remove("key")
```

#### Java

```
Tags.of(myConstruct).remove("key");
```

C#

```
Tags.Of(myConstruct).Remove("key");
```

If you are using Stage constructs, apply the tag at the Stage level or below. Tags are not applied across Stage boundaries.

## Tag priorities

The AWS CDK applies and removes tags recursively. If there are conflicts, the tagging operation with the highest priority wins. (Priorities are set using the optional `priority` property.) If the priorities of two operations are the same, the tagging operation closest to the bottom of the construct tree wins. By default, applying a tag has a priority of 100 (except for tags added directly to an AWS CloudFormation resource, which has a priority of 50). The default priority for removing a tag is 200.

The following applies a tag with a priority of 300 to a construct.

TypeScript

```
Tags.of(myConstruct).add('key', 'value', {  
  priority: 300  
});
```

JavaScript

```
Tags.of(myConstruct).add('key', 'value', {  
  priority: 300  
});
```

Python

```
Tags.of(my_construct).add("key", "value", priority=300)
```

Java

```
Tags.of(myConstruct).add("key", "value", TagProps.builder()  
    .priority(300).build());
```

C#

```
Tags.Of(myConstruct).Add("key", "value", new TagProps { Priority = 300 });
```

## Optional properties

Tags support [properties](#) that fine-tune how tags are applied to, or removed from, resources. All properties are optional.

`applyToLaunchedInstances` (Python: `apply_to_launched_instances`)

Available for `add()` only. By default, tags are applied to instances launched in an Auto Scaling group. Set this property to **false** to ignore instances launched in an Auto Scaling group.

`includeResourceTypes/excludeResourceTypes` (Python:  
`include_resource_types/exclude_resource_types`)

Use these to manipulate tags only on a subset of resources, based on AWS CloudFormation resource types. By default, the operation is applied to all resources in the construct subtree, but this can be changed by including or excluding certain resource types. Exclude takes precedence over include, if both are specified.

`priority`

Use this to set the priority of this operation with respect to other `Tags.add()` and `Tags.remove()` operations. Higher values take precedence over lower values. The default is 100 for add operations (50 for tags applied directly to AWS CloudFormation resources) and 200 for remove operations.

The following example applies the tag **tagname** with the value **value** and priority **100** to resources of type **AWS::Xxx::Yyy** in the construct. It doesn't apply the tag to instances launched in an Amazon EC2 Auto Scaling group or to resources of type **AWS::Xxx::Zzz**. (These are placeholders for two arbitrary but different AWS CloudFormation resource types.)

TypeScript

```
Tags.of(myConstruct).add('tagname', 'value', {
  applyToLaunchedInstances: false,
  includeResourceTypes: ['AWS::Xxx::Yyy'],
  excludeResourceTypes: ['AWS::Xxx::Zzz'],
  priority: 100,
});
```

JavaScript

```
Tags.of(myConstruct).add('tagname', 'value', {
  applyToLaunchedInstances: false,
  includeResourceTypes: ['AWS::Xxx::Yyy'],
  excludeResourceTypes: ['AWS::Xxx::Zzz'],
  priority: 100
});
```

Python

```
Tags.of(my_construct).add("tagname", "value",
    apply_to_launched_instances=False,
    include_resource_types=["AWS::Xxx::Yyy"],
    exclude_resource_types=["AWS::Xxx::Zzz"],
    priority=100)
```

Java

```
Tags.of(myConstruct).add("key", "value", TagProps.builder()
    .applyToLaunchedInstances(false)
    .includeResourceTypes(Arrays.asList("AWS::Xxx::Yyy"))
    .excludeResourceTypes(Arrays.asList("AWS::Xxx::Zzz"))
    .priority(100).build());
```

C#

```
Tags.Of(myConstruct).Add("tagname", "value", new TagProps
{
    ApplyToLaunchedInstances = false,
    IncludeResourceTypes = ["AWS::Xxx::Yyy"],
```

```
ExcludeResourceTypes = ["AWS::Xxx::Zzz"],  
Priority = 100  
});
```

The following example removes the tag **tagname** with priority **200** from resources of type **AWS::Xxx::Yyy** in the construct, but not from resources of type **AWS::Xxx::Zzz**.

#### TypeScript

```
Tags.of(myConstruct).remove('tagname', {  
  includeResourceTypes: ['AWS::Xxx::Yyy'],  
  excludeResourceTypes: ['AWS::Xxx::Zzz'],  
  priority: 200,  
});
```

#### JavaScript

```
Tags.of(myConstruct).remove('tagname', {  
  includeResourceTypes: ['AWS::Xxx::Yyy'],  
  excludeResourceTypes: ['AWS::Xxx::Zzz'],  
  priority: 200  
});
```

#### Python

```
Tags.of(my_construct).remove("tagname",  
    include_resource_types=["AWS::Xxx::Yyy"],  
    exclude_resource_types=["AWS::Xxx::Zzz"],  
    priority=200,)
```

#### Java

```
Tags.of((myConstruct).remove("tagname", TagProps.builder()  
    .includeResourceTypes(Arrays.asList("AWS::Xxx::Yyy"))  
    .excludeResourceTypes(Arrays.asList("AWS::Xxx::Zzz"))  
    .priority(100).build());
```

#### C#

```
Tags.Of(myConstruct).Remove("tagname", new TagProps  
{  
    IncludeResourceTypes = ["AWS::Xxx::Yyy"],  
    ExcludeResourceTypes = ["AWS::Xxx::Zzz"],  
    Priority = 100  
});
```

## Example

The following example adds the tag key **StackType** with value **TheBest** to any resource created within the Stack named **MarketingSystem**. Then it removes it again from all resources except Amazon EC2 VPC subnets. The result is that only the subnets have the tag applied.

#### TypeScript

```
import { App, Stack, Tags } from 'aws-cdk-lib';
```

```
const app = new App();
const theBestStack = new Stack(app, 'MarketingSystem');

// Add a tag to all constructs in the stack
Tags.of(theBestStack).add('StackType', 'TheBest');

// Remove the tag from all resources except subnet resources
Tags.of(theBestStack).remove('StackType', {
  excludeResourceTypes: ['AWS::EC2::Subnet']
});
```

#### JavaScript

```
const { App, Stack, Tags } = require('aws-cdk-lib');

const app = new App();
const theBestStack = new Stack(app, 'MarketingSystem');

// Add a tag to all constructs in the stack
Tags.of(theBestStack).add('StackType', 'TheBest');

// Remove the tag from all resources except subnet resources
Tags.of(theBestStack).remove('StackType', {
  excludeResourceTypes: ['AWS::EC2::Subnet']
});
```

#### Python

```
from aws_cdk import App, Stack, Tags

app = App()
the_best_stack = Stack(app, 'MarketingSystem')

# Add a tag to all constructs in the stack
Tags.of(the_best_stack).add("StackType", "TheBest")

# Remove the tag from all resources except subnet resources
Tags.of(the_best_stack).remove("StackType",
    exclude_resource_types=["AWS::EC2::Subnet"])
```

#### Java

```
import software.amazon.awscdk.App;
import software.amazon.awscdk.Tags;

// Add a tag to all constructs in the stack
Tags.of(theBestStack).add("StackType", "TheBest");

// Remove the tag from all resources except subnet resources
Tags.of(theBestStack).remove("StackType", TagProps.builder()
    .excludeResourceTypes(Arrays.asList("AWS::EC2::Subnet"))
    .build());
```

#### C#

```
using Amazon.CDK;

var app = new App();
var theBestStack = new Stack(app, 'MarketingSystem');
```



```
// Add a tag to all constructs in the stack
Tags.Of(theBestStack).Add("StackType", "TheBest");

// Remove the tag from all resources except subnet resources
Tags.Of(theBestStack).Remove("StackType", new TagProps
{
    ExcludeResourceTypes = ["AWS::EC2::Subnet"]
});
```

The following code achieves the same result. Consider which approach (inclusion or exclusion) makes your intent clearer.

#### TypeScript

```
Tags.of(theBestStack).add('StackType', 'TheBest',
{ includeResourceTypes: ['AWS::EC2::Subnet']});
```

#### JavaScript

```
Tags.of(theBestStack).add('StackType', 'TheBest',
{ includeResourceTypes: ['AWS::EC2::Subnet']});
```

#### Python

```
Tags.of(the_best_stack).add("StackType", "TheBest",
include_resource_types=["AWS::EC2::Subnet"])
```

#### Java

```
Tags.of(theBestStack).add("StackType", "TheBest", TagProps.builder()
    .includeResourceTypes(Arrays.asList("AWS::EC2::Subnet"))
    .build());
```

#### C#

```
Tags.Of(theBestStack).Add("StackType", "TheBest", new TagProps {
    IncludeResourceTypes = ["AWS::EC2::Subnet"]
});
```

## Tagging single constructs

`Tags.of(scope).add(key, value)` is the standard way to add tags to constructs in the AWS CDK. Its tree-walking behavior, which recursively tags all taggable resources under the given scope, is almost always what you want. Sometimes, however, you need to tag a specific, arbitrary construct (or constructs).

One such case involves applying tags whose value is derived from some property of the construct being tagged. The standard tagging approach recursively applies the same key and value to all matching resources in the scope. However, here the value could be different for each tagged construct.

Tags are implemented using [aspects \(p. 192\)](#), and the CDK calls the tag's `visit()` method for each construct under the scope you specified using `Tags.of(scope)`. We can call `Tag.visit()` directly to apply a tag to a single construct.

### TypeScript

```
new cdk.Tag(key, value).visit(scope);
```

### JavaScript

```
new cdk.Tag(key, value).visit(scope);
```

### Python

```
cdk.Tag(key, value).visit(scope)
```

### Java

```
Tag.Builder.create(key, value).build().visit(scope);
```

### C#

```
new Tag(key, value).Visit(scope);
```

You can tag all constructs under a scope but let the values of the tags derive from properties of each construct. To do so, write an aspect and apply the tag in the aspect's `visit()` method as shown in the preceding example. Then, add the aspect to the desired scope using `Aspects.of(scope).add(aspect)`.

The following example applies a tag to each resource in a stack containing the resource's path.

### TypeScript

```
class PathTagger implements cdk.IAspect {  
  visit(node: IConstruct) {  
    new cdk.Tag("aws-cdk-path", node.node.path).visit(node);  
  }  
}  
  
stack = new MyStack(app);  
cdk.Aspects.of(stack).add(new PathTagger())
```

### JavaScript

```
class PathTagger {  
  visit(node) {  
    new cdk.Tag("aws-cdk-path", node.node.path).visit(node);  
  }  
}  
  
stack = new MyStack(app);  
cdk.Aspects.of(stack).add(new PathTagger())
```

### Python

```
@jsii.implements(cdk.IAspect)  
class PathTagger:  
    def visit(self, node: IConstruct):  
        cdk.Tag("aws-cdk-path", node.node.path).visit(node)
```

```
stack = MyStack(app)
cdk.Aspects.of(stack).add(PathTagger())
```

#### Java

```
final class PathTagger implements IAspect {
    public void visit(IConstruct node) {
        Tag.Builder.create("aws-cdk-path", node.getNode().getPath()).build().visit(node);
    }
}

stack stack = new MyStack(app);
Aspects.of(stack).add(new PathTagger());
```

#### C#

```
public class PathTagger : IAspect
{
    public void Visit(IConstruct node)
    {
        new Tag("aws-cdk-path", node.Node.Path).Visit(node);
    }
}

var stack = new MyStack(app);
Aspects.Of(stack).Add(new PathTagger());
```

#### Tip

The logic of conditional tagging, including priorities, resource types, and so on, is built into the Tag class. You can use these features when applying tags to arbitrary resources; the tag is not applied if the conditions aren't met. Also, the Tag class only tags taggable resources, so you don't need to test whether a construct is taggable before applying a tag.

## Assets

Assets are local files, directories, or Docker images that can be bundled into AWS CDK libraries and apps. For example, an asset might be a directory that contains the handler code for an AWS Lambda function. Assets can represent any artifact that the app needs to operate.

You add assets through APIs that are exposed by specific AWS constructs. For example, when you define a [lambda.Function](#) construct, the [code](#) property lets you pass an [asset](#) (directory). Function uses assets to bundle the contents of the directory and use it for the function's code. Similarly, [ecs.ContainerImage.fromAsset](#) uses a Docker image built from a local directory when defining an Amazon ECS task definition.

## Assets in detail

When you refer to an asset in your app, the [cloud assembly \(p. 106\)](#) that's synthesized from your application includes metadata information with instructions for the AWS CDK CLI. The instructions include where to find the asset on the local disk and what type of bundling to perform based on the asset type, such as a directory to compress (zip) or a Docker image to build.

The AWS CDK generates a source hash for assets. This can be used at construction time to determine whether the contents of an asset have changed.

By default, the AWS CDK creates a copy of the asset in the cloud assembly directory, which defaults to `cdk.out`, under the source hash. This way, the cloud assembly is self-contained, so if it moved over to a different host for deployment, it can still be deployed. See [the section called "Cloud assemblies" \(p. 106\)](#) for details.

When the AWS CDK deploys an app that references assets (either directly by the app code or through a library), the AWS CDK CLI first prepares and publishes the assets to an Amazon S3 bucket or Amazon ECR repository. (The S3 bucket or repository is created during bootstrapping.) Only then are the resources defined in the stack deployed.

This section describes the low-level APIs available in the framework.

## Asset types

The AWS CDK supports the following types of assets:

### Amazon S3 assets

These are local files and directories that the AWS CDK uploads to Amazon S3.

### Docker Image

These are Docker images that the AWS CDK uploads to Amazon ECR.

These asset types are explained in the following sections.

## Amazon S3 assets

You can define local files and directories as assets, and the AWS CDK packages and uploads them to Amazon S3 through the [aws-s3-assets](#) module.

The following example defines a local directory asset and a file asset.

### TypeScript

```
import { Asset } from 'aws-cdk-lib/aws-s3-assets';

// Archived and uploaded to Amazon S3 as a .zip file
const directoryAsset = new Asset(this, "SampleZippedDirAsset", {
  path: path.join(__dirname, "sample-asset-directory")
});

// Uploaded to Amazon S3 as-is
const fileAsset = new Asset(this, 'SampleSingleFileAsset', {
  path: path.join(__dirname, 'file-asset.txt')
});
```

### JavaScript

```
const { Asset } = require('aws-cdk-lib/aws-s3-assets');

// Archived and uploaded to Amazon S3 as a .zip file
const directoryAsset = new Asset(this, "SampleZippedDirAsset", {
  path: path.join(__dirname, "sample-asset-directory")
});

// Uploaded to Amazon S3 as-is
const fileAsset = new Asset(this, 'SampleSingleFileAsset', {
  path: path.join(__dirname, 'file-asset.txt')
});
```

## Python

```
import os.path
dirname = os.path.dirname(__file__)

from aws_cdk.aws_s3_assets import Asset

# Archived and uploaded to Amazon S3 as a .zip file
directory_asset = Asset(self, "SampleZippedDirAsset",
    path=os.path.join(dirname, "sample-asset-directory")
)

# Uploaded to Amazon S3 as-is
file_asset = Asset(self, 'SampleSingleFileAsset',
    path=os.path.join(dirname, 'file-asset.txt')
)
```

## Java

```
import java.io.File;

import software.amazon.awscdk.services.s3.assets.Asset;

// Directory where app was started
File startDir = new File(System.getProperty("user.dir"));

// Archived and uploaded to Amazon S3 as a .zip file
Asset directoryAsset = Asset.Builder.create(this, "SampleZippedDirAsset")
    .path(new File(startDir, "sample-asset-directory").toString()).build();

// Uploaded to Amazon S3 as-is
Asset fileAsset = Asset.Builder.create(this, "SampleSingleFileAsset")
    .path(new File(startDir, "file-asset.txt").toString()).build();
```

## C#

```
using System.IO;
using Amazon.CDK.AWS.S3.Assets;

// Archived and uploaded to Amazon S3 as a .zip file
var directoryAsset = new Asset(this, "SampleZippedDirAsset", new AssetProps
{
    Path = Path.Combine(Directory.GetCurrentDirectory(), "sample-asset-directory")
});

// Uploaded to Amazon S3 as-is
var fileAsset = new Asset(this, "SampleSingleFileAsset", new AssetProps
{
    Path = Path.Combine(Directory.GetCurrentDirectory(), "file-asset.txt")
});
```

In most cases, you don't need to directly use the APIs in the `aws-s3-assets` module. Modules that support assets, such as `aws-lambda`, have convenience methods so that you can use assets. For Lambda functions, the [fromAsset\(\)](#) static method enables you to specify a directory or a .zip file in the local file system.

## Lambda function example

A common use case is creating Lambda functions with the handler code as an Amazon S3 asset.

The following example uses an Amazon S3 asset to define a Python handler in the local directory handler. It also creates a Lambda function with the local directory asset as the code property. Following is the Python code for the handler.

```
def lambda_handler(event, context):
    message = 'Hello World!'
    return {
        'message': message
    }
```

The code for the main AWS CDK app should look like the following.

#### TypeScript

```
import * as cdk from 'aws-cdk-lib';
import { Construct } from 'constructs';
import * as lambda from 'aws-cdk-lib/aws-lambda';
import * as path from 'path';

export class HelloAssetStack extends cdk.Stack {
    constructor(scope: Construct, id: string, props?: cdk.StackProps) {
        super(scope, id, props);

        new lambda.Function(this, 'myLambdaFunction', {
            code: lambda.Code.fromAsset(path.join(__dirname, 'handler')),
            runtime: lambda.Runtime.PYTHON_3_6,
            handler: 'index.lambda_handler'
        });
    }
}
```

#### JavaScript

```
const cdk = require('aws-cdk-lib');
const lambda = require('aws-cdk-lib/aws-lambda');
const path = require('path');

class HelloAssetStack extends cdk.Stack {
    constructor(scope, id, props) {
        super(scope, id, props);

        new lambda.Function(this, 'myLambdaFunction', {
            code: lambda.Code.fromAsset(path.join(__dirname, 'handler')),
            runtime: lambda.Runtime.PYTHON_3_6,
            handler: 'index.lambda_handler'
        });
    }
}

module.exports = { HelloAssetStack }
```

#### Python

```
from aws_cdk import Stack
from constructs import Construct
from aws_cdk import aws_lambda as lambda_

import os.path
dirname = os.path.dirname(__file__)

class HelloAssetStack(Stack):
    def __init__(self, scope: Construct, id: str, **kwargs):
```

```
super().__init__(scope, id, **kwargs)

lambda_.Function(self, 'myLambdaFunction',
    code=lambda_.Code.from_asset(os.path.join(dirname, 'handler')),
    runtime=lambda_.Runtime.PYTHON_3_6,
    handler="index.lambda_handler")
```

#### Java

```
import java.io.File;

import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.amazon.awscdk.services.lambda.Function;
import software.amazon.awscdk.services.lambda.Runtime;

public class HelloAssetStack extends Stack {

    public HelloAssetStack(final App scope, final String id) {
        this(scope, id, null);
    }

    public HelloAssetStack(final App scope, final String id, final StackProps props) {
        super(scope, id, props);

        File startDir = new File(System.getProperty("user.dir"));

        Function.Builder.create(this, "myLambdaFunction")
            .code(Code.fromAsset(new File(startDir, "handler").toString()))
            .runtime(Runtime.PYTHON_3_6)
            .handler("index.lambda_handler").build();
    }
}
```

#### C#

```
using Amazon.CDK;
using Amazon.CDK.AWS.Lambda;
using System.IO;

public class HelloAssetStack : Stack
{
    public HelloAssetStack(Construct scope, string id, StackProps props) : base(scope,
    id, props)
    {
        new Function(this, "myLambdaFunction", new FunctionProps
        {
            Code = Code.FromAsset(Path.Combine(Directory.GetCurrentDirectory(),
            "handler")),
            Runtime = Runtime.PYTHON_3_6,
            Handler = "index.lambda_handler"
        });
    }
}
```

The Function method uses assets to bundle the contents of the directory and use it for the function's code.

#### Tip

Java .jar files are ZIP files with a different extension. These are uploaded as-is to Amazon S3, but when deployed as a Lambda function, the files they contain are extracted, which you might not want. To avoid this, place the .jar file in a directory and specify that directory as the asset.

## Deploy-time attributes example

Amazon S3 asset types also expose [deploy-time attributes \(p. 122\)](#) that can be referenced in AWS CDK libraries and apps. The AWS CDK CLI command **cdk synth** displays asset properties as AWS CloudFormation parameters.

The following example uses deploy-time attributes to pass the location of an image asset into a Lambda function as environment variables. (The kind of file doesn't matter; the PNG image used here is only an example.)

### TypeScript

```
import { Asset } from 'aws-cdk-lib/aws-s3-assets';
import * as path from 'path';

const imageAsset = new Asset(this, "SampleAsset", {
  path: path.join(__dirname, "images/my-image.png")
});

new lambda.Function(this, "myLambdaFunction", {
  code: lambda.Code.asset(path.join(__dirname, "handler")),
  runtime: lambda.Runtime.PYTHON_3_6,
  handler: "index.lambda_handler",
  environment: {
    'S3_BUCKET_NAME': imageAsset.s3BucketName,
    'S3_OBJECT_KEY': imageAsset.s3ObjectKey,
    'S3_URL': imageAsset.s3Url
  }
});
```

### JavaScript

```
const { Asset } = require('aws-cdk-lib/aws-s3-assets');
const path = require('path');

const imageAsset = new Asset(this, "SampleAsset", {
  path: path.join(__dirname, "images/my-image.png")
});

new lambda.Function(this, "myLambdaFunction", {
  code: lambda.Code.asset(path.join(__dirname, "handler")),
  runtime: lambda.Runtime.PYTHON_3_6,
  handler: "index.lambda_handler",
  environment: {
    'S3_BUCKET_NAME': imageAsset.s3BucketName,
    'S3_OBJECT_KEY': imageAsset.s3ObjectKey,
    'S3_URL': imageAsset.s3Url
  }
});
```

### Python

```
import os.path

import aws_cdk.aws_lambda as lambda_
from aws_cdk.aws_s3_assets import Asset

dirname = os.path.dirname(__file__)

image_asset = Asset(self, "SampleAsset",
    path=os.path.join(dirname, "images/my-image.png"))
```



```
lambda_.Function(self, "myLambdaFunction",
    code=lambda_.Code.asset(os.path.join(dirname, "handler")),
    runtime=lambda_.Runtime.PYTHON_3_6,
    handler="index.lambda_handler",
    environment=dict(
        S3_BUCKET_NAME=image_asset.s3_bucket_name,
        S3_OBJECT_KEY=image_asset.s3_object_key,
        S3_URL=image_asset.s3_url))
```

#### Java

```
import java.io.File;

import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.amazon.awscdk.services.lambda.Function;
import software.amazon.awscdk.services.lambda.Runtime;
import software.amazon.awscdk.services.s3.assets.Asset;

public class FunctionStack extends Stack {
    public FunctionStack(final App scope, final String id, final StackProps props) {
        super(scope, id, props);

        File startDir = new File(System.getProperty("user.dir"));

        Asset imageAsset = Asset.Builder.create(this, "SampleAsset")
            .path(new File(startDir, "images/my-image.png").toString()).build()

        Function.Builder.create(this, "myLambdaFunction")
            .code(Code.fromAsset(new File(startDir, "handler").toString()))
            .runtime(Runtime.PYTHON_3_6)
            .handler("index.lambda_handler")
            .environment(java.util.Map.of( // Java 9 or later
                "S3_BUCKET_NAME", imageAsset.getS3BucketName(),
                "S3_OBJECT_KEY", imageAsset.getS3ObjectKey(),
                "S3_URL", imageAsset.getS3Url()))
            .build();
    }
}
```

#### C#

```
using Amazon.CDK;
using Amazon.CDK.AWS.Lambda;
using Amazon.CDK.AWS.S3.Assets;
using System.IO;
using System.Collections.Generic;

var imageAsset = new Asset(this, "SampleAsset", new AssetProps
{
    Path = Path.Combine(Directory.GetCurrentDirectory(), @"images\my-image.png")
});

new Function(this, "myLambdaFunction", new FunctionProps
{
    Code = Code.FromAsset(Path.Combine(Directory.GetCurrentDirectory(), "handler")),
    Runtime = Runtime.PYTHON_3_6,
    Handler = "index.lambda_handler",
    Environment = new Dictionary<string, string>
    {
        ["S3_BUCKET_NAME"] = imageAsset.S3BucketName,
        ["S3_OBJECT_KEY"] = imageAsset.S3ObjectKey,
        ["S3_URL"] = imageAsset.S3Url
    }
}
```

```
});
```

## Permissions

If you use Amazon S3 assets directly through the [aws-s3-assets](#) module, IAM roles, users, or groups, and you need to read assets in runtime, then grant those assets IAM permissions through the [asset.grantRead](#) method.

The following example grants an IAM group read permissions on a file asset.

### TypeScript

```
import { Asset } from 'aws-cdk-lib/aws-s3-assets';
import * as path from 'path';

const asset = new Asset(this, 'MyFile', {
  path: path.join(__dirname, 'my-image.png')
});

const group = new iam.Group(this, 'MyUserGroup');
asset.grantRead(group);
```

### JavaScript

```
const { Asset } = require('aws-cdk-lib/aws-s3-assets');
const path = require('path');

const asset = new Asset(this, 'MyFile', {
  path: path.join(__dirname, 'my-image.png')
});

const group = new iam.Group(this, 'MyUserGroup');
asset.grantRead(group);
```

### Python

```
from aws_cdk.aws_s3_assets import Asset
import aws_cdk.aws_iam as iam

import os.path
dirname = os.path.dirname(__file__)

    asset = Asset(self, "MyFile",
        path=os.path.join(dirname, "my-image.png"))

    group = iam.Group(self, "MyUserGroup")
    asset.grant_read(group)
```

### Java

```
import java.io.File;

import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.amazon.awscdk.services.iam.Group;
import software.amazon.awscdk.services.s3.assets.Asset;

public class GrantStack extends Stack {
    public GrantStack(final App scope, final String id, final StackProps props) {
        super(scope, id, props);
    }
}
```

```
File startDir = new File(System.getProperty("user.dir"));

Asset asset = Asset.Builder.create(this, "SampleAsset")
    .path(new File(startDir, "images/my-image.png").toString()).build();

Group group = new Group(this, "MyUserGroup");
asset.grantRead(group);  }
}
```

#### C#

```
using Amazon.CDK;
using Amazon.CDK.AWS.IAM;
using Amazon.CDK.AWS.S3.Assets;
using System.IO;

var asset = new Asset(this, "MyFile", new AssetProps {
    Path = Path.Combine(Path.Combine(Directory.GetCurrentDirectory(), @"images\my-
image.png"))
});

var group = new Group(this, "MyUserGroup");
asset.GrantRead(group);
```

## Docker image assets

The AWS CDK supports bundling local Docker images as assets through the [aws-ecr-assets](#) module.

The following example defines a Docker image that is built locally and pushed to Amazon ECR. Images are built from a local Docker context directory (with a Dockerfile) and uploaded to Amazon ECR by the AWS CDK CLI or your app's CI/CD pipeline. The images can be naturally referenced in your AWS CDK app.

#### TypeScript

```
import { DockerImageAsset } from 'aws-cdk-lib/aws-ecr-assets';

const asset = new DockerImageAsset(this, 'MyBuildImage', {
  directory: path.join(__dirname, 'my-image')
});
```

#### JavaScript

```
const { DockerImageAsset } = require('aws-cdk-lib/aws-ecr-assets');

const asset = new DockerImageAsset(this, 'MyBuildImage', {
  directory: path.join(__dirname, 'my-image')
});
```

#### Python

```
from aws_cdk.aws_ecr_assets import DockerImageAsset

import os.path
dirname = os.path.dirname(__file__)

asset = DockerImageAsset(self, 'MyBuildImage',
    directory=os.path.join(dirname, 'my-image'))
```

## Java

```
import software.amazon.awscdk.services.ecr.assets.DockerImageAsset;

File startDir = new File(System.getProperty("user.dir"));

DockerImageAsset asset = DockerImageAsset.Builder.create(this, "MyBuildImage")
    .directory(new File(startDir, "my-image").toString()).build();
```

## C#

```
using System.IO;
using Amazon.CDK.AWS.ECR.Assets;

var asset = new DockerImageAsset(this, "MyBuildImage", new DockerImageAssetProps
{
    Directory = Path.Combine(Directory.GetCurrentDirectory(), "my-image")
});
```

The `my-image` directory must include a `Dockerfile`. The AWS CDK CLI builds a Docker image from `my-image`, pushes it to an Amazon ECR repository, and specifies the name of the repository as an AWS CloudFormation parameter to your stack. Docker image asset types expose [deployment-time attributes \(p. 122\)](#) that can be referenced in AWS CDK libraries and apps. The AWS CDK CLI command `cdk synth` displays asset properties as AWS CloudFormation parameters.

## Amazon ECS task definition example

A common use case is to create an Amazon ECS [TaskDefinition](#) to run Docker containers. The following example specifies the location of a Docker image asset that the AWS CDK builds locally and pushes to Amazon ECR.

## TypeScript

```
import * as ecs from 'aws-cdk-lib/aws-ecs';
import * as ecr_assets from 'aws-cdk-lib/aws-ecr-assets';
import * as path from 'path';

const taskDefinition = new ecs.FargateTaskDefinition(this, "TaskDef", {
    memoryLimitMiB: 1024,
    cpu: 512
});

const asset = new ecr_assets.DockerImageAsset(this, 'MyBuildImage', {
    directory: path.join(__dirname, 'my-image')
});

taskDefinition.addContainer("my-other-container", {
    image: ecs.ContainerImage.fromDockerImageAsset(asset)
});
```

## JavaScript

```
const ecs = require('aws-cdk-lib/aws-ecs');
const ecr_assets = require('aws-cdk-lib/aws-ecr-assets');
const path = require('path');

const taskDefinition = new ecs.FargateTaskDefinition(this, "TaskDef", {
    memoryLimitMiB: 1024,
    cpu: 512
});
```

```
});  
  
const asset = new ecr_assets.DockerImageAsset(this, 'MyBuildImage', {  
  directory: path.join(__dirname, 'my-image')  
});  
  
taskDefinition.addContainer("my-other-container", {  
  image: ecs.ContainerImage.fromDockerImageAsset(asset)  
});
```

## Python

```
import aws_cdk.aws_ecs as ecs  
import aws_cdk.aws_ecr_assets as ecr_assets  
  
import os.path  
dirname = os.path.dirname(__file__)  
  
task_definition = ecs.FargateTaskDefinition(self, "TaskDef",  
    memory_limit_mib=1024,  
    cpu=512)  
  
asset = ecr_assets.DockerImageAsset(self, 'MyBuildImage',  
    directory=os.path.join(dirname, 'my-image'))  
  
task_definition.add_container("my-other-container",  
    image=ecs.ContainerImage.from_docker_image_asset(asset))
```

## Java

```
import java.io.File;  
  
import software.amazon.awscdk.services.ecs.FargateTaskDefinition;  
import software.amazon.awscdk.services.ecs.ContainerDefinitionOptions;  
import software.amazon.awscdk.services.ecs.ContainerImage;  
  
import software.amazon.awscdk.services.ecr.assets.DockerImageAsset;  
  
File startDir = new File(System.getProperty("user.dir"));  
  
FargateTaskDefinition taskDefinition = FargateTaskDefinition.Builder.create(  
    this, "TaskDef").memoryLimitMiB(1024).cpu(512).build();  
  
DockerImageAsset asset = DockerImageAsset.Builder.create(this, "MyBuildImage")  
    .directory(new File(startDir, "my-image").toString()).build();  
  
taskDefinition.addContainer("my-other-container",  
    ContainerDefinitionOptions.builder()  
        .image(ContainerImage.fromDockerImageAsset(asset))  
        .build());
```

## C#

```
using System.IO;  
using Amazon.CDK.AWS.ECS;  
using Amazon.CDK.AWS.Ecr.Assets;  
  
var taskDefinition = new FargateTaskDefinition(this, "TaskDef", new  
    FargateTaskDefinitionProps  
    {  
        MemoryLimitMiB = 1024,  
        Cpu = 512  
    });
```

```
var asset = new DockerImageAsset(this, "MyBuildImage", new DockerImageAssetProps
{
    Directory = Path.Combine(Directory.GetCurrentDirectory(), "my-image")
});

taskDefinition.AddContainer("my-other-container", new ContainerDefinitionOptions
{
    Image = ContainerImage.FromDockerImageAsset(asset)
});
```

## Deploy-time attributes example

The following example shows how to use the deploy-time attributes `repository` and `imageUri` to create an Amazon ECS task definition with the AWS Fargate launch type. Note that the Amazon ECR repo lookup requires the image's tag, not its URI, so we snip it from the end of the asset's URI.

### TypeScript

```
import * as ecs from 'aws-cdk-lib/aws-ecs';
import * as path from 'path';
import { DockerImageAsset } from 'aws-cdk-lib/aws-ecr-assets';

const asset = new DockerImageAsset(this, 'my-image', {
    directory: path.join(__dirname, "..", "demo-image")
});

const taskDefinition = new ecs.FargateTaskDefinition(this, "TaskDef", {
    memoryLimitMiB: 1024,
    cpu: 512
});

taskDefinition.addContainer("my-other-container", {
    image: ecs.ContainerImage.fromEcrRepository(asset.repository,
        asset.imageUri.split(":").pop())
});
```

### JavaScript

```
const ecs = require('aws-cdk-lib/aws-ecs');
const path = require('path');
const { DockerImageAsset } = require('aws-cdk-lib/aws-ecr-assets');

const asset = new DockerImageAsset(this, 'my-image', {
    directory: path.join(__dirname, "..", "demo-image")
});

const taskDefinition = new ecs.FargateTaskDefinition(this, "TaskDef", {
    memoryLimitMiB: 1024,
    cpu: 512
});

taskDefinition.addContainer("my-other-container", {
    image: ecs.ContainerImage.fromEcrRepository(asset.repository,
        asset.imageUri.split(":").pop())
});
```

### Python

```
import aws_cdk.aws_ecs as ecs
```

```
from aws_cdk.aws_ecr_assets import DockerImageAsset

import os.path
dirname = os.path.dirname(__file__)

asset = DockerImageAsset(self, 'my-image',
    directory=os.path.join(dirname, "..", "demo-image"))

task_definition = ecs.FargateTaskDefinition(self, "TaskDef",
    memory_limit_mib=1024, cpu=512)

task_definition.add_container("my-other-container",
    image=ecs.ContainerImage.from_ecr_repository(
        asset.repository, asset.image_uri.rpartition(":")[-1]))
```

#### Java

```
import java.io.File;

import software.amazon.awscdk.services.ecr.assets.DockerImageAsset;

import software.amazon.awscdk.services.ecs.FargateTaskDefinition;
import software.amazon.awscdk.services.ecs.ContainerDefinitionOptions;
import software.amazon.awscdk.services.ecs.ContainerImage;

File startDir = new File(System.getProperty("user.dir"));

DockerImageAsset asset = DockerImageAsset.Builder.create(this, "my-image")
    .directory(new File(startDir, "demo-image").toString()).build();

FargateTaskDefinition taskDefinition = FargateTaskDefinition.Builder.create(
    this, "TaskDef").memoryLimitMiB(1024).cpu(512).build();

// extract the tag from the asset's image URI for use in ECR repo lookup
String imageUri = asset.getImageUri();
String imageTag = imageUri.substring(imageUri.lastIndexOf(":") + 1);

taskDefinition.addContainer("my-other-container",
    ContainerDefinitionOptions.builder().image(ContainerImage.fromEcrRepository(
        asset.getRepository(), imageTag)).build());
```

#### C#

```
using System.IO;
using Amazon.CDK.AWS.ECS;
using Amazon.CDK.AWS.ECR.Assets;

var asset = new DockerImageAsset(this, "my-image", new DockerImageAssetProps {
    Directory = Path.Combine(Directory.GetCurrentDirectory(), "demo-image")
});

var taskDefinition = new FargateTaskDefinition(this, "TaskDef", new
    FargateTaskDefinitionProps
    {
        MemoryLimitMiB = 1024,
        Cpu = 512
    });

taskDefinition.AddContainer("my-other-container", new ContainerDefinitionOptions
    {
        Image = ContainerImage.FromEcrRepository(asset.Repository,
            asset.ImageUri.Split(":").Last())
    });
```

## Build arguments example

You can provide customized build arguments for the Docker build step through the `buildArgs` (Python: `build_args`) property option when the AWS CDK CLI builds the image during deployment.

### TypeScript

```
const asset = new DockerImageAsset(this, 'MyBuildImage', {
  directory: path.join(__dirname, 'my-image'),
  buildArgs: {
    HTTP_PROXY: 'http://10.20.30.2:1234'
  }
});
```

### JavaScript

```
const asset = new DockerImageAsset(this, 'MyBuildImage', {
  directory: path.join(__dirname, 'my-image'),
  buildArgs: {
    HTTP_PROXY: 'http://10.20.30.2:1234'
  }
});
```

### Python

```
asset = DockerImageAsset(self, "MyBulidImage",
    directory=os.path.join(dirname, "my-image"),
    build_args=dict(HTTP_PROXY="http://10.20.30.2:1234"))
```

### Java

```
DockerImageAsset asset = DockerImageAsset.Builder.create(this, "my-image"),
    .directory(new File(startDir, "my-image").toString())
    .buildArgs(java.util.Map.of( // Java 9 or later
        "HTTP_PROXY", "http://10.20.30.2:1234"))
    .build();
```

### C#

```
var asset = new DockerImageAsset(this, "MyBuildImage", new DockerImageAssetProps {
    Directory = Path.Combine(Directory.GetCurrentDirectory(), "my-image"),
    BuildArgs = new Dictionary<string, string>
    {
        ["HTTP_PROXY"] = "http://10.20.30.2:1234"
    }
});
```

## Permissions

If you use a module that supports Docker image assets, such as [aws-ecs](#), the AWS CDK manages permissions for you when you use assets directly or through [ContainerImage.fromEcrRepository](#) (Python: `from_ecr_repository`). If you use Docker image assets directly, make sure that the consuming principal has permissions to pull the image.

In most cases, you should use [asset.repository.grantPull](#) method (Python: `grant_pull`). This modifies the IAM policy of the principal to enable it to pull images from this repository. If the principal that is pulling the image is not in the same account, or if it's an AWS service that doesn't assume a role



in your account (such as AWS CodeBuild), you must grant pull permissions on the resource policy and not on the principal's policy. Use the [asset.repository.addToResourcePolicy](#) method (Python: `add_to_resource_policy`) to grant the appropriate principal permissions.

## AWS CloudFormation resource metadata

### Note

This section is relevant only for construct authors. In certain situations, tools need to know that a certain CFN resource is using a local asset. For example, you can use the AWS SAM CLI to invoke Lambda functions locally for debugging purposes. See [the section called “AWS SAM integration” \(p. 324\)](#) for details.

To enable such use cases, external tools consult a set of metadata entries on AWS CloudFormation resources:

- `aws:asset:path` – Points to the local path of the asset.
- `aws:asset:property` – The name of the resource property where the asset is used.

Using these two metadata entries, tools can identify that assets are used by a certain resource, and enable advanced local experiences.

To add these metadata entries to a resource, use the `asset.addResourceMetadata` (Python: `add_resource_metadata`) method.

## Permissions

The AWS Construct Library uses a few common, widely implemented idioms to manage access and permissions. The IAM module provides you with the tools you need to use these idioms.

AWS CDK uses AWS CloudFormation to deploy changes. Every deployment involves an actor (either a developer, or an automated system) that starts a AWS CloudFormation deployment. In the course of doing this, the actor will assume one or more IAM Identities (user or roles) and optionally pass a role to AWS CloudFormation.

If you use AWS IAM Identity Center (successor to AWS Single Sign-On) to authenticate as a user, then the single sign-on provider supplies short-lived session credentials that authorize you to act as a pre-defined IAM role. To learn how the AWS CDK obtains AWS credentials from IAM Identity Center authentication, see [Understand IAM Identity Center authentication](#) in the *AWS SDKs and Tools Reference Guide*.

## Principals

An IAM principal is an authenticated AWS entity representing a user, service, or application that can call AWS APIs. The AWS Construct Library supports specifying principals in several flexible ways to grant them access your AWS resources.

In security contexts, the term "principal" refers specifically to authenticated entities such as users. Objects like groups and roles do not *represent* users (and other authenticated entities) but rather *identify* them indirectly for the purpose of granting permissions.

For example, if you create an IAM group, you can grant the group (and thus its members) write access to an Amazon RDS table. However, the group itself is not a principal because it doesn't represent a single entity (also, you cannot log in to a group).

In the CDK's IAM library, classes that directly or indirectly identify principals implement the [IPrincipal](#) interface, allowing these objects to be used interchangeably in access policies. However, not all of them are principals in the security sense. These objects include:

1. IAM resources such as [Role](#), [User](#), and [Group](#)
2. Service principals (new iam.[ServicePrincipal](#)('service.amazonaws.com'))
3. Federated principals (new iam.[FederatedPrincipal](#)('cognito-identity.amazonaws.com'))
4. Account principals (new iam.[AccountPrincipal](#)('0123456789012'))
5. Canonical user principals (new iam.[CanonicalUserPrincipal](#)('79a59d[...]7ef2be'))
6. AWS Organizations principals (new iam.[OrganizationPrincipal](#)('org-id'))
7. Arbitrary ARN principals (new iam.[ArnPrincipal](#)(res.arn))
8. An iam.[CompositePrincipal](#)(principal1, principal2, ...) to trust multiple principals

## Grants

Every construct that represents a resource that can be accessed, such as an Amazon S3 bucket or Amazon DynamoDB table, has methods that grant access to another entity. All such methods have names starting with **grant**.

For example, Amazon S3 buckets have the methods [grantRead](#) and [grantReadWrite](#) (Python: `grant_read`, `grant_read_write`) to enable read and read/write access, respectively, from an entity to the bucket. The entity doesn't have to know exactly which Amazon S3 IAM permissions are required to perform these operations.

The first argument of a **grant** method is always of type [IGratable](#). This interface represents entities that can be granted permissions. That is, it represents resources with roles, such as the IAM objects [Role](#), [User](#), and [Group](#).

Other entities can also be granted permissions. For example, later in this topic, we show how to grant a CodeBuild project access to an Amazon S3 bucket. Generally, the associated role is obtained via a `role` property on the entity being granted access.

Resources that use execution roles, such as [lambda.Function](#), also implement [IGratable](#), so you can grant them access directly instead of granting access to their role. For example, if `bucket` is an Amazon S3 bucket, and `function` is a Lambda function, the following code grants the function read access to the bucket.

TypeScript

```
bucket.grantRead(function);
```

JavaScript

```
bucket.grantRead(function);
```

Python

```
bucket.grant_read(function)
```

Java

```
bucket.grantRead(function);
```

C#

```
bucket.GrantRead(function);
```

Sometimes permissions must be applied while your stack is being deployed. One such case is when you grant an AWS CloudFormation custom resource access to some other resource. The custom resource will be invoked during deployment, so it must have the specified permissions at deployment time.

Another case is when a service verifies that the role you pass to it has the right policies applied. (A number of AWS services do this to make sure that you didn't forget to set the policies.) In those cases, the deployment might fail if the permissions are applied too late.

To force the grant's permissions to be applied before another resource is created, you can add a dependency on the grant itself, as shown here. Though the return value of grant methods is commonly discarded, every grant method in fact returns an `iam.Grant` object.

#### TypeScript

```
const grant = bucket.grantRead(lambda);
const custom = new CustomResource(...);
custom.node.addDependency(grant);
```

#### JavaScript

```
const grant = bucket.grantRead(lambda);
const custom = new CustomResource(...);
custom.node.addDependency(grant);
```

#### Python

```
grant = bucket.grant_read(function)
custom = CustomResource(...)
custom.node.add_dependency(grant)
```

#### Java

```
Grant grant = bucket.grantRead(function);
CustomResource custom = new CustomResource(...);
custom.node.addDependency(grant);
```

#### C#

```
var grant = bucket.GrantRead(function);
var custom = new CustomResource(...);
custom.node.AddDependency(grant);
```

## Roles

The IAM package contains a [Role](#) construct that represents IAM roles. The following code creates a new role, trusting the Amazon EC2 service.

#### TypeScript

```
import * as iam from 'aws-cdk-lib/aws-iam';

const role = new iam.Role(this, 'Role', {
  assumedBy: new iam.ServicePrincipal('ec2.amazonaws.com'), // required
});
```

### JavaScript

```
const iam = require('aws-cdk-lib/aws-iam');

const role = new iam.Role(this, 'Role', {
  assumedBy: new iam.ServicePrincipal('ec2.amazonaws.com') // required
});
```

### Python

```
import aws_cdk.aws_iam as iam

role = iam.Role(self, "Role",
    assumed_by=iam.ServicePrincipal("ec2.amazonaws.com")) # required
```

### Java

```
import software.amazon.awscdk.services.iam.Role;
import software.amazon.awscdk.services.iam.ServicePrincipal;

Role role = Role.Builder.create(this, "Role")
    .assumedBy(new ServicePrincipal("ec2.amazonaws.com")).build();
```

### C#

```
using Amazon.CDK.AWS.IAM;

var role = new Role(this, "Role", new RoleProps
{
    AssumedBy = new ServicePrincipal("ec2.amazonaws.com"), // required
});
```

You can add permissions to a role by calling the role's [addToPolicy](#) method (Python: `add_to_policy`), passing in a [PolicyStatement](#) that defines the rule to be added. The statement is added to the role's default policy; if it has none, one is created.

The following example adds a Deny policy statement to the role for the actions `ec2:SomeAction` and `s3:AnotherAction` on the resources `bucket` and `otherRole` (Python: `other_role`), under the condition that the authorized service is AWS CodeBuild.

### TypeScript

```
role.addToPolicy(new iam.PolicyStatement({
  effect: iam.Effect.DENY,
  resources: [bucket.bucketArn, otherRole.roleArn],
  actions: ['ec2:SomeAction', 's3:AnotherAction'],
  conditions: {StringEquals: {
    'ec2:AuthorizedService': 'codebuild.amazonaws.com',
  }}}));
```

### JavaScript

```
role.addToPolicy(new iam.PolicyStatement({
  effect: iam.Effect.DENY,
  resources: [bucket.bucketArn, otherRole.roleArn],
  actions: ['ec2:SomeAction', 's3:AnotherAction'],
  conditions: {StringEquals: {
    'ec2:AuthorizedService': 'codebuild.amazonaws.com'
  }}
});
```

```
}}));
```

## Python

```
role.add_to_policy(iam.PolicyStatement(
    effect=iam.Effect.DENY,
    resources=[bucket.bucket_arn, other_role.role_arn],
    actions=["ec2:SomeAction", "s3:AnotherAction"],
    conditions={"StringEquals": {
        "ec2:AuthorizedService": "codebuild.amazonaws.com"}}
))
```

## Java

```
role.addToPolicy(PolicyStatement.Builder.create()
    .effect(Effect.DENY)
    .resources(Arrays.asList(bucket.getBucketArn(), otherRole.getRoleArn()))
    .actions(Arrays.asList("ec2:SomeAction", "s3:AnotherAction"))
    .conditions(java.util.Map.of( // Map.of requires Java 9 or later
        "StringEquals", java.util.Map.of(
            "ec2:AuthorizedService", "codebuild.amazonaws.com")))
    .build());
```

## C#

```
role.AddToPolicy(new PolicyStatement(new PolicyStatementProps
{
    Effect = Effect.DENY,
    Resources = new string[] { bucket.BucketArn, otherRole.RoleArn },
    Actions = new string[] { "ec2:SomeAction", "s3:AnotherAction" },
    Conditions = new Dictionary<string, object>
    {
        ["StringEquals"] = new Dictionary<string, string>
        {
            ["ec2:AuthorizedService"] = "codebuild.amazonaws.com"
        }
    }
});
```

In the preceding example, we've created a new [PolicyStatement](#) inline with the [addToPolicy](#) (Python: `add_to_policy`) call. You can also pass in an existing policy statement or one you've modified. The [PolicyStatement](#) object has [numerous methods](#) for adding principals, resources, conditions, and actions.

If you're using a construct that requires a role to function correctly, you can do one of the following:

- Pass in an existing role when instantiating the construct object.
- Let the construct create a new role for you, trusting the appropriate service principal. The following example uses such a construct: a CodeBuild project.

## TypeScript

```
import * as codebuild from 'aws-cdk-lib/aws-codebuild';

// imagine roleOrUndefined is a function that might return a Role object
// under some conditions, and undefined under other conditions
const someRole: iam.IRole | undefined = roleOrUndefined();
```

```
const project = new codebuild.Project(this, 'Project', {
  // if someRole is undefined, the Project creates a new default role,
  // trusting the codebuild.amazonaws.com service principal
  role: someRole,
});
```

#### JavaScript

```
const codebuild = require('aws-cdk-lib/aws-codebuild');

// imagine roleOrUndefined is a function that might return a Role object
// under some conditions, and undefined under other conditions
const someRole = roleOrUndefined();

const project = new codebuild.Project(this, 'Project', {
  // if someRole is undefined, the Project creates a new default role,
  // trusting the codebuild.amazonaws.com service principal
  role: someRole
});
```

#### Python

```
import aws_cdk.aws_codebuild as codebuild

# imagine role_or_none is a function that might return a Role object
# under some conditions, and None under other conditions
some_role = role_or_none();

project = codebuild.Project(self, "Project",
    # if role is None, the Project creates a new default role,
    # trusting the codebuild.amazonaws.com service principal
    role=some_role)
```

#### Java

```
import software.amazon.awscdk.services.iam.Role;
import software.amazon.awscdk.services.codebuild.Project;

// imagine roleOrNull is a function that might return a Role object
// under some conditions, and null under other conditions
Role someRole = roleOrNull();

// if someRole is null, the Project creates a new default role,
// trusting the codebuild.amazonaws.com service principal
Project project = Project.Builder.create(this, "Project")
    .role(someRole).build();
```

#### C#

```
using Amazon.CDK.AWS.CodeBuild;

// imagine roleOrNull is a function that might return a Role object
// under some conditions, and null under other conditions
var someRole = roleOrNull();

// if someRole is null, the Project creates a new default role,
// trusting the codebuild.amazonaws.com service principal
var project = new Project(this, "Project", new ProjectProps
{
    Role = someRole
});
```

Once the object is created, the role (whether the role passed in or the default one created by the construct) is available as the property `role`. However, this property is not available on external resources. Therefore, these constructs have an `addToRolePolicy` (Python: `add_to_role_policy`) method.

The method does nothing if the construct is an external resource, and it calls the `addToPolicy` (Python: `add_to_policy`) method of the role property otherwise. This saves you the trouble of handling the undefined case explicitly.

The following example demonstrates:

#### TypeScript

```
// project is imported into the CDK application
const project = codebuild.Project.fromProjectName(this, 'Project', 'ProjectName');

// project is imported, so project.role is undefined, and this call has no effect
project.addToRolePolicy(new iam.PolicyStatement({
  effect: iam.Effect.ALLOW, // ... and so on defining the policy
}));
```

#### JavaScript

```
// project is imported into the CDK application
const project = codebuild.Project.fromProjectName(this, 'Project', 'ProjectName');

// project is imported, so project.role is undefined, and this call has no effect
project.addToRolePolicy(new iam.PolicyStatement({
  effect: iam.Effect.ALLOW // ... and so on defining the policy
}));
```

#### Python

```
# project is imported into the CDK application
project = codebuild.Project.from_project_name(self, 'Project', 'ProjectName')

# project is imported, so project.role is undefined, and this call has no effect
project.add_to_role_policy(iam.PolicyStatement(
    effect=iam.Effect.ALLOW, # ... and so on defining the policy
))
```

#### Java

```
// project is imported into the CDK application
Project project = Project.fromProjectName(this, "Project", "ProjectName");

// project is imported, so project.getRole() is null, and this call has no effect
project.addToRolePolicy(PolicyStatement.Builder.create()
    .effect(Effect.ALLOW) // .. and so on defining the policy
    .build());
```

#### C#

```
// project is imported into the CDK application
var project = Project.FromProjectName(this, "Project", "ProjectName");

// project is imported, so project.role is null, and this call has no effect
project.AddToRolePolicy(new PolicyStatement(new PolicyStatementProps
{
    Effect = Effect.ALLOW, // ... and so on defining the policy
}));
```

```
}});
```

## Resource policies

A few resources in AWS, such as Amazon S3 buckets and IAM roles, also have a resource policy. These constructs have an `addToResourcePolicy` method (Python: `add_to_resource_policy`), which takes a [PolicyStatement](#) as its argument. Every policy statement added to a resource policy must specify at least one principal.

In the following example, the [Amazon S3 bucket](#) bucket grants a role with the `s3:SomeAction` permission to itself.

### TypeScript

```
bucket.addToResourcePolicy(new iam.PolicyStatement({
  effect: iam.Effect.ALLOW,
  actions: ['s3:SomeAction'],
  resources: [bucket.bucketArn],
  principals: [role]
}));
```

### JavaScript

```
bucket.addToResourcePolicy(new iam.PolicyStatement({
  effect: iam.Effect.ALLOW,
  actions: ['s3:SomeAction'],
  resources: [bucket.bucketArn],
  principals: [role]
}));
```

### Python

```
bucket.add_to_resource_policy(iam.PolicyStatement(
    effect=iam.Effect.ALLOW,
    actions=["s3:SomeAction"],
    resources=[bucket.bucket_arn],
    principals=role))
```

### Java

```
bucket.addToResourcePolicy(PolicyStatement.Builder.create()
    .effect(Effect.ALLOW)
    .actions(Arrays.asList("s3:SomeAction"))
    .resources(Arrays.asList(bucket.getBucketArn()))
    .principals(Arrays.asList(role))
    .build());
```

### C#

```
bucket.AddToResourcePolicy(new PolicyStatement(new PolicyStatementProps
{
    Effect = Effect.ALLOW,
    Actions = new string[] { "s3:SomeAction" },
    Resources = new string[] { bucket.BucketArn },
    Principals = new IPrincipal[] { role }
}));
```



## Using external IAM objects

If you have defined an IAM user, principal, group, or role outside your AWS CDK app, you can use that IAM object in your AWS CDK app. To do so, create a reference to it using its ARN or its name. (Use the name for users, groups, and roles.) The returned reference can then be used to grant permissions or to construct policy statements as explained previously.

- For users, call [User.fromUserArn\(\)](#) or [User.fromUserName\(\)](#). [User.fromUserAttributes\(\)](#) is also available, but currently provides the same functionality as [User.fromUserArn\(\)](#).
- For principals, instantiate an [ArnPrincipal](#) object.
- For groups, call [Group.fromGroupArn\(\)](#) or [Group.fromGroupName\(\)](#).
- For roles, call [Role.fromRoleArn\(\)](#) or [Role.fromRoleName\(\)](#).

Policies (including managed policies) can be used in similar fashion using the following methods. You can use references to these objects anywhere an IAM policy is required.

- [Policy.fromPolicyName](#)
- [ManagedPolicy.fromManagedPolicyArn](#)
- [ManagedPolicy.fromManagedPolicyName](#)
- [ManagedPolicy.fromAwsManagedPolicyName](#)

### Note

As with all references to external AWS resources, you cannot modify external IAM objects in your CDK app.

## Runtime context

Context values are key-value pairs that can be associated with an app, stack, or construct. They may be supplied to your app from a file (usually either `cdk.json` or `cdk.context.json` in your project directory) or on the command line.

The CDK Toolkit uses context to cache values retrieved from your AWS account during synthesis. Values include the Availability Zones in your account or the Amazon Machine Image (AMI) IDs currently available for Amazon EC2 instances. Because these values are provided by your AWS account, they can change between runs of your CDK application. This makes them a potential source of unintended change. The CDK Toolkit's caching behavior "freezes" these values for your CDK app until you decide to accept the new values.

Imagine the following scenario without context caching. Let's say you specified "latest Amazon Linux" as the AMI for your Amazon EC2 instances, and a new version of this AMI was released. Then, the next time you deployed your CDK stack, your already-deployed instances would be using the outdated ("wrong") AMI and would need to be upgraded. Upgrading would result in replacing all your existing instances with new ones, which would probably be unexpected and undesired.

Instead, the CDK records your account's available AMIs in your project's `cdk.context.json` file, and uses the stored value for future synthesis operations. This way, the list of AMIs is no longer a potential source of change. You can also be sure that your stacks will always synthesize to the same AWS CloudFormation templates.

Not all context values are cached values from your AWS environment. [the section called "Feature flags" \(p. 191\)](#) are also context values. You can also create your own context values for use by your apps or constructs.

Context keys are strings. Values may be any type supported by JSON: numbers, strings, arrays, or objects.

### Tip

If your constructs create their own context values, incorporate your library's package name in its keys so they won't conflict with other packages' context values.

Many context values are associated with a particular AWS environment, and a given CDK app can be deployed in more than one environment. The key for such values includes the AWS account and Region so that values from different environments do not conflict.

The following context key illustrates the format used by the AWS CDK, including the account and Region.

```
availability-zones:account=123456789012:region=eu-central-1
```

### Important

Cached context values are managed by the AWS CDK and its constructs, including constructs you may write. Do not add or change cached context values by manually editing files. It can be useful, however, to review `cdk.context.json` occasionally to see what values are being cached. Context values that don't represent cached values should be stored under the `context` key of `cdk.json`. This way, they won't be cleared when cached values are cleared.

## Sources of context values

Context values can be provided to your AWS CDK app in six different ways:

- Automatically from the current AWS account.
- Through the `--context` option to the `cdk` command. (These values are always strings.)
- In the project's `cdk.context.json` file.
- In the `context` key of the project's `cdk.json` file.
- In the `context` key of your `~/cdk.json` file.
- In your AWS CDK app using the `construct.node.setContext()` method.

The project file `cdk.context.json` is where the AWS CDK caches context values retrieved from your AWS account. This practice avoids unexpected changes to your deployments when, for example, a new Availability Zone is introduced. The AWS CDK does not write context data to any of the other files listed.

### Important

Because they're part of your application's state, `cdk.json` and `cdk.context.json` must be committed to source control along with the rest of your app's source code. Otherwise, deployments in other environments (for example, a CI pipeline) might produce inconsistent results.

Context values are scoped to the construct that created them; they are visible to child constructs, but not to parents or siblings. Context values that are set by the AWS CDK Toolkit (the `cdk` command) can be set automatically, from a file, or from the `--context` option. Context values from these sources are implicitly set on the App construct. Therefore, they're visible to every construct in every stack in the app.

Your app can read a context value using the `construct.node.tryGetContext` method. If the requested entry isn't found on the current construct or any of its parents, the result is undefined. (Alternatively, the result could be your language's equivalent, such as `None` in Python.)

## Context methods

The AWS CDK supports several context methods that enable AWS CDK apps to obtain contextual information from the AWS environment. For example, you can get a list of Availability Zones that are available in a given AWS account and Region, using the [stack.availabilityZones](#) method.

The following are the context methods:

### [HostedZone.fromLookup](#)

Gets the hosted zones in your account.

### [stack.availabilityZones](#)

Gets the supported Availability Zones.

### [StringParameter.valueFromLookup](#)

Gets a value from the current Region's Amazon EC2 Systems Manager Parameter Store.

### [Vpc.fromLookup](#)

Gets the existing Amazon Virtual Private Clouds in your accounts.

### [LookupMachineImage](#)

Looks up a machine image for use with a NAT instance in an Amazon Virtual Private Cloud.

If a required context value isn't available, the AWS CDK app notifies the CDK Toolkit that the context information is missing. Next, the CLI queries the current AWS account for the information and stores the resulting context information in the `cdk.context.json` file. Then, it executes the AWS CDK app again with the context values.

## Viewing and managing context

Use the **cdk context** command to view and manage the information in your `cdk.context.json` file. To see this information, use the **cdk context** command without any options. The output should be something like the following.

Context found in cdk.json:

```
#####  
# # # Key                                     # Value  
#                                     #  
# 1 # availability-zones:account=123456789012:region=eu-central-1 # [ "eu-central-1a", "eu-  
central-1b", "eu-central-1c" ] #  
#####  
# 2 # availability-zones:account=123456789012:region=eu-west-1   # [ "eu-west-1a", "eu-  
west-1b", "eu-west-1c" ]   #  
#####
```

Run `cdk context --reset KEY_OR_NUMBER` to remove a context key. If it is a cached value, it will be refreshed on the next `cdk synth`.

To remove a context value, run **cdk context --reset**, specifying the value's corresponding key or number. The following example removes the value that corresponds to the second key in the preceding example. This value represents the list of Availability Zones in the Europe (Ireland) Region.

```
cdk context --reset 2
```

Context value  
availability-zones:account=123456789012:region=eu-west-1  
reset. It will be refreshed on the next SDK synthesis run.

Therefore, if you want to update to the latest version of the Amazon Linux AMI, use the preceding example to do a controlled update of the context value and reset it. Then, synthesize and deploy your app again.

```
cdk synth
```

To clear all of the stored context values for your app, run **cdk context --clear**, as follows.

```
cdk context --clear
```

Only context values stored in `cdk.context.json` can be reset or cleared. The AWS CDK does not touch other context values. Therefore, to protect a context value from being reset using these commands, you might copy the value to `cdk.json`.

## AWS CDK Toolkit --context flag

Use the `--context` (`-c` for short) option to pass runtime context values to your CDK app during synthesis or deployment.

```
cdk synth --context key=value MyStack
```

To specify multiple context values, repeat the `--context` option any number of times, providing one key-value pair each time.

```
cdk synth --context key1=value1 --context key2=value2 MyStack
```

When synthesizing multiple stacks, the specified context values are passed to all stacks. To provide different context values to individual stacks, either use different keys for the values, or use multiple **cdk synth** or **cdk deploy** commands.

Context values passed from the command line are always strings. If a value is usually of some other type, your code must be prepared to convert or parse the value. You might have non-string context values provided in other ways (for example, in `cdk.context.json`). To make sure this kind of value works as expected, confirm that the value is a string before converting it.

## Example

Following is an example of using an existing Amazon VPC using AWS CDK context.

TypeScript

```
import * as cdk from 'aws-cdk-lib';
import * as ec2 from 'aws-cdk-lib/aws-ec2';
import { Construct } from 'constructs';

export class ExistsVpcStack extends cdk.Stack {

  constructor(scope: Construct, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    const vpcid = this.node.tryGetContext('vpcid');
    const vpc = ec2.Vpc.fromLookup(this, 'VPC', {
      vpcId: vpcid,
    });

    const pubsubnets = vpc.selectSubnets({subnetType: ec2.SubnetType.PUBLIC});

    new cdk.CfnOutput(this, 'publicsubnets', {
      value: pubsubnets.subnetIds.toString(),
    });
  }
}
```

```
}  
}
```

### JavaScript

```
const cdk = require('aws-cdk-lib');  
const ec2 = require('aws-cdk-lib/aws-ec2');  
  
class ExistsVpcStack extends cdk.Stack {  
  constructor(scope, id, props) {  
    super(scope, id, props);  
  
    const vpcid = this.node.tryGetContext('vpcid');  
    const vpc = ec2.Vpc.fromLookup(this, 'VPC', {  
      vpcId: vpcid  
    });  
  
    const pubsubnets = vpc.selectSubnets({subnetType: ec2.SubnetType.PUBLIC});  
  
    new cdk.CfnOutput(this, 'publicsubnets', {  
      value: pubsubnets.subnetIds.toString()  
    });  
  }  
}  
  
module.exports = { ExistsVpcStack }
```

### Python

```
import aws_cdk as cdk  
import aws_cdk.aws_ec2 as ec2  
from constructs import Construct  
  
class ExistsVpcStack(cdk.Stack):  
    def __init__(self, scope: Construct, id: str, **kwargs):  
        super().__init__(scope, id, **kwargs)  
  
        vpcid = self.node.try_get_context("vpcid")  
        vpc = ec2.Vpc.from_lookup(self, "VPC", vpc_id=vpcid)  
  
        pubsubnets = vpc.select_subnets(subnetType=ec2.SubnetType.PUBLIC)  
  
        cdk.CfnOutput(self, "publicsubnets",  
            value=pubsubnets.subnet_ids.to_string())
```

### Java

```
import software.amazon.awscdk.CfnOutput;  
  
import software.amazon.awscdk.services.ec2.Vpc;  
import software.amazon.awscdk.services.ec2.VpcLookupOptions;  
import software.amazon.awscdk.services.ec2.SelectedSubnets;  
import software.amazon.awscdk.services.ec2.SubnetSelection;  
import software.amazon.awscdk.services.ec2.SubnetType;  
import software.constructs.Construct;  
  
public class ExistsVpcStack extends Stack {  
    public ExistsVpcStack(Construct context, String id) {  
        this(context, id, null);  
    }  
}
```

```
}

public ExistsVpcStack(Construct context, String id, StackProps props) {
    super(context, id, props);

    String vpcId = (String)this.getNode().tryGetContext("vpcid");
    Vpc vpc = (Vpc)Vpc.fromLookup(this, "VPC", VpcLookupOptions.builder()
        .vpcId(vpcId).build());

    SelectedSubnets pubSubNets = vpc.selectSubnets(SubnetSelection.builder()
        .subnetType(SubnetType.PUBLIC).build());

    CfnOutput.Builder.create(this, "publicsubnets")
        .value(pubSubNets.getSubnetIds().toString()).build();
}
}
```

## C#

```
using Amazon.CDK;
using Amazon.CDK.AWS.EC2;
using Constructs;

class ExistsVpcStack : Stack
{
    public ExistsVpcStack(Construct scope, string id, StackProps props) : base(scope,
        id, props)
    {
        var vpcId = (string)this.Node.TryGetContext("vpcid");
        var vpc = Vpc.FromLookup(this, "VPC", new VpcLookupOptions
        {
            VpcId = vpcId
        });

        SelectedSubnets pubSubNets = vpc.SelectSubnets([new SubnetSelection
        {
            SubnetType = SubnetType.PUBLIC
        }]);

        new CfnOutput(this, "publicsubnets", new CfnOutputProps {
            Value = pubSubNets.SubnetIds.ToString()
        });
    }
}
```

You can use **cdk diff** to see the effects of passing in a context value on the command line:

```
cdk diff -c vpcid=vpc-0cb9c31031d0d3e22
```

```
Stack ExistsvpcStack
Outputs
[+] Output publicsubnets publicsubnets:
{"Value":"subnet-06e0ea7dd302d3e8f,subnet-01fc0acfb58f3128f"}
```

The resulting context values can be viewed as shown here.

```
cdk context -j
```

```
{
```

```
"vpc-provider:account=123456789012:filter.vpc-id=vpc-0cb9c31031d0d3e22:region=us-east-1":
{
  "vpcId": "vpc-0cb9c31031d0d3e22",
  "availabilityZones": [
    "us-east-1a",
    "us-east-1b"
  ],
  "privateSubnetIds": [
    "subnet-03ecfc033225be285",
    "subnet-0cded5da53180ebfa"
  ],
  "privateSubnetNames": [
    "Private"
  ],
  "privateSubnetRouteTableIds": [
    "rtb-0e955393ced0ada04",
    "rtb-05602e7b9f310e5b0"
  ],
  "publicSubnetIds": [
    "subnet-06e0ea7dd302d3e8f",
    "subnet-01fc0acfb58f3128f"
  ],
  "publicSubnetNames": [
    "Public"
  ],
  "publicSubnetRouteTableIds": [
    "rtb-00d1fd823c82289",
    "rtb-04bb1969b42969bcb"
  ]
}
```

## Feature flags

The AWS CDK uses *feature flags* to enable potentially breaking behaviors in a release. Flags are stored as [the section called “Context” \(p. 185\)](#) values in `cdk.json` (or `~/.cdk.json`). They are not removed by the `cdk context --reset` or `cdk context --clear` commands.

Feature flags are disabled by default. Existing projects that do not specify the flag will continue to work as before with later AWS CDK releases. New projects created using **cdk init** include flags enabling all features available in the release that created the project. Edit `cdk.json` to disable any flags for which you prefer the earlier behavior. You can also add flags to enable new behaviors after upgrading the AWS CDK.

A list of all current feature flags can be found on the AWS CDK GitHub repository in [FEATURE\\_FLAGS.md](#). See the CHANGELOG in a given release for a description of any new feature flags added in that release.

## Reverting to v1 behavior

In CDK v2, the defaults for some feature flags have been changed with respect to v1. You can set these back to false to revert to specific AWS CDK v1 behavior. Use the `cdk diff` command to inspect the changes to your synthesized template to see if any of these flags are needed.

@aws-cdk/core:newStyleStackSynthesis

Use the new stack synthesis method, which assumes bootstrap resources with well-known names. Requires [modern bootstrapping \(p. 195\)](#), but in turn allows CI/CD via [CDK Pipelines \(p. 282\)](#) and cross-account deployments out of the box.

@aws-cdk/aws-apigateway:usagePlanKeyOrderInsensitiveId

If your application uses multiple Amazon API Gateway API keys and associates them to usage plans.

@aws-cdk/aws-rds:lowercaseDbIdentifier

If your application uses Amazon RDS database instance or database clusters, and explicitly specifies the identifier for these.

@aws-cdk/aws-cloudfront:defaultSecurityPolicyTLSv1.2\_2021

If your application uses the TLS\_V1\_2\_2019 security policy with Amazon CloudFront distributions. CDK v2 uses security policy TLSv1.2\_2021 by default.

@aws-cdk/core:stackRelativeExports

If your application uses multiple stacks and you refer to resources from one stack in another, this determines whether absolute or relative path is used to construct AWS CloudFormation exports.

@aws-cdk/aws-lambda:recognizeVersionProps

If set to false, the CDK includes metadata when detecting whether a Lambda function has changed. This can cause deployment failures when only the metadata has changed, since duplicate versions are not allowed. There is no need to revert this flag if you've made at least one change to all Lambda Functions in your application.

The syntax for reverting these flags in `cdk.json` is shown here.

```
{
  "context": {
    "@aws-cdk/core:newStyleStackSynthesis": false,
    "@aws-cdk/aws-apigateway:usagePlanKeyOrderInsensitiveId": false,
    "@aws-cdk/aws-cloudfront:defaultSecurityPolicyTLSv1.2_2021": false,
    "@aws-cdk/aws-rds:lowercaseDbIdentifier": false,
    "@aws-cdk/core:stackRelativeExports": false,
    "@aws-cdk/aws-lambda:recognizeVersionProps": false
  }
}
```

## Aspects

Aspects are a way to apply an operation to all constructs in a given scope. The aspect could modify the constructs, such as by adding tags. Or it could verify something about the state of the constructs, such as making sure that all buckets are encrypted.

To apply an aspect to a construct and all constructs in the same scope, call [Aspects.of\(SCOPE\).add\(\)](#) with a new aspect, as shown in the following example.

TypeScript

```
Aspects.of(myConstruct).add(new SomeAspect(...));
```

JavaScript

```
Aspects.of(myConstruct).add(new SomeAspect(...));
```

Python

```
Aspects.of(my_construct).add(SomeAspect(...))
```



#### Java

```
Aspects.of(myConstruct).add(new SomeAspect(...));
```

#### C#

```
Aspects.Of(myConstruct).add(new SomeAspect(...));
```

The AWS CDK uses aspects to [tag resources \(p. 155\)](#), but the framework can also be used for other purposes. For example, you can use it to validate or change the AWS CloudFormation resources that are defined for you by higher-level constructs.

## Aspects in detail

Aspects employ the [visitor pattern](#). An aspect is a class that implements the following interface.

#### TypeScript

```
interface IAspect {  
    visit(node: IConstruct): void;} 
```

#### JavaScript

JavaScript doesn't have interfaces as a language feature. Therefore, an aspect is simply an instance of a class having a `visit` method that accepts the node to be operated on.

#### Python

Python doesn't have interfaces as a language feature. Therefore, an aspect is simply an instance of a class having a `visit` method that accepts the node to be operated on.

#### Java

```
public interface IAspect {  
    public void visit(Construct node);  
}
```

#### C#

```
public interface IAspect  
{  
    void Visit(IConstruct node);  
}
```

When you call `Aspects.of(SCOPE).add(...)`, the construct adds the aspect to an internal list of aspects. You can obtain the list with `Aspects.of(SCOPE)`.

During the [prepare phase \(p. 105\)](#), the AWS CDK calls the `visit` method of the object for the construct and each of its children in top-down order.

The `visit` method is free to change anything in the construct. In strongly typed languages, cast the received construct to a more specific type before accessing construct-specific properties or methods.

Aspects don't propagate across Stage construct boundaries, because Stages are self-contained and immutable after definition. Apply aspects on the Stage construct itself (or lower) if you want them to visit constructs inside the Stage.

## Example

The following example validates that all buckets created in the stack have versioning enabled. The aspect adds an error annotation to the constructs that fail the validation. This results in the **synth** operation failing and prevents deploying the resulting cloud assembly.

### TypeScript

```
class BucketVersioningChecker implements IAspect {
  public visit(node: IConstruct): void {
    // See that we're dealing with a CfnBucket
    if (node instanceof s3.CfnBucket) {

      // Check for versioning property, exclude the case where the property
      // can be a token (IResolvable).
      if (!node.versioningConfiguration
        || (!Tokenization.isResolvable(node.versioningConfiguration)
          && node.versioningConfiguration.status !== 'Enabled')) {
        Annotations.of(node).addError('Bucket versioning is not enabled');
      }
    }
  }
}

// Later, apply to the stack
Aspects.of(stack).add(new BucketVersioningChecker());
```

### JavaScript

```
class BucketVersioningChecker {
  visit(node) {
    // See that we're dealing with a CfnBucket
    if ( node instanceof s3.CfnBucket) {

      // Check for versioning property, exclude the case where the property
      // can be a token (IResolvable).
      if (!node.versioningConfiguration
        || !Tokenization.isResolvable(node.versioningConfiguration)
          && node.versioningConfiguration.status !== 'Enabled') {
        Annotations.of(node).addError('Bucket versioning is not enabled');
      }
    }
  }
}

// Later, apply to the stack
Aspects.of(stack).add(new BucketVersioningChecker());
```

### Python

```
@jsii.implements(cdk.IAspect)
class BucketVersioningChecker:

    def visit(self, node):
        # See that we're dealing with a CfnBucket
        if isinstance(node, s3.CfnBucket):

            # Check for versioning property, exclude the case where the property
            # can be a token (IResolvable).
            if (not node.versioning_configuration or
                not Tokenization.is_resolvable(node.versioning_configuration)
                and node.versioning_configuration.status != "Enabled"):
```

```
Annotations.of(node).add_error('Bucket versioning is not enabled')

# Later, apply to the stack
Aspects.of(stack).add(BucketVersioningChecker())
```

#### Java

```
public class BucketVersioningChecker implements IAspect
{
    @Override
    public void visit(Construct node)
    {
        // See that we're dealing with a CfnBucket
        if (node instanceof CfnBucket)
        {
            CfnBucket bucket = (CfnBucket)node;
            Object versioningConfiguration = bucket.getVersioningConfiguration();
            if (versioningConfiguration == null ||
                !Tokenization.isResolvable(versioningConfiguration.toString()) &&
                !versioningConfiguration.toString().contains("Enabled"))
                Annotations.of(bucket.getNode()).addError("Bucket versioning is not
enabled");
        }
    }
}

// Later, apply to the stack
Aspects.of(stack).add(new BucketVersioningChecker());
```

#### C#

```
class BucketVersioningChecker : Amazon.Jsii.Runtime.Deputy.DeputyBase, IAspect
{
    public void Visit(IConstruct node)
    {
        // See that we're dealing with a CfnBucket
        if (node is CfnBucket)
        {
            var bucket = (CfnBucket)node;
            if (bucket.VersioningConfiguration is null ||
                !Tokenization.IsResolvable(bucket.VersioningConfiguration) &&
                !bucket.VersioningConfiguration.ToString().Contains("Enabled"))
                Annotations.Of(bucket.Node).AddError("Bucket versioning is not
enabled");
        }
    }
}

// Later, apply to the stack
Aspects.Of(stack).add(new BucketVersioningChecker());
```

## Bootstrapping

*Bootstrapping* is the process of provisioning resources for the AWS CDK before you can deploy AWS CDK apps into an AWS [environment \(p. 114\)](#). (An AWS environment is a combination of an AWS account and Region).

These resources include an Amazon S3 bucket for storing files and IAM roles that grant permissions needed to perform deployments.

The required resources are defined in an AWS CloudFormation stack, called the *bootstrap stack*, which is usually named `CDKToolkit`. Like any AWS CloudFormation stack, it appears in the AWS CloudFormation console once it has been deployed.

**Note**

CDK v2 uses a bootstrap template dubbed the modern template. The legacy template from CDK v1 is not supported in v2.

Environments are independent. If you want to deploy to multiple environments (different AWS accounts or different Regions in the same account), each environment must be bootstrapped separately.

**Important**

You may incur AWS charges for data stored in the bootstrapped resources.

**Note**

Earlier versions of the bootstrap template created an AWS KMS key in each bootstrapped environment by default. To avoid charges for the KMS key, re-bootstrap these environments using `--no-bootstrap-customer-key`. The current default is no KMS key, which helps avoid these charges.

If you attempt to deploy an AWS CDK application into an environment that doesn't have the necessary resources, an error message reminds you to bootstrap the environment.

If you are using CDK Pipelines to deploy into another account's environment, and you receive a message like the following:

Policy contains a statement with one or more invalid principals

This error message means that the appropriate IAM roles do not exist in the other environment. The most likely cause is a lack of bootstrapping.

**Note**

Do not delete and recreate an account's bootstrap stack if you are using CDK Pipelines to deploy into that account. The pipeline will stop working. To update the bootstrap stack to a new version, instead re-run `cdk bootstrap` to update the bootstrap stack in place.

## How to bootstrap

Bootstrapping is the deployment of an AWS CloudFormation template to a specific AWS environment (account and Region). The bootstrapping template accepts parameters that customize some aspects of the bootstrapped resources (see [the section called “Customizing bootstrapping” \(p. 198\)](#)). Thus, you can bootstrap in one of two ways.

- Use the AWS CDK Toolkit's **`cdk bootstrap`** command. This is the simplest method and works well if you have only a few environments to bootstrap.
- Deploy the template provided by the AWS CDK Toolkit using another AWS CloudFormation deployment tool. This lets you use AWS CloudFormation StackSets or AWS Control Tower and also the AWS CloudFormation console or the AWS CLI. You can make small modifications to the template before deployment. This approach is more flexible and is suitable for large-scale deployments.

It is not an error to bootstrap an environment more than once. If an environment you bootstrap has already been bootstrapped, its bootstrap stack will be upgraded if necessary. Otherwise, nothing happens.

## Bootstrapping with the AWS CDK Toolkit

Use the `cdk bootstrap` command to bootstrap one or more AWS environments. In its basic form, this command bootstraps one or more specified AWS environments (two, in this example).

```
cdk bootstrap aws://ACCOUNT-NUMBER-1/REGION-1 aws://ACCOUNT-NUMBER-2/REGION-2 ...
```

The following examples illustrate bootstrapping of one and two environments, respectively. (Both use the same AWS account.) As shown in the second example, the `aws://` prefix is optional when specifying an environment.

```
cdk bootstrap aws://123456789012/us-east-1
cdk bootstrap 123456789012/us-east-1 123456789012/us-west-1
```

The CDK Toolkit always synthesizes the AWS CDK app in the current directory. If you do not specify at least one environment in the `cdk bootstrap` command, it bootstraps all the environments referenced in the app.

If a stack is environment-agnostic (meaning it doesn't have an `env` property), then the CDK's environment is applied to make the stack environment-specific. The CDK's environment is the one specified using `--profile` or environment variables, or the default AWS environment otherwise. That environment is then bootstrapped.

For example, the following command synthesizes the current AWS CDK app using the `prod` AWS profile, then bootstraps its environments.

```
cdk bootstrap --profile prod
```

## Bootstrapping from the AWS CloudFormation template

AWS CDK bootstrapping is performed by an AWS CloudFormation template. To get a copy of this template in the file `bootstrap-template.yaml`, run the following command.

macOS/Linux

```
cdk bootstrap --show-template > bootstrap-template.yaml
```

Windows

On Windows, PowerShell must be used to preserve the encoding of the template.

```
powershell "cdk bootstrap --show-template | Out-File -encoding utf8 bootstrap-template.yaml"
```

The template is also available in the [AWS CDK GitHub repository](#).

Deploy this template using the CDK CLI or your preferred deployment mechanism for AWS CloudFormation templates. To deploy using the CDK CLI, run **`cdk bootstrap --template TEMPLATE_FILENAME`**. You can also deploy it using the AWS CLI by running the command below, or [deploy to one or more accounts at once using AWS CloudFormation Stack Sets](#).

macOS/Linux

```
aws cloudformation create-stack \
  --stack-name CDKToolkit \
  --template-body file://bootstrap-template.yaml
```

Windows

```
aws cloudformation create-stack ^
```

```
--stack-name CDKToolkit ^  
--template-body file://bootstrap-template.yaml
```

## Bootstrapping template

As previously mentioned, AWS CDK v1 supported two bootstrapping templates, legacy and modern. CDK v2 supports only the modern template. For reference, here are the high-level differences between these two templates.

Feature	Legacy (v1 only)	Modern (v1 and v2)
<b>Cross-account deployments</b>	Not allowed	Allowed
<b>AWS CloudFormation Permissions</b>	Deploys using current user's permissions (determined by AWS profile, environment variables, etc.)	Deploys using the permissions specified when the bootstrap stack was provisioned (for example, by using <code>--trust</code> )
<b>Versioning</b>	Only one version of bootstrap stack is available	Bootstrap stack is versioned; new resources can be added in future versions, and AWS CDK apps can require a minimum version
<b>Resources*</b>	Amazon S3 bucket	Amazon S3 bucket
		AWS KMS key
		IAM roles
		Amazon ECR repository
		SSM parameter for versioning
<b>Resource naming</b>	Automatically generated	Deterministic
<b>Bucket encryption</b>	Default key	Customer managed key

\* We will add additional resources to the bootstrap template as needed.

An environment that was bootstrapped using the legacy template must be upgraded to use the modern template for CDK v2 by re-bootstrapping. Re-deploy all AWS CDK applications in the environment at least once before deleting the legacy bucket.

## Customizing bootstrapping

There are two ways to customize the bootstrapping resources.

- Use command line parameters with the `cdk bootstrap` command. This lets you modify a few aspects of the template.
- Modify the default bootstrap template and deploy it yourself. This gives you more complete control over the bootstrap resources.

The following command line options, when used with CDK Toolkit's **cdk bootstrap**, provide commonly needed adjustments to the bootstrapping template.

- **--bootstrap-bucket-name** overrides the name of the Amazon S3 bucket. May require changes to your CDK app (see [the section called “Stack synthesizers” \(p. 200\)](#)).
- **--bootstrap-kms-key-id** overrides the AWS KMS key used to encrypt the S3 bucket.
- **--cloudformation-execution-policies** specifies the ARNs of managed policies that should be attached to the deployment role assumed by AWS CloudFormation during deployment of your stacks. By default, stacks are deployed with full administrator permissions using the AdministratorAccess policy.

The policy ARNs must be passed as a single string argument, with the individual ARNs separated by commas. For example:

```
--cloudformation-execution-policies "arn:aws:iam::aws:policy/  
AWSLambda_FullAccess,arn:aws:iam::aws:policy/AWSCodeDeployFullAccess".
```

### Important

To avoid deployment failures, be sure the policies that you specify are sufficient for any deployments you will perform in the environment being bootstrapped.

- **--qualifier** is a string that is added to the names of all resources in the bootstrap stack. A qualifier lets you avoid resource name clashes when you provision multiple bootstrap stacks in the same environment. The default is hnb659fds (this value has no significance).

Changing the qualifier also requires that your CDK app pass the changed value to the stack synthesizer. For more information, see [the section called “Stack synthesizers” \(p. 200\)](#).

- **--tags** adds one or more AWS CloudFormation tags to the bootstrap stack.
- **--trust** lists the AWS accounts that may deploy into the environment being bootstrapped.

Use this flag when bootstrapping an environment that a CDK Pipeline in another environment will deploy into. The account doing the bootstrapping is always trusted.

- **--trust-for-lookup** lists the AWS accounts that may look up context information from the environment being bootstrapped.

Use this flag to give accounts permission to synthesize stacks that will be deployed into the environment, without actually giving them permission to deploy those stacks directly.

- **--termination-protection** prevents the bootstrap stack from being deleted. For more information, see [Protecting a stack from being deleted](#) in the *AWS CloudFormation User Guide*.

### Important

The modern bootstrap template effectively grants the permissions implied by the `--cloudformation-execution-policies` to any AWS account in the `--trust` list. By default, this extends permissions to read and write to any resource in the bootstrapped account. Make sure to [configure the bootstrapping stack \(p. 198\)](#) with policies and trusted accounts that you are comfortable with.

## Customizing the template

When you need more customization than the AWS CDK Toolkit switches can provide, you can modify the bootstrap template to suit your needs. Remember that you can obtain the template by using the **--show-template** flag.

```
cdk bootstrap --show-template
```

Any modifications you make must adhere to the [bootstrapping template contract \(p. 206\)](#). To ensure that your customizations are not accidentally overwritten later by someone running **cdk bootstrap**

using the default template, change the default value of the `BootstrapVariant` template parameter. The CDK CLI will only allow overwriting the bootstrap stack with templates that have the same `BootstrapVariant` and a equal or higher version than the template that is currently deployed.

Deploy your modified template as described in [the section called “Bootstrapping from the AWS CloudFormation template” \(p. 197\)](#), or using **`cdk bootstrap --template`**.

```
cdk bootstrap --template bootstrap-template.yaml
```

## Stack synthesizers

Your AWS CDK app needs to know about the bootstrapping resources available to it in order to successfully synthesize a stack that can be deployed. The *stack synthesizer* is an AWS CDK class that controls how the stack's template is synthesized. This includes how it uses bootstrapping resources (for example, how it refers to assets stored in the bootstrap bucket).

The AWS CDK's built-in stack synthesizer is called `DefaultStackSynthesizer`. It includes capabilities for cross-account deployments and [CDK Pipelines \(p. 282\)](#) deployments.

You can pass a stack synthesizer to a stack when you instantiate it using the `synthesizer` property.

### TypeScript

```
new MyStack(this, 'MyStack', {  
  // stack properties  
  synthesizer: new DefaultStackSynthesizer({  
    // synthesizer properties  
  }),  
});
```

### JavaScript

```
new MyStack(this, 'MyStack', {  
  // stack properties  
  synthesizer: new DefaultStackSynthesizer({  
    // synthesizer properties  
  }),  
});
```

### Python

```
MyStack(self, "MyStack",  
        # stack properties  
        synthesizer=DefaultStackSynthesizer(  
            # synthesizer properties  
        ))
```

### Java

```
new MyStack(app, "MyStack", StackProps.builder()  
    // stack properties  
    .synthesizer(DefaultStackSynthesizer.Builder.create())  
    // synthesizer properties  
    .build())  
    .build();
```



C#

```
new MyStack(app, "MyStack", new StackProps
// stack properties
{
    Synthesizer = new DefaultStackSynthesizer(new DefaultStackSynthesizerProps
    {
        // synthesizer properties
    })
});
```

If you don't provide the synthesizer property, `DefaultStackSynthesizer` is used.

## Customizing synthesis

Depending on the changes you made to the bootstrap template, you may also need to customize synthesis. The `DefaultStackSynthesizer` can be customized using the properties described as follows.

If none of these properties provide the customizations you require, you can write your synthesizer as a class that implements `IStackSynthesizer` (perhaps deriving from `DefaultStackSynthesizer`).

## Changing the qualifier

The *qualifier* is added to the name of bootstrap resources to distinguish the resources in separate bootstrap stacks. To deploy two different versions of the bootstrap stack in the same environment (AWS account and Region), the stacks must have different qualifiers.

This feature is intended for name isolation between automated tests of the CDK itself. Unless you can very precisely scope down the IAM permissions given to the AWS CloudFormation execution role, there are no permission isolation benefits to having two different bootstrap stacks in a single account. Therefore, there's usually no need to change this value.

To change the qualifier, configure the `DefaultStackSynthesizer` either by instantiating the synthesizer with the property:

TypeScript

```
new MyStack(this, 'MyStack', {
    synthesizer: new DefaultStackSynthesizer({
        qualifier: 'MYQUALIFIER',
    }),
});
```

JavaScript

```
new MyStack(this, 'MyStack', {
    synthesizer: new DefaultStackSynthesizer({
        qualifier: 'MYQUALIFIER',
    }),
})
```

Python

```
MyStack(self, "MyStack",
    synthesizer=DefaultStackSynthesizer(
        qualifier="MYQUALIFIER"
```

```
))
```

#### Java

```
new MyStack(app, "MyStack", StackProps.builder()
    .synthesizer(DefaultStackSynthesizer.Builder.create()
        .qualifier("MYQUALIFIER")
        .build())
    .build());
```

#### C#

```
new MyStack(app, "MyStack", new StackProps
{
    Synthesizer = new DefaultStackSynthesizer(new DefaultStackSynthesizerProps
    {
        Qualifier = "MYQUALIFIER"
    })
});
```

Or by configuring the qualifier as a context key in `cdk.json`.

```
{
  "app": "...",
  "context": {
    "@aws-cdk/core:bootstrapQualifier": "MYQUALIFIER"
  }
}
```

## Changing the resource names

All the other `DefaultStackSynthesizer` properties relate to the names of the resources in the bootstrapping template. You only need to provide any of these properties if you modified the bootstrap template and changed the resource names or naming scheme.

All properties accept the special placeholders `${Qualifier}`, `${AWS::Partition}`, `${AWS::AccountId}`, and `${AWS::Region}`. These placeholders are replaced with the values of the qualifier parameter and the AWS partition, account ID, and Region values for the stack's environment, respectively.

The following example shows the most commonly used properties for `DefaultStackSynthesizer` along with their default values, as if you were instantiating the synthesizer. For a complete list, see [DefaultStackSynthesizerProps](#).

#### TypeScript

```
new DefaultStackSynthesizer({
    // Name of the S3 bucket for file assets
    fileAssetsBucketName: 'cdk-${Qualifier}-assets-${AWS::AccountId}-${AWS::Region}',
    bucketPrefix: '',

    // Name of the ECR repository for Docker image assets
    imageAssetsRepositoryName: 'cdk-${Qualifier}-container-assets-${AWS::AccountId}-${AWS::Region}',

    // ARN of the role assumed by the CLI and Pipeline to deploy here
    deployRoleArn: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-deploy-role-${AWS::AccountId}-${AWS::Region}',
```

```
deployRoleExternalId: '',

// ARN of the role used for file asset publishing (assumed from the CLI role)
fileAssetPublishingRoleArn: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-file-publishing-role-${AWS::AccountId}-${AWS::Region}',
fileAssetPublishingExternalId: '',

// ARN of the role used for Docker asset publishing (assumed from the CLI role)
imageAssetPublishingRoleArn: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-image-publishing-role-${AWS::AccountId}-${AWS::Region}',
imageAssetPublishingExternalId: '',

// ARN of the role passed to CloudFormation to execute the deployments
cloudFormationExecutionRole: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-cfn-exec-role-${AWS::AccountId}-${AWS::Region}',

// ARN of the role used to look up context information in an environment
lookupRoleArn: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-
lookup-role-${AWS::AccountId}-${AWS::Region}',
lookupRoleExternalId: '',

// Name of the SSM parameter which describes the bootstrap stack version number
bootstrapStackVersionSsmParameter: '/cdk-bootstrap/${Qualifier}/version',

// Add a rule to every template which verifies the required bootstrap stack version
generateBootstrapVersionRule: true,

})
```

#### JavaScript

```
new DefaultStackSynthesizer({
  // Name of the S3 bucket for file assets
  fileAssetsBucketName: 'cdk-${Qualifier}-assets-${AWS::AccountId}-${AWS::Region}',
  bucketPrefix: '',

  // Name of the ECR repository for Docker image assets
  imageAssetsRepositoryName: 'cdk-${Qualifier}-container-assets-${AWS::AccountId}-
${AWS::Region}',

  // ARN of the role assumed by the CLI and Pipeline to deploy here
  deployRoleArn: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-
deploy-role-${AWS::AccountId}-${AWS::Region}',
  deployRoleExternalId: '',

  // ARN of the role used for file asset publishing (assumed from the CLI role)
  fileAssetPublishingRoleArn: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-file-publishing-role-${AWS::AccountId}-${AWS::Region}',
  fileAssetPublishingExternalId: '',

  // ARN of the role used for Docker asset publishing (assumed from the CLI role)
  imageAssetPublishingRoleArn: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-image-publishing-role-${AWS::AccountId}-${AWS::Region}',
  imageAssetPublishingExternalId: '',

  // ARN of the role passed to CloudFormation to execute the deployments
  cloudFormationExecutionRole: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-cfn-exec-role-${AWS::AccountId}-${AWS::Region}',

  // ARN of the role used to look up context information in an environment
  lookupRoleArn: 'arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-
lookup-role-${AWS::AccountId}-${AWS::Region}',
  lookupRoleExternalId: '',

  // Name of the SSM parameter which describes the bootstrap stack version number
```

```
bootstrapStackVersionSsmParameter: '/cdk-bootstrap/${Qualifier}/version',

// Add a rule to every template which verifies the required bootstrap stack version
generateBootstrapVersionRule: true,
})
```

## Python

```
DefaultStackSynthesizer(
    # Name of the S3 bucket for file assets
    file_assets_bucket_name="cdk-${Qualifier}-assets-${AWS::AccountId}-${AWS::Region}",
    bucket_prefix="",

    # Name of the ECR repository for Docker image assets
    image_assets_repository_name="cdk-${Qualifier}-container-assets-${AWS::AccountId}-${AWS::Region}",

    # ARN of the role assumed by the CLI and Pipeline to deploy here
    deploy_role_arn="arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-deploy-role-${AWS::AccountId}-${AWS::Region}",
    deploy_role_external_id="",

    # ARN of the role used for file asset publishing (assumed from the CLI role)
    file_asset_publishing_role_arn="arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-file-publishing-role-${AWS::AccountId}-${AWS::Region}",
    file_asset_publishing_external_id="",

    # ARN of the role used for Docker asset publishing (assumed from the CLI role)
    image_asset_publishing_role_arn="arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-image-publishing-role-${AWS::AccountId}-${AWS::Region}",
    image_asset_publishing_external_id="",

    # ARN of the role passed to CloudFormation to execute the deployments
    cloud_formation_execution_role="arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-cfn-exec-role-${AWS::AccountId}-${AWS::Region}",

    # ARN of the role used to look up context information in an environment
    lookup_role_arn="arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-lookup-role-${AWS::AccountId}-${AWS::Region}",
    lookup_role_external_id="",

    # Name of the SSM parameter which describes the bootstrap stack version number
    bootstrap_stack_version_ssm_parameter="/cdk-bootstrap/${Qualifier}/version",

    # Add a rule to every template which verifies the required bootstrap stack version
    generate_bootstrap_version_rule=True,
)
```

## Java

```
DefaultStackSynthesizer.Builder.create()
    // Name of the S3 bucket for file assets
    .fileAssetsBucketName("cdk-${Qualifier}-assets-${AWS::AccountId}-${AWS::Region}")
    .bucketPrefix('')

    // Name of the ECR repository for Docker image assets
    .imageAssetsRepositoryName("cdk-${Qualifier}-container-assets-${AWS::AccountId}-${AWS::Region}")

    // ARN of the role assumed by the CLI and Pipeline to deploy here
    .deployRoleArn("arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-deploy-role-${AWS::AccountId}-${AWS::Region}")
    .deployRoleExternalId("")
```

```
// ARN of the role used for file asset publishing (assumed from the CLI role)
.fileAssetPublishingRoleArn("arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-file-publishing-role-${AWS::AccountId}-${AWS::Region}")
.fileAssetPublishingExternalId("")

// ARN of the role used for Docker asset publishing (assumed from the CLI role)
.imageAssetPublishingRoleArn("arn:${AWS::Partition}:iam:${AWS::AccountId}:role/
cdk-${Qualifier}-image-publishing-role-${AWS::AccountId}-${AWS::Region}")
.imageAssetPublishingExternalId("")

// ARN of the role passed to CloudFormation to execute the deployments
.cloudFormationExecutionRole("arn:${AWS::Partition}:iam:${AWS::AccountId}:role/
cdk-${Qualifier}-cfn-exec-role-${AWS::AccountId}-${AWS::Region}")

.lookupRoleArn("arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-${Qualifier}-
lookup-role-${AWS::AccountId}-${AWS::Region}")
.lookupRoleExternalId("")

// Name of the SSM parameter which describes the bootstrap stack version number
.bootstrapStackVersionSsmParameter("/cdk-bootstrap/${Qualifier}/version")

// Add a rule to every template which verifies the required bootstrap stack version
.generateBootstrapVersionRule(true)
.build()
```

## C#

```
new DefaultStackSynthesizer(new DefaultStackSynthesizerProps
{
    // Name of the S3 bucket for file assets
    FileAssetsBucketName = "cdk-${Qualifier}-assets-${AWS::AccountId}-${AWS::Region}",
    BucketPrefix = "",

    // Name of the ECR repository for Docker image assets
    ImageAssetsRepositoryName = "cdk-${Qualifier}-container-assets-${AWS::AccountId}-
${AWS::Region}",

    // ARN of the role assumed by the CLI and Pipeline to deploy here
    DeployRoleArn = "arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-deploy-role-${AWS::AccountId}-${AWS::Region}",
    DeployRoleExternalId = "",

    // ARN of the role used for file asset publishing (assumed from the CLI role)
    FileAssetPublishingRoleArn = "arn:${AWS::Partition}:iam:${AWS::AccountId}:role/
cdk-${Qualifier}-file-publishing-role-${AWS::AccountId}-${AWS::Region}",
    FileAssetPublishingExternalId = "",

    // ARN of the role used for Docker asset publishing (assumed from the CLI role)
    ImageAssetPublishingRoleArn = "arn:${AWS::Partition}:iam:${AWS::AccountId}:role/
cdk-${Qualifier}-image-publishing-role-${AWS::AccountId}-${AWS::Region}",
    ImageAssetPublishingExternalId = "",

    // ARN of the role passed to CloudFormation to execute the deployments
    CloudFormationExecutionRole = "arn:${AWS::Partition}:iam:${AWS::AccountId}:role/
cdk-${Qualifier}-cfn-exec-role-${AWS::AccountId}-${AWS::Region}",

    LookupRoleArn = "arn:${AWS::Partition}:iam:${AWS::AccountId}:role/cdk-
${Qualifier}-lookup-role-${AWS::AccountId}-${AWS::Region}",
    LookupRoleExternalId = "",

    // Name of the SSM parameter which describes the bootstrap stack version number
    BootstrapStackVersionSsmParameter = "/cdk-bootstrap/${Qualifier}/version",

    // Add a rule to every template which verifies the required bootstrap stack version
    GenerateBootstrapVersionRule = true,
}
```

```
} )
```

## The bootstrapping template contract

The requirements of the bootstrapping stack depend on the stack synthesizer in use. If you write your own stack synthesizer, you have complete control of the bootstrap resources that your synthesizer requires and how the synthesizer finds them.

This section describes the expectations that the `DefaultStackSynthesizer` has of the bootstrapping template.

### Versioning

The template should contain a resource to create an SSM parameter with a well-known name and an output to reflect the template's version.

```
Resources:
  CdkBootstrapVersion:
    Type: AWS::SSM::Parameter
    Properties:
      Type: String
      Name:
        Fn::Sub: '/cdk-bootstrap/${Qualifier}/version'
      Value: 4
Outputs:
  BootstrapVersion:
    Value:
      Fn::GetAtt: [CdkBootstrapVersion, Value]
```

### Roles

The `DefaultStackSynthesizer` requires five IAM roles for five different purposes. If you are not using the default roles, you must tell the synthesizer the ARNs for the roles you want to use.

The roles are as follows:

- The *deployment role* is assumed by the AWS CDK Toolkit and by AWS CodePipeline to deploy into an environment. Its `AssumeRolePolicy` controls who can deploy into the environment. In the template, you can see the permissions that this role needs.
- The *lookup role* is assumed by the AWS CDK Toolkit to perform context lookups in an environment. Its `AssumeRolePolicy` controls who can deploy into the environment. The permissions this role needs can be seen in the template.
- The *file publishing role* and the *image publishing role* are assumed by the AWS CDK Toolkit and by AWS CodeBuild projects to publish assets into an environment. They're used to write to the S3 bucket and the ECR repository, respectively. These roles require write access to these resources.
- The *AWS CloudFormation execution role* is passed to AWS CloudFormation to perform the actual deployment. Its permissions are the permissions that the deployment will execute under. The permissions are passed to the stack as a parameter that lists managed policy ARNs.

### Outputs

The AWS CDK Toolkit requires that the following CloudFormation outputs exist on the bootstrap stack.

- `BucketName`: the name of the file asset bucket

- `BucketDomainName`: the file asset bucket in domain name format
- `BootstrapVersion`: the current version of the bootstrap stack

## Template history

The bootstrap template is versioned and evolves over time with the AWS CDK itself. If you provide your own bootstrap template, keep it up to date with the canonical default template. You want to make sure that your template continues to work with all CDK features.

This section contains a list of the changes made in each version.

Template version	AWS CDK version	Changes
1	1.40.0	Initial version of template with Bucket, Key, Repository, and Roles.
2	1.45.0	Split asset publishing role into separate file and image publishing roles.
3	1.46.0	Add <code>FileAssetKeyArn</code> export to be able to add decrypt permissions to asset consumers.
4	1.61.0	AWS KMS permissions are now implicit via Amazon S3 and no longer require <code>FileAssetKeyArn</code> . Add <code>CdkBootstrapVersion</code> SSM parameter so the bootstrap stack version can be verified without knowing the stack name.
5	1.87.0	Deployment role can read SSM parameter.
6	1.108.0	Add lookup role separate from deployment role.
6	1.109.0	Attach <code>aws-cdk:bootstrap-role</code> tag to deployment, file publishing, and image publishing roles.
7	1.110.0	Deployment role can no longer read Buckets in the target account directly. (However, this role is effectively an administrator, and could always use its AWS CloudFormation permissions to make the bucket readable anyway).
8	1.114.0	The lookup role has full read-only permissions to the target

Template version	AWS CDK version	Changes
		environment, and has a <code>aws-cdk:bootstrap-role</code> tag as well.
9	2.1.0	Fixes Amazon S3 asset uploads from being rejected by commonly referenced encryption SCP.
10	2.4.0	Amazon ECR ScanOnPush is now enabled by default.
11	2.18.0	Adds policy allowing Lambda to pull from Amazon ECR repos so it survives re-bootstrapping.
12	2.20.0	Adds support for experimental <b>cdk import</b> .
13	2.25.0	Makes container images in bootstrap-created Amazon ECR repositories immutable.
14	2.34.0	Turns off Amazon ECR image scanning at the repository level by default to allow bootstrapping Regions that do not support image scanning.

## Security Hub Findings

If you are using AWS Security Hub, you may see findings reported on some of the resources created by the AWS CDK Bootstrapping process. Security Hub findings help you find resource configurations you should double-check for accuracy and safety. We have reviewed these specific resource configurations with AWS Security and are confident they do not constitute a security problem.

### [KMS.2] IAM principals should not have IAM inline policies that allow decryption actions on all KMS keys

The Deploy Role (default name `cdk-hnb659fds-deploy-role-ACCOUNT-REGION`) has permissions to read encrypted data stored in Amazon S3. The policy does not give permission to any data by itself: only data read from Amazon S3 can be decrypted, and only from buckets that explicitly allow the Deploy Role to read from them via their Bucket Policy, and keys that explicitly allow the Deploy Role to decrypt using them using their Key Policy. This statement is used to allow AWS CDK Pipelines to perform cross-account deployments.

**Why does Security Hub flag this?** The policy contains a `Resource: *` combined with a `Condition` clause; Security Hub is flagging the `*`. The `*` is necessary because at the time the account is bootstrapped, the AWS KMS key created by AWS CDK Pipelines for the CodePipeline Artifact Bucket does not exist yet so we can't reference its ARN. In addition, Security Hub does not include the `Condition` clause in the policy statement in its reasoning.

**What if I want to fix this finding?** As long as the resource policies on your AWS KMS keys are not unnecessarily permissive, the current Role policy does not allow the Deploy Role to access any more data



than it should. If you still want to get rid of the finding, you can do so by customizing the bootstrap stack (using the process outlined above) in one of these 2 ways:

- If you are not using AWS CDK Pipelines for cross-account deployments: remove the statement with `Sid: PipelineCrossAccountArtifactsBucket` from the deploy role; or
- If you are using AWS CDK Pipelines for cross-account deployments: after deploying your AWS CDK Pipeline, look up the AWS KMS Key ARN of the Artifact Bucket and replace the `Resource: *` of the `Sid: PipelineCrossAccountArtifactsBucket` statement with the actual Key ARN.

# Abstractions and escape hatches

The AWS CDK lets you describe AWS resources using constructs that operate at varying levels of abstraction.

- *Layer 1 (L1)* constructs directly represent AWS CloudFormation resources as defined by the CloudFormation specification. These constructs can be identified via a name beginning with "Cfn," so they are also referred to as "Cfn constructs." If a resource exists in AWS CloudFormation, it exists in the CDK as a L1 construct.
- *Layer 2 (L2)* or "curated" constructs are thoughtfully developed to provide a more ergonomic developer experience compared to the L1 construct they're built upon. In a typical CDK app, L2 constructs are usually the most widely used type. Often, L2 constructs define additional supporting resources, such as IAM policies, Amazon SNS topics, or AWS KMS keys. L2 constructs provide sensible defaults, best practice security policies, and a more ergonomic developer experience.
- *Layer 3 (L3)* constructs or *patterns* define entire collections of AWS resources for specific use cases. L3 constructs help to stand up a build pipeline, an Amazon ECS application, or one of many other types of common deployment scenarios. Because they can constitute complete system designs, or substantial parts of a larger system, L3 constructs are often "opinionated." They are built around a particular approach toward solving the problem at hand, and things work out better when you follow their lead.

## Tip

For more details about AWS CDK constructs, see [the section called "Constructs" \(p. 84\)](#).

At the highest level, your AWS CDK application and the stacks in it are themselves abstractions of your entire cloud infrastructure, or significant chunks of it. They can be parameterized to deploy them in different environments or for different needs.

Abstractions are powerful tools for designing and implementing cloud applications. The AWS CDK gives you the power not only to build with its abstractions, but also to create new abstractions. Using the existing open-source L2 and L3 constructs as guidance, you can build your own L2 and L3 constructs to reflect your own organization's best practices and opinions.

No abstraction is perfect, and even good abstractions cannot cover every possible use case. Although the value of the AWS CDK's model is plain, you might sometimes find a construct that almost fits your needs, lacking only a small (or large) tweak.

For this reason, the AWS CDK provides ways to "break out" of the construct model. This lets you move to a lower level of abstraction or to a different model entirely. As their name implies, the CDK's *escape hatches* let you "escape" the AWS CDK paradigm and extend it in ways the AWS CDK designers didn't anticipate. Then you can wrap all that in a new construct to hide the underlying complexity and provide a clean API for developers.

Some situations in which you'll reach for escape hatches include:

- An AWS service feature is available through AWS CloudFormation, but there are no L2 constructs for it.
- An AWS service feature is available through AWS CloudFormation, and there are L2 constructs for the service, but these don't yet expose the feature. Because L2 constructs are developed "by hand," they may sometimes lag behind the L1 constructs.
- The feature is not yet available through AWS CloudFormation at all.

To determine whether a feature is available through AWS CloudFormation, see [AWS Resource and Property Types Reference](#).

## Using AWS CloudFormation constructs directly

If there are no L2 classes available for the service, you can fall back to the automatically generated L1 constructs. These map 1:1 to all available AWS CloudFormation resources and properties. These resources can be recognized by their name starting with `Cfn`, such as `CfnBucket` or `CfnRole`. You instantiate them exactly as you would use the equivalent AWS CloudFormation resource. For more information, see [AWS Resource and Property Types Reference](#).

For example, to instantiate a low-level Amazon S3 bucket L1 with analytics enabled, you would write something like the following.

### TypeScript

```
new s3.CfnBucket(this, 'MyBucket', {
  analyticsConfigurations: [
    {
      id: 'Config',
      // ...
    }
  ]
});
```

### JavaScript

```
new s3.CfnBucket(this, 'MyBucket', {
  analyticsConfigurations: [
    {
      id: 'Config'
      // ...
    }
  ]
});
```

### Python

```
s3.CfnBucket(self, "MyBucket",
  analytics_configurations: [
    dict(id="Config",
        # ...
    )
  ]
)
```

### Java

```
CfnBucket.Builder.create(this, "MyBucket")
    .analyticsConfigurations(Arrays.asList(java.util.Map.of( // Java 9 or later
        "id", "Config", // ...
    )))
    .build();
```

### C#

```
new CfnBucket(this, 'MyBucket', new CfnBucketProps {
    AnalyticsConfigurations = new Dictionary<string, string>
    {
        ["id"] = "Config",
        // ...
    }
});
```

```
});
```

There might be rare cases where you want to define a resource that doesn't have a corresponding `CfnXxx` class. This could be a new resource type that hasn't yet been published in the AWS CloudFormation resource specification. In cases like this, you can instantiate the `cdk.CfnResource` directly and specify the resource type and properties. This is shown in the following example.

#### TypeScript

```
new cdk.CfnResource(this, 'MyBucket', {
  type: 'AWS::S3::Bucket',
  properties: {
    // Note the PascalCase here! These are CloudFormation identifiers.
    AnalyticsConfigurations: [
      {
        Id: 'Config',
        // ...
      }
    ]
  }
});
```

#### JavaScript

```
new cdk.CfnResource(this, 'MyBucket', {
  type: 'AWS::S3::Bucket',
  properties: {
    // Note the PascalCase here! These are CloudFormation identifiers.
    AnalyticsConfigurations: [
      {
        Id: 'Config'
        // ...
      }
    ]
  }
});
```

#### Python

```
cdk.CfnResource(self, 'MyBucket',
  type="AWS::S3::Bucket",
  properties=dict(
    # Note the PascalCase here! These are CloudFormation identifiers.
    "AnalyticsConfigurations": [
      {
        "Id": "Config",
        # ...
      }
    ]
  )
)
```

#### Java

```
CfnResource.Builder.create(this, "MyBucket")
    .type("AWS::S3::Bucket")
    .properties(java.util.Map.of( // Map.of requires Java 9 or later
        // Note the PascalCase here! These are CloudFormation identifiers
        "AnalyticsConfigurations", Arrays.asList(
```

```
        java.util.Map.of("Id", "Config", // ...  
        )))  
    .build();
```

C#

```
new CfnResource(this, "MyBucket", new CfnResourceProps  
{  
    Type = "AWS::S3::Bucket",  
    Properties = new Dictionary<string, object>  
    {  
        // Note the PascalCase here! These are CloudFormation identifiers  
        ["AnalyticsConfigurations"] = new Dictionary<string, string>[]  
        {  
            new Dictionary<string, string> {  
                ["Id"] = "Config"  
            }  
        }  
    }  
});
```

For more information, see [AWS Resource and Property Types Reference](#).

## Modifying the AWS CloudFormation resource behind AWS constructs

If an L2 construct is missing a feature or you're trying to work around an issue, you can modify the L1 construct that's encapsulated by the L2 construct.

All L2 constructs contain within them the corresponding L1 construct. For example, the high-level Bucket construct wraps the low-level CfnBucket construct. Because the CfnBucket corresponds directly to the AWS CloudFormation resource, it exposes all features that are available through AWS CloudFormation.

The basic approach to get access to the L1 class is to use `construct.node.defaultChild` (Python: `default_child`), cast it to the right type (if necessary), and modify its properties. Again, let's take the example of a Bucket.

TypeScript

```
// Get the CloudFormation resource  
const cfnBucket = bucket.node.defaultChild as s3.CfnBucket;  
  
// Change its properties  
cfnBucket.analyticsConfiguration = [  
    {  
        id: 'Config',  
        // ...  
    }  
];
```

JavaScript

```
// Get the CloudFormation resource  
const cfnBucket = bucket.node.defaultChild;
```

```
// Change its properties
cfnBucket.analyticsConfiguration = [
  {
    id: 'Config'
    // ...
  }
];
```

#### Python

```
# Get the CloudFormation resource
cfn_bucket = bucket.node.default_child

# Change its properties
cfn_bucket.analytics_configuration = [
  {
    "id": "Config",
    # ...
  }
]
```

#### Java

```
// Get the CloudFormation resource
CfnBucket cfnBucket = (CfnBucket)bucket.getNode().getDefaultChild();

cfnBucket.setAnalyticsConfigurations(
    Arrays.asList(java.util.Map.of(    // Java 9 or later
        "Id", "Config", // ...
    ));
```

#### C#

```
// Get the CloudFormation resource
var cfnBucket = (CfnBucket)bucket.Node.DefaultChild;

cfnBucket.AnalyticsConfigurations = new List<object> {
    new Dictionary<string, string>
    {
        ["Id"] = "Config",
        // ...
    }
};
```

You can also use this object to change AWS CloudFormation options such as Metadata and UpdatePolicy.

#### TypeScript

```
cfnBucket.cfnOptions.metadata = {
  MetadataKey: 'MetadataValue'
};
```

#### JavaScript

```
cfnBucket.cfnOptions.metadata = {
  MetadataKey: 'MetadataValue'
};
```

#### Python

```
cfn_bucket.cfn_options.metadata = {  
    "MetadataKey": "MetadataValue"  
}
```

#### Java

```
cfnBucket.getCfnOptions().setMetadata(java.util.Map.of(    // Java 9+  
    "MetadataKey", "MetadataValue"));
```

#### C#

```
cfnBucket.CfnOptions.Metadata = new Dictionary<string, object>  
{  
    ["MetadataKey"] = "MetadataValue"  
};
```

## An unescape hatch

The AWS CDK also provides the capability to go *up* an abstraction level, which we might cheekily refer to as an "unescape" hatch. If you have an L1 construct, such as `CfnBucket`, you can create a new L2 construct (`Bucket` in this case) to wrap the L1 construct.

This is convenient when you create an L1 resource but want to use it with a construct that requires an L2 resource. It's also helpful when you want to use convenience methods like `.grantXxxxx()` that aren't available on the L1 construct.

You move to the higher abstraction level using a static method on the L2 class called `.fromCfnXxxxx()`—for example, `Bucket.fromCfnBucket()` for Amazon S3 buckets. The L1 resource is the only parameter.

#### TypeScript

```
b1 = new s3.CfnBucket(this, "buck09", { ... });  
b2 = s3.Bucket.fromCfnBucket(b1);
```

#### JavaScript

```
b1 = new s3.CfnBucket(this, "buck09", { ... } );  
b2 = s3.Bucket.fromCfnBucket(b1);
```

#### Python

```
b1 = s3.CfnBucket(self, "buck09", ...)  
b2 = s3.from_cfn_bucket(b1)
```

#### Java

```
CfnBucket b1 = CfnBucket.Builder.create(this, "buck09")  
    // ....  
    .build();  
IBucket b2 = Bucket.fromCfnBucket(b1);
```

## C#

```
var b1 = new CfnBucket(this, "buck09", new CfnBucketProps { ... });  
var v2 = Bucket.FromCfnBucket(b1);
```

L2 constructs created from L1 constructs are proxy objects that refer to the L1 resource, similar to those created from resource names, ARNs, or lookups. Modifications to these constructs do not affect the final synthesized AWS CloudFormation template (since you have the L1 resource, however, you can modify that instead). For more information on proxy objects, see [the section called “Referencing resources in your AWS account” \(p. 125\)](#).

To avoid confusion, do not create multiple L2 constructs that refer to the same L1 construct. For example, if you extract the `CfnBucket` from a `Bucket` using the technique in the [previous section \(p. 213\)](#), you shouldn't create a second `Bucket` instance by calling `Bucket.fromCfnBucket()` with that `CfnBucket`. It actually works as you'd expect (only one `AWS::S3::Bucket` is synthesized) but it makes your code more difficult to maintain.

## Raw overrides

If there are properties that are missing from the L1 construct, you can bypass all typing using raw overrides. This also makes it possible to delete synthesized properties.

Use one of the `addOverride` methods (Python: `add_override`) methods, as shown in the following example.

### TypeScript

```
// Get the CloudFormation resource  
const cfnBucket = bucket.node.defaultChild as s3.CfnBucket;  
  
// Use dot notation to address inside the resource template fragment  
cfnBucket.addOverride('Properties.VersioningConfiguration.Status', 'NewStatus');  
cfnBucket.addDeletionOverride('Properties.VersioningConfiguration.Status');  
  
// use index (0 here) to address an element of a list  
cfnBucket.addOverride('Properties.Tags.0.Value', 'NewValue');  
cfnBucket.addDeletionOverride('Properties.Tags.0');  
  
// addPropertyOverride is a convenience function for paths starting with "Properties."  
cfnBucket.addPropertyOverride('VersioningConfiguration.Status', 'NewStatus');  
cfnBucket.addPropertyDeletionOverride('VersioningConfiguration.Status');  
cfnBucket.addPropertyOverride('Tags.0.Value', 'NewValue');  
cfnBucket.addPropertyDeletionOverride('Tags.0');
```

### JavaScript

```
// Get the CloudFormation resource  
const cfnBucket = bucket.node.defaultChild ;  
  
// Use dot notation to address inside the resource template fragment  
cfnBucket.addOverride('Properties.VersioningConfiguration.Status', 'NewStatus');  
cfnBucket.addDeletionOverride('Properties.VersioningConfiguration.Status');  
  
// use index (0 here) to address an element of a list  
cfnBucket.addOverride('Properties.Tags.0.Value', 'NewValue');  
cfnBucket.addDeletionOverride('Properties.Tags.0');
```



```
// addPropertyOverride is a convenience function for paths starting with "Properties."  
cfnBucket.addPropertyOverride('VersioningConfiguration.Status', 'NewStatus');  
cfnBucket.addPropertyDeletionOverride('VersioningConfiguration.Status');  
cfnBucket.addPropertyOverride('Tags.0.Value', 'NewValue');  
cfnBucket.addPropertyDeletionOverride('Tags.0');
```

## Python

```
# Get the CloudFormation resource  
cfn_bucket = bucket.node.default_child  
  
# Use dot notation to address inside the resource template fragment  
cfn_bucket.add_override("Properties.VersioningConfiguration.Status", "NewStatus")  
cfn_bucket.add_deletion_override("Properties.VersioningConfiguration.Status")  
  
# use index (0 here) to address an element of a list  
cfn_bucket.add_override("Properties.Tags.0.Value", "NewValue")  
cfn_bucket.add_deletion_override("Properties.Tags.0")  
  
# addPropertyOverride is a convenience function for paths starting with "Properties."  
cfn_bucket.add_property_override("VersioningConfiguration.Status", "NewStatus")  
cfn_bucket.add_property_deletion_override("VersioningConfiguration.Status")  
cfn_bucket.add_property_override("Tags.0.Value", "NewValue")  
cfn_bucket.add_property_deletion_override("Tags.0")
```

## Java

```
// Get the CloudFormation resource  
CfnBucket cfnBucket = (CfnBucket)bucket.getNode().getDefaultChild();  
  
// Use dot notation to address inside the resource template fragment  
cfnBucket.addOverride("Properties.VersioningConfiguration.Status", "NewStatus");  
cfnBucket.addDeletionOverride("Properties.VersioningConfiguration.Status");  
  
// use index (0 here) to address an element of a list  
cfnBucket.addOverride("Properties.Tags.0.Value", "NewValue");  
cfnBucket.addDeletionOverride("Properties.Tags.0");  
  
// addPropertyOverride is a convenience function for paths starting with "Properties."  
cfnBucket.addPropertyOverride("VersioningConfiguration.Status", "NewStatus");  
cfnBucket.addPropertyDeletionOverride("VersioningConfiguration.Status");  
cfnBucket.addPropertyOverride("Tags.0.Value", "NewValue");  
cfnBucket.addPropertyDeletionOverride("Tags.0");
```

## C#

```
// Get the CloudFormation resource  
var cfnBucket = (CfnBucket)bucket.node.defaultChild;  
  
// Use dot notation to address inside the resource template fragment  
cfnBucket.AddOverride("Properties.VersioningConfiguration.Status", "NewStatus");  
cfnBucket.AddDeletionOverride("Properties.VersioningConfiguration.Status");  
  
// use index (0 here) to address an element of a list  
cfnBucket.AddOverride("Properties.Tags.0.Value", "NewValue");  
cfnBucket.AddDeletionOverride("Properties.Tags.0");  
  
// addPropertyOverride is a convenience function for paths starting with "Properties."  
cfnBucket.AddPropertyOverride("VersioningConfiguration.Status", "NewStatus");  
cfnBucket.AddPropertyDeletionOverride("VersioningConfiguration.Status");  
cfnBucket.AddPropertyOverride("Tags.0.Value", "NewValue");  
cfnBucket.AddPropertyDeletionOverride("Tags.0");
```

## Custom resources

If the feature isn't available through AWS CloudFormation, but only through a direct API call, there's only one solution. You must write an AWS CloudFormation Custom Resource to make the API call you need. Don't worry, the AWS CDK makes it easier to write these and wrap them up into a regular construct interface. From the perspective of a consumer of your construct, the feature feels native.

Building a custom resource involves writing a Lambda function that responds to a resource's CREATE, UPDATE, and DELETE lifecycle events. If your custom resource needs to make only a single API call, consider using the [AwsCustomResource](#). This makes it possible to perform arbitrary SDK calls during an AWS CloudFormation deployment. Otherwise, you should write your own Lambda function to perform the work you need to get done.

The subject is too broad to cover completely here, but the following links should get you started:

- [Custom Resources](#)
- [Custom-Resource Example](#)
- For a more fully fledged example, see the [DnsValidatedCertificate](#) class in the CDK standard library. This is implemented as a custom resource.

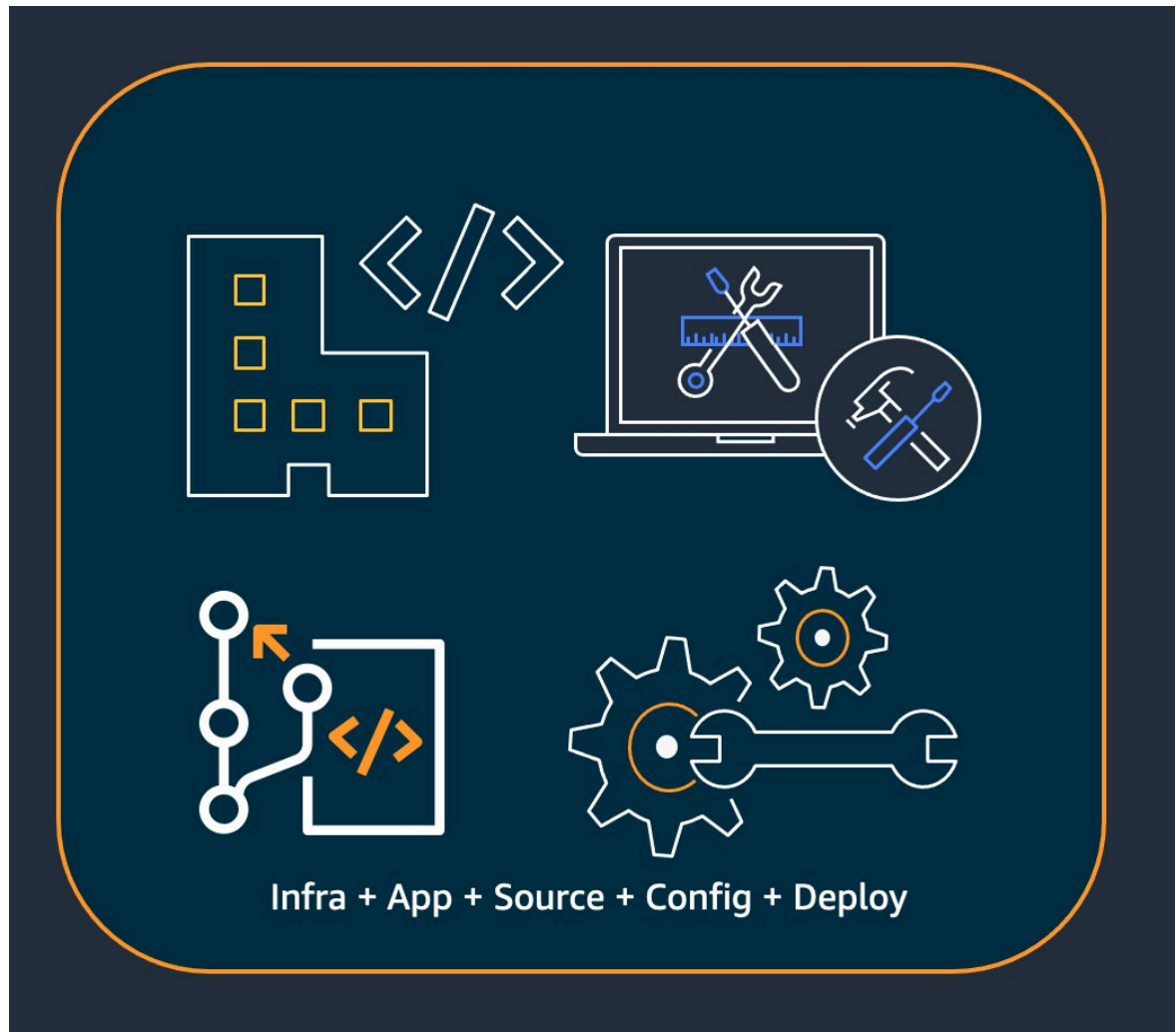
# Best practices for developing and deploying cloud infrastructure with the AWS CDK

With the AWS CDK, developers or administrators can define their cloud infrastructure by using a supported programming language. CDK applications should be organized into logical units, such as API, database, and monitoring resources, and optionally have a pipeline for automated deployments. The logical units should be implemented as constructs including the following:

- Infrastructure (such as Amazon S3 buckets, Amazon RDS databases, or an Amazon VPC network)
- Runtime code (such as AWS Lambda functions)
- Configuration code

Stacks define the deployment model of these logical units. For a more detailed introduction to the concepts behind the CDK, see [Getting started \(p. 9\)](#).

The AWS CDK reflects careful consideration of the needs of our customers and internal teams and of the failure patterns that often arise during the deployment and ongoing maintenance of complex cloud applications. We discovered that failures are often related to "out-of-band" changes to an application that aren't fully tested, such as configuration changes. Therefore, we developed the AWS CDK around a model in which your entire application is defined in code, not only business logic but also infrastructure and configuration. That way, proposed changes can be carefully reviewed, comprehensively tested in environments resembling production to varying degrees, and fully rolled back if something goes wrong.



At deployment time, the AWS CDK synthesizes a cloud assembly that contains the following:

- AWS CloudFormation templates that describe your infrastructure in all target environments
- File assets that contain your runtime code and their supporting files

With the CDK, every commit in your application's main version control branch can represent a complete, consistent, deployable version of your application. Your application can then be deployed automatically whenever a change is made.

The philosophy behind the AWS CDK leads to our recommended best practices, which we have divided into four broad categories.

- [the section called “Organization best practices” \(p. 221\)](#)
- [the section called “Coding best practices” \(p. 222\)](#)
- [the section called “Construct best practices” \(p. 223\)](#)
- [the section called “Application best practices” \(p. 225\)](#)

**Tip**

Also consider [best practices for AWS CloudFormation](#) and the individual AWS services that you use, where applicable to CDK-defined infrastructure.

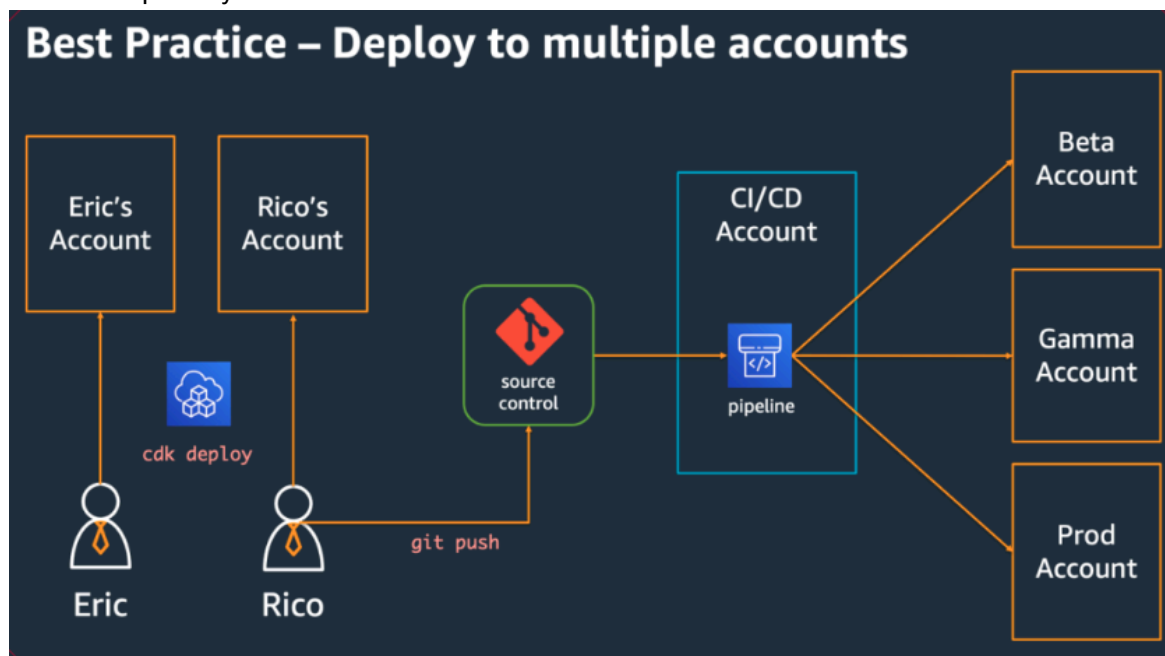
## Organization best practices

In the beginning stages of AWS CDK adoption, it's important to consider how to set up your organization for success. It's a best practice to have a team of experts responsible for training and guiding the rest of the company as they adopt the CDK. The size of this team might vary, from one or two people at a small company to a full-fledged Cloud Center of Excellence (CCoE) at a larger company. This team is responsible for setting standards and policies for cloud infrastructure at your company, and also for training and mentoring developers.

The CCoE might provide guidance on what programming languages should be used for cloud infrastructure. Details will vary from one organization to the next, but a good policy helps make sure that developers can understand and maintain the company's cloud infrastructure.

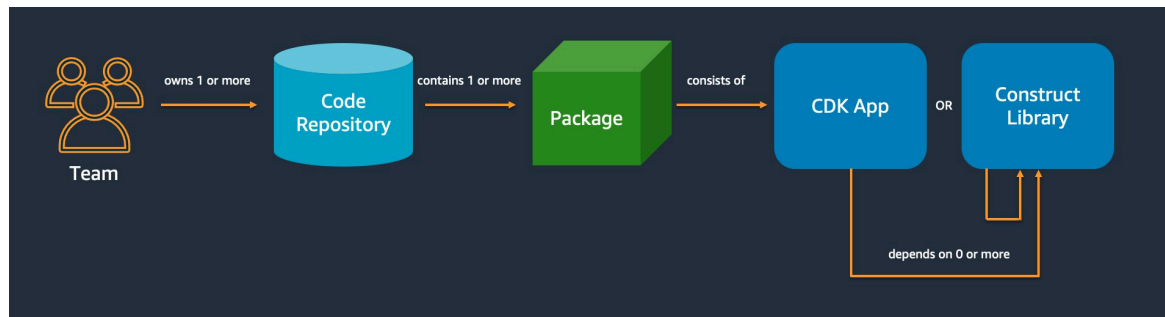
The CCoE also creates a "landing zone" that defines your organizational units within AWS. A landing zone is a pre-configured, secure, scalable, multi-account AWS environment based on best practice blueprints. To tie together the services that make up your landing zone, you can use [AWS Control Tower](#), which configures and manages your entire multi-account system from a single user interface.

Development teams should be able to use their own accounts for testing and deploy new resources in these accounts as needed. Individual developers can treat these resources as extensions of their own development workstation. Using [CDK Pipelines \(p. 282\)](#), the AWS CDK applications can then be deployed via a CI/CD account to testing, integration, and production environments (each isolated in its own AWS Region or account). This is done by merging the developers' code into your organization's canonical repository.



## Coding best practices

This section presents best practices for organizing your AWS CDK code. The following diagram shows the relationship between a team and that team's code repositories, packages, applications, and construct libraries.



## Start simple and add complexity only when you need it

The guiding principle for most of our best practices is to keep things simple as possible—but no simpler. Add complexity only when your requirements dictate a more complicated solution. With the AWS CDK, you can refactor your code as necessary to support new requirements. You don't have to architect for all possible scenarios upfront.

## Align with the AWS Well-Architected Framework

The [AWS Well-Architected](#) Framework defines a *component* as the code, configuration, and AWS resources that together deliver against a requirement. A component is often the unit of technical ownership, and is decoupled from other components. The term *workload* is used to identify a set of components that together deliver business value. A workload is usually the level of detail that business and technology leaders communicate about.

An AWS CDK application maps to a component as defined by the AWS Well-Architected Framework. AWS CDK apps are a mechanism to codify and deliver Well-Architected cloud application best practices. You can also create and share components as reusable code libraries through artifact repositories, such as AWS CodeArtifact.

## Every application starts with a single package in a single repository

A single package is the entry point of your AWS CDK app. Here, you define how and where to deploy the different logical units of your application. You also define the CI/CD pipeline to deploy the application. The app's constructs define the logical units of your solution.

Use additional packages for constructs that you use in more than one application. (Shared constructs should also have their own lifecycle and testing strategy.) Dependencies between packages in the same repository are managed by your repo's build tooling.

Although it's possible, we don't recommend putting multiple applications in the same repository, especially when using automated deployment pipelines. Doing this increases the "blast radius" of changes during deployment. When there are multiple applications in a repository, changes to one application trigger deployment of the others (even if the others haven't changed). Furthermore, a break in one application prevents the other applications from being deployed.

## Move code into repositories based on code lifecycle or team ownership

When packages begin to be used in multiple applications, move them to their own repository. This way, the packages can be referenced by application build systems that use them, and they can also be updated on cadences independent of the application lifecycles. However, at first it might make sense to put all shared constructs in one repository.

Also, move packages to their own repository when different teams are working on them. This helps enforce access control.

To consume packages across repository boundaries, you need a private package repository—similar to NPM, PyPi, or Maven Central, but internal to your organization. You also need a release process that builds, tests, and publishes the package to the private package repository. [CodeArtifact](#) can host packages for most popular programming languages.

Dependencies on packages in the package repository are managed by your language's package manager, such as NPM for TypeScript or JavaScript applications. Your package manager helps to make sure that builds are repeatable. It does this by recording the specific versions of every package that your application depends on. It also lets you upgrade those dependencies in a controlled manner.

Shared packages need a different testing strategy. For a single application, it might be good enough to deploy the application to a testing environment and confirm that it still works. But shared packages must be tested independently of the consuming application, as if they were being released to the public. (Your organization might choose to actually release some shared packages to the public.)

Keep in mind that a construct can be arbitrarily simple or complex. A `Bucket` is a construct, but `CameraShopWebsite` could be a construct, too.

## Infrastructure and runtime code live in the same package

In addition to generating AWS CloudFormation templates for deploying infrastructure, the AWS CDK also bundles runtime assets like Lambda functions and Docker images and deploys them alongside your infrastructure. This makes it possible to combine the code that defines your infrastructure and the code that implements your runtime logic into a single construct. It's a best practice to do this. These two kinds of code don't need to live in separate repositories or even in separate packages.

To evolve the two kinds of code together, you can use a self-contained construct that completely describes a piece of functionality, including its infrastructure and logic. With a self-contained construct, you can test the two kinds of code in isolation, share and reuse the code across projects, and version all the code in sync.

## Construct best practices

This section contains best practices for developing constructs. Constructs are reusable, composable modules that encapsulate resources. They're the building blocks of AWS CDK apps.

## Model with constructs, deploy with stacks

Stacks are the unit of deployment: everything in a stack is deployed together. So when building your application's higher-level logical units from multiple AWS resources, represent each logical unit as a

[Construct](#), not as a [Stack](#). Use stacks only to describe how your constructs should be composed and connected for your various deployment scenarios.

For example, if one of your logical units is a website, the constructs that make it up (such as an Amazon S3 bucket, API Gateway, Lambda functions, or Amazon RDS tables) should be composed into a single high-level construct. Then that construct should be instantiated in one or more stacks for deployment.

By using constructs for building and stacks for deploying, you improve reuse potential of your infrastructure and give yourself more flexibility in how it's deployed.

## Configure with properties and methods, not environment variables

Environment variable lookups inside constructs and stacks are a common anti-pattern. Both constructs and stacks should accept a properties object to allow for full configurability completely in code. Doing otherwise introduces a dependency on the machine that the code will run on, which creates yet more configuration information that you have to track and manage.

In general, environment variable lookups should be limited to the top level of an AWS CDK app. They should also be used to pass in information that's needed for running in a development environment. For more information, see [the section called "Environments" \(p. 114\)](#).

## Unit test your infrastructure

To consistently run a full suite of unit tests at build time in all environments, avoid network lookups during synthesis and model all your production stages in code. (These best practices are covered later.) If any single commit always results in the same generated template, you can trust the unit tests that you write to confirm that the generated templates look the way you expect. For more information, see [Testing constructs \(p. 325\)](#).

## Don't change the logical ID of stateful resources

Changing the logical ID of a resource results in the resource being replaced with a new one at the next deployment. For stateful resources like databases and S3 buckets, or persistent infrastructure like an Amazon VPC, this is seldom what you want. Be careful about any refactoring of your AWS CDK code that could cause the ID to change. Write unit tests that assert that the logical IDs of your stateful resources remain static. The logical ID is derived from the `id` you specify when you instantiate the construct, and the construct's position in the construct tree. For more information, see [the section called "Logical IDs" \(p. 145\)](#).

## Constructs aren't enough for compliance

Many enterprise customers write their own wrappers for L2 constructs (the "curated" constructs that represent individual AWS resources with built-in sane defaults and best practices). These wrappers enforce security best practices such as static encryption and specific IAM policies. For example, you might create a `MyCompanyBucket` that you then use in your applications in place of the usual Amazon S3 Bucket construct. This pattern is useful for surfacing security guidance early in the software development lifecycle, but don't rely on it as the sole means of enforcement.

Instead, use AWS features such as [service control policies](#) and [permission boundaries](#) to enforce your security guardrails at the organization level. Use [the section called "Aspects" \(p. 192\)](#) or tools like [CloudFormation Guard](#) to make assertions about the security properties of infrastructure elements before deployment. Use AWS CDK for what it does best.

Finally, keep in mind that writing your own "L2+" constructs might prevent your developers from taking advantage of AWS CDK packages such as [AWS Solutions Constructs](#) or third-party constructs from



Construct Hub. These packages are typically built on standard AWS CDK constructs and won't be able to use your wrapper constructs.

## Application best practices

In this section we discuss how to write your AWS CDK applications, combining constructs to define how your AWS resources are connected.

### Make decisions at synthesis time

Although AWS CloudFormation lets you make decisions at deployment time (using `Conditions`, `{ Fn::If }`, and `Parameters`), and the AWS CDK gives you some access to these mechanisms, we recommend against using them. The types of values that you can use and the types of operations you can perform on them are limited compared to what's available in a general-purpose programming language.

Instead, try to make all decisions, such as which construct to instantiate, in your AWS CDK application by using your programming language's `if` statements and other features. For example, a common CDK idiom, iterating over a list and instantiating a construct with values from each item in the list, simply isn't possible using AWS CloudFormation expressions.

Treat AWS CloudFormation as an implementation detail that the AWS CDK uses for robust cloud deployments, not as a language target. You're not writing AWS CloudFormation templates in TypeScript or Python, you're writing CDK code that happens to use CloudFormation for deployment.

### Use generated resource names, not physical names

Names are a precious resource. Each name can only be used once. Therefore, if you hardcode a table name or bucket name into your infrastructure and application, you can't deploy that piece of infrastructure twice in the same account. (The name we're talking about here is the name specified by, for example, the `bucketName` property on an Amazon S3 bucket construct.)

What's worse, you can't make changes to the resource that require it to be replaced. If a property can only be set at resource creation, such as the `KeySchema` of an Amazon DynamoDB table, then that property is immutable. Changing this property requires a new resource. However, the new resource must have the same name in order to be a true replacement. But it can't have the same name while the existing resource is still using that name.

A better approach is to specify as few names as possible. If you omit resource names, the AWS CDK will generate them for you in a way that won't cause problems. Suppose you have a table as a resource. You can then pass the generated table name as an environment variable into your AWS Lambda function. In your AWS CDK application, you can reference the table name as `table.tableName`. Alternatively, you can generate a configuration file on your Amazon EC2 instance on startup, or write the actual table name to the AWS Systems Manager Parameter Store so your application can read it from there.

If the place you need it is another AWS CDK stack, that's even more straightforward. Supposing that one stack defines the resource and another stack needs to use it, the following applies:

- If the two stacks are in the same AWS CDK app, pass a reference between the two stacks. For example, save a reference to the resource's construct as an attribute of the defining stack (`this.stack.uploadBucket = myBucket`). Then, pass that attribute to the constructor of the stack that needs the resource.
- When the two stacks are in different AWS CDK apps, use a static `from` method to use an externally defined resource based on its ARN, name, or other attributes. (For example, use `Table.fromArn()` for a DynamoDB table). Use the `CfnOutput` construct to print the ARN or other required value in

the output of `cdk deploy`, or look in the AWS Management Console. Alternatively, the second app can read the CloudFormation template generated by the first app and retrieve that value from the `Outputs` section.

## Define removal policies and log retention

The AWS CDK attempts to keep you from losing data by defaulting to policies that retain everything you create. For example, the default removal policy on resources that contain data (such as Amazon S3 buckets and database tables) is not to delete the resource when it is removed from the stack. Instead, the resource is orphaned from the stack. Similarly, the CDK's default is to retain all logs forever. In production environments, these defaults can quickly result in the storage of large amounts of data that you don't actually need, and a corresponding AWS bill.

Consider carefully what you want these policies to be for each production resource and specify them accordingly. Use [the section called “Aspects” \(p. 192\)](#) to validate the removal and logging policies in your stack.

## Separate your application into multiple stacks as dictated by deployment requirements

There is no hard and fast rule to how many stacks your application needs. You'll usually end up basing the decision on your deployment patterns. Keep in mind the following guidelines:

- It's typically more straightforward to keep as many resources in the same stack as possible, so keep them together unless you know you want them separated.
- Consider keeping stateful resources (like databases) in a separate stack from stateless resources. You can then turn on termination protection on the stateful stack. This way, you can freely destroy or create multiple copies of the stateless stack without risk of data loss.
- Stateful resources are more sensitive to construct renaming—renaming leads to resource replacement. Therefore, don't nest stateful resources inside constructs that are likely to be moved around or renamed (unless the state can be rebuilt if lost, like a cache). This is another good reason to put stateful resources in their own stack.

## Commit `cdk.context.json` to avoid non-deterministic behavior

Determinism is key to successful AWS CDK deployments. An AWS CDK app should have essentially the same result whenever it is deployed to a given environment.

Since your AWS CDK app is written in a general-purpose programming language, it can execute arbitrary code, use arbitrary libraries, and make arbitrary network calls. For example, you could use an AWS SDK to retrieve some information from your AWS account while synthesizing your app. Recognize that doing so will result in additional credential setup requirements, increased latency, and a chance, however small, of failure every time you run `cdk synth`.

Never modify your AWS account or resources during synthesis. Synthesizing an app should not have side effects. Changes to your infrastructure should happen only in the deployment phase, after the AWS CloudFormation template has been generated. This way, if there's a problem, AWS CloudFormation can automatically roll back the change. To make changes that can't be easily made within the AWS CDK framework, use [custom resources](#) to execute arbitrary code at deployment time.

Even strictly read-only calls are not necessarily safe. Consider what happens if the value returned by a network call changes. What part of your infrastructure will that impact? What will happen to already-

deployed resources? Following are two example situations in which a sudden change in values might cause a problem.

- If you provision an Amazon VPC to all available Availability Zones in a specified Region, and the number of AZs is two on deployment day, then your IP space gets split in half. If AWS launches a new Availability Zone the next day, the next deployment after that tries to split your IP space into thirds, requiring all subnets to be recreated. This probably won't be possible because your Amazon EC2 instances are still running, and you'll have to clean this up manually.
- If you query for the latest Amazon Linux machine image and deploy an Amazon EC2 instance, and the next day a new image is released, a subsequent deployment picks up the new AMI and replaces all your instances. This might not be what you expected to happen.

These situations can be pernicious because the AWS-side change might occur after months or years of successful deployments. Suddenly your deployments are failing "for no reason" and you long ago forgot what you did and why.

Fortunately, the AWS CDK includes a mechanism called *context providers* to record a snapshot of non-deterministic values. This allows future synthesis operations to produce exactly the same template as they did when first deployed. The only changes in the new template are the changes that *you* made in your code. When you use a construct's `.fromLookup()` method, the result of the call is cached in `cdk.context.json`. You should commit this to version control along with the rest of your code to make sure that future executions of your CDK app use the same value. The CDK Toolkit includes commands to manage the context cache, so you can refresh specific entries when you need to. For more information, see [the section called "Context" \(p. 185\)](#).

If you need some value (from AWS or elsewhere) for which there is no native CDK context provider, we recommend writing a separate script. The script should retrieve the value and write it to a file, then read that file in your CDK app. Run the script only when you want to refresh the stored value, not as part of your regular build process.

## Let the AWS CDK manage roles and security groups

With the AWS CDK construct library's `grant()` convenience methods, you can create AWS Identity and Access Management roles that grant access to one resource by another using minimally scoped permissions. For example, consider a line like the following:

```
myBucket.grantRead(myLambda)
```

This single line adds a policy to the Lambda function's role (which is also created for you). That role and its policies are more than a dozen lines of CloudFormation that you don't have to write. The AWS CDK grants only the minimal permissions required for the function to read from the bucket.

If you require developers to always use predefined roles that were created by a security team, AWS CDK coding becomes much more complicated. Your teams could lose a lot of flexibility in how they design their applications. A better alternative is to use [service control policies](#) and [permission boundaries](#) to make sure that developers stay within the guardrails.

## Model all production stages in code

In traditional AWS CloudFormation scenarios, your goal is to produce a single artifact that is parameterized so that it can be deployed to various target environments after applying configuration values specific to those environments. In the CDK, you can, and should, build that configuration into your source code. Create a stack for your production environment, and create a separate stack for each of your other stages. Then, put the configuration values for each stack in the code. Use services like [Secrets Manager](#) and [Systems Manager](#) Parameter Store for sensitive values that you don't want to check in to source control, using the names or ARNs of those resources.

When you synthesize your application, the cloud assembly created in the `cdk.out` folder contains a separate template for each environment. Your entire build is deterministic. There are no out-of-band changes to your application, and any given commit always yields the exact same AWS CloudFormation template and accompanying assets. This makes unit testing much more reliable.

## Measure everything

Achieving the goal of full continuous deployment, with no human intervention, requires a high level of automation. That automation is only possible with extensive amounts of monitoring. To measure all aspects of your deployed resources, create metrics, alarms, and dashboards. Don't stop at measuring things like CPU usage and disk space. Also record your business metrics, and use those measurements to automate deployment decisions like rollbacks. Most of the L2 constructs in AWS CDK have convenience methods to help you create metrics, such as the `metricUserErrors()` method on the [dynamodb.Table](#) class.

# API reference

The [API Reference](#) contains information about the AWS Construct Library and other APIs provided by the AWS CDK. Most of the AWS Construct Library is actually contained in a single package called `aws-cdk-lib` in NPM (it has other names for other ecosystems). The CDK API Reference is organized into submodules, one or more for each AWS service.

Each submodule has an overview that includes information about how to use its APIs. For example, the [S3](#) overview demonstrates how to set default encryption on an Amazon S3 bucket.

Separate versions of the API Reference are provided for TypeScript/JavaScript, Python, Java, C#/.NET, and Go.

## Versioning

Version numbers consist of three numeric version parts: *major.minor.patch*, and strictly adhere to the [semantic versioning](#) model. This means that breaking changes to stable APIs are limited to major releases.

Minor and patch releases are backward compatible. The code written in a previous version with the same major version can be upgraded to a newer version within the same major version. It will also continue to build and run, producing the same output.

## AWS CDK Toolkit (CLI) compatibility

The AWS CDK Toolkit (that is, the `cdk` command line command) is *always* compatible with construct libraries of a semantically *lower* or *equal* version number. It is, therefore, always safe to upgrade the AWS CDK Toolkit within the same major version.

The AWS CDK Toolkit might be, but is *not always*, compatible with construct libraries of a semantically *higher* version. This depends on whether the same cloud assembly schema version is employed by the two components. The AWS CDK framework generates a cloud assembly during synthesis; the AWS CDK Toolkit consumes it for deployment. The schema that defines the format of the cloud assembly is strictly specified and versioned. AWS construct libraries using a given cloud assembly schema version are compatible with AWS CDK toolkit versions using that schema version or later. This might include releases of the AWS CDK Toolkit that are *earlier than* a given construct library release.

When the cloud assembly version required by the construct library is not compatible with the version supported by the AWS CDK Toolkit, you receive an error message like this one.

```
Cloud assembly schema version mismatch: Maximum schema version supported is 3.0.0, but
found 4.0.0.
Please upgrade your CLI in order to interact with this app.
```

To resolve this error, update the AWS CDK Toolkit to a version compatible with the required cloud assembly version, or to the latest available version. The alternative (downgrading the construct library modules your app uses) is generally not desirable.

### Note

For more details on the cloud assembly schema, see [Cloud Assembly Versioning](#).

## AWS Construct Library versioning

The modules in the AWS Construct Library move through various stages as they are developed from concept to mature API. Different stages imply different promises for API stability in subsequent versions of the AWS CDK.

APIs in the main AWS CDK library, `aws-cdk-lib`, are stable, and the library is fully semantically versioned. This package includes AWS CloudFormation (L1) constructs for all AWS services and all stable higher-level (L2 and L3) modules. (It also includes the core CDK classes like `App` and `Stack`.) No APIs will be removed from this package (though they may be deprecated) until the next major release of the CDK. No individual API will ever have breaking changes; if a breaking change is required, an entirely new API will be added.

New APIs under development for a service already incorporated in `aws-cdk-lib` are identified using a `BetaN` suffix, where `N` starts at 1 and is incremented with each breaking change to the new API. `BetaN` APIs are never removed, only deprecated, so your existing app continues to work with newer versions of `aws-cdk-lib`. When the API is deemed stable, a new API without the `BetaN` suffix is added.

When higher-level (L2 or L3) APIs begin to be developed for an AWS service that previously had only L1 APIs, those APIs are initially distributed in a separate package. The name of such a package has an "Alpha" suffix, and its version matches the first version of `aws-cdk-lib` it is compatible with, with an alpha sub-version. When the module supports the intended use cases, its APIs are added to `aws-cdk-lib`.

## Language binding stability

From time to time, we might add support to the AWS CDK for additional programming languages. Although the API described in all the languages is the same, the way that API is expressed varies by language and might change as the language support evolves. For this reason, language bindings are deemed experimental for a time until they are considered ready for production use.

Language	Stability
TypeScript	Stable
JavaScript	Stable
Python	Stable
Java	Stable
C#/.NET	Stable
Go	Stable

# Examples

This topic contains the following examples:

- [Creating a serverless application using the AWS CDK \(p. 231\)](#) Creates a serverless application using Lambda, API Gateway, and Amazon S3.
- [Creating an AWS Fargate service using the AWS CDK \(p. 244\)](#) Creates an Amazon ECS Fargate service from an image on DockerHub.

## Creating a serverless application using the AWS CDK

This example walks you through creating the resources for a simple widget dispensing service. (For the purpose of this example, a widget is just a name or identifier that can be added to, retrieved from, and deleted from a collection.) The example includes:

- An AWS Lambda function.
- An Amazon API Gateway API to call the Lambda function.
- An Amazon S3 bucket that holds the widgets.

This tutorial contains the following steps.

1. Create an AWS CDK app
2. Create a Lambda function that gets a list of widgets with **HTTP GET /**
3. Create the service that calls the Lambda function
4. Add the service to the AWS CDK app
5. Test the app
6. Add Lambda functions to do the following:
  - Create a widget with **POST /{name}**
  - Get a widget by name with **GET /{name}**
  - Delete a widget by name with **DELETE /{name}**
7. Tear everything down when you're finished

## Create an AWS CDK app

Create the app **MyWidgetService** in the current folder.

TypeScript

```
mkdir MyWidgetService
cd MyWidgetService
cdk init --language typescript
```

JavaScript

```
mkdir MyWidgetService
cd MyWidgetService
```

```
cdk init --language javascript
```

### Python

```
mkdir MyWidgetService
cd MyWidgetService
cdk init --language python
source .venv/bin/activate
pip install -r requirements.txt
```

### Java

```
mkdir MyWidgetService
cd MyWidgetService
cdk init --language java
```

You may now import the Maven project into your IDE.

### C#

```
mkdir MyWidgetService
cd MyWidgetService
cdk init --language csharp
```

You may now open `src/MyWidgetService.sln` in Visual Studio.

### Note

The CDK names source files and classes based on the name of the project directory. If you don't use the name `MyWidgetService` as shown previously, it might be difficult to follow the rest of the steps. Some of the files that the instructions tell you to modify won't be there, because they will have different names.

The important files in the blank project are as follows. (We will also be adding a couple of new files.)

### TypeScript

- `bin/my_widget_service.ts` – Main entry point for the application
- `lib/my_widget_service-stack.ts` – Defines the widget service stack

### JavaScript

- `bin/my_widget_service.js` – Main entry point for the application
- `lib/my_widget_service-stack.js` – Defines the widget service stack

### Python

- `app.py` – Main entry point for the application
- `my_widget_service/my_widget_service_stack.py` – Defines the widget service stack

### Java

- `src/main/java/com/myorg/MyWidgetServiceApp.java` – Main entry point for the application
- `src/main/java/com/myorg/MyWidgetServiceStack.java` – Defines the widget service stack



## C#

- `src/MyWidgetService/Program.cs` – Main entry point for the application
- `src/MyWidgetService/MyWidgetServiceStack.cs` – Defines the widget service stack

Run the app and note that it synthesizes an empty stack.

```
cdk synth
```

You should see output beginning with YAML code like the following.

```
Resources:
  CDKMetadata:
    Type: AWS::CDK::Metadata
    Properties:
      ...
```

## Create a Lambda function to list all widgets

The next step is to create a Lambda function to list all of the widgets in our Amazon S3 bucket. We will provide the Lambda function's code in JavaScript.

Create the `resources` directory in the project's main directory.

```
mkdir resources
```

Create the following JavaScript file, `widgets.js`, in the `resources` directory.

```
import { S3Client, ListObjectsCommand } from "@aws-sdk/client-s3";

// The following code uses the AWS SDK for JavaScript (v3).
// For more information, see https://docs.aws.amazon.com/AWSJavaScriptSDK/v3/latest/index.html.
const s3Client = new S3Client({});

/**
 * @param {string} bucketName
 */
const listObjectNames = async (bucketName) => {
  const command = new ListObjectsCommand({ Bucket: bucketName });
  const { Contents } = await s3Client.send(command);

  if (!Contents.length) {
    const err = new Error(`No objects found in ${bucketName}`);
    err.name = "EmptyBucketError";
    throw err;
  }

  // Map the response to a list of strings representing the keys of the Amazon Simple
  // Storage Service (Amazon S3) objects.
  // Filter out any objects that don't have keys.
  return Contents.map(({ Key }) => Key).filter((k) => !!k);
};

/**
 * @typedef {{ httpMethod: 'GET' | 'POST' | 'PUT' | 'DELETE' | 'PATCH', path: string }}
  LambdaEvent
 */
```

```
/**
 *
 * @param {LambdaEvent} lambdaEvent
 */
const routeRequest = (lambdaEvent) => {
  if (lambdaEvent.httpMethod === "GET" && lambdaEvent.path === "/") {
    return handleGetRequest();
  }

  const error = new Error(
    `Unimplemented HTTP method: ${lambdaEvent.httpMethod}`
  );
  error.name = "UnimplementedHTTPMethodError";
  throw error;
};

const handleGetRequest = async () => {
  if (process.env.BUCKET === "undefined") {
    const err = new Error(`No bucket name provided.`);
    err.name = "MissingBucketName";
    throw err;
  }

  const objects = await listObjectNames(process.env.BUCKET);
  return buildResponseBody(200, objects);
};

/**
 * @typedef {{statusCode: number, body: string, headers: Record<string, string> }}
 * LambdaResponse
 */

/**
 *
 * @param {number} status
 * @param {Record<string, string>} headers
 * @param {Record<string, unknown>} body
 *
 * @returns {LambdaResponse}
 */
const buildResponseBody = (status, body, headers = {}) => {
  return {
    statusCode: status,
    headers,
    body,
  };
};

/**
 *
 * @param {LambdaEvent} event
 */
export const handler = async (event) => {
  try {
    return await routeRequest(event);
  } catch (err) {
    console.error(err);

    if (err.name === "MissingBucketName") {
      return buildResponseBody(400, err.message);
    }

    if (err.name === "EmptyBucketError") {
      return buildResponseBody(204, []);
    }
  }
}
```

```
    if (err.name === "UnimplementedHTTPMethodError") {  
      return buildResponseBody(400, err.message);  
    }  
  
    return buildResponseBody(500, err.message || "Unknown server error");  
  }  
};
```

Save it and be sure the project still results in an empty stack. We haven't yet wired the Lambda function to the AWS CDK app, so the Lambda asset doesn't appear in the output.

```
cdk synth
```

## Create a widget service

Create a new source file to define the widget service with the source code shown below.

TypeScript

File: lib/widget\_service.ts

```
import * as cdk from "aws-cdk-lib";  
import { Construct } from "constructs";  
import * as apigateway from "aws-cdk-lib/aws-apigateway";  
import * as lambda from "aws-cdk-lib/aws-lambda";  
import * as s3 from "aws-cdk-lib/aws-s3";  
  
export class WidgetService extends Construct {  
  constructor(scope: Construct, id: string) {  
    super(scope, id);  
  
    const bucket = new s3.Bucket(this, "WidgetStore");  
  
    const handler = new lambda.Function(this, "WidgetHandler", {  
      runtime: lambda.Runtime.NODEJS_18_X,  
      code: lambda.Code.fromAsset("resources"),  
      handler: "widgets.main",  
      environment: {  
        BUCKET: bucket.bucketName  
      }  
    });  
  
    bucket.grantReadWrite(handler);  
  
    const api = new apigateway.RestApi(this, "widgets-api", {  
      restApiName: "Widget Service",  
      description: "This service serves widgets."  
    });  
  
    const getWidgetsIntegration = new apigateway.LambdaIntegration(handler, {  
      requestTemplates: { "application/json": '{ "statusCode": "200" }' }  
    });  
  
    api.root.addMethod("GET", getWidgetsIntegration); // GET /  
  }  
}
```

JavaScript

File: lib/widget\_service.js

```
const cdk = require("aws-cdk-lib");
```

```
const { Construct } = require("constructs");
const apigateway = require("aws-cdk-lib/aws-apigateway");
const lambda = require("aws-cdk-lib/aws-lambda");
const s3 = require("aws-cdk-lib/aws-s3");

class WidgetService extends Construct {
  constructor(scope, id) {
    super(scope, id);

    const bucket = new s3.Bucket(this, "WidgetStore");

    const handler = new lambda.Function(this, "WidgetHandler", {
      runtime: lambda.Runtime.NODEJS_18_X,
      code: lambda.Code.fromAsset("resources"),
      handler: "widgets.main",
      environment: {
        BUCKET: bucket.bucketName
      }
    });

    bucket.grantReadWrite(handler); // was: handler.role);

    const api = new apigateway.RestApi(this, "widgets-api", {
      restApiName: "Widget Service",
      description: "This service serves widgets."
    });

    const getWidgetsIntegration = new apigateway.LambdaIntegration(handler, {
      requestTemplates: { "application/json": '{ "statusCode": "200" }' }
    });

    api.root.addMethod("GET", getWidgetsIntegration); // GET /
  }
}

module.exports = { WidgetService }
```

## Python

File: my\_widget\_service/widget\_service.py

```
import aws_cdk as cdk
from constructs import Construct
from aws_cdk import (aws_apigateway as apigateway,
                     aws_s3 as s3,
                     aws_lambda as lambda_)

class WidgetService(Construct):
    def __init__(self, scope: Construct, id: str):
        super().__init__(scope, id)

        bucket = s3.Bucket(self, "WidgetStore")

        handler = lambda_.Function(self, "WidgetHandler",
                                   runtime=lambda_.Runtime.NODEJS_18_X,
                                   code=lambda_.Code.from_asset("resources"),
                                   handler="widgets.main",
                                   environment=dict(
                                       BUCKET=bucket.bucket_name
                                   )
        )

        bucket.grant_read_write(handler)

        api = apigateway.RestApi(self, "widgets-api",
                                  rest_api_name="Widget Service",
```

```
description="This service serves widgets.")

get_widgets_integration = apigateway.LambdaIntegration(handler,
    request_templates={"application/json": '{ "statusCode": "200" }'})

api.root.add_method("GET", get_widgets_integration) # GET /
```

## Java

File: src/src/main/java/com/myorg/WidgetService.java

```
package com.myorg;

import java.util.HashMap;

import software.constructs.Construct;
import software.amazon.awscdk.services.apigateway.LambdaIntegration;
import software.amazon.awscdk.services.apigateway.Resource;
import software.amazon.awscdk.services.apigateway.RestApi;
import software.amazon.awscdk.services.lambda.Code;
import software.amazon.awscdk.services.lambda.Function;
import software.amazon.awscdk.services.lambda.Runtime;
import software.amazon.awscdk.services.s3.Bucket;

public class WidgetService extends Construct {

    @SuppressWarnings("serial")
    public WidgetService(Construct scope, String id) {
        super(scope, id);

        Bucket bucket = new Bucket(this, "WidgetStore");

        Function handler = Function.Builder.create(this, "WidgetHandler")
            .runtime(Runtime.NODEJS_18_X)
            .code(Code.fromAsset("resources"))
            .handler("widgets.main")
            .environment(java.util.Map.of( // Java 9 or later
                "BUCKET", bucket.getBucketName()))
            .build();

        bucket.grantReadWrite(handler);

        RestApi api = RestApi.Builder.create(this, "Widgets-API")
            .restApiName("Widget Service").description("This service services
widgets.")
            .build();

        LambdaIntegration getWidgetsIntegration =
LambdaIntegration.Builder.create(handler)
            .requestTemplates(java.util.Map.of( // Map.of is Java 9 or later
                "application/json", "{ \"statusCode\": \"200\" }"))
            .build();

        api.getRoot().addMethod("GET", getWidgetsIntegration);
    }
}
```

## C#

File: src/MyWidgetService/WidgetService.cs

```
using Amazon.CDK;
using Amazon.CDK.AWS.APIGateway;
using Amazon.CDK.AWS.Lambda;
```

```
using Amazon.CDK.AWS.S3;
using System.Collections.Generic;
using constructs;

namespace MyWidgetService
{
    public class WidgetService : Construct
    {
        public WidgetService(Construct scope, string id) : base(scope, id)
        {
            var bucket = new Bucket(this, "WidgetStore");

            var handler = new Function(this, "WidgetHandler", new FunctionProps
            {
                Runtime = Runtime.NODEJS_18_X,
                Code = Code.FromAsset("resources"),
                Handler = "widgets.main",
                Environment = new Dictionary<string, string>
                {
                    ["BUCKET"] = bucket.BucketName
                }
            });

            bucket.GrantReadWrite(handler);

            var api = new RestApi(this, "Widgets-API", new RestApiProps
            {
                RestApiName = "Widget Service",
                Description = "This service services widgets."
            });

            var getWidgetsIntegration = new LambdaIntegration(handler, new
            LambdaIntegrationOptions
            {
                RequestTemplates = new Dictionary<string, string>
                {
                    ["application/json"] = "{ \"statusCode\": \"200\" }"
                }
            });

            api.Root.AddMethod("GET", getWidgetsIntegration);
        }
    }
}
```

### Tip

We're using a [lambda.Function](#) in to deploy this function because it supports a wide variety of programming languages. For JavaScript and TypeScript specifically, you might consider a [lambda-nodejs.NodejsFunction](#). The latter uses **esbuild** to bundle up the script and converts code written in TypeScript automatically.

Save the app and make sure it still synthesizes an empty stack.

```
cdk synth
```

## Add the service to the app

To add the widget service to our AWS CDK app, we'll need to modify the source file that defines the stack to instantiate the service construct.

## TypeScript

File: `lib/my_widget_service-stack.ts`

Add the following line of code after the existing `import` statement.

```
import * as widget_service from '../lib/widget_service';
```

Replace the comment in the constructor with the following line of code.

```
new widget_service.WidgetService(this, 'Widgets');
```

## JavaScript

File: `lib/my_widget_service-stack.js`

Add the following line of code after the existing `require()` line.

```
const widget_service = require('../lib/widget_service');
```

Replace the comment in the constructor with the following line of code.

```
new widget_service.WidgetService(this, 'Widgets');
```

## Python

File: `my_widget_service/my_widget_service_stack.py`

Add the following line of code after the existing `import` statement.

```
from . import widget_service
```

Replace the comment in the constructor with the following line of code.

```
widget_service.WidgetService(self, "Widgets")
```

## Java

File: `src/src/main/java/com/myorg/MyWidgetServiceStack.java`

Replace the comment in the constructor with the following line of code.

```
new WidgetService(this, "Widgets");
```

## C#

File: `src/MyWidgetService/MyWidgetServiceStack.cs`

Replace the comment in the constructor with the following line of code.

```
new WidgetService(this, "Widgets");
```

Be sure the app runs and synthesizes a stack (we won't show the stack here: it's over 250 lines).

```
cdk synth
```

## Deploy and test the app

Before you can deploy your first AWS CDK app, you must bootstrap your AWS environment. Among other resources, this creates a staging bucket that the AWS CDK uses to deploy stacks containing assets. For details, see [the section called “Bootstrapping your AWS environment” \(p. 315\)](#). If you've already bootstrapped, you'll get a warning and nothing will change.

```
cdk bootstrap aws://ACCOUNT-NUMBER/REGION
```

Now we're ready to deploy the app as follows.

```
cdk deploy
```

If the deployment succeeds, save the URL for your server. This URL appears in one of the last lines in the window, where **GUID** is an alphanumeric GUID and **REGION** is your AWS Region.

```
https://GUID.execute-api-REGION.amazonaws.com/prod/
```

Test your app by getting the list of widgets (currently empty) by navigating to this URL in a browser, or use the following command.

```
curl -X GET 'https://GUID.execute-api-REGION.amazonaws.com/prod'
```

You can also test the app by completing the following steps:

1. Open the AWS Management Console.
2. Navigate to the API Gateway service.
3. Find **Widget Service** in the list.
4. Select **GET** and **Test** to test the function.

Because we haven't stored any widgets yet, the output should be similar to the following.

```
{ "widgets": [] }
```

## Add the individual widget functions

The next step is to create Lambda functions to create, show, and delete individual widgets.

Replace the code in `widgets.js` (in `resources`) with the following.

```
import {
  S3Client,
  ListObjectsV2Command,
  GetObjectCommand,
  PutObjectCommand,
  DeleteObjectCommand
} from '@aws-sdk/client-s3';

// In the following code we are using AWS JS SDK v3
```



```
// See https://docs.aws.amazon.com/AWSJavaScriptSDK/v3/latest/index.html
const S3 = new S3Client({});
const bucketName = process.env.BUCKET;

exports.main = async function(event, context) {
  try {
    const method = event.httpMethod;
    // Get name, if present
    const widgetName = event.path.startsWith('/') ? event.path.substring(1) : event.path;

    if (method === "GET") {
      // GET / to get the names of all widgets
      if (event.path === "/" ) {
        const data = await S3.send(new ListObjectsV2Command({ Bucket: bucketName }));
        const body = {
          widgets: data.Contents.map(function(e) { return e.Key })
        };
        return {
          statusCode: 200,
          headers: {},
          body: JSON.stringify(body)
        };
      }

      if (widgetName) {
        // GET /name to get info on widget name
        const data = await S3.send(new GetObjectCommand({ Bucket: bucketName, Key:
widgetName}));
        const body = data.Body.toString('utf-8');

        return {
          statusCode: 200,
          headers: {},
          body: JSON.stringify(body)
        };
      }
    }

    if (method === "POST") {
      // POST /name
      // Return error if we do not have a name
      if (!widgetName) {
        return {
          statusCode: 400,
          headers: {},
          body: "Widget name missing"
        };
      }

      // Create some dummy data to populate object
      const now = new Date();
      const data = widgetName + " created: " + now;

      const base64data = Buffer.from(data, 'binary');

      await S3.send(new PutObjectCommand({
        Bucket: bucketName,
        Key: widgetName,
        Body: base64data,
        ContentType: 'application/json'
      }));

      return {
        statusCode: 200,
        headers: {},
        body: data
      }
    }
  }
}
```

```
    };  
  }  
  
  if (method === "DELETE") {  
    // DELETE /name  
    // Return an error if we do not have a name  
    if (!widgetName) {  
      return {  
        statusCode: 400,  
        headers: {},  
        body: "Widget name missing"  
      };  
    }  
  
    await S3.send(new DeleteObjectCommand({  
      Bucket: bucketName, Key: widgetName  
    }));  
  
    return {  
      statusCode: 200,  
      headers: {},  
      body: "Successfully deleted widget " + widgetName  
    };  
  }  
  
  // We got something besides a GET, POST, or DELETE  
  return {  
    statusCode: 400,  
    headers: {},  
    body: "We only accept GET, POST, and DELETE, not " + method  
  };  
} catch(error) {  
  var body = error.stack || JSON.stringify(error, null, 2);  
  return {  
    statusCode: 400,  
    headers: {},  
    body: body  
  }  
}  
}
```

Wire up these functions to your API Gateway code at the end of the `WidgetService` constructor.

#### TypeScript

File: `lib/widget_service.ts`

```
const widget = api.root.addResource("{id}");  
  
const widgetIntegration = new apigateway.LambdaIntegration(handler);  
  
widget.addMethod("POST", widgetIntegration); // POST /{id}  
widget.addMethod("GET", widgetIntegration); // GET /{id}  
widget.addMethod("DELETE", widgetIntegration); // DELETE /{id}
```

#### JavaScript

File: `lib/widget_service.js`

```
const widget = api.root.addResource("{id}");  
  
const widgetIntegration = new apigateway.LambdaIntegration(handler);
```

```
widget.addMethod("POST", widgetIntegration); // POST /{id}
widget.addMethod("GET", widgetIntegration); // GET /{id}
widget.addMethod("DELETE", widgetIntegration); // DELETE /{id}
```

## Python

File: my\_widget\_service/widget\_service.py

```
widget = api.root.add_resource("/{id}")

widget_integration = apigateway.LambdaIntegration(handler)

widget.add_method("POST", widget_integration); # POST /{id}
widget.add_method("GET", widget_integration); # GET /{id}
widget.add_method("DELETE", widget_integration); # DELETE /{id}
```

## Java

File: src/src/main/java/com/myorg/WidgetService.java

```
Resource widget = api.getRoot().addResource("/{id}");

LambdaIntegration widgetIntegration = new LambdaIntegration(handler);

widget.addMethod("POST", widgetIntegration); // POST /{id}
widget.addMethod("GET", widgetIntegration); // GET /{id}
widget.addMethod("DELETE", widgetIntegration); // DELETE /{id}
```

## C#

File: src/MyWidgetService/WidgetService.cs

```
var widget = api.Root.AddResource("/{id}");

var widgetIntegration = new LambdaIntegration(handler);

widget.AddMethod("POST", widgetIntegration); // POST /{id}
widget.AddMethod("GET", widgetIntegration); // GET /{id}
widget.AdMethod("DELETE", widgetIntegration); // DELETE /{id}
```

Save and deploy the app.

```
cdk deploy
```

We can now store, show, or delete an individual widget. Use the following commands to list the widgets, create the widget **example**, list all of the widgets, show the contents of **example** (it should show today's date), delete **example**, and then show the list of widgets again.

```
curl -X GET 'https://GUID.execute-api.REGION.amazonaws.com/prod'
curl -X POST 'https://GUID.execute-api.REGION.amazonaws.com/prod/example'
curl -X GET 'https://GUID.execute-api.REGION.amazonaws.com/prod'
curl -X GET 'https://GUID.execute-api.REGION.amazonaws.com/prod/example'
curl -X DELETE 'https://GUID.execute-api.REGION.amazonaws.com/prod/example'
curl -X GET 'https://GUID.execute-api.REGION.amazonaws.com/prod'
```

You can also use the API Gateway console to test these functions. Set the **name** value to the name of a widget, such as **example**.

## Clean up

To avoid unexpected AWS charges, destroy your AWS CDK stack after you're done with this exercise.

```
cdk destroy
```

# Creating an AWS Fargate service using the AWS CDK

This example walks you through how to create an AWS Fargate service running on an Amazon Elastic Container Service (Amazon ECS) cluster that's fronted by an internet-facing Application Load Balancer from an image on Amazon ECR.

Amazon ECS is a highly scalable, fast, container management service that makes it easy to run, stop, and manage Docker containers on a cluster. You can host your cluster on a serverless infrastructure that's managed by Amazon ECS by launching your services or tasks using the Fargate launch type. For more control, you can host your tasks on a cluster of Amazon Elastic Compute Cloud (Amazon EC2) instances that you manage by using the Amazon EC2 launch type.

This tutorial shows you how to launch some services using the Fargate launch type. If you've used the AWS Management Console to create a Fargate service, you know that there are many steps to follow to accomplish that task. AWS has several tutorials and documentation topics that walk you through creating a Fargate service, including:

- [How to Deploy Docker Containers - AWS](#)
- [Setting Up with Amazon ECS](#)
- [Getting Started with Amazon ECS Using Fargate](#)

This example creates a similar Fargate service in AWS CDK code.

The Amazon ECS construct used in this tutorial helps you use AWS services by providing the following benefits:

- Automatically configures a load balancer.
- Automatically opens a security group for load balancers. This enables load balancers to communicate with instances without you explicitly creating a security group.
- Automatically orders dependency between the service and the load balancer attaching to a target group, where the AWS CDK enforces the correct order of creating the listener before an instance is created.
- Automatically configures user data on automatically scaling groups. This creates the correct configuration to associate a cluster to AMIs.
- Validates parameter combinations early. This exposes AWS CloudFormation issues earlier, thus saving you deployment time. For example, depending on the task, it's easy to misconfigure the memory settings. Previously, you would not encounter an error until you deployed your app. But now the AWS CDK can detect a misconfiguration and emit an error when you synthesize your app.
- Automatically adds permissions for Amazon Elastic Container Registry (Amazon ECR) if you use an image from Amazon ECR.
- Automatically scales. The AWS CDK supplies a method so you can autoscaling instances when you use an Amazon EC2 cluster. This happens automatically when you use an instance in a Fargate cluster.

In addition, the AWS CDK prevents an instance from being deleted when automatic scaling tries to kill an instance, but either a task is running or is scheduled on that instance.

Previously, you had to create a Lambda function to have this functionality.

- Provides asset support, so that you can deploy a source from your machine to Amazon ECS in one step. Previously, to use an application source you had to perform several manual steps, such as uploading to Amazon ECR and creating a Docker image.

See [ECS](#) for details.

### Important

The `ApplicationLoadBalancedFargateService` constructs we'll be using includes numerous AWS components, some of which have non-trivial costs if left provisioned in your AWS account, even if you don't use them. Be sure to clean up (**cdk destroy**) after completing this example.

## Creating the directory and initializing the AWS CDK

Let's start by creating a directory to hold the AWS CDK code, and then creating a AWS CDK app in that directory.

### TypeScript

```
mkdir MyEcsConstruct
cd MyEcsConstruct
cdk init --language typescript
```

### JavaScript

```
mkdir MyEcsConstruct
cd MyEcsConstruct
cdk init --language javascript
```

### Python

```
mkdir MyEcsConstruct
cd MyEcsConstruct
cdk init --language python
source .venv/bin/activate
pip install -r requirements.txt
```

### Java

```
mkdir MyEcsConstruct
cd MyEcsConstruct
cdk init --language java
```

You may now import the Maven project into your IDE.

### C#

```
mkdir MyEcsConstruct
cd MyEcsConstruct
cdk init --language csharp
```

You may now open `src/MyEcsConstruct.sln` in Visual Studio.

Run the app and confirm that it creates an empty stack.

```
cdk synth
```

## Create a Fargate service

There are two different ways to run your container tasks with Amazon ECS:

- Use the Fargate launch type, where Amazon ECS manages the physical machines that your containers are running on for you.
- Use the EC2 launch type, where you do the managing, such as specifying automatic scaling.

For this example, we'll create a Fargate service running on an ECS cluster fronted by an internet-facing Application Load Balancer.

Add the following AWS Construct Library module imports to the indicated file.

TypeScript

File: lib/my\_ecs\_construct-stack.ts

```
import * as ec2 from "aws-cdk-lib/aws-ec2";
import * as ecs from "aws-cdk-lib/aws-ecs";
import * as ecs_patterns from "aws-cdk-lib/aws-ecs-patterns";
```

JavaScript

File: lib/my\_ecs\_construct-stack.js

```
const ec2 = require("aws-cdk-lib/aws-ec2");
const ecs = require("aws-cdk-lib/aws-ecs");
const ecs_patterns = require("aws-cdk-lib/aws-ecs-patterns");
```

Python

File: my\_ecs\_construct/my\_ecs\_construct\_stack.py

```
from aws_cdk import (aws_ec2 as ec2, aws_ecs as ecs,
                     aws_ecs_patterns as ecs_patterns)
```

Java

File: src/main/java/com/myorg/MyEcsConstructStack.java

```
import software.amazon.awscdk.services.ec2.*;
import software.amazon.awscdk.services.ecs.*;
import software.amazon.awscdk.services.ecs.patterns.*;
```

C#

File: src/MyEcsConstruct/MyEcsConstructStack.cs

```
using Amazon.CDK.AWS.EC2;
using Amazon.CDK.AWS.ECS;
using Amazon.CDK.AWS.ECS.Patterns;
```

Replace the comment at the end of the constructor with the following code.

#### TypeScript

```
const vpc = new ec2.Vpc(this, "MyVpc", {
  maxAzs: 3 // Default is all AZs in region
});

const cluster = new ecs.Cluster(this, "MyCluster", {
  vpc: vpc
});

// Create a load-balanced Fargate service and make it public
new ecs_patterns.ApplicationLoadBalancedFargateService(this, "MyFargateService", {
  cluster: cluster, // Required
  cpu: 512, // Default is 256
  desiredCount: 6, // Default is 1
  taskImageOptions: { image: ecs.ContainerImage.fromRegistry("amazon/amazon-ecs-sample") },
  memoryLimitMiB: 2048, // Default is 512
  publicLoadBalancer: true // Default is true
});
```

#### JavaScript

```
const vpc = new ec2.Vpc(this, "MyVpc", {
  maxAzs: 3 // Default is all AZs in region
});

const cluster = new ecs.Cluster(this, "MyCluster", {
  vpc: vpc
});

// Create a load-balanced Fargate service and make it public
new ecs_patterns.ApplicationLoadBalancedFargateService(this, "MyFargateService", {
  cluster: cluster, // Required
  cpu: 512, // Default is 256
  desiredCount: 6, // Default is 1
  taskImageOptions: { image: ecs.ContainerImage.fromRegistry("amazon/amazon-ecs-sample") },
  memoryLimitMiB: 2048, // Default is 512
  publicLoadBalancer: true // Default is true
});
```

#### Python

```
vpc = ec2.Vpc(self, "MyVpc", max_azs=3) # default is all AZs in region

cluster = ecs.Cluster(self, "MyCluster", vpc=vpc)

ecs_patterns.ApplicationLoadBalancedFargateService(self, "MyFargateService",
  cluster=cluster, # Required
  cpu=512, # Default is 256
  desired_count=6, # Default is 1
  task_image_options=ecs_patterns.ApplicationLoadBalancedTaskImageOptions(
    image=ecs.ContainerImage.from_registry("amazon/amazon-ecs-sample")),
  memory_limit_mib=2048, # Default is 512
  public_load_balancer=True) # Default is True
```

#### Java

```
Vpc vpc = Vpc.Builder.create(this, "MyVpc")
```

```
        .maxAzs(3) // Default is all AZs in region
        .build();

Cluster cluster = Cluster.Builder.create(this, "MyCluster")
    .vpc(vpc).build();

// Create a load-balanced Fargate service and make it public
ApplicationLoadBalancedFargateService.Builder.create(this, "MyFargateService")
    .cluster(cluster) // Required
    .cpu(512) // Default is 256
    .desiredCount(6) // Default is 1
    .taskImageOptions(
        ApplicationLoadBalancedTaskImageOptions.builder()
            .image(ContainerImage.fromRegistry("amazon/amazon-ecs-sample"))
            .build())
    .memoryLimitMiB(2048) // Default is 512
    .publicLoadBalancer(true) // Default is true
    .build();
```

## C#

```
var vpc = new Vpc(this, "MyVpc", new VpcProps
{
    MaxAzs = 3 // Default is all AZs in region
});

var cluster = new Cluster(this, "MyCluster", new ClusterProps
{
    Vpc = vpc
});

// Create a load-balanced Fargate service and make it public
new ApplicationLoadBalancedFargateService(this, "MyFargateService",
    new ApplicationLoadBalancedFargateServiceProps
    {
        Cluster = cluster, // Required
        DesiredCount = 6, // Default is 1
        TaskImageOptions = new ApplicationLoadBalancedTaskImageOptions
        {
            Image = ContainerImage.FromRegistry("amazon/amazon-ecs-sample")
        },
        MemoryLimitMiB = 2048, // Default is 256
        PublicLoadBalancer = true // Default is true
    }
);
```

Save it and make sure it runs and creates a stack.

```
cdk synth
```

The stack is hundreds of lines, so we won't show it here. The stack should contain one default instance, a private subnet and a public subnet for the three Availability Zones, and a security group.

Deploy the stack.

```
cdk deploy
```

AWS CloudFormation displays information about the dozens of steps that it takes as it deploys your app. That's how easy it is to create a Fargate-powered Amazon ECS service to run a Docker image.



## Clean up

To avoid unexpected AWS charges, destroy your AWS CDK stack after you're done with this exercise.

```
cdk destroy
```

## AWS CDK examples

For more examples of AWS CDK stacks and apps in your favorite supported programming language, see the [AWS CDK Examples](#) repository on GitHub.

# AWS CDK how-tos

This section contains short code examples that show you how to accomplish a task using the AWS CDK.

## Topics

- [Get a value from an environment variable \(p. 250\)](#)
- [Use an AWS CloudFormation value \(p. 251\)](#)
- [Import or migrate an existing AWS CloudFormation template \(p. 251\)](#)
- [Using resources from the AWS CloudFormation Public Registry \(p. 261\)](#)
- [Get a value from the Systems Manager Parameter Store \(p. 264\)](#)
- [Get a value from AWS Secrets Manager \(p. 267\)](#)
- [Create an app with multiple stacks \(p. 269\)](#)
- [Set a CloudWatch alarm \(p. 278\)](#)
- [Get a value from a context variable \(p. 281\)](#)
- [Continuous integration and delivery \(CI/CD\) using CDK Pipelines \(p. 282\)](#)
- [AWS CDK policy validation at synthesis time \(p. 305\)](#)

## Get a value from an environment variable

To get the value of an environment variable, use code like the following. This code gets the value of the environment variable MYBUCKET.

### TypeScript

```
// Sets bucket_name to undefined if environment variable not set
var bucket_name = process.env.MYBUCKET;

// Sets bucket_name to a default if env var doesn't exist
var bucket_name = process.env.MYBUCKET || "DefaultName";
```

### JavaScript

```
// Sets bucket_name to undefined if environment variable not set
var bucket_name = process.env.MYBUCKET;

// Sets bucket_name to a default if env var doesn't exist
var bucket_name = process.env.MYBUCKET || "DefaultName";
```

### Python

```
import os

# Raises KeyError if environment variable doesn't exist
bucket_name = os.environ["MYBUCKET"]

# Sets bucket_name to None if environment variable doesn't exist
bucket_name = os.getenv("MYBUCKET")

# Sets bucket_name to a default if env var doesn't exist
```

```
bucket_name = os.getenv("MYBUCKET", "DefaultName")
```

#### Java

```
// Sets bucketName to null if environment variable doesn't exist
String bucketName = System.getenv("MYBUCKET");

// Sets bucketName to a default if env var doesn't exist
String bucketName = System.getenv("MYBUCKET");
if (bucketName == null) bucketName = "DefaultName";
```

#### C#

```
using System;

// Sets bucket name to null if environment variable doesn't exist
string bucketName = Environment.GetEnvironmentVariable("MYBUCKET");

// Sets bucket_name to a default if env var doesn't exist
string bucketName = Environment.GetEnvironmentVariable("MYBUCKET") ?? "DefaultName";
```

## Use an AWS CloudFormation value

See [the section called “Parameters” \(p. 151\)](#) for information about using AWS CloudFormation parameters with the AWS CDK.

To get a reference to a resource in an existing AWS CloudFormation template, see [the section called “Import or migrate CloudFormation template” \(p. 251\)](#).

## Import or migrate an existing AWS CloudFormation template

The [cloudformation-include.CfnInclude](#) construct converts the resources in an imported AWS CloudFormation template to AWS CDK L1 constructs. You can work with these in your app in the same way that you would if they were defined in AWS CDK code. You can use these L1 constructs within higher-level AWS CDK constructs. For example, this can let you use the L2 permission grant methods with the resources they define.

This construct essentially adds an AWS CDK API wrapper to any resource in the template. Use this capability to migrate your existing AWS CloudFormation templates to the AWS CDK a piece at a time. This way, you can take advantage of the AWS CDK's convenient higher-level abstractions. You can also use this feature to vend your AWS CloudFormation templates to AWS CDK developers by providing an AWS CDK construct API.

#### Note

AWS CDK v1 also included [aws-cdk-lib.CfnInclude](#), which was previously used for the same general purpose. However, it lacks much of the functionality of `cloudformation-include.CfnInclude`.

## Importing an AWS CloudFormation template

Here is a simple AWS CloudFormation template to use for the examples in this topic. Save it as `my-template.json`. After you've tried these examples with the provided template, you might explore

further using a template for an actual stack you've already deployed. You can get this template from the AWS CloudFormation console.

**Tip**

You can use either a JSON or YAML template. We recommend JSON if available, since YAML parsers can vary slightly in what they accept.

```
{
  "Resources": {
    "MyBucket": {
      "Type": "AWS::S3::Bucket",
      "Properties": {
        "BucketName": "MyBucket",
      }
    }
  }
}
```

And here's how you import it into your stack using `cloudformation-include`.

**TypeScript**

```
import * as cdk from 'aws-cdk-lib';
import * as cfninc from 'aws-cdk-lib/cloudformation-include';
import { Construct } from 'constructs';

export class MyStack extends cdk.Stack {
  constructor(scope: Construct, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    const template = new cfninc.CfnInclude(this, 'Template', {
      templateFile: 'my-template.json',
    });
  }
}
```

**JavaScript**

```
const cdk = require('aws-cdk-lib');
const cfninc = require('aws-cdk-lib/cloudformation-include');

class MyStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    const template = new cfninc.CfnInclude(this, 'Template', {
      templateFile: 'my-template.json',
    });
  }
}

module.exports = { MyStack }
```

**Python**

```
import aws_cdk as cdk
from aws_cdk import cloudformation_include as cfn_inc
from constructs import Construct

class MyStack(cdk.Stack):

    def __init__(self, scope: Construct, id: str, **kwargs) -> None:
```

```
super().__init__(scope, id, **kwargs)

template = cfn_inc.CfnInclude(self, "Template",
    template_file="my-template.json")
```

#### Java

```
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.amazon.awscdk.cloudformation.include.CfnInclude;
import software.constructs.Construct;

public class MyStack extends Stack {
    public MyStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public MyStack(final Construct scope, final String id, final StackProps props) {
        super(scope, id, props);

        CfnInclude template = CfnInclude.Builder.create(this, "Template")
            .templateFile("my-template.json")
            .build();
    }
}
```

#### C#

```
using Amazon.CDK;
using Constructs;
using cfnInc = Amazon.CDK.CloudFormation.Include;

namespace MyApp
{
    public class MyStack : Stack
    {
        internal MyStack(Construct scope, string id, IStackProps props = null) :
        base(scope, id, props)
        {
            var template = new cfnInc.CfnInclude(this, "Template", new
            cfnInc.CfnIncludeProps
            {
                TemplateFile = "my-template.json"
            });
        }
    }
}
```

By default, importing a resource preserves the resource's original logical ID from the template. This behavior is suitable for migrating an AWS CloudFormation template to the AWS CDK, where the logical IDs must be retained. AWS CloudFormation needs this to recognize these as the same resources from the AWS CloudFormation template.

You might instead be developing an AWS CDK construct wrapper for the template so it can be used by AWS CDK developers ("vending"). If you're doing this, have the AWS CDK generate new resource IDs instead. That way, the construct can be used multiple times in a stack without name conflicts. To do this, set the `preserveLogicalIds` property to `false` when importing the template.

#### TypeScript

```
const template = new cfninc.CfnInclude(this, 'MyConstruct', {
```

```
templateFile: 'my-template.json',
preserveLogicalIds: false
});
```

#### JavaScript

```
const template = new cfninc.CfnInclude(this, 'MyConstruct', {
  templateFile: 'my-template.json',
  preserveLogicalIds: false
});
```

#### Python

```
template = cfn_inc.CfnInclude(self, "Template",
    template_file="my-template.json",
    preserve_logical_ids=False)
```

#### Java

```
CfnInclude template = CfnInclude.Builder.create(this, "Template")
    .templateFile("my-template.json")
    .preserveLogicalIds(false)
    .build();
```

#### C#

```
var template = new cfnInc.CfnInclude(this, "Template", new cfn_inc.CfnIncludeProps
{
    TemplateFile = "my-template.json",
    PreserveLogicalIds = false
});
```

To put the imported resources under the control of your AWS CDK app, add the stack to the App as usual.

#### TypeScript

```
import * as cdk from 'aws-cdk-lib';
import { MyStack } from '../lib/my-stack';

const app = new cdk.App();
new MyStack(app, 'MyStack');
```

#### JavaScript

```
const cdk = require('aws-cdk-lib');
const { MyStack } = require('../lib/my-stack');

const app = new cdk.App();
new MyStack(app, 'MyStack');
```

#### Python

```
import aws_cdk as cdk
from mystack.my_stack import MyStack

app = cdk.App()
```

```
MyStack(app, "MyStack")
```

#### Java

```
import software.amazon.awscdk.App;

public class MyApp {
    public static void main(final String[] args) {
        App app = new App();

        new MyStack(app, "MyStack");
    }
}
```

#### C#

```
using Amazon.CDK;

namespace CdkApp
{
    sealed class Program
    {
        public static void Main(string[] args)
        {
            var app = new App();
            new MyStack(app, "MyStack");
        }
    }
}
```

To verify that there will be no unintended changes to the AWS resources in the stack, perform a diff, omitting the AWS CDK-specific metadata.

```
cdk diff --no-version-reporting --no-path-metadata --no-asset-metadata
```

When you `cdk deploy` the stack, your AWS CDK app becomes the source of truth for the stack. In the future, make changes to the AWS CDK app, not to the AWS CloudFormation template.

## Accessing imported resources

The name `template` in the example code represents the imported AWS CloudFormation template. To access a resource from it, use this object's [getResource\(\)](#) method. To access the returned resource as a specific kind of resource, cast the result to the desired type. (Casting is not necessary in Python and JavaScript.)

#### TypeScript

```
const cfnBucket = template.getResource('MyBucket') as s3.CfnBucket;
```

#### JavaScript

```
const cfnBucket = template.getResource('MyBucket');
```

#### Python

```
cfn_bucket = template.get_resource("MyBucket")
```

#### Java

```
CfnBucket cfnBucket = (CfnBucket)template.getResource("MyBucket");
```

#### C#

```
var cfnBucket = (CfnBucket)template.GetResource("MyBucket");
```

In our example, `cfnBucket` is now an instance of the [aws-s3.CfnBucket](#) class, a L1 construct that exactly represents the corresponding AWS CloudFormation resource. You can treat it like any other resource of its type, for example getting its ARN by way of the `bucket.attrArn` property.

To wrap the L1 `CfnBucket` resource in a L2 [aws-s3.Bucket](#) instance instead, use the static methods [fromBucketArn\(\)](#), [fromBucketAttributes\(\)](#), or [fromBucketName\(\)](#). Usually the `fromBucketName()` method is the most convenient. For example:

#### TypeScript

```
const bucket = s3.Bucket.fromBucketName(this, 'Bucket', cfnBucket.ref);
```

#### JavaScript

```
const bucket = s3.Bucket.fromBucketName(this, 'Bucket', cfnBucket.ref);
```

#### Python

```
bucket = s3.Bucket.from_bucket_name(self, "Bucket", cfn_bucket.ref)
```

#### Java

```
Bucket bucket = (Bucket)Bucket.fromBucketName(this, "Bucket", cfnBucket.getRef());
```

#### C#

```
var bucket = (Bucket)Bucket.FromBucketName(this, "Bucket", cfnBucket.Ref);
```

Other L2 constructs have similar methods for creating the construct from an existing resource.

Constructing the `Bucket` this way doesn't create a second Amazon S3 bucket; instead, the new `Bucket` instance encapsulates the existing `CfnBucket`.

In the example, `bucket` is now an L2 `Bucket` construct that you can use as you would one you declared yourself. For example, let's say that `lambdaFunc` is an AWS Lambda function, and you want to grant it write access to the bucket. To do so, use the bucket's convenient [grantWrite\(\)](#) method. You don't need to construct the necessary IAM policy yourself.

#### TypeScript

```
bucket.grantWrite(lambdaFunc);
```

#### JavaScript

```
bucket.grantWrite(lambdaFunc);
```



#### Python

```
bucket.grant_write(lambda_func)
```

#### Java

```
bucket.grantWrite(lambdaFunc);
```

#### C#

```
bucket.GrantWrite(lambdaFunc);
```

## Replacing parameters

If your included AWS CloudFormation template has parameters, you can replace these with build-time values when you import the template, using the `parameters` property. In the following example, we replace the `UploadBucket` parameter with the ARN of a bucket defined elsewhere in our AWS CDK code.

#### TypeScript

```
const template = new cfninc.CfnInclude(this, 'Template', {  
  templateFile: 'my-template.json',  
  parameters: {  
    'UploadBucket': bucket.bucketArn,  
  },  
});
```

#### JavaScript

```
const template = new cfninc.CfnInclude(this, 'Template', {  
  templateFile: 'my-template.json',  
  parameters: {  
    'UploadBucket': bucket.bucketArn,  
  },  
});
```

#### Python

```
template = cfn_inc.CfnInclude(self, "Template",  
    template_file="my-template.json",  
    parameters=dict(UploadBucket=bucket.bucket_arn)  
)
```

#### Java

```
CfnInclude template = CfnInclude.Builder.create(this, "Template")  
    .templateFile("my-template.json")  
    .parameters(java.util.Map.of( // Map.of requires Java 9+  
        "UploadBucket", bucket.getBucketArn()))  
    .build();
```

#### C#

```
var template = new cfnInc.CfnInclude(this, "Template", new cfnInc.CfnIncludeProps
```

```
{
    TemplateFile = "my-template.json",
    Parameters = new Dictionary<string, string>
    {
        { "UploadBucket", bucket.BucketArn }
    }
});
```

## Other template elements

You can import any AWS CloudFormation template element, not only resources. The imported elements become part of the AWS CDK stack. To import these elements, use the following methods of the `CfnInclude` object.

- [`getCondition\(\)`](#) - AWS CloudFormation [conditions](#)
- [`getHook\(\)`](#) - AWS CloudFormation [hooks](#) for blue/green deployments
- [`getMapping\(\)`](#) - AWS CloudFormation [mappings](#)
- [`getOutput\(\)`](#) - AWS CloudFormation [outputs](#)
- [`getParameter\(\)`](#) - AWS CloudFormation [parameters](#)
- [`getRule\(\)`](#) - AWS CloudFormation [rules](#) for AWS Service Catalog templates

Each of these methods returns an instance of a class representing the specific type of AWS CloudFormation element. These objects are mutable; changes that you make to them will appear in the template generated from the AWS CDK stack. The following code, for example, imports a parameter from the template and modifies its default.

### TypeScript

```
const param = template.getParameter('MyParameter');
param.default = "AWS CDK"
```

### JavaScript

```
const param = template.getParameter('MyParameter');
param.default = "AWS CDK"
```

### Python

```
param = template.get_parameter("MyParameter")
param.default = "AWS CDK"
```

### Java

```
CfnParameter param = template.getParameter("MyParameter");
param.setDefaultValue("AWS CDK")
```

### C#

```
var cfnBucket = (CfnBucket)template.GetResource("MyBucket");
var param = template.GetParameter("MyParameter");
param.Default = "AWS CDK";
```

## Nested stacks

You may import [nested stacks](#) by specifying them either when you import their main template, or at some later point. The nested template must be stored in a local file, but referenced as a `NestedStack` resource in the main template. Also, the resource name used in the AWS CDK code must match the name used for the nested stack in the main template.

Given this resource definition in the main template, the following code shows how to import the referenced nested stack both ways.

```
"NestedStack": {
  "Type": "AWS::CloudFormation::Stack",
  "Properties": {
    "TemplateURL": "https://my-s3-template-source.s3.amazonaws.com/nested-stack.json"
  }
}
```

### TypeScript

```
// include nested stack when importing main stack
const mainTemplate = new cfninc.CfnInclude(this, 'MainStack', {
  templateFile: 'main-template.json',
  loadNestedStacks: {
    'NestedStack': {
      templateFile: 'nested-template.json',
    },
  },
});

// or add it some time after importing the main stack
const nestedTemplate = mainTemplate.loadNestedStack('NestedTemplate', {
  templateFile: 'nested-template.json',
});
```

### JavaScript

```
// include nested stack when importing main stack
const mainTemplate = new cfninc.CfnInclude(this, 'MainStack', {
  templateFile: 'main-template.json',
  loadNestedStacks: {
    'NestedStack': {
      templateFile: 'nested-template.json',
    },
  },
});

// or add it some time after importing the main stack
const nestedTemplate = mainTemplate.loadNestedStack('NestedStack', {
  templateFile: 'my-nested-template.json',
});
```

### Python

```
# include nested stack when importing main stack
main_template = cfn_inc.CfnInclude(self, "MainStack",
    template_file="main-template.json",
    load_nested_stacks=dict(NestedStack=
        cfn_inc.CfnIncludeProps(template_file="nested-template.json")))

# or add it some time after importing the main stack
```

```
nested_template = main_template.load_nested_stack("NestedStack",  
    template_file="nested-template.json")
```

#### Java

```
CfnInclude mainTemplate = CfnInclude.Builder.create(this, "MainStack")  
    .templateFile("main-template.json")  
    .loadNestedStacks(java.util.Map.of(    // Map.of requires Java 9+  
        "NestedStack", CfnIncludeProps.builder()  
            .templateFile("nested-template.json").build()))  
    .build();  
  
// or add it some time after importing the main stack  
IncludedNestedStack nestedTemplate = mainTemplate.loadNestedStack("NestedTemplate",  
    CfnIncludeProps.builder()  
        .templateFile("nested-template.json")  
        .build());
```

#### C#

```
// include nested stack when importing main stack  
var mainTemplate = new cfnInc.CfnInclude(this, "MainStack", new cfnInc.CfnIncludeProps  
{  
    TemplateFile = "main-template.json",  
    LoadNestedStacks = new Dictionary<string, cfnInc.ICfnIncludeProps>  
    {  
        { "NestedStack", new cfnInc.CfnIncludeProps { TemplateFile = "nested-  
template.json" } }  
    }  
});  
  
// or add it some time after importing the main stack  
var nestedTemplate = mainTemplate.LoadNestedStack("NestedTemplate", new  
    cfnInc.CfnIncludeProps {  
        TemplateFile = 'nested-template.json'  
    }  
});
```

You can import multiple nested stacks with either or both methods. When importing the main template, you provide a mapping between the resource name of each nested stack and its template file. This mapping can contain any number of entries. To do it after the initial import, call `loadNestedStack()` once for each nested stack.

After importing a nested stack, you can access it using the main template's [getNestedStack\(\)](#) method.

#### TypeScript

```
const nestedStack = mainTemplate.getNestedStack('NestedStack').stack;
```

#### JavaScript

```
const nestedStack = mainTemplate.getNestedStack('NestedStack').stack;
```

#### Python

```
nested_stack = main_template.get_nested_stack("NestedStack").stack
```

Java

```
NestedStack nestedStack = mainTemplate.getNestedStack("NestedStack").getStack();
```

C#

```
var nestedStack = mainTemplate.GetNestedStack("NestedStack").Stack;
```

The `getNestedStack()` method returns an [IncludedNestedStack](#) instance. From this instance, you can access the AWS CDK [NestedStack](#) instance via the `stack` property (as shown in the example). You can also access the original AWS CloudFormation template object via `includedTemplate`, from which you can load resources and other AWS CloudFormation elements.

## Using resources from the AWS CloudFormation Public Registry

The AWS CloudFormation Public Registry is a collection of AWS CloudFormation extensions from both AWS and third parties. The extensions are available for use by all AWS customers. You can also publish your own extension for others to use. Extensions are of two types: resources and modules. You can use public resource extensions in your AWS CDK app using the [CfnResource](#) construct.

All public extensions published by AWS are available to all accounts in all Regions without any action on your part. However, you must activate each third-party extension you want to use, in each account and Region where you want to use it.

### Note

When you use AWS CloudFormation with third-party resource types, you will incur charges. Charges are based on the number of handler operations you run per month and handler operation duration. See [CloudFormation pricing](#) for complete details.


See [Using public extensions in CloudFormation](#) for complete documentation of this feature from the AWS CloudFormation side.

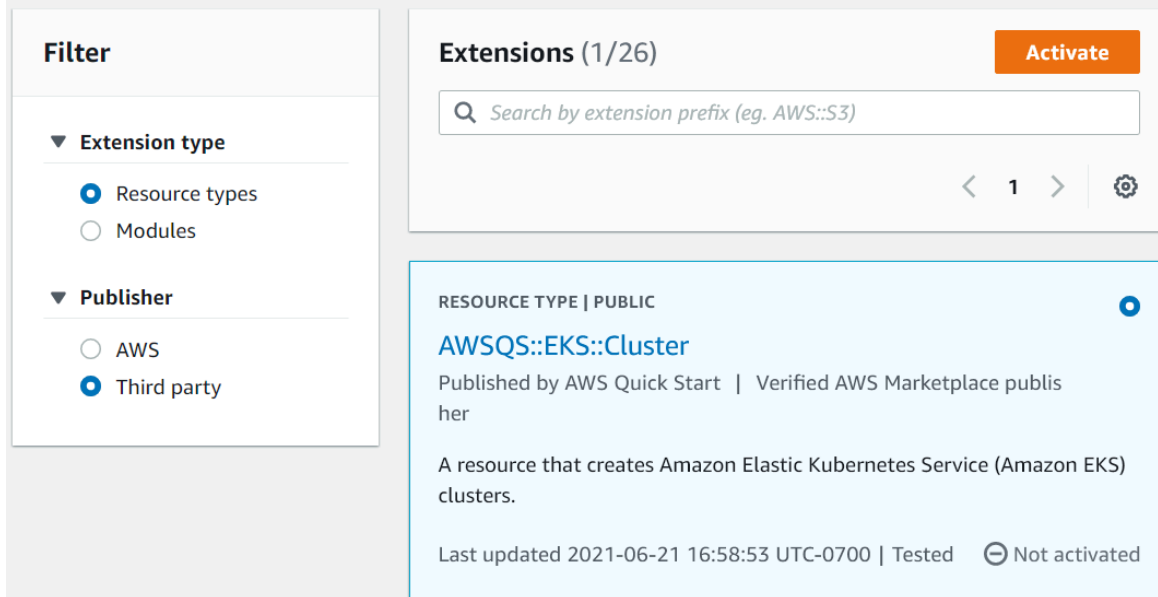
## Activating a third-party resource in your account and Region

Extensions published by AWS do not require activation; they are always available in every account and Region. You can activate a third-party extension through the AWS Management Console, via the AWS Command Line Interface, or by deploying a special AWS CloudFormation resource.

To activate a third-party extension through the AWS Management Console, or to see what resources are available, follow these steps.

## Registry: Public extensions

The CloudFormation registry lets you manage the extensions that are available for use in your CloudFormation account. Public extensions are those publicly published in the registry for use by all CloudFormation users. This includes all extensions published by Amazon, as well as third-party extension publishers. Third-party public extensions must first be activated before they can be used in your account. [Learn more](#) 



**Filter**

▼ **Extension type**

- ☒ Resource types
- ☐ Modules

▼ **Publisher**

- ☐ AWS
- ☒ Third party

**Extensions (1/26)** Activate

🔍 Search by extension prefix (eg. AWS::S3)


< 1 > ⚙️

**RESOURCE TYPE | PUBLIC** ☒

**AWS::EKS::Cluster**

Published by AWS Quick Start | Verified AWS Marketplace publisher

A resource that creates Amazon Elastic Kubernetes Service (Amazon EKS) clusters.

Last updated 2021-06-21 16:58:53 UTC-0700 | Tested  Not activated

1. Sign in to the AWS account in which you want to use the extension, then switch to the Region where you want to use it.
2. Navigate to the CloudFormation console via the **Services** menu.
3. Choose **Public extensions** on the navigation bar, then activate the **Third party** radio button under **Publisher**. A list of the available third-party public extensions appears. (You may also choose **AWS** to see a list of the public extensions published by AWS, though you don't need to activate them.)
4. Browse the list and find the extension you want to activate. Alternatively, search for it, then activate the radio button in the upper right corner of the extension's card.
5. Choose the **Activate** button at the top of the list to activate the selected extension. The extension's **Activate** page appears.
6. In the **Activate** page, you can override the extension's default name and specify an execution role and logging configuration. You can also choose whether to automatically update the extension when a new version is released. When you have set these options as you like, choose **Activate extension** at the bottom of the page.

To activate a third-party extension using the AWS CLI, use the `activate-type` command. Substitute the ARN of the custom type you want to use where indicated.

```
aws cloudformation activate-type --public-type-arn public_extension_ARN --auto-update-activated
```

To activate an extension through CloudFormation or the CDK, deploy a resource of type `AWS::CloudFormation::TypeActivation`, specifying the following properties.

- `TypeName` - The name of the type, such as `AWS::EKS::Cluster`.
- `MajorVersion` - The major version number of the extension that you want. Omit if you want the latest version.

- `AutoUpdate` - Whether to automatically update this extension when a new minor version is released by the publisher. (Major version updates require explicitly changing the `MajorVersion` property.)
- `ExecutionRoleArn` - The ARN of the IAM role under which this extension will run.
- `LoggingConfig` - The logging configuration for the extension.

The `TypeActivation` resource can be deployed by the CDK using the [CfnResource](#) construct. This is shown for the actual extensions in the following section.

## Adding a resource from the AWS CloudFormation Public Registry to your CDK app

Use the [CfnResource](#) construct to include a resource from the AWS CloudFormation Public Registry in your application. This construct is in the CDK's `aws-cdk-lib` module.

For example, suppose that there is a public resource named `MY::S5::UltimateBucket` that you want to use in your AWS CDK application. This resource takes one property: the bucket name. The corresponding `CfnResource` instantiation looks like this.

### TypeScript

```
const ubucket = new CfnResource(this, 'MyUltimateBucket', {
  type: 'MY::S5::UltimateBucket::MODULE',
  properties: {
    BucketName: 'UltimateBucket'
  }
});
```

### JavaScript

```
const ubucket = new CfnResource(this, 'MyUltimateBucket', {
  type: 'MY::S5::UltimateBucket::MODULE',
  properties: {
    BucketName: 'UltimateBucket'
  }
});
```

### Python

```
ubucket = CfnResource(self, "MyUltimateBucket",
    type="MY::S5::UltimateBucket::MODULE",
    properties=dict(
        BucketName="UltimateBucket"))
```

### Java

```
CfnResource.Builder.create(this, "MyUltimateBucket")
    .type("MY::S5::UltimateBucket::MODULE")
    .properties(java.util.Map.of( // Map.of requires Java 9+
        "BucketName", "UltimateBucket"))
    .build();
```

### C#

```
new CfnResource(this, "MyUltimateBucket", new CfnResourceProps
```

```
{
  Type = "MY::S5::UltimateBucket::MODULE",
  Properties = new Dictionary<string, object>
  {
    ["BucketName"] = "UltimateBucket"
  }
});
```

## Get a value from the Systems Manager Parameter Store

The AWS CDK can retrieve the value of AWS Systems Manager Parameter Store attributes. During synthesis, the AWS CDK produces a [token \(p. 145\)](#) that is resolved by AWS CloudFormation during deployment.

The AWS CDK supports retrieving both plain and secure values. You may request a specific version of either kind of value. For plain values only, you may omit the version from your request to receive the latest version. You must always specify the version when requesting the value of a secure attribute.

### Note

This topic shows how to read attributes from the AWS Systems Manager Parameter Store. You can also read secrets from the AWS Secrets Manager (see [Get a value from AWS Secrets Manager \(p. 267\)](#)).

## Reading Systems Manager values at deployment time

To read values from the Systems Manager Parameter Store, use the [valueForStringParameter](#) and [valueForSecureStringParameter](#) methods. Choose a method based on whether the attribute you want is a plain string or a secure string value. These methods return [tokens \(p. 145\)](#), not the actual value. The value is resolved by AWS CloudFormation during deployment.

A [limited number of AWS services](#) currently support this feature.

### TypeScript

```
import * as ssm from 'aws-cdk-lib/aws-ssm';

// Get latest version or specified version of plain string attribute
const latestStringToken = ssm.StringParameter.valueForStringParameter(
  this, 'my-plain-parameter-name'); // latest version
const versionOfStringToken = ssm.StringParameter.valueForStringParameter(
  this, 'my-plain-parameter-name', 1); // version 1

// Get specified version of secure string attribute
const secureStringToken = ssm.StringParameter.valueForSecureStringParameter(
  this, 'my-secure-parameter-name', 1); // must specify version
```

### JavaScript

```
const ssm = require('aws-cdk-lib/aws-ssm');

// Get latest version or specified version of plain string attribute
const latestStringToken = ssm.StringParameter.valueForStringParameter(
  this, 'my-plain-parameter-name'); // latest version
const versionOfStringToken = ssm.StringParameter.valueForStringParameter(
```



```
this, 'my-plain-parameter-name', 1); // version 1

// Get specified version of secure string attribute
const secureStringToken = ssm.StringParameter.valueForSecureStringParameter(
    this, 'my-secure-parameter-name', 1); // must specify version
```

## Python

```
import aws_cdk.aws_ssm as ssm

# Get latest version or specified version of plain string attribute
latest_string_token = ssm.StringParameter.value_for_string_parameter(
    self, "my-plain-parameter-name")
latest_string_token = ssm.StringParameter.value_for_string_parameter(
    self, "my-plain-parameter-name", 1)

# Get specified version of secure string attribute
secure_string_token = ssm.StringParameter.value_for_secure_string_parameter(
    self, "my-secure-parameter-name", 1) # must specify version
```

## Java

```
import software.amazon.awscdk.services.ssm.StringParameter;

//Get latest version or specified version of plain string attribute
String latestStringToken = StringParameter.valueForStringParameter(
    this, "my-plain-parameter-name"); // latest version
String versionOfStringToken = StringParameter.valueForStringParameter(
    this, "my-plain-parameter-name", 1); // version 1

//Get specified version of secure string attribute
String secureStringToken = StringParameter.valueForSecureStringParameter(
    this, "my-secure-parameter-name", 1); // must specify version
```

## C#

```
using Amazon.CDK.AWS.SSM;

// Get latest version or specified version of plain string attribute
var latestStringToken = StringParameter.ValueForStringParameter(
    this, "my-plain-parameter-name"); // latest version
var versionOfStringToken = StringParameter.ValueForStringParameter(
    this, "my-plain-parameter-name", 1); // version 1

// Get specified version of secure string attribute
var secureStringToken = StringParameter.ValueForSecureStringParameter(
    this, "my-secure-parameter-name", 1); // must specify version
```

# Reading Systems Manager values at synthesis time

It is sometimes useful to "bake in" a parameter at synthesis time. This way, the resulting AWS CloudFormation template always uses the same value, instead of resolving the value during deployment.

To read a value from the Systems Manager Parameter Store at synthesis time, use the [valueFromLookup](#) method (Python: `value_from_lookup`). This method returns the actual value of the parameter as a [the section called "Context" \(p. 185\)](#) value. If the value is not already cached in `cdk.json` or passed on the command line, it is retrieved from the current AWS account. For this reason, the stack *must* be synthesized with explicit account and Region information.

Only plain Systems Manager strings may be retrieved, not secure strings. It is not possible to request a specific version; the latest version is always returned.

### Important

The retrieved value will end up in your synthesized AWS CloudFormation template. This might be a security risk, depending on who has access to your AWS CloudFormation templates and what kind of value it is. Generally, don't use this feature for passwords, keys, or other values you want to keep private.

### TypeScript

```
import * as ssm from 'aws-cdk-lib/aws-ssm';

const stringValue = ssm.StringParameter.valueFromLookup(this, 'my-plain-parameter-name');
```

### JavaScript

```
const ssm = require('aws-cdk-lib/aws-ssm');

const stringValue = ssm.StringParameter.valueFromLookup(this, 'my-plain-parameter-name');
```

### Python

```
import aws_cdk.aws_ssm as ssm

string_value = ssm.StringParameter.value_from_lookup(self, "my-plain-parameter-name")
```

### Java

```
import software.amazon.awscdk.services.ssm.StringParameter;

String stringValue = StringParameter.valueFromLookup(this, "my-plain-parameter-name");
```

### C#

```
using Amazon.CDK.AWS.SSM;

var stringValue = StringParameter.ValueFromLookup(this, "my-plain-parameter-name");
```

## Writing values to Systems Manager

You can use the AWS CLI, the AWS Management Console, or an AWS SDK to set Systems Manager parameter values. The following examples use the [ssm put-parameter](#) CLI command.

```
aws ssm put-parameter --name "parameter-name" --type "String" --value "parameter-value"
aws ssm put-parameter --name "secure-parameter-name" --type "SecureString" --value "secure-parameter-value"
```

When updating an SSM value that already exists, also include the `--overwrite` option.

```
aws ssm put-parameter --overwrite --name "parameter-name" --type "String" --value "parameter-value"
```

```
aws ssm put-parameter --overwrite --name "secure-parameter-name" --type "SecureString" --value "secure-parameter-value"
```

## Get a value from AWS Secrets Manager

To use values from AWS Secrets Manager in your AWS CDK app, use the [fromSecretAttributes\(\)](#) method. It represents a value that is retrieved from Secrets Manager and used at AWS CloudFormation deployment time.

### TypeScript

```
import * as sm from "aws-cdk-lib/aws-secretsmanager";

export class SecretsManagerStack extends cdk.Stack {
  constructor(scope: cdk.App, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    const secret = sm.Secret.fromSecretAttributes(this, "ImportedSecret", {
      secretCompleteArn:
        "arn:aws:secretsmanager:<region>:<account-id-number>:secret:<secret-name>-<random-6-characters>"
      // If the secret is encrypted using a KMS-hosted CMK, either import or reference
      // that key:
      // encryptionKey: ...
    });
  }
}
```

### JavaScript

```
const sm = require("aws-cdk-lib/aws-secretsmanager");

class SecretsManagerStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    const secret = sm.Secret.fromSecretAttributes(this, "ImportedSecret", {
      secretCompleteArn:
        "arn:aws:secretsmanager:<region>:<account-id-number>:secret:<secret-name>-<random-6-characters>"
      // If the secret is encrypted using a KMS-hosted CMK, either import or reference
      // that key:
      // encryptionKey: ...
    });
  }
}

module.exports = { SecretsManagerStack }
```

### Python

```
import aws_cdk.aws_secretsmanager as sm

class SecretsManagerStack(cdk.Stack):
    def __init__(self, scope: cdk.App, id: str, **kwargs):
        super().__init__(scope, name, **kwargs)

        secret = sm.Secret.from_secret_attributes(self, "ImportedSecret",
            secret_complete_arn="arn:aws:secretsmanager:<region>:<account-id-number>:secret:<secret-name>-<random-6-characters>",
```

```
        # If the secret is encrypted using a KMS-hosted CMK, either import or
        reference that key:
        # encryption_key=...
    )
```

#### Java

```
import software.amazon.awscdk.services.secretsmanager.Secret;
import software.amazon.awscdk.services.secretsmanager.SecretAttributes;

public class SecretsManagerStack extends Stack {
    public SecretsManagerStack(App scope, String id) {
        this(scope, id, null);
    }

    public SecretsManagerStack(App scope, String id, StackProps props) {
        super(scope, id, props);

        Secret secret = (Secret)Secret.fromSecretAttributes(this, "ImportedSecret",
        SecretAttributes.builder()
            .secretCompleteArn("arn:aws:secretsmanager:<region>:<account-id-
number>:secret:<secret-name>-<random-6-characters>")
            // If the secret is encrypted using a KMS-hosted CMK, either import or
            reference that key:
            // .encryptionKey(...)
            .build());
    }
}
```

#### C#

```
using Amazon.CDK.AWS.SecretsManager;

public class SecretsManagerStack : Stack
{
    public SecretsManagerStack(App scope, string id, StackProps props) : base(scope,
id, props) {

        var secret = Secret.FromSecretAttributes(this, "ImportedSecret", new
        SecretAttributes {
            SecretCompleteArn = "arn:aws:secretsmanager:<region>:<account-id-
number>:secret:<secret-name>-<random-6-characters>"
            // If the secret is encrypted using a KMS-hosted CMK, either import or
            reference that key:
            // encryptionKey = ...,
        });
    }
}
```

#### Tip

Use the [create-secret](#) CLI command to create a secret from the command line, such as when testing:

```
aws secretsmanager create-secret --name ImportedSecret --secret-string
mygroovybucket
```

The command returns an ARN that you can use with the preceding example.

Once you have created a Secret instance, you can get the secret's value from the instance's `secretValue` attribute. The value is represented by a [SecretValue](#) instance, a special type of [the](#)

[section called “Tokens” \(p. 145\)](#). Because it's a token, it has meaning only after resolution. Your CDK app does not need to access its actual value. Instead, the app can pass the `SecretValue` instance (or its string or numeric representation) to whatever CDK method needs the value.

## Create an app with multiple stacks

Most of the code examples in the *AWS CDK Developer Guide* involve only a single stack. However, you can create apps containing any number of stacks. Each stack results in its own AWS CloudFormation template. Stacks are the *unit of deployment*: each stack in an app can be synthesized and deployed individually using the `cdk deploy` command.

This topic illustrates the following:

- How to extend the `Stack` class to accept new properties or arguments
- How to use these properties to affect what resources the stack contains and their configuration
- How to instantiate multiple stacks from this class

The example uses a Boolean property, named `encryptBucket` (Python: `encrypt_bucket`). It indicates whether an Amazon S3 bucket should be encrypted. If so, the stack enables encryption using a key managed by AWS Key Management Service (AWS KMS). The app creates two instances of this stack, one with encryption and one without.

### Before you begin

First, install Node.js and the AWS CDK command line tools, if you haven't already. See [Getting started with the AWS CDK \(p. 9\)](#) for details.

Next, create an AWS CDK project by entering the following commands at the command line.

#### TypeScript

```
mkdir multistack
cd multistack
cdk init --language=typescript
```

#### JavaScript

```
mkdir multistack
cd multistack
cdk init --language=javascript
```

#### Python

```
mkdir multistack
cd multistack
cdk init --language=python
source .venv/bin/activate
pip install -r requirements.txt
```

#### Java

```
mkdir multistack
```

```
cd multistack
cdk init --language=java
```

You can import the resulting Maven project into your Java IDE.

#### C#

```
mkdir multistack
cd multistack
cdk init --language=csharp
```

You can open the file `src/Pipeline.sln` in Visual Studio.

## Add optional parameter

The `props` argument of the `Stack` constructor fulfills the interface `StackProps`. In this example, we want the stack to accept an additional property to tell us whether to encrypt the Amazon S3 bucket. We should create an interface or class that includes the property. This allows the compiler to make sure that the property has a Boolean value and enables autocompletion for it in your IDE.

So open the indicated source file in your IDE or editor and add the new interface, class, or argument. The code should look like this after the changes. The lines we added are shown in bold.

#### TypeScript

File: `lib/multistack-stack.ts`

```
import * as cdk from 'aws-cdk-lib';
import { Construct } from 'constructs';

interface MultiStackProps extends cdk.StackProps {
  encryptBucket?: boolean;
}

export class MultistackStack extends cdk.Stack {
  constructor(scope: Construct, id: string, props?: MultiStackProps) {
    super(scope, id, props);

    // The code that defines your stack goes here
  }
}
```

#### JavaScript

File: `lib/multistack-stack.js`

JavaScript doesn't have an interface feature; we don't need to add any code.

```
const cdk = require('aws-cdk-stack');

class MultistackStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    // The code that defines your stack goes here
  }
}
```

```
module.exports = { MultistackStack }
```

## Python

File: multistack/multistack\_stack.py

Python does not have an interface feature, so we'll extend our stack to accept the new property by adding a keyword argument.

```
import aws_cdk as cdk
from constructs import Construct

class MultistackStack(cdk.Stack):

    # The Stack class doesn't know about our encrypt_bucket parameter,
    # so accept it separately and pass along any other keyword arguments.
    def __init__(self, scope: Construct, id: str, *, encrypt_bucket=False,
                 **kwargs) -> None:
        super().__init__(scope, id, **kwargs)

        # The code that defines your stack goes here
```

## Java

File: src/main/java/com/myorg/MultistackStack.java

It's more complicated than we really want to get into to extend a props type in Java. Instead, write the stack's constructor to accept an optional Boolean parameter. Because props is an optional argument, we'll write an additional constructor that lets you skip it. It will default to false.

```
package com.myorg;

import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.constructs.Construct;

import software.amazon.awscdk.services.s3.Bucket;

public class MultistackStack extends Stack {
    // additional constructors to allow props and/or encryptBucket to be omitted
    public MultistackStack(final Construct scope, final String id, boolean
encryptBucket) {
        this(scope, id, null, encryptBucket);
    }

    public MultistackStack(final Construct scope, final String id) {
        this(scope, id, null, false);
    }

    public MultistackStack(final Construct scope, final String id, final StackProps
props,
        final boolean encryptBucket) {
        super(scope, id, props);

        // The code that defines your stack goes here
    }
}
```

## C#

File: src/Multistack/MultistackStack.cs

```
using Amazon.CDK;
using constructs;

namespace Multistack
{

    public class MultiStackProps : StackProps
    {
        public bool? EncryptBucket { get; set; }
    }

    public class MultistackStack : Stack
    {
        public MultistackStack(Construct scope, string id, MultiStackProps props) :
        base(scope, id, props)
        {
            // The code that defines your stack goes here
        }
    }
}
```

The new property is optional. If `encryptBucket` (Python: `encrypt_bucket`) is not present, its value is undefined, or the local equivalent. The bucket will be unencrypted by default.

## Define the stack class

Now let's define our stack class, using our new property. Make the code look like the following. The code you need to add or change is shown in bold.

TypeScript

File: `lib/multistack-stack.ts`

```
import * as cdk from 'aws-cdk-lib';
import { Construct } from constructs;
import * as s3 from 'aws-cdk-lib/aws-s3';

interface MultistackProps extends cdk.StackProps {
    encryptBucket?: boolean;
}

export class MultistackStack extends cdk.Stack {
    constructor(scope: Construct, id: string, props?: MultistackProps) {
        super(scope, id, props);

        // Add a Boolean property "encryptBucket" to the stack constructor.
        // If true, creates an encrypted bucket. Otherwise, the bucket is unencrypted.
        // Encrypted bucket uses KMS-managed keys (SSE-KMS).
        if (props && props.encryptBucket) {
            new s3.Bucket(this, "MyGroovyBucket", {
                encryption: s3.BucketEncryption.KMS_MANAGED,
                removalPolicy: cdk.RemovalPolicy.DESTROY
            });
        } else {
            new s3.Bucket(this, "MyGroovyBucket", {
                removalPolicy: cdk.RemovalPolicy.DESTROY});
        }
    }
}
```



## JavaScript

File: lib/multistack-stack.js

```
const cdk = require('aws-cdk-lib');
const s3 = require('aws-cdk-lib/aws-s3');

class MultistackStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    // Add a Boolean property "encryptBucket" to the stack constructor.
    // If true, creates an encrypted bucket. Otherwise, the bucket is unencrypted.
    // Encrypted bucket uses KMS-managed keys (SSE-KMS).
    if ( props && props.encryptBucket ) {
      new s3.Bucket(this, "MyGroovyBucket", {
        encryption: s3.BucketEncryption.KMS_MANAGED,
        removalPolicy: cdk.RemovalPolicy.DESTROY
      });
    } else {
      new s3.Bucket(this, "MyGroovyBucket", {
        removalPolicy: cdk.RemovalPolicy.DESTROY});
    }
  }
}

module.exports = { MultistackStack }
```

## Python

File: multistack/multistack\_stack.py

```
import aws_cdk as cdk
from constructs import Construct
from aws_cdk import aws_s3 as s3

class MultistackStack(cdk.Stack):

    # The Stack class doesn't know about our encrypt_bucket parameter,
    # so accept it separately and pass along any other keyword arguments.
    def __init__(self, scope: Construct, id: str, *, encrypt_bucket=False,
        **kwargs) -> None:
        super().__init__(scope, id, **kwargs)

        # Add a Boolean property "encryptBucket" to the stack constructor.
        # If true, creates an encrypted bucket. Otherwise, the bucket is unencrypted.
        # Encrypted bucket uses KMS-managed keys (SSE-KMS).
        if encrypt_bucket:
            s3.Bucket(self, "MyGroovyBucket",
                encryption=s3.BucketEncryption.KMS_MANAGED,
                removal_policy=cdk.RemovalPolicy.DESTROY)
        else:
            s3.Bucket(self, "MyGroovyBucket",
                removal_policy=cdk.RemovalPolicy.DESTROY)
```

## Java

File: src/main/java/com/myorg/MultistackStack.java

```
package com.myorg;

import software.amazon.awscdk.Stack;
```

```
import software.amazon.awscdk.StackProps;
import software.constructs.Construct;
import software.amazon.awscdk.RemovalPolicy;

import software.amazon.awscdk.services.s3.Bucket;
import software.amazon.awscdk.services.s3.BucketEncryption;

public class MultistackStack extends Stack {
    // additional constructors to allow props and/or encryptBucket to be omitted
    public MultistackStack(final Construct scope, final String id,
        boolean encryptBucket) {
        this(scope, id, null, encryptBucket);
    }

    public MultistackStack(final Construct scope, final String id) {
        this(scope, id, null, false);
    }

    // main constructor
    public MultistackStack(final Construct scope, final String id,
        final StackProps props, final boolean encryptBucket) {
        super(scope, id, props);

        // Add a Boolean property "encryptBucket" to the stack constructor.
        // If true, creates an encrypted bucket. Otherwise, the bucket is
        // unencrypted. Encrypted bucket uses KMS-managed keys (SSE-KMS).
        if (encryptBucket) {
            Bucket.Builder.create(this, "MyGroovyBucket")
                .encryption(BucketEncryption.KMS_MANAGED)
                .removalPolicy(RemovalPolicy.DESTROY).build();
        } else {
            Bucket.Builder.create(this, "MyGroovyBucket")
                .removalPolicy(RemovalPolicy.DESTROY).build();
        }
    }
}
```

C#

File: src/Multistack/MultistackStack.cs

```
using Amazon.CDK;
using Amazon.CDK.AWS.S3;

namespace Multistack
{
    public class MultiStackProps : StackProps
    {
        public bool? EncryptBucket { get; set; }
    }

    public class MultistackStack : Stack
    {
        public MultistackStack(Construct scope, string id, IMultiStackProps props =
            null) : base(scope, id, props)
        {
            // Add a Boolean property "EncryptBucket" to the stack constructor.
            // If true, creates an encrypted bucket. Otherwise, the bucket is
            unencrypted.
            // Encrypted bucket uses KMS-managed keys (SSE-KMS).
            if (props?.EncryptBucket ?? false)
            {
                new Bucket(this, "MyGroovyBucket", new BucketProps
                {

```

```
        Encryption = BucketEncryption.KMS_MANAGED,  
        RemovalPolicy = RemovalPolicy.DESTROY  
    });  
    }  
    else  
    {  
        new Bucket(this, "MyGroovyBucket", new BucketProps  
        {  
            RemovalPolicy = RemovalPolicy.DESTROY  
        });  
    }  
    }  
    }  
}
```

## Create two stack instances

Now we'll add the code to instantiate two separate stacks. As before, the lines of code shown in bold are the ones you need to add. Delete the existing `MultistackStack` definition.

### TypeScript

File: `bin/multistack.ts`

```
#!/usr/bin/env node  
import 'source-map-support/register';  
import * as cdk from 'aws-cdk-lib';  
import { MultistackStack } from '../lib/multistack-stack';  
  
const app = new cdk.App();  
  
new MultistackStack(app, "MyWestCdkStack", {  
    env: {region: "us-west-1"},  
    encryptBucket: false  
});  
  
new MultistackStack(app, "MyEastCdkStack", {  
    env: {region: "us-east-1"},  
    encryptBucket: true  
});  
  
app.synth();
```

### JavaScript

File: `bin/multistack.js`

```
#!/usr/bin/env node  
const cdk = require('aws-cdk-lib');  
const { MultistackStack } = require('../lib/multistack-stack');  
  
const app = new cdk.App();  
  
new MultistackStack(app, "MyWestCdkStack", {  
    env: {region: "us-west-1"},  
    encryptBucket: false  
});  
  
new MultistackStack(app, "MyEastCdkStack", {  
    env: {region: "us-east-1"},  
    encryptBucket: true  
});
```

```
});  
  
app.synth();
```

## Python

File: ./app.py

```
#!/usr/bin/env python3  
  
import aws_cdk as cdk  
  
from multistack.multistack_stack import MultistackStack  
  
app = cdk.App()  
MultistackStack(app, "MyWestCdkStack",  
                 env=cdk.Environment(region="us-west-1"),  
                 encrypt_bucket=False)  
  
MultistackStack(app, "MyEastCdkStack",  
                 env=cdk.Environment(region="us-east-1"),  
                 encrypt_bucket=True)  
  
app.synth()
```

## Java

File: src/main/java/com/myorg/MultistackApp.java

```
package com.myorg;  
  
import software.amazon.awscdk.App;  
import software.amazon.awscdk.Environment;  
import software.amazon.awscdk.StackProps;  
  
public class MultistackApp {  
    public static void main(final String argv[]) {  
        App app = new App();  
  
        new MultistackStack(app, "MyWestCdkStack", StackProps.builder()  
            .env(Environment.builder()  
                .region("us-west-1")  
                .build())  
            .build(), false);  
  
        new MultistackStack(app, "MyEastCdkStack", StackProps.builder()  
            .env(Environment.builder()  
                .region("us-east-1")  
                .build())  
            .build(), true);  
  
        app.synth();  
    }  
}
```

## C#

File: src/Multistack/Program.cs

```
using Amazon.CDK;  
  
namespace Multistack
```

```
{
    class Program
    {
        static void Main(string[] args)
        {
            var app = new App();

            new MultistackStack(app, "MyWestCdkStack", new MultiStackProps
            {
                Env = new Environment { Region = "us-west-1" },
                EncryptBucket = false
            });

            new MultistackStack(app, "MyEastCdkStack", new MultiStackProps
            {
                Env = new Environment { Region = "us-east-1" },
                EncryptBucket = true
            });

            app.Synth();
        }
    }
}
```

This code uses the new `encryptBucket` (Python: `encrypt_bucket`) property on the `MultistackStack` class to instantiate the following:

- One stack with an encrypted Amazon S3 bucket in the `us-east-1` AWS Region.
- One stack with an unencrypted Amazon S3 bucket in the `us-west-1` AWS Region.

## Synthesize and deploy the stack

Now you can deploy stacks from the app. First, synthesize an AWS CloudFormation template for `MyEastCdkStack`—the stack in `us-east-1`. This is the stack with the encrypted S3 bucket.

```
$ cdk synth MyEastCdkStack
```

To deploy this stack to your AWS account, issue one of the following commands. The first command uses your default AWS profile to obtain the credentials to deploy the stack. The second uses a profile that you specify. For *PROFILE\_NAME*, substitute the name of an AWS CLI profile that contains appropriate credentials for deploying to the `us-east-1` AWS Region.

```
cdk deploy MyEastCdkStack
```

```
cdk deploy MyEastCdkStack --profile=PROFILE_NAME
```

## Clean up

To avoid charges for resources that you deployed, destroy the stack using the following command.

```
cdk destroy MyEastCdkStack
```

The destroy operation fails if there is anything stored in the stack's bucket. There shouldn't be if you've only followed the instructions in this topic. But if you did put something in the bucket, you must

delete the bucket contents before destroying the stack. (Do not delete the bucket itself.) Use the AWS Management Console or the AWS CLI to delete the bucket contents.

## Set a CloudWatch alarm

The [aws-cloudwatch](#) package supports setting CloudWatch alarms on CloudWatch metrics. So the first thing you need is a metric. You can use a predefined metric or you can create your own.

### Using an existing metric

Many AWS Construct Library modules let you set an alarm on an existing metric by passing the metric's name to a convenience method on an instance of an object that has metrics. For example, given an Amazon SQS queue, you can get the metric **ApproximateNumberOfMessagesVisible** from the queue's [metric\(\)](#) method.

TypeScript

```
const metric = queue.metric("ApproximateNumberOfMessagesVisible");
```

JavaScript

```
const metric = queue.metric("ApproximateNumberOfMessagesVisible");
```

Python

```
metric = queue.metric("ApproximateNumberOfMessagesVisible")
```

Java

```
Metric metric = queue.metric("ApproximateNumberOfMessagesVisible");
```

C#

```
var metric = queue.Metric("ApproximateNumberOfMessagesVisible");
```

### Creating your own metric

Create your own [metric](#) as follows, where the *namespace* value should be something like **AWS/SQS** for an Amazon SQS queue. You also need to specify your metric's name and dimension.

TypeScript

```
const metric = new cloudwatch.Metric({  
  namespace: 'MyNamespace',  
  metricName: 'MyMetric',  
  dimensions: { MyDimension: 'MyDimensionValue' }  
});
```

JavaScript

```
const metric = new cloudwatch.Metric({
```

```
namespace: 'MyNamespace',  
metricName: 'MyMetric',  
dimensions: { MyDimension: 'MyDimensionValue' }  
});
```

#### Python

```
metric = cloudwatch.Metric(  
    namespace="MyNamespace",  
    metric_name="MyMetric",  
    dimensions=dict(MyDimension="MyDimensionValue")  
)
```

#### Java

```
Metric metric = Metric.Builder.create()  
    .namespace("MyNamespace")  
    .metricName("MyMetric")  
    .dimensionsMap(java.util.Map.of(    // Java 9 or later  
        "MyDimension", "MyDimensionValue"))  
    .build();
```

#### C#

```
var metric = new Metric(this, "Metric", new MetricProps  
{  
    Namespace = "MyNamespace",  
    MetricName = "MyMetric",  
    Dimensions = new Dictionary<string, object>  
    {  
        { "MyDimension", "MyDimensionValue" }  
    }  
});
```

## Creating the alarm

Once you have a metric, either an existing one or one you defined, you can create an alarm. In this example, the alarm is raised when there are more than 100 of your metric in two of the last three evaluation periods. You can use comparisons such as less-than in your alarms via the `comparisonOperator` property. Greater-than-or-equal-to is the AWS CDK default, so we don't need to specify it.

#### TypeScript

```
const alarm = new cloudwatch.Alarm(this, 'Alarm', {  
    metric: metric,  
    threshold: 100,  
    evaluationPeriods: 3,  
    datapointsToAlarm: 2,  
});
```

#### JavaScript

```
const alarm = new cloudwatch.Alarm(this, 'Alarm', {  
    metric: metric,  
    threshold: 100,  
    evaluationPeriods: 3,
```

```
datapointsToAlarm: 2
});
```

#### Python

```
alarm = cloudwatch.Alarm(self, "Alarm",
    metric=metric,
    threshold=100,
    evaluation_periods=3,
    datapoints_to_alarm=2
)
```

#### Java

```
import software.amazon.awscdk.services.cloudwatch.Alarm;
import software.amazon.awscdk.services.cloudwatch.Metric;

Alarm alarm = Alarm.Builder.create(this, "Alarm")
    .metric(metric)
    .threshold(100)
    .evaluationPeriods(3)
    .datapointsToAlarm(2).build();
```

#### C#

```
var alarm = new Alarm(this, "Alarm", new AlarmProps
{
    Metric = metric,
    Threshold = 100,
    EvaluationPeriods = 3,
    DatapointsToAlarm = 2
});
```

An alternative way to create an alarm is using the metric's [createAlarm\(\)](#) method, which takes essentially the same properties as the Alarm constructor. You don't need to pass in the metric, because it's already known.

#### TypeScript

```
metric.createAlarm(this, 'Alarm', {
    threshold: 100,
    evaluationPeriods: 3,
    datapointsToAlarm: 2,
});
```

#### JavaScript

```
metric.createAlarm(this, 'Alarm', {
    threshold: 100,
    evaluationPeriods: 3,
    datapointsToAlarm: 2,
});
```

#### Python

```
metric.create_alarm(self, "Alarm",
    threshold=100,
    evaluation_periods=3,
```



```
) datapoints_to_alarm=2
```

#### Java

```
metric.createAlarm(this, "Alarm", new CreateAlarmOptions.Builder()  
    .threshold(100)  
    .evaluationPeriods(3)  
    .datapointsToAlarm(2)  
    .build());
```

#### C#

```
metric.CreateAlarm(this, "Alarm", new CreateAlarmOptions  
{  
    Threshold = 100,  
    EvaluationPeriods = 3,  
    DatapointsToAlarm = 2  
});
```

## Get a value from a context variable

You can specify a context variable either as part of an AWS CDK CLI command, or in `cdk.json`.

To create a command line context variable, use the **--context (-c)** option, as shown in the following example.

```
cdk synth -c bucket_name=mygroovybucket
```

To specify the same context variable and value in the `cdk.json` file, use the following code.

```
{  
  "context": {  
    "bucket_name": "myotherbucket"  
  }  
}
```

To get the value of a context variable in your app, use the `TryGetContext` method in the context of a construct. (That is, when `this`, or `self` in Python, is an instance of some construct.) The example gets the context value **bucket\_name**. If the requested value is not defined, `TryGetContext` returns undefined (`None` in Python; `null` in Java and C#; `nil` in Go) rather than raising an exception.

#### TypeScript

```
const bucket_name = this.node.tryGetContext('bucket_name');
```

#### JavaScript

```
const bucket_name = this.node.tryGetContext('bucket_name');
```

#### Python

```
bucket_name = self.node.try_get_context("bucket_name")
```

#### Java

```
String bucketName = (String)this.getNode().tryGetContext("bucket_name");
```

#### C#

```
var bucketName = this.Node.TryGetContext("bucket_name");
```

Outside the context of a construct, you can access the context variable from the app object, like this.

#### TypeScript

```
const app = new cdk.App();  
const bucket_name = app.node.tryGetContext('bucket_name')
```

#### JavaScript

```
const app = new cdk.App();  
const bucket_name = app.node.tryGetContext('bucket_name');
```

#### Python

```
app = cdk.App()  
bucket_name = app.node.try_get_context("bucket_name")
```

#### Java

```
App app = App();  
String bucketName = (String)app.getNode().tryGetContext("bucket_name");
```

#### C#

```
app = App();  
var bucketName = app.Node.TryGetContext("bucket_name");
```

For more details on working with context variables, see [the section called “Context” \(p. 185\)](#).

## Continuous integration and delivery (CI/CD) using CDK Pipelines

[CDK Pipelines](#) is a construct library module for painless continuous delivery of AWS CDK applications. Whenever you check your AWS CDK app's source code in to AWS CodeCommit, GitHub, or AWS CodeStar, CDK Pipelines can automatically build, test, and deploy your new version.

CDK Pipelines are self-updating. If you add application stages or stacks, the pipeline automatically reconfigures itself to deploy those new stages or stacks.

#### Note

CDK Pipelines supports two APIs. One is the original API that was made available in the CDK Pipelines Developer Preview. The other is a modern API that incorporates feedback from CDK

customers received during the preview phase. The examples in this topic use the modern API. For details on the differences between the two supported APIs, see [CDK Pipelines original API](#).

## Bootstrap your AWS environments

Before you can use CDK Pipelines, you must bootstrap the AWS environments to which you will deploy your stacks. An [environment \(p. 114\)](#) is an account/Region pair to which you want to deploy a CDK stack.

A CDK Pipeline involves at least two environments. One environment is where the pipeline is provisioned. The other environment is where you want to deploy the application's stacks (or its stages, which are groups of related stacks). These environments can be the same, though best practices recommend you isolate stages from each other in different AWS accounts or Regions.

### Note

See [the section called "Bootstrapping" \(p. 195\)](#) for more information on the kinds of resources created by bootstrapping and how to customize the bootstrap stack.

Continuous deployment with CDK Pipelines requires the following to be included in the CDK Toolkit stack:

- An S3 bucket
- An Amazon ECR repository
- IAM roles to give the various parts of a pipeline the permissions they need

The CDK Toolkit upgrades your existing bootstrap stack or creates a new one if necessary.

To bootstrap an environment that can provision an AWS CDK pipeline, invoke `cdk bootstrap` as shown in the following example. Invoking the AWS CDK Toolkit via the `npx` command temporarily installs it if necessary. It will also use the version of the Toolkit installed in the current project, if one exists.

**--cloudformation-execution-policies** specifies the ARN of a policy under which future CDK Pipelines deployments will execute. The default `AdministratorAccess` policy makes sure that your pipeline can deploy every type of AWS resource. If you use this policy, make sure you trust all the code and dependencies that make up your AWS CDK app.

Most organizations mandate stricter controls on what kinds of resources can be deployed by automation. Check with the appropriate department within your organization to determine the policy your pipeline should use.

You can omit the **--profile** option if your default AWS profile contains the necessary authentication configuration and AWS Region.

macOS/Linux

```
npx cdk bootstrap aws://ACCOUNT-NUMBER/REGION --profile ADMIN-PROFILE \
  --cloudformation-execution-policies arn:aws:iam::aws:policy/AdministratorAccess
```

Windows

```
npx cdk bootstrap aws://ACCOUNT-NUMBER/REGION --profile ADMIN-PROFILE ^
  --cloudformation-execution-policies arn:aws:iam::aws:policy/AdministratorAccess
```

To bootstrap additional environments into which AWS CDK applications will be deployed by the pipeline, use the following commands instead. The **--trust** option indicates which other account should have permissions to deploy AWS CDK applications into this environment. For this option, specify the pipeline's AWS account ID.

Again, you can omit the **--profile** option if your default AWS profile contains the necessary authentication configuration and AWS Region.

macOS/Linux

```
npx cdk bootstrap aws://ACCOUNT-NUMBER/REGION --profile ADMIN-PROFILE \  
  --cloudformation-execution-policies arn:aws:iam::aws:policy/AdministratorAccess \  
  --trust PIPELINE-ACCOUNT-NUMBER
```

Windows

```
npx cdk bootstrap aws://ACCOUNT-NUMBER/REGION --profile ADMIN-PROFILE ^  
  --cloudformation-execution-policies arn:aws:iam::aws:policy/AdministratorAccess ^  
  --trust PIPELINE-ACCOUNT-NUMBER
```

### Tip

Use administrative credentials only to bootstrap and to provision the initial pipeline. Afterward, use the pipeline itself, not your local machine, to deploy changes.

If you are upgrading a legacy bootstrapped environment, the previous Amazon S3 bucket is orphaned when the new bucket is created. Delete it manually by using the Amazon S3 console.

## Initialize project

Create a new, empty GitHub project and clone it to your workstation in the my-pipeline directory. (Our code examples in this topic use GitHub. You can also use AWS CodeStar or AWS CodeCommit.)

```
git clone GITHUB-CLONE-URL my-pipeline  
cd my-pipeline
```

### Note

You can use a name other than my-pipeline for your app's main directory. However, if you do so, you will have to tweak the file and class names later in this topic. This is because the AWS CDK Toolkit bases some file and class names on the name of the main directory.

After cloning, initialize the project as usual.

TypeScript

```
cdk init app --language typescript
```

JavaScript

```
cdk init app --language javascript
```

Python

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

After the app has been created, also enter the following two commands. These activate the app's Python virtual environment and install the AWS CDK core dependencies.

```
source .venv/bin/activate  
python -m pip install -r requirements.txt
```

#### Java

```
cdk init app --language java
```

If you are using an IDE, you can now open or import the project. In Eclipse, for example, choose **File > Import > Maven > Existing Maven Projects**. Make sure that the project settings are set to use Java 8 (1.8).

#### C#

```
cdk init app --language csharp
```

If you are using Visual Studio, open the solution file in the `src` directory.

#### Go

```
cdk init app --language go
```

After the app has been created, also enter the following command to install the AWS Construct Library modules that the app requires.

```
go get
```

#### Important

Be sure to commit your `cdk.json` and `cdk.context.json` files to source control. The context information (such as feature flags and cached values retrieved from your AWS account) are part of your project's state. The values may be different in another environment, which can cause unexpected changes in your results. For more information, see [the section called "Context" \(p. 185\)](#).

## Define a pipeline

Your CDK Pipelines application will include at least two stacks: one that represents the pipeline itself, and one or more stacks that represent the application deployed through it. Stacks can also be grouped into *stages*, which you can use to deploy copies of infrastructure stacks to different environments. For now, we'll consider the pipeline, and later delve into the application it will deploy.

The construct [CodePipeline](#) is the construct that represents a CDK Pipeline that uses AWS CodePipeline as its deployment engine. When you instantiate `CodePipeline` in a stack, you define the source location for the pipeline (such as a GitHub repository). You also define the commands to build the app.

For example, the following defines a pipeline whose source is stored in a GitHub repository. It also includes a build step for a TypeScript CDK application. Fill in the information about your GitHub repo where indicated.

#### Note

By default, the pipeline authenticates to GitHub using a personal access token stored in Secrets Manager under the name `github-token`.

You'll also need to update the instantiation of the pipeline stack to specify the AWS account and Region.

#### TypeScript

In `lib/my-pipeline-stack.ts` (may vary if your project folder isn't named `my-pipeline`):

```
import * as cdk from 'aws-cdk-lib';
```

```
import { Construct } from 'constructs';
import { CodePipeline, CodePipelineSource, ShellStep } from 'aws-cdk-lib/pipelines';

export class MyPipelineStack extends cdk.Stack {
  constructor(scope: Construct, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    const pipeline = new CodePipeline(this, 'Pipeline', {
      pipelineName: 'MyPipeline',
      synth: new ShellStep('Synth', {
        input: CodePipelineSource.github('OWNER/REPO', 'main'),
        commands: ['npm ci', 'npm run build', 'npx cdk synth']
      })
    });
  }
}
```

In `bin/my-pipeline.ts` (may vary if your project folder isn't named `my-pipeline`):

```
#!/usr/bin/env node
import * as cdk from 'aws-cdk-lib';
import { MyPipelineStack } from '../lib/my-pipeline-stack';

const app = new cdk.App();
new MyPipelineStack(app, 'MyPipelineStack', {
  env: {
    account: '111111111111',
    region: 'eu-west-1',
  }
});

app.synth();
```

## JavaScript

In `lib/my-pipeline-stack.js` (may vary if your project folder isn't named `my-pipeline`):

```
const cdk = require('aws-cdk-lib');
const { CodePipeline, CodePipelineSource, ShellStep } = require('aws-cdk-lib/
pipelines');

class MyPipelineStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    const pipeline = new CodePipeline(this, 'Pipeline', {
      pipelineName: 'MyPipeline',
      synth: new ShellStep('Synth', {
        input: CodePipelineSource.github('OWNER/REPO', 'main'),
        commands: ['npm ci', 'npm run build', 'npx cdk synth']
      })
    });
  }
}

module.exports = { MyPipelineStack }
```

In `bin/my-pipeline.js` (may vary if your project folder isn't named `my-pipeline`):

```
#!/usr/bin/env node

const cdk = require('aws-cdk-lib');
```

```
const { MyPipelineStack } = require('../lib/my-pipeline-stack');

const app = new cdk.App();
new MyPipelineStack(app, 'MyPipelineStack', {
  env: {
    account: '111111111111',
    region: 'eu-west-1',
  }
});

app.synth();
```

## Python

In `my-pipeline/my-pipeline-stack.py` (may vary if your project folder isn't named `my-pipeline`):

```
import aws_cdk as cdk
from constructs import Construct
from aws_cdk.pipelines import CodePipeline, CodePipelineSource, ShellStep

class MyPipelineStack(cdk.Stack):

    def __init__(self, scope: Construct, construct_id: str, **kwargs) -> None:
        super().__init__(scope, construct_id, **kwargs)

        pipeline = CodePipeline(self, "Pipeline",
                                pipeline_name="MyPipeline",
                                synth=ShellStep("Synth",
                                                input=CodePipelineSource.git_hub("OWNER/REPO", "main"),
                                                commands=["npm install -g aws-cdk",
                                                         "python -m pip install -r requirements.txt",
                                                         "cdk synth"]
                                )
        )
```

In `app.py`:

```
#!/usr/bin/env python3
import aws_cdk as cdk
from my_pipeline.my_pipeline_stack import MyPipelineStack

app = cdk.App()
MyPipelineStack(app, "MyPipelineStack",
    env=cdk.Environment(account="111111111111", region="eu-west-1")
)

app.synth()
```

## Java

In `src/main/java/com/myorg/MyPipelineStack.java` (may vary if your project folder isn't named `my-pipeline`):

```
package com.myorg;

import java.util.Arrays;
import software.constructs.Construct;
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.amazon.awscdk.pipelines.CodePipeline;
import software.amazon.awscdk.pipelines.CodePipelineSource;
```

```
import software.amazon.awscdk.pipelines.ShellStep;

public class MyPipelineStack extends Stack {
    public MyPipelineStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public MyPipelineStack(final Construct scope, final String id, final StackProps
props) {
        super(scope, id, props);

        CodePipeline pipeline = CodePipeline.Builder.create(this, "pipeline")
            .pipelineName("MyPipeline")
            .synth(ShellStep.Builder.create("Synth")
                .input(CodePipelineSource.gitHub("OWNER/REPO", "main"))
                .commands(Arrays.asList("npm install -g aws-cdk", "cdk synth"))
                .build())
            .build();
    }
}
```

In `src/main/java/com/myorg/MyPipelineApp.java` (may vary if your project folder isn't named `my-pipeline`):

```
package com.myorg;

import software.amazon.awscdk.App;
import software.amazon.awscdk.Environment;
import software.amazon.awscdk.StackProps;

public class MyPipelineApp {
    public static void main(final String[] args) {
        App app = new App();

        new MyPipelineStack(app, "PipelineStack", StackProps.builder()
            .env(Environment.builder()
                .account("111111111111")
                .region("eu-west-1")
                .build())
            .build());

        app.synth();
    }
}
```

## C#

In `src/MyPipeline/MyPipelineStack.cs` (may vary if your project folder isn't named `my-pipeline`):

```
using Amazon.CDK;
using Amazon.CDK.Pipelines;

namespace MyPipeline
{
    public class MyPipelineStack : Stack
    {
        internal MyPipelineStack(Construct scope, string id, IStackProps props =
null) : base(scope, id, props)
        {
            var pipeline = new CodePipeline(this, "pipeline", new CodePipelineProps
            {
                PipelineName = "MyPipeline",
            });
        }
    }
}
```



```
Synth = new ShellStep("Synth", new ShellStepProps
{
    Input = CodePipelineSource.GitHub("OWNER/REPO", "main"),
    Commands = new string[] { "npm install -g aws-cdk", "cdk synth" }
});
}
```

In `src/MyPipeline/Program.cs` (may vary if your project folder isn't named `my-pipeline`):

```
using Amazon.CDK;

namespace MyPipeline
{
    sealed class Program
    {
        public static void Main(string[] args)
        {
            var app = new App();
            new MyPipelineStack(app, "MyPipelineStack", new StackProps
            {
                Env = new Amazon.CDK.Environment {
                    Account = "111111111111", Region = "eu-west-1" }
            });

            app.Synth();
        }
    }
}
```

You must deploy a pipeline manually once. After that, the pipeline keeps itself up to date from the source code repository. So be sure that the code in the repo is the code you want deployed. Check in your changes and push to GitHub, then deploy:

```
git add --all
git commit -m "initial commit"
git push
cdk deploy
```

### Tip

Now that you've done the initial deployment, your local AWS account no longer needs administrative access. This is because all changes to your app will be deployed via the pipeline. All you need to be able to do is push to GitHub.

## Application stages

To define a multi-stack AWS application that can be added to the pipeline all at once, define a subclass of [Stage](#). (This is different from `CdkStage` in the CDK Pipelines module.)

The stage contains the stacks that make up your application. If there are dependencies between the stacks, the stacks are automatically added to the pipeline in the right order. Stacks that don't depend on each other are deployed in parallel. You can add a dependency relationship between stacks by calling `stack1.addDependency(stack2)`.

Stages accept a default `env` argument, which becomes the default environment for the stacks inside it. (Stacks can still have their own environment specified.)

An application is added to the pipeline by calling `addStage()` with instances of `Stage`. A stage can be instantiated and added to the pipeline multiple times to define different stages of your DTAP or multi-Region application pipeline.

We will create a stack containing a simple Lambda function and place that stack in a stage. Then we will add the stage to the pipeline so it can be deployed.

### TypeScript

Create the new file `lib/my-pipeline-lambda-stack.ts` to hold our application stack containing a Lambda function.

```
import * as cdk from 'aws-cdk-lib';
import { Construct } from 'constructs';
import { Function, InlineCode, Runtime } from 'aws-cdk-lib/aws-lambda';

export class MyLambdaStack extends cdk.Stack {
  constructor(scope: Construct, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    new Function(this, 'LambdaFunction', {
      runtime: Runtime.NODEJS_18_X,
      handler: 'index.handler',
      code: new InlineCode('exports.handler = _ => "Hello, CDK";')
    });
  }
}
```

Create the new file `lib/my-pipeline-app-stage.ts` to hold our stage.

```
import * as cdk from 'aws-cdk-lib';
import { Construct } from 'constructs';
import { MyLambdaStack } from './my-pipeline-lambda-stack';

export class MyPipelineAppStage extends cdk.Stage {
  constructor(scope: Construct, id: string, props?: cdk.StageProps) {
    super(scope, id, props);

    const lambdaStack = new MyLambdaStack(this, 'LambdaStack');
  }
}
```

Edit `lib/my-pipeline-stack.ts` to add the stage to our pipeline.

```
import * as cdk from 'aws-cdk-lib';
import { Construct } from 'constructs';
import { CodePipeline, CodePipelineSource, ShellStep } from 'aws-cdk-lib/pipelines';
import { MyPipelineAppStage } from './my-pipeline-app-stage';

export class MyPipelineStack extends cdk.Stack {
  constructor(scope: Construct, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    const pipeline = new CodePipeline(this, 'Pipeline', {
      pipelineName: 'MyPipeline',
      synth: new ShellStep('Synth', {
        input: CodePipelineSource.gitHub('OWNER/REPO', 'main'),
        commands: ['npm ci', 'npm run build', 'npx cdk synth']
      })
    });
  }
}
```

```
    pipeline.addStage(new MyPipelineAppStage(this, "test", {
      env: { account: "111111111111", region: "eu-west-1" }
    }));
  }
}
```

#### JavaScript

Create the new file `lib/my-pipeline-lambda-stack.js` to hold our application stack containing a Lambda function.

```
const cdk = require('aws-cdk-lib');
const { Function, InlineCode, Runtime } = require('aws-cdk-lib/aws-lambda');

class MyLambdaStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    new Function(this, 'LambdaFunction', {
      runtime: Runtime.NODEJS_18_X,
      handler: 'index.handler',
      code: new InlineCode('exports.handler = _ => "Hello, CDK";')
    });
  }
}

module.exports = { MyLambdaStack }
```

Create the new file `lib/my-pipeline-app-stage.js` to hold our stage.

```
const cdk = require('aws-cdk-lib');
const { MyLambdaStack } = require('./my-pipeline-lambda-stack');

class MyPipelineAppStage extends cdk.Stage {
  constructor(scope, id, props) {
    super(scope, id, props);

    const lambdaStack = new MyLambdaStack(this, 'LambdaStack');
  }
}

module.exports = { MyPipelineAppStage };
```

Edit `lib/my-pipeline-stack.ts` to add the stage to our pipeline.

```
const cdk = require('aws-cdk-lib');
const { CodePipeline, CodePipelineSource, ShellStep } = require('aws-cdk-lib/
pipelines');
const { MyPipelineAppStage } = require('./my-pipeline-app-stage');

class MyPipelineStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    const pipeline = new CodePipeline(this, 'Pipeline', {
      pipelineName: 'MyPipeline',
      synth: new ShellStep('Synth', {
        input: CodePipelineSource.gitHub('OWNER/REPO', 'main'),
        commands: ['npm ci', 'npm run build', 'npx cdk synth']
      })
    });
  }
}
```

```
        pipeline.addStage(new MyPipelineAppStage(this, "test", {
            env: { account: "111111111111", region: "eu-west-1" }
        }));
    }
}

module.exports = { MyPipelineStack }
```

## Python

Create the new file `my_pipeline/my_pipeline_lambda_stack.py` to hold our application stack containing a Lambda function.

```
import aws_cdk as cdk
from constructs import Construct
from aws_cdk.aws_lambda import Function, InlineCode, Runtime

class MyLambdaStack(cdk.Stack):
    def __init__(self, scope: Construct, construct_id: str, **kwargs) -> None:
        super().__init__(scope, construct_id, **kwargs)

        Function(self, "LambdaFunction",
            runtime=Runtime.NODEJS_18_X,
            handler="index.handler",
            code=InlineCode("exports.handler = _ => 'Hello, CDK';")
        )
```

Create the new file `my_pipeline/my_pipeline_app_stage.py` to hold our stage.

```
import aws_cdk as cdk
from constructs import Construct
from my_pipeline.my_pipeline_lambda_stack import MyLambdaStack

class MyPipelineAppStage(cdk.Stage):
    def __init__(self, scope: Construct, construct_id: str, **kwargs) -> None:
        super().__init__(scope, construct_id, **kwargs)

        lambdaStack = MyLambdaStack(self, "LambdaStack")
```

Edit `my_pipeline/my-pipeline-stack.py` to add the stage to our pipeline.

```
import aws_cdk as cdk
from constructs import Construct
from aws_cdk.pipelines import CodePipeline, CodePipelineSource, ShellStep
from my_pipeline.my_pipeline_app_stage import MyPipelineAppStage

class MyPipelineStack(cdk.Stack):
    def __init__(self, scope: Construct, construct_id: str, **kwargs) -> None:
        super().__init__(scope, construct_id, **kwargs)

        pipeline = CodePipeline(self, "Pipeline",
            pipeline_name="MyPipeline",
            synth=ShellStep("Synth",
                input=CodePipelineSource.git_hub("OWNER/REPO", "main"),
                commands=["npm install -g aws-cdk",
                    "python -m pip install -r requirements.txt",
                    "cdk synth"])

        pipeline.add_stage(MyPipelineAppStage(self, "test",
```

```
env=cdk.Environment(account="111111111111", region="eu-west-1"))
```

## Java

Create the new file `src/main/java/com.myorg/MyPipelineLambdaStack.java` to hold our application stack containing a Lambda function.

```
package com.myorg;

import software.constructs.Construct;
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;

import software.amazon.awscdk.services.lambda.Function;
import software.amazon.awscdk.services.lambda.Runtime;
import software.amazon.awscdk.services.lambda.InlineCode;

public class MyPipelineLambdaStack extends Stack {
    public MyPipelineLambdaStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public MyPipelineLambdaStack(final Construct scope, final String id, final
StackProps props) {
        super(scope, id, props);

        Function.Builder.create(this, "LambdaFunction")
            .runtime(Runtime.NODEJS_18_X)
            .handler("index.handler")
            .code(new InlineCode("exports.handler = _ => 'Hello, CDK';"))
            .build();
    }
}
```

Create the new file `src/main/java/com.myorg/MyPipelineAppStage.java` to hold our stage.

```
package com.myorg;

import software.constructs.Construct;
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.Stage;
import software.amazon.awscdk.StageProps;

public class MyPipelineAppStage extends Stage {
    public MyPipelineAppStage(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public MyPipelineAppStage(final Construct scope, final String id, final StageProps
props) {
        super(scope, id, props);

        Stack lambdaStack = new MyPipelineLambdaStack(this, "LambdaStack");
    }
}
```

Edit `src/main/java/com.myorg/MyPipelineStack.java` to add the stage to our pipeline.

```
package com.myorg;
```

```
import java.util.Arrays;
import software.constructs.Construct;
import software.amazon.awscdk.Environment;
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.amazon.awscdk.StageProps;
import software.amazon.awscdk.pipelines.CodePipeline;
import software.amazon.awscdk.pipelines.CodePipelineSource;
import software.amazon.awscdk.pipelines.ShellStep;

public class MyPipelineStack extends Stack {
    public MyPipelineStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public MyPipelineStack(final Construct scope, final String id, final StackProps
props) {
        super(scope, id, props);

        final CodePipeline pipeline = CodePipeline.Builder.create(this, "pipeline")
            .pipelineName("MyPipeline")
            .synth(ShellStep.Builder.create("Synth")
                .input(CodePipelineSource.gitHub("OWNER/REPO", "main"))
                .commands(Arrays.asList("npm install -g aws-cdk", "cdk synth"))
                .build())
            .build();

        pipeline.addStage(new MyPipelineAppStage(this, "test", StageProps.builder()
            .env(Environment.builder()
                .account("111111111111")
                .region("eu-west-1")
                .build())
            .build()));
    }
}
```

## C#

Create the new file `src/MyPipeline/MyPipelineLambdaStack.cs` to hold our application stack containing a Lambda function.

```
using Amazon.CDK;
using Constructs;
using Amazon.CDK.AWS.Lambda;

namespace MyPipeline
{
    class MyPipelineLambdaStack : Stack
    {
        public MyPipelineLambdaStack(Construct scope, string id, StackProps
props=null) : base(scope, id, props)
        {
            new Function(this, "LambdaFunction", new FunctionProps
            {
                Runtime = Runtime.NODEJS_18_X,
                Handler = "index.handler",
                Code = new InlineCode("exports.handler = _ => 'Hello, CDK';")
            });
        }
    }
}
```

Create the new file `src/MyPipeline/MyPipelineAppStage.cs` to hold our stage.

```
using Amazon.CDK;
using Constructs;

namespace MyPipeline
{
    class MyPipelineAppStage : Stage
    {
        public MyPipelineAppStage(Construct scope, string id, StageProps props=null) :
        base(scope, id, props)
        {
            Stack lambdaStack = new MyPipelineLambdaStack(this, "LambdaStack");
        }
    }
}
```

Edit `src/MyPipeline/MyPipelineStack.cs` to add the stage to our pipeline.

```
using Amazon.CDK;
using Constructs;
using Amazon.CDK.Pipelines;

namespace MyPipeline
{
    public class MyPipelineStack : Stack
    {
        internal MyPipelineStack(Construct scope, string id, IStackProps props =
        null) : base(scope, id, props)
        {
            var pipeline = new CodePipeline(this, "pipeline", new CodePipelineProps
            {
                PipelineName = "MyPipeline",
                Synth = new ShellStep("Synth", new ShellStepProps
                {
                    Input = CodePipelineSource.GitHub("OWNER/REPO", "main"),
                    Commands = new string[] { "npm install -g aws-cdk", "cdk synth" }
                })
            });

            pipeline.AddStage(new MyPipelineAppStage(this, "test", new StageProps
            {
                Env = new Environment
                {
                    Account = "111111111111", Region = "eu-west-1"
                }
            }));
        }
    }
}
```

Every application stage added by `addStage()` results in the addition of a corresponding pipeline stage, represented by a [StageDeployment](#) instance returned by the `addStage()` call. You can add pre-deployment or post-deployment actions to the stage by calling its `addPre()` or `addPost()` method.

#### TypeScript

```
// import { ManualApprovalStep } from 'aws-cdk-lib/pipelines';

const testingStage = pipeline.addStage(new MyPipelineAppStage(this, 'testing', {
  env: { account: '111111111111', region: 'eu-west-1' }
}));
```

```
testingStage.addPost(new ManualApprovalStep('approval'));
```

#### JavaScript

```
// const { ManualApprovalStep } = require('aws-cdk-lib/pipelines');

const testingStage = pipeline.addStage(new MyPipelineAppStage(this, 'testing', {
  env: { account: '111111111111', region: 'eu-west-1' }
}));

testingStage.addPost(new ManualApprovalStep('approval'));
```

#### Python

```
# from aws_cdk.pipelines import ManualApprovalStep

testing_stage = pipeline.add_stage(MyPipelineAppStage(self, "testing",
  env=cdk.Environment(account="111111111111", region="eu-west-1")))

testing_stage.add_post(ManualApprovalStep('approval'))
```

#### Java

```
// import software.amazon.awscdk.pipelines.StageDeployment;
// import software.amazon.awscdk.pipelines.ManualApprovalStep;

StageDeployment testingStage =
    pipeline.addStage(new MyPipelineAppStage(this, "test", StageProps.builder()
        .env(Environment.builder()
            .account("111111111111")
            .region("eu-west-1")
            .build())
        .build()));

testingStage.addPost(new ManualApprovalStep("approval"));
```

#### C#

```
var testingStage = pipeline.AddStage(new MyPipelineAppStage(this, "test", new
    StageProps
    {
        Env = new Environment
        {
            Account = "111111111111", Region = "eu-west-1"
        }
    }));

testingStage.AddPost(new ManualApprovalStep("approval"));
```

You can add stages to a [Wave](#) to deploy them in parallel, for example when deploying a stage to multiple accounts or Regions.

#### TypeScript

```
const wave = pipeline.addWave('wave');
wave.addStage(new MyApplicationStage(this, 'MyAppEU', {
  env: { account: '111111111111', region: 'eu-west-1' }
}));
wave.addStage(new MyApplicationStage(this, 'MyAppUS', {
  env: { account: '111111111111', region: 'us-west-1' }
}));
```



```
}});
```

#### JavaScript

```
const wave = pipeline.addWave('wave');
wave.addStage(new MyApplicationStage(this, 'MyAppEU', {
  env: { account: '111111111111', region: 'eu-west-1' }
}));
wave.addStage(new MyApplicationStage(this, 'MyAppUS', {
  env: { account: '111111111111', region: 'us-west-1' }
}));
```

#### Python

```
wave = pipeline.add_wave("wave")
wave.add_stage(MyApplicationStage(self, "MyAppEU",
    env=cdk.Environment(account="111111111111", region="eu-west-1")))
wave.add_stage(MyApplicationStage(self, "MyAppUS",
    env=cdk.Environment(account="111111111111", region="us-west-1")))
```

#### Java

```
// import software.amazon.awscdk.pipelines.Wave;
final Wave wave = pipeline.addWave("wave");
wave.addStage(new MyPipelineAppStage(this, "MyAppEU", StageProps.builder()
    .env(Environment.builder()
        .account("111111111111")
        .region("eu-west-1")
        .build())
    .build()));
wave.addStage(new MyPipelineAppStage(this, "MyAppUS", StageProps.builder()
    .env(Environment.builder()
        .account("111111111111")
        .region("us-west-1")
        .build())
    .build()));
```

#### C#

```
var wave = pipeline.AddWave("wave");
wave.AddStage(new MyPipelineAppStage(this, "MyAppEU", new StageProps
{
    Env = new Environment
    {
        Account = "111111111111", Region = "eu-west-1"
    }
}));
wave.AddStage(new MyPipelineAppStage(this, "MyAppUS", new StageProps
{
    Env = new Environment
    {
        Account = "111111111111", Region = "us-west-1"
    }
}));
```

## Testing deployments

You can add steps to a CDK Pipeline to validate the deployments that you're performing. For example, you can use the CDK Pipeline library's [ShellStep](#) to perform tasks such as the following:

- Trying to access a newly deployed Amazon API Gateway backed by a Lambda function
- Checking a setting of a deployed resource by issuing an AWS CLI command

In its simplest form, adding validation actions looks like this:

#### TypeScript

```
// stage was returned by pipeline.addStage

stage.addPost(new ShellStep("validate", {
  commands: ['../tests/validate.sh'],
}));
```

#### JavaScript

```
// stage was returned by pipeline.addStage

stage.addPost(new ShellStep("validate", {
  commands: ['../tests/validate.sh'],
}));
```

#### Python

```
# stage was returned by pipeline.add_stage

stage.add_post(ShellStep("validate",
  commands=['../tests/validate.sh']
))
```

#### Java

```
// stage was returned by pipeline.addStage

stage.addPost(ShellStep.Builder.create("validate")
  .commands(Arrays.asList("../tests/validate.sh"))
  .build());
```

#### C#

```
// stage was returned by pipeline.addStage

stage.AddPost(new ShellStep("validate", new ShellStepProps
{
    Commands = new string[] { "../tests/validate.sh" }
}));
```

Many AWS CloudFormation deployments result in the generation of resources with unpredictable names. Because of this, CDK Pipelines provide a way to read AWS CloudFormation outputs after a deployment. This makes it possible to pass (for example) the generated URL of a load balancer to a test action.

To use outputs, expose the `CfnOutput` object you're interested in. Then, pass it in a step's `envFromCfnOutputs` property to make it available as an environment variable within that step.

#### TypeScript

```
// given a stack lbStack that exposes a load balancer construct as loadBalancer
```

```
this.loadBalancerAddress = new cdk.CfnOutput(lbStack, 'LbAddress', {
    value: `https://${lbStack.loadBalancer.loadBalancerDnsName}/`
});

// pass the load balancer address to a shell step
stage.addPost(new ShellStep("lbaddr", {
    envFromCfnOutputs: {lb_addr: lbStack.loadBalancerAddress},
    commands: ['echo $lb_addr']
}));
```

#### JavaScript

```
// given a stack lbStack that exposes a load balancer construct as loadBalancer
this.loadBalancerAddress = new cdk.CfnOutput(lbStack, 'LbAddress', {
    value: `https://${lbStack.loadBalancer.loadBalancerDnsName}/`
});

// pass the load balancer address to a shell step
stage.addPost(new ShellStep("lbaddr", {
    envFromCfnOutputs: {lb_addr: lbStack.loadBalancerAddress},
    commands: ['echo $lb_addr']
}));
```

#### Python

```
# given a stack lb_stack that exposes a load balancer construct as load_balancer
self.load_balancer_address = cdk.CfnOutput(lb_stack, "LbAddress",
    value=f"https://{lb_stack.load_balancer.load_balancer_dns_name}/")

# pass the load balancer address to a shell step
stage.add_post(ShellStep("lbaddr",
    env_from_cfn_outputs={"lb_addr": lb_stack.load_balancer_address}
    commands=["echo $lb_addr"])))
```

#### Java

```
// given a stack lbStack that exposes a load balancer construct as loadBalancer
loadBalancerAddress = CfnOutput.Builder.create(lbStack, "LbAddress")
    .value(String.format("https://%s/",
        lbStack.loadBalancer.loadBalancerDnsName))
    .build();

stage.addPost(ShellStep.Builder.create("lbaddr")
    .envFromCfnOutputs( // Map.of requires Java 9 or later
        java.util.Map.of("lbAddr", loadBalancerAddress))
    .commands(Arrays.asList("echo $lbAddr"))
    .build());
```

#### C#

```
// given a stack lbStack that exposes a load balancer construct as loadBalancer
loadBalancerAddress = new CfnOutput(lbStack, "LbAddress", new CfnOutputProps
{
    Value = string.Format("https://{0}/", lbStack.loadBalancer.LoadBalancerDnsName)
});

stage.AddPost(new ShellStep("lbaddr", new ShellStepProps
{
    EnvFromCfnOutputs = new Dictionary<string, CfnOutput>
    {
        { "lbAddr", loadBalancerAddress }
    }
});
```

```
    },  
    Commands = new string[] { "echo $lbAddr" }  
  }));
```

You can write simple validation tests right in the `ShellStep`, but this approach becomes unwieldy when the test is more than a few lines. For more complex tests, you can bring additional files (such as complete shell scripts, or programs in other languages) into the `ShellStep` via the `inputs` property. The inputs can be any step that has an output, including a source (such as a GitHub repo) or another `ShellStep`.

Bringing in files from the source repository is appropriate if the files are directly usable in the test (for example, if they are themselves executable). In this example, we declare our GitHub repo as `source` (rather than instantiating it inline as part of the `CodePipeline`). Then, we pass this fileset to both the pipeline and the validation test.

#### TypeScript

```
const source = CodePipelineSource.github('OWNER/REPO', 'main');  
  
const pipeline = new CodePipeline(this, 'Pipeline', {  
  pipelineName: 'MyPipeline',  
  synth: new ShellStep('Synth', {  
    input: source,  
    commands: ['npm ci', 'npm run build', 'npx cdk synth']  
  })  
});  
  
const stage = pipeline.addStage(new MyPipelineAppStage(this, 'test', {  
  env: { account: '111111111111', region: 'eu-west-1' }  
}));  
  
stage.addPost(new ShellStep('validate', {  
  input: source,  
  commands: ['sh ../tests/validate.sh']  
}));
```

#### JavaScript

```
const source = CodePipelineSource.github('OWNER/REPO', 'main');  
  
const pipeline = new CodePipeline(this, 'Pipeline', {  
  pipelineName: 'MyPipeline',  
  synth: new ShellStep('Synth', {  
    input: source,  
    commands: ['npm ci', 'npm run build', 'npx cdk synth']  
  })  
});  
  
const stage = pipeline.addStage(new MyPipelineAppStage(this, 'test', {  
  env: { account: '111111111111', region: 'eu-west-1' }  
}));  
  
stage.addPost(new ShellStep('validate', {  
  input: source,  
  commands: ['sh ../tests/validate.sh']  
}));
```

#### Python

```
source = CodePipelineSource.git_hub("OWNER/REPO", "main")
```

```
pipeline = CodePipeline(self, "Pipeline",
    pipeline_name="MyPipeline",
    synth=ShellStep("Synth",
        input=source,
        commands=["npm install -g aws-cdk",
            "python -m pip install -r requirements.txt",
            "cdk synth"]))

stage = pipeline.add_stage(MyApplicationStage(self, "test",
    env=cdk.Environment(account="111111111111", region="eu-west-1")))

stage.add_post(ShellStep("validate", input=source,
    commands=["sh ../tests/validate.sh"],
))
```

#### Java

```
final CodePipelineSource source = CodePipelineSource.gitHub("OWNER/REPO", "main");

final CodePipeline pipeline = CodePipeline.Builder.create(this, "pipeline")
    .pipelineName("MyPipeline")
    .synth(ShellStep.Builder.create("Synth")
        .input(source)
        .commands(Arrays.asList("npm install -g aws-cdk", "cdk synth"))
        .build())
    .build();

final StageDeployment stage =
    pipeline.addStage(new MyPipelineAppStage(this, "test", StageProps.builder()
        .env(Environment.builder()
            .account("111111111111")
            .region("eu-west-1")
            .build())
        .build()));

stage.addPost(ShellStep.Builder.create("validate")
    .input(source)
    .commands(Arrays.asList("sh ../tests/validate.sh"))
    .build());
```

#### C#

```
var source = CodePipelineSource.GitHub("OWNER/REPO", "main");

var pipeline = new CodePipeline(this, "pipeline", new CodePipelineProps
{
    PipelineName = "MyPipeline",
    Synth = new ShellStep("Synth", new ShellStepProps
    {
        Input = source,
        Commands = new string[] { "npm install -g aws-cdk", "cdk synth" }
    })
});

var stage = pipeline.AddStage(new MyPipelineAppStage(this, "test", new StageProps
{
    Env = new Environment
    {
        Account = "111111111111", Region = "eu-west-1"
    }
}));

stage.AddPost(new ShellStep("validate", new ShellStepProps
```

```
{
    Input = source,
    Commands = new string[] { "sh ../tests/validate.sh" }
});
```

Getting the additional files from the synth step is appropriate if your tests need to be compiled, which is done as part of synthesis.

### TypeScript

```
const synthStep = new ShellStep('Synth', {
    input: CodePipelineSource.gitHub('OWNER/REPO', 'main'),
    commands: ['npm ci', 'npm run build', 'npx cdk synth'],
});

const pipeline = new CodePipeline(this, 'Pipeline', {
    pipelineName: 'MyPipeline',
    synth: synthStep
});

const stage = pipeline.addStage(new MyPipelineAppStage(this, 'test', {
    env: { account: '111111111111', region: 'eu-west-1' }
}));

// run a script that was transpiled from TypeScript during synthesis
stage.addPost(new ShellStep('validate', {
    input: synthStep,
    commands: ['node tests/validate.js']
}));
```

### JavaScript

```
const synthStep = new ShellStep('Synth', {
    input: CodePipelineSource.gitHub('OWNER/REPO', 'main'),
    commands: ['npm ci', 'npm run build', 'npx cdk synth'],
});

const pipeline = new CodePipeline(this, 'Pipeline', {
    pipelineName: 'MyPipeline',
    synth: synthStep
});

const stage = pipeline.addStage(new MyPipelineAppStage(this, "test", {
    env: { account: "111111111111", region: "eu-west-1" }
}));

// run a script that was transpiled from TypeScript during synthesis
stage.addPost(new ShellStep('validate', {
    input: synthStep,
    commands: ['node tests/validate.js']
}));
```

### Python

```
synth_step = ShellStep("Synth",
    input=CodePipelineSource.git_hub("OWNER/REPO", "main"),
    commands=["npm install -g aws-cdk",
        "python -m pip install -r requirements.txt",
        "cdk synth"])

pipeline = CodePipeline(self, "Pipeline",
```

```
        pipeline_name="MyPipeline",
        synth=synth_step)

stage = pipeline.add_stage(MyApplicationStage(self, "test",
        env=cdk.Environment(account="111111111111", region="eu-west-1")))

# run a script that was compiled during synthesis
stage.add_post(ShellStep("validate",
        input=synth_step,
        commands=["node test/validate.js"],
    ))
```

#### Java

```
final ShellStep synth = ShellStep.Builder.create("Synth")
    .input(CodePipelineSource.gitHub("OWNER/REPO", "main"))
    .commands(Arrays.asList("npm install -g aws-cdk", "cdk
synth"))
    .build();

final CodePipeline pipeline = CodePipeline.Builder.create(this, "pipeline")
    .pipelineName("MyPipeline")
    .synth(synth)
    .build();

final StageDeployment stage =
    pipeline.addStage(new MyPipelineAppStage(this, "test", StageProps.builder()
        .env(Environment.builder()
            .account("111111111111")
            .region("eu-west-1")
            .build())
        .build()));

stage.addPost(ShellStep.Builder.create("validate")
    .input(synth)
    .commands(Arrays.asList("node ./tests/validate.js"))
    .build());
```

#### C#

```
var synth = new ShellStep("Synth", new ShellStepProps
{
    Input = CodePipelineSource.GitHub("OWNER/REPO", "main"),
    Commands = new string[] { "npm install -g aws-cdk", "cdk synth" }
});

var pipeline = new CodePipeline(this, "pipeline", new CodePipelineProps
{
    PipelineName = "MyPipeline",
    Synth = synth
});

var stage = pipeline.AddStage(new MyPipelineAppStage(this, "test", new StageProps
{
    Env = new Environment
    {
        Account = "111111111111", Region = "eu-west-1"
    }
}));

stage.AddPost(new ShellStep("validate", new ShellStepProps
{
    Input = synth,
    Commands = new string[] { "node ./tests/validate.js" }
}));
```

```
}));
```

## Security notes

Any form of continuous delivery has inherent security risks. Under the AWS [Shared Responsibility Model](#), you are responsible for the security of your information in the AWS Cloud. The CDK Pipelines library gives you a head start by incorporating secure defaults and modeling best practices.

However, by its very nature, a library that needs a high level of access to fulfill its intended purpose cannot assure complete security. There are many attack vectors outside of AWS and your organization.

In particular, keep in mind the following:

- Be mindful of the software you depend on. Vet all third-party software you run in your pipeline, because it can change the infrastructure that gets deployed.
- Use dependency locking to prevent accidental upgrades. CDK Pipelines respects `package-lock.json` and `yarn.lock` to make sure that your dependencies are the ones you expect.
- CDK Pipelines runs on resources created in your own account, and the configuration of those resources is controlled by developers submitting code through the pipeline. Therefore, CDK Pipelines by itself cannot protect against malicious developers trying to bypass compliance checks. If your threat model includes developers writing CDK code, you should have external compliance mechanisms in place like [AWS CloudFormation Hooks](#) (preventive) or [AWS Config](#) (reactive) that the AWS CloudFormation Execution Role does not have permissions to disable.
- Credentials for production environments should be short-lived. After bootstrapping and initial provisioning, there is no need for developers to have account credentials at all. Changes can be deployed through the pipeline. Reduce the possibility of credentials leaking by not needing them in the first place.

## Troubleshooting

The following issues are commonly encountered while getting started with CDK Pipelines.

### Pipeline: Internal Failure

```
CREATE_FAILED | AWS::CodePipeline::Pipeline | Pipeline/Pipeline  
Internal Failure
```

Check your GitHub access token. It might be missing, or might not have the permissions to access the repository.

### Key: Policy contains a statement with one or more invalid principals

```
CREATE_FAILED | AWS::KMS::Key | Pipeline/Pipeline/ArtifactsBucketEncryptionKey  
Policy contains a statement with one or more invalid principals.
```

One of the target environments has not been bootstrapped with the new bootstrap stack. Make sure all your target environments are bootstrapped.

### Stack is in ROLLBACK\_COMPLETE state and can not be updated.

```
Stack STACK_NAME is in ROLLBACK_COMPLETE state and can not be updated. (Service:  
AmazonCloudFormation; Status Code: 400; Error Code: ValidationError; Request  
ID: ...)
```



The stack failed its previous deployment and is in a non-retryable state. Delete the stack from the AWS CloudFormation console and retry the deployment.

## AWS CDK policy validation at synthesis time

### Policy validation

If you or your organization use any policy validation tool, such as [AWS CloudFormation Guard](#) or [OPA](#), to define constraints on your AWS CloudFormation template, you can integrate them with the AWS CDK at synthesis time. By using the appropriate policy validation plugin, you can make the AWS CDK application check the generated AWS CloudFormation template against your policies immediately after synthesis. If there are any violations, the synthesis will fail and a report will be printed to the console.

The validation performed by the AWS CDK at synthesis time validate controls at one point in the deployment lifecycle, but they can't affect actions that occur outside synthesis. Examples include actions taken directly in the console or via service APIs. They aren't resistant to alteration of AWS CloudFormation templates after synthesis. Some other mechanism to validate the same rule set more authoritatively should be set up independently, like [AWS CloudFormation hooks](#) or [AWS Config](#). Nevertheless, the ability of the AWS CDK to evaluate the rule set during development is still useful as it will improve detection speed and developer productivity.

The goal of AWS CDK policy validation is to minimize the amount of set up needed during development, and make it as easy as possible.

#### Note

This feature is considered experimental, and both the plugin API and the format of the validation report are subject to change in the future.

#### Topics

- [For application developers \(p. 305\)](#)
- [For plugin authors \(p. 307\)](#)

### For application developers

To use one or more validation plugins in your application, use the `policyValidationBeta1` property of `Stage`:

```
import { CfnGuardValidator } from '@cdklabs/cdk-validator-cfnguard';
const app = new App({
  policyValidationBeta1: [
    new CfnGuardValidator()
  ],
});
// only apply to a particular stage
const prodStage = new Stage(app, 'ProdStage', {
  policyValidationBeta1: [...],
});
```

Immediately after synthesis, all plugins registered this way will be invoked to validate all the templates generated in the scope you defined. In particular, if you register the templates in the `App` object, all templates will be subject to validation.

#### Warning

Other than modifying the cloud assembly, plugins can do anything that your AWS CDK application can. They can read data from the filesystem, access the network etc. It's your responsibility as the consumer of a plugin to verify that it's secure to use.

## AWS CloudFormation Guard plugin

Using the [CfnGuardValidator](#) plugin allows you to use [AWS CloudFormation Guard](#) to perform policy validations. The CfnGuardValidator plugin comes with a select set of [AWS Control Tower proactive controls](#) built in. The current set of rules can be found in the [project documentation](#). As mentioned in [Policy validation \(p. 305\)](#), we recommend that organizations set up a more authoritative method of validation using [AWS CloudFormation hooks](#).

For [AWS Control Tower](#) customers, these same proactive controls can be deployed across your organization. When you enable AWS Control Tower proactive controls in your AWS Control Tower environment, the controls can stop the deployment of non-compliant resources deployed via AWS CloudFormation. For more information about managed proactive controls and how they work, see the [AWS Control Tower documentation](#).

These AWS CDK bundled controls and managed AWS Control Tower proactive controls are best used together. In this scenario you can configure this validation plugin with the same proactive controls that are active in your AWS Control Tower cloud environment. You can then quickly gain confidence that your AWS CDK application will pass the AWS Control Tower controls by running `cdk synth` locally.

## Validation Report

When you synthesize the AWS CDK app the validator plugins will be called and the results will be printed. An example report is showing below.

```
Validation Report (CfnGuardValidator)
-----
(Summary)
#####
# Status      # failure      #
#####
# Plugin      # CfnGuardValidator  #
#####
(Violations)
Ensure S3 Buckets are encrypted with a KMS CMK (1 occurrences)
Severity: medium
Occurrences:

- Construct Path: MyStack/MyCustomL3Construct/Bucket
- Stack Template Path: ./cdk.out/MyStack.template.json
- Creation Stack:
  ### MyStack (MyStack)
  # Library: aws-cdk-lib.Stack
  # Library Version: 2.50.0
  # Location: Object.<anonymous> (/home/johndoe/tmp/cdk-tmp-app/src/
main.ts:25:20)
  ### MyCustomL3Construct (MyStack/MyCustomL3Construct)
  # Library: N/A - (Local Construct)
  # Library Version: N/A
  # Location: new MyStack (/home/johndoe/tmp/cdk-tmp-app/src/main.ts:15:20)
  ### Bucket (MyStack/MyCustomL3Construct/Bucket)
  # Library: aws-cdk-lib/aws-s3.Bucket
  # Library Version: 2.50.0
  # Location: new MyCustomL3Construct (/home/johndoe/tmp/cdk-tmp-app/
src/main.ts:9:20)
  - Resource Name: my-bucket
  - Locations:
    > BucketEncryption/ServerSideEncryptionConfiguration/0/ServerSideEncryptionByDefault/
SSEAlgorithm
  Recommendation: Missing value for key `SSEAlgorithm` - must specify `aws:kms`
  How to fix:
    > Add to construct properties for `cdk-app/MyStack/Bucket`
    `encryption: BucketEncryption.KMS`
```

Validation failed. See above reports for details

By default, the report will be printed in a human readable format. If you want a report in JSON format, enable it using the `@aws-cdk/core:validationReportJson` via the CLI or passing it directly to the application:

```
const app = new App({
  context: { '@aws-cdk/core:validationReportJson': true },
});
```

Alternatively, you can set this context key-value pair using the `cdk.json` or `cdk.context.json` files in your project directory (see [Runtime context \(p. 185\)](#)).

If you choose the JSON format, the AWS CDK will print the policy validation report to a file called `policy-validation-report.json` in the cloud assembly directory. For the default, human-readable format, the report will be printed to the standard output.

## For plugin authors

### Plugins

The AWS CDK core framework is responsible for registering and invoking plugins and then displaying the formatted validation report. The responsibility of the plugin is to act as the translation layer between the AWS CDK framework and the policy validation tool. A plugin can be created in any language supported by AWS CDK. If you are creating a plugin that might be consumed by multiple languages then it's recommended that you create the plugin in TypeScript so that you can use JSII to publish the plugin in each AWS CDK language.

### Creating plugins

The communication protocol between the AWS CDK core module and your policy tool is defined by the `IPolicyValidationPluginBeta1` interface. To create a new plugin you must write a class that implements this interface. There are two things you need to implement: the plugin name (by overriding the `name` property), and the `validate()` method.

The framework will call `validate()`, passing an `IValidationContextBeta1` object. The location of the templates to be validated is given by `templatePaths`. The plugin should return an instance of `ValidationPluginReportBeta1`. This object represents the report that the user will receive at the end of the synthesis.

```
validate(context: IPolicyValidationContextBeta1): PolicyValidationReportBeta1 {
  // First read the templates using context.templatePaths...
  // ...then perform the validation, and then compose and return the report.
  // Using hard-coded values here for better clarity:
  return {
    success: false,
    violations: [{
      ruleName: 'CKV_AWS_117',
      description: 'Ensure that AWS Lambda function is configured inside a VPC',
      fix: 'https://docs.bridgecrew.io/docs/ensure-that-aws-lambda-function-is-configured-inside-a-vpc-1',
      violatingResources: [{
        resourceName: 'MyFunction3BAA72D1',
        templatePath: '/home/johndoe/myapp/cdk.out/MyService.template.json',
        locations: 'Properties/VpcConfig',
      }],
    }],
  },
}
```

```
};  
}
```

Note that plugins aren't allowed to modify anything in the cloud assembly. Any attempt to do so will result in synthesis failure.

If your plugin depends on an external tool, keep in mind that some developers may not have that tool installed in their workstations yet. To minimize friction, we highly recommend that you provide some installation script along with your plugin package, to automate the whole process. Better yet, run that script as part of the installation of your package. With npm, for example, you can add it to the `postinstall` [script](#) in the `package.json` file.

## Handling Exemptions

If your organization has a mechanism for handling exemptions, it can be implemented as part of the validator plugin.

An example scenario to illustrate a possible exemption mechanism:

- An organization has a rule that public Amazon S3 buckets aren't allowed, *except* for under certain scenarios.
- A developer is creating an Amazon S3 bucket that falls under one of those scenarios and requests an exemption (create a ticket for example).
- Security tooling knows how to read from the internal system that registers exemptions

In this scenario the developer would request an exception in the internal system and then will need some way of "registering" that exception. Adding on to the guard plugin example, you could create a plugin that handles exemptions by filtering out the violations that have a matching exemption in an internal ticketing system.

See the existing plugins for example implementations.

- [@cdklabs/cdk-validator-cfnguard](#)

# AWS CDK tools

This section contains information about the AWS CDK tools listed below.

## Topics

- [AWS CDK Toolkit \(cdk command\) \(p. 309\)](#)
- [AWS Toolkit for Visual Studio Code \(p. 324\)](#)
- [AWS SAM integration \(p. 324\)](#)

## AWS CDK Toolkit (cdk command)

The AWS CDK Toolkit, the CLI command `cdk`, is the primary tool for interacting with your AWS CDK app. It executes your app, interrogates the application model you defined, and produces and deploys the AWS CloudFormation templates generated by the AWS CDK. It also provides other features useful for creating and working with AWS CDK projects. This topic contains information about common use cases of the CDK Toolkit.

The AWS CDK Toolkit is installed with the Node Package Manager. In most cases, we recommend installing it globally.

```
npm install -g aws-cdk          # install latest version
npm install -g aws-cdk@X.YY.Z  # install specific version
```

### Tip

If you regularly work with multiple versions of the AWS CDK, consider installing a matching version of the AWS CDK Toolkit in individual CDK projects. To do this, omit `-g` from the `npm install` command. Then use `npx aws-cdk` to invoke it. This runs the local version if one exists, falling back to a global version if not.

## Toolkit commands

All CDK Toolkit commands start with `cdk`, which is followed by a subcommand (`list`, `synthesize`, `deploy`, etc.). Some subcommands have a shorter version (`ls`, `synth`, etc.) that is equivalent. Options and arguments follow the subcommand in any order. The available commands are summarized here.

Command	Function
<code>cdk list (ls)</code>	Lists the stacks in the app
<code>cdk synthesize (synth)</code>	Synthesizes and prints the CloudFormation template for one or more specified stacks
<code>cdk bootstrap</code>	Deploys the CDK Toolkit staging stack; see <a href="#">the section called “Bootstrapping” (p. 195)</a>
<code>cdk deploy</code>	Deploys one or more specified stacks
<code>cdk destroy</code>	Destroys one or more specified stacks

Command	Function
<code>cdk diff</code>	Compares the specified stack and its dependencies with the deployed stacks or a local CloudFormation template
<code>cdk metadata</code>	Displays metadata about the specified stack
<code>cdk init</code>	Creates a new CDK project in the current directory from a specified template
<code>cdk context</code>	Manages cached context values
<code>cdk docs (doc)</code>	Opens the CDK API Reference in your browser
<code>cdk doctor</code>	Checks your CDK project for potential problems

For the options available for each command, see [the section called “Built-in help” \(p. 310\)](#).

## Specifying options and their values

Command line options begin with two hyphens (--). Some frequently used options have single-letter synonyms that begin with a single hyphen (for example, --app has a synonym -a). The order of options in an AWS CDK Toolkit command is not important.

All options accept a value, which must follow the option name. The value may be separated from the name by white space or by an equals sign =. The following two options are equivalent.

```
--toolkit-stack-name MyBootstrapStack  
--toolkit-stack-name=MyBootstrapStack
```

Some options are flags (Booleans). You may specify true or false as their value. If you do not provide a value, the value is taken to be true. You may also prefix the option name with no- to imply false.

```
# sets staging flag to true  
--staging  
--staging=true  
--staging true  
  
# sets staging flag to false  
--no-staging  
--staging=false  
--staging false
```

A few options, namely --context, --parameters, --plugin, --tags, and --trust, may be specified more than once to specify multiple values. These are noted as having [array] type in the CDK Toolkit help. For example:

```
cdk bootstrap --tags costCenter=0123 --tags responsibleParty=jdoe
```

## Built-in help

The AWS CDK Toolkit has integrated help. You can see general help about the utility and a list of the provided subcommands by issuing:

```
cdk --help
```

To see help for a particular subcommand, for example `deploy`, specify it before the `--help` flag.

```
cdk deploy --help
```

Issue `cdk version` to display the version of the AWS CDK Toolkit. Provide this information when requesting support.

## Version reporting

To gain insight into how the AWS CDK is used, the constructs used by AWS CDK applications are collected and reported by using a resource identified as `AWS::CDK::Metadata`. This resource is added to AWS CloudFormation templates, and can easily be reviewed. This information can also be used by AWS to identify stacks using a construct with known security or reliability issues. It can also be used to contact their users with important information.

### Note

Before version 1.93.0, the AWS CDK reported the names and versions of the modules loaded during synthesis, instead of the constructs used in the stack.

By default, the AWS CDK reports the use of constructs in the following NPM modules that are used in the stack:

- AWS CDK core module
- AWS Construct Library modules
- AWS Solutions Constructs module
- AWS Render Farm Deployment Kit module

The `AWS::CDK::Metadata` resource looks something like the following.

```
CDKMetadata:
  Type: "AWS::CDK::Metadata"
  Properties:
    Analytics: "v2:deflate64:H4sIAND9SGAAAZXKS5AMBAA0L1b2PdZBYnEAdio3RglY60zQi7u6TWL/
XKmNU1xeQSOKwaPTBqrNhwEWU3hGHICzK0dWWFAxoL/Fd8mVnK+QkS/0X6BdjnCdgM00QKWz
+AqqLDt2Y3YMnLYWwAAAA="
```

The `Analytics` property is a gzipped, base64-encoded, prefix-encoded list of the constructs in the stack.

To opt out of version reporting, use one of the following methods:

- Use the `cdk` command with the `--no-version-reporting` argument to opt out for a single command.

```
cdk --no-version-reporting synth
```

Remember, the AWS CDK Toolkit synthesizes fresh templates before deploying, so you should also add `--no-version-reporting` to `cdk deploy` commands.

- Set **versionReporting to false** in `./cdk.json` or `~/cdk.json`. This opts out unless you opt in by specifying `--version-reporting` on an individual command.

```
{
  "app": "...",
  "versionReporting": false
}
```

## Authentication with AWS

There are different ways in which you can configure programmatic access to AWS resources, depending on the environment and the AWS access available to you.

To choose your method of authentication and configure it for the CDK Toolkit, see [Authentication and access](#) in the *AWS SDKs and Tools Reference Guide*.

The recommended approach for new users developing locally, who are not given a method of authentication by their employer, is to set up AWS IAM Identity Center (successor to AWS Single Sign-On). This method includes installing the AWS CLI for ease of configuration and for regularly signing in to the AWS access portal. If you choose this method, your environment should contain the following elements after you complete the procedure for [IAM Identity Center authentication](#) in the *AWS SDKs and Tools Reference Guide*:

- The AWS CLI, which you use to start an AWS access portal session before you run your application.
- A [shared AWSconfig file](#) having a [default] profile with a set of configuration values that can be referenced from the AWS CDK. To find the location of this file, see [Location of the shared files](#) in the *AWS SDKs and Tools Reference Guide*.
- The shared config file sets the [region](#) setting. This sets the default AWS Region the AWS CDK and CDK Toolkit use for AWS requests.
- The CDK Toolkit uses the profile's [SSO token provider configuration](#) to acquire credentials before sending requests to AWS. The `sso_role_name` value, which is an IAM role connected to an IAM Identity Center permission set, should allow access to the AWS services used in your application.

The following sample config file shows a default profile set up with SSO token provider configuration. The profile's `sso_session` setting refers to the named [sso-session section](#). The `sso-session` section contains settings to initiate an AWS access portal session.

```
[default]
sso_session = my-sso
sso_account_id = 111122223333
sso_role_name = SampleRole
region = us-east-1
output = json

[sso-session my-sso]
sso_region = us-east-1
sso_start_url = https://provided-domain.awsapps.com/start
sso_registration_scopes = sso:account:access
```

## Start an AWS access portal session

Before accessing AWS services, you need an active AWS access portal session for the CDK Toolkit to use IAM Identity Center authentication to resolve credentials. Depending on your configured session lengths, your access will eventually expire and the CDK Toolkit will encounter an authentication error. Run the following command in the AWS CLI to sign in to the AWS access portal.

```
aws sso login
```

If your SSO token provider configuration is using a named profile instead of the default profile, the command is `aws sso login --profile NAME`. Also specify this profile when issuing `cdk` commands using the `--profile` option or the `AWS_PROFILE` environment variable.

To test if you already have an active session, run the following AWS CLI command.



```
aws sts get-caller-identity
```

The response to this command should report the IAM Identity Center account and permission set configured in the shared config file.

**Note**

If you already have an active AWS access portal session and run `aws sso login`, you will not be required to provide credentials.

The sign in process may prompt you to allow the AWS CLI access to your data. Since the AWS CLI is built on top of the SDK for Python, permission messages may contain variations of the `botocore` name.

## Specifying Region and other configuration

The CDK Toolkit needs to know the AWS Region that you're deploying into and how to authenticate with AWS. This is needed for deployment operations and to retrieve context values during synthesis. Together, your account and Region make up the *environment*.

Region may be specified using environment variables or in configuration files. These are the same variables and files used by other AWS tools such as the AWS CLI and the various AWS SDKs. The CDK Toolkit looks for this information in the following order.

- The `AWS_DEFAULT_REGION` environment variable.
- A named profile defined in the standard AWS config file and specified using the `--profile` option on `cdk` commands.
- The `[default]` section of the standard AWS config file.

Besides specifying AWS authentication and a Region in the `[default]` section, you can also add one or more `[profile NAME]` sections, where *NAME* is the name of the profile. For more information about named profiles, see [Shared config and credentials files](#) in the *AWS SDKs and Tools Reference Guide*.

The standard AWS config file is located at `~/.aws/config` (macOS/Linux) or `%USERPROFILE%\aws\config` (Windows). For details and alternate locations, see [Location of the shared config and credentials files](#) in the *AWS SDKs and Tools Reference Guide*.

The environment that you specify in your AWS CDK app by using the stack's `env` property is used during synthesis. It's used to generate an environment-specific AWS CloudFormation template, and during deployment, it overrides the account or Region specified by one of the preceding methods. For more information, see [the section called "Environments" \(p. 114\)](#).

**Note**

The AWS CDK uses credentials from the same source files as other AWS tools and SDKs, including the [AWS Command Line Interface](#). However, the AWS CDK might behave somewhat differently from these tools. It uses the AWS SDK for JavaScript under the hood. For complete details on setting up credentials for the AWS SDK for JavaScript, see [Setting credentials](#).

You may optionally use the `--role-arn` (or `-r`) option to specify the ARN of an IAM role that should be used for deployment. This role must be assumable by the AWS account being used.

## Specifying the app command

Many features of the CDK Toolkit require one or more AWS CloudFormation templates be synthesized, which in turn requires running your application. The AWS CDK supports programs written in a variety of languages. Therefore, it uses a configuration option to specify the exact command necessary to run your app. This option can be specified in two ways.

First, and most commonly, it can be specified using the `app` key inside the file `cdk.json`. This is in the main directory of your AWS CDK project. The CDK Toolkit provides an appropriate command when creating a new project with `cdk init`. Here is the `cdk.json` from a fresh TypeScript project, for instance.

```
{
  "app": "npx ts-node bin/hello-cdk.ts"
}
```

The CDK Toolkit looks for `cdk.json` in the current working directory when attempting to run your app. Because of this, you might keep a shell open in your project's main directory for issuing CDK Toolkit commands.

The CDK Toolkit also looks for the `app` key in `~/.cdk.json` (that is, in your home directory) if it can't find it in `./cdk.json`. Adding the `app` command here can be useful if you usually work with CDK code in the same language.

If you are in some other directory, or to run your app using a command other than the one in `cdk.json`, use the `--app` (or `-a`) option to specify it.

```
cdk --app "npx ts-node bin/hello-cdk.ts" ls
```

When deploying, you may also specify a directory containing synthesized cloud assemblies, such as `cdk.out`, as the value of `--app`. The specified stacks are deployed from this directory; the app is not synthesized.

## Specifying stacks

Many CDK Toolkit commands (for example, `cdk deploy`) work on stacks defined in your app. If your app contains only one stack, the CDK Toolkit assumes you mean that one if you don't specify a stack explicitly.

Otherwise, you must specify the stack or stacks you want to work with. You can do this by specifying the desired stacks by ID individually on the command line. Recall that the ID is the value specified by the second argument when you instantiate the stack.

```
cdk synth PipelineStack LambdaStack
```

You may also use wildcards to specify IDs that match a pattern.

- `?` matches any single character
- `*` matches any number of characters (`*` alone matches all stacks)
- `**` matches everything in a hierarchy

You may also use the `--all` option to specify all stacks.

If your app uses [CDK Pipelines \(p. 282\)](#), the CDK Toolkit understands your stacks and stages as a hierarchy. Also, the `--all` option and the `*` wildcard only match top-level stacks. To match all the stacks, use `**`. Also use `**` to indicate all the stacks under a particular hierarchy.

When using wildcards, enclose the pattern in quotes, or escape the wildcards with `\`. If you don't, your shell may try to expand the pattern to the names of files in the current directory. At best, this won't do what you expect; at worst, you could deploy stacks you didn't intend to. This isn't strictly necessary on Windows because `cmd.exe` does not expand wildcards, but is good practice nonetheless.

```
cdk synth "**Stack"      # PipelineStack, LambdaStack, etc.  
cdk synth 'Stack?'      # StackA, StackB, Stack1, etc.  
cdk synth \"*\"          # All stacks in the app, or all top-level stacks in a CDK Pipelines  
app  
cdk synth \"**\"          # All stacks in a CDK Pipelines app  
cdk synth 'PipelineStack/Prod/**' # All stacks in Prod stage in a CDK Pipelines app
```

### Note

The order in which you specify the stacks is not necessarily the order in which they will be processed. The AWS CDK Toolkit accounts for dependencies between stacks when deciding the order in which to process them. For example, let's say that one stack uses a value produced by another (such as the ARN of a resource defined in the second stack). In this case, the second stack is synthesized before the first one because of this dependency. You can add dependencies between stacks manually using the stack's [addDependency\(\)](#) method.

## Bootstrapping your AWS environment

Deploying stacks with the CDK requires special dedicated AWS CDK resources to be provisioned. The `cdk bootstrap` command creates the necessary resources for you. You only need to bootstrap if you are deploying a stack that requires these dedicated resources. See [the section called “Bootstrapping” \(p. 195\)](#) for details.

```
cdk bootstrap
```

If issued with no arguments, as shown here, the `cdk bootstrap` command synthesizes the current app and bootstraps the environments its stacks will be deployed to. If the app contains environment-agnostic stacks, which don't explicitly specify an environment, the default account and Region are bootstrapped, or the environment specified using `--profile`.

Outside of an app, you must explicitly specify the environment to be bootstrapped. You may also do so to bootstrap an environment that's not specified in your app or local AWS profile. Credentials must be configured (e.g. in `~/.aws/credentials`) for the specified account and Region. You may specify a profile that contains the required credentials.

```
cdk bootstrap ACCOUNT-NUMBER/REGION # e.g.  
cdk bootstrap 1111111111/us-east-1  
cdk bootstrap --profile test 1111111111/us-east-1
```

### Important

Each environment (account/region combination) to which you deploy such a stack must be bootstrapped separately.

You may incur AWS charges for what the AWS CDK stores in the bootstrapped resources. Additionally, if you use `-bootstrap-customer-key`, an AWS KMS key will be created, which also incurs charges per environment.

### Note

Earlier versions of the bootstrap template created a KMS key by default. To avoid charges, re-bootstrap using `--no-bootstrap-customer-key`.

### Note

CDK Toolkit v2 does not support the original bootstrap template, dubbed the legacy template, used by default with CDK v1.

### Important

The modern bootstrap template effectively grants the permissions implied by the `--cloudformation-execution-policies` to any AWS account in the `--trust` list. By default,

this extends permissions to read and write to any resource in the bootstrapped account. Make sure to [configure the bootstrapping stack \(p. 198\)](#) with policies and trusted accounts that you are comfortable with.

## Creating a new app

To create a new app, create a directory for it, then, inside the directory, issue `cdk init`.

```
mkdir my-cdk-app
cd my-cdk-app
cdk init TEMPLATE --language LANGUAGE
```

The supported languages (*LANGUAGE*) are:

Code	Language
typescript	TypeScript
javascript	JavaScript
python	Python
java	Java
csharp	C#

*TEMPLATE* is an optional template. If the desired template is *app*, the default, you may omit it. The available templates are:

Template	Description
app (default)	Creates an empty AWS CDK app.
sample-app	Creates an AWS CDK app with a stack containing an Amazon SQS queue and an Amazon SNS topic.

The templates use the name of the project folder to generate names for files and classes inside your new app.

## Listing stacks

To see a list of the IDs of the stacks in your AWS CDK application, enter one of the following equivalent commands:

```
cdk list
cdk ls
```

If your application contains [CDK Pipelines \(p. 282\)](#) stacks, the CDK Toolkit displays stack names as paths according to their location in the pipeline hierarchy. (For example, `PipelineStack`, `PipelineStack/Prod`, and `PipelineStack/Prod/MyService`.)

If your app contains many stacks, you can specify full or partial stack IDs of the stacks to be listed. For more information, see [the section called “Specifying stacks” \(p. 314\)](#).

Add the `--long` flag to see more information about the stacks, including the stack names and their environments (AWS account and Region).

## Synthesizing stacks

The `cdk synthesize` command (almost always abbreviated `synth`) synthesizes a stack defined in your app into a CloudFormation template.

```
cdk synth          # if app contains only one stack
cdk synth MyStack
cdk synth Stack1 Stack2
cdk synth "*"      # all stacks in app
```

### Note

The CDK Toolkit actually runs your app and synthesizes fresh templates before most operations (such as when deploying or comparing stacks). These templates are stored by default in the `cdk.out` directory. The `cdk synth` command simply prints the generated templates for one or more specified stacks.

See `cdk synth --help` for all available options. A few of the most frequently used options are covered in the following section.

## Specifying context values

Use the `--context` or `-c` option to pass [runtime context \(p. 185\)](#) values to your CDK app.

```
# specify a single context value
cdk synth --context key=value MyStack

# specify multiple context values (any number)
cdk synth --context key1=value1 --context key2=value2 MyStack
```

When deploying multiple stacks, the specified context values are normally passed to all of them. If you want, you can specify different values for each stack by prefixing the stack name to the context value.

```
# different context values for each stack
cdk synth --context Stack1:key=value Stack2:key=value Stack1 Stack2
```

## Specifying display format

By default, the synthesized template is displayed in YAML format. Add the `--json` flag to display it in JSON format instead.

```
cdk synth --json MyStack
```

## Specifying output directory

Add the `--output (-o)` option to write the synthesized templates to a directory other than `cdk.out`.

```
cdk synth --output=~/templates
```

## Deploying stacks

The `cdk deploy` subcommand deploys one or more specified stacks to your AWS account.

```
cdk deploy          # if app contains only one stack
cdk deploy MyStack
cdk deploy Stack1 Stack2
cdk deploy "*"      # all stacks in app
```

### Note

The CDK Toolkit runs your app and synthesizes fresh AWS CloudFormation templates before deploying anything. Therefore, most command line options you can use with `cdk synth` (for example, `--context`) can also be used with `cdk deploy`.

See `cdk deploy --help` for all available options. A few of the most useful options are covered in the following section.

## Skipping synthesis

The **cdk deploy** command normally synthesizes your app's stacks before deploying to make sure that the deployment reflects the latest version of your app. If you know that you haven't changed your code since your last **cdk synth**, you can suppress the redundant synthesis step when deploying. To do so, specify your project's `cdk.out` directory in the **--app** option.

```
cdk deploy --app cdk.out StackOne StackTwo
```

## Disabling rollback

AWS CloudFormation has the ability to roll back changes so that deployments are atomic. This means that they either succeed or fail as a whole. The AWS CDK inherits this capability because it synthesizes and deploys AWS CloudFormation templates.

Rollback makes sure that your resources are in a consistent state at all times, which is vital for production stacks. However, while you're still developing your infrastructure, some failures are inevitable, and rolling back failed deployments can slow you down.

For this reason, the CDK Toolkit lets you disable rollback by adding `--no-rollback` to your `cdk deploy` command. With this flag, failed deployments are not rolled back. Instead, resources deployed before the failed resource remain in place, and the next deployment starts with the failed resource. You'll spend a lot less time waiting for deployments and a lot more time developing your infrastructure.

## Hot swapping

Use the `--hotswap` flag with `cdk deploy` to attempt to update your AWS resources directly instead of generating an AWS CloudFormation change set and deploying it. Deployment falls back to AWS CloudFormation deployment if hot swapping is not possible.

Currently hot swapping supports Lambda functions, Step Functions state machines, and Amazon ECS container images. The `--hotswap` flag also disables rollback (i.e., implies `--no-rollback`).

### Important

Hot-swapping is not recommended for production deployments.

## Watch mode

The CDK Toolkit's watch mode ( **cdk deploy --watch**, or **cdk watch** for short) continuously monitors your CDK app's source files and assets for changes. It immediately performs a deployment of the specified stacks when a change is detected.

By default, these deployments use the `--hotswap` flag, which fast-tracks deployment of changes to Lambda functions. It also falls back to deploying through AWS CloudFormation if you have

changed infrastructure configuration. To have `cdk watch` always perform full AWS CloudFormation deployments, add the `--no-hotswap` flag to `cdk watch`.

Any changes made while `cdk watch` is already performing a deployment are combined into a single deployment, which begins as soon as the in-progress deployment is complete.

Watch mode uses the "watch" key in the project's `cdk.json` to determine which files to monitor. By default, these files are your application files and assets, but this can be changed by modifying the "include" and "exclude" entries in the "watch" key. The following `cdk.json` file shows an example of these entries.

```
{
  "app": "mvn -e -q compile exec:java",
  "watch": {
    "include": "src/main/**",
    "exclude": "target/"
  }
}
```

`cdk watch` executes the "build" command from `cdk.json` to build your app before synthesis. If your deployment requires any commands to build or package your Lambda code (or anything else that's not in your CDK app), add it here.

Git-style wildcards, both `*` and `**`, can be used in the "watch" and "build" keys. Each path is interpreted relative to the parent directory of `cdk.json`. The default value of include is `**/*`, meaning all files and directories in the project root directory. exclude is optional.

### Important

Watch mode is not recommended for production deployments.

## Specifying AWS CloudFormation parameters

The AWS CDK Toolkit supports specifying AWS CloudFormation [parameters \(p. 151\)](#) at deployment. You may provide these on the command line following the `--parameters` flag.

```
cdk deploy MyStack --parameters uploadBucketName=UploadBucket
```

To define multiple parameters, use multiple `--parameters` flags.

```
cdk deploy MyStack --parameters uploadBucketName=UpBucket --parameters
downloadBucketName=DownBucket
```

If you are deploying multiple stacks, you can specify a different value of each parameter for each stack. To do so, prefix the name of the parameter with the stack name and a colon. Otherwise, the same value is passed to all stacks.

```
cdk deploy MyStack YourStack --parameters MyStack:uploadBucketName=UploadBucket --
parameters YourStack:uploadBucketName=UpBucket
```

By default, the AWS CDK retains values of parameters from previous deployments and uses them in later deployments if they are not specified explicitly. Use the `--no-previous-parameters` flag to require all parameters to be specified.

## Specifying outputs file

If your stack declares AWS CloudFormation outputs, these are normally displayed on the screen at the conclusion of deployment. To write them to a file in JSON format, use the `--outputs-file` flag.

```
cdk deploy --outputs-file outputs.json MyStack
```

## Security-related changes

To protect you against unintended changes that affect your security posture, the AWS CDK Toolkit prompts you to approve security-related changes before deploying them. You can specify the level of change that requires approval:

```
cdk deploy --require-approval LEVEL
```

*LEVEL* can be one of the following:

Term	Meaning
never	Approval is never required
any-change	Requires approval on any IAM or security-group-related change
broadening (default)	Requires approval when IAM statements or traffic rules are added; removals don't require approval

The setting can also be configured in the `cdk.json` file.

```
{
  "app": "...",
  "requireApproval": "never"
}
```

## Comparing stacks

The `cdk diff` command compares the current version of a stack (and its dependencies) defined in your app with the already-deployed versions, or with a saved AWS CloudFormation template, and displays a list of changes.

```
Stack HelloCdkStack
IAM Statement Changes
#####
#   # Resource                                # Effect # Action                                # Principal
#   # Condition #
#####
# + # ${Custom::S3AutoDeleteObject} # Allow # sts:AssumeRole                                #
#   # Service:lambda.amazonaws.com #
#   # sCustomResourceProvider/Role #
#   #
#   # .Arn} #
#   #
#####
# + # ${MyFirstBucket.Arn} # Allow # s3:DeleteObject*                                # AWS:
#   # ${Custom::S3AutoDeleteOb #
#   # ${MyFirstBucket.Arn}/* # # s3:GetBucket*                                #
#   # jectsCustomResourceProvider/ # #
#   # # # s3:GetObject*                                # Role.Arn}
#   # # #
#   # # # s3:List*                                #
#   # #
#####
```



```
IAM Policy Changes
#####
#   # Resource                                     # Managed Policy ARN
#
#####
# + # ${Custom::S3AutoDeleteObjectsCustomResourceProvider/Ro # {"Fn::Sub": "arn:
${AWS::Partition}:iam::aws:policy/serv #
#   # le}                                     # ice-role/
AWSLambdaBasicExecutionRole"}
#####
(NOTE: There may be security-related changes not in this list. See https://github.com/aws/
aws-cdk/issues/1299)

Parameters
[+] Parameter
  AssetParameters/4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392/S3Bucket
  AssetParameters4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392S3BucketBF7A7F3F:
  {"Type": "String", "Description": "S3 bucket for asset
  \"4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392\""}
[+] Parameter
  AssetParameters/4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392/
  S3VersionKey
  AssetParameters4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392S3VersionKeyFAF93626:
  {"Type": "String", "Description": "S3 key for asset version
  \"4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392\""}
[+] Parameter
  AssetParameters/4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392/
  ArtifactHash
  AssetParameters4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392ArtifactHashE56CD69A:
  {"Type": "String", "Description": "Artifact hash for asset
  \"4cd61014b71160e8c66fe167e43710d5ba068b80b134e9bd84508cf9238b2392\""}

Resources
[+] AWS::S3::BucketPolicy MyFirstBucket/Policy MyFirstBucketPolicy3243DEFD
[+] Custom::S3AutoDeleteObjects MyFirstBucket/AutoDeleteObjectsCustomResource
  MyFirstBucketAutoDeleteObjectsCustomResourceC52FCF6E
[+] AWS::IAM::Role Custom::S3AutoDeleteObjectsCustomResourceProvider/Role
  CustomS3AutoDeleteObjectsCustomResourceProviderRole3B1BD092
[+] AWS::Lambda::Function Custom::S3AutoDeleteObjectsCustomResourceProvider/Handler
  CustomS3AutoDeleteObjectsCustomResourceProviderHandler9D90184F
[~] AWS::S3::Bucket MyFirstBucket MyFirstBucketB8884501
## [~] DeletionPolicy
#   ## [-] Retain
#   ## [+] Delete
## [~] UpdateReplacePolicy
#   ## [-] Retain
#   ## [+] Delete
```

To compare your app's stacks with the existing deployment:

```
cdk diff MyStack
```

To compare your app's stacks with a saved CloudFormation template:

```
cdk diff --template ~/stacks/MyStack.old MyStack
```

## Configuration (cdk.json)

Default values for many CDK Toolkit command line flags can be stored in a project's `cdk.json` file or in the `.cdk.json` file in your user directory. Following is an alphabetical reference to the supported configuration settings.

Key	Notes	CDK Toolkit option
app	The command that executes the CDK application.	<b>--app</b>
assetMetadata	If <code>false</code> , CDK does not add metadata to resources that use assets.	<b>--no-asset-metadata</b>
bootstrapKmsKeyId	Overrides the ID of the AWS KMS key used to encrypt the Amazon S3 deployment bucket.	<b>--bootstrap-kms-key-id</b>
build	The command that compiles or builds the CDK application before synthesis. Not permitted in <code>~/cdk.json</code> .	<b>--build</b>
browser	The command for launching a Web browser for the <code>cdk docs</code> subcommand.	<b>--browser</b>
context	See <a href="#">the section called "Context" (p. 185)</a> . Context values in a configuration file will not be erased by <b>cdk context --clear</b> . (The CDK Toolkit places cached context values in <code>cdk.context.json</code> .)	<b>--context</b>
debug	If <code>true</code> , CDK Toolkit emits more detailed information useful for debugging.	<b>--debug</b>
language	The language to be used for initializing new projects.	<b>--language</b>
lookups	If <code>false</code> , no context lookups are permitted. Synthesis will fail if any context lookups need to be performed.	<b>--no-lookups</b>
notices	If <code>false</code> , suppresses the display of messages about security vulnerabilities, regressions, and unsupported versions.	<b>--no-notices</b>
output	The name of the directory into which the synthesized cloud assembly will be emitted (default <code>"cdk.out"</code> ).	<b>--output</b>
outputsFile	The file to which AWS CloudFormation outputs from deployed stacks will be written (in JSON format).	<b>--outputs-file</b>

Key	Notes	CDK Toolkit option
pathMetadata	If false, CDK path metadata is not added to synthesized templates.	<b>--no-path-metadata</b>
plugin	JSON array specifying the package names or local paths of packages that extend the CDK	<b>--plugin</b>
profile	Name of the default AWS profile used for specifying Region and account credentials.	<b>--profile</b>
progress	If set to "events", the CDK Toolkit displays all AWS CloudFormation events during deployment, rather than a progress bar.	<b>--progress</b>
requireApproval	Default approval level for security changes. See <a href="#">the section called "Security-related changes" (p. 320)</a>	<b>--require-approval</b>
rollback	If false, failed deployments are not rolled back.	<b>--no-rollback</b>
staging	If false, assets are not copied to the output directory (use for local debugging of the source files with AWS SAM).	<b>--no-staging</b>
tags	JSON object containing tags (key-value pairs) for the stack.	<b>--tags</b>
toolkitBucketName	The name of the Amazon S3 bucket used for deploying assets such as Lambda functions and container images (see <a href="#">the section called "Bootstrapping your AWS environment" (p. 315)</a> ).	<b>--toolkit-bucket-name</b>
toolkitStackName	The name of the bootstrap stack (see <a href="#">the section called "Bootstrapping your AWS environment" (p. 315)</a> ).	<b>--toolkit-stack-name</b>
versionReporting	If false, opts out of version reporting.	<b>--no-version-reporting</b>
watch	JSON object containing "include" and "exclude" keys that indicate which files should (or should not) trigger a rebuild of the project when changed. See <a href="#">the section called "Watch mode" (p. 318)</a> .	<b>--watch</b>

## AWS Toolkit for Visual Studio Code

The [AWS Toolkit for Visual Studio Code](#) is an open source plugin for Visual Studio Code that makes it easier to create, debug, and deploy applications on AWS. The toolkit provides an integrated experience for developing AWS CDK applications. It includes the AWS CDK Explorer feature to list your AWS CDK projects and browse the various components of the CDK application. [Install the AWS Toolkit](#) and learn more about [using the AWS CDK Explorer](#).

## AWS SAM integration

The AWS CDK and the AWS Serverless Application Model (AWS SAM) can work together to let you to locally build and test serverless applications defined in the CDK. For complete information, see [AWS Cloud Development Kit \(AWS CDK\)](#) in the AWS SAM Developer Guide. To install the SAM CLI, see [Installing the AWS SAM CLI](#).

# Testing constructs

With the AWS CDK, your infrastructure can be as testable as any other code you write. The standard approach to testing AWS CDK apps uses the AWS CDK's [assertions](#) module and popular test frameworks like [Jest](#) for TypeScript and JavaScript or [Pytest](#) for Python.

There are two categories of tests that you can write for AWS CDK apps.

- **Fine-grained assertions** test specific aspects of the generated AWS CloudFormation template, such as "this resource has this property with this value." These tests can detect regressions. They're also useful when you're developing new features using test-driven development. (You can write a test first, then make it pass by writing a correct implementation.) Fine-grained assertions are the most frequently used tests.
- **Snapshot tests** test the synthesized AWS CloudFormation template against a previously stored baseline template. Snapshot tests let you refactor freely, since you can be sure that the refactored code works exactly the same way as the original. If the changes were intentional, you can accept a new baseline for future tests. However, CDK upgrades can also cause synthesized templates to change, so you can't rely only on snapshots to make sure that your implementation is correct.

## Note

Complete versions of the TypeScript, Python, and Java apps used as examples in this topic are [available on GitHub](#).

## Getting started

To illustrate how to write these tests, we'll create a stack that contains an AWS Step Functions state machine and an AWS Lambda function. The Lambda function is subscribed to an Amazon SNS topic and simply forwards the message to the state machine.

First, create an empty CDK application project using the CDK Toolkit and installing the libraries we'll need. The constructs we'll use are all in the main CDK package, which is a default dependency in projects created with the CDK Toolkit. However, you must install your testing framework.

### TypeScript

```
mkdir state-machine && cd state-machine
cdk init --language=typescript
npm install --save-dev jest @types/jest
```

Create a directory for your tests.

```
mkdir test
```

Edit the project's `package.json` to tell NPM how to run Jest, and to tell Jest what kinds of files to collect. The necessary changes are as follows.

- Add a new `test` key to the `scripts` section
- Add Jest and its types to the `devDependencies` section
- Add a new `jest` top-level key with a `moduleFileExtensions` declaration

These changes are shown in the following outline. Place the new text where indicated in `package.json`. The `"..."` placeholders indicate existing parts of the file that should not be changed.

```
{
  ...
  "scripts": {
    ...
    "test": "jest"
  },
  "devDependencies": {
    ...
    "@types/jest": "^24.0.18",
    "jest": "^24.9.0"
  },
  "jest": {
    "moduleFileExtensions": ["js"]
  }
}
```

### JavaScript

```
mkdir state-machine && cd state-machine
cdk init --language=javascript
npm install --save-dev jest
```

Create a directory for your tests.

```
mkdir test
```

Edit the project's `package.json` to tell NPM how to run Jest, and to tell Jest what kinds of files to collect. The necessary changes are as follows.

- Add a new `test` key to the `scripts` section
- Add Jest to the `devDependencies` section
- Add a new `jest` top-level key with a `moduleFileExtensions` declaration

These changes are shown in the following outline. Place the new text where indicated in `package.json`. The `"..."` placeholders indicate existing parts of the file that shouldn't be changed.

```
{
  ...
  "scripts": {
    ...
    "test": "jest"
  },
  "devDependencies": {
    ...
    "jest": "^24.9.0"
  },
  "jest": {
    "moduleFileExtensions": ["js"]
  }
}
```

### Python

```
mkdir state-machine && cd state-machine
cdk init --language=python
```

```
source .venv/bin/activate
python -m pip install -r requirements.txt
python -m pip install -r requirements-dev.txt
```

#### Java

```
mkdir state-machine && cd state-machine
cdk init --language=java
```

Open the project in your preferred Java IDE. (In Eclipse, use **File > Import > Existing Maven Projects**.)

#### C#

```
mkdir state-machine && cd state-machine
cdk init --language=csharp
```

Open `src\StateMachine.sln` in Visual Studio.

Right-click the solution in Solution Explorer and choose **Add > New Project**. Search for MSTest C# and add an **MSTest Test Project** for C#. (The default name `TestProject1` is fine.)

Right-click `TestProject1` and choose **Add > Project Reference**, and add the `StateMachine` project as a reference.

## The example stack

Here's the stack that will be tested in this topic. As we've previously described, it contains a Lambda function and a Step Functions state machine, and accepts one or more Amazon SNS topics. The Lambda function is subscribed to the Amazon SNS topics and forwards them to the state machine.

You don't have to do anything special to make the app testable. In fact, this CDK stack is not different in any important way from the other example stacks in this Guide.

#### TypeScript

Place the following code in `lib/state-machine-stack.ts`:

```
import * as cdk from "aws-cdk-lib";
import * as sns from "aws-cdk-lib/aws-sns";
import * as sns_subscriptions from "aws-cdk-lib/aws-sns-subscriptions";
import * as lambda from "aws-cdk-lib/aws-lambda";
import * as sfn from "aws-cdk-lib/aws-stepfunctions";
import { Construct } from "constructs";

export interface StateMachineStackProps extends cdk.StackProps {
  readonly topics: sns.Topic[];
}

export class StateMachineStack extends cdk.Stack {
  constructor(scope: Construct, id: string, props: StateMachineStackProps) {
    super(scope, id, props);

    // In the future this state machine will do some work...
    const stateMachine = new sfn.StateMachine(this, "StateMachine", {
      definition: new sfn.Pass(this, "StartState"),
    });

    // This Lambda function starts the state machine.
    const func = new lambda.Function(this, "LambdaFunction", {
```

```
runtime: lambda.Runtime.NODEJS_18_X,  
handler: "handler",  
code: lambda.Code.fromAsset("./start-state-machine"),  
environment: {  
    STATE_MACHINE_ARN: stateMachine.stateMachineArn,  
},  
});  
stateMachine.grantStartExecution(func);  
  
const subscription = new sns_subscriptions.LambdaSubscription(func);  
for (const topic of props.topics) {  
    topic.addSubscription(subscription);  
}  
}  
}
```

## JavaScript

Place the following code in `lib/state-machine-stack.js`:

```
const cdk = require("aws-cdk-lib");  
const sns = require("aws-cdk-lib/aws-sns");  
const sns_subscriptions = require("aws-cdk-lib/aws-sns-subscriptions");  
const lambda = require("aws-cdk-lib/aws-lambda");  
const sfm = require("aws-cdk-lib/aws-stepfunctions");  
  
class StateMachineStack extends cdk.Stack {  
    constructor(scope, id, props) {  
        super(scope, id, props);  
  
        // In the future this state machine will do some work...  
        const stateMachine = new sfm.StateMachine(this, "StateMachine", {  
            definition: new sfm.Pass(this, "StartState"),  
        });  
  
        // This Lambda function starts the state machine.  
        const func = new lambda.Function(this, "LambdaFunction", {  
            runtime: lambda.Runtime.NODEJS_18_X,  
            handler: "handler",  
            code: lambda.Code.fromAsset("./start-state-machine"),  
            environment: {  
                STATE_MACHINE_ARN: stateMachine.stateMachineArn,  
            },  
        });  
        stateMachine.grantStartExecution(func);  
  
        const subscription = new sns_subscriptions.LambdaSubscription(func);  
        for (const topic of props.topics) {  
            topic.addSubscription(subscription);  
        }  
    }  
}  
  
module.exports = { StateMachineStack }
```

## Python

Place the following code in `state_machine/state_machine_stack.py`:

```
from typing import List  
  
import aws_cdk.aws_lambda as lambda_  
import aws_cdk.aws_sns as sns
```



```
import aws_cdk.aws_sns_subscriptions as sns_subscriptions
import aws_cdk.aws_stepfunctions as sfn
import aws_cdk as cdk

class StateMachineStack(cdk.Stack):
    def __init__(
        self,
        scope: cdk.Construct,
        construct_id: str,
        *,
        topics: List[sns.Topic],
        **kwargs
    ) -> None:
        super().__init__(scope, construct_id, **kwargs)

        # In the future this state machine will do some work...
        state_machine = sfn.StateMachine(
            self, "StateMachine", definition=sfn.Pass(self, "StartState")
        )

        # This Lambda function starts the state machine.
        func = lambda_.Function(
            self,
            "LambdaFunction",
            runtime=lambda_.Runtime.NODEJS_18_X,
            handler="handler",
            code=lambda_.Code.from_asset("./start-state-machine"),
            environment={
                "STATE_MACHINE_ARN": state_machine.state_machine_arn,
            },
        )
        state_machine.grant_start_execution(func)

        subscription = sns_subscriptions.LambdaSubscription(func)
        for topic in topics:
            topic.add_subscription(subscription)
```

#### Java

```
package software.amazon.samples.awscdkassertionssamples;

import software.constructs.Construct;
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.StackProps;
import software.amazon.awscdk.services.lambda.Code;
import software.amazon.awscdk.services.lambda.Function;
import software.amazon.awscdk.services.lambda.Runtime;
import software.amazon.awscdk.services.sns.ITopicSubscription;
import software.amazon.awscdk.services.sns.Topic;
import software.amazon.awscdk.services.sns.subscriptions.LambdaSubscription;
import software.amazon.awscdk.services.stepfunctions.Pass;
import software.amazon.awscdk.services.stepfunctions.StateMachine;

import java.util.Collections;
import java.util.List;

public class StateMachineStack extends Stack {
    public StateMachineStack(final Construct scope, final String id, final List<Topic>
        topics) {
        this(scope, id, null, topics);
    }

    public StateMachineStack(final Construct scope, final String id, final StackProps
        props, final List<Topic> topics) {
        super(scope, id, props);
```

```
// In the future this state machine will do some work...
final StateMachine stateMachine = StateMachine.Builder.create(this,
"StateMachine")
    .definition(new Pass(this, "StartState"))
    .build();

// This Lambda function starts the state machine.
final Function func = Function.Builder.create(this, "LambdaFunction")
    .runtime(Runtime.NODEJS_18_X)
    .handler("handler")
    .code(Code.fromAsset("./start-state-machine"))
    .environment(Collections.singletonMap("STATE_MACHINE_ARN",
stateMachine.getStateMachineArn()))
    .build();
stateMachine.grantStartExecution(func);

final ITopicSubscription subscription = new LambdaSubscription(func);
for (final Topic topic : topics) {
    topic.addSubscription(subscription);
}
}
```

#### C#

```
using Amazon.CDK;
using Amazon.CDK.AWS.Lambda;
using Amazon.CDK.AWS.StepFunctions;
using Amazon.CDK.AWS.SNS;
using Amazon.CDK.AWS.SNS.Subscriptions;
using Constructs;

using System.Collections.Generic;

namespace AwsCdkAssertionSamples
{
    public class StateMachineStackProps : StackProps
    {
        public Topic[] Topics;
    }

    public class StateMachineStack : Stack
    {
        internal StateMachineStack(Construct scope, string id, StateMachineStackProps
props = null) : base(scope, id, props)
        {
            // In the future this state machine will do some work...
            var stateMachine = new StateMachine(this, "StateMachine", new
StateMachineProps
            {
                Definition = new Pass(this, "StartState")
            });

            // This Lambda function starts the state machine.
            var func = new Function(this, "LambdaFunction", new FunctionProps
            {
                Runtime = Runtime.NODEJS_18_X,
                Handler = "handler",
                Code = Code.FromAsset("./start-state-machine"),
                Environment = new Dictionary<string, string>
                {
                    { "STATE_MACHINE_ARN", stateMachine.StateMachineArn }
                }
            });
        }
    }
}
```

```
    });  
    stateMachine.GrantStartExecution(func);  
  
    foreach (Topic topic in props?.Topics ?? new Topic[0])  
    {  
        var subscription = new LambdaSubscription(func);  
    }  
}  
}
```

We'll modify the app's main entry point so that we don't actually instantiate our stack. We don't want to accidentally deploy it. Our tests will create an app and an instance of the stack for testing. This is a useful tactic when combined with test-driven development: make sure that the stack passes all tests before you enable deployment.

### TypeScript

In `bin/state-machine.ts`:

```
#!/usr/bin/env node  
import * as cdk from "aws-cdk-lib";  
  
const app = new cdk.App();  
  
// Stacks are intentionally not created here -- this application isn't meant to  
// be deployed.
```

### JavaScript

In `bin/state-machine.js`:

```
#!/usr/bin/env node  
const cdk = require("aws-cdk-lib");  
  
const app = new cdk.App();  
  
// Stacks are intentionally not created here -- this application isn't meant to  
// be deployed.
```

### Python

In `app.py`:

```
#!/usr/bin/env python3  
import os  
  
import aws_cdk as cdk  
  
app = cdk.App()  
  
# Stacks are intentionally not created here -- this application isn't meant to  
# be deployed.  
  
app.synth()
```

### Java

```
package software.amazon.samples.awscdkassertionssamples;
```

```
import software.amazon.awscdk.App;

public class SampleApp {
    public static void main(final String[] args) {
        App app = new App();

        // Stacks are intentionally not created here -- this application isn't meant to
        // be deployed.

        app.synth();
    }
}
```

#### C#

```
using Amazon.CDK;

namespace AwsCdkAssertionSamples
{
    sealed class Program
    {
        public static void Main(string[] args)
        {
            var app = new App();

            // Stacks are intentionally not created here -- this application isn't
            // meant to be deployed.

            app.Synth();
        }
    }
}
```

## The Lambda function

Our example stack includes a Lambda function that starts our state machine. We must provide the source code for this function so the CDK can bundle and deploy it as part of creating the Lambda function resource.

- Create the folder `start-state-machine` in the app's main directory.
- In this folder, create at least one file. For example, you can save the following code in `start-state-machines/index.js`.

```
exports.handler = async function (event, context) {
    return 'hello world';
};
```

However, any file will work, since we won't actually be deploying the stack.

## Running tests

For reference, here are the commands you use to run tests in your AWS CDK app. These are the same commands that you'd use to run the tests in any project using the same testing framework. For languages that require a build step, include that to make sure that your tests have compiled.

#### TypeScript

```
tsc && npm test
```

#### JavaScript

```
npm test
```

#### Python

```
python -m pytest
```

#### Java

```
mvn compile && mvn test
```

#### C#

Build your solution (F6) to discover the tests, then run the tests (**Test > Run All Tests**). To choose which tests to run, open Test Explorer (**Test > Test Explorer**).

Or:

```
dotnet test src
```

## Fine-grained assertions

The first step for testing a stack with fine-grained assertions is to synthesize the stack, because we're writing assertions against the generated AWS CloudFormation template.

Our `StateMachineStack` requires that we pass it the Amazon SNS topic to be forwarded to the state machine. So in our test, we'll create a separate stack to contain the topic.

Ordinarily, when writing a CDK app, you can subclass `Stack` and instantiate the Amazon SNS topic in the stack's constructor. In our test, we instantiate `Stack` directly, then pass this stack as the `Topic`'s scope, attaching it to the stack. This is functionally equivalent and less verbose. It also helps make stacks that are used only in tests "look different" from the stacks that you intend to deploy.

#### TypeScript

```
import { Capture, Match, Template } from "aws-cdk-lib/assertions";
import * as cdk from "aws-cdk-lib";
import * as sns from "aws-cdk-lib/aws-sns";
import { StateMachineStack } from "../lib/state-machine-stack";

describe("StateMachineStack", () => {
  test("synthesizes the way we expect", () => {
    const app = new cdk.App();

    // Since the StateMachineStack consumes resources from a separate stack
    // (cross-stack references), we create a stack for our SNS topics to live
    // in here. These topics can then be passed to the StateMachineStack later,
    // creating a cross-stack reference.
    const topicsStack = new cdk.Stack(app, "TopicsStack");
```

```
// Create the topic the stack we're testing will reference.
const topics = [new sns.Topic(topicsStack, "Topic1", {})];

// Create the StateMachineStack.
const stateMachineStack = new StateMachineStack(app, "StateMachineStack", {
  topics: topics, // Cross-stack reference
});

// Prepare the stack for assertions.
const template = Template.fromStack(stateMachineStack);

}
```

### JavaScript

```
const { Capture, Match, Template } = require("aws-cdk-lib/assertions");
const cdk = require("aws-cdk-lib");
const sns = require("aws-cdk-lib/aws-sns");
const { StateMachineStack } = require("../lib/state-machine-stack");

describe("StateMachineStack", () => {
  test("synthesizes the way we expect", () => {
    const app = new cdk.App();

    // Since the StateMachineStack consumes resources from a separate stack
    // (cross-stack references), we create a stack for our SNS topics to live
    // in here. These topics can then be passed to the StateMachineStack later,
    // creating a cross-stack reference.
    const topicsStack = new cdk.Stack(app, "TopicsStack");

    // Create the topic the stack we're testing will reference.
    const topics = [new sns.Topic(topicsStack, "Topic1", {})];

    // Create the StateMachineStack.
    const stateMachineStack = new StateMachineStack(app, "StateMachineStack", {
      topics: topics, // Cross-stack reference
    });

    // Prepare the stack for assertions.
    const template = Template.fromStack(stateMachineStack);
```

### Python

```
from aws_cdk import aws_sns as sns
import aws_cdk as cdk
from aws_cdk.assertions import Template

from app.state_machine_stack import StateMachineStack

def test_synthesizes_properly():
    app = cdk.App()

    # Since the StateMachineStack consumes resources from a separate stack
    # (cross-stack references), we create a stack for our SNS topics to live
    # in here. These topics can then be passed to the StateMachineStack later,
    # creating a cross-stack reference.
    topics_stack = cdk.Stack(app, "TopicsStack")

    # Create the topic the stack we're testing will reference.
    topics = [sns.Topic(topics_stack, "Topic1")]

    # Create the StateMachineStack.
    state_machine_stack = StateMachineStack(
```

```
        app, "StateMachineStack", topics=topics # Cross-stack reference
    )

    # Prepare the stack for assertions.
    template = Template.from_stack(state_machine_stack)
```

#### Java

```
package software.amazon.samples.awscdkassertionssamples;

import org.junit.jupiter.api.Test;
import software.amazon.awscdk.assertions.Capture;
import software.amazon.awscdk.assertions.Match;
import software.amazon.awscdk.assertions.Template;
import software.amazon.awscdk.App;
import software.amazon.awscdk.Stack;
import software.amazon.awscdk.services.sns.Topic;

import java.util.*;

import static org.assertj.core.api.Assertions.assertThat;

public class StateMachineStackTest {
    @Test
    public void testSynthesizesProperly() {
        final App app = new App();

        // Since the StateMachineStack consumes resources from a separate stack (cross-
        // stack references), we create a stack
        // for our SNS topics to live in here. These topics can then be passed to the
        // StateMachineStack later, creating a
        // cross-stack reference.
        final Stack topicsStack = new Stack(app, "TopicsStack");

        // Create the topic the stack we're testing will reference.
        final List<Topic> topics =
            Collections.singletonList(Topic.Builder.create(topicsStack, "Topic1").build());

        // Create the StateMachineStack.
        final StateMachineStack stateMachineStack = new StateMachineStack(
            app,
            "StateMachineStack",
            topics // Cross-stack reference
        );

        // Prepare the stack for assertions.
        final Template template = Template.fromStack(stateMachineStack)
```

#### C#

```
using Microsoft.VisualStudio.TestTools.UnitTesting;

using Amazon.CDK;
using Amazon.CDK.AWS.SNS;
using Amazon.CDK.Assertions;
using AwsCdkAssertionSamples;

using ObjectDict = System.Collections.Generic.Dictionary<string, object>;
using StringDict = System.Collections.Generic.Dictionary<string, string>;

namespace TestProject1
{
    [TestClass]
    public class StateMachineStackTest
```

```
{
    [TestMethod]
    public void TestMethod1()
    {
        var app = new App();

        // Since the StateMachineStack consumes resources from a separate stack
        // (cross-stack references), we create a stack
        // for our SNS topics to live in here. These topics can then be passed to
        // the StateMachineStack later, creating a
        // cross-stack reference.
        var topicsStack = new Stack(app, "TopicsStack");

        // Create the topic the stack we're testing will reference.
        var topics = new Topic[] { new Topic(topicsStack, "Topic1") };

        // Create the StateMachineStack.
        var StateMachineStack = new StateMachineStack(app, "StateMachineStack", new
        StateMachineStackProps
        {
            Topics = topics
        });

        // Prepare the stack for assertions.
        var template = Template.FromStack(stateMachineStack);

        // test will go here
    }
}
```

Now we can assert that the Lambda function and the Amazon SNS subscription were created.

#### TypeScript

```
// Assert it creates the function with the correct properties...
template.hasResourceProperties("AWS::Lambda::Function", {
    Handler: "handler",
    Runtime: "nodejs14.x",
});

// Creates the subscription...
template.resourceCountIs("AWS::SNS::Subscription", 1);
```

#### JavaScript

```
// Assert it creates the function with the correct properties...
template.hasResourceProperties("AWS::Lambda::Function", {
    Handler: "handler",
    Runtime: "nodejs14.x",
});

// Creates the subscription...
template.resourceCountIs("AWS::SNS::Subscription", 1);
```

#### Python

```
# Assert that we have created the function with the correct properties
template.has_resource_properties(
    "AWS::Lambda::Function",
    {
```



```
        "Handler": "handler",  
        "Runtime": "nodejs14.x",  
    },  
)  
  
# Assert that we have created a subscription  
template.resource_count_is("AWS::SNS::Subscription", 1)
```

#### Java

```
// Assert it creates the function with the correct properties...  
template.hasResourceProperties("AWS::Lambda::Function", Map.of(  
    "Handler", "handler",  
    "Runtime", "nodejs14.x"  
));  
  
// Creates the subscription...  
template.resourceCountIs("AWS::SNS::Subscription", 1);
```

#### C#

```
// Prepare the stack for assertions.  
var template = Template.FromStack(stateMachineStack);  
  
// Assert it creates the function with the correct properties...  
template.HasResourceProperties("AWS::Lambda::Function", new StringDict {  
    { "Handler", "handler"},  
    { "Runtime", "nodejs14x" }  
});  
  
// Creates the subscription...  
template.ResourceCountIs("AWS::SNS::Subscription", 1);
```

Our Lambda function test asserts that two particular properties of the function resource have specific values. By default, the `hasResourceProperties` method performs a partial match on the resource's properties as given in the synthesized CloudFormation template. This test requires that the provided properties exist and have the specified values, but the resource can also have other properties, which are not tested.

Our Amazon SNS assertion asserts that the synthesized template contains a subscription, but nothing about the subscription itself. We included this assertion mainly to illustrate how to assert on resource counts. The `Template` class offers more specific methods to write assertions against the `Resources`, `Outputs`, and `Mapping` sections of the CloudFormation template.

## Matchers

The default partial matching behavior of `hasResourceProperties` can be changed using *matchers* from the [Match](#) class.

Matchers range from lenient (`Match.anyValue`) to strict (`Match.objectEquals`). They can be nested to apply different matching methods to different parts of the resource properties. Using `Match.objectEquals` and `Match.anyValue` together, for example, we can test the state machine's IAM role more fully, while not requiring specific values for properties that may change.

#### TypeScript

```
// Fully assert on the state machine's IAM role with matchers.  
template.hasResourceProperties(  
    "AWS::IAM::Role",  
    Match.objectEquals({  
        "AssumeRolePolicyDocument": Match.anyValue(),  
        "Path": "/",  
        "Permissions": Match.anyValue(),  
        "RoleName": "state-machine-role",  
        "Type": "AssumedRole",  
    })
```

```
"AWS::IAM::Role",
Match.objectEquals({
  AssumeRolePolicyDocument: {
    Version: "2012-10-17",
    Statement: [
      {
        Action: "sts:AssumeRole",
        Effect: "Allow",
        Principal: {
          Service: {
            "Fn::Join": [
              "",
              ["states.", Match.anyValue(), ".amazonaws.com"],
            ],
          },
        },
      },
    ],
  },
},
);
```

#### JavaScript

```
// Fully assert on the state machine's IAM role with matchers.
template.hasResourceProperties(
  "AWS::IAM::Role",
  Match.objectEquals({
    AssumeRolePolicyDocument: {
      Version: "2012-10-17",
      Statement: [
        {
          Action: "sts:AssumeRole",
          Effect: "Allow",
          Principal: {
            Service: {
              "Fn::Join": [
                "",
                ["states.", Match.anyValue(), ".amazonaws.com"],
              ],
            },
          },
        },
      ],
    },
  },
);
```

#### Python

```
from aws_cdk.assertions import Match

# Fully assert on the state machine's IAM role with matchers.
template.has_resource_properties(
    "AWS::IAM::Role",
    Match.object_equals(
        {
            "AssumeRolePolicyDocument": {
                "Version": "2012-10-17",
                "Statement": [
                    {
                        "Action": "sts:AssumeRole",
                        "Effect": "Allow",
                        "Principal": {
```

```

        "Service": {
            "Fn::Join": [
                "",
                [
                    "states.",
                    Match.any_value(),
                    ".amazonaws.com",
                ],
            ],
        },
    ],
},
],
},
),
),
)

```

#### Java

```

// Fully assert on the state machine's IAM role with matchers.
template.hasResourceProperties("AWS::IAM::Role", Match.objectEquals(
    Collections.singletonMap("AssumeRolePolicyDocument", Map.of(
        "Version", "2012-10-17",
        "Statement", Collections.singletonList(Map.of(
            "Action", "sts:AssumeRole",
            "Effect", "Allow",
            "Principal", Collections.singletonMap(
                "Service", Collections.singletonMap(
                    "Fn::Join", Arrays.asList(
                        "",
                        Arrays.asList("states.",
Match.anyValue(), ".amazonaws.com")
                    )
                )
            )
        ))
    ));

```

#### C#

```

// Fully assert on the state machine's IAM role with matchers.
template.HasResource("AWS::IAM::Role", Match.ObjectEquals(new ObjectDict
{
    { "AssumeRolePolicyDocument", new ObjectDict
    {
        { "Version", "2012-10-17" },
        { "Action", "sts:AssumeRole" },
        { "Principal", new ObjectDict
        {
            { "Version", "2012-10-17" },
            { "Statement", new object[]
            {
                new ObjectDict {
                    { "Action", "sts:AssumeRole" },
                    { "Effect", "Allow" },
                    { "Principal", new ObjectDict
                    {
                        { "Service", new ObjectDict
                        {
                            { "", new object[]
                            { "states",
Match.AnyValue(), ".amazonaws.com" }
                        }
                    }
                }
            }
        }
        }
    }
    }
}

```

```
    }  
  }  
}  
});
```

Many CloudFormation resources include serialized JSON objects represented as strings. The `Match.serializedJson()` matcher can be used to match properties inside this JSON.

For example, Step Functions state machines are defined using a string in the JSON-based [Amazon States Language](#). We'll use `Match.serializedJson()` to make sure that our initial state is the only step. Again, we'll use nested matchers to apply different kinds of matching to different parts of the object.

#### TypeScript

```
// Assert on the state machine's definition with the Match.serializedJson()  
// matcher.  
template.hasResourceProperties("AWS::StepFunctions::StateMachine", {  
  DefinitionString: Match.serializedJson(  
    // Match.objectEquals() is used implicitly, but we use it explicitly  
    // here for extra clarity.  
    Match.objectEquals({  
      StartAt: "StartState",  
      States: {  
        StartState: {  
          Type: "Pass",  
          End: true,  
          // Make sure this state doesn't provide a next state -- we can't  
          // provide both Next and set End to true.  
          Next: Match.absent(),  
        },  
      },  
    })  
  },  
});
```

#### JavaScript

```
// Assert on the state machine's definition with the Match.serializedJson()  
// matcher.  
template.hasResourceProperties("AWS::StepFunctions::StateMachine", {  
  DefinitionString: Match.serializedJson(  
    // Match.objectEquals() is used implicitly, but we use it explicitly  
    // here for extra clarity.  
    Match.objectEquals({  
      StartAt: "StartState",  
      States: {  
        StartState: {  
          Type: "Pass",  
          End: true,  
          // Make sure this state doesn't provide a next state -- we can't  
          // provide both Next and set End to true.  
          Next: Match.absent(),  
        },  
      },  
    })  
  },  
});
```

```
    },  
  })  
),  
});
```

## Python

```
# Assert on the state machine's definition with the serialized_json matcher.  
template.has_resource_properties(  
    "AWS::StepFunctions::StateMachine",  
    {  
        "DefinitionString": Match.serialized_json(  
            # Match.object_equals() is the default, but specify it here for clarity  
            Match.object_equals(  
                {  
                    "StartAt": "StartState",  
                    "States": {  
                        "StartState": {  
                            "Type": "Pass",  
                            "End": True,  
                            # Make sure this state doesn't provide a next state --  
                            # we can't provide both Next and set End to true.  
                            "Next": Match.absent(),  
                        },  
                    },  
                },  
            ),  
        ),  
    },  
)
```

## Java

```
// Assert on the state machine's definition with the Match.serializedJson()  
matcher.  
    template.hasResourceProperties("AWS::StepFunctions::StateMachine",  
        Collections.singletonMap(  
            "DefinitionString", Match.serializedJson(  
                // Match.objectEquals() is used implicitly, but we use it  
                explicitly here for extra clarity.  
                Match.objectEquals(Map.of(  
                    "StartAt", "StartState",  
                    "States", Collections.singletonMap(  
                        "StartState", Map.of(  
                            "Type", "Pass",  
                            "End", true,  
                            // Make sure this state doesn't provide  
                            a next state -- we can't provide  
                            // both Next and set End to true.  
                            "Next", Match.absent()  
                        )  
                    )  
                ))  
            )  
        ));
```

## C#

```
// Assert on the state machine's definition with the Match.serializedJson()  
matcher  
    template.HasResourceProperties("AWS::StepFunctions::StateMachine", new  
        ObjectDict
```

```
    {
      { "DefinitionString", Match.SerializedJson(
        // Match.objectEquals() is used implicitly, but we use it
        explicitly here for extra clarity.
        Match.ObjectEquals(new ObjectDict {
          { "StartAt", "StartState" },
          { "States", new ObjectDict
            {
              { "StartState", new ObjectDict {
                { "Type", "Pass" },
                { "End", "True" },
                // Make sure this state doesn't provide a next state --
                // both Next and set End to true.
                { "Next", Match.Absent() }
              }
            }
          }
        })
      })
    });
```

## Capturing

It's often useful to test properties to make sure they follow specific formats, or have the same value as another property, without needing to know their exact values ahead of time. The assertions module provides this capability in its [Capture](#) class.

By specifying a Capture instance in place of a value in `hasResourceProperties`, that value is retained in the Capture object. The actual captured value can be retrieved using the object's `as` methods, including `asNumber()`, `asString()`, and `asObject`, and subjected to test. Use Capture with a matcher to specify the exact location of the value to be captured within the resource's properties, including serialized JSON properties.

The following example tests to make sure that the starting state of our state machine has a name beginning with `Start`. It also tests that this state is present within the list of states in the machine.

### TypeScript

```
// Capture some data from the state machine's definition.
const startAtCapture = new Capture();
const statesCapture = new Capture();
template.hasResourceProperties("AWS::StepFunctions::StateMachine", {
  DefinitionString: Match.serializedJson(
    Match.objectLike({
      StartAt: startAtCapture,
      States: statesCapture,
    })
  ),
});

// Assert that the start state starts with "Start".
expect(startAtCapture.asString()).toEqual(expect.stringMatching(/^Start/));

// Assert that the start state actually exists in the states object of the
// state machine definition.
expect(statesCapture.asObject()).toHaveProperty(startAtCapture.asString());
```

### JavaScript

```
// Capture some data from the state machine's definition.
const startAtCapture = new Capture();
```

```
const statesCapture = new Capture();
template.hasResourceProperties("AWS::StepFunctions::StateMachine", {
  DefinitionString: Match.serializedJson(
    Match.objectLike({
      StartAt: startAtCapture,
      States: statesCapture,
    })
  ),
});

// Assert that the start state starts with "Start".
expect(startAtCapture.asString()).toEqual(expect.stringMatching(/^Start/));

// Assert that the start state actually exists in the states object of the
// state machine definition.
expect(statesCapture.asObject()).toHaveProperty(startAtCapture.asString());
```

## Python

```
import re

from aws_cdk.assertions import Capture

# ...

# Capture some data from the state machine's definition.
start_at_capture = Capture()
states_capture = Capture()
template.has_resource_properties(
    "AWS::StepFunctions::StateMachine",
    {
        "DefinitionString": Match.serialized_json(
            Match.object_like(
                {
                    "StartAt": start_at_capture,
                    "States": states_capture,
                }
            )
        ),
    },
)

# Assert that the start state starts with "Start".
assert re.match("^Start", start_at_capture.as_string())

# Assert that the start state actually exists in the states object of the
# state machine definition.
assert start_at_capture.as_string() in states_capture.as_object()
```

## Java

```
// Capture some data from the state machine's definition.
final Capture startAtCapture = new Capture();
final Capture statesCapture = new Capture();
template.hasResourceProperties("AWS::StepFunctions::StateMachine",
Collections.singletonMap(
    "DefinitionString", Match.serializedJson(
        Match.objectLike(Map.of(
            "StartAt", startAtCapture,
            "States", statesCapture
        ))
    )
));
```

```
// Assert that the start state starts with "Start".
assertThat(startAtCapture.asString()).matches("^Start.+");

// Assert that the start state actually exists in the states object of the
state machine definition.
assertThat(statesCapture.asObject()).containsKey(startAtCapture.asString());
```

C#

```
// Capture some data from the state machine's definition.
var startAtCapture = new Capture();
var statesCapture = new Capture();
template.HasResourceProperties("AWS::StepFunctions::StateMachine", new
ObjectDict
{
    { "DefinitionString", Match.SerializedJson(
        new ObjectDict
        {
            { "StartAt", startAtCapture },
            { "States", statesCapture }
        }
    )}
});

Assert.IsTrue(startAtCapture.ToString().StartsWith("Start"));

Assert.IsTrue(statesCapture.AsObject().ContainsKey(startAtCapture.ToString()));
```

## Snapshot tests

In *snapshot testing*, you compare the entire synthesized CloudFormation template against a previously stored baseline (often called a "master") template. Unlike fine-grained assertions, snapshot testing isn't useful in catching regressions. This is because snapshot testing applies to the entire template, and things besides code changes can cause small (or not-so-small) differences in synthesis results. These changes may not even affect your deployment, but they will still cause a snapshot test to fail.

For example, you might update a CDK construct to incorporate a new best practice, which can cause changes to the synthesized resources or how they're organized. Alternatively, you might update the CDK Toolkit to a version that reports additional metadata. Changes to context values can also affect the synthesized template.

Snapshot tests can be of great help in refactoring, though, as long as you hold constant all other factors that might affect the synthesized template. You will know immediately if a change you made has unintentionally changed the template. If the change is intentional, simply accept the new template as the baseline.

For example, if we have this `DeadLetterQueue` construct:

TypeScript

```
export class DeadLetterQueue extends sqs.Queue {
    public readonly messagesInQueueAlarm: cloudwatch.IAlarm;

    constructor(scope: Construct, id: string) {
        super(scope, id);

        // Add the alarm
        this.messagesInQueueAlarm = new cloudwatch.Alarm(this, 'Alarm', {
```



```
        alarmDescription: 'There are messages in the Dead Letter Queue',
        evaluationPeriods: 1,
        threshold: 1,
        metric: this.metricApproximateNumberOfMessagesVisible(),
    });
  }
}
```

#### JavaScript

```
class DeadLetterQueue extends sqs.Queue {
  constructor(scope, id) {
    super(scope, id);

    // Add the alarm
    this.messagesInQueueAlarm = new cloudwatch.Alarm(this, 'Alarm', {
      alarmDescription: 'There are messages in the Dead Letter Queue',
      evaluationPeriods: 1,
      threshold: 1,
      metric: this.metricApproximateNumberOfMessagesVisible(),
    });
  }
}

module.exports = { DeadLetterQueue }
```

#### Python

```
class DeadLetterQueue(sqs.Queue):
    def __init__(self, scope: Construct, id: str):
        super().__init__(scope, id)

        self.messages_in_queue_alarm = cloudwatch.Alarm(
            self,
            "Alarm",
            alarm_description="There are messages in the Dead Letter Queue.",
            evaluation_periods=1,
            threshold=1,
            metric=self.metric_approximate_number_of_messages_visible(),
        )
```

#### Java

```
public class DeadLetterQueue extends Queue {
    private final IAlarm messagesInQueueAlarm;

    public DeadLetterQueue(@NotNull Construct scope, @NotNull String id) {
        super(scope, id);

        this.messagesInQueueAlarm = Alarm.Builder.create(this, "Alarm")
            .alarmDescription("There are messages in the Dead Letter Queue.")
            .evaluationPeriods(1)
            .threshold(1)
            .metric(this.metricApproximateNumberOfMessagesVisible())
            .build();
    }

    public IAlarm getMessagesInQueueAlarm() {
        return messagesInQueueAlarm;
    }
}
```

## C#

```
namespace AwsCdkAssertionSamples
{
    public class DeadLetterQueue : Queue
    {
        public IAlarm messagesInQueueAlarm;

        public DeadLetterQueue(Construct scope, string id) : base(scope, id)
        {
            messagesInQueueAlarm = new Alarm(this, "Alarm", new AlarmProps
            {
                AlarmDescription = "There are messages in the Dead Letter Queue.",
                EvaluationPeriods = 1,
                Threshold = 1,
                Metric = this.MetricApproximateNumberOfMessagesVisible()
            });
        }
    }
}
```

We can test it like this:

## TypeScript

```
import { Match, Template } from "aws-cdk-lib/assertions";
import * as cdk from "aws-cdk-lib";
import { DeadLetterQueue } from "../lib/dead-letter-queue";

describe("DeadLetterQueue", () => {
    test("matches the snapshot", () => {
        const stack = new cdk.Stack();
        new DeadLetterQueue(stack, "DeadLetterQueue");

        const template = Template.fromStack(stack);
        expect(template.toJSON()).toMatchSnapshot();
    });
});
```

## JavaScript

```
const { Match, Template } = require("aws-cdk-lib/assertions");
const cdk = require("aws-cdk-lib");
const { DeadLetterQueue } = require("../lib/dead-letter-queue");

describe("DeadLetterQueue", () => {
    test("matches the snapshot", () => {
        const stack = new cdk.Stack();
        new DeadLetterQueue(stack, "DeadLetterQueue");

        const template = Template.fromStack(stack);
        expect(template.toJSON()).toMatchSnapshot();
    });
});
```

## Python

```
import aws_cdk_lib as cdk
from aws_cdk_lib.assertions import Match, Template
```

```
from app.dead_letter_queue import DeadLetterQueue

def snapshot_test():
    stack = cdk.Stack()
    DeadLetterQueue(stack, "DeadLetterQueue")

    template = Template.from_stack(stack)
    assert template.to_json() == snapshot
```

#### Java

```
package software.amazon.samples.awscdkassertionssamples;

import org.junit.jupiter.api.Test;
import au.com.origin.snapshots.Expect;
import software.amazon.awscdk.assertions.Match;
import software.amazon.awscdk.assertions.Template;
import software.amazon.awscdk.Stack;

import java.util.Collections;
import java.util.Map;

public class DeadLetterQueueTest {
    @Test
    public void snapshotTest() {
        final Stack stack = new Stack();
        new DeadLetterQueue(stack, "DeadLetterQueue");

        final Template template = Template.fromStack(stack);
        expect.toMatchSnapshot(template.toJSON());
    }
}
```

#### C#

```
using Microsoft.VisualStudio.TestTools.UnitTesting;

using Amazon.CDK;
using Amazon.CDK.Assertions;
using AwsCdkAssertionSamples;

using ObjectDict = System.Collections.Generic.Dictionary<string, object>;
using StringDict = System.Collections.Generic.Dictionary<string, string>;

namespace TestProject1
{
    [TestClass]
    public class StateMachineStackTest

    [TestClass]
    public class DeadLetterQueueTest
    {
        [TestMethod]
        public void SnapshotTest()
        {
            var stack = new Stack();
            new DeadLetterQueue(stack, "DeadLetterQueue");

            var template = Template.FromStack(stack);

            return Verifier.Verify(template.ToJSON());
        }
    }
}
```

```
}
```

## Tips for tests

Remember, your tests will live just as long as the code they test, and they will be read and modified just as often. Therefore, it pays to take a moment to consider how best to write them.

Don't copy and paste setup lines or common assertions. Instead, refactor this logic into fixtures or helper functions. Use good names that reflect what each test actually tests.

Don't try to do too much in one test. Preferably, a test should test one and only one behavior. If you accidentally break that behavior, exactly one test should fail, and the name of the test should tell you what failed. This is more an ideal to be striven for, however; sometimes you will unavoidably (or inadvertently) write tests that test more than one behavior. Snapshot tests are, for reasons we've already described, especially prone to this problem, so use them sparingly.

# Security for the AWS Cloud Development Kit (AWS CDK)

Cloud security at Amazon Web Services (AWS) is the highest priority. As an AWS customer, you benefit from a data center and network architecture that is built to meet the requirements of the most security-sensitive organizations. Security is a shared responsibility between AWS and you. The [Shared Responsibility Model](#) describes this as Security of the Cloud and Security in the Cloud.

**Security of the Cloud** – AWS is responsible for protecting the infrastructure that runs all of the services offered in the AWS Cloud and providing you with services that you can use securely. Our security responsibility is the highest priority at AWS, and the effectiveness of our security is regularly tested and verified by third-party auditors as part of the [AWS Compliance Programs](#).

**Security in the Cloud** – Your responsibility is determined by the AWS service you are using, and other factors including the sensitivity of your data, your organization's requirements, and applicable laws and regulations.

The AWS CDK follows the [shared responsibility model](#) through the specific Amazon Web Services (AWS) services it supports. For AWS service security information, see the [AWS service security documentation page](#) and [AWS services that are in scope of AWS compliance efforts by compliance program](#).

## Topics

- [Identity and access management for the AWS Cloud Development Kit \(AWS CDK\) \(p. 349\)](#)
- [Compliance validation for the AWS Cloud Development Kit \(AWS CDK\) \(p. 352\)](#)
- [Resilience for the AWS Cloud Development Kit \(AWS CDK\) \(p. 352\)](#)
- [Infrastructure security for the AWS Cloud Development Kit \(AWS CDK\) \(p. 353\)](#)

## Identity and access management for the AWS Cloud Development Kit (AWS CDK)

AWS Identity and Access Management (IAM) is an AWS service that helps an administrator securely control access to AWS resources. IAM administrators control who can be *authenticated* (signed in) and *authorized* (have permissions) to use AWS resources. IAM is an AWS service that you can use with no additional charge.

## Audience

How you use AWS Identity and Access Management (IAM) differs, depending on the work that you do in AWS.

**Service user** – If you use AWS services to do your job, then your administrator provides you with the credentials and permissions that you need. As you use more AWS features to do your work, you might need additional permissions. Understanding how access is managed can help you request the right permissions from your administrator.

**Service administrator** – If you're in charge of AWS resources at your company, you probably have full access to AWS resources. It's your job to determine which AWS services and resources your service users

should access. You must then submit requests to your IAM administrator to change the permissions of your service users. Review the information on this page to understand the basic concepts of IAM.

**IAM administrator** – If you're an IAM administrator, you might want to learn details about how you can write policies to manage access to AWS services.

## Authenticating with identities

Authentication is how you sign in to AWS using your identity credentials. You must be *authenticated* (signed in to AWS) as the AWS account root user, as an IAM user, or by assuming an IAM role.

You can sign in to AWS as a federated identity by using credentials provided through an identity source. AWS IAM Identity Center (successor to AWS Single Sign-On) (IAM Identity Center) users, your company's single sign-on authentication, and your Google or Facebook credentials are examples of federated identities. When you sign in as a federated identity, your administrator previously set up identity federation using IAM roles. When you access AWS by using federation, you are indirectly assuming a role.

Depending on the type of user you are, you can sign in to the AWS Management Console or the AWS access portal. For more information about signing in to AWS, see [How to sign in to your AWS account](#) in the *AWS Sign-In User Guide*.

To access AWS programmatically, AWS provides the AWS CDK, software development kits (SDKs), and a command line interface (CLI) to cryptographically sign your requests using your credentials. If you don't use AWS tools, you must sign requests yourself. For more information about using the recommended method to sign requests yourself, see [Signature Version 4 signing process](#) in the *AWS General Reference*.

Regardless of the authentication method that you use, you might be required to provide additional security information. For example, AWS recommends that you use multi-factor authentication (MFA) to increase the security of your account. To learn more, see [Multi-factor authentication](#) in the *AWS IAM Identity Center (successor to AWS Single Sign-On) User Guide* and [Using multi-factor authentication \(MFA\) in AWS](#) in the *IAM User Guide*.

## AWS account root user

When you create an AWS account, you begin with one sign-in identity that has complete access to all AWS services and resources in the account. This identity is called the AWS account *root user* and is accessed by signing in with the email address and password that you used to create the account. We strongly recommend that you don't use the root user for your everyday tasks. Safeguard your root user credentials and use them to perform the tasks that only the root user can perform. For the complete list of tasks that require you to sign in as the root user, see [Tasks that require root user credentials](#) in the *AWS Account Management Reference Guide*.

## Federated identity

As a best practice, require human users, including users that require administrator access, to use federation with an identity provider to access AWS services by using temporary credentials.

A *federated identity* is a user from your enterprise user directory, a web identity provider, the AWS Directory Service, the Identity Center directory, or any user that accesses AWS services by using credentials provided through an identity source. When federated identities access AWS accounts, they assume roles, and the roles provide temporary credentials.

For centralized access management, we recommend that you use AWS IAM Identity Center (successor to AWS Single Sign-On). You can create users and groups in IAM Identity Center, or you can connect and synchronize to a set of users and groups in your own identity source for use across all your AWS accounts and applications. For information about IAM Identity Center, see [What is IAM Identity Center?](#) in the *AWS IAM Identity Center (successor to AWS Single Sign-On) User Guide*.

## IAM users and groups

An [IAM user](#) is an identity within your AWS account that has specific permissions for a single person or application. Where possible, we recommend relying on temporary credentials instead of creating IAM users who have long-term credentials such as passwords and access keys. However, if you have specific use cases that require long-term credentials with IAM users, we recommend that you rotate access keys. For more information, see [Rotate access keys regularly for use cases that require long-term credentials](#) in the *IAM User Guide*.

An [IAM group](#) is an identity that specifies a collection of IAM users. You can't sign in as a group. You can use groups to specify permissions for multiple users at a time. Groups make permissions easier to manage for large sets of users. For example, you could have a group named *IAMAdmins* and give that group permissions to administer IAM resources.

Users are different from roles. A user is uniquely associated with one person or application, but a role is intended to be assumable by anyone who needs it. Users have permanent long-term credentials, but roles provide temporary credentials. To learn more, see [When to create an IAM user \(instead of a role\)](#) in the *IAM User Guide*.

## IAM roles

An [IAM role](#) is an identity within your AWS account that has specific permissions. It's similar to an IAM user, but isn't associated with a specific person. You can temporarily assume an IAM role in the AWS Management Console by [switching roles](#). You can assume a role by calling an AWS CLI or AWS API operation or by using a custom URL. For more information about methods for using roles, see [Using IAM roles](#) in the *IAM User Guide*.

IAM roles with temporary credentials are useful in the following situations:

- **Federated user access** – To assign permissions to a federated identity, you create a role and define permissions for the role. When a federated identity authenticates, the identity is associated with the role and is granted the permissions that are defined by the role. For information about roles for federation, see [Creating a role for a third-party Identity Provider](#) in the *IAM User Guide*. If you use IAM Identity Center, you configure a permission set. To control what your identities can access after they authenticate, IAM Identity Center correlates the permission set to a role in IAM. For information about permission sets, see [Permission sets](#) in the *AWS IAM Identity Center (successor to AWS Single Sign-On) User Guide*.
- **Temporary IAM user permissions** – An IAM user or role can assume an IAM role to temporarily take on different permissions for a specific task.
- **Cross-account access** – You can use an IAM role to allow someone (a trusted principal) in a different account to access resources in your account. Roles are the primary way to grant cross-account access. However, with some AWS services, you can attach a policy directly to a resource (instead of using a role as a proxy). To learn the difference between roles and resource-based policies for cross-account access, see [How IAM roles differ from resource-based policies](#) in the *IAM User Guide*.
- **Cross-service access** – Some AWS services use features in other AWS services. For example, when you make a call in a service, it's common for that service to run applications in Amazon EC2 or store objects in Amazon S3. A service might do this using the calling principal's permissions, using a service role, or using a service-linked role.
  - **Service role** – A service role is an [IAM role](#) that a service assumes to perform actions on your behalf. An IAM administrator can create, modify, and delete a service role from within IAM. For more information, see [Creating a role to delegate permissions to an AWS service](#) in the *IAM User Guide*.
  - **Service-linked role** – A service-linked role is a type of service role that is linked to an AWS service. The service can assume the role to perform an action on your behalf. Service-linked roles appear in your AWS account and are owned by the service. An IAM administrator can view, but not edit the permissions for service-linked roles.

- **Applications running on Amazon EC2** – You can use an IAM role to manage temporary credentials for applications that are running on an EC2 instance and making AWS CLI or AWS API requests. This is preferable to storing access keys within the EC2 instance. To assign an AWS role to an EC2 instance and make it available to all of its applications, you create an instance profile that is attached to the instance. An instance profile contains the role and enables programs that are running on the EC2 instance to get temporary credentials. For more information, see [Using an IAM role to grant permissions to applications running on Amazon EC2 instances](#) in the *IAM User Guide*.

To learn whether to use IAM roles or IAM users, see [When to create an IAM role \(instead of a user\)](#) in the *IAM User Guide*.

## Compliance validation for the AWS Cloud Development Kit (AWS CDK)

The AWS CDK follows the [shared responsibility model](#) through the specific Amazon Web Services (AWS) services it supports. For AWS service security information, see the [AWS service security documentation page](#) and [AWS services that are in scope of AWS compliance efforts by compliance program](#).

The security and compliance of AWS services is assessed by third-party auditors as part of multiple AWS compliance programs. These include SOC, PCI, FedRAMP, HIPAA, and others. AWS provides a frequently updated list of AWS services in scope of specific compliance programs at [AWS Services in Scope by Compliance Program](#).

Third-party audit reports are available for you to download using AWS Artifact. For more information, see [Downloading Reports in AWS Artifact](#).

For more information about AWS compliance programs, see [AWS Compliance Programs](#).

Your compliance responsibility when using the AWS CDK to access an AWS service is determined by the sensitivity of your data, your organization's compliance objectives, and applicable laws and regulations. If your use of an AWS service is subject to compliance with standards such as HIPAA, PCI, or FedRAMP, AWS provides resources to help:

- [Security and Compliance Quick Start Guides](#) – Deployment guides that discuss architectural considerations and provide steps for deploying security-focused and compliance-focused baseline environments on AWS.
- [AWS Compliance Resources](#) – A collection of workbooks and guides that might apply to your industry and location.
- [AWS Config](#) – A service that assesses how well your resource configurations comply with internal practices, industry guidelines, and regulations.
- [AWS Security Hub](#) – A comprehensive view of your security state within AWS that helps you check your compliance with security industry standards and best practices.

## Resilience for the AWS Cloud Development Kit (AWS CDK)

The Amazon Web Services (AWS) global infrastructure is built around AWS Regions and Availability Zones.

AWS Regions provide multiple physically separated and isolated Availability Zones, which are connected with low-latency, high-throughput, and highly redundant networking.



With Availability Zones, you can design and operate applications and databases that automatically fail over between Availability Zones without interruption. Availability Zones are more highly available, fault tolerant, and scalable than traditional single or multiple data center infrastructures.

For more information about AWS Regions and Availability Zones, see [AWS Global Infrastructure](#).

The AWS CDK follows the [shared responsibility model](#) through the specific Amazon Web Services (AWS) services it supports. For AWS service security information, see the [AWS service security documentation page](#) and [AWS services that are in scope of AWS compliance efforts by compliance program](#).

## Infrastructure security for the AWS Cloud Development Kit (AWS CDK)

The AWS CDK follows the [shared responsibility model](#) through the specific Amazon Web Services (AWS) services it supports. For AWS service security information, see the [AWS service security documentation page](#) and [AWS services that are in scope of AWS compliance efforts by compliance program](#).

# Troubleshooting common AWS CDK issues

This topic describes how to troubleshoot the following issues with the AWS CDK.

- [After updating the AWS CDK, the AWS CDK Toolkit \(CLI\) reports a mismatch with the AWS Construct Library \(p. 354\)](#)
- [When deploying my AWS CDK stack, I receive a `NoSuchBucket` error \(p. 355\)](#)
- [When deploying my AWS CDK stack, I receive a `forbidden: null` message \(p. 355\)](#)
- [When synthesizing an AWS CDK stack, I get the message `--app is required either in command-line, in cdk.json or in ~/.cdk.json` \(p. 355\)](#)
- [When synthesizing an AWS CDK stack, I receive an error because the AWS CloudFormation template contains too many resources \(p. 356\)](#)
- [I specified three \(or more\) Availability Zones for my Auto Scaling group or VPC, but it was only deployed in two \(p. 357\)](#)
- [My S3 bucket, DynamoDB table, or other resource is not deleted when I issue `cdk destroy` \(p. 357\)](#)

## After updating the AWS CDK, the AWS CDK Toolkit (CLI) reports a mismatch with the AWS Construct Library

The version of the AWS CDK Toolkit (which provides the `cdk` command) must be at least equal to the version of the main AWS Construct Library module, `aws-cdk-lib`. The Toolkit is intended to be backward compatible. The latest 2.x version of the toolkit can be used with any 1.x or 2.x release of the library. For this reason, we recommend you install this component globally and keep it up to date.

```
npm update -g aws-cdk
```

If you need to work with multiple versions of the AWS CDK Toolkit, install a specific version of the toolkit locally in your project folder.

If you are using TypeScript or JavaScript, your project directory already contains a versioned local copy of the CDK Toolkit.

If you are using another language, use `npm` to install the AWS CDK Toolkit, omitting the `-g` flag and specifying the desired version. For example:

```
npm install aws-cdk@2.0
```

To run a locally installed AWS CDK Toolkit, use the command `npx aws-cdk` instead of only `cdk`. For example:

```
npx aws-cdk deploy MyStack
```

`npx aws-cdk` runs the local version of the AWS CDK Toolkit if one exists. It falls back to the global version when a project doesn't have a local installation. You may find it convenient to set up a shell alias to make sure `cdk` is always invoked this way.

macOS/Linux

```
alias cdk="npx aws-cdk"
```

Windows

```
doskey cdk=npx aws-cdk $*
```

[\(back to list \(p. 354\)\)](#)

### When deploying my AWS CDK stack, I receive a `NoSuchBucket` error

Your AWS environment has not been bootstrapped, and so does not have an Amazon S3 bucket to hold resources during deployment. You can create the staging bucket and other required resources with the following command:

```
cdk bootstrap aws://ACCOUNT-NUMBER/REGION
```

To avoid generating unexpected AWS charges, the AWS CDK does not automatically bootstrap any environment. You must explicitly bootstrap each environment into which you will deploy.

By default, the bootstrap resources are created in the Region or Regions that are used by stacks in the current AWS CDK application. Alternatively, they are created in the Region specified in your local AWS profile (set by `aws configure`), using that profile's account. You can specify a different account and Region on the command line as follows. (You must specify the account and Region if you are not in an app's directory.)

```
cdk bootstrap aws://ACCOUNT-NUMBER/REGION
```

For more information, see [the section called "Bootstrapping" \(p. 195\)](#).

[\(back to list \(p. 354\)\)](#)

### When deploying my AWS CDK stack, I receive a `forbidden: null` message

You are deploying a stack that requires bootstrap resources, but are using an IAM role or account that lacks permission to write to it. (The staging bucket is used when deploying stacks that contain assets or that synthesize an AWS CloudFormation template larger than 50K.) Use an account or role that has permission to perform the action `s3: *` against the bucket mentioned in the error message.

[\(back to list \(p. 354\)\)](#)

### When synthesizing an AWS CDK stack, I get the message `--app is required either in command-line, in cdk.json or in ~/.cdk.json`

This message usually means that you aren't in the main directory of your AWS CDK project when you issue `cdk synth`. The file `cdk.json` in this directory, created by the `cdk init` command, contains the command line needed to run (and thereby synthesize) your AWS CDK app. For a TypeScript app, for example, the default `cdk.json` looks something like this:

```
{
  "app": "npx ts-node bin/my-cdk-app.ts"
}
```

We recommend issuing `cdk` commands only in your project's main directory, so the AWS CDK toolkit can find `cdk.json` there and successfully run your app.

If this isn't practical for some reason, the AWS CDK Toolkit looks for the app's command line in two other locations:

- In `cdk.json` in your home directory
- On the `cdk synth` command itself using the `-a` option

For example, you might synthesize a stack from a TypeScript app as follows.

```
cdk synth --app "npx ts-node my-cdk-app.ts" MyStack
```

[\(back to list \(p. 354\)\)](#)

### When synthesizing an AWS CDK stack, I receive an error because the AWS CloudFormation template contains too many resources

The AWS CDK generates and deploys AWS CloudFormation templates. AWS CloudFormation has a hard limit on the number of resources a stack can contain. With the AWS CDK, you can run up against this limit more quickly than you might expect.

#### Note

The AWS CloudFormation resource limit is 500 at this writing. See [AWS CloudFormation quotas](#) for the current resource limit.

The AWS Construct Library's higher-level, intent-based constructs automatically provision any auxiliary resources that are needed for logging, key management, authorization, and other purposes. For example, granting one resource access to another generates any IAM objects needed for the relevant services to communicate.

In our experience, real-world use of intent-based constructs results in 1–5 AWS CloudFormation resources per construct, though this can vary. For serverless applications, 5–8 AWS resources per API endpoint is typical.

Patterns, which represent a higher level of abstraction, let you define even more AWS resources with even less code. The AWS CDK code in [the section called “ECS” \(p. 244\)](#), for example, generates more than 50 AWS CloudFormation resources while defining only three constructs!

Exceeding the AWS CloudFormation resource limit is an error during AWS CloudFormation synthesis. The AWS CDK issues a warning if your stack exceeds 80% of the limit. You can use a different limit by setting the `maxResources` property on your stack, or disable validation by setting `maxResources` to 0.

#### Tip

You can get an exact count of the resources in your synthesized output using the following utility script. (Since every AWS CDK developer needs Node.js, the script is written in JavaScript.)

```
// rescount.js - count the resources defined in a stack
// invoke with: node rescount.js <path-to-stack-json>
// e.g. node rescount.js cdk.out/MyStack.template.json

import * as fs from 'fs';
const path = process.argv[2];

if (path) fs.readFile(path, 'utf8', function(err, contents) {
  console.log(err ? `${err}` :
    `${Object.keys(JSON.parse(contents).Resources).length} resources defined in
    ${path}`);
}); else console.log("Please specify the path to the stack's output .json file");
```

As your stack's resource count approaches the limit, consider re-architecting to reduce the number of resources your stack contains: for example, by combining some Lambda functions, or by breaking your

stack into multiple stacks. The CDK supports [references between stacks \(p. 123\)](#), so you can separate your app's functionality into different stacks in whatever way makes the most sense to you.

**Note**

AWS CloudFormation experts often suggest the use of nested stacks as a solution to the resource limit. The AWS CDK supports this approach via the [NestedStack \(p. 114\)](#) construct.

[\(back to list \(p. 354\)\)](#)

**I specified three (or more) Availability Zones for my Auto Scaling group or VPC, but it was only deployed in two**

To get the number of Availability Zones that you request, specify the account and Region in the stack's `env` property. If you do not specify both, the AWS CDK, by default, synthesizes the stack as environment-agnostic. You can then deploy the stack to a specific Region using AWS CloudFormation. Because some Regions have only two Availability Zones, an environment-agnostic template doesn't use more than two.

**Note**

In the past, Regions have occasionally launched with only one Availability Zone. Environment-agnostic AWS CDK stacks cannot be deployed to such Regions. At this writing, however, all AWS Regions have at least two AZs.

You can change this behavior by overriding your stack's [availabilityZones](#) (Python: `availability_zones`) property to explicitly specify the zones that you want to use.

For more information about specifying a stack's account and region at synthesis time, while retaining the flexibility to deploy to any region, see [the section called "Environments" \(p. 114\)](#).

[\(back to list \(p. 354\)\)](#)

**My S3 bucket, DynamoDB table, or other resource is not deleted when I issue `cdk destroy`**

By default, resources that can contain user data have a `removalPolicy` (Python: `removal_policy`) property of `RETAIN`, and the resource is not deleted when the stack is destroyed. Instead, the resource is orphaned from the stack. You must then delete the resource manually after the stack is destroyed. Until you do, redeploying the stack fails. This is because the name of the new resource being created during deployment conflicts with the name of the orphaned resource.

If you set a resource's removal policy to `DESTROY`, that resource will be deleted when the stack is destroyed.

TypeScript

```
import * as cdk from 'aws-cdk-lib';
import { Construct } from 'constructs';
import * as s3 from 'aws-cdk-lib/aws-s3';

export class CdkTestStack extends cdk.Stack {
  constructor(scope: Construct, id: string, props?: cdk.StackProps) {
    super(scope, id, props);

    const bucket = new s3.Bucket(this, 'Bucket', {
      removalPolicy: cdk.RemovalPolicy.DESTROY,
    });
  }
}
```

JavaScript

```
const cdk = require('aws-cdk-lib');
const s3 = require('aws-cdk-lib/aws-s3');
```

```
class CdkTestStack extends cdk.Stack {
  constructor(scope, id, props) {
    super(scope, id, props);

    const bucket = new s3.Bucket(this, 'Bucket', {
      removalPolicy: cdk.RemovalPolicy.DESTROY
    });
  }
}

module.exports = { CdkTestStack }
```

## Python

```
import aws_cdk as cdk
from constructs import Construct
import aws_cdk.aws_s3 as s3

class CdkTestStack(cdk.Stack):
    def __init__(self, scope: Construct, id: str, **kwargs):
        super().__init__(scope, id, **kwargs)

        bucket = s3.Bucket(self, "Bucket",
            removal_policy=cdk.RemovalPolicy.DESTROY)
```

## Java

```
software.amazon.awscdk.*;
import software.amazon.awscdk.services.s3.*;
import software.constructs.*;

public class CdkTestStack extends Stack {
    public CdkTestStack(final Construct scope, final String id) {
        this(scope, id, null);
    }

    public CdkTestStack(final Construct scope, final String id, final StackProps props)
    {
        super(scope, id, props);

        Bucket.Builder.create(this, "Bucket")
            .removalPolicy(RemovalPolicy.DESTROY).build();
    }
}
```

## C#

```
using Amazon.CDK;
using Amazon.CDK.AWS.S3;

public CdkTestStack(Construct scope, string id, IStackProps props) : base(scope, id,
    props)
{
    new Bucket(this, "Bucket", new BucketProps {
        RemovalPolicy = RemovalPolicy.DESTROY
    });
}
```

## Note

AWS CloudFormation cannot delete a non-empty Amazon S3 bucket. If you set an Amazon S3 bucket's removal policy to `DESTROY`, and it contains data, attempting to destroy the stack will

fail because the bucket cannot be deleted. You can have the AWS CDK delete the objects in the bucket before attempting to destroy it by setting the bucket's `autoDeleteObjects` prop to `true`.

[\(back to list \(p. 354\)\)](#)

# OpenPGP keys for the AWS CDK and jsii

This topic contains current and historical OpenPGP keys for the AWS CDK and jsii.

## Current keys

These keys should be used to validate current releases of the AWS CDK and jsii.

### AWS CDK OpenPGP key

Key ID:	0x42B9CF2286CD987A
Type:	RSA
Size:	4096/4096
Created:	2022-07-05
Expires:	2026-07-04
User ID:	AWS Cloud Development Kit <aws-cdk@amazon.com>
Key fingerprint:	69B5 2D5B A295 1D11 FA65 413B 42B9 CF22 86CD 987A

Select the "Copy" icon to copy the following OpenPGP key:

-----BEGIN PGP PUBLIC KEY BLOCK-----

```
mQINBGLgEg0sBEADCoAMwvnszMLybJ+AD9cHhVyX6+rYIUEXYSgVnfk16Z7qawIwv
wgd/a5fEs9Kiz2XJmfW59Rxb4d+0+Y11s1A+gnpw9FmLcZ1qkC9KLnS2MqvuxWLB
t3z4kjZaL9fQ+58PoD4gy/M2hDg6gZrYqR3gtJuw8FcFpb/1K1kzRQUM8eAMFxf2
TyfjP0V0tSHwCB+84oushX7fUXVMyc3+OHsCPOe/WBFMI1WgKA+n33JKIq1UUC8f
kCWBAsAFupil01CveT6mZu5s1NR1c1I3iBLjUZ3/MtLygfqAMKwUVXeaWtDvRIZe
PrAfC2Ny0DEhly2JG6K0FW7eIcvBqR3rg8U49t9Y74ELTM0kKnfd+f1vq35xWqQC
0zghnk3kDppRTN4zWBgTKiCMxBcsHXG0oGn57t4B9VY9Zy3vkeySigeiw1/Tw9nJ
PE0SRnwEc/HnjTTFX+GTG1aQVE0xSVyZ4m5ymRNCu6+rNH81Kwo5FujlXJ+GXPkp
qT+Lx6Ix/Ny7PaoweWxwtZUKLRS4pWUsg0yotZrGyIbS+X3yMEG8WBTfI9hf6HTq
0ryfi5/TsBrdrGKqWB99EC9xYEGgtHp4fK05X0yn0agV0hf0jSe8t1uyuJPGB2Gc
MQagSys5xMhdG/ZnEY4Cb+JDtH/4jc3tca0+4Z5RQ7kF9IhCncFtrbjJbwARAQAB
tC5BV1MgQ2xvdWQgRGV2ZWxvcG11bnQgS2l0IDxhd3MtY2RrQGFTYXpvi5jb20+
iQI/BBMBAgApBQJixIDrAhsvBQkHhM4ABwsJCAcDAgEGFQgCCQoLBbYCAwECHgEC
F4AACGkQrnpIobNmHo2qg//Zt9p/kN1DevflzxWkouUX0AS7UmUtRYXu5k/EEbu
wkYNHUr7+lZ+Me5YyjcIpt6UuwG9cW4SvwuxIfXucyKAWiWbEbydCQauvnrYDxDa
J6Yr/ntk7Sii6An9re99qic3IsVx+xlUXh+qJ/34ooP/1PHziCMqykvW/DwAIyhx
2qvTXy+9+010WSUBhkCnNz5XKb4XQGq73Dqa1ZX1nH4dG6fckZmYRX+dpw2njfTw
ZldZ7bkrfiL84FI4A21RfSbEU4s4ngiV17LZ9ivi1BKtBdv3da7+yc919M7C5N4J
yr1xvtyYND0qKAD2WYZAnpEbG/shu3f56Ry0Jd56tXGw19nKPh+F9y+379XthSwA
xZTURFtjWf7wWHaDZadU0DKi+Oeeszjg2f/VJaGmmS8PIg7q6GiSHHpqHqNvACHm
ZXMw12QFd3qt3xu0JmME11ZC5VBgblwpkQT004Sq1r0pJwX190DMS/ZEHAIoYmT
OR7oukn1Ax6mj9fwpavWDAAJHLdVUMYBZTXiQYFzDvx51ivvTRWkB1zTJcFdqShY
```



```
B37+Jz2jLDNdMrcHk2yfVp/VvfbxKcexg8wEwrrtQUs1TUen15jBZJouoz/wW81s
Y4U1nCPCdTK5/C7JCKzR2gVnCpe6uaxAWkkM2feQhjQJZkTC4cFVgBT+4M6WcT1r
yq4=
=ahbs
-----END PGP PUBLIC KEY BLOCK-----
```

## jsii OpenPGP key

Key ID:	0x056C4E15DAE3D8D9
Type:	RSA
Size:	4096/4096
Created:	2022-07-05
Expires:	2026-07-04
User ID:	AWS JSII Team <aws-jsii@amazon.com>
Key fingerprint:	1E07 31D4 57E5 FE87 87E5 530A 056C 4E15 DAE3 D8D9

Select the "Copy" icon to copy the following OpenPGP key:

```
-----BEGIN PGP PUBLIC KEY BLOCK-----
```

```
mQINBGLgEg0kBEAD27EPVG9g2mHQ3+M6tF6le+tfhARJ2EV7m7NKiIrTdS1CZATLWn
AVLlxG1unW34NlKZbcbR86gAxRnnAhuEhPuLoU/S5wAqPGbRiF158YjYZDNJw6U
1SSMpE401sfjxv9yAbiRihLYtvksyHHZmaDhYner2aK1PdeWu+BKq/tjfm3Yzsd2
uuVEdUJ72YoQk/29dEiG0HfT+2kUKxUX+0tJSJ9MG1Ef4NtQE4WLzrT6Xqb2SG4+
a1IiIVxIEi0XKDN7n8ZLjFwfJw0YxVYLtEUKqFWM8e8vgoc9/nYc+vDXZVED2g3Z
FWrWsnDSXbQpnMa2cLhD4xLpDHUS3i2p7r3dkJQGLo/5JG0opLibr0AbYZ72izhu
H/TuPFogSz0mNFPglrWdnLF04UIjIq420+06V4WQZC9n55Zjcbki/0hnC3B9pAdU
tiy8zg070bWq45dPGf5STkPPn7G8A2zmKefy051iLi26ZzW78siB+FvcGRhdg25
39sHJ1cmrTeC+B+k4KeV5sQ/m3UuccmrZnk1xdaiVp8mWzRqWb8bB6Rs8K9RMrMV
tFB0K0BAT2Qx0QtRGAAntVgm193E1T1cmNpD0FKAKkDdPs64rKBEwFiHxccXHbah
eMdlweVvn3AKFD6uAm8ZRMV+dyssfcQxqpo/kFT1XpA6cQe0mGD0cKBfdwARAQAB
tCNBV1MgS1NJSSBUZWFtIDxhd3MtannPaUBhbWV6b24uY29tPokCPwQTAQIAKQUC
YsSA6QIbLwUJB4TOAACLCQgHAWIBBhUIAgkKCwQWAgMBAh4BAheAAAoJEAVsThXa
49jZjU4QANoyq0JUT4gRrXshE3N0mW5Ad4i8Ke09GA62HyvTtfbsA+2nkNVGJpXm
sFMZdaF095Q65RkLS9vW4nhhjXBEC2XYNct2AnARudA/41ykjDPwU112z9ZTB9he
y4ItIeNgpHvMwr51fihl0y2nkp0D0Beiv44jScLbHyOmZfki1f5fuIu2U2IbUGK3
5FtYyeHcgRHnpYkzLuzK4Pfay0ywqQPJ7M9DWrHf+v5Cu4ZCZD0IKfzF+ew7MWwc
6KaoWHCYbFpX8jxFppbGsSF0Q8S12quoP0TLz9Wsq70KHi6C2P8JI6lM0HRL0+1M
jFbQxN0wAcN3k4HSwunAjXB1mT/6oc1RsdBdpXBaz2AWseIXwSYZqNXp+5L179uZ
vSiD3DSSUqLJbdQRV0sJi3/87V5QU59byq2dToHverjtsbVnK0TkTx9Z1gkcpjvM
BwHNqWhratV6af2Upjq2YQ0fdSB42f3pgopInxNJPMv1Ab+cCfr0Pfwu7ge7UooQ
WHTxbpCvwtN/HNctMGpWsc002WsWgoYVjnVFay/XphE77pQ9rRUKhMe6VKXfxj/n
OCZJKrydluIiW8v0NNq0+QwZ1xDEh07MaSZ10m1AuUZIXFPgaWQkPZHkiwFA/
QWnL/+shuRtMH2geTjkev198Jgb5HyXFm4SyYtZferQR0y1iEhik
=BuGv
-----END PGP PUBLIC KEY BLOCK-----
```

## Historical keys

These keys may be used to validate releases of the AWS CDK and jsii before 2022-07-05.

### Important

New keys are created before the previous ones expire. As a result, at any given moment in time, more than one key may be valid. Keys are used to sign artifacts starting the day they are created, so use the more recently-issued key where keys' validity overlaps.

## AWS CDK OpenPGP key (2022-04-07)

### Note

This key was not used to sign AWS CDK artifacts after 2022-07-05.

Key ID:	0x015584281F44A3C3
Type:	RSA
Size:	4096/4096
Created:	2022-04-07
Expires:	2026-04-06
User ID:	AWS Cloud Development Kit <aws-cdk@amazon.com>
Key fingerprint:	EAE1 1A24 82B0 AA86 456E 6C67 0155 8428 1F44 A3C3

Select the "Copy" icon to copy the following OpenPGP key:

-----BEGIN PGP PUBLIC KEY BLOCK-----

```
mQINBGJPLgUBEADt1R5jQtxtBmROQvmWlPOViqqnJNhk0dULc3tXnq8NS/16X81r
wHk+/CHG5kBunwvM0qaqLFRC6z9NnnNDxEHcTi47n+0AajWyDM6unxxWOPz8Dfaps
Uq/Zwa4by292ZeqRC9Irwdrizb69JbRjeshBw1JDAS/qtqCAqBRH/f7Zw7QSD6/
XTxyIy+K0VjZwFPFNHMRQ/NmgUc/Rfxsa0pUjk1YAj/AkvQ1lwD8DnASoBh00DP
QonZxouLqIpgp4LsGo8TZDQv30ocIj0C9DuYUiuXWlCP1YPgDj6IWf3rgpMQ6nB9
wC91x4t/L3Zg1HUD52y8aymndmbdHVN90mz1Ng4XWyc58rioYrEk57YwbDnea/Kk
Hv4kVHZRFJ4/0FPyqs5ex1X3X6rb07VvA1tflgPyw09XF2Xws8YwOWcEobaWTcnb
AzyVC6wKya8rEQzXkYJ6UkJ1hDB6g6bZwIpsI2z1imG+kSBsyFvE2oRYMS0cXPqU
o+tX0+4TvxEyW3RrUQzQHIpqXrb0X1Q8Z2idPn5dwsipDEa4gsFXtrSXmbB/0Cee
eJvVkwQAsxol3+NE9L/yoZq3cz5PWh0SSbmCLRcs781MJ23MmzbMWV7BWC9DXdY+
TywY5IkDUPjGCK1D8V1rI3TgC222bH6qaua6LYCiTtRtvpDYUJNA1UjhawARAQAB
tC5BV1MgQ2xvdWQGRGV2ZWxvcG11bnQgS2l0IDxhd3MtY2RrQGFTYXpvi5jb20+
iQI/BMBABAgApBQJiTy4FAhsvBQkHhM4ABwsJCACDAgEGFQgCCQoLBBYCAwECHgEC
F4AACGkQAVWEKB9Eo8NpbxAAiBF0kR/1Vw3vuam60mk4l0iGMVsP8Xq6g/buzbE0
2MEB4Ftk04q0noa+93S0ZiLR9PqxrsGSp4ADDX3Vtc4uxwzU1KU11ywEhQ1cwyl
YHQI3Hd75K1J81ozMEu6qJH+yF0TtTDZMeZHTH/XvuIYJW3Lx4o5ZF1sEegFPAGX
YCCpUS+k9qC6M8g2VjcltQJpyjGswsKm6FWaKHW+B9dfjd0H1ImB9E2jaknJ8eoY
zb9zHgFANluMzpZ6rYVSiCuXiEgYmazQWcVlPcMOP7nX+1hq1z11LMqeSnfE09gX
H+0Yho9cMEJkb1dzx1H9MRpylFIIn9tL+2iCp4UPJjnqi6uawWyL22tp4G11haqQq
1yAh69u233I8GZKFUySzjHwH5qWGRGBTjrZ6FdcjSS2w/wMkVKuCPkwtDvo/TJrm
msCd1Reye8SEKYqrs0ujTwm1vWmUZm006AdUjo1kWiBKes1TJrWEuG7Yk4pF0oA4
dsaq83gxp0JNVCh6M3y4DLNrv17dhF95NwTWMROPj2otw7NIjF4/cdzve2+P7YNN
pVAtyCtTJdD3eZbQPvAl3T8cf1VGqt6++pnLgnWJ0+X3TyvfmTohdJvN3TE+tg7A
7cprDX/q9c56HaXdJzVpxEzuf/YC+JuYKeHwsX3QouDhyRg3PsigdZES/02Wr8so
16U=
=MQI4
-----END PGP PUBLIC KEY BLOCK-----
```

## jsii OpenPGP key (2022-04-07)

### Note

This key was not used to sign jsii artifacts after 2022-07-05.

Key ID:	0x985F5BC974B79356
Type:	RSA
Size:	4096/4096
Created:	2022-04-07
Expires:	2026-04-06
User ID:	AWS JSII Team <aws-jsii@amazon.com>
Key fingerprint:	35A7 1785 8FA6 282D C5AC CD95 985F 5BC9 74B7 9356

Select the "Copy" icon to copy the following OpenPGP key:

-----BEGIN PGP PUBLIC KEY BLOCK-----

```
mQINBGJPLEwBEADHH4TXup/g0lHrKDZRBj8MvsMTdM6eDteA6/c32UYV/YsK9rDA
jN8Jv/x1fos0ebcHrFnFpHF9VTkmju0pN695XdwMrW/Nv1EPISTGEJf21x6ZTQ2r
1xWfYzC3s13FZmvj9XAXTmygdv+XM3TqsFgZeCaBkZVdiLbQf+FHvrovU1gotb5D
YiCQI3ofV5QTE+141jh05PkD3ZIoBG+P826LaT8NXhwS0o1XqVkJ39DCZNoFshNmR
WFZpkVCTHyv5ZhVey1NWxND8op0375htGNV4AeSmSIH9YkURD1g5F+2t7RiosKfo
kJrfPmUjhHn8IFpReGc8qmMMZX0WaV3t+VAWfOHGGyrXDfQ4xz1VCot75C2+qypM
+qhw0A00P0zA7CfI96ULZzSH/j8HuQk300DsUCybpMuKEazEMxP3tgGtRerwDaFG
jQvAlK8Rbq3v8buBI6YJuXTwSzJE8KLjleUiTFumE6WP4rsAv1P/5rBvubeMfa3n
NIMm5Rk136Z+jt3e2Z2ZqWDPpBRta8m7QHccrzhkvqu3YC3G16kdnm4Vio3Xfpg2
qtWhIQuTQ6DmItewV+weQHas3h188RPJtSrFWIIMkpbF7Y4vbX9xcnsYCLlp2Mz
tWbbnU+EWATNSsufm1/Kdnu9iEEuLmeovE11I69nwjN0q9P+GJ3r/FUb2wARAQAB
tCNBV1MgS1NJSSBUZWFtIDxhd3MtanNpaUBhbWFG6b24uY29tPokCPwQTAQIAKQUC
Yk8t7AIbLwUJB4TOAAcLCQgHAWIBBhUIAgkKCwQWAgMBAh4BAheAAoJEJhfw810
t5NWo64P/2y7gcMRy1LLW/wbrCjton204+YRocwQxKm1cBm19FVDUR5967YczNuu
EwEOfh/Pu3UA1rBfKAfxPNhKchLwYi0BNh2Wk5UUXRc1dNHTLb5jn5gxCeWNAS1/
Tc46qY+ObdBMd0f2Vu33UC0g83WLBg1bfBoA8Bm1cd0X0btLGucu606EBt1dBxKq
9UTcbJfGivY2Xjy5r4kEiMHBOLKcFrSo2Mm7VtY1E4Mabjy9+orqUio7qx0160
aa7Psa6rMvs1Ip9IOAdG7o5Y29tQpeINH0R1/u47Br1TEAgG63Dfy49w2h/1g0G
c9KPXVuN550WRiU0hsySDMk/2ERsF348TU3NURZ1tnC0xp6pH1bPJIXRVtNa9Cn
f8tbLB3y3HfA80516g+qwNYIYiqsDdV2bz+VbvmCwC0+Fe1lDZ1i831gyMga5JJ
rq7d01Er6nqjcnKiVwItTQXyFYmKTAXweQtVC72g1sd3oZiYqa7T8pvhWpKXxoJV
WP+OPBhGg/JEVC9sguhuv53tzVwayrNwb54JxJsD2nemfhQm1Wvyb2bPTEaJ3mrV
mhPUvXZj/I9rgsEq3L/sm2Xjy09nra4o3oe3bhEL8n0j11wkIodi17VaGP0y+H3s
I5zB5UztS6dy+cH+J7DoRaxzVzq7qtH/ZY2quCl1t30wwqDHUX1ef
=+iYX
```

-----END PGP PUBLIC KEY BLOCK-----

## AWS CDK OpenPGP key (2018-06-19)

Key ID:	0x0566A784E17F3870
Type:	RSA
Size:	4096/4096

Created:	2018-06-19
Expires:	2022-06-18
User ID:	AWS CDK Team <aws-cdk@amazon.com>
Key fingerprint:	E88B E3B6 F0B1 E350 9E36 4F96 0566 A784 E17F 3870

Select the "Copy" icon to copy the following OpenPGP key:

```
-----BEGIN PGP PUBLIC KEY BLOCK-----

mQINBFsovE8BEADFEVChEAVPvoQgsjVu9FPUCzxy9P+2zGIT/MLI3/vPLiULQwRy
IN2oxyBNDtCdToNa/fTkW3Ev0NTP4V1h+uBoKDZD/p+dTmSDRfByECMI0sGZ3UsG
Ohhy120f44s0sL8gdLtDnqSRLf+Zrft3gpgUnp1W7VltkLxr78jDpW4QD8p8dZ9
WNm3JgB55jyPgaJKqA1Ln4Vduni/1XkrG42nxrrU71uUdZPvPZ2ELLJa6n0/raG8
jq31e+xQh45gAIs6PGaAgy7jAsfbwkGTBHjjujITAY1DwvQH5iS310aCM9n4JNpc
xGZeJAVYTLilznf2QtS/a50t+Z0mpq67Ssp2j6qYpiumm0Lo9q3K/R4/yF0FZ8SL
1TuNX0ecXEptiMVUfTiqrLsANg18EPtLZZ0YW+ZkbcVytKdPiQj7bMwA7mI7zGCJ
1gjaTbcEm0mVdQYS1G6ZptwbTtvrgA6AfnZxX1HUxLRQ7tT/wvRtABfbQKAh85Ff
a3U9W4oC3c1MP5IyhNV1Wo8Zm0f1ZiZc0iZnojTtSG6UbcxNNL4Q8e08FWjhungj
yxSsIBnQ01Aeo1N4Bbz1I+n9iaXVDUN7Kz1QEYs4PNpjvUyrUiQ+a9C5sRA7WP+x
IE0aBBGpoAXB3oLsdTN06AcwcDd9+r2N1X1hWC4/uH2YHQUIegPqHmPWxwARAQAB
tCFBV1MgQ0RLIFRlYW0gPGF3cy1jZGtAYW1hem9uLmNvbT6JAj8EEwEIAckFAIso
vE8CGy8FCQeEzGACwkIBwMCAQYVCAIJCgsEFgIDAQIeAQIXgAAKCRAFZqeE4X84
cLGx0/XHhnoR2xvz38GM8HQ1w1Zy9W1wVhQKMNQDUavw8Zx7+iRR3m7nq3xM7Qq
BDbcbK5g11VLsBQ6H2V6vRyps0hkPSH1nN2d08DtvSKIPcxK48+1x7lm0+ksSs/+
oo1Uv0mTdaRz0itYh3k0GXHHXk/111GtF2FGQzYssX5iM4PHcjBsK1unThs56IMh
0JeZezEYzBaskTu/ytRJ236bPP2kZIEFzAvhmTytuXWUXEftx0xc6fIACYiKTha
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4gdsFb6tqwTGecuUPvvZaEuvhWEXLxAebhu780FdAPXgVTX+YCLi2zf+dWQvkFQf
80RE7ayn7BsiaLzFBVux/zz/WgvudsZX18r8tDiVQBL510Rmqw==
=0wuQ
-----END PGP PUBLIC KEY BLOCK-----
```

## jsii OpenPGP key (2018-08-06)

Key ID:	0x1C7ACE4CB2A1B93A
Type:	RSA
Size:	4096/4096
Created:	2018-08-06
Expires:	2022-08-05
User ID:	AWS JSII Team <aws-jsii@amazon.com>
Key fingerprint:	85EF 6522 4CE2 1E8C 72DB 28EC 1C7A CE4C B2A1 B93A

Select the "Copy" icon to copy the following OpenPGP key:

-----BEGIN PGP PUBLIC KEY BLOCK-----

```
mQINBFtoSs0BEAD6WweLD0B26h0F7Jo9iR6tVQ4PgQBK1Va5H/eP+A2Iqw79UyxZ
WNzHYhzQ5MjYYI1SgcPavXy5/LV1N8HJ7QzyKszybnLYpNTLPYArWE8ZM9ZmjvIR
p1GzwnVBGQfo0lxyeutE9T5ZkAn45dTS5jlno4unj4gHjnwXKf2nP1APU2CZfdK
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4umRRJBAV1aW8b1+yfaYYC02AFXX06ca0bv8IvH7Pc4leC2DoqylD3KklQARAQAB
tCNBV1MgSlNJSSBUZWFtIDxhd3MtanNpaUBhbWV6b24uY29tPokCPwQTAQgAKQUC
W2hKzQIbLwUJB4TOAAcLCQgHAwIBBhUIAgkKCwQWAgMBAh4BAheAAAoJEBx6zkyy
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njZ70sBsBK2nVVcN0H2v5ey0T1yE93o6r7x0wCwBiVp5skTCRUob
=2Tag
```

-----END PGP PUBLIC KEY BLOCK-----

# AWS CDK Developer Guide history

See [Releases](#) for information about AWS CDK releases. The AWS CDK is updated approximately once a week. Maintenance versions may be released between weekly releases to address critical issues. Each release includes a matched AWS CDK Toolkit (CDK CLI), AWS Construct Library, and API Reference. Updates to this Guide generally do not synchronize with AWS CDK releases.

## Note

The table below represents significant documentation milestones. We fix errors and improve content on an ongoing basis.

Change	Description	Date
<a href="#">IAM best practices updates (p. 366)</a>	Updated guide to align with the IAM best practices. For more information, see <a href="#">Security best practices in IAM</a> .	March 23, 2023
<a href="#">Document cdk.json (p. 366)</a>	Add documentation of cdk.json configuration values.	April 20, 2022
<a href="#">Dependency management (p. 366)</a>	Add topic on managing dependencies with the AWS CDK.	April 7, 2022
<a href="#">Remove double-braces from Java examples (p. 366)</a>	Replace this anti-pattern with Java 9 Map.of throughout.	March 9, 2022
<a href="#">AWS CDK v2 release (p. 366)</a>	Version 2 of the AWS CDK Developer Guide is released. <a href="#">Document history</a> for CDK v1.	December 4, 2021